Is there any lesson I learnt?

Marta Ruspa
Univ. Piemonte Orientale & INFN-Torino

Discussion meeting on JLEIC forward detector region
October 28th 2016

- Fundamental diffractive physics@HERA

  Much more difficult and less fundamental diffractive physics @LHC: when/if we solve the issue of pileup, we are left with rescattering effects

- Roman Pot experience:
  a nightmare@HERA, a miracle@LHC

- Proton-lead collisions: a great laboratory for exclusive photoproduction. A pity not to have the possibility to tag the proton…

- Playing with the LHC optics take us to different lands/ physics

Challenging diffraction@LHC

Challenge to tag the LRG at the LHC

- The rapidity gap(s) maybe **very forward and outside CMS-ATLAS acceptance**
- **Pileup** events destroy the gap(s)
- The **gap(s) survival probability** is low

→ LRG not always/really usable → proton tracking (and timing) detectors

- ☐ CMS-TOTEM joint data (2012-2015)
- ☐ CT-PPS, "CMS-TOTEM Precision Proton Spectrometer", (>2016)

Accessible physics menu (so far)

Diffractive measurements

- Inclusive single and double diffraction
- Central diffraction
- Low mass DPE resonances
- Exclusive χ_c production
- Single diffractive dijet production
- Single diffractive W/Z production
- Single diffractive J/psi
- Exclusive dijet production

(Inelastic) cross section

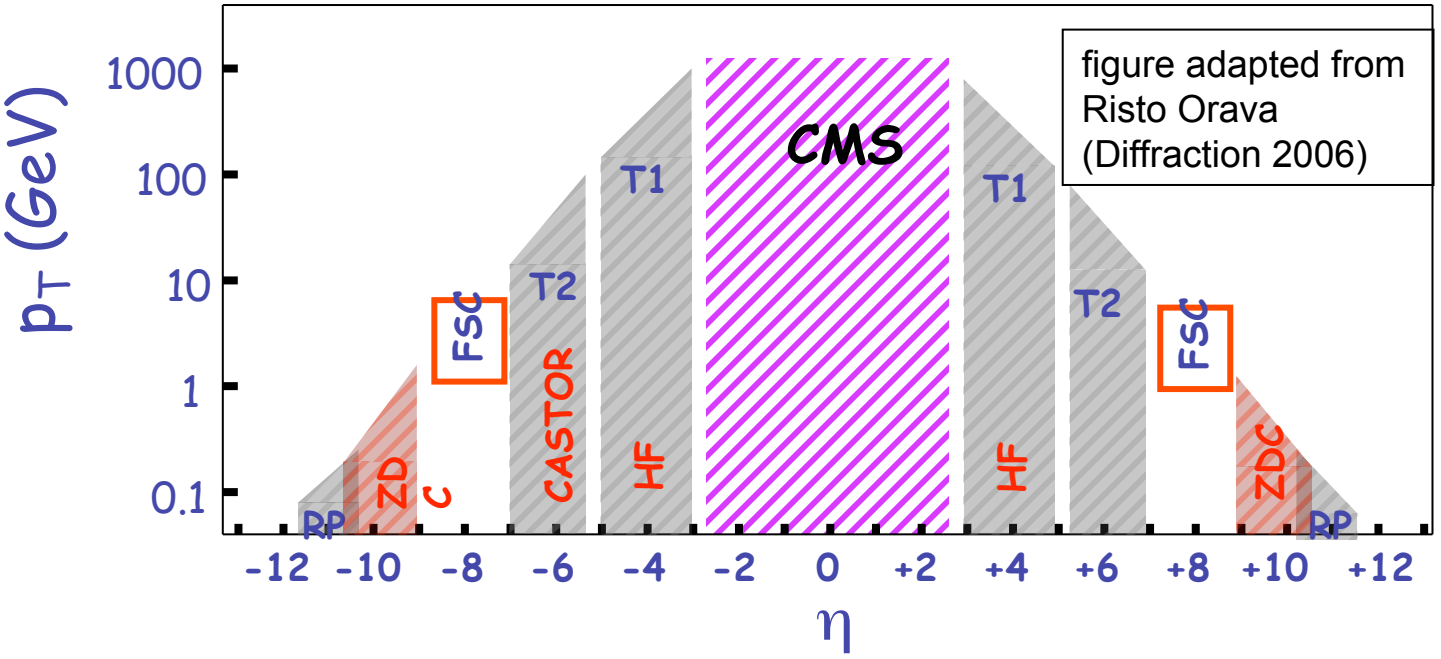
Exclusive analyses based on tracking onl

- Exclusive dilepton, diphoton
- Exclusive upsilon, rho
- Exclusive WW

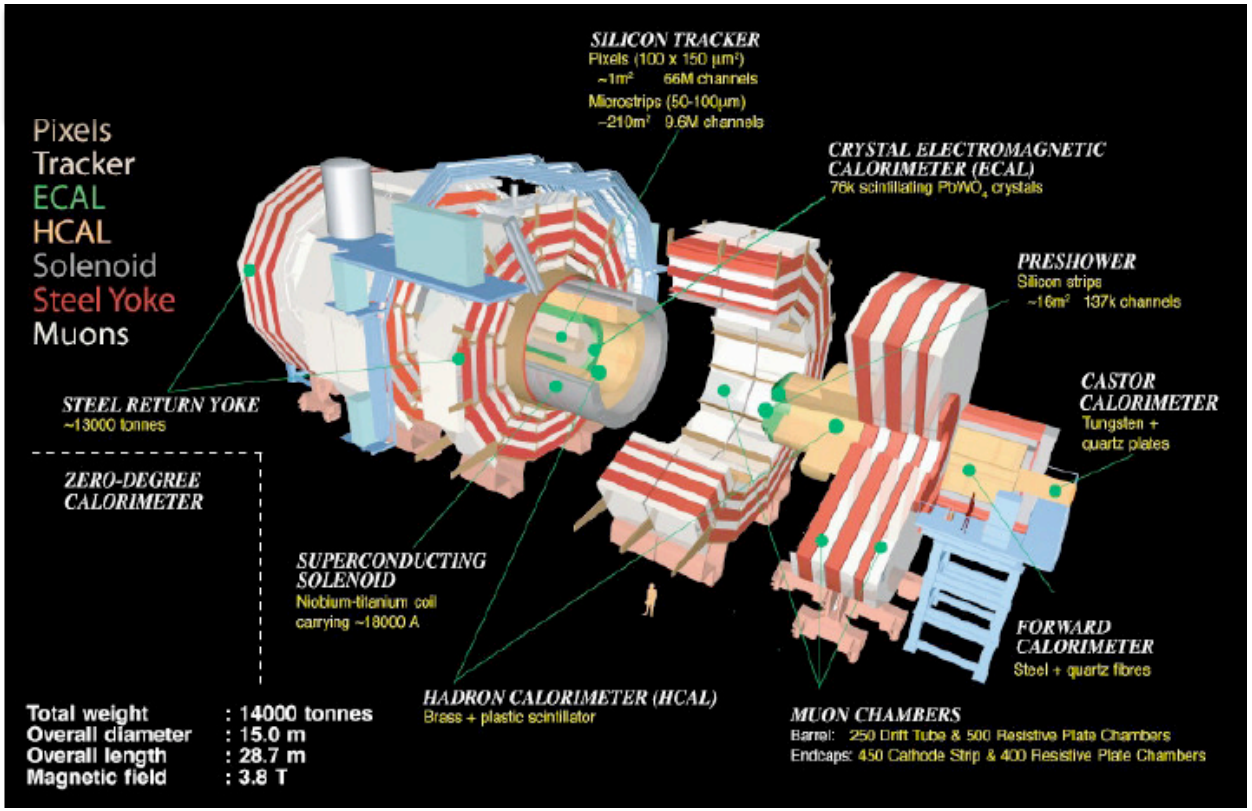
How we tag protons/diffraction

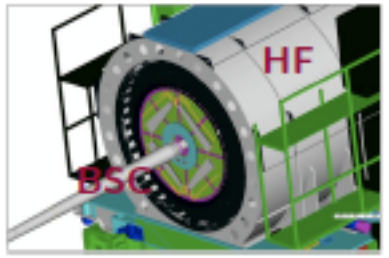
In terms of pseudorapidity

Unprecedented
η coverage!

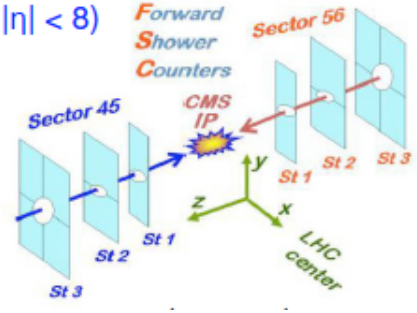


CMS detector forward instrumentation





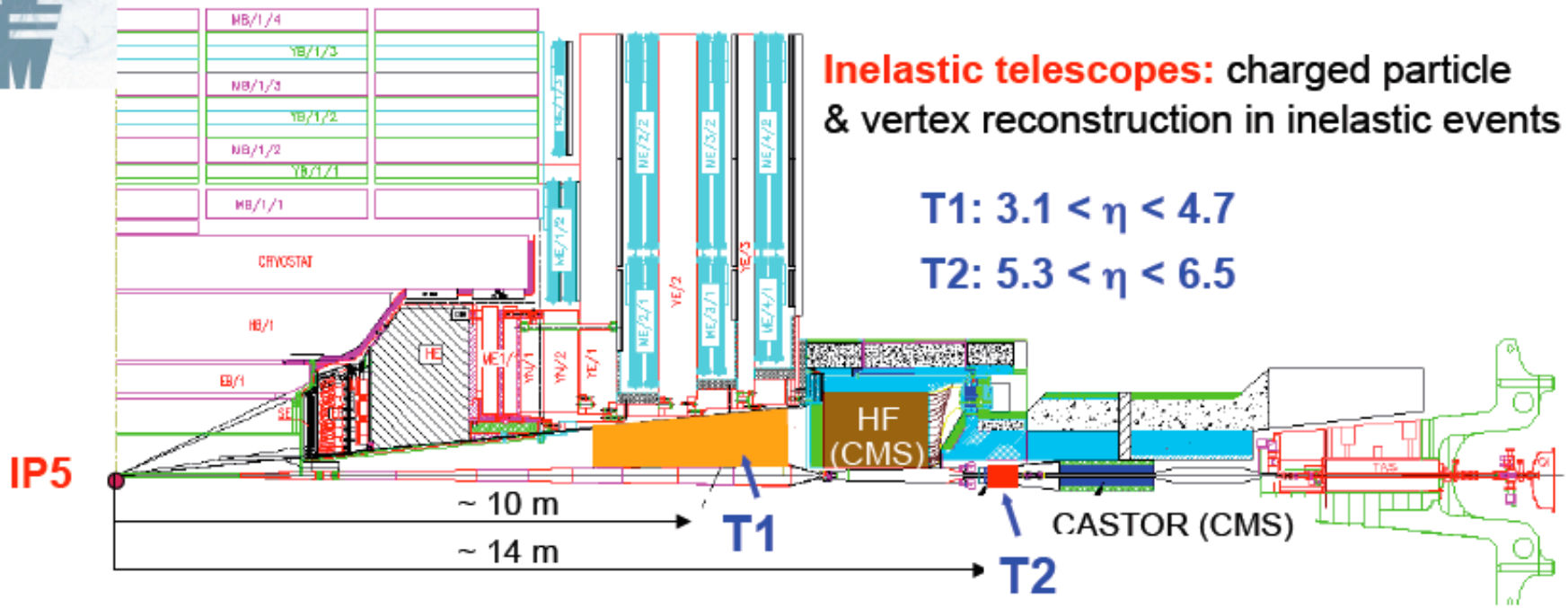
(6 < |η| < 8)



- **Hadron Forward calorimeter (HF):** 2.9 < |η| < 5.2 (10 m from IP)
- **Beam Scintillator Counters BSC :** 3.2 < |η| < 4.7 (in front of HF)
- **CASTOR calorimeter:** -6.6 < |η| < -5.2 (14.4 m from IP, one side only)
- **Forward Shower Counters FSC:** 6 < |η| < 8 (59-114 m from IP)
- **Zero Degree calorimeter:** |η| > 8.1 (140 m from IP)

+ TOTEM detector

Experimental Setup @ IP5- old setup

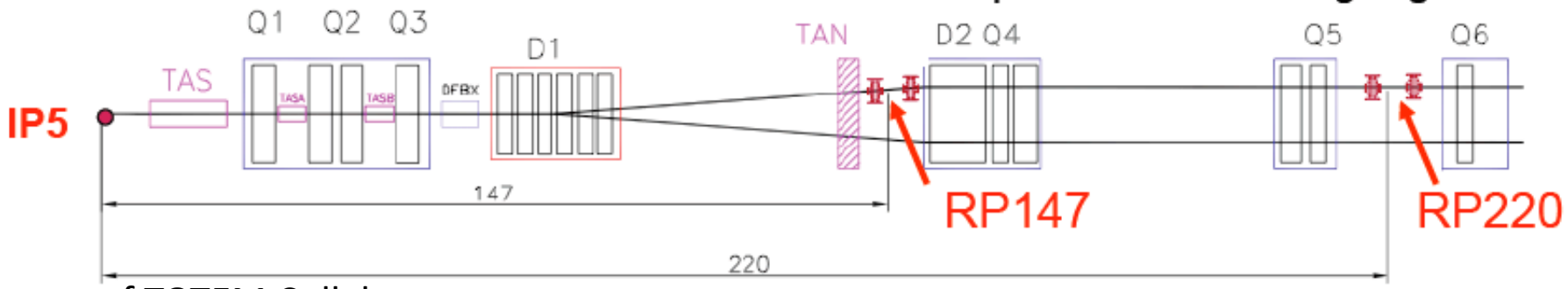


Inelastic telescopes: charged particle & vertex reconstruction in inelastic events

T1: 3.1 < η < 4.7

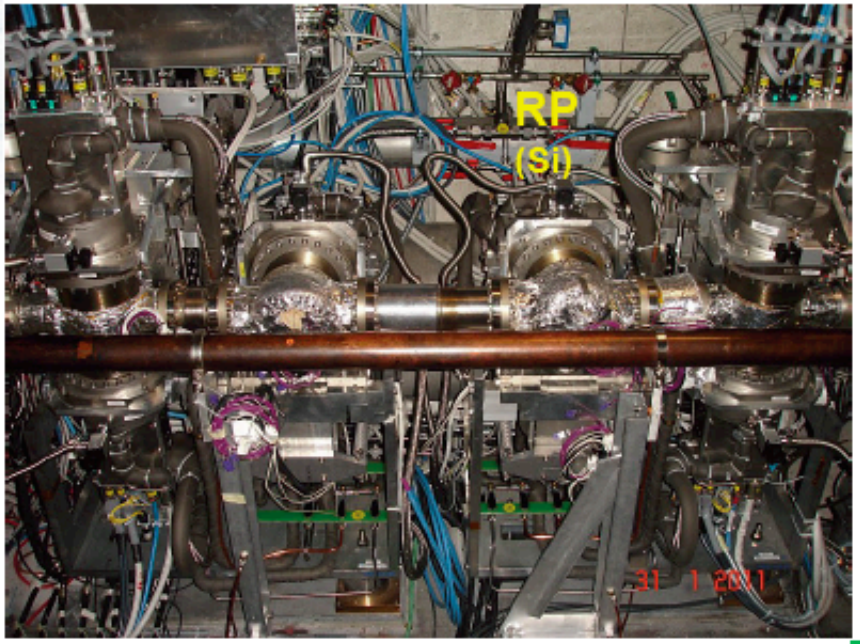
T2: 5.3 < η < 6.5

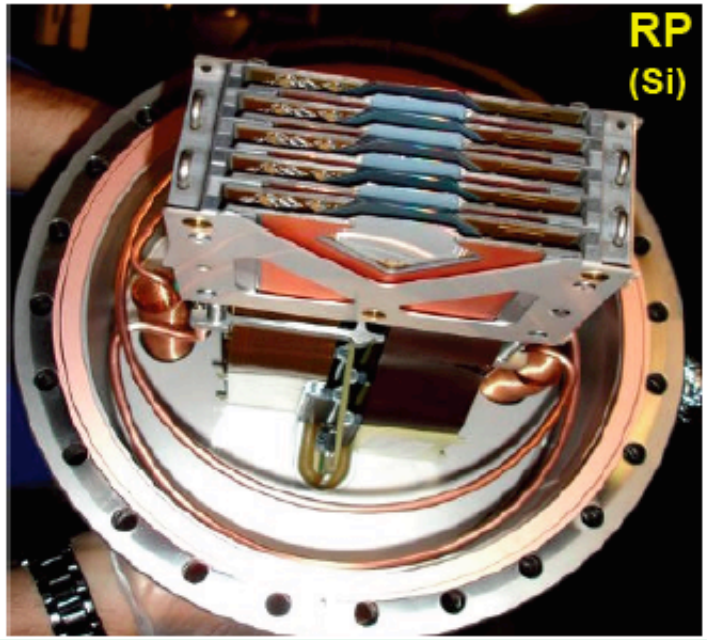
Roman Pots: measure elastic & diffractive protons close to outgoing beam

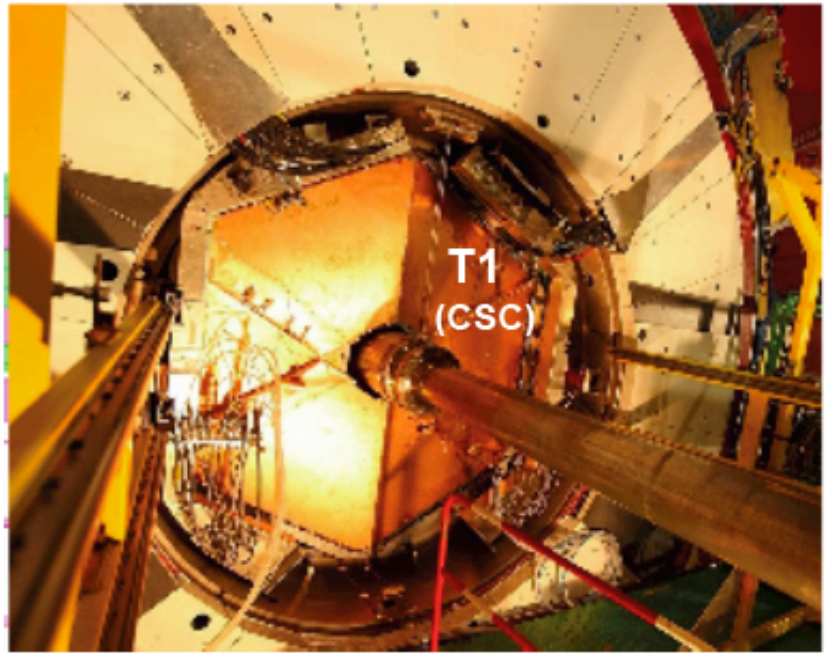


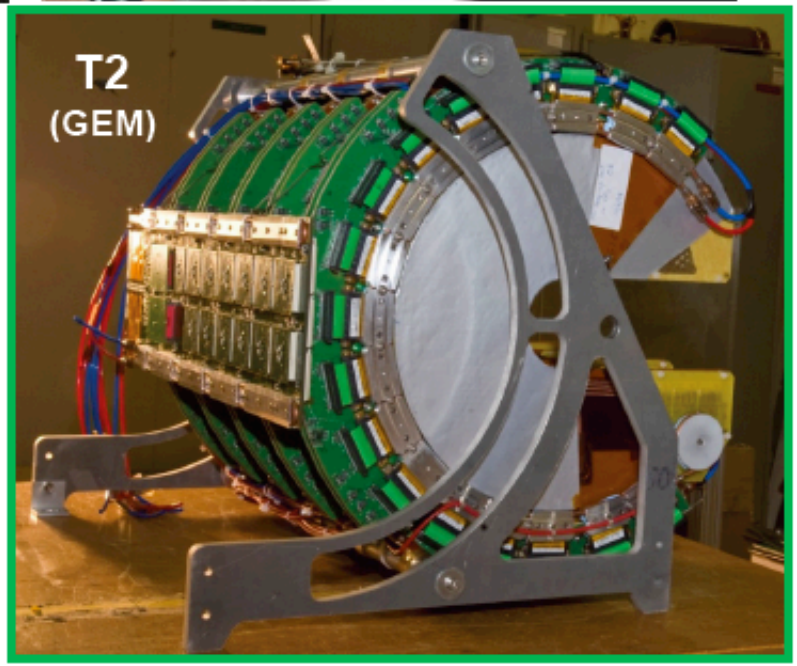
Courtesy of TOTEM Collab.

TOTEM Detectors



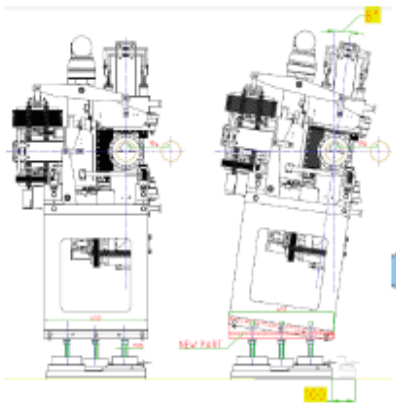


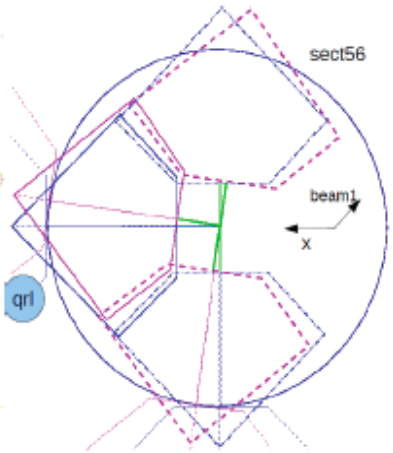


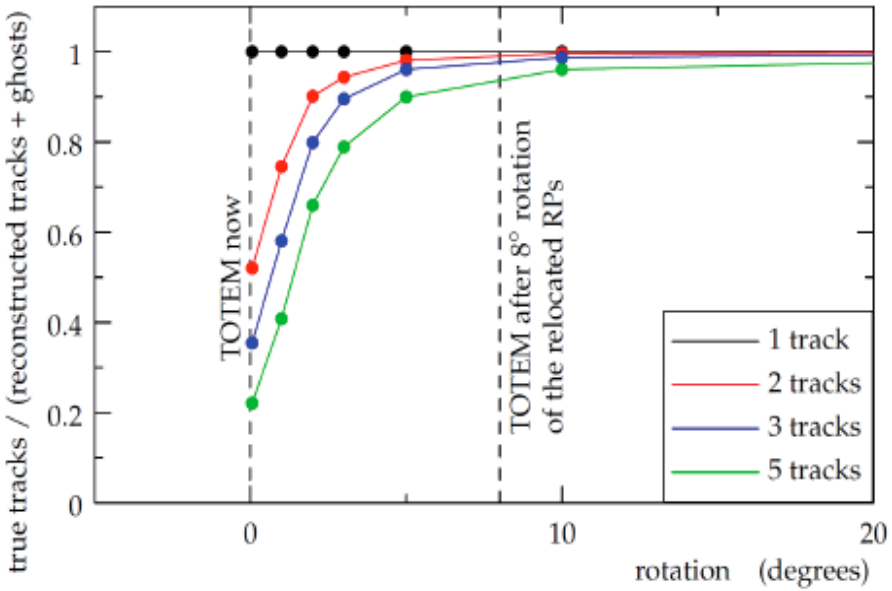


Courtesy of TOTEM Collab.

RPs Performance

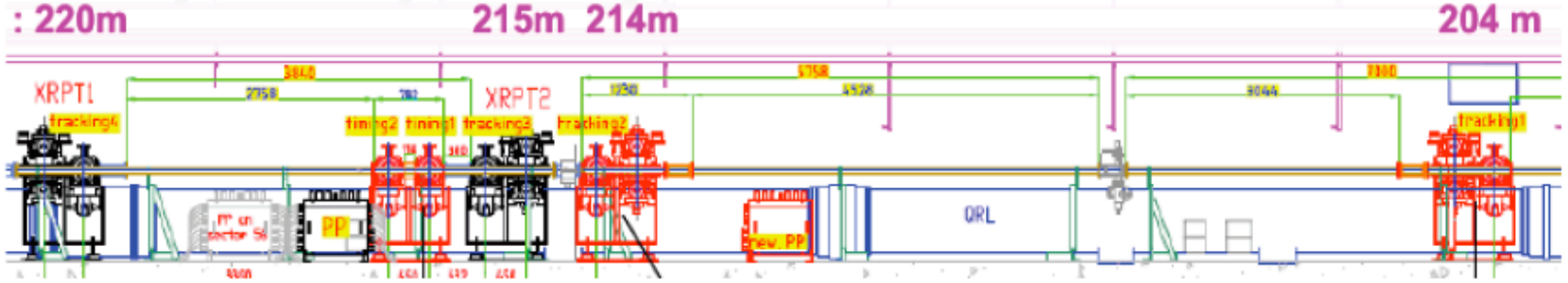






new layout:

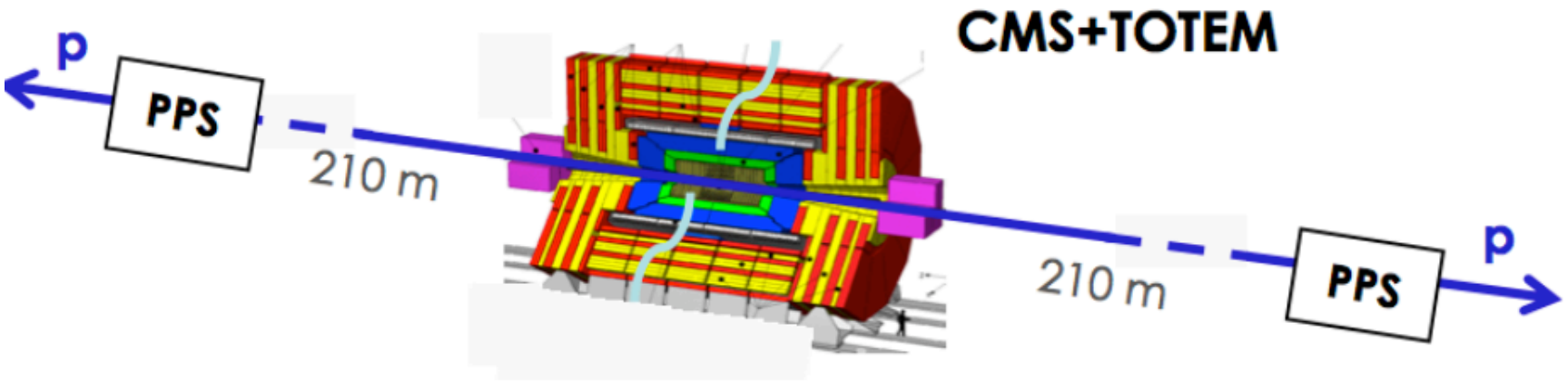
- 147 m station relocated to 204 and 214 m (increased lever arm ⇒ better angular resolution)
- RPs at 214 m rotated by 8° ⇒ multi-track capability
- ≈ 216 m new two horizontal RPs for timing detectors (improved proton left-right correlation)



Courtesy of TOTEM Collab.

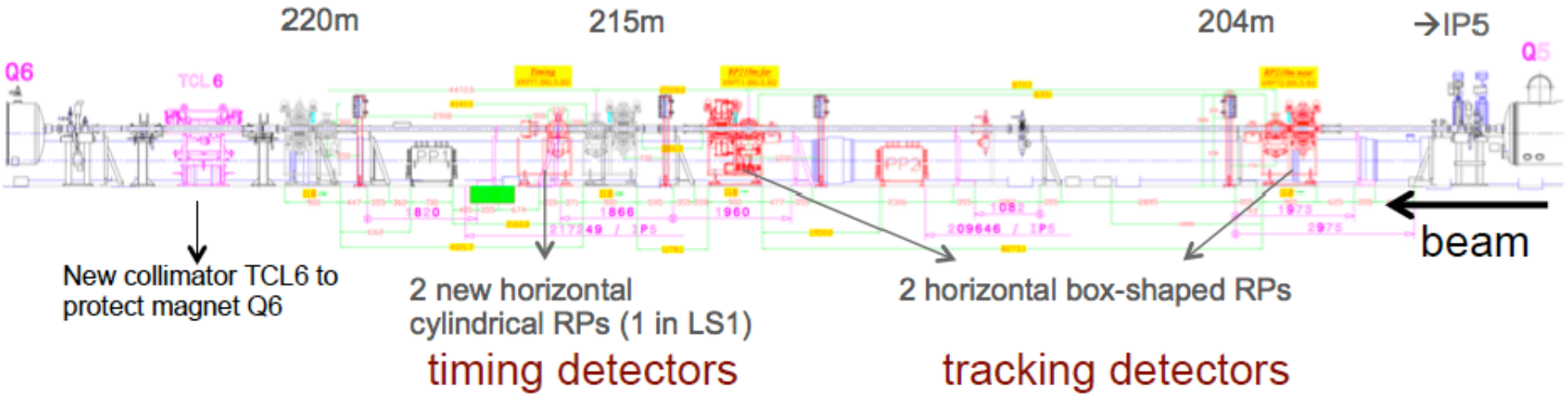
The CT-PPS project

- It is a joint CMS and TOTEM project that aims at measuring the surviving scattered protons on both sides of CMS in standard running conditions
- Tracking and timing detectors inside the beam pipe at ~210m from IP5
- Project approved in Dec. 2014 by LHCC
- Exploratory phase in 2015, data taking started in 2016 (full scope from 2017)



Experimental challenges

- Ability to operate the detectors close to beam (15-20σ) to maximize acceptance for low momentum loss (ξ) protons
- Limit impedance introduced by beam pockets
  - improved RF shielding of RPs
  - (R&D on Movable Beam Pipe as future option)
- Sustain high radiation levels
  - For 100/fb, proton flux up to $5\times10^{15}cm^{-2}$ in tracking detectors, $10^{12}n_{eq}/cm^2$ and 100Gy in photosensors and readout electronics
- Reject background in the high-pileup (μ=50) of normal LHC running



CT-PPS project status

During last pp collisions:

- Silicon and Diamonds RP detectors on each LHC sector

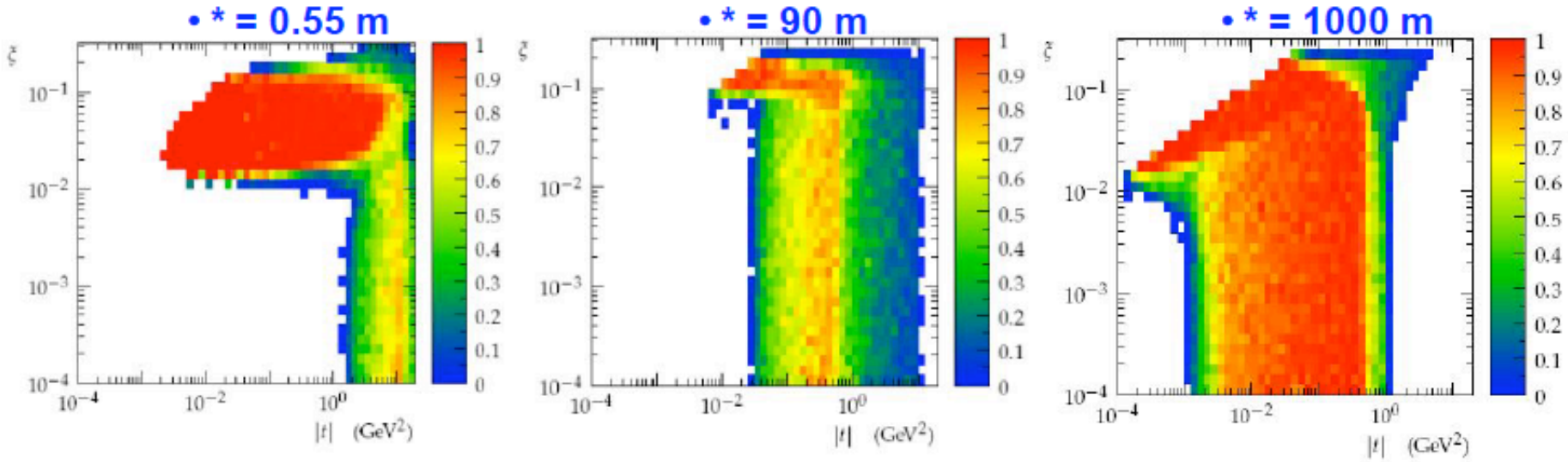
- fully integrated in the CMS global run

Playing with optics

LHC optics & proton acceptance

t: four-momentum transfer squared;

ξ: p/p: fractional momentum loss



Diffraction: • > ~0.03, low cross-section processes (hard diffraction)
Elastic scattering:large |t|

Diffraction: all ••if |t| > ••••GeV²
soft & semi-hard diffraction
Elastic scattering: low to mid |t|
Total cross-section

Elastic scattering: very low |t|, Coulomb-hadronic interference
Total cross-section

Courtesy of TOTEM Collab.

- Fundamental diffractive physics@HERA

  Much more difficult and less fundamental diffractive physics @LHC: when/if we solve the issue of pileup, we are left with rescattering effects

- Roman Pot experience:
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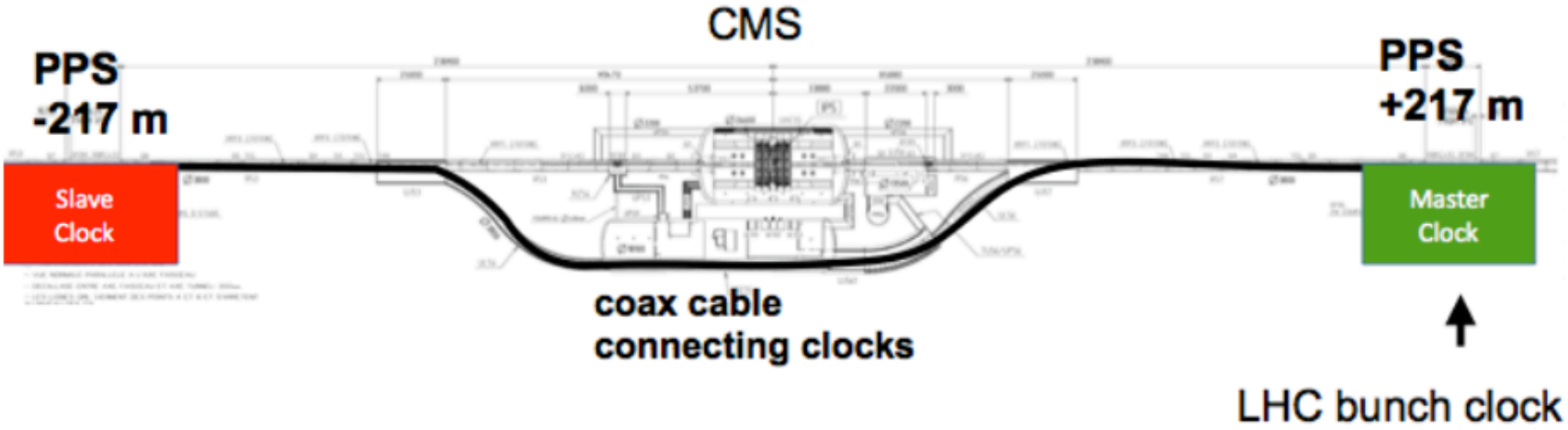
Backup

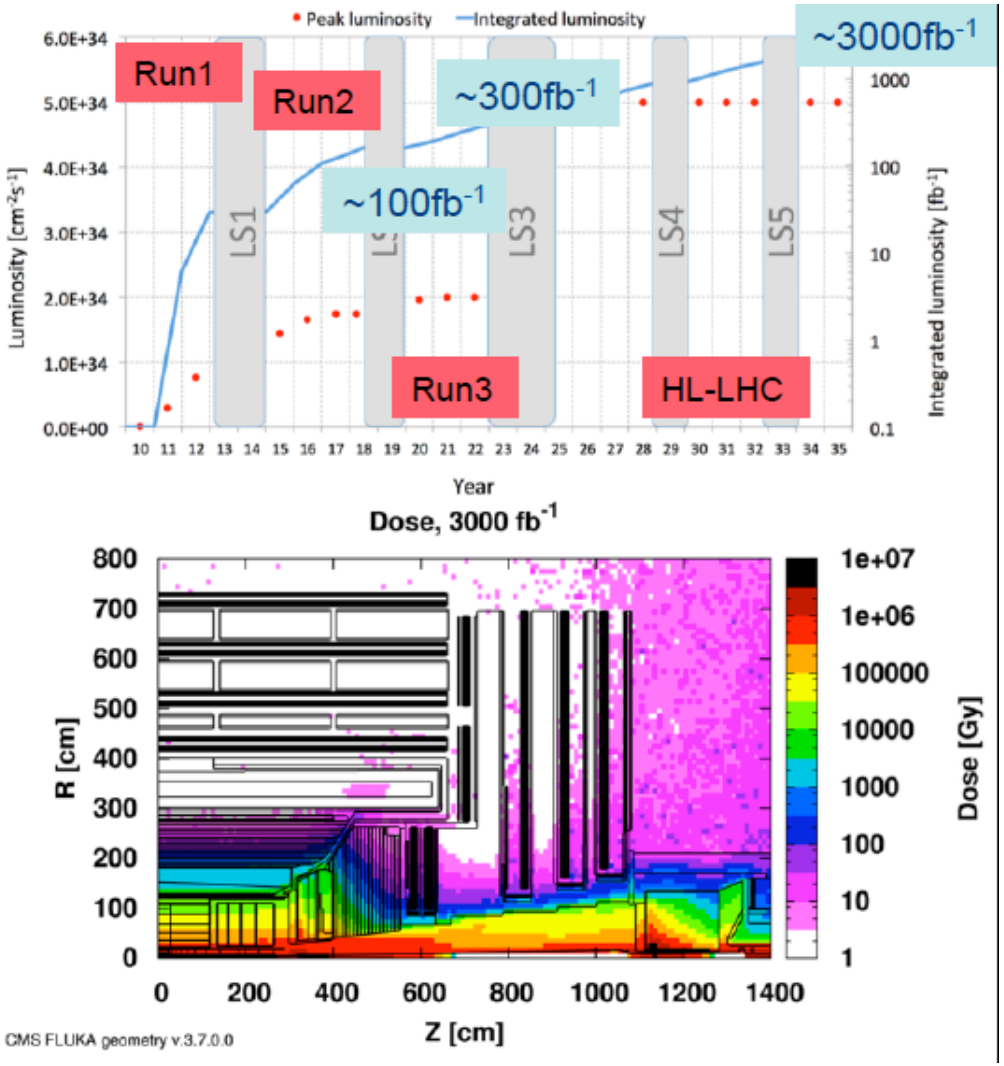
Reference timing system

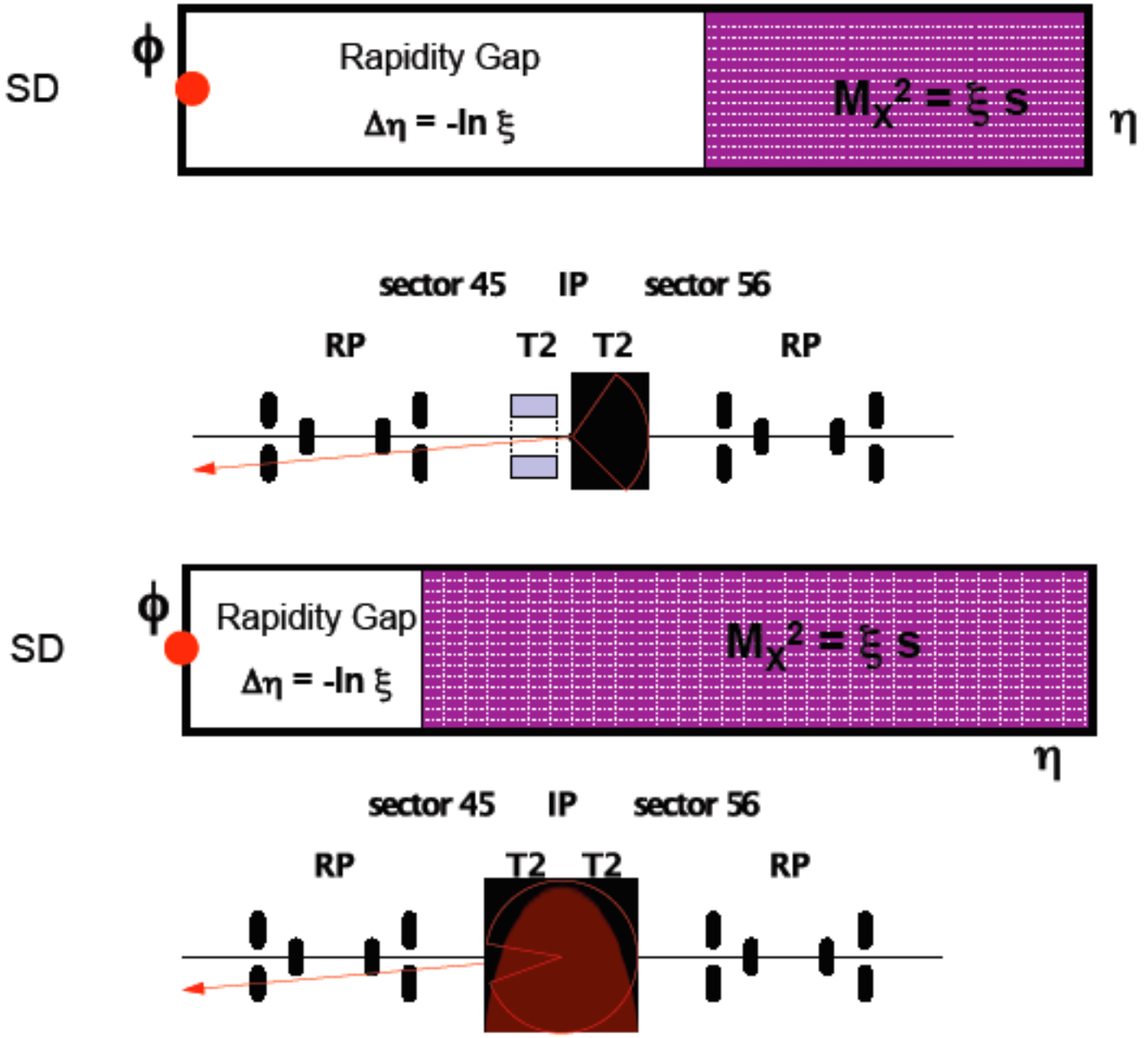


- RF cable with feedback to keep clocks at each end in sync.
- LHC bunch clock is input to master. Output of master+slave as input to motherboard.
- System jitter measured to be 30fs

HL-LHC and phase 2

- TDR in preparation for Phase 2
- Will enhance the mass reach in the search for new particles
- Need to meet experimental challenges
  - Aging of detector, improve/adapt capability
  - Integrated luminosity: 3000/fb over 10 yrs of operation (2025-)
  - peak luminosity of $2x10^{35}cm^{-2}s^{-1}$
  - pileup will be ~150 or higher
  - large radiation doses




SD
ϕ
Rapidity Gap
Δη = -ln ξ
$M_X^2 = \xi s$
η
sector 45
IP
sector 56
RP
T2
T2
RP
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RP

Where is the rapidity gap at LHC ?

- Total room for particle production @LHC: $\Delta\eta \approx \ln(s/m_p^2)$
- Rapidity range effectively populated by particles: $\Delta\eta \approx \ln(m_X^2/m_p^2)$

  Depends on M_X, e.g. with M_X= 500 GeV: $\Delta\eta \approx 12$

- The resulting gap size depends on the process, e.g. in central diffraction, assuming two symmetric gaps, each will have a size of $\Delta\eta \approx \frac{1}{2}(20-12) \approx 4$

  i.e. **very forward, often outside CMS-ATLAS acceptance**