TOTEM forward measurement: leading protons update

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on behalf of the

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

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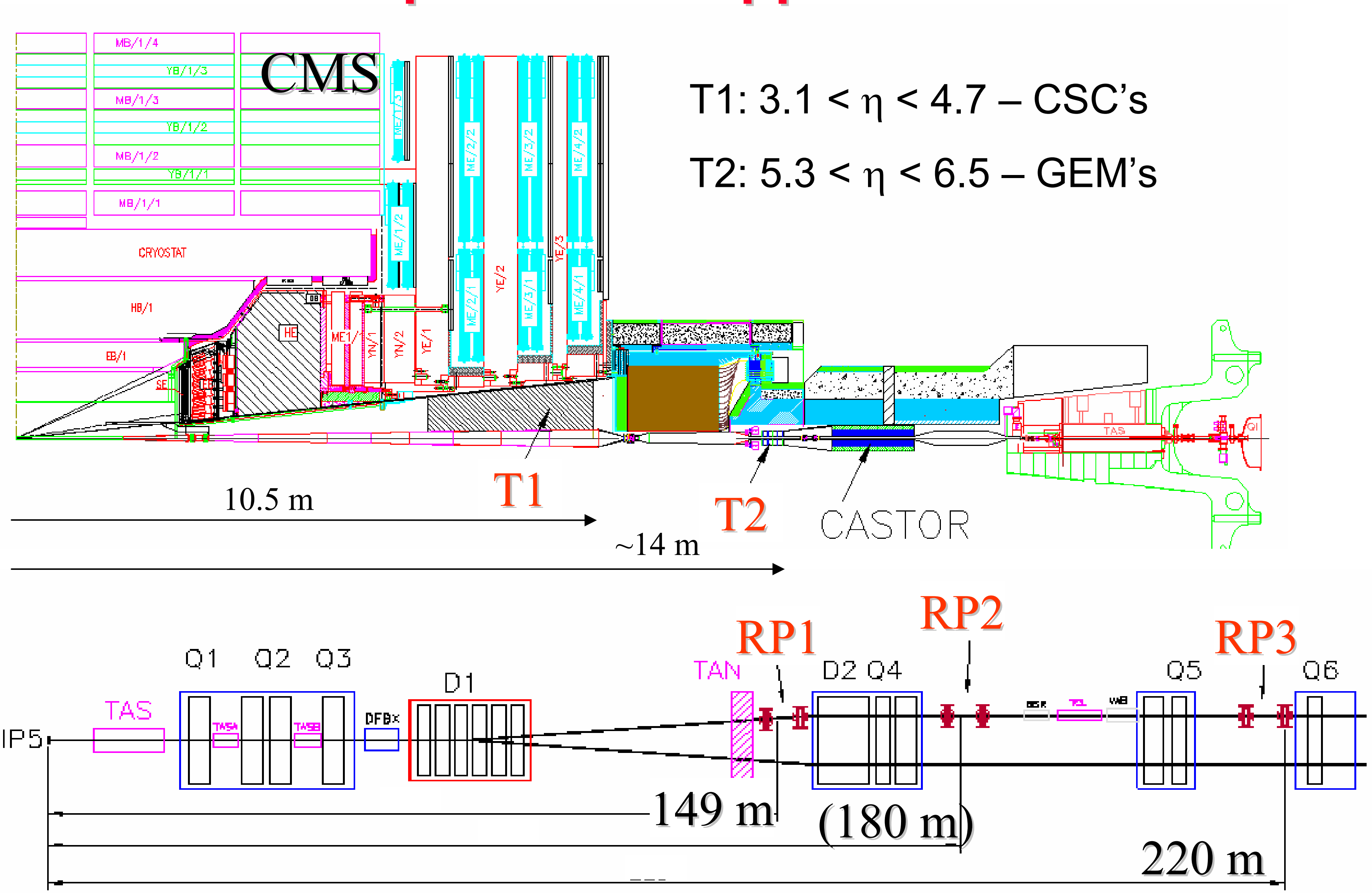
Penn State University, Pennsylvania, USA

Brunel University, Uxbridge, UK

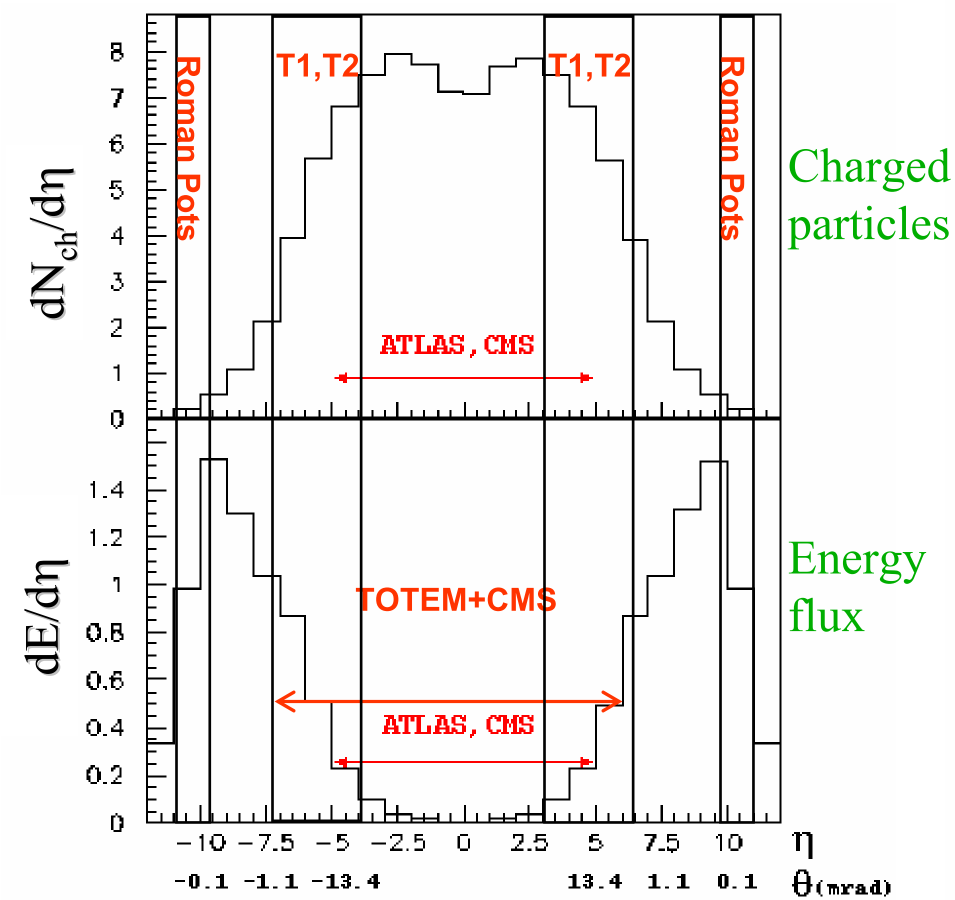
Diffractive protons @
$\beta^* = 1540$ m & $\beta^* = 0.55$ m

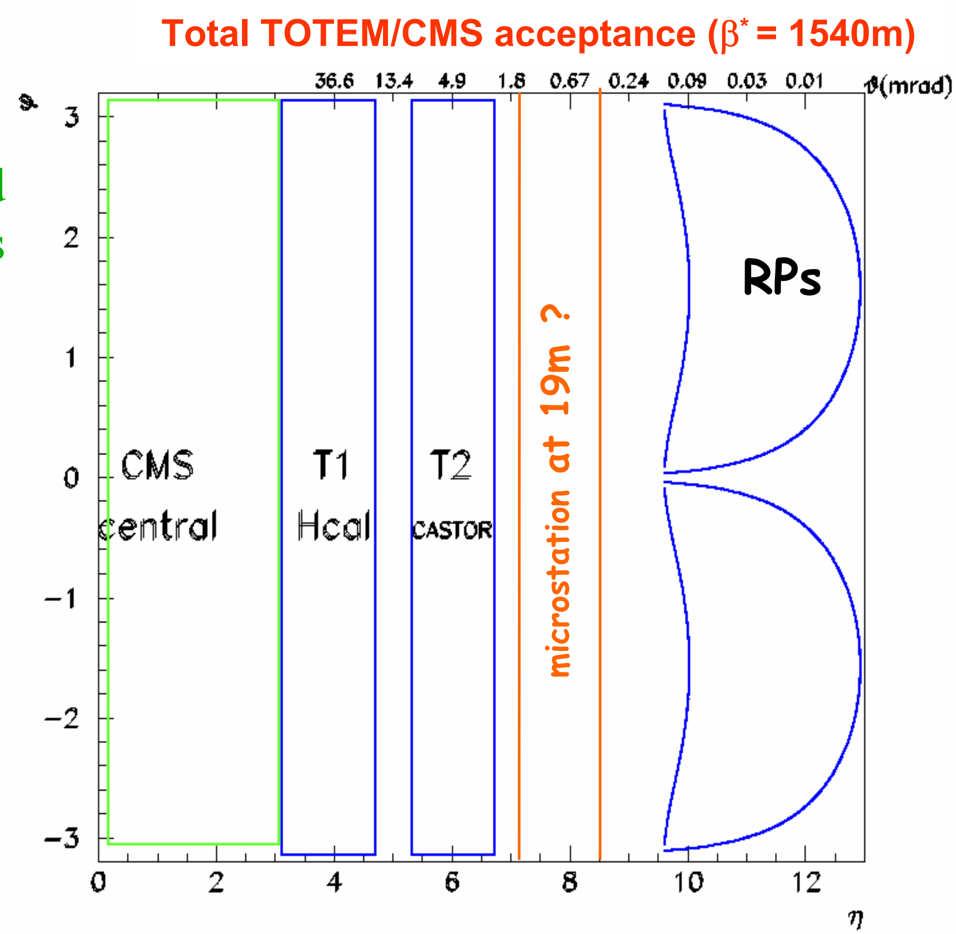
Experimental apparatus



CMS + TOTEM acceptance

CMS+TOTEM: largest acceptance detector ever built at a hadron collider





TOTEM Trigger & DAQ are CMS-compatible

(RP's up to 220 m within CMS L1 trigger latency)

Proton coordinates @ RP position

$$y(s) = L_y \Theta^*_y + v_y y^*$$

$$x(s) = L_x \Theta^*_x + v_x x^* + D\xi$$

$\beta^* = 1540$ m: maximize L & minimize v at RP location ($v_x \approx 0$, $v_y \approx 0$ @ 220 m)

Consequences:

- low angular spread at IP: $\sigma(\Theta^*_{x,y}) = \sqrt{\varepsilon / \beta^*} \approx 0.3\ \mu$rad
- large beam size at IP: $\sigma^*_{x,y} = \sqrt{\varepsilon \beta^*} \approx 0.4$ mm

($\varepsilon_N = 1\ \mu$m rad)

Reduced # of bunches $\Rightarrow$ $\mathcal{L}_{1540} = 10^{28} - 10^{29}$ cm^{-2} s^{-1} **& no X-angle**

$\beta^* = 0.55$ m: maximize $\mathcal{L}$ at IP & find RP locations with maximum |**D**|

Consequences:

- large angular spread at IP: $\sigma(\Theta^*_{x,y}) = \sqrt{\varepsilon / \beta^*} \approx 30\ \mu$rad
- small beam size at IP: $\sigma^*_{x,y} = \sqrt{\varepsilon \beta^*} \approx 16.6\ \mu$m

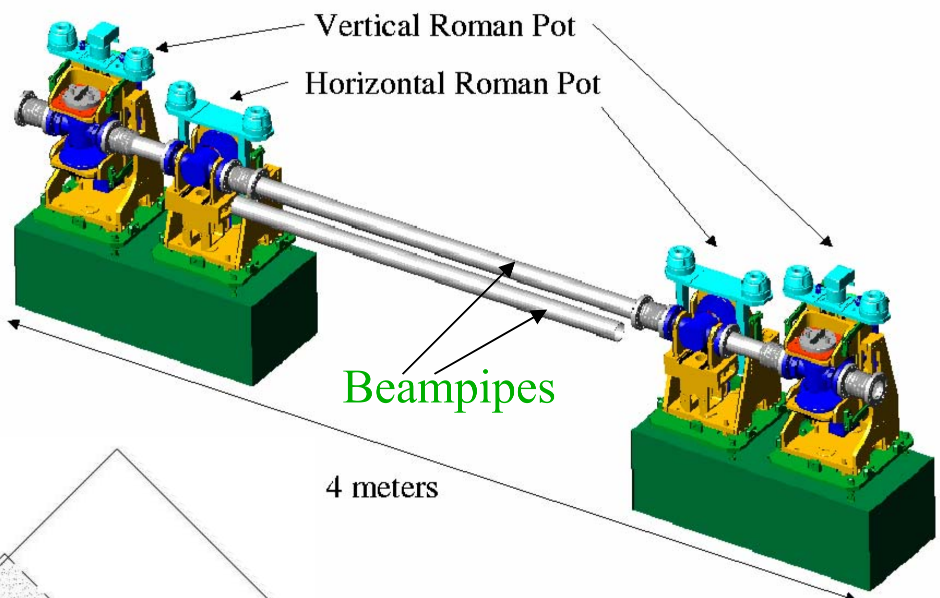
($\varepsilon_N = 3.75\ \mu$m rad)

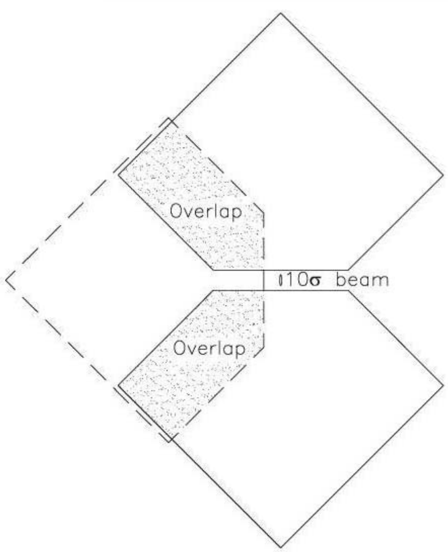
$\mathcal{L}_{0.55} > 10^{31} - 10^{32}$ cm^{-2} s^{-1}

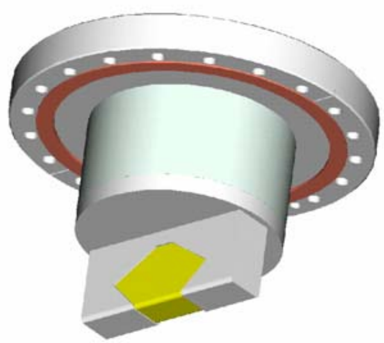
Leading proton detectors: Roman pots

Measurement of very small p scattering angles (few μrad):

Leading proton detectors approach beam to 10σ + 0.5 mm ~ 1.5 mm (220 m)

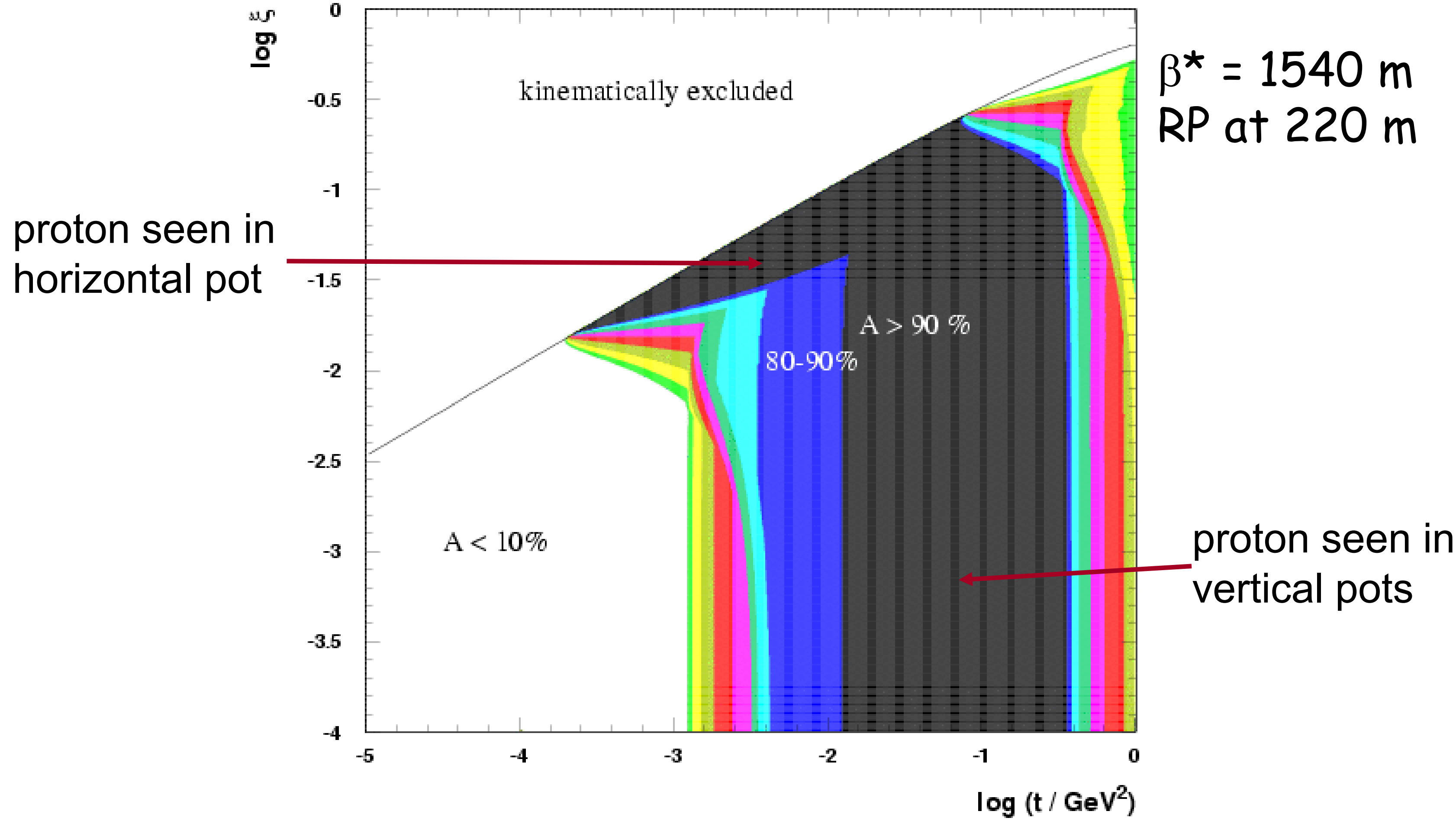






2004 prototype

Leading protons at high β*: acceptance



- ~ 90% of all diffractive protons are seen in the Roman Pots
- proton momentum can be measured with a resolution of few $\cdot 10^{-3}$
- proton acceptance for both beams similar

Low β* optics acceptance study

Acceptance studies updated with newest LHC optics V6.5 (V6.2):
β* = 0.55 (0.5) m; x* = 500 (0) μm; beam X-angle=142 (150) μrad

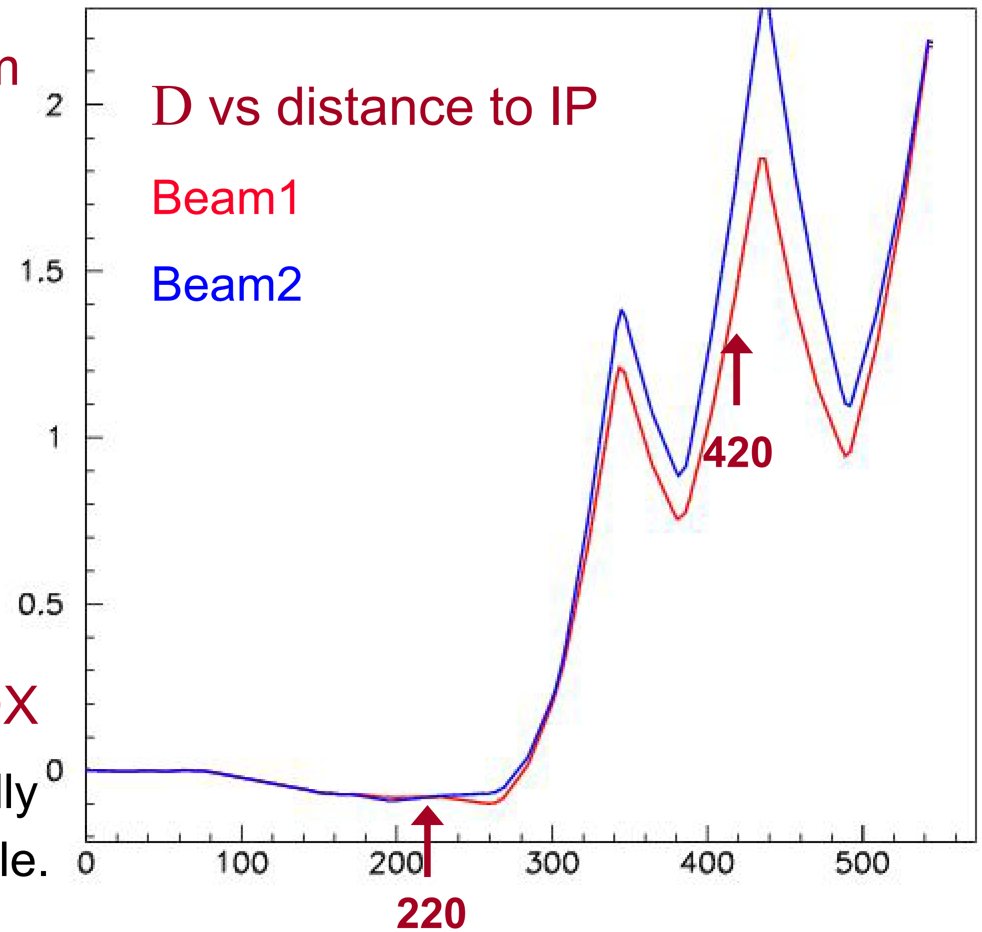
Detector approach: 10σ + 0.5mm

w.r.t. V6.2 optics:
|D| a bit larger @ 220 m
D a bit smaller @ 420 m

Beam aperture limitations:
Q5 for 220 m
Q9 for 420 m

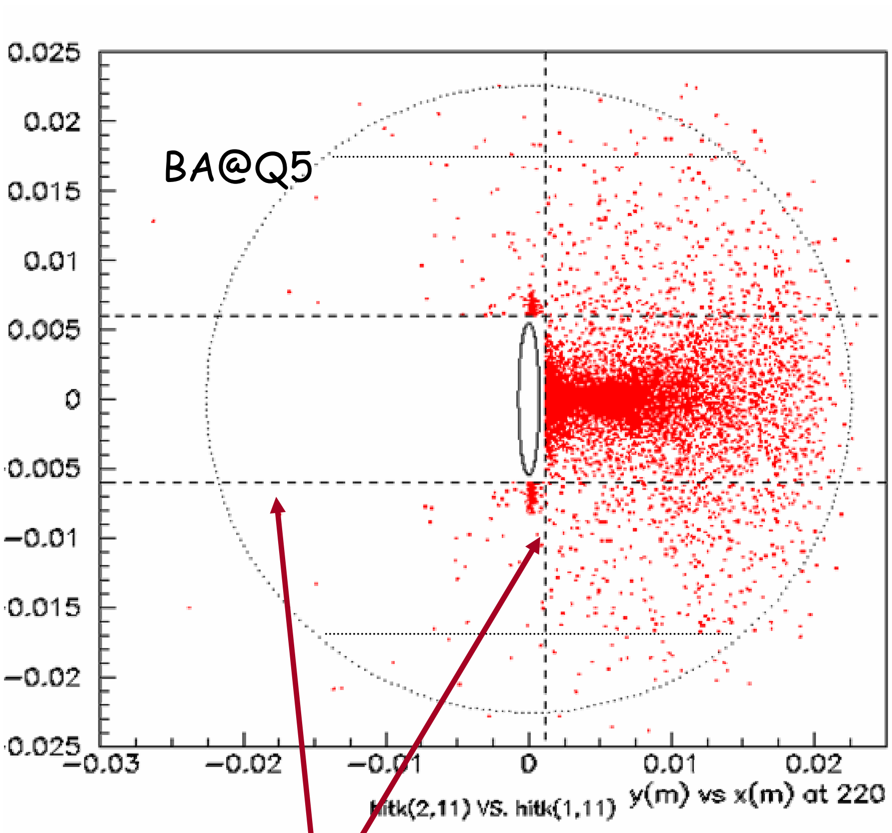
Trajectories simulated with MADX

NB! wasn't possible to do analytically as for β* = 1540 m due beam X-angle.

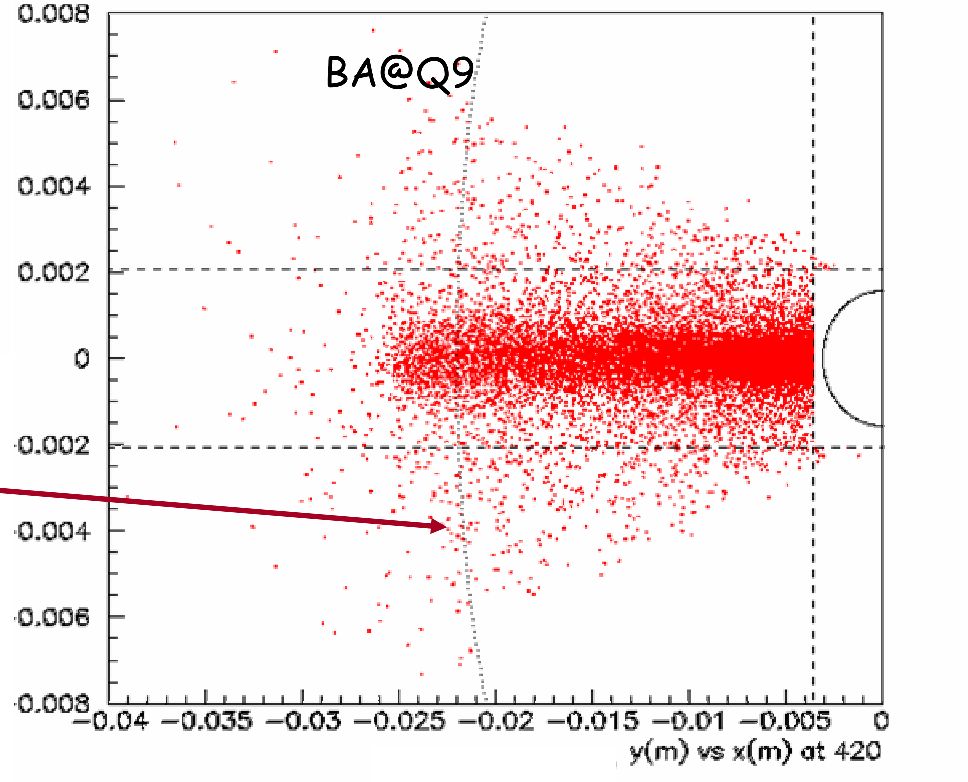


Hit distributions

β^* = 0.55 m
RP at 220 m



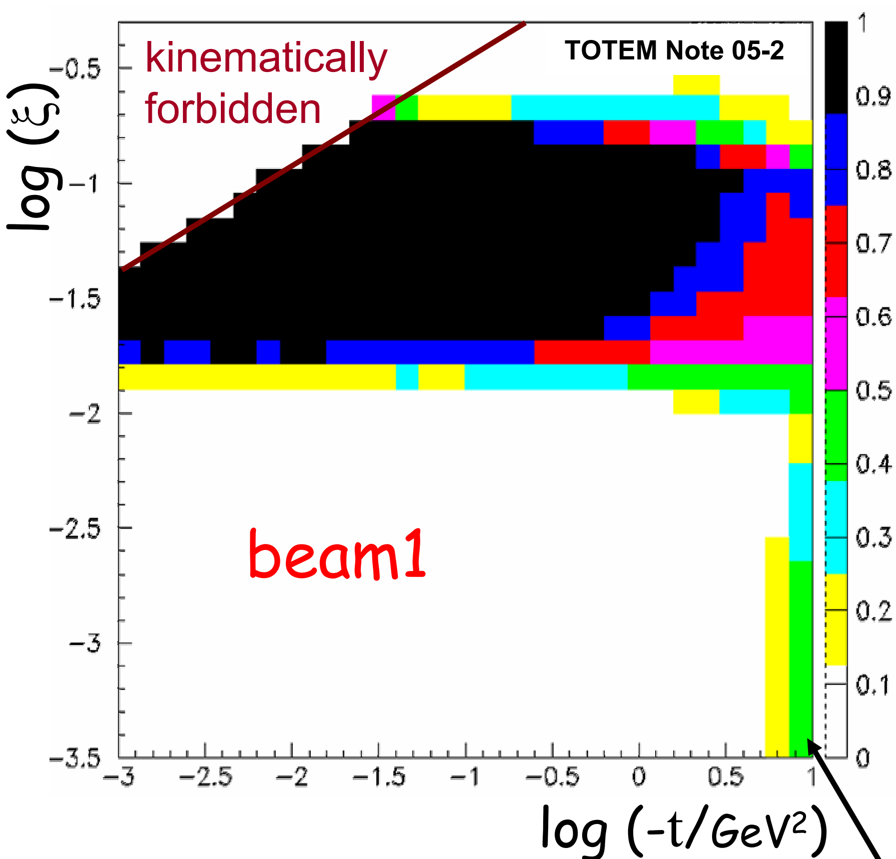
β^* = 0.55 m
RP at 420 m

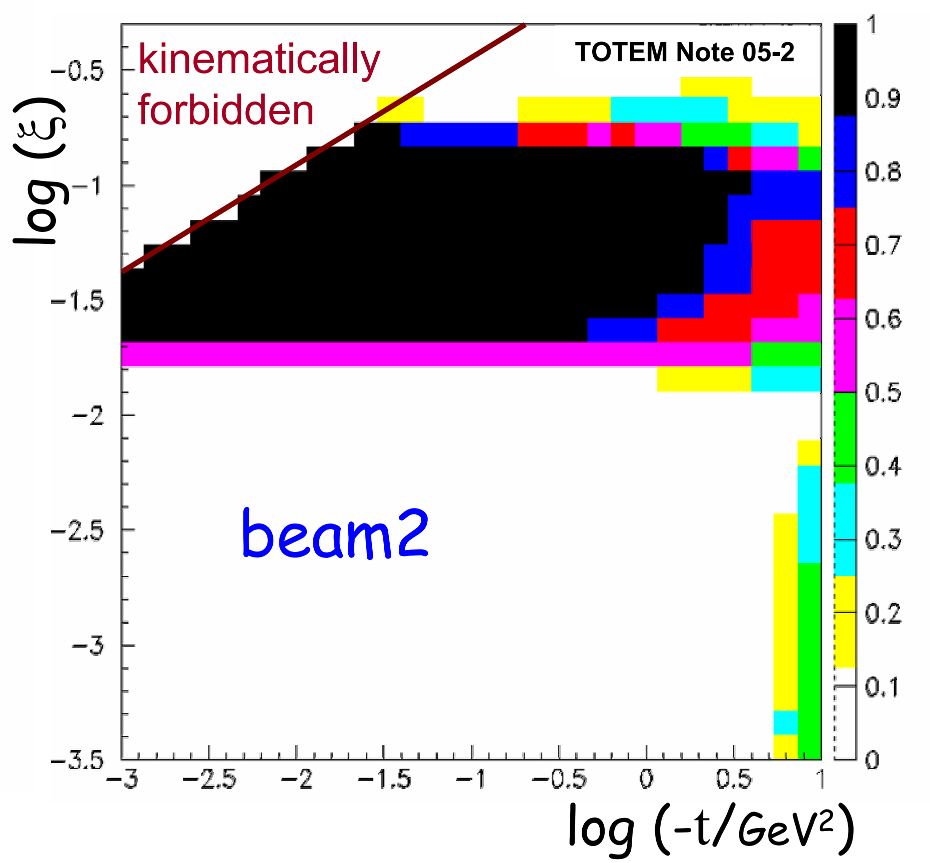


minimum detector approach

beam aperture limitation

Acceptance 220 m ($\beta^* = 0.55$ m)



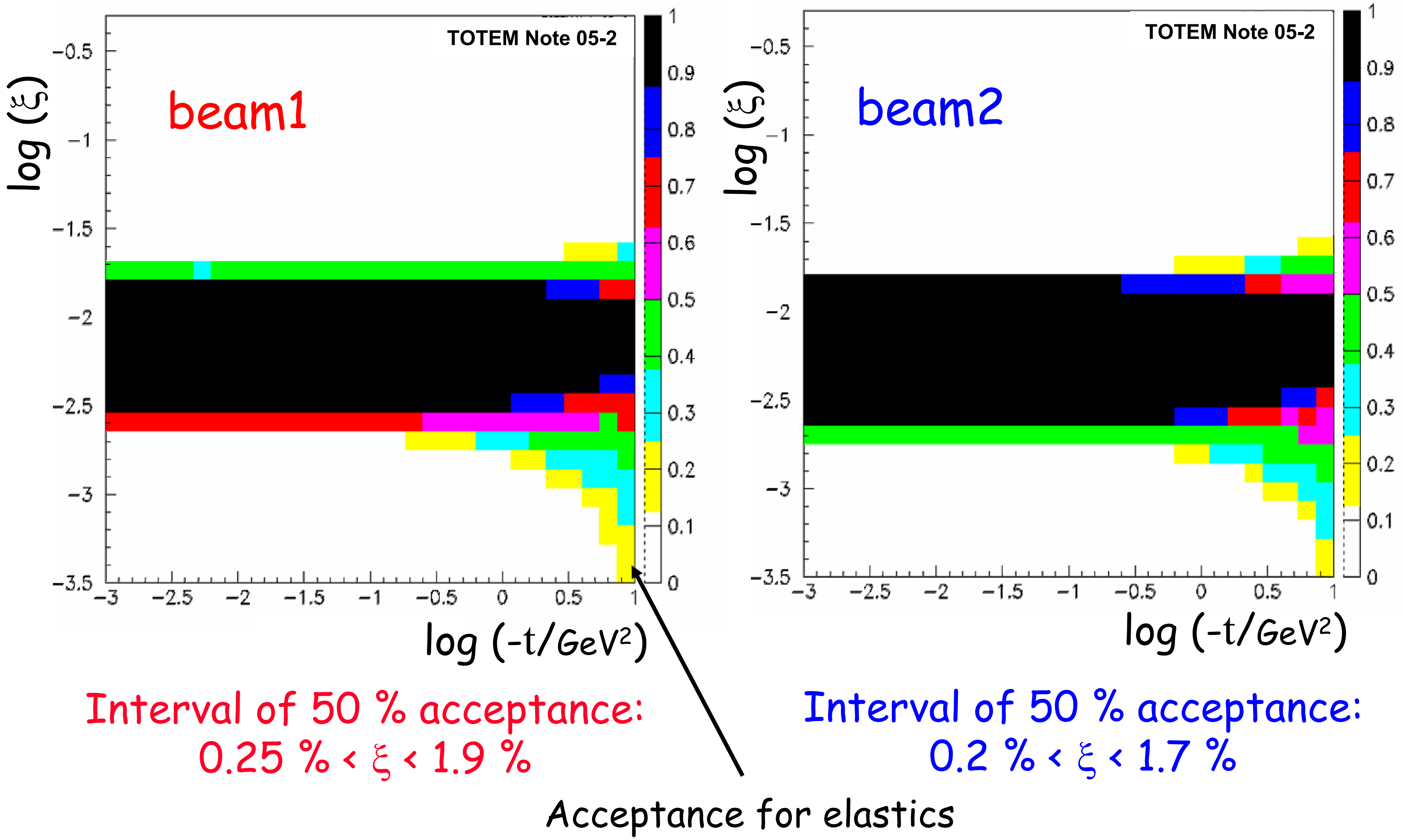


Interval of 50 % acceptance:
1.6 % < ξ < 18 %

Interval of 50 % acceptance:
1.9 % < ξ < 18 %

Acceptance for elastics

Acceptance 420 m (β^* = 0.55 m)

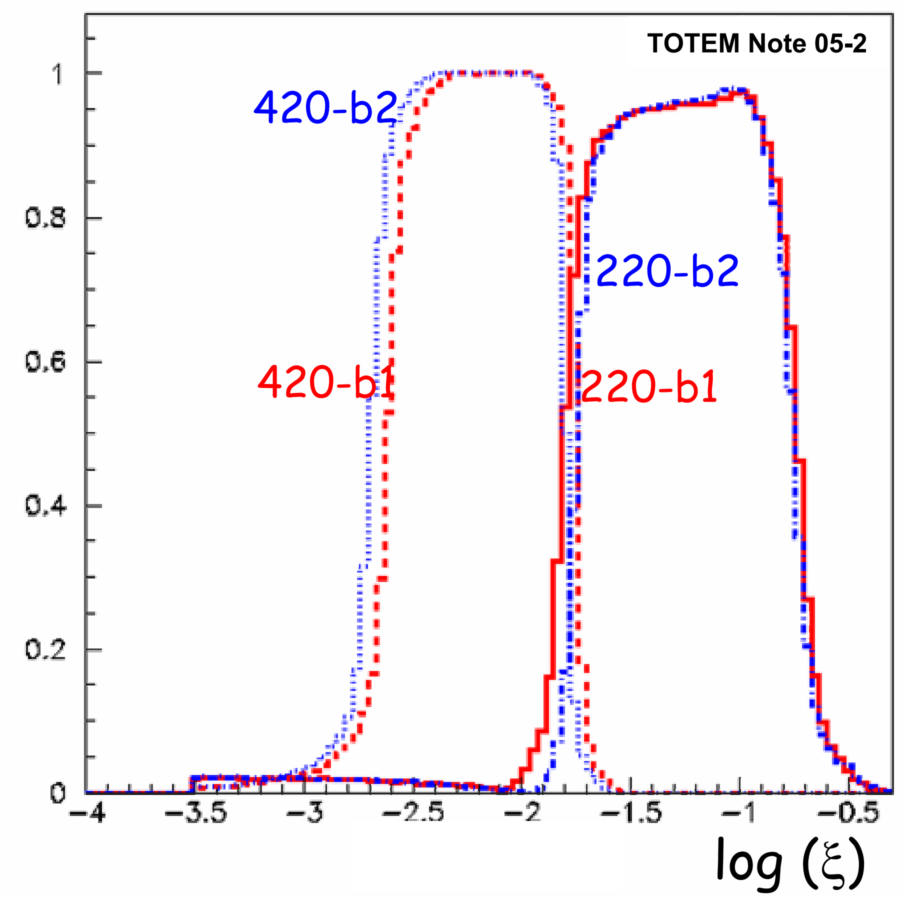


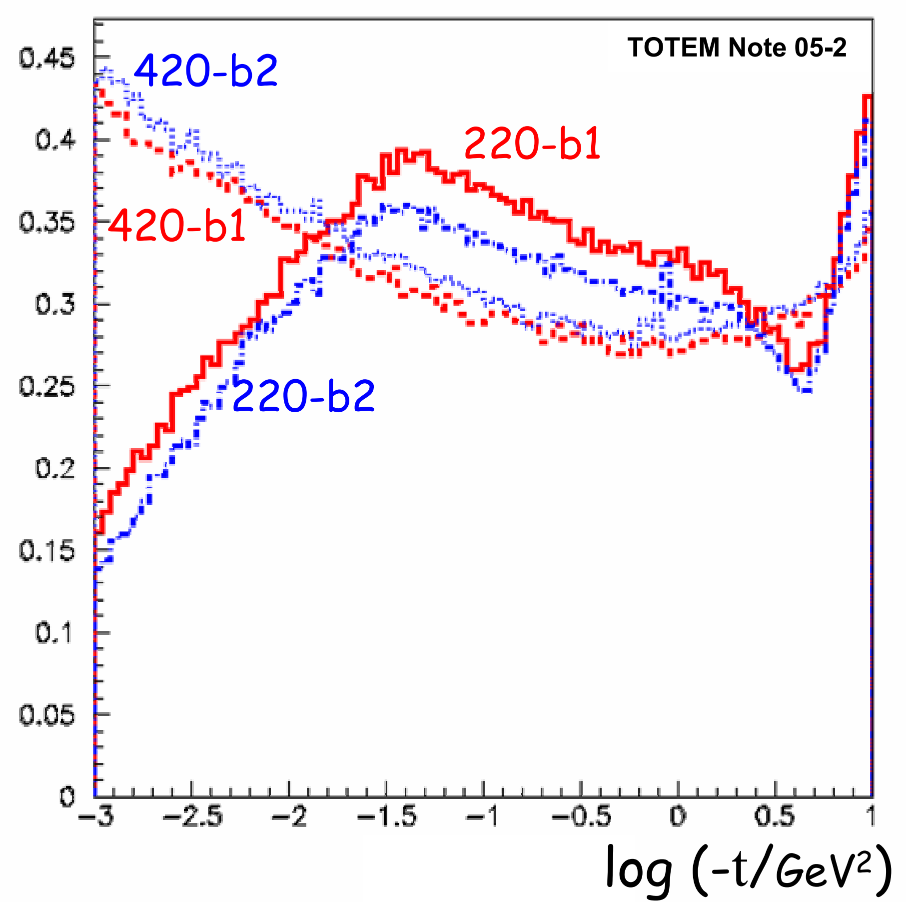
Interval of 50 % acceptance:
0.25 % < ξ < 1.9 %

Interval of 50 % acceptance:
0.2 % < ξ < 1.7 %

ξ & t acceptance 220 m & 420 m (β^* = 0.55 m)

as input a flat log(-t) & log(ξ) distribution





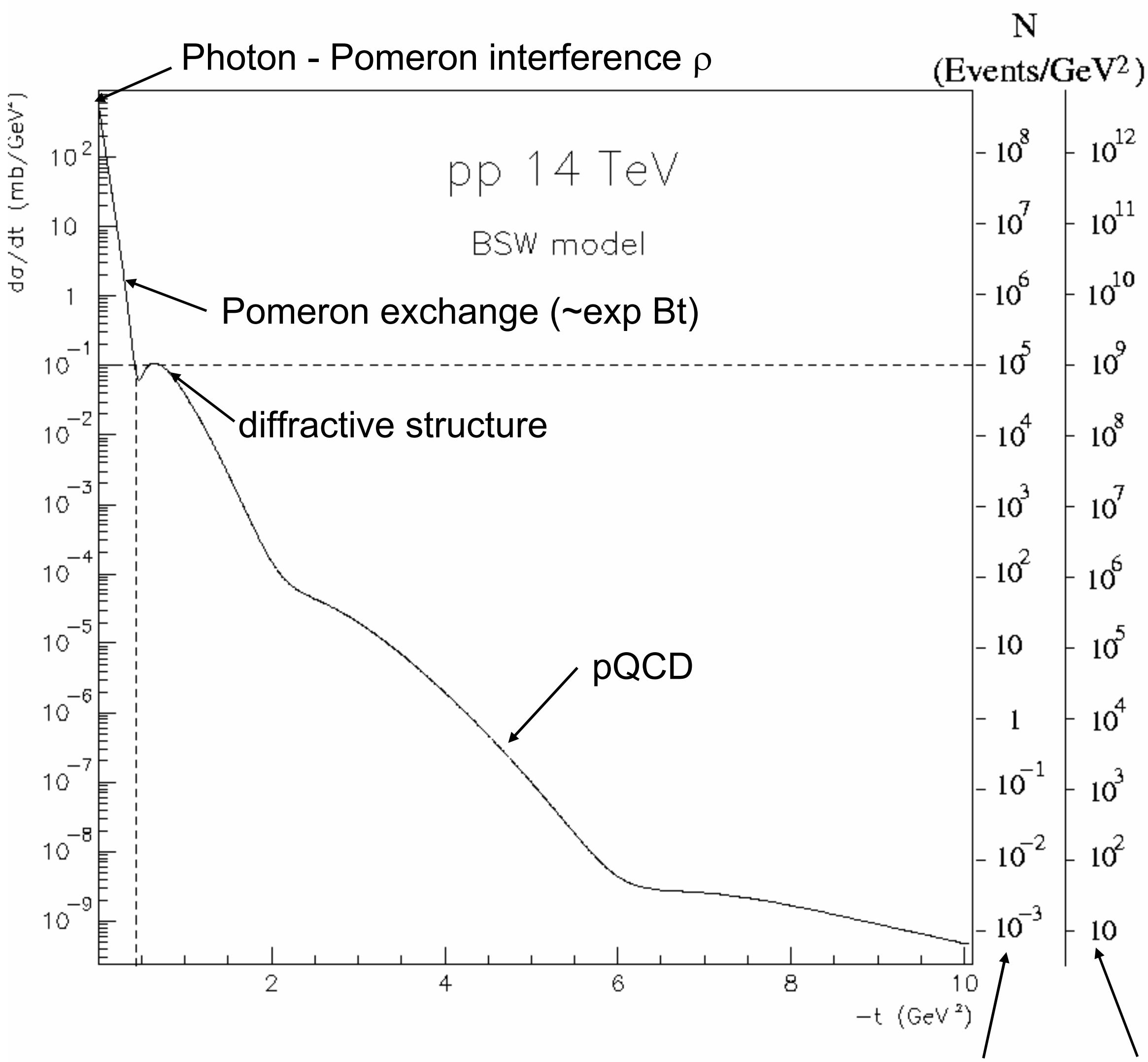
Conclusions

- Acceptance studies repeated for newest LHC optics.
- Acceptancies for LHC optics V6.2 & V6.5 quite similar.
- Will be included in L1 & physics studies for CMS/TOTEM diffractive LOI & CMS physics TDR

Future

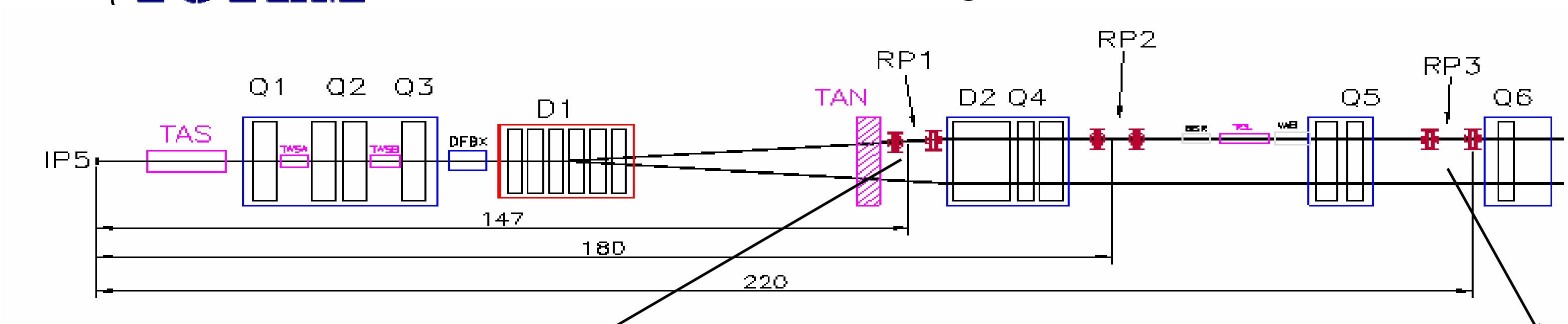
- Resolution studies with newest LHC optics.

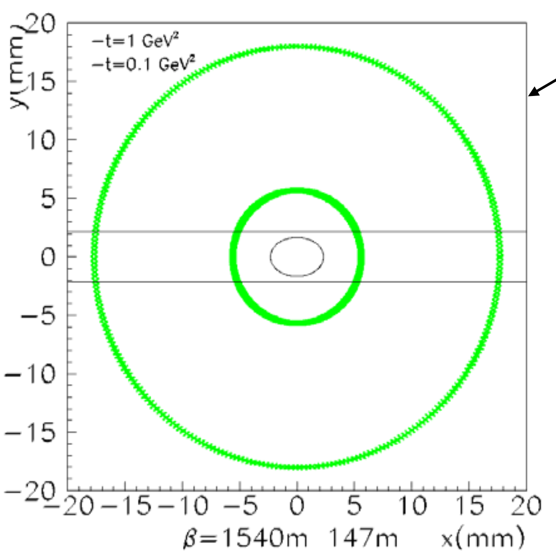
Elastic scattering: cross section



$\int \mathcal{L}\, dt = 10^{33}\ \&\ 10^{37}\ cm^{-2}$

(β^* = 1540 m & 18 m)

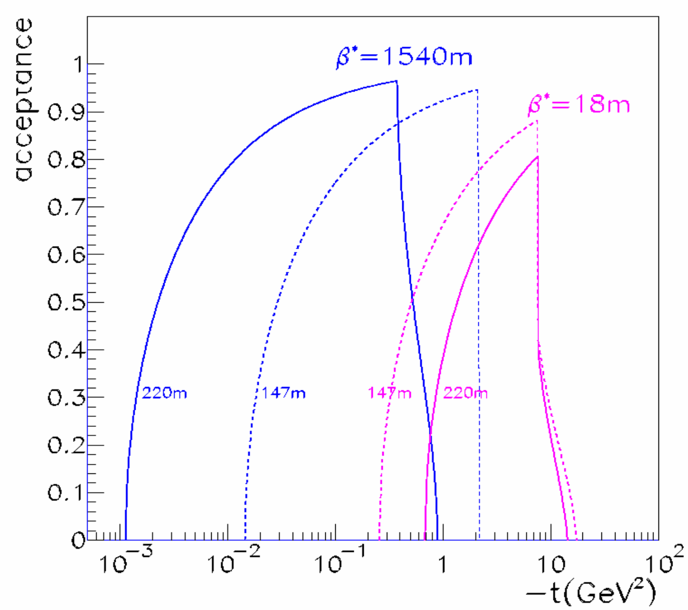


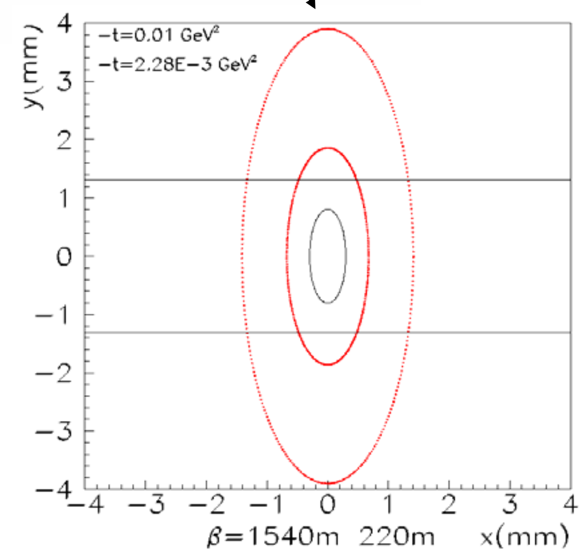


Elastic scattering

β* = 1540 m

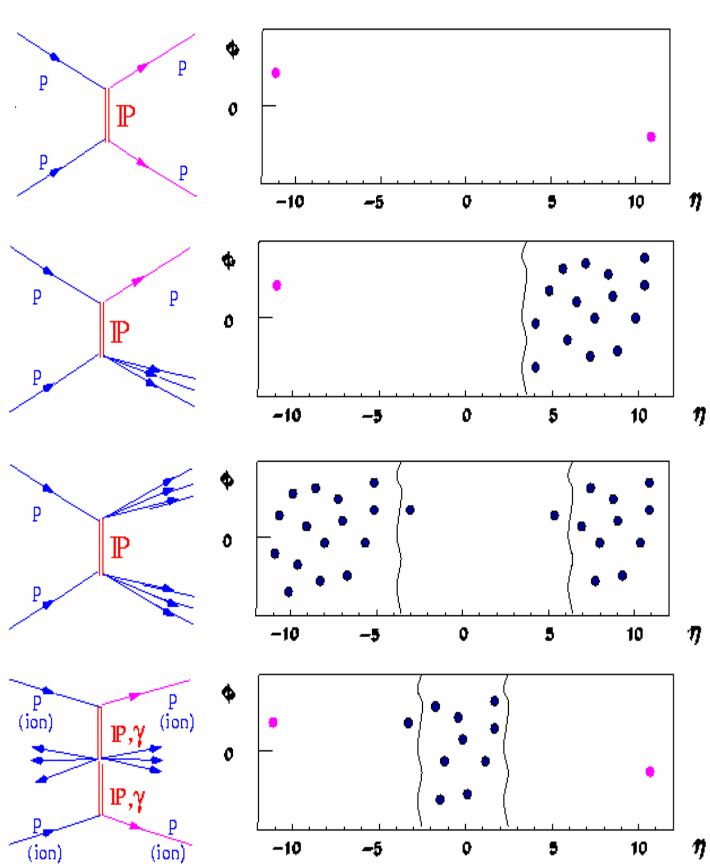
acceptance





Level-1 trigger schemes

($\mathcal{L}$ = 1.6 x 10^{28} cm^{-2} s^{-1})



Elastic Trigger:
Signal: 500 Hz
Background: 20 Hz

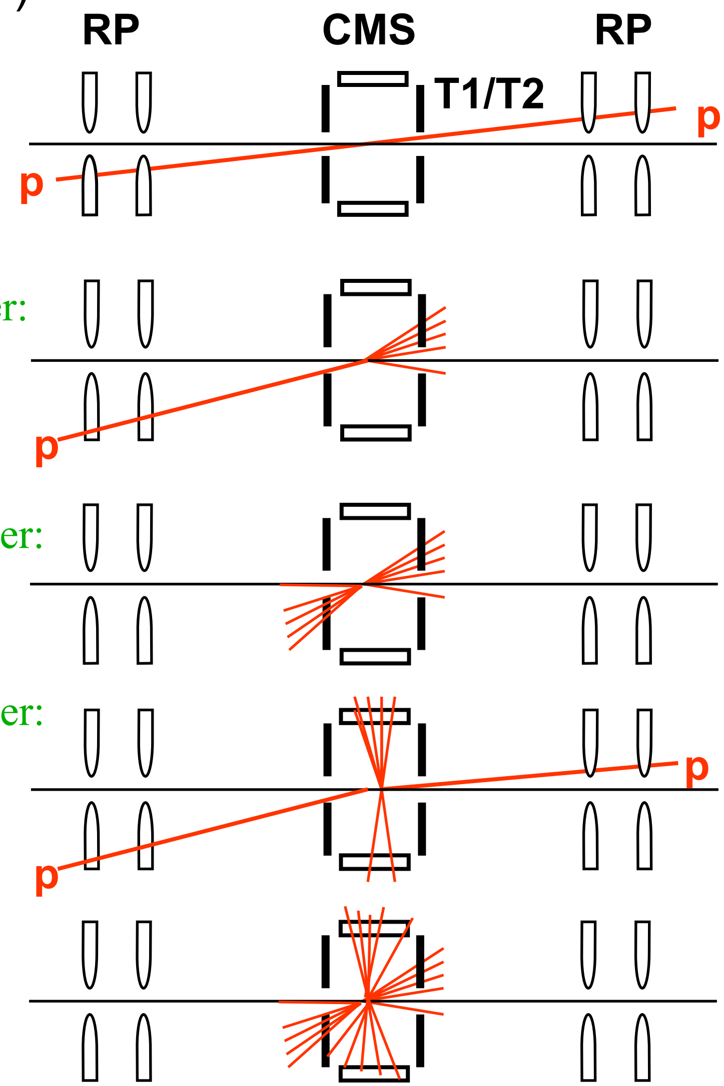
Single Diffractive Trigger:
Signal: 200 Hz
Background: < 1 Hz ?
(using vertex reconstruction in T1/T2)

Double Diffractive Trigger:
Signal: 100 Hz

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

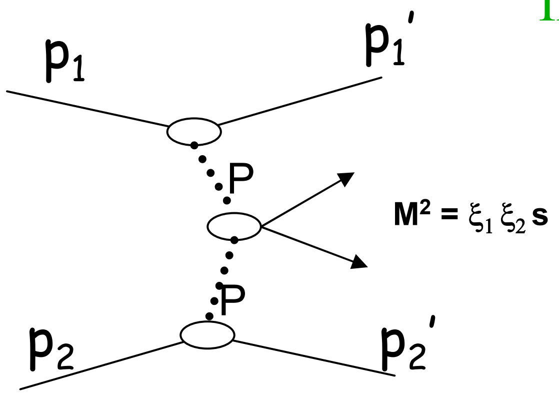
Minimum Bias Trigger:
Signal: 1 kHz

Backgrounds under study!

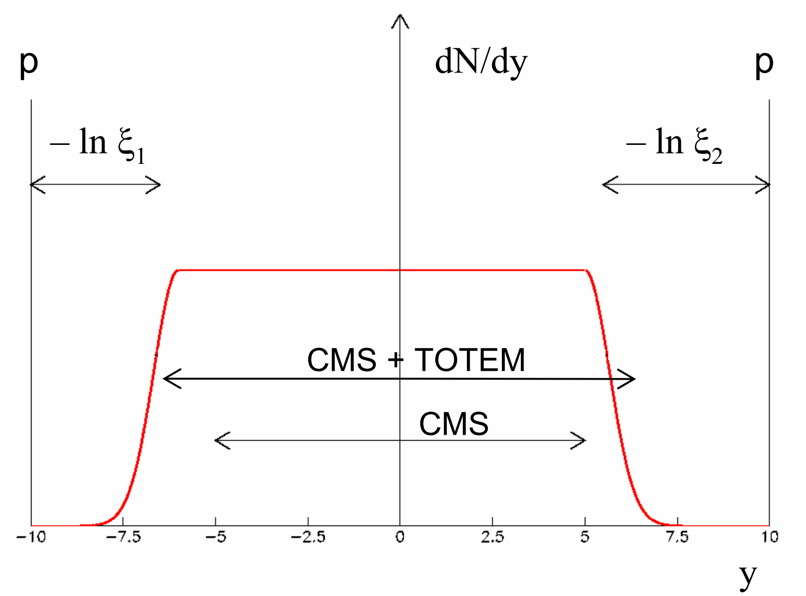


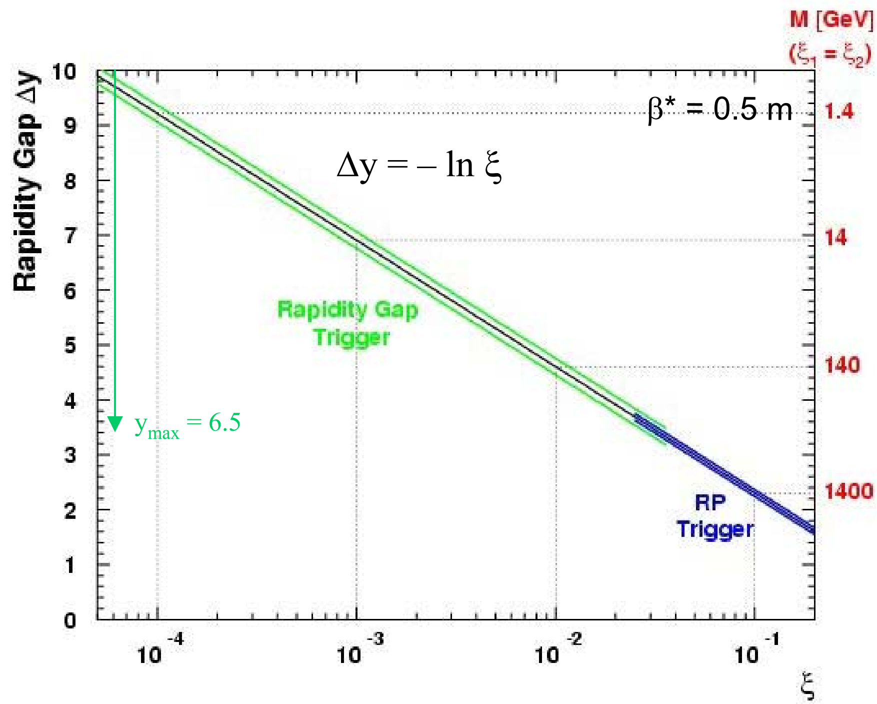
Prospects for Double Pomeron Exchange

In collaboration with CMS



$\beta^* = 1540$ m:	$\sigma_\xi = 0.5\%$	$\mathcal{L} \leq 2.4 \times 10^{29}$ cm^{-2} s^{-1}
$\beta^* = 200 \div 400$ m:	$\sigma_\xi \sim 1$ ‰	$\mathcal{L} \leq 10^{31}$ cm^{-2} s^{-1}
$\beta^* = 0.5$ m:	$\sigma_\xi \sim 1$ ‰	$\mathcal{L} > 10^{31}$ cm^{-2} s^{-1}

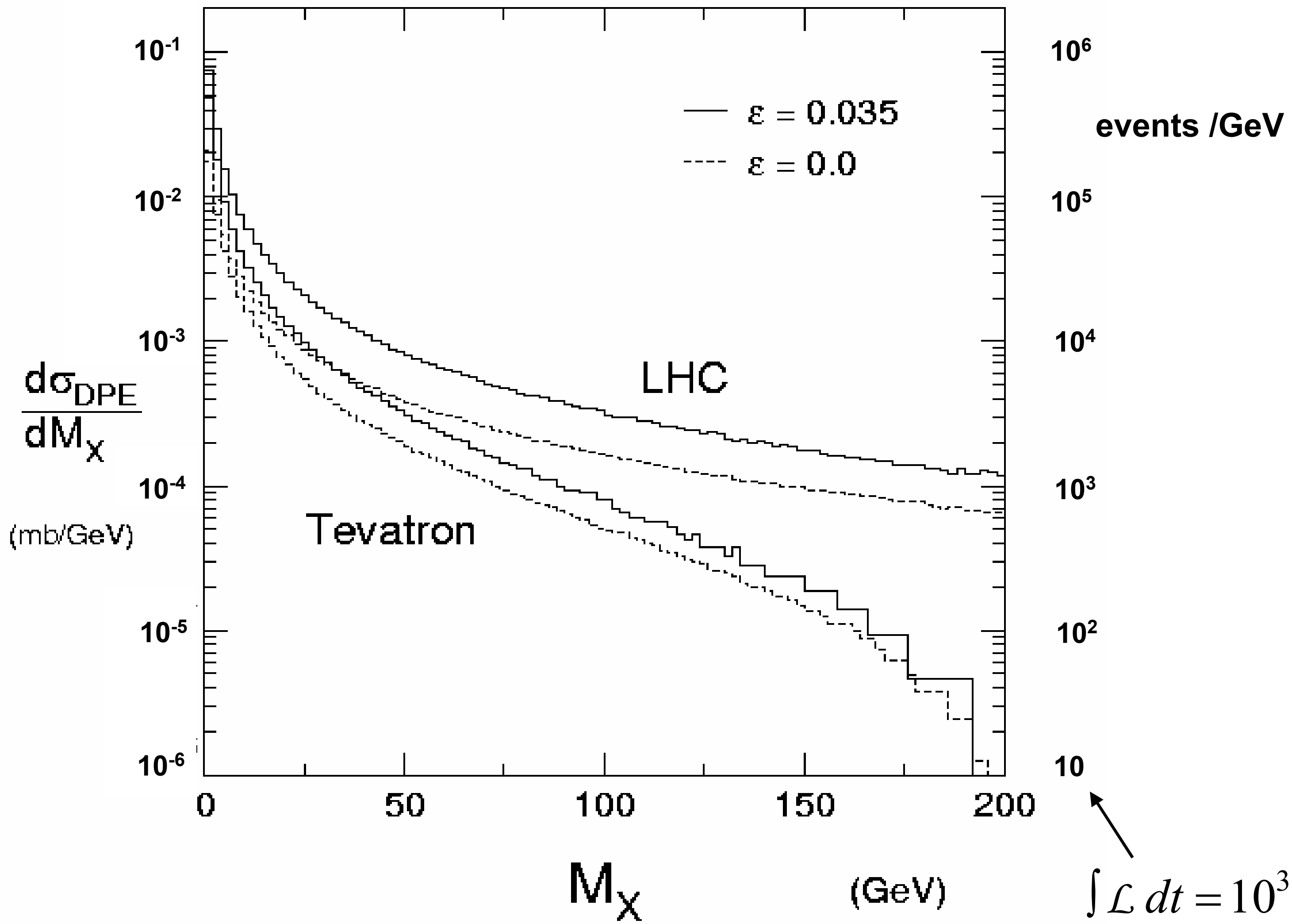




Trigger via Roman Pots $\xi > 2.5 \times 10^{-2}$

Trigger via rapidity gap $\xi < 2.5 \times 10^{-2}$

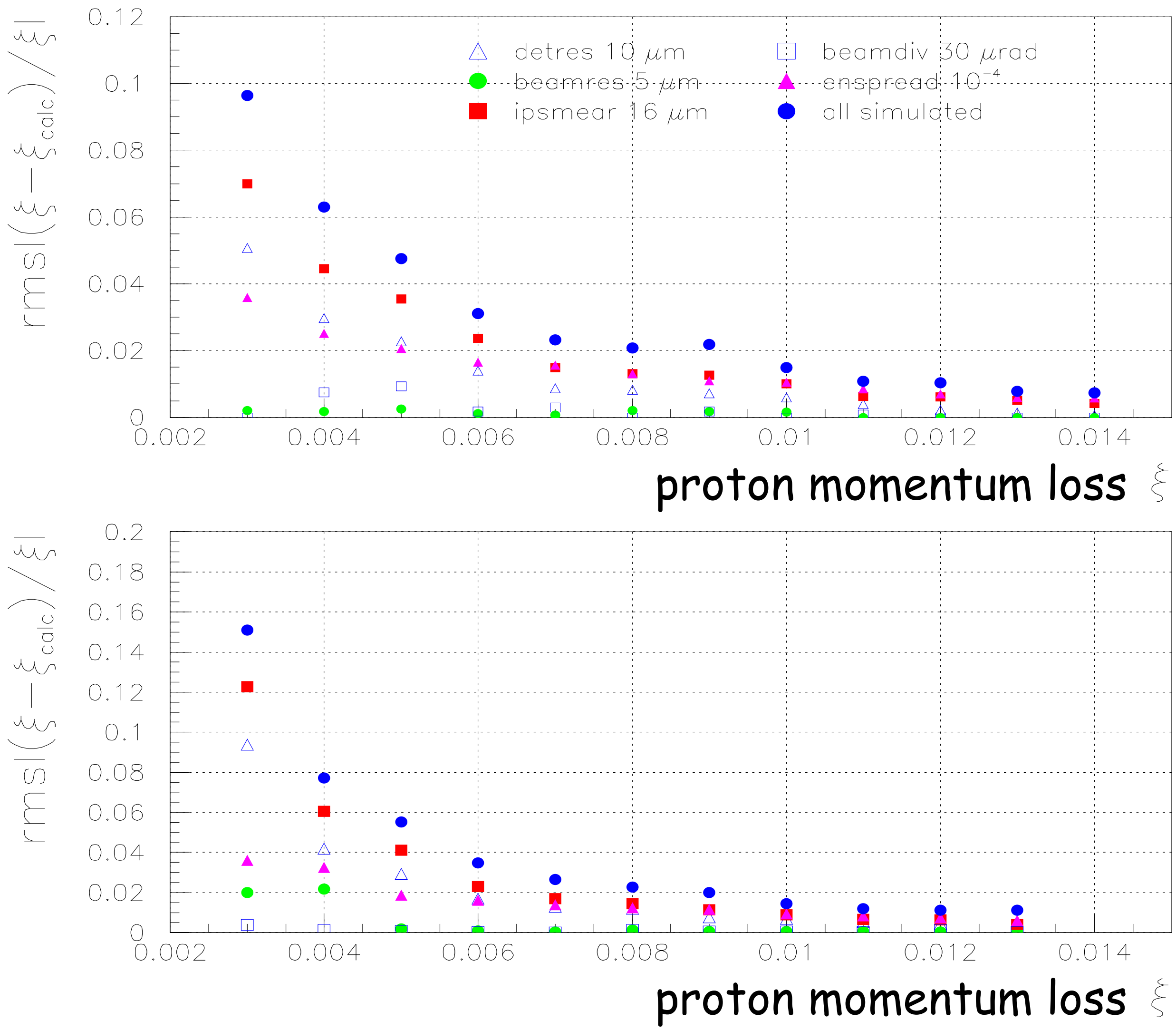
Double Pomeron exchange: cross section



$\int \mathcal{L}\, dt = 10^{37}\,\mathrm{cm}^{-2}$

(β^* = 200-400 m)

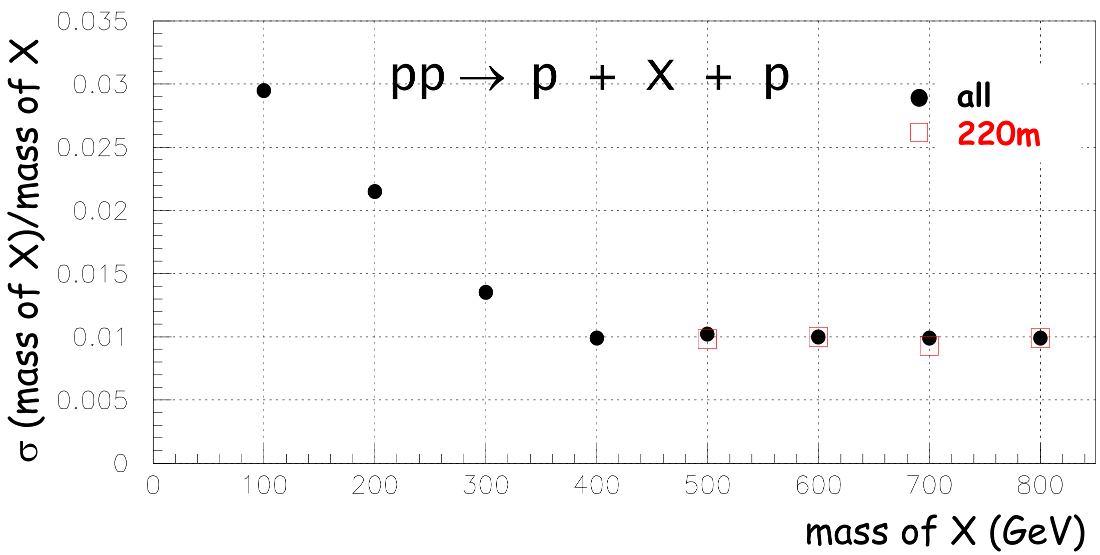
Momentum loss resolution at 420 m

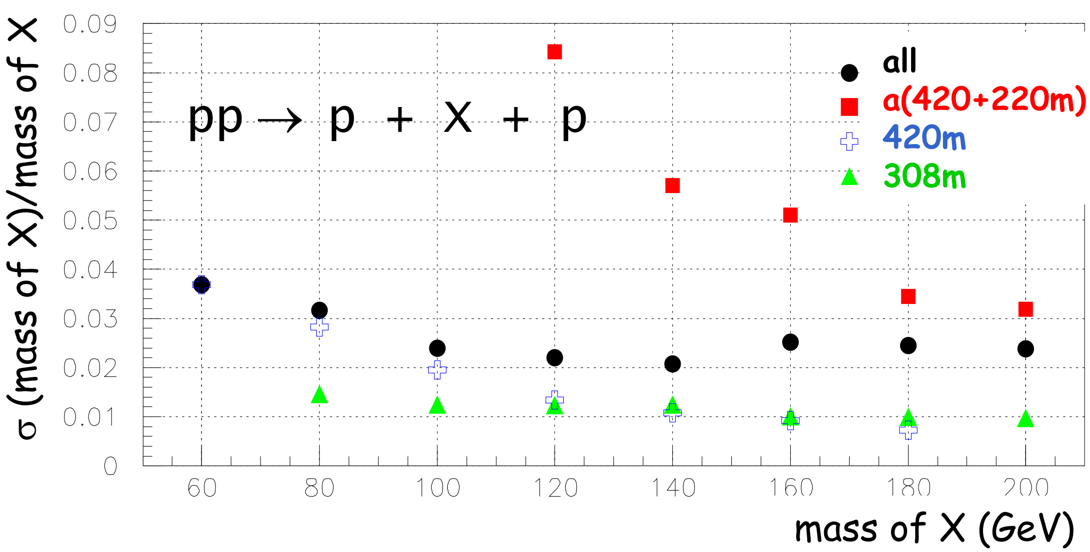


Resolution improves with increasing momentum loss

Dominant source: transverse vertex position (at small momentum loss) and beam energy spread (at large momentum loss, 420 m)/detector resolution (at large momentum loss, 215 m & 308/338 m)

Mass resolution of central system





Resolutions for separate locations and all combination ("naive" combination)

- <u>resolution ranges from ~ 4 % at low masses to ~ 1 % at high mass</u>

- <u>optimal resolution ~ 1 % for symmetric pairs (i.e. $\xi_1 \approx \xi_2$)</u>

NB! a(420+215m) = $\xi_1 >> \xi_2$ or $\xi_1 << \xi_2$

NB! Some effects are anticorrelated for ξ_1 & ξ_2 (e.g. transverse vertex position) $\Rightarrow$ $\sigma(M)/M < \frac{1}{2}\sqrt{\Sigma_i \sigma(\xi_i)/\xi_i}$