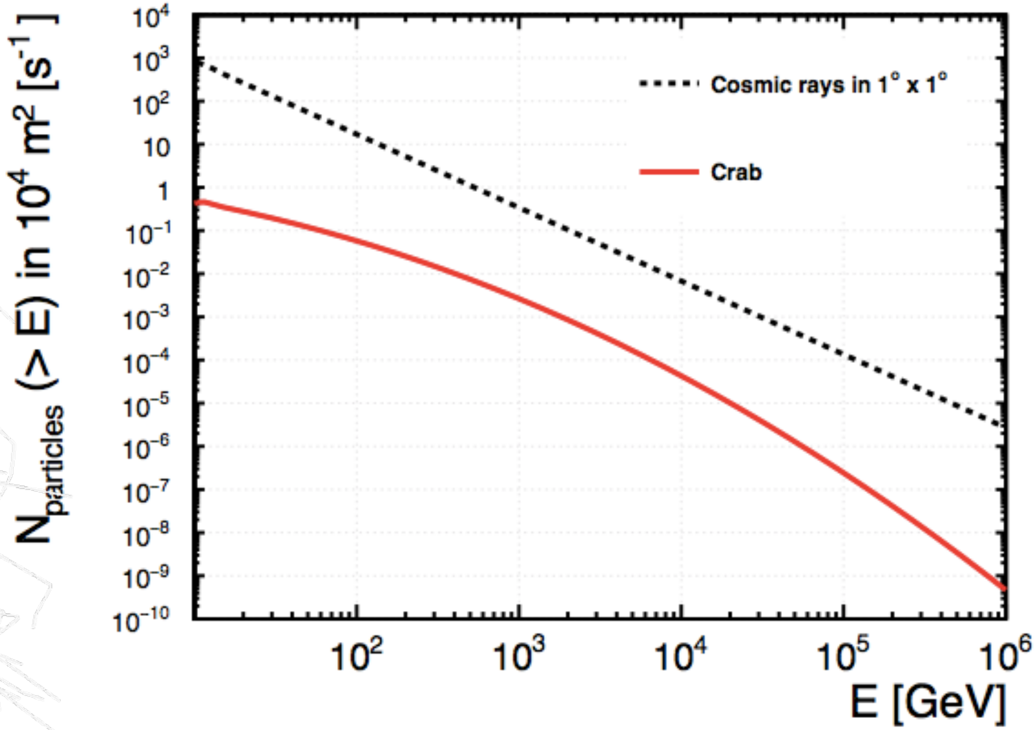
LATTES: gamma/hadron discrimination

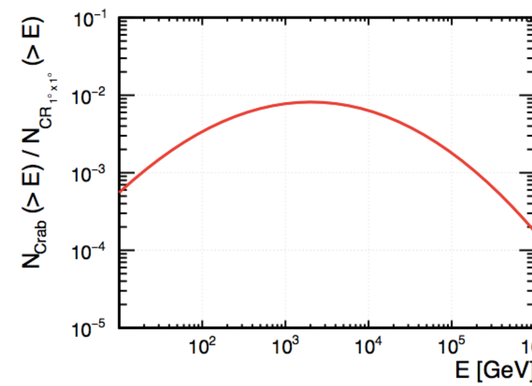
Ruben Conceição

on behalf of the LATTES team

4^{th} LATTES meeting, Rio de Janeiro, May 19^{th} 2017

The problem...





The number of hadron showers overwhelms the gamma showers by several orders of magnitude

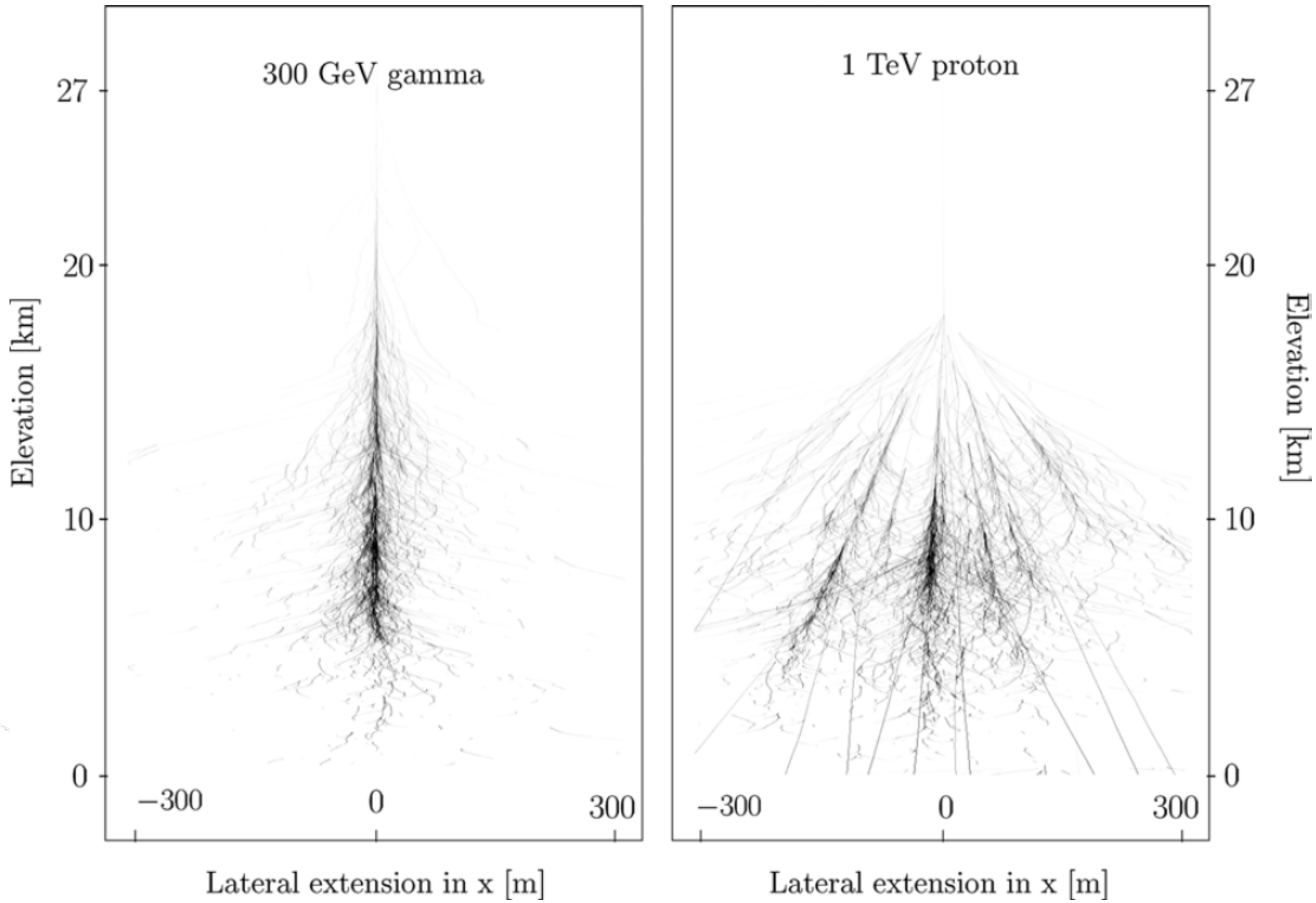
Possible solutions…

- If a gamma source emits continuously then increase the acquisition time
- Increase angular resolution
- Increase the energy reconstruction resolution
- Take advantage of shower characteristics to distinguish between a gamma/hadron induced shower

Possible solutions…

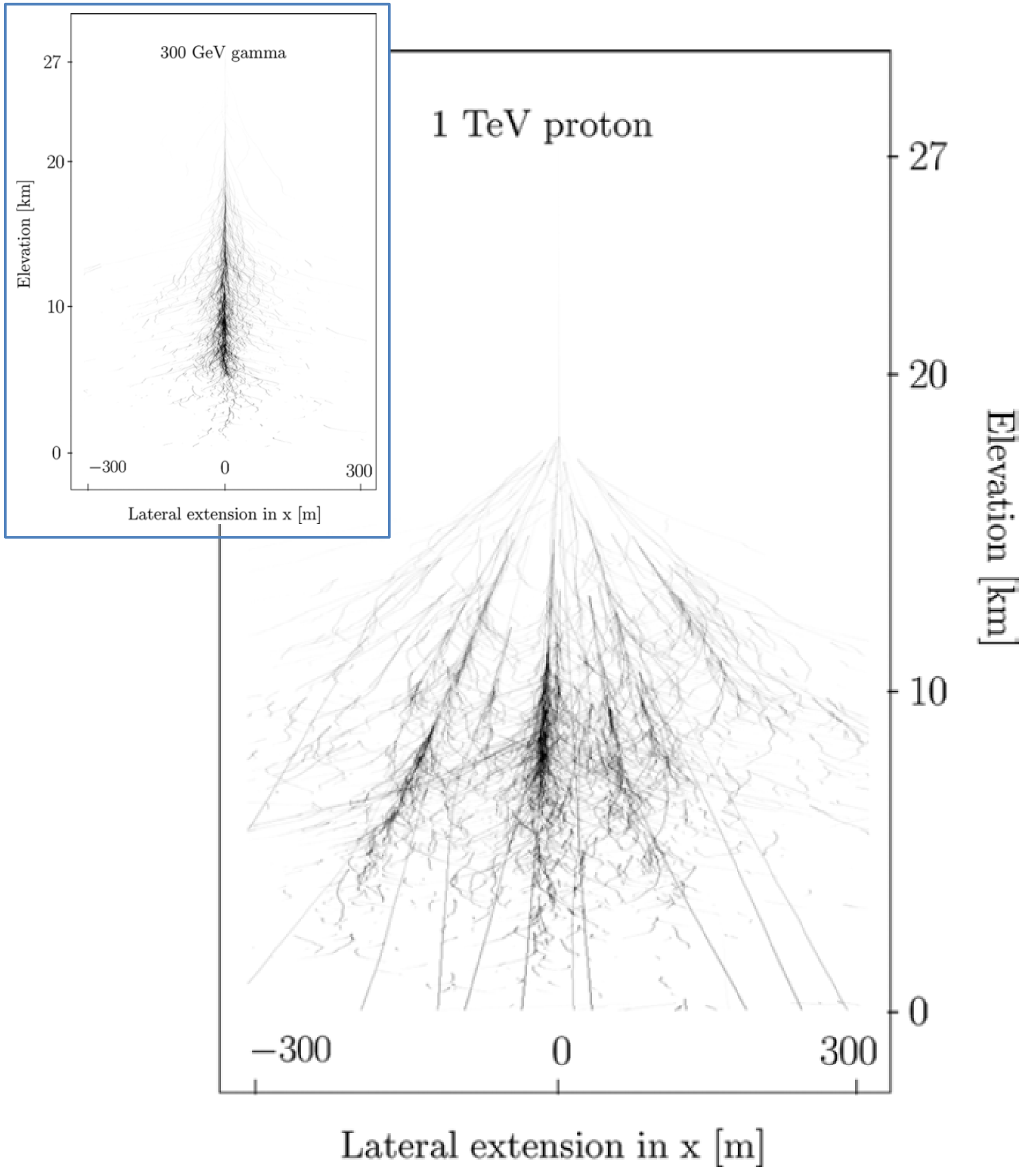
- If a gamma source emits continuously then increase the acquisition time
- Increase angular resolution
- Increase the energy reconstruction resolution
- Take advantage of shower characteristics to distinguish between a gamma/hadron induced shower

Shower characteristics



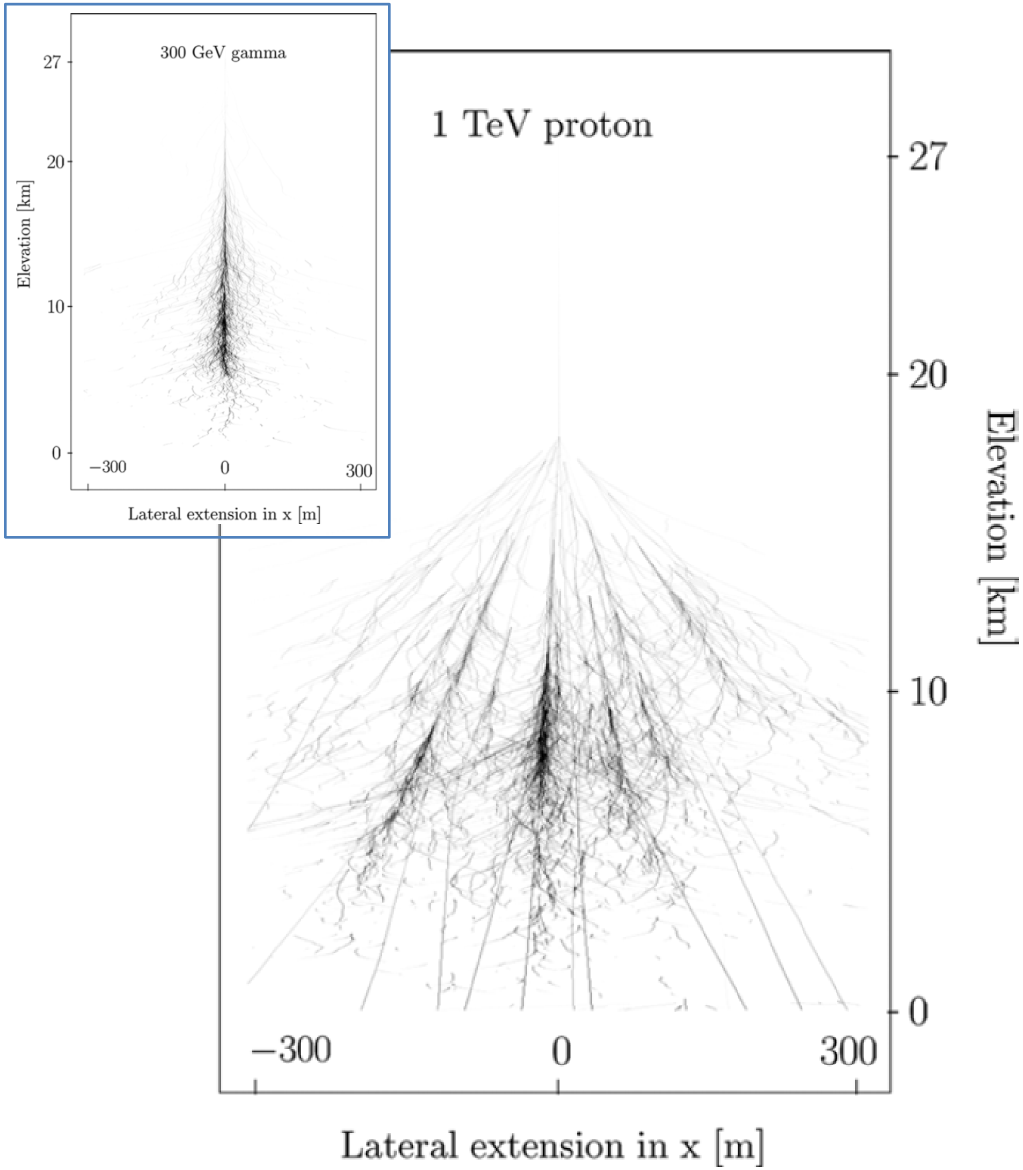
A pure electromagnetic shower (gamma) has distinct features from a shower with an hadronic component (hadron)

Strategies for primary discrimination



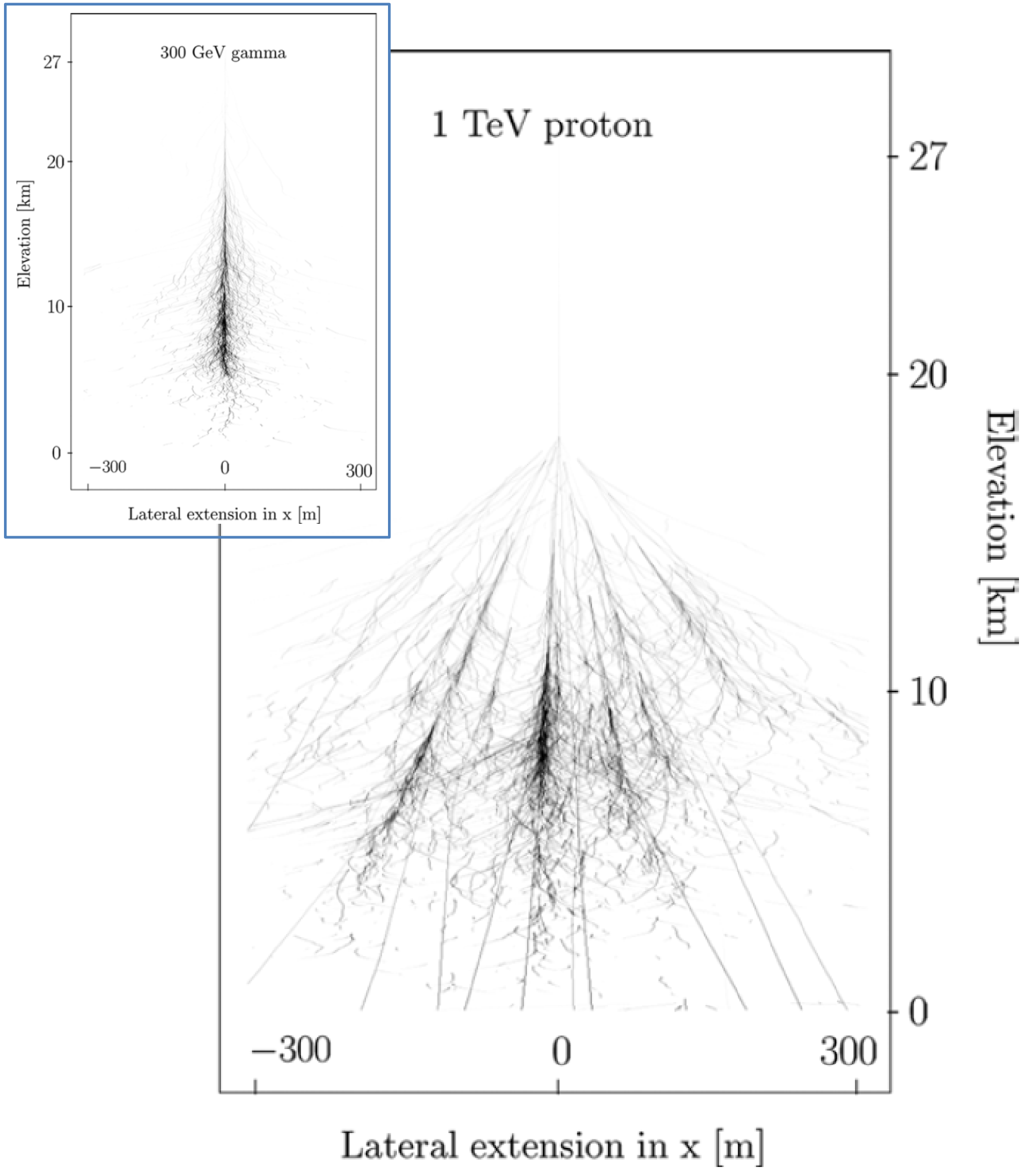
- Hit pattern at ground
- Calorimetric information at ground

Strategies for primary discrimination



- Hit pattern at ground
  - Hits from hadronic showers are more sparse than in gamma induced showers
  - RPC detectors
  - Explored by the ARGO collaboration
  - *Not explored yet for LATTTES*

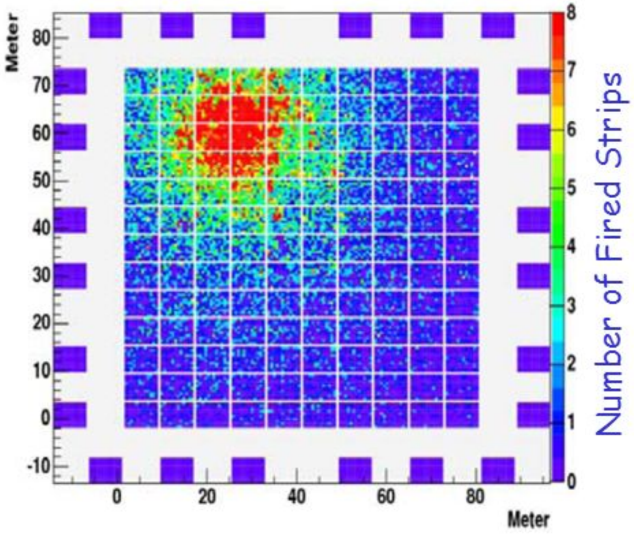
Strategies for primary discrimination



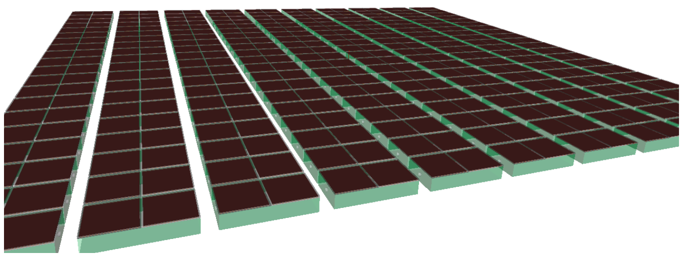
- Calorimetric information at ground
  - Search for energetic clusters far from the shower core
  - Lateral Distribution Function (LDF) steepness
  - Water Cherenkov Detectors
  - Explored by the HAWC collaboration

ARGO vs LATTES

ARGO



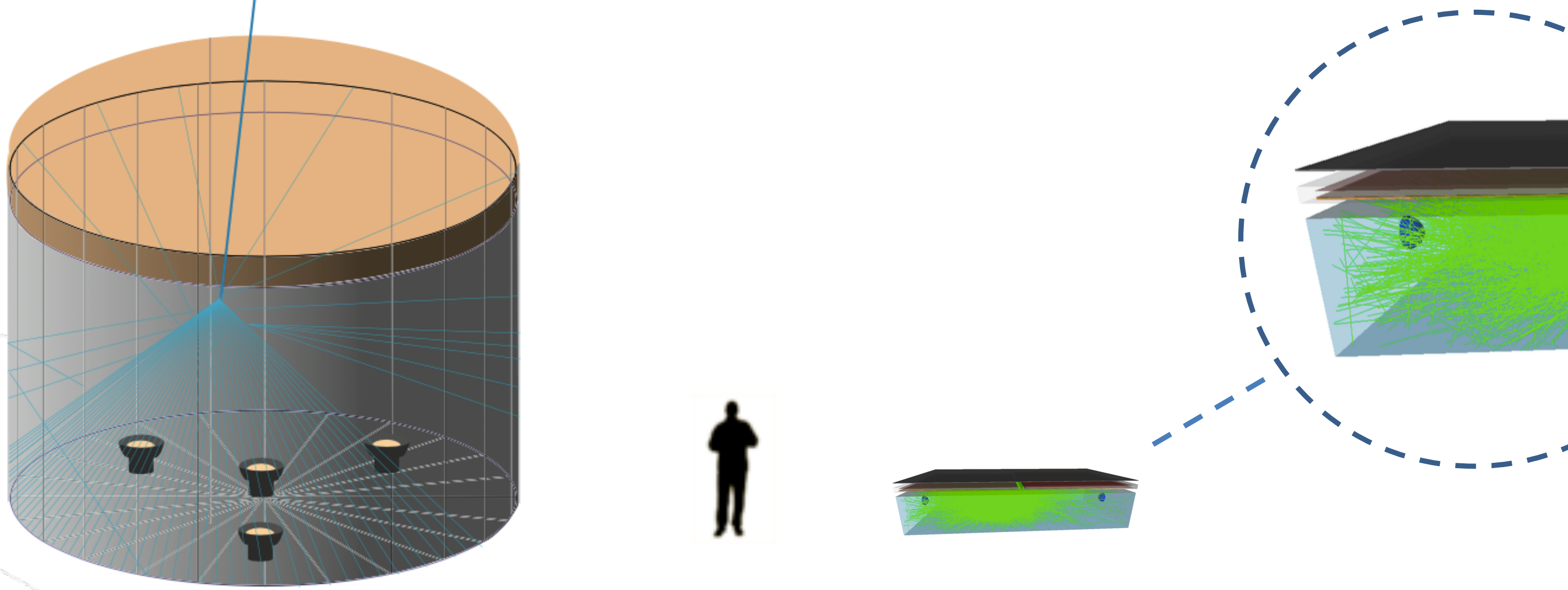
LATTES



- Argo has a higher granularity (too much?)
- Similar concept so ARGO g/h discrimination analysis should be importable to LATTES

HAWC

LATTES



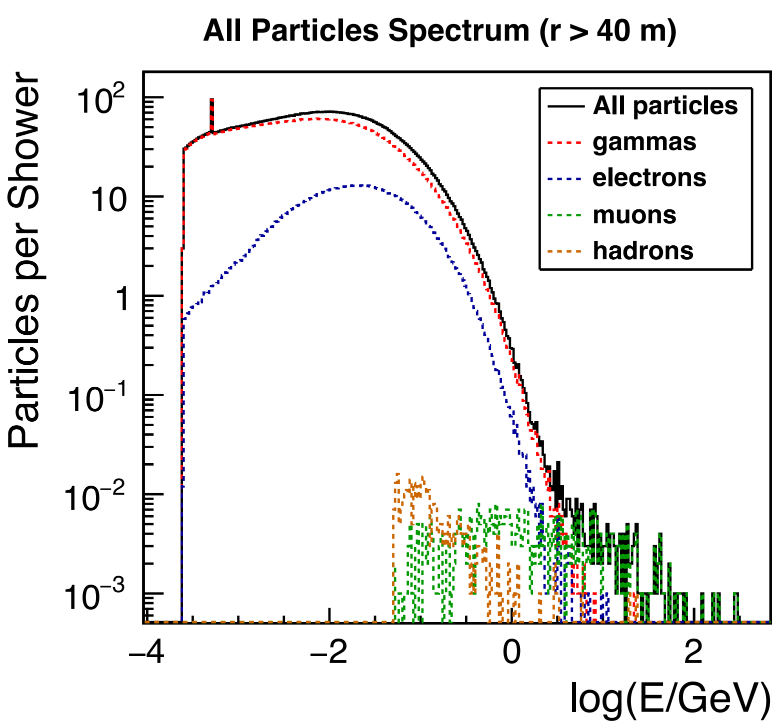
- Take advantage of hybrid detector:
  - RPCs: timing
  - WCD: calorimetry

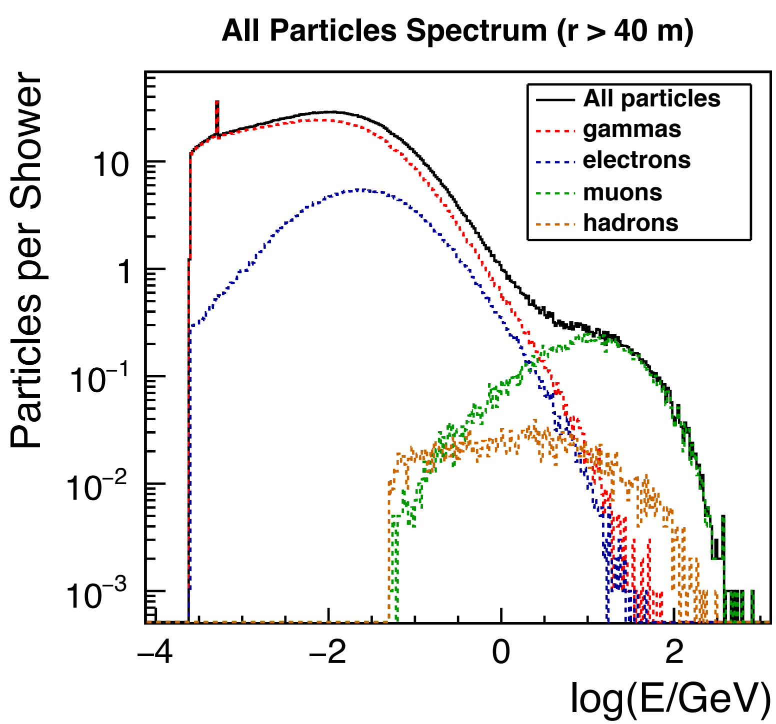
Energetic clusters far away from the shower core

Shower calorimetric information

5 TeV

Gamma showers	Proton showers

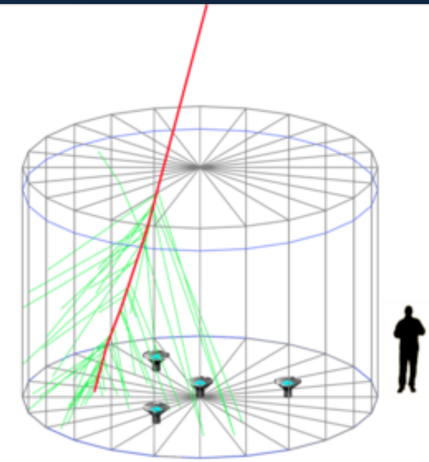




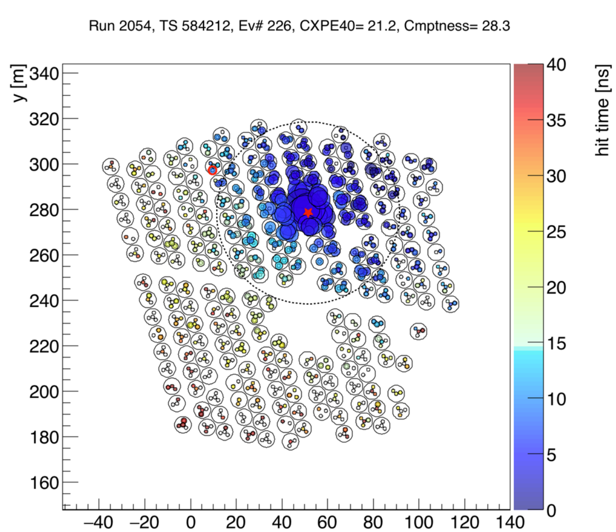
- High pT sub-shower carry large amounts of
- Look for energetic clusters far from the shower core (> 40 m)
  - Muons and high-energy photons/electrons

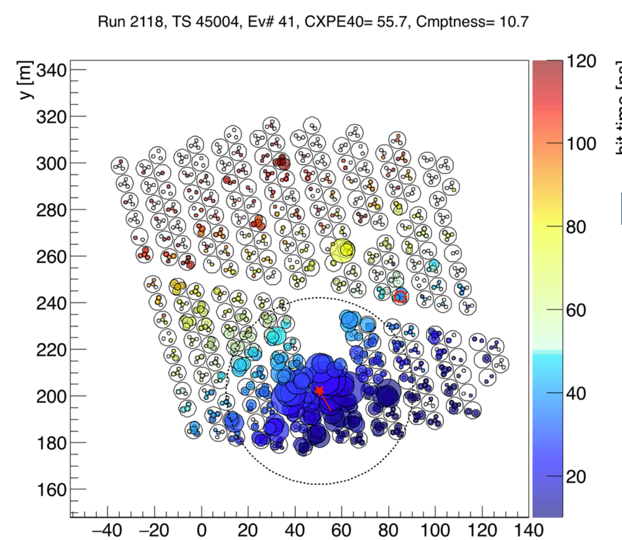
Looking for high p_t sub-showers

- HAWC g/h discrimination
  - Look for high signal far away from the shower core (> 40 m)
  - Take advantage of height of the tank to distinguish muons from electrons



gamma

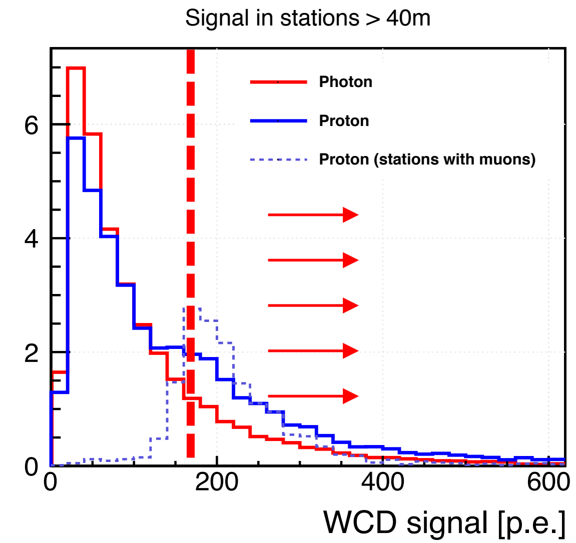


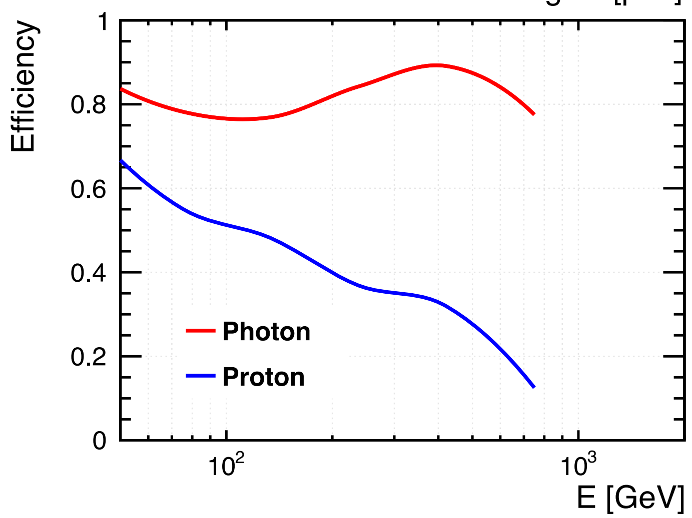


hadron

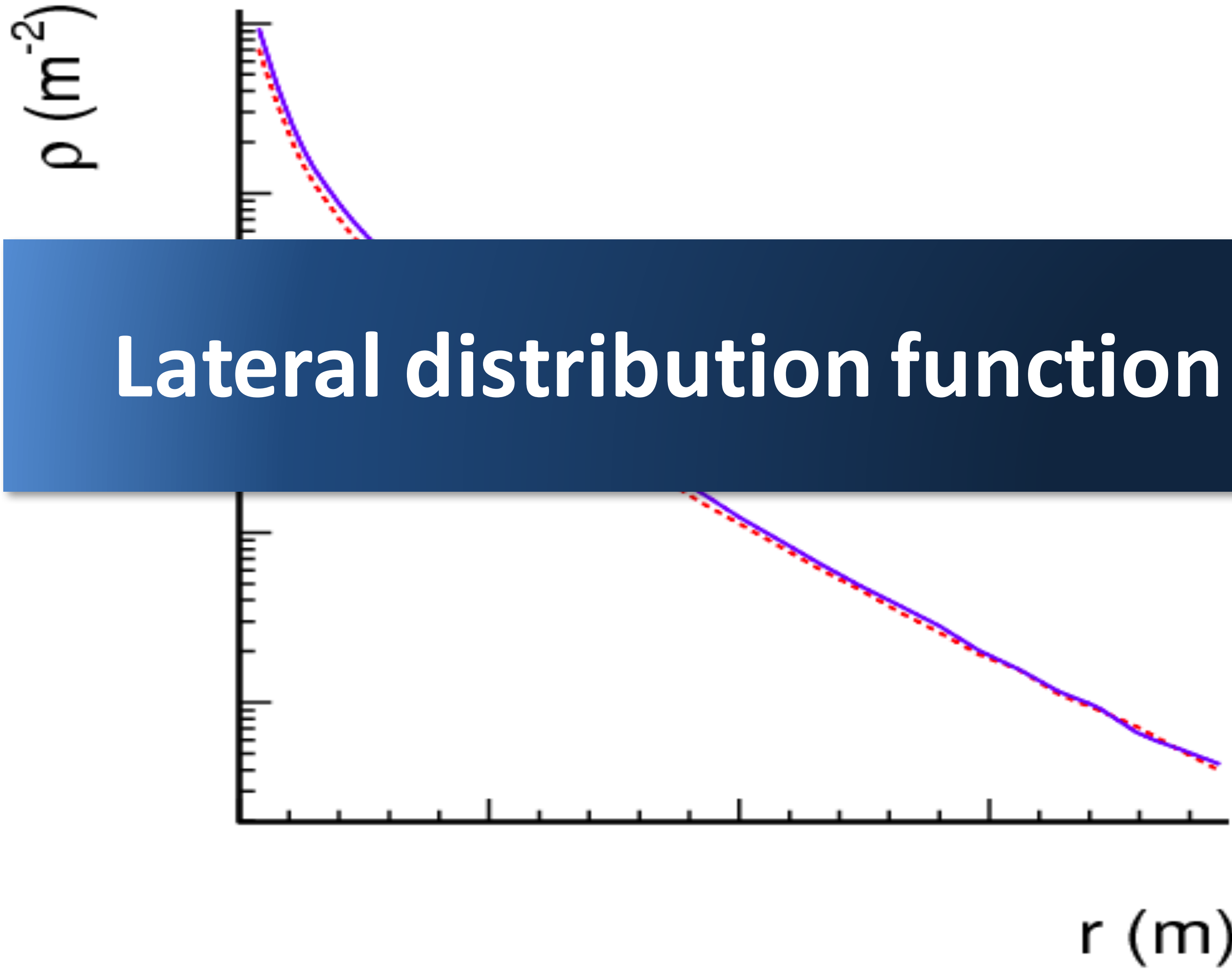
Looking for high p_t sub-showers

- LATTES g/h discrimination
  - Use only stations with a distance above 40 m
  - S40: sum all WCD stations signal
  - S40_high: sum all WCD stations that have a signal above the muon energy threshold
  - Compute S40_high / S40
  - Not optimized…

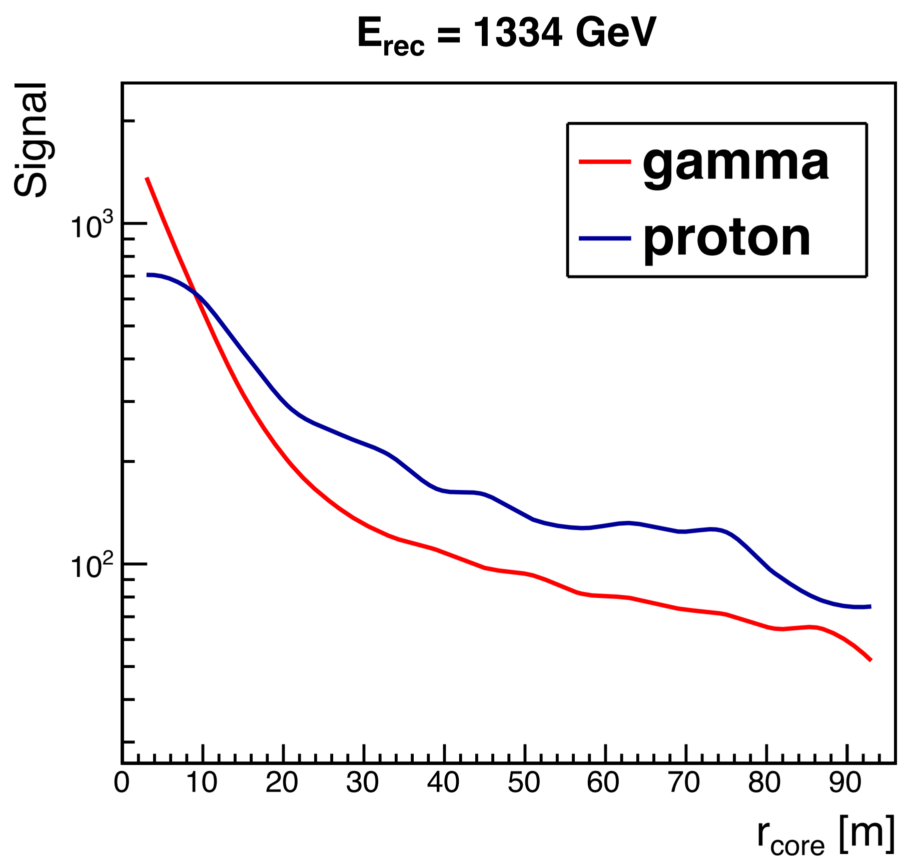




Lateral distribution function



High-energy discrimination strategy



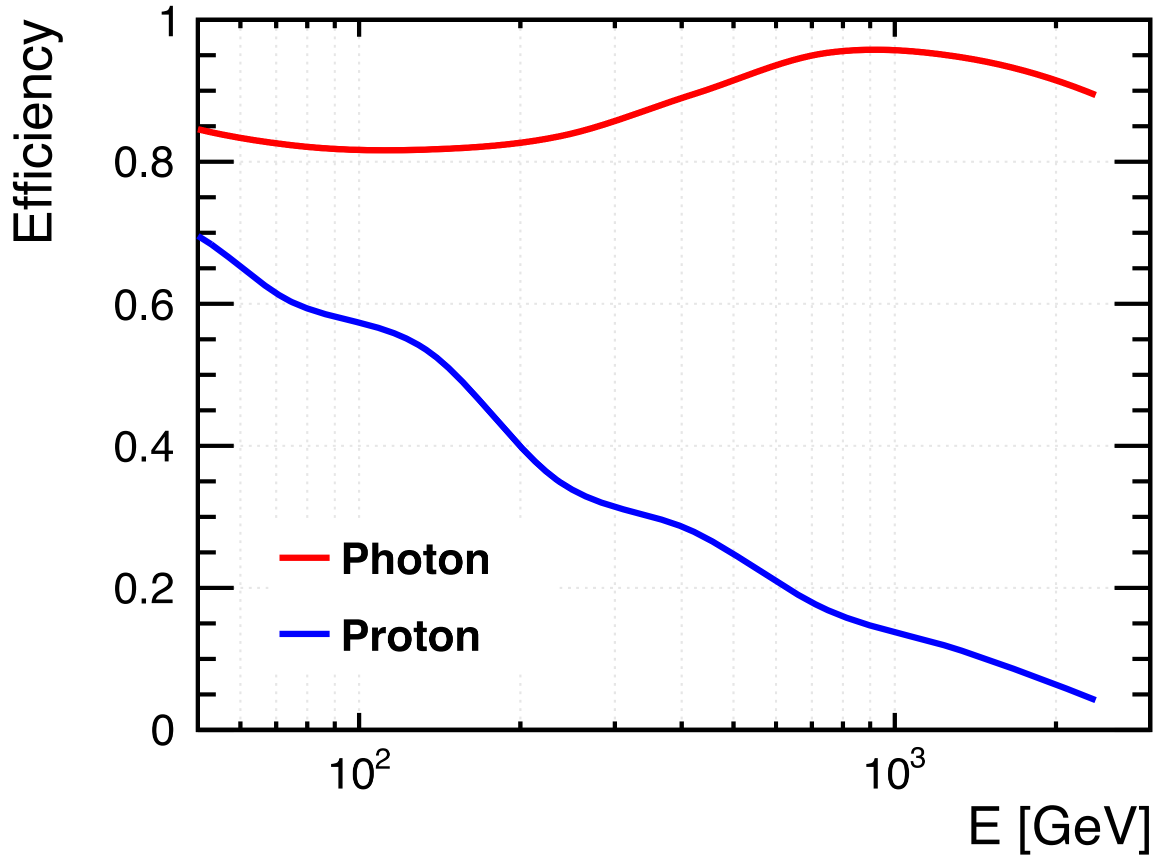
- Lateral distribution function (LDF)
  - LDF of gamma showers is more steep than the LDF of hadron showers

High-energy discrimination strategy

- Get the photon average LDF for each reconstructed energy bin
- Fit the average LDF to each single event
  - Absorb the normalization factor
- Compute the shower compactness
  - Event LDF "distance" to the photon average LDF

$$\text{Compactness} = log_{10}\left(\sum_{i}^{n} \left|\langle LDF\rangle (x_i) - y(x_i)\right|\right)$$

High-energy discrimination strategy

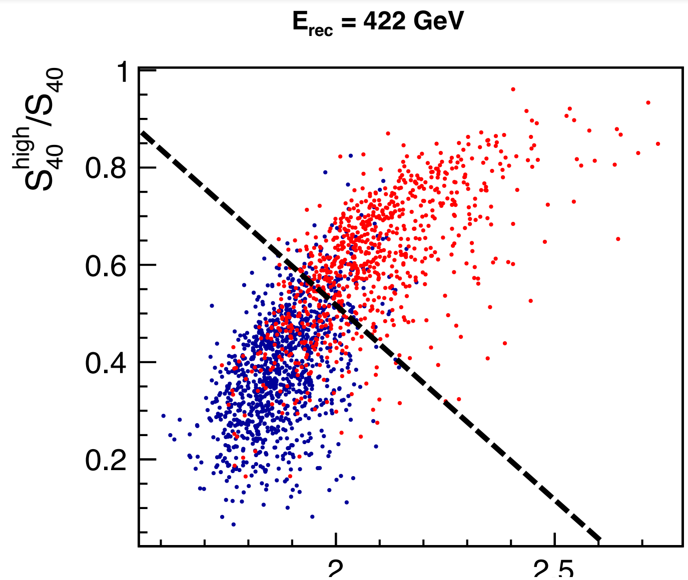


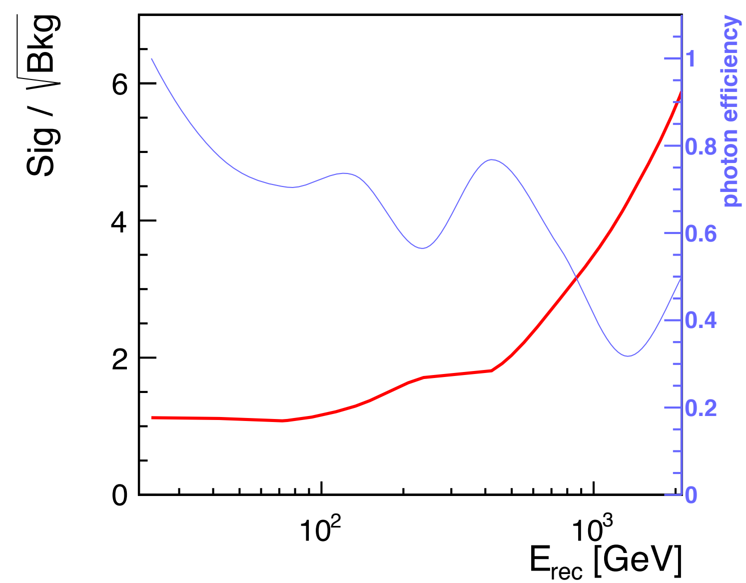
Shower compactness discrimination variable allows for a good background rejection which increases with energy

Combine information

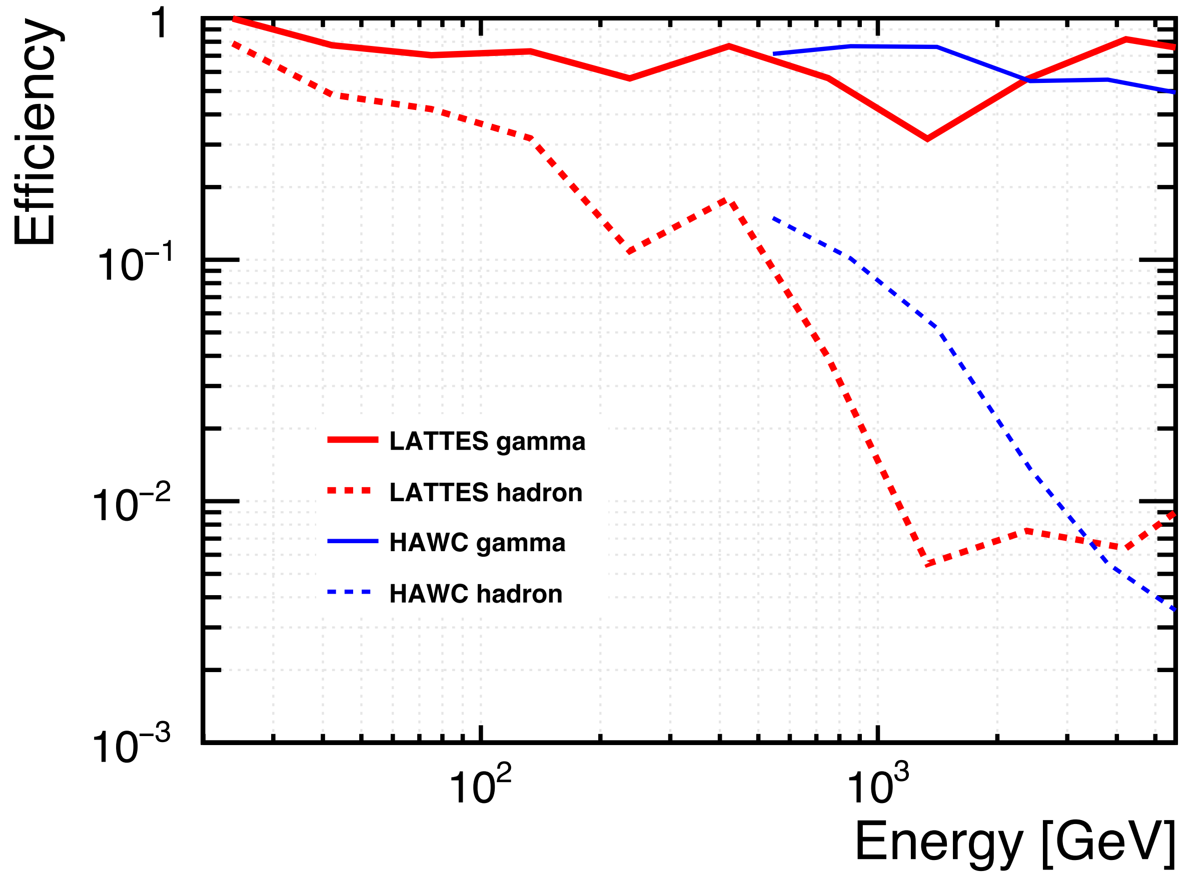
- Fisher discriminant analysis to combine the two variables
  - S40high/S40
  - Compactness
  - S/√B = 6 (at 2 TeV)

- LATTES MVA toolkit created
  - ROOT::TMVA
  - TinyXML
  - Python / C++
- Can easily be extended to:
  - add more discrimination variable
  - use higher-order methods BDT, ANN…





LATTES g/h discrimination



Although not optimized gamma/discrimination results are already very encouraging

Summary

- LATTES WCDs can be used to distinguish between gamma/hadron showers
  - First results are very encouraging
    - Analysis not optimized
    - More variables (ideas) can be easily added and tested
- LATTES RPCs still to be explored in g/h discrimination
  - Study the shower pattern at ground
- The combination of both techniques should improve further LATTES g/h discrimination

Acknowlegments

FCT
Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

COMPETE
PROGRAMA OPERACIONAL FACTORES DE COMPETITIVIDADE

QREN
QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL
PORTUGAL 2007.2013

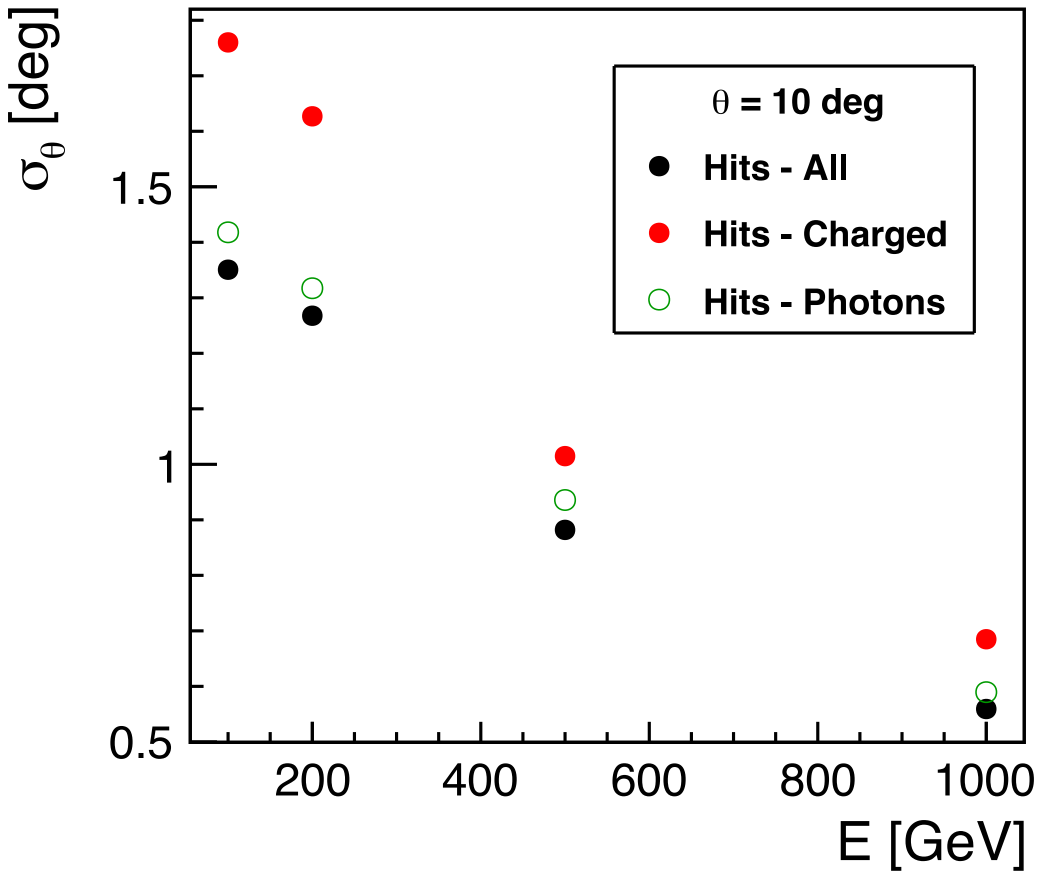
UNIÃO EUROPEIA
Fundo Europeu de Desenvolvimento Regional

LIP

TÉCNICO LISBOA

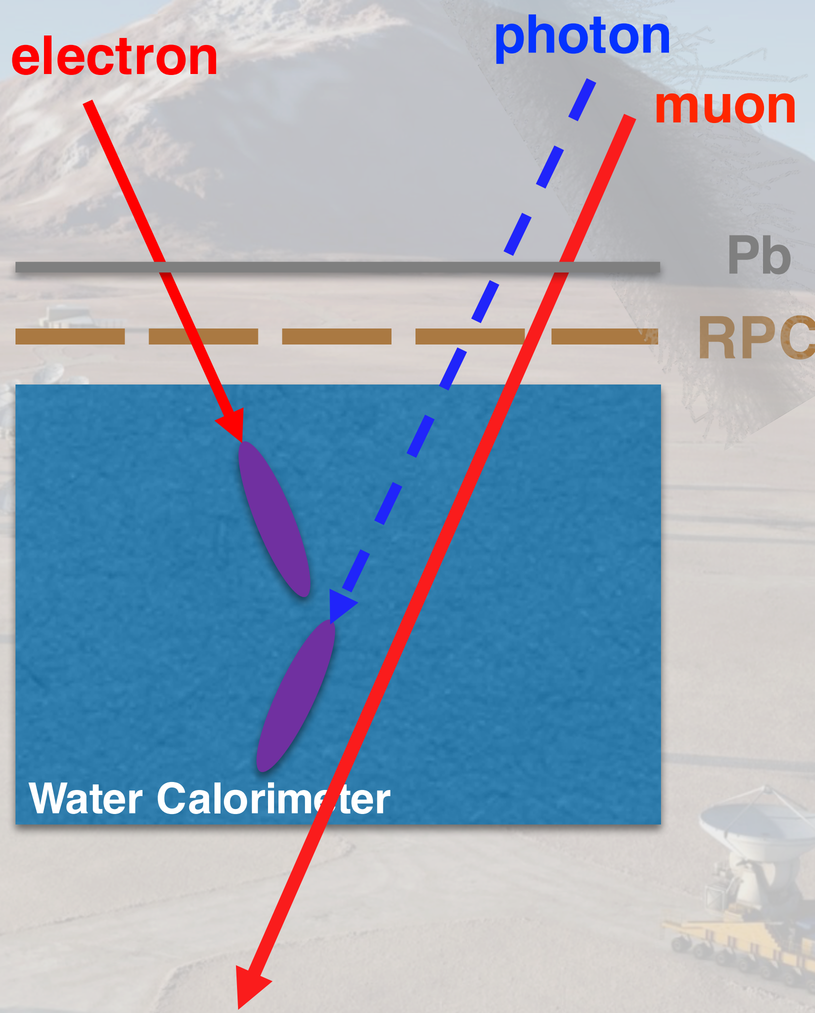
BACKUP SLIDES

Contributions to the geometric reconstruction



- **Photons** retain a **higher correlation** with the **shower geometry** than charged particles
- Could we measure photons with the RPC instead?

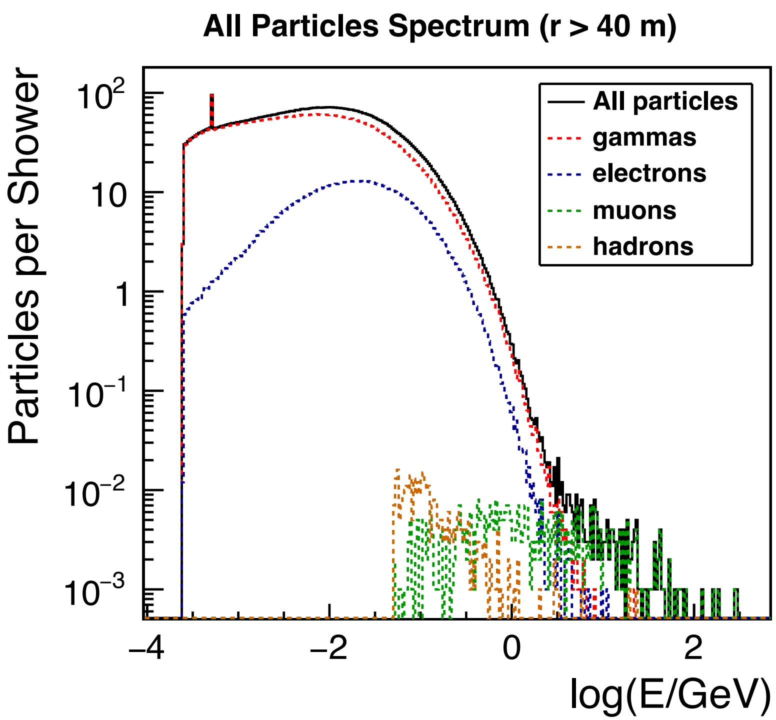
LATTES station baseline concept



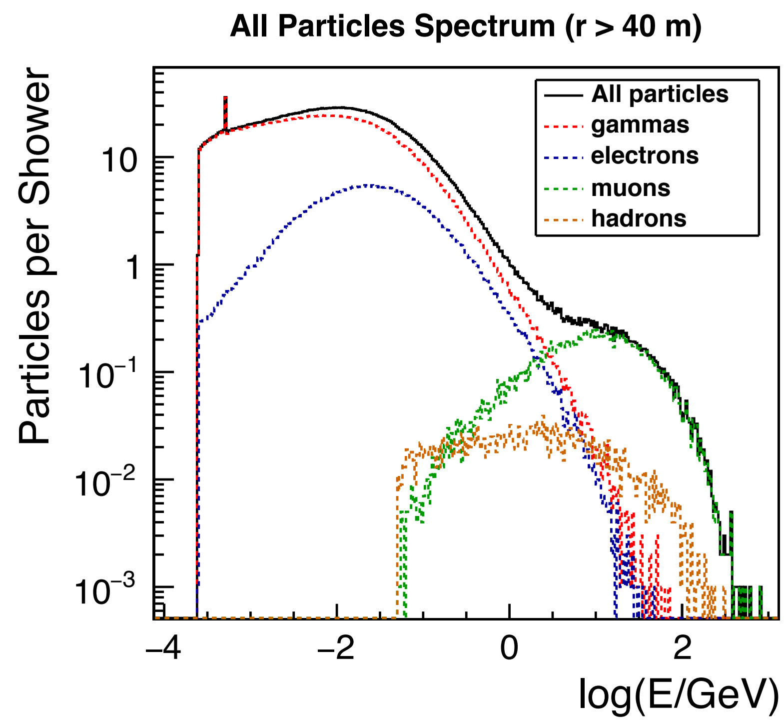
Exploring the WCD

5 TeV

Gamma showers

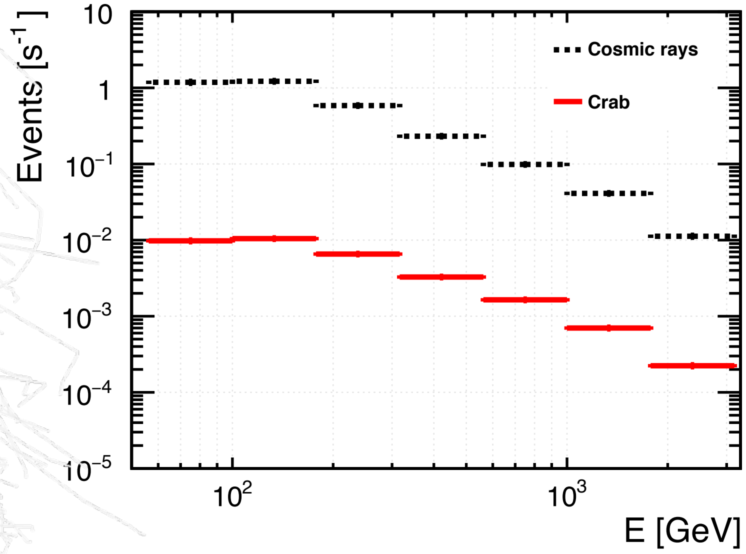


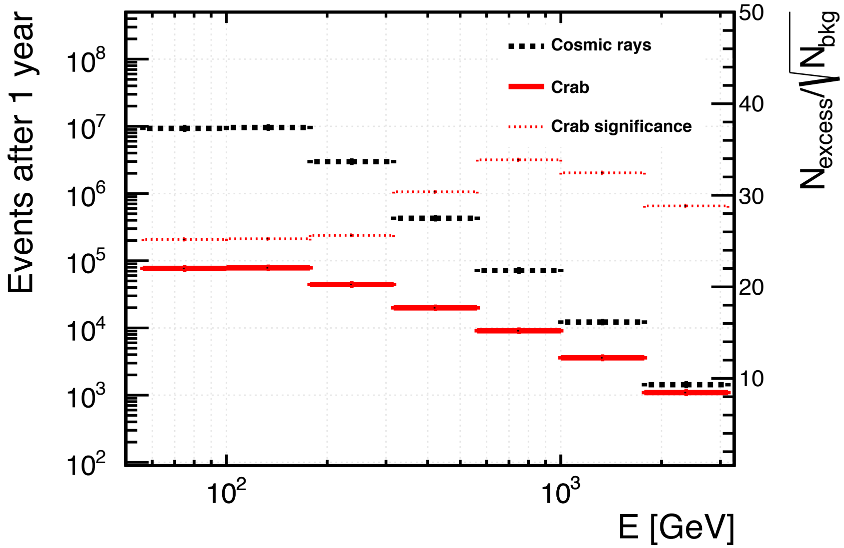
Proton showers



- What should we look for?
  - Look for energetic clusters far from the shower core
  - Above 40 m

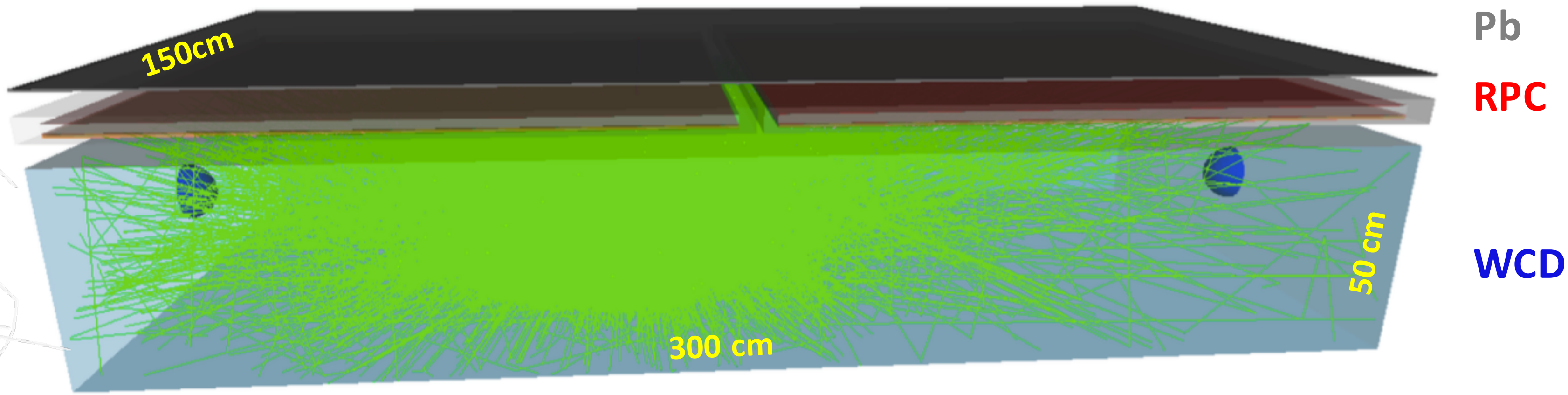
LATTES expect events from Crab





LATTES concept

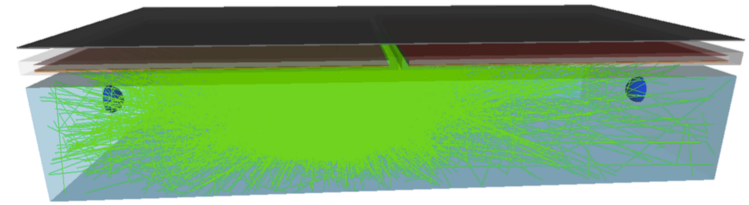
LATTES STATION



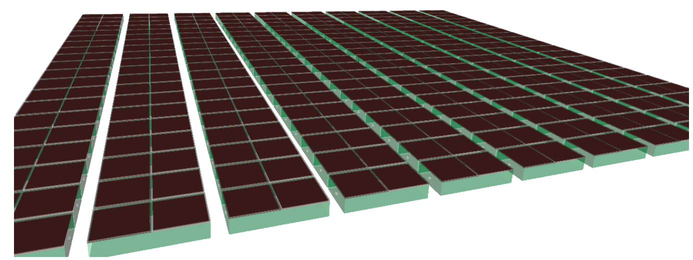
– Thin lead plate (Pb)
  - 5.6 mm (one radiation lenght)
– Resistive Plate Chambers (**RPC**)
  - 2 RPCs per station
  - Each RPC with 4x4 readout pads
– Water Cherenkov Detector (**WCD**)
  - 2 PMTs (diameter: 15 cm)
  - Inner walls covered with white diffusing paint

LATTES concept

- Hybrid detector:
  - Thin lead plate
    - To convert the secondary photons
    - Improve geometric reconstruction
  - Resistive Plates Chamber
    - Sensitive to charged particles
    - Good time and spatial resolution
    - Improve geometric reconstruction
    - Explore shower particle patterns at ground
  - Water Cherenkov Detector
    - Sensitive to secondary photons and charged particles
    - Measure energy flow at ground
    - Improve trigger capability
    - Improve gamma/hadron discrimination



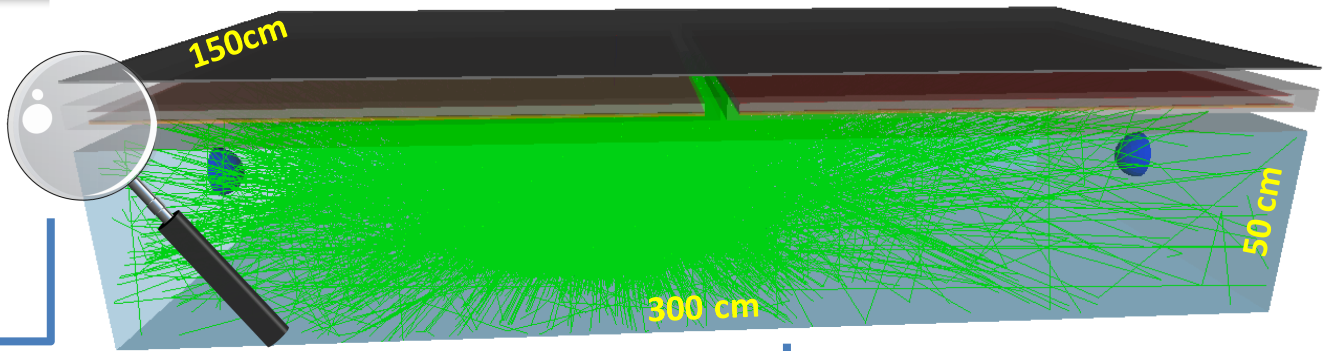
LATTES station
1.5 m x 3 m x 0.5 m



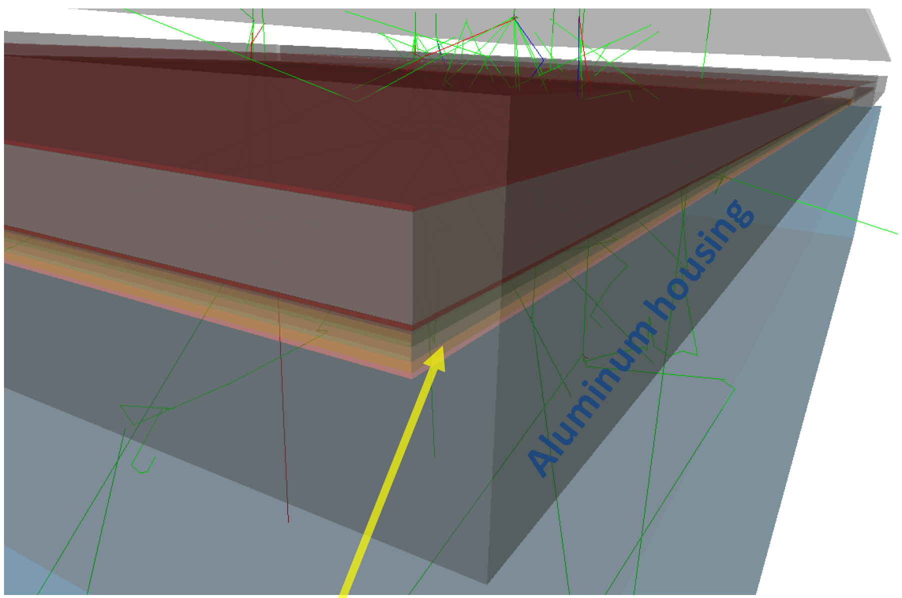
LATTES core array
30 x 60 stations
100 x 100 m²

LATTES station in Geant4

- **Realistic description**



Detailed RPC structure



Acrylic box with glass electrodes and 1 mm gas gaps

- **Explore Geant4 capabilities to simulate optical photon propagation;**
- λ dependence of all relevant processes/materials taken into account;
- **Water**
  - Attenuation length ~ 80 m @ λ = 400 nm
- **PMT**
  - Q.E.$_{max}$ ~ 30% @ λ = 420 nm
- **Tyvek**
  - Described using the G4 UNIFIED optical model;
  - Specular and diffusive properties;
  - R ~ 95%, for λ > 450 nm