Cosmic ray Physics in ALICE
Guy's Contribution

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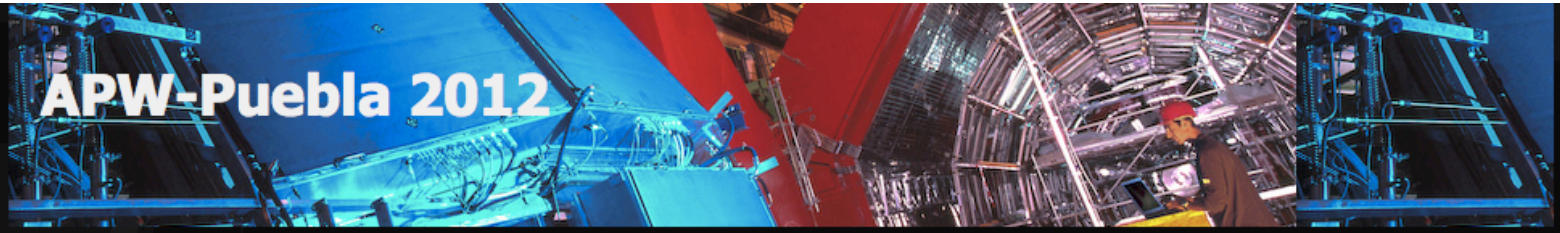
Outline

- Cosmic Ray Physics in ALICE
- ALICE Cosmic ray detector
  - Design, Construction,
  - Integration, Data taking
  - Data Analysis
- G. Paic have contributed in ALL this activities!!!
- Summary

Open issues in heavy-ion physics: symposium in honor of

Guy Paic

December 2, 2012.



The ALICE Physics Week will be held at the Autonomous University of Puebla from 27 November to 1 December

APW-Puebla will bring together members of the ALICE collaboration to discuss on their latest research progress and is the seventh in the series; following APW05(Erice), APW07(Munster), APW08 (Prague), APW10 (Paris), APW11 (Jyvaskyla) and APW12(Frascati).

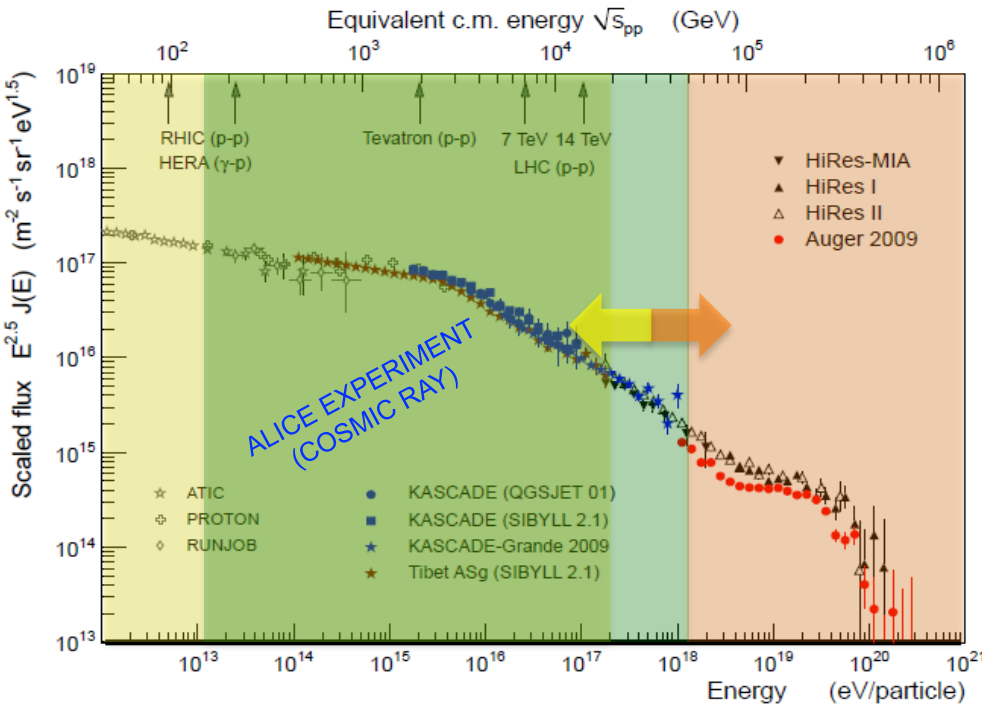
Open issues in heavy-ion physics: symposium in honor of Guy PAIC

As a separate but connected event, we will be celebrating Guy Paic's 75th birthday from Saturday 1 December afternoon until Sunday 2 December in the evening.

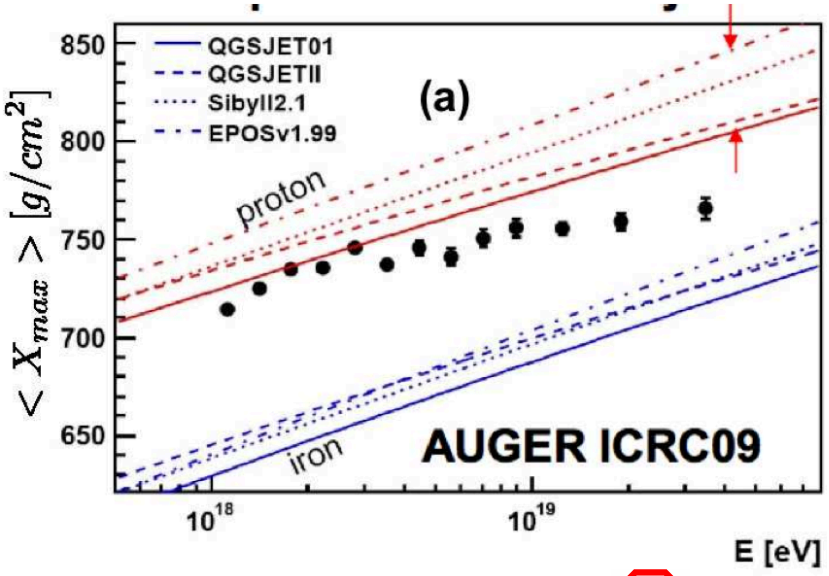
Programme

The scientific programme is now available. Visit the event page

Physics topics

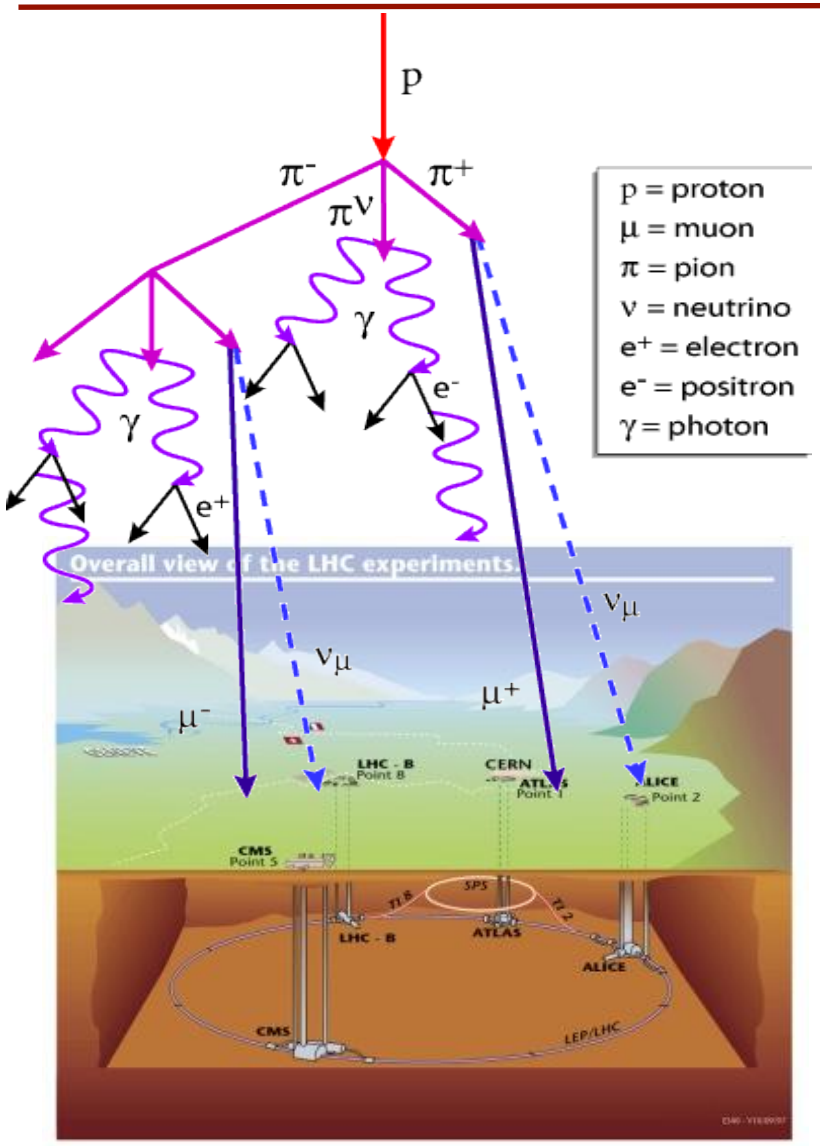


The origin and nature of cosmic rays with energies between 10^{15} eV and the Greisen-Zatsepin-Kuzmin (GZK) cutoff at about 10^{20} eV, recently measured by the HiRes and Auger experiments, remains a central open question in high-energy astrophysics. One key to solving this question is the determination of the elemental composition of cosmic rays in this energy range.



The candidate particles, ranging from protons to nuclei as massive as iron, generate "extended air-showers" (EAS) in interactions with air nuclei when entering the Earth's atmosphere. Due to their low observed flux, only indirect (yet complementary) measurements are possible using the atmosphere as "calorimeter".

Physics topics



With the ALICE's detectors it is possible to detect those muons coming from the cosmic ray that reaches the P2.

Topics of interest in Cosmic ray analysis in ALICE:

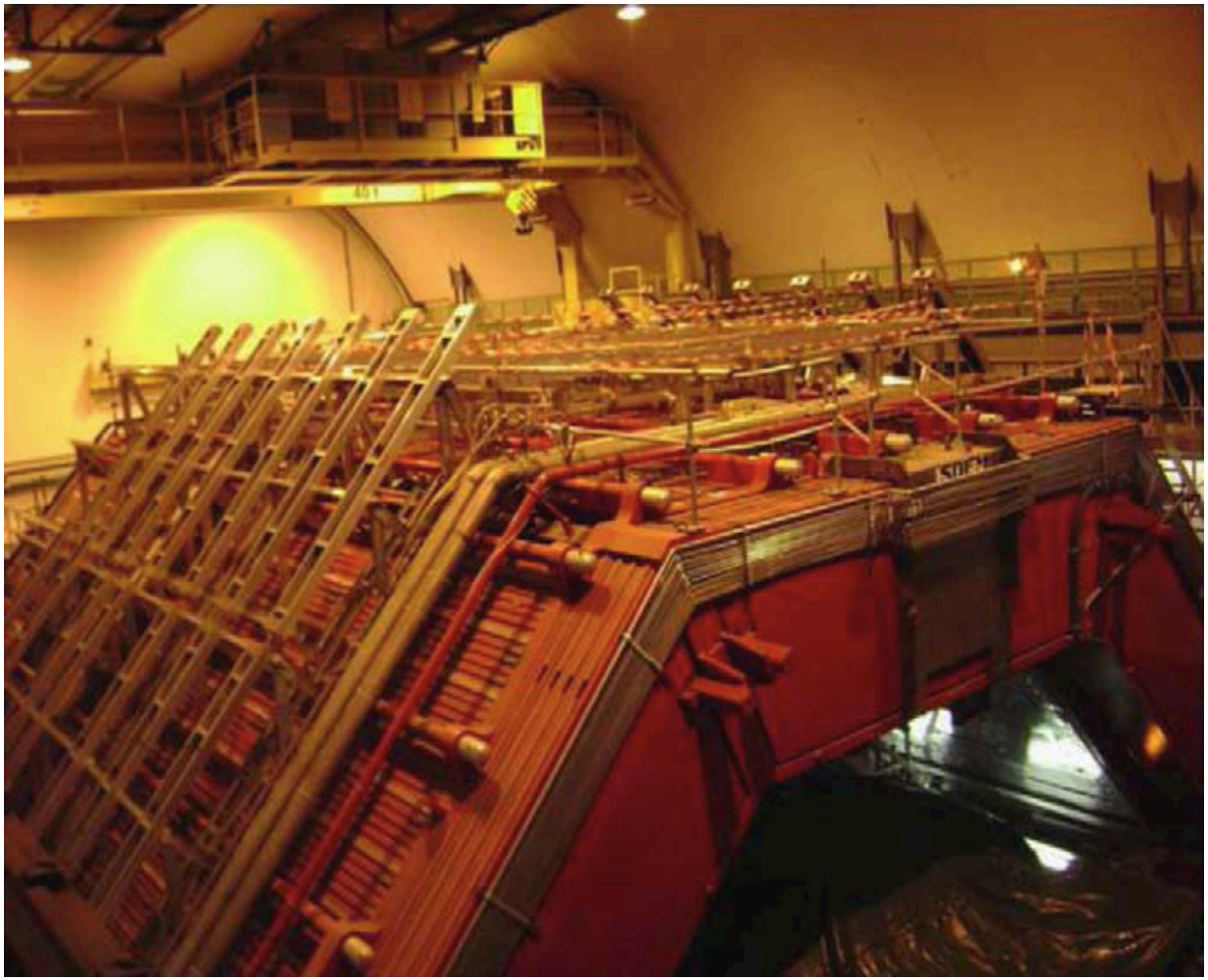
- **Muon multiplicity distribution (in progress)**
  - **Study of cosmic muon bundles (in progress)**
- **μ^+/μ^- charge ratio measurement (in progress)**
- **Study of cosmic horizontal muons**

ALICE located 40 m. underground

- 30 m of rock (molasse)
- 10 m of air

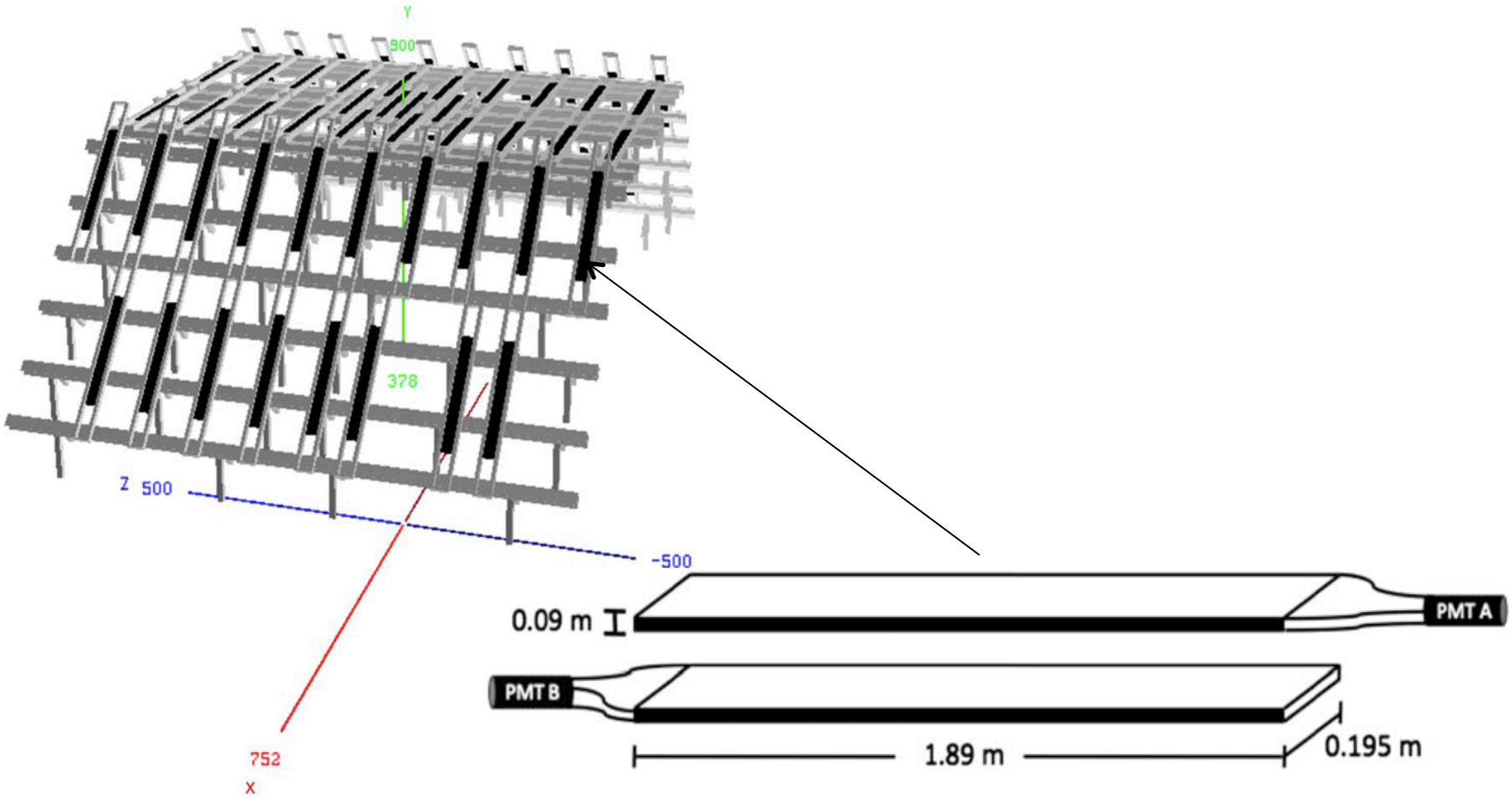
Threshold Muon Energy ~ 15 GeV

ACORDE



The subdetector ACORDE is used to trigger on atmospheric muons in ALICE. consists of an array of 60 scintillator modules located on the three top octants of the L3 magnet.

ACORDE



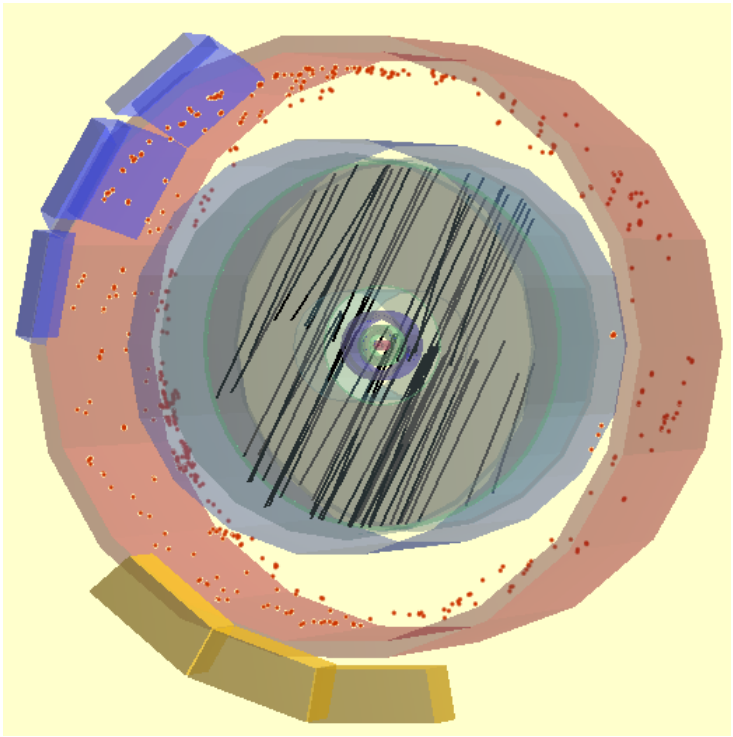
Each module consists of two superimposed plastic scintillator paddles with an effective area of 0*i376m2*

- **Data Analysis**

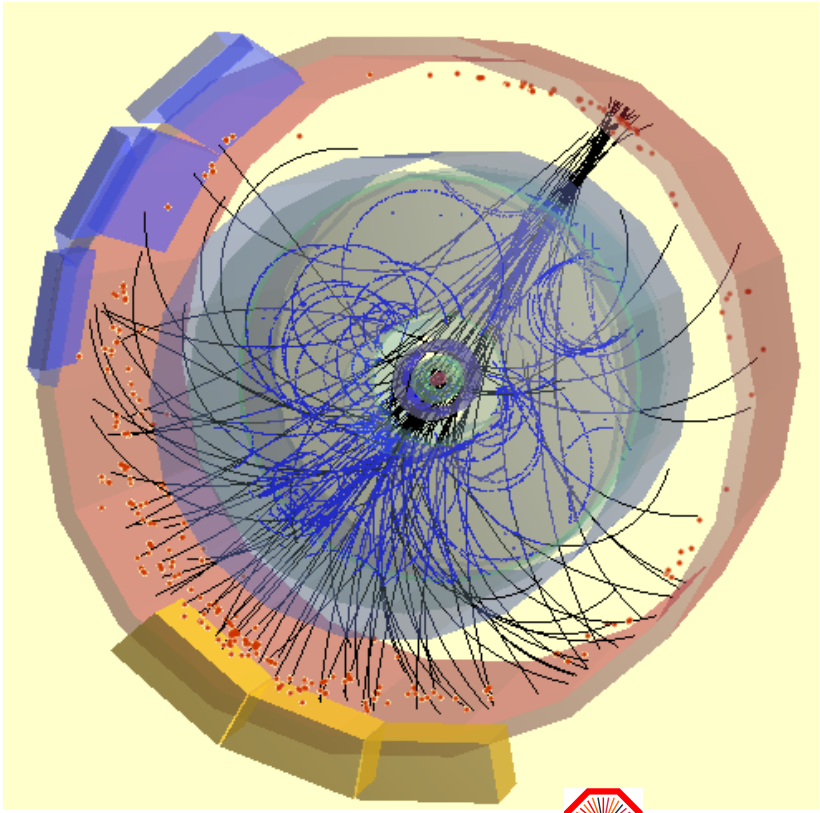
TIME PROJECTION CHAMBER (TPC) :

ALICE TPC Collaboration, J. Alme et al., "The ALICE TPC, a large 3-dimensional tracking device with fast readout for ultra-high multiplicity events.", Physics. Ins-Det/ 10011950 (2010).

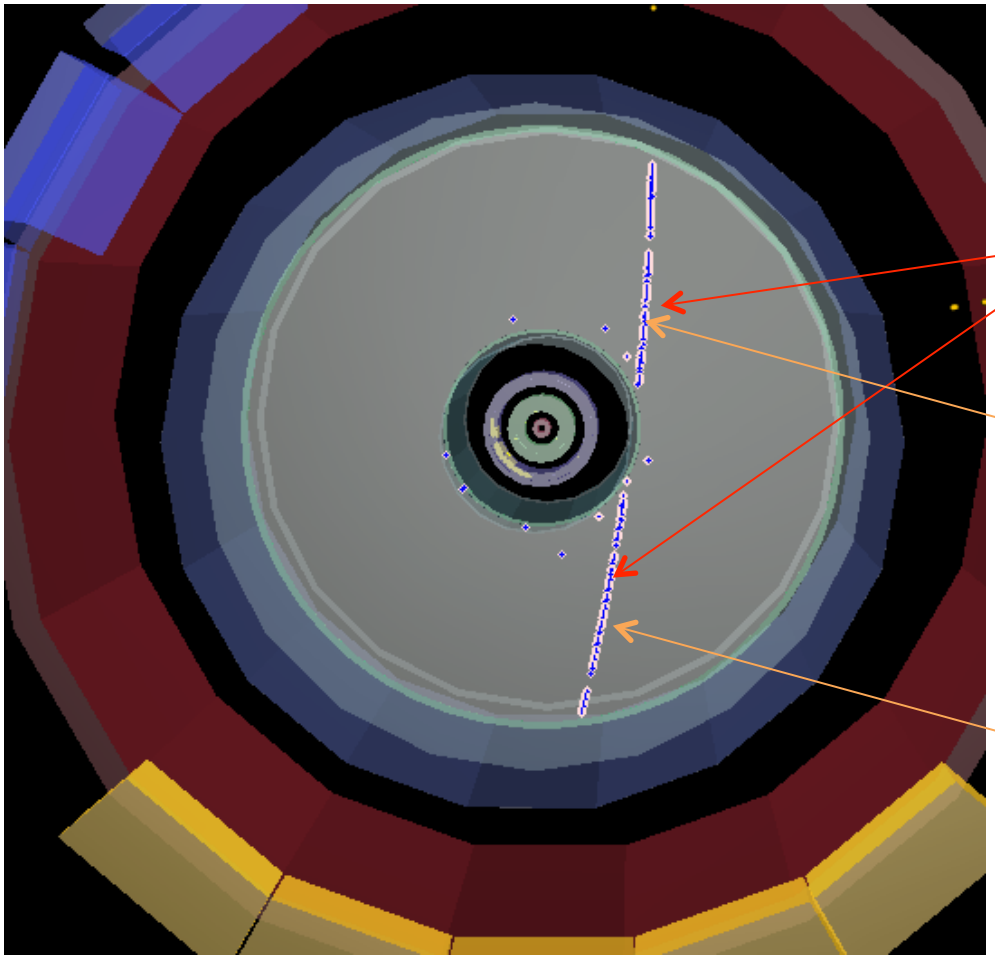
Muon Interaction Event



Standard Muon Event (multimuon)



- **Data analysis**



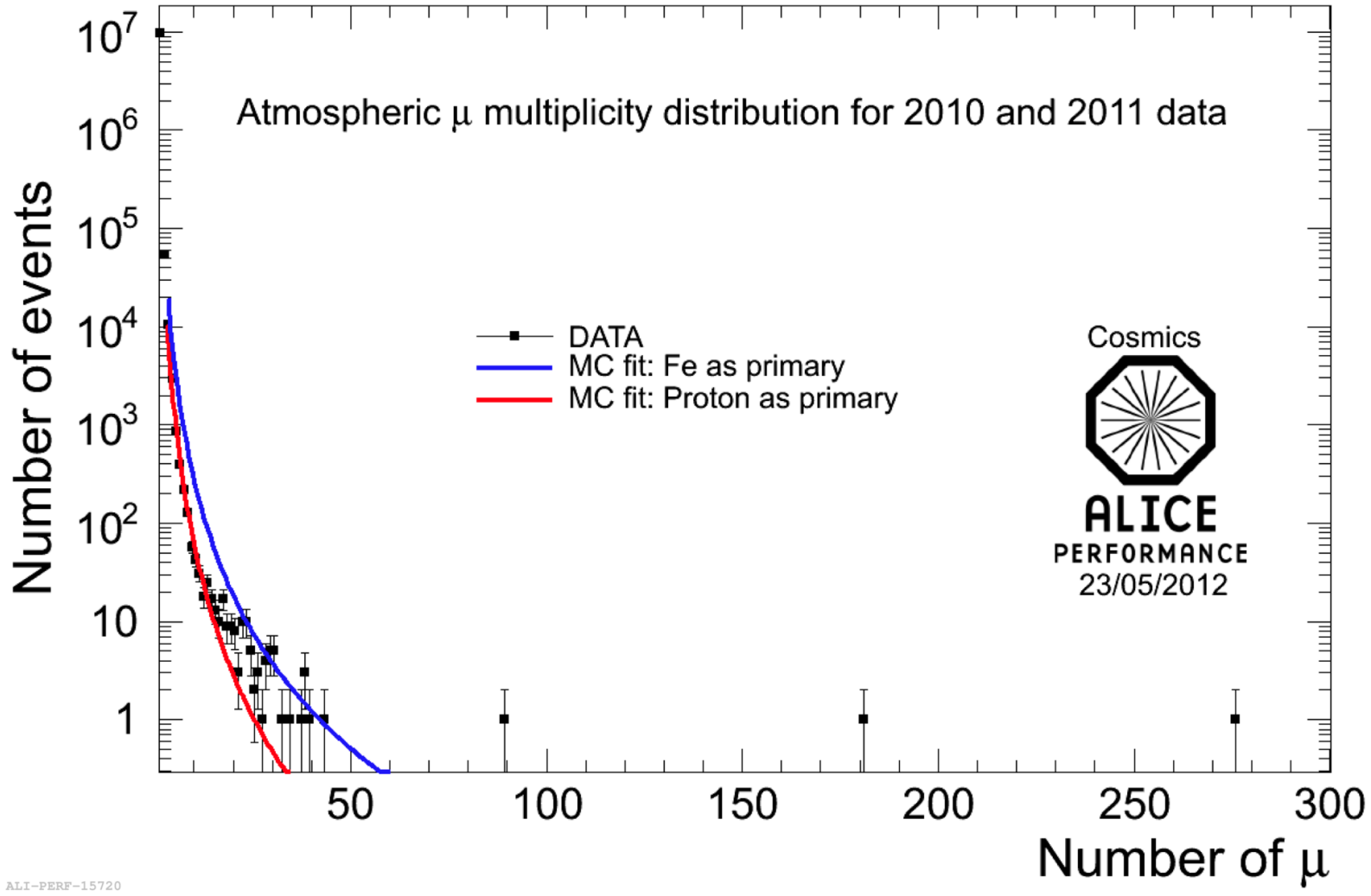
In general, by each single charged particle the TPC reconstructs 2 tracks.

Energy reconstructed for the Up-track: 3.9 GeV

Energy reconstructed for the Down-track: 3.5 GeV

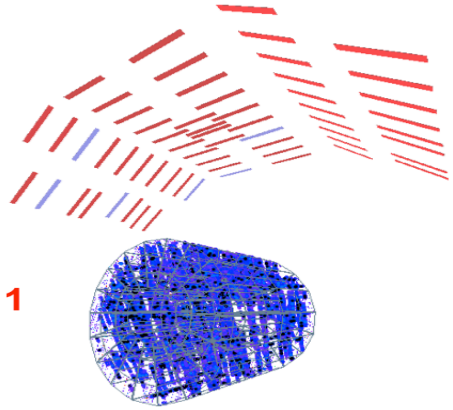
A matching algorithm that connects the track up with down to count one muon, thus the momentum is given for the two tracks : Pup and Pdown

Status of the analysis

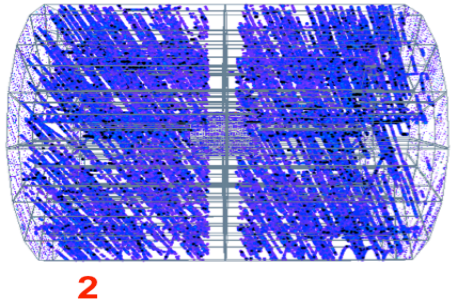


Status of the analysis

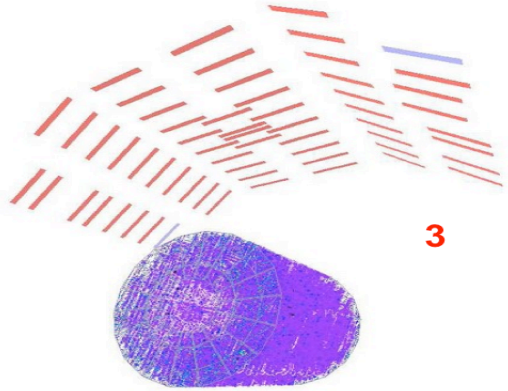
4-6 events per year

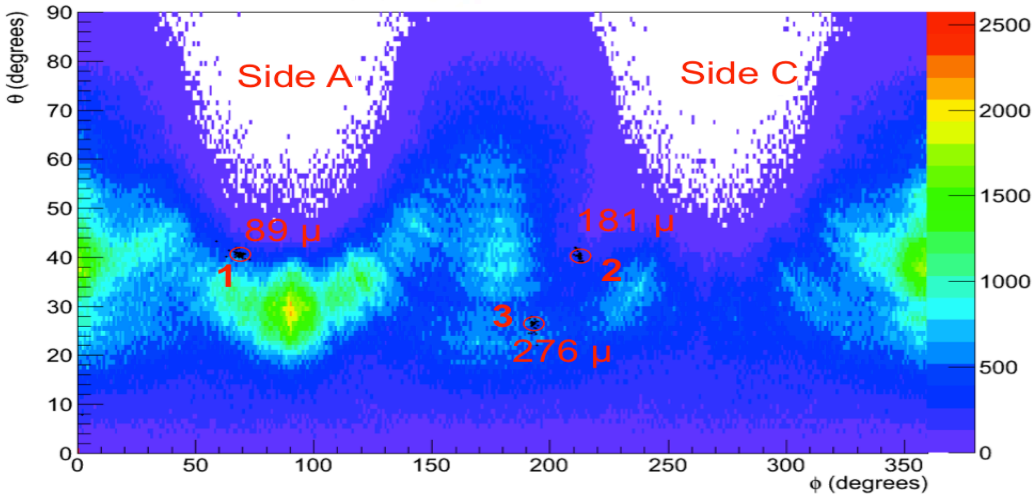


1-2 events per year



1 event every 4-5 years





- **Data analysis**

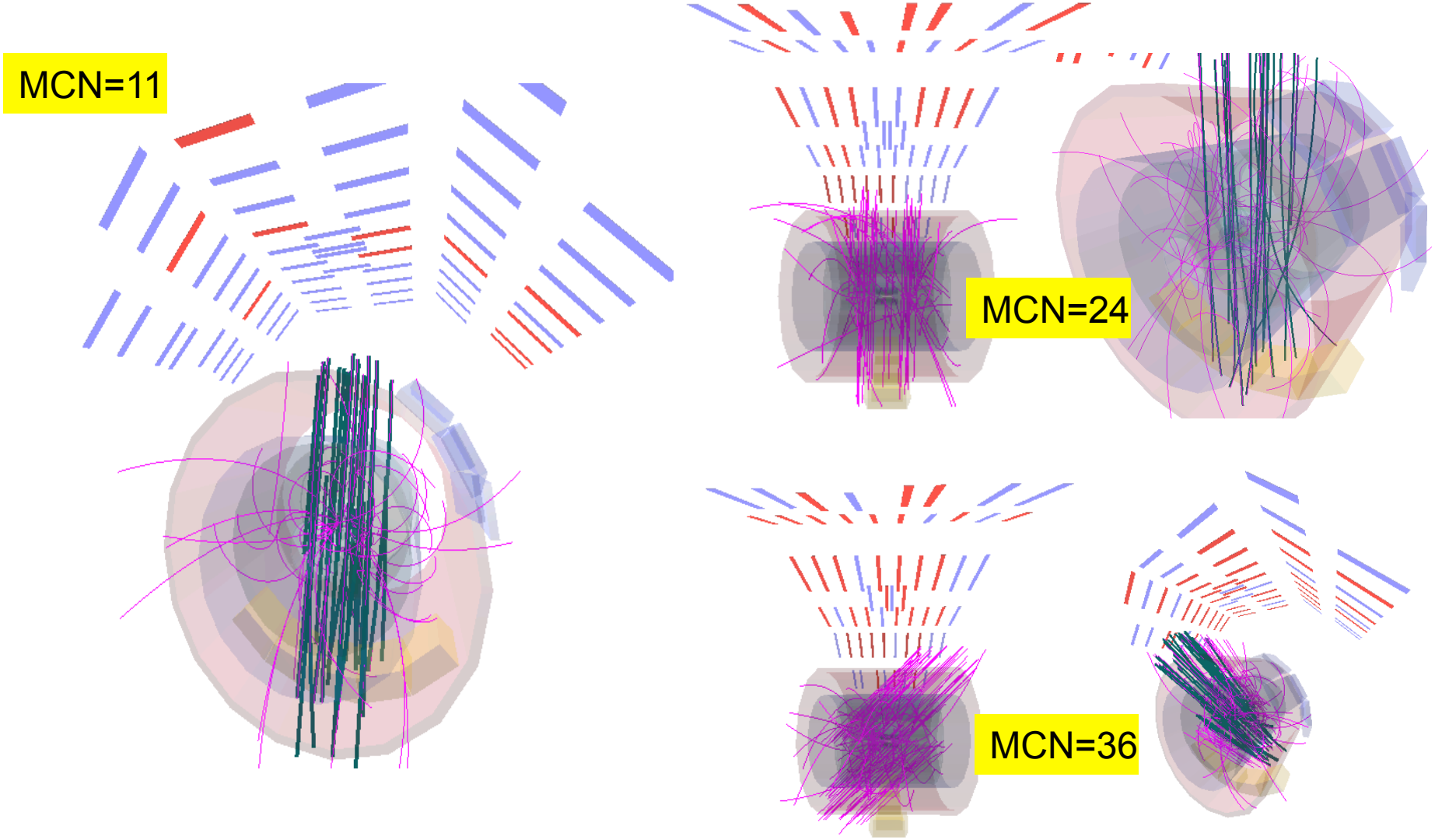
Parameters which characterize the multi muon events detected by ALICE in 2010 and 2011 data

# of μ	density [#μ/m^2]	Energy of Primary Cosmic Ray (eV)	Θ [degrees]	ϕ [degrees]	Mean momentum (GeV/c)
276	17	5*10^{16}	26	193	18
181	12	2*10^{16}	40	212	98
89	6	10^{16}	40	70	82

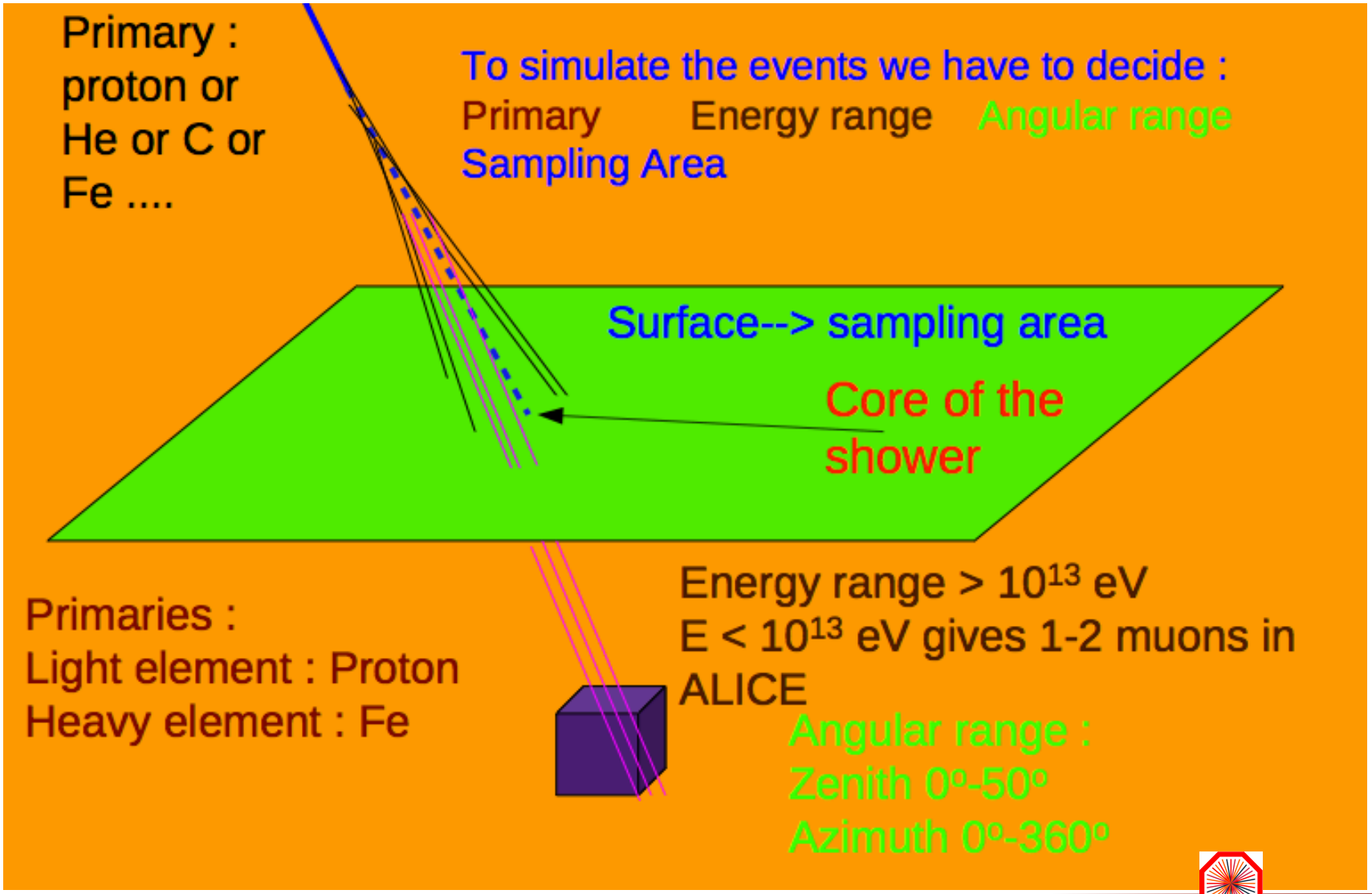
RESULTS PUBLISHED BY LEP EXPERIMENTS

	DELPHI	COSMO-ALEPH	L3 + C	ALICE
Max. number of atmospheric μ reconstructed	127 μ (EPCR<10^{16}eV)	149 μ (EPCR~10^{16}eV)	110 μ (EPCR~10^{16}eV)	276 μ

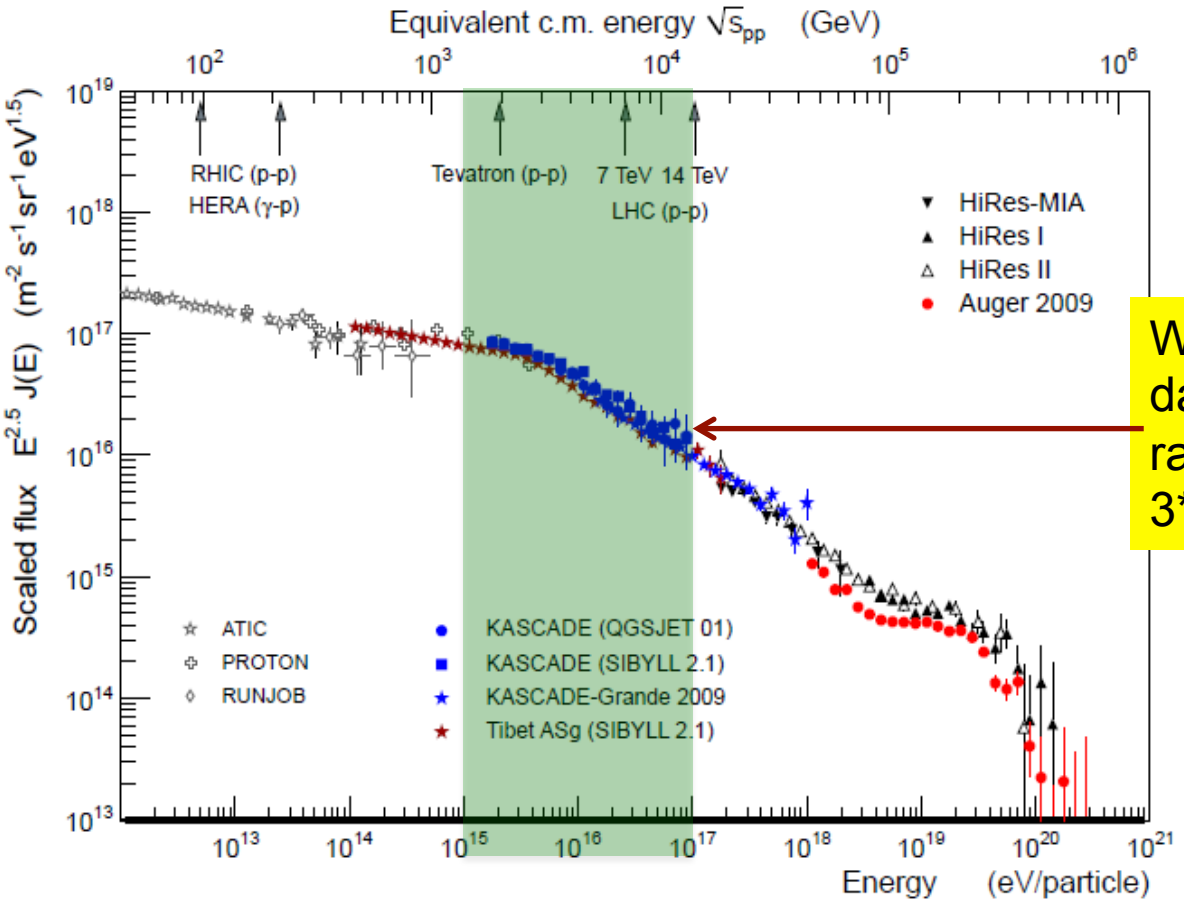
- **ACORDE trigger in p-p runs!!**



- **MC analysis**


Primary :
proton or
He or C or
Fe ....
To simulate the events we have to decide :
Primary
Energy range
Angular range
Sampling Area
Surface--> sampling area
Core of the shower
Primaries :
Light element : Proton
Heavy element : Fe
Energy range > 10^{13} eV
E < 10^{13} eV gives 1-2 muons in ALICE
Angular range :
Zenith 0°-50°
Azimuth 0°-360°

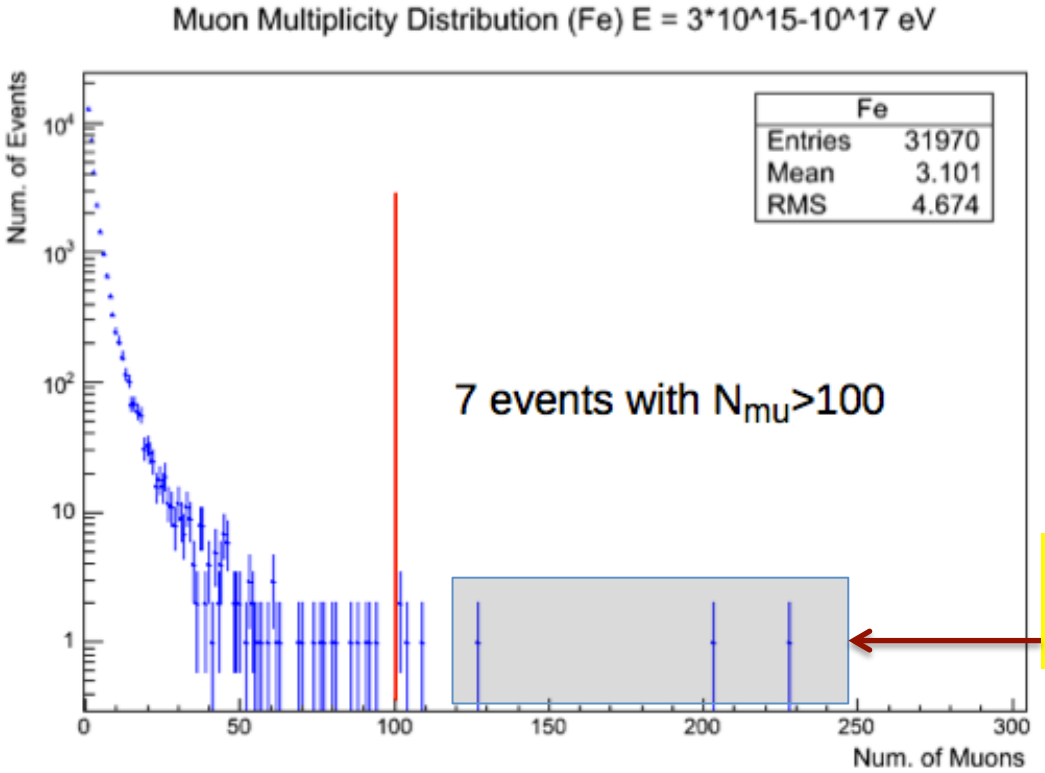
MC analysis

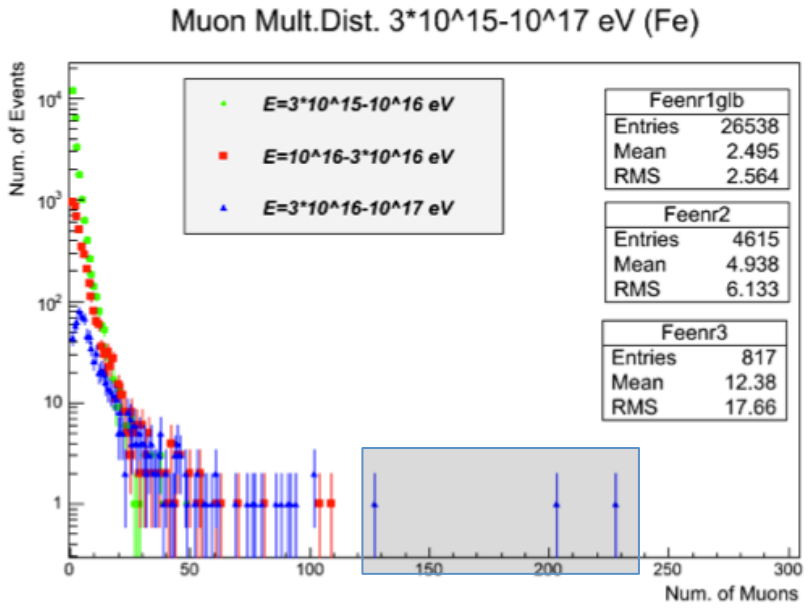


We have simulated 36.5 days of data for Fe as primary cosmic ray with an energy between $3*10^{15}$ eV – 10^{17} eV

Status of the analysis

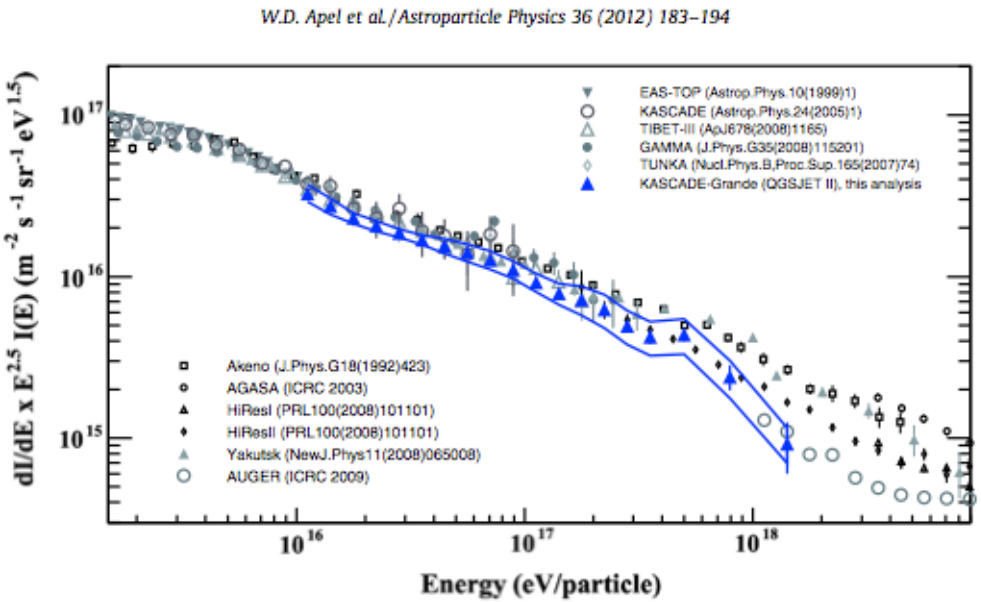
Results for 36.5 days with simulated data





Energy range of the primary cosmic ray (Fe): $3*10^{16}$ eV – 10^{17} eV

Status of the analysis



KASCADE-Grande has shown a first evidence that at about 8*10^{16} eV the spectrum of the heavy component of primary cosmic rays shows a kneelike break. The spectral steepening occurs at an energy where the charge dependent knee of primary iron is expected, when the knee at about 3–5*10^{15} eV is assumed to be caused by a decrease in the flux of primary protons (PRL 107, 171104 (2011)).

The all-particle energy spectrum in the range from 10^{16} eV to 10^{18} eV is found to exhibit some smaller structures: In particular, a hardening of the spectrum is observed at 2 *10^{16} eV and a small break-off at around 8 *10^{16} eV. These features are used to discuss the astrophysics in the transition region from galactic to extragalactic origin of cosmic rays, where a final conclusion is not possible without detailed knowledge of the elemental composition in this energy range. However, amongst others, the model proposed by Hillas (A M Hillas 2005 *J. Phys. G: Nucl. Part. Phys.* **31** R95), e.g., which assumes a second component of galactic cosmic rays in addition to the standard SNR component, can explain the observed features of the measured all-particle energy spectrum.

Can ALICE contribute to the KASKADE-Grande results?

ACORDE- Guy:

- Design (G. Herrera, CERN discussions, 2002)
- Electronics (Together with S. Vergara, G. Tejeda, 2003-205)
- Characterization (A. Ortíz, S. Roman 2005-2007)
- Installation at Cern (everybody, 2005-2006)
- Integration to ALICE CTP (I. León, G. Herrera 2007-2008)
- Data taking (2008-2012 →….)
- Analysis (B. Alessandro, M. Rodriguez, E. Cuautle,
- Phys. Forum Discussions)

ACORDE group thanks the

ADVICE,
GUIDNESS AND
FRUITFULL DISCUSSIONS

FROM PROFESSOR GUY PAIC.

FELICIDADES, GUY !!!