Gamma Ray Burst Polarimeter POLAR

Hualin Xiao, Wojtek Hajdas, R. Marcinkowski,
R. Kramert, Ken Egli, P. Socha, P. Zhang

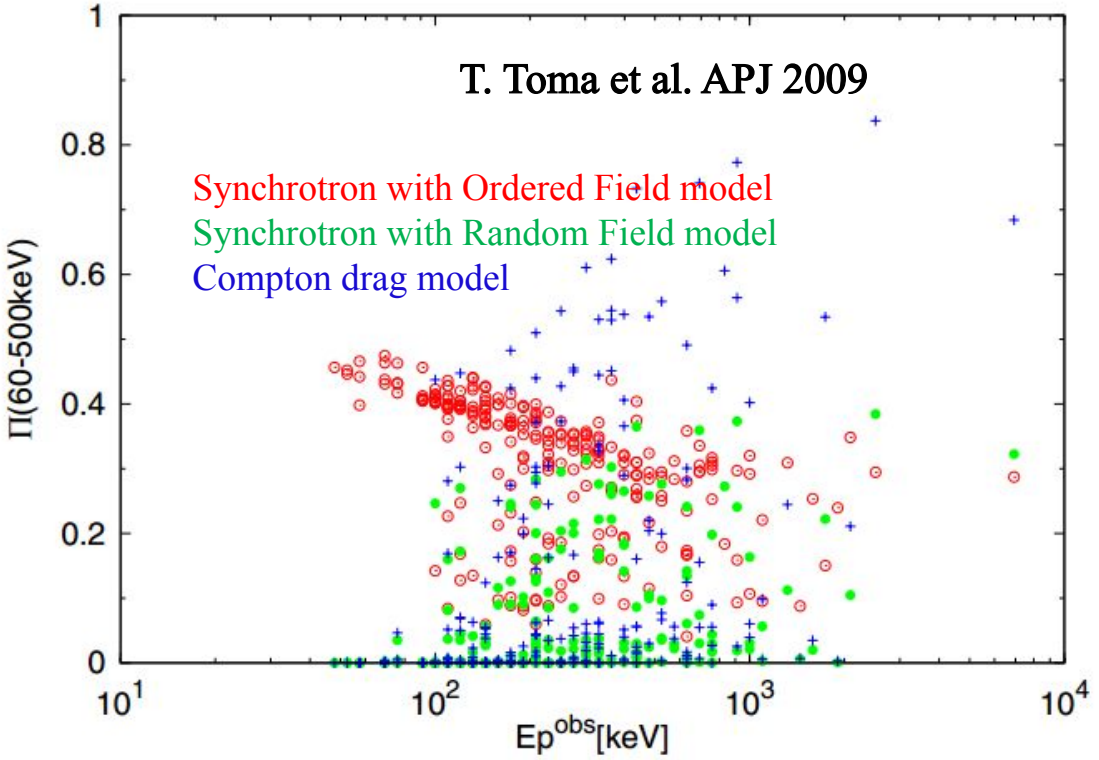
Paul Scherrer Institute

On behalf of POLAR collobration

PSI, Switzerland NCBJ, Poland ISDC, Switzerland UNIGE, Switzerland IHEP, Beijing, China

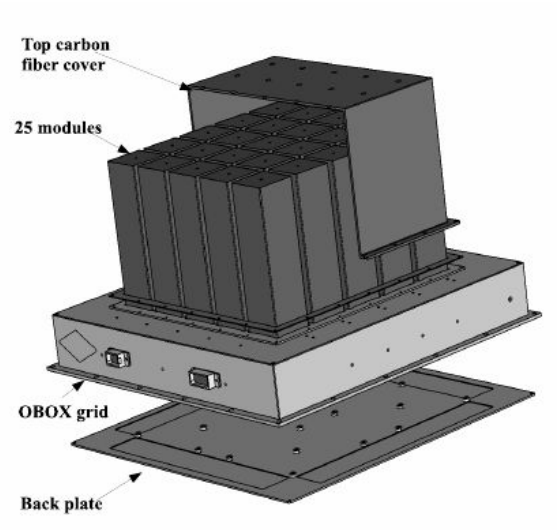
GRBs and GRB Polarization

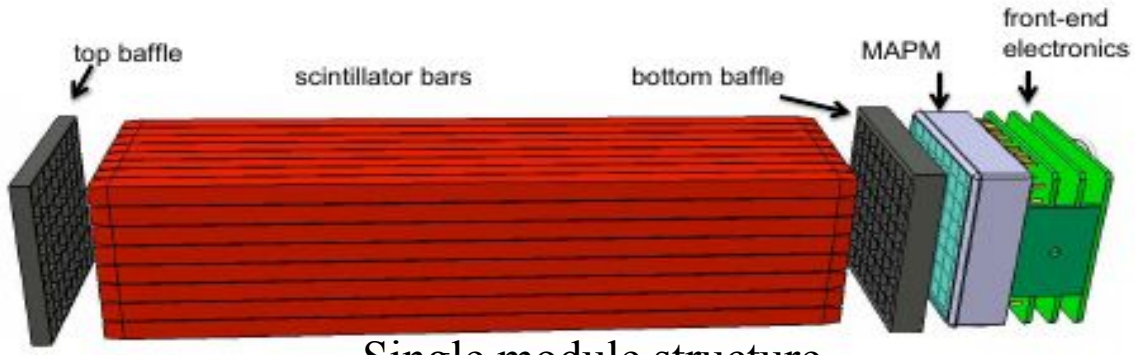
- Gamma-ray bursts (GRBs) are flashes of gamma rays appearing randomly in the sky and in time
- Brightest events in the universe since Big Bang
- Migh be caused by collapse of massive stars or compact binary mergers
- Thousands of GRB detected in the past 50 years, but their emission mechanisms still unknown
- Polarization information can help to understand GRB emission mechanisms



POLAR instrument

- A Space-borne Compton Gamma-ray burst polarimeter
- Gamma-ray detection material is1600 Plastic scintillator bars (each 6×6×176 mm^3)
- PS Bars grouped into 25 modules
- Each module read-out by 8x8 pixel MAPMT and its own Front-end
- Energy range 50-500 keV
- Minimum detectable polarization ~10%
- Expected to measure polarization degrees of 10 strong GRBs /year
- POLAR Instrument built by a collobration between China and Europe

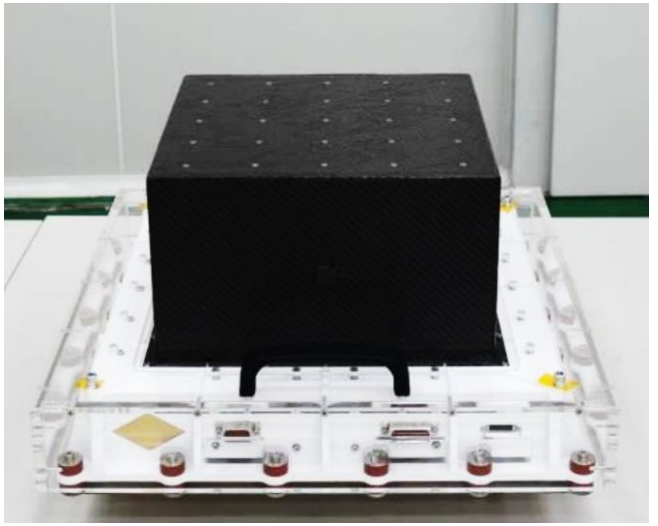




Single module structure

Hammatsu H8500C MaPMT

FEE based on IDEAS VA64



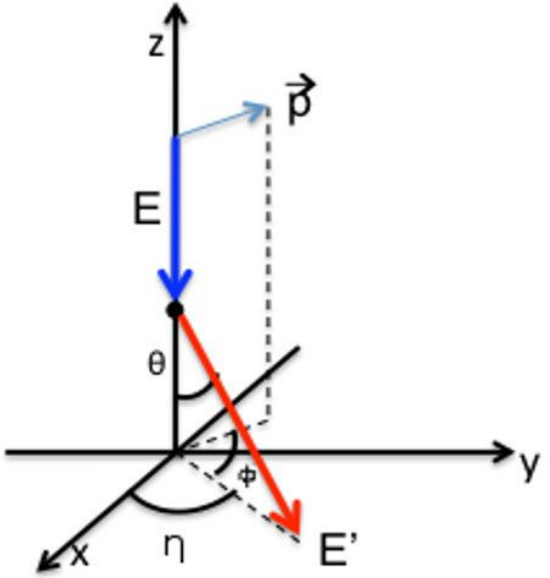
Flight model

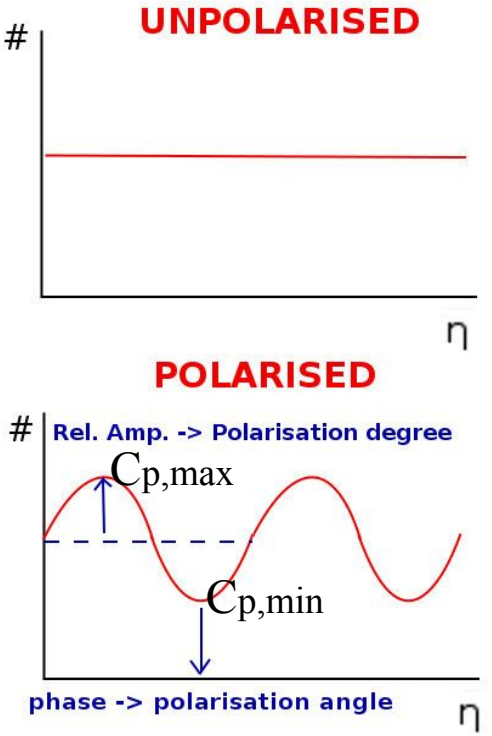
Compton polarimetry

- Polarization measurements of few hundered keV can be easily done by Compton scantering
- Photons undergoing Compton scattering tend to scatter perpendicular to their incident electric field vector

$$\frac{d\sigma}{d\Omega}(\theta,\eta)=\frac{r_0^2}{2}\left(\frac{E'}{E}\right)^2\cdot\left(\frac{E'}{E}+\frac{E}{E'}-2\sin^2\vartheta\cdot\cos^2\eta\right)$$

(Klein-Nishina Eq.)





Distribution of azimuthal scattering angle

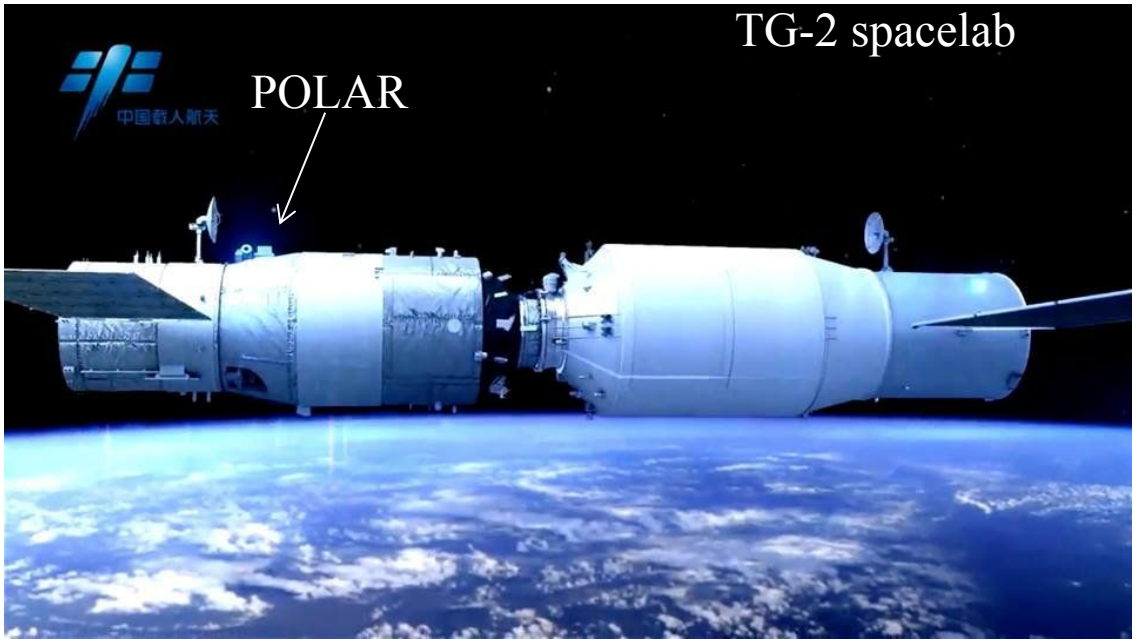
- Modulation Factor

$$\mu_p=\frac{C_{p,\max}-C_{p,\min}}{C_{p,\max}+C_{p,\min}}=\frac{A}{B}$$

- Polarization degree $p \propto \mu_p$

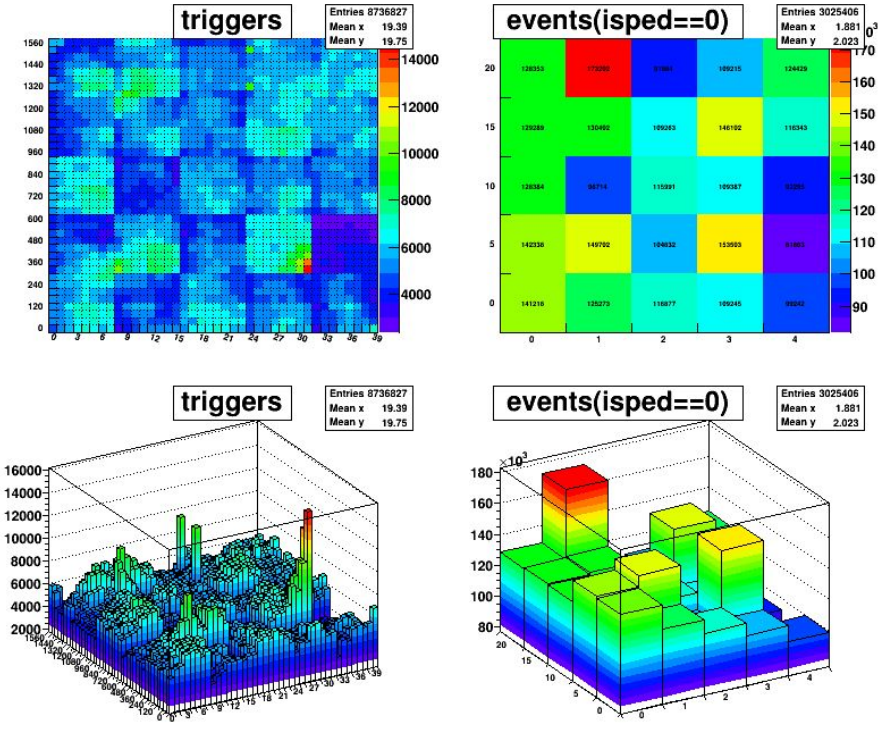
Start from China cosmodrome

- Lauched on Sept. 15th, 2016, on-board TG2 SpaceLab
- TG2 orbit inclination ~42 degree, altitude ~380 km
- POLAR points to sky permanently
- FOV 1/3 sky

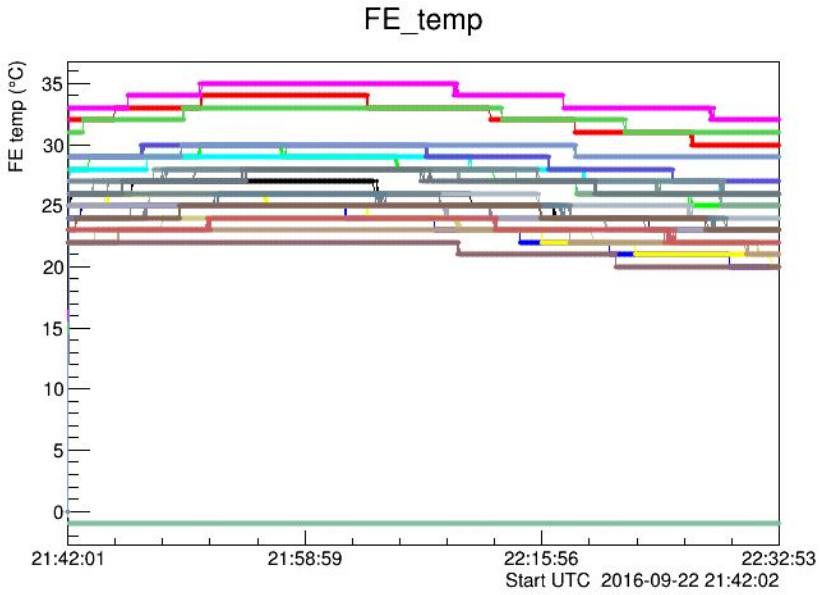


POLAR first test data

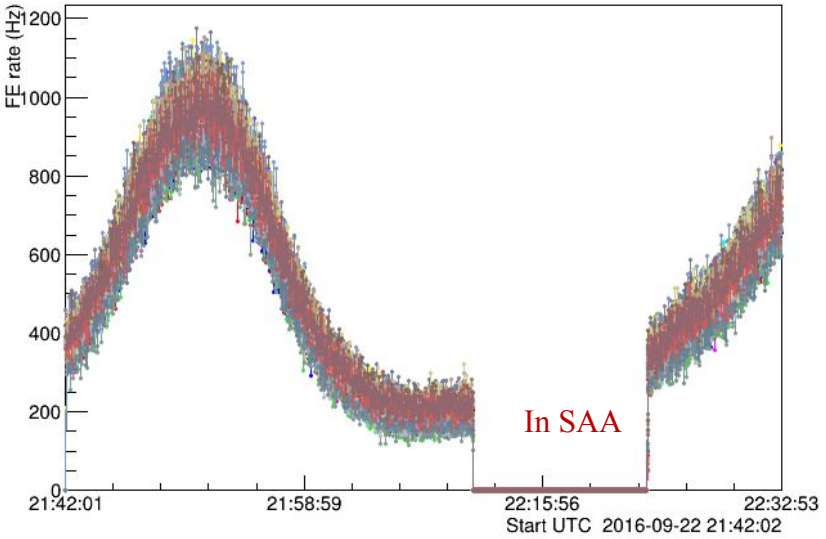
- POLAR was powered on Sept. 22nd, 2016
- Housekeeping data looks properly
- All 1600 channels working as expected
- Count rates as expected



hit map



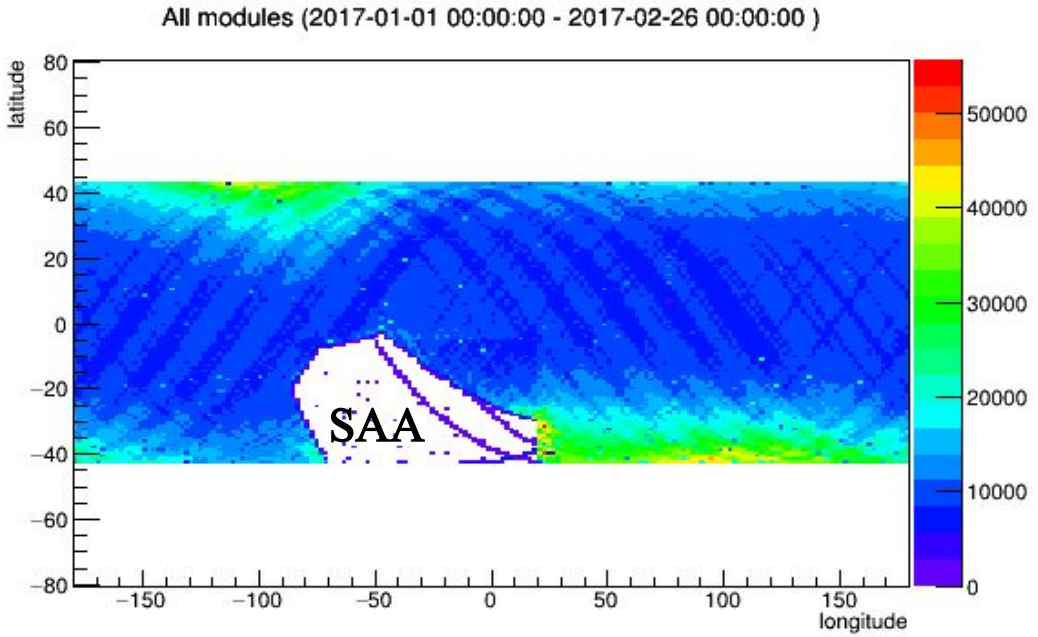
Module temperature changes within 5 degree



module count rates

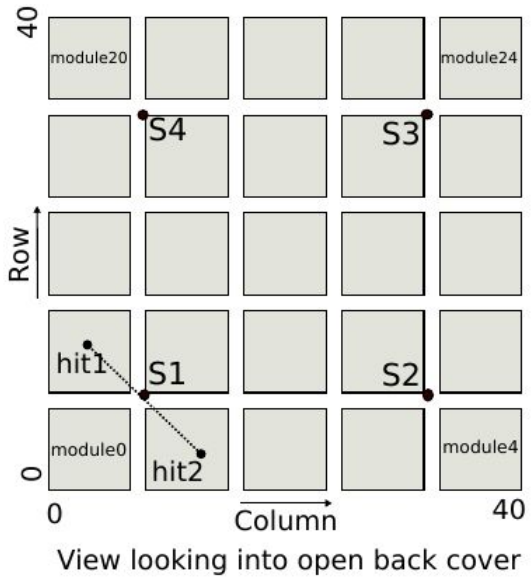
POLAR background data

- Background rates in GRB obvervation mode range from 4000 to 30 000 cps
- POLAR background main compositions
  - Trapped electrons at high latitude
  - Diffuse cosmic X-rays at low latitude
- Background map consistents with MC simulations

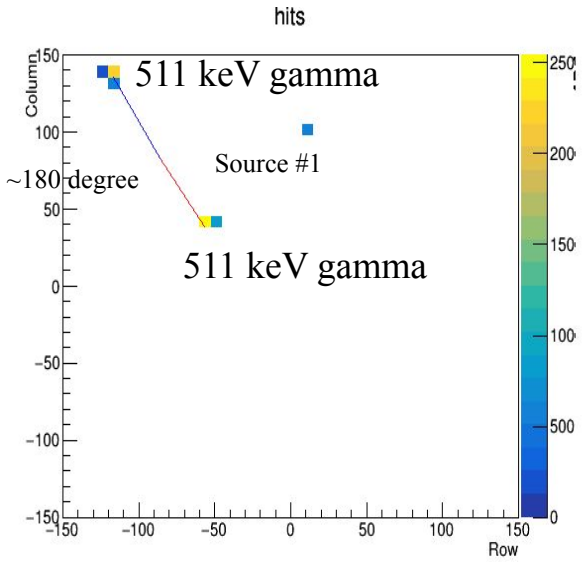


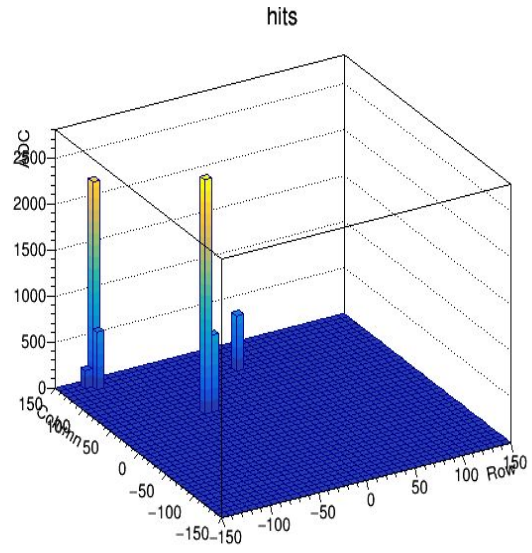
POLAR count rates at different locations

In-orbit calibration



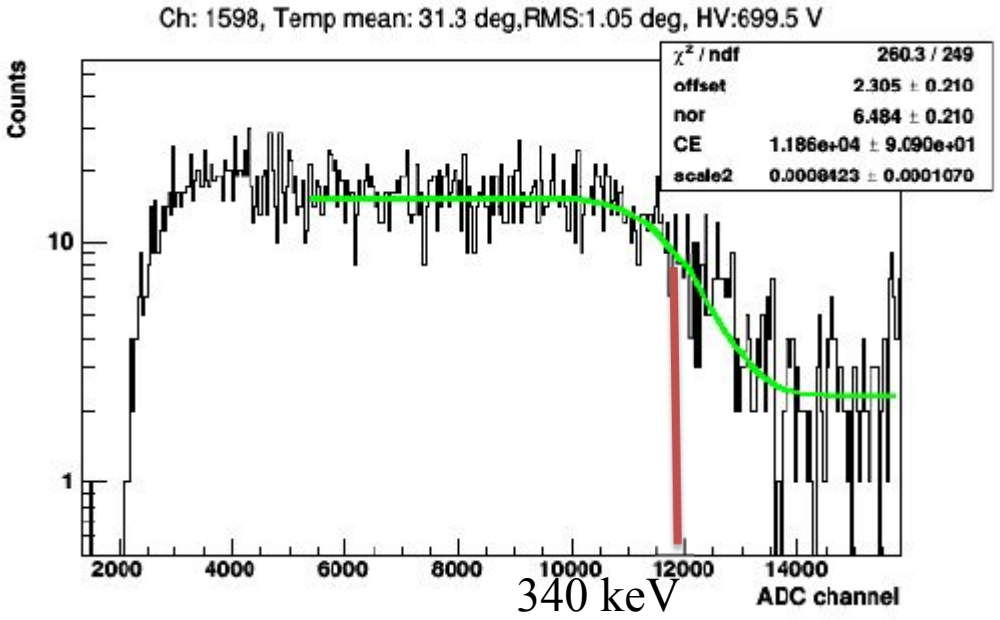
s1,s2,s3,s4: Four Na22 sources



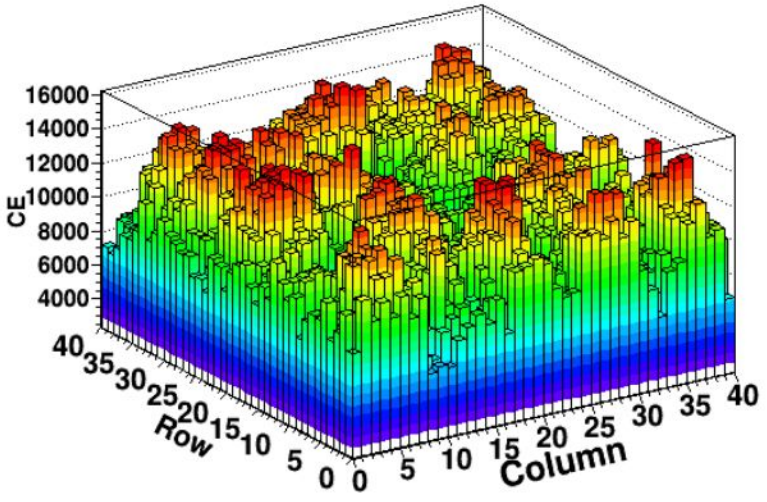


Coincidence hit pair selection example

- Energy calibration performed by four Na22 positron sources inside POLAR
- Source activity ~200 Bq each
- Two 511 keV gamma-rays with opposit directions could produce coincidence signals on bars
- Coincidence hit selection could reject most backgrounds



24 hours' calibration data used



Compton edge positions of all channels
(The first calibration run data used)

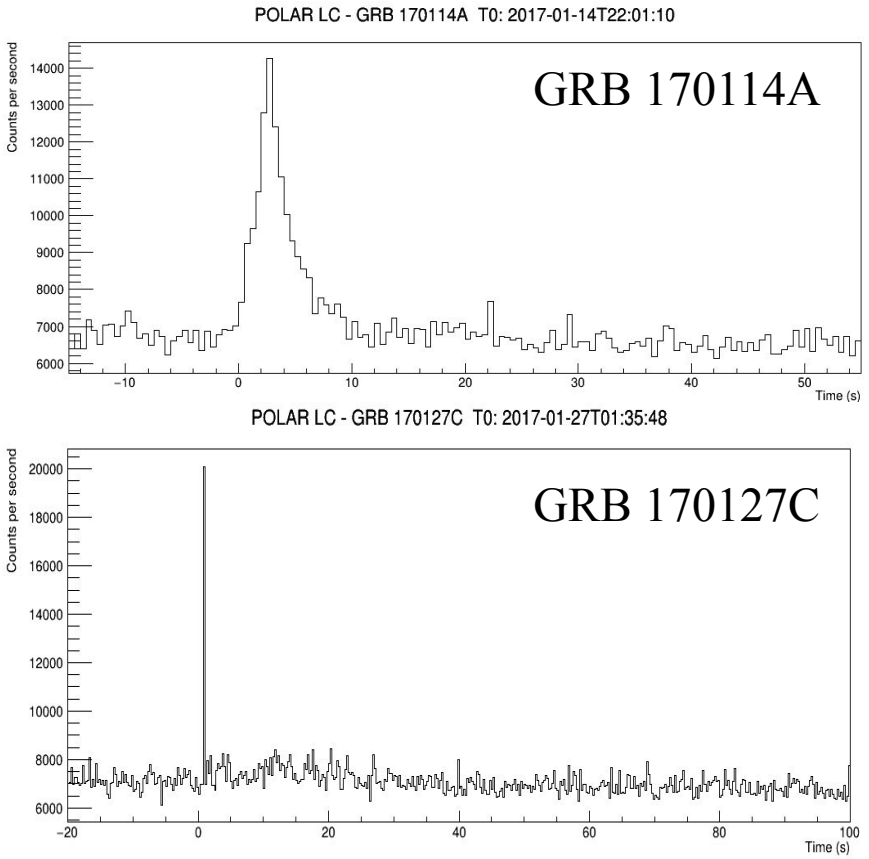
- Clear Compton edge at 340 keV could be seen on the spectra of coincidence hits
- Energy calibration factor:

$$c = CE\ (ADC\ channel)\ /340.6\ keV$$

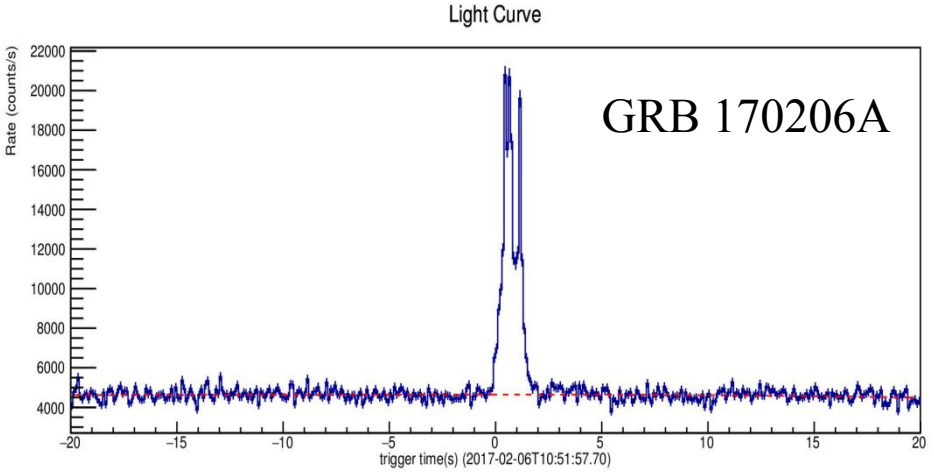
- Analysis of the first phase calibration data is completed

Detected Gamma-ray Bursts

- As of today, 41 GRBs have been detected by POLAR
- Three bright GRBs with small incident angles are good for polarization study
- Data analysis ongoing



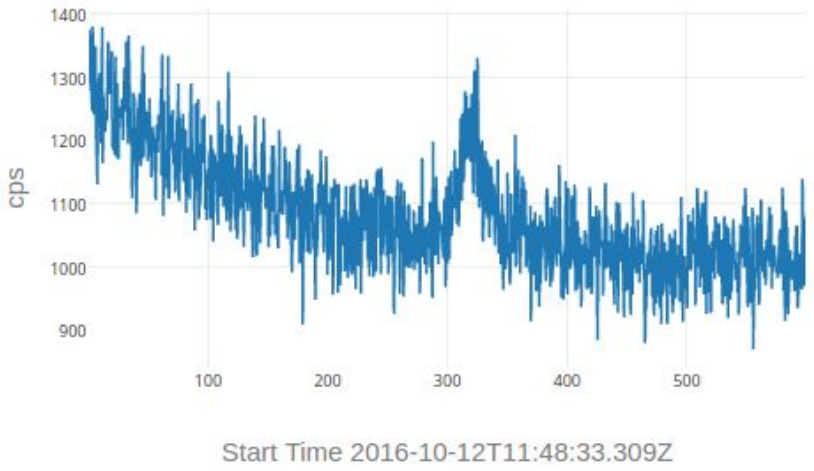
http://polar.psi.ch/pub

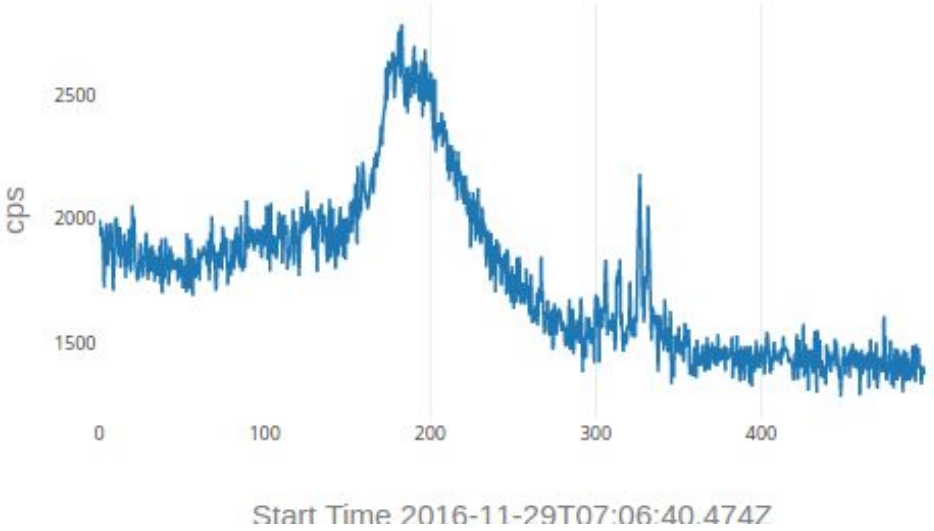


Detected GRB list:
http://polar.psi.ch/pub

Detected Solar Flares

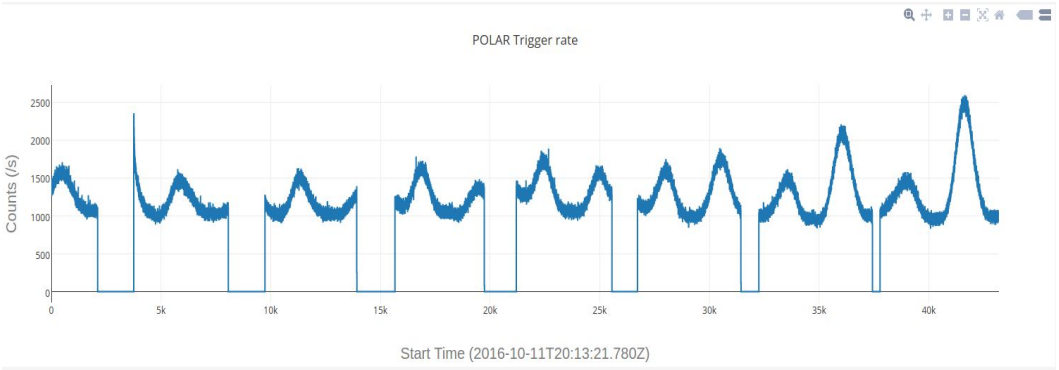
- 11 weak Solar Flares detected
  - Not good for polarization study due to large incident angles or too low SN



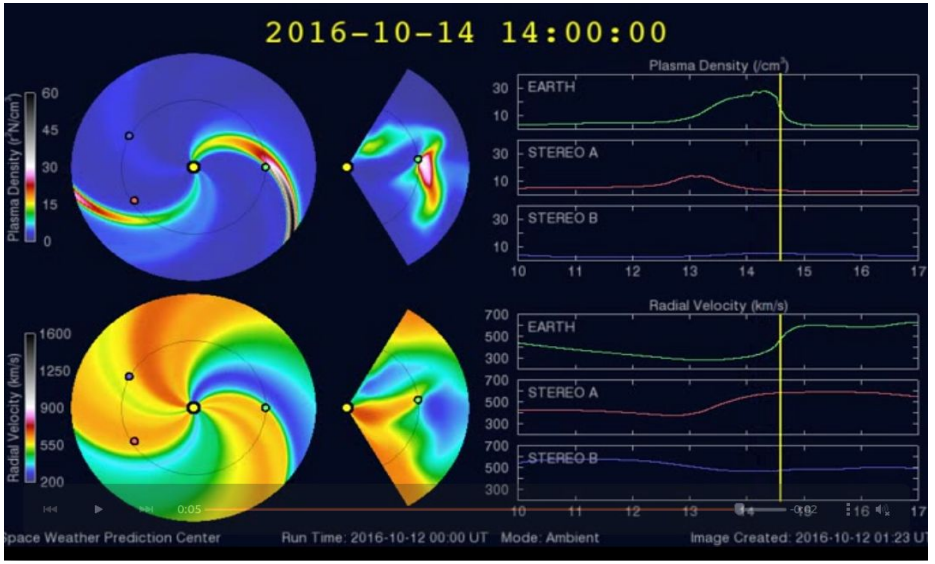


Space Weather events

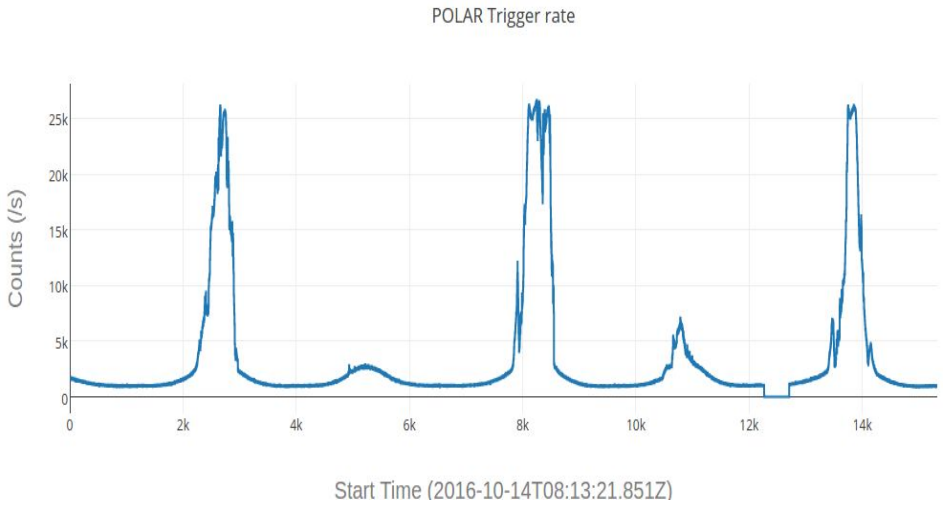
- POLAR is sensitive to space weather events



Before the geomagnetic storm

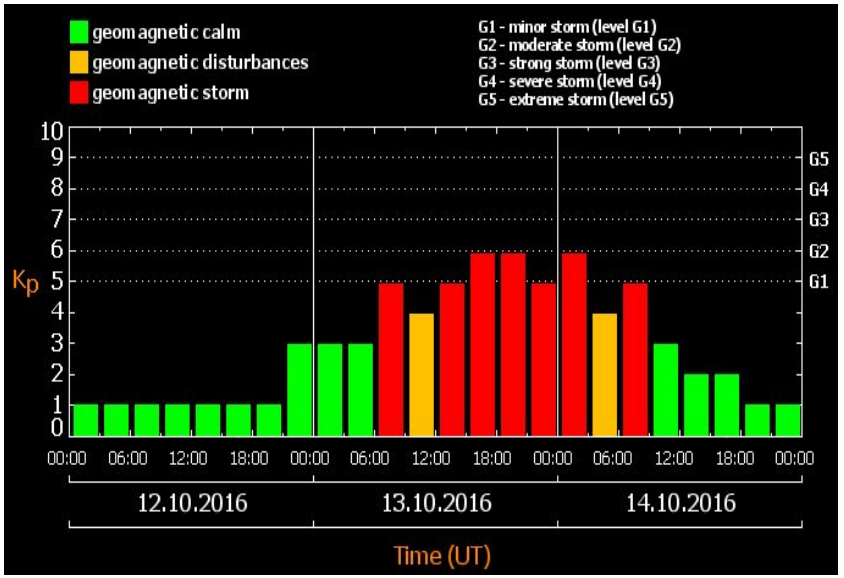


Taken from NASA Space Weather Prediction Center



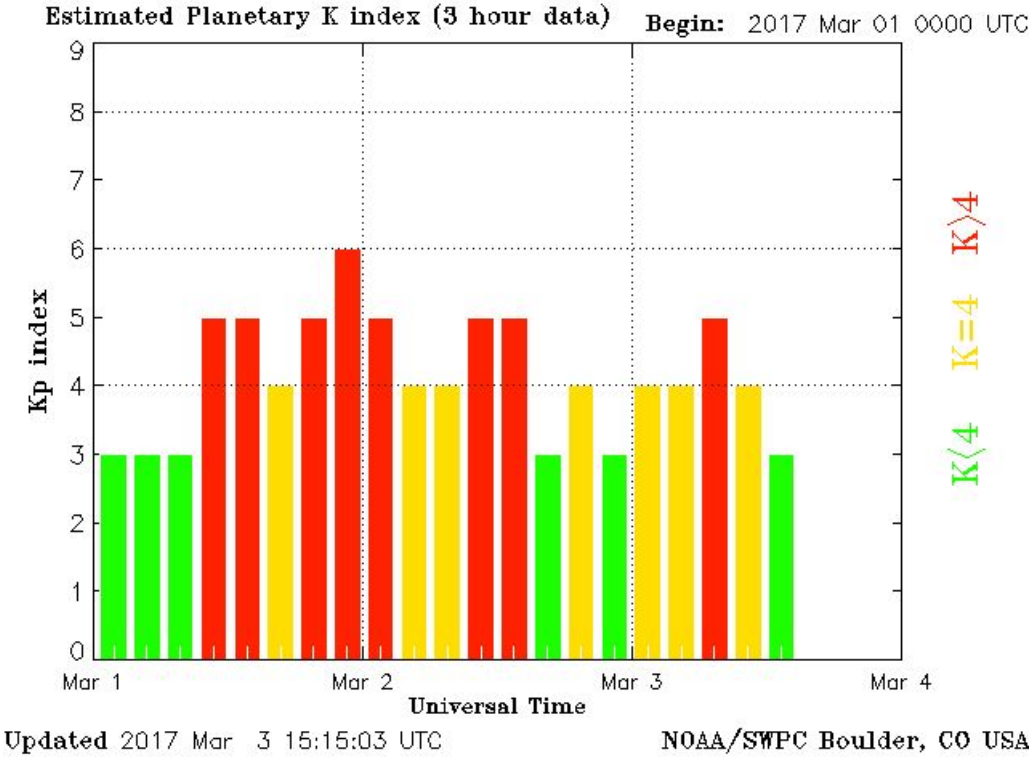
During the geomagnetic storm on Oct. 14th, 2016

POLAR Light curves

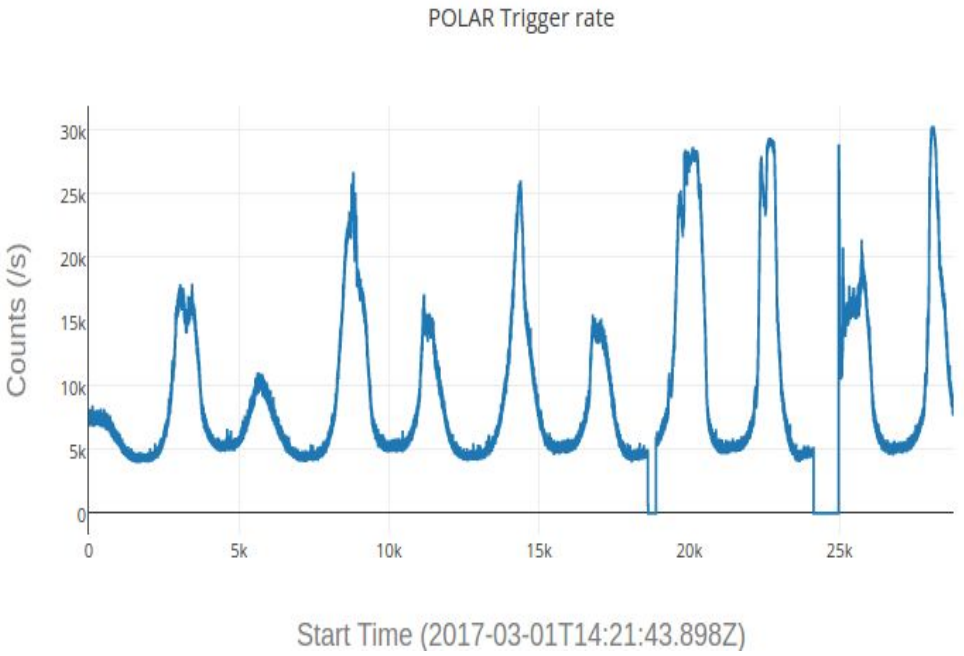


Planetary k-index (from TESIS)

Geomagnetic storm on March 1st, 2017



k- index on March 1st, 2017, taken from NASA



POLAR light curve during the storm

POLAR Data Center at PSI

- POLAR Telemetry data in space reaches 50 GB data per day
- A dedicated data center established at PSI
- Hardware consists of
  - A high performance server for data processing
  - A 80 TB storage server
  - PSI cluster for Monte Carlo Simulations
- Fully automated and safe guarded software developed at PSI
- Software consists of
  - Database
  - Data processing software
  - Web Interfaces (http://polar.ihep.ac.cn)

Summary

- POLAR developed by a collaboration between Europe and China
- First phase calibration is completed
- Commissioning period will finish in April
- Analysis of GRB data and Solar flare data ongoing
- POLAR is capable of studying
  - GRBs
  - Solar Flares
  - Space weather events

More information on POLAR is available at
http://polar.psi.ch