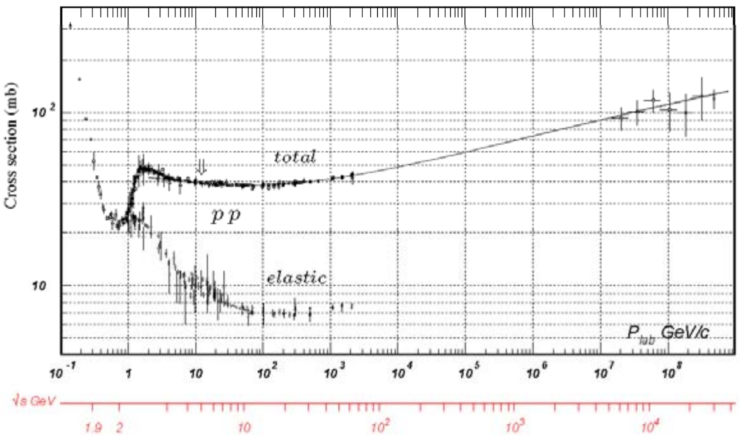
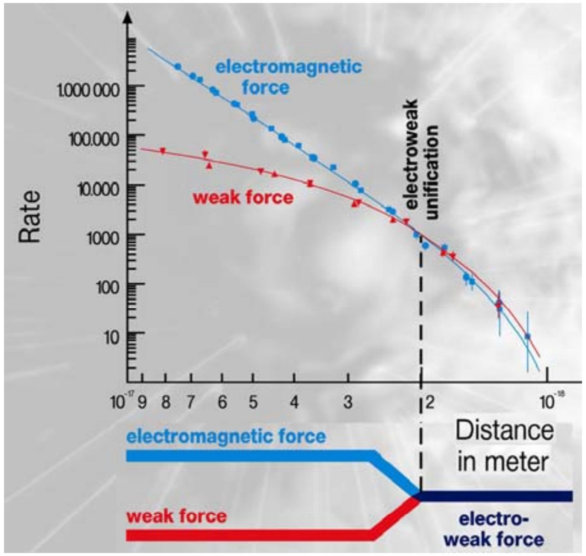
Interactions



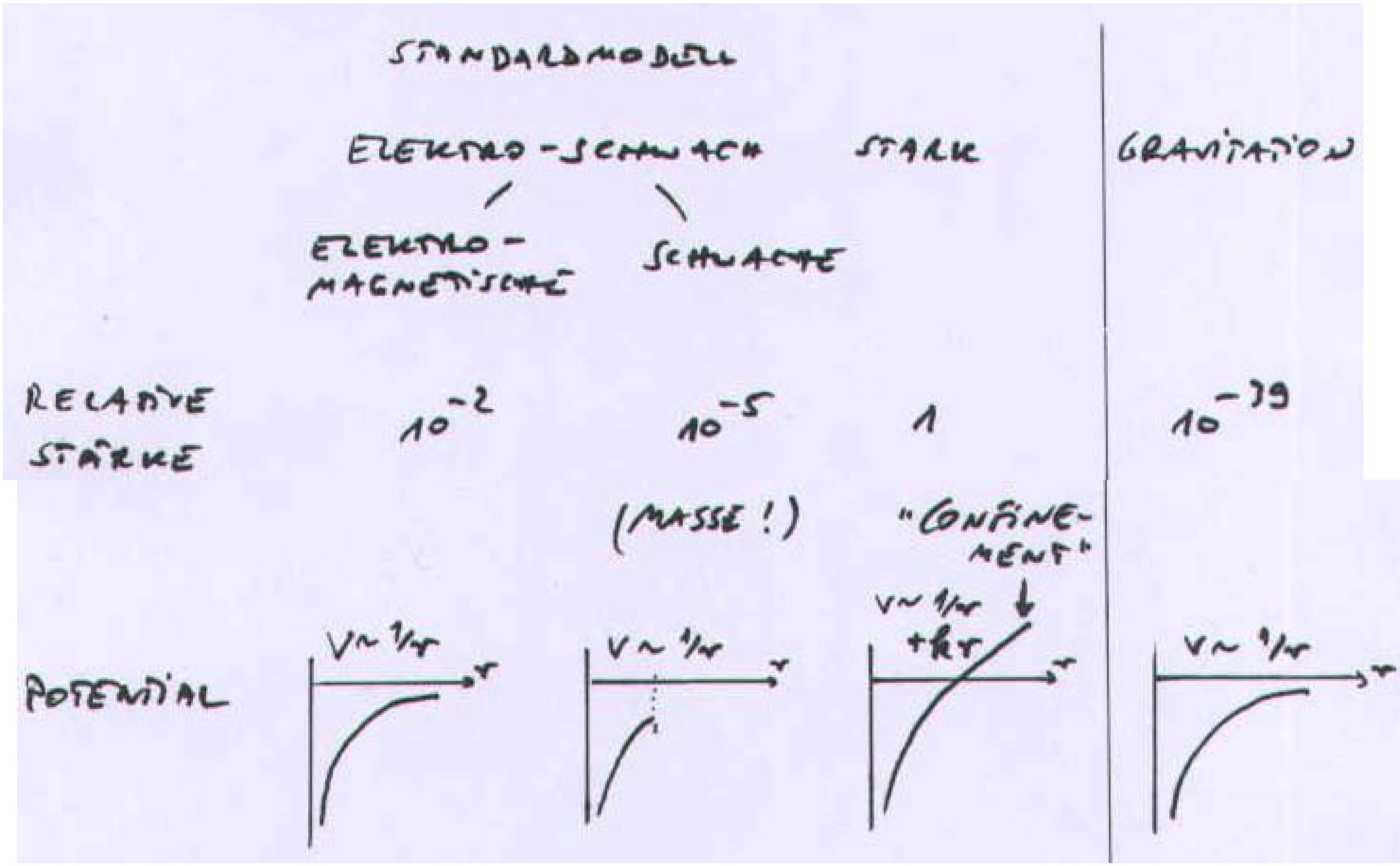


Prof. Dr. Martin Erdmann

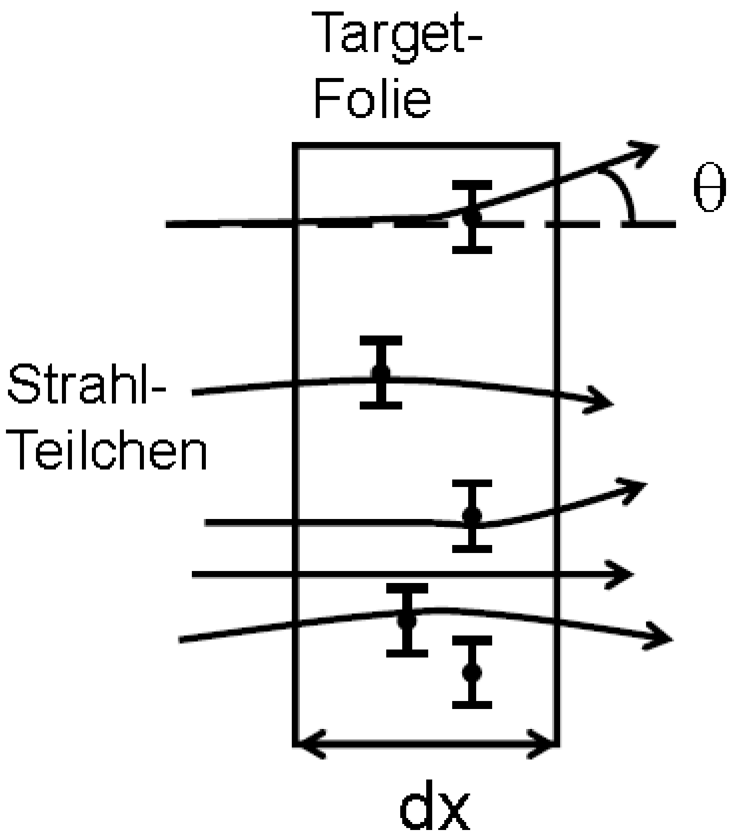
RWTH Aachen University

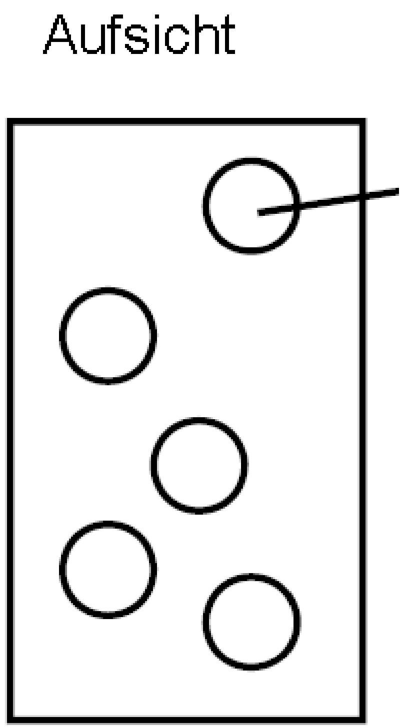
7-Oct-2010

Fundamental Interactions



Total Cross Section





$$\sigma = \pi \cdot r^2$$

active area

$$1\ \mathrm{b} = 10^{-28}\ \mathrm{m}^2$$

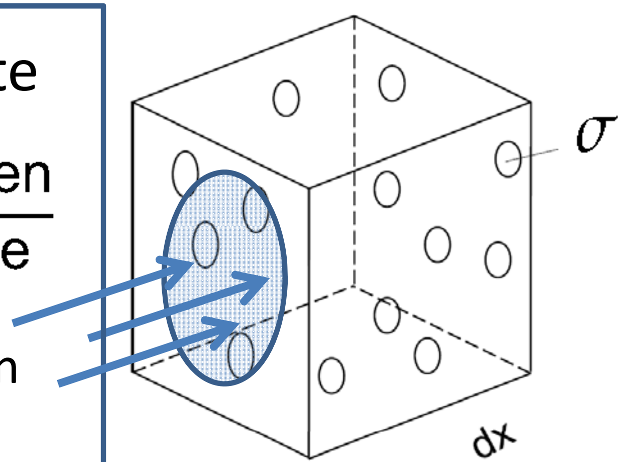
Measurement: Total Cross Section

Teilchenflussdichte

$$\dot{N} = \frac{\text{Strahlteilchen}}{\text{Zeit} \cdot \text{Fläche}}$$

Anzahl Strahlteilchen pro Zeit

$$\dot{N}\ F$$



Targetdichte

$$n = \frac{\text{Targetteilchen}}{\text{Volumen}}$$

Anzahl der Targetteilchen

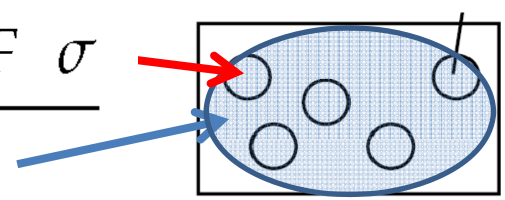
$$n\ \Delta x\ F$$

Aktive Fläche aller Targetteilchen

$$n\ \Delta x\ F\ \sigma$$

Gestreute Teilchen / Strahlteilchen   Aktive Fläche / Gesamtfläche

$$\frac{\dot{N}'}{\dot{N}\ F} = \frac{n\ \Delta x\ F\ \sigma}{F}$$



Total cross section

$$\sigma = \frac{1}{\dot{N}\ F\ n\ \Delta x}\ \dot{N}'$$

scattered particles

1/Luminosity

Mean Free Path Length

Beam particles not scattered:

$$\dot{N}_u' = \dot{N} \, F \, (1 - n \, \Delta x \, \sigma)$$

Number of unscattered particles as function of target thickness:

$$d\dot{N} = -\dot{N} \, n \, dx \, \sigma$$

$$\int_{\dot{N}_\circ}^{\dot{N}'} \frac{d\dot{N}}{\dot{N}} = -\sigma n \int_0^{\Delta x} dx$$

$$\dot{N}' = \dot{N}_\circ \cdot e^{-\sigma n \, \Delta x}$$

Mean free path length

$$\boxed{\Lambda = \frac{1}{\sigma n}}$$

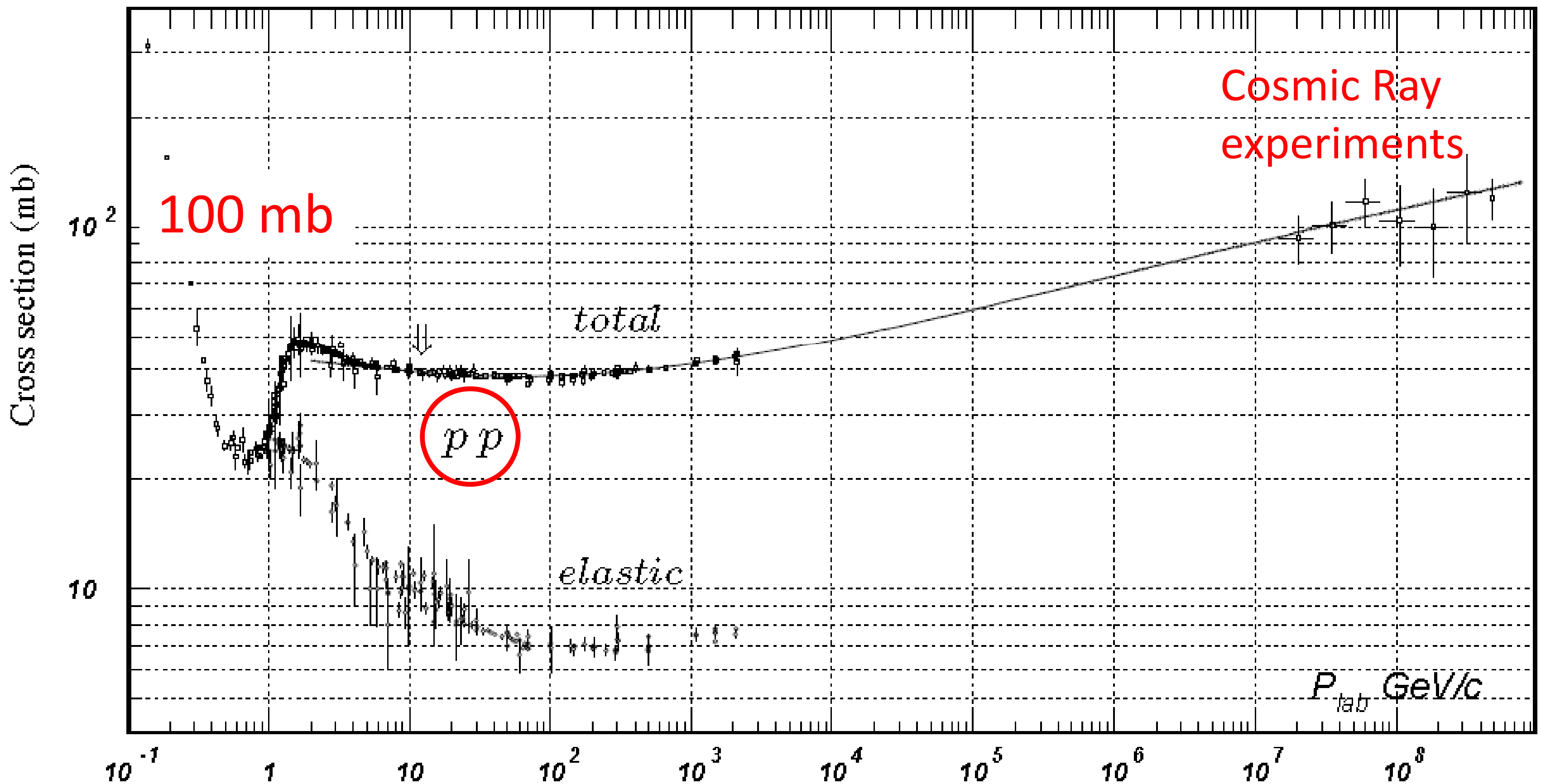
σ: Total Cross Section

n: Target Density

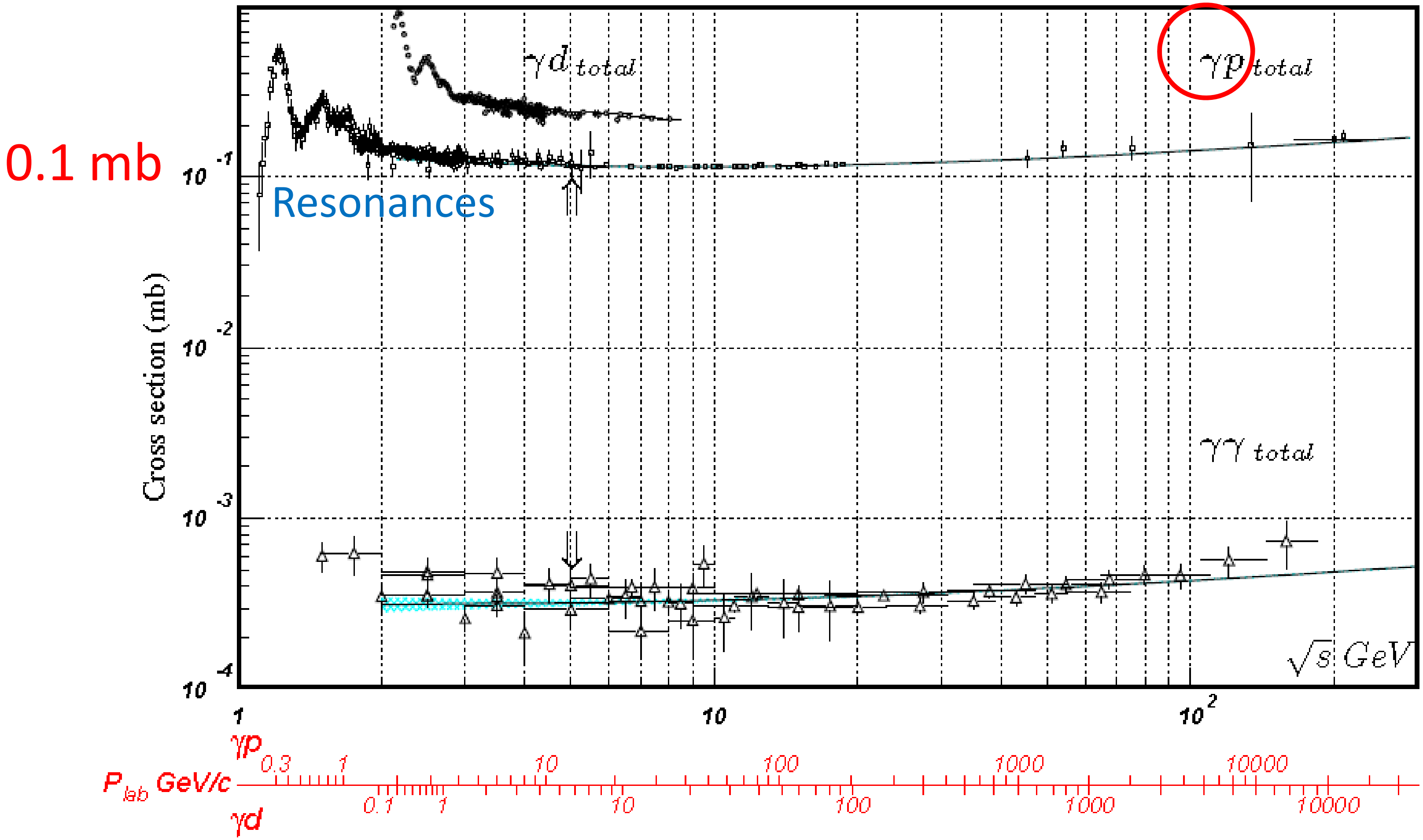
Cross Section Strong Interactions

$$\sigma = \frac{1}{\dot{N}\, F\, n\, \Delta x}\, \dot{N}'$$

$$\Lambda = \frac{1}{\sigma n}$$

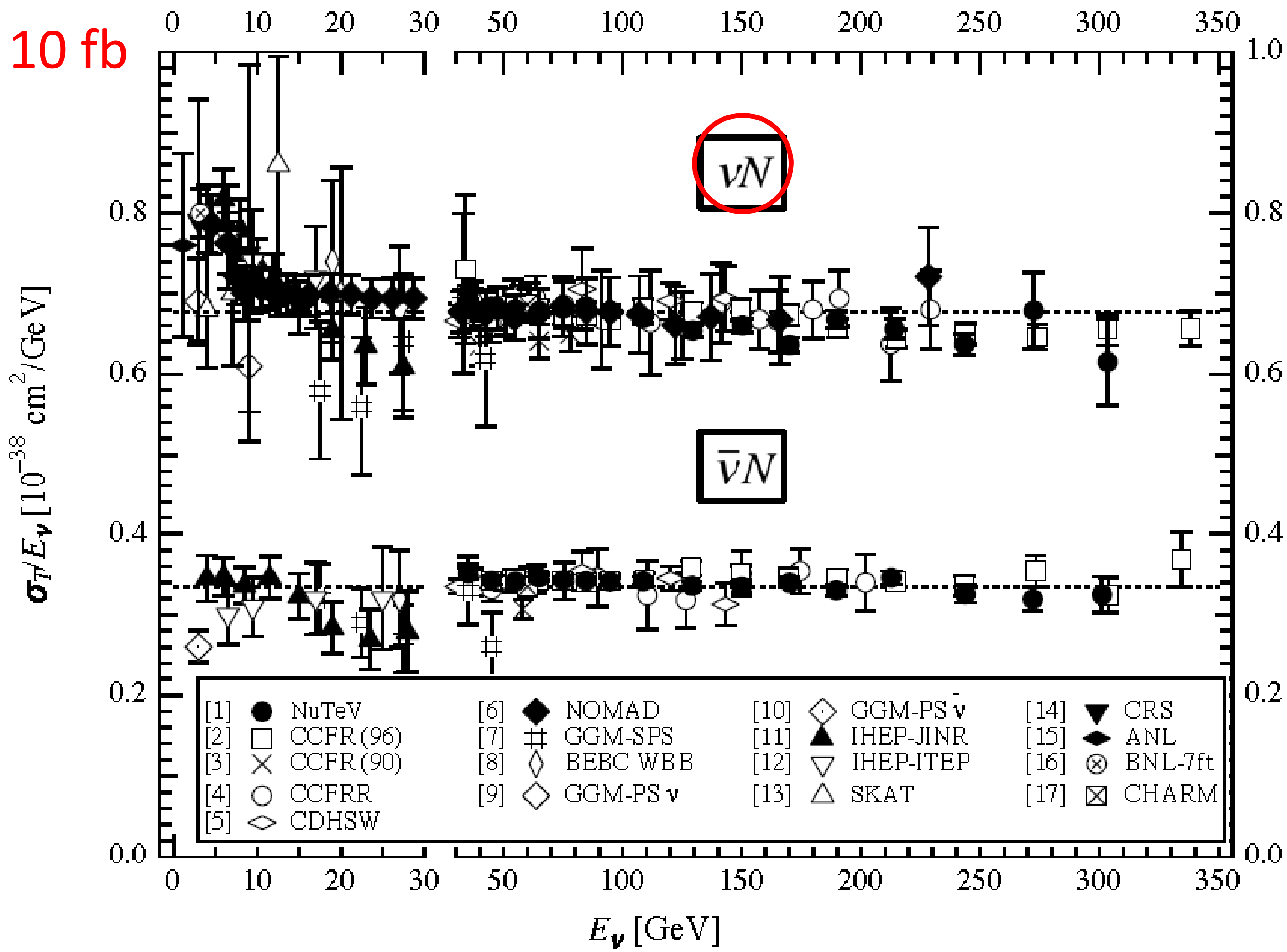


Cross Section Electromagnetic Interactions



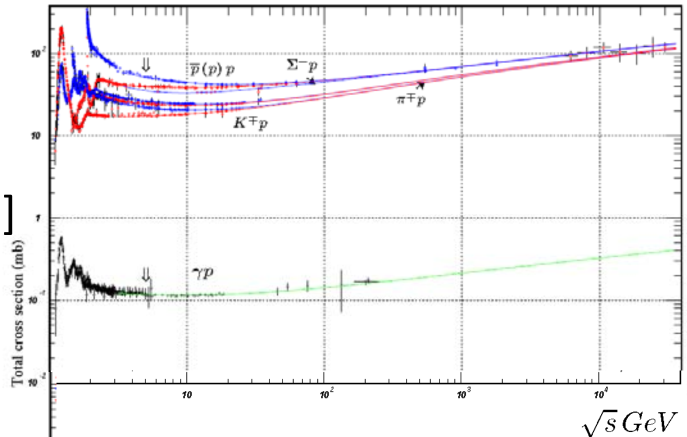
Cross Section Weak Interactions

Muon Neutrino and Anti-Neutrino Charged-Current Total Cross Section



Comparison of Cross Sections

pp 100 mb



strong

1

[mb]

γp 0.1 mb

electromagnetic

1 μb 10^{-3}

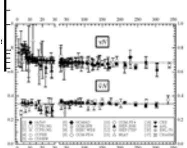
Total Cross Section

mean free path

1 nb 10^{-6}

1 pb 10^{-9}

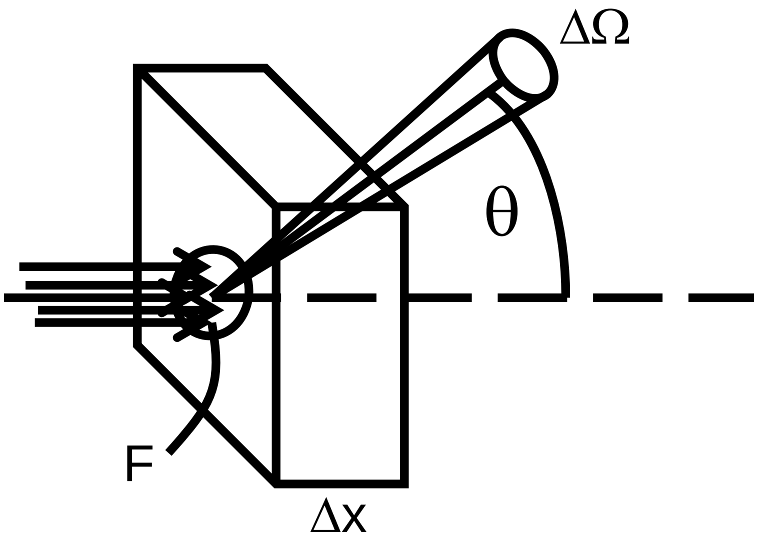
νp 10 fb 10^{-11}



weak

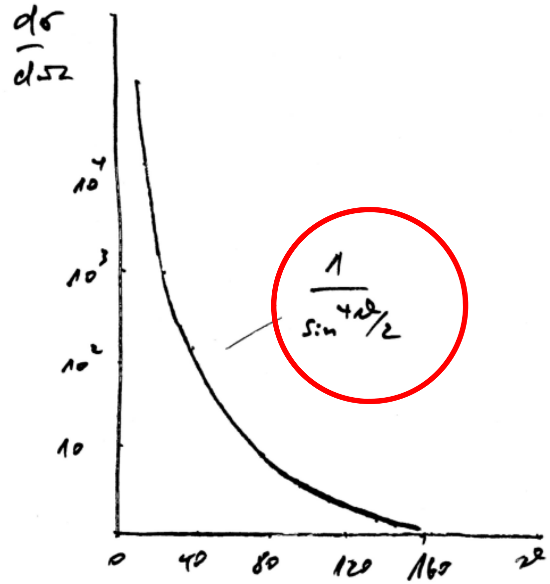
10^{13}

Differential Cross Section

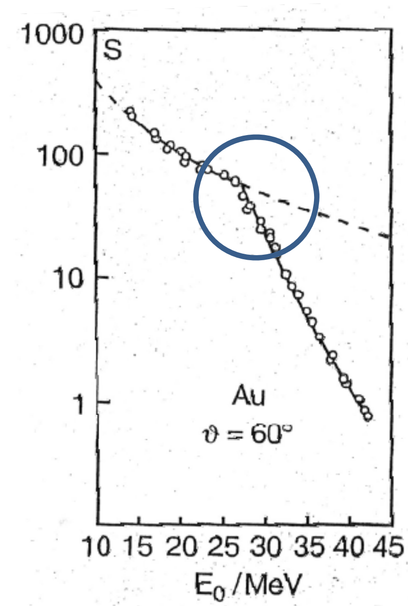


Rutherford cross section

$$\frac{d\sigma}{d\Omega} = \frac{1}{4}\left(\frac{q_1 q_2}{4\pi\epsilon_\circ\, \mu v_\circ^2}\right)^2 \frac{1}{\sin^4\frac{\theta}{2}}$$



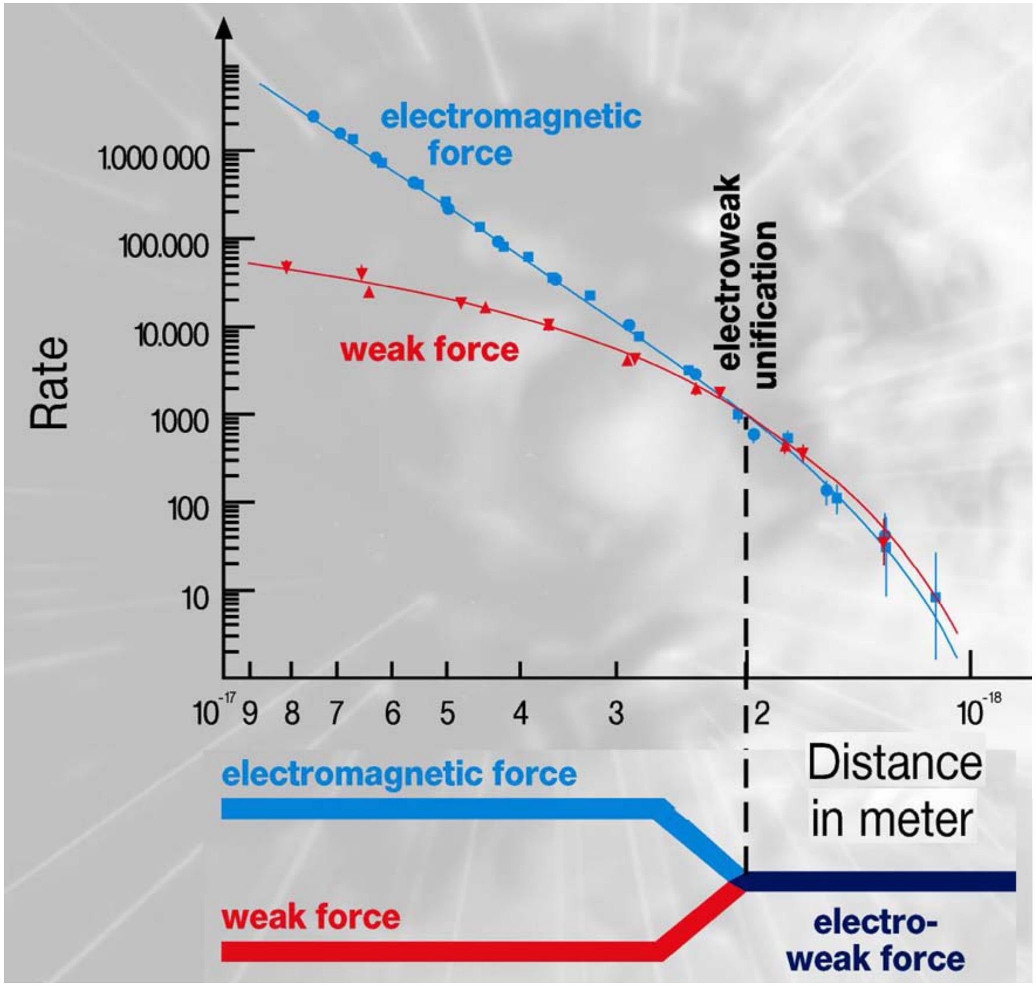
electromagnetic interaction of point sources



direct interaction of nuclei

Electroweak Unification

$$\frac{d\sigma}{dQ^2}$$

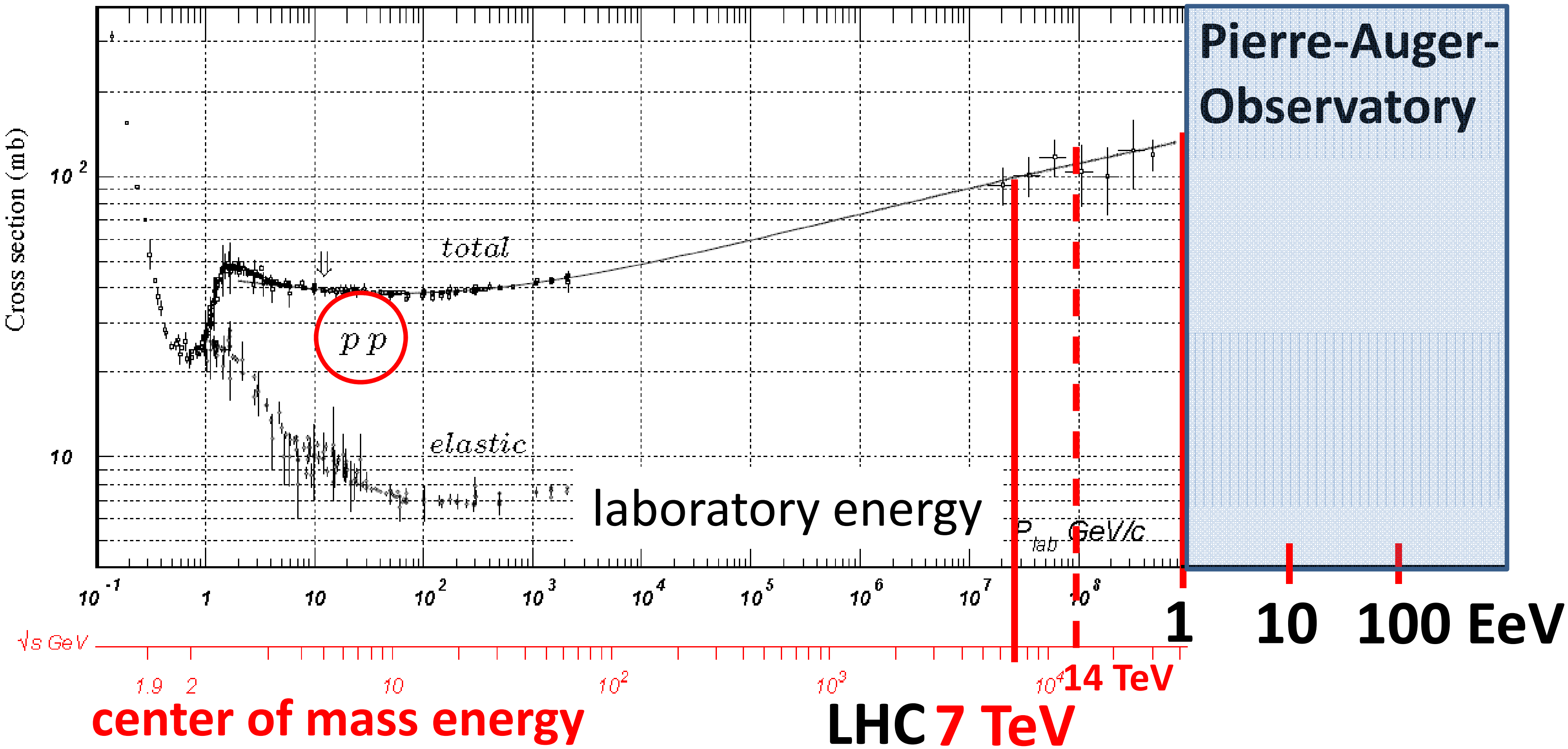


$$r = \frac{h}{p} = \frac{h}{\sqrt{Q^2}}$$

$$Q^2 \sim \sin^2\frac{\theta}{2}$$

at small distances: cross sections become equally large

LHC & Cosmic Ray Energies



size of structures

10^{-17} 10^{-18} 10^{-19} 10^{-20} [m]

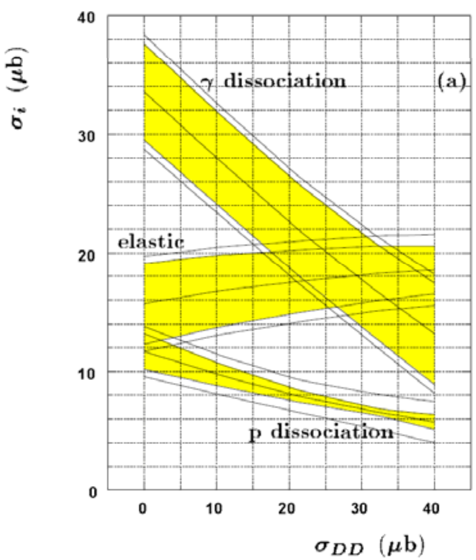
$$r = \frac{h}{p}$$

Total Cross Section Contributions

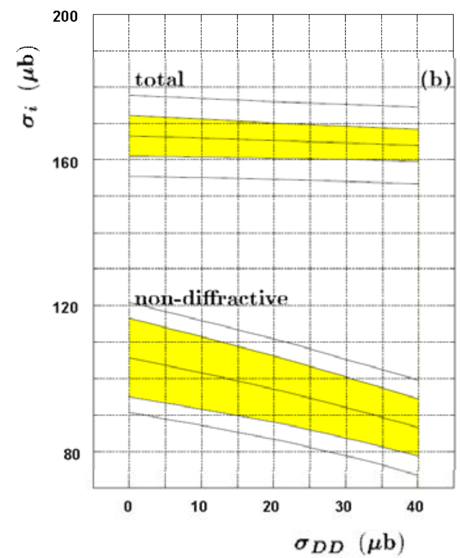
elastic | single diffractive | double diffractive | inelastic

15% | 10% | 10% | 65%

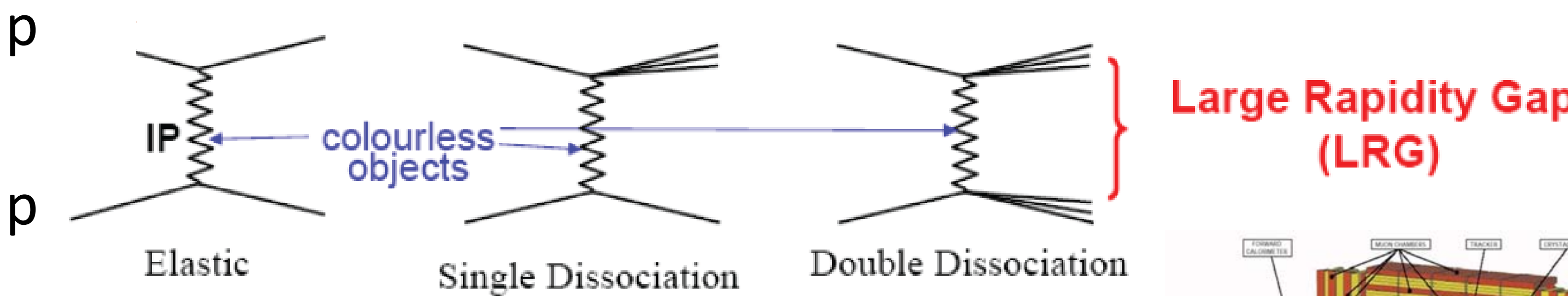
Colour singlet exchange

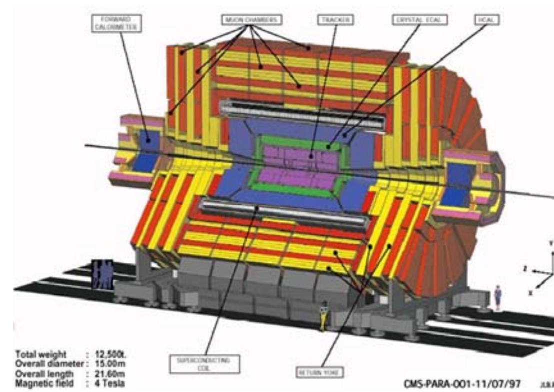


difficult to measure contribution of individual processes

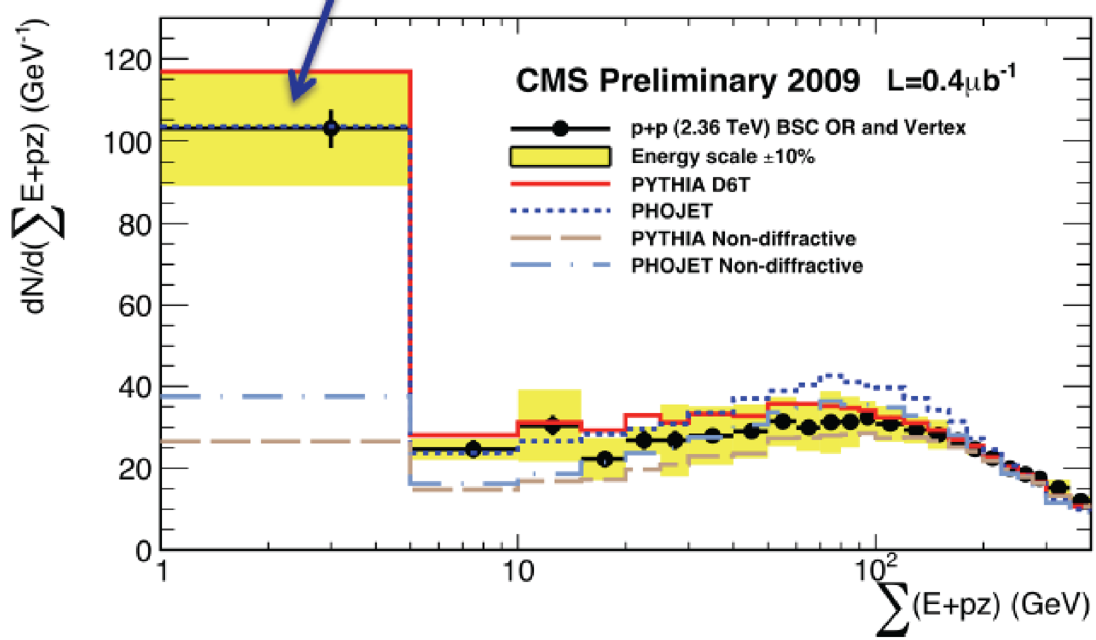


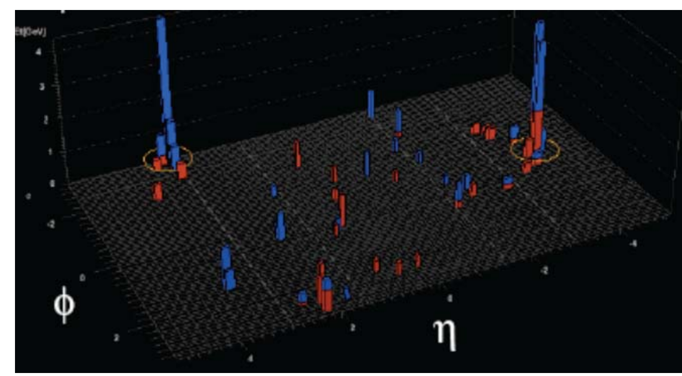
CMS: Diffractive Scattering



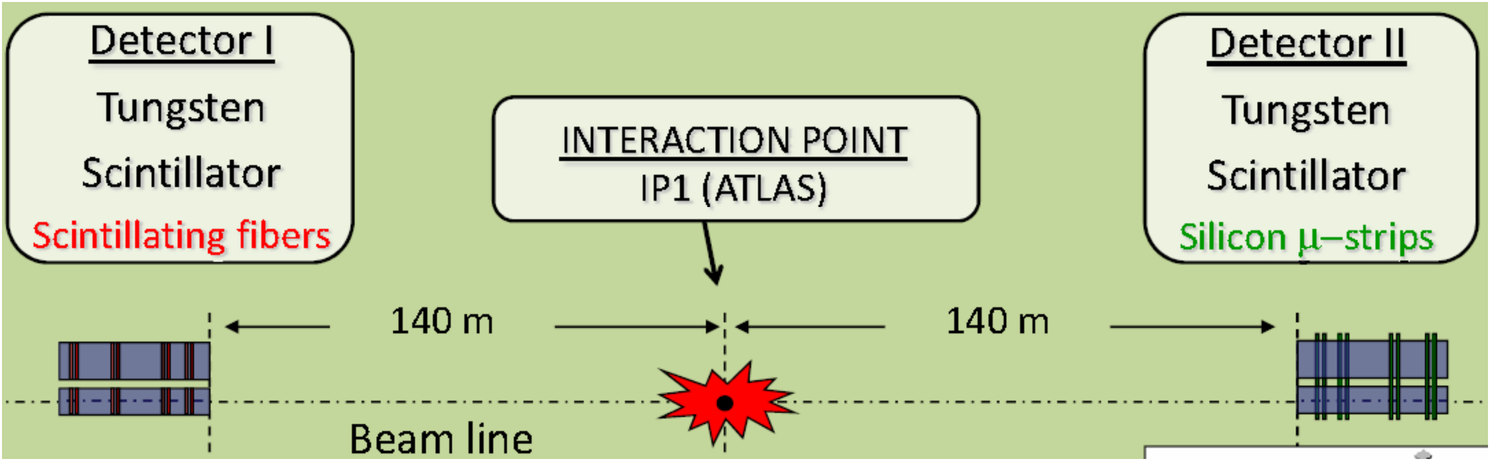


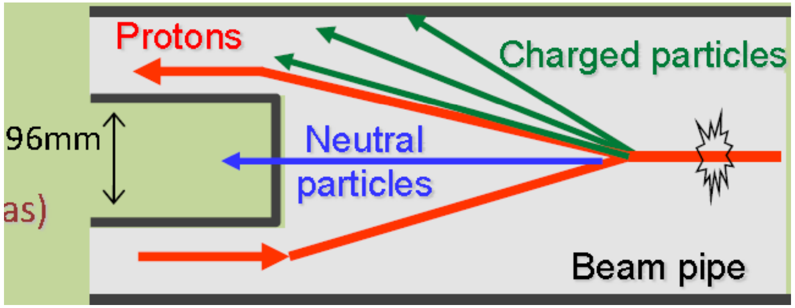
→ **THE PEAK at 0 is from Diffractive events !**

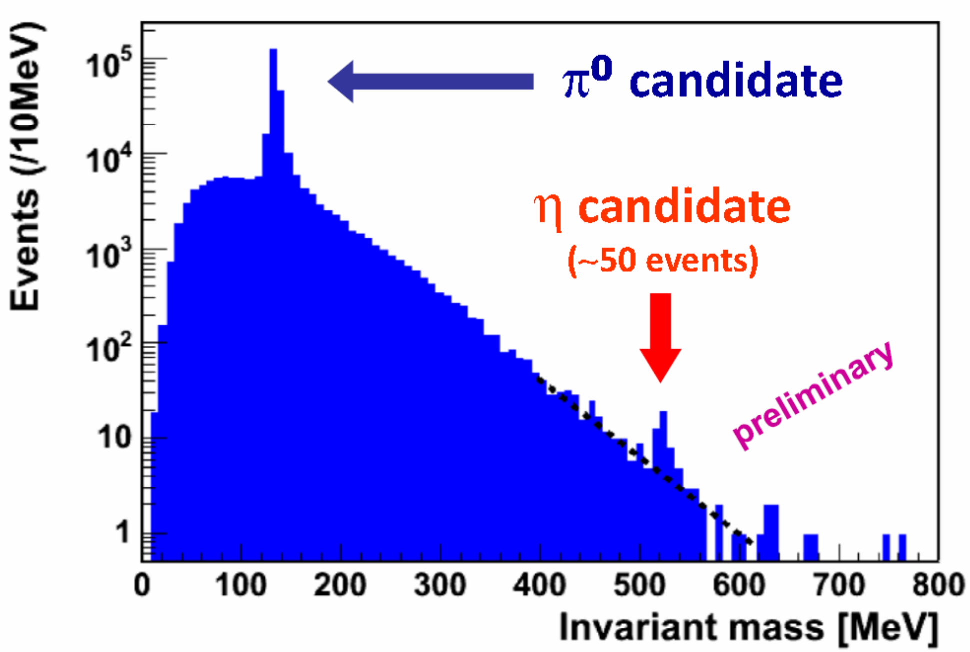




LHC-F: Forward Detector







Summary

Cross section measurements and comparisons to cross section calculations are a unique way of obtaining microscopic information on structures and interactions.