Longitudinal Energy Profiles from Auger

Odd One In

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Institut für Experimentelle Kernphysik

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Overview

- Experiment
- Measurement of fluorenscence light
- Energy profiles with “double bumps”
- Outlook

Pierre Auger Observatory

- What?

  A high energy cosmic ray experiment

  Area 3000 km^2 Proposed 1992 First data 2004

- How?

  Surface detector: 1600 water tanks (Cherenkov radiation)

  Fluorescene detector: 4 telescope sites

  Extensions: HEAT, INFILL, AERA

- Where?

  Auger South: Argentina. Auger North: tba.

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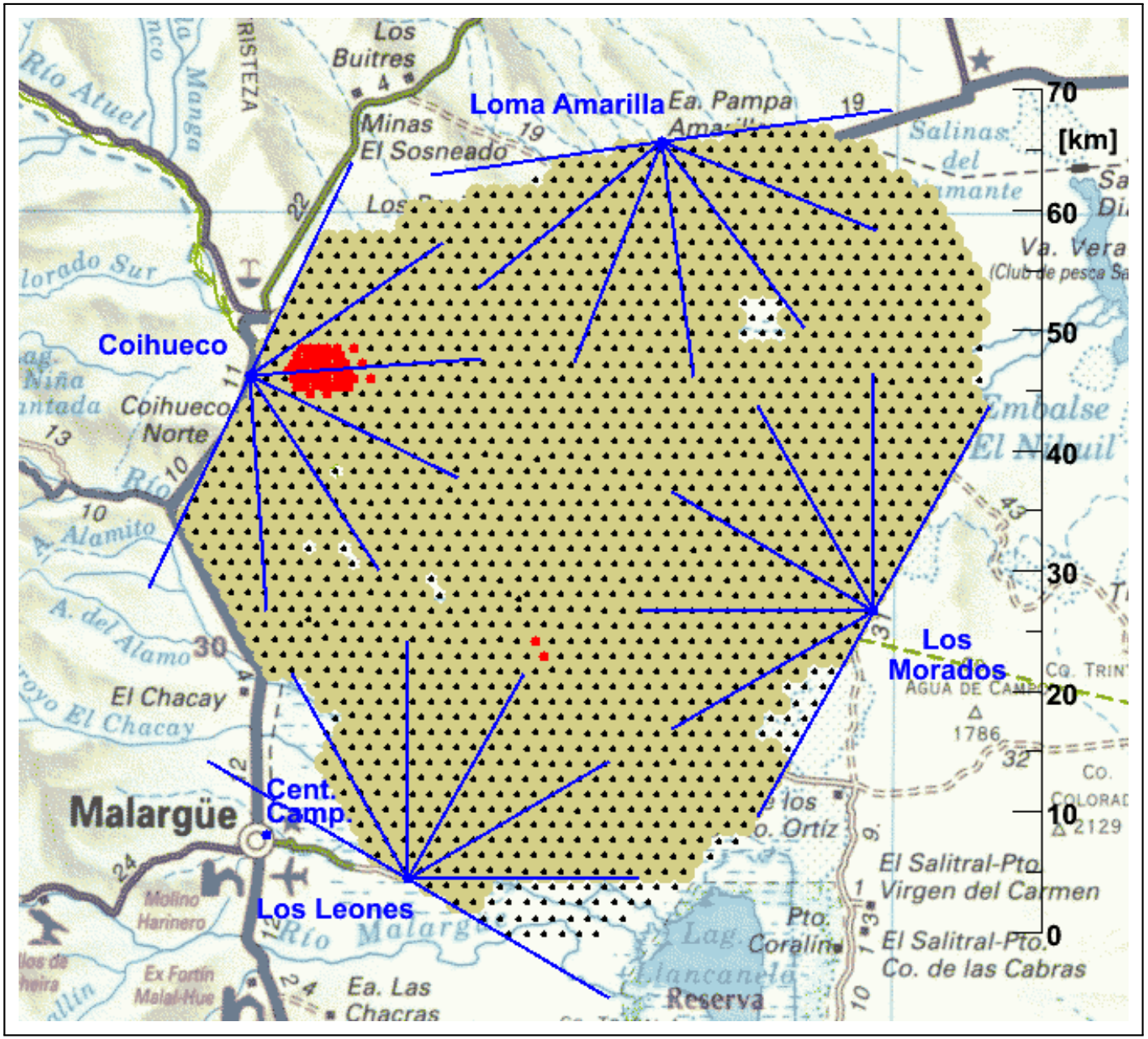

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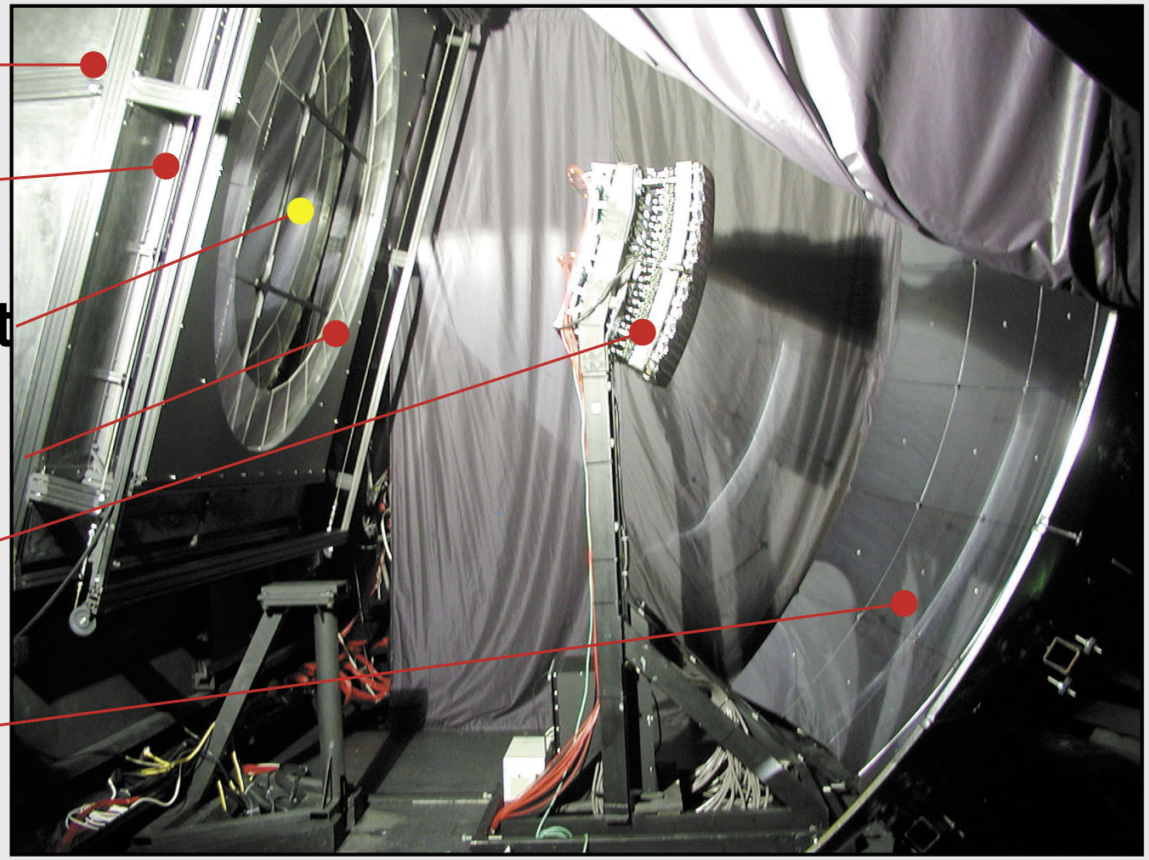
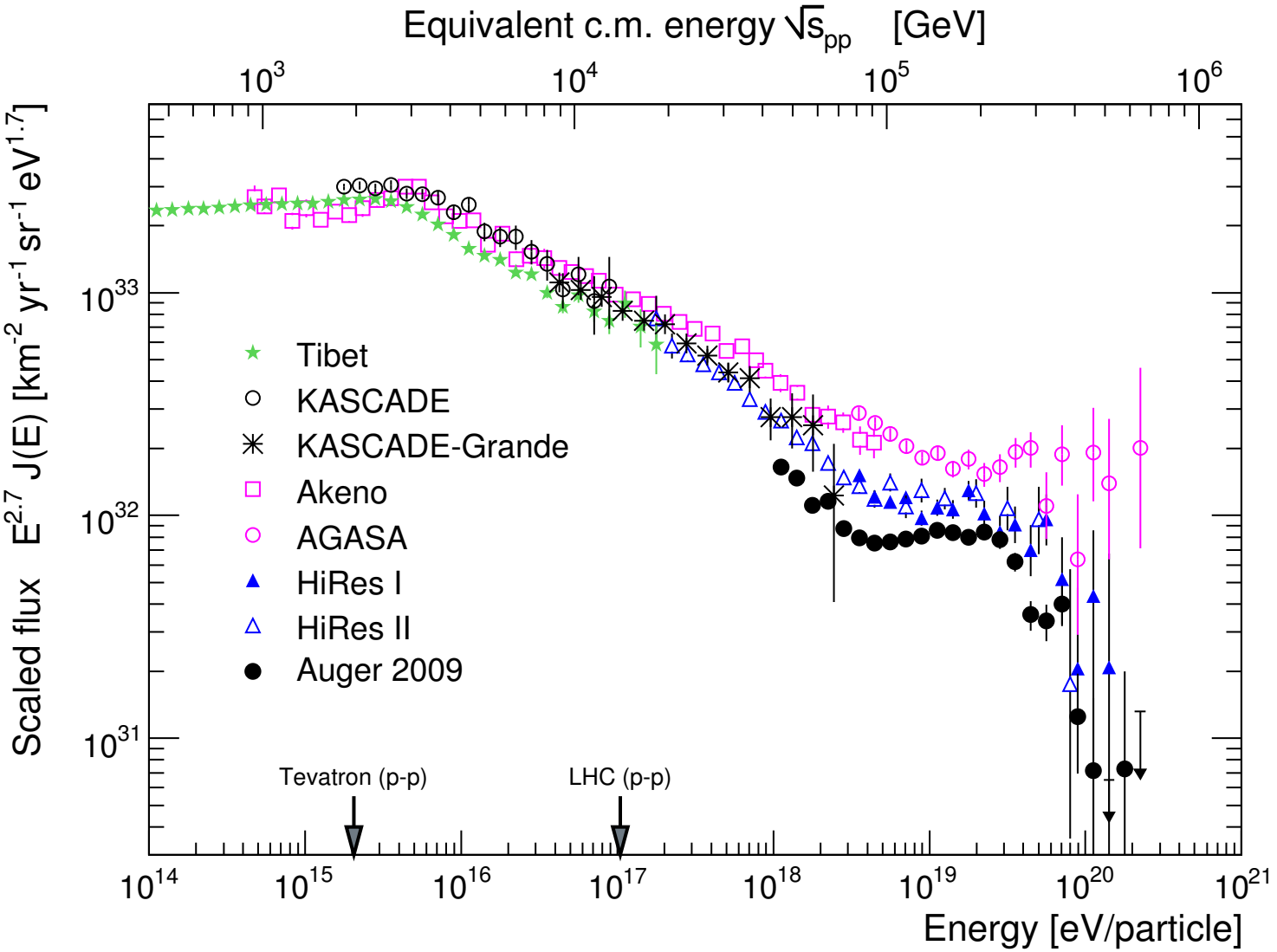
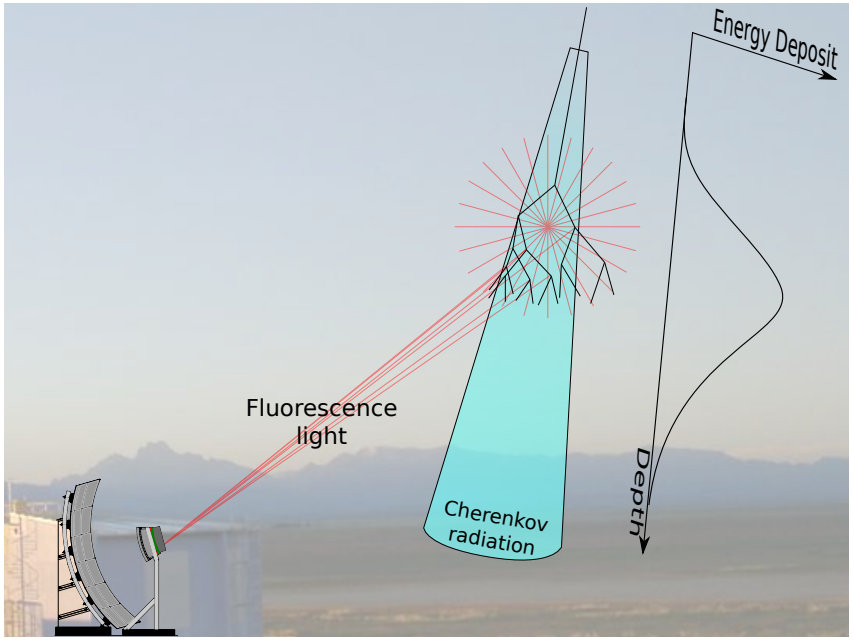


Energy Range



Measuring Fluorescence Light



Reconstruction

- Measurement only during moonless nights (duty cycle $\simeq$ 10%)
- Fluorescence light emitted by exited N_2-molecules
- Cone of Cherenkov light narrow (zenith angle $\rightarrow$ detection)

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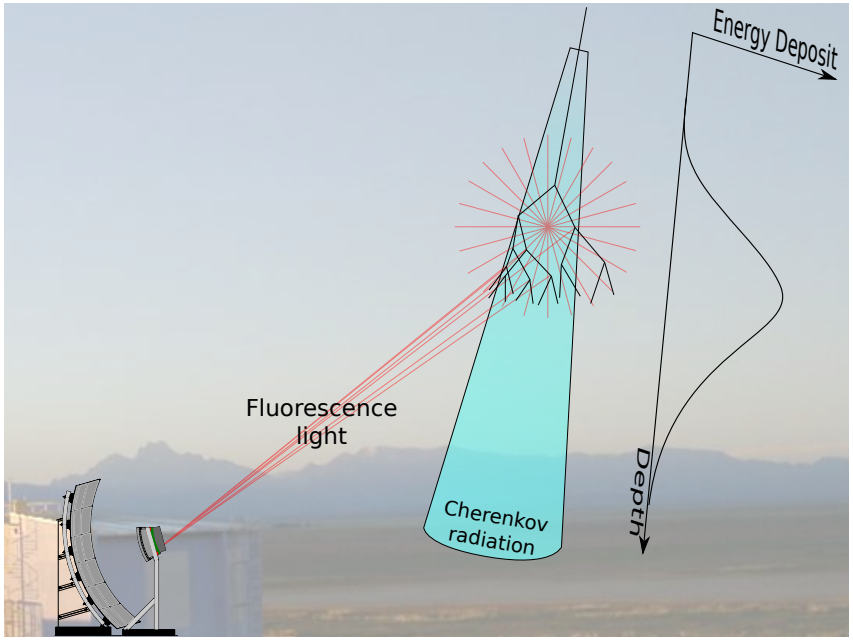

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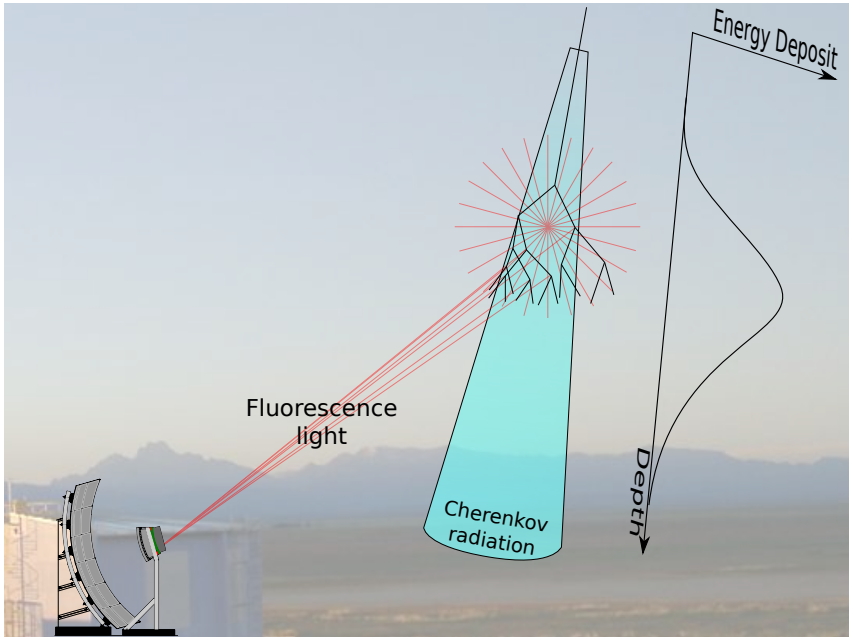

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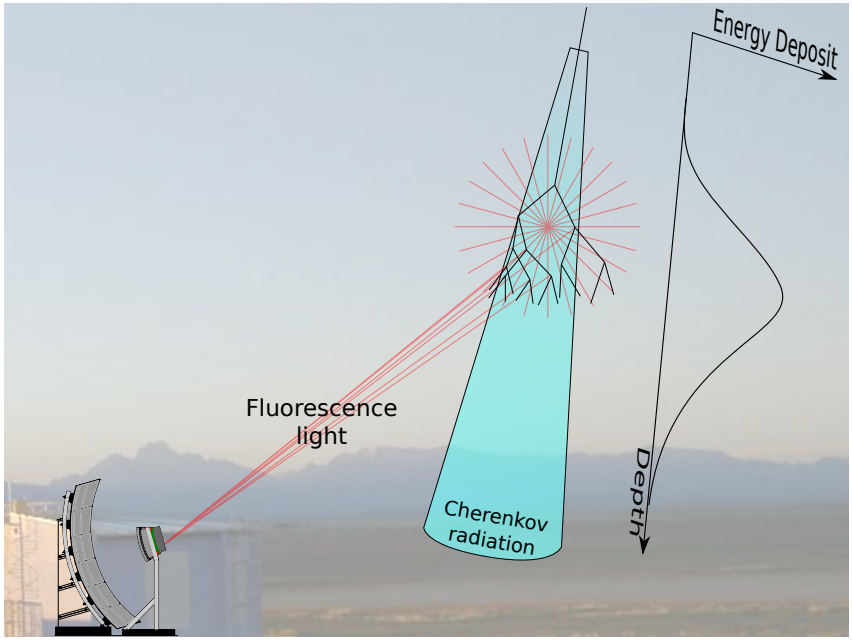

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- Each mirror has a camera with 440 PMTs (detect 3 to 10^5 photoelectrons per 100 ns)
- Time info gives us geometry of shower (hybrid mode: shower arrival resolution 0.6°)

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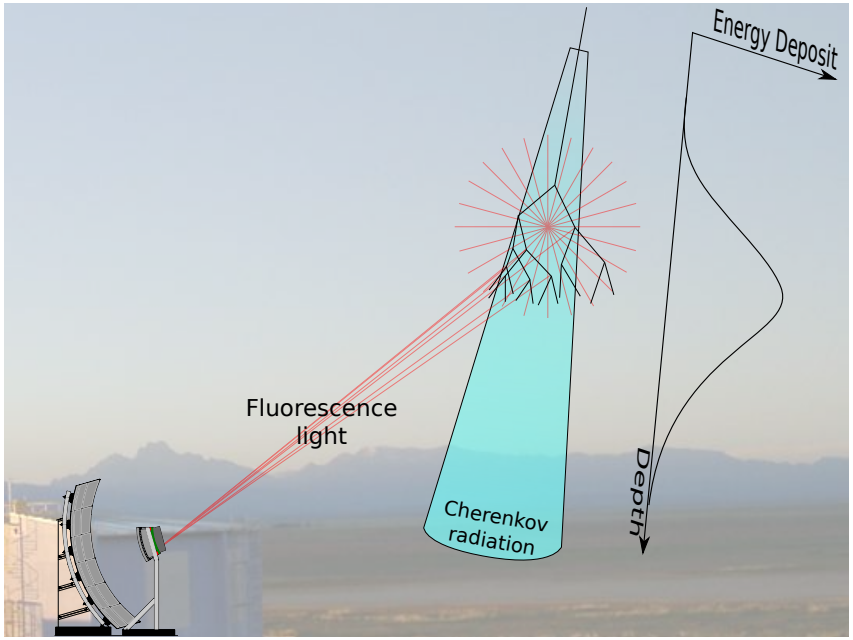

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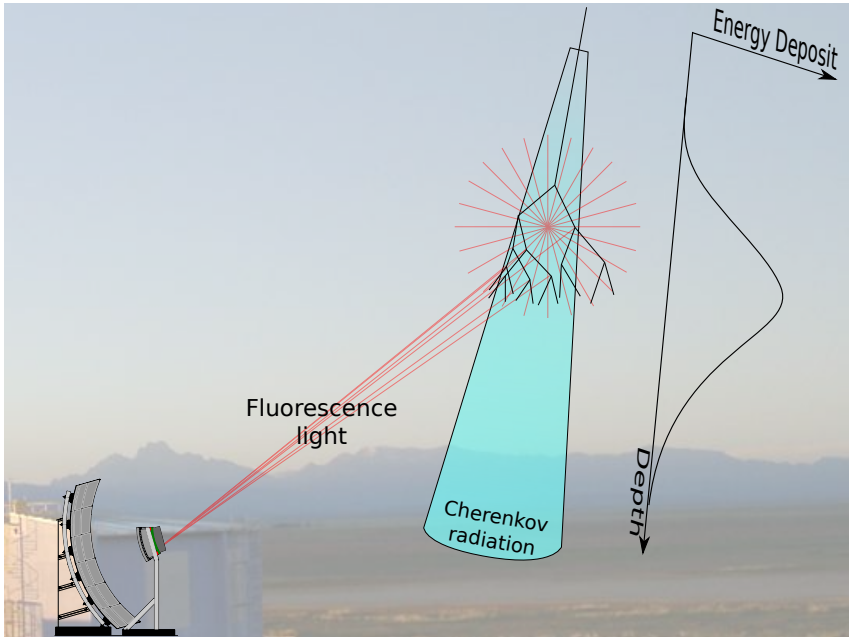

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- Light as function of time $\Rightarrow$ energy as function of slant depth
- These energy profiles can be described with Gaisser-Hillas function

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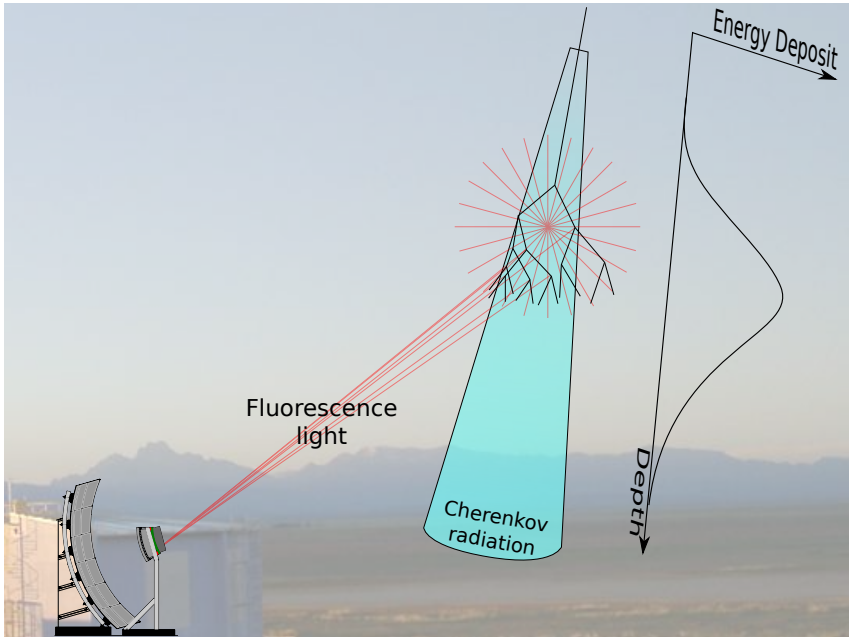

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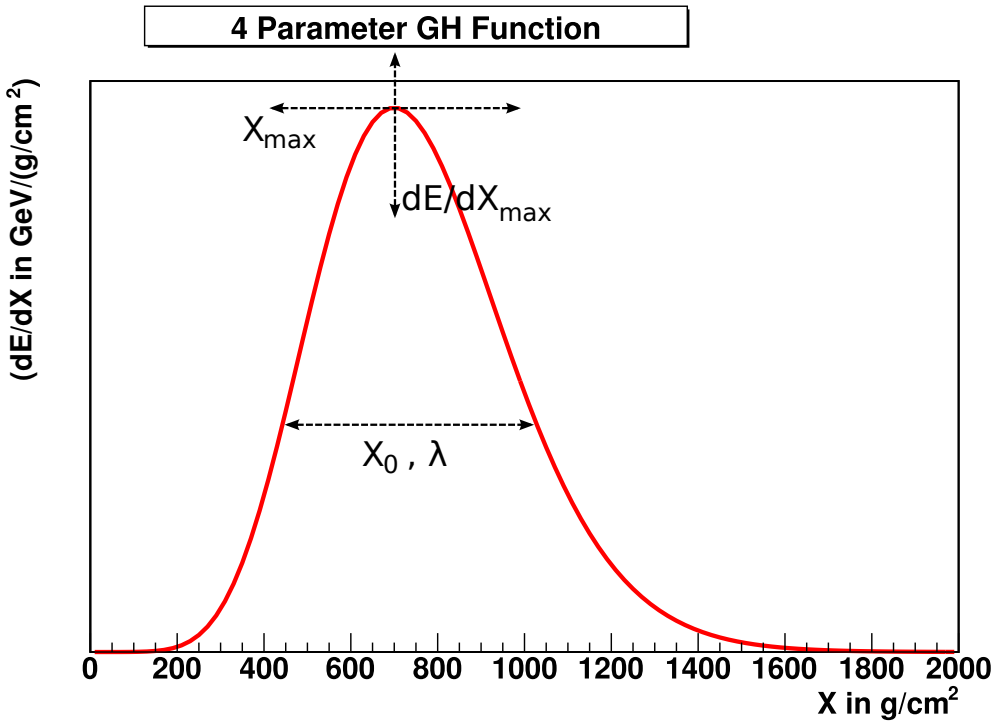
Gaisser-Hillas Function



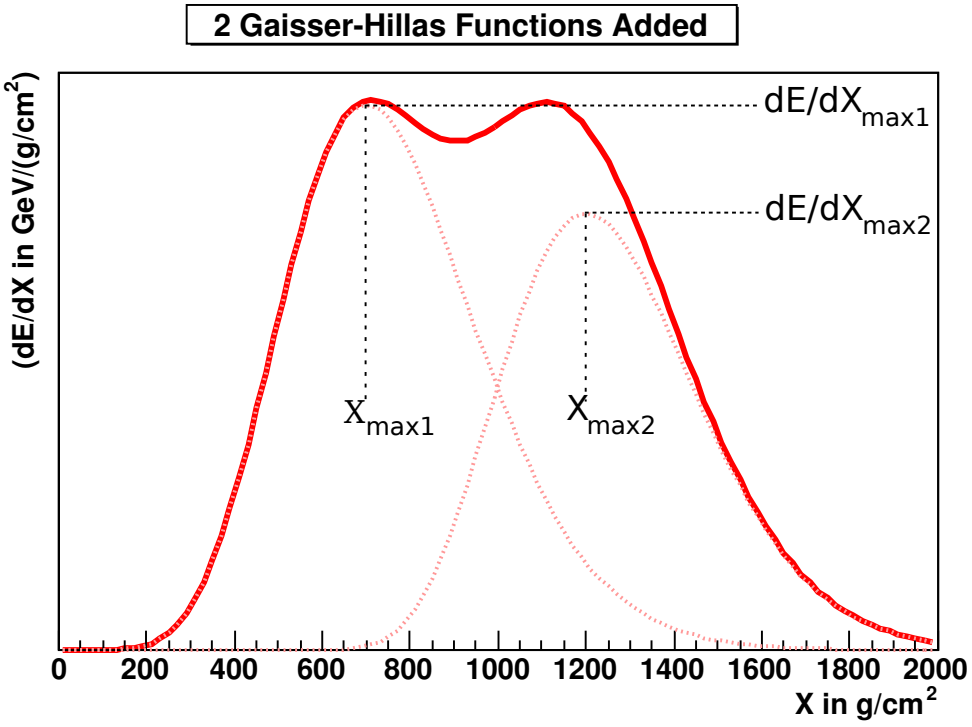
Formula

$$f_{GH}(X) = dEdX_{max} \cdot \left(\frac{X - X_0}{X_{max} - X_0}\right)^{(X_{max} - X_0)/\lambda} \cdot e^{(X_{max} - X)/\lambda}$$

Calorimetric energy

- $dE/dX \sim lg(E)$

What Are Double Bumps?



Sub showers

- Difference in depth between interaction 1 and 2:

  $\Delta X = X_{\mathrm{max}2} - X_{\mathrm{max}1}$

- Inelasticity: $\kappa = 1 - \frac{(dE/dX)_{\mathrm{max}2}}{(dE/dX)_{\mathrm{max}1} + (dE/dX)_{\mathrm{max}2}}$

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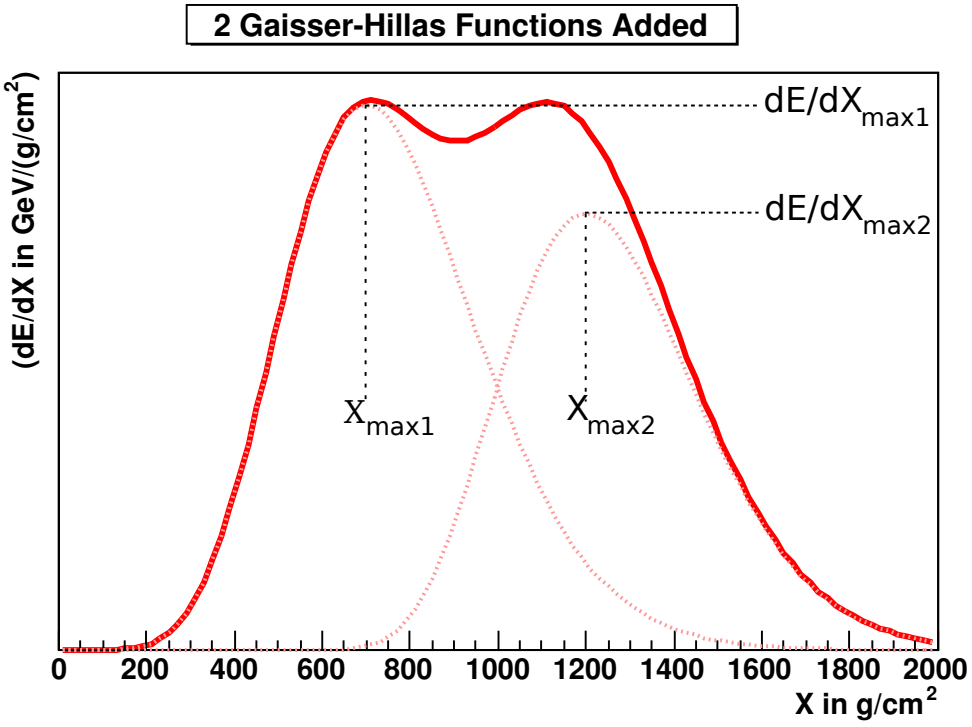

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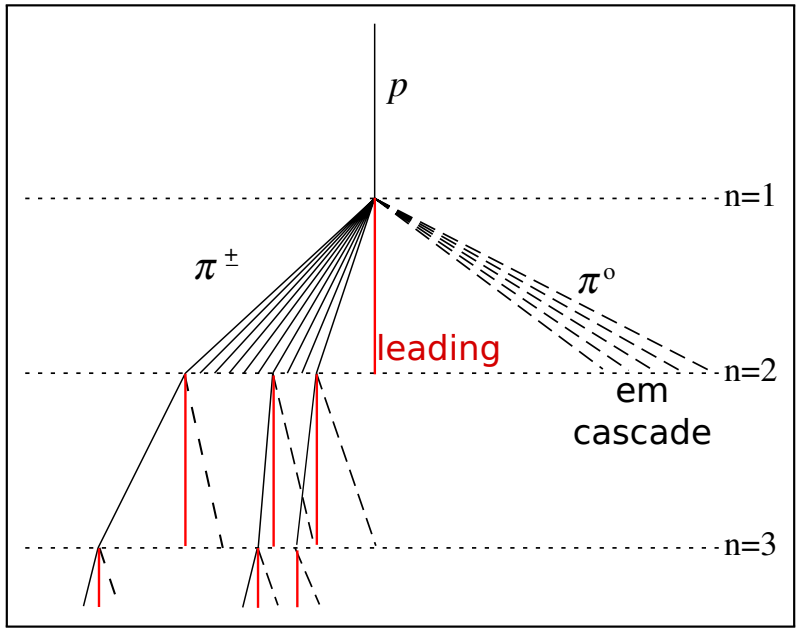

- Channels:

  $\pi\pm \rightarrow \mu^{\pm} + \nu_{\mu}$

  $\pi^0 \rightarrow \gamma \rightarrow e^+ + e^-$
- Simulations suggest a leading particle (large fraction, highest energy) being produced
- Leading particle has $E = (1 - \kappa)E_0$, with inelasticity κ
- Exact value unknown $\kappa \simeq 0.5$

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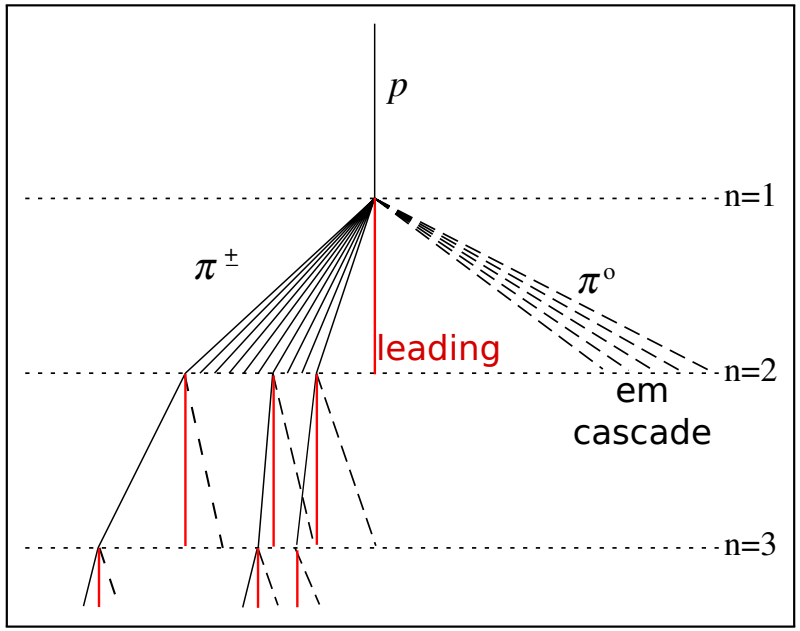

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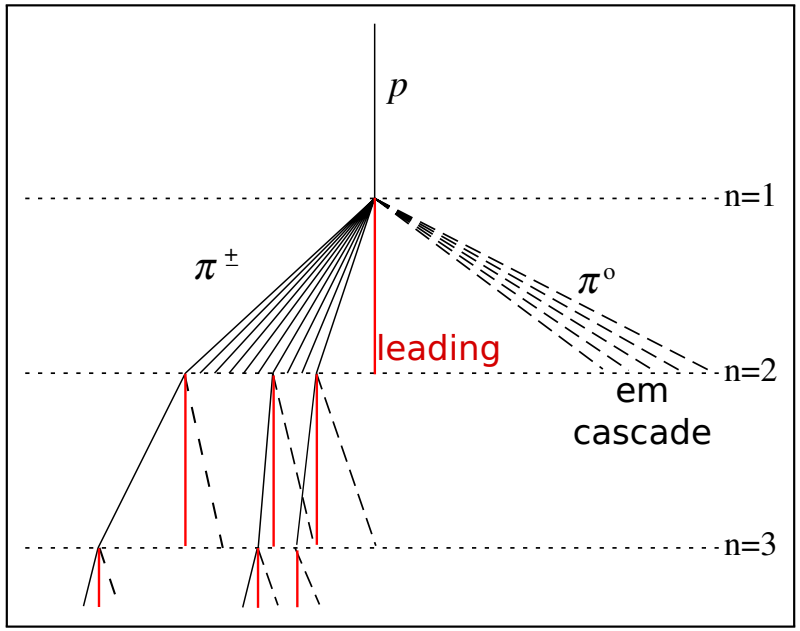

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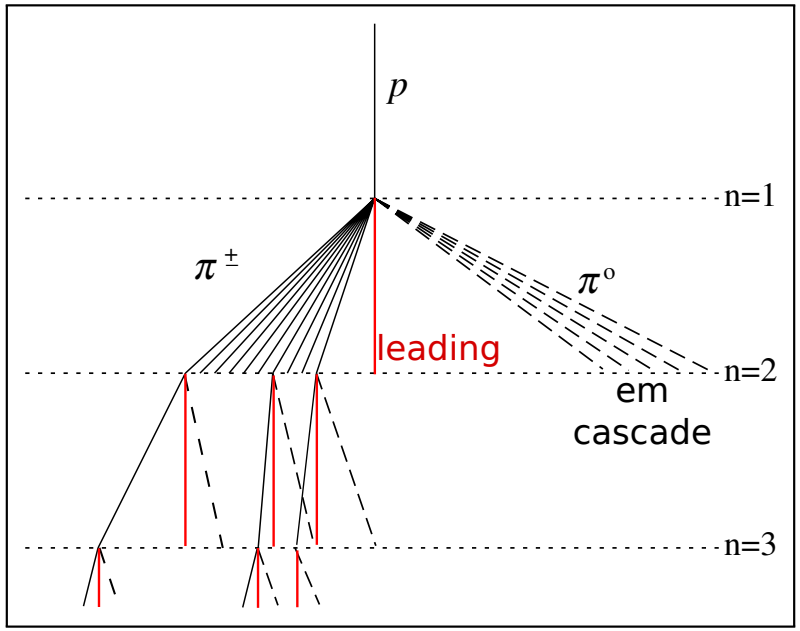

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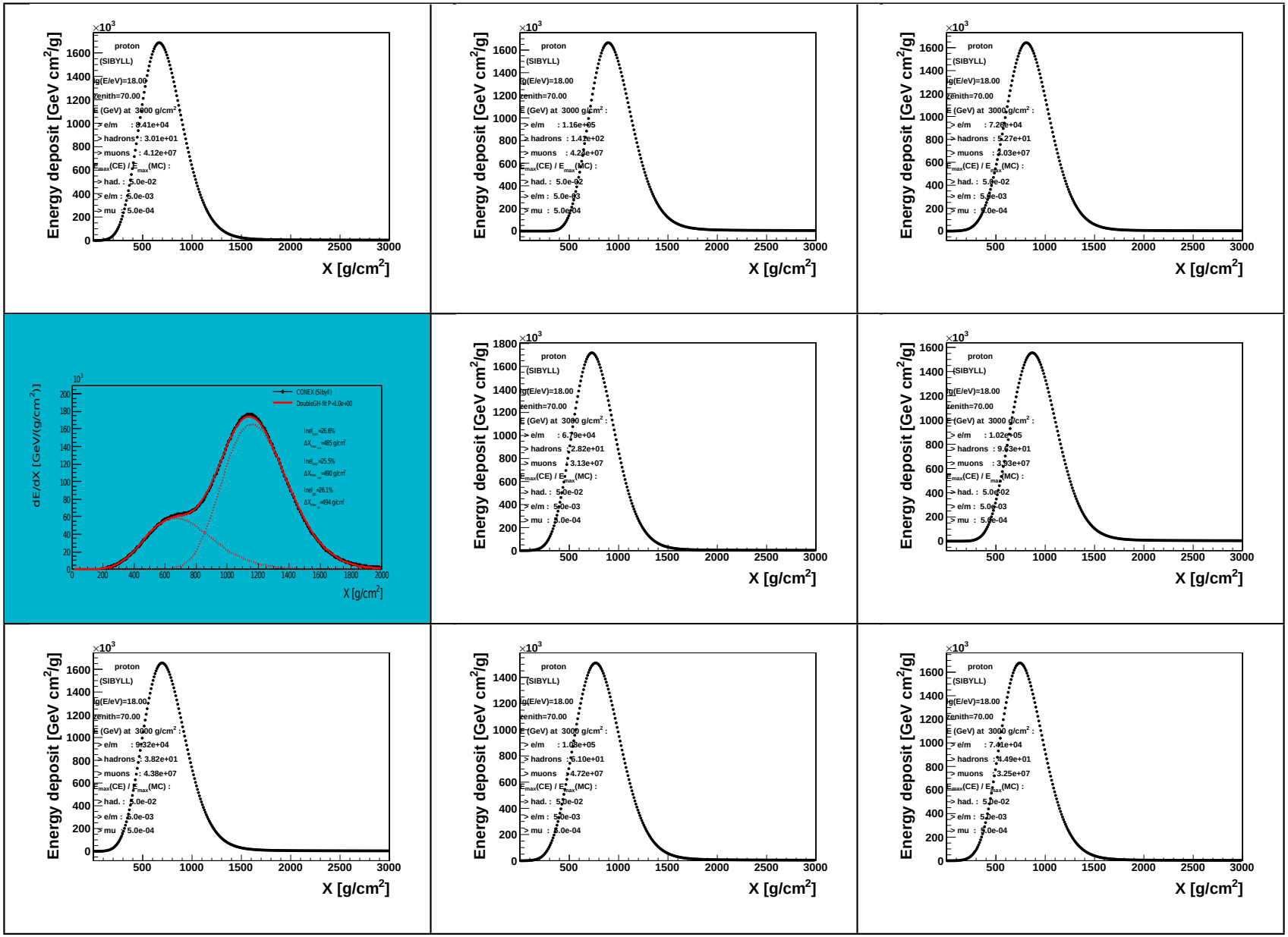
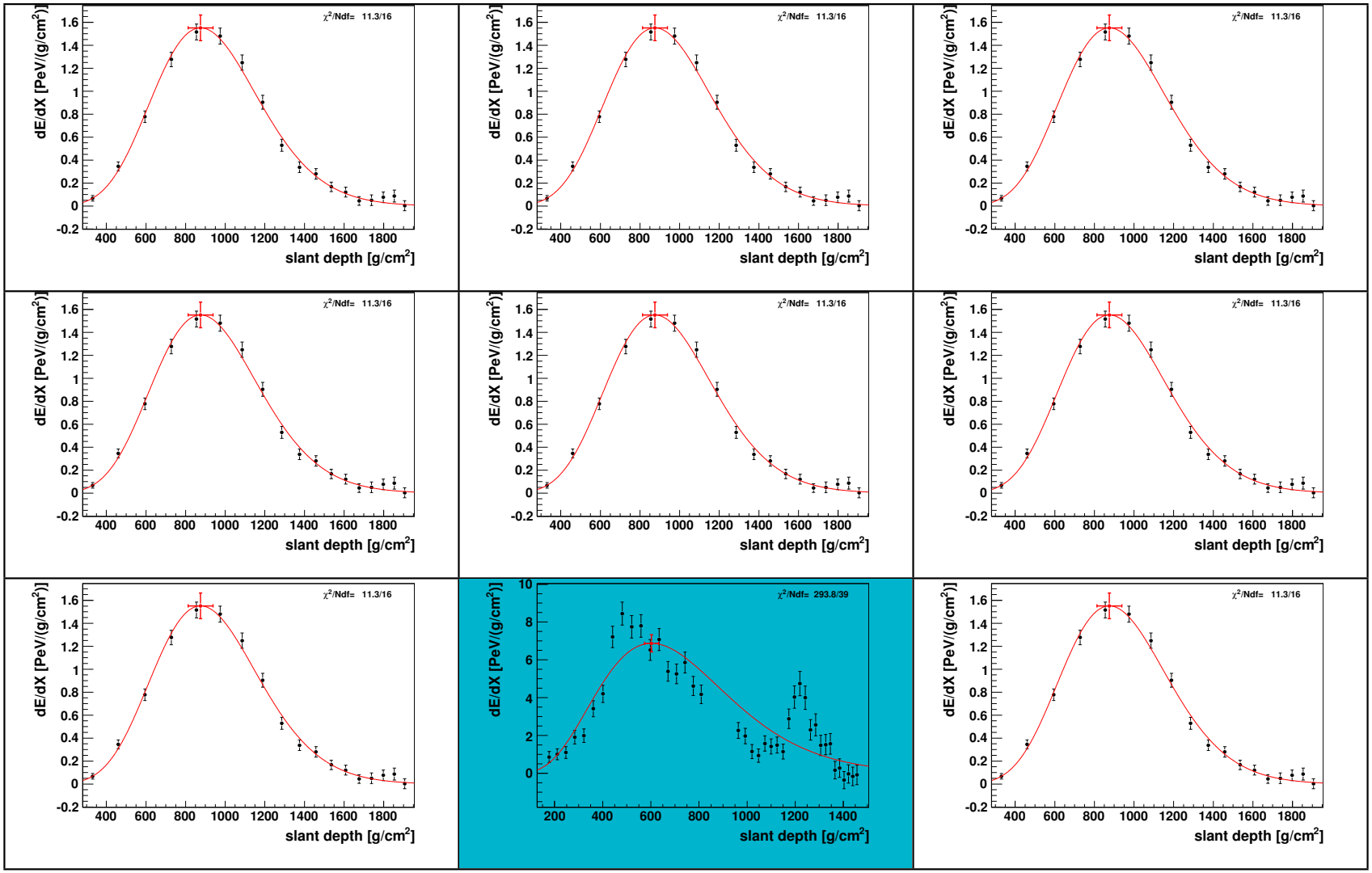


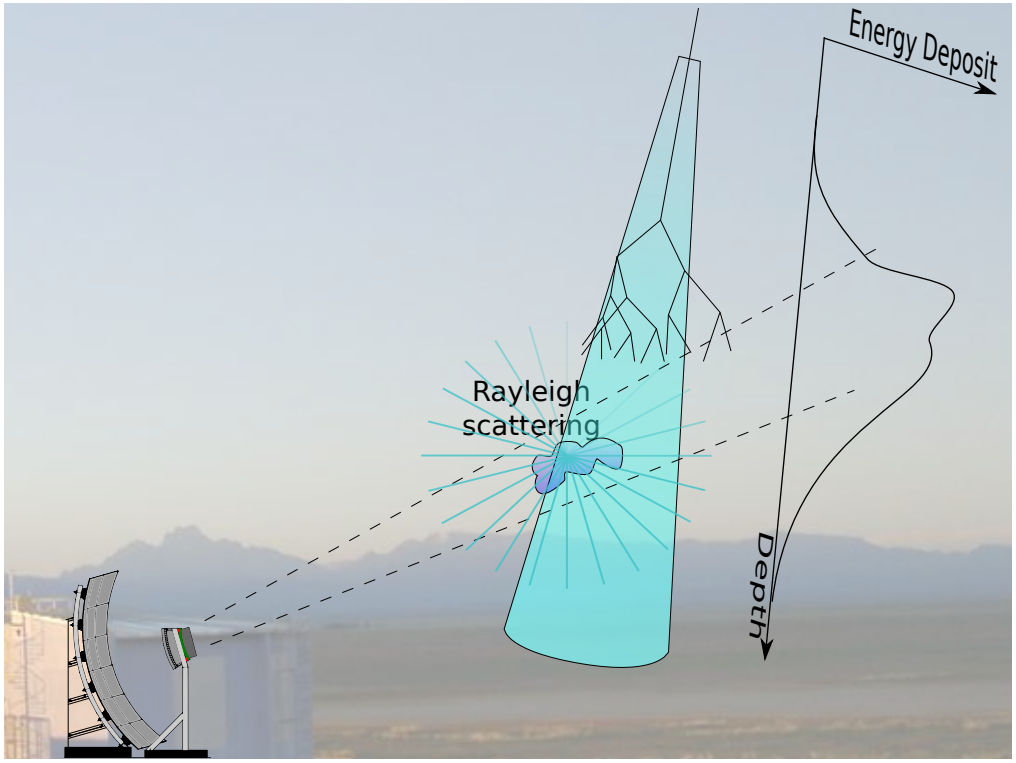
Odd One In (Data)



Why Do We Study Double Bumps?

- Interaction length (protons @ $> 10^{18} eV$!!!)
- Proton fraction (heavier elements $\rightarrow$ less double bumps)
- Consistency of inelasticity

Problem 1: Clouds



Producing double bumps

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- Will then be detected as narrow peak in detector

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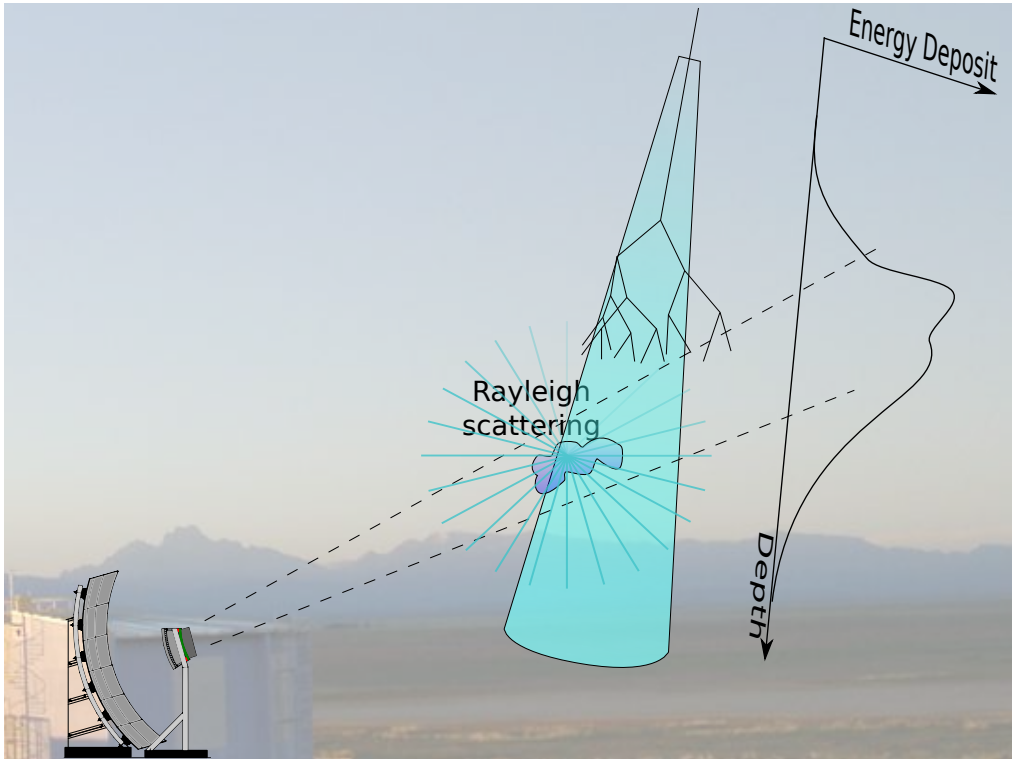

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Solution LIDAR

Detecting Clouds with LIDAR

- Works just like RADAR
- LASER tracks shower axis. Measures reflection
- Implemented online decision when to shoot
- If double bump and no clouds $\Rightarrow$ real event

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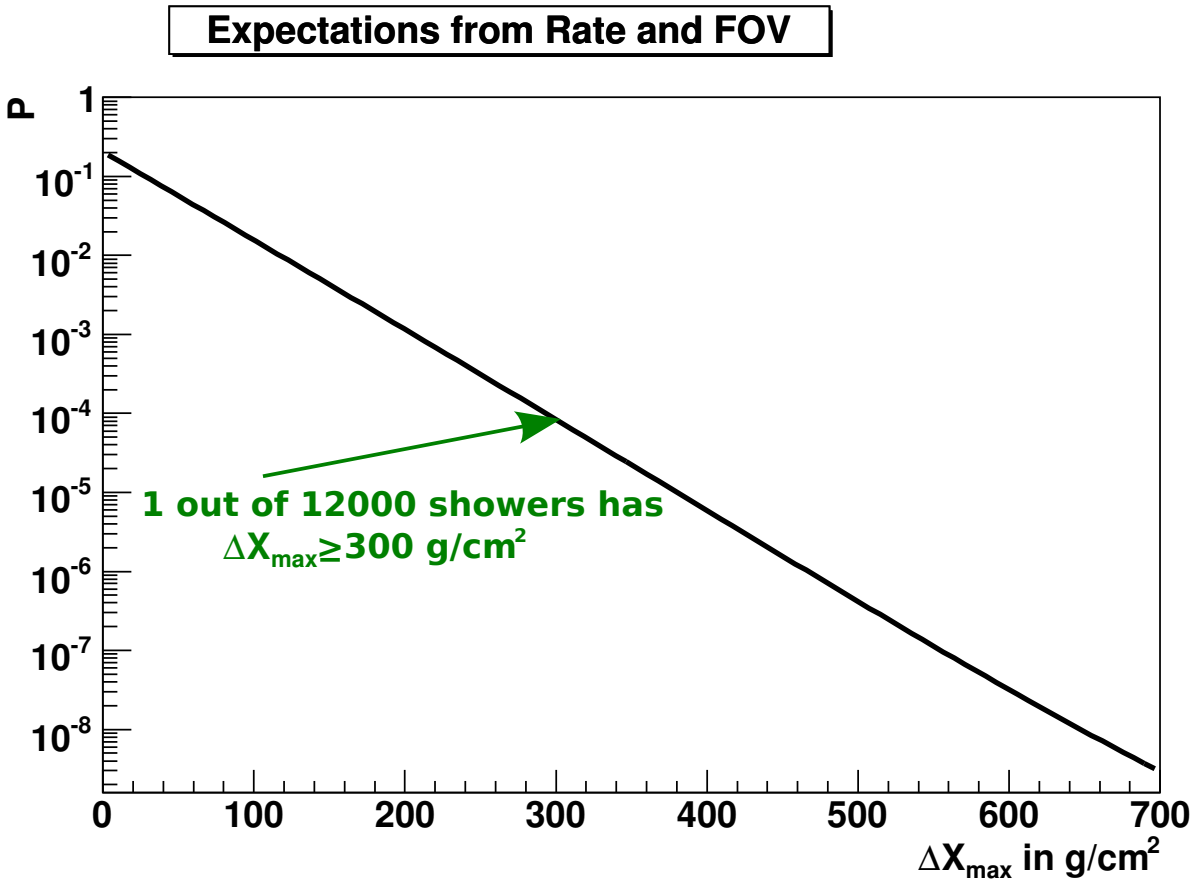
Method for identifying double bumps

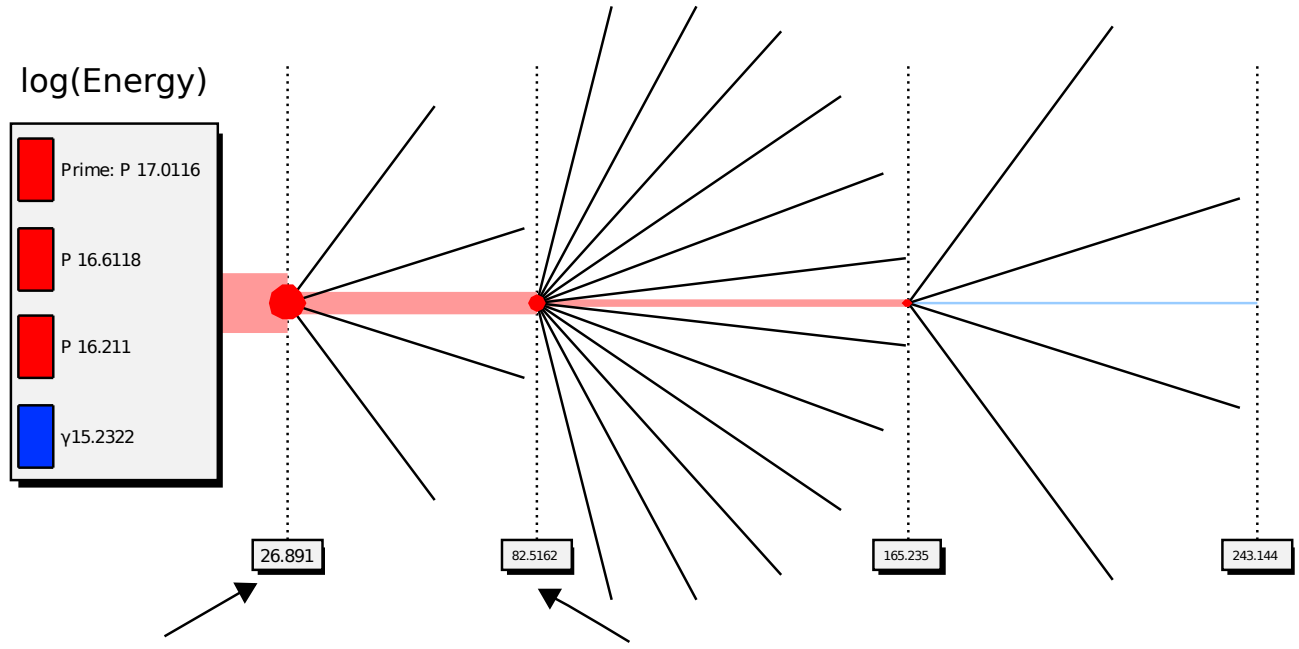
Problem 2: Expected Rate



Solution

More time

While waiting. . .



Outlook

- From now on data will be taken with cloud information
- $\simeq$ 10 new events/year
- In this diploma thesis I will have to make use of the 60 events in current data set without good cloud information