EXPERIMENTAL SEARCH FOR P (CP) VIOLATION IN RHIC COLLISIONS

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[inspired by work of Riken-BNL Theorists]

(e.g. D. Kharzeev, R.D. Pisarski, and M.H.G. Tytgat)

Approaches

Λ^0 decay - parity (weak) violating decay allows a measurement of longitudinal polarization of Λ - a signal that parity was violated in Λ^0 production

- But, can never be certain Λ^0 was not a Ξ^- daughter $\Xi^- \to \Lambda^0 + \pi^-$ is a (weak int) parity violating decay.

$\phi \to K_s^0 K_s^0$ - not allowed in usual strong interaction $(J^{PC} = 0^{++})$ - signals a violation if observed
Huan Huang will discuss in more detail

- But, if ϕ decays outside of P violating domain this will not occur
  ϕ $\Gamma = 4.43$ MeV (long τ)
  also worry about $K_L K_s \to K_s K_s$ via regen.

Approaches (cont'd)

Non zero expectation value for a P odd observable

e.g.

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

where $\hat{\lambda}$ is a unit vector along a fixed direction

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

- If some of tracks are not pions "P" is still parity odd don't need particle I.D.

- With good (tight) vertex cuts most pions (particles) that are charged come from the primary vertex

- If some tracks from a parity violating weak decays $\langle P \rangle$ still $= 0$ unless a corelated pair +, − both come from decay.

Statistical Analysis

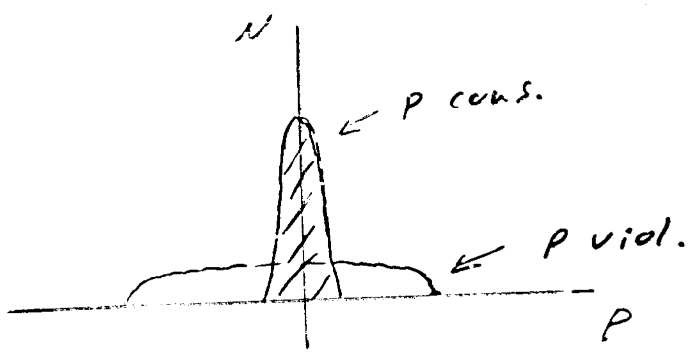
Parity conservation means that the distribution of P_i

$$P_i = \left[\frac{(\vec{P}_{\pi^+} \times \vec{P}_{\pi^-}) \cdot \hat{\lambda}}{|\vec{P}_{\pi^+}||\vec{P}_{\pi^-}|} \right]_{\text{pair } i}$$

Should be symmetrical around zero (HIJING example)

Parity violation of the sort hypothesized means that in a given event $\langle P \rangle$ has a value $\neq 0$. But this value will be different for different events and may well be symmetrically distributed around zero. So $\langle P \rangle = 0$!!

However the distribution of P will reflect the variance induced by the parity violation in each event.



A better statistical method using these ideas is to consider the number of the P_i which are + (i.e. $P_i > 0$).

If parity is conserved this is a binomial distribution (coin tossing problem!)

Prob. to get N_+ $P_i > 0$ in N P_i's

$$= \frac{N! \left(\frac{1}{2}\right)^{N_+} \left(\frac{1}{2}\right)^{N-N_+}}{N_+! \, (N-N_+)!}$$

For large N this becomes a Gaussian with std. dev. σ

$$\sigma = \sqrt{N\left(\tfrac{1}{2}\right)\left(\tfrac{1}{2}\right)} = \frac{\sqrt{N}}{2}$$

the fraction of P_i with $P_i > 0$ (N_+/N) is the distributed as a Gaussian around .5 with std. dev. σ

$$\sigma = \frac{1}{N} \frac{\sqrt{N}}{2} = \frac{1}{2\sqrt{N}}$$

Now N can be the number of pairs in any desired size group of events.

ADVANTAGE: Dist. of $\frac{N_+}{N}$ completely known if P OK

Simulation Studies

Use event generator HIJING

put in "reasonable" STAR acceptance cuts:

$$p_\perp > 250 \text{ MeV/c}$$

$$\theta > 22^\circ$$

$$\Delta\theta_{+-} > 10 \text{ mr}$$

(>10 mr angular separation between +, − tracks)

To see the effect of resolution errors we did two cases

a) NO errors (perfect meas.)

b) each momentum component "smeared" by 3% - uncorrellated

i.e. $$\frac{(\delta p_x)_{rms}}{p_x} = \frac{(\delta p_y)_{rms}}{p_y} = \frac{(\delta p_z)_{rms}}{p_z} = .03$$

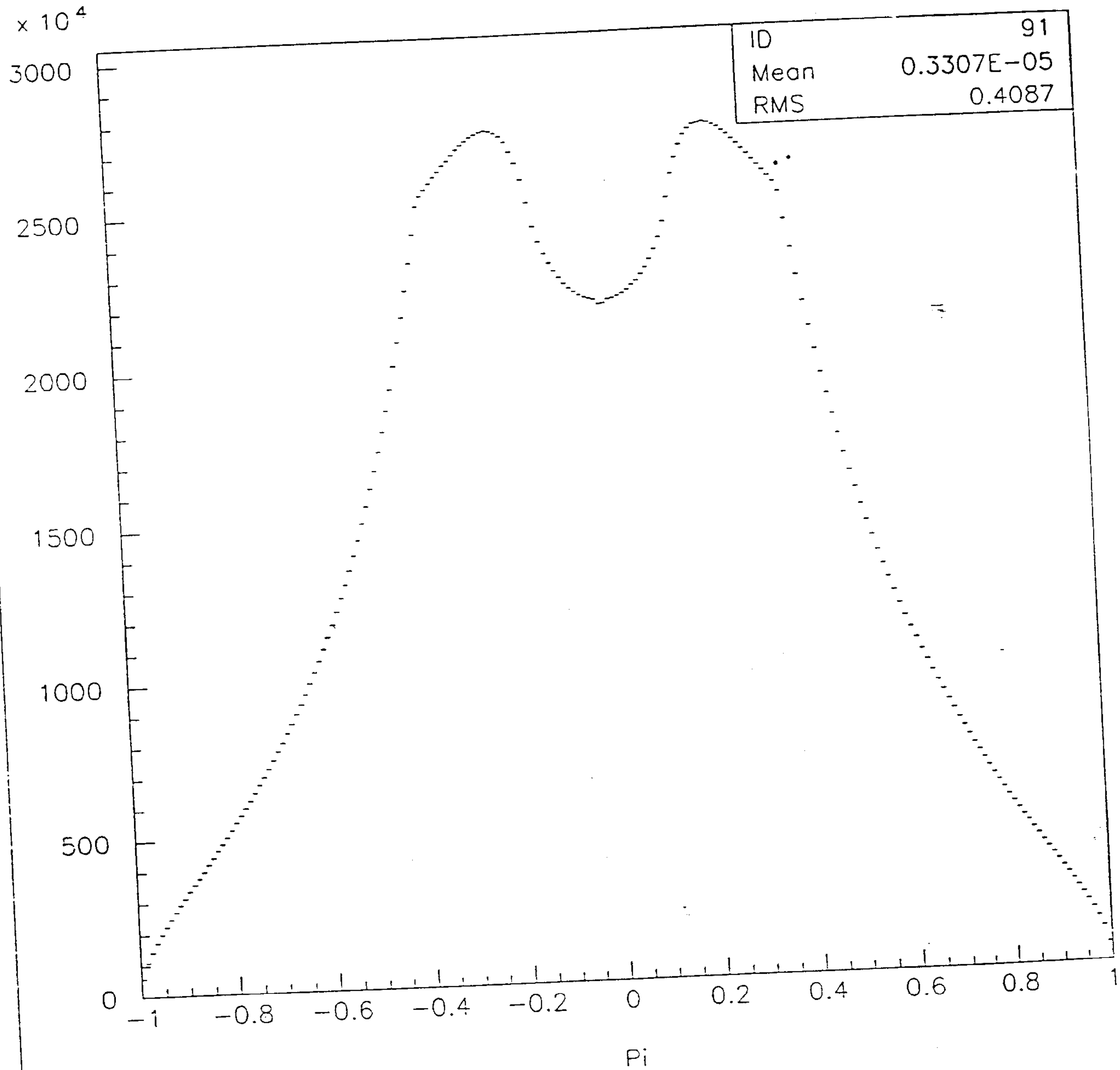
Finally, we did one "BIAS" study (later)

~10^4 events

$P_t > 250$ MeV

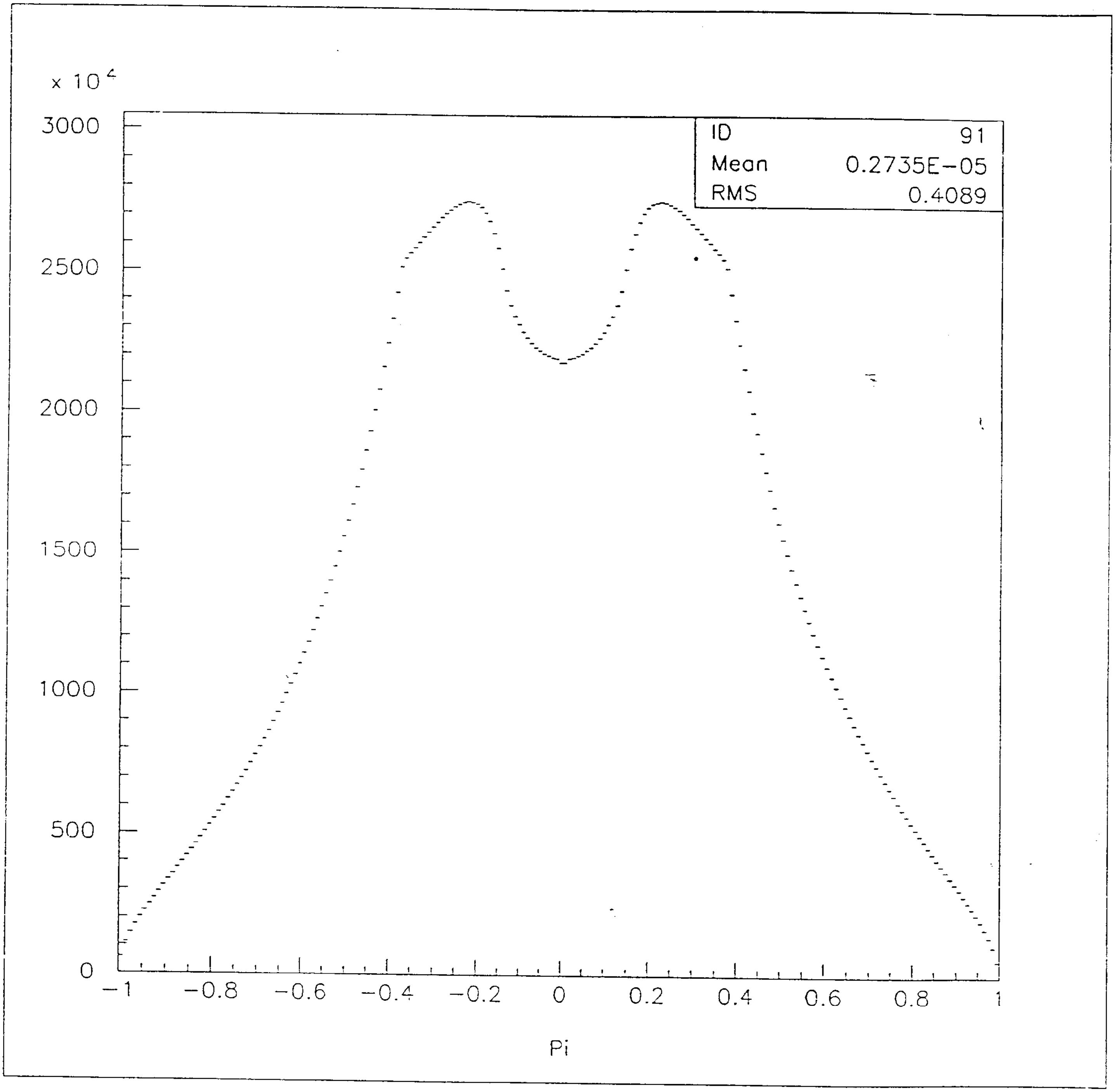
$|\theta| > 22^\circ$ Op.ang. > 10 mrad

$\frac{\Delta P_i}{P_i} = 0$



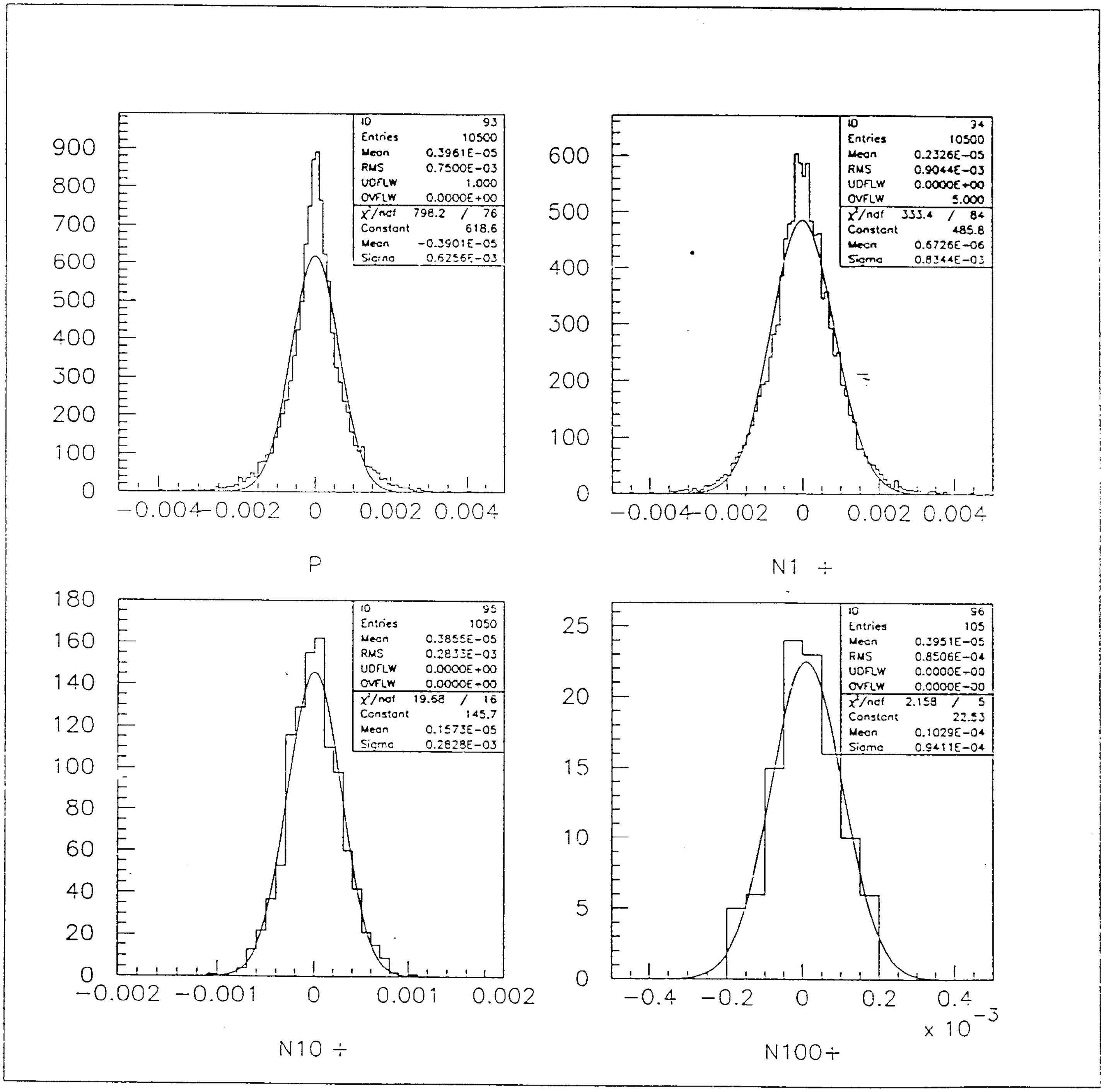
$P_t > 250$ MeV
$|\theta| > 22^\circ$
Op. Ang. > 10 mrad

$$\frac{\Delta P_i}{P_i} = 3\%$$



$P_t > 250$ MeV
$|\theta| > 22^\circ$
Op. ang < 10 mrad

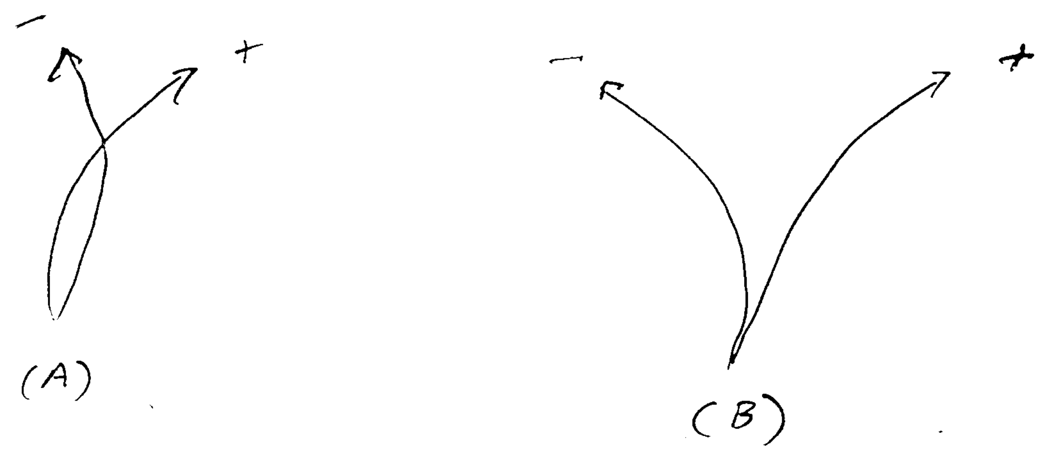
$\frac{\Delta p_i}{p_i} = 3\%$



Bias Study

Expt. biases are the major concern with the viability of this approach.

To get some idea of effects we "induced" a bias.



Event classes (A) and (B) must be detected with equal probability if meas. is to be unbiased. But in (A) tracks stay close together longer - maybe confuse tracking software leading to loss of efficiency for (A) w.r.t. (B)

We took as model:

$$\Delta\theta_{+-} > 30 \text{ mr} \quad \text{for A}$$

$$\Delta\theta_{+-} > 10 \text{ mr} \quad \text{for B}$$

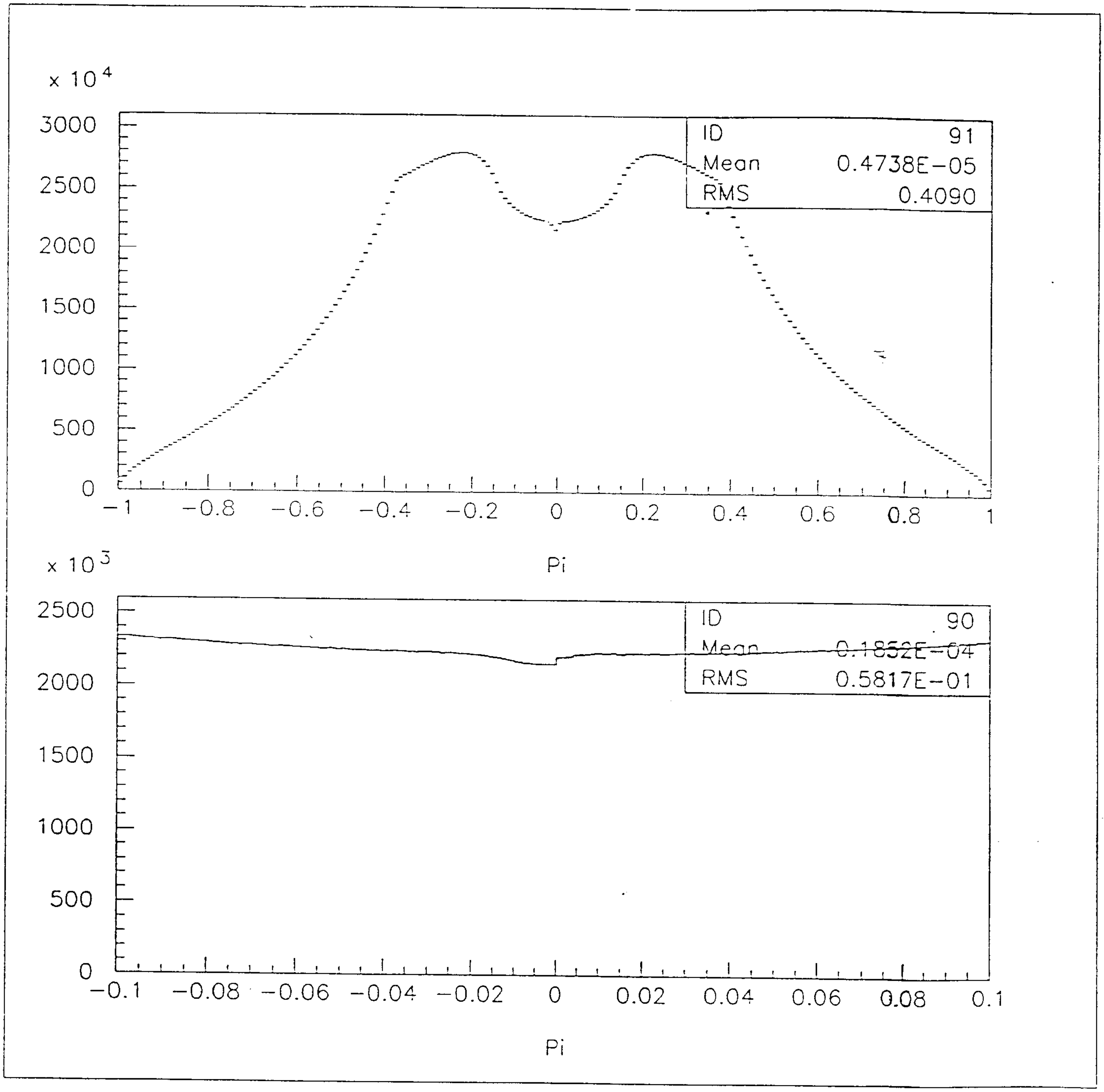
Note: running equally with opposite STAR magnetic field removes this bias.

$P_t > 250$ MeV $\frac{\Delta P_i}{P_i} = 3\%$

$|\theta| > 22^\circ$

Op. Ang > 10 mrad

for $P_i < 0$, OpAng > 30 mrad.

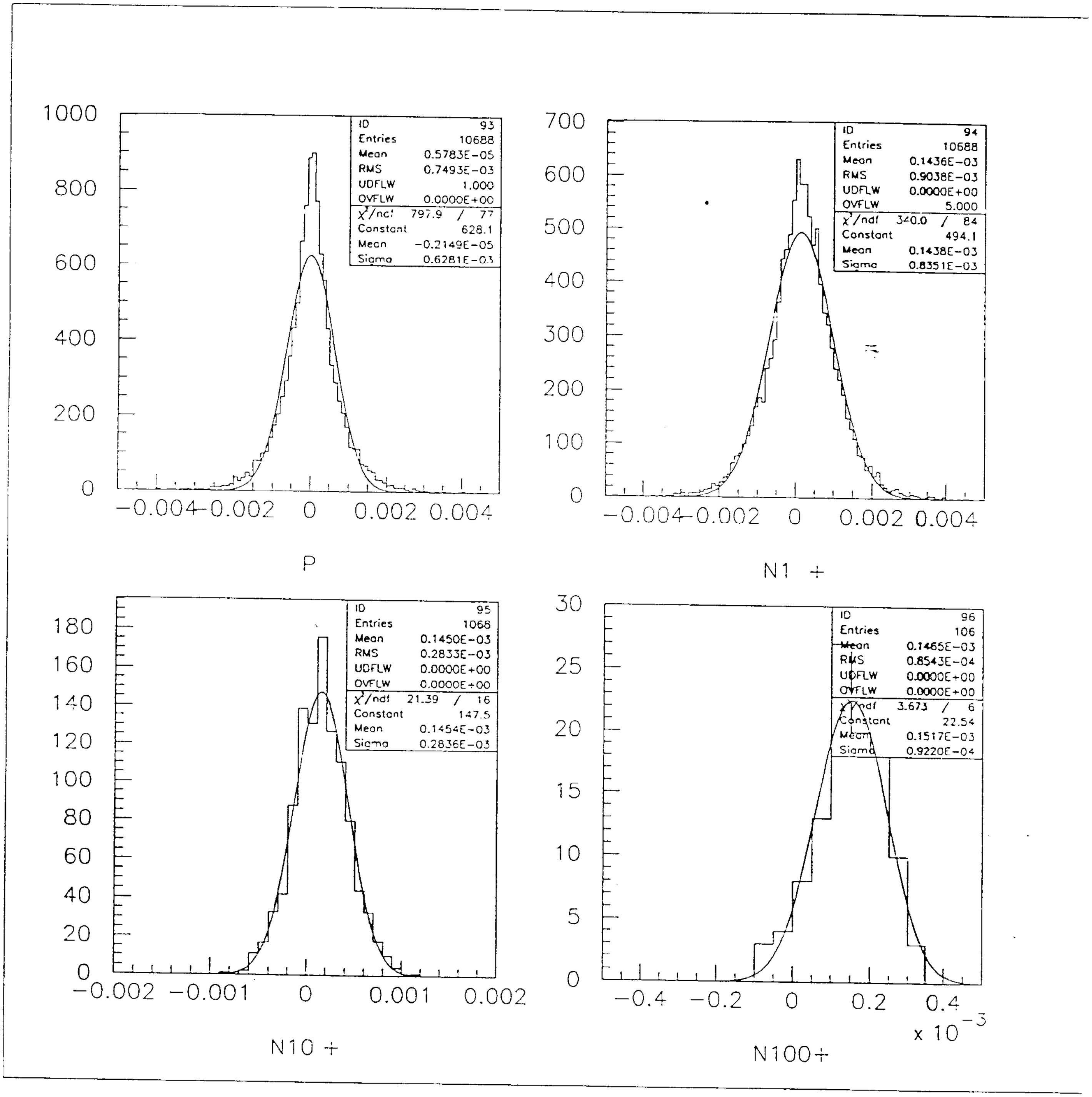


$P_t > 250$ $\frac{\delta P_i}{P_i} = 3\%$

$|\theta| > 22^\circ$

Op.Ang > 10 mrad

for $P_i < 2$, Op.Ang > 30 mrad



CONCLUSIONS

- Although much (!) work remains to be done, it is a "reasonable" expectation that effects with
$$\langle P \rangle_{event} \gtrsim 10^{-5}$$
can be detected.

- Reversing the magnetic field is crucial

- Perhaps the most important work remaining to be done at this point is to make an estimate of the spread in $\frac{N_+}{N} - 0.5$ which can be expected.

More precisely:

what accuracy in $\frac{N_+}{N} - 0.5$ is interesting if no effect is observed?