Multiple parton interactions in $p\bar{p}$ collisions in D0 experiment at the Tevatron

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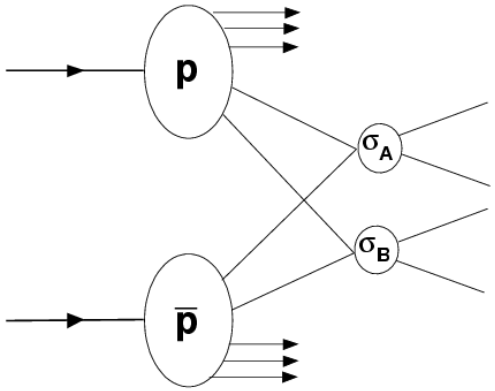
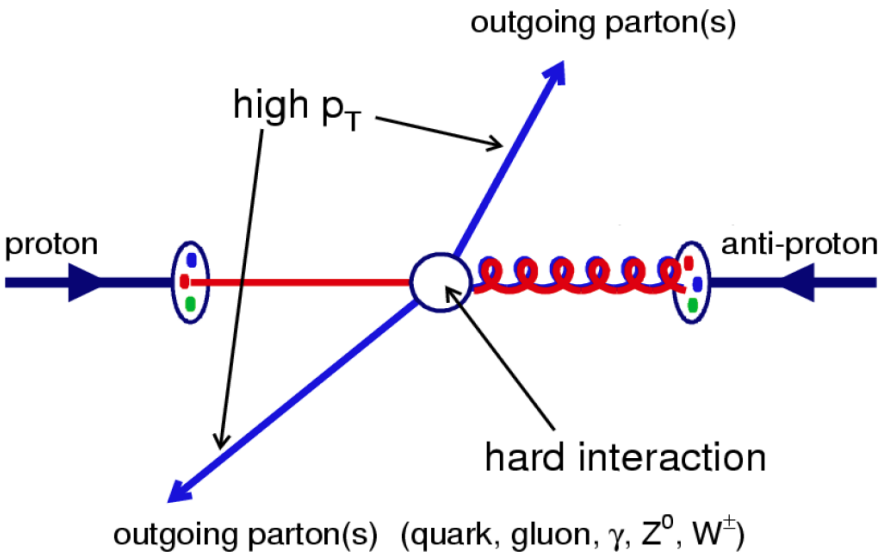
Outline

- Motivation
- Multiple parton interactions
- Estimation of Double Parton event fraction
- σ_{eff} measurement
- Conclusion



Structure of a hadron-hadron collision



Hard $2 \rightarrow 2$ scattering

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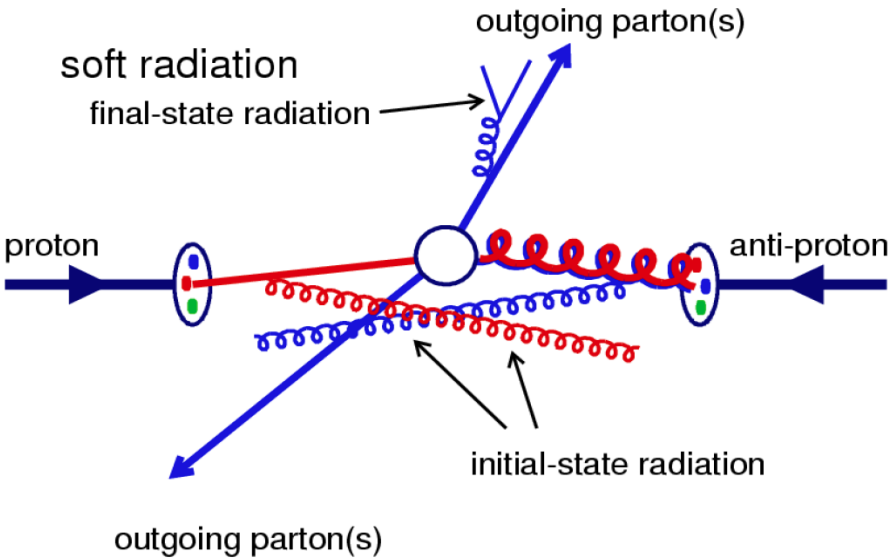
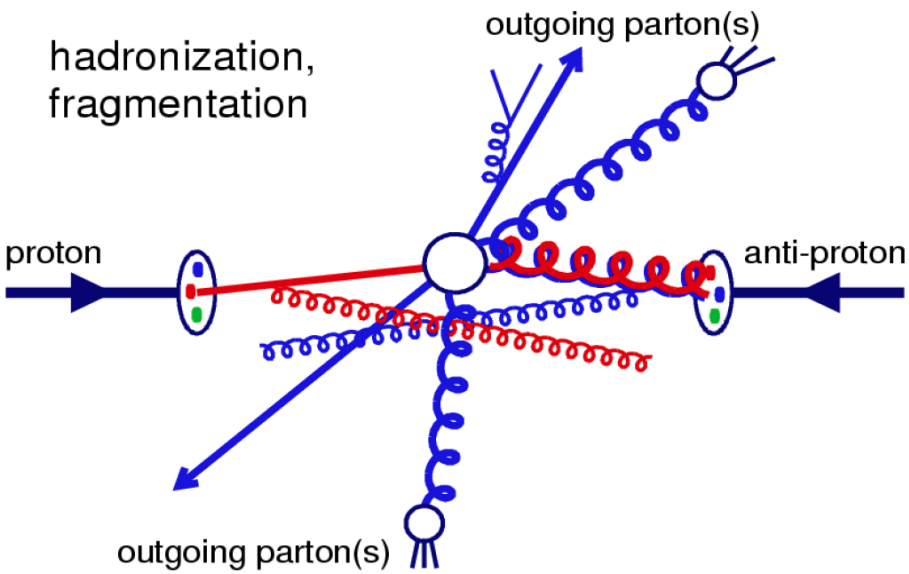


Hard $2 \rightarrow 2$ scattering

+ Gluon radiation in initial and final states

Structure of a hadron-hadron collision

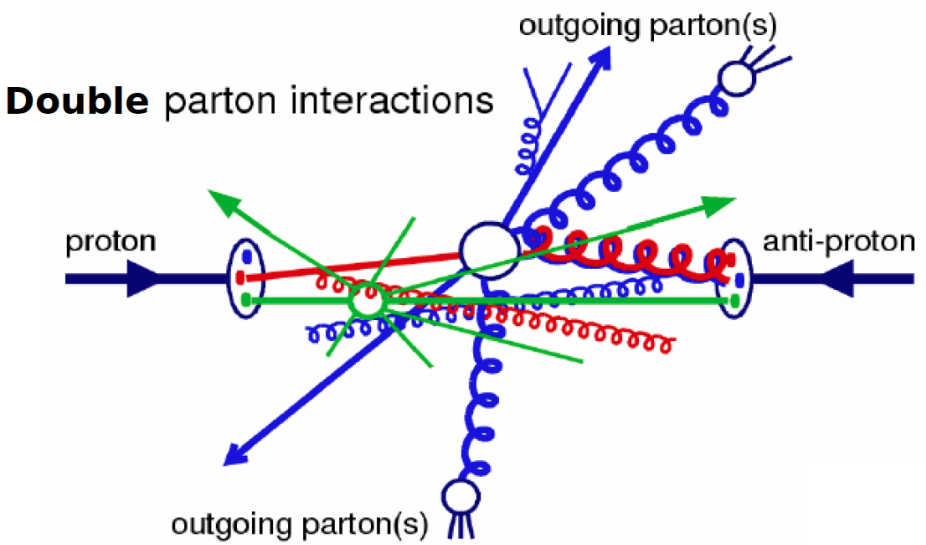


Hard $2 \rightarrow 2$ scattering

+ Gluon radiation in initial and final states

+ Hadronization, fragmentation

Structure of a hadron-hadron collision



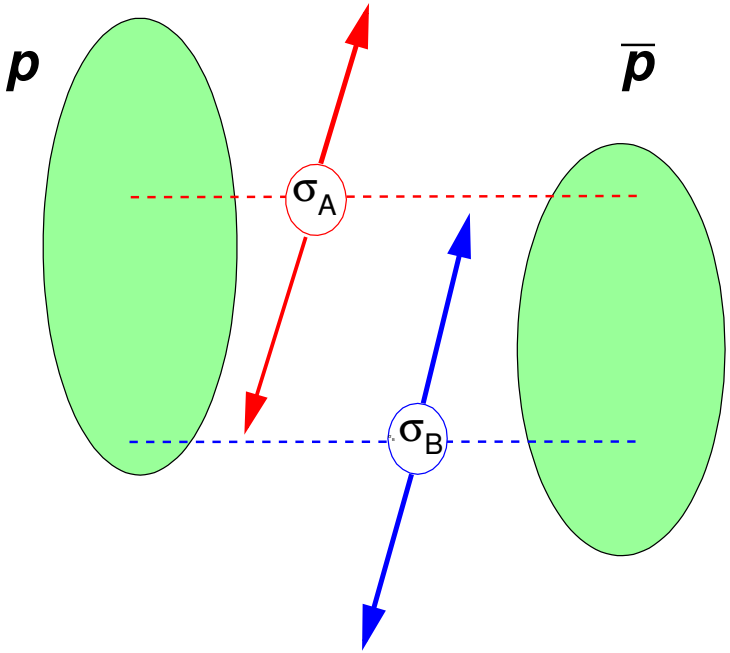
Hard $2 \rightarrow 2$ scattering

+ Gluon radiation in initial and final states

+ Hadronization, fragmentation

+ Additional parton-parton scattering

Double parton-parton interaction

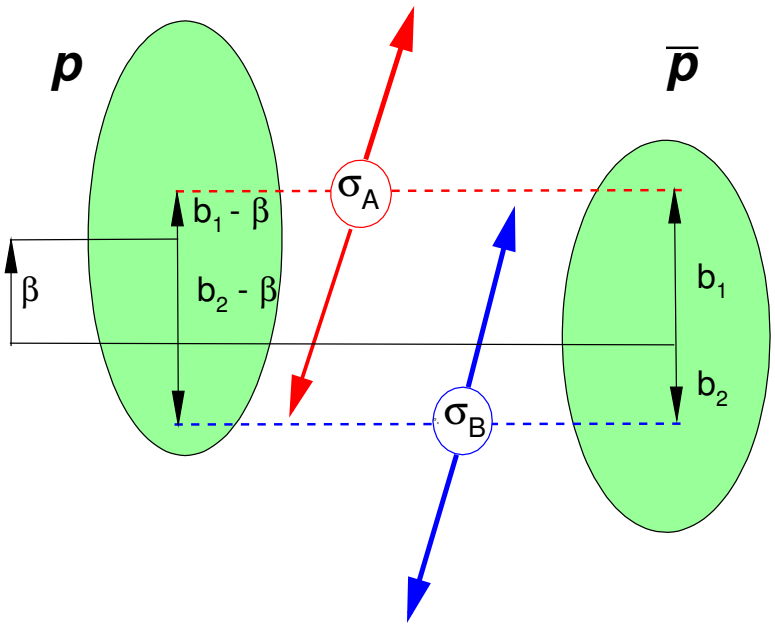


Double parton-parton cross section:

$$\sigma_{DP} = \frac{\sigma_A \sigma_B}{\sigma_{eff}} \quad (1)$$

Effective cross section σ_{eff} – a parameter which characterizes size of the effective interaction region of partons in a proton $\rightarrow$ contains information about spatial distribution of partons within a hadron.

Effective cross section



Effective cross section is directly related to the parton density within a hadron:

$$\sigma_{eff} = \left[\int d^2\beta [F(\beta)]^2 \right]^{-1} \quad (2)$$

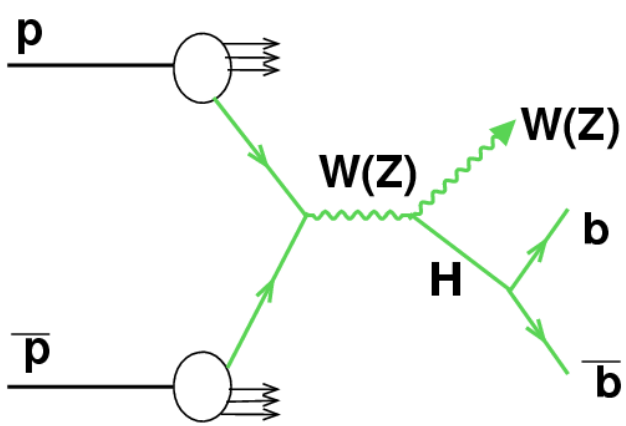
$$F(\beta) = \int d^2\beta f(b) f(b-\beta), \quad (3)$$

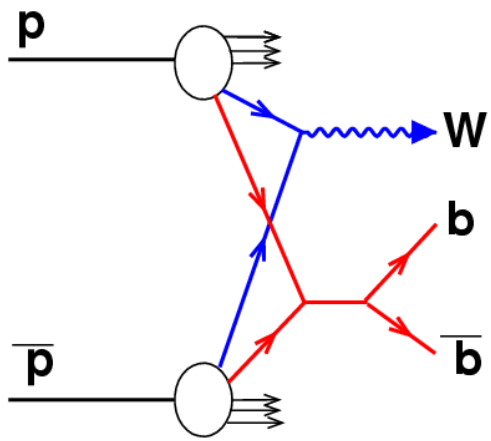
where β – impact parameter,
$f(b)$ – parton density function.

Being phenomenological, σ_{eff} strongly needs experimental input in order to estimate $f(b)$.

Motivations

- Distinctive feature: interaction of two parton-parton pairs within the same $p\bar{p}$ collision.
- The rate of multiparton interactions in $p\bar{p}$ collisions is directly related to the transverse spatial distribution of partons within the proton.
- Proper estimation of the background to rare processes especially with multi-jet final state.

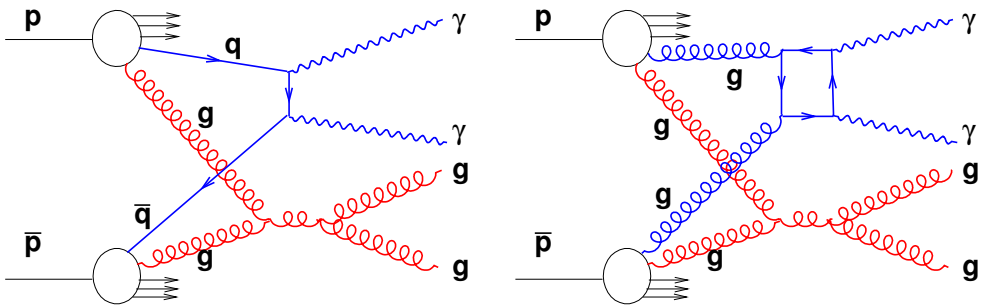


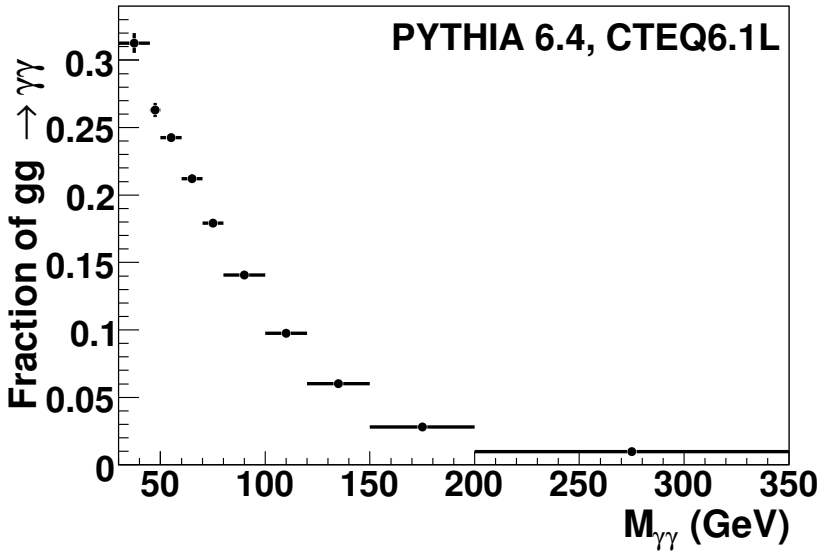


Diphoton production at the Tevatron

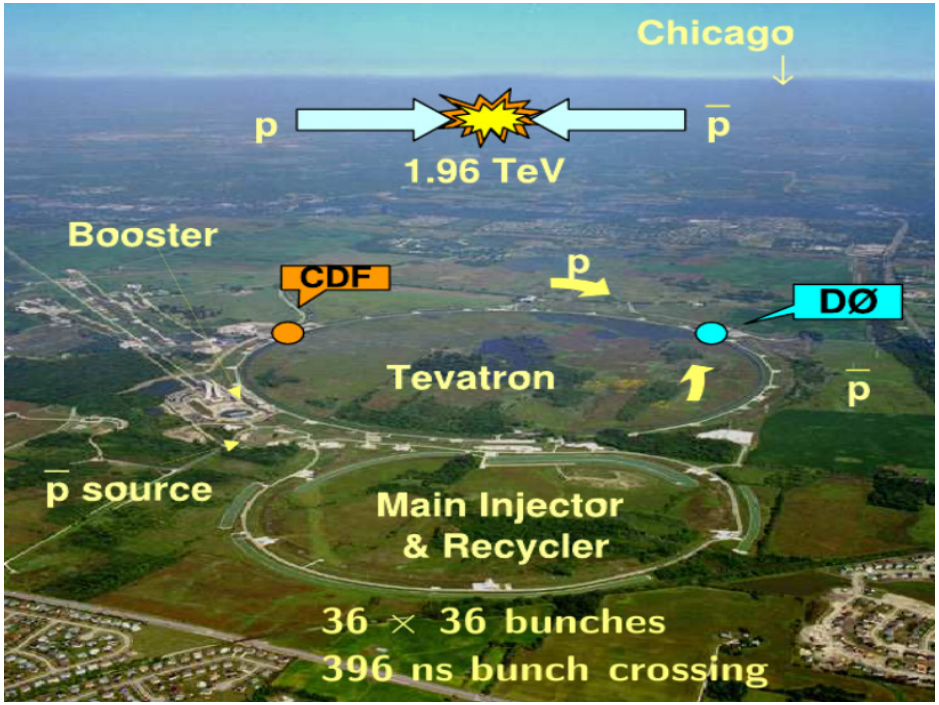
Main contribution to diphoton production at the Tevatron:

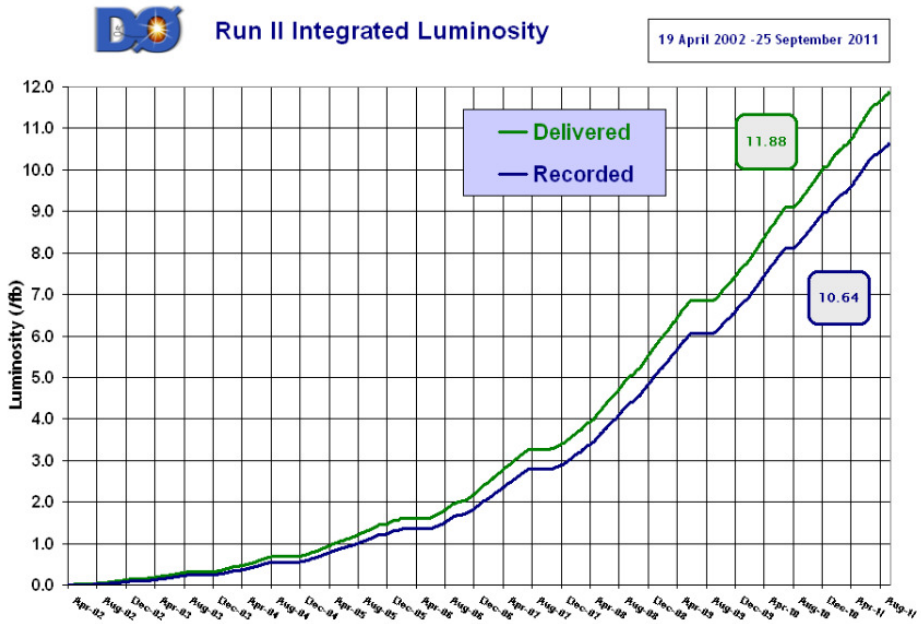
- $q\bar{q} \to \gamma\gamma$ (Born process)
- $gg \to \gamma\gamma$ (Box process)
- Additional LO processes with double patron-to-photon fragmentation are mostly suppressed by photon isolation requirements.
- The Born scattering significantly dominates over box process, with its fraction of 70-80%.





DØ @ Tevatron





- A decade of successful running;
- $\sim 12\ \mathrm{fb}^{-1}$ delivered with DØ data-taking efficiency >90%;
- Current analysis is based on $8.7\ \mathrm{fb}^{-1}$.

Signal and background event types

Background: Single Parton event

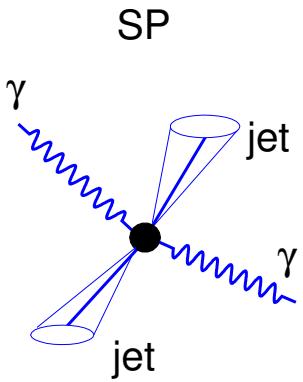
Single $2 \to 4$ scattering with two bremsstrahlung jets in event with 1 $p\bar{p}$ collision.

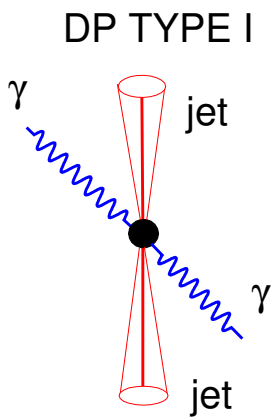
Signal: Double Parton event

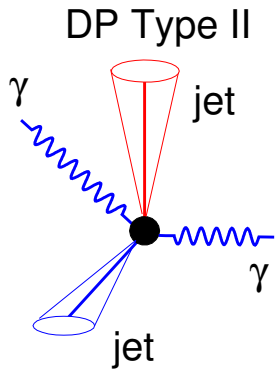
Two $2 \to 2$ scatterings:

I 1st scattering produces $\gamma\gamma$ pair, 2nd scattering - dijet;

II $\gamma\gamma + 1$ bremsstrahlung jet from 1st scattering plus one observed jet from 2nd scattering.



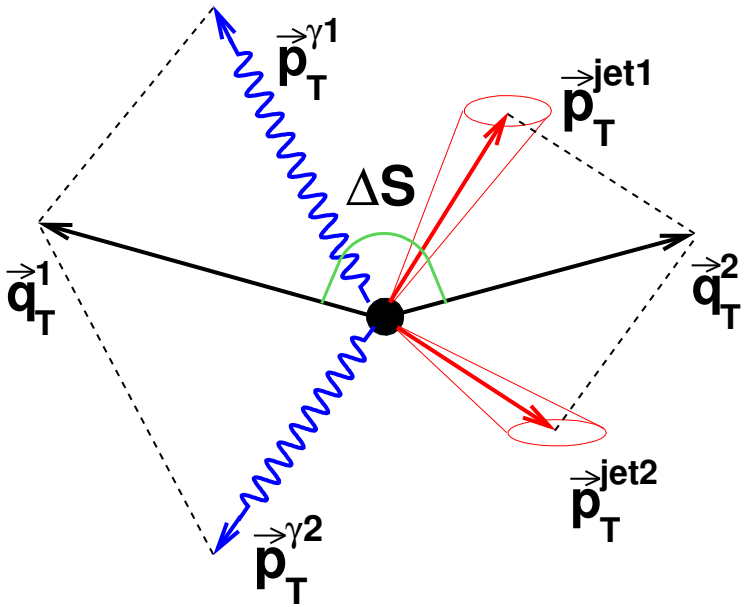




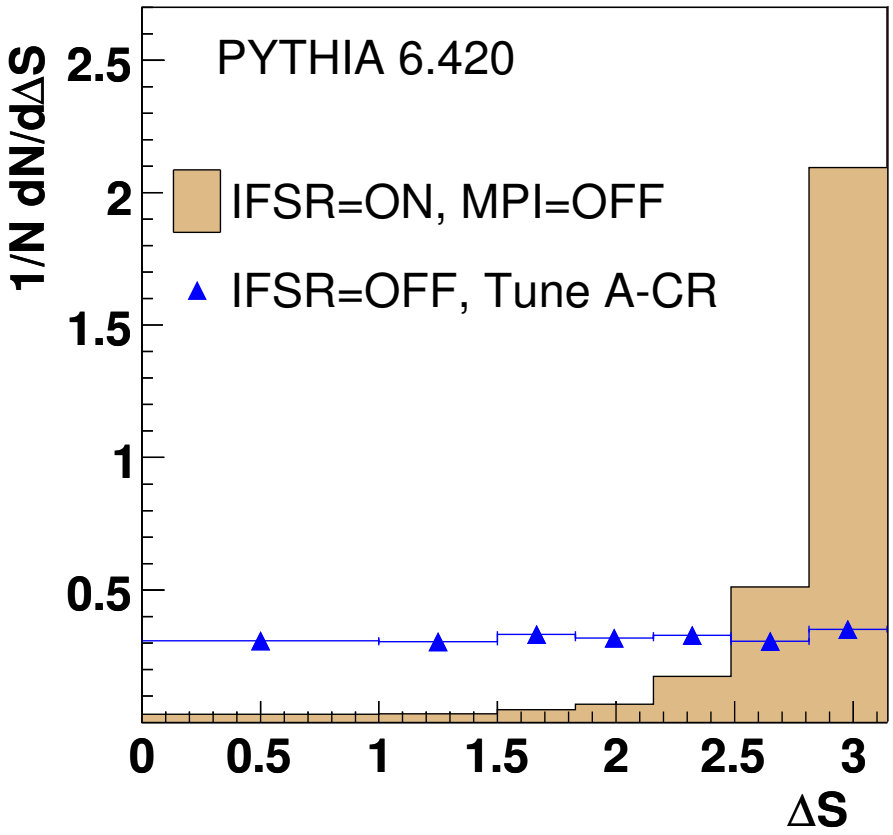
Discriminating variable

$$\Delta S = \Delta\phi(\vec{q}^{\,1}_T, \vec{q}^{\,2}_T),$$

an azimuthal angle between imbalance vectors of diphoton ($\vec{q}^{\,1}_T$) and dijet ($\vec{q}^{\,2}_T$) pairs.



DP Type I



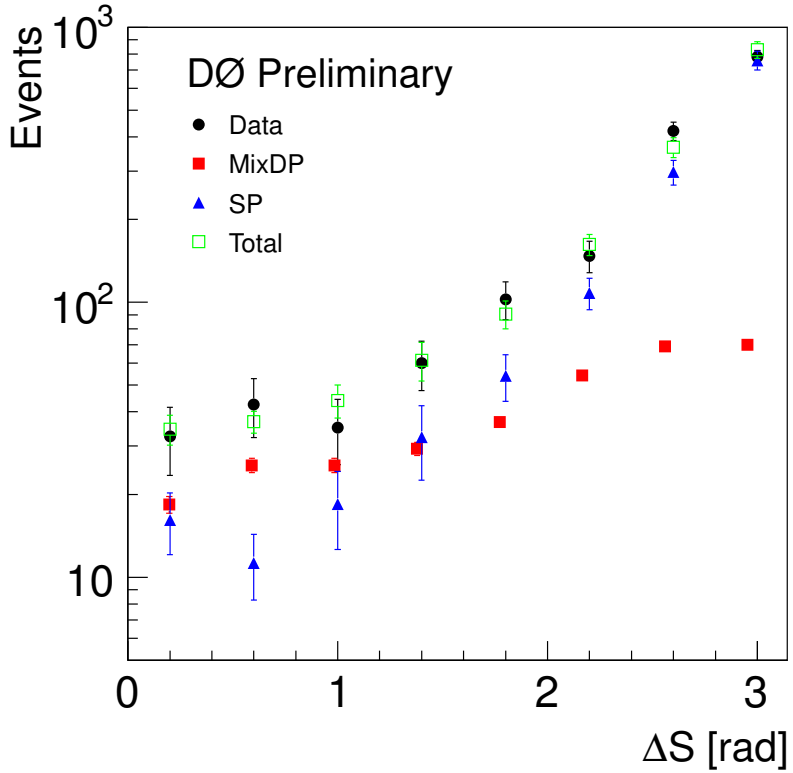
Double parton event fraction

- DP event fraction is found by calculating the efficiency to pass specific ΔS cut in data, signal (MIXDP) and background (SHERPA) event models:

$$f_{DP} = \frac{\epsilon_{DATA} - \epsilon_{SP}}{\epsilon_{DATA} - \epsilon_{DP}} \quad (4)$$

$$f_{DP} = 0.191 \pm 0.008 \quad (5)$$

- As a cross check, DP event fraction is found by fitting ΔS shapes in Single Parton and Double Parton event models to data.

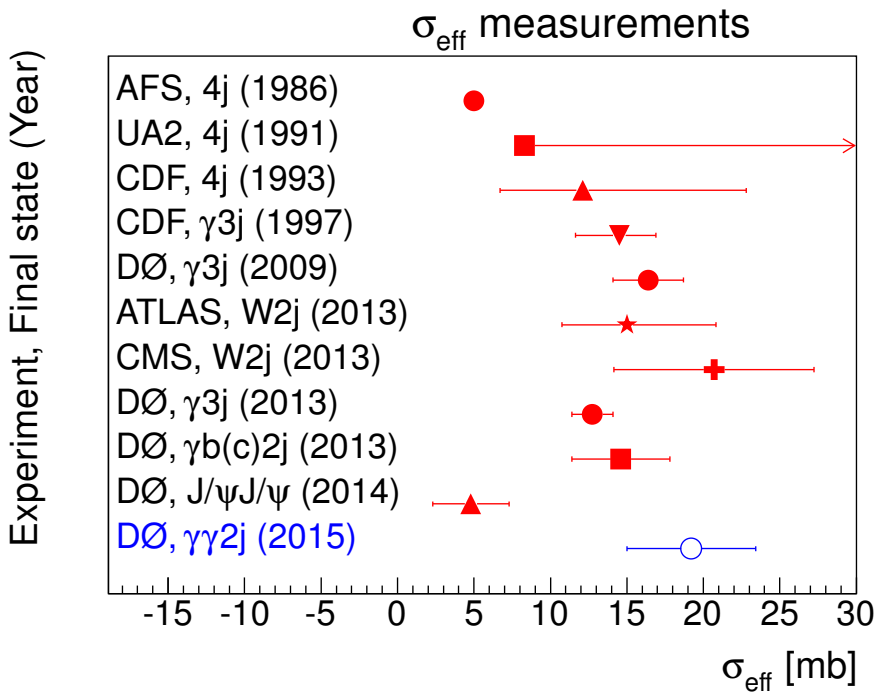


$$f_{DP}^{fit} = 0.195 \pm 0.067 \quad (6)$$

Both results are consistent.

Effective cross section

- Having measured number of DP events and corresponding acceptances and efficiencies one can calculate σ_{eff}.
- Measured σ_{eff} is in agreement with most Tevatron and LHC measurements within uncertainties.



$$\sigma_{eff} = 19.3 \pm 1.4(stat) \pm 7.8(syst) mb \quad (7)$$

Conclusion

- Kinematic features of Double Parton events have been studied using $\gamma\gamma$ + dijet final state for the first time;
- The fraction of DP events is found to be 0.191 ± 0.008;
- Effective cross section (defines rate of Double Parton events), σ_{eff}, has been measured using $\gamma\gamma$ + dijet final state and found to be $19.2 \pm 1.5(stat) \pm 4.1(syst)$ mb.
- The obtained σ_{eff} value is in agreement with most LHC and previous Tevatron measurements.

Thanks for your attention!