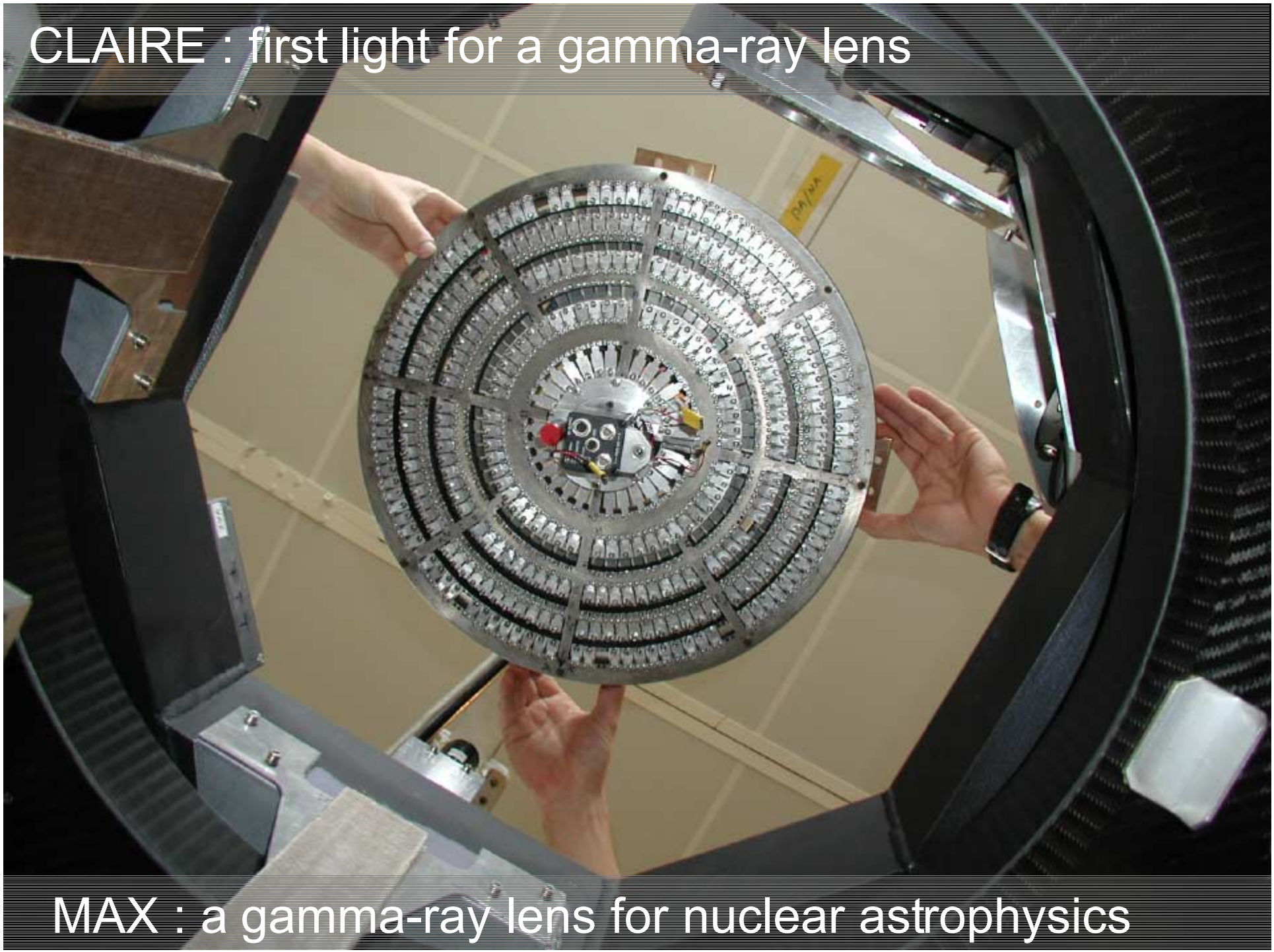

CLAIRE : first light for a gamma-ray lens
MAX : a gamma-ray lens for nuclear astrophysics

a gamma-ray lens for nuclear astrophysics

Huber Halloin (MPE) and Peter von Ballmoos (CESR)*

The Laue lens

focusing gamma-ray : why ? how ?

CLAIRE' first light

the CLAIRE lens

performance on a 200 m optical bench

the balloon flight in 2001 - first light from the Crab

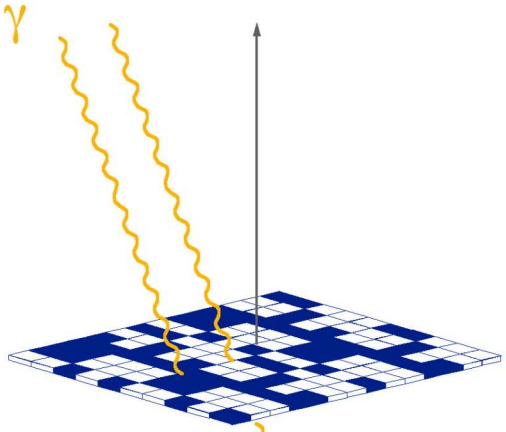
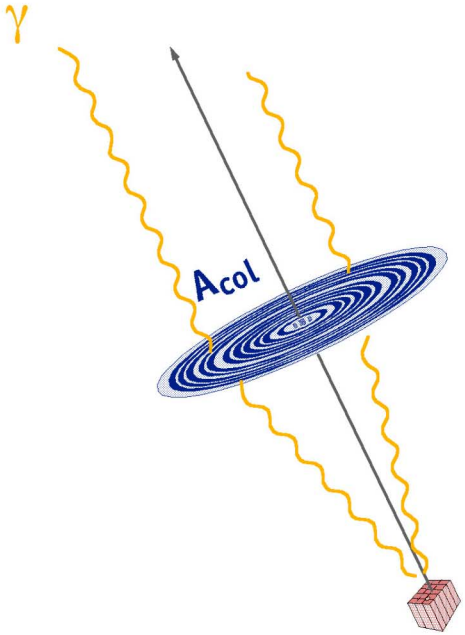
The MAX mission

scientific potential

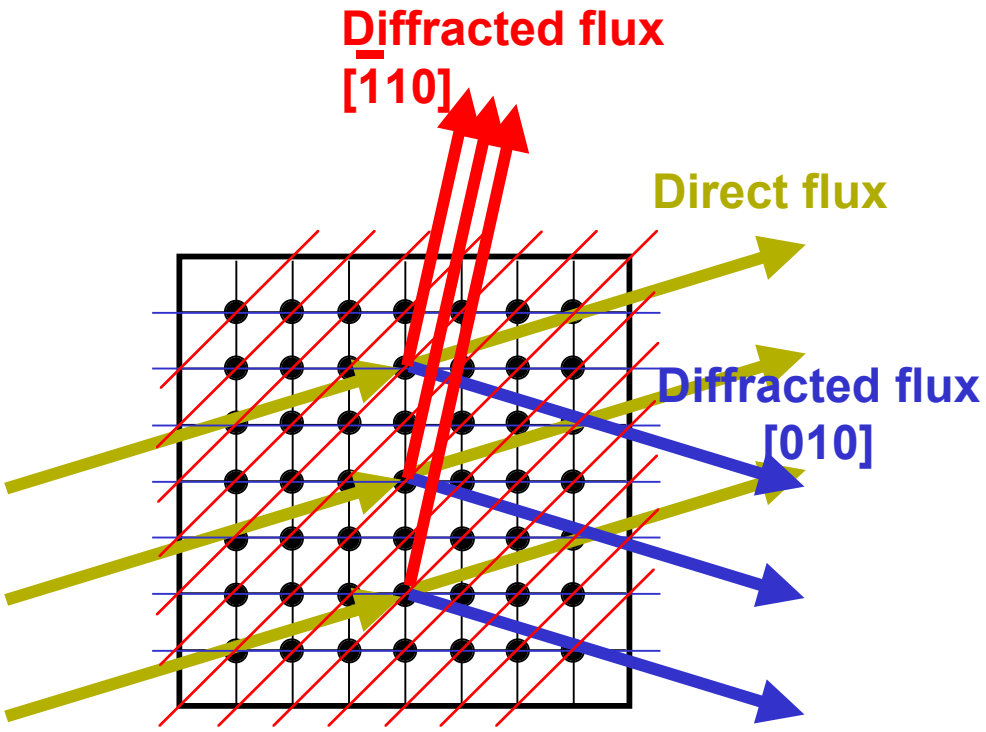
mission concept and performance

* for the CLAIRE and MAX collaborations : CNES, IN2P3, CEA Saclay, ILL Grenoble, IEEC Barcelona, IKZ Berlin, ANL Chicago, IASF Roma and Bologna, Observatory of Geneva, IAP Paris, LAM Marseille, CESR Toulouse

Focusing Gamma-Rays - why ?

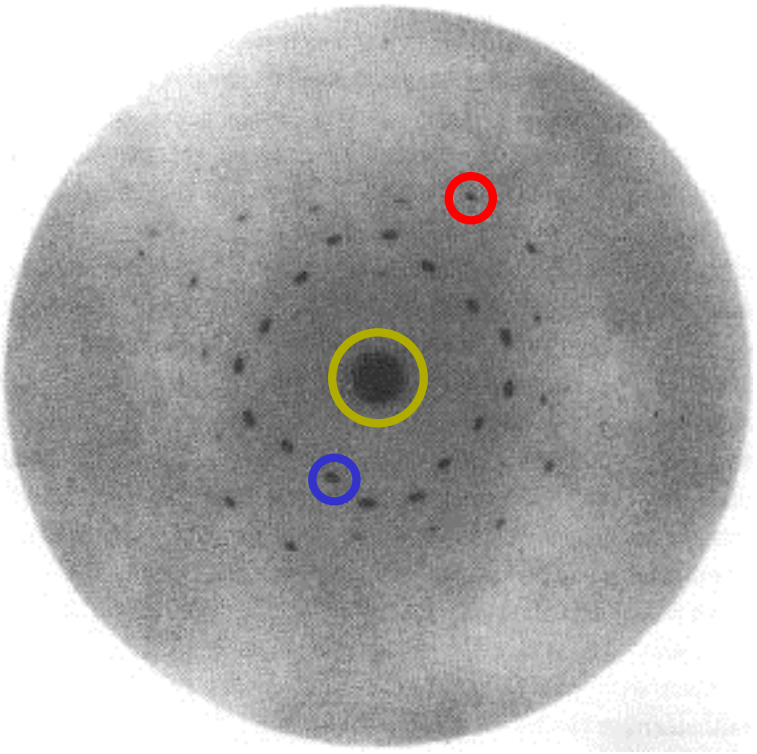
aperture / effect	modulating aperture systems geometric optics absorption	crystal lens telescopes wave optics coherent scattering
aperture system		
detector		
	$A_{det} = A_{col}$	A_{det}
signal S ~	A_{col}	A_{col}
background B ~	$V_{det} \sim A_{det} = A_{col}$	$V_{det} \sim A_{det} << A_{co}$
S/B ≈	const (A)	A_{col}/A_{det}

Focusing Gamma-Rays - how ?



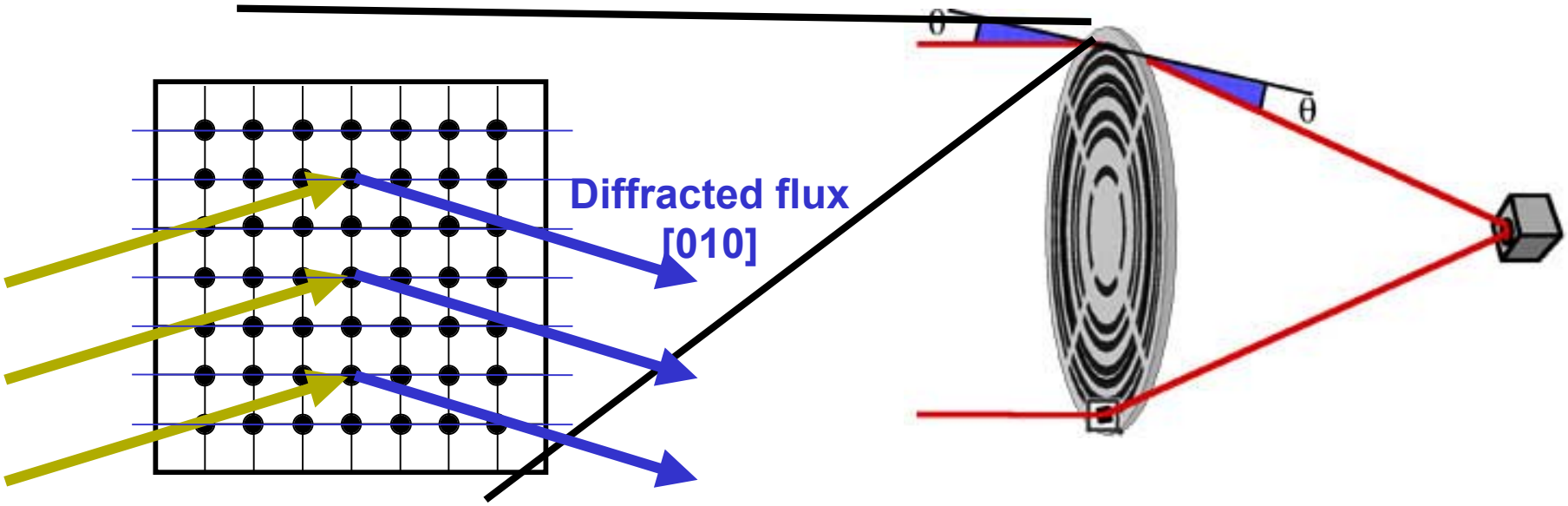
$$2d_{hkl} \sin\theta = n\lambda$$

Bragg diffraction in a crystal



Laue, Friedrich et Knipping, 1912

Focusing Gamma-Rays - how ?



$$2d_{hkl} \sin\theta = n\lambda$$

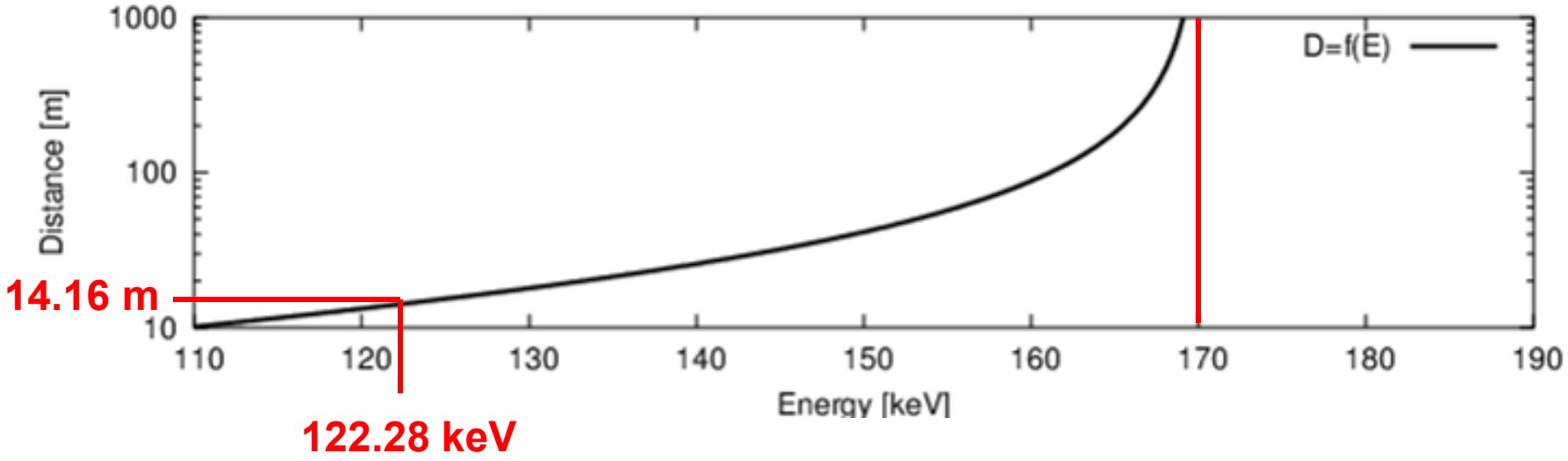
CLAIRE : First Light for a Crystal Diffraction Telescope

Tuning the lens - principle

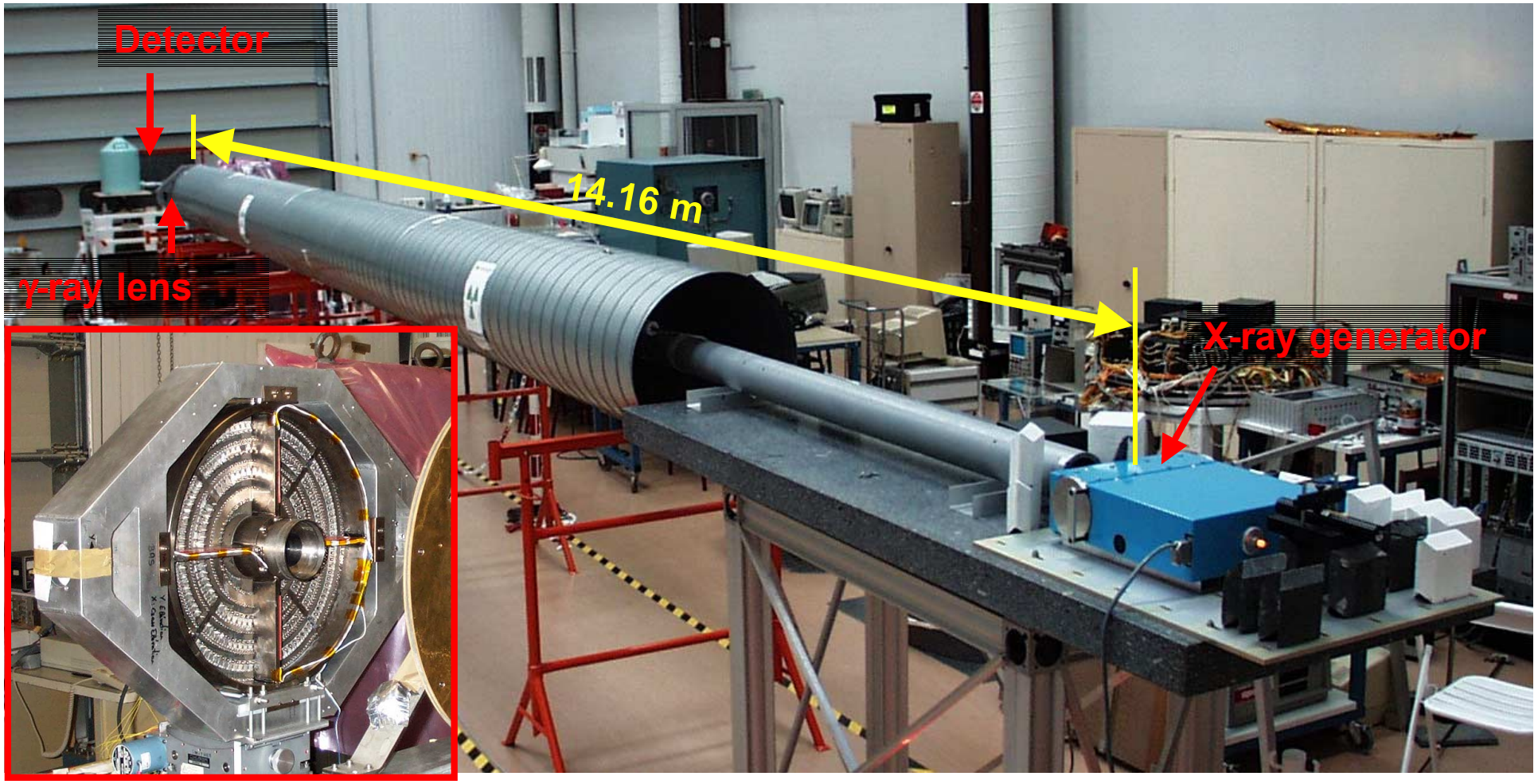
Relationship between source distance and diffracted energy :

$$\frac{100\,\mathrm{keV}}{E} = \frac{100\,\mathrm{keV}}{E_\infty} + 0.3251\left(\frac{10\,\mathrm{m}}{D}\right)$$

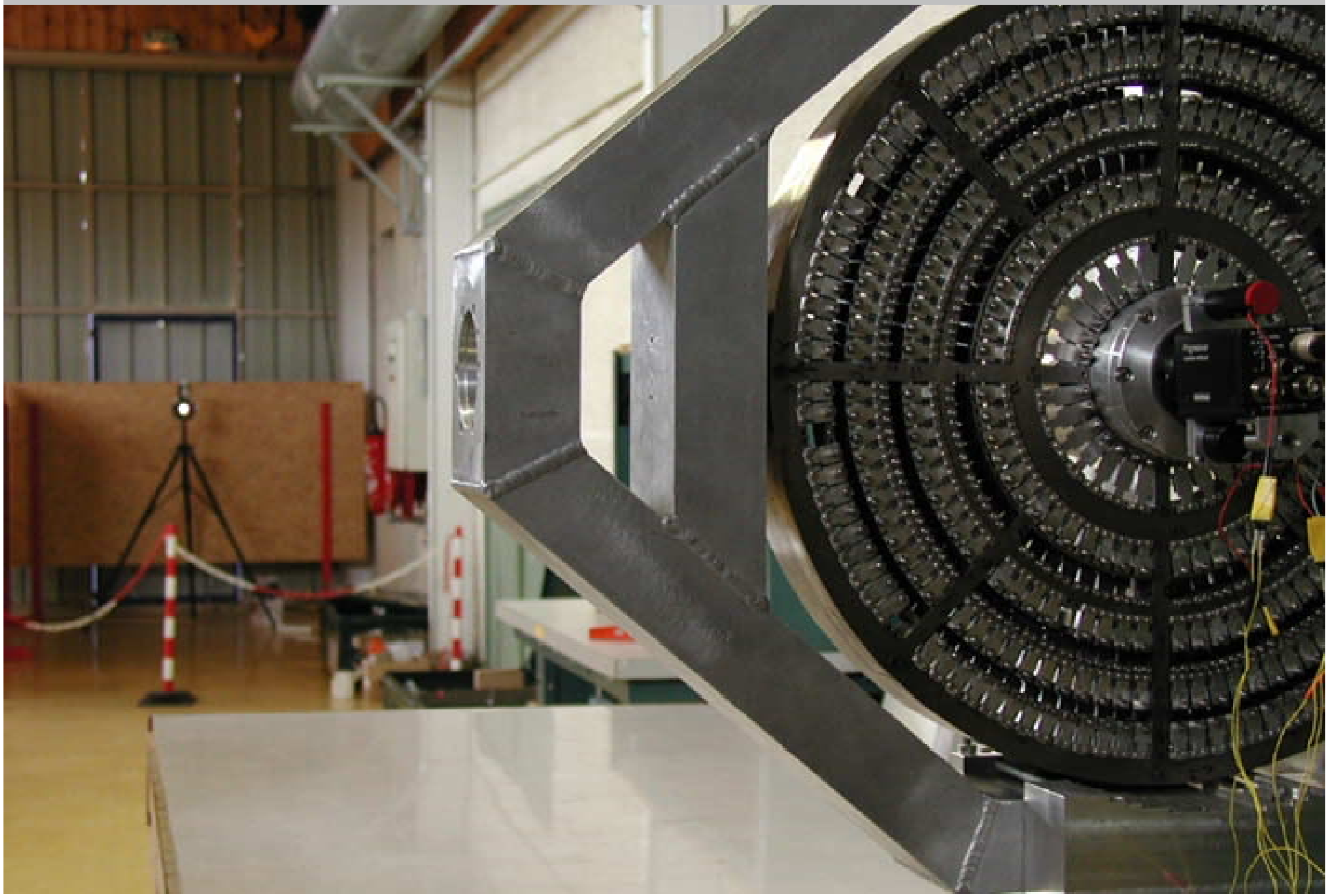
with E_∞ = 170 keV



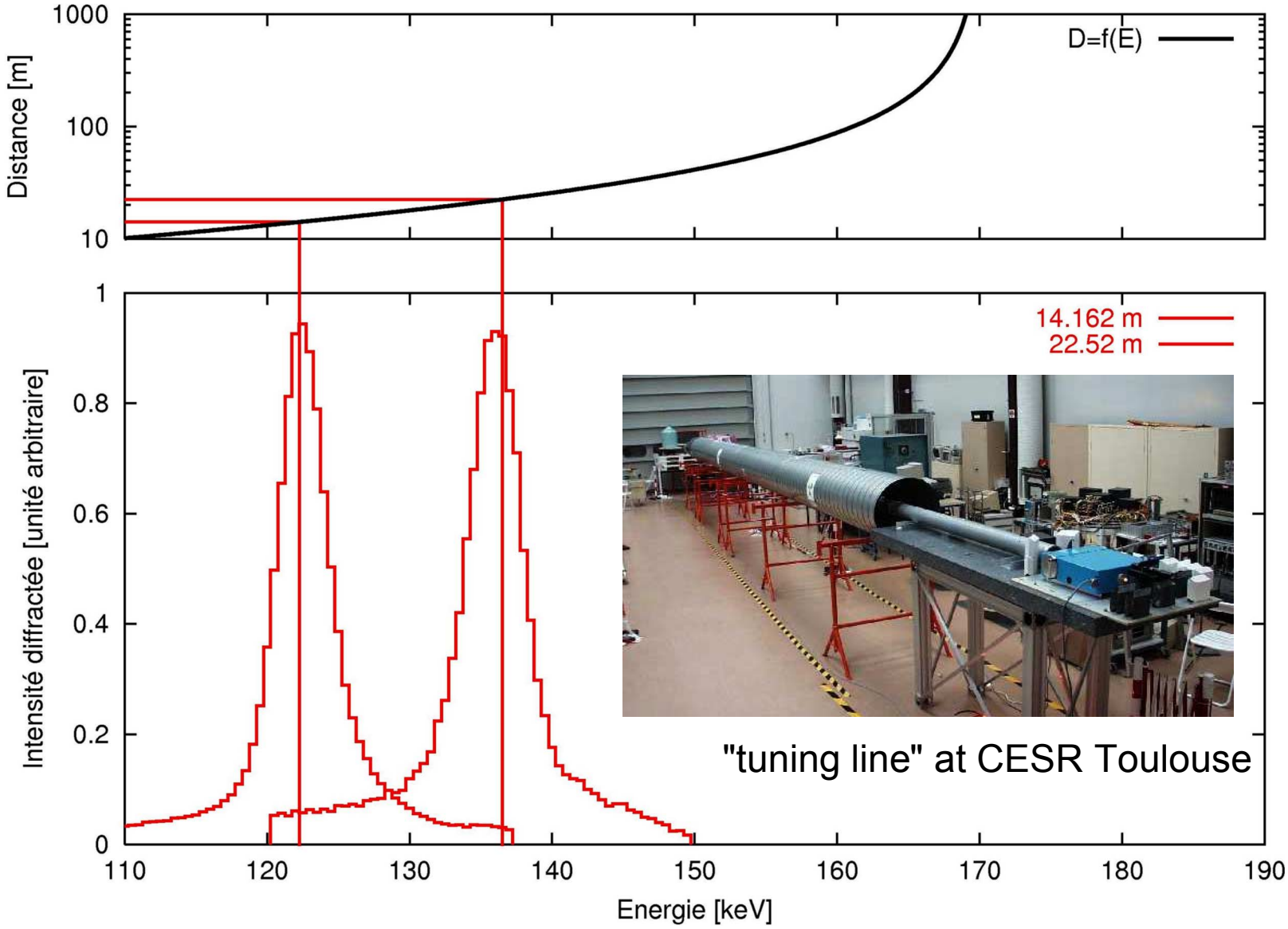
Tuning the lens - the gamma-ray bench at CESR



CLAIRE : ground measurements

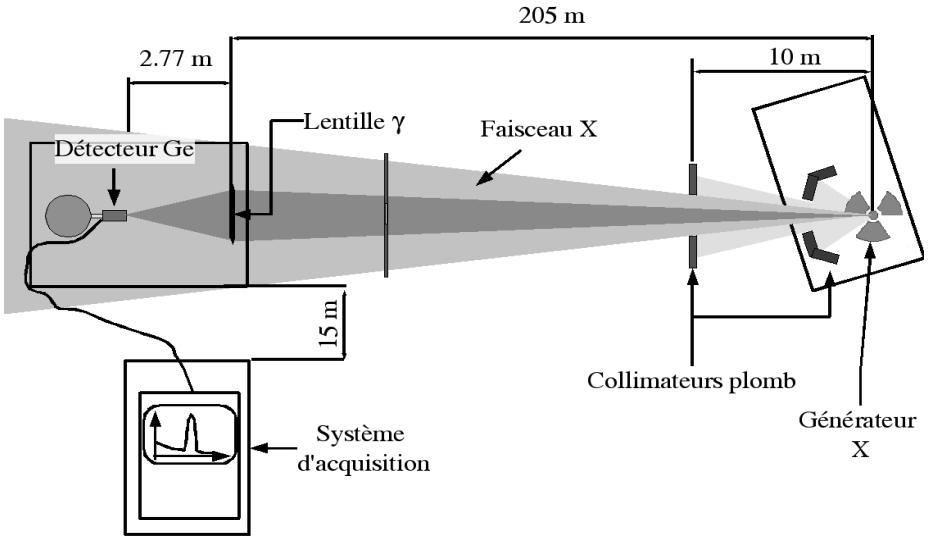


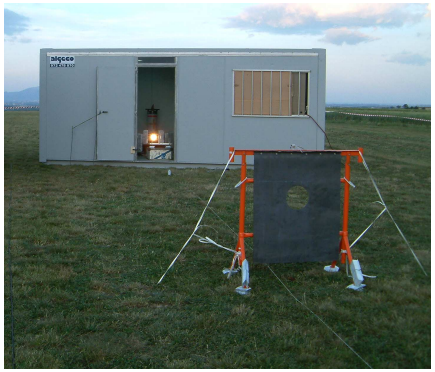
CLAIRE : testing the lens in the lab ... and beyond



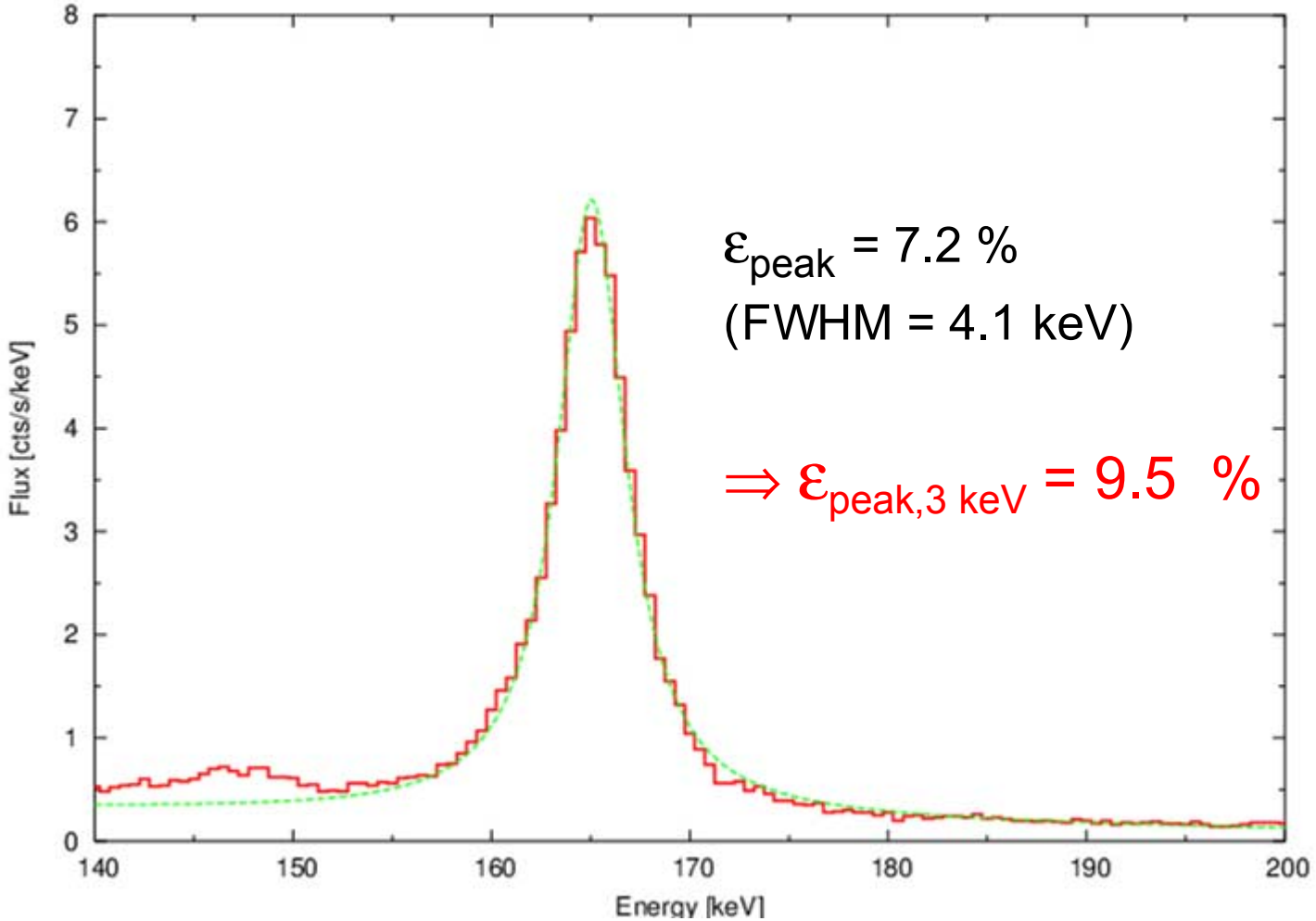
"tuning line" at CESR Toulouse

CLAIRE TGD : a source close to "infinity" ...

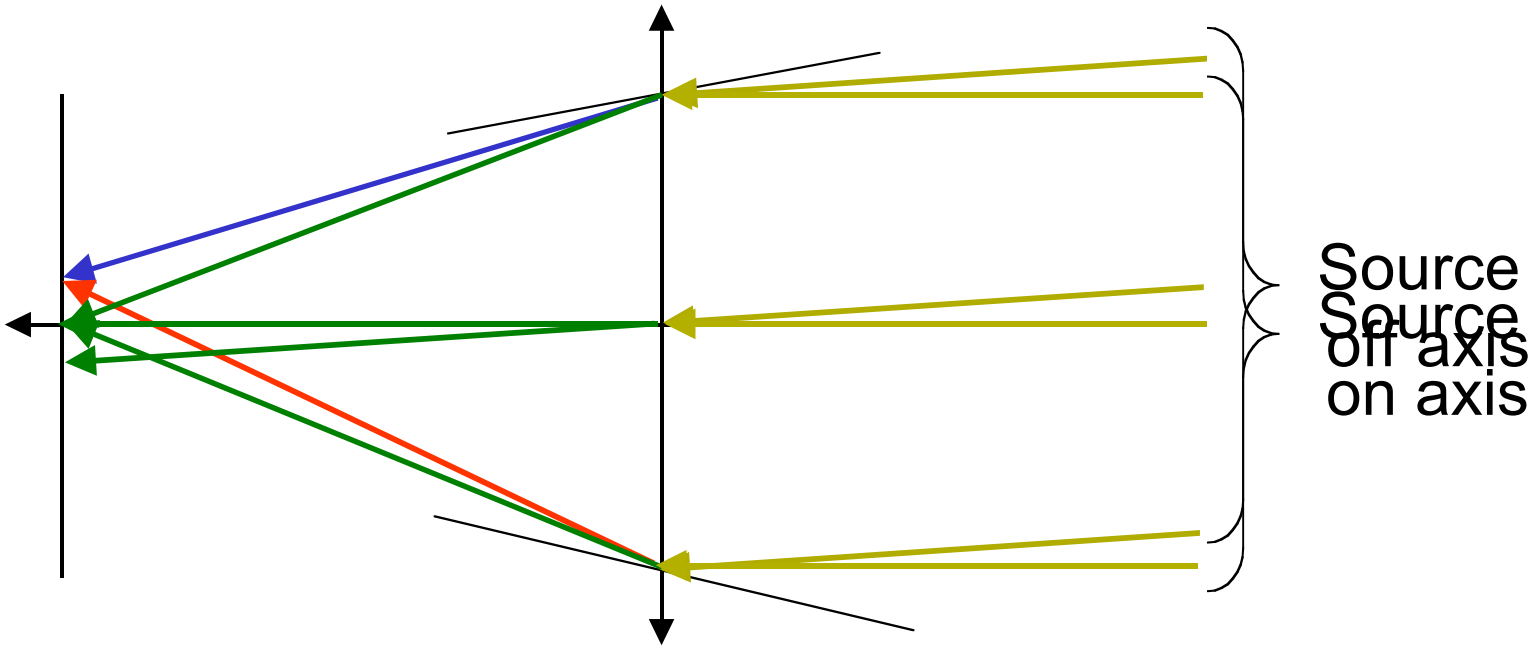




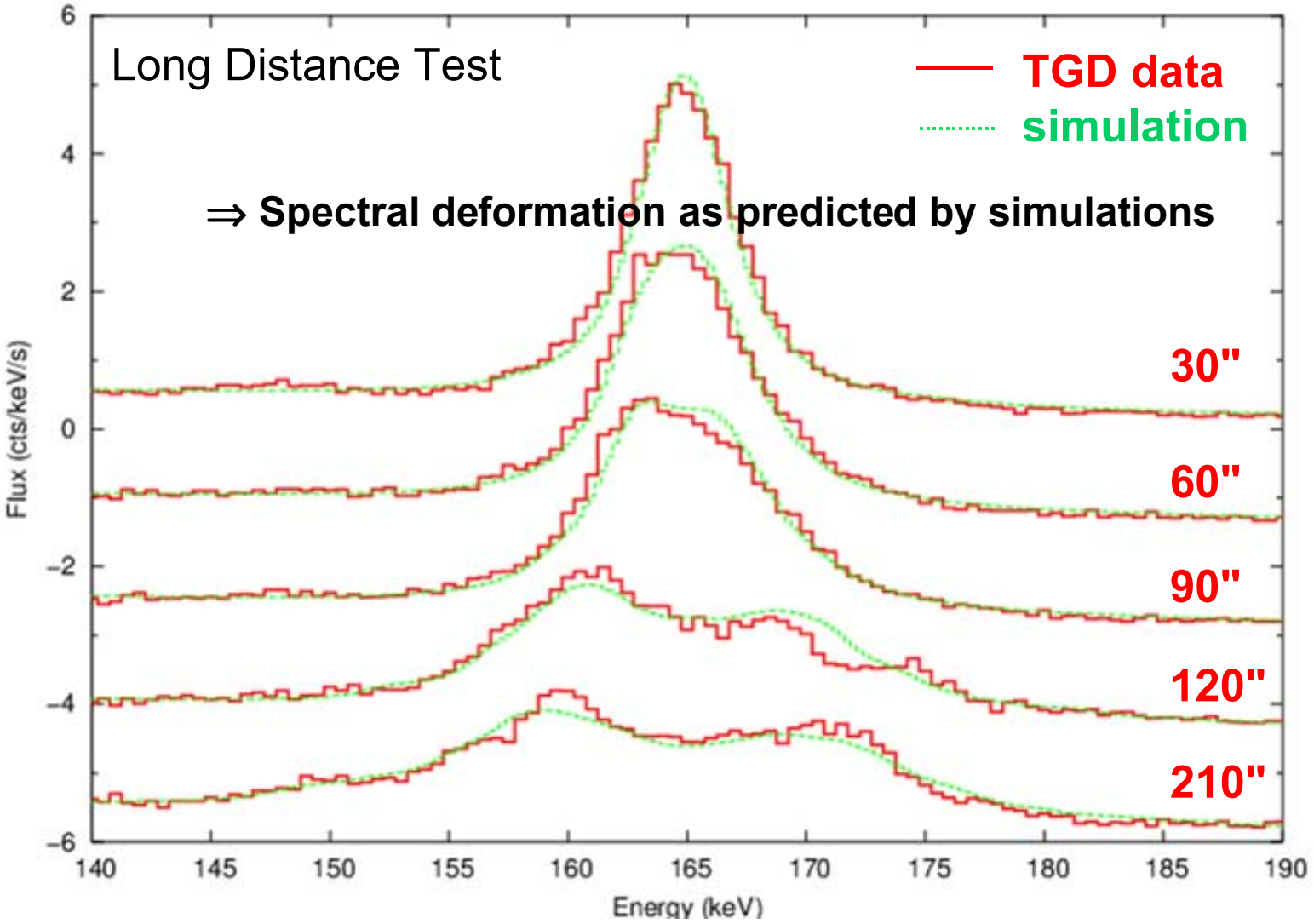
CLAIRE TGD - diffraction efficiency



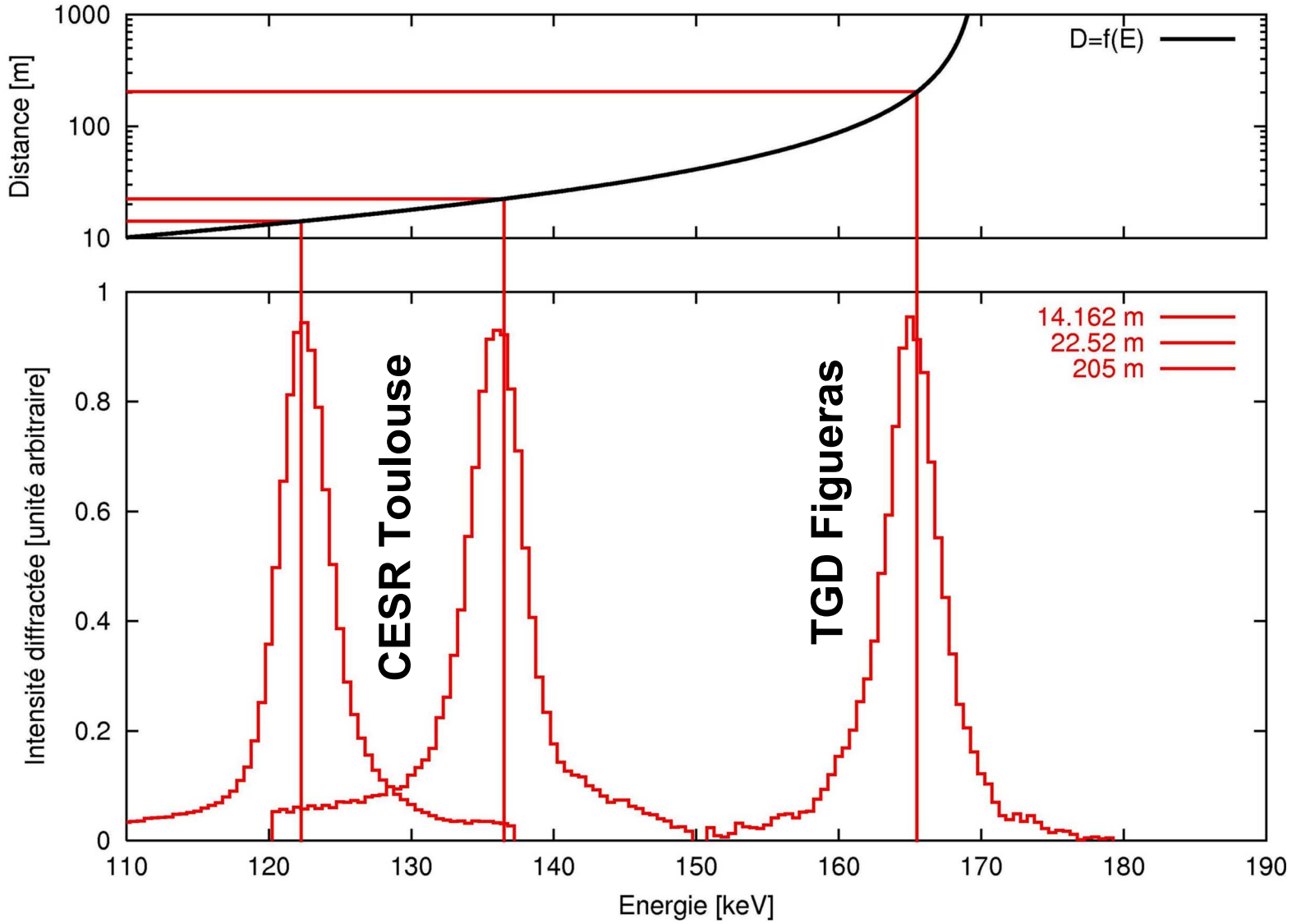
Instrumental response of a Laue lens - principle



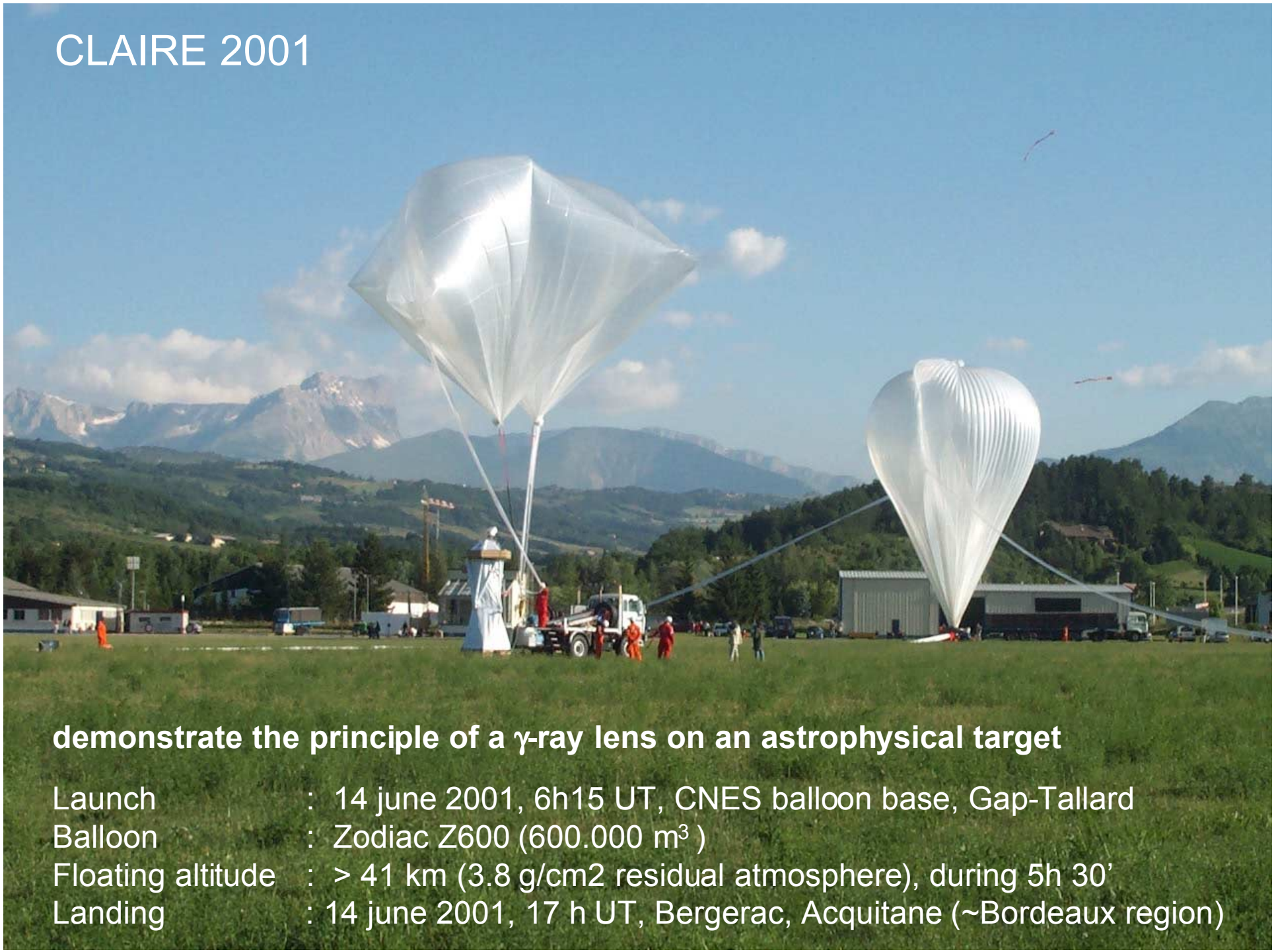
CLAIRE TGD : off axis response



CLAIRE TGD : 14 m, 22.5 m ... and 205 m



CLAIRE 2001

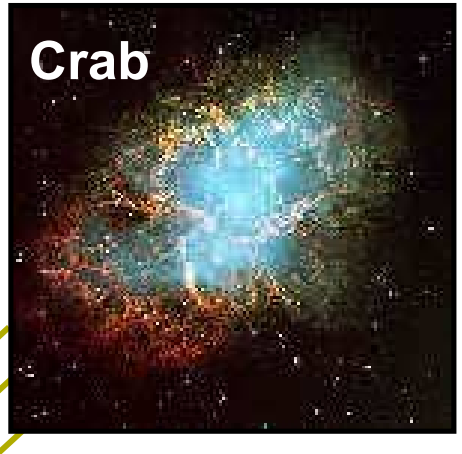


demonstrate the principle of a γ-ray lens on an astrophysical target

Launch : 14 june 2001, 6h15 UT, CNES balloon base, Gap-Tallard
Balloon : Zodiac Z600 (600.000 m^3)
Floating altitude : > 41 km (3.8 g/cm2 residual atmosphere), during 5h 30'
Landing : 14 june 2001, 17 h UT, Bergerac, Acquitane (~Bordeaux region)

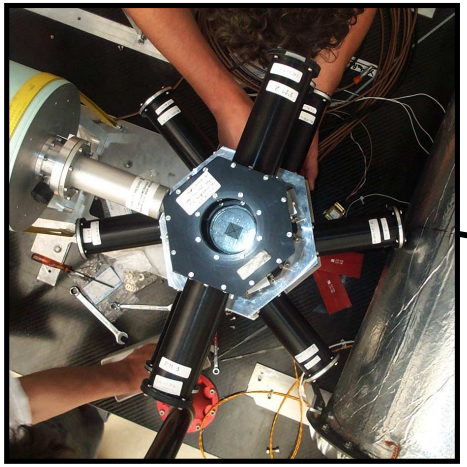
CLAIRE 2001 : the instrument

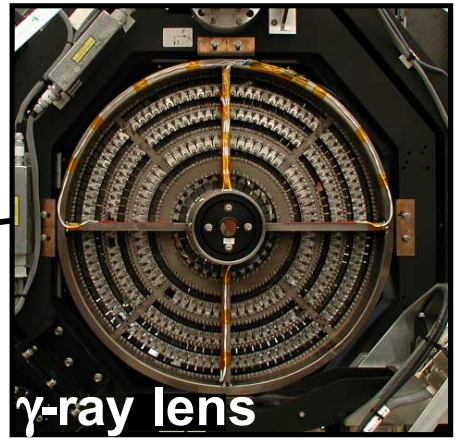
standard candle, polychromatic
close to the Sun (~1° on June 15)



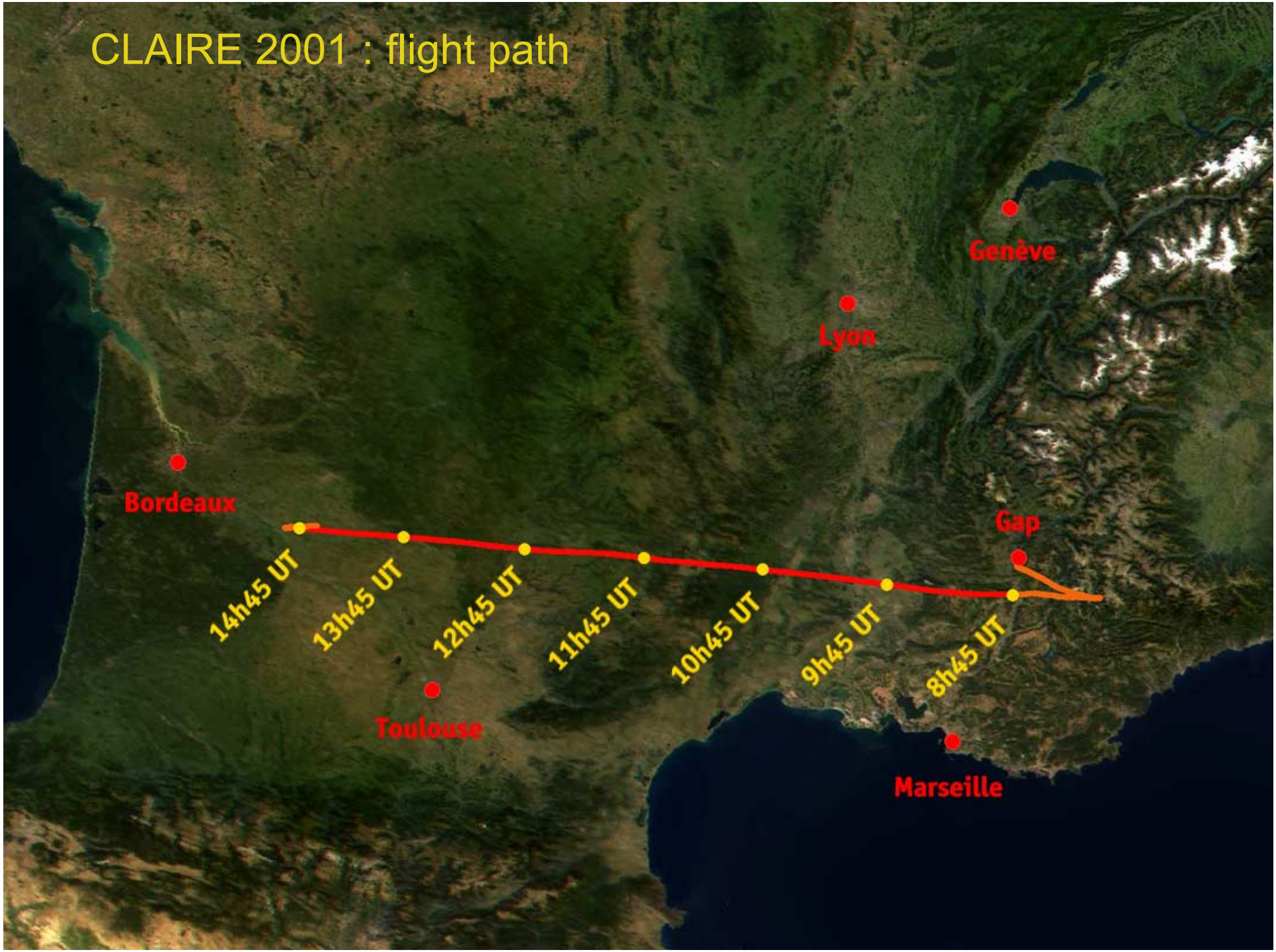
Detector
- 3x3 matrix
- high purity Ge
  1.5*1.5*4 cm

AC shield
- CsI
- BGO

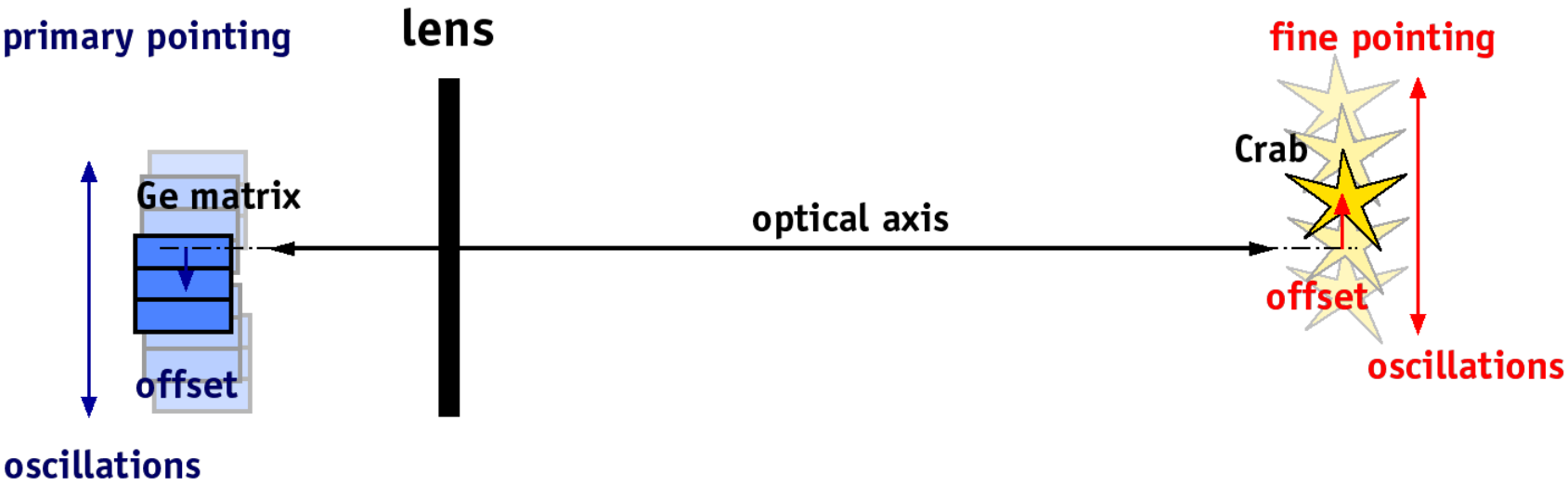


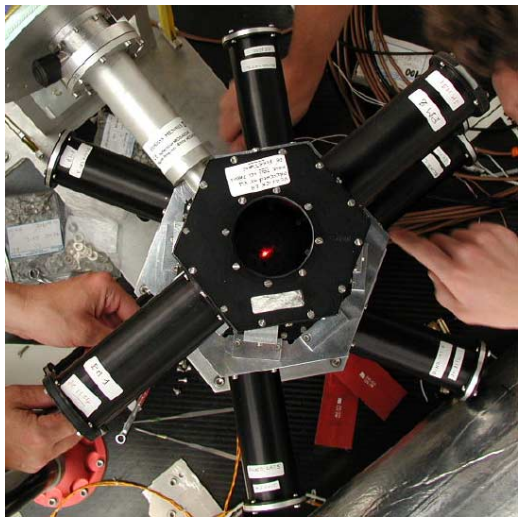


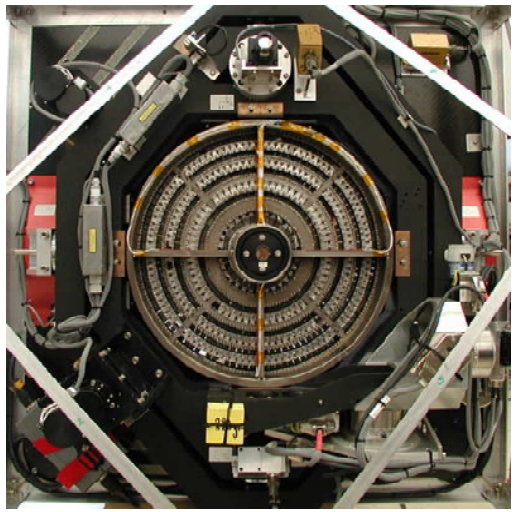
- 563 crystals
- E = 170 keV
- FWHM ~ 3 keV

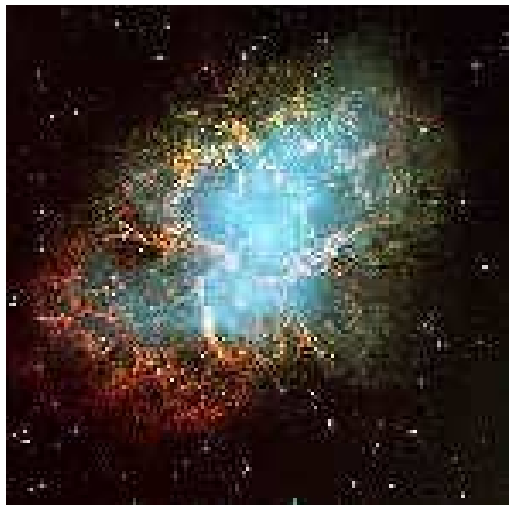

CLAIRE 2001 : flight path
Genève
Lyon
Bordeaux
Gap
14h45 UT
13h45 UT
12h45 UT
11h45 UT
10h45 UT
9h45 UT
8h45 UT
Toulouse
Marseille

CLAIRE 2001 : primary and fine pointing system

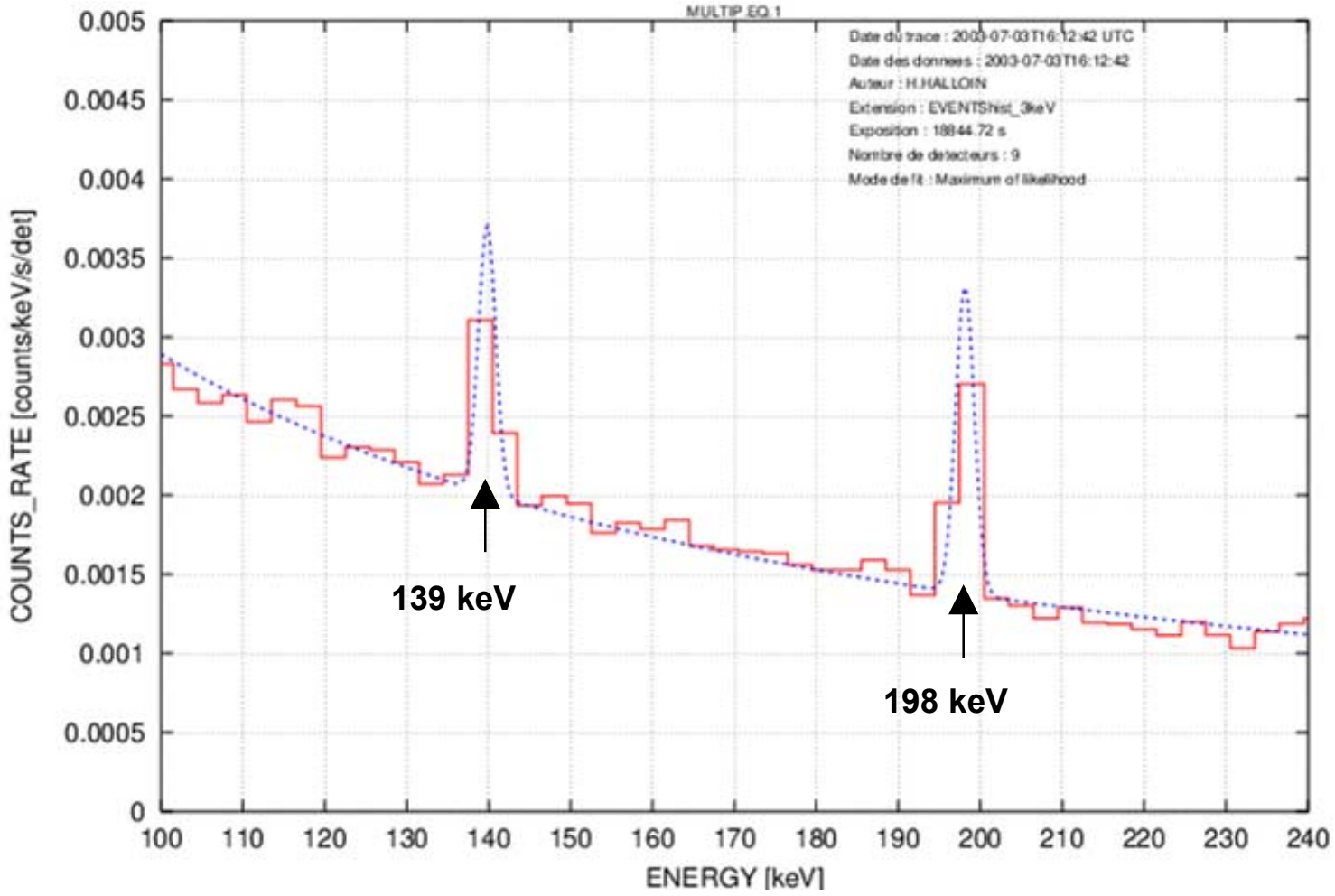




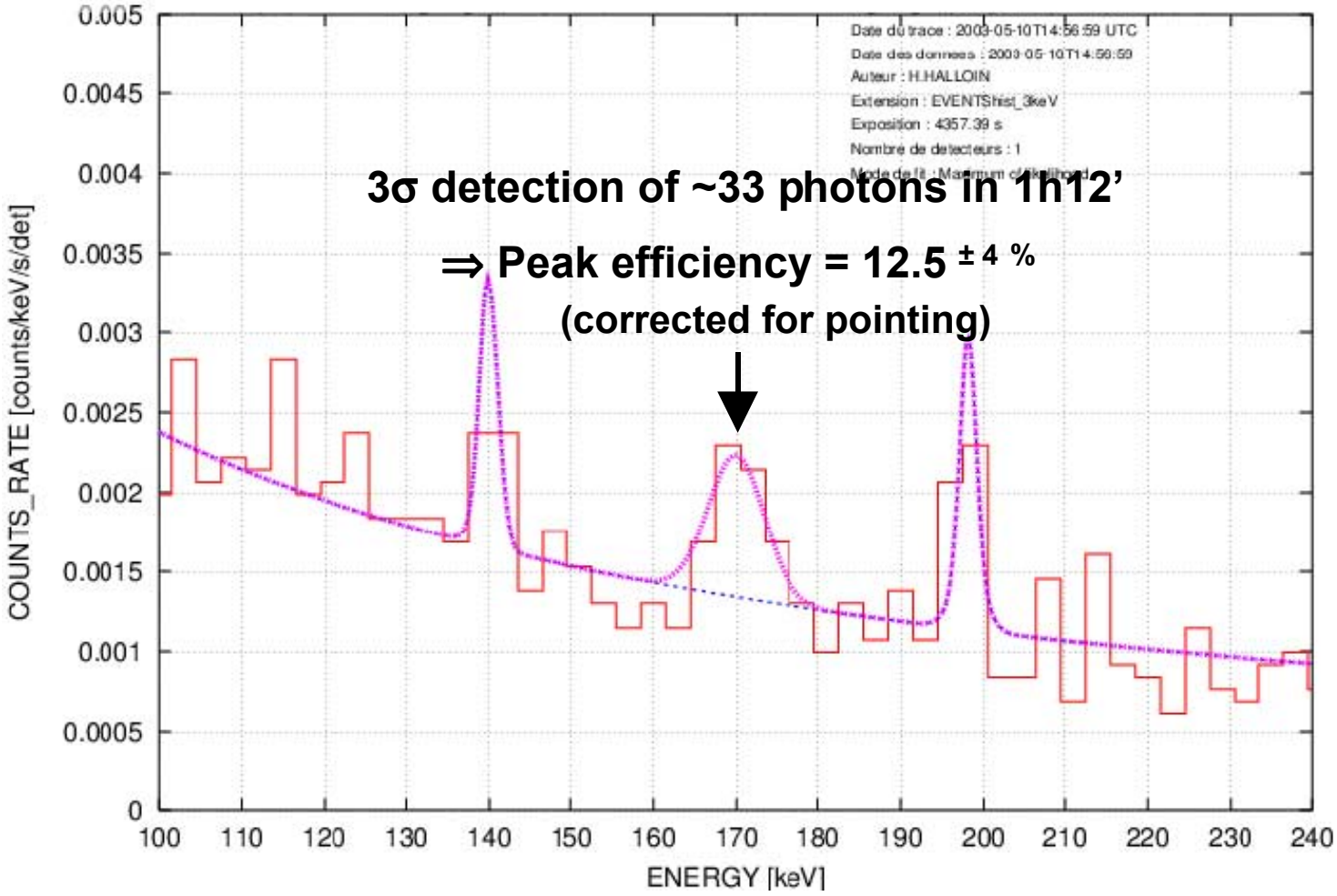




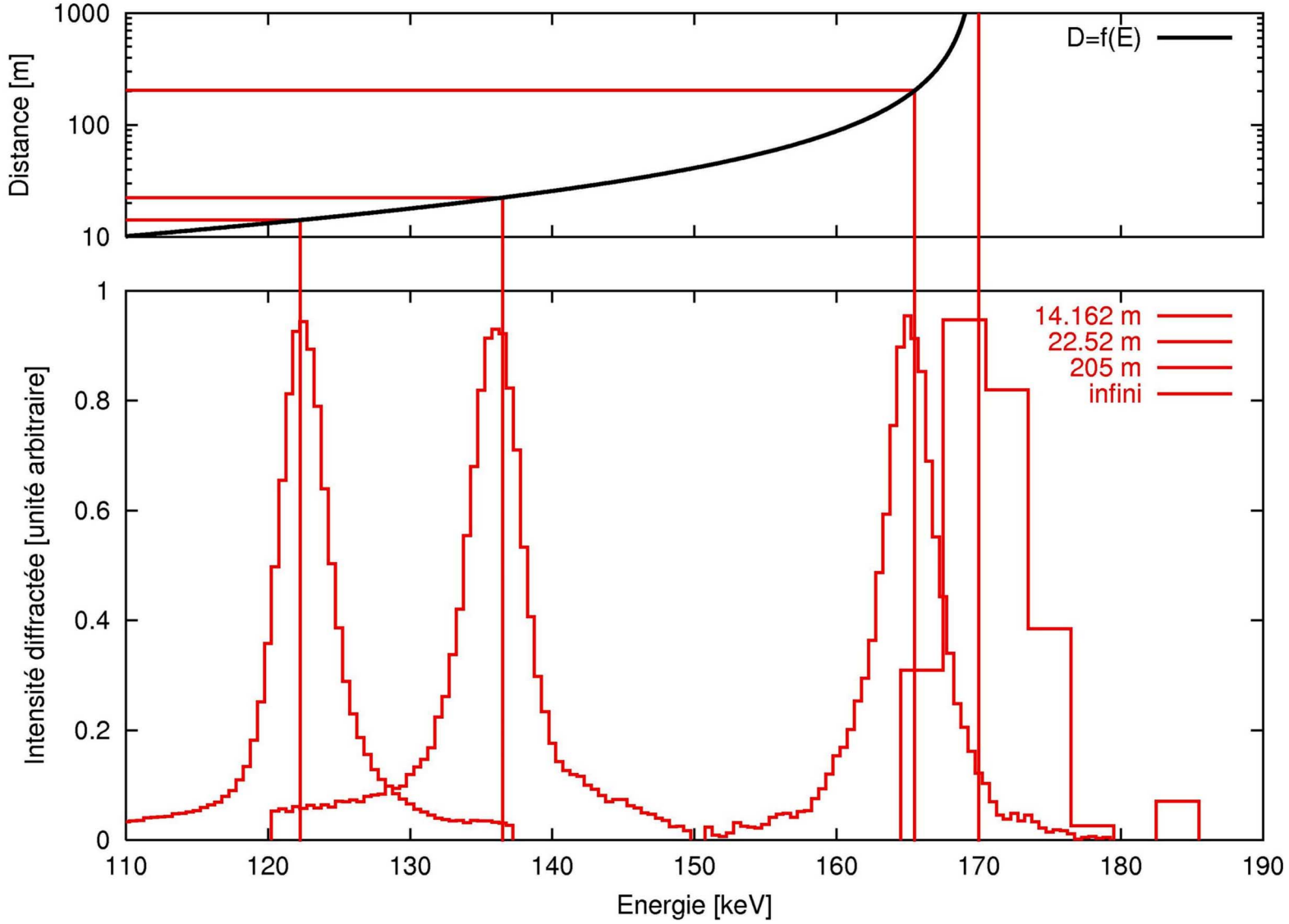
CLAIRE 2001 : background spectrum at float altitude



CLAIRE 2001 : first light from an astronomical source

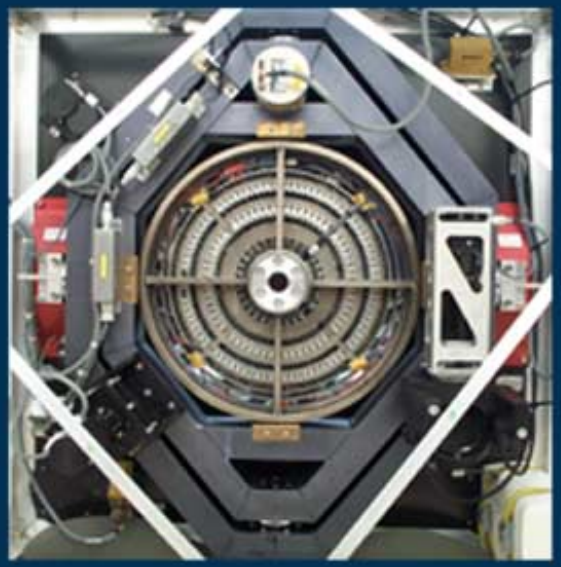


CLAIRE 2001 : 14 m, 22.5 m, 205 m ... infinity !

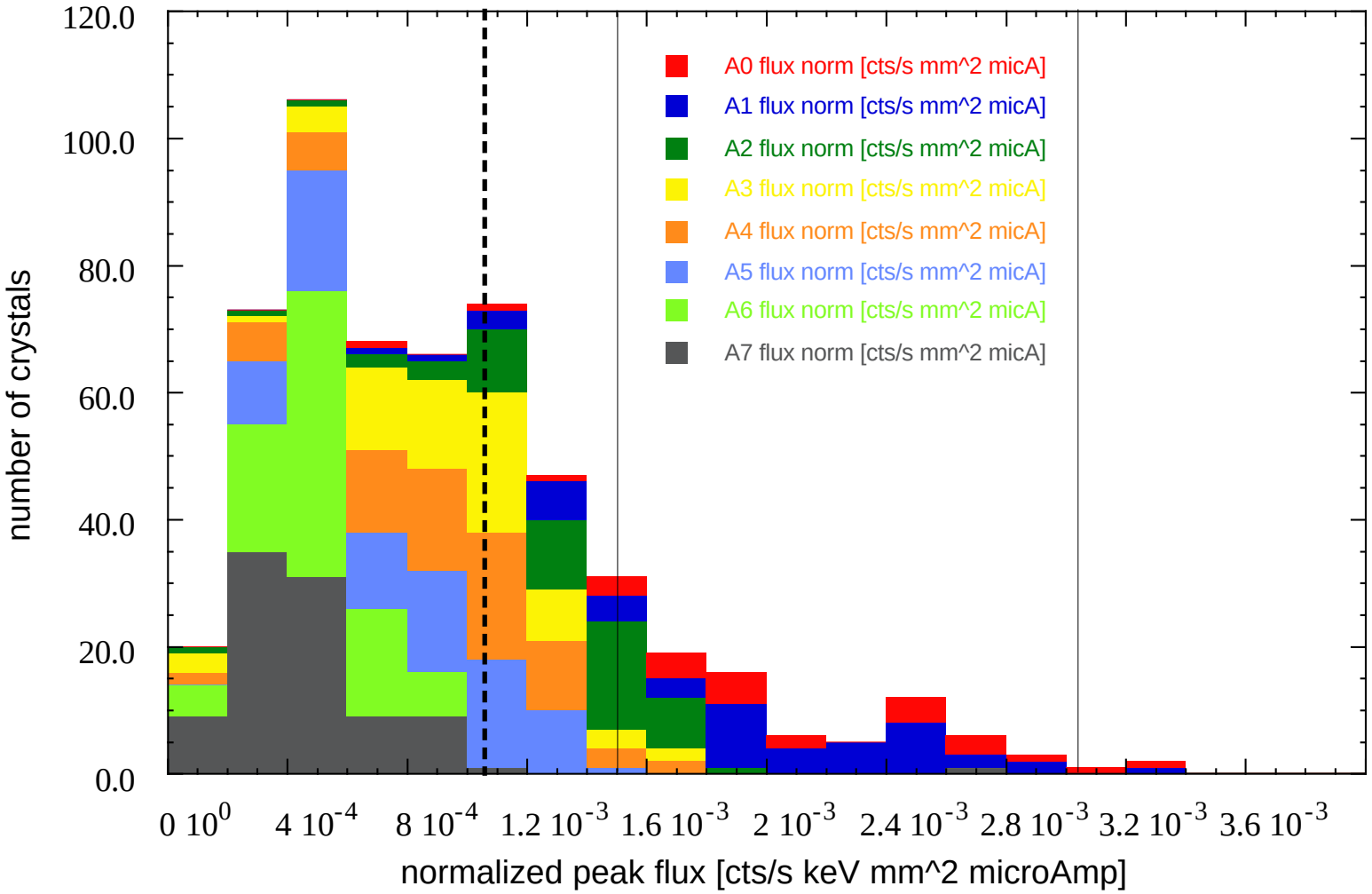


gamma-ray
astronomy
starts to see

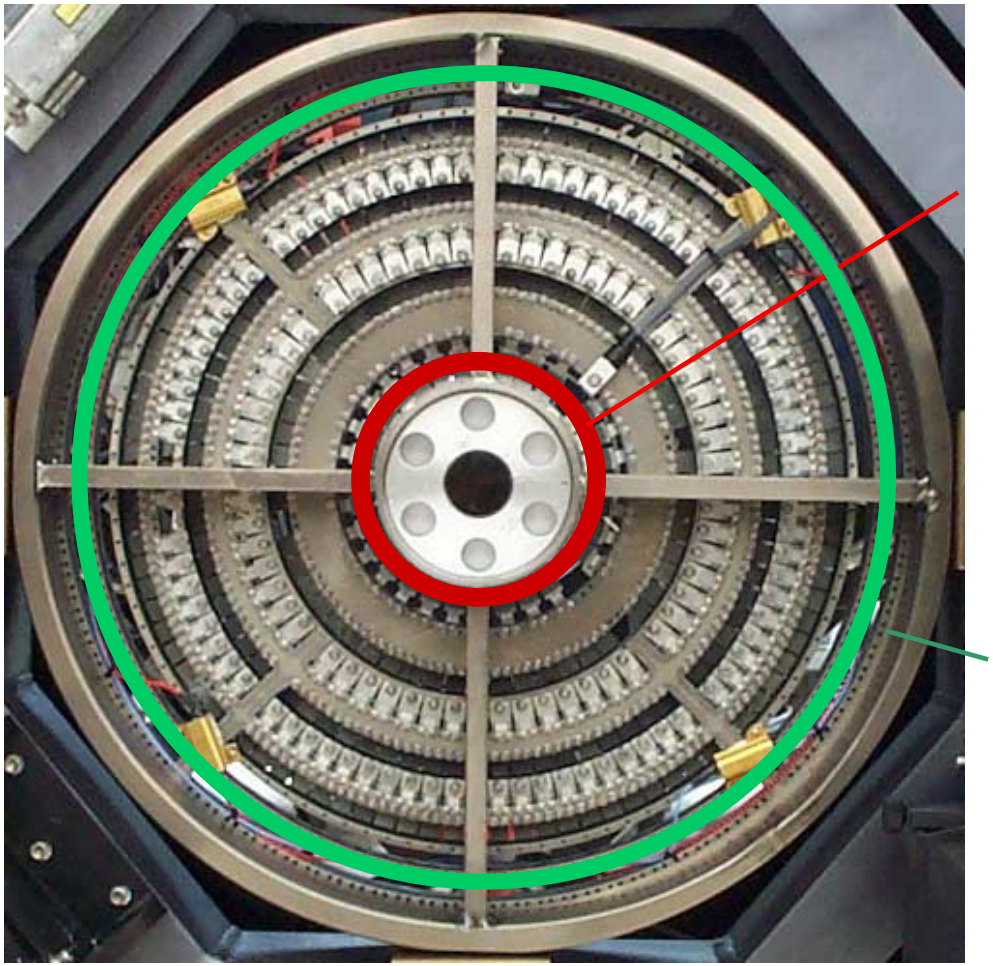
CLAIRE



CLAIRE : diffracted flux of 516 individual crystals



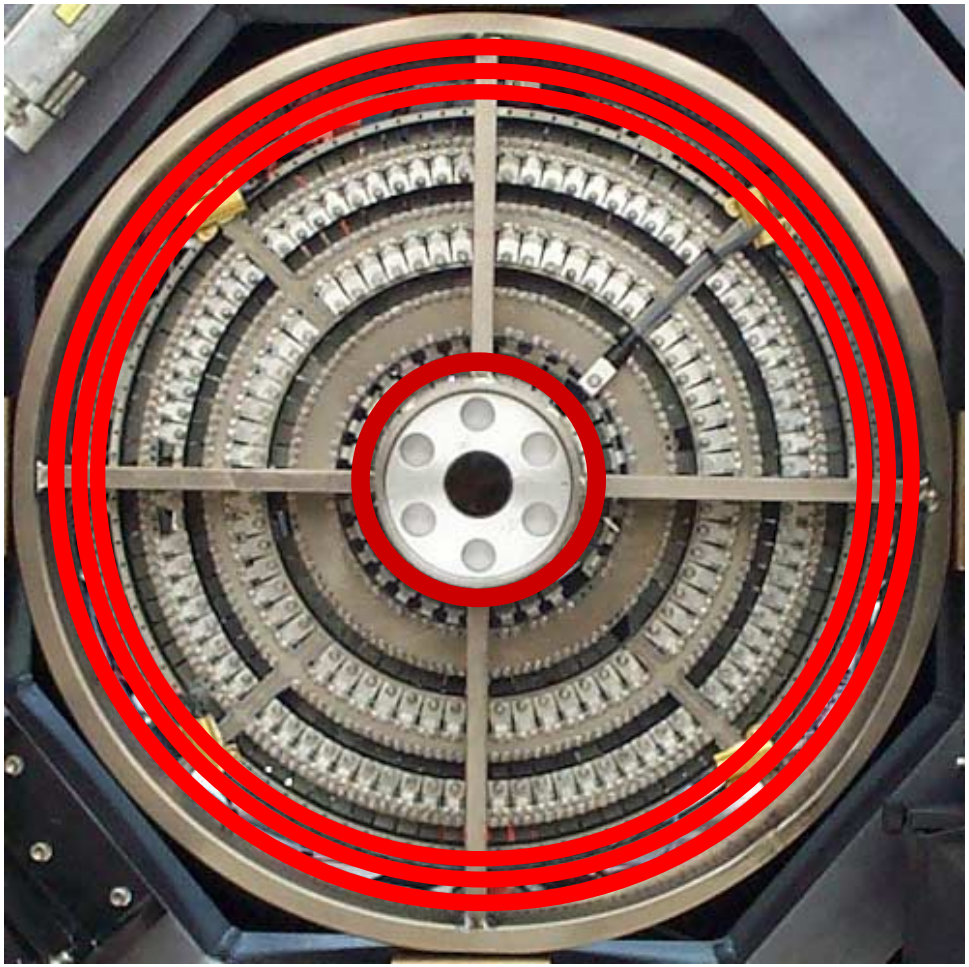
from CLAIRE to MAX



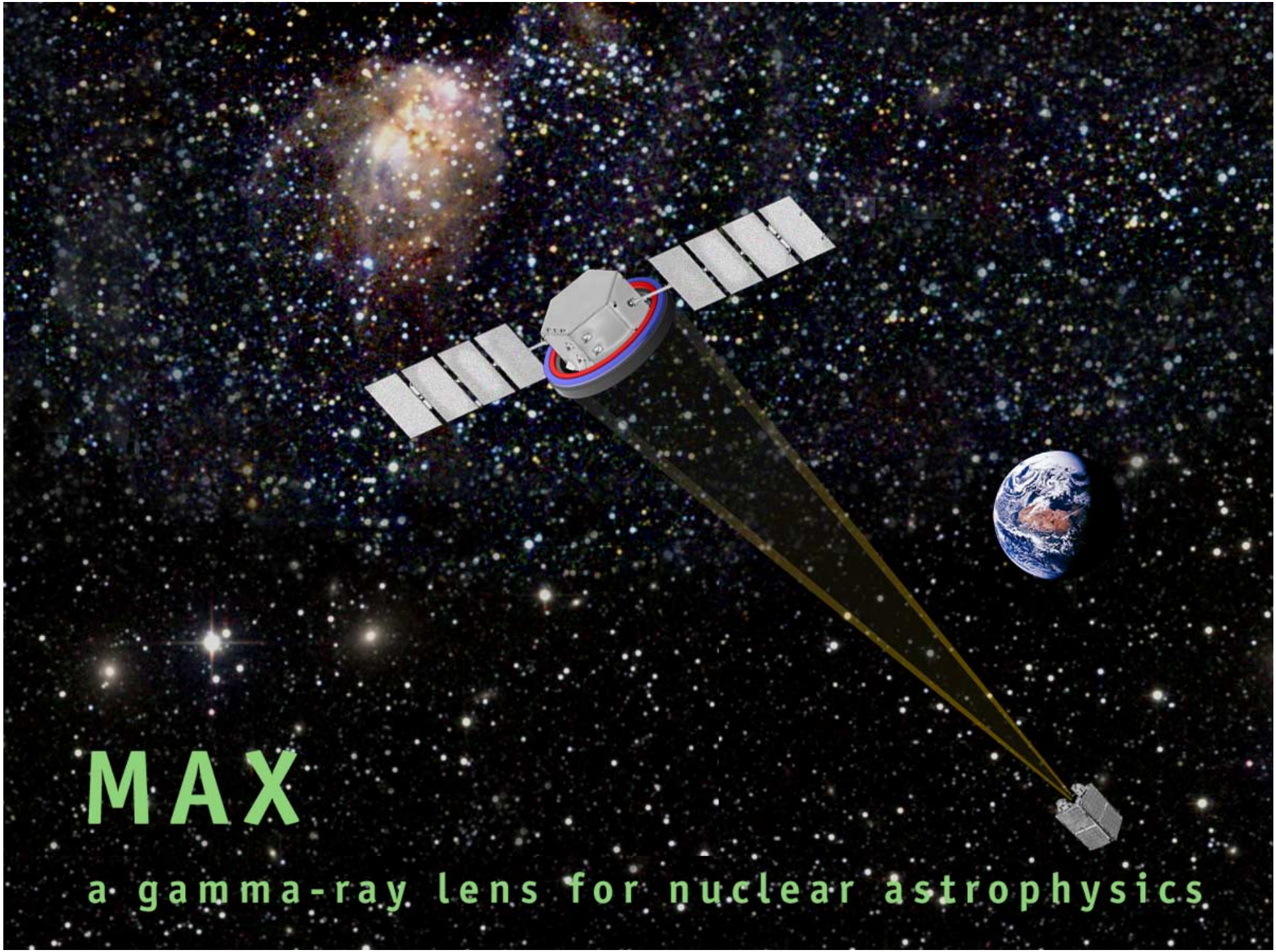
[111] ring
$\varepsilon_{diff} \leq 25\ \%$

[440] ring
$\varepsilon_{diff} \leq 7\ \%$

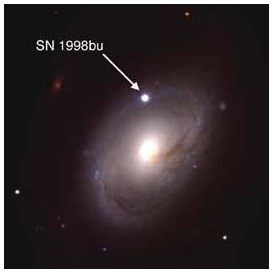
from CLAIRE to MAX



using low order planes such as Ge[111], Cu[111], [200] results in long focal lenghts ...

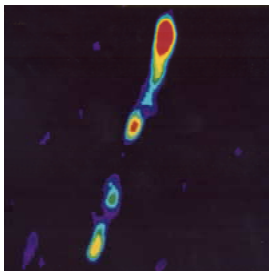

MAX
a gamma-ray lens for nuclear astrophysics

MAX - the promise for nuclear astrophysics



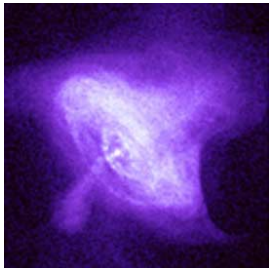
explosive nucleosynthesis

- supernovae, novae **-** origin of chemical elements
- SN1a : standart candles for cosmology



e^+e^- annihilation

- from microquasars to light dark matter ...



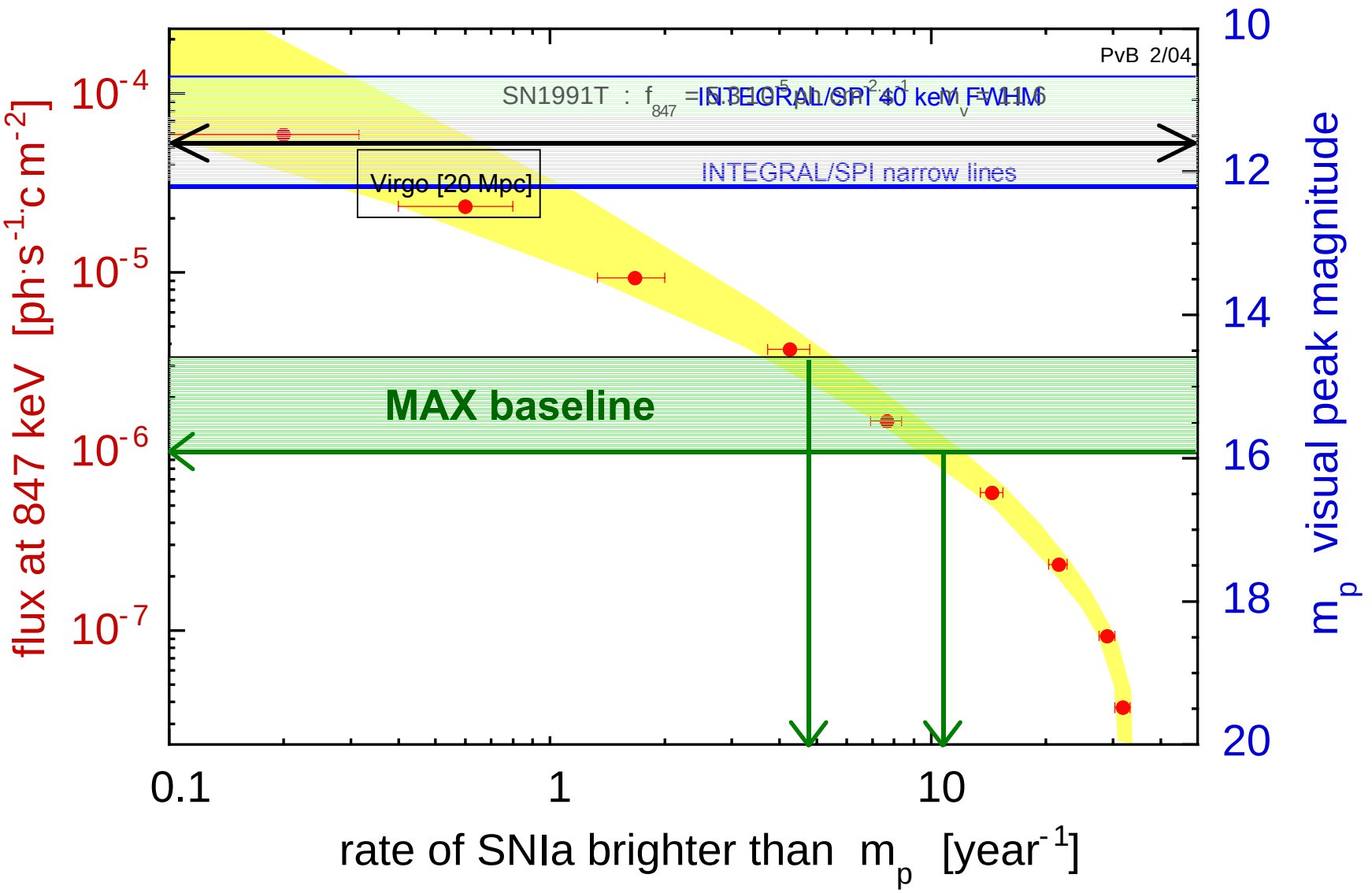
neutron stars

- pairs from NS magnetospheres

MeV Blazars

- Compton up-scattered γ's - polarization ?

SN1a rate, peak magnitude and 847 keV flux

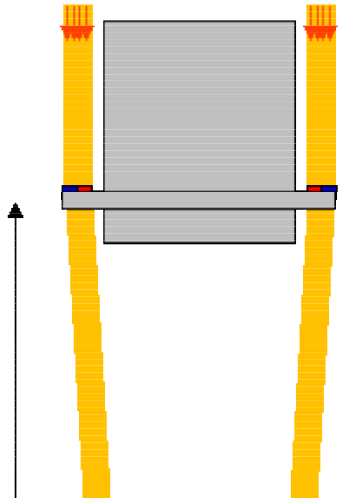


MAX scientific requirements

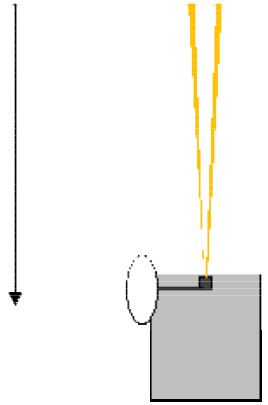
	band 1	band 2
principal gamma-ray lines	$^{56}Fe^*$	e^+ e^- annihilation $^{7}Li^*(\alpha + \alpha)$
bandpass	800 à 900 keV	450 à 550 keV

sensitivity		$\leq 10^{-6}$ [photons cm^{-2} s^{-1}]
spectral resolution	$E/\Delta E$	~ 500
angular resolution		1 arcmin
temporal resolution		< 1 microscec

MAX V2.2 - baseline



86 m



Laue lens:

mosaic crystals	30" mosaicity
low E rings (18)	Ge[111], Cu[111]
high E rings (18)	Cu[111], Cu[200], Ge[311]
max/min diameter :	114 cm/220 cm
weight :	140 kg

detector options

- segmented Ge detector
- CdTe Compton telescope
- stripped Ge Compton telescope
- cryogenic phonon detector

formation flying

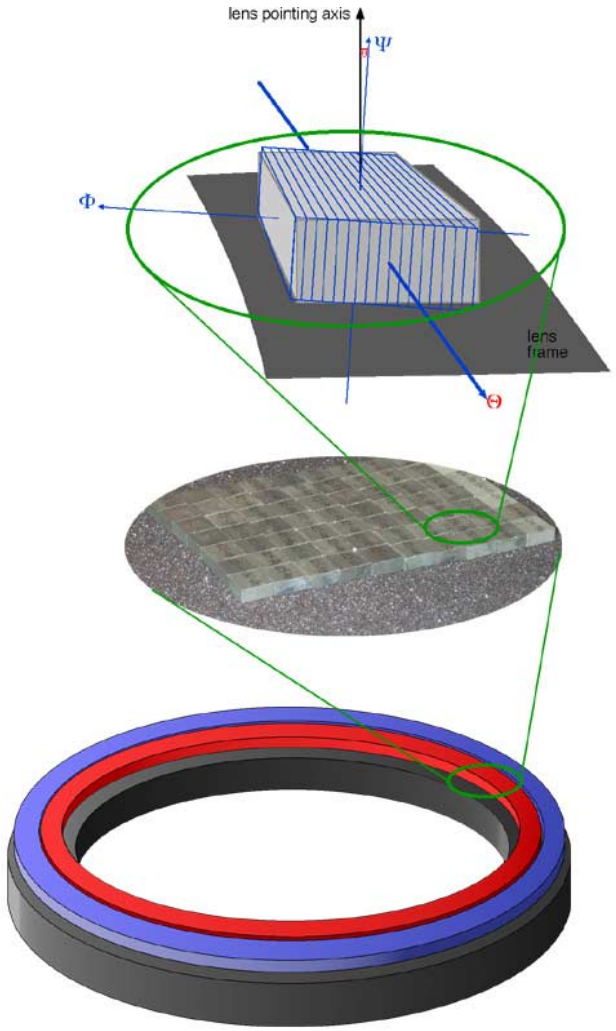
focal length	86 m
station keeping	± 1 mm lateral, ± 0.1 m axial
orbit	> 60'000 km, circular

MAX - a broad bandpass "ring lens"

- mosaic crystals (CLAIRE type)

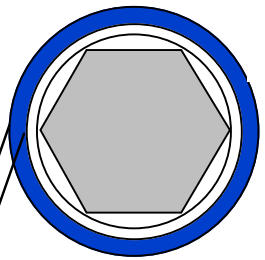
- dense packing of the crystals

- only most efficient orders
  - outer rings [111], [311] Ge
  - inner rings [111], [200] Cu

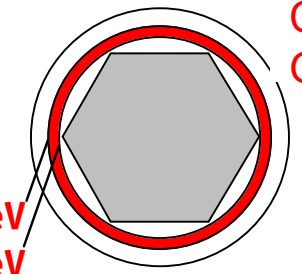


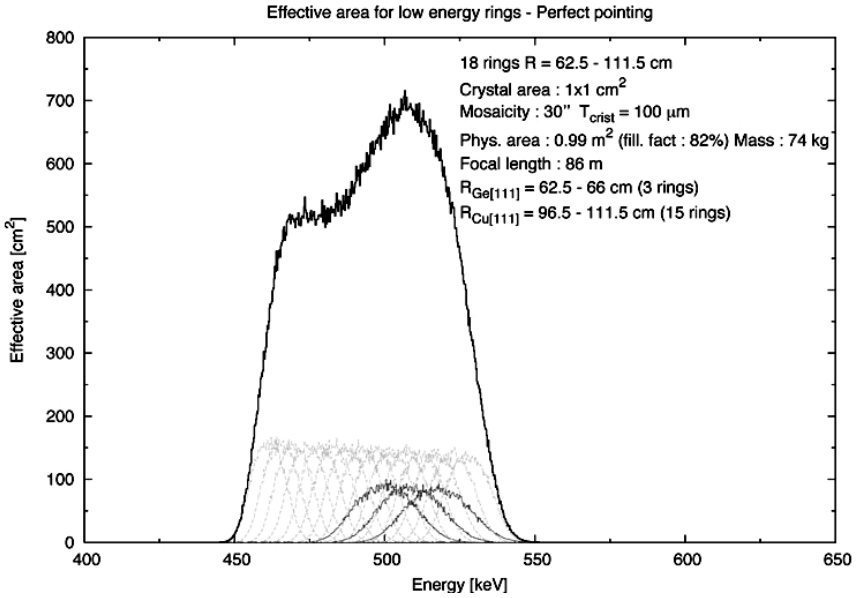
MAX - effective area

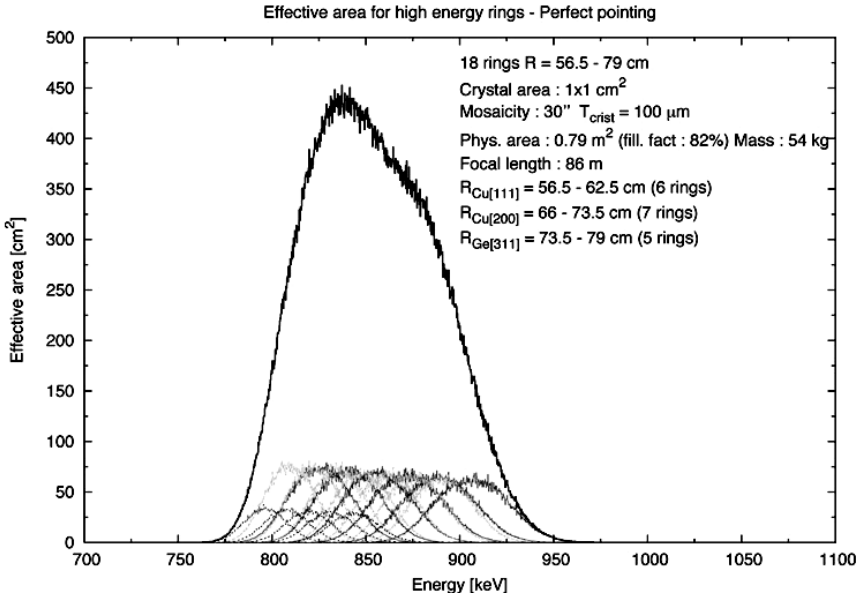
511 keV band
Ge [111] crystals
Cu [111] crystals



847 keV band
Cu [111] crystals
Cu [200] crystals
Ge [311] crystals







MAX - 3σ narrow line sensitivity

two broad energy bands diffracting simultaneously

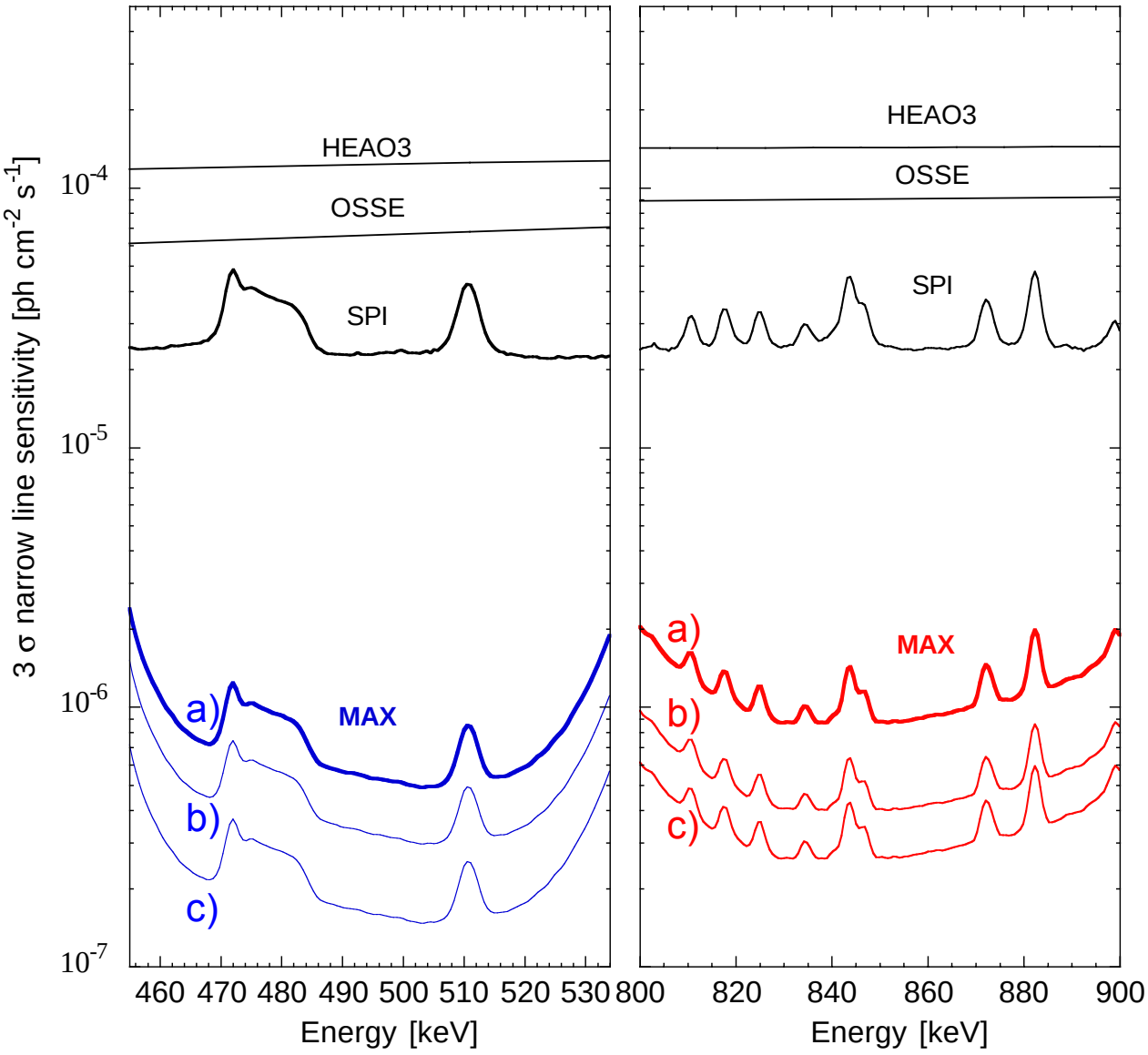
- energy res. ~ 500
- ang.res. ~ 1'
- polarization

options

a) baseline
- CLAIRE crystals
- SPI measured BG

b) improved BG
- Compton reconstr.

c) improved crystals
- gradient crystals



MAX CNES' formation flying AO

call for ideas : science with a formation flying demonstrator

January 6, 2003 : CNES issues AO
March 8, 2003 : deadline for proposals
July 2004 : selection for phase A
2005 : prototype (phase A)
2006 – 2009 : realization, integration, tests …
2010 : launch

support needed : the science case of MAX

what are the relevant scientific objectives for 2010 ?
support MAX (letter to pvb@cesr.fr)
attend the MAX meeting today

Are the energy bands (460-520 keV and 800-900 keV) relevant ?

Are there other lines that need to be accessible ?

Which observations would benefit from polarization measurement ?

What is the sensitivity level which is REALLY needed ?

How important is energy resolution ?

What is the cross-fertilization with other instruments ?

Is there need for low-energy capability to accompany lens detections ?

MAX meeting

Wednesday 18 February, 14:00 to 16:00
at the Bavarian Academy of Sciences


MAX meeting
Wednesday 18 February, 14:00 to 16:00
at the Bavarian Academy of Sciences