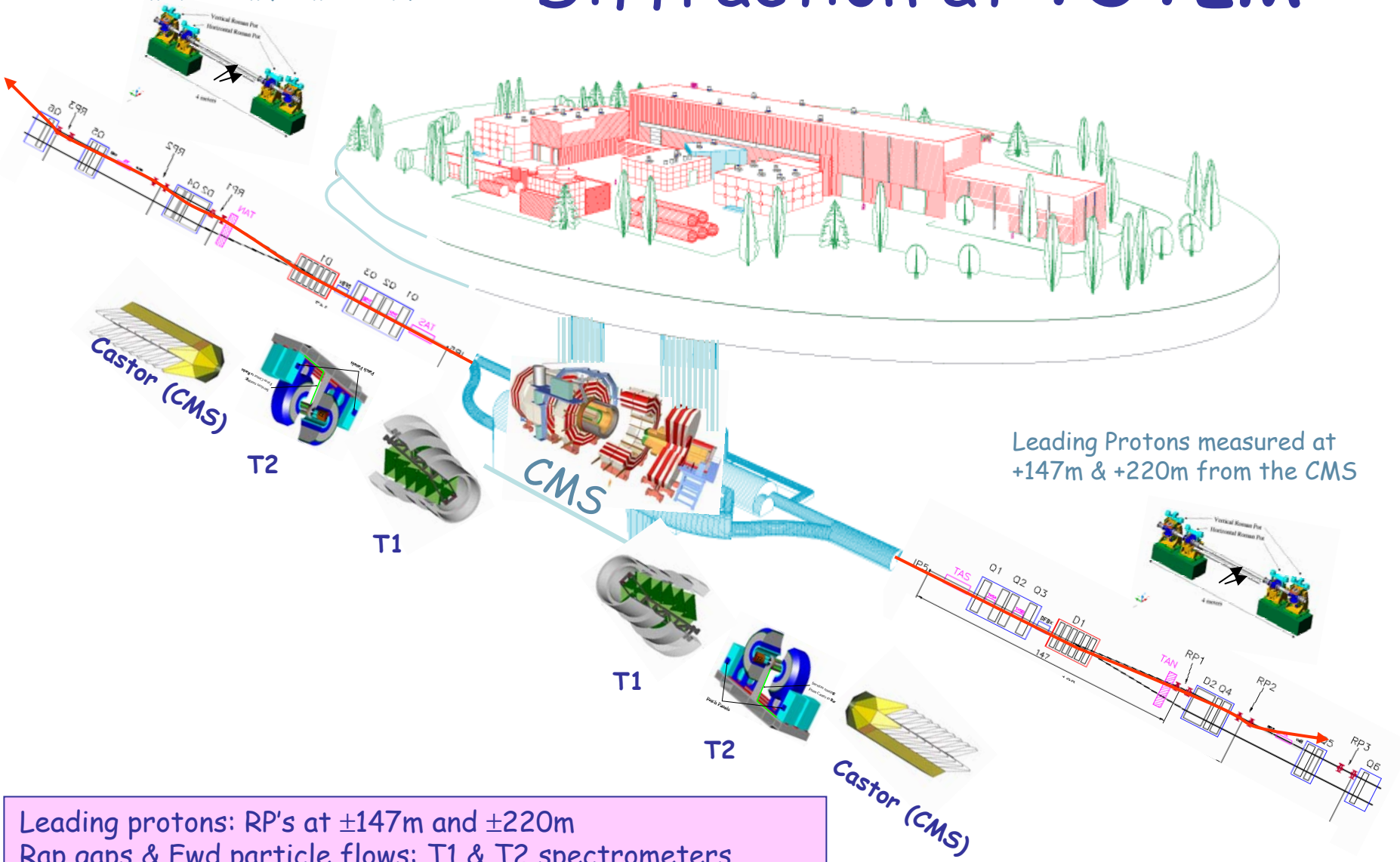
Diffraction at TOTEM

Leading Protons measured at
-220m & -147m from the CMS



Leading protons: RP's at ±147m and ±220m
Rap gaps & Fwd particle flows: T1 & T2 spectrometers
Fwd energy flows: Castor & ZDC (CMS)
Veto counters at: ±60m & ±140m?

TOTEM Collaboration

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(5m Totem slice/person !)

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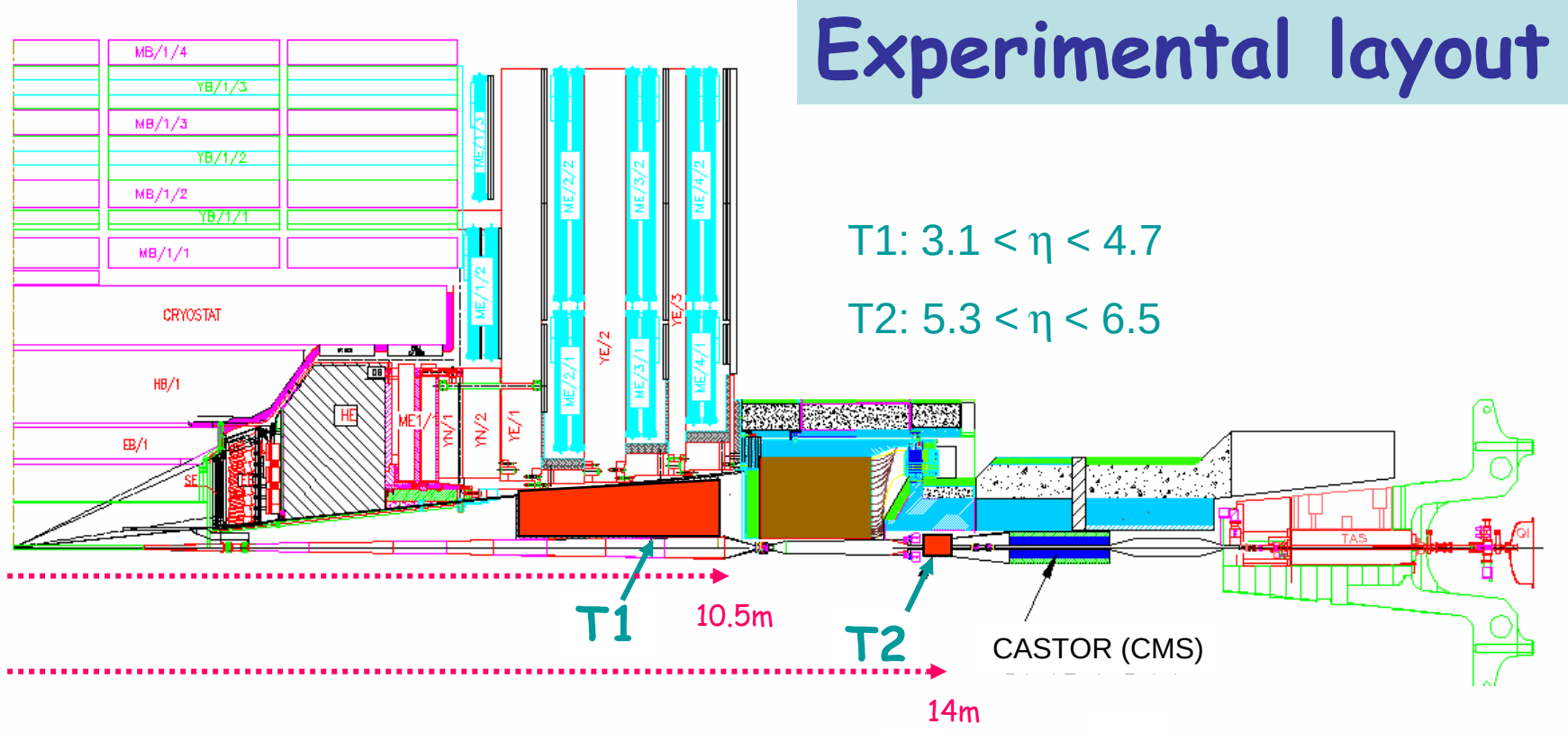
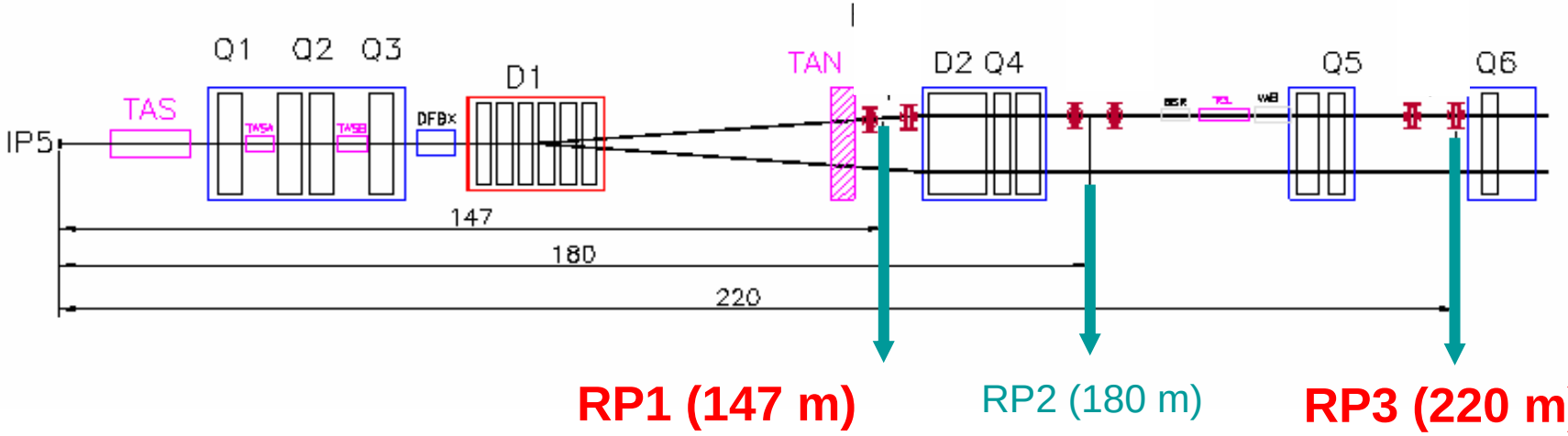
[n] University of Hawaii (USA) **(14)**

Experimental layout

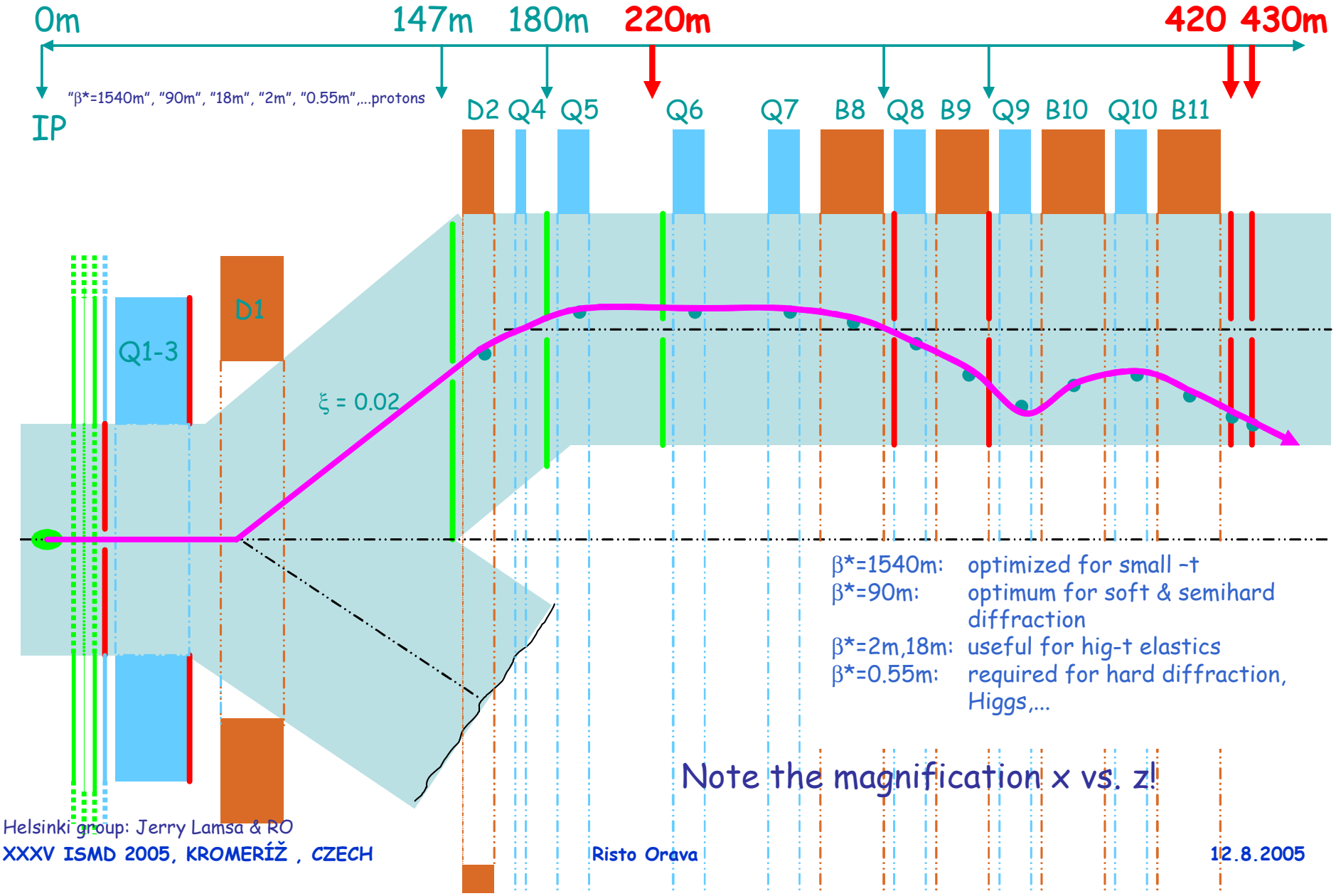


T1: 3.1 < η < 4.7

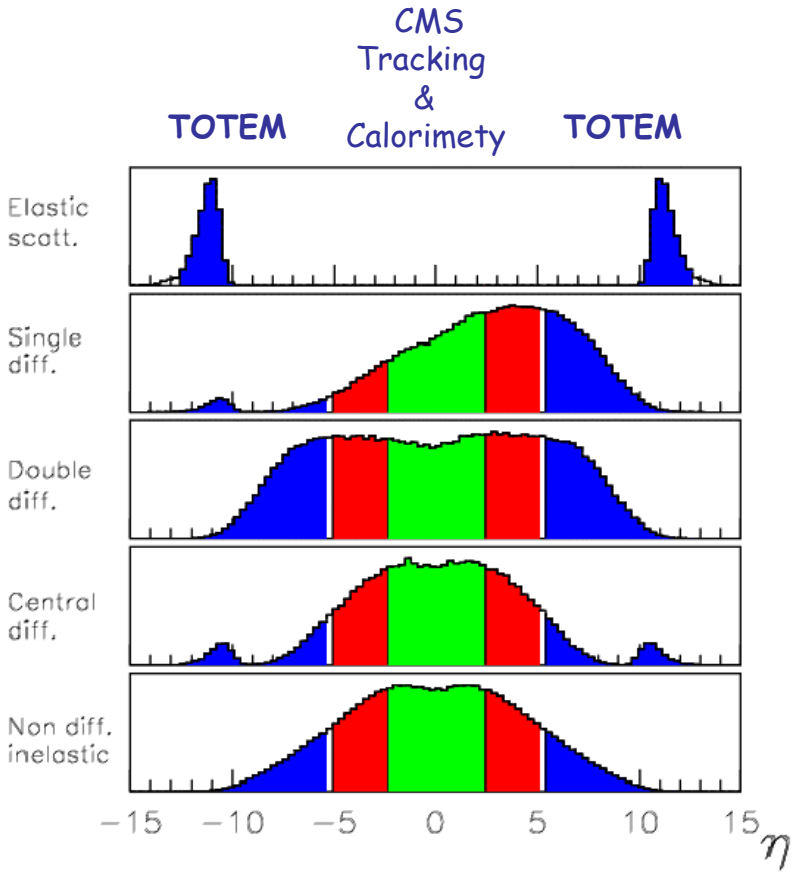
T2: 5.3 < η < 6.5



Leading Proton Detection-An Example



TOTEM measurements



1. Total pp cross section with a precision of $\approx 1\%$

2. Elastic pp scattering:
   $10^{-3} < t = (p\theta)^2 < 10\ GeV^2$

3. Leading particles:
   $2\times10^{-3} < \xi < 2 \times 10^{-1}$

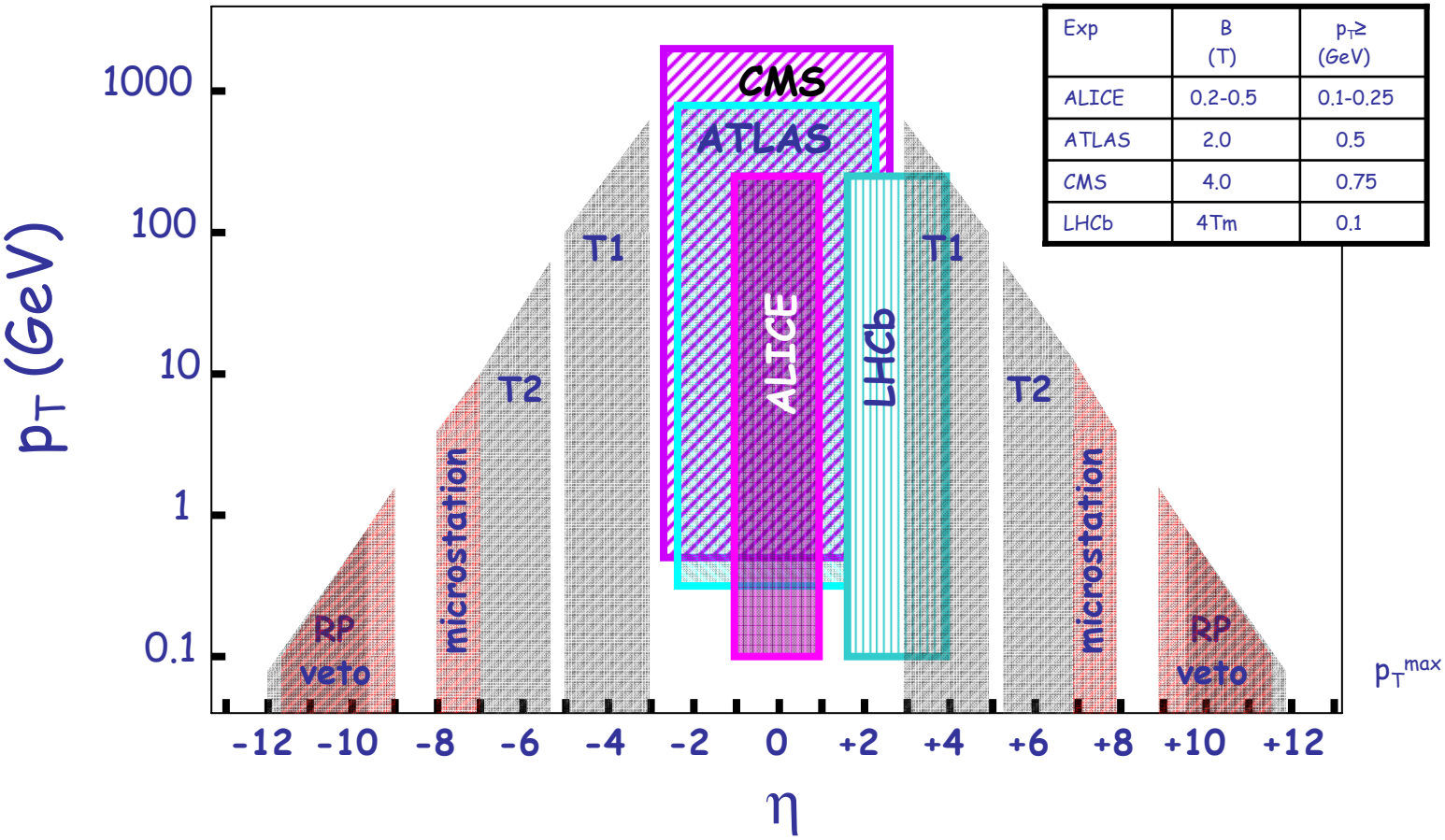
   Particle flows, rap gaps:
   $3.1 < \eta < 4.7$ and $5.3 < \eta < 6.5$

$\Rightarrow$ Investigate diffractive & forward phenomena together with CMS.

Note: Rapidity coverage could be further improved by veto counters at ±60m to ±140m, microstations at 19m etc.

LHC Experiments: p_T-η coverage

CMS fwd calorimetry up to $|\eta| \approx 5$ + Castor + ZDC

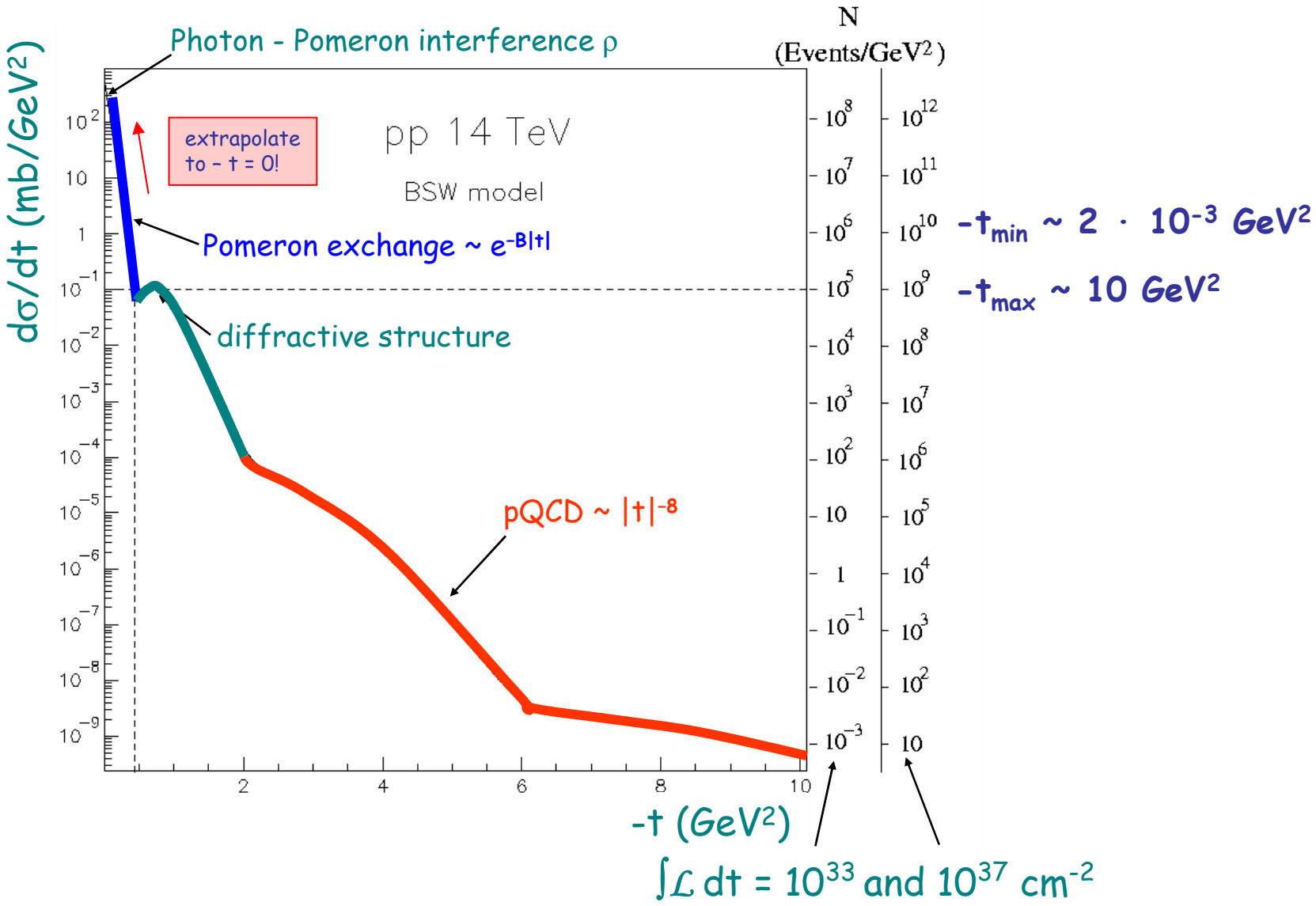


Exp	B (T)	$p_T \geq$ (GeV)
ALICE	0.2-0.5	0.1-0.25
ATLAS	2.0	0.5
CMS	4.0	0.75
LHCb	4Tm	0.1

$p_T^{max} \sim \sqrt{s}\ \exp(-\eta)$

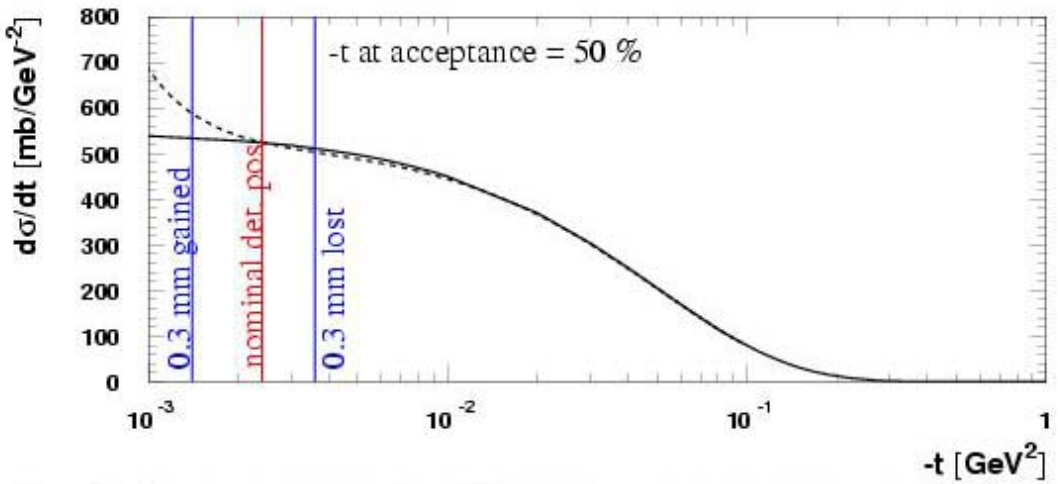
The base line LHC experiments will cover the central rapidity region.
TOTEM⊕CMS will complement the coverage in the forward region.

Elastic Scattering: dσ/dt



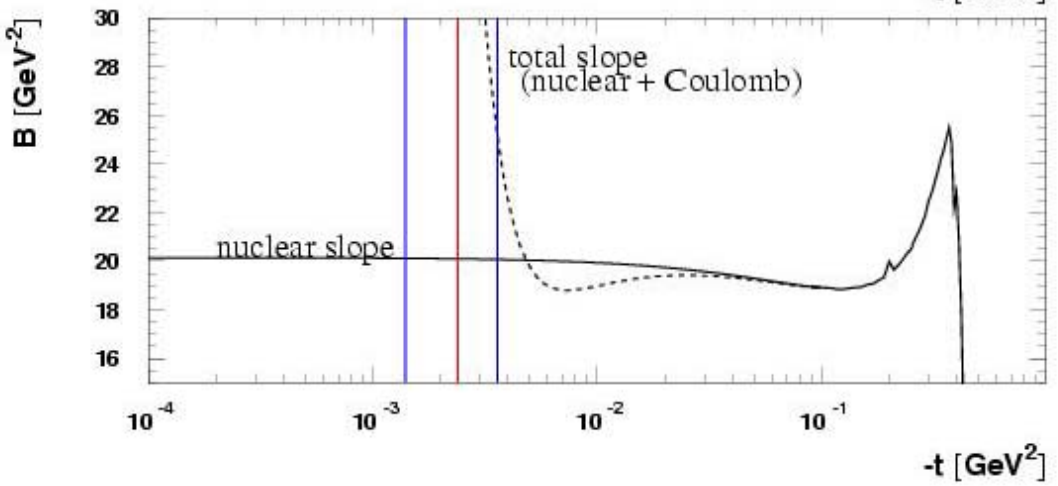
Elastic Scattering at small -t

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



deviations from single exponential slope expected

$$B(t) = -\frac{\frac{d}{dt}\left(\frac{d\sigma}{dt}\right)}{\frac{d\sigma}{dt}}$$

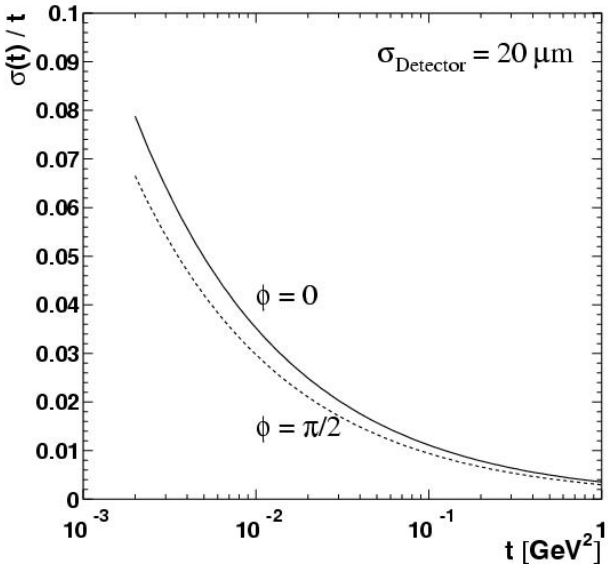


nominal Totem run scenario allows to probe the inteference region

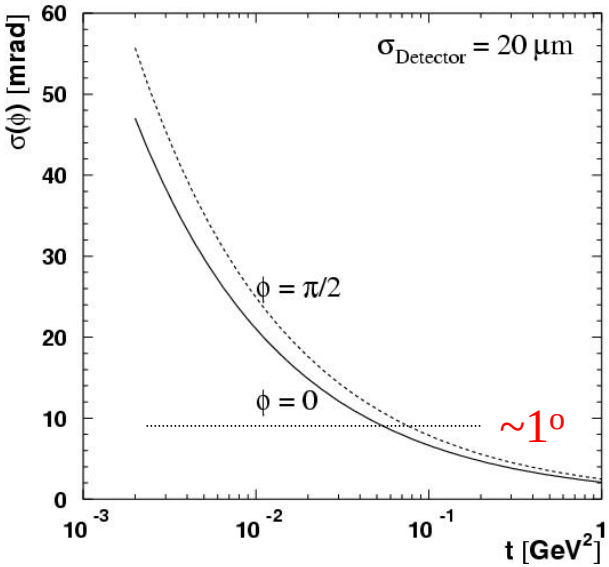
- for the required precision in $d\sigma/dt|_{t=0}$, moderate $-t_{min}$ ($\approx 10^{-2}$ GeV^2) seems sufficient
- at lower –t –values learn about the (non-exponential) behaviour & get better extrapolation

Elastic Scattering - Resolution

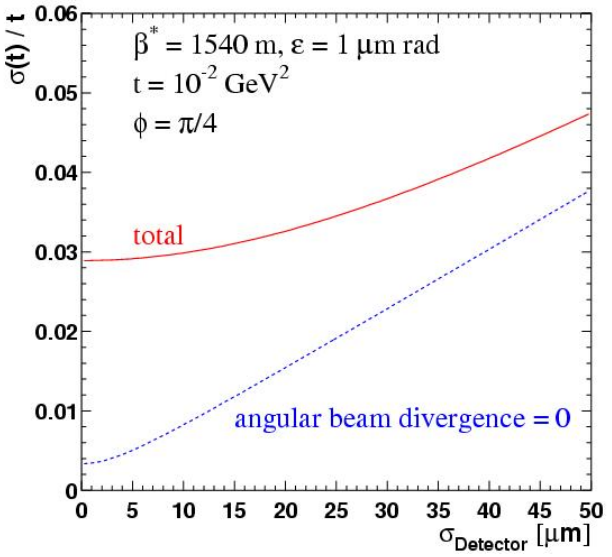
t-resolution (both arms)



φ-resolution (one arm)



Collinearity test for tracks in both arms to reduce bacgrounds & tag CD

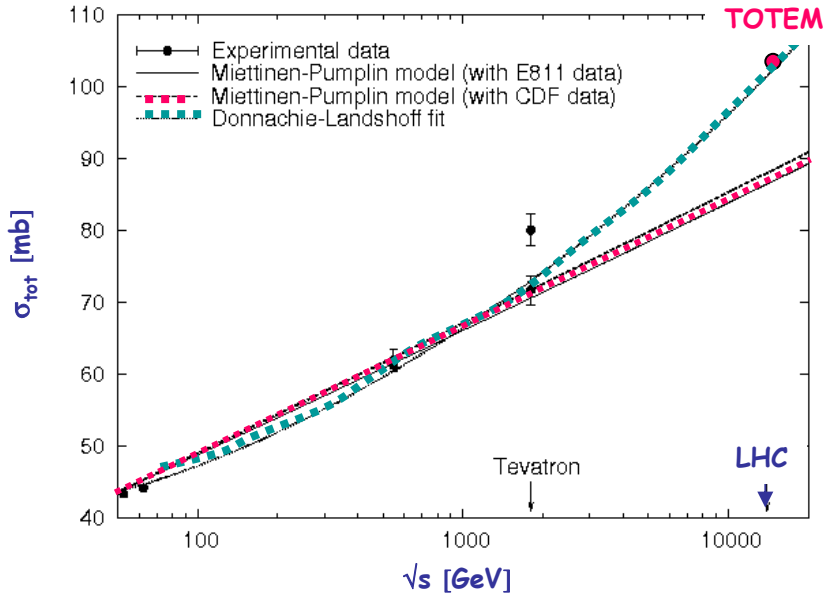


Effect		Uncertainty in Extrapolation
Resolution, statistics (10h@10^{28}):	10^7 events	0.07 %
Beam energy uncertainty	0.05 %	0.1 %
Beam -- detector alignment	20 μm	0.08 %
Angular spread	0.2 μrad	0.1 %
Total		**0.2 %**

Measurement error to be smaller than physics effects due to non-exponential cross-section (**0.5 %**).

TOTAL & DIFFRACTIVE CROSS SECTIONS σ_{tot} and σ^{SD}

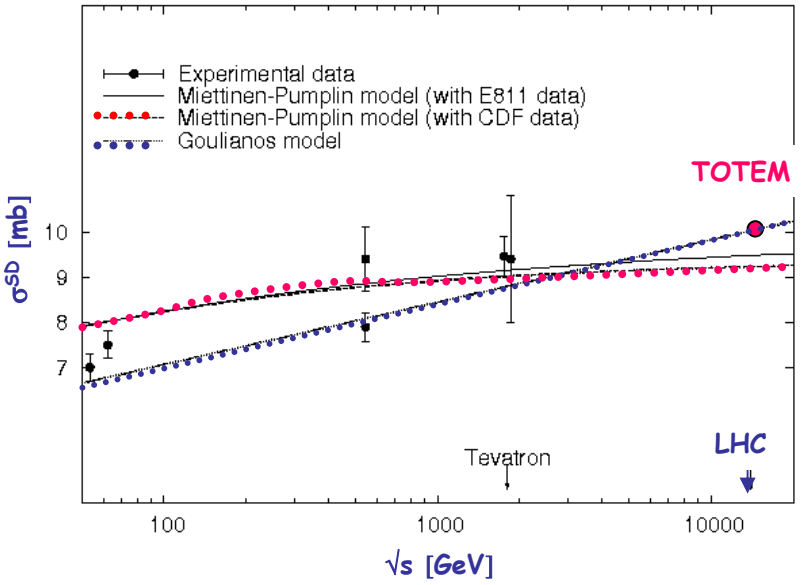
total pp cross section



-measurement of σ_{tot} to 1% will distinguish between different models

$\sigma_{tot} \propto (\ln s)^{\varepsilon}$ as $s \to \infty$
ε = 0, 1, 2, or - 0.08 ??

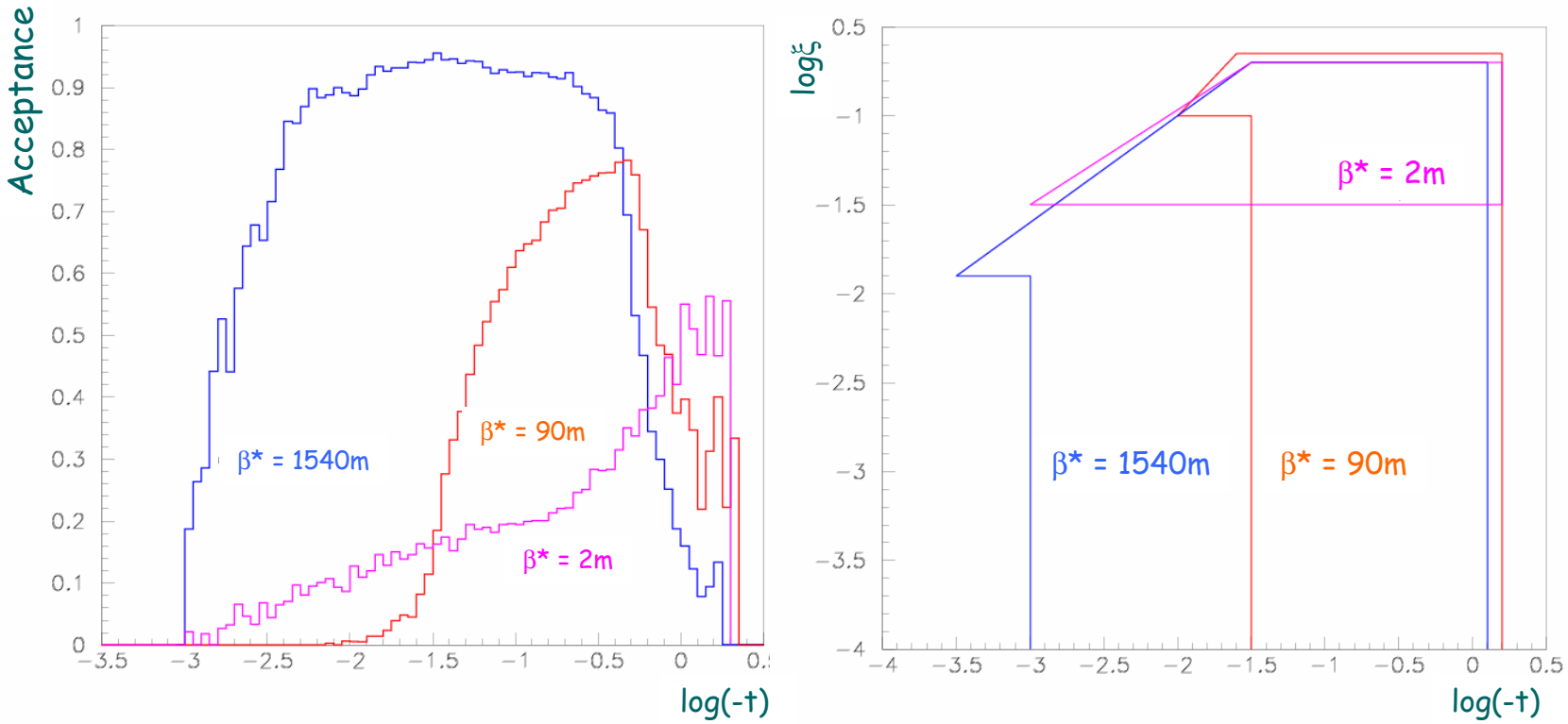
single diffractive cross section



-measurement of σ^{SD} to 10% allows tests of diffractive models

Acceptance in ξ & -t vs. Run Scenario

Acceptance of leading protons produced in Central Diffractive events (Phojet)



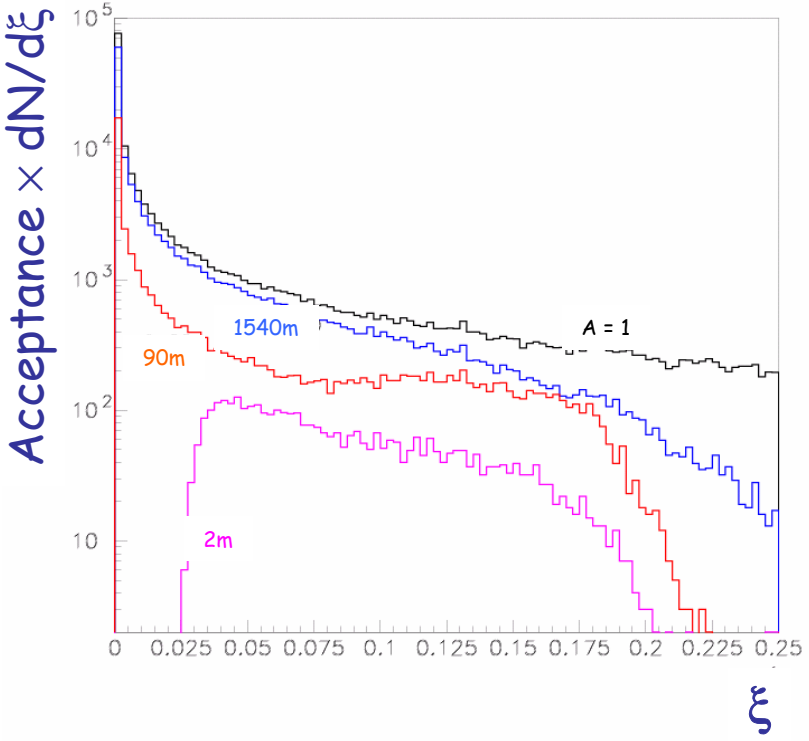
β* = 90m: CD protons detected by their scattering angle in the vertical RP detectors, $-t \geq 3\times 10^{-2}$ GeV^2, almost independently of ξ, ≈ 50% of CD protons seen (standard LHC injection optics, p-to-p in vertical plane ⇒ horizontal displacement proportional to ξ & vx positon/CMS)

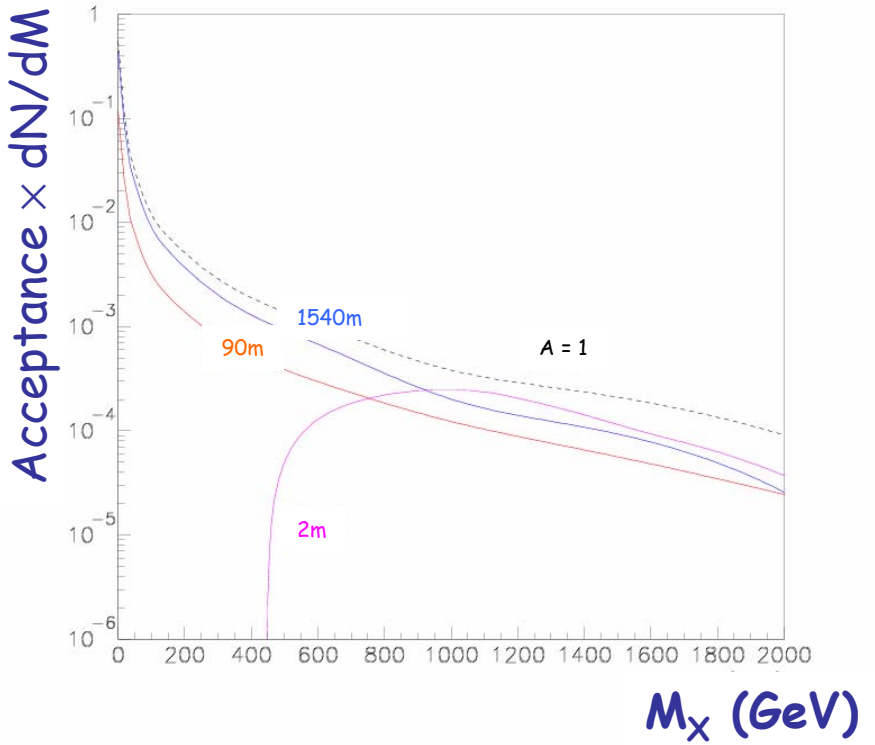
β* = 1540m: $-t \geq 1\times 10^{-3}$ GeV^2, ≈ 85% of CD protons seen (very low -t reach)

β* = 2m: CD protons seen in the horizontal detectors, only, $0.02 < \xi < 0.1$, $-t \geq 2$ GeV^2, poor acceptance (high -t) (420m RP's with $\xi_{min} \approx 0.002$ would help!)

Acceptance in ξ & M_X vs. Run Scenario

90m optics: ≈ 50% of CD protons seen, $\mathcal{L} \leq 2 \times 10^{30}$ cm^{-2}s^{-1}, i.e. ≈ 1 pb^{-1} in a few days.

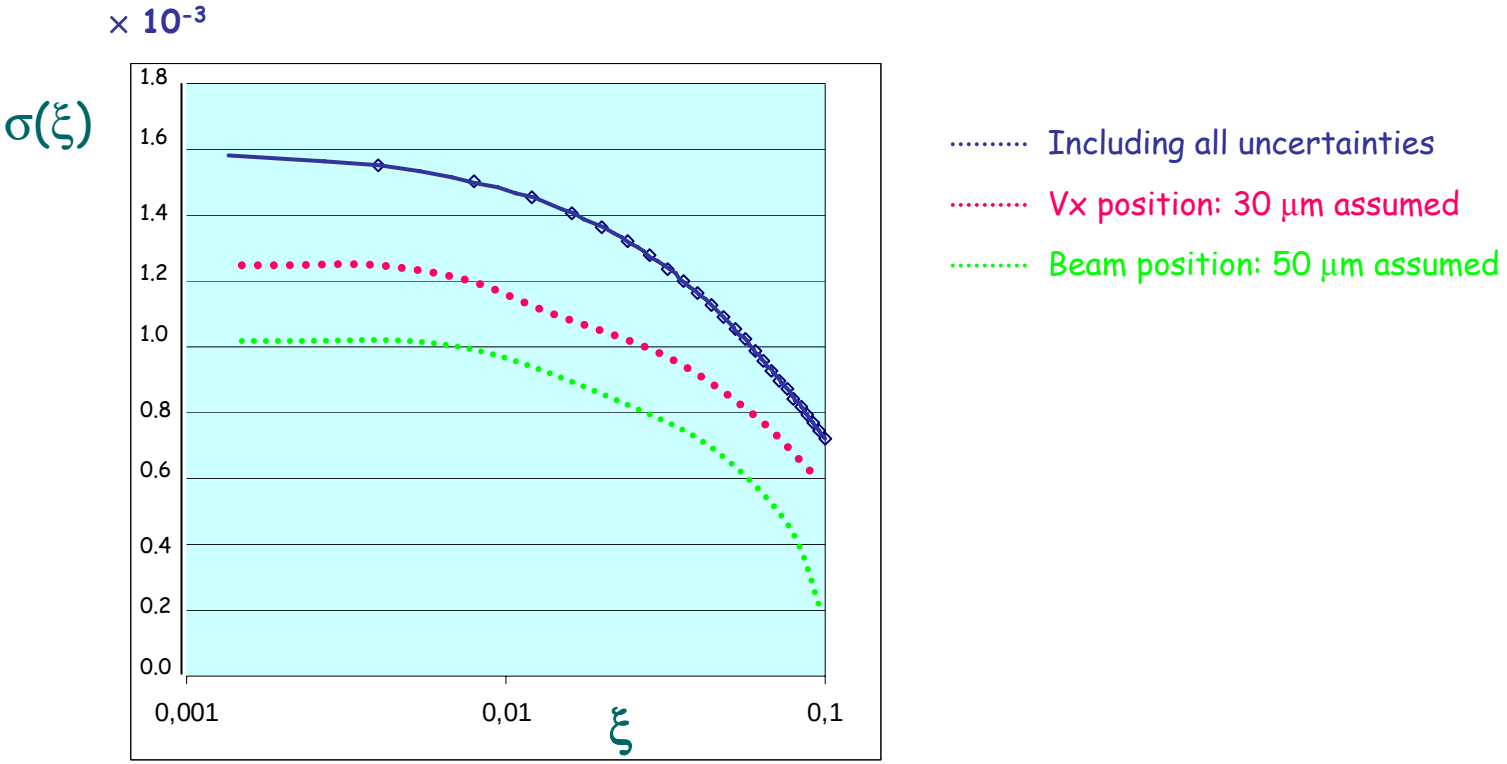




For hard diffraction need nominal optics: diffractive protons with $\xi \geq 0.02$ (0.002 at 420m location) seen, $\mathcal{L} = 10^{32}$-10^{33} cm^{-2}s^{-1} yields 1 – 10 fb^{-1} in a year.

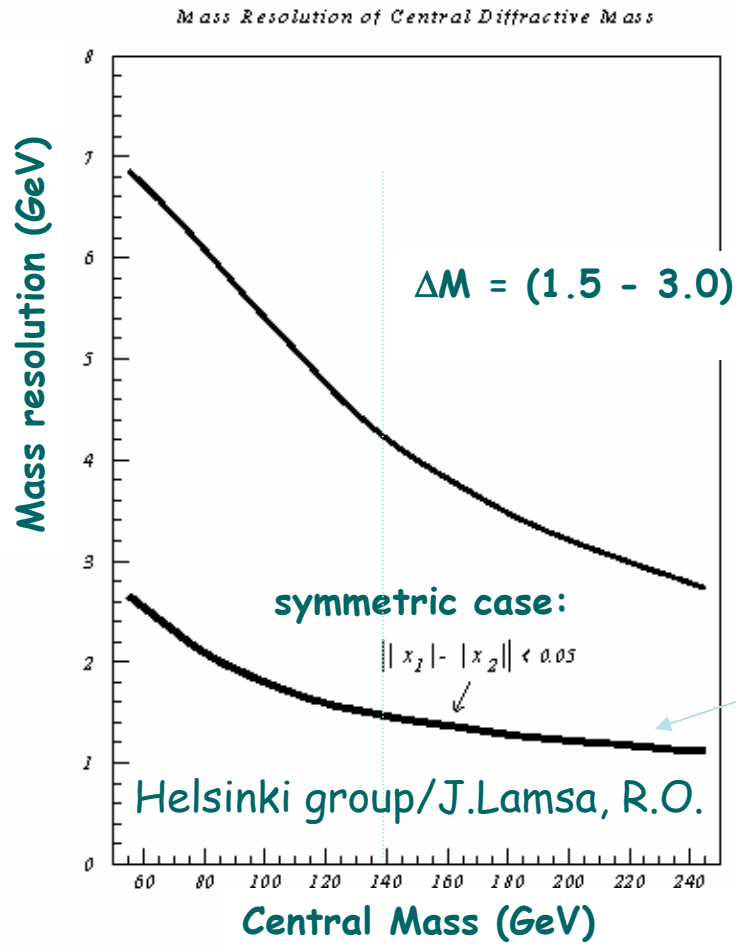
90 m optics: ξ resolution

Resolution in ξ is dominated by: (1) vertex position (30 μm precision by CMS assumed), (2) beam position (50 μm assumed)



A historical note....

CED Mass Measurement at 400m...



Mass resolution vs. central mass assuming $\Delta x_F/x_F = 10^{-4}$

ΔM = (1.5 - 3.0) GeV ($\Delta x_F/x_F$ = (1-2)×10^{-4})

≈ 65% of the data

20 GeV < M_X < 160 GeV

(M_{Xmax} determined by the aperture of the last dipole,B11,
M_{Xmin} by the minimum deflection = 5mm)

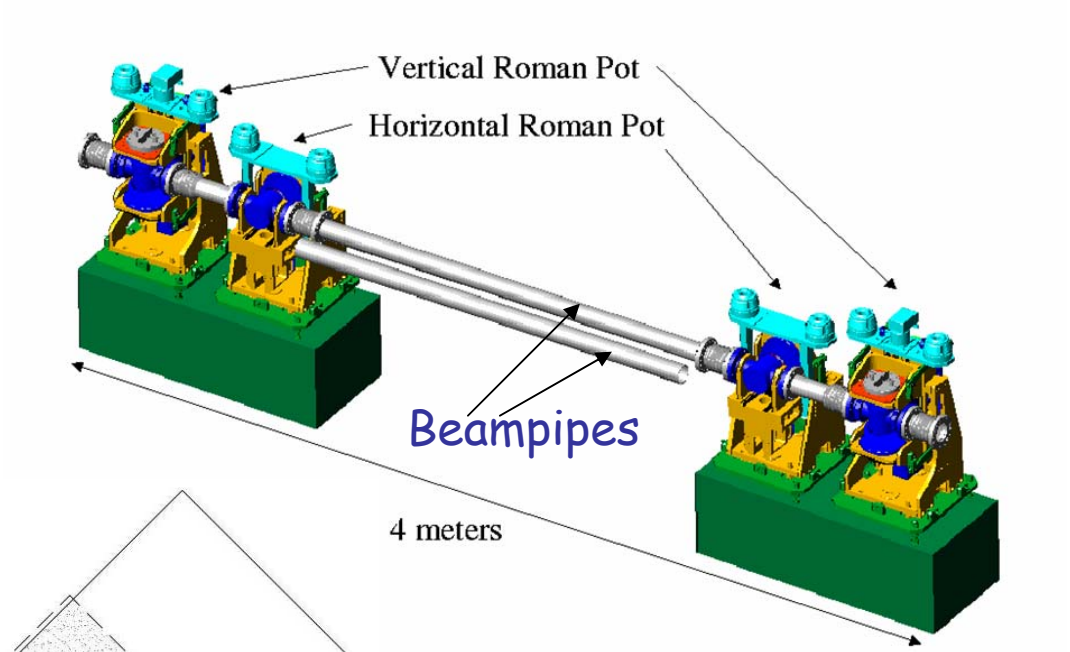
Workshop on Diffractive Physics
4. – 8. February 2002
Rio de Janeiro, Brazil

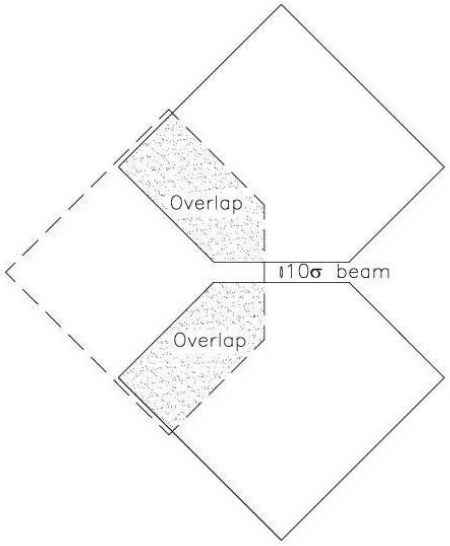
TOTEM⊕CMS Physics Reach

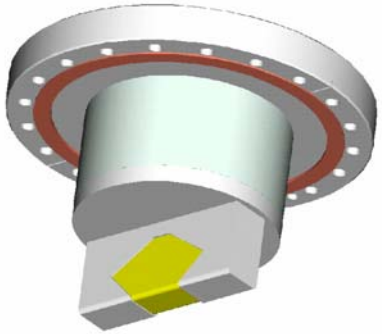
Run Scenario	β* [m]	k [no.of bunches]	N × 10^{11} [no.of protons per bunch]	$\mathcal{L}$ [$cm^{-2}s^{-1}$]	Physics Reach
1	1540	156	1.0	2×10^{29}	• elastics, σ_{tot} • soft diffr.
2	90	156	1.0	3×10^{30}	• (semi-) hard diffraction
3	18	936 → 2808	1.0	1×10^{32}	• hard diffr. • low-x
4	≤ 2	936 → 2808	1.0	$10^{32} \rightarrow 10^{33}$	• CED Higgs • beyond SM

Leading protons: Roman Pots

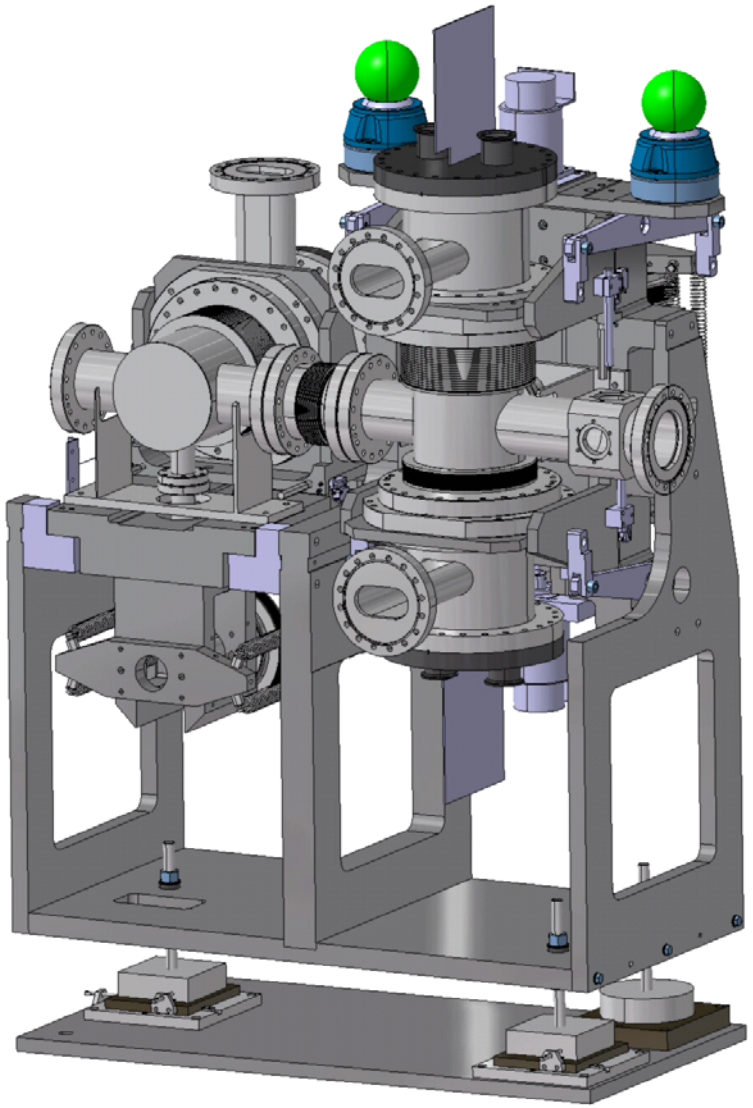
Measurement of very small p scattering angles (few μrad):
Leading proton detectors in RPs approach beam to 10 σ + 0.5 mm ≈ 1.5 mm





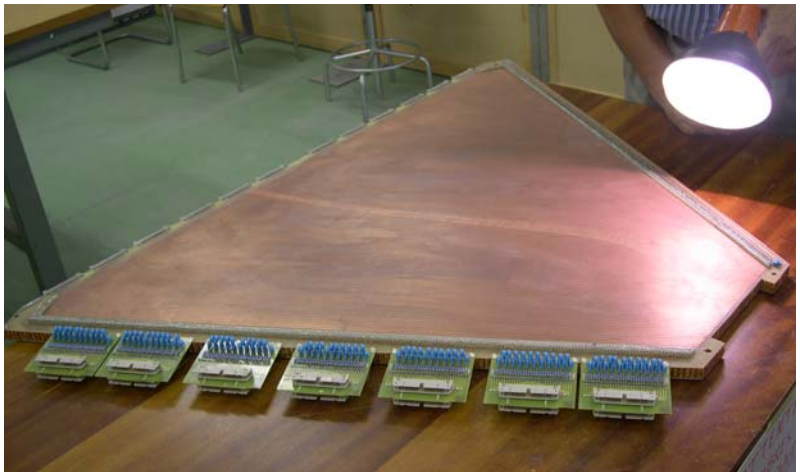


Roman Pots

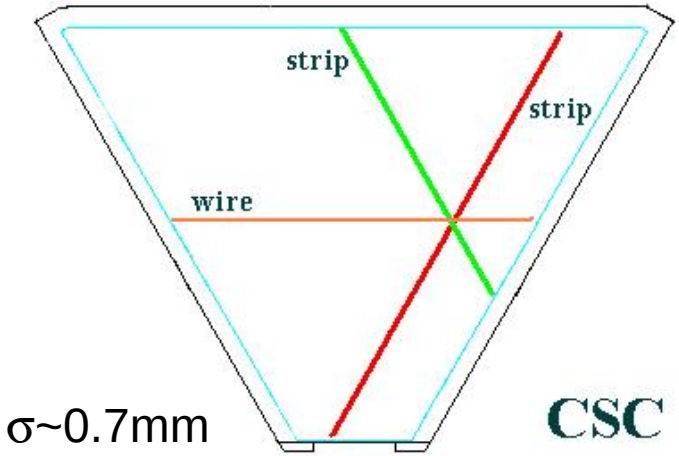


- Preparation on Surface January-October 2006
  - Roman Pot equipment assembled on surface without detector
  - UHV Test of the system
  - Commissioning of the full system on surface (detectors, cooling, vacuum)
  - Relative alignment by metrology of the moving components Calibration of motors and encoders
  - Test beam on a fixed target (only for one or two units)
- Underground access through the PM56 shaft October-February 2007
  - Installation of the cooling system
  - Installation at the defined locations along the tunnel
  - Check of the cabling (motors, controls interlocks)
  - Vacuum Chambers connection
  - Alignment on the beam
- Roman Pot Commissioning
- After the LHC commissioning and just before the pilot runs
  - Installation of the detectors assembly in the pots
  - Connection to the patch panels and to the cooling plant

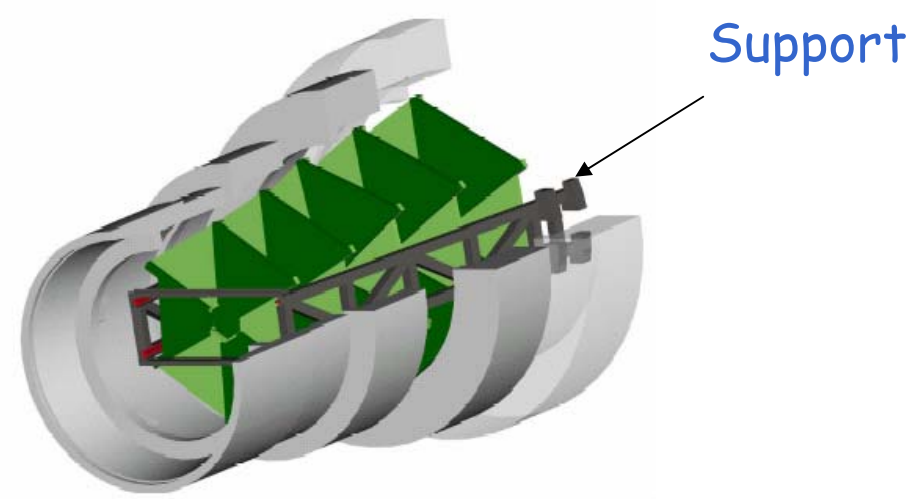
T1 Telescope



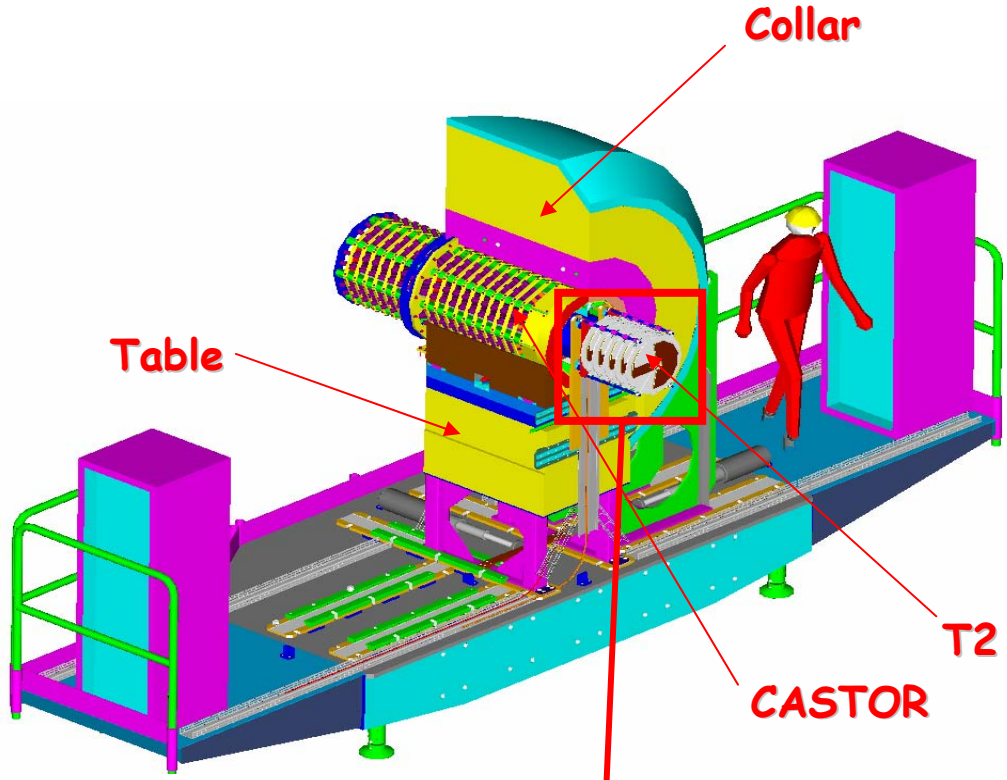
- 5 planes with measurement of three coordinates per plane.
- 3 degrees rotation and overlap between adjacent planes
- Primary vertex reconstruction
- Trigger with CSC wires

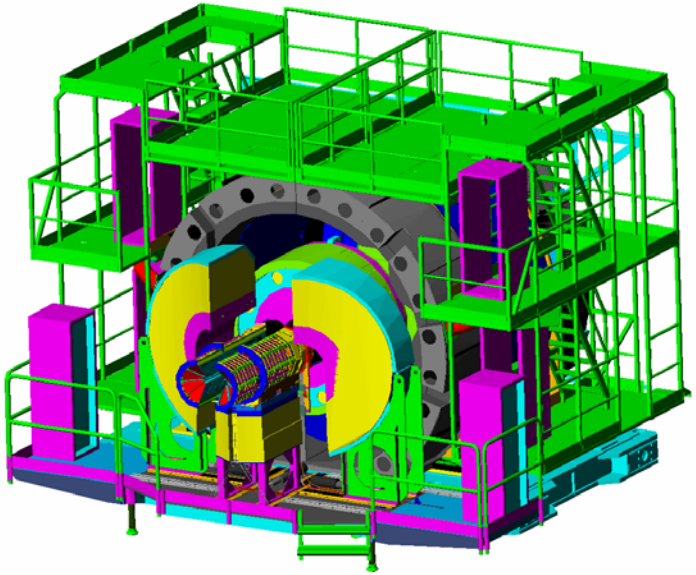


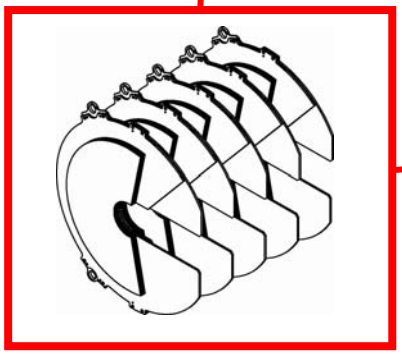
1 arm

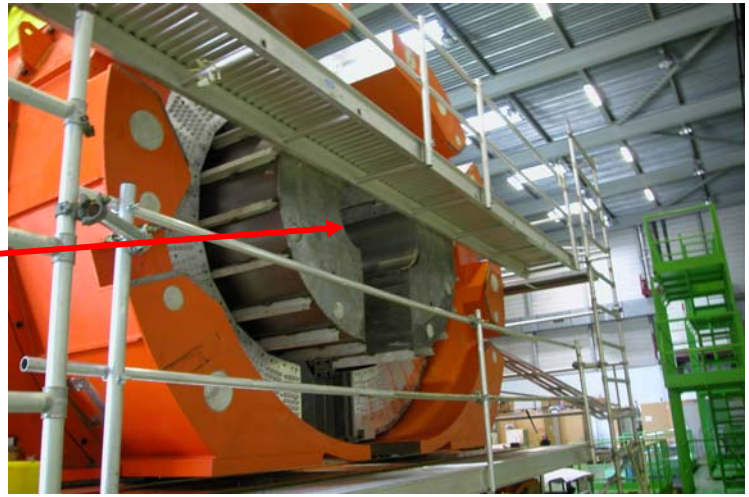


T2 Telescope





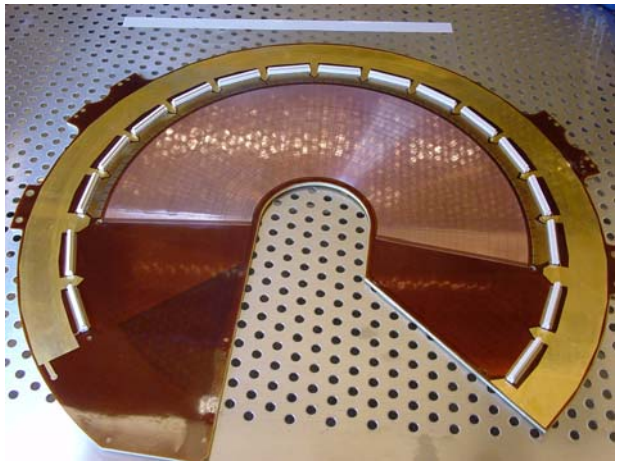


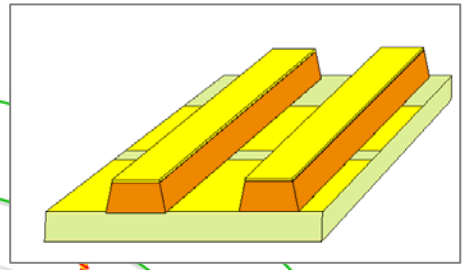


10 detector planes on each side of IP

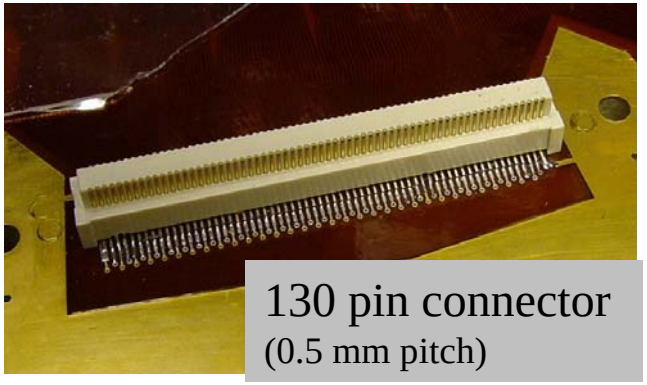
READOUT STRUCTURE

512 strips (width 80 μm, pitch of 400 μm)
65*24=1560 pads (2x2 mm^2 -> 7x7 mm^2)
readout via connectors





VFAT- fully digital readout
(no analog information out)



130 pin connector
(0.5 mm pitch)