Recent Results from CDF on Soft QCD and Diffraction

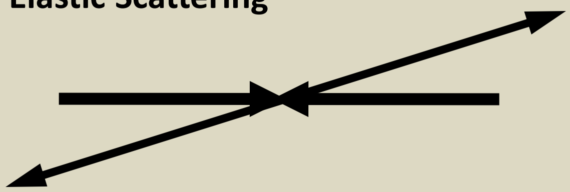
Christina Mesropian

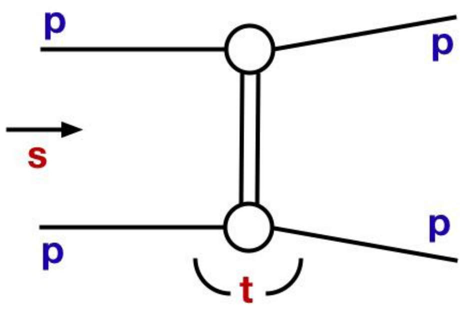
The Rockefeller University

What Happens when hadrons collide?

Proton-(anti)Proton Collisions

Elastic Scattering





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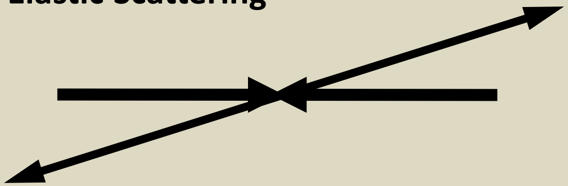
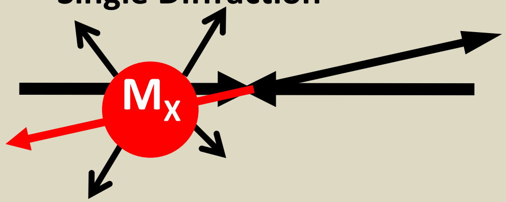
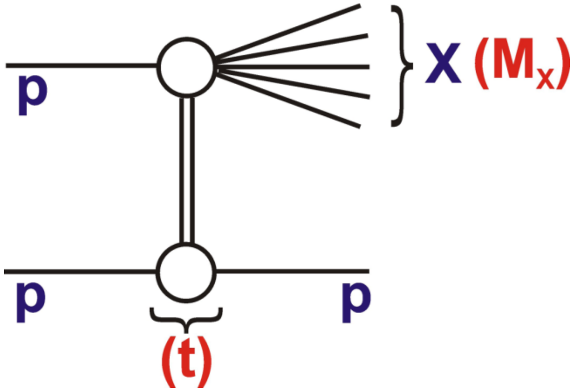


Single Diffraction





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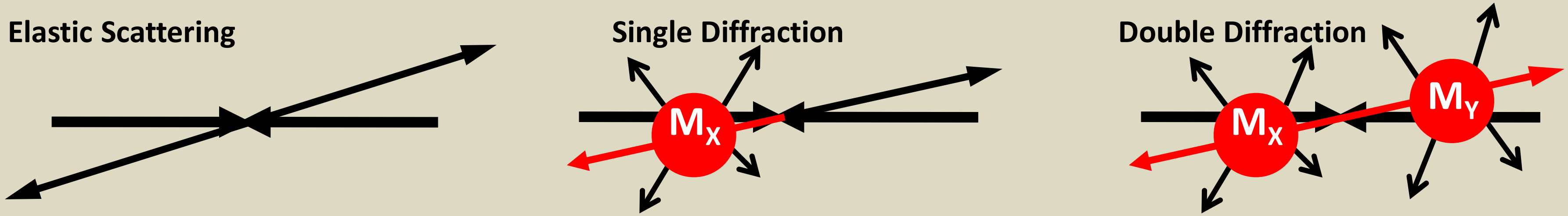

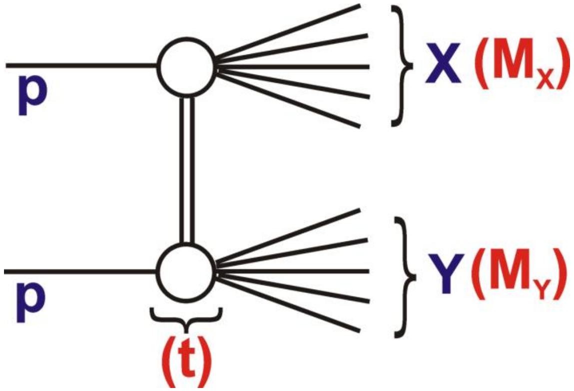

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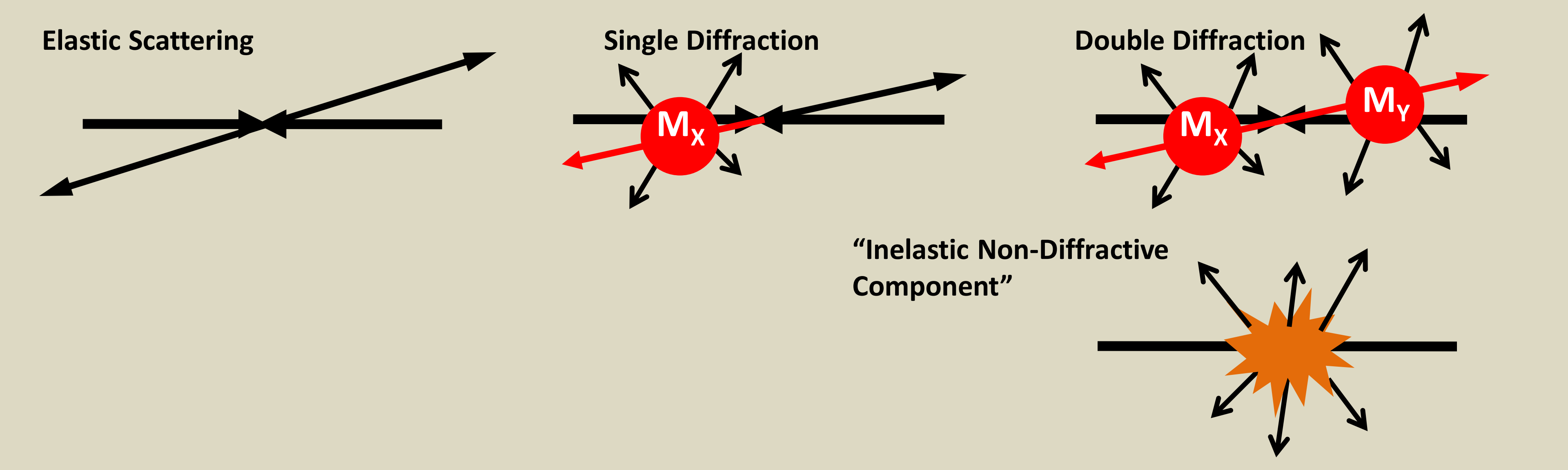
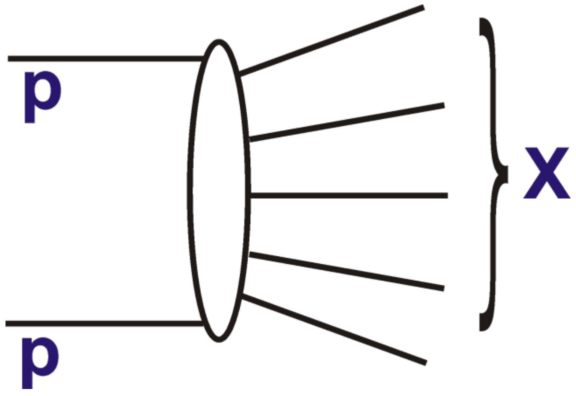
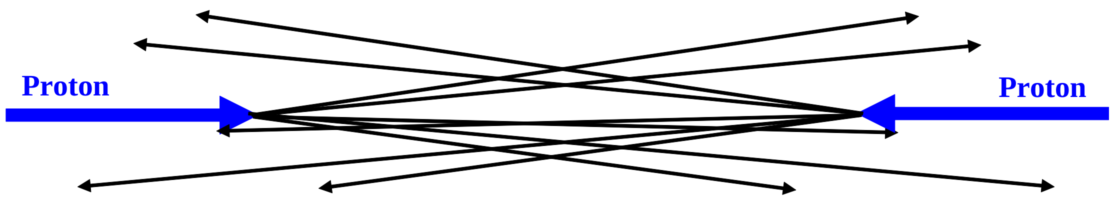
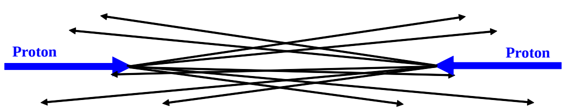




The Inelastic Non-Diffractive Cross-Section





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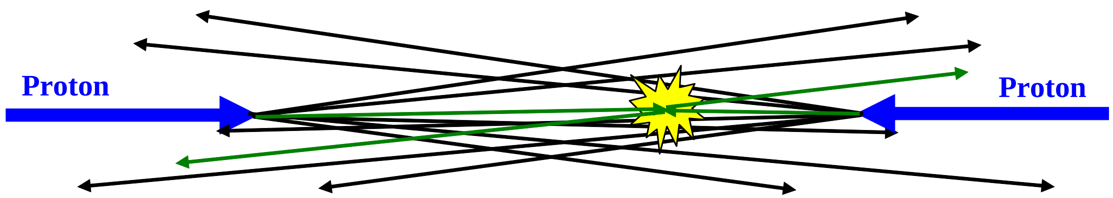
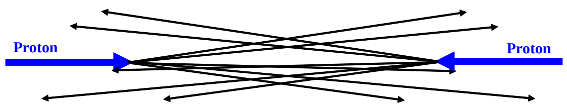
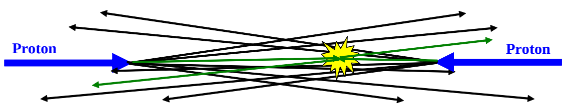


"Semi-hard" parton-parton collision (p_T < ≈2 GeV/c)



+



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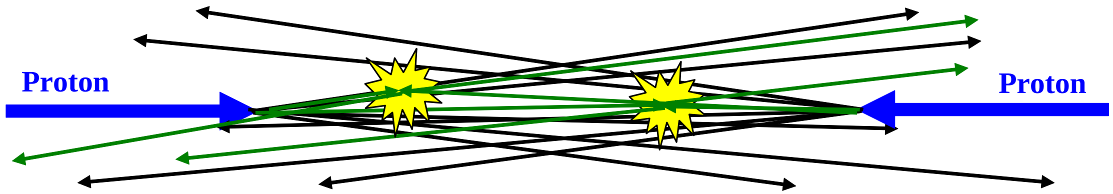
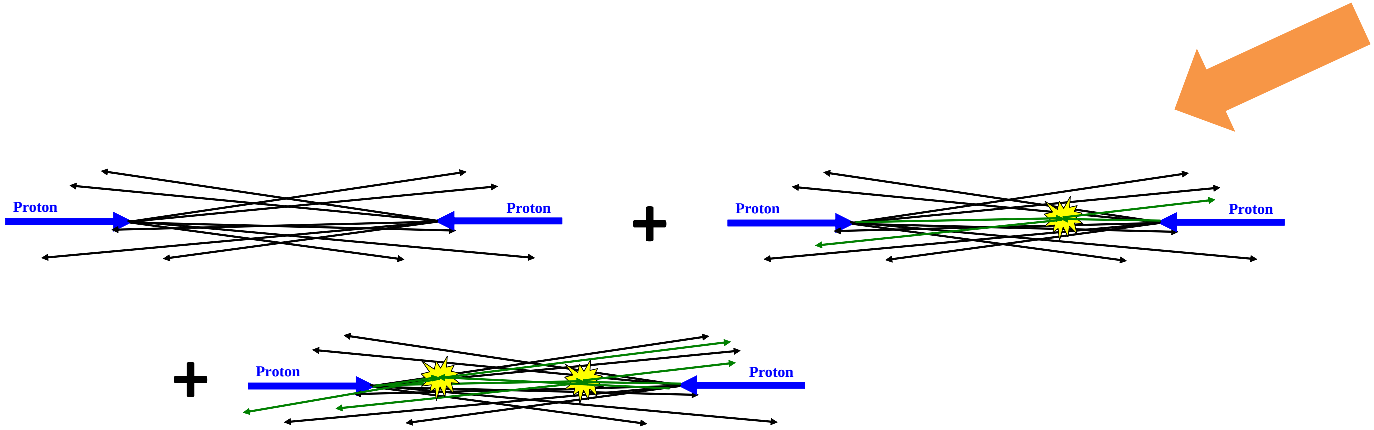


“Semi-hard” parton-parton collision ($p_T < \approx 2$ GeV/c)



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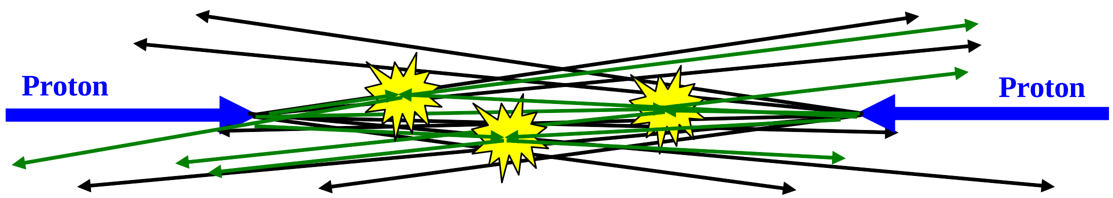

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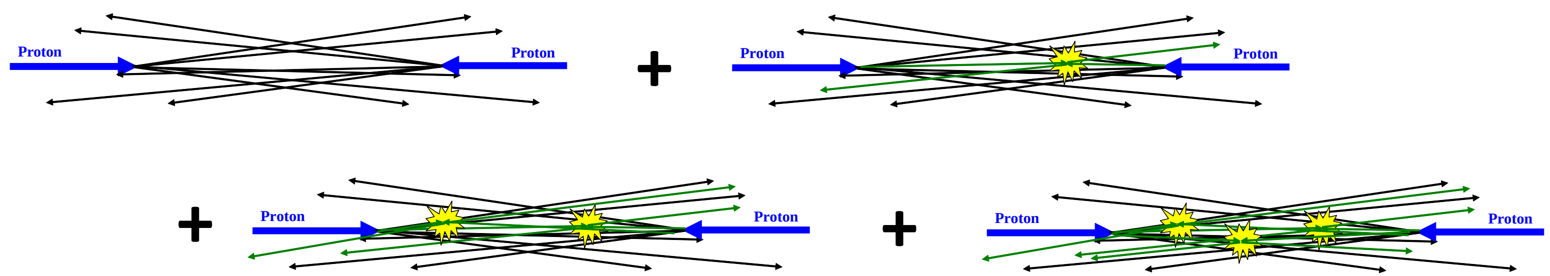
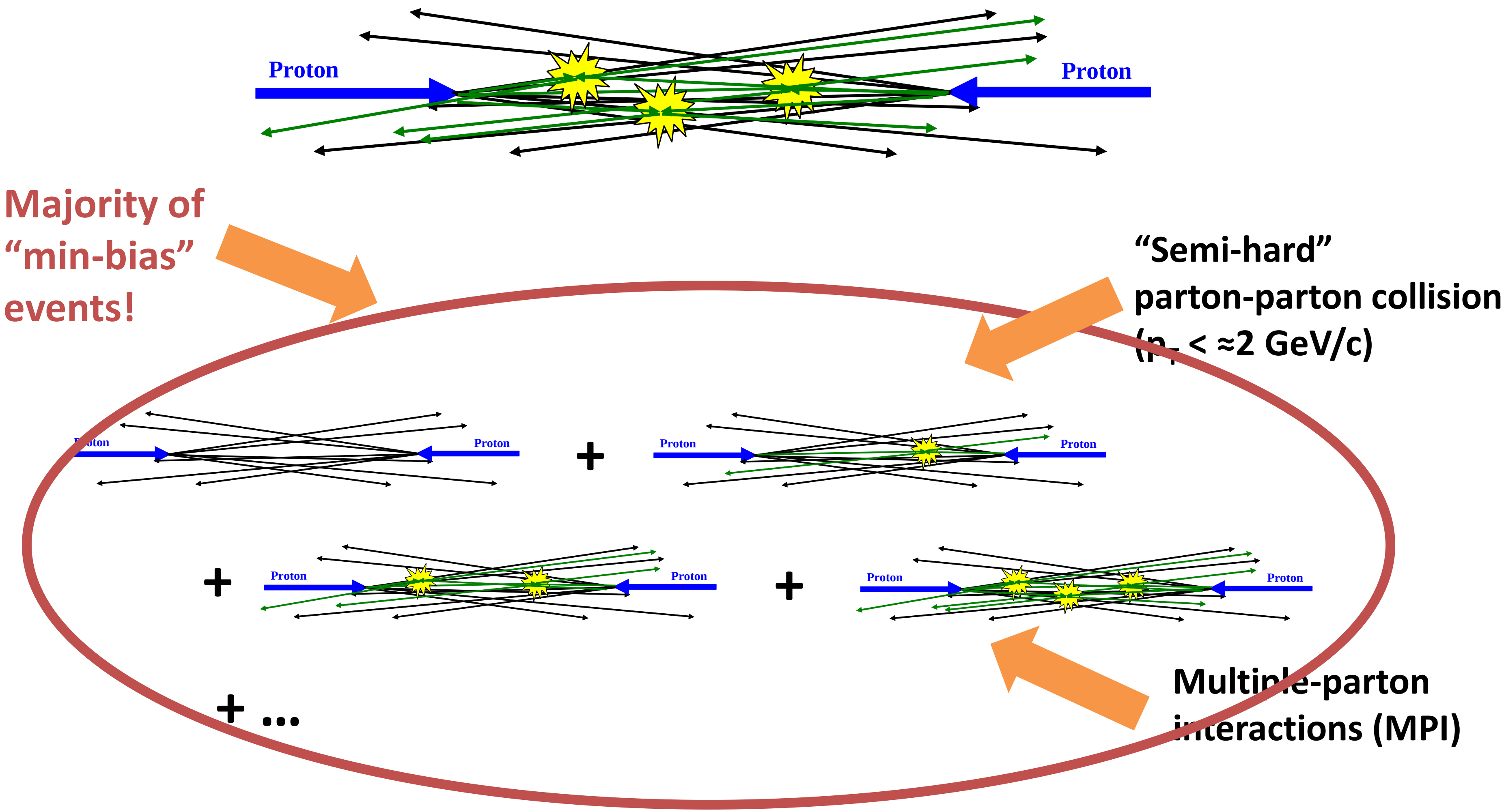


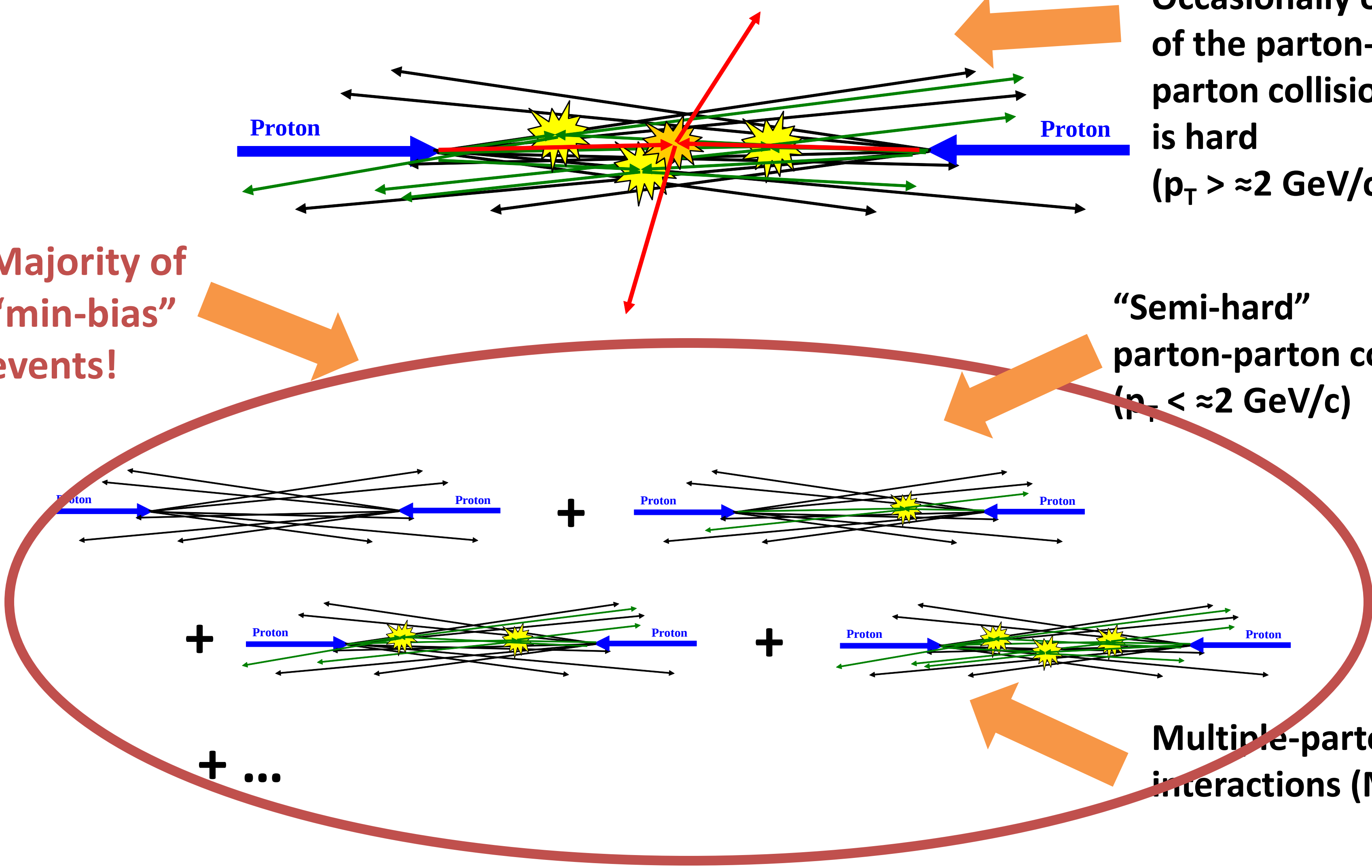
Multiple-parton interactions (MPI)

The Inelastic Non-Diffractive Cross-Section



The Inelastic Non-Diffractive Cross-Section

Occasionally one of the parton-parton collisions is hard ($p_T > \approx 2$ GeV/c)



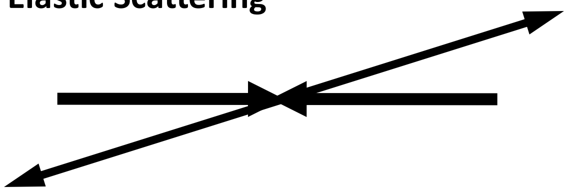
Majority of "min-bias" events!

"Semi-hard" parton-parton collision ($p_T < \approx 2$ GeV/c)

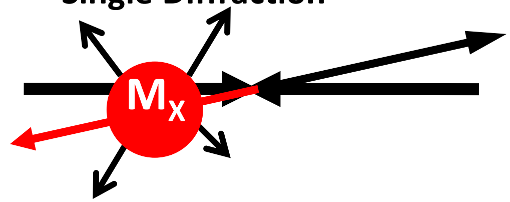
Multiple-parton interactions (MPI)

Proton-(anti)Proton Collisions

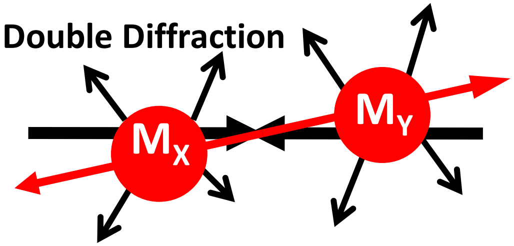
Elastic Scattering



Single Diffraction

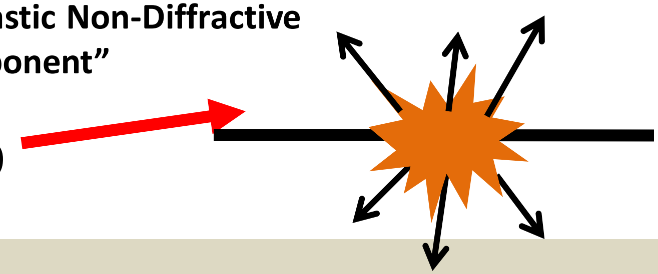


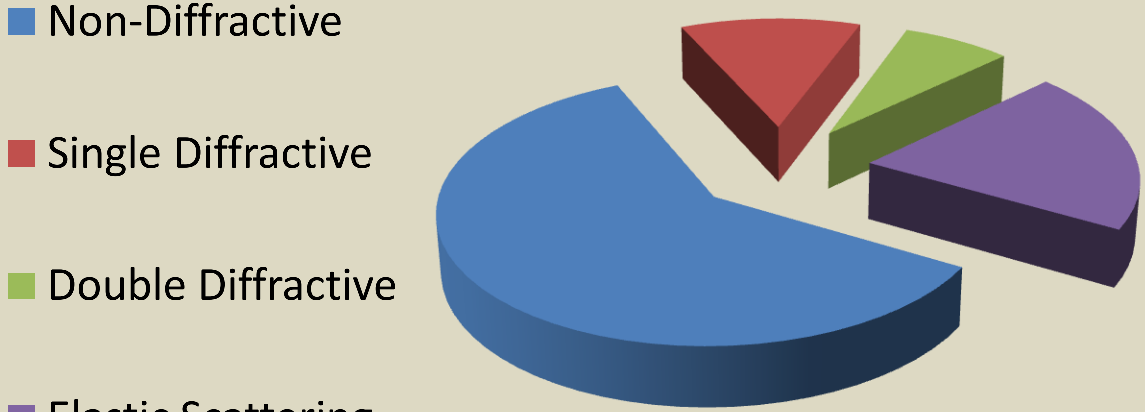
Double Diffraction



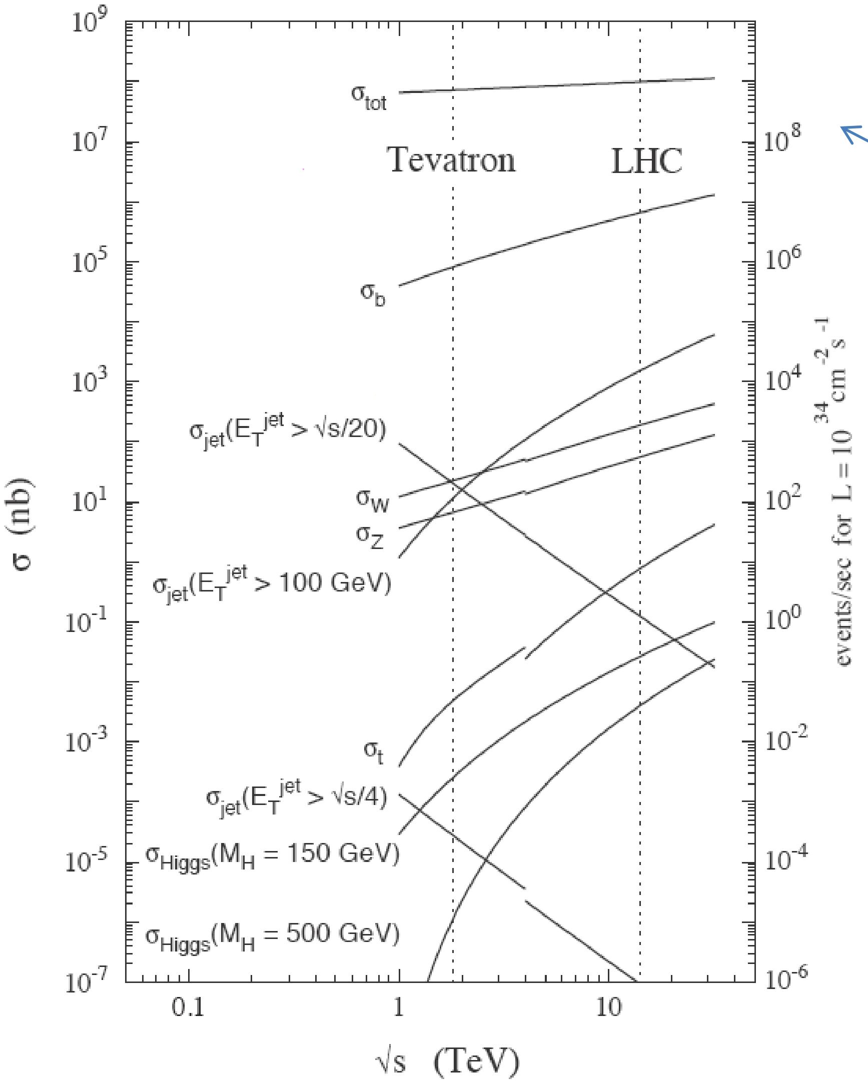
"Inelastic Non-Diffractive Component"

$$\sigma_{Total} = \sigma_{EL} + \sigma_{SD} + \sigma_{DD} + \sigma_{ND}$$





Proton-(anti)Proton Collisions

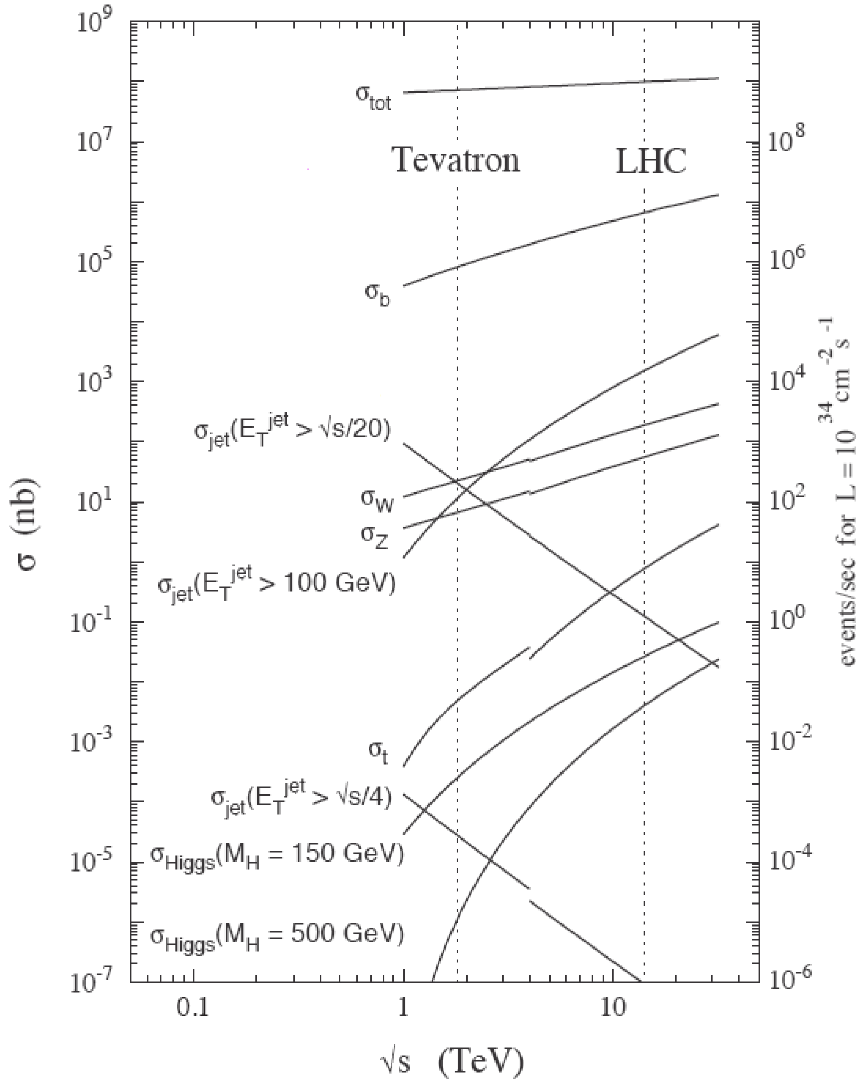


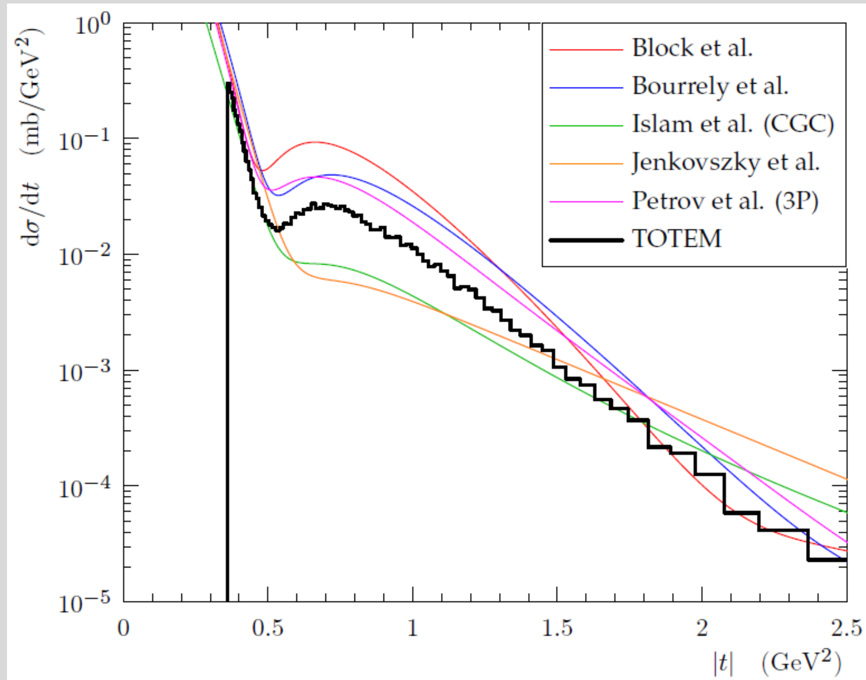
much harder to calculate this

than

this

Proton-(anti)Proton Collisions



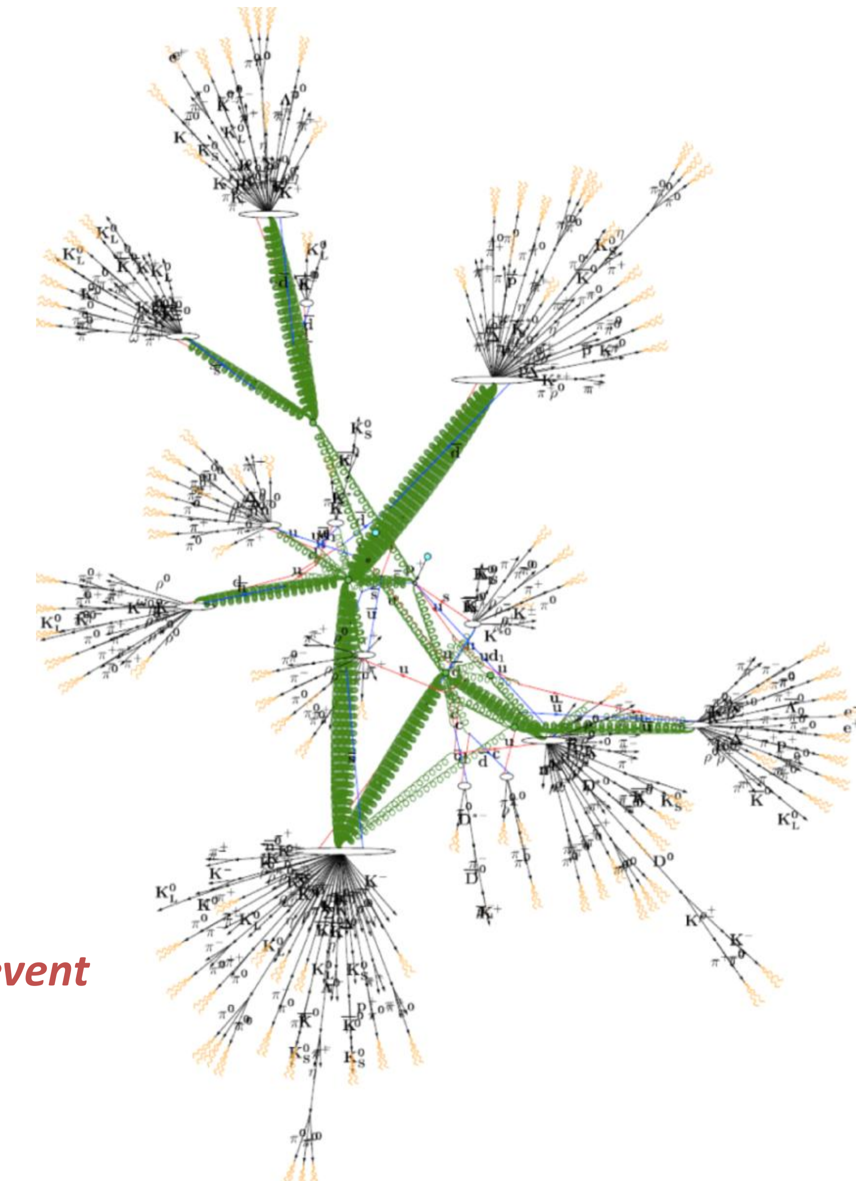


Comparison of recent TOTEM results on the total cross section with several theoretical models

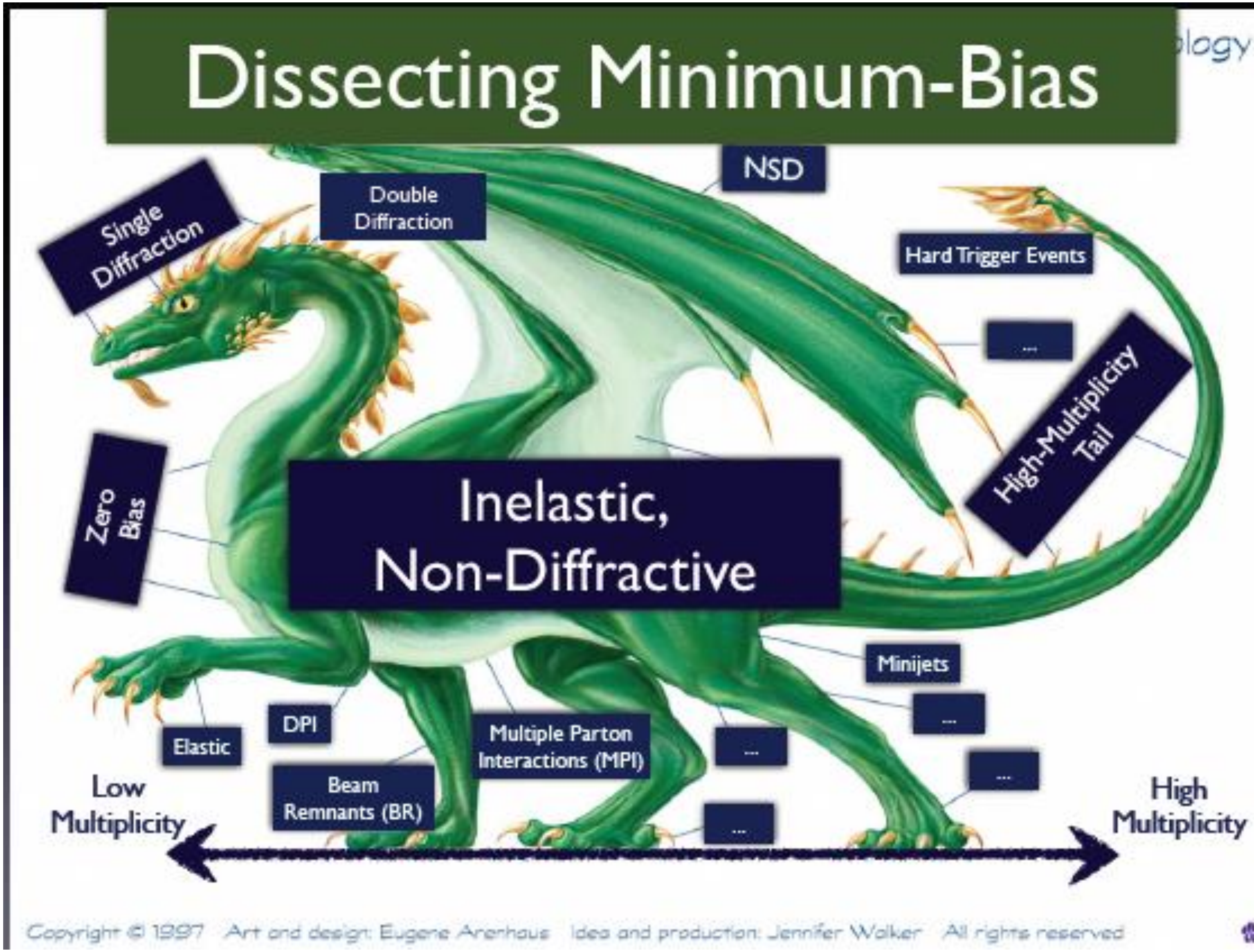
Soft Processes

It's complicated:

- **data often ahead of phenomenology**
- **non-perturbative contributions important even for hard-scattering studies**



visualization of "minimum bias" event
in pp $\sqrt{s}$=7 TeV collisions
in PYTHIA8 with MCViz



slide from talk by Peter Scands at "MB & UE Workshop" at CERN, March 2010

Motivation

Why Study soft QCD:

Dominant strong interaction processes fundamental to our basic understanding of the Standard Model.

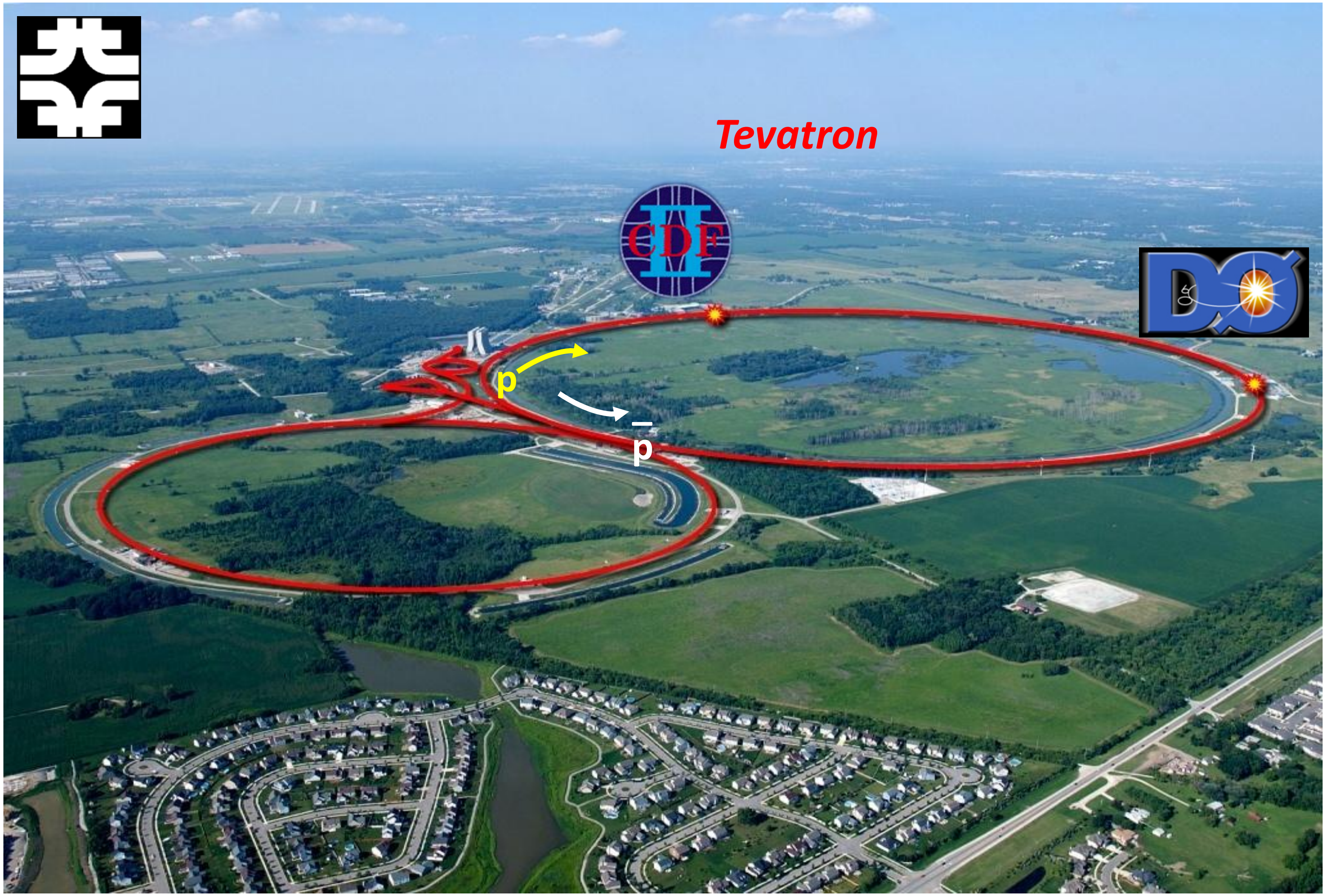
“Big” questions:

confinement
hadronic mass generation
non-perturbative degrees of freedom
strong coupling and super-Gravity…

Practical aspects:

UE modeling at LHC
Pile-up modeling at LHC
Cosmic ray showers modeling

Tevatron $p\bar{p}$ Collider at FNAL



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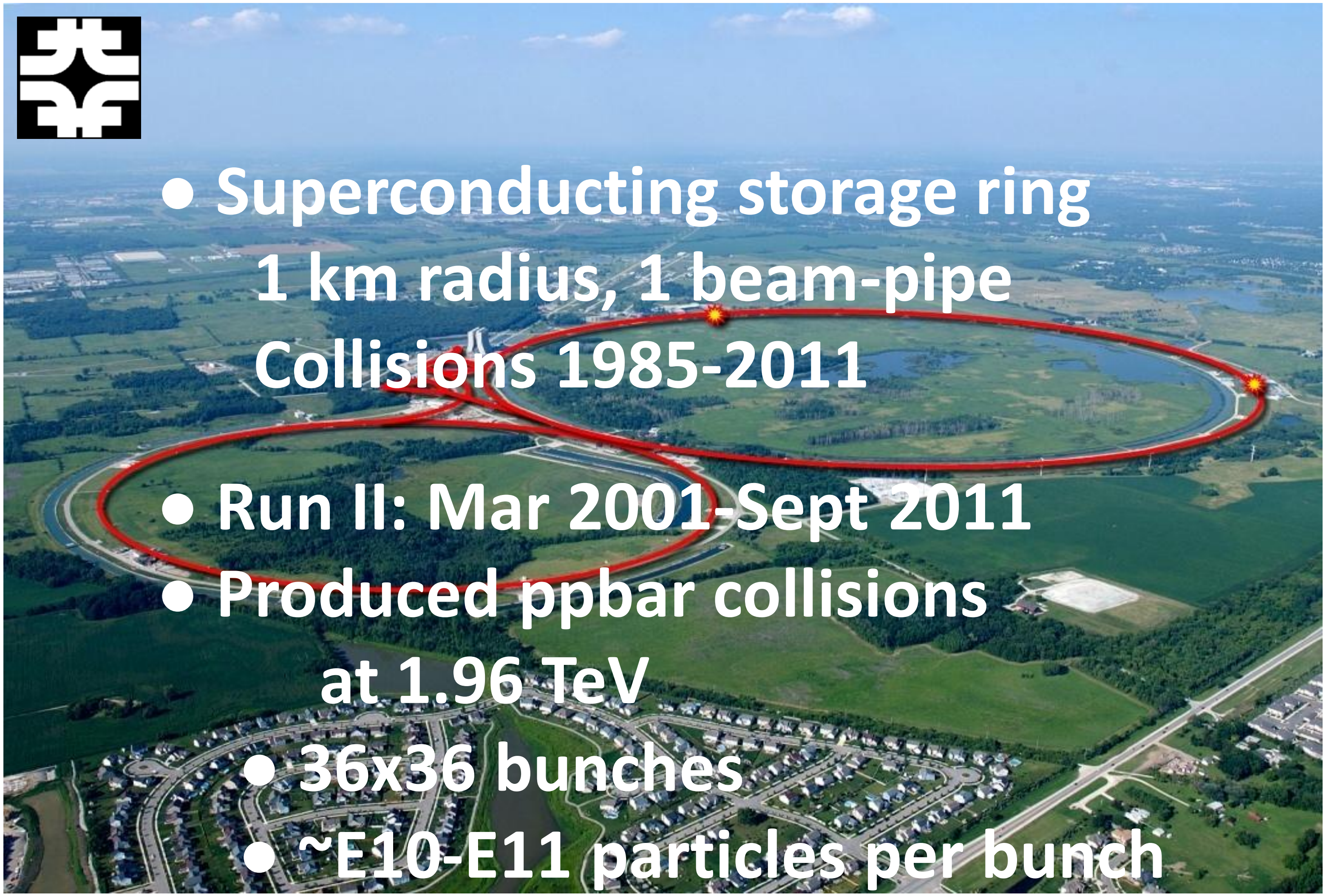
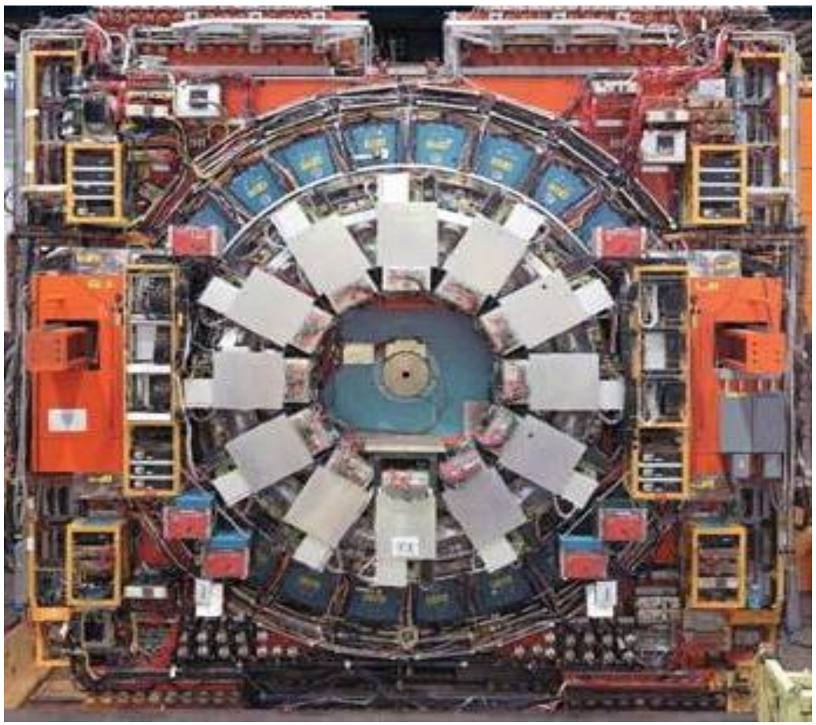
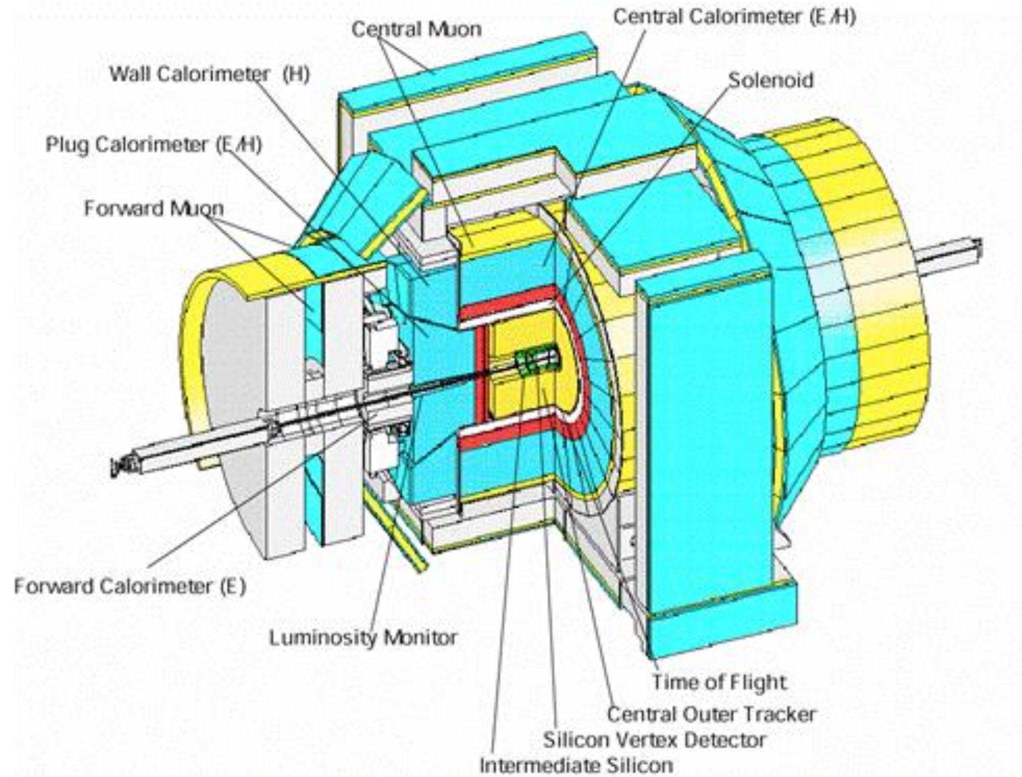


- Superconducting storage ring
  - 1 km radius, 1 beam-pipe
  - Collisions 1985-2011
- Run II: Mar 2001-Sept 2011
- Produced ppbar collisions at 1.96 TeV
  - 36x36 bunches
  - ~E10-E11 particles per bunch

The Collider Detector at Fermilab (CDF)



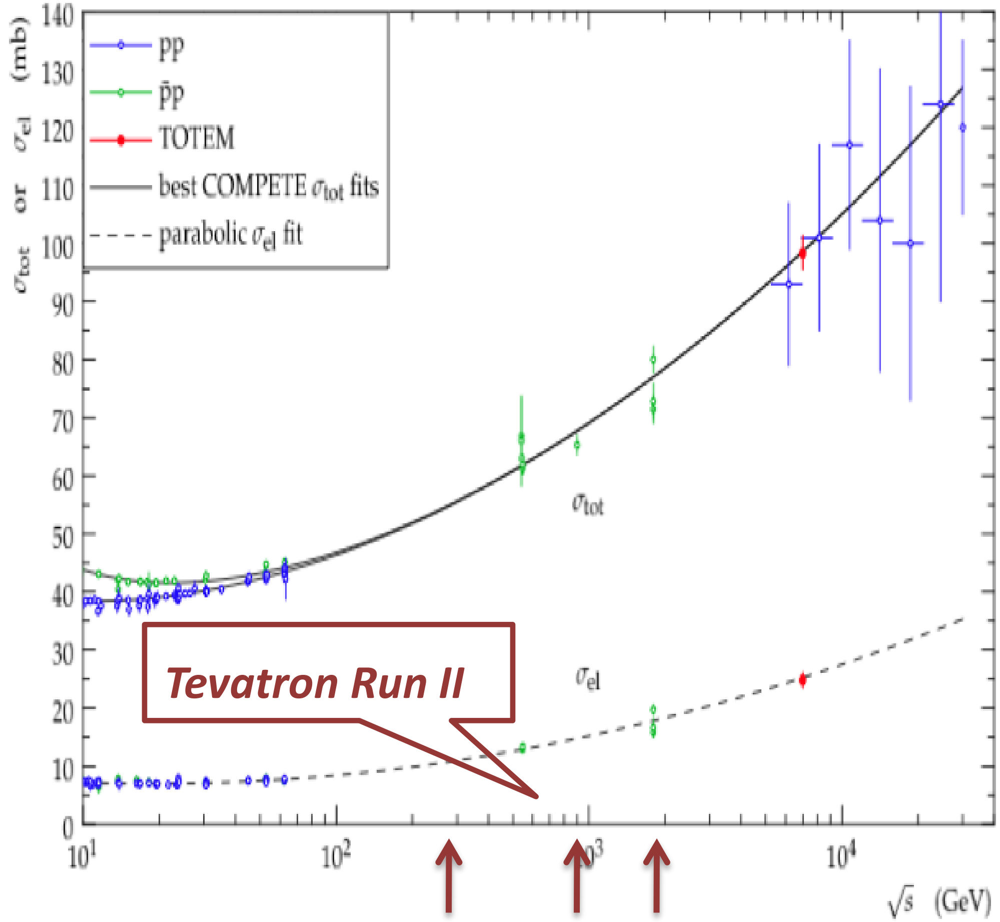


- Top performance (>85% data taking efficiency)
- ~10 fb^{-1} good for analysis data

Tevatron energy scan

Study s-dependence of high cross-sections physics

…mostly non-pQCD



1. **Study of MB events:**
2. **Study of UE events**
3. **Gap-X Gap events**

Tevatron energy scan - data

September 8 – 16, 2011

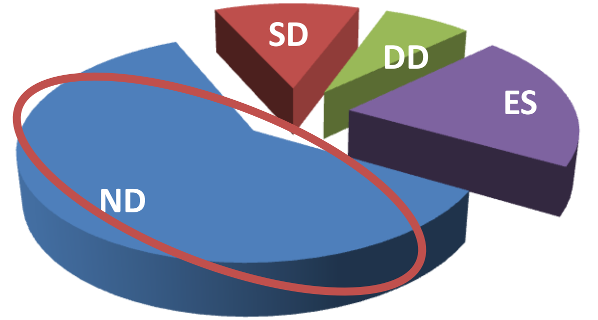
- 3x3 bunches
- Special trigger
- 1 interaction per crossing (no pile-up)

Total data taking time :

10 h at 300 GeV and 39 h at 900 GeV

$\sqrt{s}$	0-bias	Minbias	Gap-X-Gap	Jets	e,μ,ν	Total # events
300	1.89 M	12.1 M	9.2 M	8.3 K	352	23.2 M
900	8.0 M	54.3 M	21.8 M	550 K	16 K	84.7 M

Definitions: MB and UE

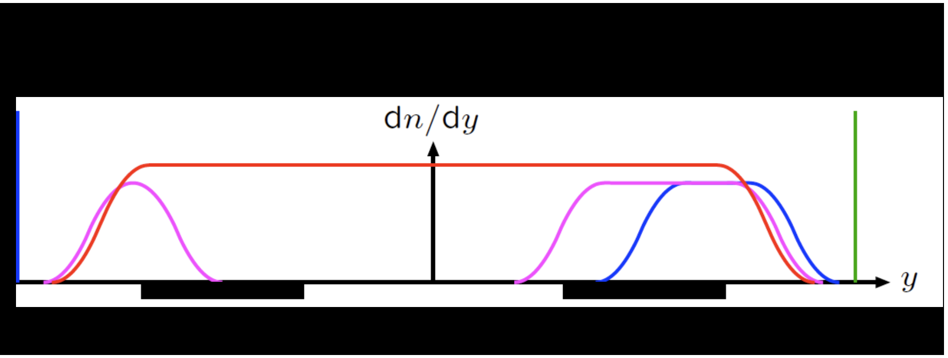


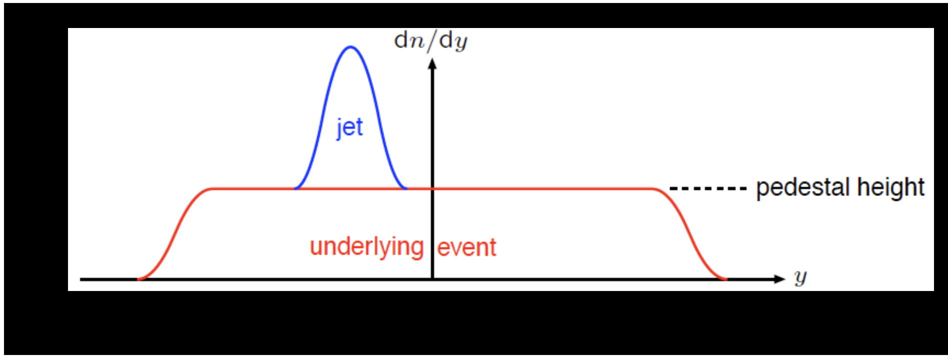
Minimum Bias (MB) – is the name of trigger

data sample is defined by trigger implementation

Underlying Event (UE) – is defined on event by event basis

everything else except 2->2 hard scatter





MB is background to high luminosity pile-up events

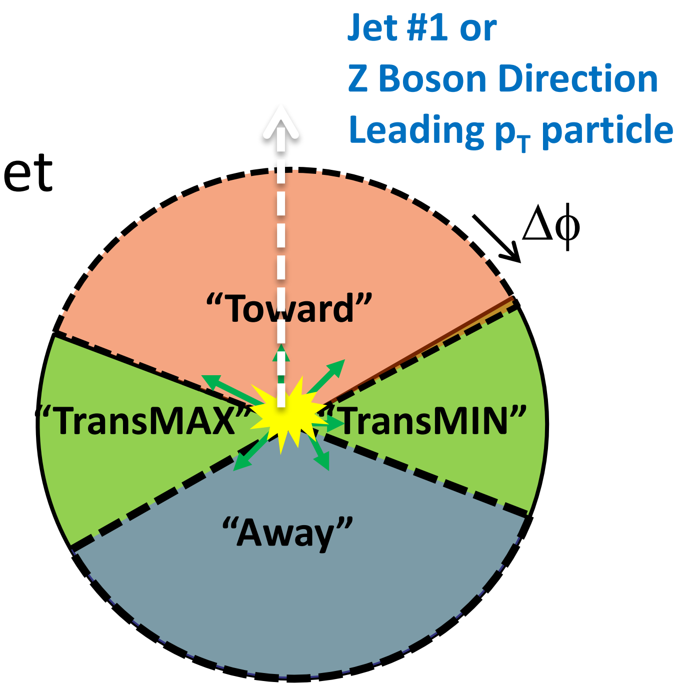
UE is background to high p_T observables (jets etc…)

The Underlying Event

PRD 65, 092002 (2002)
PRD 70, 072002 (2004)
PRD 82, 034001 (2010)

$\Delta\phi$ relative to the leading calorimeter jet (or the Z-boson, or leading p_T particle)

- $|\Delta\phi| < 60^o$ as **Toward**
- $60^o < |\Delta\phi| < 120^o$ as **Transverse**
- $|\Delta\phi| > 120^o$ as **Away**
- TransMAX (MIN) - “Transverse” region with largest (smallest) number of charged particles



Underlying Event is
Beam Beam Remnants (BBR)
Final State Radiation (FSR)
Initial State Radiation (ISR)
Multi-Parton Interactions (MPI)

Data corrected to the particle level:
Tracks p_T>0.5 GeV/s; $|\eta|$<1
Jets with $|\eta|$<2
Drell-Yan : *ll = ee, $\mu\mu$*
p_T>20 GeV/c; $|\eta|$<1
70 GeV/c^2<M_{pair}<110 GeV/c^2

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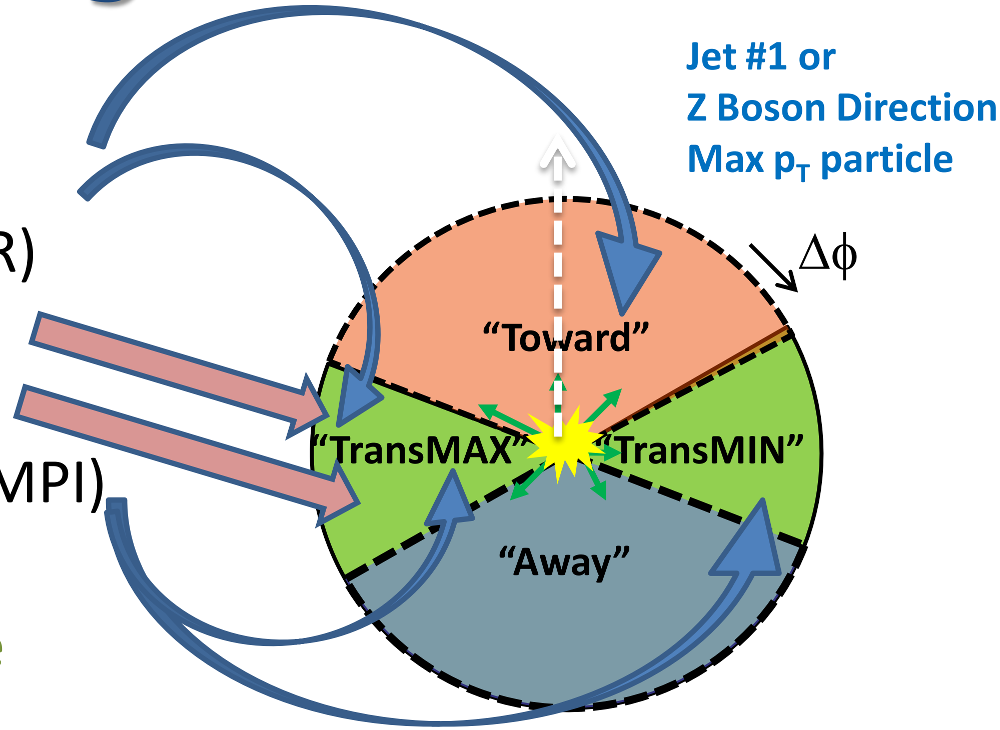

Different regions sensitive to different contributions:

TransMIN – BBR+MPI
TransMAX – BBR+MPI+ ISR+FSR

Data corrected to the particle level:
Tracks p_T>0.5 GeV/s; $|\eta|<1$
Jets with $|\eta|<2$
Drell-Yan : *ll = ee, $\mu\mu$*
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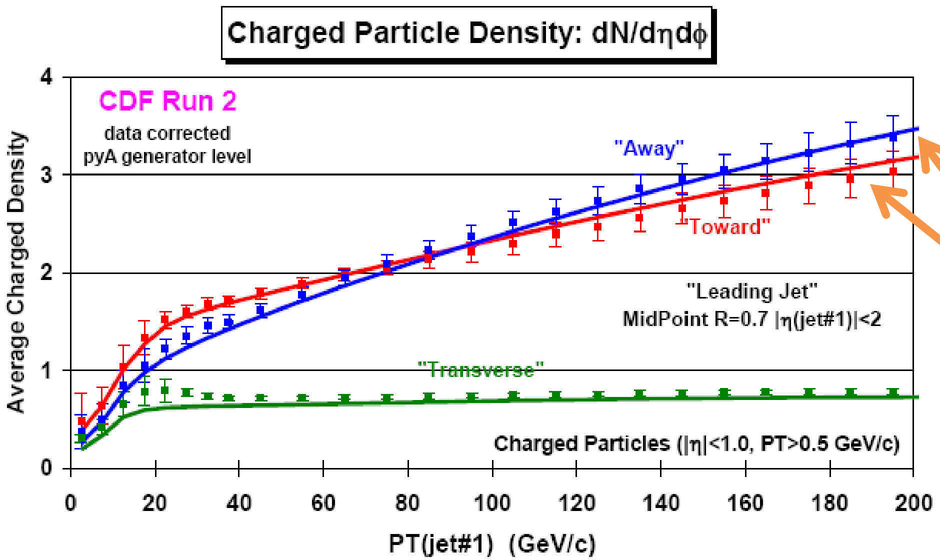
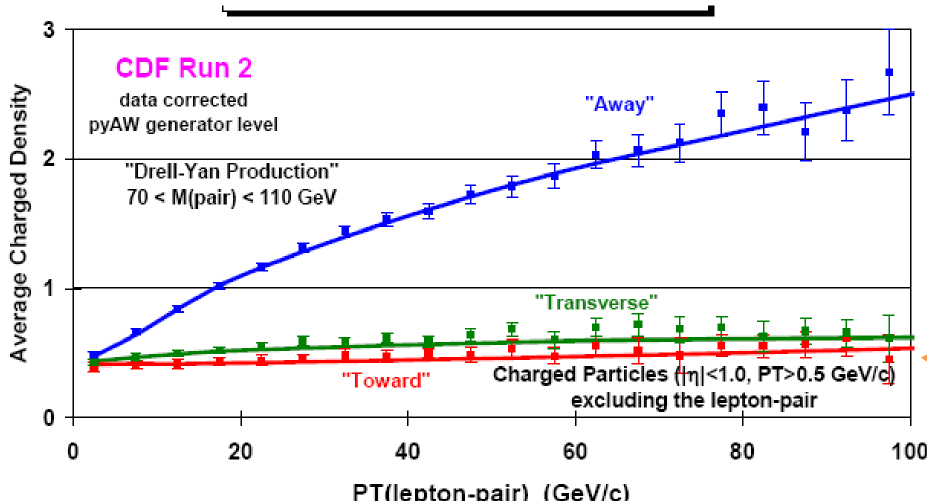
70 GeV/c^2<M_{pair}<110 GeV/c^2

UE in Drell-Yan and incl. jet events

[Phys. Rev. D82, 034001 (2010)]





Event topologies:

- Leading Jet
- Drell-Yan

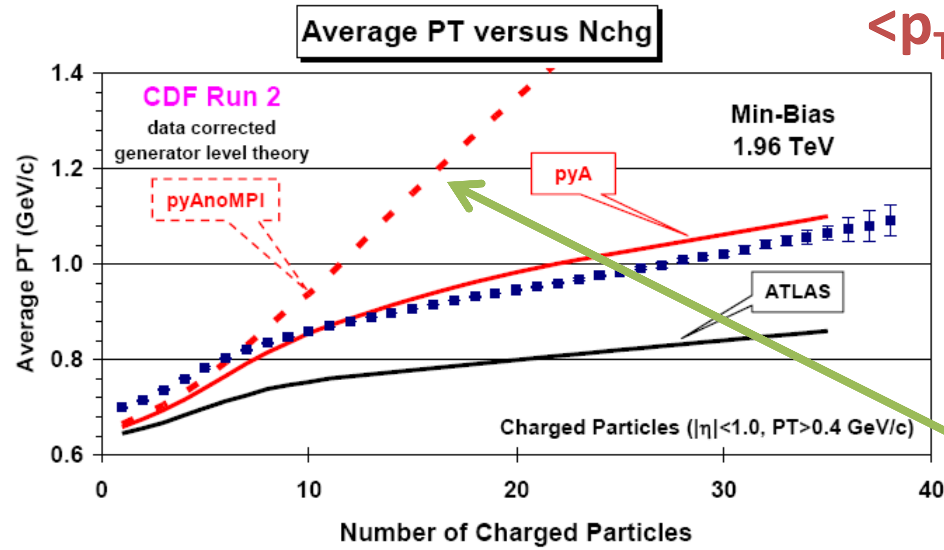
at high leading jet p_T – "toward"-side and "away"-side jets

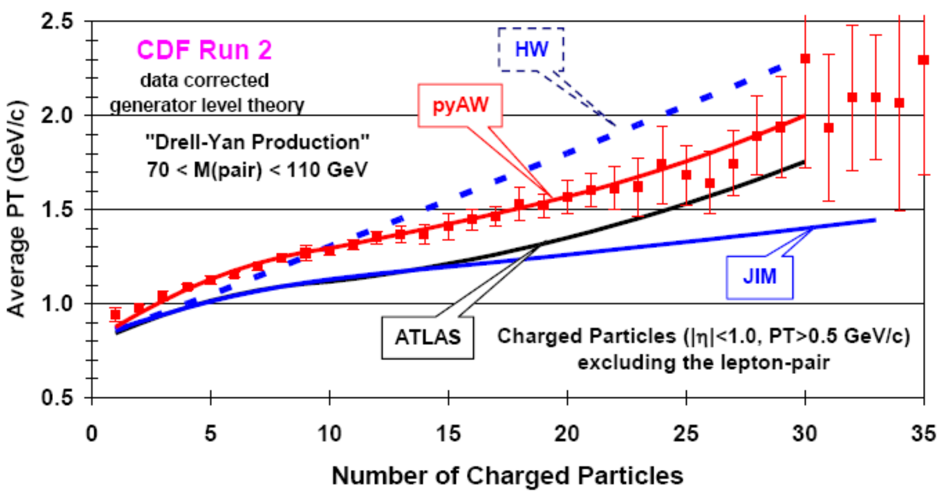
away side jet

no FSR!
exclude leptons
"towards"="Trans"

MB studies: MPI contributions

[Phys. Rev. D82, 034001 (2010)](#)





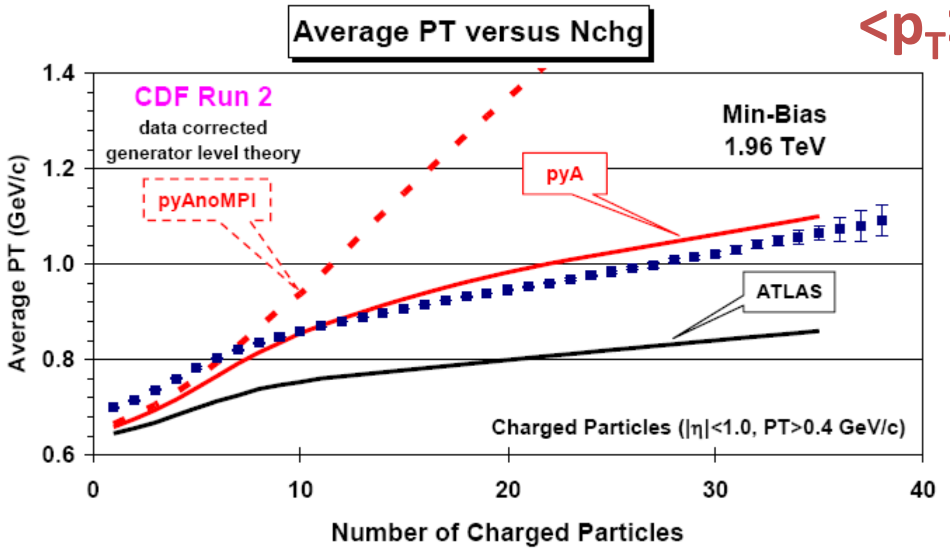
$\langle p_T \rangle$ vs charged particle multiplicity –

a measure of the amount of **hard** vs **soft** processes contributing to minimum-bias collisions; variable sensitive to simulation of multi parton interactions (MPI)

if only hard-scatter would contribute

flat dependence if only soft beam remnants would contribute

MB studies: MPI contributions



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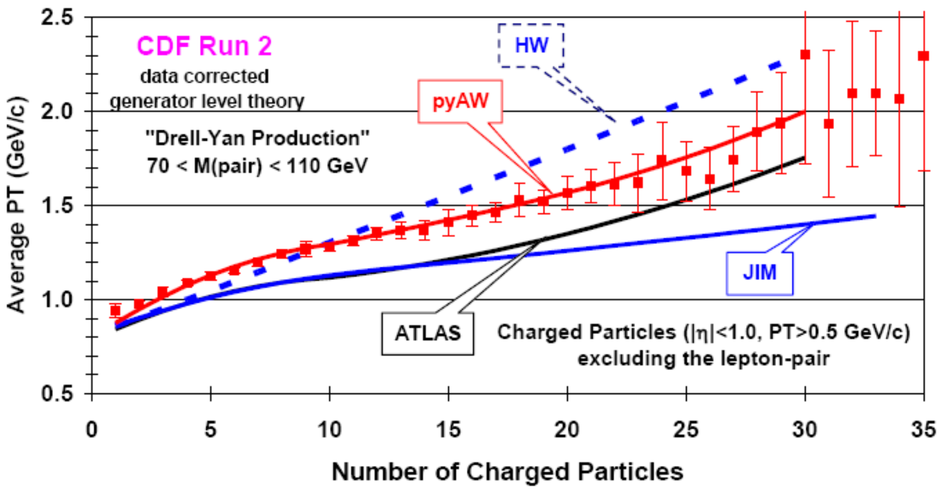
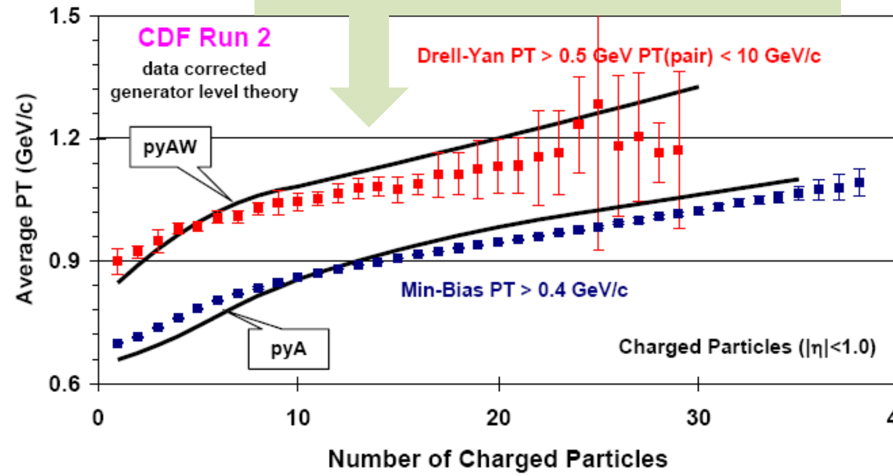


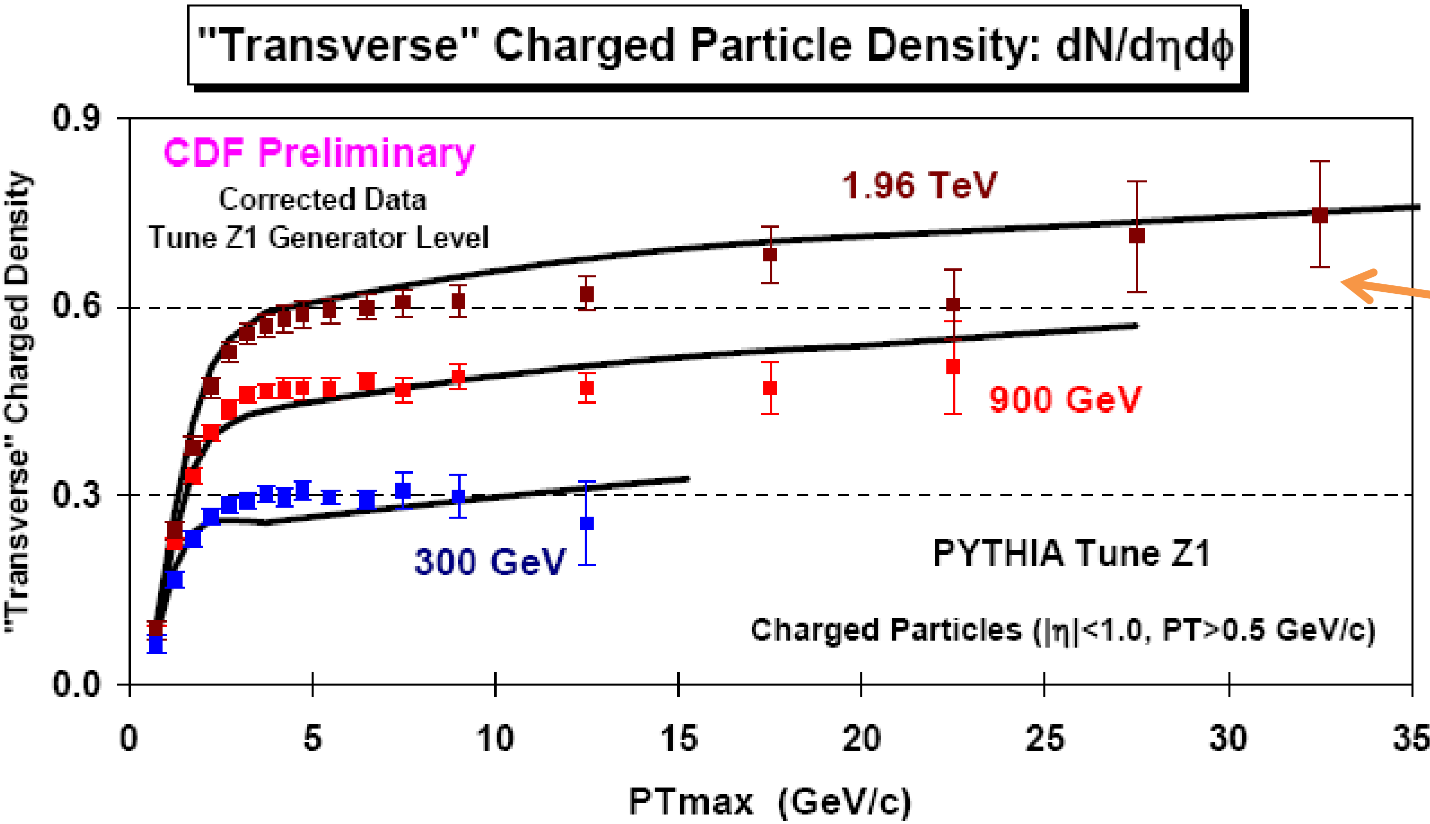
very similar behavior



Energy Dependence of UE

use "Tevatron energy scan" data at 300 GeV, 900 GeV, 1960 GeV

studying charged particles (p_T>0.5 GeV, $|\eta|$<0.8(1.0)) produced in association with the leading charged particle P_{Tmax}



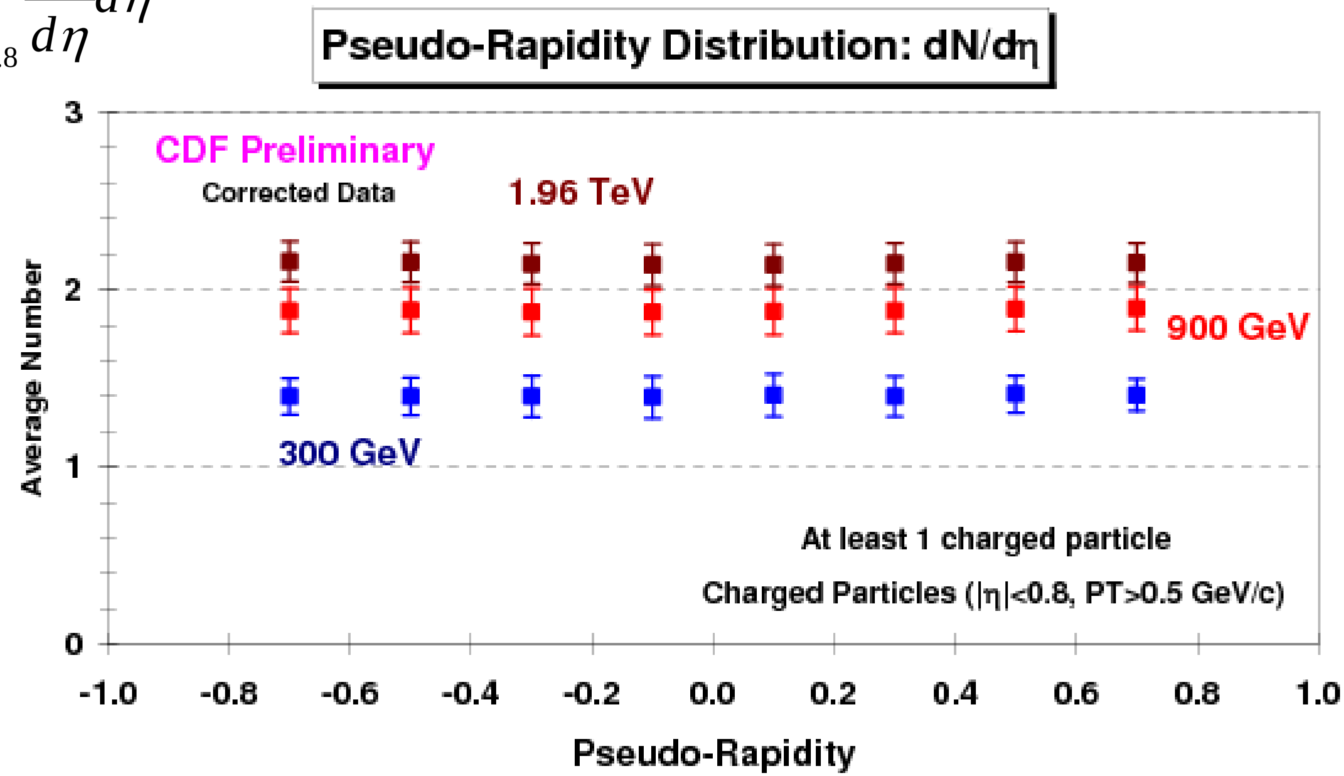
good agreement with PYTHIA Tune Z1

Energy Dependence of MB

use "Tevatron energy scan" data at 300 GeV, 900 GeV, 1960 GeV

studying pseudo-rapidity distribution, dN/dη, for charged particles (p_T>0.5 GeV, |η|<0.8(1.0))

$$N_{chg} = \int_{-0.8}^{0.8} \frac{dN}{d\eta} d\eta$$



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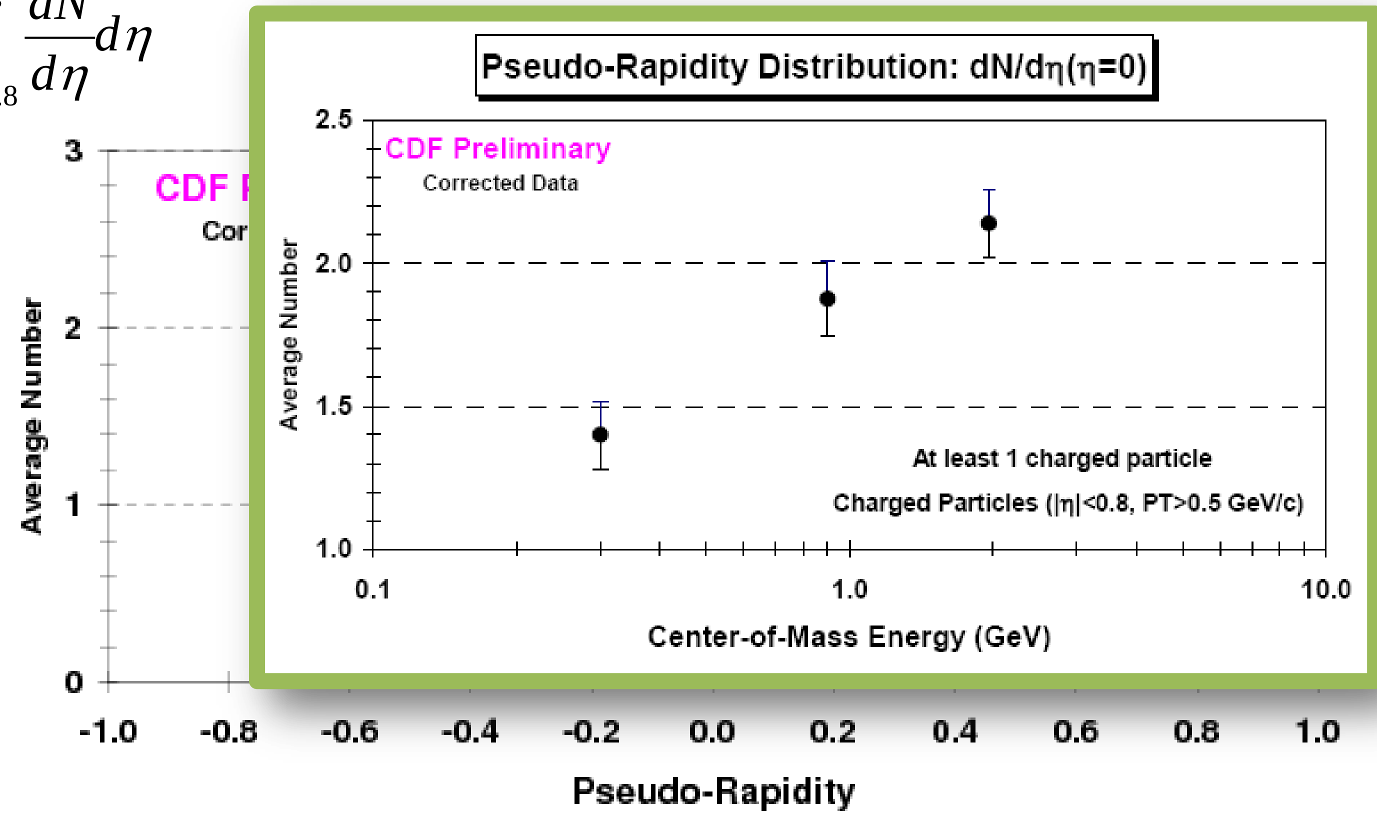

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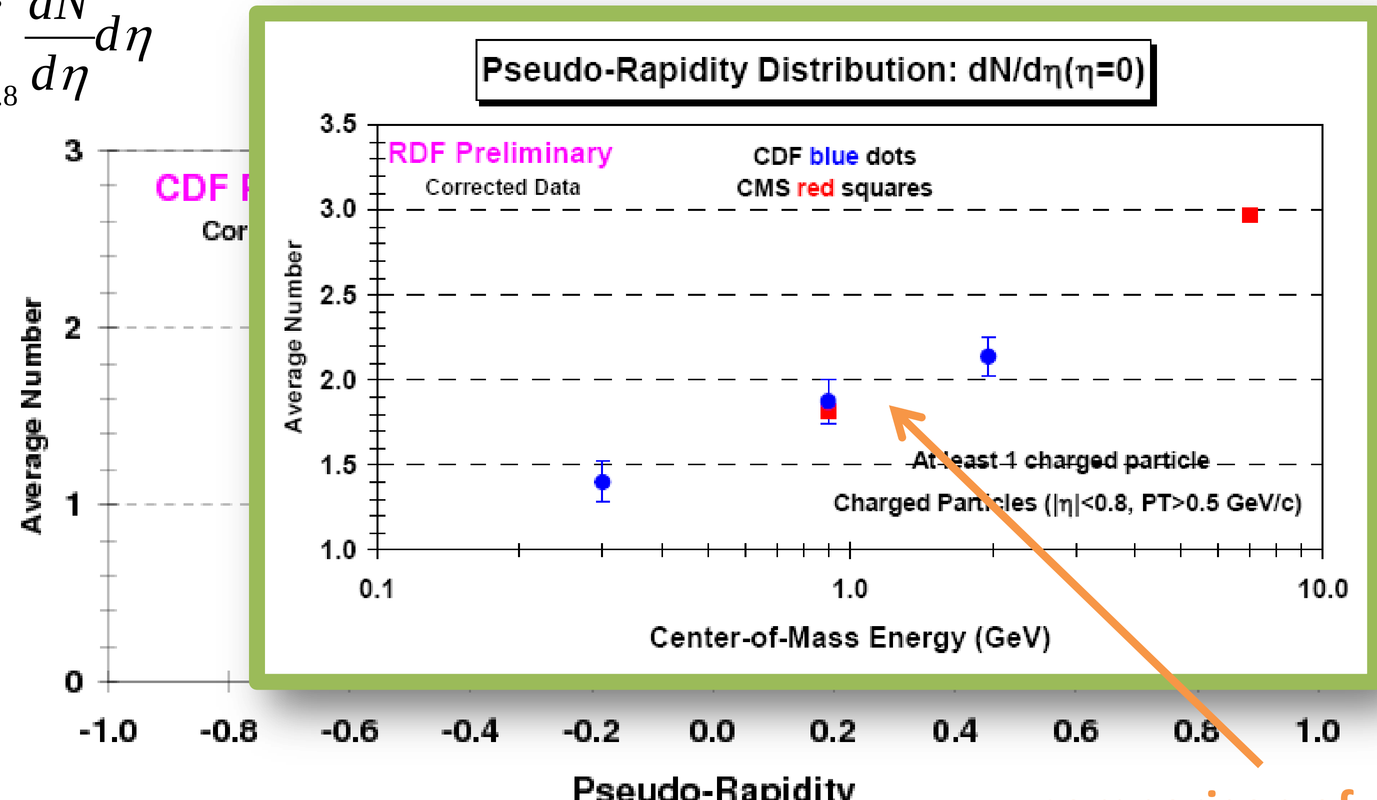
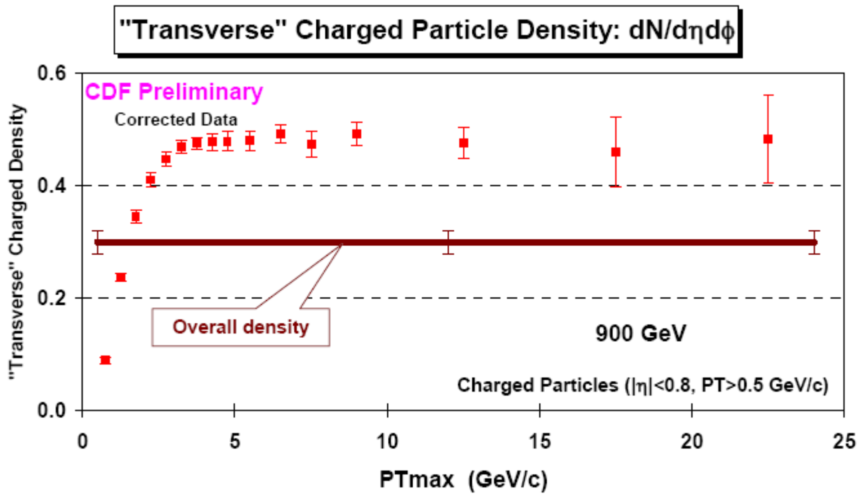
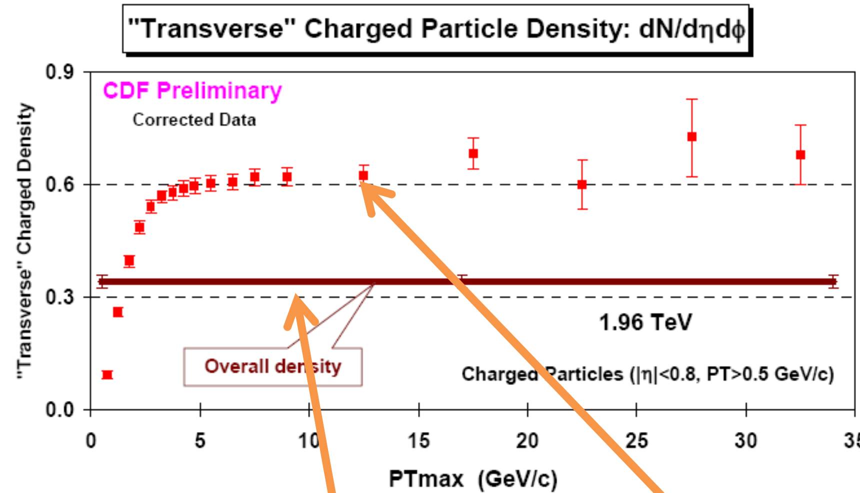
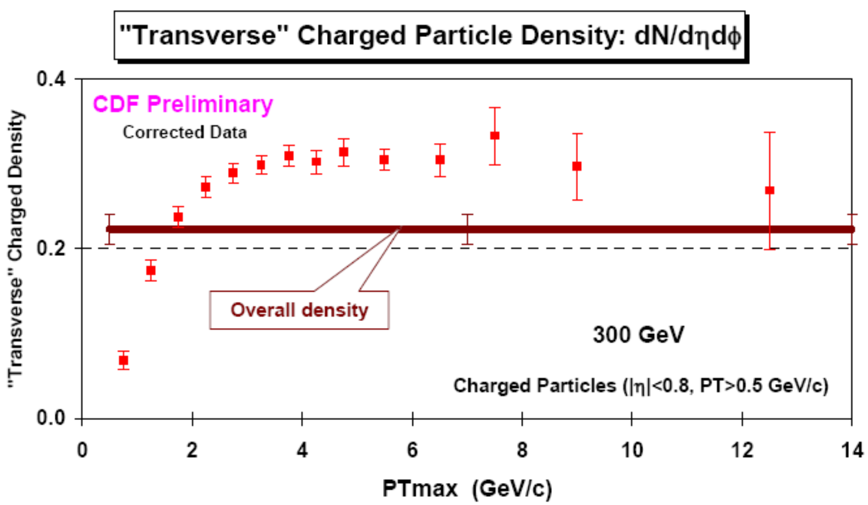


comparison of
CDF and CMS points

Comparing MB and UE different √s



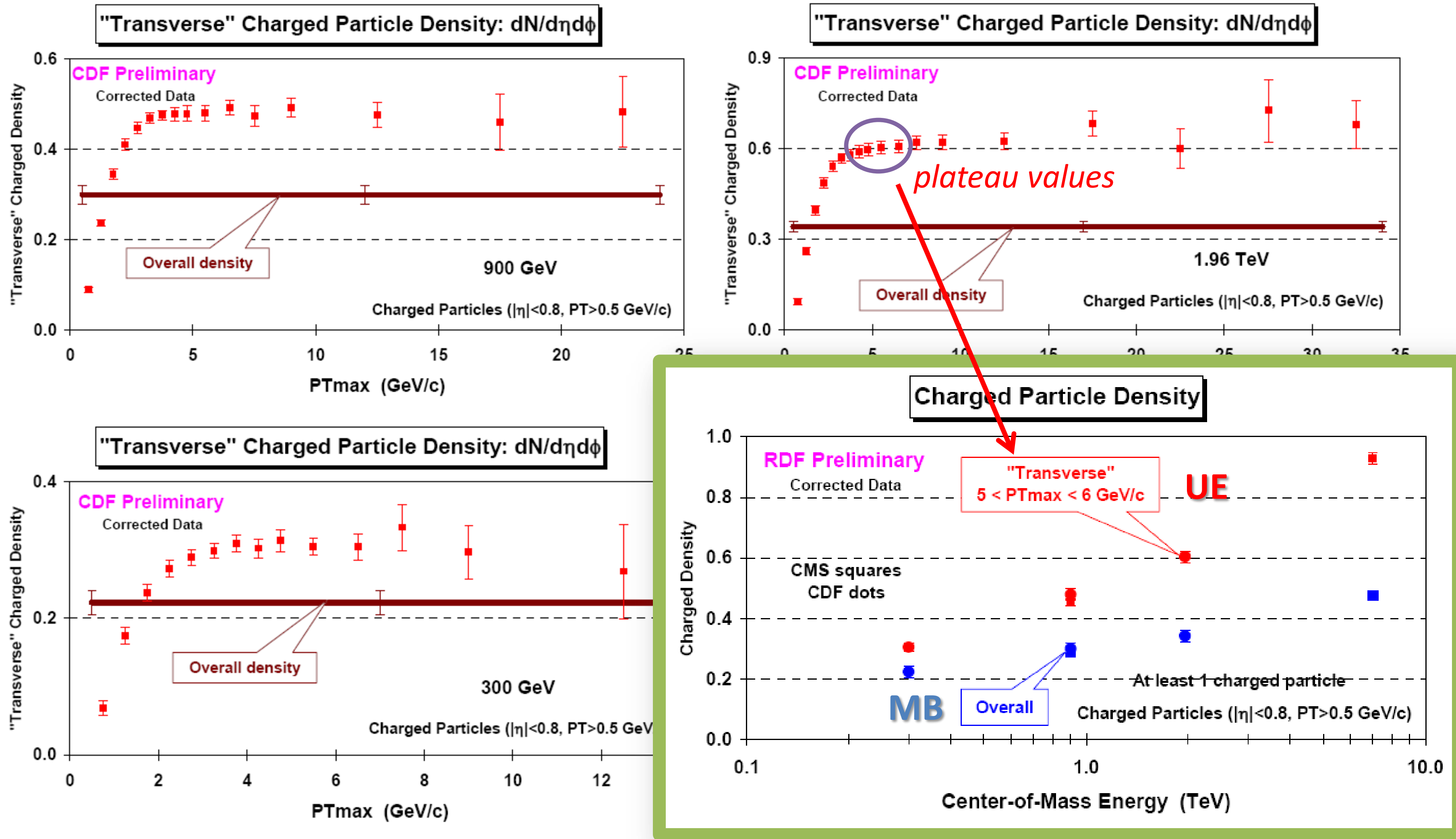




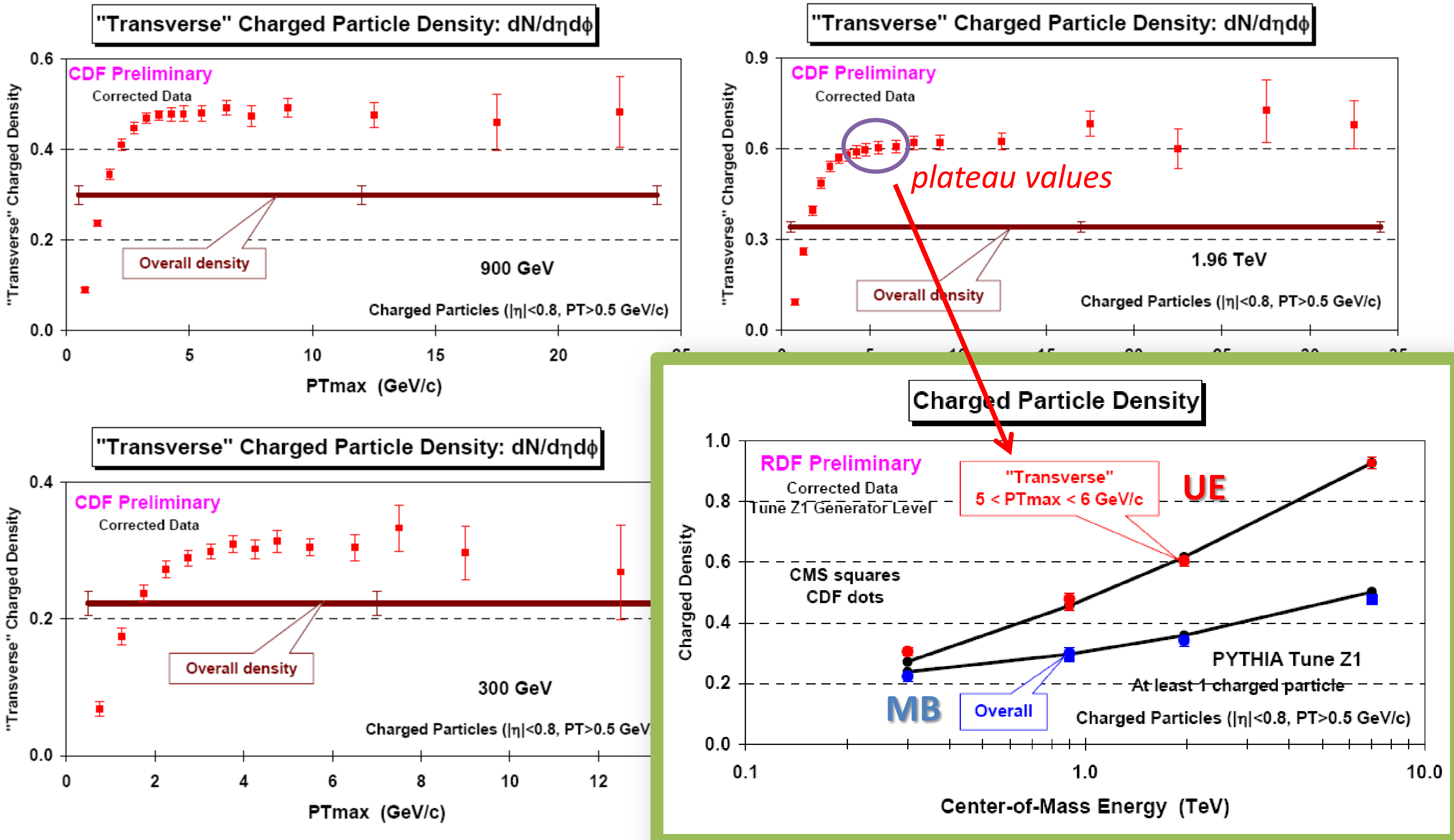
UE – "transverse" charged particle density, dN/dη

MB –overall charged particle density, dN/dη

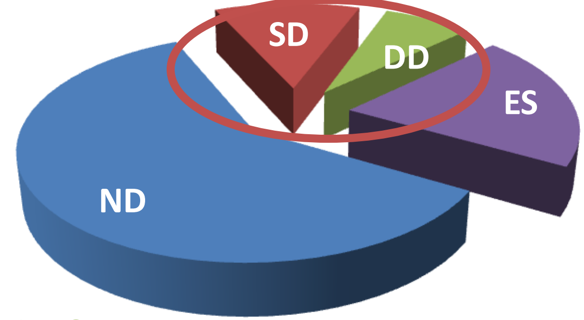
Comparing MB and UE different √s



Comparing MB and UE different $\sqrt{s}$



Definitions: Diffraction



- **Diffractive reactions at hadron colliders are defined as reactions in *which no quantum numbers* are exchanged between colliding particles**

Identified by presence of:

intact **leading particle** or

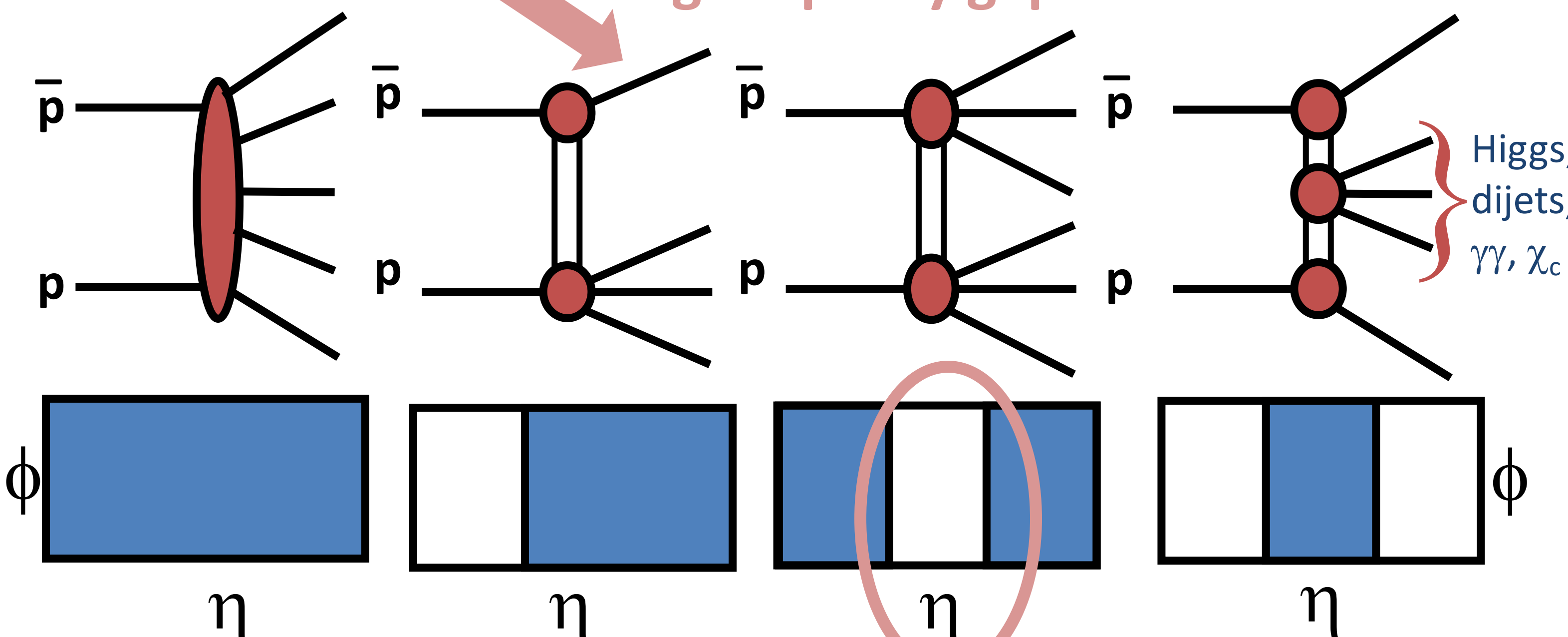
large rapidity gap

Non- Diffractive (ND)

Single Diffraction (SD)

Double Diffraction (DD)

Double Pomeron Exchange (DPE)



Diffractive Processes

Hadronic processes can be characterized by an energy scale:

soft processes **-** energy scale of the order of the hadron size (~ 1 fm)
pQCD is inadequate to describe these processes

hard processes – "hard" energy scale (> 1 GeV^2)
can use pQCD,
"factorization theorems" - can separate perturbative part
from non-perturbative

Diffractive processes mostly belong to "soft processes" , however
discovery of ***hard diffraction*** - jet production in ppbar collisions
with a leading proton in the final state (1988 UA8)

Hard diffractive processes allow to study diffraction in the pQCD framework.

At the Tevatron we study both soft and hard diffractive processes.

Diffraction: definitions

y - rapidity

η - pseudorapidity

$y = 1/2 \ln((E+p_z)/E-p_z))$

$\eta \equiv y\,|_{m=0} = -\ln\tan(\vartheta/2)$

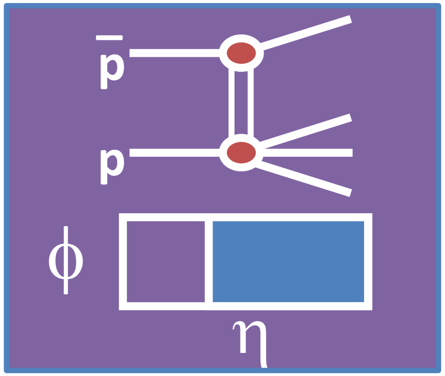
t - four-momentum transfer squared

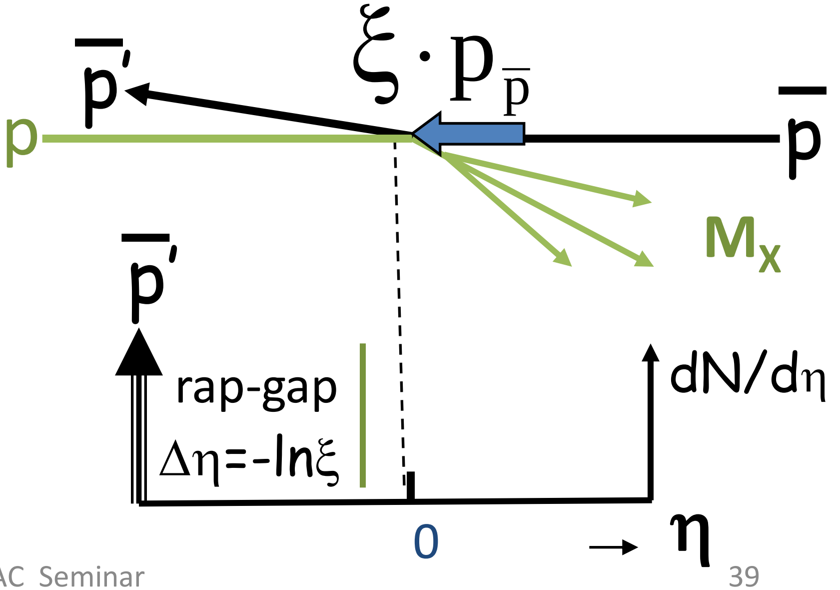
ξ - fractional momentum loss of pbar

$\mathbf{M_X}$ - mass of diffractive system X

$\xi = M_X^2/s$

$\Delta\eta \approx \ln(s/M_X^2)$

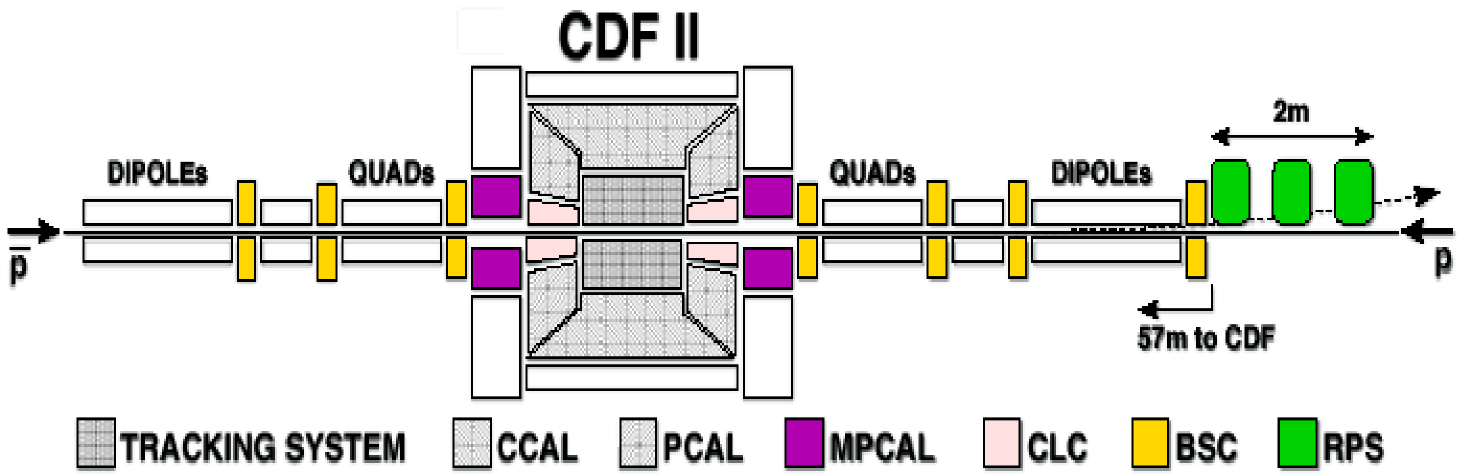




Definitions: Diffraction

Diffractive events at CDF are Identified by presence of:

intact leading particle or large rapidity gap

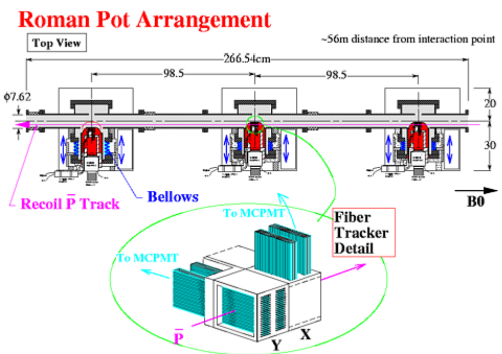


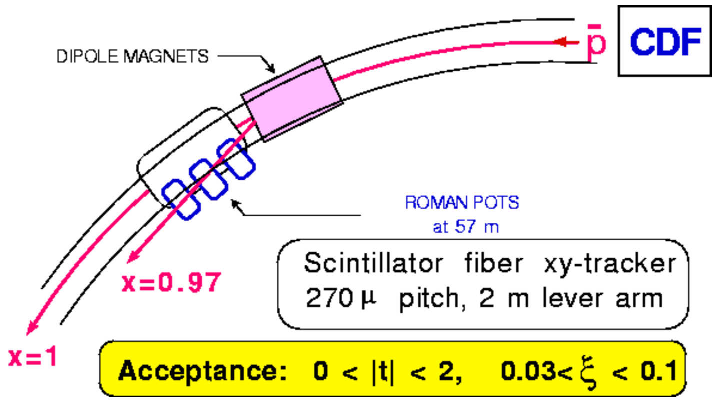
Tracking	–	Tracking Detectors	$|\eta| < 2.0$
CCAL, PCAL	–	Calorimeters	$|\eta| < 3.6$
RPS	–	Roman Pot Spectrometers	
BSC	–	Beam Shower Counters	$5.4 < |\eta| < 7.4$
MPCAL	–	MiniPlug Calorimeters	$3.5 < |\eta| < 5.1$

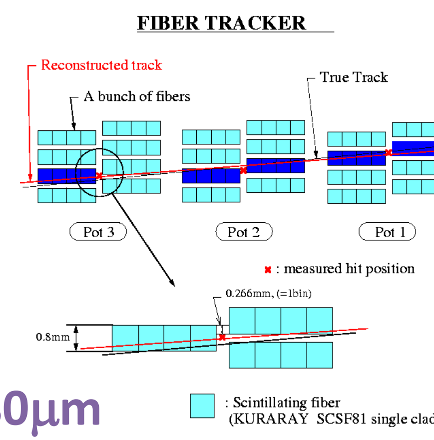
Forward Detectors at CDFII:
Roman Pot Spectrometers (RPS)

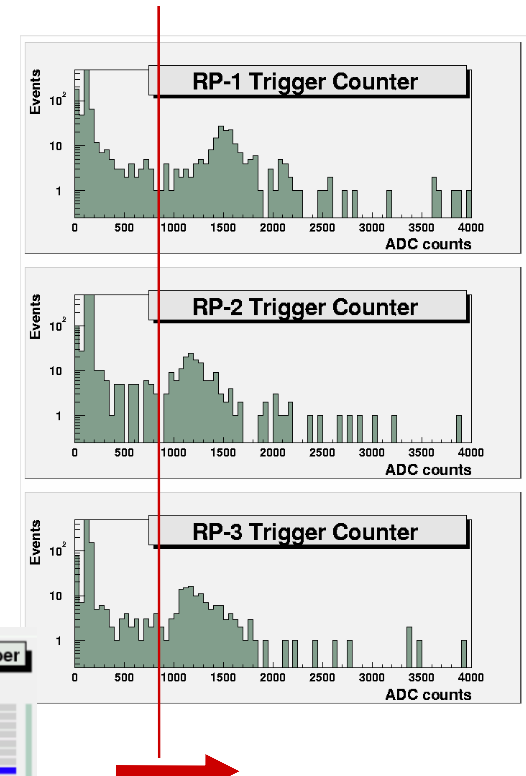
Fiber Tracker

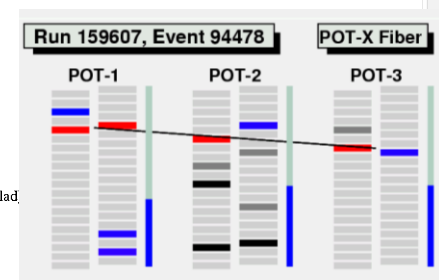
- 3 stations
- 57 meters from IP











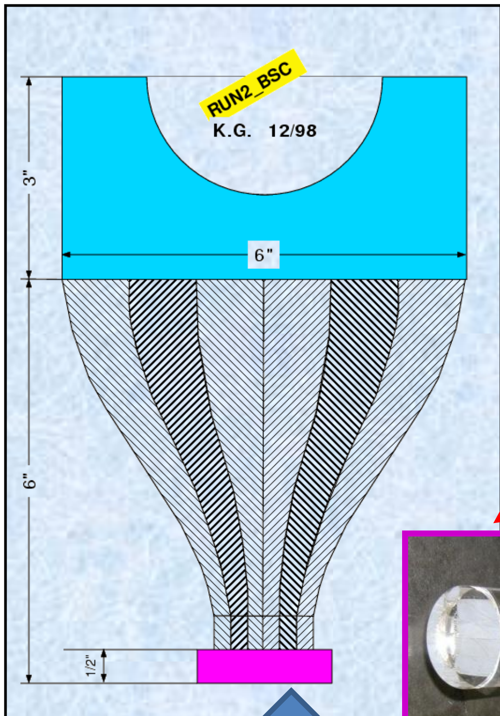
- 3 trigger counters
- 240 channels

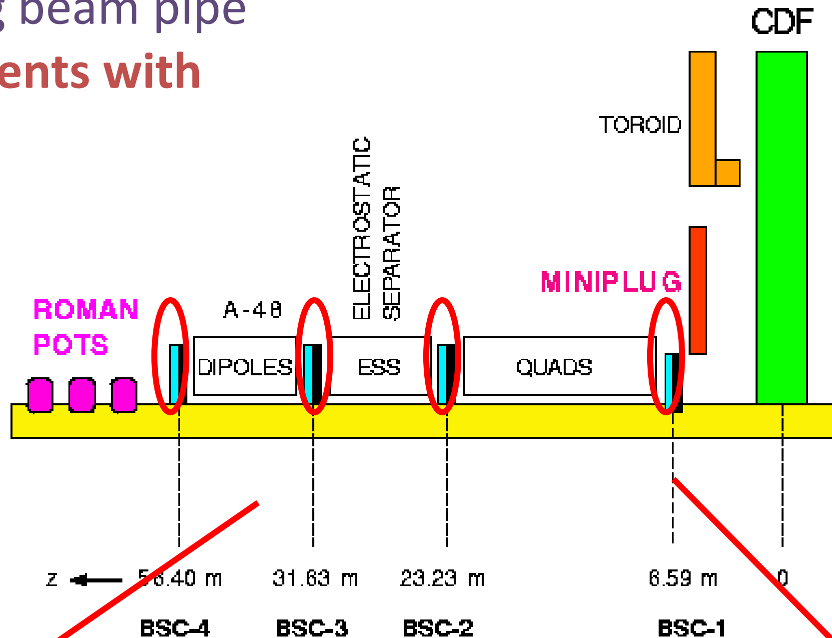
MIPs (>1000 counts)

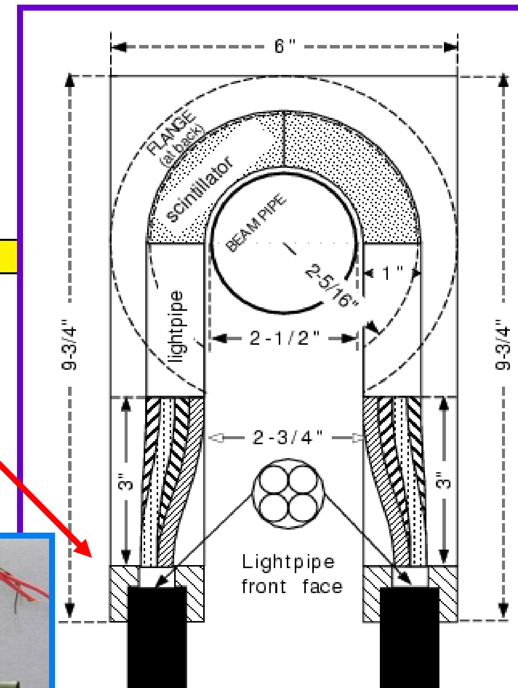
position resolution ±80μm
typical resolutions
in ξ $\delta\xi = \pm 0.001$; in t $\delta t = \pm 0.07 GeV^2$

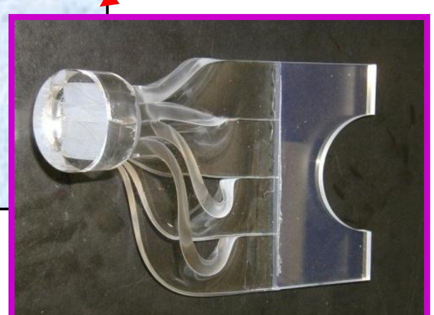
Forward Detectors at CDFII:
Beam Shower Counters (BSCs)

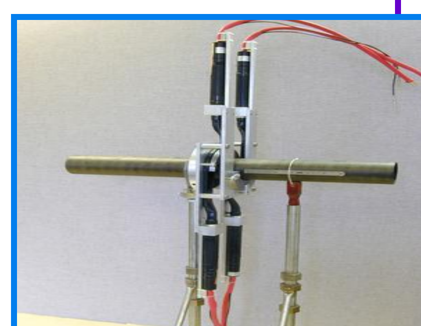
BSCs are located along beam pipe used for **triggering events with forward rapidity gaps**











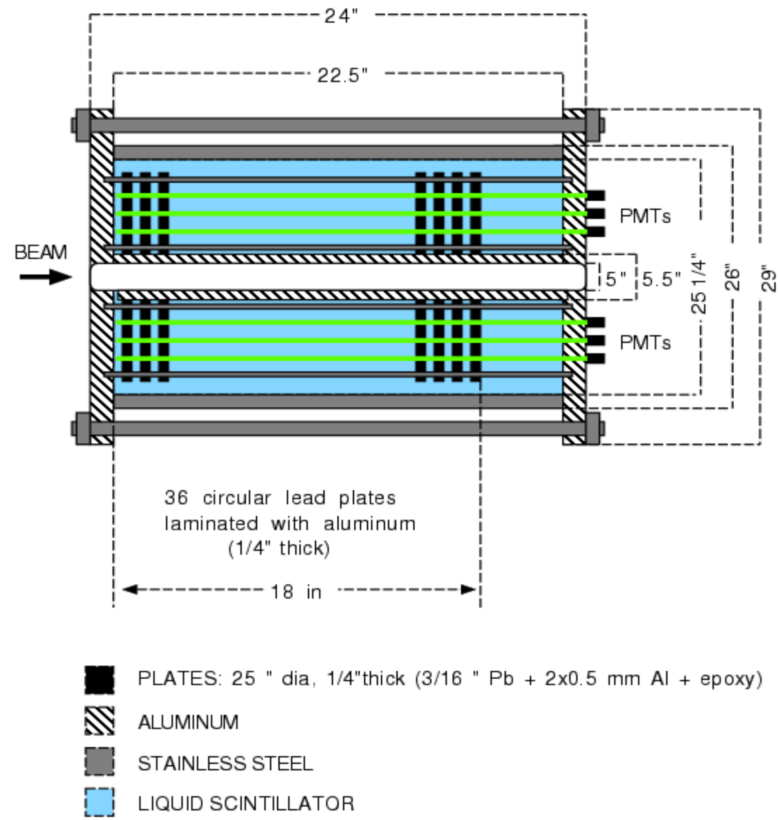
BSC-2,3,4

BSC-1

Forward Detectors at CDFII: MiniPlug Calorimeters (MPs)

Nucl. Instrum. Meth. ***A**518 (2004) 42.*

Nucl. Instrum. Meth. ***A**496 (2003) 333.*



designed to **measure the energy and lateral position** of both electromagnetic and hadronic showers

“towerless” geometry – no dead regions

Challenges and Methods

Methodologies were developed to get around the challenges:

Results are mostly MC free

ξ variable can be determined in two ways

- Determine ξ using Roman Pots tracking
- Also can determine ξ from E_T in calorimeters

important to have MiniPlugs ↗

$$\xi^{cal} = \sum_{towers} \frac{E_T}{\sqrt{s}} e^{-\eta}$$

Main challenge: multiple interactions spoiling diffractive signatures

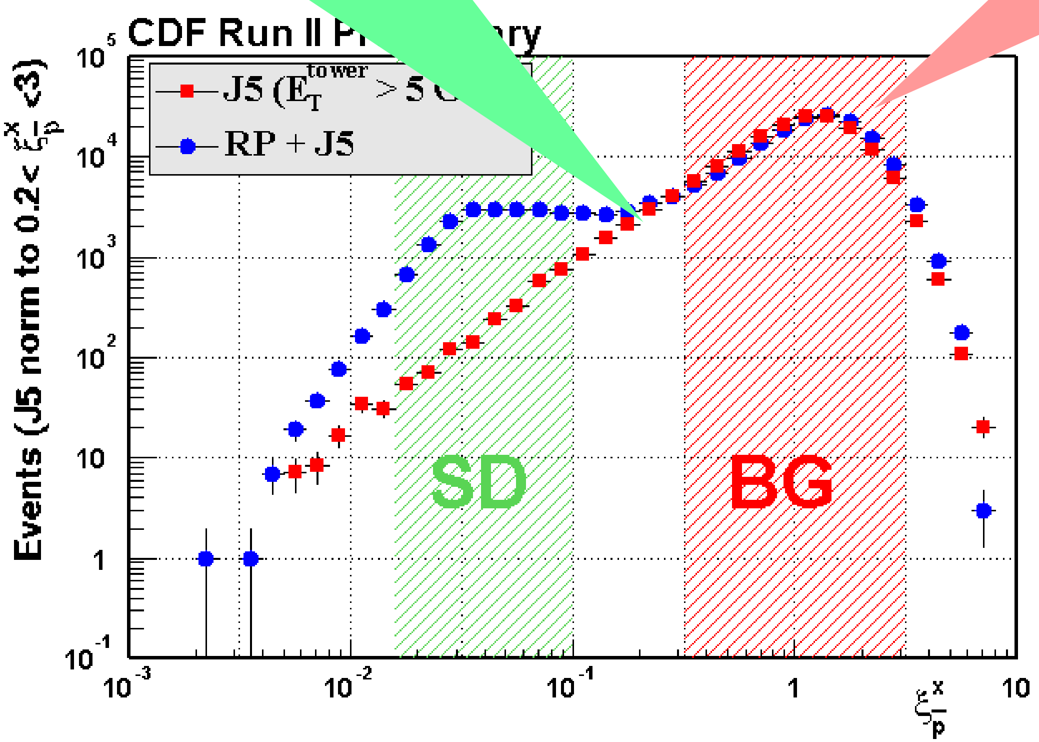
use $\xi^{cal} < 0.1$ to reject overlap events → non-diffractive contributions

Challenges and Methods: ξ distributions

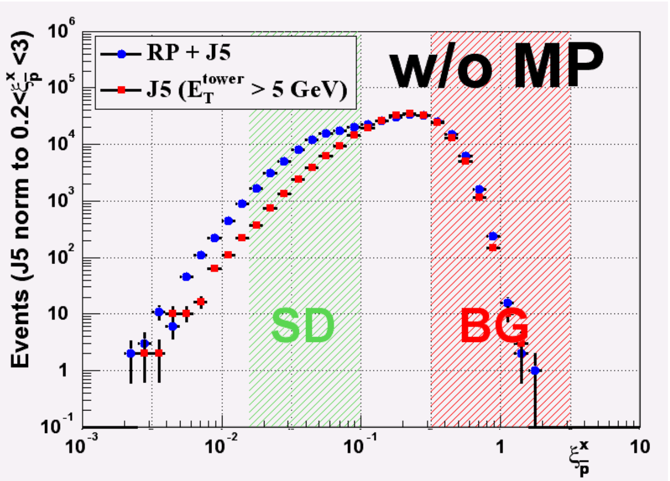
Flat part at ξ < 0.1

$$\frac{d\sigma}{d\xi} \propto \frac{1}{\xi} \rightarrow \frac{d\sigma}{d(\log\xi)} = const$$

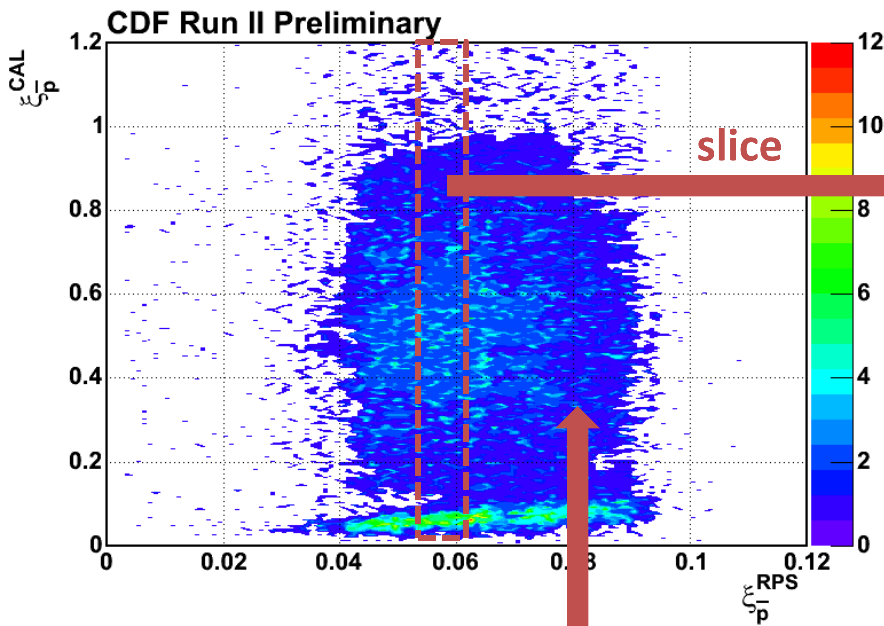
Peak at ξ= 1
-overlap events from
multiple interactions

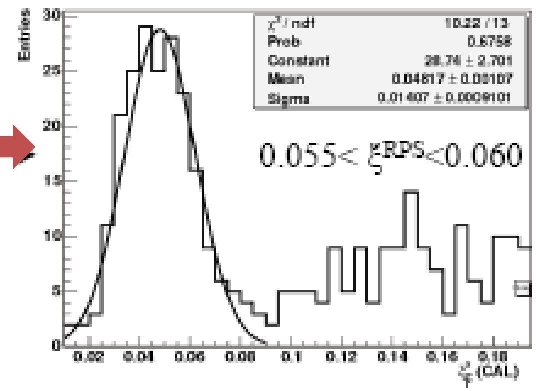


MP calorimeters allow to separate diffractive and non-diffractive parts

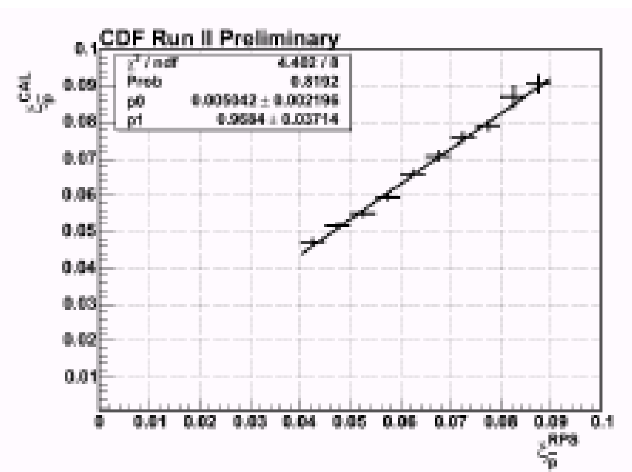


Methods and Challenges:
ξ with RPS and calorimeter info



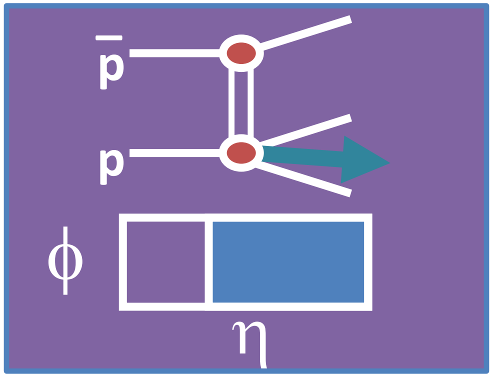


pile-up events



calibration of ξ from calorimeter with ξ from RPS

Hard Single Diffraction



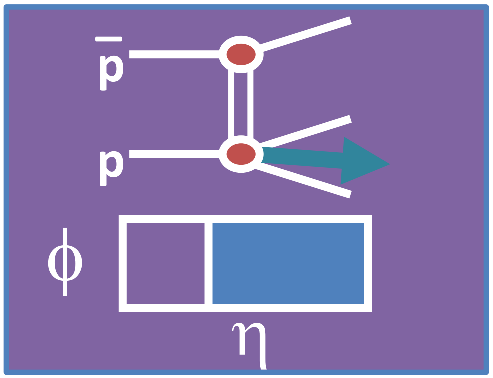
Diffractive signature:

- ❑ large rapidity gap
- ❑ intact pbar detected in RPS

Can study diffractive production of high p_T objects:
jets, W, J/Ψ, b
different insight into the nature of Pomeron

Method: measure ratio of diffractive to non-diffractive production

Hard Single Diffraction



Diffractive signature:

large rapidity gap –
slightly different
gap definitions

method used as a model for LHC analyses

Hard component	Fraction (R) %
Dijet	0.75 ± 0.10
W	1.15 ± 0.55
b	0.62 ± 0.25
J/ψ	1.45 v 0.25

Fraction:
R≡SD/ND ratio
@ 1800 GeV

All fractions ~ 1%
(differences due to kinematics)

➢ ~ uniform suppression

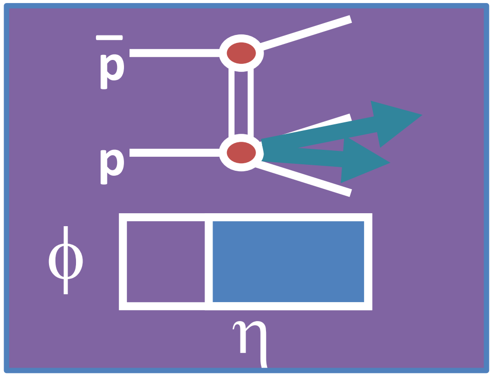
Diffractive Structure Function

Diffractive dijet cross section

$$\sigma(\bar{p}p \rightarrow \bar{p}X) \approx F_{jj} \otimes F_{jj}^{D} \otimes \hat{\sigma}(ab \rightarrow jj)$$

Study the diffractive structure function

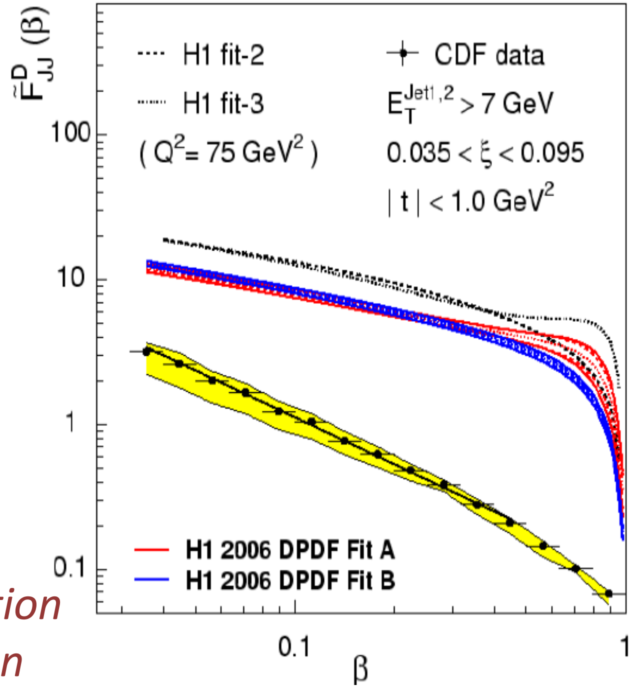
$$F_{jj}^{D} = F_{jj}^{D}(x, Q^2, t, \xi)$$



Experimentally determine diffractive structure function F_{jj}^{D}

at LO $$R_{\frac{SD}{ND}}(x,\xi) = \frac{\sigma(SD_{jj})}{\sigma(ND_{jj})} = \frac{F_{jj}^{D}(x,Q^2,\xi)}{F_{jj}(x,Q^2)}$$

Data **known PDF**

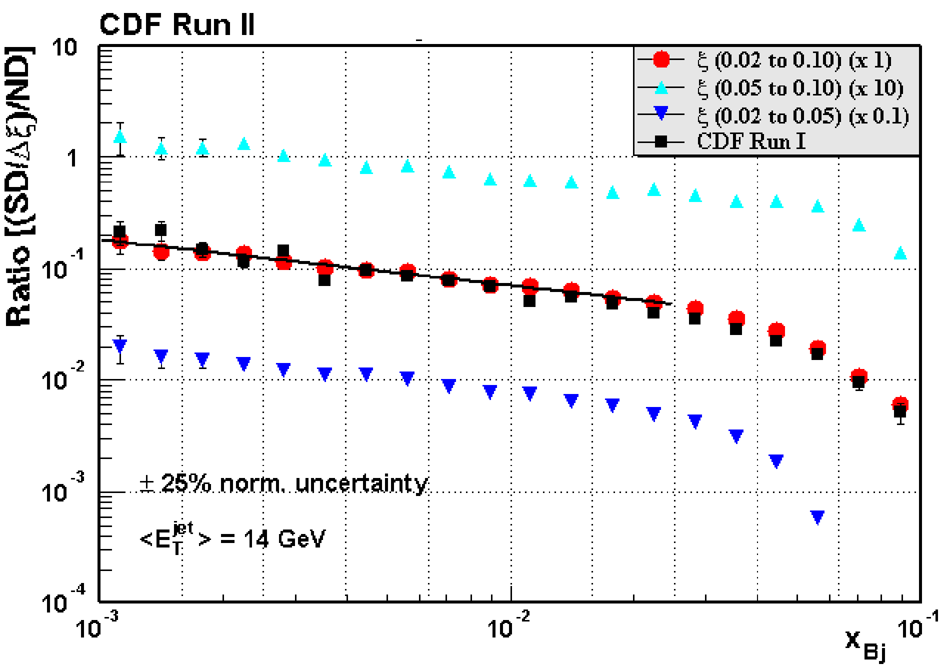


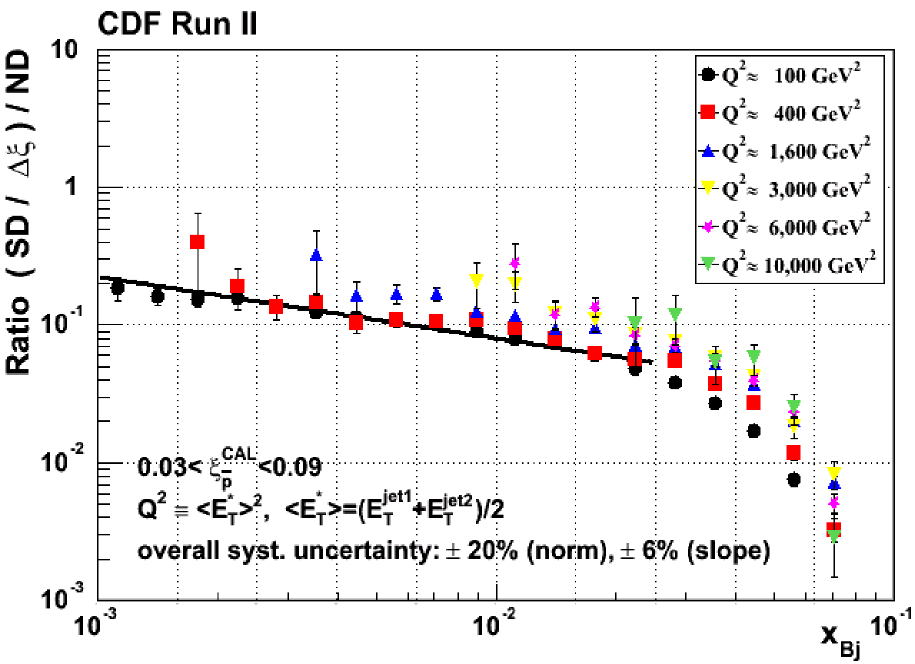
β - momentum fraction of parton in pomeron

The Diffractive Structure Function

$\sqrt{s}$= 1.96 TeV

PRD 86, 032009 (2012)

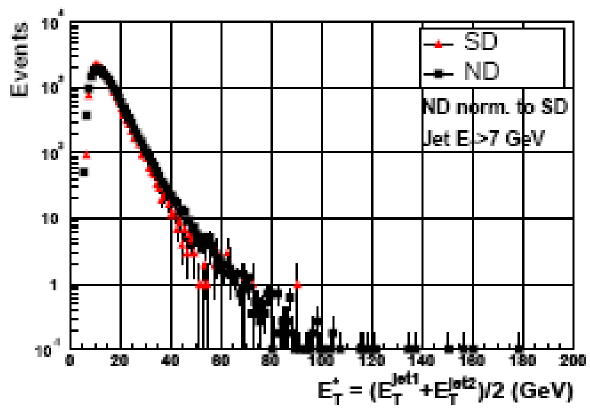




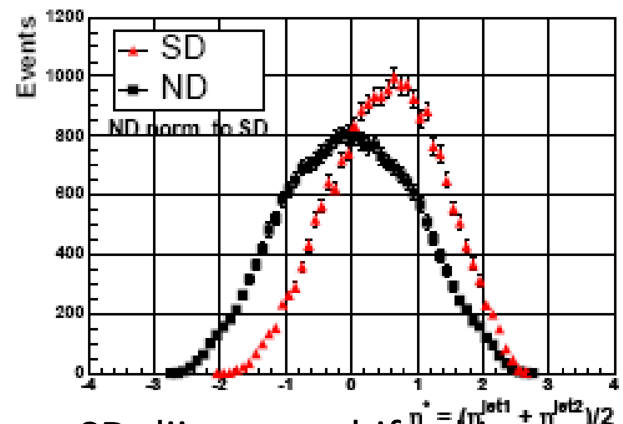
same behavior for different ξ values

same behavior for different Q^2

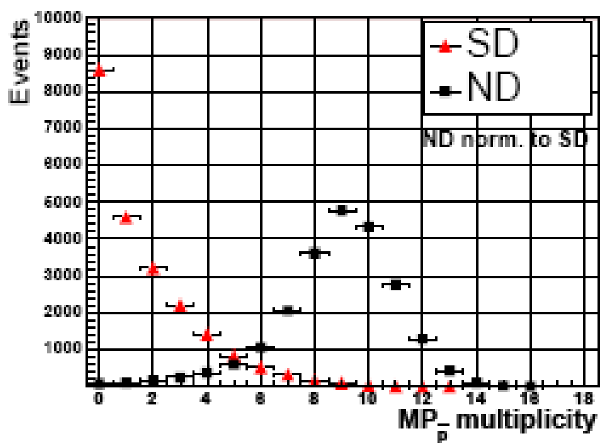
Kinematic Distributions for SD dijets



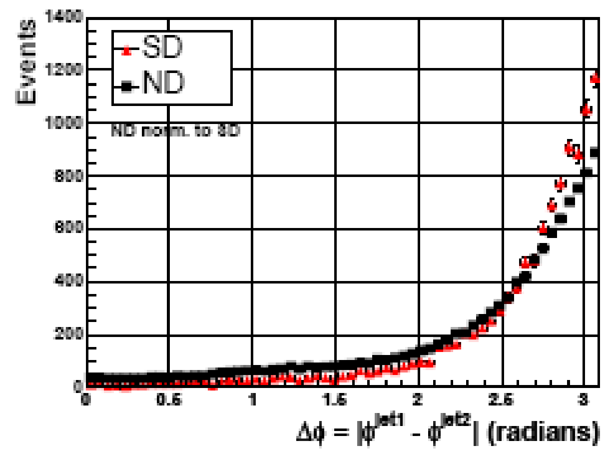
SD and ND dijets have similar E_T distributions



SD dijets are shifted in + η



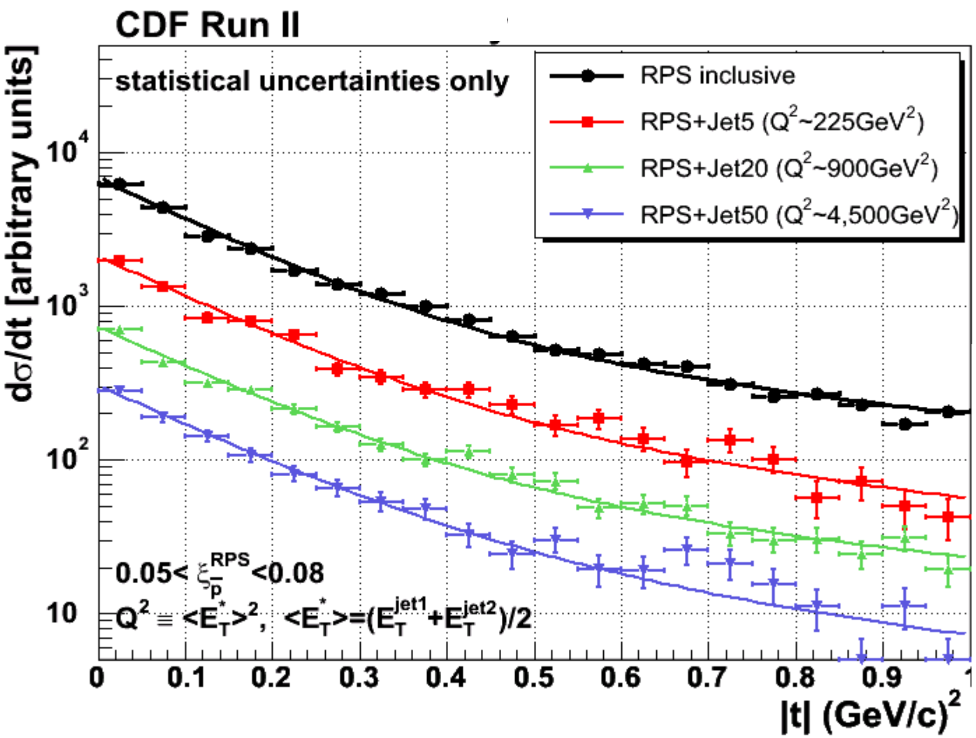
The multiplicity distributions in MP



SD dijets are more back to back

t distribution

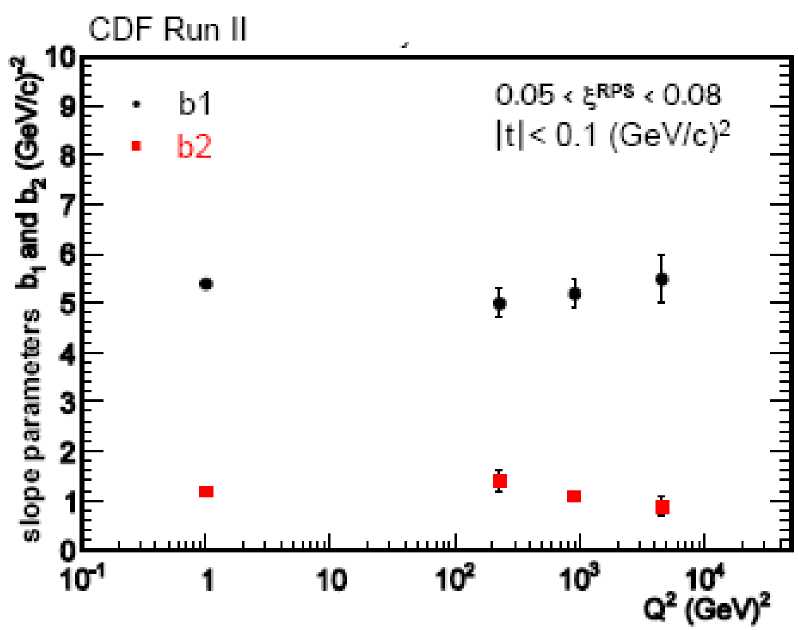
PRD 86, 032009 (2012)



antiproton |t| distribution

- **no diffractive dips**
- **no Q^2 dependence**

  in slope from inclusive to $Q^2 \sim 10^4$ GeV^2

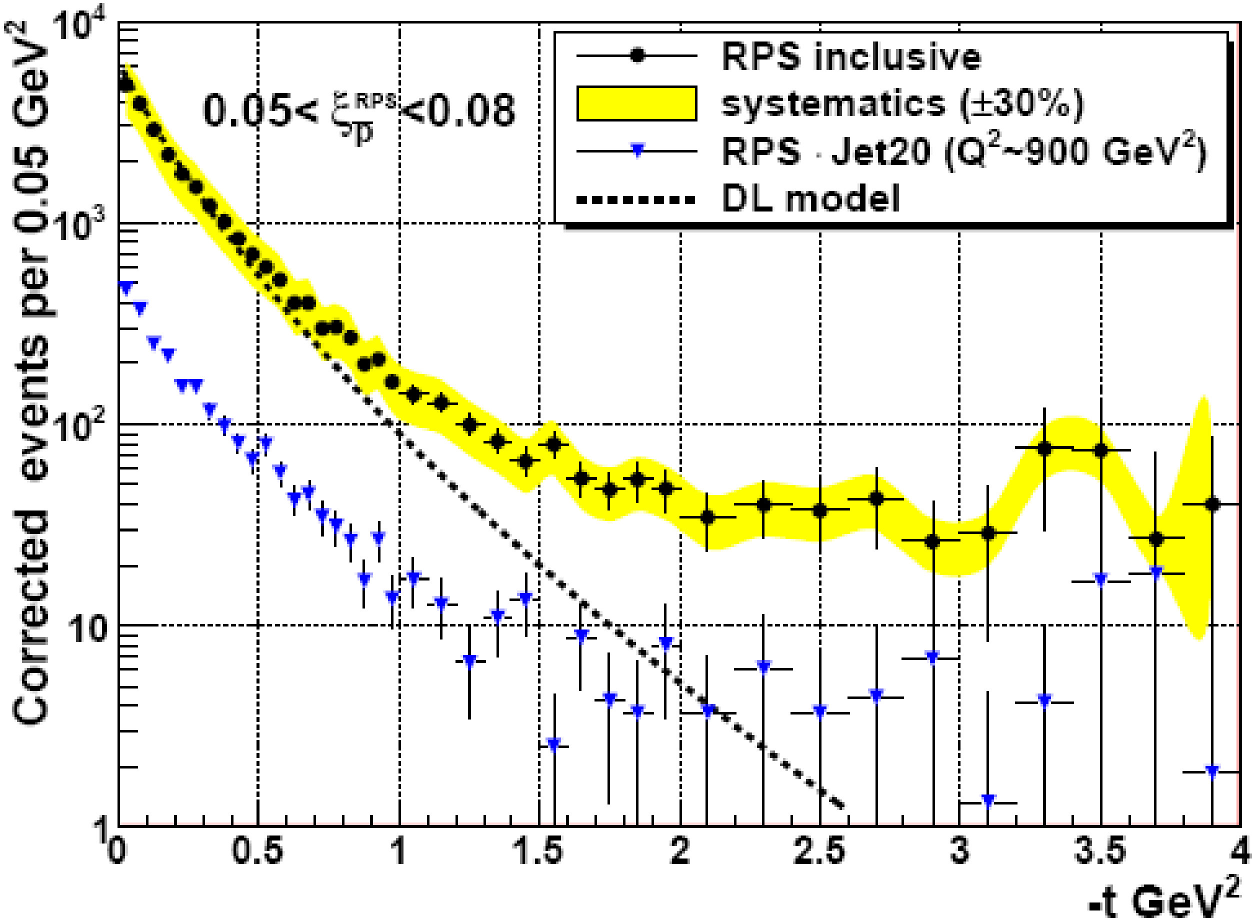


Fit to double exponential function:

$d\sigma/dt \propto 0.9\ e^{b1\ t} + 0.1\ e^{b2\ t}$

t distributions for SD

PRD 86, 032009 (2012)

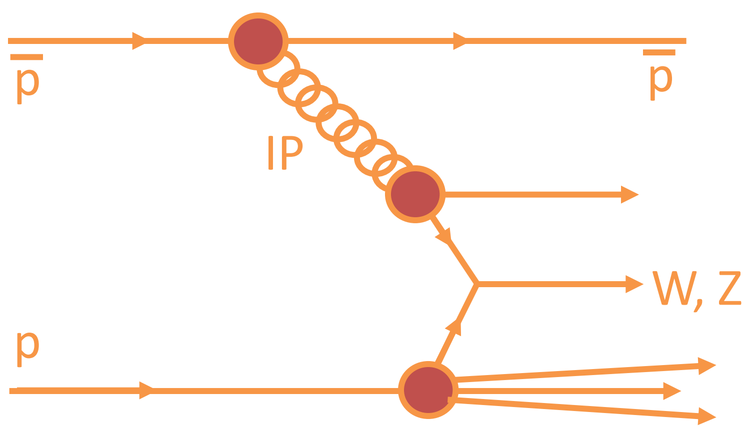


Search for diffraction minimum around *t* of 2.5 GeV²?

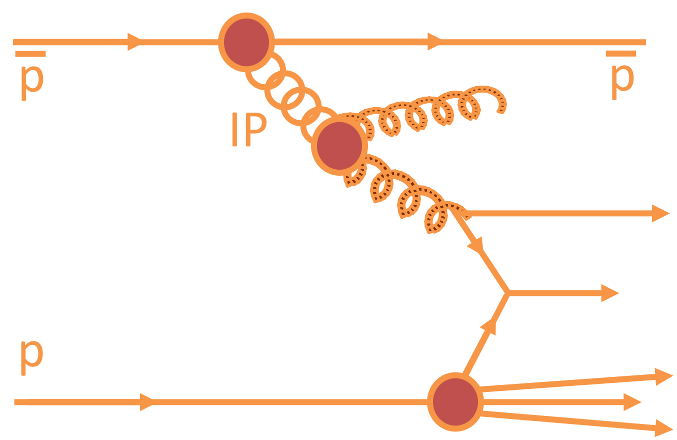
Diffractive W/Z Production

Diffractive W/Z production probes the quark content of the Pomeron

- to Leading Order
  the W/Z are produced
  by a **quark** in the Pomeron



- production by gluons is
  suppressed by a factor
  of α_s
  and can be distinguished by
  an associated jet



Diffractive W Production

Identify diffractive events using Roman Pots:

accurate event-by-event ξ measurement
no gap acceptance correction needed
can still calculate ξ^{cal}

$$\xi^{cal} = \sum_{towers} \frac{E_T}{\sqrt{s}} e^{-\eta}$$

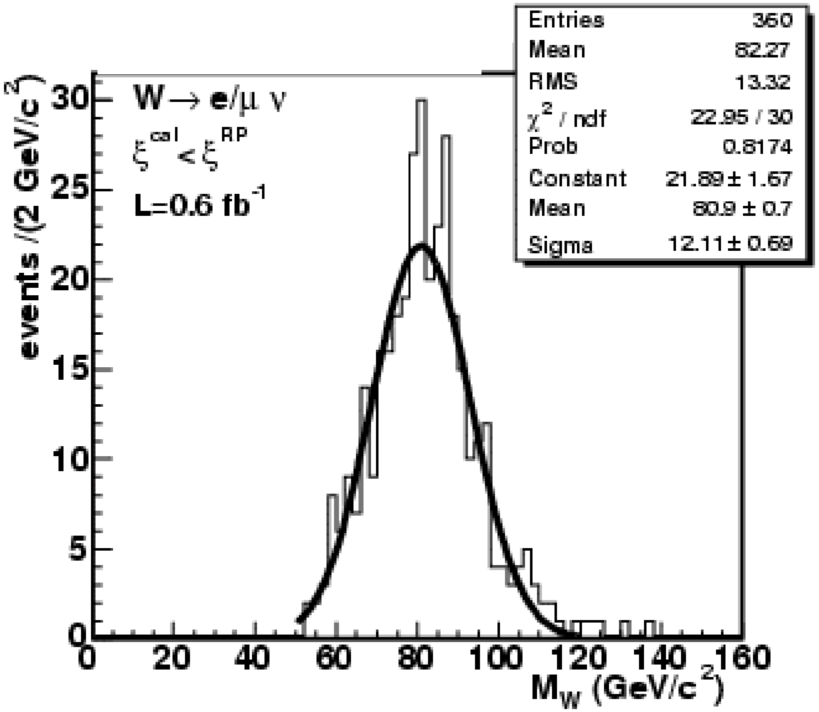
In W production, the difference between ξ^{cal} and ξ^{RP} is related to missing E_T and η_ν

$$\xi^{RP} - \xi^{cal} = \frac{E_T}{\sqrt{s}} e^{-\eta_\nu}$$

allows to determine:

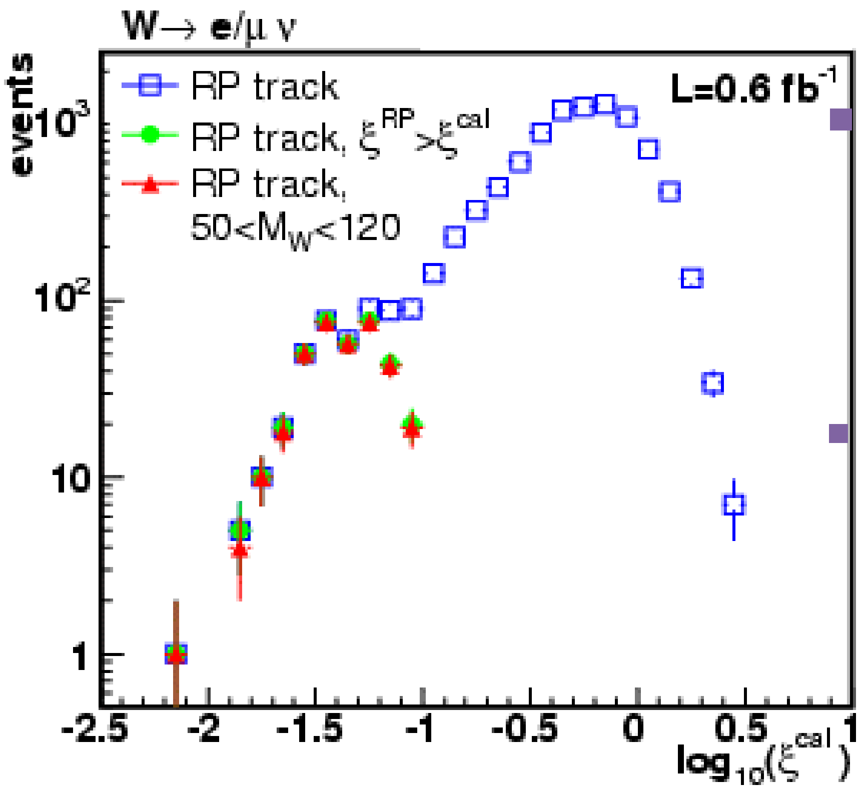
neutrino and W kinematics
x_{bj}

Phys. Rev. D 82, 112004, 2010



reconstructed diffractive W mass

Diffractive W Production



$\xi^{cal} < \xi^{RP}$ requirement removes most events with multiple pbar-p interactions

$50 < M_W < 120$ GeV/c^2 requirement on the reconstructed W mass cleans up possible mis-reconstructed events

Fraction of diffractive W

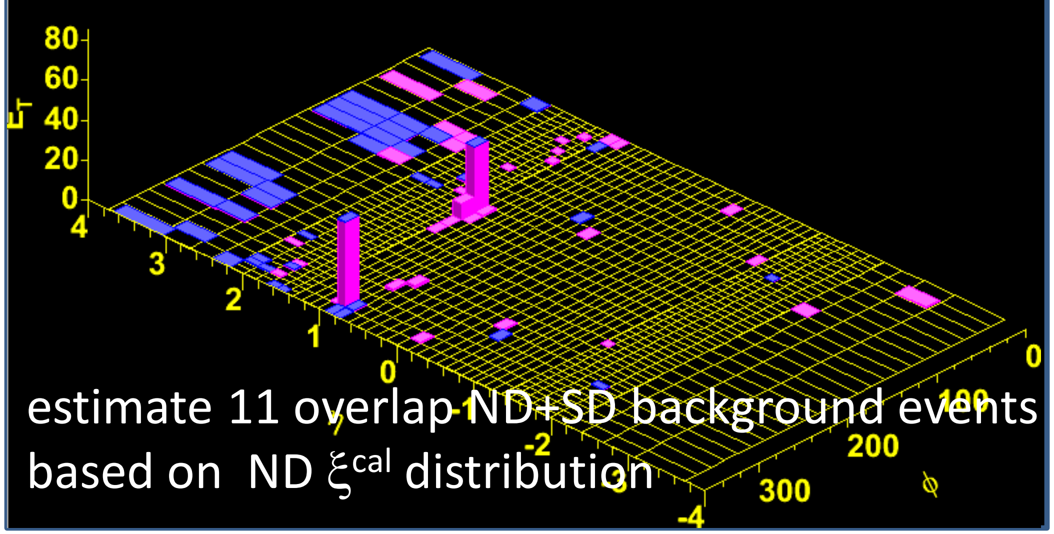
R_W (0.03<ξ<0.10, |t|<1)= [0.97 ±0.05(stat) ±0.10(syst)]%

consistent with Run I result, extrapolated to all ξ

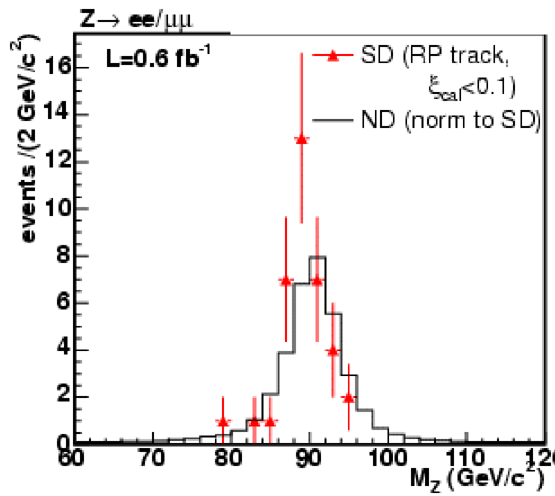
Diffractive Z Production

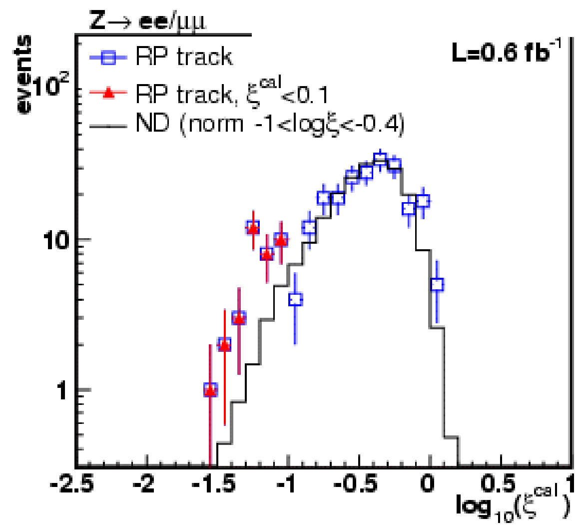
Phys. Rev. D 82, 112004, 2010

37 diffractive $Z \to ee/\mu\mu$ candidates
(RP track, ξ^{cal}<0.1)



estimate 11 overlap ND+SD background events based on ND ξ^{cal} distribution





Fraction of diffractive Z

R_Z (0.03< ξ <0.10, |t|<1)= [0.85±0.20(stat) ±0.08(syst)]%

W/Z Results

R^W (0.03 < ξ < 0.10, |t|<1)= [0.97 ± 0.05(stat) ± 0.11(syst)]%

Run I: R^W (ξ<0.1)=[1.15±0.55] % → **0.97±0.47 %** in **0.03 < ξ < 0.10 & |t|<1**

R^Z (0.03 < x < 0.10, |t|<1)= [0.85 ± 0.20(stat) ± 0.11(syst)]%

CDF/DØ Comparison – Run I (ξ < 0.1)

CDF PRL 78, 2698 (1997)
R^W=[1.15±0.51(stat)±0.20(syst)]%
gap acceptance A^{gap}=0.81

Uncorrected for A^{gap}

R^W=(0.93±0.44)%

DØ Phys Lett B **574**, 169 (2003)
R^W=[5.1±0.51(stat)±0.20(syst)]%
gap acceptance A^{gap}=(0.21±4)%

Uncorrected for A^{gap}

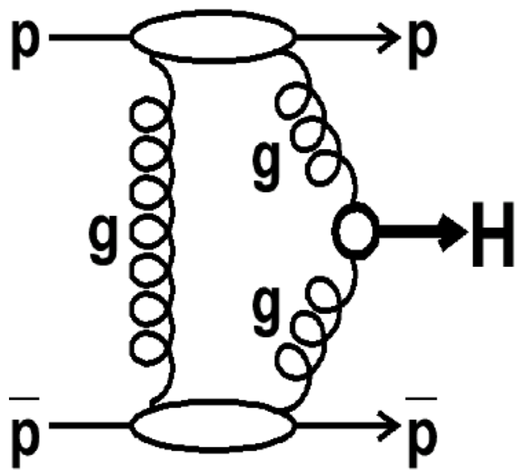
R^W=[0.89+0.19-0.17]%

R^Z=[1.44+0.61-0.52]%

This analysis is a good example of agreement between RPS and large rapidity gap identification methods

Exclusive Production

LHC

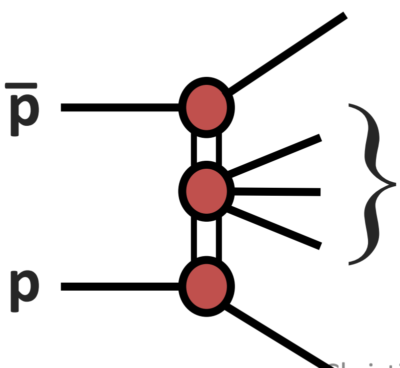


➔ suppression at LO of the background sub-processes (J_z=0 selection rule)

➔ "exclusive channel" → clean signal (no underlying event)

- At the Tevatron we use similar processes with larger cross sections to test and calibrate theor. predictions

CDF



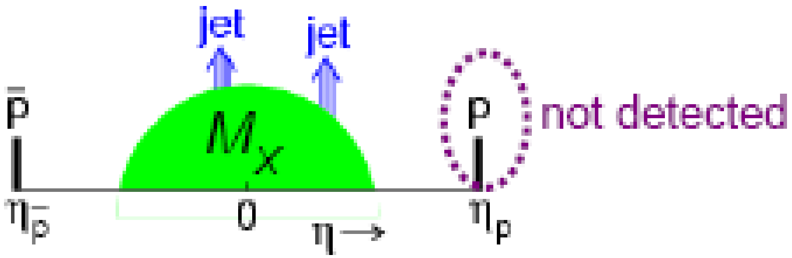
Dijets,

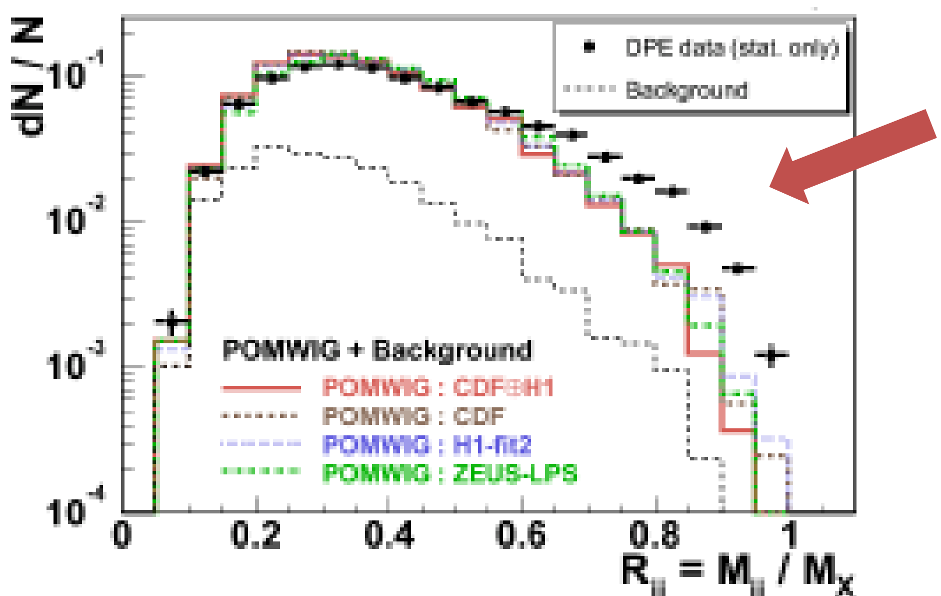
$\gamma\gamma$,

χ_c

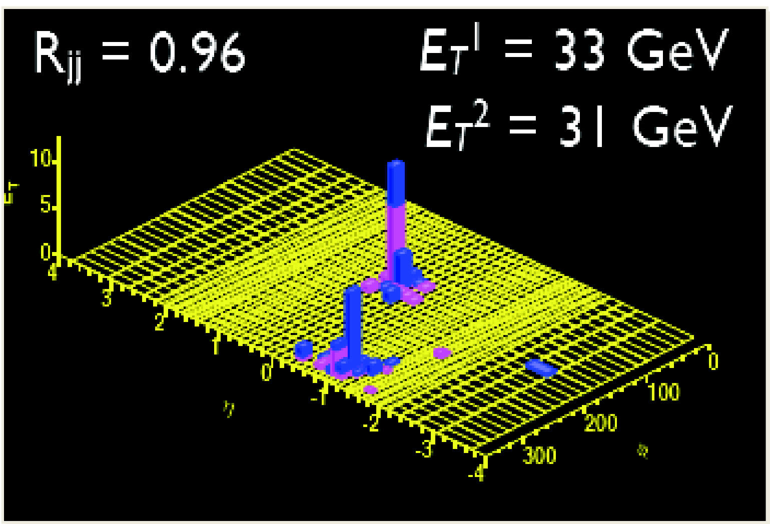
Observation of Excl. Dijet Production

PRD 77, 052004 (2008)





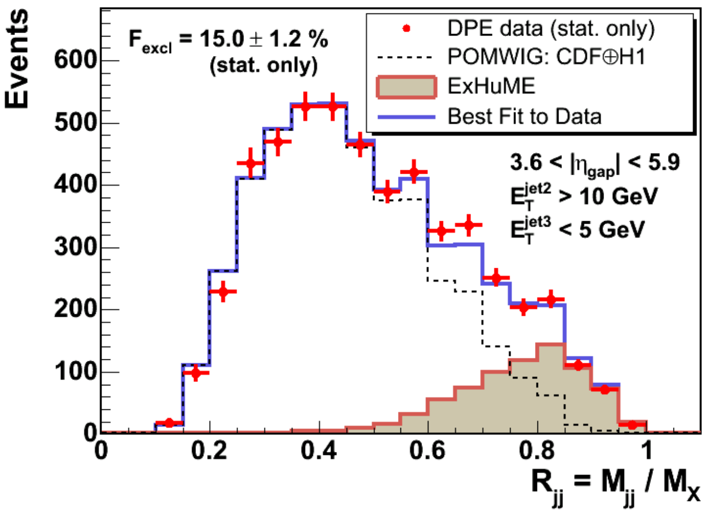
Reconstruct $\mathbf{R_{jj}=M_{jj}/M_X}$, where
M_{jj} mass of dijet system, M_x – mass of system X

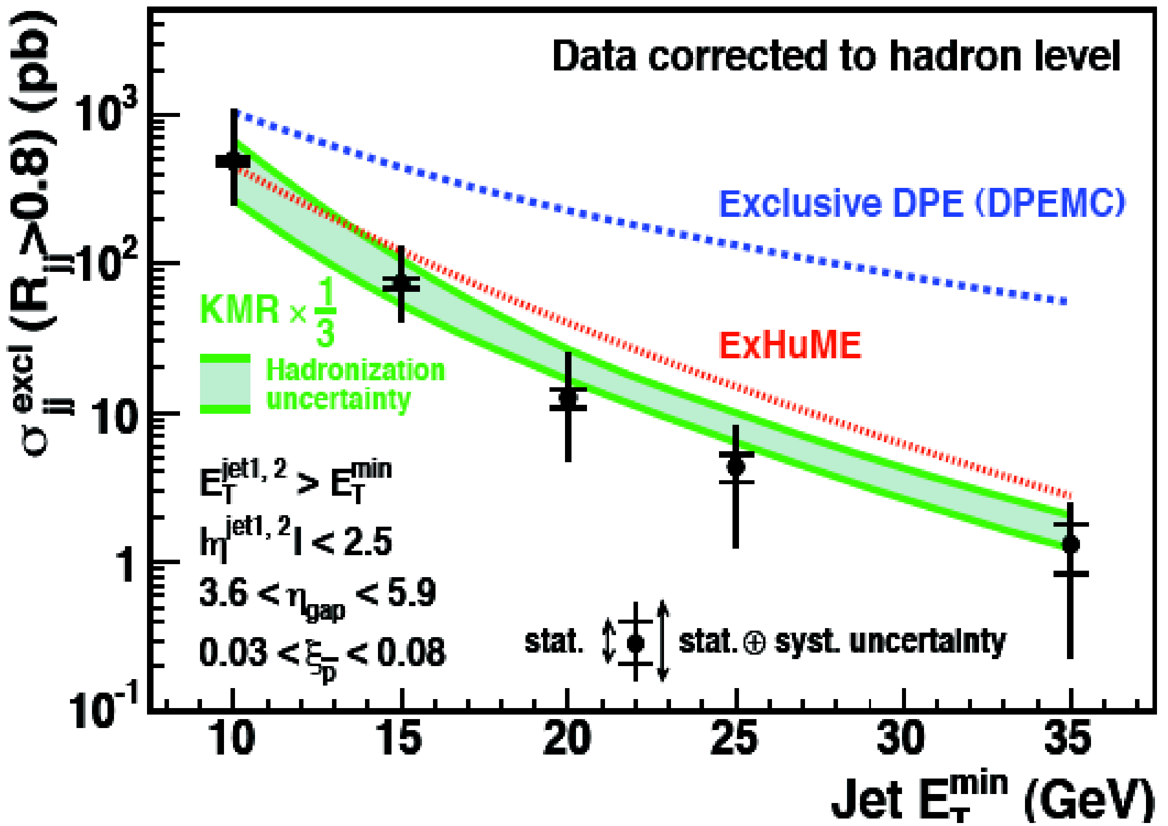


Observe excess over inclusive DPE dijet MC's at high dijet mass fraction

Signal at R_{jj}=1 is smeared due to shower/hadronization effects, NLO $gg \rightarrow ggg, q\bar{q}g$ contributions

Exclusive Dijet Cross Section



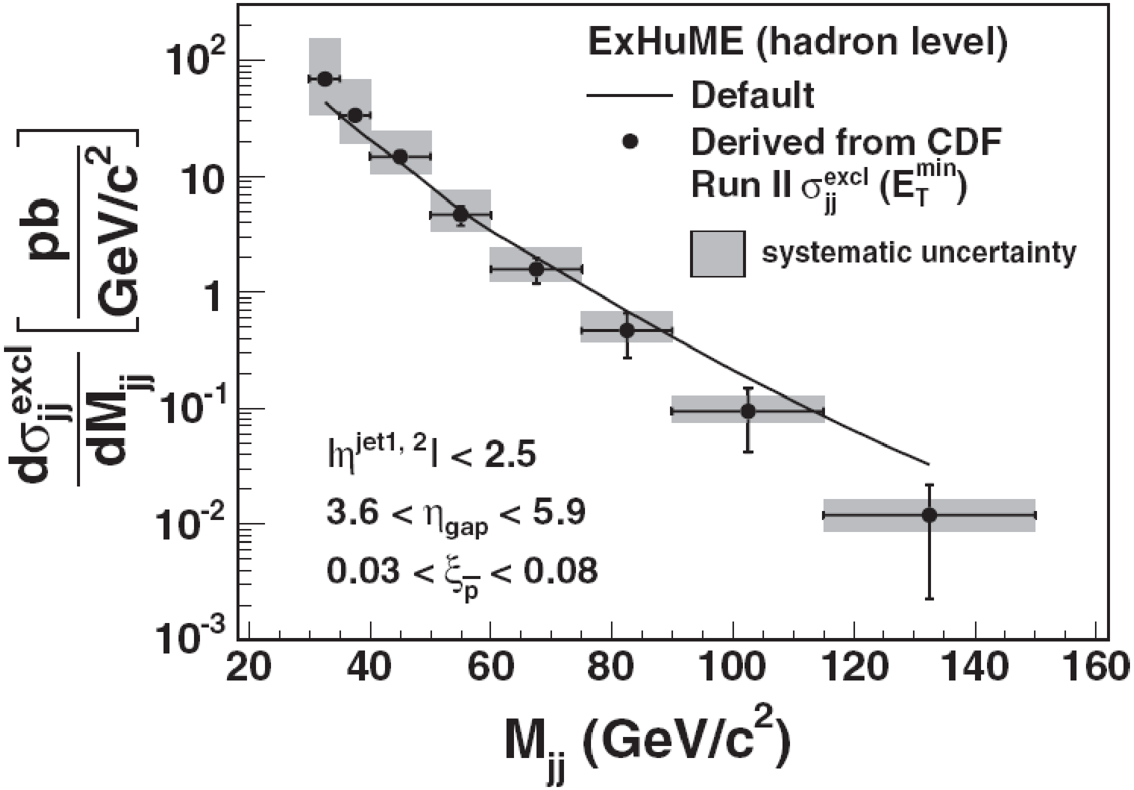


- → Calculation by KMR is consistent within its factor of 3 uncertainty.

*Eur. Phys J C**14, 525 (2000).***

$d\sigma_{jj}^{excl}$ vs Dijet Mass

derived from CDF excl. dijet x-sections using ExHuME



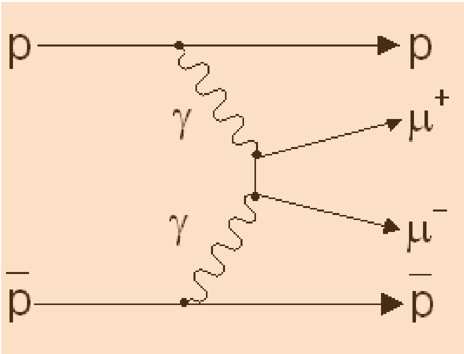
- Stat. and syst. errors are propagated from measured cross section uncertainties using M_{jj} distribution shapes of ExHuME generated data.

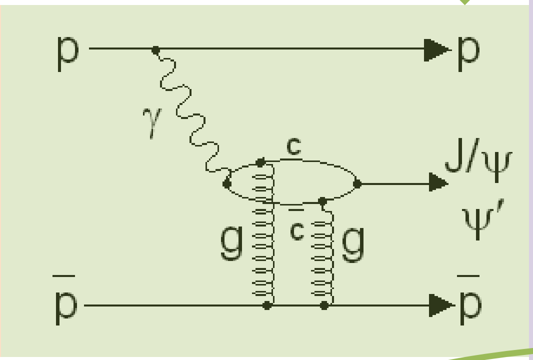
Exclusive Dimuon Production

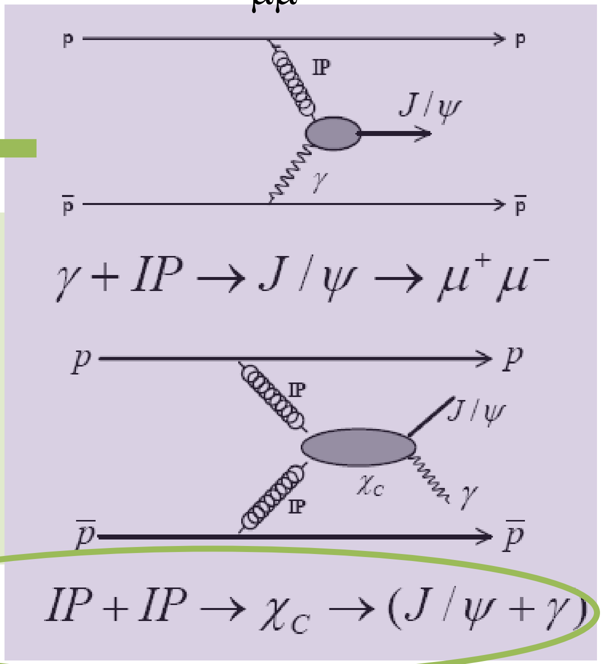
$$\bar{p} + p \rightarrow \bar{p} + \mu^{+}\mu^{-} + p$$

3 GeV/c^2 < $M_{\mu\mu}$ < 4 GeV/c^2

Many Physics Processes in this data:



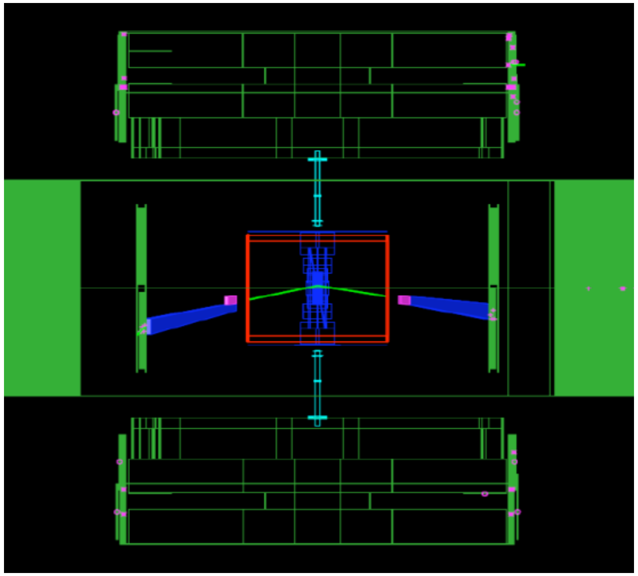


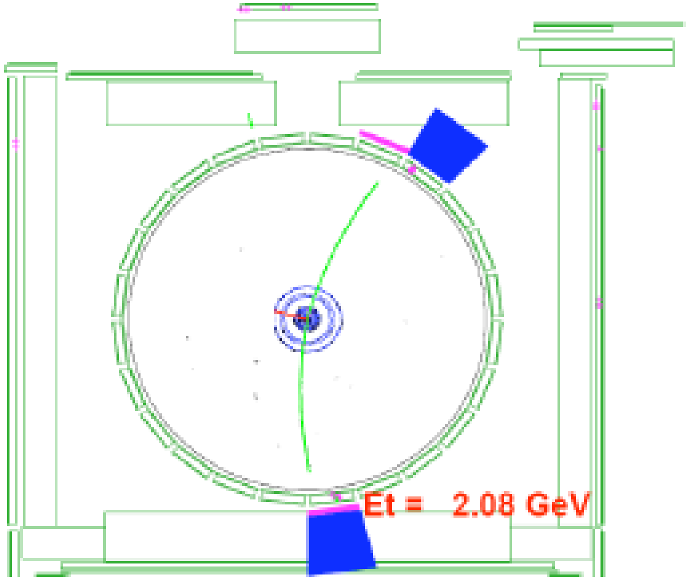


exclusive χ_c in DPE

- Observation of exclusive χ_c PRL 102 242001 (2009)

Exclusive dimuon production





$$p + \bar{p} \to p + \mu^+ \mu^- + \bar{p}$$

$3\ GeV/c^2 < M_{\mu\mu} < 4\ GeV/c^2$

Trigger:

muon + track + forward rapidity gaps in BSCs

2 oppositely charged muon tracks with $p_T > 1.4$ GeV/c, $|\eta| < 0.6$

$\varepsilon_{excl} \sim 0.093$ => $L = 1.48\ fb^{-1}$ but $L_{eff} \sim 140 pb^{-1}$

Exclusive J/ψ and ψ(2s)

J/ψ production

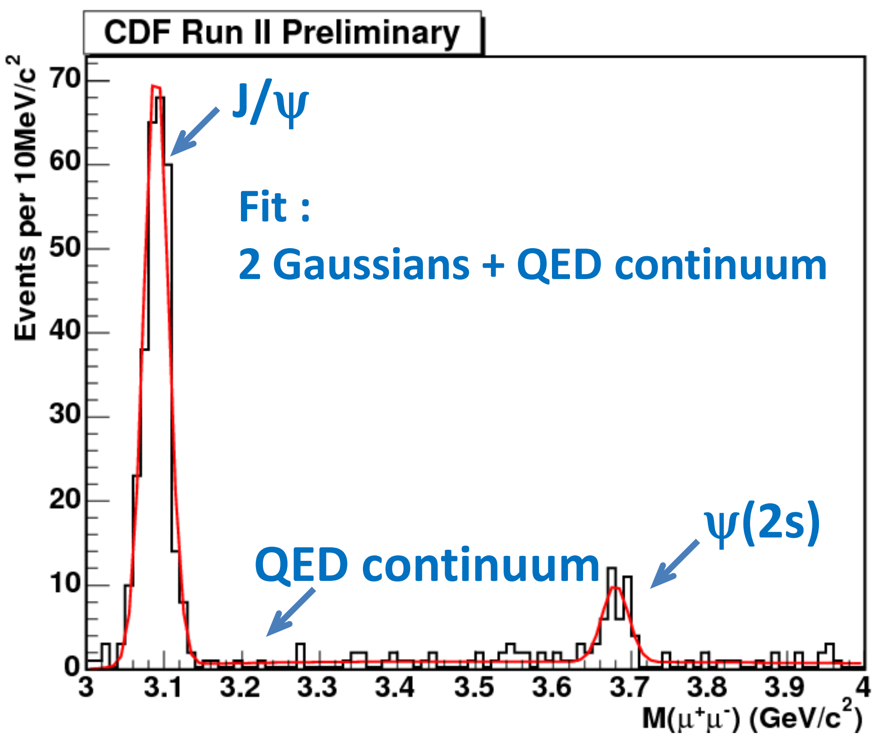
243 ±21 events

dσ/dy|$_{y=0}$ = 3.92 ± 0.62 nb

Theoretical Predictions

2.8 nb [Szczurek07,],
2.7 nb [Klein&Nystrand04],
3.0 nb [Conclaves&Machado05], and
3.4 nb [Motkya&Watt08].

PRL 242001 (2009)



Ψ(2s) production

34±7 events

dσ/dy|$_{y=0}$ = 0.54 ± 0.15 nb

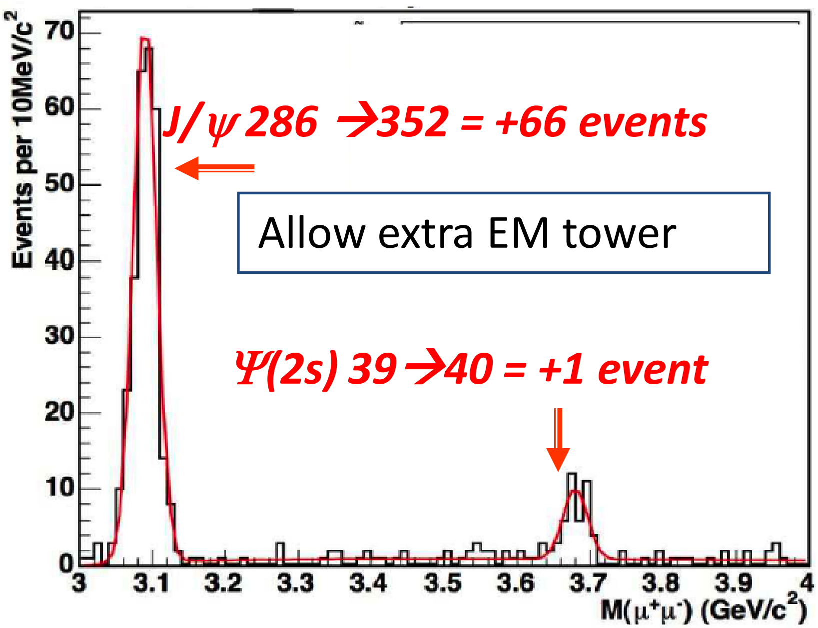
R = ψ(2s)/J/ψ = 0.14 ± 0.05

In agreement with HERA:

R = 0.166 ± 0.012 in a similar kinematic region

Exclusive $\chi_c \to J/\psi(\to\mu^+\mu^-)+\gamma$

PRL 242001 (2009)



➔ Allowing EM towers (E_T>80MeV)

large increase in the J/ψ peak

minor change in the ψ(2s) peak

↓

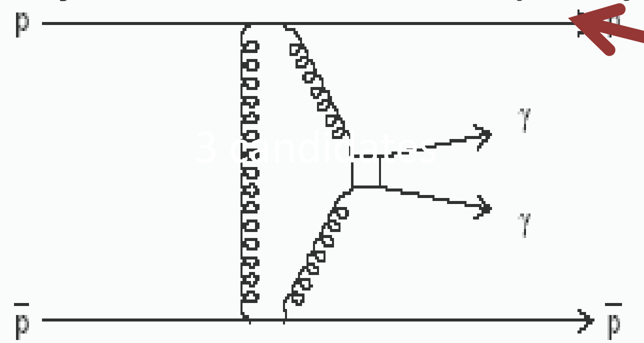
Evidence for

$\chi_c \to J/\psi + \gamma$ production

$d\sigma/dy|_{y=0}$ = 75 ± 14 nb,
compatible with theoretical predictions
160 nb (Yuan 01)
90 nb (KMR01)

Exclusive $\gamma\gamma$ Production

Phys.Rev.Lett. 99,242002 (2007)



3 candidates observed, limit set

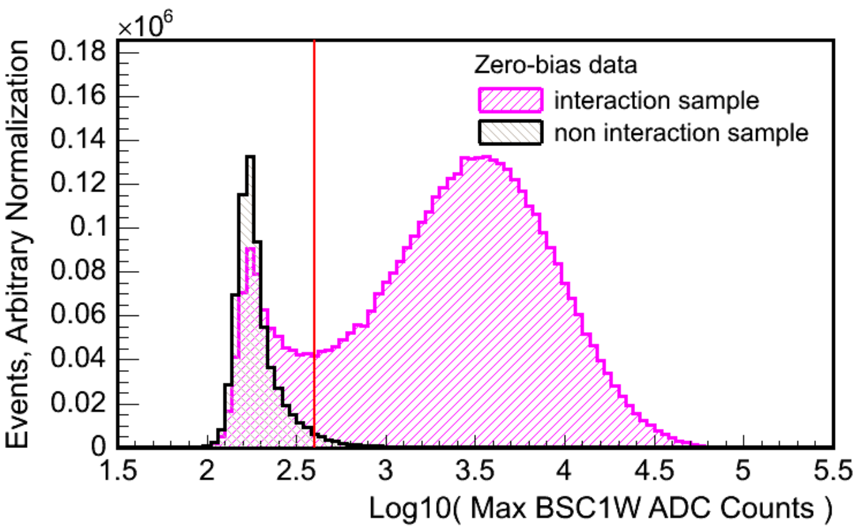
more data!
adjusted triggers

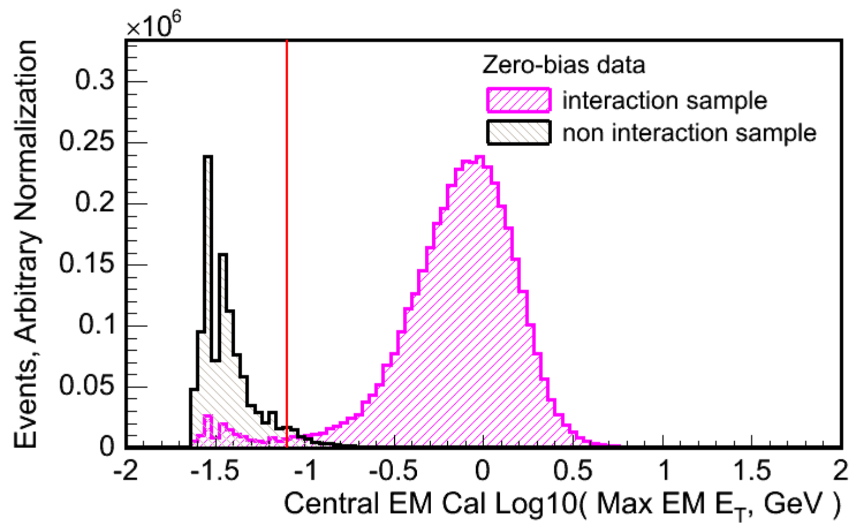
Requirements : no other particles in the detectors up to $|\eta| < 7.4$

Study noise level by looking at "zero-bias" events:

"no interaction" class of events

"interaction" class of events





Exclusive $\gamma\gamma$ Production

Use control sample to understand

$$p+\overline{p}\rightarrow p+e^{+}e^{-}+\overline{p}\ via\ \gamma+\gamma\ (QED)$$

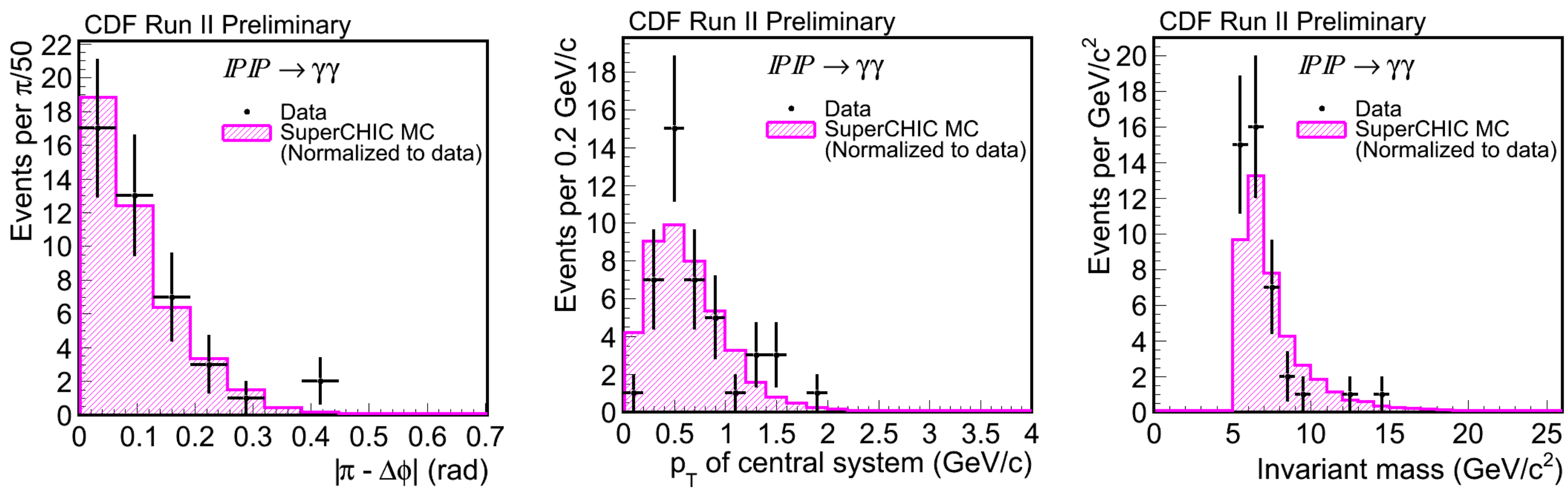
$$\sigma_{e^+e^-\text{excl.}}^{|\eta|<1,E_T>2.5\text{GeV}} = 2.88 \pm 0.59(\text{stat}) \pm 0.62(\text{sys})\ \text{pb}$$

$$\sigma_{\text{LPair}}^{|\eta|<1,E_T>2.5\text{GeV}} = 3.25 \pm 0.07\ \text{pb}$$

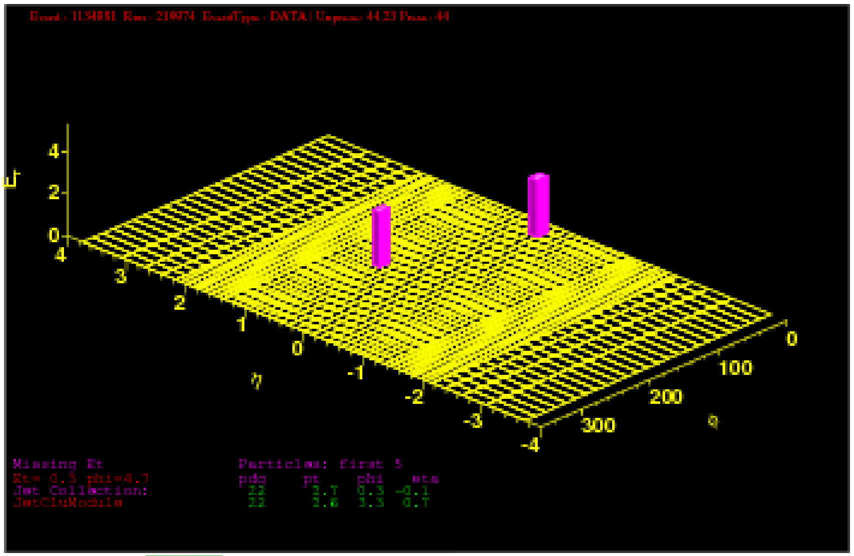
$$\sigma_{e^+e^-\text{excl.}}^{|\eta|<1,E_T>5.0\text{GeV}} = 0.60 \pm 0.28(\text{stat}) \pm 0.14(\text{sys})\ \text{pb}$$

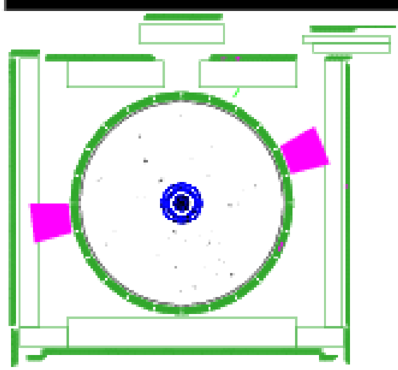
$$\sigma_{\text{LPair}}^{|\eta|<1,E_T>5.0\text{GeV}} = 0.58 \pm 0.003\ \text{pb}$$

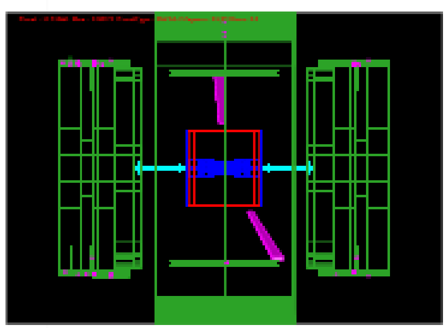
Kinematic distributions of photon pair



Exclusive $\gamma\gamma$ Production





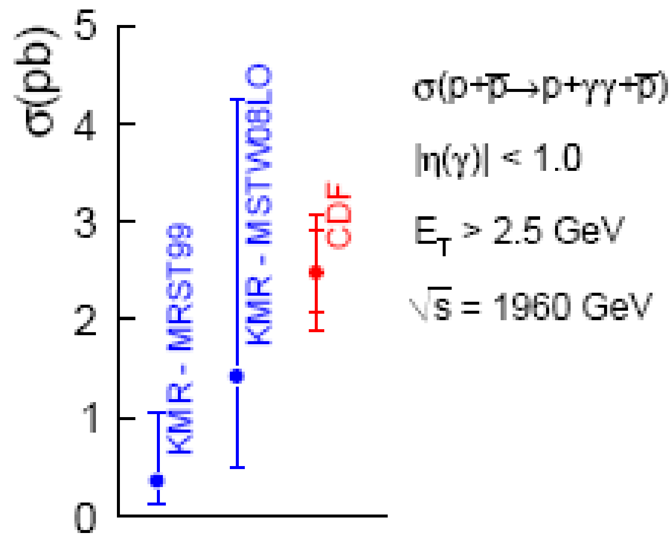


PRL 108, 081801 (2012)

Observed 43 events >> 5 σ

$\sigma_{\gamma\gamma_{excl}}$=2.48±0.42(stat)±0.41(sys) pb

Good agreement with
the theoretical predictions



Conclusions

- **We have very extensive program of soft QCD and diffractive studies at the Tevatron –**

  new forward detectors R&D, new methodologies developed, many pioneering measurements performed.

- **Working on datasets collected at**

  $\sqrt{s}$=300 and 900 GeV – some results in the process to be published, more in the pipeline

not shown here – studies of DPS, exclusive studies in Gap – X – Gap at different ✓s

Conclusions

*So what is in the **future for soft and diffractive studies** at the LHC and beyond?*

- already have new types of data – wide variety of variables for non-diffractive studies,
- more activity in developing MC tools,

✓ reliable MC simulations are essential

✓ new types of measurements

✓ new methods for identification of diffractive events

Ref: Papers on diffraction at CDF

Soft Diffraction

Double Pomeron Exc.
PRL 93,141603 (2004)

Multi-Gap Diffraction
PRL 91, 011802 (2003)

Single Diffraction
PRD 50, 5355 (1994)

Double Diffraction
PRL 87, 141802 (2001)

Hard Diffraction

Dijets:
1.8 TeV PRL 85, 4217 (2000)
1.96 TeV PRD 77, 052004 (2008)

Di-photons
1.96 TeV PRL 99, 242002 (2007)
1.96 TeV PRL 108,081801 (2012)

Charmonium
1.96 TeV PRL 102, 242001 (2009)

Rapidity Gap Tag
W PRL 78, 2698 (1997)
Dijets PRL 79, 2636 (1997)
b-quark PRL 84, 232 (2000)
J/Ψ PRL 87, 241802 (2001)

Roman Pot Tag

Dijets:
1.96 TeV PRD 86, 032009 (2012)
1.8 TeV PRL 84, 5043 (2000)
630 GeV PRL 88, 151802 (2002)

W/Z:
1.96 TeV PRD 82,112004 (2010)

Jet-Gap-Jet
1.8 TeV PRL 74, 855 (1995)
1.8 TeV PRL 80, 1156 (1998)
630 GeV PRL 81, 5278 (1998)

Elastic Scattering

- The particles after scattering are the same as the incident particles
  $\xi=\Delta p/p=0$ for elastic events; $t = -(p_i-p_f)^2$

- The cross section can be written as:

$$\frac{d\sigma/dt}{(d\sigma/dt)|_{t=o}} = e^{bt} \cong 1-b(p\theta)^2$$

$\sqrt{s}$	Exp.	t-range [GeV^2]	B[GeV^{-2}], ρ
546 GeV	CDF	$0.025 \div 0.08$	$B = 15.28 \pm 0.58$
1.8 TeV	CDF	$0.04 \div 0.29$	$B = 16.98 \pm 0.25$
	E710	$0.034 \div 0.65$	$B = 16.3 \pm 0.3$
		$0.001 \div 0.14$	$B = 16.99 \pm 0.25$ $\rho = 0.140 \pm 0.069$
	E811	$0.002 \div 0.035$	using $\langle B\rangle_{\mathrm{CDF,E710}}$ $\rho = 0.132 \pm 0.056$
1.96 TeV	DØ	$0.9 \div 1.35$	–

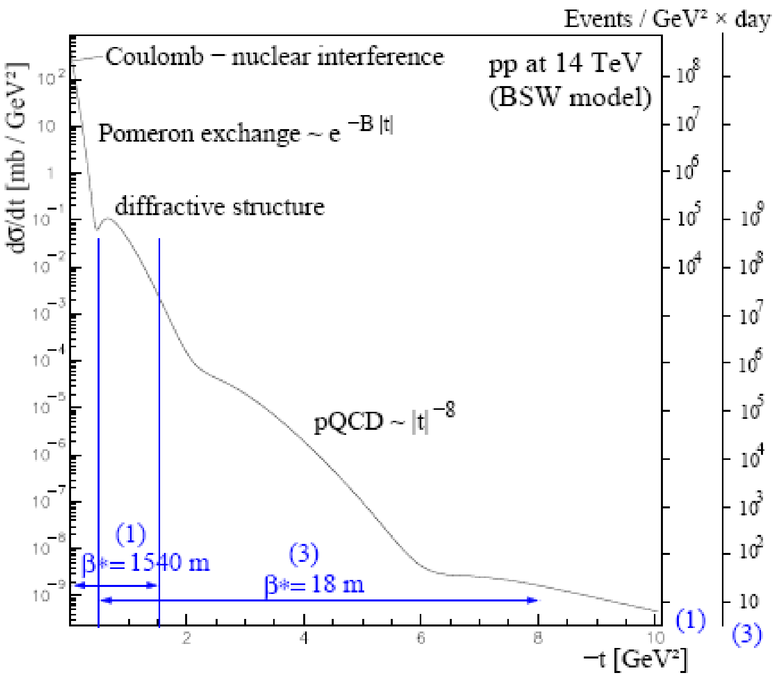


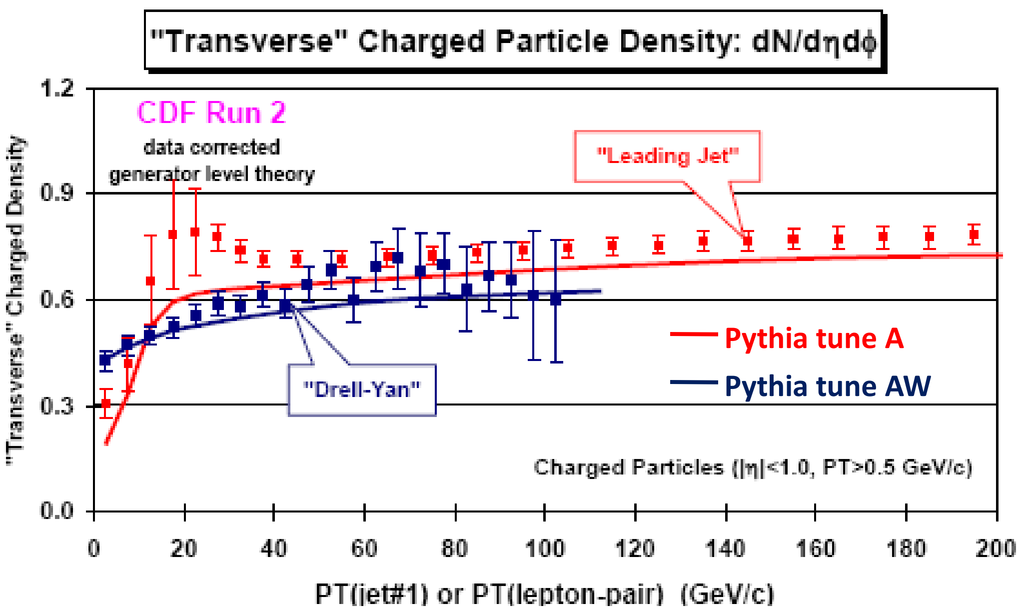
Fig. fromTOTEM publications

UE in Drell-Yan and incl. jet events

Event topologies:

- Leading Jet
- Drell-Yan

Transverse Region

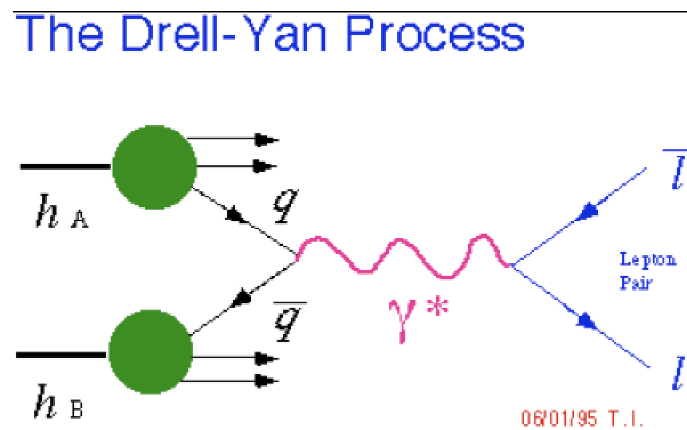


Drell-Yan:

less gluon radiation,
easier to reconstruct

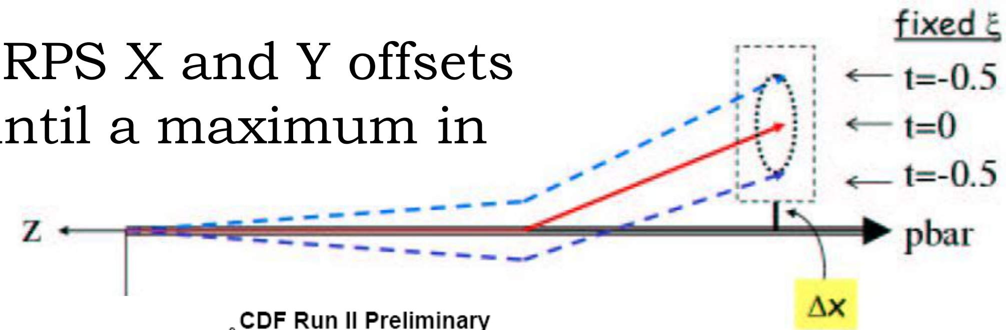
ll = ee, μμ

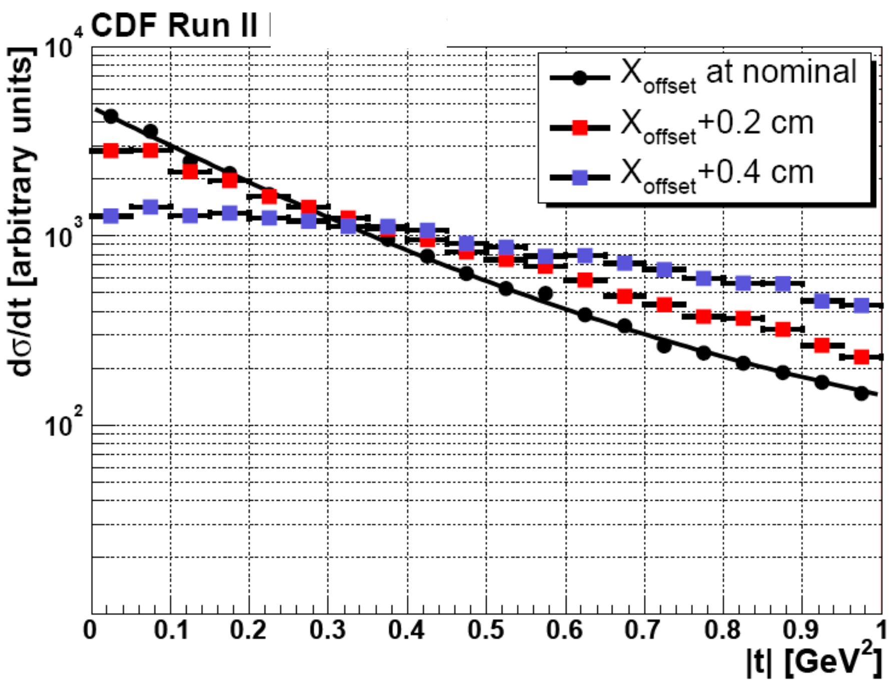
p_T>20 GeV/c
|η|<1
70 GeV/c^2<M_{pair}<110 GeV/c^2
|η(pair)|<6

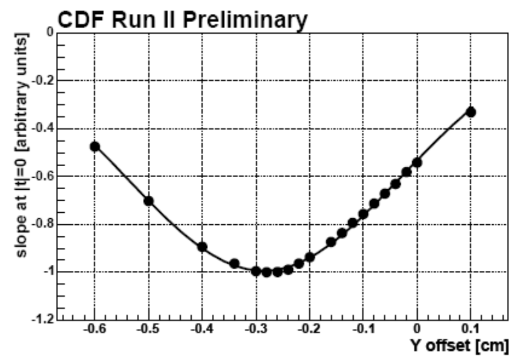


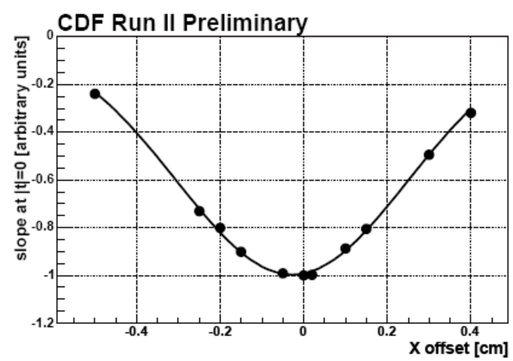
Dynamic alignment of the RPS

Method: iteratively adjust the RPS X and Y offsets from the nominal beam axis until a maximum in the b-slope is obtained at t=0.



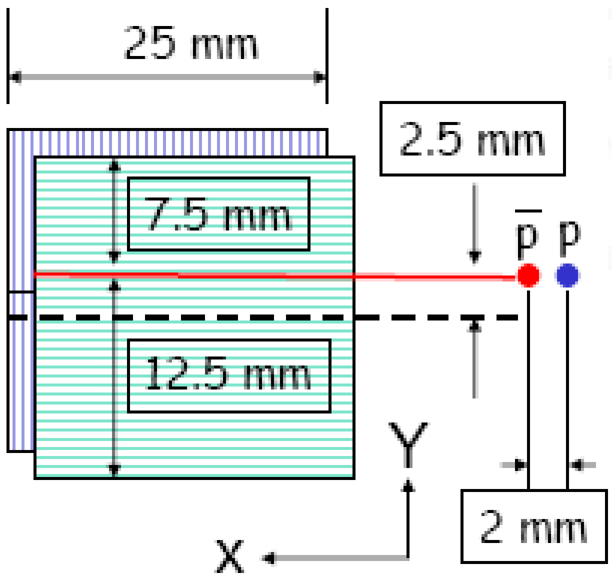




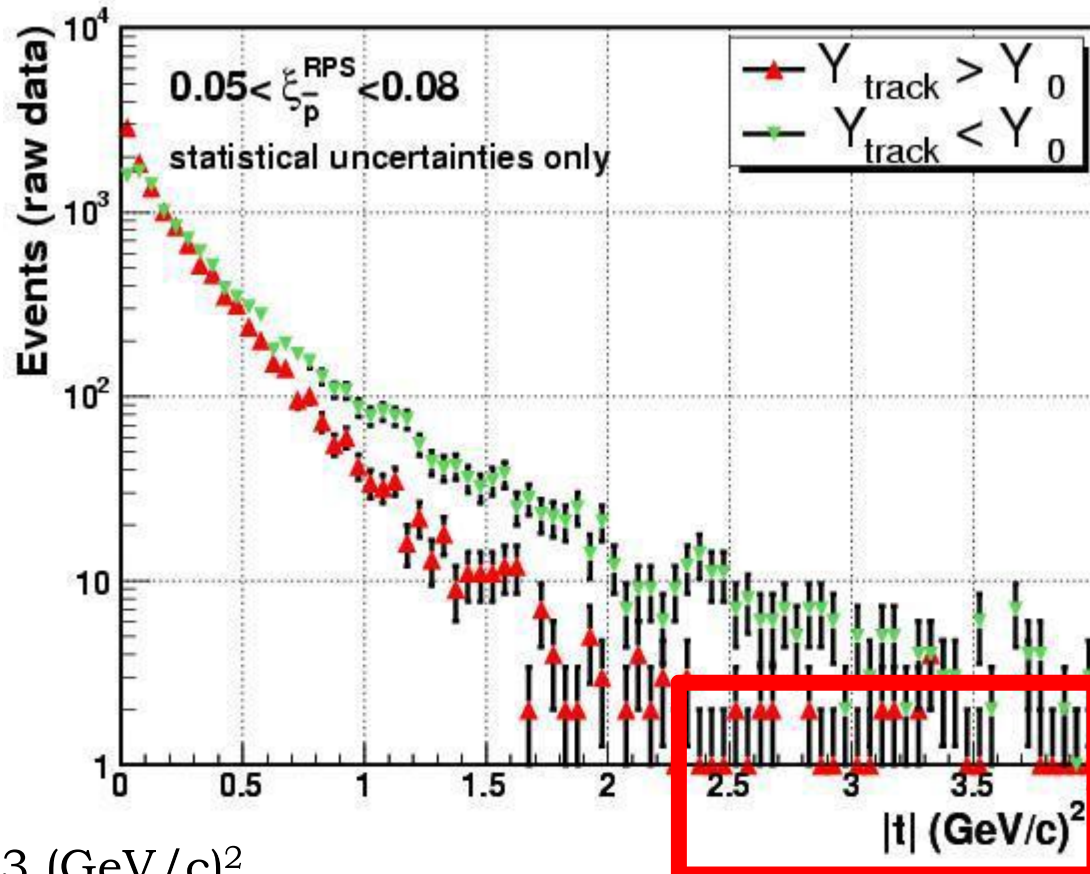


Background evaluation

schematic view of
fiber tracker



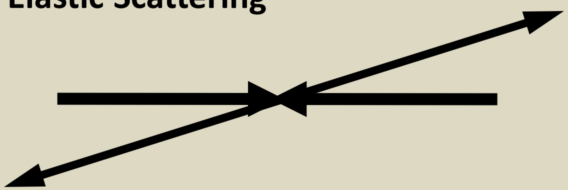
PRD 86, 032009 (2012)

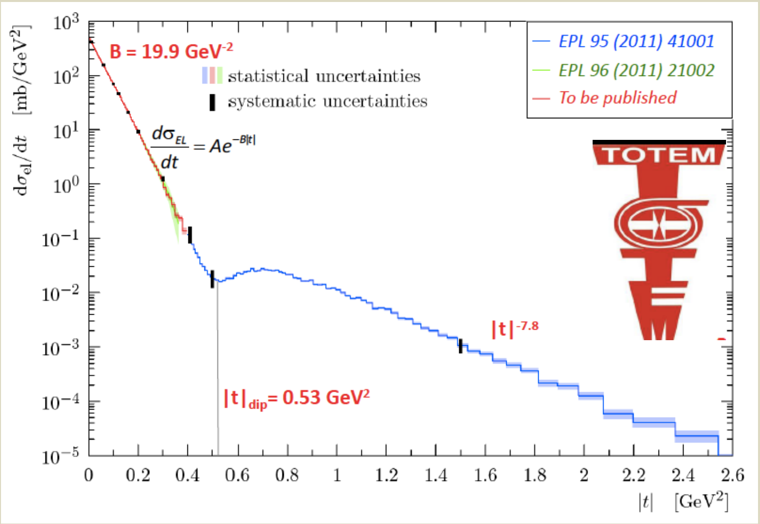


- tracker's upper edge: |t|=2.3 (GeV/c)^2
- the lower edge is at |t|= 6.5 (GeV/c)^2 (not shown)
- background level: region of Y_{track}>Y_o data for |t|>2.3 (GeV/c)^2

Proton-(anti)Proton Collisions

Elastic Scattering



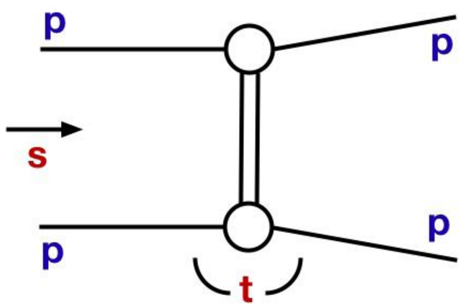


t - four-momentum transfer squared

usually t<<1 GeV ^{2}

for fixed s :

$$\frac{d\sigma}{dt} = \frac{d\sigma}{dt}\Big|_{t=0} e^{-B|t|}$$



B, slope parameter "measures" size of interaction region