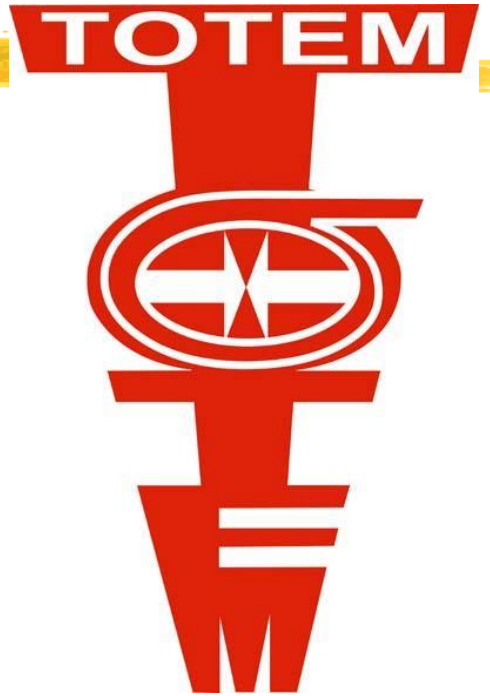
Status and perspective of the TOTEM experiment at LHC.

F.S. Cafagna
INFN Bari unit
On behalf of TOTEM Collaboration



TOTEM Physics goals

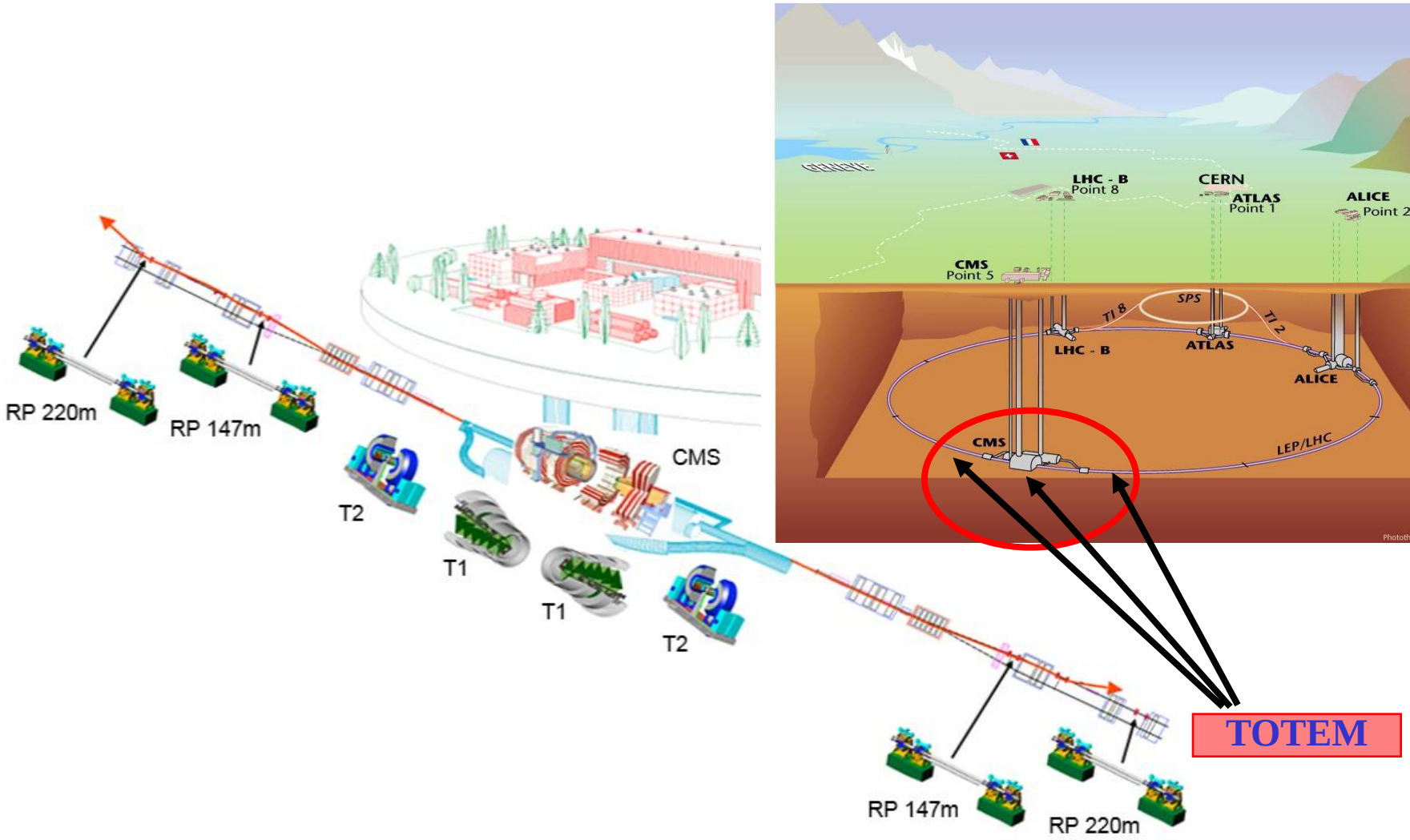
- TOTEM (TOTal cross section, Elastic scattering and diffraction dissociation Measurement at the LHC)
  - σ_{TOT}^{pp} with a precision ~ 1-2%, luminosity independent method (optical theorem) simultaneously measuring:
    - N_{el} down to -t ~10^{-3} GeV^2
    - N_{inel} with losses < 3%

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

$$\sigma_{tot}^2 = \frac{16\pi}{1+\rho^2}\frac{d\sigma_{el}}{dt}|_{t=0}, \quad \sigma_{inel} = \sigma_{tot} - \sigma_{el}.$$

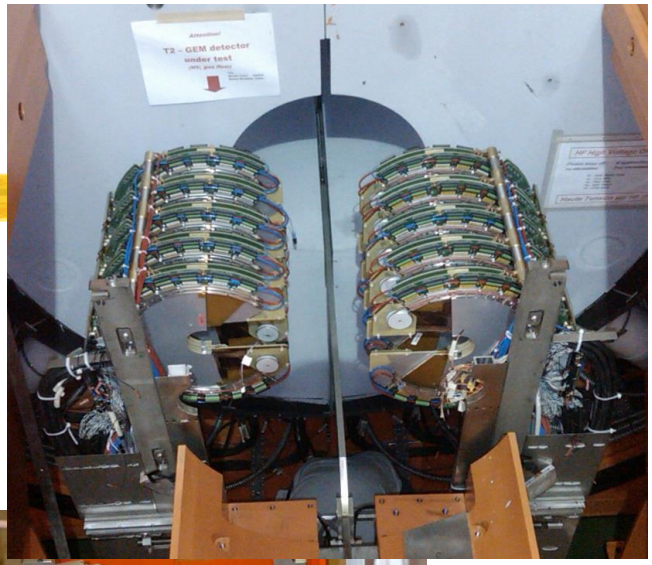
  - Elastic pp scattering in the range $10^{-3} < |t| \sim (p\theta)^2 < 10$ GeV^2
  - Soft diffraction (SD and DPE)
  - Particle flow in the forward region (cosmic ray MC validation/tuning)

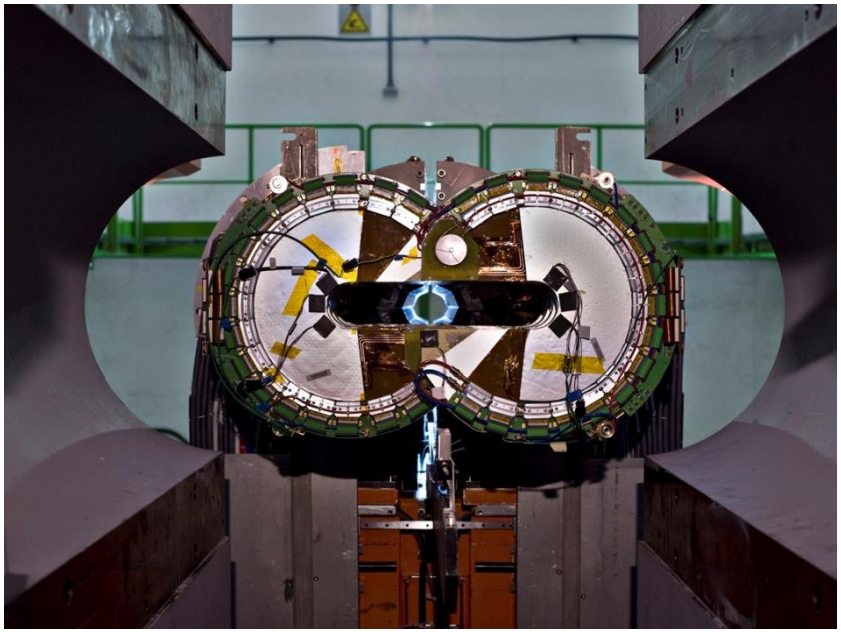
TOTEM Experiment LHC Run I



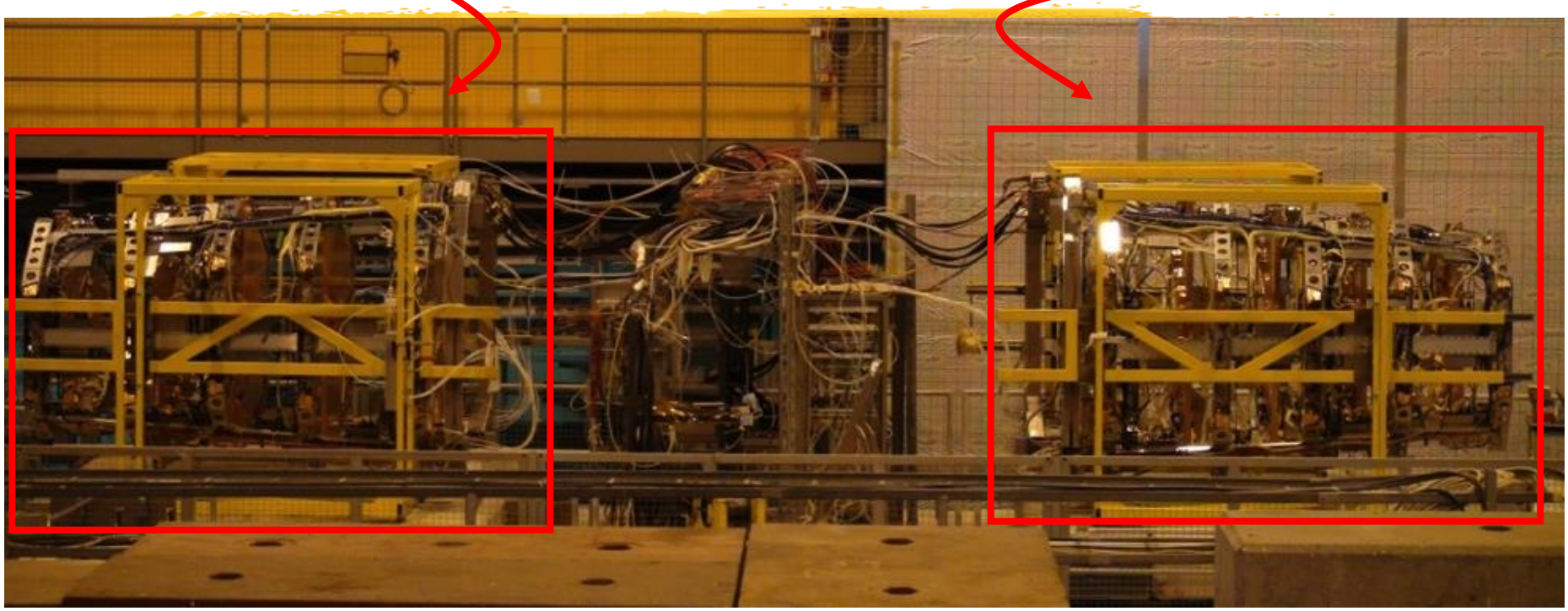
T2 Detector

- T2 telescope is based on GEM chambers.





T1 detector



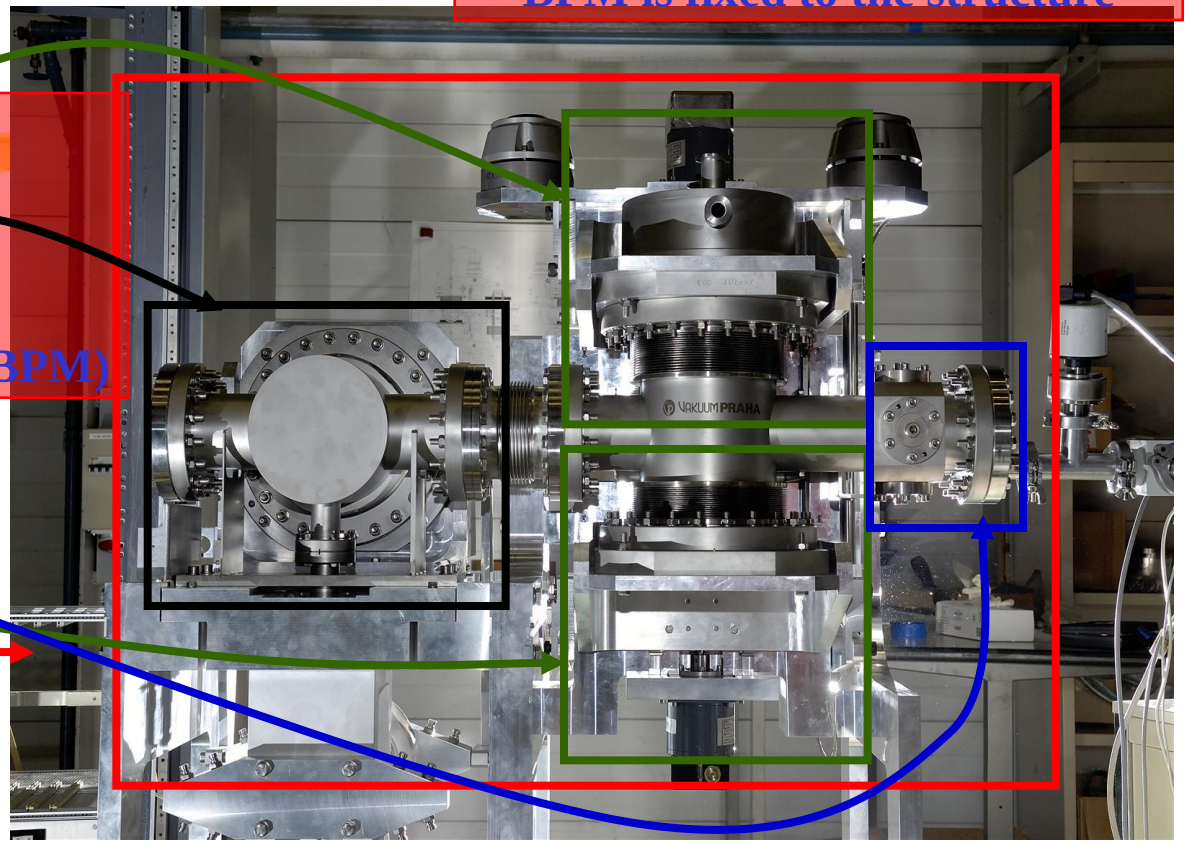
- T1 telescope uses cathode strip chambers (CSC)

Roman pots

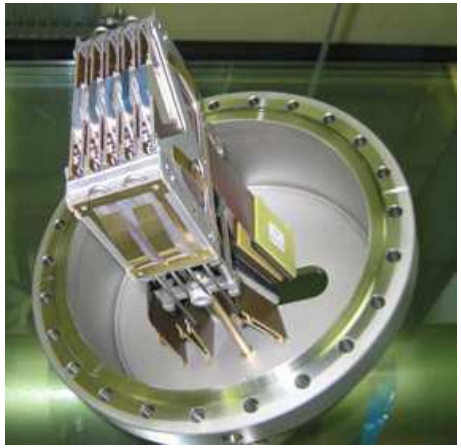
BPM is fixed to the structure

One RP station:
- 2 units

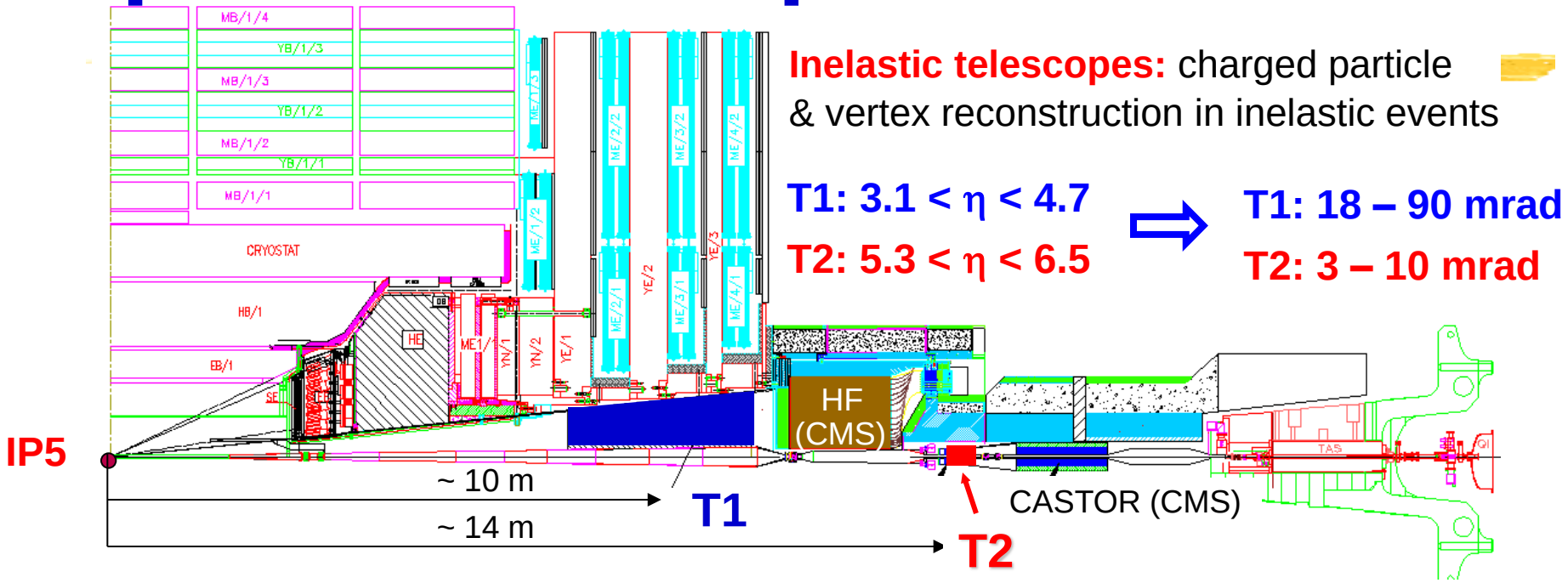
One unit:
- 2 vertical pot
- 1 horizontal pot
- 1 Beam Position Monitor (BPM)



- During LHC RunI, 12 Roman pots, distributed in 4 stations at ±220 and ±147 m.
- Each RP is equipped with a stack of 10 silicon strip detectors, designed with the specific objective of reducing the insensitive area at the edge facing the beam to only a few tens of μm



Experimental Setup @ IP5 LHC Run I

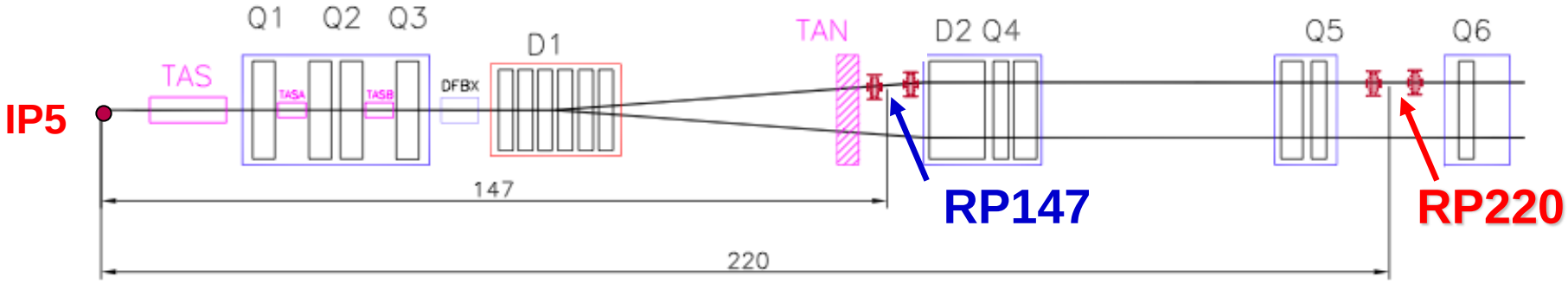


Inelastic telescopes: charged particle & vertex reconstruction in inelastic events

T1: 3.1 < η < 4.7 ⇨ **T1: 18 – 90 mrad**

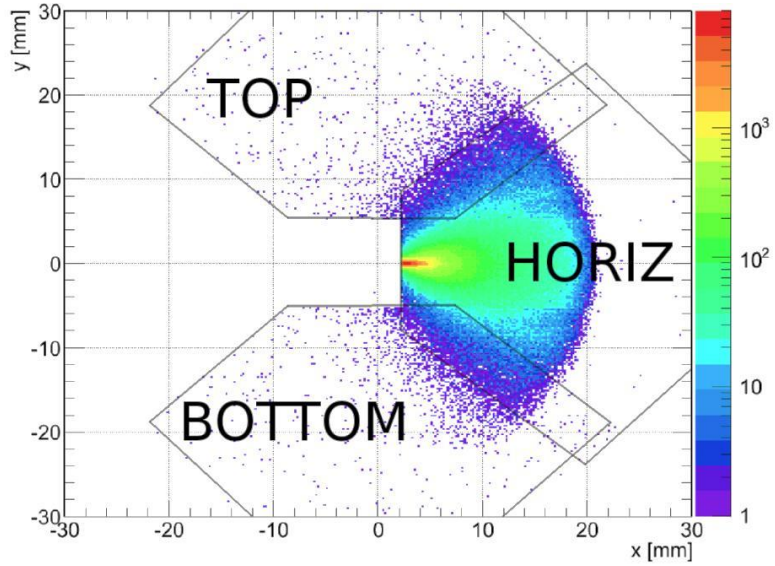
T2: 5.3 < η < 6.5 ⇨ **T2: 3 – 10 mrad**

Roman Pots: measure elastic & diffractive protons close to outgoing beam



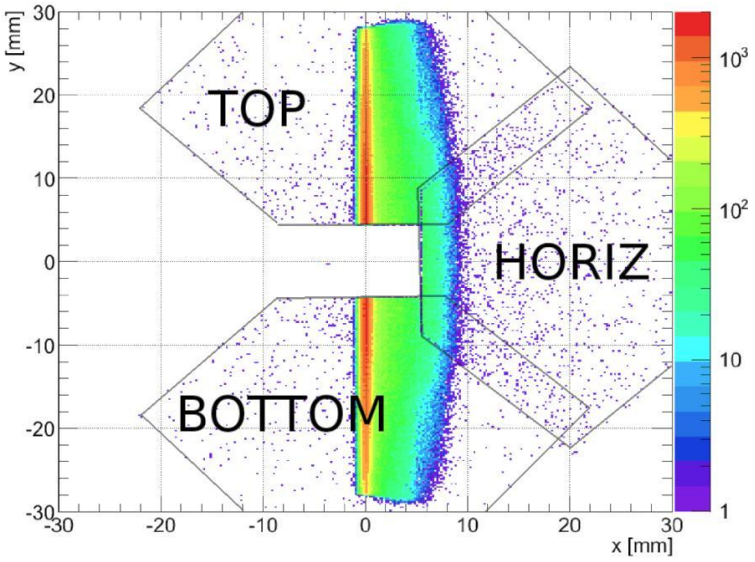
LHC Optics

β* = 0.55 m (low β* = standard at LHC)



- **Diffractive** protons are mainly in the **horizontal** pot
- **Elastic** protons in the **vertical** pot near X~0

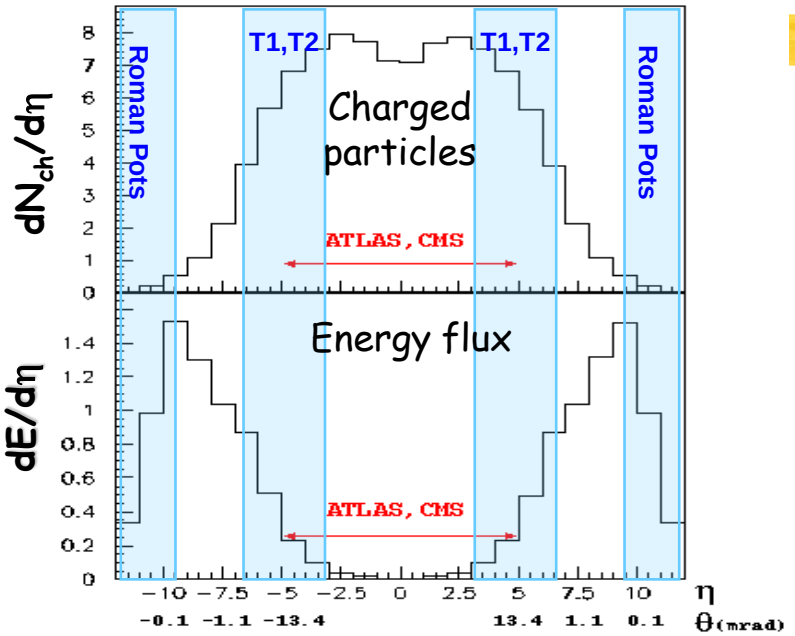
β* = 90 m (special optic for RP runs)

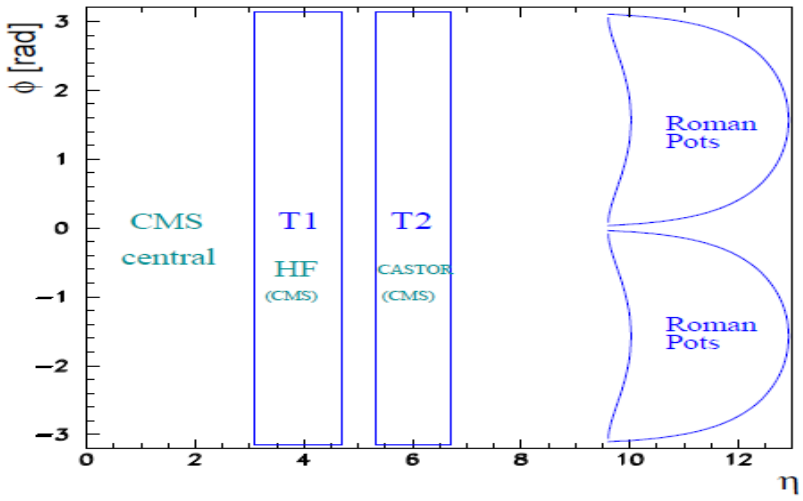


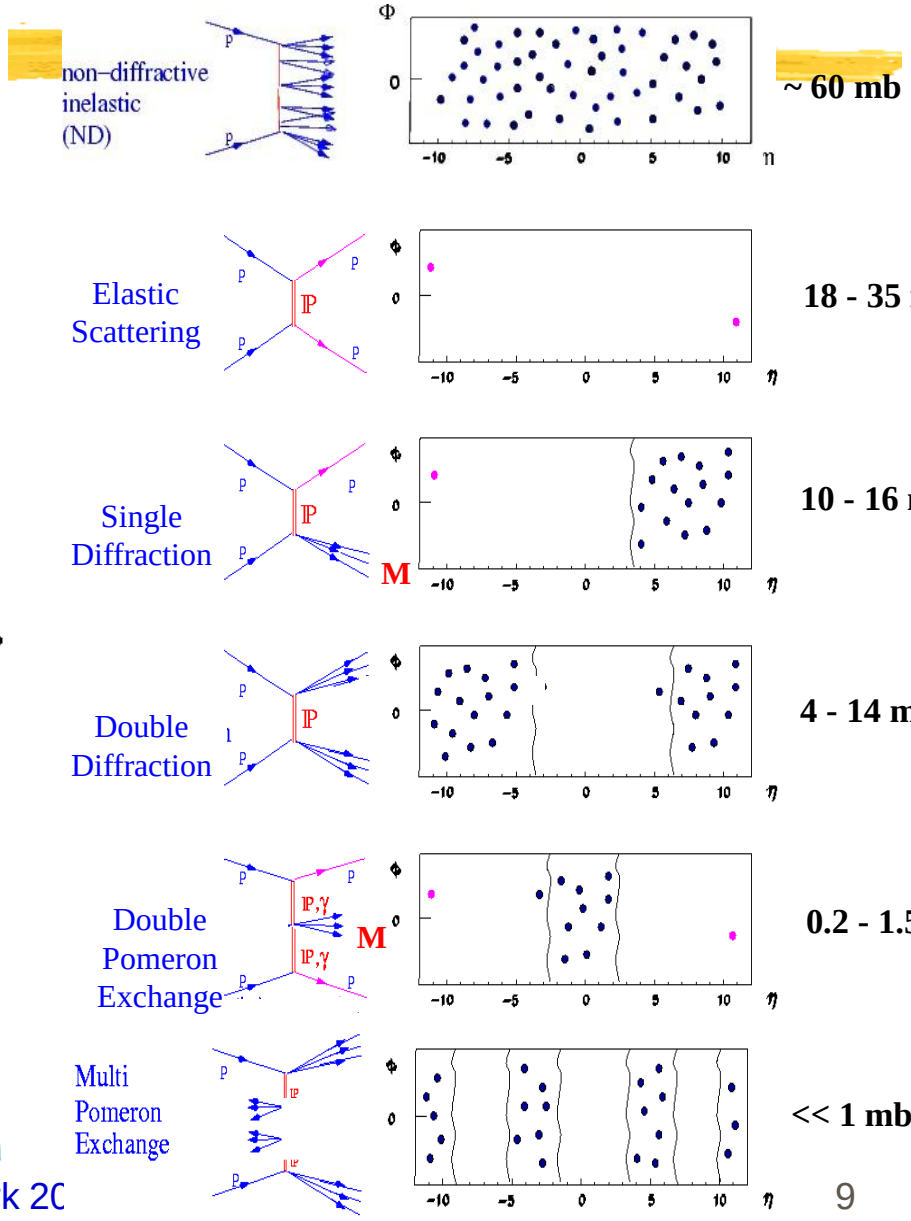
- **Diffractive** protons are mainly in the **vertical** pot.
- **Elastic** protons in a **narrow band** at X~0

Event Topology & η coverage

LHC, inelastic collisions







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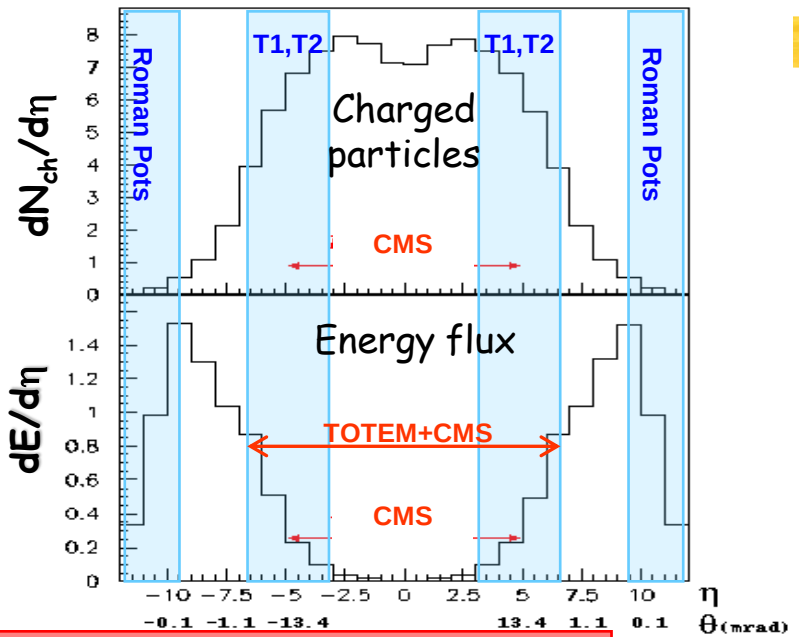
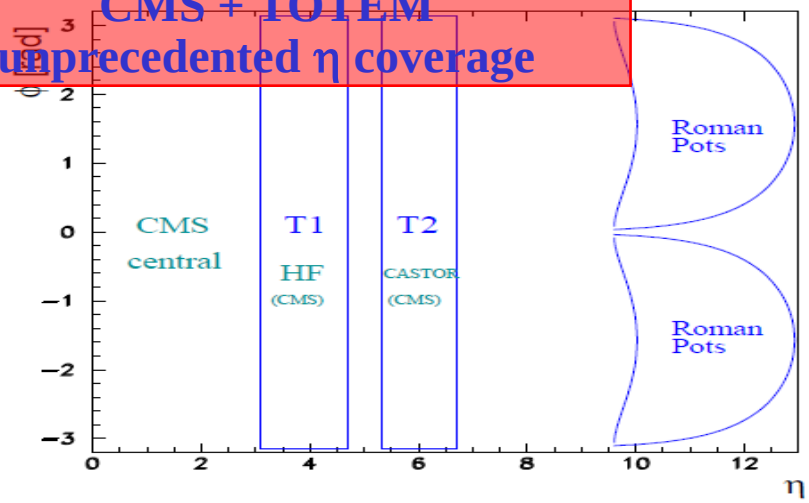
  - Soft diffraction (SD and DPE)
  - Particle flow in the forward region (cosmic ray MC validation/tuning)
- TOTEM & CMS
  - Soft and hard diffraction in SD and DPE (production of jets, bosons, h.f.)
  - Central exclusive particle production
  - Low-x physics
  - Particle and energy flow in the forward region

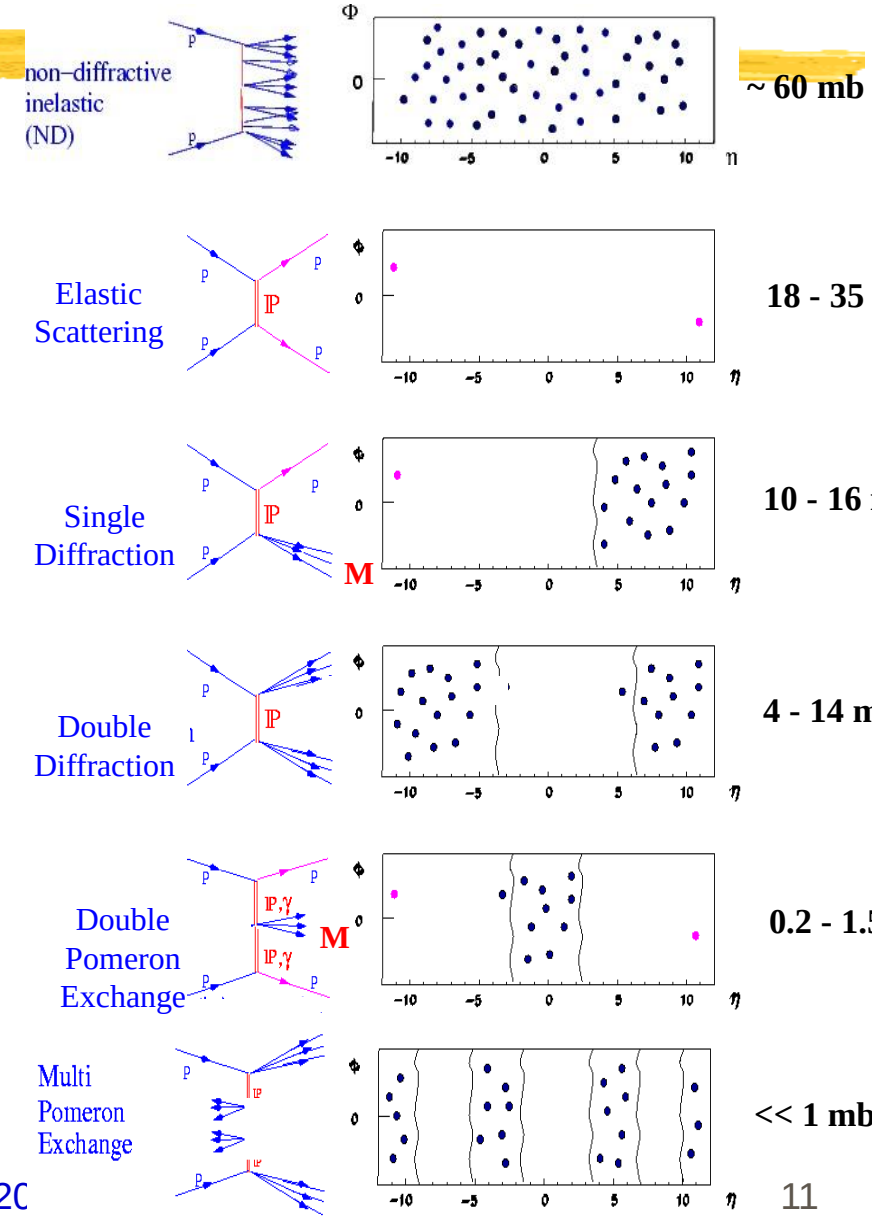
Event Topology & η coverage

LHC, inelastic collisions



CMS + TOTEM unprecedented η coverage





Cross-sections

elastic observables only:

$$\sigma_{tot}^2 = \frac{16\pi}{1+\varrho^2}\,\frac{1}{\mathcal{L}}\,\left.\frac{dN_{el}}{dt}\right|_0$$

June 2011 (EPL96): σ_{tot} = (98.3 ±2.8) mb
Oct. 2011 (EPL101): σ_{tot} = (98.6 ±2.2) mb

σ_{tot}

ϱ-independent:

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

σ_{tot} = (99.1 ± 4.3) mb

luminosity-independent:

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

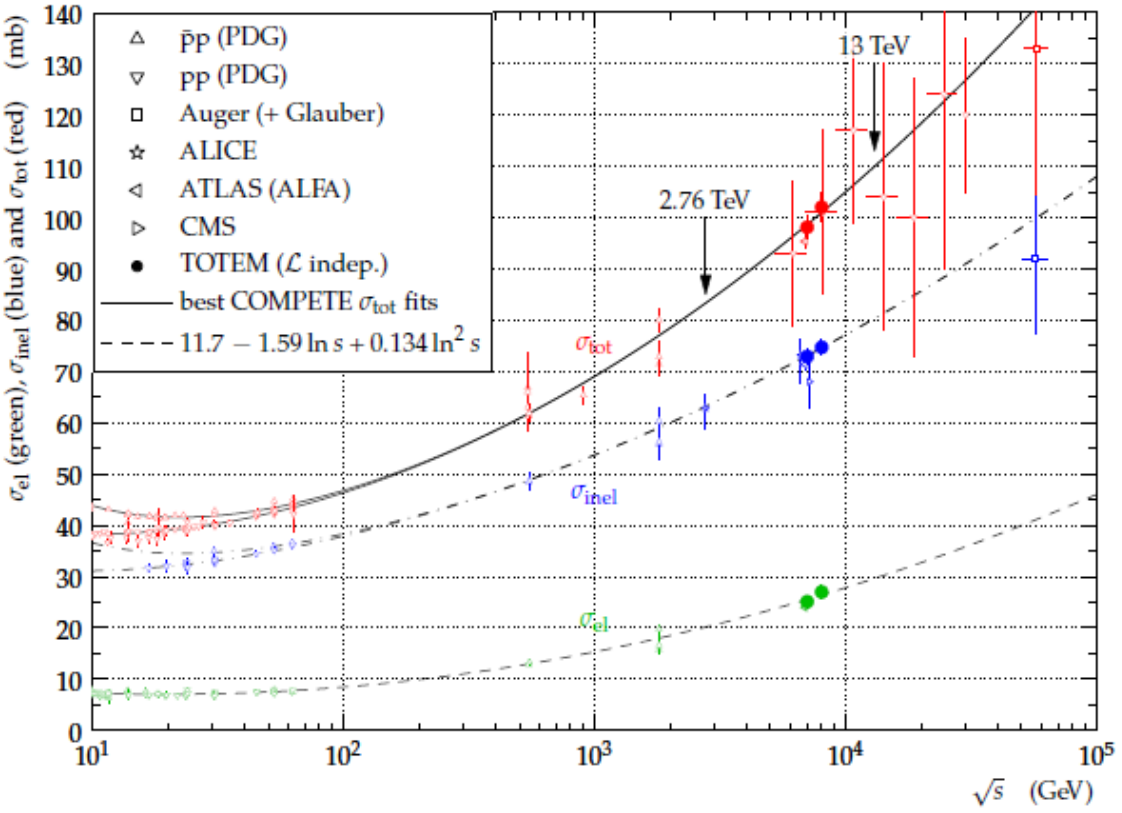
σ_{tot} = (98.0 ± 2.5) mb

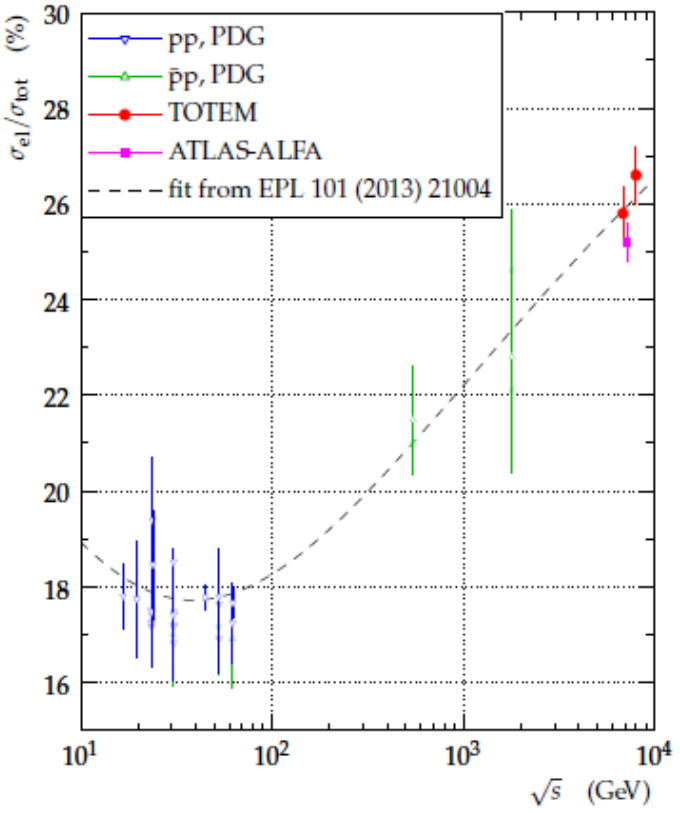
- At $\sqrt{s}$ = 7 TeV: all 3 methods consistent;
- Only lumi-independent method at $\sqrt{s}$ = 8 TeV;
- Analysis on-going for $\sqrt{s}$ = 2.6 & 13 TeV;

TOTEM total cross-section

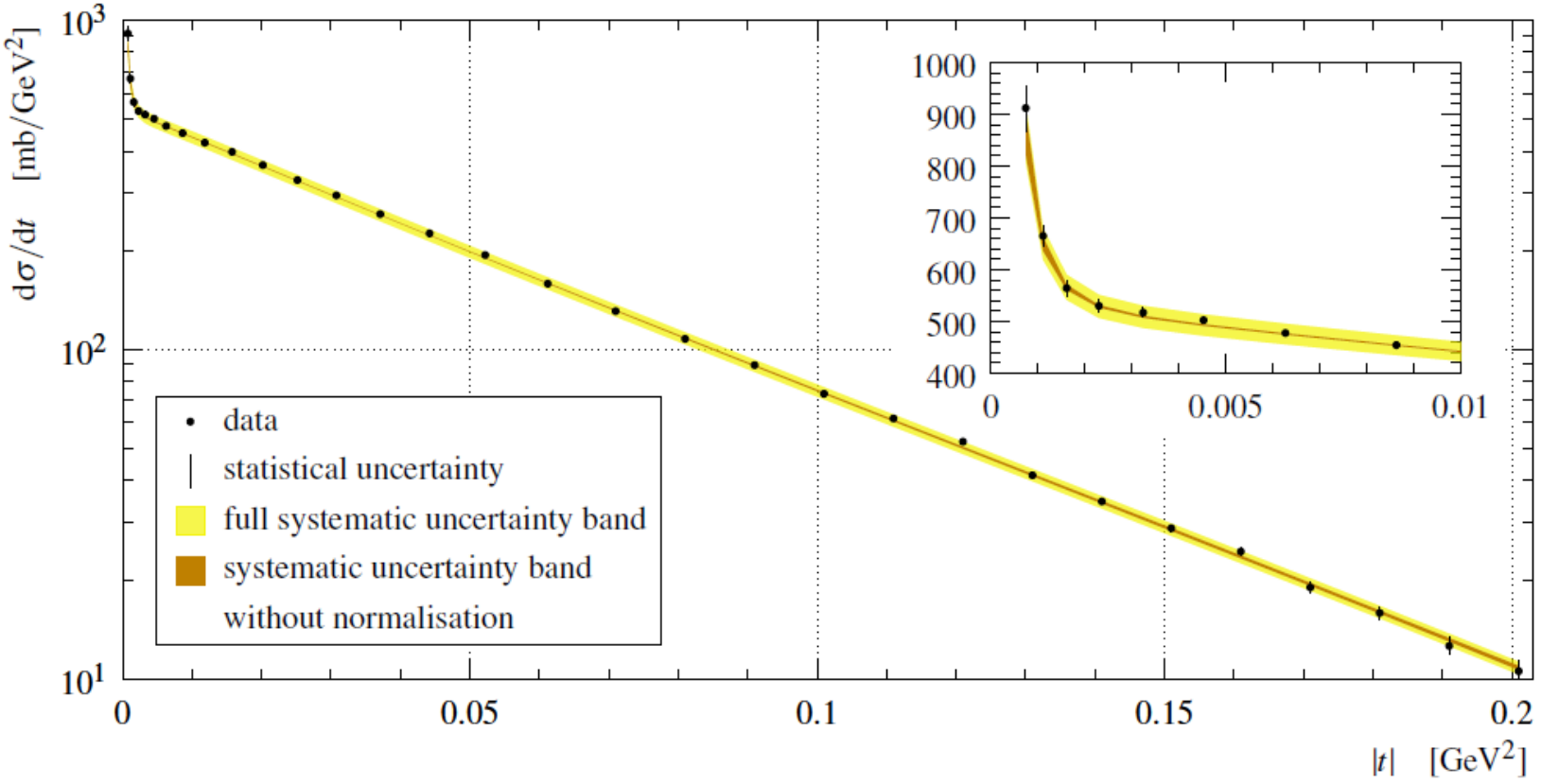
	$\mathscr{L}$ independent at $\sqrt{s} = 7$ TeV, eq. 1.1	$\mathscr{L}$ independent at $\sqrt{s} = 8$ TeV, eq. 1.1
σ_{tot} (mb)	98.0 ± 2.5	101.7 ± 2.9
σ_{inel} (mb)	72.9 ± 1.5	74.7 ± 1.7
σ_{el} (mb)	25.1 ± 1.1	27.1 ± 1.4

	$\sqrt{s} = 7$ TeV, $4.7 < \lvert\eta_{min}\rvert < 6.5$
σ_{DD} (μb)	116 ± 25





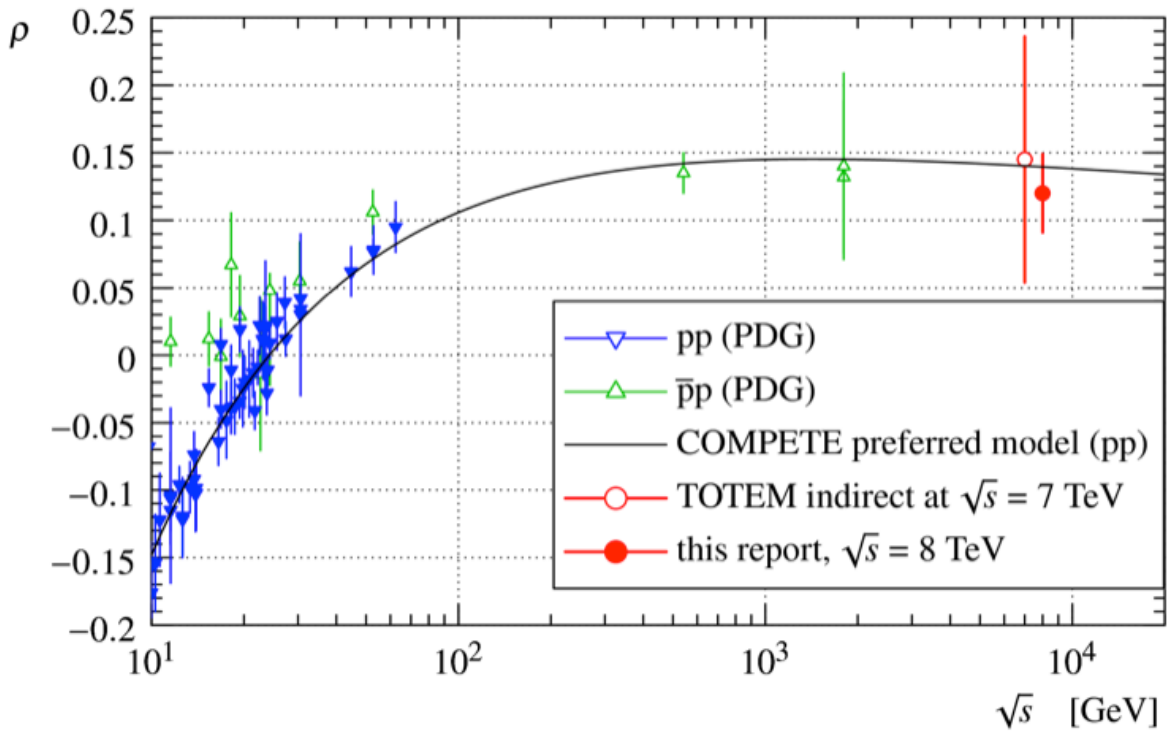
Coulomb Nuclear interference region



- Measurement down to $|t| \sim 6 \times 10^{-4}$ GeV^2:
  - $\beta^* = 1000$ m optics;
  - Roman Pot at 3σ from the beam;

Coulomb Nuclear interference: ρ

	KL, constant	KL, peripheral
step 1: χ^2/ndf	$25.7/25 = 1.03$	$25.0/25 = 1.00$
step 2: χ^2/ndf	$57.5/56 = 1.03$	$57.6/56 = 1.03$
a [mb/GeV^2]	549 ± 24	549 ± 24
b_1 [GeV^{-2}]	20.47 ± 0.14	19.56 ± 0.13
b_2 [GeV^{-4}]	8.8 ± 1.6	-3.3 ± 1.5
b_3 [GeV^{-6}]	20 ± 6	-13 ± 5
ρ	0.12 ± 0.03	0.12 ± 0.03
ζ_1		800
κ		2.311
ν [GeV^{-2}]		8.161
σ_{tot} [mb]	102.9 ± 2.3	103.0 ± 2.3



- First LHC determination from Coulomb-hadronic interference at √s=8TeV: ρ = 0.12±0.03.
- Cross-section measurements compatible with lumi-independent one.

Ruling out SWY approach

- High-statistics data with β^*=90m at $\sqrt{s}$ = 8 TeV, can be used to compare differential elastic cross-section, with a pure exponential

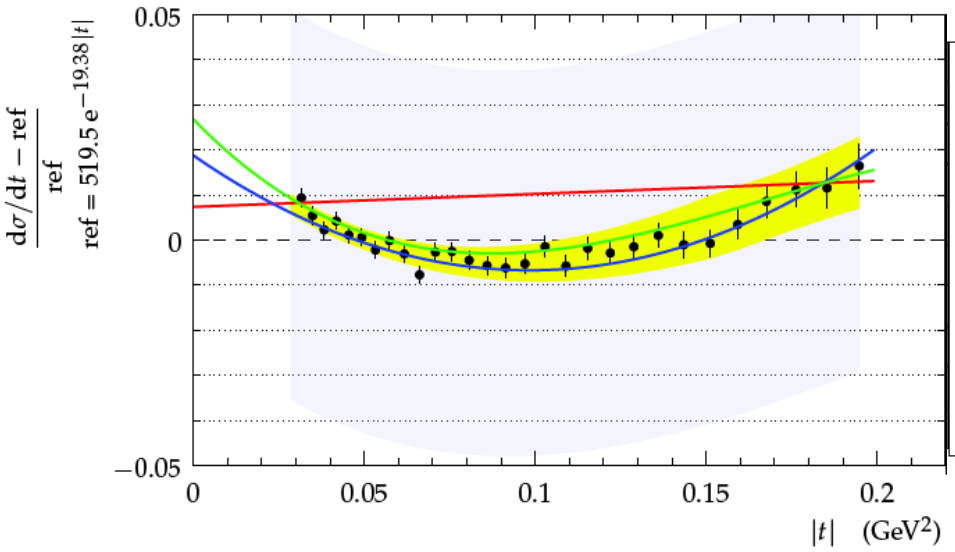
$d\sigma/dt \propto |F^{C+H}|^2$ = Coulomb + hadronic + "interference"

from QED

constrained by measured $e^{-B(t)}$
$B(t) = b_1 t + b_2 t^2 + \ldots$
N_b = # parameters in exp.

***Simplified West-Yennie (SWY)* [1]: often used "standard", only compatible with pure exponential amplitude & constant phase**

- Now exclude Coulomb-hadronic interference with constant phase & constant exponential slope for hadronic amplitude (N_b= 1) at >7σ using same data ⇒ ruling out SWY approach



diagonals combined
- data (binning ob)
- statistical uncertainties
- systematic uncertainty band: analysis+normalisation
- systematic uncertainty band: analysis only

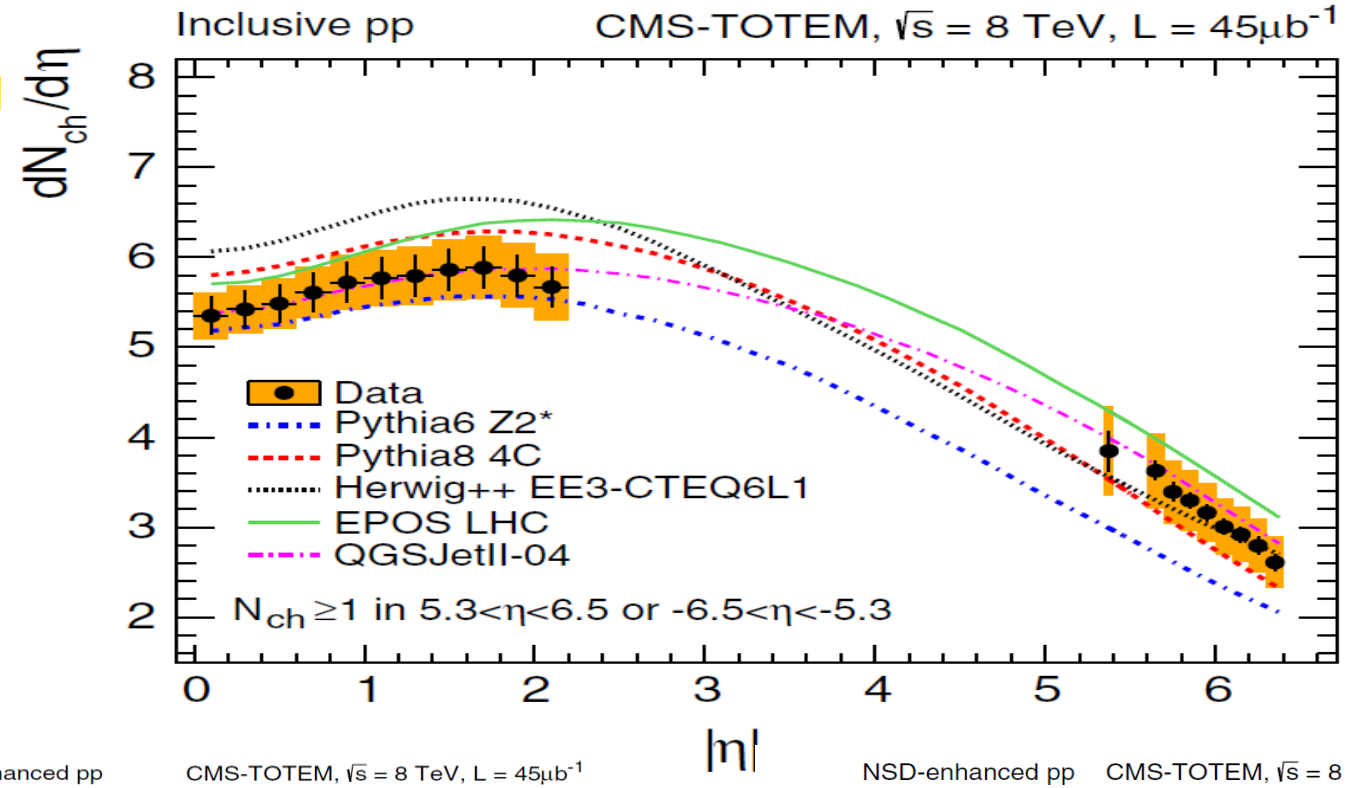
fit parametrisation: $a \exp(\sum_{n=1}^{N_b} b_n t^n)$

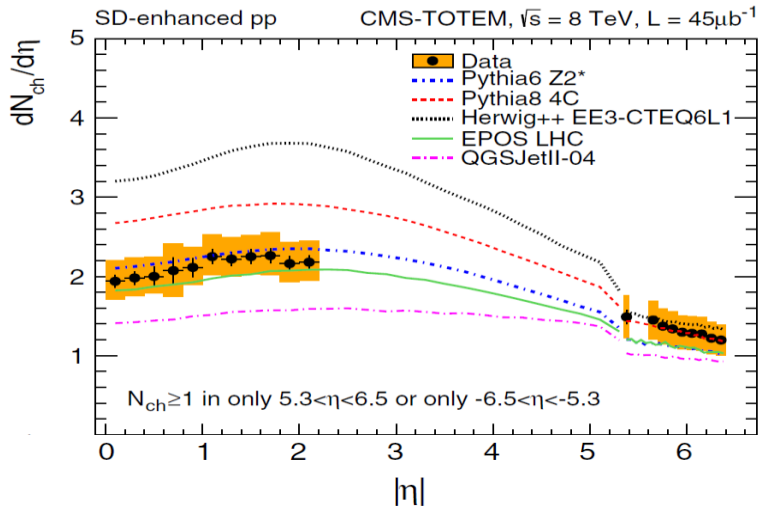
fits with statistical and systematic uncertainties:

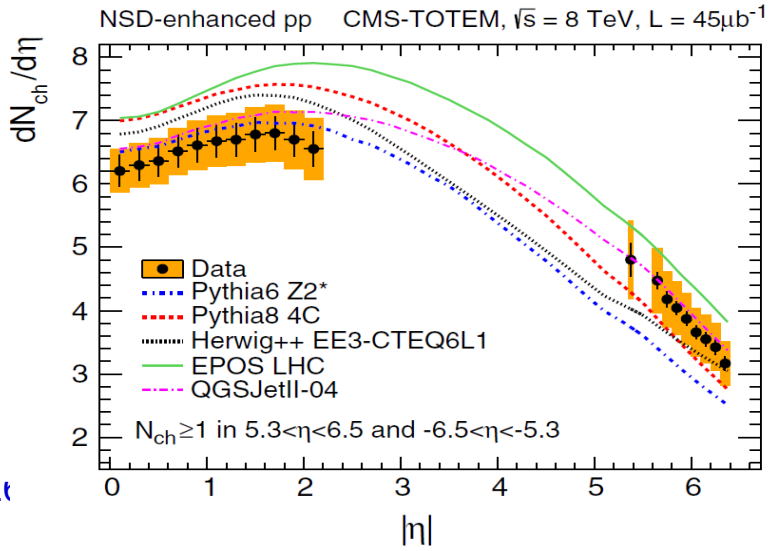
$N_b = 1$: $\chi^2/\text{ndf} = 117.5/28 = 4.198 \Rightarrow$ p-value $= 6.14 \times 10^{-13}$, significance = 7.20 σ
$N_b = 2$: $\chi^2/\text{ndf} = 29.3/27 = 1.085 \Rightarrow$ p-value $= 3.47 \times 10^{-1}$, significance = 0.94 σ
$N_b = 3$: $\chi^2/\text{ndf} = 25.5/26 = 0.980 \Rightarrow$ p-value $= 4.92 \times 10^{-1}$, significance = 0.69 σ

[1] G. B. West and D. R. Yennie, Phys. Rev. 172 (1968) 1413.

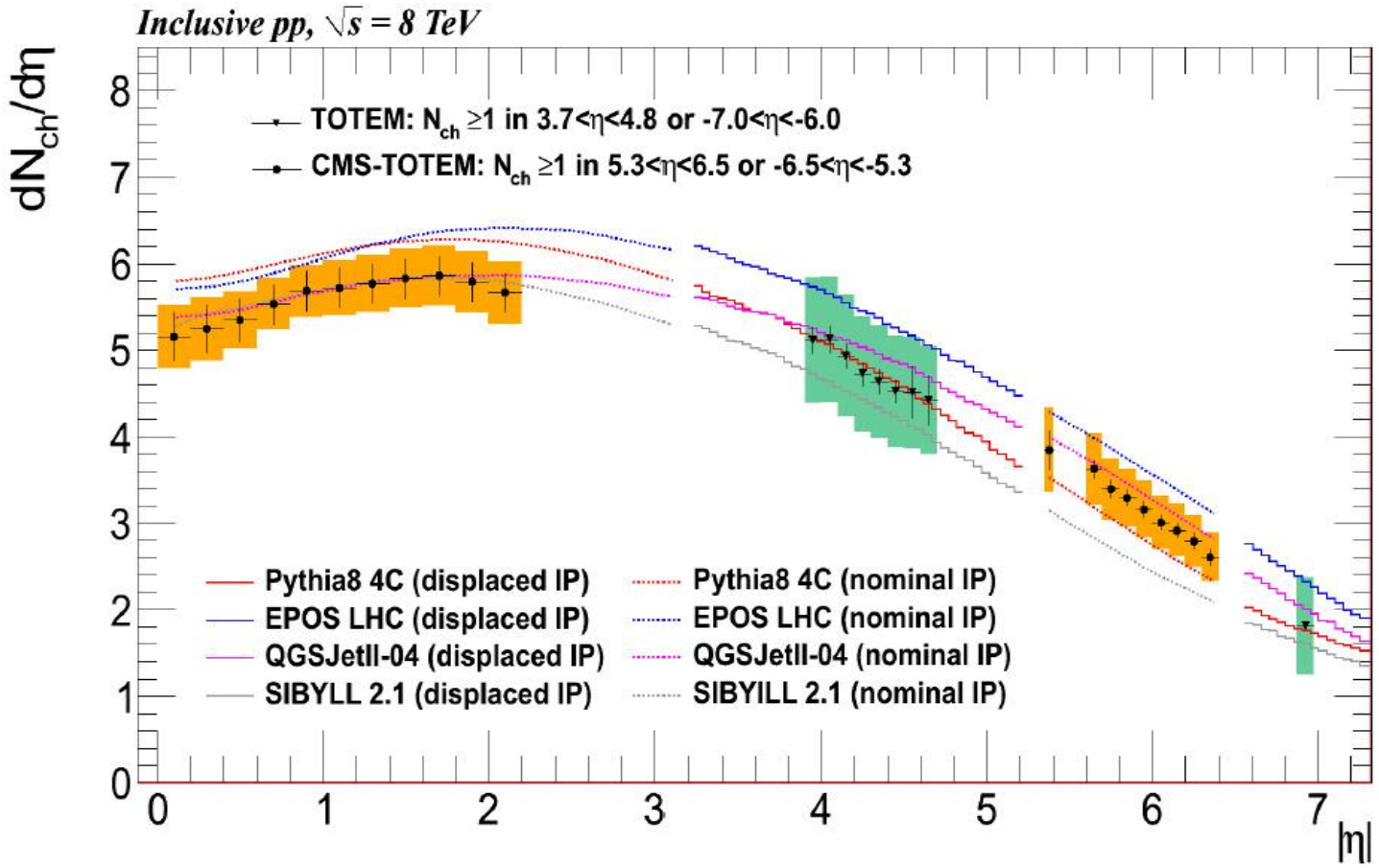
CMS-TOTEM Forward Charged Multiplicity

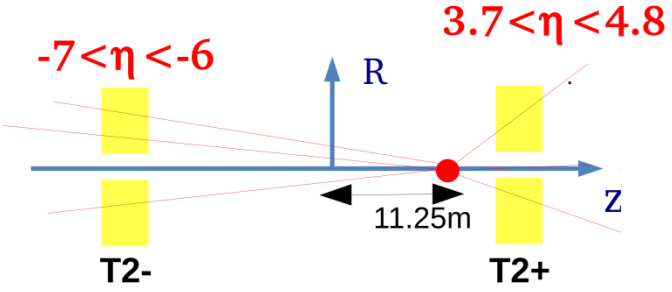




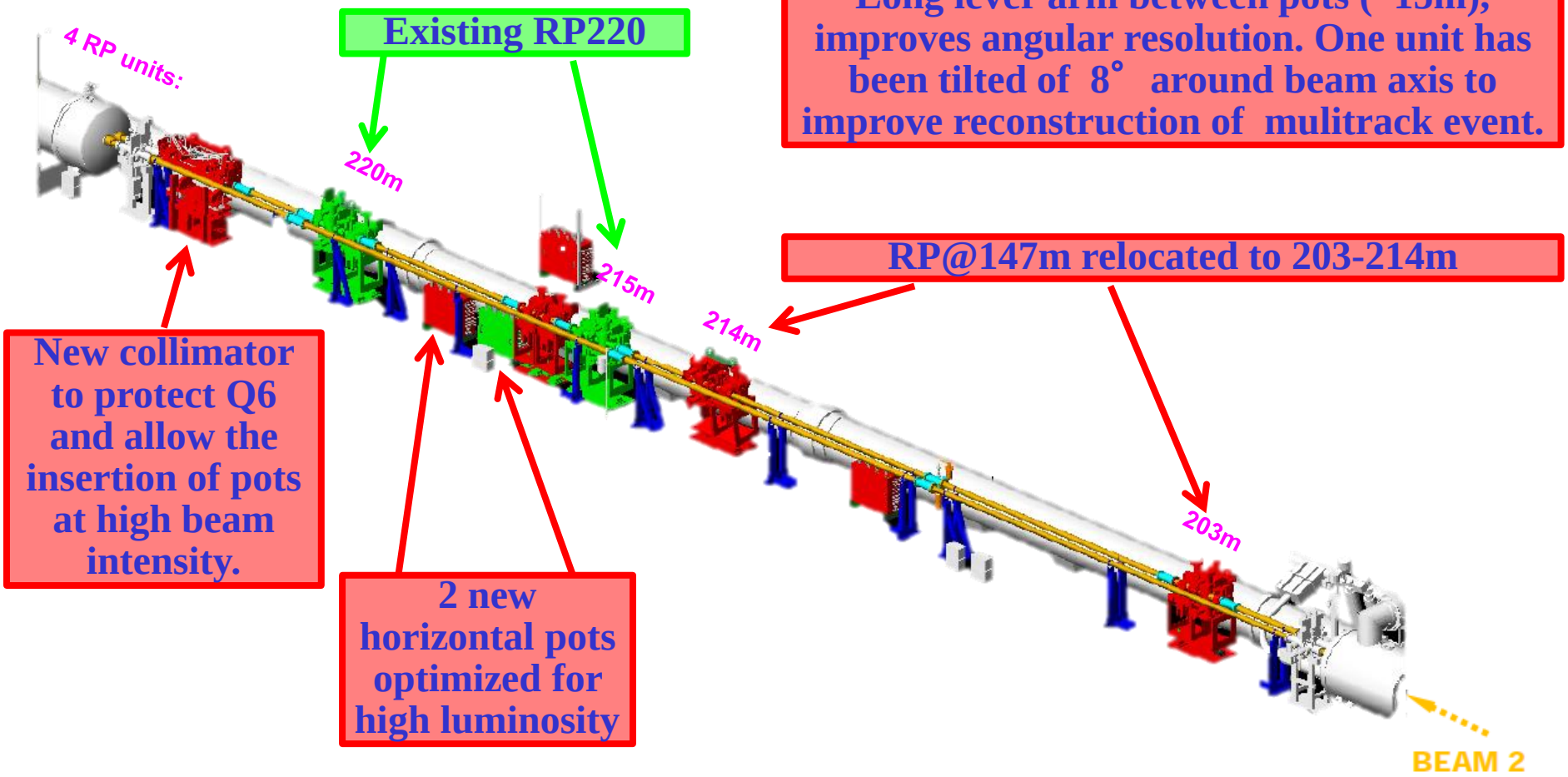


TOTEM Extended Forward Charged Multiplicity





TOTEM Program for RUN II



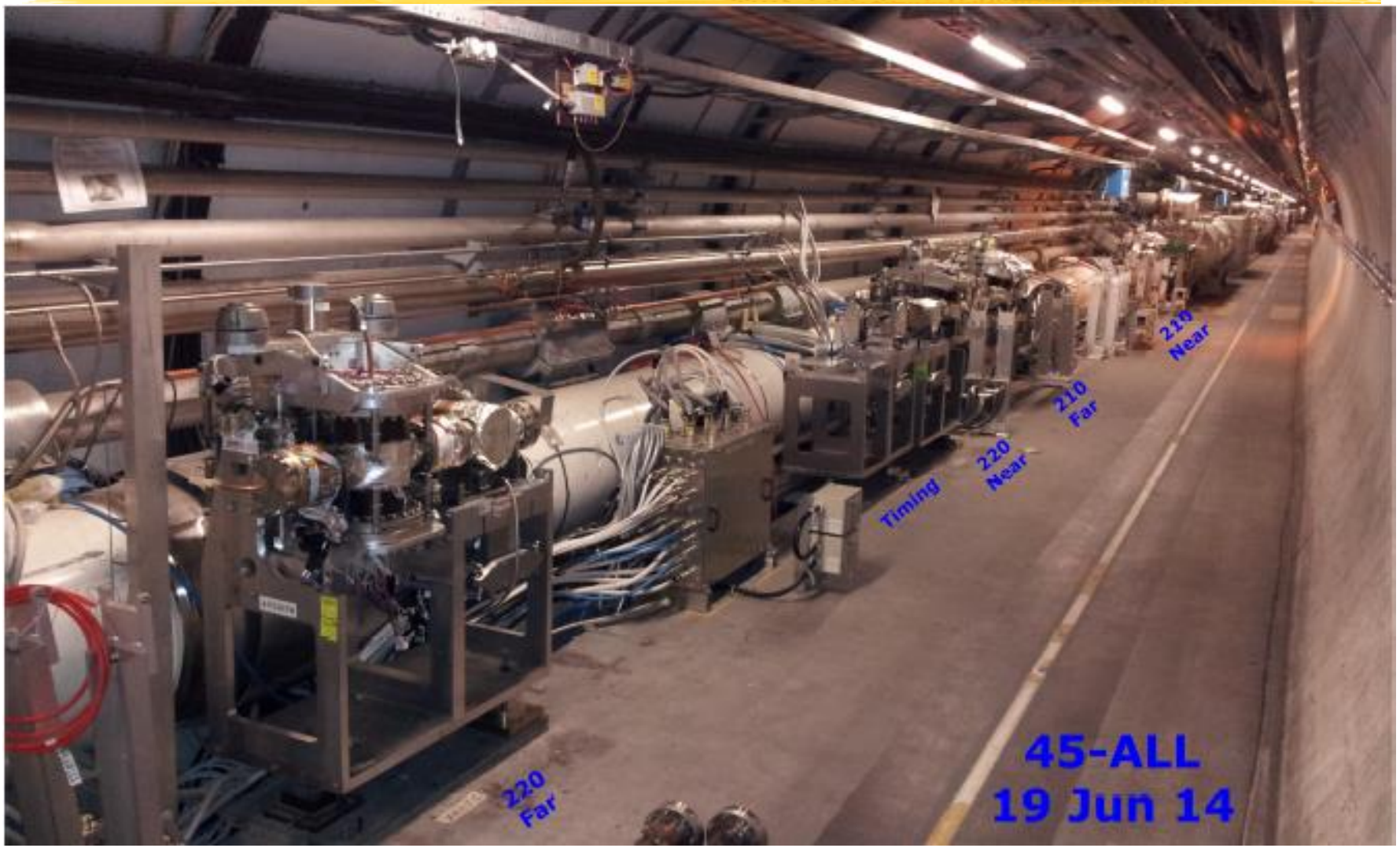
Long lever arm between pots (~15m), improves angular resolution. One unit has been tilted of 8° around beam axis to improve reconstruction of mulitrack event.

RP@147m relocated to 203-214m

New collimator to protect Q6 and allow the insertion of pots at high beam intensity.

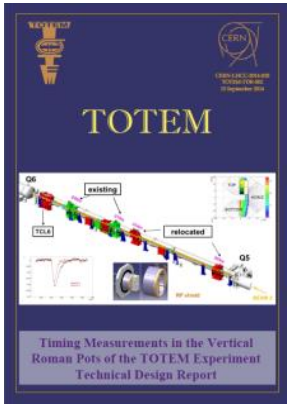
2 new horizontal pots optimized for high luminosity

Roman Pot new layout for Run II

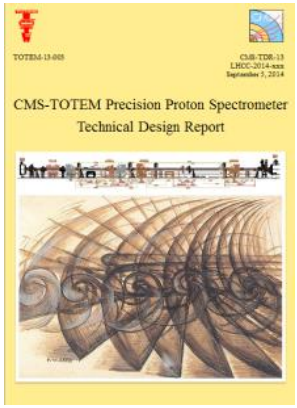


Two TDRs

- Two TDR released, two complementary projects:
  - **Timing Measurements in the Vertical Roman Pots of the TOTEM Experiment**
    - **High β^* (90 m), special runs, low luminosity;**
    - All **vertical RPs** with one equipped with timing detectors (TOTEM R&D);
    - Integrated Luminosity of the order of 1-100 pb^{-1};
    - CMS and TOTEM common data taking;



  - **CMS-TOTEM Precision Proton Spectrometer**
    - **Low β^* (0.5 m), standard runs, high luminosity;**
    - CMS & TOTEM collaboration for a common R&D for detectors to be installed in the relocated **horizontal RPs** and newly constructed **horizontal RPs**;
    - Integrated Luminosity of the order of fb^{-1}.



The TOTEM timing TDR

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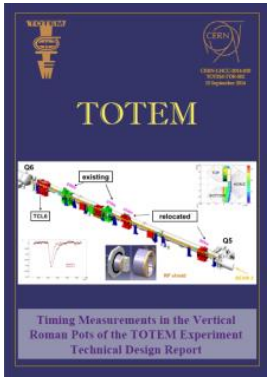

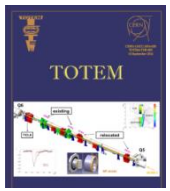

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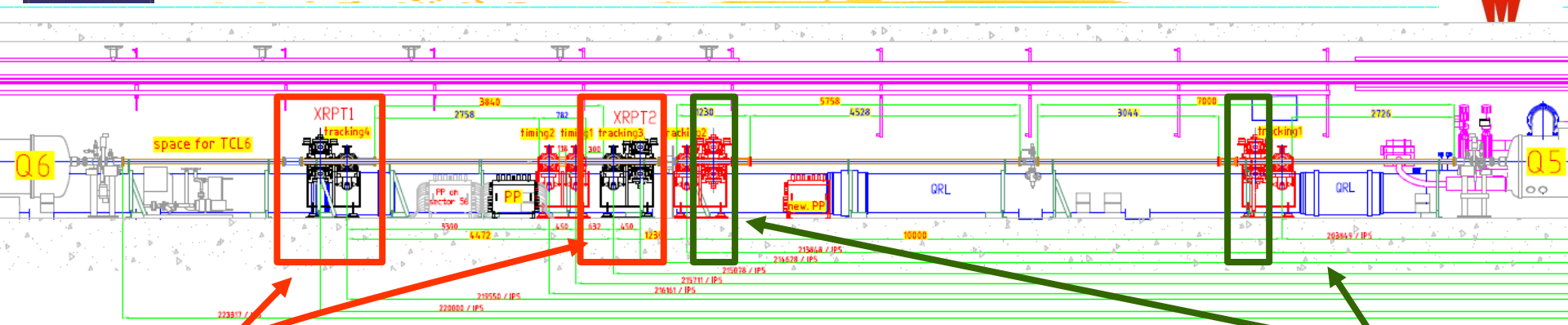
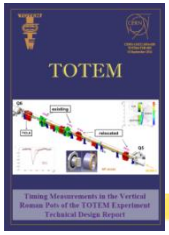
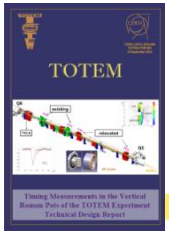


- In this measurements all TOTEM tracking detectors in **all vertical RPs** will be used, i.e. existing RP at 220 m and relocated RP at 203-213 m.
- New timing detector will be installed in a **vertical RP**.



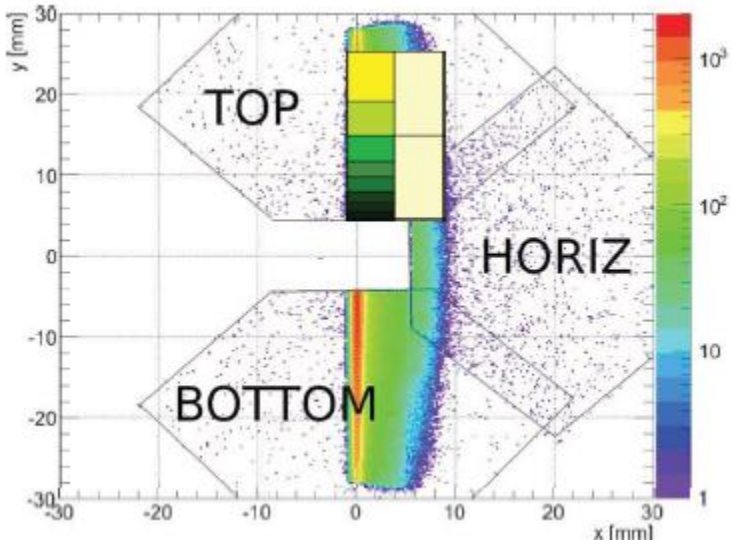
The TOTEM timing TDR

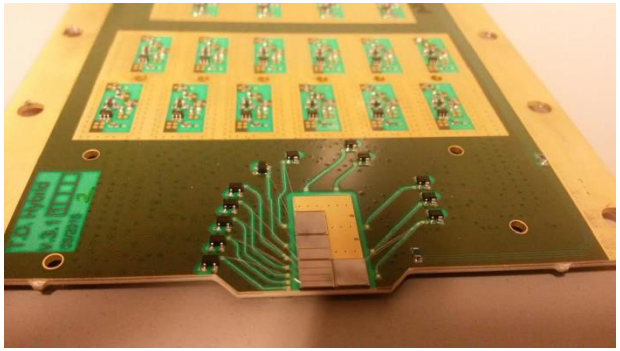
- Scientific objectives:
  - Exclusive central diffraction;
  - Low mass resonances and glueball states;
  - Exclusive charmonium state;
  - Search for missing mass and momentum candidates;
  - Exclusive jet production.
- The integrated luminosities, required by the cross-sections of the processes, imply a pileup from ~10% up to ~50% -> TIMING detectors are needed above 15%.

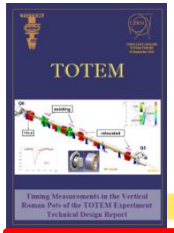


The TOTEM timing TDR

- Timing detectors in the relocated vertical RPs:
  - Limited space available -> Solid State Detectors: Diamond
  - Time resolution & performances: 50 ps per pot (~100ps per detector), reduce PU by a factor 4 (50% ->~ 12%).
  - One RP with 4 diamonds planes , with final front end and digitization (SAMPIC) electronics has been installed in the LHC during the technical stop 3 (2015).





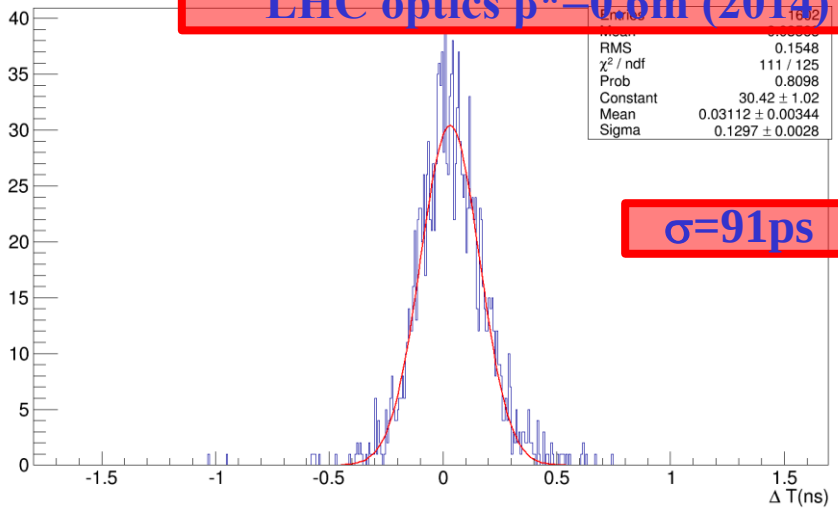


The TOTEM timing TDR

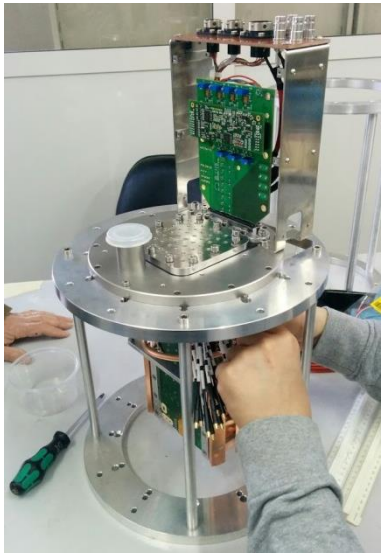
Time resolution measured at LHC

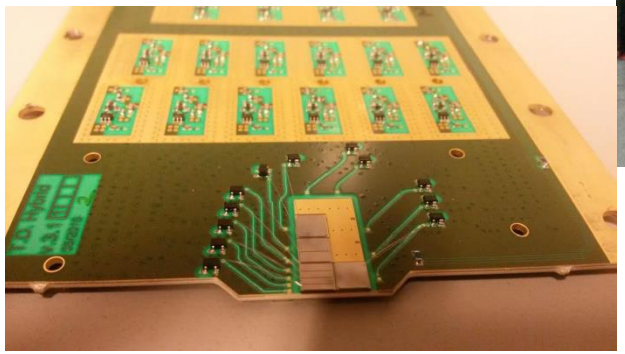
From CT-PPS TDR

LHC optics β*=0.6m (2014)



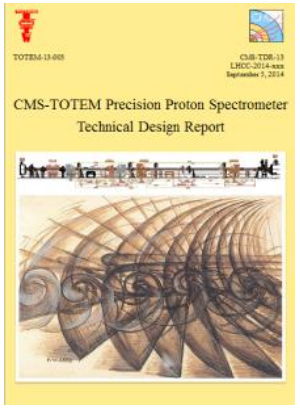
σ=91ps

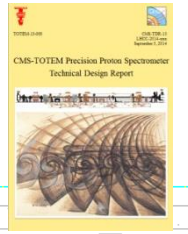




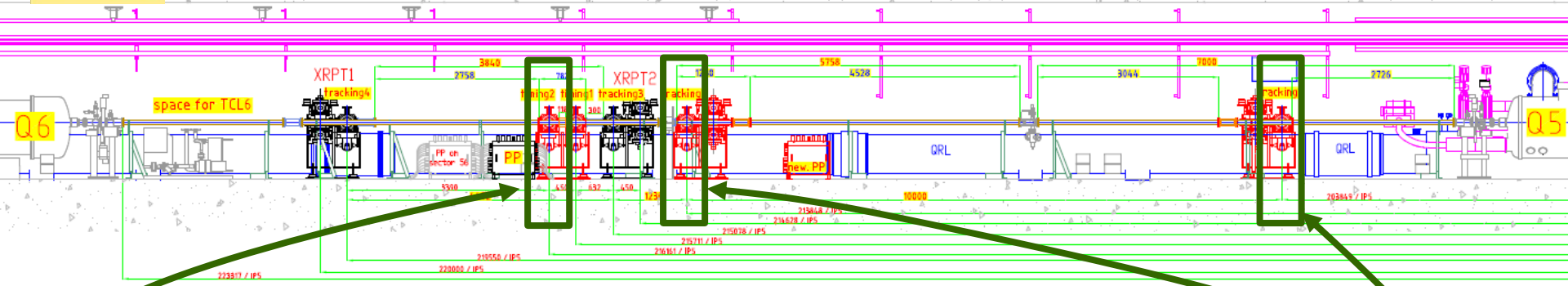
The CT-PPS TDR

- **CMS-TOTEM Precision Proton Spectrometer**
  - **Low β^* (0.5 m), standard runs, high luminosity;**
  - CMS & TOTEM collaboration for a common R&D for detectors to be installed in the relocated **horizontal RPs** and newly constructed **horizontal RPs**;
  - Integrated luminosity of the order of fb^{-1}.

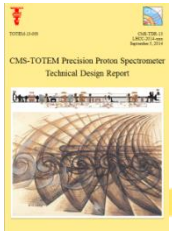




The CT-PPS layout

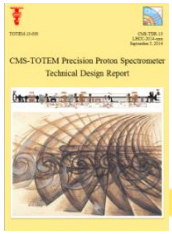


- Tracking detectors will be installed in the two relocated **horizontal RPs**.
- Timing detectors in one new **horizontal RP.**



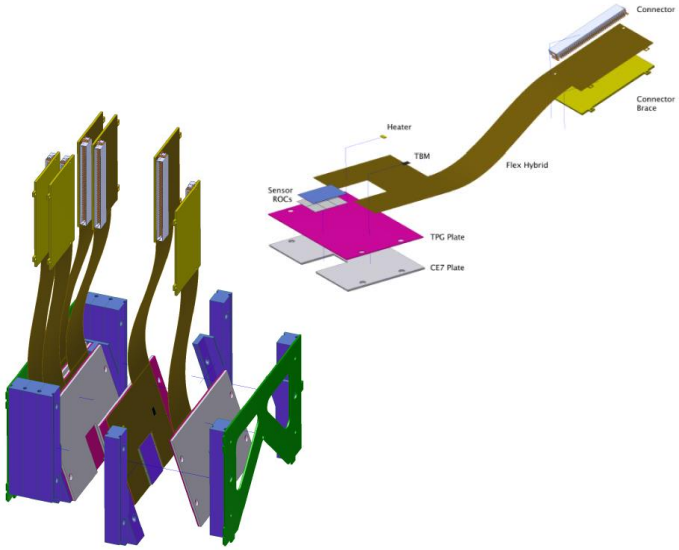
The CT-PPS TDR

- Scientific objectives:
  - Study of Central Exclusive Production (CEP) in p-p collision during standard low-β* runs at high luminosity.
    - EWK: LHC used as photon-photon collider:
      - Measure $\gamma\gamma$ -> W^+W^-, e^+e^-, $\mu^+\mu^-$, $\tau^+\tau^-$;
      - Searche for AQGC with high sensitivity;
      - Search for SM forbidden $ZZ\gamma\gamma$, $\gamma\gamma\gamma$ couplings
    - QCD:
      - Exclusive two and three jet events, with M up to ~ 700-800 GeV.
      - Test of pQCD mechanisms of exclusive production.
      - Gluon jet samples with small component of quark jets
    - BSM: Search for new resonances in CEP
      - Clean events (no underlying pp event)
      - Indemendent mass measurement from pp system
      - J^PC quantum numbers 0++, 2++



The CT-PPS TDR

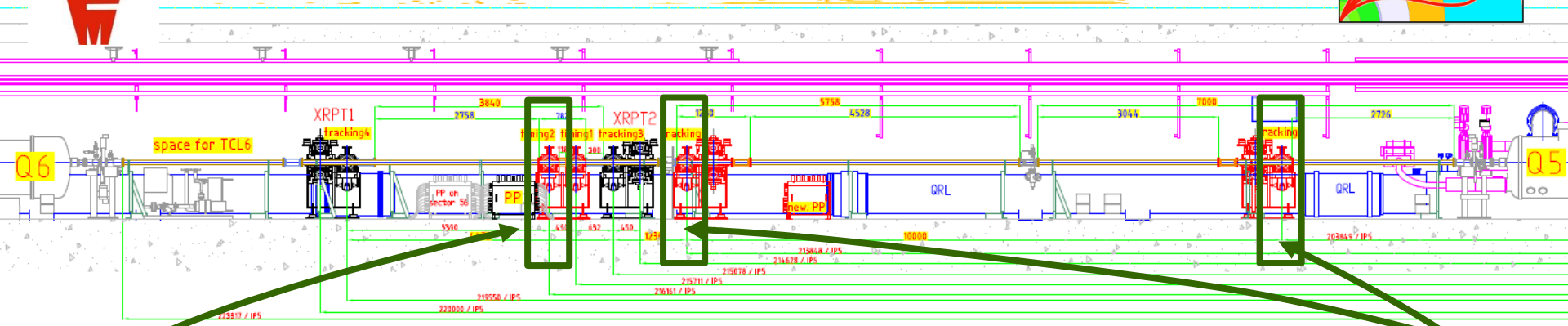
- Tracking detectors in the two relocated **horizontal RPs**:
  - Baseline: 3D silicon sensors (FBK), 6 planes/RP;
  - PSI46dig ROC.
- Timing detectors in new **horizontal RP**:
  - Baseline: Solid State detectors: Ultra Fast Silicon Detector (UFSD) or TOTEM diamond detectors;



The quest for diphoton resonance

- **CT-PPS can anticipate running operations in 2016**.
  - $\gamma\gamma$ candidate at 750 GeV could be produced exclusively and seen in CT-PPS
    - Fichet, von Gersdorff, Royon (arXiv:1601.01712, arXiv:1512.05751)
    - Csaki, Hubisz, Terning (arXiv:1512.05776, arXiv:1601.00638)
    - Harland-Lang, Khoze, Ryskin (arXiv:1601.07187)
- CT-PPS physics can start one year earlier than foreseen.

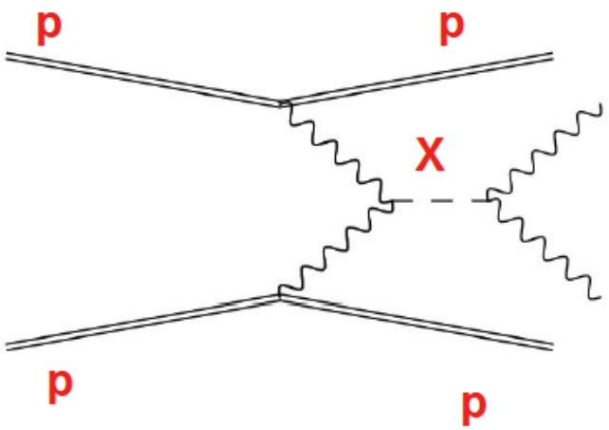
The CT-PPS 2016 strategy

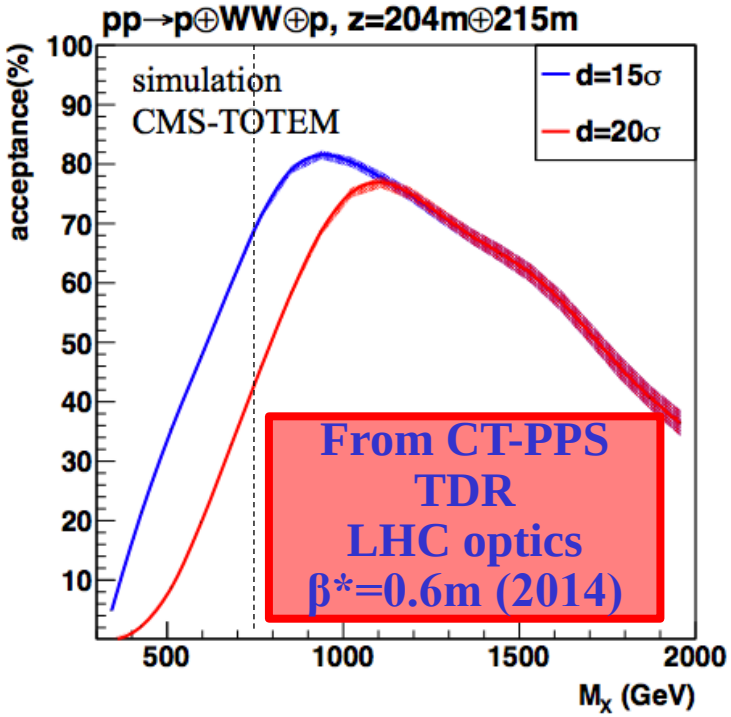


- Leverage the fact that the **relocated horizontal RP**, are qualified for high intensity run and **use current Totem Si Strip detectors**, while the new 3D pixel are under production (installation scheduled in 2017). An estimate of correct working over 10 fb-1 per telescope. Two groups of telescopes are available to get up to 20 fb-1 of integrated luminosity before loosing tracking efficiency.
- Since no high β*=90m medium luminosity run is foreseen in 2016, we decided to install 2 TOTEM diamond detector packages, developed for the vertical Roman Pots, in the **new cylindrical horizontal one** during TS1. In addition to the TOF, they will give some proton tagging with enough ξ resolution to complement Si strip, when they would loose efficiency.

The quest for diphoton resonance

- Expected LHC luminosity in 2016 is around 20-30 fb^{-1}
  - Exclusive cross section of the production of a 750 GeV resonance, via photon-photon fusion, in the diphoton decay channel is estimated ~0.3-0.6 fb (under the hypothesis that the resonance is dominantly produced in $\gamma\gamma$ fusion).





TOTEM-CMS DAQ integration

Feb 9th

- 1st meeting with CMS DAQ
- Documentation opened
- System requirements identified

Apr 6th

- 1st MiniDAQ readout test at 10Hz with emulated data
- Files available to offline/dqm

Apr 27th

- 1st MiniDAQ high rate test ok w. emulated data
- Slink data transfer error identified and fixed
- ReSync fast-command test
- ~90kHz rate limit reached w/o errors

May 2nd

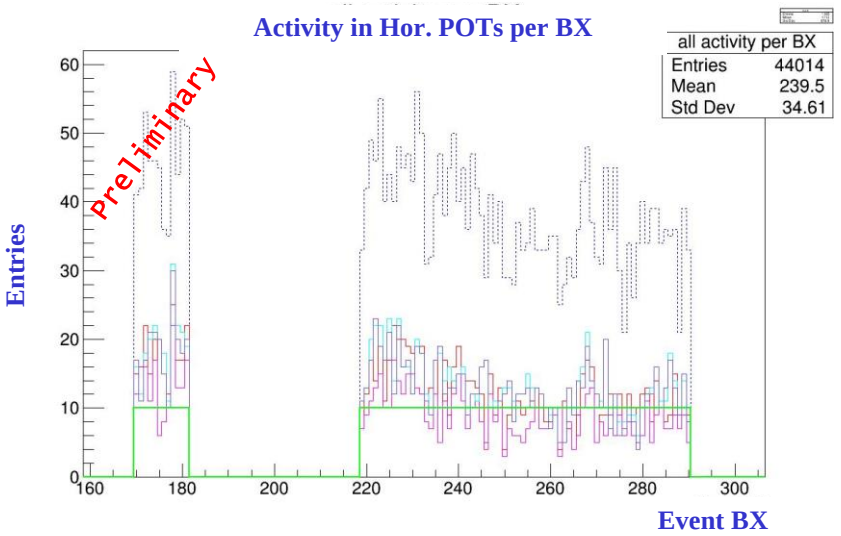
- 1st MiniDAQ test with Si-Strip ON
- ReSynch fast-command test OK
- RAW data mode tested
- Zero-suppr. mode tested lowering the VFAT's thresholds

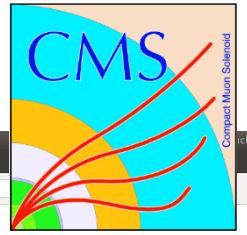
May 4th

- Si-Strip in global running with CMS
- Stress test 90k rate w. periodic ReSync OK

May 18th

- Si-Strip timed w. LHC beam and CMS global trigger





Run Summary

All times are in UTC.
TRIGGERS and L1 triggers numbers are the total pre-deadtime triggers, including Calibration and Random ones.

RUN	LUMI_NB_LIVE_DELIV	SEQUENCE	TRIGGER_MODE	L1_KEY	HLT_KEY	STARTTIME	STOPTIME	TRIGGERS	BFIELD	TIER0	COMPONENTS
272524	0.000000 0.000000	GLOBAL-RUN toppro	l1_hlt_cosmics2016/v98	cosmics2016_TSC/v56	/cdaq/cosmic/commissioning2016 /firstCollisions/v2.1/HLT/V8	2016.05.04 17:11:15	null	802418	3.799	1	CSC DAQ DCS DQM ECAL ES PIXEL RPC SCAL TCDS TRG
272514	0.000000 0.000000	PRIVATE-GLOBAL-CALO ecalpro	MANUAL	null	/minidaq/EcalCalibration /v7.0/EcalCalibration_MiniDAQ/V3	2016.05.04 16:21:46	2016.05.04 16:22:30	null	3.799	1	DAQ ES TCDS
272512	0.000000 0.000000	GLOBAL-RUN toppro	l1_hlt_cosmics2016/v98	cosmics2016_TSC/v56	/cdaq/cosmic/commissioning2016 /firstCollisions/v2.1/HLT/V8	2016.05.04 16:06:42	2016.05.04 16:37:22	100949818	3.799	0	DAQ DCS DQM RPC SCAL TCDS TOTEM TRG
272511	0.000000 0.000000	GLOBAL-RUN toppro	l1_hlt_cosmics2016/v98	cosmics2016_TSC/v56	/cdaq/cosmic/commissioning2016 /firstCollisions/v2.1/HLT/V8	2016.05.04 15:45:27	2016.05.04 15:55:54	412543	3.799	1	DAQ DCS DQM ECAL PIXEL RPC SCAL TCDS TOTEM TRACKER TRG
272507	0.000000 0.000000	GLOBAL-RUN toppro	l1_hlt_cosmics2016/v98	cosmics2016_TSC/v56	/cdaq/cosmic/commissioning2016 /firstCollisions/v2.1/HLT/V8	2016.05.04 15:22:16	2016.05.04 15:25:54	33837	3.799	1	DAQ DCS DQM ECAL PIXEL SCAL TCDS TOTEM TRACKER TRG
272506	0.000000 0.000000	PRIVATE-GLOBAL-TOTEMCTPPS totempro	MANUAL	null	/minidaq/2016/Basic/HLT/V3	2016.05.04 15:17:02	2016.05.04 15:17:26	null	3.799	1	DAQ TCDS TOTEM
272505	0.000000 0.000000	GLOBAL-RUN toppro	l1_hlt_cosmics2016/v98	cosmics2016_TSC/v56	/cdaq/cosmic/commissioning2016 /firstCollisions/v2.1/HLT/V8	2016.05.04 15:11:27	2016.05.04 15:16:07	179438	3.799	1	DAQ DCS DQM ECAL PIXEL SCAL TCDS TRACKER TRG
272499	0.000000 0.000000	PRIVATE-GLOBAL-MUTRG triggerdev	MANUAL	null	/minidaq/2016/Basic/HLT/V3	2016.05.04 14:57:07	2016.05.04 15:08:59	null	3.799	0	DAQ TCDS
272496	0.000000 0.000000	GLOBAL-RUN toppro	l1_hlt_cosmics2016/v98	cosmics2016_TSC/v56	/cdaq/cosmic/commissioning2016 /firstCollisions/v2.1/HLT/V8	2016.05.04 14:52:43	2016.05.04 15:01:42	359077	3.799	1	DAQ DCS DQM PIXEL SCAL TCDS TRACKER TRG
272495	0.000000 0.000000	PRIVATE-GLOBAL-MUTRG triggerdev	MANUAL	null	/minidaq/2016/Basic/HLT/V3	2016.05.04 14:50:03	2016.05.04 14:55:51	null	3.799	0	DAQ TCDS
272494	0.000000 0.000000	PRIVATE-GLOBAL-MUTRG triggerdev	MANUAL	null	/minidaq/2016/Basic/HLT/V3	2016.05.04 14:41:23	2016.05.04 14:46:35	null	3.799	0	DAQ TCDS
272493	0.000000 0.000000	PRIVATE-GLOBAL-TOTEMCTPPS totempro	MANUAL	null	/minidaq/2016/Basic/HLT/V3	2016.05.04 14:21:56	2016.05.04 14:43:49	null	3.799	1	DAQ TCDS TOTEM
272492	0.000000 0.000000	PRIVATE-GLOBAL-TOTEMCTPPS totempro	MANUAL	null	/minidaq/2016/Basic/HLT/V3	2016.05.04 14:16:12	2016.05.04 14:21:14	null	3.799	1	DAQ TCDS TOTEM
272491	0.000000 0.000000	PRIVATE-GLOBAL-TOTEMCTPPS totempro	MANUAL	null	/minidaq/2016/Basic/HLT/V3	2016.05.04 13:58:16	2016.05.04 14:15:54	null	3.799	1	DAQ TCDS TOTEM
272490	0.000000 0.000000	PRIVATE-GLOBAL-TOTEMCTPPS totempro	MANUAL	null	/minidaq/2016/Basic/HLT/V3	2016.05.04 13:55:23	2016.05.04 13:56:20	null	3.799	1	DAQ TCDS TOTEM
272489	0.000000 0.000000	PRIVATE-GLOBAL-TOTEMCTPPS totempro	MANUAL	null	/minidaq/2016/Basic/HLT/V3	2016.05.04 13:43:36	2016.05.04 13:51:33	null	3.799	1	DAQ TCDS TOTEM
272488	0.000000 0.000000	GLOBAL-RUN toppro	l1_hlt_test2016/v6	cosmics2016_TSC/v53	/cdaq/special/VirginRaw/Apr2016/HLT/V2	2016.05.04 13:41:46	2016.05.04 14:42:21	6462014	3.799	1	DAQ DCS DQM SCAL TCDS TRACKER TRG
272487	0.000000 0.000000	PRIVATE-GLOBAL-HCAL hcalpro	MANUAL	null	/minidaq/2016/HCAL/HLT/V3	2016.05.04 13:42:35	2016.05.04 13:44:15	null	3.799	0	DAQ HCAL HF TCDS

The Si-Strip integration

Feb
- CTPPS "accelerated" approved by the two collaborations

Mar
- Existing Reconstruction SW refactorized in CMSSW81X
- SW Integration started

Apr 1st half
- 1st MiniDAQ readout test at low rate
- Files available for SW validation

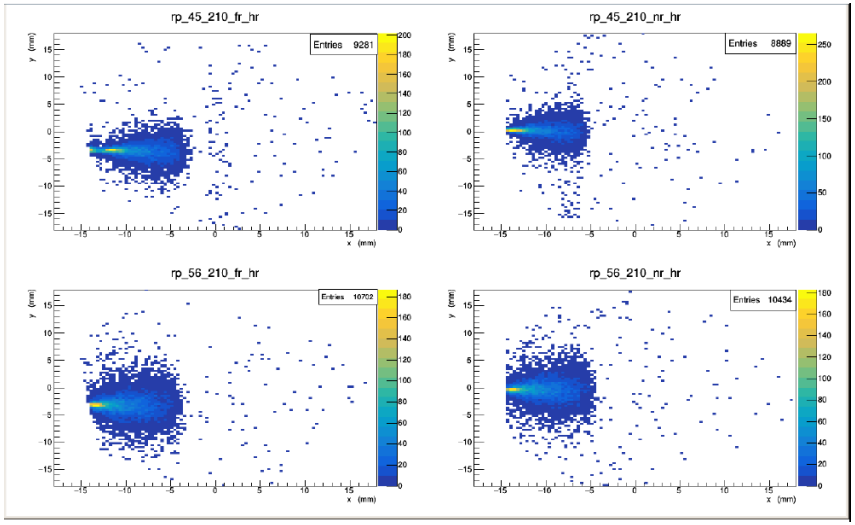
Apr 2nd half
- 1st MiniDAQ high rate test
- Beam based alignment of RP
- RP Insertion commissioning at high luminosity

May 1st half
- 1st MiniDAQ test with Si-Strip ON
- Si-Strip in global run with CMS

20th May
- Si-Strip timed w. LHC beam and CMS global trigger

3rd June
- RPs reached their nominal position (15σ)

June 2nd half
- Reconstruction SW fully merged in CMSSW80X
- >3/fb collected!



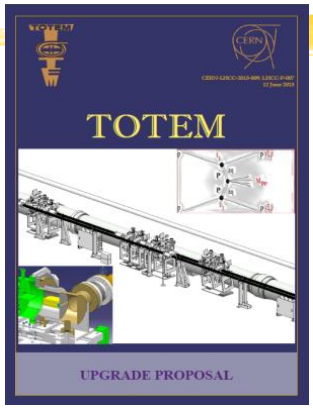
Conclusion

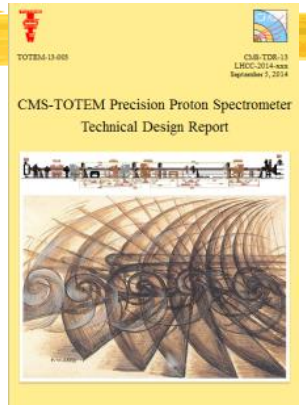
- Stay tuned for more results from TOTEM and CMS from Run I and Run II in 2015.
- TOTEM DAQ increased an average of 50 times the Run I trigger rate. A lot more statistics is available for analysis.
- CT-PPS project is anticipating data taking in 2016, using TOTEM strip detectors, to look for diphoton resonance.
- Integration, of DAQ and detectors, with CMS has been achieved in very short time scale, and common data taking at high luminosity, is on going.
- A very promising channel, with very low background, can be investigated by CT-PPS.

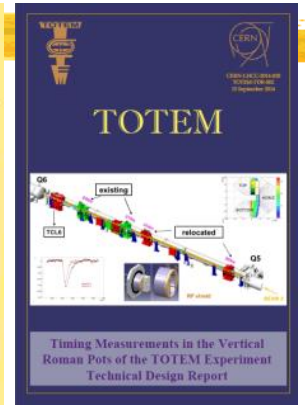
THANKS!!!

Spares

ROMAN POT: Milestones







March 2013

June 2013
consolidation
& upgrade

January 2014
CMS-TOTEM
MoU

September 2014
TOTEM timing TDR
CT-PPS TDR

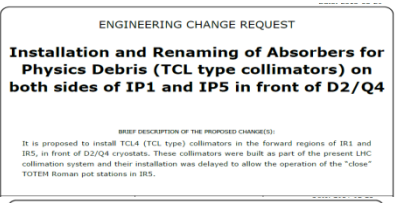
March 2015
Restart LHC
Run 2

LHC LS1 access for RP installation

DP Si operation
& RP movement

August 2014

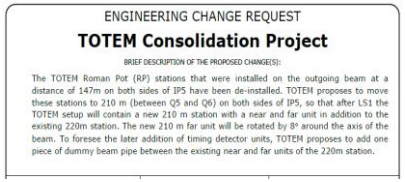
RP operation
with DAQ


ENGINEERING CHANGE REQUEST

Installation and Renaming of Absorbers for Physics Debris (TCL type collimators) on both sides of IP1 and IP5 in front of D2/Q4

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

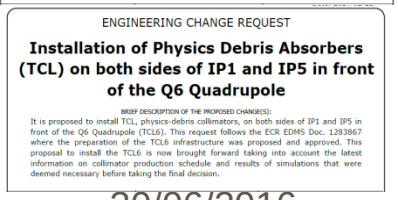
It is proposed to install TCL4 (TCL type) collimators in the forward regions of IR1 and IR5, in front of D2/Q4 cryostats. These collimators were built as part of the present LHC collimation system and their installation was delayed to allow the operation of the "close" TOTEM Roman pot stations in IR5.


ENGINEERING CHANGE REQUEST

TOTEM Consolidation Project

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

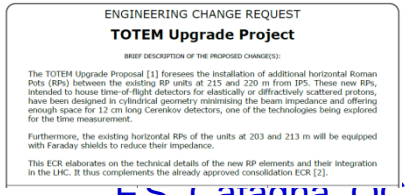
The TOTEM Roman Pot (RP) stations that were installed on the outgoing beam at a distance of 147m on both sides of IP5 have been de-installed. TOTEM proposes to move these stations to 210 m (between Q5 and Q6) on both sides of IP5, so that after LS1 the TOTEM setup will contain a new 210 m station with a near and far unit in addition to the existing 220m station. The new 210 m far unit will be rotated by 8° around the axis of the beam. To foresee the later addition of timing detector units, TOTEM proposes to add one piece of dummy beam pipe between the existing near and far units of the 220m station.


ENGINEERING CHANGE REQUEST

Installation of Physics Debris Absorbers (TCL) on both sides of IP1 and IP5 in front of the Q6 Quadrupole

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

It is proposed to install TCL, physics-debris collimators, on both sides of IP1 and IP5 in front of the Q6 Quadrupole (TCL6). This request follows the ECR EDMS Doc. 1283867 where the preparation of the TCL6 infrastructure was proposed and approved. This proposal to install the TCL6 is now brought forward taking into account the latest information on collimator production schedule and results of simulations that were deemed necessary before taking the final decision.


ENGINEERING CHANGE REQUEST

TOTEM Upgrade Project

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

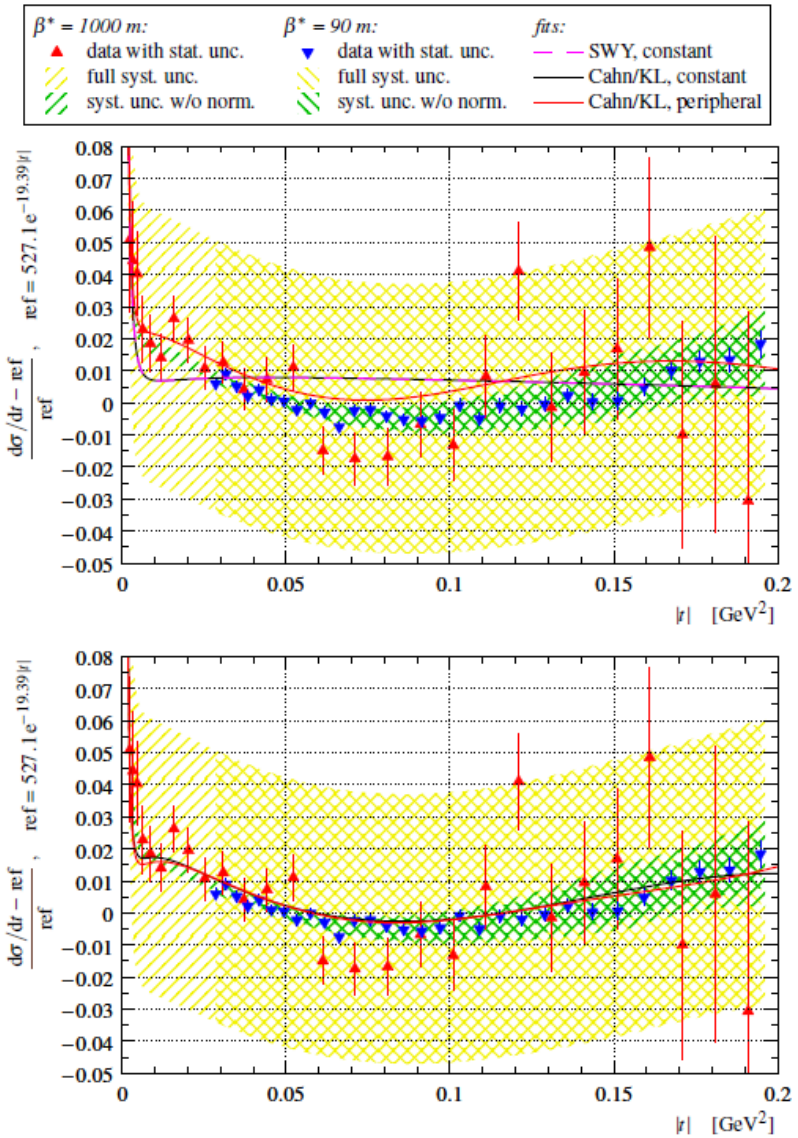
The TOTEM Upgrade Proposal [1] foresees the installation of additional horizontal Roman Pots (RPs) between the existing RP units at 215 and 220 m from IP5. These new RPs, intended to house time-of-flight detectors for elastically or diffractively scattered protons, have been designed in cylindrical geometry minimising the beam impedance and offering enough space for 12 cm long Cerenkov detectors, one of the technologies being explored for the time measurement.

Furthermore, the existing horizontal RPs of the units at 203 and 213 m will be equipped with Faraday shields to reduce their impedance.

This ECR elaborates on the technical details of the new RP elements and their integration in the LHC. It thus complements the already approved consolidation ECR [2].

All Components integrated
in the LHC beam line by
August 2014

Elastic scattering : *Coulomb interference – Fits*



⇐ **purely-exponential hadronic amplitude**

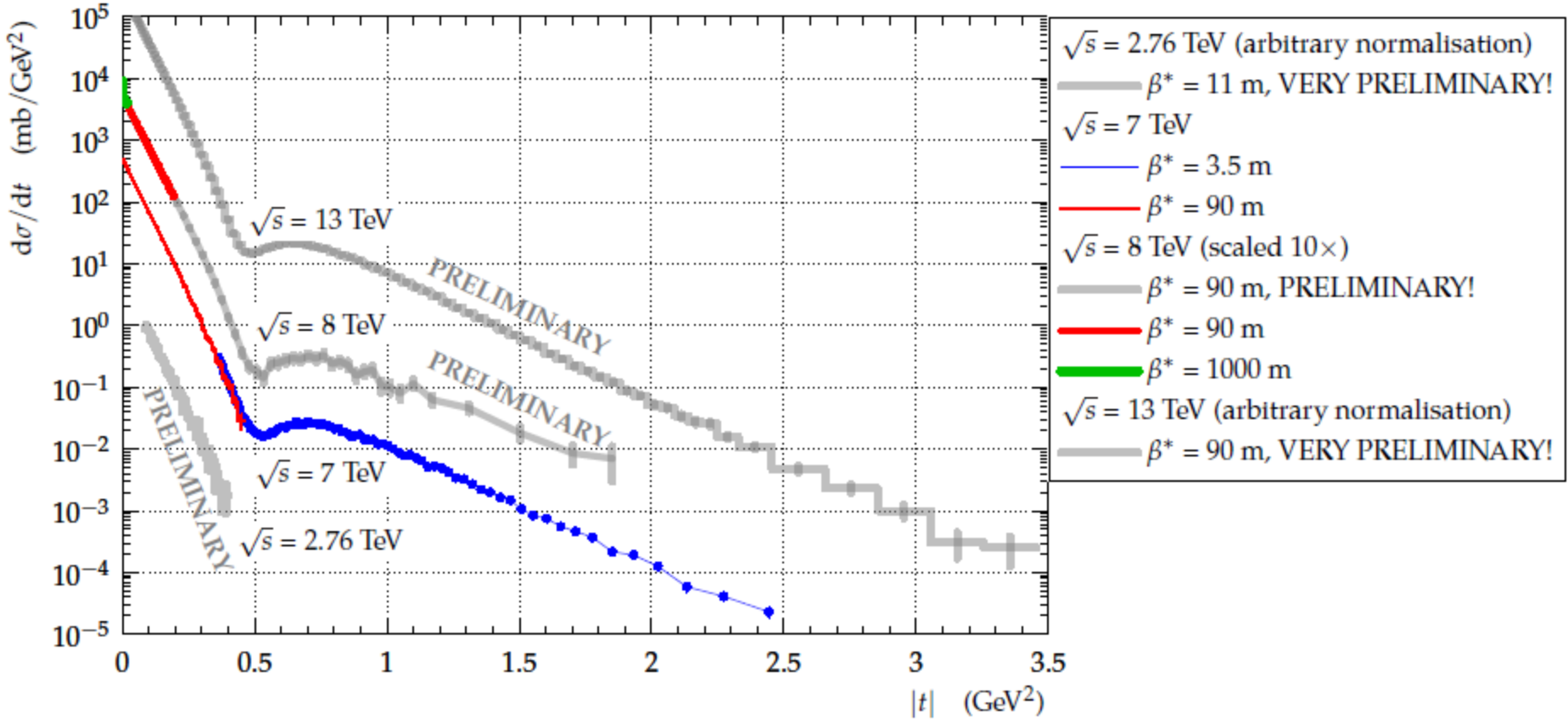
- *constant phase excluded* (with both SWY and KL formulae) ⇒ application of SWY formula excluded too
- *peripheral phase* not excluded by data, but *disfavoured*
  - ρ value outside a consistent pattern of other fits and theoretical predictions
  - number of theoretical reasons for non-exponential hadronic amplitude

⇐ **non-exponential hadronic amplitude**

- both constant and peripheral phases compatible with data ⇒ *centrality not necessity*

Elastic scattering : $p + p \to p + p$

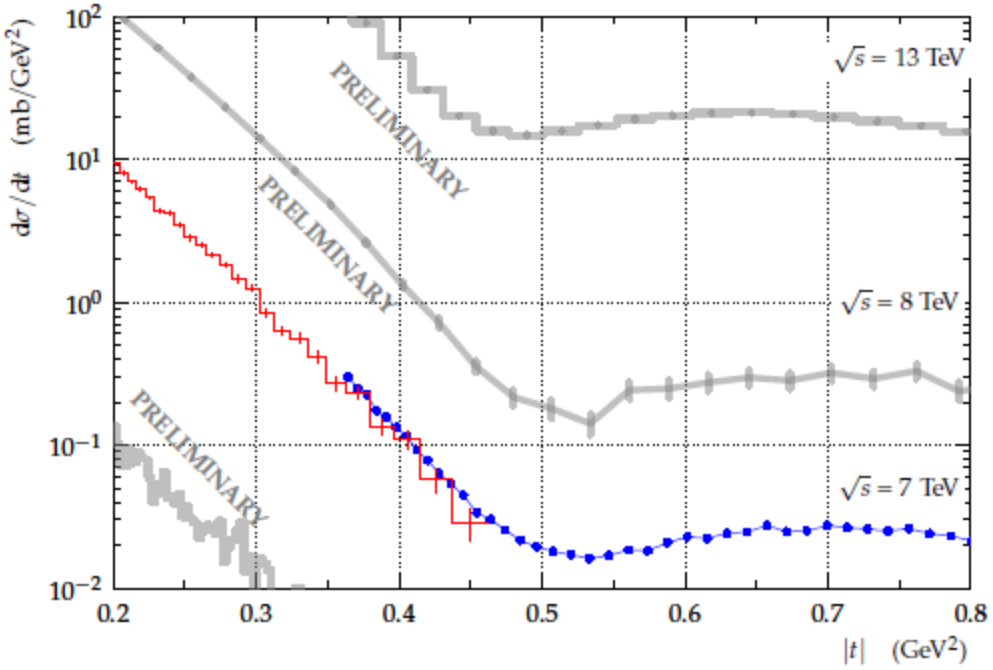
- selection: two anti-collinear protons from the same vertex
- (almost) purely data-driven analysis
- data overview (selection), gray = preliminary

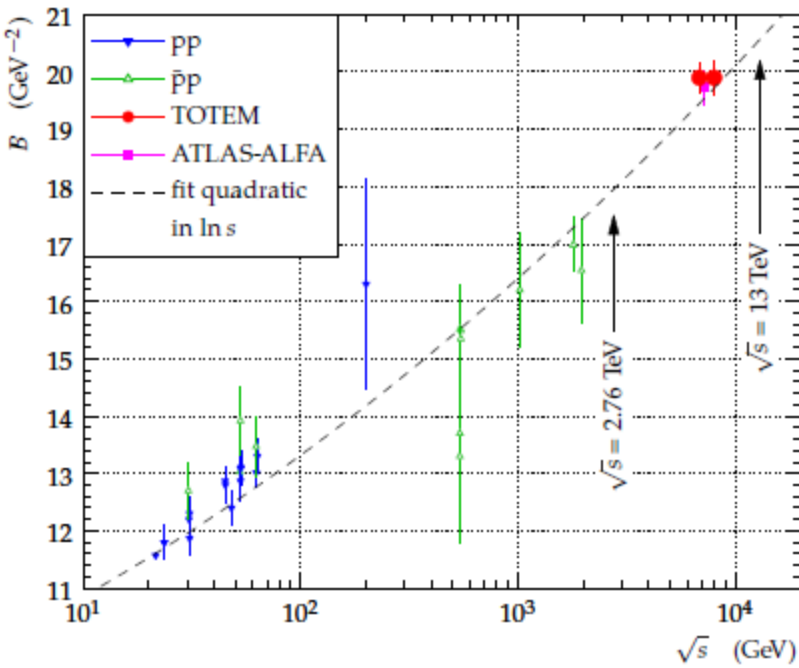


- different $|t|$ probe *different physics regimes* – from lowest to highest $|t|$: Coulomb interference, diffractive cone, dip-bump, transition to pQCD

Elastic scattering : *Trends*

(gray = preliminary)





- *dip position*
  - $\sqrt{s} = 8$ TeV: limited statistics
  - $\sqrt{s} = 7 \rightarrow 13$ TeV: dip moves to lower $|t|$
    - 13 TeV results preliminary! (the yet missing unfolding correction likely to move the dip to lower $|t|$)
- *forward slope* $B = \frac{\mathrm{d}}{\mathrm{d}t} \ln \frac{\mathrm{d}\sigma}{\mathrm{d}t}\Big|_{t=0}$
  - increase wrt. previous experiments

Elastic scattering : *Coulomb interference*

- 8 TeV data with $\beta^* = 1000$ m optics
  - RPs very close to the beam: $\approx 3\,\sigma_{\text{beam}}$
  - $|t|_{\text{min}} \approx 6 \cdot 10^{-4}$ GeV^2