Simulation of Parity Violating Effect in RHIC Collisions

Goal

find a method of simulating the effect of phenomena like those suggested in PRL 81, 512 (1998) n collisions which may be observed at RHIC.

why?

1) To find "best" methods of analyzing the events for the purpose of tablishing a P (CP) violation or of setting a physically meaningfull limit

2) To have a method of estimating the effects of various "experimental realities" on the measurement. We must understand how the real effect would show up to understand how errors can fake a real effect

Goals (cont'd)

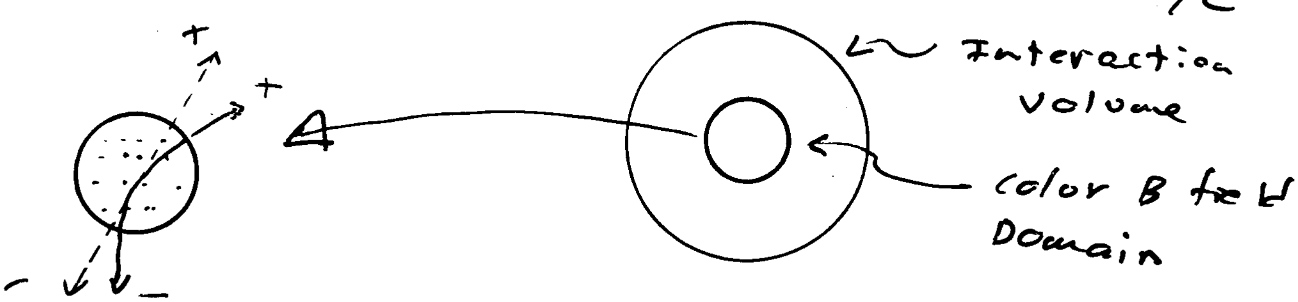
3) To estimate the limits of the experimental search for these effects in the "first year" of data at RHIC.

Basic Approach

The theory of Kharzeev et al. suggests that in a given event a domain of non zero $(\vec{E} \cdot \vec{B})_{Chromo}$ may exist.

The chromo magnetic field will deflect +, − color charges oppositely. The magnitude of the color magnetic field and the size of the domain are "estimated" by the theory.

A "reasonable" size is $r \sim 2$ fm and "B" such that maximum momentum kick is ~ 30 MeV/c



Our Simulation

1) we simulate the effect by placing a domain (later maybe several) with an electromagnetic field $\vec{B}$.

$\vec{B}$ orientation at random
(in each domain - same direction in a given domain

$|\vec{B}|$ adjusted so that $|q| = e$ charge gets a maximum Transverse deflection of
30 MeV/c.

In future studies we can (will) vary:

- Size of domain
- strength of deflection
- Number of domains

2) We choose the overall interaction volume to be a sphere of Radius R
domain radius r, centered.

3) We assume particles are produced uniformly throughout interaction Volume with η, p_T predicted by HIJING.

1 we assume that particles are produced (born) originally with no particle- particle corelation

i.e. Prob. of + part. at $\theta_+ = G_+(\theta_+)$

prob. of − part. at $\theta_- = G_-(\theta_-)$

prob. of a + at θ_+ and a − at θ_-

$$P(\theta_+, \theta_-) = G_+(\theta_+) G_-(\theta_-)$$

To date we have also assumed

$$G_+(x) = G_-(x) = G(x)$$

This is pretty nearly true for pions which are the dominant species

A Subtlety

We tested the method in a very simplified case

$R = 2\,\text{fm}$

max. Detl. $= 30$ MeV/c

$\vec{B}$ always in same orient. $\vec{B} = B_0 \hat{x}$

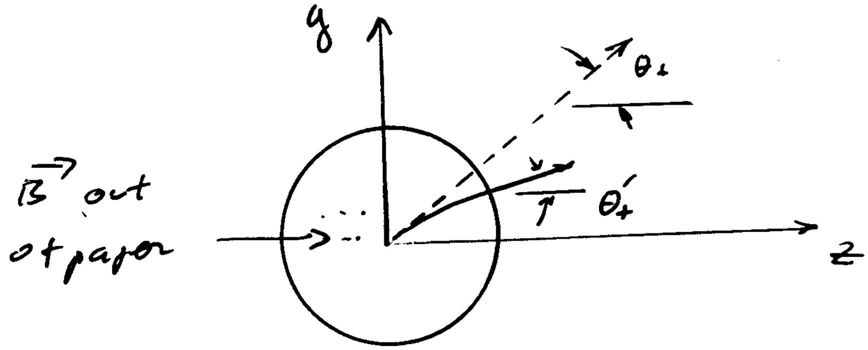
Saw NO Effect!! i.e $\sum_{\text{pairs}} \frac{\vec{P}_+ \times \vec{P}_-}{|\vec{P}_+||\vec{P}_-|} \hat{\lambda} = 0$

for $\hat{\lambda} = \hat{x}$, or $\hat{y}$, or $\hat{z}$

This is because of the symmettries caused by the identical incident particles and the (assumed) lack of polarization in the beam - leading to azimuthal symmetry around the beam direction.

Best seen by a simple model

Take previous case but limit $p_x \to 0$ (becomes a 2-D situation)



let "birth" angles be θ_+, θ_-
let observed angles be θ_+', θ_-'
let magnetic deflection be
δ for + particles
$-\delta$ for - particles

Prob. of observing θ_+', θ_-' is

$$P(\theta_+', \theta_-') = G(\theta_+' - \delta)\, G(\theta_-' + \delta)$$

the triple product in this case is essentially $\sin(\theta_+' - \theta_-')$

The relevant quantity is then
$\langle \sin(\theta_+' - \theta_-') \rangle$

$$\langle \sin(\theta_+' - \theta_-') \rangle = \iint \sin(\theta_+' - \theta_-')\, G(\theta_+' - \delta)\, G(\theta_-' + \delta)\, d$$

Now $G(x) = G(-x)$
$G(x) = G(\pi - x) = G(\pi + x)$
(of course x modulo 2π)
$G(x) = G(x - \pi)$

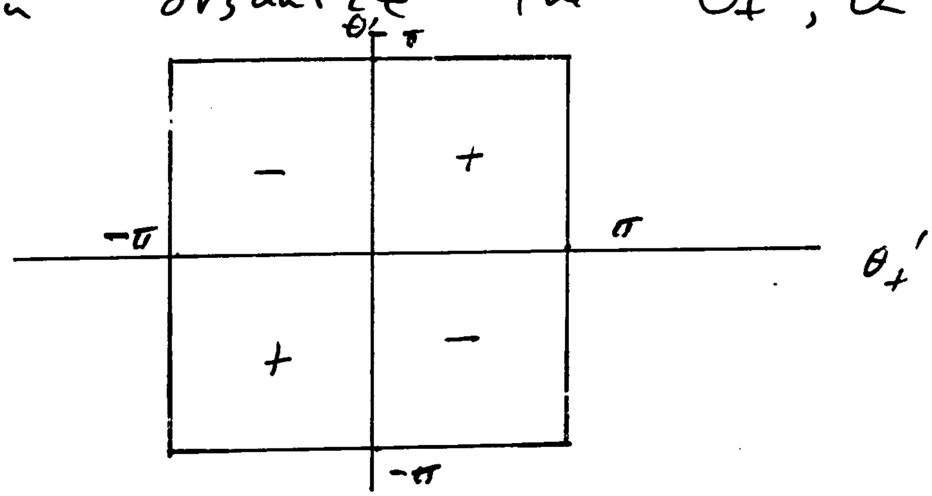
consider θ_+', θ_-' and $\theta_+' - \pi, \theta_-' - \pi$
The two G terms are the sa

and so is ... $\sin(\theta_+' - \pi - (\theta_-' - \pi)) = \sin(\theta_+' - \theta_-')$

Now consider θ_+', θ_-' and $\theta_+' - \pi, \theta$
The two G terms are the s

but $\sin(\theta_+' - \pi - \theta_-') = -\sin(\theta_+' - \theta$

so we can organize the θ_+', θ_-' p



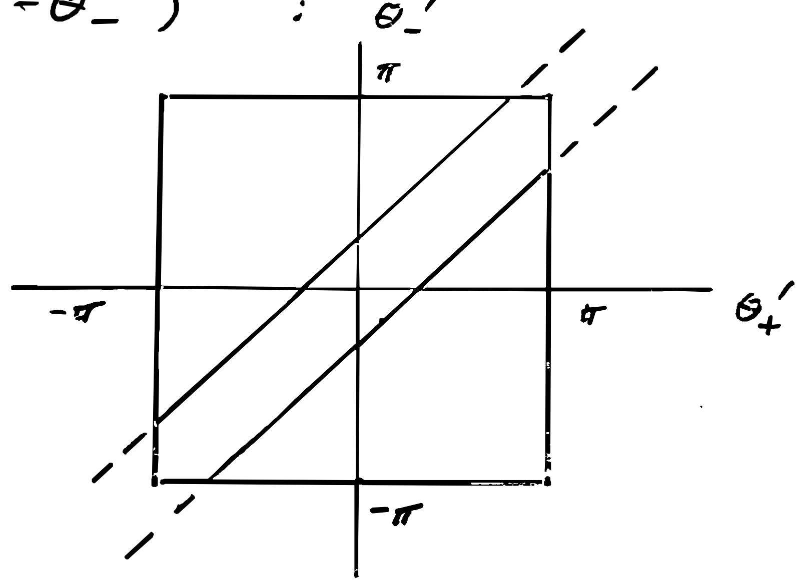
so each quandrant contributes the same magnitude to $\langle \sin(\theta_+' - \theta_-') \rangle$ but the + quadrants have the opposite sign to the - quadrants.

Thus, if we integrate over full θ_+', θ_-' range i.e. if we calculate

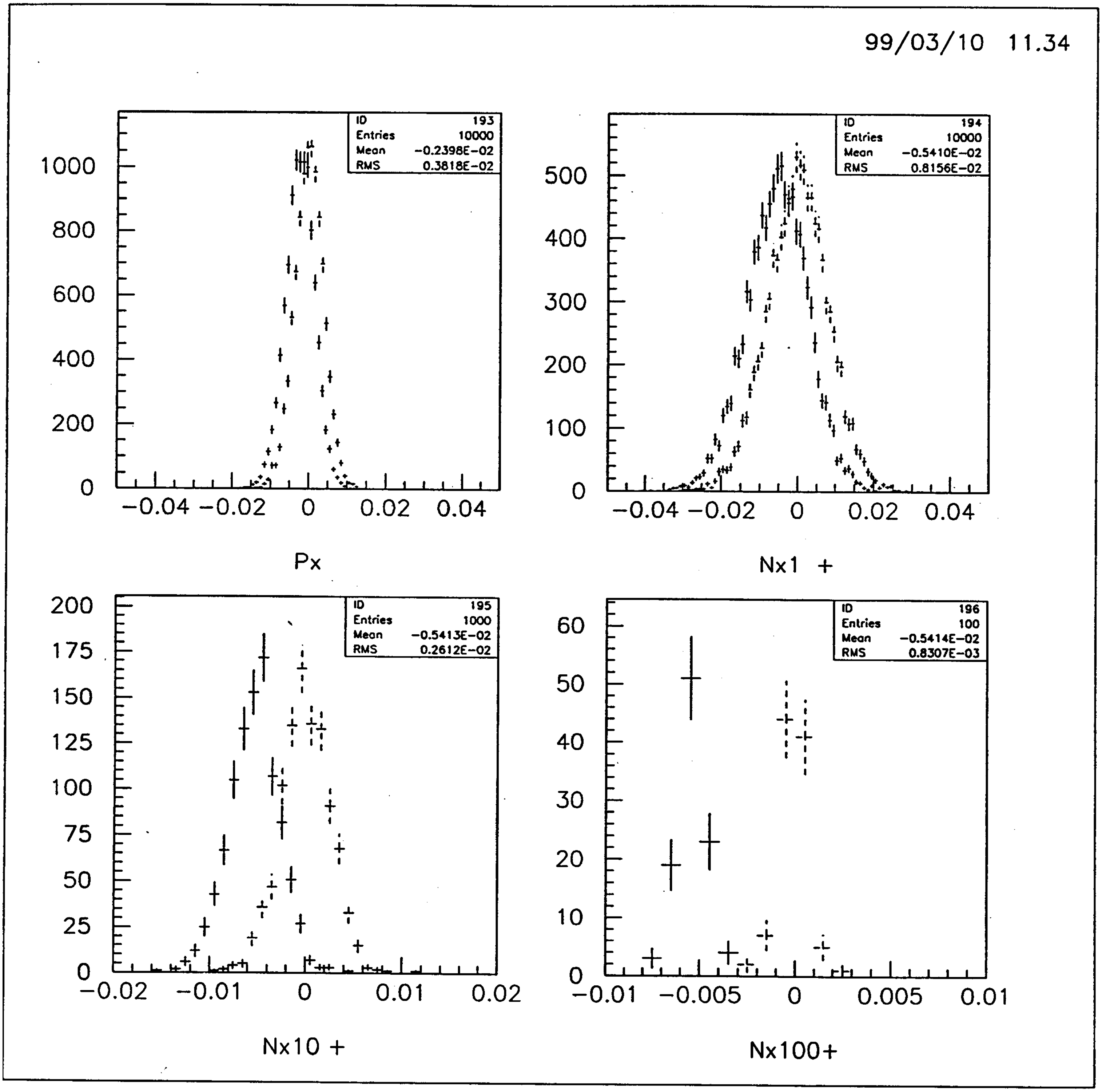
$$\sum_{\text{all pairs}} \frac{\vec{P}_{\pi^+} \times \vec{P}_{\pi^-}}{|\vec{P}_{\pi^+}||\vec{P}_{\pi^-}|} \cdot \hat{\lambda}$$

we get zero! Even with $\vec{B}$ field

Solution: limit magnitude of $\sin(\theta_+' - \theta_-')$:



Now a definitive effect should be seen (and is!).



$\vec{B} = B_0 \hat{x}$ or $\vec{B} = 0$ 30 MeV/c Max $|\vec{p}|$

$+$ --+--

and $P_x = 0$

(No. of Pairs with $P_i > 0$) − 0.5