Startup running of a combined CMS-TOTEM trigger

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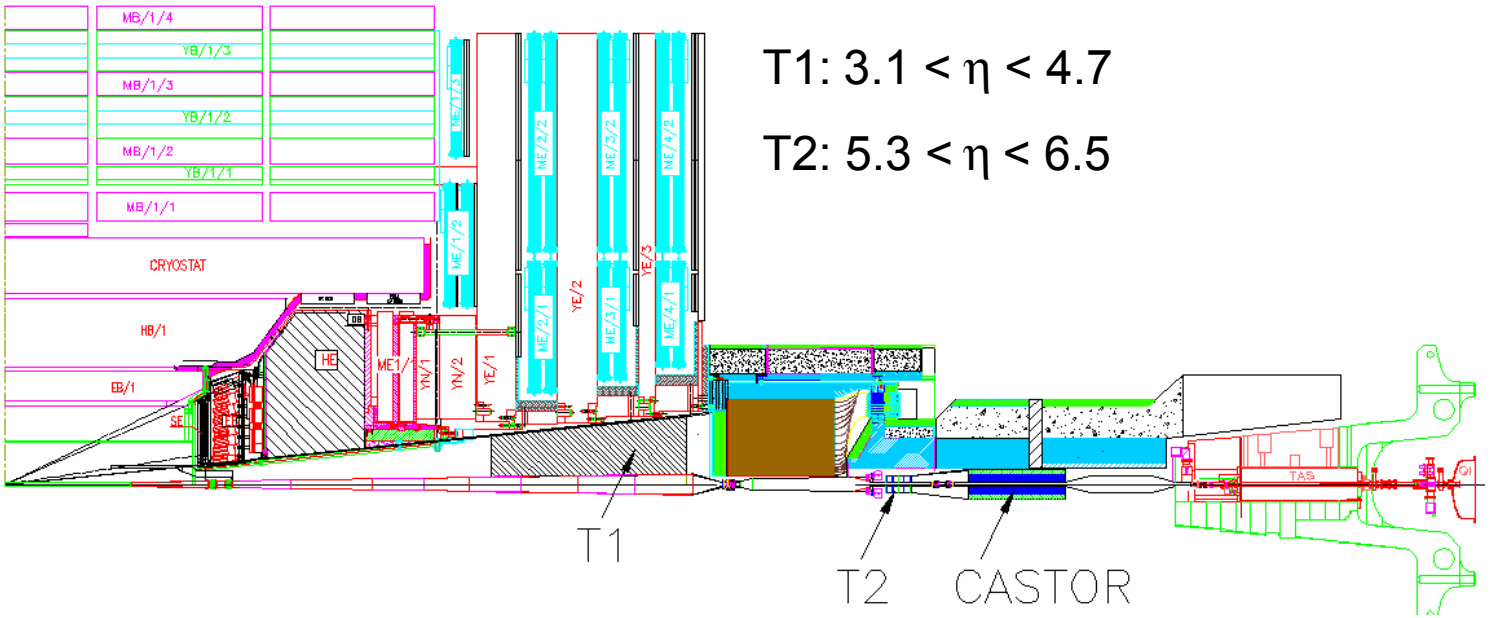
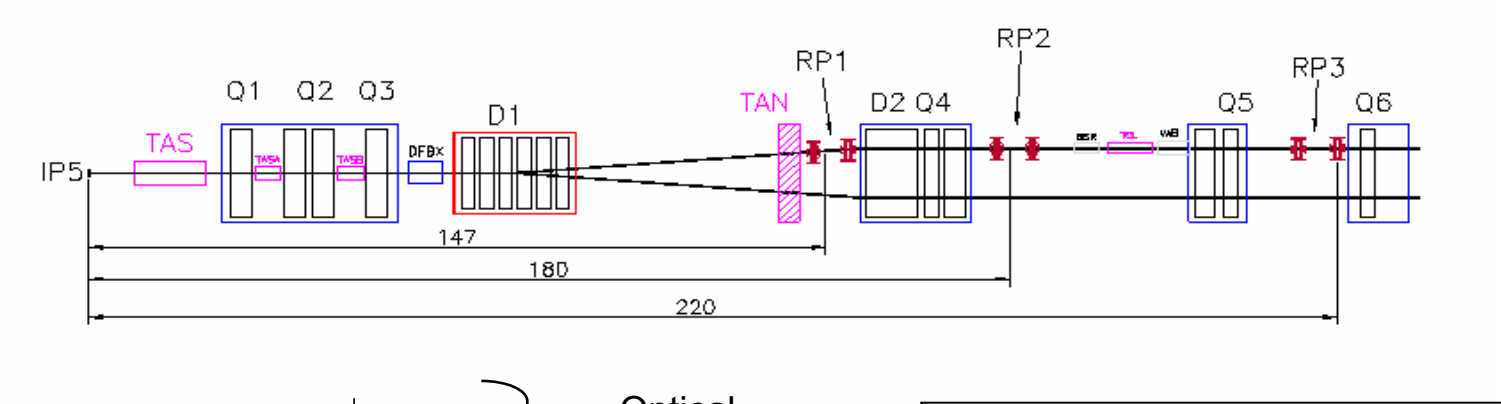
on behalf of the
TOTEM/CMS Collaboration

LHC/HERA workshop, WG 4 (17. Jan. 2005)



T1: $3.1 < \eta < 4.7$

T2: $5.3 < \eta < 6.5$



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

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

Optical Theorem

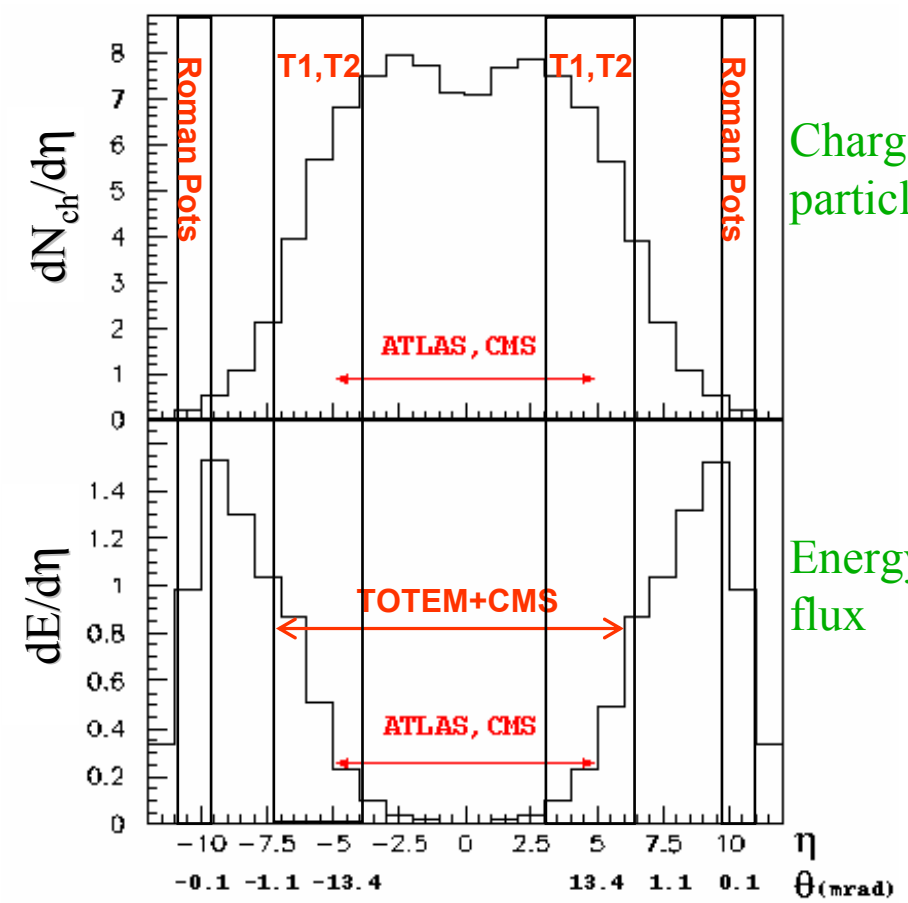
$$\sigma_{tot} = \frac{16\pi}{1+\rho^2} \times \frac{(dN/dt)\big|_{t=0}}{N_{el} + N_{inel}}$$

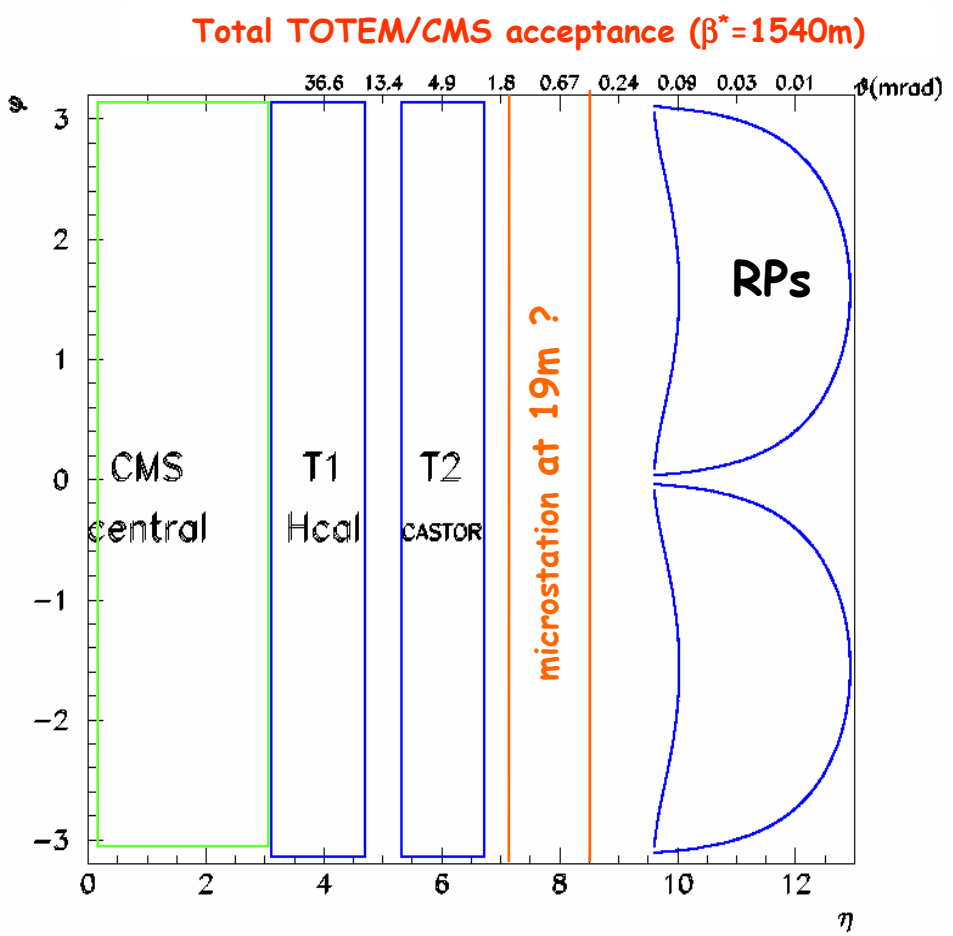
CMS + TOTEM: Acceptance

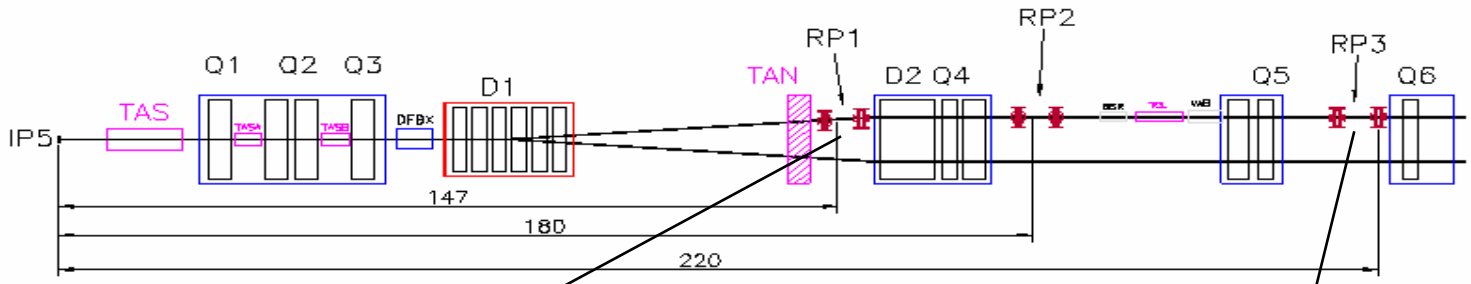
CMS+TOTEM: largest acceptance detector ever built at a hadron collider

> 90 % of all diffractive protons are detected

10 million min. bias events, including all diffractive processes, in a 1 day run with $\beta^* = 1540$ m

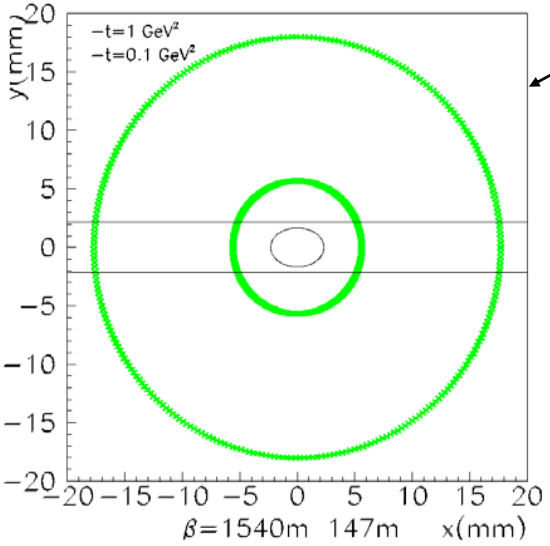


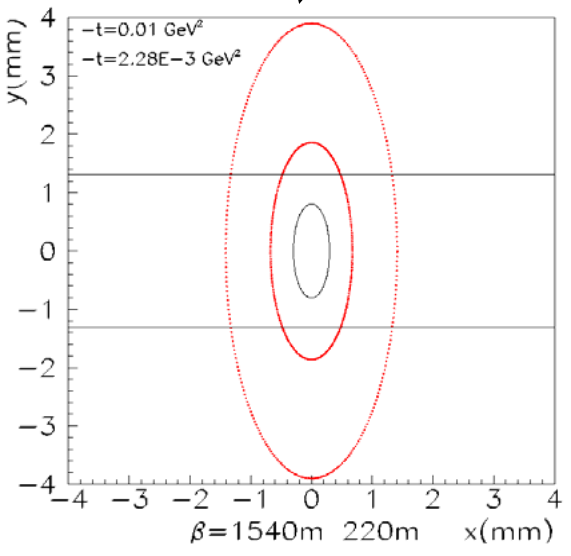




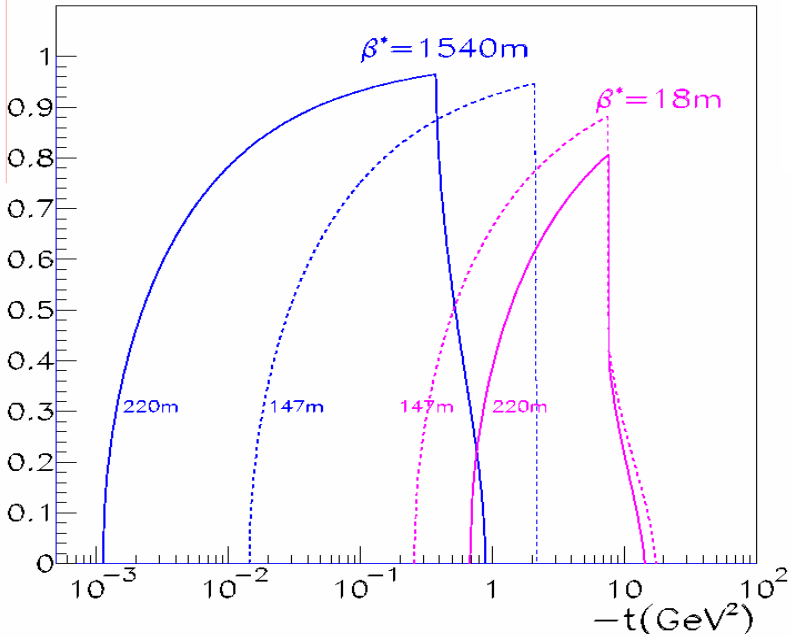
Elastic Scattering

β* = 1540 m

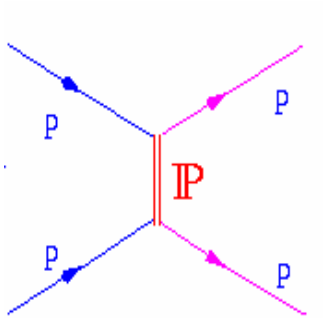




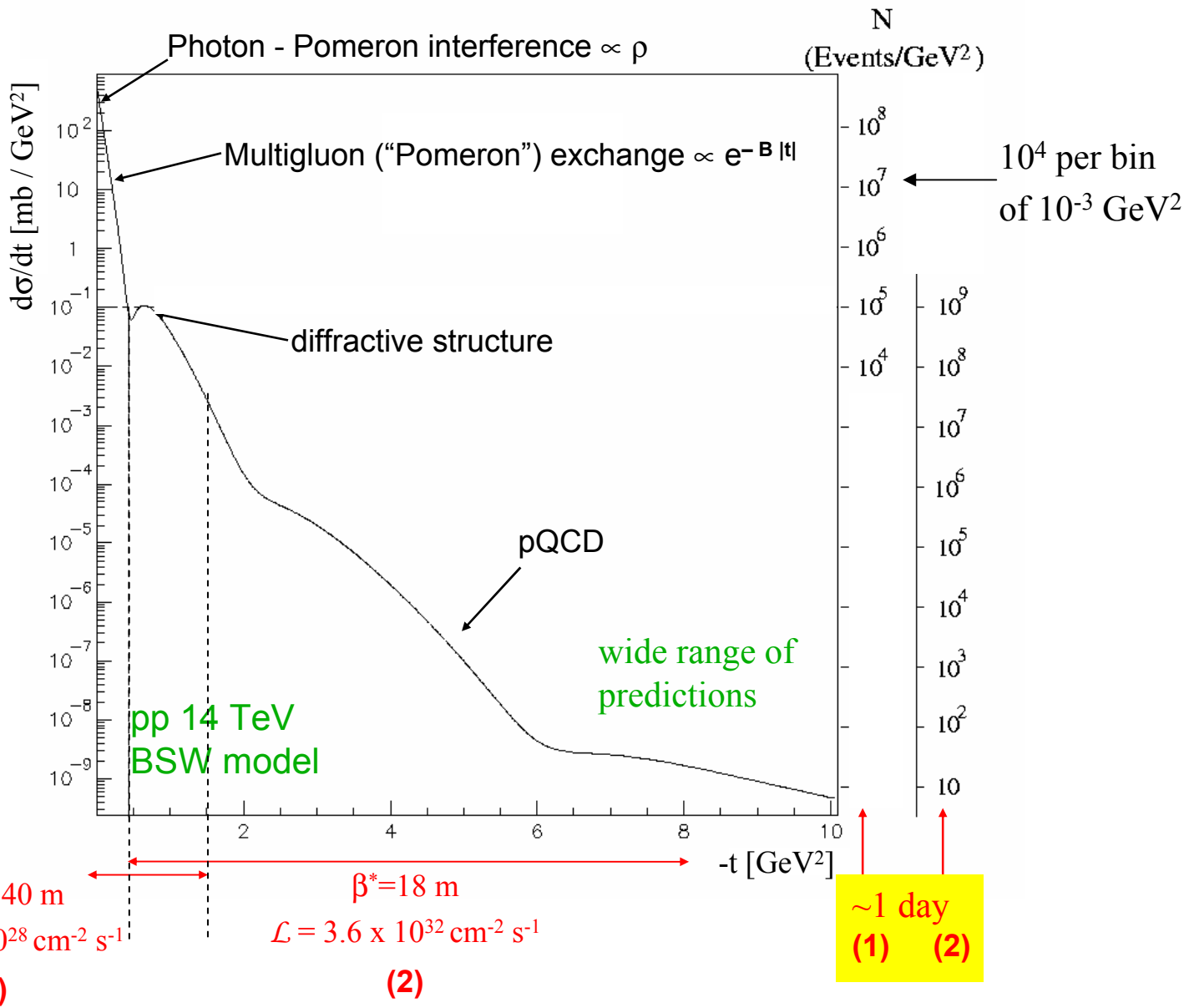
acceptance



Elastic Scattering Cross-Section

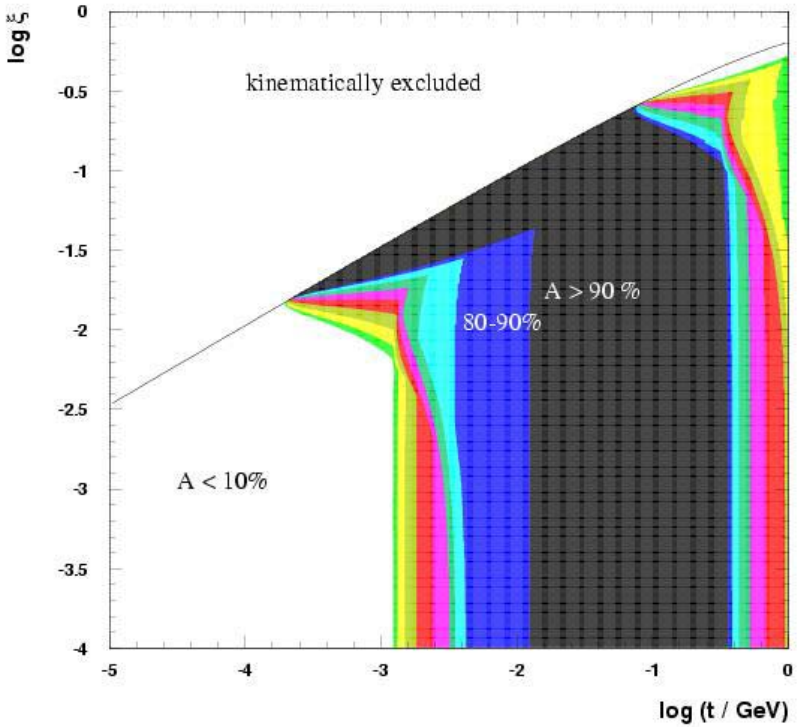


$-t \approx p^2 \theta^2$



Diffraction at high β*: Acceptance

Leading protons in diffraction characterized by $t = -p^2 \theta^2$ and $\xi = \Delta p / p$



β* = 1540 m,
RP at 220 m:

~ 90 % of all diffractive protons are seen in the Roman Pots

(assuming $\frac{d\sigma}{d\xi\, dt} \propto \frac{1}{\xi} e^{-5.6|t|}$ **).**

Resolution in ξ:

β* = 1540 m: $\sigma(\xi) = 5 \times 10^{-3}$ ($\mathcal{L} \leq 2.4 \times 10^{29}$ cm^{-2} s^{-1})

CMS / TOTEM : ideal detector to study diffractive and forward physics with proton measurements

- Soft and hard diffraction in Single and Double Pomeron Exchange production of jets, W, J/ψ, heavy flavours, hard photons
- Excellent proton measurement: gap survival
- Double Pomeron exchange as a gluon factory
  - Production of low mass systems (SUSY, χ ,D-Y,jet-jet, …)
  - Glue balls, …
  - Higgs production ?
- Structure functions (parton saturation) with and without detected protons
- Forward physics: DCC, particle and energy flow
- $\gamma\gamma$ physics

Different running scenarios (β^* = 1540, 172, 18, 0.5 m)

Running Scenarios

Scenario Physics:	1 low |t| elastic, σ_{tot}, min. bias, soft diffraction	2 diffraction	3 large |t| elastic	4 hard diffraction
β^* [m]	1540	1540	18	172
N of bunches	43	156	2808	936 - 2808
N of part. per bunch	0.3×10^{11}	$(0.6 - 1.15) \times 10^{11}$	1.15×10^{11}	1.15×10^{11}
Half crossing angle [μrad]	0	0	150	150
Transv. norm. emitt. [μm rad]	1	1 - 3.75	3.75	3.75
RMS beam size at IP [μm]	454	454 - 880	95	294
RMS beam diverg. [μrad]	0.29	0.29 - 0.57	5.28	1.7
t_{min} @ 220 m [GeV^2]	2×10^{-3}	2×10^{-3}	1.3	2×10^{-2}
t_{max} @ 220 m [GeV^2]	0.6	0.6	7	0.6
Peak luminosity [cm^{-2} s^{-1}]	1.6×10^{28}	2.4×10^{29}	3.6×10^{32}	$(1 - 4) \times 10^{31}$

New optics β^*=172 m

- L_y large (~270 m)

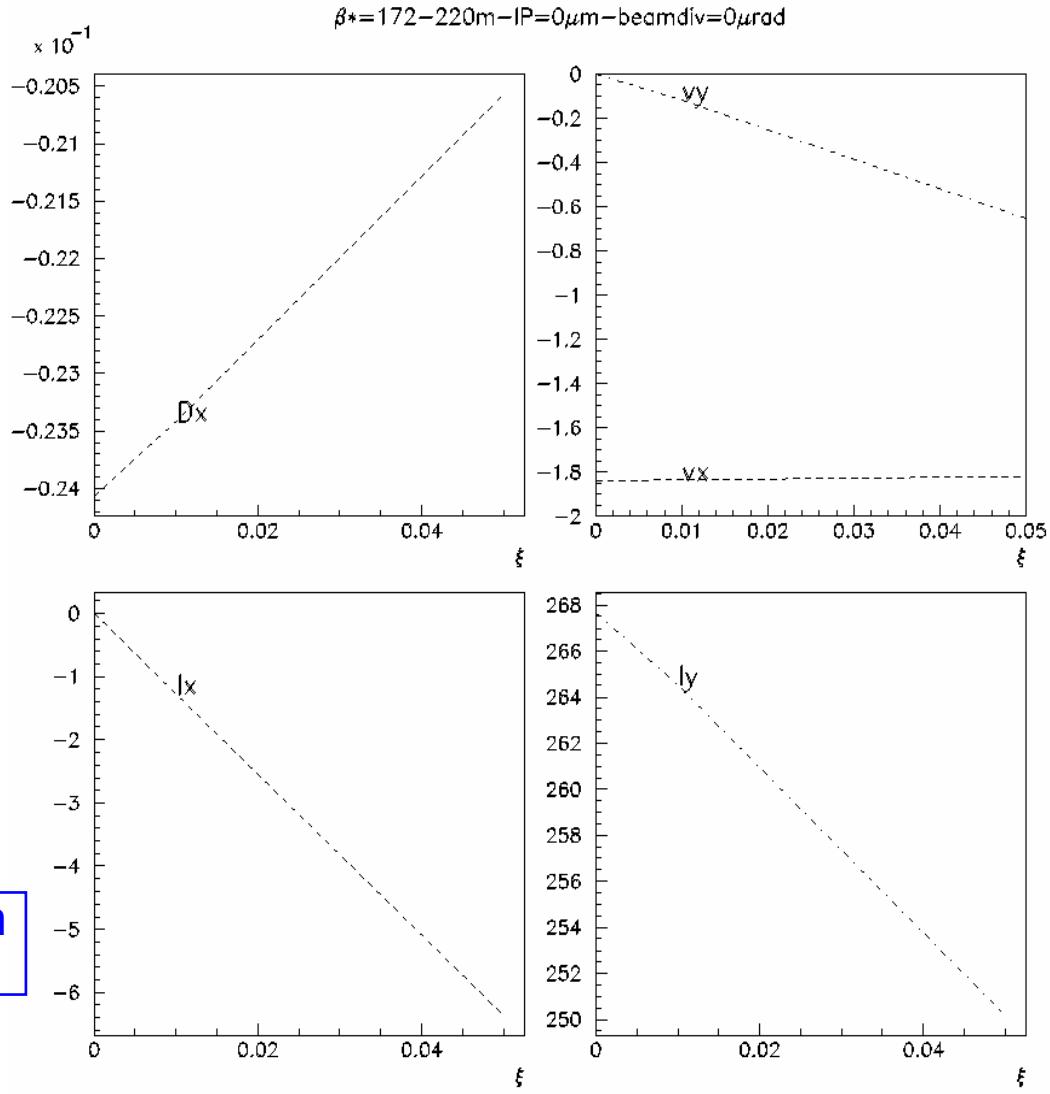
  $\Rightarrow$ t_{min} =2 x 10^{-2} GeV^2

  ~90% of all diffractive protons are seen

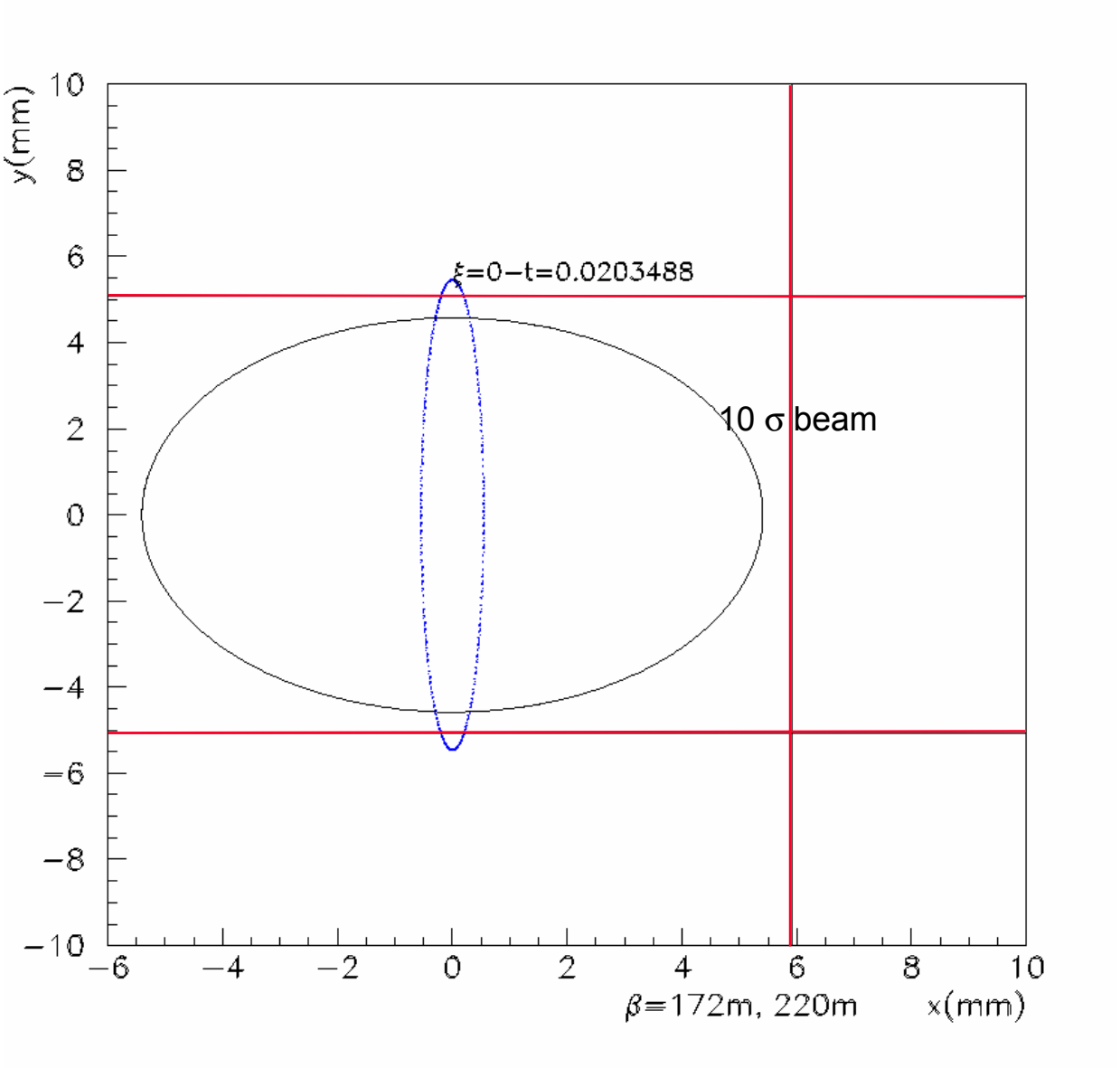
- L_x ~ 0 $\Rightarrow$ θ independent

- Vertex measured by CMS

$\Rightarrow$ ξ determination with a precision of few 10^{-4}



$t_{min} \sim 2 \times 10^{-2}$ GeV^2



Conclusion on new optics (β^*=172 m) - preliminary

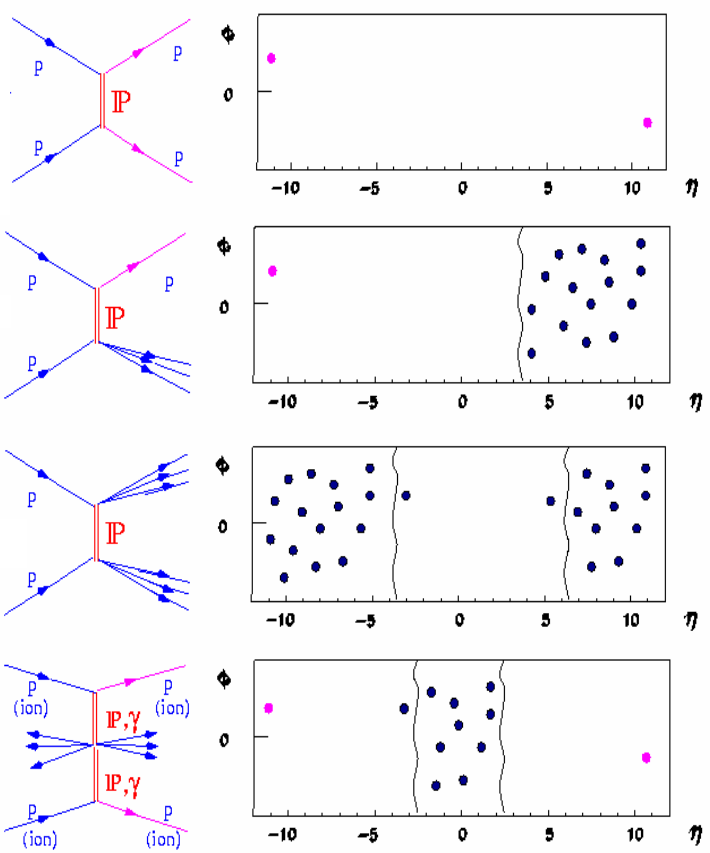
- Luminosity of 4 x 10^{31} cm^{-2} s^{-1}
- About 90% of diffractive protons are seen in the RP at 220 m
- ξ resolution of few 10^{-4} to 10^{-3}
- θ resolution of few μrad

Future:

- more detailed studies on acceptance and resolution
- further optimization towards higher luminosity

Level-1 Trigger Schemes for min. bias physics

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



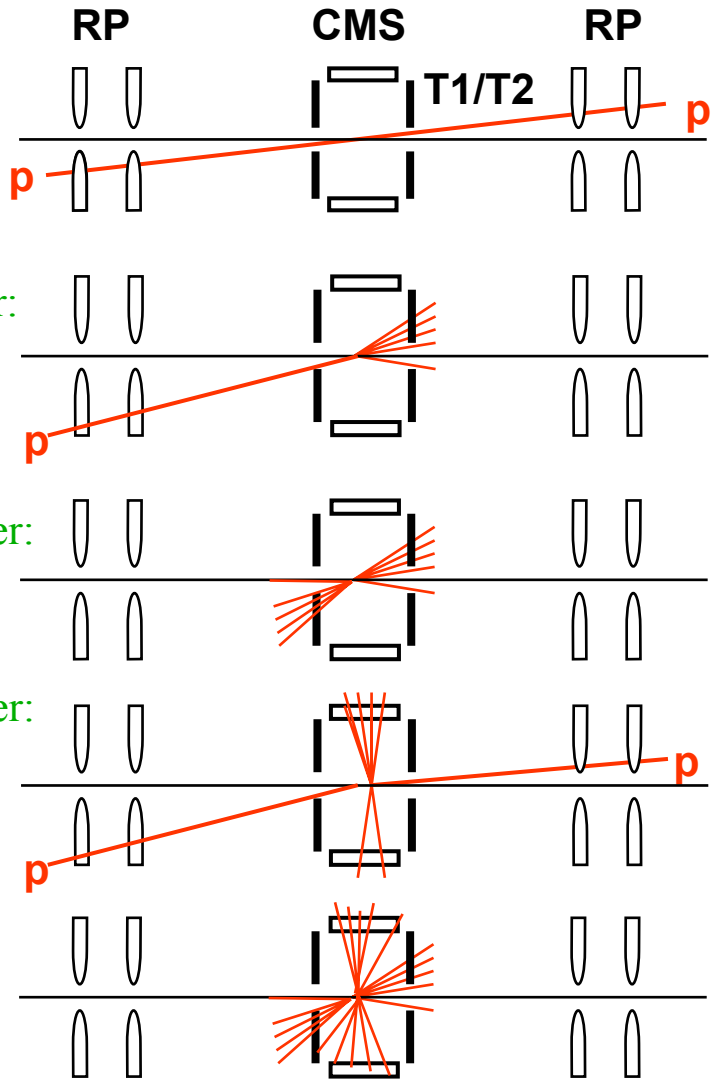
Elastic Trigger:
Signal: 500 Hz
Background: 20 Hz

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!

Runs with ~90% detection of diffractive protons

- Initial several one day runs with $\beta^* = 1540$ m and 43 bunches

  $L = 1.6 \times 10^{28}$ cm^{-2} s^{-1}

  10^8 min. bias events / day

  1000 events / μbarn per day

  Trigger combinations: CMS min bias, T1, T2, forward protons

- $\beta^* = 1540$ m and 156 bunches — $L = 2.4 \times 10^{29}$ cm^{-2} s^{-1}

  20 events / nbarn per day

  central diffraction: $p_{left} \times p_{right}$ x central activity

  single diffraction: (T1, T2, CMS forward cal.)$_{left} \times p_{right}$

  heavy flavours, jets : low pt leptons, min jets

- $\beta^* = 172$ m and 2808 bunches — $L = 4 \times 10^{31}$ cm^{-2} s^{-1}

  3000 events / nbarn per day

  Trigger combinations: low pt leptons, jets, diffr. protons

Exclusive Production by DPE: Examples

Advantage: Selection rules: $J^P = 0^+, 2^+, 4^+$; $C = +1$

$\Rightarrow$ reduced background, determination of quantum numbers.

Good ϕ resolution in TOTEM: determine parity: $P = (-1)^{J+1} \Leftrightarrow d\sigma/d\phi \sim 1 +\!\!- \cos 2\phi$

Particle	σ_{excl}	Decay channel	BR	Rate at 2×10^{29} cm^{-2} s^{-1} (no acceptance / analysis cuts)	Rate at 10^{31} cm^{-2} s^{-1} (no acceptance / analysis cuts)
χ_{c0} (3.4 GeV)	3 μb [KMRS]	$\gamma J/\psi \rightarrow \gamma \mu^+\mu^-$ $\pi^+\pi^- K^+ K^-$	6×10^{-4} 0.018	1.5 / h 46 / h	62 / h 1900 / h
χ_{b0} (9.9 GeV)	4 nb [KMRS]	$\gamma \Upsilon \rightarrow \gamma \mu^+\mu^-$	$< 10^{-3}$	0.07 / d	3 / d
H (120 GeV)	0.1 ÷ 100 fb assume 3 fb	$b\bar{b}$	0.68	0.02 / y	1 / y

Higgs needs $L \sim 10^{33}$ cm^{-2} s^{-1}, i.e. a running scenario for $\beta^* = 0.5$ m:

- try to modify optics locally,
- try to move detectors closer to the beam,
- install additional Roman Pots in cold LHC region at a later stage.

High luminosity runs (β^*=0.5m) with ξ>2.5%

$L = 0.5 \times 10^{33}\ cm^{-2}\ s^{-1}$

Trigger condition 1: jets and leptons x p_{left} x p_{right}

Trigger condition 2 : jets and leptons x p_{left} x gap_{right}

define the trigger thresholds:

2 jets with pt > 40 GeV for the Higgs

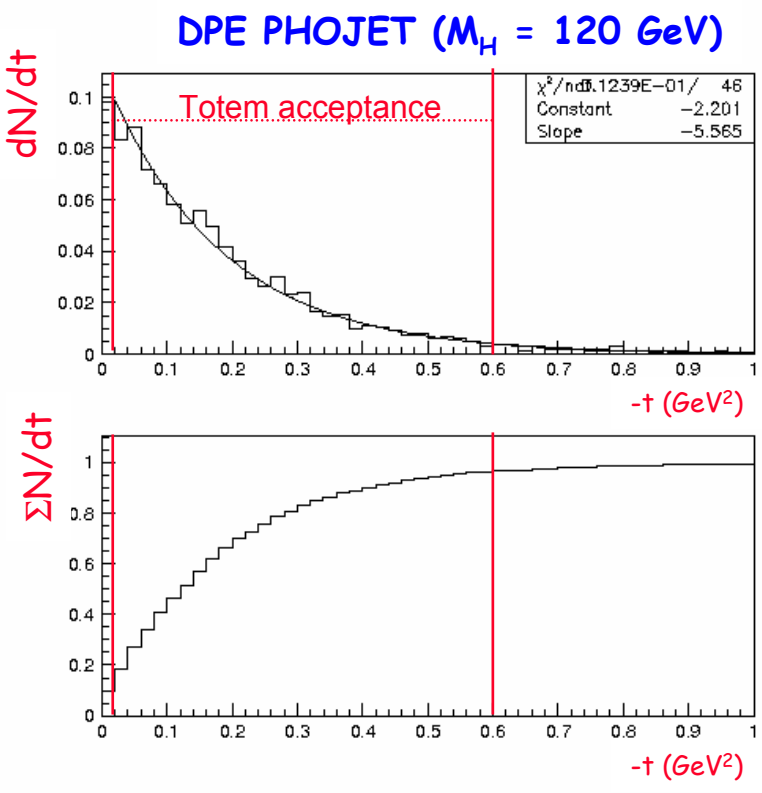
2 large pt jets for high mass central diffraction

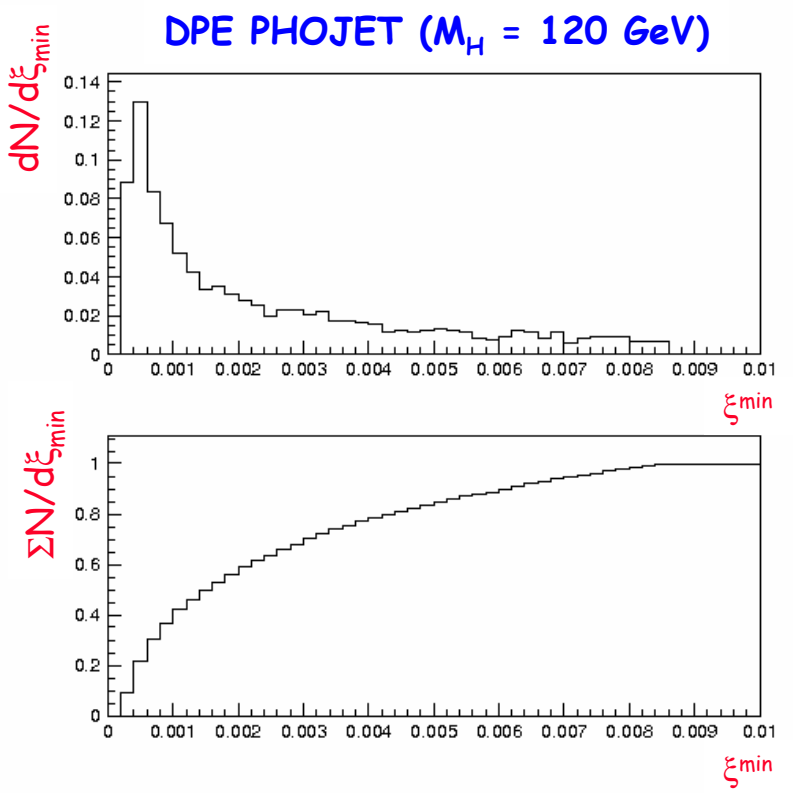
Higgs event Characteristics: dN/dt & ξ_{min}

$\xi_{min} < 0.3\%$ for one side trigger with $\xi_{max} > 2.5\%$

$-t < 1\ GeV^2$

ξ acceptance?





$\Rightarrow dN/dt \propto \exp(6t)$

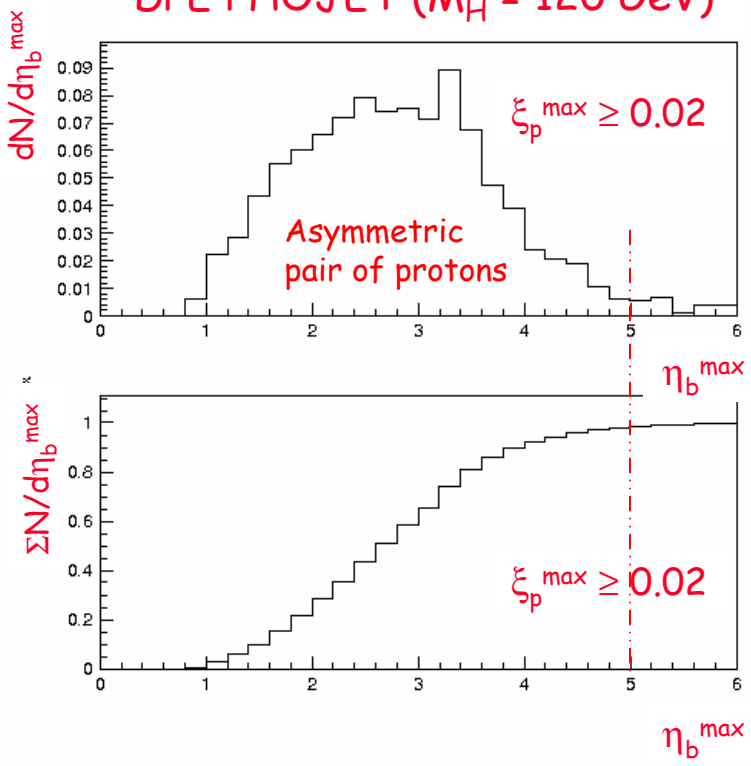
$\Rightarrow$ should detect p's down to $\xi \leq 10^{-3}$

Event Characteristics: Where do the decay b-jets go?

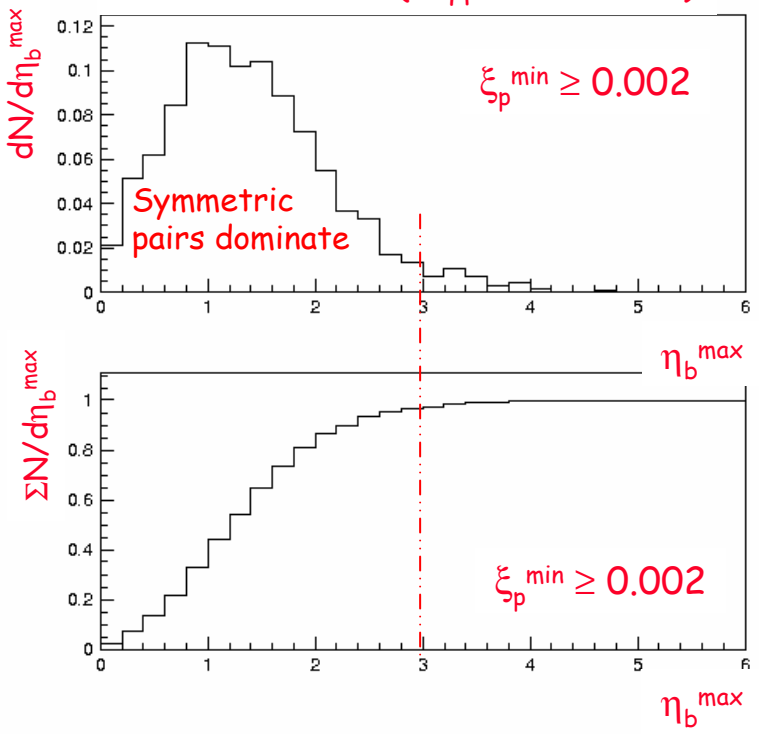
Asymmetric pair of protons

A typical – symmetric - pair of protons

DPE PHOJET (M_H = 120 GeV)



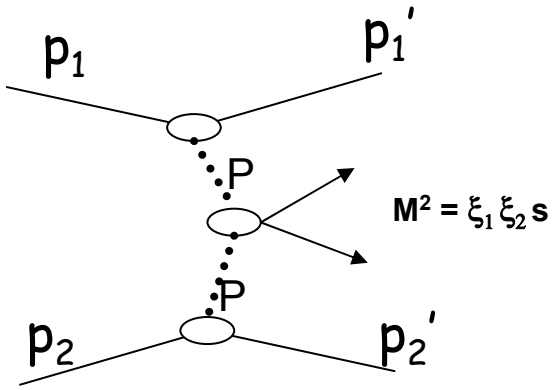
DPE PHOJET (M_H = 120 GeV)



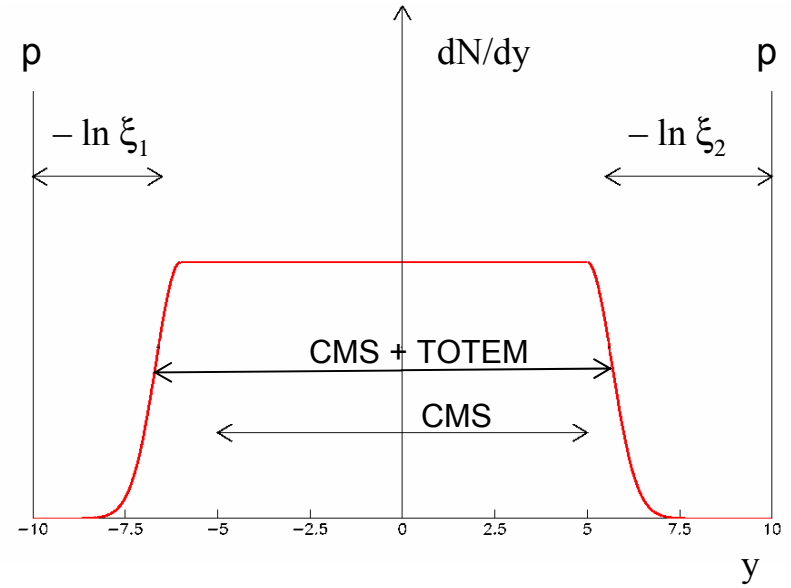
⇒ All the b-jets are confined within $|\eta| \leq 5$.

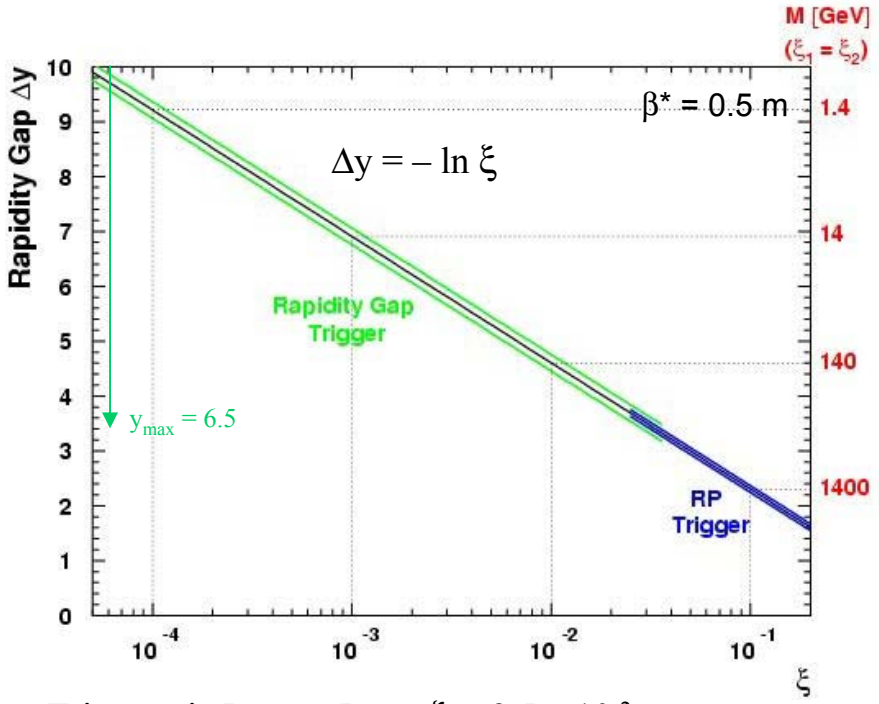
Detection Prospects for Double Pomeron Events

In collaboration with CMS



β* = 1540 m:	σ_ξ = 0.5%	$\mathcal{L} \leq$ 2.4 x 10^{29} cm^{-2} s^{-1}
β* = 172 m :	σ_ξ ~ few 10^{-4}	$\mathcal{L}$ ~ 4 10^{31} cm^{-2} s^{-1}
β* = 0.5 m:	σ_ξ ~ 1 ‰	$\mathcal{L}$ ~ 10^{33} cm^{-2} s^{-1}



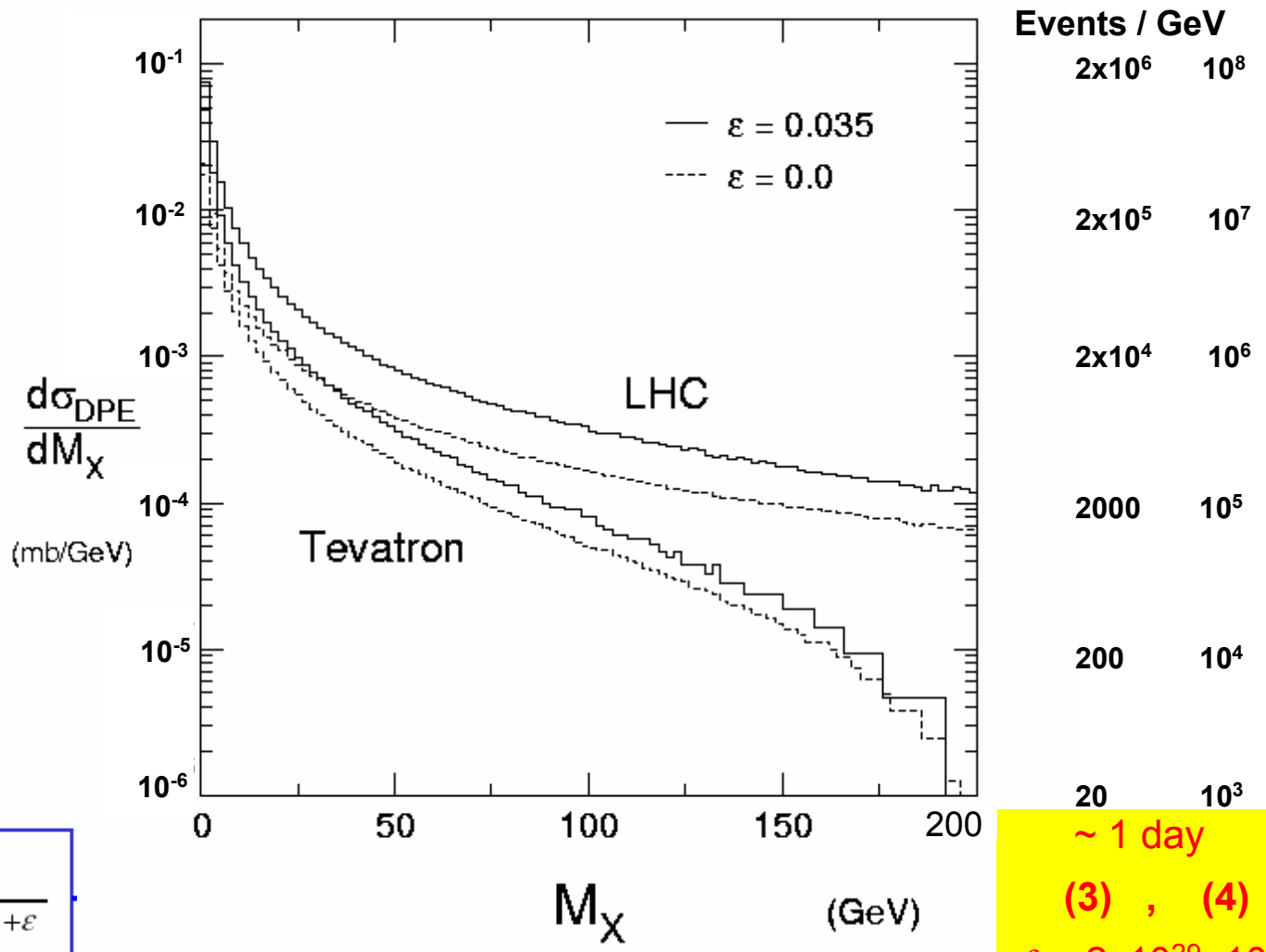


Trigger via Roman Pots $\xi > 2.5 \times 10^{-2}$

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

Double Pomeron Exchange: Cross-Section

$\sigma_{DPE} = 0.5 - 1$ mb $\Rightarrow$ (1–2) x 10^7 events per day at $\beta^* = 1540$ m, $\mathcal{L} = 2 \times 10^{29}$ cm^{-2} s^{-1}



$$\frac{d\sigma}{dM^2} \propto \frac{1}{(M^2)^{1+\varepsilon}}$$

[ε from Pomeron trajectory $\alpha(t) = 1 + \varepsilon + \alpha' t$]

~ 1 day

(3) , (4)

$\mathcal{L} = 2 \times 10^{29}, 10^{31}$ cm^{-2}s^{-1}


TOTEM


TOTEM