Discrimination of gamma/proton primaries using the EAS muon content for IACTs

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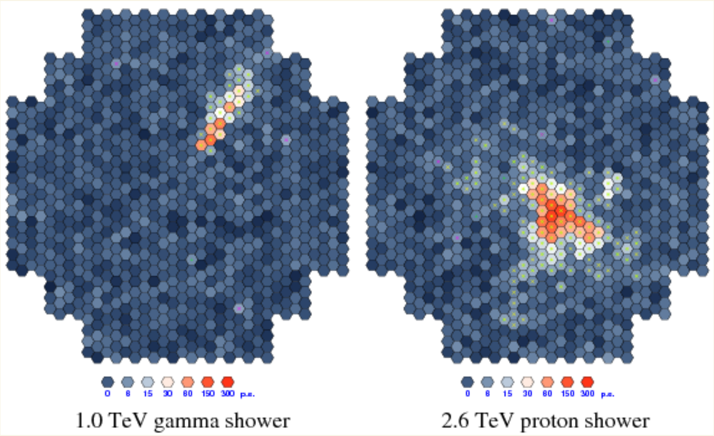
LIP

Thanks to Alessandro De Angelis

Motivation

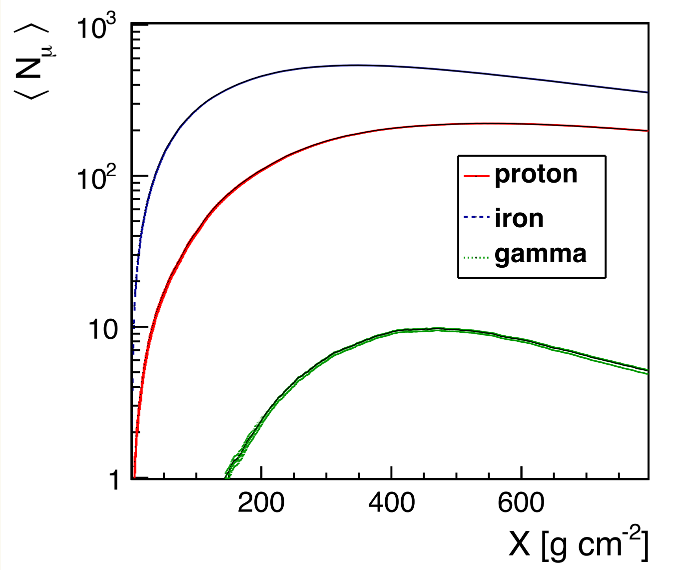
- IACTs are used to detect photon primaries
  - Collect the Cherenkov light produced during the shower development in the atmosphere
- Need to distinguish photon induced shower from hadronic (proton, iron...) showers
  - Huge background (around 3 orders of magnitude above signal)
  - IACTs use sophisticated analysis based on shower shape in camera
    - From a known photon astrophysical source the contamination due to hadronic particles is about 1:10
    - From an unknown source is about 1:1

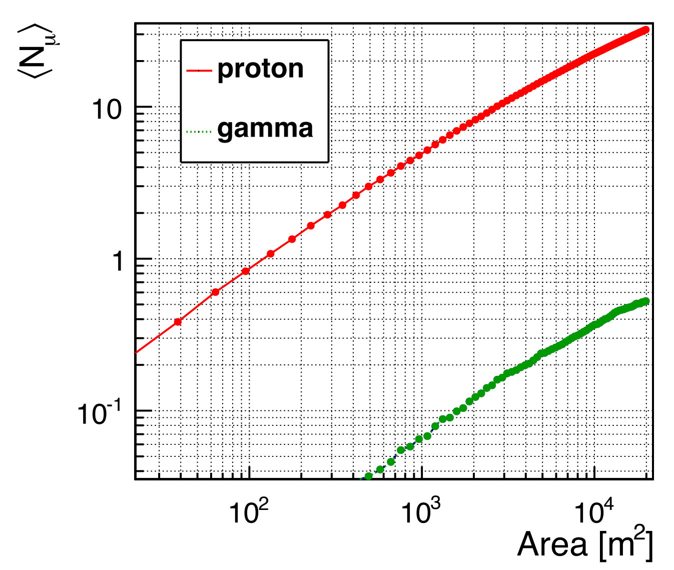


Can we improve the discrimation?

- Look at the shower secondary particles that arrive at the ground
- Why? Because the muon EAS content in a electromagnetic shower is 10 times smaller that the one initiated by a primary of hadronic nature
  - Good estimator for photon shower
  - Complementary discriminator for IACTs
- Need to cover a relatively big area
  - 10000 m^2
- Necessity of a cheap detector sensitive to muons
  - RPCs?

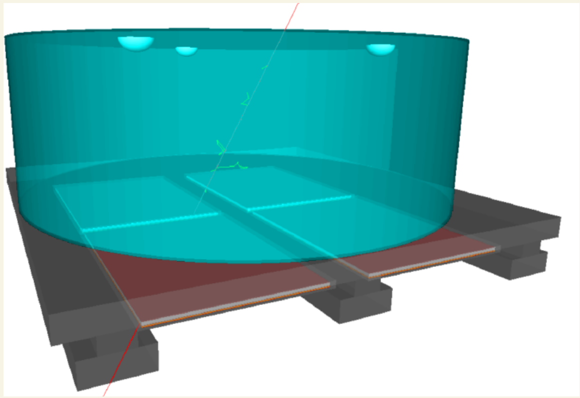
E = 10 TeV

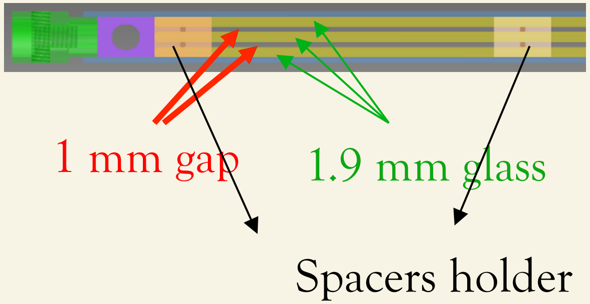


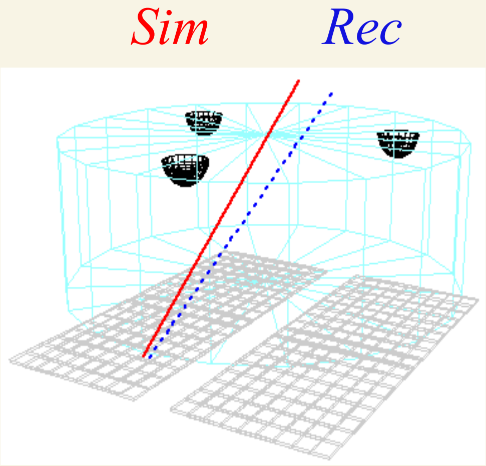


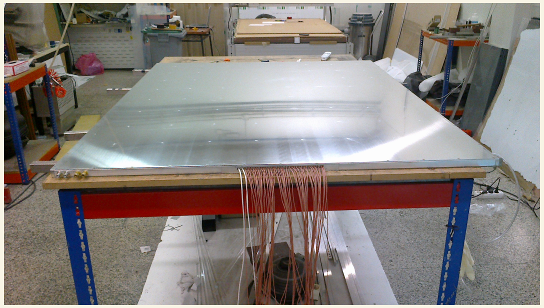
Resistive Chamber Plates (RPC)

- Being studied at Pierre Auger Observatory as a possible solution to enhance the muon measurement capabilities
  - Gaseous detector
  - Measures charge particles
  - A lot R&D work and development of analysis

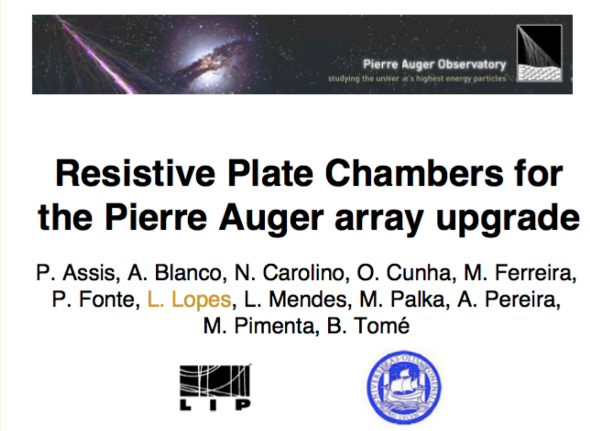








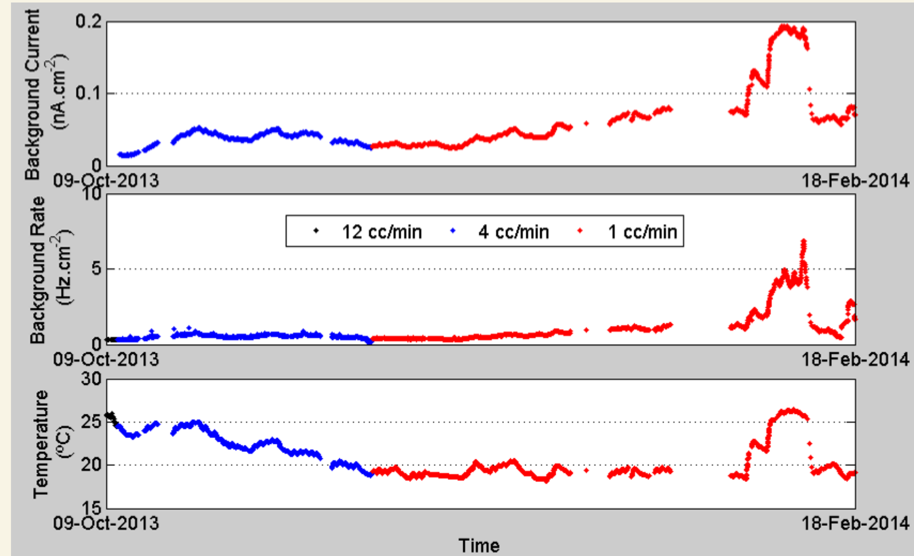
RPC – R&D challenges

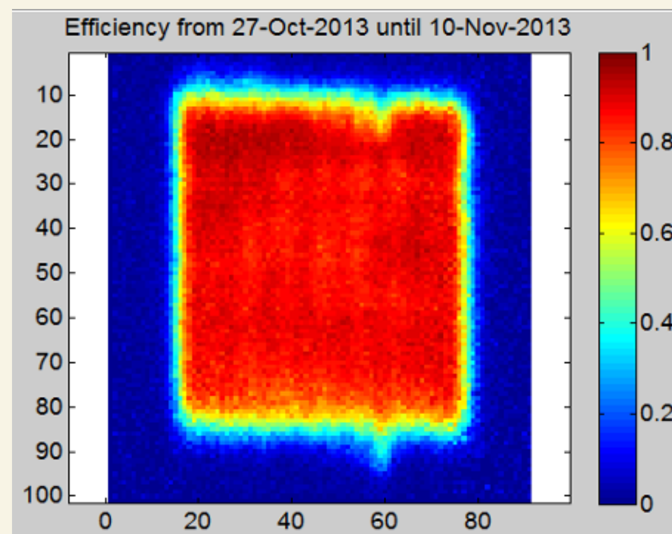

Pierre Auger Observatory

Resistive Plate Chambers for the Pierre Auger array upgrade

P. Assis, A. Blanco, N. Carolino, O. Cunha, M. Ferreira, P. Fonte, L. Lopes, L. Mendes, M. Palka, A. Pereira, M. Pimenta, B. Tomé

- Requirements:
  - Very large area @ low cost
  - Segmented readout for particle counting, fiducial area selection, etc.
  - Reasonable timing (~5ns)
  - Standalone operation
  - Outdoors operation -> resilience to environmental effects
  - Low maintenance -> very low gas flow
  - Little aging at zero particle flow (mostly dark current)

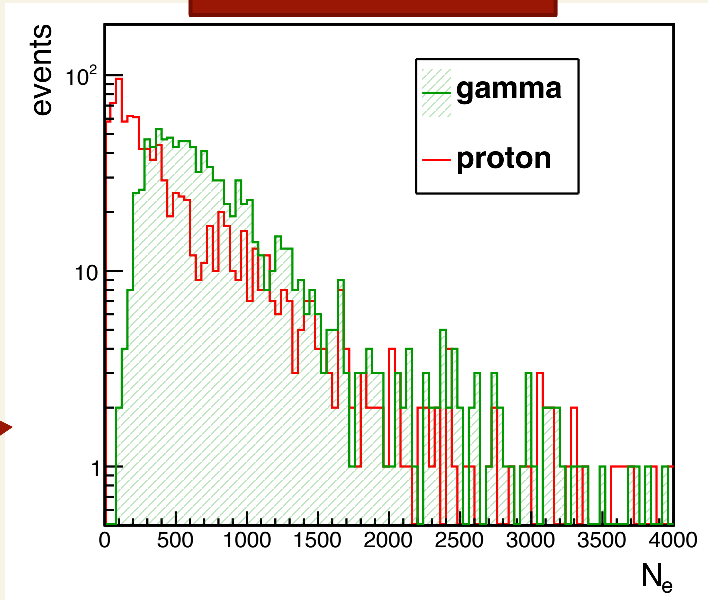


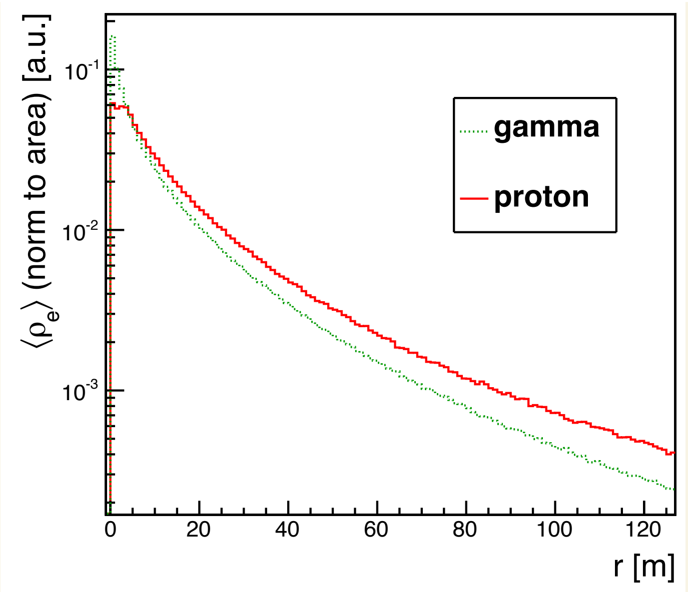


Discrimination variables

- All the studies were done using CORSIKA simulations
  - Energy range from (1 TeV – 100 TeV)
  - Vertical showers collected at 2200 m of altitude
- Several observables were tested as possible photon discriminants:
  - Number of electrons
  - Number of photons
  - Number of muons
  - Particles (photons, electrons and muons) arrival time
    - all particles arrive within the first 100 ns
  - Shower front curvature
  - Lateral distribution (LDF) slope
    - high fluctuation

E = 10 TeV





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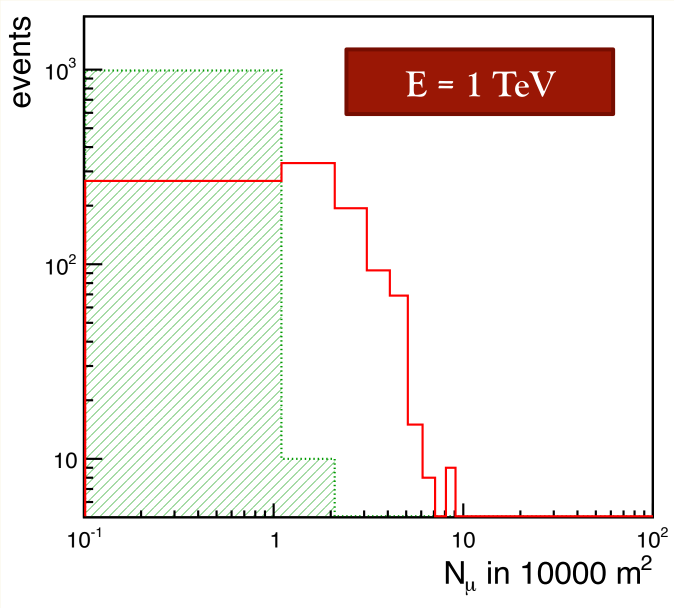

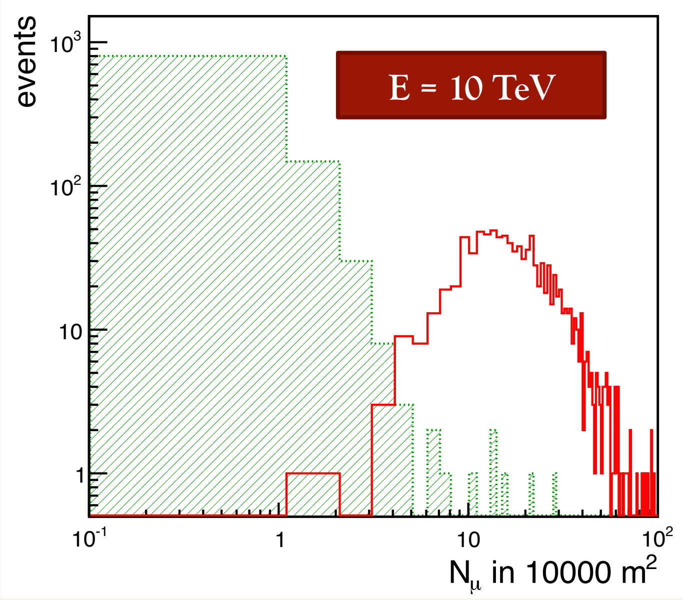

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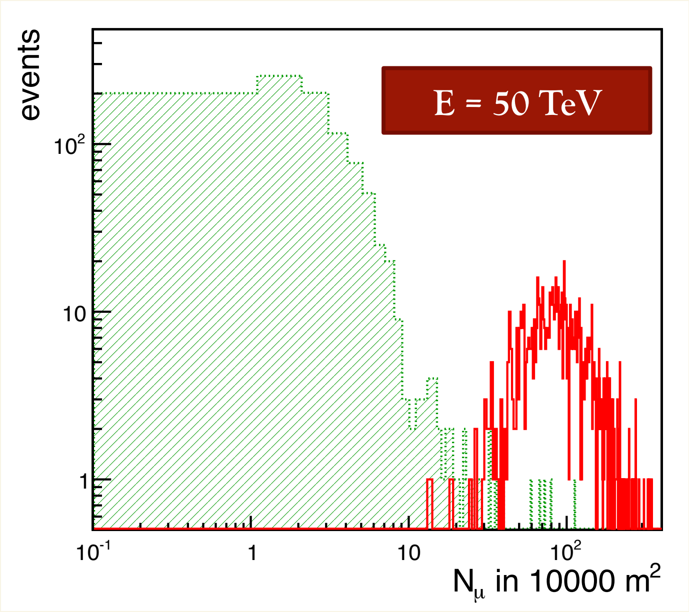
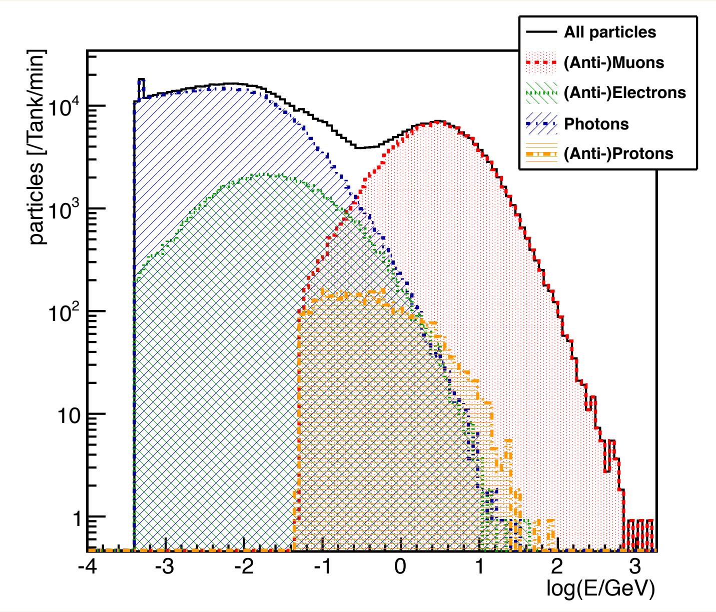


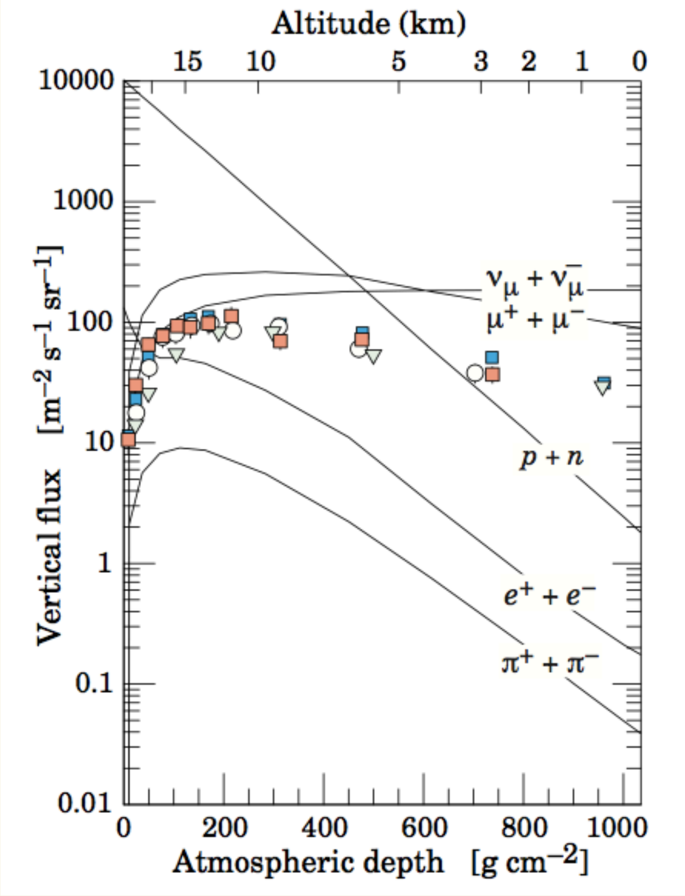
Works even better at higher energies

Background sources

- Atmospheric particles
  - low energy showers secondaries
  - In a time window of 100 ns is expected less than 1 particle for an area of 10000 m^2

Energy spectrum of a realistic simulation of atmospheric particles at Auger – 1400 m altitude



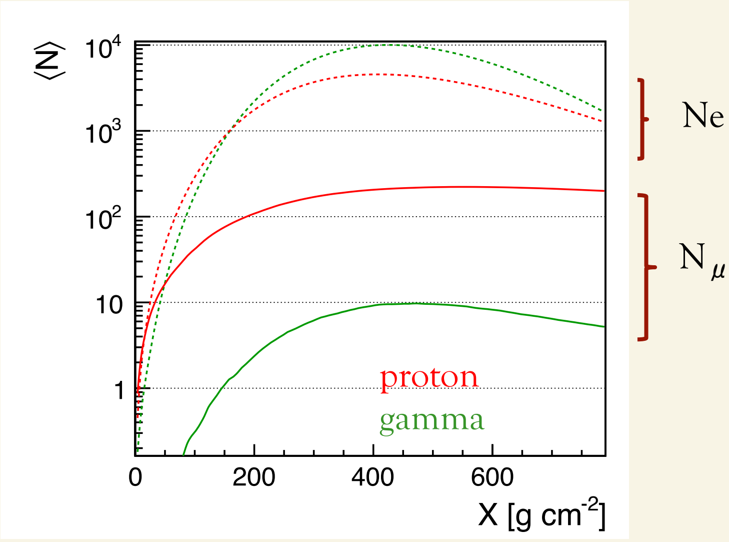


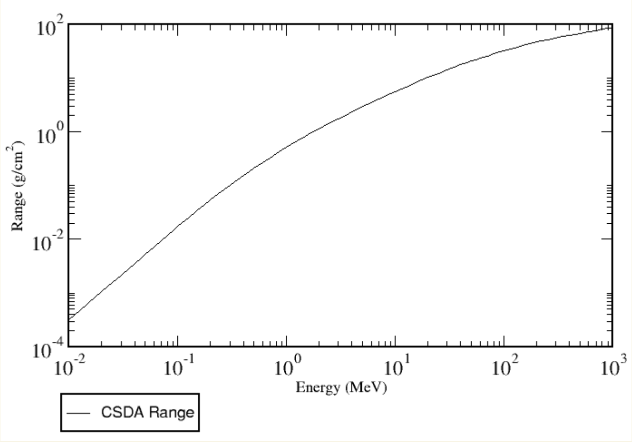
So, atmospheric particles are not a problem!!

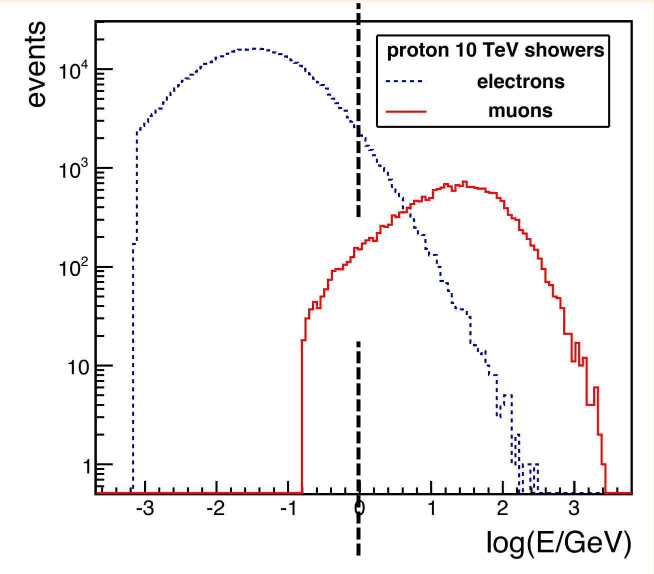
Background sources

- Shower electromagnetic component
  - 20 times greater than the muonic component for proton showers at 10 TeV
- Need to bury the detector to shield the RPC from muons
  - About 0.5 m of earth should attenuate most of the electrons up to 1 GeV

Average longitudinal profiles for 10 TeV showers

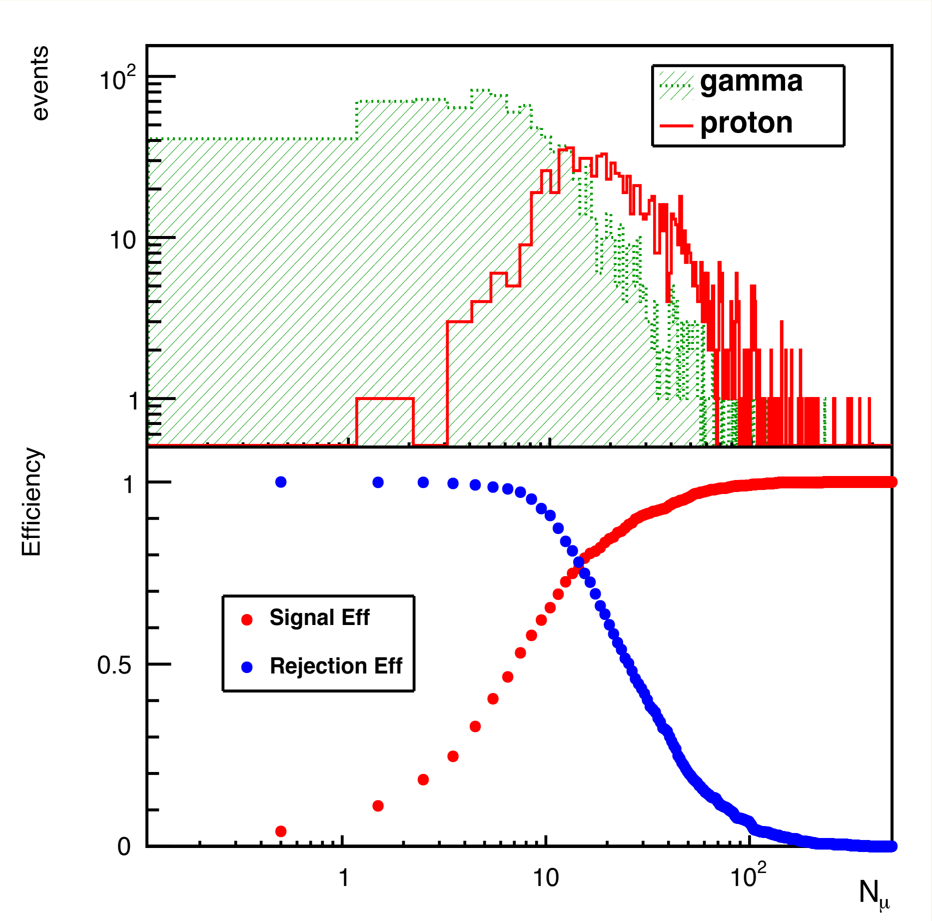






Discrimination with buried RPCs

- Still possible to distinguish photons from protons for 10 TeV showers
- No assessment of contamination level yet:
  - Intended as a complementary technique to the IACTs
  - Need dedicated IACT simulations to show what is the improvement
  - But principle works!
    - And it works even better at higher energies (100 TeV)



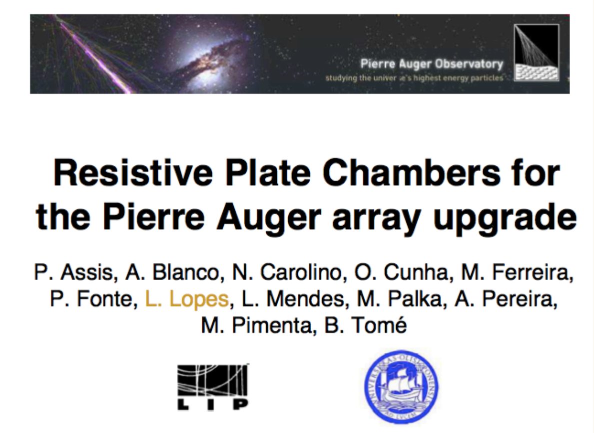
Summary and Prospects

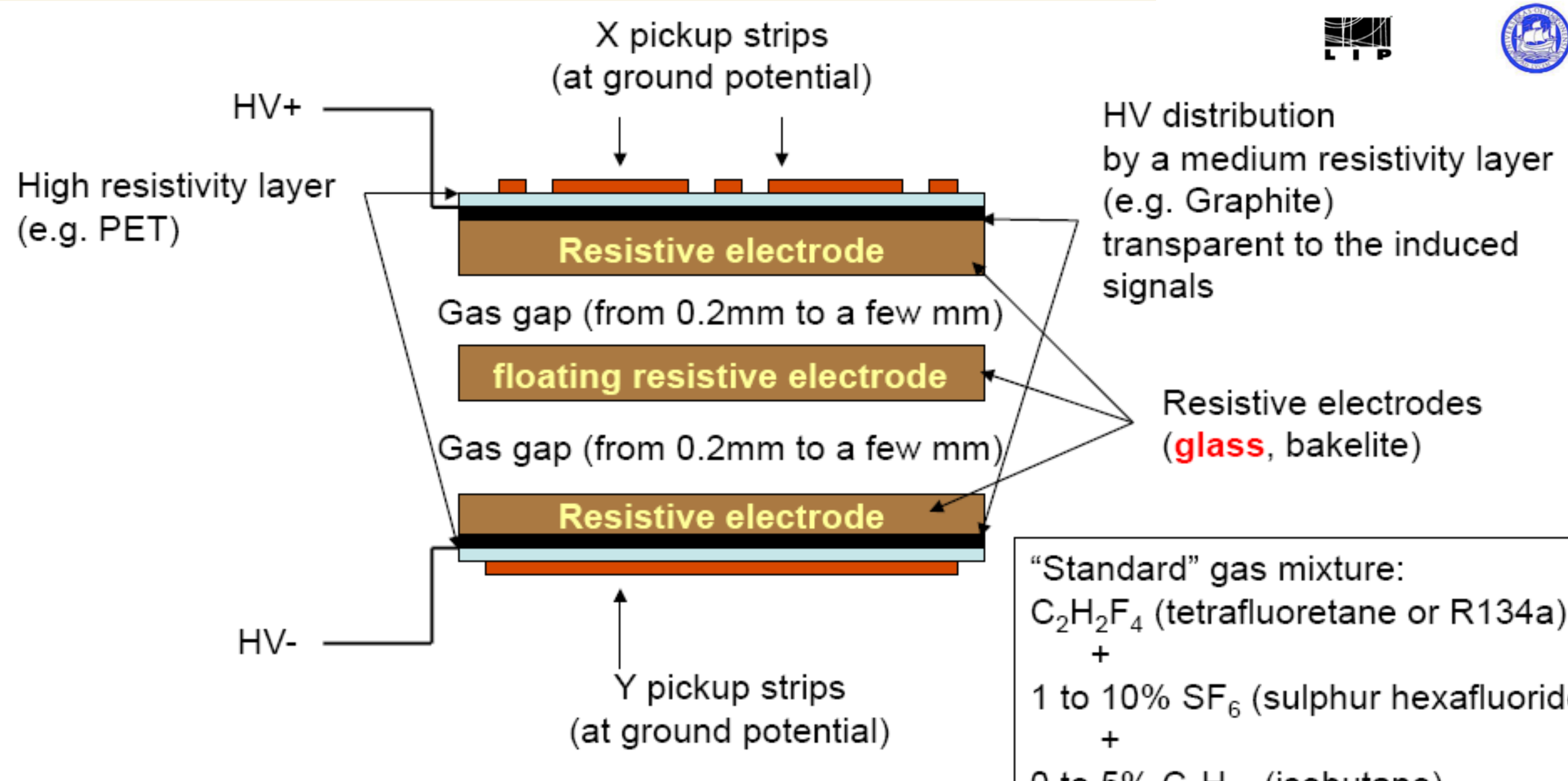
- Possible complementary technique to IACT primary discrimination
  - Measurement of number of muons in an area of 10000 m^2
  - Shielding is necessary to eliminate the e.m. shower background
    - 0.5 m of earth should be enough
- RPCs are a good candidate to such measurement
  - Outdoor operation
    - (R&D at Auger)
  - Cheap detector
    - About 5-7M$ to cover an area of 10000 m^2
- Repeat the exercise with a dedicated IACT simulation/reconstruction to obtain expected hadronic contamination

Backup

RPC – basis structures

- Cost depends essentially of the electronics used to capture the signals
  - about $500 per square meter





"Standard" gas mixture:
$C_2H_2F_4$ (tetrafluoretane or R134a)
+
1 to 10% SF_6 (sulphur hexafluoride)
+
0 to 5% C_4H_{10} (isobutane)