Latest results from TOTEM and the CT-PPS project

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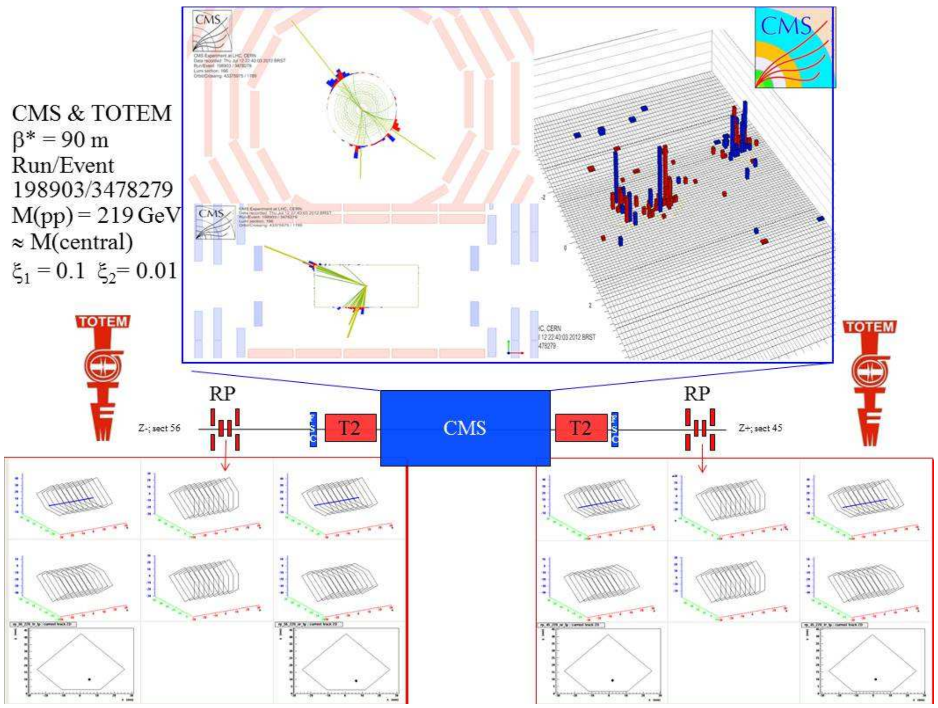
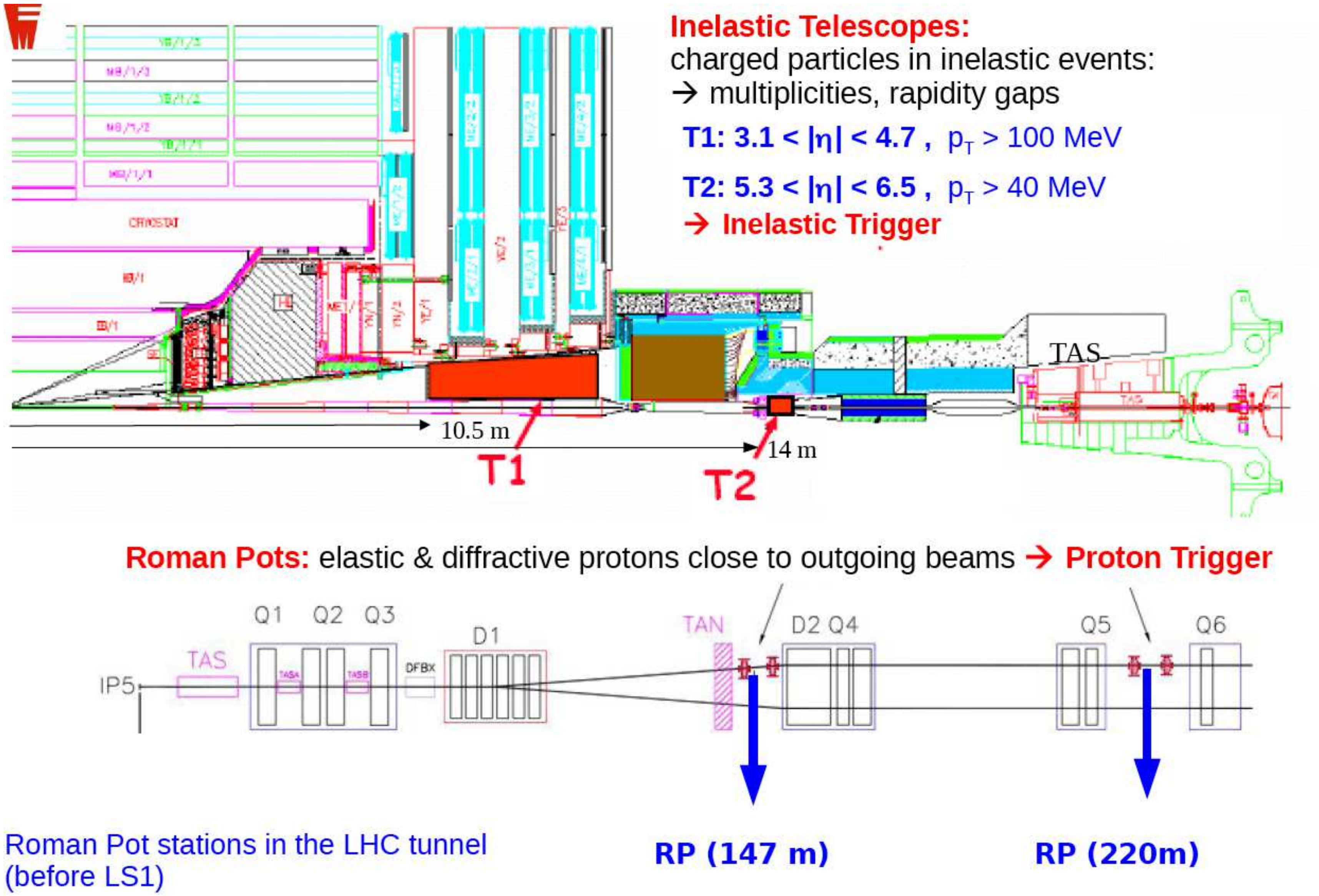
Contents:

- TOTEM elastic measurements at 7 and 8 TeV
- TOTEM total cross section measuremnts
- CT-PPS project



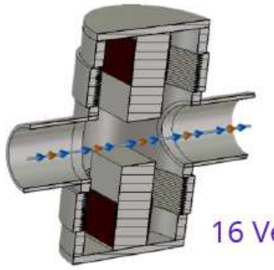
Forward coverage in CMS-TOTEM



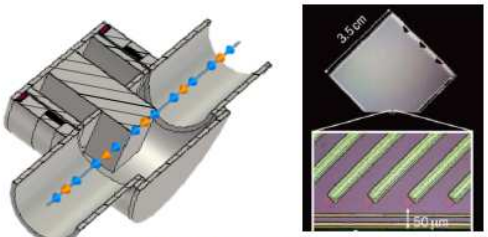
- Forward coverage with T1 and T2 detectors: useful to measure inelastic cross section (used as a trigger)
- Roman pots at 147 m (dismounted now) and 220 m

TOTEM Roman pot detectors

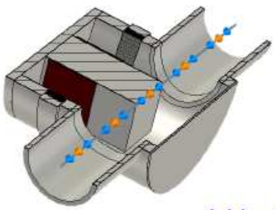
- For elastic measurements, TOTEM installed vertical roman pot detectors at 220 m from CMS
- Trigger for elastics using proton in opposite configurations: Up (Down) on one side, Down (Up) on the other side
- For diffractive measurements together with CMS: horizontal roman pots, measure diffraction at low and medium masses



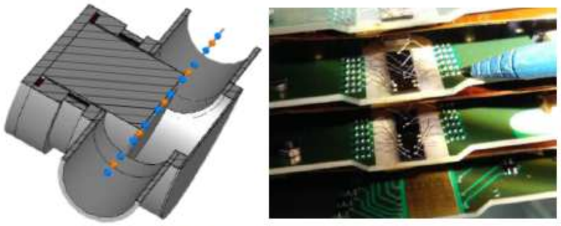
16 Vertical RPs



4 Shielded RPs
for high-luminosity operation



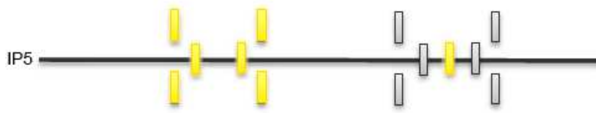
4 Horizontal RPs



2 Cylindrical RPs
for time-of-flight detector

High intensity runs

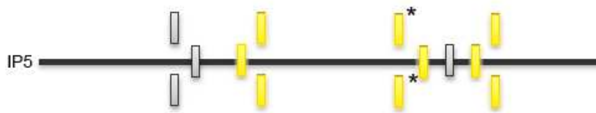
- 4 Vertical RPs (per arm)
- 2 Shielded RPs
- Cylindrical RP



Dedicated runs

$\beta^* = 90\ m, 1\ km, 2.5\ km$

- 6 Vertical RPs
- 2 Horizontal RPs
- 1 Shielded RP



*: Si strip removed, waiting for timing detectors..

Different measurements of the total cross section

Measured using Roman Pots

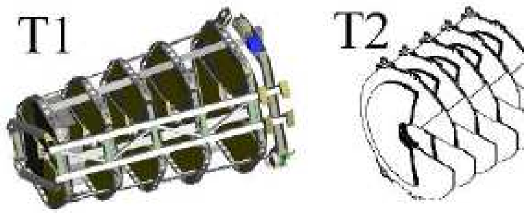
Optical Theorem, Elastic $\frac{d\sigma}{dt}$ extrapolated to t = 0

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

$\sigma_{tot} = 98.3 \pm 2.8$ mb

Explicit dependency on $\mathcal{L}$: $\sigma^2_{\rm tot} = \frac{16\pi}{1+\varrho^2} \frac{1}{\mathcal{L}} \left.\frac{dN_{\rm el}}{dt}\right|_0$

$\sigma_{tot} = 98.6 \pm 2.2$ mb



Elastic + Inelastic measurement: no dependency on ρ

$$\sigma_{\rm tot} = \frac{1}{\mathcal{L}}(N_{\rm el} + N_{\rm inel})$$

$\sigma_{tot} = 99.1 \pm 4.3$ mb

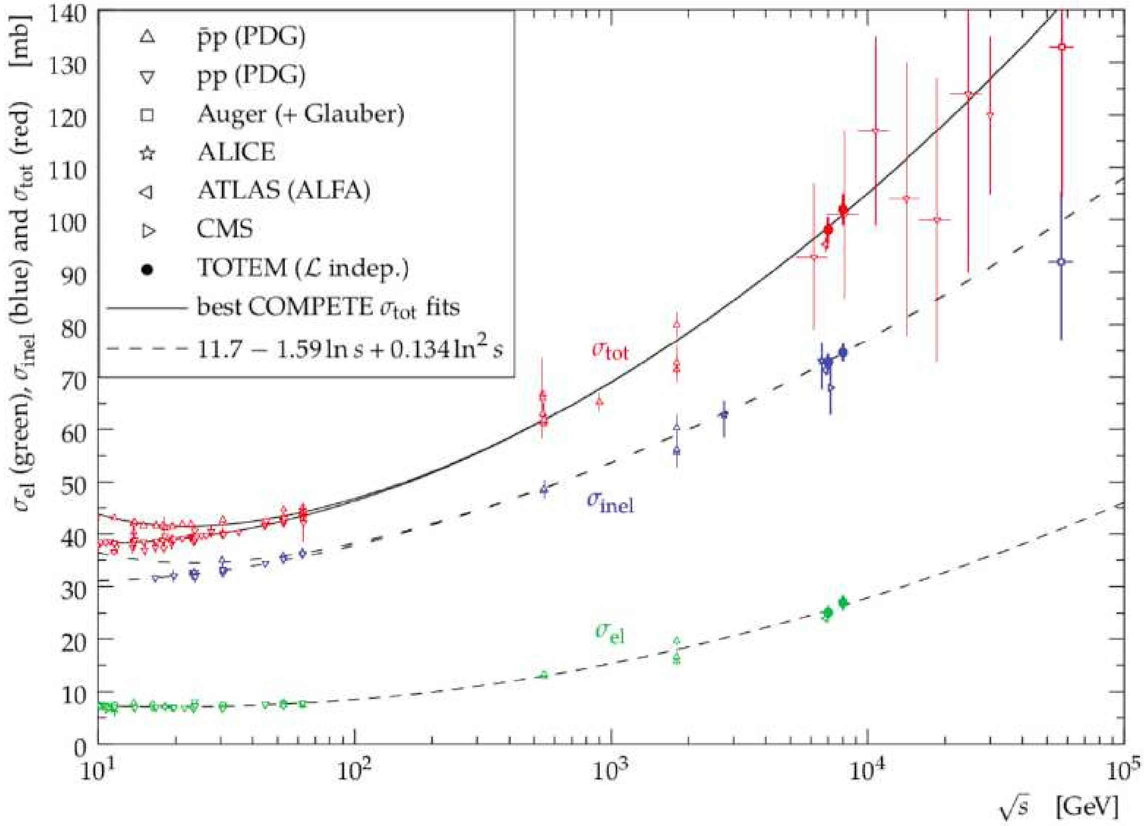
Elastic + Inelastic measurement: no dependency on $\mathcal{L}$

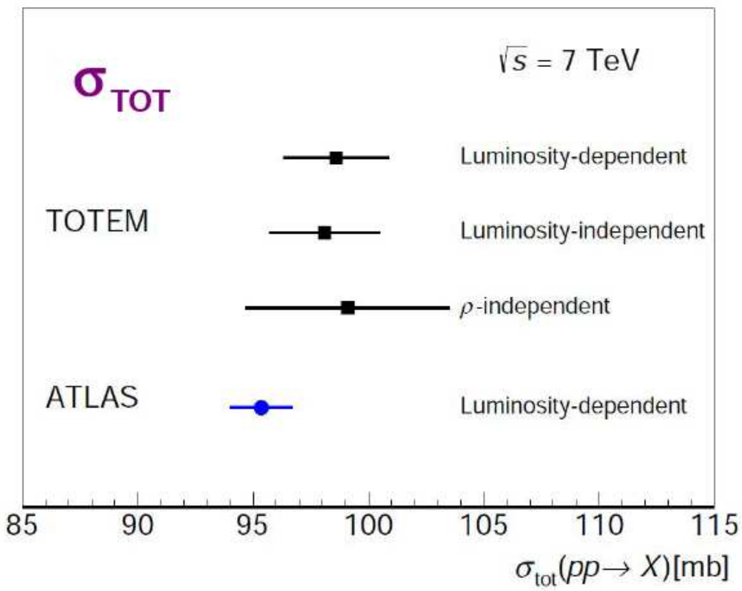
$$\sigma_{\rm tot} = \frac{16\pi}{1+\varrho^2} \frac{dN_{\rm el}/dt|_0}{N_{\rm el}+N_{\rm inel}}$$

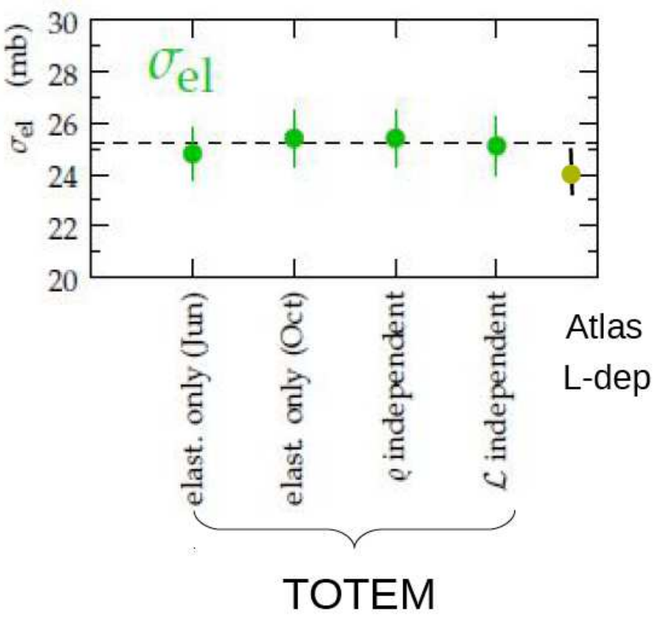
$\sigma_{tot} = 98.0 \pm 2.5$ mb

7 and 8 TeV: EPL 96 (2011) 21002, EPL 101 (2013) 21004, Phys. Rev. Lett. 111, 012001 (2013), Eur. Phys. J. C76 (2016) 661

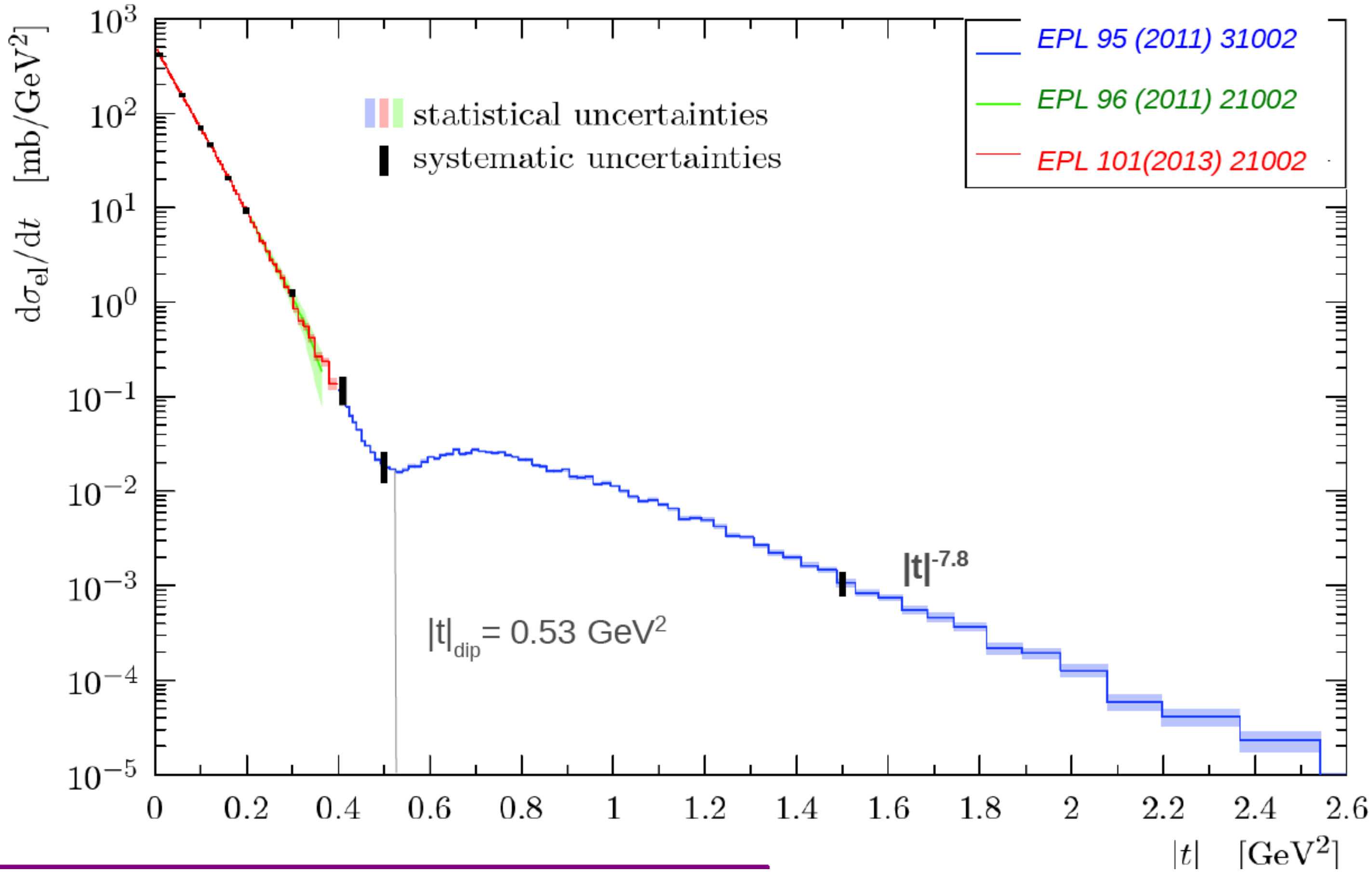
Total cross section measurement





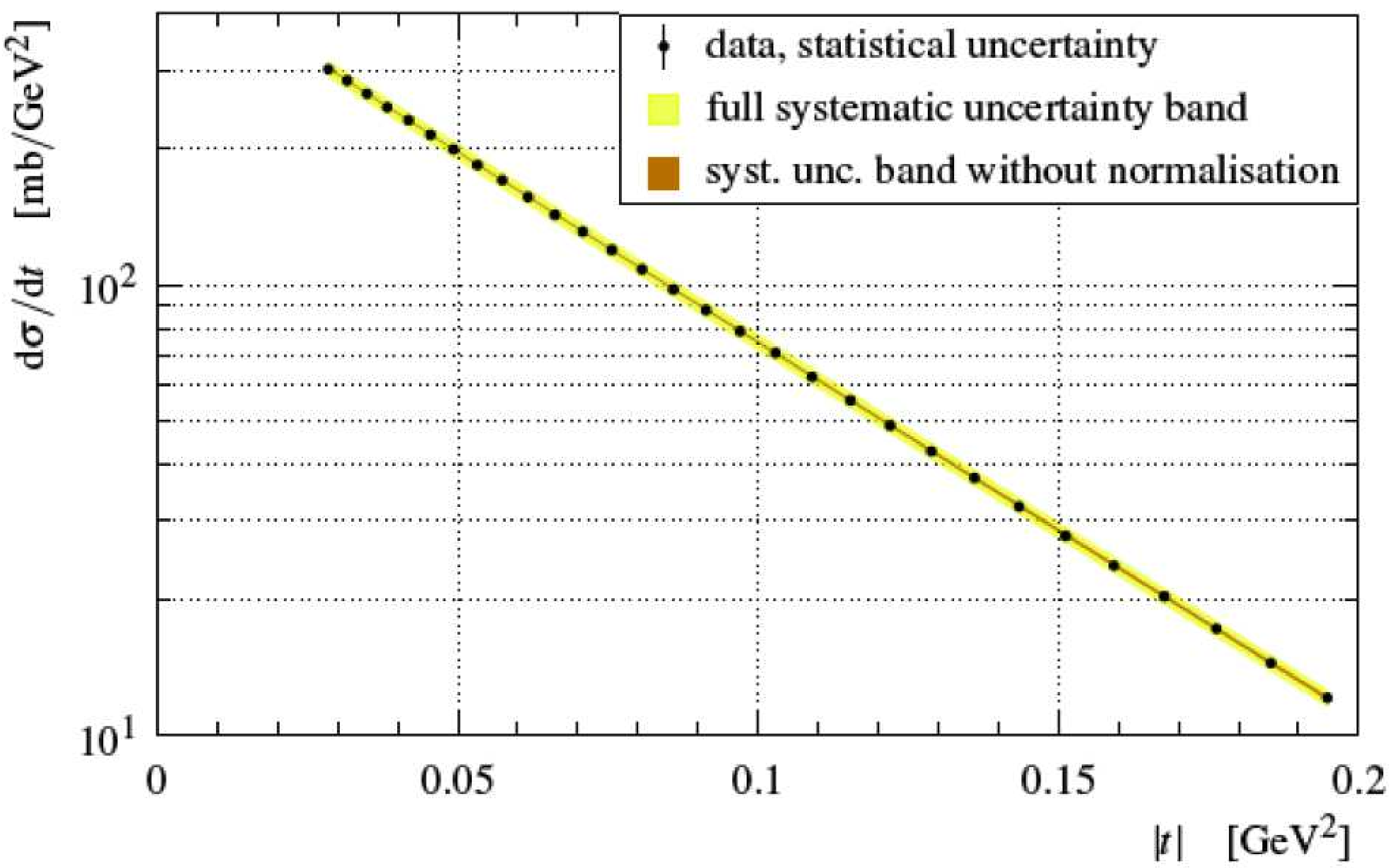


pp scattering at 7 TeV



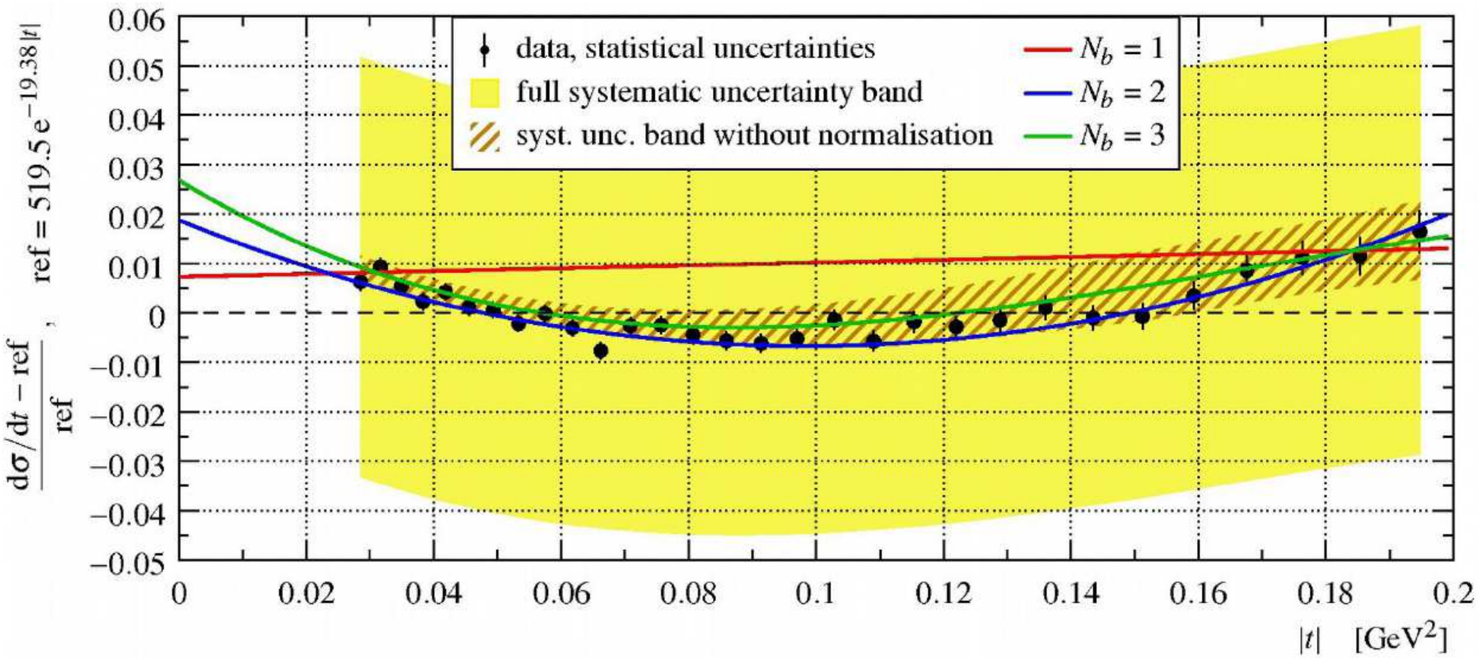
- Wide range of measurement in t: $0.005 < |t| < 0.2$ GeV^2, results in red, $0.002 < |t| < 0.33$ GeV^2, results in green
- Simple exponential fit: $A = 506.4 \pm 23(stat) \pm 0.9(syst)$, $A = 503.0 \pm 26.7(syst) \pm 1.5(stat)$; $B = 19.89 \pm 0.27(syst) \pm 0.03(stat)$, $B = 20.1 \pm 0.3(syst) \pm 0.2(stat)$
- See EPL 101 (2013) 21004, EPL 101 (2013) 21003, EPL 101 (2013) 21002,, EPL 96 (2011) 21002

pp scattering at 8 TeV



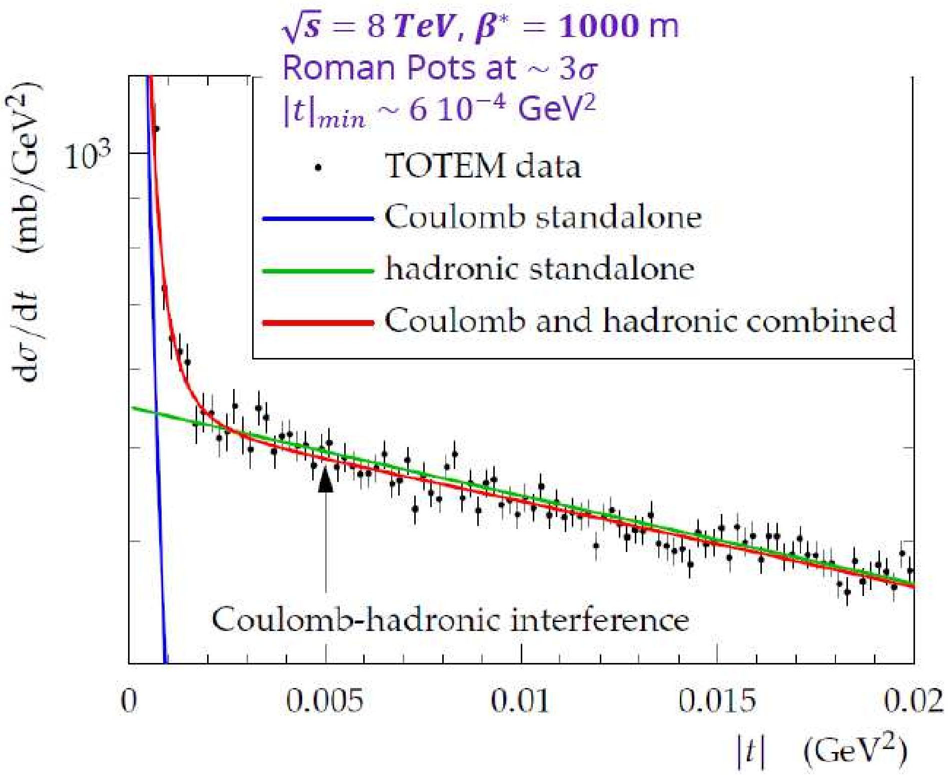
- High statistics data set ($\beta^* = 90$m, 7 million elastic events, $0.027 < |t| < 0.2$ GeV^2)
- $\sigma_{el} = 27.1 \pm 1.4$ mb
- Phys. Rev. Lett. 111, 012001 (2013)

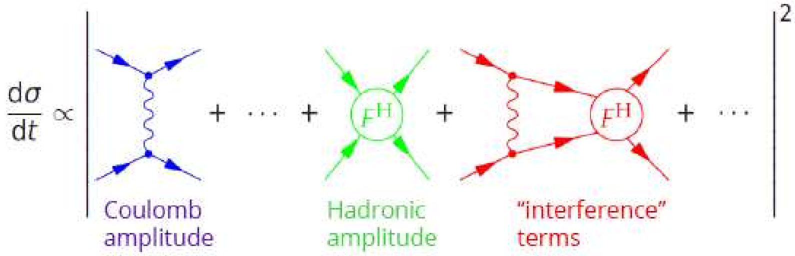
pp scattering at 8 TeV



- Exponential fit: $d\sigma/dt = A\exp(-B(t)|t|)$
- Pure exponential form $(N_b = 1)$ excluded at 7.2 σ
  - $N_b = 1$ $B = b_1$, reference
  - $N_b = 2$, $B = b_1 + b_2 t$
  - $N_b = 3$, $B = b_1 + b_2 t + b_3 t^2$
  - See Nucl. Phys. B 899 (2015) 527-546

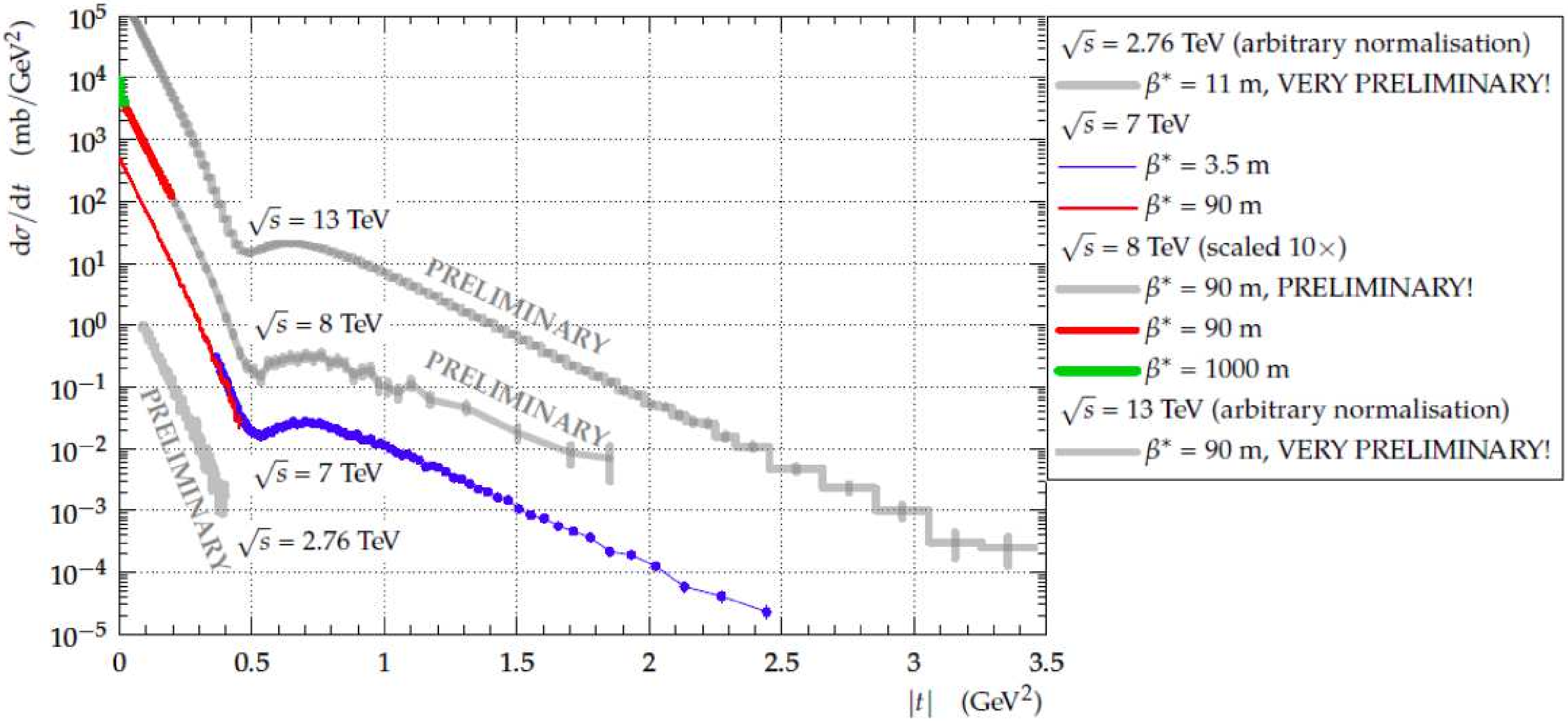
Elastic scattering in the Coulomb-Nuclear interference region





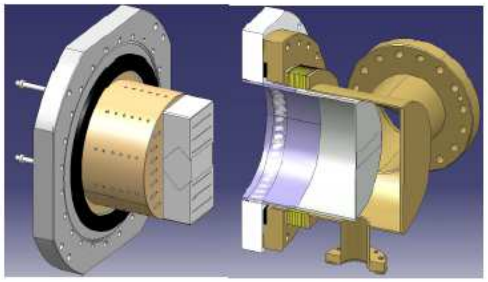
- Measure elastic scattering at $|t|$ as low as 6. 10^{-4} GeV^2 using high β^*=1000 m optics
- Detectors approach the beam at 3σ from the beam center
- $\rho = 0.12 \pm 0.03$
- See Eur. Phys. J. C76 (2016) 661

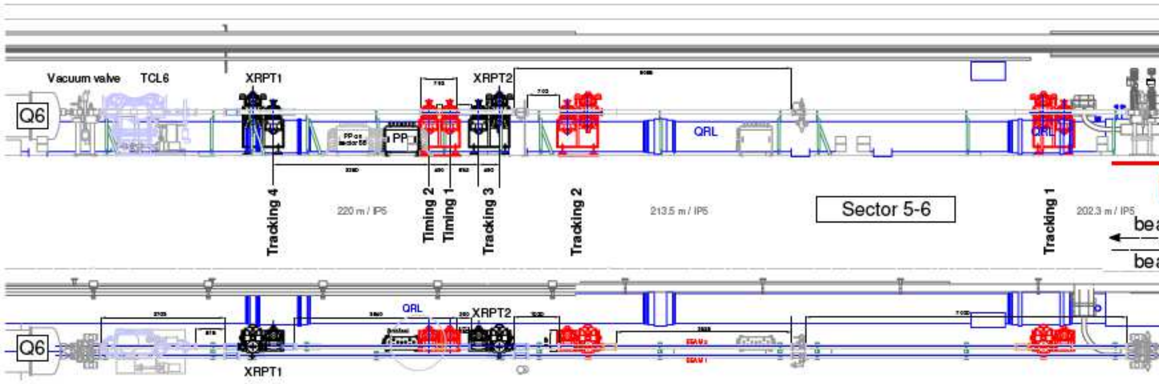
Preliminary results



- Non-exponentiality confirmed at 13 TeV
- While going from 7 to 13 TeV, the dip moves to lower $|t|$
- Forward slope $B = d/dt(ln(d\sigma/dt, t = 0))$ increases with respect to previous lower energy measurements
- No structure at high $|t|$

The CT-PPS project

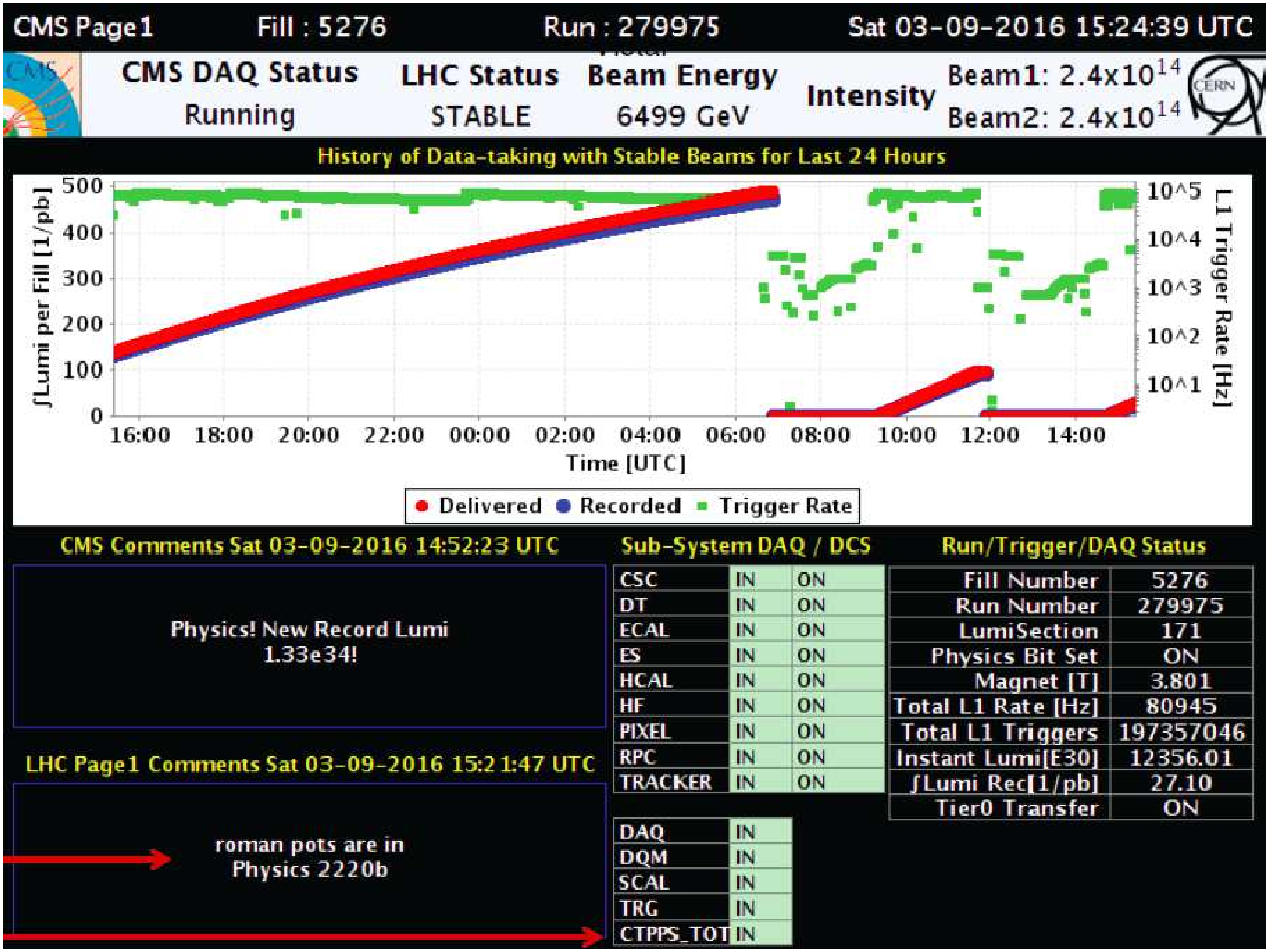




- Horizontal roman pots installed in the very forward region: good acceptance at high diffractive mass for nominal running
  - 2 roman pots with tracking detectors at 204 and 215 m
  - 2 roman pots for timing detectors (1 currently installed at 215 m)
- Successful insertions in Spring 2016 at 15 σ with 49, 600, 1700 bunches
- Data taking since end of spring together with CMS: $\sim$ 15 fb^{-1} accumulated
- In 2016, CT-PPS has proven the feasibility of operating a near-beam proton spectrometer at high luminosity
- Two phases: TOTEM tracking and diamond timing detectors and the ≥ 2017 final detectors (Si pixels, and ultrafast Si timing detectors)

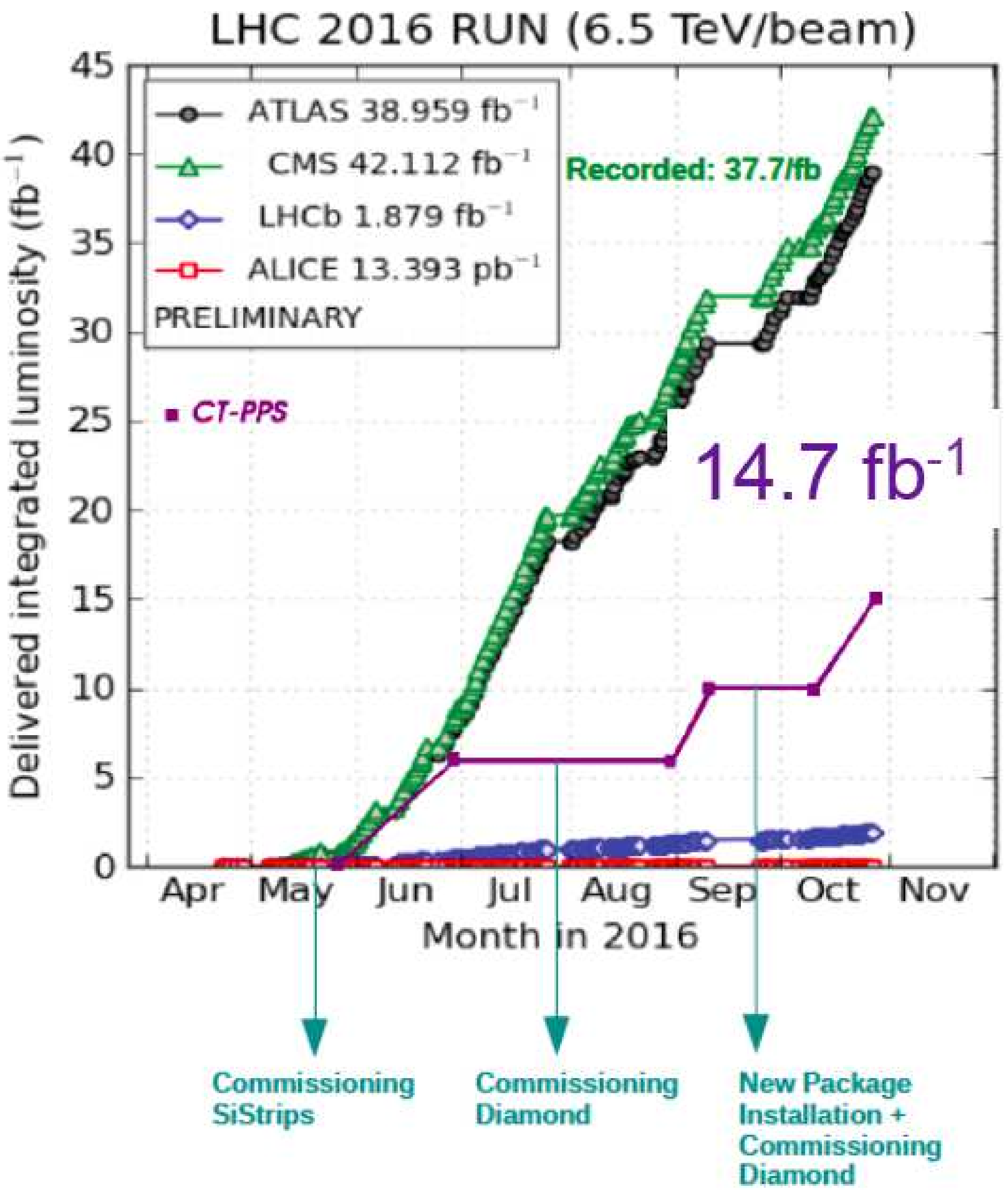
The CT-PPS project

CT-PPS roman pots are included in standard data taking

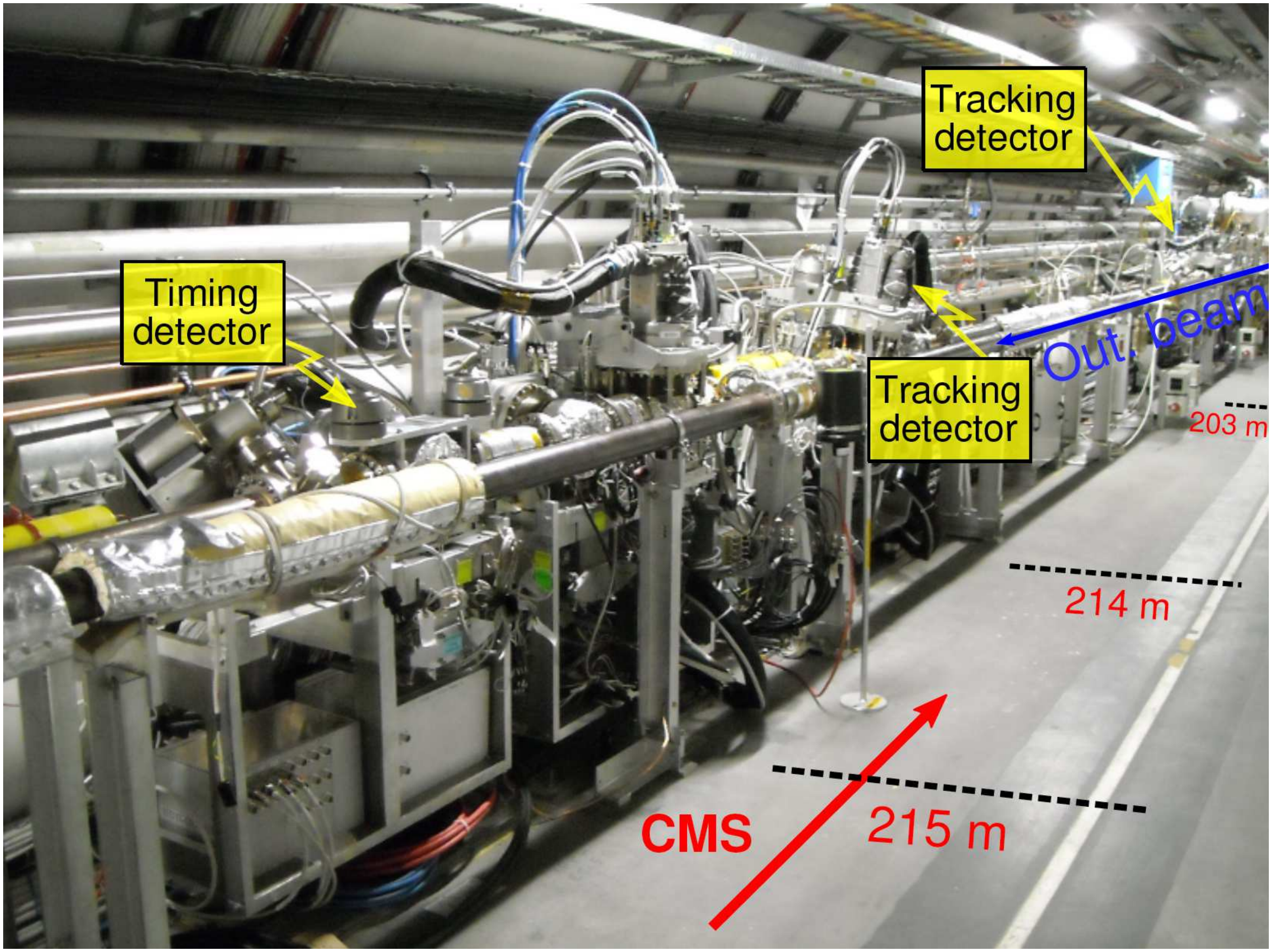


The CT-PPS project

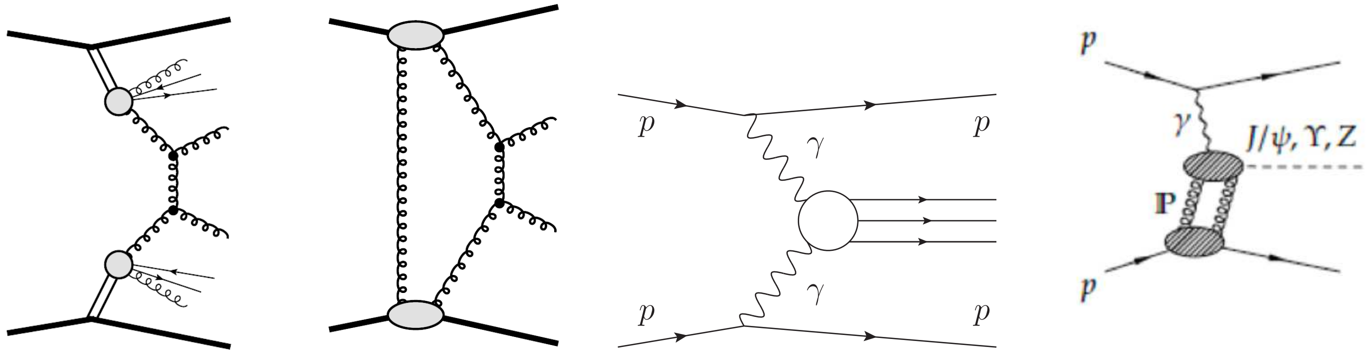
Almost 15 fb^{-1} have been coolected



CT-PPS in the tunnel

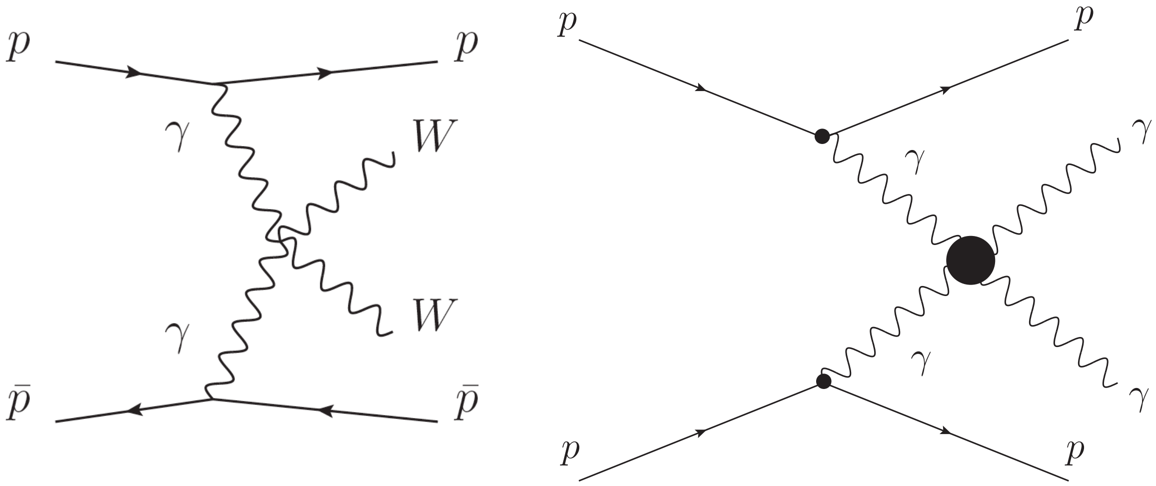


Physics topics with CT-PPS: standard model

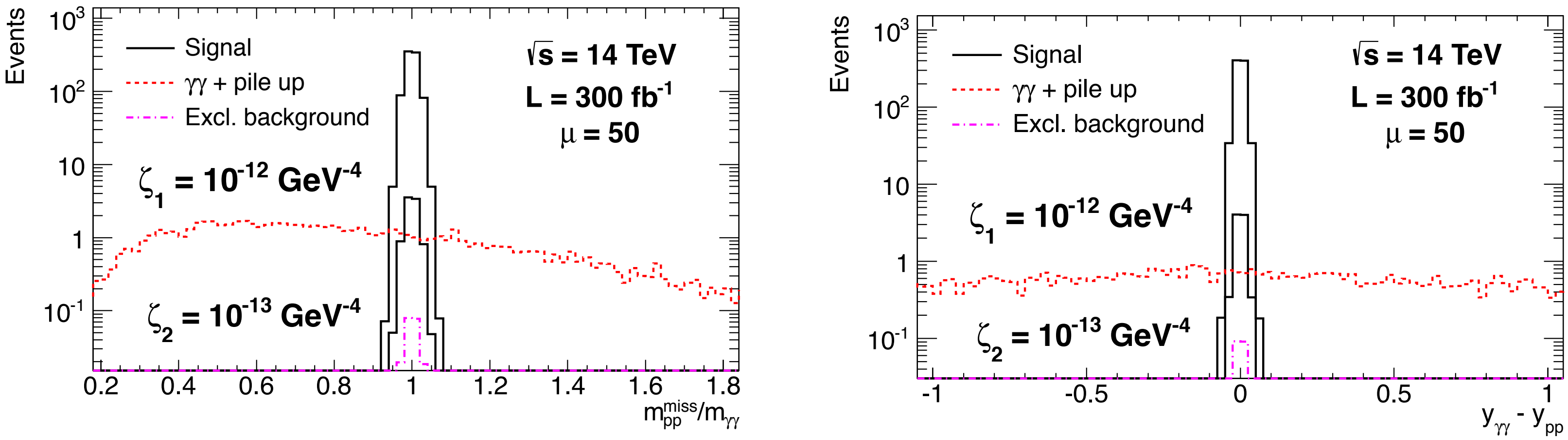


- Better understanding of the pomeron structure
- Many exclusive channels can be studied: jets, χ_C, charmonium, J/Ψ....
- Possibility to reconstruct the properties of the object produced exclusively (via photon and gluon exchanges) from the tagged proton
- With CMS-TOTEM and CT-PPS: possibility to cover a large domain of diffractive mass going from low mass diffraction (vector mesons, glueballs...) to search for new physics at high mass
- Advantage of detecting all objects in the final state: constraints on kinematics allowing to reject background

Physics topics with CT-PPS: beyond standard model

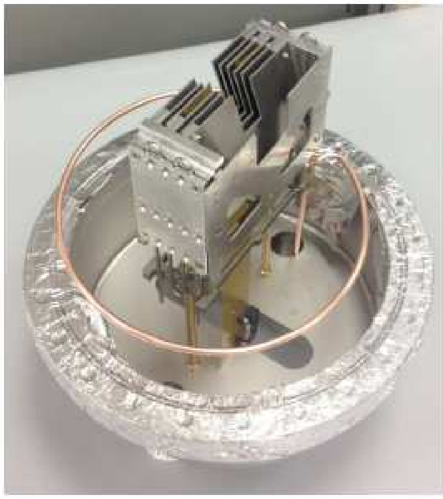


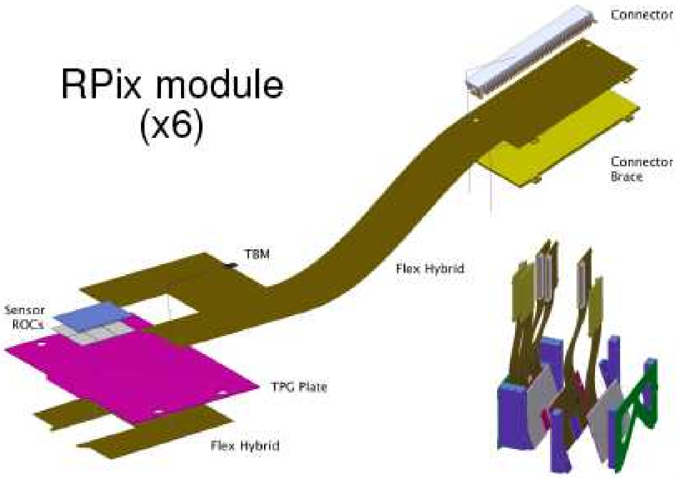
- Process sensitive to anomalous couplings: $\gamma\gamma WW$, $\gamma\gamma ZZ$, $\gamma\gamma\gamma\gamma$; motivated by studying in detail the mechanism of electroweak symmetry breaking, predicted by extradim. models
- Best possible sensitivity at the LHC

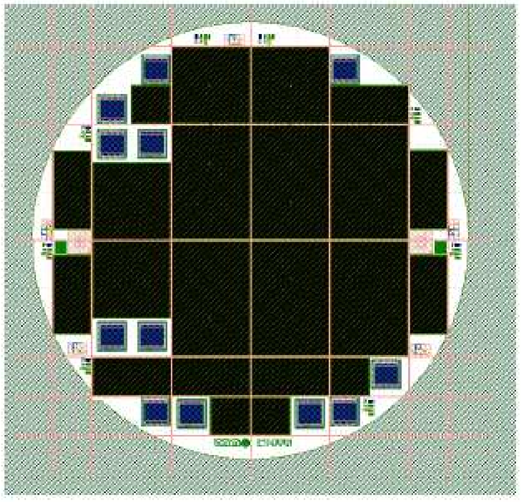


CT-PPS tracking detector

- Accelerated plan: TOTEM silicon strip detector: sustain high trigger rates, already part of CMS data taking, but not radiation hard
- 3D silicon pixels
  - 200 μm thin edges for minimal beam distance of approach
  - radiation-hard
  - 6 planes per station
  - full spatial resolution under 30 μm
  - Available towards the end of 2016

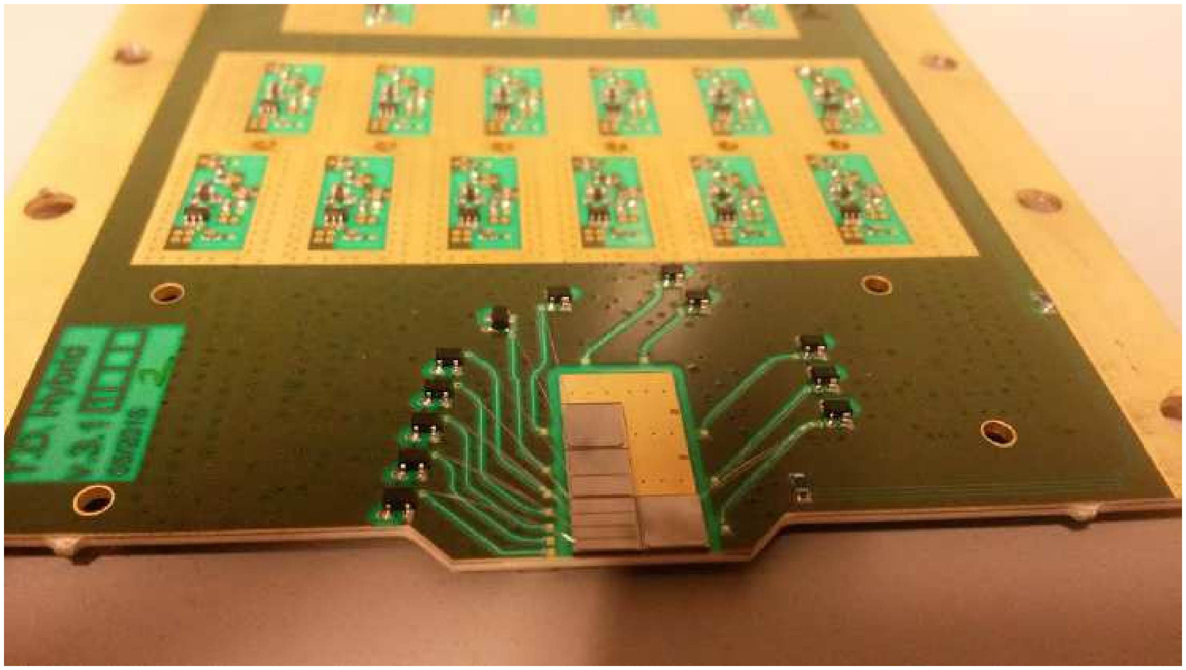






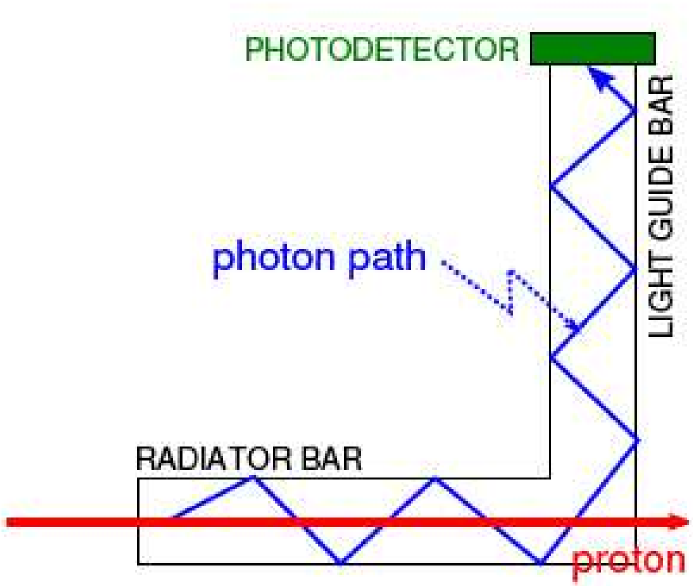
CT-PPS timing detector: TOTEM diamond detectors

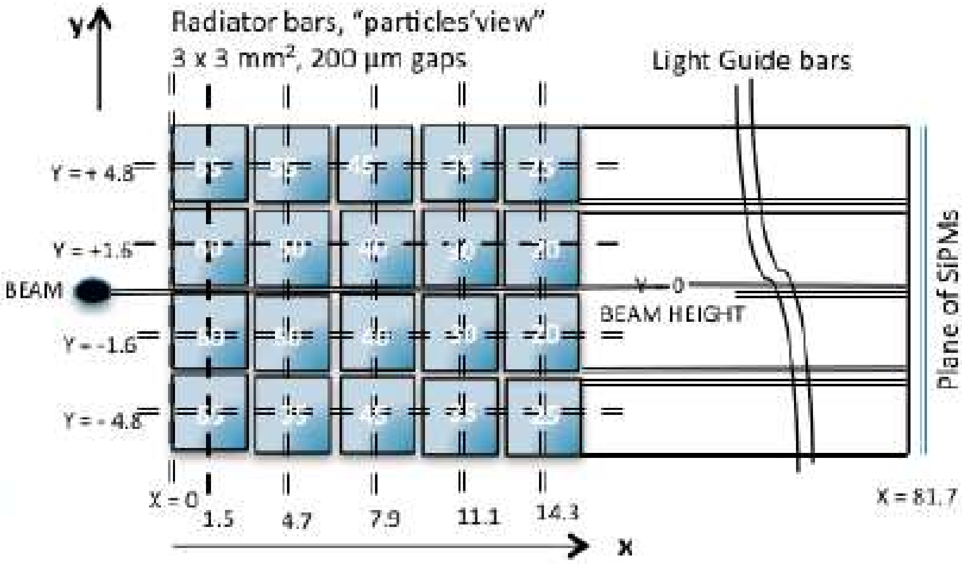
- accelerated detectors: TOTEM diamond detectors
- Hybrid design produced and tested in Jan-Feb 2016
- Time resolution $\sim$ 80 ps/plane, and so a combined resolution of 50 ps for 4 planes
- Plane geometry optimised in order to increase spatial resolution (the density of events is higher close to the beam): $\sim$ 150 μm
- Taking data since October 2016: 2.5 fb^{-1} accumulated



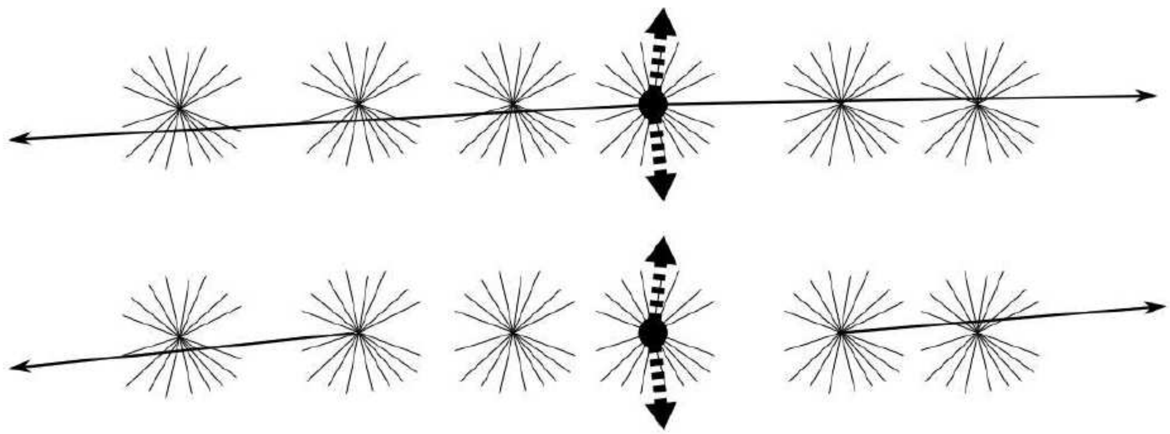
CT-PPS timing detector

- Ultrafast Si detectors
  - favored option
  - Goal: 30 ps per plane for $50 \mu m$ thickness
  - Performance in beam tests: 35-40 ps per plane
  - Installation foreseen in 2017
- Other solutions: QUARTIC / GasTOF
  - Grid of 4 $\times$ 4 quartz bars, timing resolution in early beam tests: 30 ps
  - GasTOF: good time resolution but problem getting a good space resolution



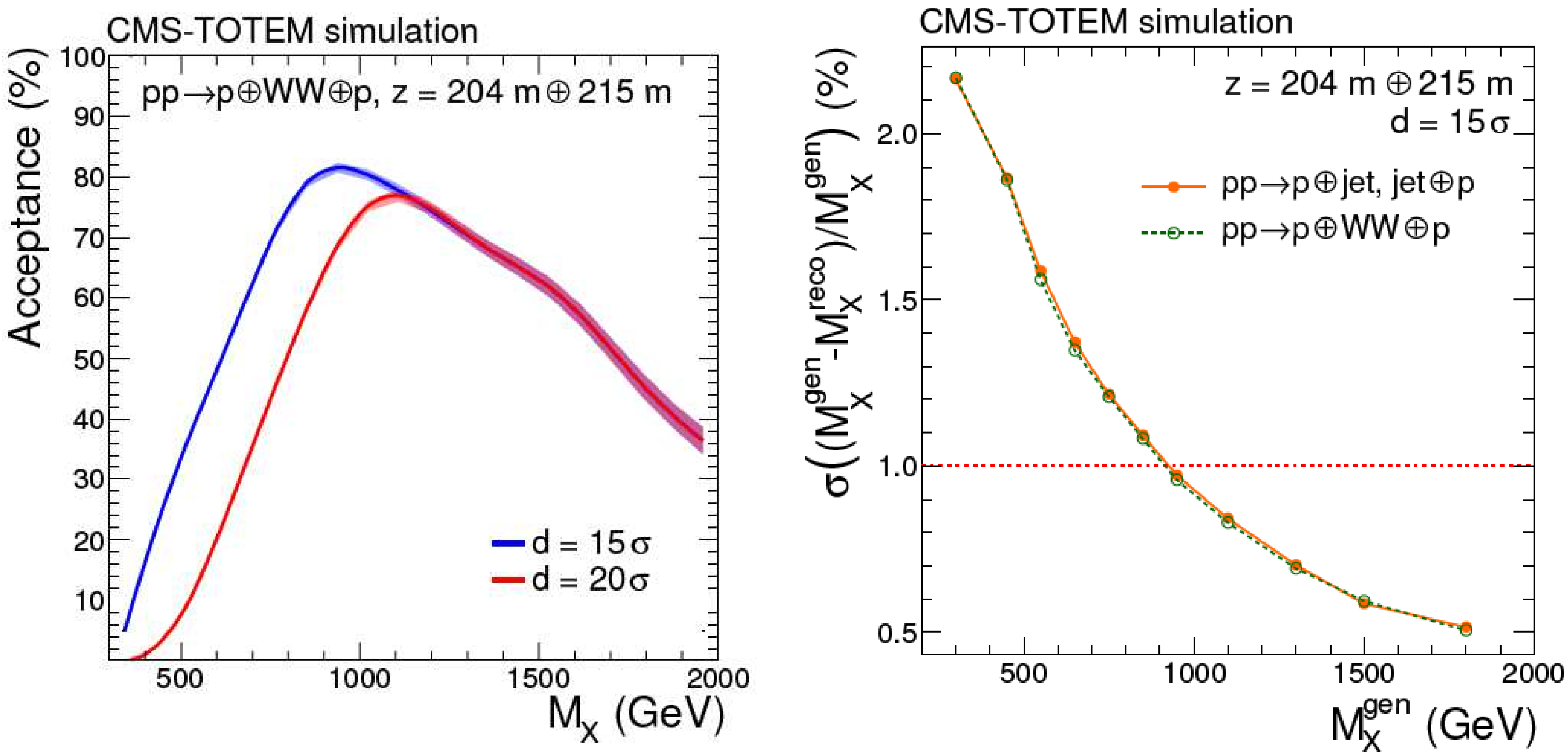


Removing pile up: measuring proton time-of-flight



- Measure the proton time-of-flight in order to determine if they originate from the same interaction as our photon
- Typical precision: 10 ps means 2.1 mm as an example
- 15-20 ps can be achieved with a few layers of ultrafast Si, even better timing resolution in development

CT-PPS: performance



- Good acceptance in masse between 450 and 1700 GeV (for a nominal optics)
- Mass resolution: 1.5% at $M \sim 500 GeV$, 1.2% at $M \sim 800 GeV$
- Real acceptance for 2017 still in discussion: probably increased toards high masses up to 1.9 TeV

Conclusion

- Many results from TOTEM elastic, total cross section measurements, different methods lead to similar results
- Non exponential form of $d\sigma/dt$ observed at 8 and 13 TeV
- $\rho = 0.12 \pm 0.03$
- CT-PPS project Well on track, taking data since end of Spring 2016, may fb^{-1} accumulated
- Present CT-PPS detector: TOTEM tracking detector, Diamond timing detectors
- Future CT-PPS detector: pixel Si , ultra fast silicon