Physics Department
Sensor and Semiconductor Lab

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

Riccardo Camattari, Vincenzo Guidi, Valerio Bellucci and Ilaria Neri
Department of Physics, University of Ferrara, Via Saragat 1/c, 44122 Ferrara and
CNR - IDASC SENSOR Lab., Italy.

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.

Fig. 1

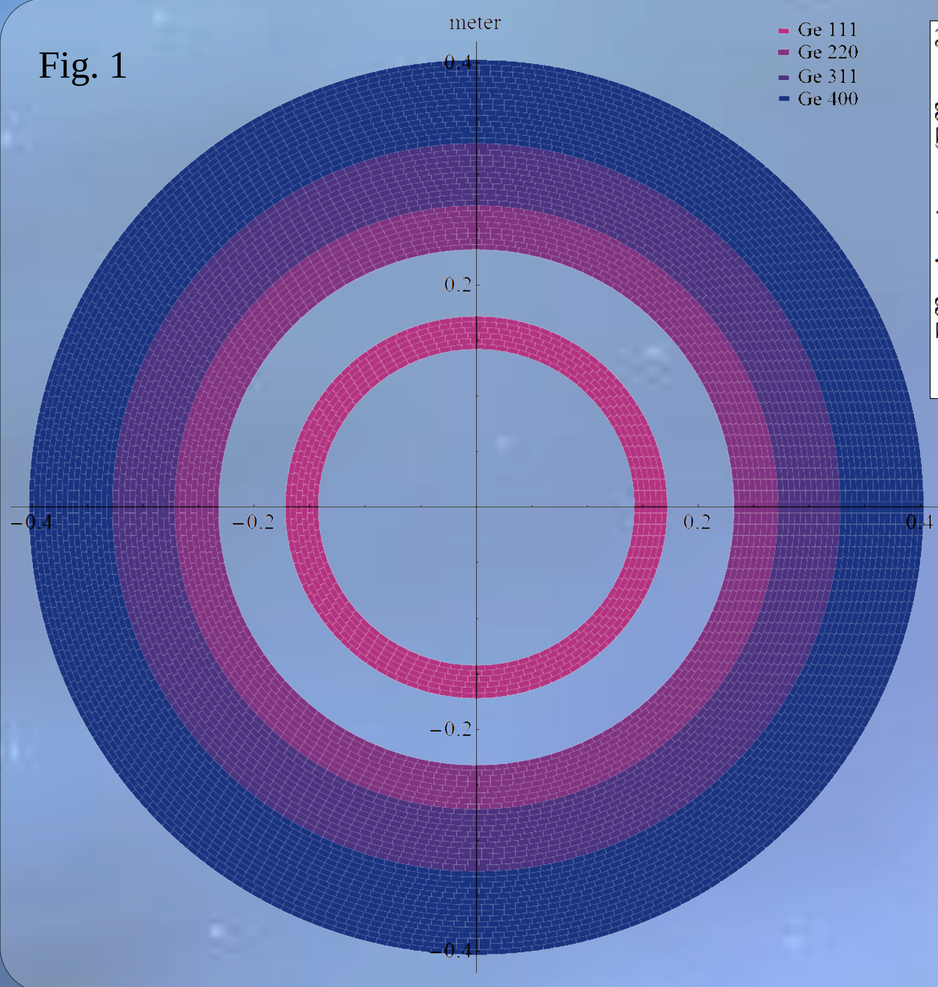


Fig. 2

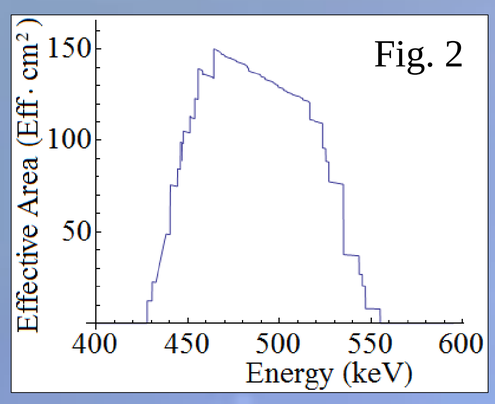


Fig. 3

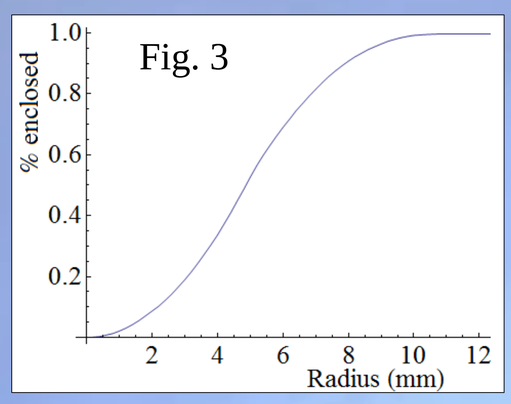
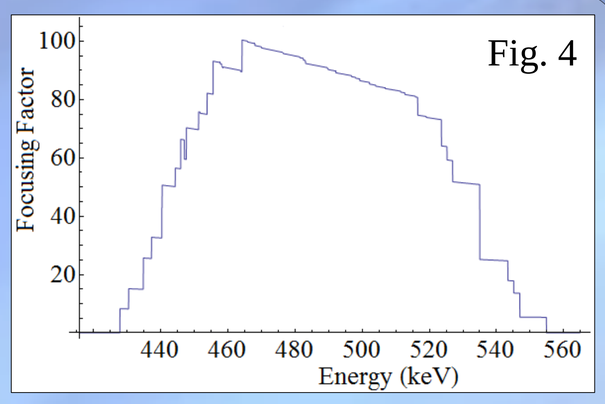


Fig. 4



Ring	Number of rings	Reflectivity at 511 keV	Crystal thickness (mm)	Curvature Radius (m)
Ge 111	6	18.8%	18	47.6
Ge 220	8	17.8%	18	48.8
Ge 311	11	7.9%	21	56.3
Ge 400	15	10.5%	21	54.4

Focal length: 20 m
Energy passband: 428 – 535 keV
Filling factor: 97.9%
Crystal spread: 78 arcsec
Crystal radial dimension: 5 mm
Crystal tangential dimension : 10 mm

Fig. 1: Rings of Ge crystals with several diffracting plane.

Fig. 2: Effective Area of the Laue lens.

Fig. 3: Encircled photons onto the detector.
At R = 4.9 mm -> 50%. At R = 7.9 mm -> 90%.

Fig. 4: G Factor [1].

Fig. 5

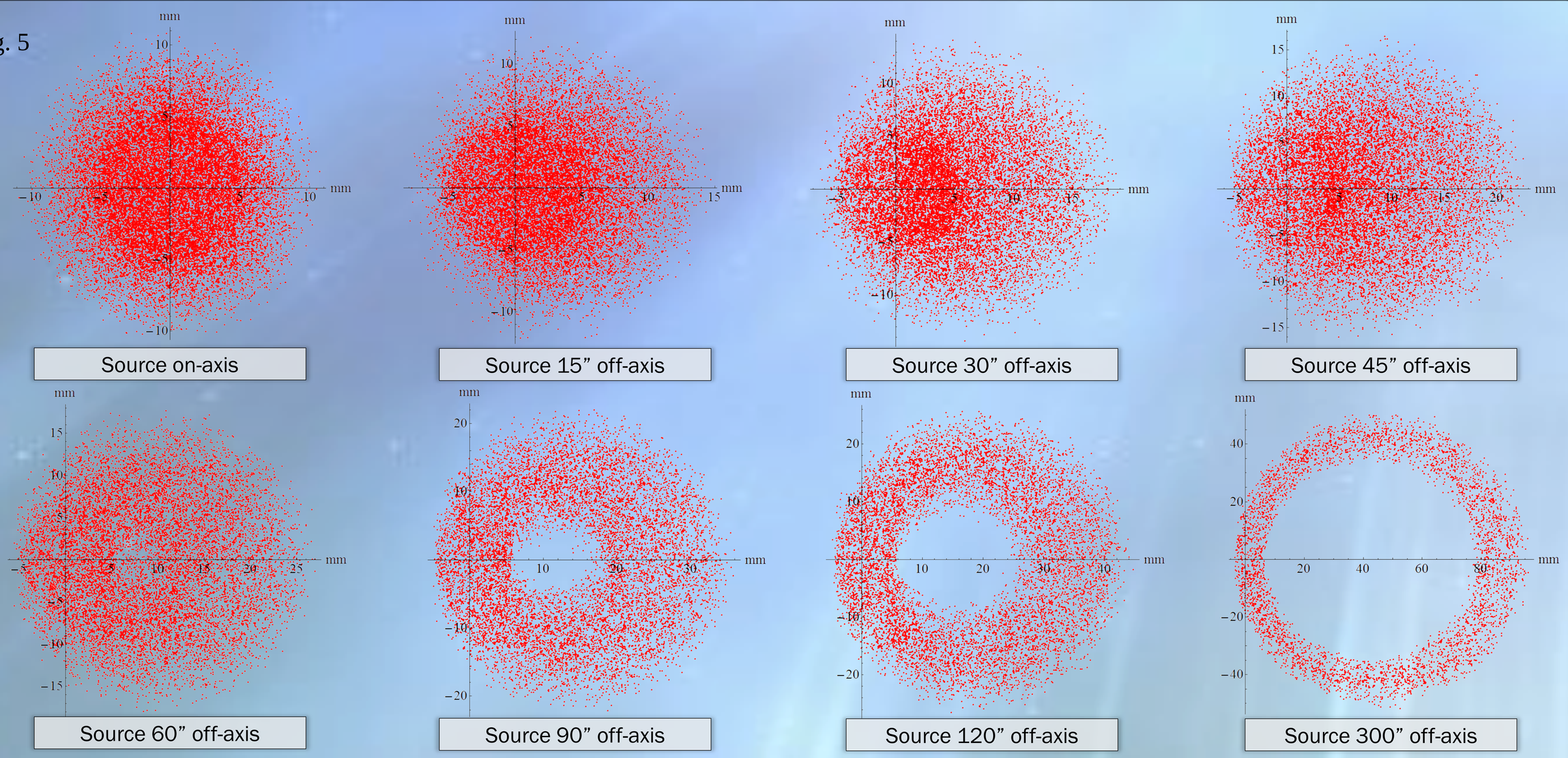


Fig. 5: Photons distribution on the focal plane with source on-axis and off-axis

A Laue lens, based on Ge crystals intrinsically curved, has been simulated. The combined effect of good reflectivity and small size of the photon distribution on the focal plane results in a high sensitive Laue lens, as can be seen from graphics in Fig. 2, Fig.3 and Fig. 4. The lens can be assembled in a larger structure. Using curved crystals, energy passband and FOV of the lens can be very well-controlled.

[1] Laue Gamma-Ray Lenses for Space Astrophysics: Status and Prospects