

# The LAGO project, status and prospects

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Centro Atómico Bariloche. Argentina

Third School on Cosmic Rays and Astrophysics, Arequipa, Perú, 1<sup>st</sup> September 2008

# Outline



- 1 **Gamma Ray Bursts**
  - Discovery and Basic Understanding: Vela and BATSE
  - To the Sources: Beppo-SAX
  - Present and Future: SWIFT, GLAST
  - High Energy Detection
- 2 **GRB detection by WCD**
  - The Pierre Auger Observatory
  - The Large Aperture GRB Observatory
  - LAGO: Prototypes WCD and status
  - Possible Future

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# Discovery of GRBs: Vela 5

## GRBs - Vela 5

Discovered accidentally in the 60's  
by US military satellites

## GRB

- $\Delta t \approx 0.01 \text{ s} - 100 \text{ s}$
- $E > 100 \text{ keV}$

## Enigma for 30 years

- origin
- distance
- luminosity



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## BATSE: 1991 - 2000



### Compton Gamma Ray Observatory

- OSSE 50 keV - 10 MeV
- BATSE 20 keV - 20 MeV
- COMPTEL 800 keV - 30 MeV
- EGRET 20 MeV - 30 GeV

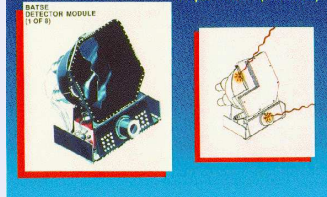
### BATSE

- Field of view:  $4\pi$  sr
- Flux  $> 0.1 \gamma \text{ cm}^{-2} \text{ s}^{-1}$
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### Burst and Transient Source Experiment (BATSE)



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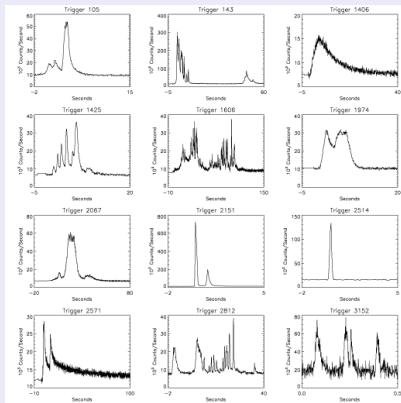
1 GRB per day (30% efficiency)

Duration

2 distinct populations

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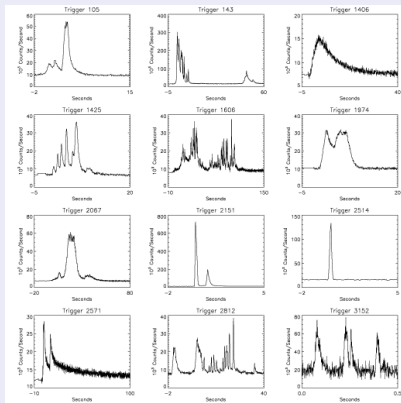


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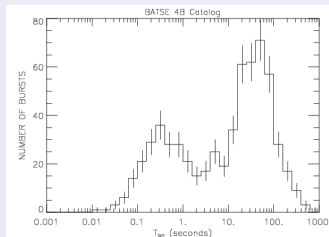
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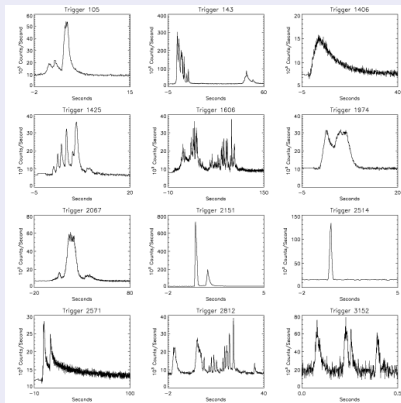
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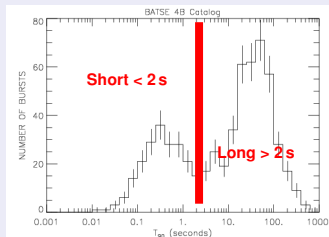
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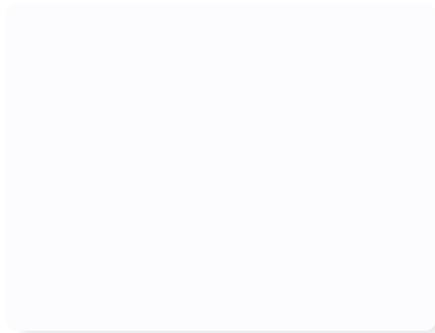
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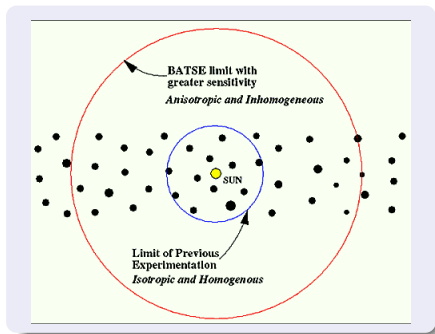
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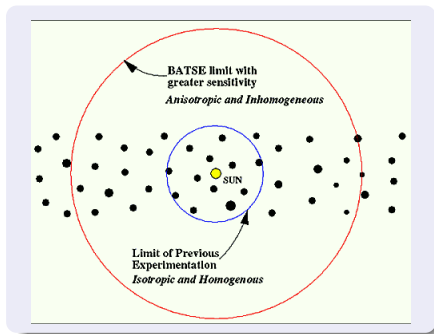
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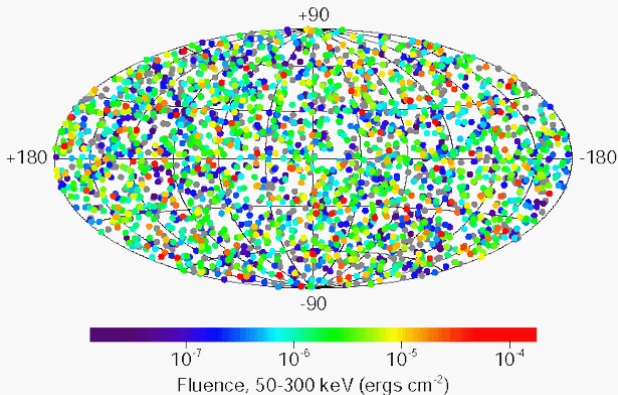
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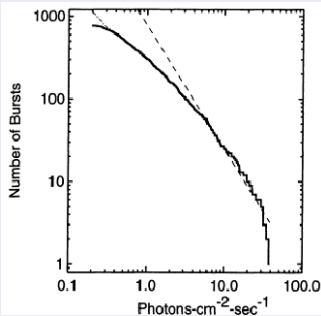
# BATSE sky

## 2704 BATSE Gamma-Ray Bursts





# Luminosity distribution



## Deficit at low luminosity

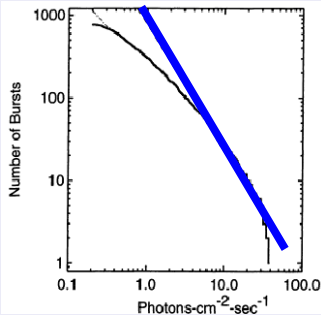
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- GRBs are isotropes
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Need to measure the distance to GRBs

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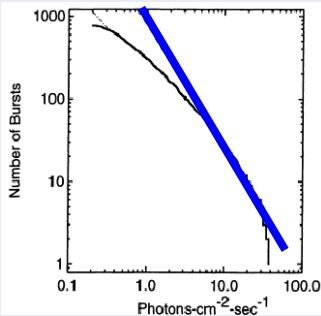
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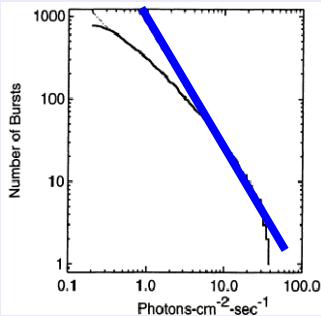
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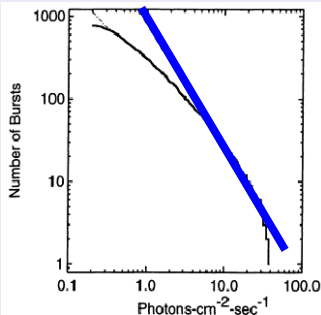
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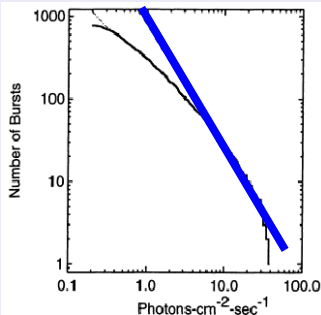
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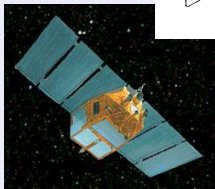
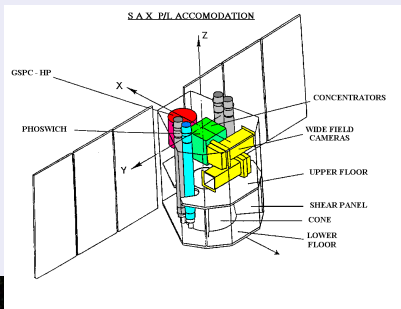
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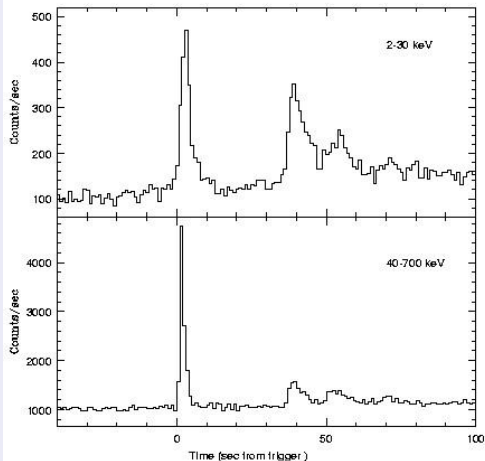
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# Beppo-SAX - 1996-2002



- GRB 40-700 keV monitor
- Various X-rays detectors
- Angular resolution: 50"

# GRB 970228



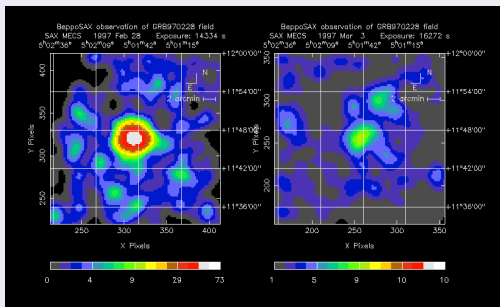
First coincidence  
Gamma - X

First afterglow,  
various days

Observation with  
other telescopes



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28 February

3 March

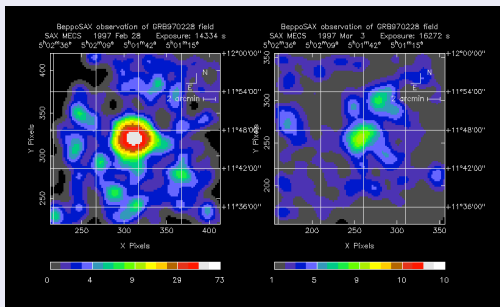
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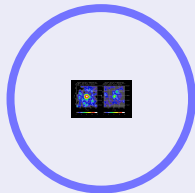


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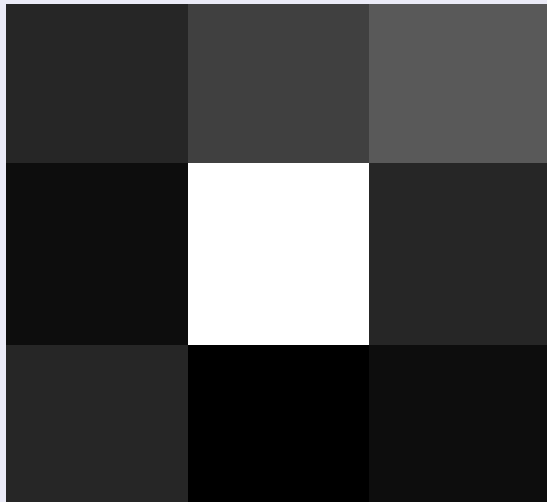


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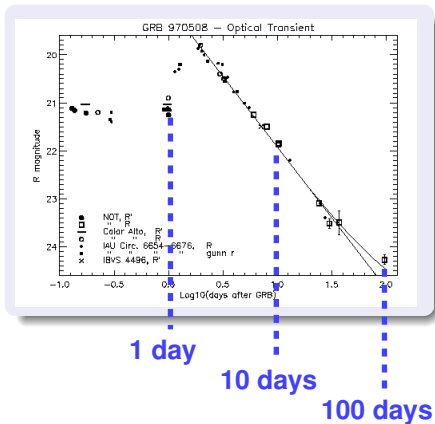


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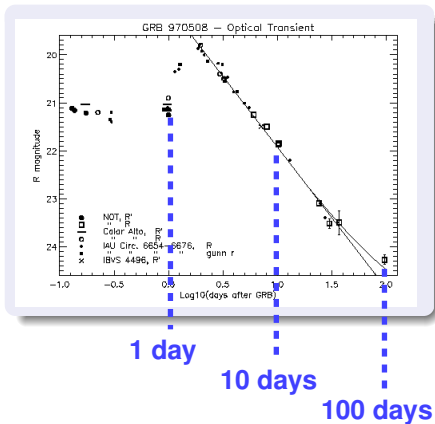


Observation of absorption lines  
in the optical spectrum of the  
afterglow

Redshift:  $Z \approx 0.84$

Cosmological origin

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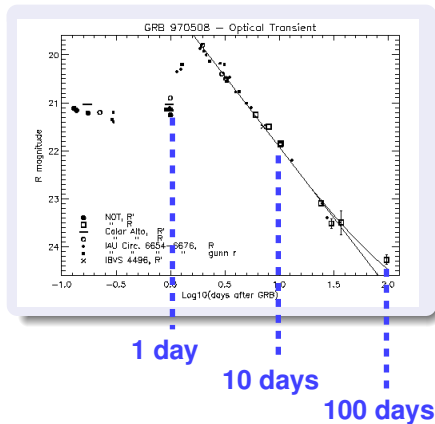


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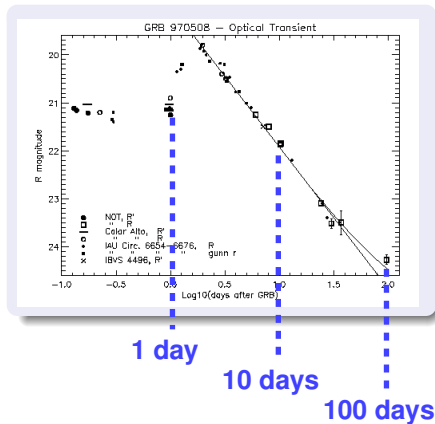
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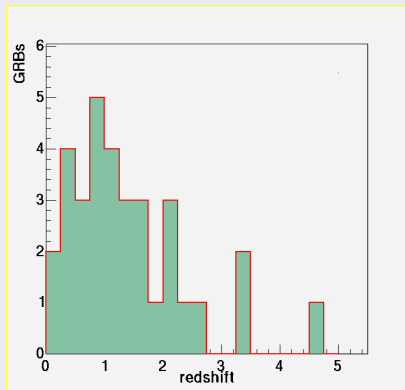


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Typically  $10^{51}$ - $10^{54}$  erg

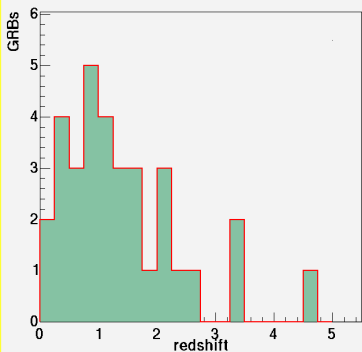
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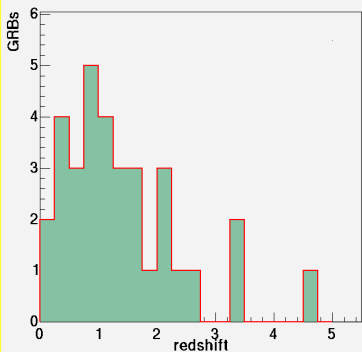
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## Long GRBs

- happen in star formation zone
- likely to be core-collapse of massive stars
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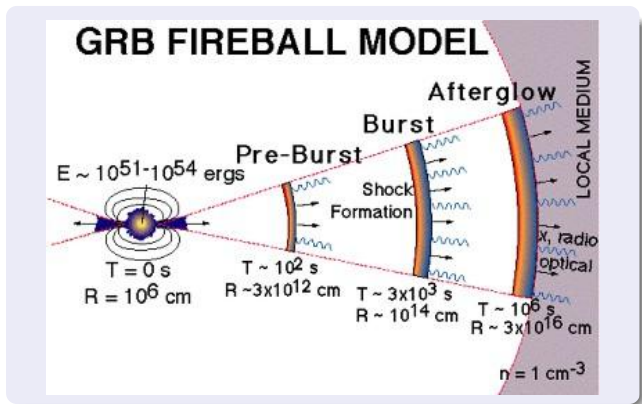
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# The Fireball model





## Near Future: towards higher energies

### EGRET

- detected 16 GRBs
- spectrum with a power law of about  $\approx 2.2$
- 3 GRBs with photons of  $E_\gamma > 1 \text{ GeV}$
- maximum energy 18 GeV

Observation at higher energy could help

GLAST (June 12 2008) should give the answer  
Fermi Gamma-Ray Space Telescope

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No background

Flux limited

## Ground based experiments

Huge background

Can get large collection surface

Atmosphere effect:

absorbs low energy

multiplies high energy

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## Example of Ground based capabilities

Chacaltaya

5200 m a.s.l.

Background about 8 kHz/m<sup>2</sup>

$\sqrt{\text{background}} \approx 90 \text{ Hz}$

1 s burst  $8 \sigma$  is about 720 particles

One 100 GeV photon produces about 1000 particles at ground level at 5200 m a.s.l.

A fluence of 1 particle per m<sup>2</sup> at 100 GeV can be seen from the ground

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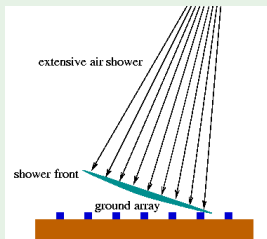
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## A different use of a ground array

### Normal mode (shower)



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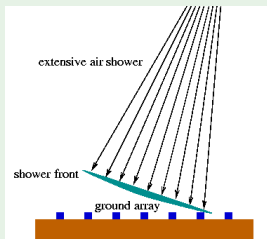
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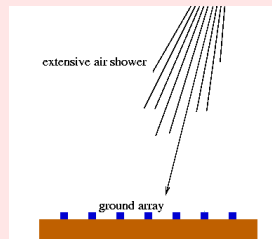
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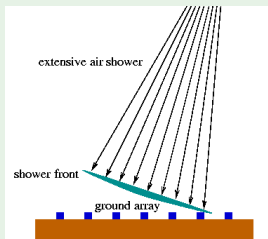
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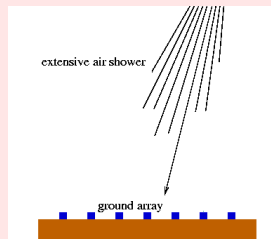
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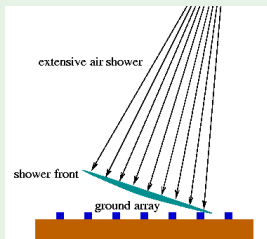
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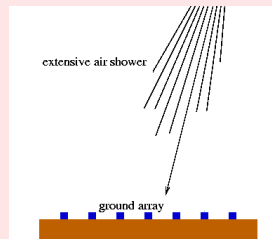
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## What reaches ground

- Photons (90%)
- Electrons (9%)
- Muons (<1%)

## Scintillator

- NO
- YES
- YES

## WCD

- YES
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If a GRB emits at high energies ( $> 1$  GeV),  
HE photon flux is expected at the top of the atmosphere,  
Secondary photon flux is expected to increase during the burst

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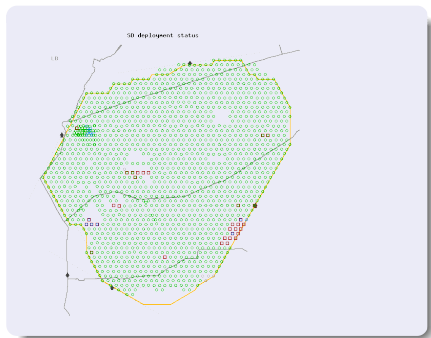
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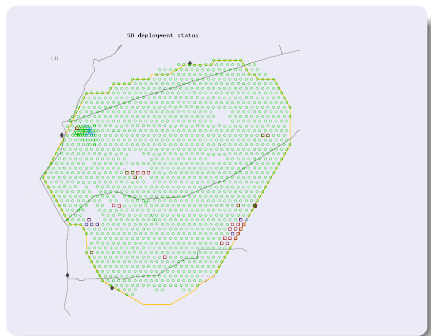


- Located in Malargüe, Mendoza, at 1400 m asl
- 1600 Water Cherenkov Detectors in operation
- (fluorescence telescopes)

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Low ( $3 \text{ ADC} \approx 6 \text{ pe} \approx 15 \text{ MeV}$ ) scaler count,  
Muon ( $20 \text{ ADC} \approx 100 \text{ MeV}$ ) scaler count,  
Send to central DAQ difference of both every second

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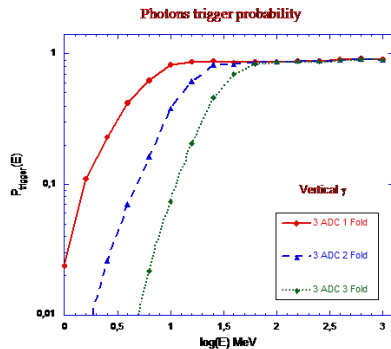
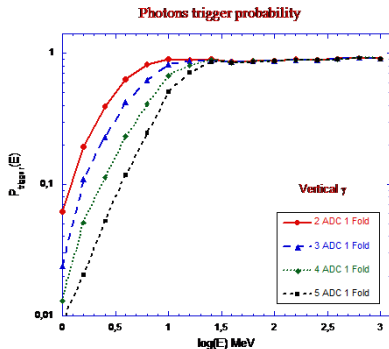
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# Simulation of Auger WCD Response

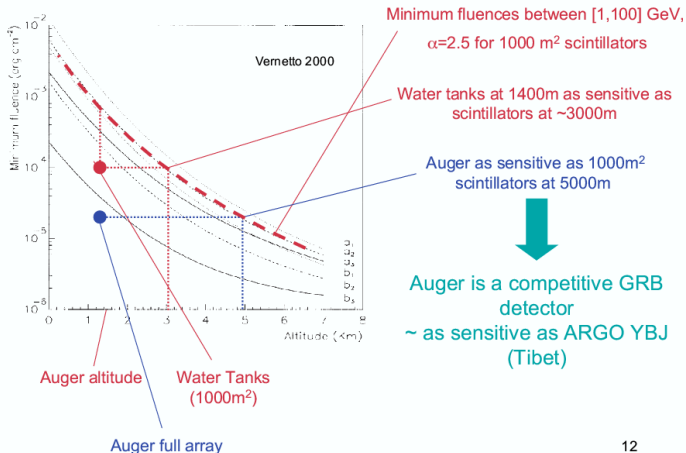
1.4 billion showers simulated with CORSIKA (no thinning)  
between 10 MeV and 10 TeV, 0 and 30 degrees  
Detector response with G4FastSim (Auger fast version of G4)





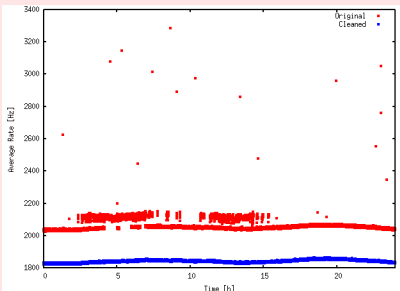
# Comparison of Auger Response with Scintillator array

## Comparison with other detectors



# Auger Scaler data analysis

## Basic Cleaning

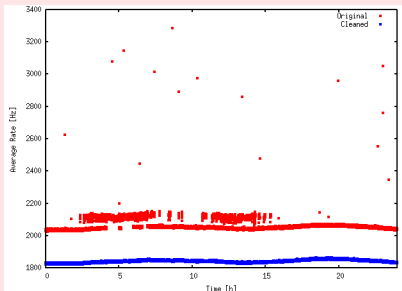


- 300 tanks minimum
- min 500 Hz
- keep 95% median tanks

## Array cut

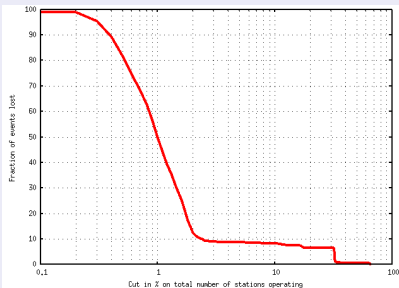
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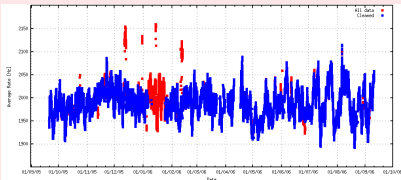
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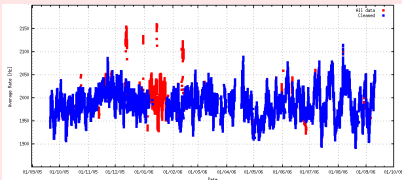
## Yearly rates



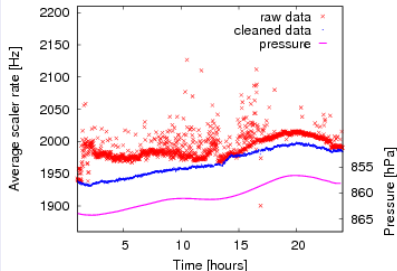
## Pressure Effect

# Auger Scaler data analysis

## Yearly rates

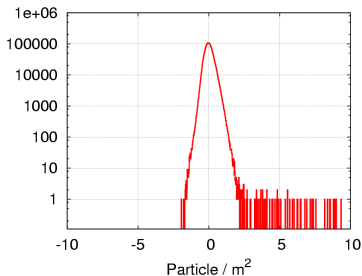


## Pressure Effect



# Auger Data

## Scalers since September 2005



Sensitivity  $\approx 2$  particles/m<sup>2</sup>

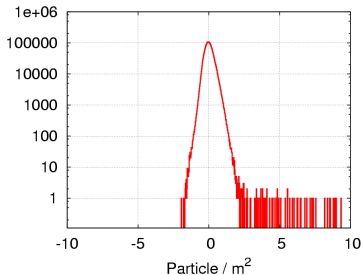
Rate vs Time

Rate vs Station Id

Only Lightning Events

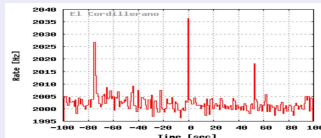
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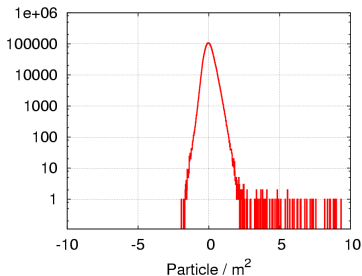


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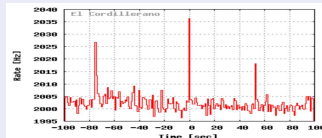
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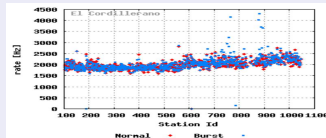


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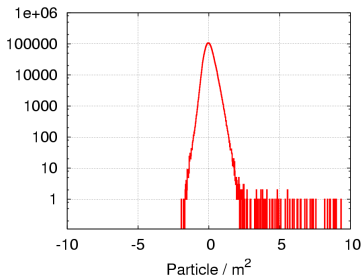


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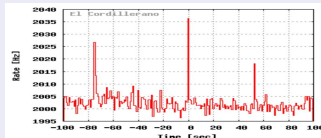
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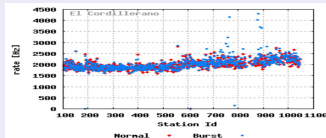


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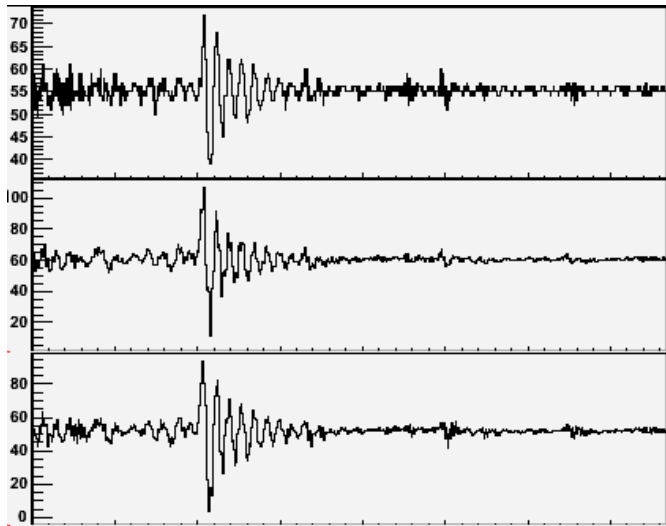


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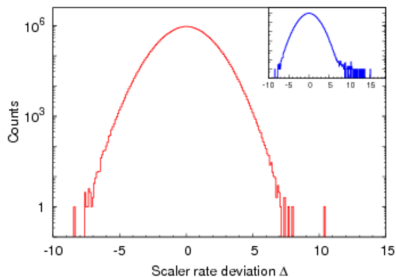


Only Lightning Events

# Lightning in Auger

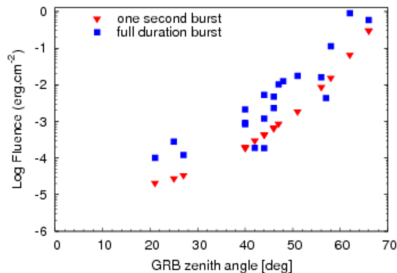
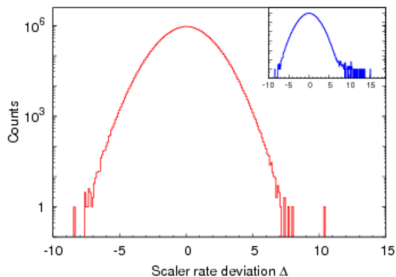


## Auger Results for 18 months of data (March 2007)



No GRB detected: limit on GRB high energy fluence

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# LAGO

## LAGO

### Large Aperture GRB Observatory

#### Idea

Detect GRB at high energy from the ground

#### Who?

Argentina

Bolivia

Mexico

Venezuela

+ France, Italy, Peru

#### How?

Using WCD:

- Easy to calibrate
- Detect Photons

#### Where?

In high altitude  
mountain sites  
( $> 4500$  m)

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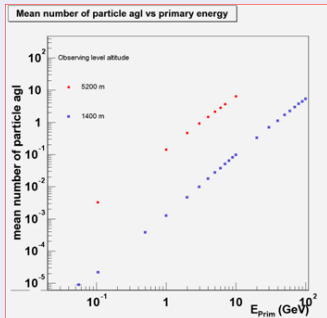
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# Why going in altitude

## Particles at ground level



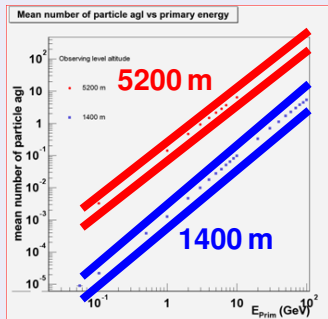
At 5200 m

- 100 × more signal
- 8 × more noise
- $S/\sqrt{N} \approx 35 \approx \sqrt{1600}$

1 detector at 5200 m  $\approx$  1600 Auger detectors at 1400 m

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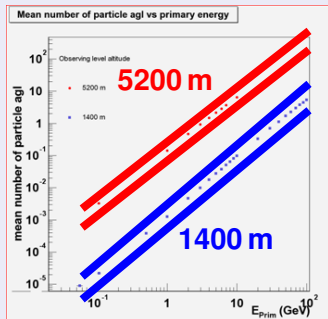
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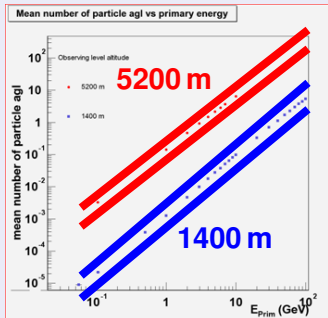
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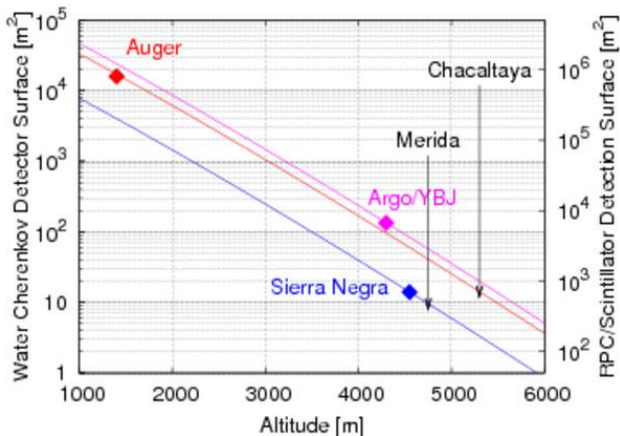


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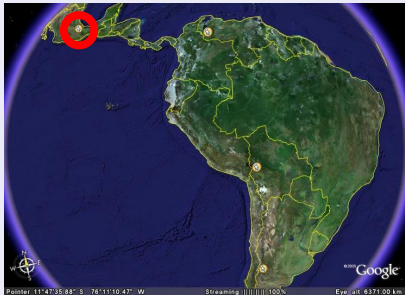
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# Sensitivity vs Altitude and Size



## LAGO Sites



### Various sites

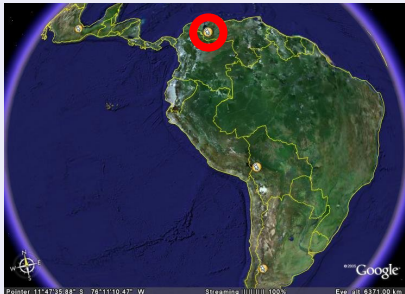
- Sierra Negra, Mexico
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Detection in coincidence

$$\Delta\Omega_{[Auger, Chacaltaya]} \approx 15^\circ$$

Other sites in Argentina and/or Peru?

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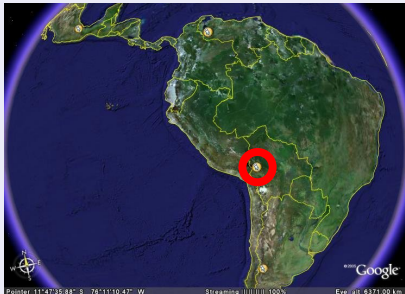
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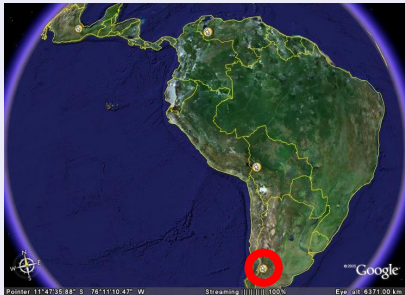
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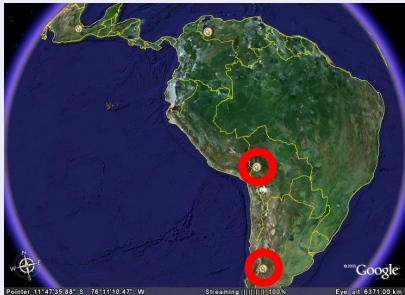
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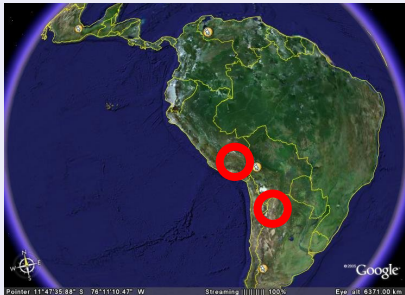
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# Pictures

Chacaltaya - 5300 m asl



Sierra Negra - 4600 m asl



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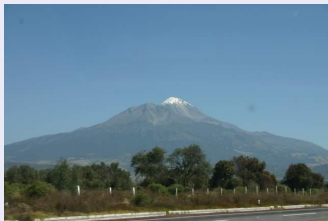
Chacaltaya - 5300 m asl



Sierra Negra - 4600 m asl



## Pictures II: Sierra Negra





# Prototype Detectors

## Prototypes for Chacaltaya

- Old prototype equipment from Auger (EA):
  - Electronics
  - PMTs
- Commercial water tanks:
  - 1 PMT per tank
  - 6 tanks per electronic
- Software rewritten:
  - 4 scalers per PMT
  - 5 ms time sampling

Low cost

## La Paz prototype

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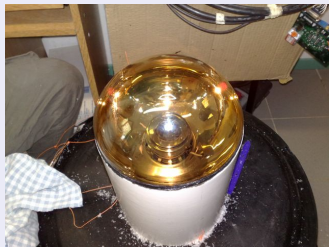
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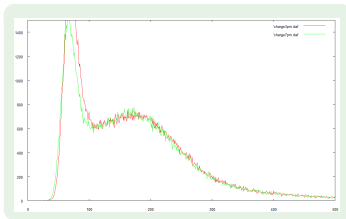
## La Paz prototype



## Building Bariloche prototype: Nahuelito



## Last built prototype: Mérida, Venezuela



## Going up to Pico Espejo



X. Bertou



The LAGO project



# Current Status

## Bariloche

Running 1 m<sup>2</sup> prototype detector

## Chacaltaya

Running 1 m<sup>2</sup> detector at 5200 m  
Two 3.8 m<sup>2</sup> in calibration stage

## Mérida

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## Sierra Negra

14 m<sup>2</sup> with running DAQ

- 2 × 1 m<sup>2</sup> detectors
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More than 6 months of  
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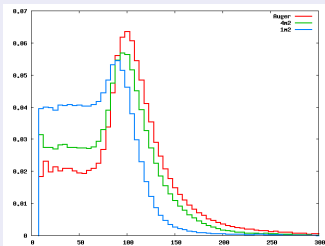
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Broken since mid august

# Issues - Theory

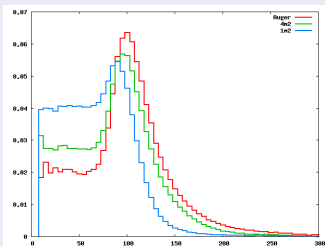
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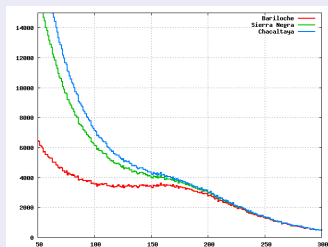
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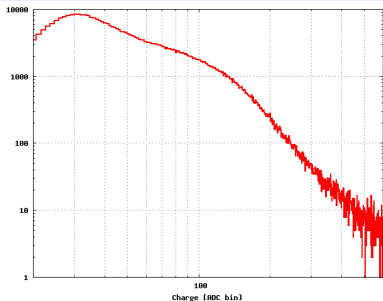


## High background flux



## Issues - Real data

### Calibration at high altitude



Use muon "shoulder"  
No muon decay

### Light leaks

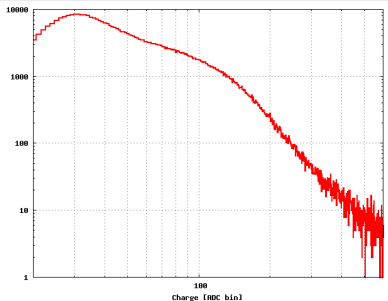
### Lightning

Use one scaler below baseline  
or one unconnected channel



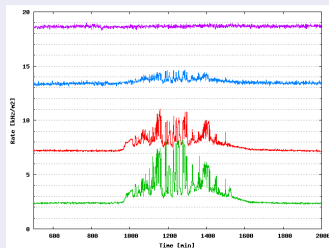
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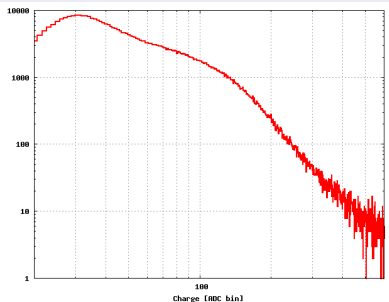


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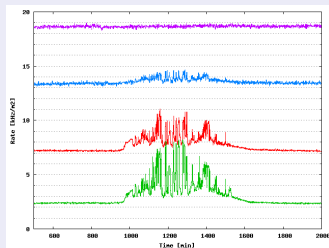
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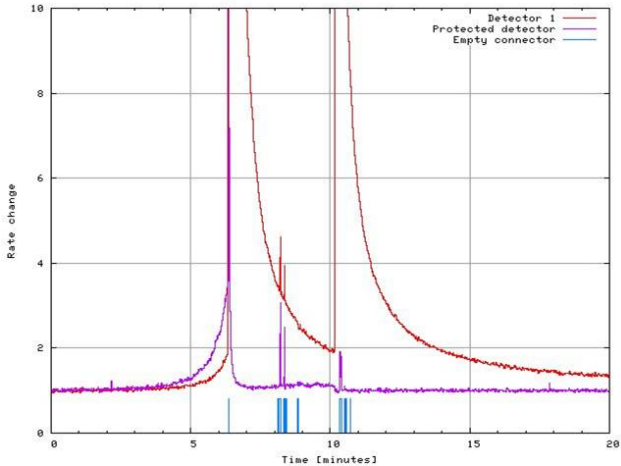
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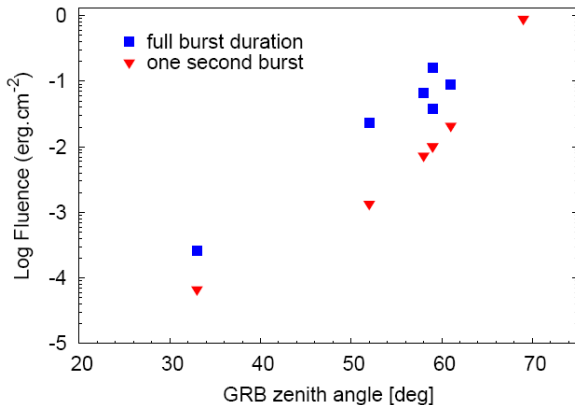
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## Results for SN site (October 2007)

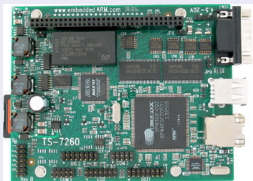


# LAGO Improvements

## Sierra Negra: Stability

DAQ PC replaced by SBC:

- 200 MHz ARM, 32 MB
- Debian Linux
- 3 COM ports, 2 USB, 10/100 eth
- < 1 W



## New sites

- higher gain PMT (SPE)
- wavelength shifter (Amino-G)
- higher altitude
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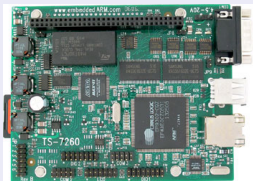
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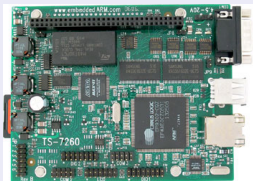
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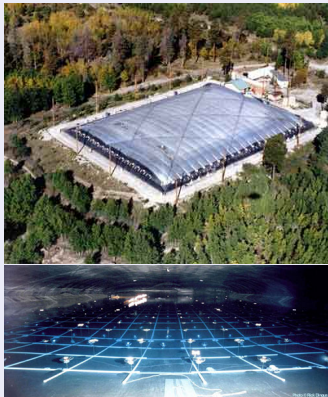
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### Milagro goes to Sierra Negra



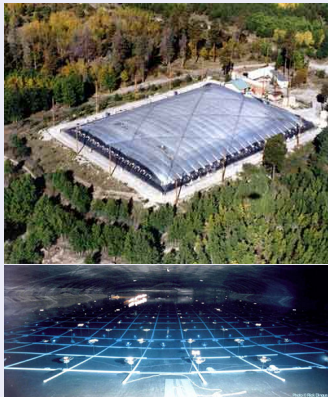
Need for an HAWC Sur?  
*(Galactic Center)*

Other detection technique:  
Fluorescence?  
*Auger, Sierra Negra*



## Further steps

### Milagro goes to Sierra Negra

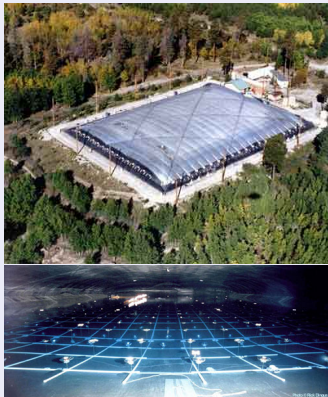


Need for an HAWC Sur?  
*(Galactic Center)*

Other detection technique:  
Fluorescence?  
*Auger, Sierra Negra*

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## Conclusion

GRBs are no longer such a mystery  
Waiting for information at high energies (low fluxes)

WCD are very efficient to detect GRB from the ground

Auger is competitive with dedicated ground based experiments

An efficient dedicated experiment can be done  
at low cost by using WCD at high altitude

Good expectation to observe high energy component of GRBs  
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*Pico Espejo, Venezuela, 4750 m a.s.l.*

*Thank You !!!*



*Sierra Negra, Mexico, 4650 m a.s.l.*