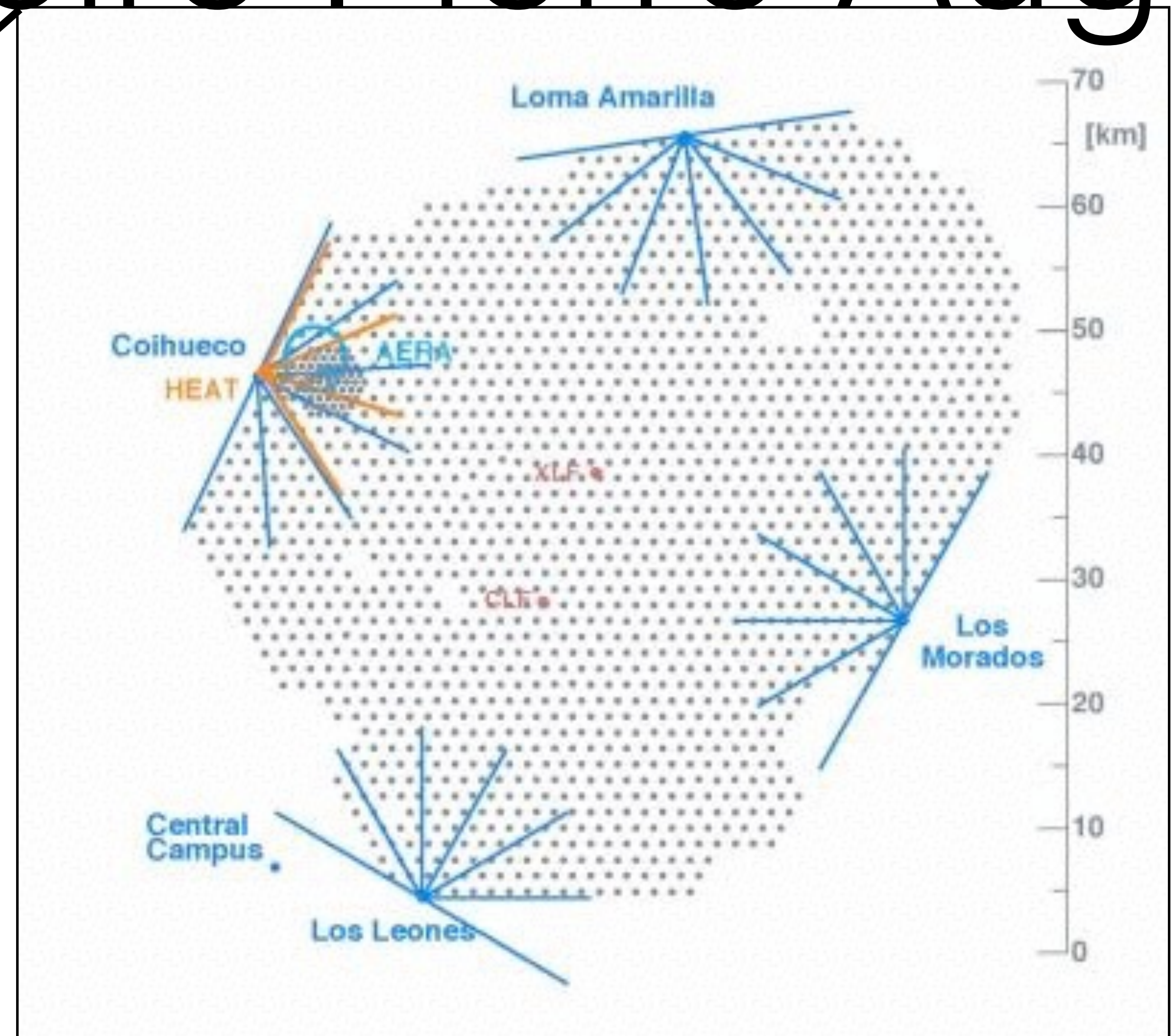
Auger & GIGAS

Bilan & Perspectives

R. Gaïor

Biennale LPNHE 2016

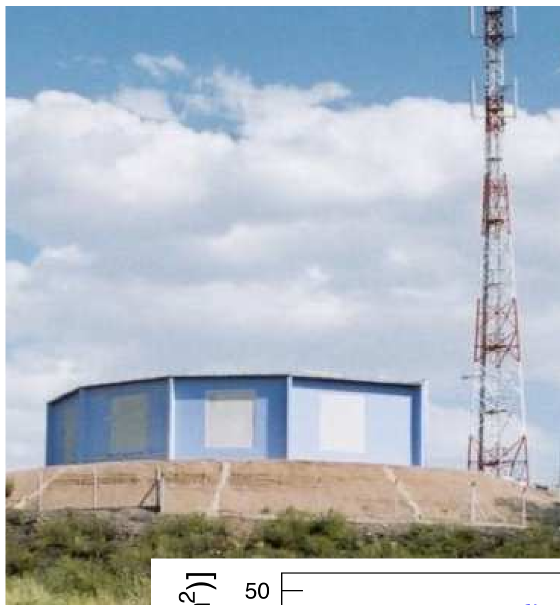
L'observatoire Pierre Auger

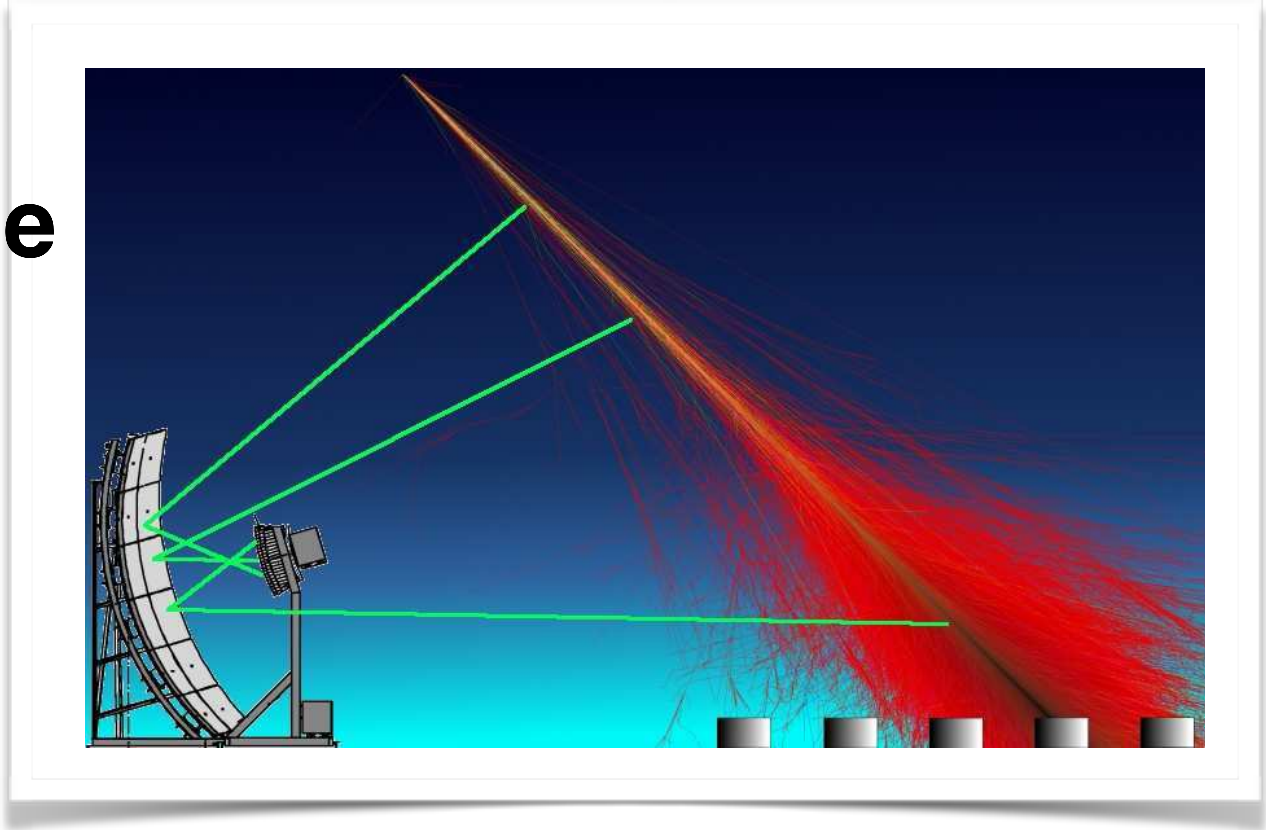


- Plus grand observatoire de RC (3000km^2)
- Design pour E > 10^{18}eV
- Detection hybride:
    - 1660 detecteurs de surface
    - 5 sites de detection de fluorescence

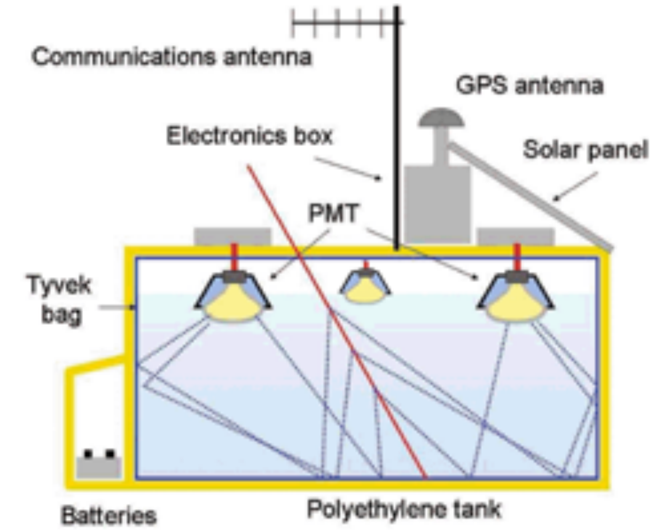
L'observatoire Pierre Auger

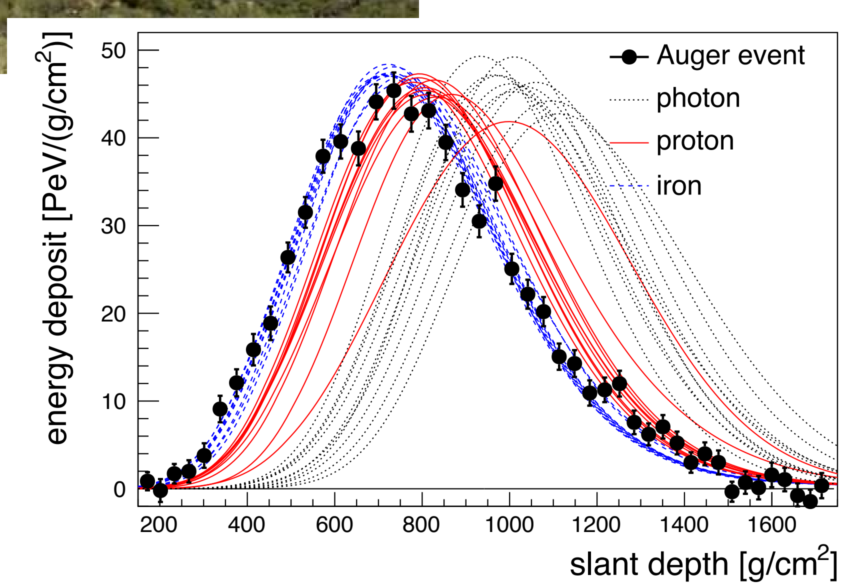
Detecteur de fluorescence

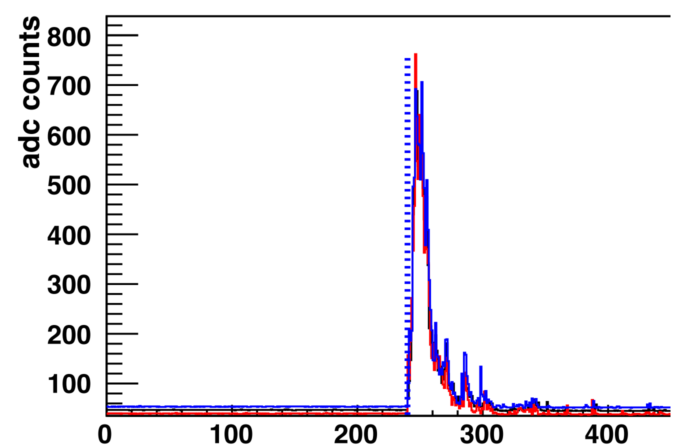


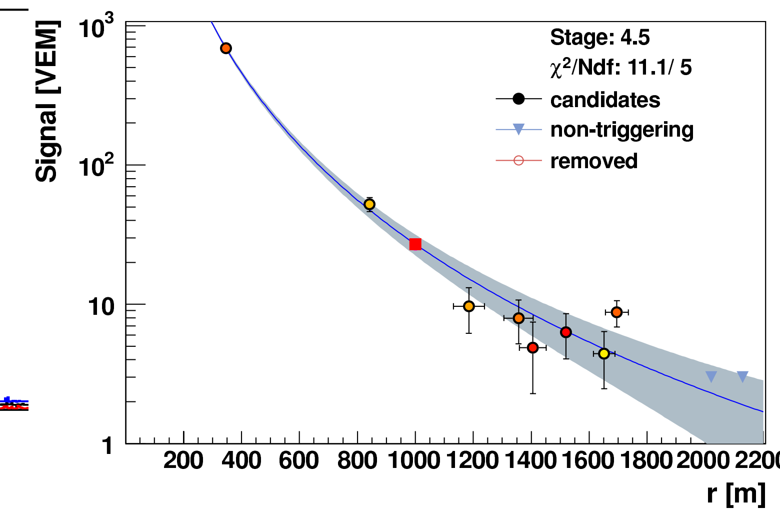


Detecteur de surface



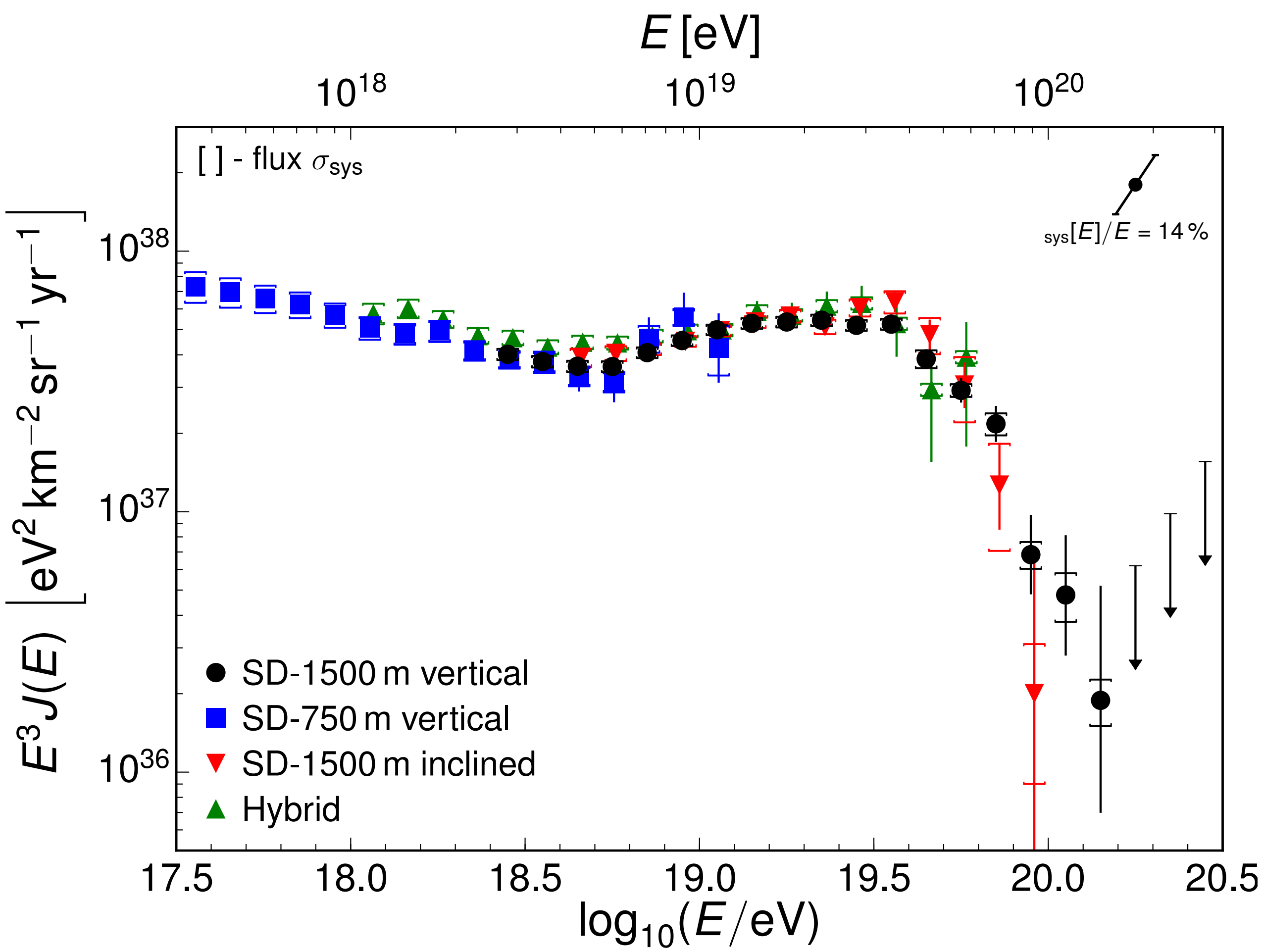


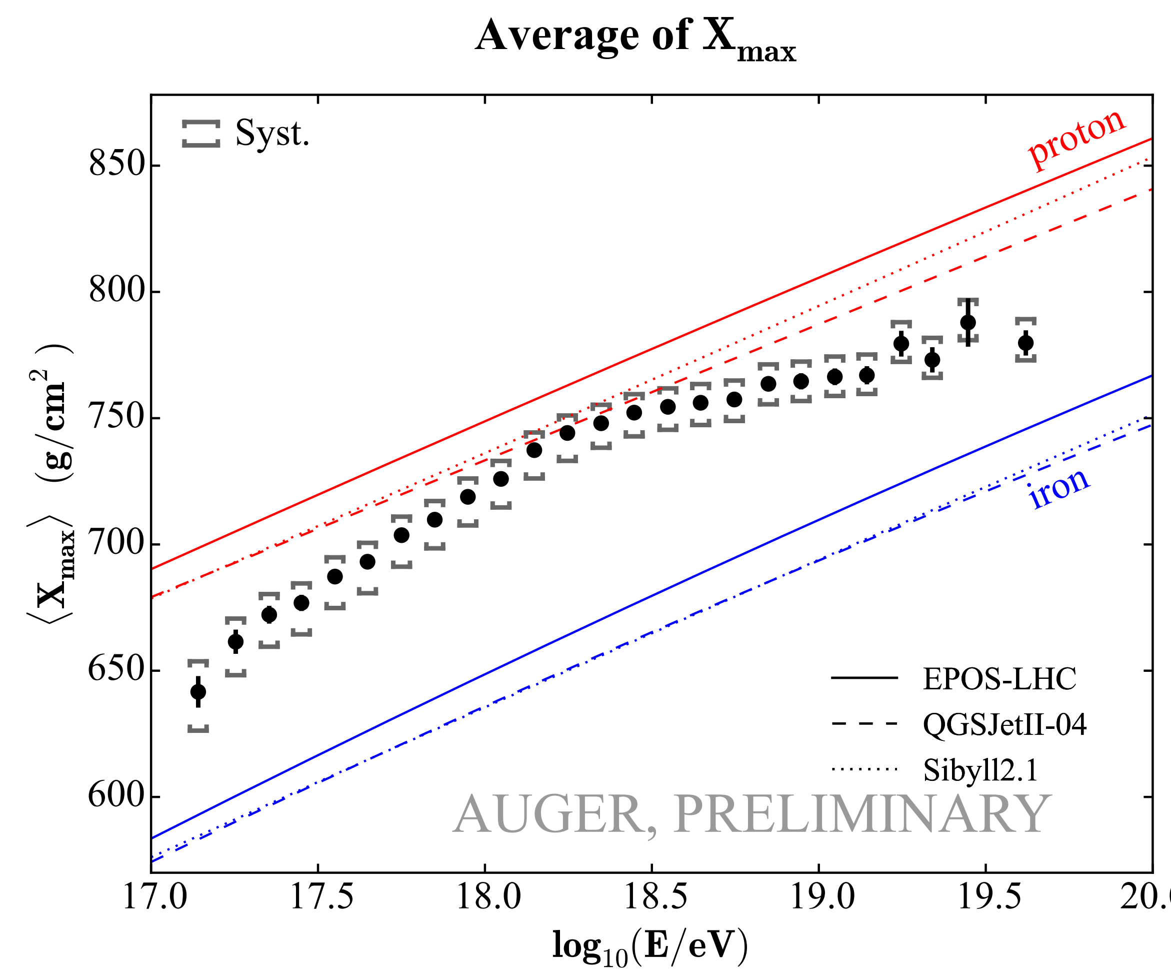




- calibration en énergie croisée (grace a la mesure calorimétrique du FD)
- FD: 13% cycle utile, SD 100%

Principaux résultats

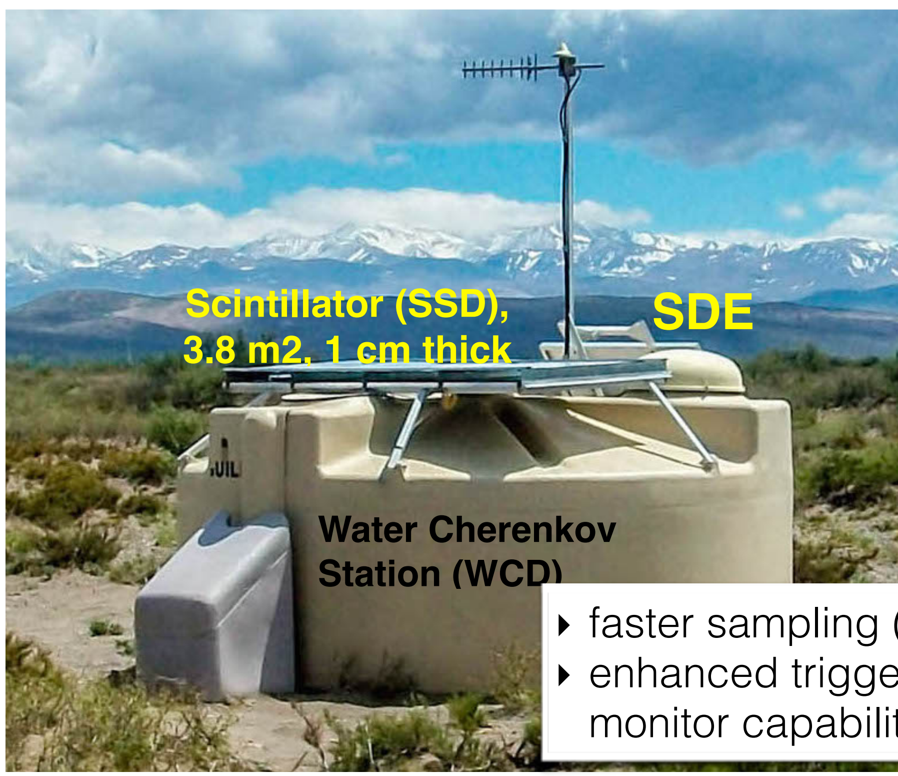




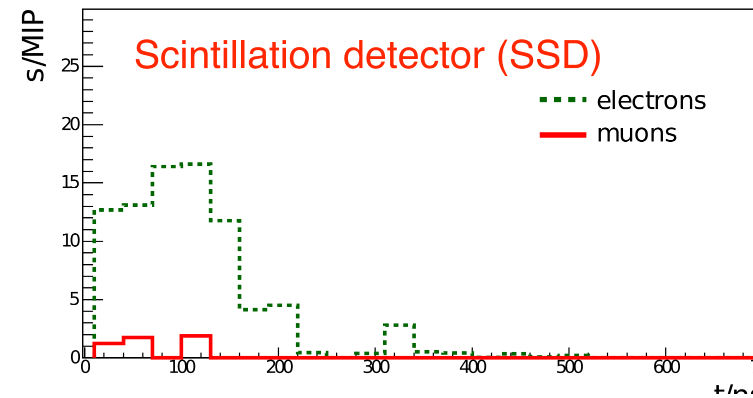
- <u>coupure du flux après $10^{19.5}$ eV</u>: GZK ou simplement plus de flux ?
- évolution dans la composition après $10^{18.5}$ eV
- forte isotropie à petite échelle

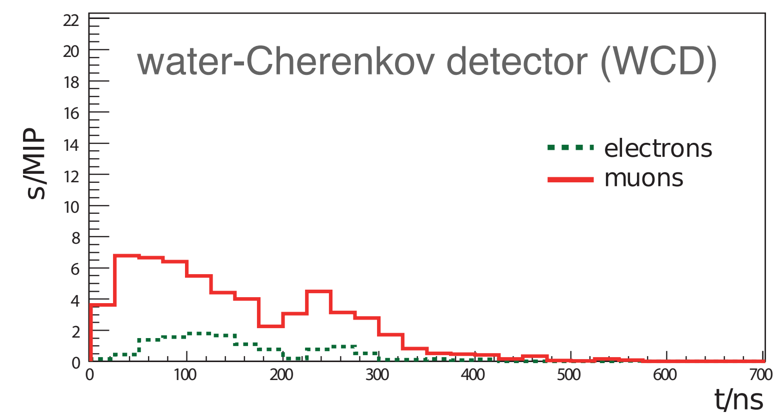
AugerPrime

- S_μ from WCD and SSD signals
- $\frac{\sigma[S_\mu(800)]}{\langle S_\mu(800)\rangle} \sim$ 15% (iron)-20% (proton)
- resolution X_{max} ~ 30 g/cm^2



- faster sampling (120 MHz)
- enhanced trigger and monitor capabilities





$$S_{\mu,\mathrm{WCD}} = a S_{\mathrm{WCD}} + b S_{\mathrm{SSD}}$$

Objectifs d'apres AugerPrime preliminary design report:

- Elucidate the mass composition and the origin of the flux suppression at the highest energies
- Search for a flux contribution of protons (constraint on possible HE gammas, neutrino observatory)
- Study Extensive Air Shower and hadronic interaction

Activités au LPNHE (2014-2016)

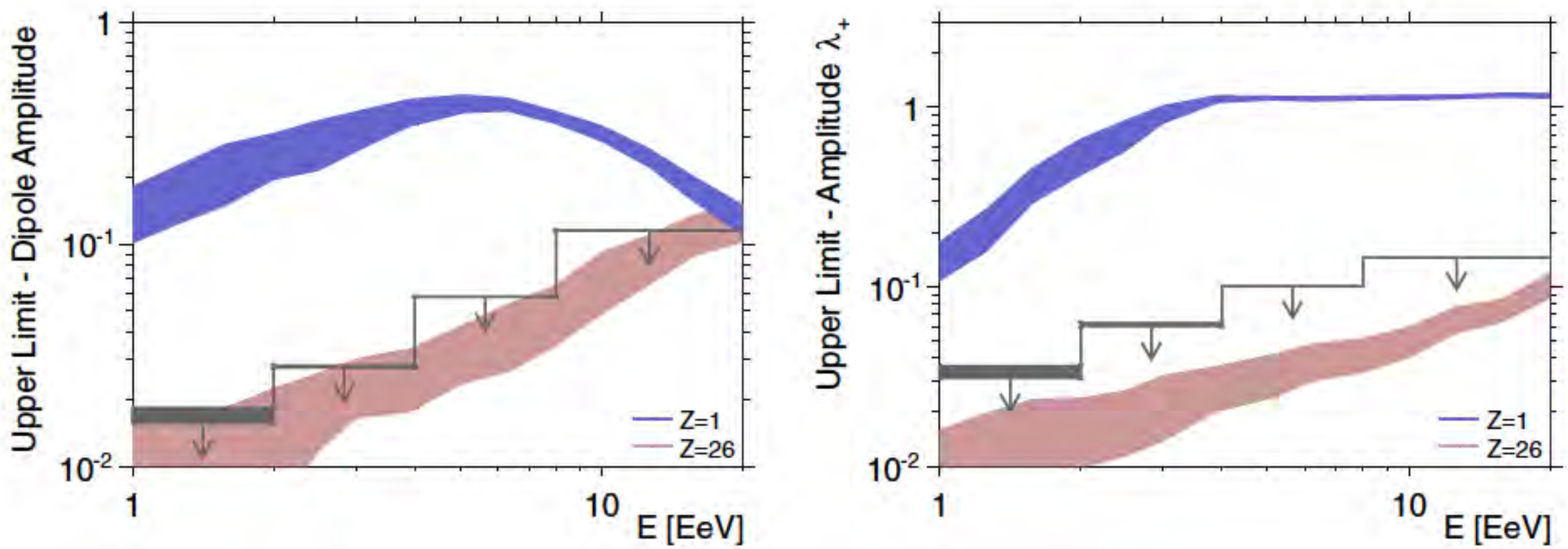
- Chef de groupe: A. Letessier Selvon
- Anisotropies: A. Letessier Selvon / J. Aublin / P. Ghia / L. Caccianiga (PhD en 2015) / I. Al Samarai
- Composition/Hadronic interaction: A. Letessier Selvon / M.Blanco (PhD en 2014) / Laura Collica (PhD 2014) / Pierre Billoir.
- Photon haute energie: M. Settimo / P. Billoir
- Nouveau trigger: P. Billoir
- R & D LSD: A. Letessier Selvon / P. Billoir / I. Maris / M. Settimo / M. Blanco
- R & D GIGAS: A. Letessier Selvon / I. Maris / M. Settimo / M. Blanco / I. Al Samarai / R. Gaïor
  J. David / H. Lebbolo / J. Coridian / J.M. Parraud / Ph. Repain

Responsabilités au LPNHE

- **Responsablités au niveau des working group:**
  - P. Ghia (publication Commitee) / J. Aublin (Anisotropie) M. Settimo (photons)
    I. Al Samarai / R Gaior (Detection GHz)
- **Theses achevées:**
  - M. Blanco Otano (*Different approaches to determine the composition of the ultra high energy cosmic rays in the Pierre Auger Observatory* 2014)
  - L. Caccianiga (*Cosmic-ray astronomy at the highest energies with ten years of data of the Pierre Auger observatory* 2015):
  - L. Collica (*Mass composition studies of Ultra High Energy cosmic rays through the measurement of the Muon Production Depths at the Pierre Auger Observatory 2014* en co-tutelle)
- **Responsabilités au niveau du symposium UHECR**
  - P. Ghia J. Aublin: Anisotropies / M. Settimo: Multi messenger
- **Publications:**
  - LSD: description du principe + résultats du 1er prototype en Argentine (*Layered Water Cherenkov detector for the study of ultra-high energy cosmic rays", Nucl. Instr.. and Methods A 767 (2014), 41, arXiv:1405.5699.*)
  - New method for mass composition determination (*Exploiting the geomagnetic distortion of inclined atmospheric showers - Billoir, Pierre et al. Astropart.Phys. 74 (2016) 14-26 arXiv:1508.04354 [astro-ph.IM]*)
  - contributions à l'ICRC2015
  - GIGAS: calcul de flux microonde par Molecular Bremstrahlung
    (*Al Samarai et al. :Astropart Phys 67 (2015) arXiv: 1409.5051*
    Al Samarai Phys. Rev. D 93, 052004)

Anisotropies Grandes Echelles

Imen Al Samarai for the Pierre Auger Collaboration, Indications of anisotropy at large angular scales in, the arrival directions of cosmic rays detected at the Pierre Auger Observatory, Proc. of the 34th ICRC.



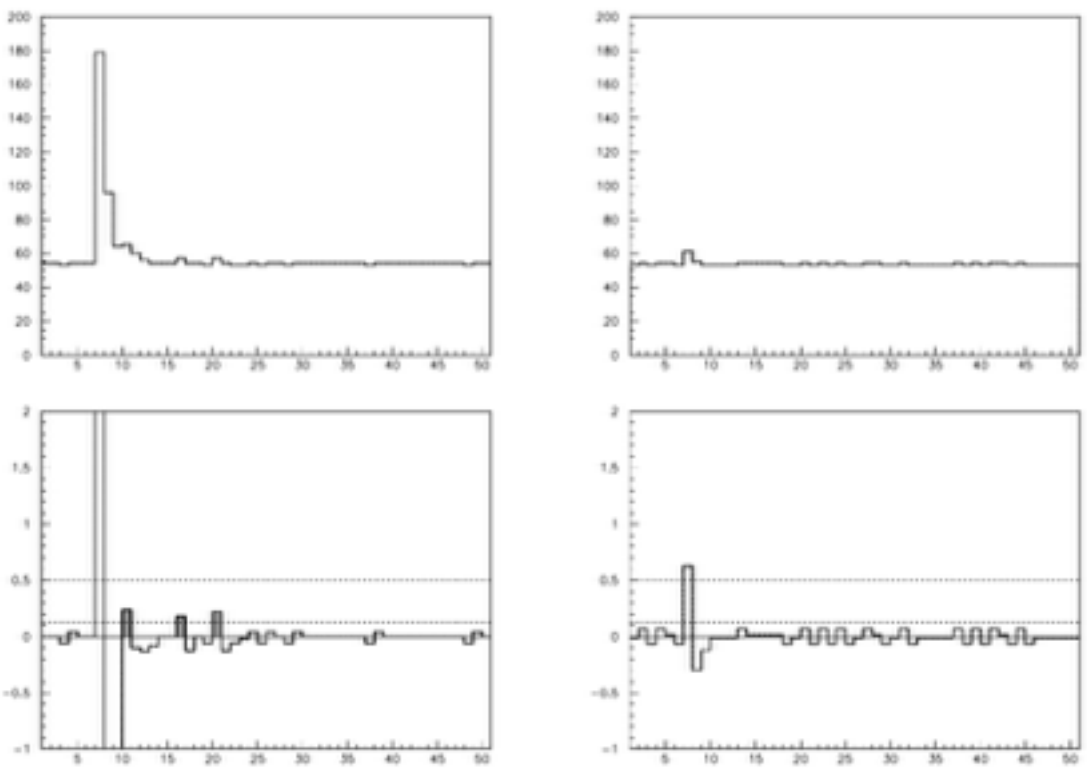
- concept: projeter les directions d'arrivée des RC sur une base de fonctions orthogonales (type harmoniques spheriques)
  Analyser les contributions de dipole, quadrupole

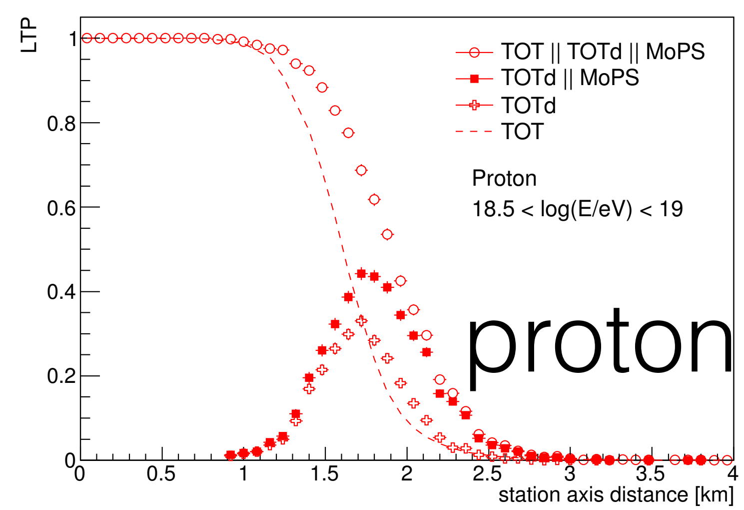
- analyse très fine: effet de couverture, champ géomagnétique, atmosphérique

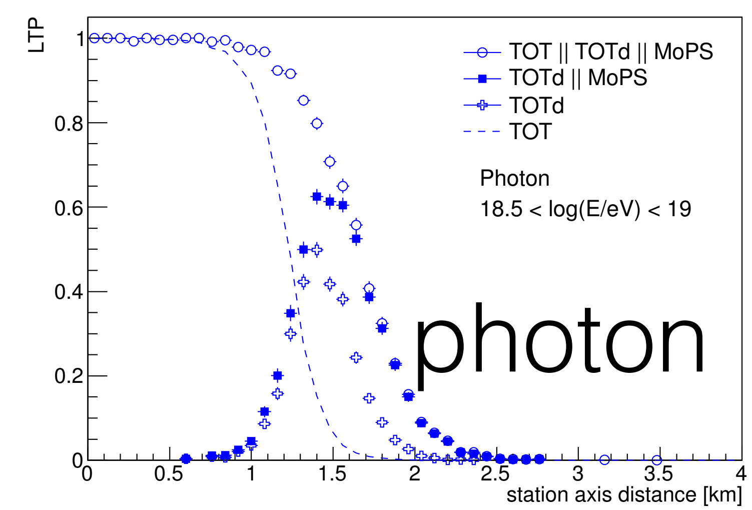
- permet de contraindre des modèles (ici protons issus de sources stationnaires dans le disque galactique)

Nouveaux Triggers

P. Billoir, P. Ghia, I. Maris, M. Settimo

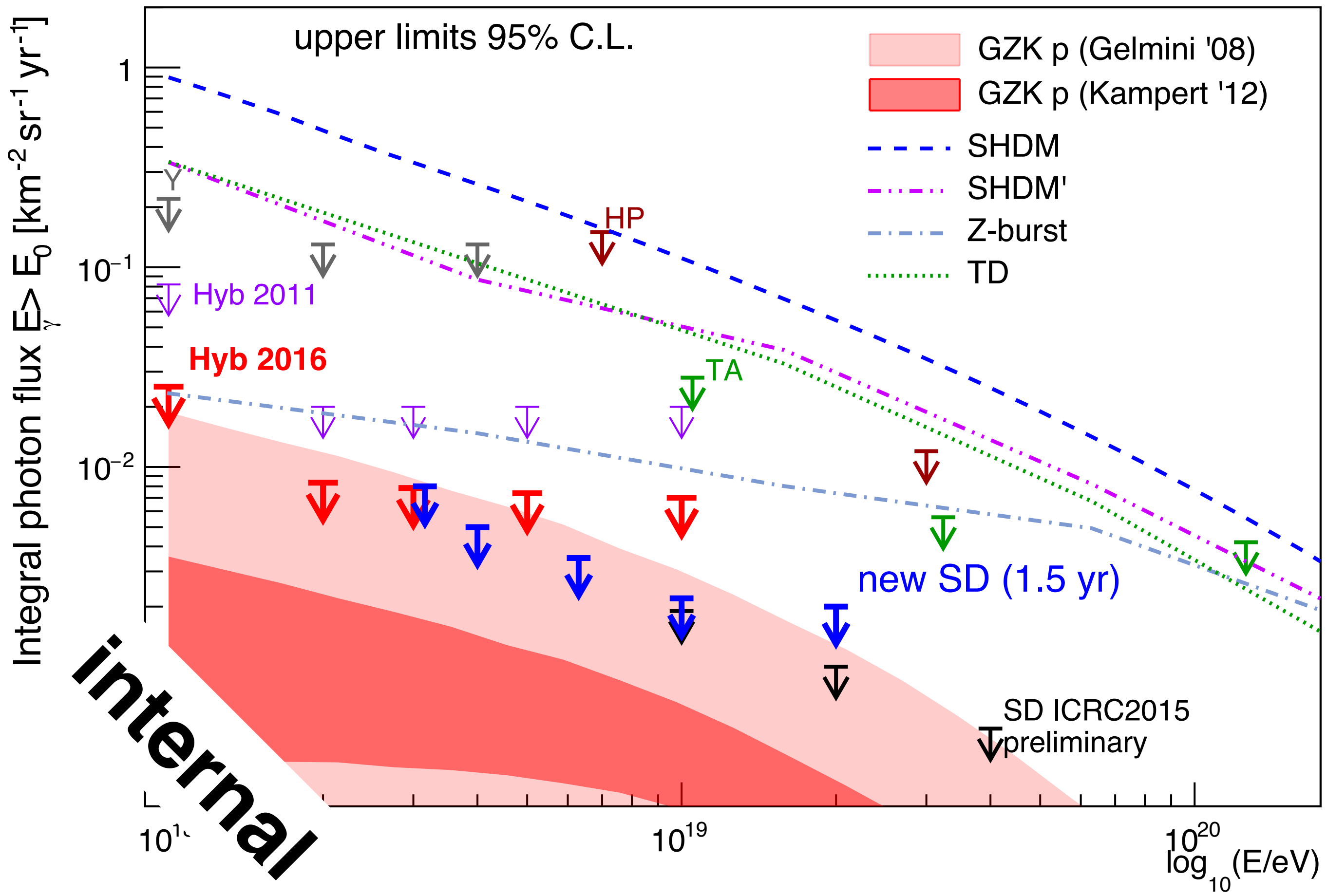






- <u>concept</u>: - TOTd: deconvolué la trace ADC du detecteur (pour compter les pics)
  - MOPs: comptage de sauts positifs (apres TOTd)
- augmente la statistique du detecteur (à basse E)
- augmente la sensibilité à la recherche de photon à basse E

UHE photons

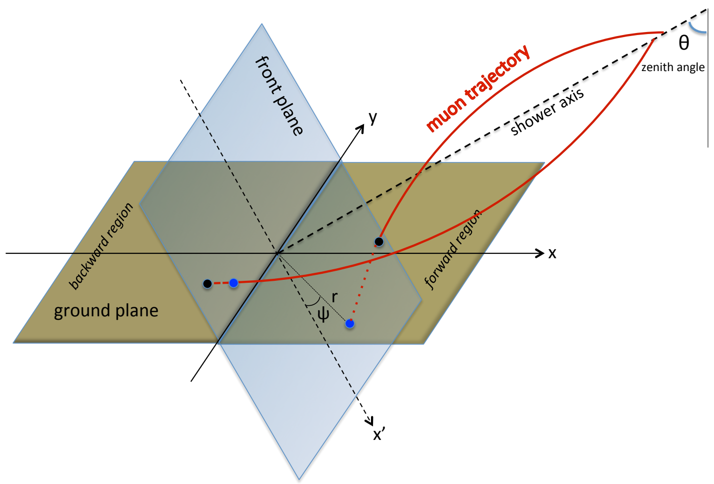


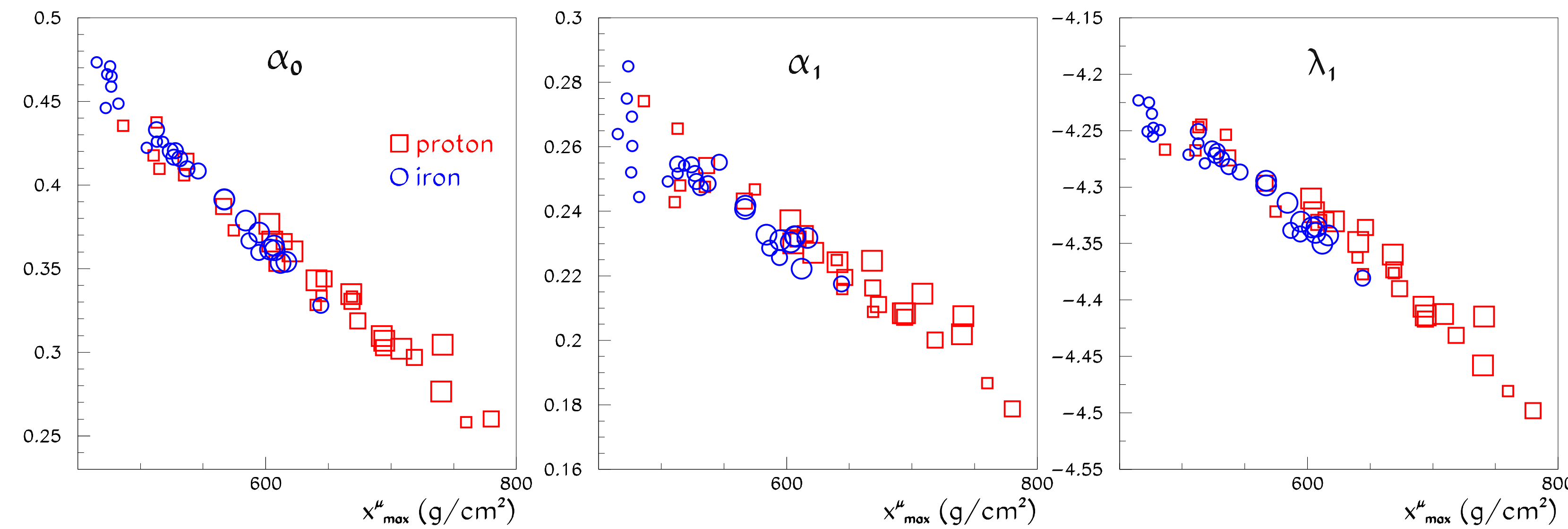
M. Settimo

- concept: recherche de gerbe profondes, a composante électromagnétique dominante
- test direct de théorie type massive particle decay
- test de modèles GZK

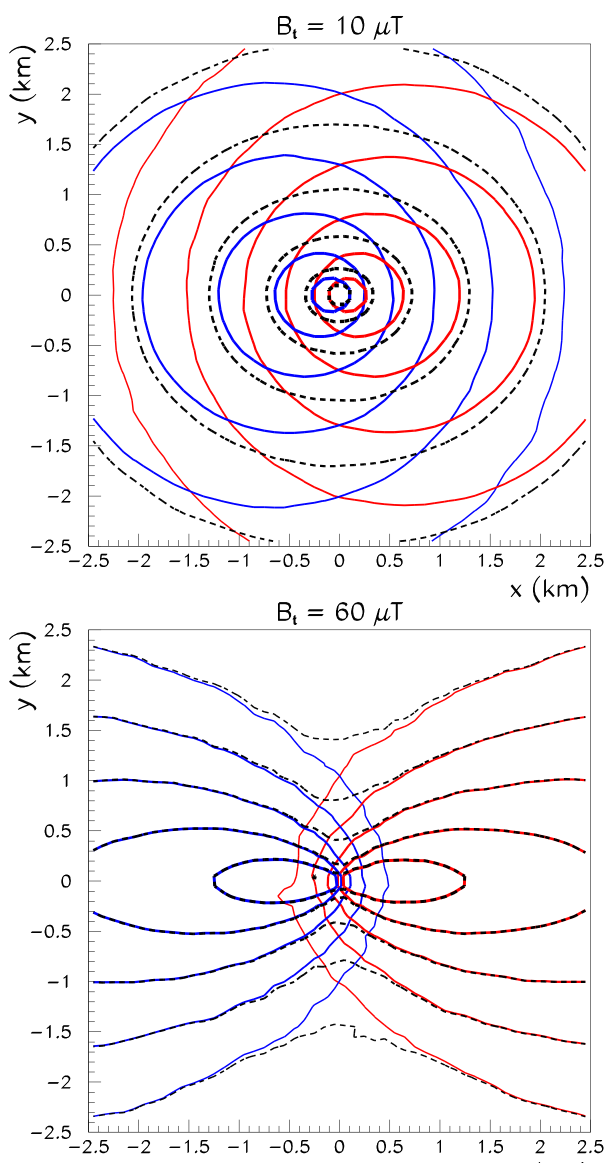
Composition: distorsion géomagnétique

P.Billoir, M. Blanco, M. Settimo



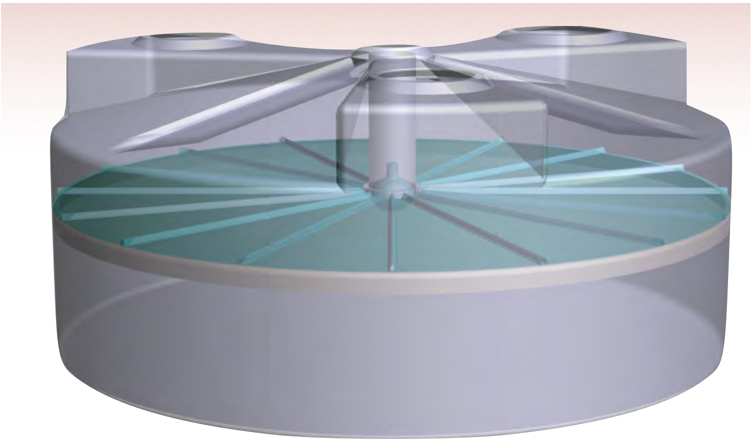


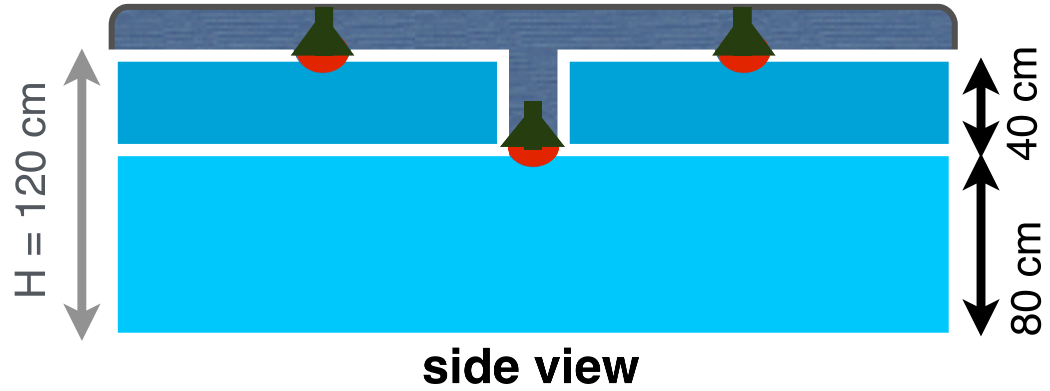
Exploiting the geomagnetic distortion of inclined atmospheric showers
Billoir, Pierre et al. Astropart.Phys. ***74*** *(2016) 14-26 arXiv:1508.04354 [astro-ph.IM])*

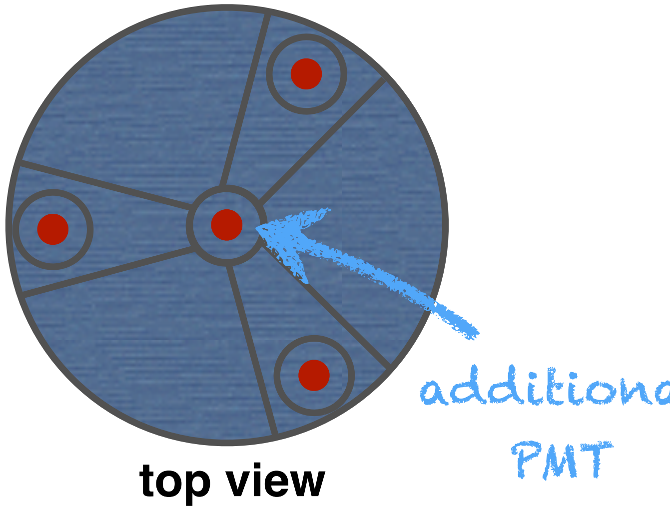


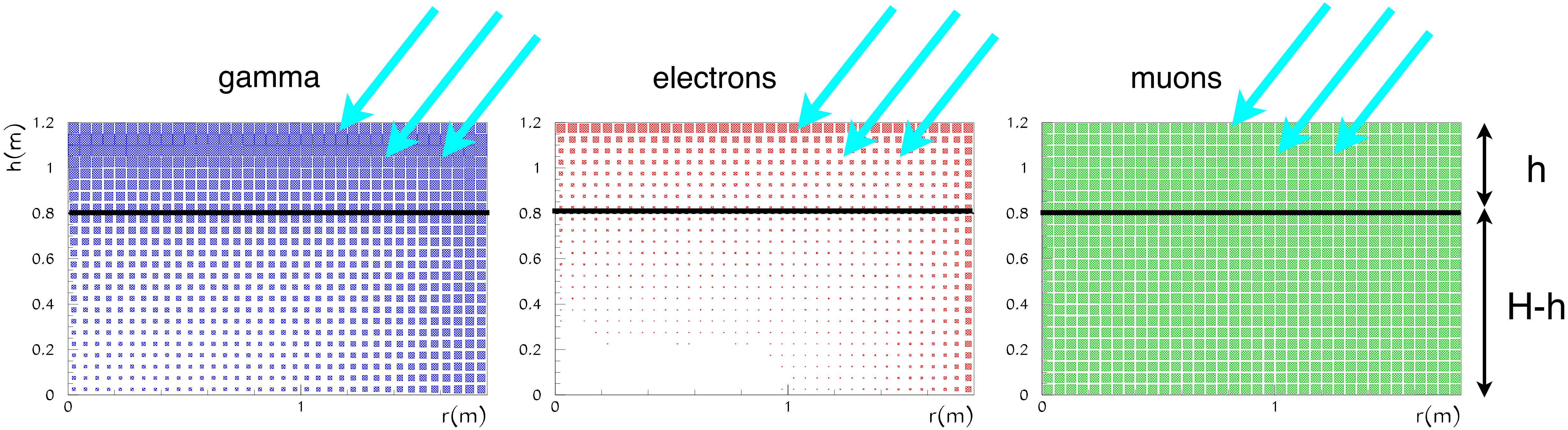
- <u>concept</u>:
  - empreinte des muons au sol modifiée par le champs géomagnétique
  - cette modification depend du maximum de production des muons
  —> paramètre sensitif à la composition du primaire

Layered **S**urface **D**etector







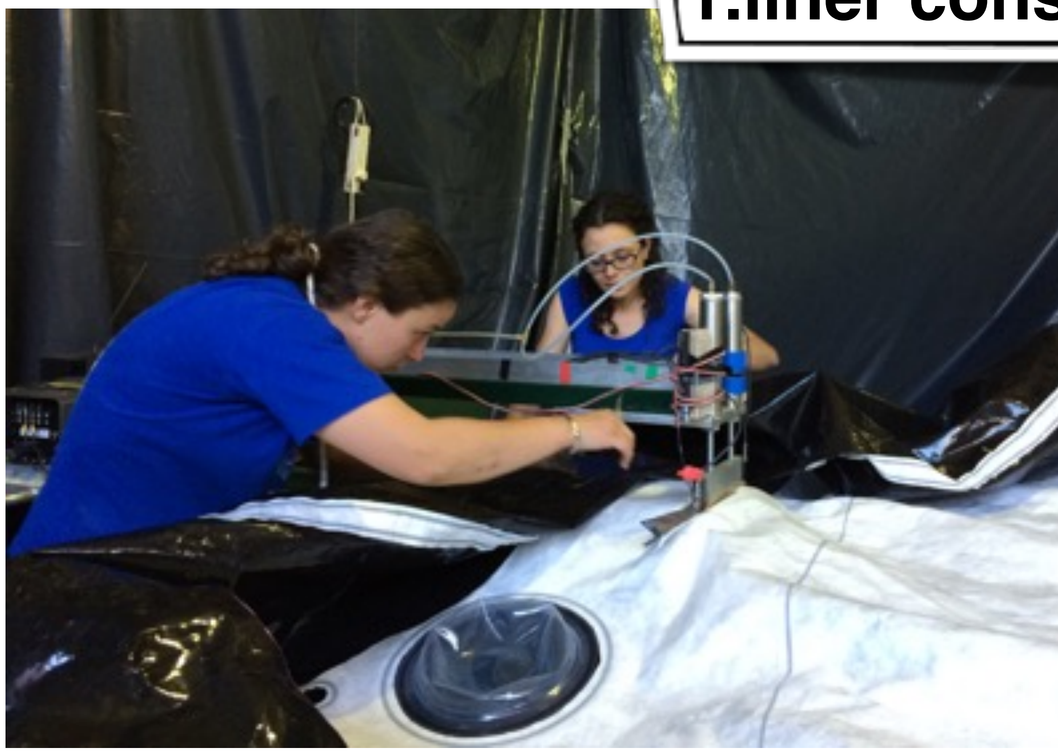


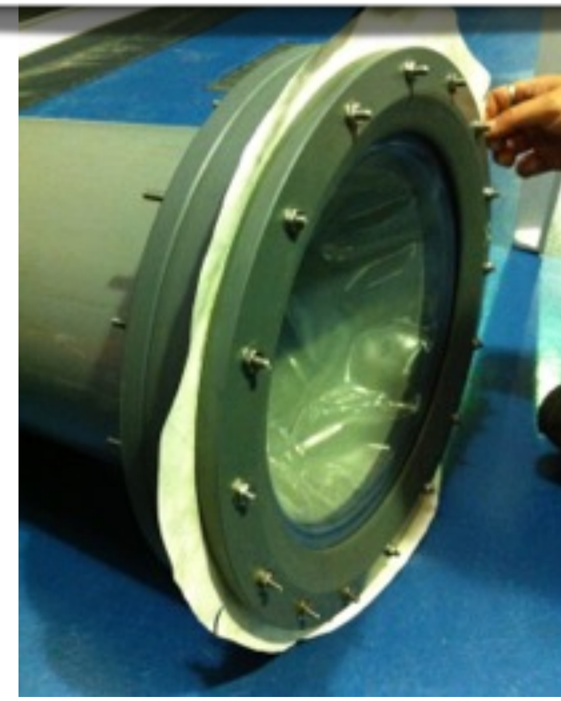
$$\begin{pmatrix} S_{\text{top}} \\ S_{\text{bot}} \end{pmatrix} = \mathcal{M} \begin{pmatrix} S_{\text{EM}} \\ S_{\mu} \end{pmatrix} = \begin{pmatrix} a & b \\ 1-a & 1-b \end{pmatrix} \begin{pmatrix} S_{\text{EM}} \\ S_{\mu} \end{pmatrix}$$

a % of EM signal in top part
b % of μ signal in top part

Layered **S**urface **D**etector

1.liner construction and tube preparation





2. water/light leakage test

Layered **S**urface **D**etector

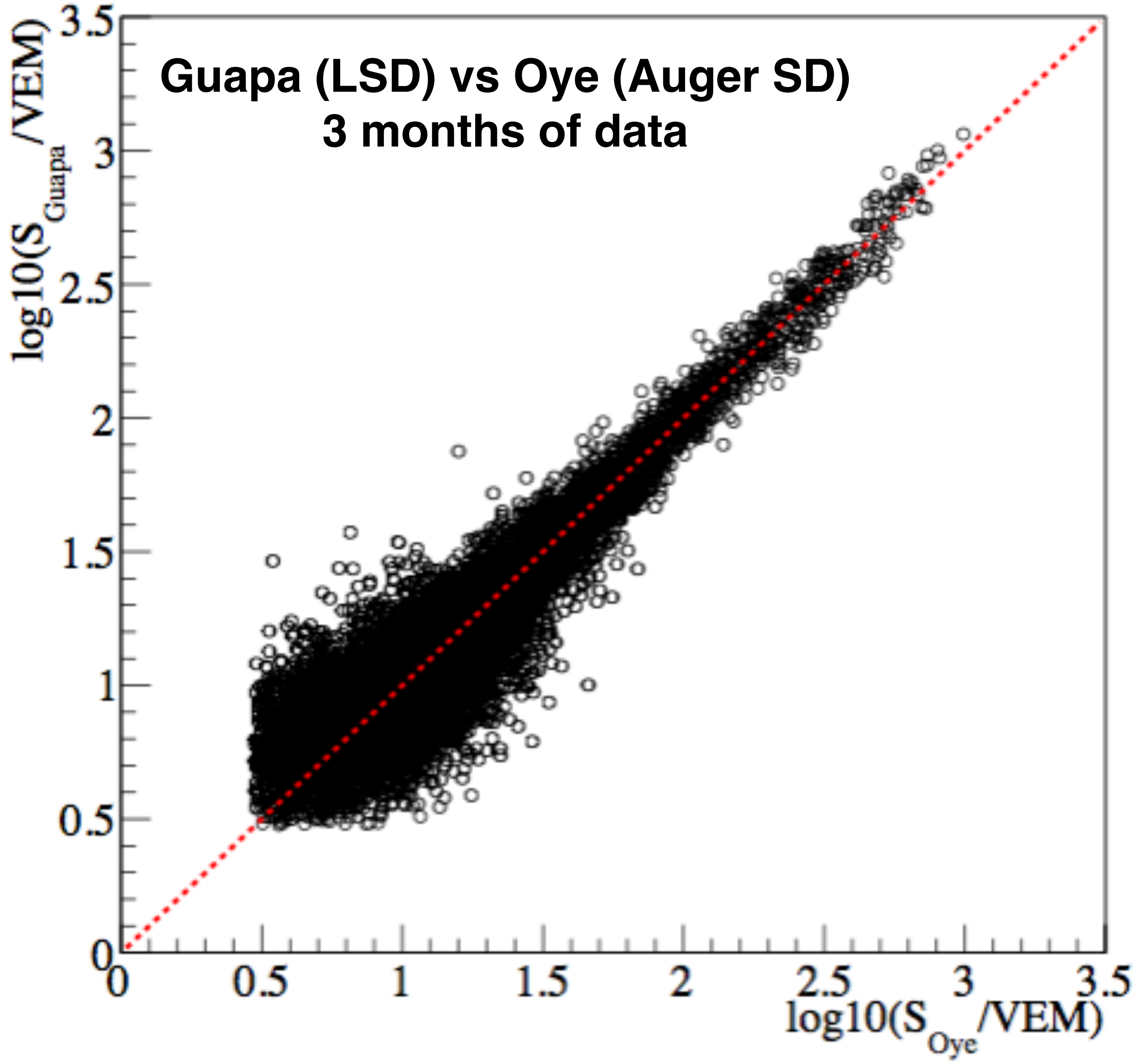
deployment ....

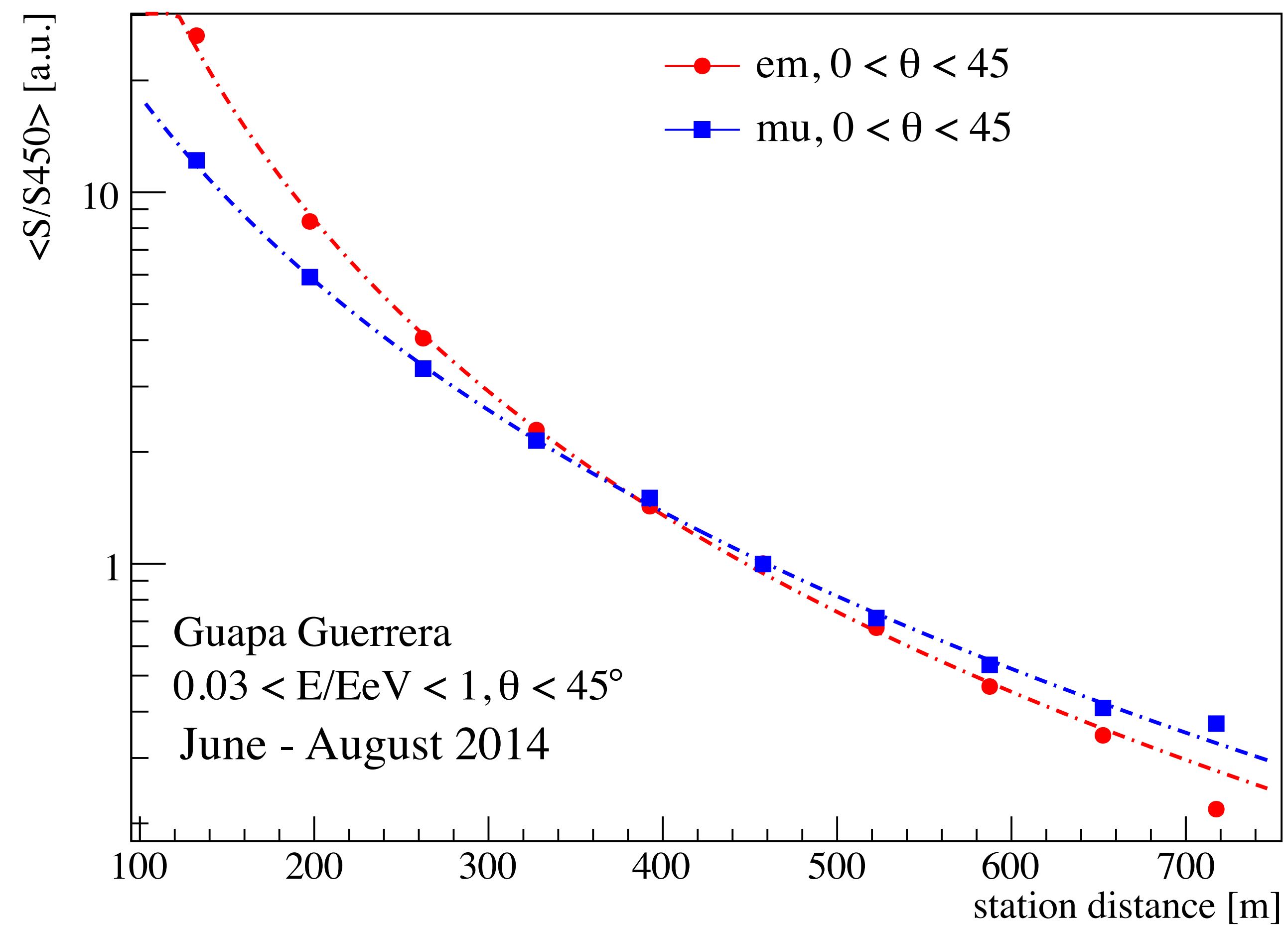
... and water filling

Layered **S**urface **D**etector

… in the meantime:
enjoying the asado!

Layered **S**urface **D**etector

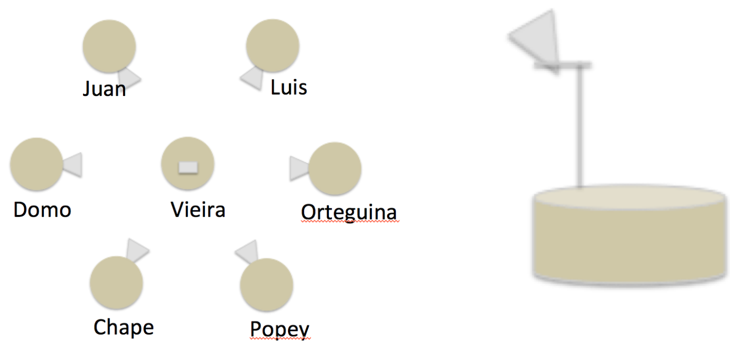




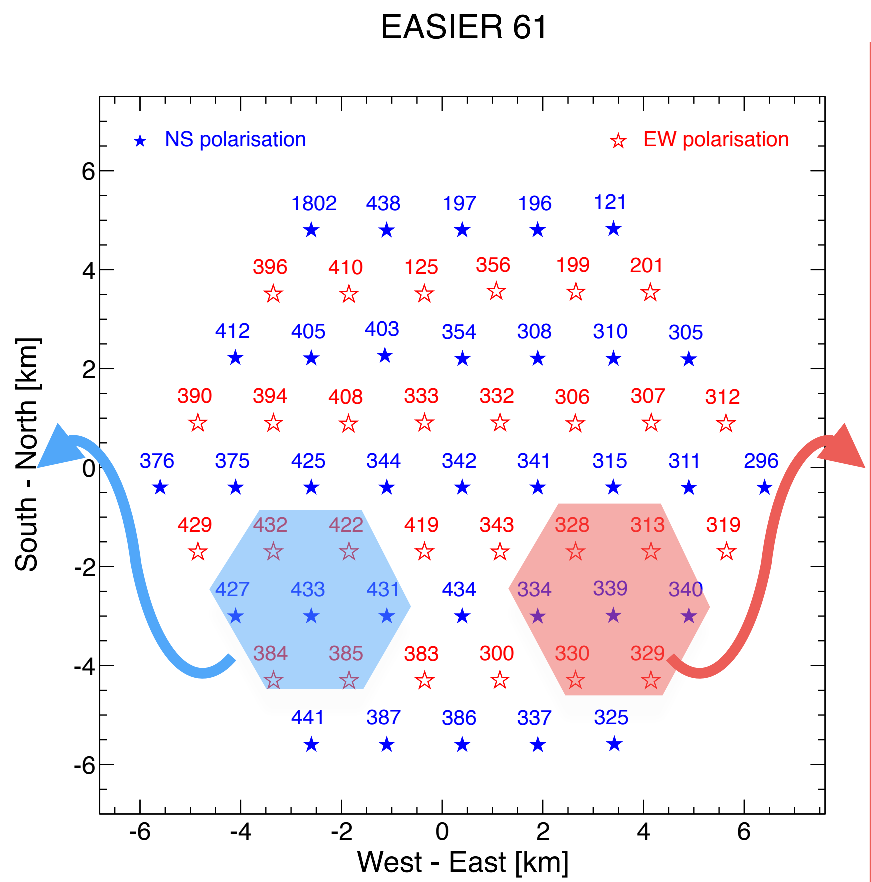
- 3 stations installées (en doublet)
- le demonstrateur a très bien fonctionné
- possibilité de séparer les composantes em/mu démontrée
- pas choisie par la collaboration (malheureusement)

EASIER/GIGADuck

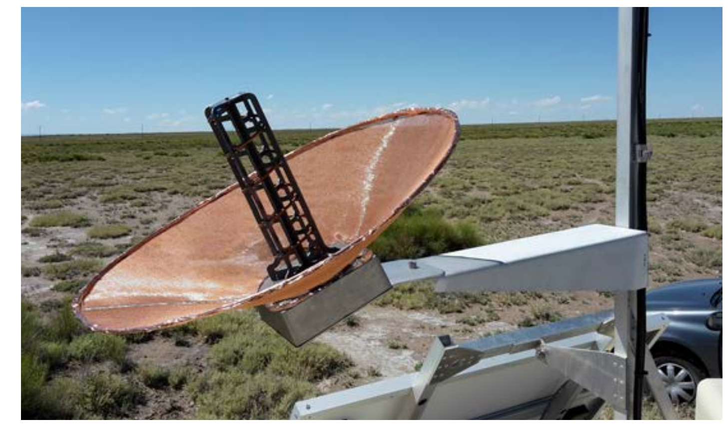
GIGADuck C-band



- 1 hexagon (installed 2015/03)
  - 6 pointing to 20˚ / 1 to zenith
- Horn: ATM Info (G_{max} =15dB)
- C-band: 3.4 - 4.2 GHz
- HPBW ~ 30˚
- LNB: Norsat 8115F



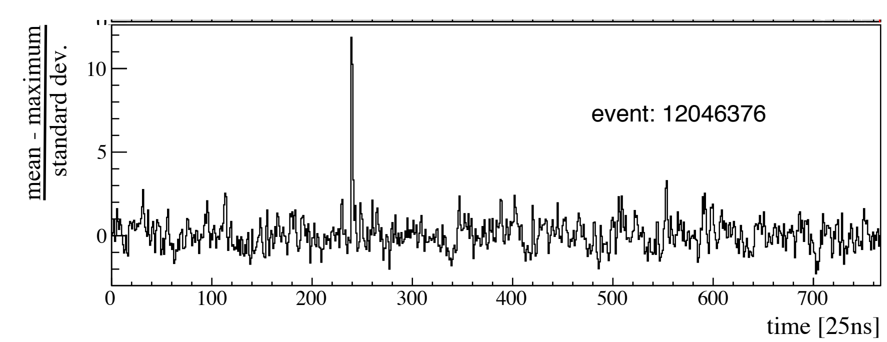
GIGADuck L-band



- 1 hexagon (installed 2015/03)
  - 6 pointing to 20˚ / 1 to zenith
- Helix antenna: (G_{max} =15dB)
- L-band: 1 - 1.5 GHz
- HPBW ~ 30˚
- LNA: Wenteq 50dB / T=50K

EASIER

- 61 detectors hexagon
- installed in 2 phases first in 2011 then in 2012
- all pointing to zenith
- LNBf: DMX 241 (G_{max} =10dB)
- C-band: 3.4 - 4.2 GHz
- HPBW ~ 50˚



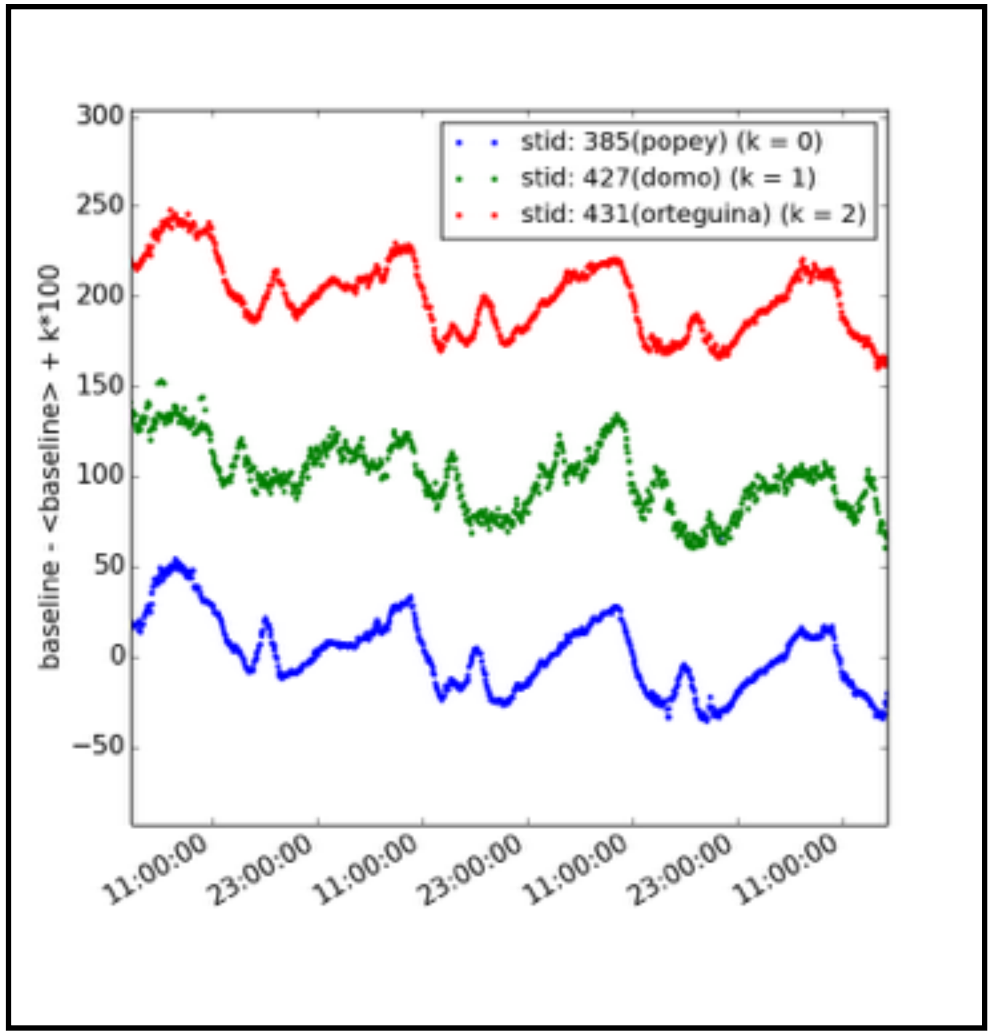
first event in the C-band

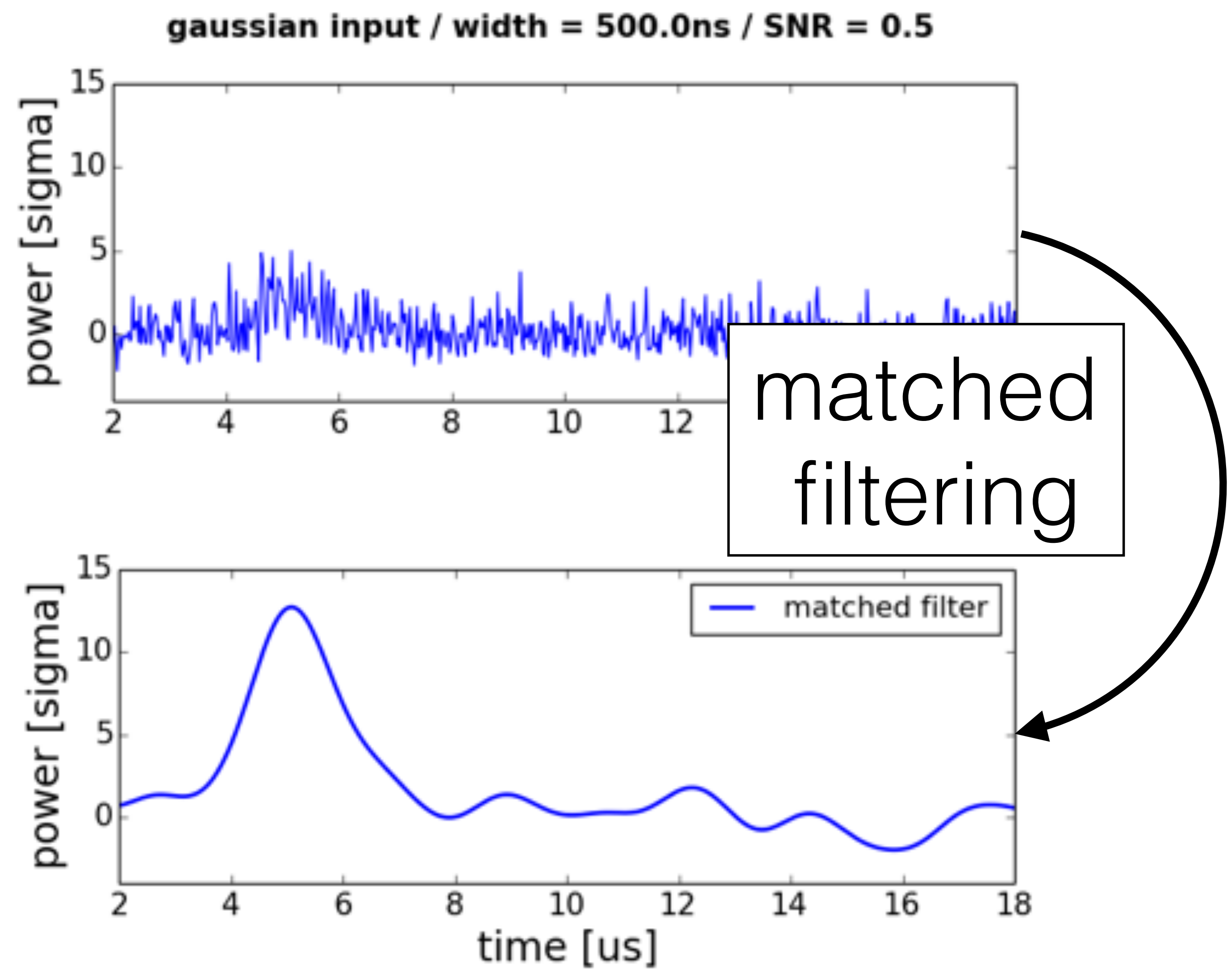
EASIER/GIGADuck: status

- Projet LPNHE / LPSC / IPN (ANR —> fin 2017)
- Contribution LPNHE
    - electronique (J. David, H. Lebbolo, J.Coridian): design/production/test des cartes alimentation et signal
    - theorie: estimation du signal attendu
    - Analyse: calibration/simulation/analyse des données
    - papier en écriture (sur la bande C)
- Status des detecteurs:
    - EASIER: ~ 50 detecteurs installés, prise de données stable
    - GIGADuck C-band: dev. en 2013-14, installation en 2015, prise de données stable
    - GIGADuck L-band: dev. en 2013-14, installation en 2015, reparation en cours (developpement d'une carte LNA) ré-installation avant fin 2016

➡ decommissioning à fin 2017

EASIER/GIGADuck: travail en cours



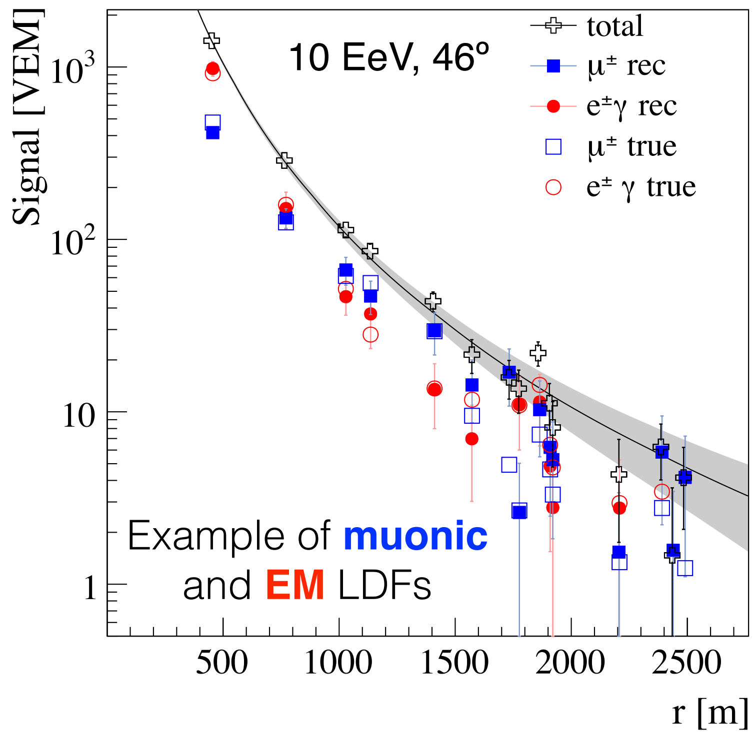


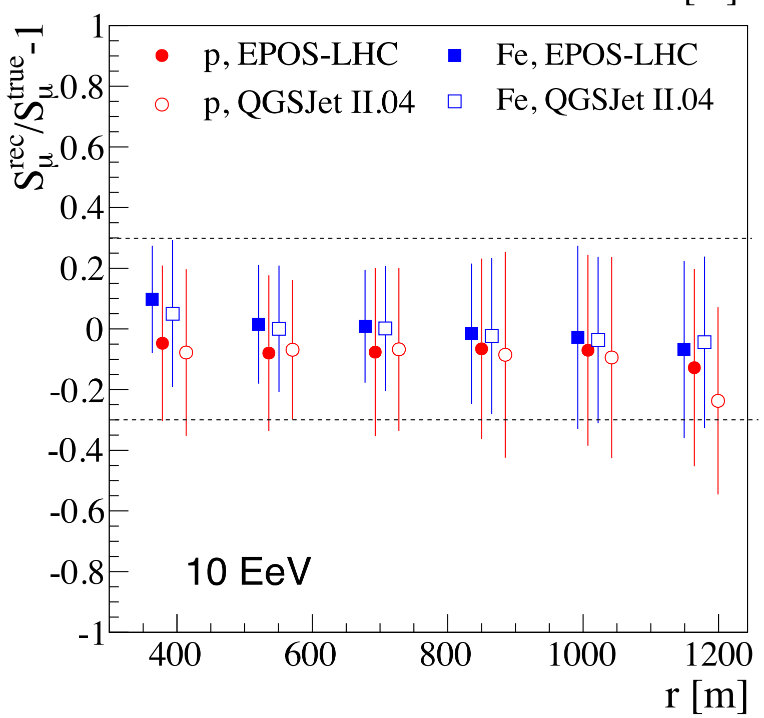
- calibration in situ du détecteur grace au soleil
- amelioration du SNR grace a des technique de traitement du signal

Conclusions

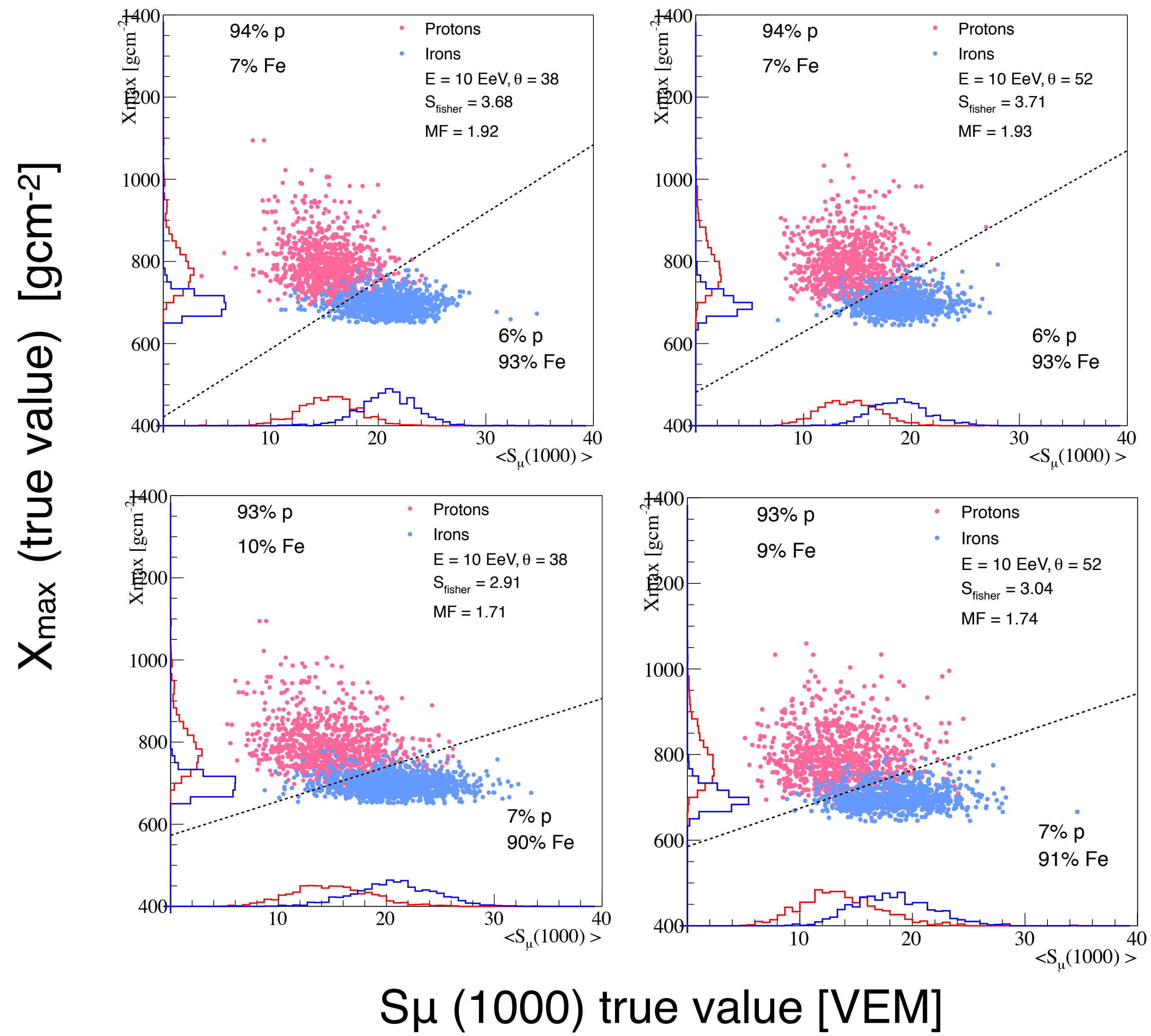
- Le groupe a apporté de larges contributions au long des dernières années (analyses et R&D)
- L'implication du groupe est fortement réduite (pas d'implication dans AugerPrime, GIGAS seule activité restante)
- la R&D GIGAS continue jusqu'à fin 2017

LSD performance simulation





A preliminary multivariate (Xmax,Sμ) analysis



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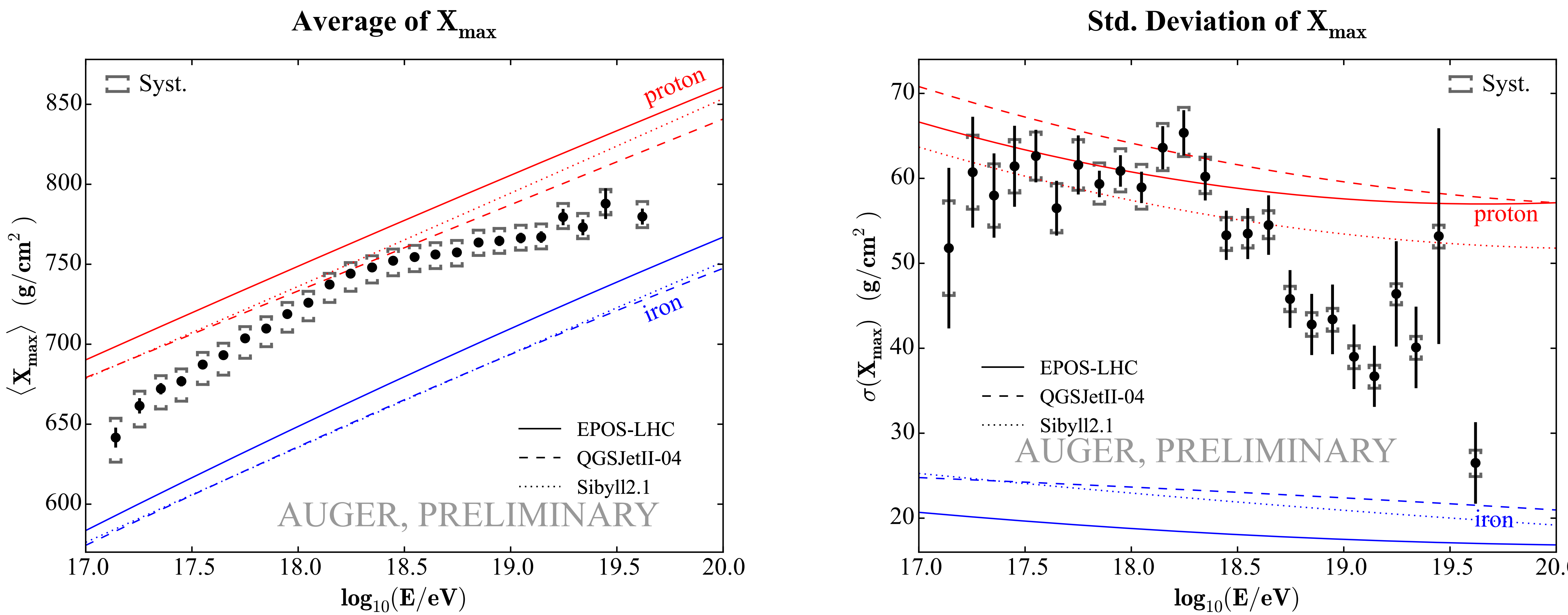
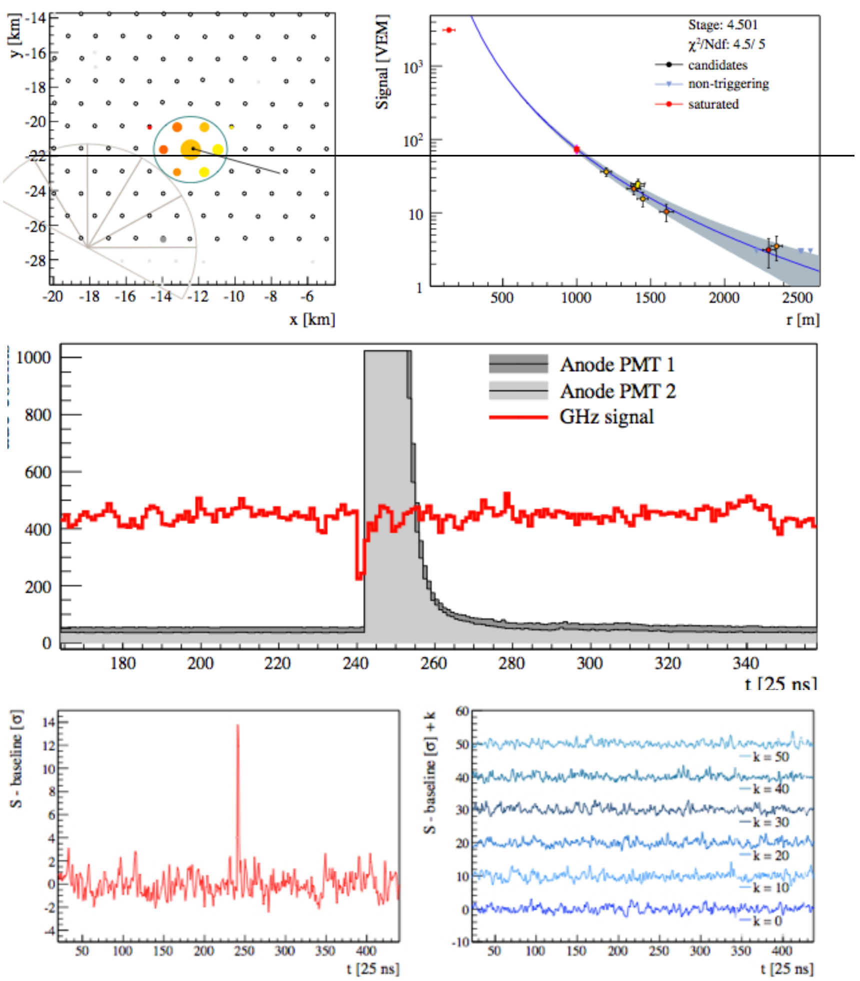
mass composition



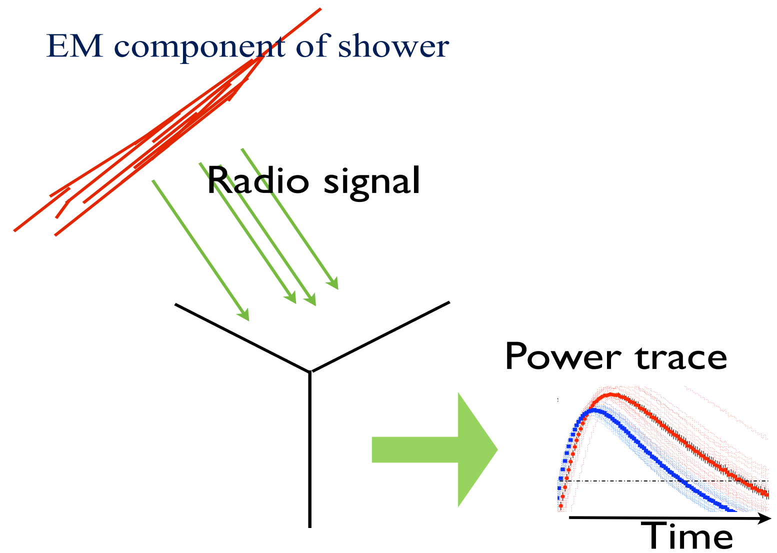
1st Event

On the 11th of june 2011 the EASIER prototype detector installed on the Auger site in the province of Mendoza detected for the first time in the world the microwave emission from a 10^{19} eV extensive air shower. The event is shown below.



The distance of the central tank to the shower core is 136±40m. Other tanks are at distance larger than about 1.5 km. Given the shower geometry (close to vertical with a zenith angle of 30o) and given our current system temperature we did not expect to see a signal in those peripheral antennas. (Middle) Time traces of the PMT signal (in gray) and of the GHz antenna (log scale in red). The GHz signal is about 50 ns in front of the PMT one due to the transit time in the large Auger phototubes. (Bottom-left) Distribution for background traces of the power received in each time bin in units of the mean power (power fluctuations). (Bottom-Right) Power trace for the selected event, after mean power subtraction and in units of the power fluctuations. The signal is nearly 14-sigma.

The detection principle



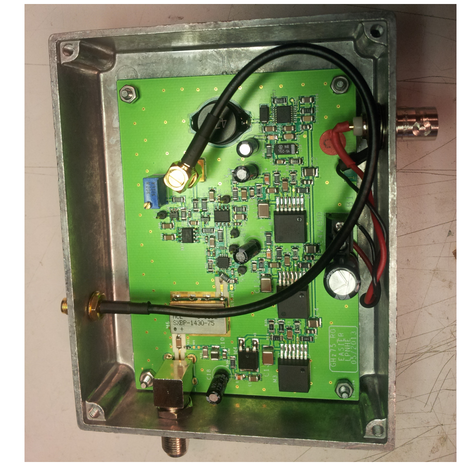
When developing in the atmosphere the electromagnetic cascade radiates in the microwave band. Each microwave antenna measures continuously the radiation of the cascade as a function of time. The interface electronic converts this signal to its power envelope and feed it to the tank front end electronics.

The power envelope is recorded using one of the Fast Analog to Digital Converter (FADC) channel of the Auger Cherenkov tank front end every time this associated surface detector element sees the cascade of particles reaching the ground. It is important to note that, given this external triggering system, no requirement is placed on the signal-to-noise ratio of the radio emission.

A single microwave antenna has about 120 degree vertical viewing angle. Each antenna is associated with one Auger particle detector. The signal is amplified with a large bandwidth low noise amplifier and then converted to a power trace by means of a commercial power detector. The power trace is measured continuously and only recorded when the associated particle detector is triggered. Shallow or deep showers have a distinct time profiles (red and blue lines respectively in the small plot).

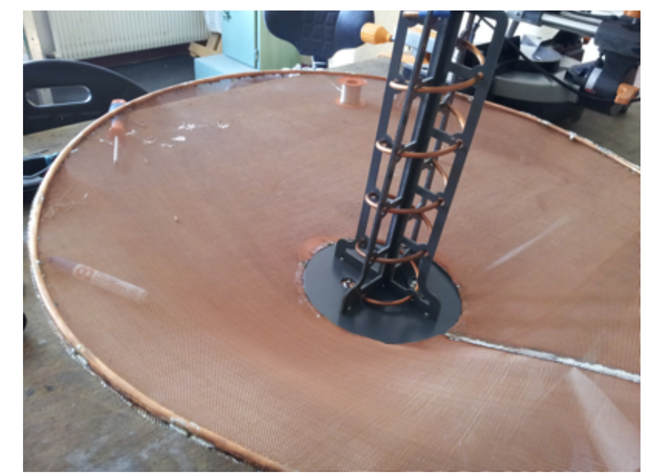
LNB electronic for FPV

This aluminium box contains the low noise amplifier the filters and the bias T for the helicoidal FPV antenna



Adaptation electronic box

This custom electronic board allows to connect the antenna system to the Auger Unified electronic Board on the Tanks.



Helicoidal FPV antenna with its copper reflector

This antenna records GHz emission in the 1 to 2 GHz band. The copper reflector protects from the ground emission.

Front cover illustration

The two antenna system. Top C-band system with its mechanical attachement. Bottom the FPV helicoidal system sketched on an Auger tank. The arrow indicate the mechanical attachement system and the LNB electronic box,

A world premiere

Our prototype array of 61 antennas, shown on the front illustration detected - for the first time in the world - a very significant multi-GHz signal from a 10^19 eV extensive air shower.

Détection radio au GHz

▶ **Premier modèle dans le domaine** Emission Bremsstrahlung moléculaire (MBR) dans les gerbes atmosphériques

Publications:
- I. Al Samarai et al. ***Astropart. Phys. 67 (2015)*** *26*, arXiv :1409.5051
- **2 Notes internes**: *GAP 2014-076, GAP 2014-084*
- I. Al Samarai et al., ***submitted to Phys. Rev. D (2016)***, arXiv :1601.00551
- **3 Notes internes**: *GAP 2014-076, GAP 2014-084, GAP 2015-090*

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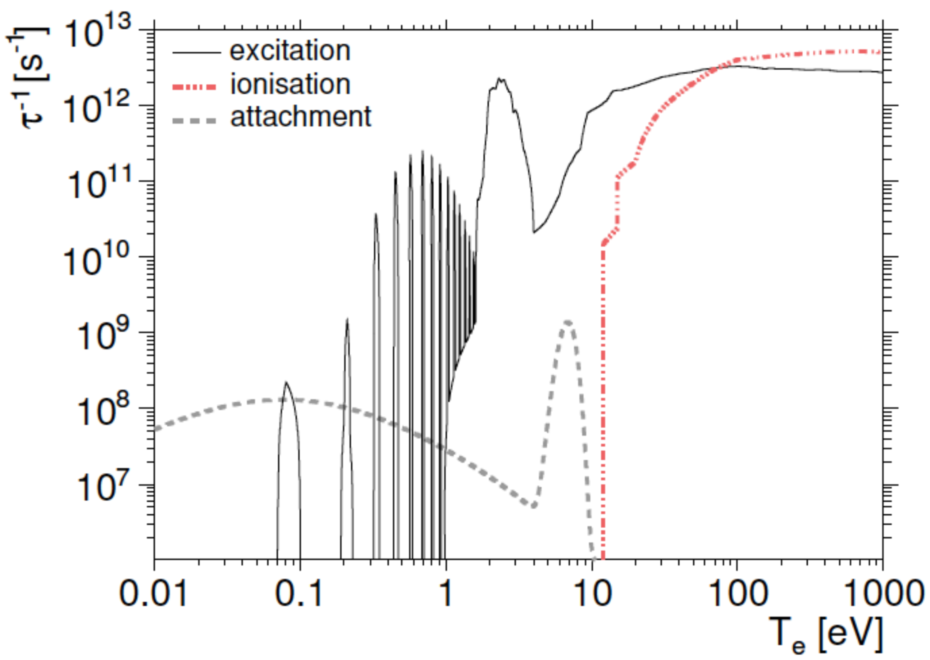
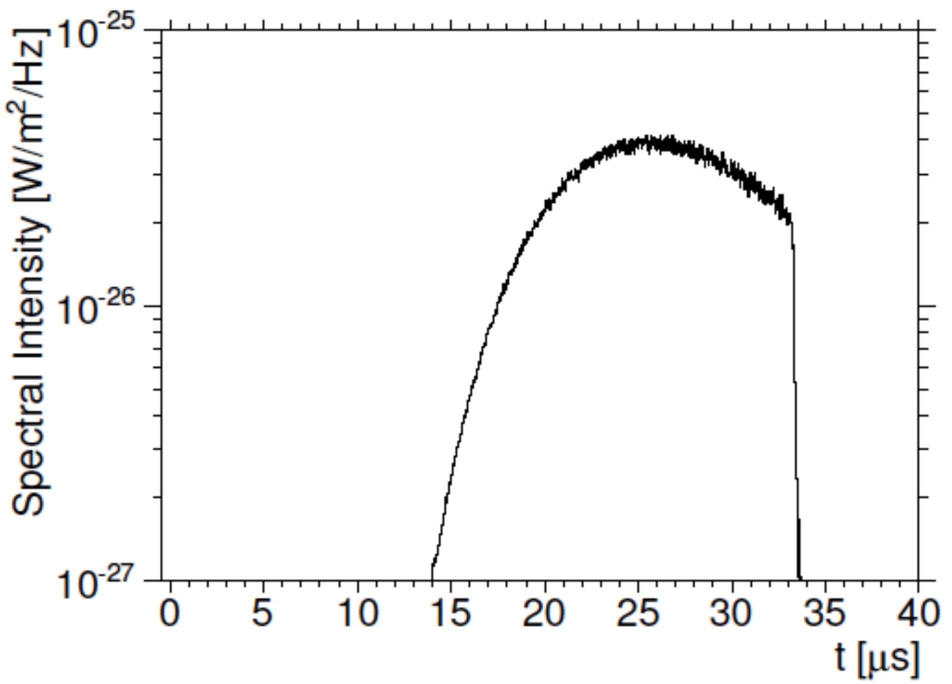


Taux de collisions des électrons secondaires en fonction de l ‘énergie pour plusieurs processus



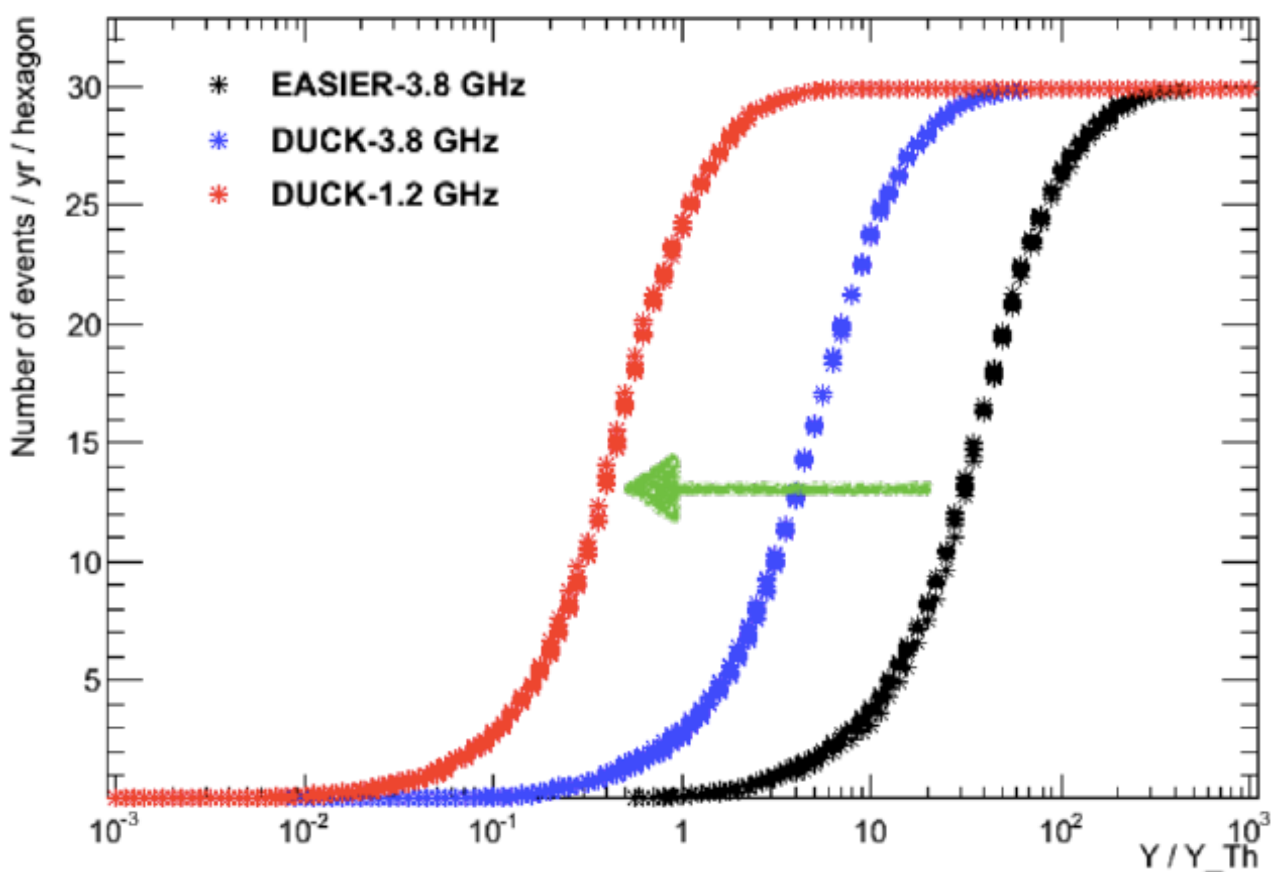
Intensité MBR attendue d'une gerbe de $10^{17.5}$eV à 10 km

Détection radio au GHz

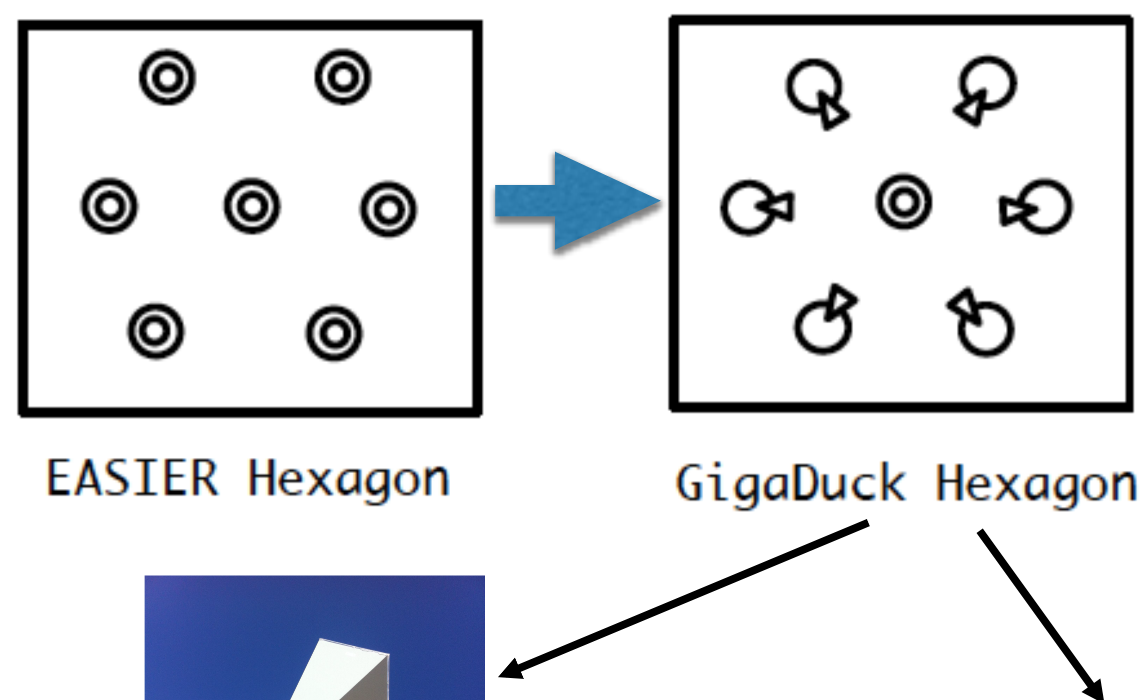
★ Phénoménologie ★ **Sensibilités** ★ Activités techniques ★ Installation

- Nouvelles antennes et configuration de réseau
- Chaîne de simulation complète

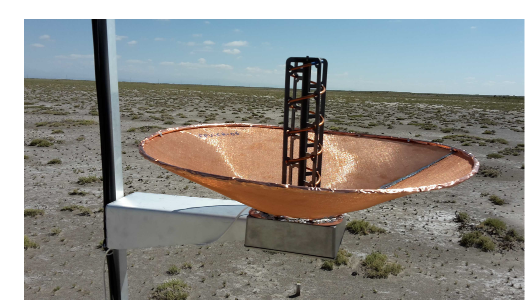
- **Note interne:** GAP 2015-078



Sensibilité attendue jusqu'à ~x100 avec le nouveau dispositif



3-4 GHz

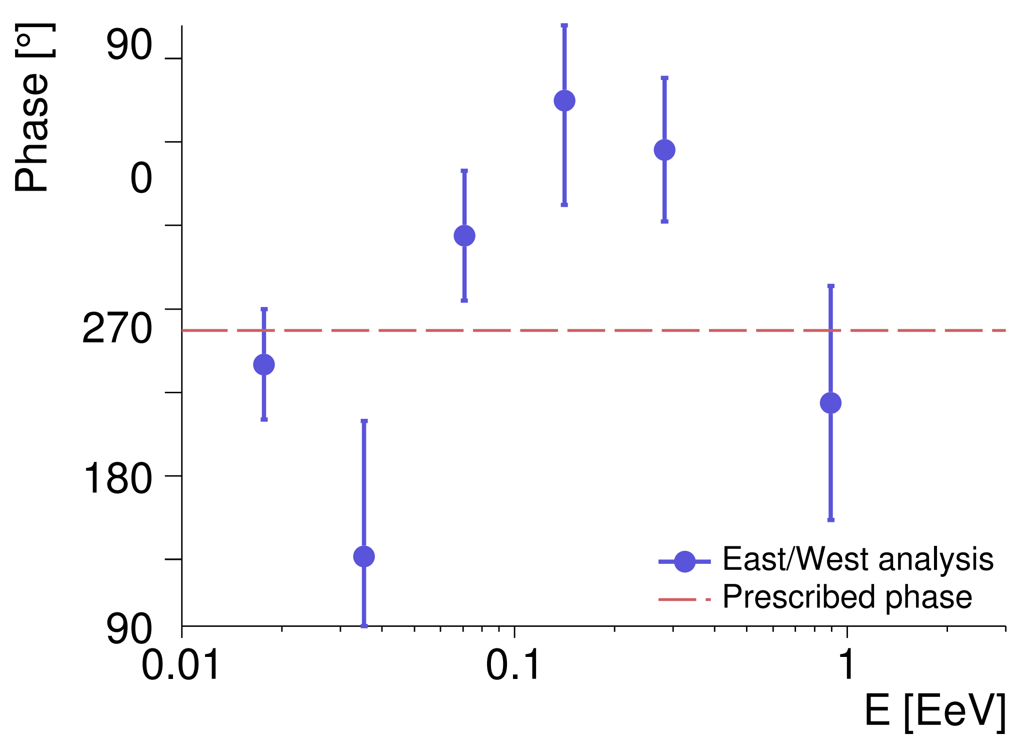


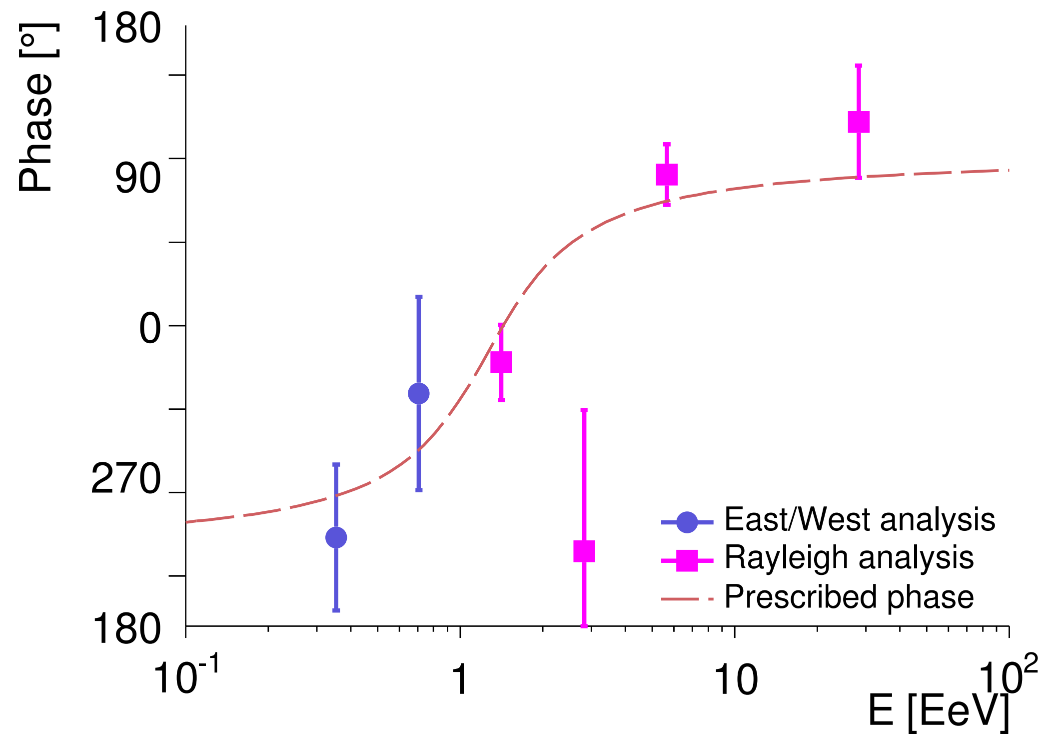
1-2 GHz

LSA: phase

Rayleigh Methd

$$\Phi(\alpha) = \frac{1}{\omega(\alpha)}\frac{dN}{d\alpha} = a_0^\alpha + \sum_{n>0} a_n^\alpha \cos n\alpha + \sum_{n>0} b_n^\alpha \sin n\alpha.$$





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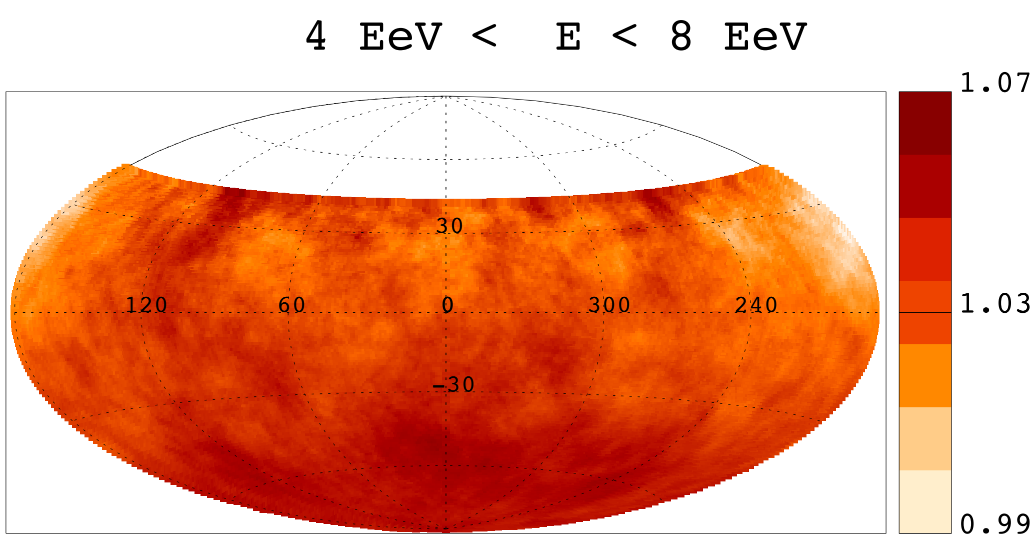
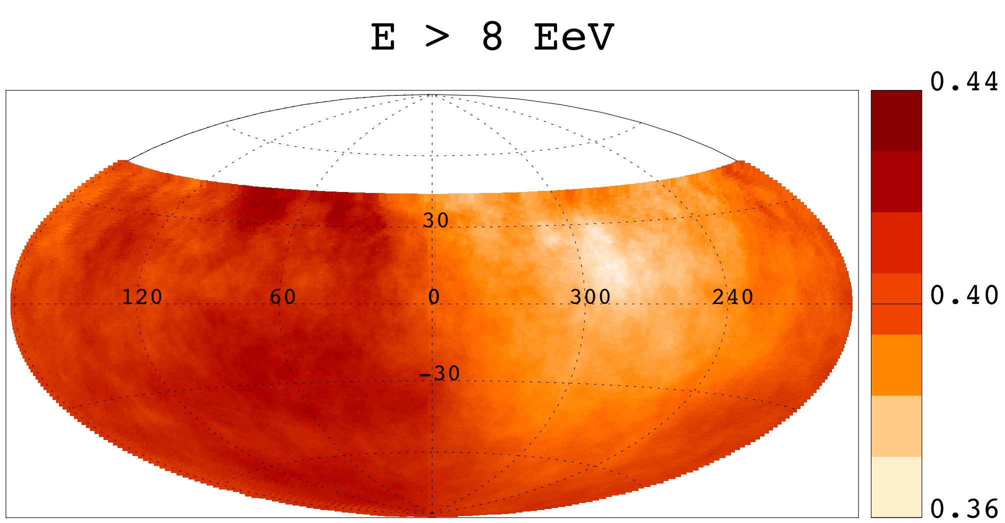
LSA: amplitude





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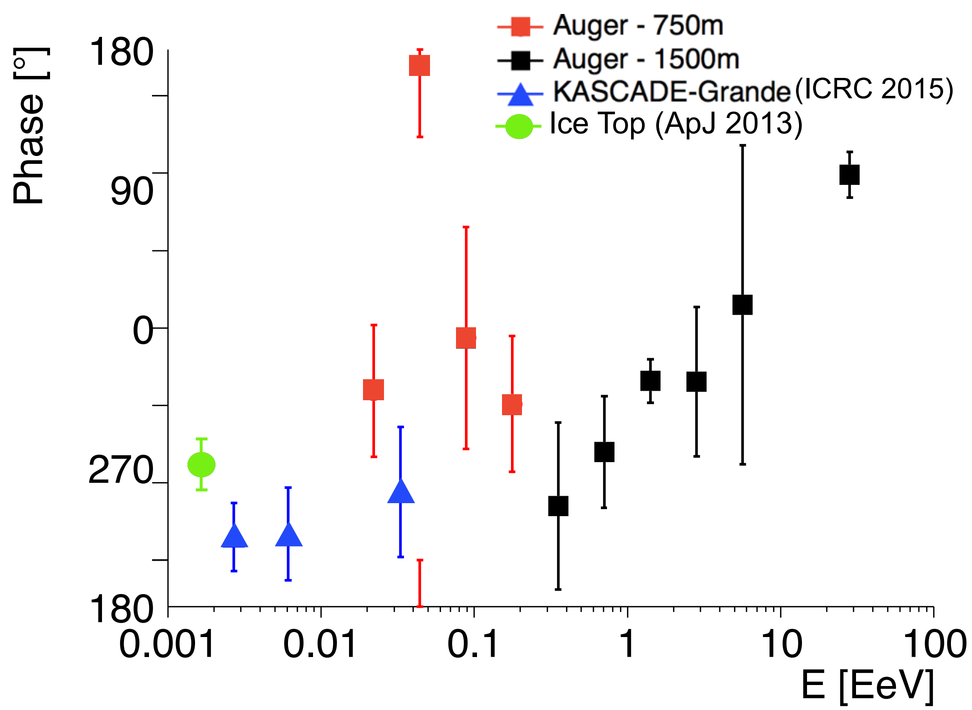
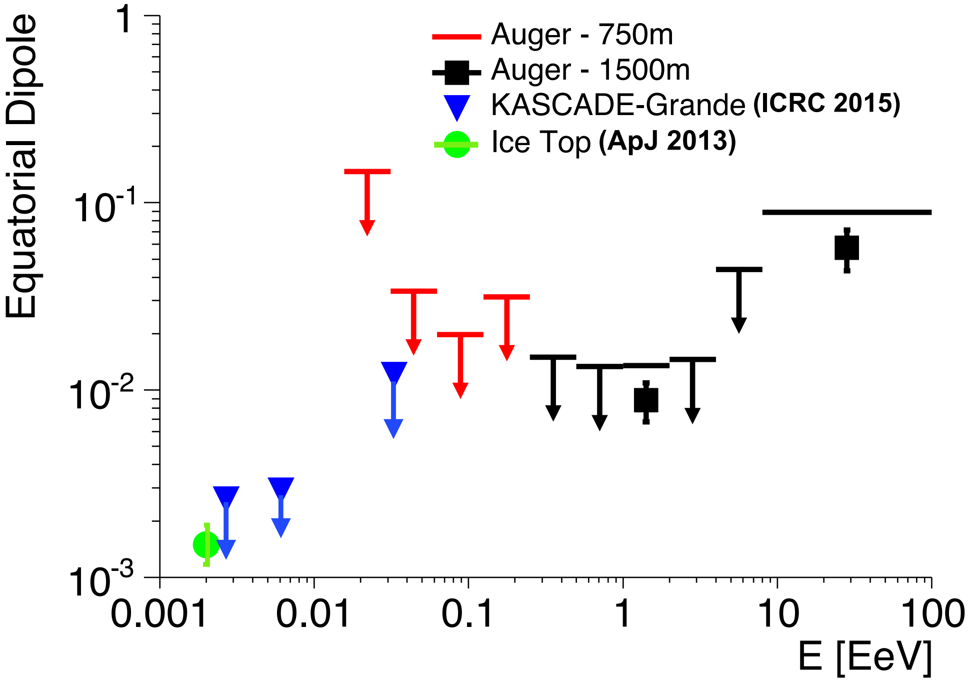
LSA: amplitude





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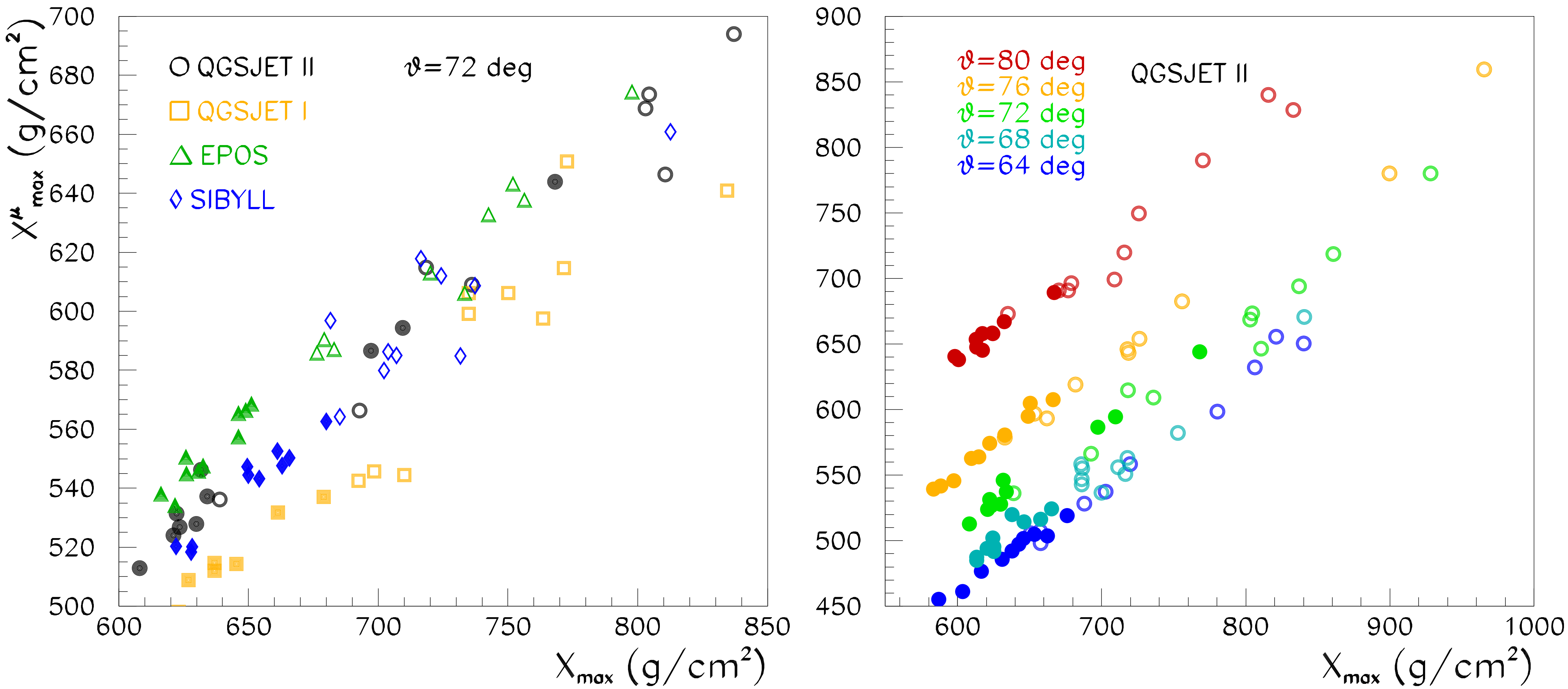
Mass compo



QGSJET II
QGSJET I
EPOS
SIBYLL
ϑ=72 deg
X^{μ}_{max} (g/cm²)
X_{max} (g/cm²)
ϑ=80 deg
ϑ=76 deg
ϑ=72 deg
ϑ=68 deg
ϑ=64 deg
QGSJET II
X_{max} (g/cm²)