Proton-proton cross-sections
The interplay between density and radius

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L I P

Santiago Compostela
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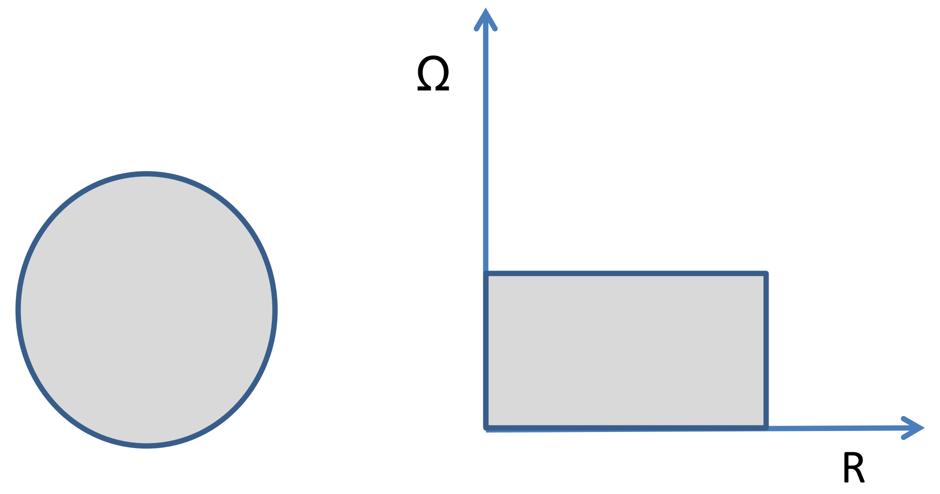
The grey disk model



$$\sigma_{tot}(s) = 2\pi \int d^2b F(s,b) \rightarrow 2\pi(1 - e^{-\overline{\Omega}(s)})R^2(s)$$

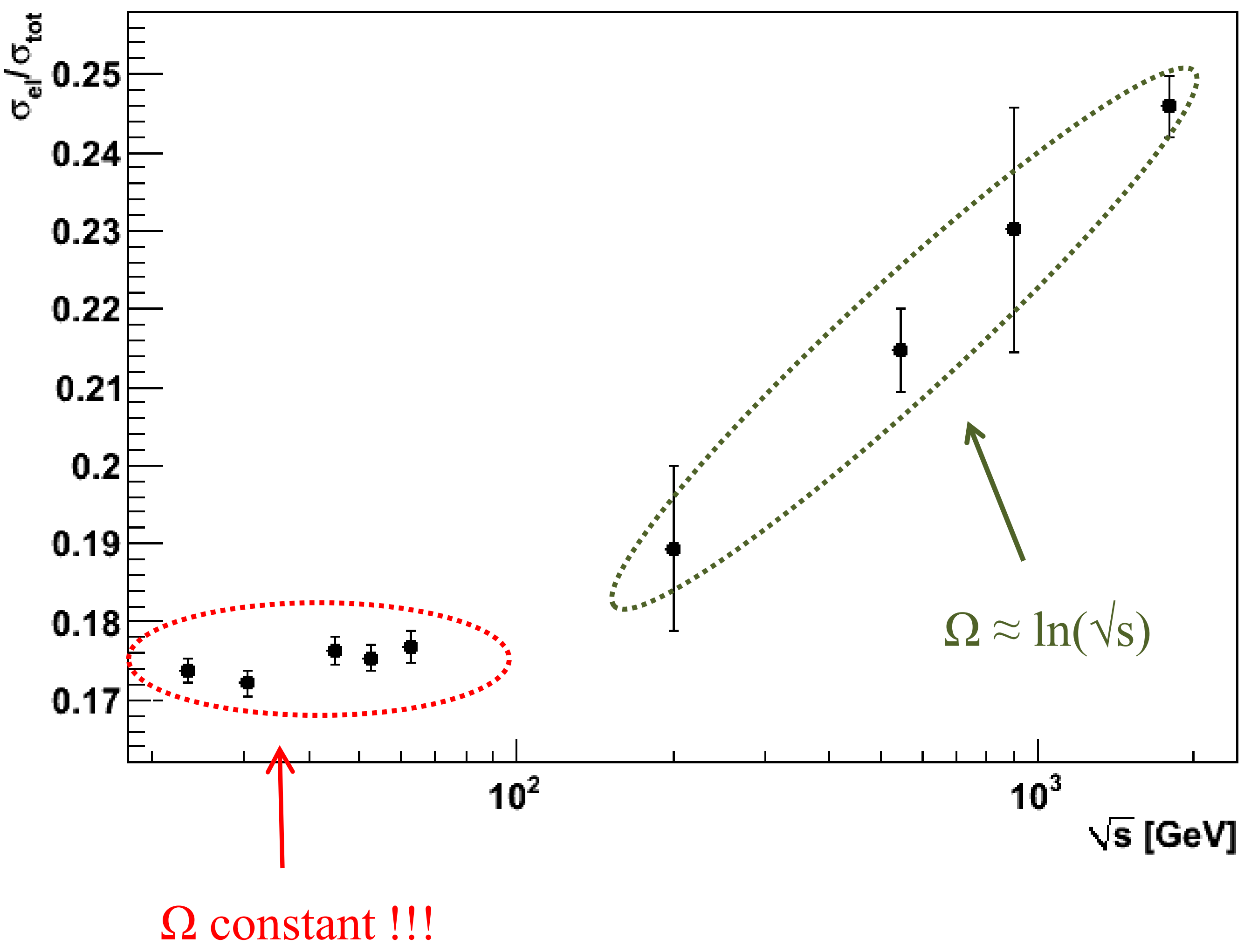
$$\sigma_{el}(s) = \pi \int d^2b \left(F(s,b)\right)^2 \rightarrow \pi(1 - e^{-\overline{\Omega}(s)})^2 R^2(s)$$

$$\sigma_{inel}(s) = \sigma_{tot}(s) - \sigma_{el}(s) = \pi(1 - e^{-2\overline{\Omega}(s)})R^2(s)$$

$$\frac{\sigma_{el}(s)}{\sigma_{tot}(s)} = \frac{1}{2}\left(1 - e^{-\overline{\Omega}(s)}\right)$$

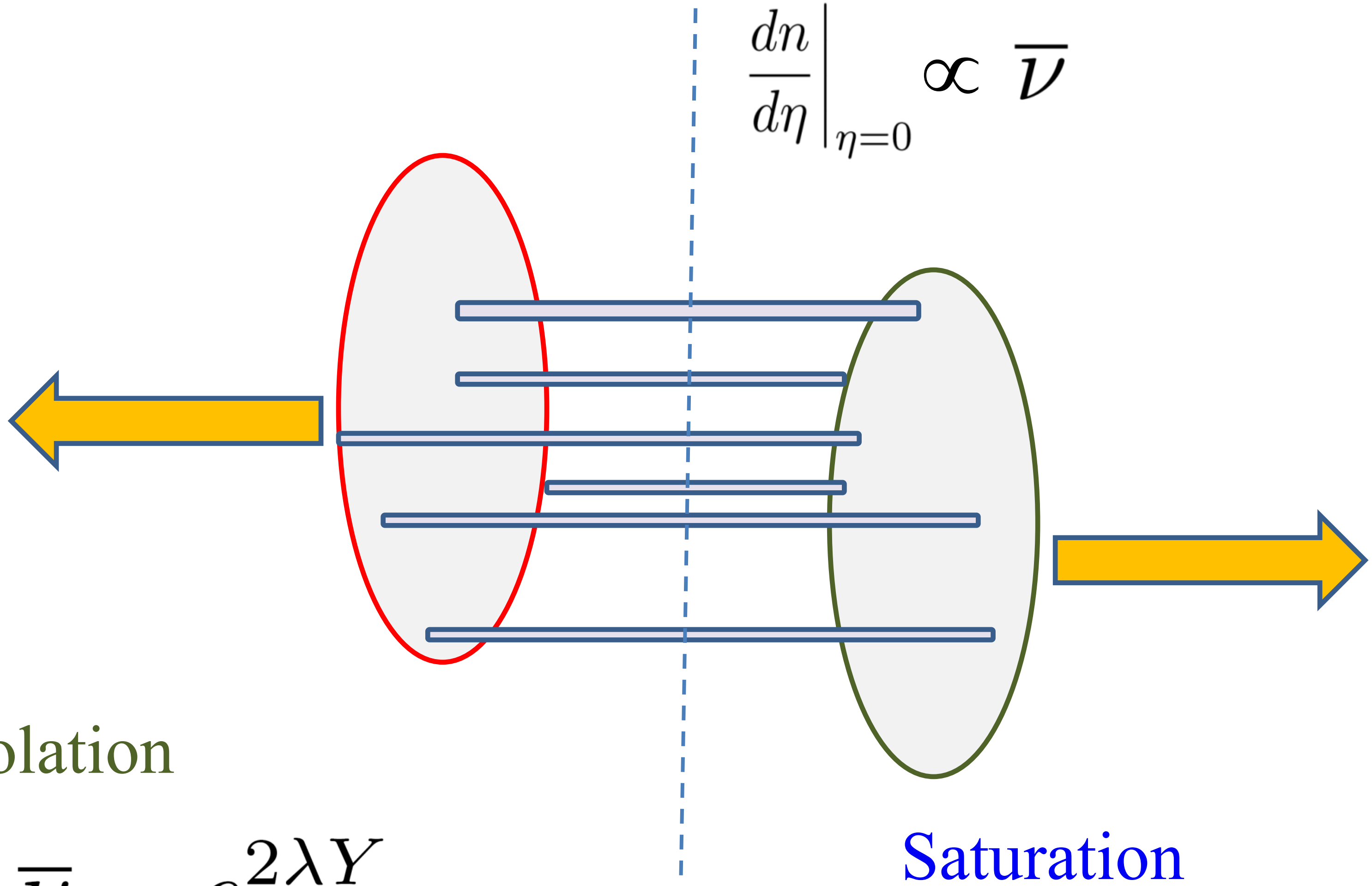
Is just a function of Ω !!!

$$\frac{\sigma_{el}(s)}{\sigma_{tot}(s)}$$



$$\left.\frac{dn}{d\eta}\right|_{\eta=0}$$

$$\left.\frac{dn}{d\eta}\right|_{\eta=0} \propto \overline{\nu}$$



String percolation

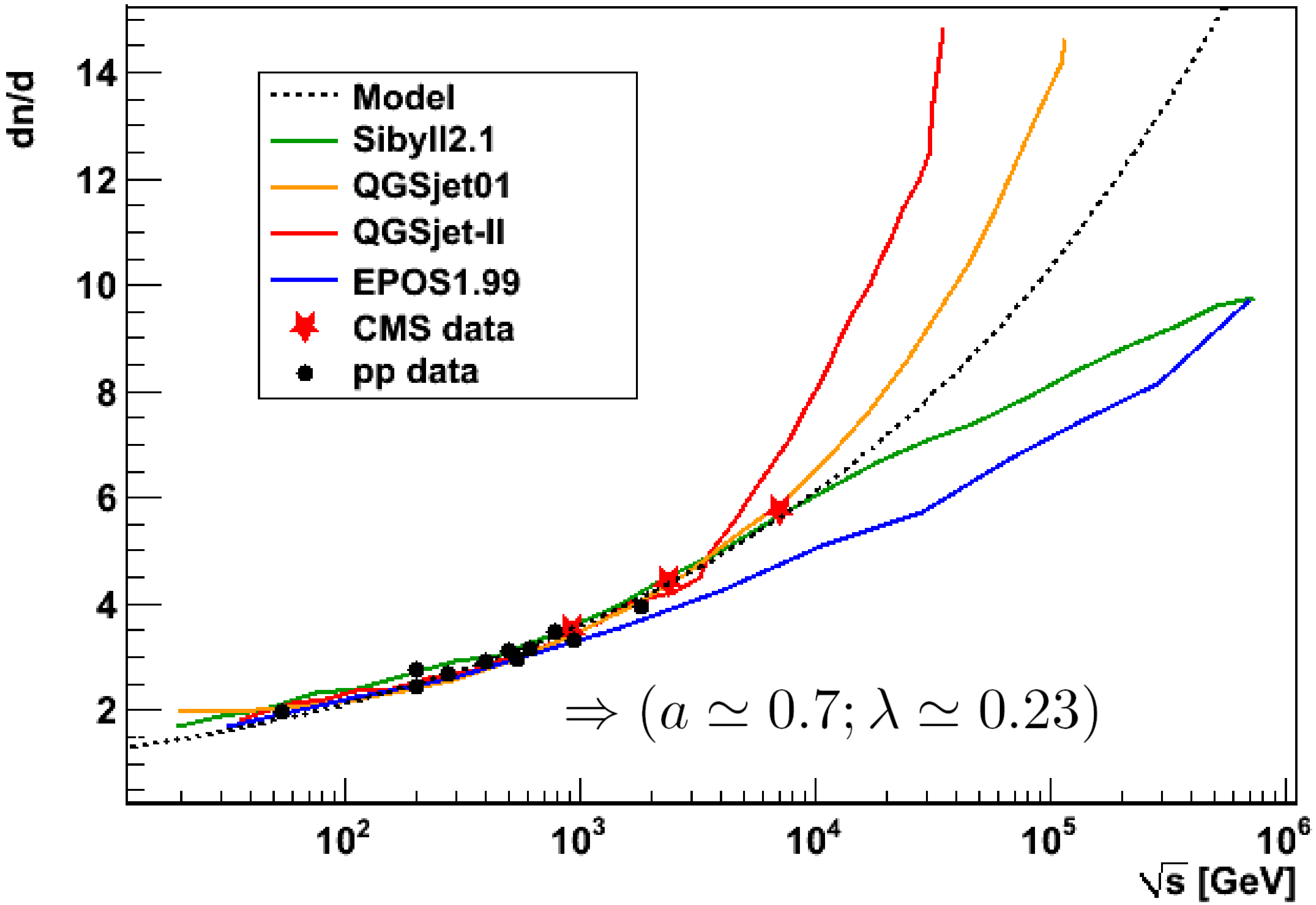
$$\overline{\nu} \propto \mathrm{s}^{\lambda}, \overline{\nu} = e^{2\lambda Y}$$

$$Y = \ln\left(\sqrt{s}/m_p\right)$$

Saturation

$$\left.\frac{dn}{d\eta}\right|_{\eta=0} \propto \sqrt{\overline{\nu}}$$

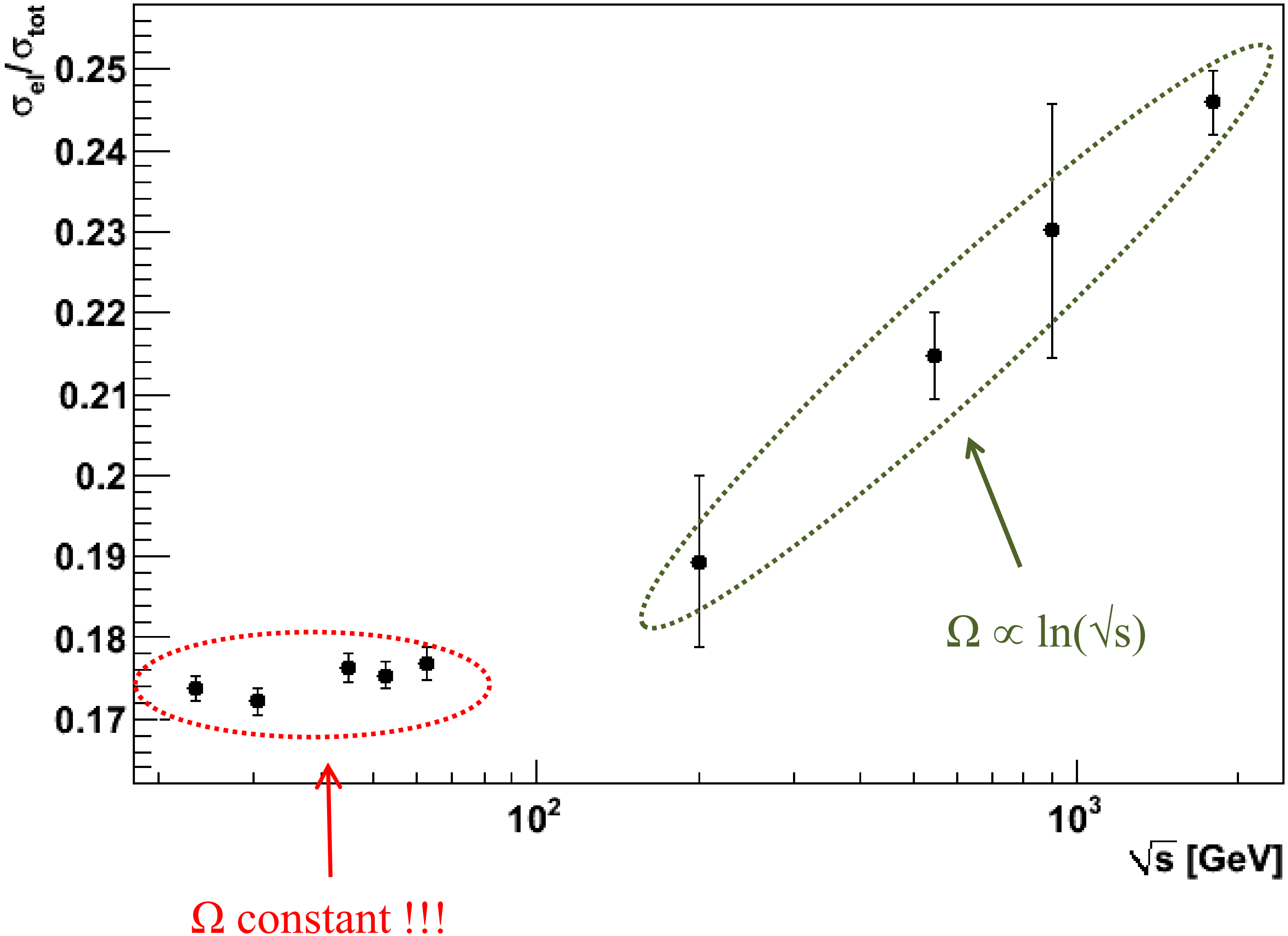
$$\left.\frac{dn}{d\eta}\right|_{\eta=0} = ae^{\lambda Y}$$



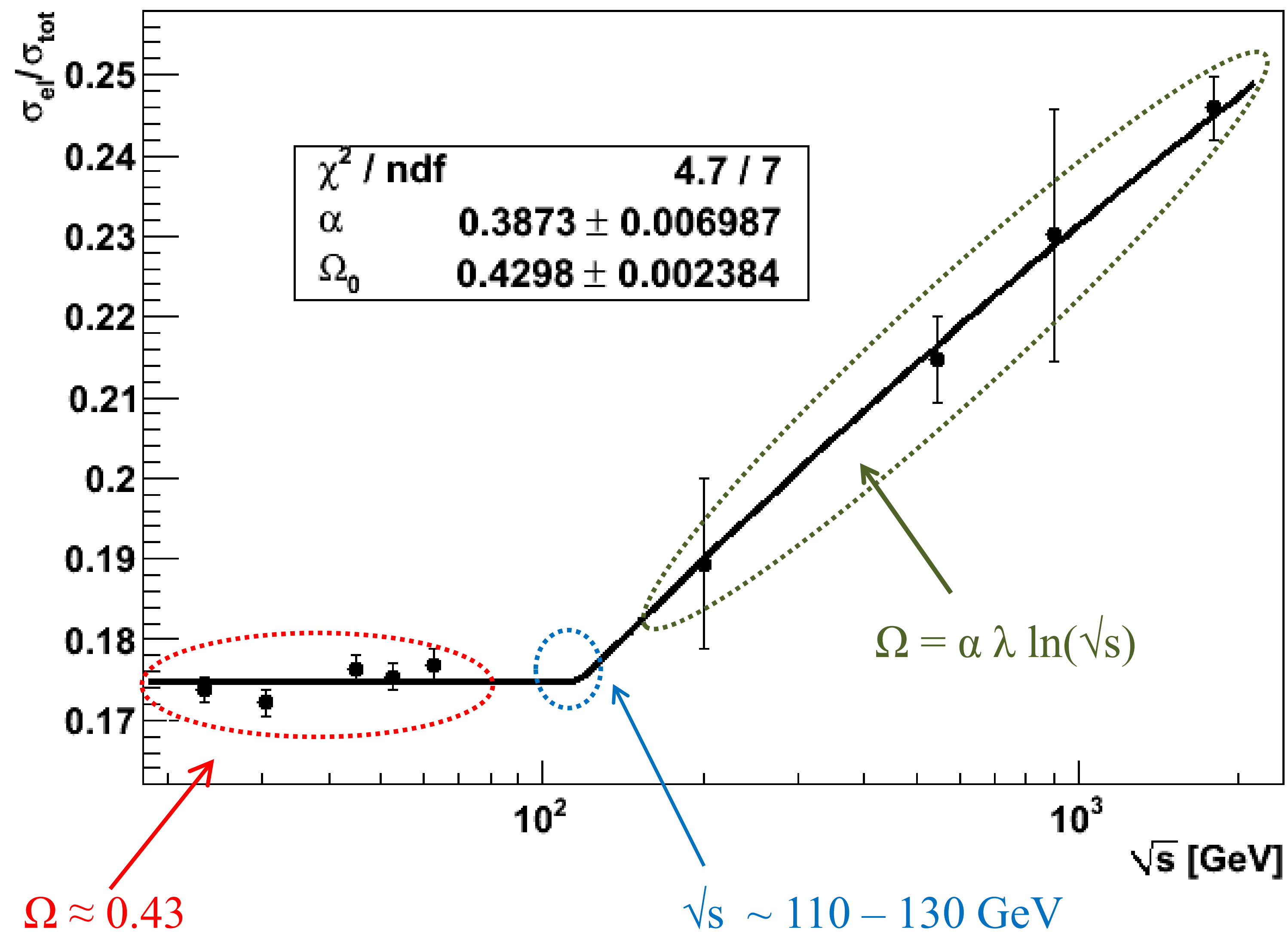
$$\Rightarrow (a \simeq 0.7; \lambda \simeq 0.23)$$

$$\overline{\nu}(s) = e^{k\overline{\Omega}(s)} \simeq 1 + k\overline{\Omega}(s) + \ldots \qquad \overline{\Omega}(s) = \frac{2}{k}\lambda Y$$

$$\frac{\sigma_{el}(s)}{\sigma_{tot}(s)}$$

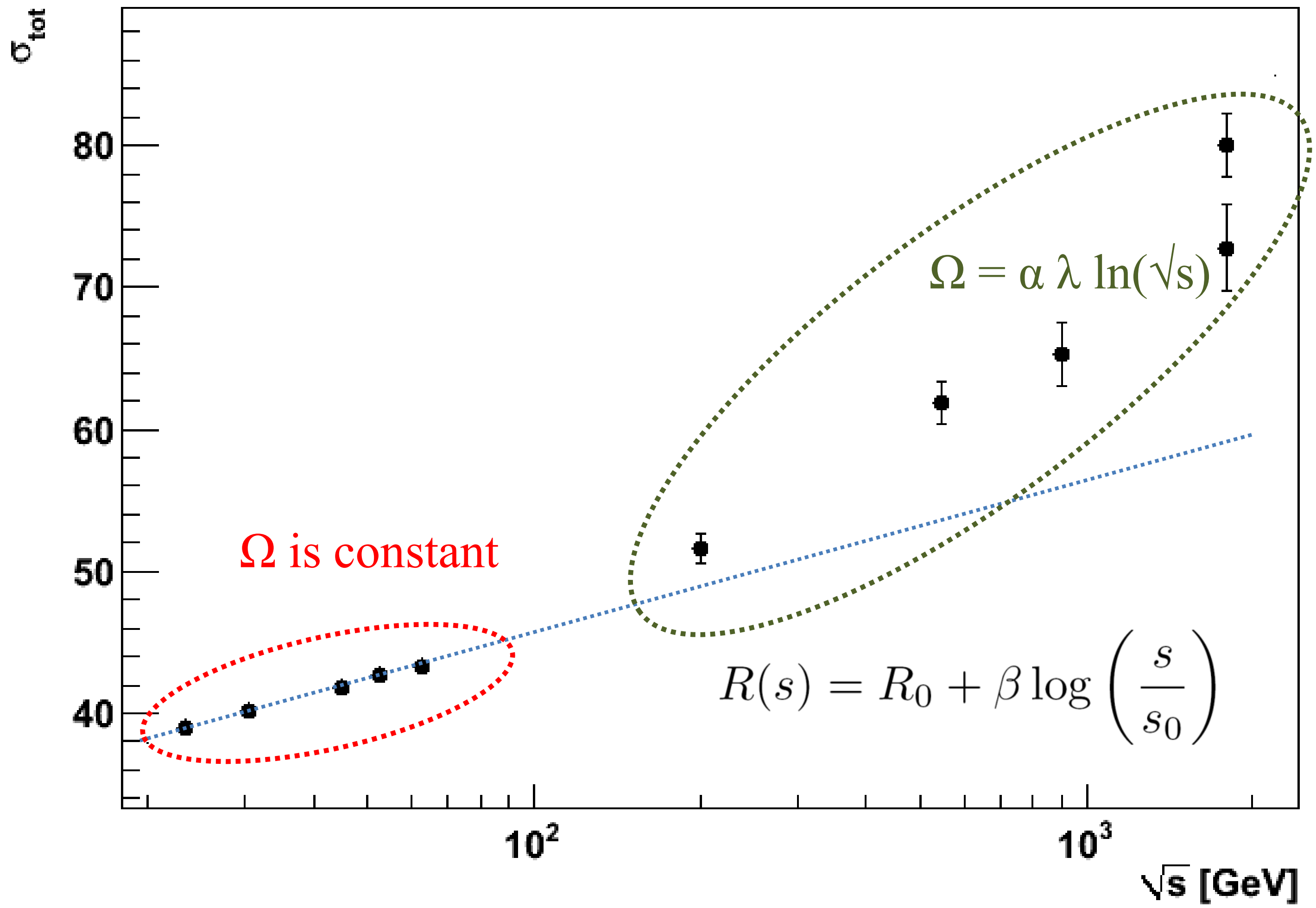


$$\frac{\sigma_{el}(s)}{\sigma_{tot}(s)}$$



$\sigma_{tot}(s)$

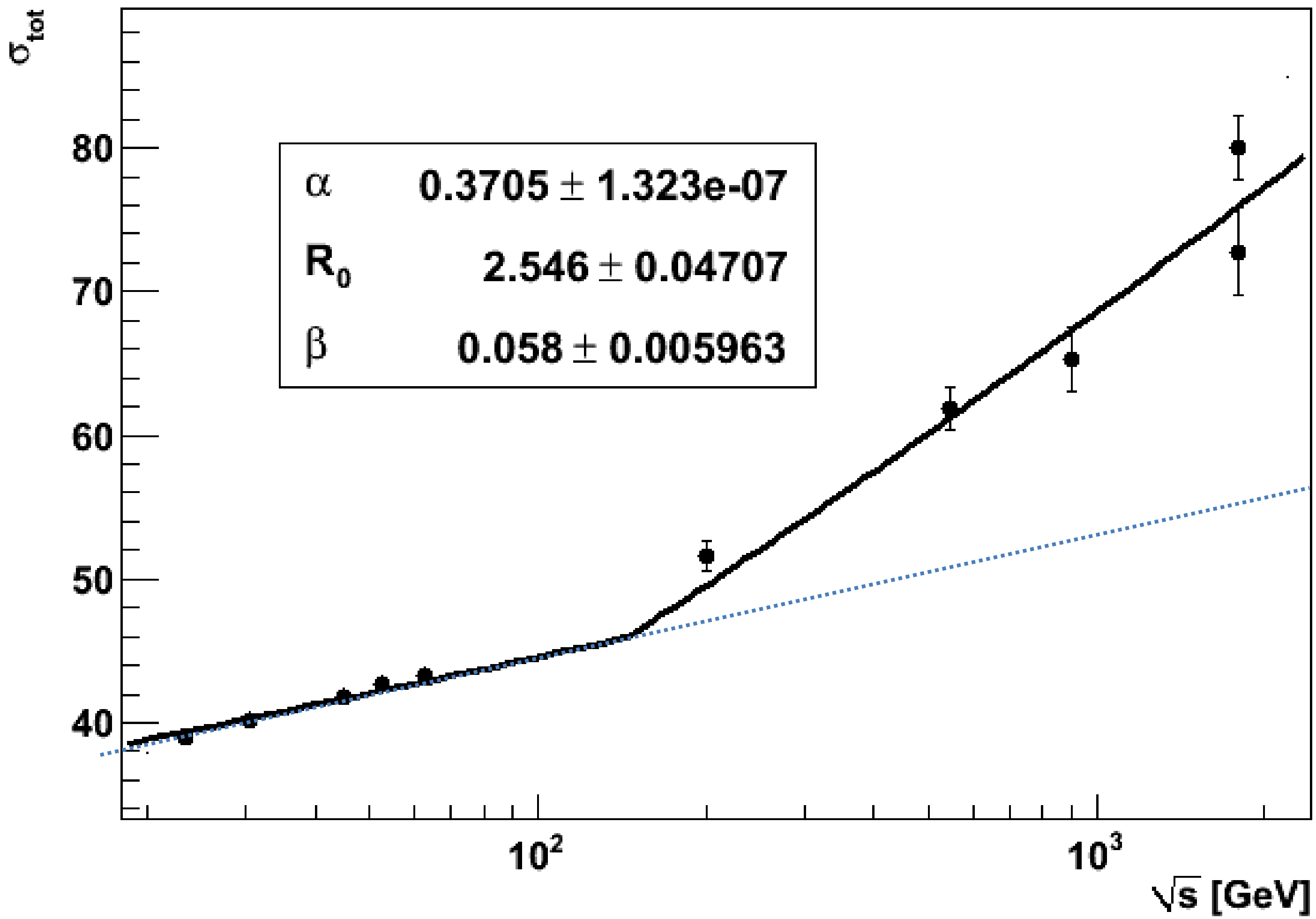
$$\sigma_{tot}(s) = 2\pi(1 - e^{-\overline{\Omega}(s)})R^2(s)$$



$\sigma_{tot}(s)$

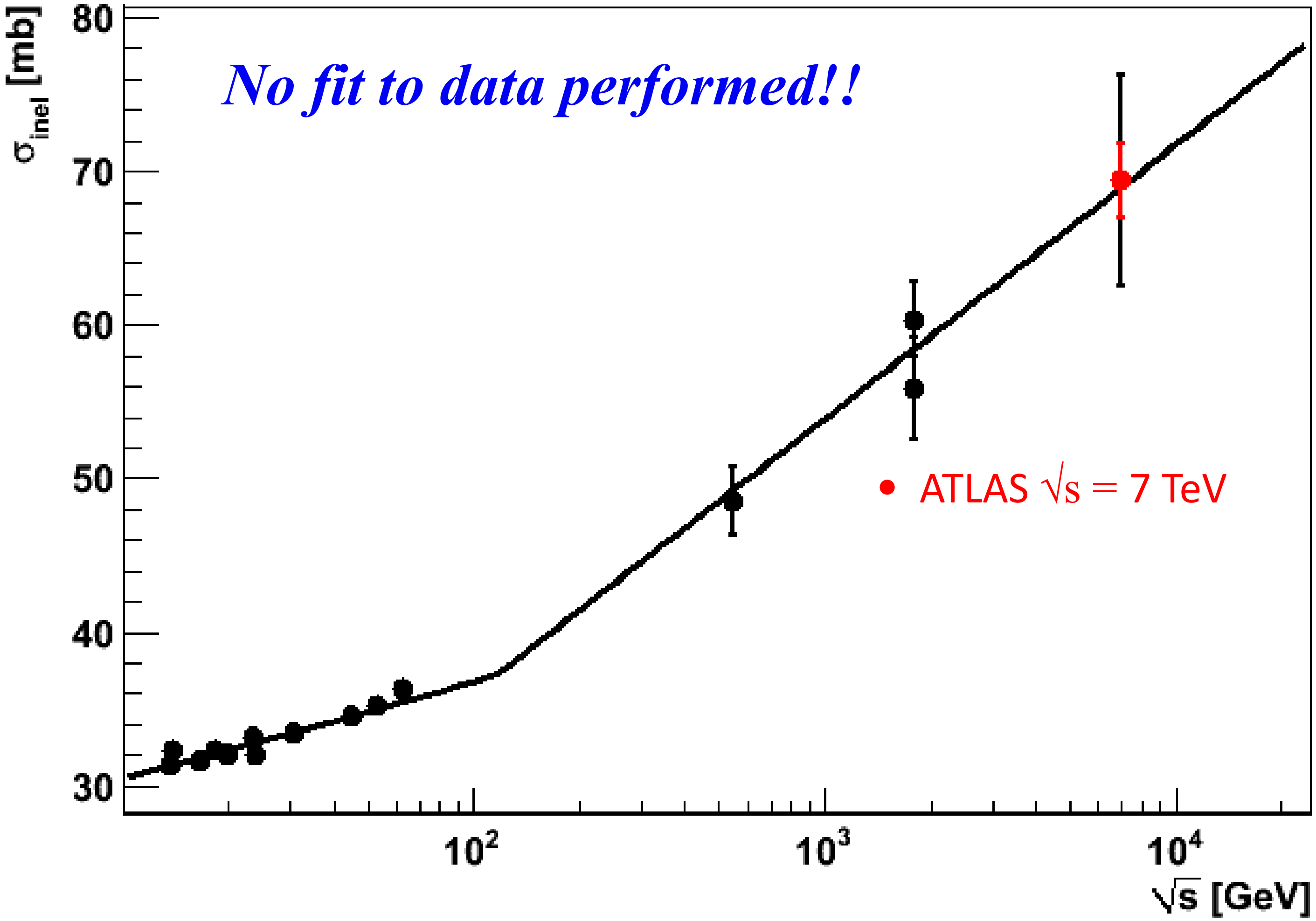
$$\sigma_{tot}(s) = 2\pi(1 - e^{-\overline{\Omega}(s)})R^2(s)$$

$$R(s) = R_0 + \beta \log\left(\frac{s}{s_0}\right)$$



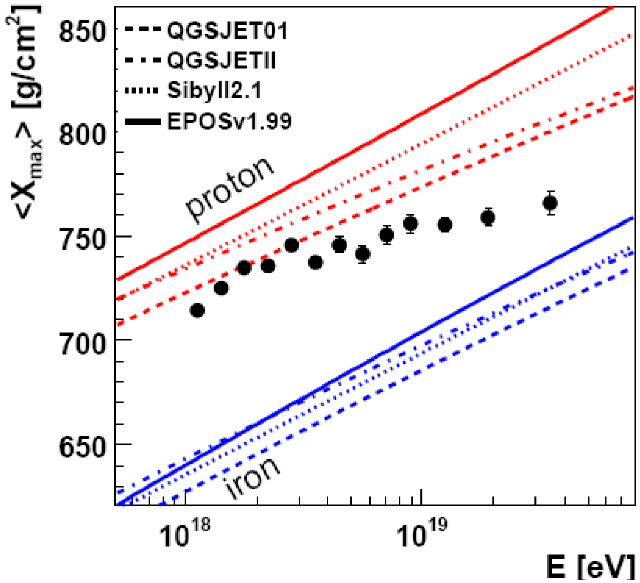
$$\sigma_{inel}(s)$$

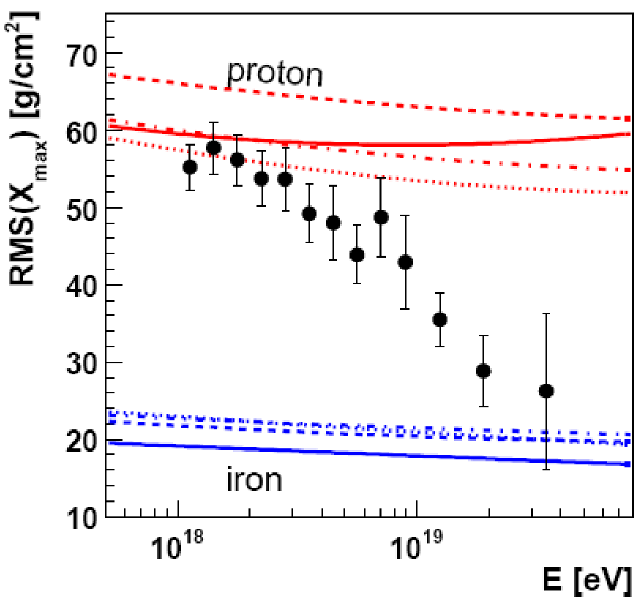
$$\sigma_{inel}(s) = \pi(1 - e^{-2\overline{\Omega}(s)})R^2(s)$$

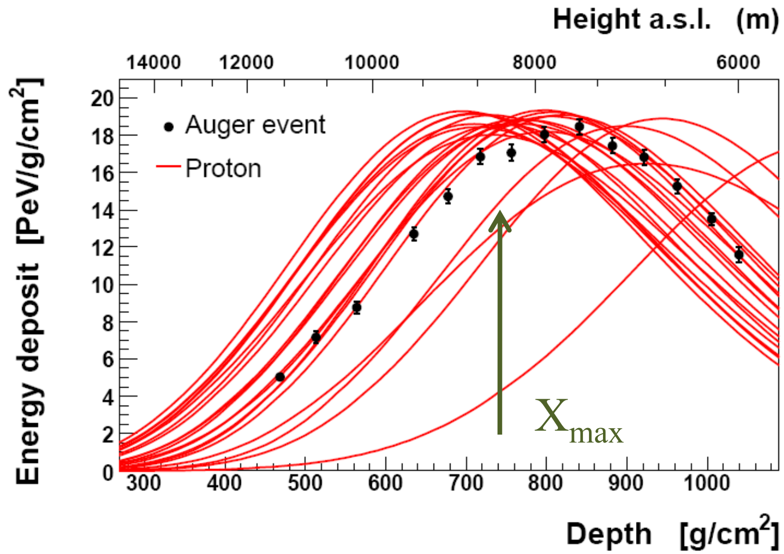


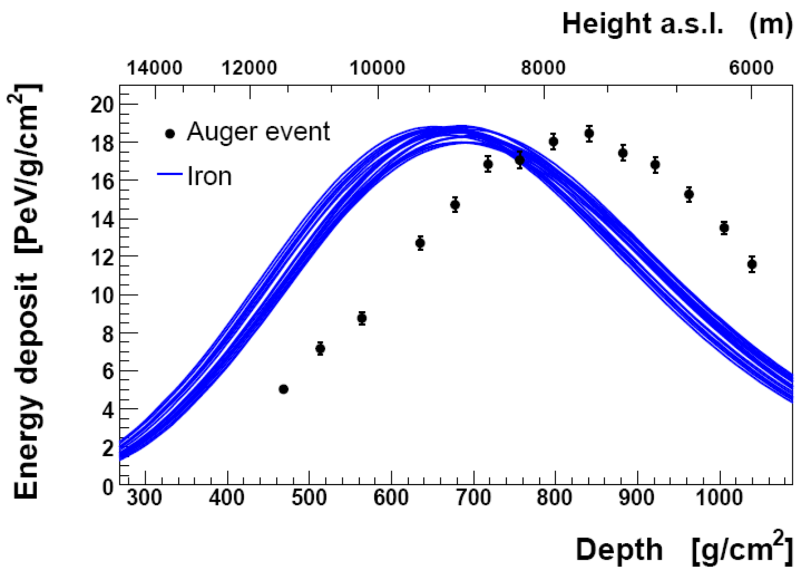
Pierre Auger Observatory results

Longitudinal shower profile

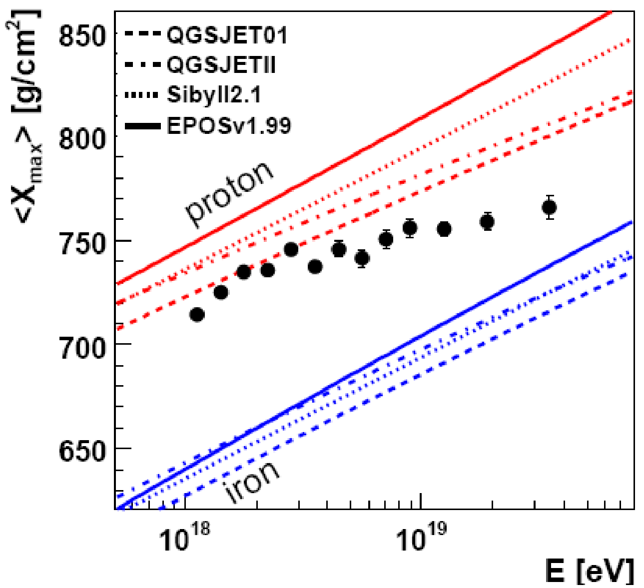


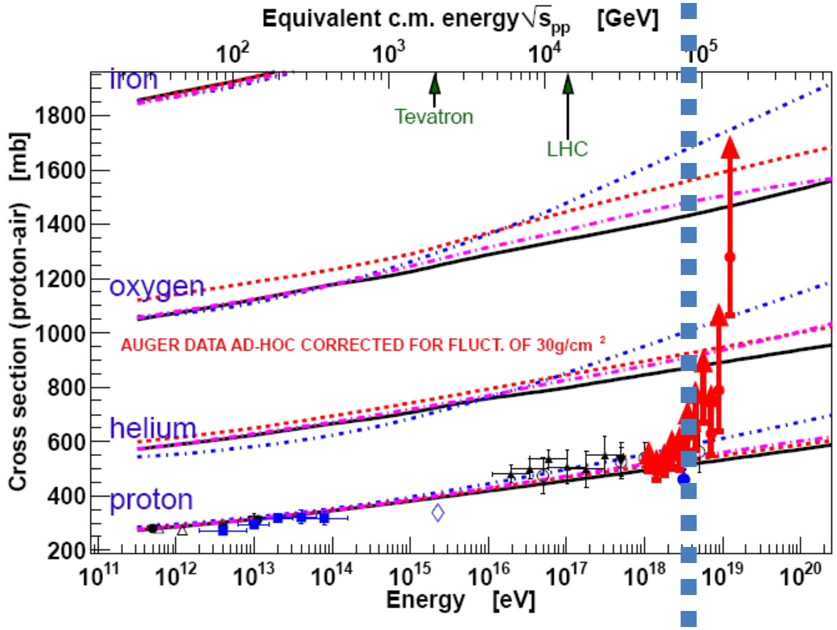




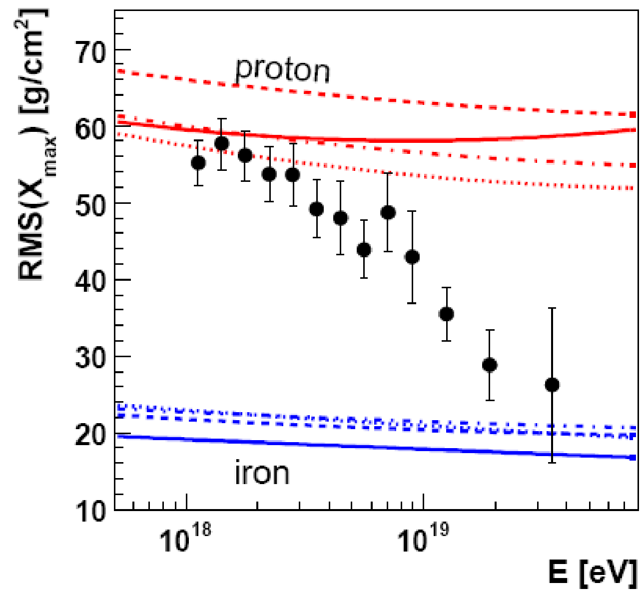


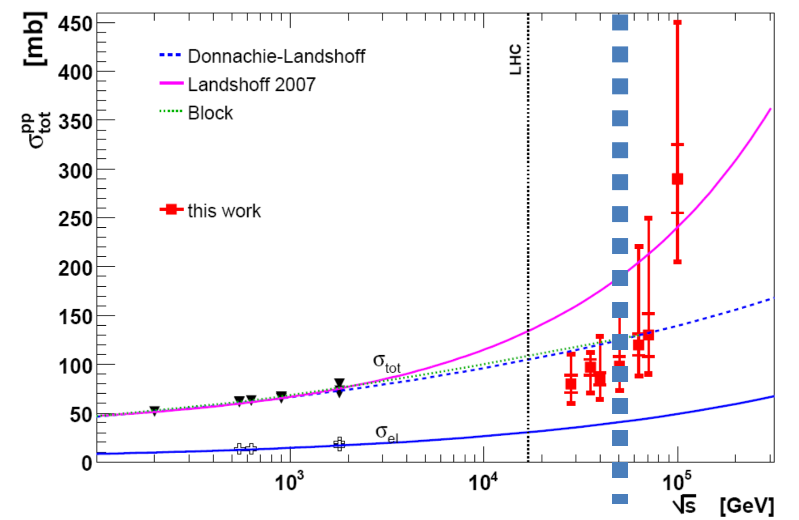
Pierre Auger Observatory results





(Auger $X_{\max}$-data from PRD2010, 90 % C.L.)

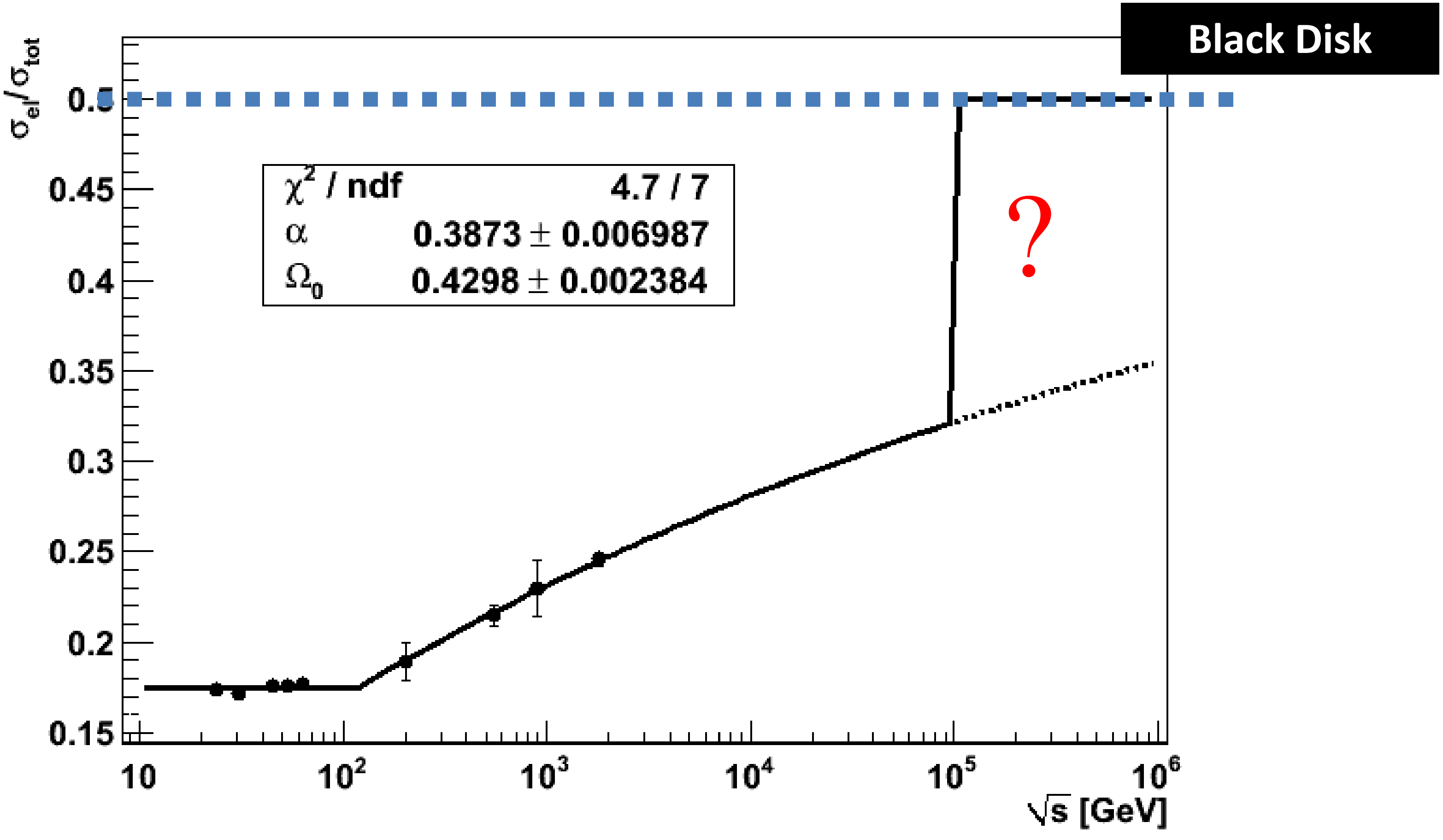




Ralph Ulrich

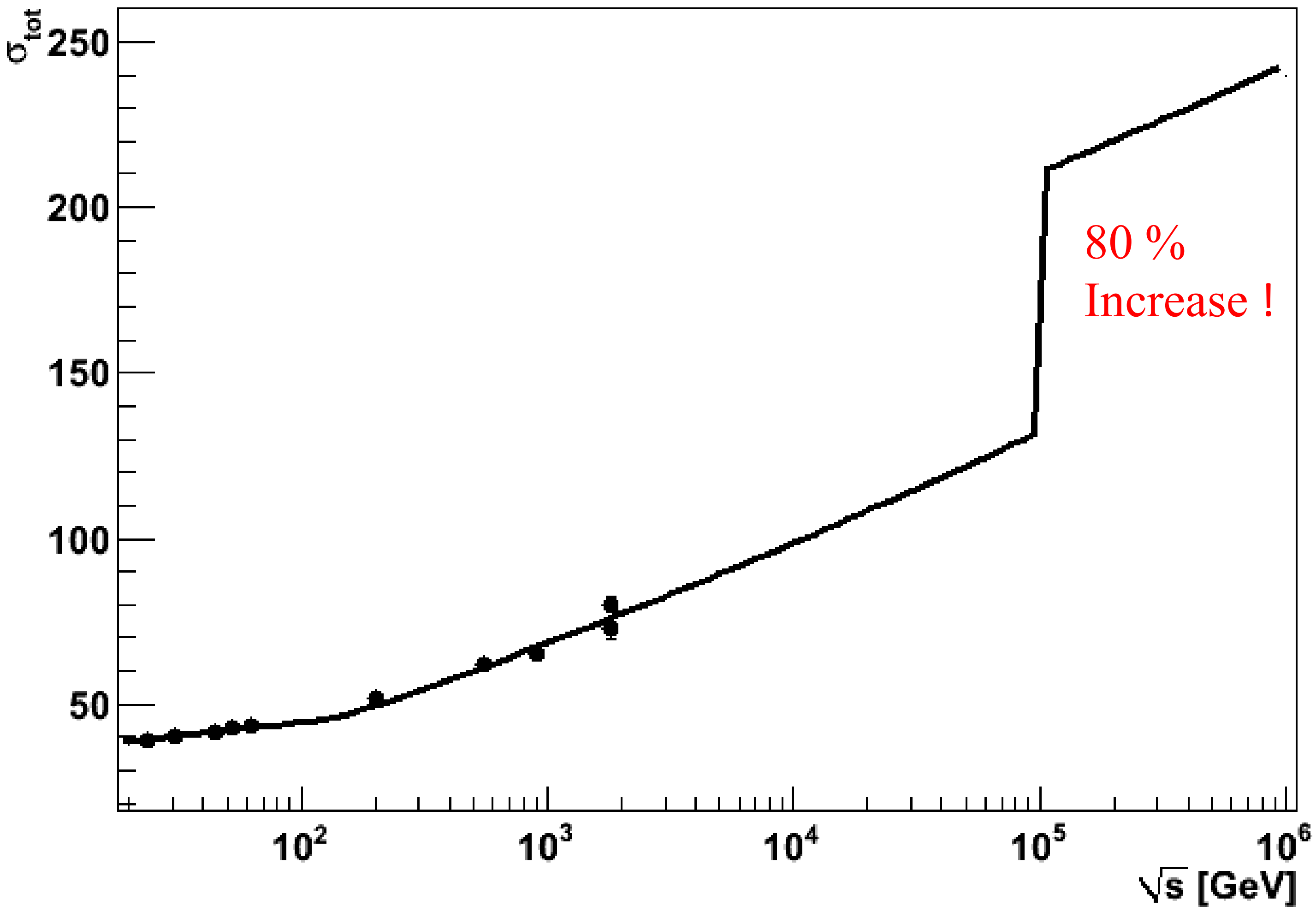
Towards the black disk

$$\frac{\sigma_{el}(s)}{\sigma_{tot}(s)}$$



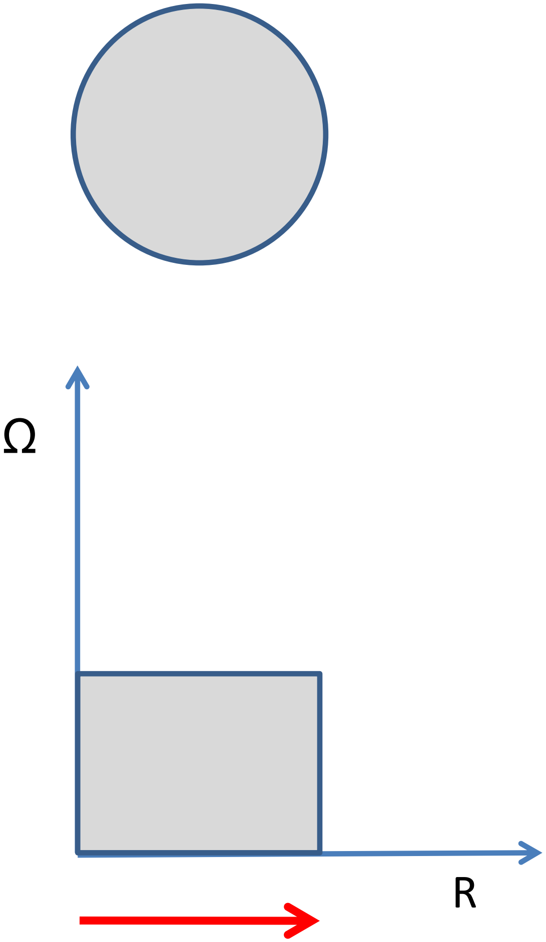
Without a fast transition at the cosmic rays energy the disk should became black at $\sqrt{s} = 10^{19}$ GeV

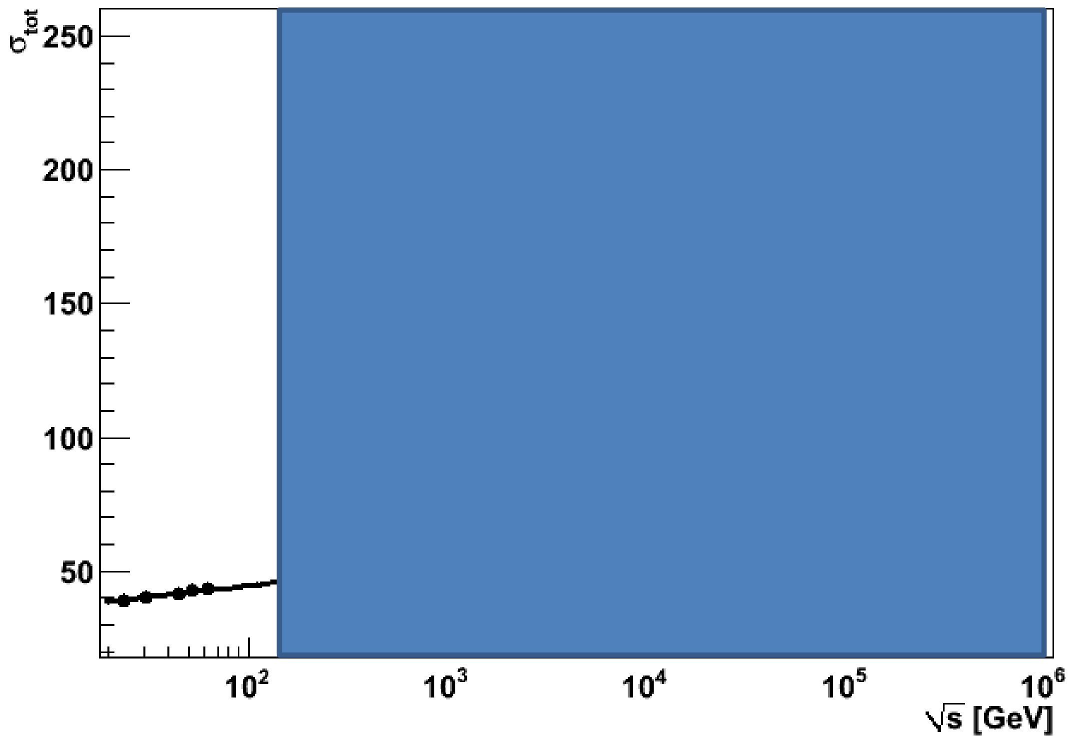
$$\sigma_{tot}(s)$$



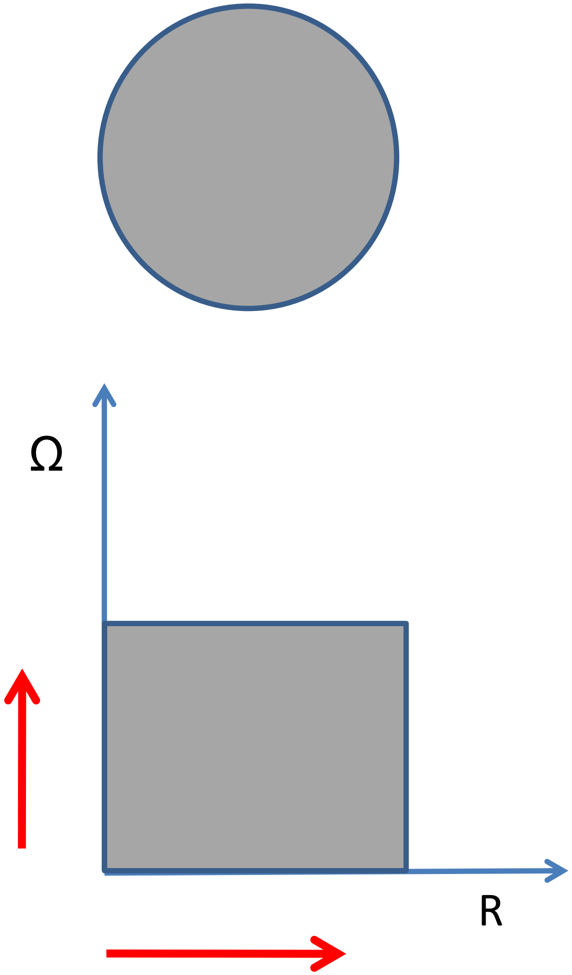
σ_{tot}
250
200
150
100
50
10^2
10^3
10^4
10^5
10^6
$\sqrt{s}$ [GeV]
80 %
Increase !

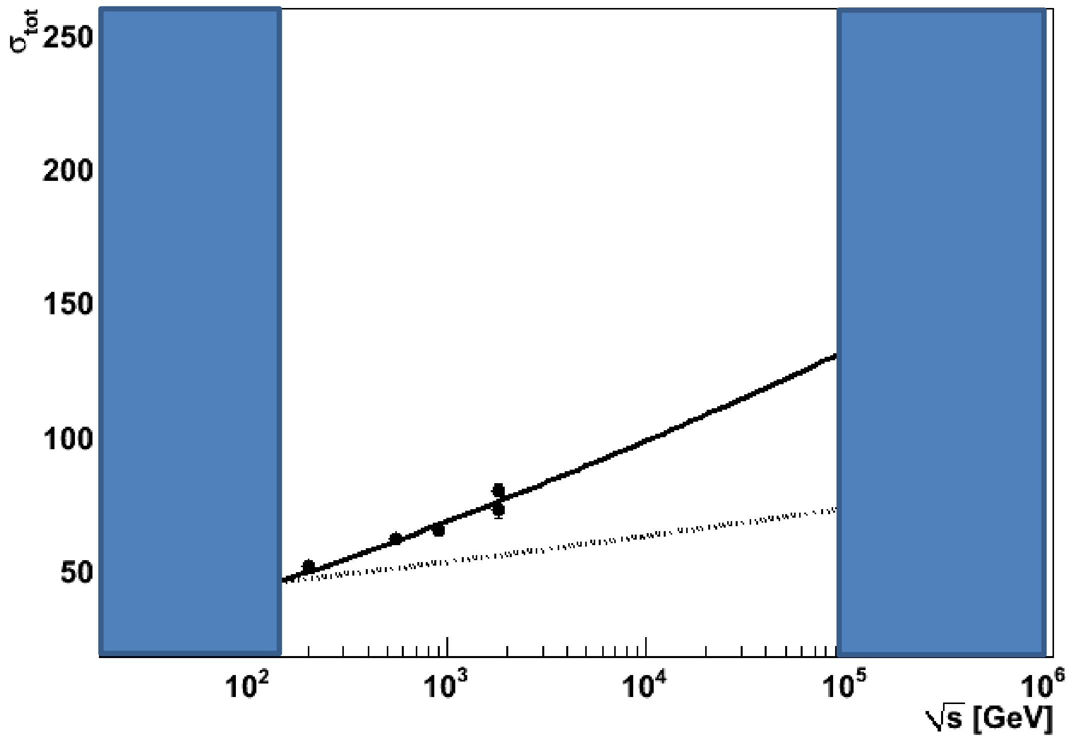
The Proton ($\sqrt{s}$) – Low energy



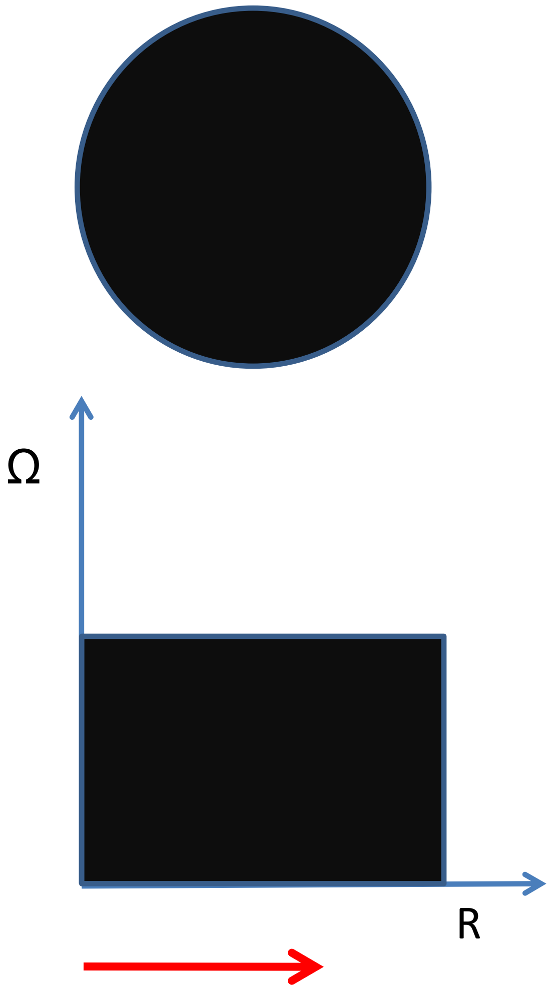


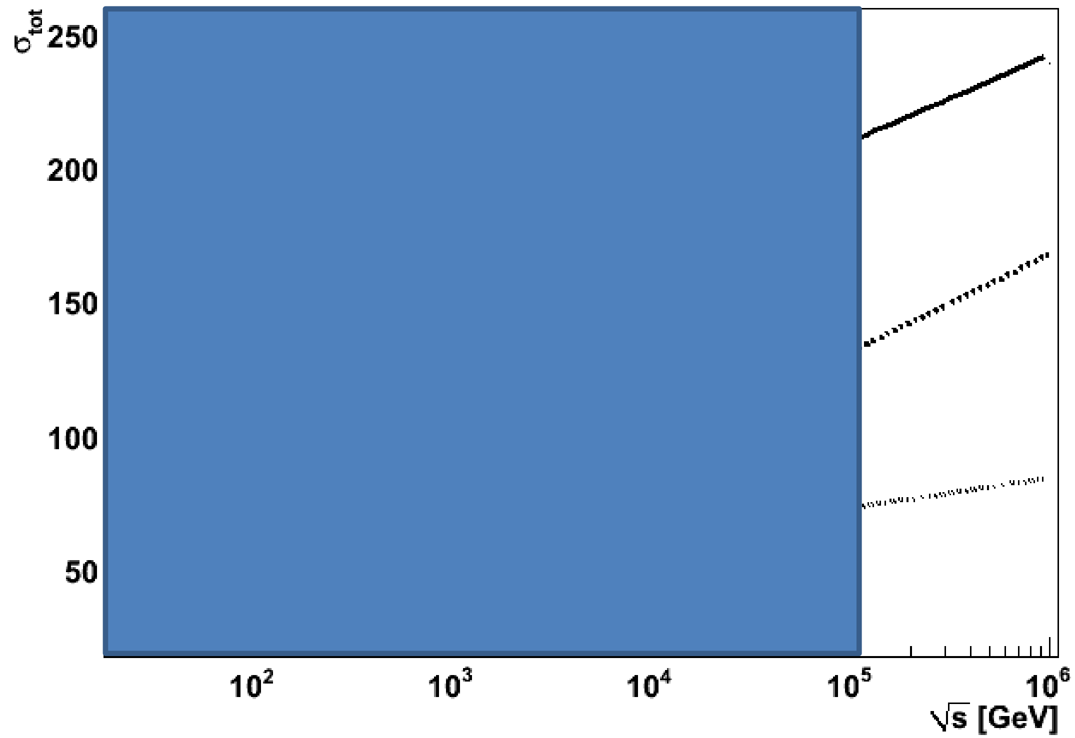
The Proton (√s) – Intermediate energy





The Proton (√s) – High energy





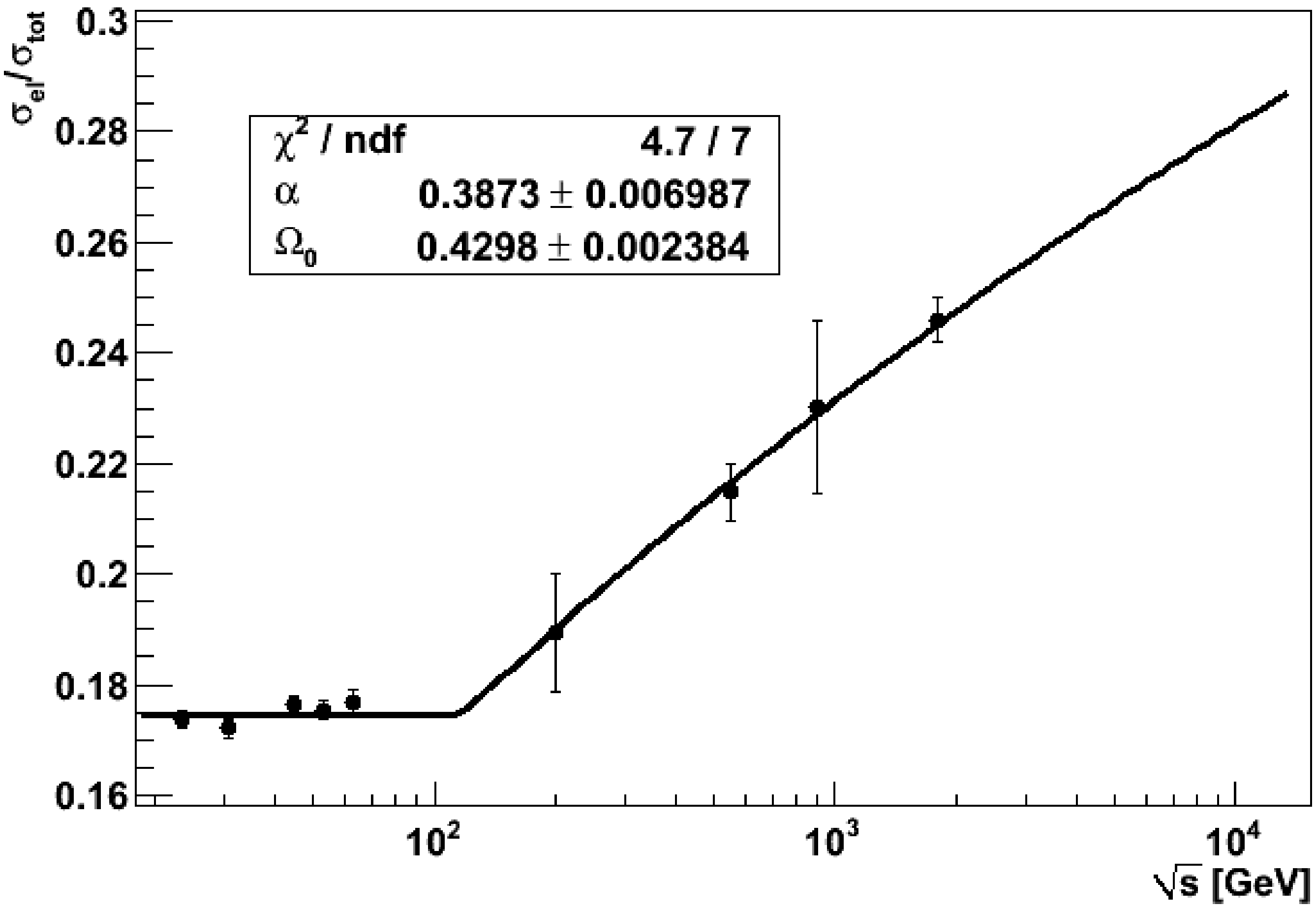
Conclusions

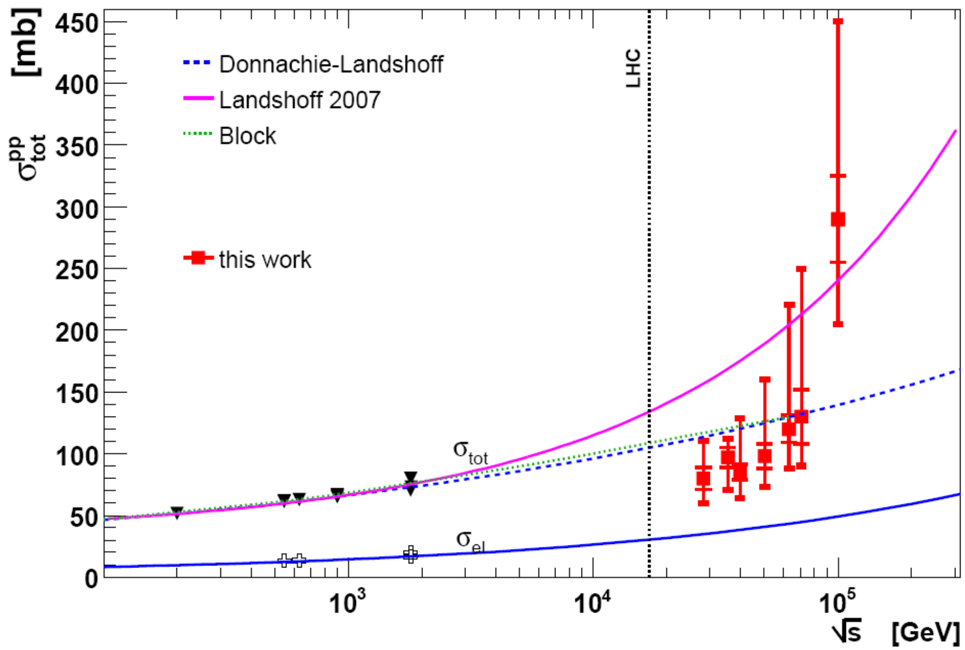
- A simple grey disk model is able to reproduce all cross section data (σ_{tot}, σ_{in}, σ_{elas})

- $R = R_0 + \beta \log(s/s_0)$
- Ω is constant for $\sqrt{s} \sim 110 - 130$ GeV
- $\Omega \propto \lambda \ln(\sqrt{s})$ for $\sqrt{s} > 110 - 130$ GeV

- A fast transition to the black disk at $\sqrt{s} \sim 100$ TeV can accommodate an ~ 80% increase in the total cross-section

BACKUP


σel/σtot
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
χ2 / ndf 4.7 / 7
α 0.3873 ± 0.006987
Ω0 0.4298 ± 0.002384
10^2
10^3
10^4
√s [GeV]



σ_{tot}^{pp} [mb]
450
400
350
300
250
200
150
100
50
0
Donnachie-Landshoff
Landshoff 2007
Block
this work
LHC
σ_{tot}
σ_{el}
10^3
10^4
10^5
$\sqrt{s}$ [GeV]