Scaling properties of elastic pp and pbarp scattering - H(x) and A(x) comparisons

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Content

- Comparison of published $d\sigma/dt$ differential cross-sections of elastic pp and ppbar scattering at ISR and LHC energies

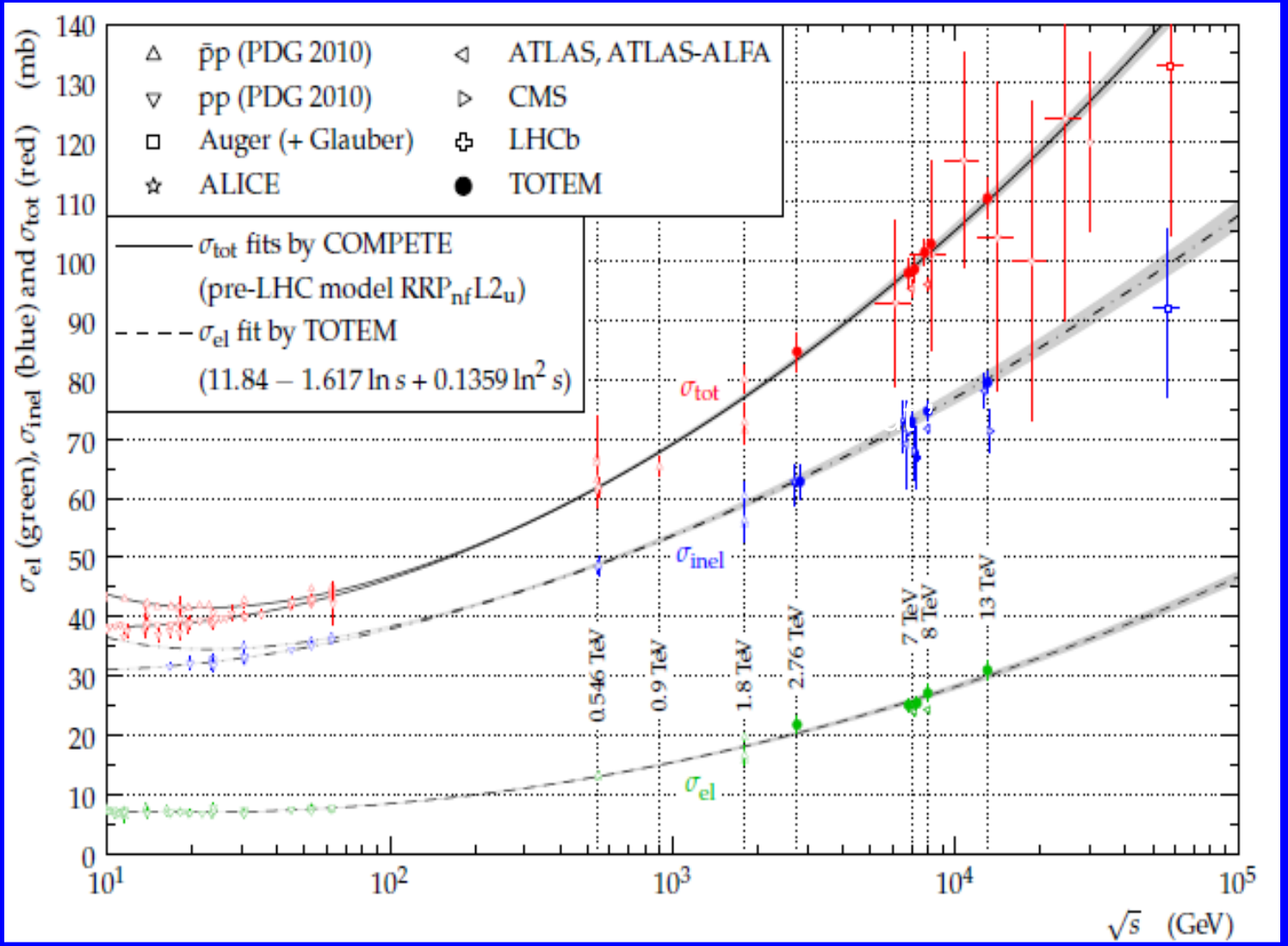
- Scaling law of $d\sigma/dt$'s

- Comparison of scaling functions H(x)

- Scaling function H(x) ratios and A(x) asymmetries

- Conclusion - Odderon effect

Differential cross-sections of pp and ppbar elastic scattering



Why important?

For example, to get:

σ_{tot}, σ_{el}, σ_{inel}

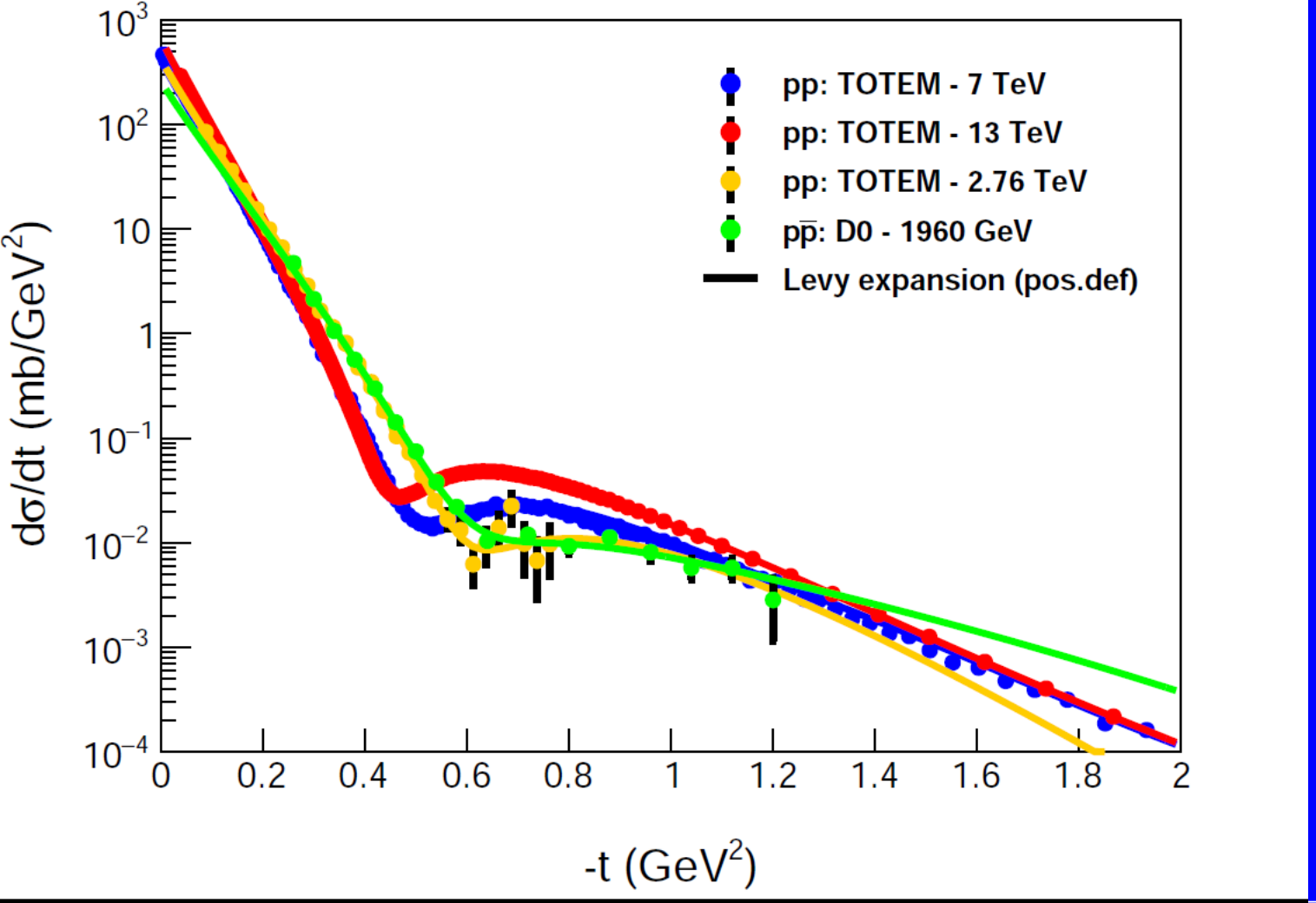
(optical theorem)

$$\sigma_{tot}^2 = \frac{16\pi (\hbar c)^2}{1+\rho^2} \left.\frac{d\sigma_{el}}{dt}\right|_0$$

Or, are pp and ppbar $d\sigma/dt$'s different? ➡

Odderon effect?

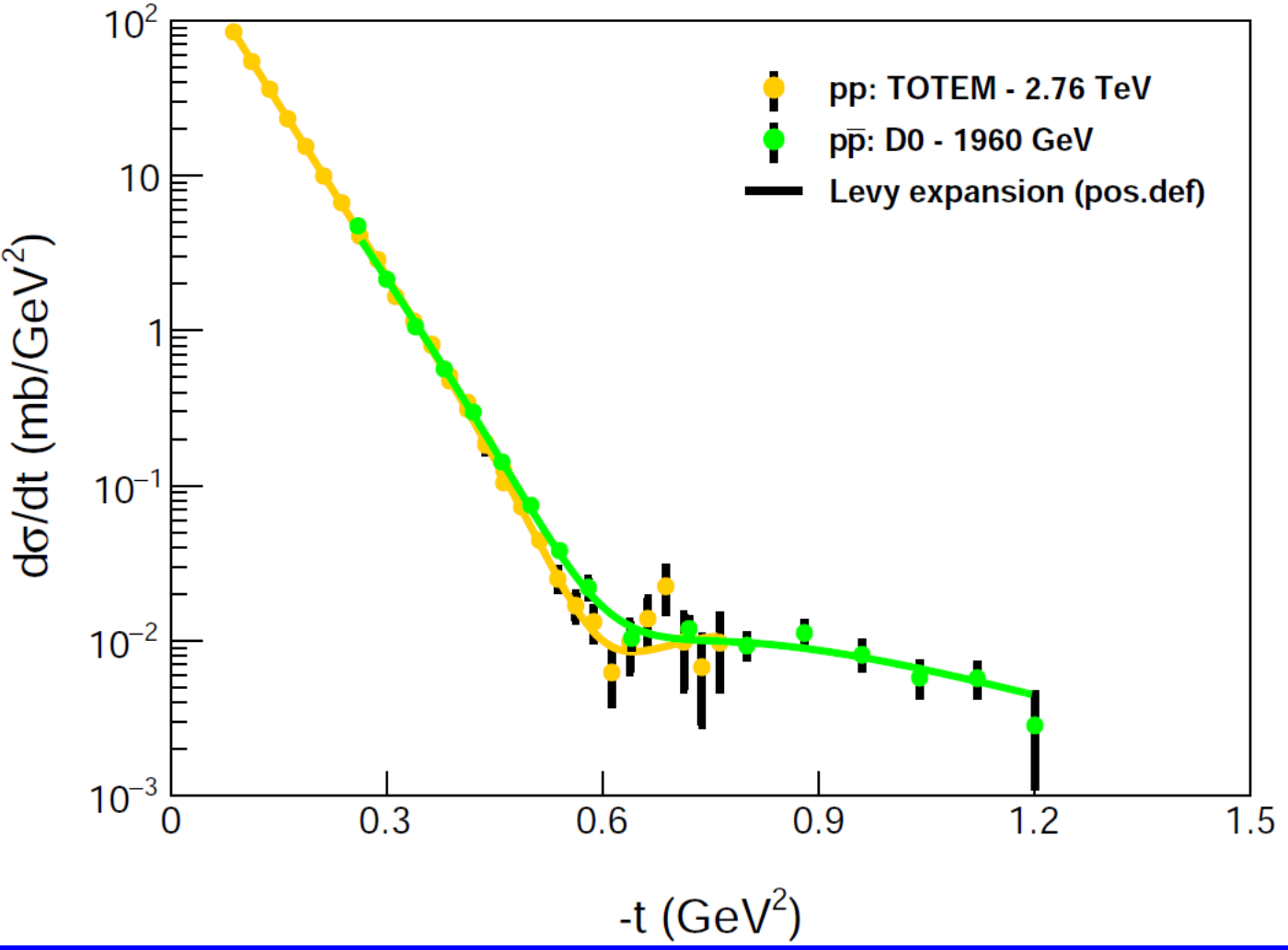
Differential cross-sections of pp and ppbar elastic scattering



Published data at TeV energies

They are remarkably different at different energies

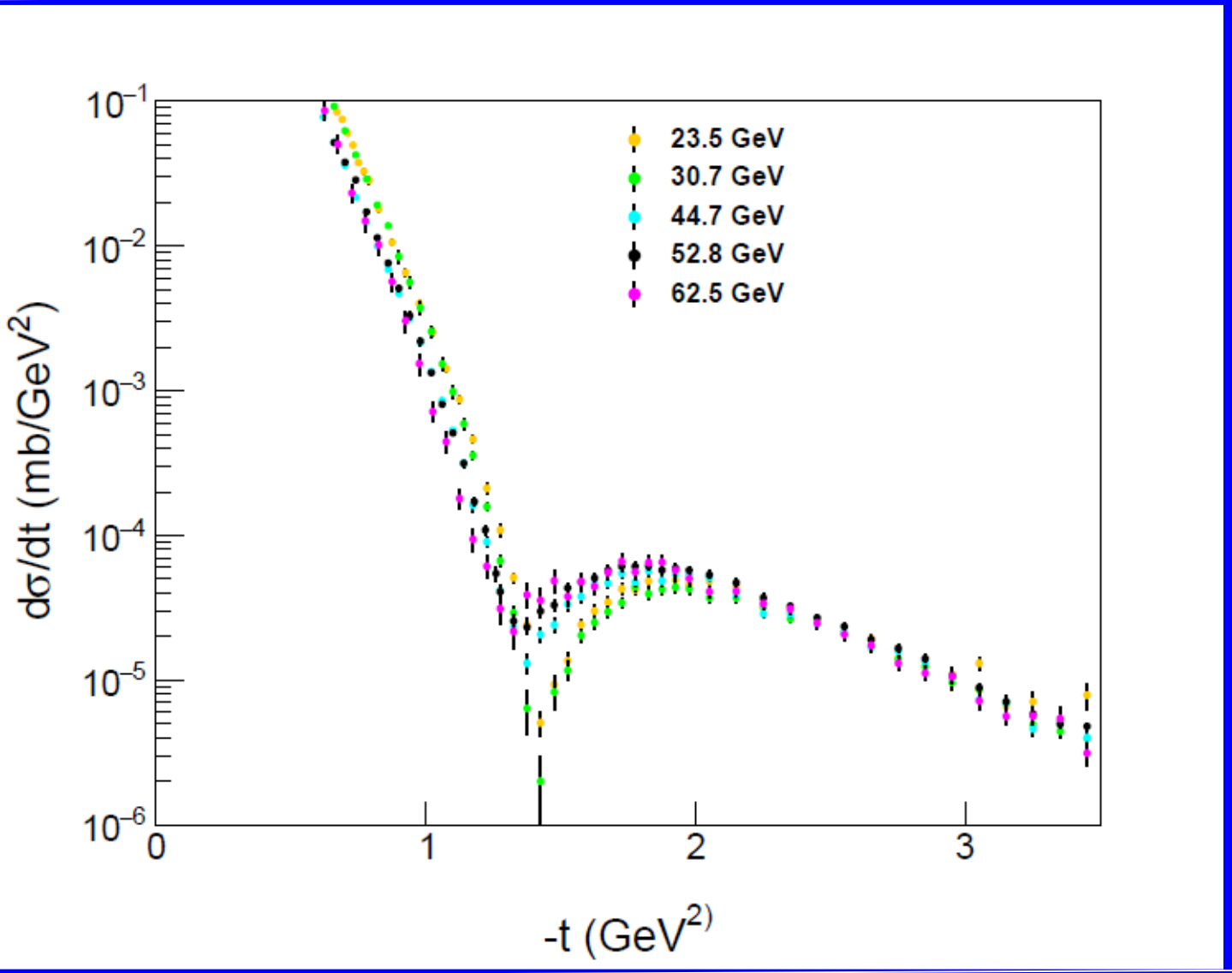
Differential cross-sections of pp and ppbar elastic scattering



Published data at 2.76 TeV (pp) and 1.96 TeV (ppbar) energies

Not enough and precise 2.76 TeV data for a fair comparison

Differential cross-sections of pp and ppbar elastic scattering



Published pp data at CERN ISR energies

They are also remarkably different

Scaling law of dσ/dt 's

Definition of an energy and model-independent scaling function H(x) based exclusively on available data sets:

$$H(x,s)=(1/B\sigma_{\mathrm{el}})d\sigma/dt$$

Where $x=-tB$ and:

$$\sigma_{\mathrm{el}}=\int_0^\infty d|t|\frac{d\sigma}{dt}, \quad B=\frac{d}{dt}\ln\frac{d\sigma}{dt}\Big|_{t\to 0}$$

Scaling law of dσ/dt 's

It has been found that for pp scatterings within a few factor of collision energies the H(x) functions are energy independent:

$$H(x,s_1)=H(x,s_2)$$

Further advantage of H(x) is that possible normalization uncertainties are transferred out of the system

Comparison of scaling functions H(x)

A generalized χ^2 has been defined for comparison of two datasets

$$\chi^2_{2\to1} = \sum_{j=1}^{n_{21}} \frac{(d_1^j+\epsilon_{b,1}e^j_{B,1}-d_{21}^j-\epsilon_{b,21}e^j_{B,21})^2}{(\tilde{e}^j_{A,1})^2+(\tilde{e}^j_{A,21})^2}+\epsilon^2_{b,1}+\epsilon^2_{b,21},$$

$$\tilde{e}^j_{A,k} = e^j_{A,k}\frac{d_k^j+\epsilon_{b,k}e^j_{B,k}}{d_k^j},$$

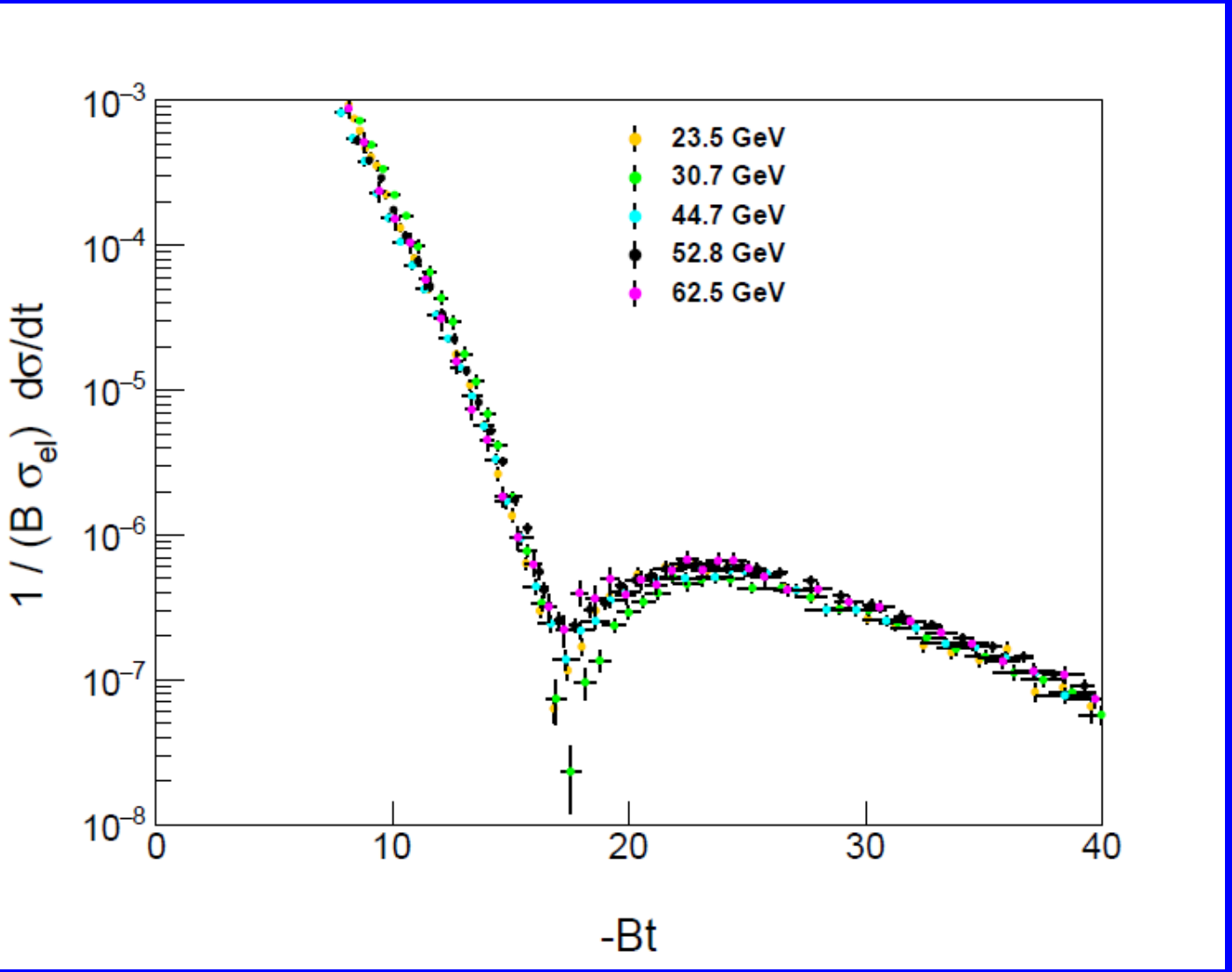
$$e^j_{M,k} = \sqrt{(\sigma^j_{M,k})^2+(d'^{,j}_k)^2(\delta^j_{M,k}x)^2},$$

ε_b controls the systematic type B errors

For details see:: T. Csörgo, T. Novák, R. Pasechnik, A. Ster, and I. Szanyi (2019), 1912.11968v2

This formula is on a PHENIX definition in Ref.: Phys. Rev. C 77 (2008) 064907

Comparison of H(x) scaling functions

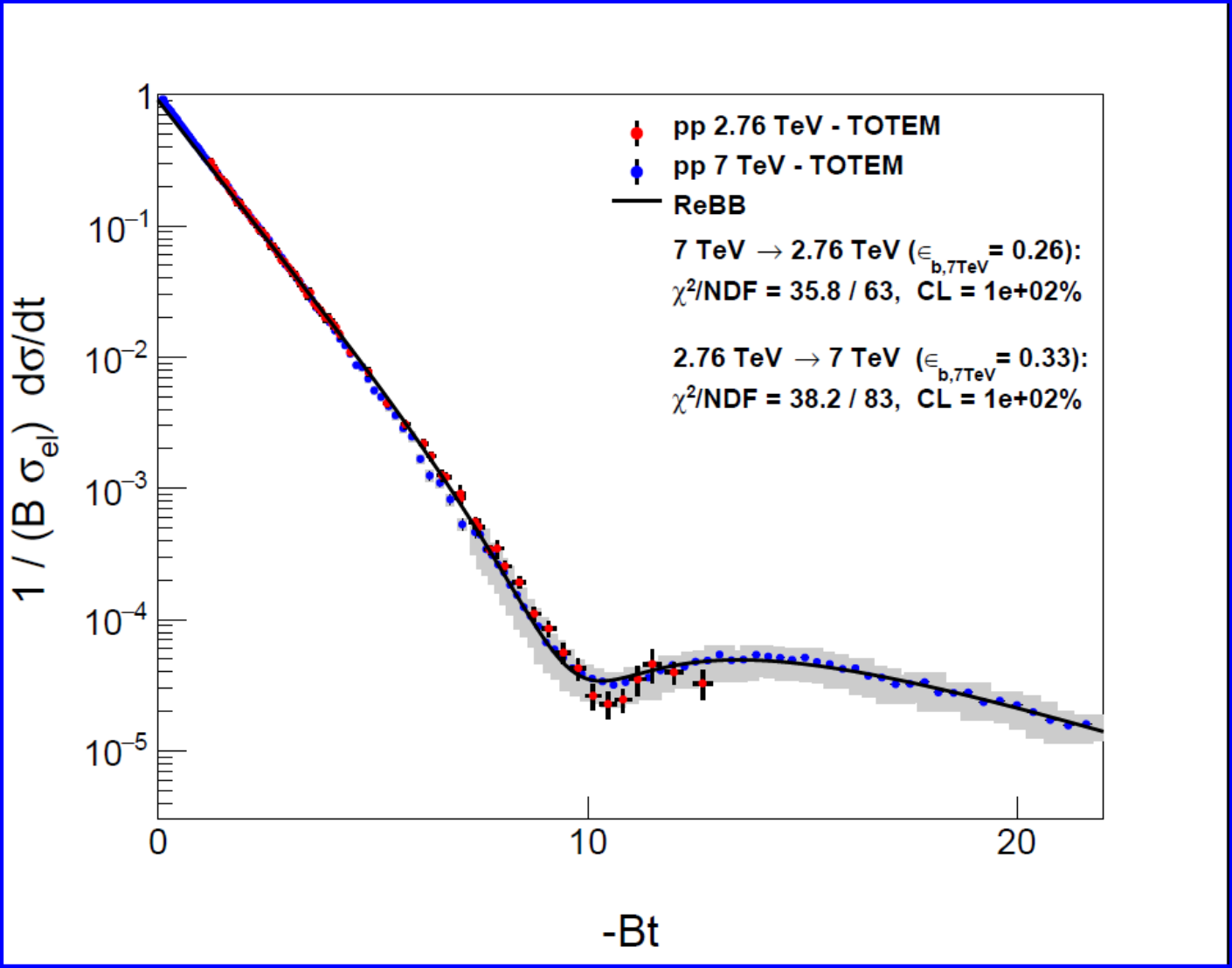


Comparison of H(x)'s of ISR pp data at GeV energies

With the generalized χ^2 each data set pair have a difference of about a smal σ <1 significance

Full agreement is found

Comparison of H(x) scaling functions



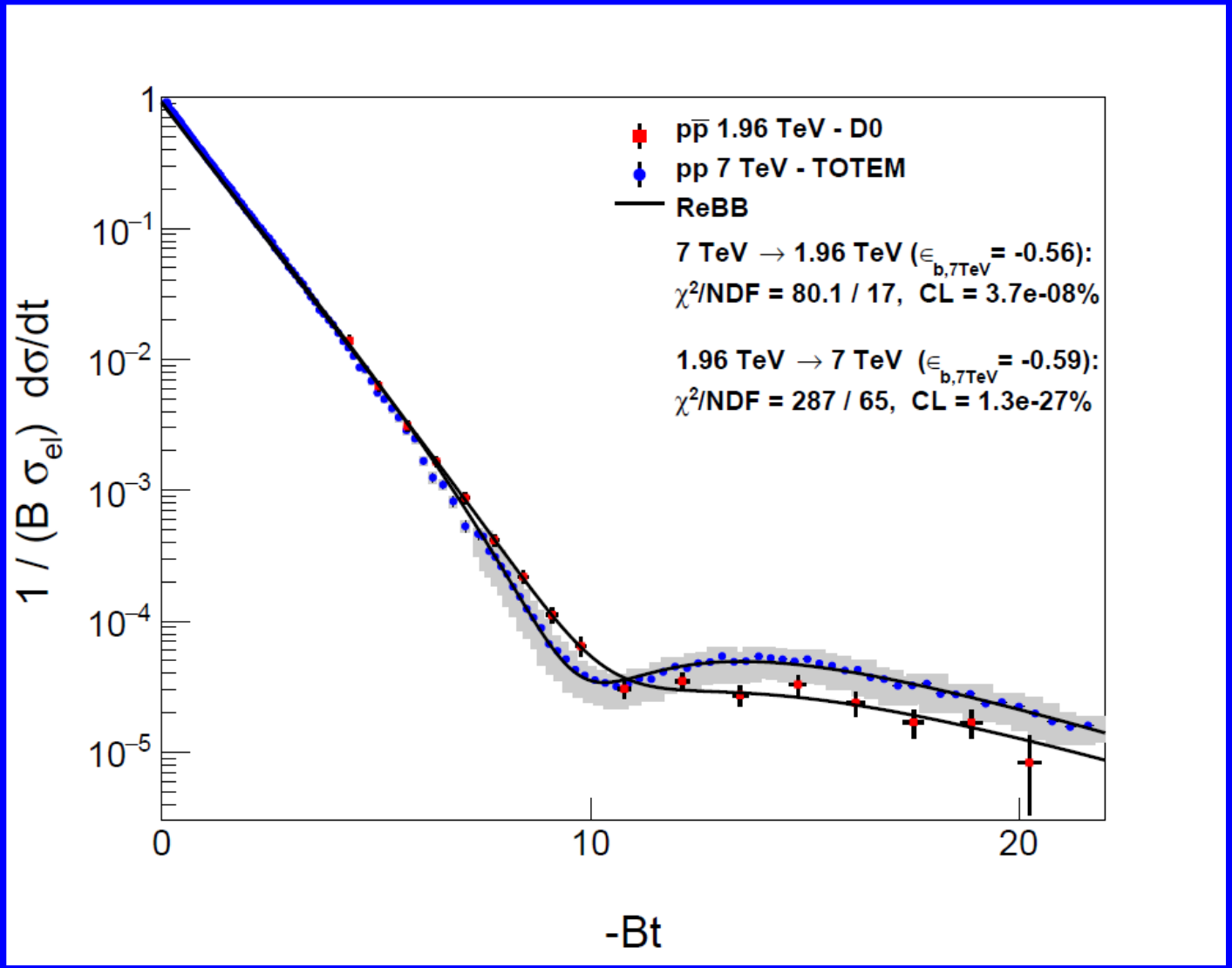
Comparison of H(x)'s of 2.76 TeV (pp) and 7 TeV (pp) energies

Both projections to x's of one of the data sets were investigated

Full agreement is found

A model-dependent (ReBB) theoretical curve is shown, too

Comparison of H(x) scaling functions



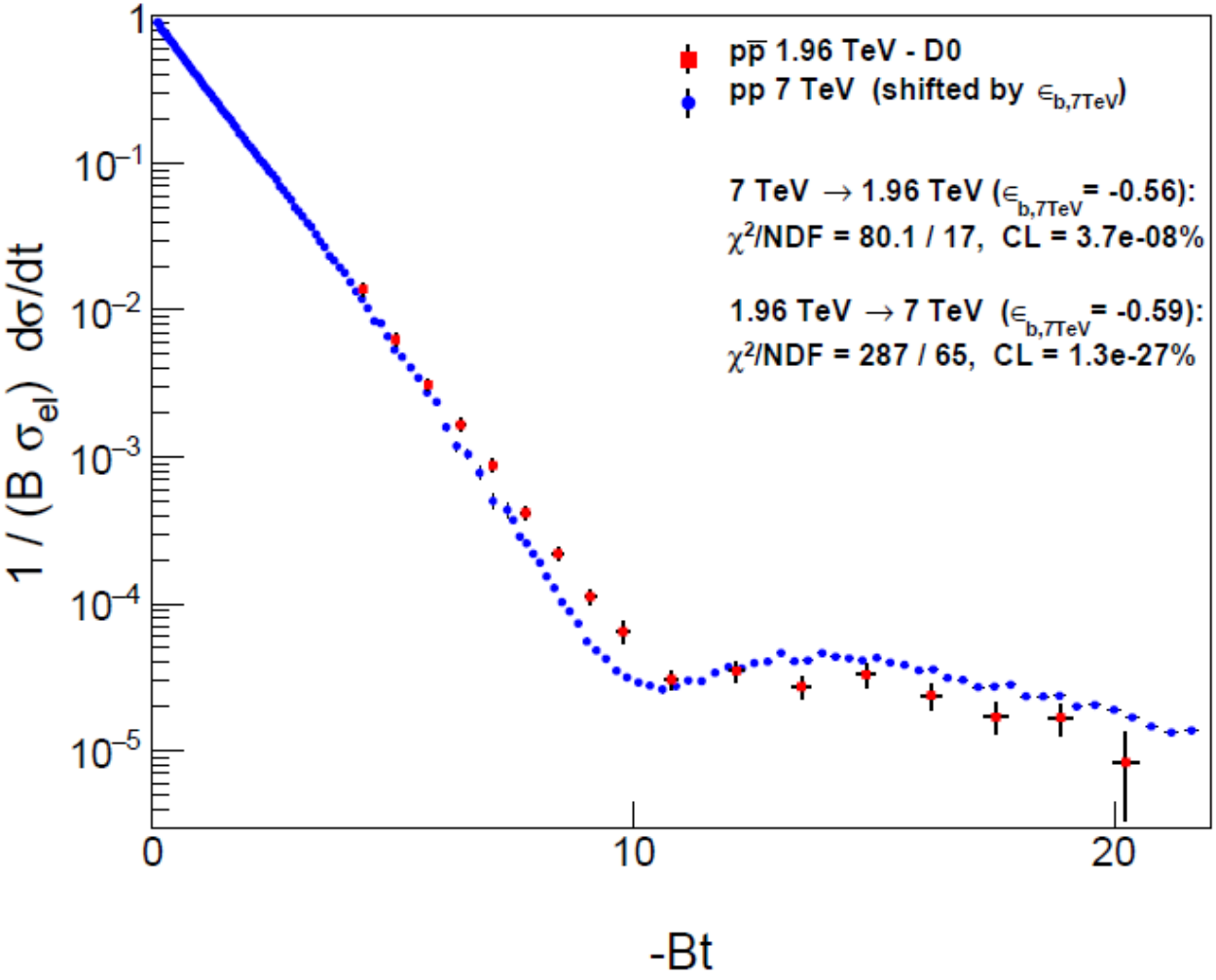
Comparison of H(x)'s of 1.96 TeV (pbarp) and 7 TeV (pp) energies

Both projections to x's of one of the data sets were investigated

No agreement was found with σ_{min}=6.26 significance, which is attributed the the presence of the Odderon contributing anti-symmetric manner to the pp and pbarp cross sections

A model-dependent (ReBB) theoretical curve is shown, too

Comparison of H(x) scaling functions

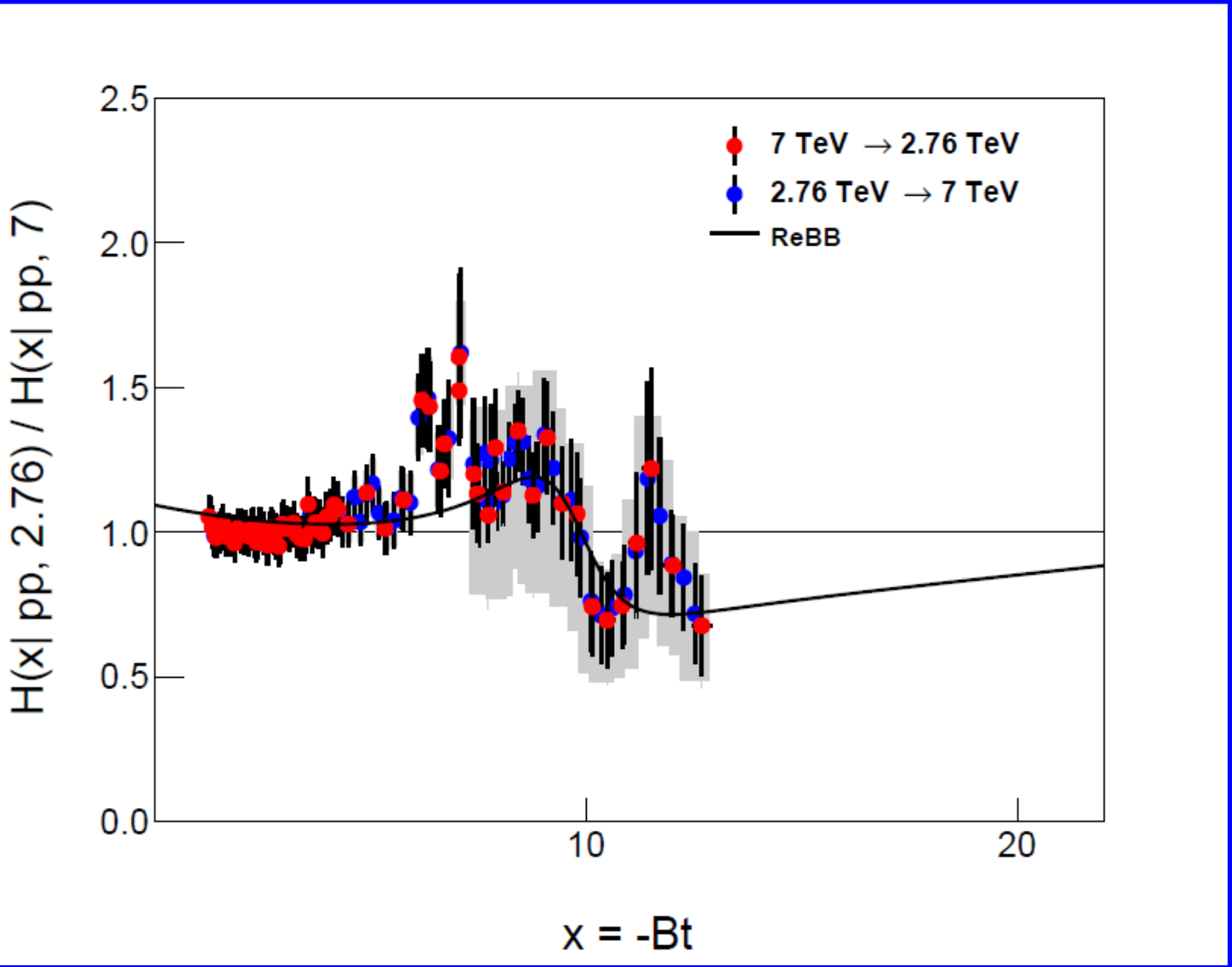


Comparison of H(x)'s of 1.96 TeV (pbarp) and 7 TeV (pp) energies

7 TeV data are shifted by $\varepsilon_{b,7TeV}$ within their systematic errors

Only statistical errors are present this time. The deviations are visible

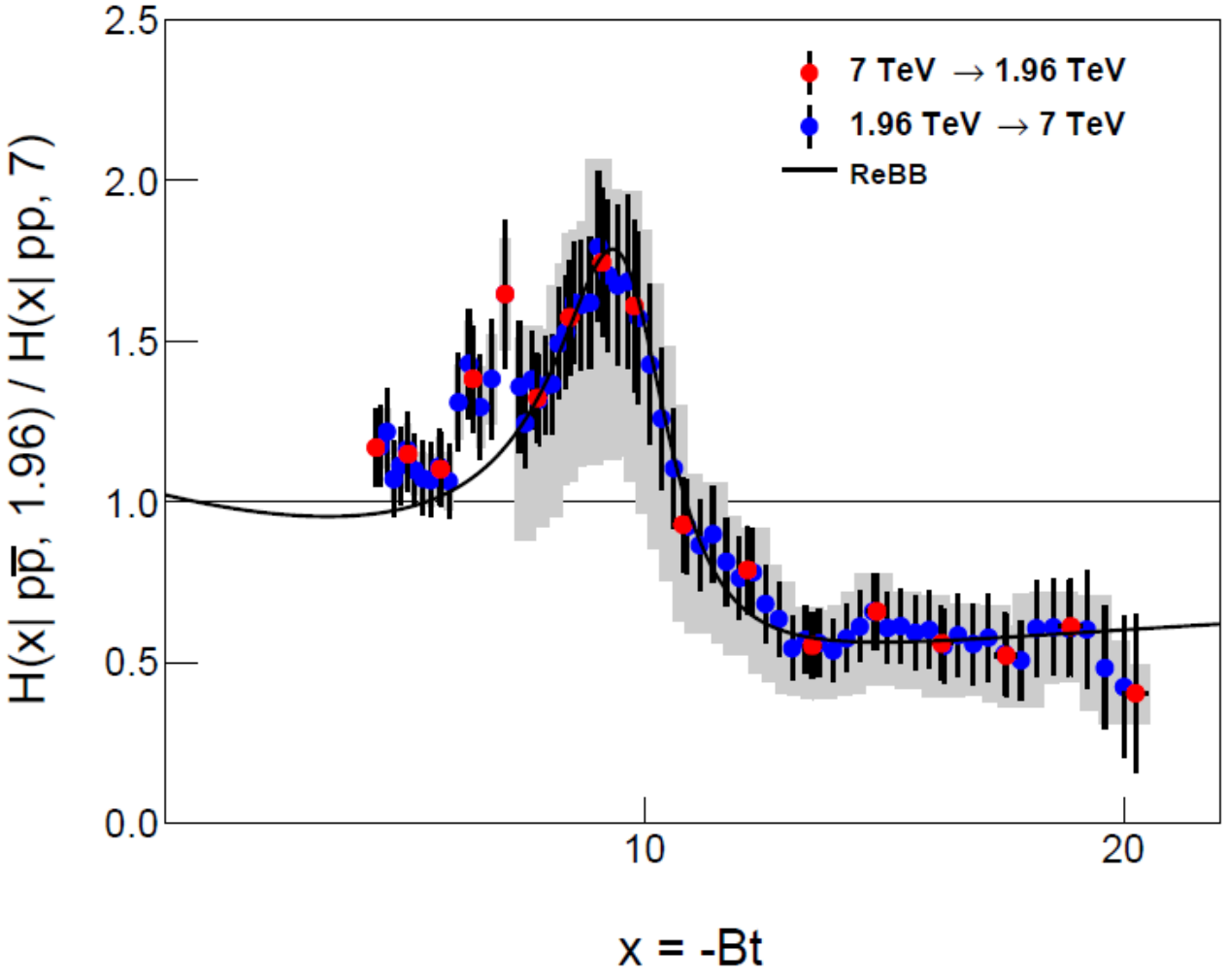
Comparison of H(x) scaling functions



Comparison of H(x)'s of 2.76 TeV (pp) and 7 TeV (pp) energies via their ratio

Just for visualization

Comparison of H(x) scaling functions



Comparison of H(x)'s of 1.96 TeV (pbarp) and 7 TeV (pp) energies via their ratio

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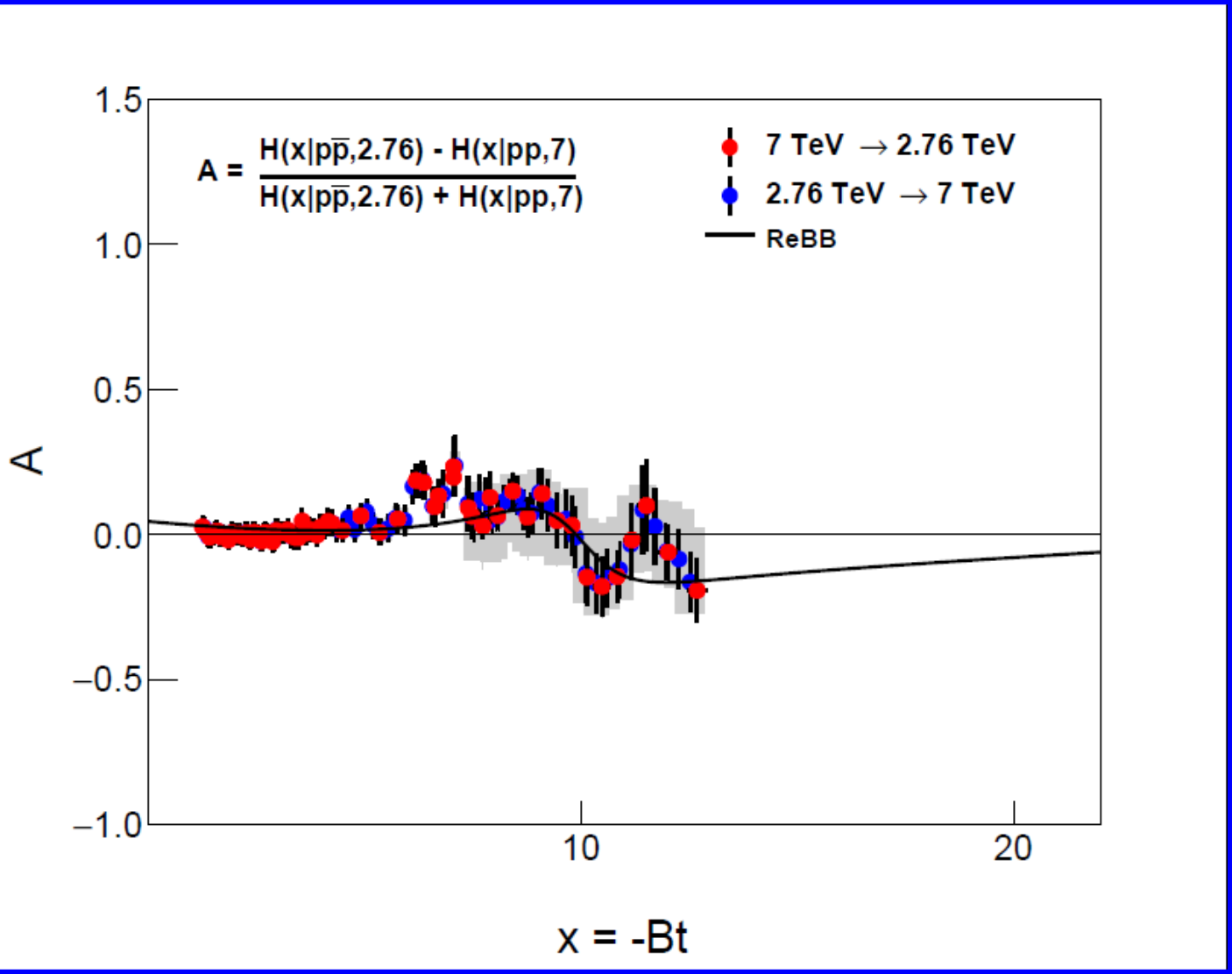
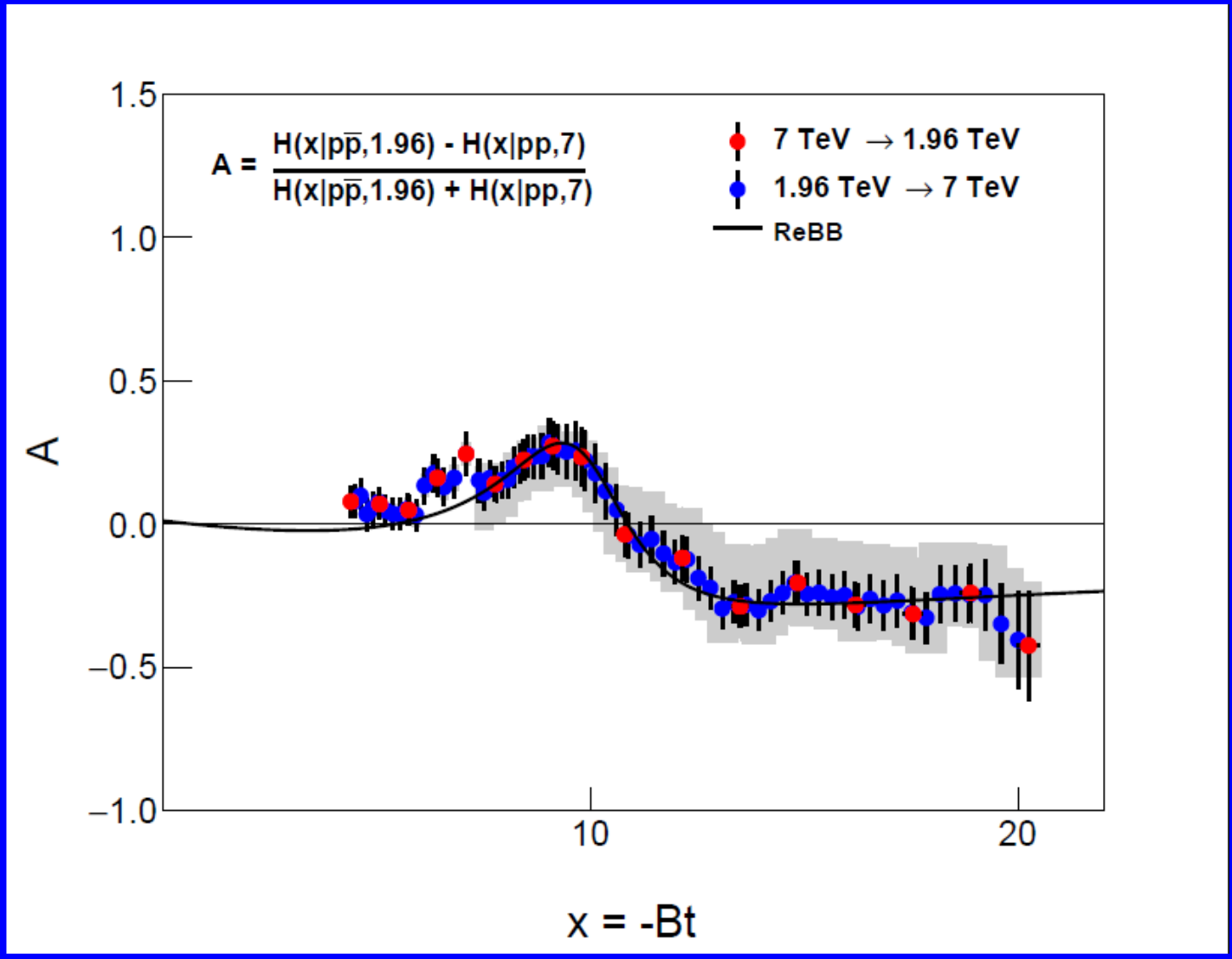


Comparison of H(x)'s of 2.76 TeV (pp) and 7 TeV (pp) energies via their A asymmetric parameter

Just for visualization

Comparison of H(x) scaling functions



Comparison of H(x)'s of 1.96 TeV (pbarp) and 7 TeV (pp) energies via their A asymmetric parameter

Just for visualization

Conclusion

A model independent scaling law of pp elastic scattering has been found within a few factors of collision energies.

A generalized χ^2 calculation method has been defined and applied to the scaling functions H(x) of published pp and ppbar elastic scattering data for a fair comparison.

It has been found that the H(x) scaling functions of pp 7 TeV and ppbar 1.96 TeV deviate significantly with $\sigma = 6.26$ standard deviation signaling the existence of the Odderon.