COSMIC RAY PHYSICS IN THE ALICE EXPERIMENT

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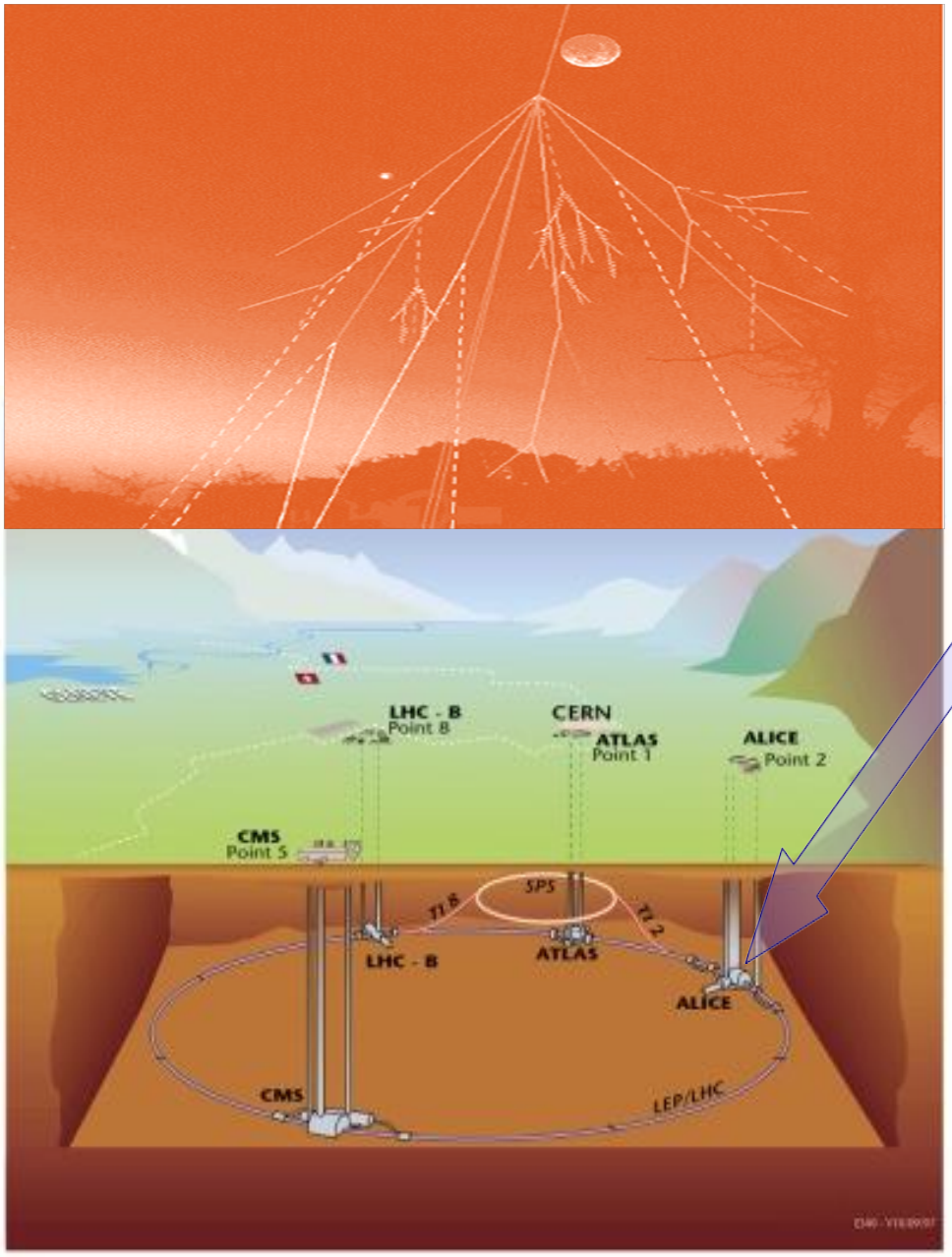
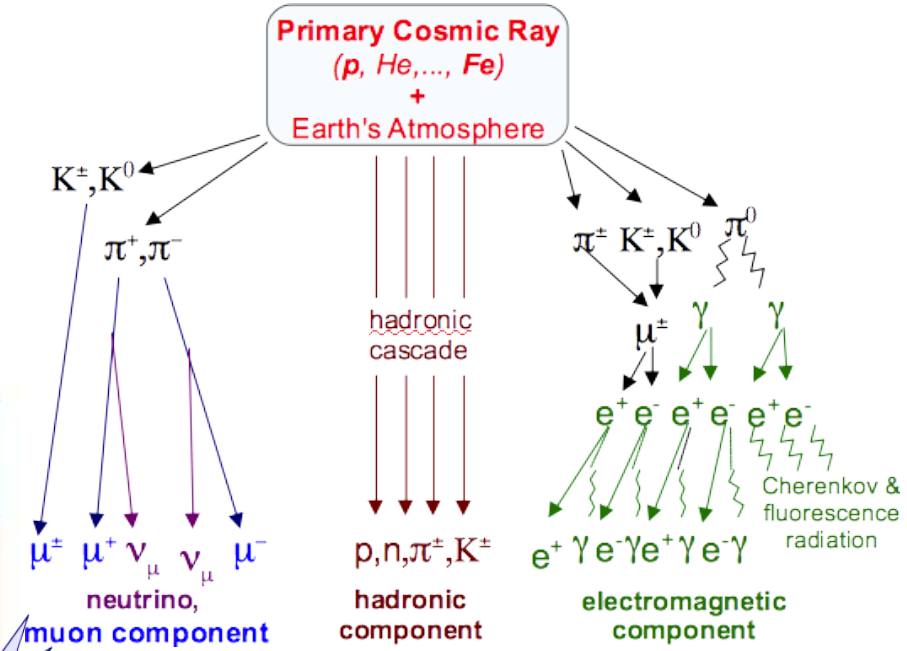
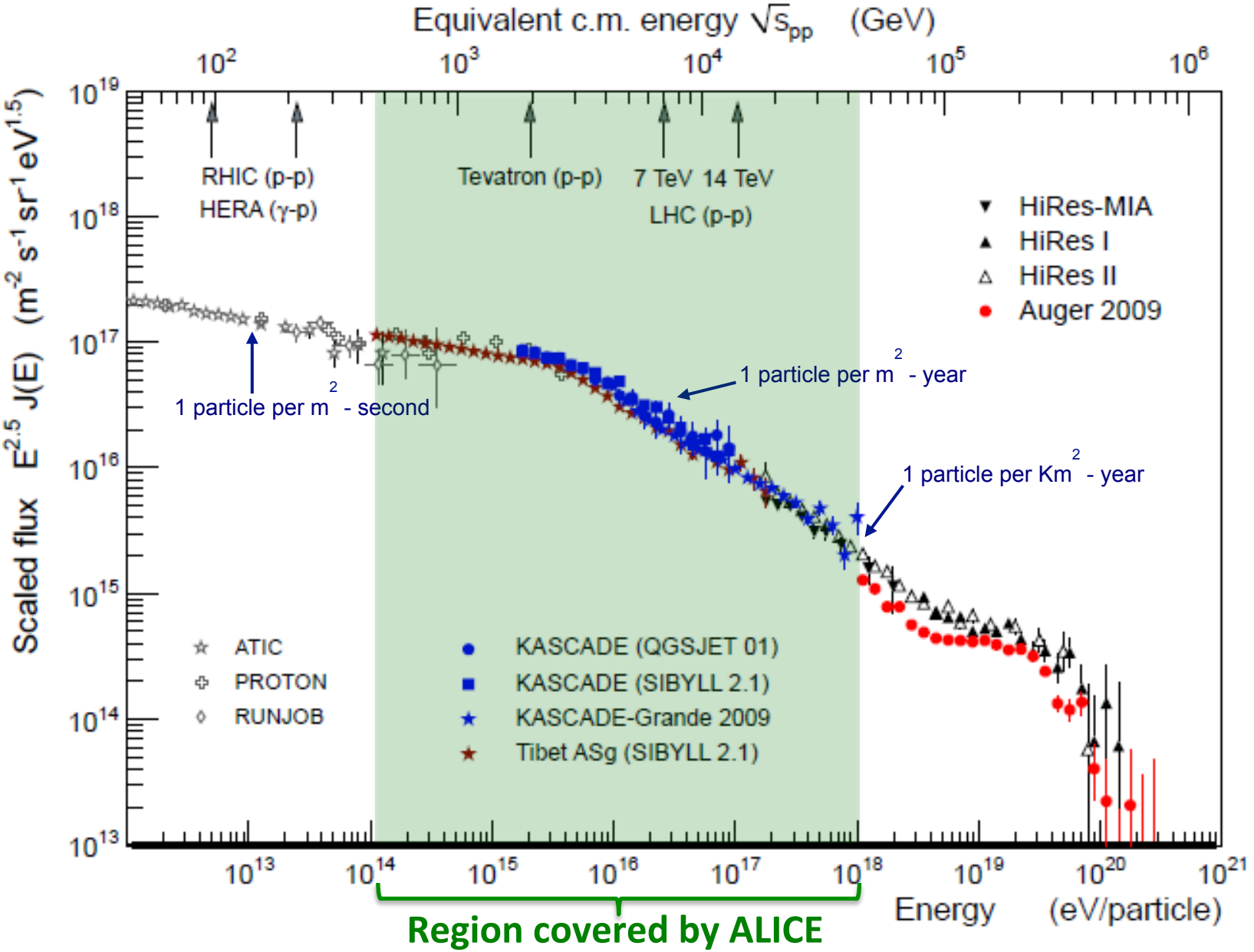
Detection of atmospheric muons in ALICE





ALICE is located 52 meters underground with 28 meters of overburden rock. The rock absorbs all of the electromagnetic and hadronic components of the observed EAS, so that only muons with a surface energy $E \geq 16$ GeV reach the detector.

Primary energy spectrum



Cosmic data taking (Run I)

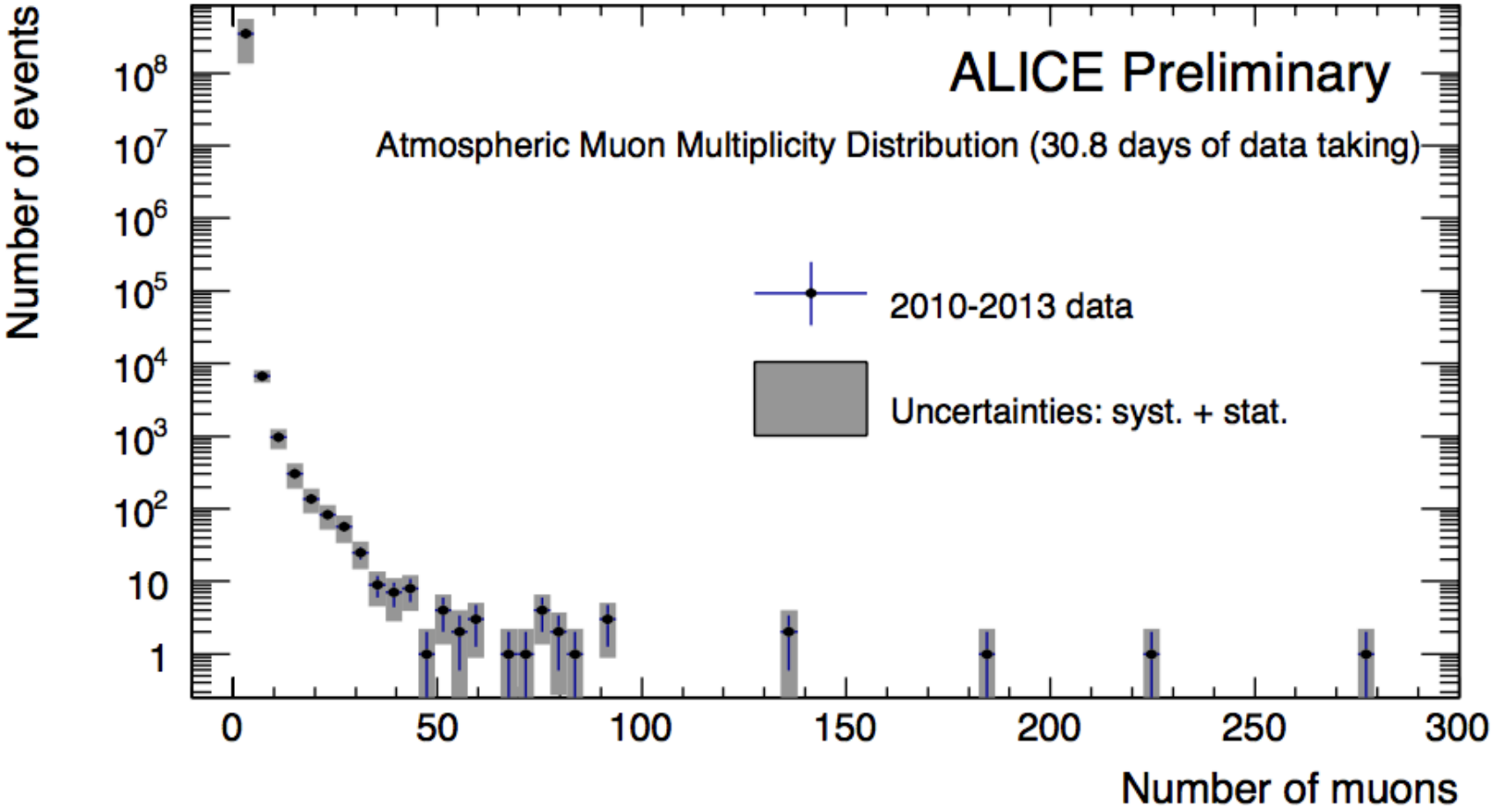
Between 2010 and 2013, ALICE collected several millions of events during the cosmic data taking sessions with standard cosmic triggers.

Year	Days of data taking	B ≠ 0	B = 0
2010	4.45	3.34	1.11
2011	13.71	12.94	0.77
2012	10.02	7.85	2.17
2013	2.63	2.60	0.03
Total	**30.81**	**26.73**	**4.08**

The large size and excellent tracking capability of the ALICE Time Projection Chamber was exploited to register and analyze cosmic muon events. It was used to reconstruct the trajectory of cosmic muons passing through the active volume of the detector. Muons are reconstructed as two tracks, one in the upper half (up track) and the other in the lower half (down track), which are matched to create a single muon track.

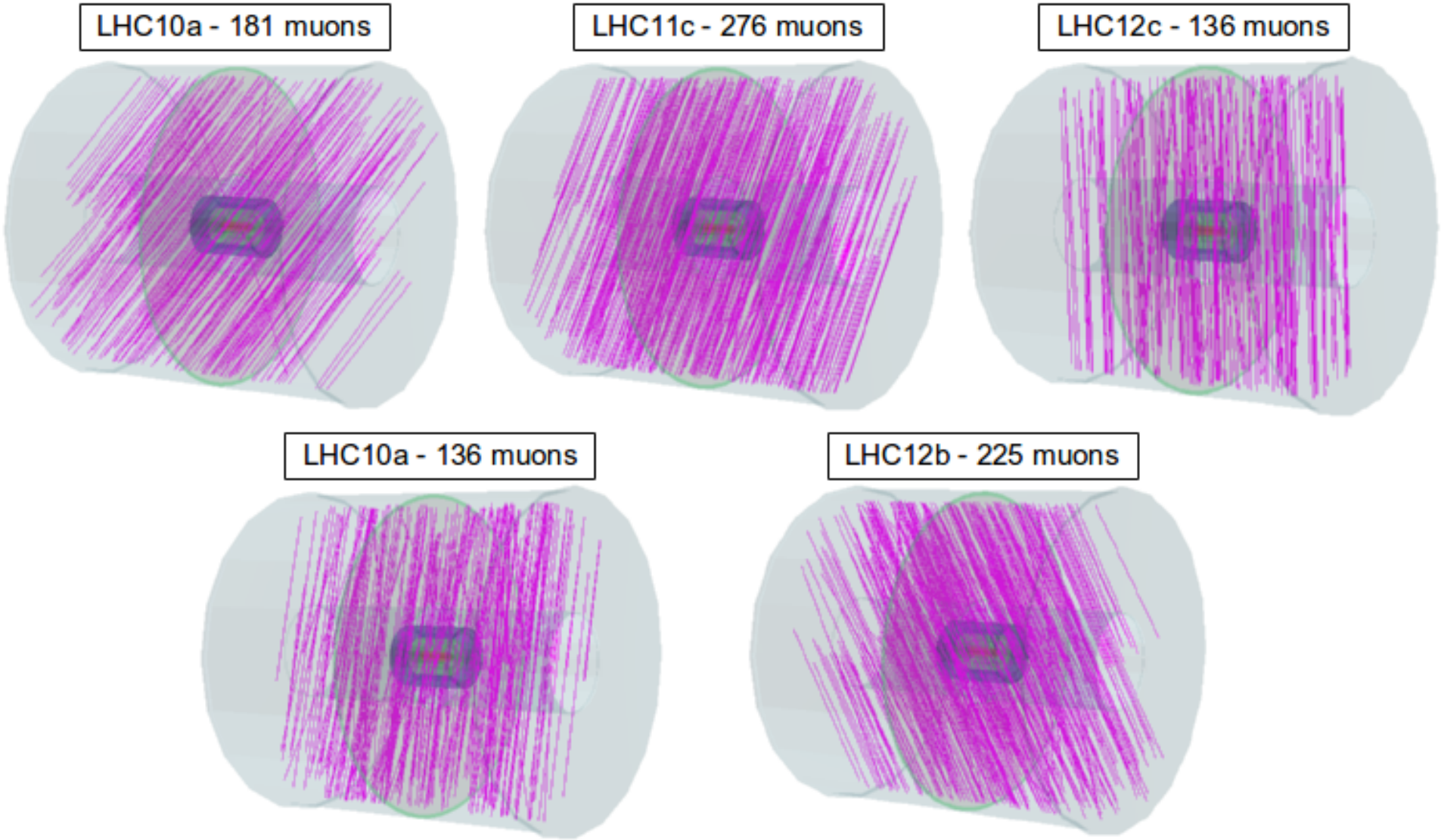
Muon Multiplicity Distribution (MMD)

Data Analysis



ALICE collected **5 high muon multiplicity events** (with more than 100 atmospheric muons) during 30.8 days of data taking in the period 2010-2013.

High muon multiplicity events (HMM)



Monte Carlo to study MMD and HMM

- We adopted CORSIKA[1] with QGSJET[2] as interaction model for the primary cosmic ray interaction with the atmosphere:

CORSIKA version 6990
QGSJET II-03

CORSIKA version 7350
QGSJET II-04

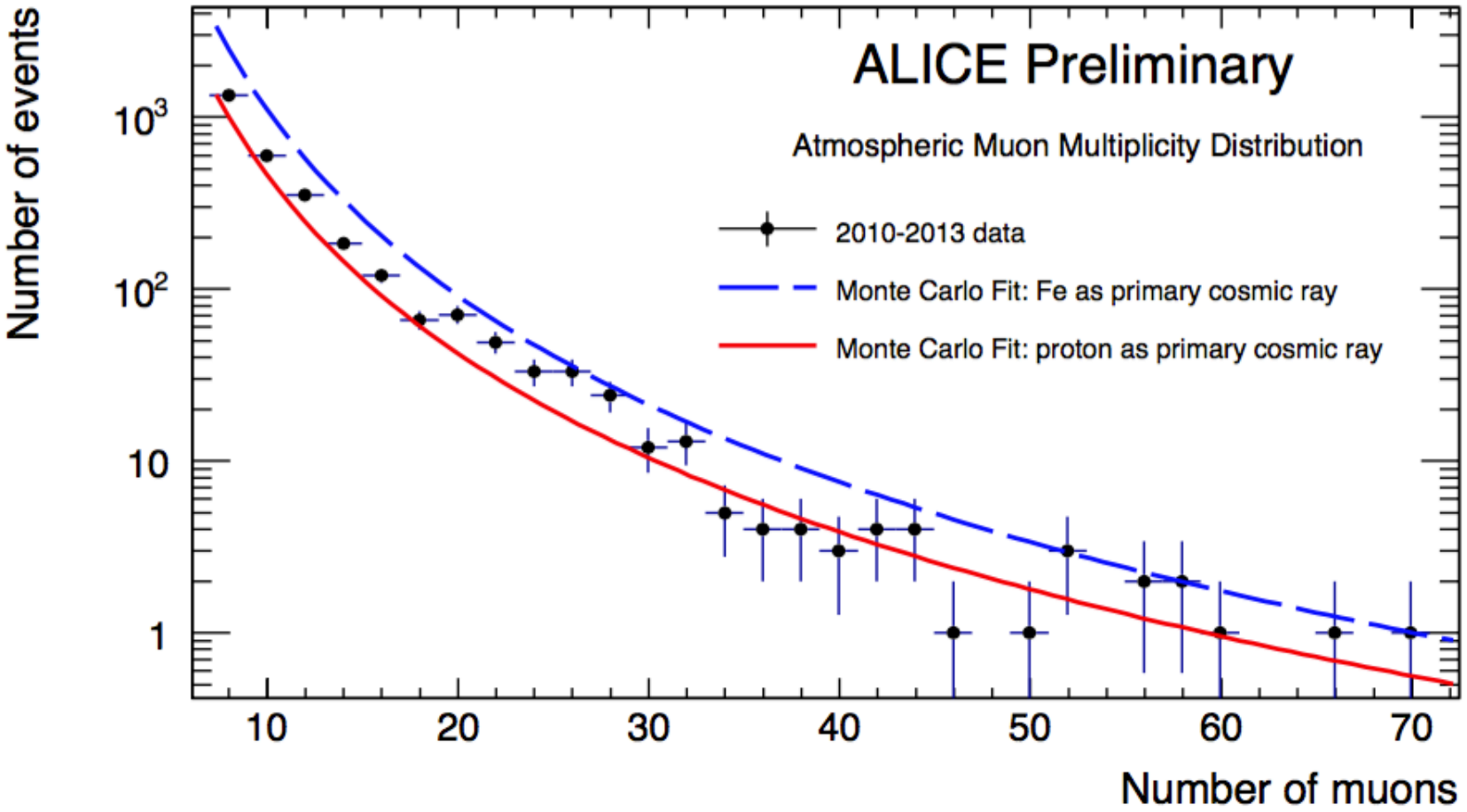
} To study muon multiplicity distribution at low-intermediate multiplicity and high muon multiplicity events

CORSIKA: COsmic Ray SImulation for KAscade

[1] D. Heck et al., Report FZKA 6019 (1998), Forschungszentrum Karlsruhe
http://www-ik.fzk.de/corsika/physicsdescription/corsikaphys.html
[2] S. S. Ostapchenko, Nucl. Phys. B (Proc. Suppl.) 151, 143 (2006); Phys. Rev. D 74, 014026

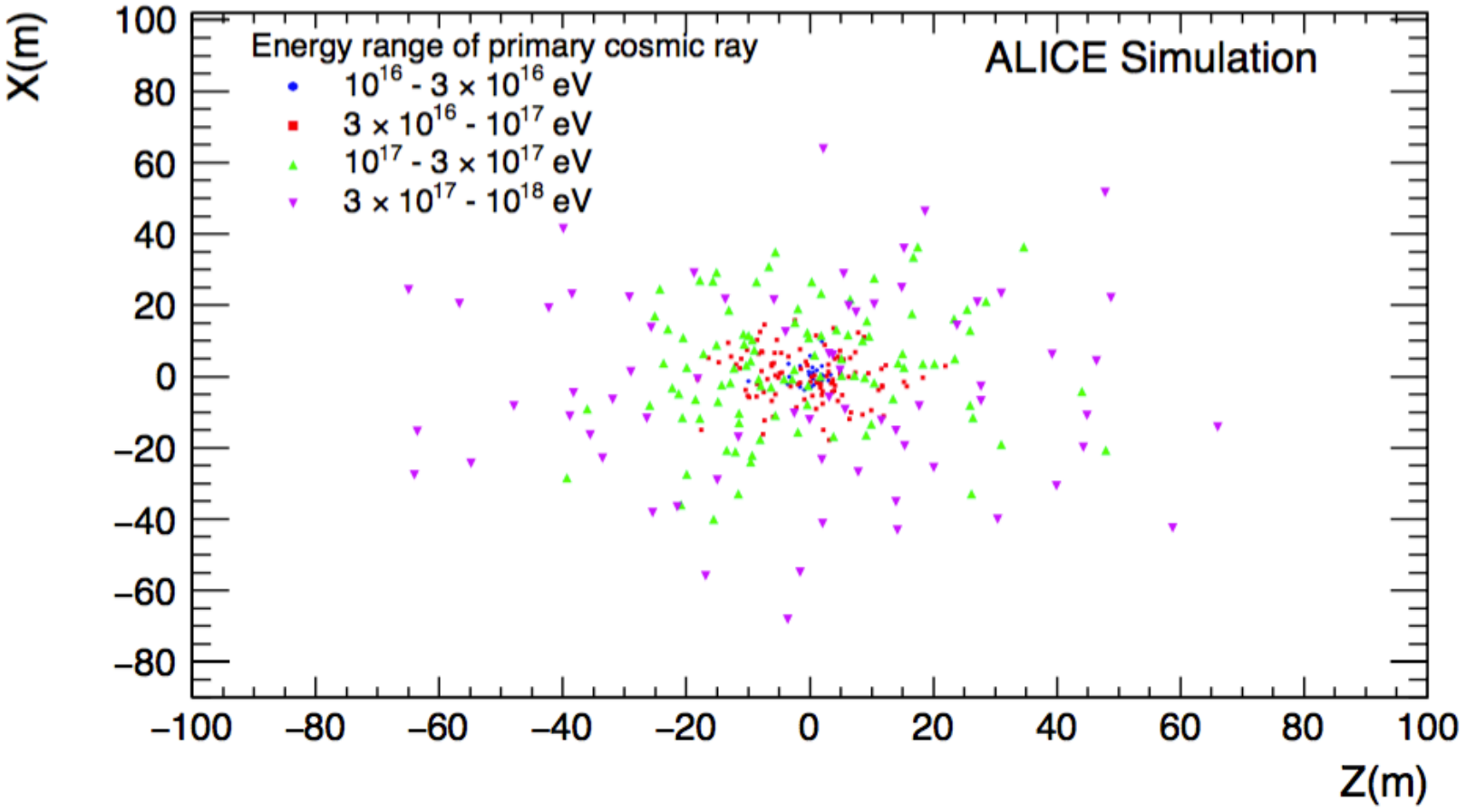
MMD at intermediate range

The measured muon multiplicity distribution compared with the fits obtained from CORSIKA simulations with proton or iron primary cosmic rays for 26.6 days live time



Spatial distribution of simulated EAS

Monte Carlo simulation of the EAS giving rise to more than 100 muons in the ALICE TPC. The simulation was for iron primaries in the energy range 10^{16} – 10^{18} eV, corresponding to the equivalent of 5 years of data taking.



RESULTS
Data *vs* Monte Carlo comparison

Model	Primary cosmic ray	HME rate [/day]	HME rate [Hz x 10^{-6}]	Uncertainty (%), sys.+stat. in quadrature
QGSJET II-03	proton	1 event in 15.5 days	0.75	13
	iron	1 event in 8.6 days	1.3	16
QGSJET II-04	proton	1 event in 11.6 days	1.0	8
	iron	1 event in 6.0 days	1.9	20
Real data		**1 event in 6.2 days**	**1.9**	**40**

- This type of events, was detected in the past by LEP experiments such as ALEPH and DELPHI, without satisfactory explanations. **Similar HME have been recorded in ALICE**.
- The latest CORSIKA version with QGSJET II-04 model, tuned to take into account the new results from CERN LHC, predicts **a rate of HME much closer to the data**.
- The analysis of these data suggests a **mixed composition with an increasing average mass of the primary cosmic rays at higher energies**. This is in agreement with the main cosmic ray experiments working around the energy of the knee.