TOTEM
Status Report

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CERN & INFN-BA
on behalf of TOTEM Collaboration
Outline

- Detector status;
- The two released TDRs:
  - 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

- 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.
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, ~20x 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 $\beta^*$ (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 $\beta^*$ (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

- Timing Measurements in the Vertical Roman Pots of the TOTEM Experiment
  - High $\beta^*$ (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;
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.
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 (~100ps per detector), reduce PU by a factor 4 (50% -> ~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;
A precise, low jitter clock distribution is mandatory;

This system strengths:
- It is scalable. More clock signals can be added as needed (e.g. CT-PPS);
- It is based on robust industrial telecomunication 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

- CMS-TOTEM Precision Proton Spectrometer
  - Low $\beta^*$ (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 $\gamma\gamma \rightarrow W^+W^-, e^+e^-, \mu^+\mu^-, \tau^+\tau^-;$
    - 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++
- 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 3x3 mm²;
- 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).
  
  $$x_{\text{gluon}} \sim 10^{-3} - 10^{-4} \text{ gluons} \Rightarrow \text{pure gluon pair} \Rightarrow M_X \sim 1-4 \text{ GeV}$$

- $X = f_0$ & $f_2 \rightarrow \pi^+\pi^- , K^+K^-, \rho^0\rho^0 , \eta\eta...$

  - double arm RP triggered data sample
  - $\rho^+\rho^-$ 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
  - $\pi/K$ identification using CMS tracker dE/dx
  - spin determination from decay angles & proton azimuthal correlations

- Single diffractive jets & J/$\psi$ 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

24-09-2014  F.S. Cafagna, LHCC open session
Analysis highlights

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

Inclusive pp, $\sqrt{s} = 8$ TeV

- TOTEM: $N_{\text{ch}} \geq 1$ in $3.7 < \eta < 4.8$ or $-7.0 < \eta < -6.0$
- CMS-TOTEM: $N_{\text{ch}} \geq 1$ in $5.3 < \eta < 6.5$ or $-6.5 < \eta < -5.3$

- Not possible to make reliable measurement in $-6.9 < \eta < -6$ due to large material amount.

Total uncertainty

Measurement with bin-to-bin uncertainty

24-09-2014

F.S. Cafagna, LHCC open session
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 \(\sqrt{s} = 8\text{ TeV}\)
  \[
  \frac{d\sigma}{dt} \propto |F_{C+H}|^2 = \text{Coulomb} + \text{hadronic} + \text{“interference”}
  \]
  constrained by measured \(e^{-B(t)}\)
  \[
  B(t) = b_1t + b_2t^2 + \ldots
  \]
  \(N_b = \) # 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 \(>7\sigma\) using same data ⇒ ruling out SWY approach

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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!!