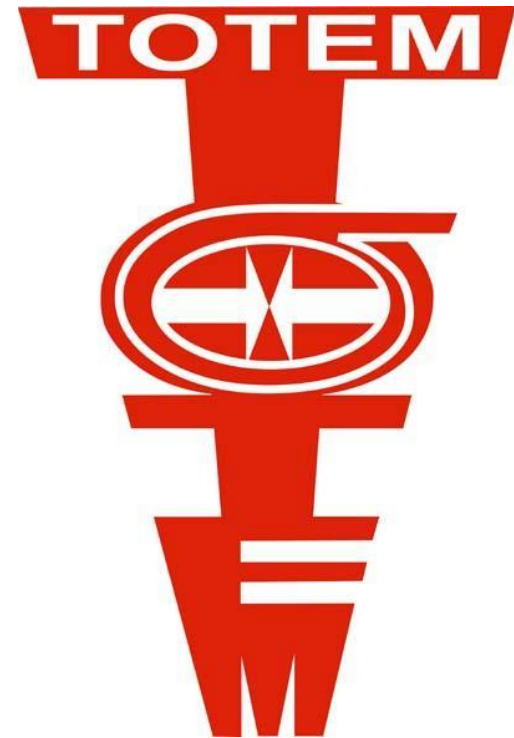


TOTEM

Status Report

F.Cafagna
CERN & INFN-BA
on behalf of TOTEM Collaboration



Outline

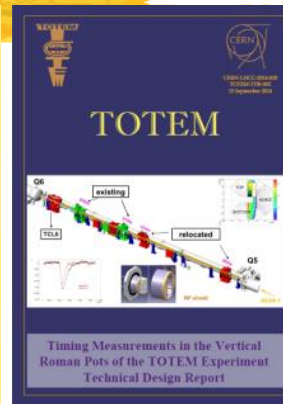
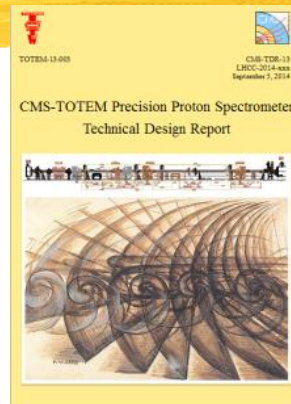
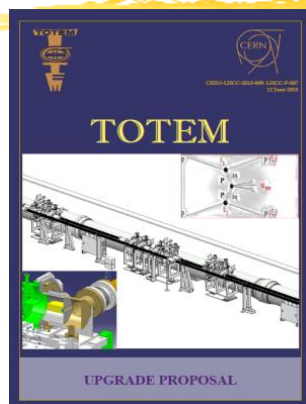


- Detector status;
- The two released TDRs:
 - **Timing Measurements in the Vertical Roman Pots of the TOTEM Experiment** (CERN-LHCC-2014-020 ; TOTEM-TDR-002; <https://cds.cern.ch/record/1753189/>);
 - **CMS-TOTEM Precision Proton Spectrometer** (CERN-LHCC-2014-021 ; TOTEM-TDR-003 ; CMS-TDR-13; <https://cds.cern.ch/record/1753795?ln=en>);
- Physics/Analysis status.

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**

**RP
operation
with DAQ**

August 2014

**All Components integrated
in the LHC beam line by
August 2014**

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 CHANGES:
It is proposed to install TCL4 (TCL type) collimators in the forward regions of IP1 and IP5, 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 IP5.

ENGINEERING CHANGE REQUEST
TOTEM Consolidation Project

BRIEF DESCRIPTION OF THE PROPOSED CHANGES:
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 Q3 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 CHANGES:
It is proposed to install TCL4 physics-debris collimators, on both sides of IP1 and IP5 in front of the Q6 Quadrupole (TCL6). This request follows the ECR EDMS Doc. 1283667 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 CHANGES:
The TOTEM Upgrade Proposal [1] foresees the installation of additional horizontal Roman Pots (RP) 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 minimizing 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].

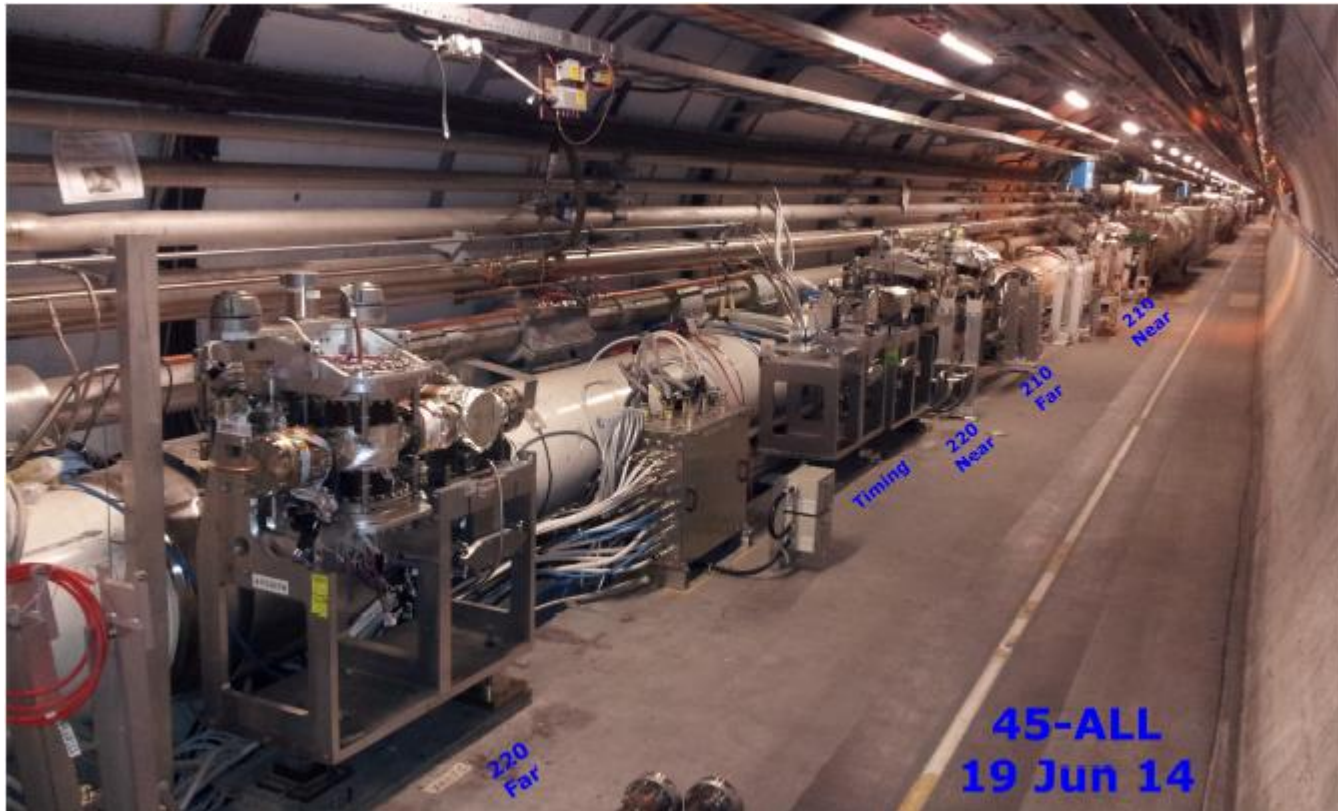


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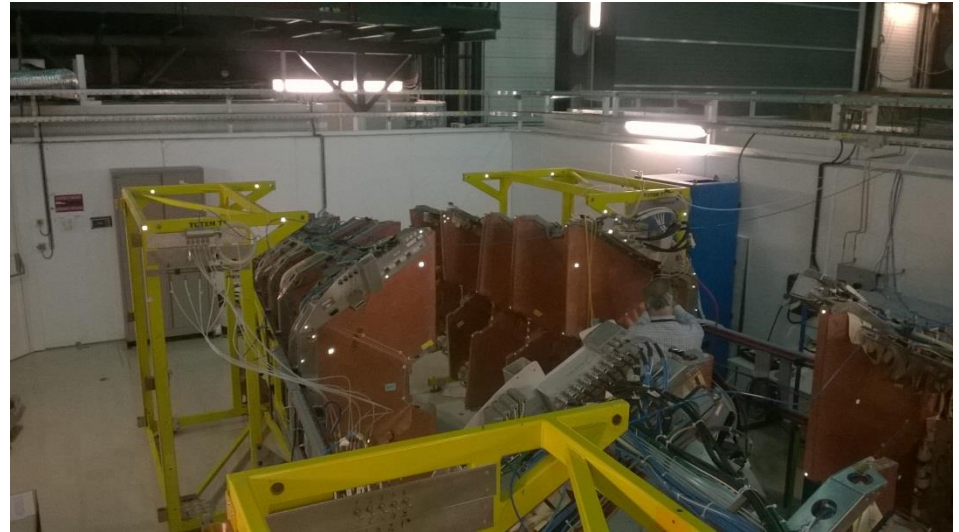
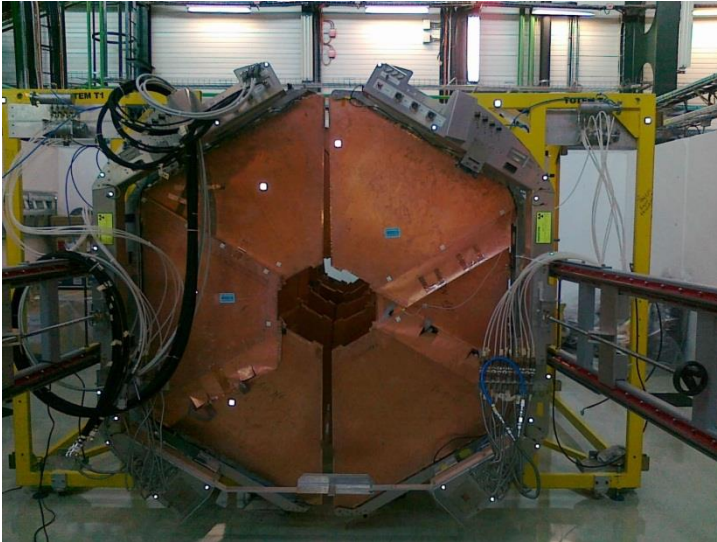
F.S. Caragna, LHCC open session

Roman Pot

- Detector Packages (DP) installed in 4-5.
- DP in 5-6 and movement system on schedule



T1 telescope

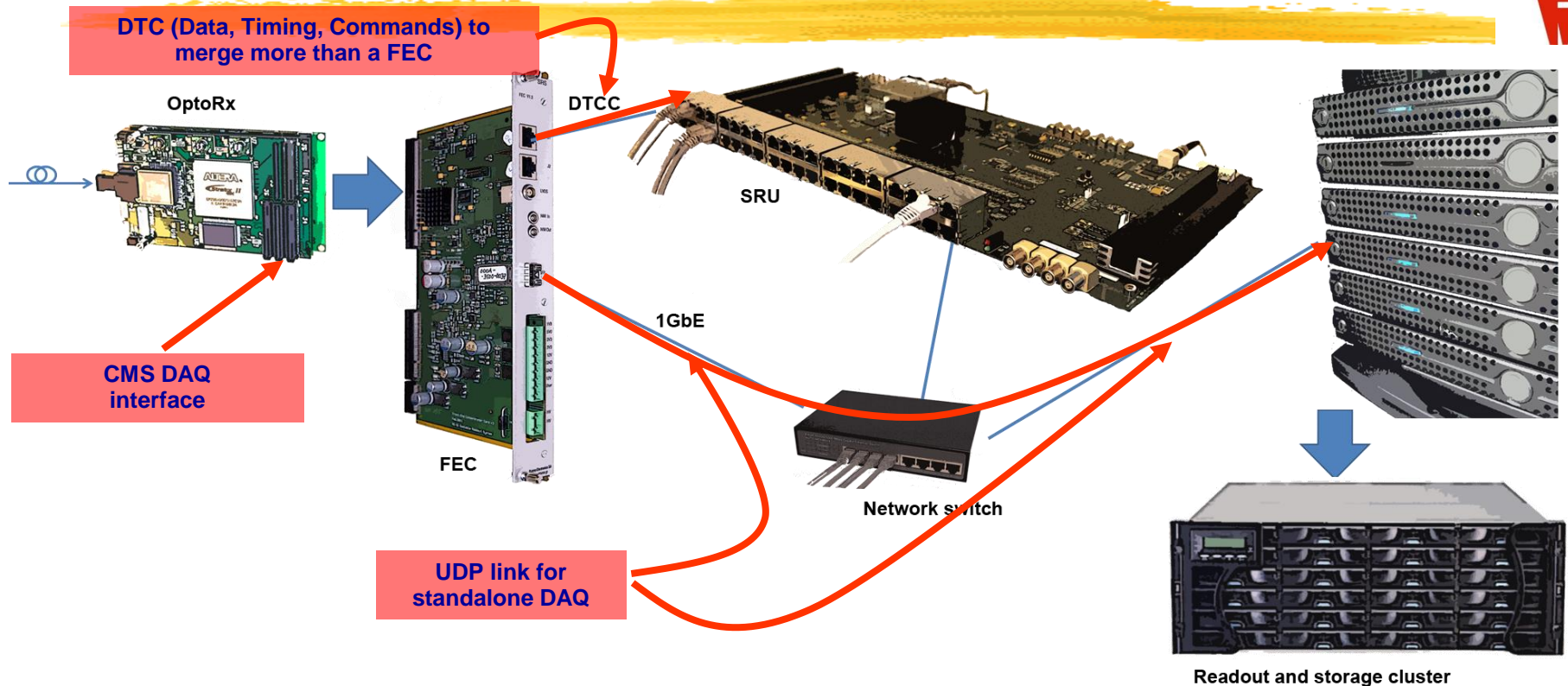


- Maintenance is over;
- Commissioning done at surface;
- Ready to be installed.
- Integrated in the CMS installation schedule.

T2 telescope

- New front-end electronics installed;
- Detector assembled:
 - Re-insertion in HF scheduled in October;
- Commissioning started:
 - Low Voltage and High Voltage tests passed;
- Next steps:
 - DAQ tests;
 - Calibrations.

DAQ

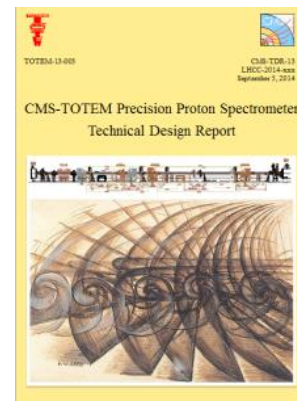
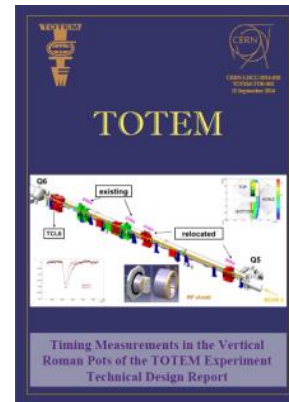


- Replacement of the VME back-end with Ethernet 1Gb links, using RD51 FEC cards;
- Full compatibility with CMS DAQ and LHC TTC;
- Procurement completed;
- Commissioning done in the test-bed (20kHz trigger rate, $\sim 20\times$ w.r.t. previous DAQ system), ready for installation in IP5.

The 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;

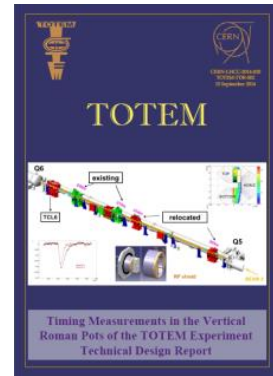
- **CMS-TOTEM Precision Proton Spectrometer**
 - **Low β^* (0.5 m), standard runs, high luminosity;**
 - CMS & TOTEM collaboration for a common R&D for detectors to be installed in the relocated **horizontal RPs** and newly constructed **horizontal RPs**;
 - Integrated Luminosity of the order of fb⁻¹.

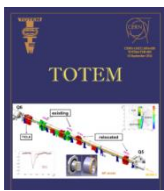


The TOTEM timing TDR

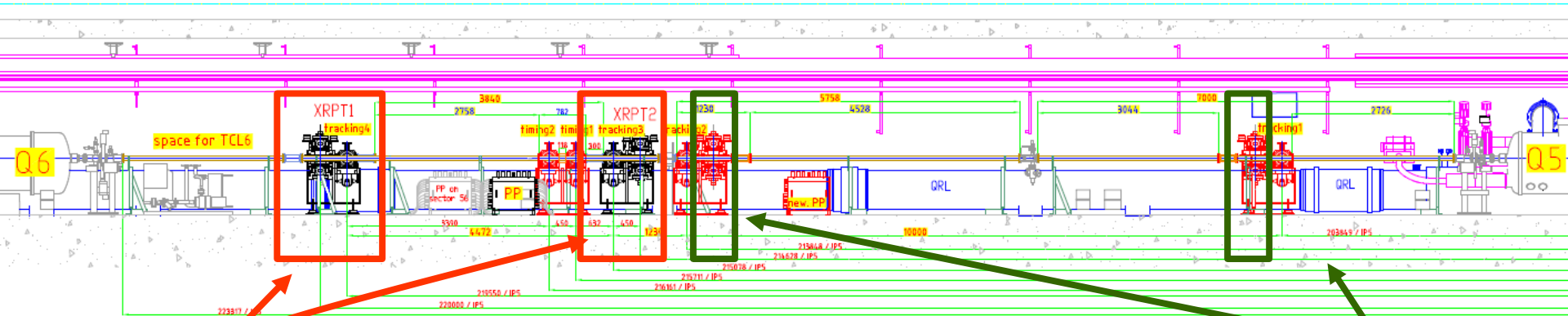


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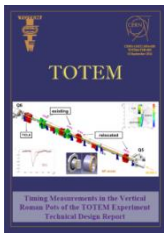




The TOTEM timing TDR



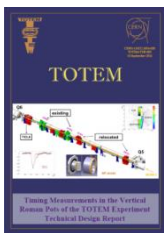
- In this measurements all TOTEM tracking detectors in **all vertical RPs** will be used, i.e. existing RP at 220 m and relocated RP at 203-213 m.
- New timing detector will be installed in a **vertical RP**.



The TOTEM timing TDR

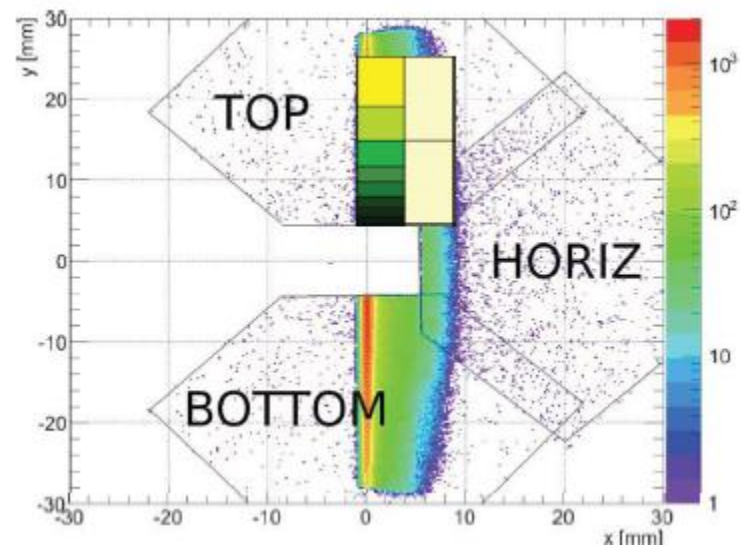


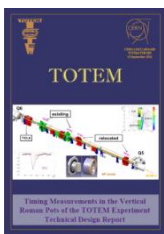
- Scientific objectives:
 - Exclusive central diffraction;
 - Low mass resonances and glueball states;
 - Exclusive charmonium state;
 - Search for missing mass and momentum candidates;
 - Exclusive jet production.
- The integrated luminosities, required by the cross-sections of the processes, imply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



The TOTEM timing TDR

- Timing detectors in the relocated vertical RPs:
 - Limited space available -> Solid State Detectors:
 - Diamond
 - Silicon
 - Time resolution & performances: 50 ps per pot (~ 100 ps per detector), reduce PU by a factor 4 (50% -> $\sim 12\%$).
- R&D in progress:
 - From June to August, three beam tests done.
 - Two more beam test on October and November;
 - Optimization of the front-end & hybrid board for better timing performances in progress;

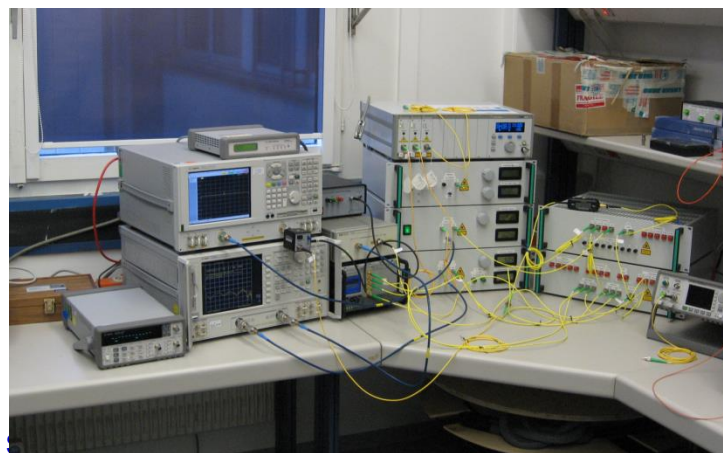




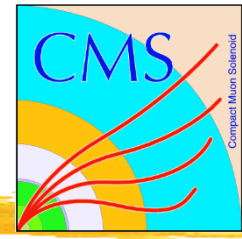
The TOTEM timing TDR

- A precise, low jitter clock distribution is mandatory;
- We are adapting M. Bousonville "*Universal Picosecond Timing System*", developed for FAIR at GSI:
(<http://link.aps.org/doi/10.1103/PhysRevSTAB.12.042801>).
- This system strenghts:
 - It is scalable. More clock signals can be added as needed (e.g. CT-PPS);
 - It is based on robust industrial telecommunication standards, like DWDM (Dense Wavelength Division Multiplexing);
 - Can be monitored;
 - Already installed and proven to work at GSI

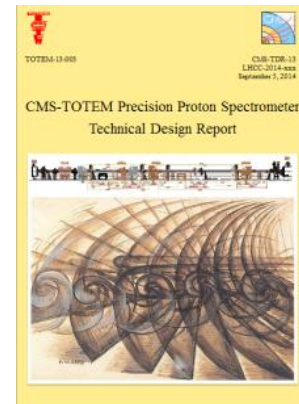
**The system under test at
GSI.**
(Courtesy of M. Bousonville.)

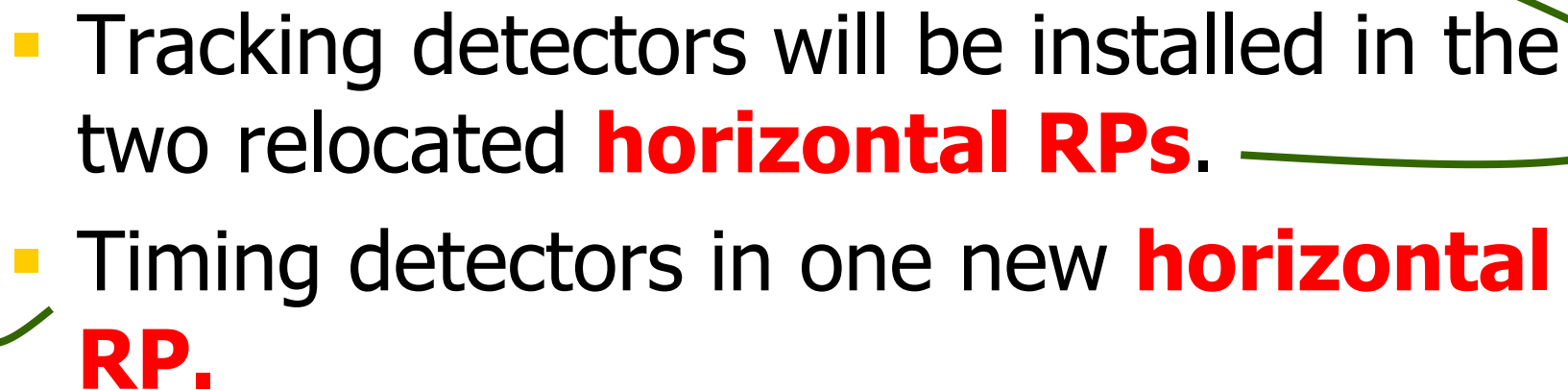


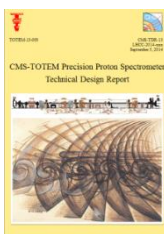
The CT-PPS TDR



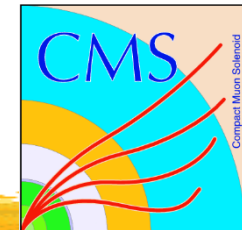
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 - Integrated luminosity of the order of fb^{-1} .





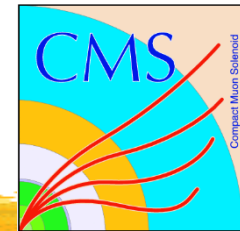


The CT-PPS TDR



- 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 $\gamma\gamma \rightarrow W^+W^-, e^+e^-, \mu^+\mu^-, \tau^+\tau^-$;
 - Search for AQGC with high sensitivity;
 - Search for SM forbidden $ZZ\gamma\gamma, \gamma\gamma\gamma\gamma$ 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)
 - Independent mass measurement from pp system
 - J^{PC} quantum numbers $0^{++}, 2^{++}$

The CT-PPS TDR



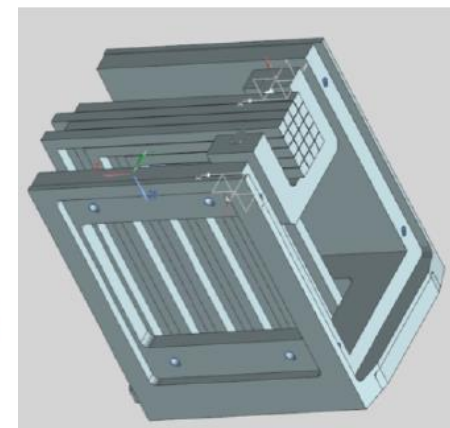
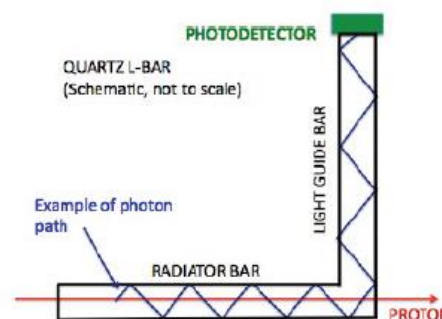
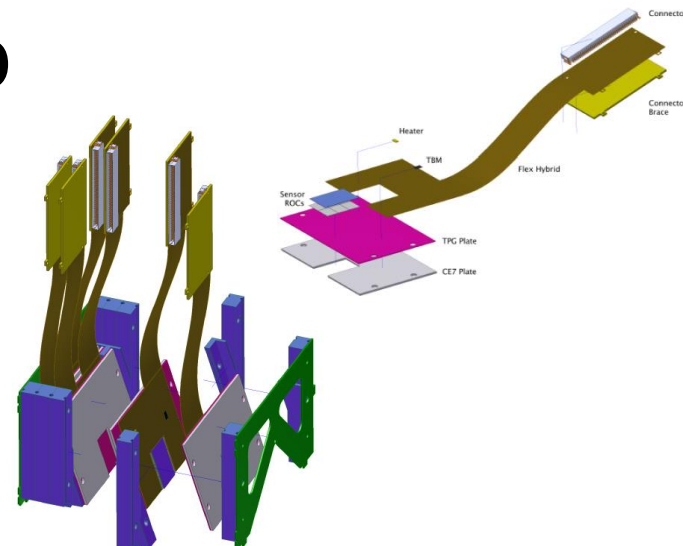
- Tracking detectors in the two relocated **horizontal RPs**:

- Baseline: 3D silicon sensors (FBK), 6 planes/RP;
- PSI46dig ROC.

- Timing detectors in new **horizontal RP**:

- Baseline: Quartic Cherenkov, 20 quartz bars $3 \times 3 \text{ mm}^2$;

- R&D on solid state detectors



Publications (since last LHCC)



- Accepted for publication by the journal:
 - *"Measurement of pseudorapidity distributions of charged particles in proton-proton collisions at $\sqrt{s} = 8$ TeV by the CMS and TOTEM experiments"* in Eur. Phys. J C (**first joint CMS and TOTEM publication!!**)
 - *"LHC Optics Determination with Proton Tracks Measured in the Roman Pots Detectors of the TOTEM Experiment"* by New J. Phys
- To be submitted (editorial process being finalized):
 - *"Measurement of the forward charged particle pseudorapidity density in pp collisions at $\sqrt{s} = 8$ TeV using a displaced interaction point"*;
- In preparation:
 - The measurement of the differential elastic cross-section at $\sqrt{s} = 8$ TeV;
 - A study of Coulomb-hadronic interference in elastic scattering at $\sqrt{s} = 8$ TeV

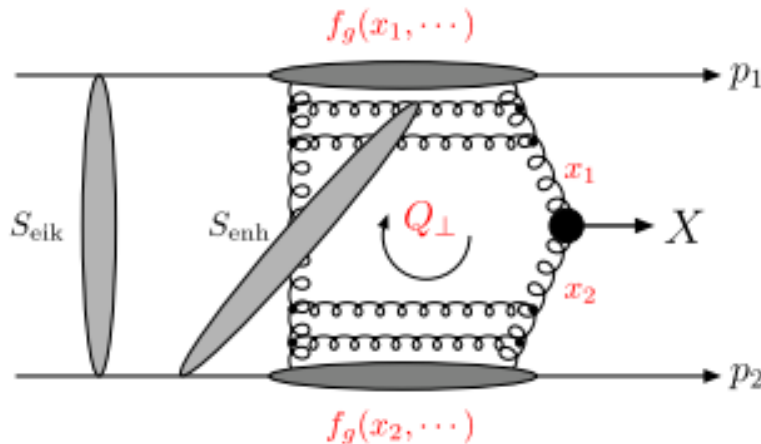
Advanced analysis



- Exclusive production of low mass resonance at $\sqrt{s} = 8$ TeV (together with CMS, joint task force).

$$x_{\text{gluon}} \sim 10^{-3} - 10^{-4} \text{ gluons} \Rightarrow \text{pure gluon pair} \Rightarrow M_X \sim 1-4 \text{ GeV}$$

$$X = f_0 \text{ \& } f_2 \rightarrow \pi^+\pi^-, K^+K^-, \rho^0\rho^0, \eta\eta\ldots$$

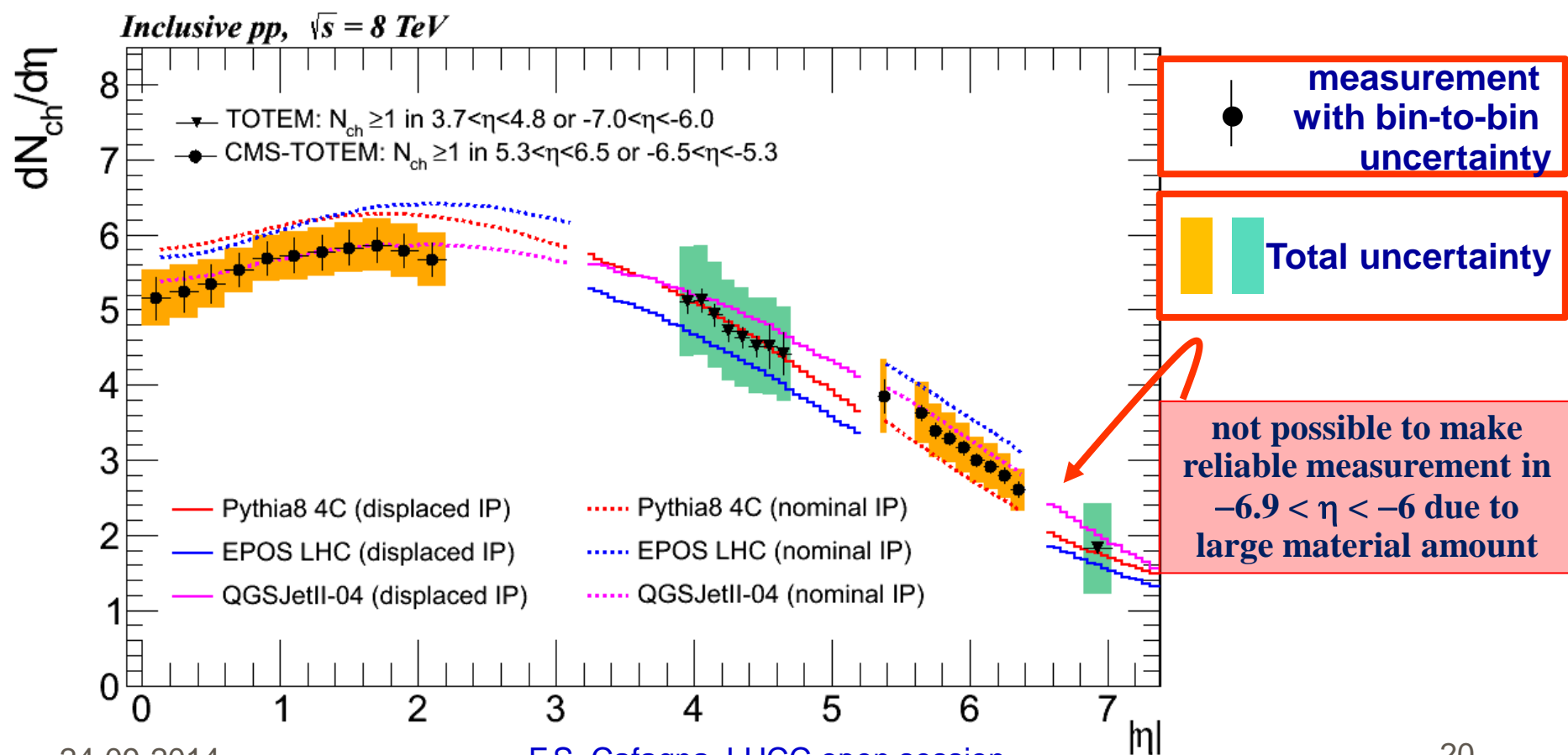
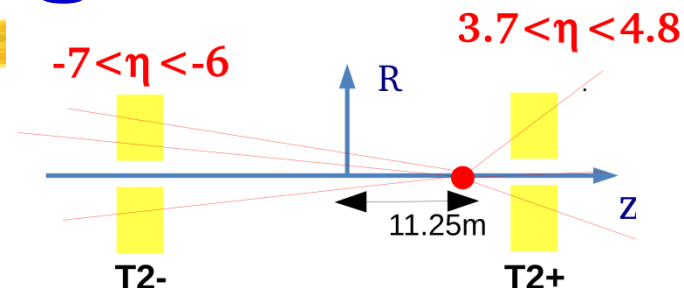


- double arm RP triggered data sample
- $n\pi^+ n\pi^-$ only central states ($n = 1 - 4$)
- $p_T(pp) = p_T(\text{central})$ (within resolution)
- horizontal vertex for pp (assuming $\xi_p \sim 0$)
- T2 veto
- π/K identification using CMS tracker dE/dx
- spin determination from decay angles & proton azimuthal correlations

- Single diffractive jets & J/ψ at $\sqrt{s} = 8$ TeV (together with CMS)
- Forward electrons & jets in pA (together with CMS)
- Soft single diffraction at $\sqrt{s} = 7$ TeV
- Large- t elastic scattering at $\sqrt{s} = 7$ TeV
- Total, inelastic and elastic cross-section at $\sqrt{s} = 2.76$ TeV

Analysis highlights

- Measurement of the forward charged particle pseudorapidity density in pp collisions at $\sqrt{s} = 8$ TeV using a displaced interaction point



Analysis highlights

- Previously excluded pure exponential slope ($N_b = 1$) of differential elastic cross-section at $>7\sigma$ using $\beta^* = 90\text{m}$ data at $\sqrt{s} = 8\text{ TeV}$

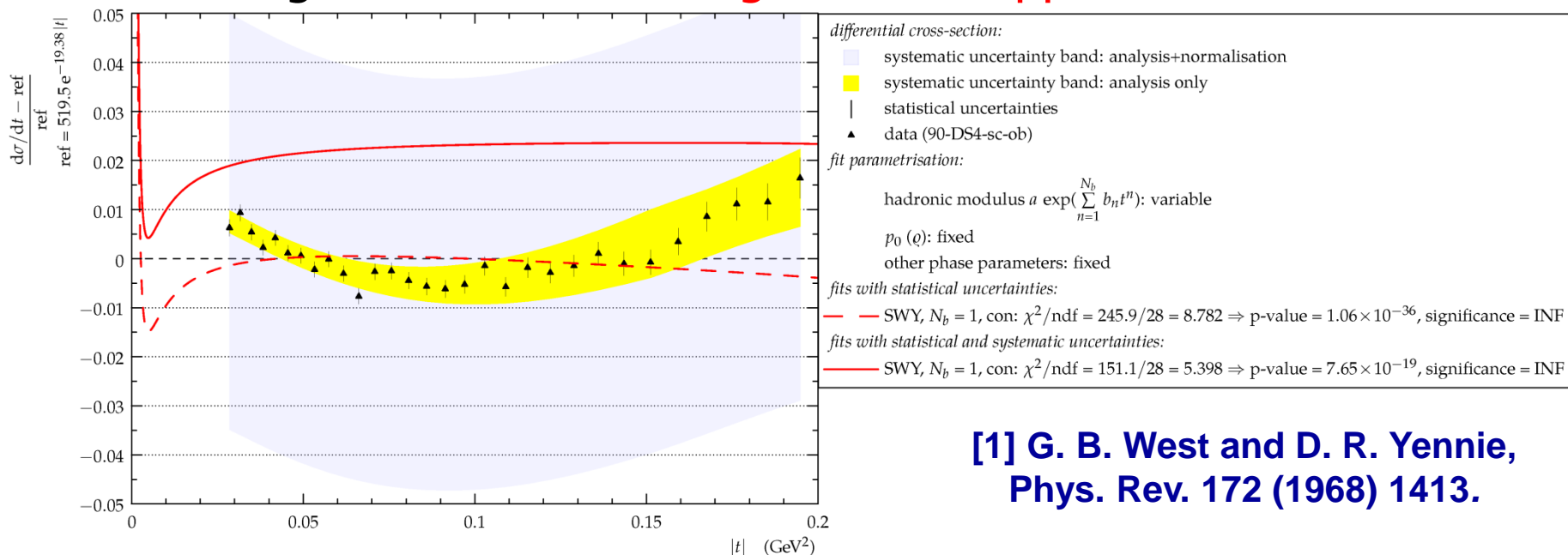
$$d\sigma/dt \propto |F^{C+H}|^2 = \text{Coulomb} + \text{hadronic} + \text{"interference"}$$

from QED

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

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 $>7\sigma$ using same data \Rightarrow **ruling out SWY approach**



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

Conclusions

- All RP services have been installed in the tunnel!
- RP detectors installed in 4&5.
- T1, T2 and DAQ on schedule.
- The two TDRs submitted and R&D activities started.
- 2 paper published, 1 paper to be submitted, 2 papers in preparation. Analysis ongoing.

THANKS!!