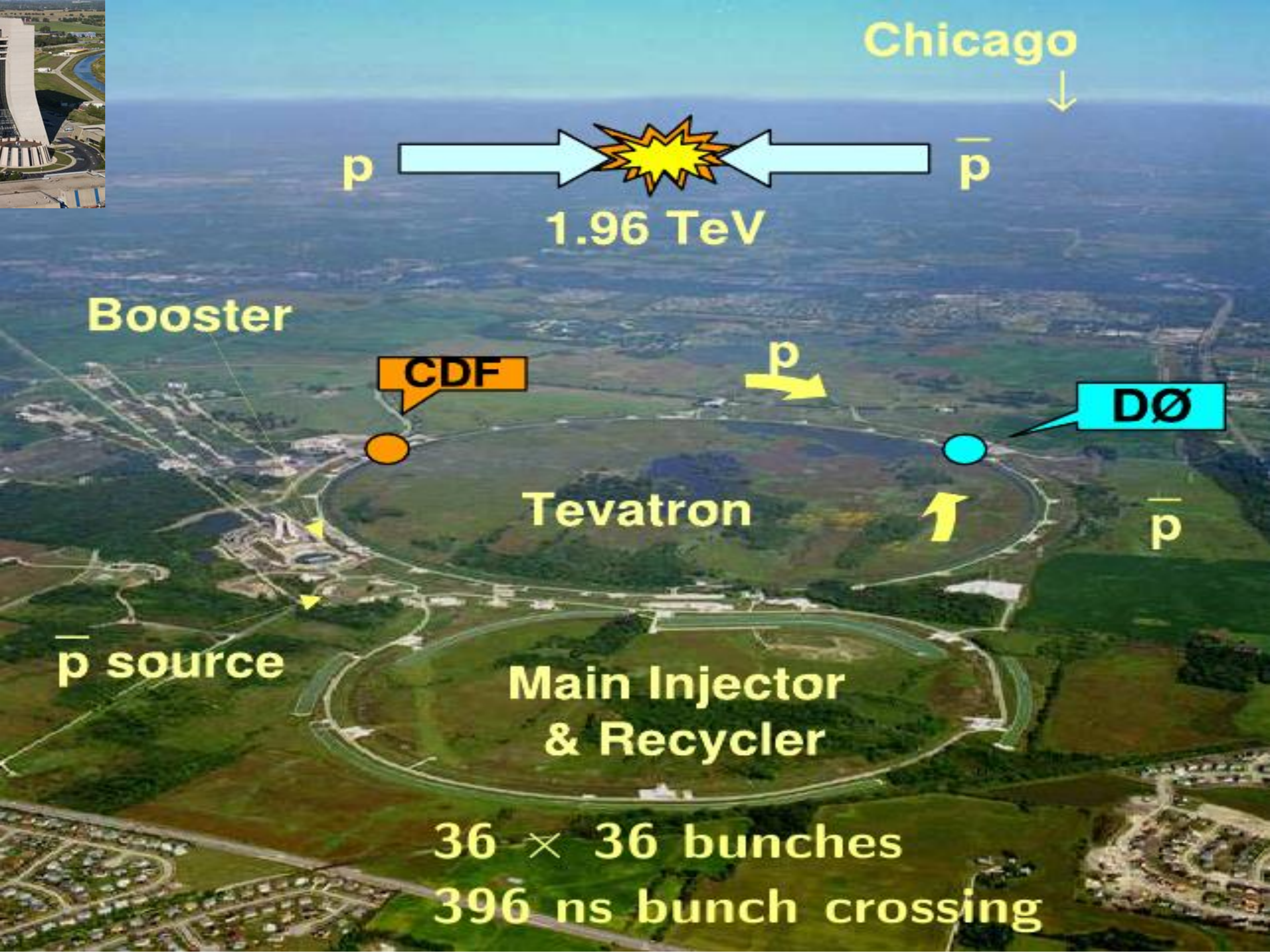
QCD at the Tevatron: RunII

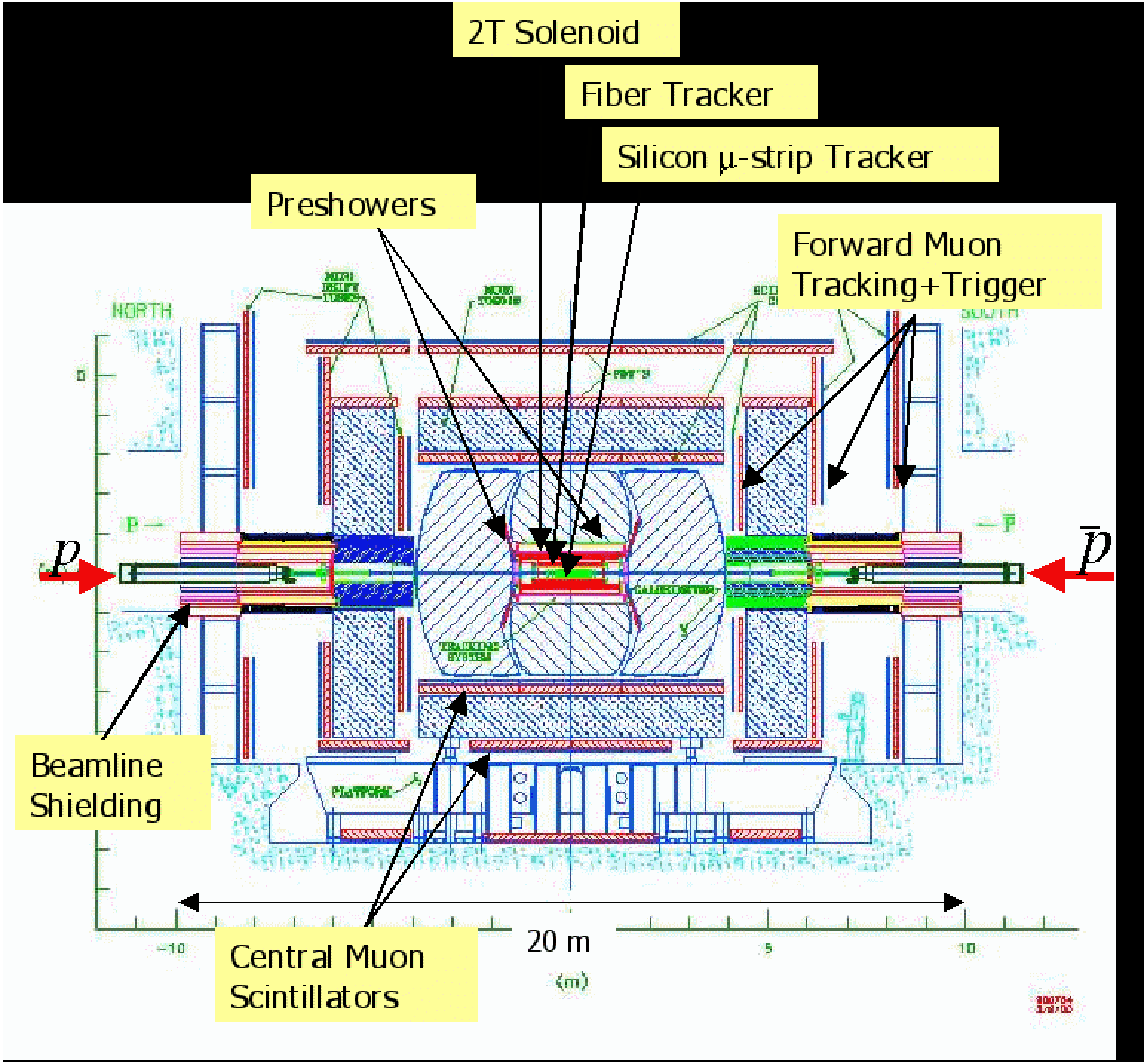
N.B. Skachkov (JINR, Dubna, on behalf of the D0 Collaboration)

Results of primary authors: N.Skachkov, G.Golovanov, A.Verkheev (JINR) D.Bandurin (FNAL)

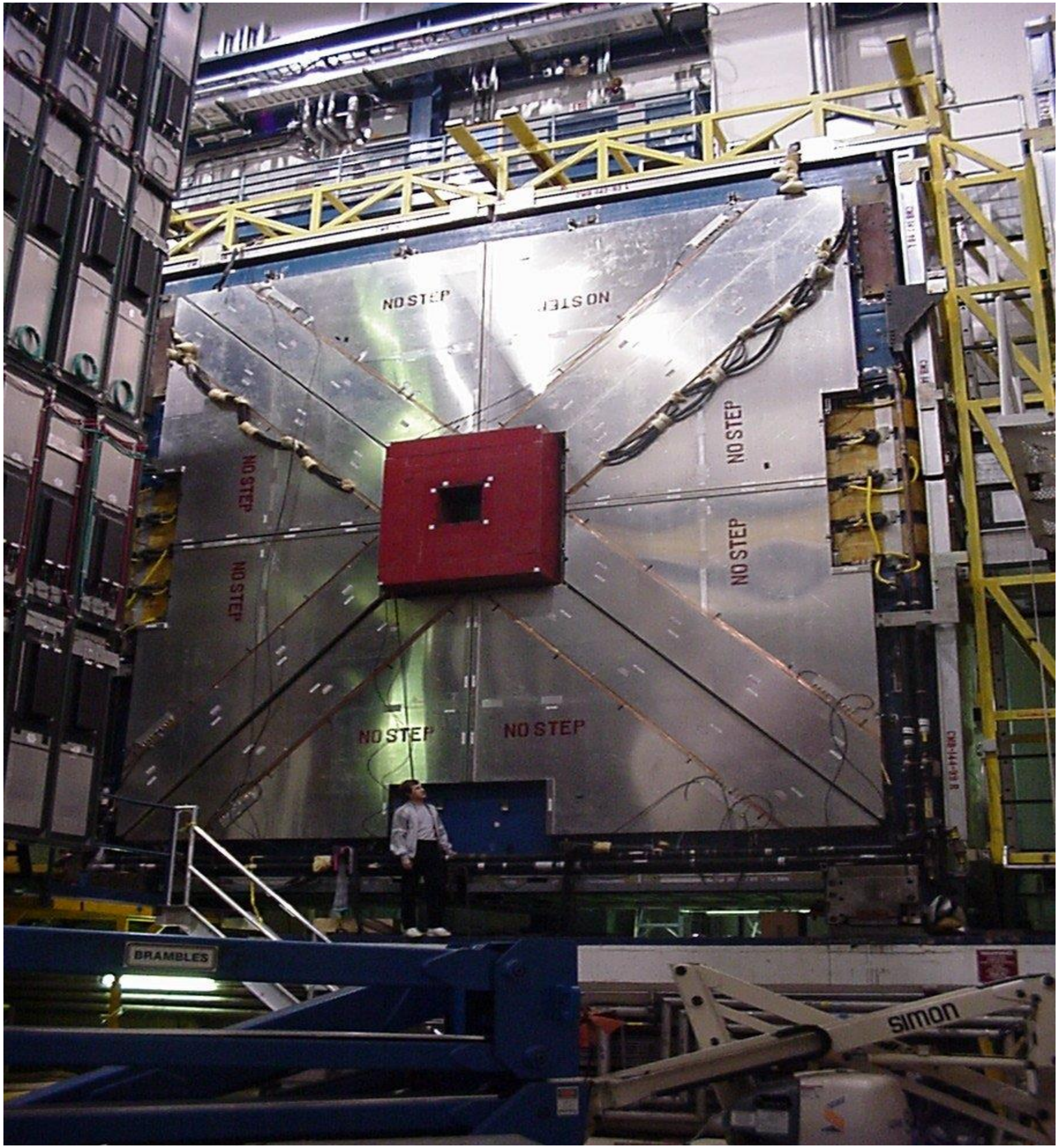
Physics:

1. Direct photon production and QCD problems,
2. Multiple parton interactions in p-pbar (and other) collisions.
3. Multiple parton interactions & background.


Chicago
p
$\bar{p}$
1.96 TeV
Booster
CDF
p
DØ
Tevatron
$\bar{p}$
$\bar{p}$ source
Main Injector
& Recycler
36 × 36 bunches
396 ns bunch crossing



2T Solenoid
Fiber Tracker
Silicon μ-strip Tracker
Preshowers
Forward Muon
Tracking+Trigger
NORTH
p
p̄
Beamline
Shielding
Central Muon
Scintillators
20 m
-10
5
10
(m)



NO STEP
NO STEP
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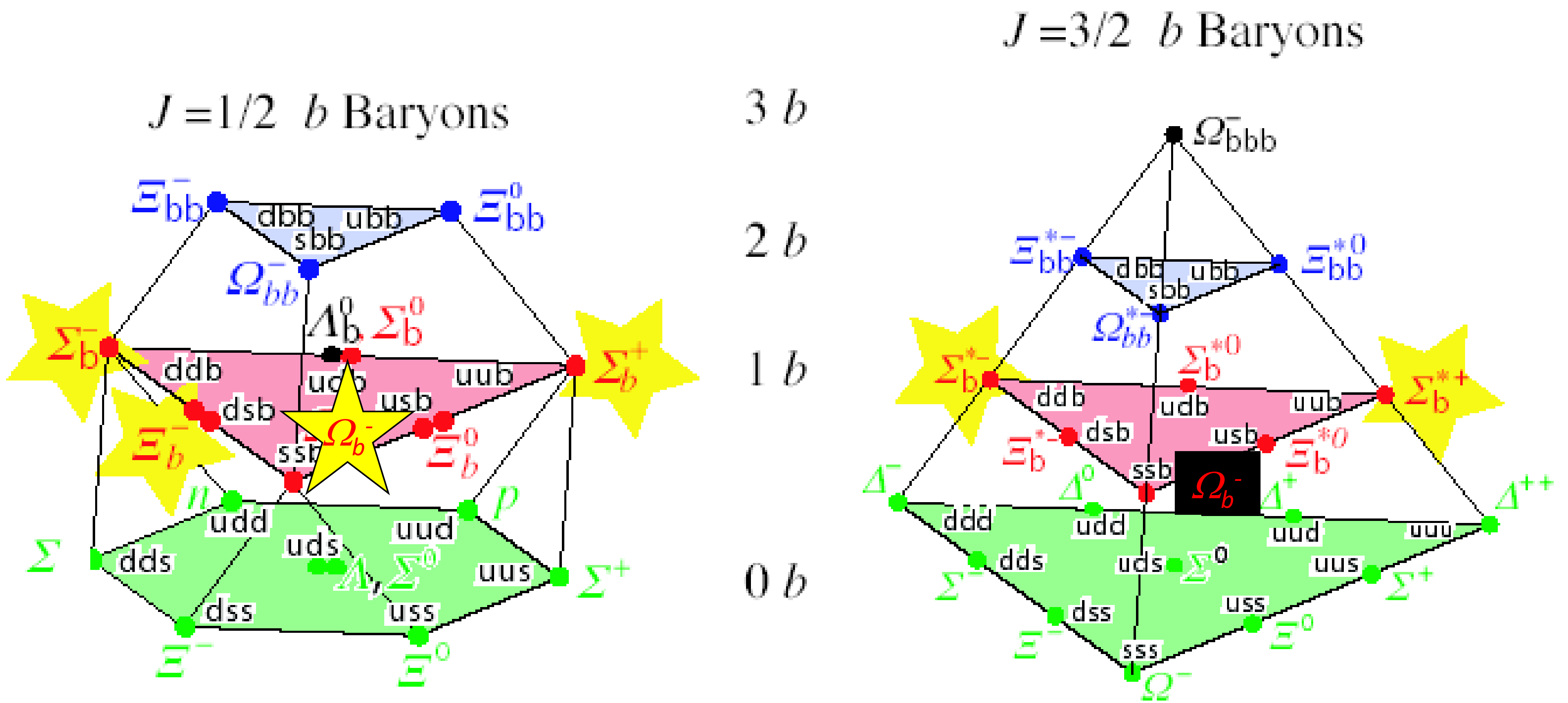
BRAMBLES
SIMON

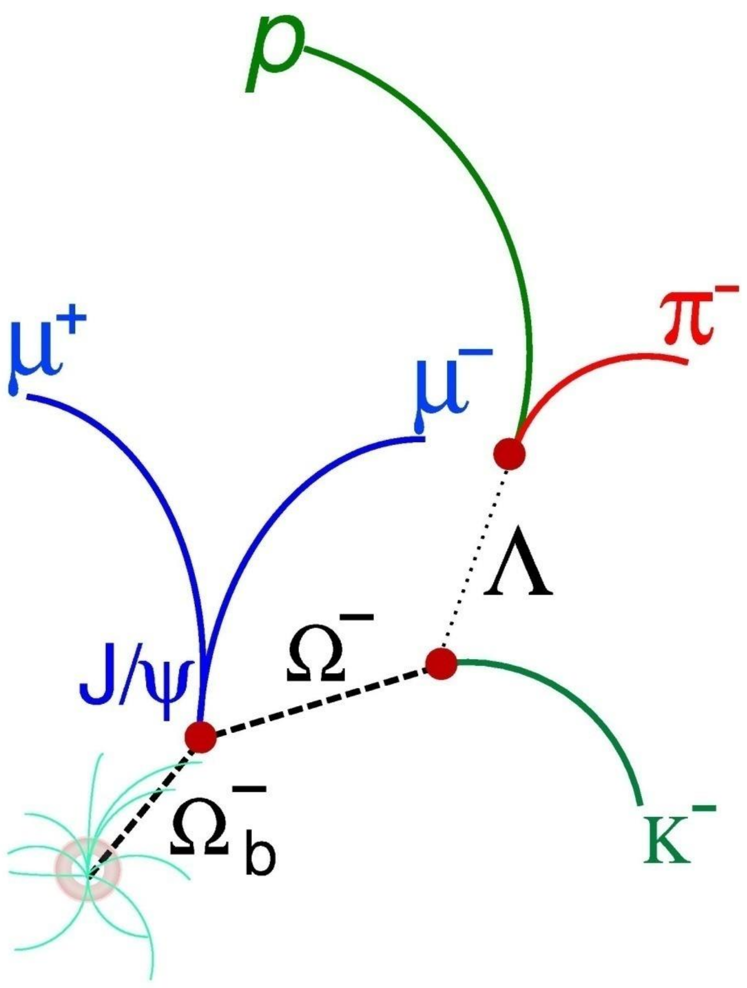
b Baryons

- B spectroscopy measurements provide sensitive tests of potential models, heavy quark effective theory (HQET), and lattice gauge theory



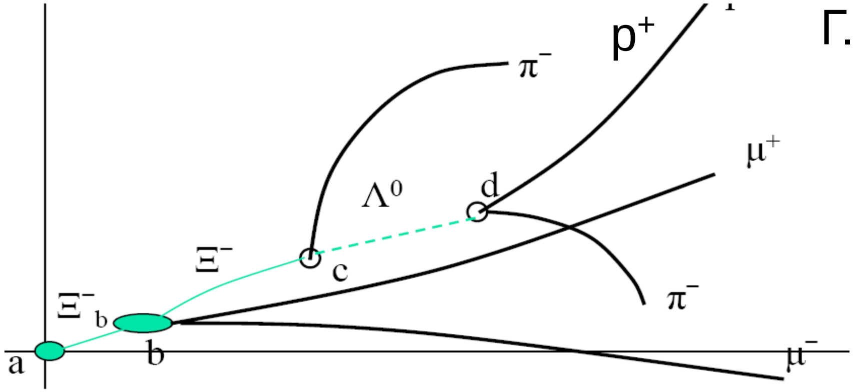
Ω_b^- (ssb) Baryon Observation

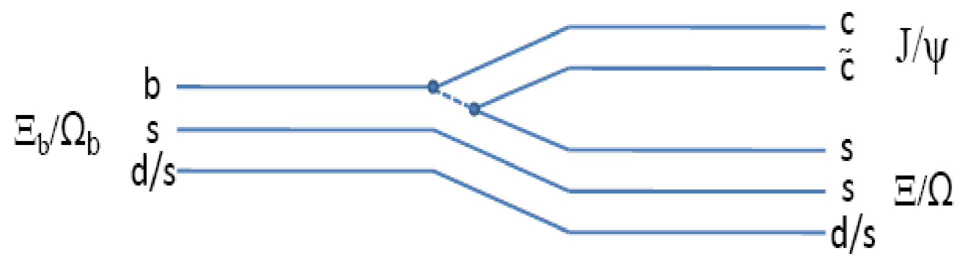
- Use $J/\psi \rightarrow \mu^+\mu^-$ sample
- Need to reconstruct three decay vertices
- DØ uses BDT selection, unbinned likelihood mass fit and $\Xi_b^- \rightarrow J/\psi\ \Xi^-$ decays for many cross-checks
- CDF uses a cut-based selection with $B^0 \rightarrow J/\psi K^{*0}$ and $B^0 \rightarrow J/\psi K_s^0$ decays for cross-checks

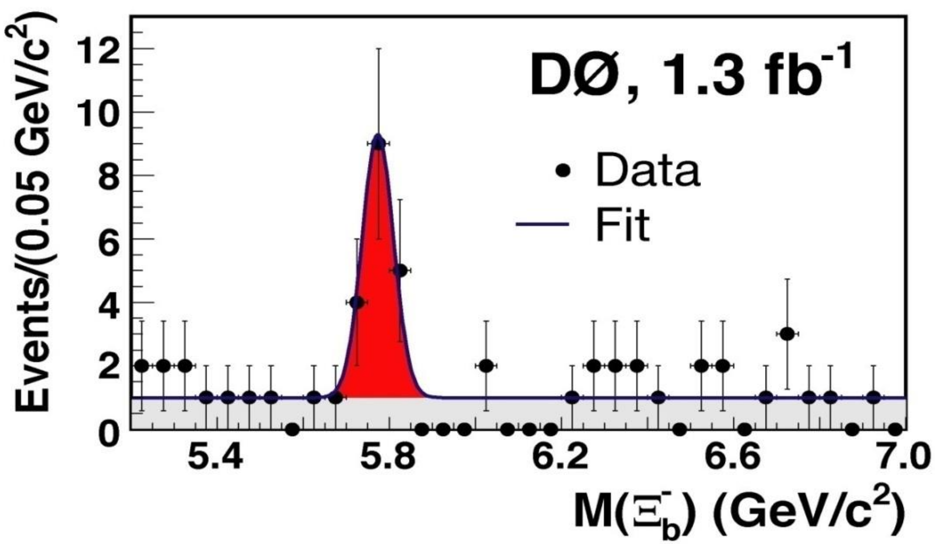


Основные результаты группы ОИЯИ по b-физике: обнаружение Ξ_b и Ω_b барионов

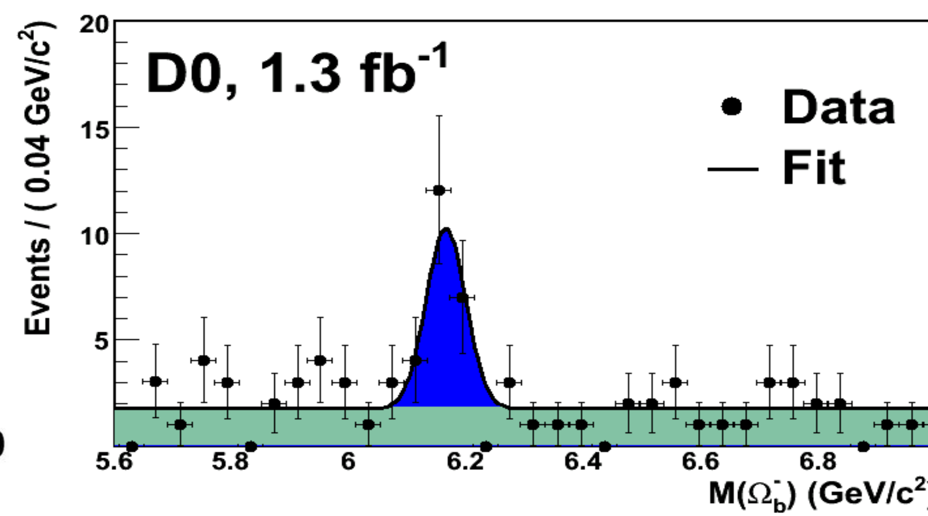
Г.Алексеев, Л.Вертоградов, Ю.Вертоградова, Ю.Мереков, Г.Панов, А.Рождественский





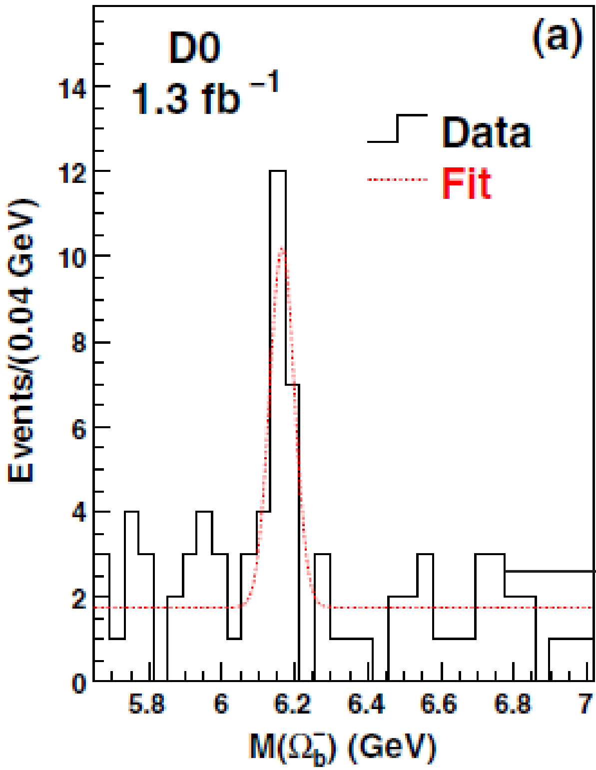


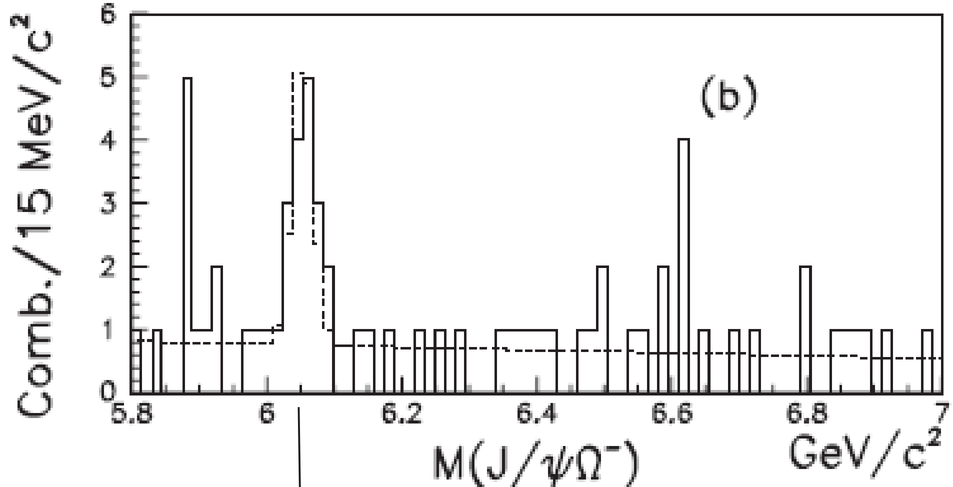
V.M.Abazov et al., Direct Observation of the Strange b Baryon Ξ_b^-
Phys. Rev. Lett. 99 (2007); citation: 132



V.M.Abazov et al., Observation of the Doubly Strange b Baryon Ω_b^-
Phys. Rev. Lett. 101 (2008); citation: 90

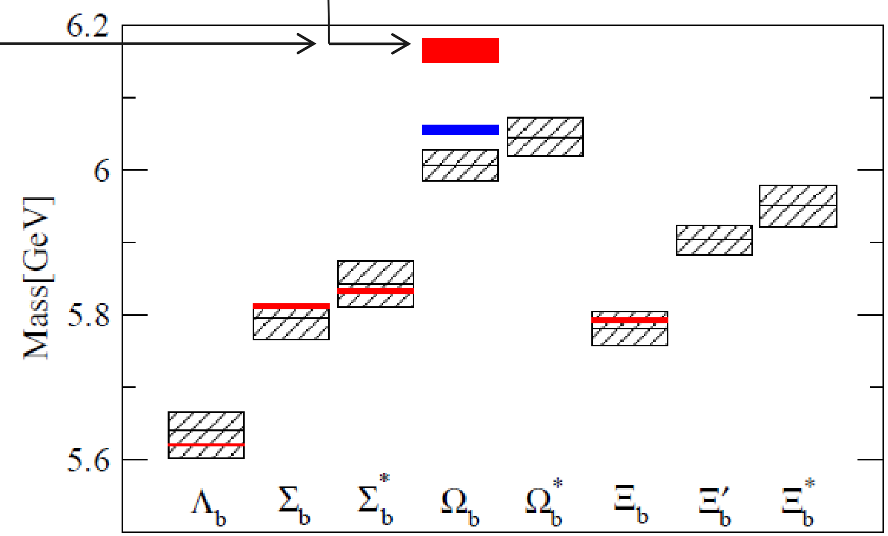
Ω_b^- (ssb) Baryon Observation





M(Ω_b^-)=6054.4±6.8(stat)±0.9(syst) MeV/c^2
PRD **80,** 072003 (2009)

M(Ω_b^-)=6165±10(stat)±13(syst) MeV/c^2
PRL **101**, 232002 (2008)

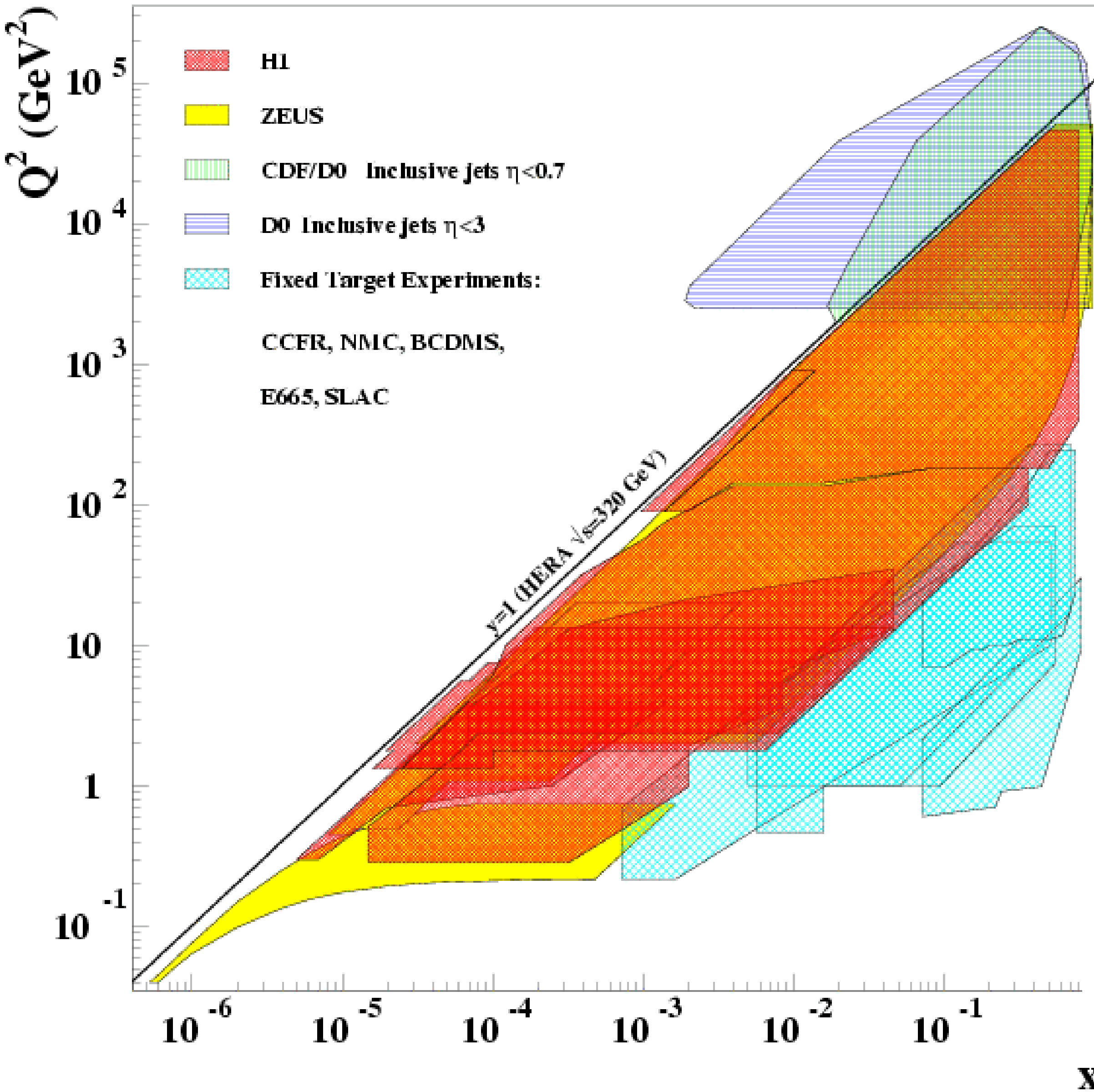


$\Delta M = |M_{D0} - M_{CDF}| \sim 6\sigma$

Ω_b^- (ssb) Baryon Observation

- CDF and DØ measurements of the Ξ_b^- mass agree
  - DØ: M(Ξ_b^-)=5774±11(stat)±15(syst) MeV/c^2 (PRL 99, 052001 (2007))
  - CDF: M(Ξ_b^-)=5790.9±2.6(stat)±0.9(syst) MeV/c^2
- DØ is performing new analysis with 5 x data
  - Half the new sample includes the new Layer 0 silicon detector
- CDF could at best double its dataset, but could also include additional channels

Kinematical regions in x - Q**2 plane

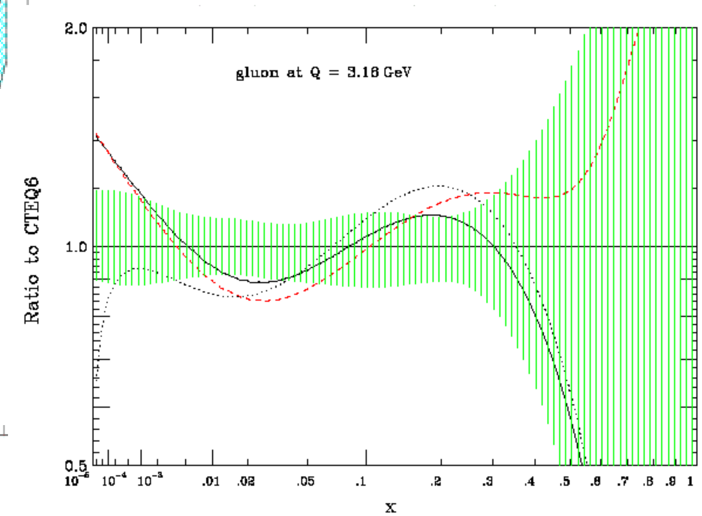


high p_T →

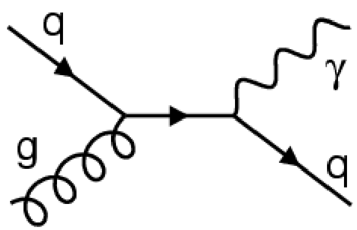
hard

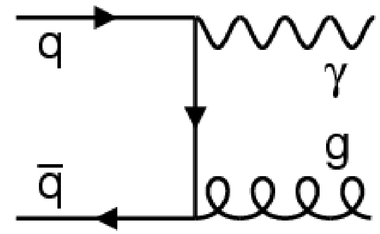
partonic scattering

CTEQ6.1 gluon uncertainty



Direct Photon Production

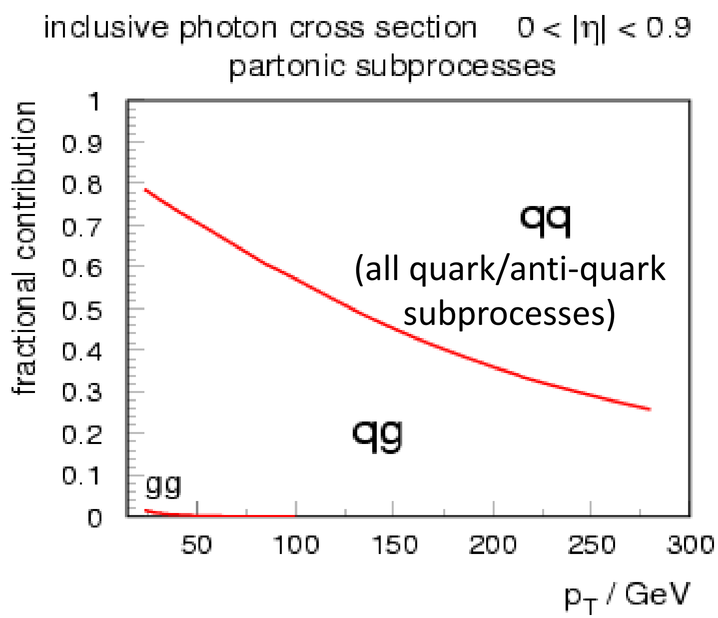




direct photons emerge unaltered from the hard subprocess

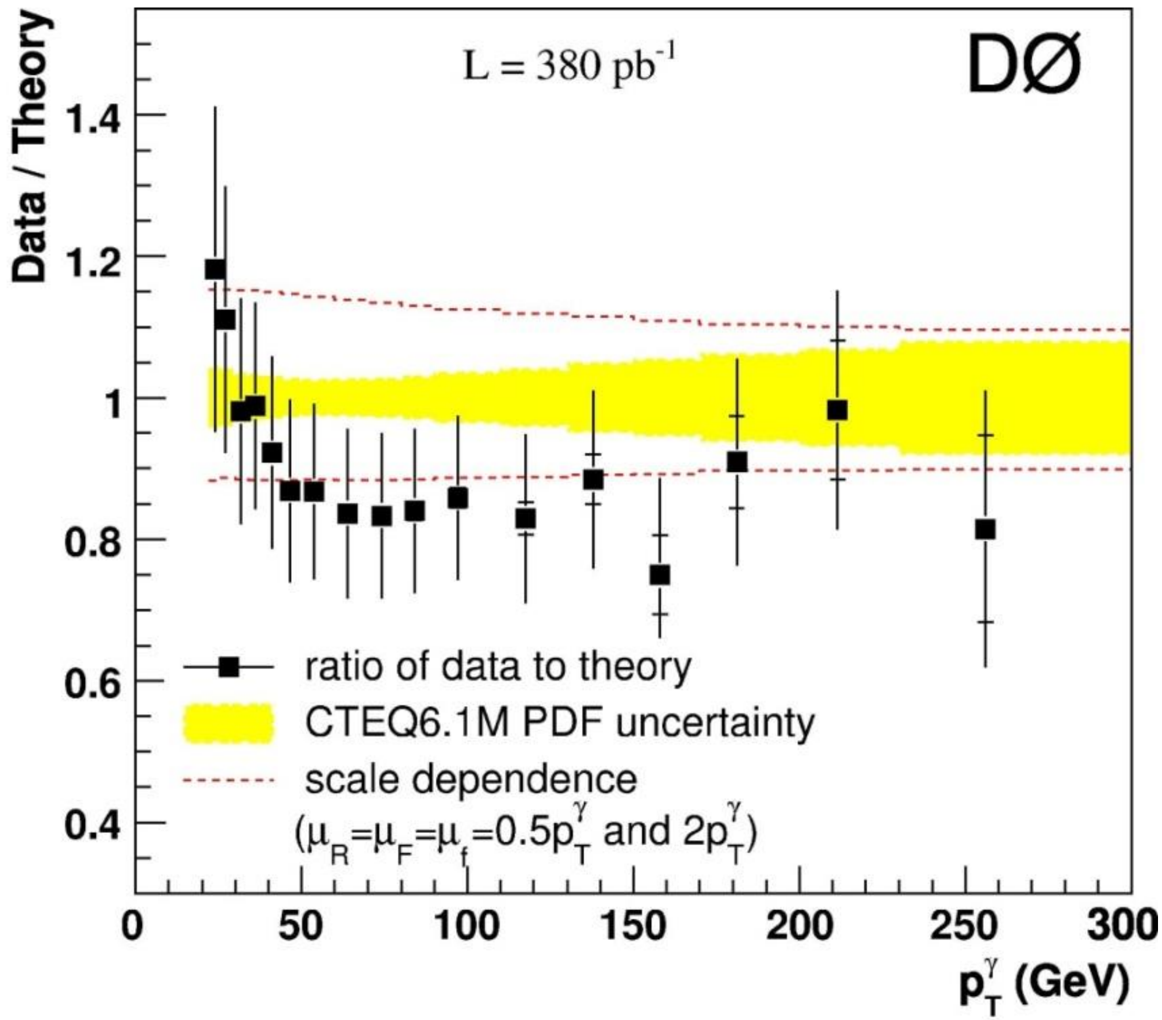
→ direct probe of the hard scattering dynamics

→ sensitivity to PDFs (gluon!) …but only if theory works



Inclusive Isolated Photons

Phys. Lett. B, **639**, 151 (2006), D0



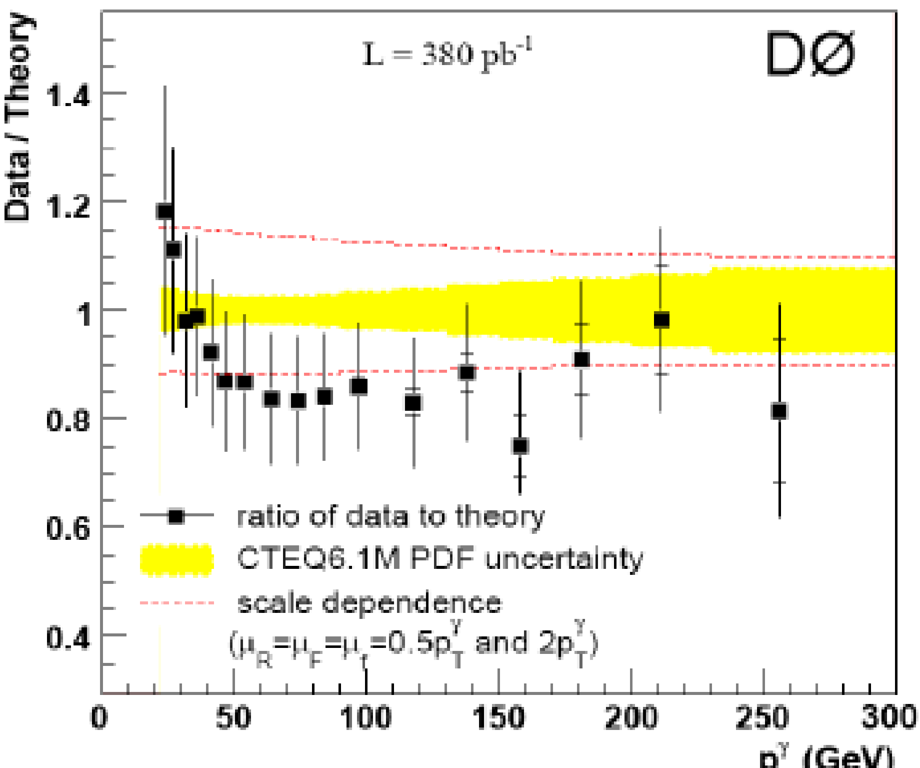
In D0 2006 publication on the prompt photons production the deviations from the corresponding pQCD predictions, previously founded in RunI data, are observed in a more wide kinematical region and with higher statistics. This result was confirmed by CDF measurement in 2009 (DIS09, Madrid).

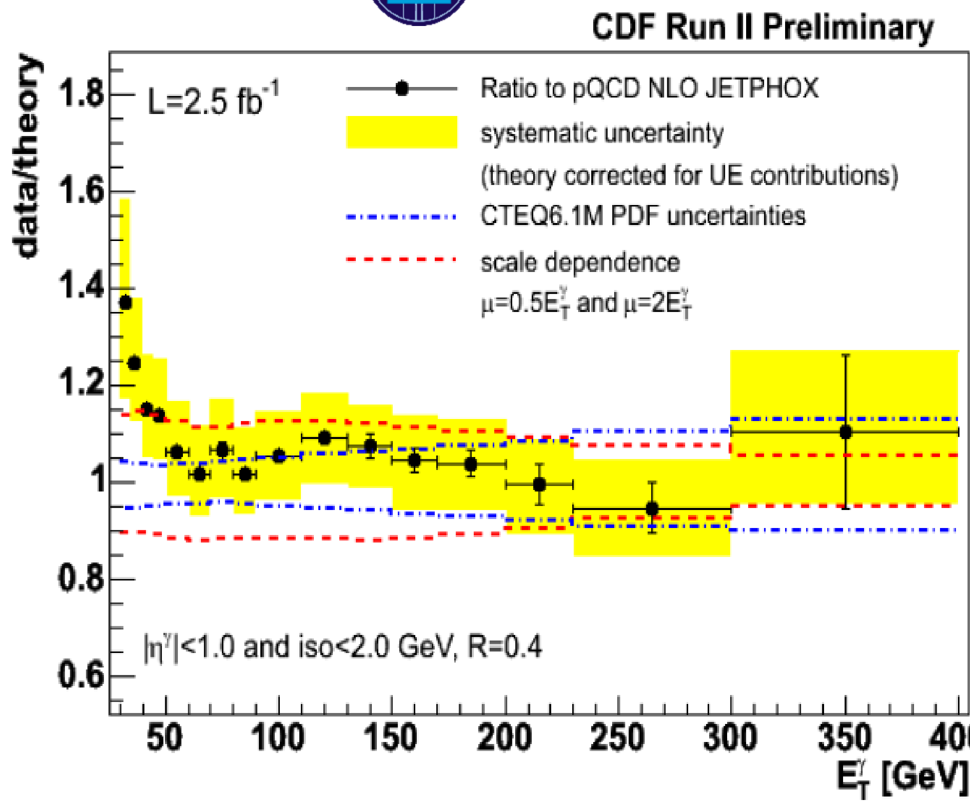
D0 (2006) ratio: data/QCD_NLO

CDF (2009) ratio : data/QCD_NLO

Phys. Lett. **B**, **639**, 151 (2006), D0

Phys. Rev. **D** 80, 11106 (2009), CDF





Measurement of the differential cross section for the production of isolated photon with associated jet in p-pbar collisions at sqrt(s) = 1.96 TeV

Phys. Lett. B 666, 435 (2008)

Luminosity: 1 fb-1

Isolated Photon + Jet and Tripple cross section

$$\frac{d^3\sigma}{dp_T^\gamma\, d\eta^\gamma\, d\eta^{jet}}$$

The FIRST measurement →

Phys. Lett. B666 (2008) 435--445

pseudorapidity η = Y rapidity;

Provides new kinematical variables:

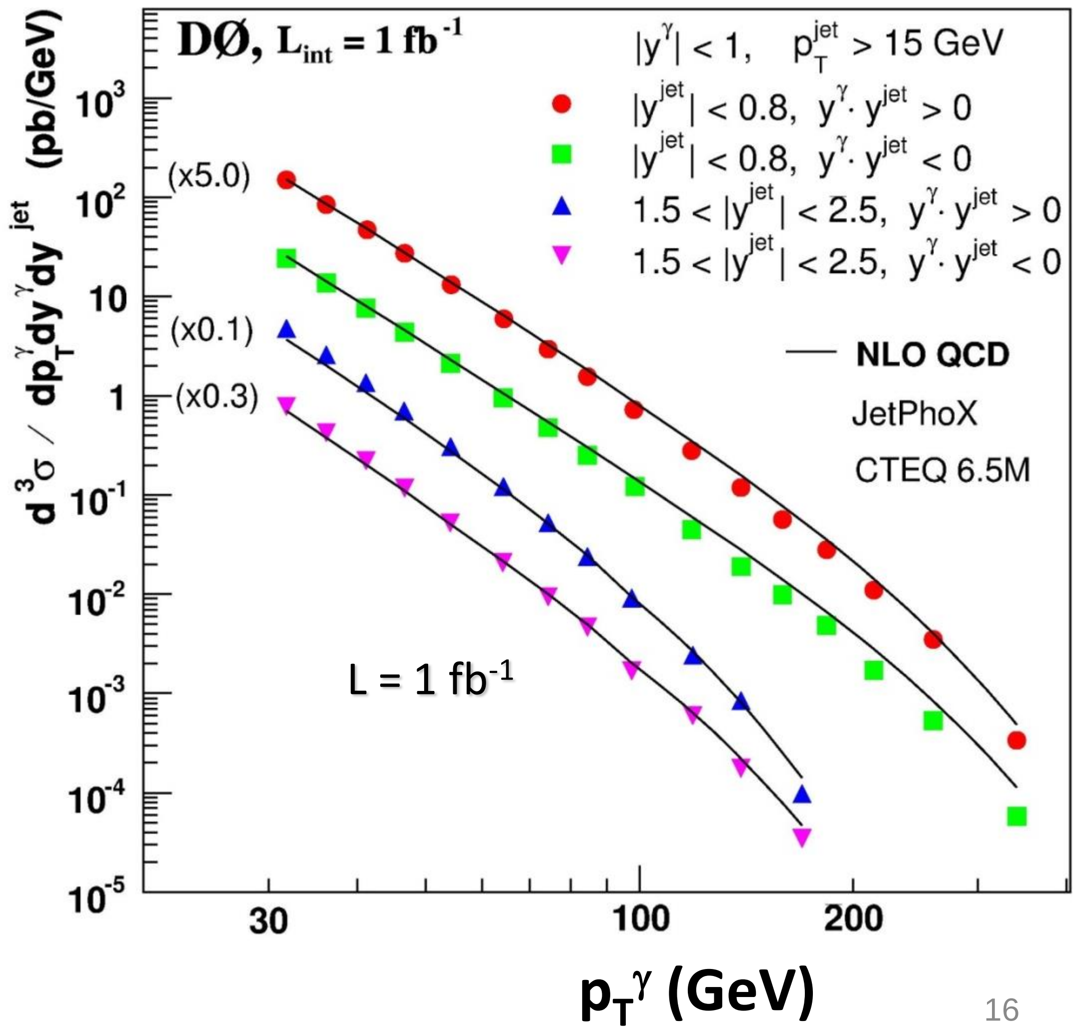
y_jet, y_gamma, P_T-jet, ets…. У=η

Measure more differential:

- tag **photon and jet**
  → reconstruct full event kinematics

- Measure in 4 regions of y^γ / y^{jet}
  - photon: central
  - jet: central / forward
  - same side / opposite side

- different PDF sensitivity in different y^γ / y^{jet} regions



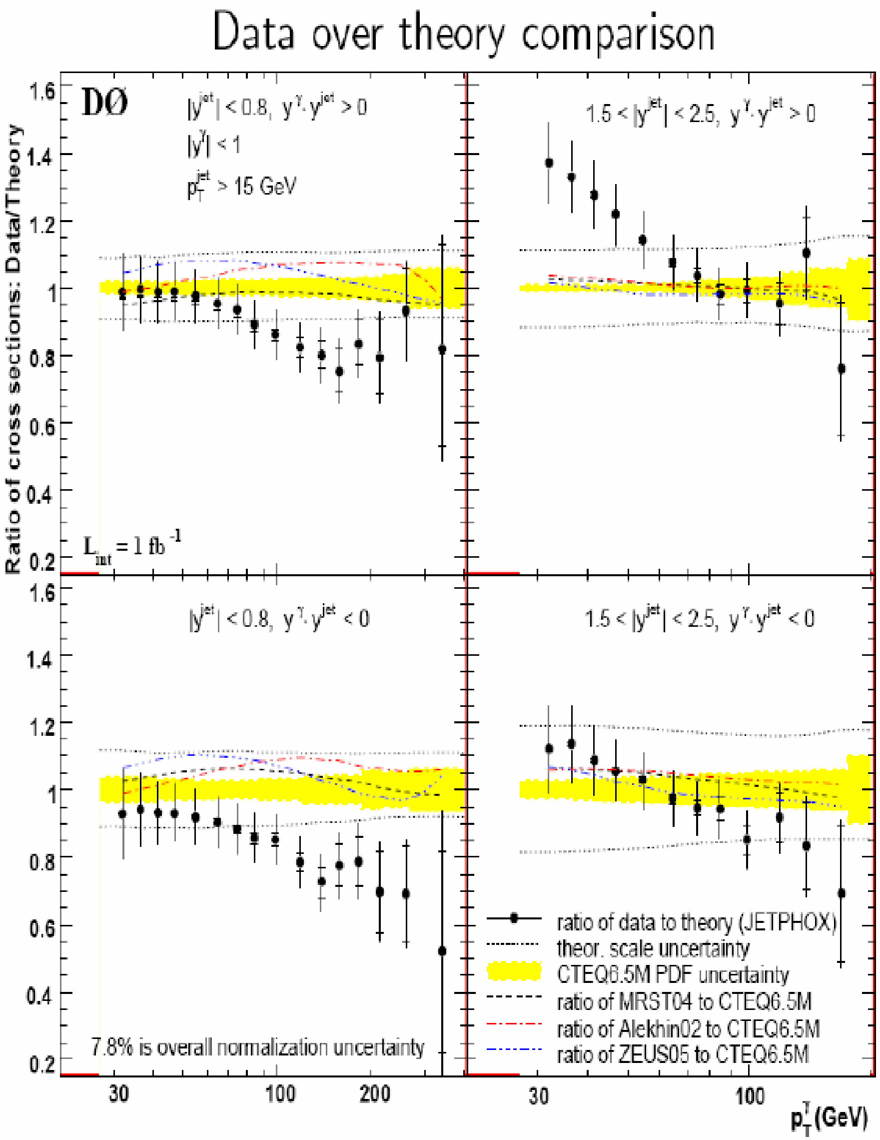
Shows a disagreement in data/theory

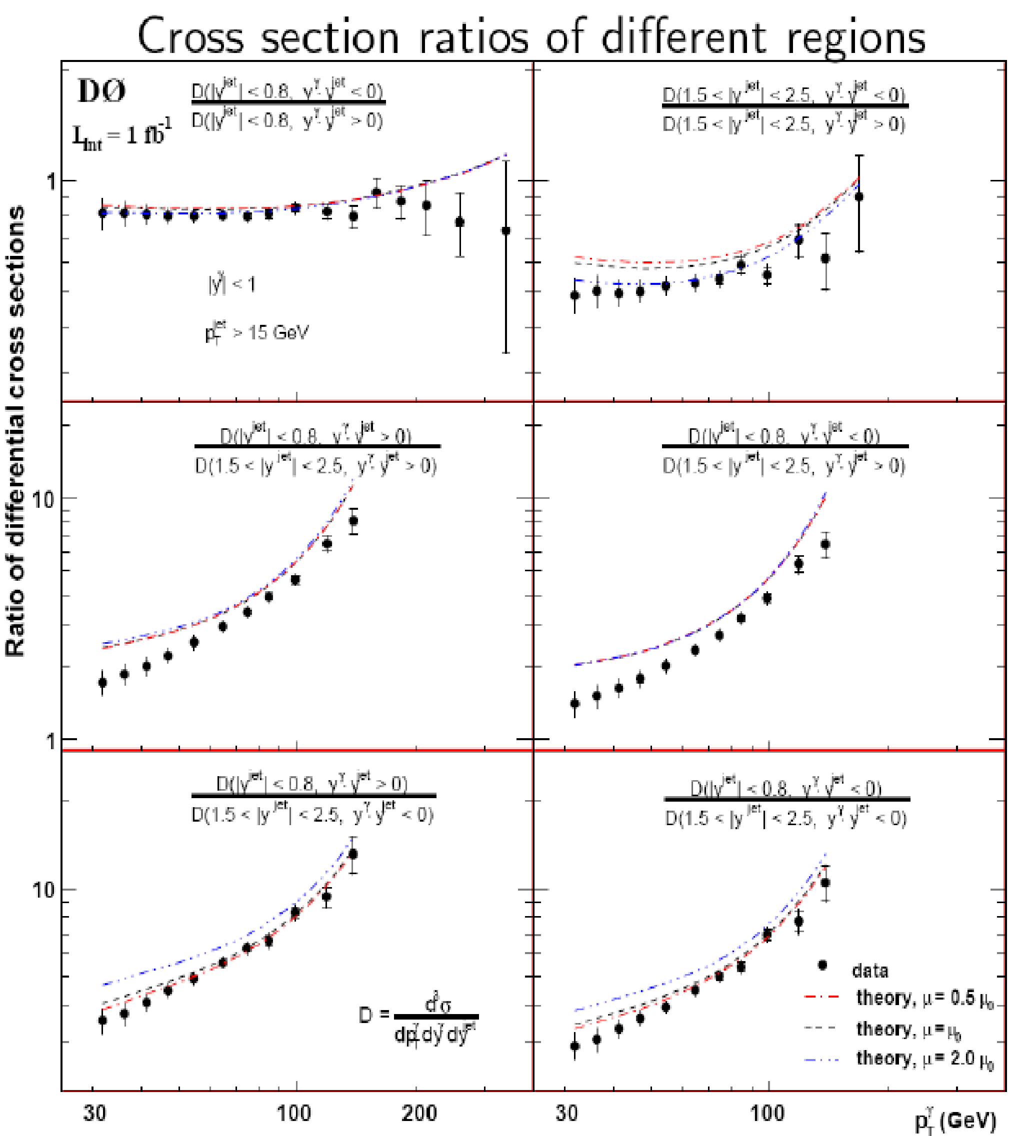
DØ, arXiv: 0804.1107 [hep-ex]

Difference between data and QCD predictions for cross sections (left) and their ratios (right) in 4 different rapidity (y) regions

We found the sizeable deviations from theory predictions

Phys. Lett. B666 (2008) 435--445





Measurement of the differential cross section of photon plus jet production in pp collisions at √s = 1.96 TeV

Phys. Rev. D 88, 435 (2013)

Luminosity: 8.7 fb-1

The FIRST measurement →

Fermilab Today
Thursday, Aug. 15, 2013

Calendar

[Have a safe day!]

Thursday, Aug. 15

2:30 p.m.
Theoretical Physics Seminar - Curia II
Speaker: Chia-Cheng Chang, University of Illinois at Chicago and Fermilab
Title: Local D^0 Hadronic Matrix Elements from 2+1 Lattice QCD

3:30 p.m.
DIRECTOR'S COFFEE BREAK - 2nd Flr X-Over

4 p.m.
Accelerator Physics and

Current Security Status

Secon Level 3

Current Flag Status

Flags at full staff

Wilson Hall Cafe

Thursday, Aug. 15

- Breakfast: Canadian bacon, egg and cheese Texas toast
- Breakfast: Greek omelet
- Chicken fajita club sandwich
- Asian beef and vegetables
- Chicken cacciatore
- Italian loaf sandwich
- Tex-Mex grilled-chicken salad
- Vegetarian chili
- Chef's choice soup

Wilson Hall Cafe menu

Feature

art lessons for scientists

A new product called *art* allows experiments to build on a common underlying software layer.

While many physicists enjoy writing software to reconstruct and analyze the events coming from their detectors, few want to attend to the low-level bookkeeping tools. To date, most high-energy physics experiments have written their code essentially from

experimenters. To help them acquire these skills, Kutschke is authoring an *art* Workbook that guides users through a set of exercises designed to illuminate the structure, user environment, configuration language and user-code requirements of *art*. This is the first phase of a planned documentation suite that will also include a users' guide, a reference manual and a technical reference for *art* developers.

Alpha release v. 0.5, made available Aug. 7 on the *art* website, includes both an introduction outlining prerequisites and the first five Workbook exercises (of about two dozen planned). SCD has been engaging new Intensity Frontier experimenters to test-drive the documentation this summer; the goal is to develop it into an educational tool that will significantly reduce the time that it takes new collaborators to produce scientific results for their experiments.

—*Anne Heavey*

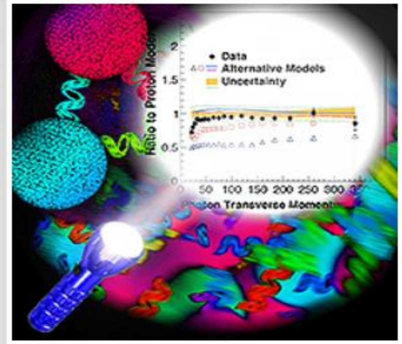
A version of this article appeared in the July issue of Computing Bits.

Death

In Memoriam: Frederick Mills

Frontier Science Result: DZero

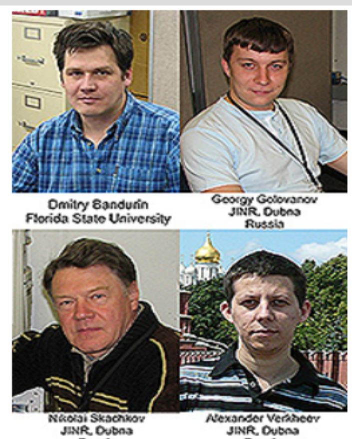
Spotlight studies the proton's glue



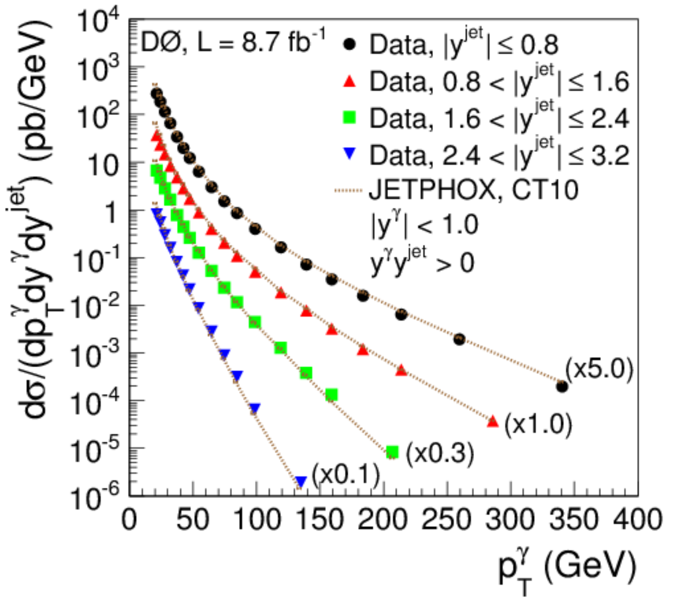
Photons, the particles of light, make excellent probes of the strong-force interactions that hold the proton together.

However, in some regions the data showed trends that did not match any prediction. The new observations, which have precision on par with many of the predictions, will be useful for improving models of the proton and gaining an even deeper understanding of the strong force.

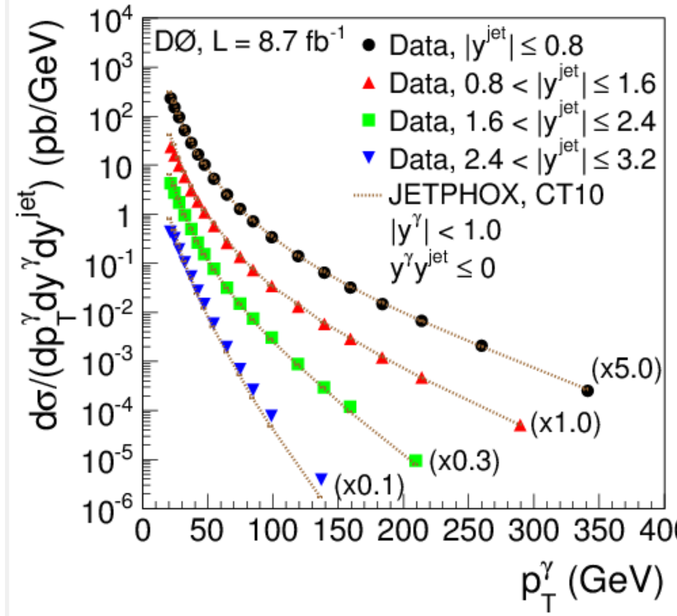
—*Mike Cooke*



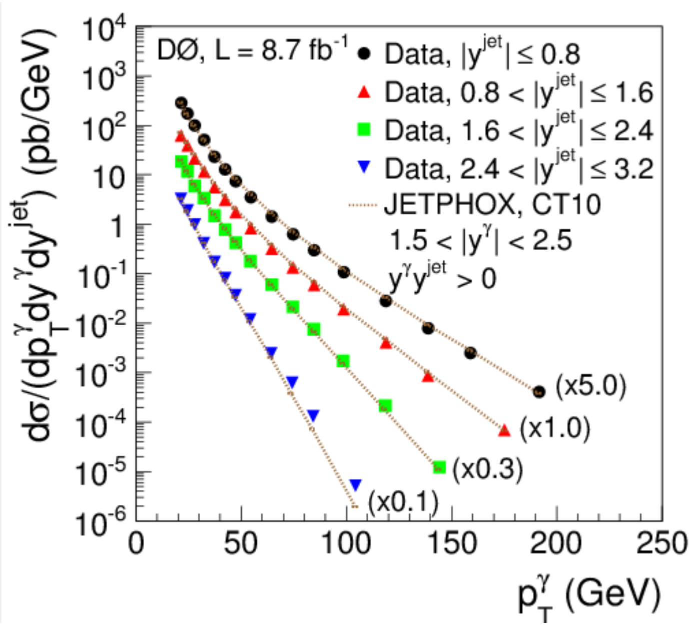
These physicists made major contributions to this analysis.



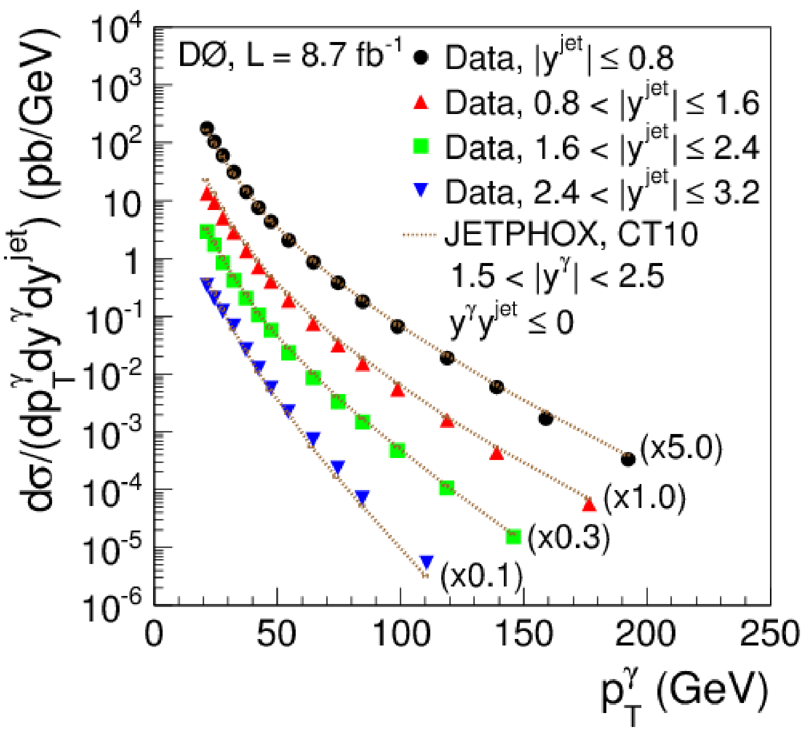
DØ, L = 8.7 fb^{-1}
Data, $|y^{jet}| \leq 0.8$
Data, $0.8 < |y^{jet}| \leq 1.6$
Data, $1.6 < |y^{jet}| \leq 2.4$
Data, $2.4 < |y^{jet}| \leq 3.2$
JETPHOX, CT10
$|y^{\gamma}| < 1.0$
$y^{\gamma}y^{jet} > 0$
(x5.0)
(x1.0)
(x0.3)
(x0.1)
$d\sigma/(dp_T^{\gamma}dy^{\gamma}dy^{jet})$ (pb/GeV)
p_T^{γ} (GeV)



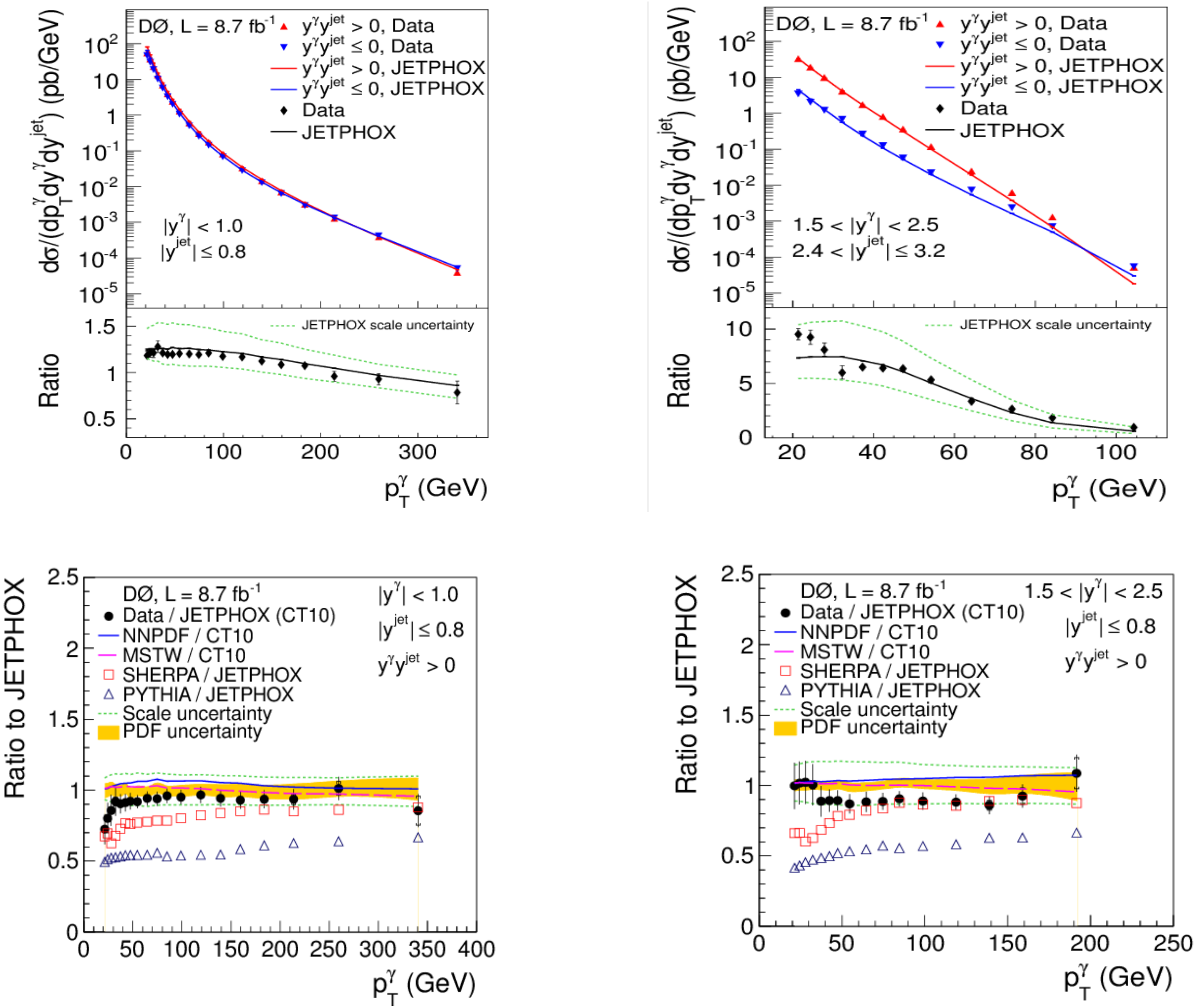
DØ, L = 8.7 fb^{-1}
Data, $|y^{jet}| \leq 0.8$
Data, $0.8 < |y^{jet}| \leq 1.6$
Data, $1.6 < |y^{jet}| \leq 2.4$
Data, $2.4 < |y^{jet}| \leq 3.2$
JETPHOX, CT10
$|y^{\gamma}| < 1.0$
$y^{\gamma}y^{jet} \leq 0$
(x5.0)
(x1.0)
(x0.3)
(x0.1)
$d\sigma/(dp_T^{\gamma}dy^{\gamma}dy^{jet})$ (pb/GeV)
p_T^{γ} (GeV)



DØ, L = 8.7 fb^{-1}
Data, $|y^{jet}| \leq 0.8$
Data, $0.8 < |y^{jet}| \leq 1.6$
Data, $1.6 < |y^{jet}| \leq 2.4$
Data, $2.4 < |y^{jet}| \leq 3.2$
JETPHOX, CT10
$1.5 < |y^{\gamma}| < 2.5$
$y^{\gamma}y^{jet} > 0$
(x5.0)
(x1.0)
(x0.3)
(x0.1)
$d\sigma/(dp_T^{\gamma}dy^{\gamma}dy^{jet})$ (pb/GeV)
p_T^{γ} (GeV)



DØ, L = 8.7 fb^{-1}
Data, $|y^{jet}| \leq 0.8$
Data, $0.8 < |y^{jet}| \leq 1.6$
Data, $1.6 < |y^{jet}| \leq 2.4$
Data, $2.4 < |y^{jet}| \leq 3.2$
JETPHOX, CT10
$1.5 < |y^{\gamma}| < 2.5$
$y^{\gamma}y^{jet} \leq 0$
(x5.0)
(x1.0)
(x0.3)
(x0.1)
$d\sigma/(dp_T^{\gamma}dy^{\gamma}dy^{jet})$ (pb/GeV)
p_T^{γ} (GeV)



DØ, L = 8.7 fb^{-1}
$y^{\gamma}y^{jet} > 0$, Data
$y^{\gamma}y^{jet} \leq 0$, Data
$y^{\gamma}y^{jet} > 0$, JETPHOX
$y^{\gamma}y^{jet} \leq 0$, JETPHOX
Data
JETPHOX
$|y^{\gamma}| < 1.0$
$|y^{jet}| \leq 0.8$
$d\sigma/(dp_T^{\gamma}dy^{\gamma}dy^{jet})$ (pb/GeV)
JETPHOX scale uncertainty
Ratio
p_T^{γ} (GeV)
DØ, L = 8.7 fb^{-1}
$y^{\gamma}y^{jet} > 0$, Data
$y^{\gamma}y^{jet} \leq 0$, Data
$y^{\gamma}y^{jet} > 0$, JETPHOX
$y^{\gamma}y^{jet} \leq 0$, JETPHOX
Data
JETPHOX
$1.5 < |y^{\gamma}| < 2.5$
$2.4 < |y^{jet}| \leq 3.2$
$d\sigma/(dp_T^{\gamma}dy^{\gamma}dy^{jet})$ (pb/GeV)
JETPHOX scale uncertainty
Ratio
p_T^{γ} (GeV)
DØ, L = 8.7 fb^{-1}
Data / JETPHOX (CT10)
NNPDF / CT10
MSTW / CT10
SHERPA / JETPHOX
PYTHIA / JETPHOX
Scale uncertainty
PDF uncertainty
$|y^{\gamma}| < 1.0$
$|y^{jet}| \leq 0.8$
$y^{\gamma}y^{jet} > 0$
Ratio to JETPHOX
p_T^{γ} (GeV)
DØ, L = 8.7 fb^{-1}
$1.5 < |y^{\gamma}| < 2.5$
Data / JETPHOX (CT10)
NNPDF / CT10
MSTW / CT10
SHERPA / JETPHOX
PYTHIA / JETPHOX
Scale uncertainty
PDF uncertainty
$|y^{jet}| \leq 0.8$
$y^{\gamma}y^{jet} > 0$
Ratio to JETPHOX
p_T^{γ} (GeV)

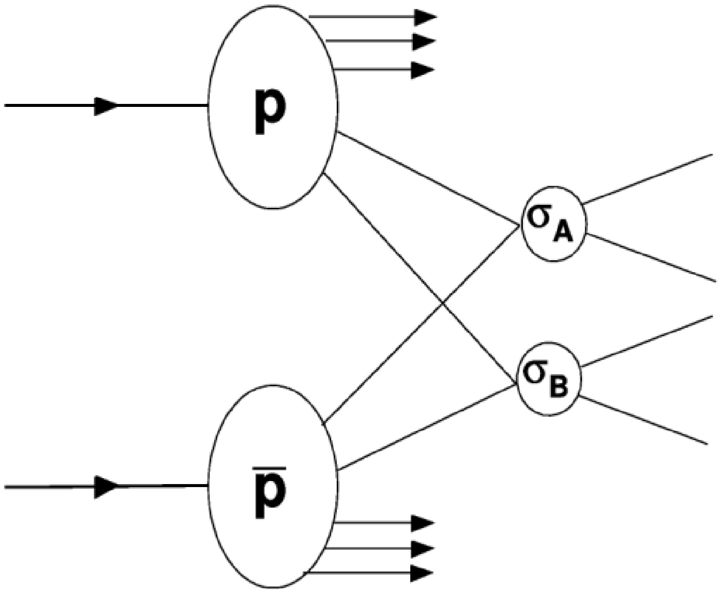
Double parton interactions in photon+3 jet events in p-pbar collisions $\sqrt{s}$=1.96 TeV

Phys.Rev. D81 (2010) 052012

Luminosity: 1 fb-1

FERMILAB-PUB-09-644-E

Double Parton Scattering



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

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

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

→ contains information on the spatial distribution of partons.

Uniform: σ_{eff} is large and σ_{DP} is small

Clumpy: σ_{eff} is small and σ_{DP} is large

History of measurements

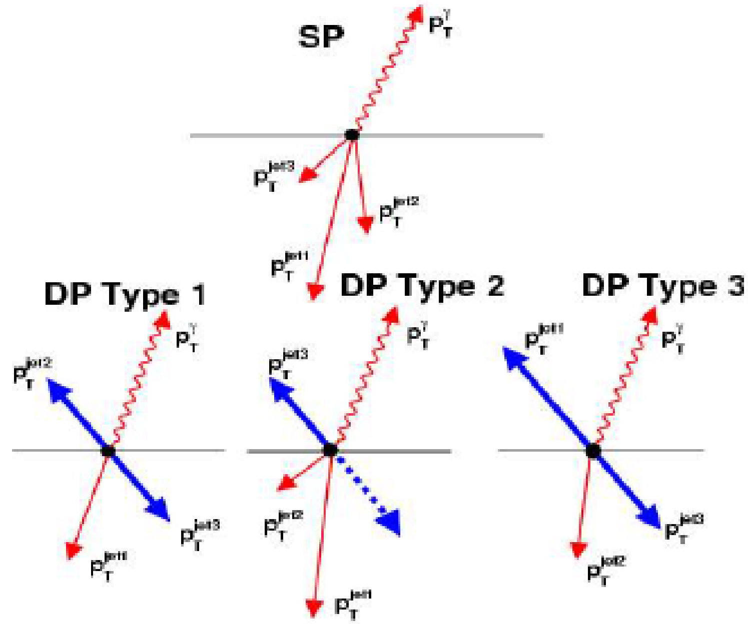
- Theoretical discussion on DPS continues for many years (~beginning of 80's)
- Very small amount of experimental results

	$\sqrt{s}$ (GeV)	final state	p_T^{min} (GeV/c)	η range	Result
AFS, 1986	63	$4jets$	$p_T^{jet} > 4$	$\lvert\eta^{jet}\rvert < 1$	$\sigma_{eff} \sim 5$ mb
UA2, 1991	630	$4jets$	$p_T^{jet} > 15$	$\lvert\eta^{jet}\rvert < 2$	$\sigma_{eff} > 8.3$ mb (95% C.L.)
CDF, 1993	1800	$4jets$	$p_T^{jet} > 25$	$\lvert\eta^{jet}\rvert < 3.5$	$\sigma_{eff} = 12.1^{+10.7}_{-5.4}$ mb
CDF, 1997	1800	$\gamma + 3jets$	$p_T^{jet} > 6$	$\lvert\eta^{jet}\rvert < 3.5$	
			$p_T^{\gamma} > 16$	$\lvert\eta^{\gamma}\rvert < 0.9$	$\sigma_{eff} = 14.5 \pm 1.7^{+1.7}_{-2.3}$ mb

- Experimental problem is extracting DP signal from more probable double bremsstrahlung background.

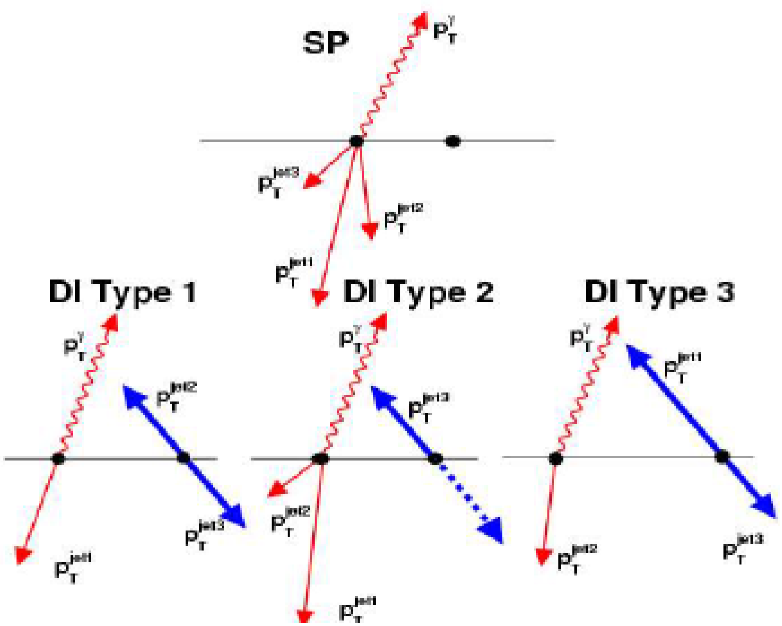
In the first 3 experiments [AFS, UA2, CDF(1993)] the events with **4 jets** in the final state were considered. In the CDF(1997) "γ" = γ/π^0 , and **5** ≤ pT^jet ≤ **7** GeV (misprint in the Table)→ **DP-Fraction= 51%**

γ+3 jets events topology: DP and DI events



B: Single Parton (SP) 1PV production:
single hard scattering with bremsstrahlung radiation in 1vtx events.

S: Double Parton (DP) production:
1[st] process produces photon-jet pair, while 2[nd] produces dijet pair or photon plus 2 jets from 1[st] interaction plus 1 observed jet from dijet pair.



B: Single Parton (SP) 2PV production:
Single hard scattering in 1vtx with bremsstrahlung radiation.

S: Double Interaction (DI) production:
two separate collisions within the same beam crossing.

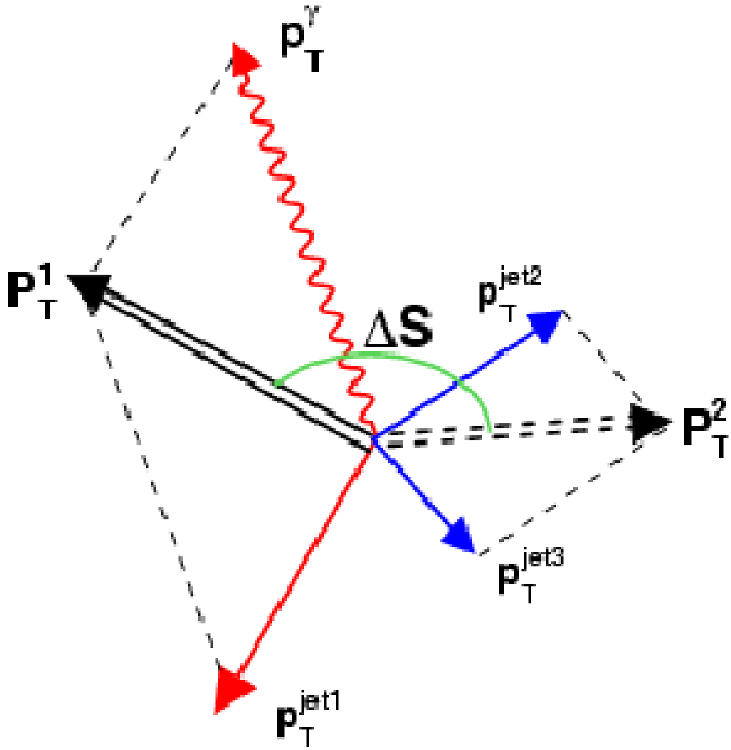
Discriminating Variables

$$\Delta S = \Delta\phi(p_T^{\gamma,\,\mathrm{jet}}, p_T^{\mathrm{jet}_i,\,\mathrm{jet}_k})$$

- $\Delta\phi$ angle between two best pT-balancing pairs
- The pairs should correspond to a minimum ΔS value:

$$S_\phi = \frac{1}{\sqrt{2}}\sqrt{\left(\frac{\Delta\phi(\gamma,i)}{\delta\phi(\gamma,i)}\right)^2 + \left(\frac{\Delta\phi(j,k)}{\delta\phi(j,k)}\right)^2}$$

$$S_{p_T} = \frac{1}{\sqrt{2}}\sqrt{\left(\frac{|\vec{P_T}(\gamma,i)|}{\delta P_T(\gamma,i)}\right)^2 + \left(\frac{|\vec{P_T}(j,k)|}{\delta P_T(j,k)}\right)^2}$$



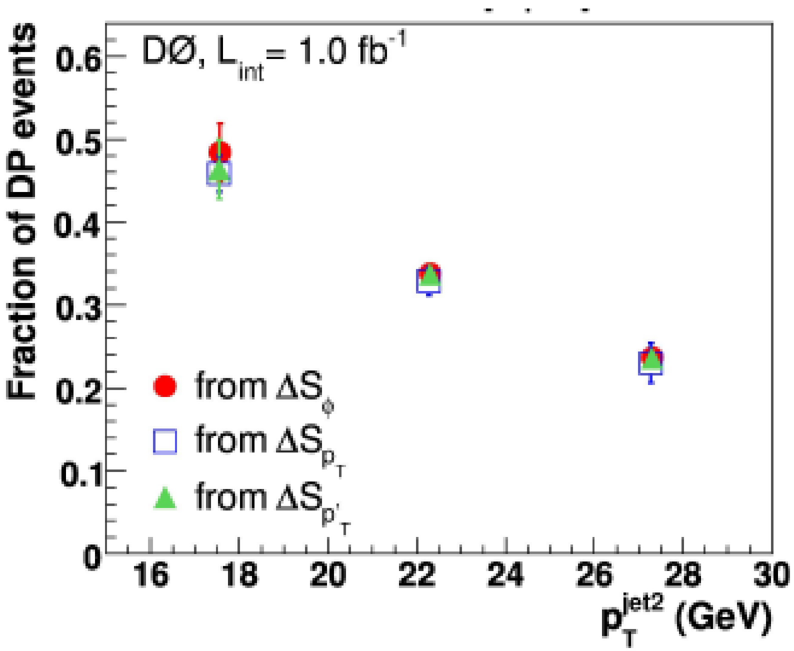
In the signal sample most likely (>94%) S-variables are minimized by pairing photon with the leading jet.

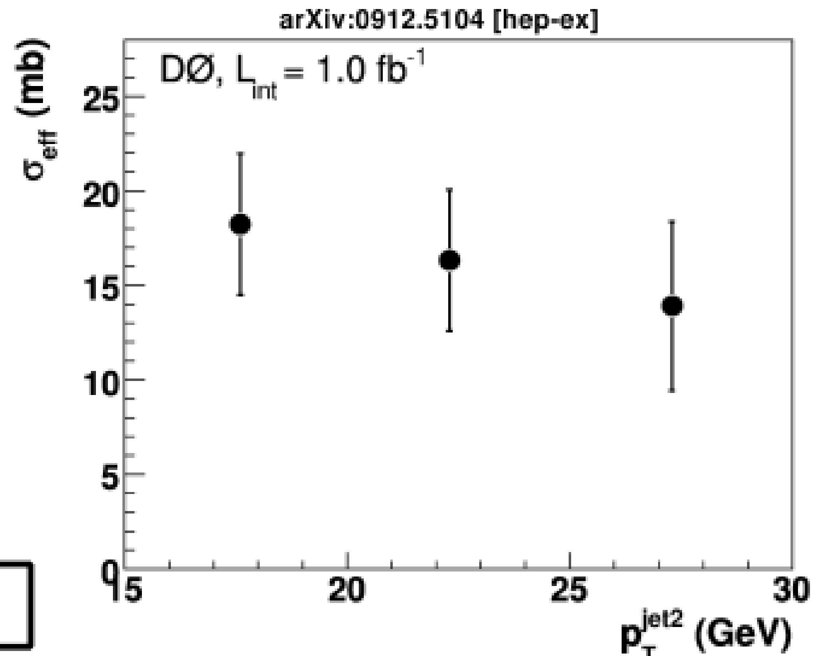
Luminosity: 1 fb-1

Three bins in Pt of the second jet

Double parton cross sections, D0

Phys. Rev. D **81**, 052012 (2010)





Fraction of DP events decreases as expected.

$$\sigma_{eff}^{ave} = 16.4 \pm 0.3\,(stat) \pm 2.3\,(syst)\; mb$$

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

TABLE III: Fractions of DP events in the three $p_T^{\rm jet2}$ bins.

$p_T^{\rm jet2}$ GeV	$\langle p_T^{\rm jet2} \rangle$ (GeV)	$f_{\rm DP}$
15 − 20	17.6	0.466 ± 0.041
20 − 25	22.3	0.334 ± 0.023
25 − 30	27.3	0.235 ± 0.027

→ $14.5 \pm 1.7^{+1.7}_{-2.3}$ mb

Phys. Rev. Lett. 79, 584

Phys. Rev. D 56, 3811

Differential Cross sections of photon+2(3) jets events

Azimuthal decorrelations and multiple parton interactions

in photon+2 jet and photon+3 jet events in

p-pbar collisions at S=sqrt (1.96) TeV

Luminosity: 8.7 fb-1

Phys.Rev. D, 83 052008 (2011);

$(1/\sigma_{\gamma 3j})d\sigma_{\gamma 3j}/d\Delta S$ cross sections

$\gamma + 3$ jet

$15 < p_T^{jet2} < 30$ GeV

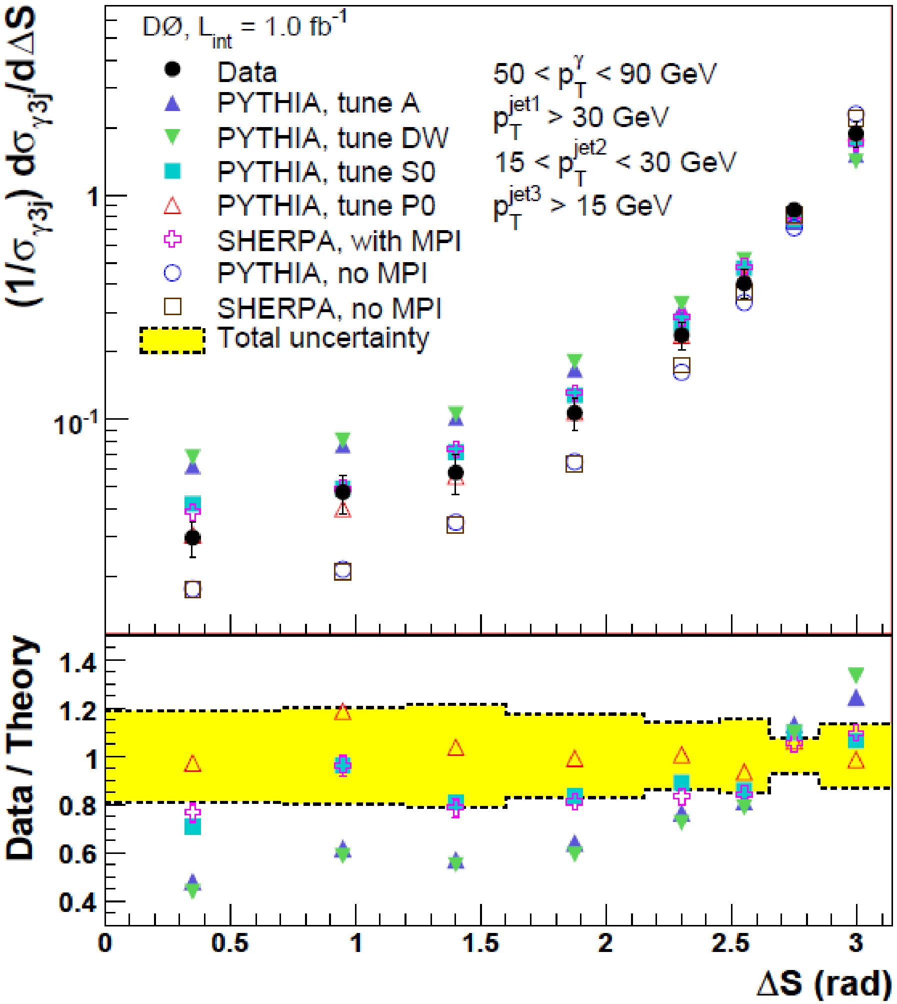


FIG. 5: Normalized differential cross section in $\gamma + 3$ jet events, $(1/\sigma_{\gamma 3j})d\sigma_{\gamma 3j}/d\Delta S$, in data compared to MC models and the ratio of data over theory, only for models including MPI, in the range $15 < p_T^{jet2} < 30$ GeV.

TABLE I: Measured normalized differential cross sections $(1/\sigma_{\gamma 3j})d\sigma_{\gamma 3j}/d\Delta S$ for $15 < p_T^{jet2} < 30$ GeV.

ΔS bin (rad)	$\langle \Delta S \rangle$ (rad)	N_{data}	Normalized cross section	Uncertainties (%) δ_{stat}	δ_{syst}	δ_{tot}
0.00 – 0.70	0.36	495	2.97×10^{-2}	11.3	14.7	18.6
0.70 – 1.20	0.97	505	4.74×10^{-2}	12.3	15.6	19.9
1.20 – 1.60	1.42	498	5.80×10^{-2}	13.4	15.8	20.7
1.60 – 2.15	1.90	1315	1.11×10^{-1}	7.5	15.3	17.0
2.15 – 2.45	2.32	1651	2.38×10^{-1}	6.0	12.0	13.4
2.45 – 2.65	2.56	1890	4.04×10^{-1}	5.6	13.6	14.7
2.65 – 2.85	2.76	3995	8.59×10^{-1}	3.2	5.6	6.4
2.85 – 3.14	3.02	12431	1.89×10^{0}	1.0	13.0	13.0

$(1/\sigma_{\gamma 2j})d\sigma_{\gamma 2j}/d\Delta\phi$ cross sections

$\gamma + 2$ jet

$15 < p_T^{jet2} < 20$ GeV

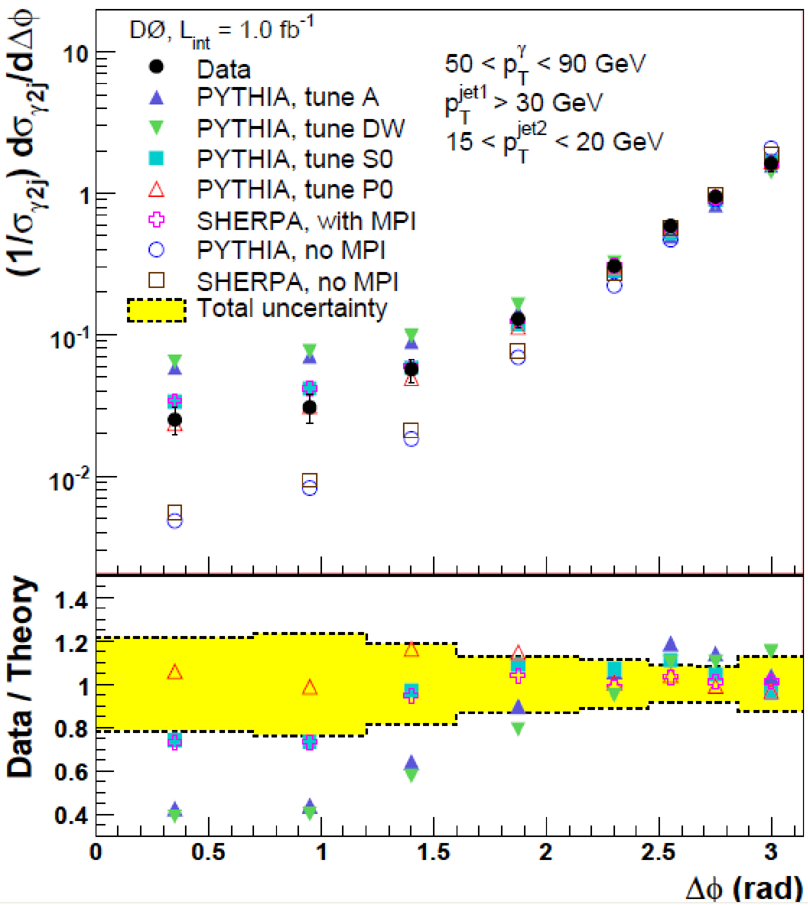


TABLE II: Measured normalized differential cross sections $(1/\sigma_{\gamma 2j})d\sigma_{\gamma 2j}/d\Delta\phi$ for $15 < p_T^{jet2} < 20$ GeV.

$\Delta\phi$ bin (rad)	$\langle\Delta\phi\rangle$ (rad)	N_{data}	Normalized cross section	Uncertainties (%) δ_{stat}	δ_{syst}	δ_{tot}
0.00 – 0.70	0.36	1028	2.49×10^{-2}	9.4	19.1	21.3
0.70 – 1.20	0.96	822	3.06×10^{-2}	11.8	20.3	23.4
1.20 – 1.60	1.42	1149	5.68×10^{-2}	9.6	15.5	18.2
1.60 – 2.15	1.92	3402	1.29×10^{-1}	4.9	11.5	12.5
2.15 – 2.45	2.32	4187	3.06×10^{-1}	4.5	9.5	10.5
2.45 – 2.65	2.56	5239	5.88×10^{-1}	4.0	6.3	7.4
2.65 – 2.85	2.76	8246	9.43×10^{-1}	3.0	6.8	7.5
2.85 – 3.14	3.01	20337	1.63×10^{0}	1.1	12.3	12.3

FIG. 6: Normalized differential cross section in $\gamma + 2$ jet events, $(1/\sigma_{\gamma 2j})d\sigma_{\gamma 2j}/d\Delta\phi$, in data compared to MC models and the ratio of data over theory, only for models including MPI, in the range $15 < p_T^{jet2} < 20$ GeV.

$(1/\sigma_{\gamma 2j})d\sigma_{\gamma 2j}/d\Delta\phi$ cross sections

$\gamma + 2$ jet

$20 < p_T^{jet2} < 25$ GeV

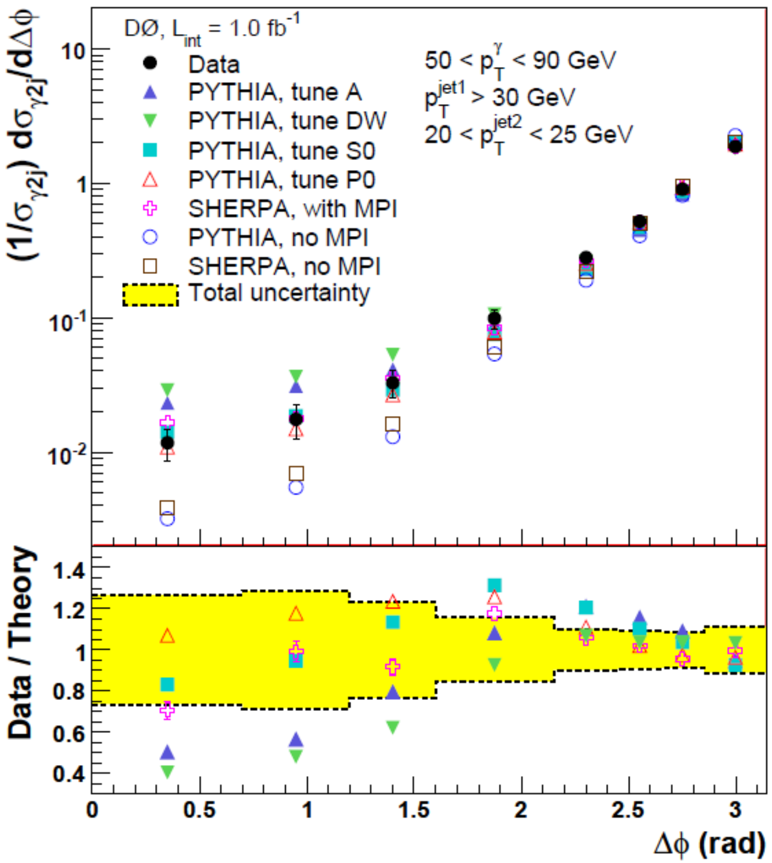


FIG. 7: Normalized differential cross section in $\gamma + 2$ jet events, $(1/\sigma_{\gamma 2j})d\sigma_{\gamma 2j}/d\Delta\phi$, in data compared to MC models and the ratio of data over theory, only for models including MPI, in the range $20 < p_T^{jet2} < 25$ GeV

TABLE III: Measured normalized differential cross section $(1/\sigma_{\gamma 2j})d\sigma_{\gamma 2j}/d\Delta\phi$ for $20 < p_T^{jet2} < 25$ GeV.

$\Delta\phi$ bin (rad)	$\langle\Delta\phi\rangle$ (rad)	N_{data}	Normalized cross section	Uncertainties (%) δ_{stat}	δ_{syst}	δ_{tot}
0.00 – 0.70	0.35	388	1.17×10^{-2}	12.5	23.2	26.4
0.70 – 1.20	0.96	358	1.75×10^{-2}	17.7	22.2	28.5
1.20 – 1.60	1.42	489	3.29×10^{-2}	15.6	17.0	23.1
1.60 – 2.15	1.92	1848	9.84×10^{-2}	6.2	13.8	15.1
2.15 – 2.45	2.33	2682	2.80×10^{-1}	4.6	8.2	9.4
2.45 – 2.65	2.56	3208	5.21×10^{-1}	4.5	7.1	8.4
2.65 – 2.85	2.77	5404	9.01×10^{-1}	3.2	7.3	8.0
2.85 – 3.14	3.02	15901	1.88×10^{0}	1.0	10.8	10.8

$(1/\sigma_{\gamma 2j})d\sigma_{\gamma 2j}/d\Delta\phi$ cross sections

$\gamma + 2$ jet

$25 < p_T^{\text{jet2}} < 30$ GeV

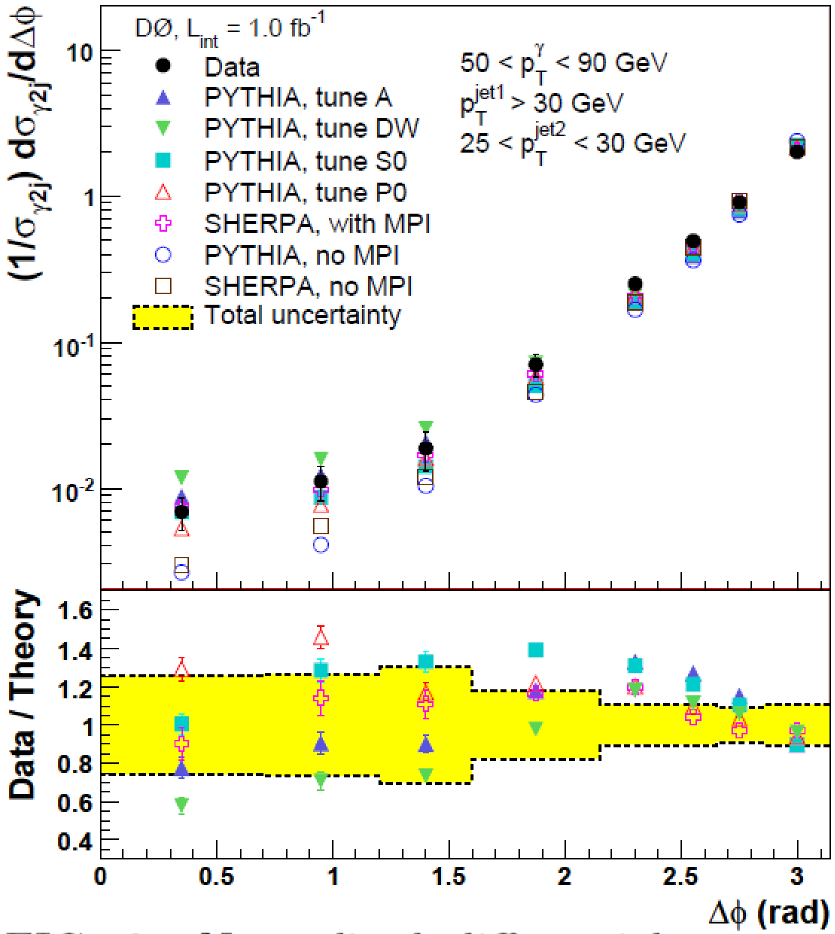


FIG. 8: Normalized differential cross section in $\gamma + 2$ jet events, $(1/\sigma_{\gamma 2j})d\sigma_{\gamma 2j}/d\Delta\phi$, in data compared to MC models and the ratio of data over theory, only for models including MPI, in the range $25 < p_T^{\text{jet2}} < 30$ GeV.

TABLE IV: Measured normalized differential cross section $(1/\sigma_{\gamma 2j})d\sigma_{\gamma 2j}/d\Delta\phi$ for $25 < p_T^{\text{jet2}} < 30$ GeV.

$\Delta\phi$ bin (rad)	$\langle\Delta\phi\rangle$ (rad)	N_{data}	Normalized cross section	Uncertainties (%) δ_{stat}	δ_{syst}	δ_{tot}
0.00 – 0.70	0.32	158	6.82×10^{-3}	16.1	19.8	25.5
0.70 – 1.20	0.94	155	1.11×10^{-2}	20.9	16.4	26.6
1.20 – 1.60	1.45	190	1.87×10^{-2}	24.0	17.9	30.0
1.60 – 2.15	1.92	910	7.00×10^{-2}	7.0	15.9	17.4
2.15 – 2.45	2.32	1683	2.50×10^{-1}	5.0	8.6	9.9
2.45 – 2.65	2.57	2155	4.93×10^{-1}	4.5	8.9	10.0
2.65 – 2.85	2.77	3894	9.09×10^{-1}	3.1	7.5	8.1
2.85 – 3.14	3.03	12332	2.01×10^{0}	1.0	10.2	10.2

$\gamma + 2$ jet

TABLE VIII: DP fractions (%) in data as a function of the $\Delta\phi$ interval for three $p_T^{\rm jet2}$ bins.

$p_T^{\rm jet2}$ (GeV)	$\Delta\phi$ interval (rad) $0-\pi$	$0-2.85$	$0-2.65$	$0-2.45$	$0-2.15$	$0-1.6$
$15-20$	11.6 ± 1.4	18.2 ± 2.4	25.0 ± 2.9	33.7 ± 3.8	45.0 ± 5.5	47.4 ± 11.4
$20-25$	5.0 ± 1.2	9.4 ± 1.2	13.4 ± 2.1	19.6 ± 3.1	28.1 ± 4.3	63.7 ± 17.2
$25-30$	2.2 ± 0.8	3.8 ± 1.3	5.0 ± 1.5	6.2 ± 2.2	9.8 ± 4.5	27.8 ± 11.5

TABLE VII: Fractions of DP events (%) with total uncertainties for $0 \le \Delta\phi \le \pi$ in the three $p_T^{\rm jet2}$ bins.

$p_T^{\rm jet2}$ (GeV)	$\langle p_T^{\rm jet2}\rangle$ (GeV)	$f_{\rm dp}^{\gamma 2j}$ (%)	Uncertainties (in %) Fit	$\delta_{\rm tot}$	SP model
$15-20$	17.6	11.6 ± 1.4	5.2	8.3	6.7
$20-25$	22.3	5.0 ± 1.2	4.0	20.3	11.0
$25-30$	27.3	2.2 ± 0.8	27.8	21.0	17.9

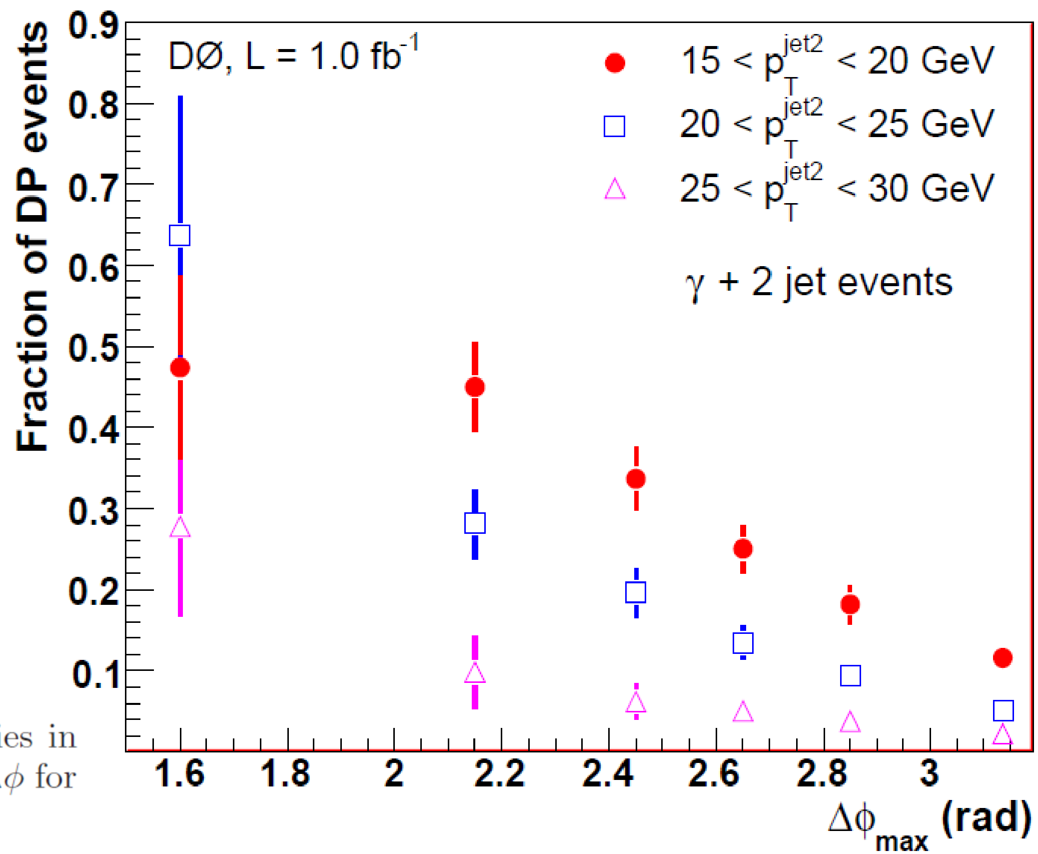


FIG. 12: Fractions of DP events with total uncertainties in $\gamma + 2$ jet final state as a function of the upper limit on $\Delta\phi$ for the three $p_T^{\rm jet2}$ intervals.

Bin-by-bin distances in the numbers of total experimental uncertainties between data and predictions. From $\triangle S$ distribution.

Table XIII: The difference between measured data points and model predictions in δ_{tot} units for ΔS distributions (see also Fig. 37) and overall χ^2 of the data-model agreement in all bins $\chi^2_{dm}(8)$ and using only the first four bins $\chi^2_{dm}(4)$.

ΔS bin	SP Models		MPI Models/ Tunes									
(rad)	Pythia	Sherpa	A	DW	S0	P0	P-nocr	P-soft	P-hard	P-6	P-X	Sherpa
0.00 – 0.70	2.2	2.2	5.7	6.8	2.2	0.2	0.1	2.5	0.0	0.1	0.3	1.6
0.70 – 1.20	2.8	2.8	3.1	3.6	0.2	0.8	0.9	0.6	1.1	0.8	0.6	0.2
1.20 – 1.60	1.9	2.0	3.6	3.9	1.1	0.2	0.1	1.2	0.5	0.0	0.1	1.3
1.60 – 2.15	2.3	2.4	3.3	4.0	1.2	0.0	0.1	1.6	0.1	0.1	0.3	1.3
2.15 – 2.45	2.3	1.9	2.2	2.8	0.9	0.0	0.3	1.0	0.0	0.1	0.2	1.4
2.45 – 2.65	1.2	0.6	1.6	1.8	1.1	0.5	0.4	0.8	0.9	0.4	0.1	1.3
2.65 – 2.85	2.6	0.8	1.8	1.4	1.4	0.9	1.0	1.6	0.2	0.9	1.3	0.8
2.85 – 3.14	1.7	1.3	1.5	1.9	0.5	0.1	0.2	0.5	0.0	0.1	0.2	0.7
$\chi^2_{dm}(4)$	7.2	7.5	21.8	30.1	2.5	0.2	0.3	3.6	0.5	0.2	0.2	2.0
$\chi^2_{dm}(8)$	5.4	4.1	11.2	15.3	1.6	0.3	0.3	2.2	0.3	0.3	0.4	1.5

-- Bins, most sensitive to DP events

-- Most preferable MPI models

Double parton interactions as a background to associated HW production at the Tevatron

JHEP 1104 (2011) 054

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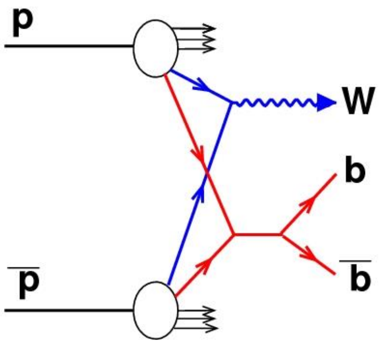
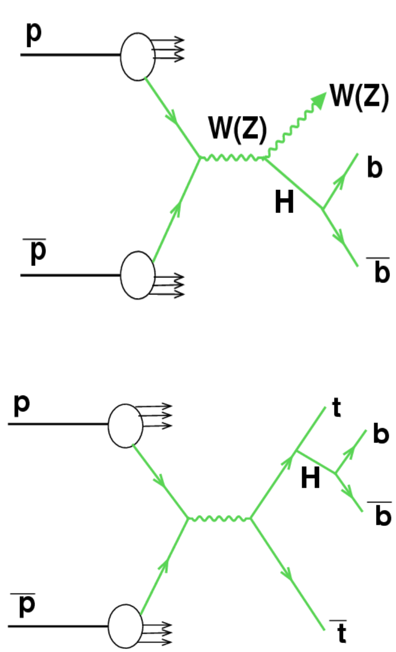
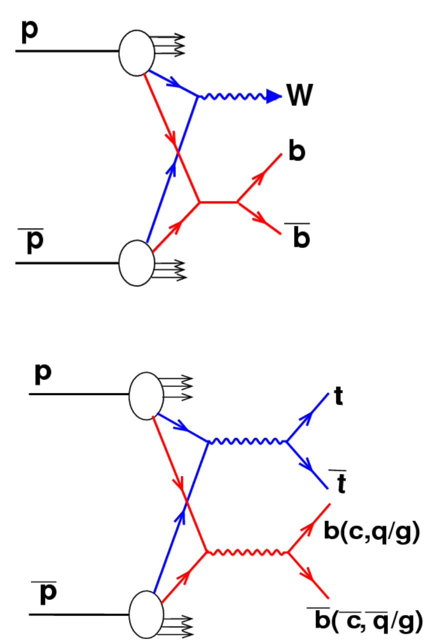


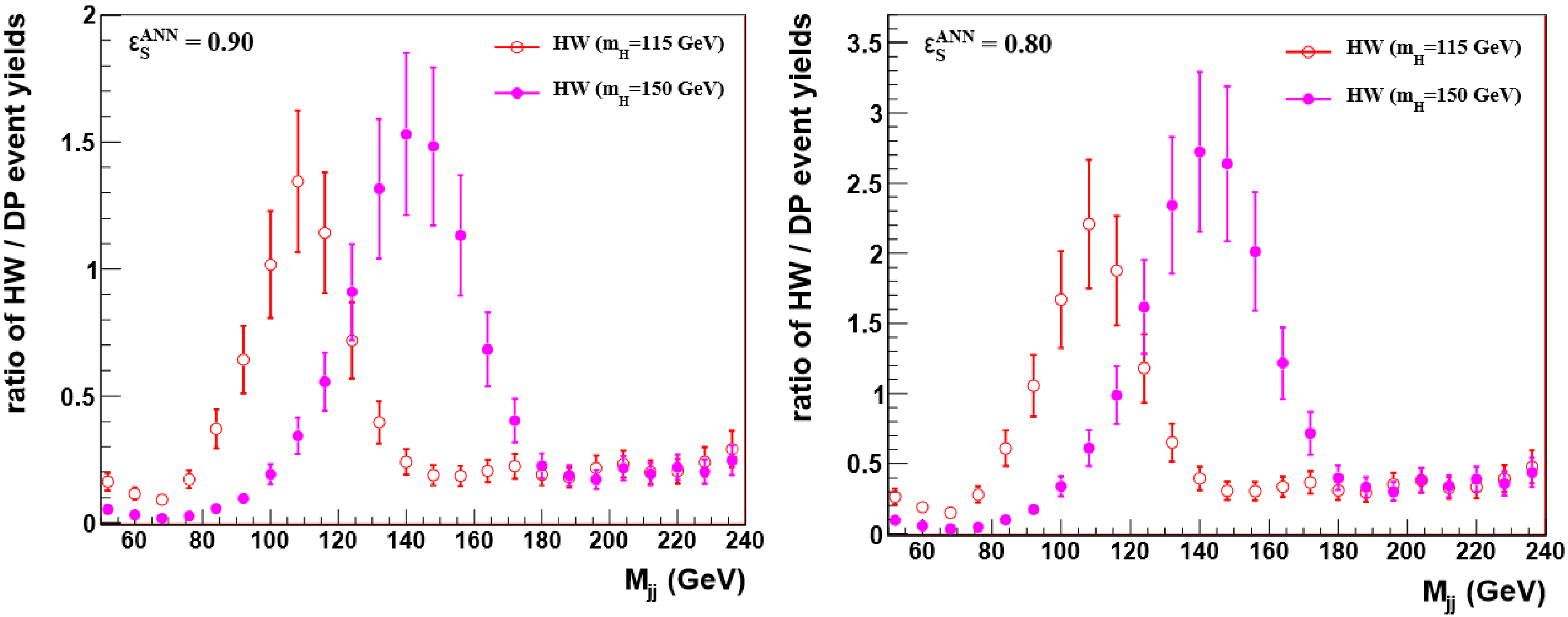
Double Parton Scattering

Signal



DP





Ratio of the HW event yields to the DP ones with account of the ANN selection efficiencies taken for the HW events to be 90% on the left and 80% on the right plot.

Calendar

[Have a safe day!](#)

Thursday, Feb. 6

9 a.m.
P5 Virtual Town Hall Meeting - One West

10:30 a.m.
All-Hands Meeting - Auditorium

Noon
Academic Lecture Series (NOTE TIME) - One West
Speaker: Boris Kayser,

Extended forecast
Weather at Fermilab

Current Security Status

Secon Level 3

Current Flag Status

Flags at full staff

Wilson Hall Cafe

Thursday, Feb. 6

- Breakfast: Canadian bacon, egg and cheese Texas toast
- Breakfast: corned-beef hash and eggs
- Carolina pulled-pork sandwich
- Mediterranean-style ziti with asparagus
- Honey baked ham
- Buffalo chicken tender wrap
- Grilled- or crispy-chicken Caesar salad
- White-chicken chili
- Chef's choice soup

Special Announcement

All-hands meeting - today in Ramsey Auditorium

Please plan to attend an all-hands meeting today at 10:30 a.m. in Ramsey Auditorium. Topics will include the laboratory's goals and priorities, the FY14 budget, employee feedback and the Fermilab Campus Master Plan. The meeting will be streamed live.

In Brief

P5 virtual town hall meeting - today in One West

closely to the art, Strommen has inscribed messages on the reverse sides of some of his gleaming glass-and-clay tablets. Ultimately, that close inspection could bring the viewer back to the elements that lie at the foundation of the interaction.

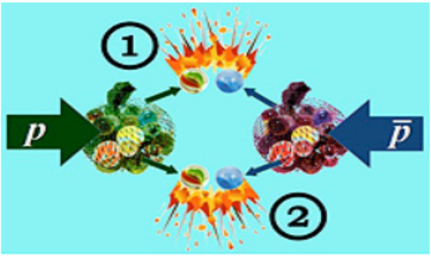
"I'm collaborating with nature and tradition," he said. "I'm a catalyst that's bringing the elements together in a framed environment."

Photo of the Day

Booster in winter

Frontier Science Result: DZero

Seeing double in proton-antiproton collisions



Protons and antiprotons are composite objects, formed from a constantly changing mixture of quarks and gluons (partons). In a small fraction of

indicates that the probability of a double-parton interaction is the same regardless of the flavor of the initial parton: Unlike most of us, parton interactions don't seem to be influenced by charm and beauty!

—*Mark Williams*

These DZero members all made significant contributions to this publication.

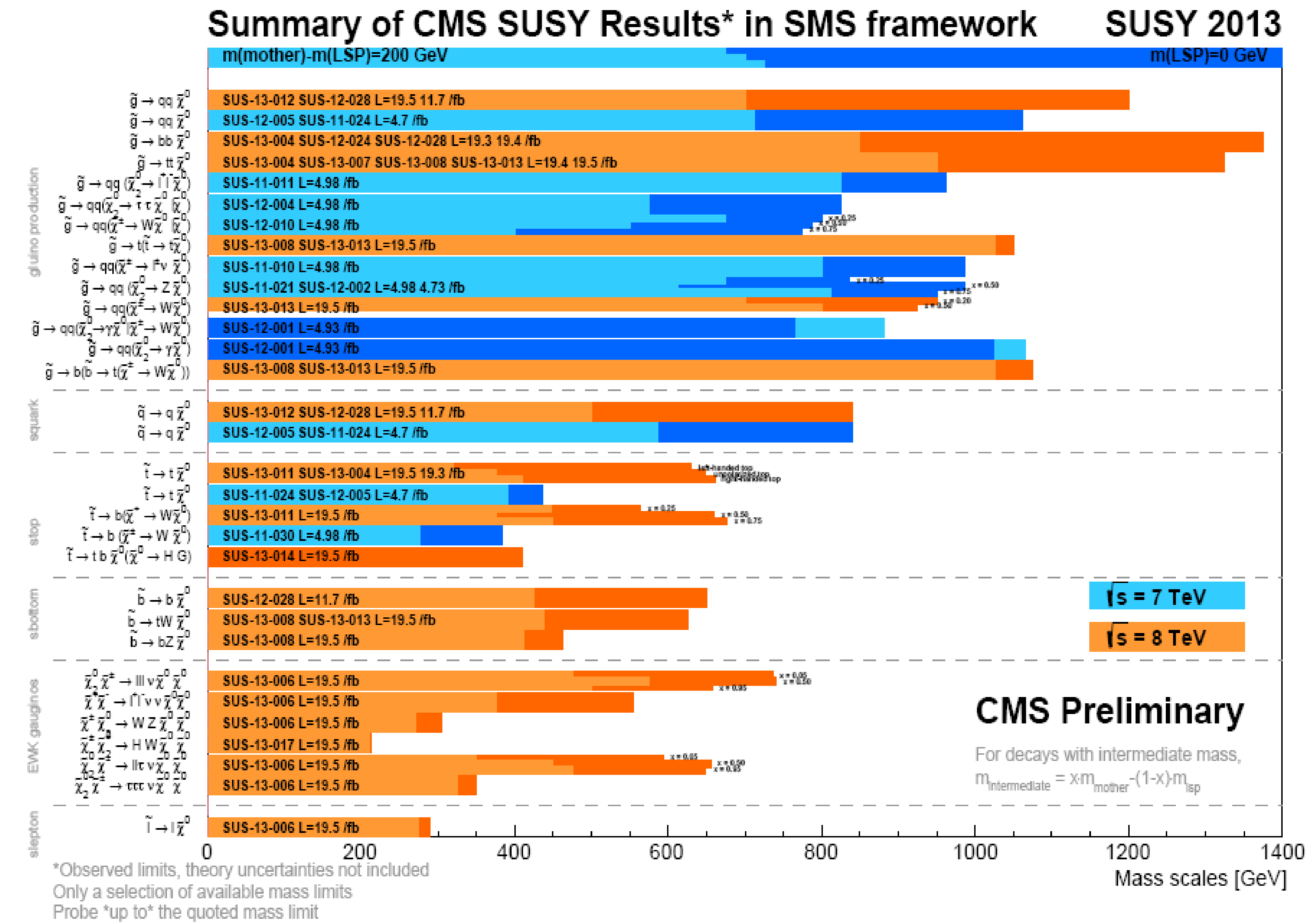
PHYSICS of:

1. Direct photon production and QCD problems,
2. Multiple parton interactions in p-pbar (and other) collisions.
3. Multiple parton interactions & backgrounds.

direct photons emerge unaltered from the hard subprocess

→ direct probe of the hard scattering dynamics

→ sensitivity to PDFs (gluon!) …but only if theory works



Summary of CMS SUSY Results* in SMS framework
SUSY 2013
m(mother)-m(LSP)=200 GeV
m(LSP)=0 GeV
SUS-13-012 SUS-12-028 L=19.5 11.7 /fb
SUS-12-005 SUS-11-024 L=4.7 /fb
SUS-13-004 SUS-12-024 SUS-12-028 L=19.3 19.4 /fb
SUS-13-004 SUS-13-007 SUS-13-008 SUS-13-013 L=19.4 19.5 /fb
SUS-11-011 L=4.98 /fb
SUS-12-004 L=4.98 /fb
SUS-12-010 L=4.98 /fb
SUS-13-008 SUS-13-013 L=19.5 /fb
SUS-11-010 L=4.98 /fb
SUS-11-021 SUS-12-002 L=4.98 4.73 /fb
SUS-13-013 L=19.5 /fb
SUS-12-001 L=4.93 /fb
SUS-12-001 L=4.93 /fb
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SUS-13-006 L=19.5 /fb
gluino production
squark
stop
sbottom
EWK gauginos
slepton
√s = 7 TeV
√s = 8 TeV
CMS Preliminary
For decays with intermediate mass,
m_intermediate = x·m_mother - (1-x)·m_lsp
0
200
400
600
800
1000
1200
1400
Mass scales [GeV]
*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe *up to* the quoted mass limit