Extracting the Odderon from pp and $p\bar{p}$ scattering data

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- Fitting the model to data
- Results: the Pomeron and the Odderon
- Conclusions

Introduction

The basic idea: The pp and p$\bar{\text{p}}$ elastic scattering amplitude can be well described as a function of "even" and "odd" parts with Pomeron (P), Odderon (O) and secondary Reggeons (f, ω):

$$A\left(s,t\right)_{pp}^{\bar{p}p} = A_P\left(s,t\right) + A_f\left(s,t\right) \pm \left[A_\omega\left(s,t\right) + A_O\left(s,t\right)\right]$$

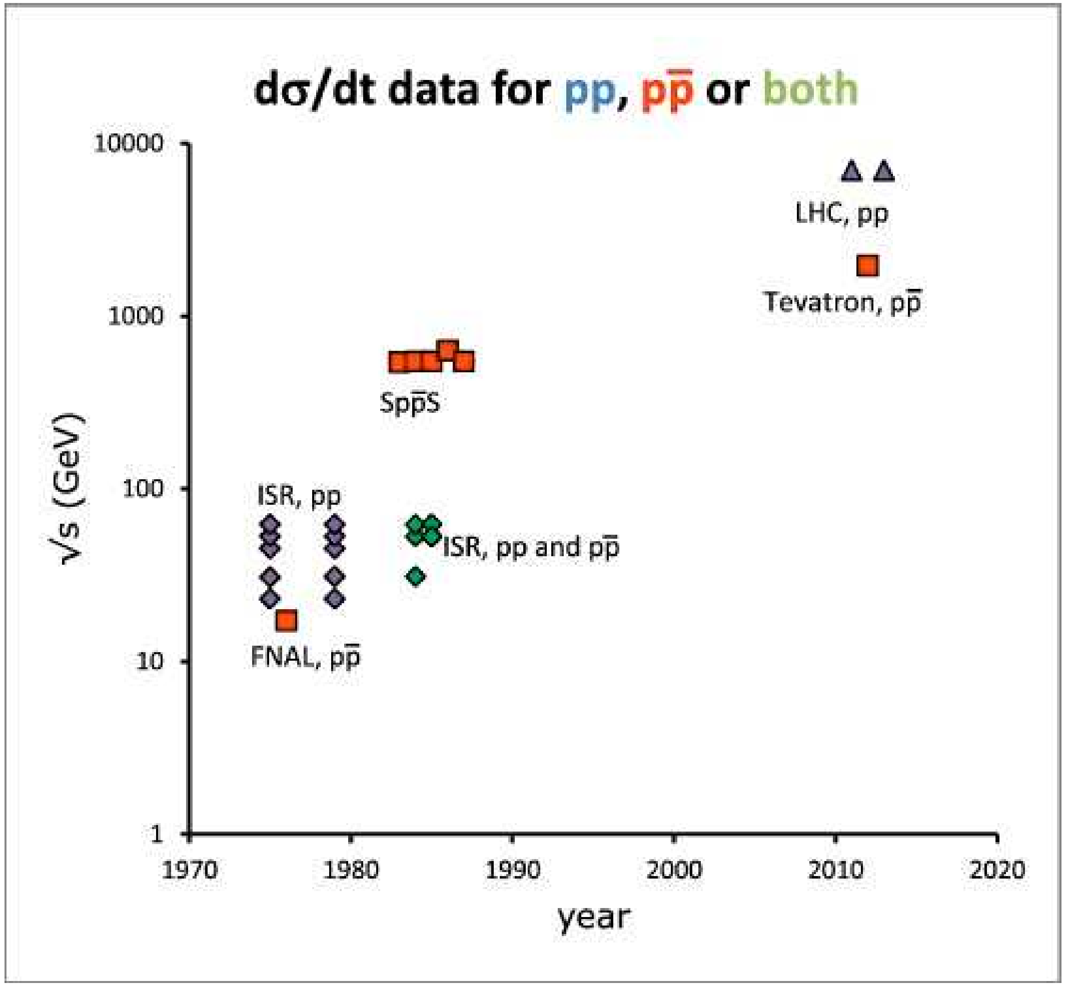
$$\mathcal{A}_{pp}^{\bar{p}p} = \mathcal{A}_{even} \pm \mathcal{A}_{odd}$$

At higher energies (LHC) secondary Reggeons are negligible:

$$\mathcal{A}^{\bar{p}p} - \mathcal{A}^{pp} = \mathcal{A}_{Odd}$$

Introduction

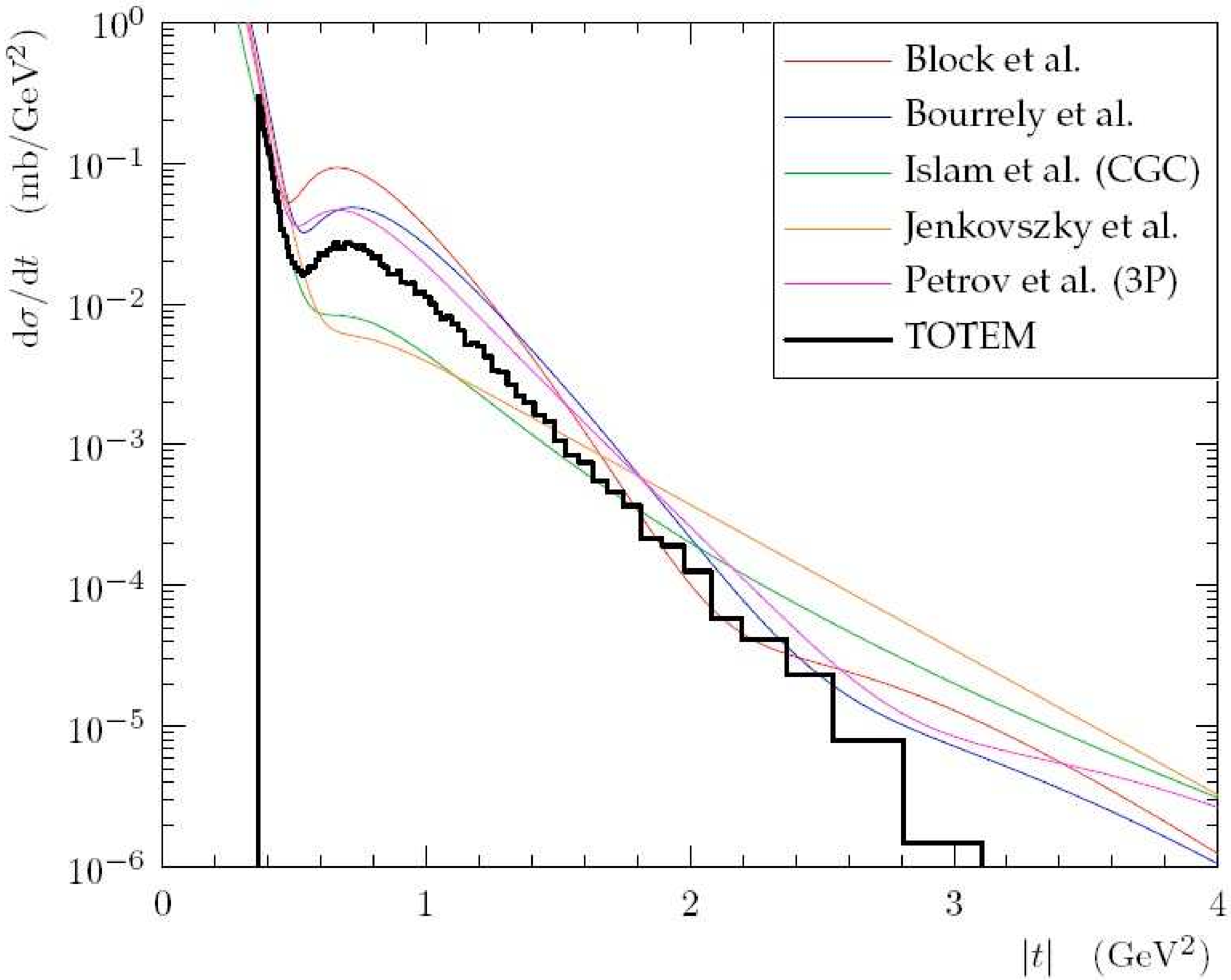
Problem: available elastic $p\bar{p}$ and pp data do not macth in energy



Possible solution: interpolation of scattering amplitudes in energy

Introduction

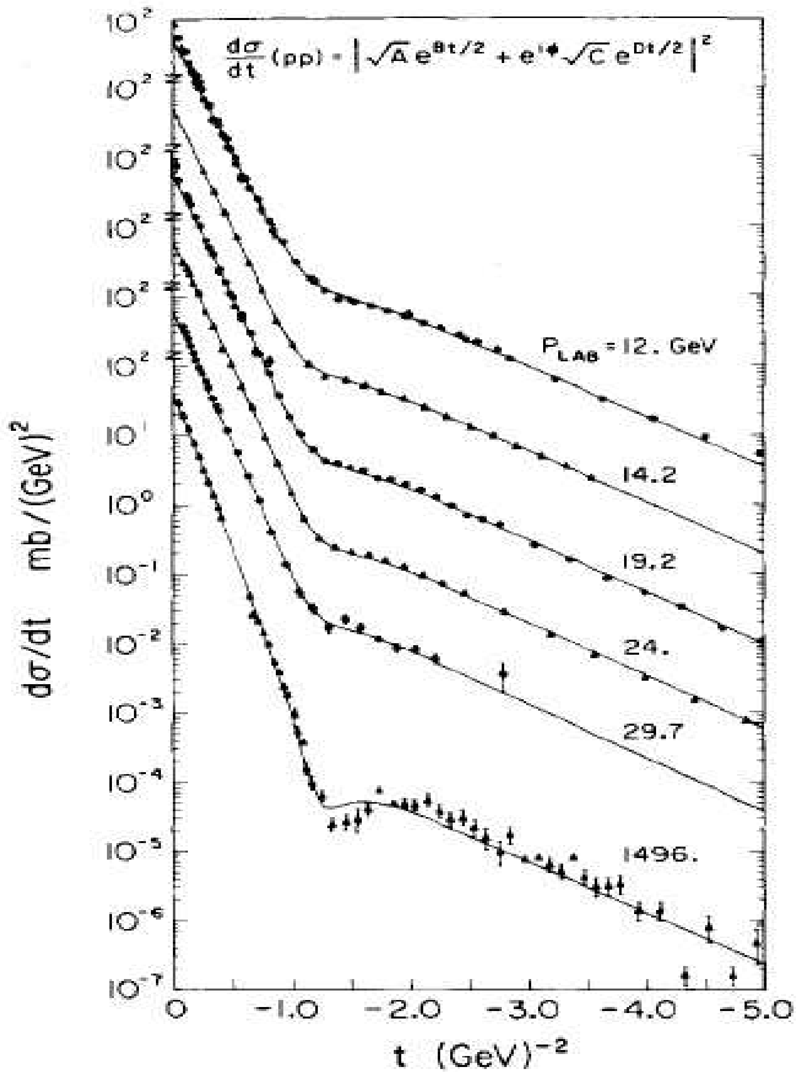
A model describing the elastic pp and p$\bar{\text{p}}$ scattering data is needed:



(Plot from a TOTEM presentations)

Introduction

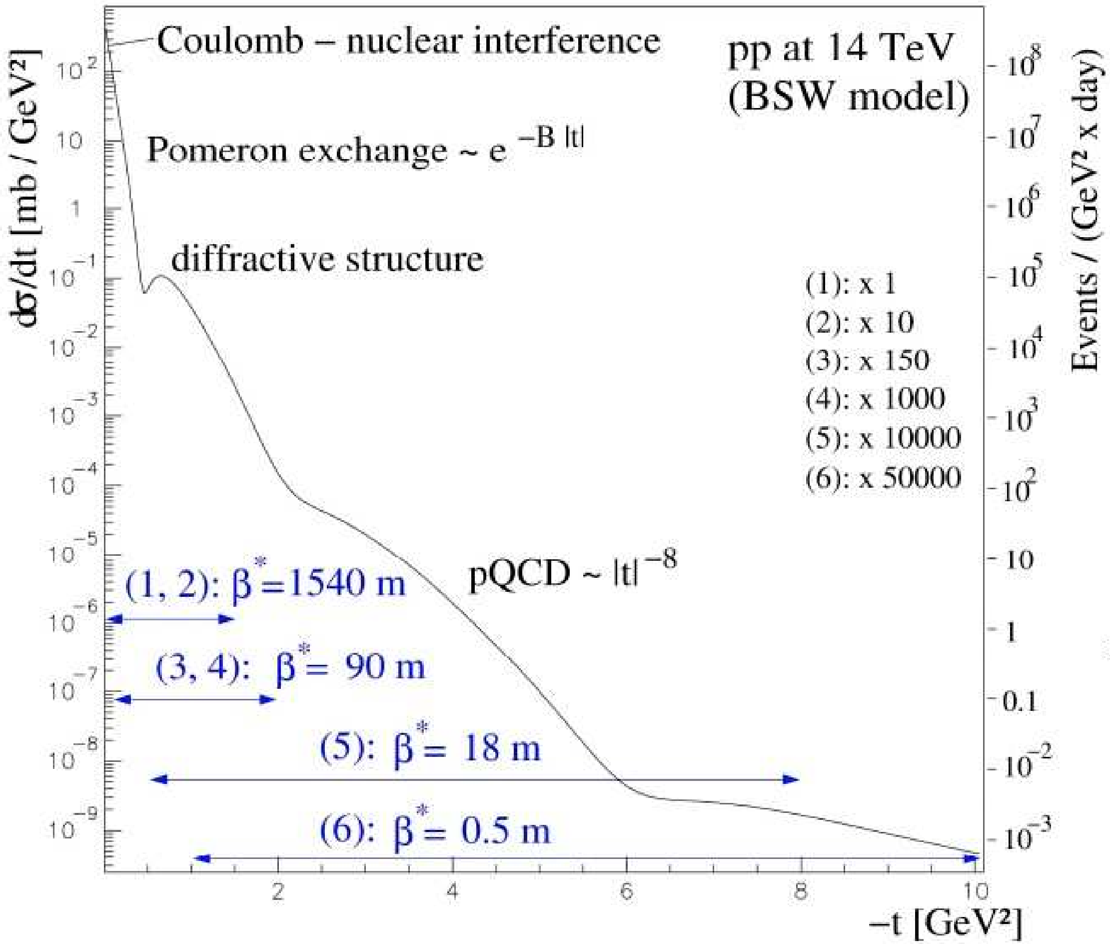
A simple and quasi-succesful parametrization is an empirical one of Phillips and Barger for elastic pp scattering with two exponentials:



R. J. N. Phillips and V. D. Barger, Phys. Lett. 46B, 412 (1973)

Introduction

The applicable range in t for the PB ansatz is limited:



Possible solution for low -t : improving parametrization

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Fagundes et al., Phys. Rev. D 88, 094019 (2013)

(A TOTEM plot of Risto Orava)

The generalized PB Model

Keep the original PB ansatz introducing *s* dependance of the model parameters in the elastic scattering amplitude:

$$\mathcal{A}(s,t) = i[\sqrt{A}\exp(Bt/2) + \exp(i\phi(s))\sqrt{C}\exp(Dt/2)]$$

The observales:

$$\frac{d\sigma}{dt} = \pi|\mathcal{A}(t)|^2 = \pi[Ae^{Bt} + Ce^{Dt} + 2\sqrt{A}\sqrt{C}e^{(B+D)t/2}\cos\phi]$$

$$\sigma_{tot} = 4\pi\Im A(t=0) = 4\pi[\sqrt{A} + \sqrt{C}\cos\phi]$$

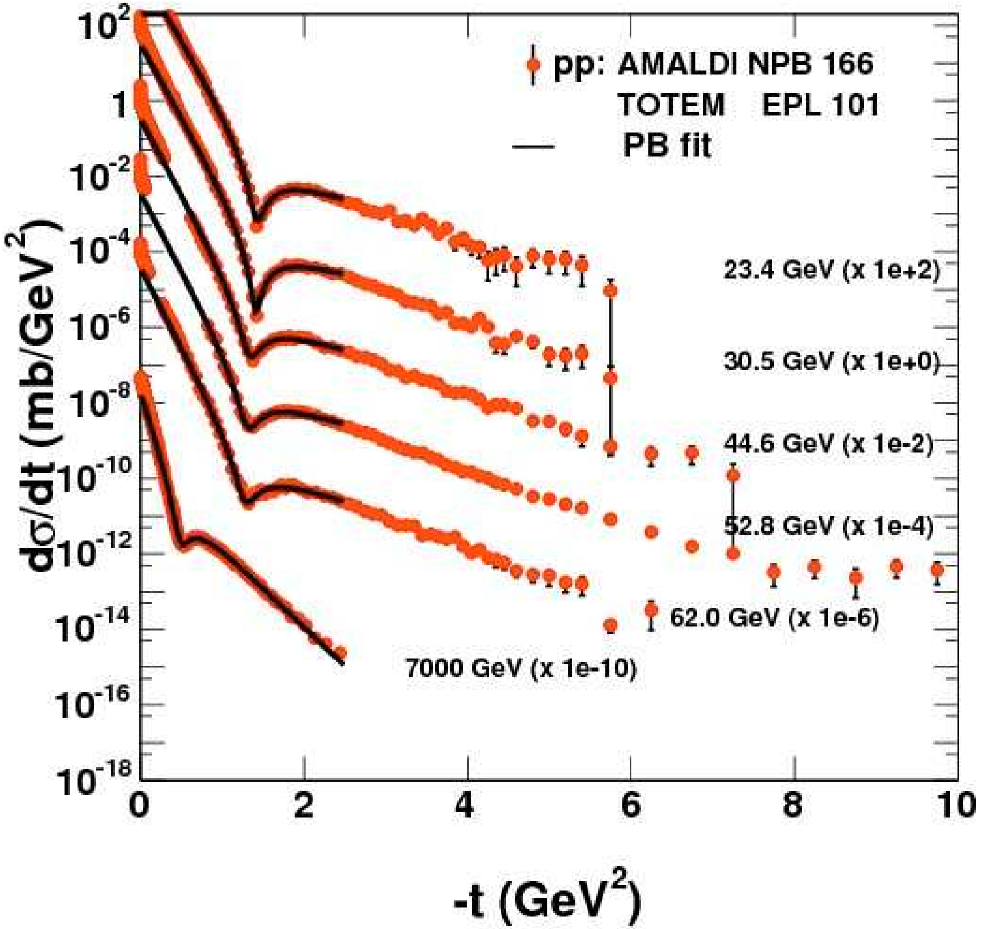
Fitting the model to data

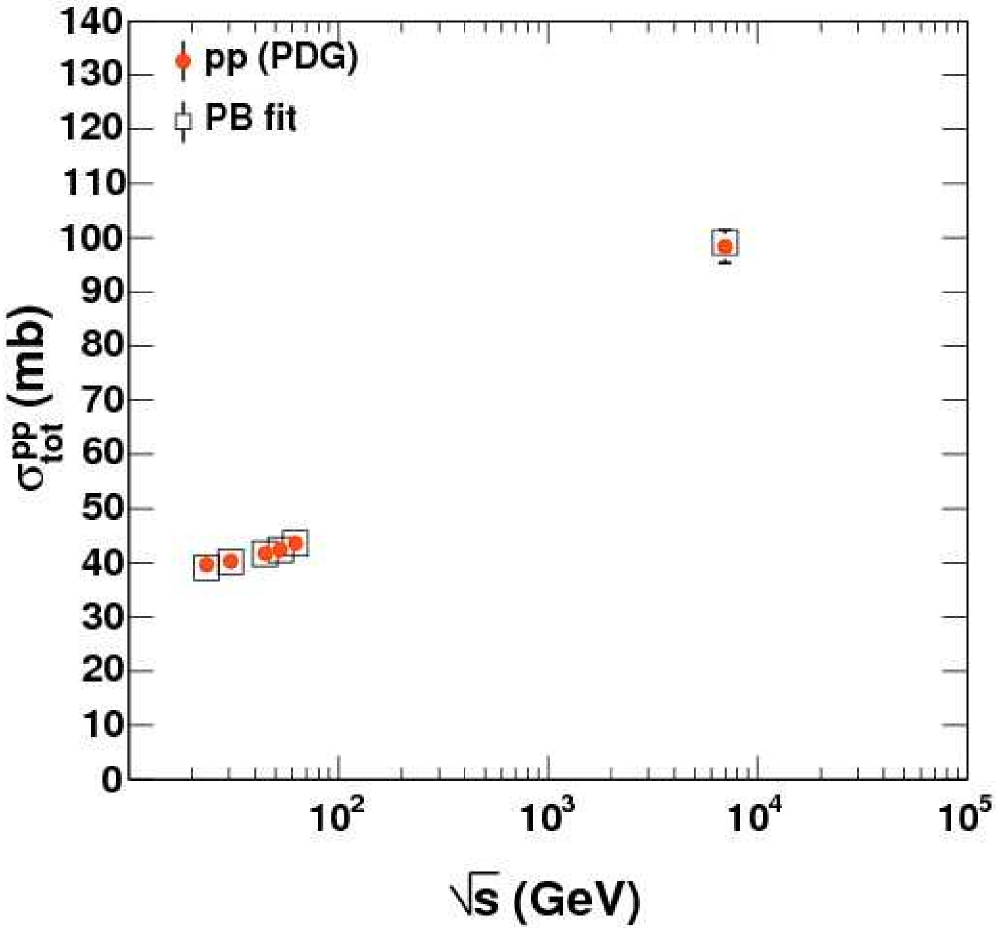
Imposed quality fit criterias:

- Simultaneous fits to elastic and σ_{tot} data for each energy
- Only fits with good χ^2 are accepted
- Setting the fitted -t range from 0.35 GeV^2 to 2.5 GeV^2
- Recontructing σ_{tot} in the whole available energy range

Fitting the model to data

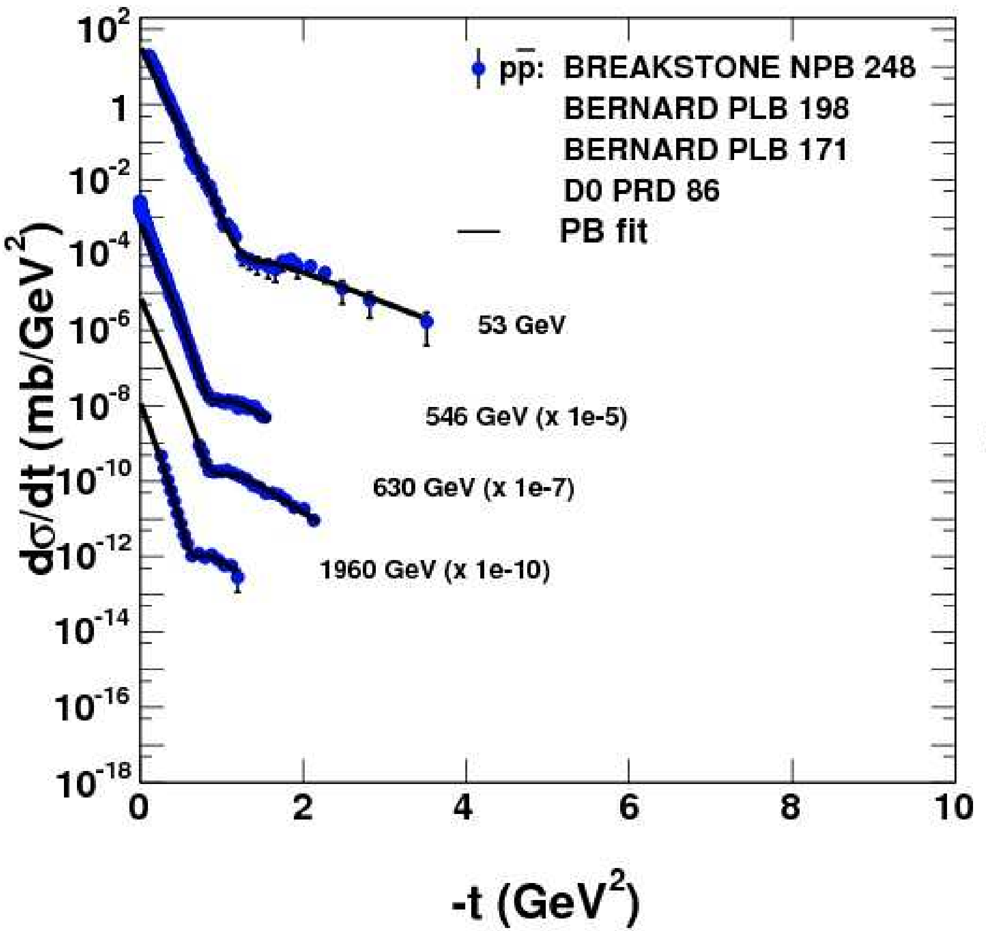
Simultaneous fits to elastic and σ_{tot} pp data for each energy:

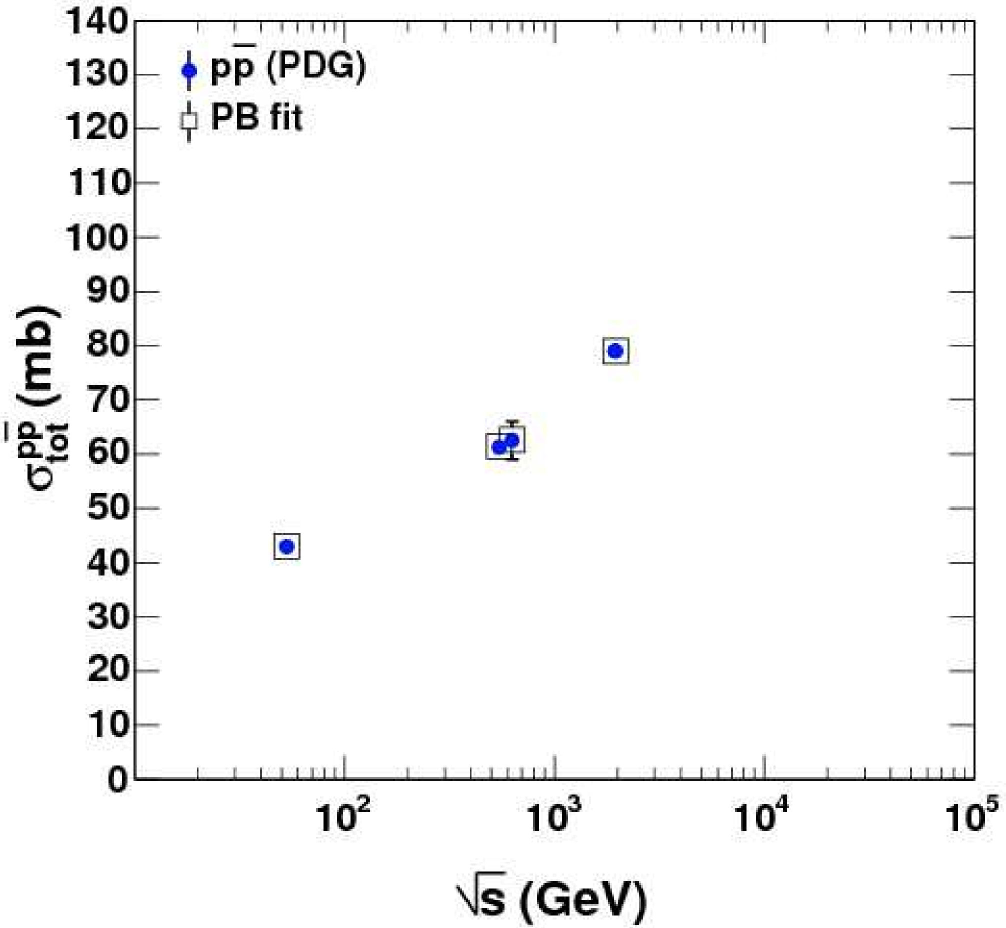




Fitting the model to data

Simultaneous fits to elastic and σ_{tot} $p\bar{p}$ data for each energy:





Fitting the model to data

Energy (GeV)	$\sqrt{A}$	B	$\sqrt{C}$	D	$cos(\phi)$	χ^2/NDF
23.4	3.13± 0.6%	8.66± 0.4%	0.019± 8.3%	1.54± 5.1%	-0.97± 0.3%	1.6
30.5	3.21± 0.2%	8.95± 0.3%	0.014± 7.4%	1.28± 5.6%	-0.98± 0.2%	1.1
44.6	3.33± 0.7%	9.32± 0.5%	0.017± 8.0%	1.45± 5.3%	-0.93± 0.8%	1.7
52.8	3.38± 0.3%	9.44± 0.6%	0.017± 7.6%	1.43± 5.0%	-0.92± 0.9%	1.1
62.0	3.49± 0.5%	9.66± 0.6%	0.018± 9.9%	1.53± 6.3%	-0.92± 1.6%	1.5
7000.0	8.51± 1.6%	15.05± 0.8%	0.670± 2.3%	4.71± 0.8%	-0.93± 0.3%	1.4

Energy (GeV)	$\sqrt{A}$	B	$\sqrt{C}$	D	$cos(\phi)$	χ^2/NDF
63	3.43± 1.1%	10.07± 1.3%	0.022±30.8%	1.90±14.8%	-0.60±22.7%	0.7
546	5.06± 1.2%	11.25± 1.3%	0.204±21.0%	3.55± 8.6%	-0.86± 2.7%	0.6
630	5.13± 3.9%	11.26± 3.7%	0.176±26.6%	3.23± 9.6%	-0.81± 7.9%	0.5
1960	6.85± 3.7%	12.46± 3.3%	0.629±41.6%	4.69±15.4%	-0.90± 3.6%	0.4

Model parameter fit results

Fitting the model to data

Specifying (Regge type) *s* dependent model parameters:

$$\sqrt{A} \to \sqrt{A(s)} = a_1 s^{-\epsilon_{a1}} + a_2 s^{\epsilon_{a2}}, \quad \sqrt{C} \to \sqrt{C(s)} = c s^{\epsilon_c}$$

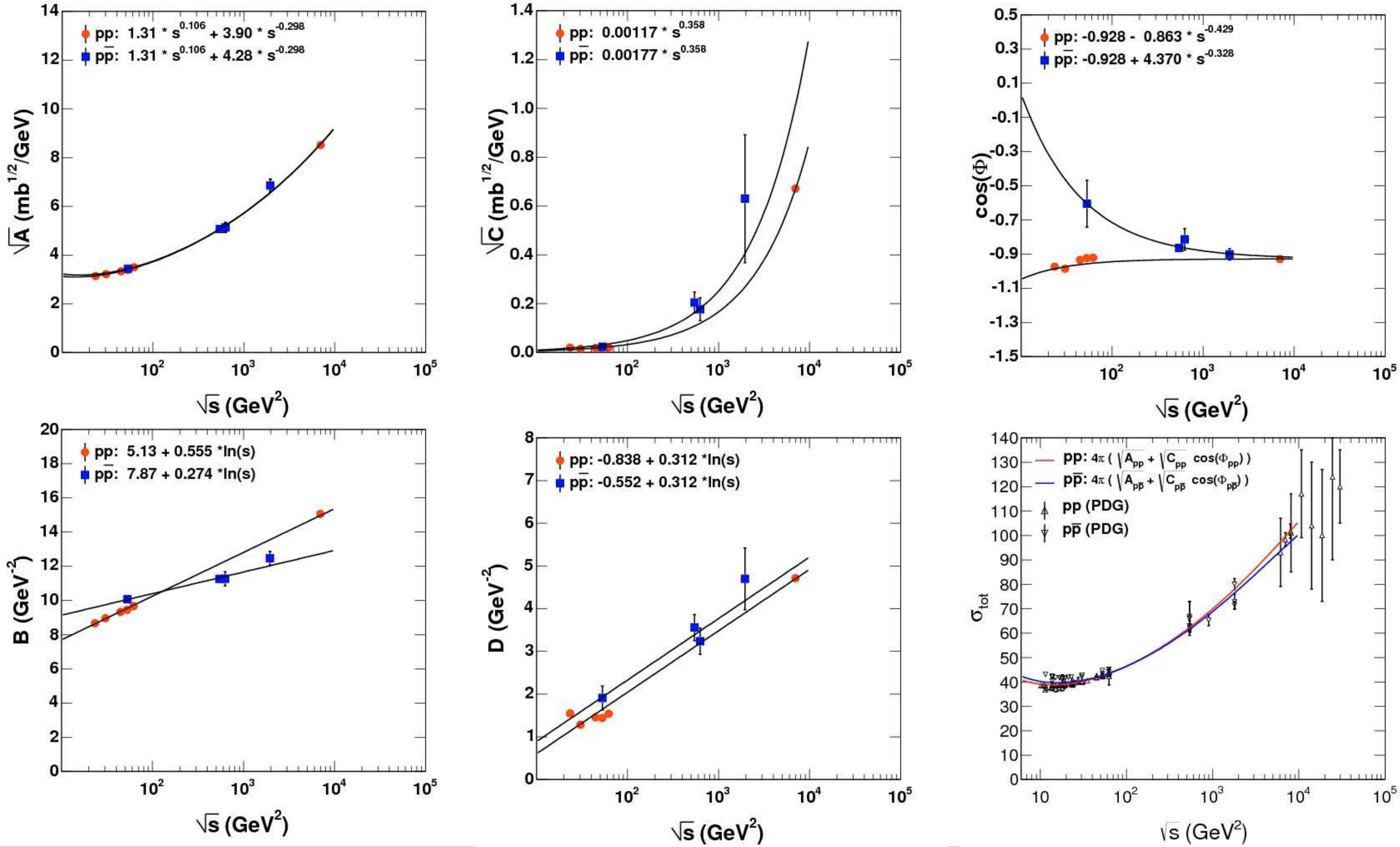
$$B \to B(s) = b_0 + b_1 \ln(s/s_0), \qquad D \to D(s) = d_0 + d_1 \ln(s/s_0)$$

$$cos(\phi(s)) = k_0 + k_1 s^{-\epsilon_{cos}}$$

The *s* dependent differential cross section:

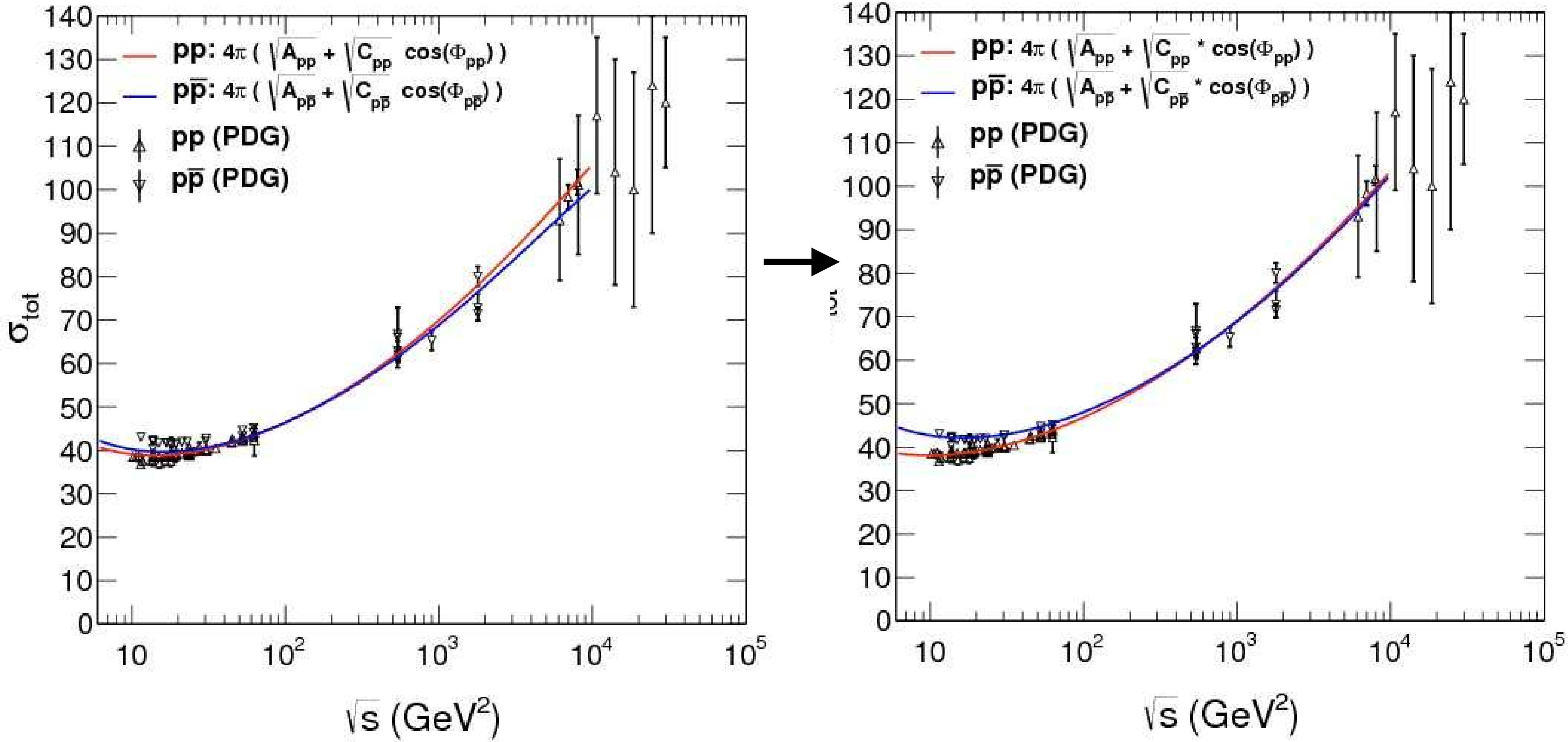
$$\frac{d\sigma}{dt} = \pi |\mathcal{A}(t)|^2 = \pi [A e^{Bt} + C e^{Dt} + 2\sqrt{A}\sqrt{C} e^{(B+D)t/2} \cos\phi]$$

Fitting the model to data

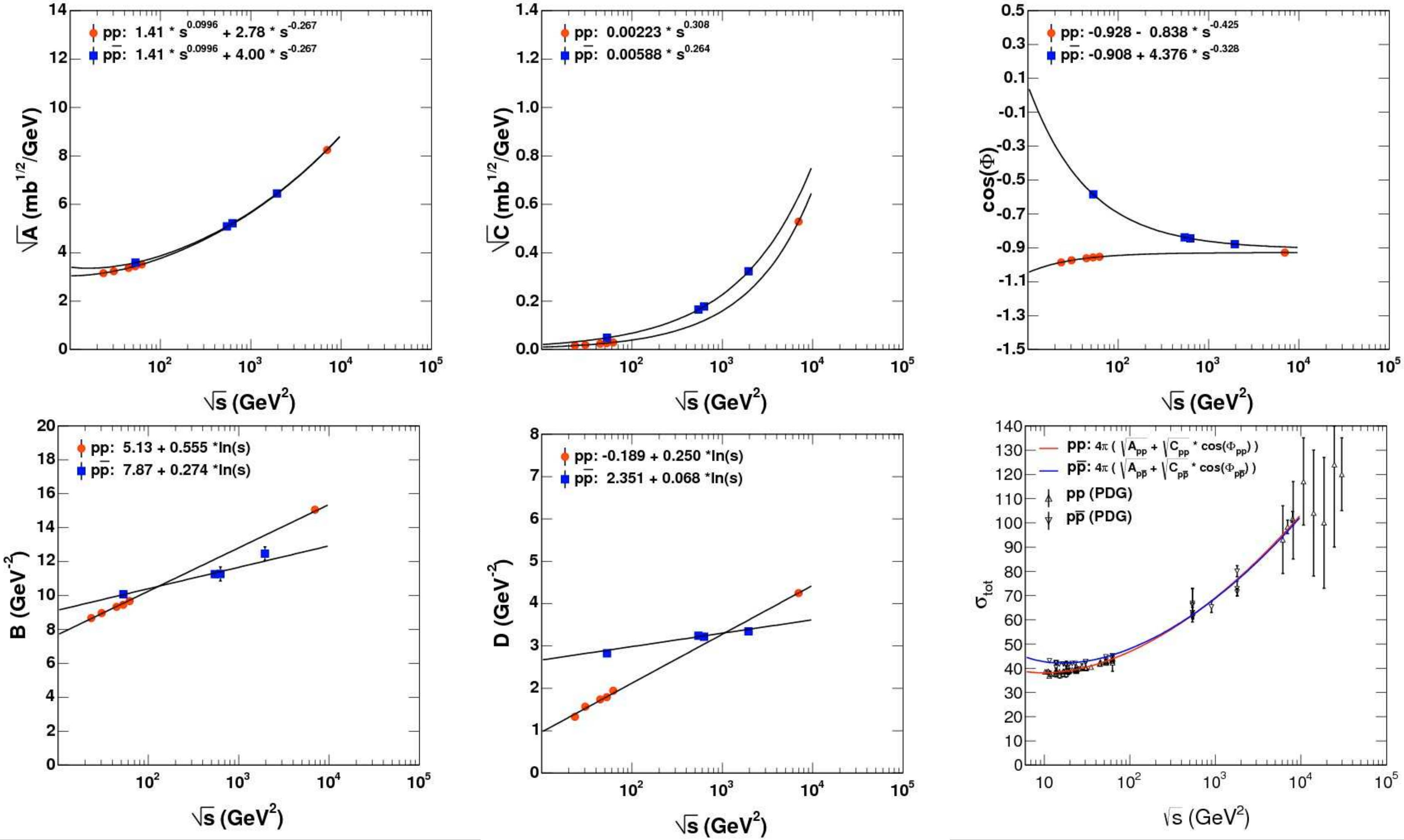


Fitting the model to data

Second step: tuning model parameters to fit σ_{tot} data for the whole energy range with data:



Fitting the model to data



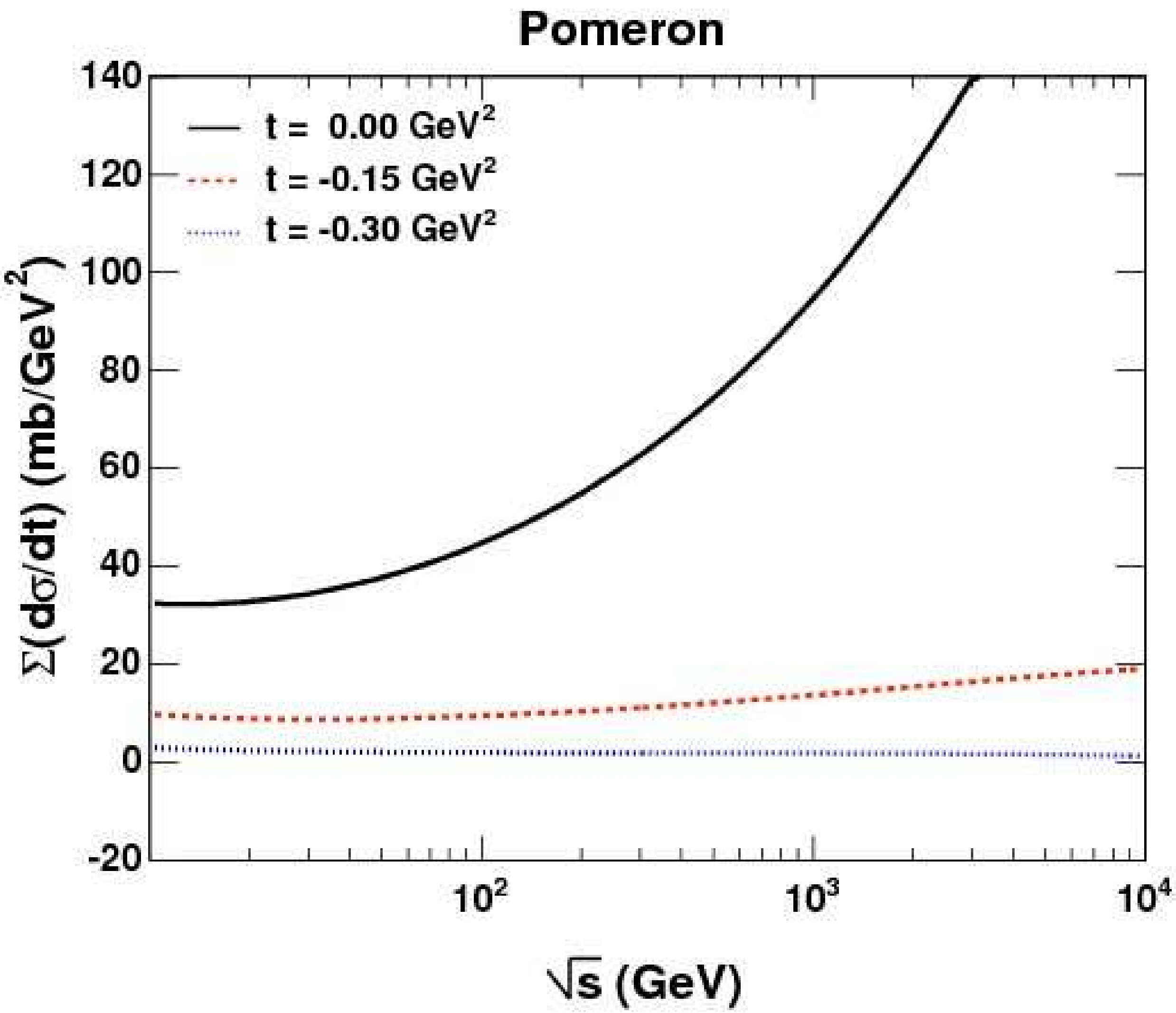
Fitting the model to data

The final extracted *s* dependent model parameters:

$$\sqrt{A_{pp}(s)} = 1.41 s^{0.0966} + 2.78 s^{-0.267},$$
$$\sqrt{C_{pp}(s)} = 0.00223 s^{0.308},$$
$$B_{pp}(s) = 4.86 + 0.586 \ln s,$$
$$D_{pp}(s) = -0.189 + 0.250 \ln s.$$
$$cos(\phi_{pp}(s)) = -0.928 - 0.838 s^{-0.425}.$$

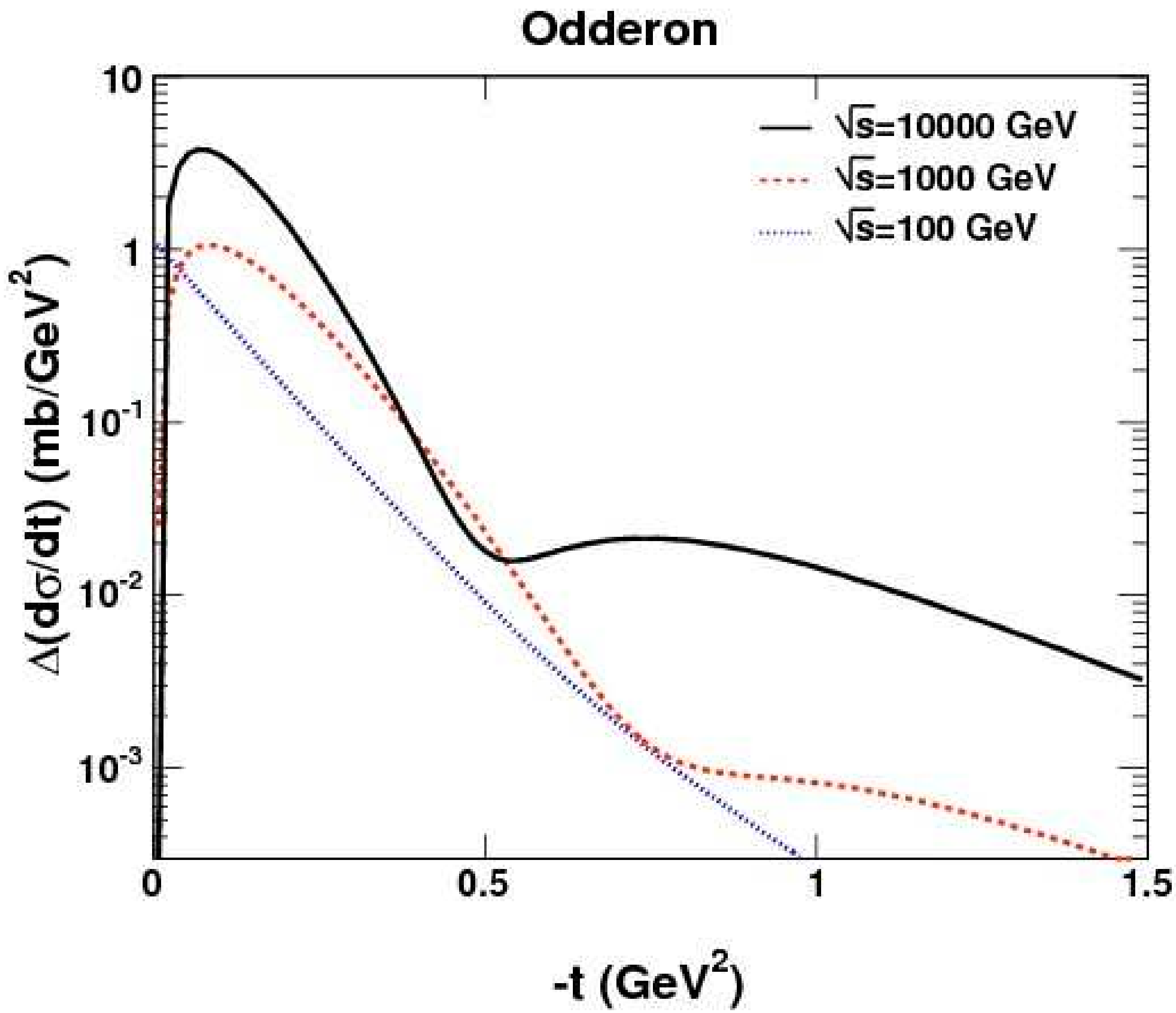
$$\sqrt{A_{p\bar{p}}(s)} = 1.41 s^{0.0996} + 4.00 s^{-0.267},$$
$$\sqrt{C_{p\bar{p}}(s)} = 0.00588 s^{0.264},$$
$$B_{p\bar{p}}(s) = 6.55 + 0.398 \ln s,$$
$$D_{p\bar{p}}(s) = 2.351 + 0.068 \ln s,$$
$$cos(\phi_{p\bar{p}}(s)) = -0.908 + 4.376 s^{-0.328}.$$

Results: the Pomeron and the Odderon



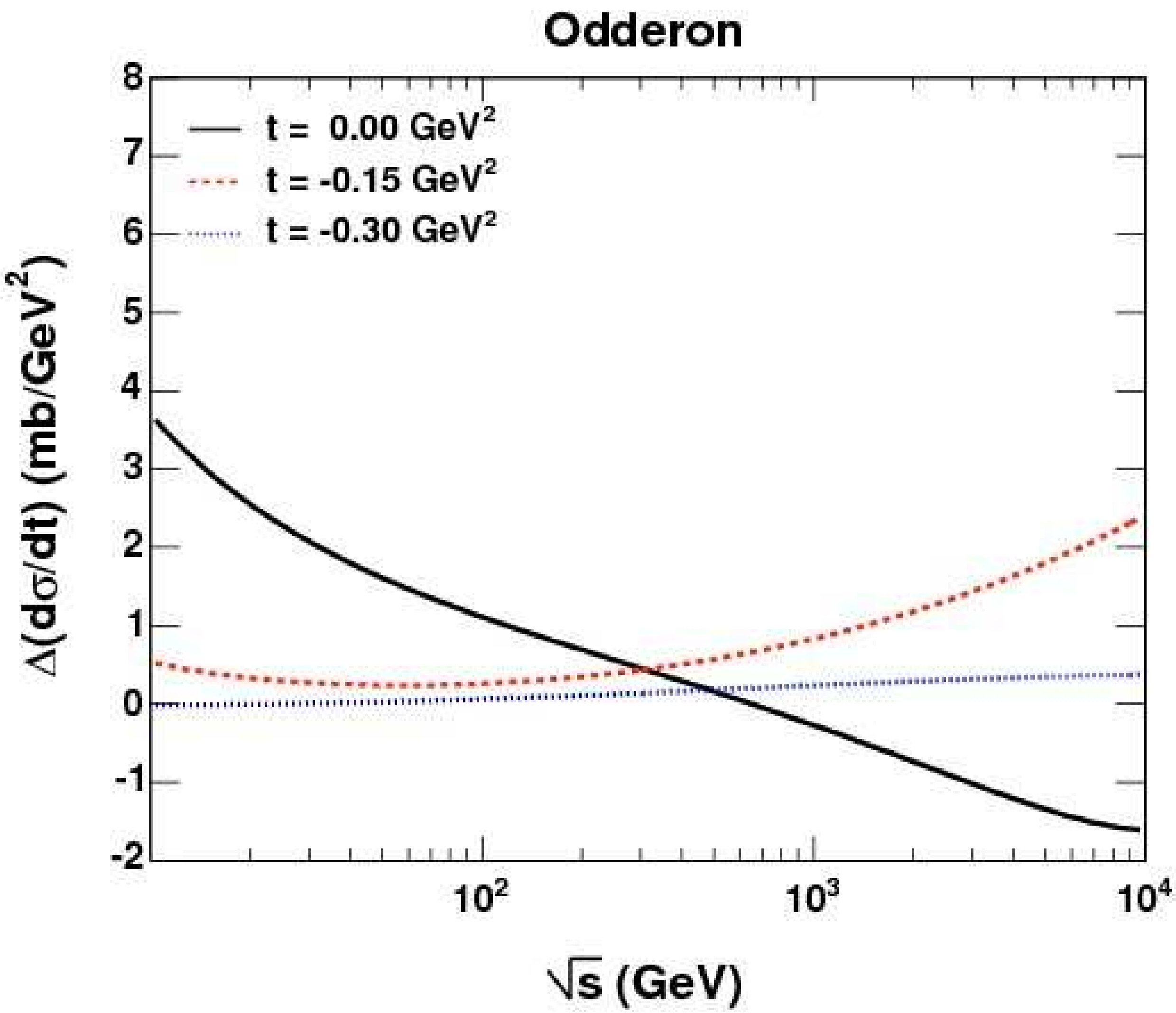
$$|\mathcal{A}|^2_{\bar{p}p} + |\mathcal{A}|^2_{pp} = \Sigma_{Pom}$$

Results: the Pomeron and the Odderon



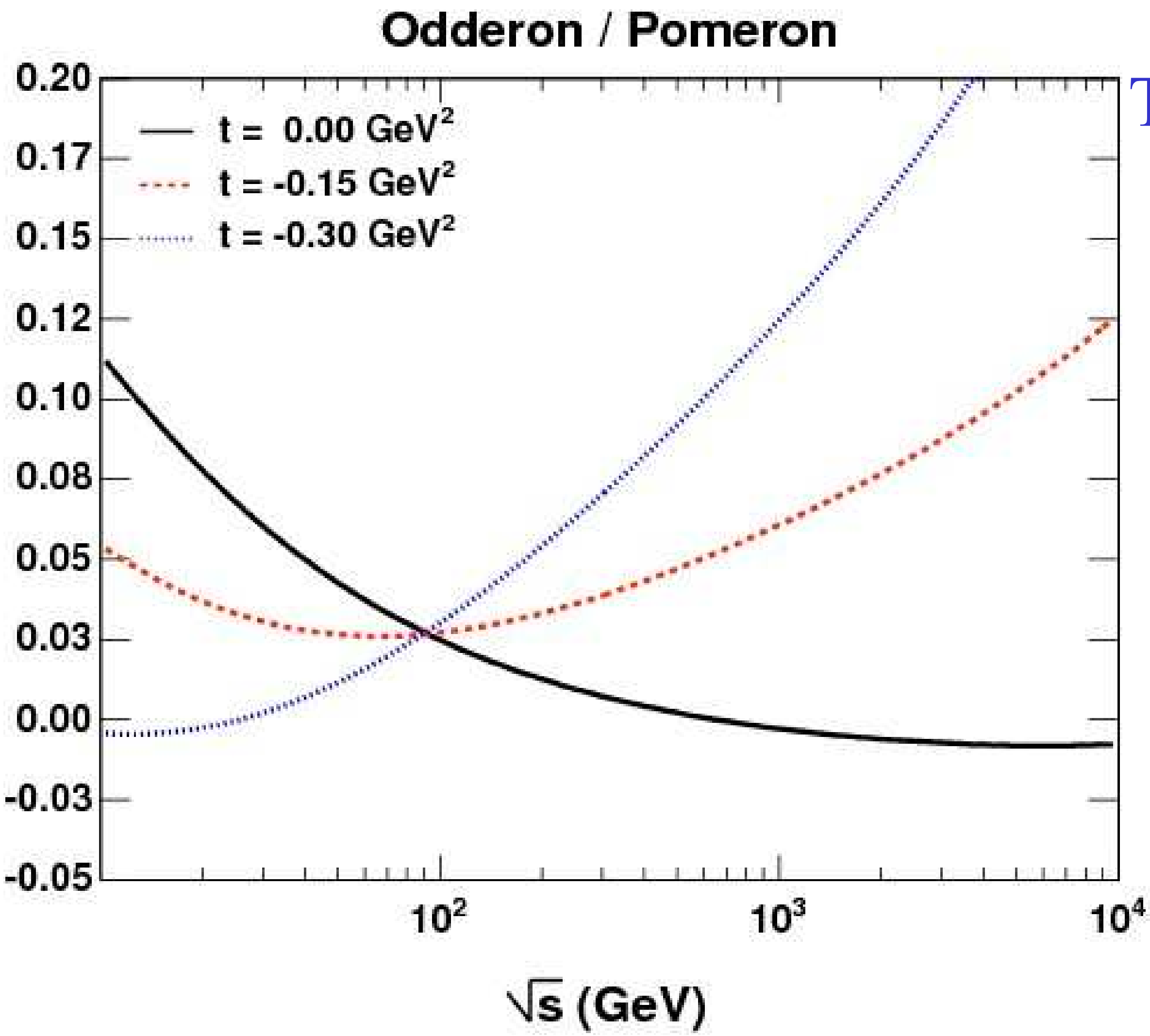
$$|\mathcal{A}|^2_{\bar{p}p} - |\mathcal{A}|^2_{pp} = \Delta_{Odd}$$

Results: the Pomeron and the Odderon



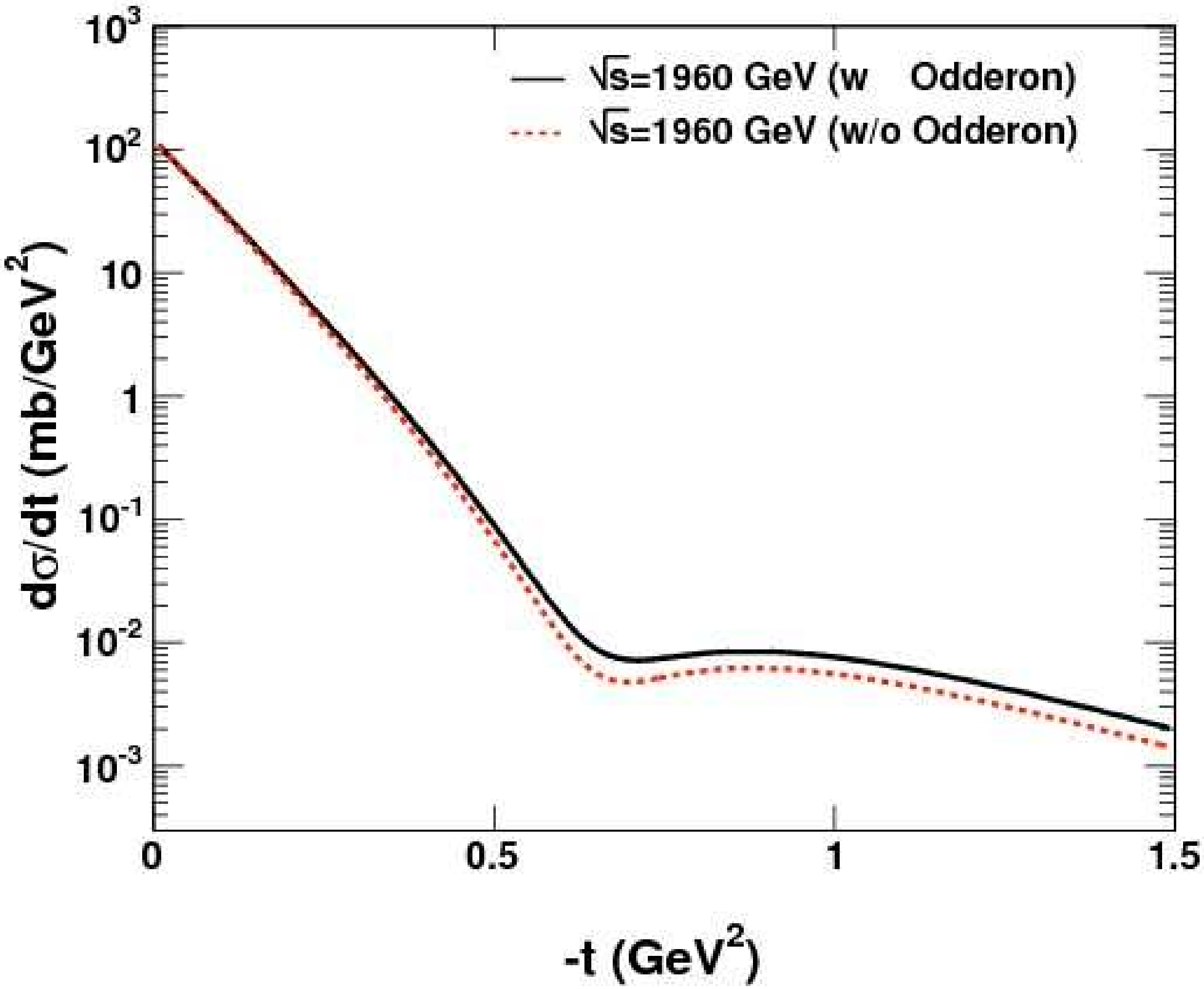
$$|\mathcal{A}|^2_{\bar{p}p} - |\mathcal{A}|^2_{pp} = \Delta_{Odd}$$

Results: the Pomeron and the Odderon



The Odderon/Pomeron ratio

Results: the Pomeron and the Odderon



Reflections on earlier remarks:

Differential cross sections with and without Odderon are plotted (left side)

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The dip-bump region is not coupled to Odderon exclusively

Outlook

Next steps:

- Include low and high |*t*| data in the fits (its a collaboration with Fagundes et al.) by improving the model.

- The phase (ϕ) parameter is expected to be *t* dependant.

- Estimate better the contributions of secondary Reggeons.

- .....

Conclusions

pp and pp elasctic and σ_{tot} data were successfully fitted by a model based on the empirical Phillips-Barger expression.

The (*s*, *t*) functional form of the Pomerons and the Odderons were extracted.

The Odderons and Pomerons were plotted and compared in function of the collision and transferred energies.