Impact of different scenarios of the energy dependence of σ_{tot} on ρ (real/imaginary part of elastic amplitude)

Per Grafstrom
University of Bologna
November 2018

Work together with
Grazia Cabras,
Benedetto Giacobbe
Karlheinz Hiller

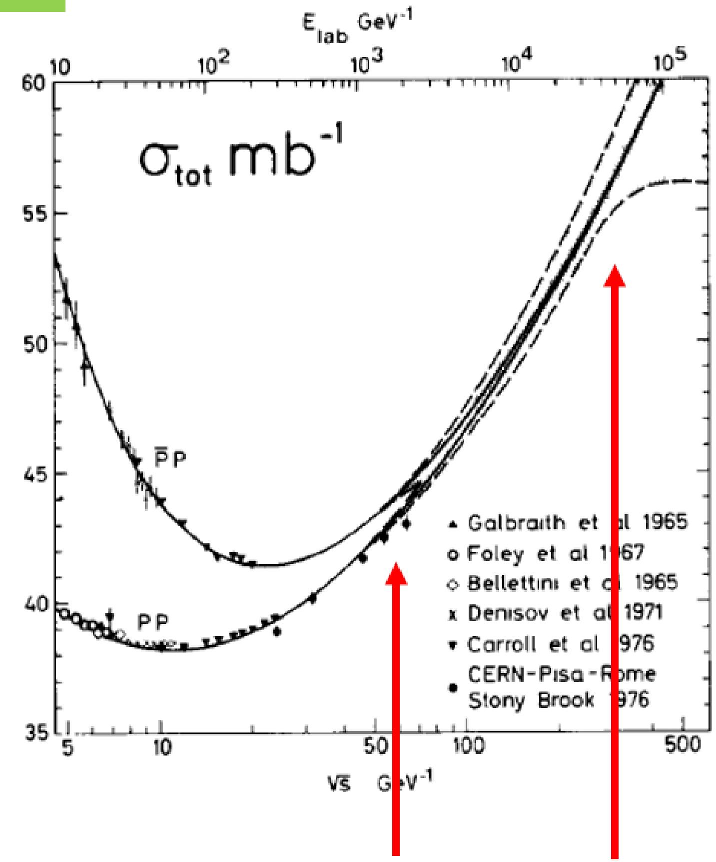
Starting point ISR

Amaldi et al. PLB 66(1977)390.

$\sqrt{s}$ (GeV)	Number of events	σ_{tot} (mb)	Slope	ρ
30.6	774000	40.1 ± 0.4	12.2 ± 0.3	0.042 ± 0.011
44.7	2478000	41.7 ± 0.4	12.8 ± 0.3	0.062 ± 0.011
52.9	2752000	42.4 ± 0.4	13.1 ± 0.3	0.078 ± 0.010
62.4	2290000	43.1 ± 0.4	13 3 ± 0.3	0.095 ± 0.011

Precision in ρ

Common fit to σ_{tot} and ρ via dispersion relations using data up to $\sqrt{s}$ = 62 GeV



$\sqrt{s}$ =60 GeV $\sqrt{s}$ =300 GeV

boundaries corresponds to chi2 +1

Clear prediction of σ_{tot} at an energy a factor 5 higher than the energy at which ρ had been measured

What is behind?

$$\rho_\pm\sigma_\pm = \frac{B}{p} + \frac{E}{\pi p}\,\mathrm{P}\int_{m_p}^{\infty}\left[\frac{\sigma_\pm}{E'(E'-E)} - \frac{\sigma_\mp}{E'(E'+E)}\right]p'\,dE'$$

Integral dispersion relations

The integral has an singularity at the energy, E, at which ρ is calculated.
→ the sensitivity to ρ on σ_{tot} is largest at this energy.

In practice: the ρ-value at the energy E is determined by the integral of the total cross section from E/10 to 10 x E….i.e roughly one order of magnitude lower and one order of magnitude higher relative the energy at which you want to calculate ρ.

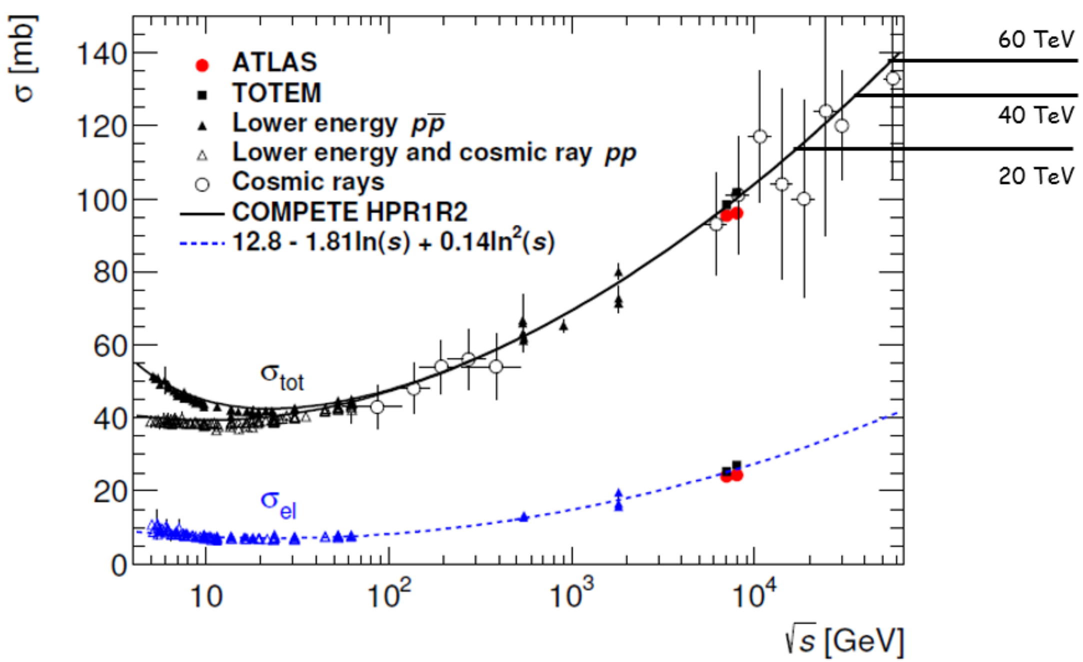
Also observe that the cross section is in general known in the range from E/10 to E and thus it is the unknown behaviour of the cross section between E and 10 x E that determines the ρ-value at E.

This method was used both at the ***ISR*** and the ***SppS collider*** to make predictions of σ_{tot}.

1. Our first simple attempt to get a feeling for sensitivities at LHC energies

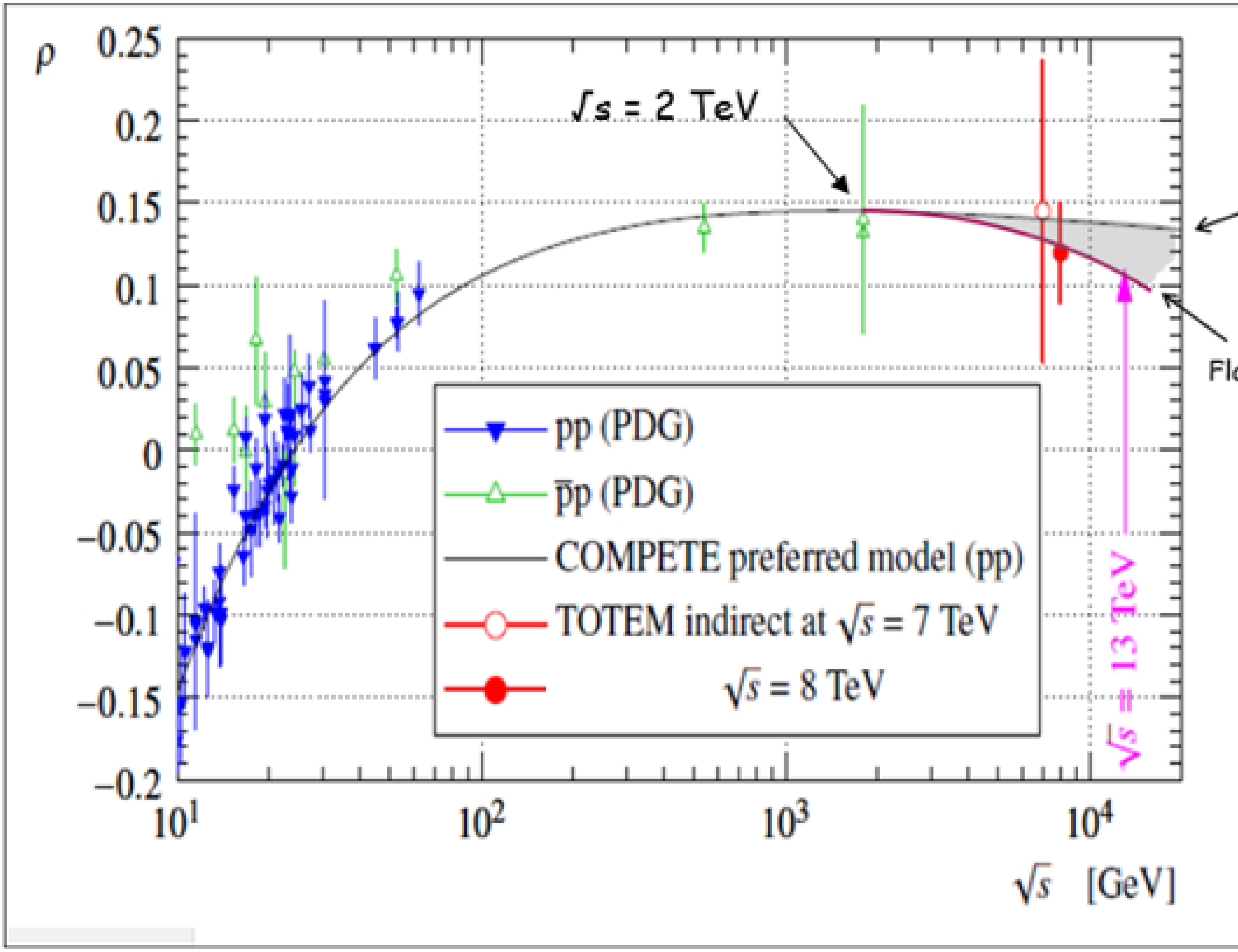
Calculate via dispersion relation the value of ρ at e.g. $\sqrt{s}$ = 13 TeV for different high energy scenarios of the total cross section.

Try simple flattening out of σ_{tot} at 20 TeV, 40 TeV and 60 TeV



The cross section becomes constant at 20, 40 or 60 TeV

the result….

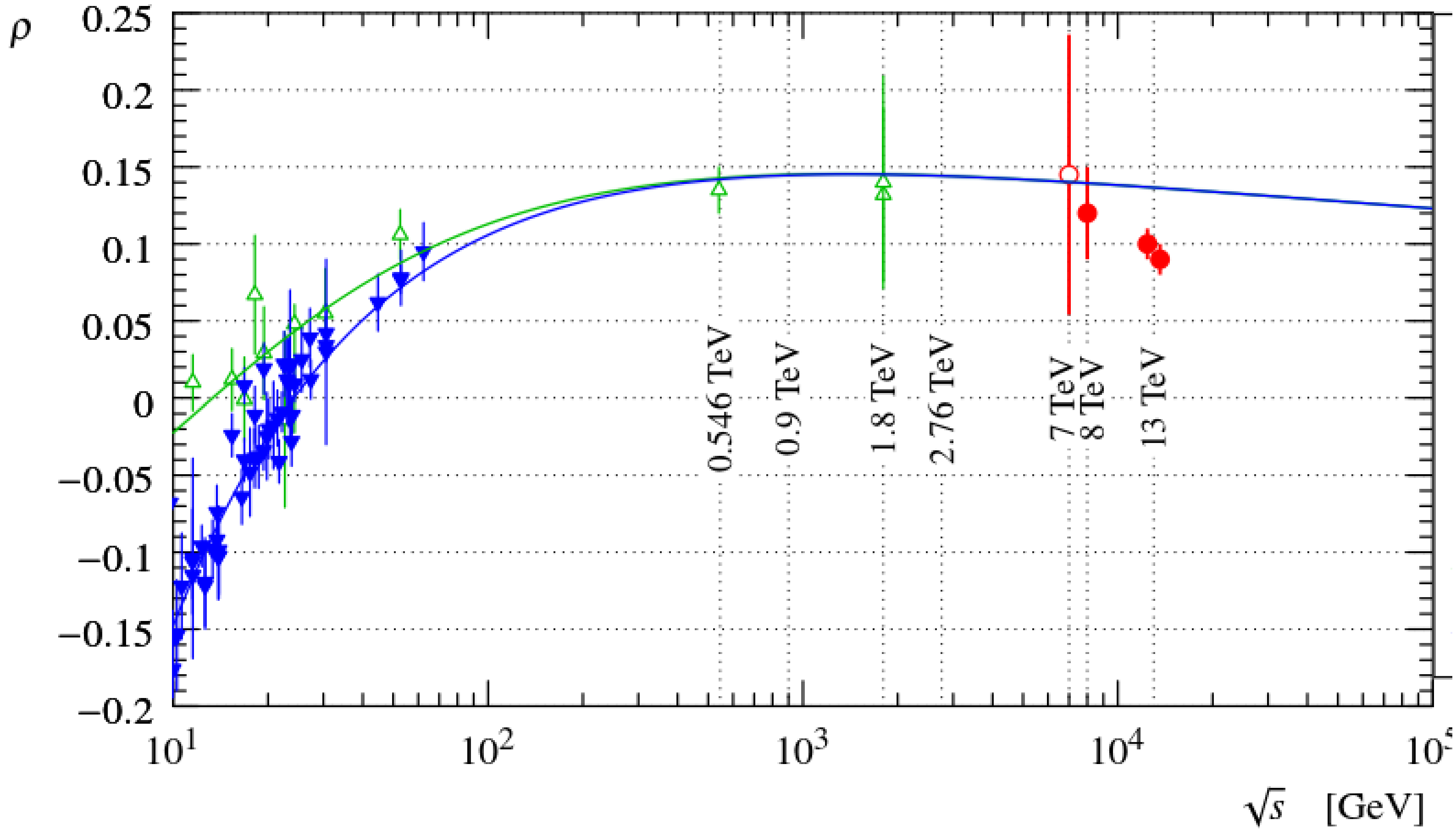


Depending on the precision in the rho measurement prediction could be made up to a range of 20, 40,60 or 80 TeV

Observe this was done before the rho measurement of TOTEM at 13 TeV

The TOTEM data at 13 TeV changed the paradigm.

Red points ...TOTEM published



Does this data tell us something about the high energy behavior of σ_{tot}

...or is it rather an indication of an Odderon ?

Why does the TOTEM data change the paradigm?

Observe- Very important:

We use the so called "one subtracted " integral dispersion relation

$$\boxed{\rho_\pm \sigma_\pm = \frac{B}{p} + \frac{E}{\pi p} \mathrm{P} \int_{m_p}^{\infty} \left[\frac{\sigma_\pm}{E'(E'-E)} - \frac{\sigma_\mp}{E'(E'+E)} \right] p' \, dE'}$$

which in the derivation assumes :

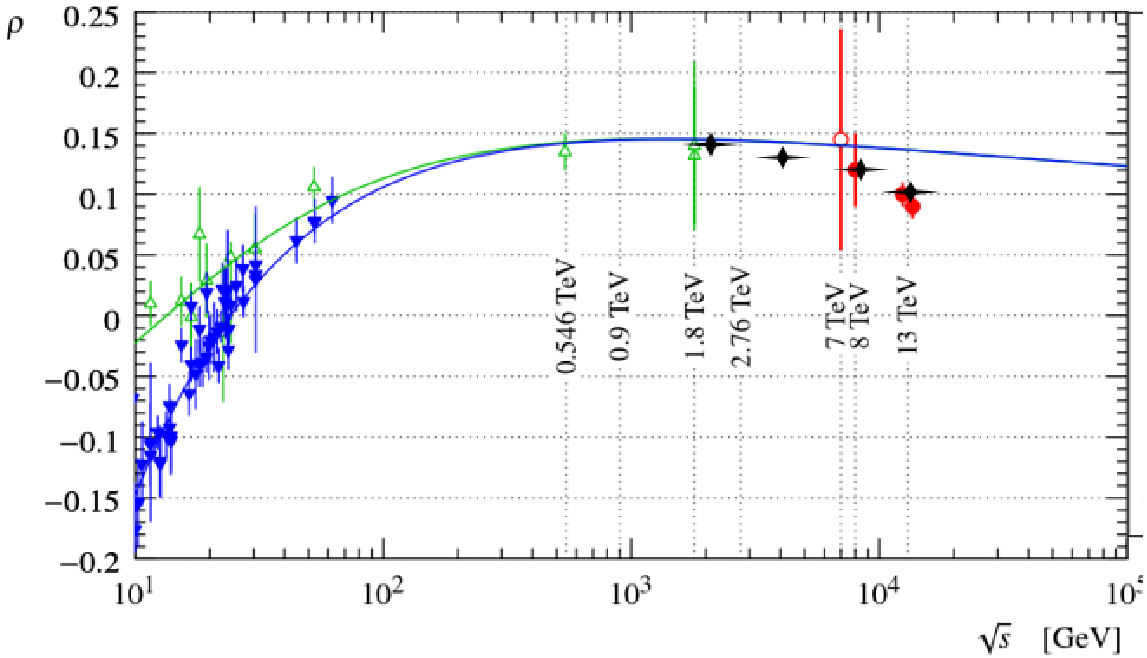
$\Delta\sigma = \sigma_{pp} - \sigma_{ppbar} \longrightarrow 0$ at high energies

....if this is not the case (Odderon!) the formula above can not be used!

Thus the TOTEM data either tell us something about the high energy behavior of σ_{tot}.......

...or it is an indication of an Odderon !

2. After the very simplified flattening out to a constant value we tried a scenario where the exponent of the ln (s) term change from 2 to 1.6 at 15 TeV



ρ calculated assuming σ_{tot} goes like $\ln^2(s)$ to 15 TeV and then $\sigma_{tot} \propto \ln^{1.6}(s)$ above 15 TeV

Observe :This is not a model but just an example of a functional form that can describe the data ….or an indication of what a possible slowing down of the rise of σ_{tot} does to ρ

3. Next step : we tried a bit more physics motivated approach..

A suggestion from Block & Cahn Rev Modern Physics Vol 57 1985

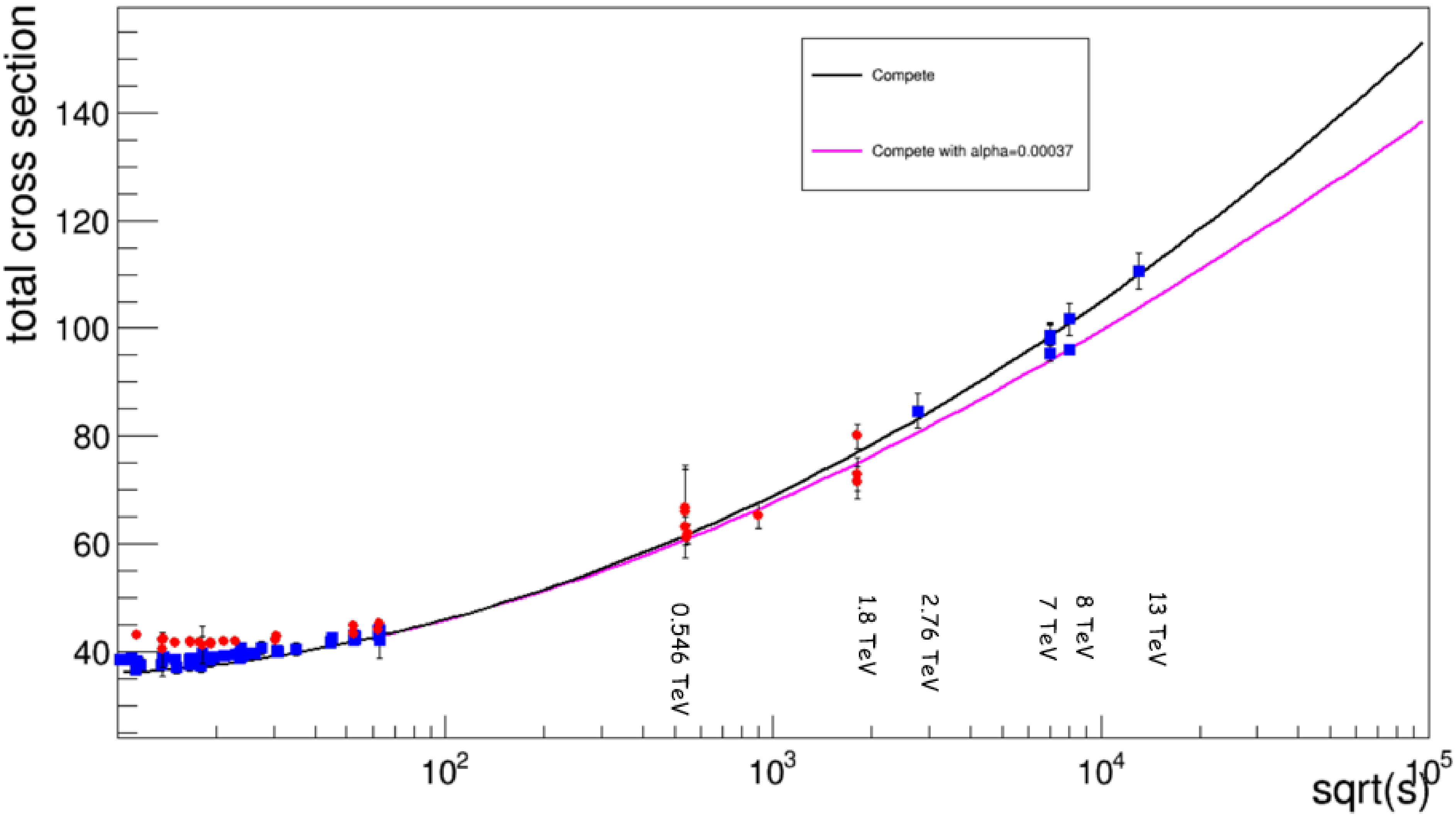
Instead of $\ln^2(s/so)$ the suggest a slowing down factor a

$$\ln^2(s/so)/(1+a \ln^2(s/so)$$

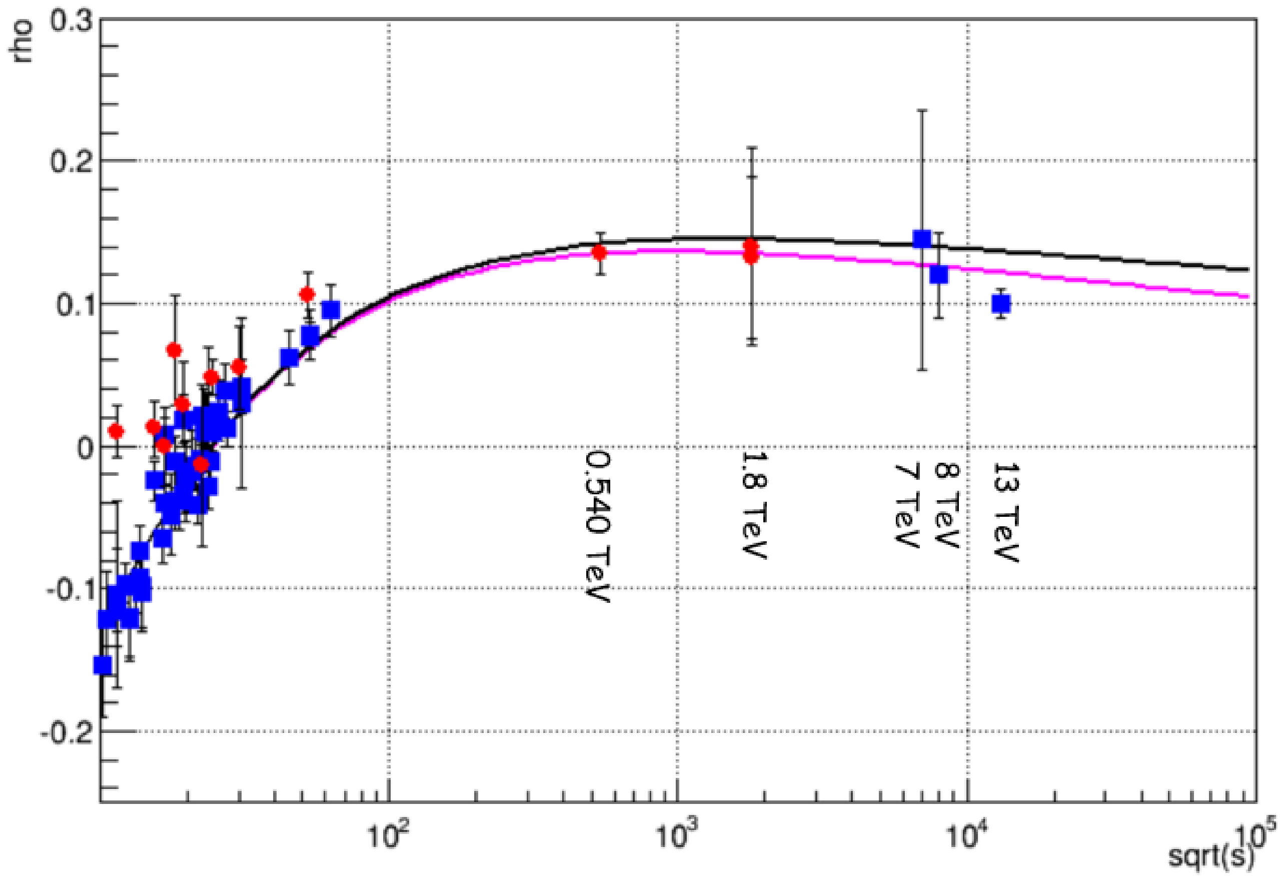
were a is a small positive number

According to the authors a is related to an energy scale where deviation from $\ln^2 s$ starts.
Analogous to a scale parameter in QED to measure departure from an idealized theory of point particles

As an example…try α=0.00037



…and corresponding rho from dispersion relations…..



4. Further step. More physics input. Recent paper from KMR (Khoze, Martin and Ryskin)

Elastic and diffractive scattering at the LHC

arXiv:1806.05970v1 [hep-ph] 15 Jun 2018

Basic framework is a two-channel eikonal model.

Eikonal ⟶ amplitudes described by the opacity of the proton $\Omega(s,b)$

Two-channel ⟶ two effective low mass diffractive eigenstates (< M_x=3.5 GeV)

Good-Walker formalism for the diffractive eigenstates

The parameters

	2013	2018
Δ	0.115	0.13
α'_P (GeV^{-2})	0.11	0.052
σ_0 (mb)	33	23
γ	0.4	0.56
$\lvert a_1\rvert^2$	0.25	0.505
b_1 (GeV^{-2})	8.0	10.0
c_1 (GeV^2)	0.18	0.233
d_1	0.63	0.462
b_2 (GeV^{-2})	6.0	4.9
c_2 (GeV^2)	0.58	0.52
d_2	0.47	0.47

⟵ Pomeron intercept and slope

⟵ The coupling of the diffractive eigen states to the pomeron

⟵ Describing the form factors of The two diffractive eigen states

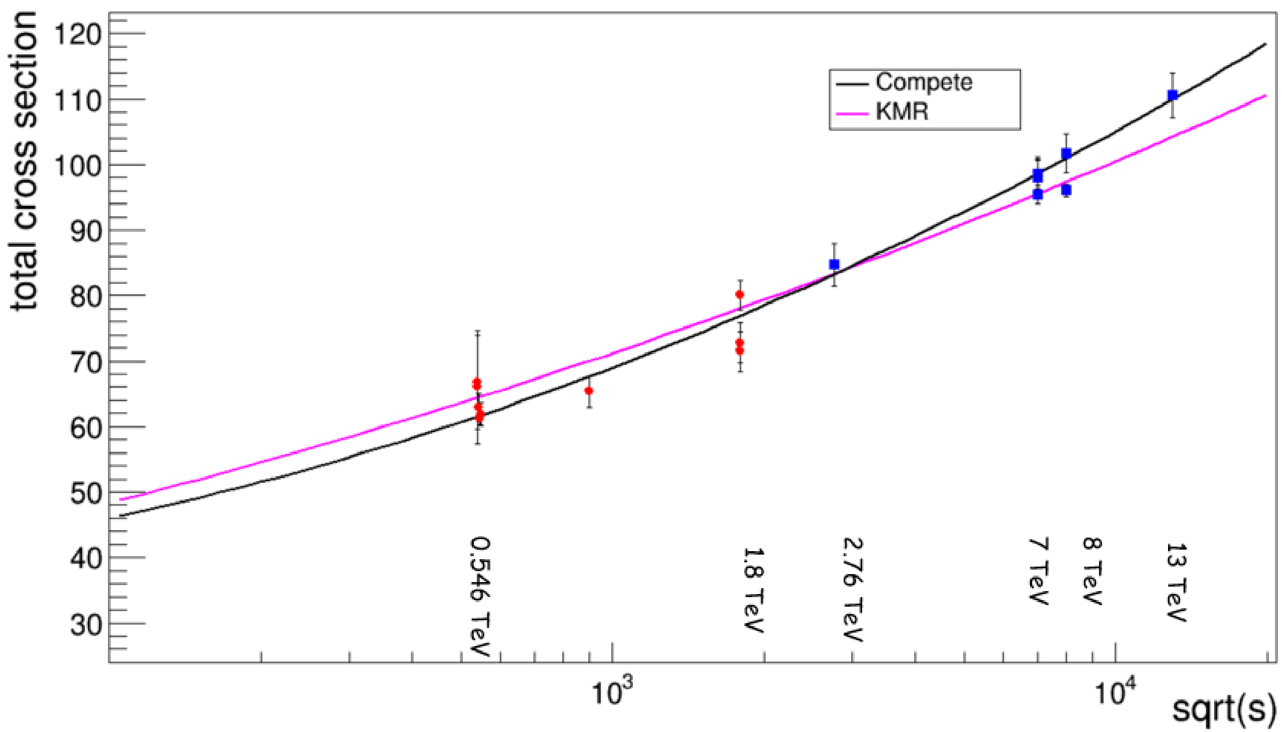
The model depends in a crucial way on experimental input for low-mass diffraction

They calculate σ_{tot} for 7 different energies between 100 GeV and 100 TeV
In order to be able to calculate ρ via dispersion relations we have parametrized those 7 points with the same structure as COMPETE RRPL2U is parametrized.
(without the low energy Regge terms)

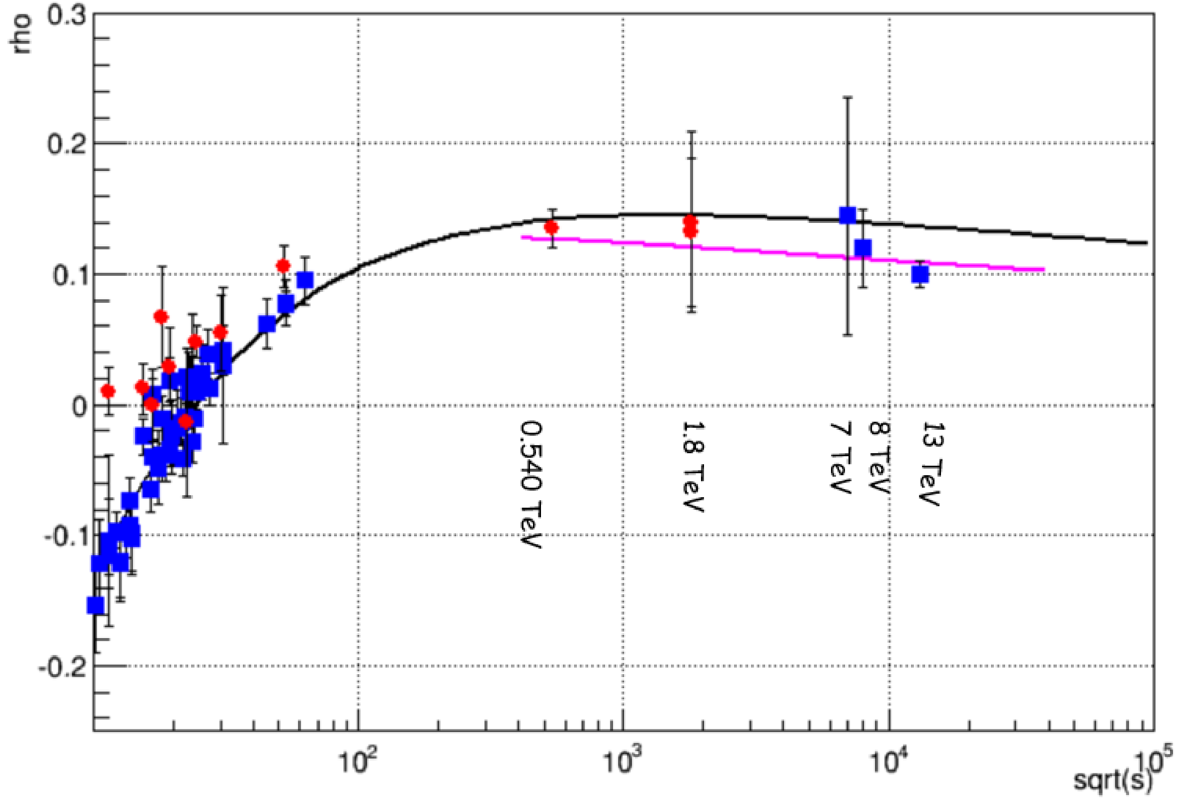
COMPETE RRPL2U : $\sigma_{tot} = 0.307 \ln^2 (s/29.1) + 35.5$ (mb and GeV)

Our parametrization of KMR: $\sigma_{tot} = 0.1509 \ln^2 (s/29.1) + 2.5128 \ln(s/29.1) + 28.5)$
(perfect description of KMR in the given energy range)

Basically smaller coefficient for $\ln^2 s$ and an additional $\ln s$ term



In magenta corresponding rho from our dispersion relation calculation



Observe that KMR also can calculate ρ within their framework

	546 GeV	1.8 TeV	8 TeV	13 TeV
Our disp. Rel.	0.128	0.120	0.111	0.108
KMR	0.129	0.121	0.112	0.109

5. Last step. Compare with thorough phenomenological work of a Brazilian group

Forward Elastic Scattering and Pomeron Models

M. Broilo[1*], E.G.S. Luna[1†] and M.J. Menon[2‡]
[1] *Instituto de Física, Universidade Federal do Rio Grande do Sul*
CEP 91501-970, Porto Alegre – RS, Brazil
[2] *Instituto de Física Gleb Wataghin,*
Universidade Estadual de Campinas
CEP 13083-859, Campinas – SP, Brazil
(Dated: September 25, 2018)

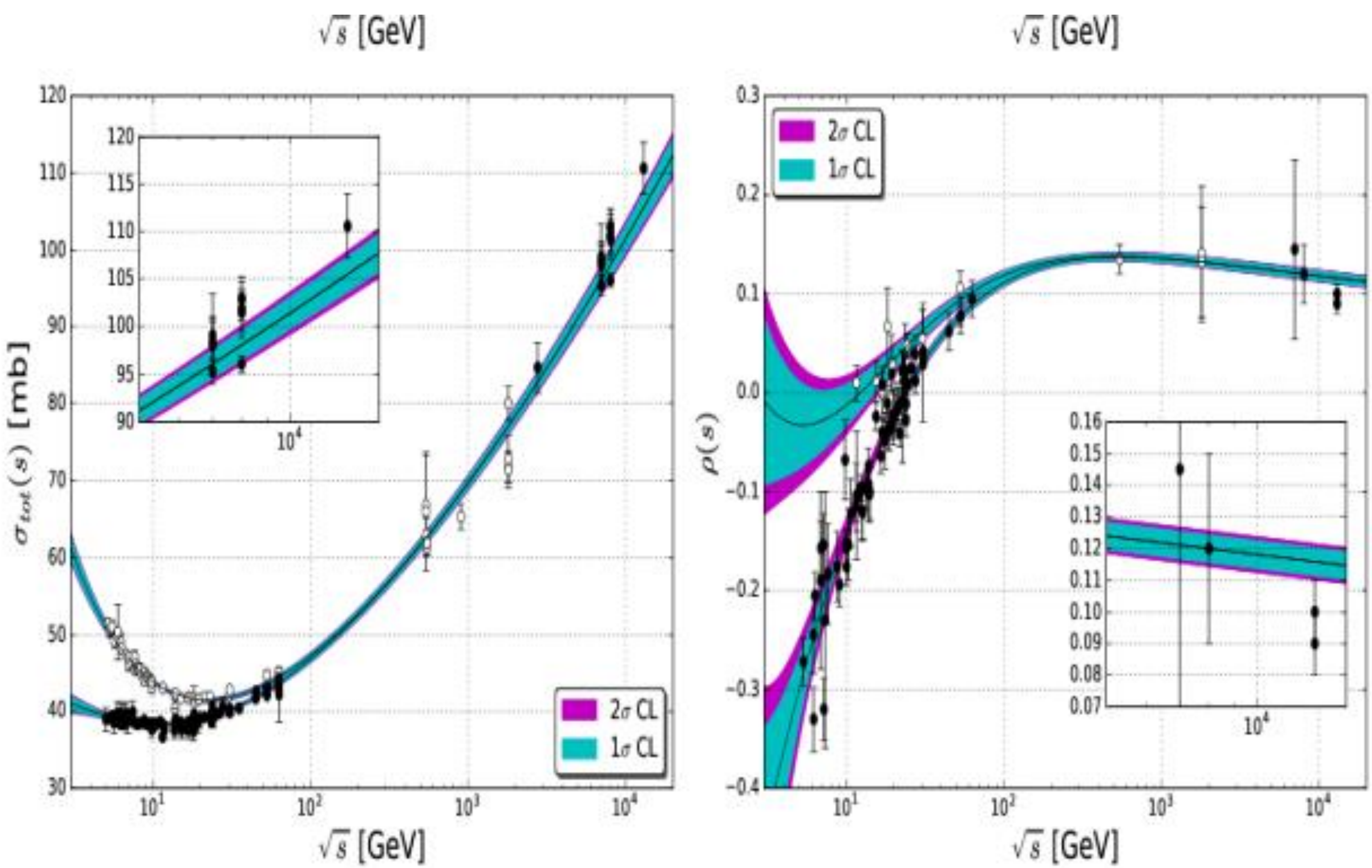
arXiv:1807.10337v2 [hep-ph] 23 Sep 2018

Very general starting point

$$\sigma_{\rm tot}(s) = a_1\left[\frac{s}{s_0}\right]^{-b_1} + \tau a_2\left[\frac{s}{s_0}\right]^{-b_2} + A + B\left[\frac{s}{s_0}\right]^{\epsilon} + C\ln\left(\frac{s}{s_0}\right) + D\ln^2\left(\frac{s}{s_0}\right), \qquad (4)$$

- Model III: $A = B = 0$, $\epsilon = 0$ $\Rightarrow$ $\sigma^P_{III} = C \ln\left(\frac{s}{s_0}\right) + D \ln^2\left(\frac{s}{s_0}\right)$ (BH-type)

$C=3.67$ mb $D=0.132$ mb $S_o=4m_p^2$



Conclusion

No real conclusion but a personal point of view.

It might well be that the TOTEM data of ρ at 13 TeV indicates the presence of the Odderon.

However strong statements of discovery are a bit premature.

A slowing down of the rise of the cross section can not be excluded as an alternate explanation.