Status of TOTEM

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On behalf of the TOTEM collaboration

TOTEM collaboration

Politecnico di Bari and Sezione INFN, Bari, Italy

Institut für Luft- und Kältetechnik, Dresden, Germany

CERN, Geneva, Switzerland

Università di Genova and Sezione INFN, Genova, Italy

University of Helsinki and HIP, Helsinki, Finland

Academy of Sciences, Praha, Czech Republic

Brunel University, Uxbridge, UK

- **TOTEM TDR** LHCC-2004-002 has just been **approved** by the LHCC.

Outline

- Physics goals
- Detectors
- Simulation
- Physics performance

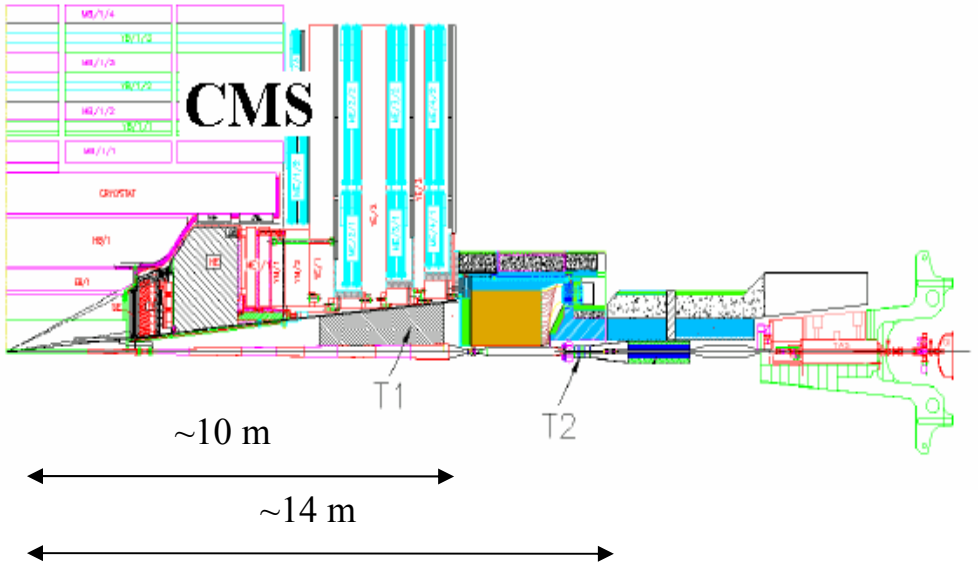
Physics goals

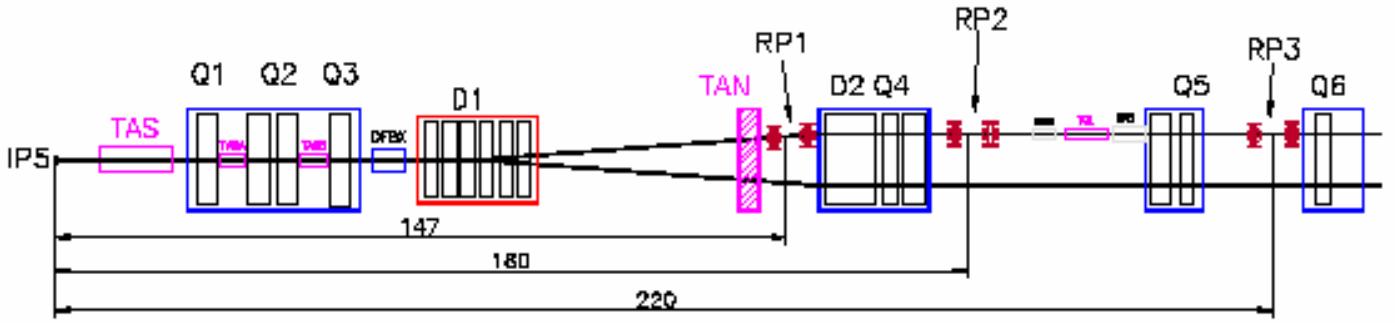
- Measurement of the total p-p cross-section at 14 TeV with ~1% error
- Measurement of the p-p elastic scattering in the range $10^{-3} < -t < 8\ GeV^2$
- Study diffraction (single, double, central).

TOTEM detectors

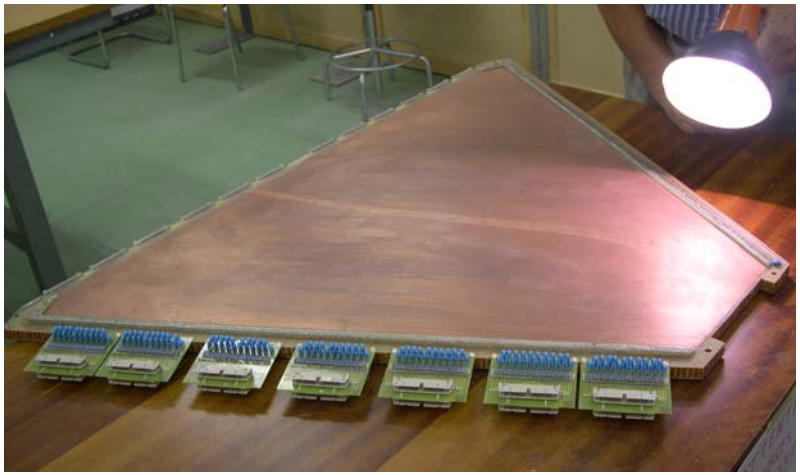
- Inelastic detectors
  - T1 – CSC Coverage 3.1<|η|<4.7
  - T2 – GEM Coverage 5.3<|η|<6.6
- Leading proton detectors
  - Silicon detectors inside Roman Pots (at 147,180,220 m from IP)

Detectors on both sides.

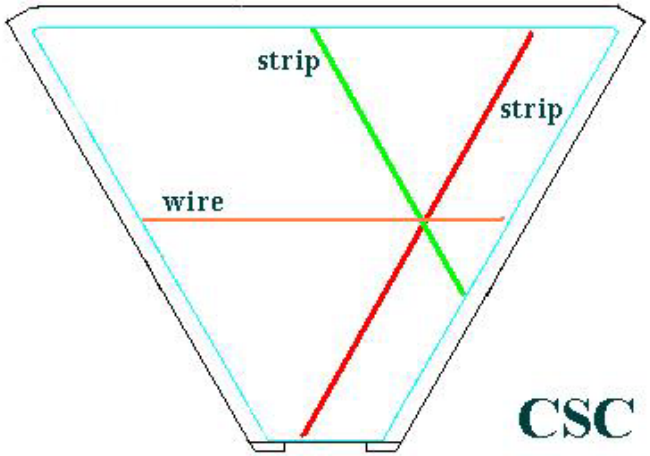




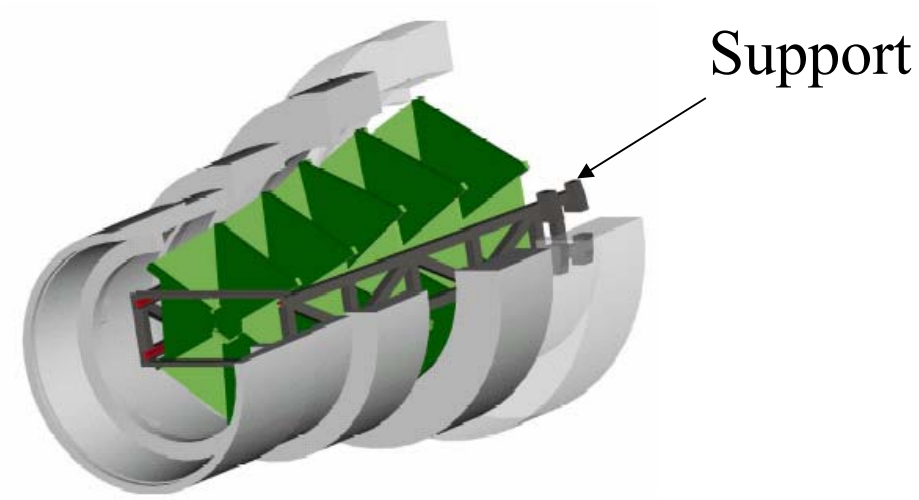
T1 telescope



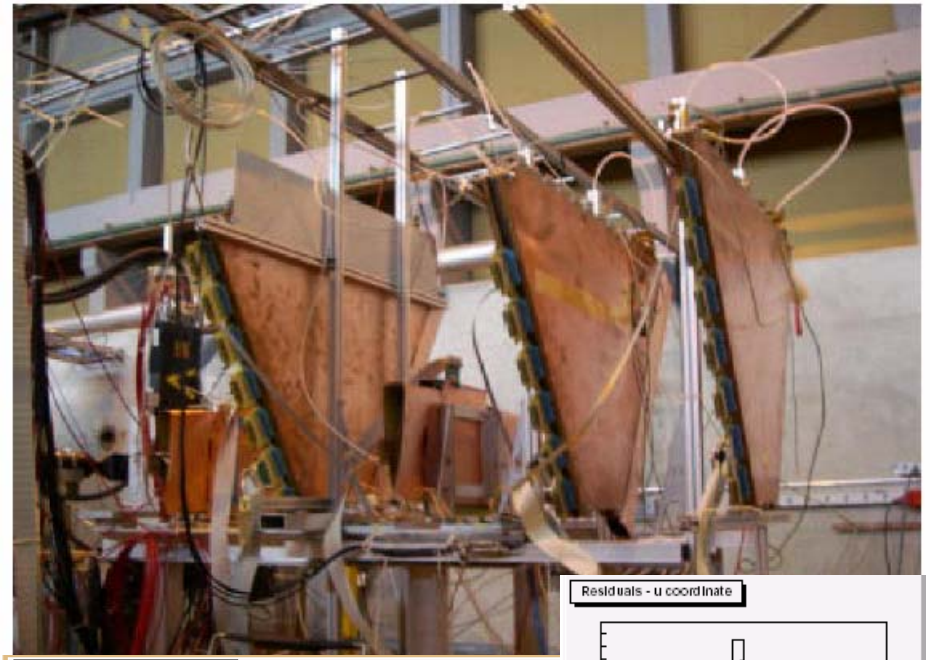
- **5 planes with measurement of three coordinates per plane.**
- 3 degrees rotation and overlap between adjacent planes
- Primary vertex reconstruction
- Trigger with CSC wires

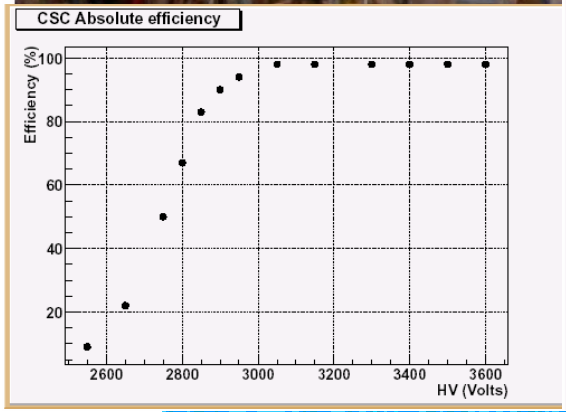


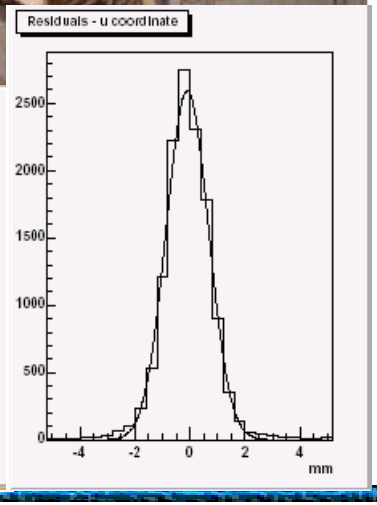
1 arm



T1: testbeam







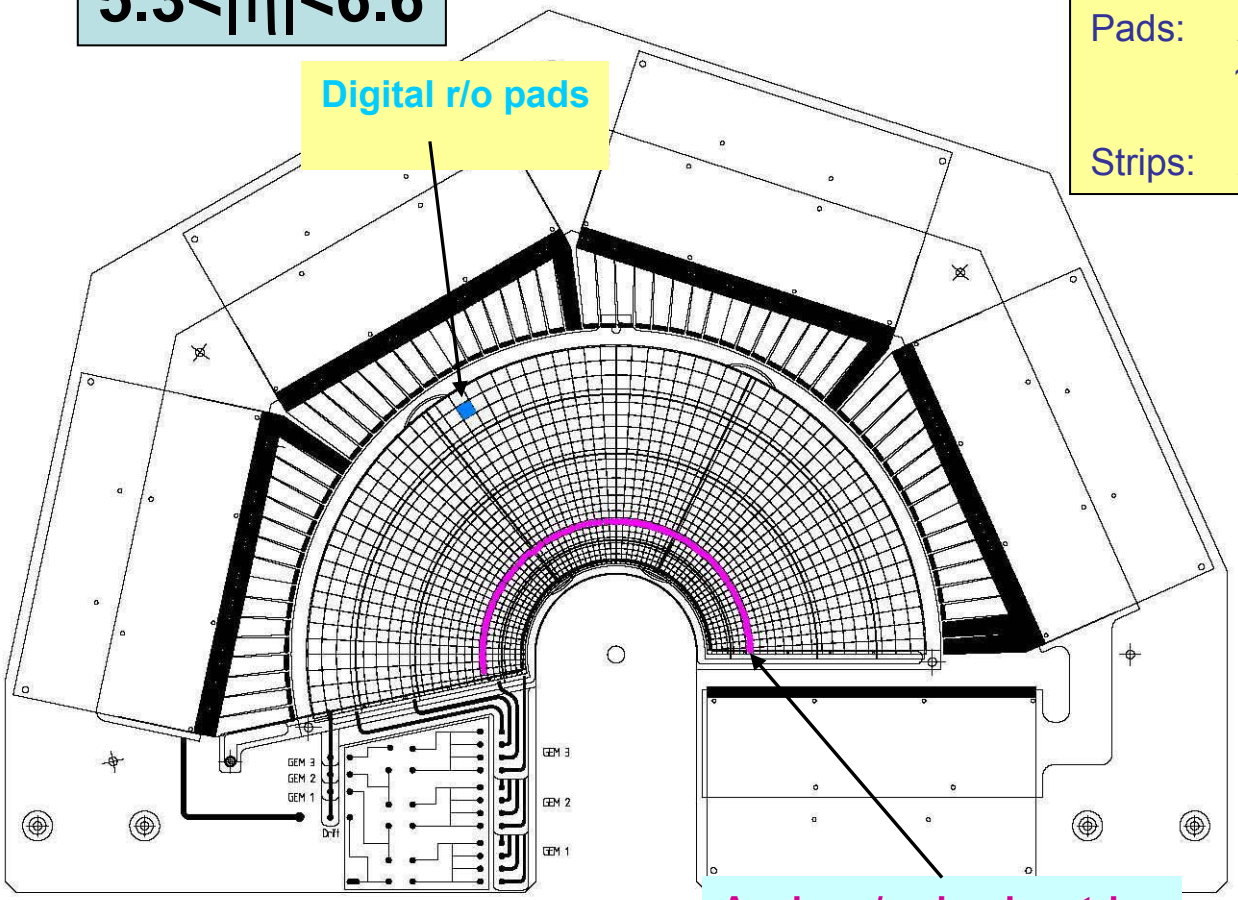
Final prototype test in 2003 with SPS beam

- Efficiency (plateau starting at 3200V)
- Spatial resolution (σ~0.7mm)
- Track reconstruction

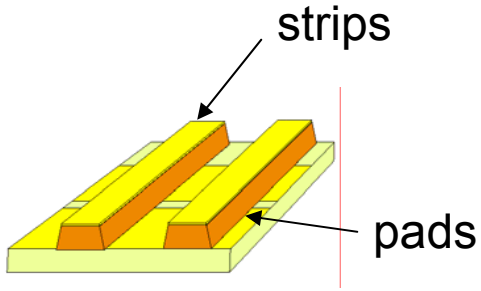
T2: telescope

8 triple-GEM planes, to cope with high particle fluxes

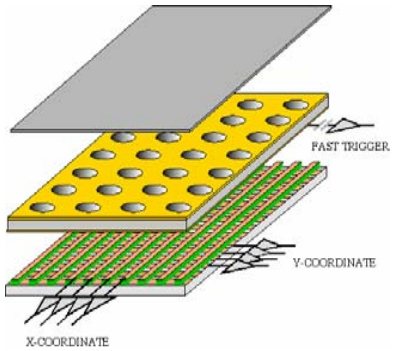
5.3<|η|<6.6



Pads:	54(φ) x 22(η) = 1536 pads Δη x Δφ = 0.06 x 0.018π ~2x2 mm² – ~7x7 mm²
Strips:	256 (width: 80 μm,pitch: 400 μm)



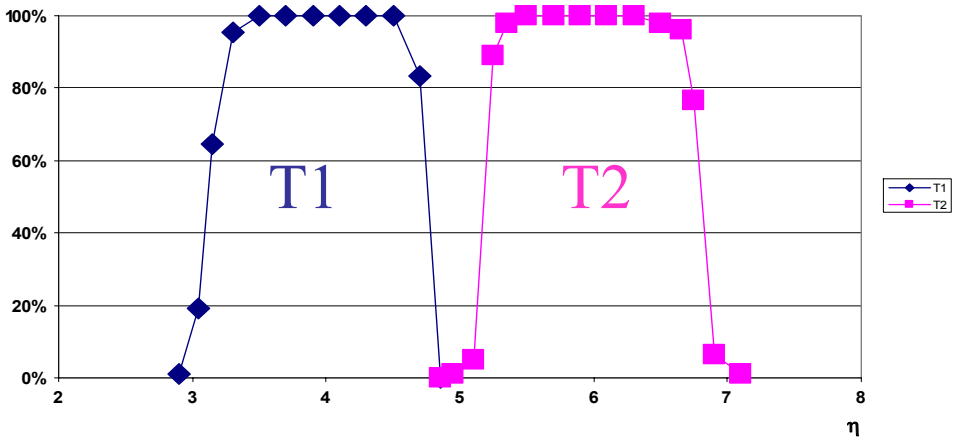
Technology used in COMPASS



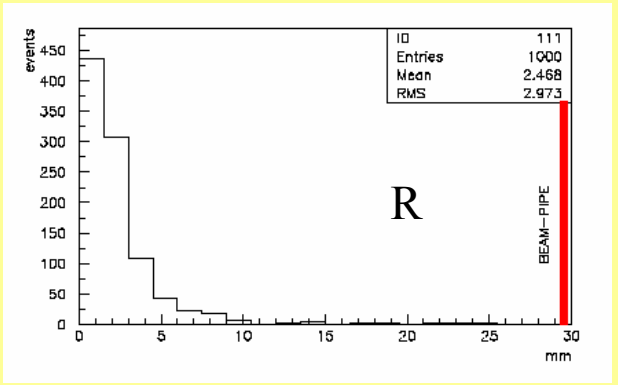
T1 and T2: simulation and performances

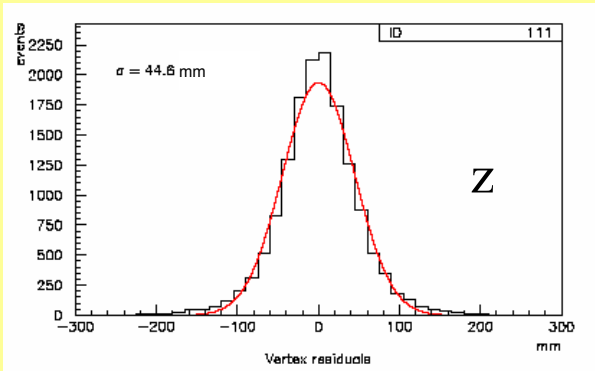
- Reconstructed vertex well inside the beampipe (σ~3mm) and within ±5 cm along the beam axis

Geometric acceptance



Primary vertex resolution





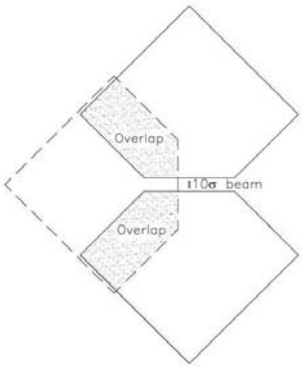
The primary vertex resolution is sufficient to discriminate beam-beam from beam-gas events.

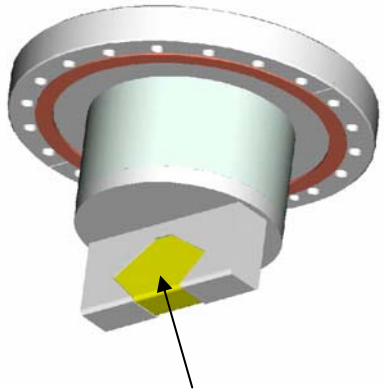
Roman Pots

A prototype with vertical movement ready to be tested in the SPS.

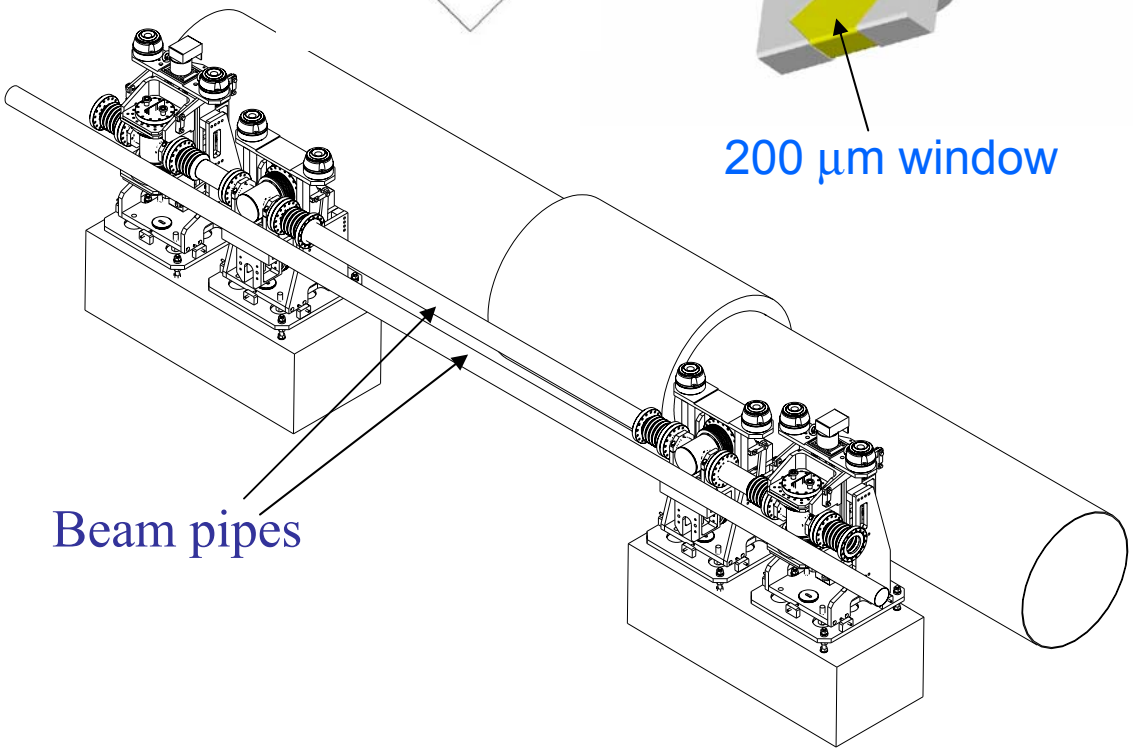
2004 prototype

Detector overlapping





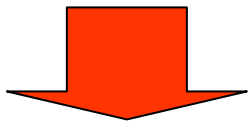
200 μm window

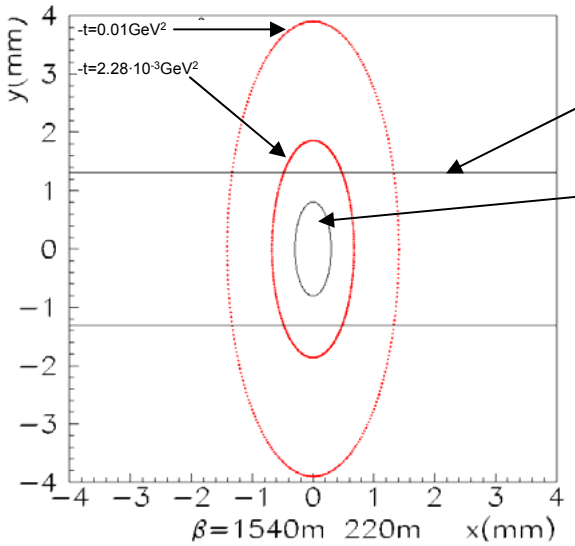


Beam pipes

Leading proton detectors

- Full efficiency as close to the detector edge as possible : ***edge-less***
- ***radiation-hard*** (Expected maximum flux ~10^{13} n eq./cm^2):
- ***resolution*** ~20μm
- size ~3x4 cm^2



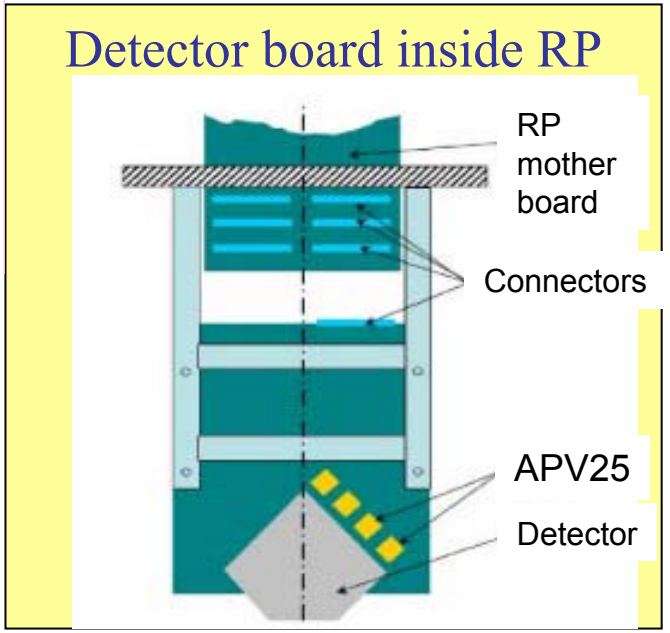


Detector edge

$10\sigma_{beam}$

Solutions:

- Si planar with current terminating guard rings
- Si planar 3D
- Si 3D

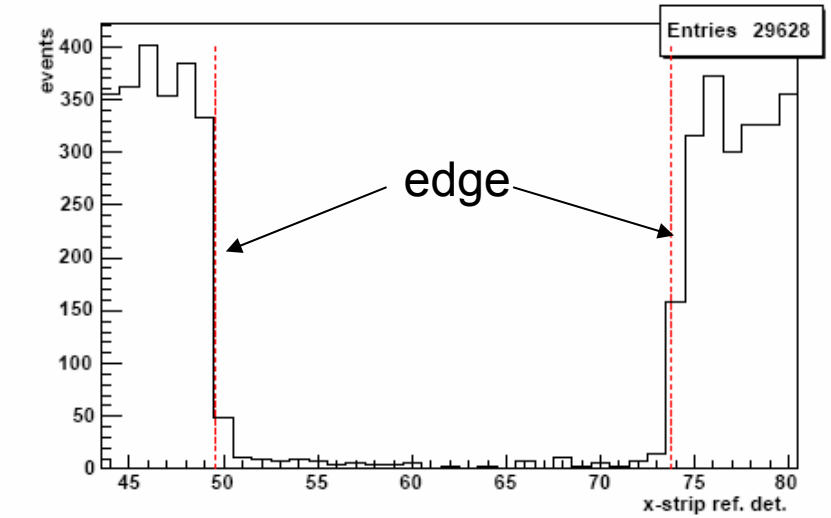


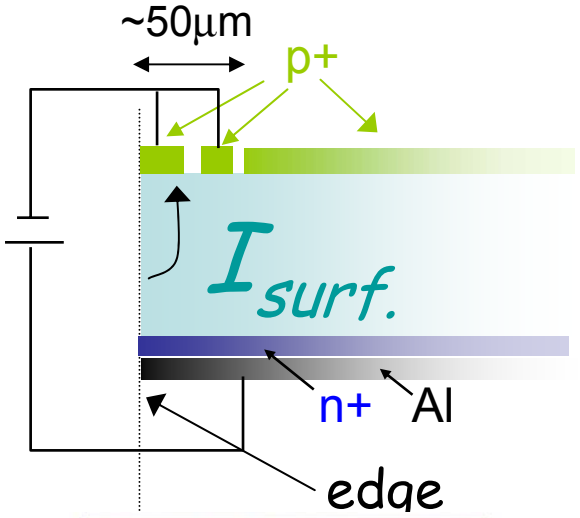
Current Terminating Structure on Microstrip detectors

(in collaboration with IOFFE PTI St. Petersburg/RIMST Moscow)

- Use Standard Planar Technology
- Working Temperature >-20°C
- Dead zone ~50-60μm
- Increase of efficiency in <20μm

2003 test beam results

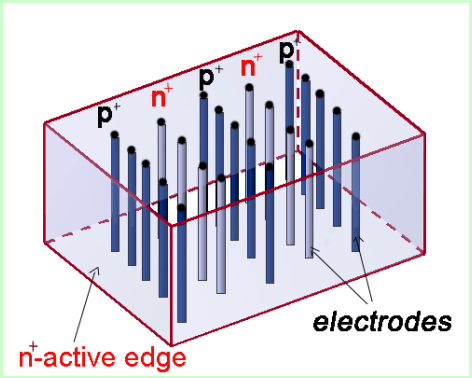




Full size detector for 2004 test at SPS

1 cm

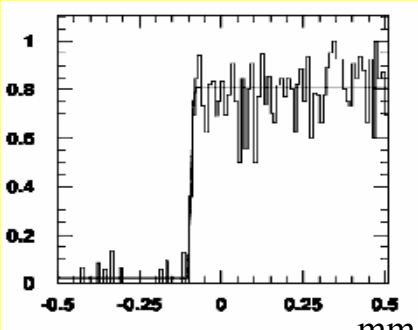
3D



The electrodes are created in the bulk.

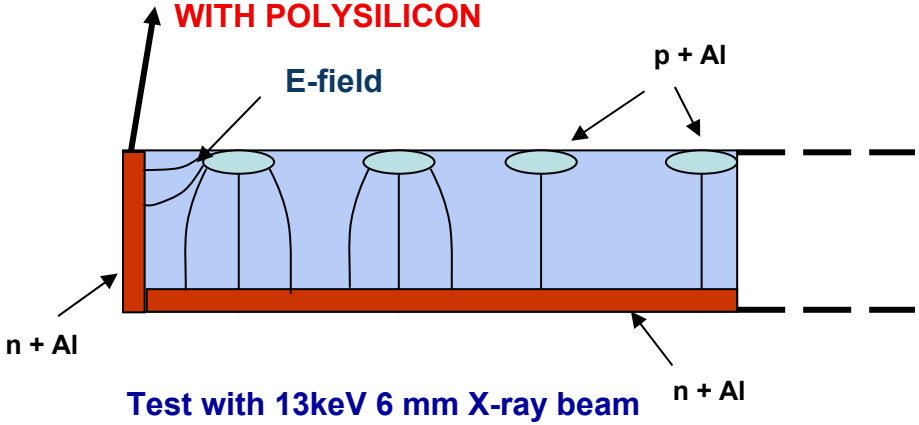
The edge is an electrode.

SPS test:
transition in
~6μm
Rad. Hardness:
>10^{15} "n"/cm^2



Planar 3D

TRADITIONAL PLANAR DETECTOR + DEEPLY ETCHED EDGE FILLED WITH POLYSILICON

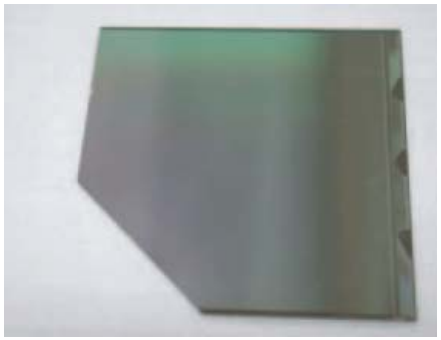


Test with 13keV 6 mm X-ray beam

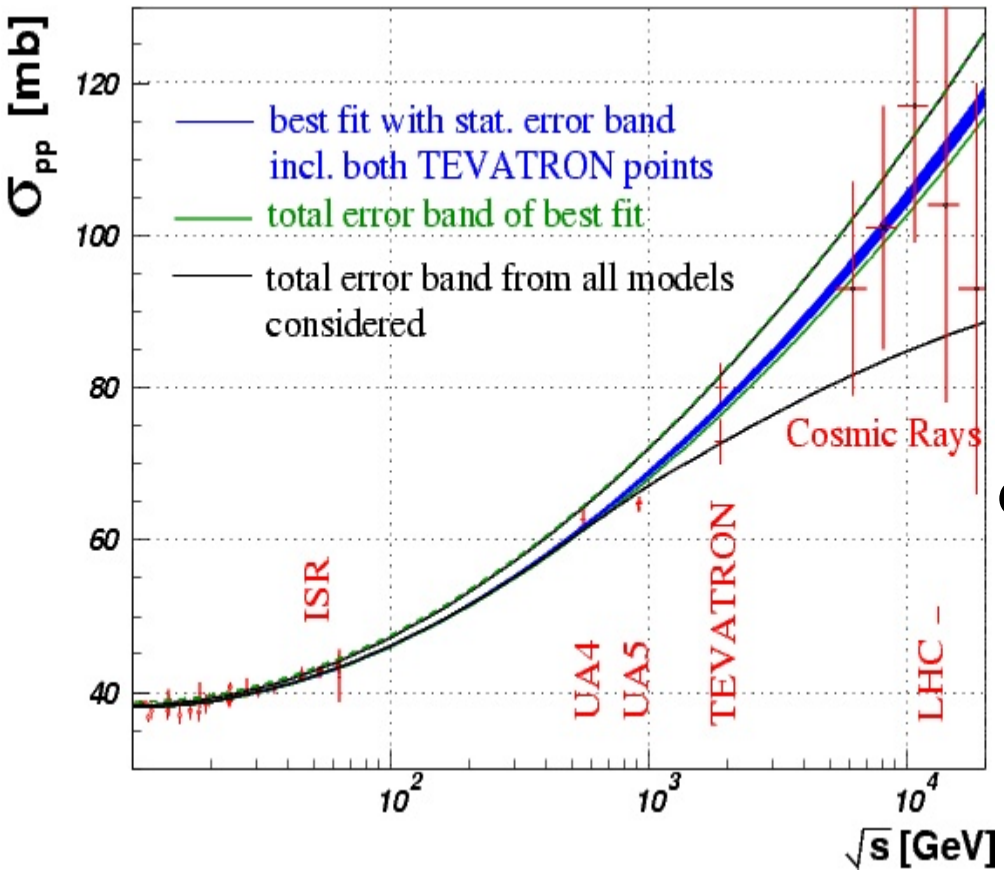
Insensitive edge = ~ 5 μm

Tolerant up to 10^{14} "n"/cm^2 if operated at -20 C

Full size prototype



Total cross-section: experimental results



Previous measurements: PS, ISR, SPS, TEVATRON, Cosmic Rays

$\sigma \sim (\log(s))^{\gamma}$ with $\gamma \sim 2$

COMPETE fit predicts at the LHC energy:

$$\sigma = 111.5 \pm 1.2^{+4.1}_{-2.1} mb$$

$$\rho = \frac{\mathrm{Re}(F)}{\mathrm{Im}(F)} = 0.1361 \pm 0.0015^{+0.0058}_{-0.0025}$$

σ_{tot}: experimental method

Luminosity independent measurement using the **Optical theorem**.

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

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

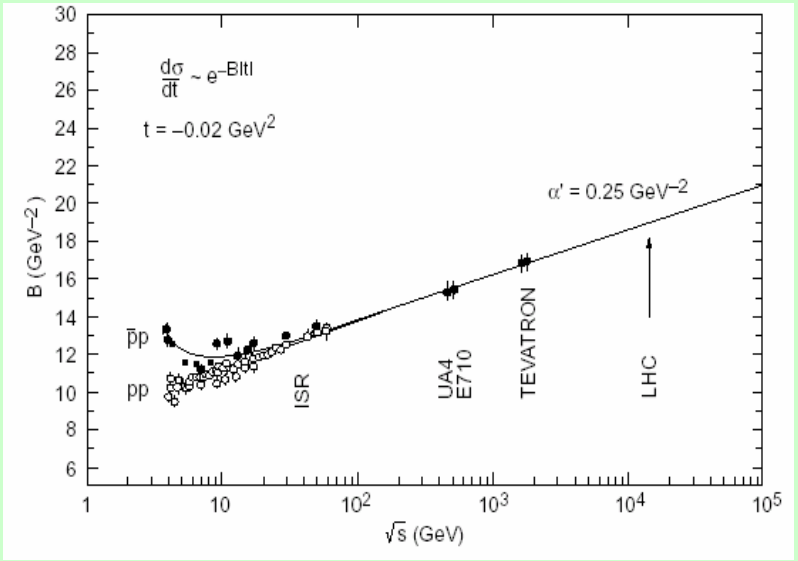
$$\Rightarrow \boxed{\sigma_{tot} = \frac{16\pi}{1+\rho^2} \times \frac{\left.(dN_{el}/dt)\right|_{t=0}}{N_{el} + N_{inel}}}$$

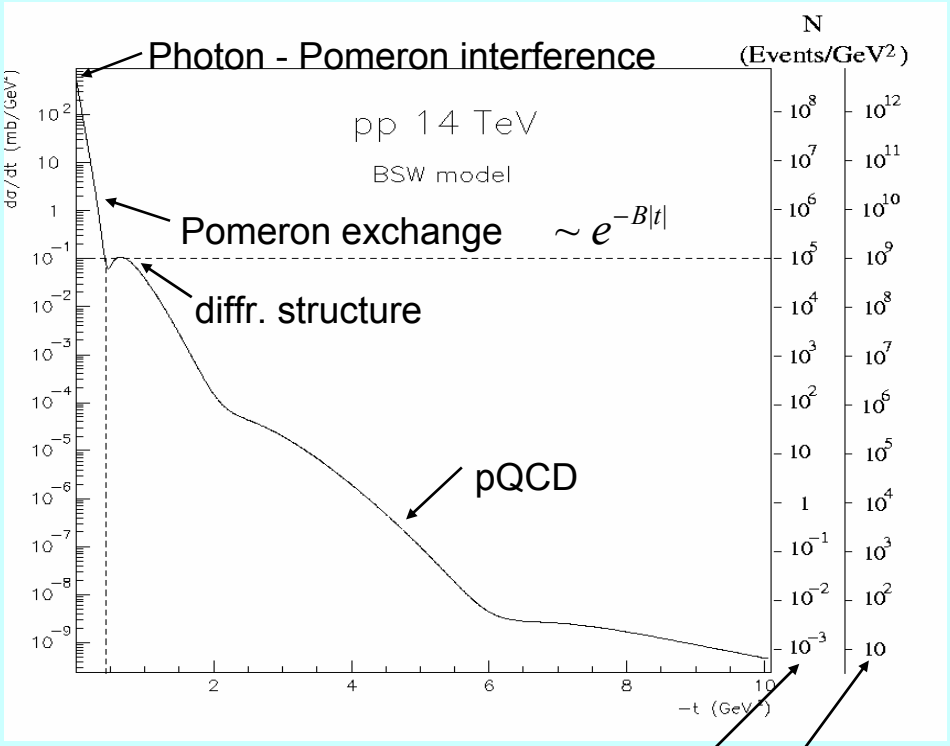
- $(dN_{el}/dt)_{t=0}$
- total rate $(N_{el} + N_{inel})$

< 1% precision

Elastic scattering: dσ/dt

$$\frac{d\sigma}{dt} \sim e^{-B|t|}$$





TOTEM Optics Conditions

$\mathcal{L}_{TOTEM} \sim 10^{28}\ cm^{-2}\ s^{-1}$

TOTEM needs dedicated short runs at high-β* (1540m) and low ε

Scattering angles of a few μrad

High-β optics for precise measurement of the scattering angle $\sigma(\theta^*) = \sqrt{\varepsilon / \beta^*} \sim 0.3\ \mu rad$

As a consequence large beam size $\sigma(y^*) = \sqrt{\varepsilon\ \beta^*} \sim 0.4\ mm$

Reduced number of bunches (43 and 156) to avoid interactions further downstream

Parallel-to-point focusing (v=0) in both projections

Trajectories of proton scattered at the same angle but at different vertex locations

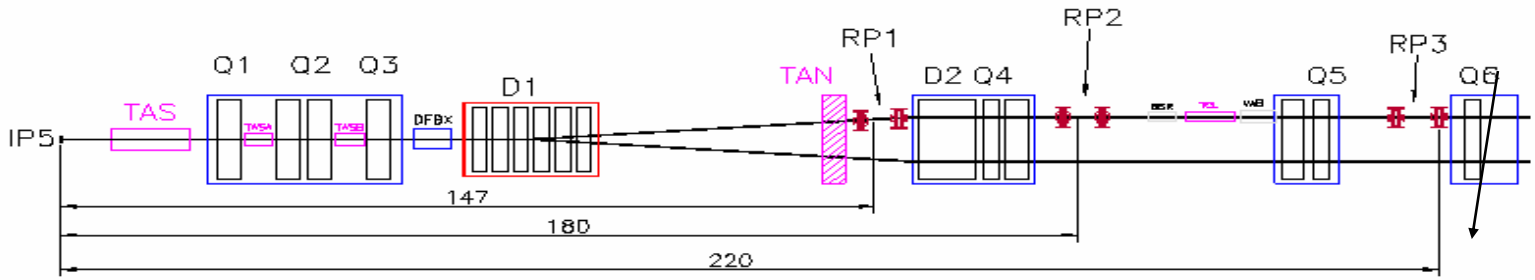
$$y = L_y\ \theta_y^* + v_y\ y^* \qquad L = (\beta\beta^*)^{1/2} \sin \mu(s)$$

$$x = L_x\ \theta_x^* + v_x\ x^* + \xi\ D_x \qquad v = (\beta/\beta^*)^{1/2} \cos \mu(s)$$

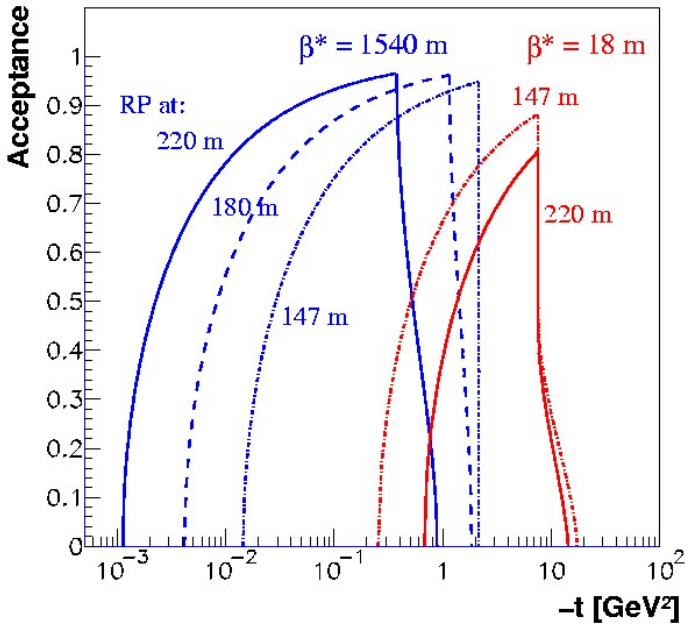
$\mu(s) \sim \pi/2$

Maximize L and minimize v

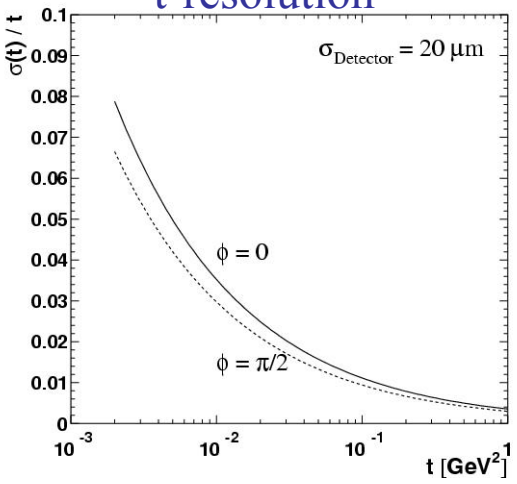
Elastic Scattering



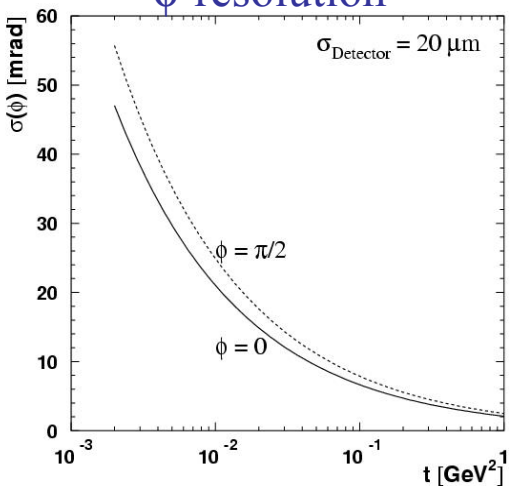
β* = 1540 m



t-resolution

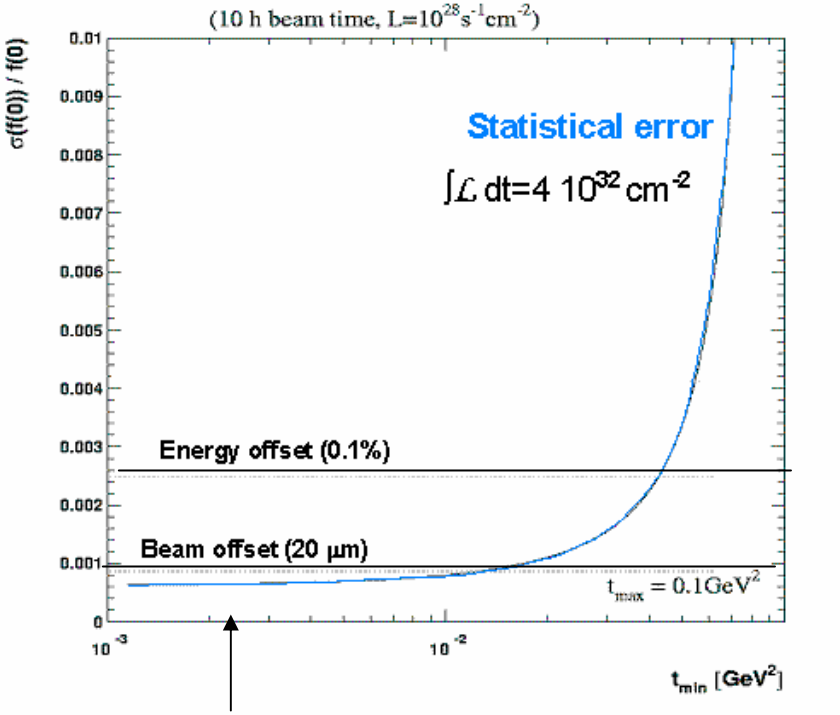


ϕ-resolution



Test collinearity of particles in the 2 arms
⇒ Background reduction.

Extrapolation to t=0



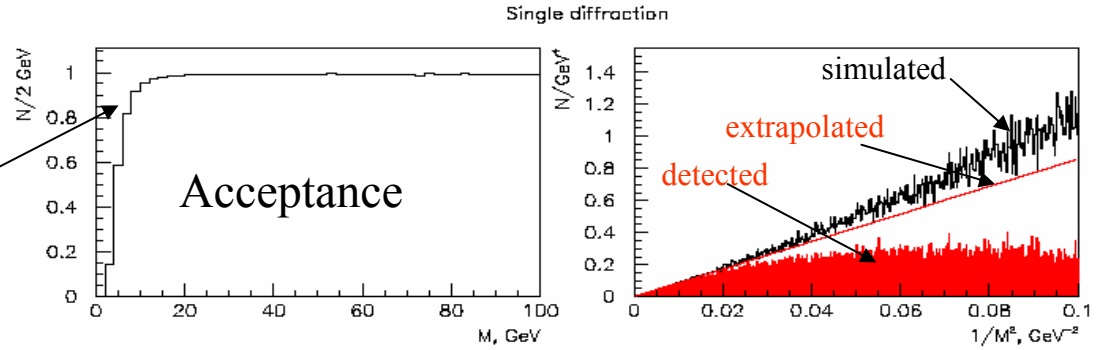
	Uncertainty	Fit error
Statistics	0.1 %	
Beam divergence	10%	0.05%
Energy offset	0.05%	0.1%
Beam/ detector offset	20μm	0.06/0.08 %
Crossing angle	0.2μrad	0.08/0.1%
Theoretical uncertainty	(model dependent)	~ 0.5%

Inelastic and total cross section

Inelastic event selection:

- trigger from T1 or T2 (*double arm o single arm*)
- Vertex reconstruction (to eliminate beam-gas bkg.)
- 2.8 mb lost because of acceptance in diffractive events. Extrapolation needed

Loss at low masses



Pythia generator

Losses	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

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

Conclusion

- TOTEM TDR approved by LHCC
- TOTEM will use dedicated short runs with high-β^*optics
- TOTEM will measure:
  - Total cross-section within 1%
  - Elastic scattering up to -t = 8 GeV^2
  - Diffractive events (see talk of M.Deile)