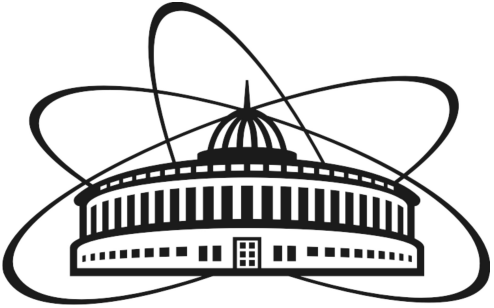


STUDY OF DOUBLE PARTON INTERACTIONS IN THE PROCESSES WITH PHOTON AND JETS IN THE FINAL STATE IN $p\bar{p}$ COLLISIONS AT DØ.

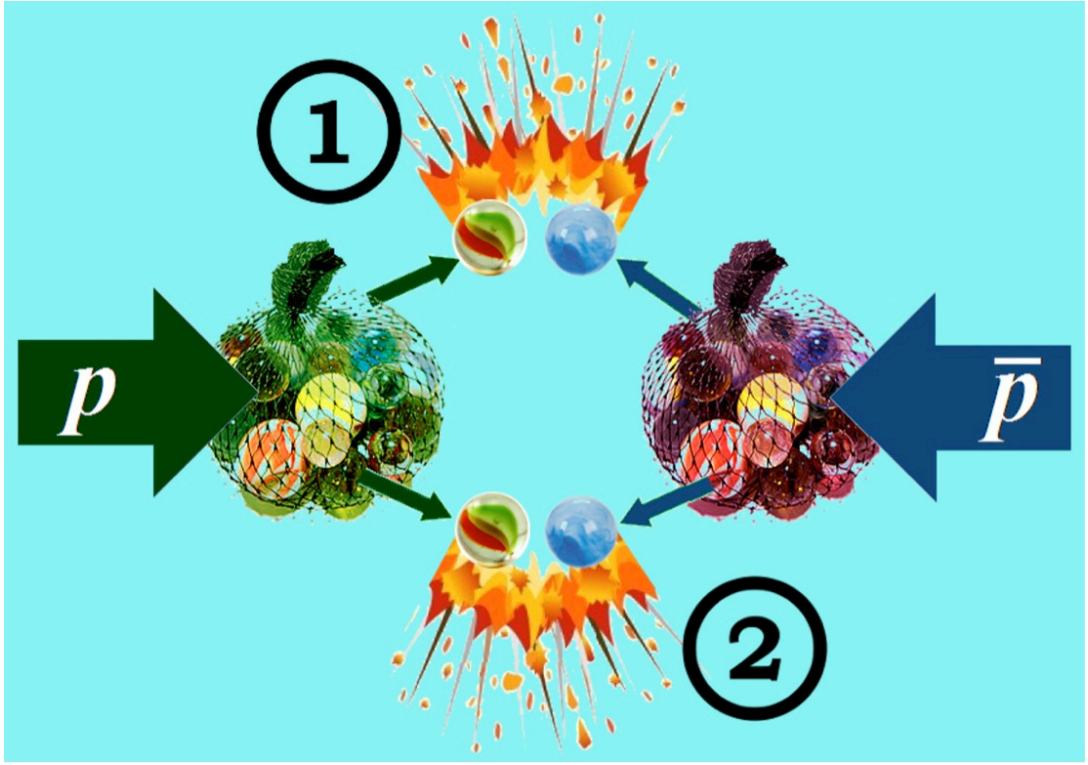
ALEXANDER VERKHEEV FOR DØ COLLABORATION

JINR, DUBNA

ISSP, 2015, Erice

OUTLINE

- Tevatron and D0 detector
- Motivation
- DP fraction
- Effective cross section
- Summary

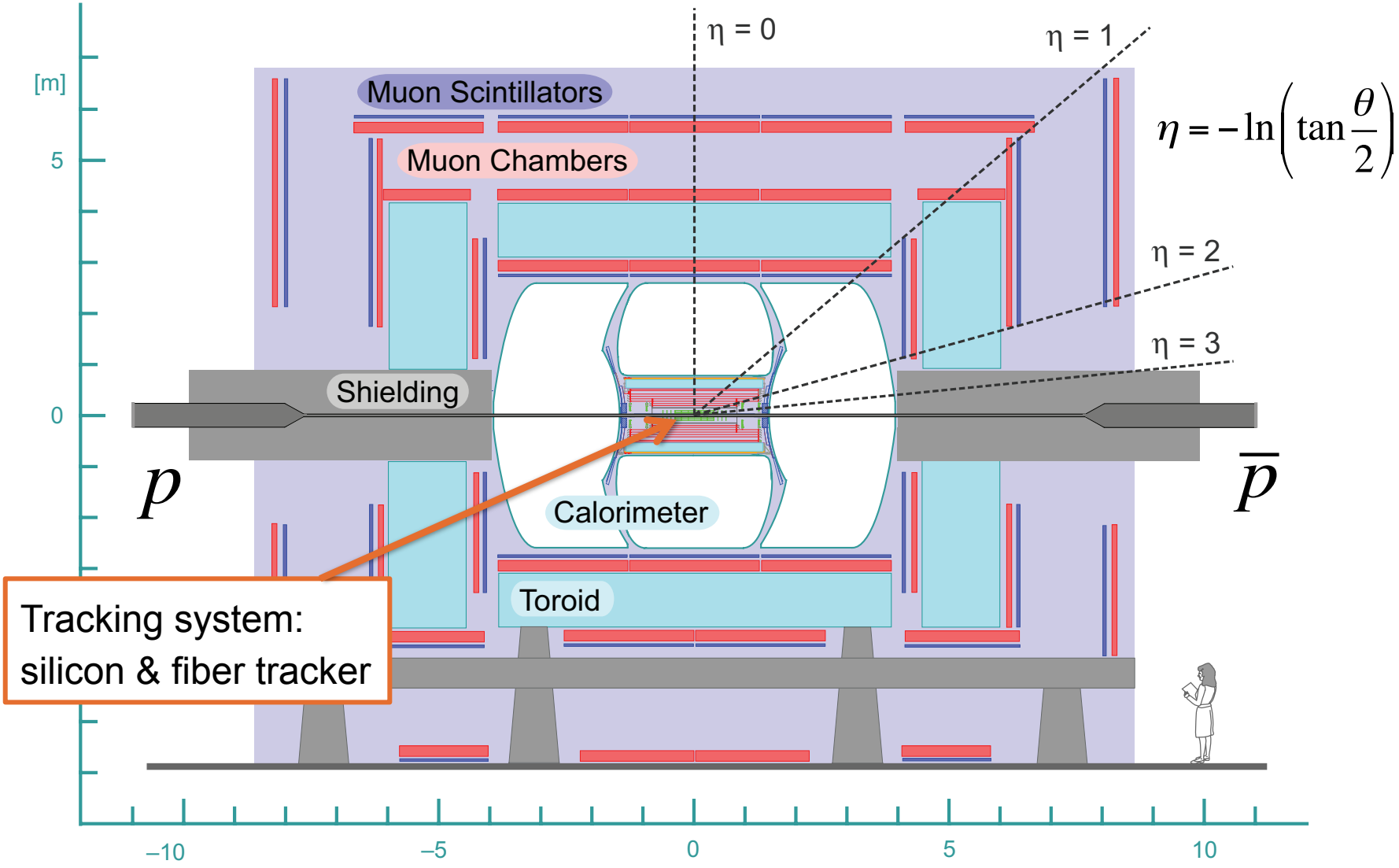


FNAL

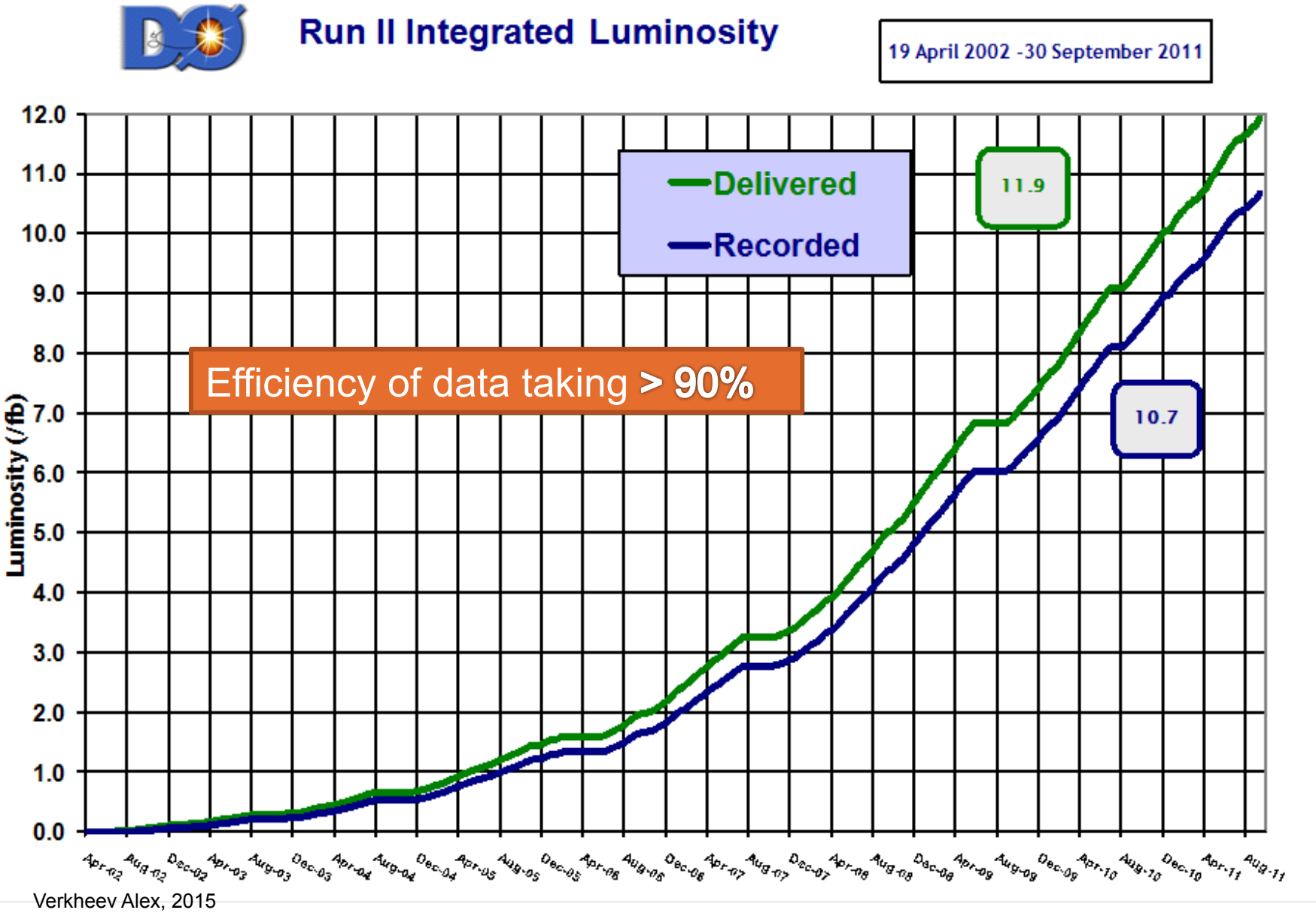

CDF
DØ
Booster
Tevatron
pbar source
Main Injector & Recycler

FNAL

DØ DETECTOR


η = 0
η = 1
η = 2
η = 3
$\eta = -\ln\left(\tan\frac{\theta}{2}\right)$
[m]
5
0
Muon Scintillators
Muon Chambers
Shielding
Calorimeter
Toroid
p
$\bar{p}$
Tracking system:
silicon & fiber tracker
–10
–5
0
5
10

LUMINOSITY


Run II Integrated Luminosity
19 April 2002 -30 September 2011
Delivered
Recorded
11.9
10.7
Efficiency of data taking > 90%
Luminosity (/fb)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Apr-02
Aug-02
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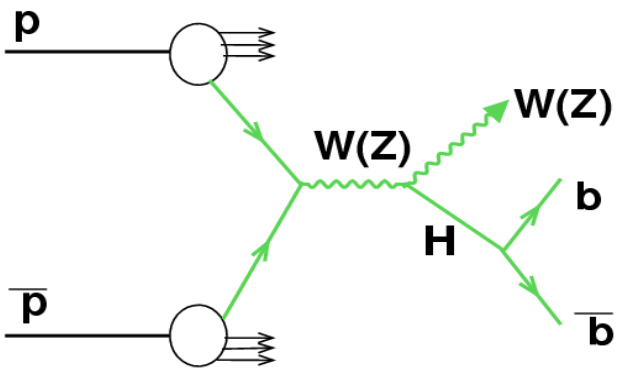
Dec-10
Apr-11
Aug-11

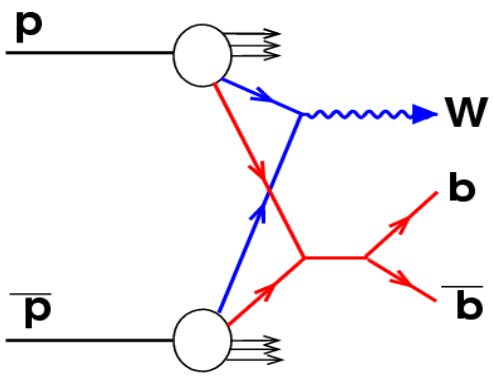
MOTIVATION

- Main purpose of the study is providing more information on properties of hard events with double parton interactions.
- The rate of multiparton interactions in pp^- collisions is directly related to the transverse spatial distribution of the partons within proton.
- Being phenomenological, hadron structure and parton -> hadron fragmentation models need experimental input, especially at high-pT regime.
- Info about DP events is needed for an understanding of nature of signal events and correct estimation of background to many rare processes.

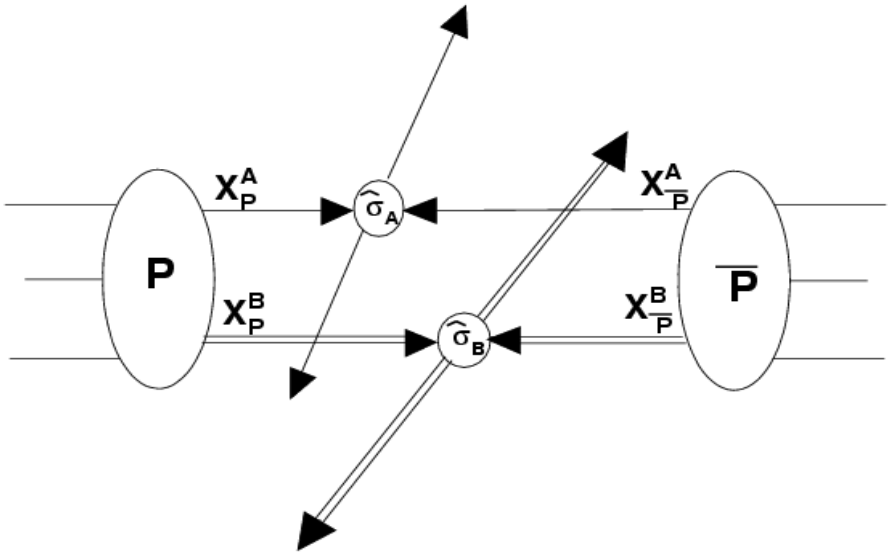
Higgs signal



DP background



EFFECTIVE CROSS SECTION



$$\sigma_{DP} = \frac{\sigma_A \sigma_B}{\sigma_{eff}}$$

σ_{DP} - double parton cross section for processes A and B

σ_{eff} -factor characterizing size of effective interaction region

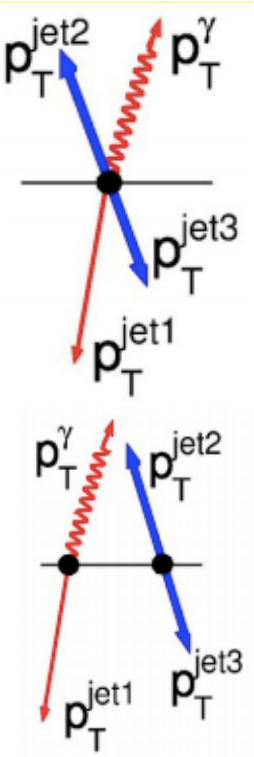
σ_{eff} contains information about the parton spatial density distribution:

Uniform parton distribution: σ_{eff} is large and σ_{DP} is small;

Clumpy parton distribution: σ_{eff} is small and σ_{DP} is large.

HISTORY OF MEASUREMENTS

Experiment	$\sqrt{s}$ (GeV)	Final state	p_T^{min} (GeV)	η range	σ_{eff}
AFS	63	4 jets	$p_T^{\text{jet}} > 4$	$\lvert\eta^{\text{jet}}\rvert < 1$	≈ 5
UA2	630	4 jets	$p_T^{\text{jet}} > 15$	$\lvert\eta^{\text{jet}}\rvert < 2$	> 8.3 (95% C.L.)
CDF	1800	4 jets	$p_T^{\text{jet}} > 25$	$\lvert\eta^{\text{jet}}\rvert < 3.5$	$12.1^{+10.7}_{-5.4}$
CDF	1800	$\gamma + 3$ jets	$p_T^{\text{jet}} > 6$	$\lvert\eta^{\text{jet}}\rvert < 3.5$	14.5 ± 1.7 (stat) $^{+1.7}_{-2.3}$ (syst)
			$p_T^{\gamma} > 16$	$\lvert\eta^{\gamma}\rvert < 0.9$	
DØ	1960	$\gamma + 3$ jets	$60 < p_T^{\gamma} < 80$	$\lvert\eta^{\gamma}\rvert < 1.0$	16.4 ± 0.3 (stat) ± 2.3 (syst)
			$p_T^{\text{jet}} > 15$	$1.5 < \lvert\eta^{\gamma}\rvert < 2.5$	
ATLAS	7000	$W + 2$ jets	$p_T^{\text{jet}} > 20$	$\lvert\eta^{\text{jet}}\rvert < 2.8$	15 ± 3 (stat) $^{+5}_{-3}$ (syst)
CMS	7000	$W + 2$ jets	$p_T^{\text{jet}} > 20$	$\lvert\eta^{\text{jet}}\rvert < 2.0$	20.7 ± 0.8 (stat) ± 6.6 (syst)



AFS'86, UA2'91 and CDF'93

choose 4-jets sample motivated by a large dijet cross section (but low DP fractions). Use theory predictions for the dijet cross sections.

CDF'97, D0'10

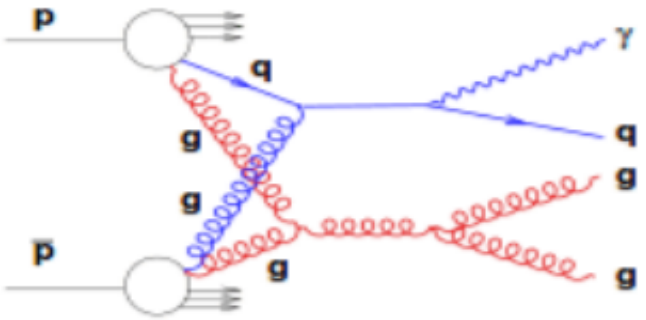
γ+3jets events, data-driven method: use rates of Double Interaction (two separate pp^- collisions) and Double Parton (single pp^- collision) to extract σ_{eff} from their ratio. Reduce dependence on MC and NLO QCD theory predictions.

A GOAL

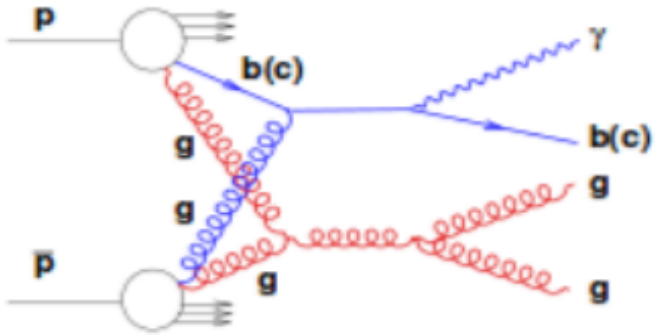
Is there a dependence on initial parton flavor?

For the first time → **Phys. Rev. D 89, 072006 (2014)**

Case 1: No leading jet flavor requirement (Inclusive sampe)



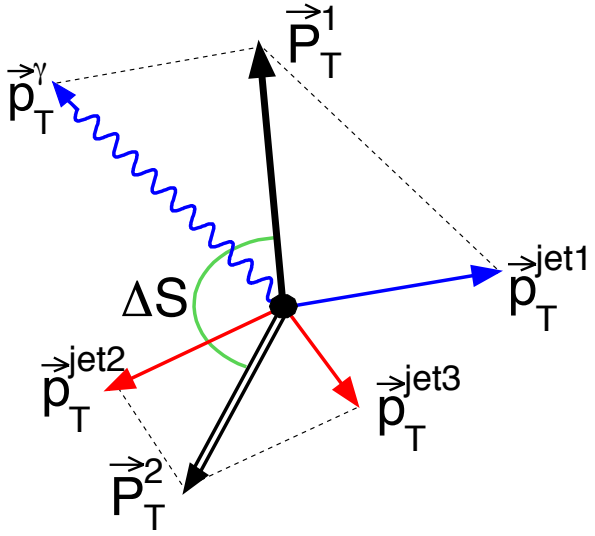
Case 2: Leading jet Heavy flavor requirement (HF sample)

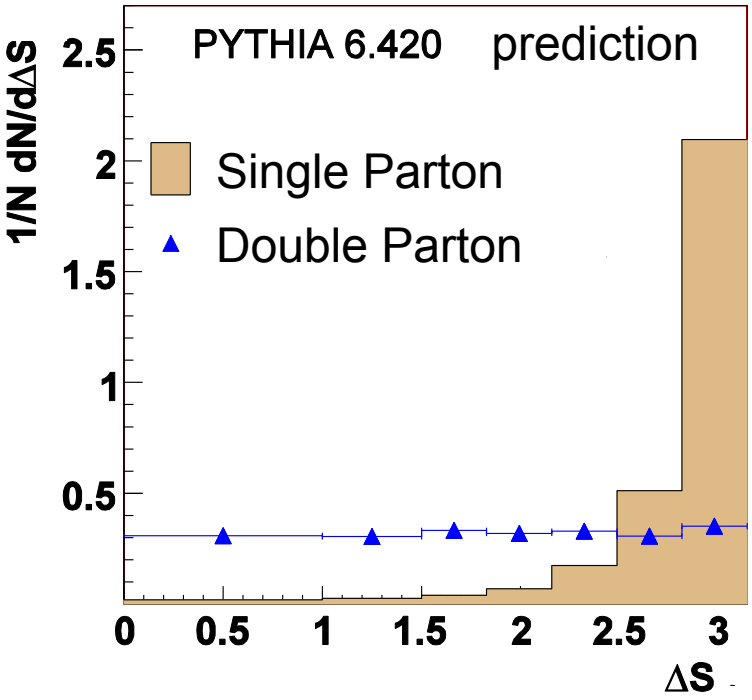


DISCRIMINATING VARIABLE

$$\Delta S = \Delta\varphi\left(P_T^1, P_T^2\right)$$

an azimuthal angle between two imbalance vectors.



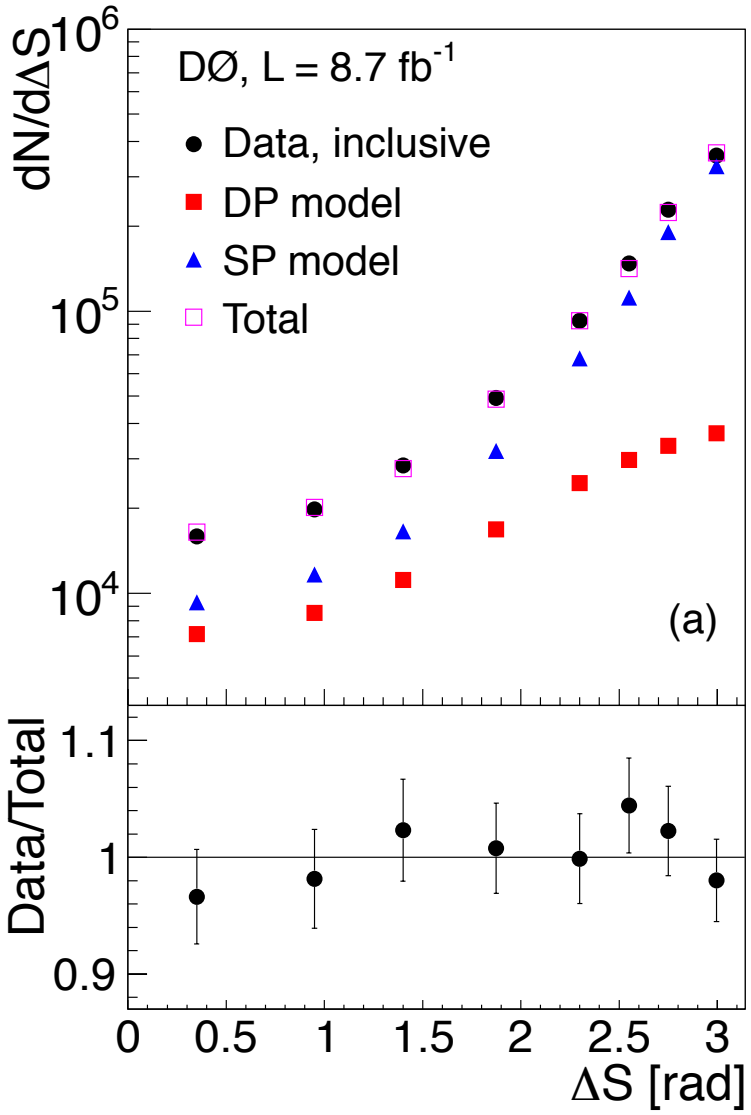


In Single Parton (SP) events ΔS is expected to peak at π due to the momenta conservation in an event,
while in Double Parton events it should be flat due to the independence of two parton interactions.

FRACTION OF DOUBLE PARTON EVENTS

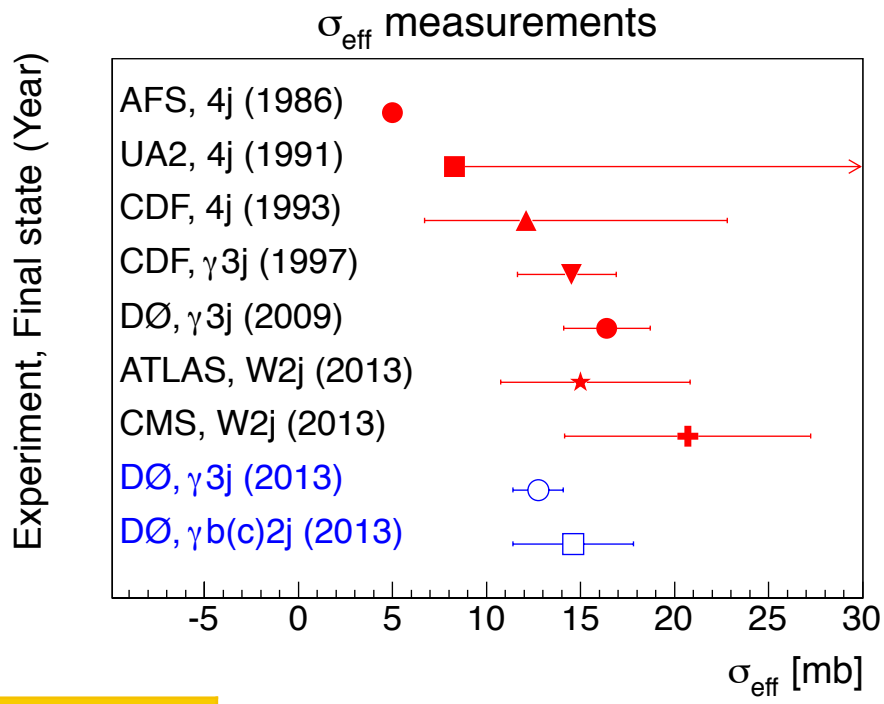
DP event fraction is found by fitting Single Parton event model and Double Parton signal event model to data.

γ + 3 jets	γ + HF + 2 jets
0.202 ± 0.007	0.171 ± 0.020



EFFECTIVE CROSS SECTION

- Having measured number of DP and DI events and corresponding acceptances and efficiencies one can calculate σ_{eff} for both final states.
- Measured σ_{eff} is in agreement with all Tevatron and LHC measurement.



σ_{eff} =

γ + 3 jets	γ + HF + 2 jets
12.7± 1.32	14.6 ± 3.26

For the first time it is shown that

There is NO dependence of σ_{eff} on the initial parton flavor.

SUMMARY

- Effective cross section (defines rate of Double Parton events) σ_{eff} has been measured using γ+3 jets final state and found to be 12.7 ± 0.2 (stat) ± 1.3 (syst) mb.
- Effective cross section has also been measured using γ+b/c+2jets final state and found to be 14.6 ± 0.6 (stat) ± 3.2 (syst) mb.
- No dependence of σ_{eff} on initial parton flavor has been found.
- The obtained σ_{eff} values are in agreement with those measured by CDF, DØ, ATLAS and CMS collaborations.
- More details in **Phys. Rev. D 89, 072006 (2014)**

GRAZIE PER L'ATTENZIONE

BACKUP

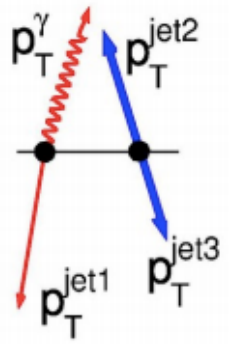
CALCULATION OF σ_{eff}

Two hard scattering events at two separate pp^- collisions (Double Interaction)

$$P_{DI} = 2\left(\frac{\sigma^{\gamma j}}{\sigma_{hard}}\right)\left(\frac{\sigma^{jj}}{\sigma_{hard}}\right)$$

The number of DI events:

$$N_{DI} = 2\frac{\sigma^{\gamma j}}{\sigma_{hard}}\frac{\sigma^{jj}}{\sigma_{hard}}N_c(2)A_{DI}\varepsilon_{DI}\varepsilon_{2vtx}$$

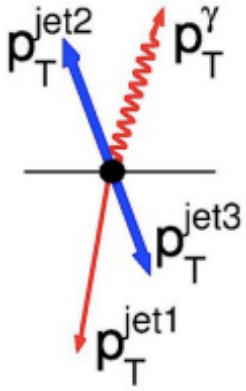


Two hard interactions at on pp^- collision (Double parton scattering)

$$P_{DP} = \left(\frac{\sigma^{\gamma j}}{\sigma_{hard}}\right)\left(\frac{\sigma^{jj}}{\sigma_{eff}}\right)$$

The number of DP events:

$$N_{DP} = \frac{\sigma^{\gamma j}}{\sigma_{hard}}\frac{\sigma^{jj}}{\sigma_{eff}}N_c(1)A_{DP}\varepsilon_{DP}\varepsilon_{1vtx}$$



Data-driven method:

$$\sigma_{eff} = \frac{N_{DI}}{N_{DP}}\frac{N_c(1)}{N_c(2)}\frac{A_{DP}}{A_{DI}}\frac{\varepsilon_{DP}}{\varepsilon_{DI}}\frac{\varepsilon_{1vtx}}{\varepsilon_{2vtx}}\sigma_{hard}$$