TOTEM status report

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on behalf of
TOTEM collaboration

LHCC open session 30.11.2016

Outline:
✓ TOTEM physics
✓ CT-PPS
TOTEM physics (special runs)

- Total pp cross-section ($\sigma_{\text{tot}}$)
- $\rho$ (ratio of real & elastic hadronic amplitude at $t = 0$)
- Glueball candidate & low mass resonance study (with CMS)
\( \sigma_{\text{tot}} \) measurements

Luminosity independent method:

- \( \sqrt{s} = 7 \) TeV (\( \beta^* = 90 \text{m} \)) & 8 TeV (\( \beta^* = 90 \text{ m} \) & 1 km) results published
- \( \sqrt{s} = 2.76 \) TeV (\( \beta^* = 11 \text{ m} \)) close to be completed
- \( \sqrt{s} = 13 \) TeV (\( \beta^* = 90 \text{ m} \)) progressing well
$\sigma_{\text{tot}} @ \sqrt{s} = 2.76 \text{ TeV elastic}$

Jan 2013, RPs at 4.3$\sigma$

$\beta^* = 11 \text{ m optics (not optimized for } \sigma_{\text{tot}} \text{ measurement)}$

- Optics more sensitive to LHC perturbations & IP vertex size
- Beam divergence large ($\sim 20 \mu\text{rad}$) ⇒ limits scattering angle resolution
- Extrapolation to $t = 0$ longer (observe $\sim 3 \%$ of $\sigma_{\text{el}} \leftrightarrow 80 - 90 \%$ at $\beta^* = 90\text{m}$)

Other challenges overcome:

- Horizontal RPs not inserted ⇒ RP top – RP bottom relative alignment from $\phi$ symmetry of elastic scattering
- Only $\sim 60 \%$ of elastic single track in RP (due to overlapping activity) ⇒ dedicated multitrack RP reconstruction to recover majority of elastic
\( \sigma_{\text{tot}} \sqrt{s} = 2.76 \text{ TeV} \)

**Inelastic rate completed:**
analysis method identical to 7 & 8 TeV

- Count events with charged particles in T1 & T2 (~97 % of inelastic).
- Trigger: at least one track in T2.
- Uncertainty: ~2 % (< @ 7 & 8 TeV)

largest contribution:
**low mass diffraction** \((M_{\text{diff}} < 2.1 \text{ GeV})\)

**Elastic almost completed:**
analysis method similar to 7 & 8 TeV

Analysis steps:
1. Geometrical & beam divergence acceptance corrections (completed)
2. Unfolding (completed)
3. DAQ efficiency (completed)
4. Optics reconstruction (completed)
5. Alignment (completed)
6. Multitrack (completed)
7. Single & double RP inefficiency (being verified)
8. Trigger inefficiency (on-going)
9. Extrapolation to \(t = 0\) (tested)
10. Integral of \(t\)-distribution \(N_{\text{el}}\) (tested)

Aim at similar uncertainty for \(\sigma_{\text{tot}}\) as 7 & 8 TeV despite added complexity for elastic part
\( \sigma_{\text{tot}} @ \sqrt{s} = 13 \text{ TeV} \)

Elastic & inelastic analysis progressing well:
analysis method identical to 7 & 8 TeV \( \beta^* = 90 \text{ m} \)

Elastic analysis:
\( \beta^* = 90 \text{ m}, \text{Oct 2015, RPs at 5}\sigma \& 10\sigma \)
fill dependent cuts & corrections being tuned

No structures at high-\(|t|\)!

- Rules out many model
- Physics interpretation: transition between diffraction & pQCD a la Donnachie-Landshoff
By studying Coulomb-hadronic interference at very low $|t|$ able to measure $\rho$:

$$\rho = \frac{RAN^N}{SAN^N} \bigg|_{t=0}$$

measure $\rho$ with 0.01 precision.

$\beta^* = 2.5$ km run @ 13 TeV in Sep 2016

RPs (red) used in run

8 TeV article accepted by EPJC

$\sqrt{s} = 8$ TeV

$\sqrt{s} = 13$ TeV
\[ \beta^* = 2.5 \text{ km run } @ \text{13 TeV} \]

RPs at \( 3\sigma \Rightarrow |t|_{\text{min}} \approx 4 \cdot 10^{-4} \)

\[ \mathcal{L}_{\text{int}} \approx 0.38 \text{ nb}^{-1} \]

\( \sim 6.3 \text{ M elastic candidates} \)
(if requiring 4 RP out of 4)

<table>
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<th>fill</th>
<th>length</th>
<th>periods</th>
<th>( \mathcal{L}_{\text{int}} ) (nb(^{-1}))</th>
<th>( N_{\text{ev}} )</th>
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<td>9</td>
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<td>0.7 M</td>
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</table>

Reasonable background \( \Rightarrow \) regular beam cleaning procedure

Black: reconstructed tracks, red: activity not reconstructed, green: 4 RP out of 4
2.5 km analysis

Impression from first analysis: data quality good, alignment, optics & background not an issue \( \Rightarrow |t|_{\text{min}} \)

acceptance possible to optimize using 2 RP out of 4

Collinearity of \( \Theta_x^* \) 

Collinearity of \( \Theta_y^* \) 

Same vertex x

Background estimate: left-right \( \Theta_y^* \) difference as function of elastic selection steps
Glueball candidate & low mass resonance studies

CMS-TOTEM $\sqrt{s} = 13$ TeV, Oct 2015, $\beta^* = 90$ m, $L_{\text{int}} = 0.4$ pb$^{-1}$

L1 Trigger exchange, dedicated exclusive low mass trigger independent DAQs $\Rightarrow$ offline merging

- Tuning and validation of special low $p_T$ tracking & vertexing to optimize reconstruction for such topologies (low multiplicity & low mass (1-2 GeV)) during summer 2016

- Exclusive low mass trigger data stream re-reconstructed & remerged ($\sim$ few months) $\Rightarrow$ significant increase of statistics in analysis, quantitative effects on glueball candidate study being evaluated

- Analysis also on-going on other trigger streams eg. dimuon & dijet
CT-PPS

- CMS-TOTEM Precision Proton Spectrometer (PPS)
- Data taking
- Diamond
- Physics potential
- EYETS activities

CT-PPS has initiated high luminosity diffractive physics program at LHC
CT-PPS

Motivation: study high mass exclusive central production at standard high luminosity runs

Accelerated CT-PPS for 2016: using existing/advanced developed technology

- Beam pockets: horizontal RPs (with RF shields or new cylindrical design)
- Tracking detectors: TOTEM Si strips (red)
- Timing detectors: TOTEM diamonds

CT-PPS detectors fully integrated into CMS DAQ
CT-PPS data taking

RPs at $15\sigma$ & readout as part of CMS standard high luminosity running

2016 luminosity with CT-PPS:
- Strip detectors $15 \text{ fb}^{-1}$
- Diamond detectors $2.5 \text{ fb}^{-1}$

$\sim 2/3$ of data strip detector fully efficient, $\sim 1/3$ efficiency loss in most occupied region due to radiation damage in silicon

e.g. in 56 210-far:

New strip detectors & diamond
HV increase
Diamond detector data taking

Diamond included in standard high luminosity data taking during last week of pp run (~ 2.5 fb\(^{-1}\))

synchronisation verified with strip detector data

Diamond pixels (colour) on 45 arm in coincidence with strip detectors (yellow)

Diamond detectors misaligned with respect to beam by about 2 mm in both arms
CT-PPS mass acceptance

Contour lines for $M_{\text{min}}$ in the $(D_x, \sigma_x)$ space:

Minimum mass reach 2016 (assuming nominal optics)

Upper mass limit 2016: 1950 GeV

For 2017 discussions with optics team started

strips

strips
diamond

prepared for high lumi 2017
CT-PPS physics potential

Exclusive Production:
- photon-photon fusion
- gluon-gluon fusion in colour-singlet state ($J^{PC} = 0^{++}, 2^{++}$ ..)

Strategy: require correlation central system & forward protons

Early analyses (does not require timing detectors):

Diphoton production sensitive to anomalous quartic couplings ($\gamma\gamma\gamma\gamma$).

Proton kinematic reconstruction cross-checked using $pp \rightarrow p + \mu\mu + X$ events

With timing detectors and/or more statistics:
- Exclusive WW
- Exclusive dijets
- Inclusive missing mass/missing energy
Main EYETS activities

**Preparation of horizontal RP220 far for operation at high luminosity**
- exchange ferrites & install RF shields in RP220 far
- installation of additional line for warm mode cooling in RP220 near
- separate the secondary vacuum lines of the RP 210 & 220 and separate cooling of RP cylindrical (timing)
  - independent pressure/temperature operation points of the tracking and timing detectors

**Installation of detectors**
- installation of pixel detector packages
- Installation of timing detector components

Level beam tube and RPs (CMS request)
TOTEM run strategy

- Run at full luminosity with CTPPS whole year in 2017 (BSM searches)

- Low $\sqrt{s}$ [450-900 GeV] run with special high $\beta^*$ optics to measure $\rho$ in SppS region (whenever convenient)

- Continue to explore physics cases for joint $\beta^* = 90$ m runs with CMS (missing mass, glueballs,...)

- Readiness for special run at $\beta^* = 90$ m to measure $\sigma_{\text{tot}}$ at $\sqrt{s} = 14$ TeV (whenever 14 TeV will be reached)
Summary

TOTEM physics:

- $\sigma_{\text{tot}}$ at $\sqrt{s} = 2.76$ TeV soon finalized
- $\sigma_{\text{tot}}$ at $\sqrt{s} = 13$ TeV progressing well
- $\beta^* = 2.5$ km data large potential for precise $\rho$ measurement

CT-PPS:

- RPs operated at $15\sigma$ & highest luminosity
- 15 fb$^{-1}$ of data with CT-PPS (in $\sim 2/3$ strips 100 % efficient)
- Commissioned diamond detectors & collected first data
- First analysis on-going
- Prepare RP220 far for high luminosity running

CT-PPS has proven for the first time the feasibility of operating a near-beam proton spectrometer at high luminosity on a regular basis.

CMS and TOTEM have paved the way for other such spectrometers.
Backup
STRIPS (PACK2) : 45 NR-FR / 56 FR
DIAMONDS : 45 / 56
OPTICS_140
L=2.5/fb

STRIPS (PACK2) : 45 NR-FR / 56 FR
OPTICS_140
L=2.8/fb

STRIPS (PACK1) : 45 NR-FR / 56 NR-FR
OPTICS_185
L=3.8/fb

STRIPS (PACK1) : 45 NR-FR / 56 NR-FR
OPTICS_185
L=5.6/fb

STRIPS (PACK1) : 45 NR-FR / 56 NR-FR
With margin
OPTICS_185
L=0.6/fb

TOTAL : 15.3/fb