Preliminary Results from the TOTEM Experiment

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(on behalf of the TOTEM Collaboration)

MPI@LHC 2010

Glasgow – December 2, 2010

- **Experiment Overview**
- **Detector Commissioning**
- **Preliminary Results**

TOTEM @ CERN Large Hadron Collider (LHC)

LHC

- p-p collisions at $\sqrt{s}$ up to 14 TeV
- $\mathcal{L}_{inst}$ up to ~ 10^{33} $cm^{-2}s^{-1}$
- started in Fall 2009
- 6 experiments

TOTEM

- Total Cross Section
- Elastic Scattering
- Diffractive Dissociation

Total and **E**lastic **M**easurement

TOTEM Collaboration: Bari, Budapest, Case Western Reserve, CERN, Genova, Helsinki, Pisa/Siena, Prague, Tallin (~ 80 physicists)

TOTEM Physics Program Overview

Stand-Alone

- **σ_{TOT}^{pp}** with a precision ~ 1-2%, simultaneously measuring:

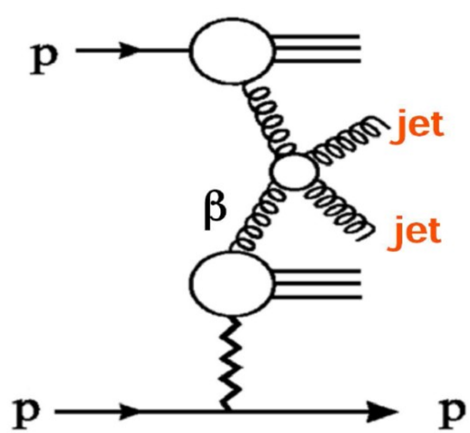
  N_{el} down to $-t \sim 10^{-3}$ GeV^2 and

  N_{inel} with losses < 3%

- Elastic pp scattering in the range $10^{-3} < |t| \sim (p\theta)^2 < 10$ GeV^2
- Soft diffraction (SD and DPE)
- Particle flow in the forward region (cosmic ray MC validation/tuning)

CMS-TOTEM **(CMS/TOTEM Physics TDR, CERN/LHCC 2006-039/G-124)**

- Soft and hard diffraction in SD and DPE (production of jets, bosons, h.f.)
- Central exclusive particle production
- Low-x physics
- Particle and energy flow in the forward region



Total Cross Section σ_{PP}

- Current models predict at $\sqrt{s}$ = 14 TeV: σ_{PP} = 90 - 130 mb

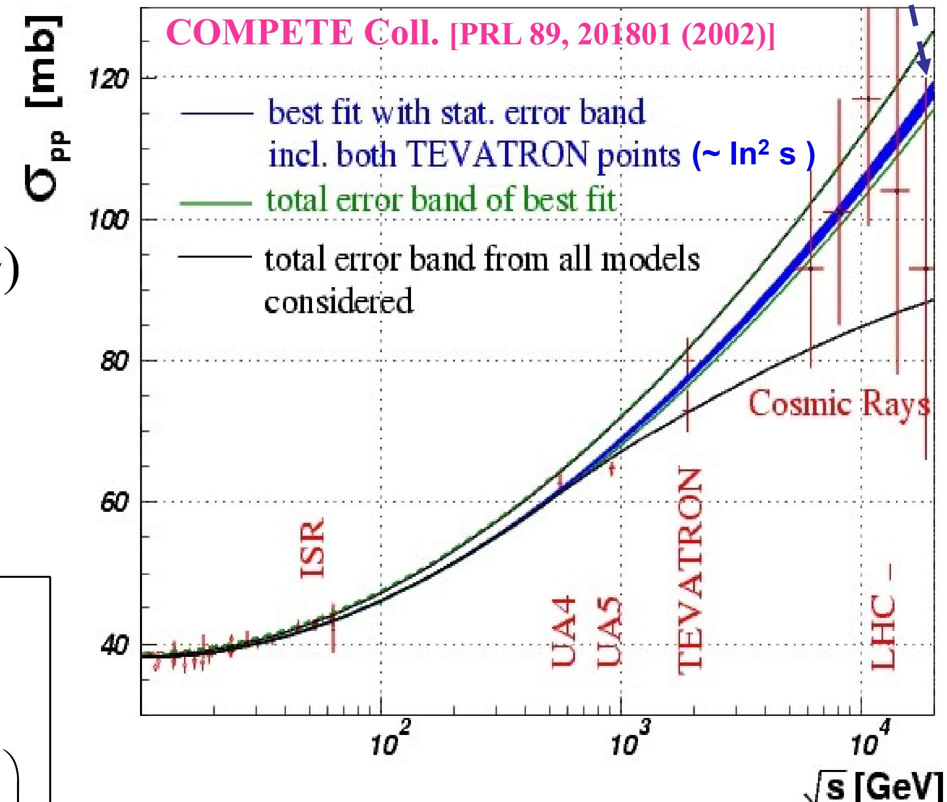
$$\sigma_{tot} = 111.5 \pm 1.2 \, {}^{+4.1}_{-2.1} \text{ mb}$$

- TOTEM goal: absolute error ~ 1mb ($\mathcal{L}_{inst} \sim 10^{28}$ cm^{-2}s^{-1})

  ⇒ possibility to distinguish among different models

- **Luminosity independent method**:
  - elastic scattering (down to $|t| \sim 10^{-3}$ GeV^2)
  - inelastic scattering

  ⇒ proper tracking acceptance in forward region required



Optical Theorem:

$$\sigma_T = \frac{8\pi}{p\sqrt{s}} \operatorname{Im} F(s,t)\big|_{t=0}$$

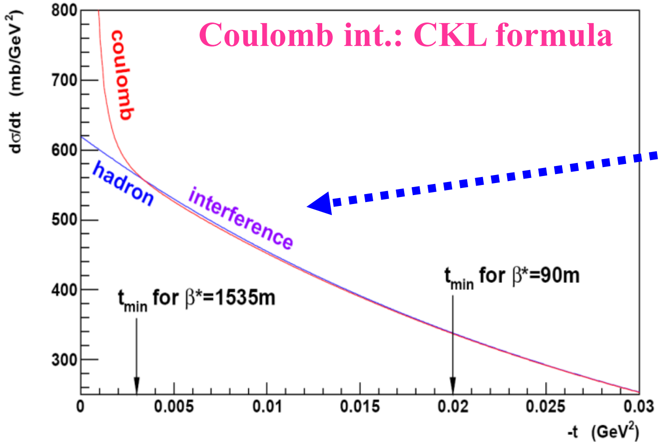
$$L\,\sigma_T^2 = \frac{16\pi}{1+\rho^2} \times \left.\frac{dN_{el}}{dt}\right|_{t=0} \qquad \left(\rho = \left.\frac{\operatorname{Re} F}{\operatorname{Im} F}\right|_{t=0} \sim 0.136 \right)$$

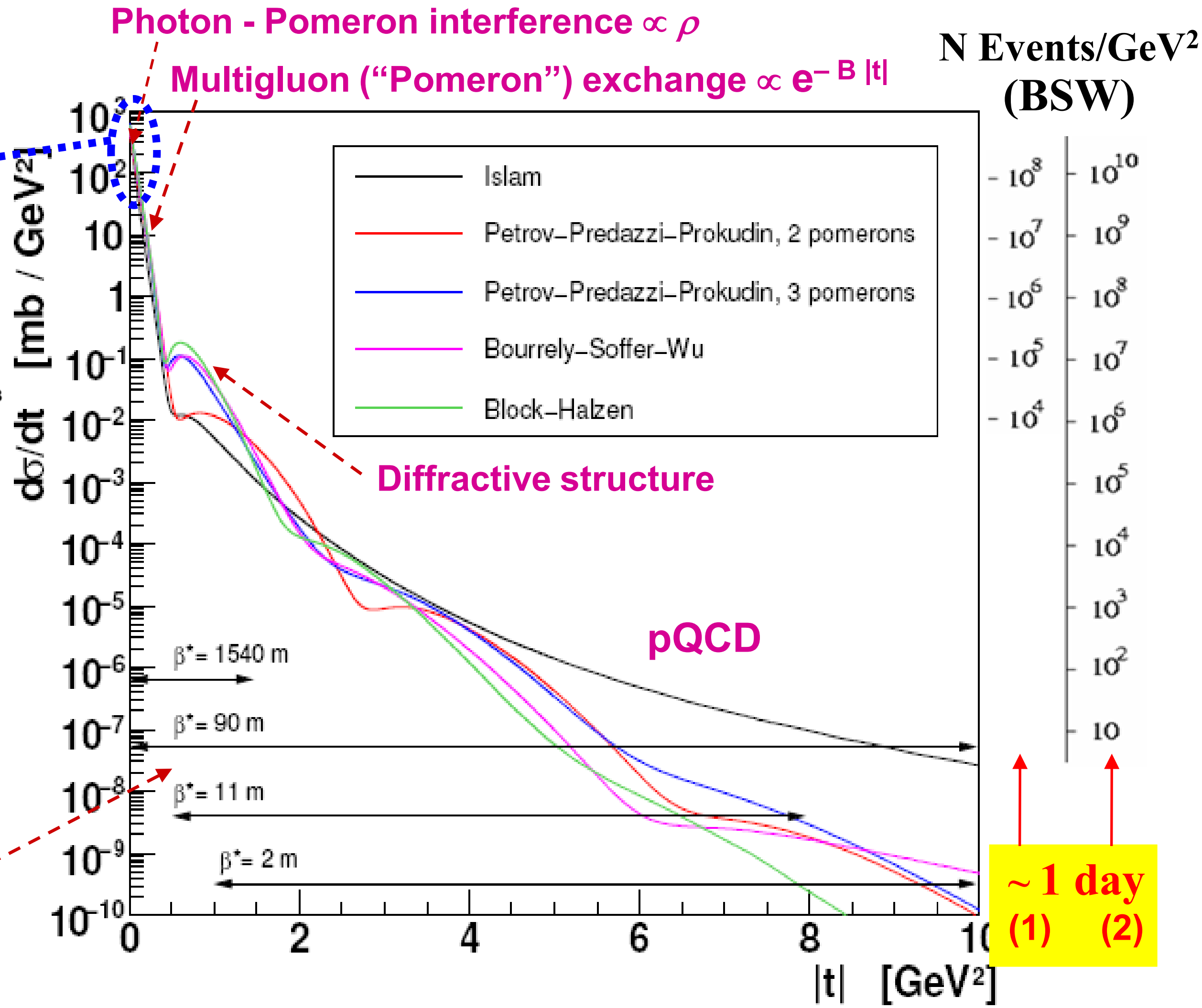
$$L\,\sigma_T = N_{el} + N_{inel}$$

⇒

$$\sigma_T = \frac{16\pi}{1+\rho^2} \times \frac{(dN_{el}/dt)\big|_{t=0}}{N_{el} + N_{inel}}$$

Elastic Scattering Cross Section $d\sigma_{PP}^{el}/dt$ ($\sqrt{s}$ = 14 TeV)





Predicted at LHC:

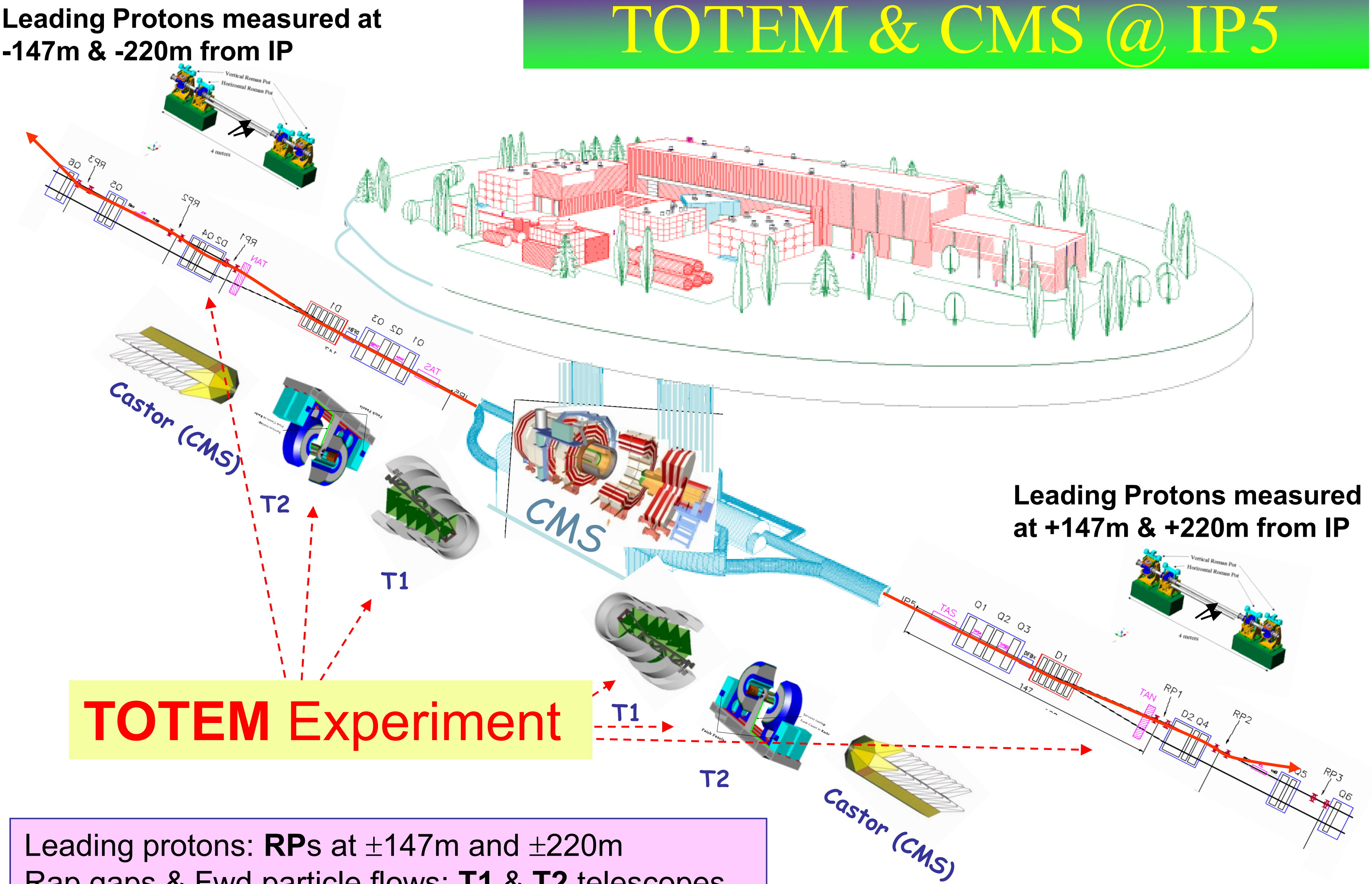
σ_{PP}^{el} ~ 18 - 35 mb

Wide range of predictions; big uncertainties at large |t|; whole |t| range measured with good statistics.

Allowed |t| range

Dedicated short runs at high-β* (and reduced ε) are required for precise measurement of the scattering angles of a few μrad

TOTEM & CMS @ IP5



Leading protons: **RP**s at ±147m and ±220m
Rap gaps & Fwd particle flows: **T1** & **T2** telescopes
Fwd energy flows: Castor & ZDC (CMS)

TOTEM Detectors: Setup in IP5

De

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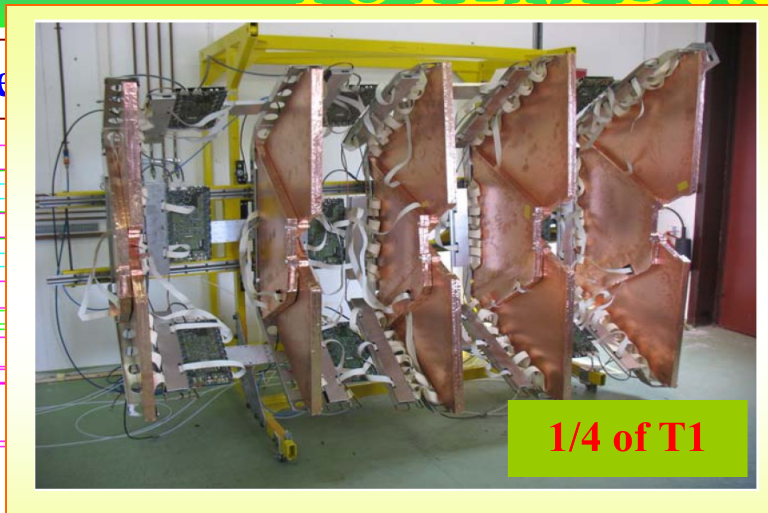
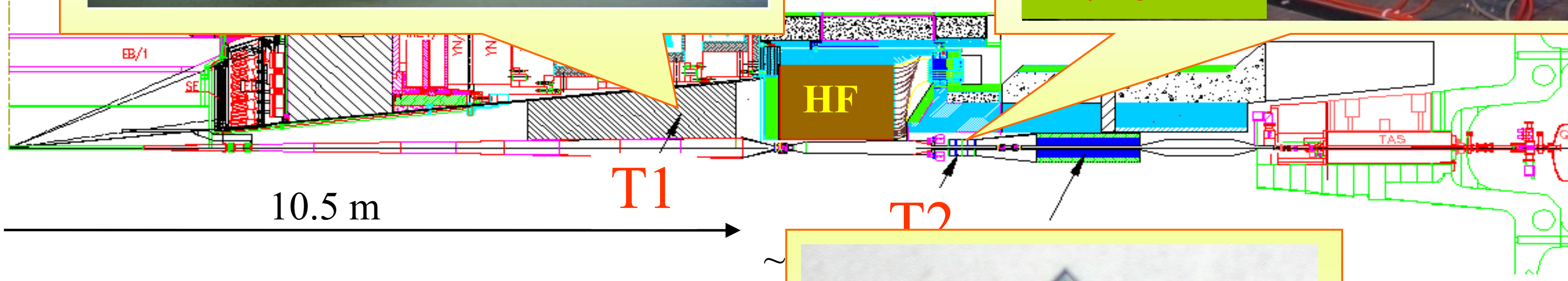
trigger ca

T1: 3.1 <

T2: 5.3 <

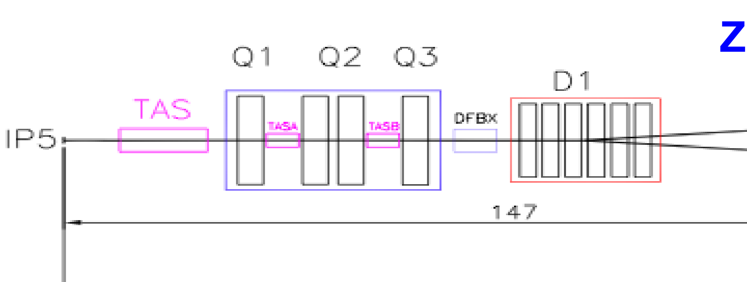
d

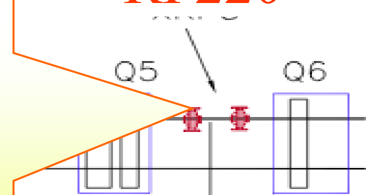


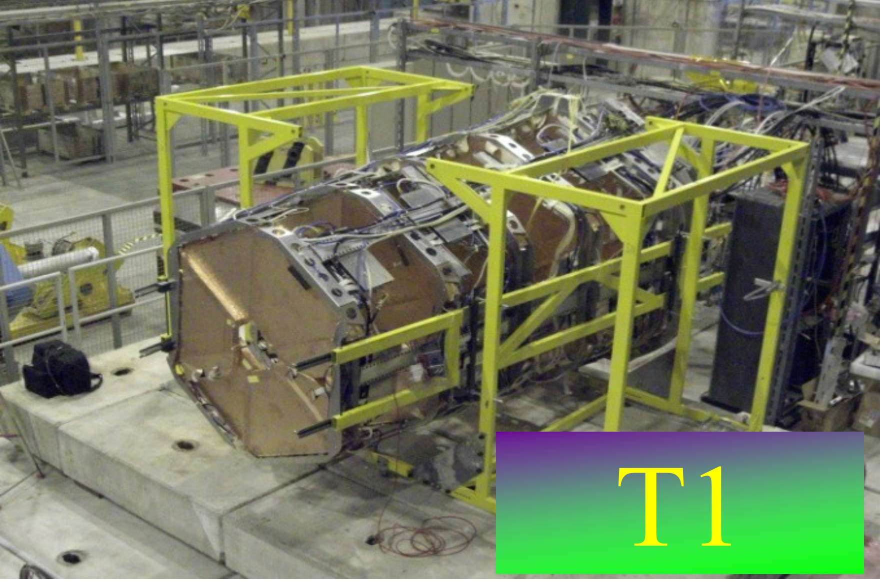


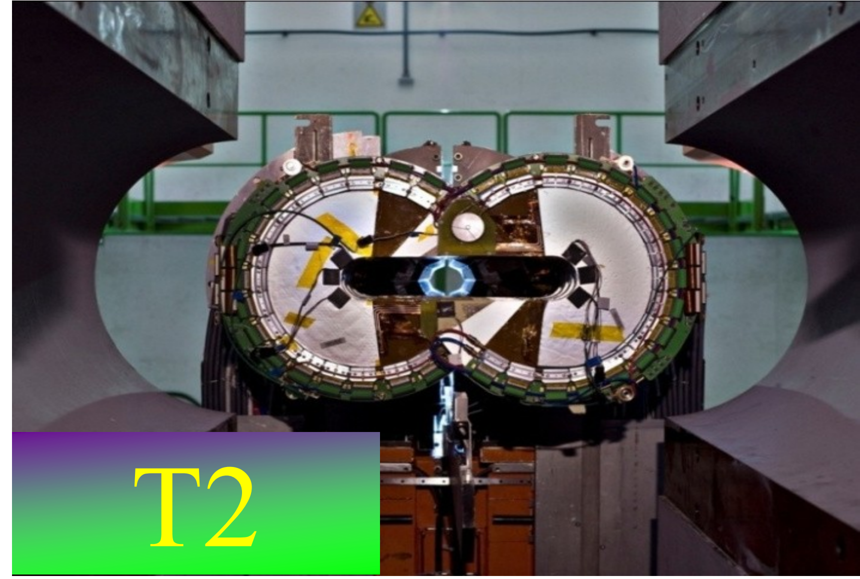
Elastic Detectors (Roman Pots): re cattered and diff. p

Active area down to 1-1.5 mm from beam: 5









Each arm: (T1)

- **5 planes** with 3 coordinates/plane, each formed by 6 trapezoidal **CSC** detectors
- Trigger from anode wires
- Resolution: **$\sigma \sim$ 1 mm**

Ageing studies at CERN GIF: no loss of performance during test with a dose equivalent to ~ 5 years at $\mathcal{L}_{inst}=10^{30}\ cm^{-2}s^{-1}$

Installation foreseen for Winter 2010 shutdown

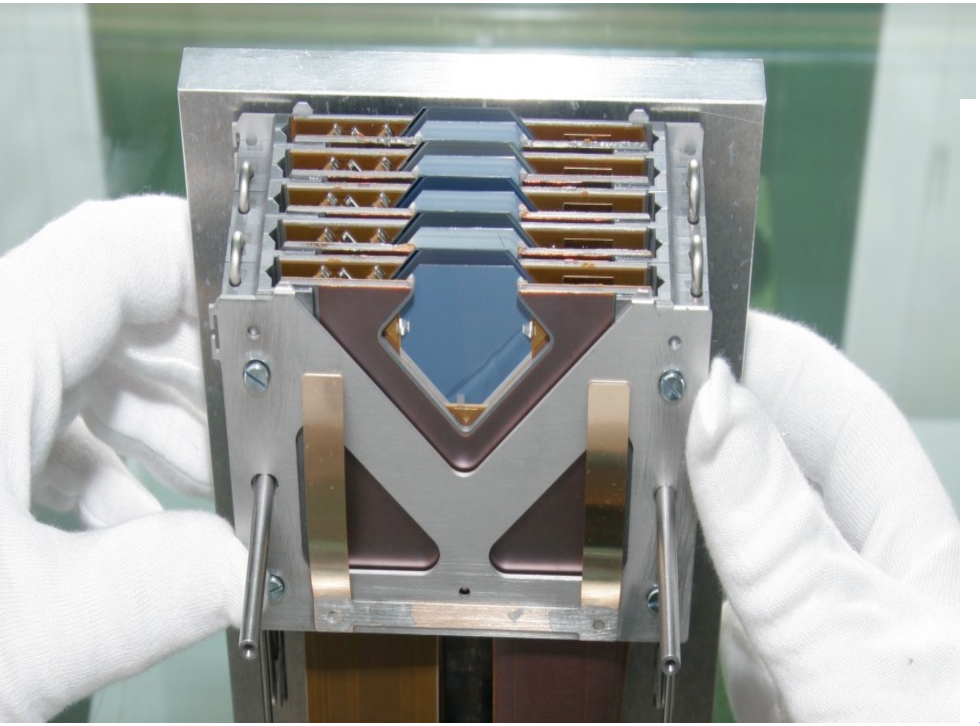
Each arm: (T2)

- **10 planes**, each formed by 2 "triple-**GEM**" semi-circular detectors
- Double readout layer: Strips for radial position (R); Pads for R, ϕ
- Trigger from Pads
- Resolution: $\boldsymbol{\sigma_R \sim 100\ \mu m,\ \sigma_\phi \sim 1^o}$

T2 triple-GEM technology adequate to work at least 1 yr at $\mathcal{L}=10^{33}\ cm^{-2}s^{-1}$

Fully installed

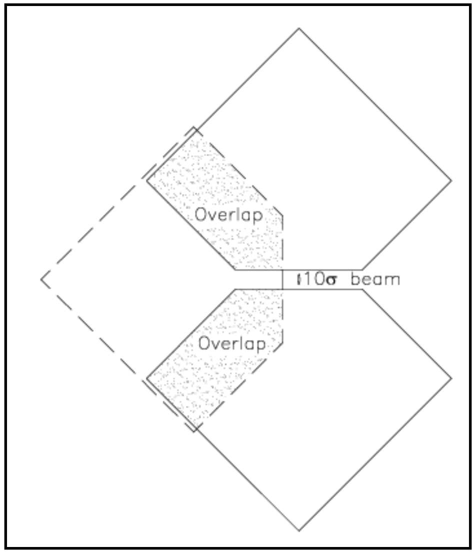
Roman Pots



Each Pot:

- **10 planes** of Si detectors
- 512 strips at 45° orthogonal
- Pitch: 66 μm
- Resolution: $\sigma \sim 20$ μm

Detectors expected to work up to $\mathcal{L}_{int} \sim 1\ fb^{-1}$



Horizontal Pot: extend acceptance; overlap for relative alignment using common track.

Absolute (w.r.t. beam) alignment from beam position monitor **(BPM)**

<u>RP 220m fully installed</u>

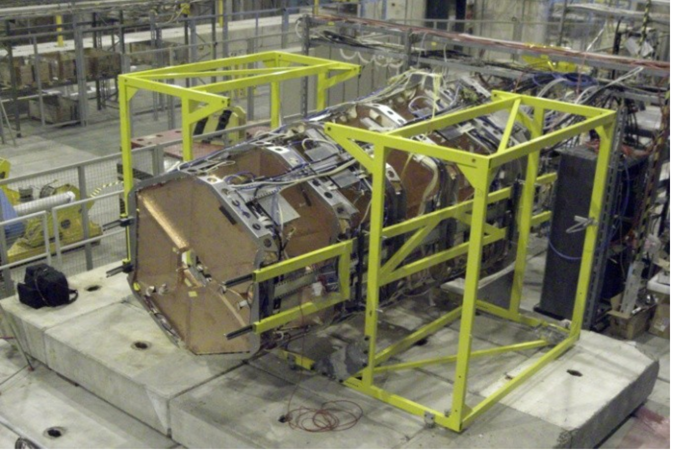
<u>RP 147m installation foreseen in Winter 2010 shutdown</u>

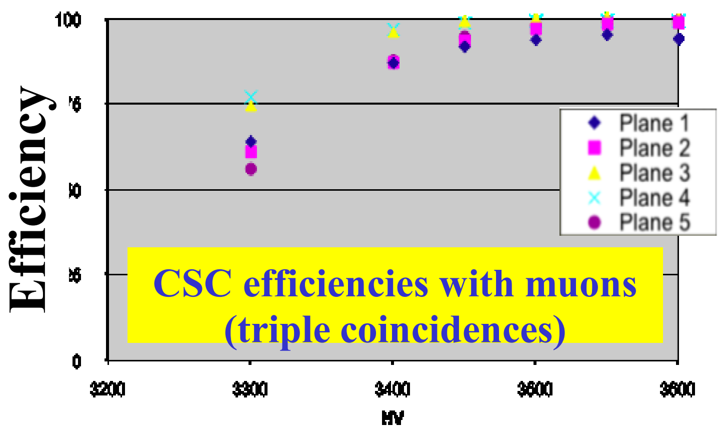
Detector Commissioning & Preliminary Results

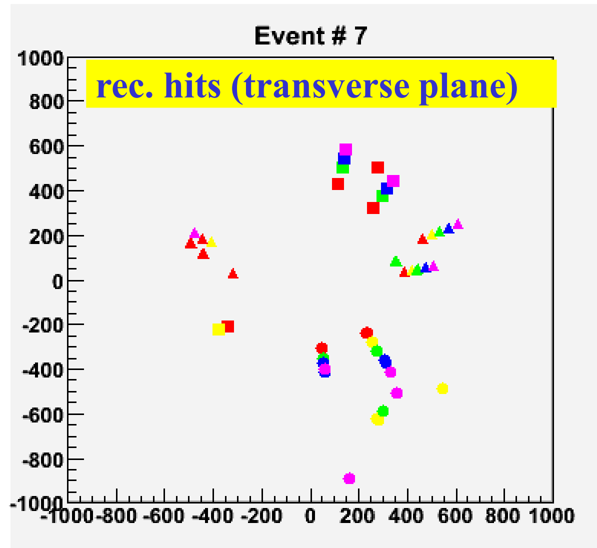
T1 Telescope

READY FOR INSTALLATION (Winter 2010 shutdown)

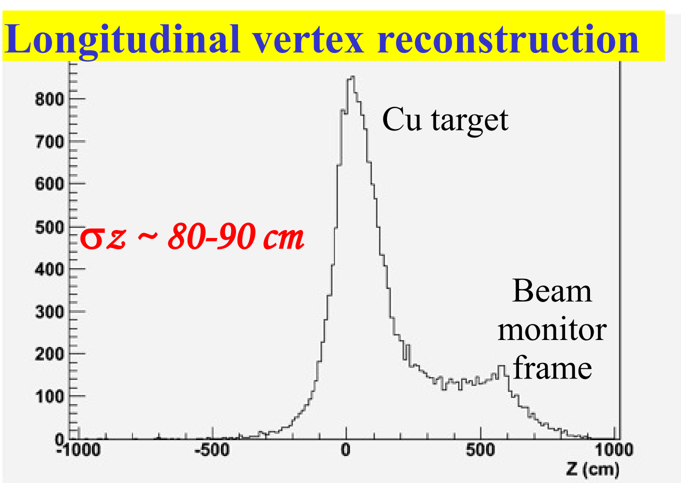
Both arms assembled and successfully tested with pion and muon beams in the test line H8

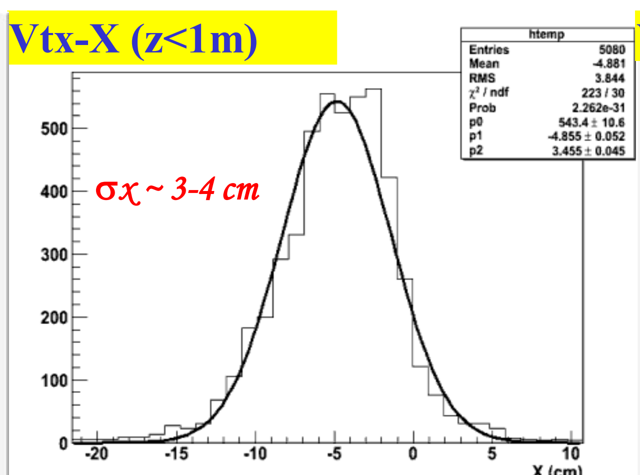


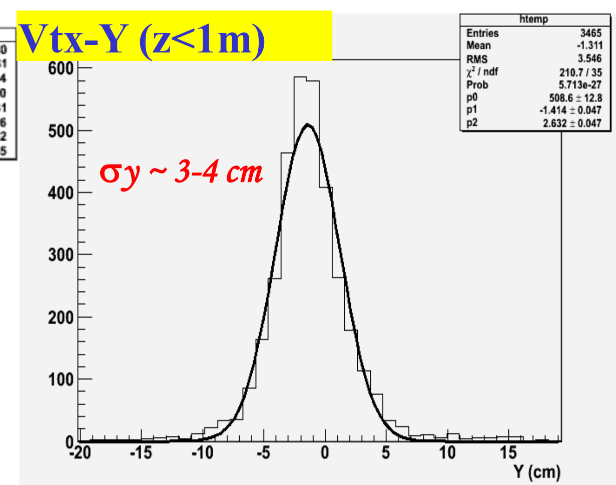




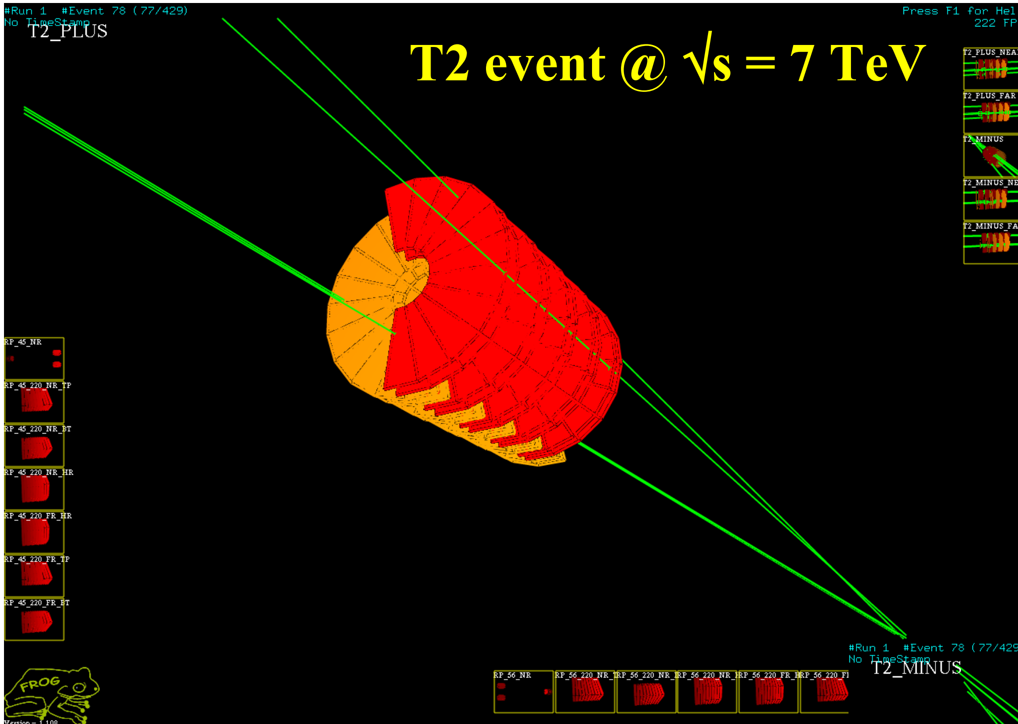
Pions on Cu target to get many-trk events



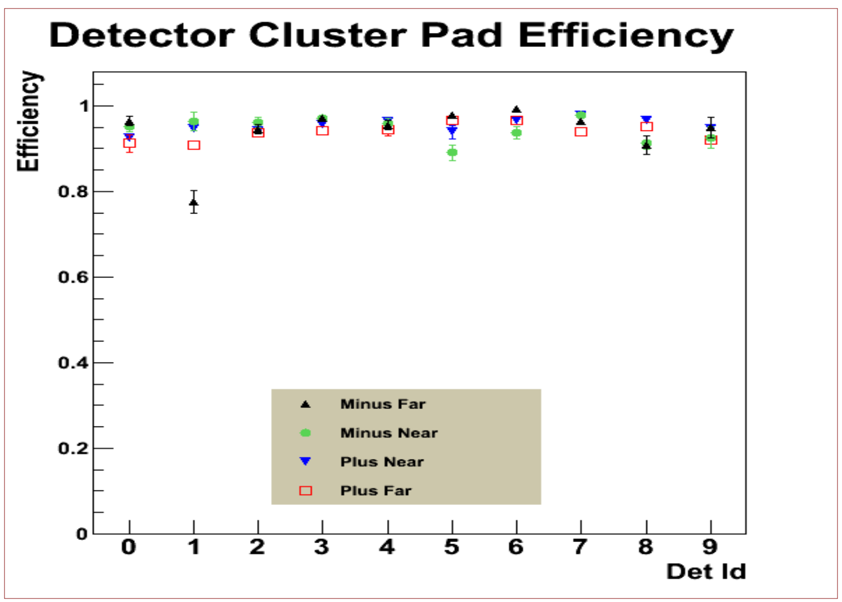


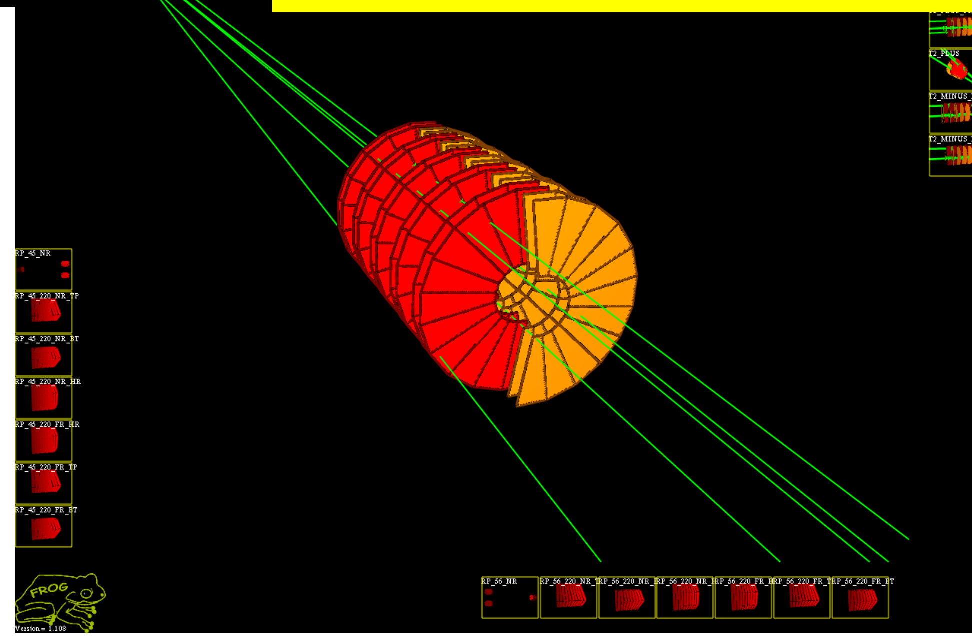


T2 Telescope



Fully installed, operative and commissioned on data





T2 Alignment - I

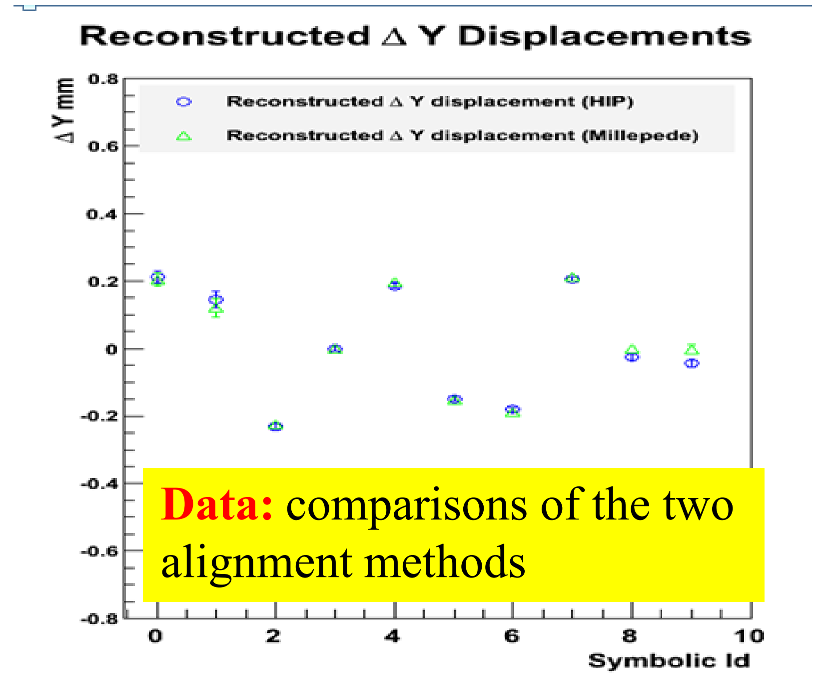
Not negligible effects to be corrected for:

- internal alignment (among planes in a quarter)
- quarter-quarter alignment (using overlap region)
- global alignment (arm respect to the vertex)

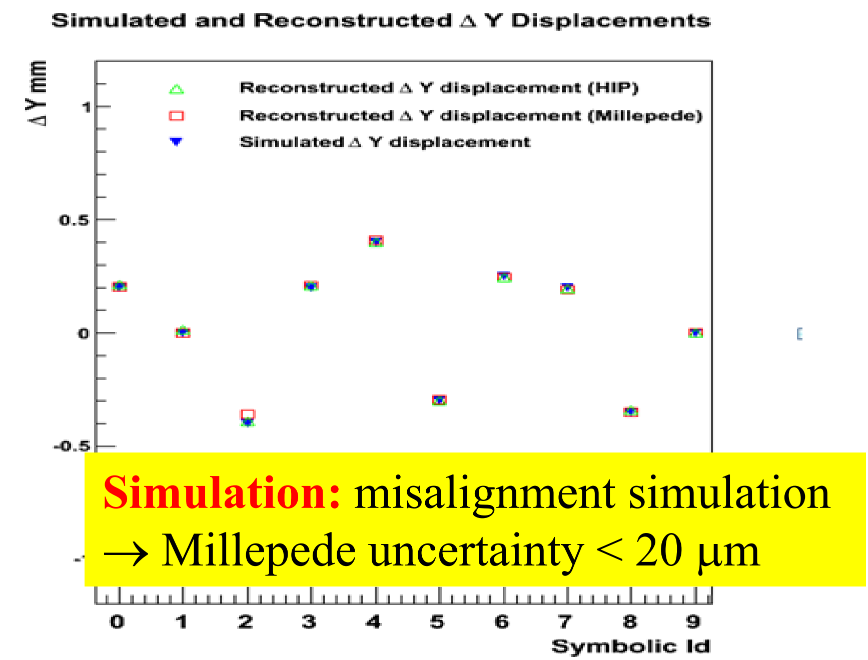
Internal alignment

Relative shifts (ΔX, ΔY) among planes are the most important source of this misalignment

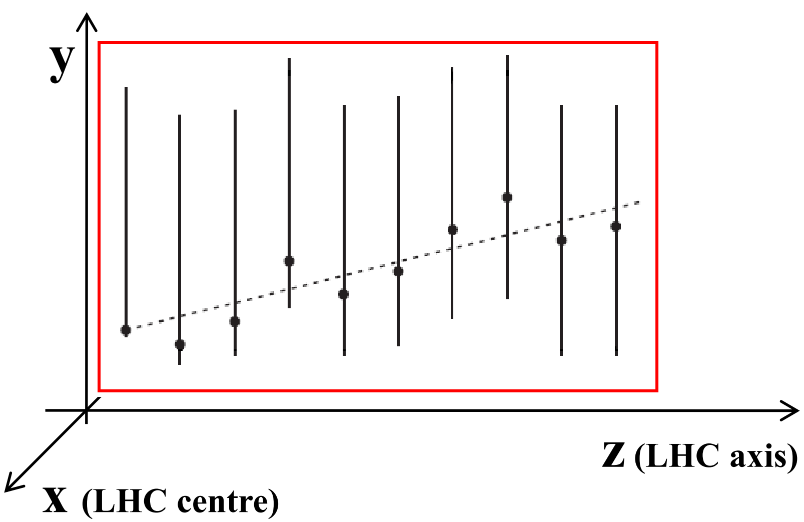
Two different methods (HIP and Millepede) implemented in order to resolve misalignment



Data: comparisons of the two alignment methods



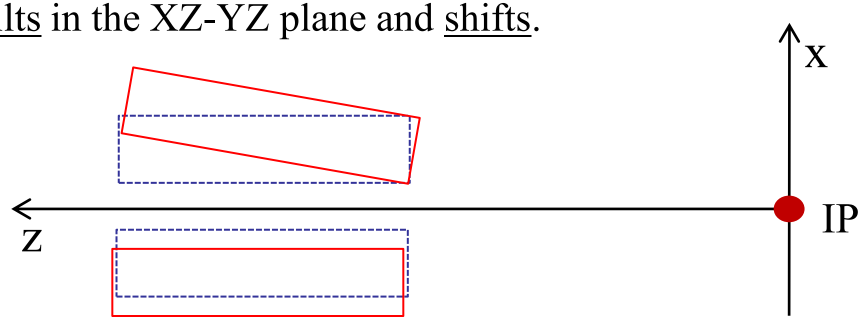
Simulation: misalignment simulation → Millepede uncertainty < 20 μm



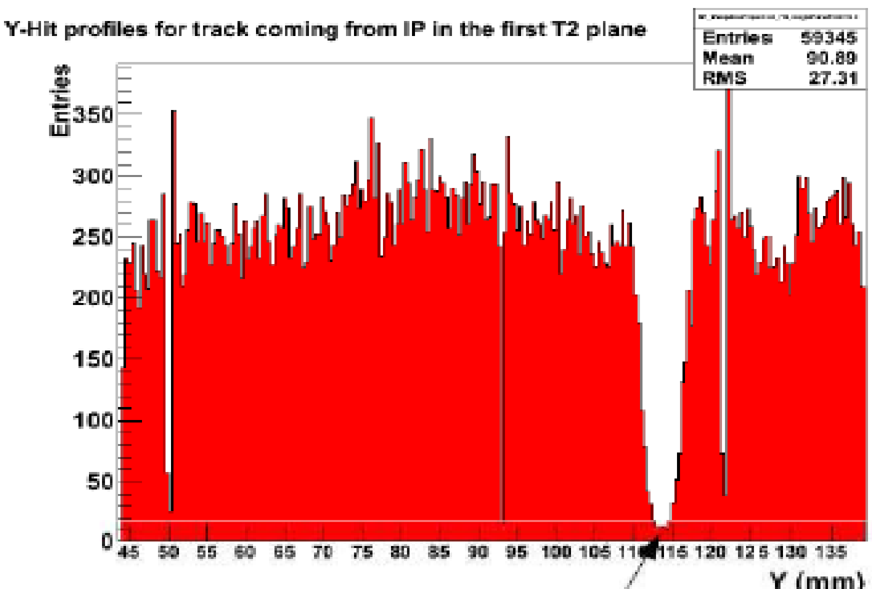
T2 Alignment - II

Quarter-quarter and global alignment

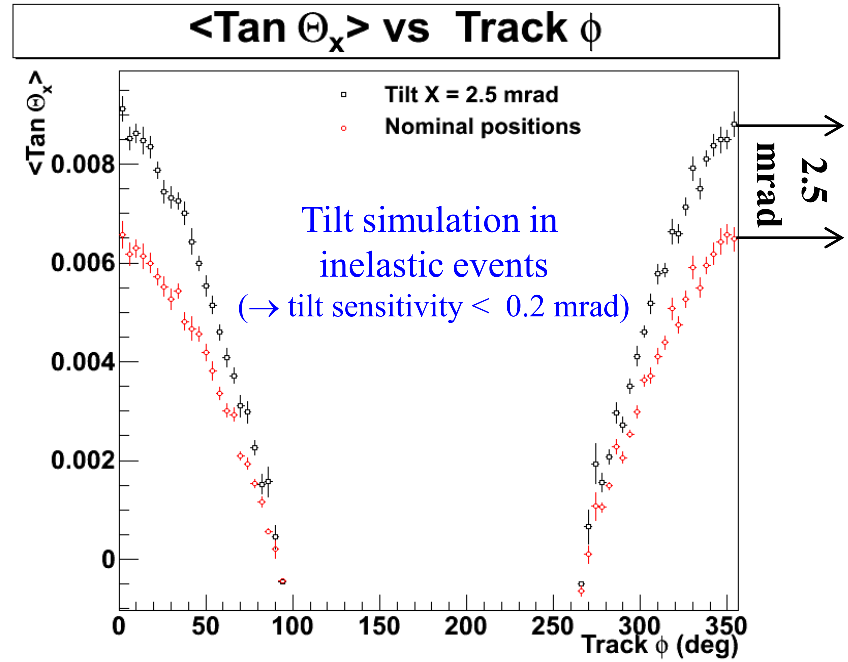
Most important quarter global misalignment: tilts in the XZ-YZ plane and shifts.

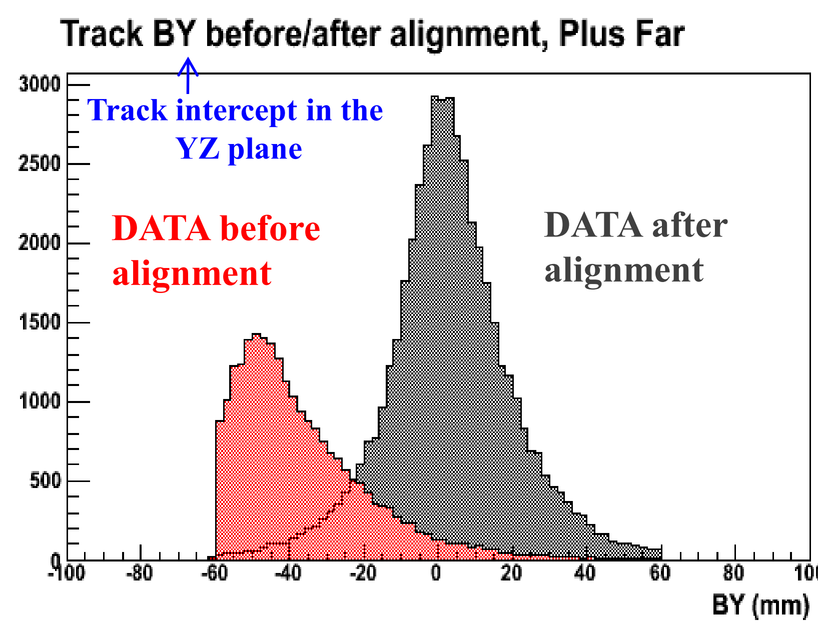


Tilts: corrections from expected symmetry in the parameter distribution of the tracks coming from the vtx

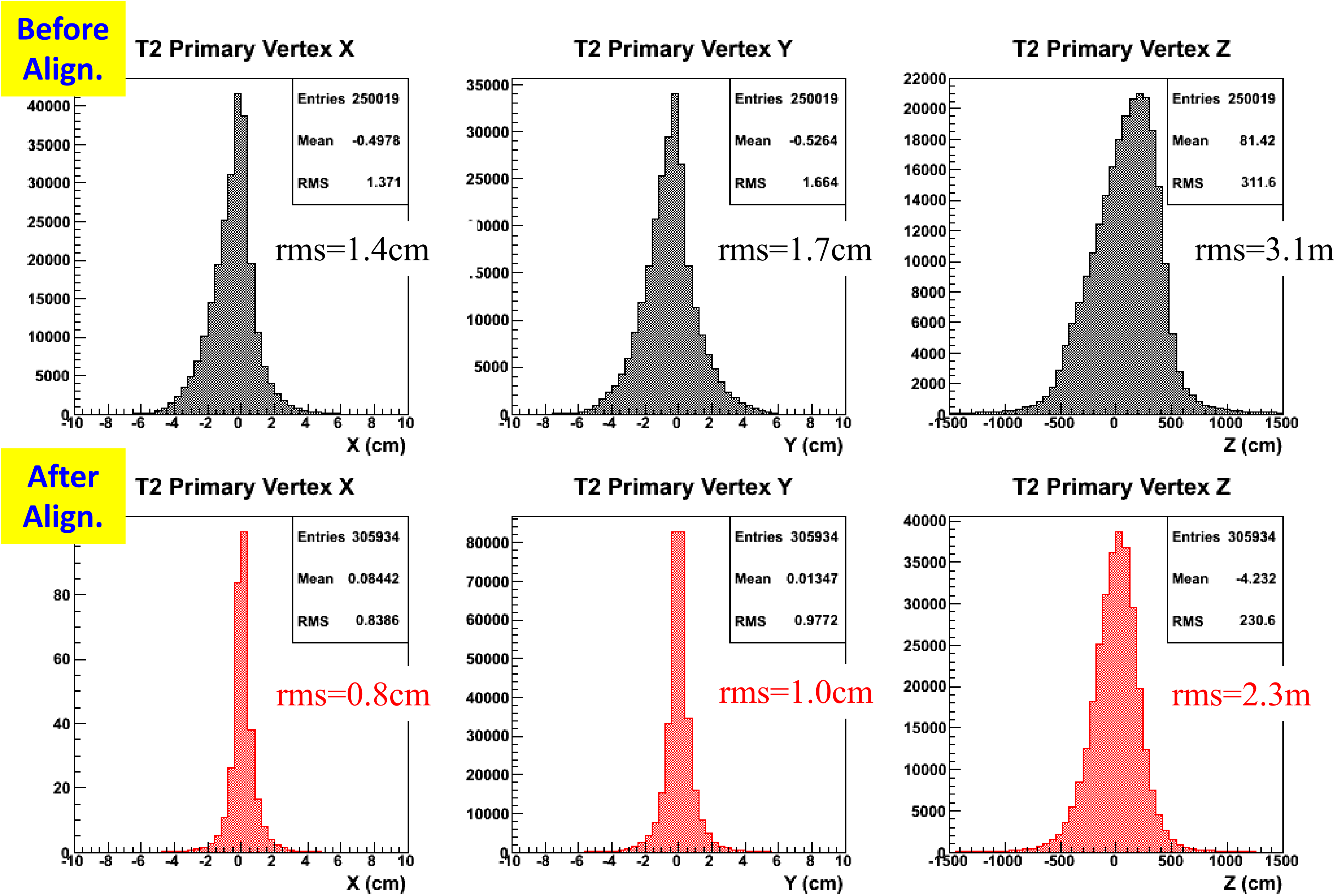


Shifts: corrections from expected position of the Beam pipe "shadow" on each plane

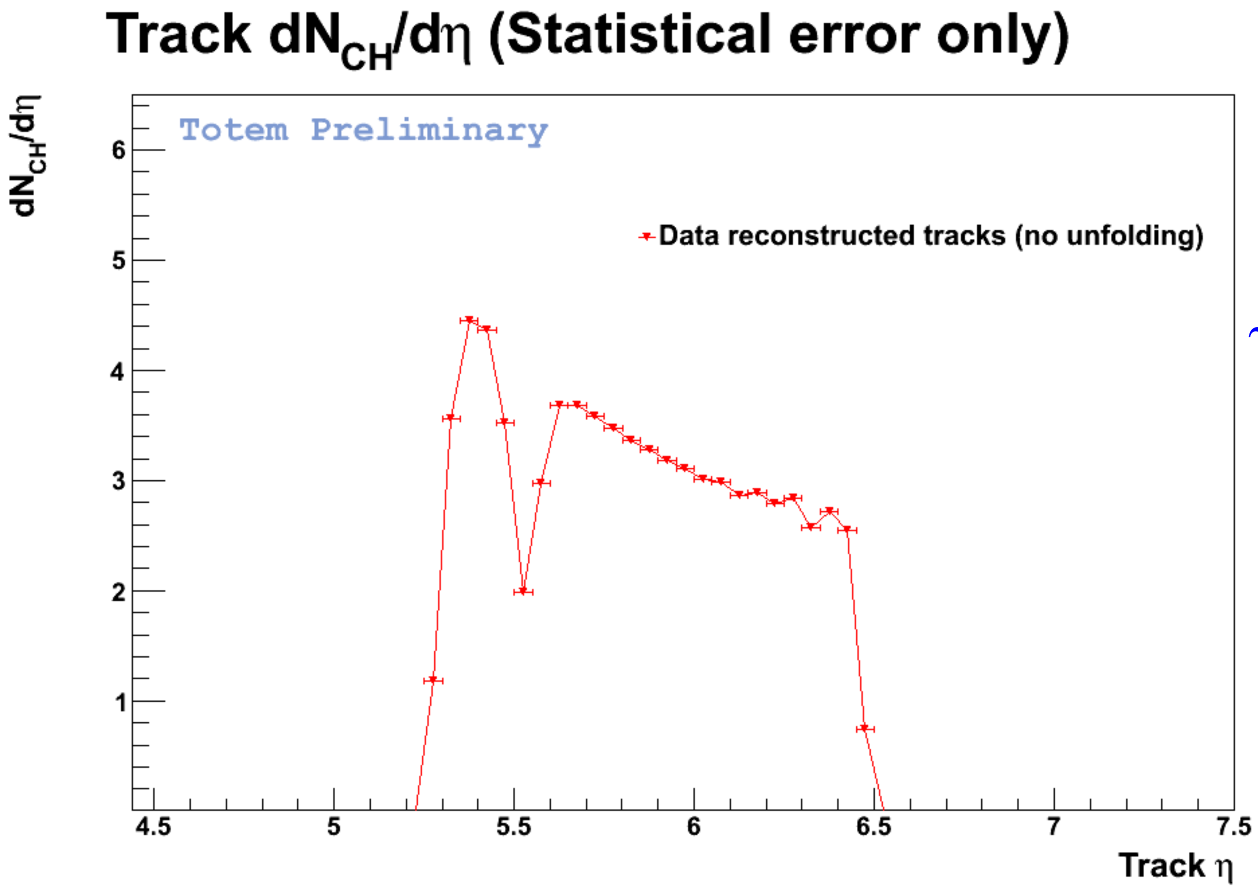




T2 Global Alignment and Vertex Reconstruction



Inelastic Processes: Preliminary $dN_{ch}/d\eta$ Distribution



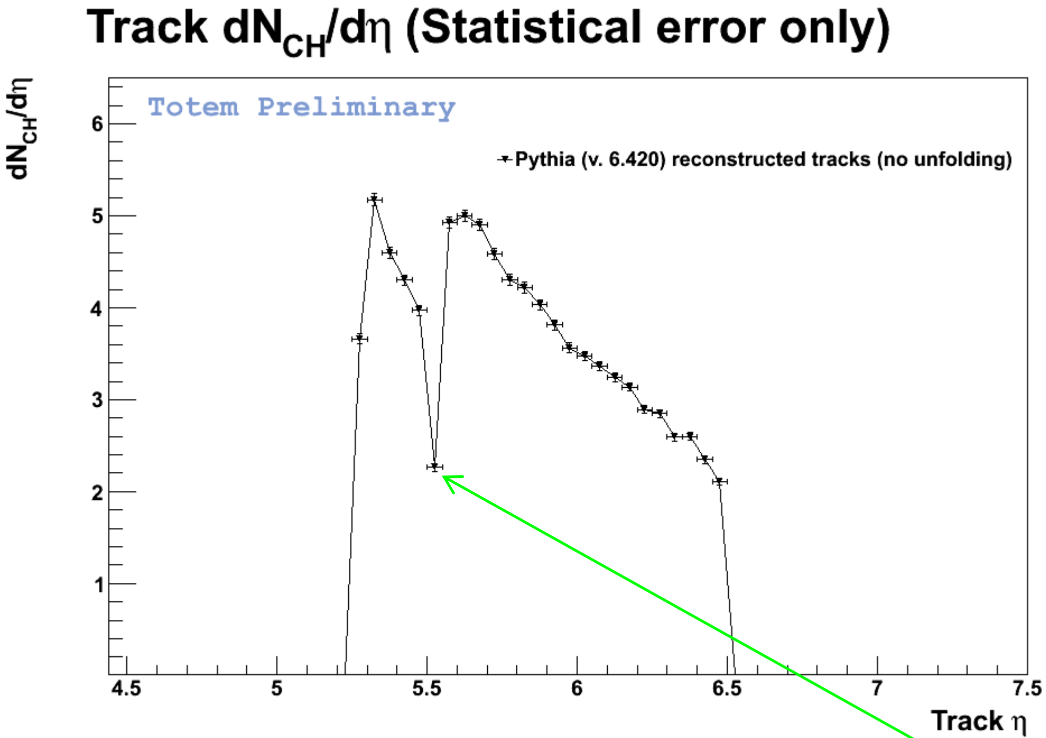
~ 400K inelastic events from 30/10/10 TOTEM dedicated run with low proton density bunches.

<u>"Raw" distribution</u>:

- No smearing corrections
- No efficiency corrections
- No secondaries contribution subtraction

Work ongoing on unfolding corrections

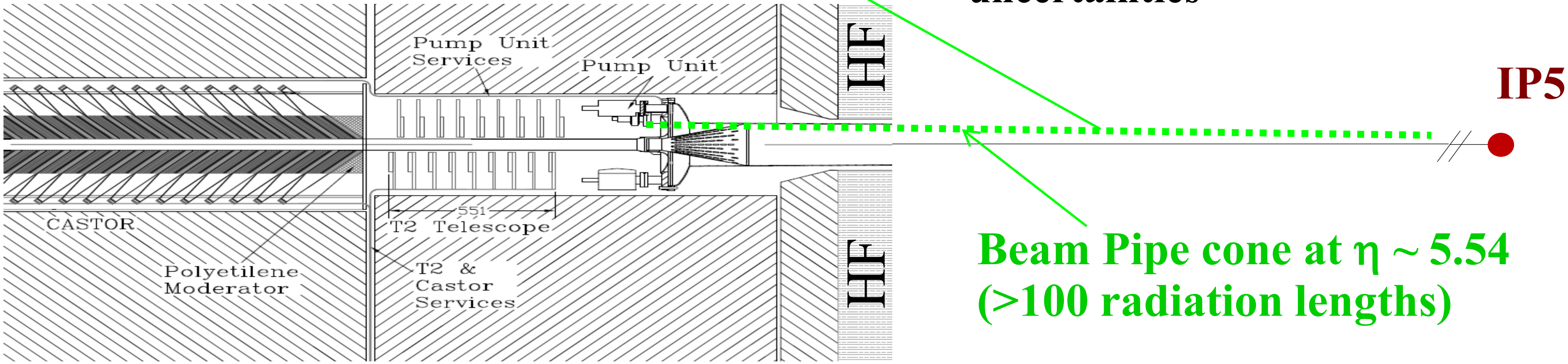
Towards the Unfolding Corrections



Preliminary study with Pythia + full Geant detector simulation

Work in progress on:

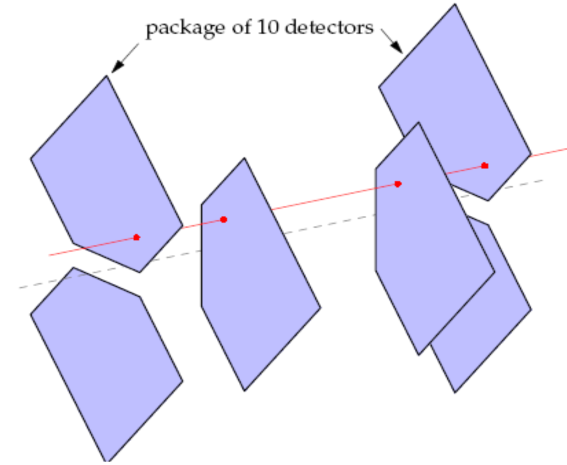
- Understanding secondary contribution and smearing effects
- Proper tuning of detector performance simulation
- Optimization of trk algorithm and selection cuts for improved rejection of secondary charged tracks,
- Estimation of systematic uncertainties



Beam Pipe cone at $\eta \sim 5.54$ (>100 radiation lengths)

Roman Pot Alignment

Fundamental for any physics measurement:

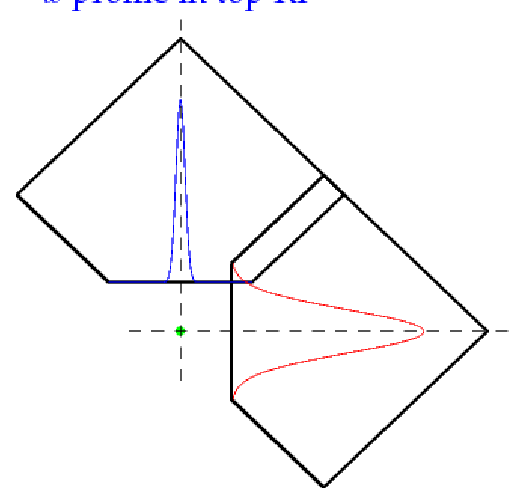


Resolve **misalignments within detector assembly**
method: local track

Resolve **relative positions of the pots**
(principal information from motor control → calibration, reliability, …)
method: local track based (detector overlap)

Resolve **position of beam**
(uncertainties and variations of optics):
method: hit profiles from physics events and Beam Halo
Cross-check: Beam Position Monitors, alignment with collimators

Resolve **left-right position**
method: global (elastic) track based

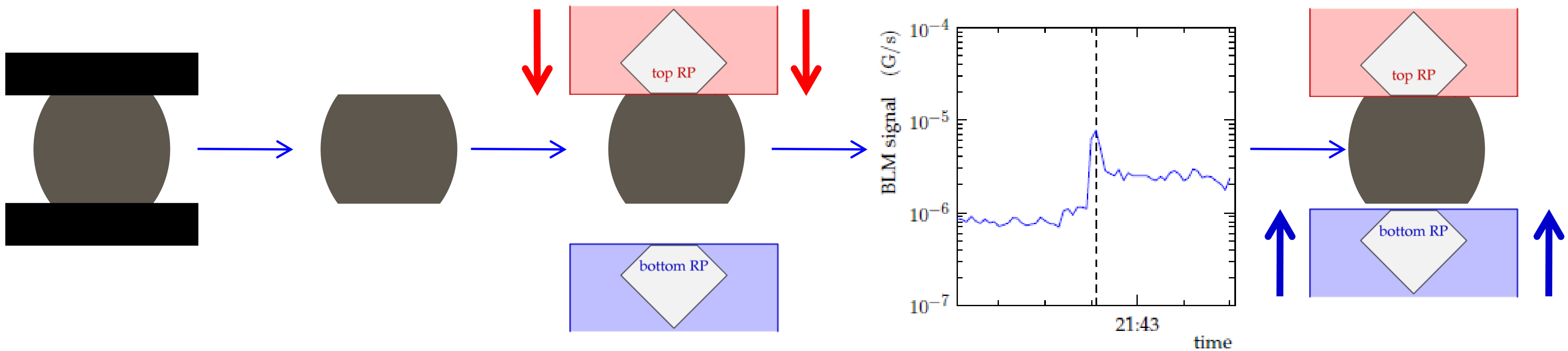


Expected precision of the alignment correction methods: few μm (internal), ~10 μm (beam position, using elastic scattering)

RP Alignment w.r.t. the Beam: Beam-Based Method

Test done at 450 GeV and at 3.5 TeV using BLM (beam loss monitor) signal during special collimator/RP setup runs

Collimator cuts a sharp beam edge symmetrically to the centre	RP approaches this edge until it scrapes …	… producing spike in BLM downstream	The second RP approaches



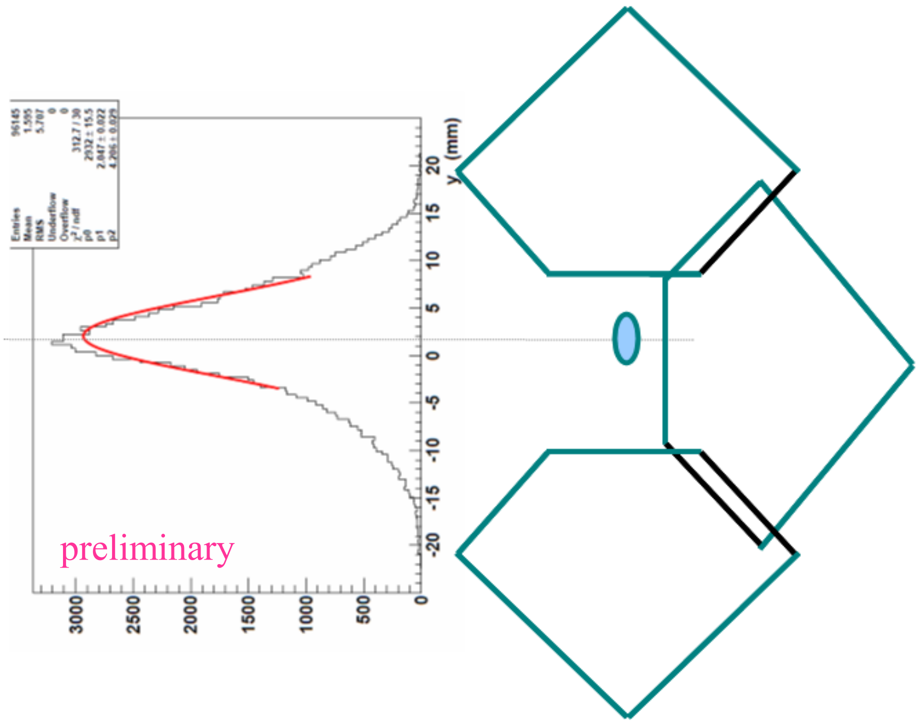
When both top and bottom pots "feel" the edge: they are at the same number of sigmas from the beam centre as the collimator and the beam centre is exactly in the middle between top and bottom pot

Procedure repeated in different configurations, allowing safe insertion down to 18σ (V) in standard runs and down to 7σ (V) in special runs.

(1 σ_x (σ_y) = 0.19 (0.42) mm @ β^* = 3.5 m)

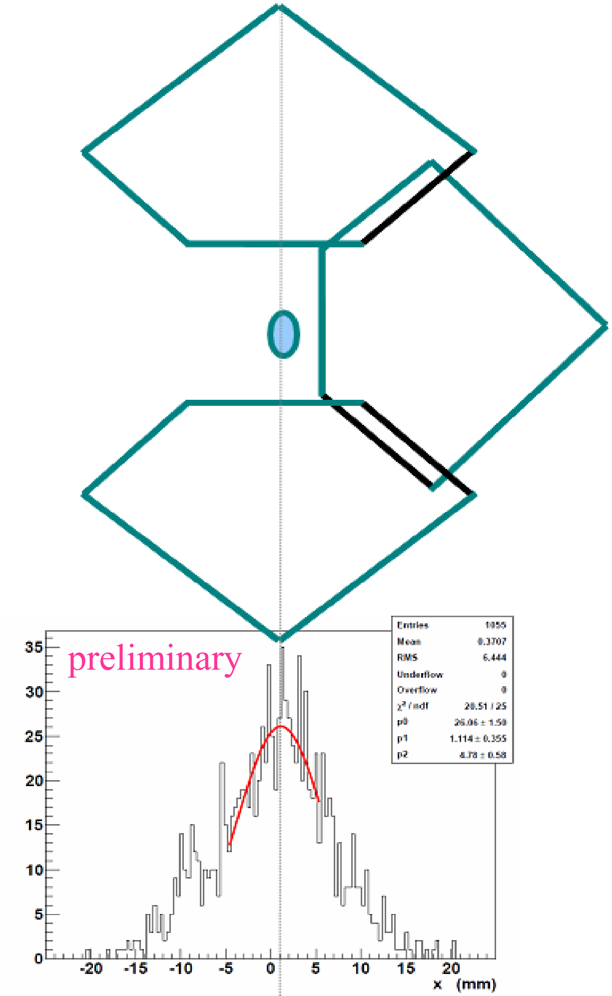
RP Alignment (Example @ 20σ): Track Profiles

Vertical alignment



Tracks in horizontal pot (diffractive protons)

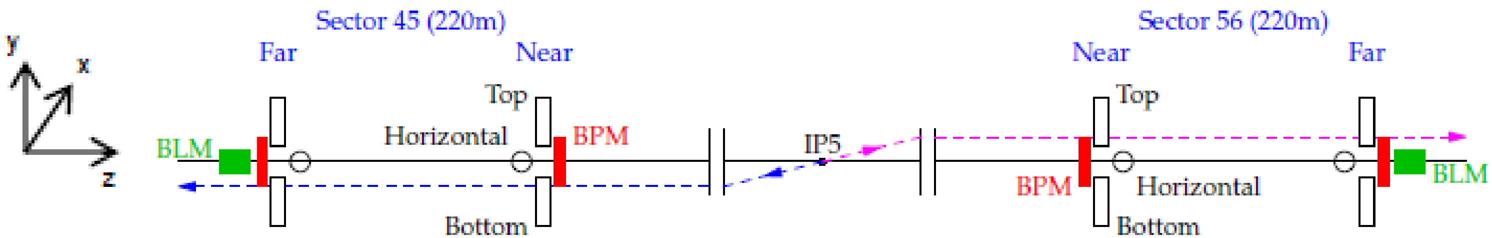
Horizontal alignment

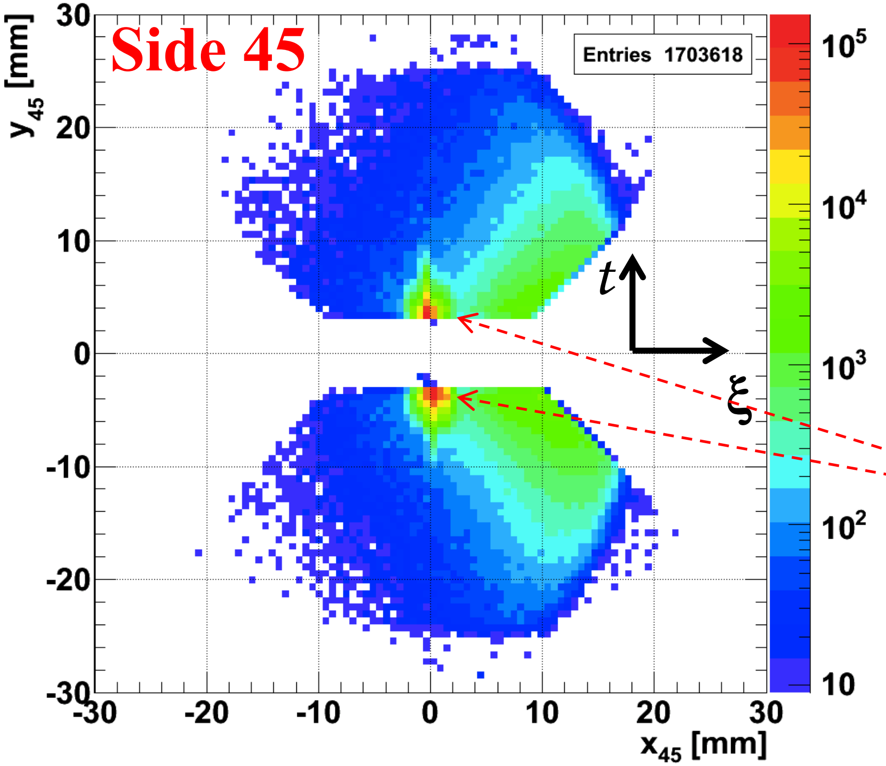


Tracks in vertical pot (halo protons)

Now done with elastic protons

"Raw" Data: Hit Map for L-R Coincidences (El. Scat.)





$$y(s) = v_y(\xi, s) \cdot y^* + L_y(\xi, s) \cdot \Theta_y^*$$
$$x(s) = v_x(\xi, s) \cdot x^* + L_x(\xi, s) \cdot \Theta_x^* + \xi \cdot D(\xi, s)$$

with

$\xi = \Delta p/p$; $t = t_x + t_y$; $t_i \sim -(p\theta_i^*)^2$

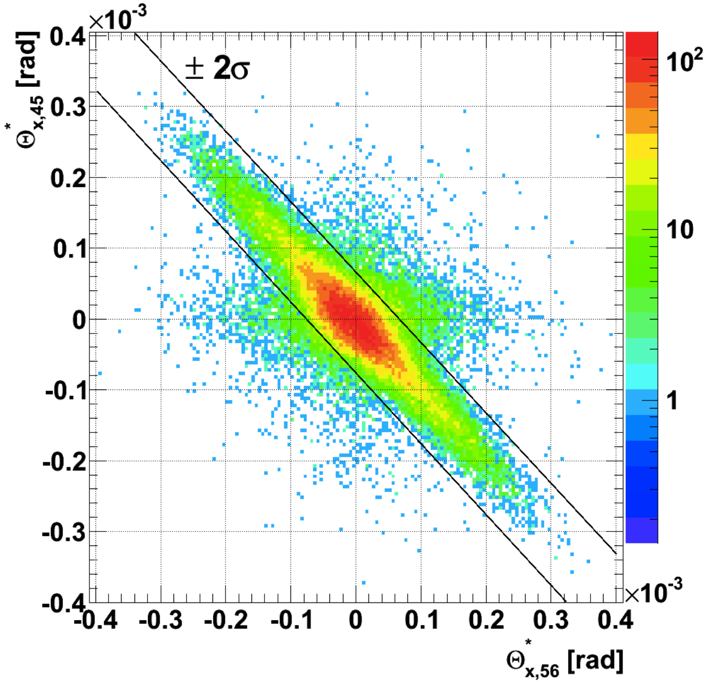
(x^*, y^*): vertex position at IP

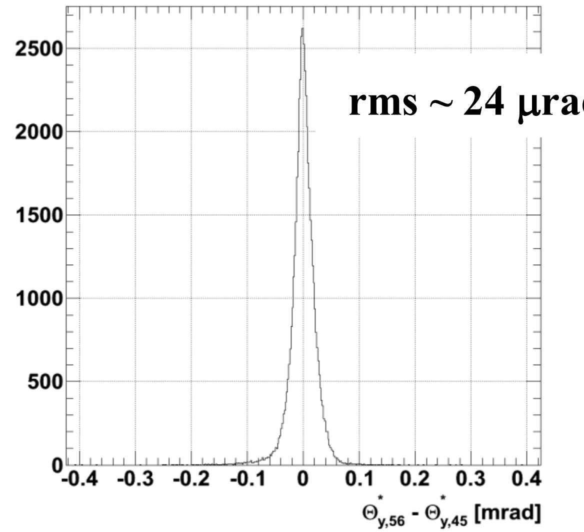
(θ_x^*, θ_y^*): emission angle at IP

Hits related to elastic scattering candidates

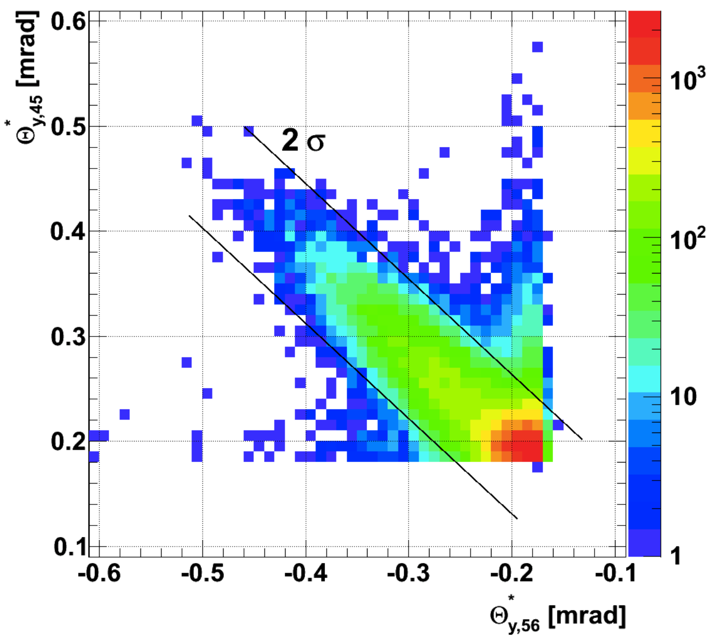
Tracks reconstructed in "left" (45) and "right" (56) sides

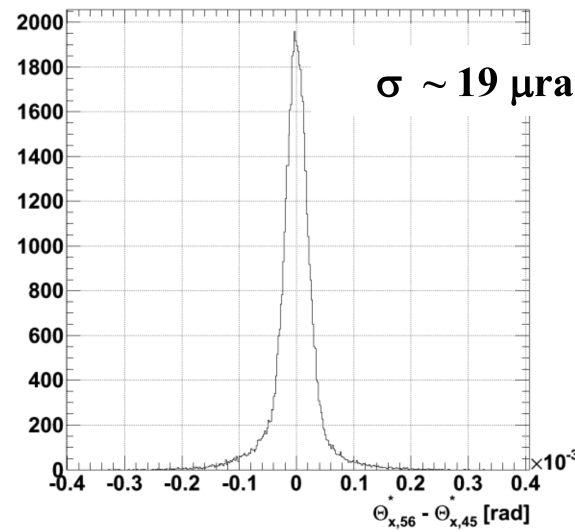
Elastic Scattering Selection: Collinearity in θ^*_y (θ^*_x)





Low ξ, i.e.:
|x| < 0.4 mm,
2σ cut in $\Delta\theta^*_x$ ($\Delta\theta^*_y$)

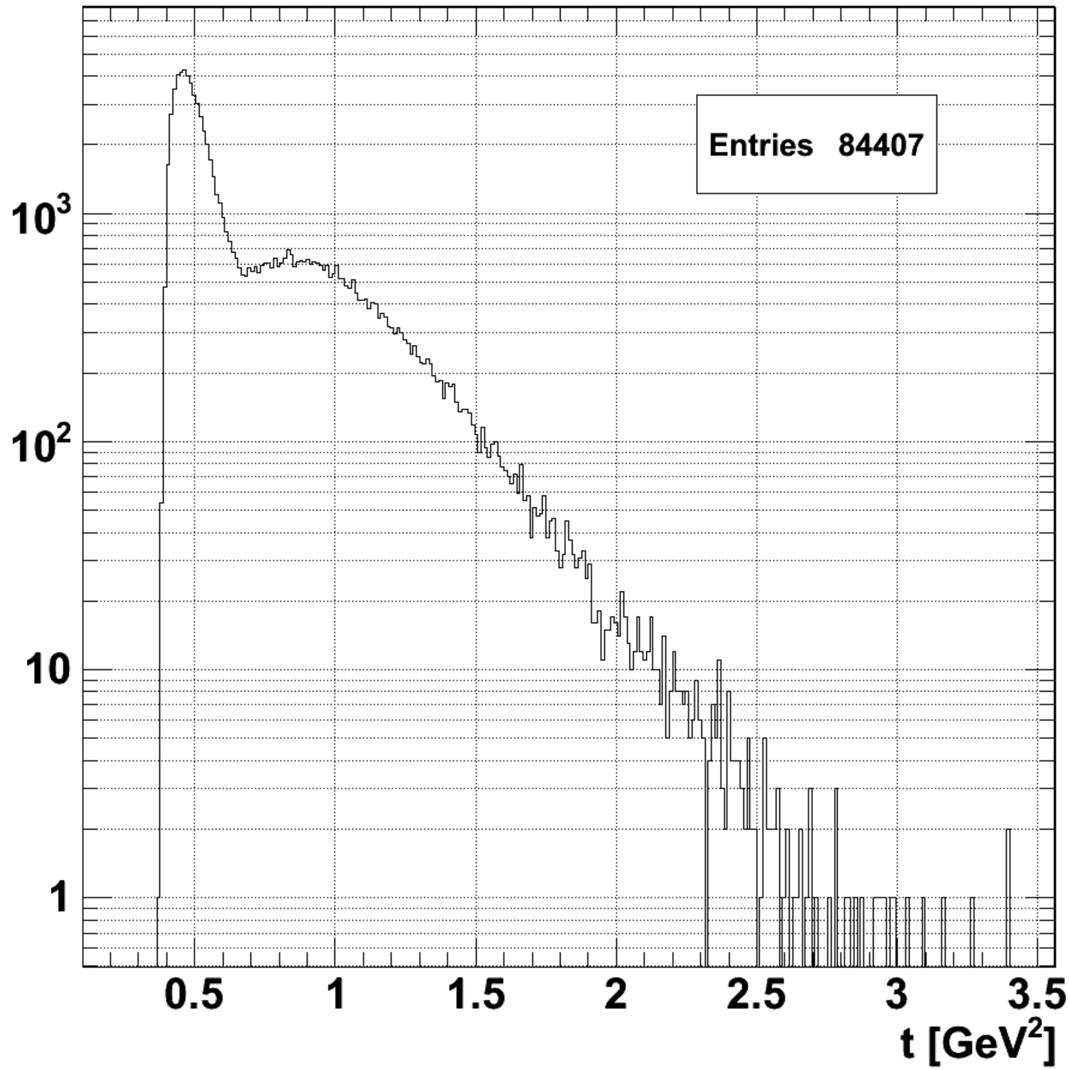




Compatible with
Beam divergence
(17 μrad, for nominal
ε = 3.75 μrad)

Elastic Scattering: Preliminary t Distribution

~ 84K elastic scattering candidate events from 30/10/10 TOTEM special run



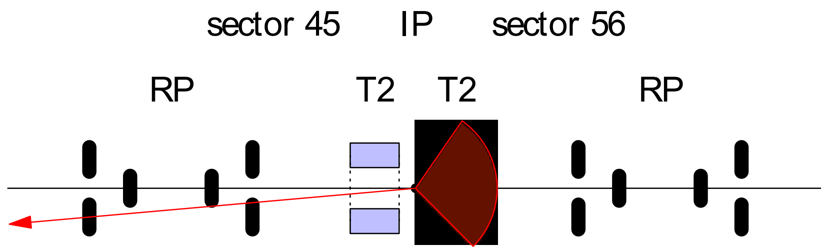
$\sqrt{s}$ = 7 TeV
β^* = 3.5 m
RPs @ 7 σ (V) and 16 σ (H)

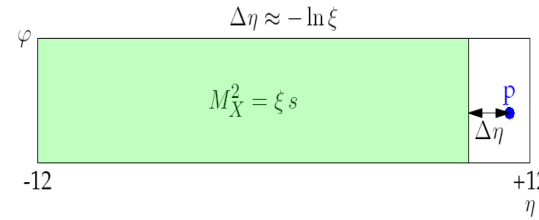
"Raw" distribution:

- No smearing corrections
- No acceptance corrections
- No background subtraction

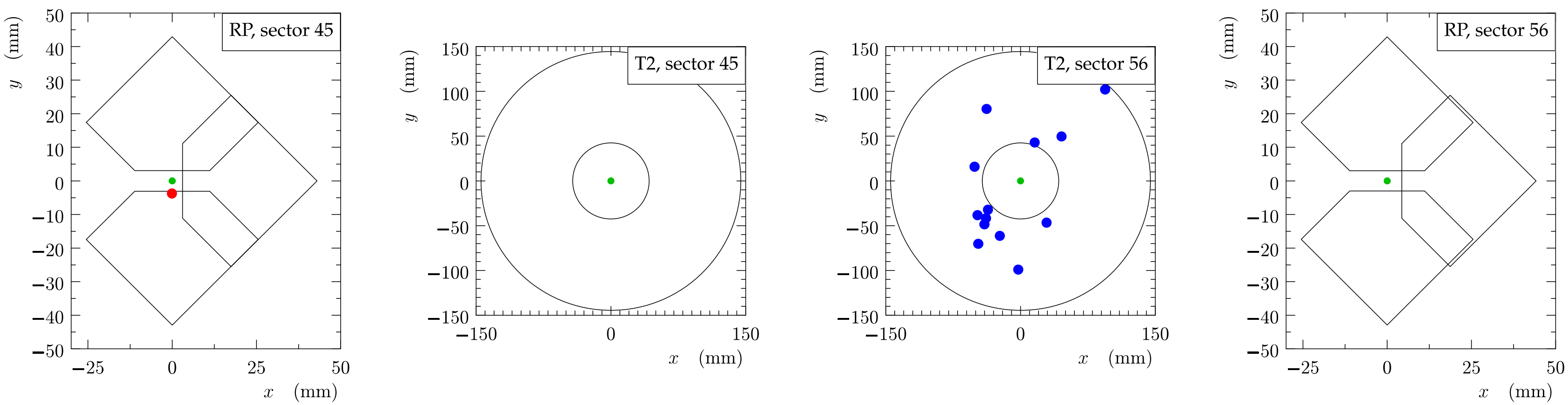
Sys. err. sources under study: alignment, beam position and divergence, background, optical functions, efficiency, …

Topologies of Diffractive Events: SD @ Low ξ

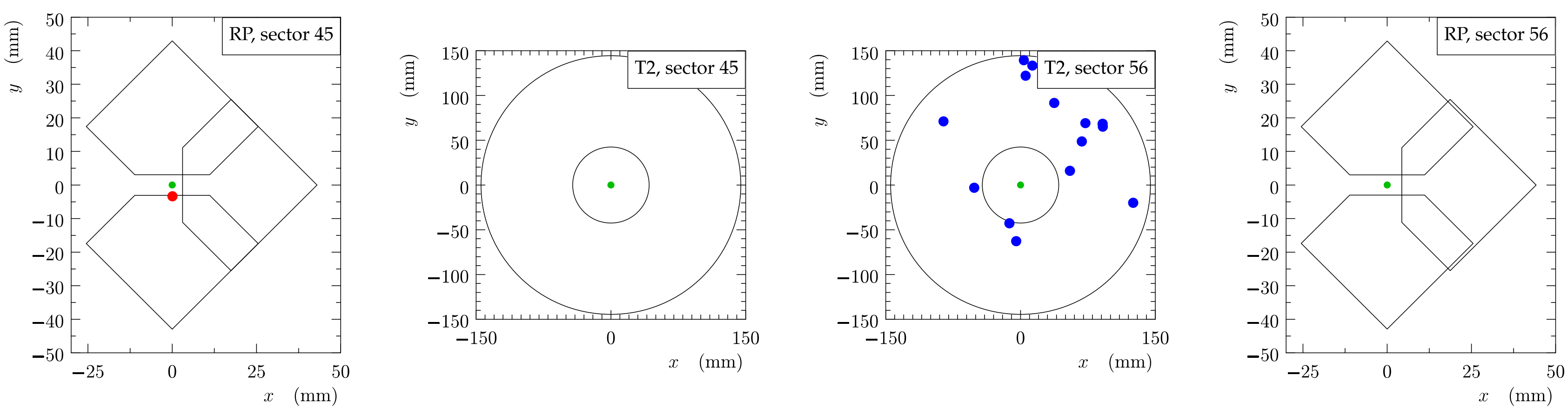




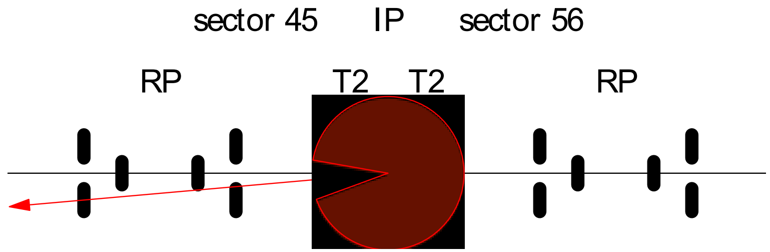
run: 37280003, event: 3000

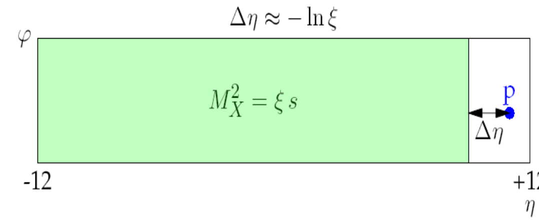


run: 37280004, event: 22784

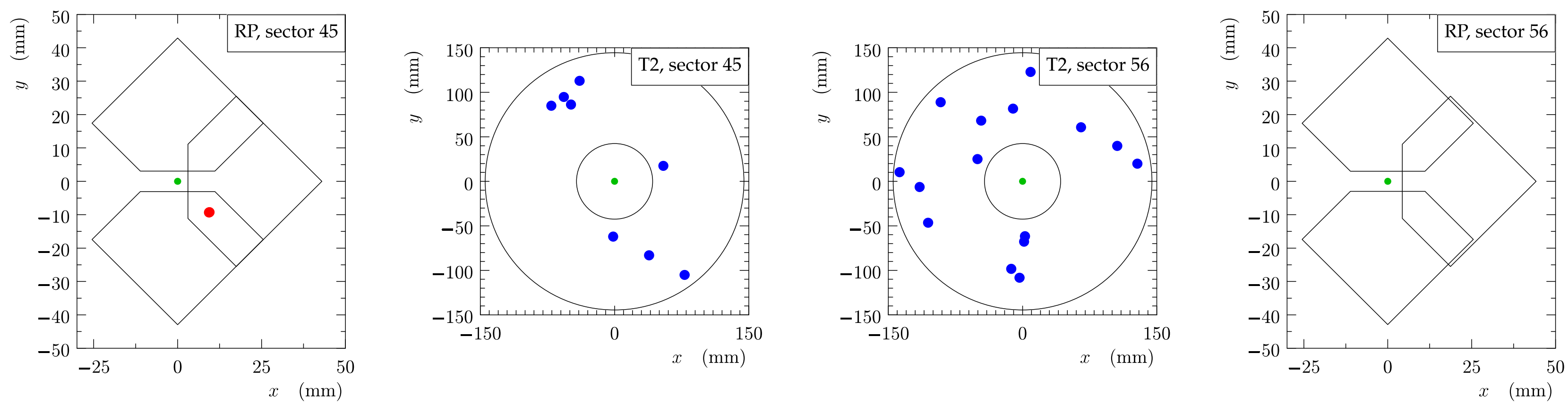


Topologies of Diffractive Events: SD @ High ξ

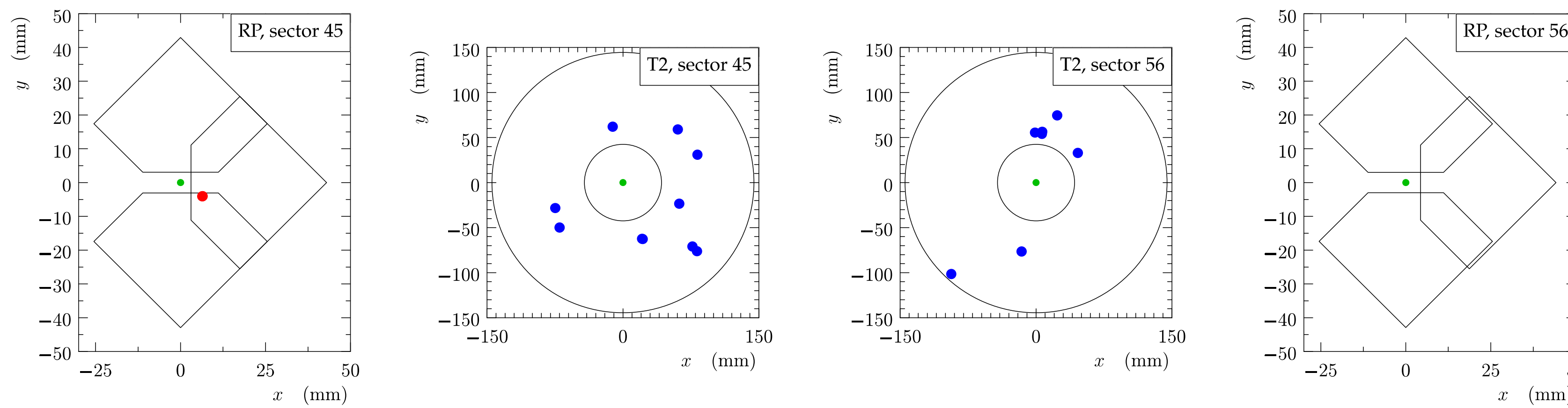




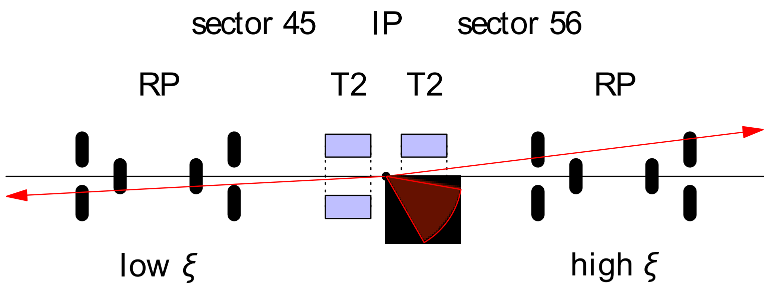
run: 37280006, event: 9522

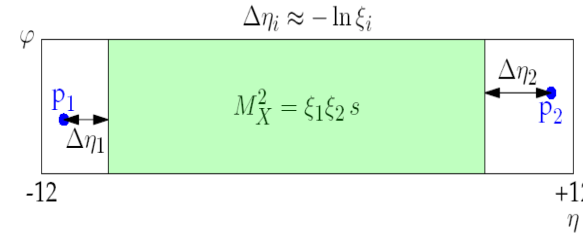


run: 37280006, event: 6074

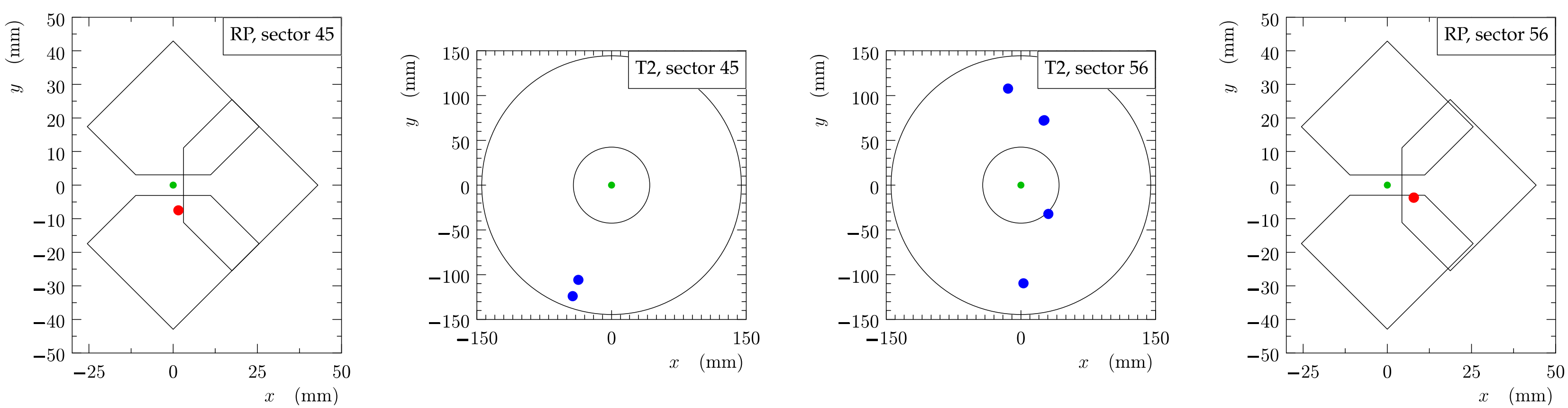


Topologies of Diffractive Events: DPE

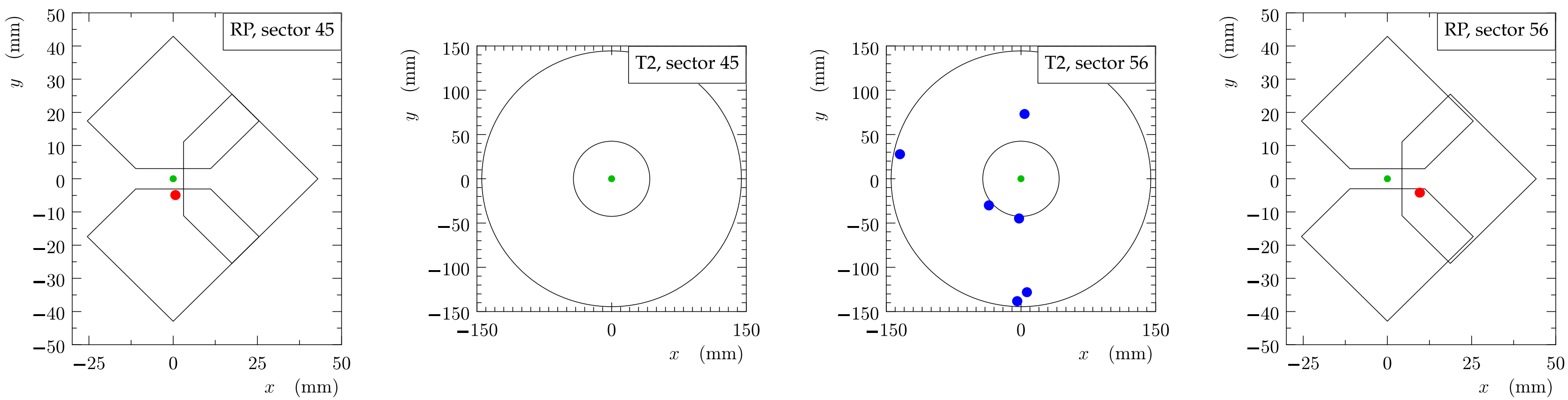




run: 37250009, event: 14125



run: 37220007, event: 9904



Summary & Conclusions

- **TOTEM** RP220 and T2 detectors fully installed and operative.
- Commissioning on collision data finished.
- First data analysis is ongoing on special TOTEM run data taking, early measurements with $\beta^* = 3.5$ m at $\sqrt{s} = 7$ TeV:
  - study of SD and DPE at high mass
  - elastic scattering at large $|t|$ ($0.5 < |t| < 5$ GeV^2)
  - measurement of forward charged multiplicity.
- Analysis work focused in understanding efficiencies, systematics and biases from secondary particles and background.
- Installation of RP147 and T1 scheduled for Winter 2010 shutdown.
- The measurement of ***total pp cross-section*** (and $\mathcal{L}$) with a precision of **5% (1-2%)** with $\beta^* = 90$ m (1540 m), and the study of elastic scattering and diffraction in a wider $|t|$ and η range, will require dedicated runs of data taking with the detector <u>fully</u> equipped.
- Looking forward for new data in 2011!

TOTEM

TOTEM

Backup Slides

Running Scenarios

Scenario Physics:	1 low |t| elastic, σ_{tot} (@ ~1%), MB, soft diffr.	2 low/large |t| elastic, σ_{tot} (@ ~5%), MB, soft/semi-h. diffr.	3 large |t| elastic, hard diffraction
β^* [m]	1540	90	$2 \div 0.5$
N of bunches	$43 \div 156$	156	$936 \div 2808$
Bunch spacing [ns]	$2025 \div 525$	525	25
N of part. per bunch	$(0.6 \div 1.15) \times 10^{11}$	1.15×10^{11}	1.15×10^{11}
Half crossing angle [μrad]	0	0	92
Transv. norm. emitt. ε_n [μm rad]	1	3.75	3.75
RMS beam size at IP [μm]	450	213	32
RMS beam diverg. at IP [μrad]	0.3	2.3	16
Peak Luminosity [$cm^{-2}\,s^{-1}$]	$10^{28} \div 2 \times 10^{29}$	3×10^{30}	10^{33}

← Cross section   Luminosity →

β^* (m)	1540	90	2	0.5
L ($cm^{-2}\,s^{-1}$)	10^{29}	10^{30}	10^{32}	10^{33}
	TOTEM runs		Standard runs	

beam ang. spread at IP: $\sigma_{\theta^*} = \sqrt{(\varepsilon / \beta^*)}$

beam size at IP: $\sigma^* = \sqrt{(\varepsilon\, \beta^*)}$

- Optimal β^* = 1540m optics requires special injection optics: probably NOT available at the beginning of LHC
- ‘Early’ β^* = 90m optics achievable using the standard LHC injection optics

Accessible physics depends on luminosity & β^*

Combined Uncertainty in σ_{tot}

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

$$\mathcal{L} = \frac{1+\rho^2}{16\pi} \frac{(N_{el}+N_{inel})^2}{dN_{el}/dt|_{t=0}}$$

	β* = 90 m	1540 m
❑ **Extrapolation of elastic cross-section to t = 0:**	± 4 %	± 0.2 %
❑ **Total elastic rate (strongly correlated with extrapolation):**	± 2 %	± 0.1 %
❑ **Total inelastic rate:** (error dominated by Single Diffractive trigger losses)	± 1 %	± 0.8 %
❑ **Error contribution from $(1+\rho^2)$:** (using full COMPETE error band $d\rho/\rho$ = 33 %)	± 1.2 %	

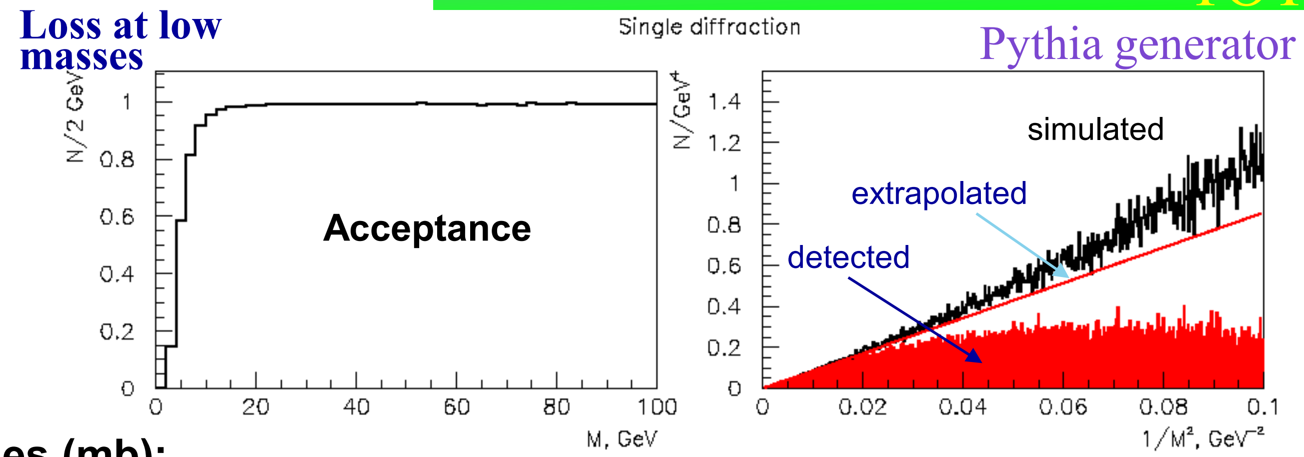
⇒ Total uncertainty in σ_{tot} including correlations in the error propagation:

β^* = 90 m : ± 5% **β^* = 1540 m : ± (1 ÷ 2) %**

Slightly worse in $\mathcal{L}$ (~ total rate squared) : ± 7 % (± 2 %)

β* = 90 m required for early σ_{tot} measurement at √s = 7 TeV (foreseen in 2011)

Measurement of σ_{TOT} at ~1%



Trigger Losses (mb):

	σ(mb)	Double arm T1/T2	Single arm T1/T2	Uncertainty after Extrapolation (mb)
Minimum bias	58	0.3	0.06	0.06
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

Total **0.8**%

$$\Delta\sigma_T/\sigma_T \sim \sqrt{[(0.006)^2 + (0.002)^2 + (0.012)^2]} \sim 0.014$$

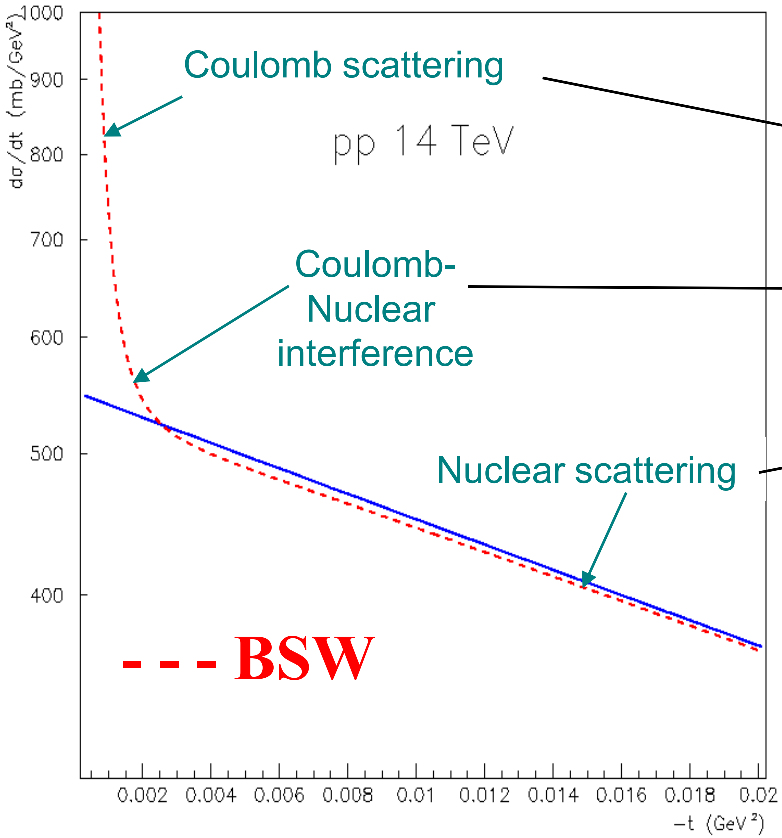
Inelastic + Elastic Error

Extrapolation t=0 Error

Error on ρ

Determination of dσ/dt at t=0

Model dependent uncertainty due to Coulomb interferences



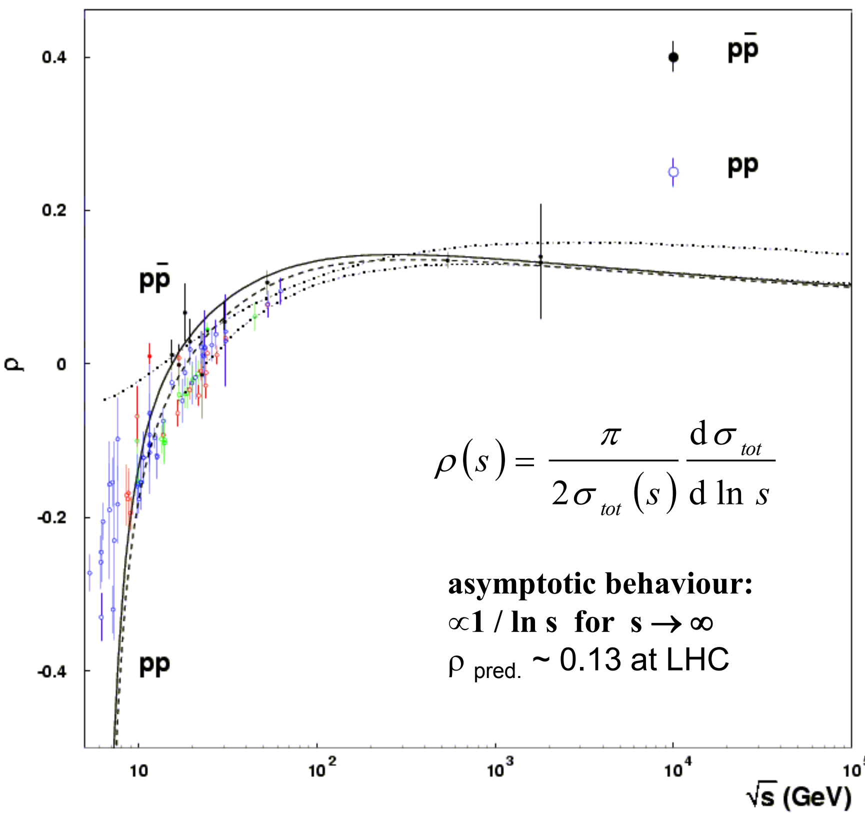
$$\frac{d\sigma}{dt} = \frac{4\pi\alpha^2(\hbar c)^2 G^4(t)}{|t|^2} + \frac{\alpha(\rho-\alpha\phi)\sigma_{tot} G^2(t)}{|t|} e^{-B|t|/2} + \frac{\sigma_{tot}^2(1+\rho^2)}{16\pi(\hbar c)^2} e^{-B'|t|}$$

Very approximate formula:
West and Yenneie model for Coulomb-Nuclear interference
(ρ(t) = const)

- α = fine structure constant
- φ = relative Coulomb-nuclear phase
- G(t) = nucleon em form factor = $(1 + |t|/0.71)^{-2}$
- ρ = Re/Im f(**p**→ **p**)

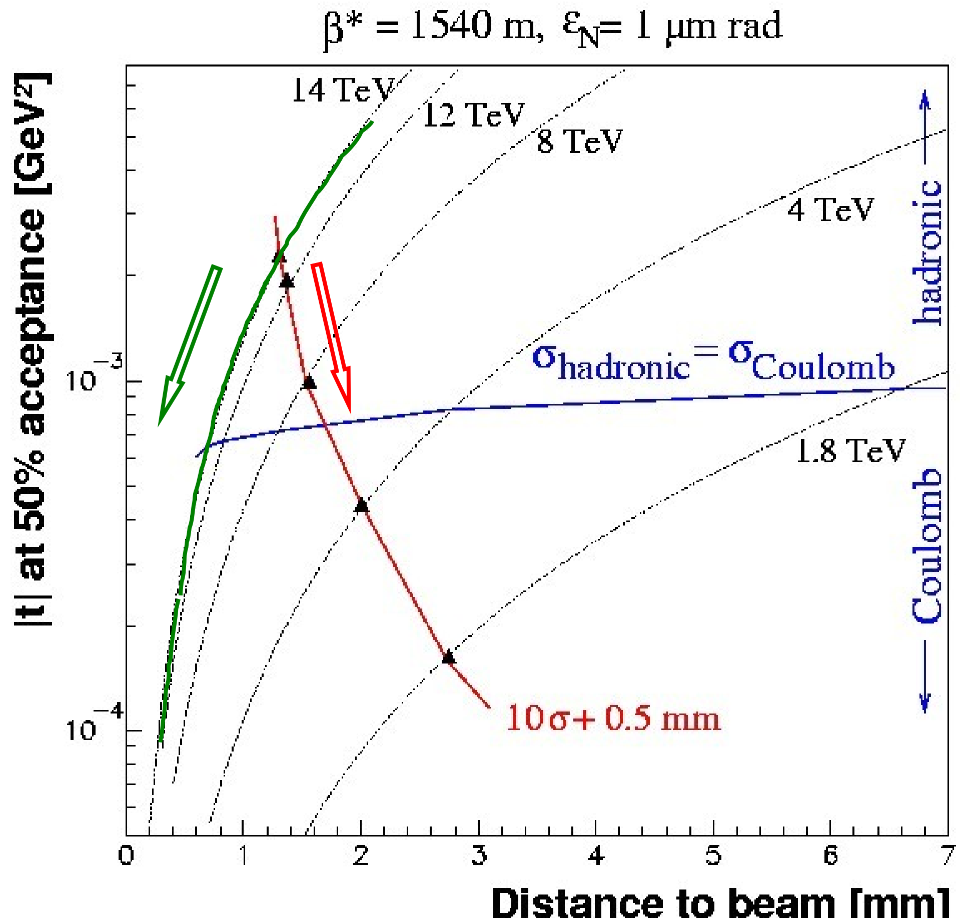
Measurement of the exponential slope B in the t-range 0.002 - 0.2 GeV² needs beams with tiny angular spread ⇒ large β*

Possibilities of ρ measurement



$$\rho(s) = \frac{\pi}{2\sigma_{tot}(s)} \frac{d\sigma_{tot}}{d \ln s}$$

asymptotic behaviour:
$\propto 1 / \ln s$ for $s \to \infty$
$\rho_{pred.} \sim 0.13$ at LHC



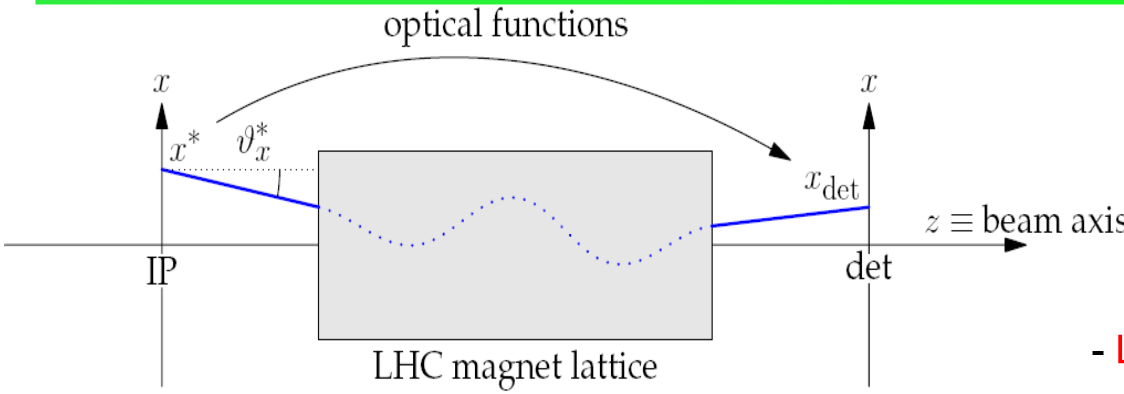
Try to reach the Coulomb region and measure interference:

- **move the detectors closer to the beam than 10σ + 0.5 mm**
- **run at lower energy @ √s < 14 TeV**

Pythia 6.420 Settings

```
'MSTJ(11)=3     ! Choice of the fragmentation function',
'MSTJ(22)=2     ! Decay those unstable particles',
'PARJ(71)=10 .  ! for which ctau  10 mm',
'MSTP(2)=2      ! which order running alphaS',
'MSTP(33)=3     ! no K factors in hard cross sections',
'MSTP(51)=7     ! choice of proton parton-distribution set (D=7 and means CTEQ 5L)',
'MSTP(52)=1     ! choice of proton pdf library (D=1 and means internal pythia one, according to MSTP(51) above',
'MSTP(81)=1     ! multiple parton interactions 1 is Pythia default',
'MSTP(82)=4     ! Defines the multi-parton model',
'MSTU(21)=1     ! Check on possible errors during program execution',
'PARP(82)=1.9409   ! pt cutoff for multiparton interactions',
'PARP(89)=1960. ! sqrts for which PARP82 is set',
'PARP(83)=0.5   ! Multiple interactions: matter distrbn parameter',
'PARP(84)=0.4   ! Multiple interactions: matter distribution parameter',
'PARP(90)=0.16  ! Multiple interactions: rescaling power',
'PARP(67)=2.5    ! amount of initial-state radiation',
'PARP(85)=1.0  ! gluon prod. mechanism in MI',
'PARP(86)=1.0  ! gluon prod. mechanism in MI',
'PARP(62)=1.25   ! ',
'PARP(64)=0.2    ! ',
'MSTP(91)=1     !',
'PARP(91)=2.1   ! kt distribution',
'PARP(93)=15.0  ! ')
```

Details on Beam Optics



Proton transport equation:

$$x = L_x \theta_x^* + v_x x^* + D\xi$$

$$y = L_y \theta_y^* + v_y y^*$$

Optical functions:

- L (effective length); - v (magnification);
- D (machine dispersion)

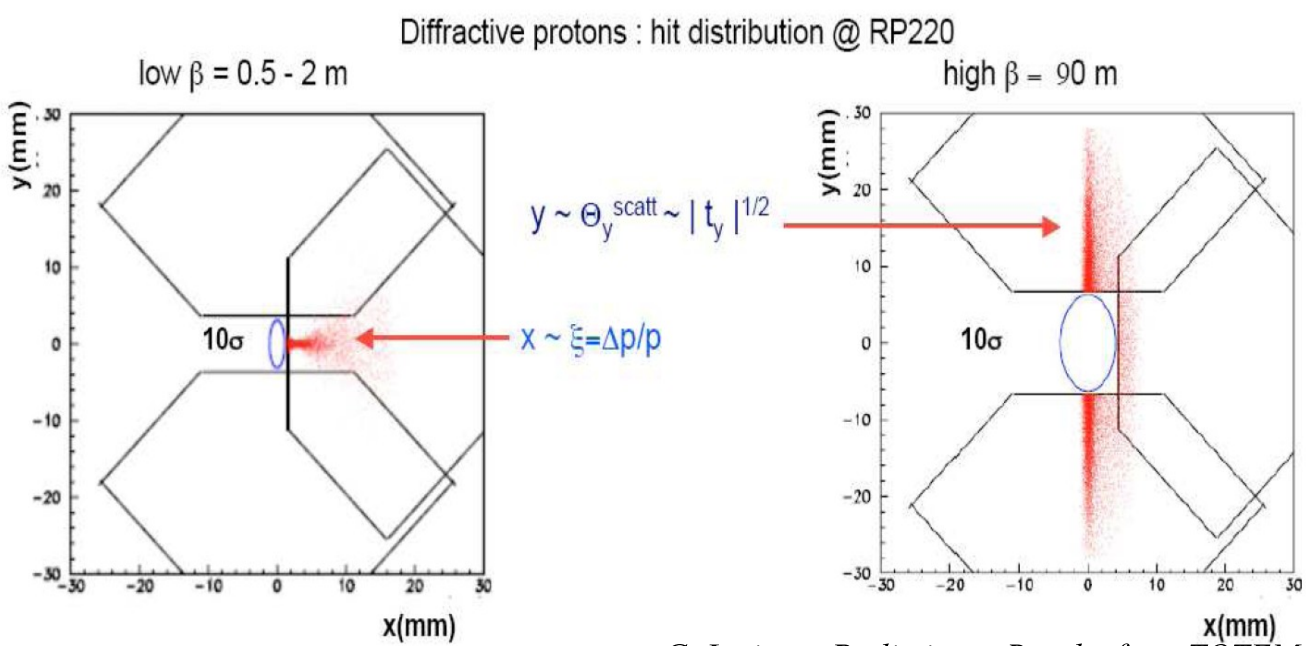
$\xi = \Delta p/p$; $t = t_x + t_y$; $t_i \sim -(p\theta_i^*)^2$

(x^*, y^*): vertex position at IP

(θ_x^*, θ_y^*): emission angle at IP

Describe the explicit path of particles through the magnetic elements as a function of the particle parameters at IP.

$\Rightarrow$ Define t and ξ range (acceptance)

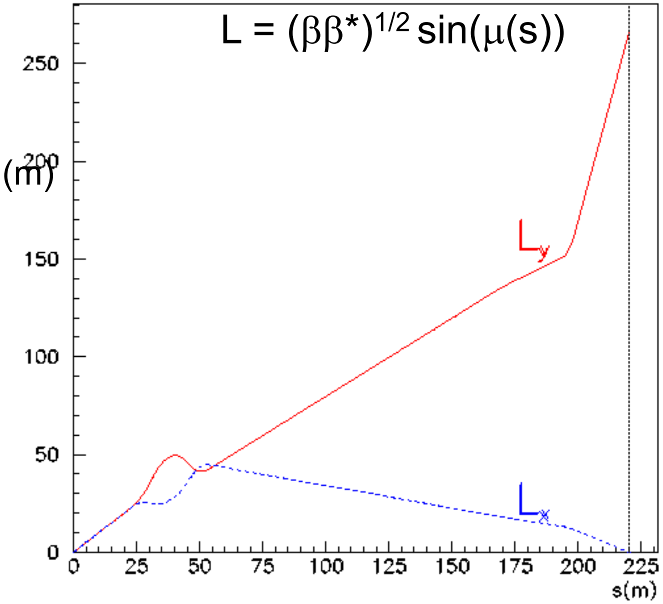


Example

same sample of diffractive protons at different β*

- **low β*: p detected by momentum loss (ξ)**
- **high β*: p detected by trans. momentum (t_y)**

Optical Functions: Example at $\beta^* = 90$ m



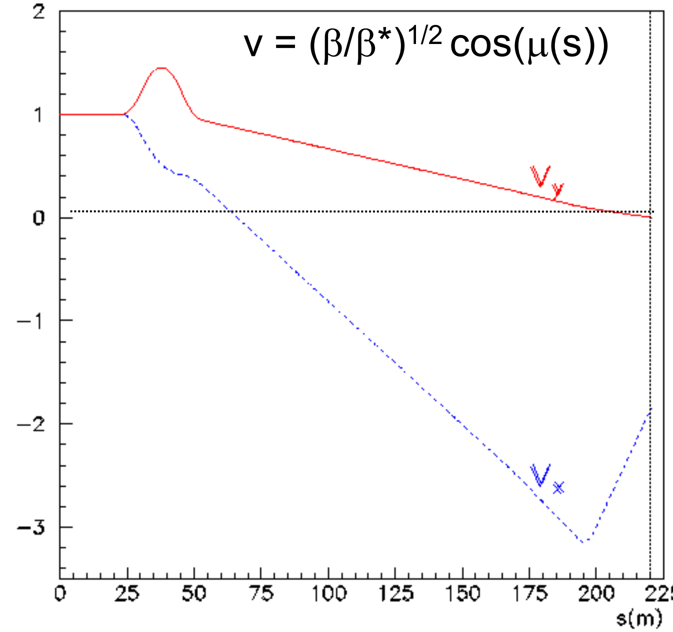
Idea:

L_y large $\quad L_x = 0$

$v_y = 0$

$\mu_y(220) = \pi/2 \quad \mu_x(220) = \pi$

(parallel-to-point focussing on y)



$$\mathbf{x = L_x\theta_x^* + v_x x^* + D\xi}$$

$$\mathbf{y = L_y\theta_y^* + v_y y^*}$$

$\xi = \Delta p/p$

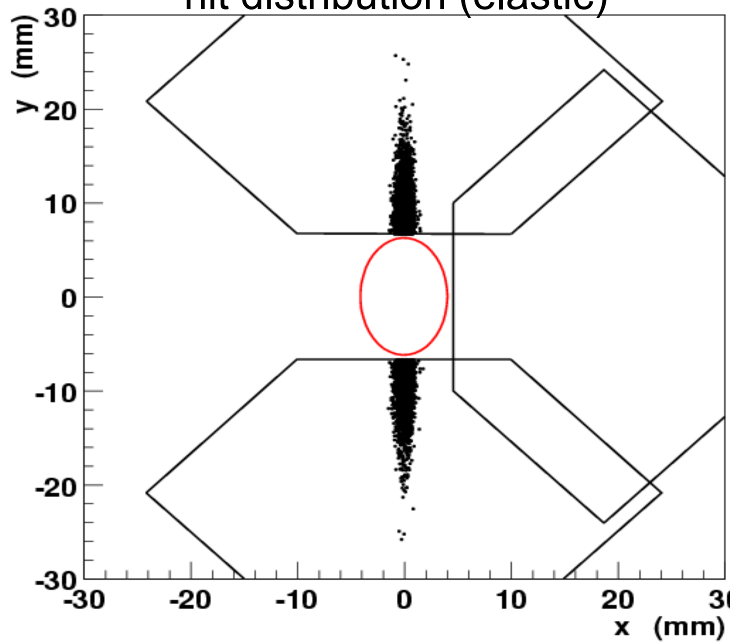
(x^*, y^*): vertex position at IP

(θ_x^*, θ_y^*): emission angle at IP

$$t = t_x + t_y$$

$$t_i \sim -(p\theta_i^*)^2$$

hit distribution (elastic)



Optical functions:

- L (effective length)
- v (magnification)

defined by β (betatron function) and μ (phase advance);

- D (machine dispersion)

$\Rightarrow$ describe the explicit path of particles through the magnetic elements as a function of the particle parameters at IP

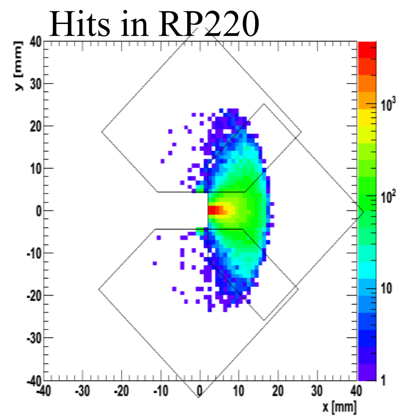
Physics with Low β* Optics

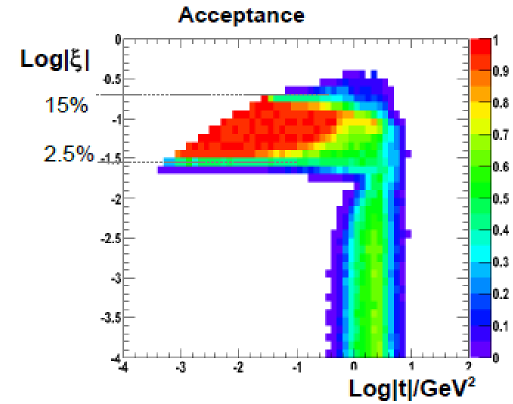
Single Diffraction

dσ/dM: $0.025 < \xi < 0.15$

$1 < M < 3$ TeV

$\sigma(M)/M \sim 2 - 5\%$

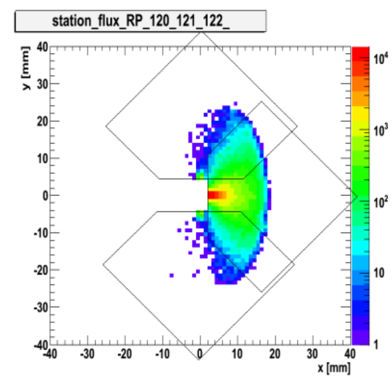


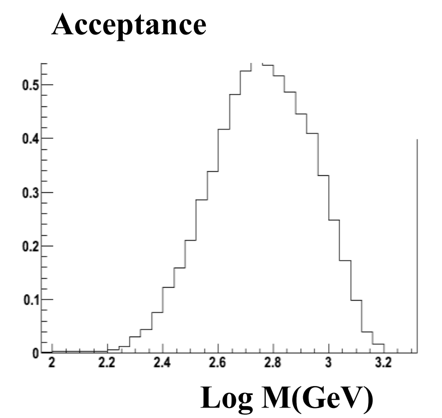


Central Diffraction

dσ/dM: $0.2 < M < 1$ TeV

$\sigma(M)/M \sim 2 - 5\%$

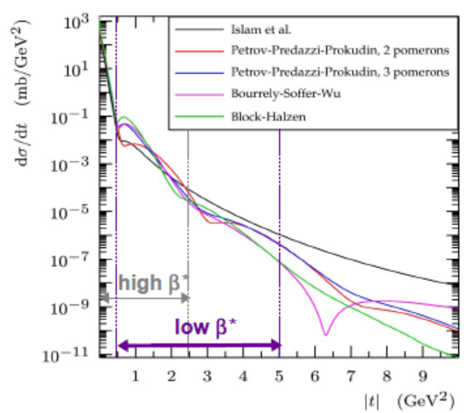


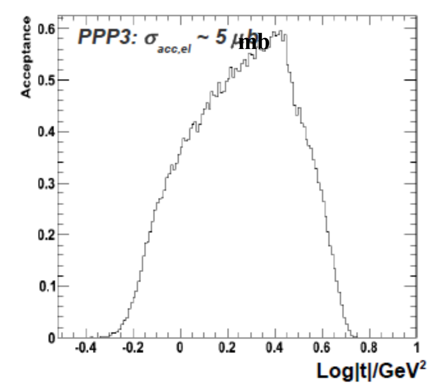


Elastic Scattering

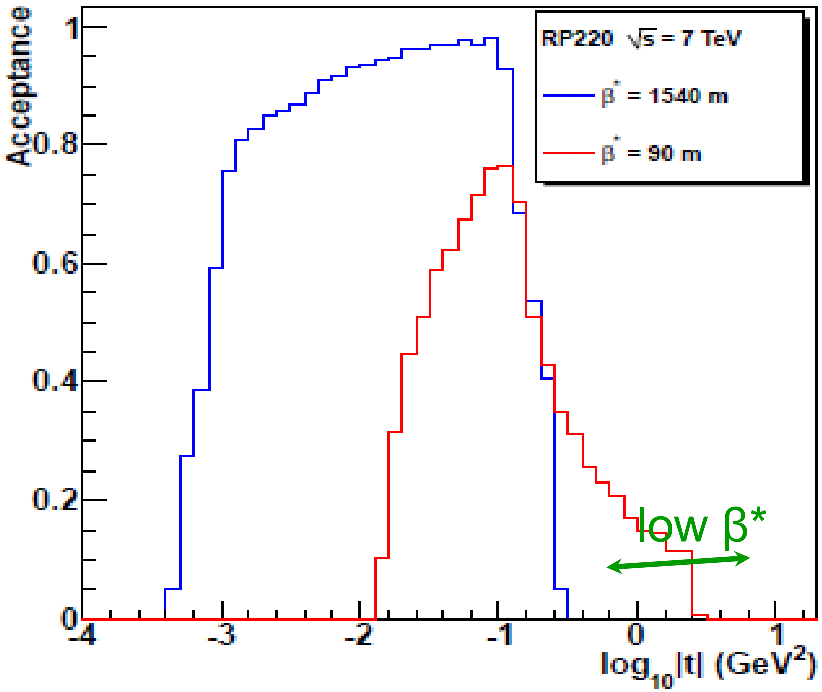
$0.5 < |t| < 5$ GeV^2

$\sigma(|t|) \sim 0.2\sqrt{|t|}$

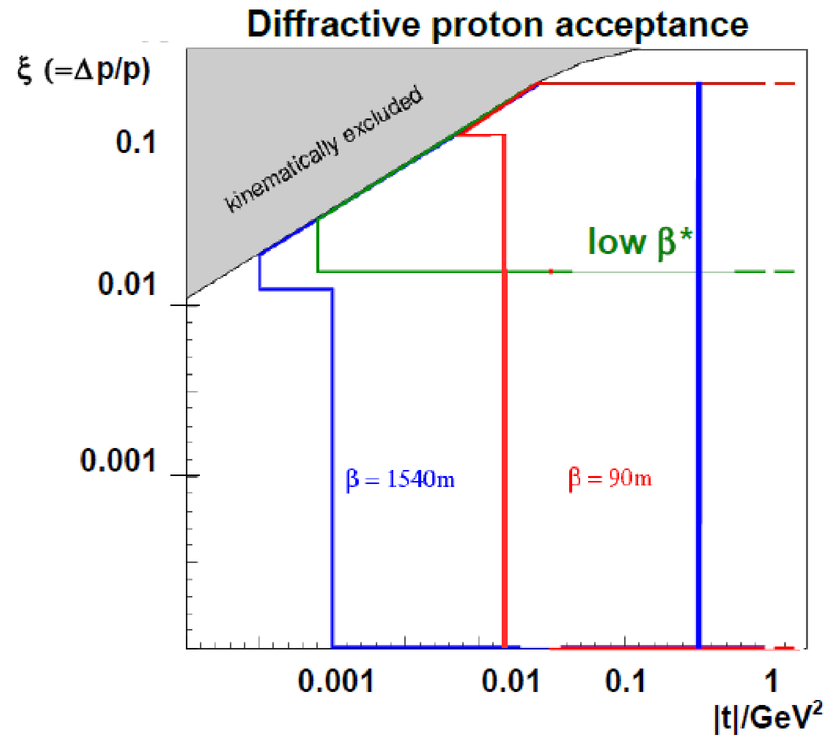




Physics with High β* Optics

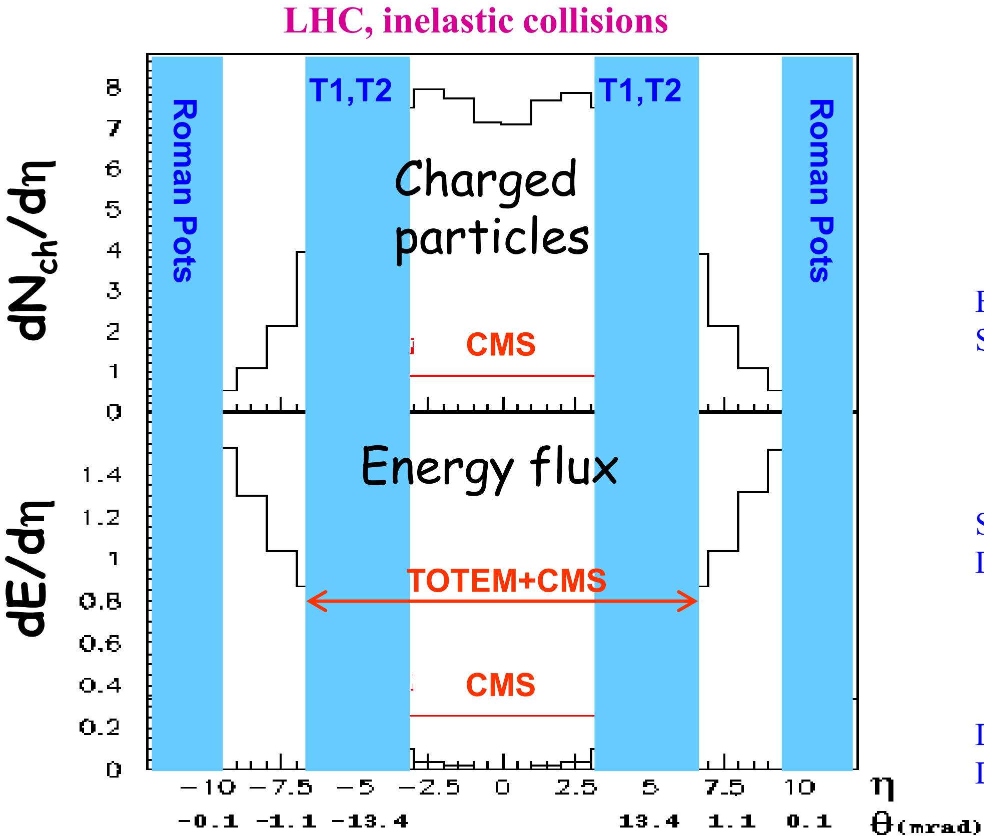


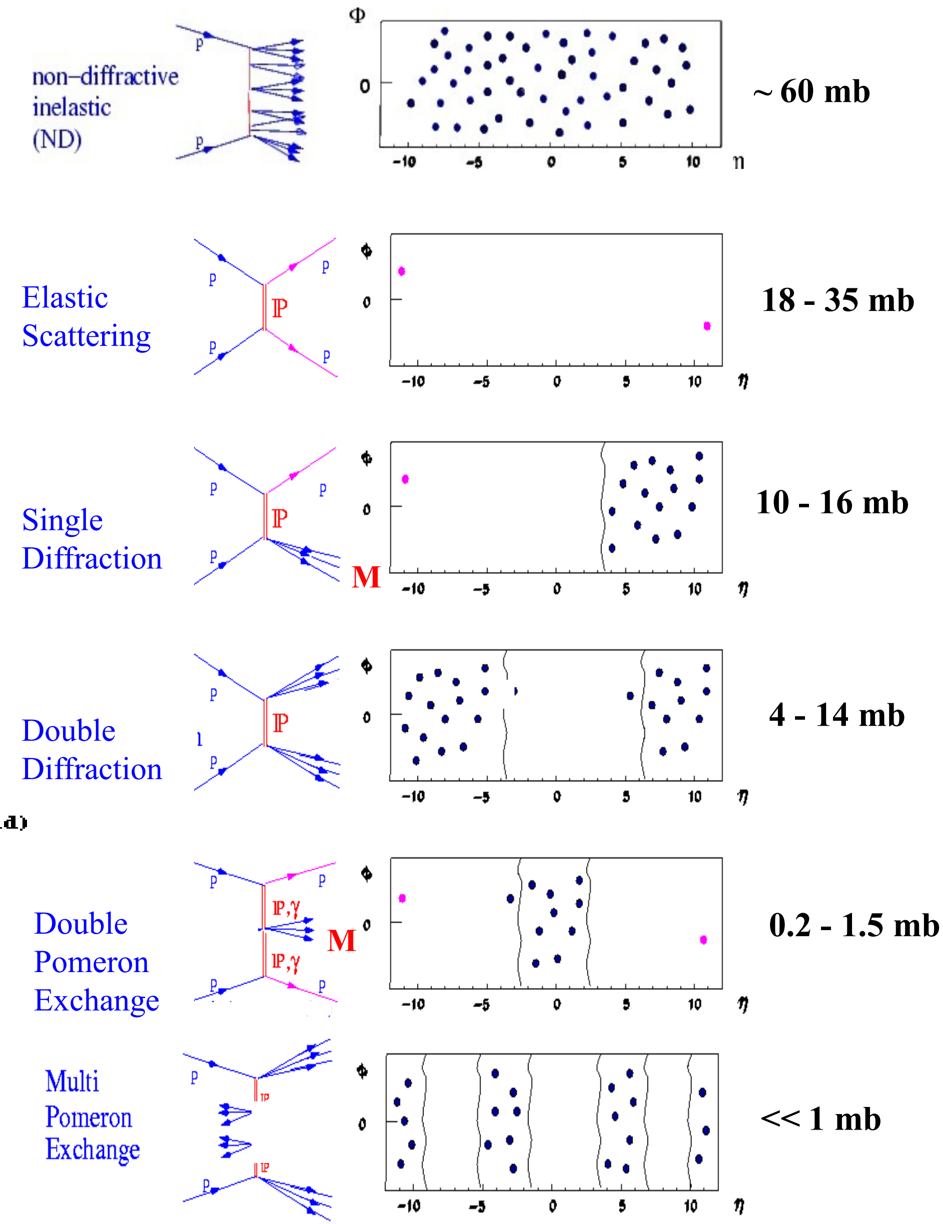
-t = $4\cdot10^{-4}$ 0.012 0.3 2.5



- Total cross section measurement at ~5 % (~1%)
- Elastic scattering: $0.0004<|t|< 2.5$ GeV^2
- Soft diffraction: all masses - 65 % of diffractive protons seen
- Classification of inelastic events: rates & multiplicity

CMS/TOTEM Common Physics Program

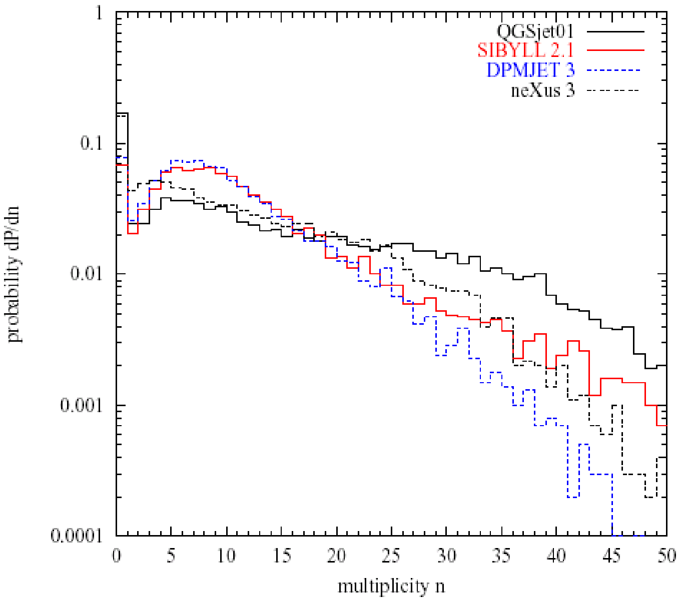


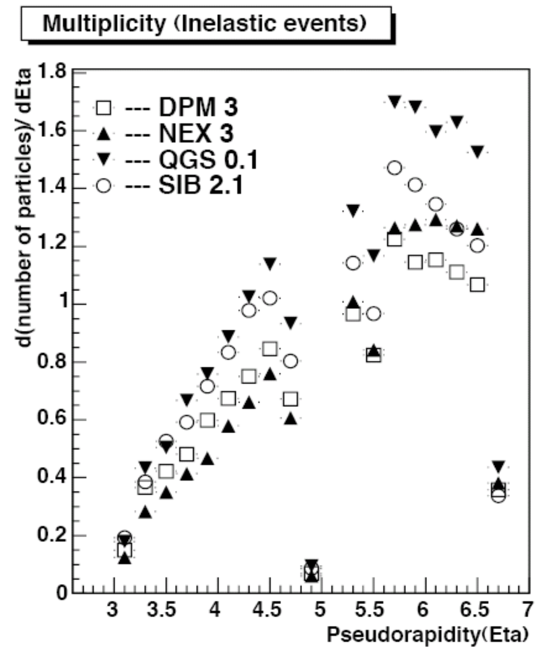


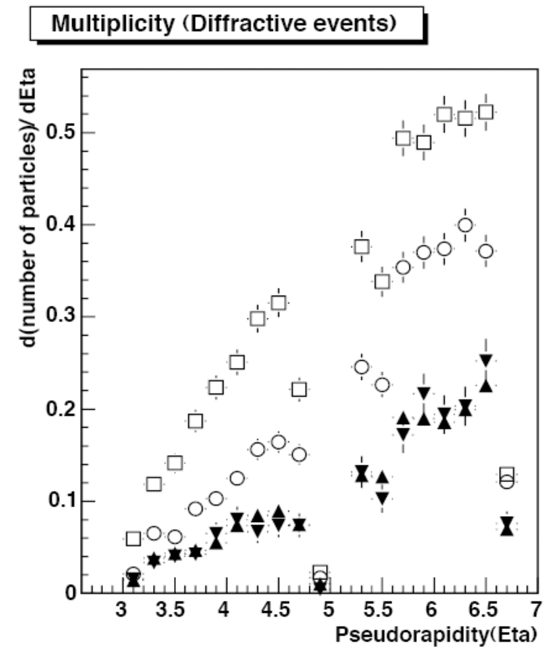
CMS + TOTEM ⇒ largest acceptance detector ever built at a hadron collider: the large η coverage and p detection on both sides allow the study of a wide range of physics processes in diffractive interactions

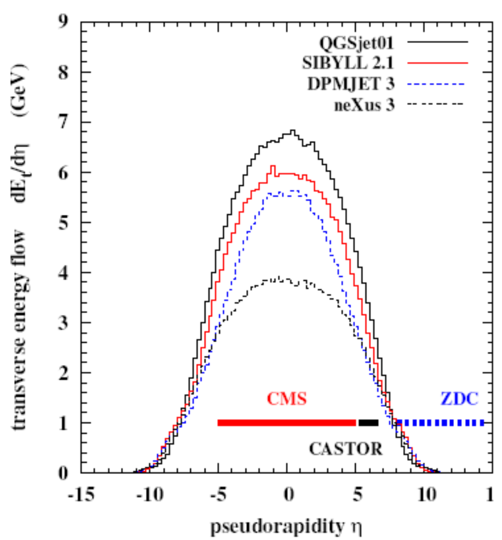
Forward Physics: VHE Cosmic Ray Connection

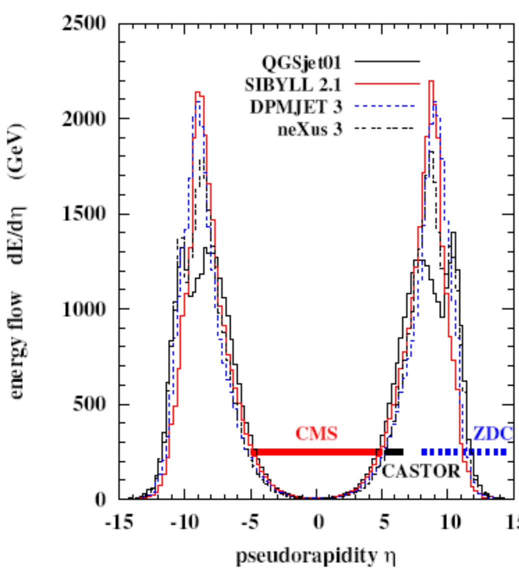
Total multiplicity in T2 (5<η<7)











p-p collisions @ LHC as predicted by generators tipically used to model hadronic showers generated by VHE CR

Interpreting cosmic ray data depends on hadronic simulation programs.
Forward region poorly known/constr.
Models differ by factor 2 or more.
Need forward particle/energy measurements e.g. dN/dη, dE/dη…

Machine Induced Background

T1/T2 Detectors:

- **beam-gas interactions: prel. ext. ~ 14 Hz per beam;**
  ~ 19 KHz for MB events (σMB = 80 mb, L = 2.4 $\cdot 10^{29}$ cm^{-2} s^{-1})
  ⇒ reduced by vertex reconstruction
- **muon halo (expected to be very small, not yet quantified)**

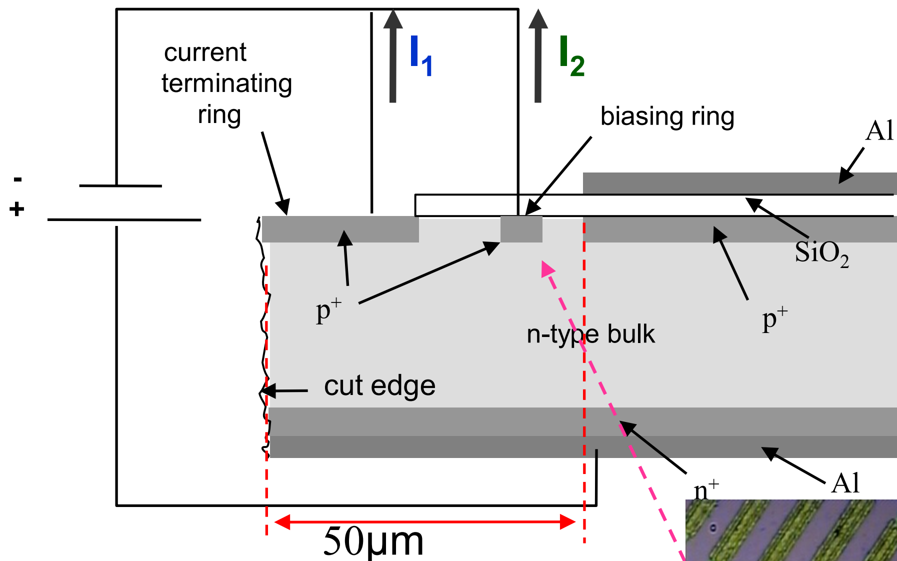
Roman Pot Detectors:

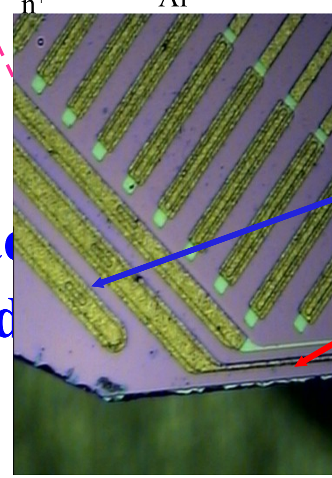
- **beam halo (protons out of design orbit): ext. (β^* = 1540m) ~ $12 \cdot 10^{-4}$/bunch**
  ⇒ reduced by requiring coincidence between RP arms
- **beam-gas interactions: ext. (β^* = 1540m) ~ $3 \cdot 10^{-4}$/bunch after cuts**
  ⇒ reduced with cuts on track angles and multiplicities
- **p-p collision (at IP) background: ext (β^* = 1540m) ~ $(0.4 \div 2) \cdot 10^{-4}$/bunch after cuts**
  ⇒ reduced with cuts on track angles and hit multiplicities

Tot. elast. evts ~ 3 KHz (L = 10^{29} cm^{-2} s^{-1}); prel. expt. S/B ~ $(0.6 \div 0.7) \cdot 10^3$

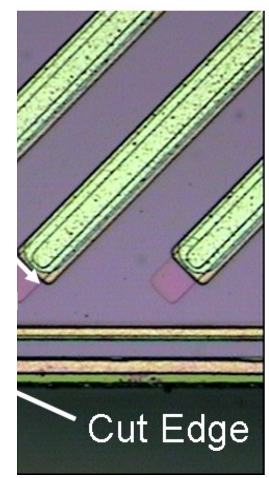
Si CTS Edgeless Detectors for Roman Pots

Planar technology with CTS
(Current Terminating Structure)





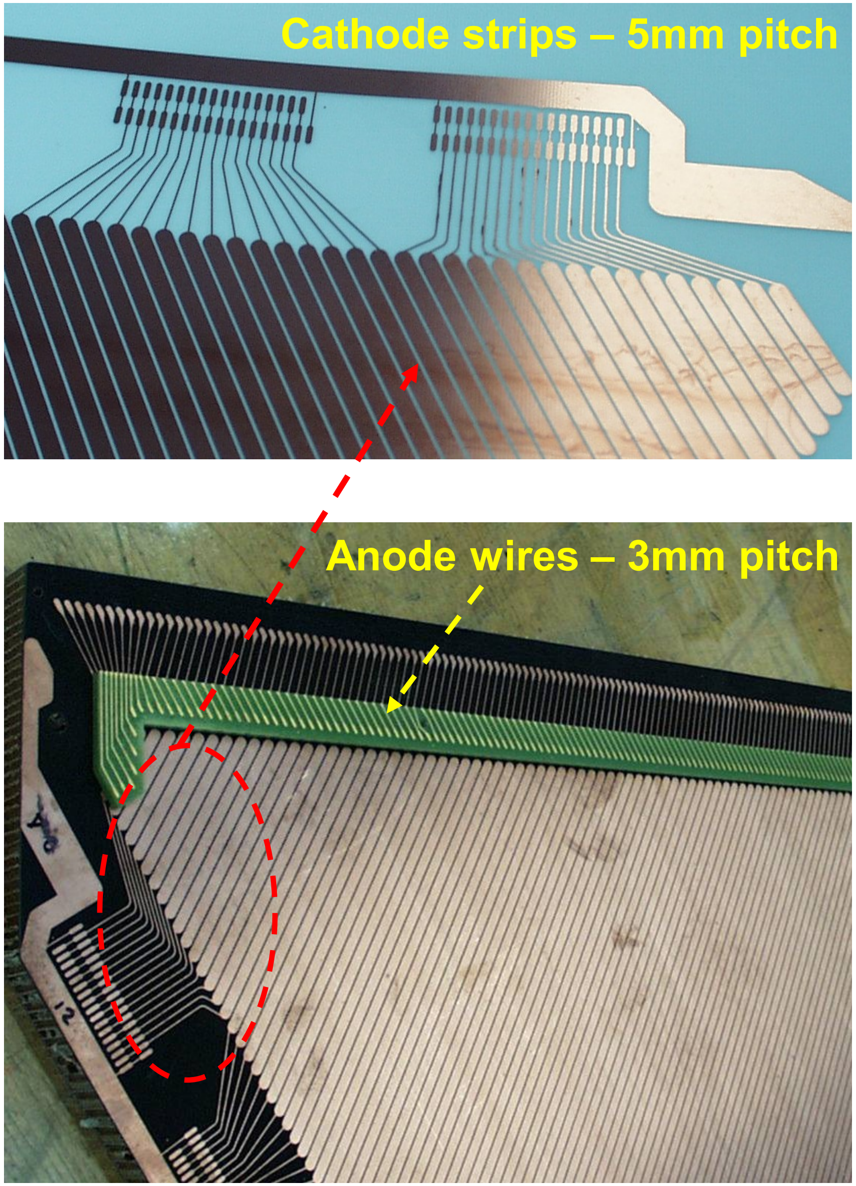
Integration of traditional Voltage Terminating Structure with the Current Terminating Structure



AC coupled microstrips ma
technology with novel guard
and biasing scheme

50 μm of dead area

T1 Cathode Strip Chamber (CSC)

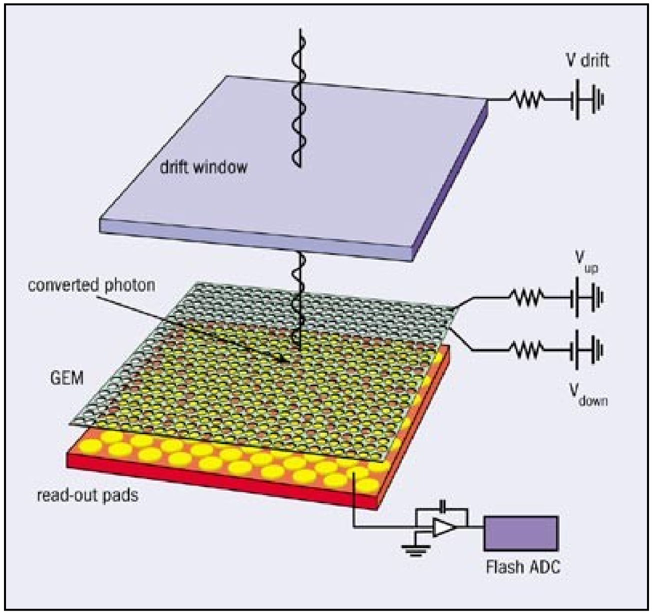


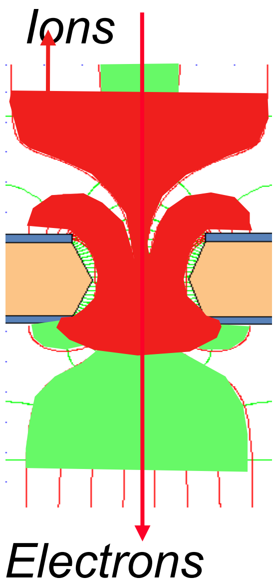
- Detector design similar to CMS CSC muon chamber
- Gas Mixture $Ar/CO_2/CF_4$
- Max size: ~ 1m x 0.68 m
- Gas gap: 10 mm
- Anode wires: ∅30µm, 3mm pitch
- Cathode strips: 4.5 mm width, 5mm pitch
- Digital readout (VFAT)

Ageing studies at CERN Gamma Irradiation Facility:

no loss of performance during 12-month test, with ~0.07 C/cm accumulated charge on wires corresponding to a dose equivalent to ~ 5 years at $L=10^{30}cm^{-2}s^{-1}$

Gas Electron Multiplier (GEM)

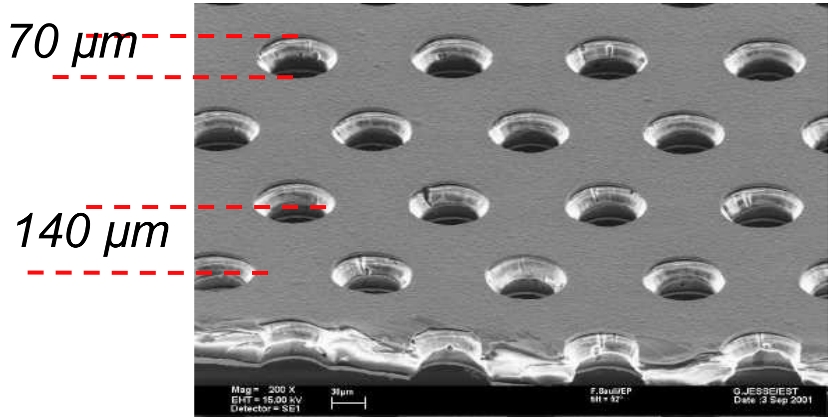


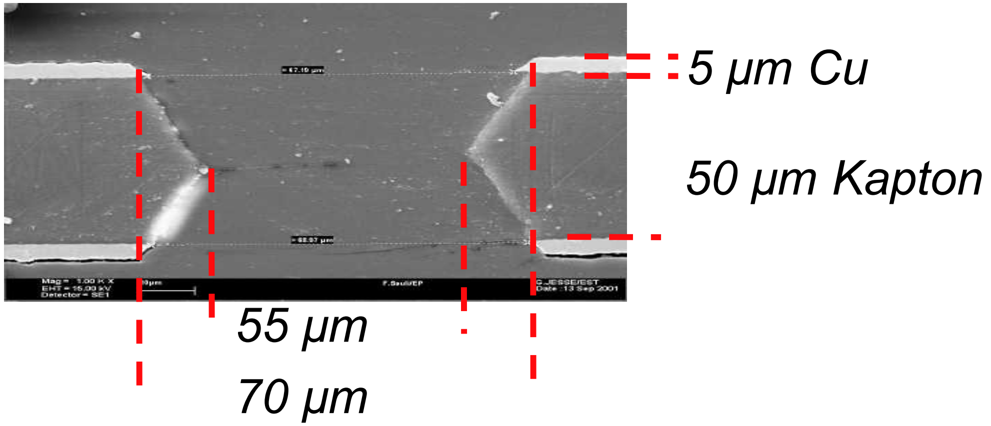


GEM Technology

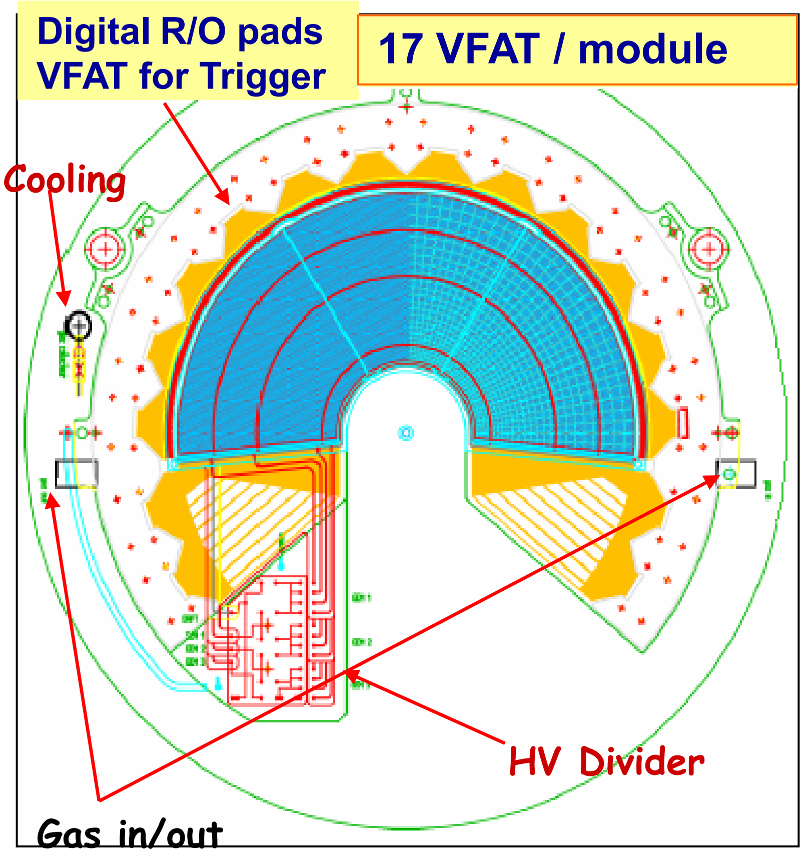
- Developed at CERN (F. Sauli ~ 1997)
- Used in COMPASS, LHCb, …
- Gas Detector
- "Rad-hard", high rate, good spatial and timing resolution
- Electrodes: 50 µm kapton + 2x5 µm Cu
- Density: 50-100 holes/mm^2
- Electric field (channel) ~ 100 KV/cm (V_{gem} = 500 V) ⇒ electron cascade
- Gain: 10 - 100

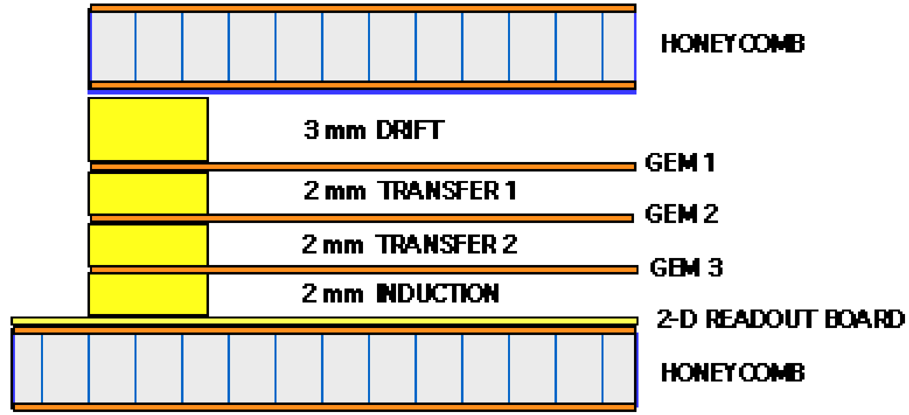
T2 GEM:

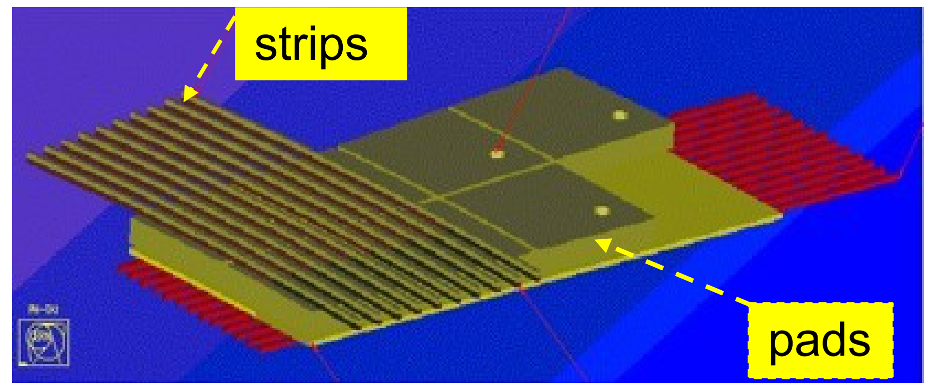




T2 Triple-GEM Detectors







- Ar/CO_2 70/30 gas mixture
- Operating gas gain M = 8000
- Digital readout (VFAT)
- T2 Triple GEM technology adequate to work at least 1 yr at $L=10^{33}$ $cm^{-2}s^{-1}$

Pads: 65(φ) x 24(η) = 1560 pads
$\Delta\eta \times \Delta\varphi = 0.06 \times 0.018\pi$
~2x2 mm^2 - ~7x7 mm^2

Strips: 256x2 (width 80 μm, pitch 400 μm)