# Total, elastic and inelastic cross section at 7 TeV 

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On behalf of the TOTEM collaboration.

## The Totem Detectors




- T1 and T2 detectors are installed and fully operational
- $\mathbf{2 2 0} \mathbf{~ m}$ Roman Pot Silicon detectors are fully operational
- $\quad \mathbf{1 4 7} \mathbf{m}$ Roman Pot detectors are installed and tested


## P-P Elastic Cross Section measurement



Kinematics correlations and background subtraction



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## Acceptance corrections

Both diagonals



Correction of $\theta_{y}{ }^{*}$ dist. for missing 'corners' of acceptance


Diagonal 1

Correction for missing $\varphi$ accept.:
Correction $=2 \pi /$ accepted $\varphi(\mathrm{t})$
Near edge region to be removed

## Luminosity

The data where taken in a special run oct 302010. The 220 m pots where inserted at $7 \sigma$ from the beam. $\beta^{*}=3.5 \mathrm{~m}$


| Time | Events | Eff. DAQ | Eff. trigger | Luminosity |
| :--- | :--- | :---: | :---: | :---: |
| Oct 302010 | $5.48^{*} 10^{6}$ | 0.99 | 0.995 | $6.187 \mathrm{nb}^{-1}$ |

## Elastic scattering - from ISR to Tevatron




Diffractive minimum: analogous to Fraunhofer diffraction: $\quad|t| \sim p^{2} \theta^{2}$


## Proton Proton Elastic Cross Section




Global elastic differential cross section

## P-P Cross Section and Models Comparison



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## P-P Cross Section and Models Comparison



## Low t elastic cross section measurement



$$
\begin{aligned}
& \beta^{*}=90 \mathrm{~m} \\
& L_{\mathrm{y}} \sim 260 \mathrm{~m} \\
& L_{\mathrm{x}} \sim 0-3 \mathrm{~m}
\end{aligned}
$$

Integrated luminosity : $1.65 \mu_{\text {barn }}{ }^{-1}$ Inel. pile-up ~ $0.005 \mathrm{ev} / \mathrm{bx}$

Protons $x-y$ Raw distribution

## $\Theta_{\mathrm{x}}$ and $\Theta_{\mathrm{y}}$ correlations of both arms



$\theta_{y}^{*}$ resolution (very large Ly) in agreement with beam divergence
$\theta_{\mathrm{x}}^{*}$ 'resolution' includes also the detector and the vertex spread in plot above, but vertex effect vanishes when computing $\theta$ with elastic constraint

## Elastic differential cross section

Exponential slope:

$$
\left.B\right|_{t=0}=20.1 \mathrm{GeV}^{-2}
$$

Extrapolation to $\mathbf{t}=\mathbf{0}$ :
$\left.\frac{d \sigma}{d t}\right|_{t=0}=5.037 \times 10^{2} \mathrm{mb} / \mathrm{GeV}^{2}$


## Integral Elastic Cross-Section

$$
\sigma_{\mathrm{EL}}=8.3 \mathrm{mb}^{(\text {extrapol. })}+16.5 \mathrm{mb}^{(\text {measured })}=24.8 \mathrm{mb}
$$

## Cross-Section Formulae

Optical Theorem: $\quad \sigma_{T O T}^{2}=\left.\frac{16 \pi(\mathrm{~h} c)^{2}}{1+\rho^{2}} \cdot \frac{d \sigma_{E L}}{d t}\right|_{t=0}$

Using luminosity from CMS: $\frac{d \sigma_{E L}}{d t}=\frac{1}{L} \cdot \frac{d N_{E L}}{d t}$
$\rho$ from COMPETE fit: $\quad \rho=0.14_{-0.08}^{+0.01}$

$$
\begin{aligned}
& \sigma_{T O T}=\sqrt{\left.19.20 \mathrm{mb} \mathrm{GeV}^{2} \cdot \frac{d \sigma_{E L}}{d t}\right|_{t=0}} \\
& \sigma_{T O T}=\sigma_{E L}+\sigma_{I N E L}
\end{aligned}
$$

## TOTEM: pp Total Cross-Section

Elastic exponential slope:

$$
\left.B\right|_{t=0}=\left(20.1 \pm 0.2^{(s \text { sat })} \pm 0.3^{(s s s t)}\right) \mathrm{GeV}^{-2}
$$

Elastic diff. cross-section at optical point: $\left.\quad \frac{d \sigma_{e l}}{d t}\right|_{t=0}=\left(503.7 \pm 1.5^{(s \text { stat })} \pm 26.7^{(s s s t)}\right) \mathrm{mb} / \mathrm{GeV}^{2}$
Optical Theorem, $\rho=0.14_{-0.08}^{+0.01}$

## Total Cross-Section

$$
\sigma_{T}=\left(98.3 \pm 0.2^{(\text {stat })} \pm 2.7^{(\text {syst })}\left[\begin{array}{l}
+0.8 \\
-0.2
\end{array}\right]^{(\text {syst from } \rho)}\right) \mathrm{mb}
$$

## TOTEM: pp Inelastic Cross-Section

$$
\sigma_{\mathrm{el}}=\left(24.8 \pm 0.2^{(\text {stat) }} \pm 1.2^{(\text {syst) })}\right) \mathrm{mb} \quad \sigma_{T}=\left(98.3 \pm 0.2^{(\text {stat) }} \pm 2.7^{(\text {syst })}\left[\begin{array}{c}
+0.8 \\
-0.2
\end{array}\right]^{(\text {syst from } \rho)}\right) \mathrm{mb}
$$

## Inelastic Cross-Section

$$
\sigma_{\text {inel }}=\sigma_{t o t}-\sigma_{e l}=\left(73.5 \pm 0.6^{(\mathrm{stat})}\left[\begin{array}{c}
+1.8 \\
-1.3
\end{array}\right](\mathrm{syst}) \mathrm{mb}\right.
$$

$$
\begin{aligned}
& \sigma_{\text {inel }}(C M S)=\left(68.0 \pm 2.0^{(\text {syst })} \pm 2.4^{(\text {lumi) }} \pm 4.0 \text { (extrap) }\right) \mathrm{mb} \\
& \sigma_{\text {inel }}(\text { ATLAS })=\left(69.4 \pm 2.4^{\text {(exp) }} \pm 6.9^{(\text {(extrap) })}\right) \mathrm{mb} \\
& \sigma_{\text {inel }}(\text { ALICE })=\left(72.7 \pm 1.1^{(\text {mod })} \pm 5.1^{(\text {(umi) })} \mathrm{mb}\right.
\end{aligned}
$$

A new direct analysis, based on the inelastic telescopes data, is almost completed and leads to a measurement of the inelastic cross-section which is highly consistent with the one presented here

## Total, Elastic, Inelastic Cross-Section



## Charged particle $\mathrm{dN} / \mathrm{d} \eta$ measurement in the pseudorapidity range $5.3<\eta<6.4$

- In 2011 the T2 detector has been used to evaluate the charged tracks density.
- The runs used for this purpose where low luminosity runs to avoid the pileup.
- The detector sit after a large amount of material from the vacuum chamber and most of the analysis work has been devoted on the evaluation of the fraction of primary tracks.


## Vacuum chamber shadow, and secondary particles production



## BeamPipe cone at $\eta \sim 5.54$ (>100 radiation length)



The beam pipe shadows the particle flux in a specific angle corresponding to $\eta \sim 5.54$


## Charged particle $\mathrm{dN} / \mathrm{d} \eta$



## Track density compared with central measurements



## Conclusions

- The TOTEM experiment has performed the total and elastic P-P cross section at 7 TeV measurement using the Roman Pots placed at 220 m from IP5.
- The measurement is done using the CMS estimation of Luminosity
- The inelastic cross section is currently under evaluation directly using the inelastic detector T1 and T2 and is in agreement with the value estimated by subtraction
- The direct measurement of the total cross section using the luminosity independent method is almost finalized.
- The inelastic detector allowed us to estimate the charged track density at large pseudorapidity values.


## Backup

## Systematics and Statistics

- $t: \pm[0.6: 1.8] \%^{\text {syst optics }} \pm<1 \%$ align. $\pm[3.4: 11.9] \%^{\text {stat }}$ (before unfolding)
- $\mathrm{d} \sigma / \mathrm{dt}: \pm 4 \%$ syst lumin $; \pm 1 \%$ syst (acc.+eff. $\mathrm{tbackg} .+\mathrm{tag}$ ) $\pm 0.7 \%$ syst unfold.
- $\mathrm{B}: \pm 1 \%$ stat $\pm 1 \%$ syst from $\mathrm{t} \pm 0.7 \%$ syst from unfolding
- $\mathrm{d} \sigma / \mathrm{dt}_{(\mathrm{t}=0)}: \pm 0.3 \%^{\text {stat }} \pm 0.3 \%^{\text {syst (optics) }} \pm 4 \%^{\text {syst lumin }} \pm 1 \%$ syst (acc.+eff.+backg.+tag)
- $\int \mathrm{d} \sigma / \mathrm{dt}: \pm 4 \%$ syst lumin $\pm 1 \%$ syst (acc. +eff. +backg. +tag ) $\pm 0.8 \%$ stat extrap.
- $\sigma_{\text {TOT }}:(+0.8 \%-0.2 \%)^{\text {syst } \rho} \pm 0.2 \%^{\text {stat }} \pm 2.7 \%^{\text {syst }}=(+2.8 \%-2.7 \%)^{\text {syst }} \pm 0.2 \%{ }^{\text {stat }}$
- $\sigma_{E L}: \pm 5 \%{ }^{\text {syst }} \pm 0.8 \%$ stat
- $\sigma_{\text {INEL }}:(+2.4 \%-1.8 \%)^{\text {syst }} \pm 0.8 \%$ stat


## Secondary tracks evaluation




