Model independent femtoscopic Levy imaging of elastic p+p collisions

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(Work in Progress)

Content

- Motivations and introductions
- Levy function fit parameter definitions
- Levy function fit partial terms
- Levy function fits to elastic pp data
- Levy function fit parameter excitation functions
- Conclusion

Motivations

Motivation examples for studying elastic pp scattering data.

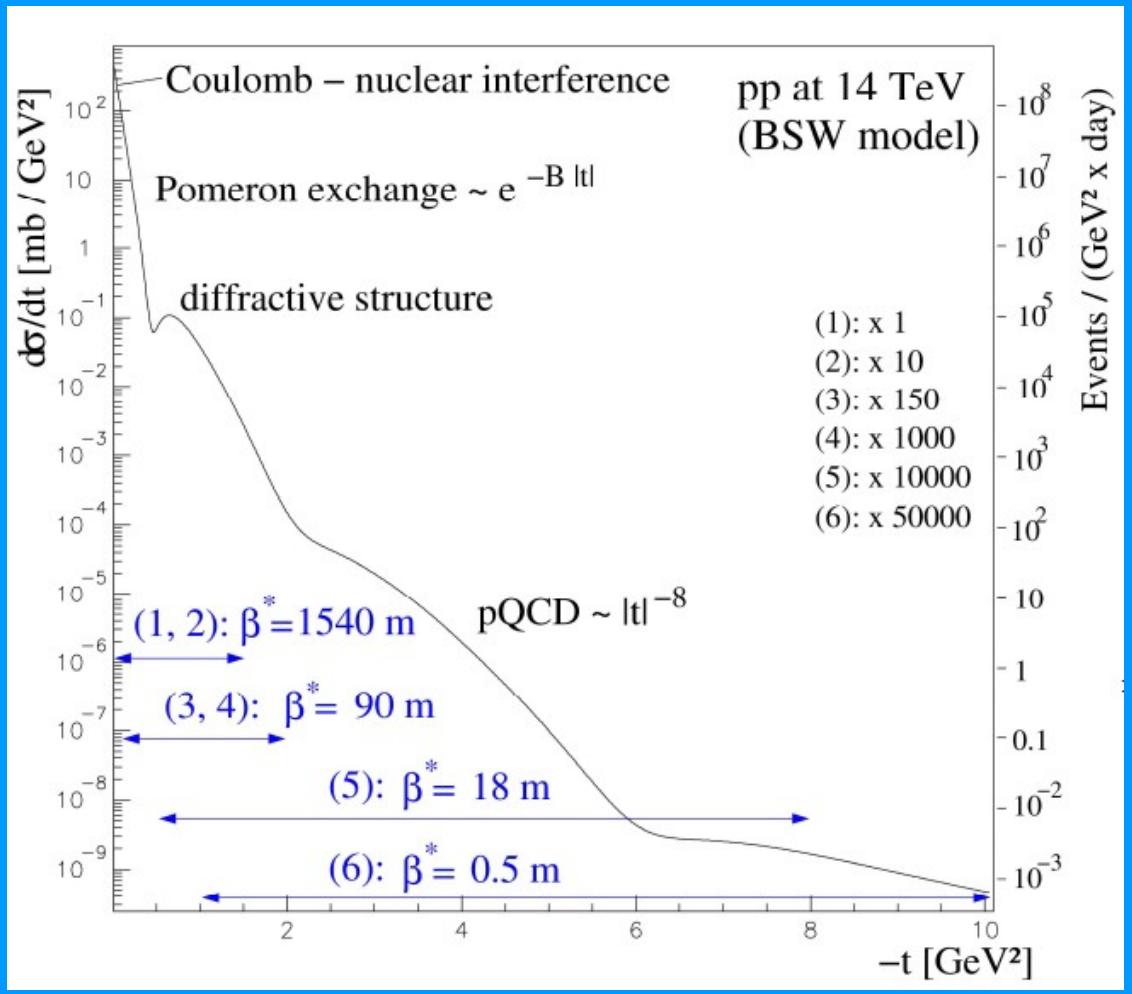
a) Studying interaction phenomena

b) Calculation of σ_{tot} using $d\sigma/dt$ (t=0)

c) Extraction of Odderon

Introductions

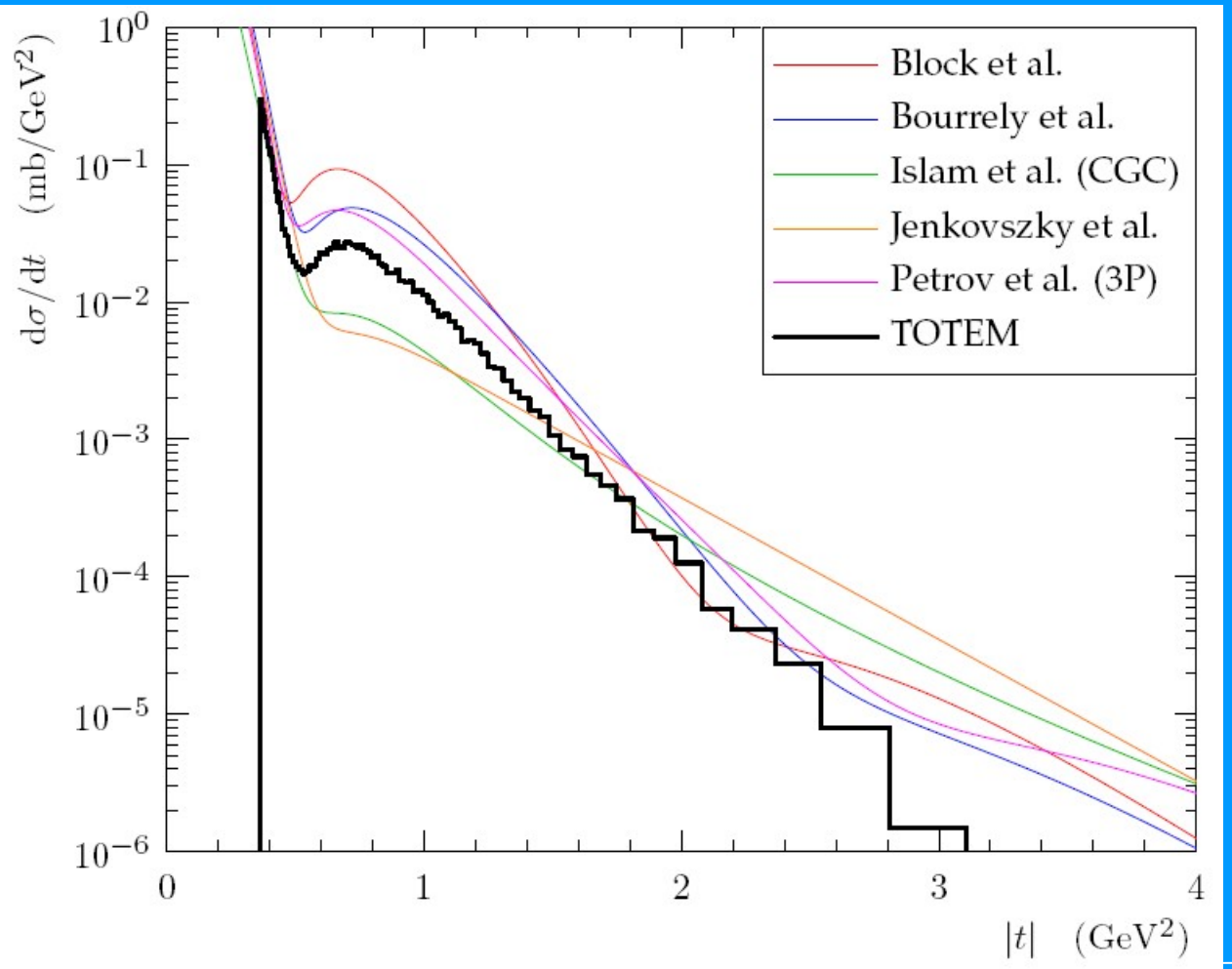
Characterization of elastic pp scattering.



(A TOTEM plot)

Introductions

Various models try to describe elastic pp scattering data.



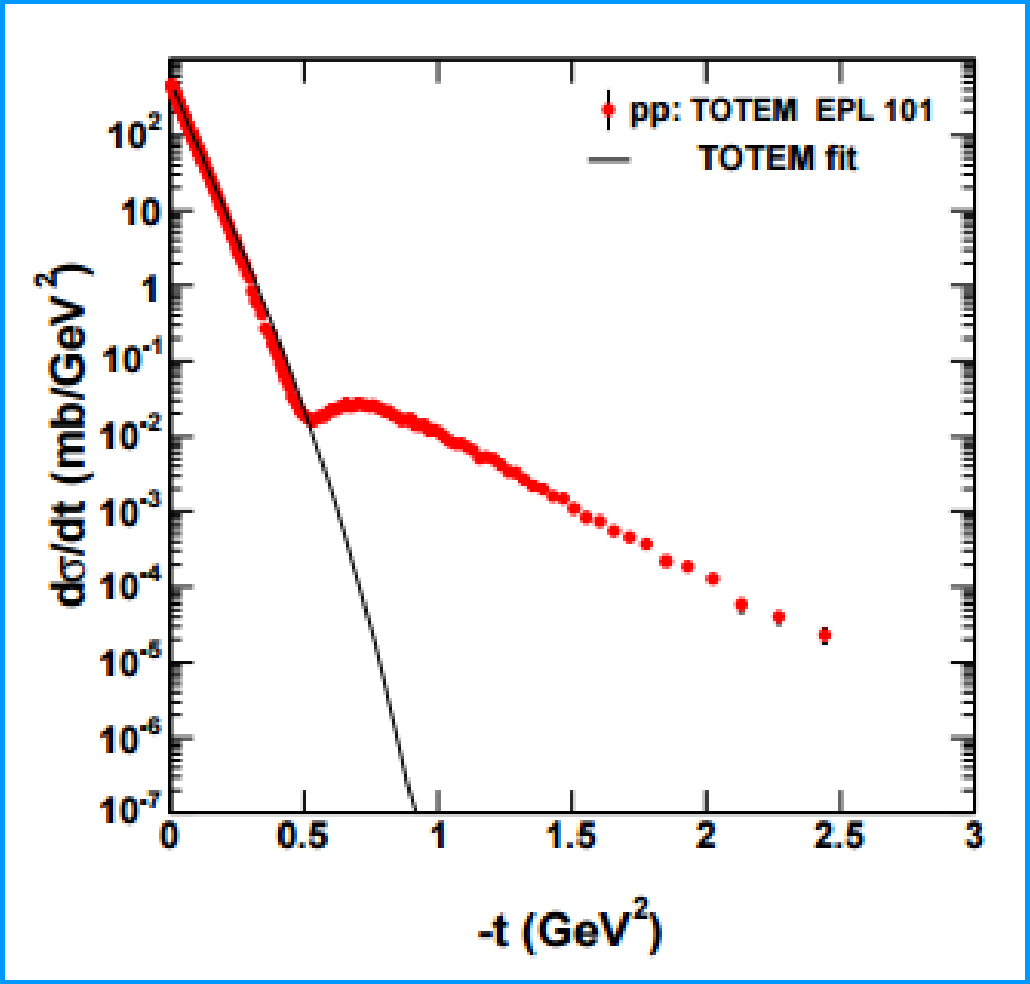
TOTEM preferred to use (256) models of COMPETE collaboration

`Lot of room for improvements`

(A plot from an older TOTEM presentations)

Introductions

Exponentials parametrized by TOTEM do not work for larger -t's.



Introductions

Total pp cross-sections can be obtained via the optical theorem in luminosity-independent way by extrapolating $d\sigma/dt$ to t=0.

$$\sigma_{\text{tot}} = \frac{16\pi}{1+\rho^2} \frac{(dN_{\text{el}}/dt)_{t=0}}{(N_{\text{el}} + N_{\text{inel}})}$$

TOTEM is a dedicated LHC experiment to determine total pp cross-sections with a few percent precision at high energies.

Observables from the scattering amplitudes

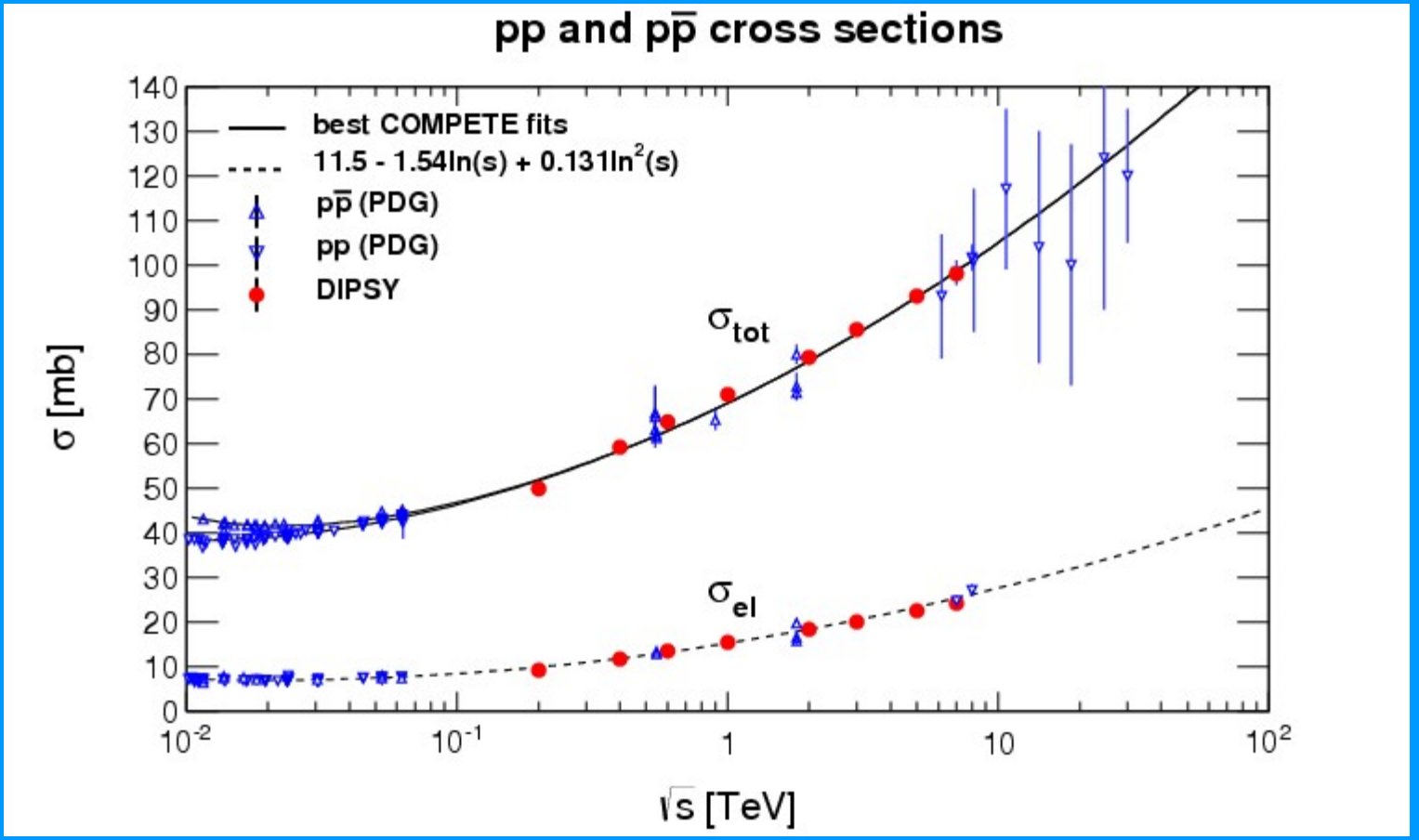
$$\frac{d\sigma}{dt} = \pi |\mathcal{A}(t)|^2$$

$$\sigma_{tot} = 4\pi \Im A(t=0)$$

$$\rho(t) \equiv \frac{\mathrm{Re}\, T_{el}(\Delta)}{\mathrm{Im}\, T_{el}(\Delta)} = - \left. \frac{\sum_{i=1}^{\infty} b_i l_i(z|\alpha)}{1 + \sum_{i=1}^{\infty} a_i l_i(z|\alpha)} \right|_{z=tR^2}$$

Introductions

Increasing pp and pp total cross-sections including 7 and 8 TeV TOTEM data with small errors and DIPSY simulation results.



G. Gustafson, L. Lönnblad, A. Ster, T. Csögő, J. High Energy Phys. 1510 (2015) 22

Definition of the Levy function and parameters

$$\frac{d\sigma}{dt} = A\, w(z|\alpha) \left| 1 + \sum_{j=1}^{\infty} c_j l_j(z|\alpha) \right|^2 ,$$

$$w(z|\alpha) = \exp(-z^\alpha) ,$$

$$z = |t| R^2 \geq 0 ,$$

$$c_j = a_j + i b_j ,$$

$$\mu_{n,\alpha} = \int_0^\infty dz\; z^n \exp(-z^\alpha) = \frac{1}{\alpha} \Gamma\left(\frac{n+1}{\alpha}\right)$$

$$l_j(z\,|\,\alpha) = D_j^{-\frac{1}{2}} D_{j+1}^{-\frac{1}{2}} L_j(z\,|\,\alpha),$$

$$D_0(\alpha) = 1,$$

$$D_1(\alpha) = \mu_{0,\alpha},$$

$$D_2(\alpha) = \det \begin{pmatrix} \mu_{0,\alpha} & \mu_{1,\alpha} \\ \mu_{1,\alpha} & \mu_{2,\alpha} \end{pmatrix},$$

$$D_3(\alpha) = \det \begin{pmatrix} \mu_{0,\alpha} & \mu_{1,\alpha} & \mu_{2,\alpha} \\ \mu_{1,\alpha} & \mu_{2,\alpha} & \mu_{3,\alpha} \\ \mu_{2,\alpha} & \mu_{3,\alpha} & \mu_{4,\alpha} \end{pmatrix},$$

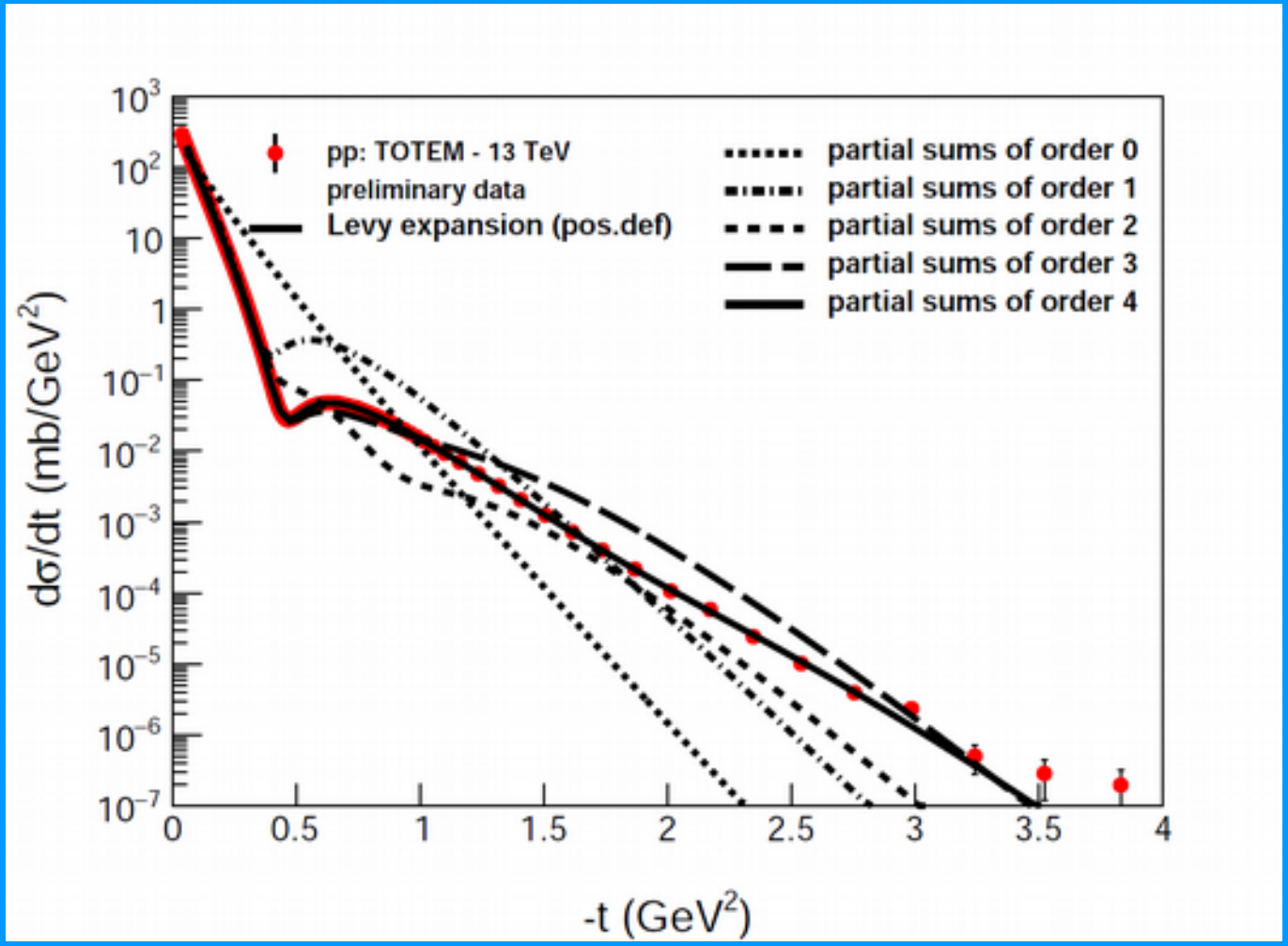
$$L_0(z\,|\,\alpha) = 1,$$

$$L_1(z\,|\,\alpha) = \det \begin{pmatrix} \mu_{0,\alpha} & \mu_{1,\alpha} \\ 1 & z \end{pmatrix},$$

$$L_2(z\,|\,\alpha) = \det \begin{pmatrix} \mu_{0,\alpha} & \mu_{1,\alpha} & \mu_{2,\alpha} \\ \mu_{1,\alpha} & \mu_{2,\alpha} & \mu_{3,\alpha} \\ 1 & z & z^2 \end{pmatrix},$$

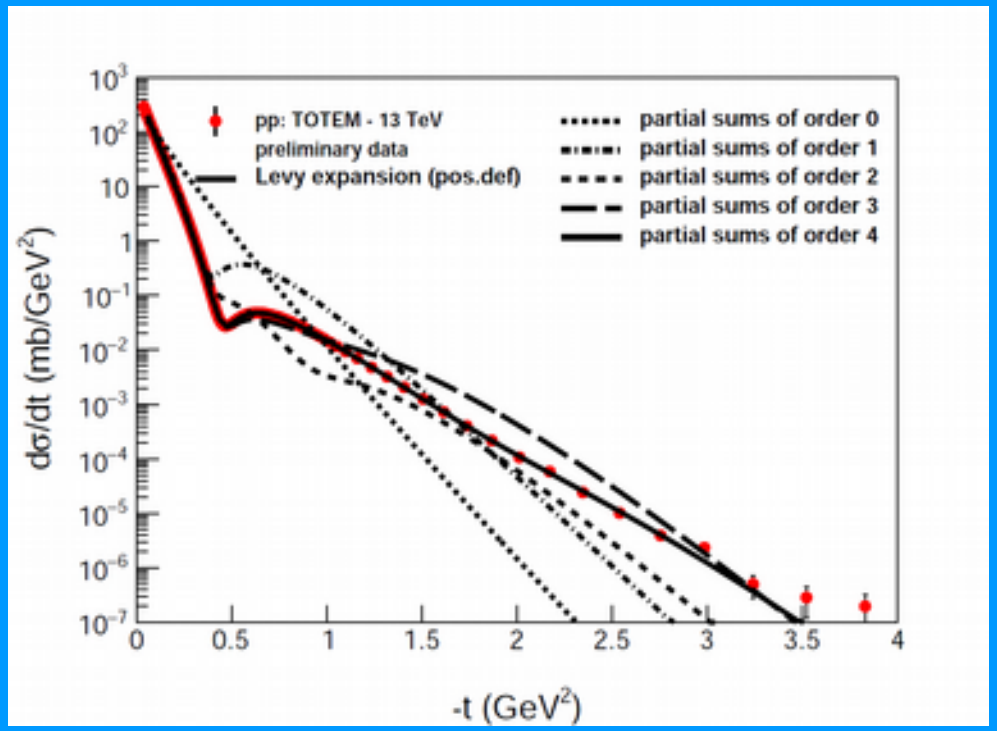
$$L_3(z\,|\,\alpha) = \det \begin{pmatrix} \mu_{0,\alpha} & \mu_{1,\alpha} & \mu_{2,\alpha} & \mu_{3,\alpha} \\ \mu_{1,\alpha} & \mu_{2,\alpha} & \mu_{3,\alpha} & \mu_{4,\alpha} \\ \mu_{2,\alpha} & \mu_{3,\alpha} & \mu_{4,\alpha} & \mu_{5,\alpha} \\ 1 & z & z^2 & z^3 \end{pmatrix},$$

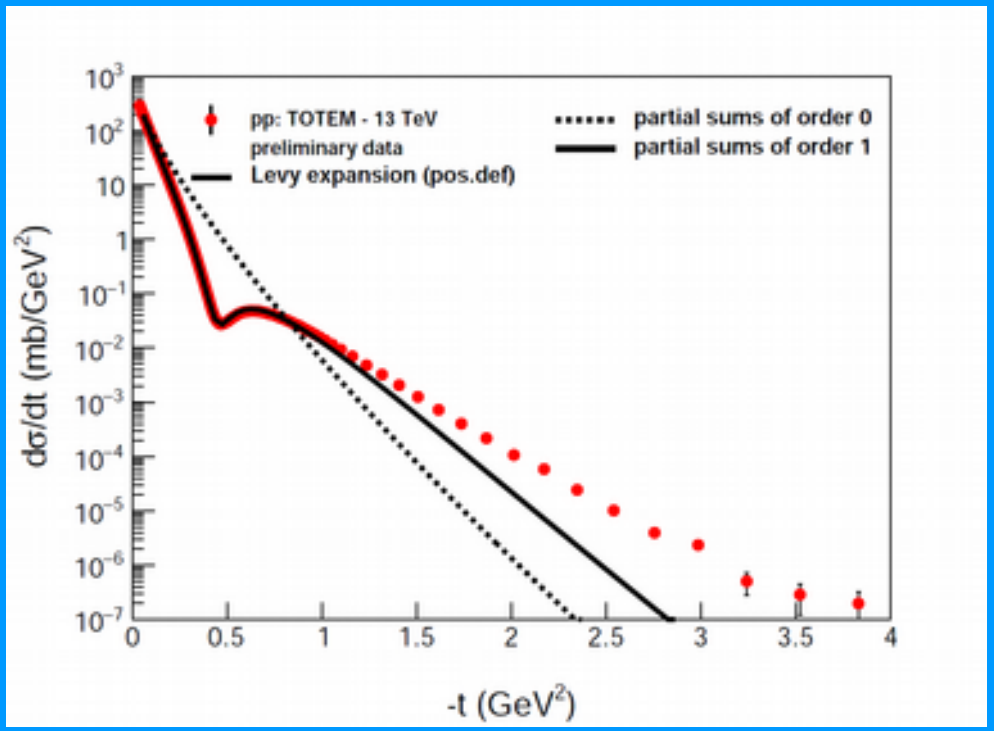
Levy function fit partial sums



Higher order Levy calculations pronounce at larger -t

Levy function fit partial sums

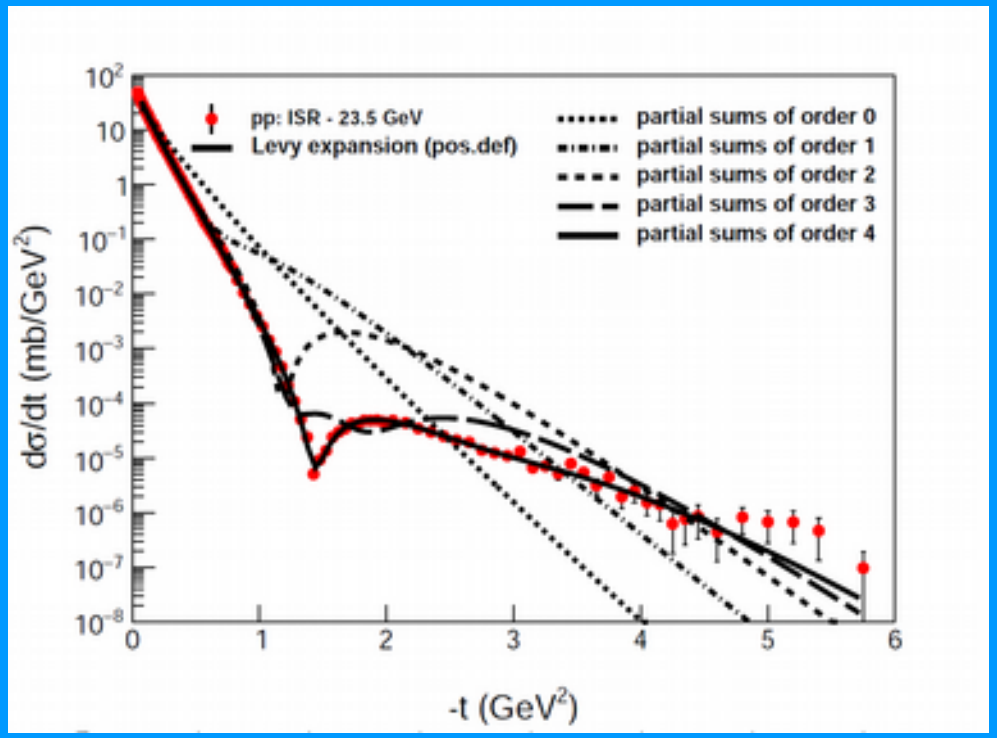


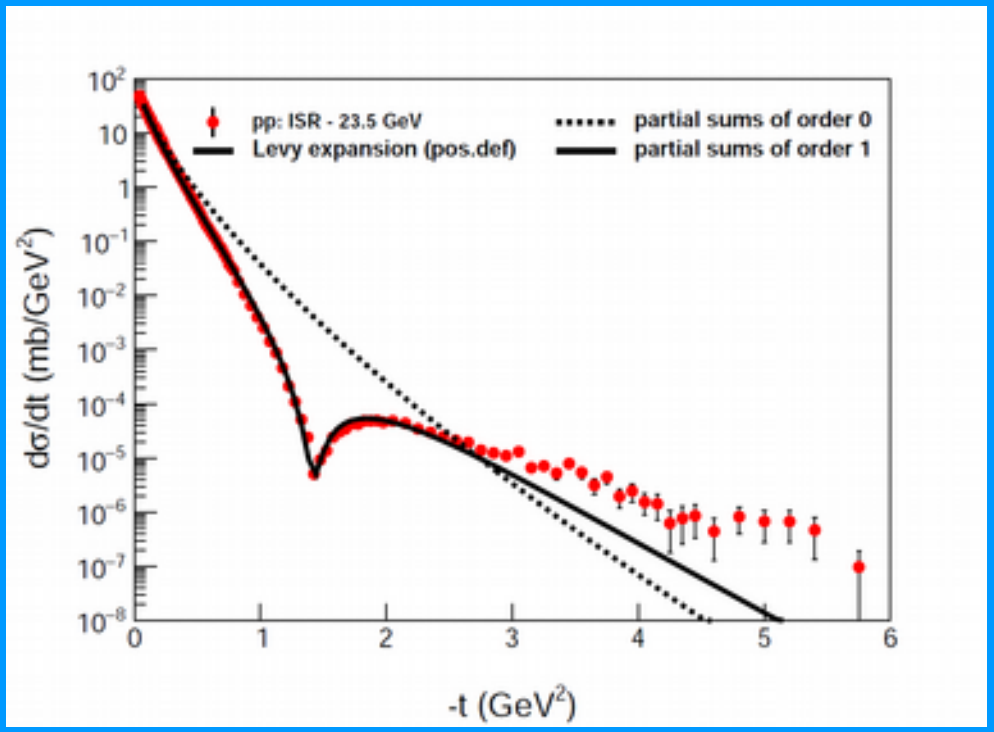


4th and 1st order Levy fits at LHC energies.

Dip and bump structures can appear at 1st order , too.

Levy function fit partial sums

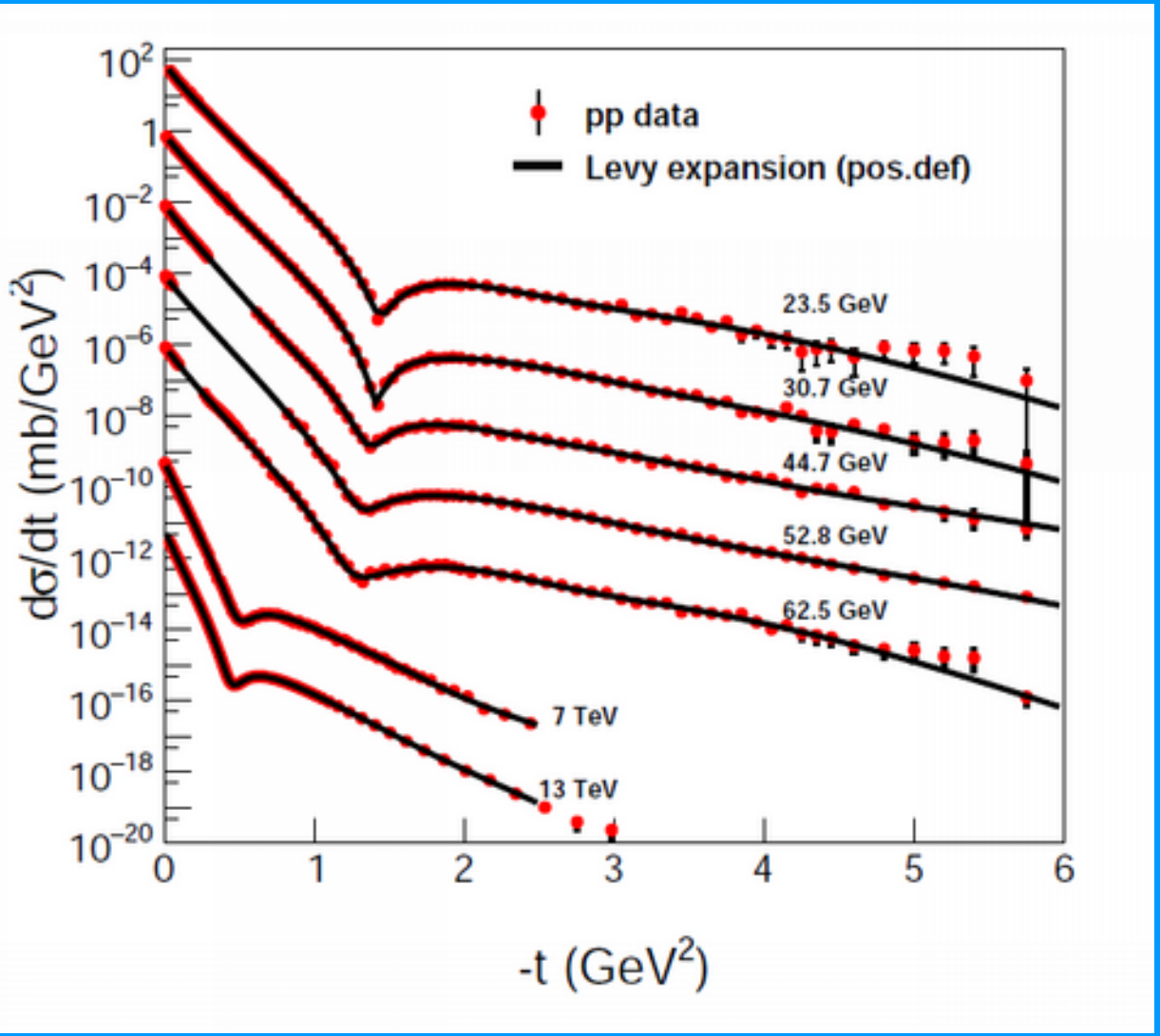




4th and 1st order Levy fits at ISR energies.

Dip and bump structures can appear at 1st order , too.

Levy fits & results

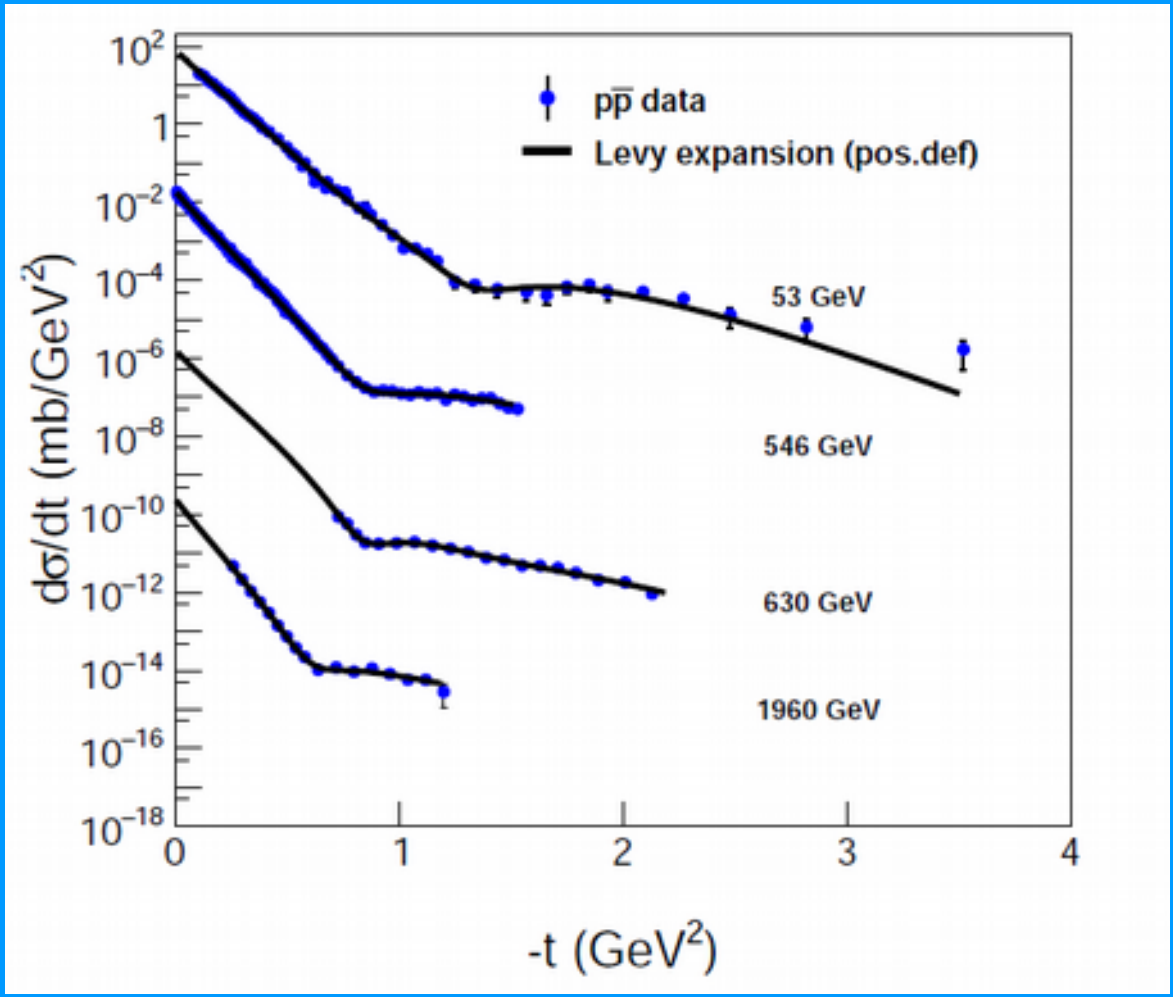


4th order good Levy fits for 5 ISR and 2 TOTEM p+p data sets.

The 13TeV one is preliminary

(a comprehensive study is submitted for publication. Arxiv:1807.02897)

Levy fits & results

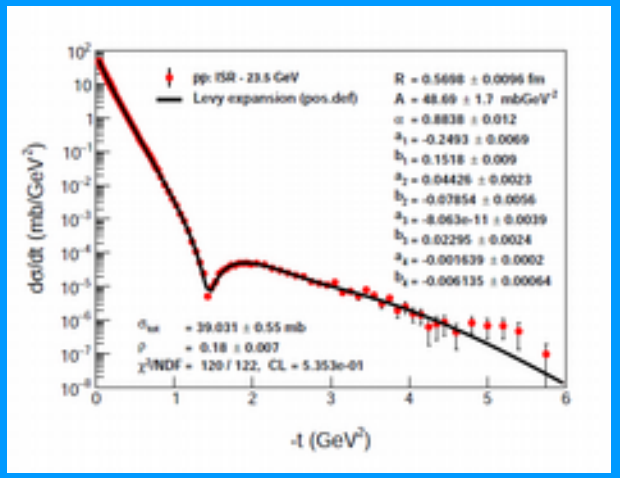


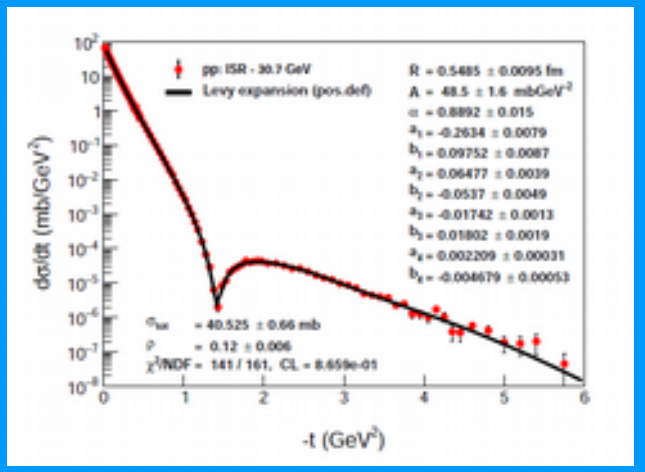
3rd order good Levy fits for 1 ISR 2 UA4 and 1 D0 p+pbar data sets.

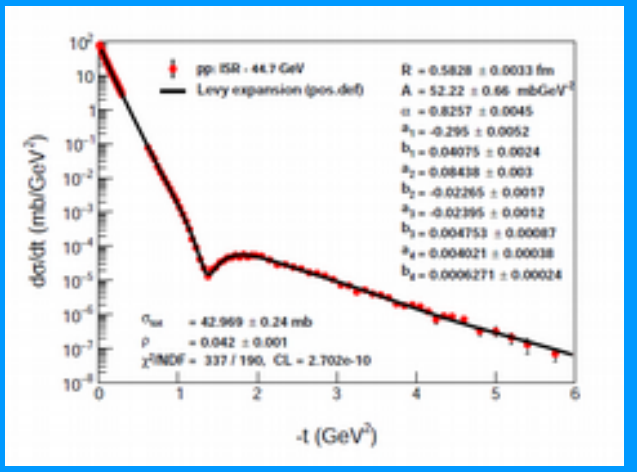
There are more data sets but without dip and bump, hence no good fits can be achieved.

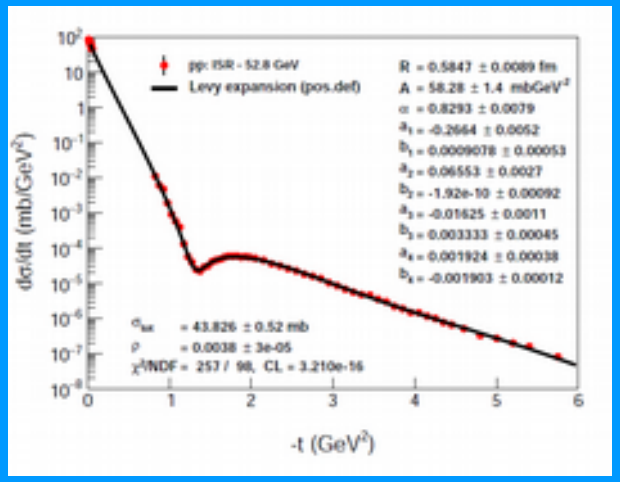
(With $\alpha = 0.9$)

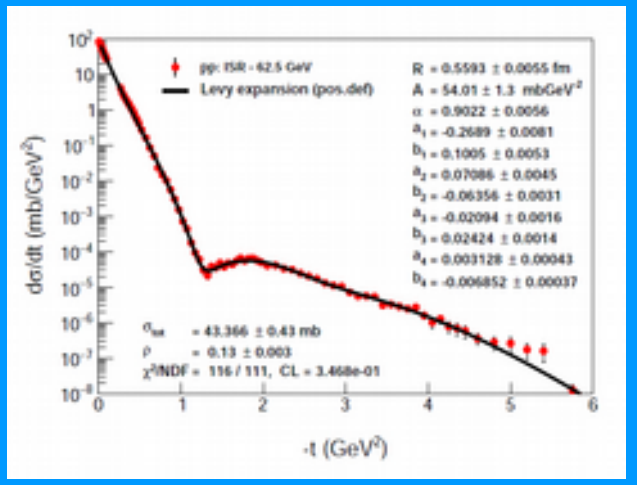
Levy fits & results (ISR data)



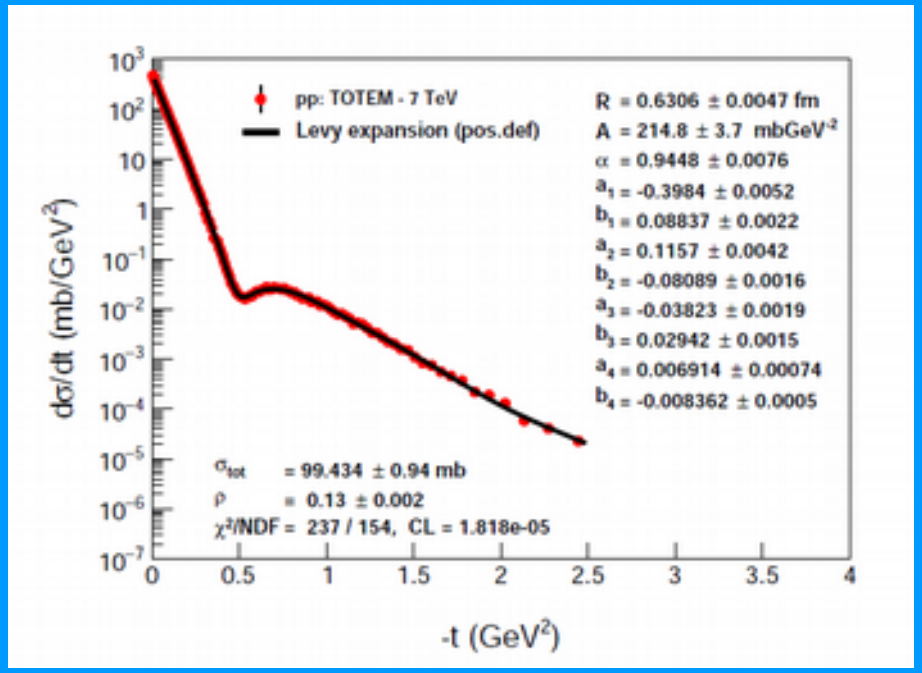


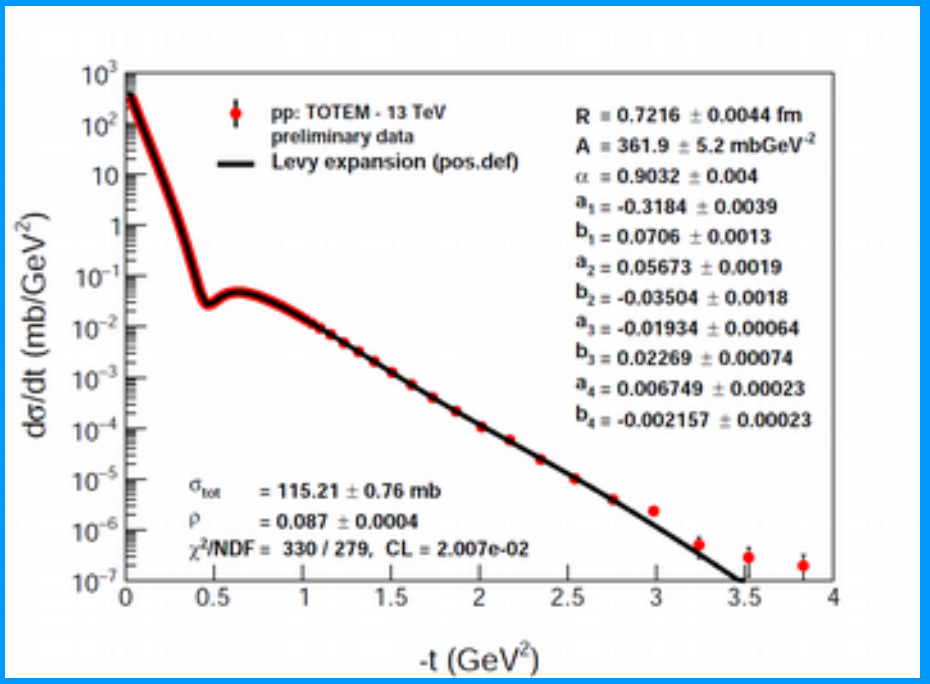






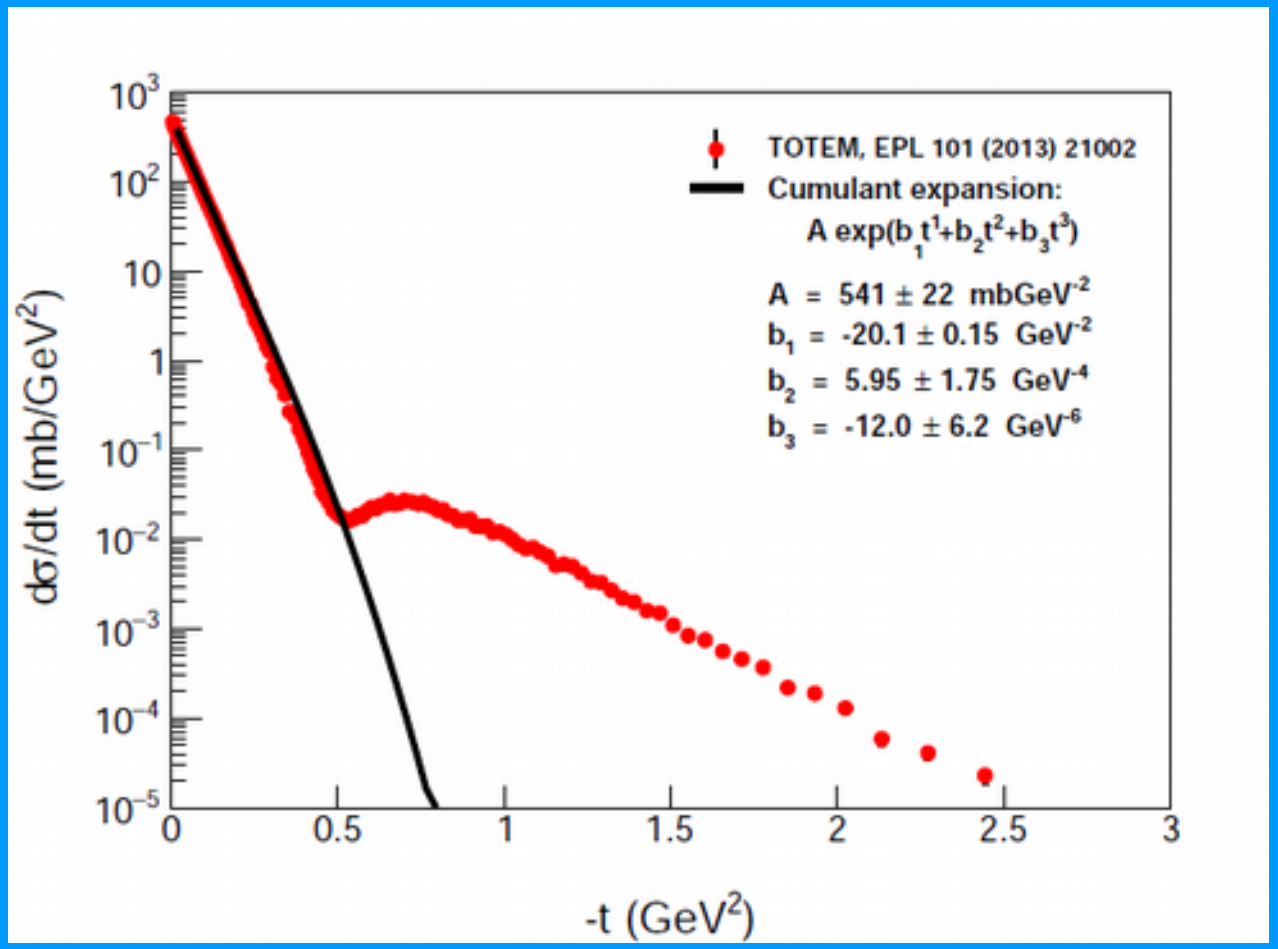
Levy fits & results (TOTEM data)





To increase fit quality of 13 TeV data TOTEM suggested to combine statistical and systematical errors in quadrature

Levy fits & results: 7 TeV



As a comparision: TOTEMs earlier fit to 7 TeV data with a cumulant expansion

This plot made us to apply Levy expansion for a better description

Levy fits & results: excitation functions

Considerations

Levy parameters scatter too much with collision enrgies due to large systematic errors

To improve fit consistency

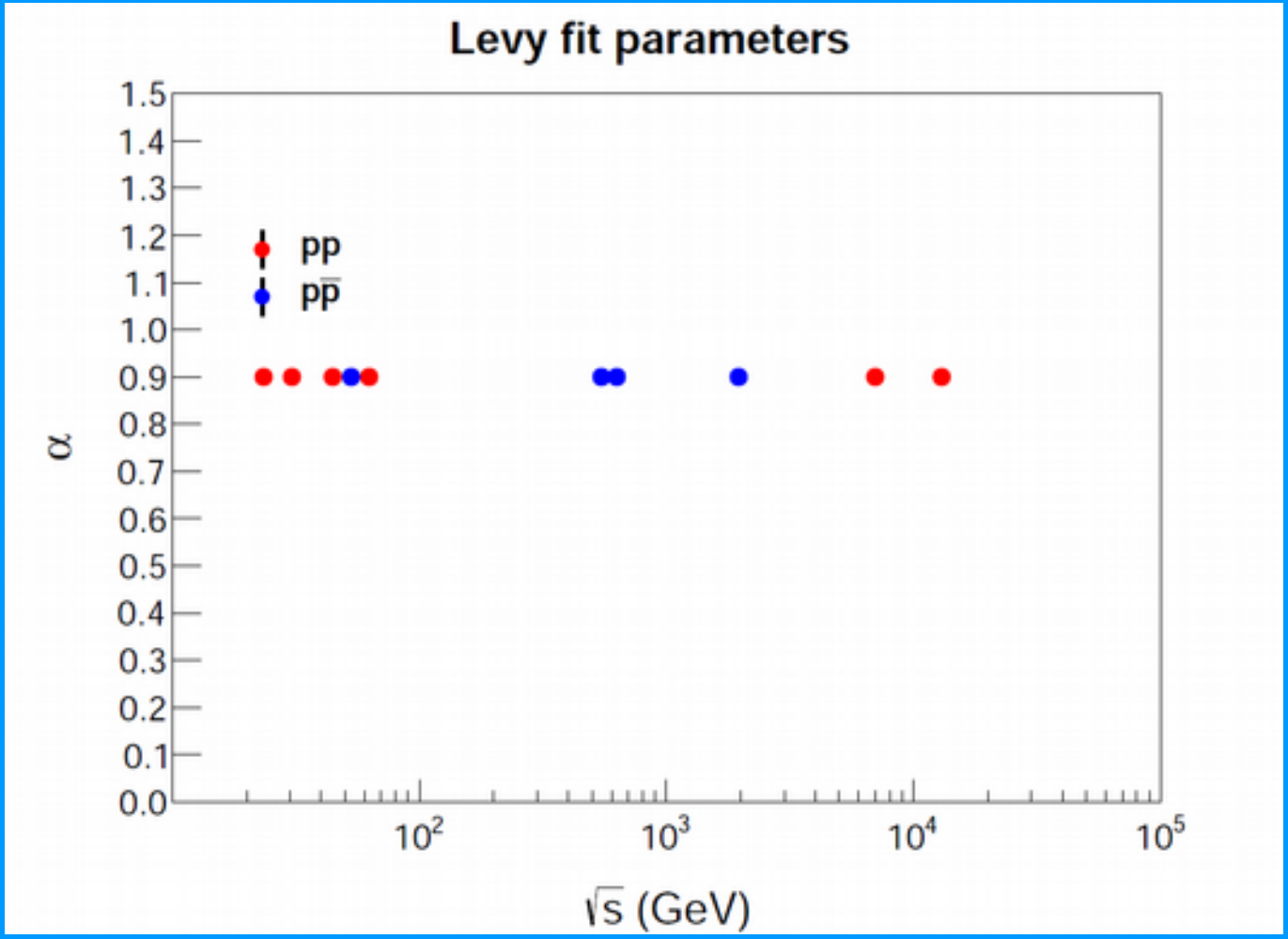
1) Data were refitted with the same error conditions as for 13 TeV (stat+sys)

2) Exponent parameter α was fixed to the typical value of 0.9 for all energies

3) Soure size parameters R were released for p+pbar data fits, too

4) Bad chi2 fits were excluded from the excitation function fits

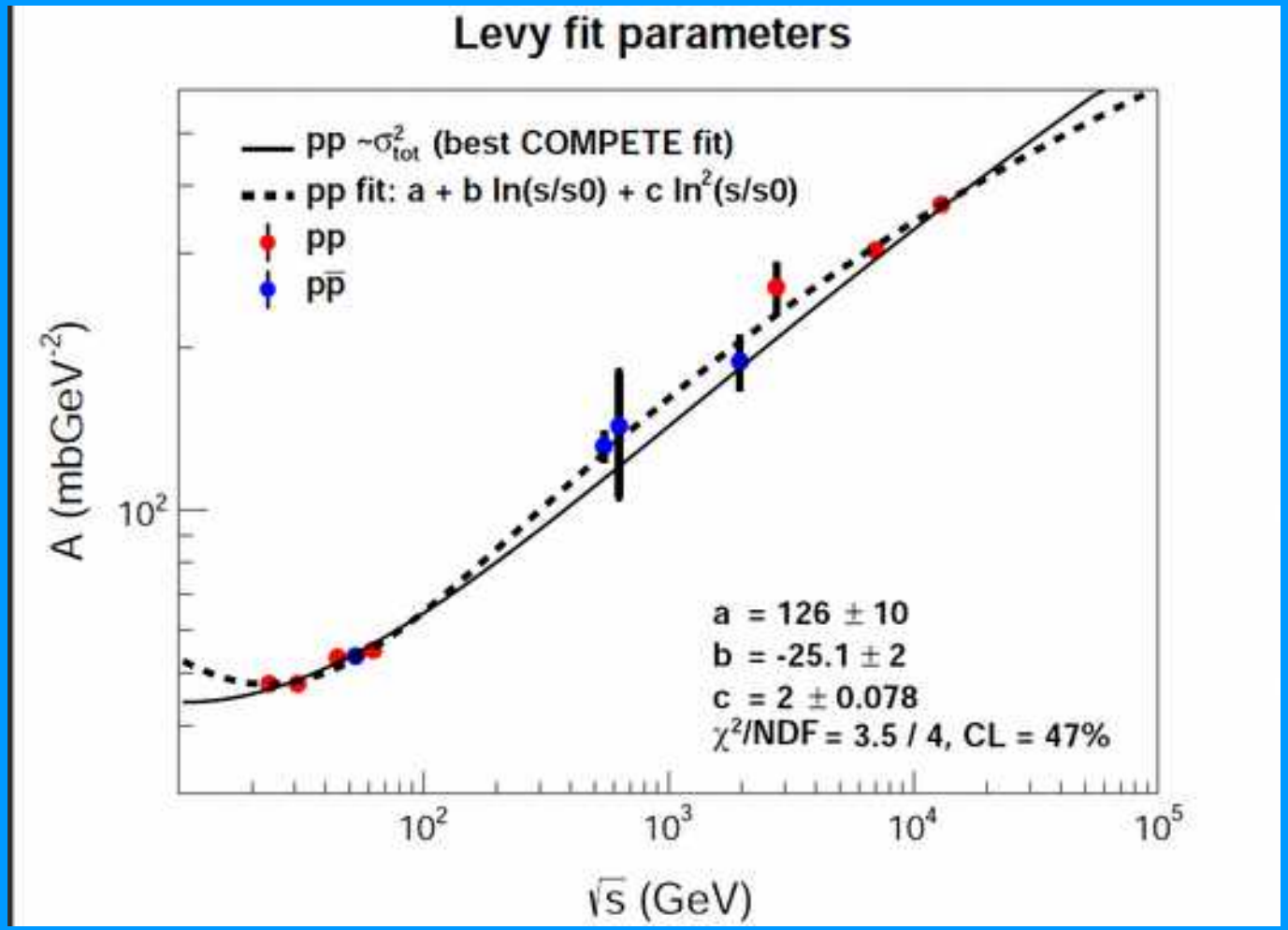
Levy fits & results: excitation functions



Exponent parameter α

It is fixed to the typical value of 0.9 for all energies

Levy fits & results: excitation functions



Amplitude parameter A

Levy fits & results: excitation functions

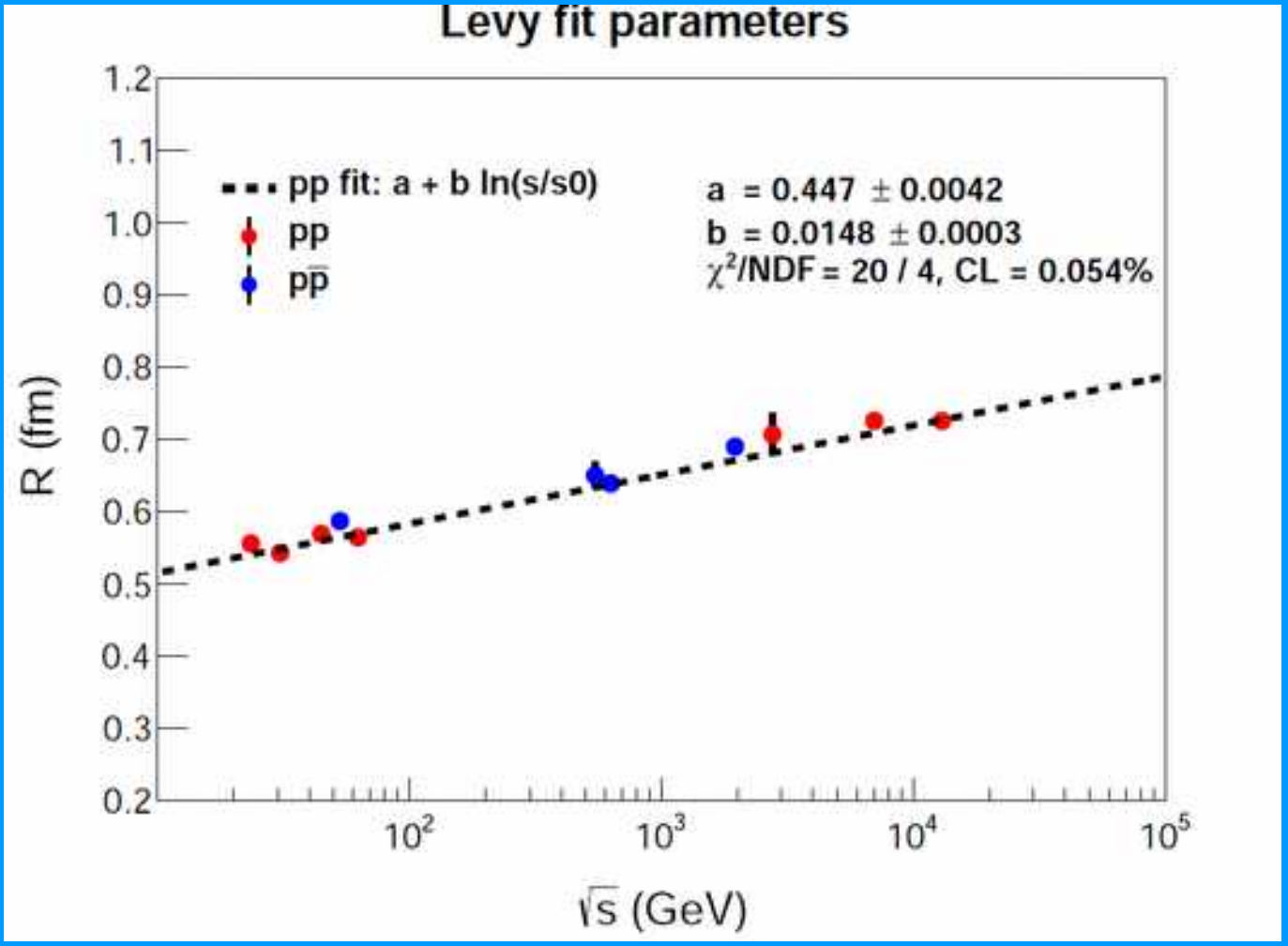
23.5	A = 47.6,	stot2 =1527.655,	stot2/A =32.09
30.5	A = 47.8,	stot2 =1636.537,	stot2/A =34.23
44.6	A = 53.4,	stot2 =1769.849,	stot2/A =33.16
62.7	A = 54.7,	stot2 =1894.083,	stot2/A =34.60
7000.0	A =303.2,	stot2 =10434.90,	stot2/A =34.41
13000.0	A =368.5,	stot2 =13390.64,	stot2/A =36.33
53.0	A = 53.7,	stot2 =1629.604,	stot2/A =30.32
546.0	A =131.6,	stot2 =4098.440,	stot2/A =31.15
630.0	A =143.3,	stot2 =3660.108,	stot2/A =25.54
1960.0	A =188.8,	stot2 =5866.150,	stot2/A =31.07

Amplitude parameter A vs $\sigma^2_{\tau o \tau}$ (where $\sigma = 4 \pi f(0)$)

23.5	A = 47.6,	dsdt0 =79.068,	dsdt0/A = 1.66
30.5	A = 47.8,	dsdt0 =84.434,	dsdt0/A = 1.77
44.6	A = 53.4,	dsdt0 =90.678,	dsdt0/A = 1.70
62.7	A = 54.7,	dsdt0 =97.878,	dsdt0/A = 1.79
7000.0	A =303.2,	dsdt0 =534.66,	dsdt0/A = 1.76
13000.0	A =368.5,	dsdt0 =686.56,	dsdt0/A = 1.86
53.0	A = 53.7,	dsdt0 =83.452,	dsdt0/A = 1.55
546.0	A =131.6,	dsdt0 =210.04,	dsdt0/A = 1.60
630.0	A =143.3,	dsdt0 =187.13,	dsdt0/A = 1.31
1960.0	A =188.8,	dsdt0 =303.20,	dsdt0/A = 1.61

Amplitude parameter A vs $d\sigma_{el}/dt$ (t=0).

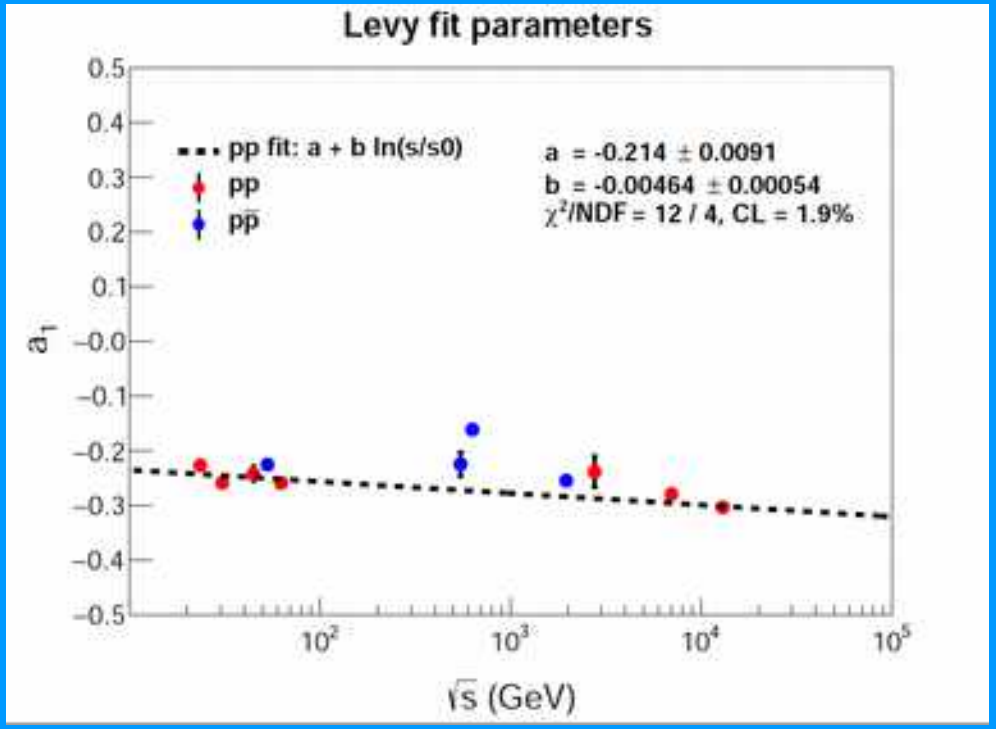
Levy fits & results: excitation functions

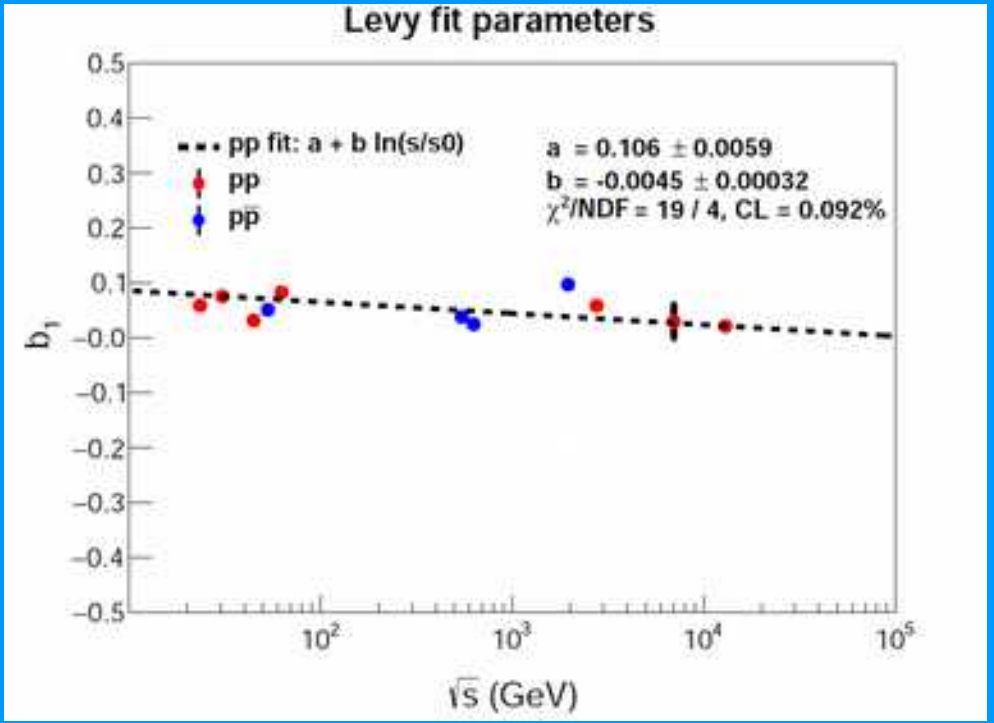


Size parameter R

Levy fits & results: excitation functions

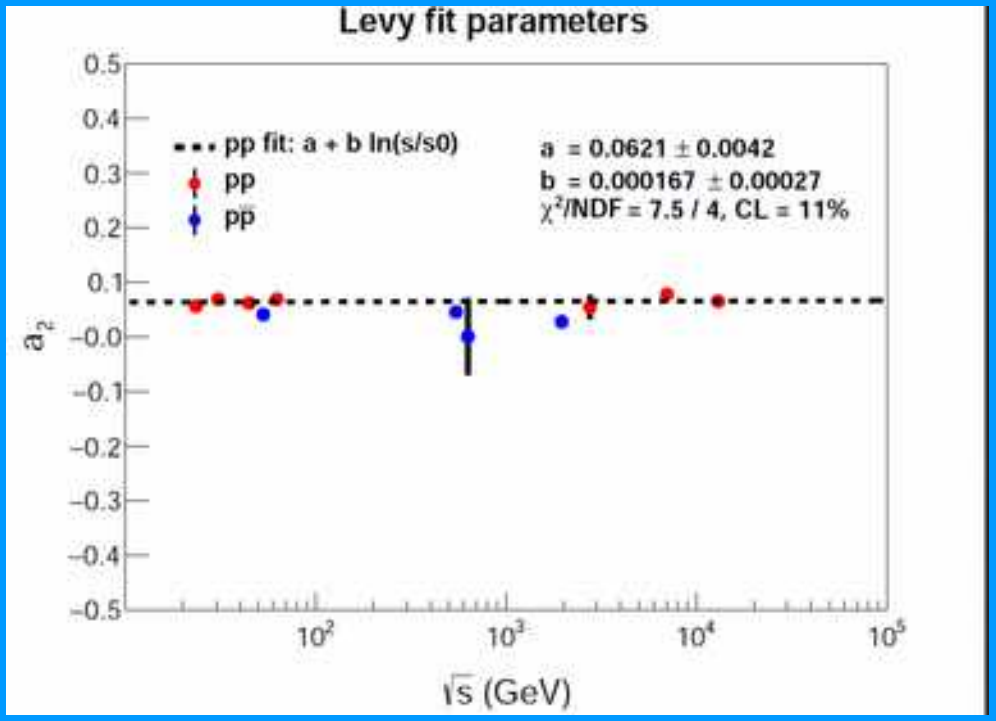
Expansion parameters a_1 and b_1

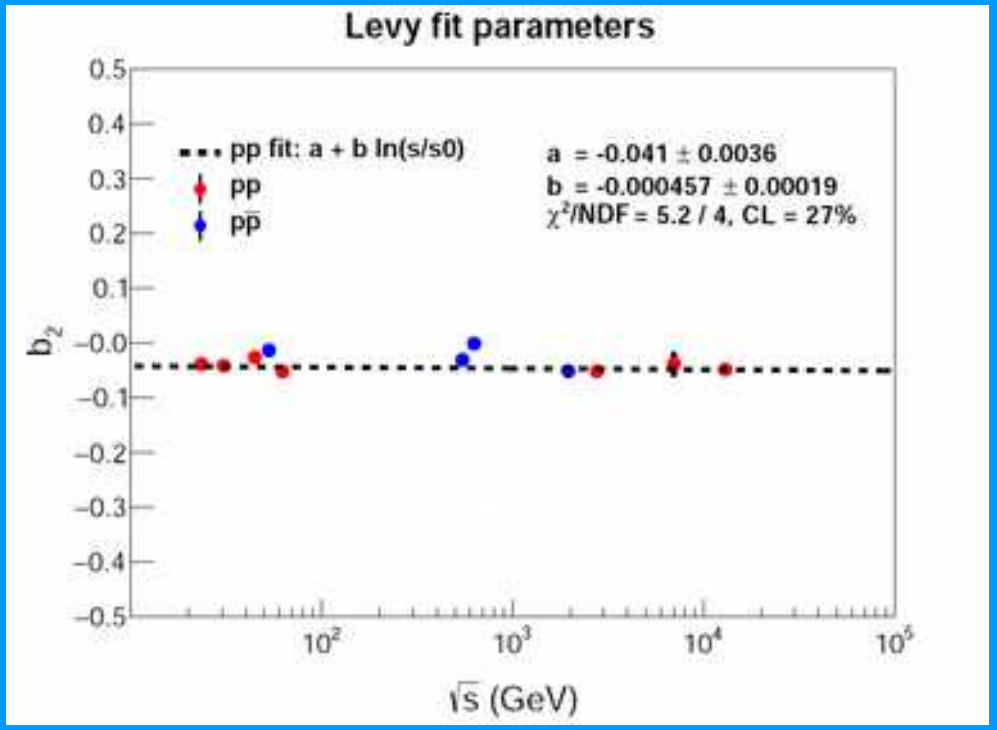




Levy fits & results: excitation functions

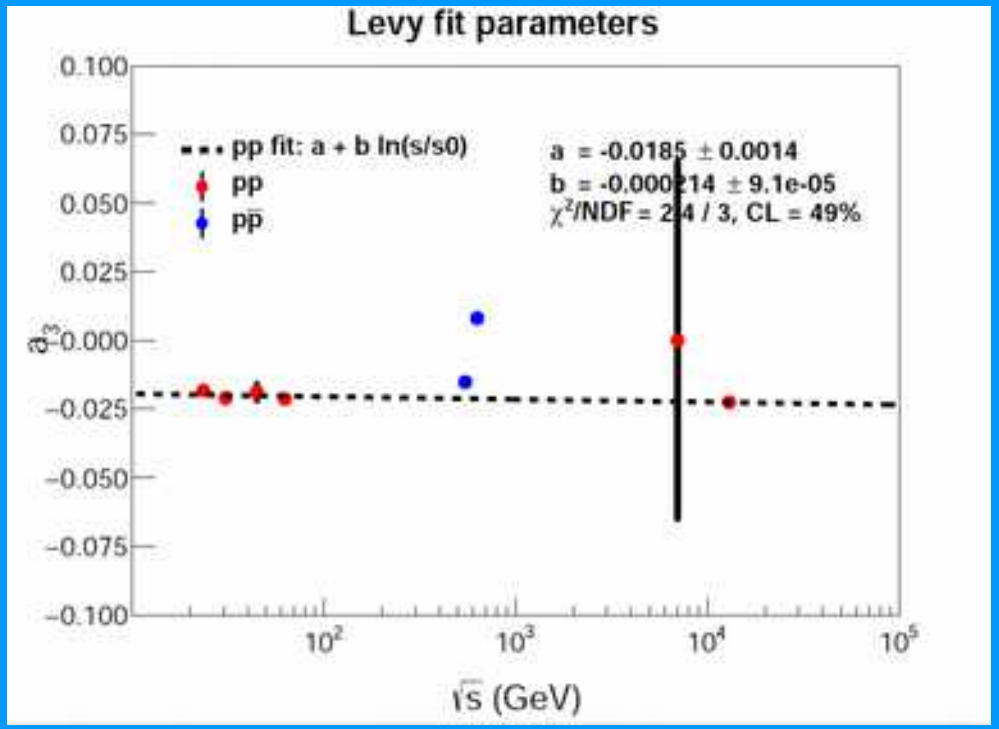
Expansion parameters a_2 and b_2

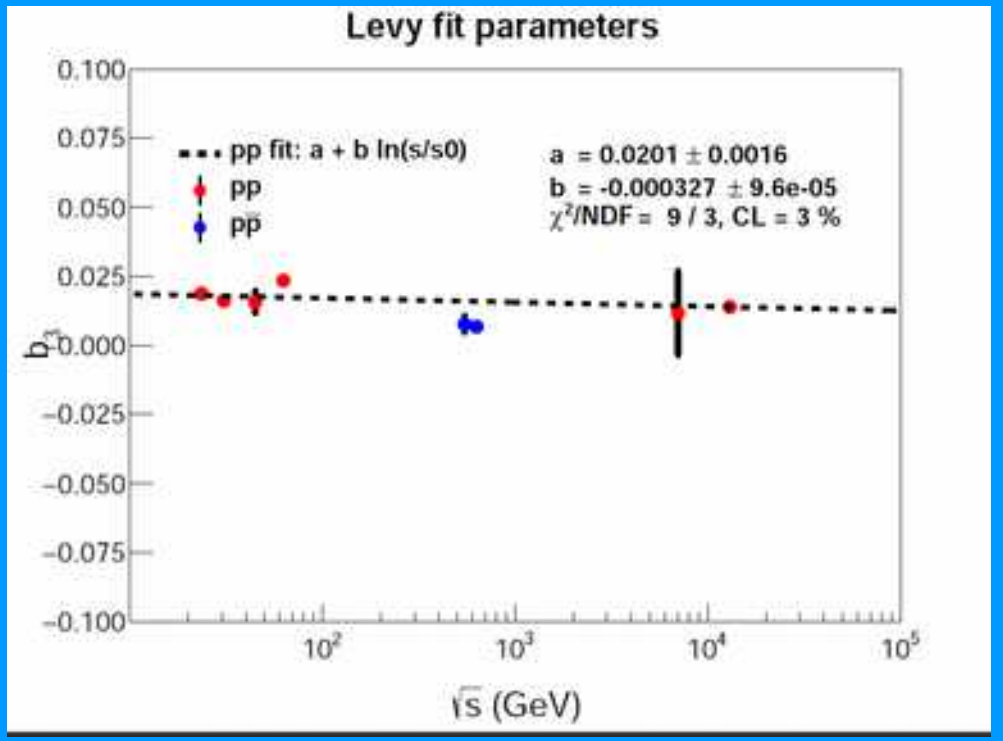




Levy fits & results: excitation functions

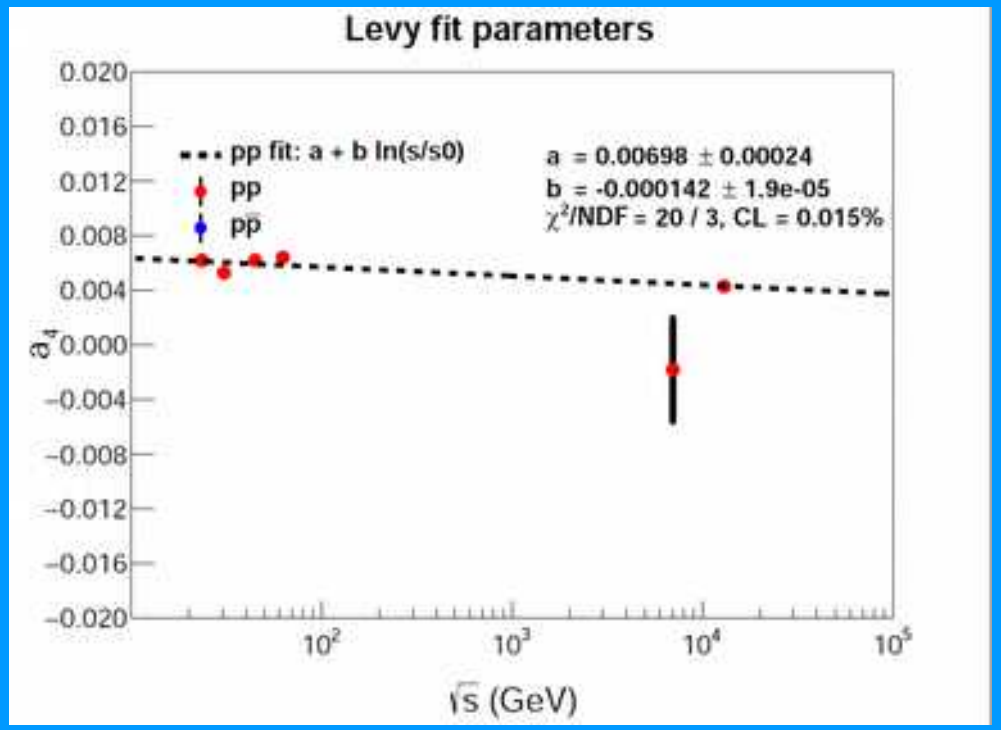
Expansion parameters a_3 and b_3

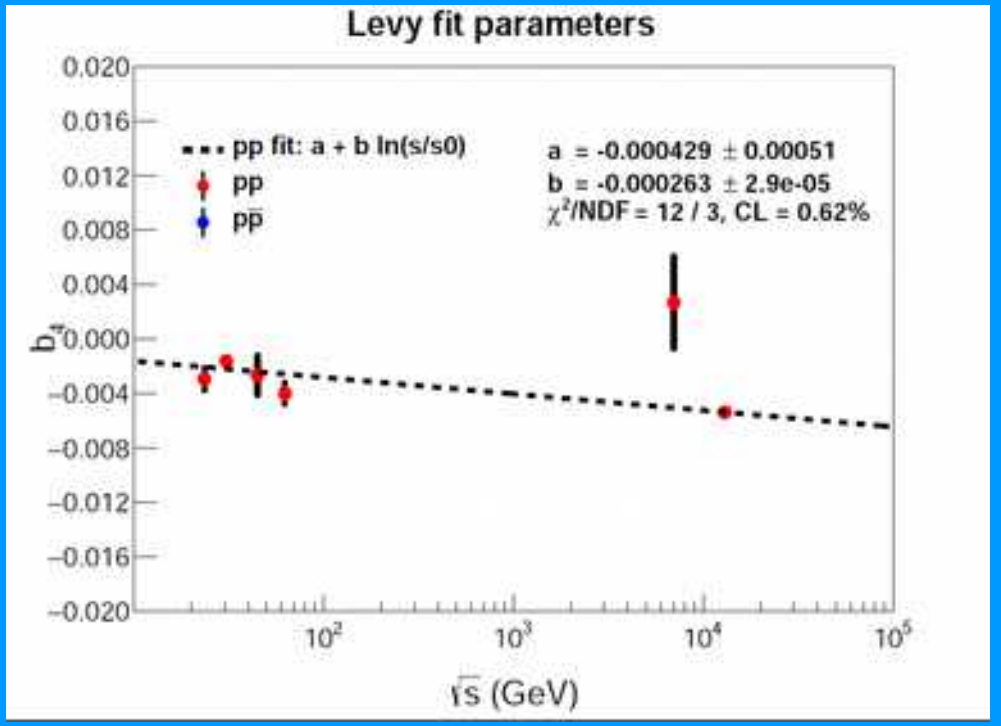




Levy fits & results: excitation functions

Expansion parameters a_4 and b_4





Conclusion

First preliminary excitation functions of Levy fit parameters of elastic p+p and p+pbar data are extracted

Elastic data amplitudes can well be described by logarithmic terms of collision energies

The average sizes of the sources seem to simply increase logaritmically

Deviations between p+p and p+pbar seem to occure from 1st and 2nd order Levy calculations

Thank You!