

# **Energy-dependent polarization of Gamma-Ray Bursts' prompt emission with POLAR and POLAR-2**

EAS Annual Meeting  
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Nicolas De Angelis<sup>1</sup> for the POLAR and POLAR-2 collaborations<sup>2</sup>

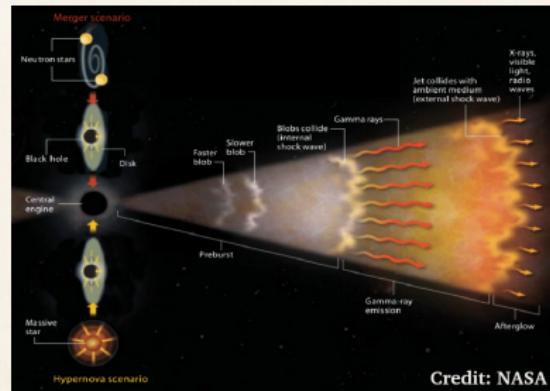
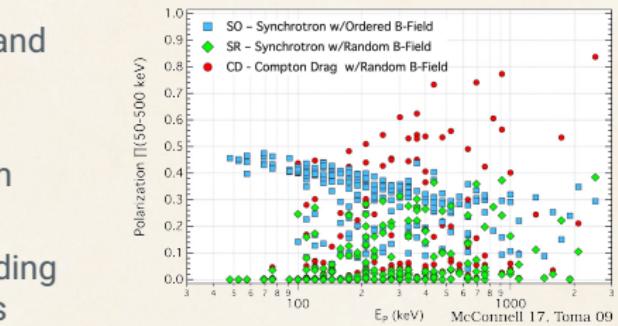
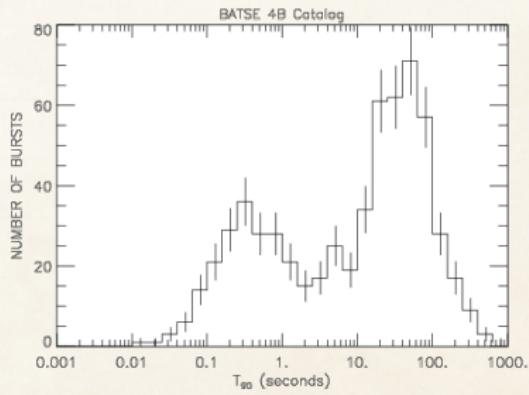
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<sup>2</sup><https://www.astro.unige.ch/polar/collaboration>  
<https://www.unige.ch/dpnc/polar-2>

# Gamma-Ray Bursts paradigm

- Bright and short transient event in  $\gamma$  band followed by an afterglow (in all wavelengths)
- Extragalactic, 2 categories: short (from BNS) and long (from SN)
- Polarization brings a better understanding of the jet and magnetic field structures



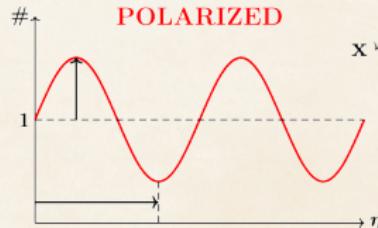
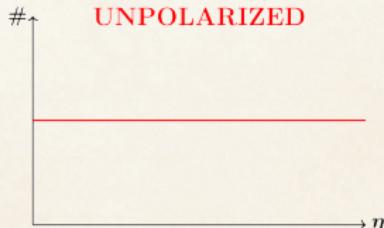
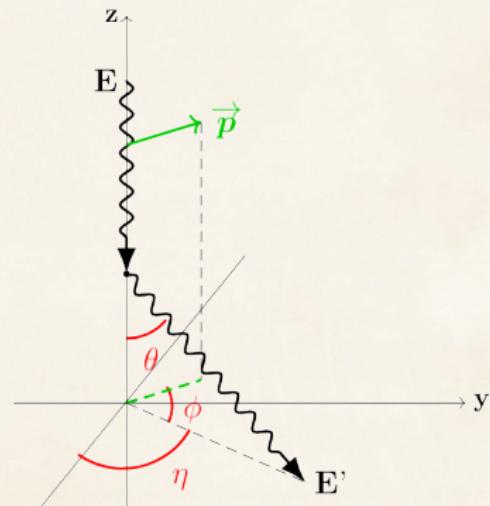
# Polarimetry with the Compton scattering

Compton scattering can be used to determine the polarization of a source:

- Azimuthal scattering angle distribution provides information on polarization degree and angle
- So called modulation curved, parametrized by the Klein-Nishina cross-section:

$$\frac{d\sigma}{d\Omega} = \frac{r_e^2}{2} \left( \frac{E'}{E} \right)^2 \left[ \frac{E'}{E} + \frac{E}{E'} - 2 \sin^2(\theta) \cos^2(\phi) \right]$$

- Relative amplitude  $\leftrightarrow$  PD, phase  $\leftrightarrow$  PA



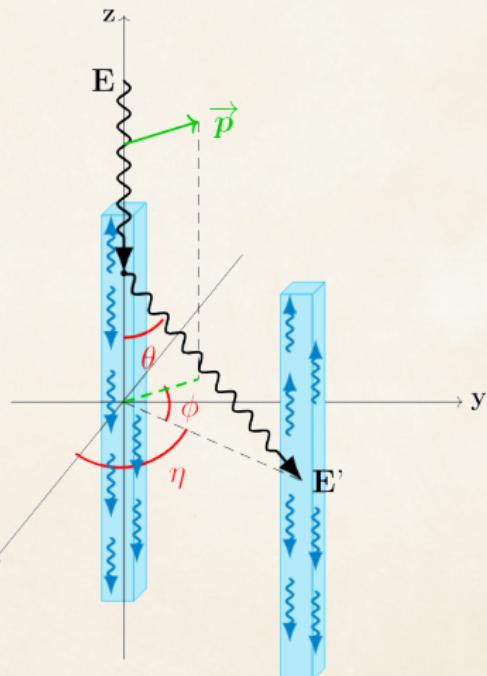
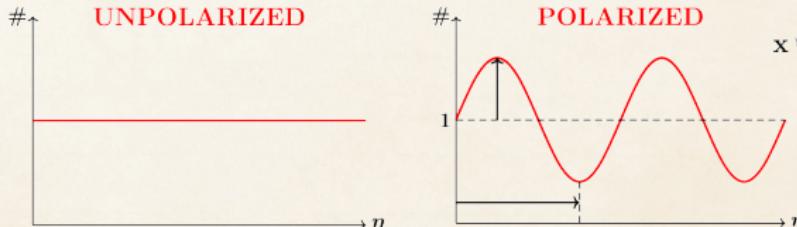
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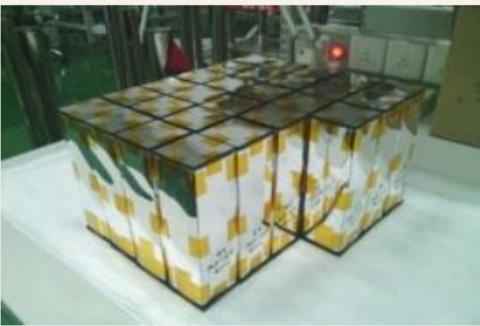
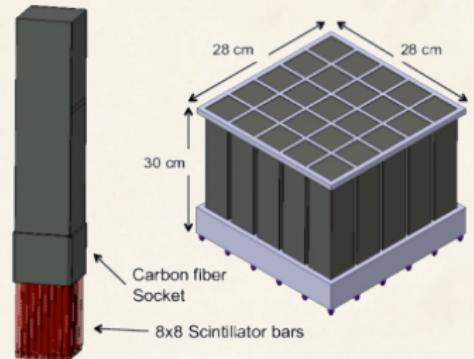
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- Relative amplitude  $\leftrightarrow$  PD, phase  $\leftrightarrow$  PA
- **A segmented array of scintillators can be used to measure the scattering angle distribution (aka modulation curve)**



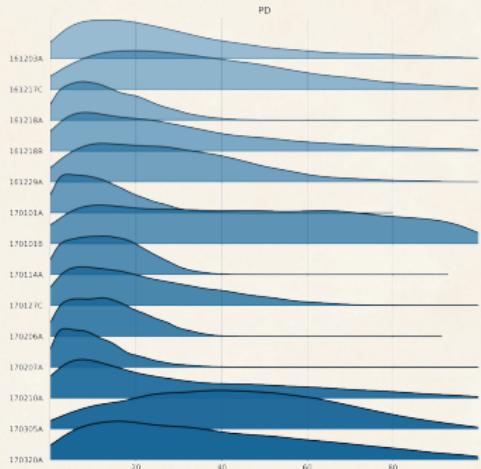
# The POLAR instrument

- POLAR was a dedicated gamma polarimeter composed of a  $40 \times 40$  scintillator array
- Divided in  $5 \times 5$  modules each made of 64 plastic scintillator bars ( $176 \times 5.8 \times 5.8 \text{ mm}^3$ , EJ-248M), each module being readout by Multi-Anode PMTs
- Optimized for Compton scattering in the 50-500keV range thanks to its low-Z scintillators
- 30kg instrument, half-sky FoV,  $\sim 300\text{cm}^2$  effective area at 400 keV
- Design described in Produit et al. 2018 (DOI: [10.1016/j.nima.2017.09.053](https://doi.org/10.1016/j.nima.2017.09.053))
- Launched in Sept 2016 on the Tiangong-2 Chinese space lab for 6 months of operation

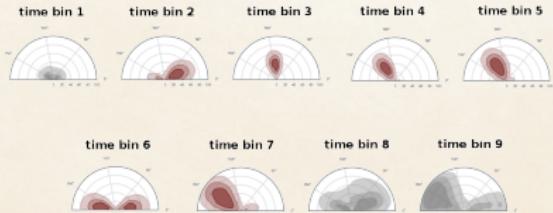


# POLAR energy integrated and time resolved results

- Catalog of 14 GRBs analysed, results show a low or null polarization degree (excluding synchrotron emission models from toroidal magnetic field, compatible with photospheric emission model and other synchrotron models)
- High quality analysis of 5 GRBs published in Nat Astron 3, 258–264 (2019)
- Time resolved analysis show a hint of quickly evolving polarization angle that washes out polarization degree on time integrated analysis  $\implies$  need more statistics to make proper time resolved analysis

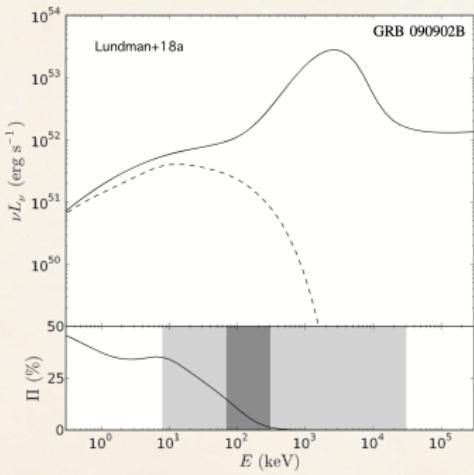
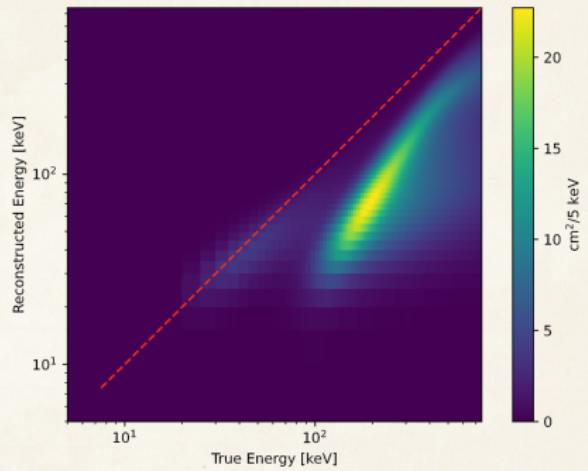


A&A 644, A124 (2020)

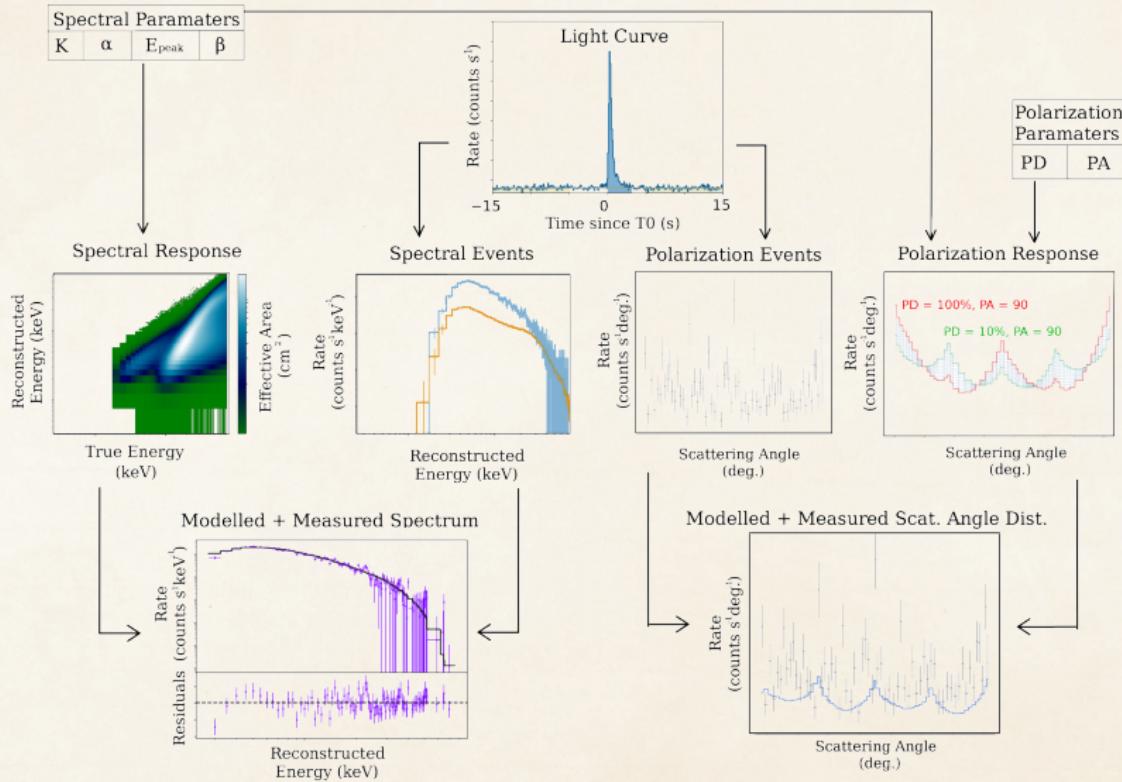


A&A 627, A105 (2019)

# Energy dependence of prompt emission's polarization



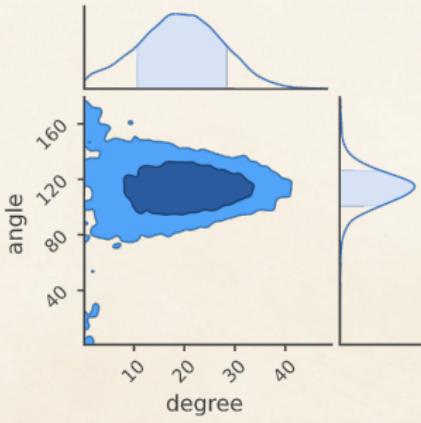
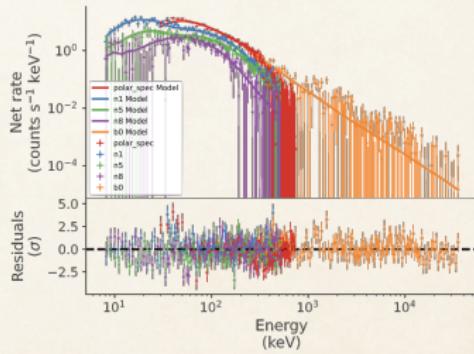
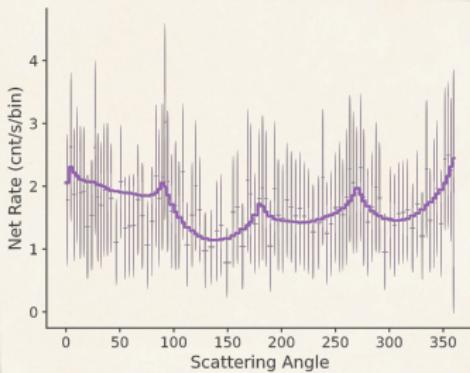
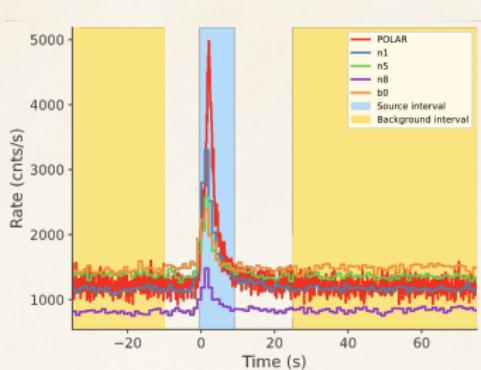
# Joint polarization-spectral GRB analysis method



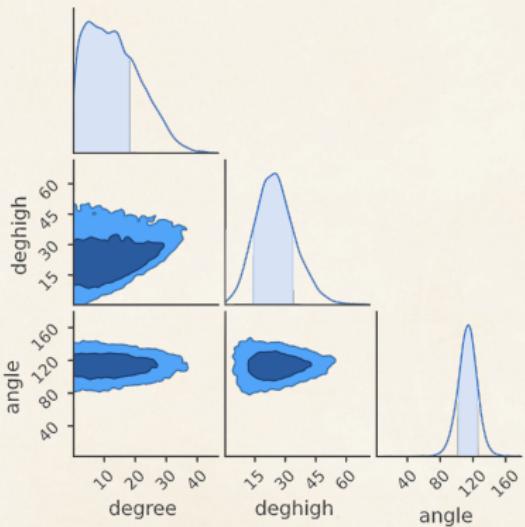
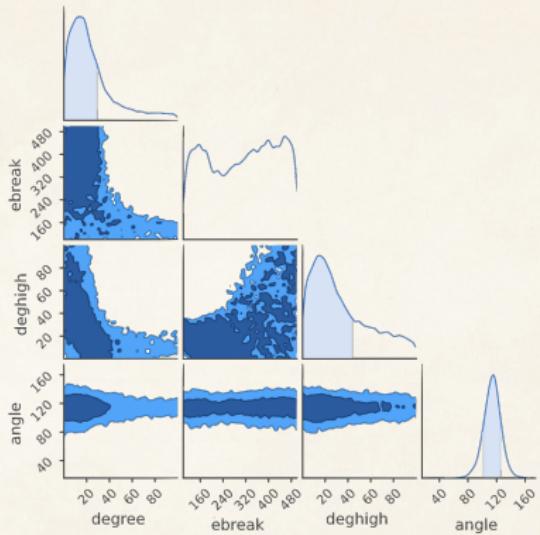
<https://github.com/threeML/threeML>

A&A 644, A124 (2020)

# Energy integrated results: GRB170114A



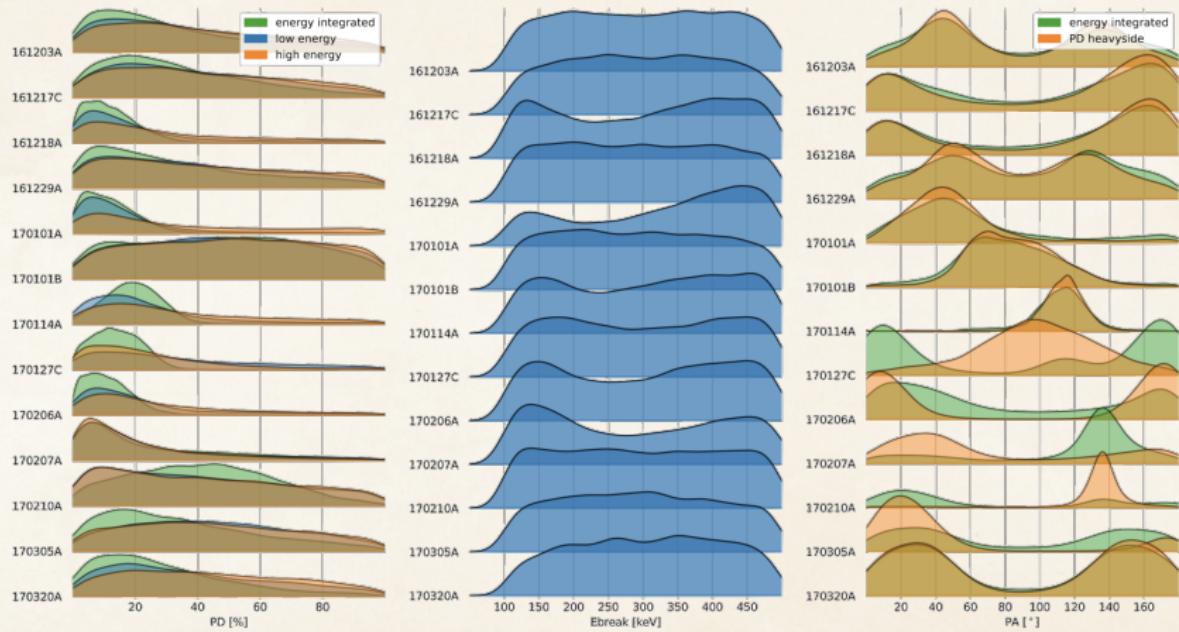
# PD Energy resolved results on GRB170114A



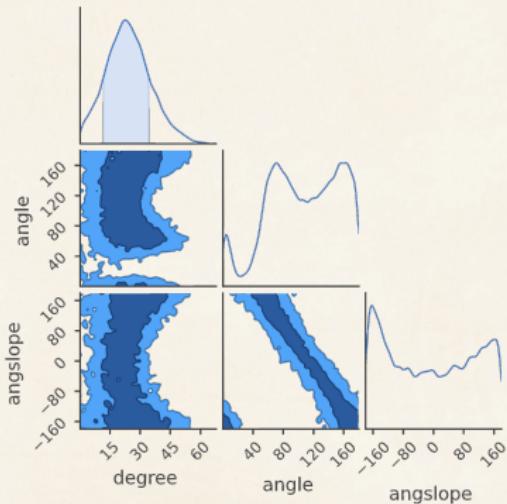
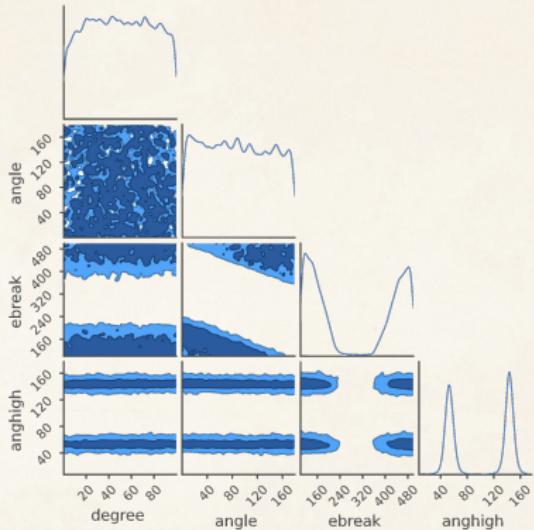
Fitting PD vs. energy with a Heavyside function

Energy of the step fixed to 150keV

# Polarization Degree heavyside fitting on the POLAR catalog

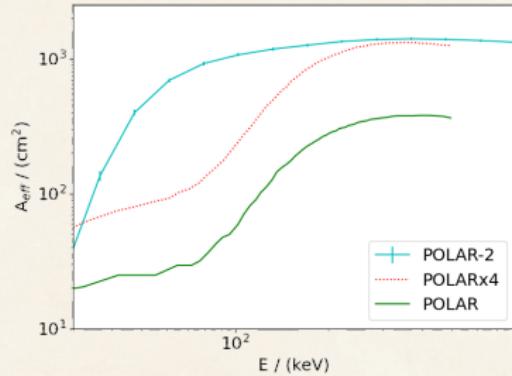
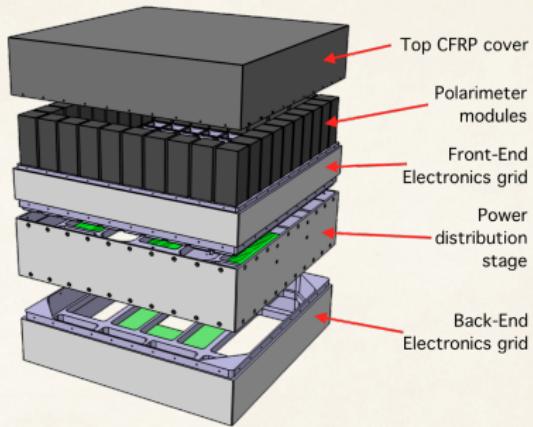


## PA Energy resolved results on GRB170114A



Preliminary results, still has to be run over the full catalog. We should keep limited the number of trials for fitting with energy-dependent polarization functions.

# Future prospects: the POLAR-2 mission



Next task: predicting POLAR-2's sensitivity to polarization energy dependence