Top quark production with proton tagging at CERN LHC

C. Baldenegro[1], A.Bellora[2], S. Fichet[3], G. von Gerdorff[4], M. Pitt[5], C. Royon[1]

[1]Kansas University

[2]Università degli Studi di Torino e INFN Torino

[3]Departamento de Fısica, Pontifıcia Universidade Catolica de Rio de Janeiro, Rio de Janeiro, Brazil

[4]ICTP South American Institute for Fundamental Research (ICTP-SAIFR), Sao Paulo, Brazil

[5]CERN

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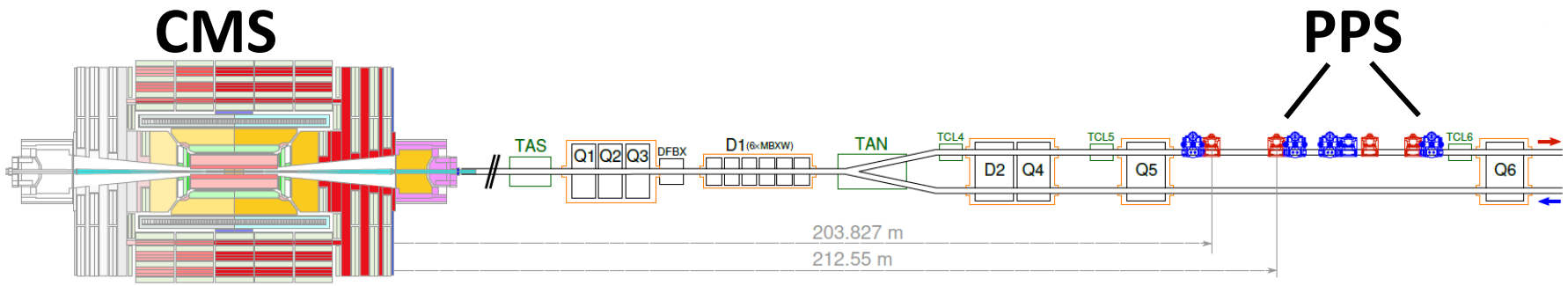
Intact protons at CERN LHC

Diffractive collisions could preserve protons in the final state:

$$pp \rightarrow p + X + p$$



- PPS detectors installed in Roman Pots (RP) can tag the outgoing protons
- For exclusive processes, the proton measurement allows:
  - Complete reconstruction of the final state
  - Indipendent measurement of the central system mass and rapidity

Why top quarks?

- Top quark production in diffractive processes have never been measured
- If observed can lead to better understanding of the pomeron structure
- They are the heaviest particles in the SM, hence more likely to be sensitive to BSM physics

Which processes can we explore?

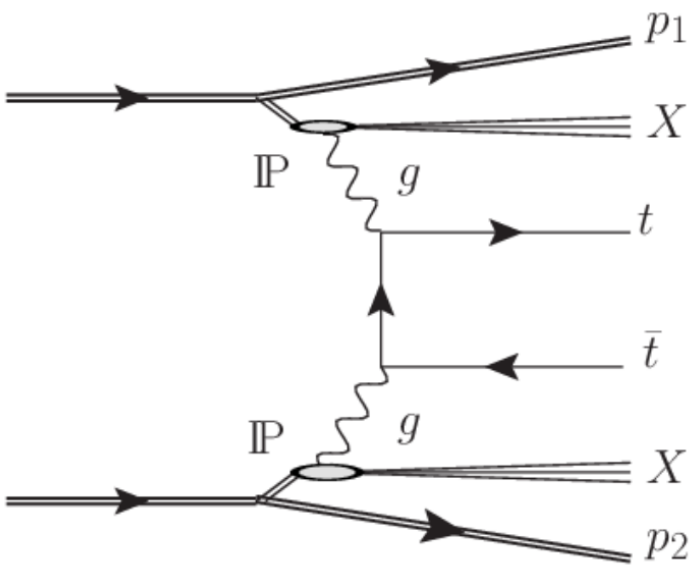
- Inclusive diffractive $t\bar{t}$ production:
  - $pp \to p + t\bar{t} + X$
  - $pp \to p + t\bar{t} + X + p$

- Inclusive diffractive single t production:
  - $pp \to p + tW + X$
  - $pp \to p + tW + X + p$

- Exclusive $t\bar{t}$ production via photon fusion:
  - $pp \to p + t\bar{t} + p$

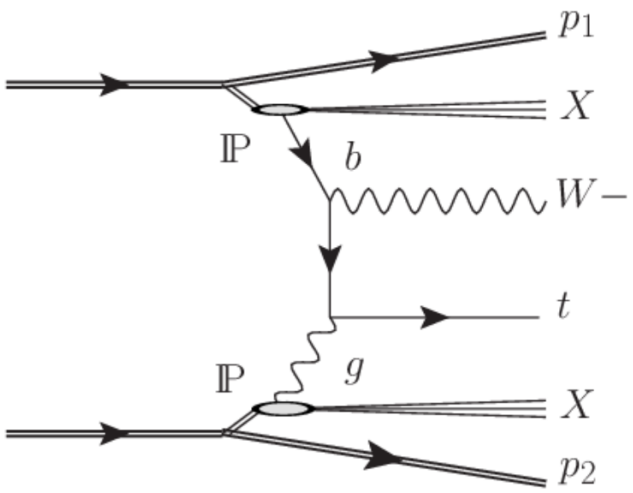
Inclusive diffractive $t\bar{t}$ production

- New probe to constrain the diffractive structure function of the proton, which is still ill understood
- Sensitive to the quark/gluon content of the pomeron
- Cross section ~1 pb at 13 TeV, with survival probabilities included



- Needs specific low pileup running conditions to be observed, to suppress combinatory backgrounds coming from pileup protons

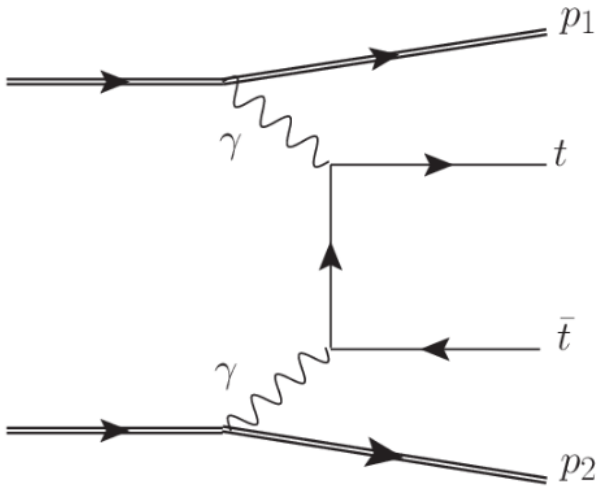
Inclusive diffractive single t production



- Constrain the bottom quark content of the diffractive structure function
  - H1 and ZEUS were not sensitive to it, so it was assumed to be zero in the dPDF fits
- Possibly challenge the assumption of quark flavor symmetry in parton densities, used by ZEUS and H1 in the extraction of dPDFs
- Requires the same measurement conditions as inclusive $t\bar{t}$

Exclusive $t\bar{t}$ production via photon fusion

- Theoretically well modeled,
  expected cross section of ~0.1 fb at 13 TeV



- Can be probed in standard luminosity
  LHC conditions data is available.
- Proton tagging allows to strongly suppress backgrounds
- Unprecedented observation to be probably achieved with HL-LHC data
- Sensitive to BSM physics

EFT models for exclusive $t\bar{t}$

- Add all dimension-8 operators for $\gamma\gamma t\bar{t}$

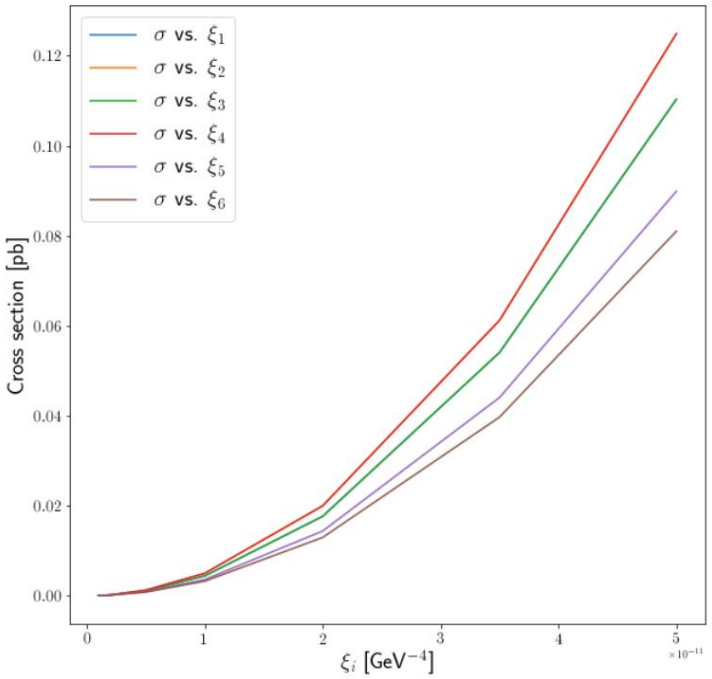
$$\mathcal{L} = \mathcal{L}_{SM} + \frac{1}{\Lambda^4}\sum_i \mathcal{O}_i$$

  - 2-derivatives terms CP-even: $\mathcal{O}_1, \mathcal{O}_2$
  - 2-derivatives terms CP-odd: $\mathcal{O}_3, \mathcal{O}_4$
  - 3-derivatives terms CP-even: $\mathcal{O}_5$
  - 3-derivatives terms CP-odd: $\mathcal{O}_6$

- Add them to the generator and check sensitivity, one by one

FPMC implementation

- Forward Physics Monte Carlo (FPMC): Herwig6 based generator
  - Allows to study a wide variety of processes, including all of those in which we are interested
- By using the standalone C++ export of Ma implemented the EFT model in FPMC
- Currently, tests are ongoing…



Summary

- Proton tagging at CERN LHC allows us to tackle physics processes that have never been accessible
- Loads of different processes can be explored!
- EFT models for $t\bar{t}$ have been implemented in FPMC, to probe the sensitivity to EFT couplings both with current and future LHC data