Caliste-MM, a Spectro-Polarimeter for Soft X-ray Astrophysics

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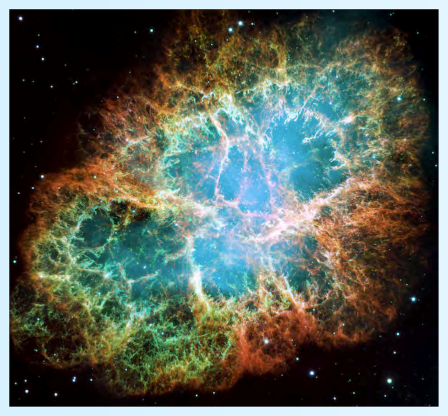
X-ray Polarimetry in Astrophysics

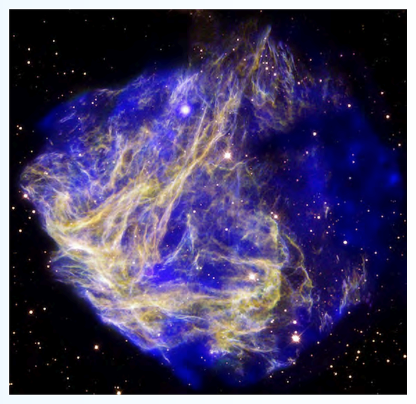
Before 2000, only 2 techniques for X-Ray polarimetry : Bragg diffraction and Thomson Scattering

Consequences : Few flying experiments, with low sensitivity

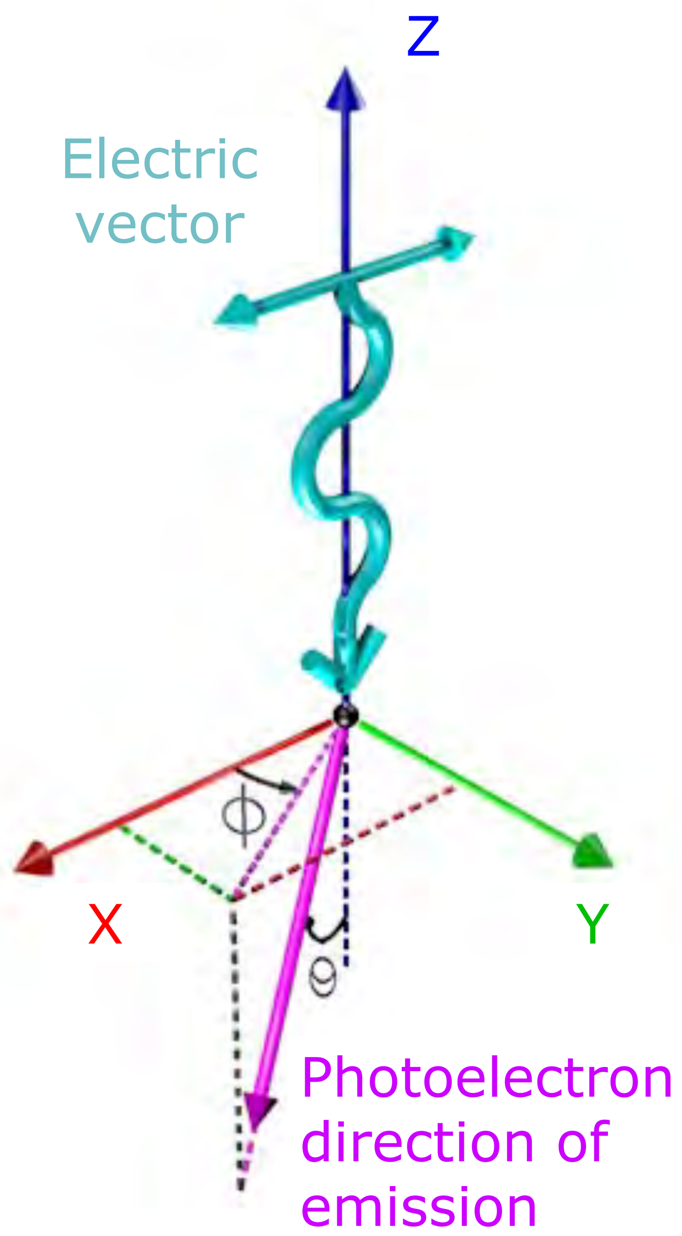
Improvement of gaseous detector in late 1990s gave new way to perform soft X-Ray polarimetry

Wide range of applications, such as cosmic-ray acceleration in SNR [1]





Soft X-Ray Polarimetry in gases



Conversion of photon done by photo-electric effect

Heitler photo-electric differential cross section:

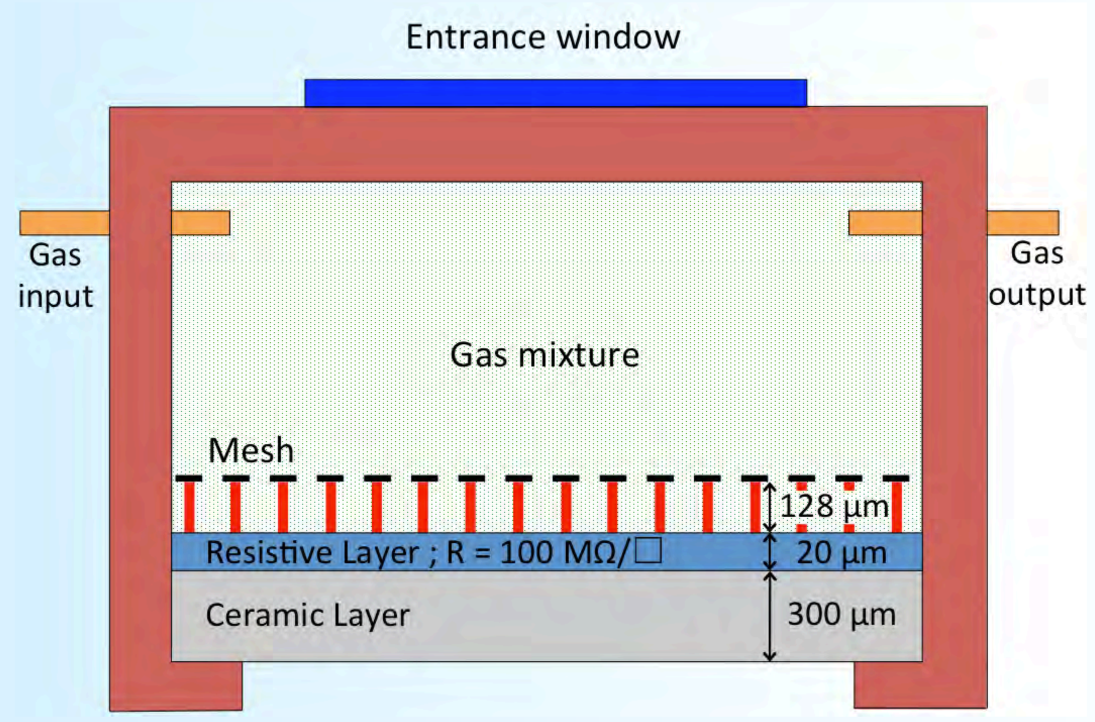
$$\frac{d\sigma_{Ph}}{d\Omega} = r_0^2 \alpha^4 Z^5 \left(\frac{m_e c^2}{E}\right)^{\frac{7}{2}} \frac{4\sqrt{2}\sin^2(\theta)\cos^2(\phi)}{(1-\beta\cos(\theta))^4}$$

Emission probability modulated by $\cos(\Phi)^2$:
The photo-electron has a greater probability of being ejected at the angle $\Phi=0$

The azimuthal distribution of the photo-electrons gives the polarization of the source

The Piggyback Micromegas

MicroMegas principle, bulk technology [2]
Anode = Resistive layer
NO ELECTRONICS INSIDE THE DETECTOR



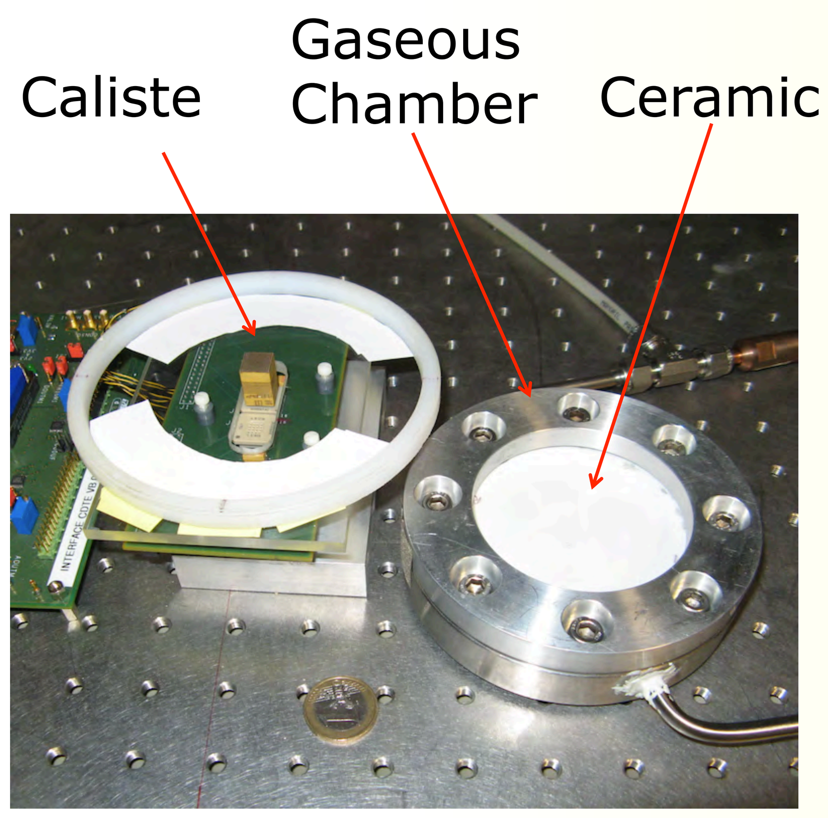
The Caliste Electronics

[3]

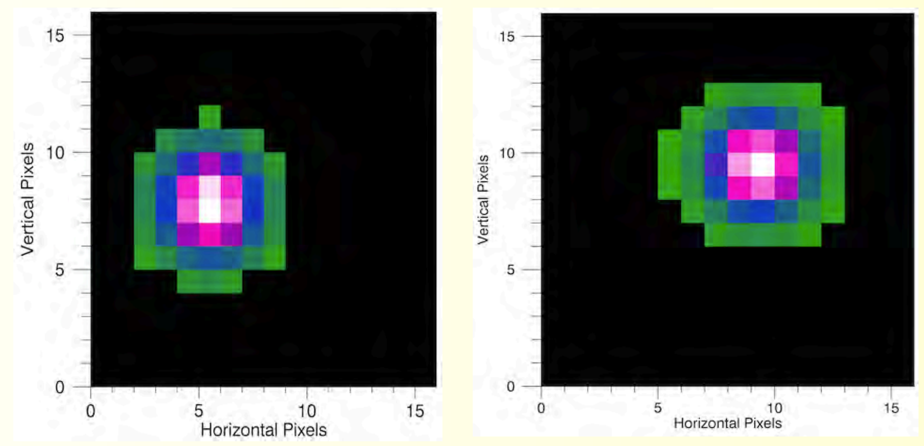
- 10x10x20.7 mm³
- 256 Pixels (16x16 array)
- Pixel Ø = 500 µm
- Pixel Pitch = 580 µm
- 850 µW/channel
- ENC = 50 e⁻ RMS
- Space Qualified

Caliste is a low Noise, finely pixelated chip and able to performe spectrometry
→ perfect candidate to read semi-conductor detectors

The Setup



Events and Model

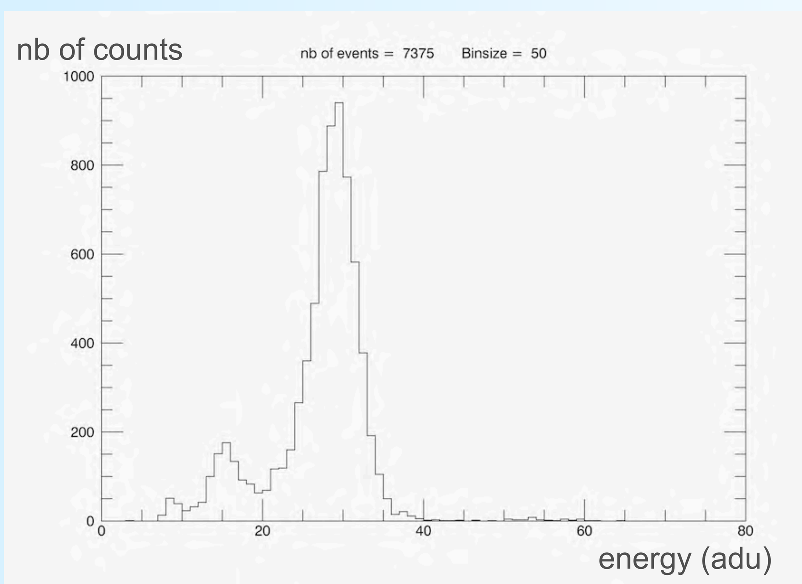


Left: 6 keV photon conversion as read on the Caliste

Right: Simulation of a 6 keV photon conversion, based on a diffusion model in the resistive layer using Fick's laws

Spectrometry

Gas = Ar-C_2H_6 (90% - 10%)
Atmospheric pressure
6 keV photons

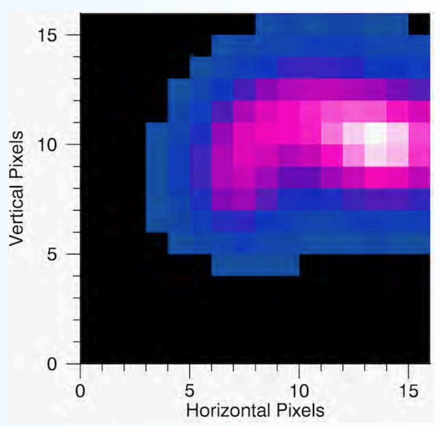


Spectrum of the events
Resolution = 17.8% FWHM

Polarimetry

Gas = He-CO_2 (90% - 10%)
8 keV photons

Helium allows the photo-electron to recoil

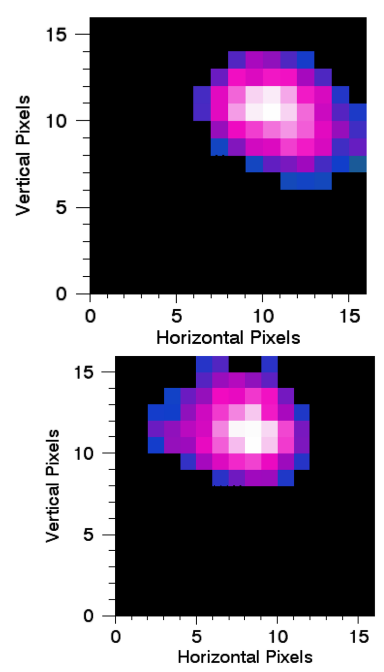


The ejection direction of the photo-electron is visible

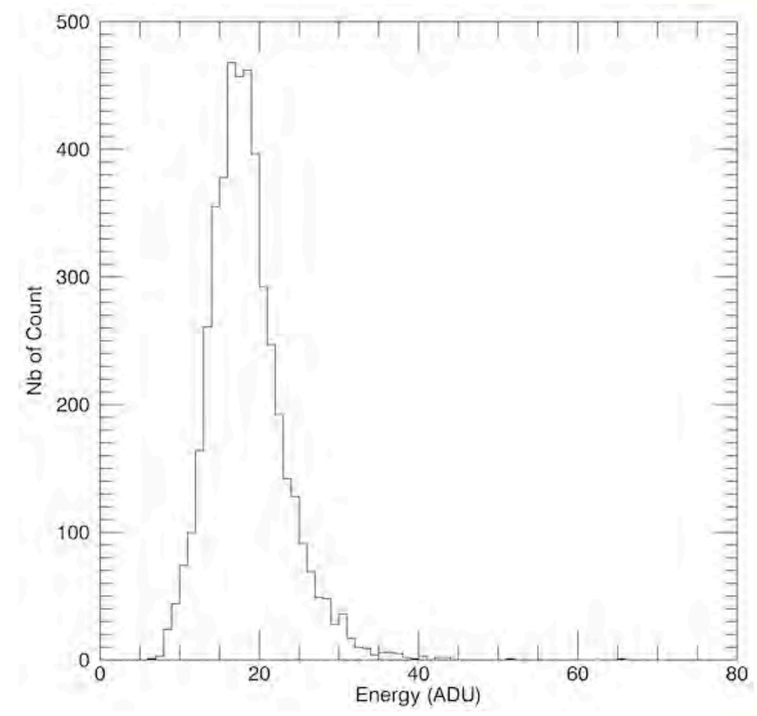
With Helium it is possible to perform polarimetry, but not spectrometry

Spectro-Polarimetry

Gas = Ne-CF_4-C_2H_6 (90% - 5% - 5%)
P = 375 mbar
6 keV Photons



Tracks visible



Resolution ≈ 30% FWHM

Perspectives

Thin mesh piggybacks to reach a better resolution at 6 keV (11% FWHM expected)

Larger gap piggybacks to increase gain at low pressure and be able to use argon to perform spectro-polarimetry

Tests in 100% polarized beam to make a polarimetry measurement and measure the modulation factor

[1] Soffitta et al., arXiv:1309.6995
[2] D. Attié et al., JINST 1305 (2013) P05019
[3] O. Limousin et al., NIMA, **647**, pp.46-54