HERA and the LHC workshop

TOTEM: inelastic scattering

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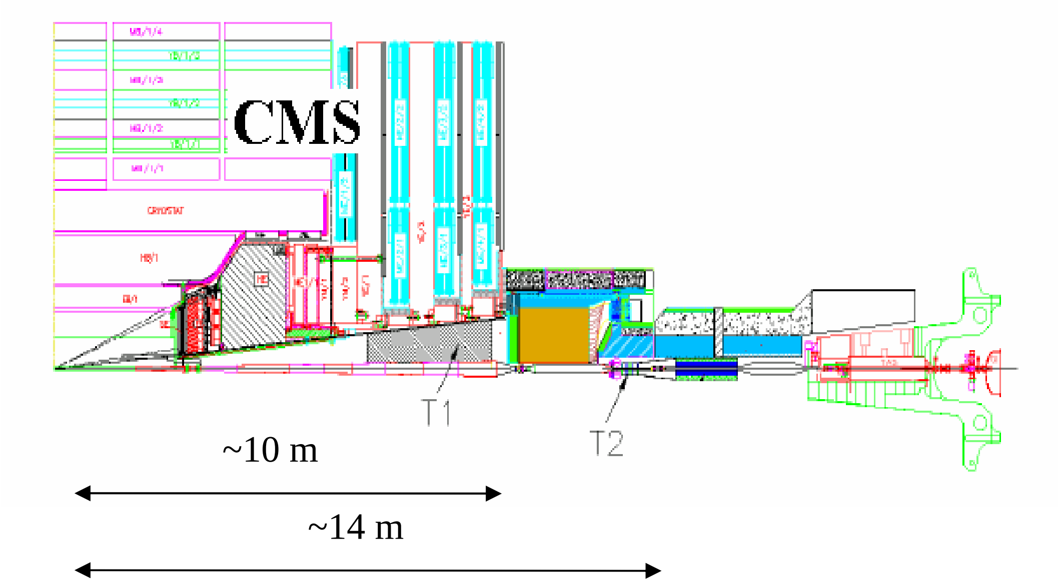
http://totem.web.cern.ch/Totem/

Outline

- Inelastic detectors: general considerations, simulation and ongoing studies
- Inelastic scattering: general considerations and studies published in the TDR
- Future plans: a proposal for an *Inelastic scattering* working group

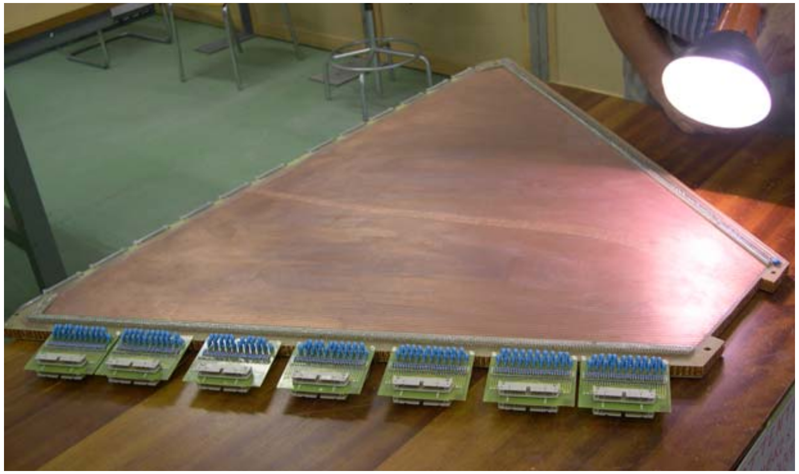
TOTEM inelastic detectors

- Inelastic detectors
  - T1 – CSC Coverage ~3<|η|<~5
  - T2 – GEM Coverage ~5<|η|<~7

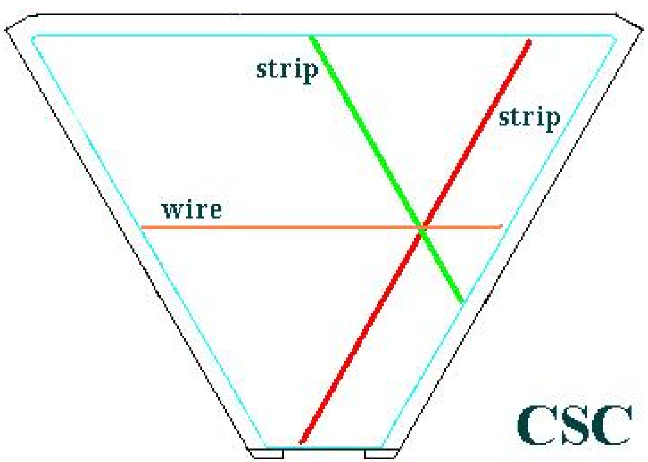


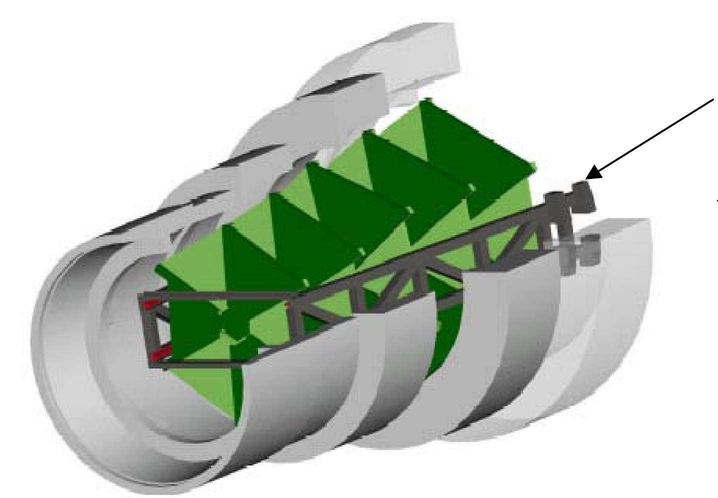
TOTEM inelastic detectors are trackers which have been designed to discriminate between beam-beam events and background (eg. beam-gas) events by means of the primary vertex reconstruction.

T1



- CSC: trigger (signal from anode wires) and reconstruction of the primary vertex. **(5 planes and measurement of 3 coordinates per plane).**
- planes 3deg rotated w.r.t. each other to easy pattern recognition

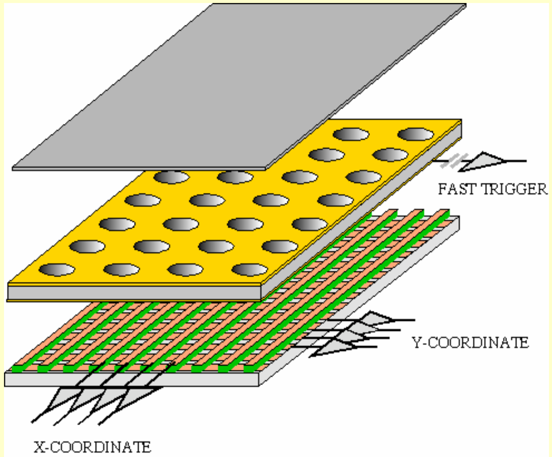


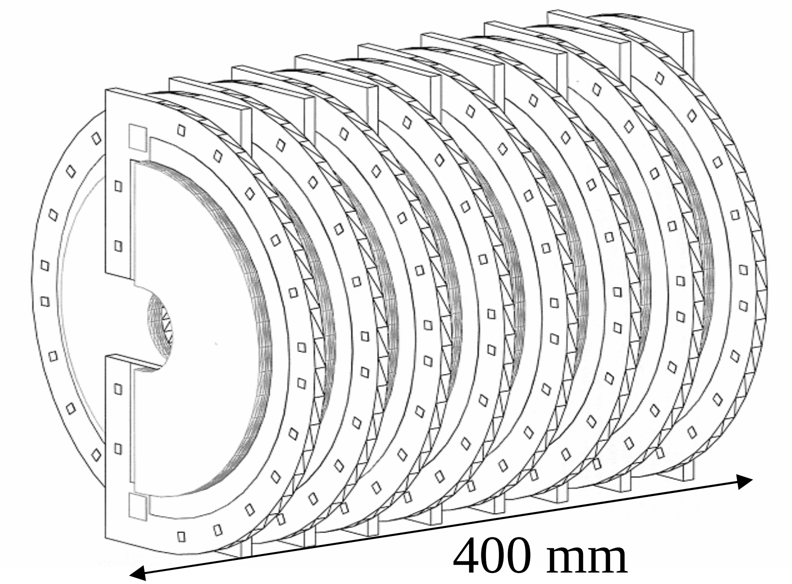


T2

Placed at ~13.5m from IP. GEM (Gas Electron Multiplier) technology to cope with the high rates and high radiation doses (see HERA-B, COMPASS).

GEM layout

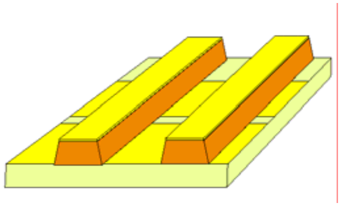




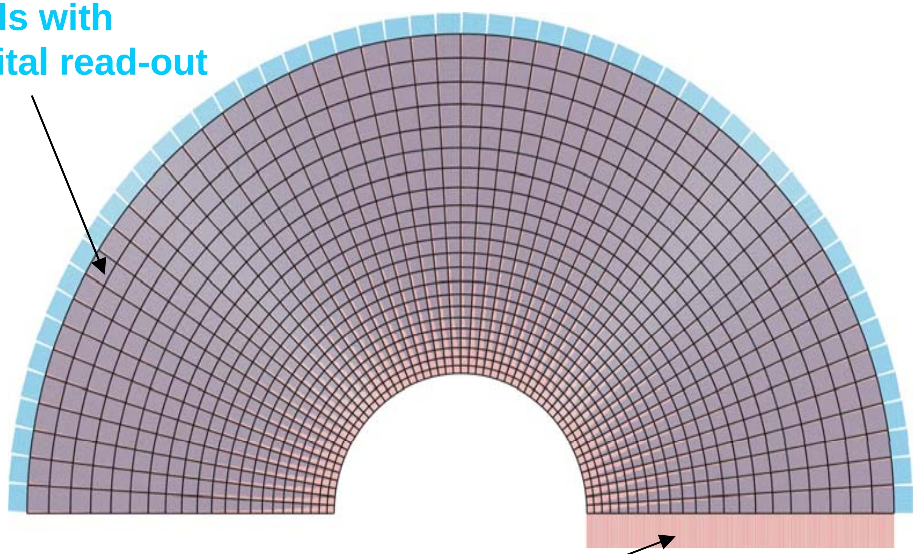
T2: single plane

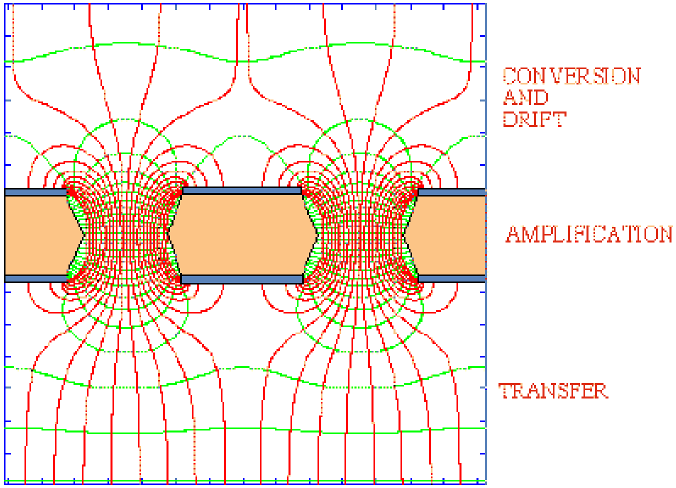
Pads: $54(\varphi) \times 22(\eta) = 1188$ pads
$\Delta\eta \times \Delta\varphi = 0.06 \times 0.18\pi$
~2x2 mm^2 — ~7x7 mm^2

Strips: 256 (width: 80 μm, pitch: 400 μm)



Technology developed for COMPASS





Electric field

T1 and T2: simulation and performance

The simulation of the inelastic detectors is done in the CMS framework (OSCAR). This allows to generate and analyze datasets also for the common CMS/TOTEM physics program.

The simulation is Geant4 based.

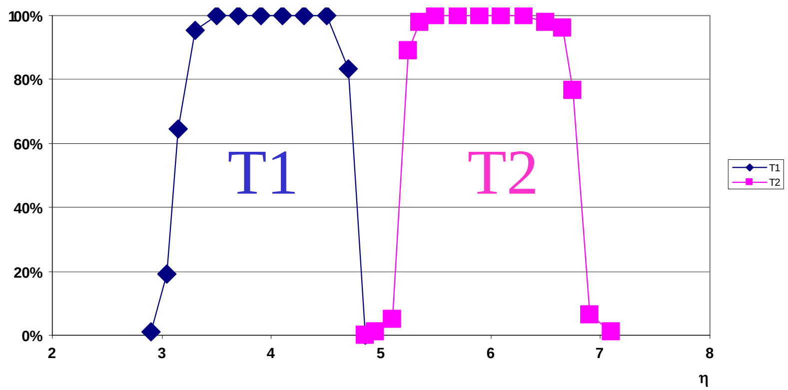
~100000 minimum bias, double and single diffractive events have been generated (Pythia).

This allowed to test the reconstruction capability of the telescopes and to estimate the background due to **secondary interactions** in the beampipe and due to the **beamgas events**.

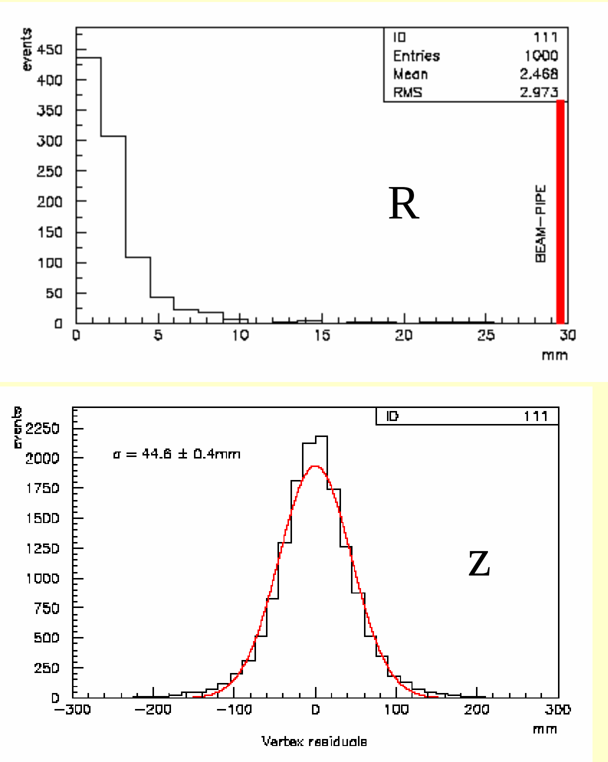
T1 and T2: simulation and performance

- Geometrical acceptance
- Pattern recognition
- Track fit
- Vertex fit

Geometrical acceptance



Primary vertex resolution



Primary vertex resolution is sufficient for discriminating between beam-beam and beam-gas events.

Charged flux

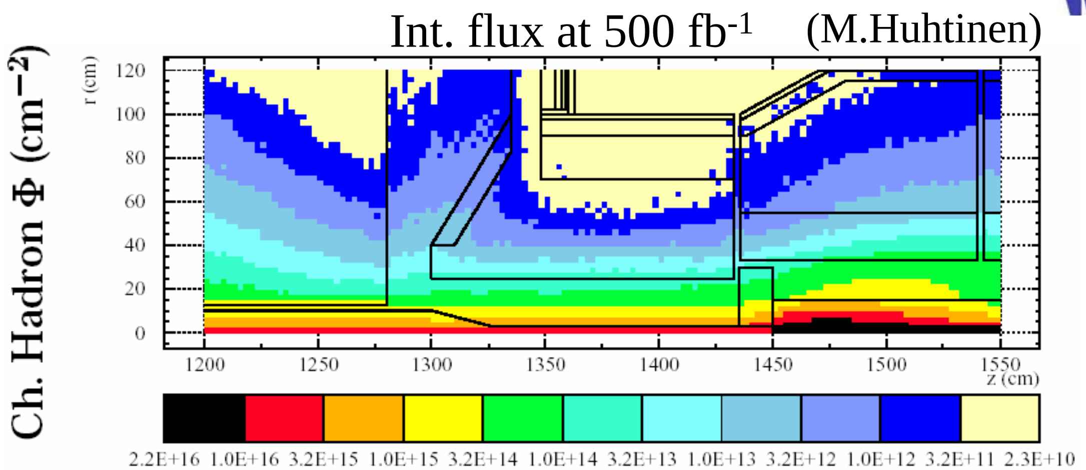
T1 and T2 will have to withstand a large charged flux.

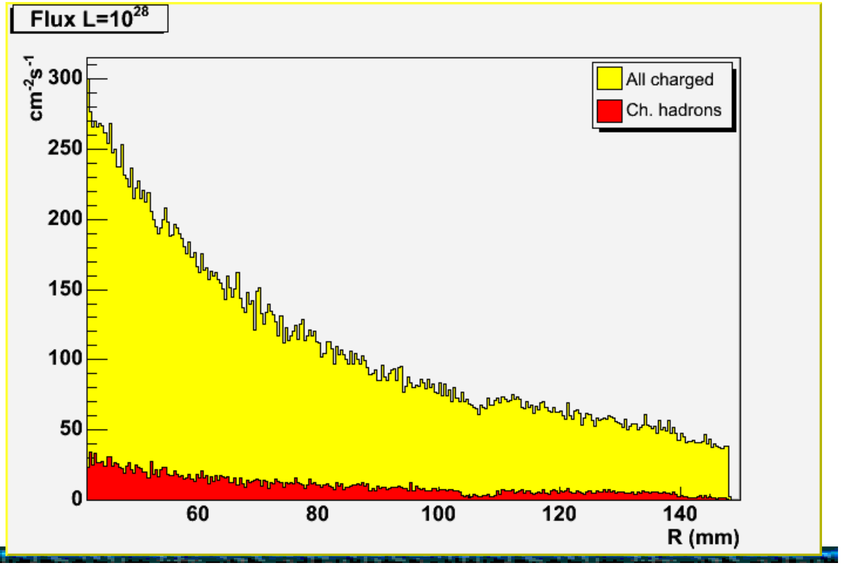
T1: ~1.5 Hz/cm²

T2: >100 Hz/cm²

at $L=10^{28}$

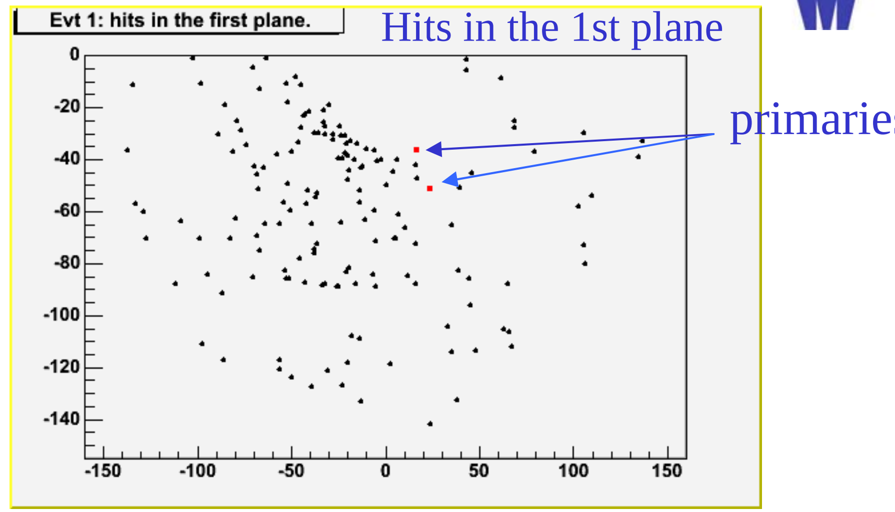
T1 and T2 will be able to operate up to $L=10^{32}$. Probably more for T2.

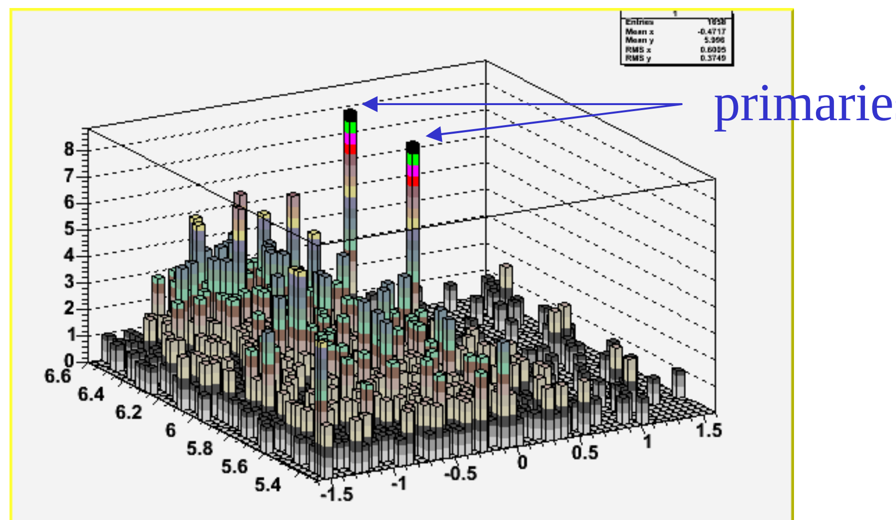




Pattern recognition studies

Example (T2)





- Main aim: find track candidates and evaluate event multiplicity.
- Method: group hits in *roads* to reduce hit combinations and to simplify track fitting.
- Idea: tracks coming from the interaction point travel with constant η and ϕ (magnetic field off).
- Procedure: project on a η-ϕ plane the hits of the detector 5 planes.

Measurement of σ_{tot}

Measurement of the total cross section with the luminosity independent method using the Optical Theorem.

$$L\sigma_{tot}^2 = \frac{16\pi}{1+\rho^2} \times \left.\frac{dN}{dt}\right|_{t=0}$$

$$L\sigma_{tot} = N_{elastic} + N_{inelastic}$$

$$\Rightarrow \quad \sigma_{tot} = \frac{16\pi}{1+\rho^2} \times \frac{\left.(dN/dt)\right|_{t=0}}{N_{el} + N_{inel}}$$

Measurement of the elastic and inelastic rate with a precision better than 1%.

Inelastic cross section

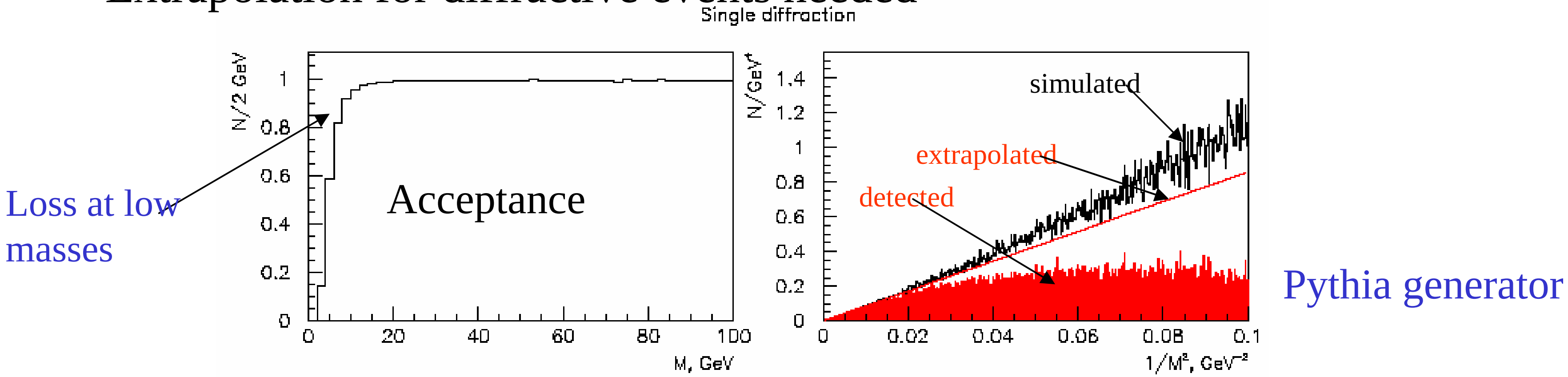
Event selection:

- trigger from T1 or T2 (*double arm o single arm*)
- Vertex reconstruction (to eliminate beam-gas bkg.)

Lost events

Losses	Double arm		Single arm	
Process	%	mb	%	mb
Minimum bias	0.5	0.3	< 0.1	< 0.06
Double Diffractive	39.5	2.8	4.6	0.3
Single Diffractive	-	-	17.9	2.5

Extrapolation for diffractive events needed



Total cross section

($\sigma_{inel.}$~80mb, $\sigma_{el.}$~30mb)

Losses (mb)

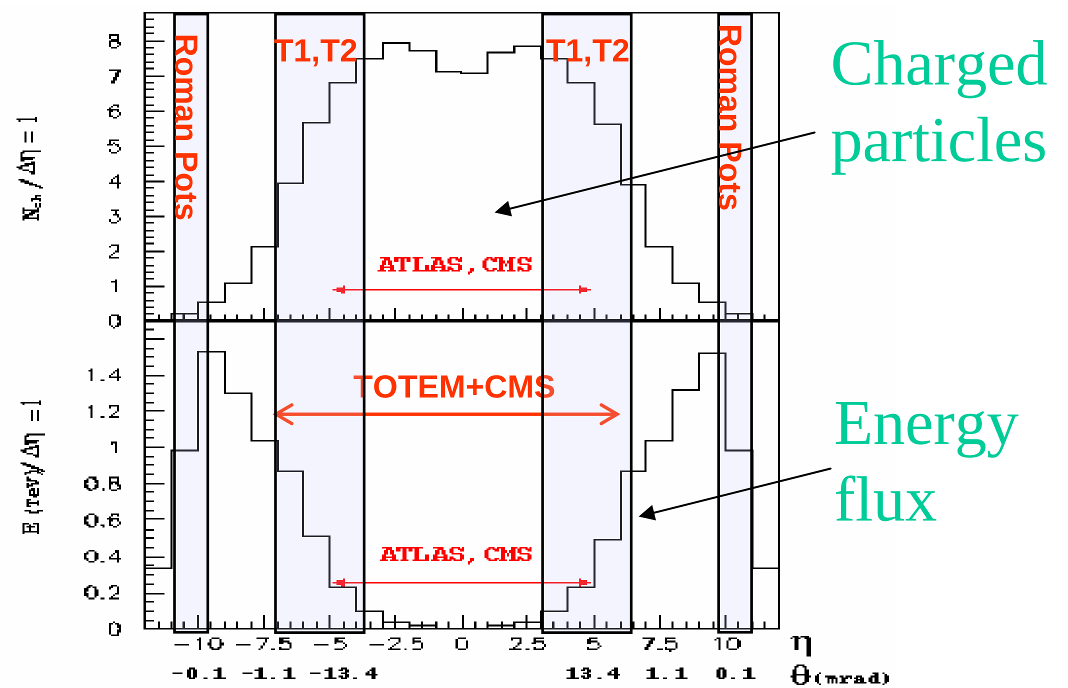
	σ(mb)	Double arm	Single arm	Uncertainty after extrapolation
Minimum bias	58	0.3	0.06	0.06
2 x single diffractive	14	-	2.5	0.6
Double diffractive	7	2.8	0.3	0.1
Double Pomeron	1	-	-	0.02
Elastic Scattering	30	-	-	0.1

$$\frac{\Delta\sigma_{tot}}{\sigma_{tot}} \approx \sqrt{0.008^2 + 0.005^2} \approx 0.01$$

1%

CMS/TOTEM

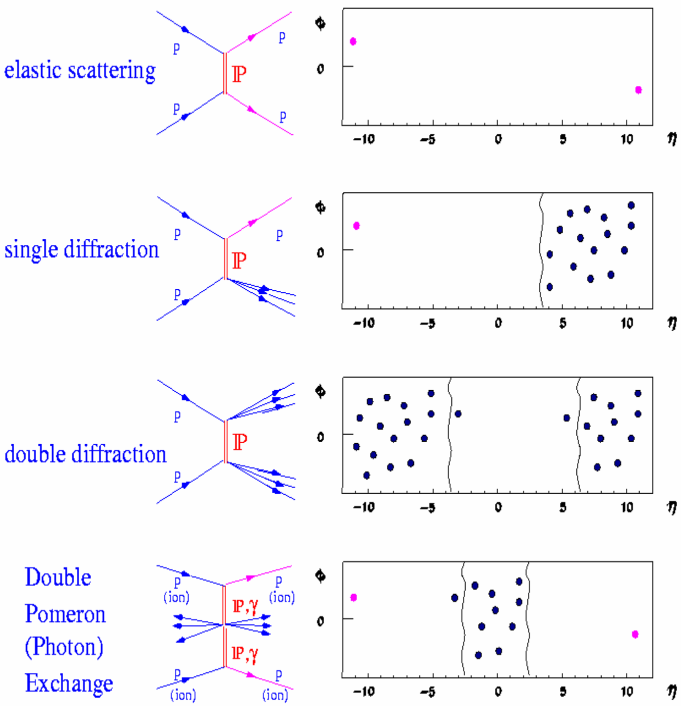
- T1 and T2 will be able to run as “subdetectors” of CMS
- A common CMS/TOTEM physics program on diffraction is going to be defined in details.
- For the first time at a collider large acceptance detector which measures the forward energy flow
- 1 day run at large beta (1540m) and $L=10^{29}cm^{-2}s^{-1}$:
  100 million minimum bias events, including all diffractive processes
- >90% of all diffractive protons are detected



Level-1 Trigger

$L=10^{28}cm^{-2}\,s^{-1}$

All the following trigger typologies will need T1/T2.



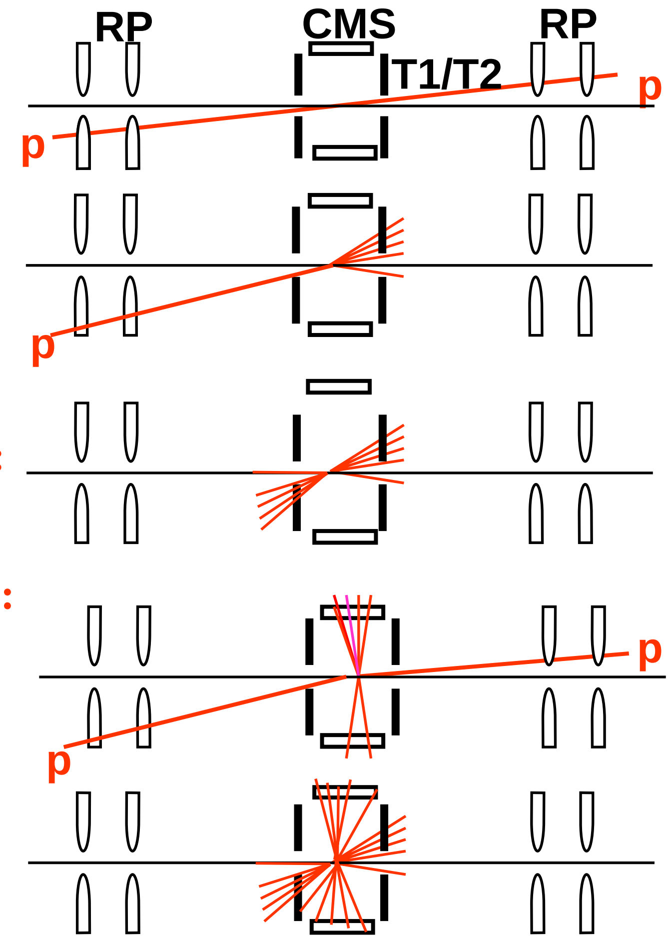
Elastic Trigger:
Signal: 500 Hz
Background: 20 Hz

Single Diffractive Trigger:
Signal: 200 Hz
Background: 0.1 Hz

Double Diffractive Trigger:
Signal: 100 Hz

Central Diffractive Trigger:
Signal: 10 Hz
Background: 2 Hz

Minimum Bias Trigger:
Signal: 1 kHz



Luminosity $2\cdot10^{29}$ cm $^{-2}$ s $^{-1}$

Data taking for soft diffraction : 20 mb → 4 kHz → $4\cdot10^{8}$ events / 1 eff. Day

Double Pomeron : 1 mb → $2\cdot10^{7}$ events / 1 eff. Day

Precise study of soft diffraction phenomena

Luminosity 10^{31} cm $^{-2}$ s $^{-1}$

Few day runs with 4 10^{5} s → 4 10^{36} cm $^{-2}$ → 4000 evts / nb

Double Pomeron exchange

High masses order of TeV

χ_c → 10^{6-7} events before decay

χ_b → 10^{3-4} events before decay

Large pt di jets → coplanar dijet with two accompanying protons and nothing else

Single diffraction with high pt jets and leptons

Study of rapidity gaps with identified protons

Proposal for a working group on inelastic scattering

- Main aim: to facilitate the simulation tasks necessary for the physics feasibility studies
- Some issues:
  - To complete the implementation, in the CMS software, of the detector digitization and reconstruction tools
  - To study in details the capability of the detectors of doing a pointing trigger
  - To study how to use elastic and inelastic scattering simulations together
  - To study the possibility of identifying rapidity gaps with T2
  - To understand how T2 (and T1) can contribute in the study of interesting physics channels (e.g. χ_c)
  - Suggestions are welcome … **foward jets, mini-jets, multiple rap gaps,..**