Summary of completed/on going analysis performed at 7,8 TeV and Plans for LHC-II

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Definition of Run Scenario

1) High beta, low luminosity

β^*=90m, $N_{bunch} \leq 100$, reduced bunch intensity, μ ~ few %, $\mathscr{L}$ ~ $10^{28} – 10^{30}$ Hz/cm^2

RP approach 5-10 σ

2) High beta, medium luminosity

β^*=90m, N_{bunch} ~ 1000 , μ ~ 0.5 , $\mathscr{L}$ ~ 10^{31} Hz/cm^2

RP approach 10-15 σ

3) Low beta

β^*=0.6m, N_{bunch} ~ 2800 , μ ~ 30-50, $\mathscr{L}$ ~ $10^{33} – 10^{34}$ Hz/cm^2

RP approach 15 σ

Total Cross Section : methods

$$\sigma_{tot}^2 = \frac{16\pi}{(1+\rho^2)} \frac{1}{\mathcal{L}} \left(\frac{dN_{el}}{dt} \right)_{t=0}$$

Based on Elastic scattering

$$\sigma_{tot} = \sigma_{el} + \sigma_{inel}$$

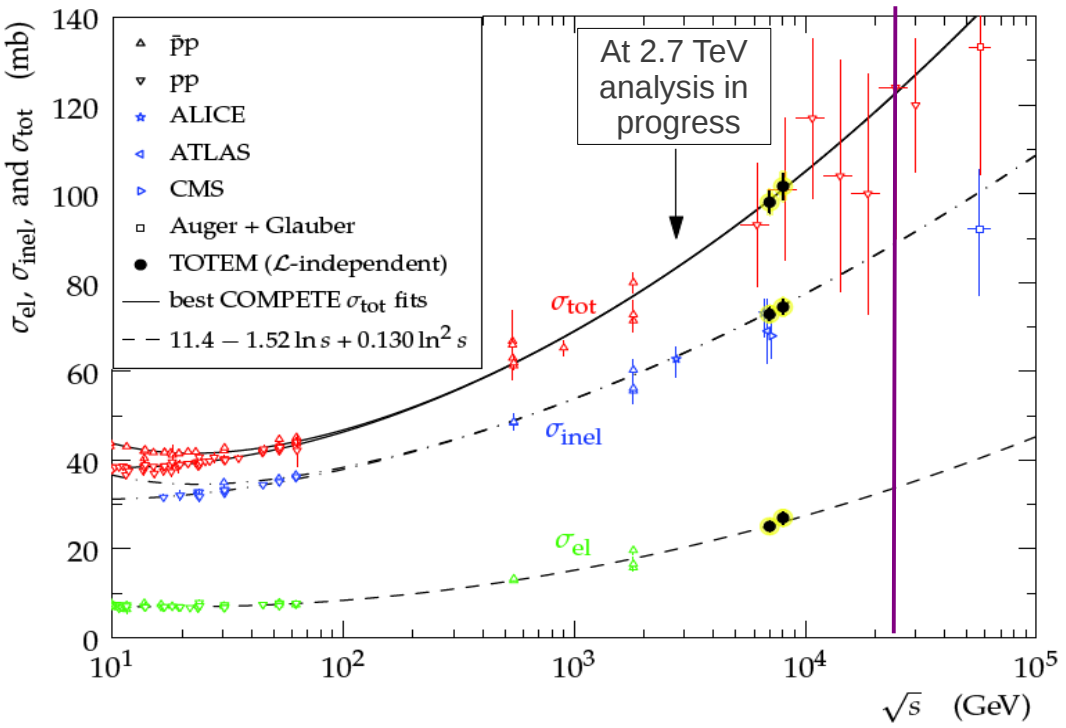
ρ independent

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

$\mathscr{L}$ independent

Cross sections

REFs : EPL 95 (2011) 41001
EPL 96 (2011) 21002
EPL 101 (2013) 21002
EPL 101 (2013) 21003
EPL 101 (2013) 21004
PRL 111 (2013) 12001



What has been measured @7,8 TeV

Elastic cross section:

$t_{min} = 5 \cdot 10^{-3}$ GeV^{-2} @ 5σ β^*=90m

$t_{min} = 6 \cdot 10^{-4}$ GeV^{-2} @ 3σ β^*=1000m

Inelastic cross section (for diffractive masses down to 3.4 GeV)

Total cross section

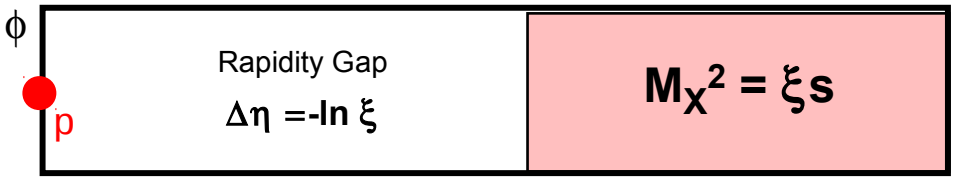
Challenges:

- physics pile-up contamination
- reachable t_{min} in elastic
- optics determination
- beam-halo in RP
- RP alignment
- low statistics at high t

Run Scenario @ 13 TeV:

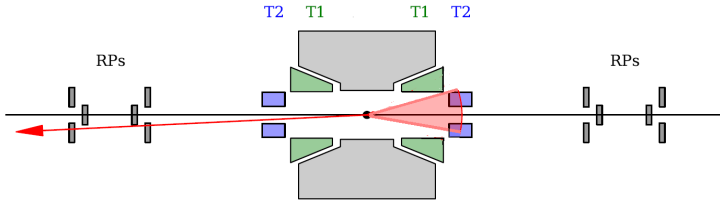
- optics : $\beta^* \geq 90$m
- β^*=90m : t_{min} ~ 0.04 GeV^2 @ nominal RP approach
  ~ $9 \cdot 10^{-3}$ GeV^2 @ 5σ, only special fill
- dedicated trigger (min bias, elastic, zero bias)
- Coulomb interference region & ρ : need β^* ~ 2km
- high-t region needs higher luminosity

Soft Single Diffractive cross section

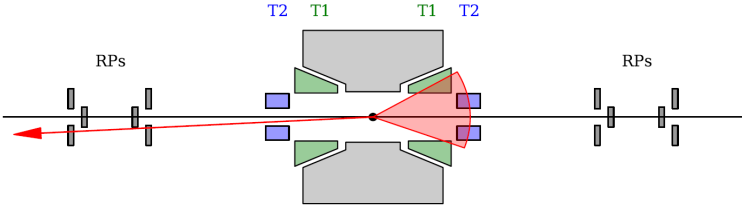


ξ=Δp/p

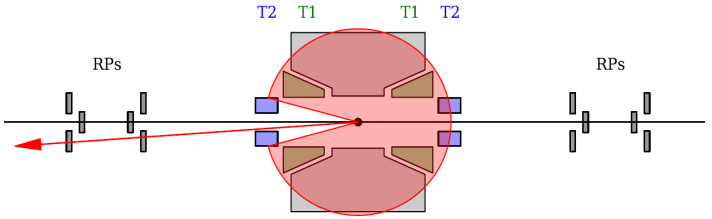
- **SD events trigger with T2, only 1 proton required in RP**
- M obtained from the rapidity gap estimation based on charged track in T1 and T2: $M^2 \sim \exp(-\Delta\eta)$. This allows a better ξ resolution ($\sigma(\xi)/\xi \sim 1$) for low-medium mass.



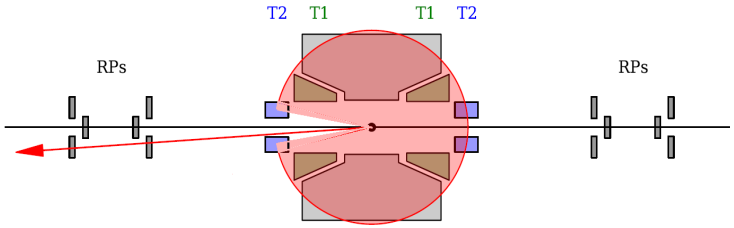
proton& T2_opposite | $2\ 10^{-7}<\xi<10^{-6}$ | *M=3.4 – 7 GeV* | **Low Mass**



proton& T1&T2opposite | $10^{-6}<\xi<0.25\%$ | *M=7 – 350 GeV* | **Medium Mass**



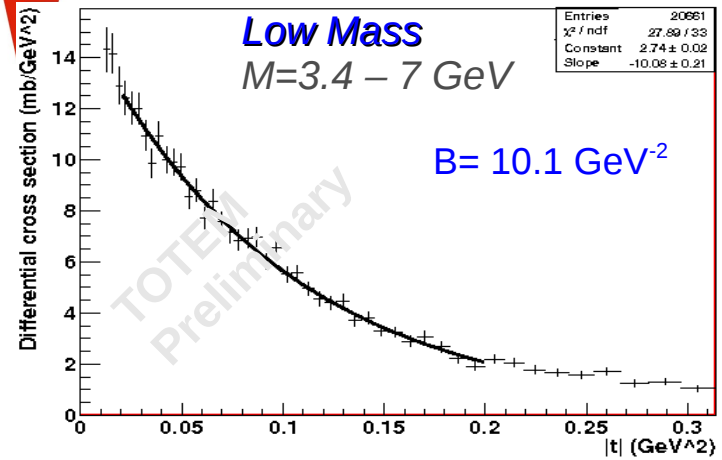
proton& T1same& T2opposite | $0.25\%<\xi<2.5\%$ | *M=0.35– 1.1 TeV* | **High Mass**



proton& T2 both arms | $\xi > 2.5\%$ | *M>1.1TeV* | **Very high Mass**

Soft Single diffraction

REF: LHC students poster session
13 March 2013



What has been measured @7,8 TeV (in progress)

σ_{SD} in different mass ranges, down to 3.4 GeV
Proton t- distribution & slope in different mass ranges

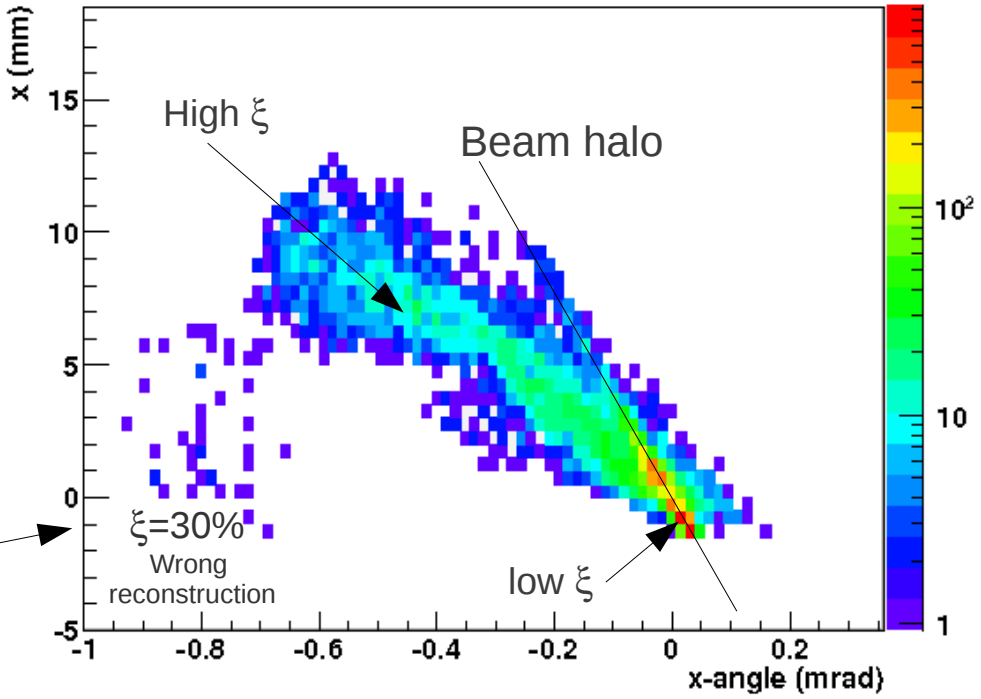
Analysis including CMS detector in progress

Challenges:

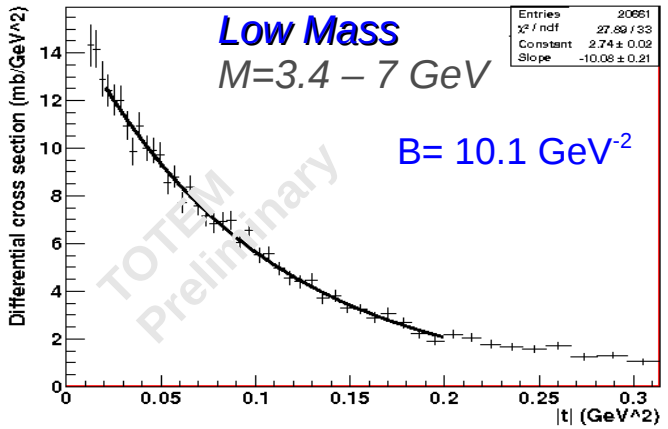
- optics determination & ξ reconstruction
- Background determination from data :
  from zero bias triggered events extract
  the incidence of beam halo protons in RP and
  associate it to the different topologies in T1, T2
- acceptance corrections due to correlations

Combining CMS&TOTEM:
- improve background determination for category I & II
- further segmentation of category II

High ξ region:
- Non detectable rapidity gap
- Mass based on ξ
- proton background from optics characteristic



Soft Single diffraction



What has been measured @7,8 TeV (not yet final)

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Proton t- distribution & slope in different mass ranges

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High ξ region:
- Non detectable rapidity gap
- Mass based on ξ
- proton background from optics characteristic

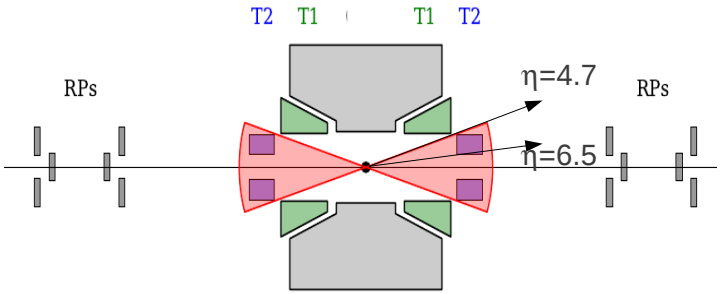
Run Scenario @ 13 TeV:

- β^*=90m : nominal RP approach (to avoid near edge beam halo)
  Low pile-up run
  Access to very low mass (T2 limit)
  Statistics is not an issue
  Better estimate of the central diffraction background in the high ξ region

- low β^* : ξ>3%
  Only with low pile-up
  Better ξ resolution but only high mass

Double diffraction

REF: CERN-PH-EP-2013-170
Submitted to PRL



What has been measured @7,8 TeV:

σ_{DD} for diffractive system with $4.7<|\eta_{min}|<6.5$

Not yet planned: totem + cms

Aim at full coverage measurement @13 TeV

Challenges:

- limited η coverage

- background determination:

ND background estimated scaling the MC prediction using a control sample from data dominated by ND (2T1+2T2 events)

SD background estimated completely from data using a SD-dominated control sample (0T1+1T2) with protons in the RP

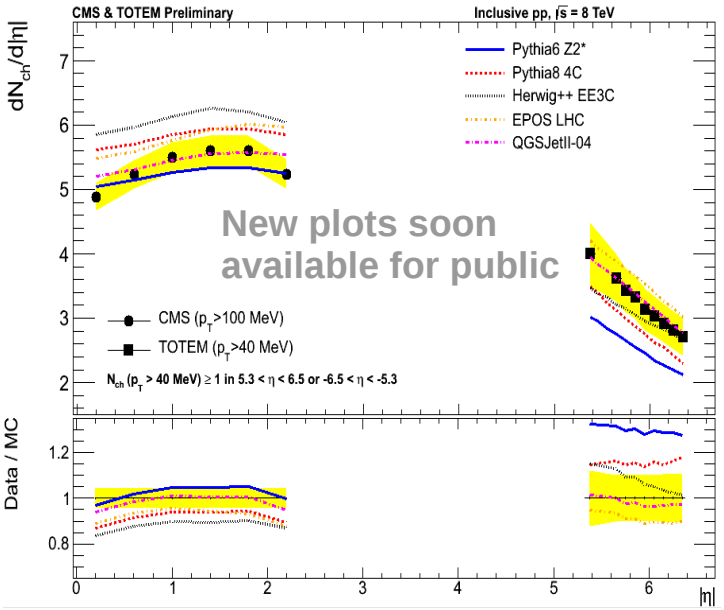
Run Scenario @ 13 TeV:

In any optics condition
- low pile-up (~0.05) is mandatory!
- Min Bias trigger (T2)

The detection of the proton can help in the determination of the Single diffractive background

Very forward $dN_{CH}/d\eta$ measurement

REF: EPL 98 (2012) 31002
CMS FSQ-12-026/TOTEM-2013-03



What has been measured @7,8 TeV

$dN_{CH}/d\eta$ for inelastic events with at least a charged particle in

- $5.3<|\eta|<6.5$ (INELASTIC)
- $5.3<\eta<6.5$ and $-6.5<\eta<-5.3$ (NSD enhanced)
- $5.3<\eta<6.5$ and none in $-6.5<\eta<-5.3$ and viceversa (SD enhanced)

Not yet done: measure the spread of $dN_{CH}/d\eta$

Measure correlations forward-backward/forward-central

Challenges:

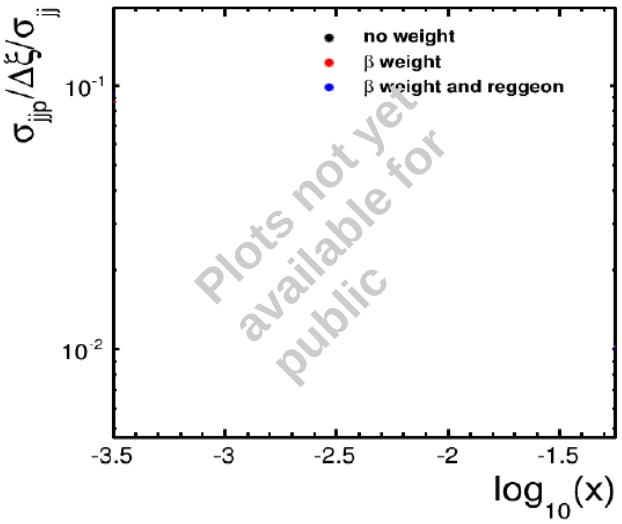
- primary/secondary separation especially in forward direction
- correlation forward , central
- pT cut in central tracking
- T2 occupancy

Run Scenario @ 13 TeV:

- any optics
- low pile-up (~0.05) is mandatory!
- Min Bias trigger (T2?)
- Zero Bias trigger to extend the topologies? [mind the statistics!]

Single Diffractive dijets

REF: CMS-TOTEM SD diffractive dijets
FSQ-12-033



What has been measured @7,8 TeV (in progress):

Sample : β*=90m, 112 bunches, $\mathscr{L}$ ~ 43nb^{-1} , dijet trigger p_T>20 GeV

Fraction of dijets (p_T >30 GeV) events with proton 0.03<ξ<0.1 ; 0.03<|t|<1 GeV^2

t-distribution of the diffractive proton

Challenges:

- optics determination & ξ reconstruction
- acceptance corrections due to correlations (θ^*_x and ξ)
  CMS+TOTEM full simulation not yet available
- background (beam halo, pile-up): ~ 20-30% per arm
  Large part of background can be rejected using selection based on energy/momentum conservation
  ξ_{CMS}-ξ_{TOTEM}<0
  Remaining contribution is estimated from ZeroBias data combined with MC prediction of signal

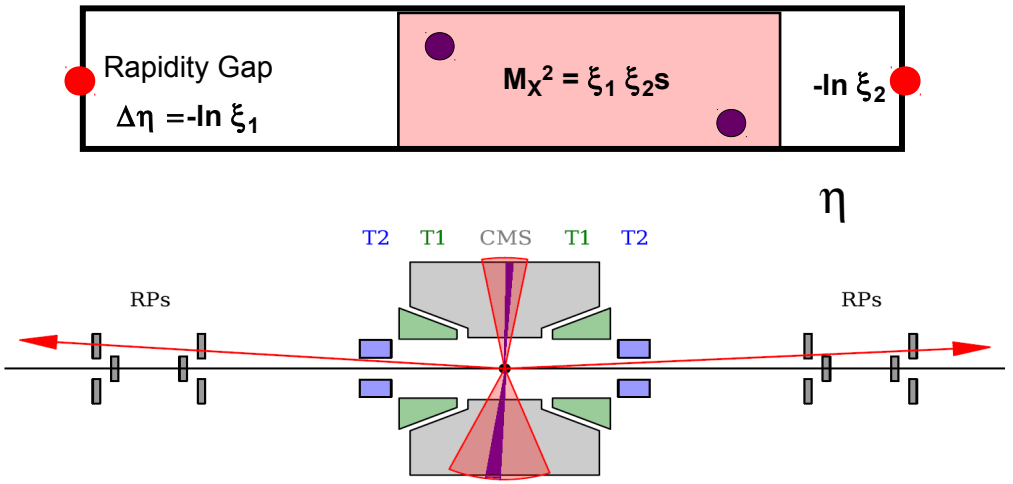
- gap survival probability estimation, comparison with Tevatron results and dPDFs predictions

Run Scenario @13 TeV:

- β*=90m
low pile up / "low" luminosity
statistics should not be an issue
Possibility of low $p_T$jet threshold

- any scenario with high pile-up and high luminosity make this measurement even more challenging

Central diffraction : TOTEM + CMS



Large η-coverage:

- CMS: -5.5<η<5.5
- T1: 3.1 < |η| < 4.7
- T2: 5.3 < |η| < 6.5
- FSC: 6 < |η| < 8

Double-arm proton detection

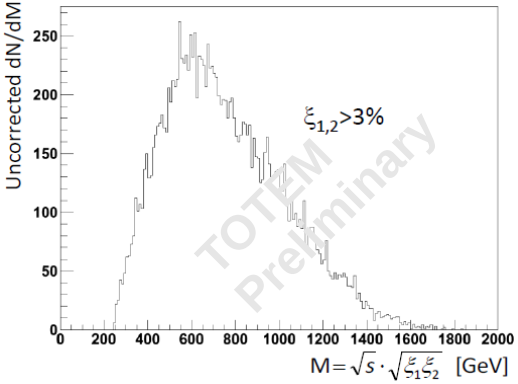
Prediction of mass to be seen in CMS from reconstructed protons: $M^2 = s\,\xi_1\xi_2$

Initial vs. final state comparison: M_{TOTEM} (pp) =? M_{CMS}

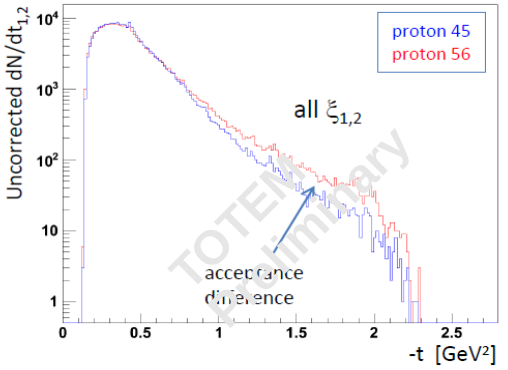
Prediction of central particle flow topology from proton ξ's (rapidity gaps): $\Delta\eta_{1,2} = -\ln\xi_{1,2}$

Masses up to 1.8 TeV with pp survival!

Analysis in progress



t-distribution



Central Diffraction : soft & hard

REFs :
- LHC Seminar- TOTEM Physics program, analysis and results- H. Niewiadomski
- CMS-DP-2013-004

What has been measured @7,8 TeV

β^*=90m: 112 bunches, $\mathscr{L}_{int}$ ~ 43nb^{-1} — 3 bunches, $\mathscr{L}_{int}$ ~ 0.8 nb^{-1}

Trigger on central jets (p_T>20 GeV) — RP double arm

~100 events — ~ 300k events

Lack of statistics!

Challenges:

• Rapidity gap partial coverage [T1, T2, Castor, FSC....]

• Background suppression in RP near edge area (cut in t_min)

• Background (low pile-up)
  - Soft CD: beam-halo, 2xSD ~ 20%
  - Hard CD: Hard_SD + Soft_SD ~ 30%

ξ<1% $\sigma(x_{vertex}[RP])$ ~ 10 μm resolve pileup in RP

ξ>1% protons vs central Energy & momentum consistency

Run Scenario @ 13 TeV:

– β^*=90m, 1000b, $\mathscr{L}_{int}$ ~ 7 pb^{-1}/day, μ~0.5

Require vertex measurement with timing detectors

Full ξ range, but limited resolution ($\sigma(\xi)$~1% ; σ(M)~50GeV)

Low threshold on central system (eg pT of jets)

Rapidity gap still accessible

- low β^*, $\mathscr{L}_{int}$ ~ 1 fb^{-1}/day *(FWD_PHY dedicated stream)*, μ~30

Require vertex measurement with timing detectors (and with good resolution!)

Limited ξ range (ξ>3%) but good resolution ($\sigma(\xi)$~0.2% ; σ(M)~15GeV)

Rapidity gap not visible

More on going.....

- Single Diffractive J/ψ
  Few events only. Need larger statistics!
- Central diffraction at very low ξ (see Ken' talk)
- Missing mass in central diffraction (see Ken' talk)
- Classification of soft processes
- .....

Plans for the Yellow Report contribution

Describe briefly the results obtained during LHC-RUN-I

Estimate the performances at higher energies, as well as the most suitable running scenario