

Exclusive Central Meson Production in Proton Antiproton Collisions at the Tevatron at $\sqrt{s} = 1960$ GeV and 900 GeV

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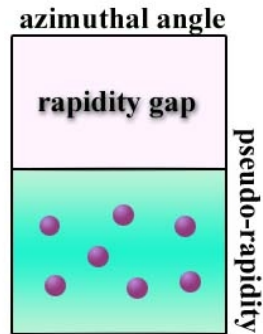
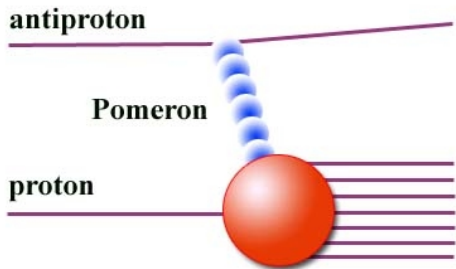
on behalf of the CDF Collaboration



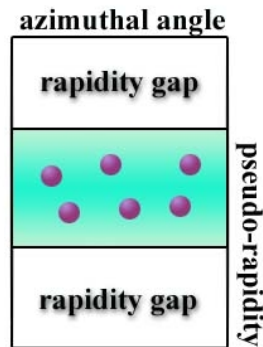
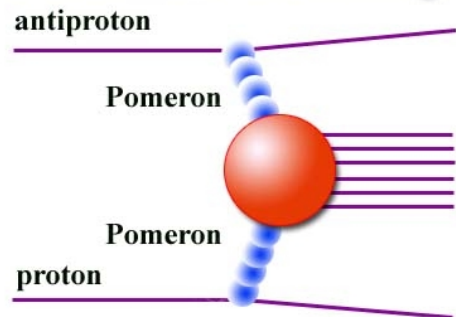
Physics Motivation

Double Pomeron Exchange (DPE)

Single Diffraction



Double Pomeron Exchange



Pomeron:

- Carrier of 4-momentum between protons
- Strongly interacting color singlet combination of gluons and quarks
- Quantum numbers of vacuum
- LO: $P = gg$

Analysis

GXG reaction

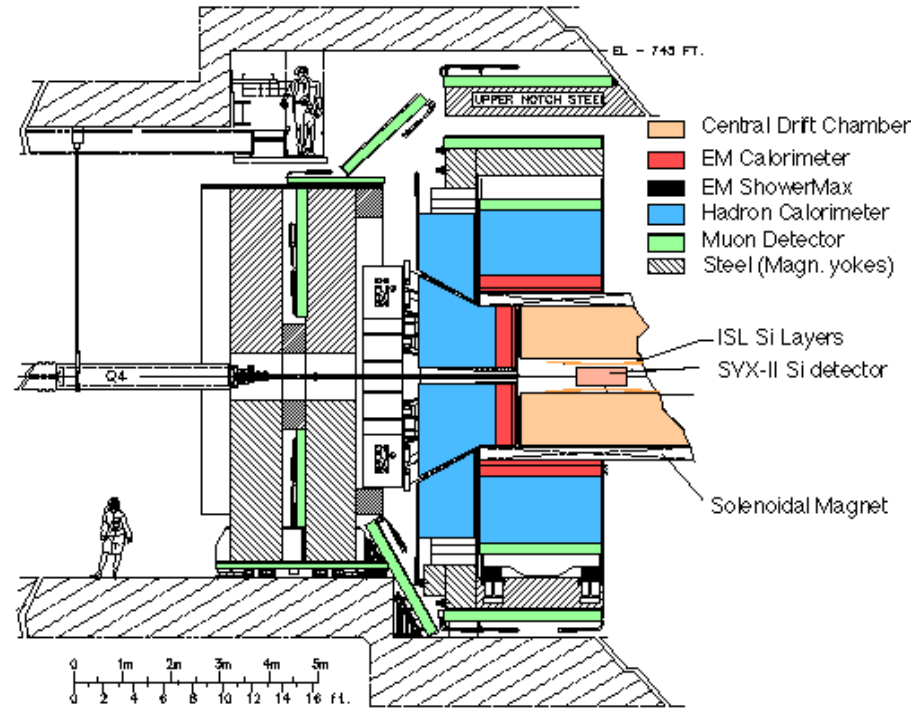
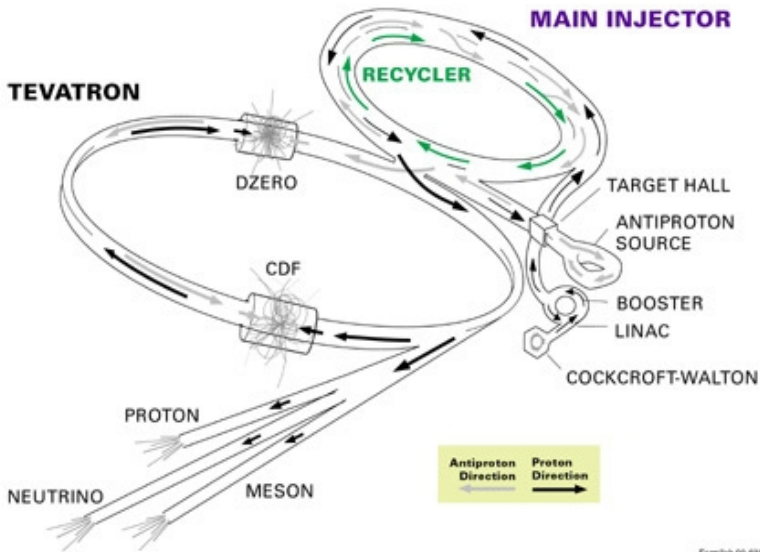


- **X** (in this study):
- hadron pair mostly $\pi^+ \pi^-$
- central $|y(\pi^+ \pi^-)| < 1.0$
- between rapidity gaps $\Delta\eta > 4.6$
- $Q = S = 0, C = +1, J = 0 \text{ or } 2, I=0$

Expected to be dominated by DPE in the t-channel!

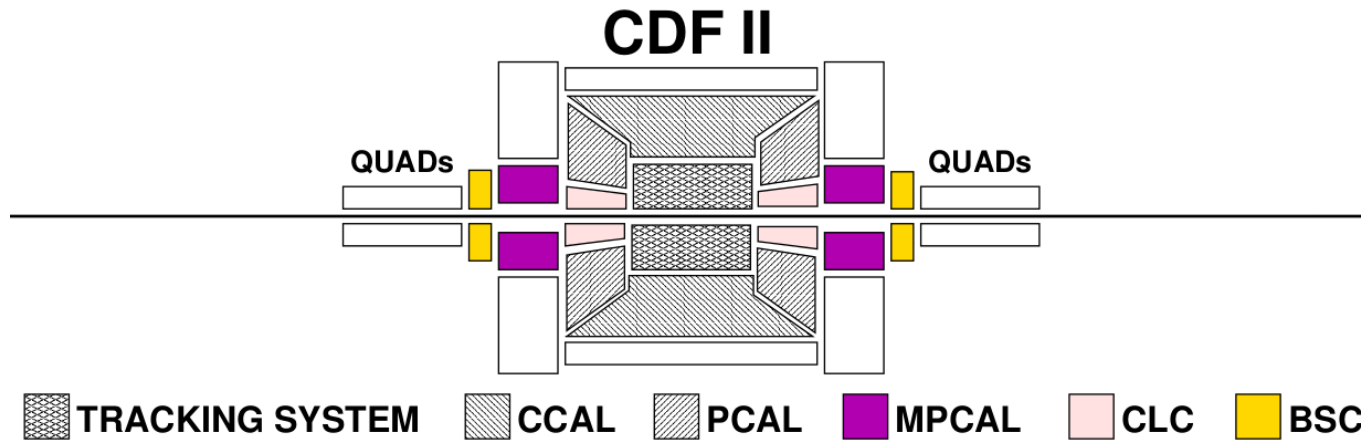
Collider Detector at Fermilab

FERMILAB'S ACCELERATOR CHAIN



$\sqrt{s} = 1960 \text{ GeV}$
 $\sqrt{s} = 900 \text{ GeV}$

Collider Detector at Fermilab



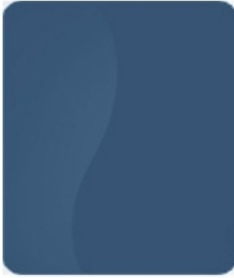
- We do not detect outgoing protons
- Forward detectors in veto

- BSC – Beam Shower Counters
- CLC – Cherenkov Luminosity Counters
- PCAL – Plug Calorimeter

We require all detectors, $|\eta| < 5.9$, to be empty except for two tracks

Central Hadronic State Analysis

Candidates selection



Trigger requirements:

- 2 central ($|\eta| < 1.3$) towers with $E_t > 0.5$ GeV
- PCAL ($2.11 < |\eta| < 3.64$) in veto
- CLC ($3.75 < |\eta| < 4.75$) in veto
- BSC1 ($5.4 < |\eta| < 5.9$) in veto

Gap cuts:

To determine noise levels in subdetectors we divide zero-bias sample from same periods into two sub-samples:

No Interaction:

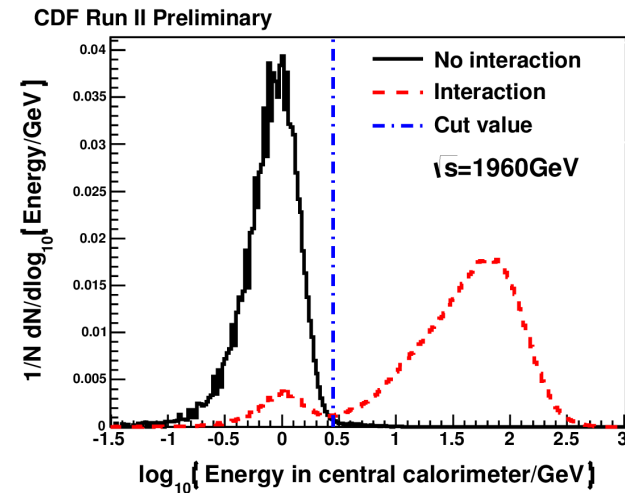
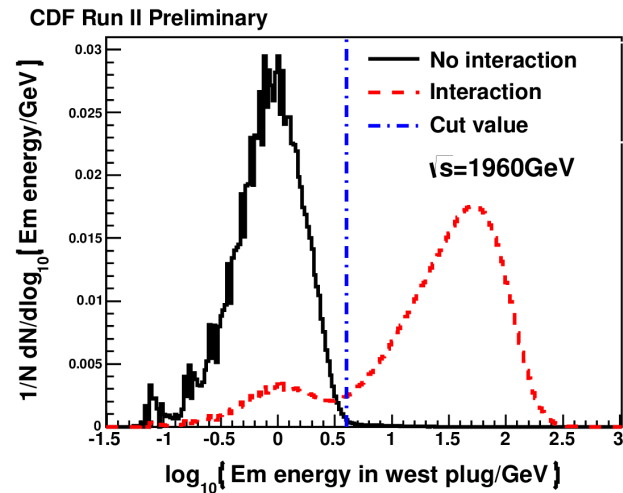
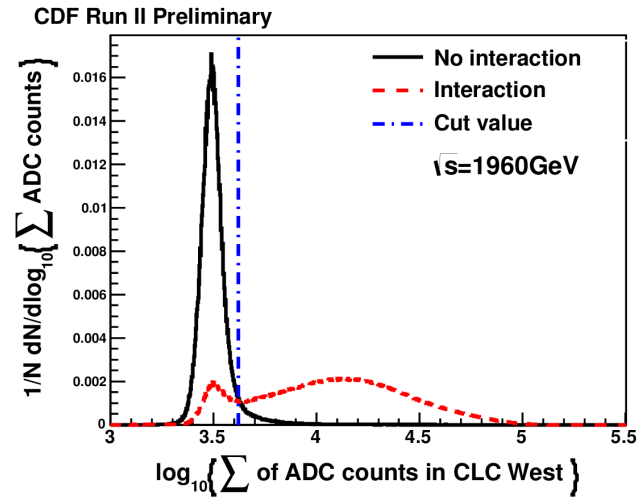
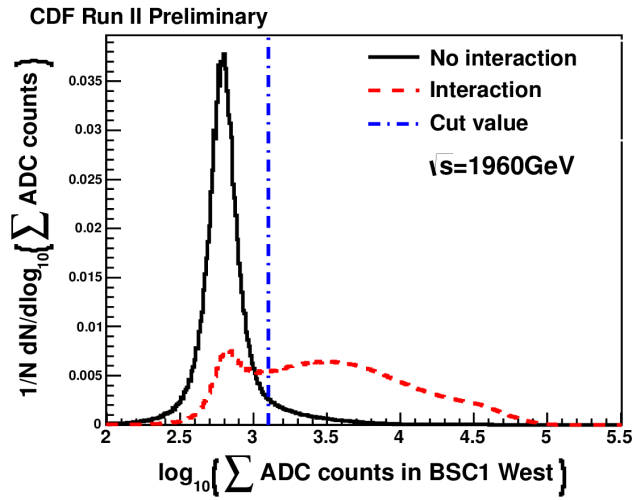
- No tracks and
- No CLC hits and
- No muon stubs

Interaction:

At least one

- Track or
- CLC hit or
- Muon stub

Exclusivity cuts



Central Hadronic State Analysis

Candidates selection

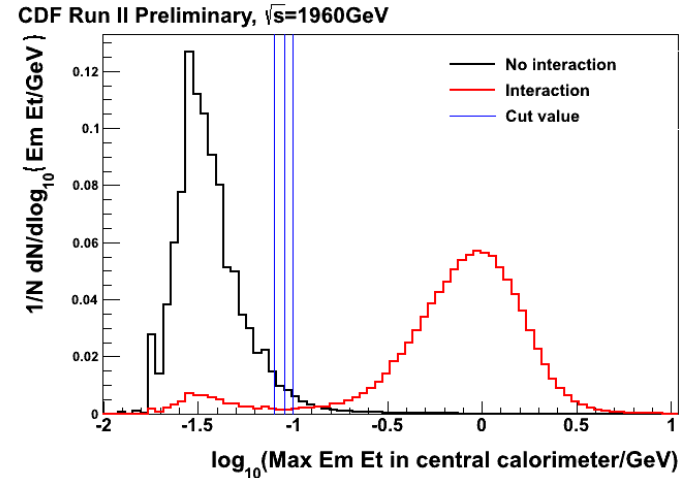
Exclusive 2 tracks:

- Similar technique in region of central calorimeter
- excluding cones of $R=0.3$ around each track extrapolation.

$$R = \sqrt{(\Delta \eta)^2 + (\Delta \varphi)^2}$$

Additional cuts:

- quality of tracks
- cosmic ray rejection
- 2 oppositely charged tracks



The “hottest” EM tower must be less than 90 MeV

Effective exclusive luminosity

- Determination of efficiency of having no-pileup using zero-bias sample.

We measure ratio of empty events (all detectors on noise level) to all events.

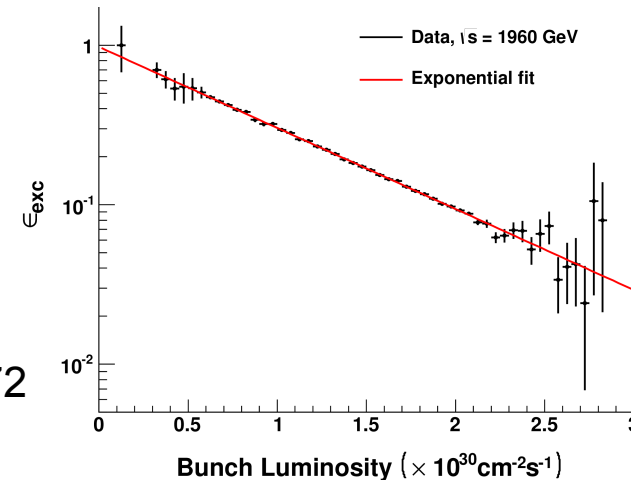
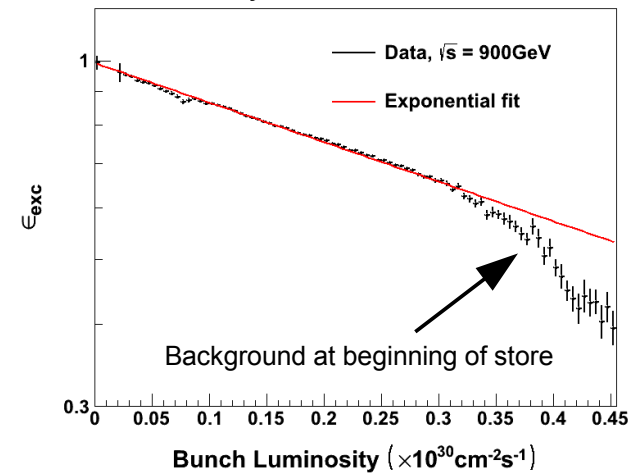
- Exponential drop with bunch luminosity.
- Slope corresponds to total detected inelastic cross section.

	1960 GeV	900 GeV
$\sigma_{\text{obs}} (\eta < 5.9)$	55.9 mb	65.8 mb
L_{eff}	1.15/pb	0.059/pb

L renormalization factor based on σ_{inel} for 900 GeV: 0.72

Higher dissociation masses allowed at 1960 GeV

CDF Run II Preliminary



Central Hadronic State Analysis

Acceptance and cut efficiency

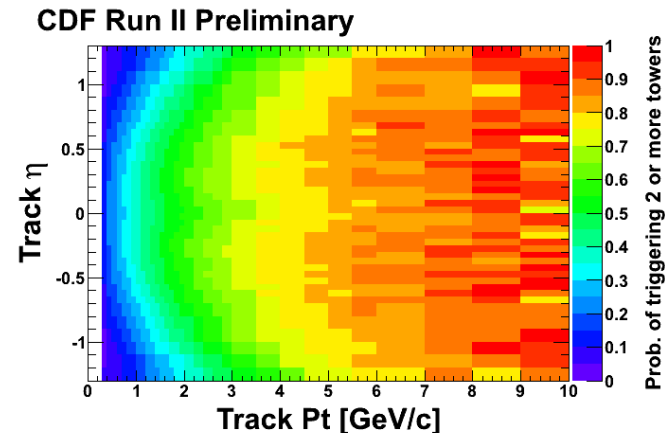
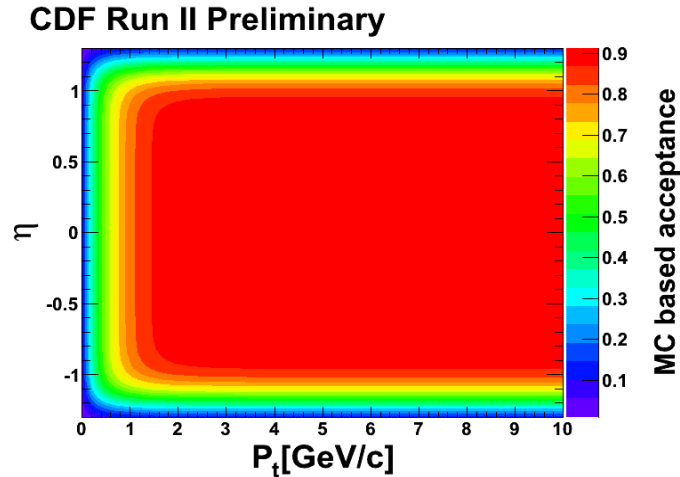
Model independent analysis

Kinematic cuts:

- $P_t(\pi) > 0.4 \text{ GeV}/c$
- $|\eta(\pi)| < 1.3$
- $|y(\pi^+ \pi^-)| < 1.0$

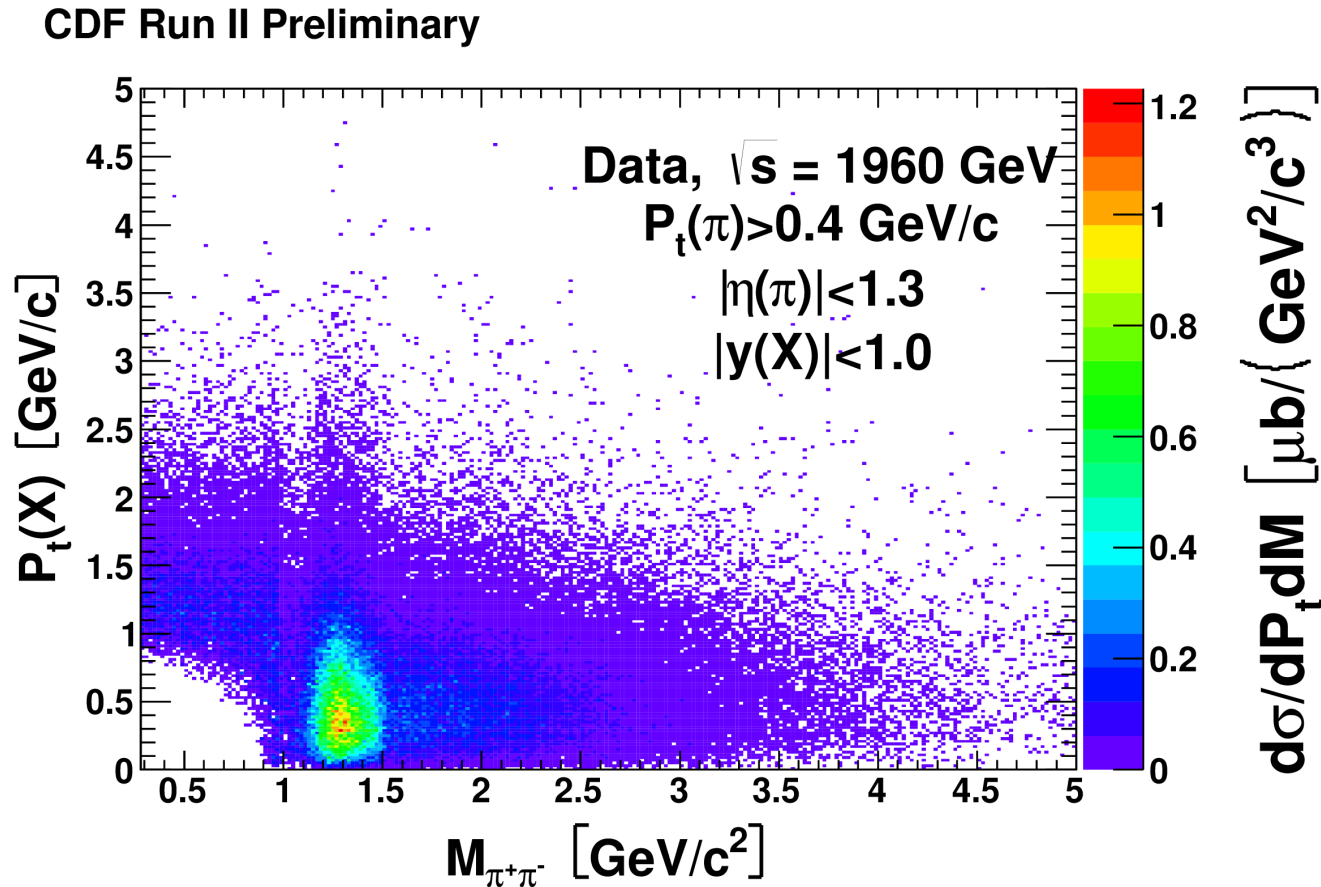
3 components:

- Trigger efficiency
- Single track acceptance
- 2 tracks acceptance



Central Hadronic State Analysis

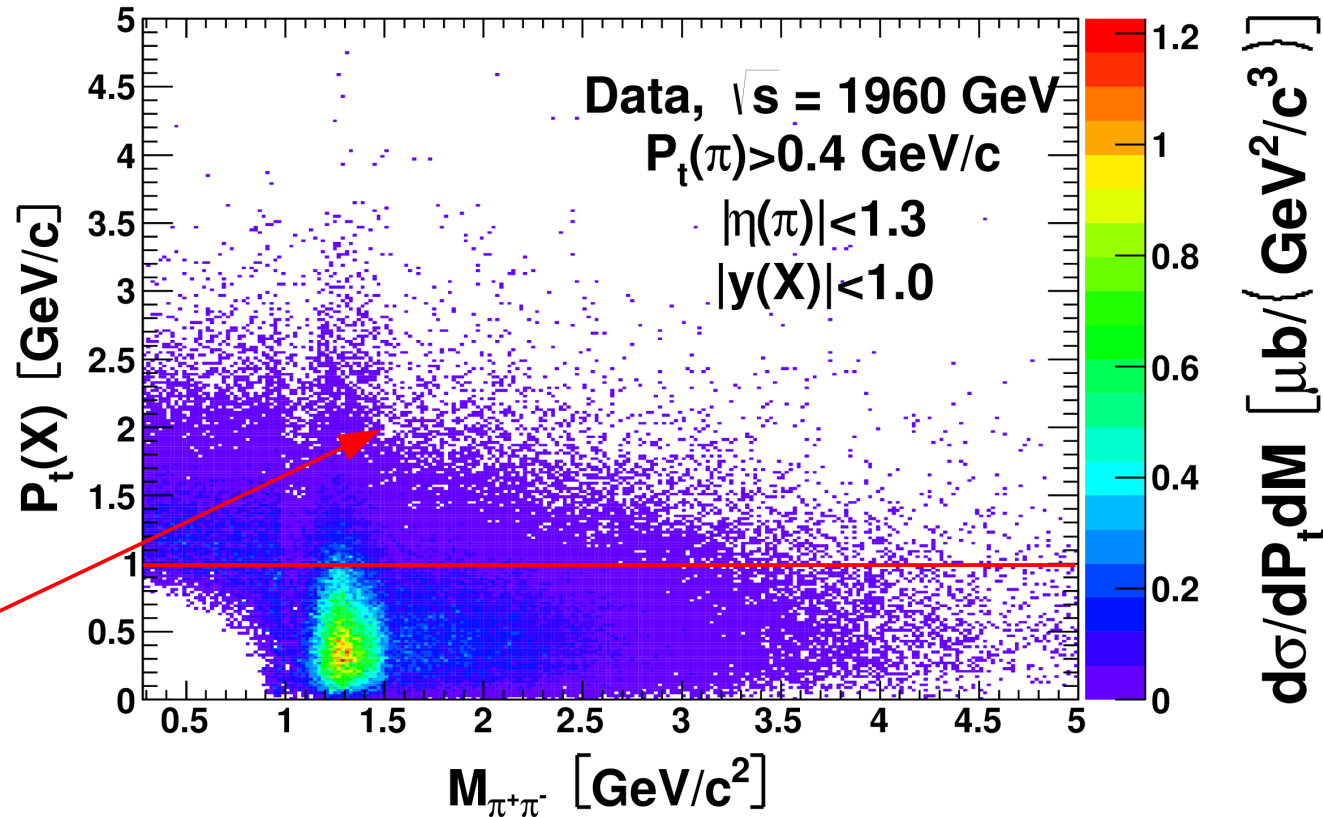
$M(\pi^+\pi^-)$ vs $P_t(X)$ for 1960 GeV



Central Hadronic State Analysis

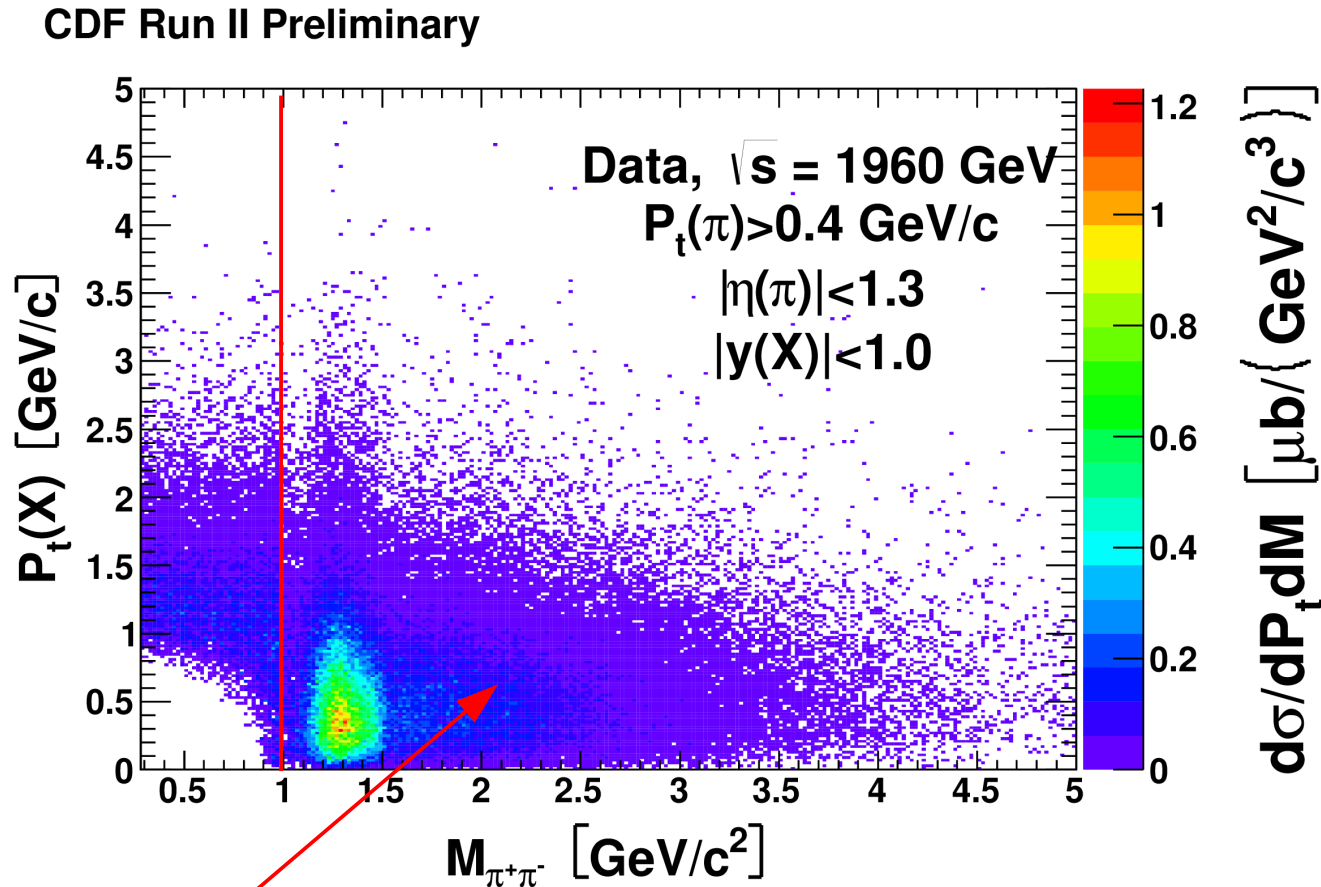
$M(\pi^+\pi^-)$ vs $P_t(X)$ for 1960 GeV

CDF Run II Preliminary



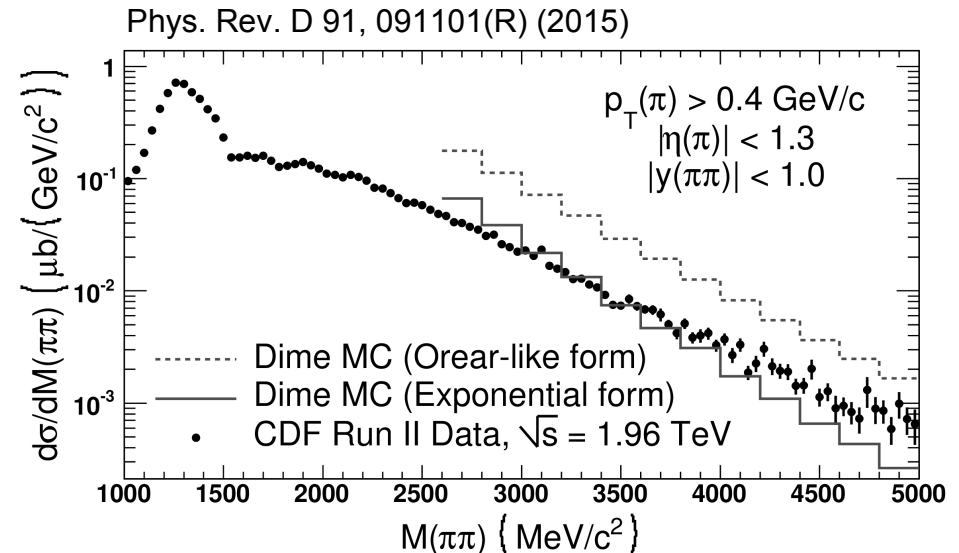
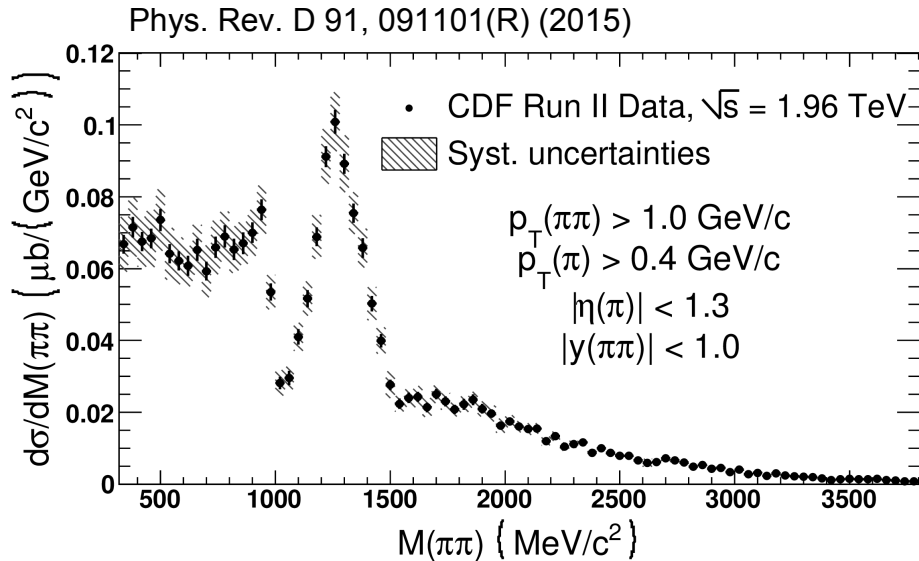
Central Hadronic State Analysis

$M(\pi^+\pi^-)$ vs $P_t(X)$ for 1960 GeV



Central Hadronic State Analysis

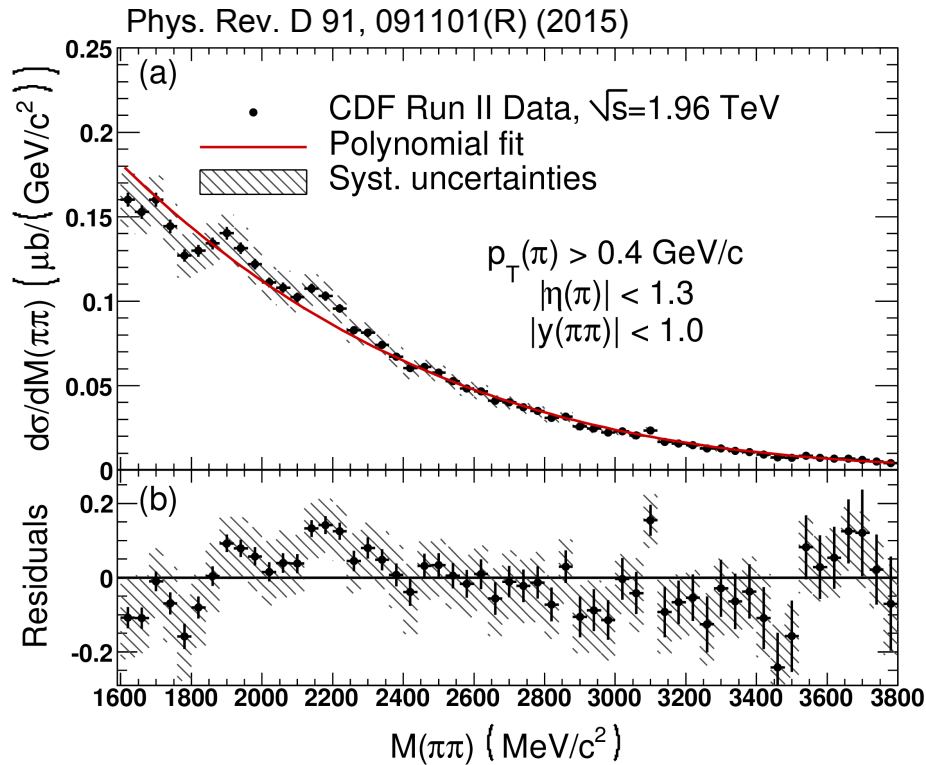
$M(\pi^+\pi^-)$ for 1960 GeV



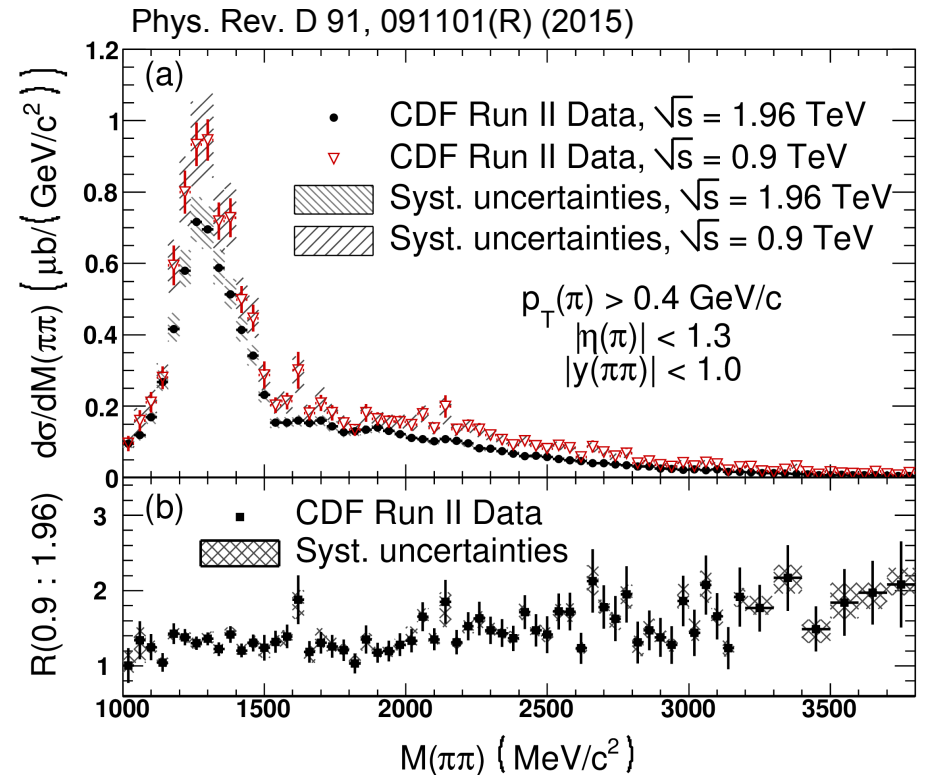
- Broad continuum below 1 GeV/c²
- Cusp at 1 GeV/c²
- Resonant enhancement around 1.0 – 1.5 GeV/c² dominated by $f_2(1270)$

Central Hadronic State Analysis

$M(\pi^+\pi^-)$ for 1960 GeV and 900 GeV



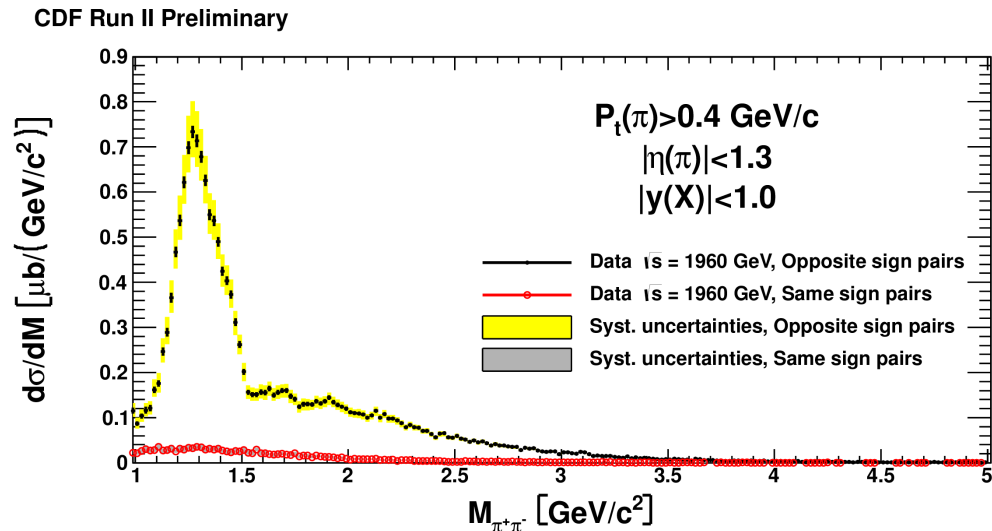
Indications of structure up to 2.4 GeV/c^2



Non-exclusive background

Same sign sample

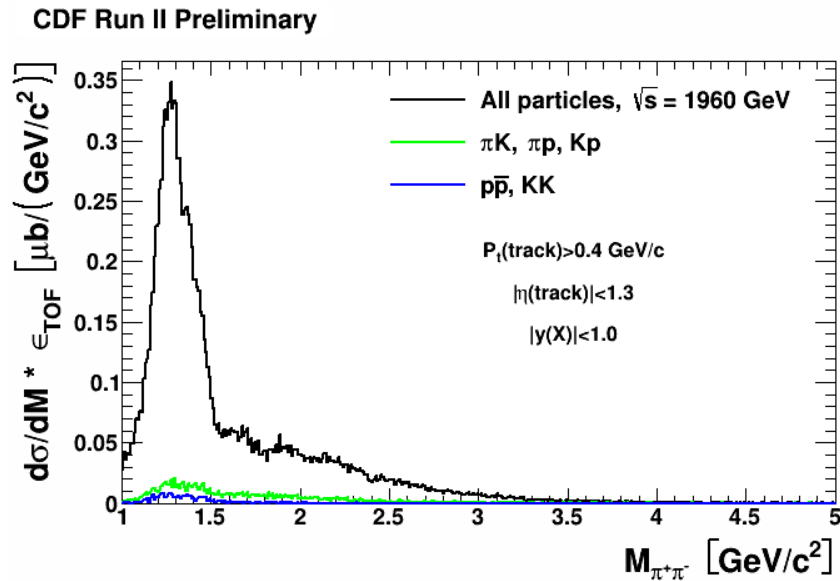
- The events with two same charge tracks: 6.1% (900 GeV) and 7.1% (1960 GeV)
- Sign of non-exclusive background with 2 or more undetected charged particles:
 - very low p_T (no reconstructed track and low calorimeter E)
 - very forward



The $M(\pi^+\pi^-)$ distribution for $++/- -$ pairs is featureless

- But! indication of a similar background from $\pi^+\pi^-\pi^+\pi^-$ events in $\pi^+\pi^-$ sample
- No subtraction

Non- $\pi^+\pi^-$ background



ToF counter information used (coverage in $|\eta| < 0.9$)

For $|\eta| < 1.3$: 67% of the pairs have both particles identified
→ $\pi^+\pi^-$ pairs – 89%

For $|\eta| < 0.7$: 90% of the pairs have both particles identified
→ No significant change in the composition

No non- $\pi^+\pi^-$ background subtraction

Conclusions

- **We have measured $\pi^+\pi^-$ pairs between large rapidity gaps at the Tevatron, which should be dominated by double pomeron exchange.**
- **Contribution of non- $\pi^+\pi^-$ pairs background and non-exclusive background is small**
- **The mass spectra show several structures:**
 - Broad continuum below $1 \text{ GeV}/c^2$,
 - Sharp drop at $1 \text{ GeV}/c^2$
 - Resonant enhancement around $1.0 - 1.5 \text{ GeV}/c^2$.
- **This is the only measurement from the Tevatron, and has much higher statistics than preliminary data from the LHC experiments.**



MIND THE GAP

Backup slides

Acceptance calculation

Model independent analysis

Kinematics cuts:

- $P_t(\pi) > 0.4 \text{ GeV}/c$
- $|\eta(\pi)| < 1.3$
- $|y(X)| < 1.0$

3 components:

- Trigger efficiency
- Single track acceptance
- 2 tracks acceptance

Trigger efficiency

1. Sample of min-bias data, good quality isolated (no other tracks in cone with $R=0.4$) tracks.
2. Checking how often they fired 0, 1, 2 or more trigger towers (≥ 4 bits) in 3×3 box around track extrapolation.
3. Trigger efficiency composed from those 3 probability distributions (which are functions of P_t and η)

Trigger efficiency

Probability of triggering 2 or more towers in the central detector by two independent tracks „a” and „b”:

$$\varepsilon = P_2(a) + P_1(a) * [P_1(b) + P_2(b)] + P_0(a) * P_2(b)$$

P_0 – probability of triggering no towers

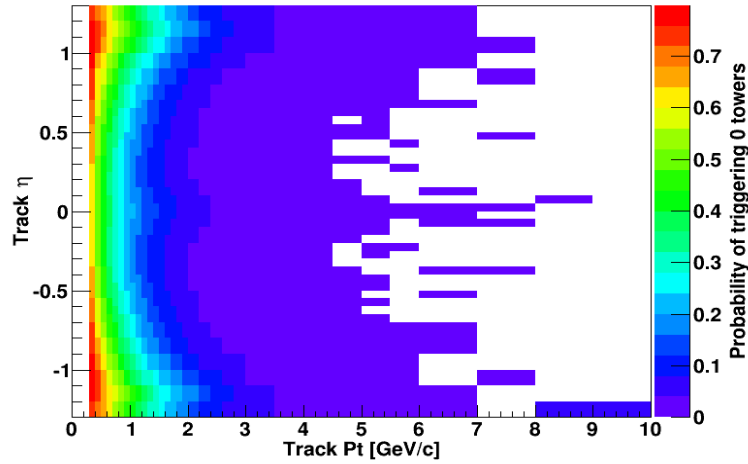
P_1 – probability of triggering one tower

P_2 – probability of triggering two or more towers

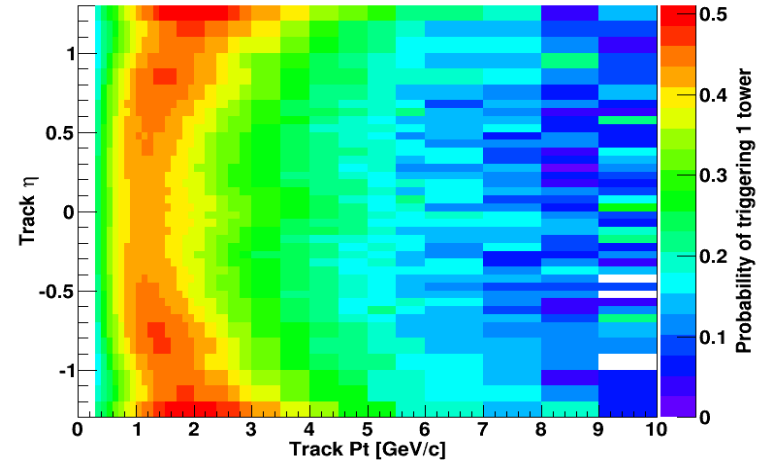
	P_2b	P_1b	P_0b
P_2a	X	X	X
P_1a	X	X	
P_0a	X		

Trigger efficiency

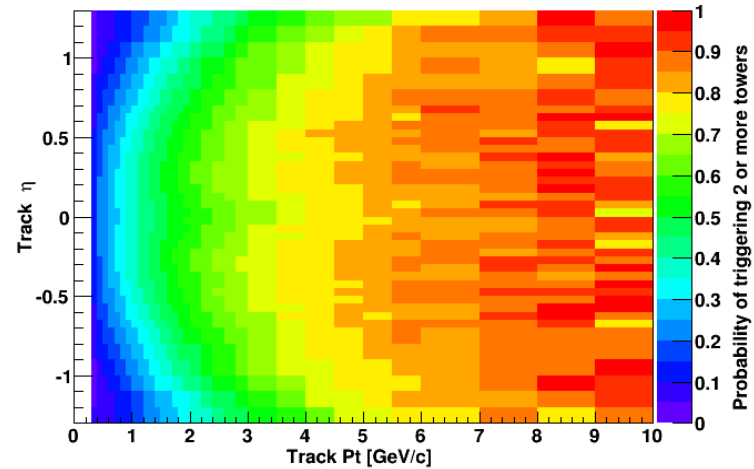
CDF Run II Preliminary



CDF Run II Preliminary



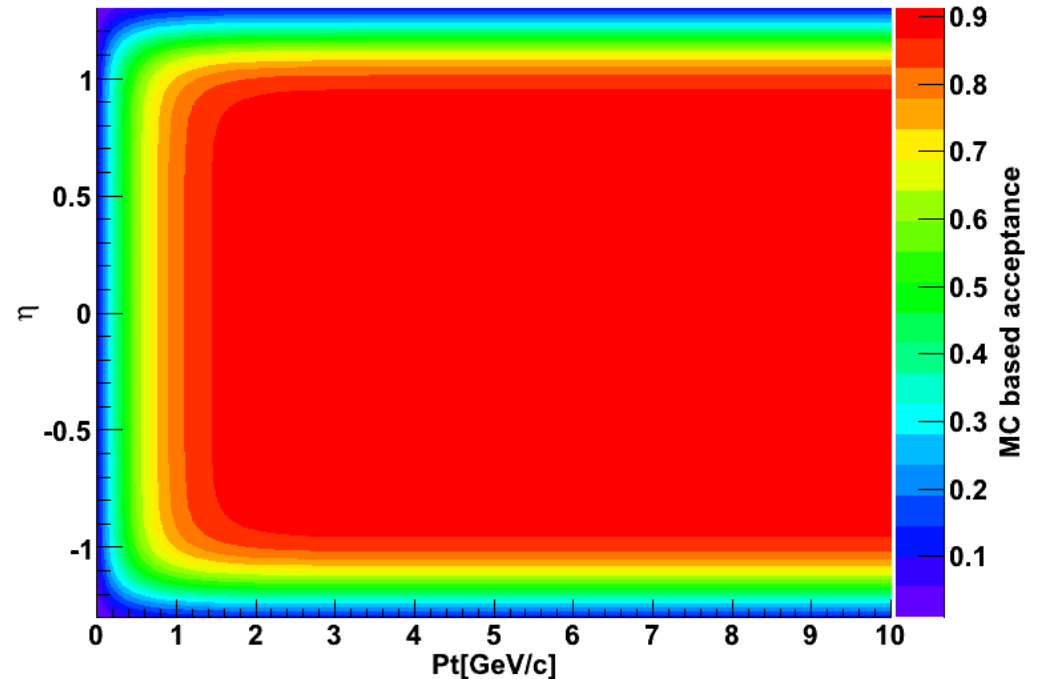
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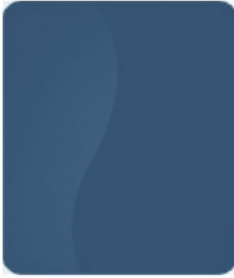
Single track acceptance

1. Single pion generation,
flat in phi
2. Acceptance as a function
of $P_t(\text{track})$ and eta
 - Probability that track will
be reconstructed at all
 - Probability that track will
pass all single track
quality cuts

CDF Run II Preliminary



2 tracks cuts acceptance

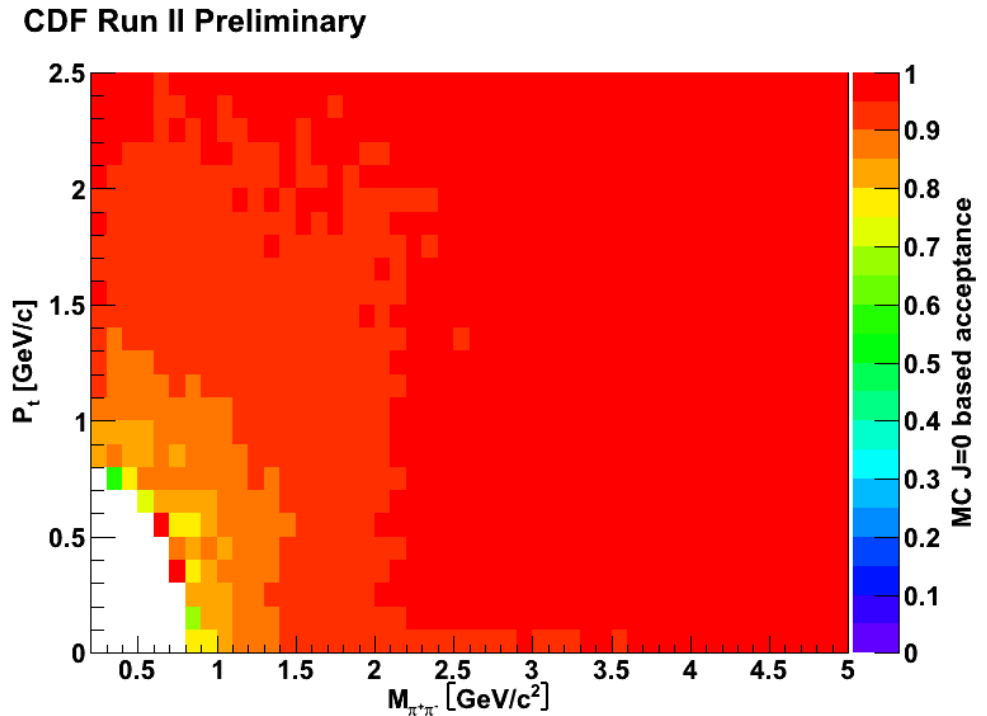


Cuts:

- 3D opening angle
- y of central state
- Separation
- ΔZ_0

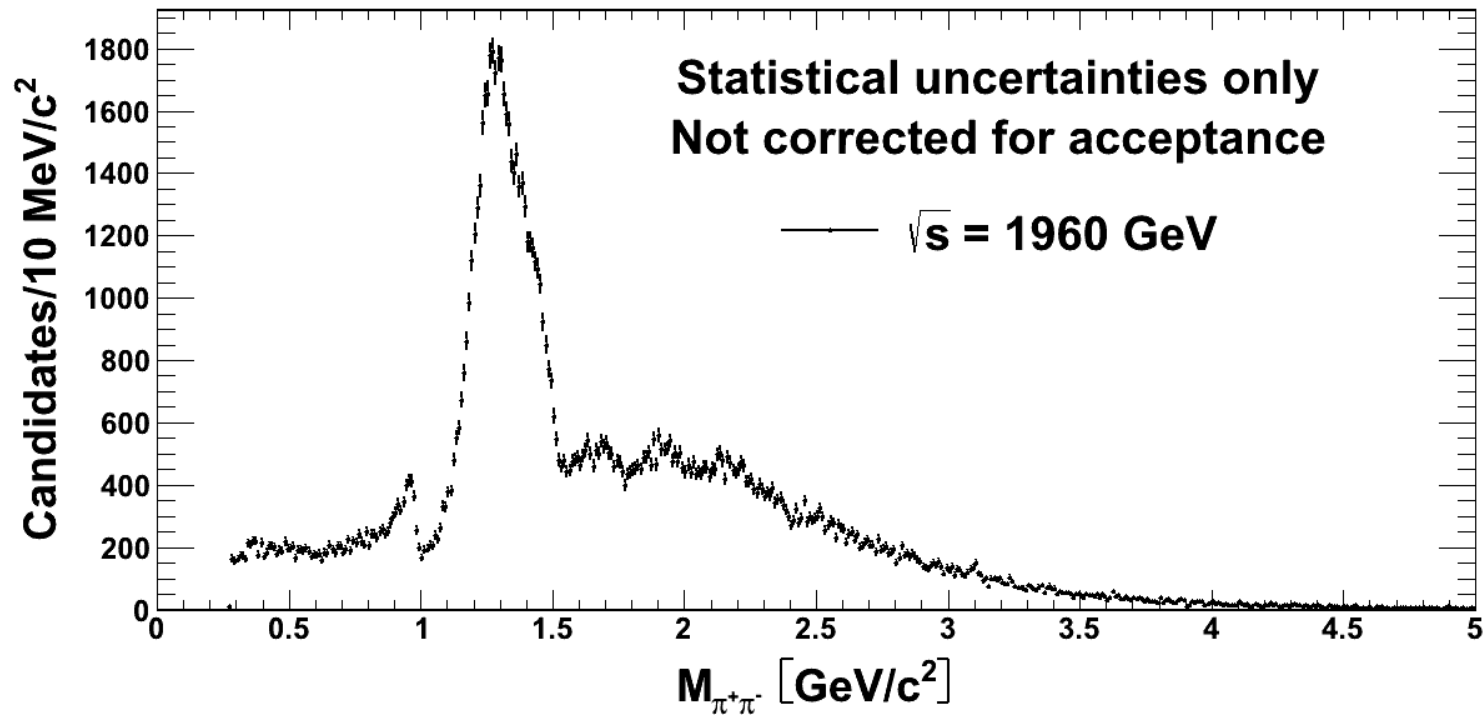
Based on $J=0$ phase space model

All previous cuts applied before

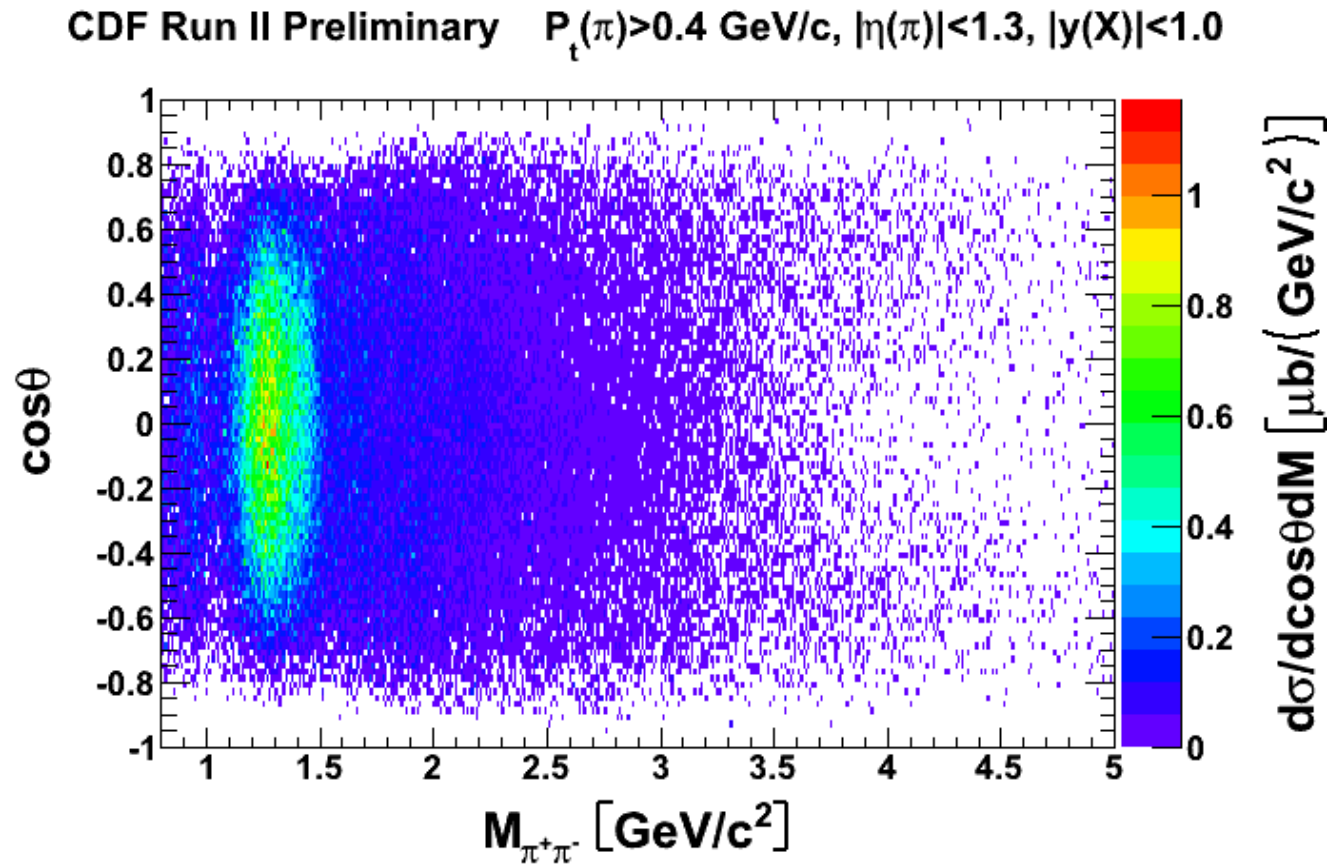


Invariant mass distribution

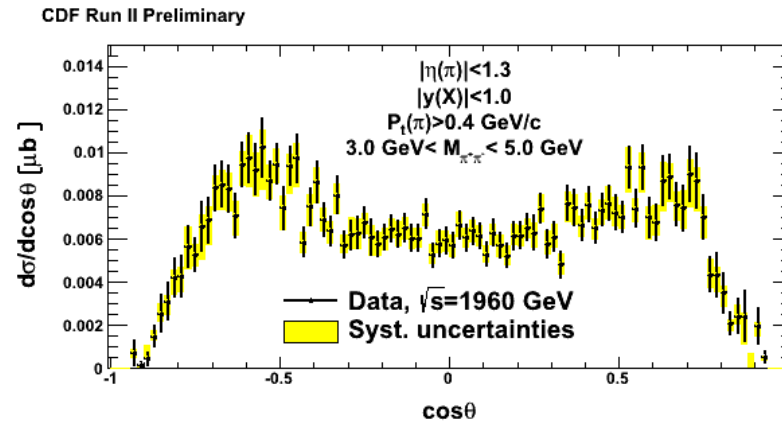
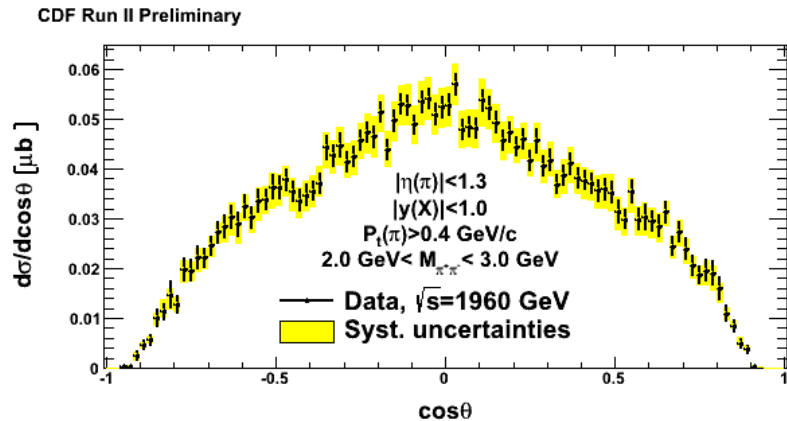
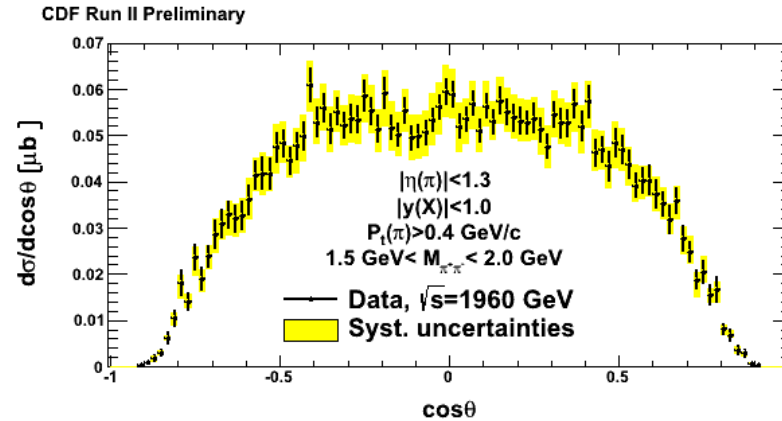
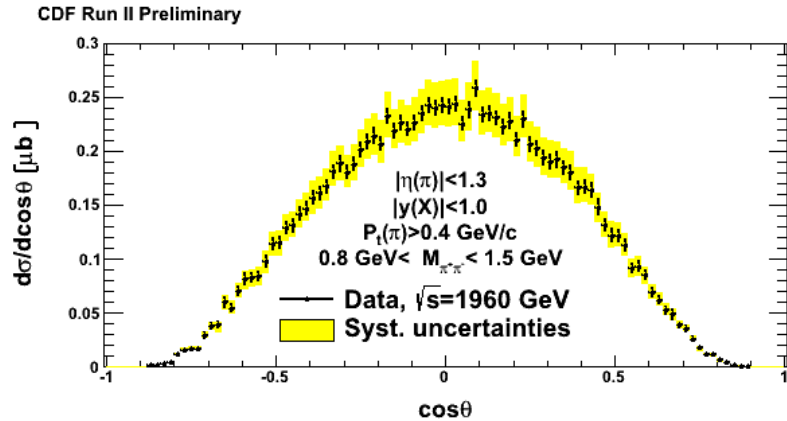
CDF Run II Preliminary



Partial wave analysis

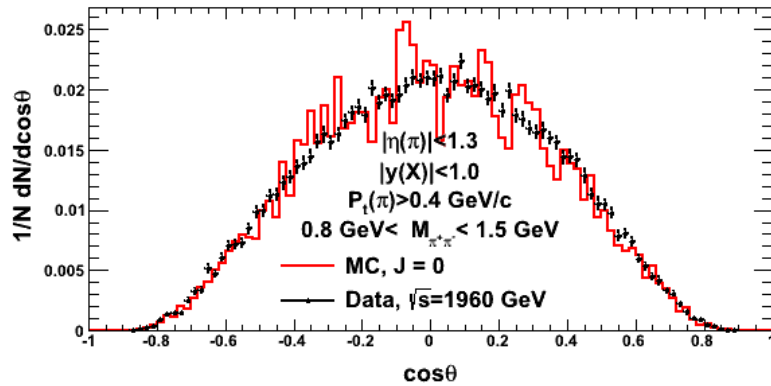


Partial wave analysis

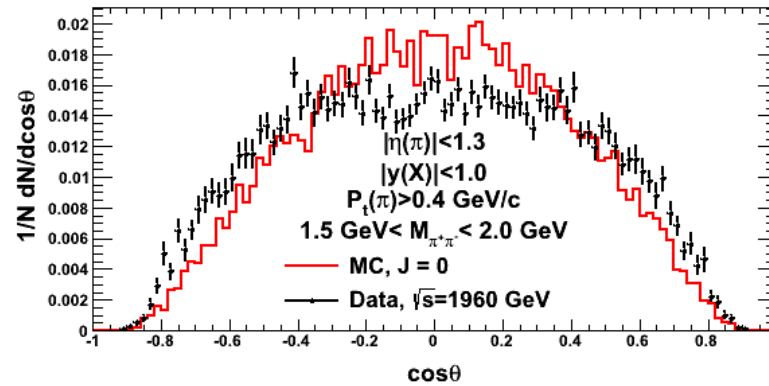


Partial wave analysis

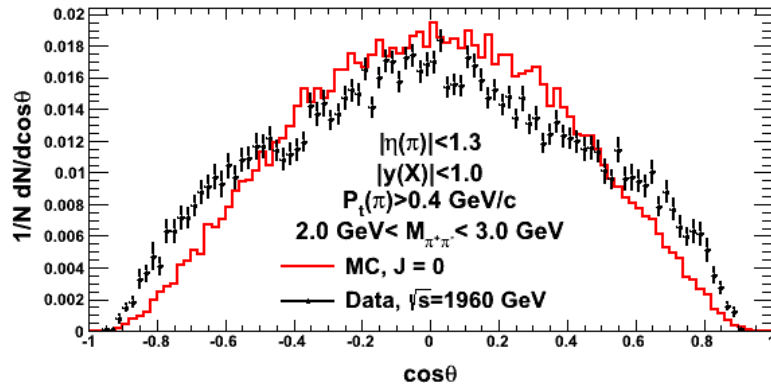
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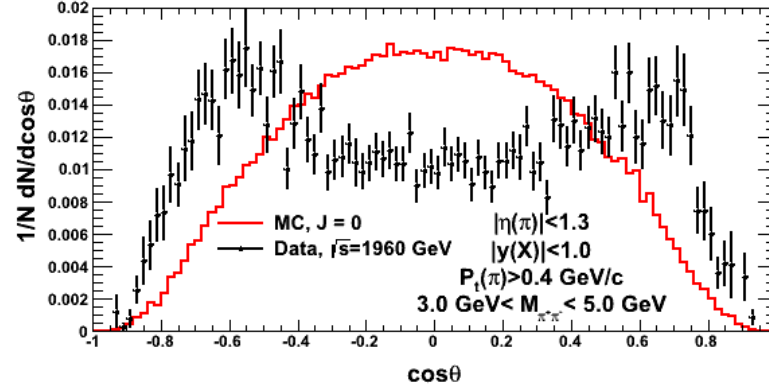
CDF Run II Preliminary



CDF Run II Preliminary



CDF Run II Preliminary



Partial wave analysis

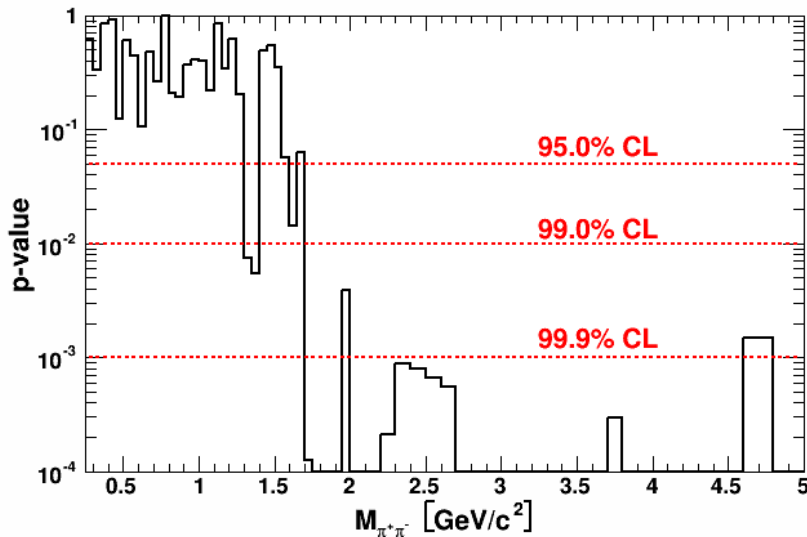
Comparison of data/MC s-wave $\cos(\theta)$ distributions
 H_0 : $\cos(\theta)$ distributions for data and s-wave MC are the same (in mass bins)

- H_1 : not H_0 .
- Test type: Smirnow
- Test statistics: λ Kolmogorov

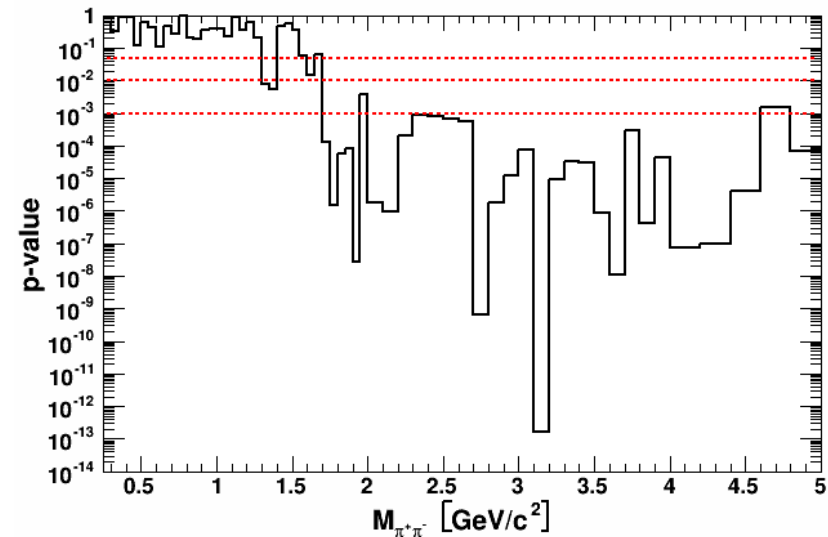
Partial wave analysis



CDF Run II Preliminary



CDF Run II Preliminary



If p-value is smaller than 0.05 we reject the H_0 ($s = 0$) in favour of H_1 on the 95% CL
If p-value is greater than 0.05 we cannot reject the null hypothesis H_0 ($s = 0$) on the 95% CL