New Results on Diffractive and Exclusive Production from CDF

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      - dijet-2008, dimuon→χ_c-J/ψ(2s)-2009, $\gamma\gamma$-2012
- Central Exclusive Production of $\pi^+\pi^-$ →NEW!

DIFFRACTION IN QCD

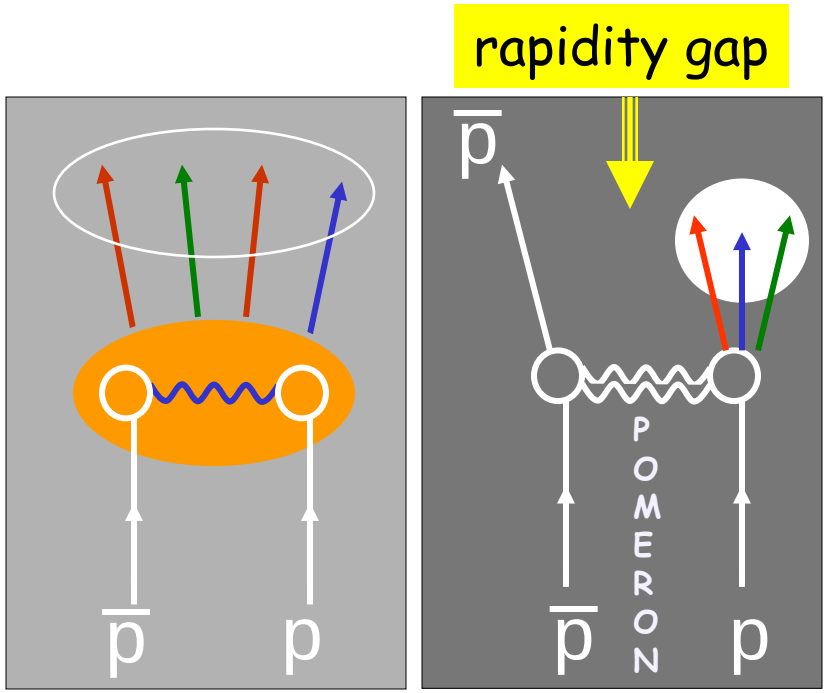
Non-diffractive events

- color-exchange ➔ η-gaps exponentially suppressed

Diffractive events

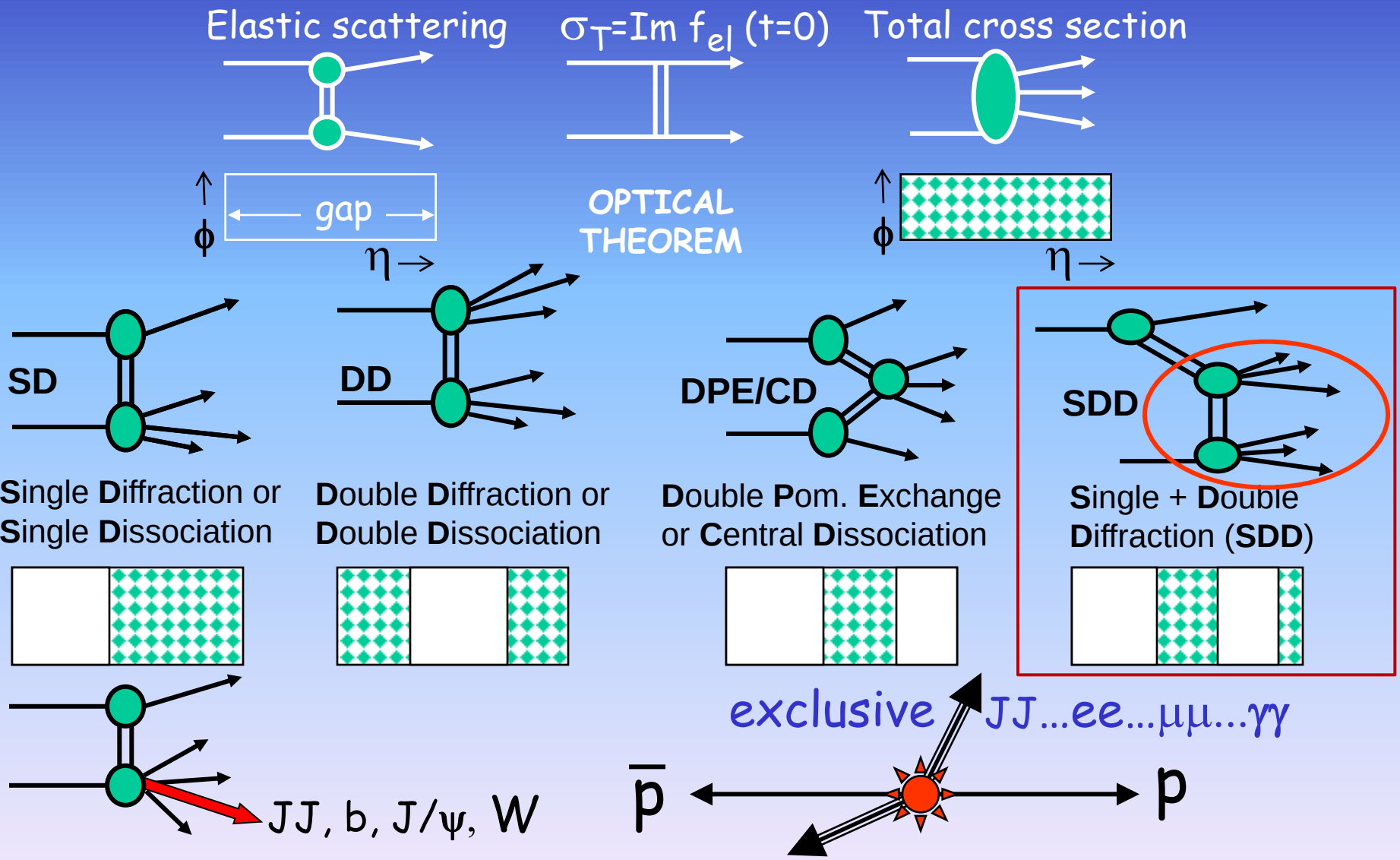
- Colorless vacuum exchange

➔ η-gaps not exp'ly suppressed



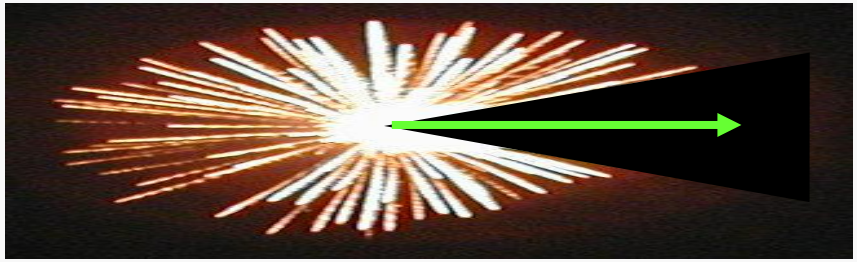
Goal: probe the QCD nature of the diffractive exchange

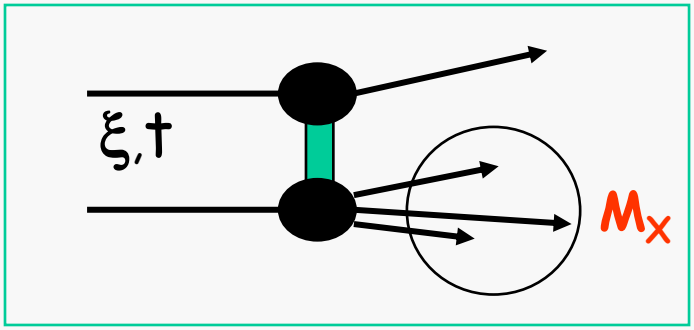
DIFFRACTION AT CDF



DEFINITIONS

SINGLE DIFFRACTION

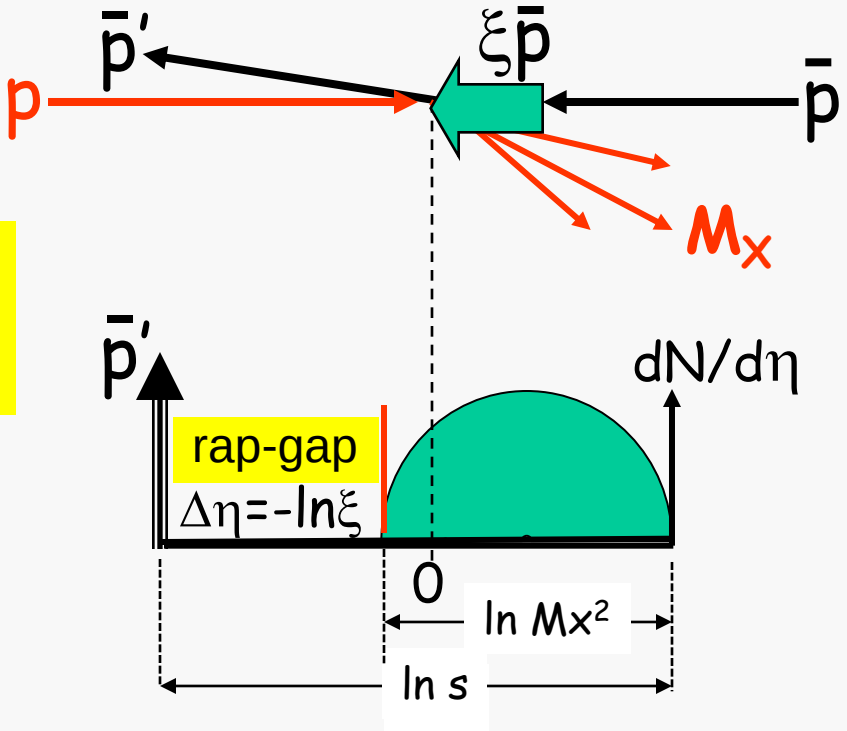




$$1\text{-}x_L \equiv \xi = \frac{M_X^2}{s}$$

Forward momentum loss

$$\xi^{CAL} \equiv \frac{\sum_{i=1}^{all} E_{i=1}^{i-tower} e^{-\eta_i}}{\sqrt{s}}$$

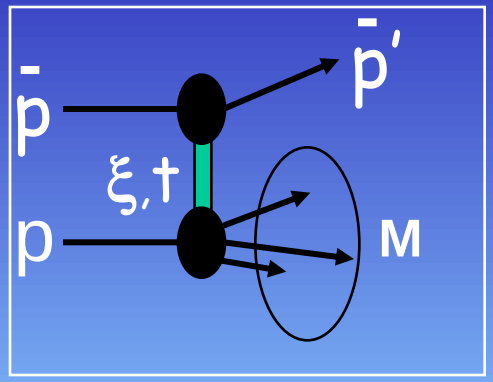


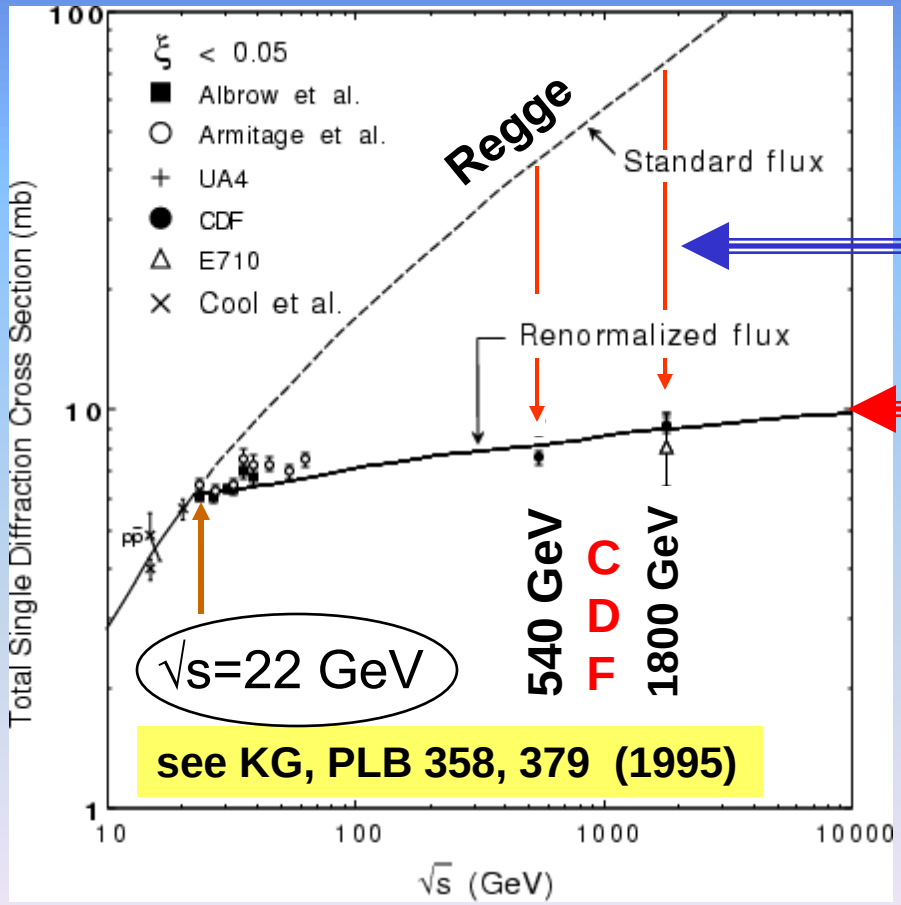
since no radiation →
no price paid for increasing diffractive-gap width

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

FACTORIZATION BREAKING IN SOFT DIFFRACTION

➔diffractive x-section suppressed relative to Regge prediction as √s increases





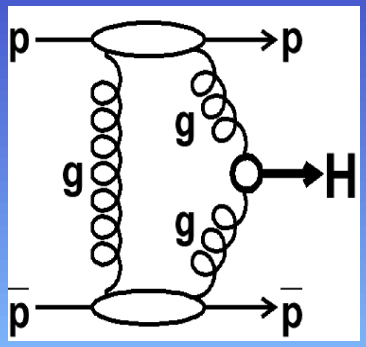
Factor of ~8 (~5) suppression at √s = 1800 (540) GeV

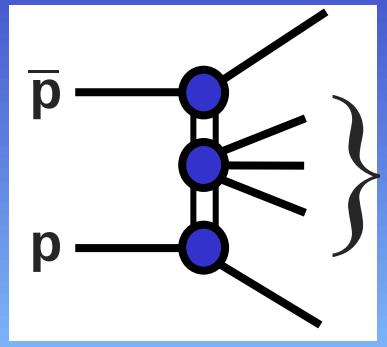
RENORMALIZATION

Interpret flux as gap formation probability that saturates when it reaches unity

EXCLUSIVE Dijet→ Excl. Higgs

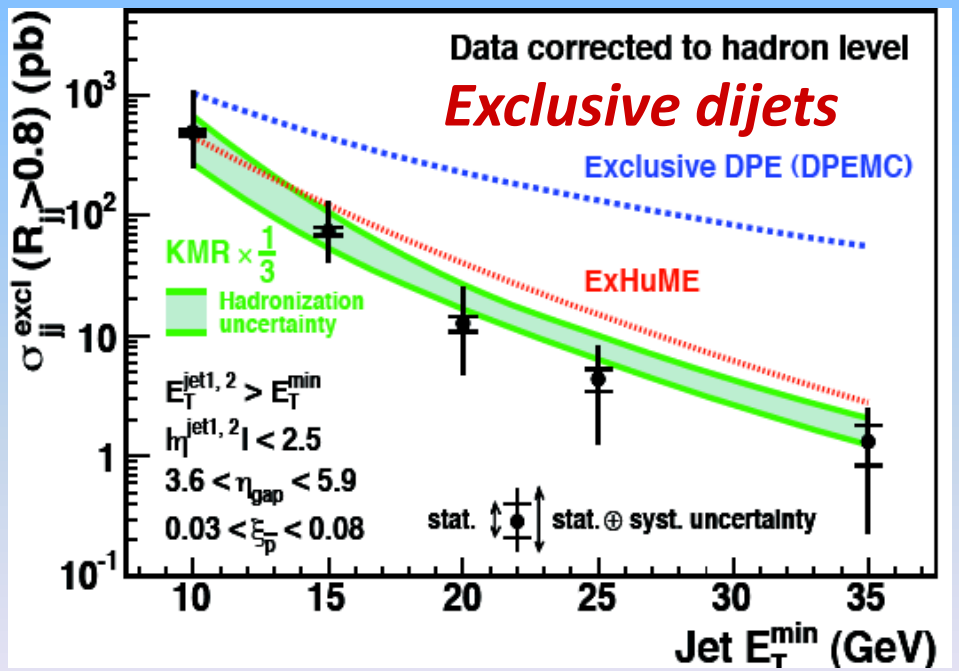
THEORY CALIBRATION

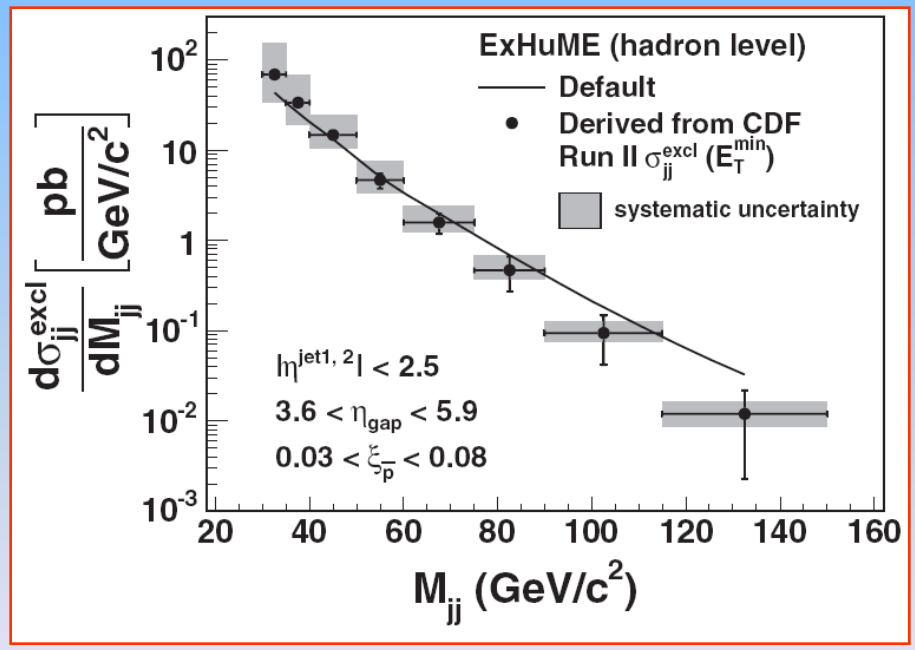




JJ *PRD 77, 052004 (2008)*

χ_c *PRL 102 , 242001 (2009)*



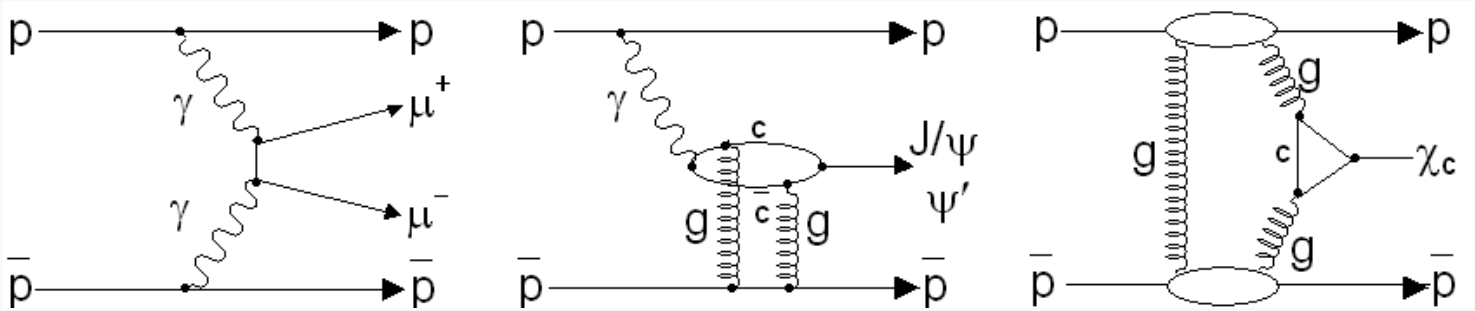


Exclusive dimuon production

PRL 102, 242001 (2009)

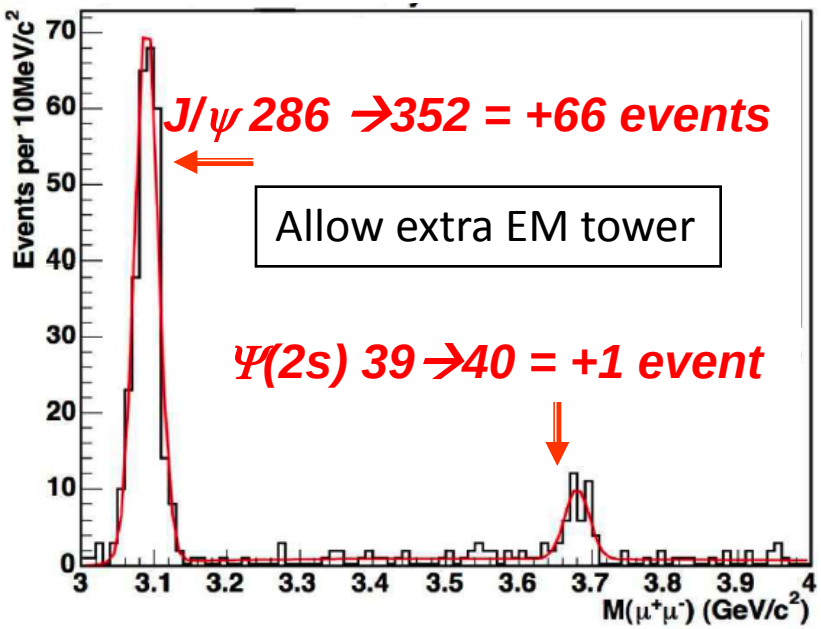
$\bar{p} + p \rightarrow \bar{p} + \mu^+\mu^- + p$ $\quad 3\ \mathrm{GeV}/c^2 < M_{\mu\mu} < 4\ \mathrm{GeV}/c^2$

- Several physics processes in this dataset:



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

PRL 102, 242001 (2009)



- Allowing EM towers (E_T >80MeV)
  → large increase in the J/ψ peak & minor change in the $\psi(2s)$ peak
- → Evidence for:

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

$d\sigma/dy|_{y=0}$ = 75 ± 14 nb,

compatible with theoretical predictions

- 160 nb (Yuan 01)
- 90 nb (KMR01)

Exclusive J/ψ and ψ(2s)

J/ψ producton

243 ±21 events

$d\sigma/dy|_{y=0}$= 3.92± 0.62 nb

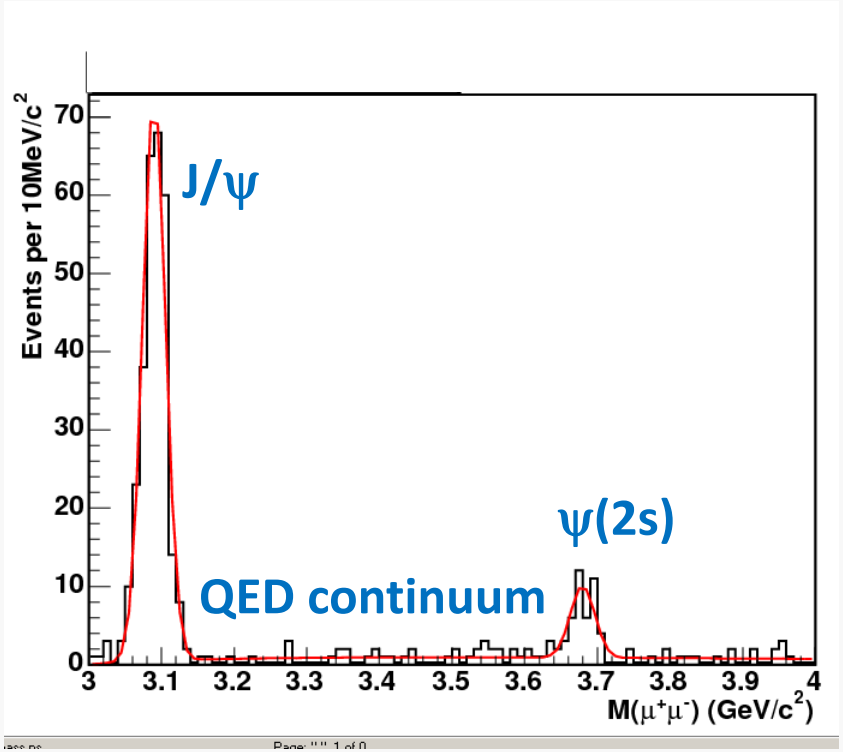
Theoretical Predictions

2.8 nb [Szczurek07,],

2.7 nb [Klein&Nystrand04],

3.0 nb [Conclaves&Machado05], and

3.4 nb [Motkya&Watt08].



Ψ(2S) production

34±7 events

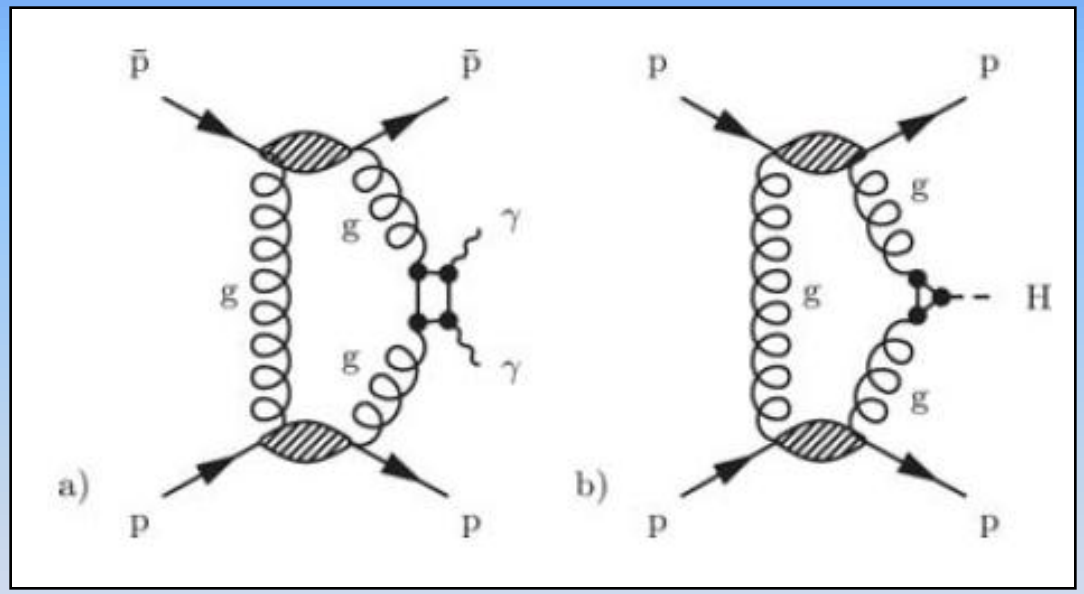
$d\sigma/dy|_{y=0}$ = 0.54 ± 0.15 nb

R = ψ(2s)/J/ψ = 0.14 ± 0.05

In agreement with HERA: R = 0.166 ± 0.012 in a similar kinematic region

Exclusive $\gamma\gamma$ production-2012

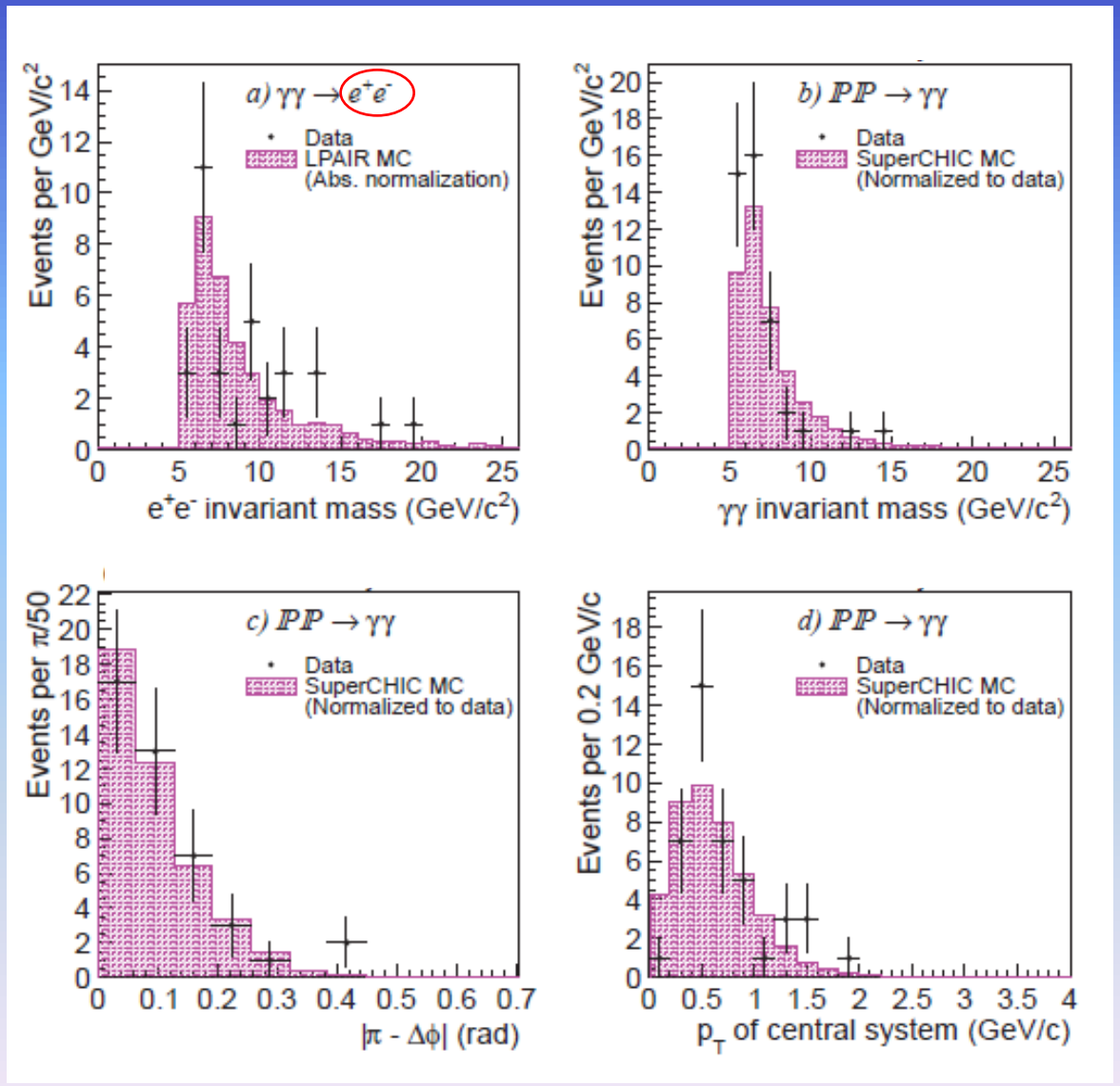
PRL 108, 081801 (2012)



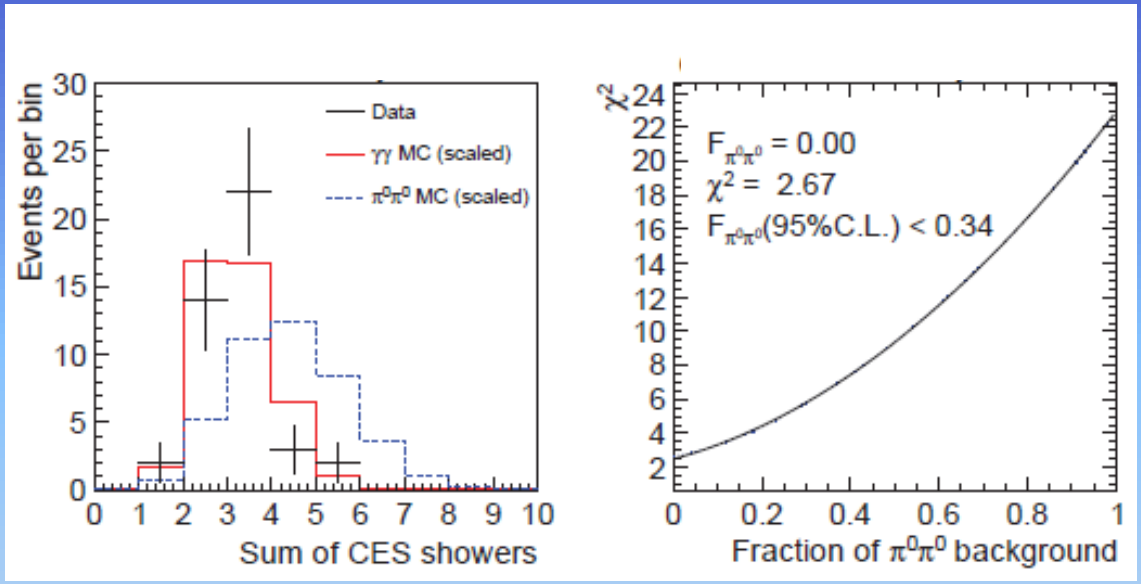
Exclusive $\gamma\gamma$ and e^+e^- events

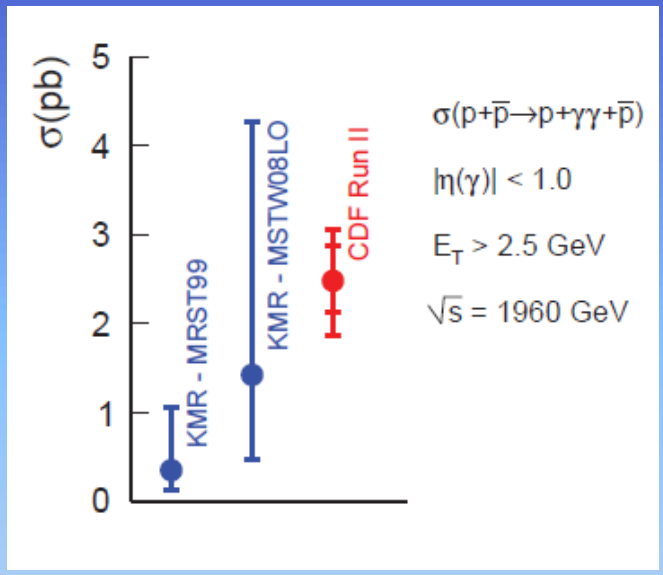
Integrated luminosity $\mathcal{L}_{\text{int}}$	1.11 ± 0.07 fb^{-1}
Exclusive efficiency	0.068 ± 0.004 (syst)
Exclusive $\gamma\gamma$	
Events	43
Photon pair efficiency	0.40 ± 0.02 (stat) ± 0.03 (syst)
Probability of no conversions	0.57 ± 0.06 (syst)
$\pi^0\pi^0$ b/g (events)	0.0, < 15 (95% C.L.)
Dissociation b/g (events)	0.14 ± 0.14 (syst)
Exclusive e^+e^-	
Events	34
Electron pair efficiency	0.33 ± 0.01 (stat) ± 0.02 (syst)
Probability of no radiation	0.42 ± 0.08 (syst)
Dissociation b/g (events)	3.8 ± 0.4 (stat) ± 0.9 (syst)

Exclusive $\gamma\gamma$ data vs MC



Exclusive $\gamma\gamma$ cross section



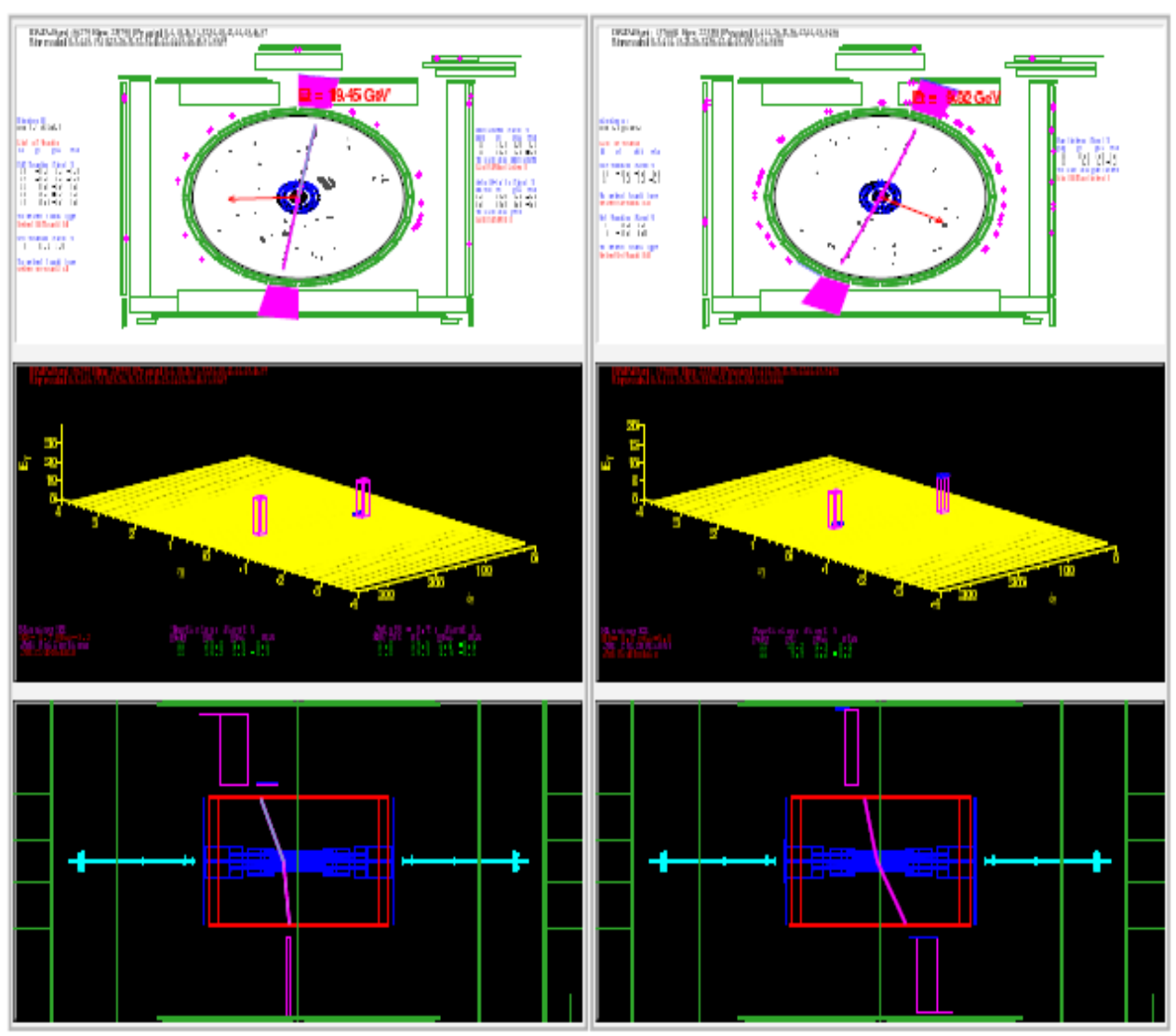


$$s^{|\eta|<1,\,E_T>5\,\mathrm{GeV}}_{\mathrm{SuperCHIC}} = 0.35^{\times 3}_{\div 3}\ \mathrm{pb}\ (\mathrm{MRST99})$$

$$s^{|\eta|<1,\,E_T>5\,\mathrm{GeV}}_{\mathrm{SuperCHIC}} = 1.42^{\times 3}_{\div 3}\ \mathrm{pb}\ (\mathrm{MSTW08LO})$$

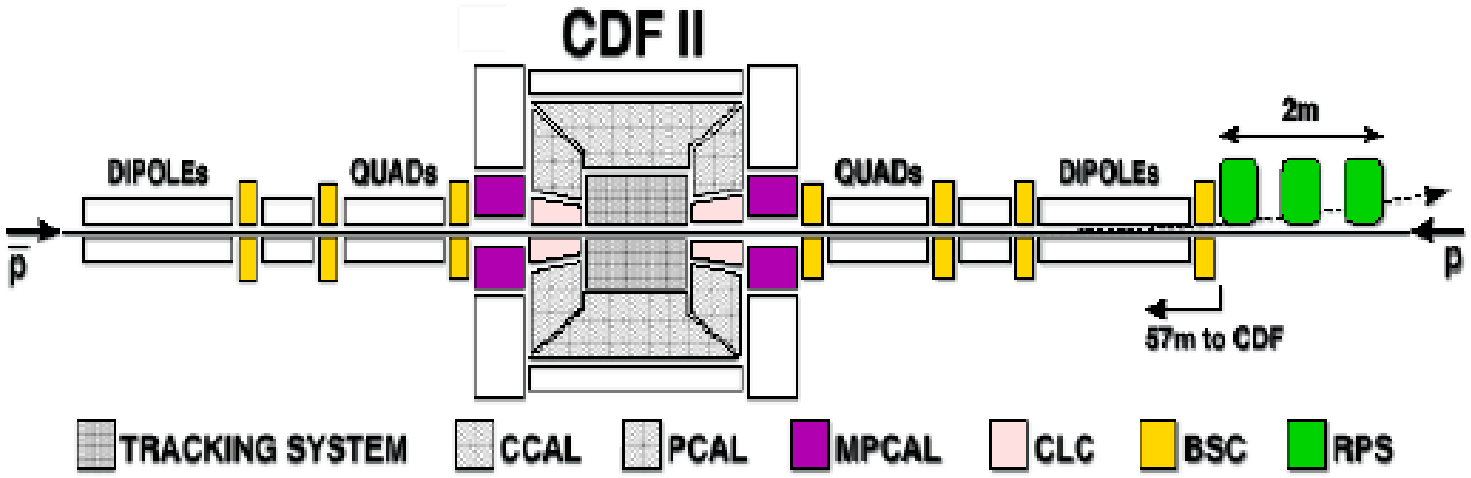
$$s^{|\eta|<1,\,E_T>5\,\mathrm{GeV}}_{\gamma\gamma\,\mathrm{excl}} = 2.48^{\times 3}_{\div 3} \pm 0.42(\mathrm{stat}) \pm 0.41(\mathrm{syst})\,\mathrm{pb}$$

Exclusive $\gamma\gamma$ event candidate



Central Exclusive Poroduction of $\pi^+\pi^-$

DETECTOR



Tracking – Tracking Detectors $|\eta| < 2.0$

CCAL, PCAL – Calorimeters $|\eta| < 3.6$

NOT USED RPS – Roman Pot Spectrometers $0.02 < \xi < 0.1$, $0 < |t| < 2\ \text{GeV}^2$

use only $|\eta|$=5.4-5.9 BSC – Beam Shower Counters $5.4 < |\eta| < 7.4$

NOT UED MPCAL – MiniPlug Calorimeters $3.5 < |\eta| < 5.1$

Central Exclusive Production of $\pi^+\pi^-$

NEW DATA

- **TRIGGERS**
  - **Two Central Calorimeter towers ($|\eta|<1.3$) w/E≥0.5 GeV (a very low threshold) and no energy in BSC ($|\eta|=5.4$-5.9) and in the Forward Plug Calorimeters ($|\eta|=2.11$-3.64).**
  - **"zero-bias" bunch crossing events with no tracks → to study noise/exclusivity cuts.**

- **DATA SETS**
  - **Recorded 90(22)×10^6 events at $\sqrt{s}$=1960 (900) GeV.**

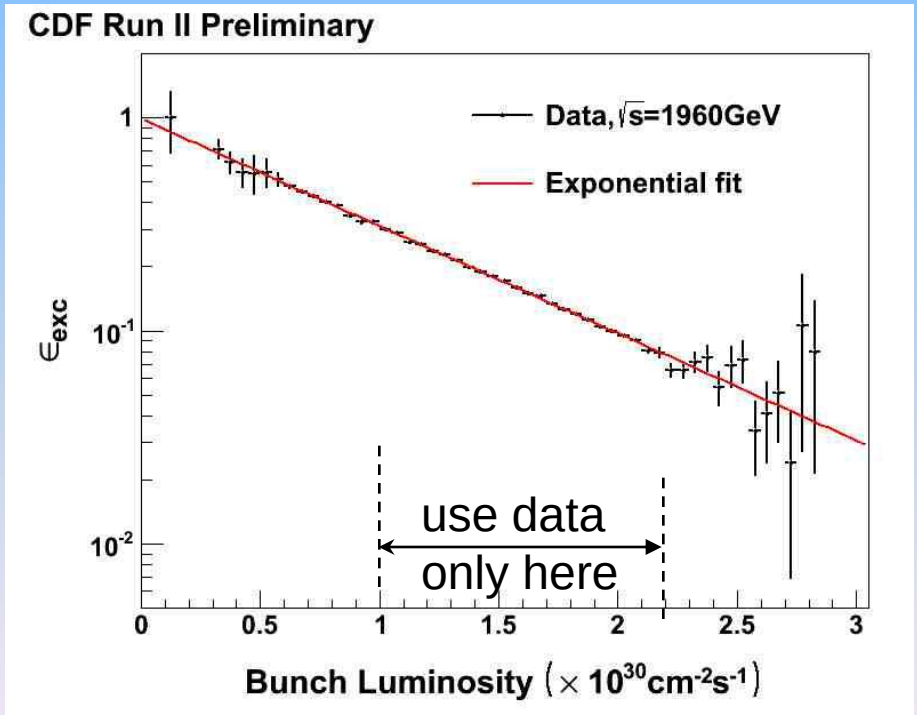
- **PRELIMINARY RESULTS**
  - **$|y(\pi^+\pi^-)|<1.0$, $M_{\pi+\pi-}<0.8$ where there is some acceptance at all p_T.**

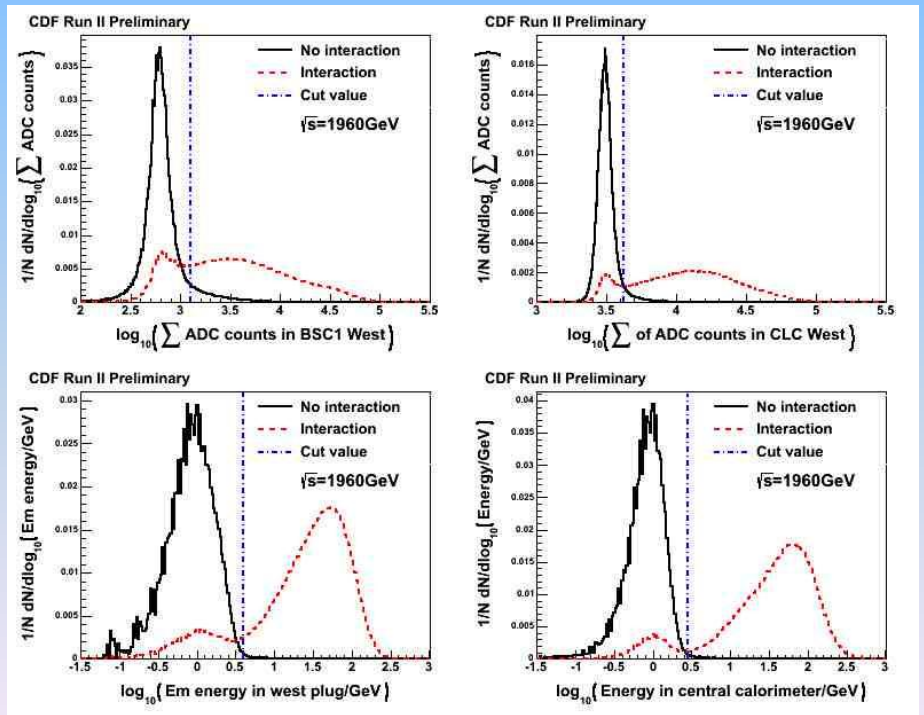
Notice: **no particle ID is (yet) being used and the observed tracks are assumed to be due to pions (until further notice – stay tuned!).**

“Empty” events ➔ detector noise levels

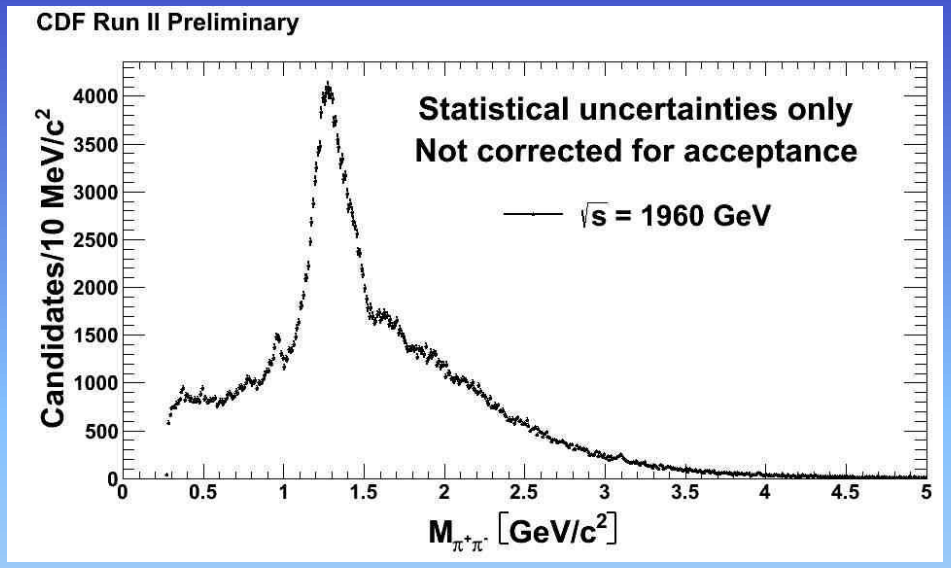
- Empty-event selection
- Select region of bunch luminosity with low overlaps and high yied

- Detector noise levels:
- Determined separately for interaction and no-interaction events
- Rejected “noise” events below vertical dashed lines

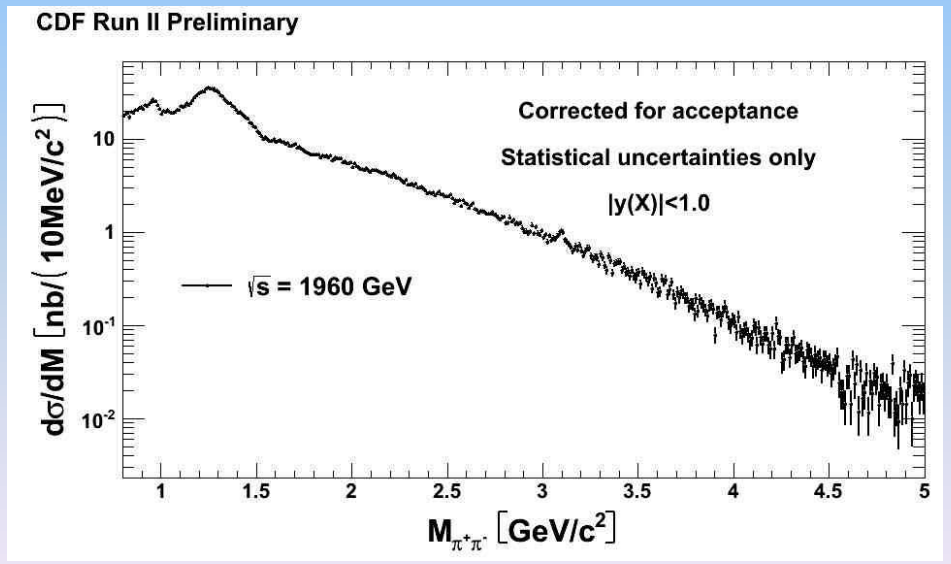




$M_{\pi^+\pi^-}$ distributions at 1960 GeV



- not-corrected for acceptance

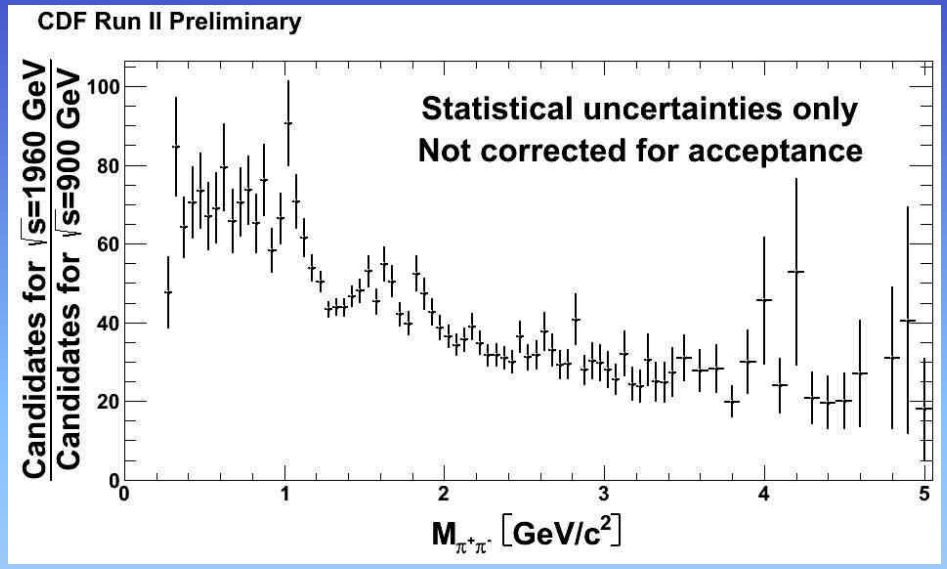


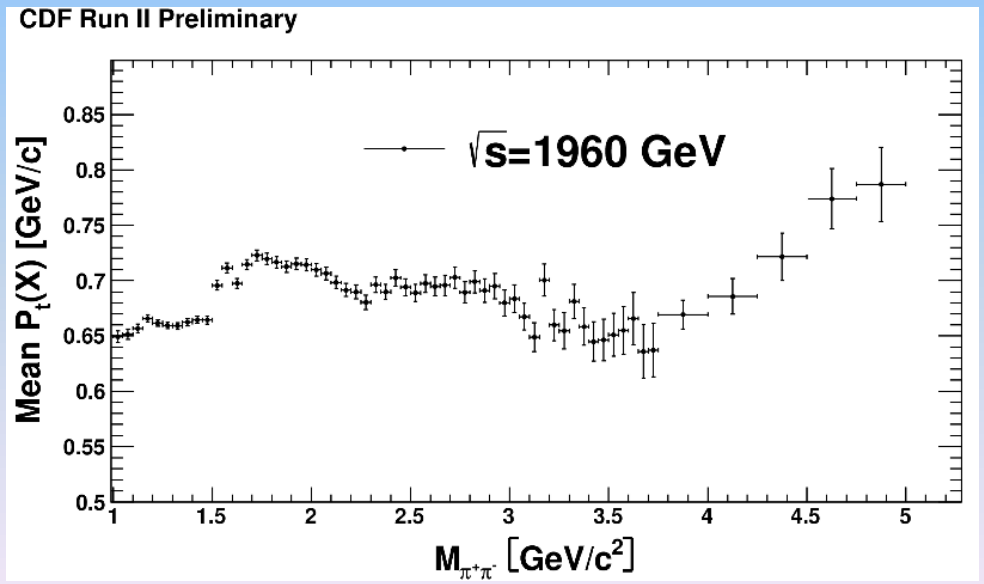
- corrected for acceptance

- we clearly see $f_0(980)$, $f_2(1270)$ and $f_0(1370)$.
- the small but significant peak at 3.1 GeV is understood to be from $J/\psi \rightarrow e^+e^-$ with masses assumed as $m_{\pi^+}m_{\pi^-}$.

Event ratio of 1960/900 GeV and average P_T at 1960 GeV

- Ratio of candidates at √s=1960/900 GeV vs M(*pair*) ➔

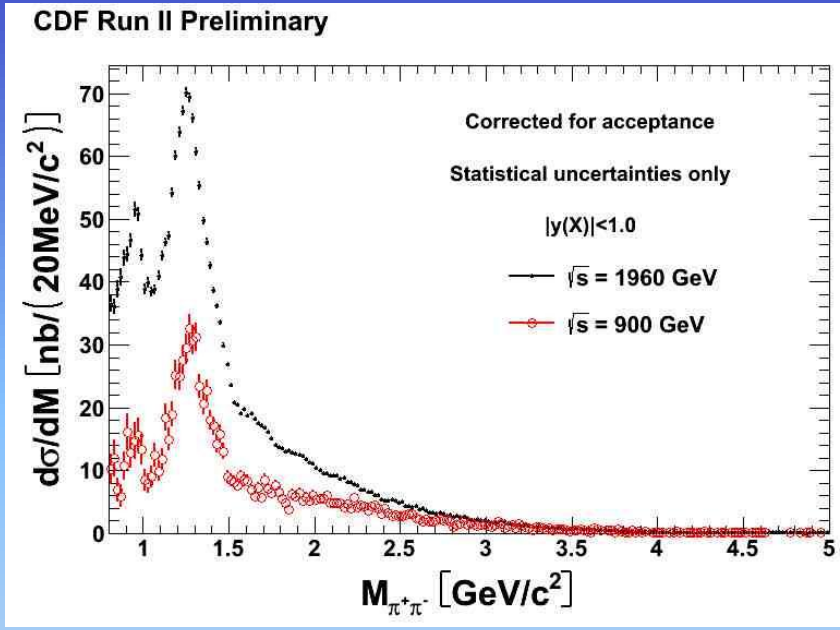


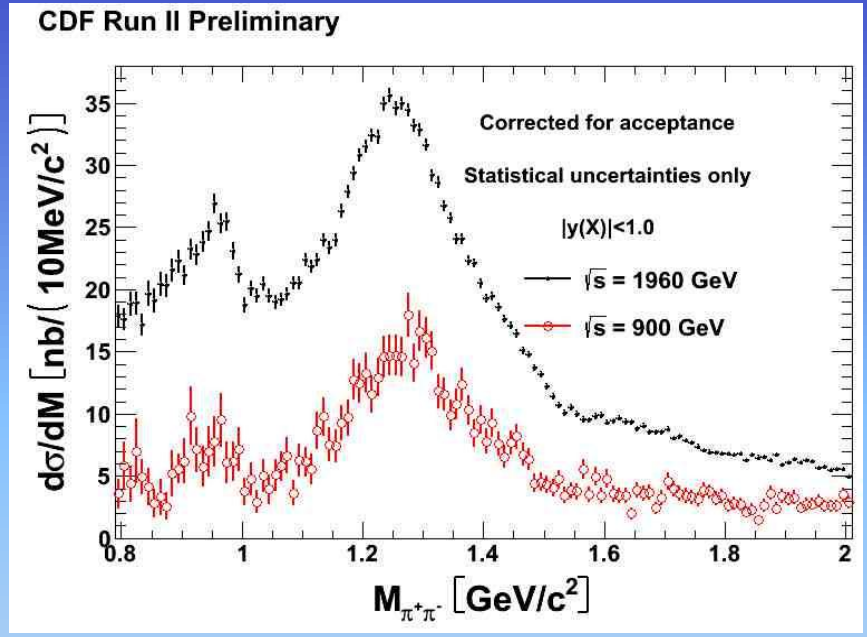


- Mean p_T(*pair*) in GeV/*c* as a function of M(*pair*)

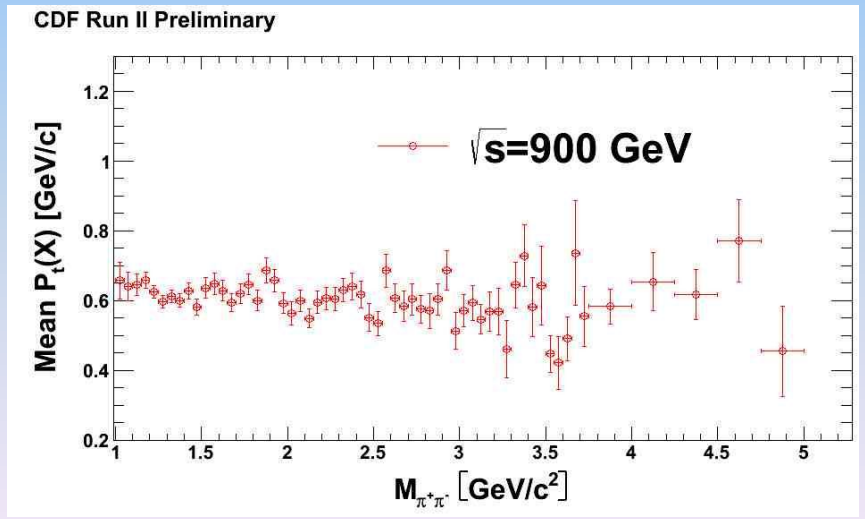
➔

Comparisons of $d\sigma/dM_{\pi+\pi-}$ events per bin





- The structures observed in the mass region of less than ≈1 GeV are under investigation.



SUMMARY

- Reviewed briefly exclusive production at CDF.
- Measured exclusive $\pi^+\pi^-$ production (no particle ID yet, tracks assumed to be due to pions) at $\sqrt{s}$=900 GeV and $\sqrt{s}$=1960 GeV with higher statistics than in earlier studies.
- Explored the low mass region: found well known structures from AFS at ISR at $\sqrt{s}$=63 GeV for $M_{\pi^+\pi^-} < 1.5$ GeV, and also features that are not yet understood for $M_{\pi^+\pi^-} > 1.5$ GeV.
- Partial wave analysis currently underway – stay tuned!

Thank you for your attention