

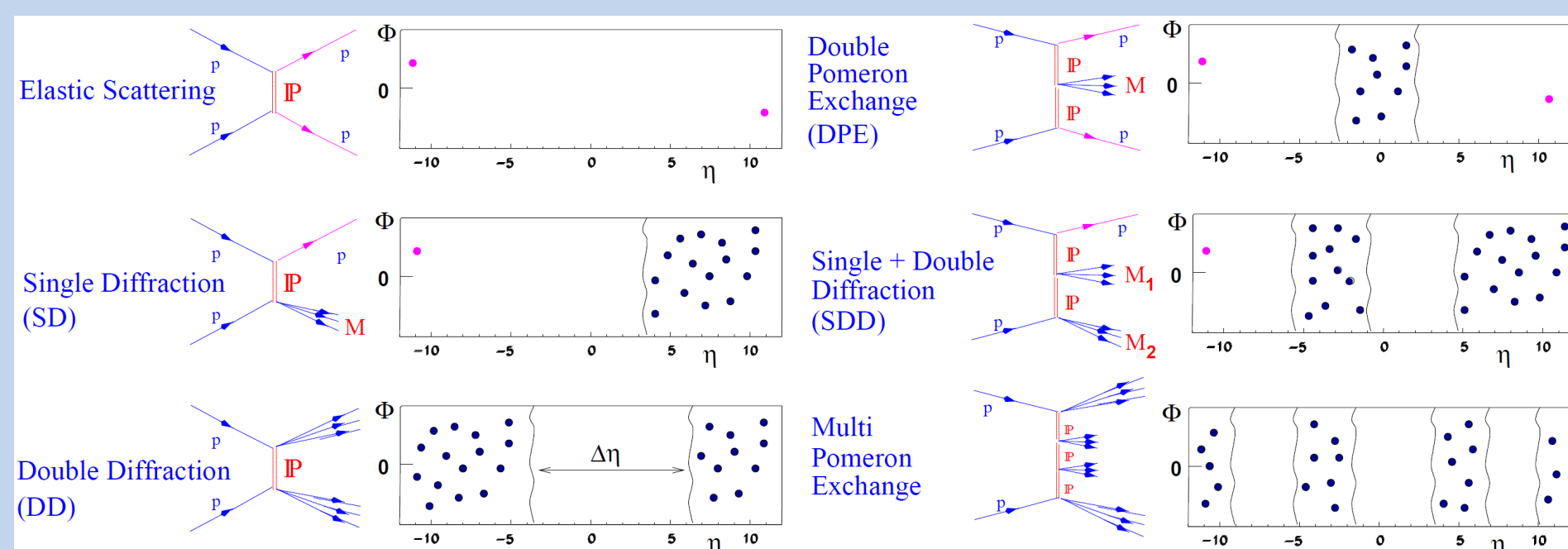
The TOTEM Experiment at the LHC

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TOTEM Physics

- Complements general purpose experiments
- Records events in the very forward region
- Measures σ_{tot} with large precision
- Measures $\frac{d\sigma_{\text{el}}}{dt}$ over wide $|t|$ region
- Studies diffractive processes comprehensively
- Event classification in TOTEM:



- Measures elastic and inelastic rates:

$$N_{\text{el}}, N_{\text{inel}}, \left. \frac{dN_{\text{el}}}{dt} \right|_{t=0}$$

- cross section from rate & CMS luminosity:

$$\mathcal{L} \frac{d\sigma}{dt} = \frac{dN}{dt}$$

- Total cross section using differential elastic cross sections and the optical theorem

$$\sigma_{\text{tot}}^2 = \frac{16\pi(\hbar c)^2}{1 + \rho^2} \left. \frac{d\sigma_{\text{el}}}{dt} \right|_{t=0}$$

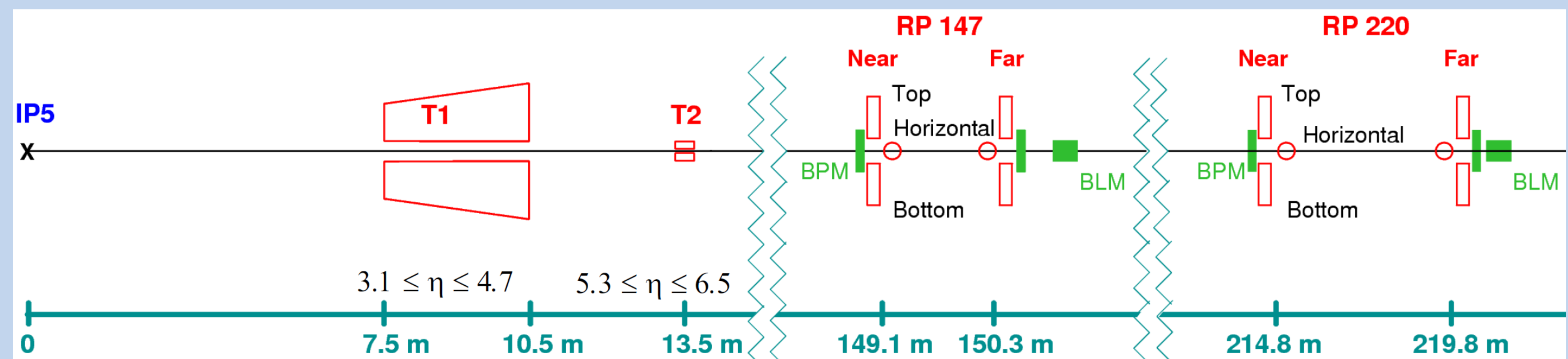
- Luminosity independent method:

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

- ρ : connected to forward nuclear elastic scattering amplitude via $\mathcal{R}(f_{\text{c.m.}}(0))/\mathcal{I}(f_{\text{c.m.}}(0))$
- From COMPETE theoretical prediction
- Since $\rho = 0.14^{+0.01}_{-0.08}$, its impact is small.

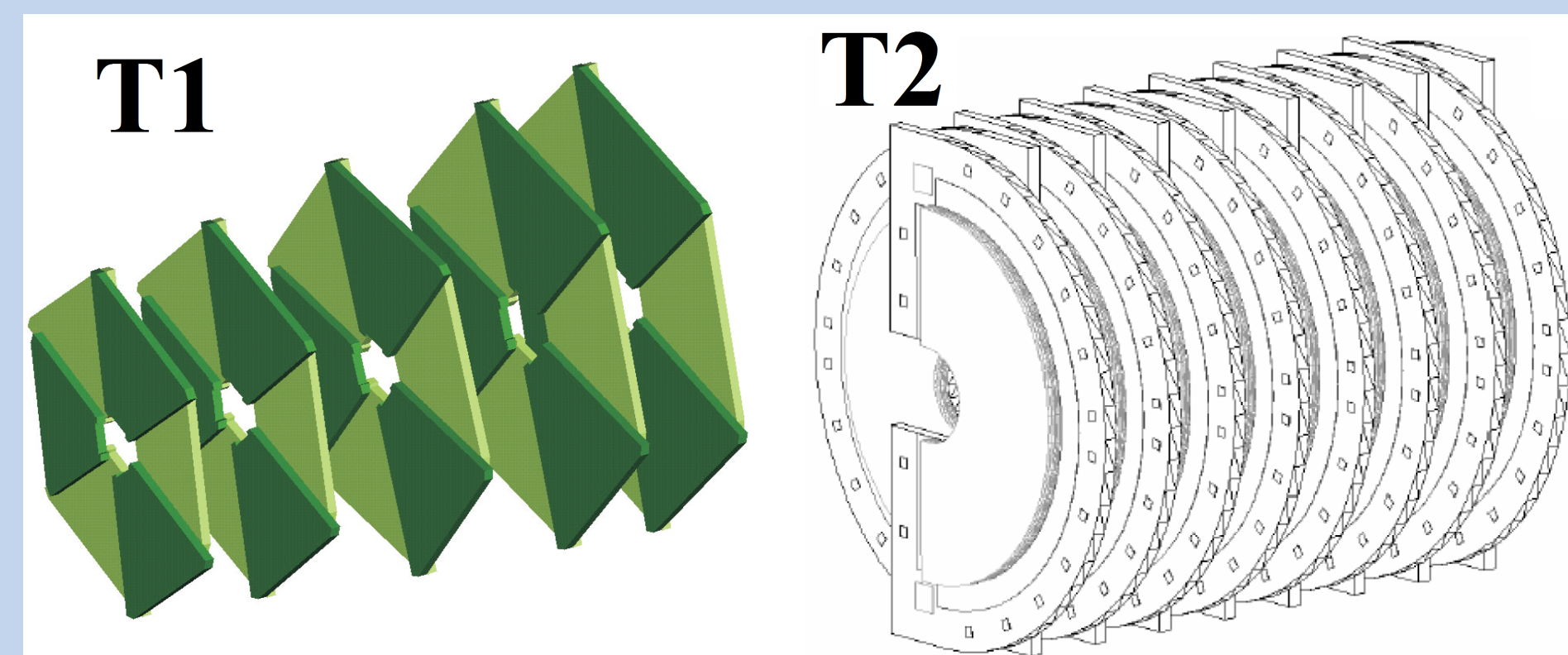
The TOTEM detectors

- Apparatus is located on both sides of the interaction point IP5, shared with CMS
- T1 and T2 tracking detectors, embedded inside the forward region of CMS
- “Roman Pot” (RP) stations about ± 147 m and ± 220 m from IP5, very high pseudorapidity
- Tracking down to a few μrad in scattering angle Θ or 12 in pseudorapidity $\eta = -\ln \tan(\Theta/2)$
- Full 2π acceptance in azimuthal angle ϕ
- Momentum transfer squared region $10^{-3} \text{ GeV}^2 < |t| < 10 \text{ GeV}^2$



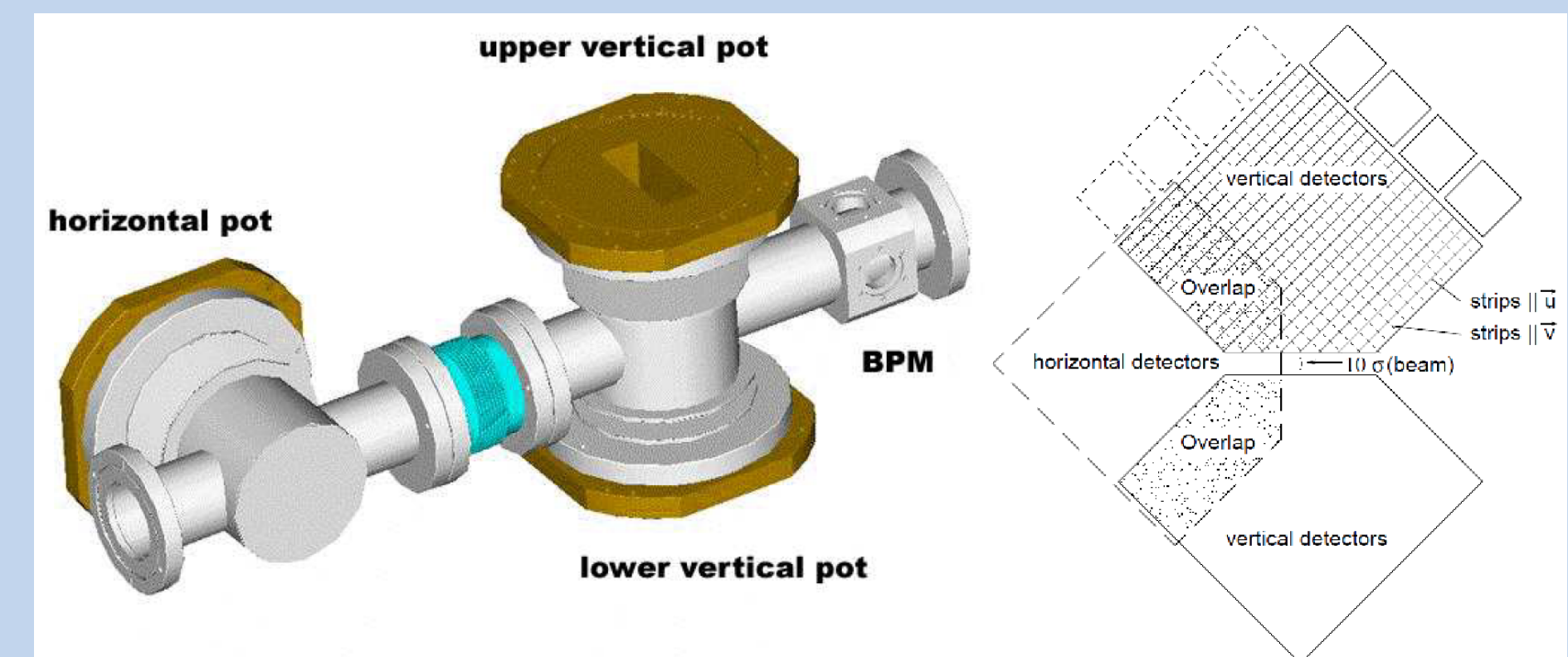
The Telescopes

- T1: $3.1 < |\eta| < 4.7$, T2: $5.3 < |\eta| < 6.5$ on both sides of IP5
- T1: 5 equally spaced planes of six trapezoidal “Cathode Strip Chambers” (CSC)
- T2: 20 almost circular “Gas Electron Multiplier” (GEM) detectors per arm



The Roman Pot detectors

- Very close to the beam, in secondary vacuum
- 4 stations, 2 units per station, 3 pots per unit
- 10 planes per pot, 512 “edgeless” Si strips each
- Resolution of $16 \mu\text{m}$
- Relative alignment: common tracks, $10 \mu\text{m}$ precision

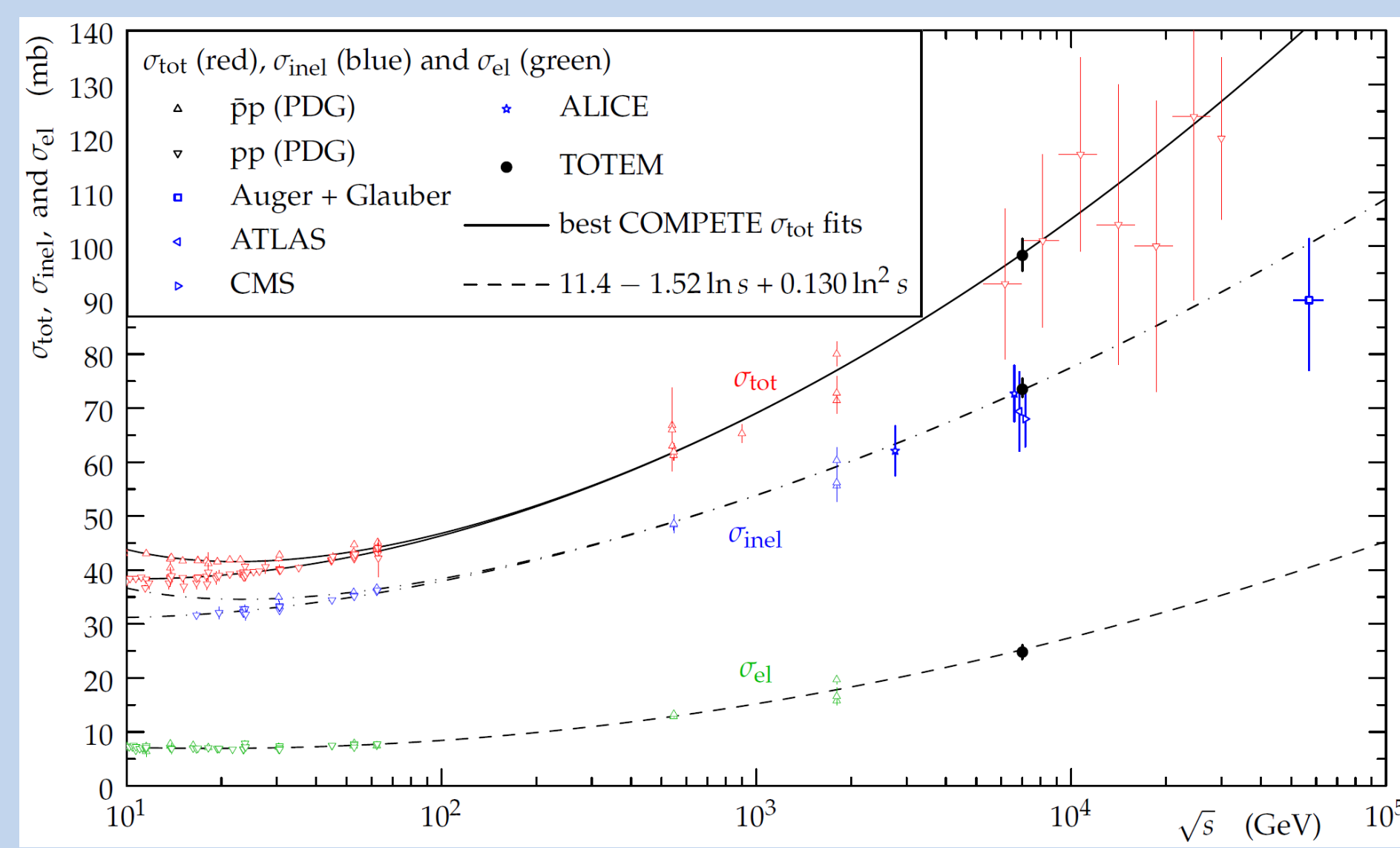


TOTEM Optics

- TOTEM measurements need low $|t|$ values
- Need to approach beam as close as possible
- Roman pots far from IP5: good understanding of LHC optics needed
- Beam divergence $\propto 1/\sqrt{\beta^*}$ needs to be small
- High β^* : low $|t|$ acceptance
- High β^* optics are favoured
- Regular LHC optics $\beta^* = 3.5$ m: $|t| < 1 \text{ GeV}^2$
- Dedicated $\beta^* = 90$ m optics: $|t| > 0.03 \text{ GeV}^2$
- Ultimate $\beta^* = 1540$ m: $|t| > 0.002 \text{ GeV}^2$

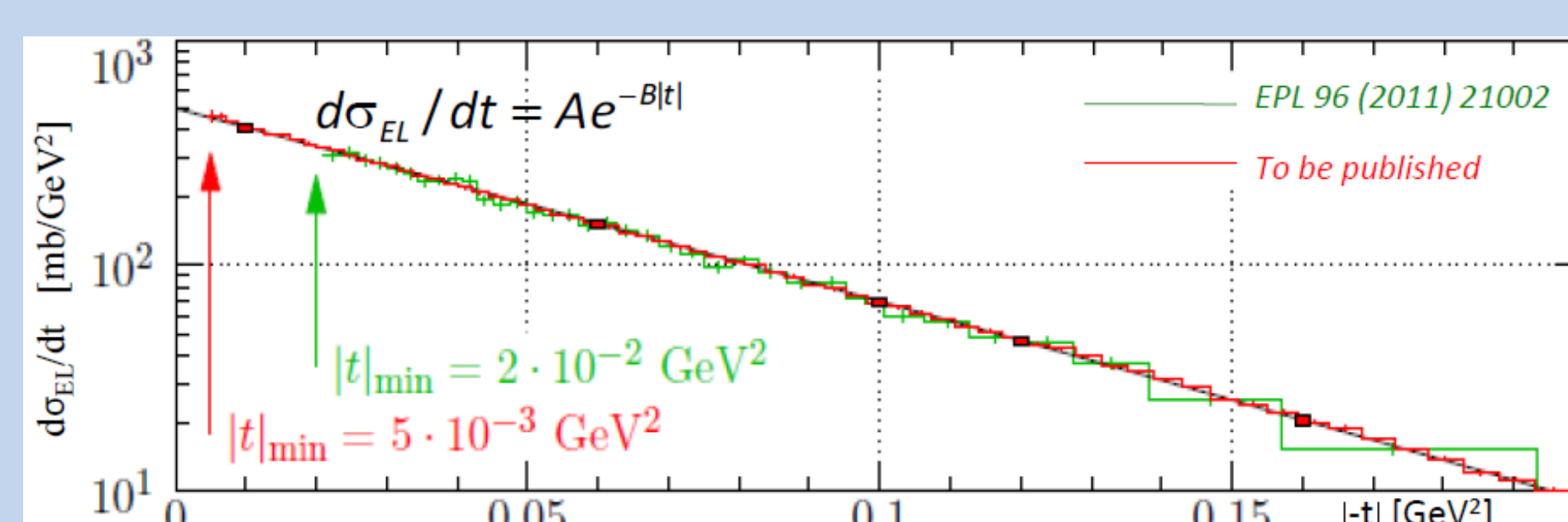
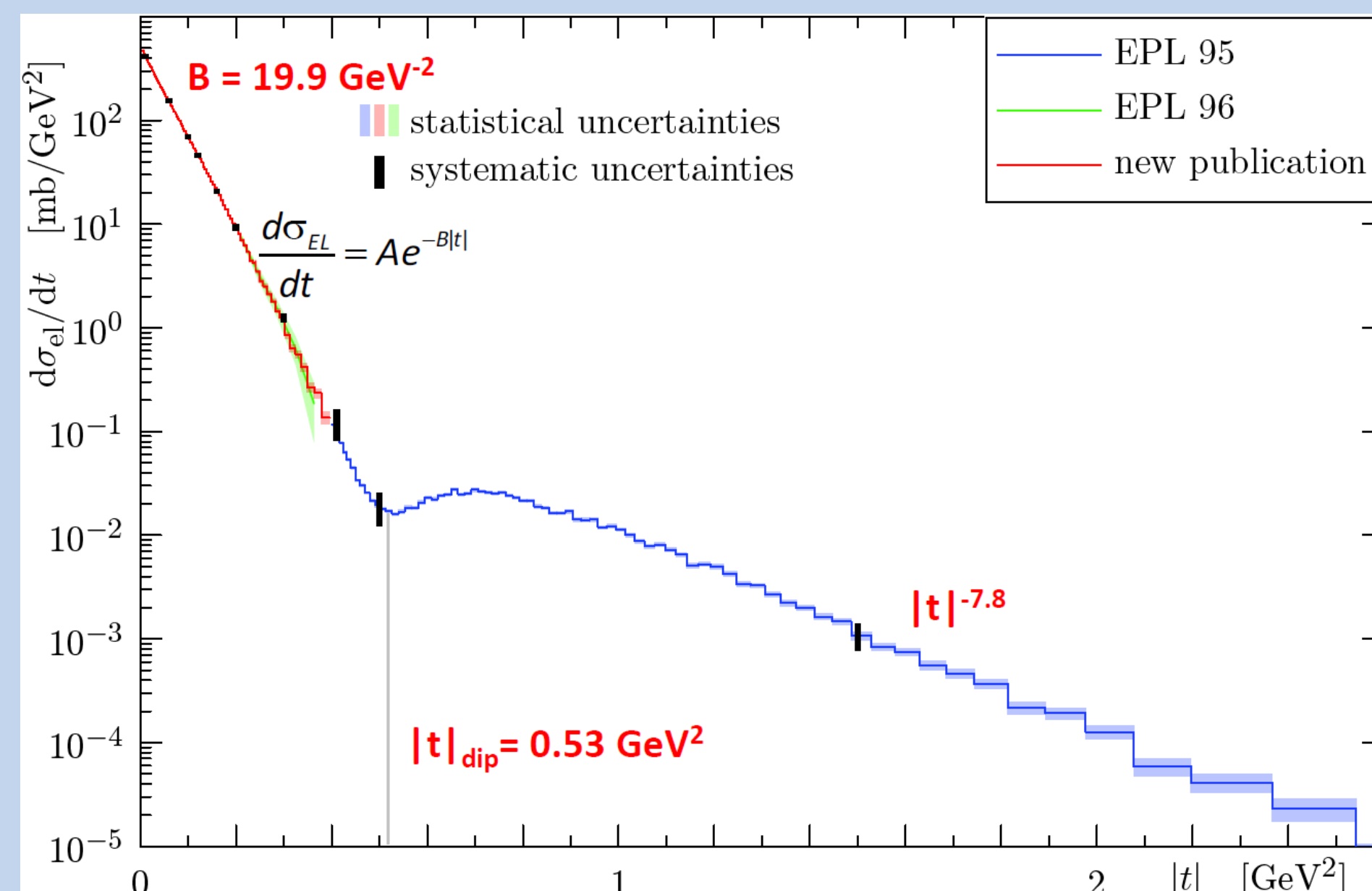
Total cross section results

- $\sqrt{s} = 7 \text{ TeV}$, dedicated $\beta^* = 90$ m optics
- $d\sigma_{\text{el}}/dt$ measured, see box on the right
- After extrapolation to $|t| = 0$: $\sigma_{\text{el}} = (24.8 \pm 0.2^{\text{stat}} \pm 1.2^{\text{syst}}) \text{ mb}$
- Via optical theorem (and CMS luminosity): $\sigma_{\text{tot}} = (98.3 \pm 0.2^{\text{stat}} \pm 2.8^{\text{syst}}) \text{ mb}$
- Inelastic cross section from the above: $\sigma_{\text{inel}} = (73.5 \pm 0.6^{\text{stat}} \pm 1.8^{\text{syst}}) \text{ mb}$
- Good agreement with overall COMPETE fit
- Ref.: Europhys. Lett. **96**, 21002 (2011)
- New results to come: paper in prep.



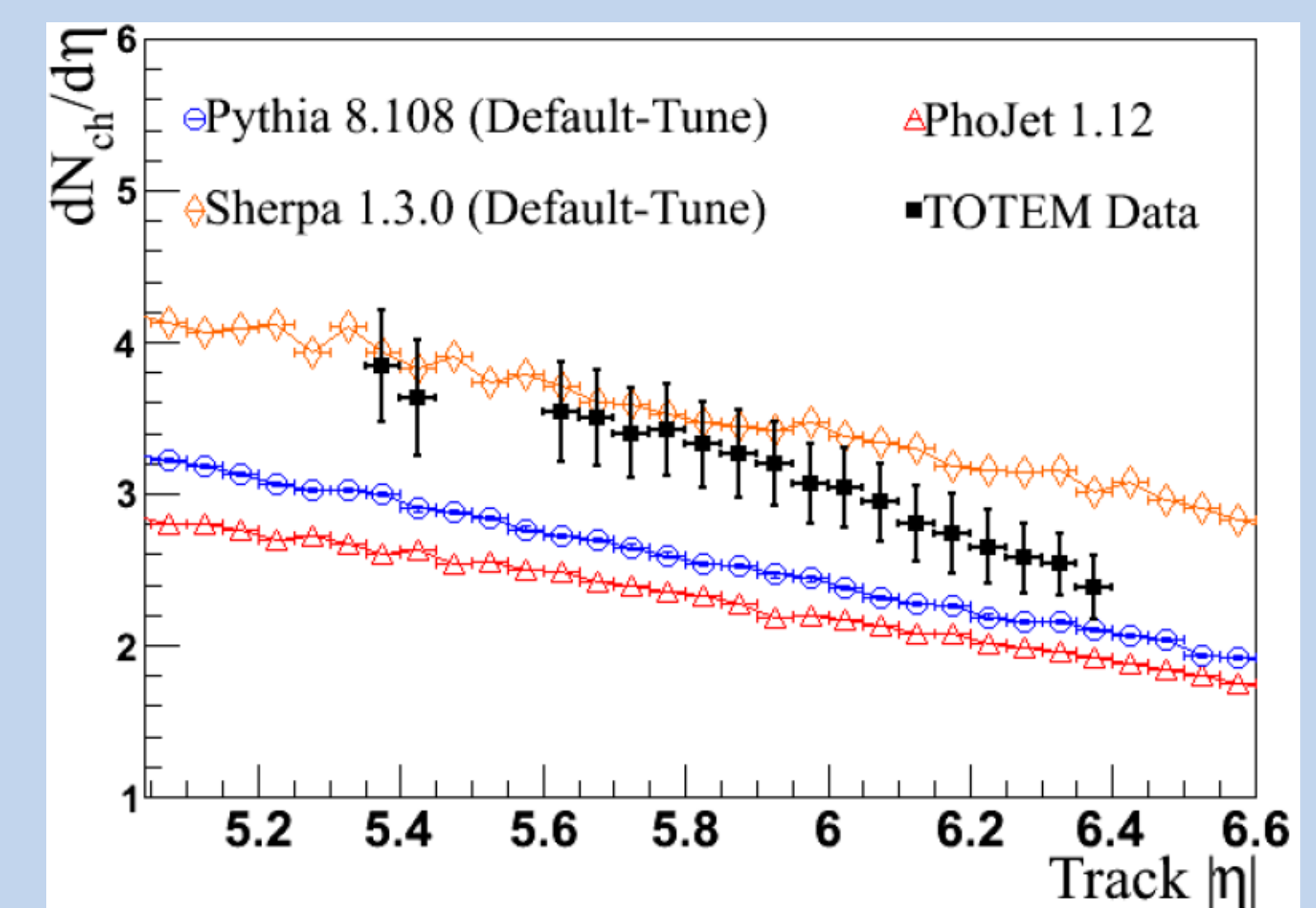
$d\sigma_{\text{el}}/dt$ results

- $\sqrt{s} = 7 \text{ TeV}$, regular & dedicated optics
- Low $|t|$: exponential $\frac{d\sigma_{\text{el}}}{dt} = \left. \frac{d\sigma_{\text{el}}}{dt} \right|_{t=0} e^{-B|t|}$
- In the $|t|$ range $0.36 - 0.47 \text{ GeV}^2$ [1]: $B = (23.6 \pm 0.5^{\text{stat}} \pm 0.4^{\text{syst}}) \text{ GeV}^{-2}$
- For $|t|$ in $0.02 - 0.33 \text{ GeV}^2$ [2]: $B = (20.1 \pm 0.2^{\text{stat}} \pm 0.3^{\text{syst}}) \text{ GeV}^{-2}$
- New results for $|t|$ in $0.005 - 0.2 \text{ GeV}^2$ [3]: $B = (19.9 \pm 0.04^{\text{stat}} \pm 0.3^{\text{syst}}) \text{ GeV}^{-2}$
- Significant diffractive minimum at $|t| = (0.53 \pm 0.01^{\text{stat}} \pm 0.01^{\text{syst}}) \text{ GeV}^2$
- For $|t| > 1.5 \text{ GeV}^2$: power law behaviour with exponent $-7.8 \pm 0.3^{\text{stat}} \pm 0.1^{\text{syst}}$
- Strong discriminative power on models
- [1] Europhys. Lett. **95**, 41001 (2011)
- [2] Europhys. Lett. **96**, 21002 (2011)
- [3] New paper in preparation



$dN_{\text{ch}}/d\eta$ results

- $\sqrt{s} = 7 \text{ TeV}$, η range $5.3 - 6.4$, regular optics
- Measurement based on T2 trigger
- Extends measurements of the other LHC experiments to unexplored large η region
- Event selection: at least one charged particle with transverse momentum above $40 \text{ MeV}/c$
- More than 99% of non-diffractive processes
- Single and double diffractive processes with diffractive masses above $\sim 3.4 \text{ GeV}/c^2$
- $dN_{\text{ch}}/d\eta$ found to decrease with $|\eta|$
- No MC generator found to fully describe the data within given uncertainty
- Ref.: Europhys. Lett. **98**, 31002 (2012)



Outlook, prospects

- New measurements at $\beta^* = 90$ m: $|t| > 0.005 \text{ GeV}^2$ region
- More precise σ_{inel} , σ_{el} and σ_{tot} measurement
- Luminosity independent σ_{tot} measurement
- Measurements at higher energies
- Joined $dN/d\eta$ with the large experiments, spanning the largest η region
- Common trigger & data taking with CMS: already started!