TOTEM: status and prospects

Emilio Radicioni – INFN/CERN
Overall Configuration @IP5

Forward Telescopes: measure primary/secondary tracks

\[ T1 : 3.1 < | \eta | < 4.7 \]
\[ T1 : 5.3 < | \eta | < 6.5 \]

Roman Pots: measure scattered protons
T1 telescope with Cathode Strip Chambers (CSCs)

- 5 planes with measurement of 3 coordinates per plane
- 3 deg rotation and overlap between adjacent planes
- Primary vertex reconstruction allows background rejection
- Trigger with anode wires

• Wire pitch: 3mm
• Cathode pitch: 5mm
• Gas gap: 10mm
• Total anodes: 1124
• Total strips: 15936

CMS muon end-caps

3.1 < |\(\eta| \) < 4.7

Wire pitch: 3mm
Cathode pitch: 5mm
Gas gap: 10mm
T2 telescope (GEM chambers)

- 65(ϕ) x 24(=1560 pads)
- Pads: ΔηΔΦ = 0.06 x 0.015π
- 2x2 mm² → 7x7 mm²
- Strips: 256 (width/pitch: 80/400 μm)

- TOTAL strips: 256x10x2
- TOTAL pads: 1560x10x2
RP system: total 122880 channels in 4 stations (+/- 220m). 4 additional stations to be installed (+/-147m).
- Planar *edge-less* (50 μm) silicon sensor

- Specific guard ring configuration to minimize dead edge
Status
T2 very forward GEM chambers

- Present status: commissioning and alignment
- Track reconstruction in an hostile environment, large particle density
- Severe backgrounds in the very forw cone
- Beam gas and halo interactions
- Photon and hadron interactions producing showers

- Vertex pointing / impact parameter calculation important to reject re-interactions

**all 4 quarters installed & operational.**

trigger: min bias track, \( \geq 5 \) out of 10 planes in road-coincidence.

**Vertex reconstruction**

Precision: \( \sigma \sim 2 \text{ cm} \)
T2 event at $\sqrt{s} = 7$ TeV
Roman Pots with edgeless Silicon detectors

Measure elastic & diffractive protons close to the outgoing beams

all 12 pots at 220 m equipped & operational
Track trigger: 3 out of 5 planes in u & v projection road-coincidence
RP in retracted position
Only background
RP tracking in retracted position

Top
Too many combinations (shower)

Bottom
Too many combinations (shower)
Moving RPs w.r.t. Collimators
1 RP @4.4σ (12/2009)

BLM spike

BLM

Beam

\[ d = 4 \text{ mm} \ (\sim 4.4\sigma) \]

RP out of collimator shadow

Screenshot from the LHC Control Center
Fully operational T1 in commissioning area

Reconstructed vertex ($\pi$ on target)

- Cu target
- Beam monitor frame

Strip efficiency / HV
Plans for measurements
RP system acceptance

- Machine optics determines acceptance
- Likely running scenarios in 2010/2011:
  - $\beta^* = 2\text{m}$
  - $\beta^* = 90\text{m}$
- Acceptance for diffractive protons and capabilities to extrapolate towards $t=0$ change dramatically

Acceptance for RP 220m

$x/y$ plane

$\xi/t$ plane

Diffractive protons: hit distribution @ RP220m

- Low $\beta^*$: $0.5 - 11\text{ m}$
- $\beta^* = 90\text{ m}$
  - $y \sim \Theta_{y}^{\text{scatt}} \sim \sqrt{t_{\chi_{10}}} y_{10}$
  - $x \sim \xi = \Delta p/p$
Elastic Scattering $\sqrt{s} = 7$ TeV, $\beta^* = 2m$

trigger: $\text{RP}_{\text{vert,45}}$ and $\text{RP}_{\text{vert,56}}$

Elastically scattered proton flux

At larger $|t|$, $\sigma$ is several orders of magnitude smaller ($\approx$ mHz) → dedicated long runs with vertical pots at largest possible luminosity

rate few 10 Hz ($\text{RP @} 10 \sigma_{\text{beam}} \quad \beta^* = 2m, \ N= 43 \ & N/\text{bx} = 5 \times 10^{10}$)
Pythia SD: $\sigma_{\text{acc, sd}} \approx 1.2 \text{ mb (x2)} / \sigma_{\text{sd}} \approx 13.7 \text{ mb}$

Phojet CD: $\sigma_{\text{acc, cd}} \approx 0.05 \text{ mb} / \sigma_{\text{cd}} \approx 1.33 \text{ mb}$

Diffractive $p \@ \beta^* = 2m$
Diffractive p @ $\beta^* = 2m$

Courtesy K. Osterberg

diffractive p in horizontal RP’s + diffractive system in T2

trigger: $\text{RP}_{\text{hori},+(-)}$ & $\text{T2}_{-(+)}$ (SD), $\text{RP}_{\text{hori},+}$ & $\text{RP}_{\text{hori},-}$ (CD)

rates large (SD ~ tens kHz, CD ~ 200 Hz for $\beta^* = 2$ m, $N_b = 43$ & $N_p/b = 5 \times 10^{10}$)

$\frac{d\sigma_{SD}}{dM}$

- $0.015 < \xi < 0.15 \Rightarrow 850 < M < 2500$ GeV

$\sigma(M) \approx 25$ GeV

$\frac{d\sigma_{CD}}{dM}$

- $125 < M < 800$ GeV

$\sigma(M) \approx 10$ GeV, $\sigma(\phi) \approx 6^\circ/\sqrt{|t|}$

CD backgrounds: 2 separate SD in same bx & SD + DPE (only 1 p seen) in same bx

($\sim 100$ & $\sim 30$ Hz for $\beta^* = 2$ m, $N_b = 43$ & $N_p/b = 5 \times 10^{10}$)
Summary measurements $\mathcal{R}^* = 2m$

<table>
<thead>
<tr>
<th>$\beta^*$ [m]</th>
<th>Process</th>
<th>$\sigma_{\text{beam}}$ [mb]</th>
<th>Accepted rate @ $L = 5 \times 10^{30}/s\cdot\text{cm}^2$ [Hz]**</th>
<th>$&lt;\text{Events/bx}&gt; @ L_{bx} = 10^{25}/s\cdot\text{cm}^2$**</th>
<th>Acceptance range in $t$ [GeV$^2$] or $\xi$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Elastic scattering (PPP3*)</td>
<td>0.004</td>
<td>20</td>
<td>0.000004</td>
<td>$\sim 0.6 &lt; t &lt; \sim 5$</td>
</tr>
<tr>
<td>2</td>
<td>SD, Pythia</td>
<td>2.4</td>
<td>12k</td>
<td>0.024</td>
<td>$0.02 \leq \xi \leq 0.2$</td>
</tr>
<tr>
<td>2</td>
<td>CD, Phojet</td>
<td>0.05</td>
<td>250</td>
<td>0.0005</td>
<td>$0.02 \leq \xi \leq 0.2$</td>
</tr>
<tr>
<td>2</td>
<td>Min bias, Pythia</td>
<td>60</td>
<td>300k</td>
<td>0.6</td>
<td>$N_{\text{track,T2}} \geq 1$</td>
</tr>
</tbody>
</table>

* PPP3: Petrov-Predazzi-Prokudin model, 3 pomeron

** $N_{\text{bunch}} = 43$, $N_{p/bunch} = 5 \cdot 10^{10}$ & $\beta^* = 2m \Rightarrow L_{bx} = 10^{25} \text{ cm}^{-2}$
Studies @ $\beta^*=90m$

- Access to a much larger $|t|$ and $\xi$ range

$\Rightarrow$

- Elastic scattering in a wider $|t|$ range
- Total cross section at 5% ÷ 6% accuracy
  - T1 to complete $\eta$ coverage
- Soft diffraction in a large M range (65% of diffractive protons are detectable)
- Systematic study the event classification of interest for HECR: SD, inelasticity, rates and multiplicity
T2-only studies (5.3<\eta<6.5)

- May be performed at any \( \beta^* \)
- \( dN_{\text{charged}}/d\eta \)
- Search for high charged multiplicity events
- Rate very high at \( \beta^*=2m \)
- Conditions
  - Trigger: \( T2_{\text{plus}}(\geq n \, \text{track}) \) .or. \( T2_{\text{minus}}(\geq n \, \text{track}) \)
  - Require \( \leq 1 \) interaction/bx, i.e. \( \leq 0.35/\text{bx} \)
    - At standard bunch intensity, take data at end of fill?
  - Require good understanding of tracking, vertexing and primary/secondary track discrimination
Summary

- Early measurements at all $\beta^*$
  - Large $|t|$ elastic ($0.65 < |t| < 5$ GeV$^2$)
  - Large mass SD and CD
  - Forward charged multiplicity (T2-only)
  - (+ training for better optics)
- Later measurements with special optics, $\beta^*$=90m
  - Early measurements of $\sigma_{tot}$ with precision 5%÷6%
  - Elastic scattering in a lower range ($0.15 < |t| < 2.5$ GeV$^2$)
  - SD and CD in a large M range
  - Classification of inelastic events
TOTEM setup completed with success
TOTEM crew owes a good bottle
to the LHC crew