7th International Workshop on

New Worlds in Astroparticle Physics

São Tomé, 08 – 10 September 2009

THE AMIGA PROJECT

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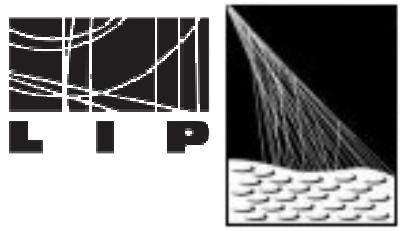
LIP

S. Tomé, 8th September 2009



OUTLINE

- Motivation
- Cosmic Ray Spectrum
- Extensive Air Showers
- Pierre Auger Observatory
- Pierre Auger Observatory Results
- AMIGA
- AMIGA simulations at LIP
- Prospects and conclusions

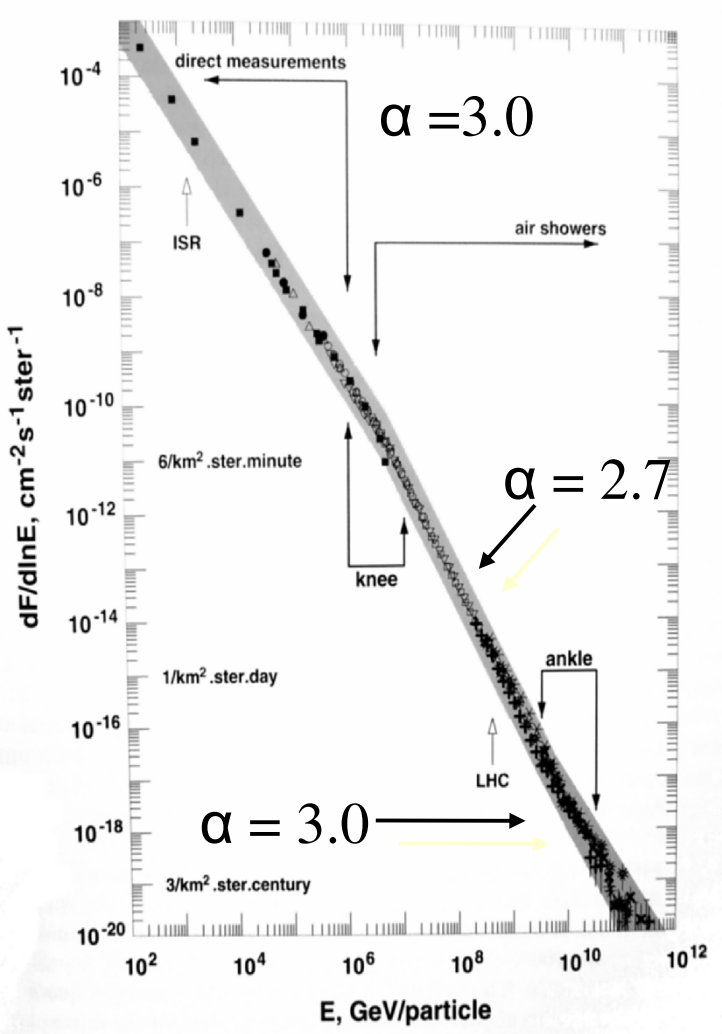
MOTIVATION

- The Pierre Auger Observatory is the largest UHECR detector in the world
  - A Hybrid detector:
    - Fluorescence Telescopes
    - Čerenkov water tanks

- AMIGA is an extension of the Auger Observatory
  - Study the 2nd knee and ankle region of the cosmic rays
  - Independent and direct measurements of the muon component

➢ Independent primary composition determination
➢ Improving High Energy Hadronic Models

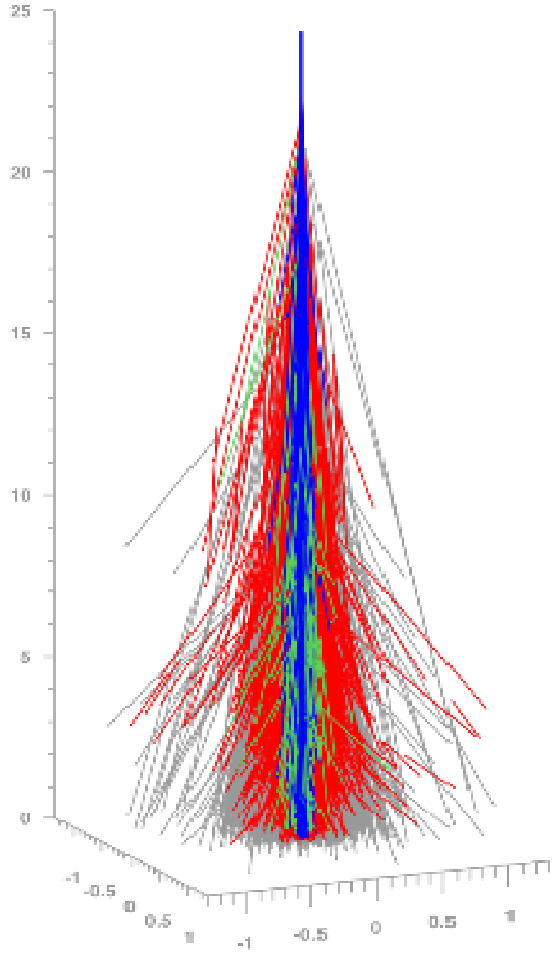
COSMIC RAY SPECTRUM



- High energetic particles
- $\frac{dN}{dE} = E^{-\alpha}$
  - Knee
  - Ankle
  - GZK cutoff

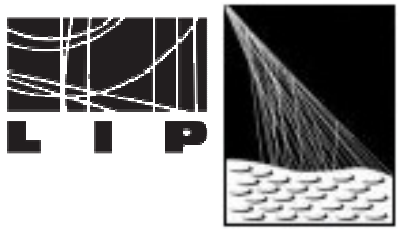
EXTENSIVE AIR SHOWERS – EAS COMPONENTS

Proton or nuclei initiated showers:



- Hadronic
  - $\pi^0 \rightarrow \gamma\gamma$
  - $\pi^{\pm} \rightarrow \mu^{\pm} + \upsilon$
- Electromagnetic
  - $\gamma \rightarrow e^+ + e^-$
- Muons
  - $\mu^{\pm} \rightarrow e^{\pm} + \upsilon_{\mu} + \upsilon_{e}$
- Neutrinos

EXTENSIVE AIR SHOWERS – MUONS IN EAS



- Messengers of the high energy hadronic interactions ocorring high in the atmosphere
- Small attenuation
  - Few muons decay
  - Small energy loss
- Very penetrating
- Sensitive to the primary composition and energy

$$N_\mu^A = A\left(\frac{E_0/A}{\varepsilon_\pi}\right)^\beta = A^{1-\beta} N_\mu^p \qquad \text{(Superposition Principle)}$$

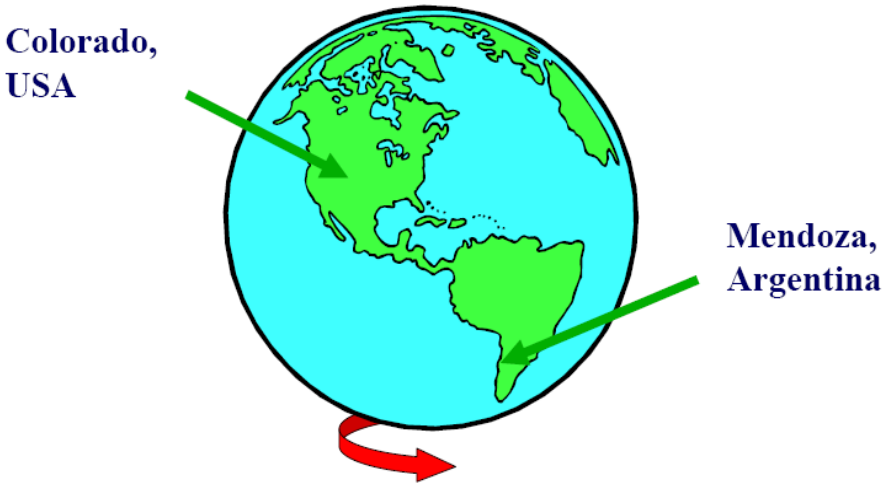
ß is model dependent!

PIERRE AUGER OBSERVATORY

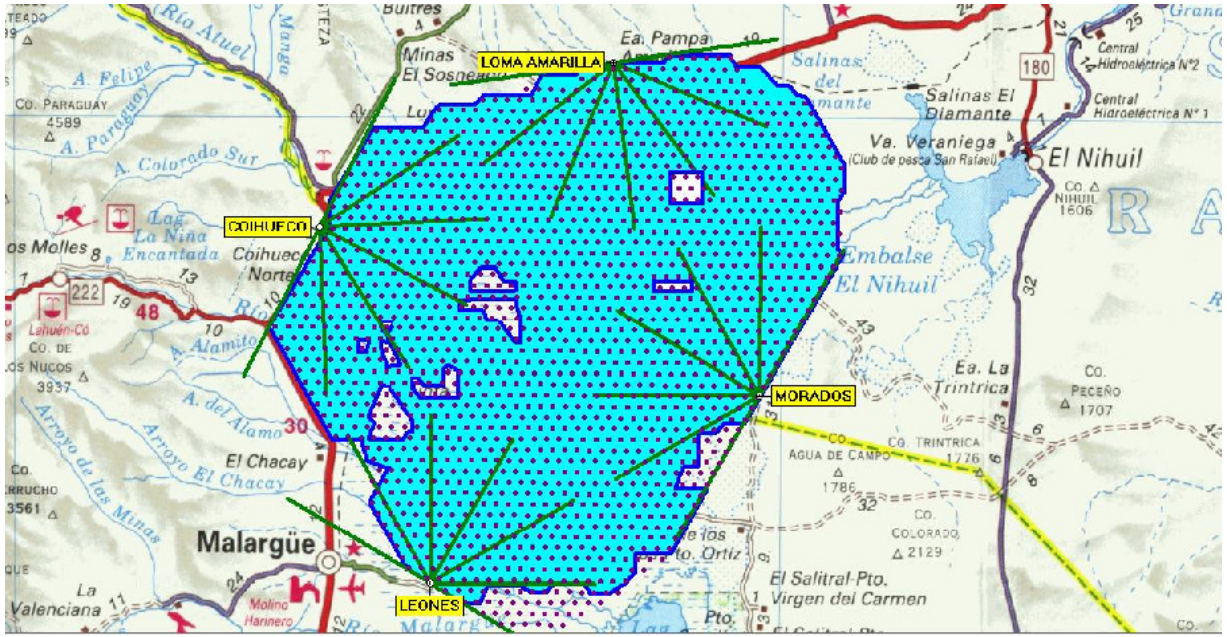
- Study the origin and composition of the highest energy cosmic rays ($E > 3 \times 10^{18}$ eV)

- Hybrid observatory
  - Fluorescence Detectors (FD)
  - Surface Detectors (SD)

- Full sky coverage
  - Southern site:
    - Malargüe, Argentina
    (3000 km^2 - complete)
  - Northern site:
    - Lamar, USA
    (21000 km^2 – in study)



PIERRE AUGER OBSERVATORY – THE SOUTHERN SITE

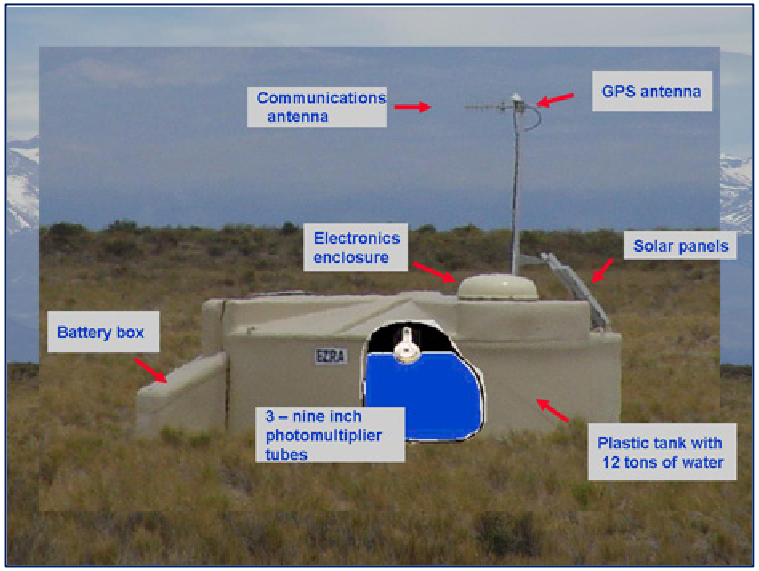


Malargüe, Argentina

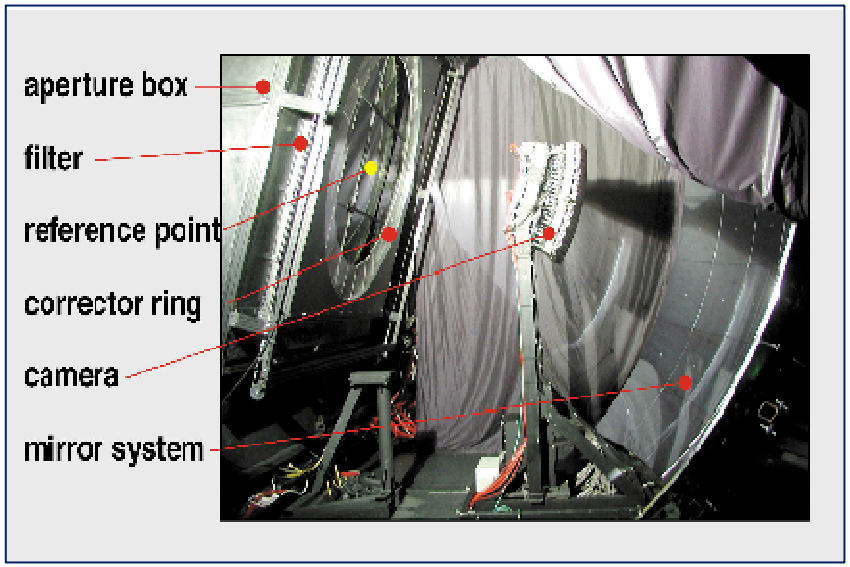
- 3000 km^2
  - 1600 Čerenkov water tanks – Surface Detectors
  - 4 Fluorescence Eyes
    - 6 fluorescence telescopes per eye

PIERRE AUGER OBSERVATORY – THE SOUTHERN SITE (II)

A Surface Detector



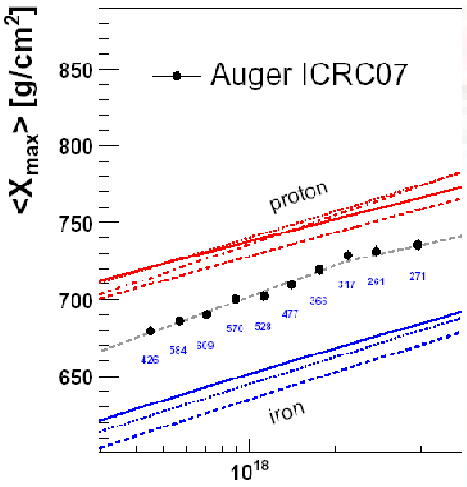
A Fluorescence Telescope

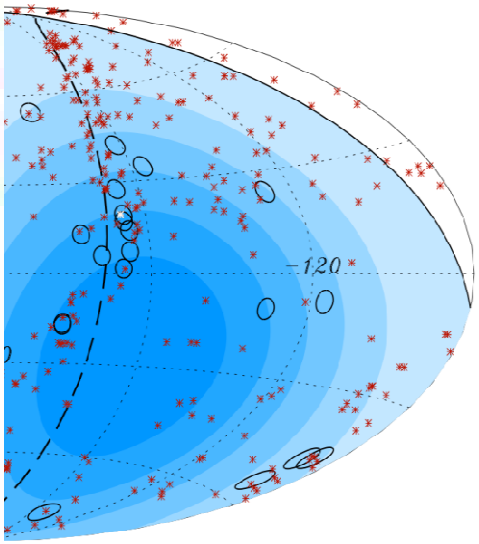


Lateral shower profile
(Electromagnetic component + Muons)

Longitudinal shower profile
(Electromagnetic component)

PIERRE AUGER OBSERVATORY RESULTS





Elongation ra lts for UHECR:
Trend to a **heavy** **ed composition**

Slopes are mode nsity of extra-
Galactic magnetic fields

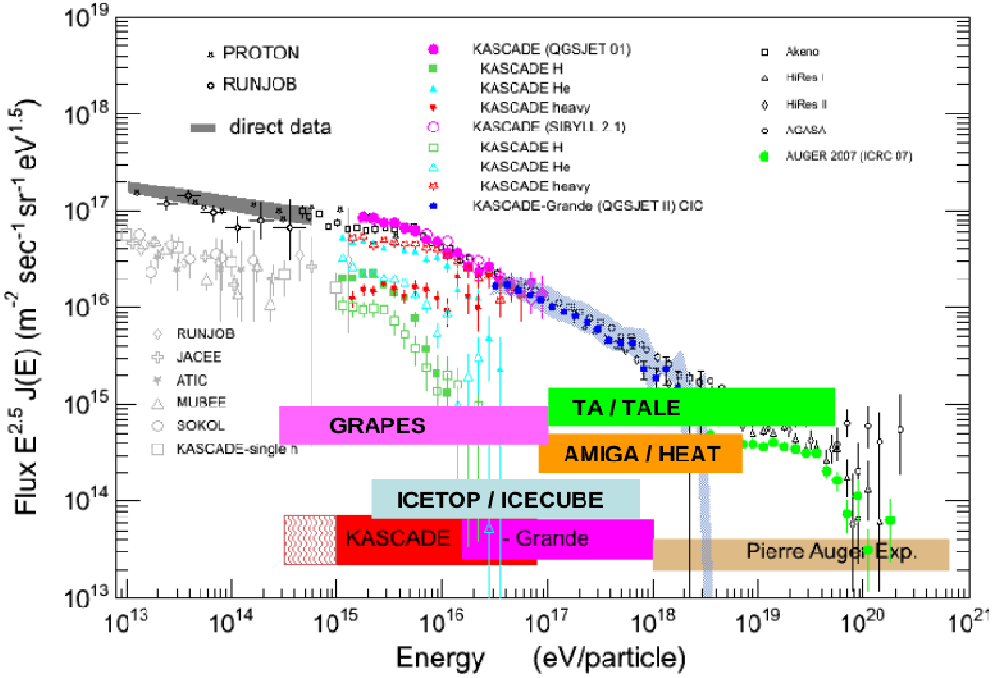
Muons can help to solve this mistery!

AMIGA

Auger Muons and Infill for the Ground Array

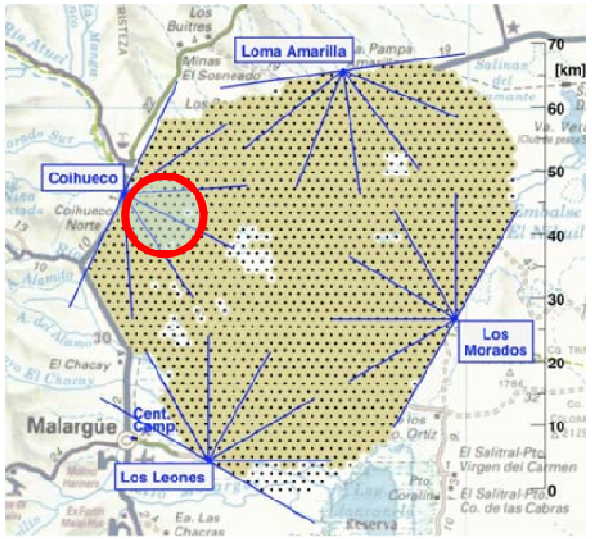
Low energy extension of Auger South

(10^{17} < E < 10^{19} eV – Second knee and ankle region)

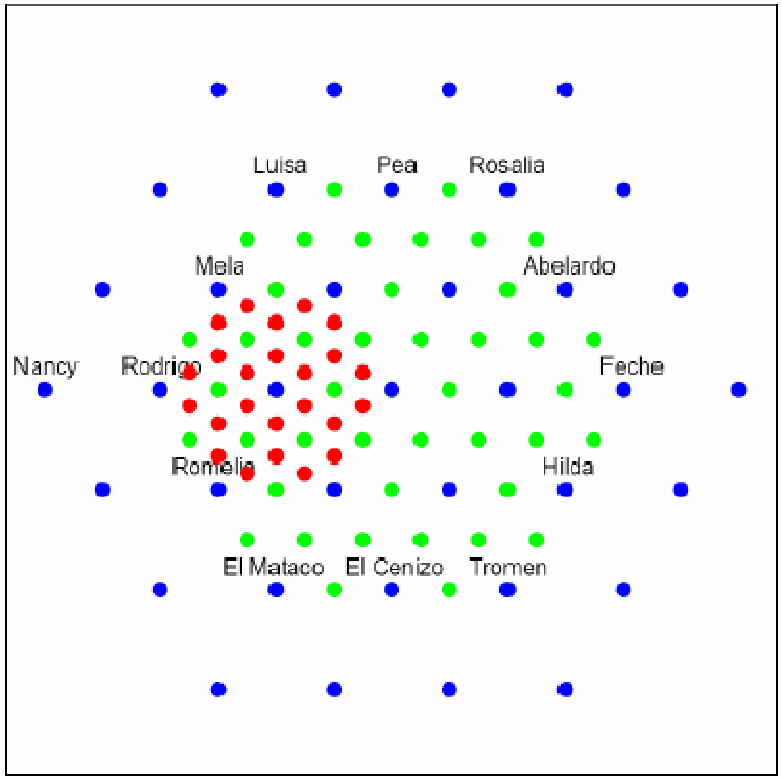


Infilled area

- SD tanks
- Buried muon counters



AMIGA –
THE AMIGA LAYOUT

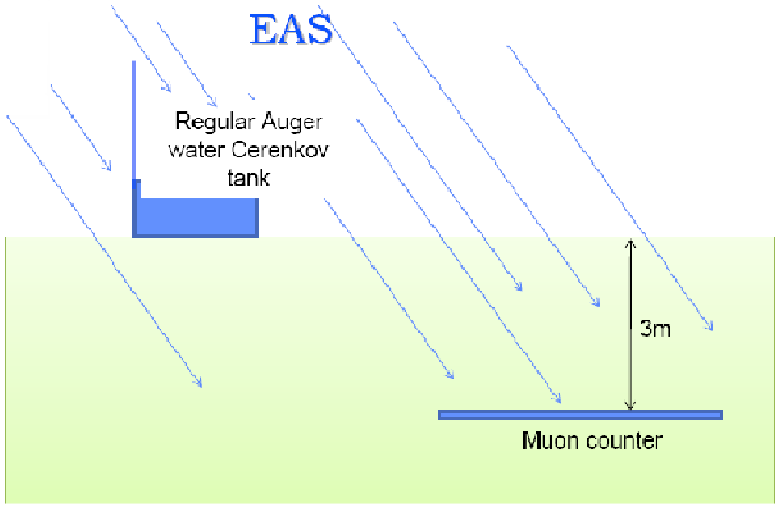


2 Infill arrays:

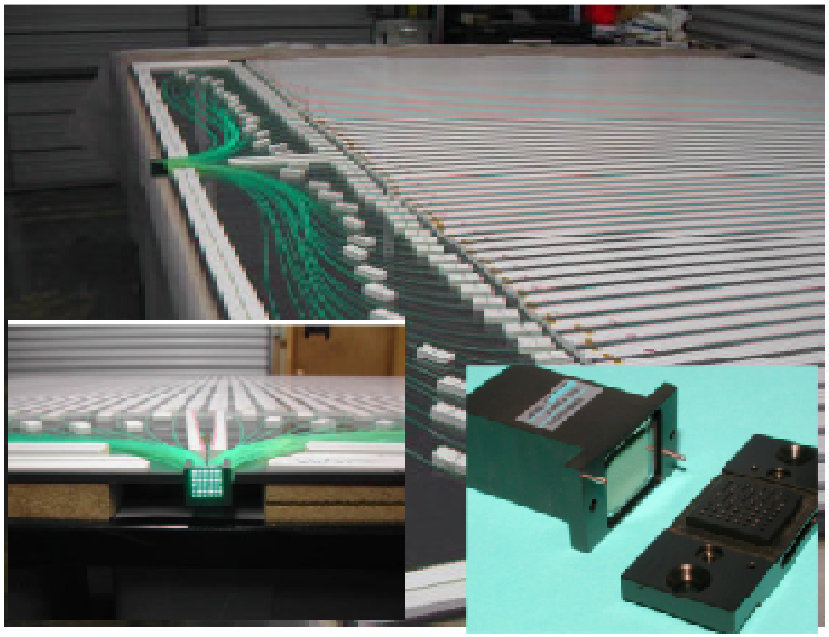
- **750 m**
  - 23.5 km^2
  - E > 3.5 × 10^{17} eV
  - 61 pairs of detectors
- **433 m**
  - 5.9 km^2
  - E > 10^{17} eV
  - 43 pairs of detectors

AMIGA –
THE MUON COUNTERS PLACEMENT

- Placed at ~3 m underground
  - Shielding against e.m. component
- Trigger given by the nearest SD tank
- Horizontal displacement w.r.t. the SD tank
  - Avoid shadow effects
- Shared GPS & communication signals



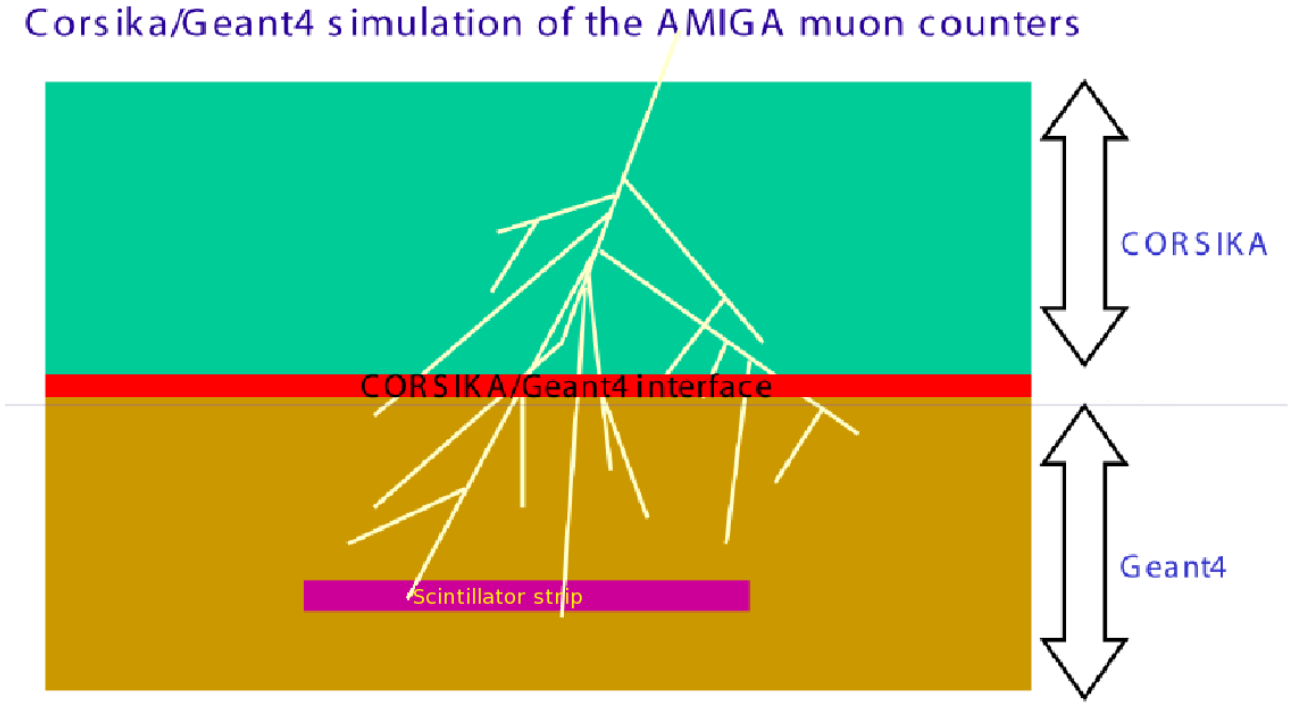
AMIGA –
THE MUON COUNTERS



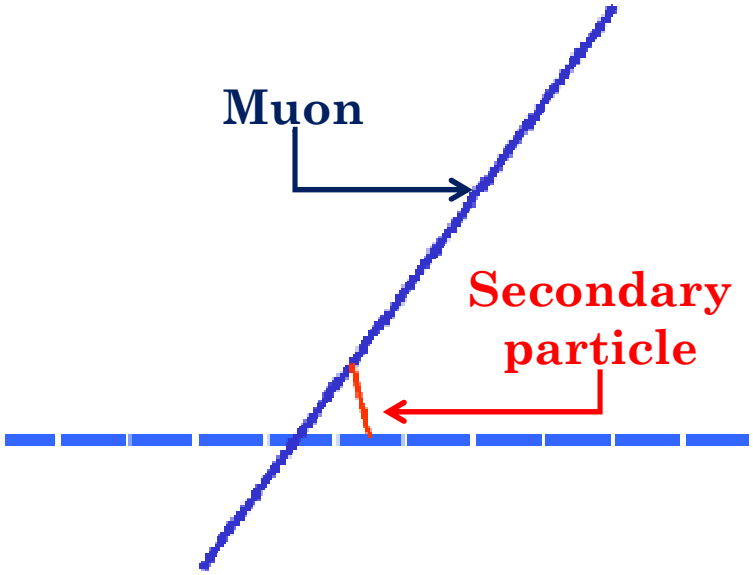
- 30 m^2
- 3 × 64 polystyrene slabs
  - 4 m × 4.1 cm × 1 cm
  - Optical fiber glued in each slab
- Fibers bundled and read by a 64 channel MAPMT
- Pile-up : only one muon counted
  - per slab
  - per time interval

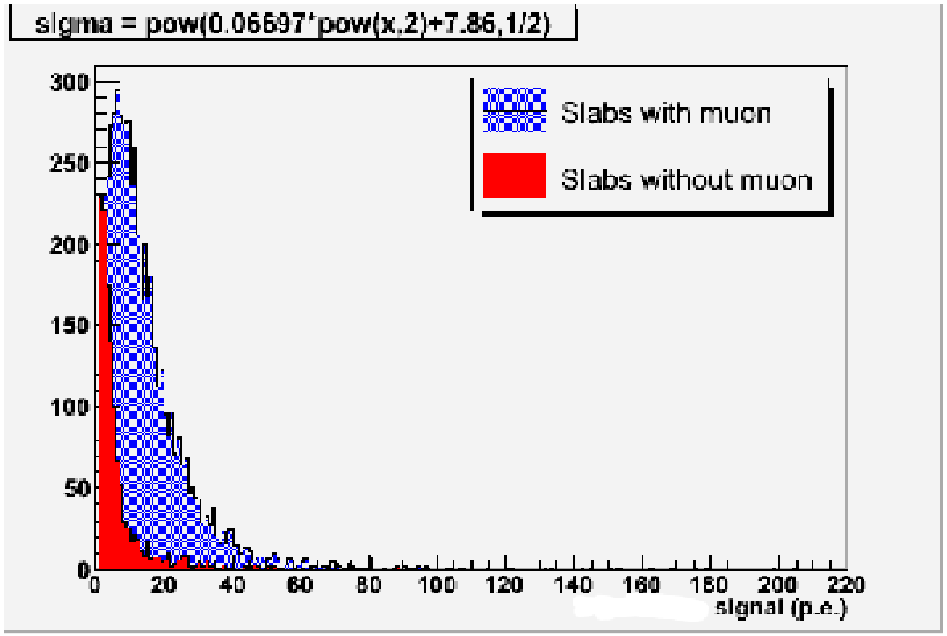
AMIGA SIMULATIONS AT LIP – THE SIMULATION FRAMEWORK

- EAS simulation on the atmosphere with CORSIKA
- Particle tracking and propagation on the soil with Geant4



AMIGA SIMULATIONS AT LIP – MULTI-HIT PATTERNS FROM THE MUONS SECONDARY PARTICLES





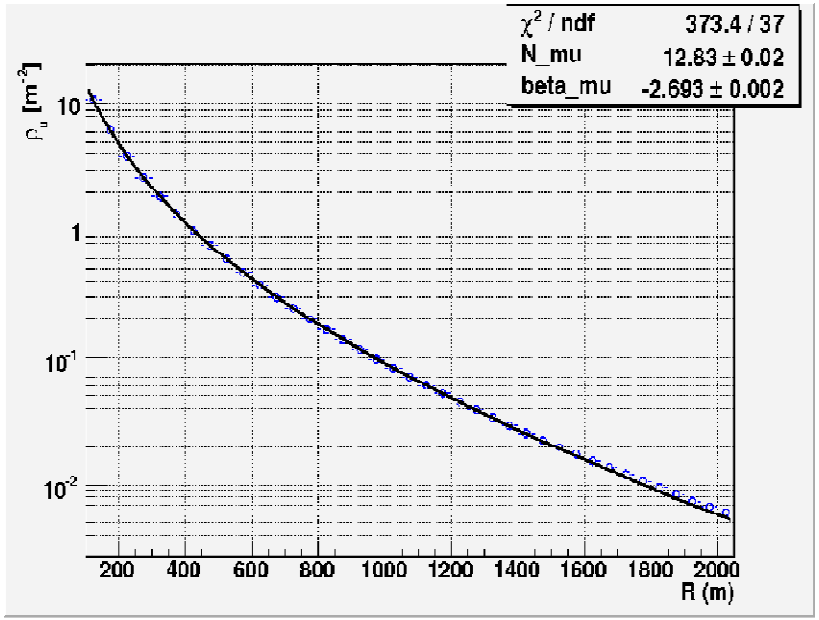
Multi-hit event

~10 % contamination by multi-hit events

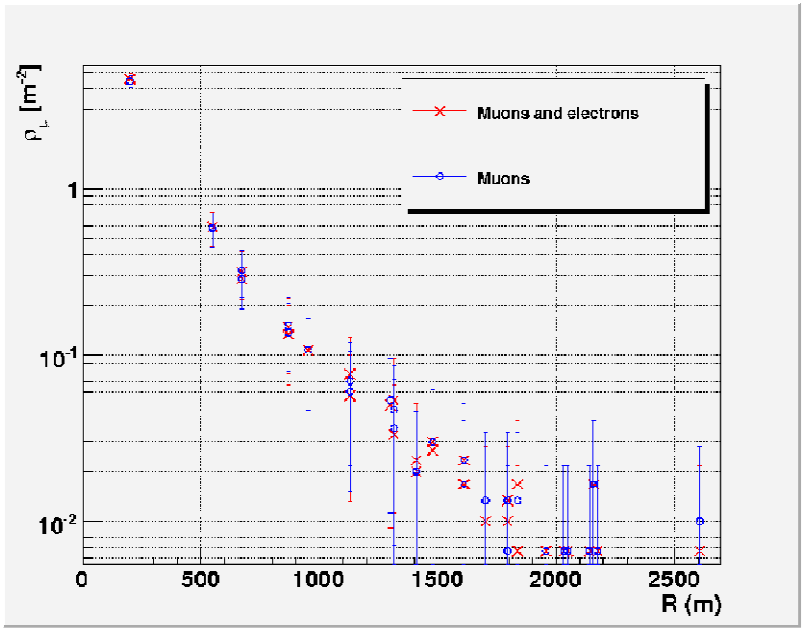
AMIGA SIMULATIONS AT LIP –
THE AMIGA MUON LATERAL PROFILE

Simulations for 750 m array:

- Muon detectors placed at 2.5 m depth (450 g / cm^2)



Ideal detector

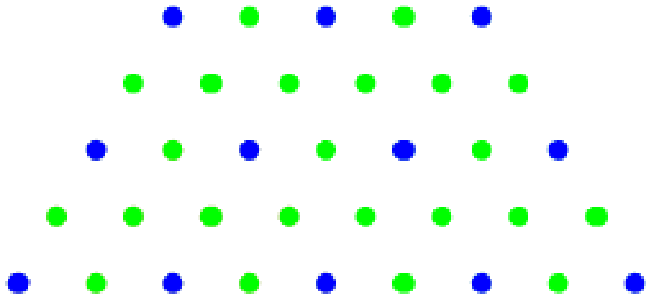


Real detector
Secondaries + Pile-up

The Muon LDF slope will shed new light towards the high energy hadronic models

PROSPECTS AND CONCLUSIONS

- AMIGA will allow a direct and independent measurement of the muon content for the Auger Observatory
- One muon detector prototype already buried and taking data
- Half of the 750 m infill tanks deployed and taking data
- A unitary cell comprising 7 muon counters and SD tanks taking data by March 2011



Thanks for your attention!