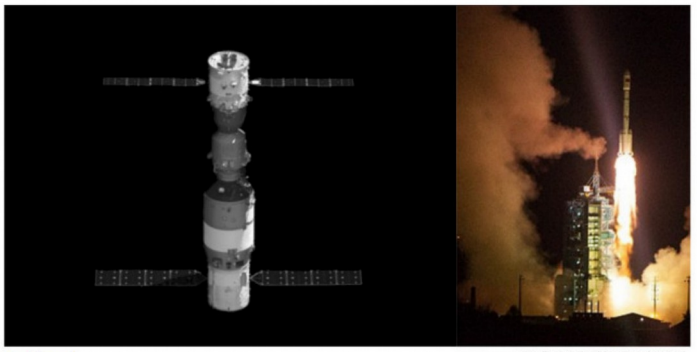
POLAR and POLAR-2

12th INTEGRAL Conference and 1st AHEAD Gamma-ray workshop.
February 2019 Geneva
Nicolas Produit, university of Geneva, astronomy department

POLAR

Collaboration:

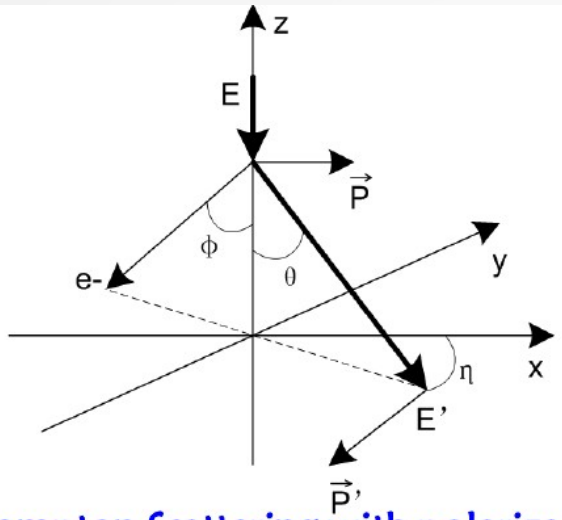
Switzerland, Poland, China



Credit: South China Morning Post

- Launch Sept 2016 on TG-2 Chinese space lab
- End of operation 1st April 2017
- 55 confirmed GRB

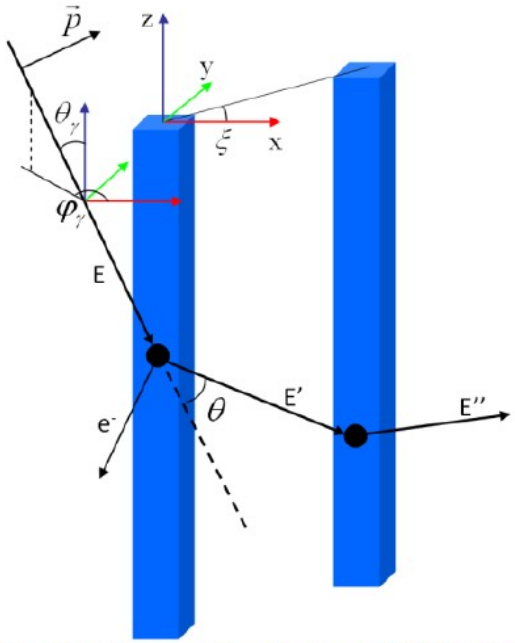
Compton polarimetry



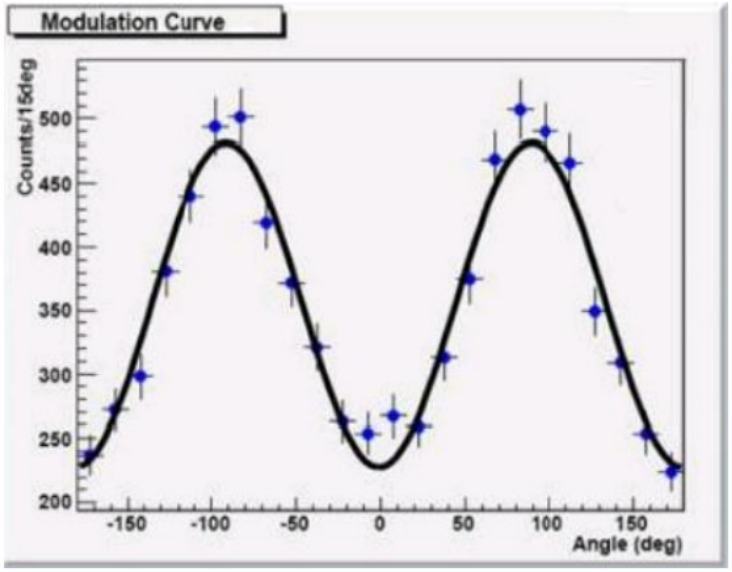
Compton Scattering with polarization

Klein-Nishina equation:

$$\frac{d\sigma_P}{d\Omega} = \frac{1}{2} r_0^{\,2} \varepsilon^2 (\varepsilon + \varepsilon^{-1} - 2\sin^2\theta\cos^2\eta)$$



Detection principle of POLAR



Modulation curve

Distribution function

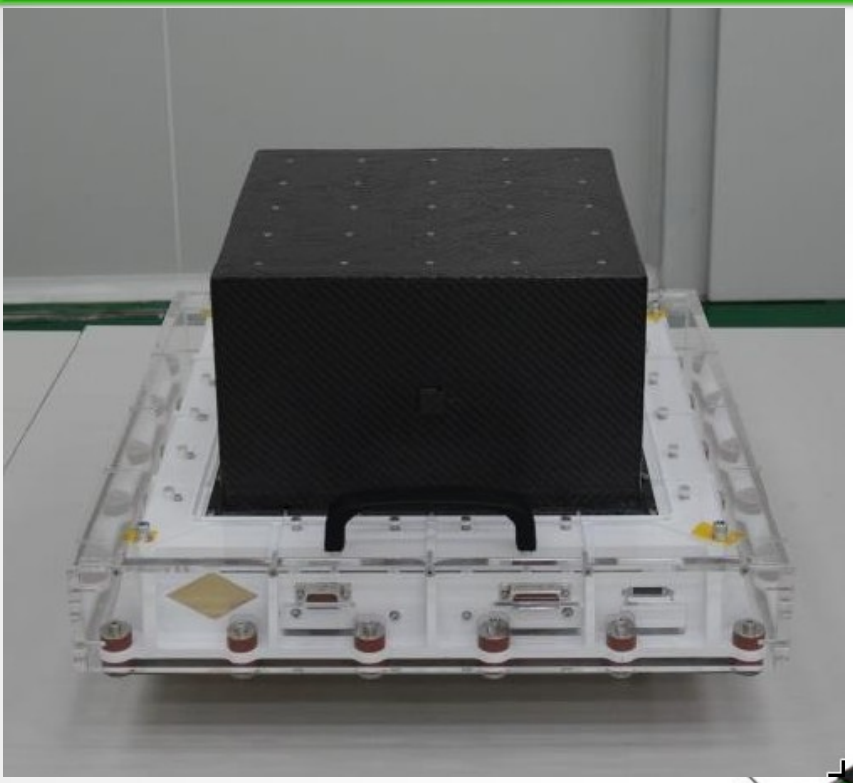
$$C(\xi) = A\cos(2(\xi - \varphi + \frac{\pi}{2})) + B$$

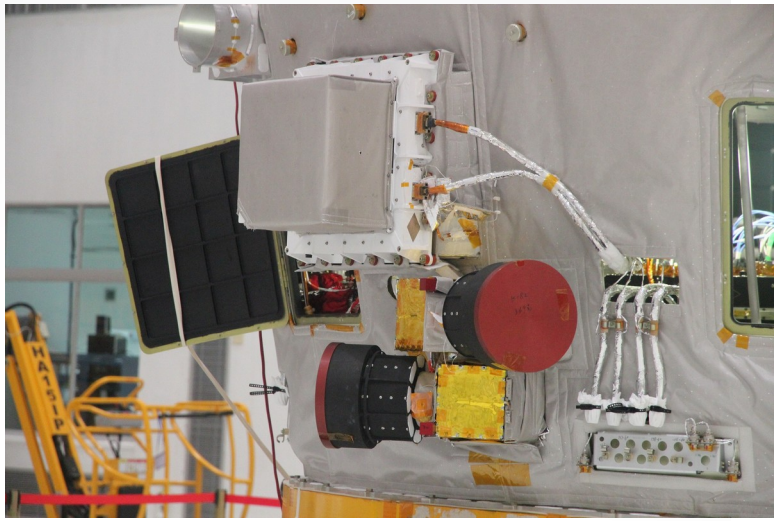
$$\mu = \frac{C_{\max} - C_{\min}}{C_{\max} + C_{\min}} \Rightarrow P = \frac{\mu}{\mu_{100}}$$

Modulation factor

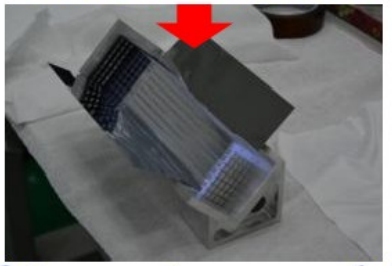
Polarization level

Detector



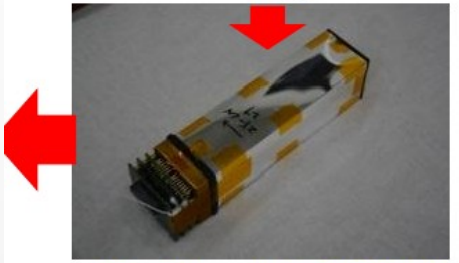


PS bar screen

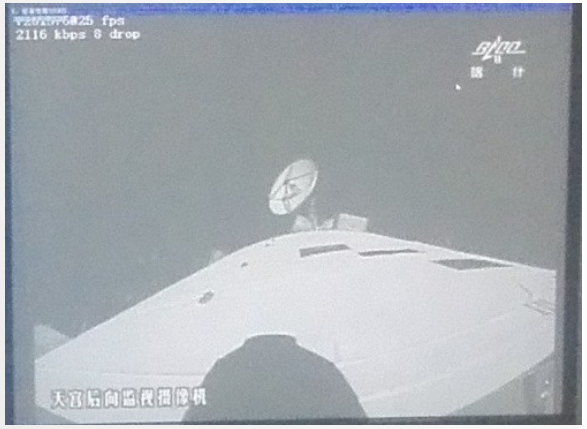


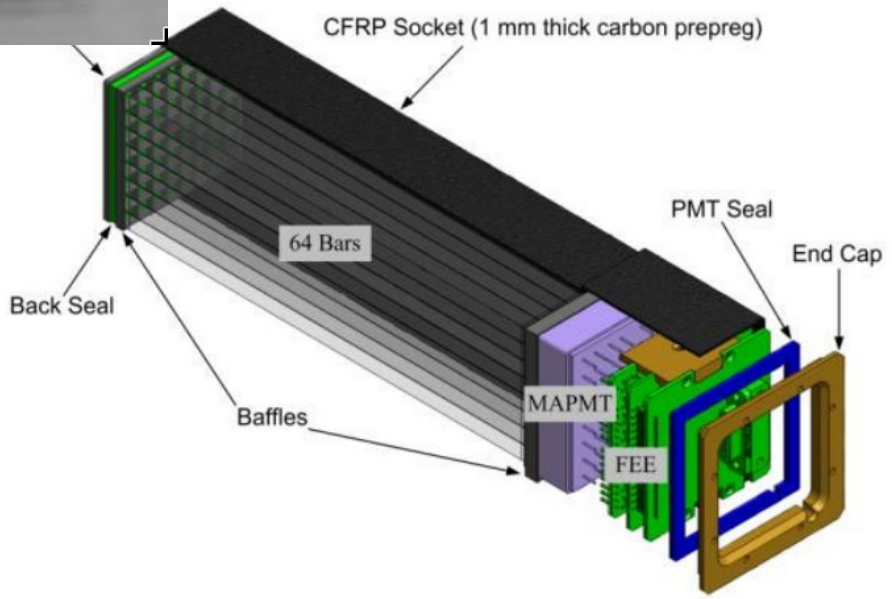
PS target assembly

PS targets



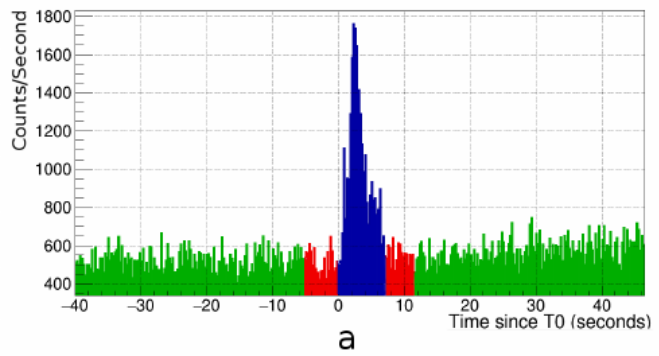
Naked DMU



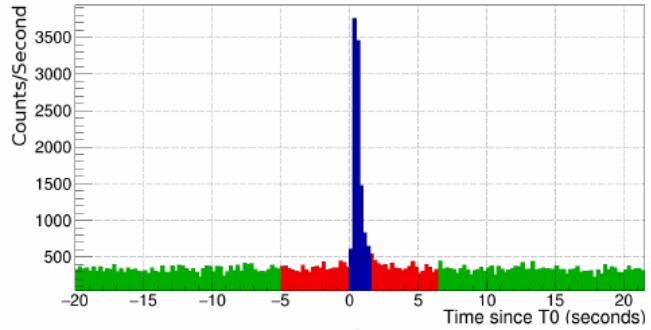


The 5 “easiest” GRB

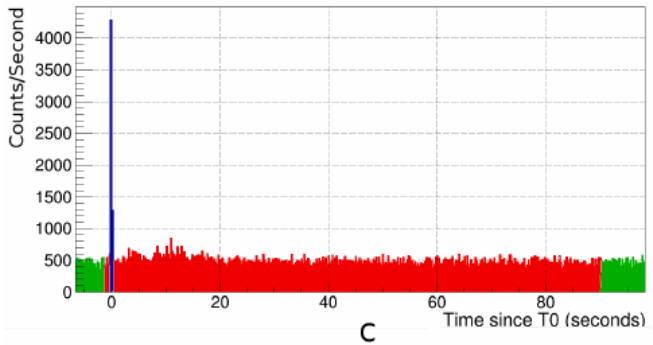
- 161218A
- 170101A
- 170114A
- 170127C
- 170206A



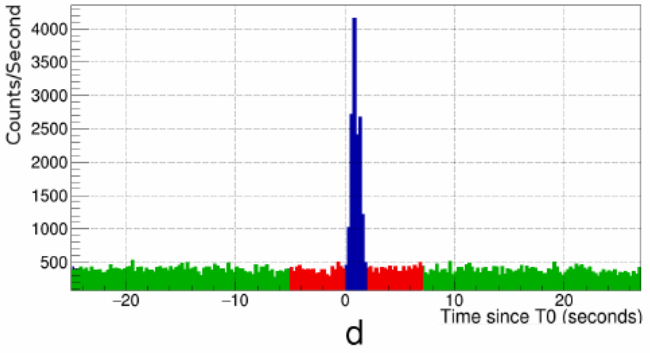
a



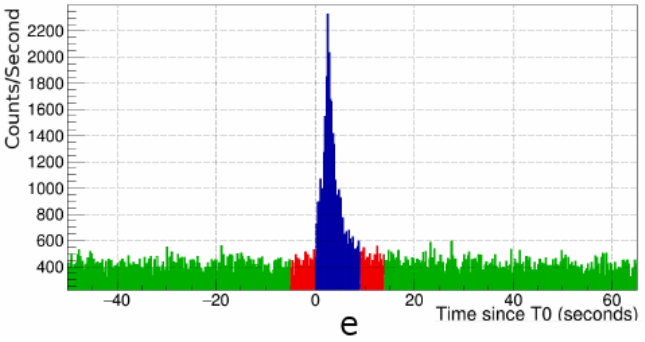
b



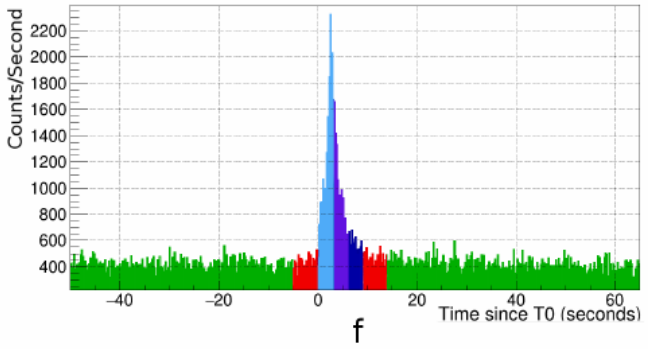
c



d

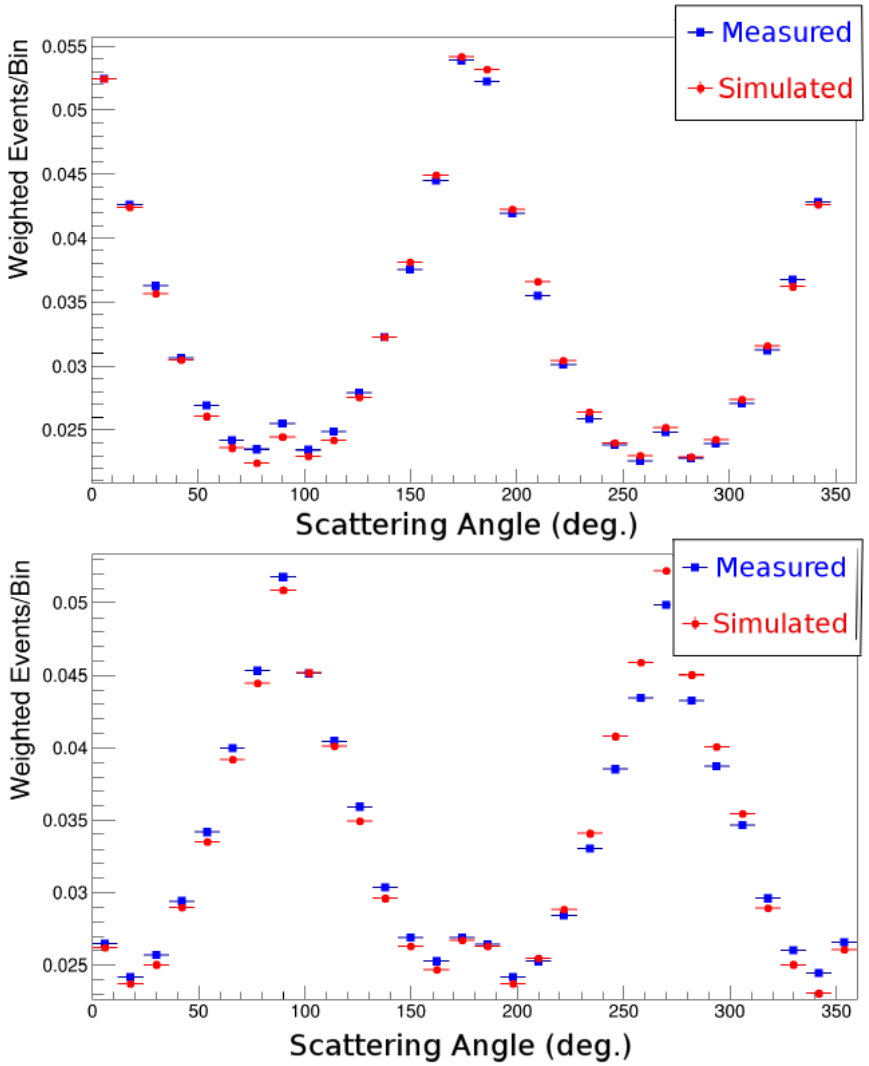


e



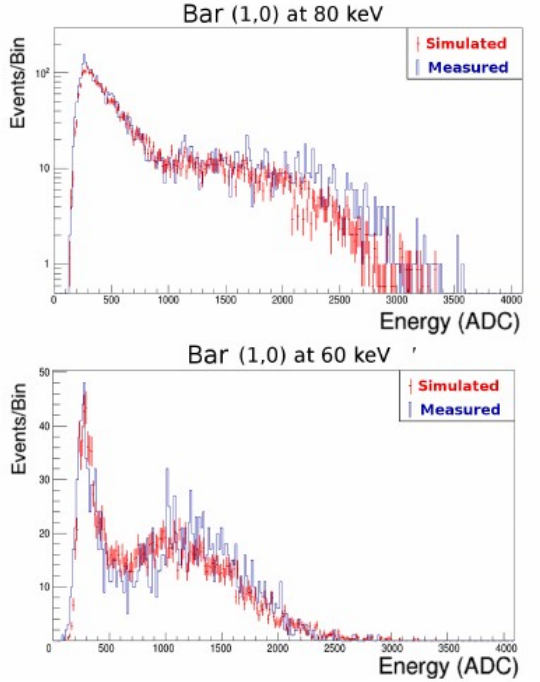
f

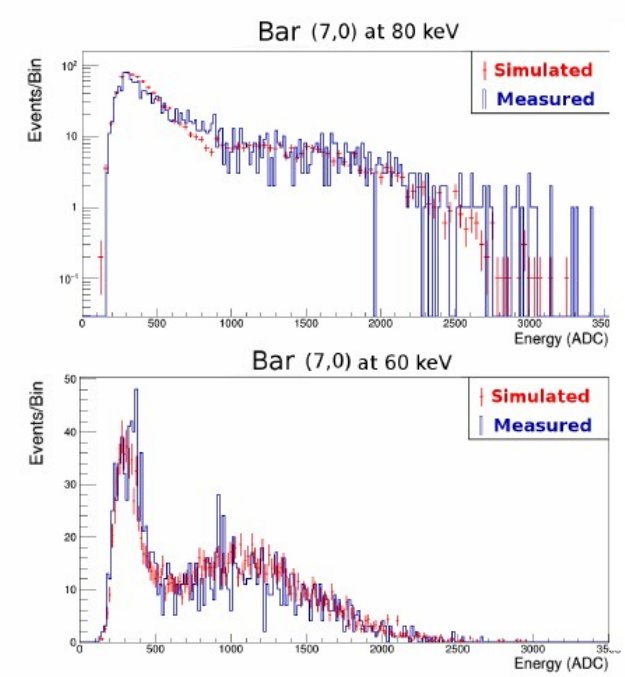
Very well calibrated

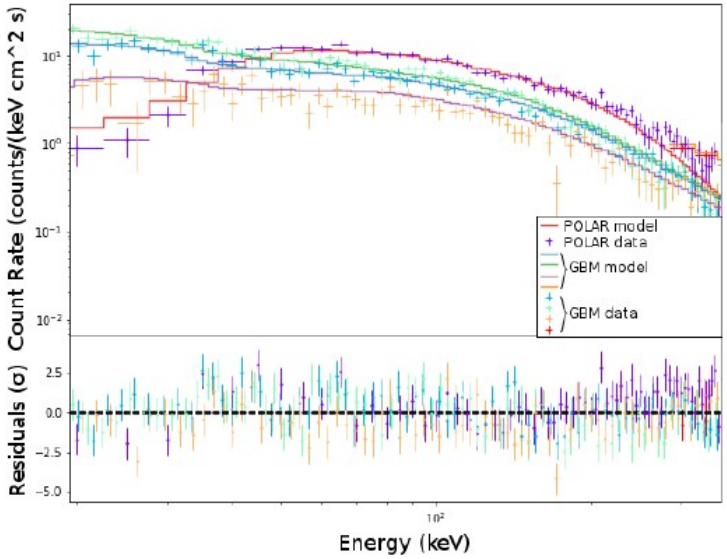


- Real measured modulation curve looks slightly more messy
- Main effort: reproducing measured modulation curves with simulations
- Instrument was calibrated very carefully on ground (see Kole et al. arXiv:1708.00664)
- Careful calibration in-orbit (see Li et al. (arXiv:1805.07605)
- Built a fully parameterized respone which reproduces data

Bad energy resolution but very well understood

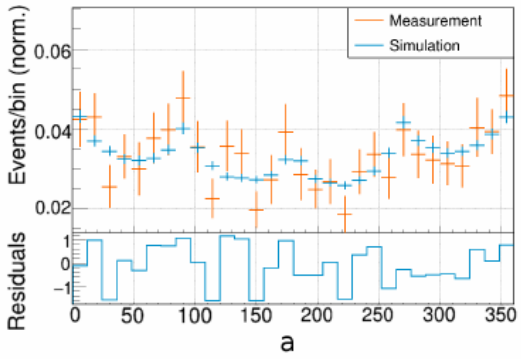


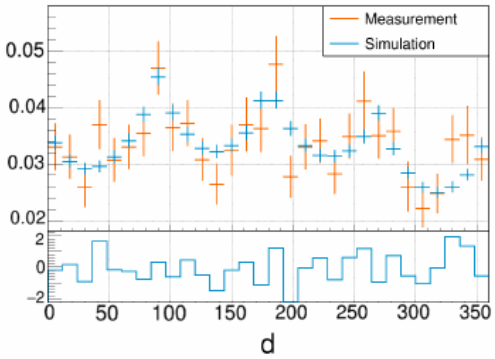


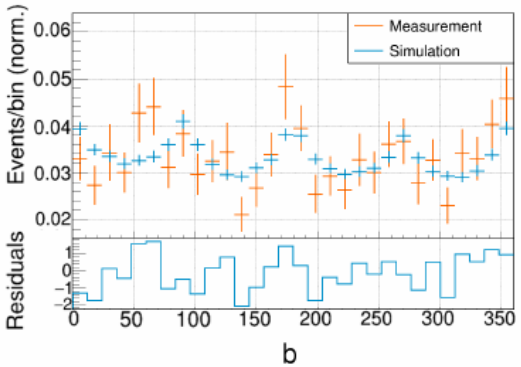


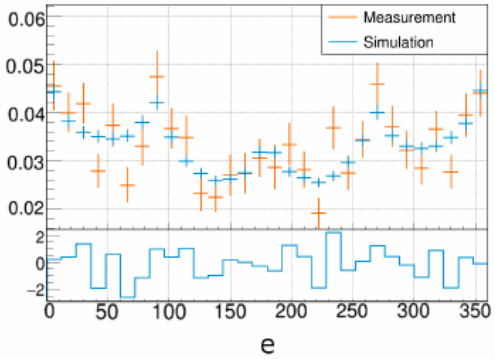
- Response includes temperature dependence, non-linear effects in electronics for each bar
- Final uncertainties calibration result in a systematic error of 2% in the polarization measurements

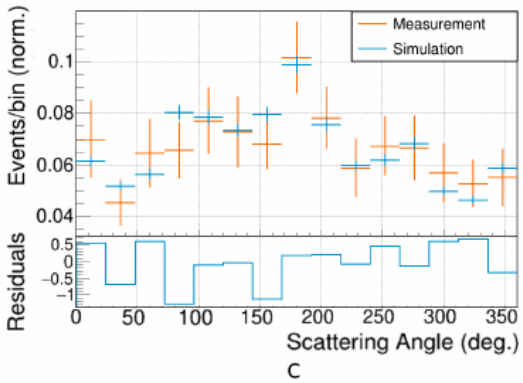
Compare with MC

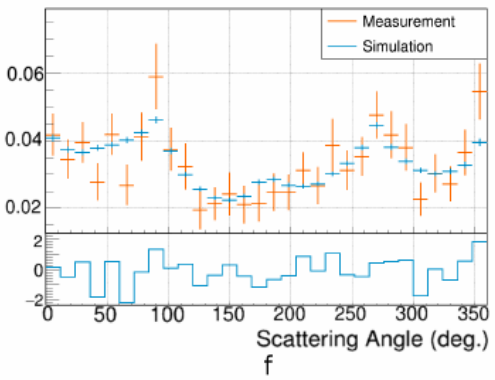










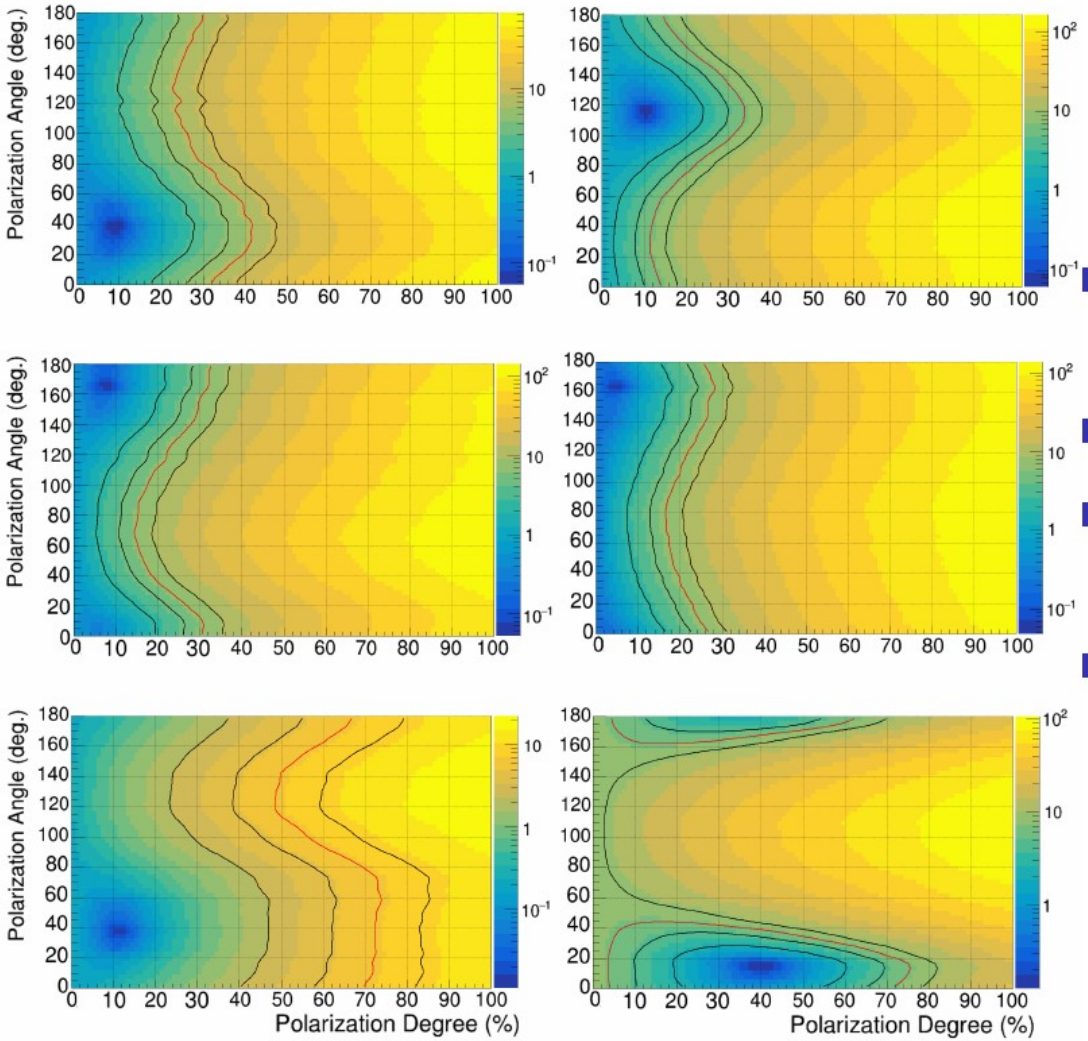


- Once we have the response the rest is easy
- For each individual GRB we simulate modulation curves
- Find the best curves
- Residuals look flat

Finding best match

Nature astronomy 2019/01/14 Detailed polarization measurements of the prompt emission of five gamma-ray bursts

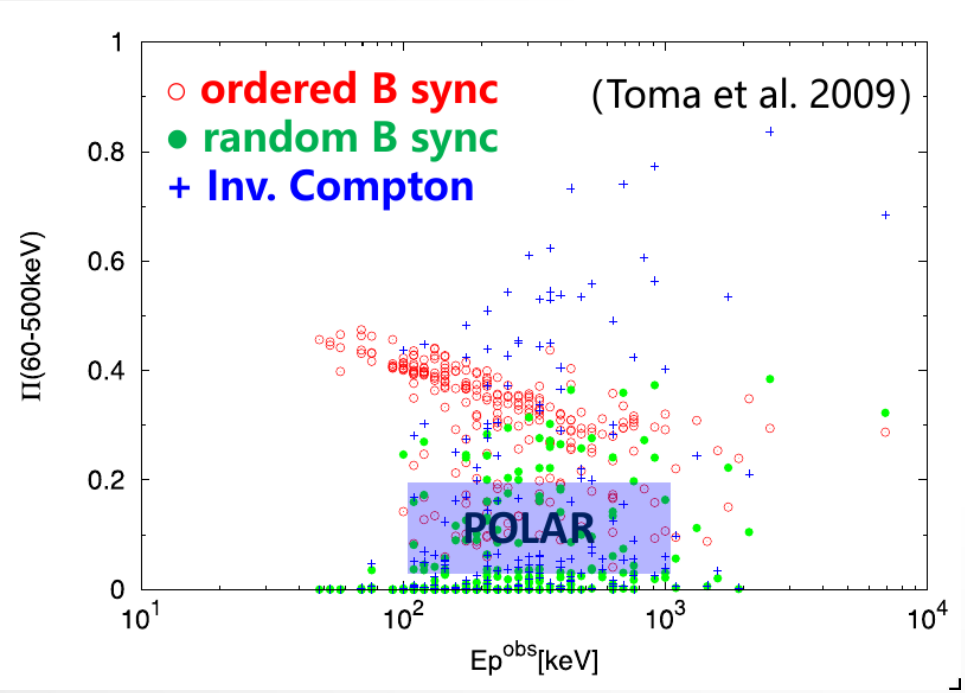
ArXiv:1901.04207

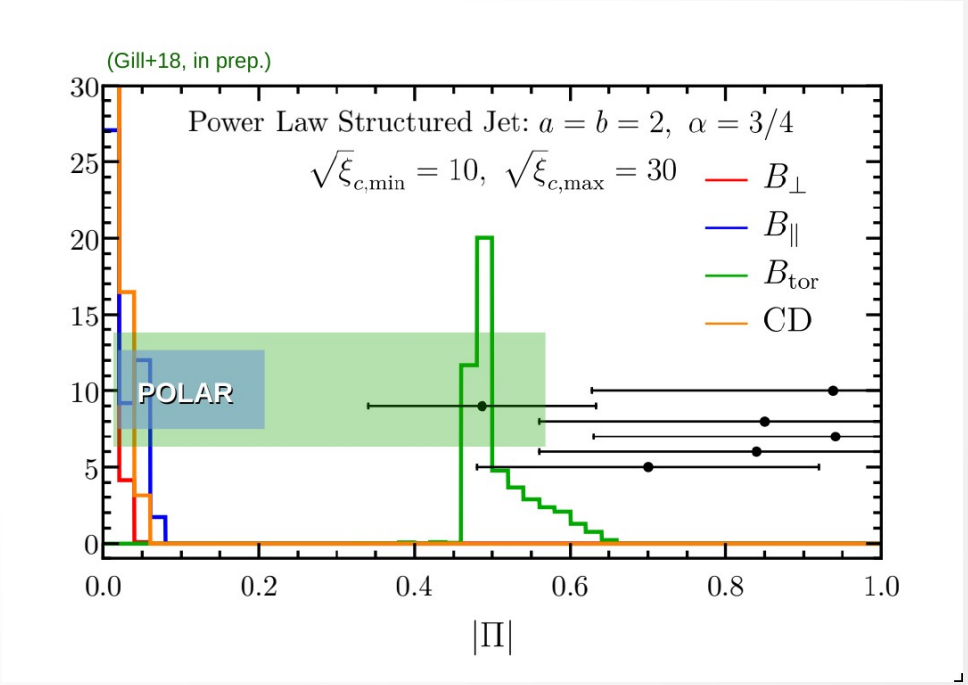


- Calculate the χ^2 of each MC result with the measured one
- Produce $\Delta\chi^2$ map
- Calculate confidence intervals based on the $\Delta\chi^2$
- First conclusion: Polarization is rather low!

Compare with theory

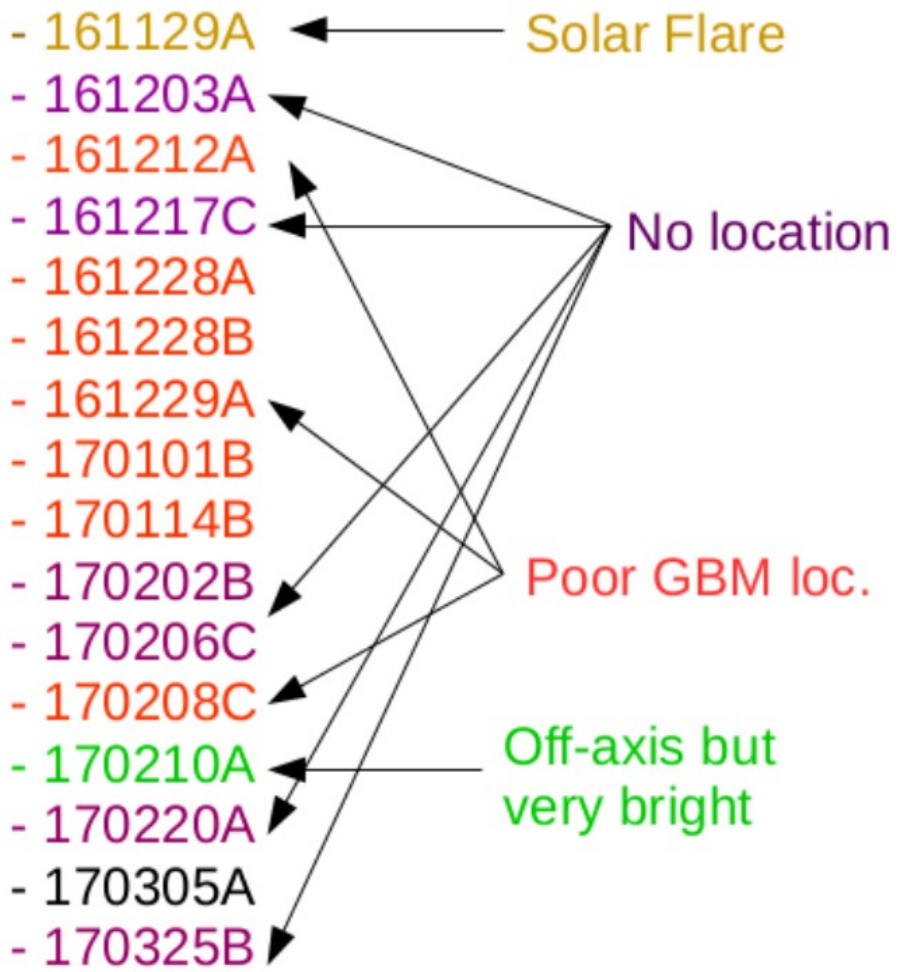
Theory can accommodate many different results.
Polarization changes during burst is more constrained.





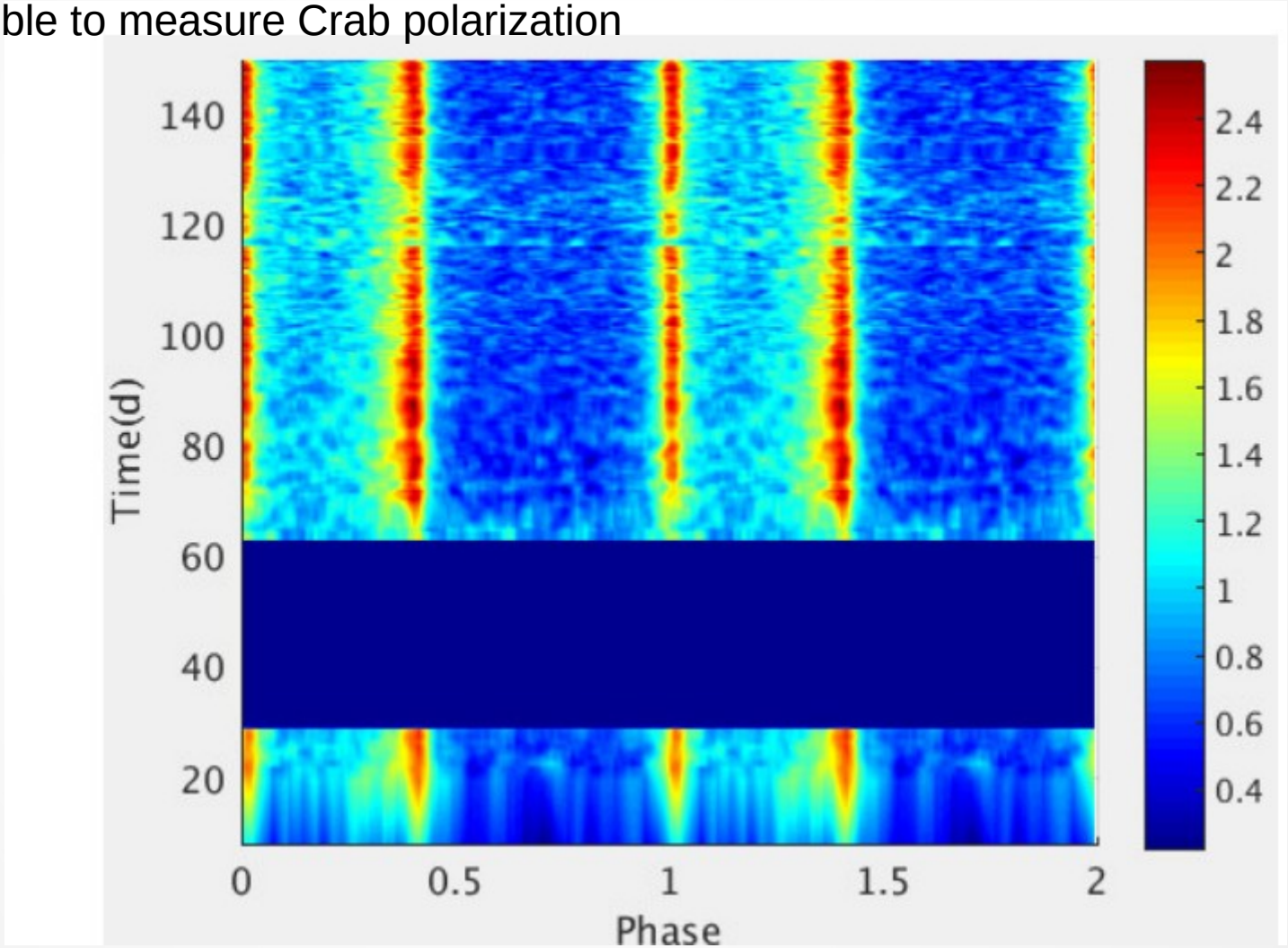
Future papers

- In total we measured 55 GRBs
- Analyzed 5 so far
- Another 5-10 good candidates



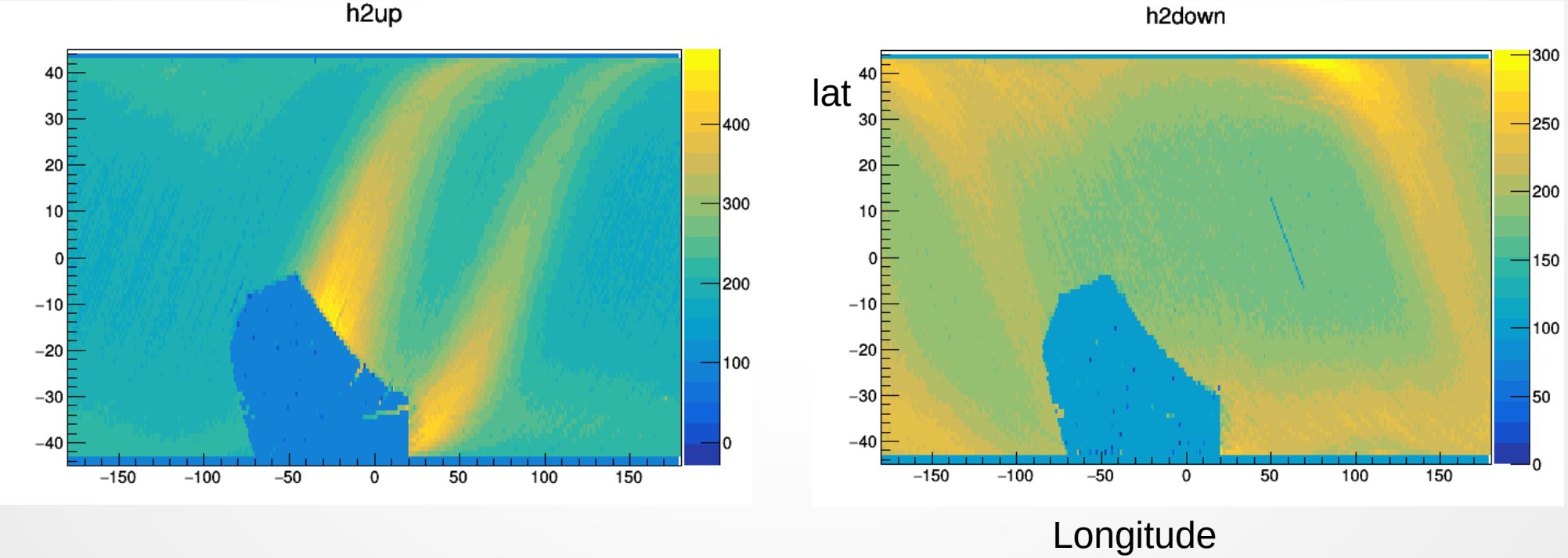
Other physics

We see pulsation of the Crab (3 steradian FOV!)
We see pulsation of B1509
We can use this to correct orbital elements of TG-2
We are working on Crab phase resolved spectra.
Probably not possible to measure Crab polarization



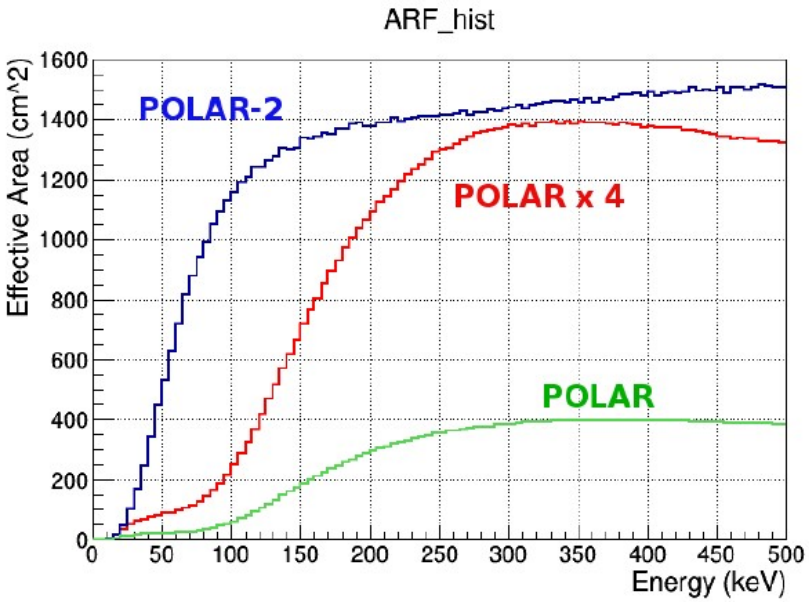
Background

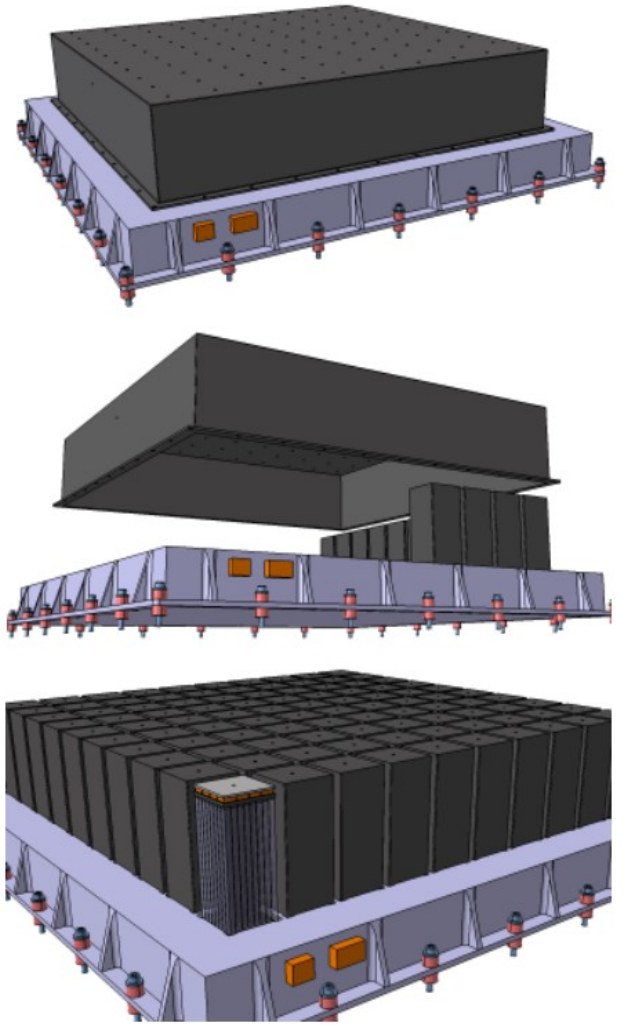
Most of the background is due to SAA and to polar caps activation.
No real long term accumulation
Some solar flares
Calibration sources (4x100 Bq)
Diffuse emission of galaxy, Crab transit not yet seen.
Understanding of background important for next mission (material activation)



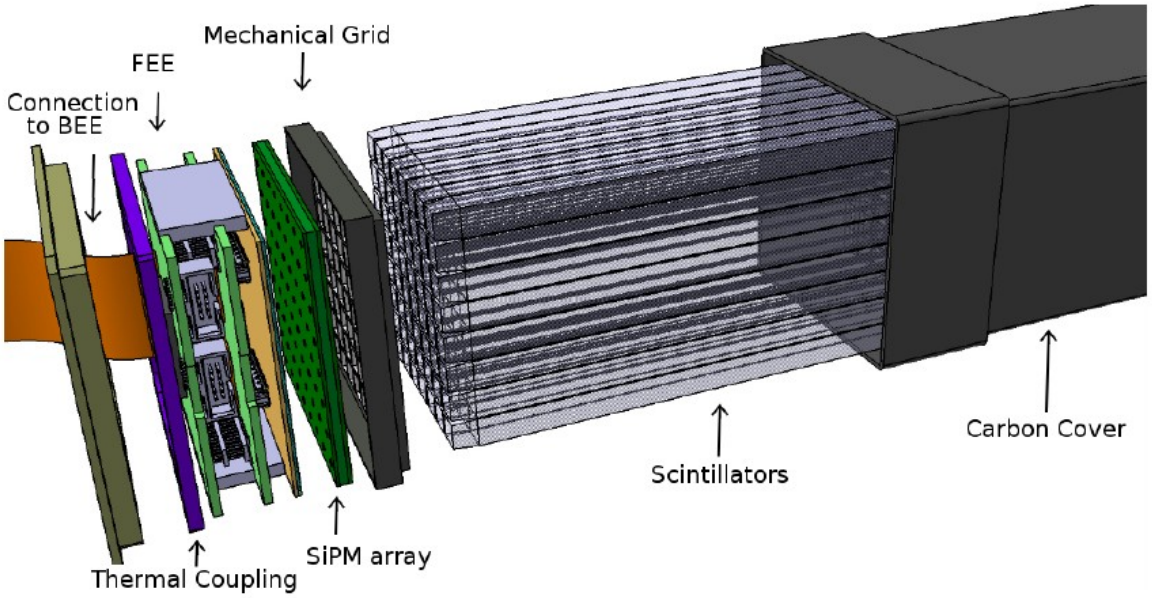
POLAR-2

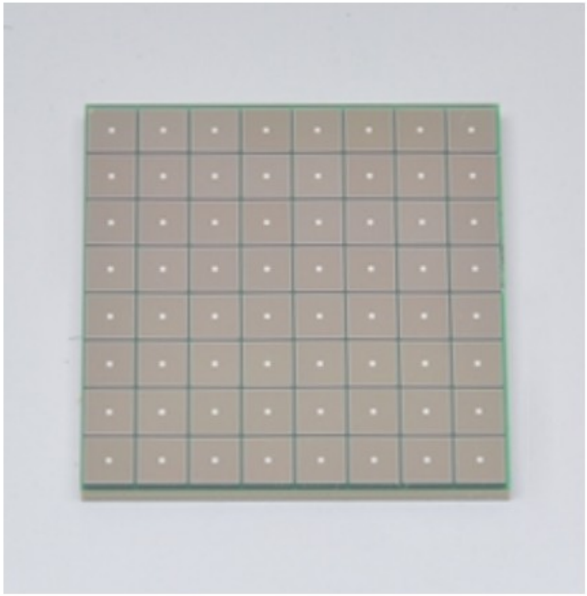
- SiPMs instead of PMTs → sensitivity improves by factor 2.5
- Increase size by factor 4
- Total instrument is 80 kg
- Size: 800x800x300 mm^3
- Power consumption = 100 W





Improved technology





- Hamamatsu sells SiPM arrays with the same size as out MAPMTs!
- Higher photon detection sensitivity (50% instead of 20%)
- Scintillators can be directly coupled to SiPMs $\rightarrow$ much less Xtalk
- More robust
- So seems like a perfect replacement

Launch opportunities and financing

UNIVERSITÉ DE GENÈVE

NCBJ

MPE

Institute of High Energy Physics
Chinese Academy of Sciences

- Currently studying launch possibility
- Applied for UN call for space on CSS
- Other opportunities will be discussed with CSU
- Launch foreseen in 2024
- Applied for funding through Humboldt Foundation
- Currently small scale tests/component space qualification