QUARKS, Валдай, 2018

The ODDERON: myths and reality

(following the LHC (TOTEM) measurement of the real part of the pp scattering amplitude at 13 TeV)

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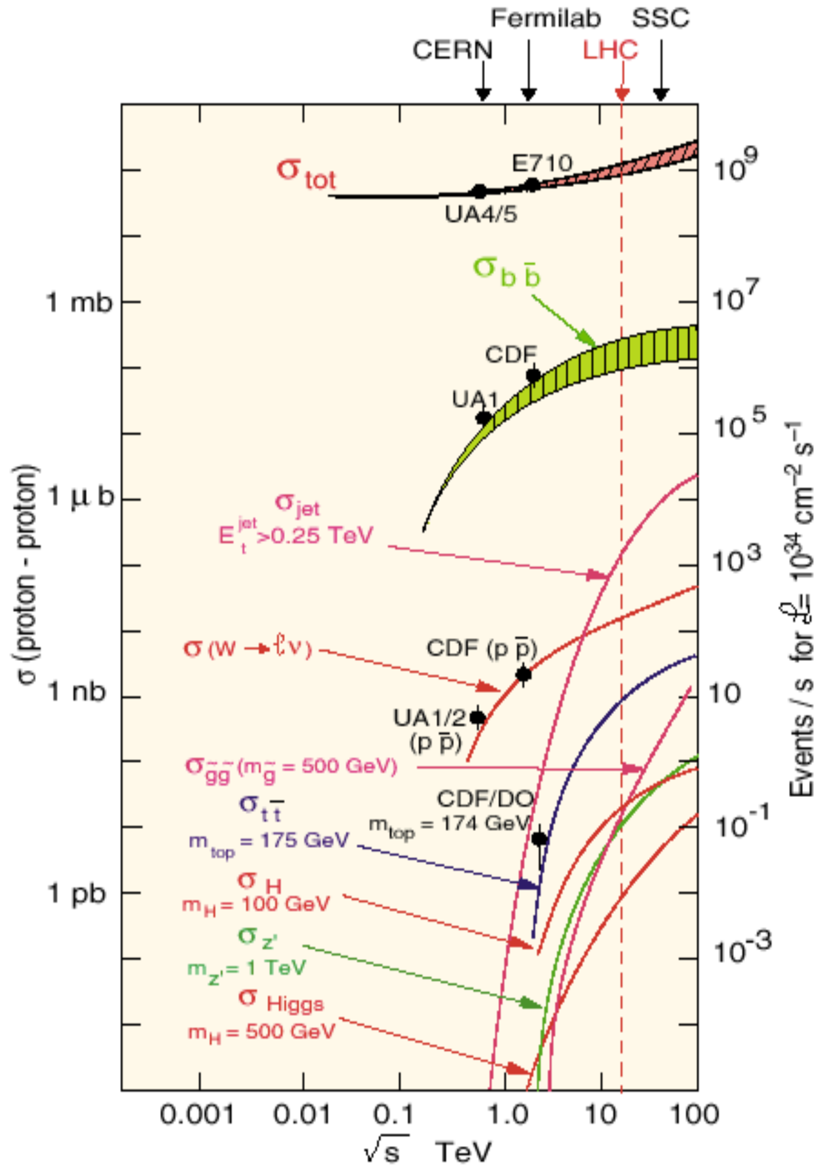
- Total cross section at LHC
  $\sigma(pp \rightarrow \text{anything}) \sim 0.1$ barn
- So a 1 pb Higgs cross section corresponds to one being *produced* every 10^{11} interactions!
  (further reduced by BR × efficiency)
- Experiments have to be designed so that they can separate such a rare signal process from the background
- Rate = $L \cdot \sigma$
  where luminosity L (units $cm^{-2}s^{-1}$) is a measure of how intense the beams are
  LHC design luminosity = 10^{34} $cm^{-2}s^{-1}$



Observables:

- Elastic differential cross section:

$$\frac{d\sigma_{el}}{dt}(s,t) = \frac{\pi}{s^2}|A(s,t)|^2$$

- Total, (integrated) elastic and inelastic cross sections:

$$\sigma_{tot}(s) = \frac{4\pi}{s}\mathrm{Im}A(s,t=0)$$

$$\sigma_{el}(s) = \int_{t_{min}}^{t_{max}} \frac{\sigma_{el}(s,t)}{dt}dt$$

$$\sigma_{in}(s) = \sigma_{tot}(s) - \sigma_{el}(s)$$

- The (forward) phase, $\boldsymbol{\rho}$:

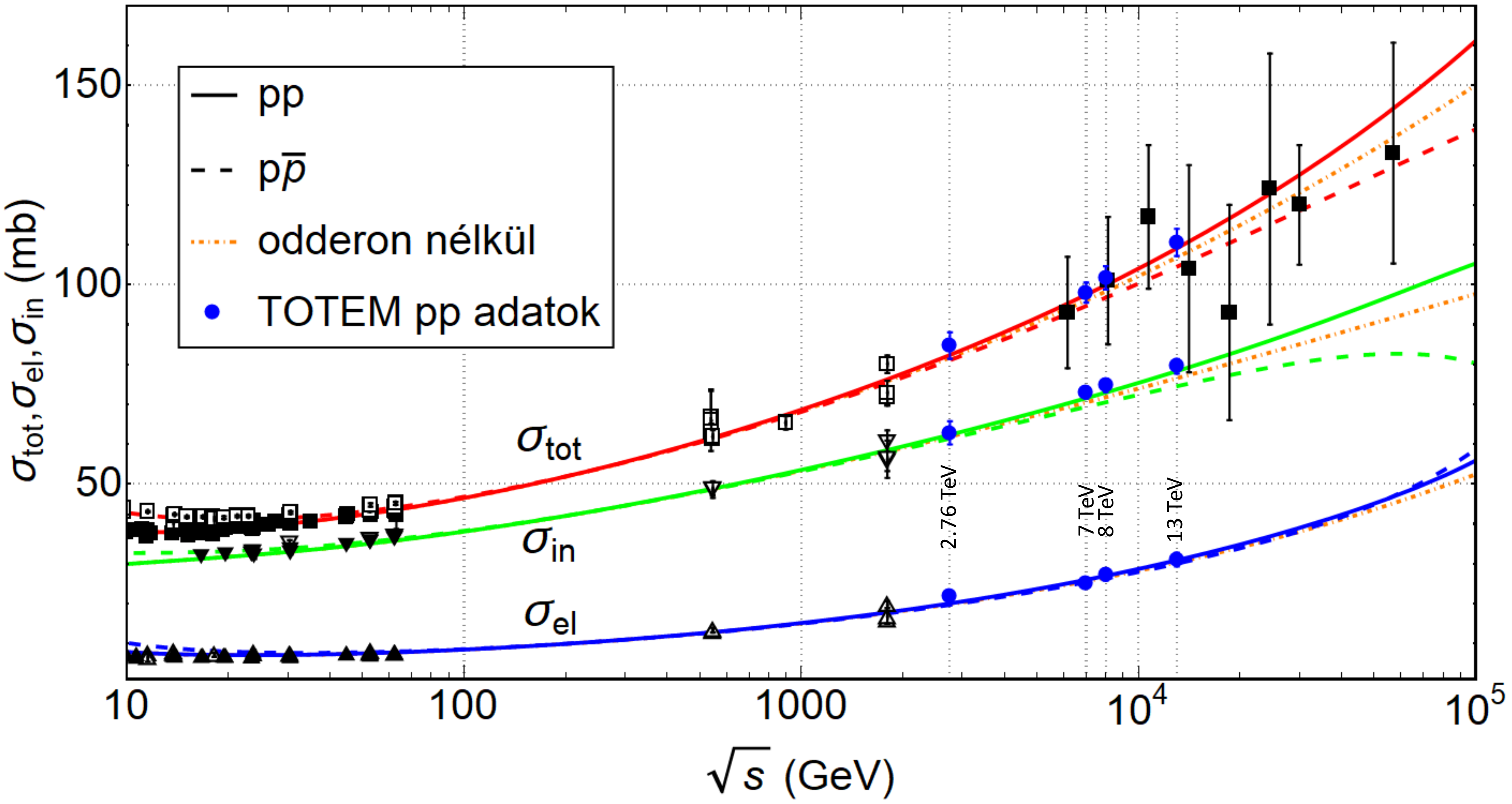
$$\rho(s) = \frac{\mathrm{Re}A(s,t=0)}{\mathrm{Im}A(s,t=0)}$$

- Slope of the (forward) slope ($B(s)\sim R^2(s)$):

$$B(s) = \frac{d}{dt}\left(\ln\frac{d\sigma_{el}}{dt}(s,t)\right)\Bigg|_{t=0}$$

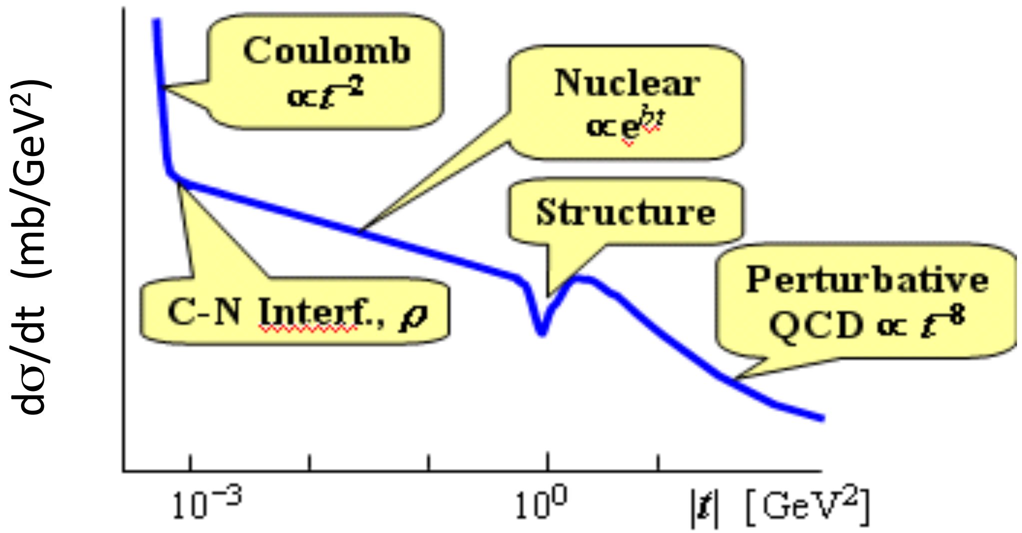
Total, elastic and inelastic cross-sections

- $30 \leq \sqrt{s} \leq 57000$ GeV



Elastic Scattering

$\sqrt{s}$ = 14 TeV prediction of BSW model



momentum transfer -t ~ $(p\theta)^2$

θ = beam scattering angle

p = beam momentum

$$\rho = \left.\frac{\mathrm{Re}(f_{el}(t))}{\mathrm{Im}(f_{el}(t))}\right|_{t\to 0}$$

$$\left.\frac{dN}{dt}\right|_{t=CNI} = L\pi|f_C + f_N|^2 \approx L\pi\left|-\frac{2\alpha_{EM}}{|t|} + \frac{\sigma_{tot}}{4\pi}(i+\rho)e^{-\frac{b|t|}{2}}\right|^2$$

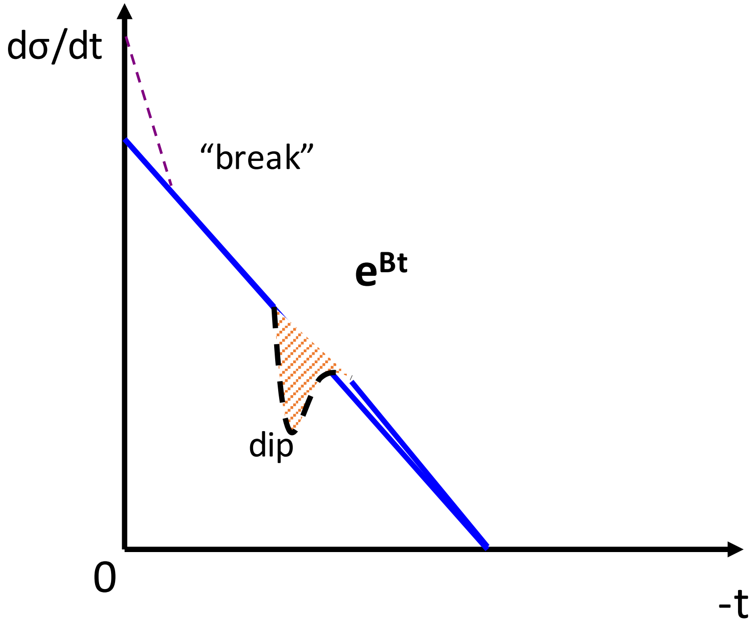
L, **σ_{tot}**, **b**, and **ρ** from FIT in CNI region (UA4)

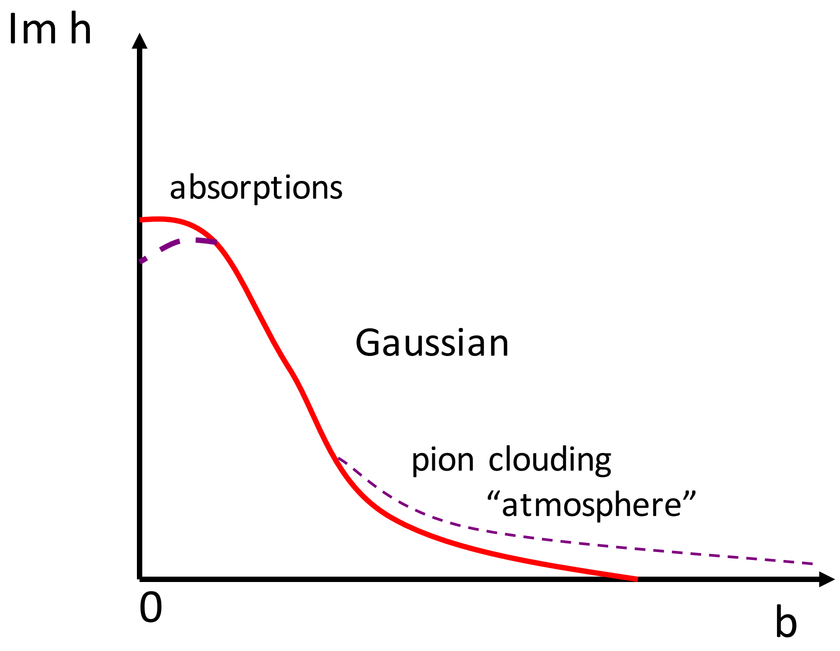
CNI region: $|f_C| \sim |f_N|$ → @ LHC: -t ~ 6.5 10^{-4} GeV^2; θ_{min}~3.4 μrad

(θ_{min}~120 μrad @ SPS)

1. **On-shell (hadronic) reactions (s,t, Q^2=m^2);**

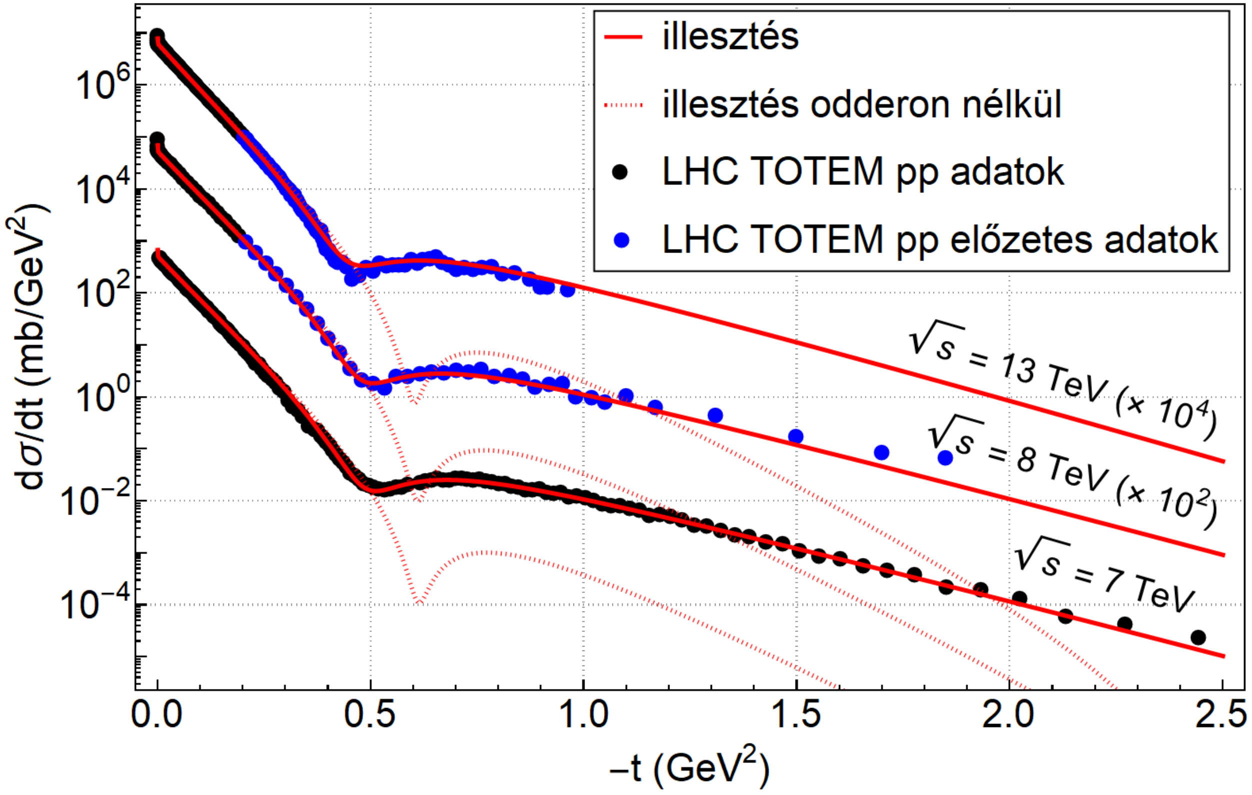
   t ←→ *b* **Fourier-Bessel transform dictionary:**



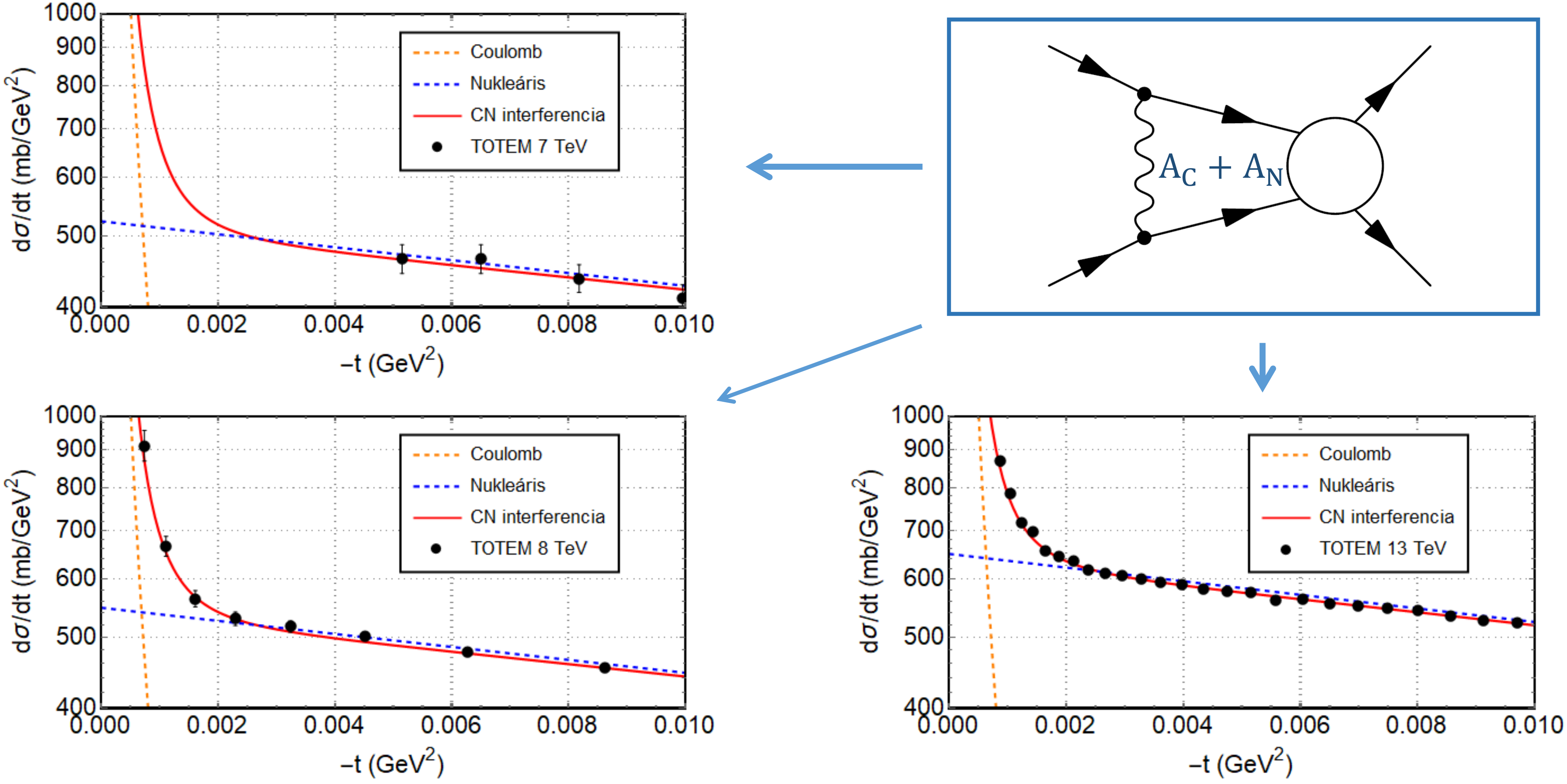


7 TeV : 8 TeV: 13 TeV:

$0.35 \leq |t| \leq 2.5 \text{ GeV}^2$ $0.0007 \leq |t| \leq 1.9 \text{ GeV}^2$ $0.0008 \leq |t| \leq 1 \text{ GeV}^2$



Coulomb-nuclear interference



f & ω reggeons:

$$A_{pp}^{p\bar{p}}(s,t) = \mathbf{A_f}(s,t) \pm \mathbf{A_\omega}(s,t) + A_P(s,t) \pm A_O(s,t)$$

$$\mathbf{A_f}(s,t) = a_f e^{b_f t} e^{-\frac{i\pi\alpha_f}{2}} (s/s_{0f})^{\alpha_f}$$

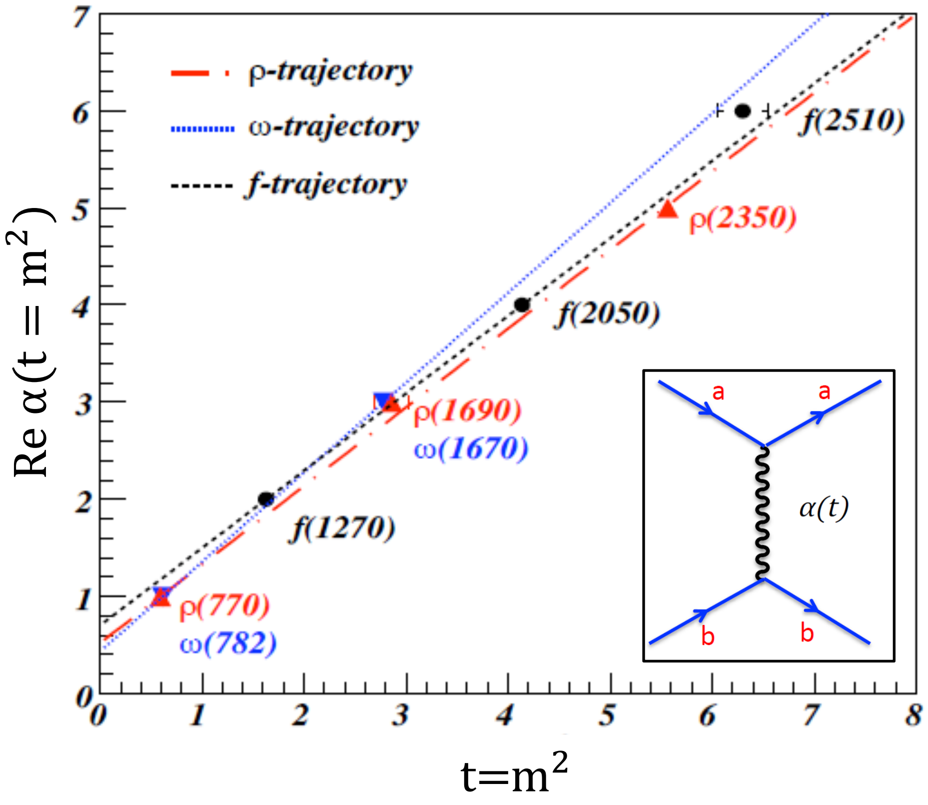
$$\mathbf{A_\omega}(s,t) = i a_\omega e^{b_\omega t} e^{-\frac{i\pi\alpha_\omega}{2}} (s/s_{0\omega})^{\alpha_\omega}$$

$$\alpha_f \equiv \alpha_f(t) = 0.703 + 0.84t$$

$$\alpha_\omega \equiv \alpha_\omega(t) = 0.435 + 0.93t$$

Fitted parameters:

$$a_f, b_f, s_{0f}, a_\omega, b_\omega, s_{0\omega}$$



Chew-Frautschi plot.

Pomeron

$$A_{pp}^{p\bar{p}}(s,t) = A_f(s,t) \pm A_\omega(s,t) + \mathbf{A_P}(s,t) \pm A_O(s,t)$$

- **Dipole Pomeron :**

$$\mathbf{A_P}(s,t) = i\frac{a_P s}{b_P s_{0P}}\left[r_{1P}^2(s)e^{r_{1P}^2(s)[\alpha_P - 1]} - \varepsilon_P r_{2P}^2(s)e^{r_{2P}^2(s)[\alpha_P - 1]}\right]$$

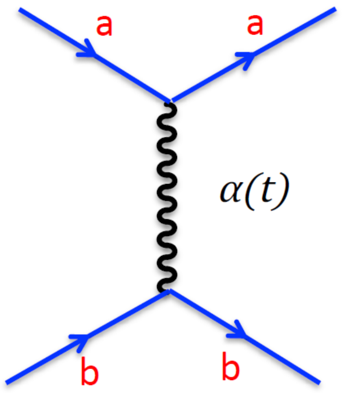
$$r_{1P}^2(s) = b_P + L_P - i\pi/2$$

$$r_{2P}^2(s) = L_P - i\pi/2$$

$$L_P \equiv \ln(s/s_{0P})$$

- **Pomeron trajectory:**

$$\alpha_P \equiv \alpha_P(t) = 1 + \delta_P + \alpha_{1P}t$$



- **Fitted paramers:**

$$a_P,\ b_P,\ \varepsilon_P,\ s_{0P},\ \delta_P,\ \alpha_{1P}$$

Odderon

$$A_{pp}^{p\bar{p}}(s,t) = A_f(s,t) \pm A_\omega(s,t) + A_P(s,t) \pm \mathbf{A_O}(s,t)$$

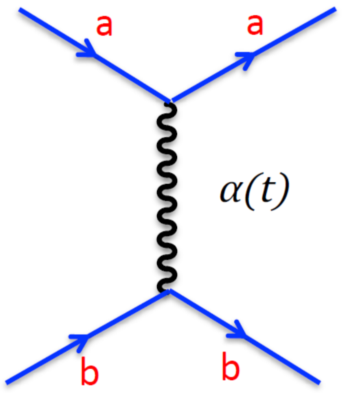
- **Odderon contribution:**

$$\mathbf{A_O}(s,t) = \frac{a_O s}{b_O s_{0O}} \left[r_{1O}^2(s) e^{r_{1O}^2(s)[\alpha_O - 1]} - \varepsilon_O r_{2O}^2(s) e^{r_{2O}^2(s)[\alpha_O - 1]} \right]$$

$$r_{1P}^2(s) = b_O + L_O - i\pi/2 \qquad r_{2O}^2(s) = L_O - i\pi/2 \qquad L_O \equiv \ln(s/s_{0O})$$

- **Odderon trajectory:**

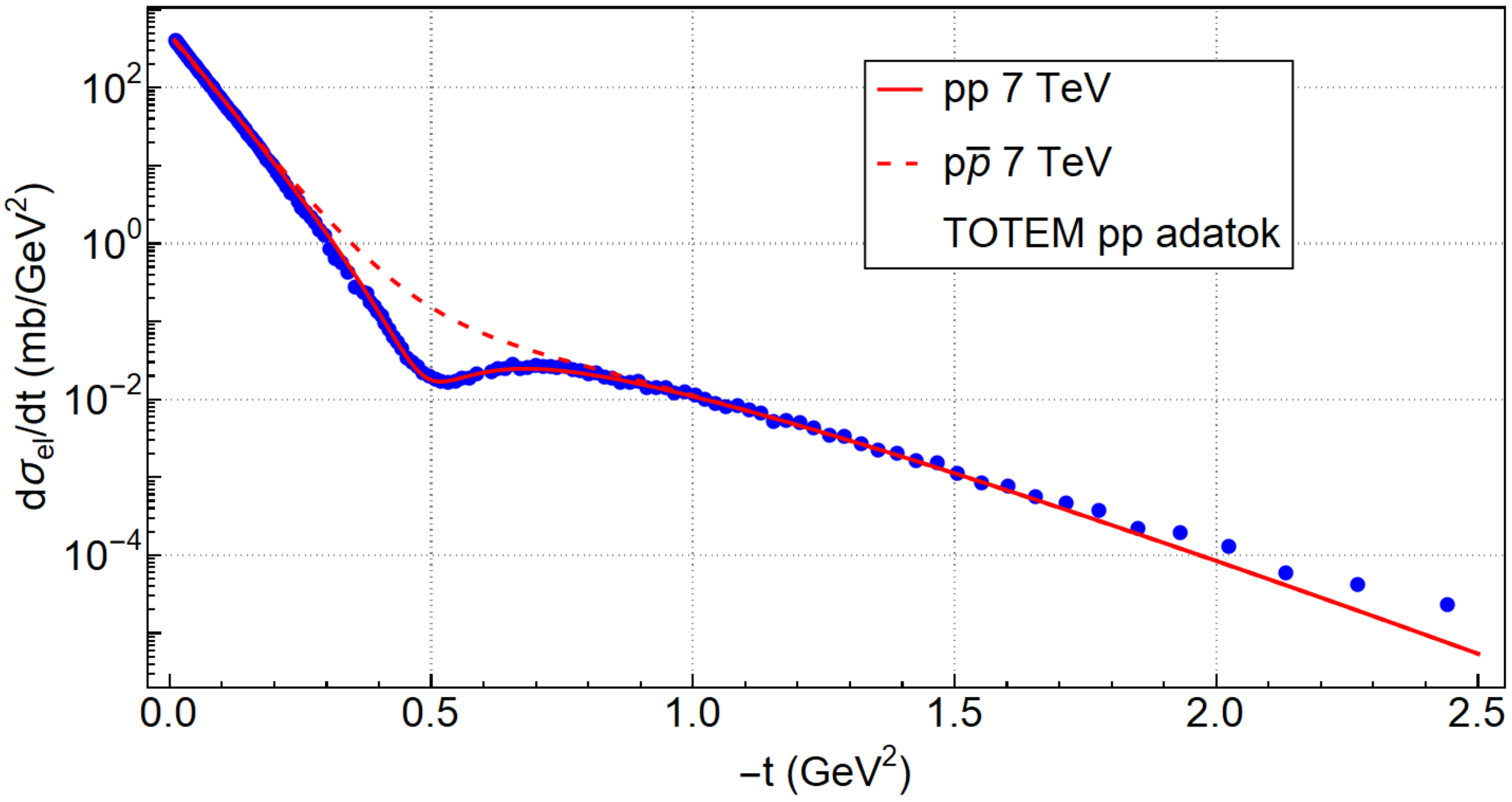
$$\alpha_O \equiv \alpha_O(t) = 1 + \delta_O + \alpha_{1O} t$$



- **Fitted parameters:**

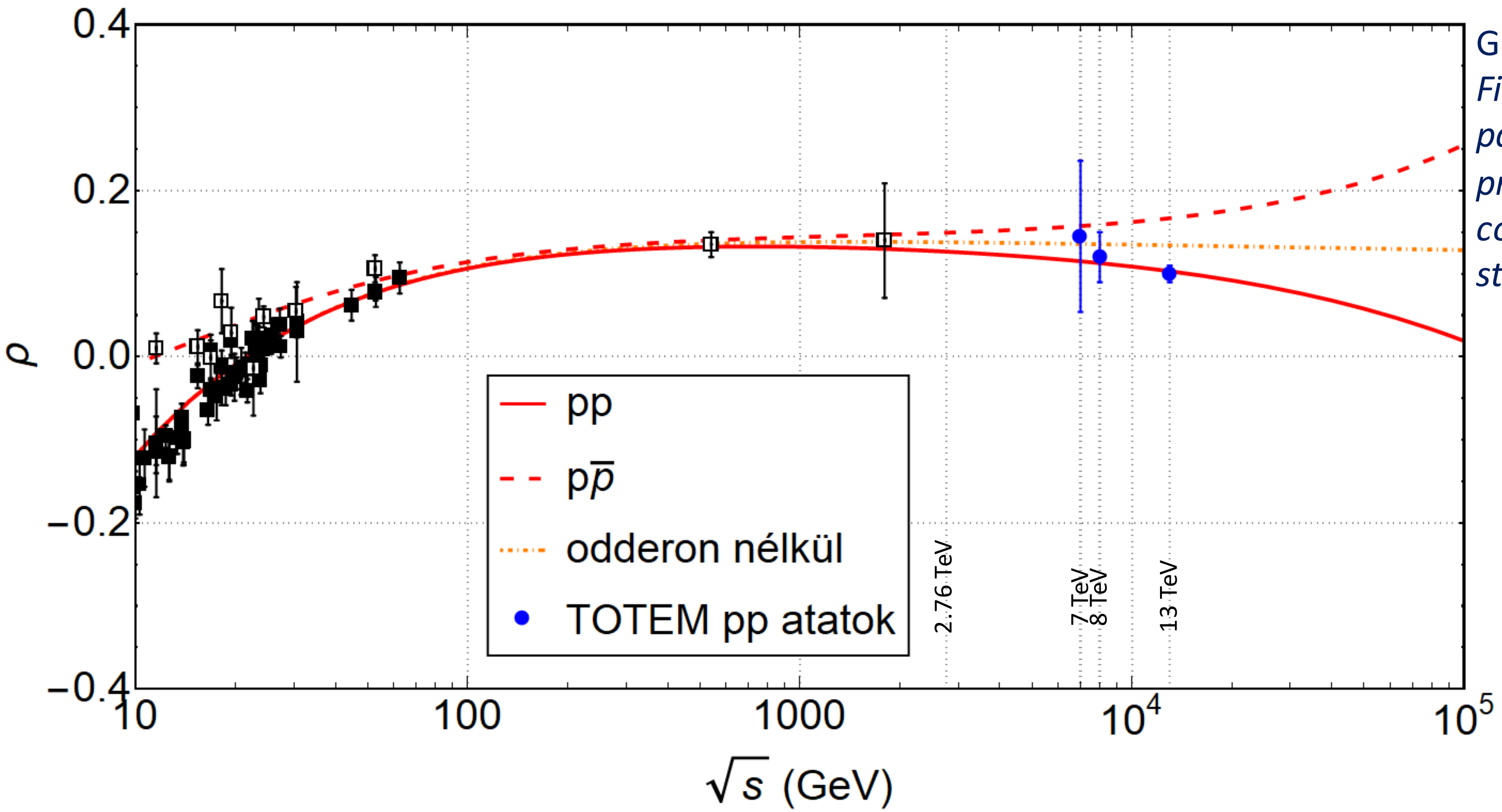
$$a_O, b_O, \varepsilon_O, s_{0O}, \delta_O, \alpha_{1O}$$

Fit to the differencial cross section



The ratio ρ (phase)

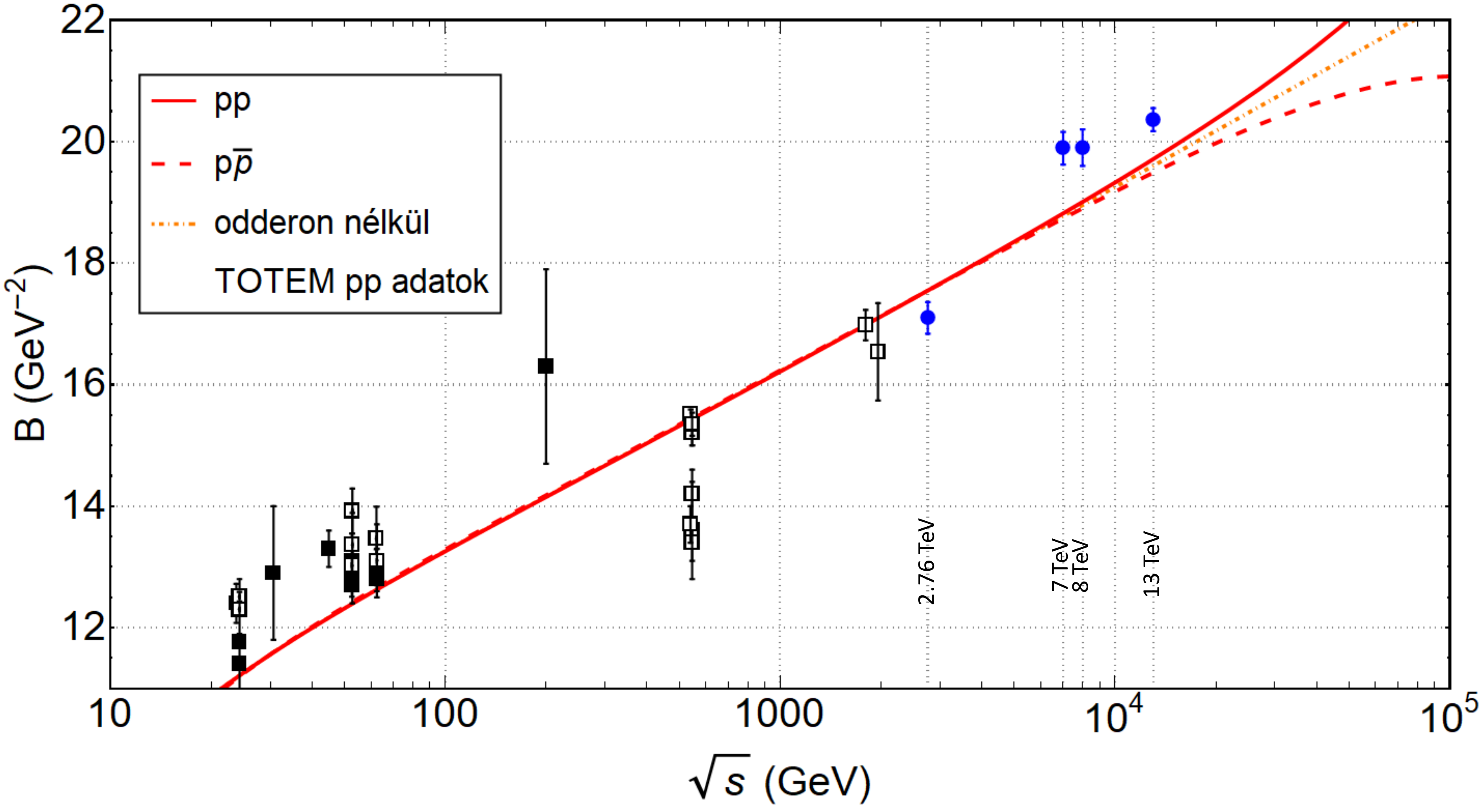
- $30 \leq \sqrt{s} \leq 13000$ GeV.



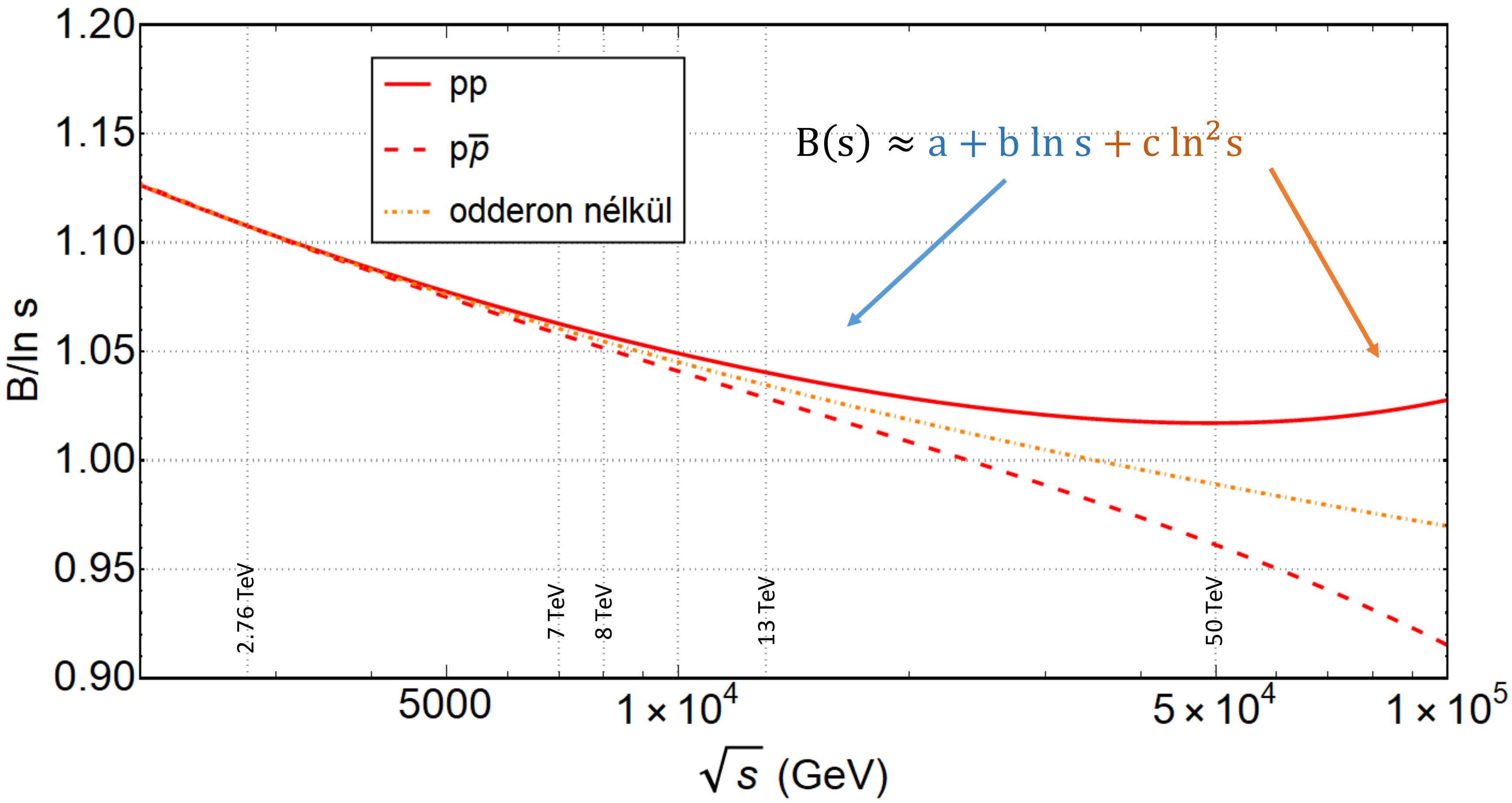
G. Antchev (TOTEM Collab.): *First determination of the ρ parameter at √s = 13 TeV – probing the existence of a colourless three-gluon bound state.* **CERN-EP-2017-335**

Forward elastic slope B(s)

- $B(s) \sim \ln s \rightarrow \ln^2 s\ ?!$



„Scaled”: B(s)/Ln s



Fitted values of the parameters

CERN ROOT MINUIT2 Migrad fit

Pomeron		Odderon		f- és ω-reggeon	
a_P	**250** (rögzített)	a_O	**0.115449** ± 0.00304799	a_f	**-13** (fixed)
b_P	**14.7362** ± 0.276352	b_O	**0.711359** ± 0.00201975	b_f	**0** (fixed)
δ_P	**0.0514965** ± 0.000694922	δ_O	**0.479593** ± 0.00271713	s_{0f}	**1** (fixed)
α_{1P}	**0.336121** ± 0.00209166	α_{1O}	**0.239799** ± 0.0034584	a_ω	**9** (fixed)
ε_P	**0.0139516** ± 0.000344159	ε_O	**1.44154** ± 0.0011131	b_ω	**0** (fixed)
s_{0P}	**100** (rögzített)	s_{0O}	**100** (rögzített)	$s_{0\omega}$	**1**)fixed)
$\mathrm{NDF} = 57$		$\chi^2 = 49.2$		$\chi^2/\mathrm{NDF} = 0.86$	

Local dispersion relations (Bronzan, Kane, Sukhatme, 1974);

$$\rho(s) = \frac{\mathrm{ReA}(s,t=0)}{\mathrm{ImA}(s,t=0)} = \frac{d\,Ln\,\sigma_{tot}(s)}{d\,Ln\,s}.$$

Hivatkozások

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THANK YOU !