Gamma-ray polarimeter POLAR

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Outline

Gamma Ray Burst

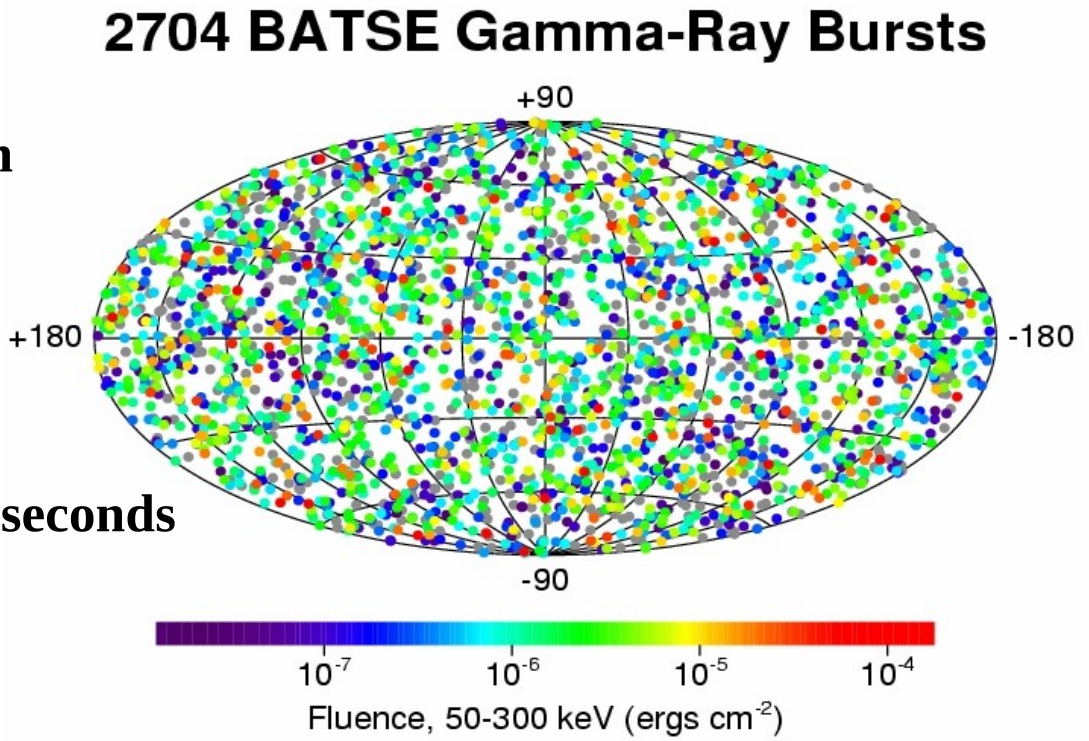
Why polarization?

POLAR experiment

Gamma Ray Bursts

Gamma ray bursts (GRB) are brief flashes of gamma rays randomly distributed in the sky and time.

- **Isotropic distribution, no concentration towards the plane of the Milky Way;**
- **Explosion releases the giant energy (~ 10^{49} - 10^{51} ergs);**
- **Duration of the flash from fractions of seconds to a little over 100 sec**
- **Reddening are in the range z = 0.08 to z = 9.3**
- **CGRO, Swift, Integral, RHESSI, BeppoSAX, ...**



Positions on the sky of all gamma-ray bursts detected during the BATSE mission (1991-2000)

GRB are among candidate sources for UHECRs

UHECR acceleration at GRB internal shocks

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ABSTRACT

We study the acceleration of cosmic-ray protons and nuclei at GRB internal shocks. Physical quantities (magnetic fields, baryon and photon densities, shock velocity) and their time evolution, relevant to cosmic-ray acceleration and energy losses, are estimated using the internal shock modeling implemented by Daigne & Mochkovitch (1998). Within this framework, we consider different hypotheses about the way the energy dissipated at internal shocks is shared between accelerated cosmic-rays, electrons and the magnetic field. We model cosmic-ray acceleration at mildly relativistic shocks, using numerical tools inspired by the work of Niemiec & Ostrowski (2004), including all the significant energy loss processes that might limit cosmic-ray acceleration at GRB internal shocks.

HIGH-ENERGY COSMIC RAYS FROM GAMMA-RAY BURST SOURCES: A STRONGER CASE

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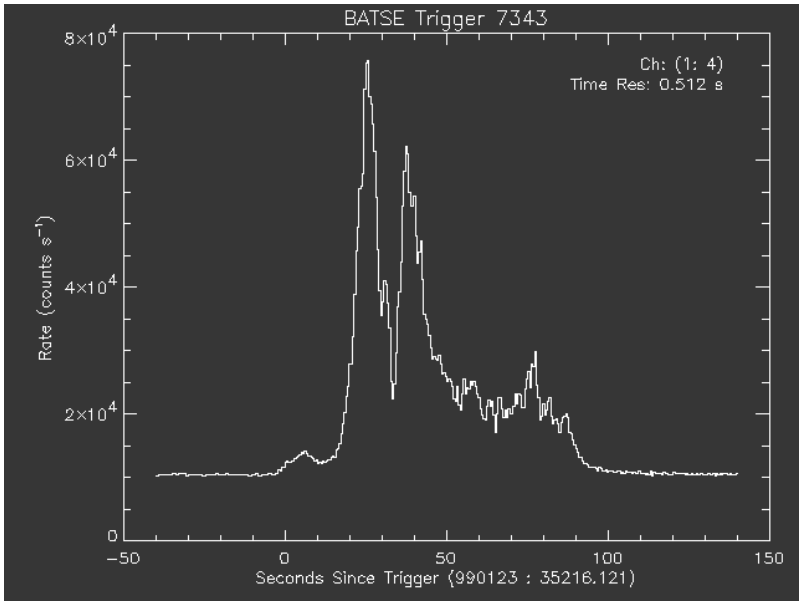
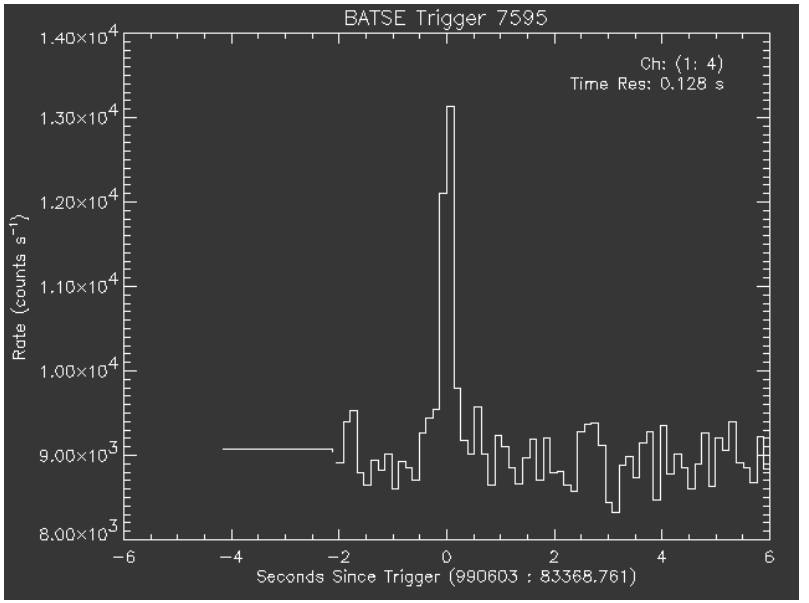
ABSTRACT

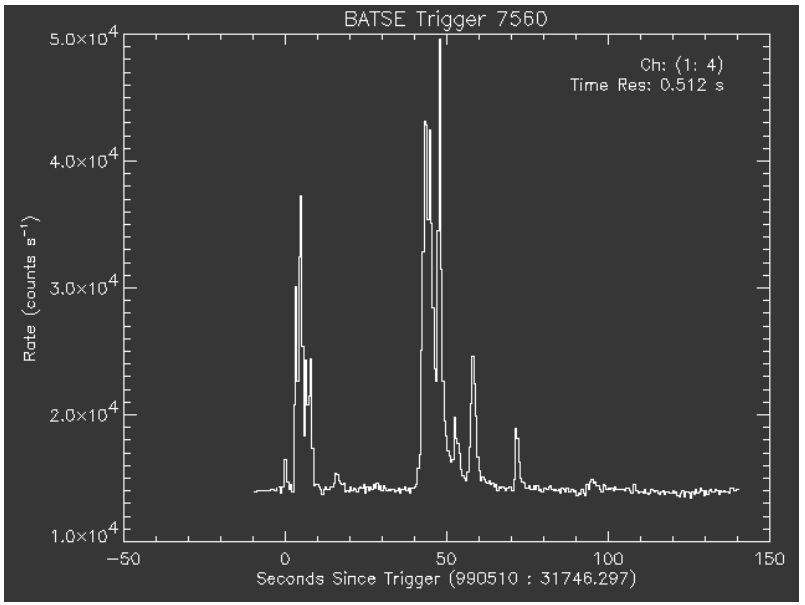
The suggested association between the sources of γ-ray bursts (GRBs) and the sources of ultrahigh-energy cosmic rays (UHECRs) is based on two arguments: (1) the constraints that UHECR sources must satisfy in order to allow proton acceleration to greater than 10^{20} eV are similar to those inferred for GRB sources from γ-ray observations, and (2) the average energy generation rate of UHECRs is similar to the γ-ray generation rate of GRBs. We show that recent GRB and UHECR observations strengthen both arguments and hence strengthen the suggested association.

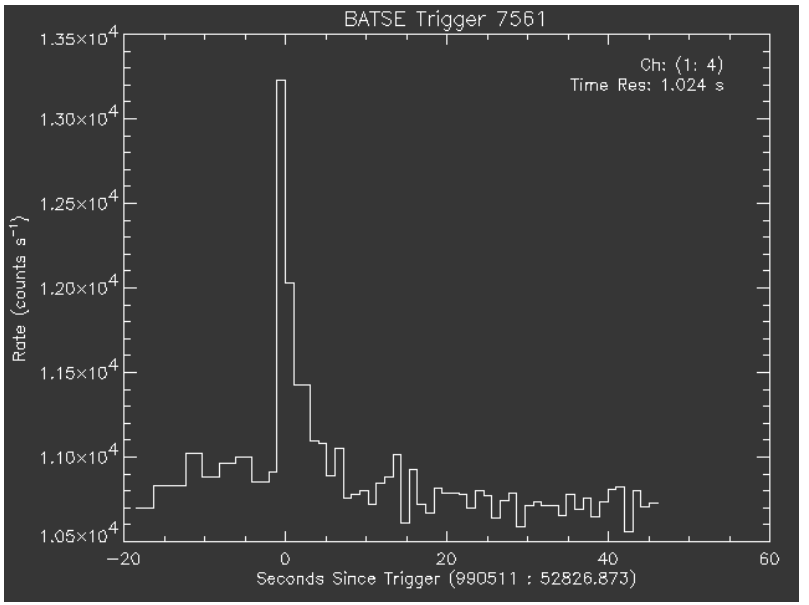
Subject headings: cosmic rays — gamma rays: bursts

GRB Light Curves





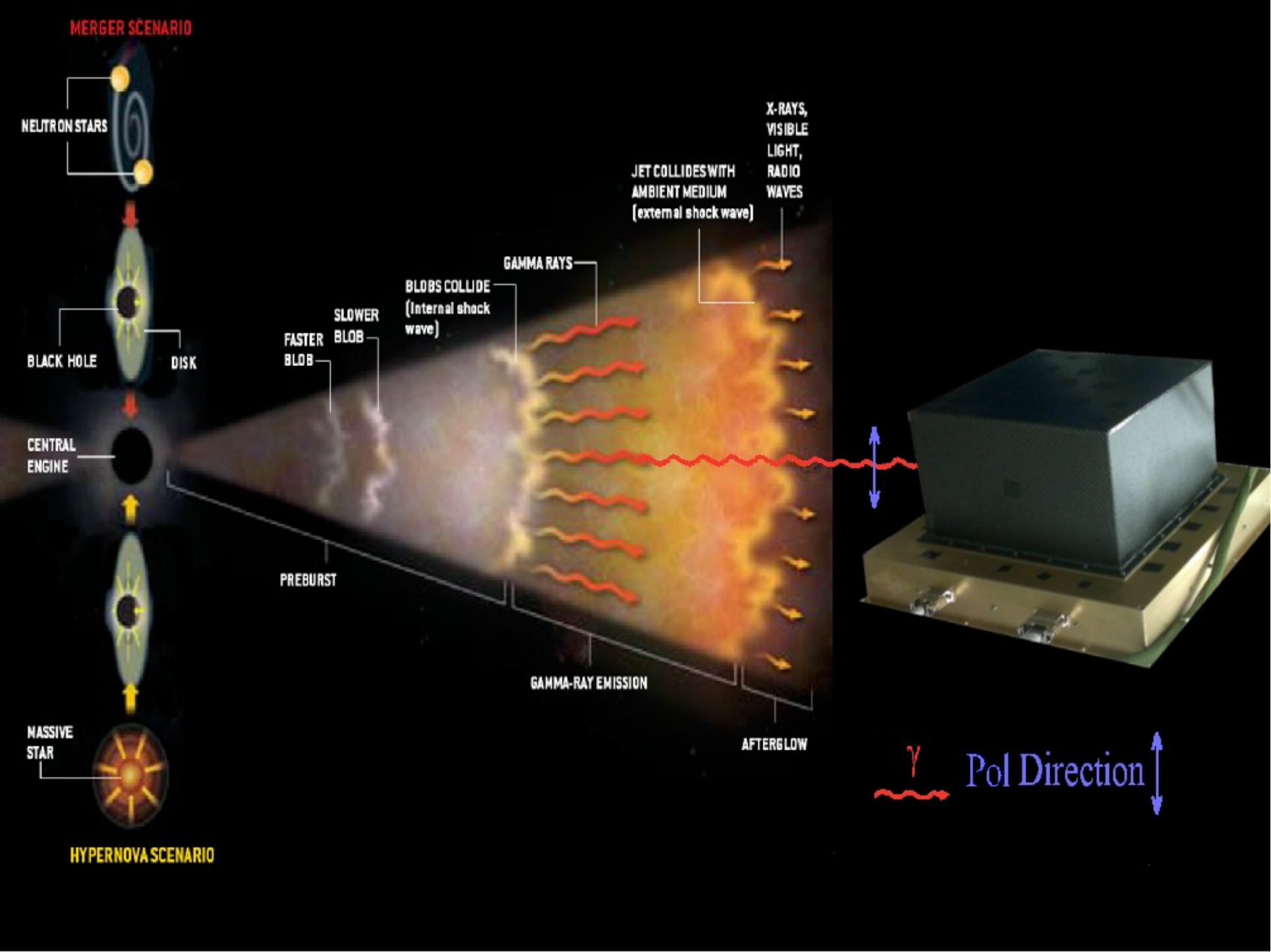




Long GRBs (duration > 2 s)

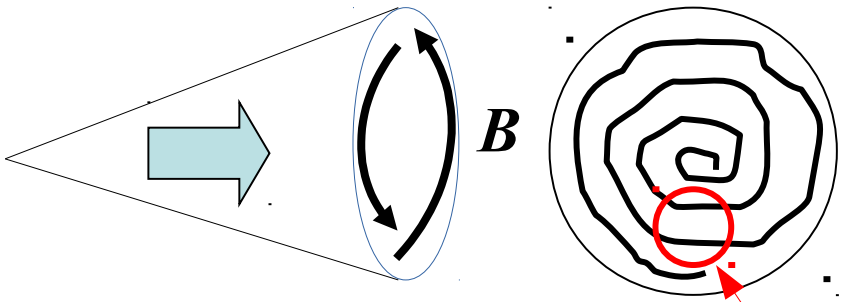
Short GRBs (duration < 1 s)

Possibly two different types of GRBs: Long and short bursts


MERGER SCENARIO
NEUTRON STARS
BLACK HOLE
DISK
CENTRAL ENGINE
MASSIVE STAR
HYPERNOVA SCENARIO
PREBURST
FASTER BLOB
SLOWER BLOB
BLOBS COLLIDE (Internal shock wave)
GAMMA RAYS
JET COLLIDES WITH AMBIENT MEDIUM (external shock wave)
X-RAYS, VISIBLE LIGHT, RADIO WAVES
GAMMA-RAY EMISSION
AFTERGLOW
γ
Pol Direction

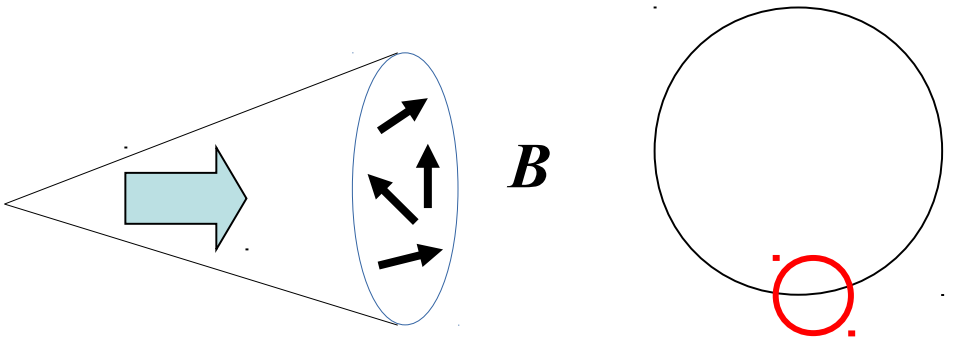
Models

Synchrotron with ordered field (Granot 03; Lyutikov et al. 03)

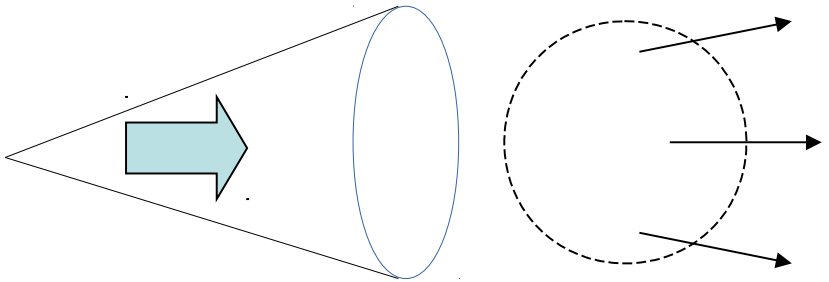


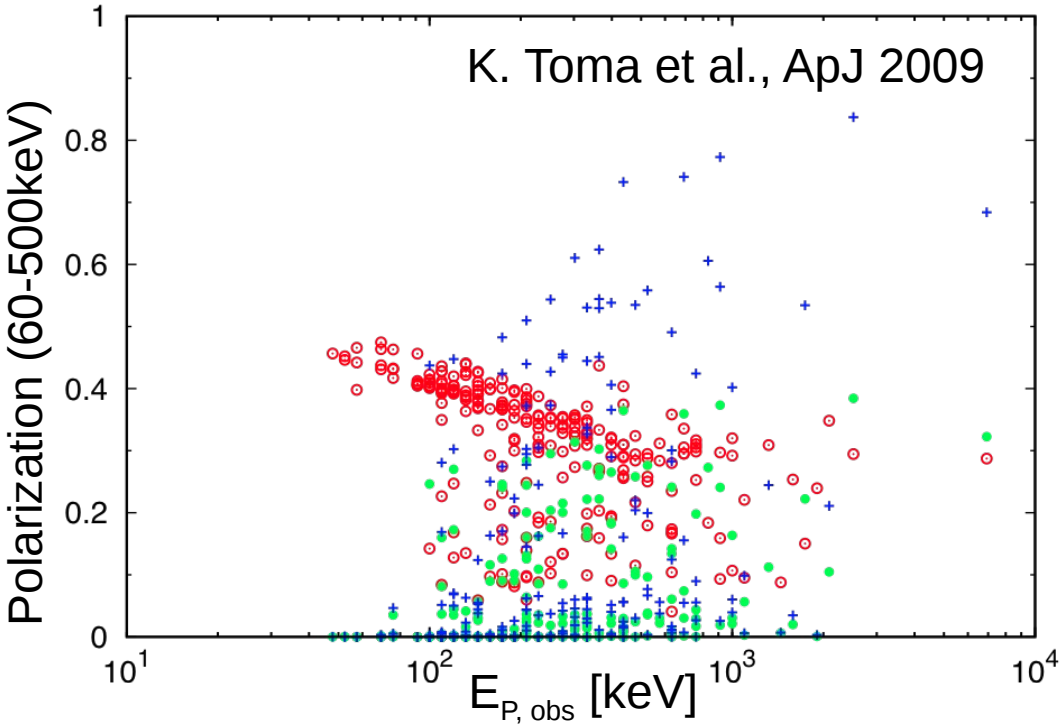
Visible region

Synchrotron with small-scale random field (Granot 03; Nakar et al. 03)

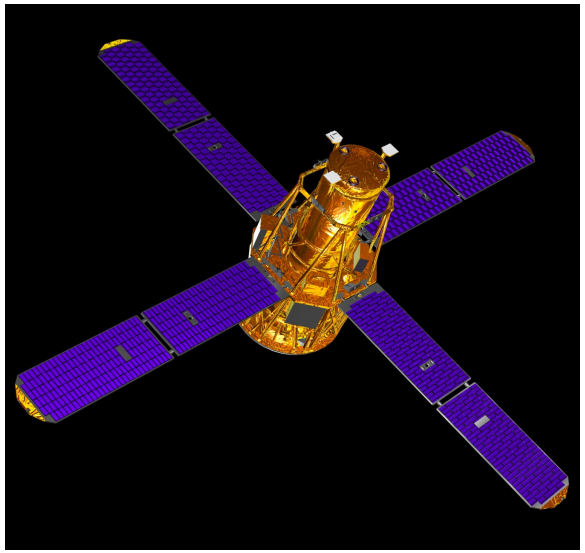


Bulk Compton scattering (Lazzati et al. 04)



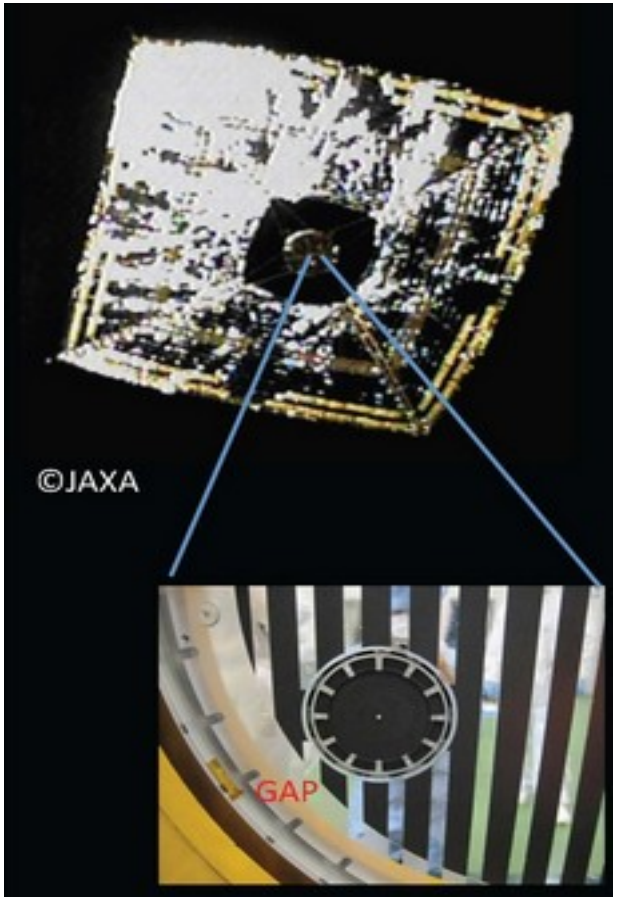


Observations



RHESSI

INTEGRAL- SPI -IBIS



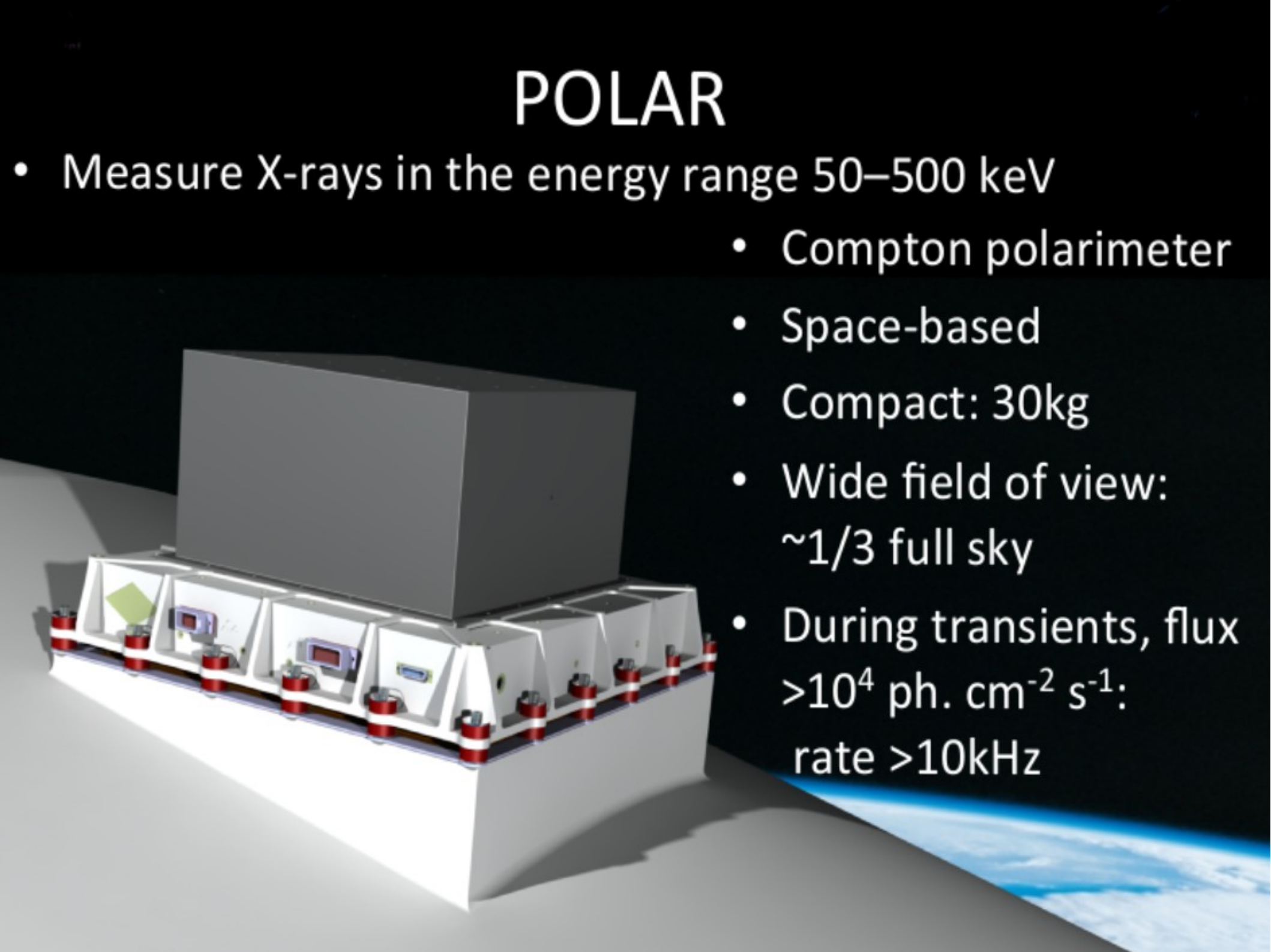
GAP aboard IKAROS satellit.

Event name	Π	Detection sig
GRB 100826A	27±11%	2.9σ
GRB 110301A	70±22%	3.7σ
GRB 110721A	84±16%	3.3σ

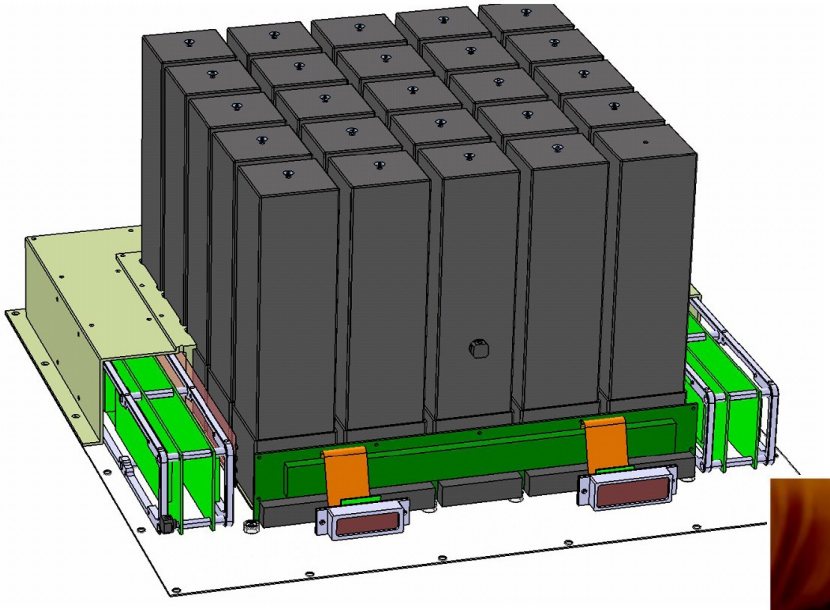
The polarimetric data taken together with the light-curve and spectral data may reveal the driving mechanism of the jets and nature of the central engines.

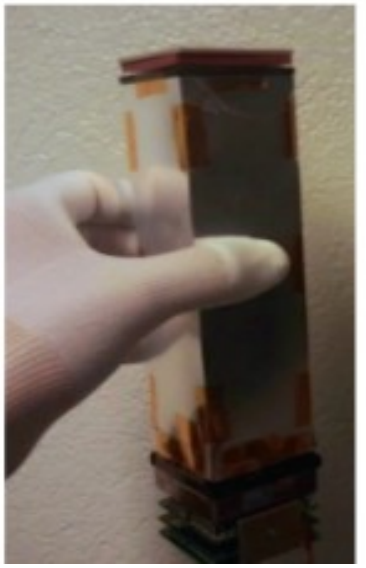
POLAR

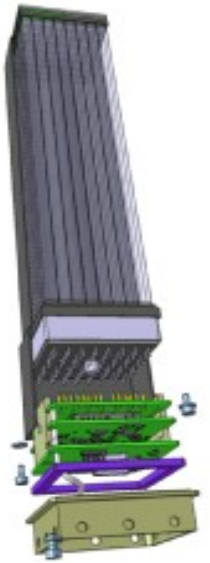
- Measure X-rays in the energy range 50–500 keV
  - Compton polarimeter
  - Space-based
  - Compact: 30kg
  - Wide field of view: ~1/3 full sky
  - During transients, flux $>10^4$ ph. cm^{-2} s^{-1}: rate >10kHz

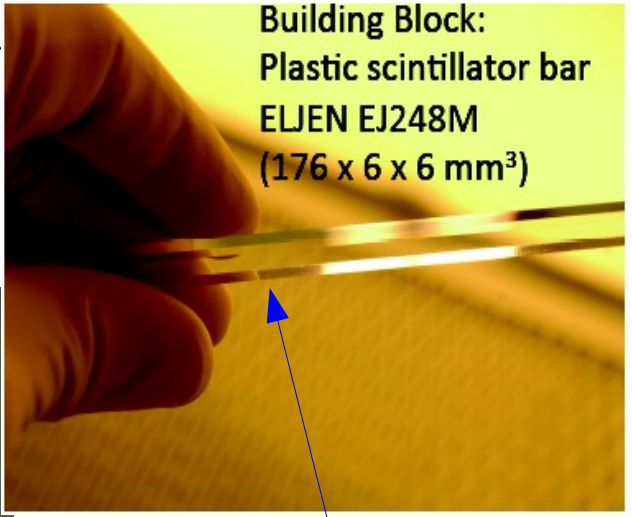


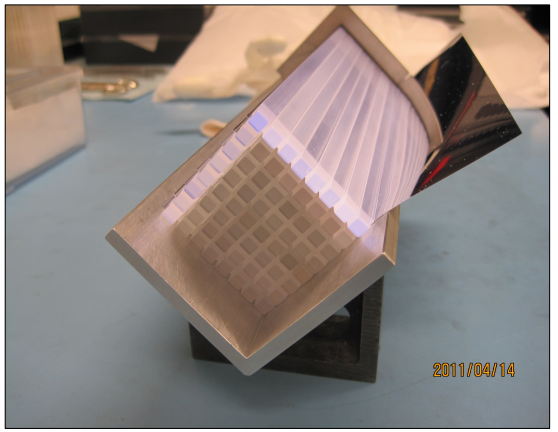
POLAR Design

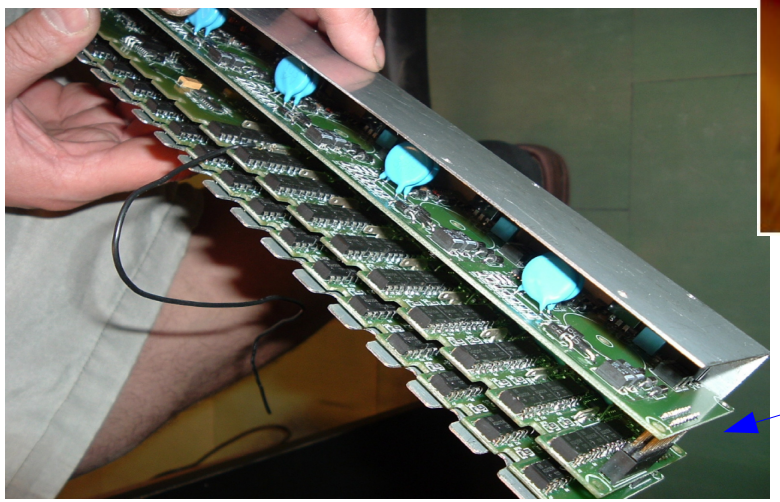




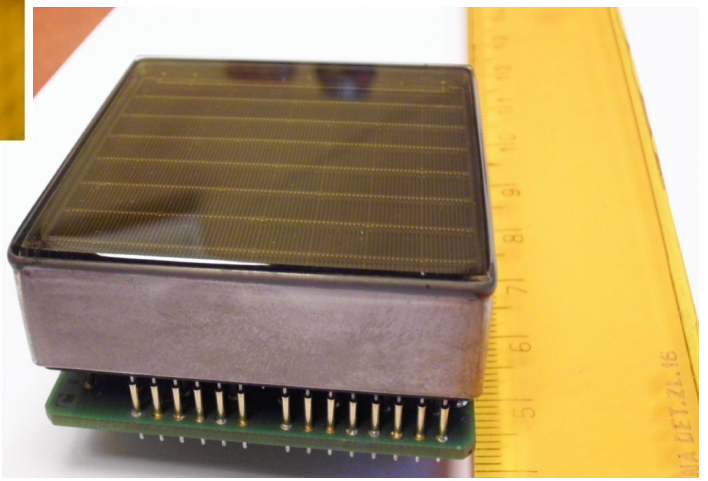




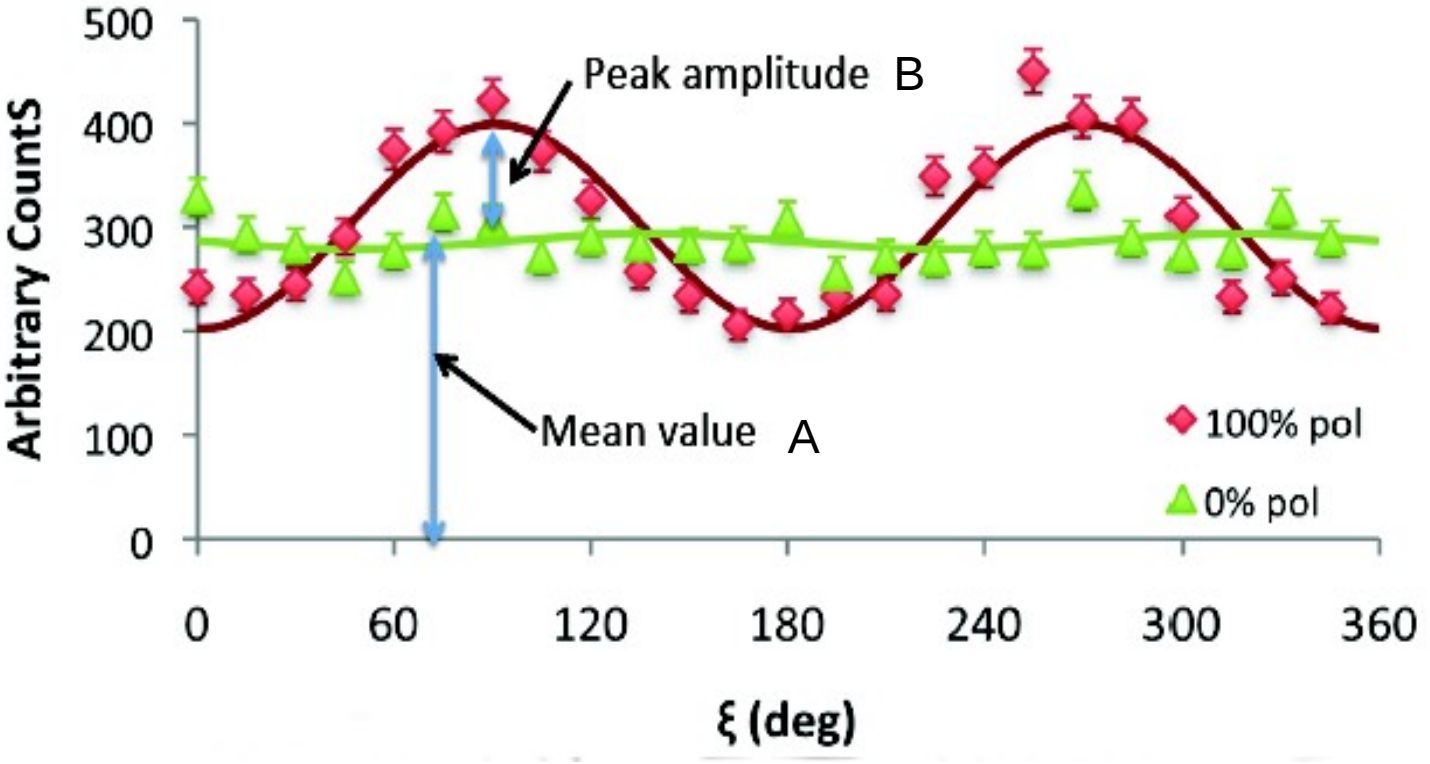


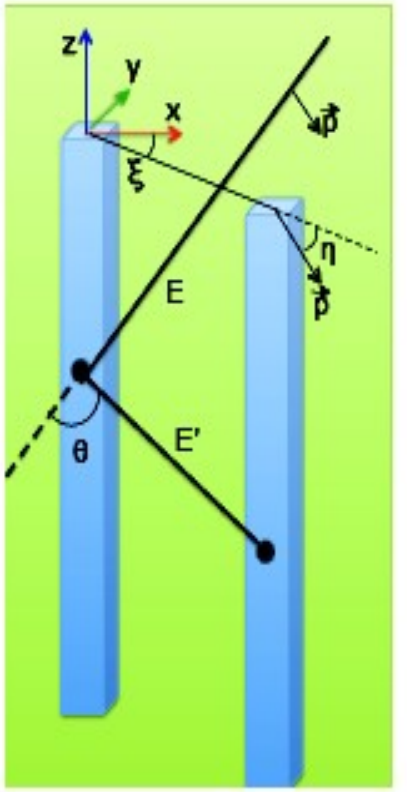


Made by NCBJ



Modulation Curve





***Fit function*:** $f(\xi) = A + B\cos^2(\xi - \xi_0)$

***Polarization*:** $\Pi = \frac{\mu}{\mu_{100}}$

***Modulation factor*:** $\mu = \frac{Peak\ amplitude}{Mean\ value}$

It describes the response of the polarimeter to a photon flux with a polarization degree Π

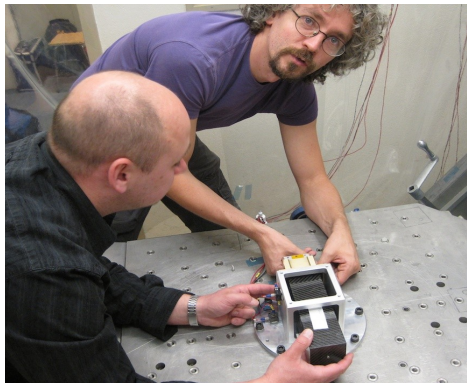
μ_{100} *is the modulation factor for* 100% *polarized photons*

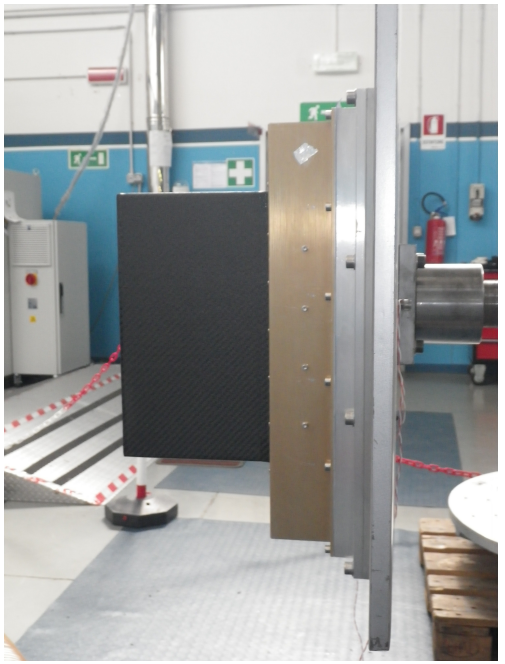
Tests of the detector elements

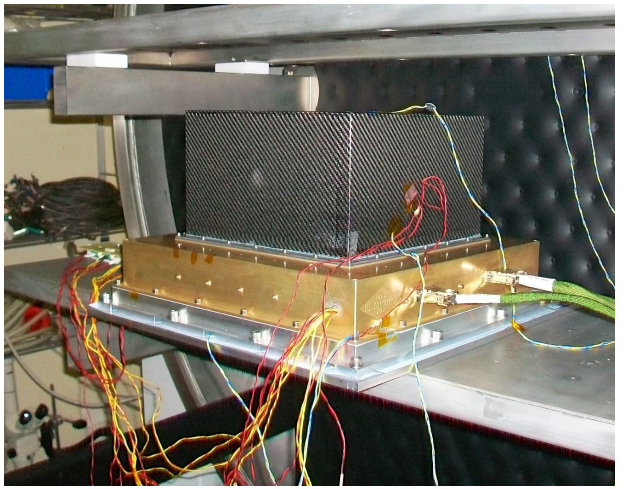
Two criteria for specialization: qualification level and acceptance level.

QM was meant to be the qualification model (QM1, QM2, QM3)

- Vibration was tested at component level (PMT, module) very early.
- Specific thermal test and radiation test of front end electronic was performed.
- Then test where done at level of the whole assembly







Design of final qualification model is taken as Flight Model (FM). Flight model and flight spare have to pass acceptance level test.

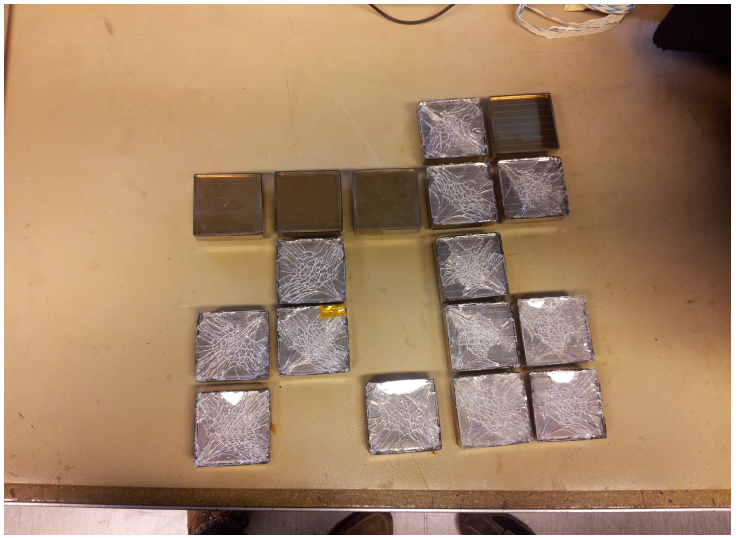
Tests of the detector elements

QM 1

- Qualification test started with it but had problem during vibration (on coil of HVPS detached).
- QM1 was repaired
- Then a model was needed in China for integration and EMC tests so QM1 was sent to China. December 2012

QM 2

- QM2 constructed to resume qualification tests.
- All tests passed (acceleration, EMC, thermal, thermovacuum, vibration, lateral shocks)
- But QM2 was destroyed during longitudinal shock (900g) (very last test)

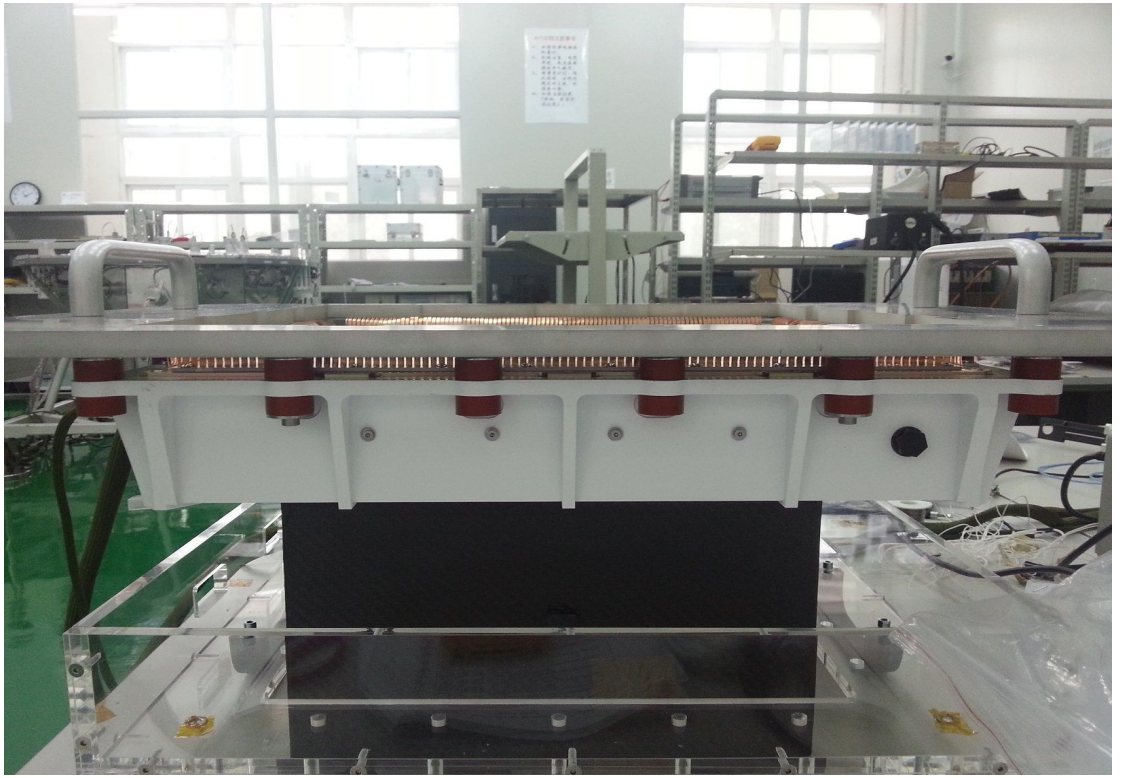


QM 3

- Redesigned detector (grid more stiff, mounted on shock absorbers, redesign thermal contact)
- Resume all qualification campaign
- Finished successfully (including shocks)

Status of project

- Flight Model (FM) and Flight Model Spare (FMS) are ready in Geneva
- Acceptance test in this year
- Fly in 2016



Summary and Conclusion

The polarimetric data taken together with the light-curve and spectral data may reveal the driving mechanism of the jets and nature of the central engines of GRB.

The suggested association between the sources of GRB and the sources of the UHECR is motivating for further study.

Summary and Conclusion

POLAR is pathfinder for further GRB polarization study.
A prototype of gamma polarimeter is built and tested for GRB but also possible for sun burst.

Detector features:

- large field of view
- uniform structure
- relatively cheap

but projected angle for modulation curve is measured.

If successful an array of these modules can be used.

Qualification goes slowly but regularly.

To be a launch in 2016.