TOTEM physics results

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on behalf of the TOTEM collaboration

LHC Working Group on Forward Physics and Diffraction
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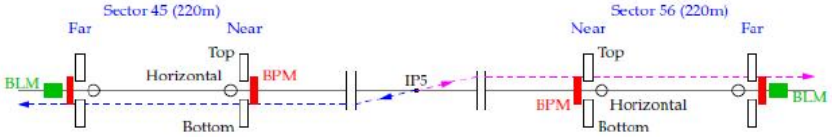
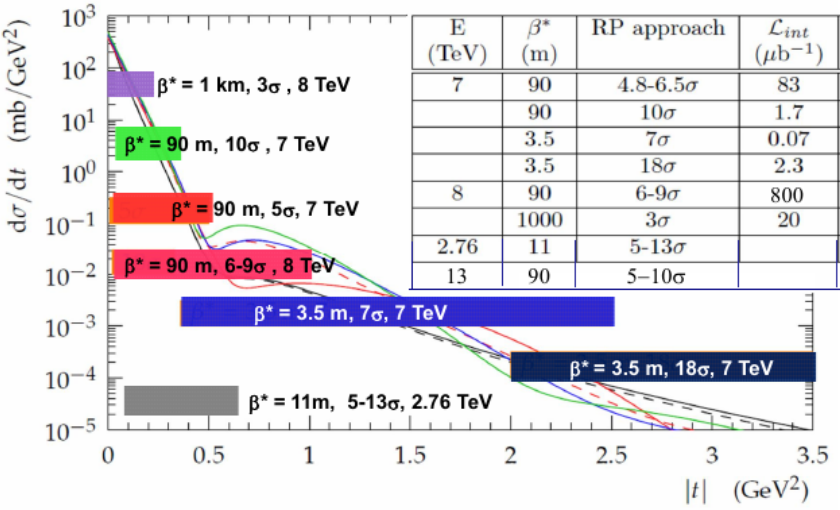
Elastic pp scattering: selection & data sets

Selected based on topology, low $|\xi|$, collinearity & vertex



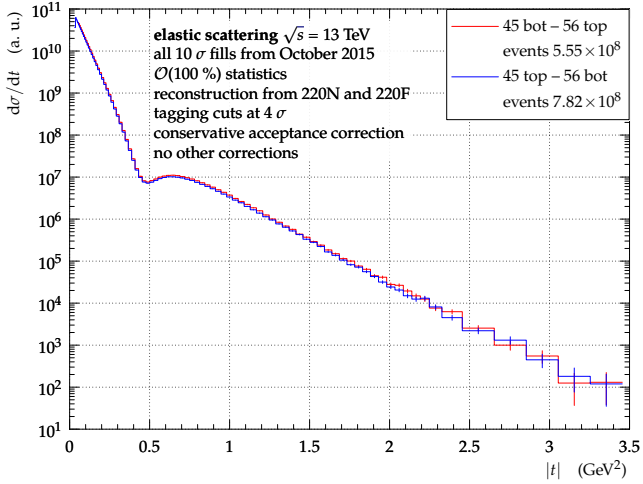
Key issues: RP alignment & optics

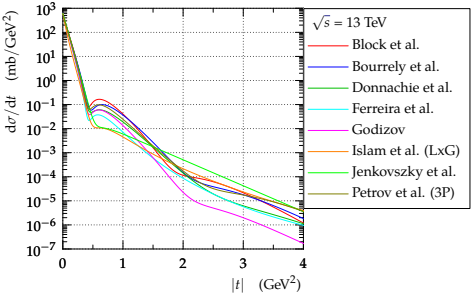
Data sets at different conditions to measure over as wide |t|-range as possible



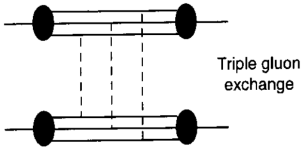
E (TeV)	β^* (m)	RP approach	$\mathcal{L}_{int}$ (μb^{-1})	t range (GeV^2)	Elastic events
7	90	4.8-6.5σ	83	$7\cdot10^{-3}$ - 0.5	1M
	90	10σ	1.7	0.02 - 0.4	14k
	3.5	7σ	0.07	0.36 - 3	66k
	3.5	18σ	2.3	2 - 3.5	10k
8	90	6-9σ	800	0.01 - 1	7M
	1000	3σ	20	$6\cdot10^{-4}$ - 0.2	0.4M
2.76	11	5-13σ		0.05-0.6	45k
13	90	5–10σ			~ 3000M

- very preliminary, but already very strong results





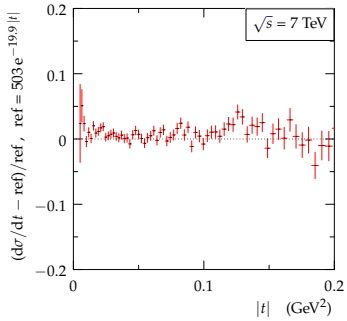
- high-$|t|$ data: no structures!
  - rules out many models
  - rules out physics mechanism: “optical” models
  - physics interpretation: transition between diffraction and pQCD

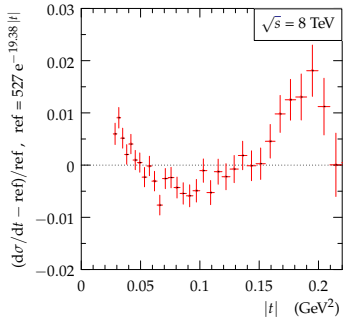


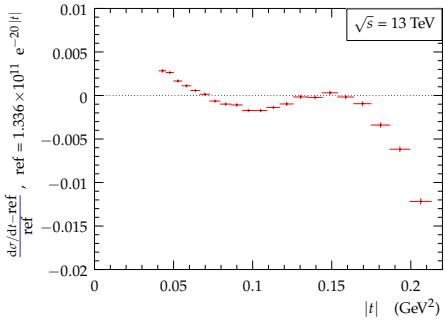
- magnify deviations from pure exponential $\Rightarrow$ plot:

$$\frac{\mathrm{d}\sigma/\mathrm{d}t - \mathrm{ref}}{\mathrm{ref}}$$

- $\beta^* = 90$ m measurements at different energies (stat. unc. only):





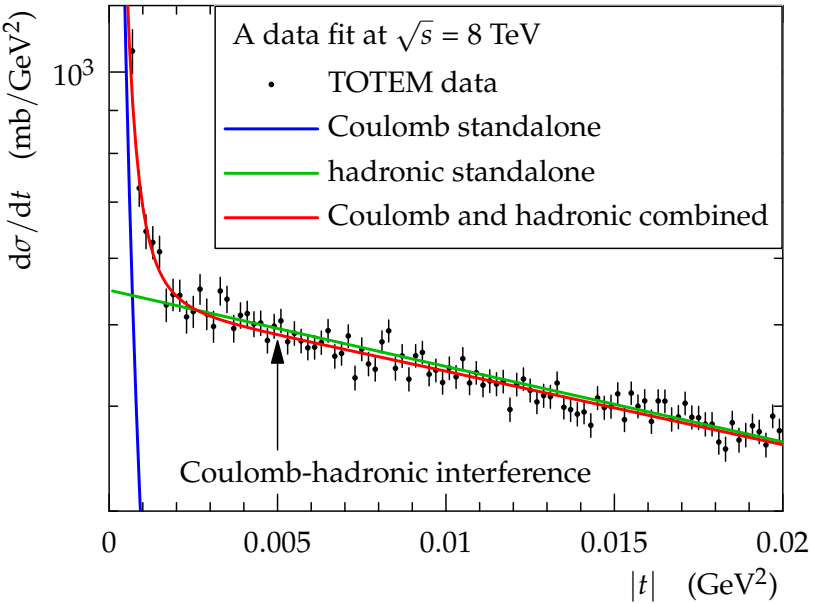


- non-exponentiality observed at 8 and 13 TeV!
  - non-exponentiality of the observed cross-section:

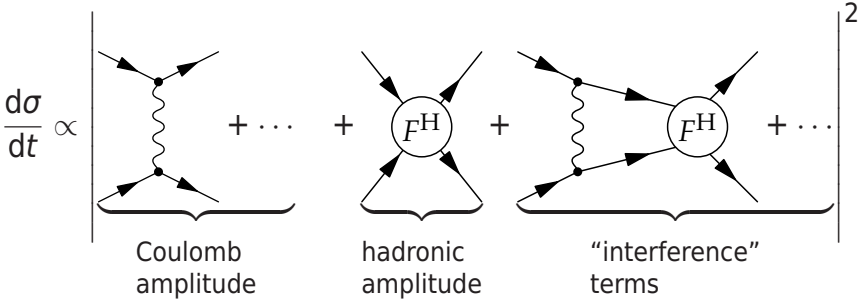
$$\mathrm{d}\sigma/\mathrm{d}t = \mathrm{nuclear} + \mathrm{Coulomb} + \mathrm{interference}$$

  - details studied at 8 TeV: CERN-PH-EP-2015-325

- data with $\beta^* = 1000$ m optics
  - RPs at 3 σ_{beam}
  - $|t|^{\text{min}} \approx 6 \cdot 10^{-4}$ GeV^2



- observed cross-section



- interference formula: summation for practical applications
  - *simplified West-Yennie (SWY)*: QFT framework, traditional but heavy simplifications (constant hadronic phase, constant slope)
  - *Kundrat-Lokajicek (KL)*: eikonal framework, no explicit simplifications
- interference ⇒ phase of hadronic amplitude exposed in cross-section
  - phase t-dependence needs to be considered in analysis
  - constraints from data ⇒ *determination of ρ parameter*

$$\rho = \left.\frac{\Re\mathcal{A}^H}{\Im\mathcal{A}^H}\right|_{t=0}$$

central question:
observed non-exponentiality – due to hadronic, Coulomb or both?

- fits with 2 different assumptions on hadronic component
  - *purely-exponential* – non-exponentiality due to Coulomb (+interference)
  - *flexible enough* to describe non-exponentiality even without Coulomb

- role of hadronic phase t-dependence?
  - largest weight in interference formula: rate of change at low $|t|$
    - same quantity controls behaviour in impact-parameter space
  - considered two families
    - *central*: preference for low impact parameters
    - *peripheral*: preference for high impact parameters

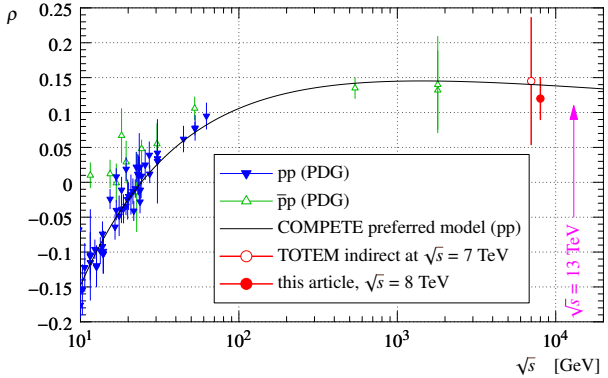
	central	peripheral
hadronic: purely exponential	*excluded*	*disfavoured*
hadronic: more flexible	*compatible*	*compatible*

- SWY formula excluded
- purely-exponential hadronic modulus + peripheral phase = disfavoured
  - ρ value outside a consistent pattern of other fits and theoretical predictions
  - number of theoretical reasons for non-exponential hadronic amplitude
- central description: not a necessity
- ρ – first LHC determination from Coulomb-hadronic interference:

$$\rho = 0.12 \pm 0.03$$

- σ_{tot} – results consistent with previous publications, but for the first time:
  - Coulomb component explicitly separated
  - determined in the same analysis as ρ

- Coulomb-nuclear interference measurement at 13 TeV
  - need larger β^* for low $|t|$ at higher energy $\Rightarrow$ $\beta^* = 2500$ m
  - experimental key improvement: higher statistics at low $|t|$
    - leading source of uncertainty on ρ
    - hardware improvement in Run II: both diagonals can be used $\Rightarrow$ factor 2
    - longer running time: 3 days requested



- theoretical improvements welcome
  - interference formulae
  - constraints on hadronic component (modulus and phase)

Outlook: Odderon considerations

- Odderon = (hypothetical) cross-odd partner of Pomeron
- Odderon searches
  - comparison pp vs. anti-pp (dip): not applicable at LHC
  - spin analyses: not applicable at LHC
  - structures in $d\sigma/dt$: where Pomeron contribution small
    - high-$|t|$: disfavoured by 13 TeV measurements
    - low-$|t|$: shifts of ρ value $\Rightarrow$ within reach of TOTEM