Latest TOTEM results

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on behalf of the TOTEM Collaboration

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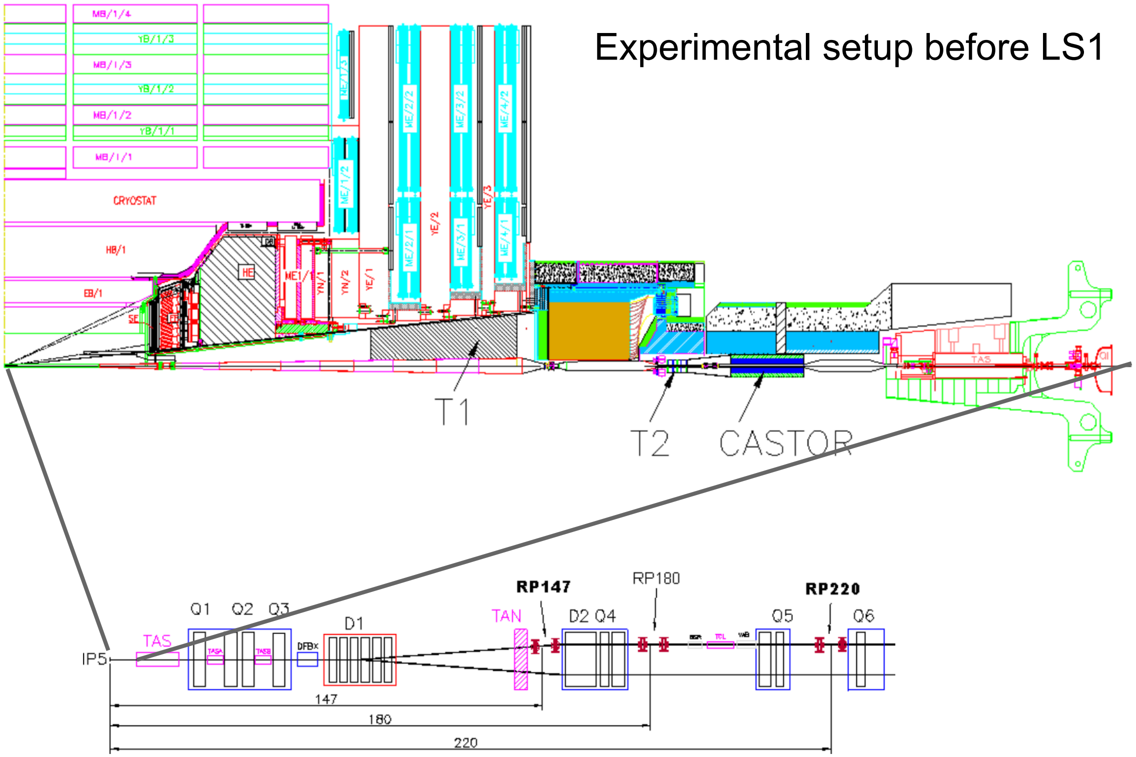
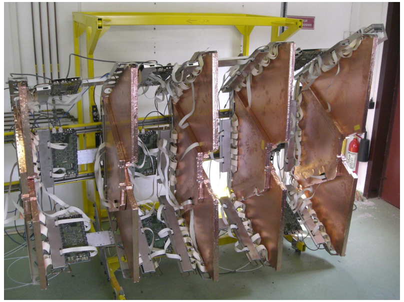
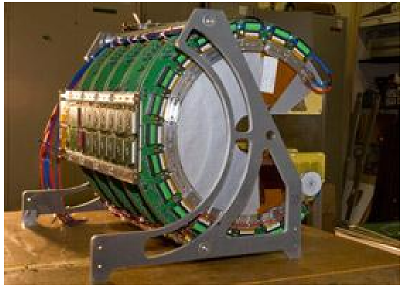
TOTEM experiment - detectors

Experimental setup before LS1

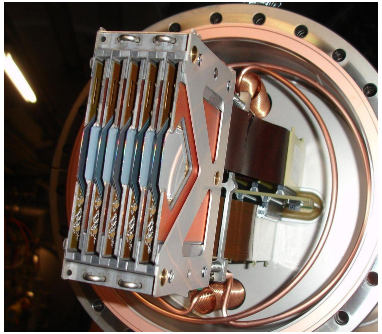




T1



T2



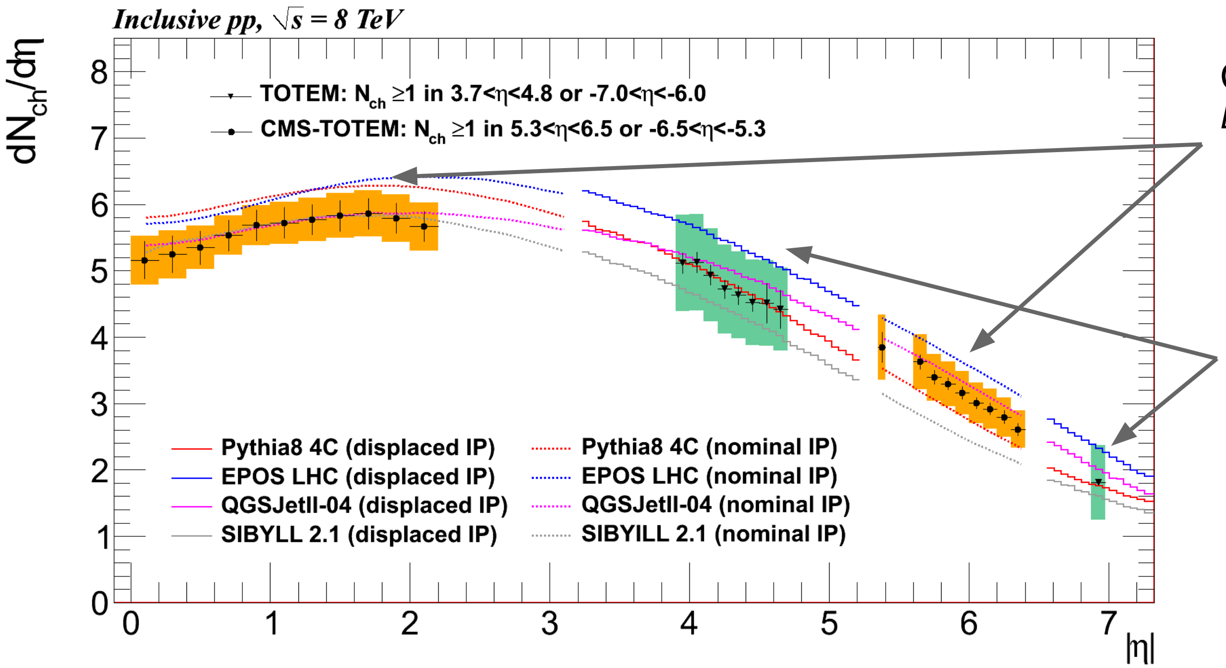
RP

LHC Run I measurements

- Elastic scattering : total & differential cross section measured at 7 and 8 TeV, large |t|-interval (0.0006 to 2.5 GeV^2) (*EPL 95 (2011) 41001, EPL 101 (2013) 21002, EPL 101 (2013) 21004*)
- Total cross section at 7 & 8 TeV: several methods (*EPL 101 (2013) 21004,PRL 111 (2013) 012001*)
- Inelastic scattering cross section at 7 & 8 TeV (*EPL 101 (2013) 21003, EPL 101 (2013) 21004*)
- Charge particle distribution 7 & 8 TeV: TOTEM alone & CMS-TOTEM (*EPL 98 (2012) 31002, Eur. Phys. J. C (2014) 74:3053, Eur. Phys. J. C (2015) 75:126)*
- Double diffraction cross-section (*Phys. Rev. Lett. 111 (2013) 262001*)
- Total, inelastic and elastic cross section at $\sqrt{s}$=2.76 TeV : in progress
- Single Diffraction cross section: in progress
- Single diffractive dijet cross section: in progress
- Central diffraction (soft, dijets) : in progress
- Quasi-elastic process in pA : in progress
- Other channels investigated, producing perfomance/feasibility results due to the limited statistics

Measurements at 8 TeV - forward ch. particles dens.

Measurement of the forward charged particle pseudorapidity density in pp collisions at √s = 8 TeV



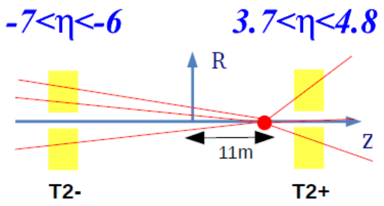
CMS+TOTEM data

Eur. Phys. J. C (2014) 74:3053

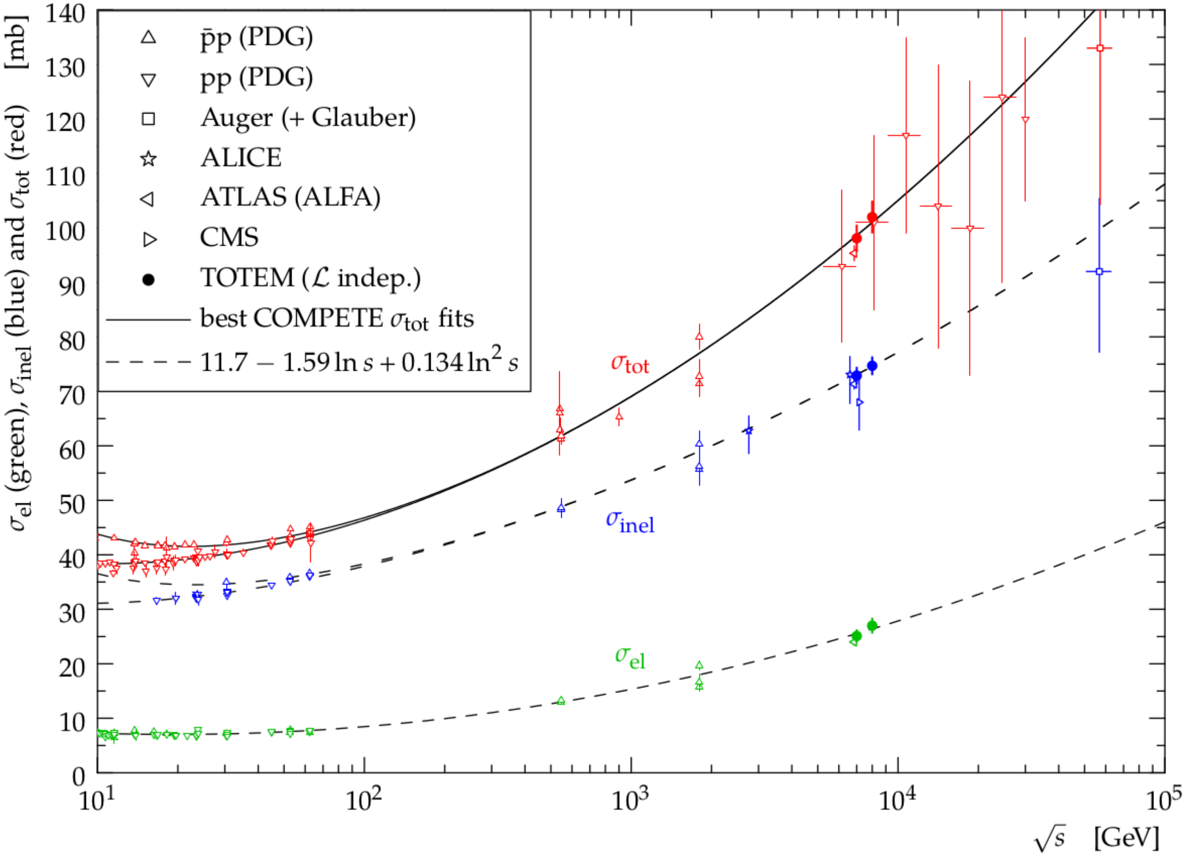
TOTEM data

Eur. Phys. J. C (2015) 75:126

displaced vertex



Total cross-section measurements



Compilation of the pp cross-section measurements

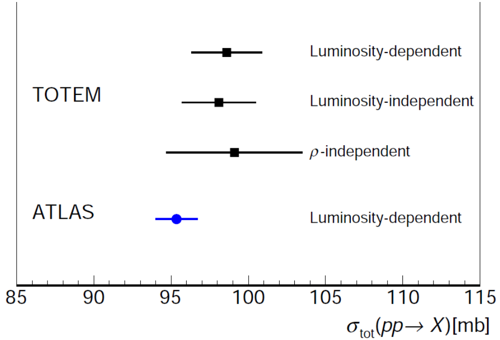
EPL 101 (2013) 21004 - 7 TeV

σ_{el} = 25.1 ± 1.1 mb

σ_{inel} = 72.9 ± 1.5 mb

σ_{tot} = 98.0 ± 2.5 mb

(luminosity independent)



PRL 111 (2013) 012001 - 8 TeV

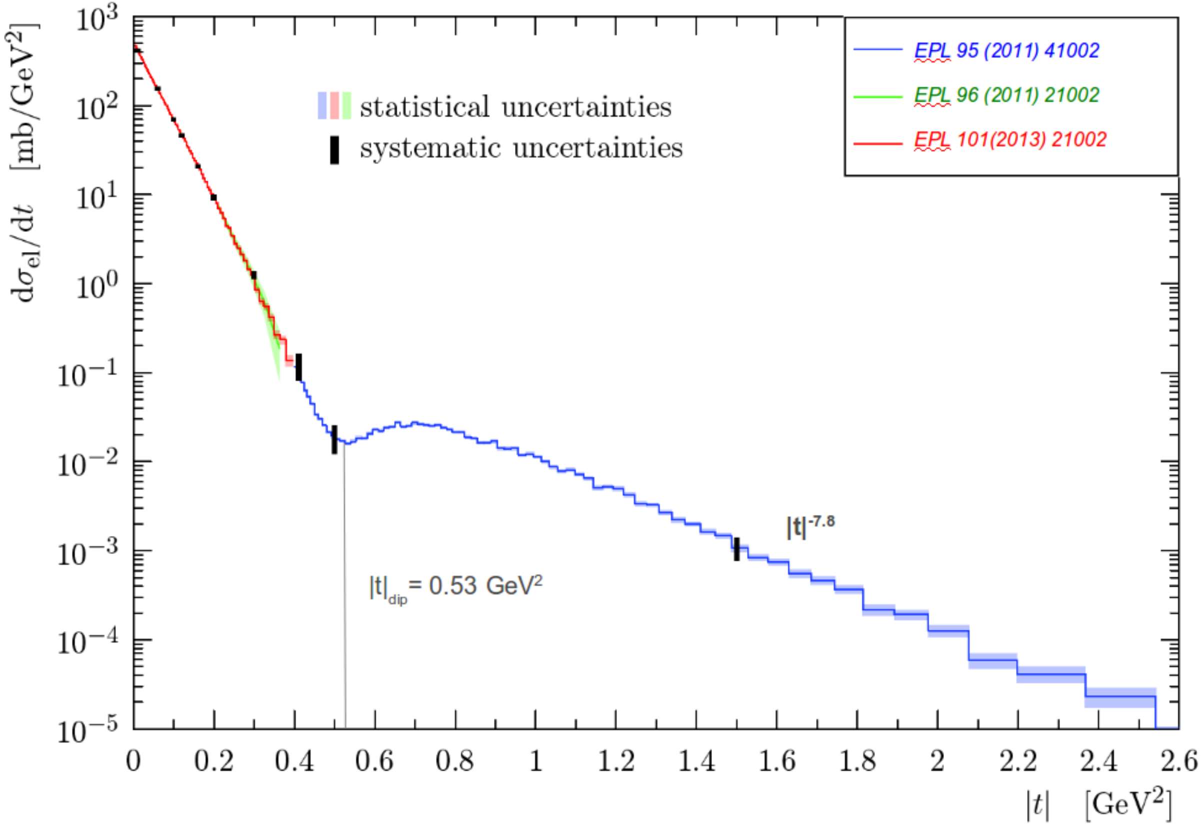
σ_{el} = 27.1 ± 1.4 mb

σ_{inel} = 74.7 ± 1.7 mb

σ_{tot} = 101.7 ± 2.9 mb

(luminosity independent)

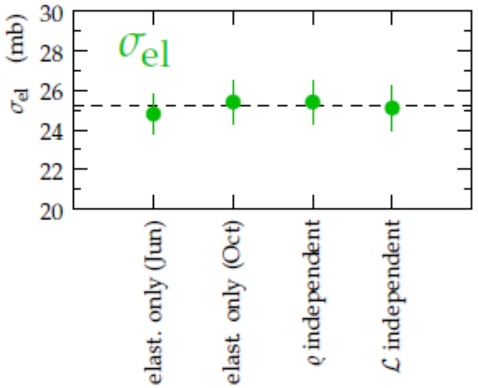
Measurements at 7 TeV - elastic pp



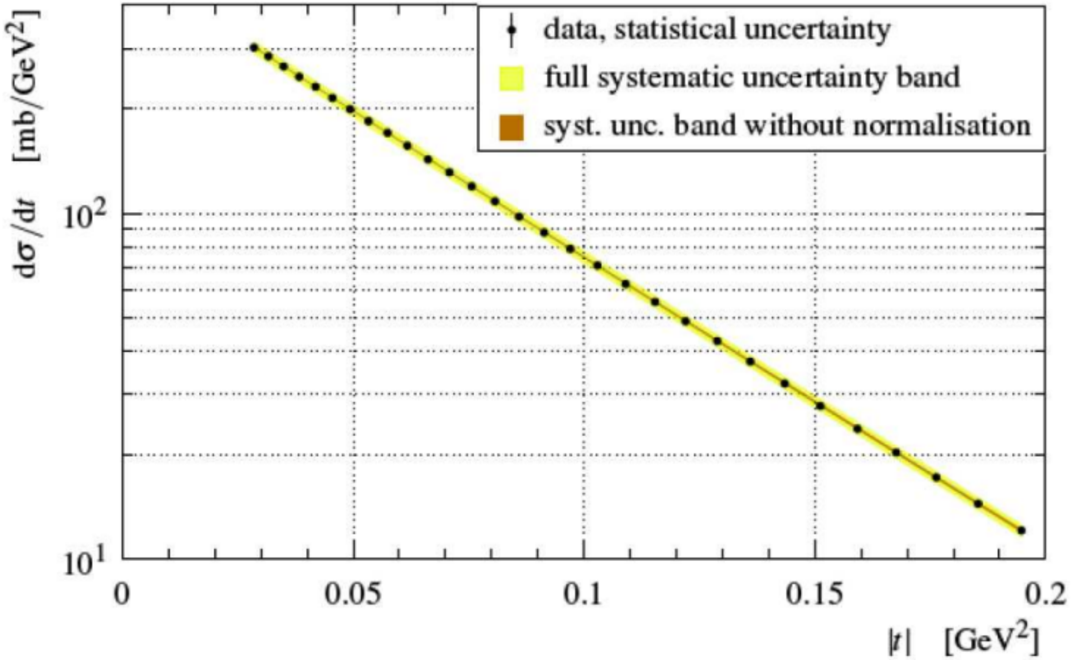
Elastic differential cross-section

elastic differential cross-section

σ_{el} = **25.43** ± 1.07 mb



Measurements at 8 TeV - elastic pp



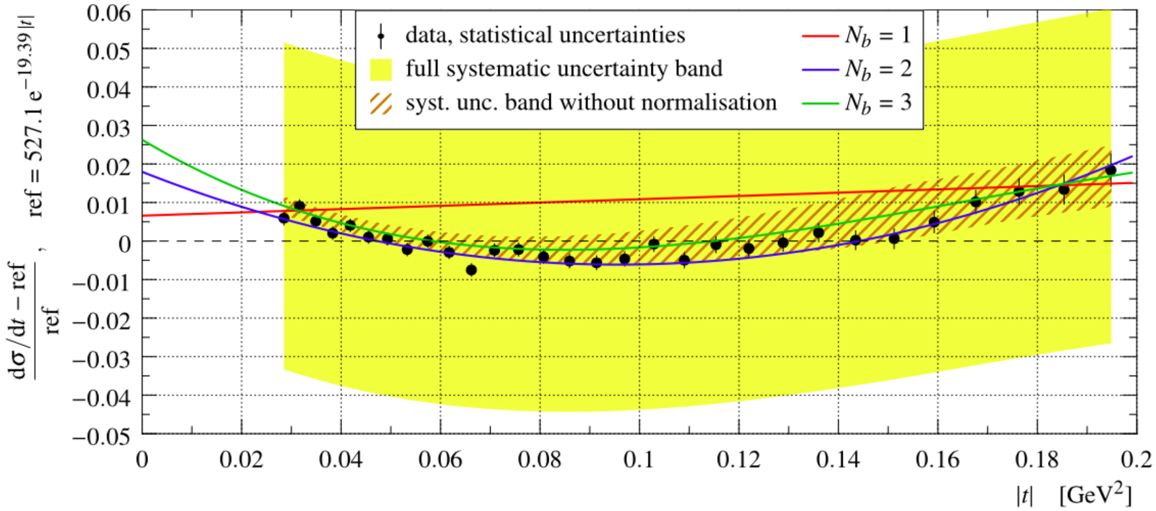
Elastic differential cross-section

7M el. events, β*=90m,
0.027 < |t| < 0.2 GeV^2
σ_{el} = **27.1** ± 1.4 mb

PRL 111, 012001 (2013)

seems perfectly exponential, but…

Ruling-out purely exponential approach



$d\sigma / dt = A \exp(-B(t) |t|)$

$N_b=1$: $B(t) = b_0$

$N_b=2$: $B(t) = b_0 + b_1 t$

$N_b=3$: $B(t) = b_0 + b_1 t + b_2 t^2$

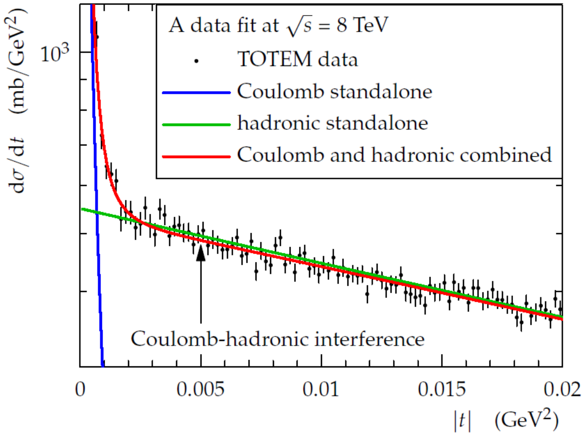
N_b	χ^2/ndf	p-value	significance
1	$117.5/28 = 4.20$	$6.1 \cdot 10^{-13}$	$7.2\,\sigma$
2	$29.3/27 = 1.09$	0.35	$0.94\,\sigma$
3	$25.5/26 = 0.98$	0.49	$0.69\,\sigma$

Differential cross-section as a relative difference from reference exponential. *Nucl. Phys. B (2015) 527-546*

Purely exponential form excluded at 7.2 σ significance.

The Coulomb-hadronic interface

$F^{C+H} = F^C + F^H \exp(i\alpha\Psi)$
$|F^H|$ - constrained by measurement in nucl. region
$\arg(F^H)$ - little guidance by data

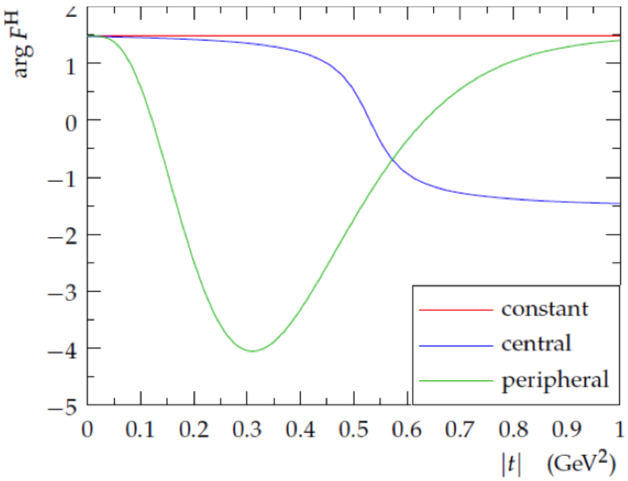


Measuring elastic scattering at $|t|$ down to $6*10^{-4}$ GeV^2 to investigate Coulomb-nuclear interference

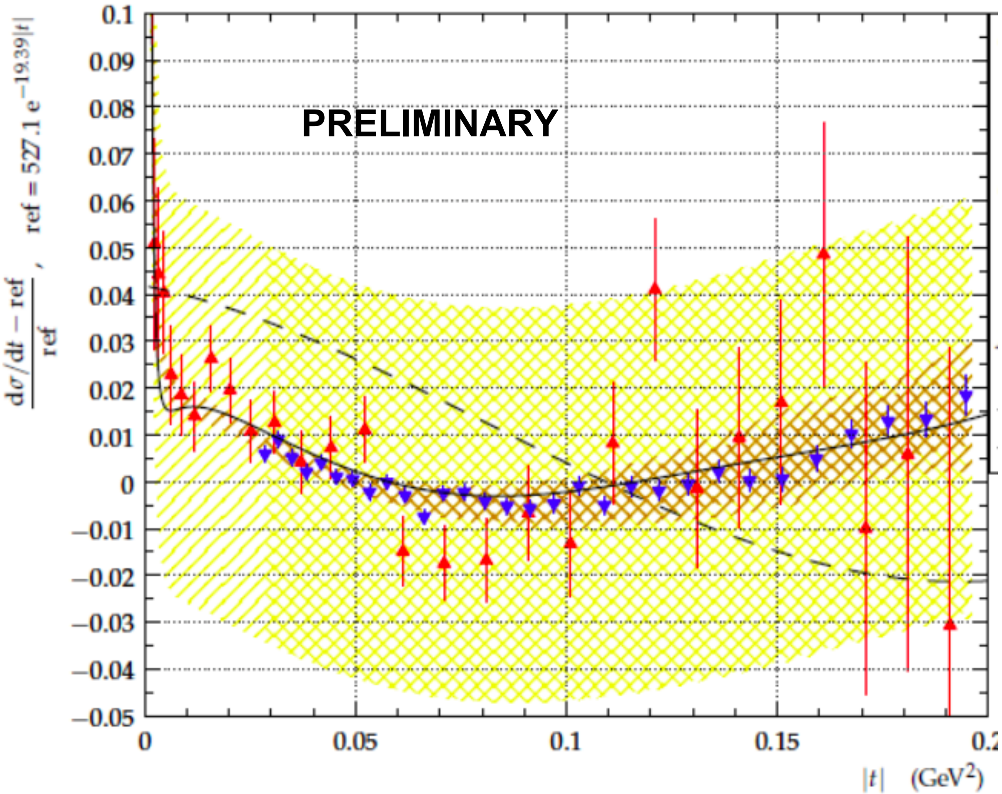
Different nuclear phase models:

- constant phase
  - $\arg F^H(t) = p_0$
- central phase
  - $\arg F^H(t) = \pi/2 - \operatorname{atan}(\cot p_0 / (1 - t/t_d))$
- peripheral phase
  - $\arg F^H(t) = p_0 + \xi_1 |t/t_0|^\kappa \exp(\nu t)$

$\rho = \cot \arg F^H(0)$ - model dependent



The Coulomb-hadronic interface



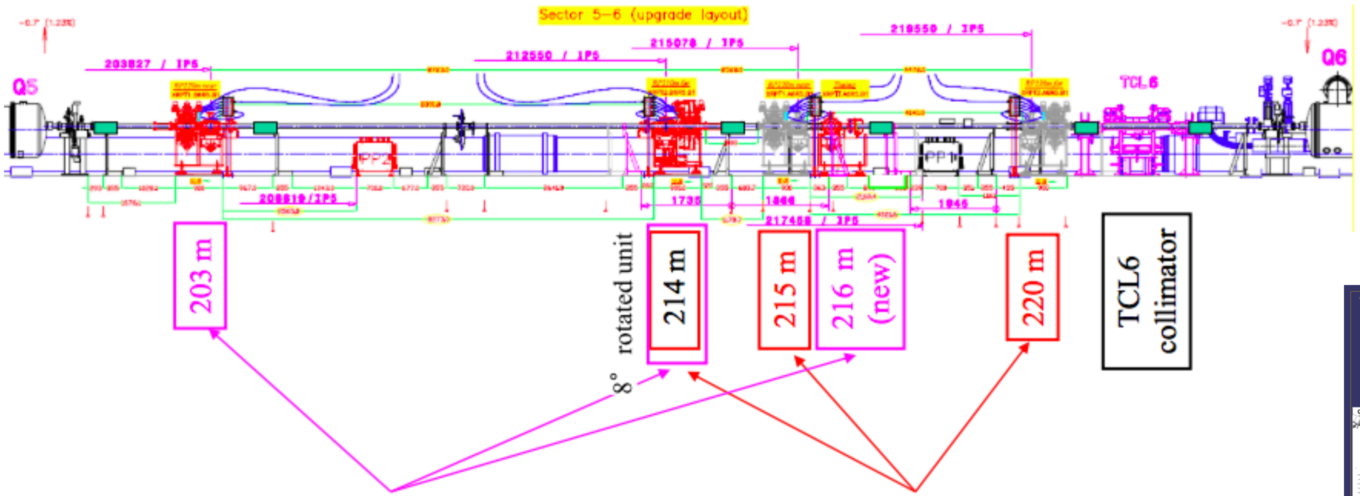
Parabolic exp. slope, peripheral phase with fixed shape models fitted to two data samples (β*=90m and 1000m)

- Red - data points β*=1000m (low |t|)
- Blue - data points β*=90m
- solid line - coulomb+hardonic fit
- dashed line - hadronic only fit

Ongoing study of phase models and ρ value choices.

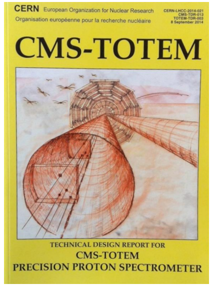
Hadronic slope	Constant phase	Peripheral phase
Nb=1 (exponential)	excluded	disfavoured
Nb=3 (parabolic)	possible	possible

Detector setup for LHC run II



Operation at low β* (< 1 m), high luminosity, standard runs

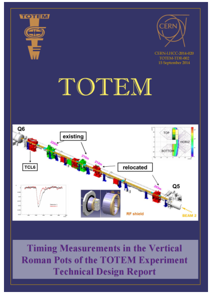
Operation at high β* (19 m, 90 m, > 1 km), Low - medium luminosity, special runs

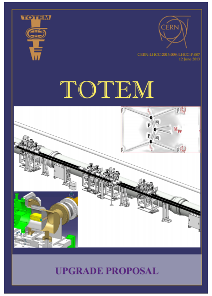


CMS-TOTEM Precision spectrometer (CT-PPS)

see K. Piotrzkowski talk

Timing measurements in Vertical Roman Pots of the TOTEM experiment





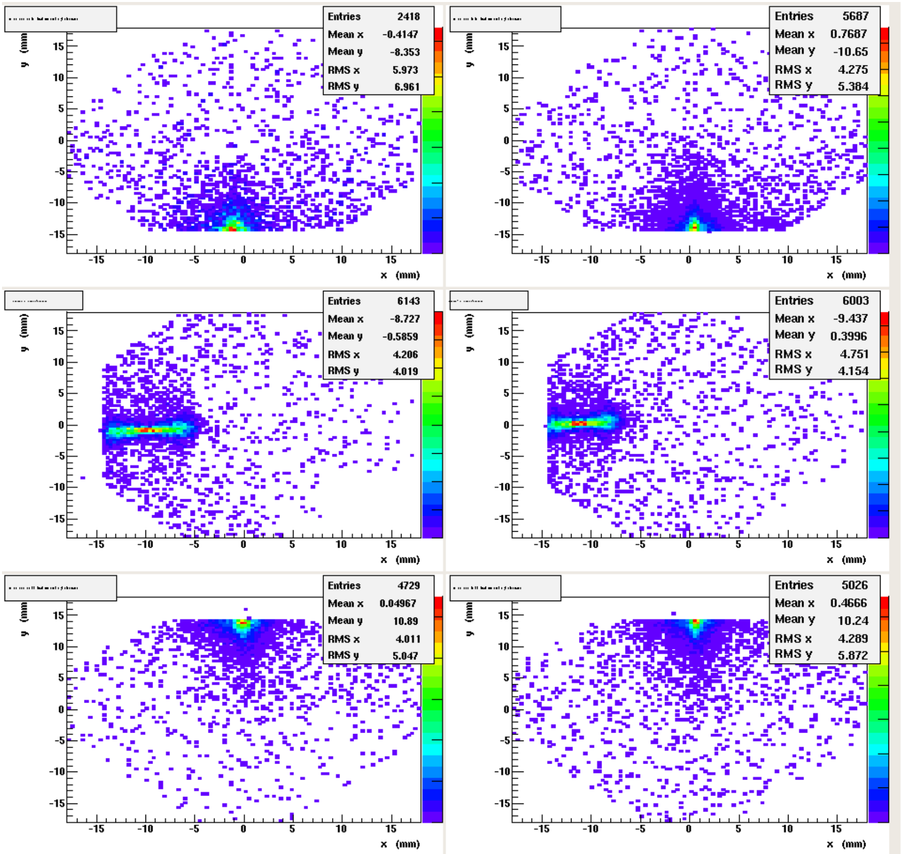
Run II first datataking

<u>June 2015:</u>

- Several milions min. bias events: T1, T2 ("LHCf fills")
- Beam optics √s=13 TeV β*=19m

<u>August 2015:</u>

- Data taken with CMS and TOTEM (T2,RP) standalone during "VdM fills"
- Beam optics √s=13 TeV β*=19m
- Collected ~ 40nb^{-1} integrated luminosity
- Experience gained before next datataking with β*=90m.
- pileup μ ~ 0.5
- Trigger:
  - RP single/double arm
  - CMS dijet, muon



Proton tracks in RP station at 220m (sector 56)

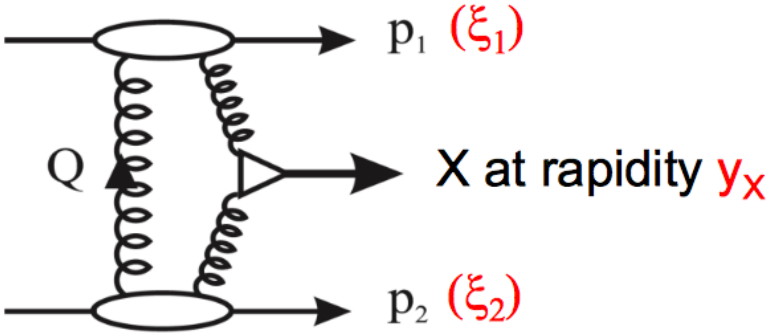
Planned measurements for Run II

- Total, inelastic and elastic cross section at 13 TeV
- Central (Exclusive) Diffraction:
  - low mass resonances & glueballs candidates
  - ccbar production (χ_c , J/ψ, ...)
  - search for missing mass signal
- Single and Central diffraction jet production
- Single diffractive J/ψ, W and Z production

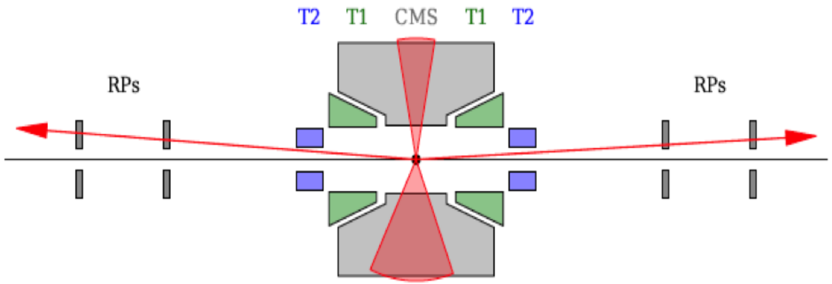
Physics programme: central diffractive processes

- both proton survive with momentum losses (ξ_1,ξ_2)
- excellent η coverage TOTEM+CMS
- feasibility studies using β*=90m 2012 data
- event selection by kinematics comparison:

  M_{pp}?=?$M_{central}$ (the same with P_{Tz} & vertex)

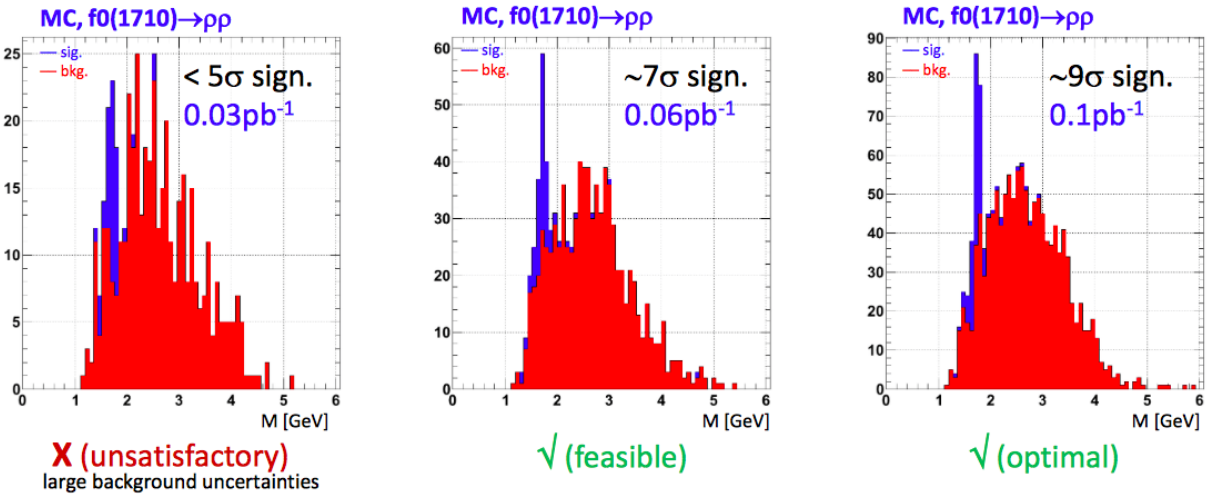


- missing mass searches
- exclusive central diffractive jets production
- glueball studies



Glueball studies

- Pomeron ~ colourless gluon pair/ladder, likely to produce glueballs
  - Candidates for 0^{++} glueball: $f_0(1500)$ or $f_0(1710)$ - favoured by QCD
- $f_0(1500)$ - mass, decay channels, branching ratios known, $f_0(1710)$ - lack of data
- Goal: characterise $f_0(1710)$ and compare with known $f_0(1500)$
- CMS+TOTEM data from 2012 show sensitivity to $f_0(1710) \rightarrow \rho\rho \rightarrow 4\pi$

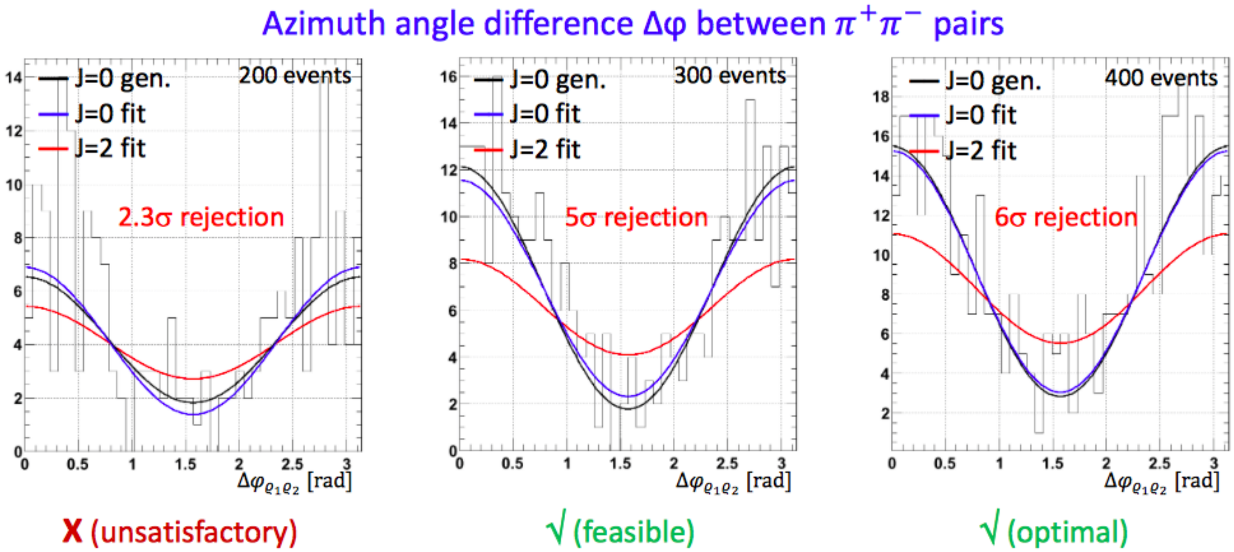


Need 0.6 pb^{-1} of data to have feasible decay characterisation

Simulation of $f_0(1710) \rightarrow \rho\rho$ with CMS acceptance
(background - DIME MC)

Glueball studies

Spin analysis of $f_0(1710) \rightarrow \rho\rho \rightarrow 4\pi$ to determine J=0 or 2:

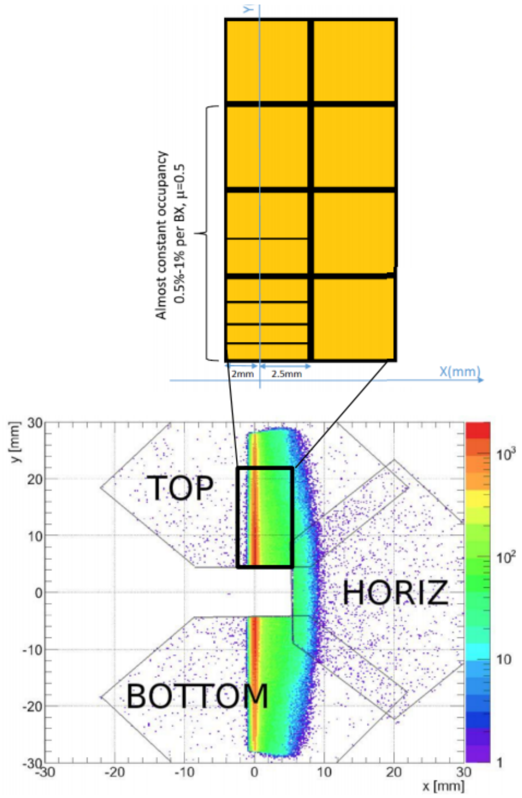


Distinction from neighbouring resonances and non-resonant background:
spin analysis in mass bins < 40 MeV needs ~5 pb^{-1}

Future prospects - diamond TOF detectors

Overview:

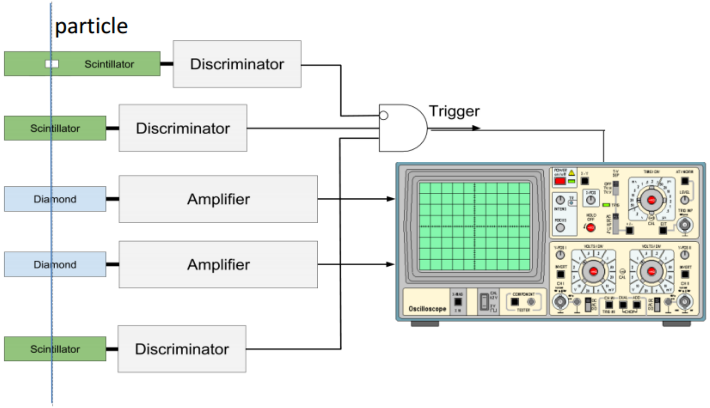
- expected high pileup (μ ~ 0.5) in 2016 data (β* = 90m)
- time-of-flight difference leads to vertex position at IP
- longitudinal vertex reconstruction (few cm resolution) - needed to couple TOTEM and CMS datasets via vertex location

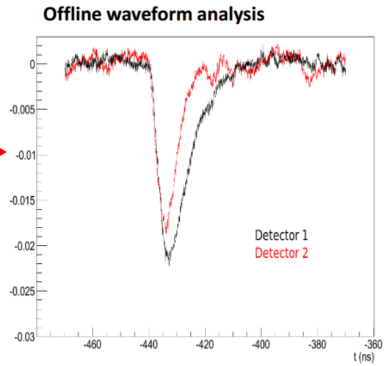


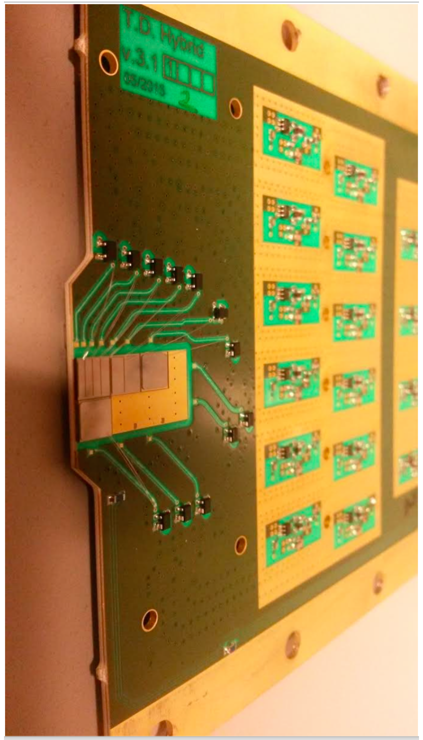
Objective:

- 4 timing detectors per arm in **vertical** RPs
- Detector installation foreseen later in 2015
- 50 ps resolution per arm (100 ps per detector) enough since at β*=90m the pileup μ < 0.6
- adjusted track occupancy

Future prospects - diamond TOF detectors







Outlook:

- ongoing studies on the performance (TOF vs capacitance)
- 100 ps / plane resolution achieved during last measurements on test beam data (PRELIMINARY)

Conclusions

- Extensive measurements @ Run I : done, published.
- Ongoing analyses on run I data
- Starting the analysis of first run II data
- To fullfill “challenging” physics programme:
  - Dedicated run at β^*=90 m : ~1 pb^{-1} of data for low-mass central diff. spectroscopy (2015)
  - Finalisation and installation of diamond timing detectors (2015)
  - Runs at β^*=90m with timing detectors pileup ~0.5-1 acceptable (2016)
  - Runs at β^*~2500m for more studies of Coulomb-nuclear interference (2016)