Preliminary Results from MiniMax

- Introduction
- Physics of DCCs
- Description of the Apparatus
- Backgrounds, Triggers and Rates
- Data Analysis
- Conclusions & Outlook

DPF August 96

URL=http://fnmine.fnal.gov/

Jon Streets, for the MiniMax Collaboration...

MiniMax Collaboration

Case Western Reserve University

T.C.Brooks, M.E.Convery, W.L.Davis, K.W.Delsignore[a], T.L.Jenkins, E.Kangas, M.G.Knepley, K.L.Kowalski, **C.C.Taylor**[b]

Duke University

S.H.Oh, W.D.Walker

Fermi National Accelerator Laboratory

P.L.Colestock, B.Hanna, M.Martens, J.Streets

University of Michigan

R.Ball, H.R.Gustafson, L.W.Jones, M.J.Longo

Stanford Linear Accelerator Center

J.D.Bjorken[b]

Virginia Polytechnic Institute

A.Abashian, N.Morgan

Wayne State University

C.A.Pruneau

a. Now at University of Michigan

b. Co-Spokesperson

Introduction

Pre-History

- 1991-1992 FAD initiative at the SSC
- Sept. 1992 - March 1993 - MAX proposal at Fermilab
- April 1993 - 1996 MiniMax

Goals

- Far-Forward Collider Experimentation to look at Multiparticle Production
- Search for Cosmic-Ray Anomalies (Centauro, Anti-Centauro - JACEE)
- Search for Disoriented Chiral Condensate (DCC)

Physics - What is a DCC?

Disoriented Chiral Condensates are used to explain some high multiplicity events seen in Cosmic Ray experiments. These events have anomalous values of

$$f = \frac{N_{\pi^0}}{N_{\pi^0} + N_{\pi^{ch}}}$$

and low relative p_T (*a.k.a.* Chiron Behavior).

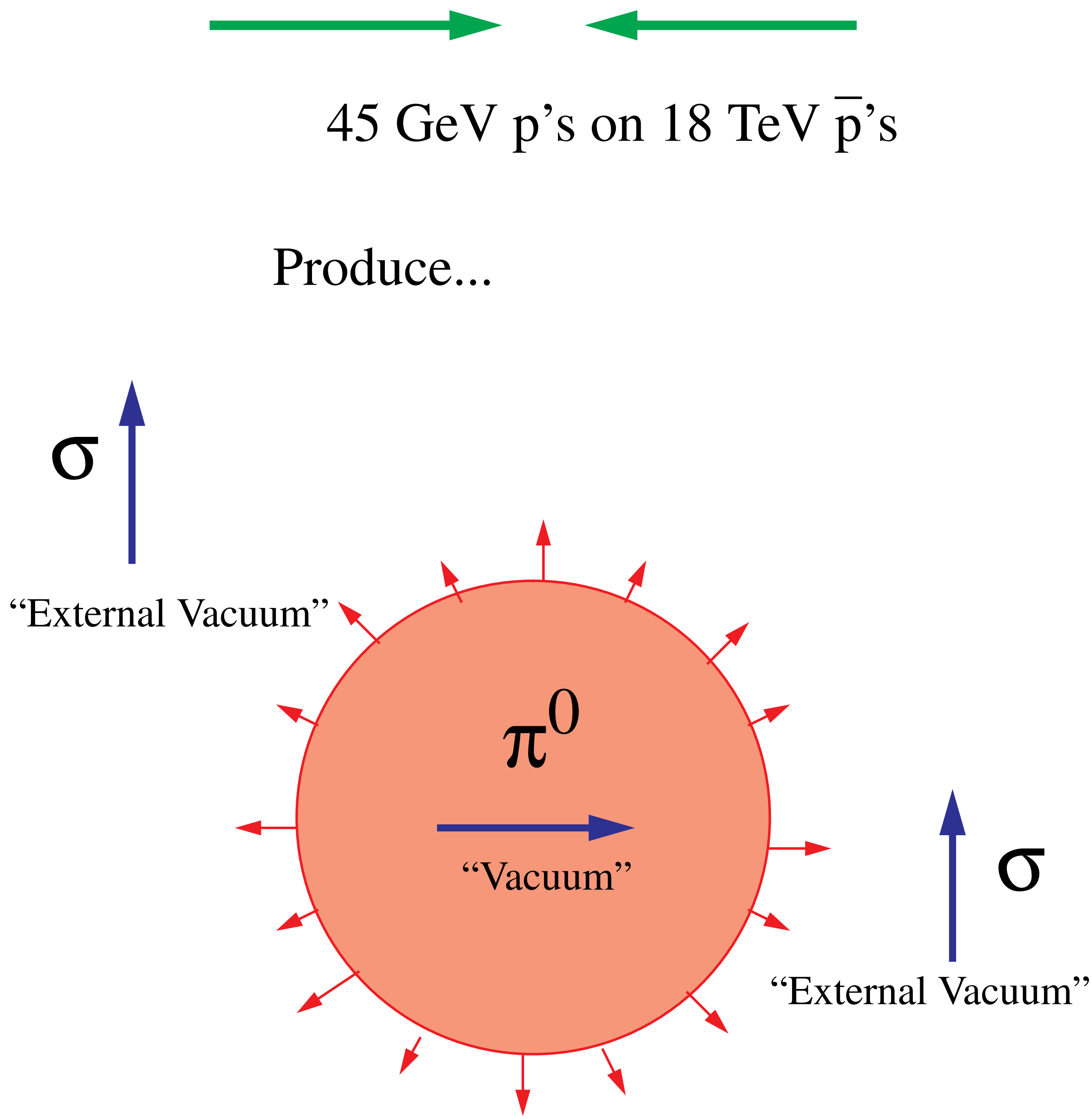
DCCs are produced in collisions where the debris expand a few fermi before hadronising.

The relatively cold interior of the collision region is a strong-interaction vacuum.

It is almost degenerate due to the approximate $SU(2)_L \times SU(2)_R$ chiral symmetry, and described by the $(\sigma,\underline{\pi})$ model, where $\underline{\pi}=(\pi^+,\pi^-,\pi^0)$.

The orientation of the σ field defines the pionic content of the condensate, and affects the coherent hadronisation of the hot exterior.

DCC from the Strong-Interaction Vacuum



Disoriented Chiral Condensate within an Expanding Hot Shell which Evolves into a Coherent Pulse of Pions.

Generic (Binomial) distribution

In the generic model, we assume equal probabilities for production of π^+, π^- and π^0's. This leads to a probability P[n,N] of n π^0's from N π's:

$$P[n, N] = \left(\frac{1}{3}\right)^n \left(\frac{2}{3}\right)^{(N-n)} \frac{N!}{n!\,(N-n)}$$

where

$$n = N_{\pi^0}, N = N_{\pi^0} + N_{\pi^+} + N_{\pi^-}$$

and

$$\langle f \rangle = \frac{1}{3}$$

DCC distribution

The Probability distribution for n π^0's from N particles can be shown to be:

$$P[n, N] = \left(\frac{2^N N!}{2^n n!}\right)^2 \frac{(2n)!}{(2N+1)}$$

which leads to

$$P(f)\,df = \frac{1}{(2\sqrt{f})}\,df$$

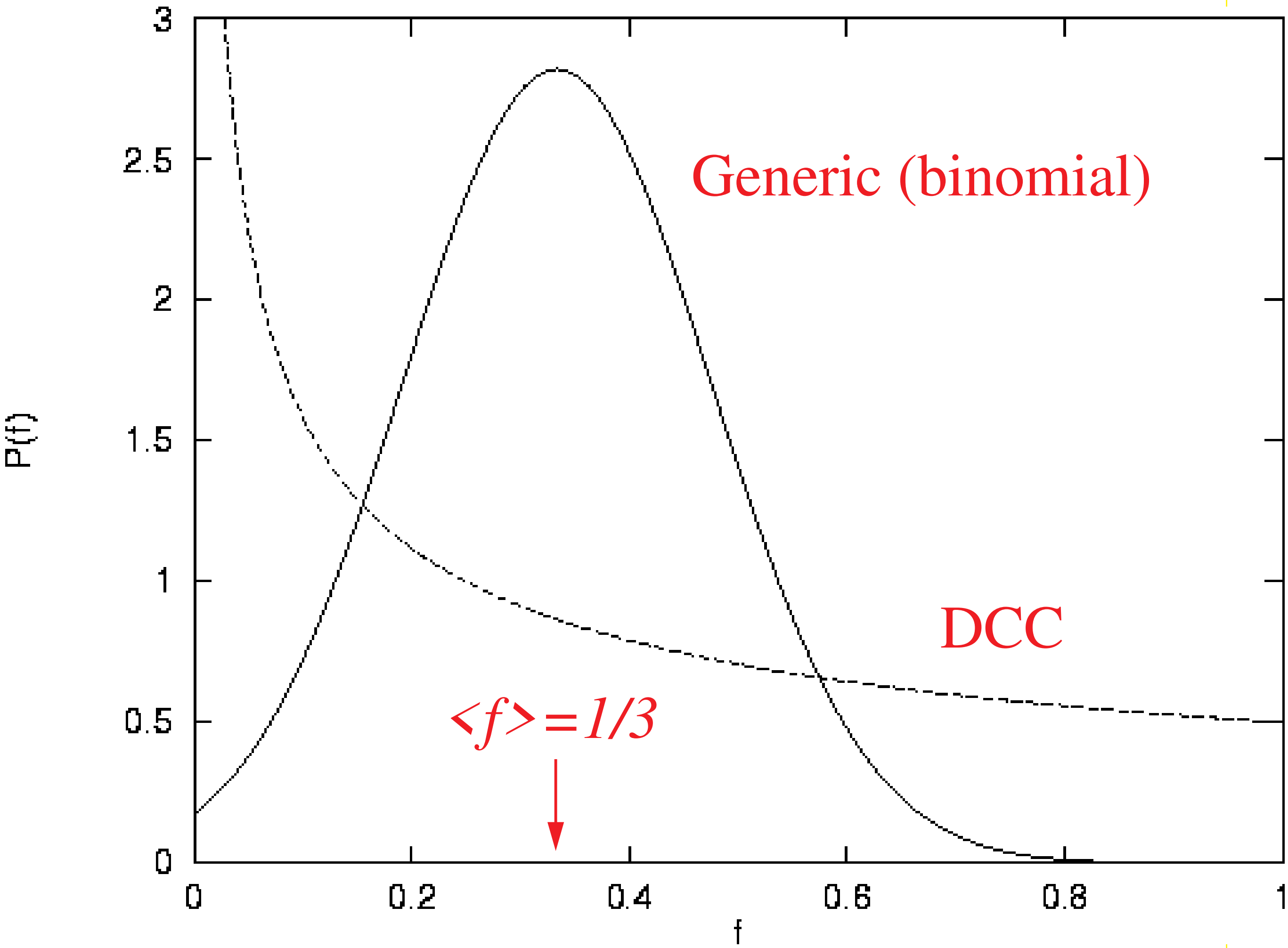
and again

$$\langle f \rangle = \frac{1}{3}$$

This probability distribution gives higher values for f=0 and f=1 than the generic case.

Comparison of the generic and DCC distributions

$$f = \frac{N_{\pi^0}}{N_{\pi^0} + N_{\pi^{ch}}}$$



Cosmic Ray Evidence

Centauro Events

- $n_{ch} \sim 100$
- $n_\gamma \sim 0$
- CMS Energies ~ 1 *TeV*
- Seen in forward direction ($\eta \sim 3.5$ to 4.5)
- Relative p_T of secondaries is low (Chiron Behavior)
- Possibly Diffractive

Anti-Centauro Event(s)

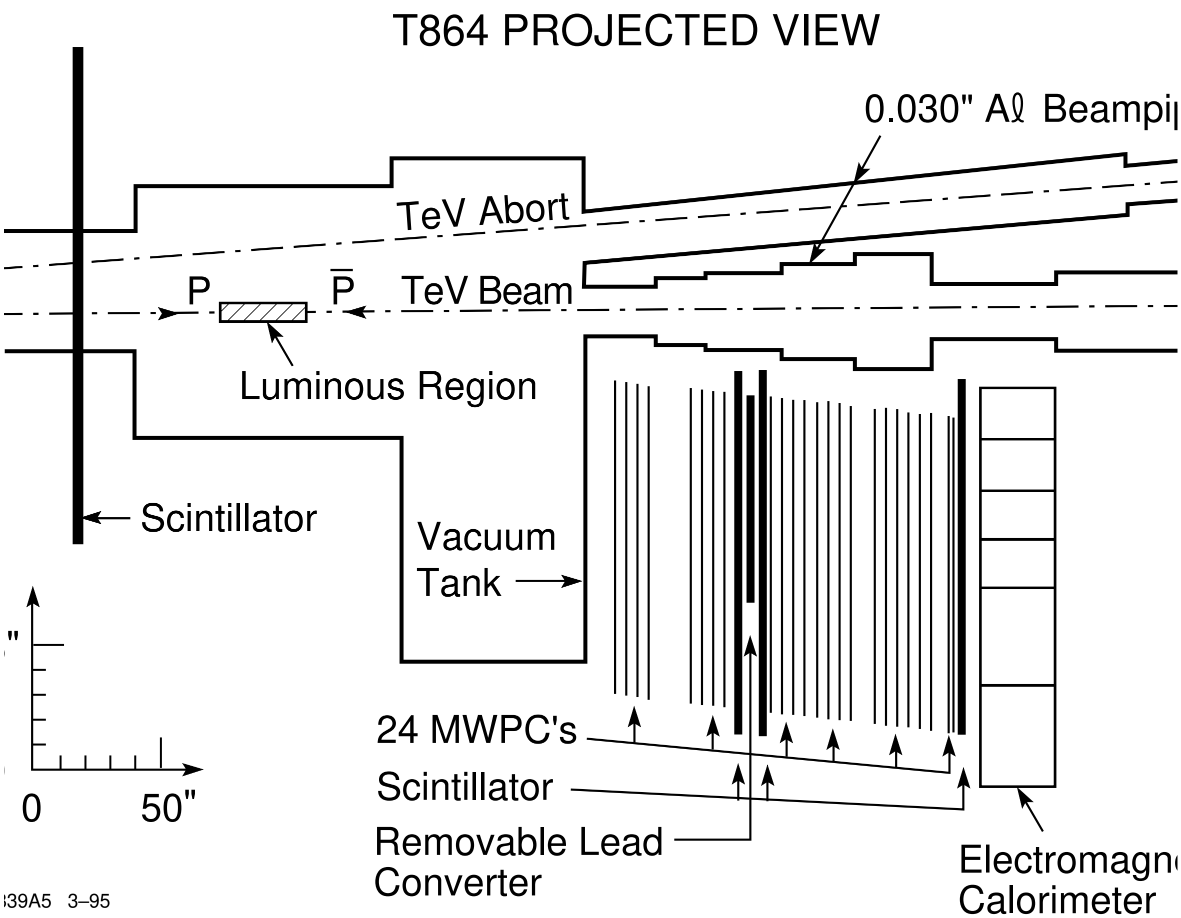
- $n_{ch} \sim 18$
- $n_\gamma \sim 60$
- CMS Energy > 200 *GeV*
- Chiron Behavior

Is there evidence at the Tevatron, in a rest frame with 45 *GeV* p's on 18 TeV $\overline{\text{p}}$'s?

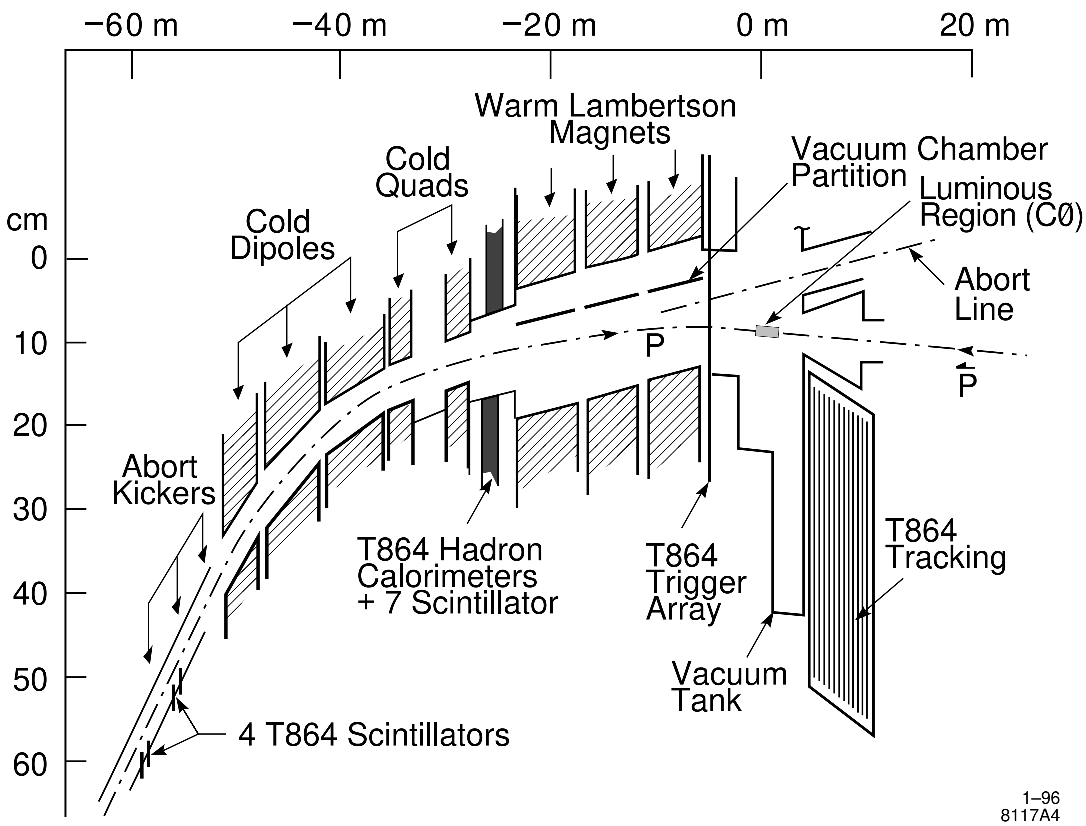
Description of the Apparatus

- Located at the C0 interaction region of the Tevatron.
- Run parasitically to E811 and $\bar{p}$ production (with beam separators switched off at C0 and E0).
- Acceptance - (η,ϕ) radius of 0.65 at η=4.1
- 24 MWPC, each have 128 wires with 0.1" spacing. 5-30% occupancy per wire, > 95% efficiency.
- Movable Lead and Iron Converters after 8th MWPC (X_0 = 0.5, 1, 2)
- Pb-Scintillator EM calorimetry behind chambers, and Pb-Scint. Fibre EM CAL 25m upstream.
- Trigger scintillators inside MWPC telescope & upstream, and far upstream.
- DAQ - CAMAC (50% Michigan ADCs, 50% Nanometric Latches) read via VAX 3200.

Apparatus Layout



Interaction Region



Backgrounds, Triggers and Rates

- Triggered on upstream $\bar{p}$ counter in coincidence with telescope counter.
- Beam gas (with separators on) give 5-20 *Hz*
- With separators off, see 300 *Hz*, at $1 \times 10^{30} cm^{-2} sec^{-1}$
- Measure 35-40 *mb* of total cross-section σ_{pp}=50 *mb*
- High trigger efficiency due to showers from beam-pipe, floor, *etc*.

Upstream tagging

- Calorimeter placed at 25*m* - accept $\bar{p}$'s with $x_F = 0.5 \pm 0.1$. Very little change in tracking data.
- Scintillator at 60*m* - accept $\bar{p}$'s with $x_F = 0.87 \pm 0.05$. See change in $\bar{p}$ trigger scintillator multiplicity distribution.

Data Analysis

Method used to detect DCC contribution in data sample.

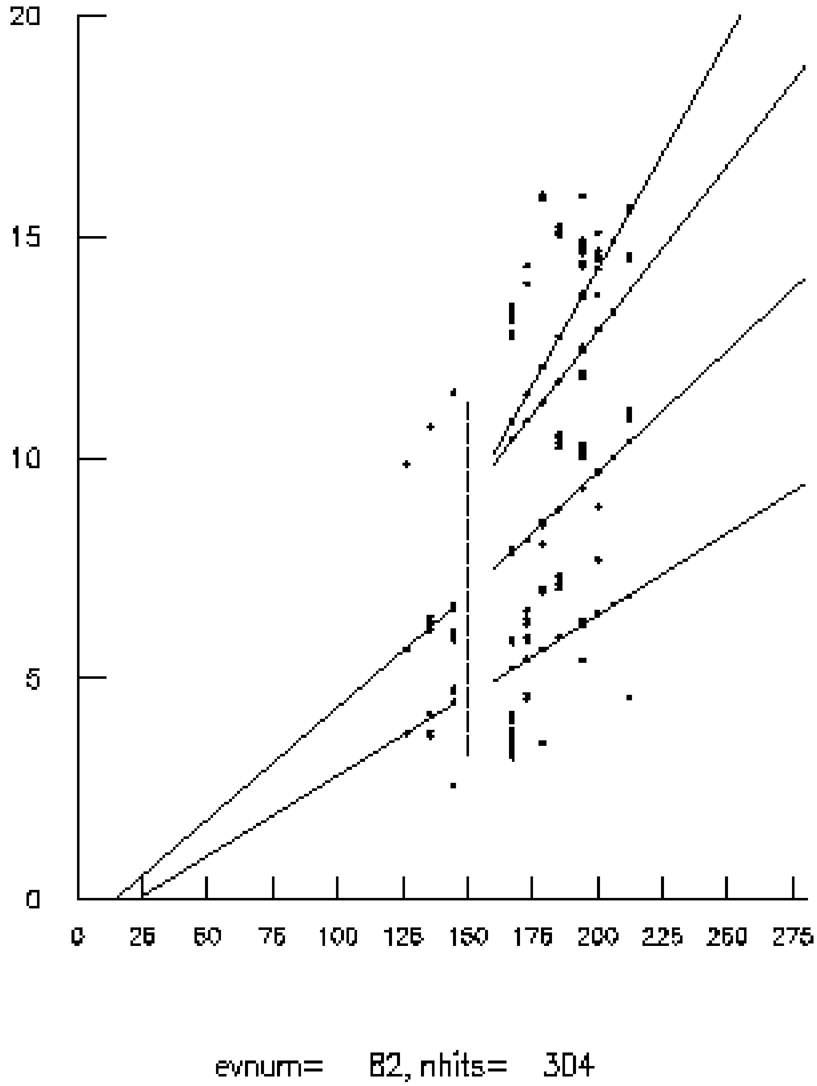
- Measure tracks in front (charged tracks) and behind converter (charged tracks and conversions from π^0's), as a functions of Pb thickness.
- Compare numbers of tracks seen with GEANT simulations of generic (PYTHIA) and DCC generators.

Problems

- Small acceptance for both γ's from π^0
- Conversion efficiency in Pb is 50% per γ
- Not all observed tracks come from π^+ and π^-'s
- Momentum & multiplicity dependence of charged and neutral detection

Preliminary Results from MiniMax

Typical Event



Cancelling the Systematics

We measure the numbers of charged tracks, and use a vertex algorithm at the plane of the Pb converter to measure the number of γ's assumed to come from π^0's.

We find reasonable shapes of

$$\frac{dN}{d\eta} and \frac{dN}{d\phi}$$

and normalizations consistent with extrapolations from UA5 and CDF.

Just a MiniMax moment

Consider the generating function $G(z_{ch},z_0)$, which is the product of the probability that a hadron will fragment and the fraction z of the hadrons momentum:

$$G(z_{ch}, z_0) = \sum_{N_{ch}, N_0}^{\infty} z_{ch}^{N_{ch}} z_0^{N_0} P(N_{ch}, N_0)$$

It can be shown that the Factorial Moments

$$F_{mn} = (m,n)^{th} \text{ Derivative of } G(z_{ch},z_{\gamma})$$

$$\text{at } z_{ch} = z_0 = 1$$

are independent of the fragmentation model if the following track detection efficiencies are uncorrelated:

- ε_{ch} = Probability of observing a charged pion track
- $\varepsilon_0,\varepsilon_1,\varepsilon_2$ = Probability of seeing 0, 1 or 2 γ's from a decaying π^0.

More MiniMax Moments

These moments are calculated to be quantities which we can extract directly from the data:

- $F_{10} = \langle N_{ch} \rangle$
- $F_{01} = \langle N_{\gamma} \rangle$
- $F_{11} = \langle N_{ch} N_{\gamma} \rangle$
- $F_{20} = \langle N_{ch}(N_{ch}-1) \rangle$
- $F_{30} = \langle N_{ch}(N_{ch}-1)(N_{ch}-2) \rangle$
- $F_{21} = \langle N_{ch}(N_{ch}-1)N_{\gamma} \rangle$

Ratios of these moments are independent of Efficiency corrections and different for Generic and DCC fragmentations.

$$r_{11} = \frac{F_{11}F_{10}}{F_{20}F_{01}} = 1\,(Generic),\ \frac{1}{2}\,(DCC)$$

$$r_{21} = \frac{F_{21}F_{10}}{F_{30}F_{01}} = 1\,(Generic),\ \frac{1}{3}\,(DCC)$$

Preliminary Results from MiniMax

Values of r_{ij}, Statistical Errors only.

r_{ij}	PYTHIA and GEANT	pure DCC	DCC and GEANT	Data
r_{11}	1.01±.02	0.500	0.56±.01	0.98±.01
r_{21}	1.02±.05	0.333	0.40±.03	0.99±.02
r_{31}	1.09±.14	0.250	0.34±.05	1.03±.04
r_{02}	1.38±.04		1.60±.06	1.52±.01
r_{12}	1.41±.10		0.66±.06	1.42±.03
r_{22}	1.58±.31		0.41±.08	1.41±.08
r_{03}	2.24±.26		3.16±.42	3.09±.11
r_{13}	2.21±.50		1.08±.25	2.65±.19

Also checked

- No significant Run to Run dependence
- No significant Dependence on Converter Thickness or composition
- Data consistent with x_F=0.9 trigger

Results - Summary

- Data is consistent with Generic (Binomial) Production Mechanisms
- Dependence of r_{ij} on Systematic Effects $\leq 5\%$
- Sensitivity to DCC Admixture is at 10-20% level (model dependent)

Work in Progress !

MM

Conclusions and Outlook

- Data Quality is good
- No evidence for DCC as Yet (though not ruled out at 1% level)
- Need better understanding of photon finding
- Factorial-Moment Method a MiniMax Moment looks promising

To Be Done

- Integrate Calorimetry and Tracking
- VEE's, to measure spectra of $K^0{}_S$ and Λ's
- Correlation Studies; Intermittency
- Effect of Upstream Tags

Long Range Plans

- C0 may have a future with far forward physics
- New Initiative for LHC: FELIX (Forward ELastic and Inelastic eXperiment).