International Workshop on

Positrons in Astrophysics

19-23 March 2012
Mürren, Switzerland

The workshop is organized with the help of

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Workshop Objectives

Positrons are the most common and easily produced form of antimatter, both in the laboratory and in astrophysical scenarios. In the eighty years since their prediction and their experimental discovery they have become a major player in physics and astrophysics, spanning very disparate fields from galactic astrophysics to semi-conductor and surface physics, not to mention medical and industrial applications. In each of these wide domains huge progress has been made in theory, experimental methods, and modelling. Yet major questions and puzzles remain. The breadth and diversity of the fields involved have tended to limit the extent to which the various "positron communities" interact and learn from each other. A key aim of this meeting is to bring scientists working in the disciplines of atomic, molecular, surface and materials physics together with colleagues whose interests lie in various astrophysical fields.

While the emphasis will be on topics directly related to positrons both in physics and in astronomy, the scope of the workshop will also include other forms of antimatter both in the laboratory and in space. Review talks on a variety of antimatter topics will set the context and summarize the current state of the art in the different fields, while more specialized presentations will report on the latest developments. The objectives of the workshop are to identify the specific issues to be tackled next in each domain and to encourage future progress through interactions between the different research areas within and beyond positron science.

GENERAL INFORMATION

Presentations

All speakers are encouraged to make their talks generally accessible to a multi-disciplinary audience, which will include both theorists and experimentalists from a variety of domains. This is a different kind of workshop than the ones you usual go to, and a large part of the audience may be unfamiliar with the jargon of your community. Please make sure that the context and relevance of your contribution are understandable to ALL participants.

Context Setting Summary Talks are 30 minutes plus 15 minutes discussion.
Contributed talks are 15 minutes and 5 minutes discussion.
Posters will be displayed throughout the workshop.

Conference desk

The conference desk will be open at Hotel Alpin Palace on Monday March 19 from 17h30 to 19h30 and on Tuesday from 8h00 - 9h30. Participants who haven't done so shall pay the workshop fee at the conference desk (400 Euros or 480 Swiss Francs). Students contribute a reduced fee of 100 Euros (120 CHF). The participation in the social events (welcome/aperitif and dinner of Thursday evening) for accompanying persons is 150 Euros (180 CHF). Although cash is preferred, credit cards can also be accepted. In order to avoid congestion on Tuesday morning, we encourage you to register on Monday evening.

Internet Connection

Workshop participants have the possibility to connect to the internet through WIFI routers in the conference-areas.

Contacting the LOC during the workshop

mail : info@astropositron.org
in urgent cases : +41 77 492 23 09


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8 Alfred's Sporthaus
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10 Intersport Stäger Sport Station
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2 Hotel Palace
3 Hotel Alpenruh
4 Hotel Bellevue
5 Hotel Blumental
6 Hotel Edelweiss
7 Hotel Jungfrau
8 Hotel Alpenblick
9 Hotel Alpina
10 Eiger Guesthouse
11 Hotel Regina
12 Sportchalet

Tuesday, March 20

08:30	Welcome & Introduction	
Session 1 - Direct Detection of Cosmic-Ray Positrons - Chair : Roberto Battiston		
08:40	Direct detection of cosmic-ray positrons	Mirko Boezio
09:25	Positron and Antiproton Measurements in the Cosmic Rays with the PAMELA Space Experiment	Emiliano Mocchiutti
09:45	Anisotropy studies in cosmic ray electron/positron flux with the PAMELA satellite	Ugo Giaccari
10:05	Cosmic-Ray Positron Measurement with the Fermi-LAT	Warit Mitthumsiri
10:25	Coffee break	
Session 2 - Positron and Positronium Scattering - Chair : Cliff Surko		
10:45	Positron and Positronium scattering and annihilation in atomic and molecular systems	Michael Charlton
11:30	Recent experiments on positronium negative ions	Y. Nagashima
11:50	Collisions of Positrons and Positronium with Atoms and Molecules	Simon Brawley
Session 3 - Astrophysical Sources of Galactic Positrons - Chair : Nidhal Guessoum		
16:30	Astrophysical sources of Galactic positrons	Nikos Prantzos
17:15	Positron generation in the magnetospheres of neutron stars	Ya.N. Istomin
17:35	Wide-Band Spectra of Magnetar Persistent and Burst Emission	Y. E. Nakagawa
17:55	Electron-positron plasmas in large-scale cosmic structures: origin, evolution and interaction	Sergio Colafrancesco
18:15	Coffee break	
Session 4 - Other Aspects of Positron-matter Interactions - Chair : Toshio Hyodo		
18:30	Positron annihilation on atomic core electrons and in positive ions.	Dermot G. Green
18:50	Positron annihilation in a superstrong magnetic field.	Jerzy Dryzek
19:10	Plans for a laboratory electron-positron plasma experiment	Thomas Sunn Pedersen

Wednesday, March 21

Session 5 - Low-Energy Positron-Matter Interactions - Chair : Paul Coleman		
08:30	Theory of low-energy positron-matter interactions	Gleb Gribakin
09:15	Bound states of positron with nitrile species with several multi-component molecular theories	Masanori Tachikawa
09:35	Close-coupling approach to positron-atom collisions	Igor Bray
09:55	Implications of Feshbach resonances for molecular annihilation spectra of astrophysical relevance	Cliff Surko
10:15	Coffee break	

Session 6 - Antimatter in Cosmic Rays - Chair : Pierre Jean		
10:35	Antimatter search in Cosmic Rays	Roberto Battiston
11:20	Probing the CR positron/electron ratio at the TeV regime through Moon shadow observation with atmospheric Cherenkov telescopes.	Pierre Colin
11:40	A Novel Electromagnetic Calorimeter for a Balloon Borne Spectrometer	Alexander Howard

Session 7 - Antihydrogen - Chair : Michael Charlton		
16:30	Trapped Antihydrogen : A new frontier in fundamental physics	Niels Madsen
17:15	Positron and positronium for the GBAR experiment	Laszlo Liszkay
17:35	Calculations of antihydrogen loss from collisions with hydrogen and Helium	Svante Jonsell
17:55	AEGIS: testing the WEP with a pulsed cold beam of antihydrogen	Michael Doser
18:10	Coffee break	

Session 8 - Annihilation Detection - Chair : Michael Doser		
18:30	The AX-PET experiment: A demonstrator for an axial Positron Emission Tomography	Chiara Casella
18:50	A Scintillation-Solid State Detector as the Perspective Tool for Registration of Beams of High Energy Particles in Visible and Infrared Region	Anatoly Maltsev
19:10	Positronium: our spy to the Mirror World.	Paolo Crivelli

Thursday, March 22

Session 9 - Galactic e-e+ Annihilation - Chair : Peter von Ballmoos		
08:30	Observation of Galactic e-e+ Annihilation Radiation	Roland Diehl
09:15	Can positrons from Sgr A* produce the 511 keV emission in the galactic bulge?	Pierre Jean
09:35	The INTEGRAL search for 511 keV emission line from Galactic X-ray binaries	Giovanni De Cesare
09:55	The 511 keV sky as seen by INTEGRAL/SPI, CGRO-OSSE and GRS/SMM combined	Gerry Skinner
10:15	Coffee break	
Session 10 - Antimatter from Dark or Domestic Matter - Chair : Céline Boehm		
10:35	Positrons and antiprotons from dark matter	Pierre Salati
11:20	Interacting dark matter contribution to the Galactic 511 keV gamma ray signal: constraining the morphology of INTEGRAL/SPI observations	Aaron C. Vincent
11:40	A local contribution to the Galactic 511 keV annihilation radiation	Nidhal Guessoum
16:45	Excursion / Conference Dinner meeting-point : Schilthornbahn Mürren	

Friday, March 23

Session 11 - Positron and Positronium Interactions with Solids - Chair : Gleb Gribakin		
08:30	Positron and positronium interactions with condensed matter	Paul G. Coleman
09:15	Positronium formation, cooling and emission into vacuum from porous silica at low temperature	R.S. Brusa
09:35	Laboratory experiments with the high-intensity low-energy positron beam POSH: Positronium emission from oxides	Stephan Eijt
09:55	Application of positronium annihilation lifetime spectroscopy for the evaluation of the size of the free space in porous materials	Toshio Hyodo
10:15	Coffee break	

Session 12 - Terrestrial and Extraterrestrial Positrons - Chair : Gerry Skinner		
10:35	A direct observation of positrons with an astrophysics instrument	Michael S. Briggs
10:55	Runaway positrons in magnetized plasmas	Tünde Fülöp
11:15	Annihilation Radiation in Solar Flares and Supernova Remnants	Charles Dermer
11:35	Positron science with the Soft Gamma-ray Detector onboard ASTRO-H and future Compton telescope missions	Hirokazu Odaka

Session 13 - Baryon Asymmetry		
16:30	Why does the Universe contain matter?	John Ellis
17:15	Coffee break	

Session 14 - Future instruments for Observing e-e+ Radiation - Chair : Mark Leising		
17:30	Broad band Laue lenses for deep studies of the 511 keV celestial annihilation line	Filippo Frontera
17:50	Curved crystals as high-reflectivity components of a Laue lens to focus the 511-keV annihilation line	V. Guidi
18:10	NCT Goals and Performance on Mapping the Galactic Positron Emission	Alexander Lowell
18:30	What's next in the observation of Galactic Positron Annihilation ?	Peter von Ballmoos

Poster Session - posters are on display during the entire workshop		
P1	The 511 keV Emission and the Past Higher Activity of the Galactic Center Black Hole	A. Totani
P2	The matter content of active galactic nuclei jets	Roland Walter et al.
P3	Monte Carlo simulations of propagation and annihilation of nucleosynthesis positrons in the Galactic disk	Anthony Alexis et al.
P4	Galactic annihilation emission from nucleosynthesis positrons	Pierrick Martin et al.
P5	Resonance phenomena in heavy nuclei collisions and structurization of positron spectrum	A.V. Glushkov
P6	Plans for laboratory pair plasma diagnostics	X. Sarasola et al.
P7	A Simple Monte Carlo Approach to the Diffusion of Positrons in Gaseous Media	M.Girardi-Schappo et al.
P8	In-situ observation of near-surface structural changes in water ice films during sublimation by positron beam spectroscopy	S. Townrow et al.
P9	Correlation of pick-off annihilation cross section and the collisional cross section for Ps-atom/molecule collisions	Toshio Hyodo et al.
P10	Low energy positron-methane scattering	A. Tenfen et al.
P11	Excitation rates for nuclear isomers in hot plasma and photon-plasmon transitions in positronium and astrophysical plasma	O.Yu. Khetselius et al.
P12	Measurement of the photodetachment cross section of positronium negative ion	K. Michishio et al.
P13	Synthesis of Cold Antihydrogen in a Cusp Trap for Hyperfine Transition Experiments	Dan Murtagh et al.
P14	AD-ELENA, The Low Energy Antiproton Facility at CERN	Gerard Tranquille et al.
P15	How to find positrons in space	Ya.N. Istomin et al.
P16	Possibilities of Positron Diagnostics for Research of Dust Space Plasma	E.P.Prokopev et al.
P17	Simulation study of the 511 keV annihilation Line Observation with the Soft Gamma-ray Detector onboard ASTRO-H	Yuto Ichinohe et al.
P18	Large-Volume Cadmium Zinc Telluride Detectors for Future Astrophysical Instrumentation	Michelle L. Galloway et al.
P19	Proposal for a Laue lens tuned on the 511-keV annihilation line	A. Camattari et al.

Tuesday, March 20 08:30 **Context Setting Summary Talk**

Direct detection of cosmic-ray positrons

Mirko Boezio

Istituto Nazionale di Fisica Nucleare Sezione di Trieste
Area di Ricerca, Padriciano 99 - 34149 Trieste, Italy

Positrons are a natural component of the cosmic radiation being produced in the interaction between cosmic rays and the interstellar matter. They have been shown to be extremely interesting for understanding the propagation mechanisms of cosmic rays. Furthermore, positrons may also be created by dark matter particle annihilations in the galactic halo or in the magnetospheres of near-by pulsars. The nature of dark matter is one of the most prominent open questions in science today. An observation of positrons from pulsars would open a new observation window on these sources. Cosmic-ray positrons were first observed in pioneering experiments in the sixties. Several experiments, equipped with state-of-the art detectors, have recently presented or are going to present new results on the composition of the charged cosmic radiation with a significant improvement in statistics and systematics with respect to existing data. In this talk we will review these experiments and present their most recent scientific results.

Tuesday, March 20 09:15

Positron and Antiproton Measurements in the Cosmic Rays with the PAMELA Space Experiment

E. Mocchiutti on behalf of the PAMELA Collaboration
INFN, Sezione di Trieste
Padriciano 99, I-34149 Trieste, Italy

Presenter : Emiliano Mocchiutti

The PAMELA satellite-borne experiment has presented new results on cosmic-ray positrons that can be interpreted in terms of dark matter annihilation or pulsar contribution. PAMELA is collecting data since June 2006 when it was launched on board the Russian satellite Resurs-DK1. Consisting of a permanent magnet spectrometer with MDR exceeding 1 TV, an electromagnetic calorimeter 16 X0 deep, a neutron detector, time of flight system and anti-counters, PAMELA apparatus has been specifically tuned in order to identify and study the antiparticle component of the cosmic rays. Main results after five years of data taking will be presented with a particular focus on positron and antiproton analyses.

Tuesday, March 20 09:35

Anisotropy studies in cosmic ray electron/positron flux with the PAMELA satellite

Donatella Campana, Ugo Giaccari, Giuseppe Osteria for the Pamela Collaboration
INFN Napoli
Via Cintia, I-80126, Italy

Presenter : Ugo Giaccari

Recent observations from PAMELA show that the cosmic-ray positron fraction e+/(e+ + e-) increases sharply at energy above 10 GeV. This behavior cannot easily be explained with the secondary positrons produced in the collisions of the cosmic ray nuclides with the interstellar medium.
Possible explanations rely on astrophysical positron sources, dark matter (DM) annihilations or DM decays. Such explanations could be tested from the predicted anisotropy in the arrival directions of electrons and positrons. In the astrophysical explanation, electron-positron pairs can indeed be produced in astrophysical sources like pulsars and supernova remnants and an anisotropy could be observed due to the contributions of the nearby sources. Also the DM scenario could lead an anisotropy signal for the inhomogeneities in the DM spatial distribution towards the local DM clumps (for instance in the Galactic Center).
In this talk we will present the over density studies of the electrons and positrons detected by the PAMELA to find possible excesses of events for different angular scale up to 90¯. We will also discuss the possibility to find a significant dipole anisotropy which constitutes a powerful tool to discriminate between the astrophysical and DM origins of the positron excess.

Tuesday, March 20 09:55

Cosmic-Ray Positron Measurement with the Fermi-LAT

M. Ackermann(1), S. Funk(1), W. Mitthumsiri(1), C. Sgrò(2), J. Vandenbroucke(1),
and the Fermi-LAT Collaboration

(1) W. W. Hansen Experimental Physics Laboratory,
Kavli Institute for Particle Astrophysics and Cosmology,
Department of Physics and SLAC National Accelerator Laboratory, Stanford University, Stanford, CA 94305, USA;
(4) Istituto Nazionale di Fisica Nucleare, Sezione di Pisa
I-56127 Pisa, Italy

Presenter : Warit Mitthumsiri

The Fermi-LAT does not carry an on-board magnet and, therefore, is not expected to be able to measure the charge of a particle. However, with an up-to-date geomagnetic field model, we are able to calculate a cosmic-ray particle's trajectory and use the arrival direction to differentiate electrons from positrons. This technique allows Fermi to measure the electron and positron spectra separately between 20-200 GeV and confirm that the positron fraction is increasing with energy in that energy range. We present the analysis principle, background subtraction methods, and the recently published results of this measurement.

Tuesday, March 20 10:35 **Context Setting Summary Talk**

Positron and Positronium scattering and annihilation in atomic and molecular systems

Michael Charlton

Department of Physics, College of Science, Swansea University
Singleton Park, Swansea, SA2 8PP, UK

Studies of the rich variety of interactions of positrons and positronium with atoms and molecules have been underway for around six decades. Early work relied upon the stopping of beta-particles emitted from a radioactive source directly inside the sample under investigation. Although much progress was made, ultimately the experimenter had almost no influence on the collision energy or process. The advent of controlled, quasi-mono-energetic positron beams has revolutionised this field and accurate energy-resolved cross sections are known for an array of targets and processes. These include the important processes of ionization and positronium formation in the positron case, and annihilation. We will review the experimental situation with respect to positron and positronium impact on atoms and molecules together with aspects of relevant theory. We will focus our discussion on species and processes likely to be of most interest and importance in the astrophysical context.

Tuesday, March 20 11:20

Recent experiments on positronium negative ions

Y. Nagashima

Tokyo University of Science
1-3 Kagurazaka, Shinjuku, Tokyo 162-8601, Japan

It is well known that an electron can bind to a positron to form a positronium. Another electron can also bind to the positronium weakly to form a positronium negative ion. The electron binding energy to the positronium was calculated to be about 0.33eV, which is less than half the binding energy of hydrogen negative ions.
The existence of the positronium negative ions was confirmed in the pioneering work by Mills in 1981 using the beam-foil method. After this experiment, there have been only a few experiments concerning the ions, due to the extremely low production efficiency.
In 2006, we developed a new method of producing the ions. Some of slow positrons injected onto a tungsten surface lose their energy in the bulk, diffuse back to the surface and then are emitted as the ions. Although the formation efficiency observed was less than 0.01%, a dramatic enhancement of the efficiency to 1% has been achieved by coating Cs or Na onto the surface. This technique has enabled us to do new experiments. We have succeeded in the first observation of the photo-detachment of the ions.
This presentation will give an overview of recent experimental studies on the ions.

Tuesday, March 20 11:40

Collisions of Positrons and Positronium with Atoms and Molecules

G. Laricchia, S. Brawley, D. Cooke, P. Fransman, D.J. Murtagh and M. Shipman

UCL Department of Physics and Astronomy, University College London, London WC1E 6BT, United Kingdom

Presenter : Simon Brawley

Recent progress in the study of positrons and positronium colliding with atoms and molecules at energies in the range (1-1000) eV will be presented. The focus will be on experimental techniques and results. Measurements of positronium formation and direct ionization by positron impact now include cross-sections for Ps formation in an excited state and/or excitation of the residual ion. Data on the scattering and fragmentation of positronium have also been acquired. Comparisons with theories and other projectiles will be made where possible, and future prospects considered.

Tuesday, March 20 16:30 **Context Setting Summary Talk**

Astrophysical sources of Galactic positrons

Nikos Prantzos

Institut d'Astrophysique de Paris
98 bis boulevard Arago - 75014 Paris, France

I will review the properties of the various astrophysical sources of Galactic positrons, in the light of current observational constraints. I will discuss, in particular, the constraints imposed by the 511 keV emission of positron annihilation, which has been detected almost 40 years ago and which still constitutes a puzzle for high energy astronomy.

Tuesday, March 20 17:15

Positron generation in the magnetospheres of neutron stars

Ya.N. Istomin

Lebedev Physical Institute
Leninsky Prospect 53, Moscow, Russia

We discuss the processes of the generation of relativistic positrons in magnetospheres of rotating magnetized neutron stars. Both not very strong magnetic fields, B=10^12 Gauss, typical for radio pulsars, and superstrong magnetic fields, B=10^14, 10^15 Gauss, typical for so- called magnetars, are considered. It is shown that superstrong magnetic fields do not suppress particle production. Intervals of neutron star parameters, first of all rotation periods and magnetic field strengths, allowing effective positron generation have been found. We investigate also absorption of a high energy photon from the external cosmic gamma ray background in the inner vacuum neutron star magnetosphere which triggers the generation of a secondary positron-electron plasma and gives rise to a lightning - a lengthening and simultaneously expanding plasma tube. The number of positrons produced by one photon in the lightning during its lifetime reaches 10^28.

Tuesday, March 20 17:35

Wide-Band Spectra of Magnetar Persistent and Burst Emission

Y. E. Nakagawa(1), K. Makishima(2), T. Enoto(3), T. Sakamoto(4), T. Mihara(5), M. Sugizaki(5), K. Yamaoka(6), K. Hurley(7), A. Yoshida(6), P. Gandhi(8), M. Tashiro(9), M. Mikio(10)

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(9) Department of Physics, Saitama University, 255 Shimo-Okubo, Sakura-ku, Saitama, Saitama 338-8570, Japan;
(10) Department of Physics, Tokyo Institute of Technology, Ookayama 2-12-1, Meguro-ku, Tokyo 152-8551, Japan

Presenter : Y. E. Nakagawa

Magnetars are highly magnetized neutron stars with field strengths greater than the quantum critical level 4.4*10^13G (Thompson & Duncan 1995). Soft gamma repeaters (SGRs) and anomalous X-ray pulsars (AXPs) are phenomenologically defined to be magnetars showing persistent X-ray emission and sporadic bursts. These energetic phenomena are presumably related to electron-positron plasmas in their magnetospheres (Thompson & Beloborodov 2005). The spectra of the persistent emission consist of a thermal component <10keV and a hard X-ray component >10keV (e.g., Kuiper et al. 2006; Enoto 2010). Using data from Suzaku (Nakagawa et al. 2011; Enoto et al. submitted) and HETE-2 (Nakagawa et al. 2007, 2009), we discovered that burst spectra consist of the same components. Luminosities of the former component are correlated with that of the latter component over a few orders of magnitude (Nakagawa et al. 2011). These results suggest the possibility that the persistent emission may consist of numerous micro-bursts (Nakagawa et al. 2009, 2011). We observed the recently activated AXP4U0142+614 on 7 September 2011 using Suzaku. The spectra of the persistent emission in the active phase might be softer than that in the non-active phase. In this talk, we discuss the wide-band spectra of magnetar emission based on the luminosity correlation.

Tuesday, March 20 17:55

Electron-positron plasmas in large-scale cosmic structures: origin, evolution and interaction

Sergio Colafrancesco

INAF-AOR
Via di Frascati, 33, I-00040 Monte Porzio

Electron-positron plasmas can be ubiquitously found within the atmospheres of cosmic structures on large scales, from galaxies to galaxy clusters, as well as in the jets of active galaxies.
We discuss here the models for their origin and evolution and the consequences of their interaction with other thermal and non-thermal plasmas as well as with radiation and magnetic fields permeating large-scale cosmic structures.

Tuesday, March 20 18:30

Positron annihilation on atomic core electrons and in positive ions

D. G. Green and G. F. Gribakin

Department of Applied Mathematics and Theoretical Physics, Queen's University Belfast, BT71NN, Northern Ireland, United Kingdom

Presenter : Dermot G. Green

Low-energy positrons annihilate predominantly on the outermost valence electrons in atoms, molecules and in condensed matter systems.
Small fractions of positrons can, however, tunnel through the repulsive nuclear potential and annihilate on the core electrons.
The gamma rays produced in the annihilation events give rise to a Doppler-broadened energy spectrum that is characteristic of the electronic states involved: e.g., annihilation on the tightly-bound core electrons results in a distinct signature in the high-energy region of the spectrum.
A dramatic role is played in the annihilation process by short-range electron-positron and positron-atom correlations: they significantly enhance the annihilation rate and alter the shape and magnitude of the gamma spectra.

We use diagrammatic many-body theory to calculate the gamma spectra and rates for positrons annihilating with the core electrons of many-electron atoms and positive ions.
We find that the short-range correlation enhancement is significant for both the valence and core subshells.
Its magnitude is shown to follow a simple and physically motivated scaling with the subshell ionization energy (or analogously, the charge Z of the ions).
Overall, excellent agreement is obtained with the experimental data for annihilation on noble atoms of the Surko group at the University of California (San Diego).

Tuesday, March 20   18:50

Positron annihilation in a superstrong magnetic field

Sylwia Lewicka(1) and Jerzy Dryzek (2)

(1) The Henryk Niewodniczański's Institute of Nuclear Physics, PAN ul. Radzikowskiego 152, 31-342 Kraków, Poland
(2) Institute of Physics, Opole University, ul. Oleska 48, 45-052 Opole, Poland

Presenter : Jerzy Dryzek

We consider the process of annihilation of positrons in strong magnetic field above the critical field, i.e. 4.4x10^13 G as it is in the pulsar magnetosphere with plasma or magnetostars. The exact solution of the Dirac equation for an electron/positron in the magnetic field allows us to obtain the expression for the cross section for the two-photon annihilation process in first order of approximation of the perturbation theory. The obtained total cross section is an almost linear function of the magnetic field instead of exponential as it was reported by other authors. The calculations indicate also the focus of the annihilation radiation in the direction of the magnetic field. The energetic spectra of the annihilation in flight photons depend on the magnetic field. We consider also the positronium state in the superstrong magnetic field. Using the full wave function obtained by the use of Bethe-Salpeter equation we have calculated the positron annihilation density and then the annihilation photon angular correlation function. Its shape and intensity strongly depend on the magnetic field. We conclude that the shape parameter or FWHM of the annihilation line which occur in magnetars increase as the power function of the values of magnetic field.

Tuesday, March 20 19:10

Plans for a laboratory electron-positron plasma experiment

Thomas Sunn Pedersen(1), Xabier Sarasola(1), Christoph Hugenschmidt(2), Cliff M. Surko(3), James R. Danielson(3), Lutz Schweikhard(4), Gerrit Marx(4)

(1) Max-Planck Institute for Plasma Physics, Greifswald, Germany
(2) Dept. of Physics, Technical University of Munich, Munich Germany
(3) Dep. of Physics, University of California, San Diego, USA
(4) Dept. of Physics, Ernst-Moritz-Arndt University, Greifswald, Germany

Presenter : Thomas Sunn Pedersen

Electron-positron (pair) plasmas are believed to be abundant in space but have not yet been created on Earth, even though they have attracted attention not just because of their astrophysical relevance but also because of the unique plasma physics behavior that is expected of these plasmas. The lack of experimental success is in part because a suitable trap was not yet identified, and in part because available positron sources are relatively weak. In 2002, a stellarator was proposed as an adequate trap for a pair plasma [T. Sunn Pedersen and A. H. Boozer, Phys. Rev. Letters 88, 205002]. Preparatory experimental research started in 2004 in the Columbia Non-neutral Torus (CNT) stellarator. This research has now concluded successfully, and a new stellarator pair plasma experiment, by the name of APEX (A Positron Electron eXperiment), is currently being designed. The experiment will be built at the world's most intense source of moderated positrons, NEPOMUC in Munich, Germany, and will be combined with a Positron Accumulation eXperiment (PAX).
This talk will review the relevant lessons learned from operation of the CNT stellarator, and will describe the plans and goals for APEX and PAX.

Wednesday, March 21 08:30 **Context Setting Summary Talk**

Theory of low-energy positron-matter interactions

Gleb Gribakin

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Positron interactions with atomic and molecular targets are strongly affected by many-body correlations involving the positron and valence electrons. Physically these correlations describe target polarisation and virtual positronium formation. For low-energy positrons these effects overcome the positron repulsion from the nucleus and result in an attractive interaction between positrons and neutral atomic and molecular species. This attraction gives rise to low-lying positron virtual levels and, for more polarisable targets, positron bound states with neutral species. As a result, positron-atom elastic cross sections and annihilations rates at low energies are strongly enhanced. Here much insight and good agreement with experiment is obtained by many-body theory calculations. An even greater enhancement of the annihilation rates is observed in polyatomic molecule. For molecules positron binding leads to the emergence of vibrational Feshbach resonances, which increase the probability of annihilation by orders of magnitude.
In spite of the complexity of the system, much understanding has been obtained recently due to joint theoretical and experimental efforts [1]. [1] G. F. Gribakin, J. A. Young, and C. M. Surko, Positron-molecule interactions: Resonant attachment, annihilation, and bound states, Rev. Mod. Phys. 82, 2557-2607 (2010).

Wednesday, March 21 09:15

Bound states of positron with nitrile species with several multi-component molecular theories

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Presenter : Masanori Tachikawa

Characteristic features of the positron binding structure of some nitrile (-CN functional group) species such as acetonitrile, cyanoacetylene, acrylonitrile, and propionitrile are discussed with the configuration interaction scheme of multi-component molecular orbital calculations [1]. This method can take the electron-positron correlation contribution into account through single electronic - single positronic excitation configurations. Our positron affinity (PA) value of HCN molecule with electronic 6-31++G(2df,2pd) and positronic [15s15p3d2f1g] GTF basis sets is 38 meV, which is in reasonable agreement with our previous QMC value of 38(5) meV [2], though our variational energy of [HCN;e+] species is still 0.5 hartree higher than that obtained by QMC. Our PA value of acetonitrile is calculated as 135meV, which agrees to within 25% with the recent experimental value of 180meV [3]. Our PA values of acrylonitrile and propionitrile (155 and 164 meV) are largest among these species, which is consistent with the relatively large dipole moments of the latter two systems.

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Wednesday, March 21 09:35

Close-coupling approach to positron-atom collisions

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Presenter : Igor Bray

Positron scattering on atoms is inherently a two-centre (atom and Ps) problem that poses considerable computational difficulty. Yet its understanding is of considerable importance in a range of terrestrial applications, pure sciences, and as a prototype of all chemical reactions. The ability to accurately calculate rearrangement collisions, as happens in all chemical reactions, remains a challenge without uniform solution. Ps-formation is an example of a rearrangement channel that the close-coupling method can include explicitly, though at the cost of considerable technical challenge. Nevertheless, immense progress has been recently achieved with several benchmarks established.

Wednesday, March 21 09:55

Implications of Feshbach resonances for molecular annihilation spectra of astrophysical relevance*

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Presenter : Cliff Surko

Positrons bind to most molecules. As a result, vibrational Feshbach resonances dominate the annihilation spectra at low energies [1]. As a consequence, resonant annihilation rates can be orders of magnitude larger than the Dirac rate predicted for simple two-body collisions. This resonant process is reviewed, and the annihilation signatures expected for molecules are described, including those of astrophysical relevance [e.g., polycyclic aromatics (PAHs)]. A new resonant annihilation mechanism, statistical multimode resonant annihilation (SMRA) will be discussed [2]. SMRA extends to energies beyond the molecular vibrations (e.g., in some cases _ 1 eV) and is present in most, if not all, resonant annihilation spectra observed to date. In cases where the positron-molecule binding energy is large, such as the PAHs, SMRA can dominate important regions of the spectra.

* This work is supported by the U. S. NSF, grant PHY 10-68023.

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Wednesday, March 21 10:35 **Context Setting Summary Talk**

Antimatter search in Cosmic Rays

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Since the detection of the first positron by Anderson, the search of antimatter in cosmic rays has been a challenging, sometimes rewarding, sometimes frustrating endeavor. Starting from an historical perspective, we will review the current status and perspective in this field.

Wednesday, March 21 11:20

Probing the CR positron/electron ratio at the TeV regime through Moon shadow observation with atmospheric Cherenkov telescopes.

Pierre Colin for the MAGIC collaboration

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Recent measurements of the CR electrons and positrons with the PAMELA and Fermi-LAT experiments show an unexpected increase of the positron fraction above 10 GeV up to ~200 GeV. There are different interpretations to explain that rise, the most discussed ones being the signature of nearby compact astrophysical source(s) or of dark matter annihilation/decay. Probing the positron fraction above 200 GeV would help to disentangle among the different scenarios. However, the current detectors, based on satellite or balloon, have limited collection area and radiation lengths that prevent measurement at such high energies. In contrast, Imaging Atmospheric Cherenkov Telescopes (IACT) can extract the cosmic lepton signal from the hadronic CR background between a few hundred GeV and a few TeV and reconstruct the energy and incident direction with a very good resolution. In addition, by using the natural spectrometer formed by the Moon and the geomagnetic field, it is possible to measure the positron fraction at the TeV regime through the observation of the CR Moon shadow. Despite the technique is particularly challenging because of the high background light induced by the Moon, the MAGIC collaboration has performed for the first time such observations in 2010 and 2011. Here we present the observation strategy and the performance achieved during this campaign as well as the perspective for the next generation of IACT arrays (CTA).

Wednesday, March 21 11:40

A Novel Electromagnetic Calorimeter for a Balloon Borne Spectrometer

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Presenter : Alexander Howard

The electromagnetic calorimeter is a critical component for any balloon based cosmic ray spectrometer for both energy resolution and also background rejection. The development, fabrication and testing of a novel sampling calorimeter will be presented. The design is a lead-scintillator sandwich with wavelength-shifting fibres embedded into segmented scintillator plates. Fibres are read-out with different Silicon-PMTs on each end - Hamamatsu MPPCs and Zekotek MAPDs. The Zekotek device benefits from 15000 pixels/mm2 giving a higher saturation tolerance, but also reduced gain. By utilising both types of Si-PMTs the dynamic range of the calorimeter can be complete from MIPs up to the TeV energy scale for positrons. The design concept should offer an energy resolution of 15%/sqrt(E) and proton rejection up to 10^4. With a magnet and tracker the proton rejection factor could be extended to in excess of 10^6. A 24 layer 400mm x 400mm prototype calorimeter is in the process of being produced for a test beam in summer 2012. First characterisation and uniformity results will be presented. Results from a 2010 testbeam with a smaller prototype which used mixed-gain/attenuated read-out will also be shown. Potential physics reach of a balloon spectrometer beyond PAMELA and FERMI-LAT will also be discussed.

Wednesday, March 21 16:30 **Context Setting Summary Talk**

Trapped Antihydrogen: A new frontier in fundamental physics

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Antihydrogen, the bound state of an antiproton and a positron, has been produced at low energies at CERN since 2002. Antihydrogen is of interest for use in a precision test of nature's fundamental symmetries. The charge conjugation/parity/time reversal (CPT) theorem, a crucial part of the foundation of the standard model of elementary particles and interactions, demands that hydrogen and antihydrogen have the same spectrum. Given the current experimental precision of measurements on the hydrogen atom, subjecting antihydrogen to rigorous spectroscopic examination would constitute a compelling, model-independent test of CPT. Antihydrogen could also be used to study the gravitational behaviour of antimatter. However, until recently, experiments have produced antihydrogen that was not confined, precluding detailed study of its structure. Experimenters working to trap antihydrogen have faced the challenge of trapping and cooling relativistic antiprotons and use them to make antihydrogen cold enough to be trapped in a magnetic minimum trap with a depth of only 50 _V. In November 2010 the ALPHA collaboration demonstrated the first trapping of antihydrogen thus opening the door to precision measurements on anti- atoms which can soon be subjected to many of the same techniques as developed for atoms. In this talk I will show how we succeeded in observing the release of trapped antihydrogen from our magnetic trap and how some of the key challenges faced to reach this milestone were met. I will also discuss these results in the general context of antihydrogen research and the implications for future precision comparisons of matter and antimatter

Wednesday, March 21 17:15

Positron and positronium for the GBAR experiment

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The aim of the GBAR (Gravitational Behaviour of Antihydrogen in Rest) collaboration is to measure the acceleration of neutral antihydrogen atoms in the gravitational field of the Earth. The experimental scheme requires a high density ortho-positronium cloud that would serve as target for antiprotons for the Antiproton Decelerator facility at CERN. We constructed a slow positron source at IRFU CEA Saclay, based on a low energy (4.3 MeV) linear electron accelerator (linac). The source will feed positrons into a high field particle trap. Intense positron pulses from the trap will be converted to slow ortho-positronium by a converter, based on porous silica films. We give a short description of the GBAR experimental scheme, present the first results on the performance of the positron source and give a short summary on the ongoing work to develop an efficient positron- ortho-positronium converter setup.

Wednesday, March 21 17:35

Calculations of antihydrogen loss from collisions with hydrogen and Helium

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Presenter : Svante Jonsell

The life time of trapped antihydrogen in an imperfect vacuum is determined by the rate of collisions with the background gas. Antihydrogen can be destroyed both by direct annihilation processes (antiproton-nucleus or electron-positron) or through rearrangement processes where the antiproton sticks to an atomic nucleus, with the binding energy carried away by complexes like Ps, PsÓ or an unbound positron and/or electrons. Since magnetic traps for antihydrogen are shallow compared to the expected temperature of the background gas, elastic collisions is also a source of antihydrogen loss. We calculate relevant cross sections for helium-antihydrogen and (atomic) hydrogen-antihydrogen scattering for energies up to 0.01 atomic units (or 3000 Kelvin). Our calculation includes elastic scattering, direct antiproton - nucleus annihilation, and rearrangement into ground-state positronium. For Helium-antihydrogen scattering we find evidence of shape resonances which enhance loss rates at energies around 30 Kelvin.

Wednesday, March 21 17:55

AEGIS: testing the WEP with a pulsed cold beam of antihydrogen

Michael Doser (on behalf of the AEGIS collaboration)

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AEGIS (Antimatter Experiment: Gravity, Interferometry, Spectroscopy) is an experiment currently being set up at CERN with the goal of measuring the gravitational interaction between matter and antimatter. In AEGIS, antihydrogen will be produced by charge exchange reactions of cold antiprotons with positronium atoms excited in a Rydberg state (n~20). In the first phase of the experiment, acceleration in a controlled way by an electric field gradient (Stark effect) and subsequent measurement of free fall in a Moiré deflectometer will allow a first test of the weak equivalence principle with antimatter. In the present talk, after a general description of the experiment, the present status of advancement will be reviewed, with special attention to the production and excitation of positronium atoms.

Wednesday, March 21 18:30

The AX-PET experiment:
A demonstrator for an axial Positron Emission Tomography

Chiara Casella (on behalf of the AX-PET collaboration)

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PET (Positron Emission Tomography) is a tool for in-vivo functional imaging, successfully used since the earliest days of nuclear medicine. It is based on the detection of the two coincident 511 keV photons from the annihilation of a positron, emitted from a radiotracer injected into the body. Tomographic analysis of the coincidence data allows for a 3D reconstructed image of the source distribution.
The AX-PET experiment proposes a novel geometrical approach, in which long scintillator crystals (LYSO) are placed axially in the tomograph, and are individually readout by G-APD (Geiger-mode Avalanche Photo Diodes). Arrays of WLS strips, also individually readout by G-APD, are placed behind each layer of crystals, to measure the axial coordinate of the photon interaction point.
Two AX-PET modules have been built and fully characterized with point-like sources, demonstrating competitive performance in term of spatial (R_FWHM ~ 1.35 mm in the axial direction) and energy (R_FWMH ~ 12% at 511 keV) resolutions. Used in coincidence, the two modules represent the demonstrator for a PET prototype. The demonstrator has been used for the reconstruction of images of several phantoms filled with F-18 based radiotracers.
The AX-PET detector, its performance and the first reconstructed images of different phantoms will be shown.

Wednesday, March 21 18:50

A Scintillation-Solid State Detector as the Perspective Tool for Registration of Beams of High Energy Particles in Visible and Infrared Region

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Presenter : Anatoly Maltsev

Application of the solid-state scintillation detector in complex diagnostics system of beams of high energy particles in visible and infrared region is considered.

Wednesday, March 21 19:10

Positronium: our spy to the Mirror World

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The understanding of the origin of dark matter has great importance for cosmology and particle physics. Several interesting extensions of the standard model dealing with solution of this problem motivate the concept of hidden sectors. Among these models, the mirror matter (MM) model is certainly one of the most interesting. It explains the origin of parity violation in weak interactions and provides a natural ground for the explanation of dark matter. The MM could have a portal to our world through photon-mirror photon mixing. This mixing would lead to orthopositronium (o-Ps) to mirror orthopositronium oscillations, the experimental signature of which is the apparently invisible decay of o-Ps. In this talk, we will review this concept and describe an experiment to search for o-Ps$\rightarrow$invisible decays by using a slow positron beam and a massive 4π crystal calorimeter. The expected sensitivity in the mixing strength of 10^{-9} is more than one order of magnitude below the current BBN limit and in a region of parameter space of great theoretical and phenomenological interest. An experiment with such sensitivity is particularly timely in light of the recent claims of the observation of the annual modulation signal consistent with a mirror type dark matter interpretation.

Thursday, March 22 08:30 **Context Setting Summary Talk**

Our Galaxy as it Shines in Positron Annihilation Gamma-Rays

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Positrons are ejected from cosmic sources into interstellar space, where their annihilation gamma-rays have been measured since about 50 years. It took considerable time and effort to clearly discriminate and identify the characteristic gamma-ray emission to interstellar annihilation mostly, also because hopes for new information about specific types of high-energy sources had been placed on measuring their positrons. Initially measured in our Sun, positron emission has been sought from magnetized neutron stars, accretion flows onto compact stars and black holes including their plasma jets and the nuclei of active galaxies, and gamma-ray burst sources. Also radioactive decay produces positrons and is attributed to sources of nucleosynthesis. Gamma-ray telescopes aboard survey missions CGRO and INTEGRAL provided quality spectra and a map of the sky in the emission from annihilations of positrons. We learned that a warm, partially ionized medium is the site where the observed gamma-rays originate. The are puzzled by the gamma-ray emission map, as it is dominated by a bright and extended apparently spherical emission region from around the Galaxy's center, with only weak emission from the disk of the Galaxy. This on one hand may confirm earlier expectations that positrons should arise predominantly from sources of nucleosynthesis distributed throughout the plane of the Galaxy. But the other plausible sources of positrons may be more significant as positron sources on the Galactic scale than thought before, in the plane and therefore also in the bulge of the Galaxy. Only when we understand the surprisingly bright emission from the central region in the Galaxy, we could consider a tantalizing alternate and new interpretation of the inner-Galaxy signal as a first direct detection of dark matter through annihilations in the Galaxy's gravitational well. The various aspects of positron astrophysics will be discussed, and also related to the respective gamma-ray telescope capabilities.

Thursday, March 22 09:15

Can positrons from Sgr A* produce the 511 keV emission in the galactic bulge?

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Presenter : P. Jean

The supermassive black hole SgrA* is a good candidate source of positrons in trying to explain the 511 keV line emission that has been observed from the Galactic Center since the seventies.
Several processes have been proposed for the production of positrons by SgrA*: jet of electron-positron pairs, wind of pairs from its accretion disk, burst of positrons following the disruption/accretion of a massive star in the vicinity of SgrA*, etc. However, these proposed scenarios have not taken into account the propagation of positrons in this region in a realistic, physical fashion, and thus their ability to fill the Galactic bulge (as observed) has remained unclear.
We have investigated the transport of positrons in the central 10 pc around Sgr A*, using Monte Carlo simulations. We employed a detailed model of the interstellar gas and magnetic field in this region. We then computed the fraction of positrons escaping the central 10 pc as well as the spectral and temporal properties of the annihilation emission as functions of proposed scenarios.
Our results allow us to set constraints on the models of positron production from Sgr A* (initial energies, processes, etc.) and on the propagation required to reproduce the observed emission features.

Thursday, March 22 09:35

The INTEGRAL search for 511 keV emission line from Galactic X-ray binaries

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Presenter : G. De Cesare

There is a suggestion that at least a fraction of the Galactic positrons can originate in X-ray binaries. Evidence of a transient annihilation broad line from the source 1E 1740.7-2942 was measured by GRANAT/SIGMA in 1990 and reported, but not confirmed by the CGRO/OSSE data. More recently the INTEGRAL data suggested some evidence of an asymmetry of the 511 keV emission along the Galactic longitude, possibly correlated with the distribution of the hard X (E > 20 keV) Low Mass X-ray Binaries. Also in this case, subsequent data analysis did not confirm these results. With the imager IBIS on-board INTEGRAL satellite, using about 5 years of observations we find no evidence of 511 keV point sources. In the center of the Galaxy we estimate a 1.6 x 10^{-4} ph $cm^{-2}s^{-1}$ flux upper limit; a similar limit is given in a wide area in the Galactic center region. Recently Laurent & Titarchuk (2012) demonstrate that in BH binaries the lack of a 511 keV radiation can be explained by that photons related to 511 keV line are reprocessed in the local environment and even if they escape directly to the Earth observer they are seen at much lower energies, in the 15-25 keV range because the gravitational redshift.

Thursday, March 22 09:55

The 511 keV sky as seen by INTEGRAL/SPI, CGRO-OSSE and GRS/SMM combined

Gerry Skinner(2,1), Peter von Ballmoos(1), Pierre Jean(1), Jürgen Knödlseder(1), Mark Leising(3), Peter Milne(4), Georg Weidenspointner(5,6)

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Presenter : Gerry Skinner

Over more than 30 years three space-borne spectrometers have accumulated a wealth of data on the angular and spectral distribution of the 511 keV Galactic e-/e+ annihilation radiation: GRS on the Solar Maximum Mission monitored the 511 keV line from the Galactic Center region in the eighties, the first maps of the inner Galaxy were produced by OSSE/CGRO in the nineties, and since 2002 SPI/INTEGRAL has been performing high resolution imaging spectroscopy over the entire sky. Until now our understanding of the 511 keV emission, and hence of the origin of the Galactic positrons, has been largely based on the independent analysis of the individual dataset.
We present an analysis of the combined data, constraining the spatial distributions of the galactic e-/e+ annihilation radiation by fitting the same models to the three data sets, and discuss how the spatial distribution constrains the potential source(s) of galactic positrons.

Thursday, March 22 10:35 **Context Setting Summary Talk**

Positrons and antiprotons from dark matter

Pierre Salati

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Weakly interacting and massive particles (WIMP) have been, suggested as plausible candidates to the astronomical dark matter (DM). Should the putative WIMPs exist, they would continuously annihilate, within the Milky Way halo and yield rare antimatter particles -- such as, antiprotons and positrons. But these are already manufactured inside, the Galactic disc by high-energy cosmic ray protons and helium nuclei, impinging on the interstellar medium. I will review how the DM signal, and its astrophysical background are modelled. I will gauge the accuracy, of the theoretical predictions. A central issue is the transport of charged, particles throughout the Galactic magnetic halo.
The discovery three years ago of a cosmic ray lepton anomaly has raised, the tremendous hope that WIMPs were not just a fantasy. The dust has now settled down. The WIMP explanation of the PAMELA excess seems in difficulty, whereas a much more natural -- and convincing -- explanation based on pulsars, has been proposed.

Thursday, March 22 11:20

Interacting dark matter contribution to the Galactic 511 keV gamma ray signal: constraining the morphology of INTEGRAL/SPI observations

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Presenter : Aaron C. Vincent

We compare the full-sky morphology of the 511 keV gamma ray excess measured by the SPI/INTEGRAL experiment to predictions of models based on dark matter (DM) scatterings that produce low-energy positrons: either MeV-scale DM that annihilates directly into e+ e- pairs, or
heavy DM that inelastically scatters into an excited state (XDM) followed by decay into e+e- and the ground state. The required scattering cross section is 4.6*10^-25 (m_chi/GeV)^2 cm^3 s^-1. By direct comparison to the data, we find that such explanations are consistent with dark matter halo profiles predicted by numerical many-body simulations. Our results favor an Einasto profile over the cuspier NFW distribution and exclude decaying dark matter scenarios whose predicted spatial distribution is too broad. Our analysis is independent of the details of the DM model, and we obtain a good fit to the shape of the signal using six fewer degrees of freedom than previous best empirical fits to the 511 keV data. We find that the ratio of flux from the galactic bulge to that of the disk is between 1.9 and 2.4, taking into account that 73% of the disk contribution may be attributed to the beta decay of radioactive 26Al.

Thursday, March 22 11:40

A local contribution to the Galactic 511 keV annihilation radiation

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Presenter : Nidhal Guessoum

Besides a narrow bulge at the Galactic Center and an extended disk-like contribution, the distribution of the 511 keV emission observed by SPI/INTEGRAL shows a wide halo component. The considerable width of this halo (10¯-20¯), and a still poorly explored asymmetry in the disk or halo component, are suggestive for a local component of annihilating positrons. Through the reanalysis of about eight years of SPI data, we are assessing the contribution from nearby potential annihilation sites to the gamma ray line flux at 511 keV. We then discuss possible positron production sites, positron transport and annihilation in a number of potential sites in the local Galactic environment.

Friday, March 23   08:30   **Context Setting Summary Talk**

Positron and positronium interactions with condensed matter

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Positrons and positronium (Ps) have been used to probe electrons in condensed matter, and hence gain information on the structural, electronic and chemical nature of materials on an atomic scale, for over fifty years. High-energy positrons entering a sample are rapidly thermalized (in ~1ps) and diffuse for up to 100-200ps (~ ns if Ps has been formed) before annihilation. The measurement of mean positron lifetimes yields information on electron density and has applications in the study of open-volume defects, in which diffusing positrons may be efficiently trapped; angular correlation of the annihilation gamma photons to study electron momentum densities with high precision (and thus, for example, map out Fermi surfaces), and Doppler broadening of annihilation radiation to monitor mean electron momenta with low resolution but high speed, enabling real-time measurements of structural changes. Additionally, by studying the formation and decay of Ps, particularly in liquids and soft matter, the field of Ps chemistry developed. Until the 1980's the field focused on bulk materials and the positron source was a radioisotope such as 22Na. The study of thin films and the surface and near-surface regions of solids was made possible by the development of controllable-energy (0.05 - 60 keV) positron beams, and all three techniques developed for bulk studies have been used in conjunction with such beams. This talk will aim to present a general overview of what has been achieved in the laboratory by applying positron and Ps spectroscopies to condensed matter. As well as fundamental positron-solid interactions, yielding information for example on the probability of trapping at, re-emission from, or Ps formation at, a solid surface, positron and Ps spectroscopies have been applied widely, for example to measure and monitor phase changes, the formation and evolution of structural defects (especially atomic-scale vacancies and nm pores), electronic structure, the chemistry of soft matter, and free volume in polymers, both in the bulk at or near the surfaces of materials.

Friday, March 23 09:15

Positronium formation, cooling and emission into vacuum from porous silica at low temperature

Roberto S. Brusa

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About 97 % of the annihilations in the Galaxy are known to occur after that positronium atoms are formed [1]. One among the processes bringing to Ps formation is the interaction of positrons with interstellar dust grains of different composition and different porosity. The different processes of Ps formation and emission from metal surfaces and from dielectrics will be briefly reviewed [2] and the need of information on Ps processes at low temperature will be pointed out. Recent results on positronium formation, cooling and emission into vacuum from porous silica held at low temperature will be presented and discussed [3-5].

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Friday, March 23 09:35

Laboratory experiments with the high-intensity low-energy positron beam POSH: Positronium emission from oxides

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The reported features of positron annihilation in the galaxy indicate a large positronium (Ps) fraction. The linewidth of the main component of the galactic 511 keV annihilation peak is about 2.5 keV, and is in certain models attributed to Ps annihilation in the warm partially ionized gas of the interstellar medium (ISM) at temperatures of the order of 10^4 K (_hot-Ps_). Oxides form a major fraction of dust particles in the ISM, and may contribute significantly to the observed positronium annihilation in the galaxy. We present laboratory experiments on a set of oxides which show pronounced positronium emission upon positron implantation at low-energy. High-resolution 2-dimensional images of the momenta of emitted para-positronium from MgO and SiO2 were obtained with the 2D-Angular Correlation of Annihilation Radiation (2D-ACAR) setup coupled to the Delft intense positron beam POSH. The Ps momentum distributions for these types of oxides were analyzed in terms of a Boltzmann distribution in order to extract the characteristic temperatures, which are situated in the hot-Ps range of 3û10^3 K to 3û10^4 K. Positronium fractions will be discussed. Finally, the possibilities for external users to perform laboratory experiments using the Delft intense low-energy positron beam POSH will be presented.

Friday, March 23 09:55

Application of positronium annihilation lifetime spectroscopy for the evaluation of the size of the free space in porous materials

Ken Wada and Toshio Hyodo

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High Energy Accelerator Organization (KEK), 1-1 Oho
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Presenter : Toshio Hyodo

Positron annihilation lifetime spectroscopy has been widely used for the evaluation of the size of pores in porous materials. It utilizes the reduction of the lifetime of ortho-positronium (o-Ps) due to the pick-off annihilation interactions with the cavity surfaces. The original and best-known model for such analysis, called Tao-Eldrup model [1, 2] is useful for the pores of sub-nm size. Extensions of this model for larger pores which have wide variety of industrial applications have also been reported [3,4]. This presentation reviews models developed so far, and then a new model for the extension to larger pores is presented. The new model is based on a straightforward classical picture valid in the large pore size limit, where the quenching rate of o-Ps is given by the pick-off annihilation probability per collision with the cavity wall times the collision frequency. When the model is adjusted so that its o-Ps lifetime-cavity size relation merges smoothly with that of the Tao-Eldrup model, it agrees with a model based on quantum mechanical picture [4] surprisingly well.

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[3] K. Ito, H. Nakanishi and Y. Ujihira, J. Phys. Chem. B 103, 4555 (1999).
[4] T. L. Dull, W. E. Frieze, D. W. Gidley, J. N. Sun and A. F. Yee, J. Phys. Chem. B 105, 4657 (2001).

Friday, March 23 10:35

A direct observation of positrons with an astrophysics instrument

Michael S. Briggs for the GBM TGF Team

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The Fermi Gamma-ray Burst Monitor (GBM) discovered unexpectedly strong positron emission from thunderstorms. Terrestrial Gamma-ray Flashes (TGFs) were discovered as intense flashes of gamma-rays produced by thunderstorms. Relativistic electrons are produced in the upper atmosphere by Compton scattering from the gamma-rays, as are positrons by pair production. Once the scattering length becomes long enough, the charged particles follow the Earth's magnetic field, forming a beam of relativistic particles. If a detector is on the field line that connects to the source, the particles are directly detected and position annihilation occurs in the spacecraft and detector, producing the signature 511 keV gamma-ray line. TGFs exhibit nearby many of the high-energy processes which we wish to observe in distant sources.

Friday, March 23 10:55

Runaway positrons in magnetized plasmas

T. Fülöp, G. Papp

Department of Applied Physics, Chalmers University of Technology
Göteborg, Sweden

Presenter : Tünde Fülöp

Runaway electron avalanches have been frequently observed in large tokamak disruptions and in electric discharges associated with thunderstorms. The energetic runaways produced in the avalanches may give rise to electron-positron pair production. At birth, these positrons are highly relativistic, and in addition they experience acceleration by the electric field. In this work we calculate the positron distribution produced by a typical avalanching runaway electron distribution and the fraction of positrons that run away. To obtain the positron velocity distribution, the Fokker-Planck equation including the positron production and annihilation rates and slowing-down terms has been solved. Detection of the annihilation radiation of runaway positrons is difficult, because it is overwhelmed by the Bremsstrahlung radiation from the electron population. On the other hand, the synchrotron (and Bremsstrahlung) radiation of runaway positrons is peaked in the direction opposite from that of the runaway electrons and that may be possible to detect. We have calculated the synchrotron radiation spectrum of the positrons for an avalanching positron distribution. The maximum of the synchrotron radiation spectrum should be around 1 micrometers. Since the radiated power is sensitive to the impurity concentration, temperature and other parameters, detection of positrons should give valuable information about these.

Friday, March 23 11:15

Annihilation Radiation in Solar Flares and Supernova Remnants

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Presenter : Charles Dermer

Ions accelerated in solar flares interact with the solar atmosphere to produce pions and radioactive isotopes of various elements. Charged pions decay, producing positrons which then make continuum gamma-ray emission via bremsstralung and highly Doppler-broadened positron annihilation radiation from those positrons that annihilate in flight with ambient electrons. The positrons that slow down annihilate to produce the 0.511 MeV positron annihilation line. The radioactive isotopes decay and produce positrons which then annihilate. We calculate both the pion-decay emission spectrum (from neutral pion gamma rays, secondary electron/positron bremsstrahlung and Compton scattering, and electron-positron annihilation radiation) and the detailed spectrum of the annihilation line. We compare these calculations with flare gamma-ray measurements and show how they provide constraints on the accelerated ion spectrum and the ambient medium where the positrons annihilate. We also apply the calculations to supernova remnant environments and calculate gamma-ray annihilation line and continuum spectra from different cosmic-ray proton and alpha-particle spectra for a range of conditions likely to hold in supernova remnants. These results are used to determine the annihilation line flux to continuum gamma-ray ratio if cosmic ray hadrons make the gamma rays.

Friday, March 23 11:35

Positron science with the Soft Gamma-ray Detector onboard ASTRO-H and future Compton telescope missions

H. Odaka (1), Y. Ichinohe (1), T. Sato (1), S. Takeda (1), S. Watanabe (1), M. Kokubun (1), T. Takahashi (1), H. Tajima (2), T. Tanaka (3), Y. Uchiyama (4), K. Nakazawa (5)

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(5) Department of Physics, Graduate School of Science, University of Tokyo, Hongo 7-3-1, Bunkyo, Tokyo, 113-0033, Japan

Presenter : Hirokazu Odaka

Compton telescopes composed of high-resolution detectors are promising instruments for sub-MeV and MeV gamma-ray astrophysics. In addition to gamma rays radiated by relativistic particles and nuclear gamma-ray lines in the universe, 511 keV line and continuum emissions originated from annihilations of positron and electron pairs near energetic sources (e.g. the Galactic center, black hole binaries) are important targets of such telescopes.
The Soft Gamma-ray Detector (SGD) onboard the ASTRO-H X-ray observatory, which is scheduled for launch in 2014, will be the first Compton telescope in orbit that is optimized for sensitive detection of soft gamma rays below 600 keV. Although soft-gamma-ray observations suffer from in-orbit background mainly due to radioactivation inside the detector through an orbital radiation environment, the SGD, which consists of multi-layer stacks of high-resolution semiconductor detectors, greatly improves the gamma-ray sensitivity by effective background-rejection technique based on the Compton kinematics.
In this talk, we present the current status of the SGD and its observational prospects for the positron astrophysics. Compton All-Sky Telescope, a future all-sky mission based on the SGD technology, is discussed as well.

Friday, March 23 16:30 **Context Setting Summary Talk**

Why does the Universe contain matter?

John Ellis

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Following the suggestion of Sakharov, it is generally thought that the presence of matter and absence of antimatter in the Universe is due to microscopic CP violation in particle interactions, but the precise mechanism for realizing this scenario remains unclear. The CKM mechanism for CP violation seems to be inadequate for this purpose, and options for realizing Sakharov's idea at the TeV scale are being constrained by experiments at the LHC. A promising alternative is CP violation in the decays of heavy singlet (right-handed) neutrinos, whose supersymmetric partners might have inflated the Universe, possibly leaving distinctive signatures in the cosmic microwave background radiation.

Friday, March 23 17:30

Broad band Laue lenses for deep studies of the 511 keV celestial annihilation line

Filippo Frontera on behalf of the "Laue" project Collaboration

University of Ferrara, Physics Department, Via Saragat, 1
44100 Ferrara, Italy

The development status of the LAUE project devoted to develop broad band (80-600 keV) Laue lenses will be reported, with particular emphasis to its science objectives, in particular the deep study of the celestial 511 keV annihilation line.

Friday, March 23 17:50

Curved crystals as high-reflectivity components of a Laue lens to focus the 511-keV annihilation line

V. Guidi, V. Bellucci, R. Camattari, I. Neri

University of Ferrara, Physics Department, Via Saragat, 1
44100 Ferrara, Italy

Presenter : V. Guidi

Observation of the 511-keV emission line resulting from the electron-positron annihilation would carry information about the distribution of positrons in the Galaxy. With this aim, a Laue lens as space-borne telescope would be an excellent tool to concentrate x-rays. Crystals with curved diffracting planes (CDP) can be used as high-efficiency optical components for the Laue lens, because they present no theoretical limitation about diffraction efficiency and their energy passband is controlled by simply adjusting their curvature. Amongst crystals with CDP, special interest is given to those within which the strain is generated with no need for any external bending devices. Here surface grooving is proposed as an efficient technique to reproducibly obtain self-standing bent crystals. Both silicon and germanium plates can be plastically bent by grooving one of their major surfaces, resulting in very good control of the curvature by proper adjustment of experimental parameters. Measurements carried out at ESRF on Si and Ge grooved crystals exhibited very high diffraction efficiency up to 700 keV. A Si crystal showed record diffraction efficiency of 95% at 150 keV. A systematic experimental study and a model based on the theory of elasticity are presented to investigate the properties of grooved crystals.

Friday, March 23 18:10

NCT Goals and Performance on Mapping the Galactic Positron Emission

Alexander Lowell (1), S.E. Boggs (1), N. Barriere (1), A. Zoglauer (1), M. Amman (2), P. Luke (2), P. von Ballmoos (3), P. Jean (3), H.-K. Chang (4), J.-L. Chiu (4), Y.-H. Chang (5), C.-H. Chang (6), M.-A. Huang (7)

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(7) National United University, 1, Lienda, Miaoli 36003, Taiwan, R.O.C

Presenter : Alexander Lowell

The Nuclear Compton Telescope (NCT) is a balloon-borne soft gamma-ray (0.2-10 MeV) telescope designed to perform wide-field imaging, high-resolution spectroscopy, and novel polarization analysis of astrophysical sources. NCT employs a novel Compton telescope design, utilizing 12 high spectral resolution germanium detectors, with the ability to localize photon interaction in three dimensions. NCT underwent its first science flight from Fort Sumner, NM in Spring 2009, and was partially destroyed during a second launch attempt from Alice Springs, Australia in Spring 2010. We have begun the rebuilding process and used this as an opportunity to optimize various aspects of NCT. We expect to return to flight readiness by Fall 2013, at which point we will recommence science flights. One of the primary science goals of the next NCT campaign is to map the 511 keV emission from the galactic center. As a Compton imager, NCT is well-suited for this task as it is particularly sensitive to diffuse emission, and has a large field of view. Additionally, we will discuss potential techniques for improving the angular resolution of NCT at 511 keV. We outline our expectations of NCT for the next flight campaign given the results of GEANT simulations of the new geometry and experience from previous flight campaigns

Friday, March 23   18:30

What's next in the observation of Galactic Positron Annihilation ?

Peter von Ballmoos

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Despite having observed the annihilation of Galactic positrons for almost four decades with balloon and satellite experiments, their origin and propagation has remained as enigmatic as ever. Yet, no new space mission is on the horizon to succeed INTEGRAL which is studying the gamma-ray sky since 2002.
Setting out from what we presently know about Galactic positron annihilation, requirements for a future space-based telescope dedicated to the observation of e-e+ emission are discussed. The various instrumental concepts and developments that promise a breakthrough in performance are reviewed and a possible concept for a future Positron Annihilation Monitor is outlined.

Posters

posters will be on display during the entire workshop in the lobby

The 511 keV Emission and the Past Higher Activity of the Galactic Center Black Hole

Tomonori Totani

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Kyoto 606-8502, Japan

I will present scenarios to explain the 511 keV annihilation emission observed toward the Galactic Center (GC) by the past activity of the supermassive black hole (SMBH) at GC higher than now. I will review the observational evidences of the past higher activity of GC on various scales and wavelengths. The recent detection of the Fermi bubble (large bubble like structure toward GC observed in GeV gamma-rays) further strengthens the case for the past higher GC activity. Observations indicate that the mean accretion rate onto the SMBH was higher than now by a factor of ~10^3 during the past ~10^7 yrs, and in this case the amount of positrons produced in the accretion flow around SMBH and then ejected by outflow is roughly consistent with the observed annihilation rate. Another proposed scenario is to produce positrons in stellar capture events by the GC BH. I will also discuss why the current activity of GC is quite low. The advantages of the GC scenario for the 511 keV emission compared with other sources (e.g., supernovae) will be summarized.

poster presentation P2

The matter content of active galactic nuclei jets

Roland Walter(1) and Pierre Jean(2)

(1) ISDC, Genève University,
Genève, Suisse
(2) IRAP, CNRS/Toulouse University
Toulouse, France

The matter content of jets, either e+- e– pairs or normal p+- e– plasma, is an important unresolved question of the physics of active galactic nuclei. The composition of a jet is related to the physical processes that create and energize it. This issue is very controversial and various attempts to solve it by indirect means led to contradictory results. The most direct method is to detect, or fail to detect, the annihilation emission line. Bulk and internal motion in jets however decrease the cross section to annihilation and broaden the line up to energies as large as 100 MeV, making any direct detection very challenging. Clusters of galaxies host several types of positron sources. Jets of active galactic nuclei could be the main contributor to a narrow annihilation line. Under certain assumptions, nearby clusters could have emissivity close to the current sensitivity. We give a first report on the search for the presence of an annihilation in the Virgo cluster using a deep exposure obtained with the INTEGRAL spectrometer.

poster presentation P3

Monte Carlo simulations of propagation and annihilation of nucleosynthesis positrons in the Galactic disk

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(4) American University of Sharjah, College of Arts and Sciences
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We modelled the spatial and spectral distributions of the annihilation emission induced by positrons that are released in the decay of 26Al, 44Ti and 56Ni nuclei in the Galactic disk, which are historically assumed to be the most likely origin of galactic positrons via their β^+-decay. This was carried out through Monte Carlo simulations that take into account the propagation of positrons in the interstellar medium. The 26Al and 44Ti distributions were assumed to follow the free-electron spatial distribution that is strongly correlated with the massive stars distribution. The 56Ni distribution was assumed to follow a young and old stellar population linked to the SNIa population. The gas distribution is based on the model given by Ferrière (1998). Due to large uncertainties in the regime of positron transport in the ISM, we only tested the collisional transport mode in order to test if galactic disk positrons could reach the inner regions of the Galaxy. We also tested several galactic magnetic field models and several escape fractions of positrons released by 56Ni in SNIa ejecta. We then compared all of our 66 simulations to the INTEGRAL/SPI observations.

poster presentation P4

Galactic annihilation emission from nucleosynthesis positrons

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Our Galaxy hosts a population of low-energy positrons that annihilate mostly in the inner regions, as shown by gamma-ray space telescopes. The origin of these particles is currently unknown. We estimated the contribution to the annihilation signal of positrons generated in the decay of radioactive 26Al, 56Ni and 44Ti. We used a diffusion code to simulate the transport and annihilation of radioactivity positrons in a model of our Galaxy. We explored several possible propagation scenarios to account for the large uncertainties on the transport of MeV positrons in the interstellar medium. We then compared the predicted intensity distributions to about 8 years of INTEGRAL/SPI observations.

poster presentation P5

Resonance phenomena in heavy nuclei collisions and structurization of positron spectrum

A.V. Glushkov

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Existence of a narrow e+ line in the positron spectra obtained from heavy ions collisions near the Coulomb barrier [1]. We present a consistent unified relativistic quantum-mechanical approach for studying the electron-positron pair production (EPPP) process in the heavy nuclei collisions. Resonance phenomena in the nuclear system lead to structurization of the positron spectrum produced. The positron spectrum narrow peaks as a spectrum of the resonance states of compound super heavy nucleus are treated. To calculate the EPPP cross-section we used the modified versions of the relativistic energy approach, based on the S-matrix Gell-Mann and Low formalism, and operator perturbation theory approach [2]. The nuclear and electron subsystems are considered as two parts of the complicated system, interacting with each other through the model potential. The nuclear system dynamics is treated within the Dirac equation with an effective potential. All the spontaneous decay or the new particle (particles) production processes are excluded in the zeroth order. The calculation results for cross-sections at different collision energies (non-resonant energies and resonant ones), corresponding to energies of different resonances of the compound 238U+238U, 232Th+250Cf and 238U+248Cm nuclei are presented. Calculation of the cross-sections with the more exact two-pocket nuclear potential is carried out and leads to principally the same physical picture as the calculation with the one-pocket one [2], however we discover some new peaks.

1. J.Reinhardt, U.Muller, W.Greiner, Z.Phys.A303, 173 (1981); V.Zagrebaev, W.Greiner, J. Phys. G34, 1 (2007).
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Plans for laboratory pair plasma diagnostics

X. Sarasola, T. Sunn Pedersen

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Positron-electron (pair) plasmas have been studied theoretically and numerically for decades, however these plasmas have not been created on Earth so far. APEX (A Positron-Electron eXperiment) is a stellarator currently being designed to confine pair plasmas for the first time in a laboratory. The design of APEX is based on CNT stellarator [1]. However, CNT relied primarily on internal material probes for diagnostics, while APEX must be diagnosed without invasive probes, to avoid prompt annihilation on these probes. The low densities of plasmas expected in APEX (10^{13} m^{-3}) make the use of non-perturbative diagnostics used in fusion plasmas (e.g., reflectometry or Thomson scattering) very challenging. However, for the 10^{11} positrons and electrons simultaneously confined in APEX, there will be about one annihilation event every microsecond, which can be used for diagnostics. The energy Doppler shift of the 511 keV annihilation photons will be detected in a set of coincident High-Purity Germanium detectors to measure the plasma temperature, and a dense matrix of coincident scintillator detectors will be used to verify the successful accumulation of positrons and estimate the plasma density. Progress on the design of the set of pair plasma diagnostics at APEX will be presented.

[1] T. Sunn Pedersen et al., Fusion Sci. and Technol. 50, p. 372 (2006)

A Simple Monte Carlo Approach to the Diffusion of Positrons in Gaseous Media

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In this work, we present and characterize a simple model to study the diffusion of positrons within a certain gaseous medium, which can be composed by one or more types of molecules or atoms. The positron-atom interaction is described by the partial cross sections for positron-target scattering, where target is one of the medium's components. In order to characterize the positron dynamics, we calculate quantities as the Doppler-shifted annihilation signal, penetration depths, the mean lifetime of positrons, the most probable ionization/excitation distances, and some other quantities. Simulations of this kind may be useful, for example, for astrophysicists to analyze the interstellar medium or for medical physicists to study the Positron Emission Tomography technique.

poster presentation P8

In-situ observation of near-surface structural changes in water ice films during sublimation by positron beam spectroscopy

P.G. Coleman(1), **S. Townrow**(1), C.J. Edwardson(1), Y.C. Wu(2), J. Jiang(2) and S.J. Wang(2)

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The sublimation of ice is a fundamental phenomenon with relevance to the understanding of many astrophysical phenomena such as the outgassing of volatiles from cometary systems, the evolution of the surfaces of particles in Saturnian rings, satellites in the outer solar system and interstellar grains.
With the aim of providing new information on the near-surface structure of thin vapor-deposited water ice films during sublimation in vacuum conditions, a study has been carried using in-situ positron annihilation spectroscopy. We have recently shown that this technique can provide depth-dependent information on the phase of thin ice films and, when extended to the measurement of the probability of positronium formation and decay, can yield direct information on pore formation and collapse.
Micro- and interconnected meso-pores have been observed in the top few tens of nm of the ice films during sublimation. Responses to these near-surface pores are much more pronounced in films grown at 170/180K than in those grown at lower temperatures, suggesting the presence of in-grown seeds for bubble formation in the former. The observation is reversible, disappearing as the film temperature is reduced and then reappearing when returned to 170/180K

poster presentation P9

Correlation of pick-off annihilation cross section and the collisional cross section for Ps-atom/molecule collisions

Ken Wada and **Toshio Hyodo**

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When Positronium (Ps) collides with an atom or molecule, the positron in Ps may annihilate with an electron in the atom/molecule. When this happens without forming bound or resonance state of Pa with the molecule, the process is called pick-off annihilation. The pickoff annihilation is possible in any gases and is much more remarkable on the spin triplet, ortho-Ps than the spin singlet, para-Ps since the intrinsic self-annihilation rate of the former is three orders of magnitude smaller than that of the latter.
In this work a regularity was found by plotting all the available data of the pickoff annihilation rate against geometrical collisional cross sections. The regularity is that the probability of the pickoff annihilation per collision is practically constant for all the atoms and molecules investigated. The ratio of the cross section for the pickoff annihilation to the collisional cross section is

$$\sigma_{\text{pick-off}} / \sigma_{\text{coll}} \sim 6.0 \cdot 10^{-7}$$

This indicates that the pickoff annihilation is a process whose probability is extremely small compared with that of ordinary atomic processes, and consistent with the observation that the o-Ps in gases thermalizes before annihilation regardless of the gas density unless the density is too low.

poster presentation P10

Low energy positron-methane scattering

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The collision of positrons and atoms or molecules is an interesting event in the astrophysics context. However, the mechanisms of interaction between positrons and molecules is not well defined, so in order to study this kind of event is necessary to propose a model or use one available in the literature. In this work we used the polarization correlation model (PCOP) to take in account the polarization of the molecule, in addition with the static potential. Using the method of continued fractions we obtain the elastic differential and integral cross sections, and the results are compared with measurements and theoretical data.

poster presentation P11

Excitation rates for nuclear isomers in hot plasma and photon-plasmon transitions in positronium and astrophysical plasma

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The short-lived excited states of nuclei in a hot plasma with excitation energies on the order of the temperature of the plasma reach thermal equilibrium with the nuclear ground state and their relative population is determined by a Boltzmann distribution. These states are usually taken into consideration in the standard nucleosynthesis calculations, though the data about their nucleonic reaction properties are not sufficient. The purpose of our work is to study the rates for electromagnetic excitation of the isotopes of several isomers of interest both in astrophysics and nuclear physics (235U, 193Ir, and 87,88Y) and photon-plasmon transitions in positronium. We use the consistent quantum approaches [1,2] to calculate the key characteristics of the electromagnetic processes, namely, photo-absorption, inverse internal conversion, inelastic e-e+ scattering, Coulomb excitation etc. Further the energy approach in QED theory [1] is applied to modelling photon-plasmon transitions with emission of photon and Langmuir quanta in the astrophysical plasma. It is well known that the positronium Ps is an exotic hydrogen isotope with ground state binding energy of 6.8 eV. The ortho-Ps atom has a metastable state 2(3s1) and probability of two-photon radiation transition from this state to 1(3s1) state 0.0018 s(-1). In the space plasma there is the competition process of destruction of the metastable level - the photon-plasmon transition 2s-1s with emission of a photon and a Langmuir quanta. We carried out calculating the probability of the photon-plasmon transition in the Ps within the relativistic energy approach [1]. The approach represents the decay probability as an imaginary part of energy shift dE, which is defined by QED S-scattering matrix. Standard S-matrix calculation with using an expression for tensor of dielectric permeability of the isotropic plasma and dispersion relationships for transverse and Langmuir waves allows getting the corresponding probability P(ph-pl). Numerical value of P(ph-pl) is 5.3x10(6) s(-1), where U is density of the Langmuir waves energy. Our value is correlated with other estimates [1,2]: P(ph-pl)=6x10(6) s(-1). Comparison of obtained probability with lifetime t (3 gamma) allows getting the condition of predominance of the photon-plasmon transition over three-photon annihilation. The considered transition may control the population of 2s level and search of the long-lived Ps state can be used for diagnostics of the astrophysical plasma.

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poster presentation P12

Measurement of the photodetachment cross section of positronium negative ion

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The positronium negative ion (Ps^{-}), a bound state of one positron and two electrons, is one of the promising candidates for testing the three body problems because all the constituents of the ions have the same mass unlike H_{2}^{+} or H^{-}. Since the existence was demonstrated in a variational calculation by Wheeler, many theoretical studies have been challenged to explore the nature of Ps^{-}. However, measurements of the lifetime have been the only experiments conducted so far, limited by the extremely weak beam intensity. Recently, development of a method to produce the ions efficiently using a Na coated tungsten surface has enabled the _rst observation of the photodetachment of Ps^{-}. This success opens the full-fledged studies of photodetachment process of Ps^{-}.

In the present work, measurement of the total photodetachment cross section of Ps^{-} for the wavelength of 1064 nm has been demonstrated using the crossed beam method of a pulsed Ps^{-} beam and a high power pulsed laser light. The photodetachment cross section was estimated by measuring the number of Ps produced by the photodetacment as a function of the photon flux density. The obtained value is consistent with the theoretical calculations reported so far.

Synthesis of Cold Antihydrogen in a Cusp Trap for Hyperfine Transition Experiments

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Anti-hydrogen is the combination of an anti-proton and a positron, it is the simplest stable atomic system containing a positron. A target of anti-hydrogen amenable to spectroscopic investigation will allow precision tests of CPT due to the high precision measurements of its matter counterpart. The MUSHASHI subgroup of the ASACUSA collaboration based at CERN has been developing a cusp trap arrangement consisting of a multi-ringed electrode trap within a cusp magnetic field generated by a pair of anti-helmholtz coils. This arrangement has the unique property that anti-hydrogen atoms formed into low field seeking states are preferentially focused along the axis of the trap producing a beam of spin-polarised anti-hydrogen. Synthesis of cold anti-hydrogen has been demonstrated within this arrangement [1].

Low energy positrons are produced using a 22Na source in combination with a reflection mode polycrystaline tungsten moderator. These are then accumulated in a compact trap utilizing the molecular nitrogen buffer gas method. The entire apparatus is located within a uniform magnetic field of 2.5 Tesla. Approximately 4e5 positrons are accumulated then transferred to the cusp trap arrangement where they are stored ready for combination with anti-protons. During the storage and stacking period, the rotating wall method is used to compress the positron cloud to increase the density. Within the non-uniform magnetic field of the cusp trap arrangement, a resonance like structure has been observed at certain rotating wall drive frequencies for plasma compression.

[1] Y. Enomoto et al., Phys. Rev. Lett. 105, 243401 (2010).

AD-ELENA, The Low Energy Antiproton Facility at CERN

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ELENA (Extra Low ENergy Antiproton ring) is a compact ring for cooling and further deceleration of the 5.3 MeV antiprotons delivered by the AD (Antiproton Deccelerator). A significant increase (between one and two orders of magnitude) in the antiproton trapping efficiency by the experiments is expected thanks to the efficient deceleration to 100 keV and adiabatic blowup compensation obtained by using an electron cooler. In addition, a second extraction channel is foreseen, opening the possibility for the installation of further experiments in the AD hall.

poster presentation P15

How to find positrons in space

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Usually we deal with the square correlation function of a radiation electric field which is called the polarization tensor. The polarization tensor gives all Stocks parameters I,U,V.Because of the electric field E is proportional to the value of charge q of the radiated particle the polarization tensor does not contain the information about the sign of the q. But odd correlation functions of more high orders are proportional to the sign of q. The simplest is the third order correlation function <EEE>. Let us to suggest the radiated system consists of many particles of q charge radiated independently. The free particle radiates the broad frequency spectrum. Let choose the fixed frequency 1. Particle radiates also at twice frequency 2. The correlation function <E(1)E(1)E(2)> dose not depends on the phase of radiation of single particle and is proportional to the cube of the electric charge q. Thus, for positrons the value of <E(1)E(1)E(2)> for their radiation will have the opposite sign than that for electrons. That is the way to find positrons in space observing their electromagnetic radiation.

poster presentation P16

Possibilities of Positron Diagnostics for Research of Dust Space Plasma

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The analysis the scale-spectra [1], received by an observatory INTEGRAL, has allowed authors to draw a conclusion, that the observable-line with energy 0,511 MeV is caused of positron annihilation from pair-positronium state. In this connection in [1,2] it has been shown, that positronium formation in dust space plasma with the big concentration of the charged particles of a dust can occur as processes of interaction of positrons to atoms and free electrons [1], and processes of interaction of a positron with negatively charged particles [3,4] of dust space plasma with formation of positronium atom [2]. In such space plasma the positronium output about what speak experimental data of space laboratory Integral [1] is possible practically 100 %. In the lead reasonings it was supposed, that depth of implantation of positrons in particles of a dust does not exceed length of diffusion of thermalized positrons in the environment, otherwise a part of positrons annihilated in a free condition, or participating in pick-off-annihilation, that will lead to increase in a share of the -annihilation channel. Depth of implantation l depends on energy of positrons E and from properties (density) of environment [5]. Knowing diffusion coefficient (terrestrial experiments) and time of a life of positrons in the environment, it is possible to estimate the size of particles of a dust and initial energy of positrons. So, for example, diffusion lengths of positrons in Si and Al are accordingly equal 0,5 and 0,15 microns [5], and for the majority of the condensed environments have the same order. The share of positrons (positronium), reaching a surface from the general number of positrons in the environment, depends on energy of positrons, i.e. from a parity of length of diffusion and length of absorption. So, lengths of absorption of positrons with energy 1.5 MeV in Si and Al accordingly will be ~600 and ~500 microns, and for positrons with energy 2 keV the same sizes will be already on three orders less. Broadening of annihilation lines 511 keV in experiments the INTEGRAL makes size (2,37±0,25) keV [1]. To it broadening there corresponds energy of annihilation electron-positron pairs in some (1¸2) eV, i.e. energy of quasithermalized positronium.

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Simulation study of the 511 keV annihilation Line Observation with the Soft Gamma-ray Detector onboard ASTRO-H

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The 511 keV line generated by an e+/e- annihilation from astrophysical sources (e.g. the Galactic center, black hole binaries), is one of the key targets of the Soft Gamma-ray Detector (SGD) onboard ASTRO-H, the next international X-ray observatory scheduled for launch in 2014.
In this work, we studied, for the first time, the feasibility of 511 keV line observations with the SGD. The SGD sensitivity at 511 keV is limited by in-orbit background, of which the most dominant origin is radiation caused by the radioactivation inside the detector.
In order to study the SGD performance for the annihilation line, we therefore conducted Monte-Carlo simulations with full implementation of the detector mass model and detailed event analysis, considering realistic activation background estimation based on the radiation environment at the low Earth orbit.
We present the simulation results and discuss the feasibility of the annihilation line observation from several astrophysical sources. In addition, we mention the future mission CAST, the Compton All Sky Telescope.

poster presentation P18

Large-Volume Cadmium Zinc Telluride Detectors for Future Astrophysical Instrumentation

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Cadmium Zinc Telluride (CZT) semiconductor detectors are being investigated for use in a future astrophysical gamma-ray imaging instrument. Laboratory measurements and benchmarked simulations have been performed using 1-cm^3 CZT coplanar-grid detectors that are currently being developed for the High Efficiency Multimode Imager (HEMI). These high-Z material detectors have the advantage of large pixels, room-temperature operation, good active to passive material ratios, and low energy consumption, making them an ideal candidate for a Compton telescope absorption plane or focal plane for a Laue lens.

In the presentation we will show the current capabilities of the HEMI CZT detectors based on laboratory measurements (efficiency, energy resolution). In addition, we will provide an initial assessment of the achievable efficiency, energy resolution, and angular resolution at 511 keV of a 2-detector Compton telescope utilizing a Silicon tracker based on the Gamma-Ray burst Investigation via Polarimetry and Spectroscopy (GRIPS) telescope with a CZT backplane.

poster presentation P19

Proposal for a Laue lens tuned on the 511-keV annihilation line

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Study of the 511-keV emission line resulting from the electron-positron annihilation would be precious to search for the location of positron sources in the Galaxy. In order to study galactic positrons and their sources through the 511-keV line, existing operating telescopes have to achieve a sensitivity leap by at least one order of magnitude. Thus, focusing optics are necessary to concentrate photons from a large collection area of a crystal diffraction lens onto a very small detector to improve the signal-to-noise ratio. Crystals having curved diffracting planes (CDP) are very promising for broad-band Laue lens, because they allow concentrating x and gamma rays with high reflectivity. For this aim, we propose to use bent Ge crystals to concentrate the 511-keV photons. The energy passband would be a water-bag distribution, as determined by the curvature of crystal. If such a distribution is tuned across the 511 keV line, very high signal-to-noise detection of such radiation is foreseen. A simulation of a narrow passband Laue lens tuned on the 511 keV electron-positron annihilation line is proposed. Very high effective area can be achieved at these energies. Moreover, thanks to CDP crystals, energy passband and FOV of the lens can be very well controlled.

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