The TOTEM Experiment

Consolidation and Upgrade

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Outline

- Introduction
- TOTEM Detectors
- Roman Pot
- Results
- Consolidation and Upgrade
- Summary

Introduction

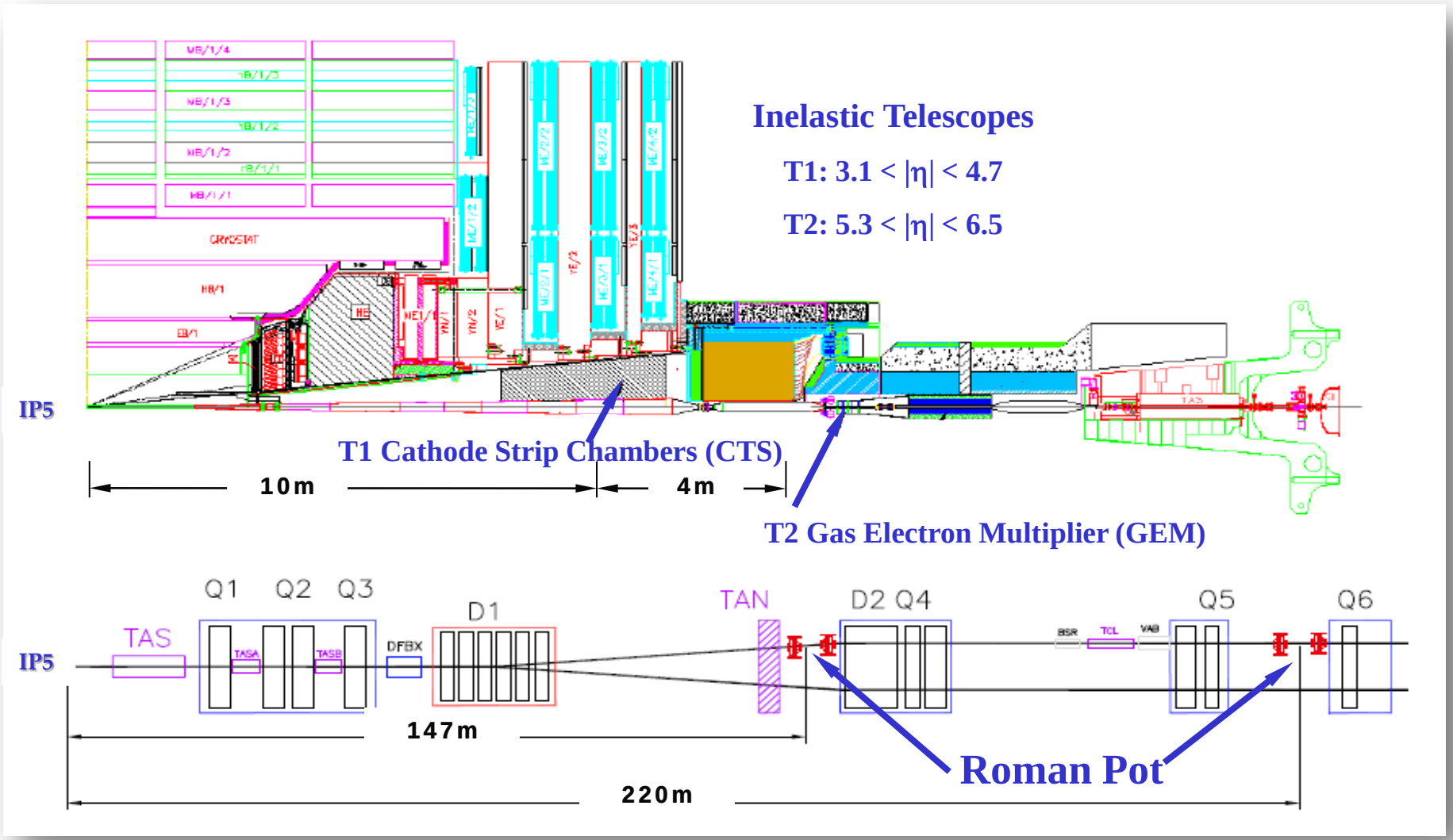
What is TOTEM Experiment at LHC?

Dedicated experiment for

TOT*al cross section,* ***E****lastic scattering and diffraction dissociation* ***M****easurements*

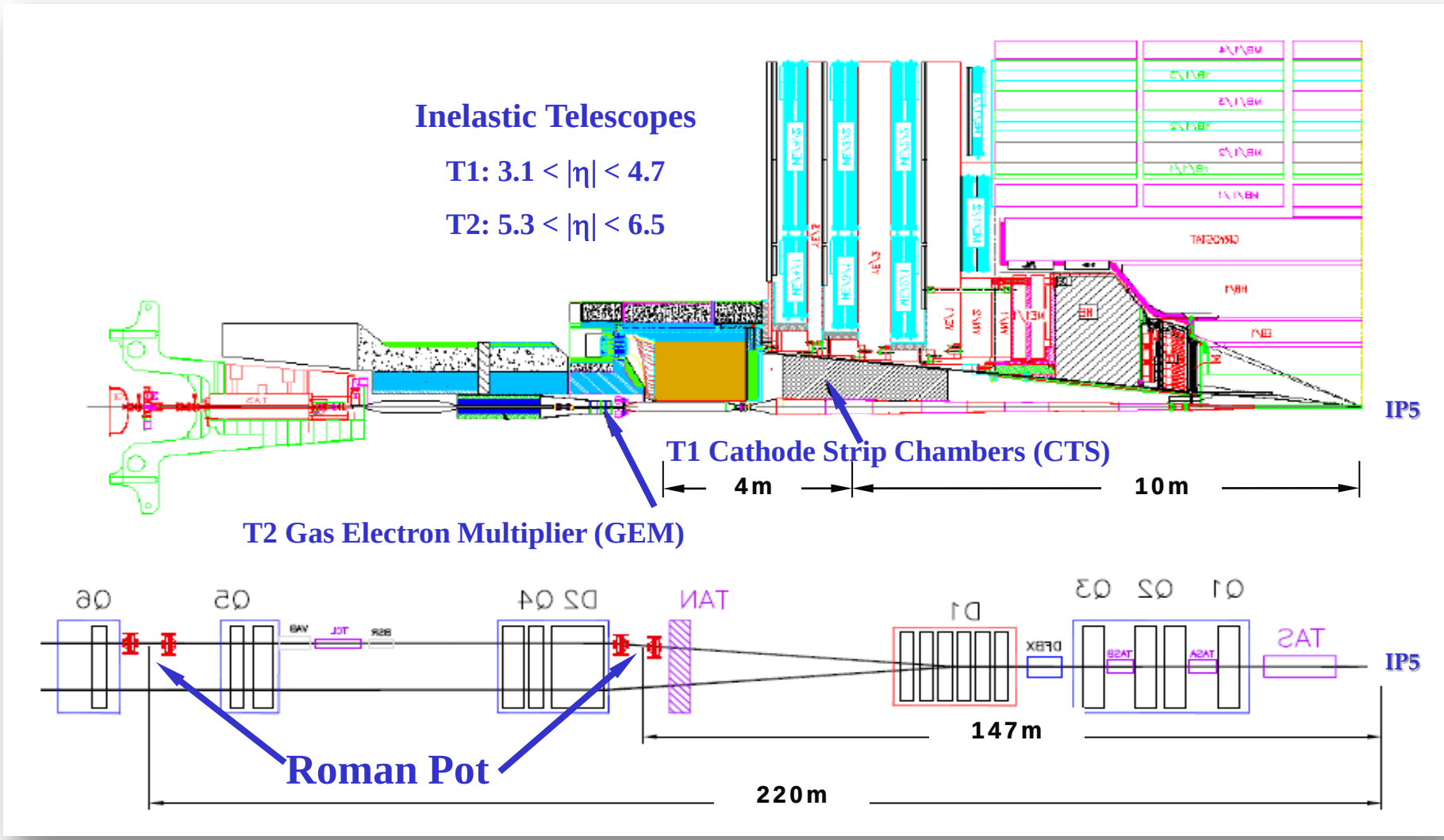
Collaboration	**TOTEM**	**CMS**
Countries:	9	41
Institutes:	15	180
Collaborators:	~ 100	~ 4400
Authors:	~ 80	~ 2100
Construction:	~ 7 MCHF	~ 500 MCHF

TOTEM Detectors (1)



Same scheme on both sides of IP5

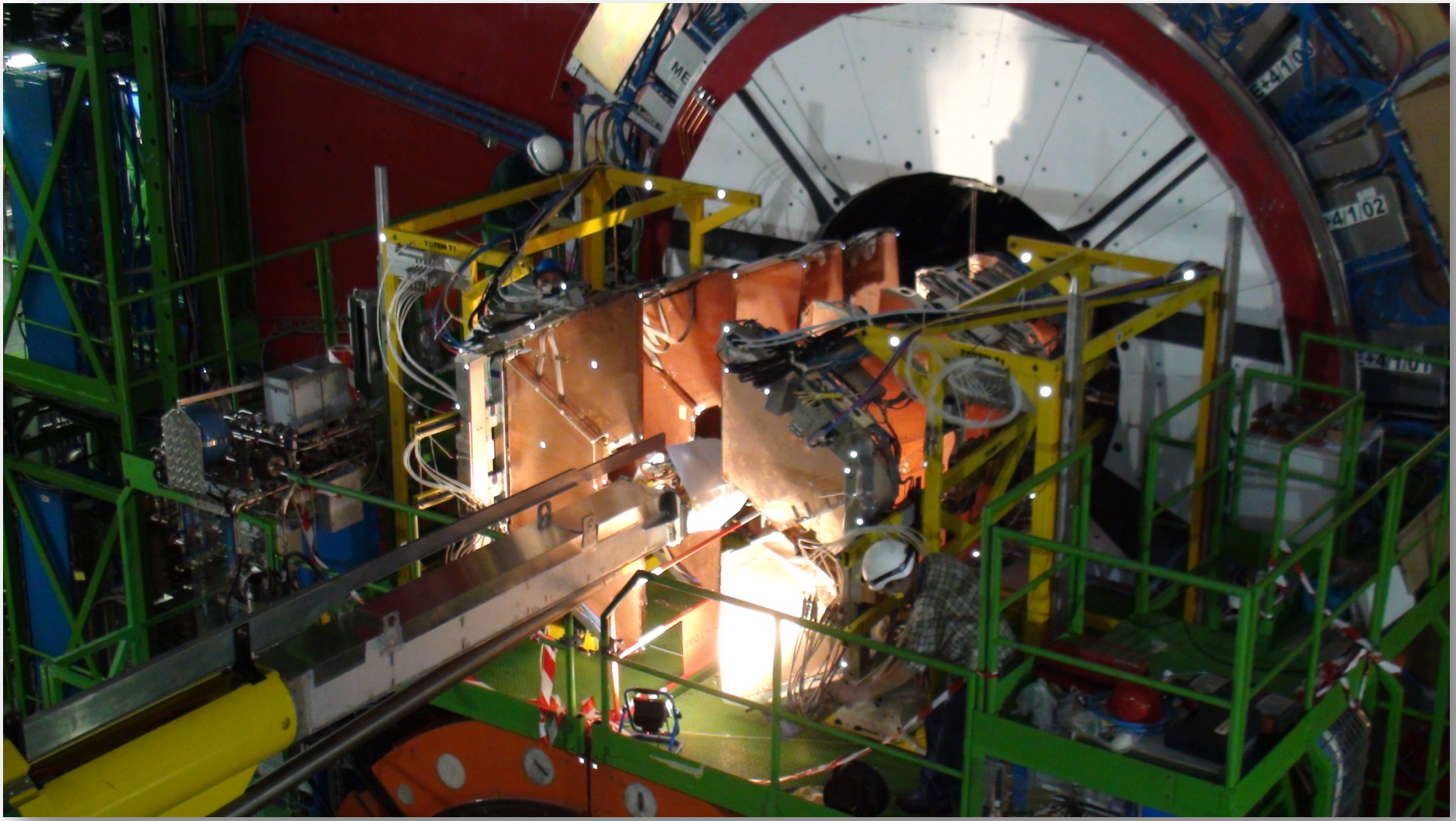
TOTEM Detectors (2)



Same scheme on both sides of IP5

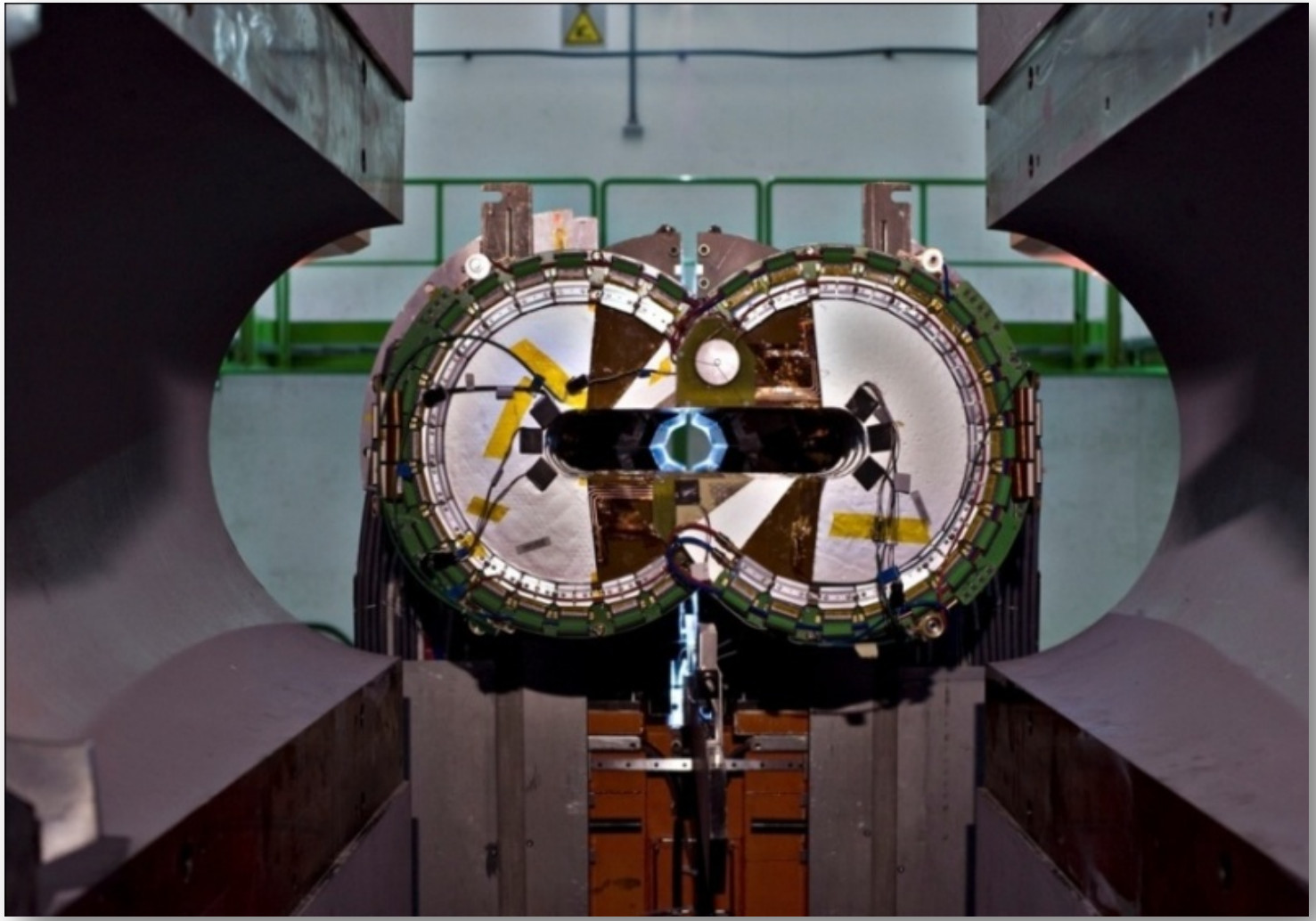
TOTEM Detectors (3)

T1 (CSC)



TOTEM Detectors (4)

T2 (GEM)



TOTEM Detectors (5)

Roman Pot

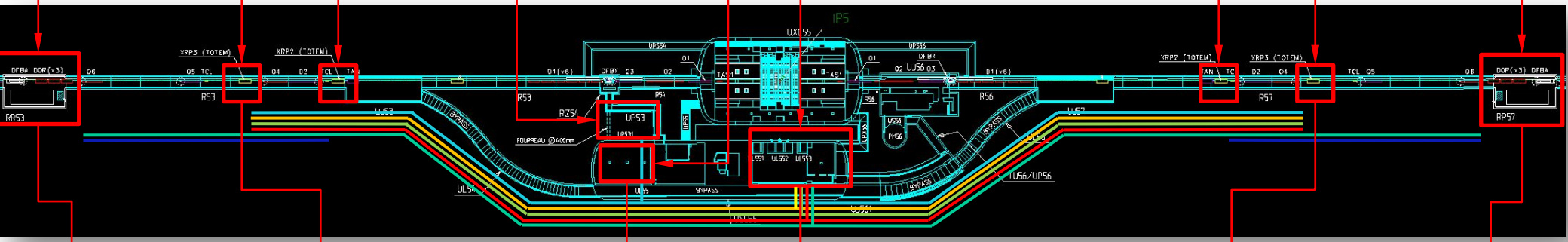
Roman Pot Infrastructure

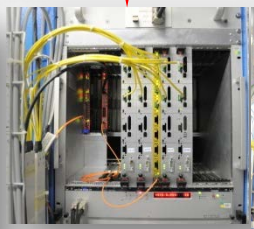
RR53 Alcove RR57

220m Stations

147m Stations

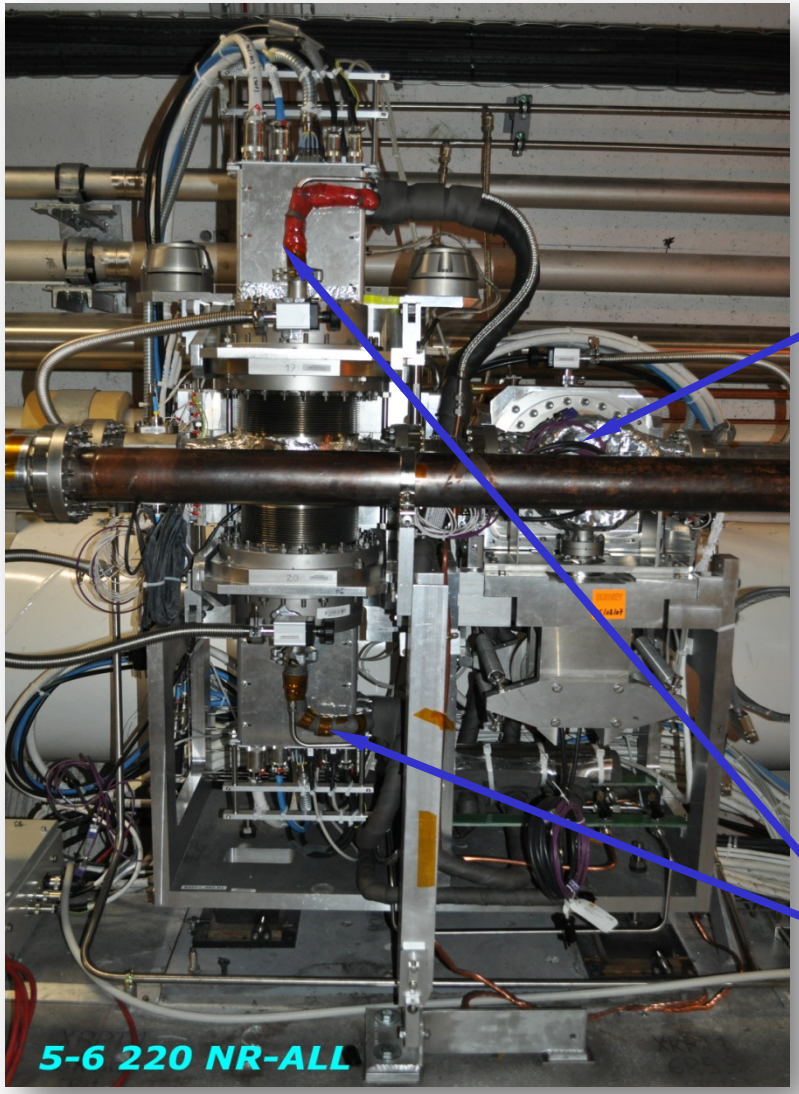
Cooling Plant Counting Rooms S1/S2/S4





Cooling
DCS / DSS / RADMON
Fibers
HV
Control
LV

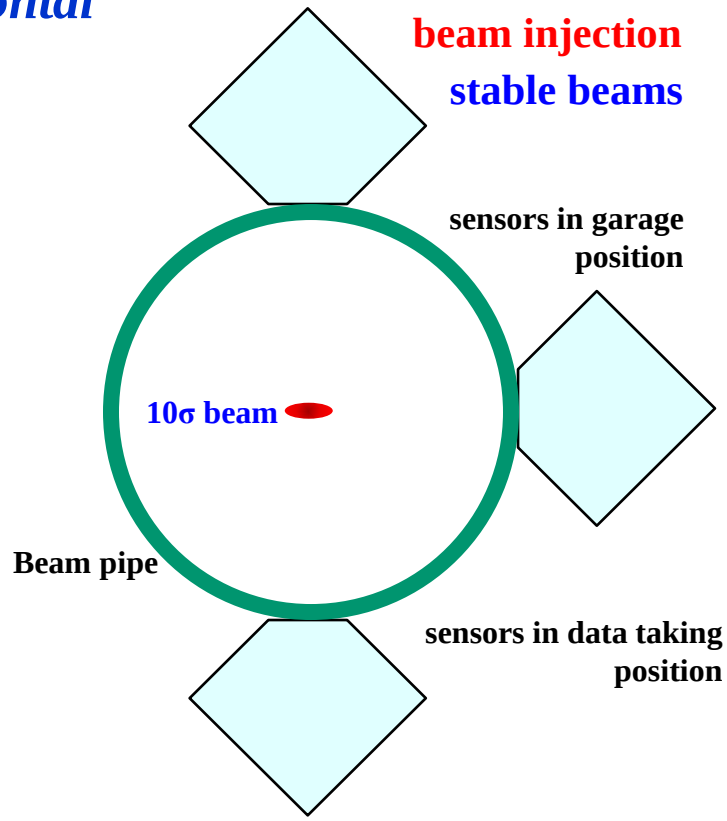
Roman Pot Station



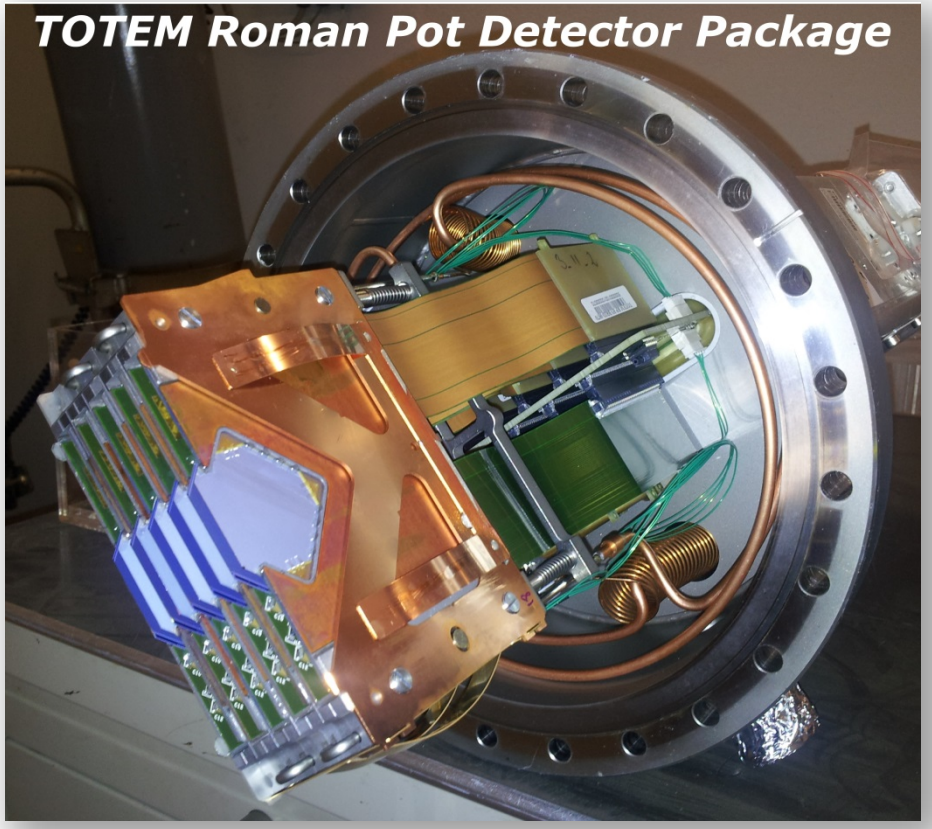
Horizontal

Verticals

Photo of sector 5-6 220m near RP unit

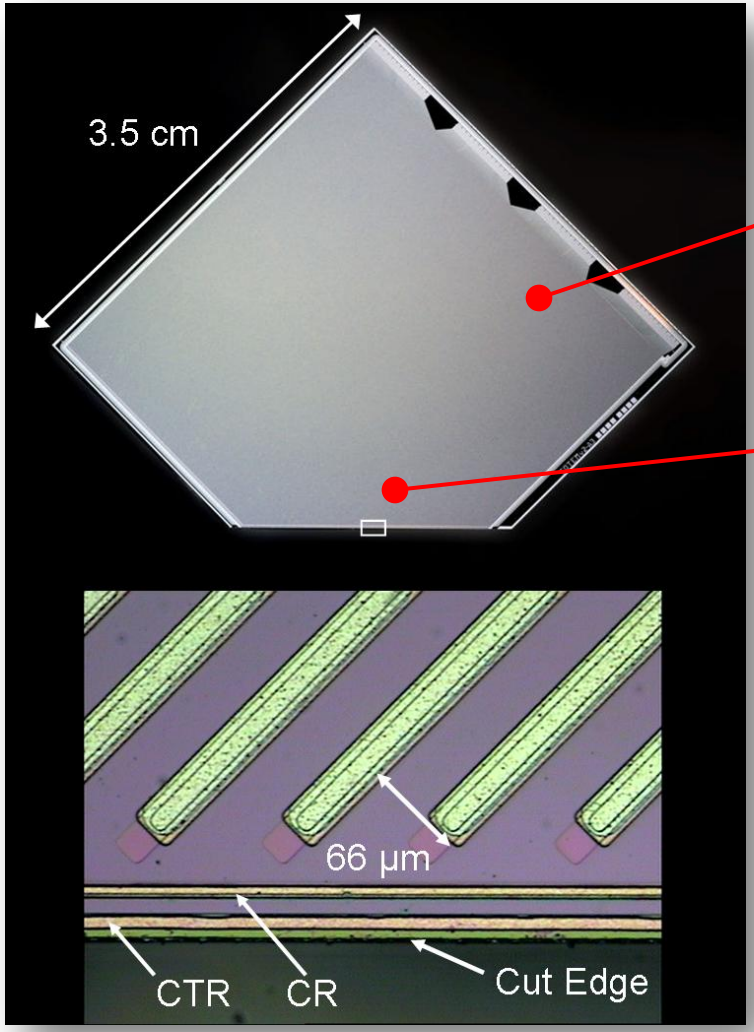


Detector Package



- Stack of 10 hybrids.
- Flipping the hybrid and mounting it face-to-face with the next one results in orthogonal strips which give the U and V coordinate information.
- All electrical components are mounted on one side to avoid losing space between the hybrids.

The Edgeless Sensor



Only 50µm from end of strip to end of sensor!

Technology

- Very High Resistivity Si n-type, 300um thick.
- Standard planar technology fabrication.

Design

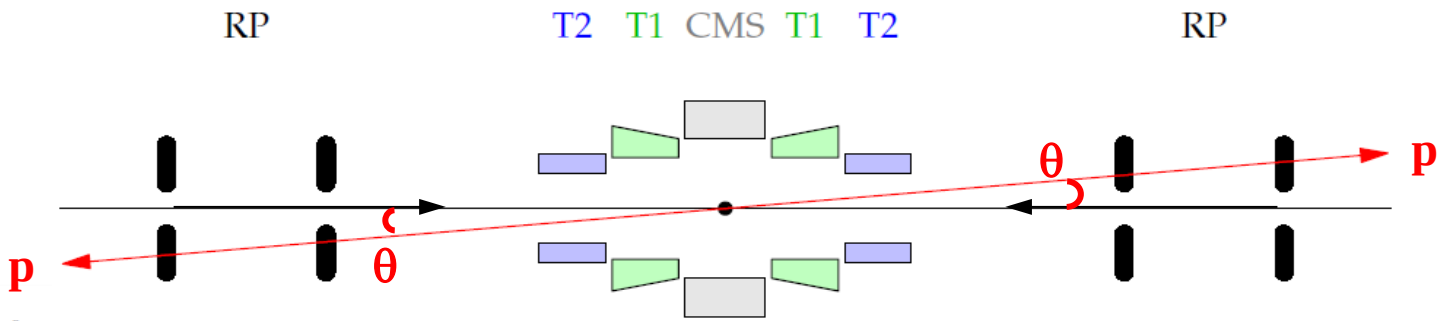
- Single sided detector, 512 micro strips (pitch 66 µm) strips at 45° from the "sensitive" edge.
- Voltage Terminating Structure (VTS) on non-sensitive edges.
- Current Terminating Structure (CTS) on sensitive edges.

(50 µm): Current Terminating Ring (CTR) and Cleanup Ring (CR).

Results (1)

- The TOTEM Experiment with its Roman Pot detectors has been set up in a relatively short time: TDR in 2004 and first data taking in 2009 with RP@220m.
- The overall performance of the Roman Pot with its edgeless silicon detectors is excellent.
- The effort spent in the development and construction of the experiment has started to pay off with physics results.
- The proton-proton elastic scattering and inelastic scattering and the first measurement of the proton-proton scattering total cross-section at the LHC has been completed by the TOTEM experiment at CERN in special runs with Roman Pot detectors.
- The results are published in EPL journals.

Results (2)



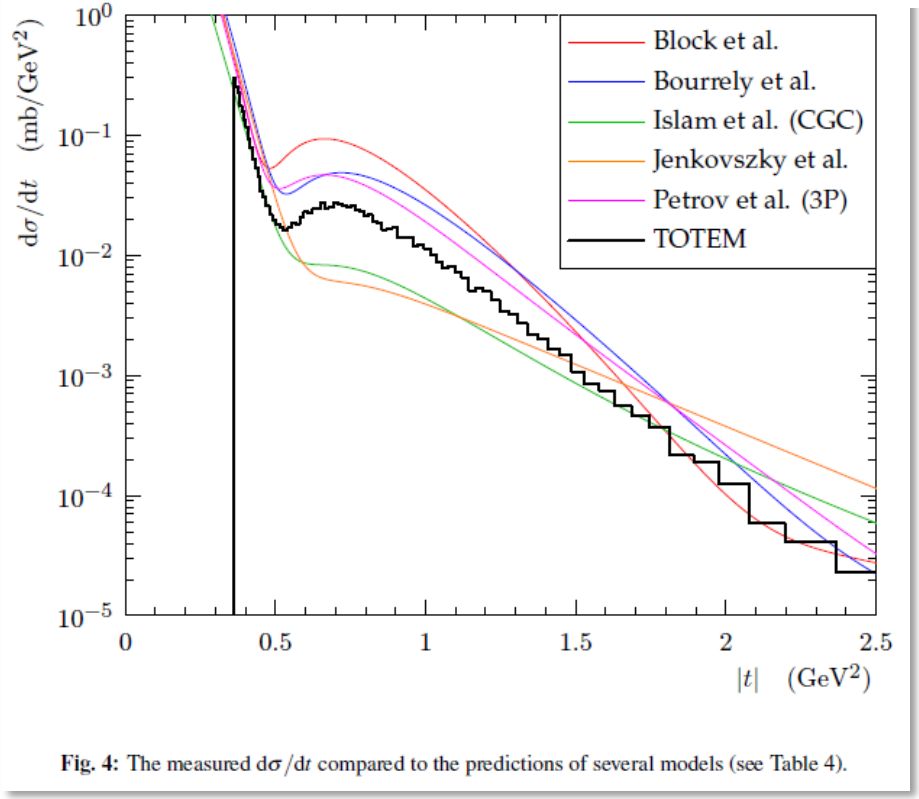


Fig. 4: The measured dσ/dt compared to the predictions of several models (see Table 4).

$|t| \approx p^2\,\theta^2$

"Proton-proton elastic scattering at the LHC energy of sqrt s = 7 TeV", CERN-PH-EP-2011-101, EPL 95 (2011) 41001

Results (3)

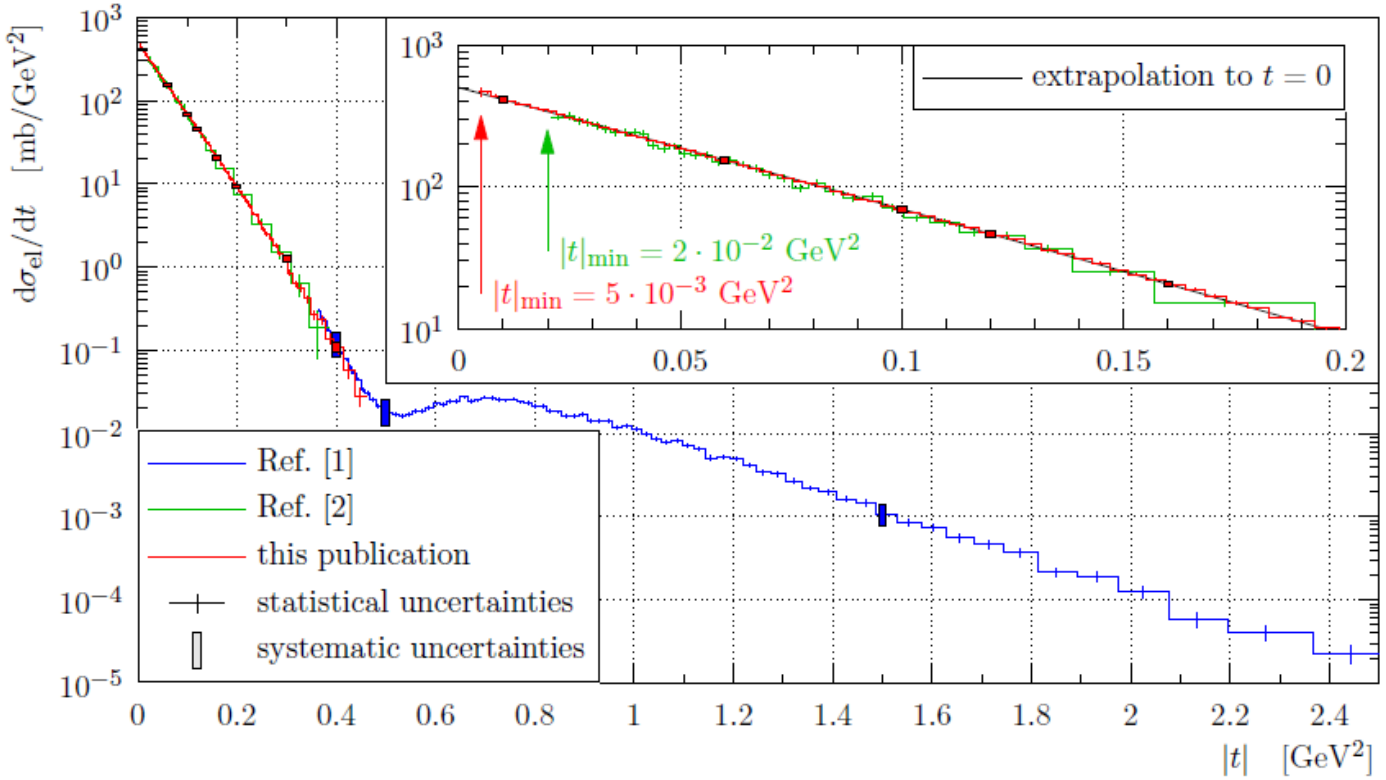
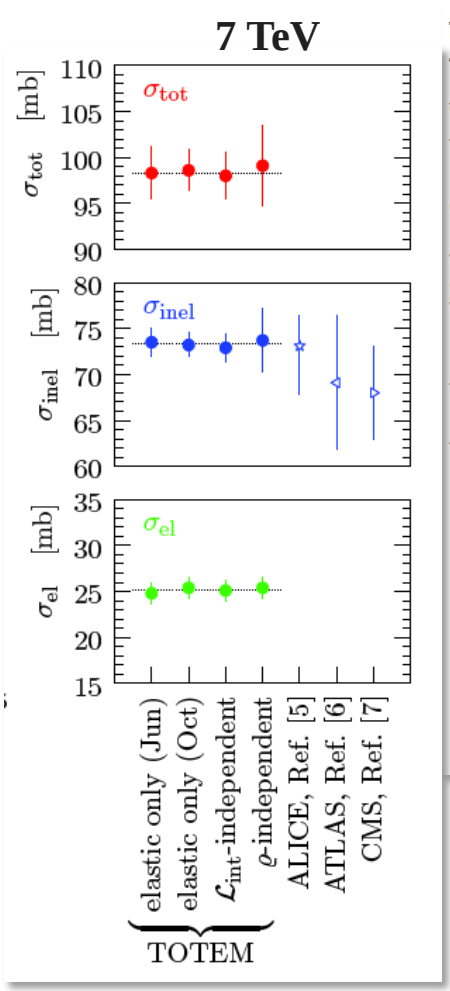
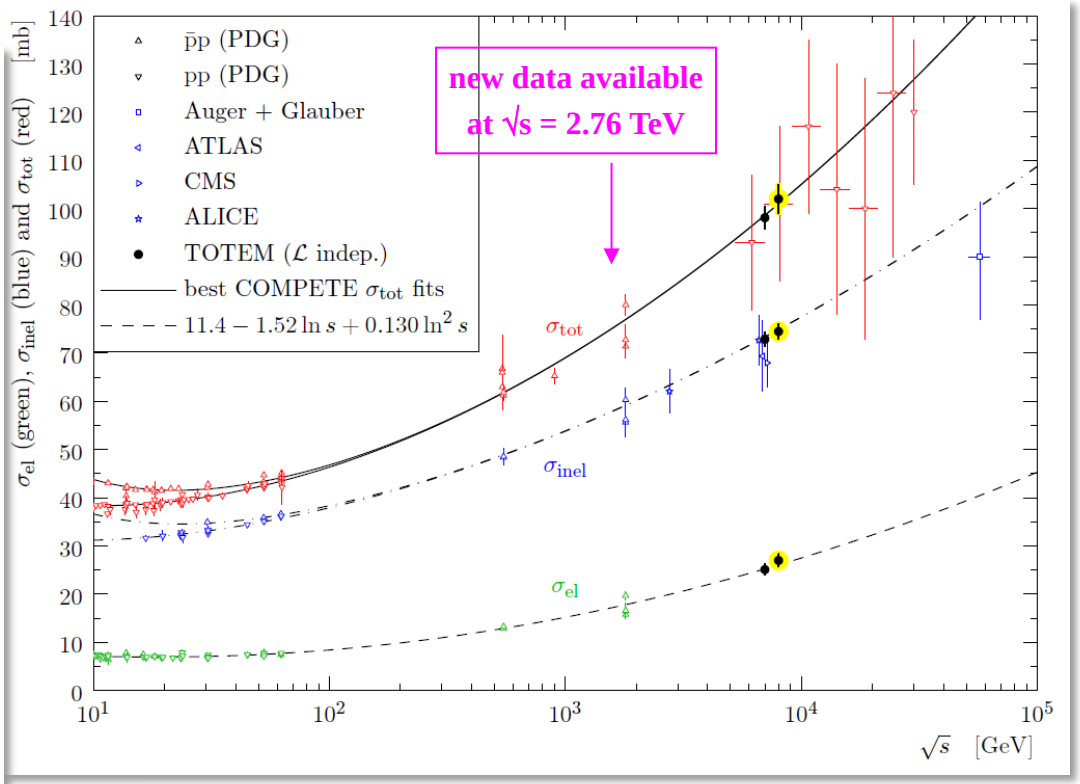


Fig. 2: The elastic differential cross-section measurements by TOTEM. Each measurement is shown in a different color. The embedded figure provides a zoom of the region used for extrapolation to $t = 0$, showing the lowest $|t|$-values accessible in the analysis from Ref. [2] (green) and this analysis (red).

"Measurement of proton-proton elastic scattering and total cross-section at sqrt s = 7 TeV", CERN-PH-EP-2012-239, EPL 101 (2013) 21002

Results (4)





8 TeV

quantity		value	systematic uncertainty				
			el. t-dep	el. norm	inel	ρ	⇒ full
σ_{tot}	[mb]	101.7	±1.8	±1.4	±1.9	±0.2	⇒ ±2.9
σ_{inel}	[mb]	74.1	±1.2	±0.6	±0.9	±0.1	⇒ ±1.7
σ_{el}	[mb]	27.1	±0.5	±0.7	±1.0	±0.1	⇒ ±1.4

"Luminosity-independent measurements of total, elastic and inelastic cross-sections at sqrt s = 7 TeV ", CERN-PH-EP-2012-353, EPL 101 (2013) 21004

"A luminosity-independent measurement of the proton-proton total cross-section at sqrt s = 8 TeV" CERN-PH-EP-2012-354 Phys. Rev. Lett. 111, 012001 (2013)

Consolidation and Upgrade (1)

Motivation

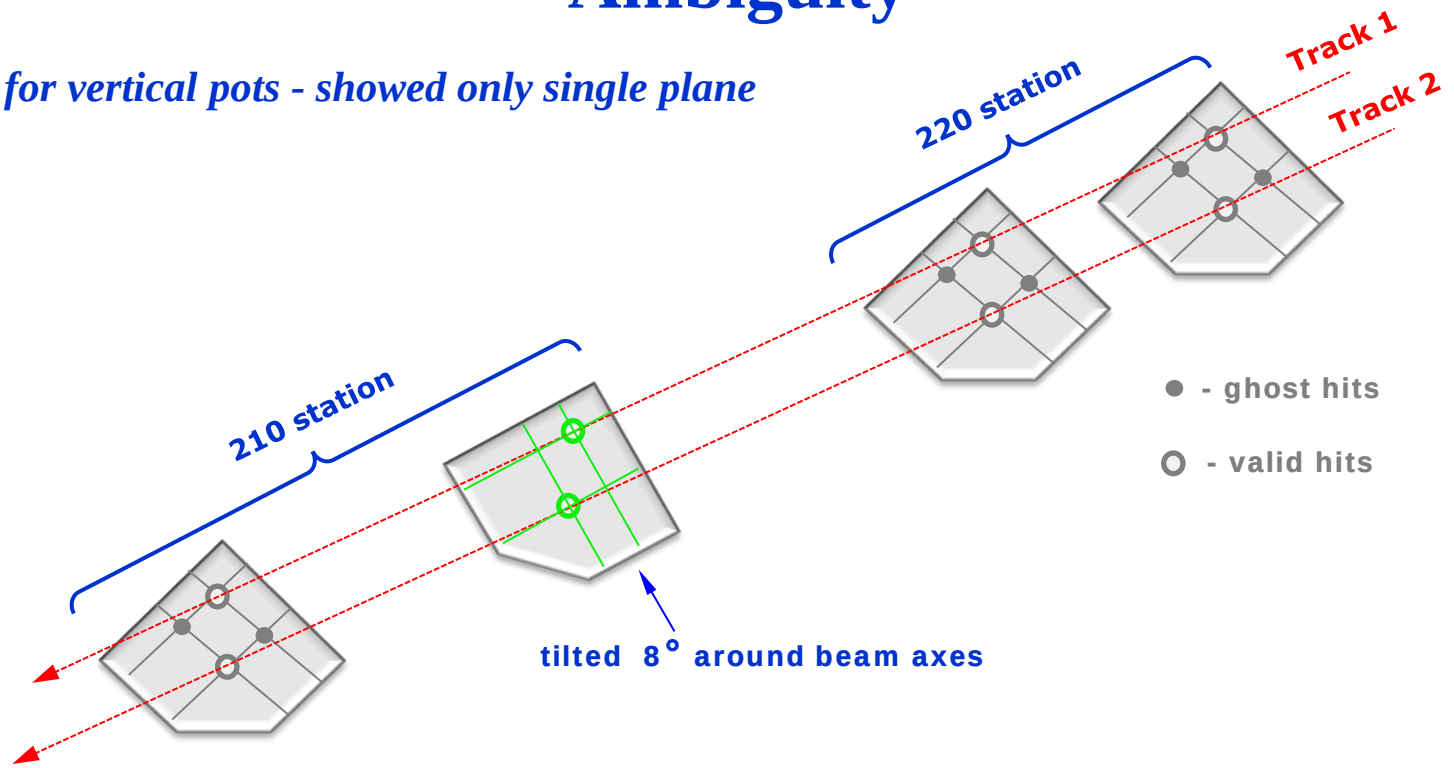
- TOTEM collected data at $\sqrt{s}$ = 7 and 8TeV in special runs at reduced luminosity allowing:
  - Analysis of large cross-section processes like elastic scattering and soft diffractive channels.
  - Measurements the total pp cross-section and the pseudorapidity distribution of charged particles.
- Repeat those measurements at the new LHC energies of $\sqrt{s}$ = 13 and 14TeV:
  - The collaboration's goal is to extend its scope to diffractive and other forward phenomena with lower cross-sections.
  - Thus more integrated luminosity is required.
- Combine TOTEM and CMS detectors with common triggers of high flexibility.

Strategy

- Resolve event pileup and multiple track in proton detectors by:
  - Relocation of 147m stations to 210m (the region between quadrupole Q5 and 220m station).
  - Tilt half of the relocated station on 8°.
- TOTEM proposes the installation of two new horizontal Roman Pots designed to:
  - Accommodate timing detectors for reconstructing the longitudinal vertex position of the leading protons in central diffractive events.
- TOTEM Upgrade proposal CERN-LHCC-2013-009 / LHCC-P-007 was submitted in June 2013.

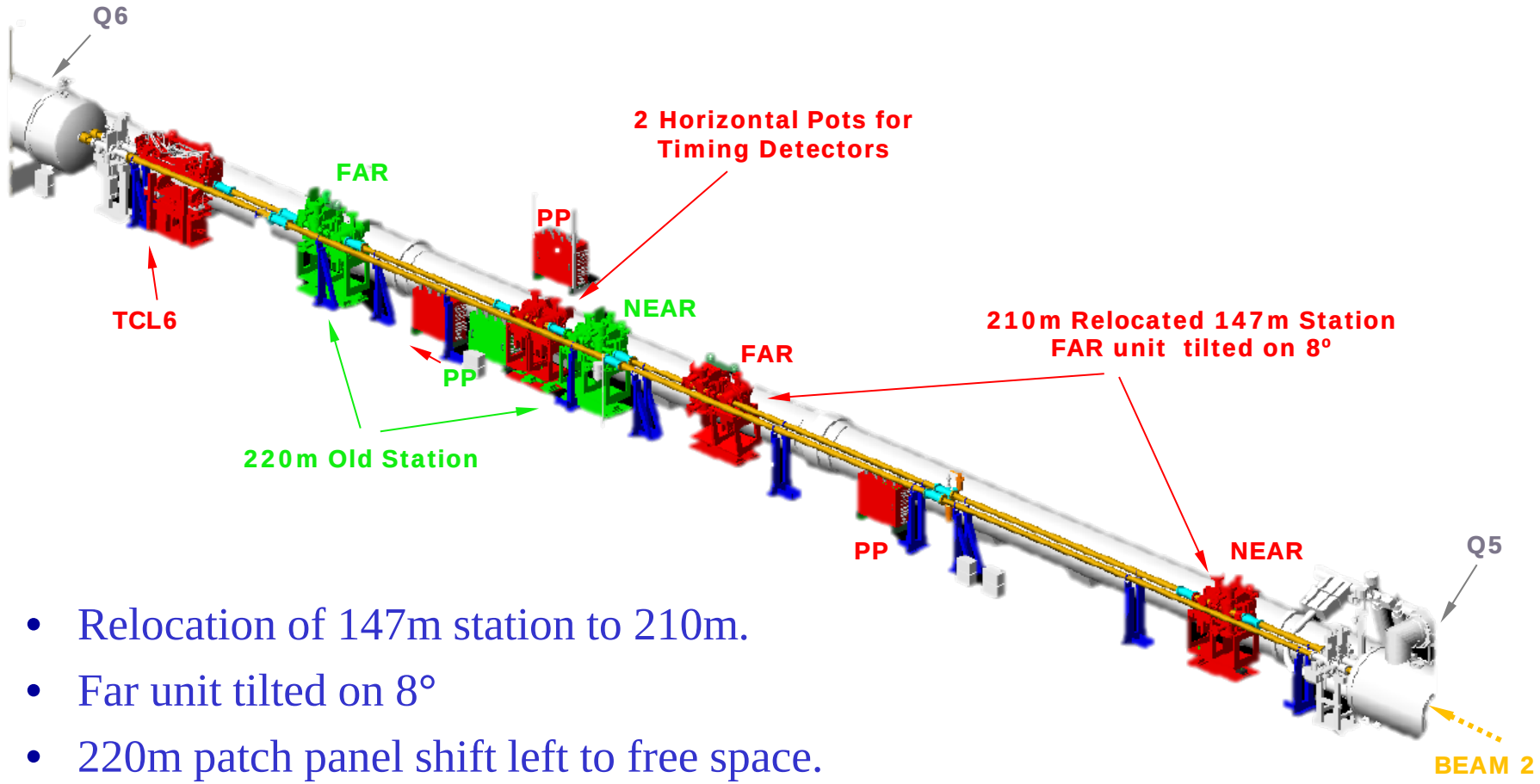
Ambiguity

Example for vertical pots - showed only single plane



- Multiple tracks in the same bunch crossing, high pileup.
- Ambiguity. Ghost hits removal.
- Half station is tilted on 8° (i.e. one Horizontal and two Vertical pots).
- This will help to resolve the problem.

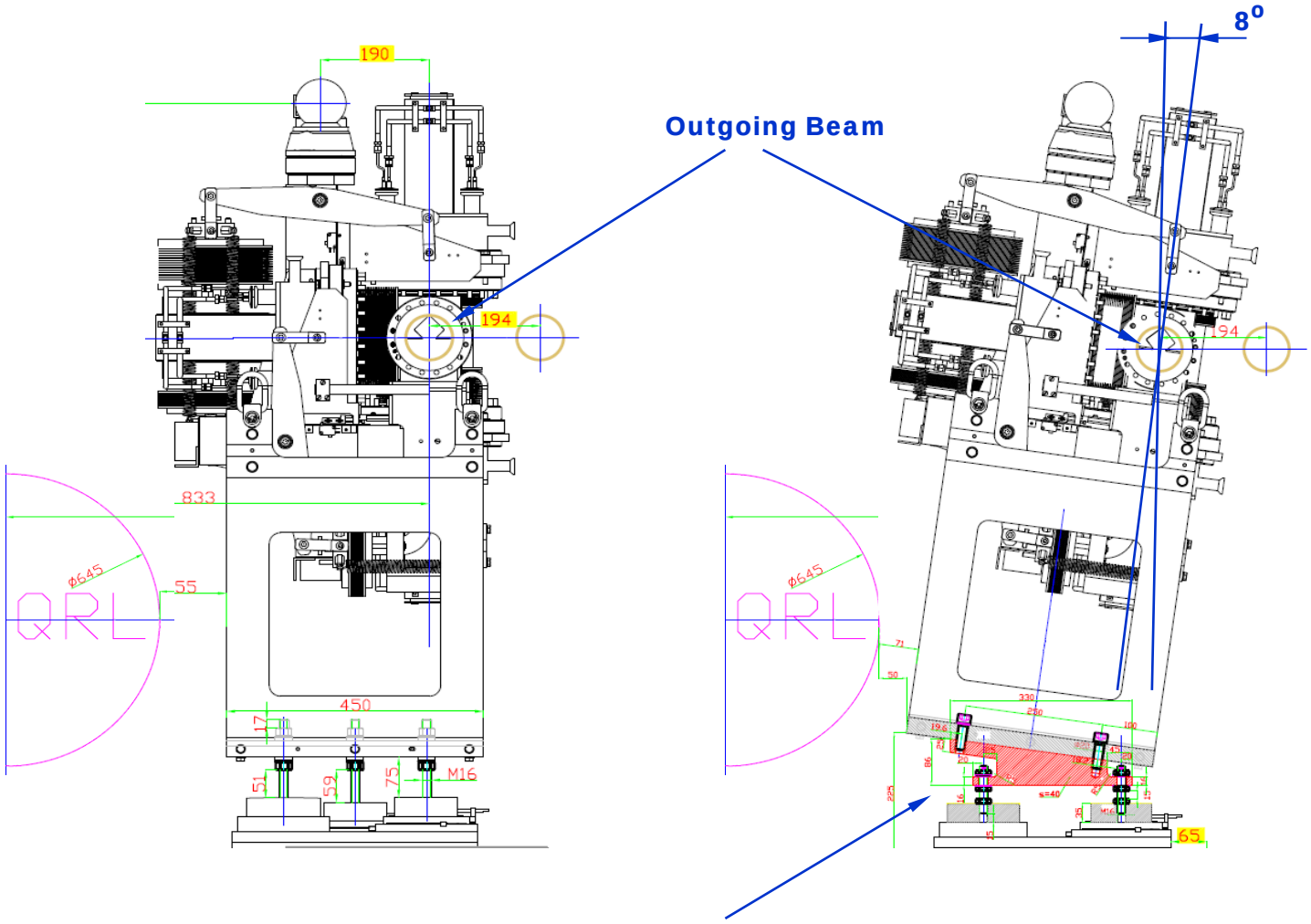
Experimental Setup – shown sector 4-5



- Relocation of 147m station to 210m.
- Far unit tilted on 8°
- 220m patch panel shift left to free space.
- 2 horizontal Roman Pots between 220m near and far unit.
- New TCL6 collimator to protect Q6.

Consolidation and Upgrade (5)

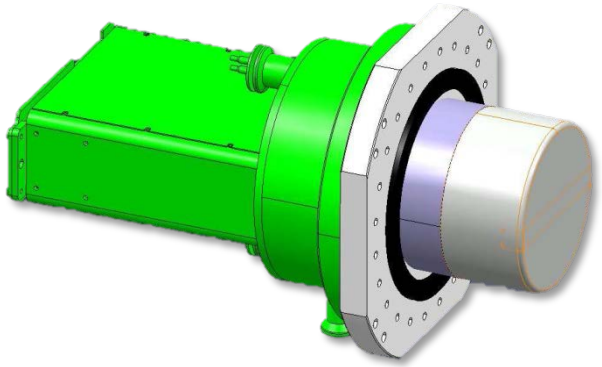
Normal and Tilted Roman Pot Unit – side view

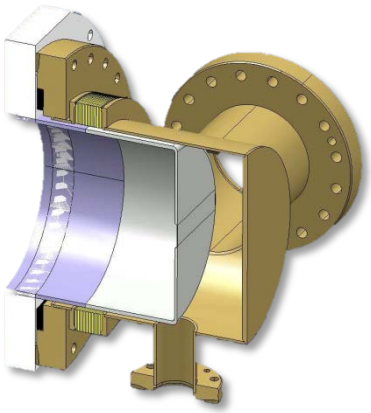


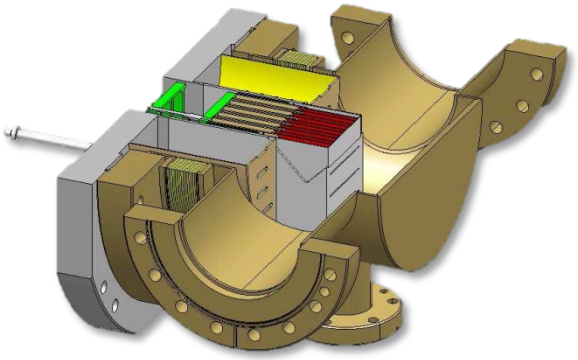
- Mechanical support changed to achieve this rotation.

New Roman Pot

- Several different options have been considered to:
  - Provide the necessary volume to host timing detectors.
  - To reduce the beam coupling impedance.
- Cylindrical shape was chosen.
- The RF shield and new ferrite ring to be integrated.
- On existing Roman Pot replacement of the old ferrite is foreseen:
  - The same geometry.
  - New material TT2-111R.





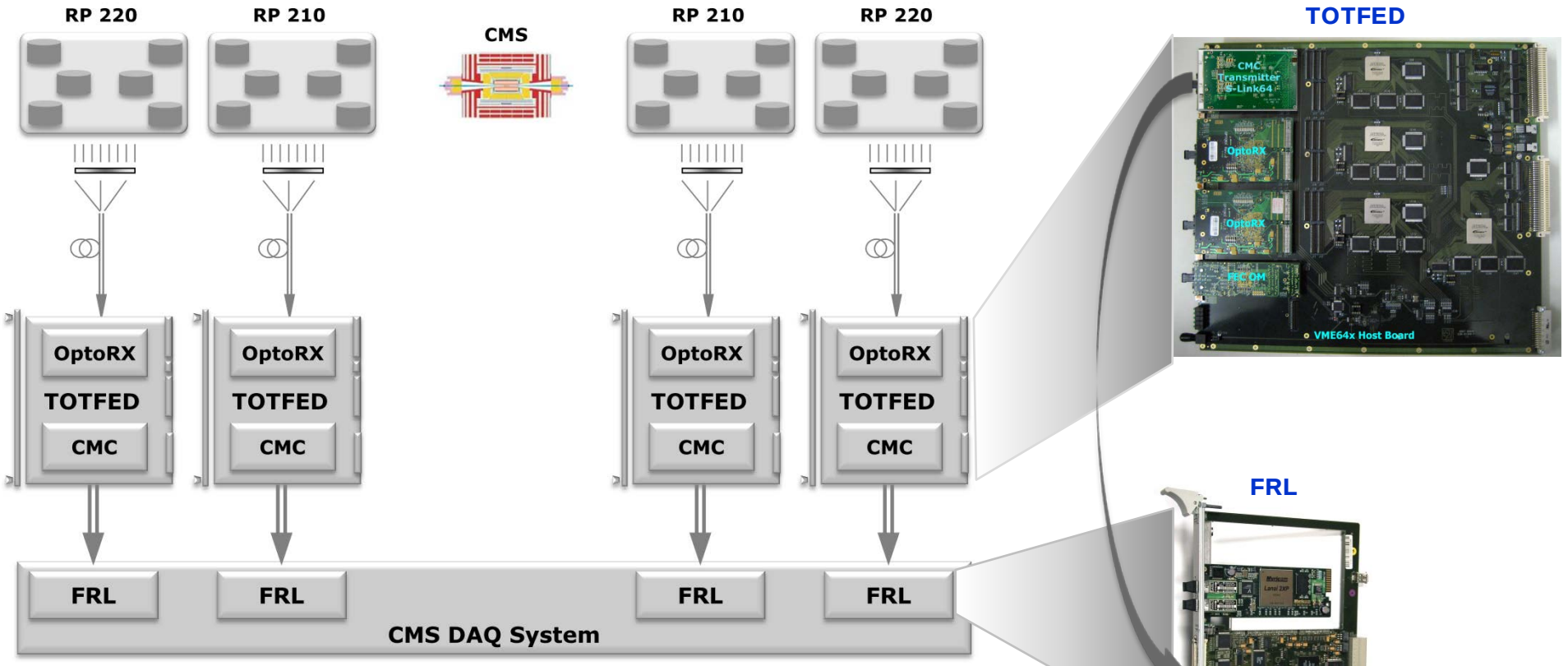


Timing Detectors

- To distinguish the timing difference in particle arrivals at two opposite sides of the IP the following components are needed:
  - Particle sensor:
    - Two Cherenkov type L bars 6cm each, formed detector of up to 12 cm along the beam.
    - Diamond detectors.
    - 3D detectors with resolutions reached between ~180 and ~30 ps.
  - Distributions of timing difference:
    - Timing signal coherent with the beam available in the counting room to be distributed optically to both ends via splitter and feedback for correction.
    - CERN white rabbit development to distribute timing to Ethernet.
  - TDC to measure the difference between two signals:
    - Several developments ongoing – chips, FPGA, etc.
    - Need 10ps resolution.

Consolidation and Upgrade (8)

Integration with CMS DAQ



- Based on modular TOTEM Front End Driver (TOTFED).
- Connection via CMC Transmitter S-Link64 to CMS FRL .
- CMS DAQ compatible data, high bandwidth and second level trigger.

Summary

- The TOTEM experiment consolidation and upgrade during technical stop LS1 are an ongoing process.
- Several work packages function in parallel:
  - Production of new cylindrical Roman Pot.
  - Ferrite elements.
  - Calibration and movement system test in the laboratory.
  - Relocation of 147m stations to 210m on both sides:
    - New beam pipes and bellows.
    - Positions, patch panels, cables, fibers.
    - Interlock and DCS.
    - Cooling and vacuum systems.
  - CMS DAQ integration:
    - New connections and configurations, XDAQ.
- The consolidation and upgrade program also relies on the extensive help from different CERN groups and external collaborators.

Thank you!