Diffractive production of top quark(s) in SM and beyond

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Outline

Part 1: Exclusive production of top quark pairs

Part 2: Single diffractive events with top quark(s)

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Part 1: Exclusive production of top quark pairs

Part 2: Single diffractive events with top quark(s)

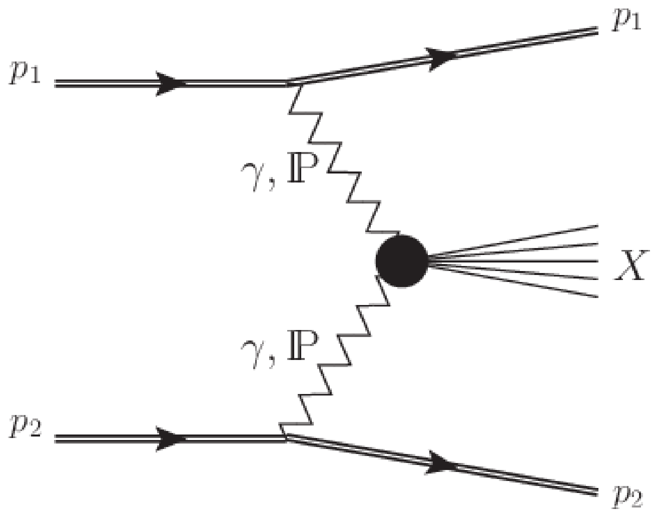
The CEP ttbar studies is a broad effort. Other people also inspire these studies

E.Robutti, S.Tosi, F.Ferro, M.Pisano, R.Mulargia (Genova), A.Bellora, A.Solano (Turin), C. Beldenegro, C.Royon (Kansas), B Ribeiro Lopes, J.Hollar, M.Gallinaro (LIP), D. d'Enteria, M.Pitt, P.da Silva, M.Mulders (CERN)

Central Exclusive production

CEP with tagged protons:

- The main signature of CEP is that the protons remain intact



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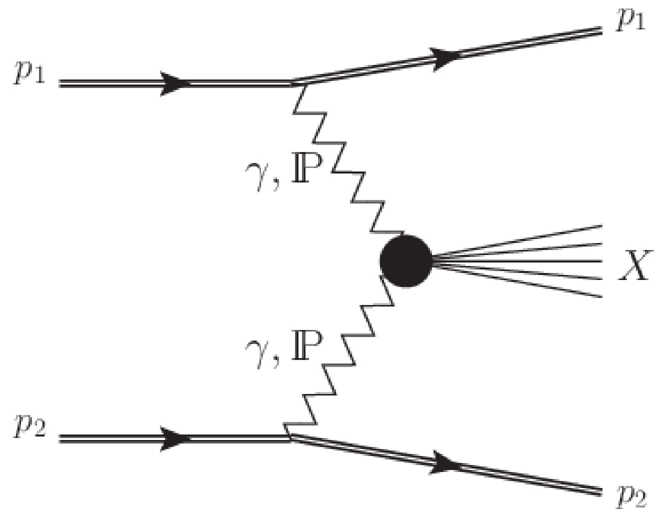

- We can use these protons to tag the CEP events, by measuring them with forward detectors (e.g., AFP or CT-PPS)

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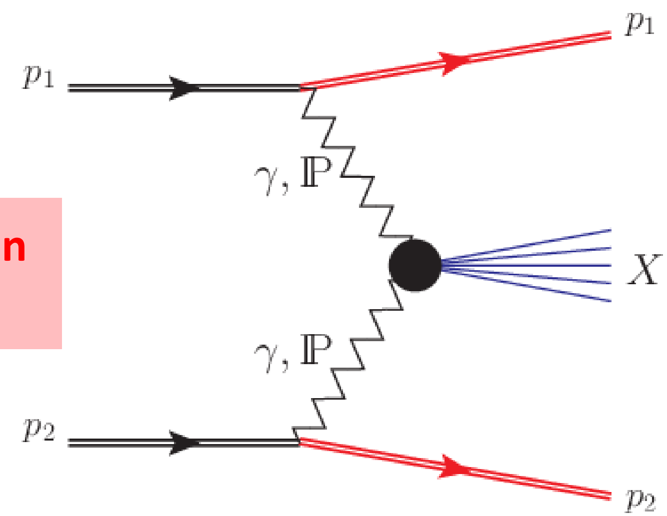
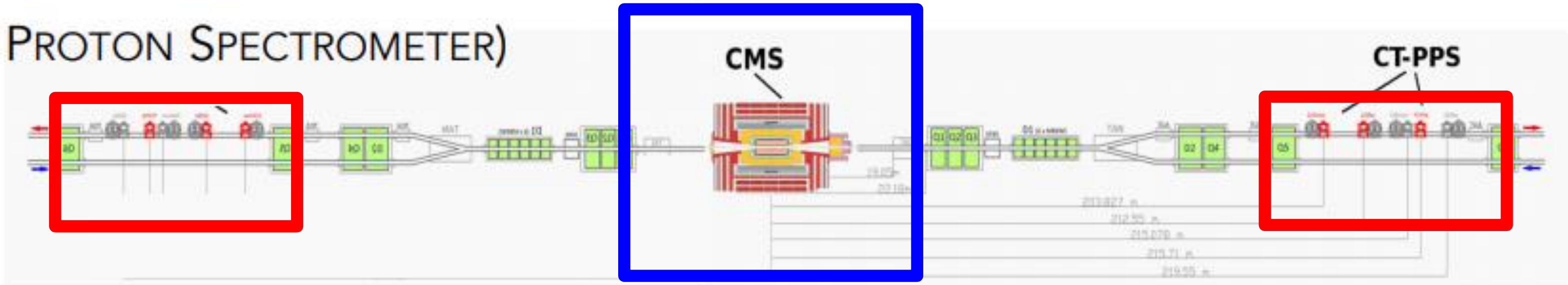
Forward protons detected in CT-PPS



Central ttbar event triggered and measured in CMS

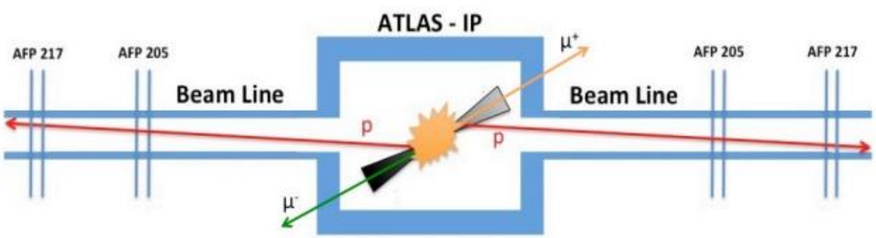
- We can use these protons to tag the CEP events, by measuring them with forward detectors. **For example CMS + CT-PPS:**

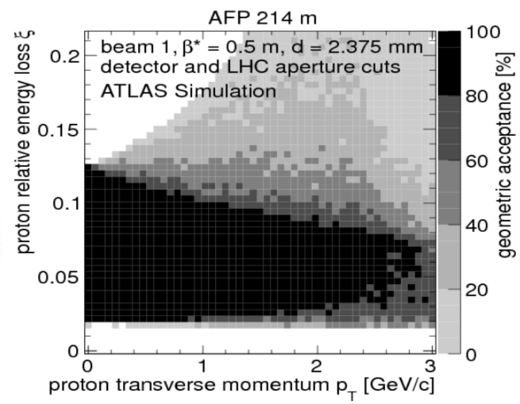
(Precision Proton Spectrometer)

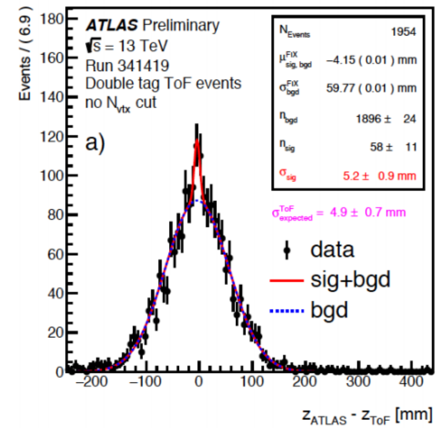


Acceptance of forward protons

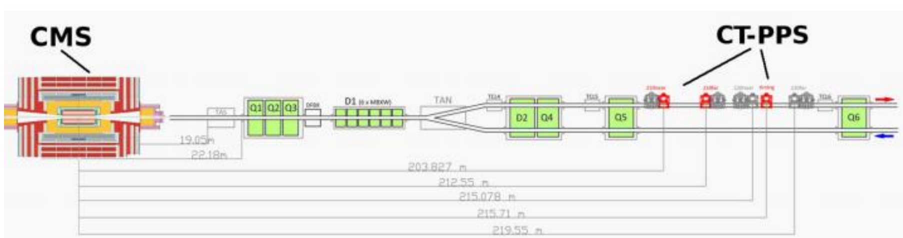
- Forward detectors usually cover only fraction of momentum loss



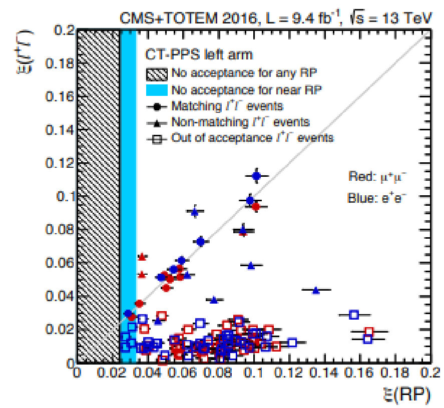




[V. Petousis, "AFP status and prospects" June 10th, 2019]



[J. Williams, "PPS physics and prospects" June 10th, 2019]



CT-PPS Timing?

We will follow next acceptance

Beam – detector distance: $\xi \geq 2\%$

Collimator settings: $\xi \leq 15\%$

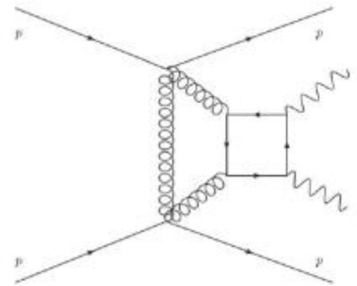
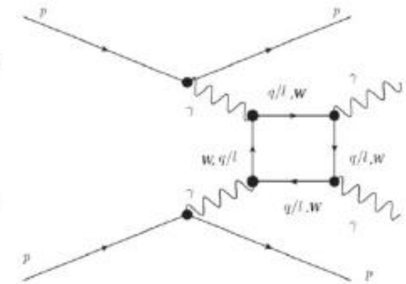
Central Exclusive production

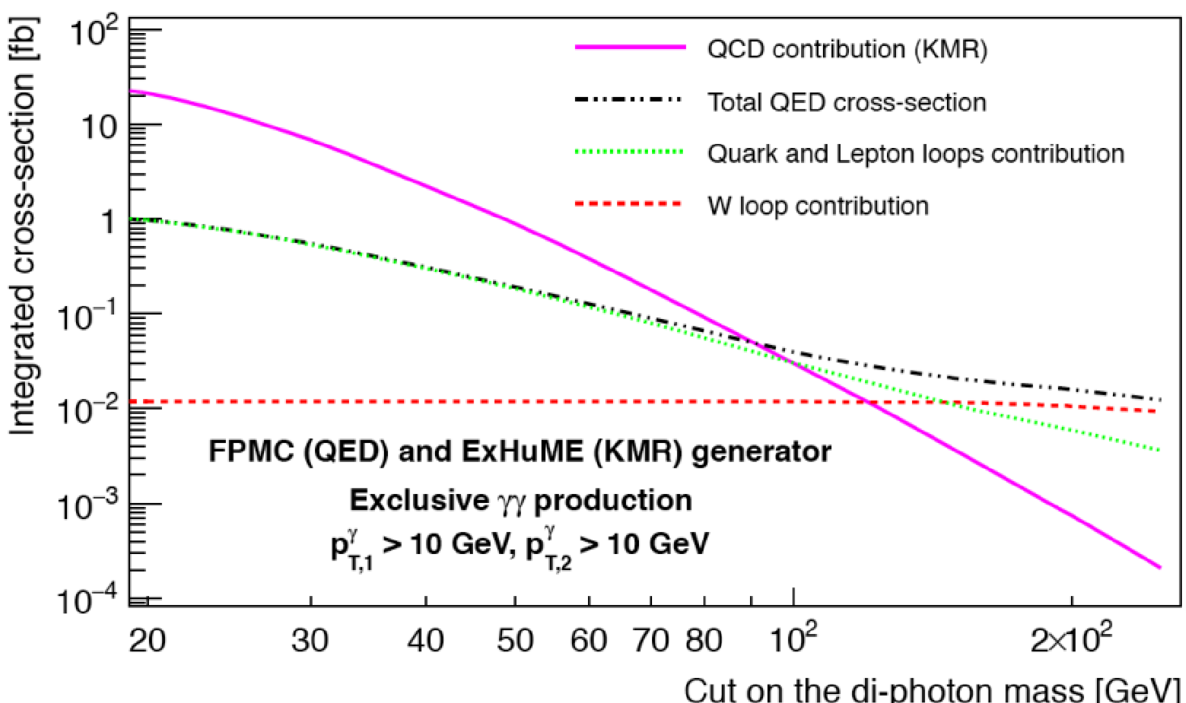
Photon vs pomeron – initiated

- Acceptance of 2%:

$$m_X > 2\% \times 13TeV = 260\ GeV$$

- From C. Royon talk yesterday (link):



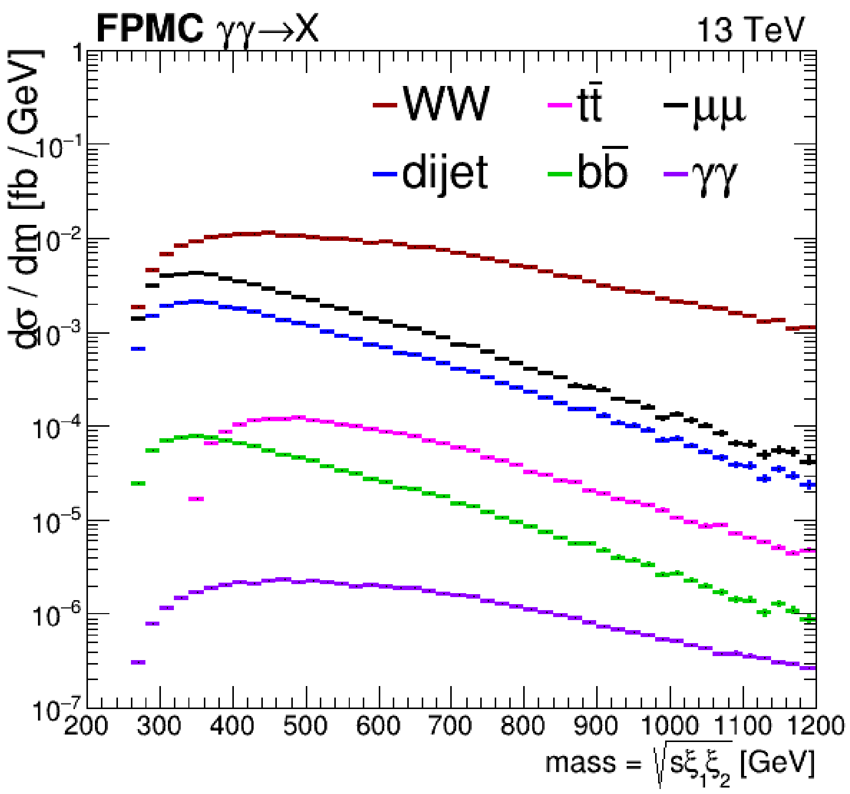
ξ ≥ 2%

Warning! not the same for quarks.
Yet, we will ignore IP contributions for now

Central Exclusive production

Cross section of CEP at $\sqrt{s} = 13$ TeV

- Apply Forward Detector acceptance (2% ≤ ξ ≤ 15%):

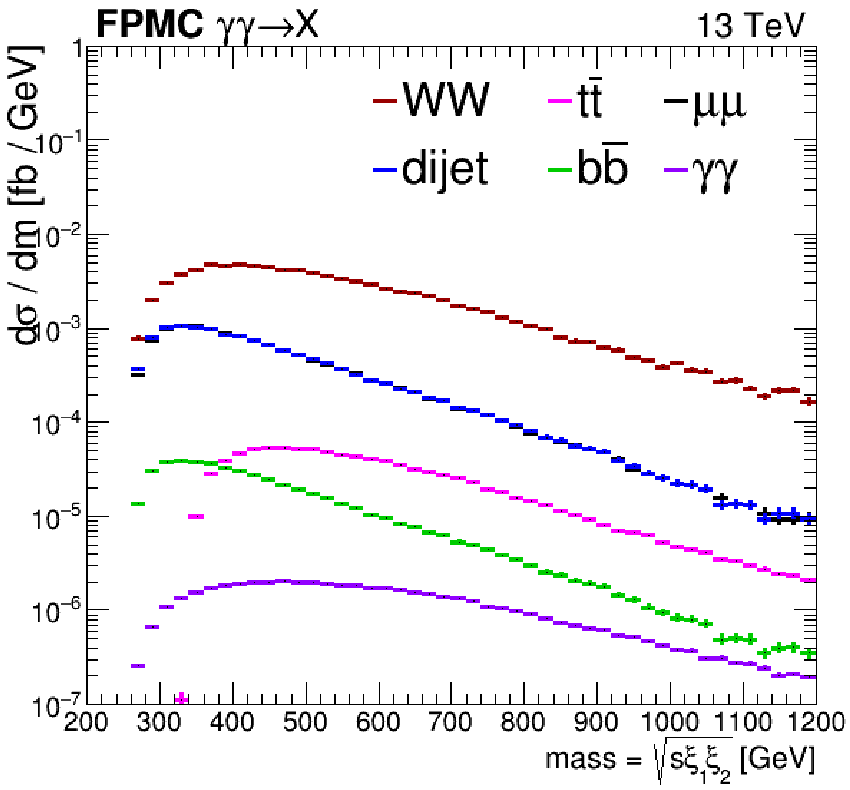


IPROC	Xsec $[fb]$
WW	14.6
$\mu\mu$	3.05
$dijet$	1.55
$t\bar{t}$	0.112
$b\bar{b}$	0.057
$\gamma\gamma$	0.003

Central Exclusive production

Cross section of CEP at $\sqrt{s} = 13$ TeV

- Apply Forward Detector acceptance (2% ≤ ξ ≤ 15%):
- + central detector cuts: $p_T^{jet} > 20GeV, p_T^{l,\gamma} > 30GeV, |\eta^{lep,jet,\gamma}| < 2.5$



IPROC	Xsec $[fb]$
WW	4.54
$\mu\mu$	0.67
$dijet$	0.68
$t\bar{t}$	0.05
$b\bar{b}$	0.025
$\gamma\gamma$	0.0025

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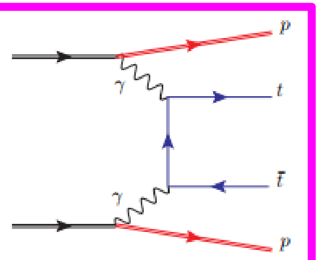

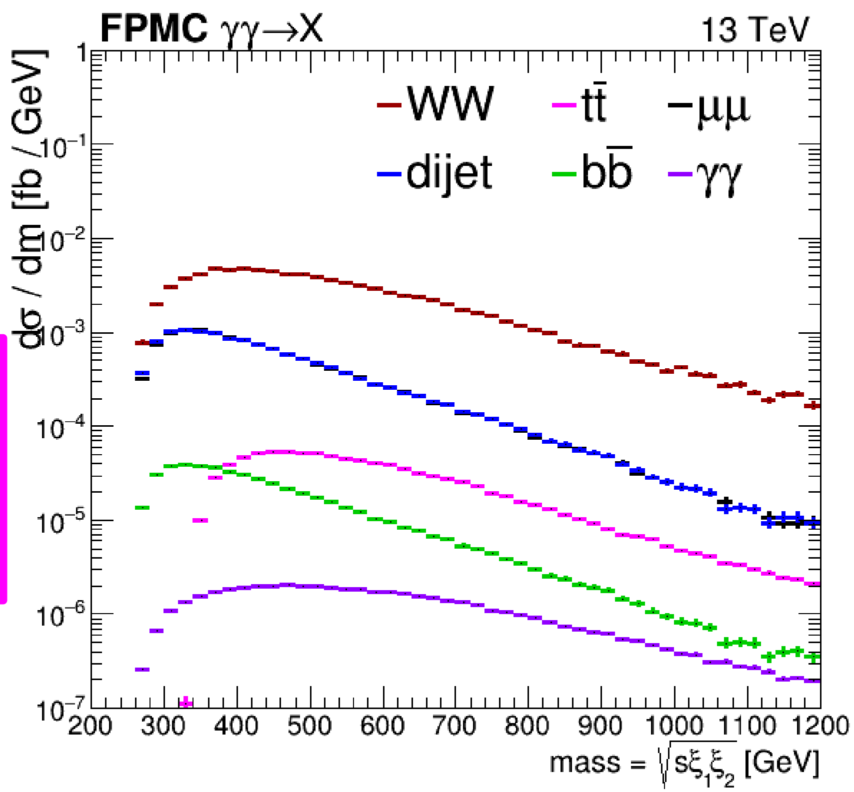

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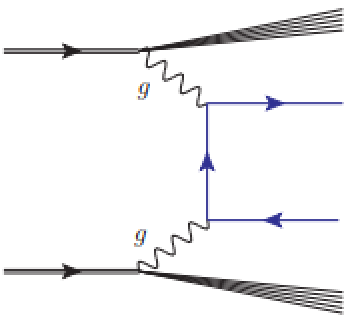
We will focus on ttbar production

Backgrounds in CEP

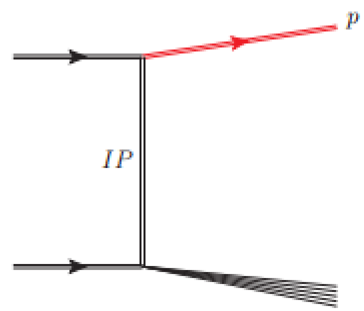
Background in standard runs (<μ> > 25)

- With increasing pileup, combinatorial backgrounds of SM ttbar + 2 protons from PU is also increasing

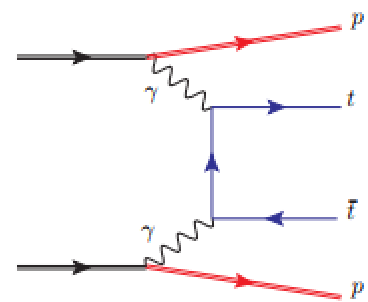
Background



+ 2x



Signal



SM inclusive ttbar production

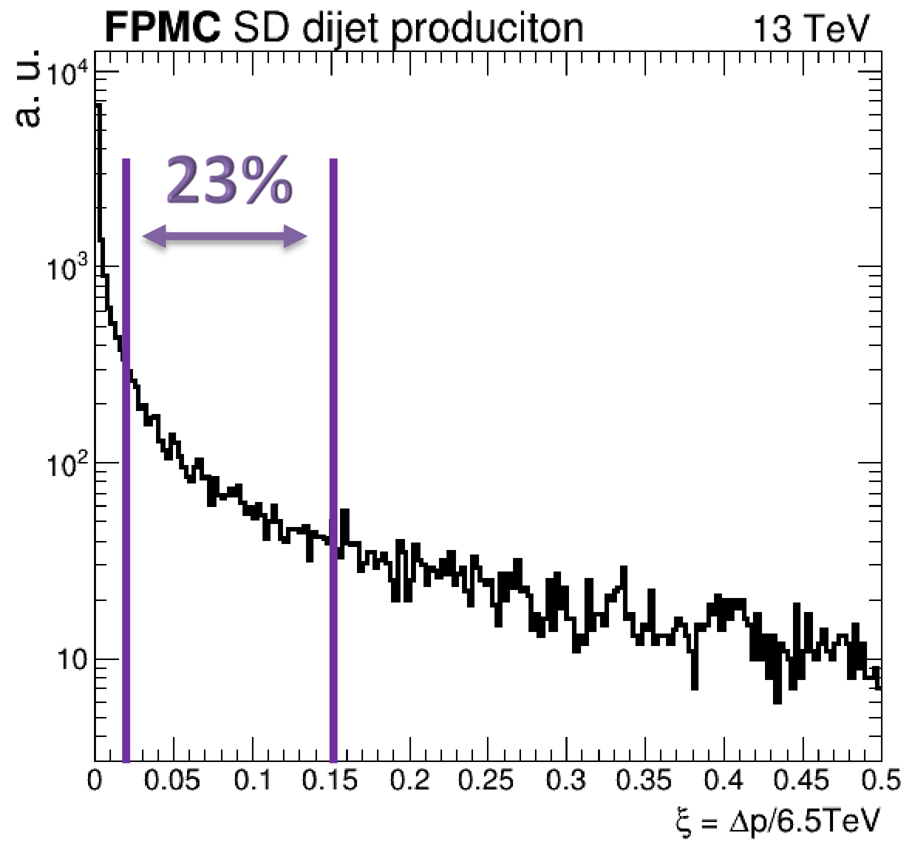
Single diffractive *pp* scattering (PU)

SM exclusive ttbar production

Backgrounds in CEP

Background rates

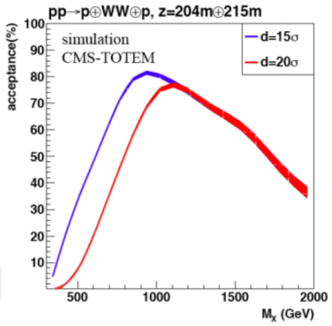
- From the fraction of SD and DD events, and the probability that the ξ is within the acceptance, can estimate rate of the SM backgrounds.
- The efficiency of diffractive proton from SD event to be within the acceptance of the the forward detector is ~23%.

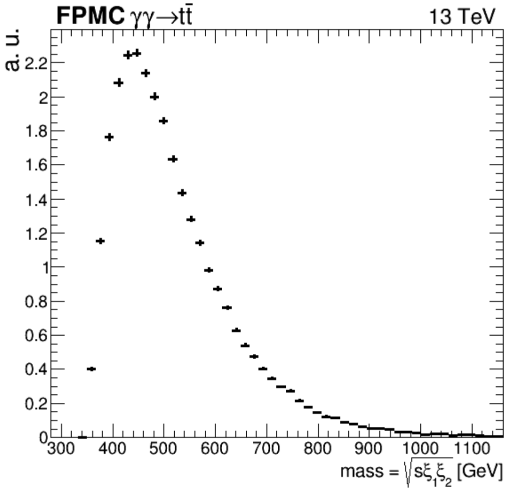


CEP Event selection with tag. protons

Tagged protons as a measure the ttbar event

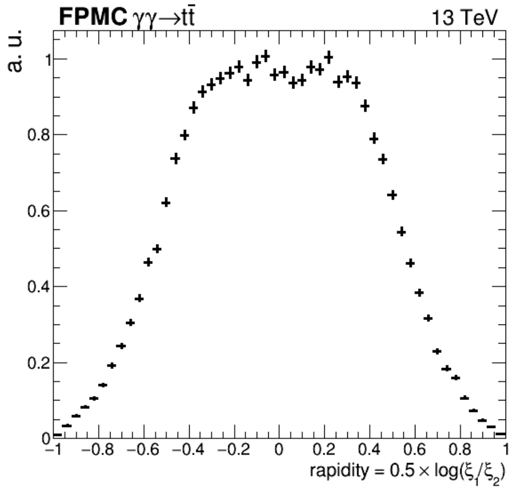
- The mass and the rapidity of the central event can be expressed in terms of proton momentum loss. Hence, from the correlation between the central event and tagged protons, the background can be rejected

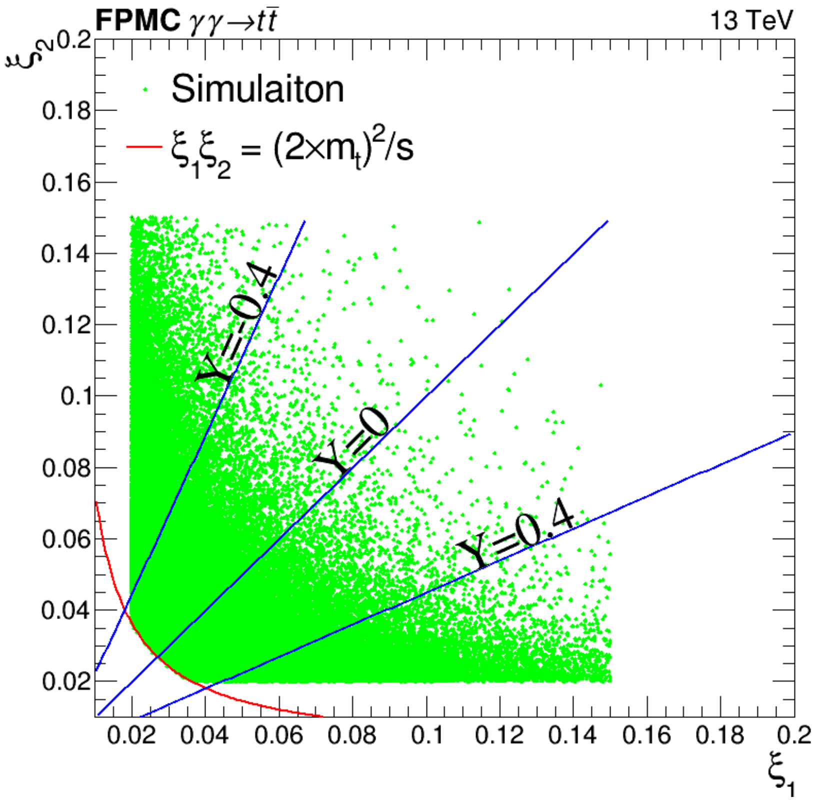




$$Y = \frac{1}{2} Log\left(\frac{\xi_1}{\xi_2}\right)$$

$$m_{tt} = \sqrt{s\xi_1\xi_2}$$





CEP Event selection with tag. protons

Central detector event selection

- Apply basic selection cuts for inclusive ttbar and exclusive ttbar events.
- Divide according to top decay mode and apply corresponding selection
- Estimated event yields for 300 fb^{-1} and $<\mu>=25$

Cut	Exclusive (signal)	Inclusive (bkg)
proton acceptance	3.05	1.7e+07
Leptons (n=0,1,≥2)	2.06	1.4e+07
Jets (n≥6,3,1)	1.87	1.1e+07
b-Jets (n≥1)	1.65	9.6e+06
$\left\|m_{pp} - m_{tt}\right\| \&\& \left\|y_{pp} - y_{tt}\right\|^{*}$	1.56	2640

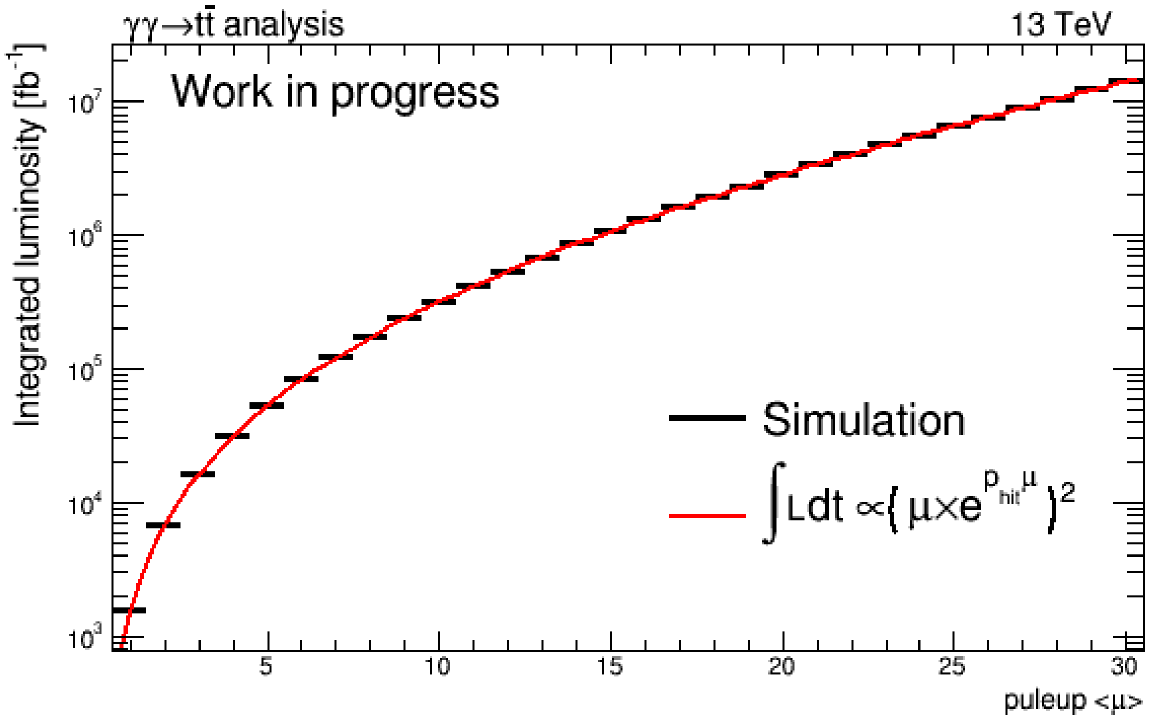
Further background reduction is possible, this is just a rough estimation

* For signal assume 95%

Sensitivity to CEP ttbar production

Discovery of potential vs pileup and luminosity

- Assuming that after event correlation, we accept 1 of 3600 background events, to achieve 5 sigma we need the following amount of data for given pileup profile:



$$\frac{s}{\sqrt{b}}(\mu, \mathcal{L}) \propto \frac{e^{-p_{hit}\cdot\mu}}{\mu}\sqrt{\mathcal{L}}$$

p_{hit}: probability for a PU proton to hit forward detector (here taken as 0.04)

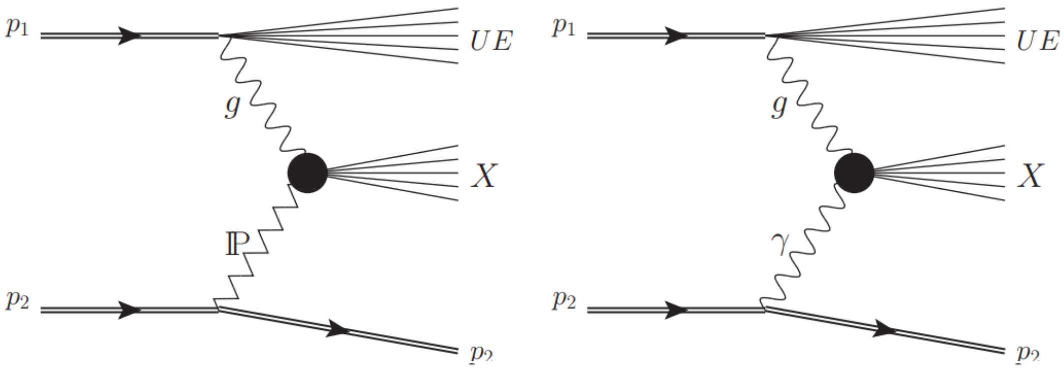
Pileup has a non-linear relation with integrated luminosity if we desire to achieve the same sensitivity:

$$\mathcal{L} \propto (\mu e^{p_{hit}\cdot\mu})^2$$

Single diffraction in pp

Single diffractive (SD) processes with tagged protons:

- The SD can split into two categories:

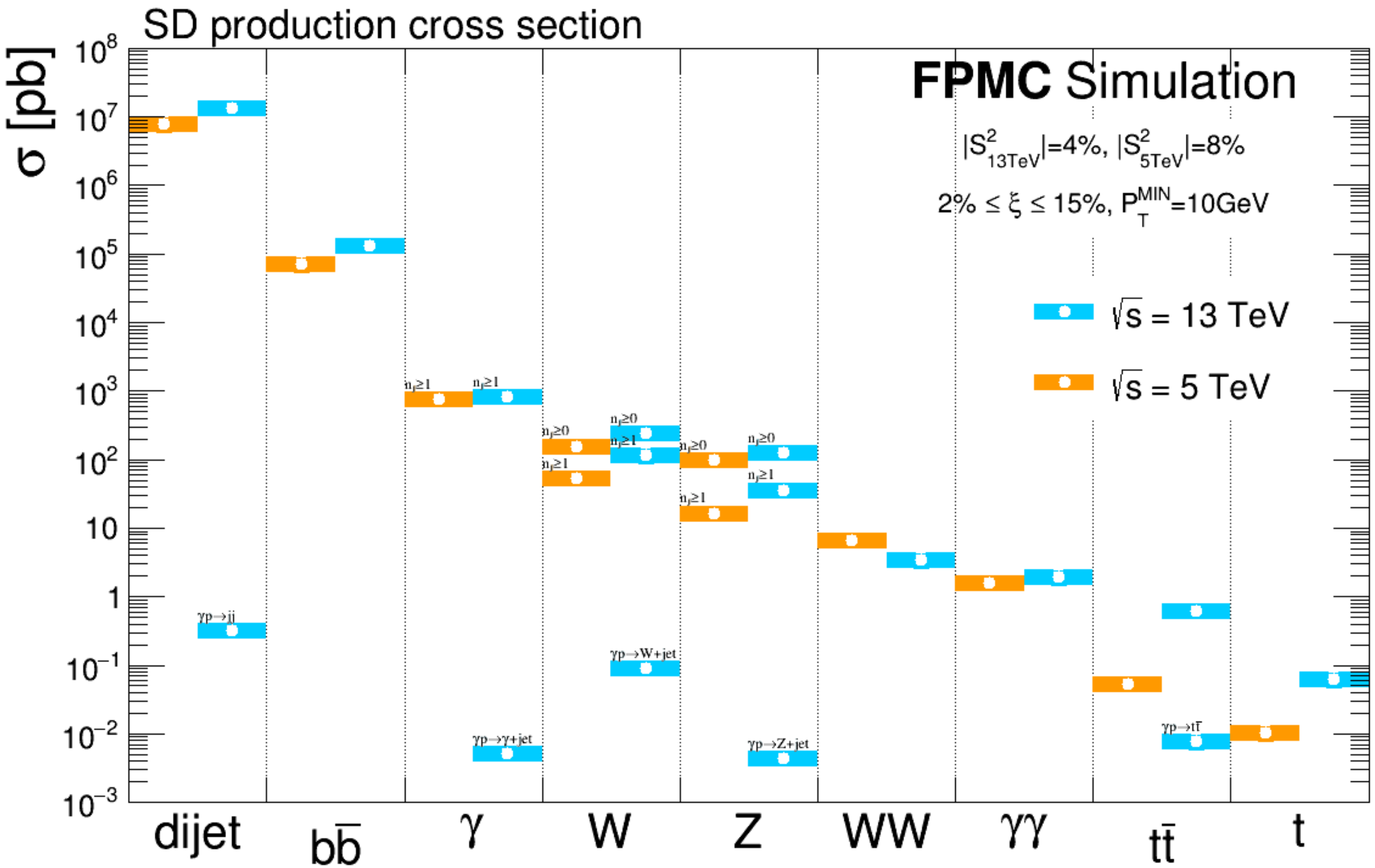


(a) Pomeron exchange (b) Photoproduction

- With tagged proton in one of the forward detectors, we can probe the physics of single diffractive events.
- High ξ cuts can select pure samples of SD events, yet for pure event sampling low PU event should be considered.

Single diffraction in pp

- Single diffractive processes have large Xsec (typically few % from inclusive)
- At high pileup hard to identify SD using proton tagging



Single diffraction in pp

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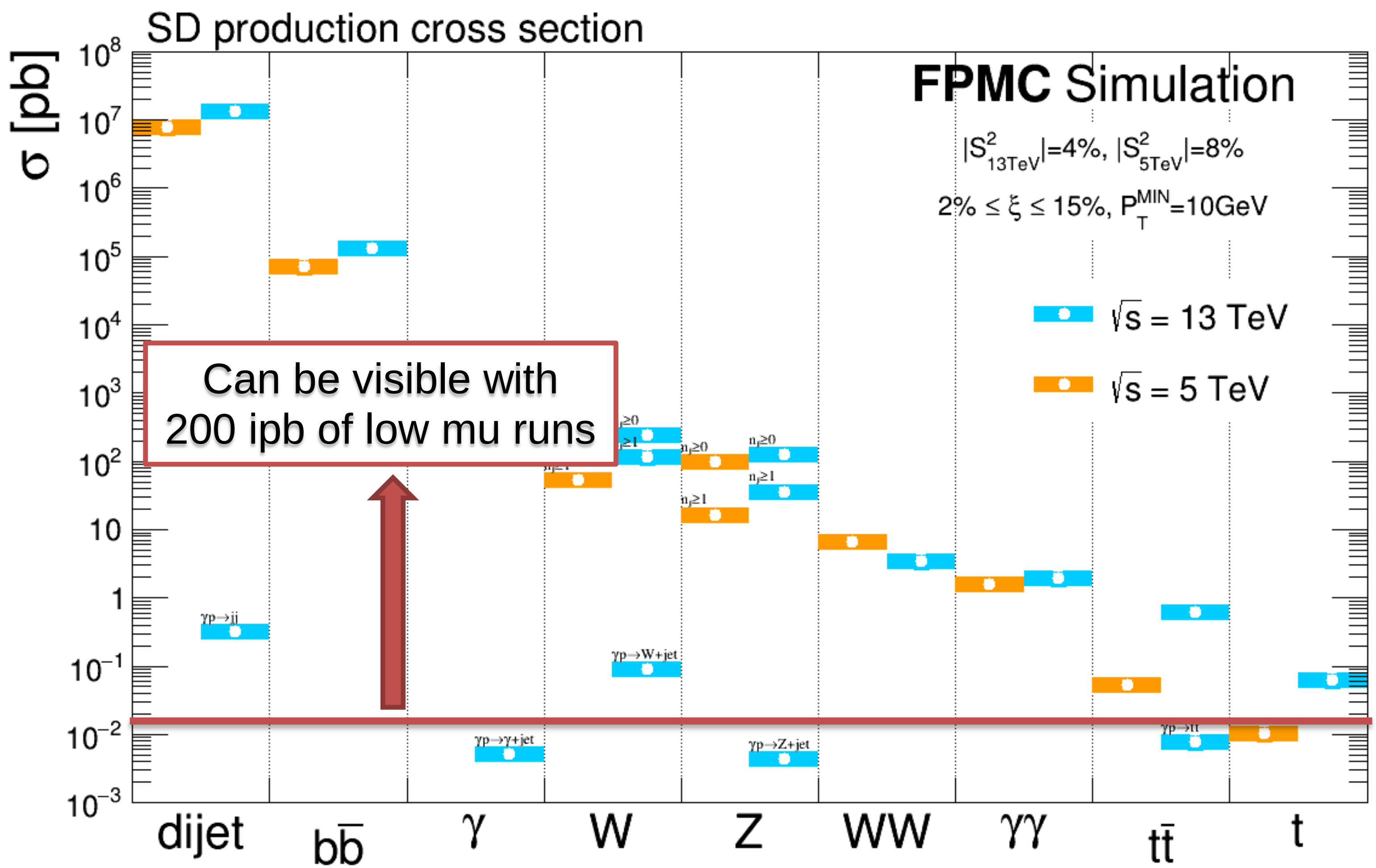
- BUT low – mu runs with ~200pb^{-1} open window for clean SD measurements



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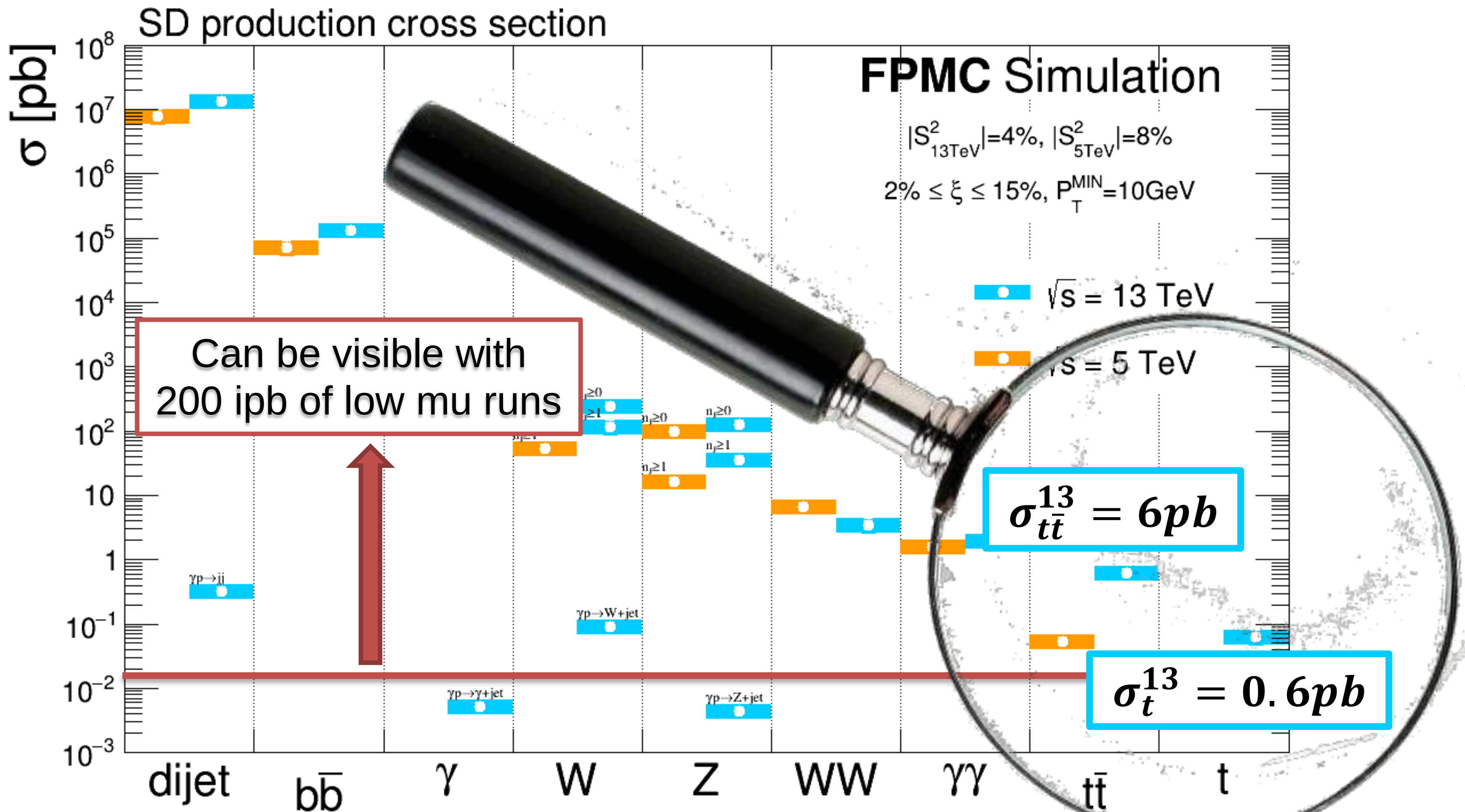
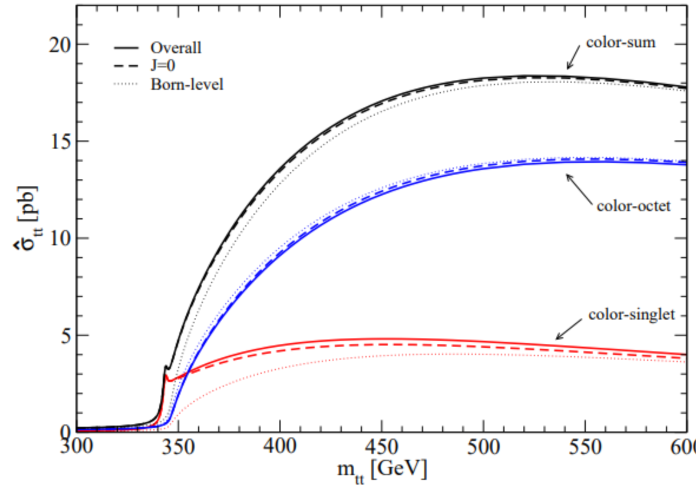
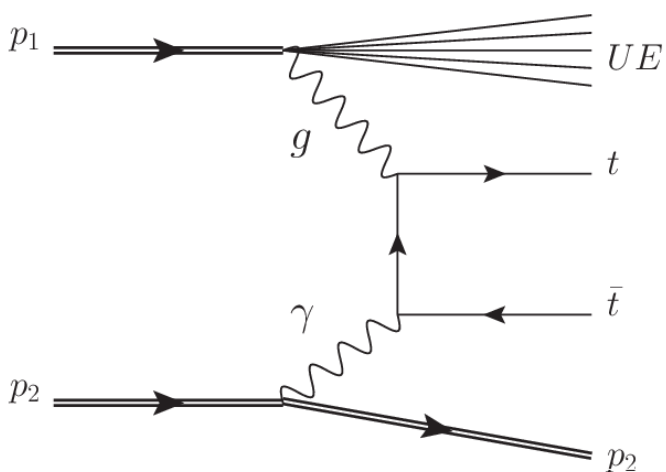


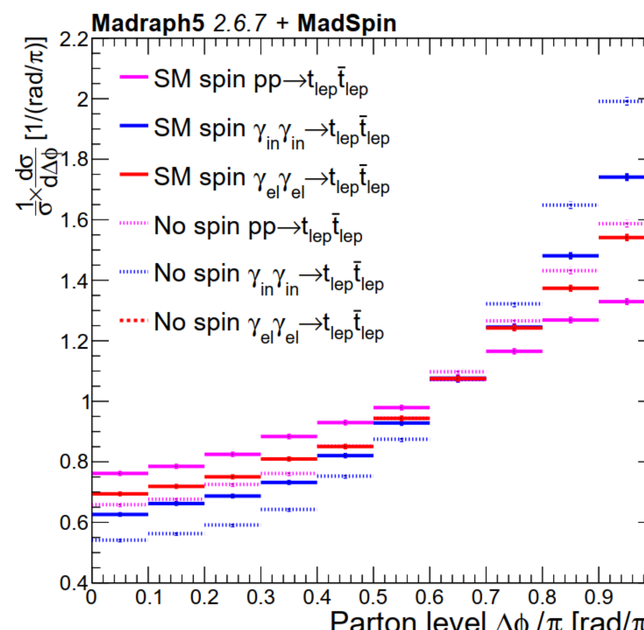
SD ttbar events

JHEP 1009:034,2010

- Color singlet top quark pairs is challenging to probe within the gluon-gluon production. With SD events we can investigate color flow of ttbar and compare to the inclusive production
- Top quark are probes the scale/mode of the production through it decay properties – like spin correlations
- Photoproduction of ttbar can be probed both in pPb and pp data. The measurement can serve as a reference for the pPb runs





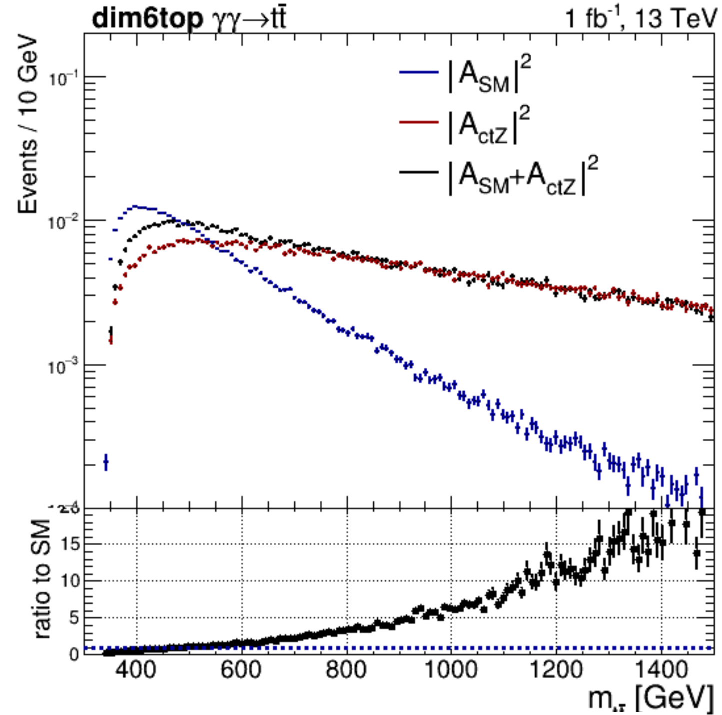


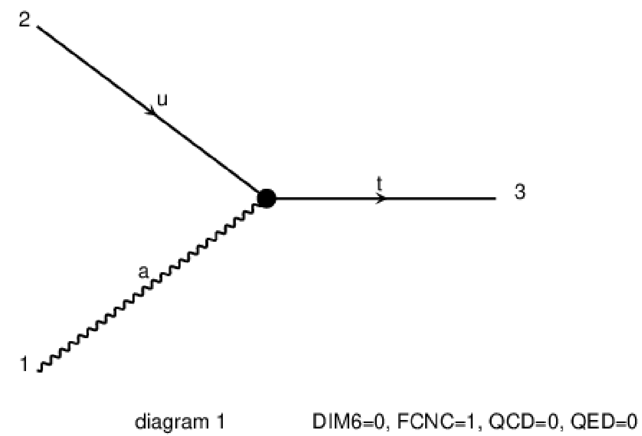
BSM in diffractively produced top(s)

- Although a low sensitivity to SM exclusive ttbar production, this channel gives a unique opportunity to probe directly the ttγγ vertex.

- ttγ vertex is not constrained as for direct ttγ measurement, but still might be valid for alternative constrain of ttγ coupling

- Single top in SD events is sensitive to FCNC coupling from single top photoproduction





Summary

- A new phase-space of SM can be reached using the tagged protons.
- ttbar production is not yet visible with LHC data, but it will be good to establish an analysis.
- Single Diffractive SM ttbar is visible with LHC data, and it will be interesting to explore this physics.
- The increase of pileup has a way too negative effect on the sensitivity. It would be good in Run3 to have more low pileup runs.
- Single Diffractive SM processes have large potential for probing diffractive physics as well as SM top and EW physics.

Backup