Can EMMA solve the puzzle of the knee?

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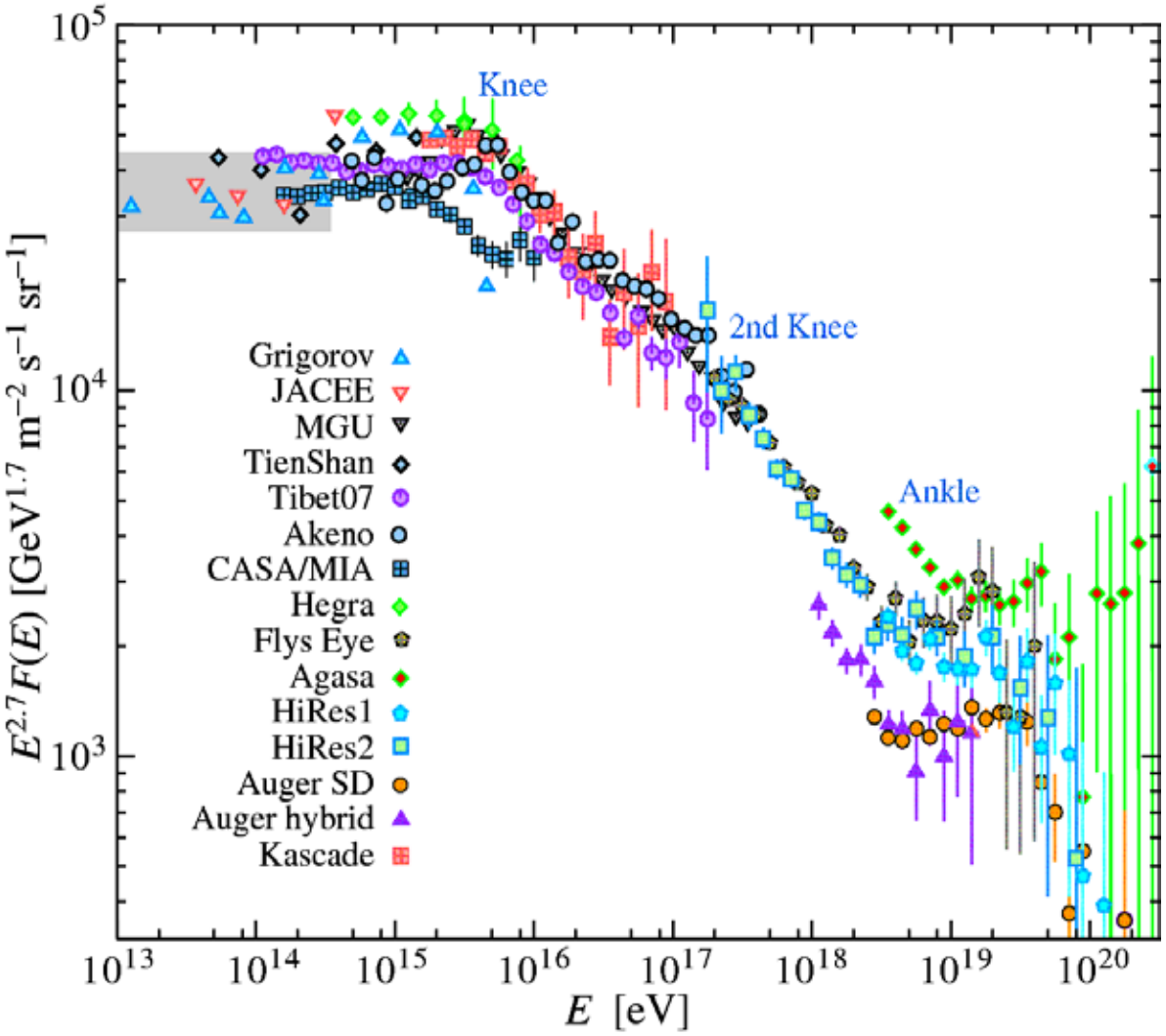
Knee



K. Nakamura *et al.* (Particle Data Group), J. Phys. G **37**, 075021 (2010)

Knee explanations?

4 classes of explanations (see for example J.R. Hörandel, Astroparticle physics 21 (2004) 241)

- Changes in acceleration processes around the knee energy (more numerous lower energy processes run out of steam)
  - Models with variations of diffusive shock acceleration
    - Different A/Z dependencies between models
  - Galactic wind re-acceleration model
    - Z dependence
  - Cannonball model (A. De Rújula, Nucl. Phys. B (Proc. Suppl.) 151 (2006) 23)

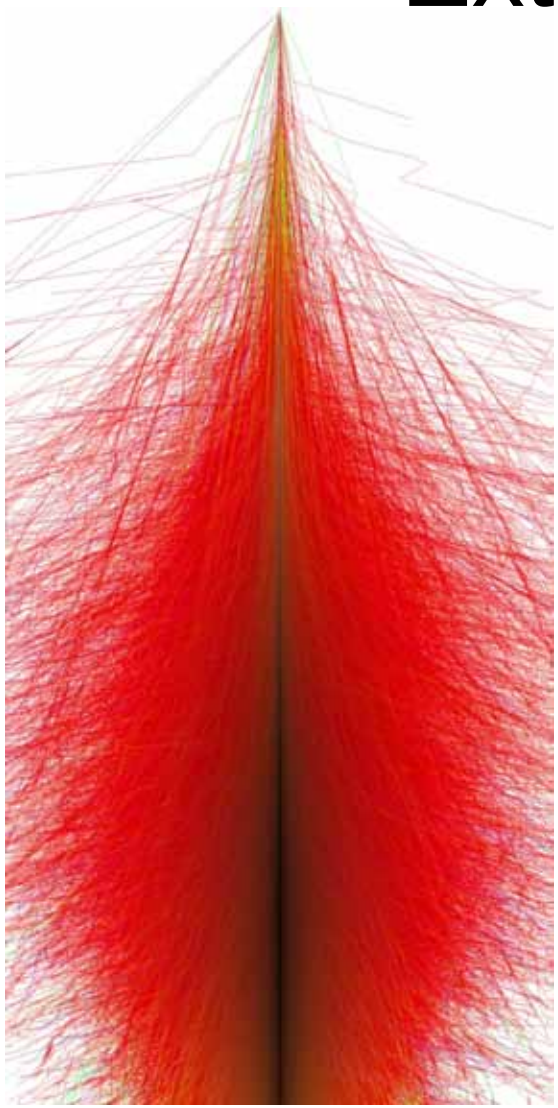
Knee explanations 2?

- Leakage of cosmic rays from the Galaxy with non-changing spectral slope from the acceleration
  - Models with leakage through diffusion and/or drift
    - Different Z and A dependencies between models
- Losses via interactions with background particles in the Galaxy
  - For example pair-production, pion-photoproduction on nucleons and photo-disintegration of nuclei
    - Some of these effects have A dependence.

Knee explanations 3?

- NEW PHYSICS
  - Experiments at and above knee are not measuring cosmic ray particles directly. They measure the shower of particles created by cosmic ray particle hitting atom in atmosphere. The analyses are based on simulations beyond measured cross-sections.

Extensive Air Showers



1 PeV

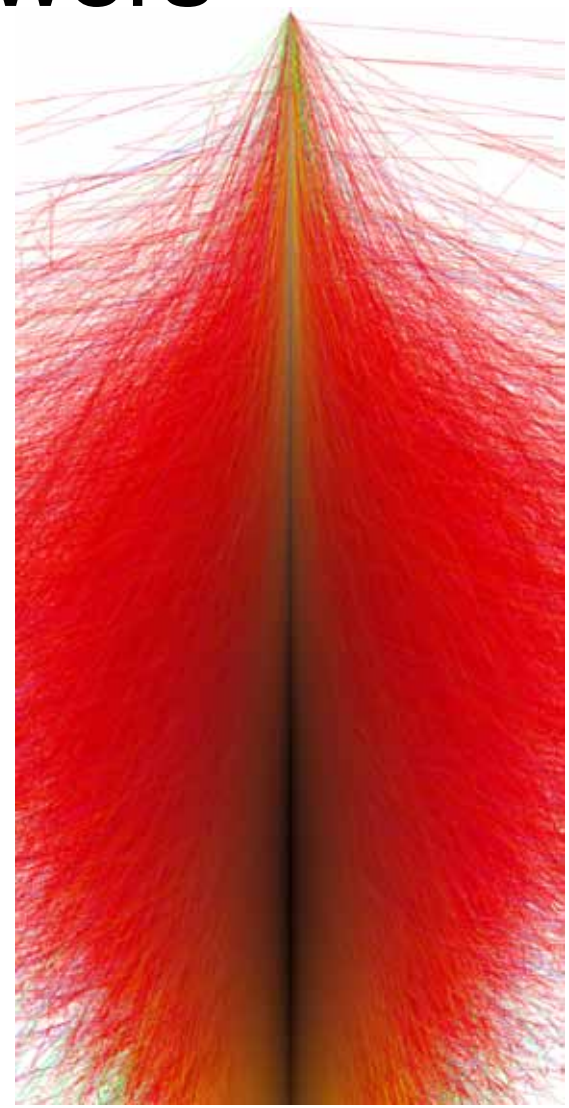
Proton | Iron

e^+, e^- and photons

muons

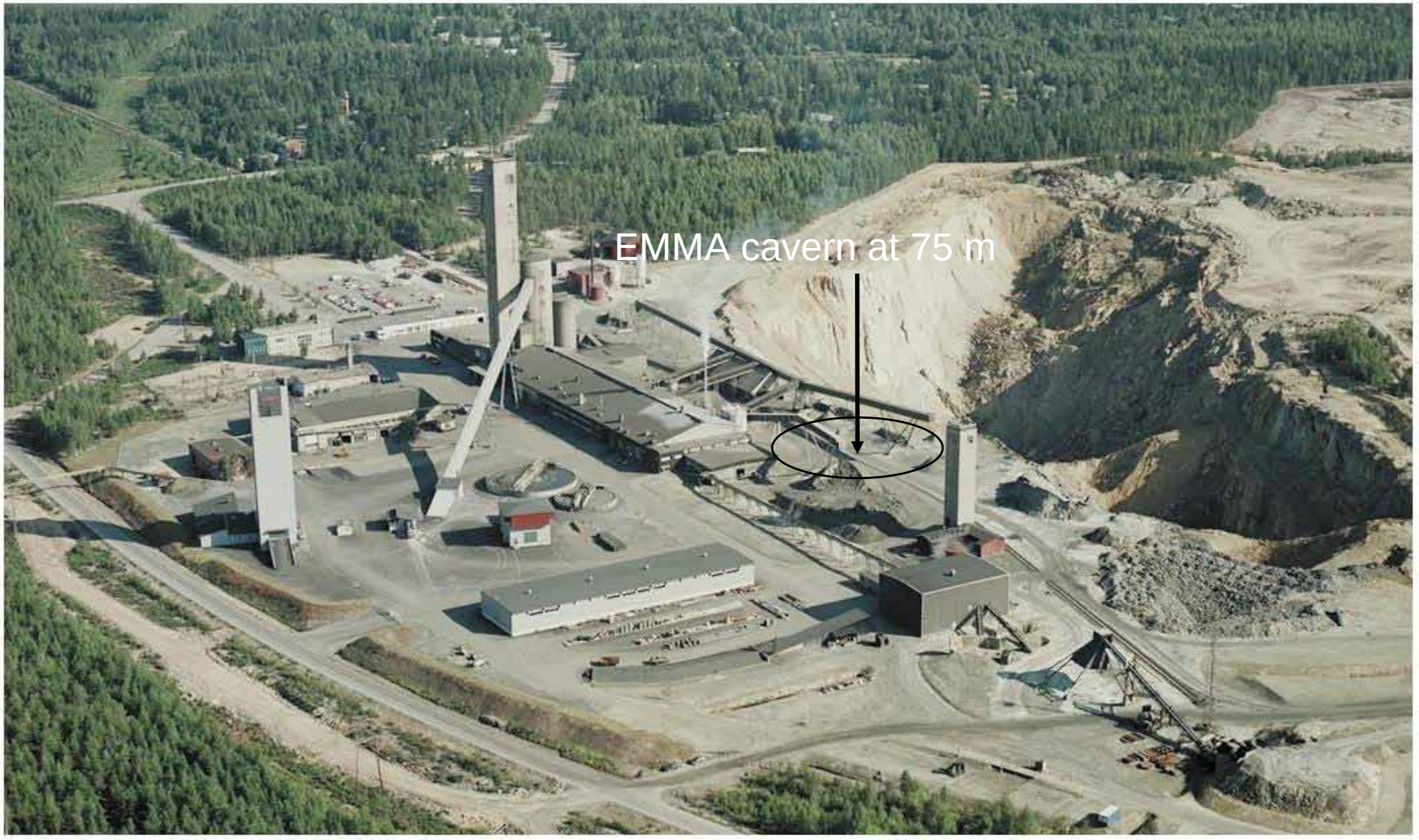
hadrons

F. Schmidt, “CORSIKA shower images”, http://www.ast.leeds..ac.uk/~fs/showerimages.html

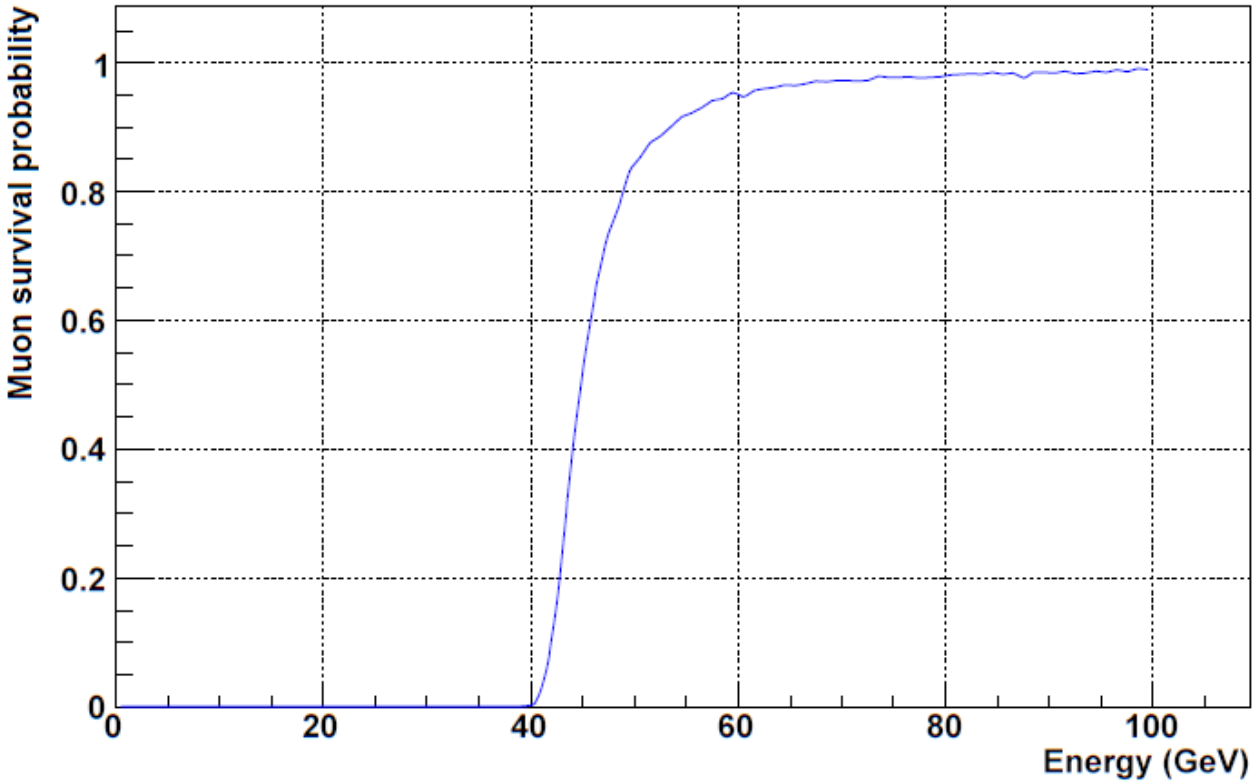


EMMA = Experiment with MultiMuon Array

EMMA Location

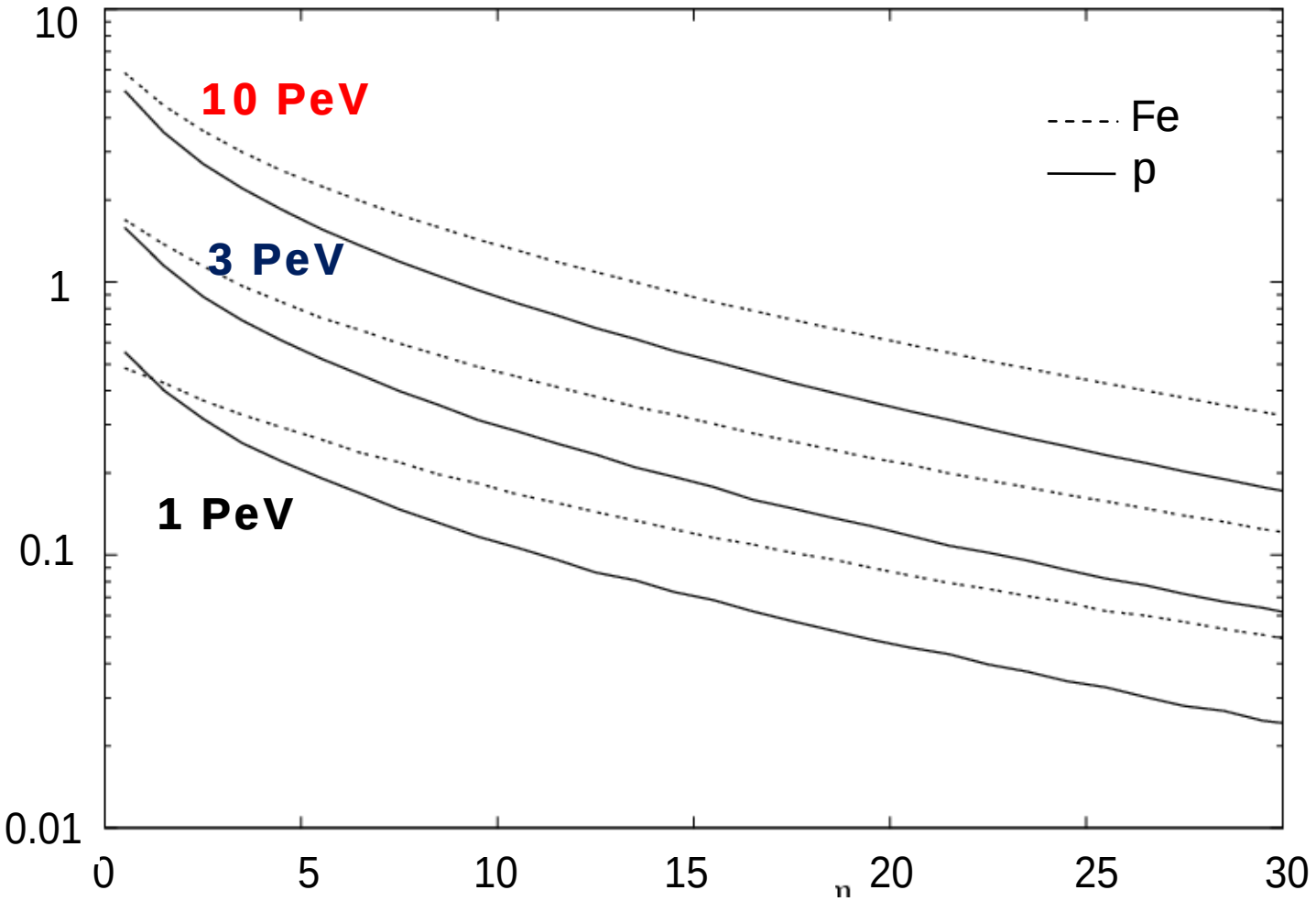


Muons reaching EMMA



Simulated muon distributions

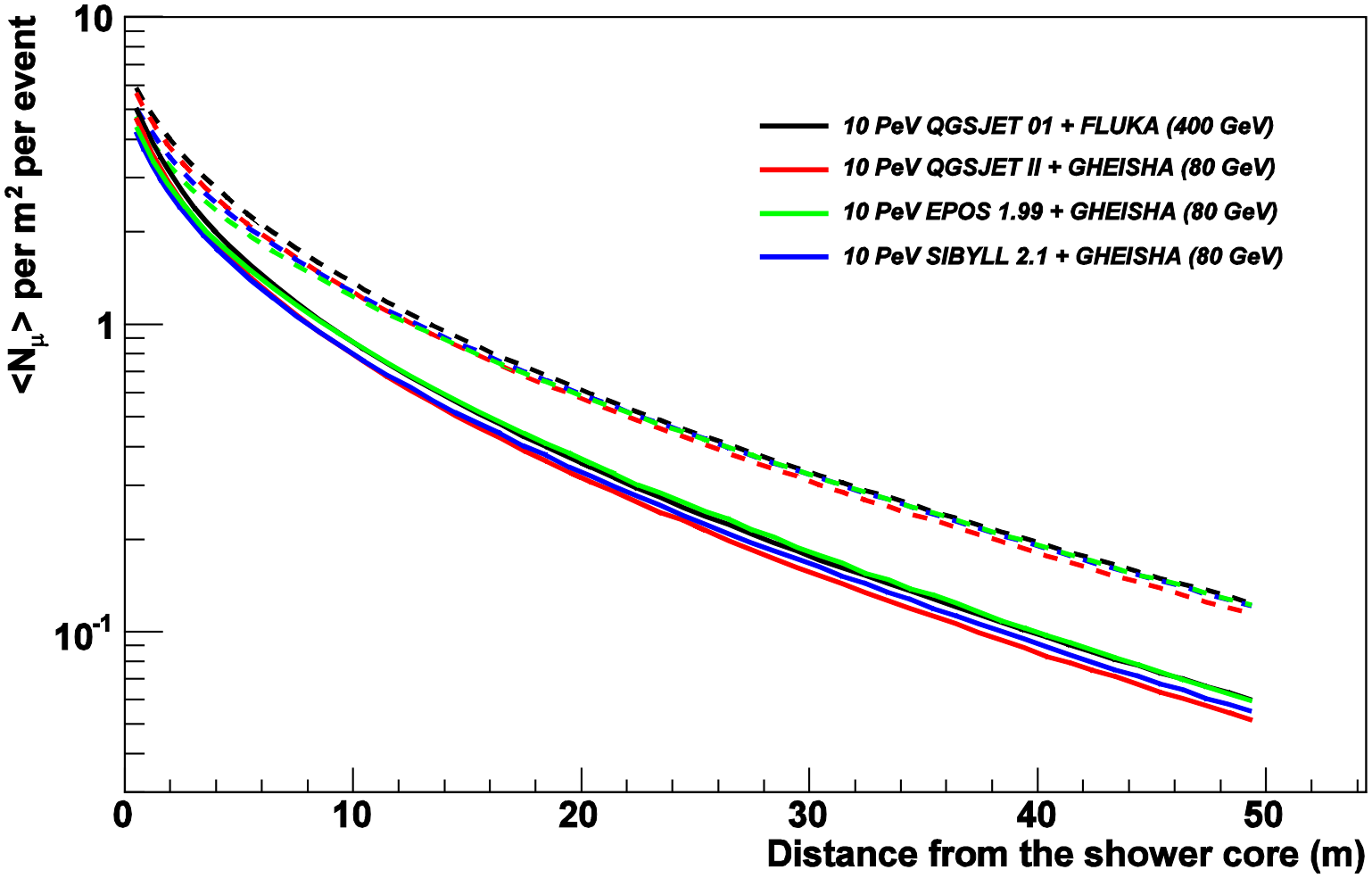
(CORSIKA+QGSJET 01 with **50 GeV cut-off**)



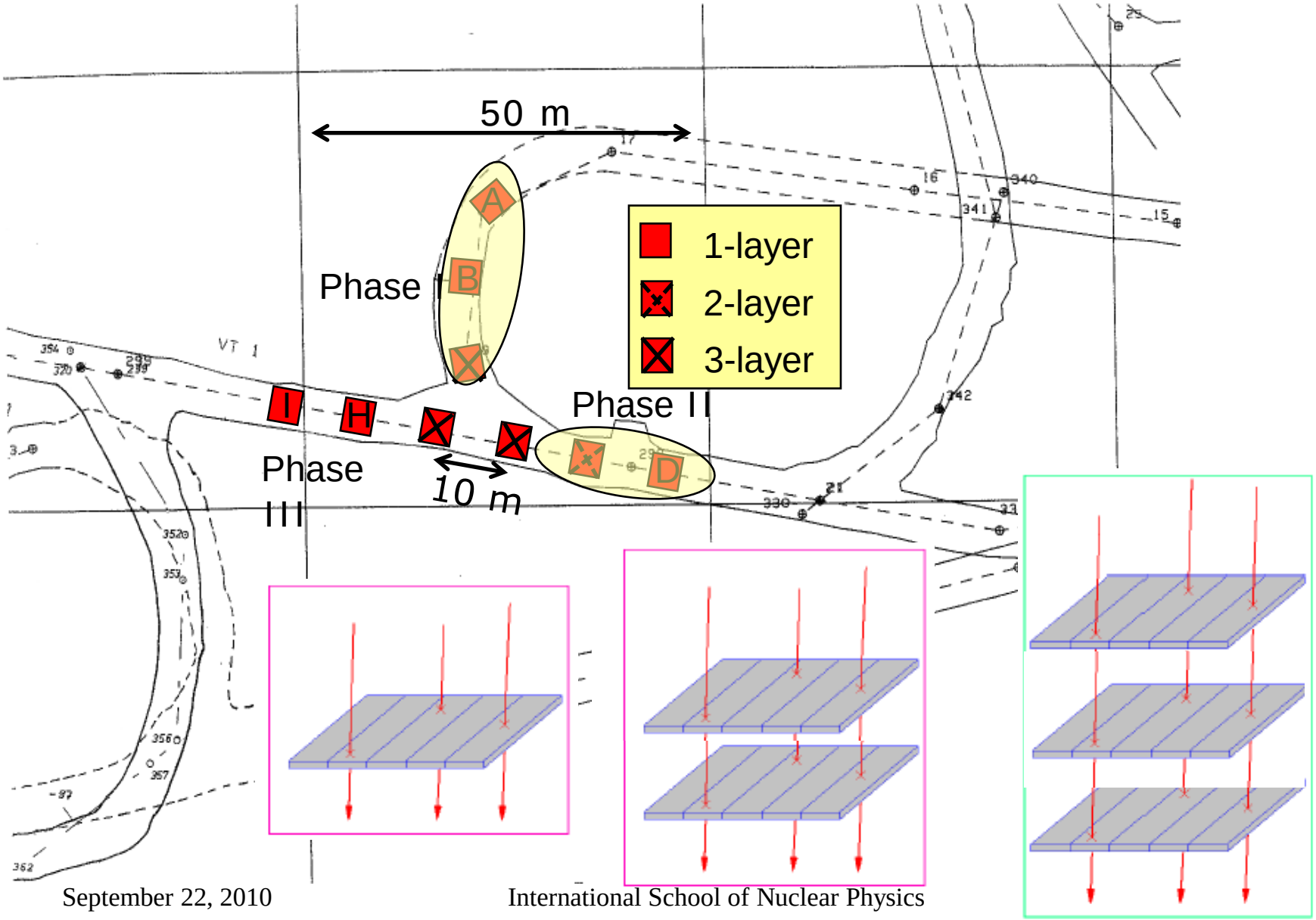
Energy ~ muon density at the core

Mass ~ muon density in the tail

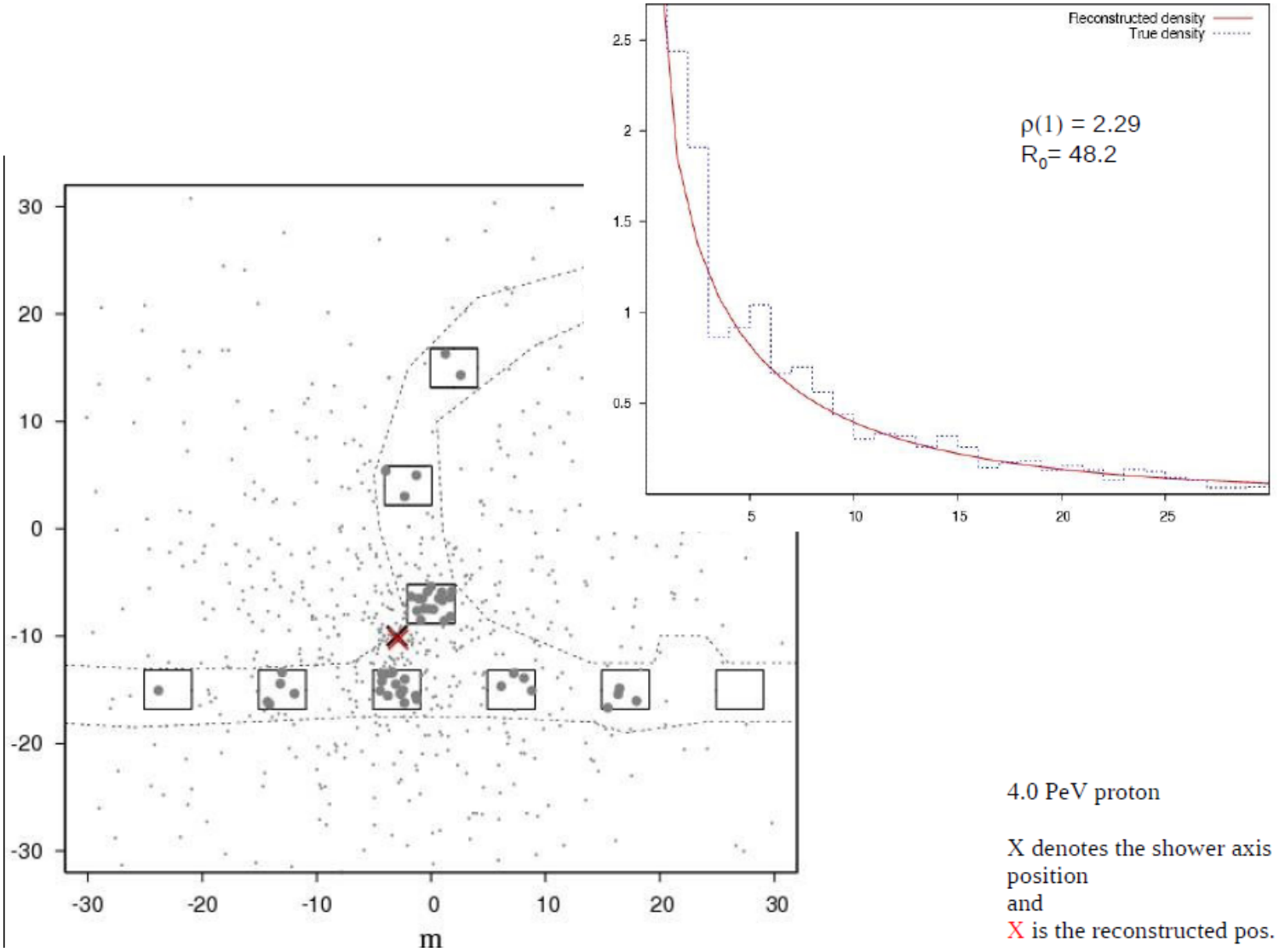
Model comparison for EMMA



EMMA - Layout at 75 m



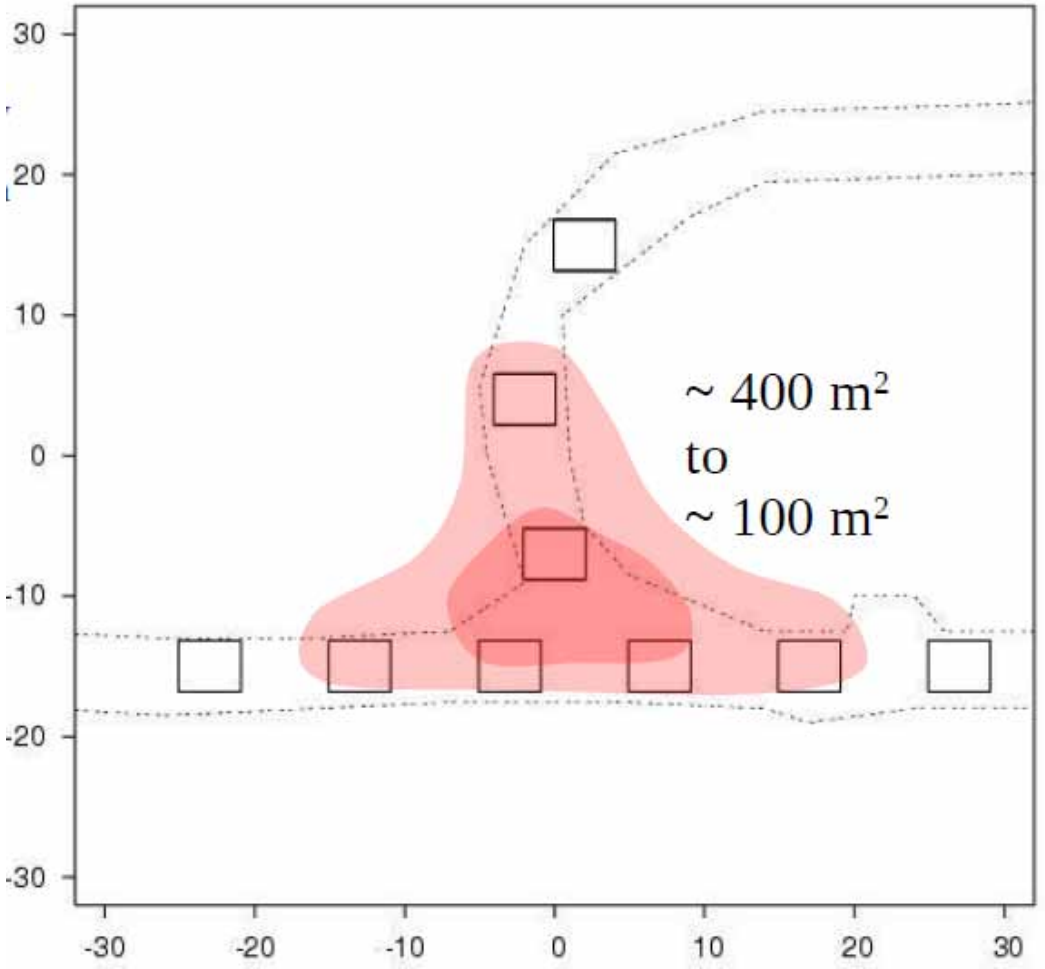
Shower reconstruction 1



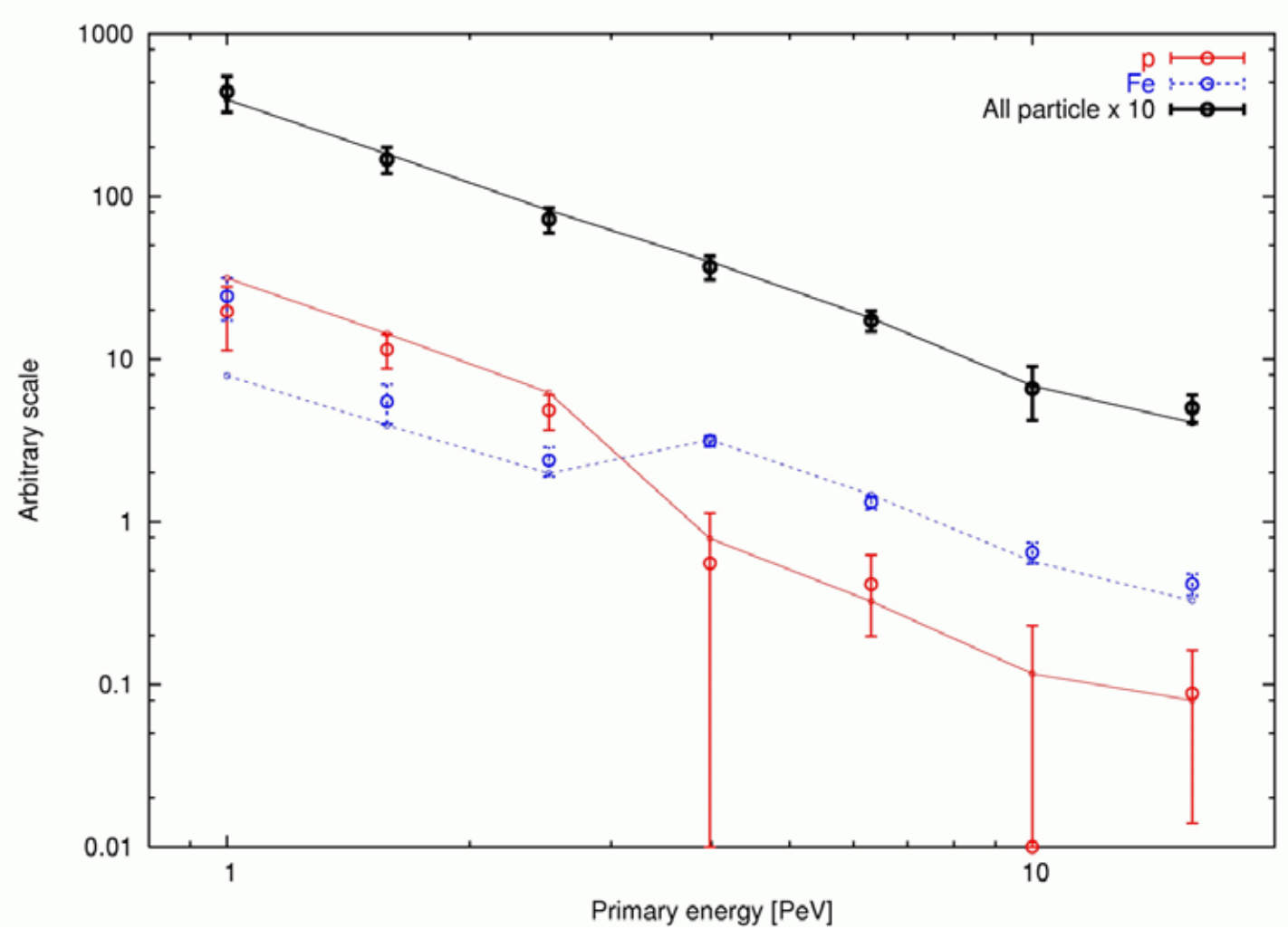
4.0 PeV proton

X denotes the shower axis position
and
X is the reconstructed pos.

EMMA Detectors effective area



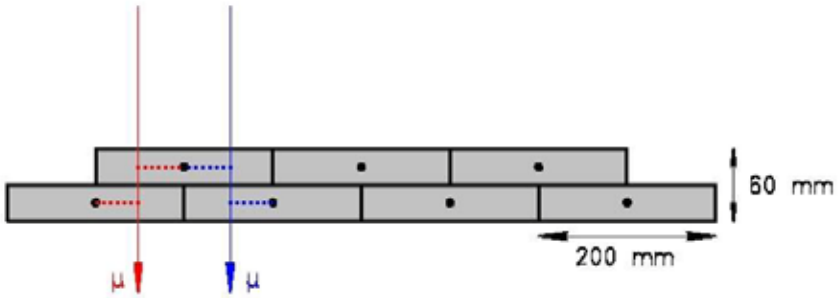
Simulated change of p / Fe ratio from 80/20 to 20/80 reconstructed by EMMA after 12 months running



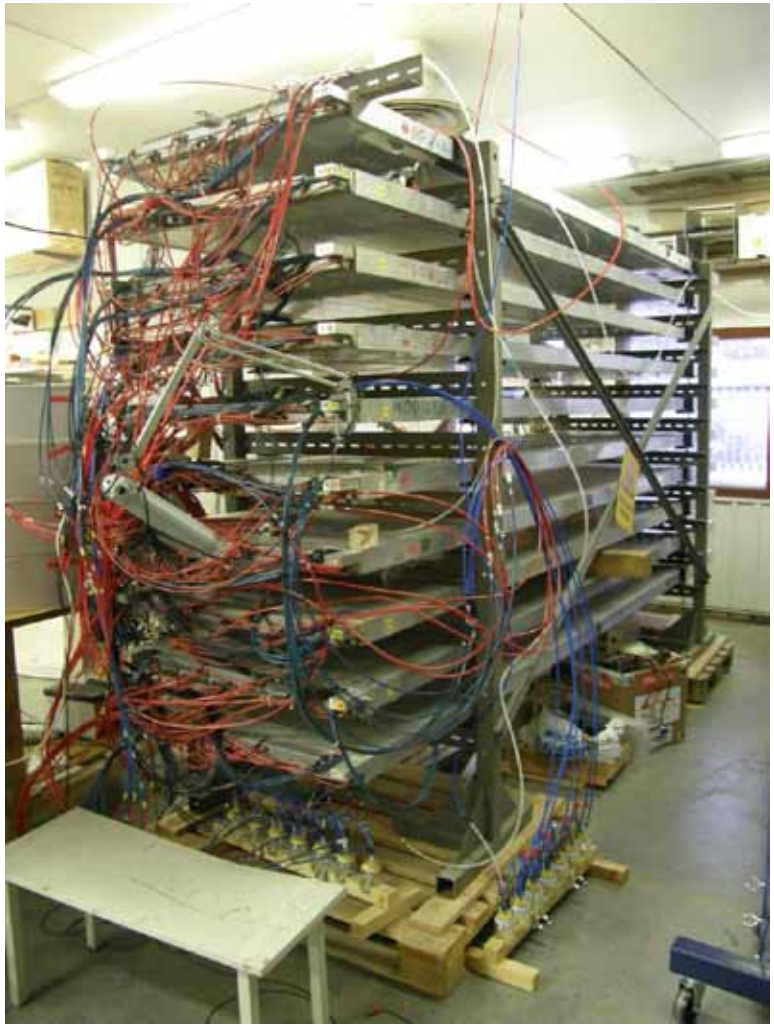
EMMA Detectors

Drift chambers from Delphi (MUB)

- Single detector element (plank) consists out of 7 chambers, each $20*365cm^2$



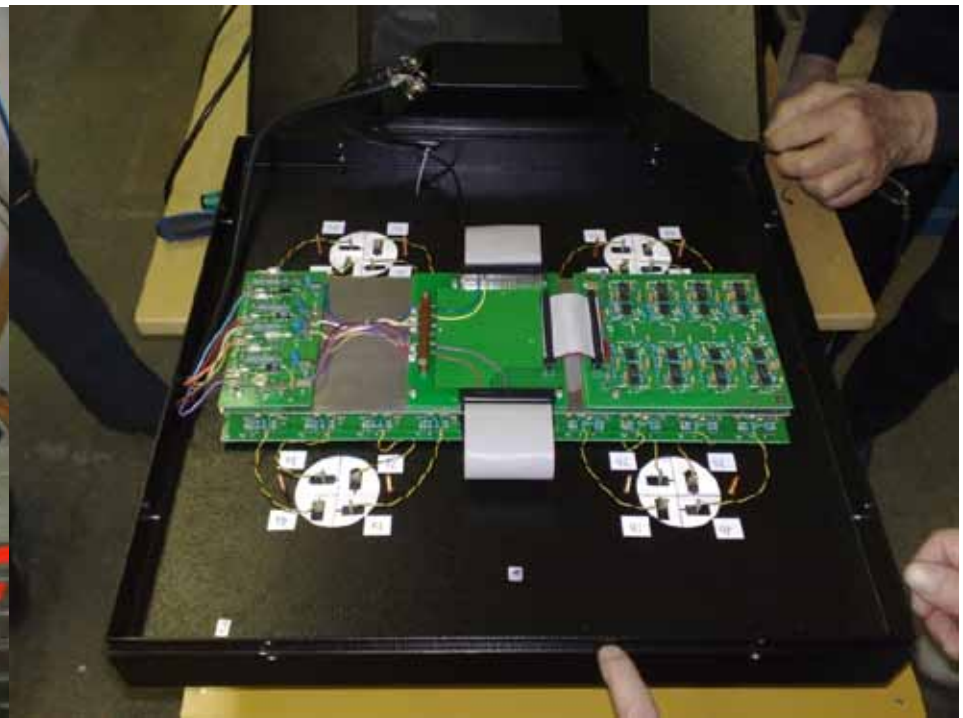
- Position resolution ~ $1cm^2$

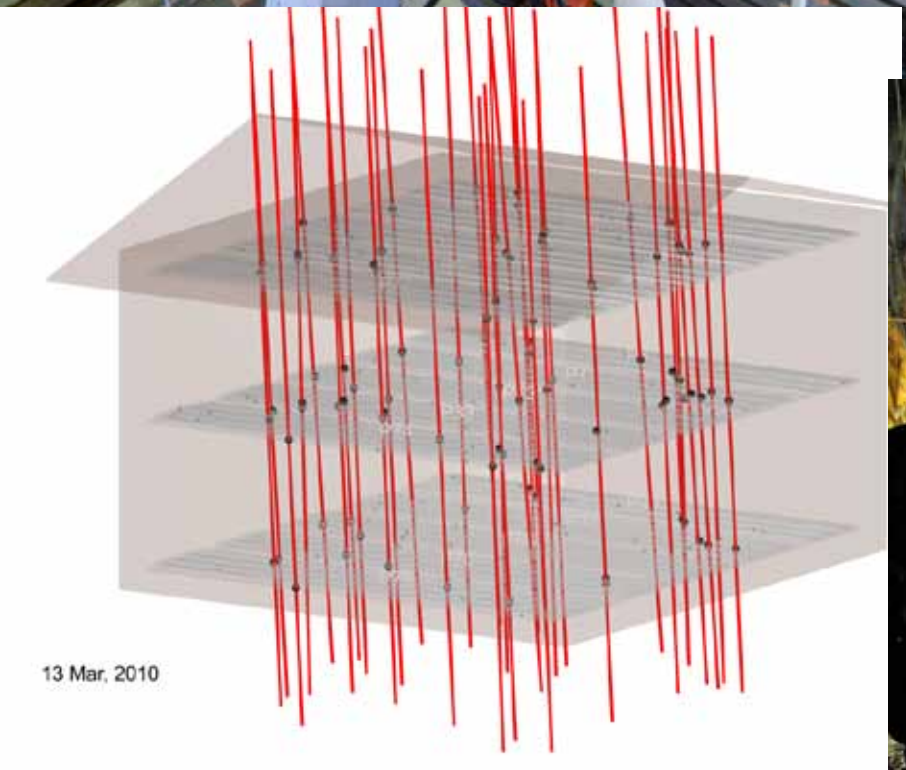


EMMA Detectors 2

Plastic scintillators

- 50 ´ 50 cm^2, height » 13 cm, m » 20 kg,
- arranged to 16 individual pixels, 12 ´ 12 cm^2, 3 cm thick each,
- employ APDs (avalanche photodiodes),
- time resolution ~ 1 ns.
- to be used for trigger and improving tracks




13 Mar, 2010