R&D for the EASIER experiment

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Outline

- The EASIER project
- The prototype detector
- Noise measurements
- Expected signal
- Future plans

The collaboration:

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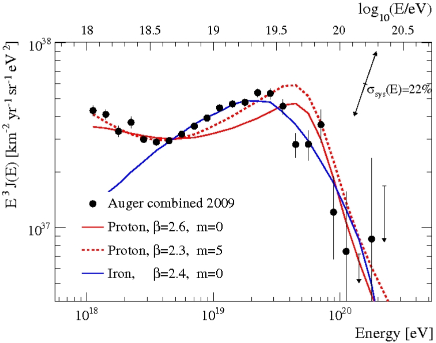
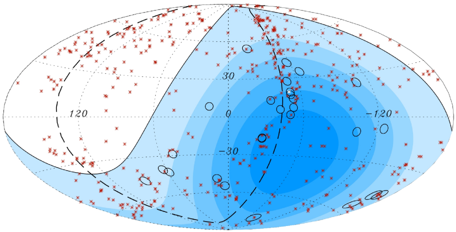
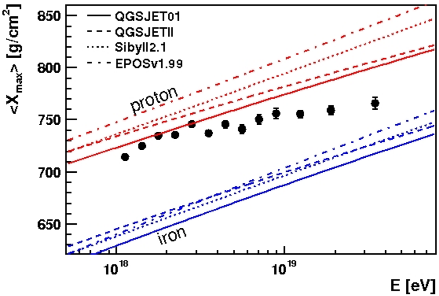
Institutions:

CAB, LPNHE, IPNO, LPSC, UFRJ

Auger results



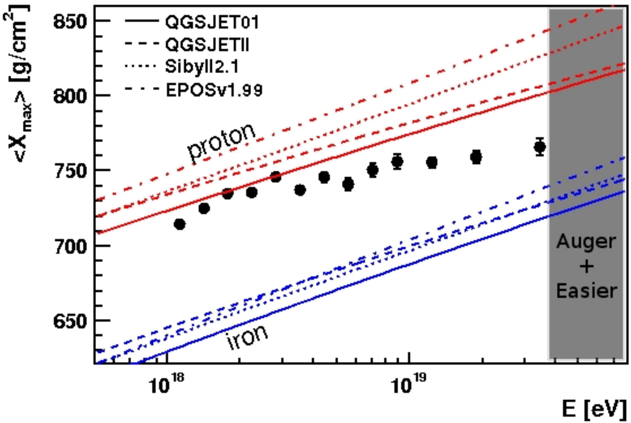




- GZK: mass composition important
- $< X_{max} >$: composition shows a trend towards heavy nuclei
- Data up to March 2009: 38% correlate

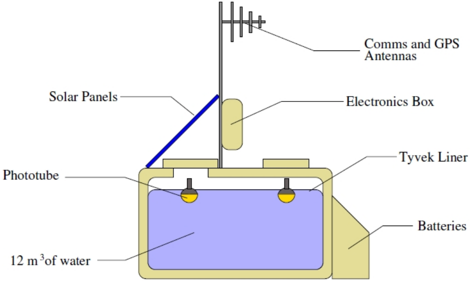
EASIER's goal

- Improve particle indentification of UHECR
- Measure UHECR composition at higher energies
- Measure hadronic cross section at higher energies
- Constraints and parametrization of interaction models



The detector

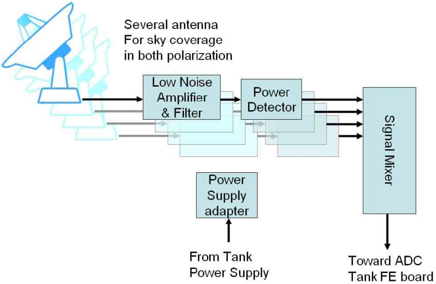
Extensive Air Shower Identification using Electron Radiometer

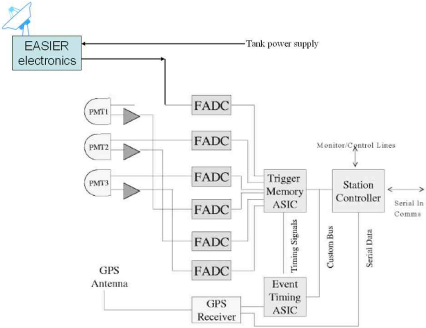


- Integrated radio receiver
- EM component of the shower
- Power trace
- Local DAQ

Detection principle

- Detection of radio emission of the EM cascade
- Two possible bands: VHF (10-100 MHz) and MW (1-10 GHz)
- Trigger and timing via tank DAQ





- Signal proportional to the EM energy
- Time shape related to the cascade evolution and X_{max}
- Muonic signal in the tank by substraction

$\approx$ 100% duty cycle telescope with the coverage of a surface detector, integrated in the array

Radio physics

Signal: geosynchrotron radiation

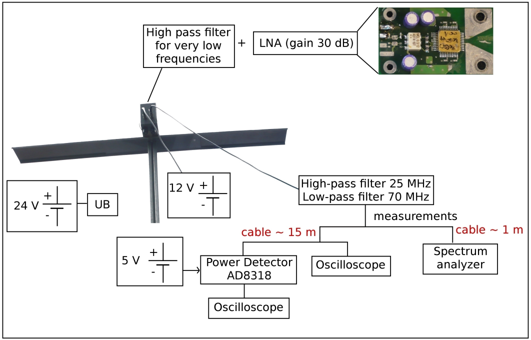
$$\mathbf{E}\,[\mu\mathrm{V/m}] = 178\frac{E_0}{10^{17}\,\mathrm{eV}}(-\mathbf{v}\times\mathbf{B})\cos\theta\exp\left(\frac{-d}{D_0(\theta)}\right)$$

State of art in the detection:

- Collimated radiation
- Main experiments: LOPES, CODALEMA, AERA
- Large areas at low cost
- Problems in trigger setup
- Actual detectors few hundred meters apart

External trigger can overcome these difficulties

Plan of noise measurements

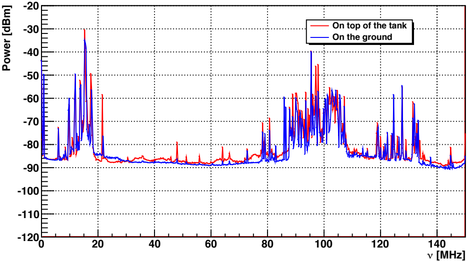


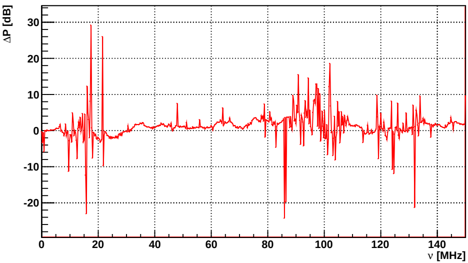
Measurements taken in Orsay (Paris) at the Auger prototype tank:

- Environmental noise
- Constant noise from the tank electronics
- Noise from PMTs signal

Environmental noise

Measurements with the antenna in different positions

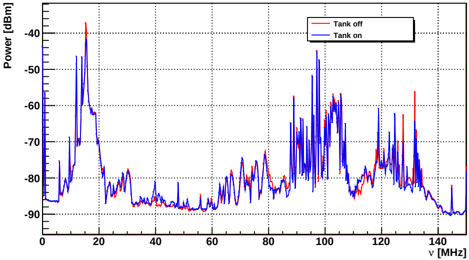




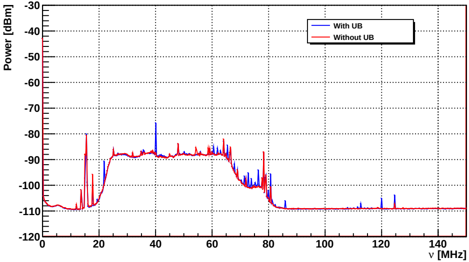
- Noise level on top of the tank: -128 dBm/Hz
- Difference between the spectra: (1.17 ± 0.17) dB

Antenna lobes not influenced by the position with respect to the tank

Constant noise from the tank



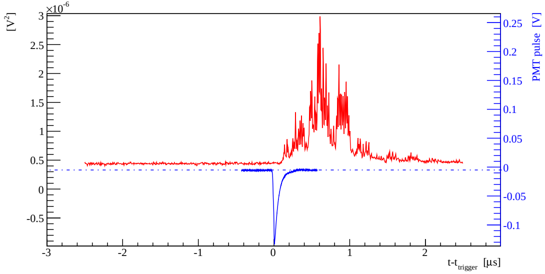
- No emission visible from the PMTs



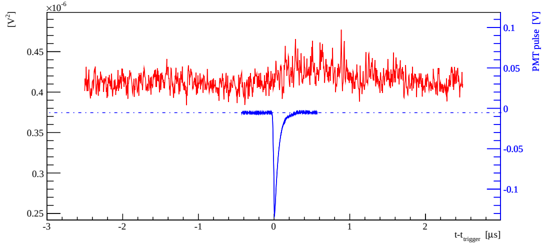
- Noise at 40 MHz from the UB

Noise from PMTs

Antenna next to PMT



Antenna on top of the tank



- 2000 traces averaged
- Baseline: averaging before the trigger
- Peak: considering 1 μs and 100 ns sliding windows
- Evaluating the correspondig electric field

Antenna on top of the tank is a good configuration

Noise from PMTs for 1 μs window: 0.19 dB

Noise from PMTs for 100 ns window: 0.28 dB

Noise from PMTs

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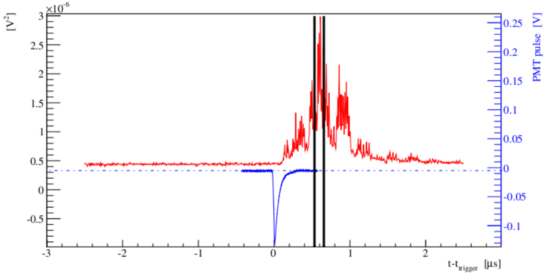

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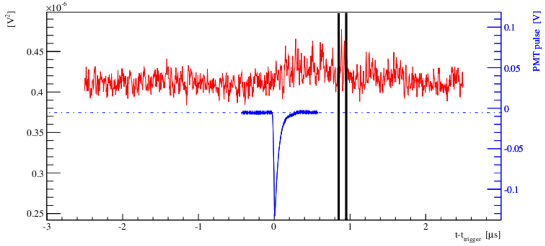

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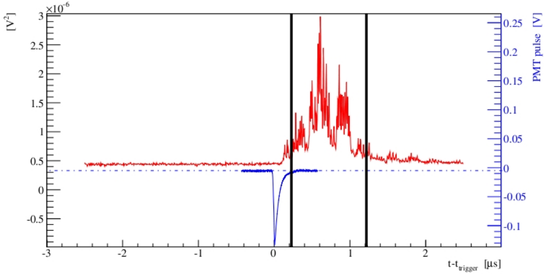

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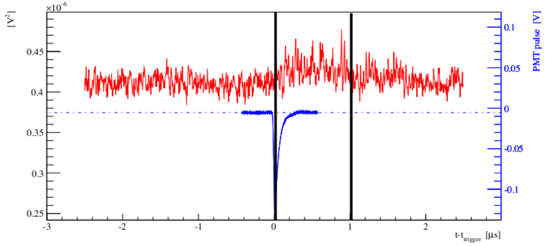

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Sensitivity

Chosen configuration: antenna on top of the tank

- Distribution of the average power measured in a chosen time window for 2000 traces
- The sensitivity is the variance of the distribution
- Two parameters computed for two windows: 1 μs and 100 ns

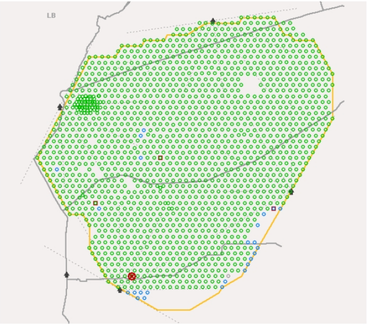
Measurement	σ_W [nW]	σ_E [μV/M]
1 μs baseline	1.50	3.90
100 ns baseline	3.48	9.07
1 μs peak	1.71	4.36
100 ns peak	3.73	9.39

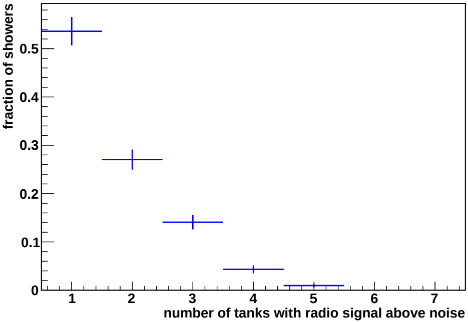
Worst case: signal around the peak within a 100 ns window
$\Rightarrow$ 1.45 $\mu\mathrm{V/m/MHz}$

Expected trigger rate

Event number expected in the Vieira hexagon:

- SD events from May to August 2010
- Corresponding electric field higher than sensitivity

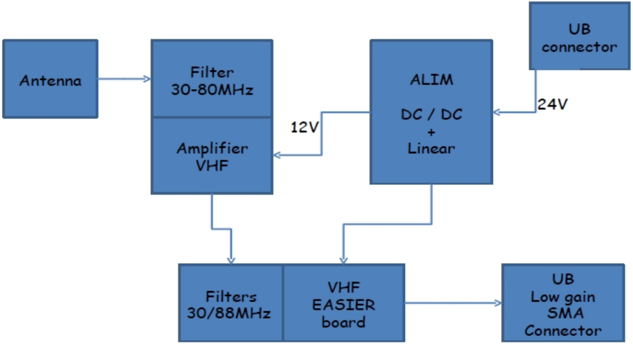


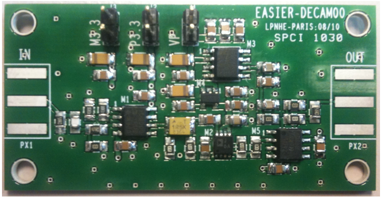


5 events/day in our hexagone

VHF setup: acquisition chain

FAT dipole antenna, LNA (CODALEMA) + EASIER board + Auger UB





- Filters (30-88 MHz)
- Power detector (AD8310)
- Inverter

The Molecular Bremsstralhung Radiation

Gorham et al. "Observation of microwave continuum emission from air shower plasmas", Phys.Rev.D78,2008.

- EAS particles dissipate their energy through ionization
- A plasma of $T_e \simeq 10^{4-5}\,\mathrm{K}$ is created
  - Secondary electrons excite $N_2 \Rightarrow$ fluorescence radiation
  - Secondary electrons themselves produce their own emission like bremsstralhung in field of neutral molecules: EMISSION IN THE MICROWAVE RANGE

Characteristics:

- Isotropic radiation $\Rightarrow$ FD like detector
- Around 100% duty cycle
- Minimal atmospheric attenuation (even with clouds and rain)

State of art:

- Observed in laboratory at accelerator experiment
- Never observed in field
- Main experiments: AMBER, MIDAS, CROME

Slave trigger helps improving problem of detectability due to SNR

Scaling to air showers

Expected intensity:

$$I_{exp} = I_{lab} \cdot \Gamma \cdot \rho \left(\frac{d}{R} \right)^2$$

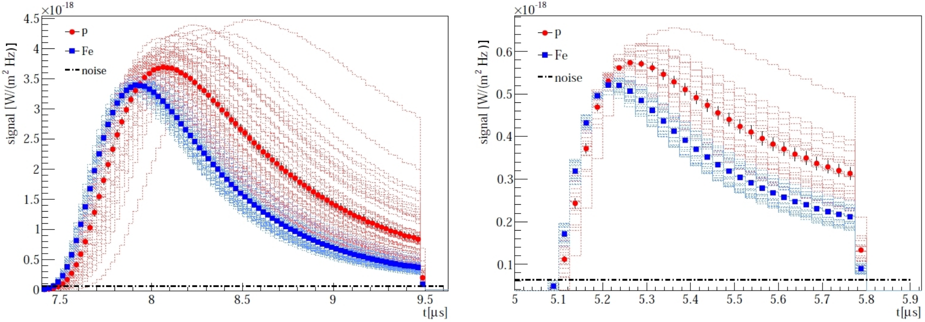
- $I_{lab} = 4 \cdot 10^{-16}\,\mathrm{W/m^2/Hz}$, reference shower: 0.34 EeV
- R distance to the observed axis
- ρ ratio of electron density at a shower altitude to sea level electron density in reference shower
- Γ time scaling factor, ratio of a trial shower lenght per e-folding time to observed reference shower lenght
- Yield $=2 \cdot 10^{-18}\,\mathrm{W/m^2/Hz}$

Gorham et al., Table 2

Signal calculation

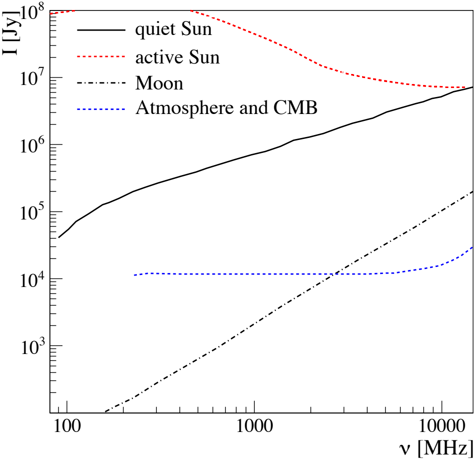
Scaling of the accelerator data from the Gorham paper taking into account the shower development and antenna FOV. Expected intensity:

- Coherent emission $I \propto N_e^2$
- Uncoherent emission $I \propto N_e$



Traces expected at 900 m, for $\theta = 38\,^{\mathrm{o}}$

Noise



Sun contribution (4 GHz)

$$W_{activesun} = 1.4 \cdot 10^{-19} \frac{\mathrm{W}}{\mathrm{m^2 Hz}}$$

Other contributions (overestimated)

$$W_{other} = 1 \cdot 10^{-20} \frac{\mathrm{W}}{\mathrm{m^2 Hz}}$$

$$P = A_{eff} \left(W_{other} + \frac{\Omega_{Sun}}{\Omega_A} W_{Sun} \right) \Delta f + k_B T_A \Delta f$$

Antenna temperature is an important parameter

Experimental setup


GLOBAL SATELLITE
WS International
DISTRIBUTION

Digital Ready Expanded C Band LNBF

Input Frequency:	3.4-4.2GHz
Output Frequency:	950-1750MHz
Noise Figure:	13K
Gain:	70dB
Polarity:	1 (Hor or Ver)
LO Frequency:	5150MHz
Image Rejection	45dB Min
Switch Voltage	
Vertical:	14V DC
Horizontal:	18V DC
Output Impedance:	75Ohms
Output Connector:	F-Female

Private Label Available

Super High Gain of 70dB

WS International Global Satellite Distribution
1200 Cobb Parkway North ~ Suite 100B ~ Marietta, GA 30062-2418 USA
Tel: +770 420 5272 ~ Fax: +770 420 5350
Email: sales@wsidigital.com ~ Web: www.wsidigital.com

Commercial horn antenna DMX 242:

- 3.4 to 4.2 GHz
- output 0.95 to 1.75 GHz
- Gain 70 dB (announced)
- Temperature 13 K (announced)

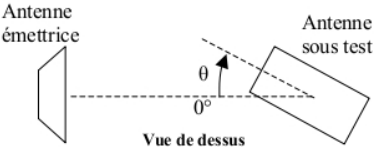
Power Detector AD8318

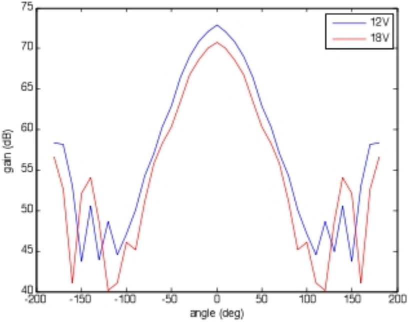
Antenna's data sheet does not exist
⇒ we have to characterize our receiver

Antenna characterization

Measurements done in anechoic chamber @ Valence

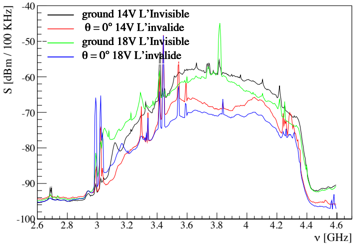
- Source at 3.4-4.18 GHz
- Theta and Phi variable

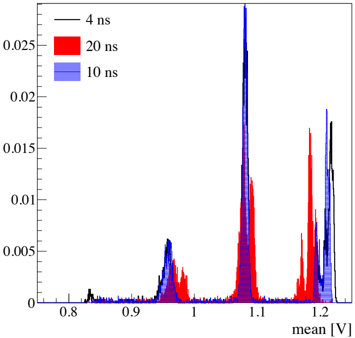




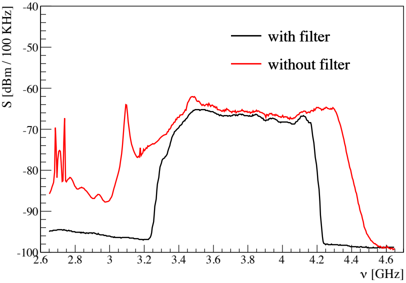
- 4.18 GHz, θ variable, $\phi = 0$
- Gain in our band
- Back lobes present $\Rightarrow$ influence on the system temperature

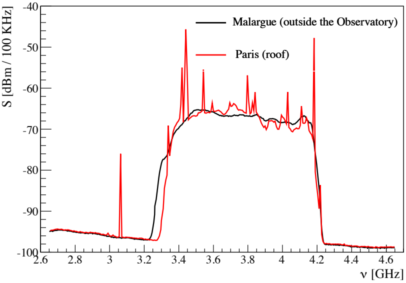
Noise measurements in Paris





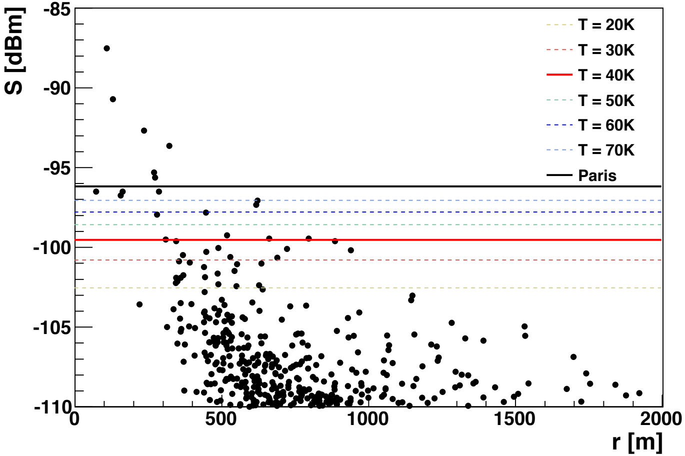
Measurements in Malargüe



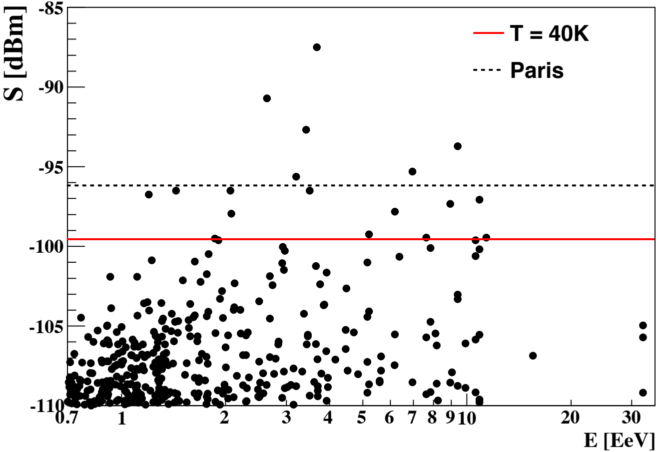


Event rate

- SD events detected in 10 months in 2010
- Maximum signal above our noise



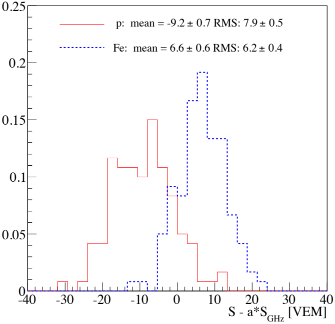
Event rate



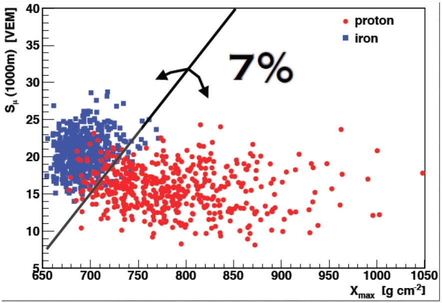
rate: 0.6 - 1.6 events/month

Analysis tools

Study of shower universality to recover the muonic signal from the electromagnetic signal detected by EASIER



S_μ by substraction of the S_{em} measured by EASIER



Anti-correlation between X_{max} and S_μ from simulated showers

Study of the recovery of muonic signal from Golden Hybrids events

Conclusions

VHF band

- Antenna chosen and tested
- Noise from the tank evaluated
- Acquisition chain tested
- Trigger rate estimated:

  5 events/day

MW band:

- Antenna chosen and tested
- Partial charaterization of the receiver done
- Acquisition chain do be validated
- Trigger rate estimated:

  2 events/month

Deployment on the first hexagone foreseen at the beginning of February!