Development and science perspectives of the POLAR-2 instrument: a large scale GRB polarimeter

Nicolas De Angelis* for the POLAR-2 collaboration

*Department of Nuclear and Particle Physics (DPNC), University of Geneva, Switzerland

Abstract

Polarization measurements of Gamma-Ray Bursts (GRBs) are essential to gain a more clear and complete picture of these extreme sources. A dedicated γ-ray polarimeter, POLAR, was launched into space in 2016. After 6 months of operation, the POLAR mission detected 55 GRBs and has reported a low polarization degree and a hint of a temporal evolution of the polarization angle. Starting early 2024 and based on the legacy of the POLAR results, the POLAR-2 instrument will aim to provide a catalog of high quality GRB polarization measurements. The technical design of the polarimeter modules as well as the expected scientific performances of the instrument will be discussed.

Introduction: GRB Polarization Measurement

- GRBs are among the brightest astrophysical events. They consist of a prompt emission of X/γ-rays followed by an afterglow in all wavelengths. GRBs are divided in 2 types depending on the burst duration: short (NS mergers) and long (hypernovae)
- Polarization measurements are crucial to disentangle between the different existing emission models
- Using a segmented array of scintillator, an incoming γ-ray will Compton scatter in a first bar (Klein-Nishina cross section) and be absorbed in a second. The polarization angle is computed from the polarization angle, extracted from the relative position of the 2 bars

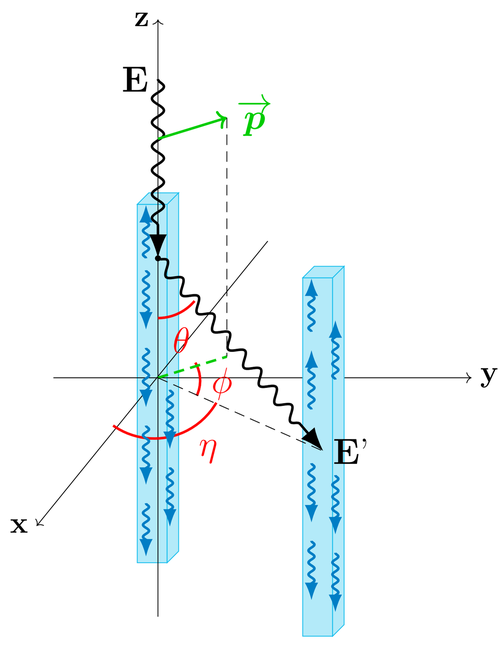

Figure 1:Polarization measurement

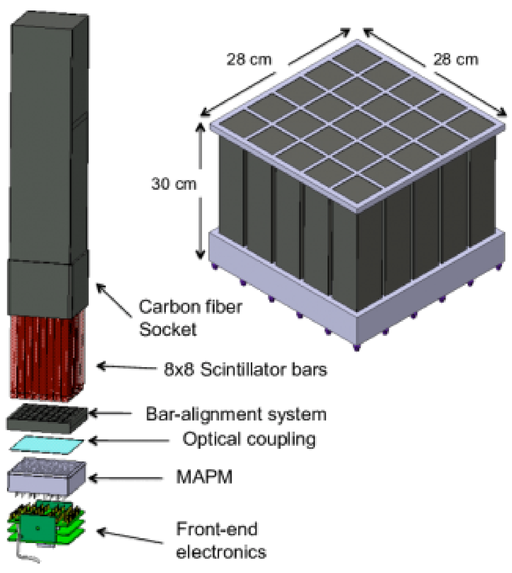

Figure 2:POLAR instrument design

The POLAR Dedicated GRB Polarimeter

- POLAR was a Compton polarimeter. It consisted of a segmented array of 40×40 elongated scintillator bars (5.8×5.8×176mm^3) divided in 5×5 modules, all readout by Multi-Anode PMTs
- 30kg instrument, 50-500 keV half-sky FoV, ∼300 cm^2 effective area at 400 keV, 6 months of operation from Sept 2016 on the Tiangong-2 Chinese space lab, detection of 55 GRBs and pulsars
- Results: 14 GRBs analyzed, showing a low polarization degree (PD) and a hint for time evolving polarization angle (PA). More statistics are needed for proper analysis $\Longrightarrow$ bigger polarimeter

POLAR-2 Instrument

- Based on the POLAR legacy, 4 times bigger polarimeter
- Proposed by a Swiss (UniGe), Chinese (IHEP), Polish (NCBJ), and German (MPE) collaboration (`unige.ch/dpnc/polar-2`)
- Accepted for launch early 2024 to China Space Station (CSS)
- Technological upgrades: shorter ($\Longrightarrow$ better SNR) and wider ($\Longrightarrow$ less dead volume) scintillators (5.9×5.9×125mm^3); using SiPM arrays (S13361-6075PE from Hamamatsu) $\Longrightarrow$ higher PDE and better light yield; increased contact surface between scintillators and sensors ($\Longrightarrow$ better light yield); thermal cooling based on Peltier elements to compensate for the SiPM dark noise
- 150kg instrument, 300W power consumption, 590×648×700mm^3
- Several spectrometer modules (CeBr3 or LaBr3) for source localization and joint polarization-spectral analysis

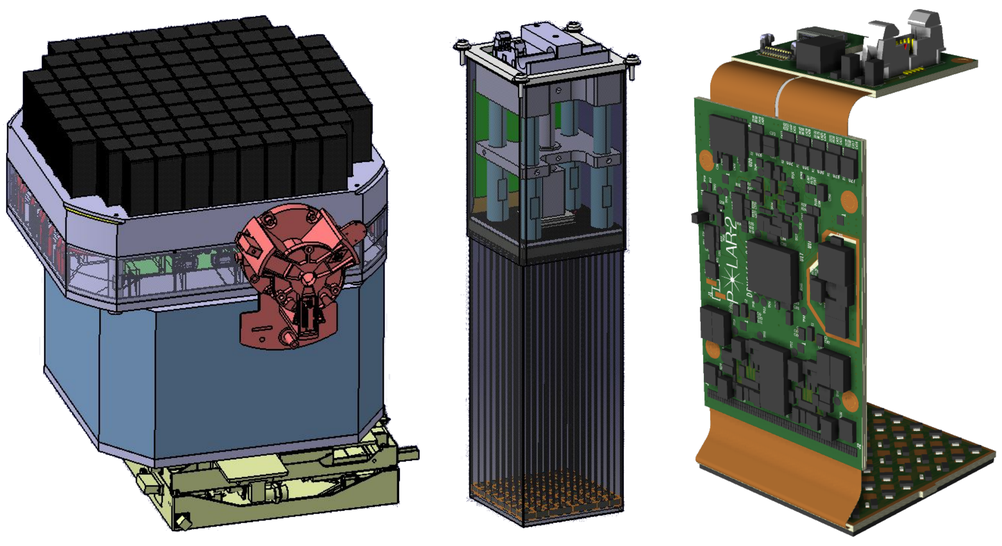

Figure 3:POLAR-2 instrument, module and electronics CAD models

POLAR-2 Polarimeter Module Development

- Calibration setup using Am241 (59.5keV photopeak) and Cs137 (470keV Compton edge) sources.
- Current readout with the BabyMIND experiment FEB (based on CITIROC-1A ASIC), POLAR-2 FEE has just been designed and will be used in a few months
- Light yield improved to 1.6p.e./keV (0.3p.e./keV in POLAR), allowing to lower the energy threshold to a few keV
- Optical cross talk between scintillators reduced by one order of magnitude (∼1.5-2.5%), measurements compatible with Geant4 optical simulations

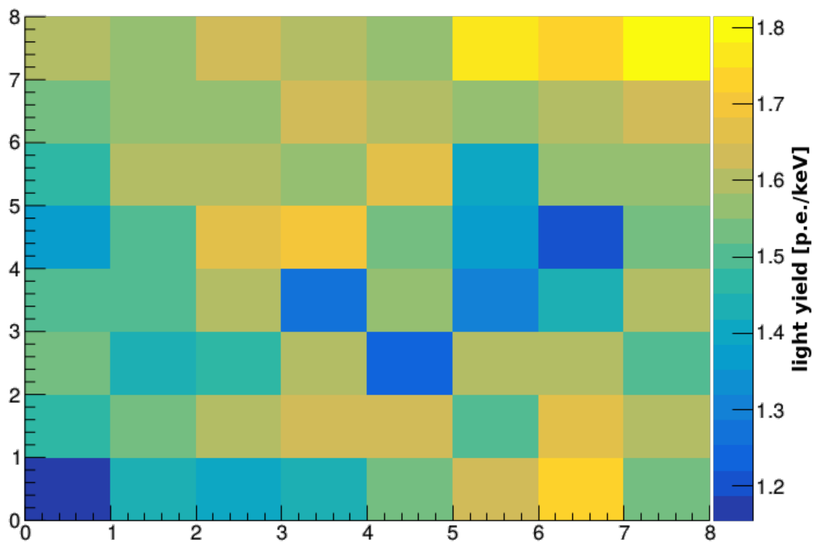

Figure 4:Light yield map measured on a prototype module

POLAR-2 Anticipated Science Performances

- POLAR-2 instrument implemented in Geant4 for science performance analyses
- Effective area improvement compared to a 4×POLAR configuration, especially below 200keV, thanks to technological upgrade of the polarimeter modules
- Improved sensitivity to polarization, especially at low energies where the M_{100} is over twice higher than for POLAR

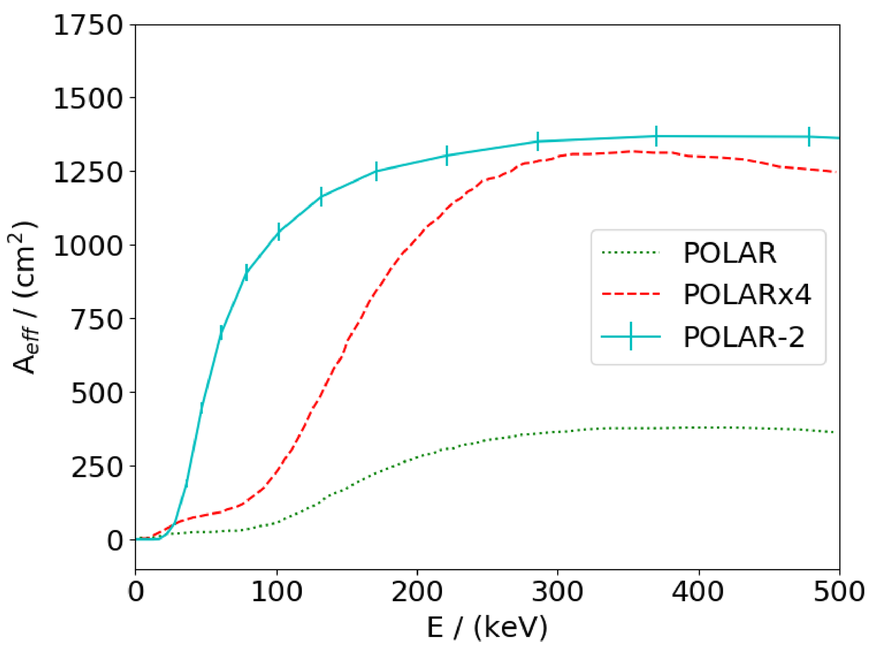

Figure 5:Effective area and modulation factor M_{100} for POLAR vs. POLAR-2

Contact Information

- Presenter: nicolas.deangelis@unige.ch
- Collaboration webpage: `https://www.unige.ch/dpnc/polar-2`

Related Proceeding of Science

`https://pos.sissa.it/395/580/`