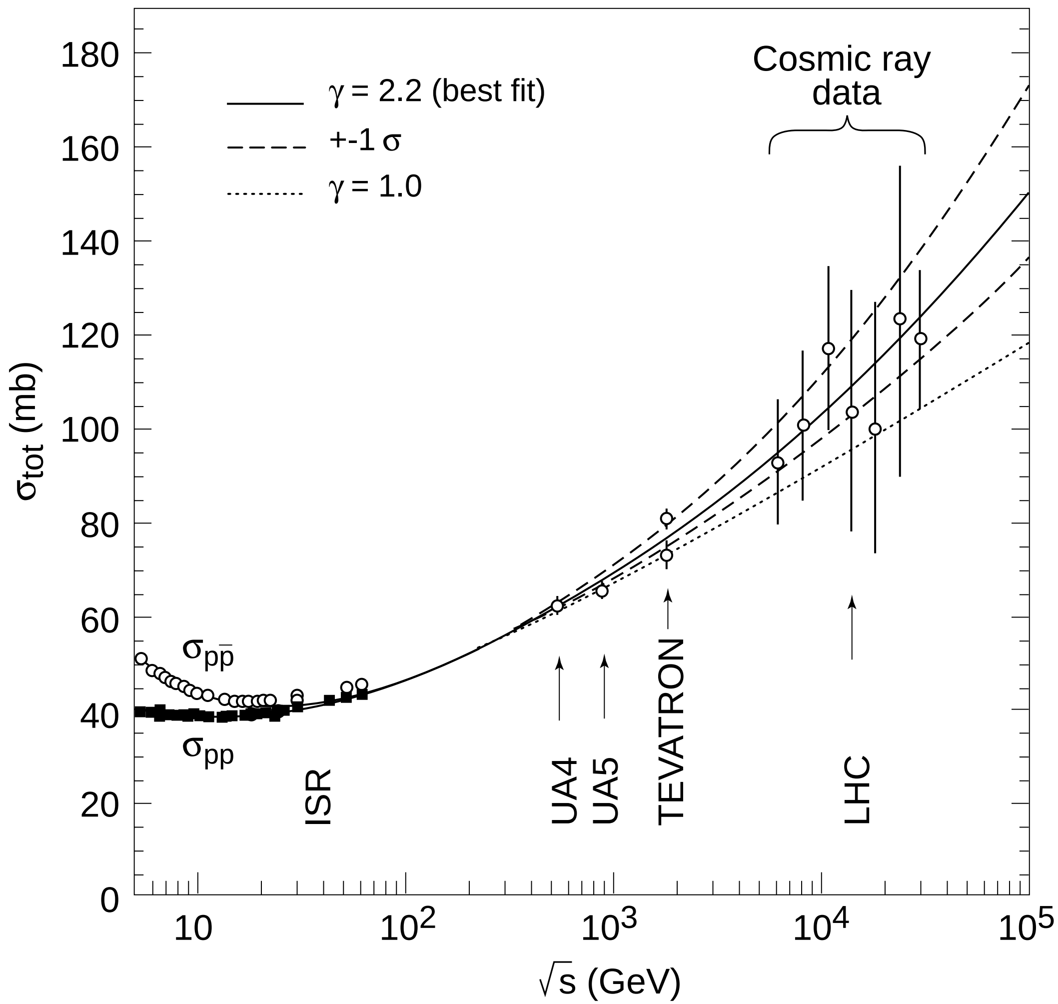
Luminosity Measurement with TOTEM

- Overview
- Inelastic rates
- Absolute calibration
- Inelastic telescopes
- Monitoring Luminosity

TOTAL CROSS SECTION



Proton-proton

Proton-antiproton

Extrapolation to LHC energy:

log s ~ 95 mb

$(\log s)^2$ 109 ± 8 mb

(UA4 and lower energy data)

Dispersion relation fit from

C.Augier et al., Phys. Lett. B315 (1993) 503.

TOTEM designed to measure with accuracy ~1 mb

Sufficient to discriminate between two options and current models prediction

The experimental method

- Well known **"luminosity independent"** method
  - Only method of practical use
- Total cross section and machine integrated Luminosity

$$N_{el} + N_{inel} = L\,\sigma_{tot}$$

- Total cross section and imaginary part of forward amplitude (Optical Theorem)

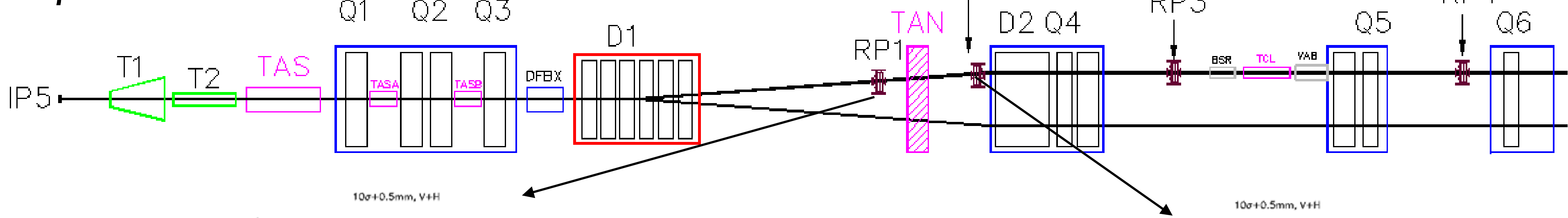
$$\left(\frac{dN_{el}}{dt}\right)_{t=0} = L\left(\frac{d\sigma}{dt}\right)_{t=0} = L\,\frac{\sigma_{tot}^2\left(1+\rho^2\right)}{16\,\pi}$$

- Combining the two, one writes the total cross section as a function of measurable quantities

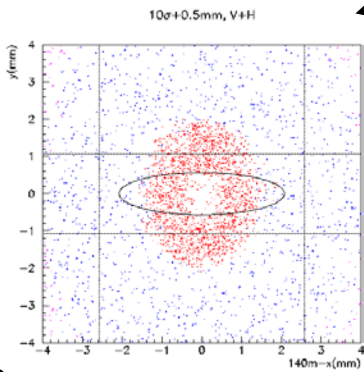
$$\sigma_{tot} = \frac{16\pi\,\left(dN_{el}/dt\right)_{t=0}}{\left(1+\rho^2\right)\,\left(N_{el}+N_{inel}\right)}$$

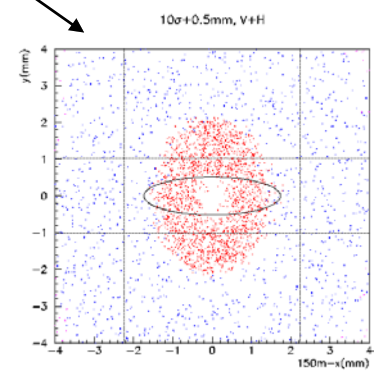
- **Simultaneous measurement of low t elastic scattering and of inelastic interactions**

β* = 1100 m

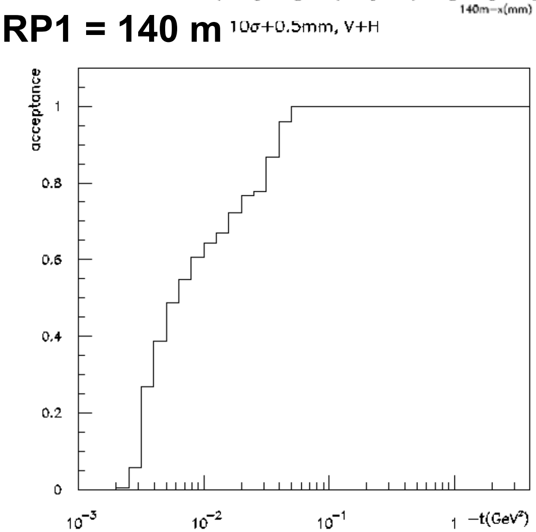


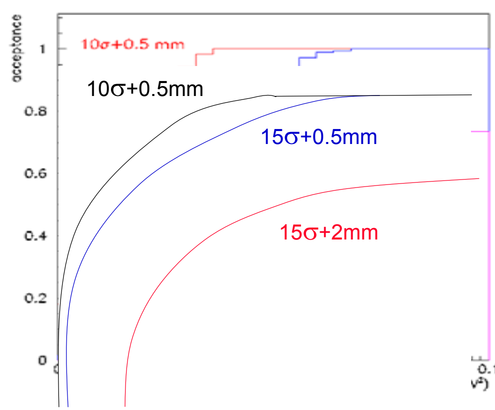
Elastic Scattering



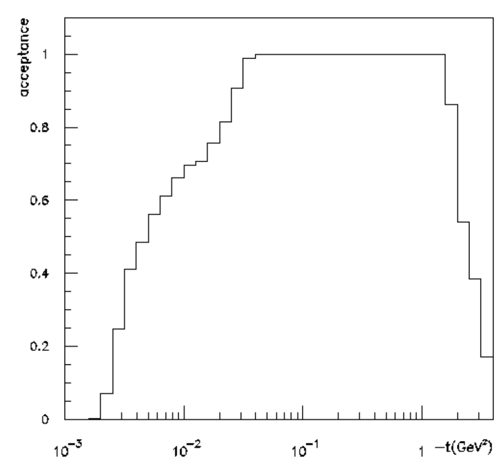


RP1 = 140 m





10σ+0.5mm, V+H **RP2 = 150 m**



The inelastic rate

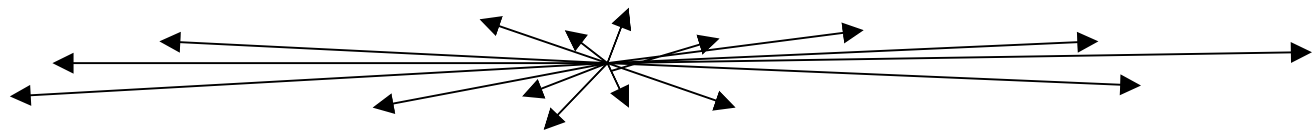
Inelastic detectors will measure over the pseudorapidity interval:

$$3 \leq \eta \leq 7$$

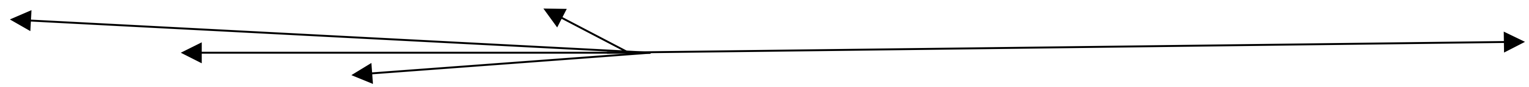
$$100 \geq \theta \geq 2 \text{ mrad}$$

•With **Fully inclusive trigger ("Minimum bias")**

•**"Normal events" (NSD) (80-85% of inel. cross section)**



• **Single diffractive events (SD) (15-20% of inel. cross section)**

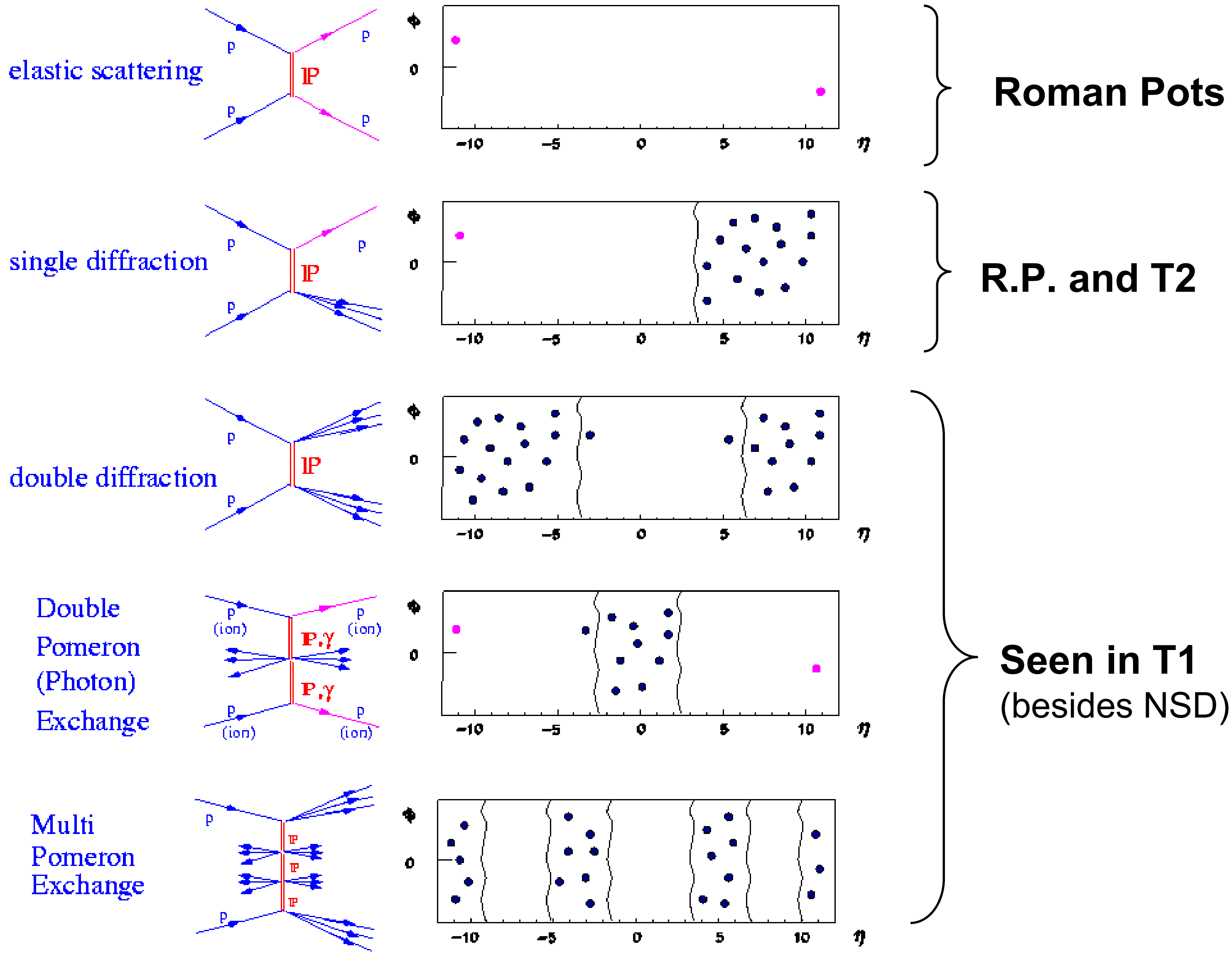


• **Two main trigger combinations:**

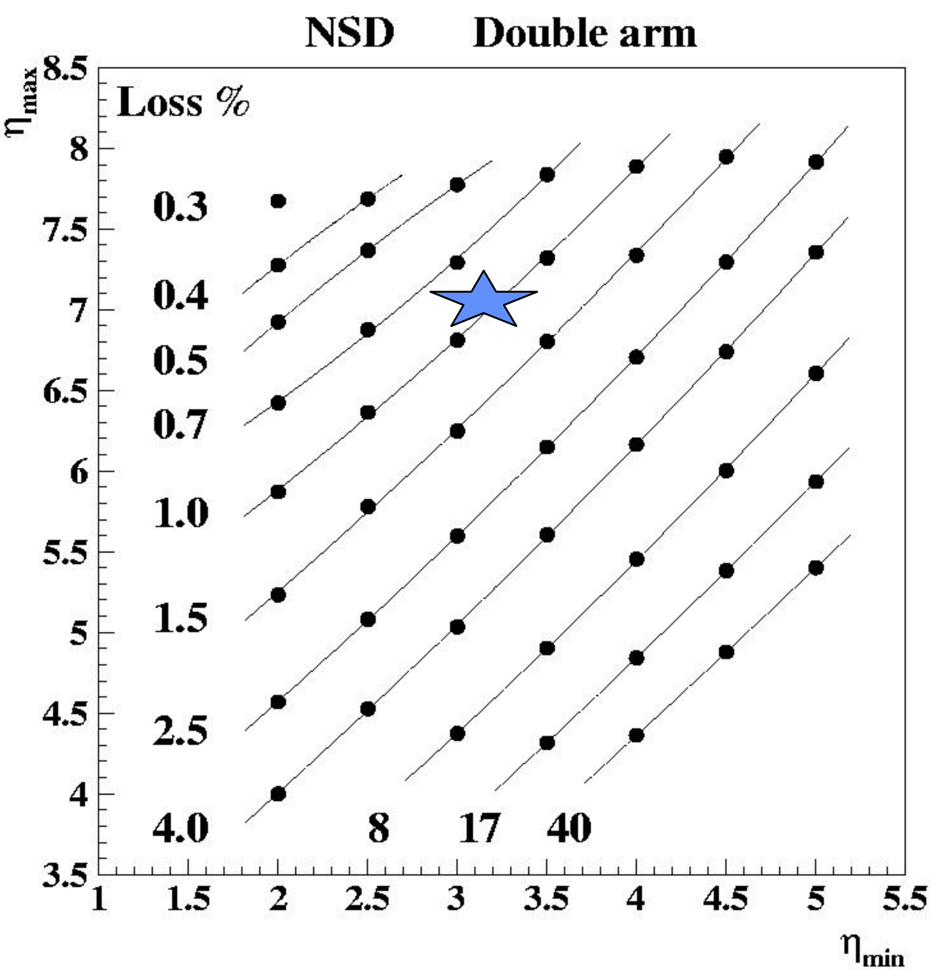
- **Left * Right** (coinc) - **Single arm**

• **Identification of beam-beam events against background**

• **Reconstruction of the collision vertex**


elastic scattering
single diffraction
double diffraction
Double Pomeron (Photon) Exchange
Multi Pomeron Exchange
p
IP
P,γ
(ion)
Φ
0
−10
−5
0
5
10
η
Roman Pots
R.P. and T2
Seen in T1
(besides NSD)

Efficiency of Left-Right trigger for NSD events

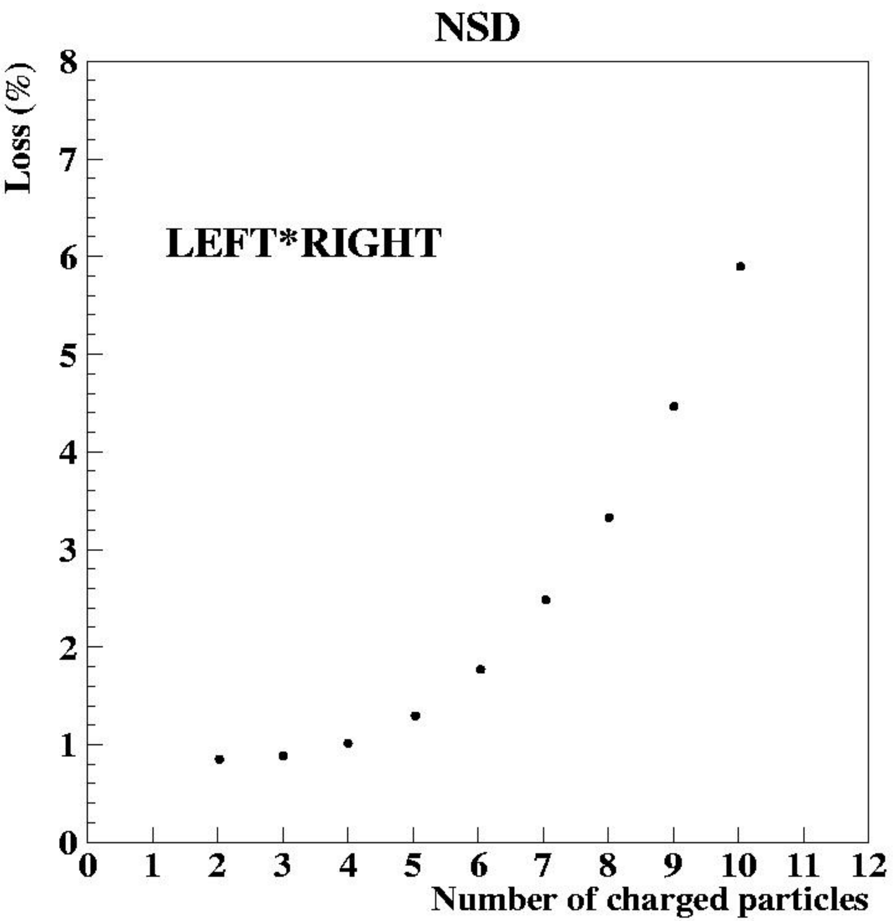


NSD is the main component of the inelastic cross section, it is of the order of 85 %

Left-Right trigger is clean, low background

Plot for
"One track left, one track right"

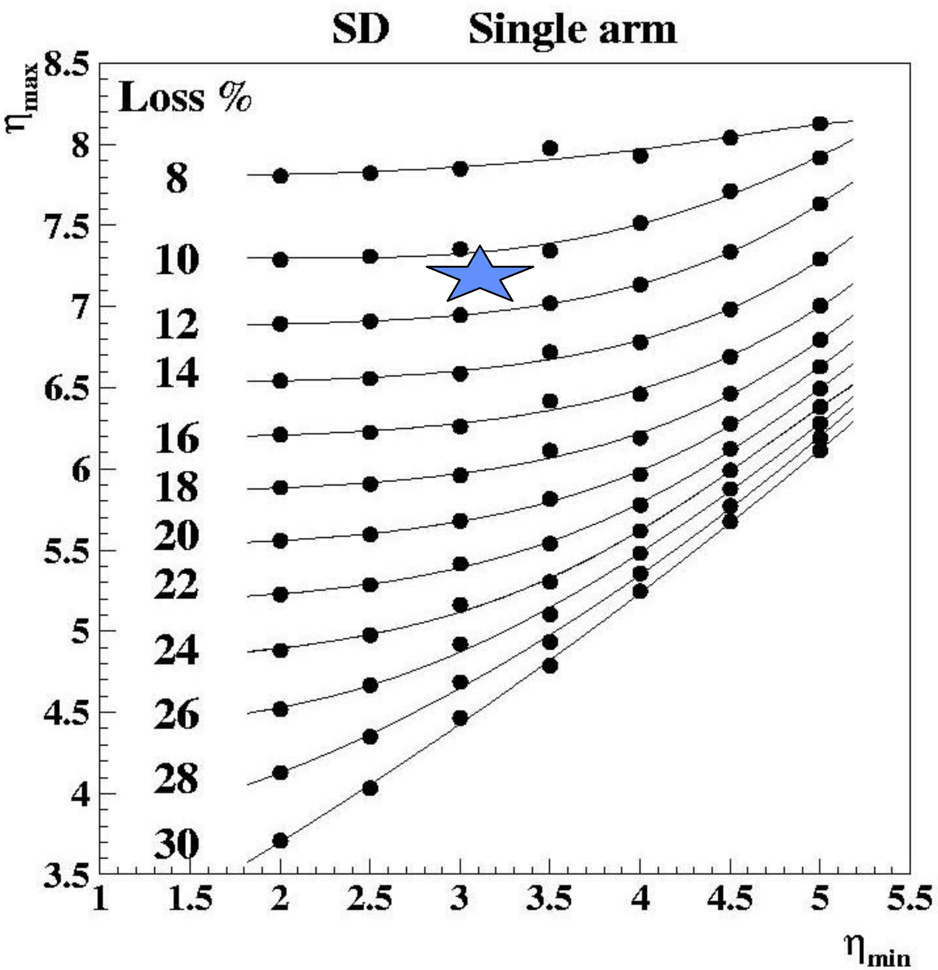
Left-Right trigger vs. total number of particles



Losses in NSD as a function of number of particles seen in each telescope.

Expected loss on NSD ~1 - 2 %

Efficiency of Single arm trigger for SD events



SD, minor component of inelastic cross section, of the order of 15 %

Two tracks loss 10 - 15 %

Estimated losses on the inelastic rate

- NSD - main component of the inelastic rate (about 85%)
  measured well with 1-2 % loss
- SD - minor component of the inelastic rate (about 15%)
  measured with 10-15 % loss

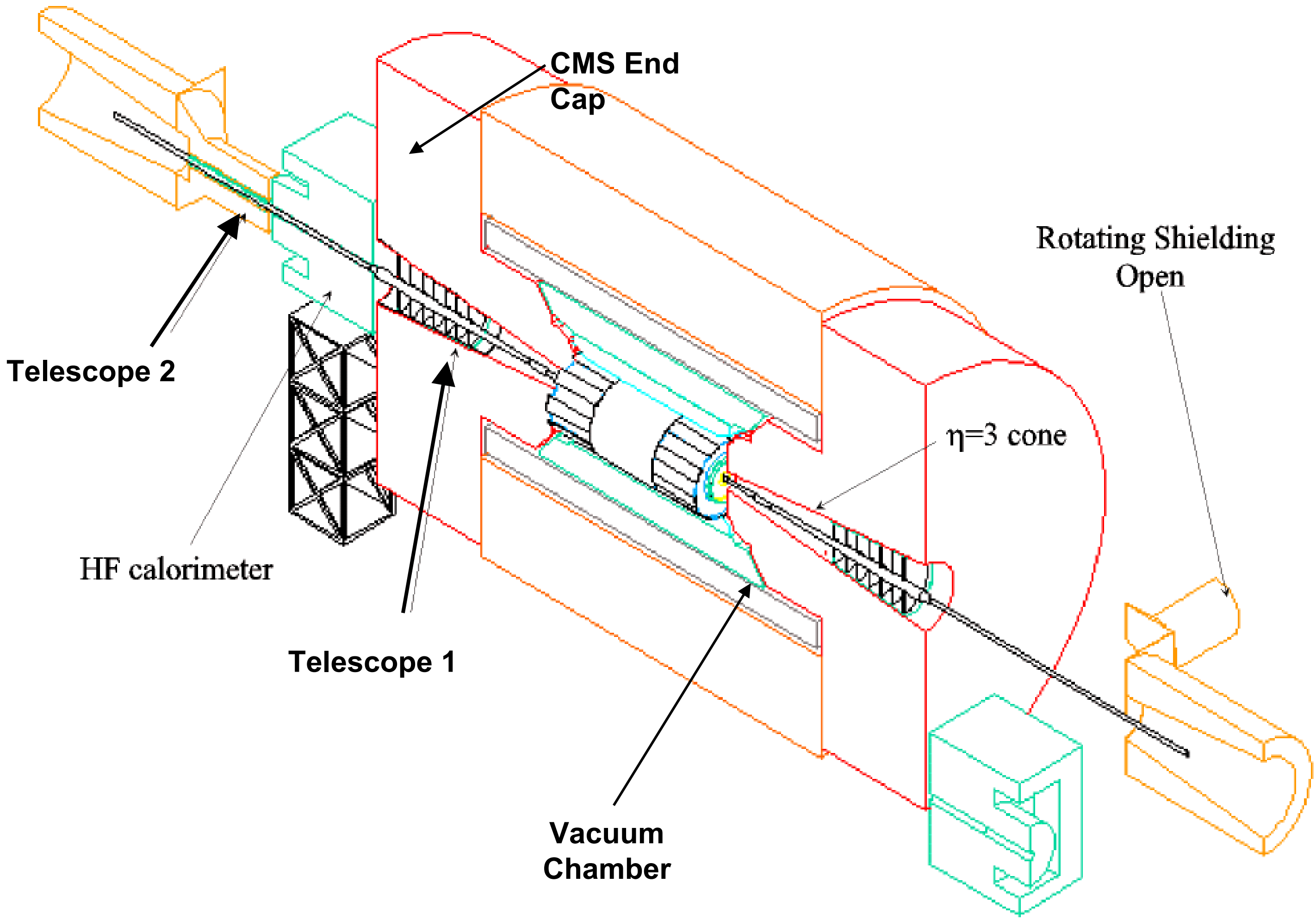
- The overall losses on the observed inelastic rate should be less than 3-4 %.
- With Monte Carlo tuned on the data calculate correction

Final error around 1 %.

Inelastic rate detectors

- T1 installed inside CMS ($3.1 < \eta < 4.8$) measures mainly central interactions
  - Good efficiency, low background
  - Rejection of wrong direction halo, reconstruction of vertex position
- T2 installed in front of fixed shielding ($5.6 < \eta < 7.5$) sees mainly single diffractive events
  - Small masses (few GeV's) large rapidity gaps
  - At high β identify thin jet as SD by measuring the proton on the opposite side
  - Possibility to identify interaction vertex useful to identify beam-beam in low beta runs (when used as luminosity monitor)
- Background measurement very important
  - Single beam runs with high and low beta to directly measure correction

CMS/TOTEM Layout



Single Diffraction triggers

- **Topology of events very similar to beam gas**
- **Necessary to have good separation between beam-beam and beam-gas**
- **Two different triggers to identify the two components**
  - **T1 or T2 only on one side (**with good single beam measurement to measure beam-gas and other backgrounds**)**
  - **T1 or T2 only in one side and requiring a proton in roman pots on other side** (>95% acceptance for high beta runs**)**
  - **NOTE: at injection or low beta optics the fraction of SD (**very energetic jets contained in small cone, order of cm at T2**) will have a measured proton only in a very small fraction (~1%) of cases**
    - **This is an important subset of the data sample to track the absolute calibration from lower luminosities: Monte Carlo checks the relative efficiency.**

Hence aim at the *best ξ acceptance* for roman pots

Monitoring luminosity

- Absolute measurement of Luminosity is performed during the special TOTEM runs
- Monitors/detectors calibrate their counting rates.
  (run is at very low luminosity 10^{28} cm^{-2} sec^{-1})
- To maintain precision in extrapolation to higher luminosity… problems may be due to rates and pile-up
  - Cross correlate rates with ‘ones’ of detectors at larger angle or with reduced acceptance
  - Pile-up corrections to monitors by counting interactions’ vertices in z (feasible up to a ~10 events/crossing)
- T2 will see SD (fraction of cross section →lower rate) and also DD with possibility of regular calibration check with short runs at high beta
  - particular event topology less sensitive to pile-up
  - Runs at injection beta to check calibration at ‘*intermediate*’ Luminosity
  - Monitor capable to disentangle beam-beam and beam-gas with its limited vertex reconstruction capability (if event topology not sufficient by itself)

Requests to the machine

- The smallest beam emittance possible will allow to reach smaller t values in the special TOTEM run
- We need to know the beam position at the 10 micron precision to check the consistency of our alignment procedures.
- We are interested in having the Machine monitors story recorded regularly and made available for the off-line analysis during the TOTEM runs.
- Bunch particle numbers and other related parameters with the best precision.

conclusions

- **TOTEM will measure total cross section in special runs at low luminosity.**
- **Aim at total cross section measurement with 1% precision**
- **Absolute measurement of Integrated machine luminosity will allow calibration of monitors in IP5 (CMS and others…)**
- **Extrapolation at higher luminosities with TOTEM forward Monitor (T2 telescope) and cross correlating detectors with different acceptance and background**