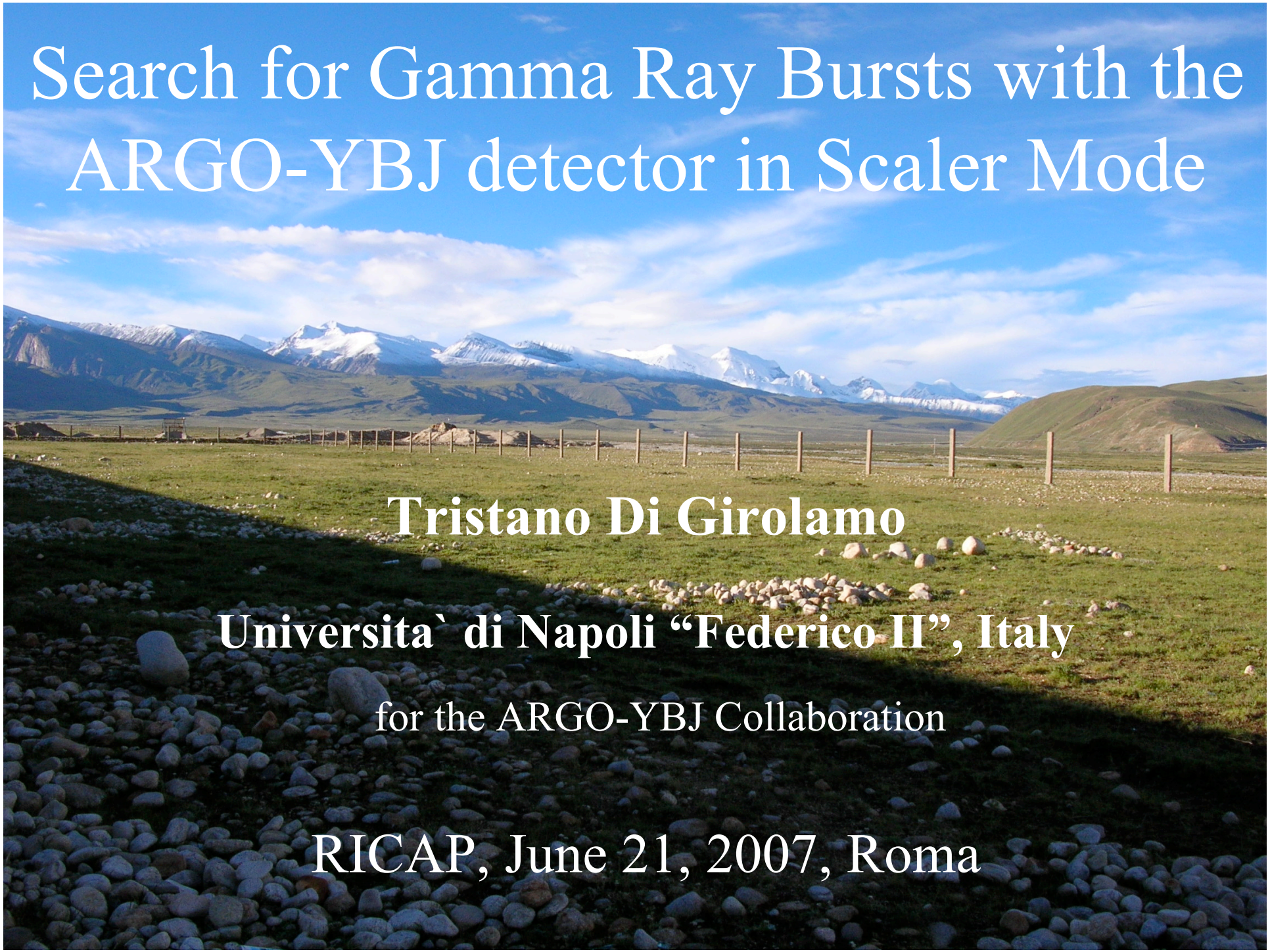
Search for Gamma Ray Bursts with the ARGO-YBJ detector in Scaler Mode



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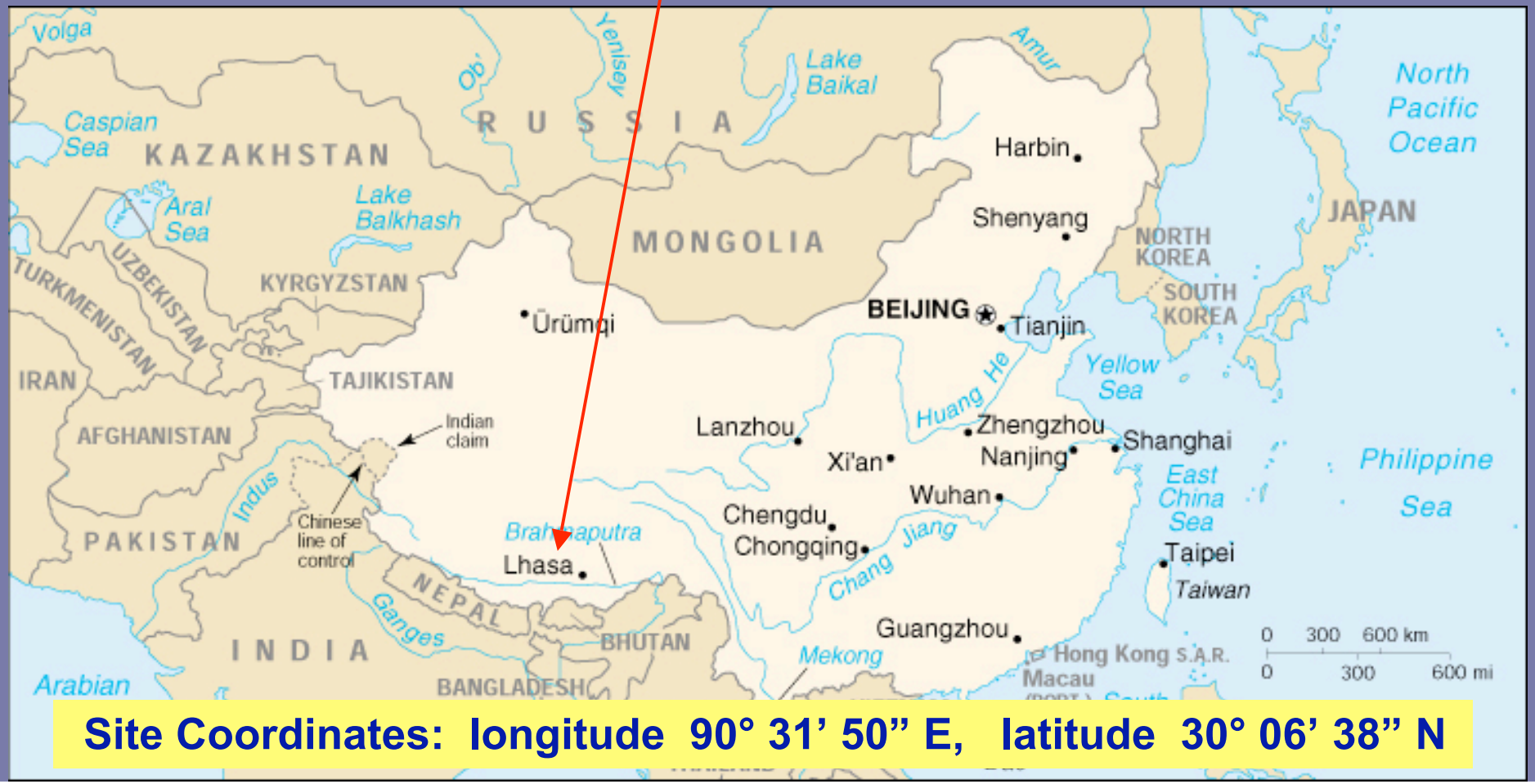
The ARGO-YBJ experiment

- Collaboration between:
  - Istituto Nazionale di Fisica Nucleare (INFN) – Italy
  - Chinese Academy of Science (CAS)

- Site: YangBaJing Cosmic Ray Laboratory (Tibet, P.R. of China), 4300 m a.s.l.



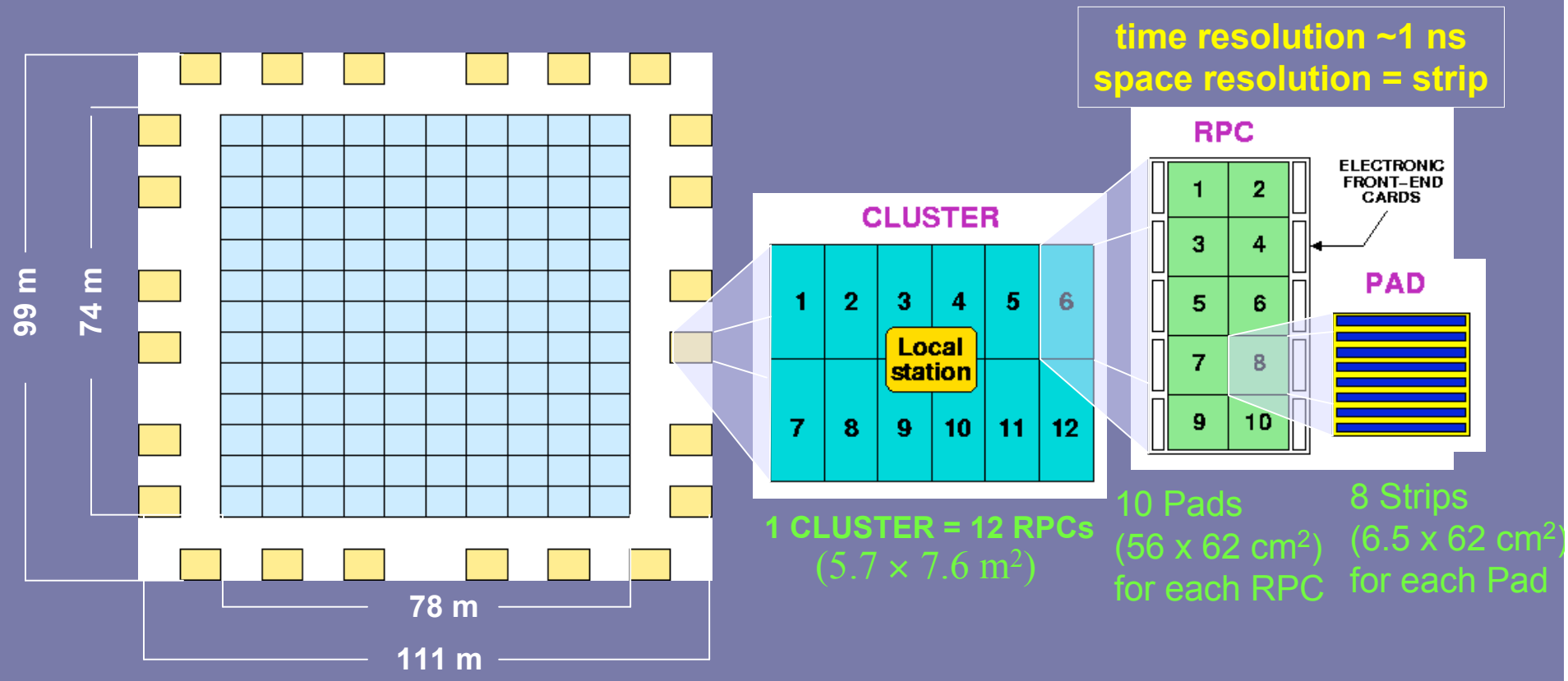
Site Coordinates: longitude 90° 31' 50" E, latitude 30° 06' 38" N

Physics Goals

- **γ-ray Astronomy**: search for galactic and extragalactic point sources with a large field of view (>2 sr) and a duty cycle ~100%, at an energy threshold of a few hundreds of GeV
- **Diffuse γ-Rays**
  from the Galactic plane and SuperNova Remnants
- **Gamma Ray Burst (GRB) physics**
  in the full GeV – TeV energy range
- **Cosmic Ray physics**:
  - spectrum and composition up to ≈ 10^3 TeV
  - anti-p / p ratio at energy ≈ TeV
- **Sun and Heliosphere physics**
  with an energy threshold ≈ 10 GeV

through **the observation of *Extensive Air Showers (EASs)* produced in the atmosphere by γ-rays and primary nuclei**

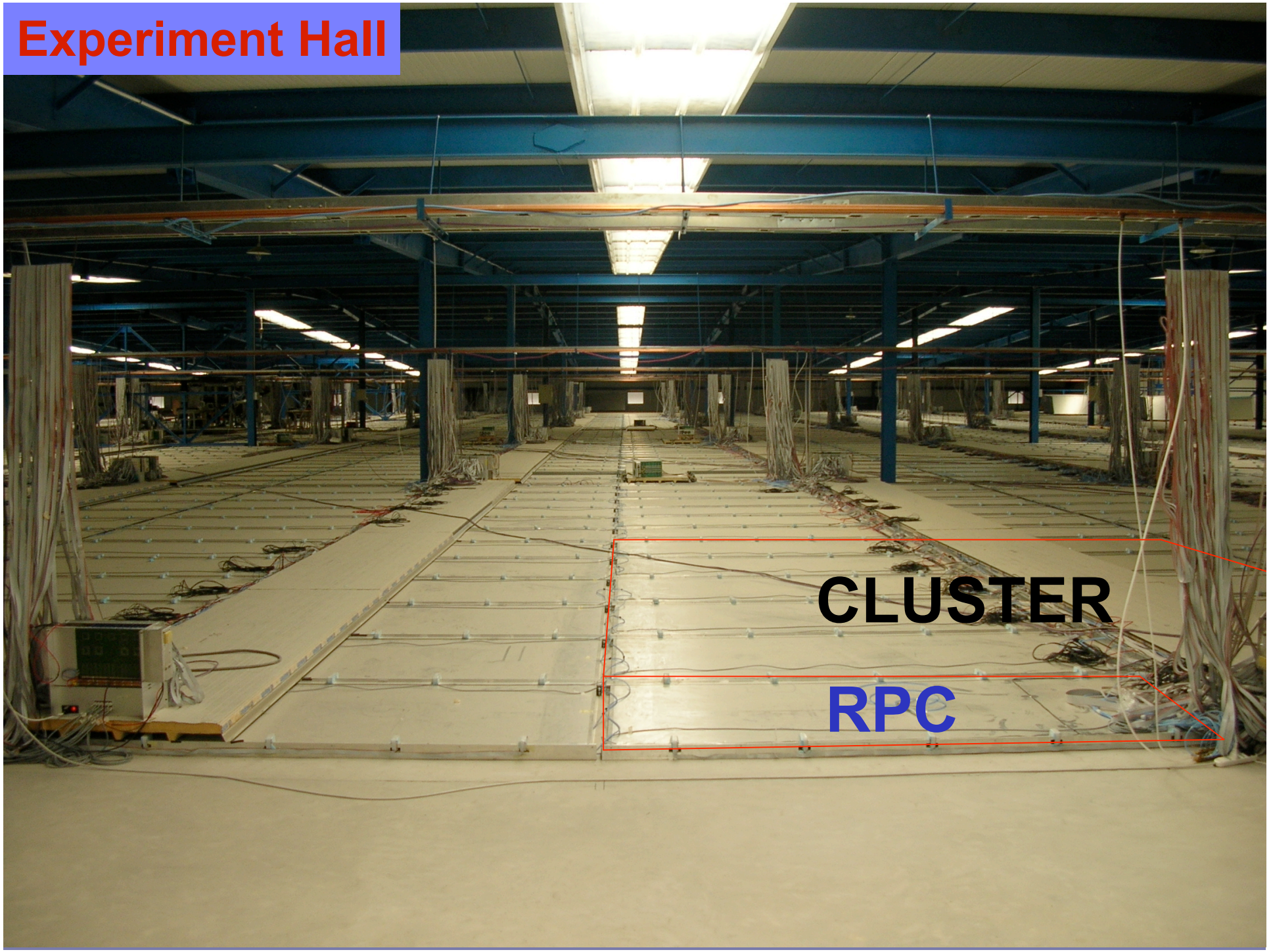
Detector layout



Single layer of Resistive Plate Chambers (RPCs)
with a full coverage (92% active surface) of a large area (5600 m²)
+ sampling guard ring + 0.5 cm of lead converter

⇒ detection of small showers (low energy threshold)

Experiment Hall



Data Acquisition

The detector carpet is connected to two different DAQ systems, working independently:

Shower Mode:
for each event the location and timing of each detected particle is recorded, allowing the reconstruction of the lateral distribution and of the arrival direction
(talk of D'Ali' Staiti)

Scaler Mode:
the counting rate of each CLUSTER is measured every 0.5 s, with no information on the space distribution and arrival direction of the detected particles
(in the following slides)

Scaler Mode DAQ

- For each CLUSTER 4 scalers record every 0.5 s the rates of counts ≥1, ≥2, ≥3 and ≥4 in a time window of 150 ns
- Measured rates are, respectively, ~ 40 kHz, ~ 2 kHz, ~ 300 Hz and ~ 120 Hz
- Counting rates for a given multiplicity are then obtained with the relation $n_i = n_{\geq i} - n_{\geq i+1}$ (i=1,2,3)
- The energy threshold is about 1 GeV, lower than the highest energies detected by satellite experiments
- The modular structure of the detector allowed to collect data during the different mounting phases
- During data taking, the detector active area increased from 693 to 5632 m^2

Physics Goals in Scaler Mode

- GRBs: search for the high energy tail and spectral cutoff
- Solar physics: Forbush Decreases and Ground Level Enhancements in correlation with neutron monitors
- Long term modulations: Compton-Getting effect and sidereal anisotropies
- Correlation with changes of the Atmospheric Electric Field (thunderstorms)

I will focus on the search for emission from GRBs

GRB High Energy Tails ?

- EGRET detected emission above 1 GeV from 3 GRBs, with photons up to 18 GeV (GRB940217, about 90 minutes after the burst start)
- Hints of emission at higher energies from GRB970417a (E > 650 GeV, Milagrito) and GRB920925c (E > 20 TeV, HEGRA)
- The Tibet Air Shower array found an indication of 10 TeV emission in a stacked analysis of 57 bursts
- Many theoretical models predict a significant high energy tail for GRBs
- High energy γ-rays are absorbed by the Extragalactic Background Light (EBL), whose amount however is not yet well known.
  The γ-ray extinction increases with the GRB distance.
- The GeV – TeV energy range may reveal the spectral cutoff of GRBs, constraining emission models

Search Triggered by Satellites

- Search started since the first GRB detection by Swift on December 17, 2004 (as a Follow-Up instrument)
- Selection of GRBs within ARGO-YBJ field of view (θ <45°)
- Search for an excess in the scaler counts in coincidence with the satellite detection
- In case of no signal evidence, calculation of the fluence upper limit (with statistical significance k = 4) using A_{eff}
- Search for a delayed or anticipated signal of fixed duration
- Search for a signal from stacked GRBs

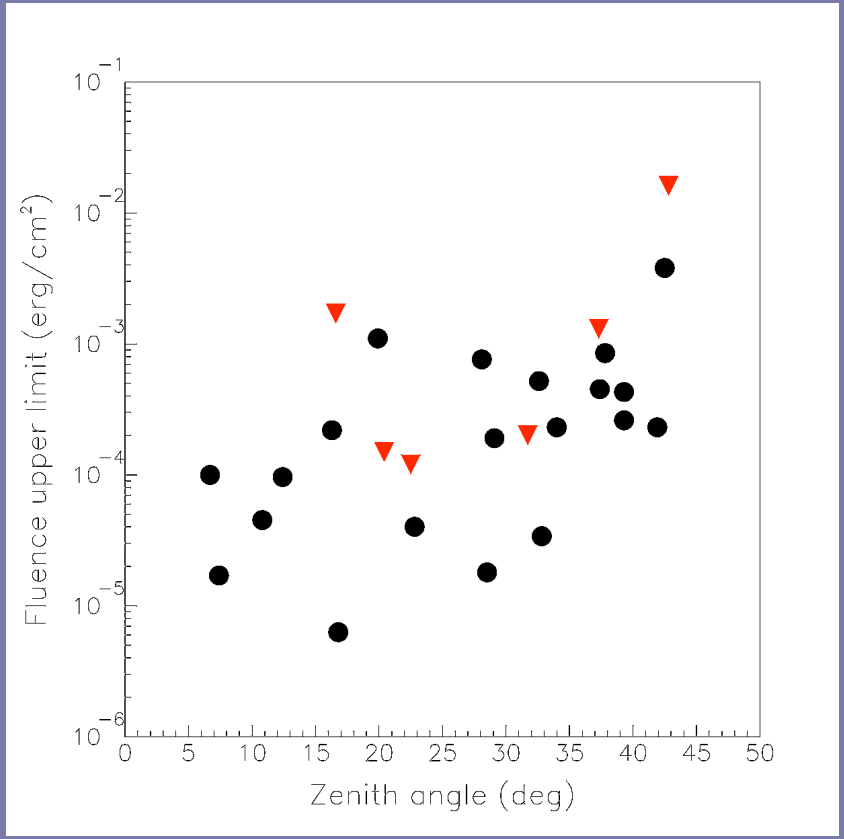
GRBs with unknown redshift

GRB	SAT	T90/dur (sec)	Zenith Angle (°)	Photon Index	Detector Area (m^2)	n_σ
041228	Swift	62	28.1	1.56	693	-0.45
050509A	Swift	12	34.0	2.10	1820	-1.3
050528	Swift	11	37.8	2.30	1820	0.78
051105A	Swift	0.03	28.5	1.33	3379	0.67
051114	Swift	2	32.8	1.22	3379	1.1
051227	Swift	8	22.8	1.31	3379	1.5
060105	Swift	55	16.3	1.11	3379	1.5
060111A	Swift	13	10.8	1.63	3379	0.47
060121	HETE	1.6	41.9	BAND	4505	1.5
060421	Swift	11	39.3	1.53	4505	-0.34
060424	Swift	37	6.7	1.72	4505	0.86
060427	Swift	64	32.6	1.87	4505	-0.65
060510A	Swift	21	37.4	1.55	4505	2.4
060717	Swift	3	7.4	1.72	5632	0.38
060801	Swift	0.5	16.8	0.47	5632	1.1
060805B	IPN	8	29.1	BAND	5632	-0.95
060807	Swift	34	12.4	1.57	5632	0.96
061122	Integral	18	33.5	CPL	5632	0.98
070201	IPN	0.3	20.6	CPL	5632	-1.4
070219	Swift	17	39.3	1.8	5632	-0.59
070306	Swift	210	19.9	1.72	5632	-0.27

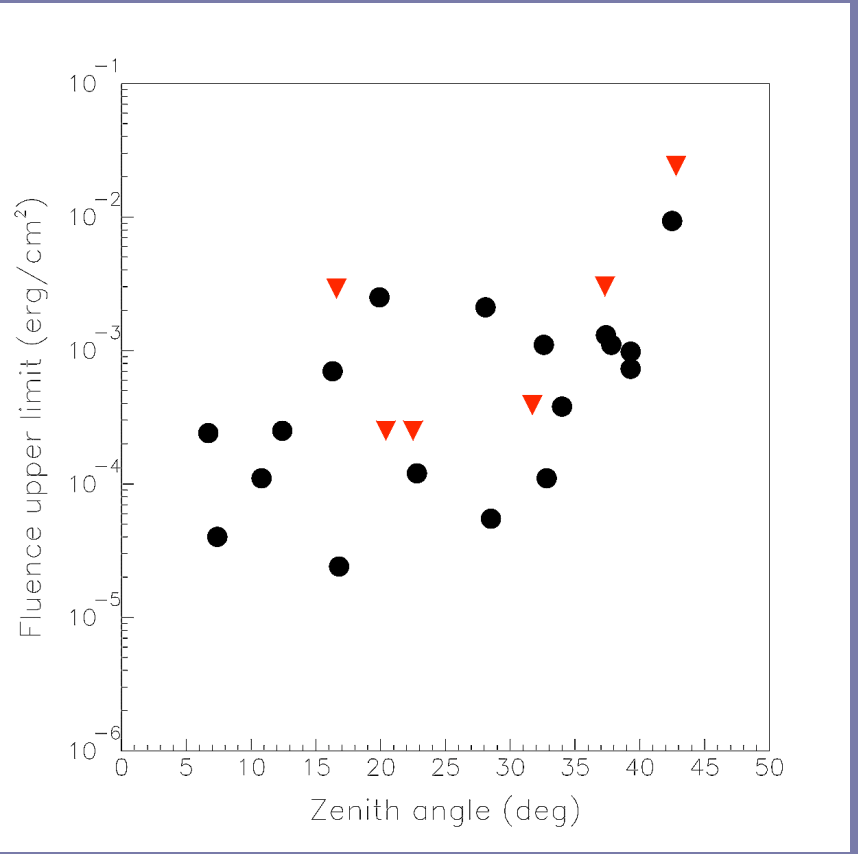
GRBs with known redshift

GRB	SAT	T90/dur (sec)	Zenith Angle (°)	Redshift z	Photon Index	Detector Area (m^2)	n_σ
050408	HETE	15	20.4	1.24	1.98	1820	-1.3
050802	Swift	13	22.5	1.71	1.55	1820	-0.35
060115	Swift	142	16.6	3.53	1.76	4505	-0.07
060526	Swift	14	31.7	3.21	1.66	4505	0.68
060714	Swift	115	42.8	2.71	1.99	5632	-0.67
060927	Swift	23	31.6	5.6	1.65	5632	0.05
061110A	Swift	41	37.3	0.76	1.67	5632	-0.16

Upper Limits in the 1–100 GeV range



Fluence upper limits obtained extrapolating the keV spectra measured by satellites

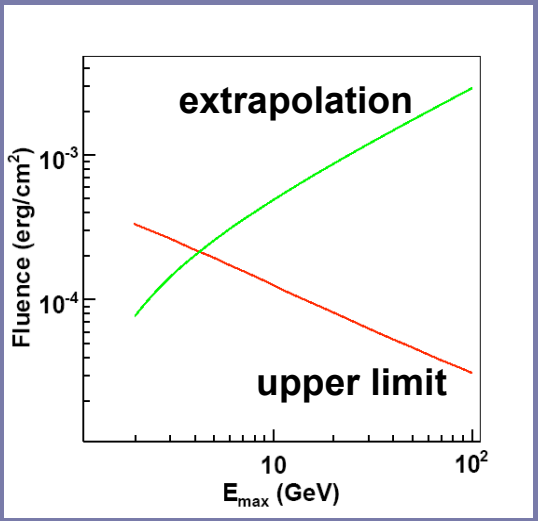


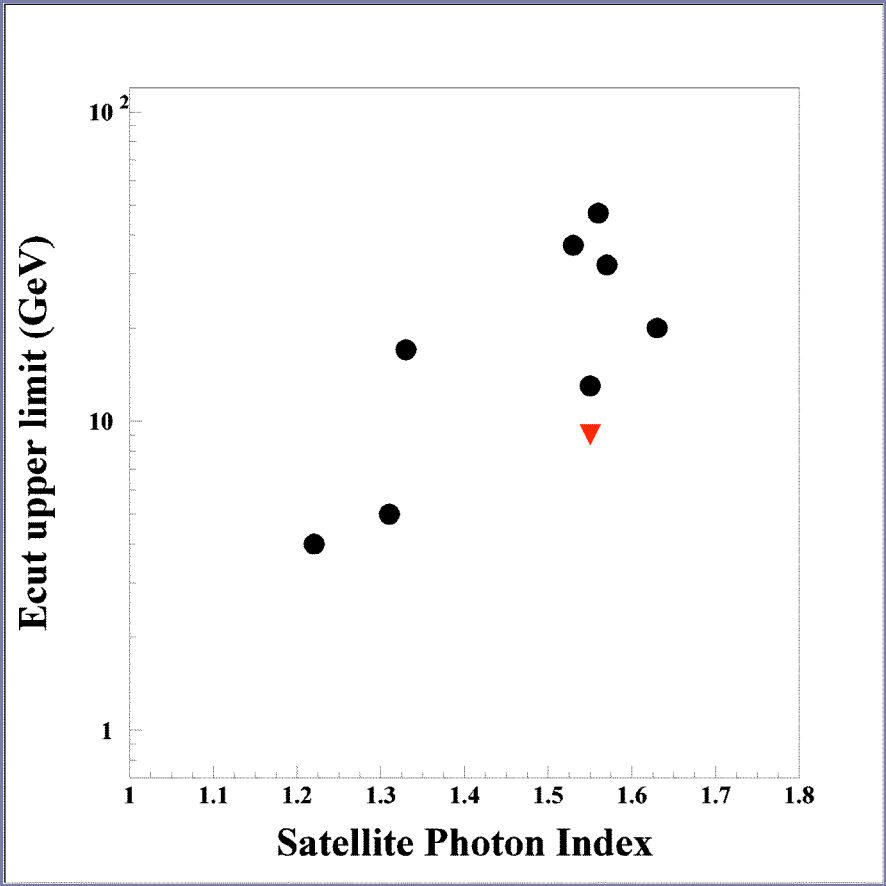
Fluence upper limits obtained assuming a "Band spectrum" with a photon index 2.5 after 230 keV (peak of BATSE E_{break} distribution)

The red triangles represent GRBs with known redshift, for which absorption by the EBL has been considered

Upper Limits on the Cutoff Energy

An upper limit on the GRB cutoff energy is given by the intersection of the fluence upper limit, as a function of the cutoff energy, with the extrapolation of the fluence measured by satellites



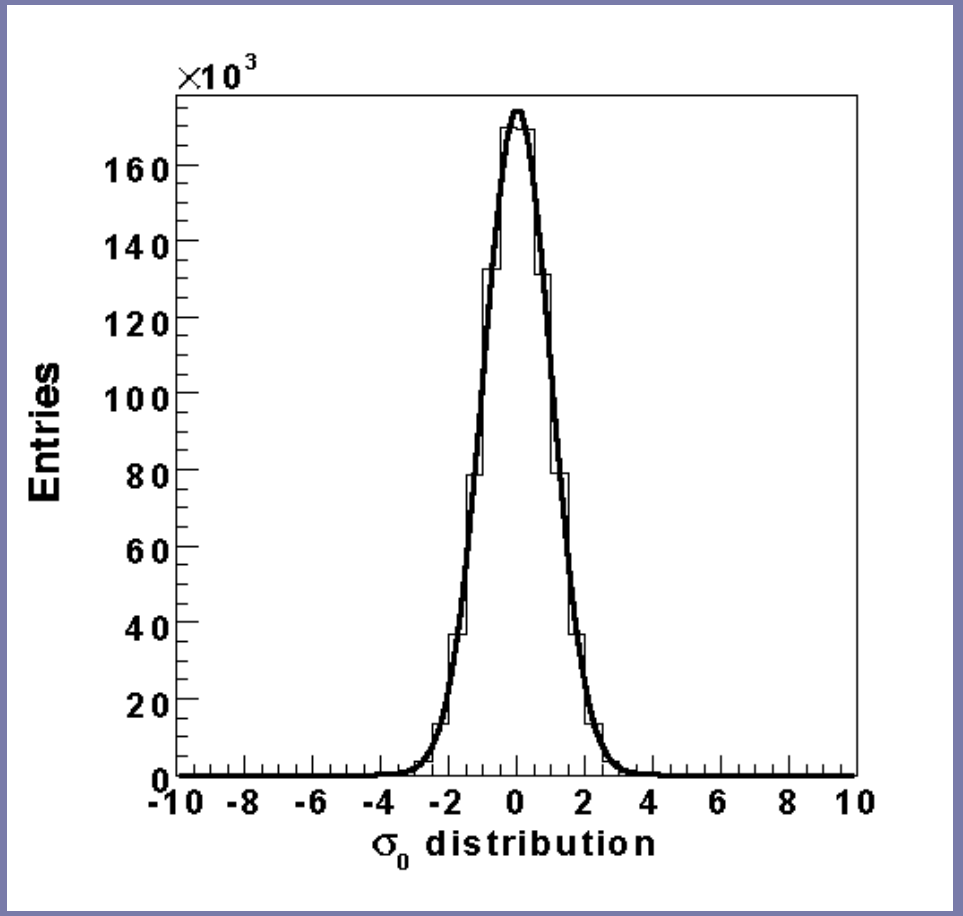


If the spectra of these GRBs extended up to E_{cut} with the index measured by satellites, a signal of 4 σ would have been produced

Search for Delayed or Anticipated Signals

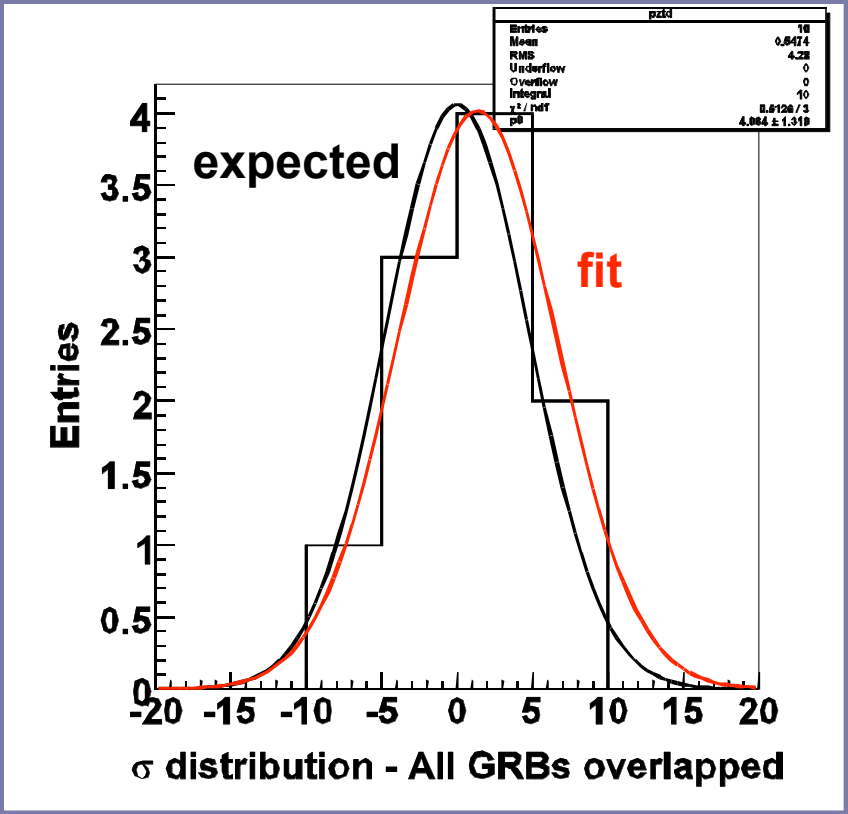
We considered time windows of fixed durations Δt=0.5, 1, 2, 5, 10, 20, 50, 100, 200 s and T90 shifted by steps of Δt inside a $\pm$2 hr interval around the GRB start recorded by satellites

Comparison with the expected standard normal distribution G(0, 1) shows that for our set of GRBs no statistically significant excess is found in any time window (statistical behaviour of the detector and correct determination of the significances)



Stacked GRBs

All the GRBs with T90 ≥ 5 s (long GRBs) have been added up in phase scaling their total duration, in order to search for a possible cumulative high energy emission at a certain phase of the low burst



The resulting significance spectrum of 10 phase bins shows that also in this case no evidence of emission has been detected so far

The overall significance of the GRB stack with respect to background fluctuations is 1.14 σ

Conclusions

- Until now, the search for emission from GRBs with the ARGO-YBJ detector has given no positive result
- The simple scaler mode has shown a good sensitivity, with fluence upper limits down to $\approx 10^{-5}$ erg/cm^2 in the 1–100 GeV energy range
- The directional capability of the shower mode at energies of a few hundreds of GeV allows to study GRBs in the whole 1 GeV – 1 TeV energy range