Central Exclusive K^+K^- production in CDF

PROGRESS REPORT

Antonio Gioiosa
University of Molise – INFN

On behalf of the CDF Collaboration at Fermilab

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Introduction

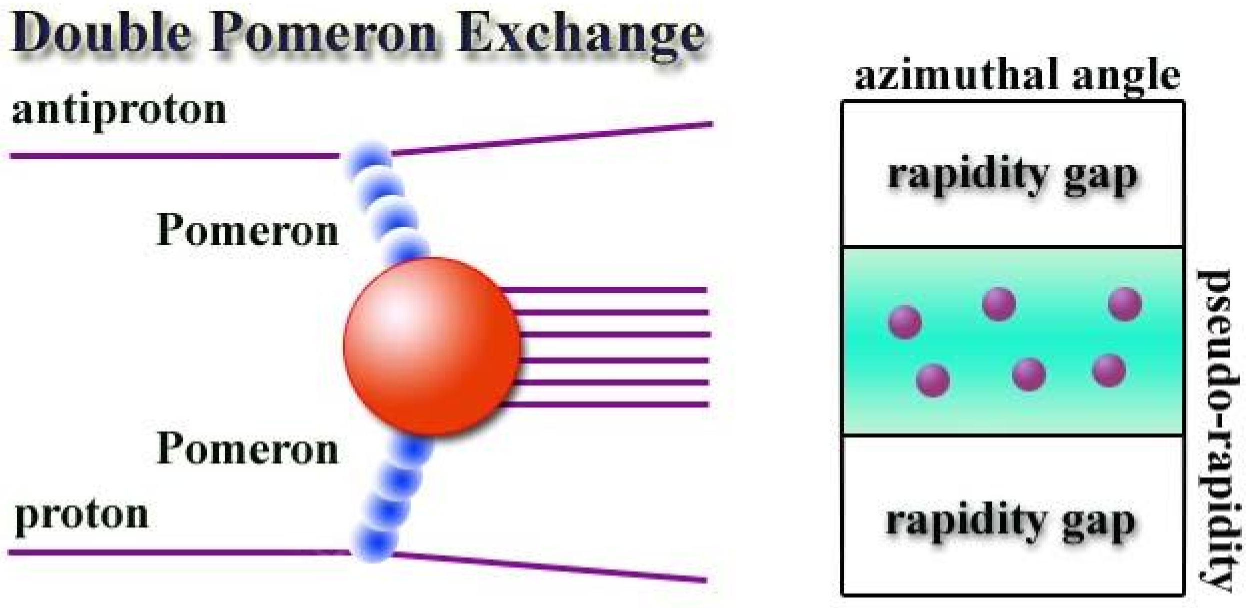
Motivation

1)
Pomeron: Strongly interacting color singlet exchange
Carrier of 4-momentum (t-channel) in elastic scattering
and other diffractive – large rapidity gap – interactions

Non-perturbative QCD: models required for calculations
At leading order gluon pair {gg} in color singlet
Vacuum quantum numbers I PC = 0 ++ and even spin J
s-channel continuation would be a glueball {gg}

Introduction

2)
Double Pomeron Exchange (DPE) : P + P -> X
Excellent channel for meson spectroscopy $I^G J^{PC} = 0^+ \text{ even}^{++}$
Especially for scalar and tensor (J=2) glueballs
Uniquely produced in isolation (or an isolated pair)



Introduction

Established light (i.e. excluding charm and beauty) meson states in Particle Data Group (PDG)
Summary table allowed in DIPE. (Branching fractions are in % - PDG 2010)

Name	M(MeV/c^2)	Γ(MeV)	$I^G J^{PC}$	$\pi\pi$	$K\bar{K}$	Other modes
$f_0(600)/\sigma$	400-1200	600-1000	0^+0^{++}	$\sim$100	-	-
$f_0(980)$	980$\pm$10	40-100	0^+0^{++}	dominant	seen	-
$f_2(1270)$	1275.1$\pm$1.2	185$\pm$3	0^+2^{++}	$84.8^{+2.4}_{-1.2}$	4.6 $\pm$ 0.4	$2\pi^+2\pi^-$ 2.8%
$f_0(1370)$	1200-1500	150-250	0^+0^{++}	seen	seen	$\rho\rho$ dominant
$f_0(1500)$	1505$\pm$6	109$\pm$7	0^+0^{++}	34.9$\pm$2.3	8.6$\pm$1.0	4π 49.5$\pm$3.3
$f_2'(1525)$	1525$\pm$5	76$\pm$10	0^+2^{++}	0.8$\pm$0.2	88.7$\pm$2.2	$\eta\eta$ 10.4$\pm$2.2
$f_0(1710)$	1720$\pm$6	135$\pm$8	0^+0^{++}	seen	seen	$\eta\eta$ seen
$f_2(1950)$	1944$\pm$12	472$\pm$18	0^+2^{++}	seen	seen	$\eta\eta$ seen
$f_2(2010)$	2011$\pm\sim$ 70	202$\pm\sim$ 70	0^+2^{++}	-	seen	$\phi\phi$ seen
$f_2(2300)$	2297$\pm$28	149$\pm$41	0^+2^{++}	-	seen	$\phi\phi$ seen
$f_2(2340)$	2339$\pm$55	319^{+81}_{-69}	0^+2^{++}	-	-	$\phi\phi$ seen
$f_6(2510)$	2465$\pm$50	255$\pm$ 40	0^+6^{++}	6.0$\pm$1.0	-	

Introduction

The only low-mass central hadron DPE data from the Tevatron collider is the CDF paper [*] on central $\pi^+ \pi^-$.

With this study we are improving hadron identification, to extract the $K^+ K^-$ and $p^+ p^-$.

Only 67% of all pairs have both particles identified by Time of Flight (ToF) as π, K, or p, mainly because of the limited |η|-coverage of the TOF detectors, and for these (89 ± 1)% are $\pi^+ \pi^-$.

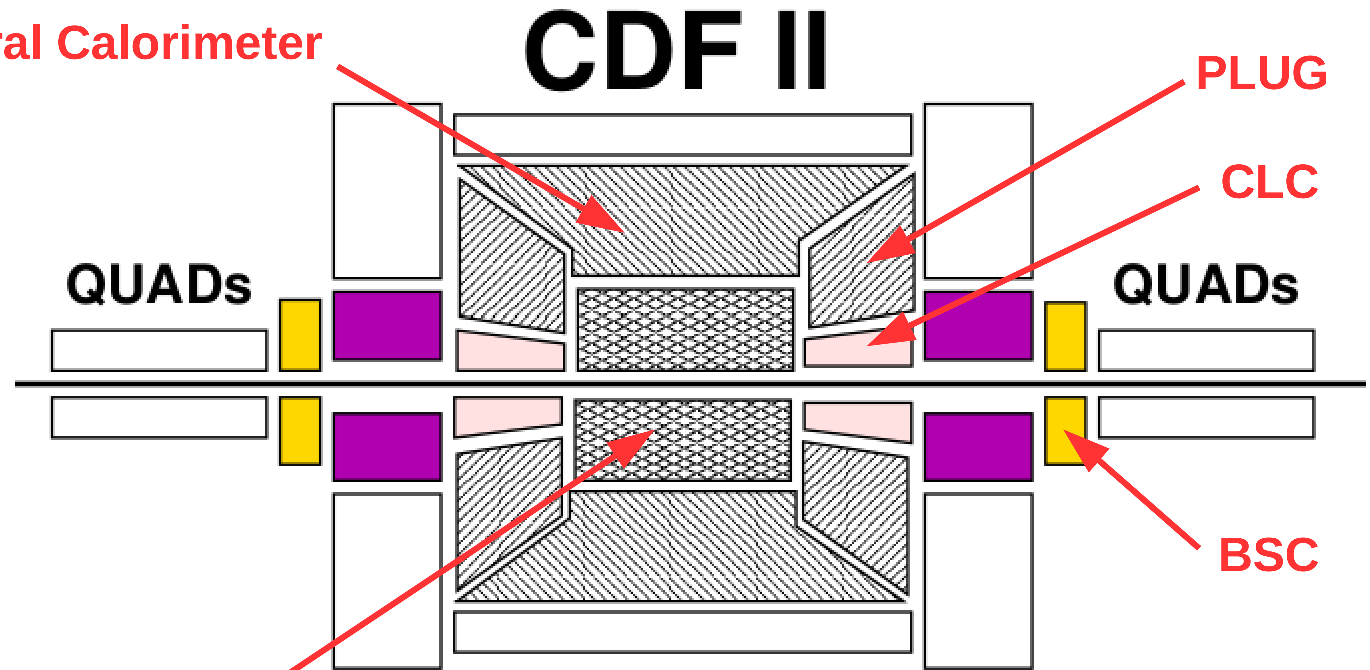
In this analysis we focus on improving the π/K/p identification using primarily the ToF (with only two tracks there are fewer constraints than in a high-multiplicity event) and with ionization dE/dx as a tool to check it, especially in the lower momentum region.

[*] T.Aaltonen et al. (CDF), Phys.Rev. D 91, 091101 (2015).

CDF DETECTORS Trigger and Data set

√s = 1960 GeV p-pbar
& √s = 900 GeV
(special run for these studies)

We are blind to |η| > 5.9 (the BSC-1 limit),
and accept events where the proton was quasi-elastically scattered or where it dissociated into a low mass state.



Level 1 Trigger:
2 Calo towers |η| < 1.3 with E_T > 0.5 GeV
& all these in VETO :
BSC = Beam Shower Counters |η| = 5.4 - 5.9
CLC = Cherenkov Lumi Counters |η| = 3.75-4.75
Plug Calorimeter |η| = 2.11 – 3.64

CDF DETECTORS Trigger and Data set

For the results in this study we used all the CDF detectors except the silicon trackers.

The muon chambers are used only to reject muon stubs.

We select events with exactly 2 COT tracks, with $\Sigma Q = 0$.

We want to select events with no other hadrons produced, and we will require no other charged tracks and that all the calorimetry (except around the impact points of the charged particles), the BSC-1 counters, and the CLC to have no signals above the noise levels.

Central region exclusivity

We only use events with no pile-up, where the full CDF detector with $-5.9 < \eta < +5.9$ is empty (noise levels) except for two charged tracks measured in the central tracker.

The trigger was activated when the mean pile-up was low (data mostly at end of stores).

Off-line select exactly two tracks on a common vertex.
The tracks are extrapolated to the calorimeters, and allowing for any energy in a cone of radius R = 0.3 (excluding cone)

$$R = \sqrt{\Delta\phi^2 + \Delta\eta^2}$$

Exclusive selection

To understand the noise levels in all the detectors (exclusivity cuts) we use *zero bias* (bunch crossing) triggers, taken during the same periods.

We divided the 0-bias data into two classes:

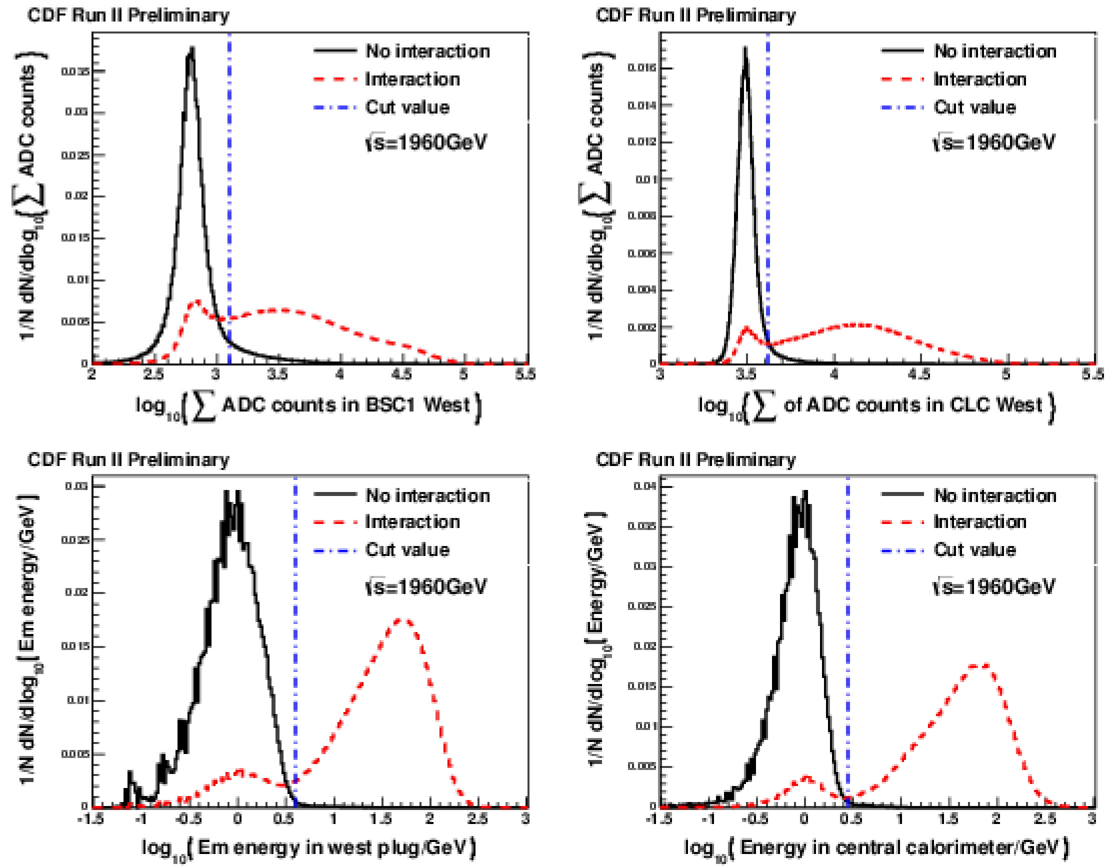
A)“No Interaction”, defined as no tracks, no CLC hits, no muon stubs

B)“Interaction” = All other events

For each subdetector we compare the signals in the two classes, with (A) dominated by noise, using plot distributions of A and B for ΣE, ΣADC counts, hottest PMT all required to be less than a cut.

Exclusive selection

Interaction / non-interaction samples : examples of signals in BSC-W , CLC-W, EM energy in Plug-W, Energy in Central Calorimeter. All are required to be below cut (blue line). (*CDF public note 11034*)



Two exclusive tracks: track quality cuts

We define the central region (i.e. region for reconstructed tracks) to be in $|\eta| < 1.3$ where the trigger was active.

An opening angle cut eliminate the small background from cosmic ray tracks with $\theta_{3D} = \pi$. Cut at 3.1 $\Delta\varphi$.

To have a well-defined fiducial region and avoid rapidly changing thresholds we require both tracks to have P_T (track) > 0.4 GeV/c.

Additionally to be able to calculate the proper acceptance, we require that extrapolated tracks match two of the trigger towers with ±1 tower tolerance in η and ϕ, and the rapidity of the two-track state to be $|y(\pi^+\pi^-)| < 1$.

Two exclusive tracks: track quality cuts

The track quality cuts consists of:

- Impact parameter to the nominal beam line cut, $d_0 < 0.1$ mm
- The two-track difference in z projected to the beam line $|dz_0| < 1.0$ cm
- The number of COT hits in axial layers >= 25
- The number of COT hits in stereo layers >= 25
- χ^2/DoF < 2.5

Two exclusive tracks: track quality cuts

Numbers of 2-track events after sequential requirements.
(*CDF public note 11034*)

$\sqrt{s}$ =	1960 GeV	900 GeV
Triggered events	90230×10^3	21737×10^3
After Forward exclusivity cuts	59538×10^3	18749×10^3
Exactly 2 tracks	4721×10^3	271×10^3
Quality, exclusivity, cosmic rejection	137128	6646
Opposite sign	127340	6240

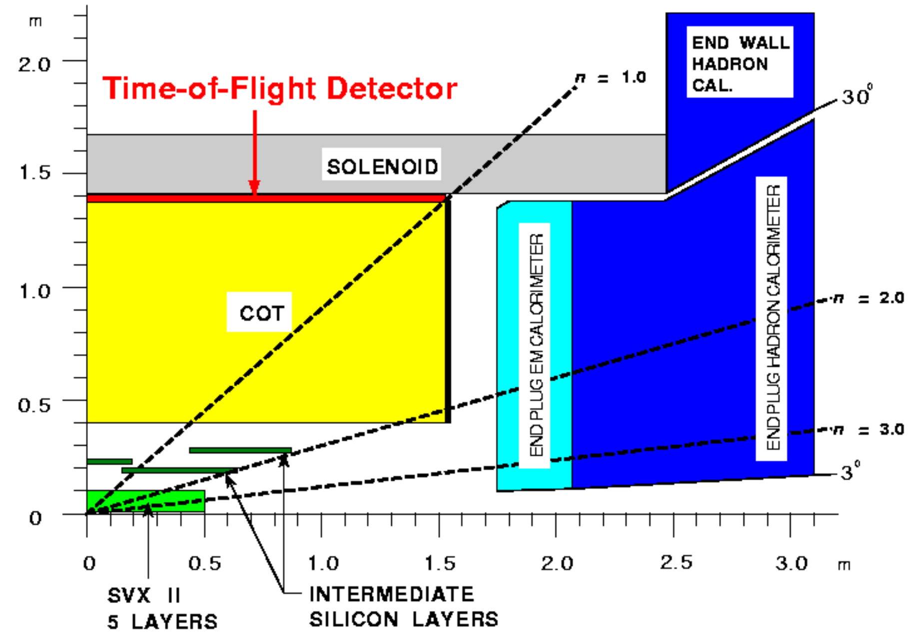
Identification of hadron-pairs using Time-of-Flight

We use standard "out-of-the-box" values for M^2_{tof}.

Due to the resolution of the time measurement a track can have ct < L (apparently superluminal) so it is M^2_{tof} that is calculated, using:

$$M^2_{tof} = \left(\frac{p}{c}\right)^2 \left(\frac{c^2.t^2}{L^2} - 1\right)$$

where L is the track path length, p is its momentum, and t is the flight time.



Identification of hadron-pairs using Time-of-Flight

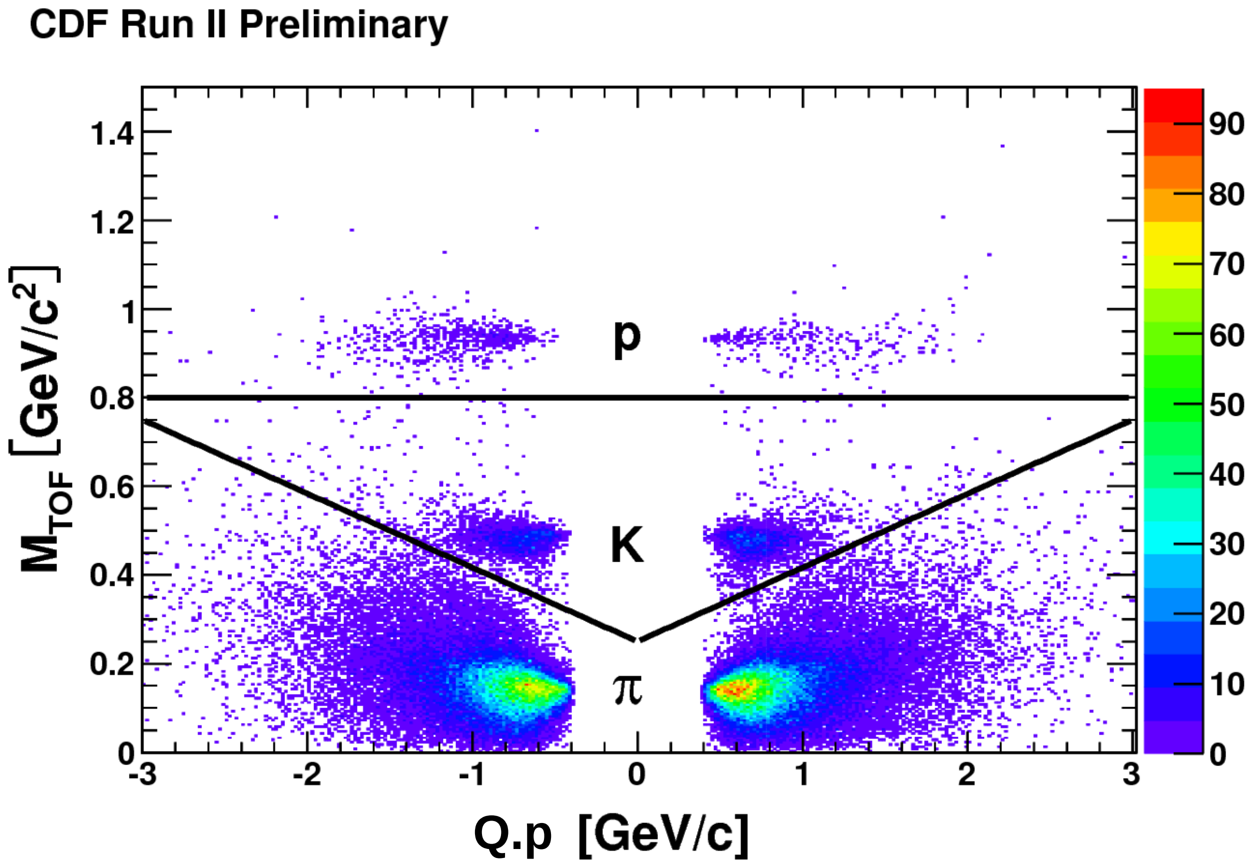
Mass calculated using Time of Flight as a function of particle momentum.

Only +ve values of M^2_{tof} shown.

Visible bands correspond to pions, kaons and protons respectively.

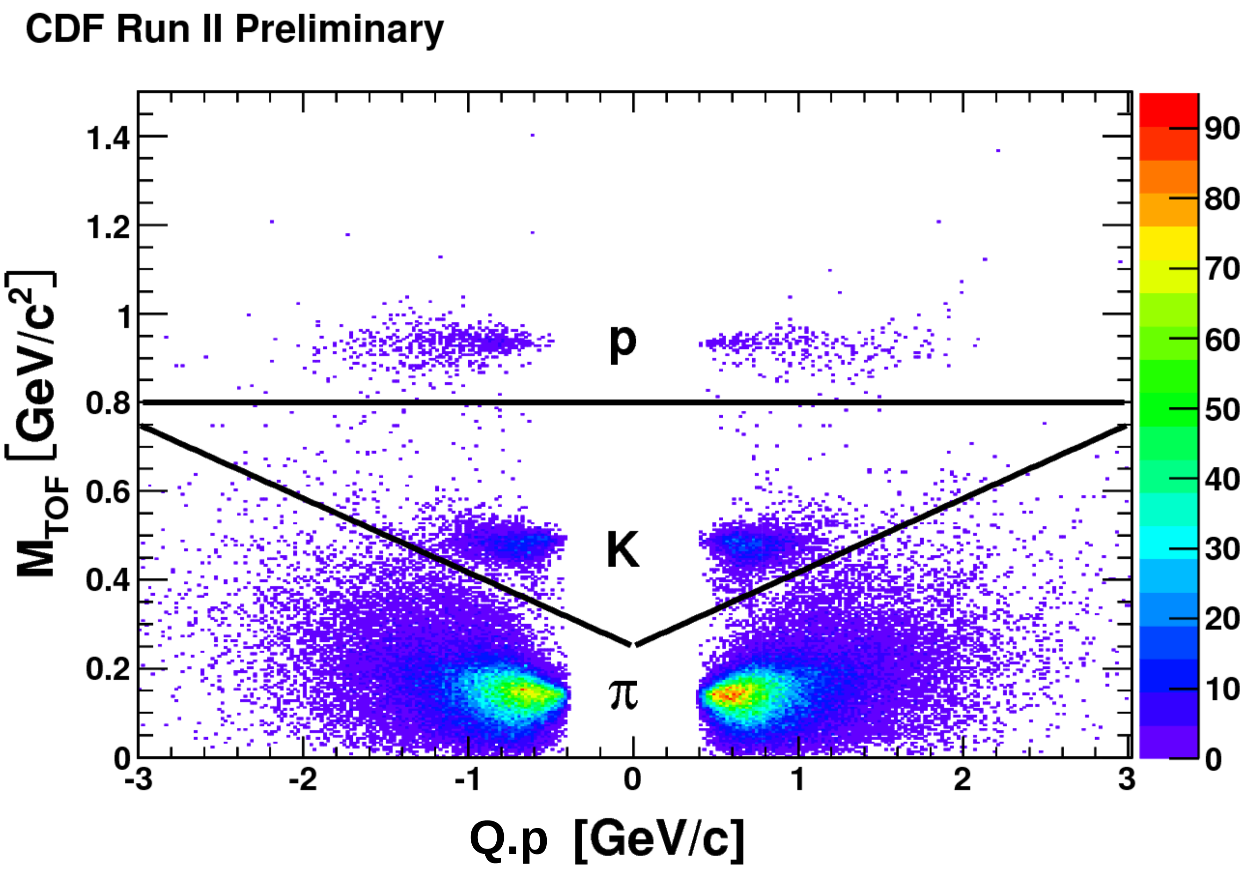
Negative momenta correspond to negatively charged particles.

(*CDF public note 11034*)



Identification of hadron-pairs using Time-of-Flight

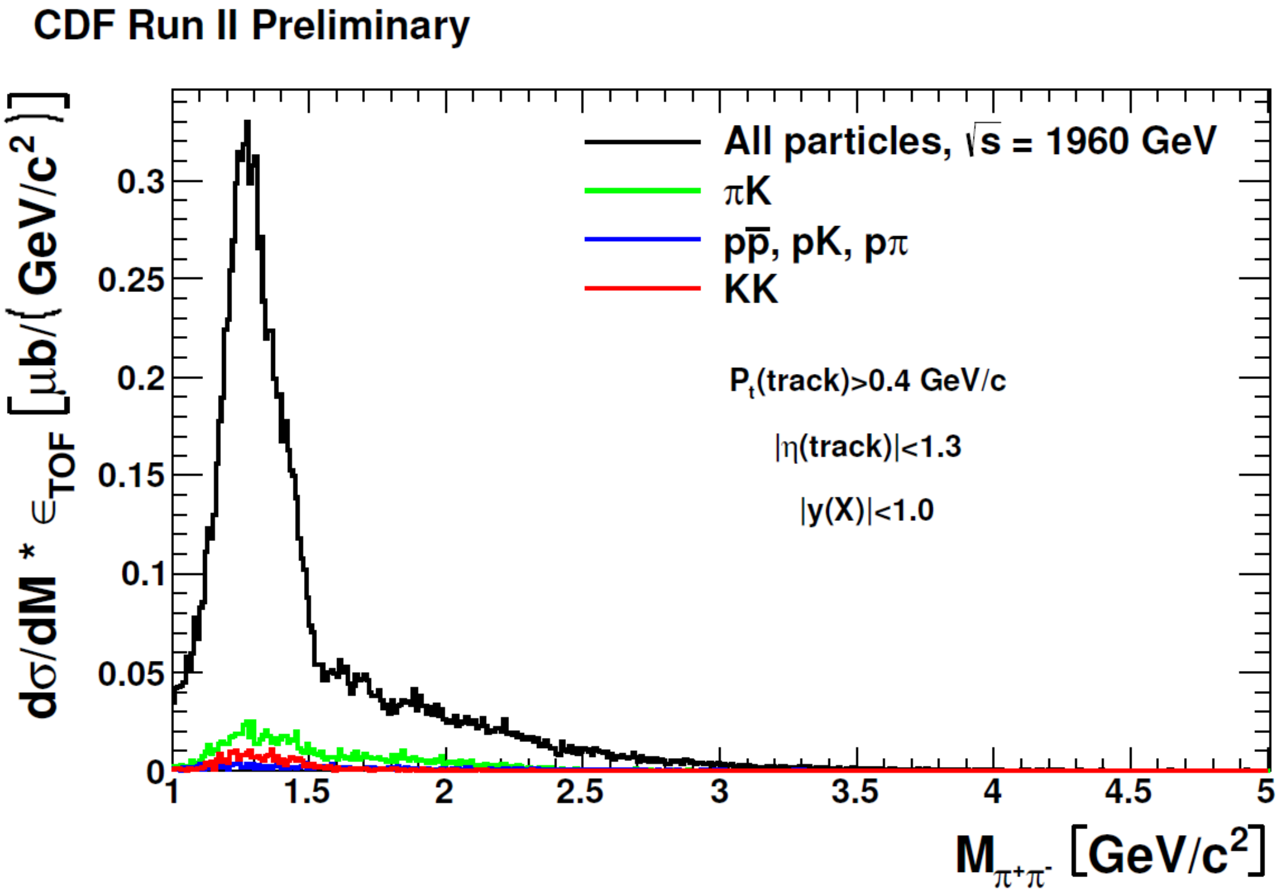
The momentum-dependent cut is empirical, to avoid the dominant pions feeding into the kaon band at high momentum, where the mass resolution is poor.



Identification of hadron-pairs using Time-of-Flight

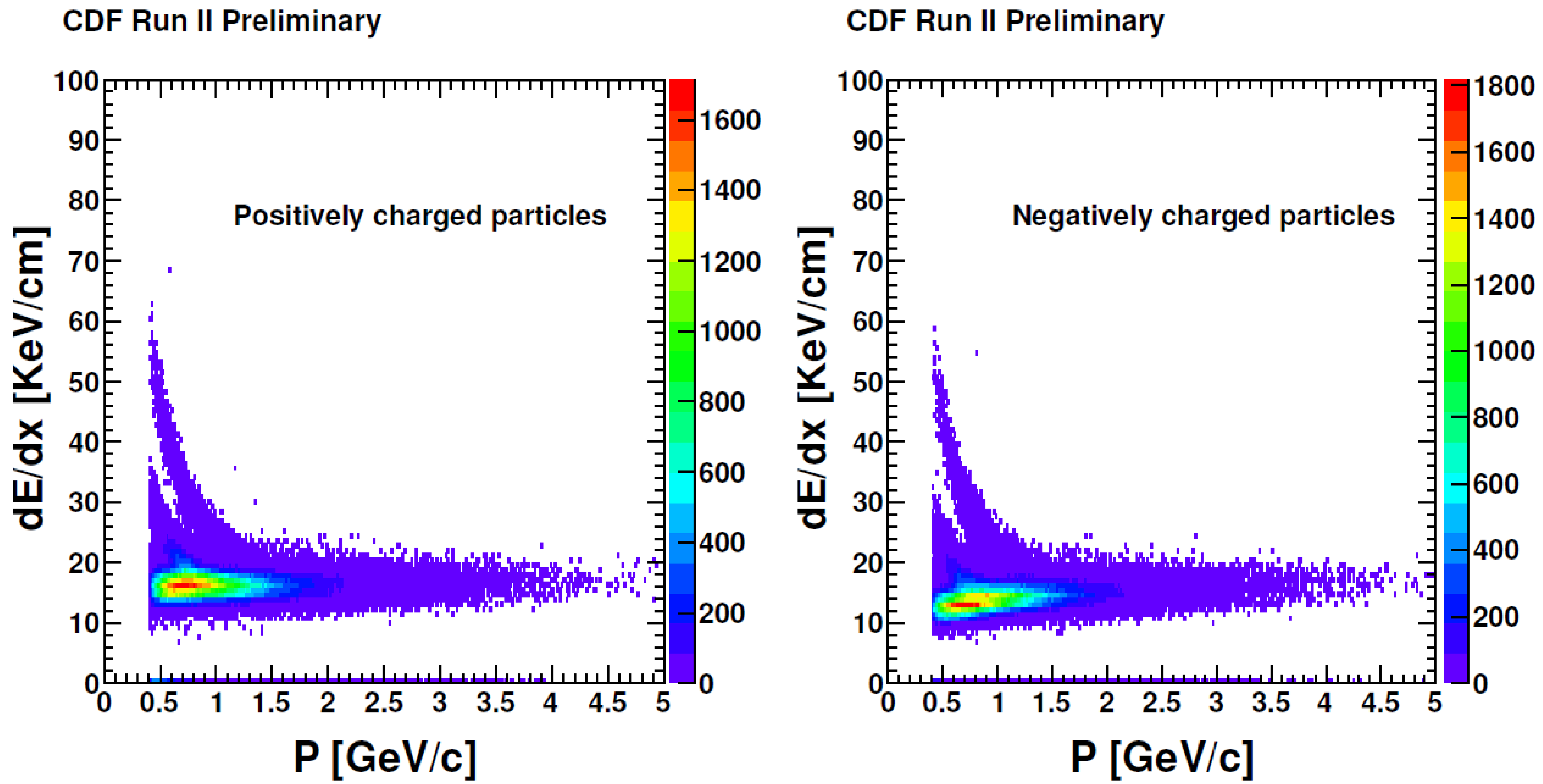
Invariant mass distribution for all selected particles assuming pions masses with contributions coming from non-background identified with TOF method. (*CDF public note 11034*)

~89% are identified as $\pi^+\pi^-$



Identification of hadron-pairs using the ionization of the COT tracks (dE/dx)

dE/dx versus track momentum for positively and negatively charged particles.
<u>Only useful for p < about 0.8 GeV/c</u>.



Summary and Conclusions

We are analysing a large sample of (semi-)exclusive h^+h^- events at $\sqrt{s}$ = 1960 GeV.

In the extracted data sample (89 ± 1)% are $\pi^+ \pi^-$ (published).

We study and improve the time-of-flight identification and check it with dE/dx in particular to investigate K^+K^- pairs.

The tracks with momenta less than 1 GeV/c are well identified.

Some K-π and p-π events (background) being studied.