DIFFRACTION @ CDF

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CDF COLLABORATION MEETING

PUERTO VALLARTA, MEXICO, Jan. 31 – Feb. 6 2010

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- Diffraction at CDF: 17 PRLs / PRD's

ongoing analyses

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Central gaps……	Mesropian	– final stage of analysis

- Diffraction at LHC

Alignment, backgrounds and calibrations

Hot topics: Exclusive Higgs production, Mueller-Navelet jets, diffractive W/Z, exclusive Z production

- Phenomenology
  - Pomeron intercept and slope: a QCD connection: PRD 80,111901 (R) 2009
  - Diffractive and total pp cross sections at LHC:: submitted to PRD (R)

p-p Interactions

Non-diffractive:

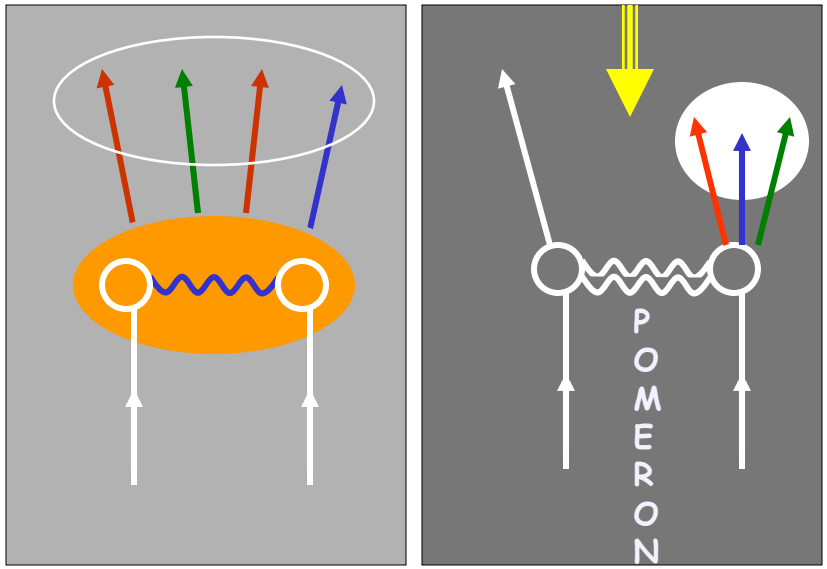
Color-exchange

Diffractive:

Colorless exchange carrying vacuum quantum numbers

rapidity gap

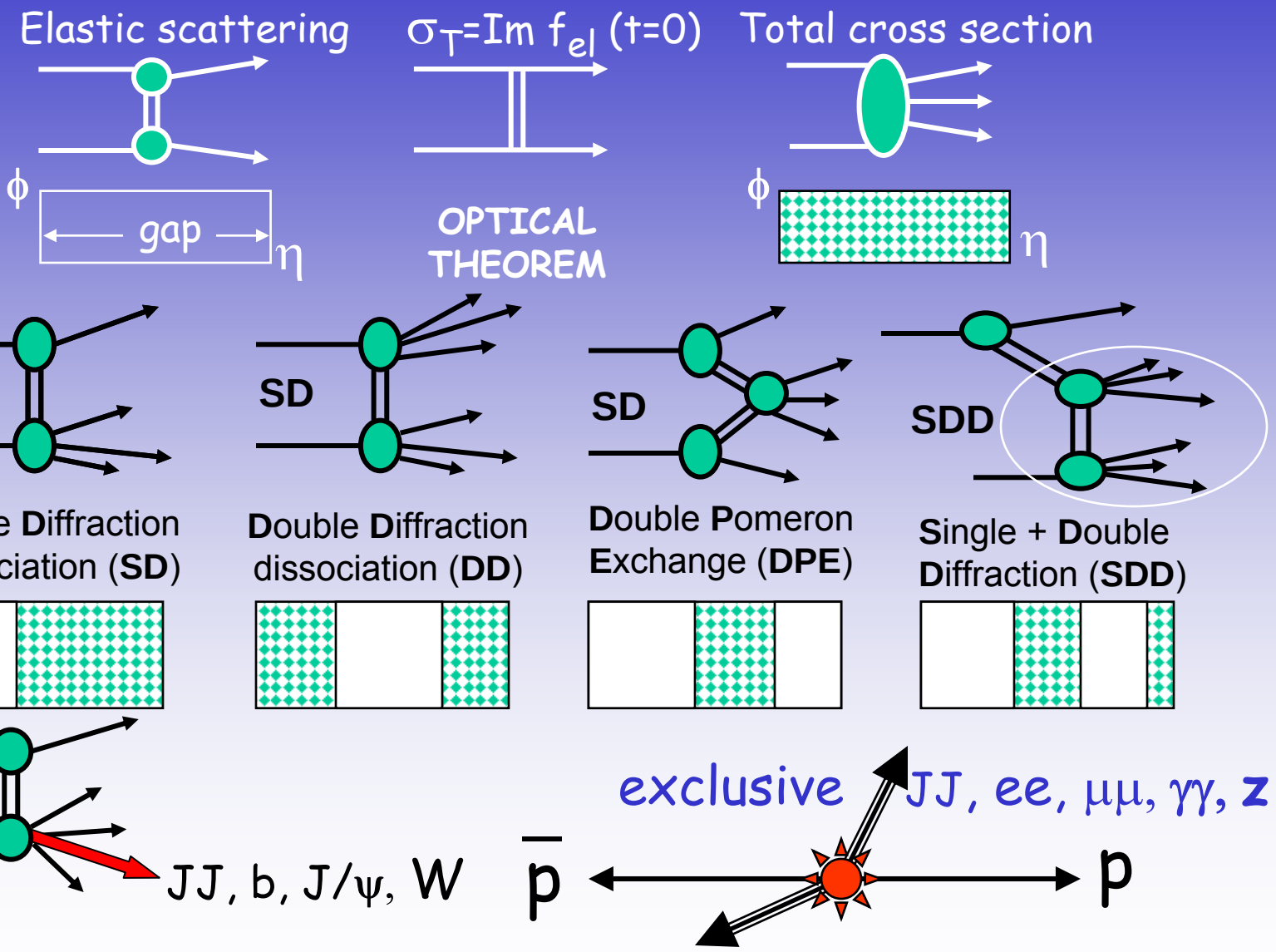
Incident hadrons acquire color and break apart



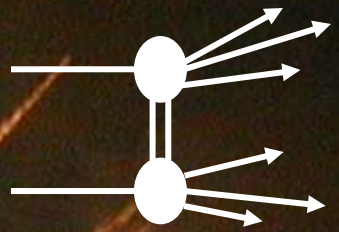
Incident hadrons retain their quantum numbers remaining colorless

Goal: understand the QCD nature of the diffractive exchange

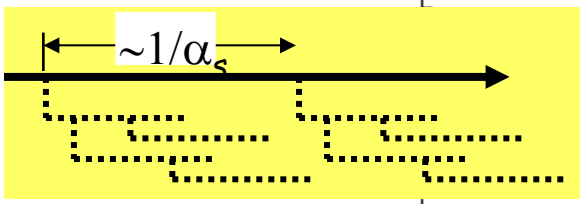
Diffraction at CDF



Rapidity Gaps in Fireworks



$\sigma^{T}_{pp/\bar{p}p}$ vs. Collision Energy



From: Covolon, Montagna & KG, PLB 389, 176 (1996)

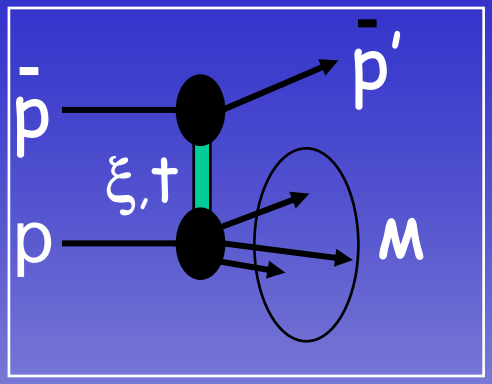
Global fit to $p^{\pm}p$, $p^{\pm}$ and $K^{\pm}p$ cross sections

❖ σ @ LHC $\sqrt{s}$=14 TeV: 122 ± 5 mb Born, 114 ± 5 mb eikonal

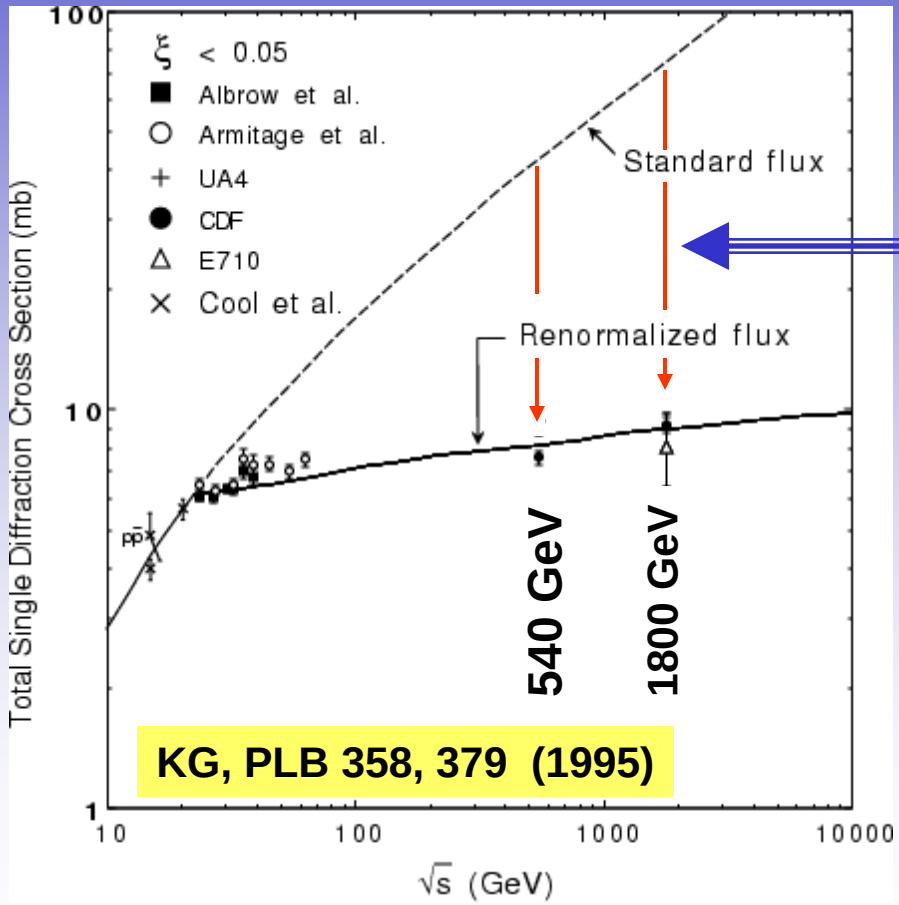
➔ error estimated from the error in ε given in CMG-96

σ^{T}_{SD} (pp & $\bar{p}p$)

➔ suppressed relative to Regge prediction

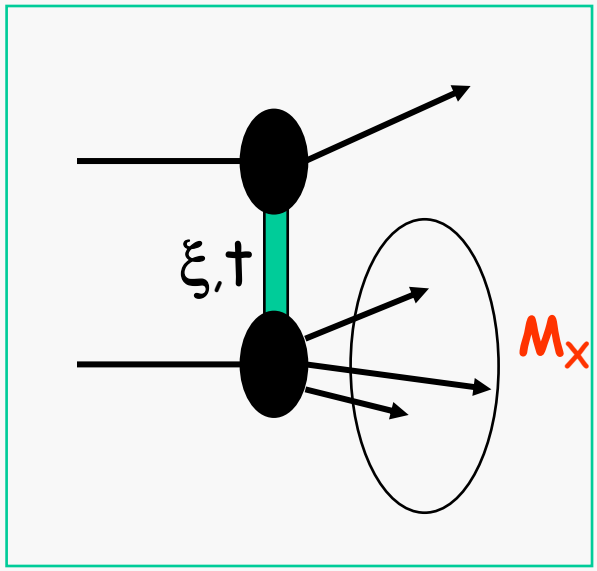


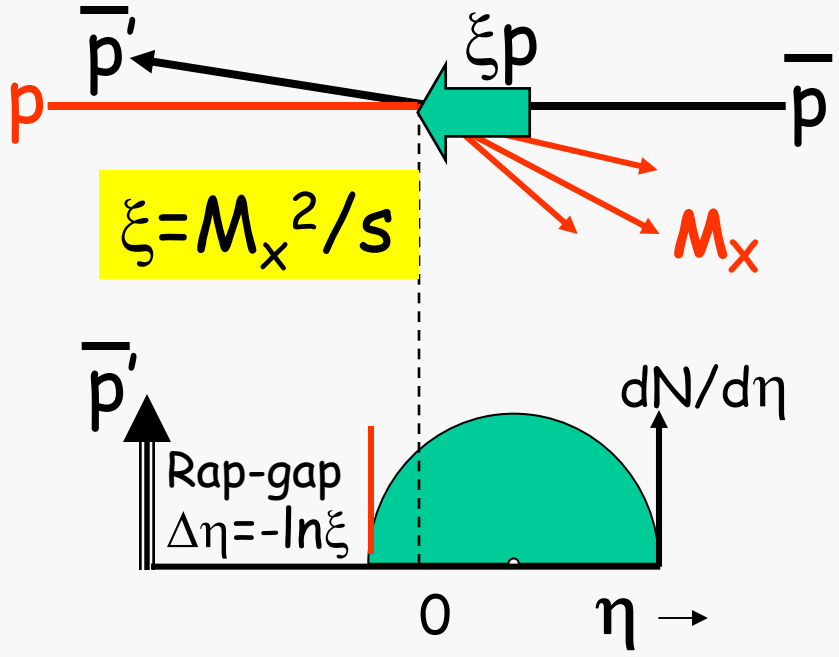
σ^{T}_{SD} mb



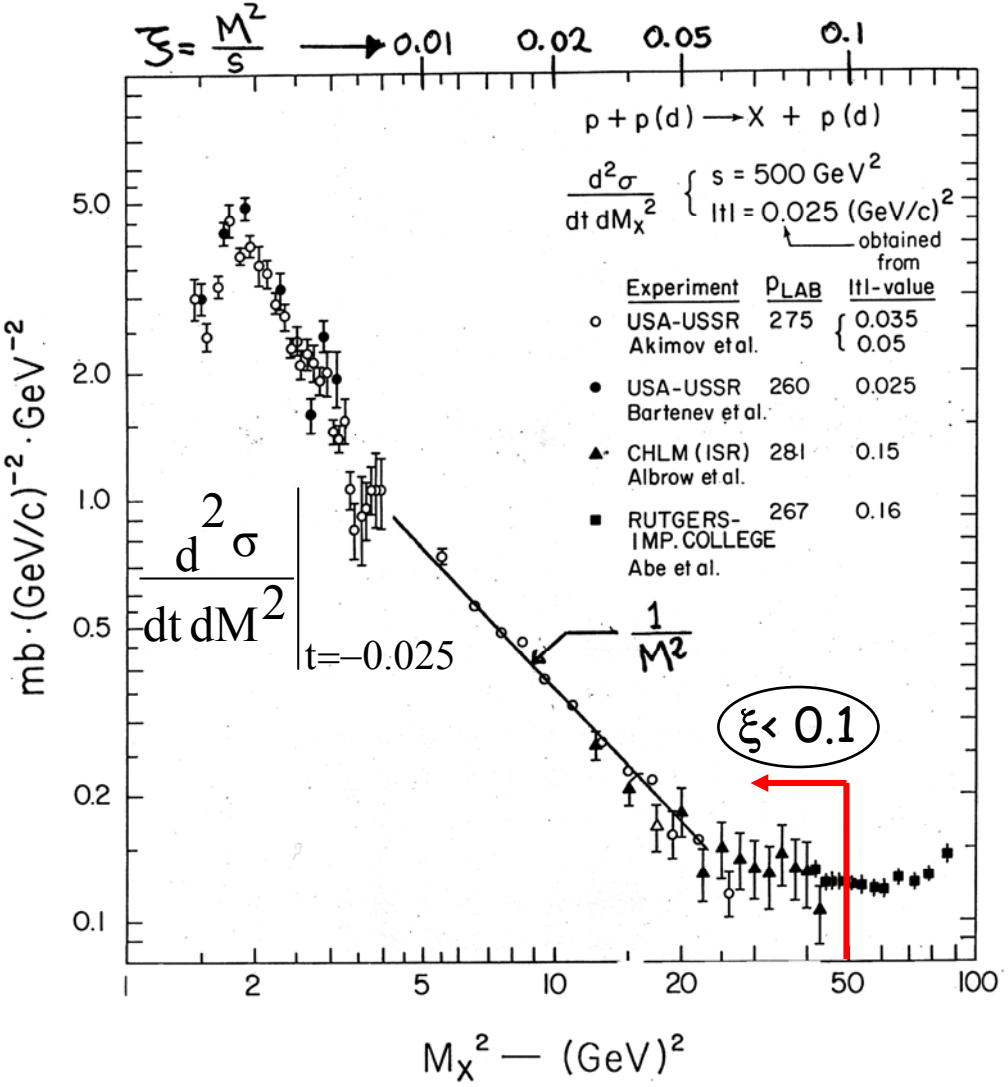
Factor of ~8 (~5) suppression at $\sqrt{s}$ = 1800 (540) GeV

Definitions



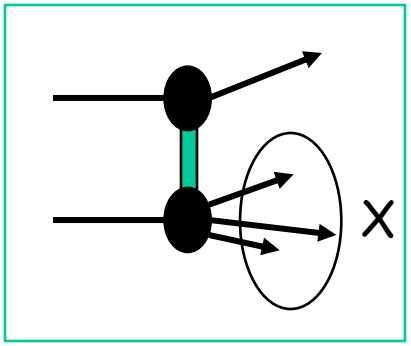


Dσ/dM² distribution

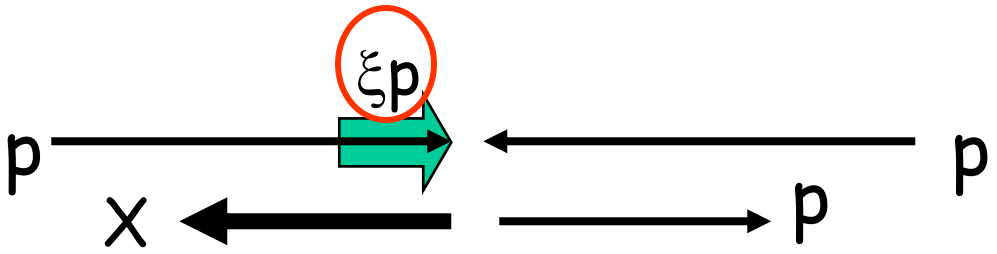


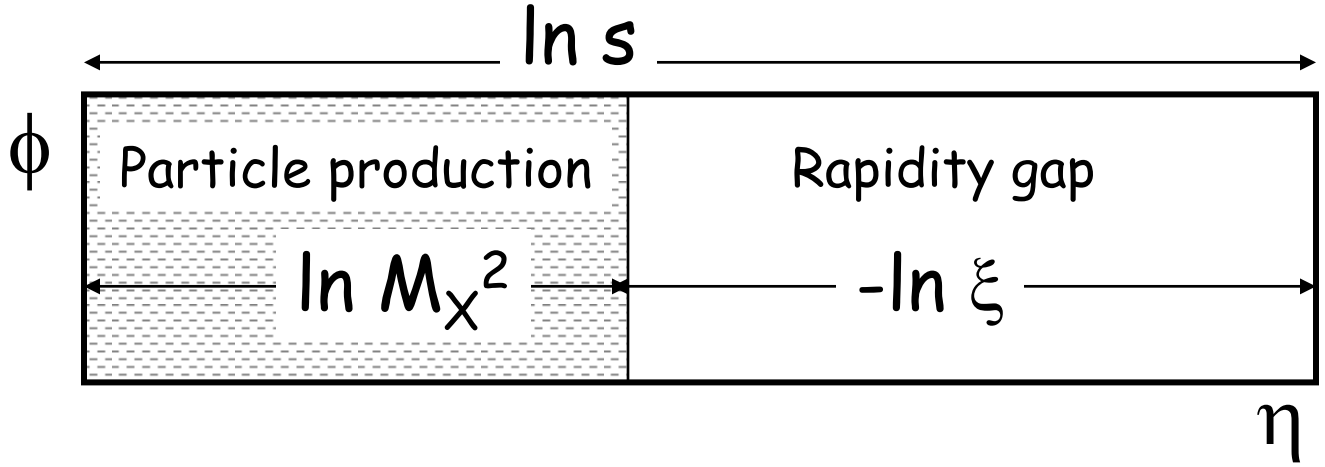
KG, Phys. Rep. 101, 169 (1983)

$$\frac{d\sigma}{dM^2} \sim \frac{1}{dM^2} \Rightarrow \frac{d\sigma}{d\xi} \sim \frac{1}{\xi}$$



Diffractive Rapidity Gaps





$$\left(\frac{d\sigma}{d\Delta\eta}\right)_{t=0} \approx \text{constant} \Rightarrow \frac{d\sigma}{dM^2} \sim \frac{1}{M^2} \Rightarrow \frac{d\sigma}{d\xi} \sim \frac{1}{\xi}$$

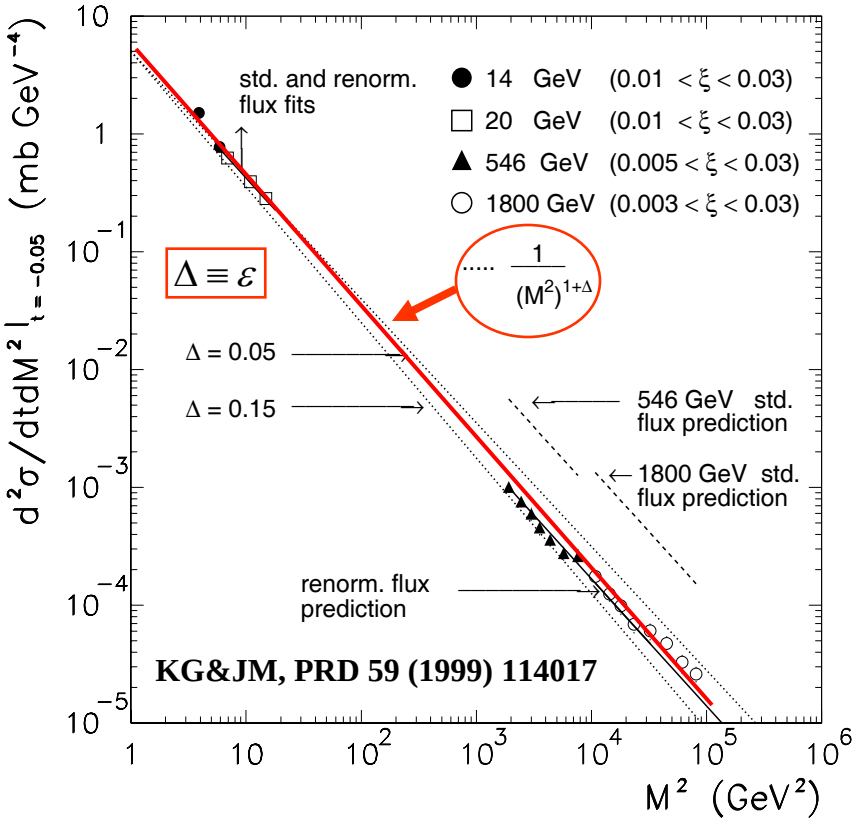
M^2 scaling

➔ $d\sigma/dM^2$ independent of s over 6 orders of magnitude!

renormalization

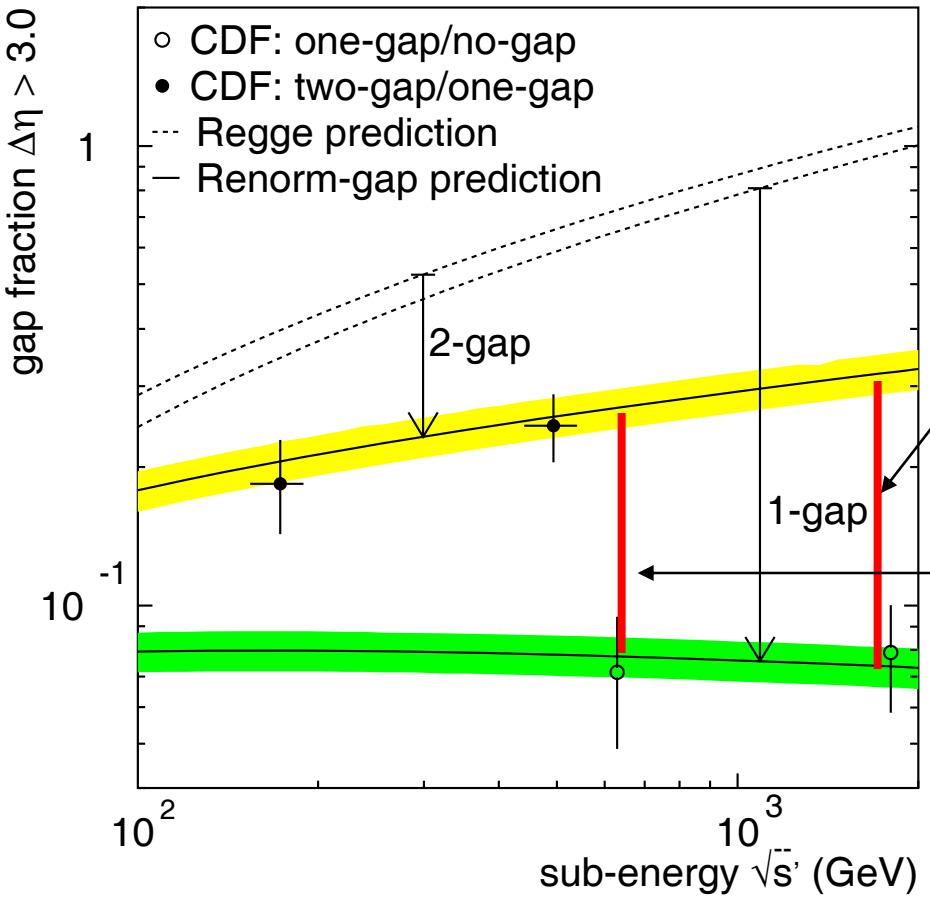
$$\frac{d\sigma}{dM^2} \propto \frac{s^{2\varepsilon} \to 1}{(M^2)^{1+\varepsilon}}$$

➔ Independent of s over 6 orders of magnitude in M^2 !



➔ factorization breaks down to ensure M^2 scaling!

Gap survival probability - S



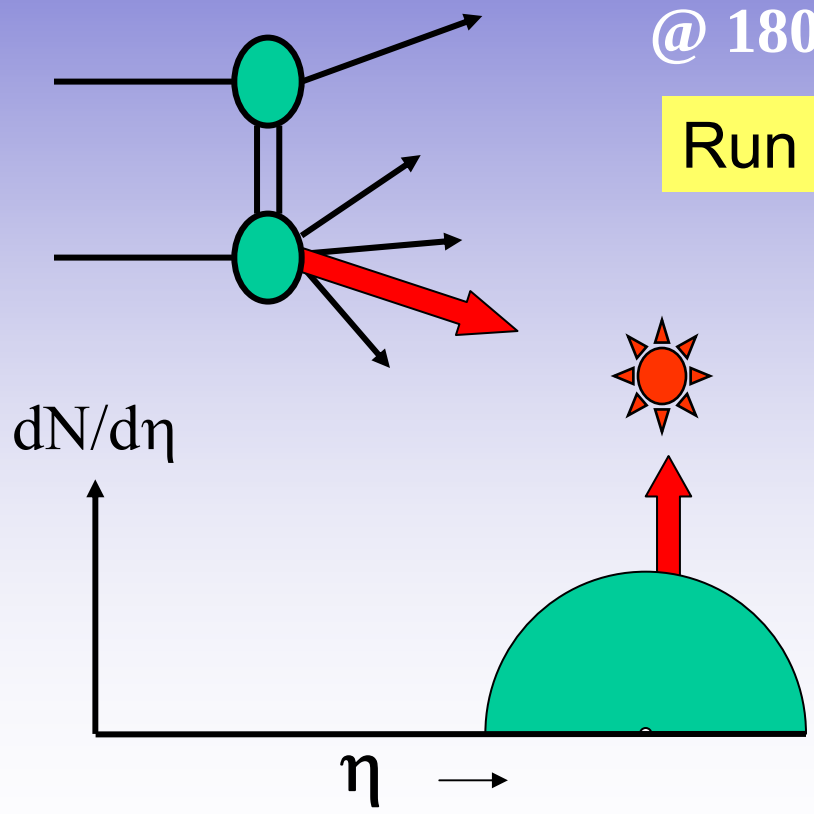
$$S = \frac{\phi\text{-}\eta \,/\, \phi\text{-}\eta}{\phi\text{-}\eta \,/\, \phi\text{-}\eta}$$

$$S^{1-gap/0-gap}_{2-gap/1-gap}(1800\ \text{GeV}) \approx 0.23$$

$$S^{1-gap/0-gap}_{2-gap/1-gap}(630\ \text{GeV}) \approx 0.29$$

Hard diffractive fractions

$$\bar{p}p \rightarrow (\odot + X) + \text{gap}$$



Fraction: SD/ND @ 1800 GeV

Run I

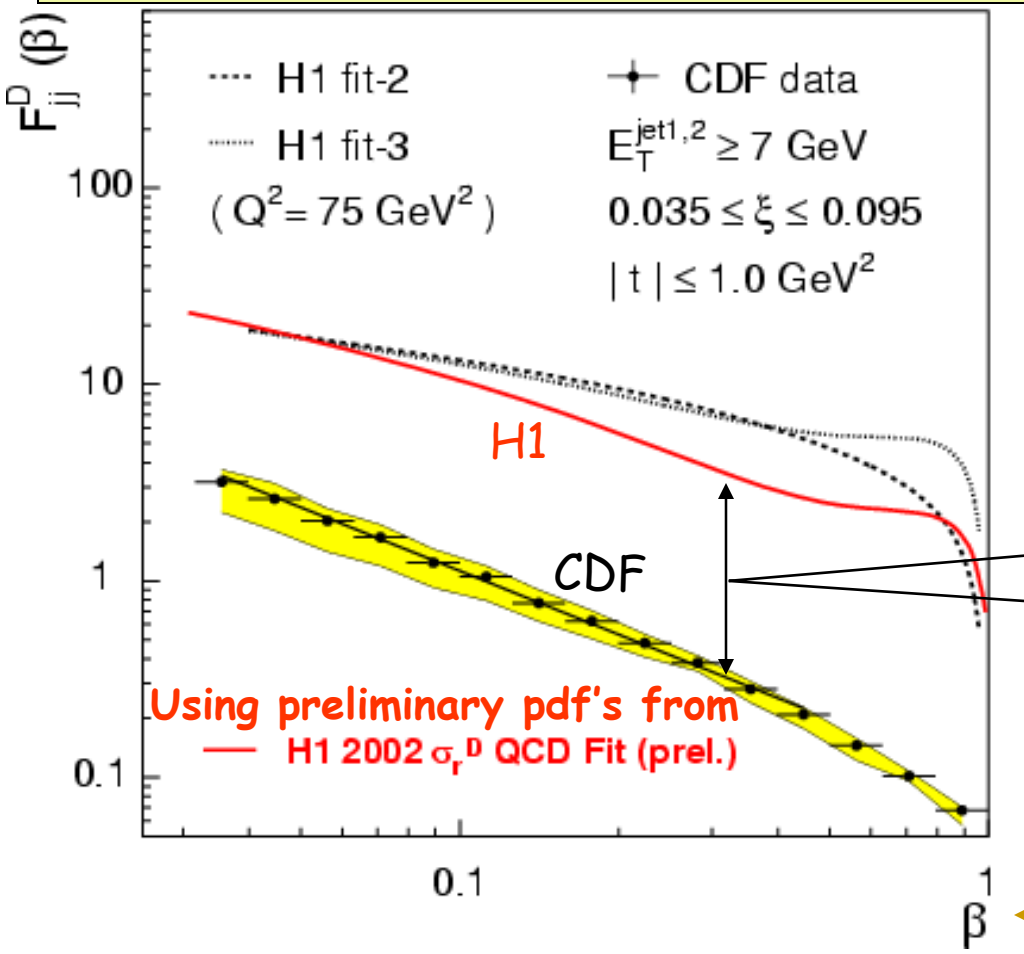
⊙	Fraction (%)
JJ	0.75 +/- 0.10
W	0.115 +/- 0.55
b	0.62 +/- 0.25
J/ψ	1.45 +/- 0.25

All fractions ~ 1%
(differences due to kinematics)

- ~ uniform suppression
- ~ FACTORIZATION !

Run I – Diffractive Structure Function

$$R(x_{Bj}) \equiv \frac{\text{Rate}_{jj}^{SD}(x_{Bj})}{\text{Rate}_{jj}^{ND}(x_{Bj})} \Rightarrow \frac{F_{jj}^{SD}(x_{Bj})}{F_{jj}^{ND}(x_{Bj})}$$



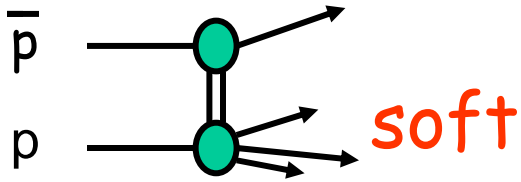
$$\bar{p}p \rightarrow \bar{p} + \text{dijet} + X$$

Breakdown of QCD factorization

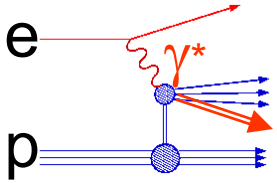
HOWEVER:
same suppression as in soft diffraction

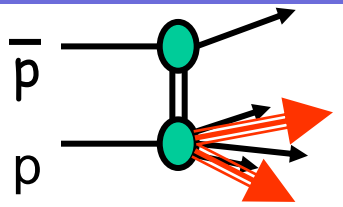
momentum fraction of parton in Pomeron

σ^{T}_{SD} and Dijets



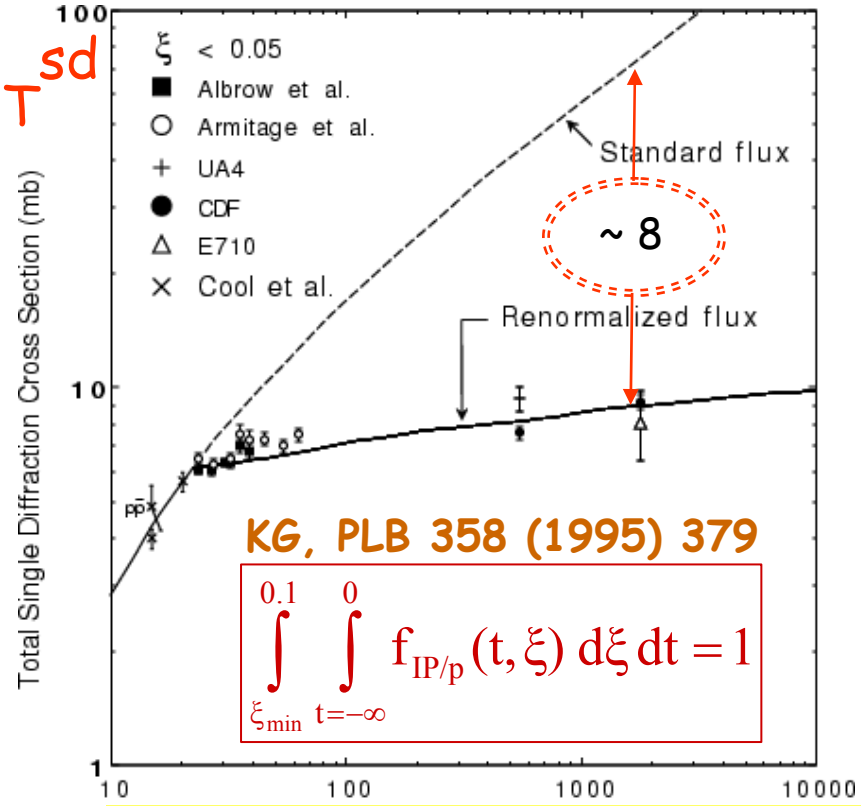
soft

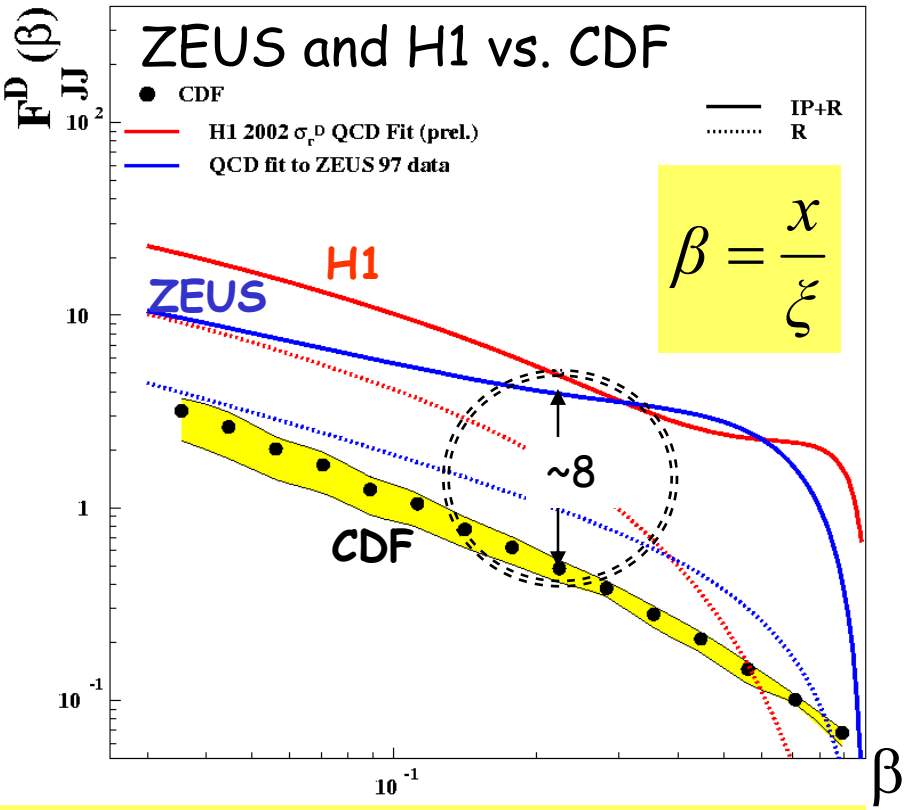




dijet

σ_T^{sd}





Magnitude: same suppression factor in soft and hard diffraction!
Shape of β distribution: ZEUS, H1, and Tevatron – why different slapes?

Diffraction at CDF: ongoing analyses

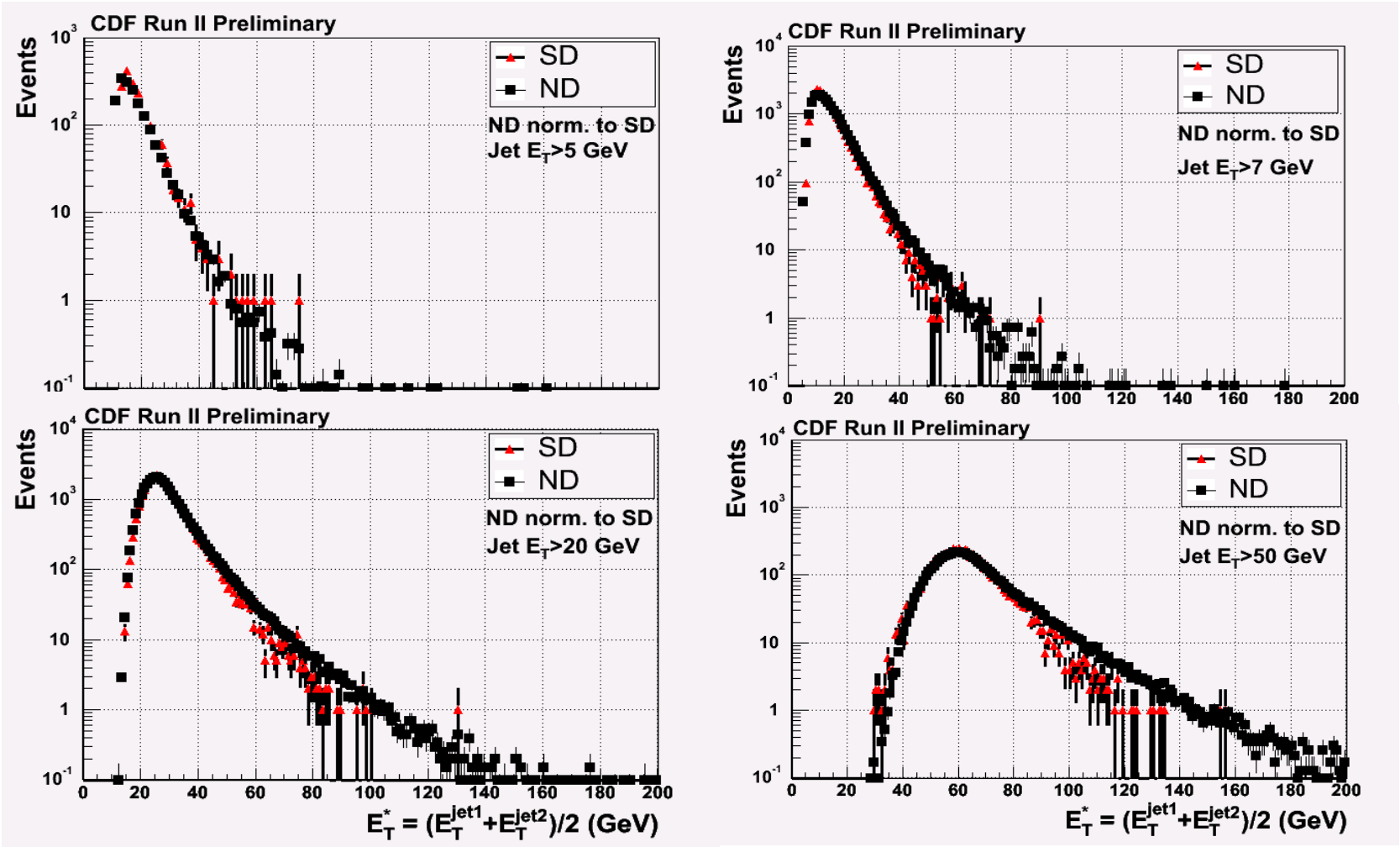
Diffractive dijets…….Gallinaro under godparent review

Diffractive dijet production in $p\bar{p}$ collisions at $\sqrt{s}$=1.96 TeV

M. Gallinaro, K. Goulianos, and K. Terashi
CDF collaboration
(Dated: December 8, 2009)

DSF in DPE…… Terashi final stage of analysis
Diffractive W/Z…….Convery under godparent review
Central gaps……Mesropian final stage of analysis

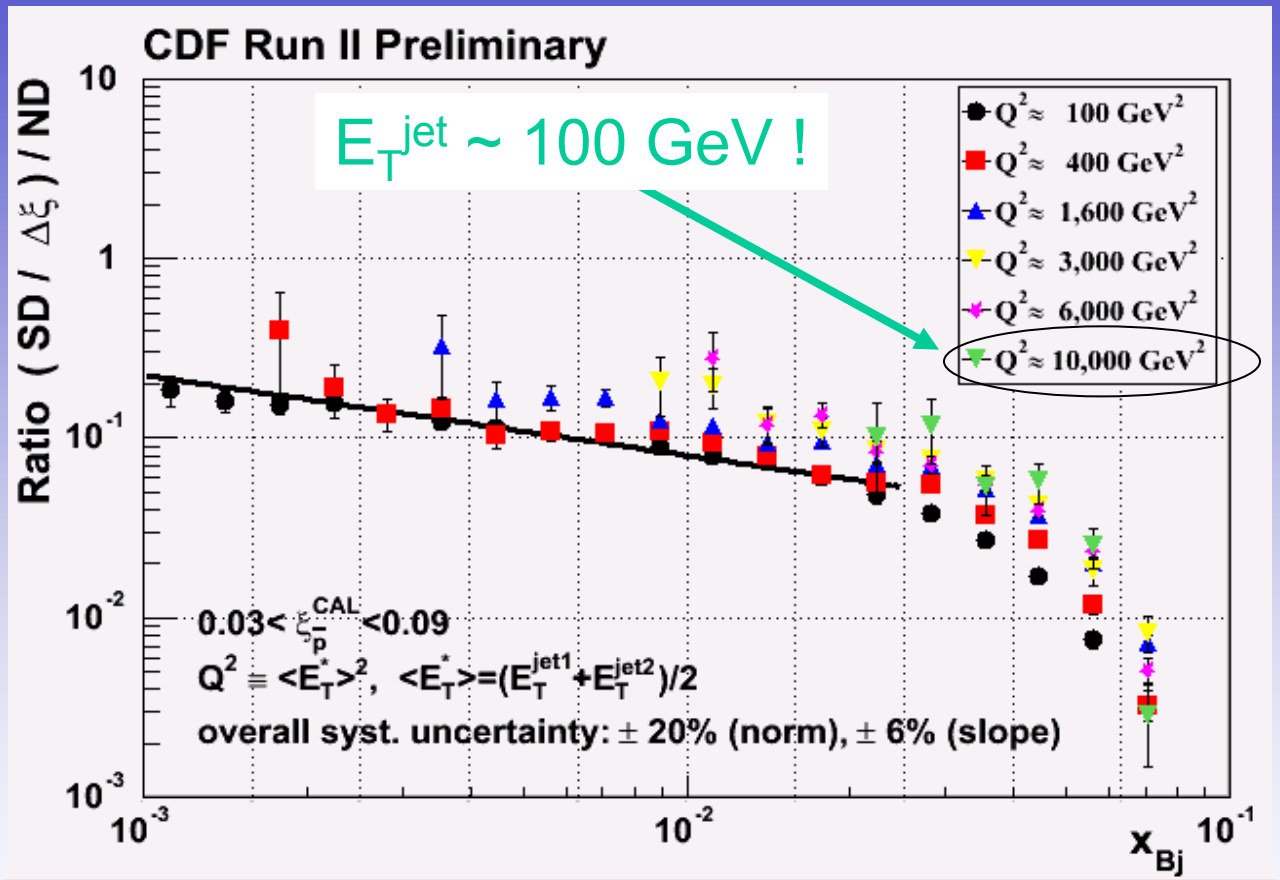
Dijets - E_T distributions



➔ similar for SD and ND over 4 orders of magnitude

Kinematics

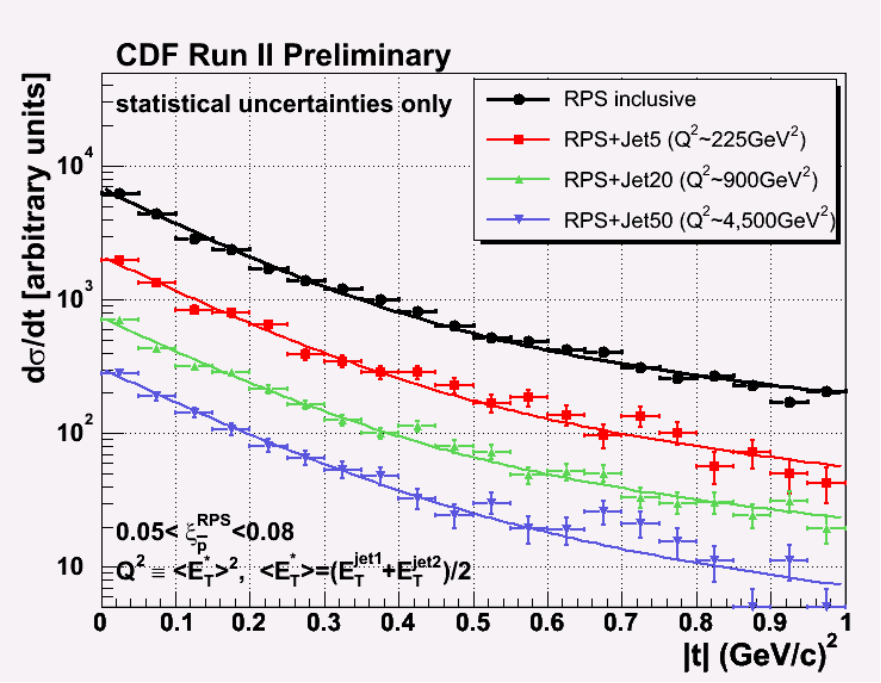
Dijet DSF: x_{Bj} and Q^2 dependence

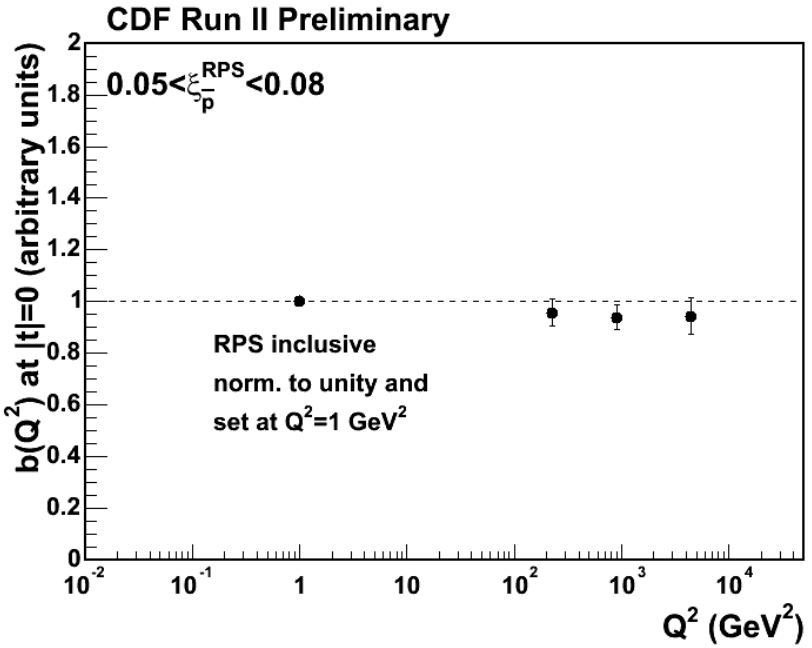


Small Q^2 dependence in region $100 < Q^2 < 10{,}000$ GeV^2

⇨ Pomeron evolves as the proton!

Dijets - diffractive structure function
t- dependence





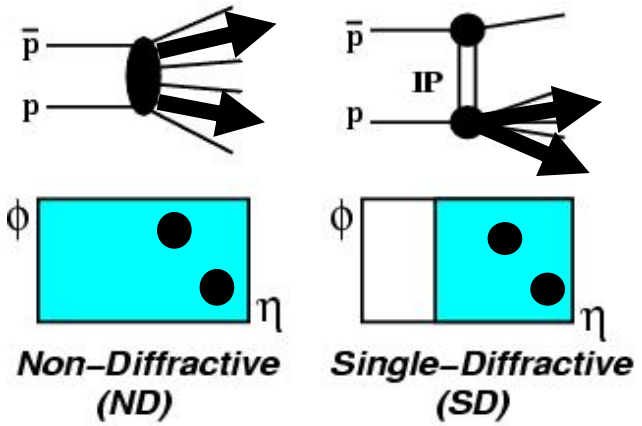
Fit $d\sigma/dt$ to a double exponential

$$F = 0.9 \cdot e^{b_1 \cdot t} + 0.1 \cdot e^{b_2 \cdot t}$$

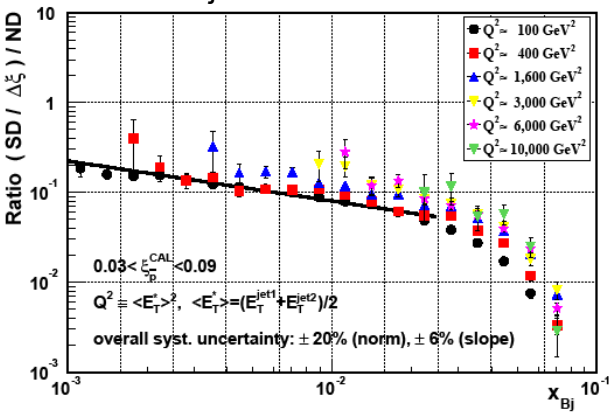
- No Q2 dependence in slope from inclusive to Q^2~10^4 GeV^2
- Same slope over entire region of ~1< Q^2 < 4,500 GeV^2

DSF from Dijets in Run II

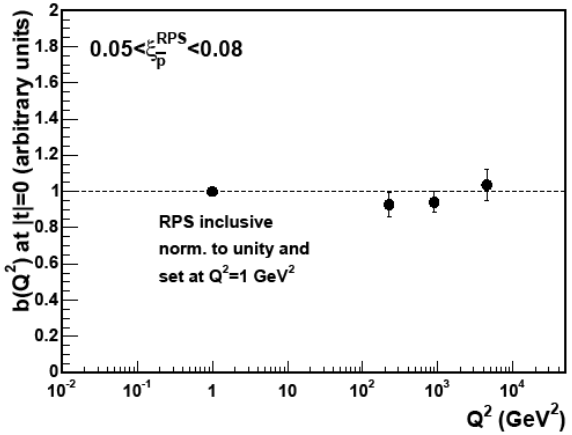
$$R(x_{Bj}) \equiv \frac{Rate_{jj}^{SD}(x_{Bj})}{Rate_{jj}^{ND}(x_{Bj})} \Rightarrow \frac{F_{jj}^{SD}(x_{Bj})}{F_{jj}^{ND}(x_{Bj})}$$



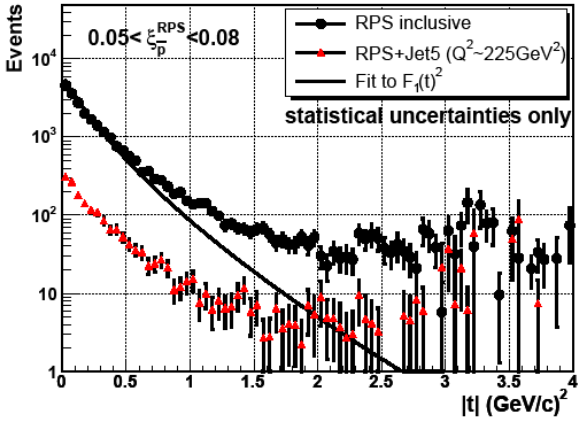
x_{Bj} - distribution



b - slope of t-distribution



t - distribution



- The x_{Bj}-distribution of the SD/ND ratio has no strong Q^2 dependence
- the slope of the t-distribution is independent of Q^2
- the t-distribution displays a diffraction minimum at $|t| \sim 2.5$ (GeV/c)^2 (?)

➢ all three results ➔ "first observation"

Diffraction at CDF: ongoing analyses

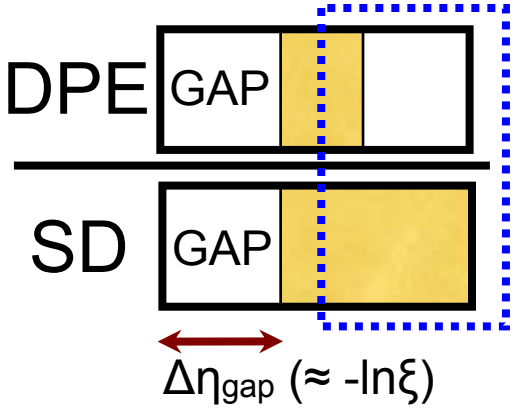
Diffractive dijets…….Gallinaro under godparent review

DSF in DPE…… Terashi final stage of analysis

Diffractive W/Z…….Convery under godparent review
Central gaps……Mesropian final stage of analysis

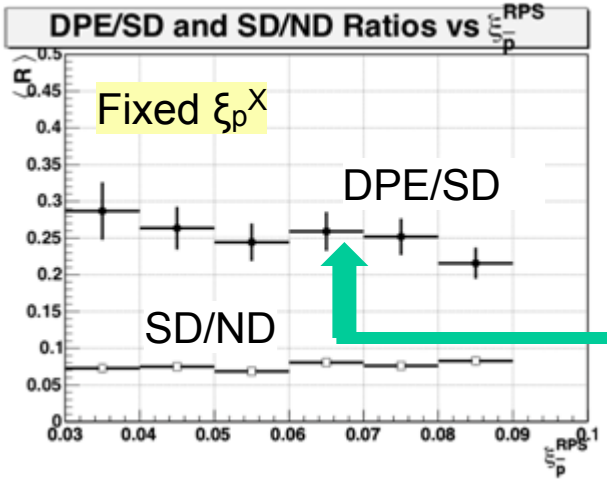
DSF from Dijets in DPE

QCD factorization holds for the formation of the 2nd gap



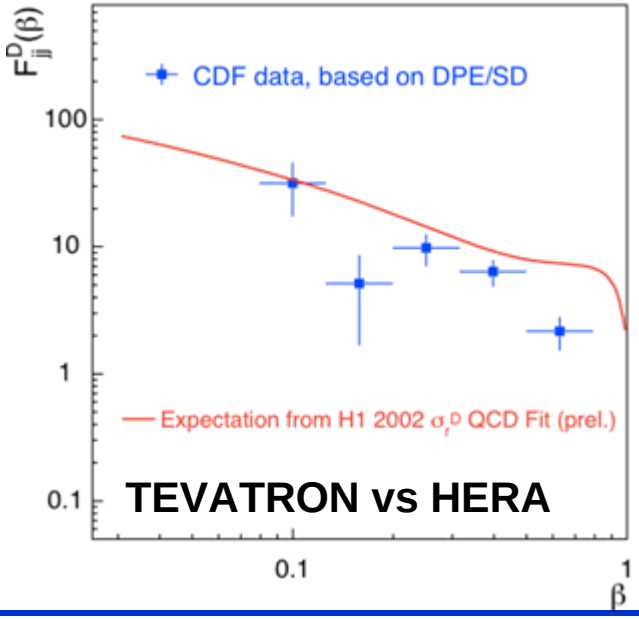
F_{jj}^{D}

ξ_{pbar}^{RPS} dependence

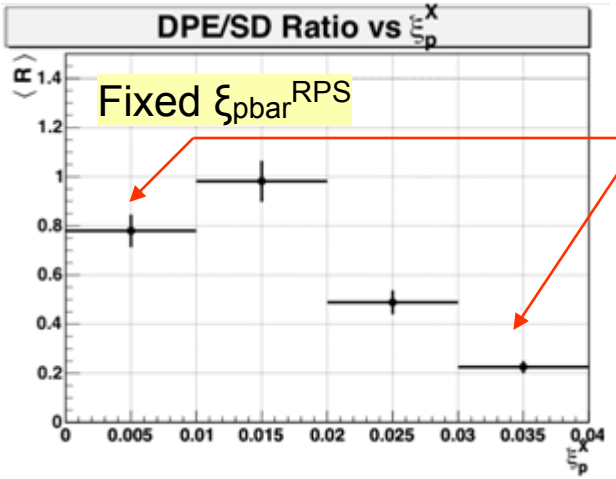


- $E_T^{Jet1,2}$>10 GeV
- 3.6<η_{gap}<5.9
- RP good track
- 0.01<ξ_{pbar}^{X}<0.12

factorization restored



ξ_p^X dependence



Ratio falls off at low and high ξ_p^X → kinematics

Diffraction at CDF: ongoing analyses

Diffractive dijets…….Gallinaro under godparent review
DSF in DPE…….. Terashi final stage of analysis

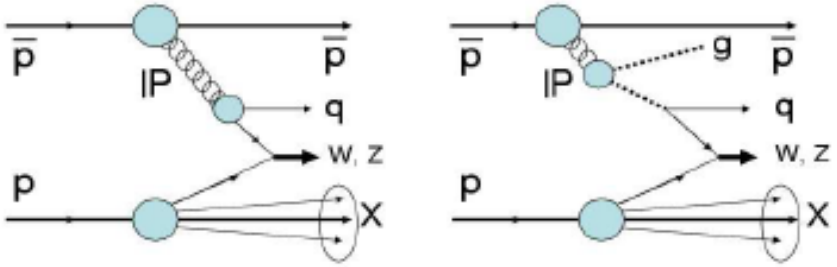
Diffractive W/Z…….Convery under godparent review

Central gaps……Mesropian final stage of analysis

Diffractive W/Z Production -cont

- probes the quak content of vacuum exchange

Paper 1st draft for PRD (R) under GP review



Diffractive W and Z Production at the Fermilab Tevatron

M.E. Convery and K. Goulianos

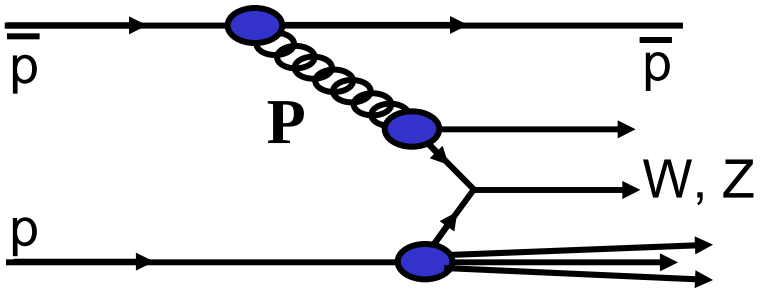
(Dated: January 7, 2010)

TABLE I: W and Z events passing successive selection cuts.

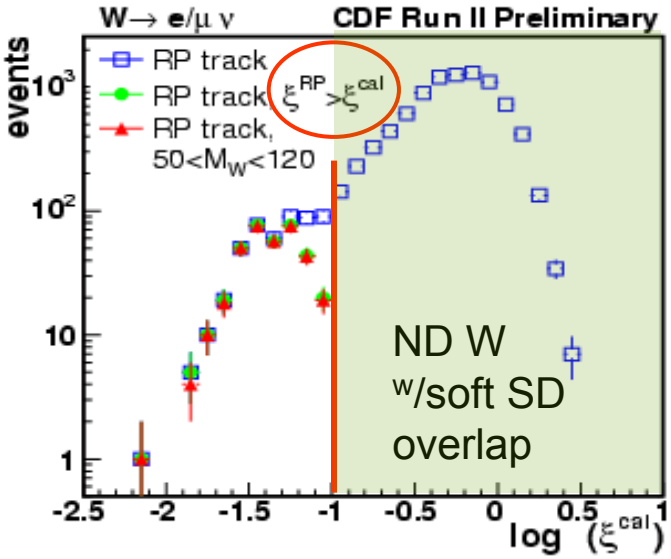
	$W \to e\nu$	$W \to \mu\nu$	$W \to l\nu$
RPS-trigger-counters	6663	5657	12 320
RPS-track	5124	4201	9325
$50 < M_W < 120$	192	160	352
	$Z \to ee$	$Z \to \mu\mu$	$Z \to ll$
RPS-trigger-counters	650	341	991
RPS-track	494	253	747
$\xi < 0.10$	24	12	36

Diffractive W/Z Production

- probes the quak content of the Pomeron

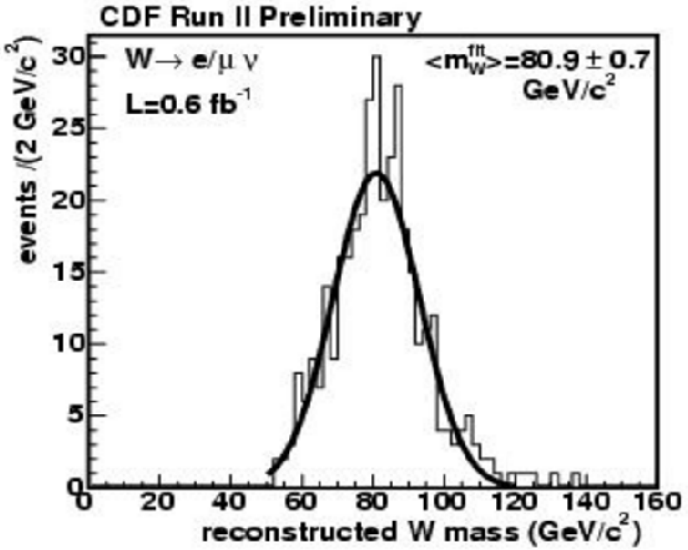


- use CAL and Roman pots to get η_ν



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

$$\xi^{RPS} - \xi^{cal} = \frac{\not{E}_T}{\sqrt{s}} e^{-\eta_\nu}$$



CDF (press release 2007): 80,413 +/- 48 MeV/c^2

RESULTS

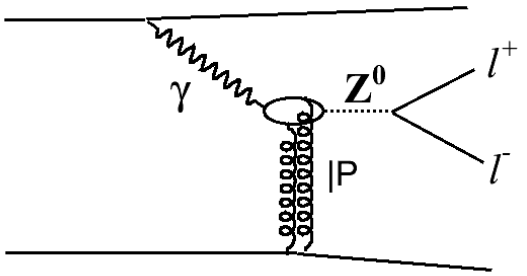
R^W (0.03 < ξ < 0.10, |t|<1)= [0.97 ± 0.05(stat) ± 0.11(syst)]%

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

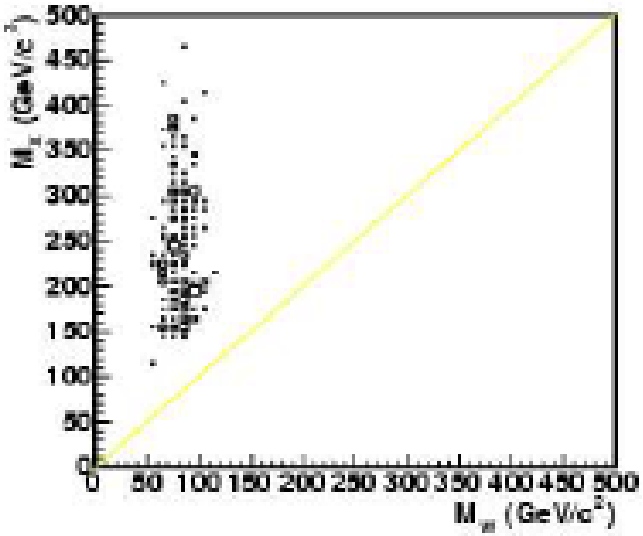
R^Z (0.03 < ξ < 0.10, |t|<1)= [0.85 ± 0.20(stat) ± 0.11(syst)]%

Diffractive W/Z Production -cont

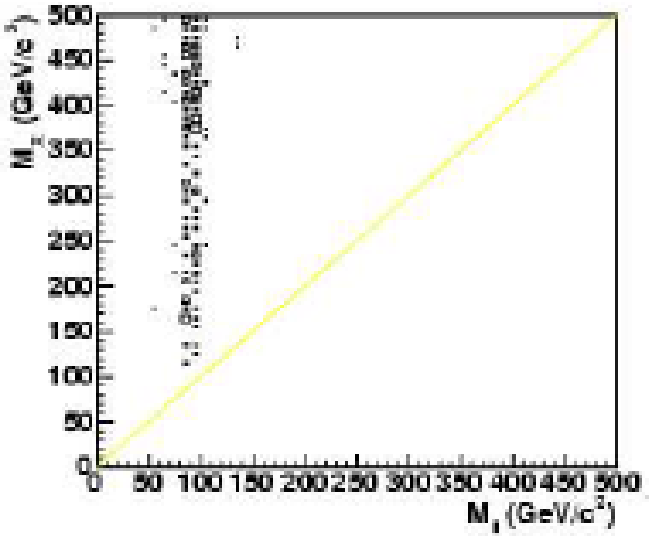
- search for exclusive Z production



M_X



M_W



M_{ll}

FIG. 5: System mass M_X vs. M_W (left) for W events with a RPS track and $\xi^{\rm cal} < \xi^{\rm RPS}$, and mass M_{ll} (right) for dilepton events with a RPS track and lepton $p_T > 25$ GeV/c^2. Exclusive W/Z candidates are expected to fall on the diagonal.

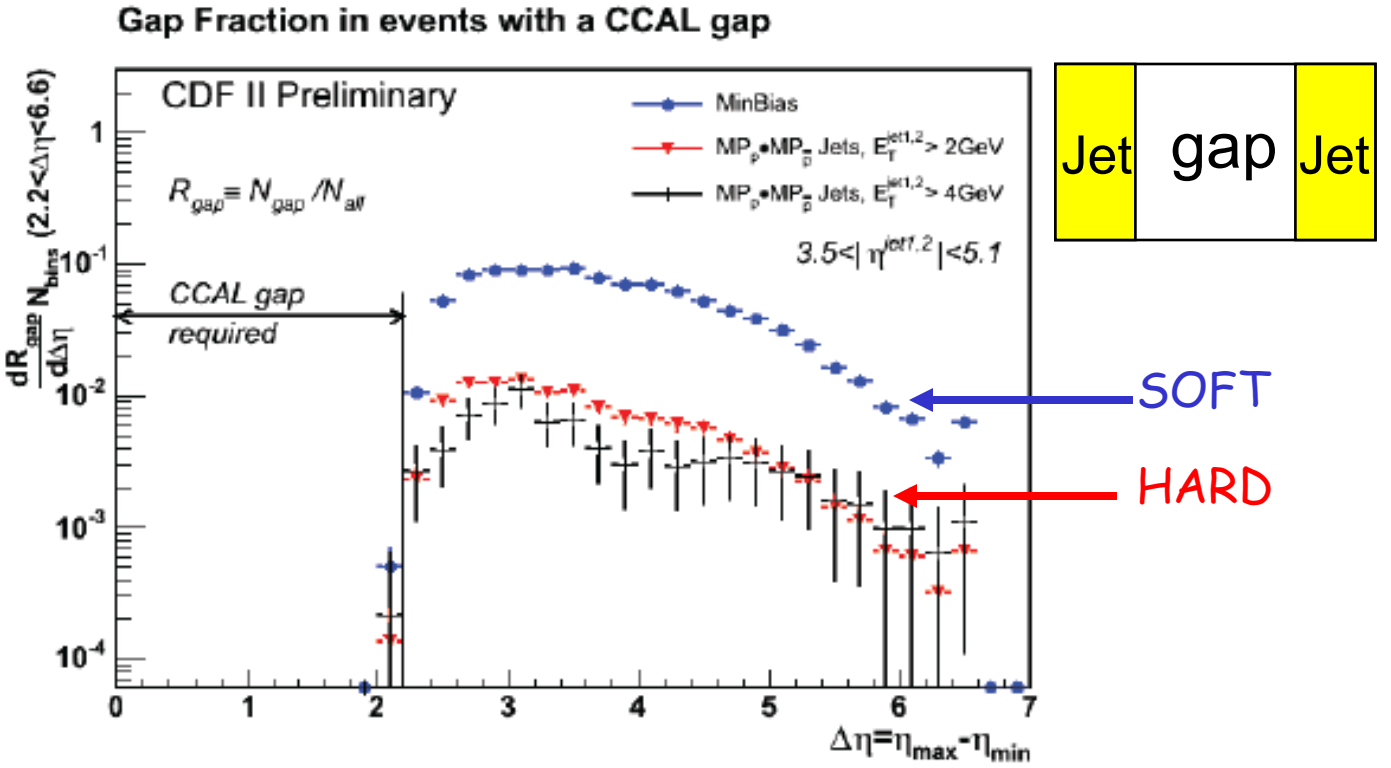
No exclusive Z events were found in our sample

Diffraction at CDF: ongoing analyses

Diffractive dijets……	Gallinaro	under godparent review
DSF in DPE……	Terashi	final stage of analysis
Diffractive W/Z……	Convery	under godparent review

Central gaps……	Mesropian	final stage of analysis

Central gaps

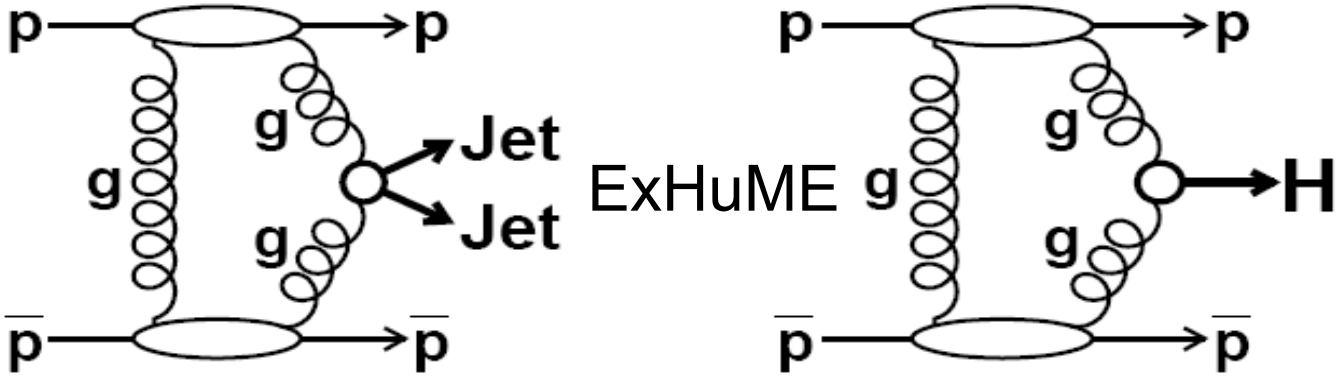


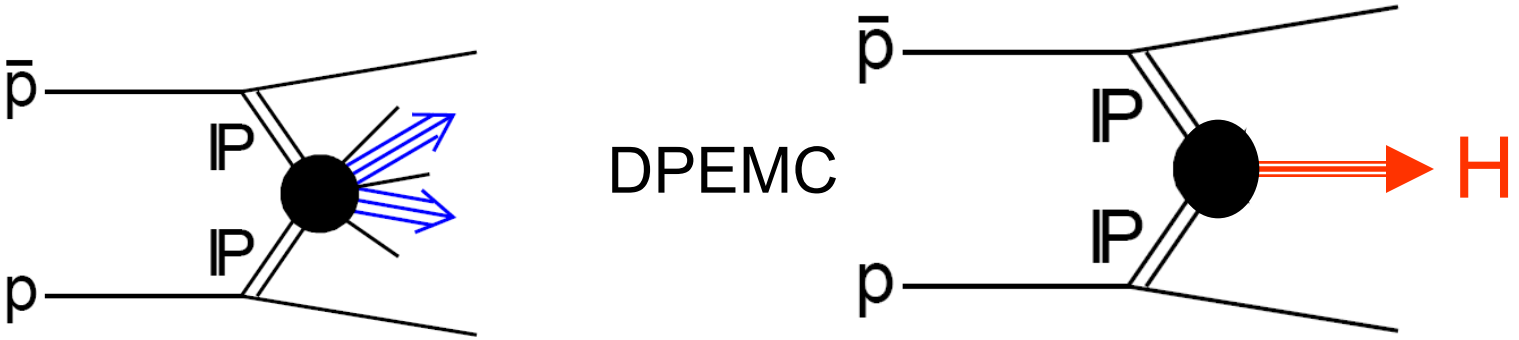
The distribution of the gap fraction $R_{gap}=N_{gap}/N_{all}$ vs $\Delta\eta$ for MinBias ($CLC_p \bullet CLC_{pbar}$) and MiniPlug jet events ($MP_p \bullet MP_{pbar}$) of $E_{T(jet1,2)}>2$ GeV and $E_{T(jet1,2)}>4$ GeV.

The distributions are similar in shape within the uncertainties.

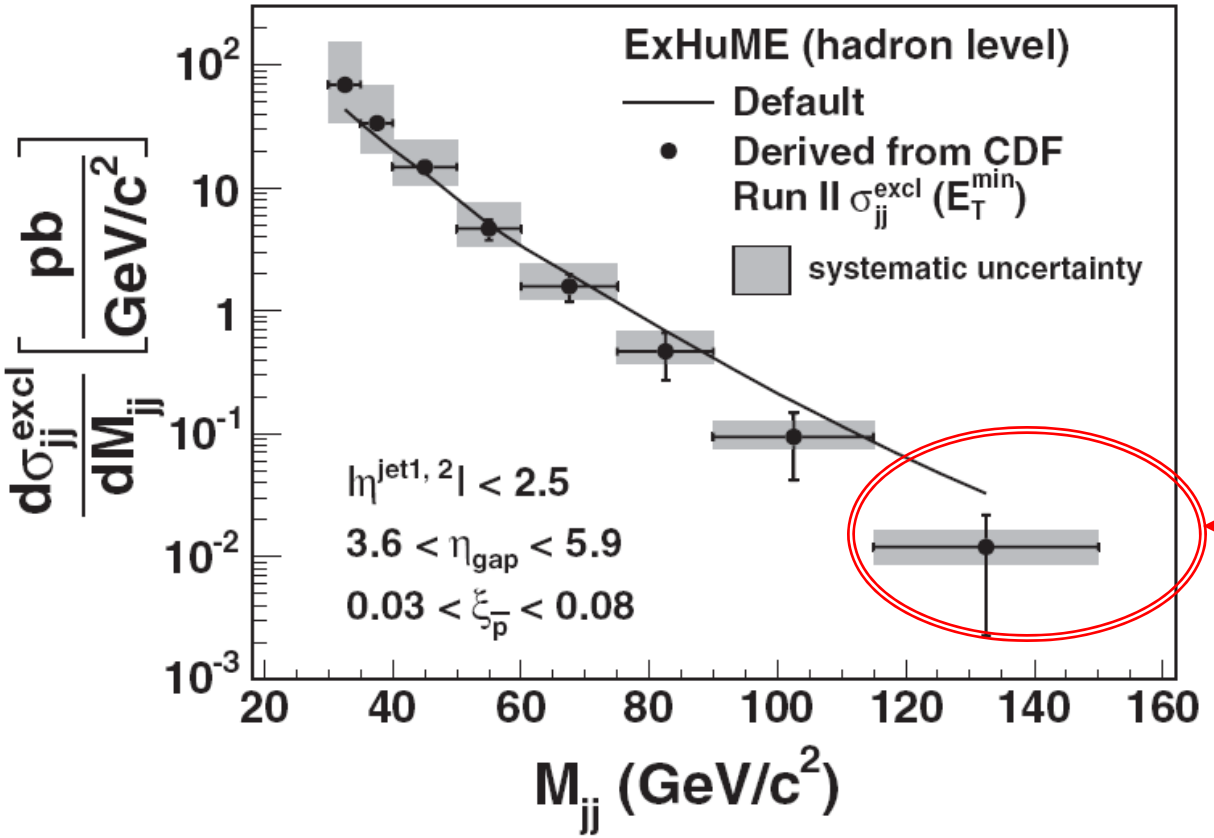
Exclusive Dijet and Higgs Production

Phys. Rev. D 77, 052004





Exclusive Dijet x-section vs. M_{jj}



line: ExHuME hadron-level exclusive di-jet cross section vs. di-jet mass
points: derived from CDF excl. di-jet x-sections using ExHuME

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

Detectors at the Tevatron

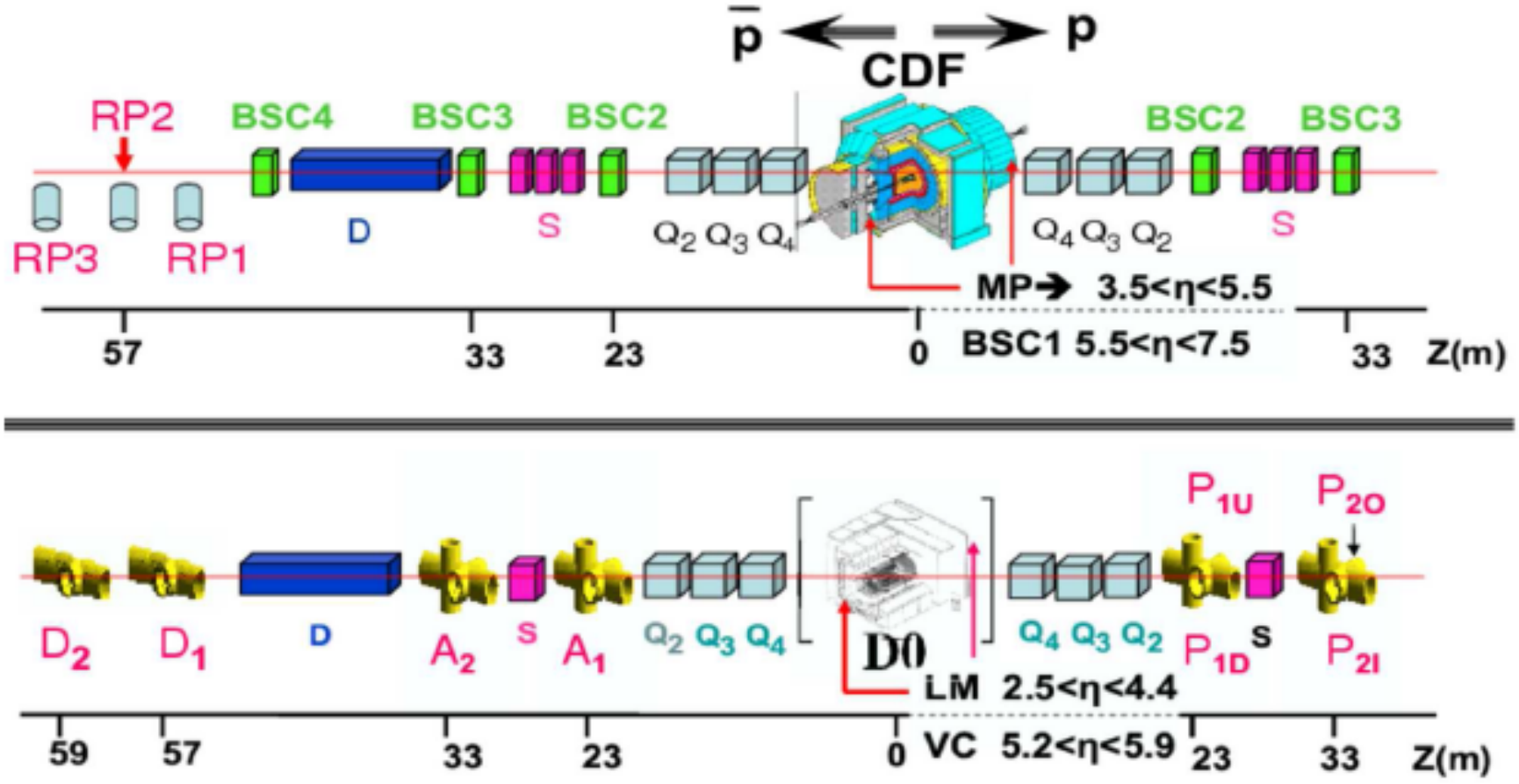
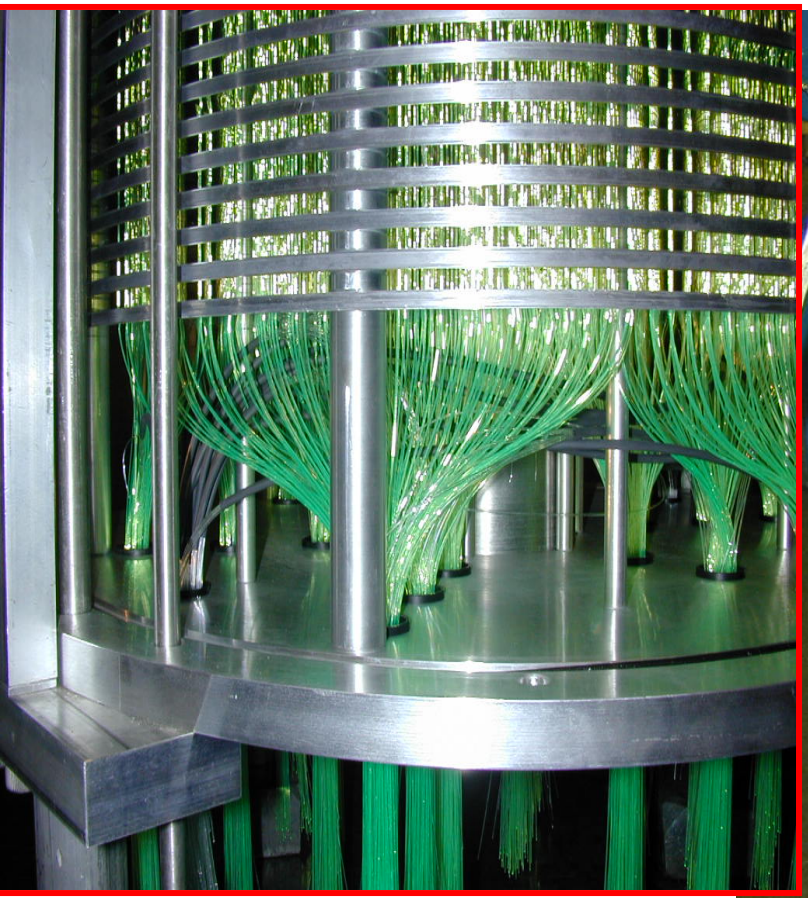


Figure 1: The CDF and D0 detectors in Run II

The MiniPlug Calorimeters

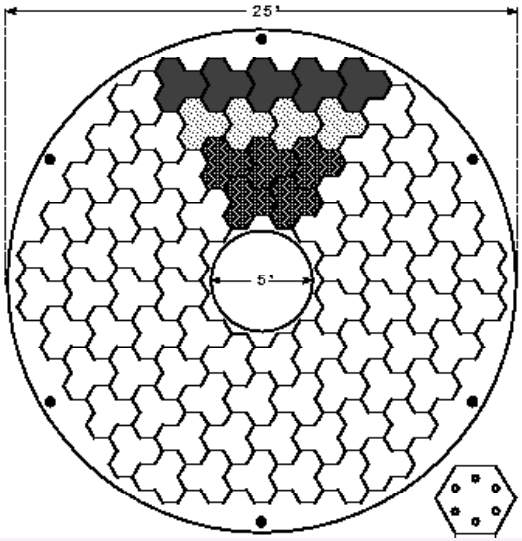




About 1500 wavelength shifting fibers of 1 mm dia. are 'strung' through holes drilled in 36x$\frac{1}{4}$" lead plates sandwiched between reflective Al sheets and guided into bunches to be viewed individually by multi-channel photomultipliers.

The MiniPlugs @ CDF

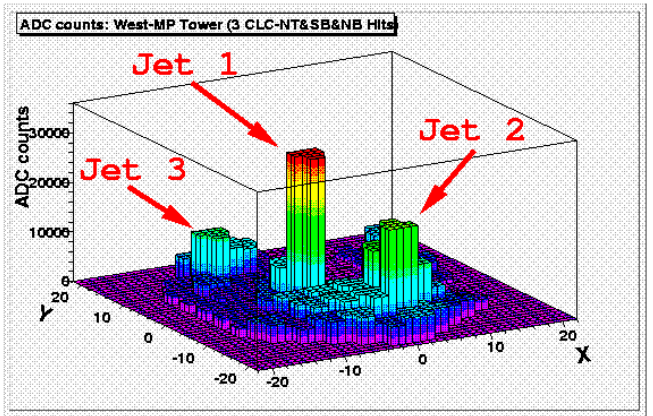
Measurements w/the MiniPlugs

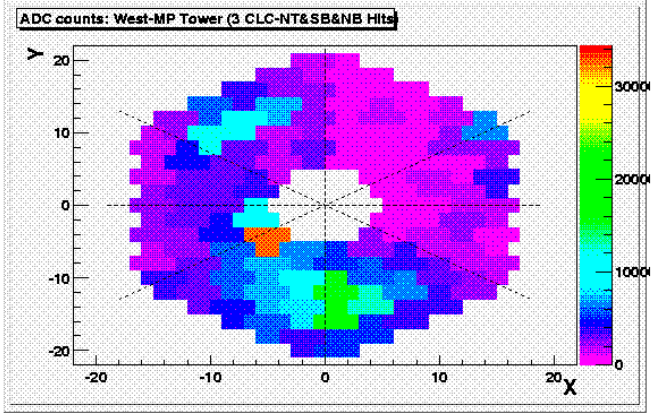


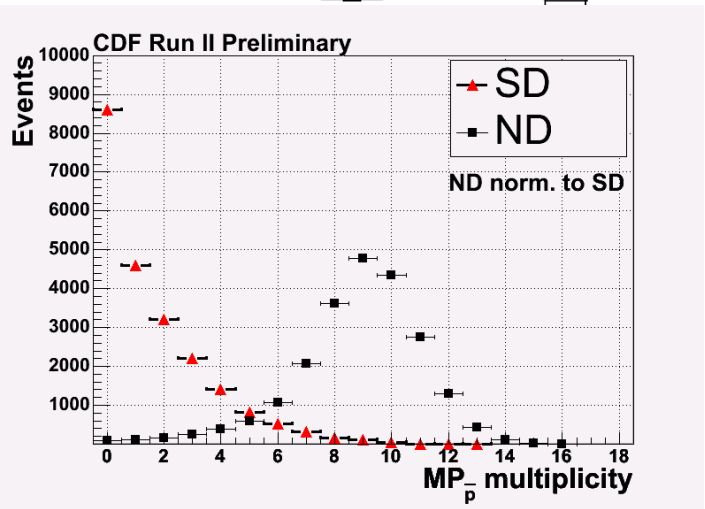
MP TOWER STRUCTURE

MULTIPLICITY @ POSITION

ENERGY







Multiplicity of SD and ND events

$$\xi^{CAL} = \frac{\Sigma_i E_T^i e^{-\eta_i}}{\sqrt{s}}$$

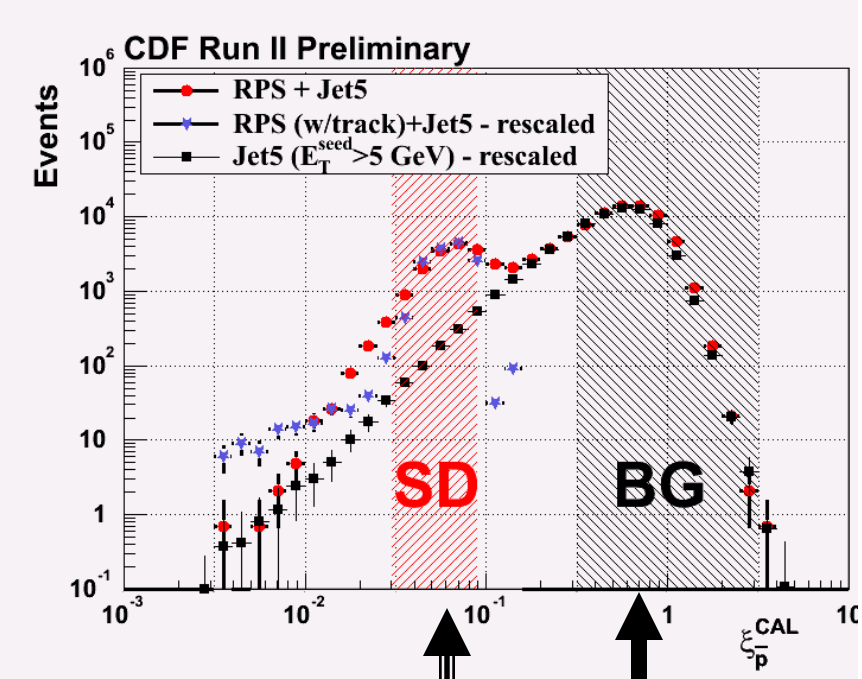
NIM A 430 (1999)
NIM A 496 (2003)
NIM A 518 (2004)

ADC counts in MiniPlug towers in a pbar-p event at 1960 GeV.

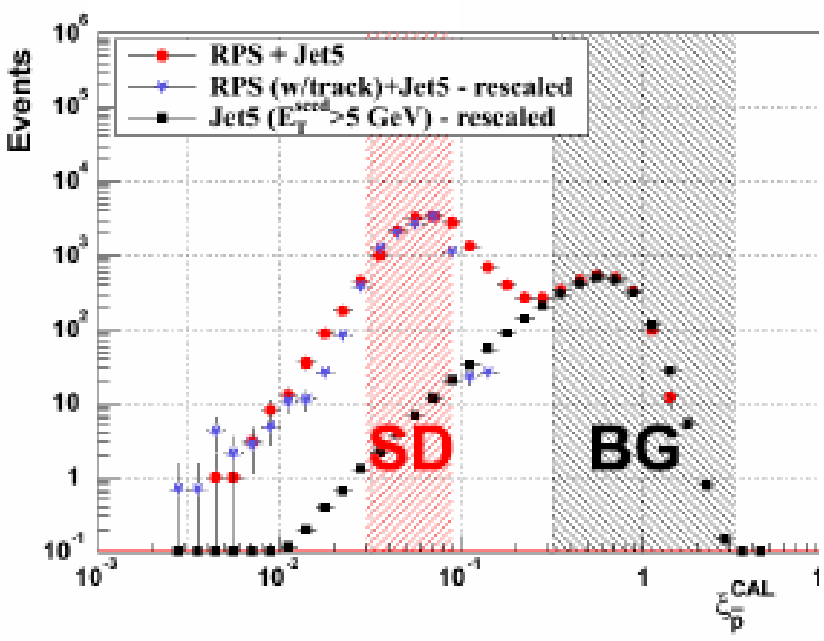
- **"jet" indicates an energy cluster and may be just a hadron.**
- **1000 counts ~ 1 GeV**

Overlap Background Rejection

2002-2003 data: <InstL> ~1.5E31



Low InstLum ~0.5E30



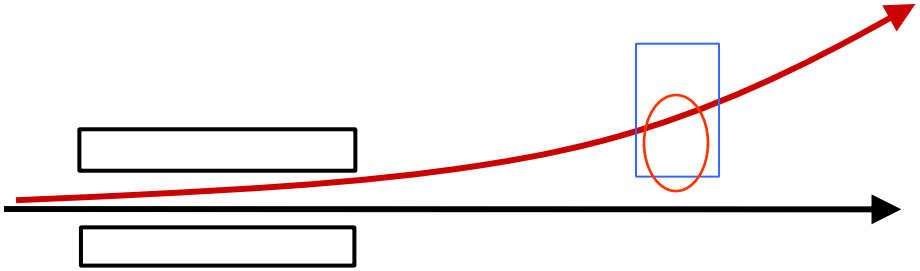
BG➔ ND dijet + soft SD

$$\frac{d\sigma}{d\xi} \propto \frac{1}{\xi} \Rightarrow \frac{d\sigma}{d\log\xi} = \text{constant}$$

$$\xi^{CAL} = \frac{\Sigma_i E_T^i e^{-\eta_i}}{\sqrt{s}}$$

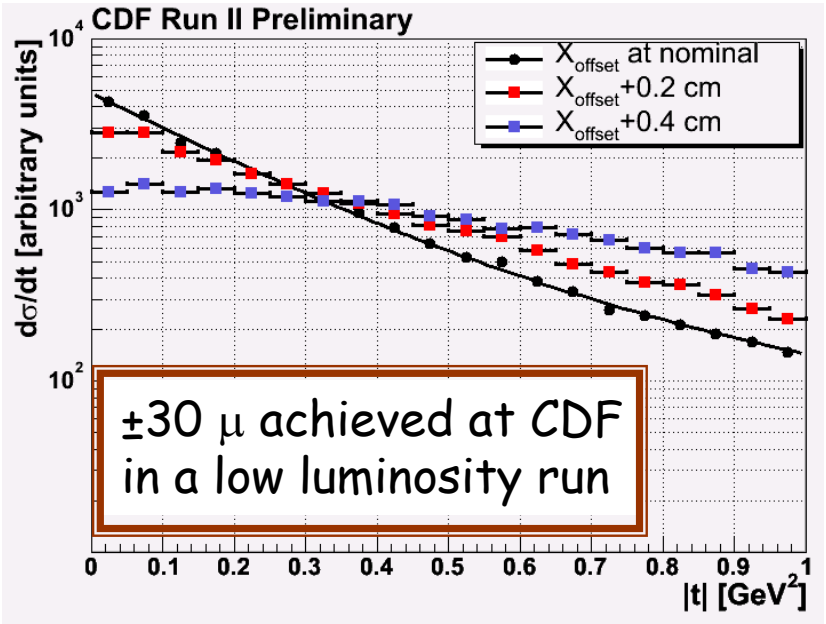
Alignment of RPS using Data

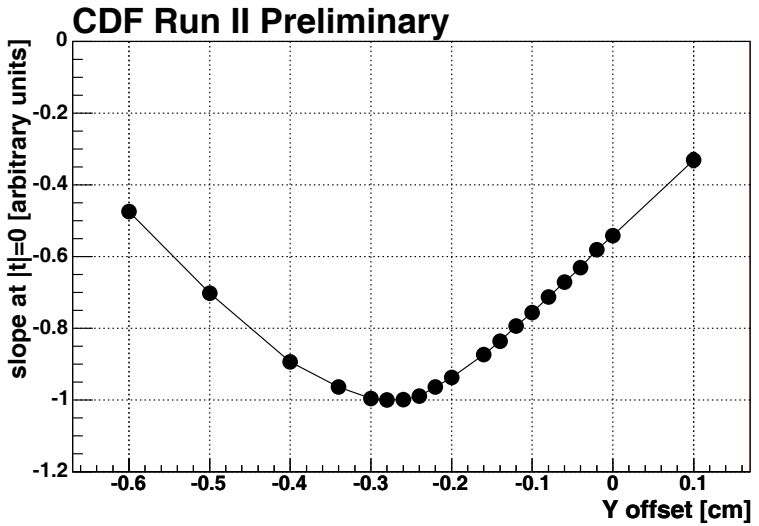
Proposed for the FP420 project at the LHC

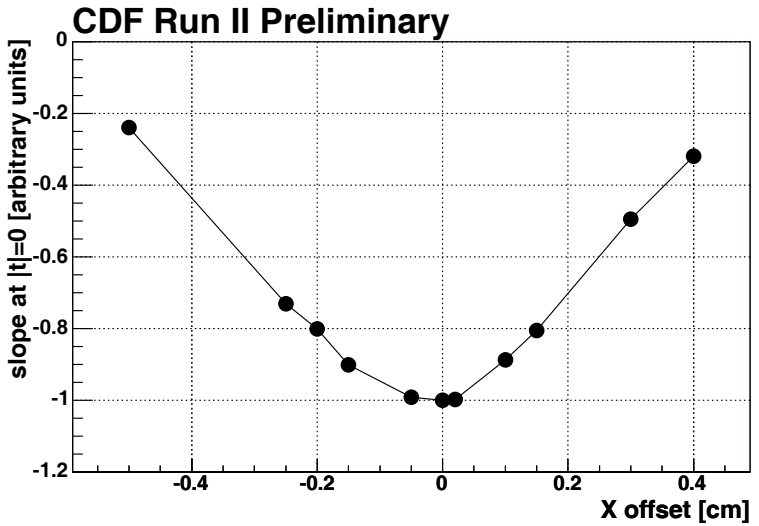


maximize the |t|-slope

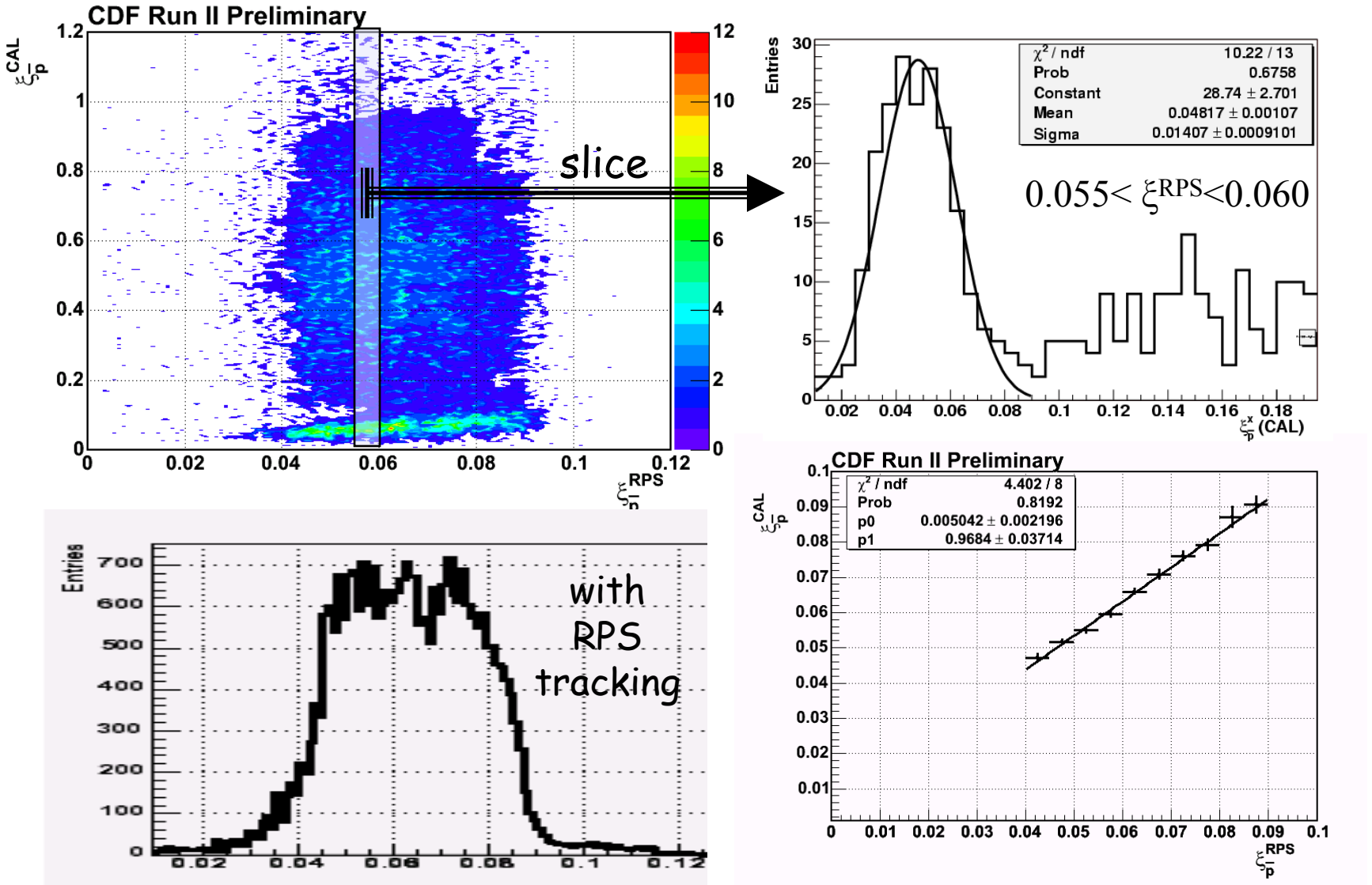
⇨ determine X and Y offsets



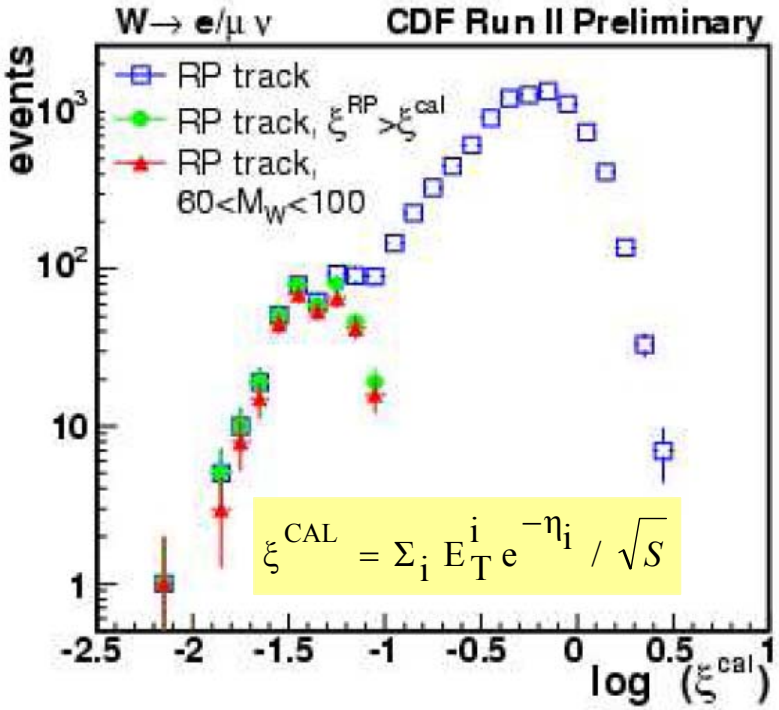


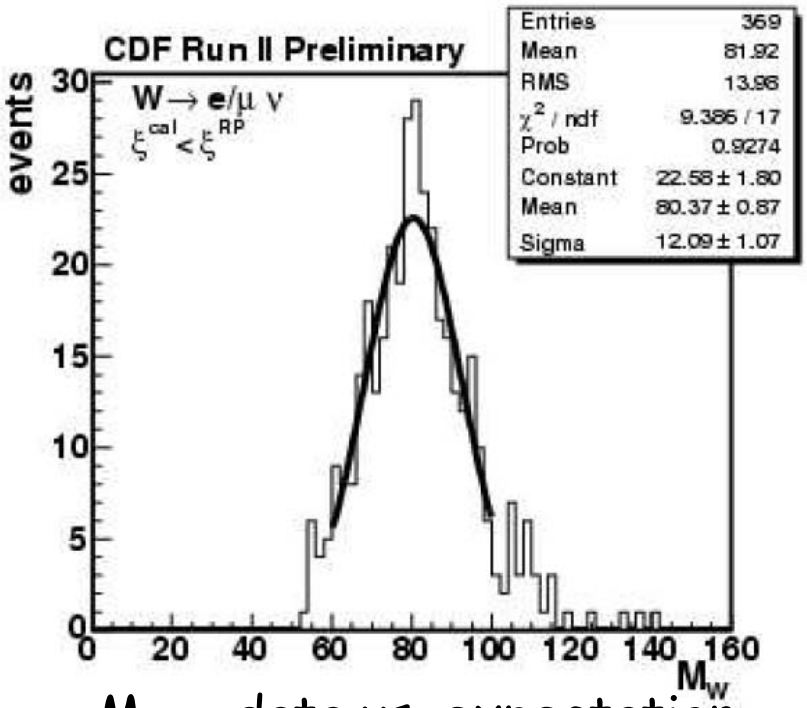


RPS Tracking Calibration



Measurements w/the RPS: P_L Balance → M_W





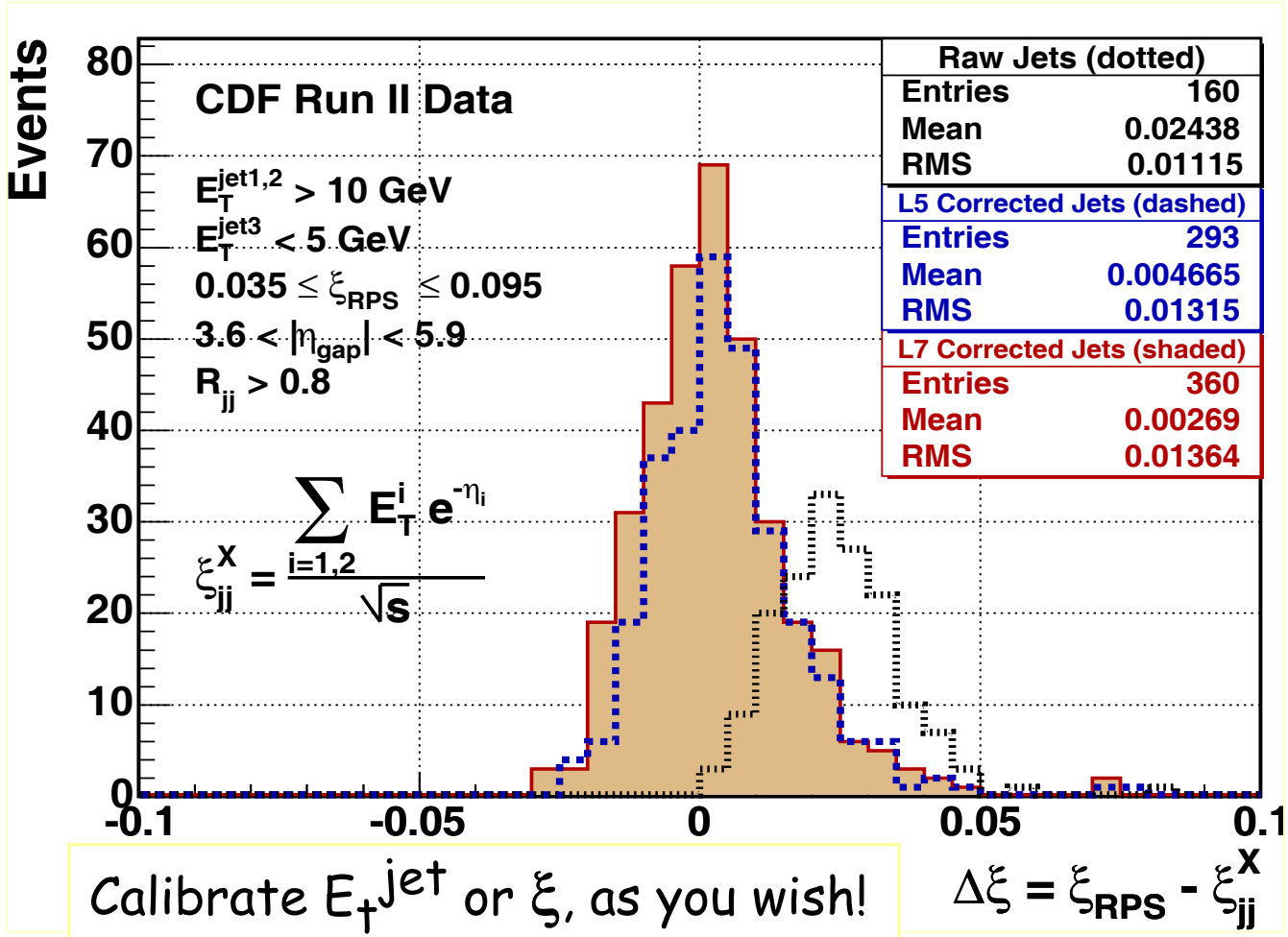
M_W - data vs. expectation

$$p_L^\nu = (1-\xi) \times p_{beam} - \sum_{cal} p_L$$

$$p_T^\nu = \text{missing } E_T$$

→ M_W

Measurements w/the RPS
E_T^{jet} Calibration
➔use RPS information to check jet energy corrections➔



Diffraction at LHC

What can we learn/expect *on elastic and diffractive scattering* from the LHC experiments ?

K. Goulianos

- contribution to the discussion session

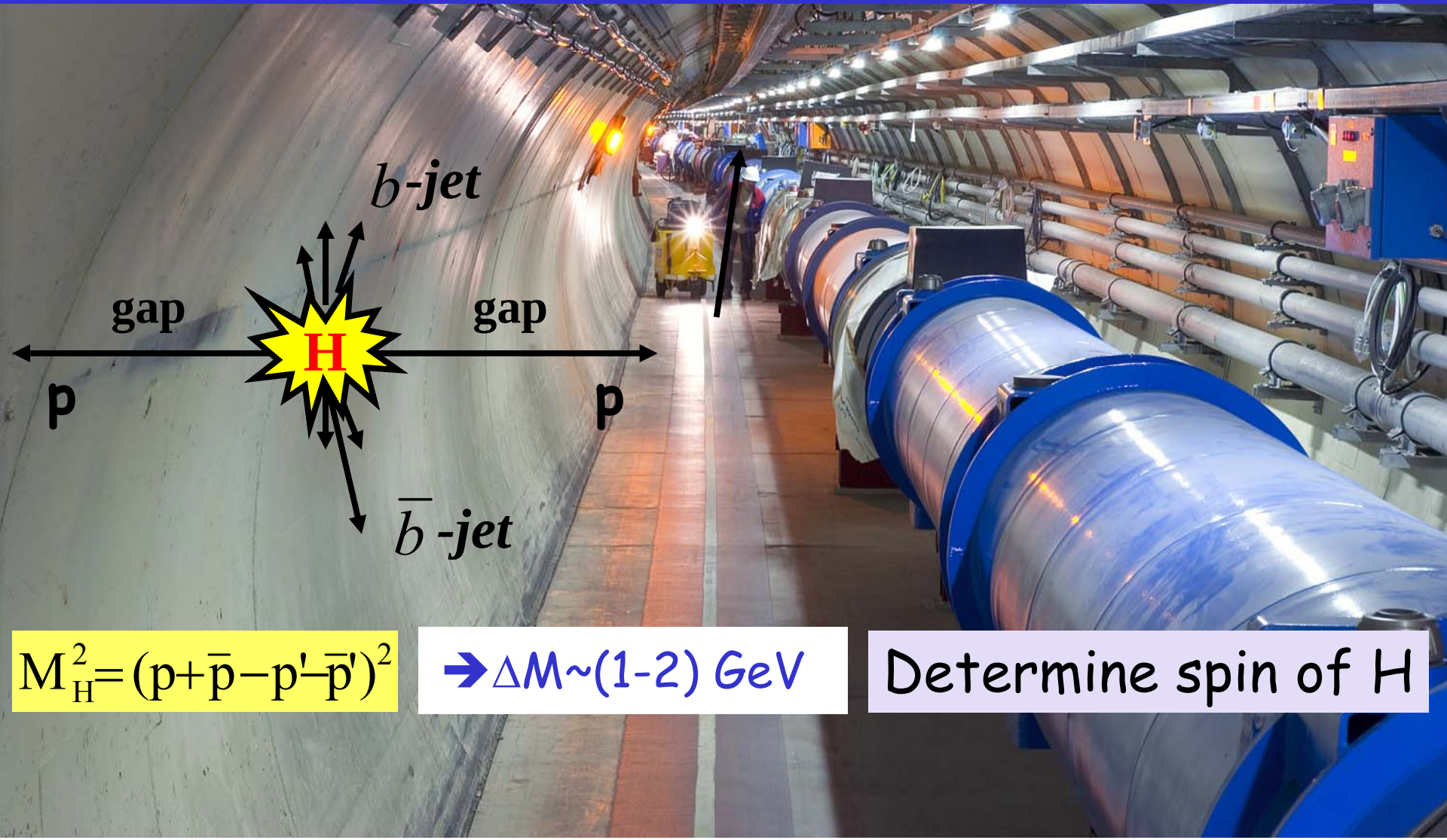


2 What to do at the LHC

goal	· understand the QCD basis of diffraction and discover new physics
exploit	· large $\sqrt{s} \Rightarrow$ large σ, $\Delta\eta$, E_T
TEV2LHC	· from Tevatron to LHC: confirm, extend, discover...
	$\Rightarrow$ confirm Tevatron results and extend them into the new kinematic domain
specifics	· elastic diffractive, total cross sections, and ρ-value
	$\Rightarrow$ diffractive structure function: dijets vs. W-boson, ...
	$\Rightarrow$ multi-gap configurations
	$\Rightarrow$ jet·gap·jet: $d\sigma/d\Delta\eta$ vs. $E_T^{\rm jet} \Rightarrow$ BFKL, Mueller-Navelet jets

- FP420 project – forward proton at 420 - Joint CMS / ATLAS R&D project
- HPS project – high precision spectrometer - a CMS proposal

The engine of the diffractive program at LHC: EXCLUSIVE JJ & HIGGS BOSON PRODUCTION



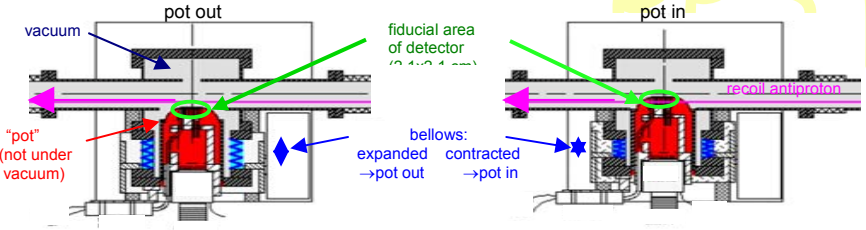
$M_H^2 = (p + \bar{p} - p' - \bar{p}')^2$

➔ $\Delta M \sim (1\text{-}2)$ GeV

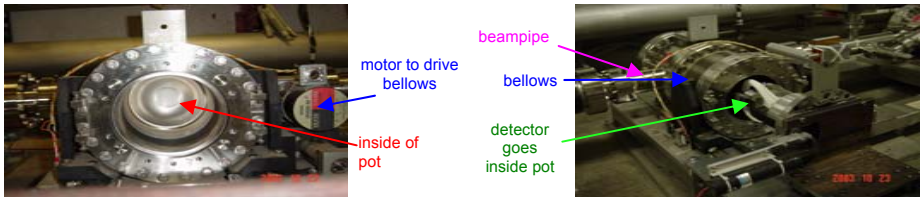
Determine spin of H

The Roman-Pot Detectors at CDF

Concept of a Roman Pot

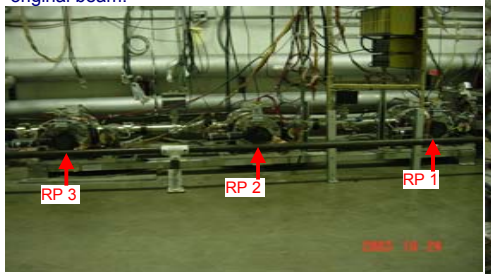


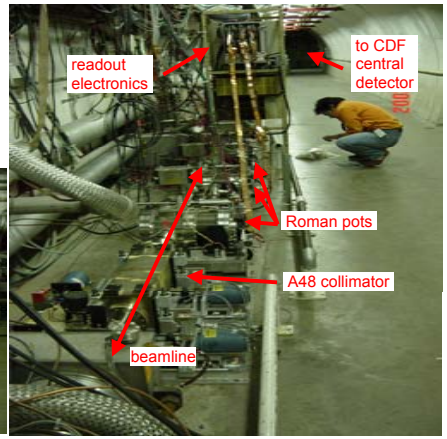
Bellows allow detectors to move close to the beam while maintaining vacuum



In the Tevatron Tunnel

CDF had three Roman pots (RP1, RP2, RP3) located 57m downstream of the interaction point along the antiproton beam direction.
They were used to detect antiprotons which underwent a "diffractive" interaction and were scattered in a direction very close to that of the original beam.

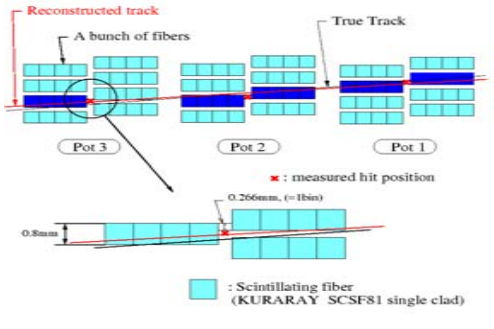




Roman-Pot Detector Design – by The Rockefeller University

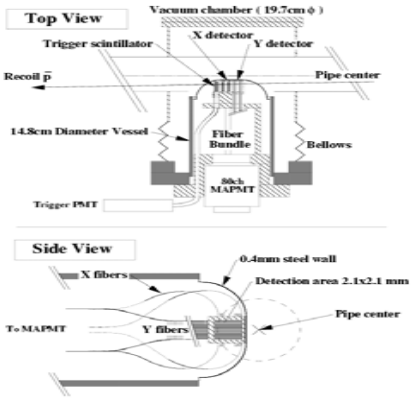
The three Roman pots each contain detectors consisting of:

- Trigger scintillation counter 2.1x2.1x0.8 cm^3
- 40 X + 40 Y fiber readout channels
  - Each consists of 4 (→ bigger signal) clad scintillating fibers 0.8x0.8 mm^2 (new technology at the time)
  - X,Y each have 2 rows of 20 fibers spaced 1/3 fiber width apart for improved position resolution (three times better than with a single row)



Expected position resolution	80 μm
Expected angle resolution	60 μrad

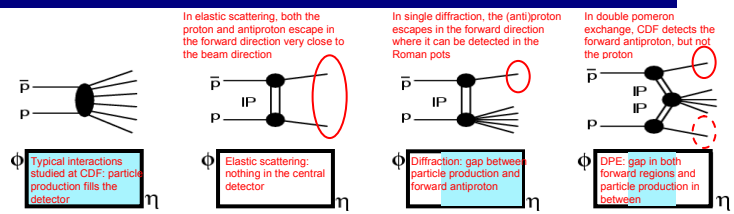
CDF "Tokyo"-Pot Detectors – Built by the University of Tsukuba, Japan





Physics Using the Roman-Pot Detectors

- The Roman-pot detectors are used to study diffractive interactions
- Elastic scattering was measured by CDF in 1988-1989 using Roman pots (not those described here) in both the proton and antiproton direction



Path of the Antiproton through the Tevatron Magnets

- Dipole magnets bend recoil antiprotons which have lost momentum towards the inside of the Tevatron ring, into the Roman pots
- Knowledge of the beam optics, the collision vertex position, and the antiproton track position and angle in the Roman-pot detectors are used to reconstruct the kinematics of the diffractive antiproton

