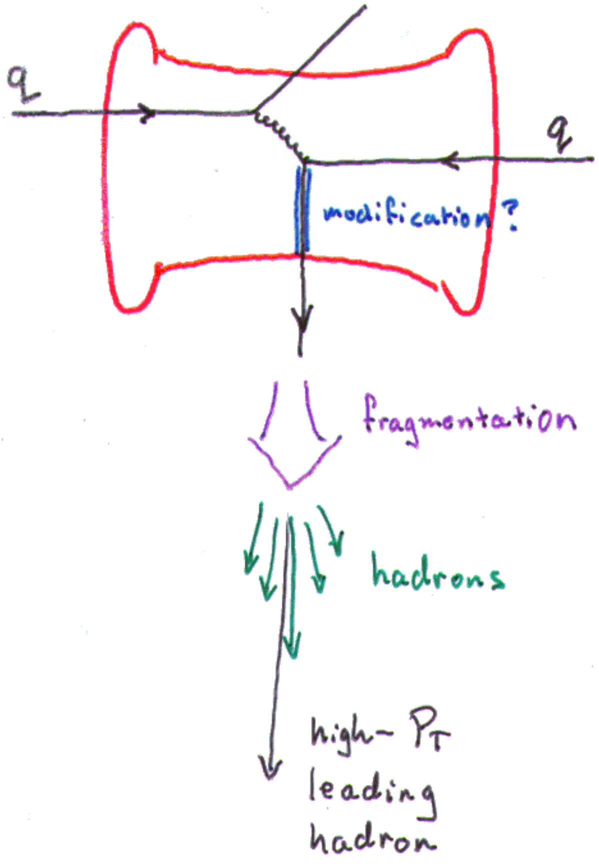
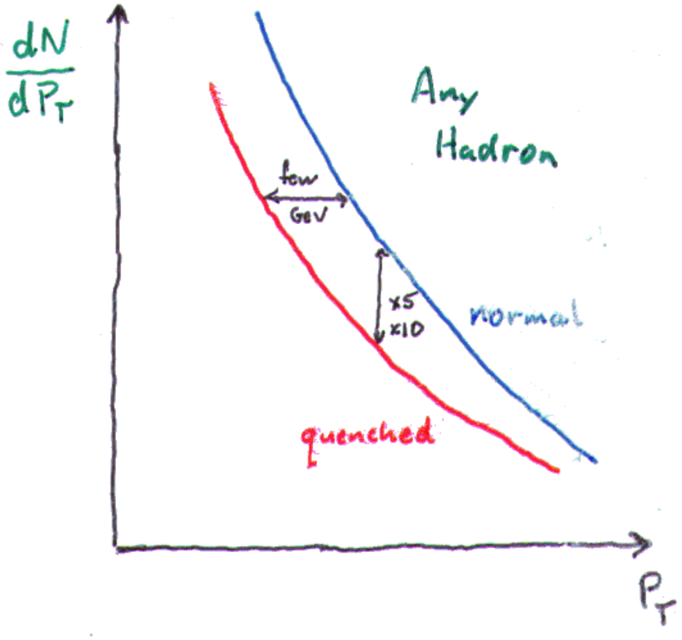
Search for Jet-Like Behavior in 158 A-GeV Pb+Pb Collisions

Paul Stankus, ORNL
RHIC Winter Workshop
LBNL, Jan 1999

1. Jet Quenching
2. Correlated Back-to-back Pairs
3. First Look Results





See:

- Gyulassy Wang NPB 94
- Baier Dokshitzer Mueller Peigne Shiff PLB 95
- Zakharov JETP L 96

Where is the jet quenching in $Pb+Pb$ collisions at 158 AGeV?

PRL 1998

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Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA
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Seattle, WA 98195-1550
(April 20, 1998)

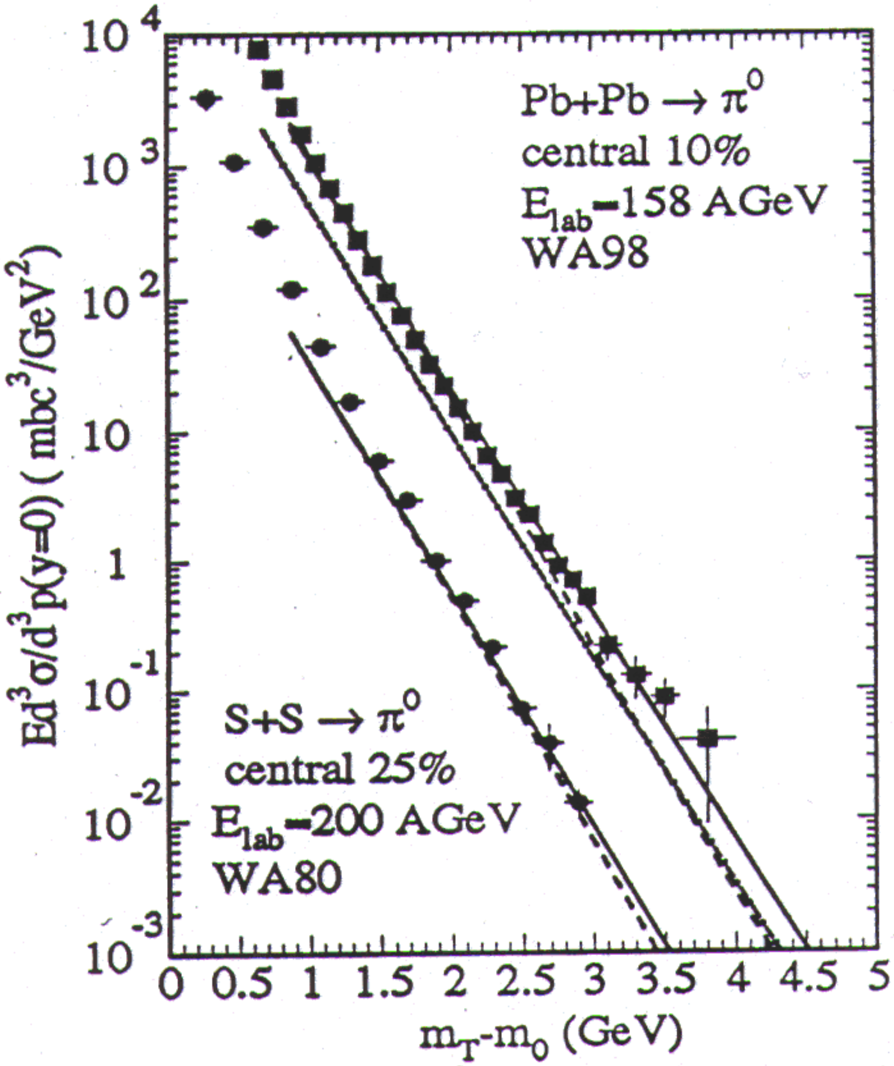
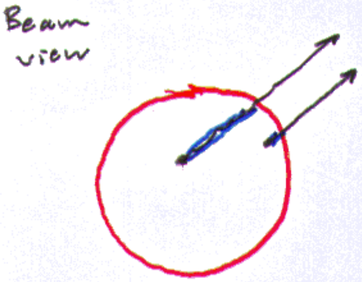


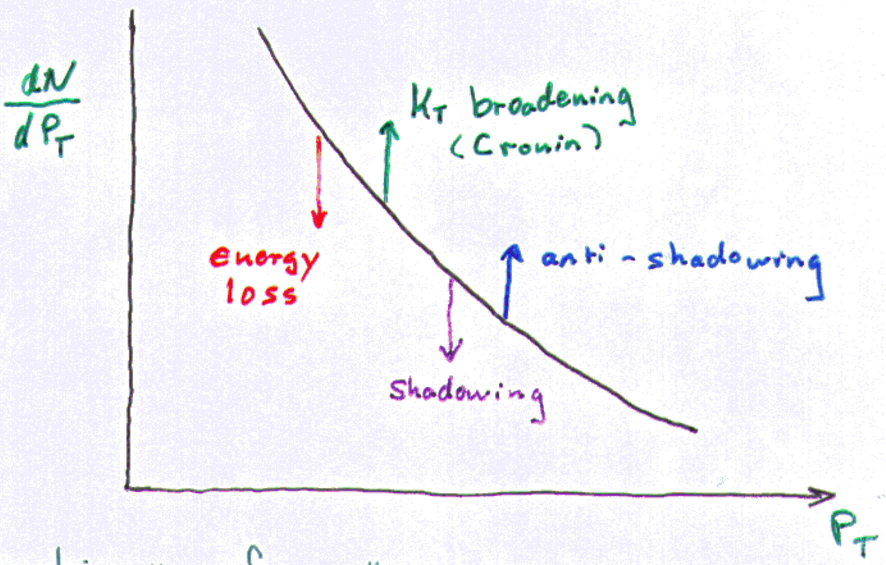
FIG. 2. Single-inclusive π^0 spectra in central $S+S$ at $E_{lab}=200$ GeV and $Pb+Pb$ collisions at $E_{lab}=158$ GeV. The solid lines are pQCD calculations with initial-k_T broadening and dashed lines are without. The $S+S$ data are from WA80 [27] and $Pb+Pb$ data are from WA98 [28]. The dot-dashed line is obtained from the solid line for $Pb+Pb$ by shifting p_T by 0.2 GeV/c.

pQCD calculation matches high - P_T hadron spectrum :

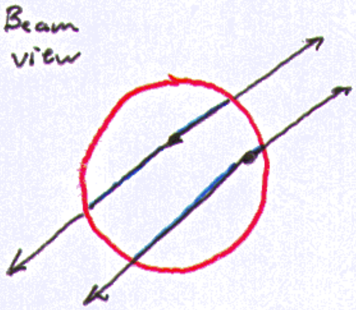
No evidence for parton energy loss!



Singles spectrum involves many effects:



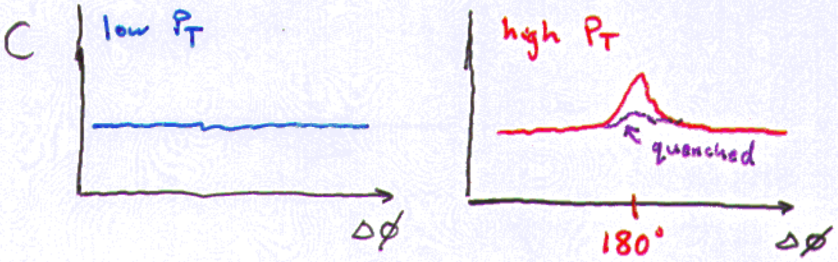
Also: ambiguity from "pre-equilibrium" and "thermal" sources



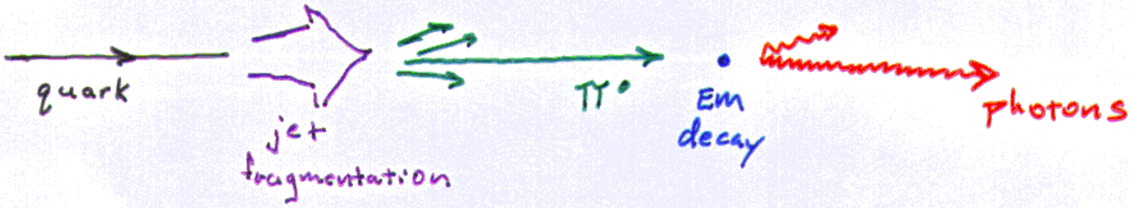
Back-to-back hadron pairs more strongly affected than singles

Look at: Opposite Pair mass
Pseudo-Fragmentation Functions

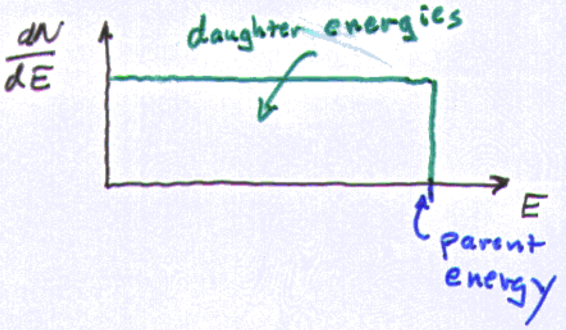
But Step 1: Angular correlations

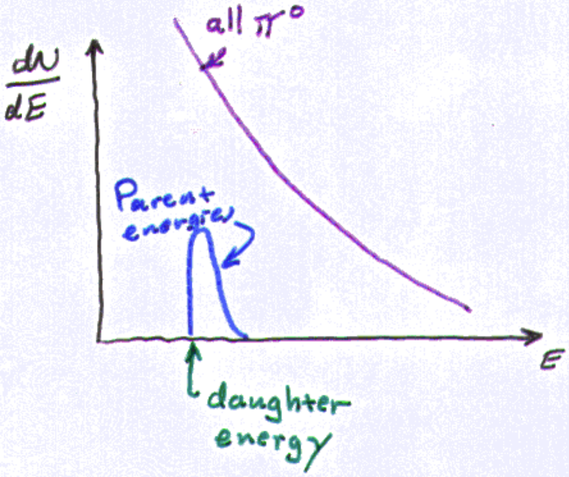


High-energy inclusive photons are fragments of jet fragments



Photons grow up to be just like their parents:





$$\frac{dN}{de}\,\text{photons} = \int_e^\infty dE\,\frac{dN}{dE}^{\pi^0}\,g(e,E)$$

$\hookrightarrow g(e,E) = \frac{1}{E}$

Steeply falling
Characteristic width P_0
"local exponential slope"

$$\frac{dN^\gamma}{de} = \left.\frac{dN^{\pi^0}}{dE}\right|_{E=e}\frac{P_0}{e}$$

Correlations:

$$\boxed{\pi^0} \qquad \frac{dN}{dE} = P(E)$$

$$C^{\pi^0} = \frac{d^2N/dE_1\,dE_2}{dN/dE_1 \quad dN/dE_2} = \frac{\overset{\text{uncorrelated}}{P(E_1)\,P(E_2)} + \overset{\text{correlated}}{Q(E_1,E_2)}}{P(E_1)\;P(E_2)}$$

$$\lim Q \ll P^2$$

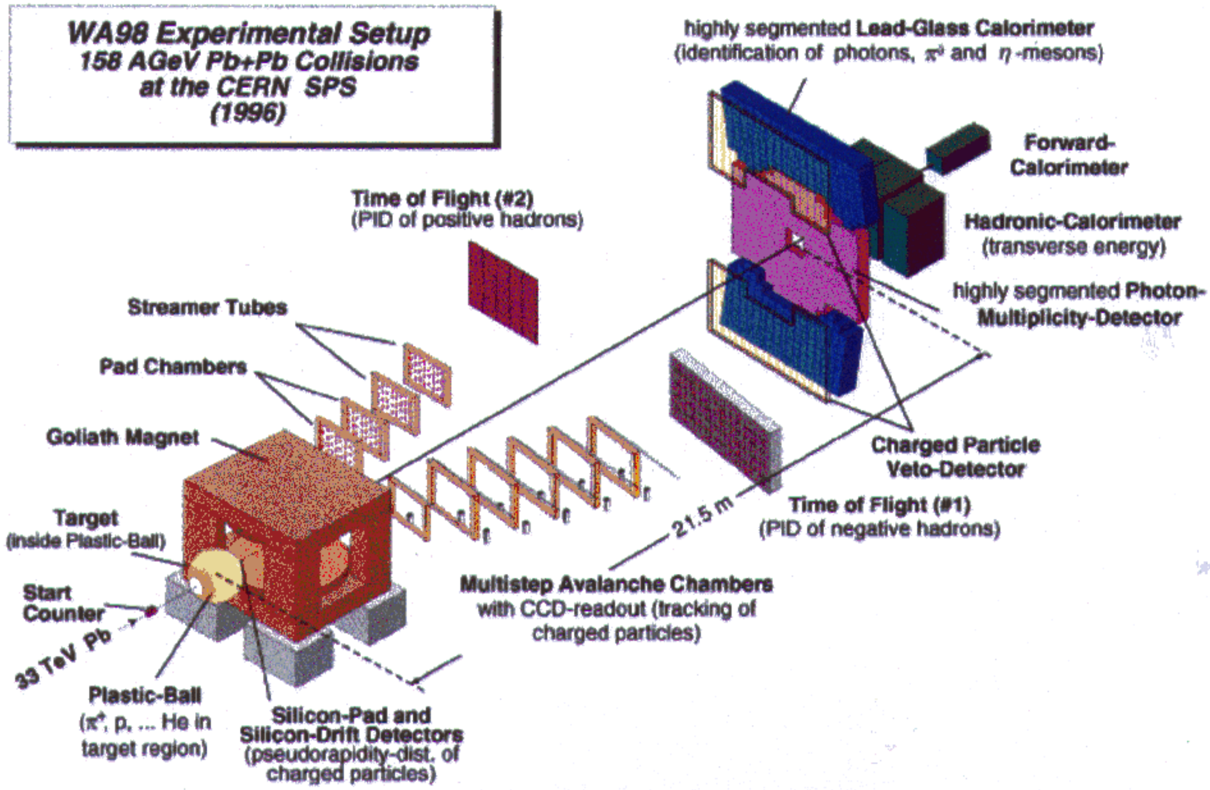
$$= 1 + \frac{Q(E_1,E_2)}{P(E_1)\,P(E_2)}$$

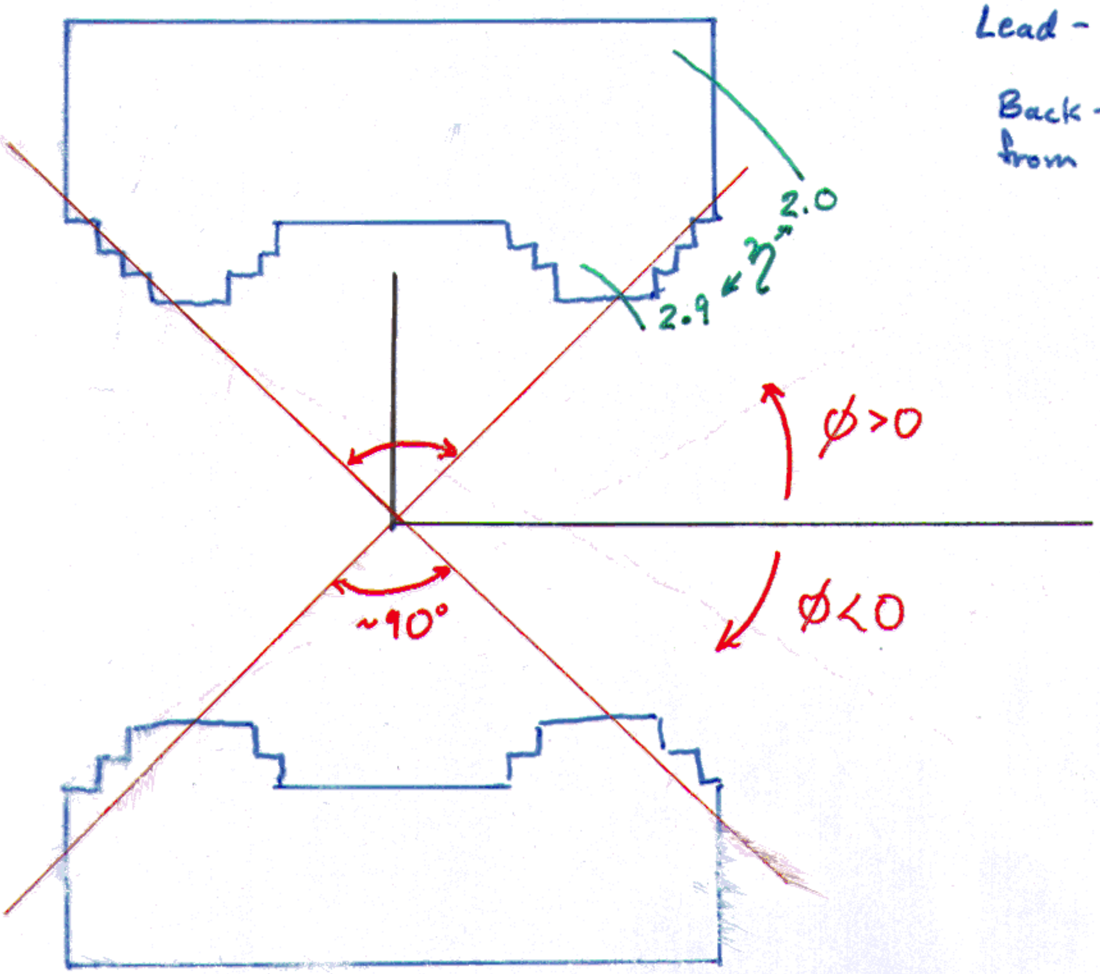
$$\boxed{\begin{array}{c}\text{Inclusive}\\ \gamma\end{array}} \qquad \frac{dN}{de_1} = P(e_1)\,\frac{p_1}{e_1} \qquad \frac{dN}{de_2} = P(e_2)\,\frac{p_2}{e_2}$$

$$\frac{d^2N}{de_1\,de_2}^{\text{correlated}} = Q(e_1,e_2)\,\frac{q_1 q_2}{e_1 e_2}$$

$$C^{\gamma} = 1 + \frac{Q(e_1,e_2)\quad q_1 q_2/e_1 e_2}{P(e_1)\;p_1/e_1 \quad P(e_2)\;p_2/e_2}$$

$$= 1 + \frac{Q(e_1,e_2)}{P(e_1)\;P(e_2)}\;\underbrace{\frac{q_1 q_2}{p_1 p_2}}_{\substack{\text{Order}\\ 1}} \simeq C^{\pi^0}$$



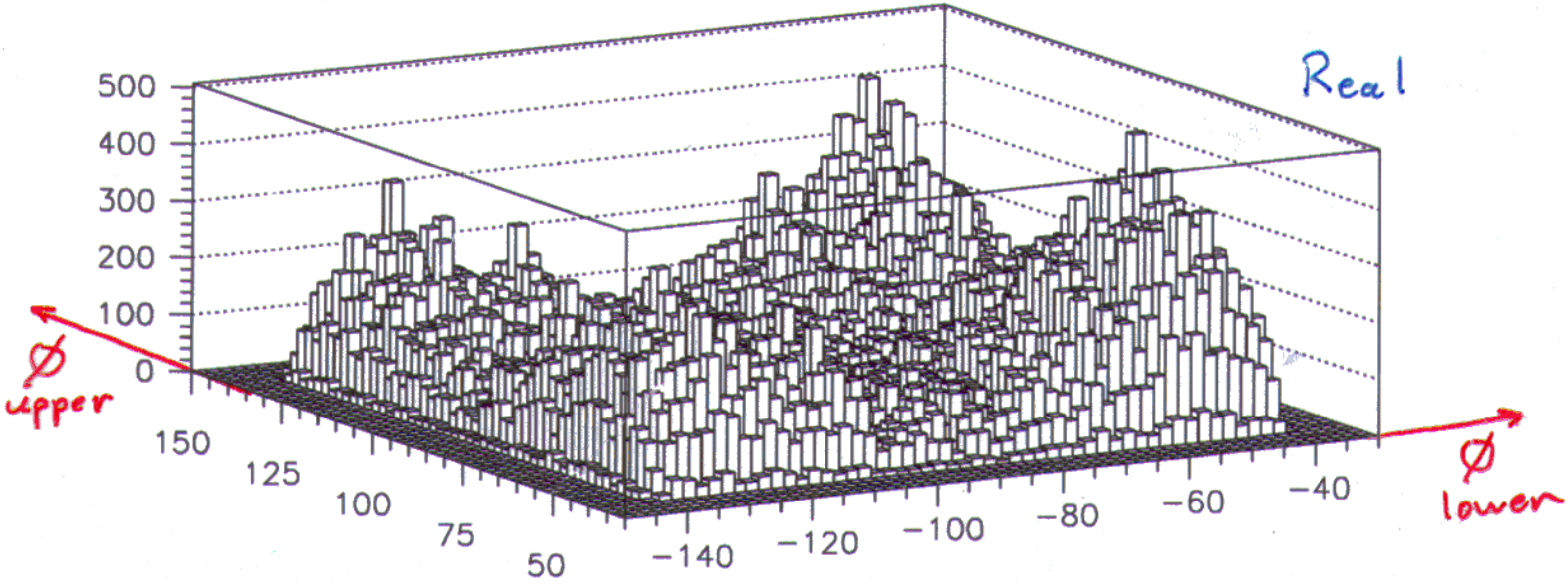


Lead-Glass Spectrometer

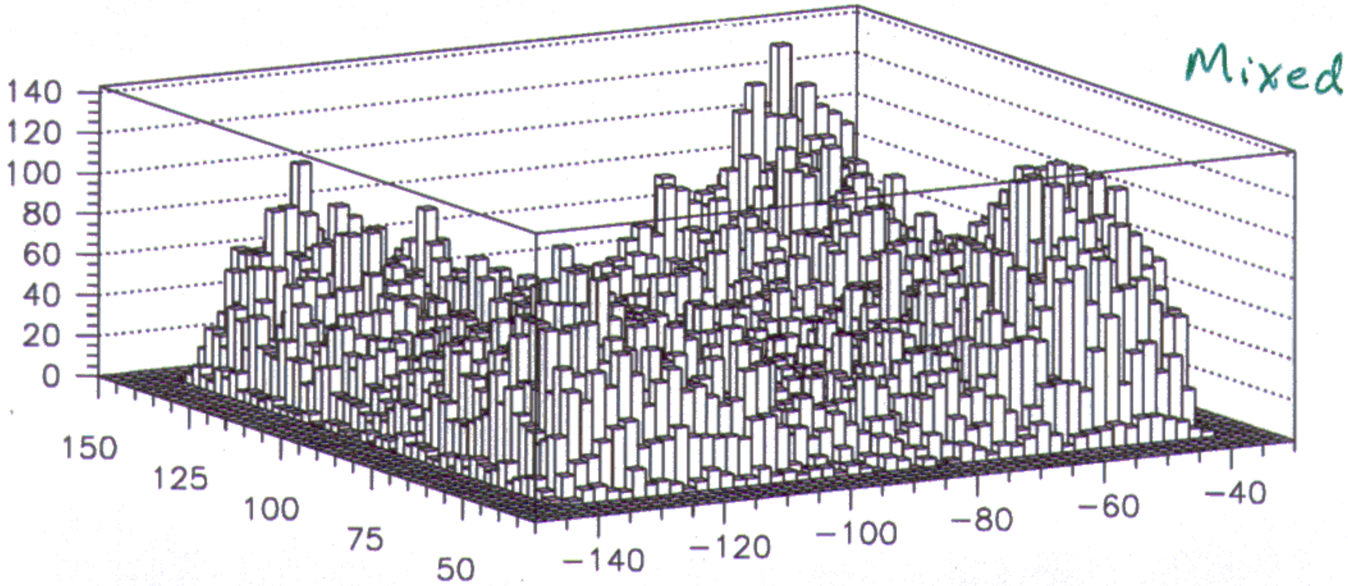
Back-to-back coverage from

$90^\circ \leq \Delta\phi < 180^\circ$

Phi 1 vs Phi 2



Real Central, pt gt 1.0



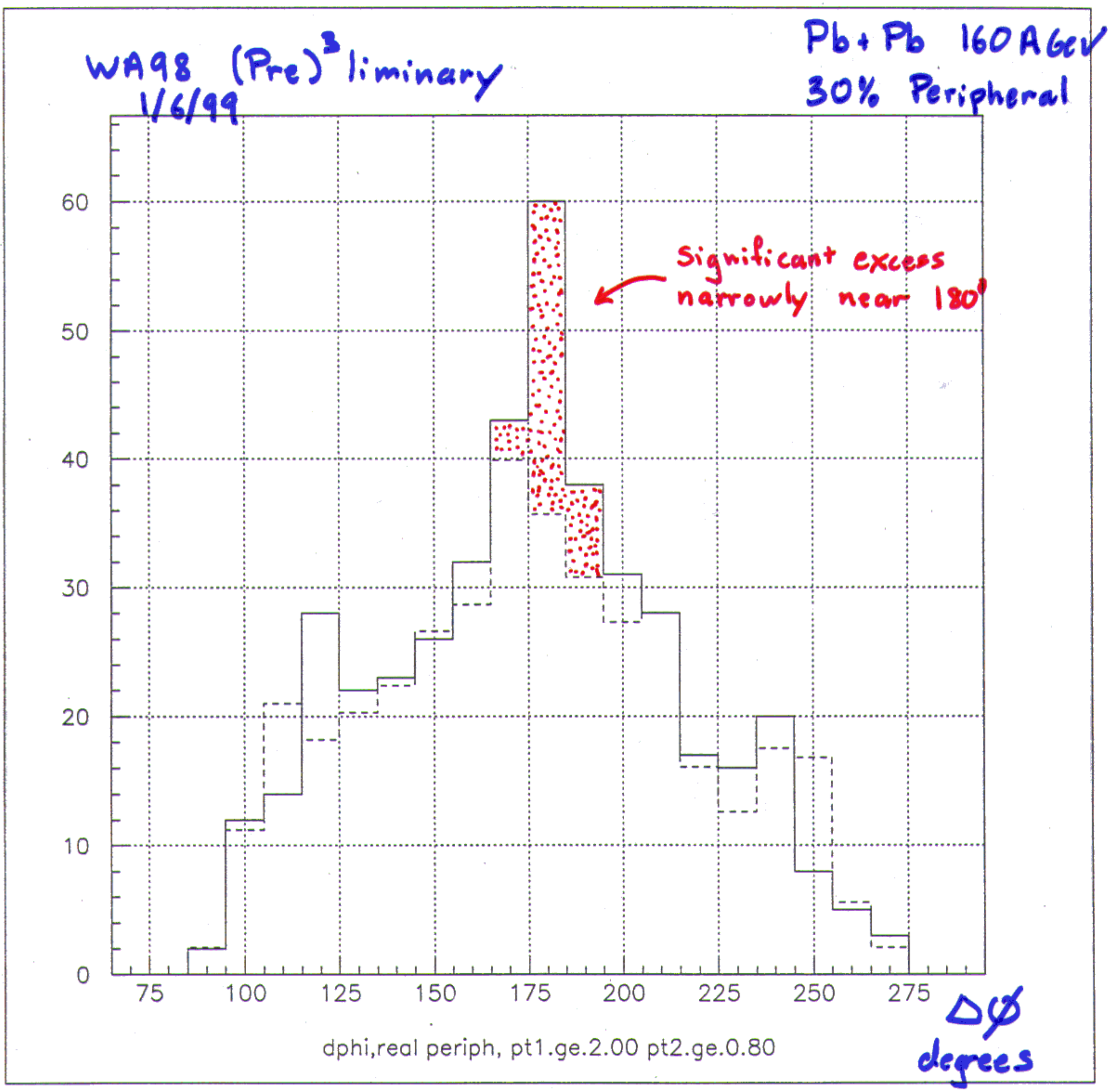
Bkgd Central, pt gt 1.0

Cut P_T^1 , $P_T^2 \geq 1.0$ GeV

No stunning enhancement
around $\Delta\phi = 180°$

Δ∅ distributions

real pairs ———
mixed pairs - - - - -

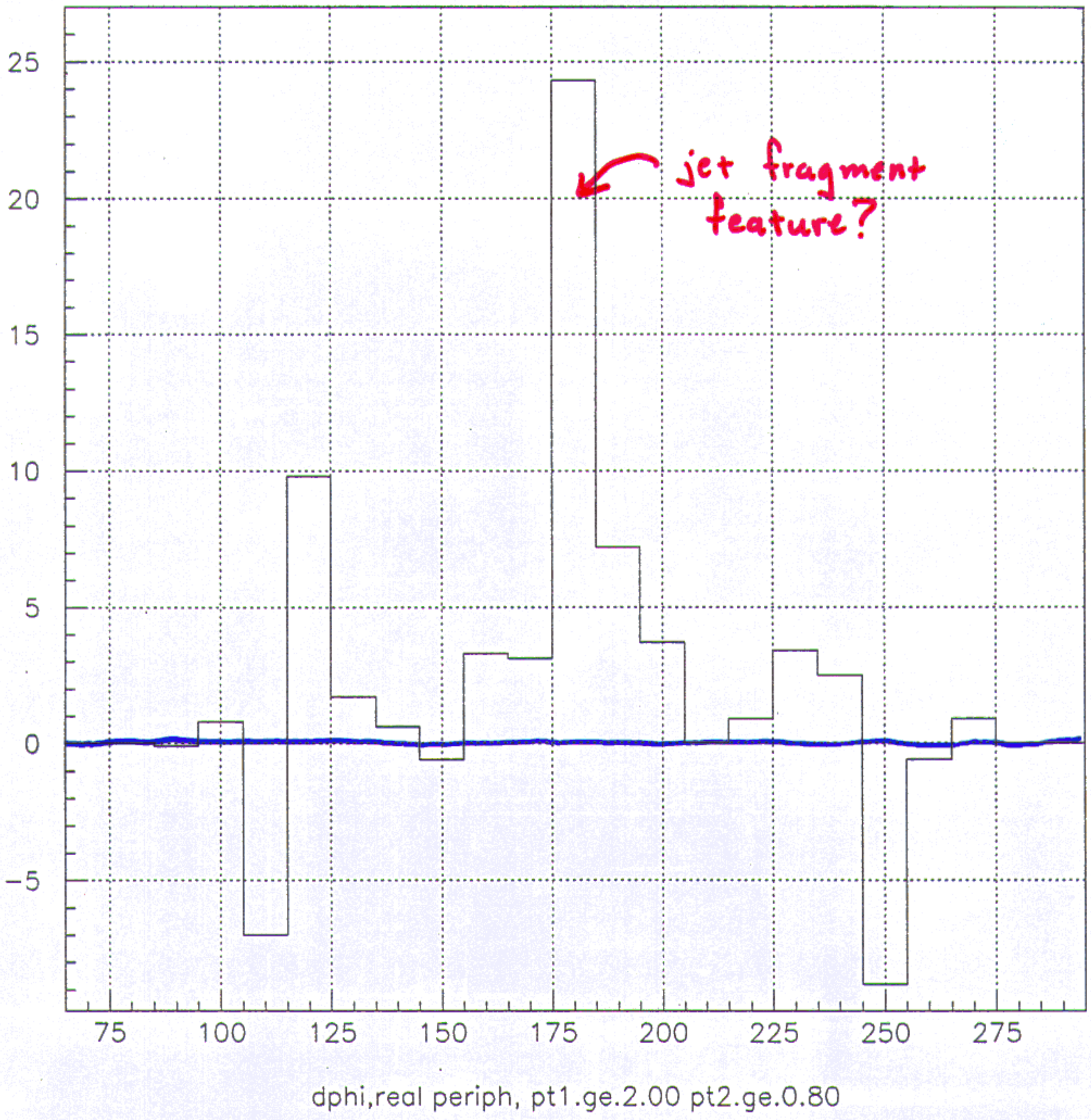


$P_T^{upper} \geq 2.0$ GeV/c

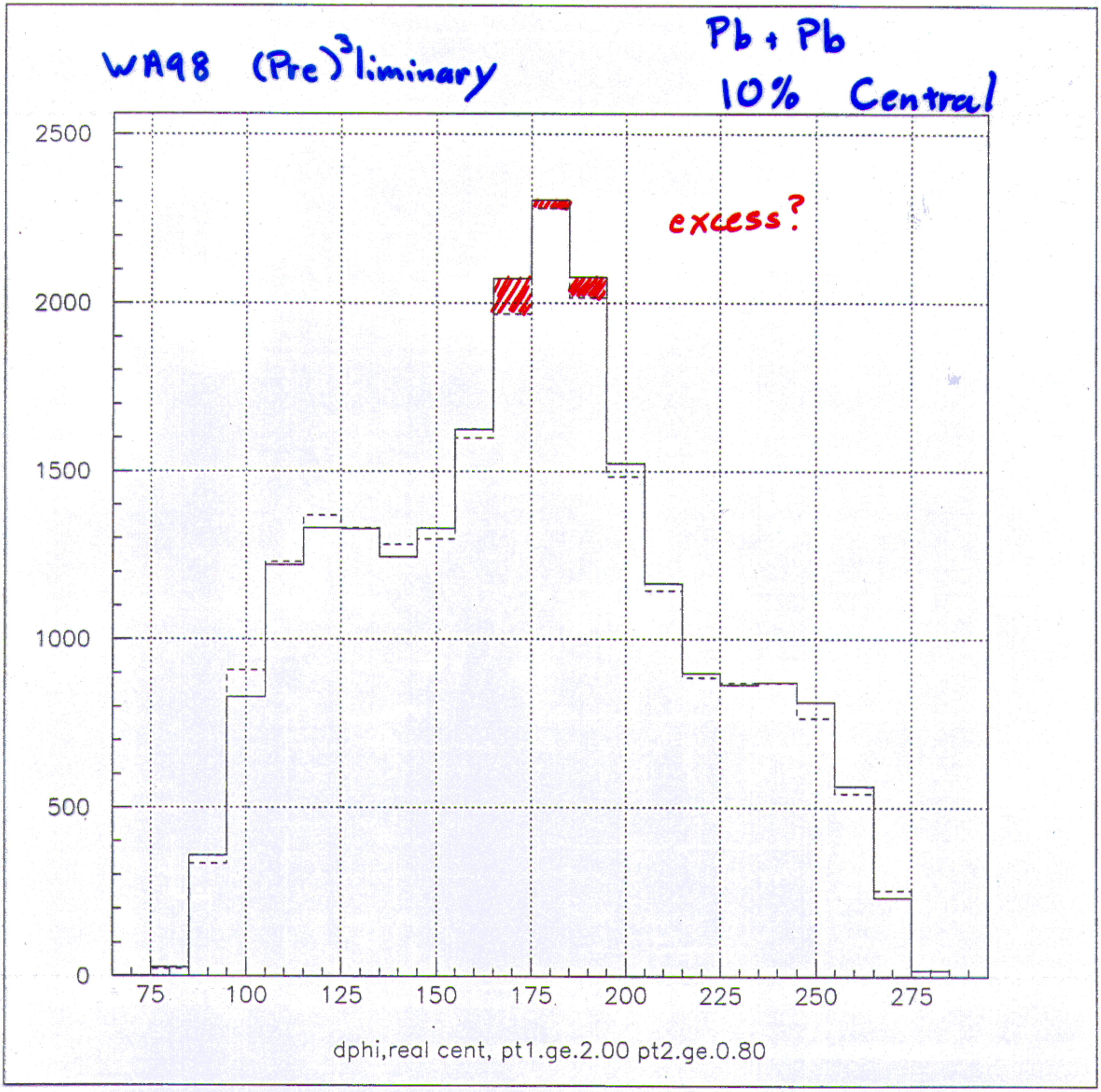
$P_T^{lower} \geq 0.8$ GeV/c

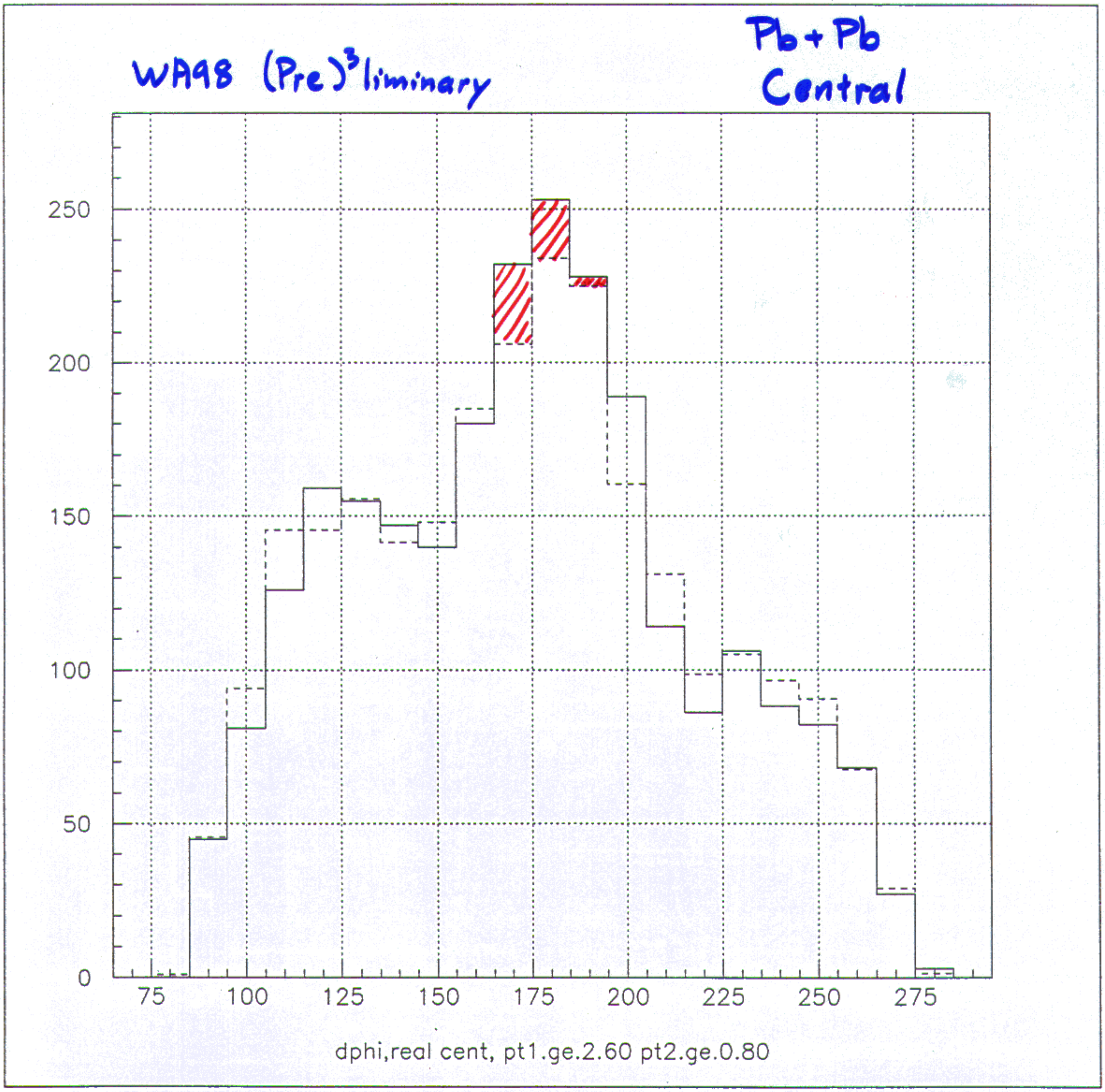
$\Delta\phi$, real − mixed

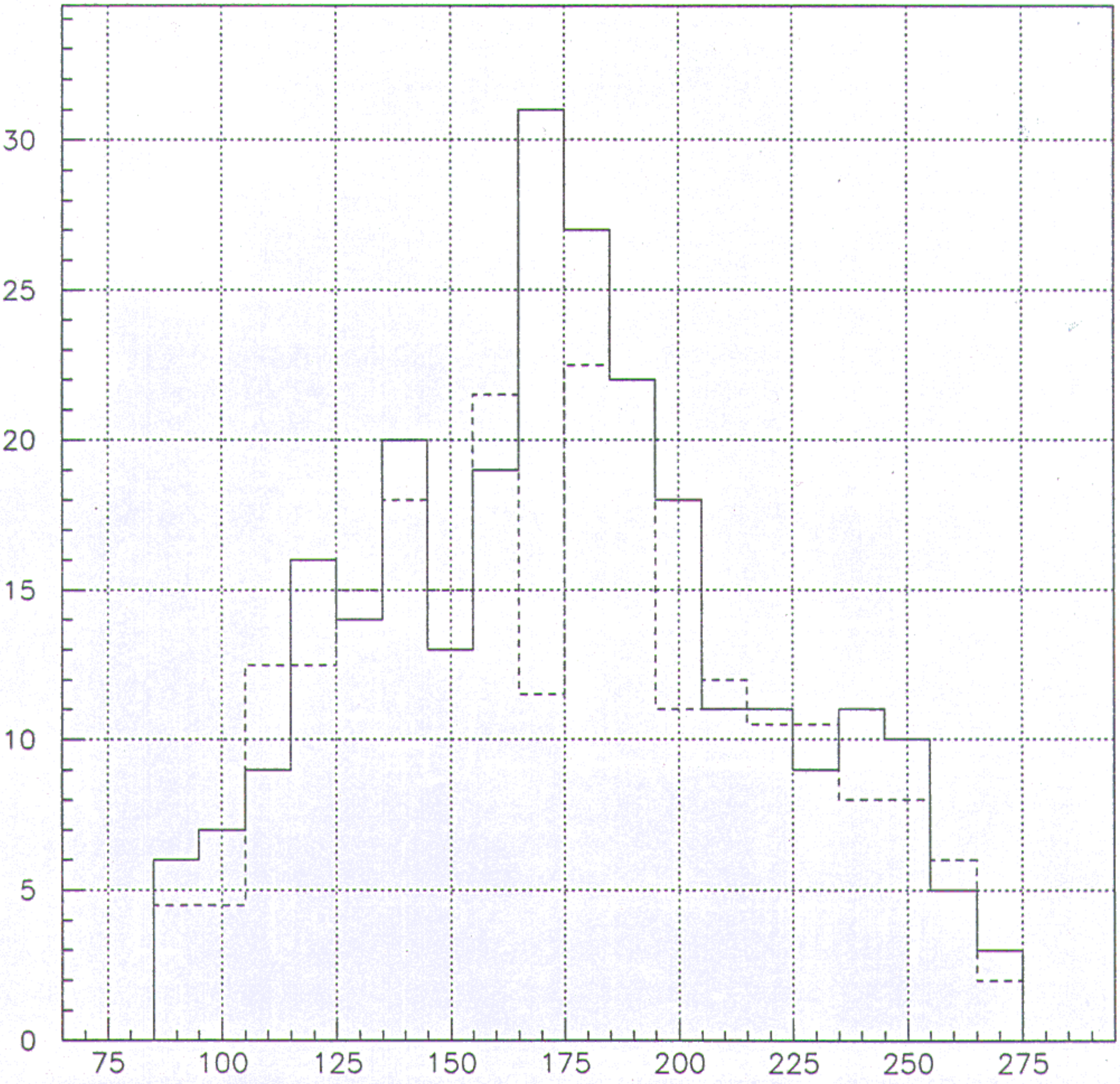
WA98 (Pre)^{3}liminary



jet fragment feature?


WA98 (Pre)^{3}liminary
Pb + Pb
10% Central
excess?
2500
2000
1500
1000
500
0
75
100
125
150
175
200
225
250
275
dphi,real cent, pt1.ge.2.00 pt2.ge.0.80


WA98 (Pre)^{3}liminary
Pb+Pb
Central
0
50
100
150
200
250
75
100
125
150
175
200
225
250
275
dphi,real cent, pt1.ge.2.60 pt2.ge.0.80



dphi,real cent, pt1.ge.3.00 pt2.ge.1.00

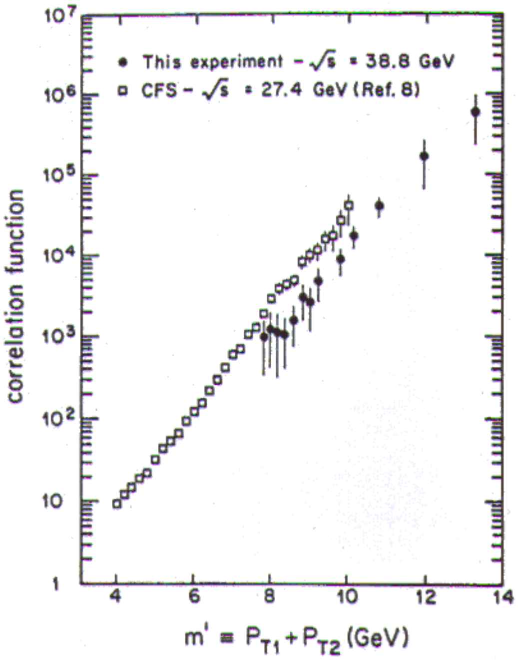


FIG. 2. Measurements of the hadron-hadron unlike-sign correlation are plotted as a function of pseudomass (sum of the transverse momenta) and compared to previous measurements in proton-beryllium collisions. Both experiments use symmetric pairs with a transverse-momentum difference less than 1.1 GeV.

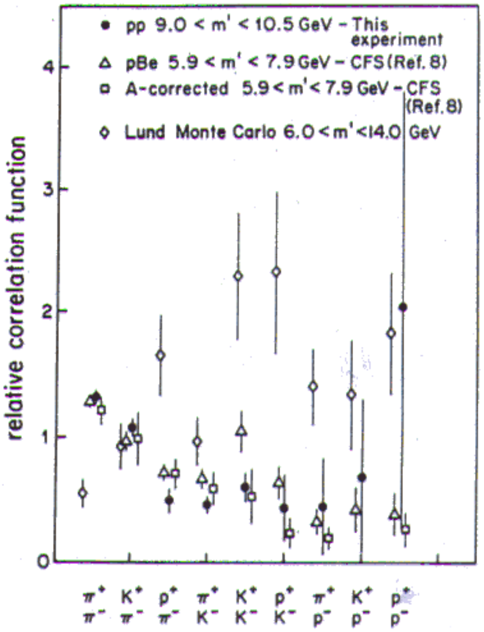


FIG. 3. Measurements of the relative correlation function in proton-proton collisions for each pair species are compared to measurements using a beryllium target and predictions using the Lund model.

tiproton (which are often below Cherenkov threshold). This type of systematic uncertainty was estimated by comparing the pair species composition resulting from events in which Cherenkov photons from both hadrons strike the same detector to the composition resulting when they do not strike the same detector.

In Fig. 3 the relative correlation functions $r_{\alpha\beta}$ measured by this experiment (statistical uncertainties only) and the CFS Collaboration are shown. Table I contains the measured values of $r_{\alpha\beta}$ with the statistical and systematic uncertainties. The CFS points labeled "*A*-corrected" are an extrapolation from proton-beryllium to proton-nucleon collisions, correcting for anomalous nuclear enhancement.[8] Agreement of the *pp* relative correlation functions and the "*A*-corrected" values of the CFS Collaboration confirms the validity of this technique within the precision of the two measurements, and indicates that these relative correlation functions do not depend strongly on m' or $\sqrt{s}$.

If only valence-quark-quark scattering contributed to the production of single hadrons and dihadrons in the kinematic region studied here ($m'/\sqrt{s} \approx 0.26$), then the relative correlation function for all species of unlike-sign pairs would be unity since the mediating gluon carries no flavor. However, some interactions (gluon-gluon and quark-antiquark), involving nonvalence constituents, can introduce flavor correlations between two opposing hadrons. These nonvalence interactions should, for instance, increase the K^+K^- correlation since there is no net flavor in the initial constituent state.

Predictions based on the Lund model[14] are also shown in Fig. 3. The fragmentation portion of this model has been quite successful in parametrizing e^+e^- data. However, the high-p_T event generator (PYTHIA) has not been tested in the kinematic region under study, and Fig. 3 suggests[15] that it gives too much importance to the nonvalence interactions mentioned above.

A mechanism by which the measured relative correlation for K^+K^- can be less than 1 has been previously suggested.[8] Single-hadron events (as opposed to symmetric pairs) select initial constituents with a p_T directed toward the relevant trigger element. Consequently the relative correlation functions need to be corrected for the effects of confinement (constituent p_T) before comparison to free-constituent-scattering models. These corrections[8] are in the proper directions and have sufficient magnitudes (using an average p_T kick of 1 GeV) to bring the corrected values for all species into consistency with one. (Note that this correction should not be made before comparison

TABLE I. Relative correlation functions.

Pair species	$r_{\alpha\beta}$	Statistical uncertainty	Systematic uncertainty
$\pi^+\pi^-$	1.32	0.05	0.04
$K^+\pi^-$	1.08	0.07	0.02
$p^+\pi^-$	0.50	0.10	0.18
π^+K^-	0.47	0.07	0.01
K^+K^-	0.60	0.12	0.05
p^+K^-	0.44	0.26	0.04
π^+p^-	0.45	0.39	0.24
K^+p^-	0.69	0.60	0.18
p^+p^-	2.03	1.79	0.98

Thoughts for RHIC

Do try this at home! It's easy and it's fun!

Basic observable $$\frac{d^3N}{dP_T^1\, dP_T^2\, d(\Delta\phi)}$$

1	2
γ^{incl}	$h^\pm$
γ	γ
π^0	$h^\pm$
$h^\pm$	$h^\pm$

Th: Predict pair rates and back-to-back enhancement with/without quenching, shadowing, $\langle K_T \rangle$, etc

Exp: Multiply by $\mathcal{L}^{RHIC}$, acceptances, triggers, reconstruction, PID, etc.

- Back-to-back high-P_T pairs identify a PQCD process unambiguously
- Quenching/shadowing/etc effects should be umistakeable at RHIC
- This is Year-1 Physics! even at reduced luminosity; $P_T^1 \sim 5 - 15$ GeV/c should be accessible in RHIC Year 1.

Conclusions

Medium effects on quarks + gluons can modify high-P_T hadrons and pairs.

High-P_T photons carry most of the information about high-P_T π^0's.

Back-to-back analysis underway in WA98 data; nothing conclusive yet but technique is tractable.

Should be straightforward early analysis in PHENIX and STAR; SPS results form baseline.