

Wit Busza

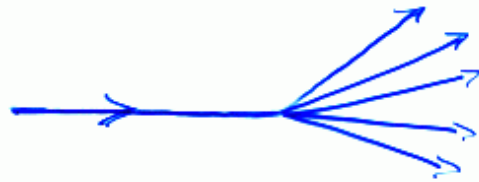
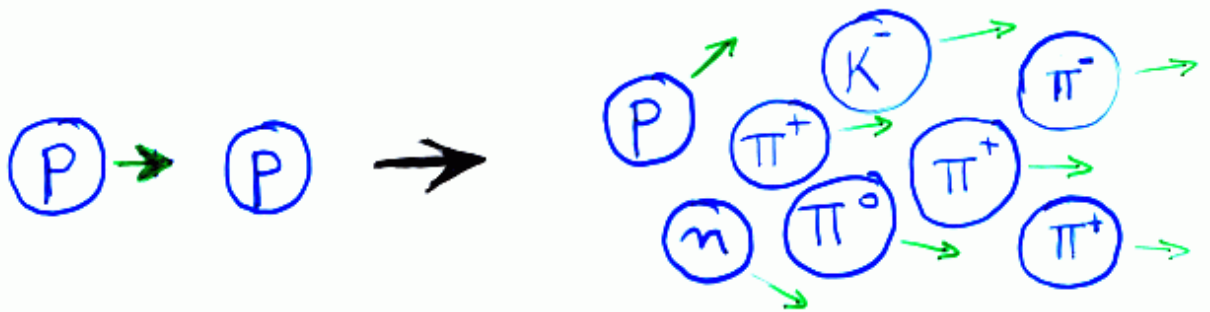
Goldhaber Symposium

October 7, 2001

COLLIDING NUCLEI AT ULTRA RELATIVISTIC VELOCITIES



PP COLLISION @ 100 GeV

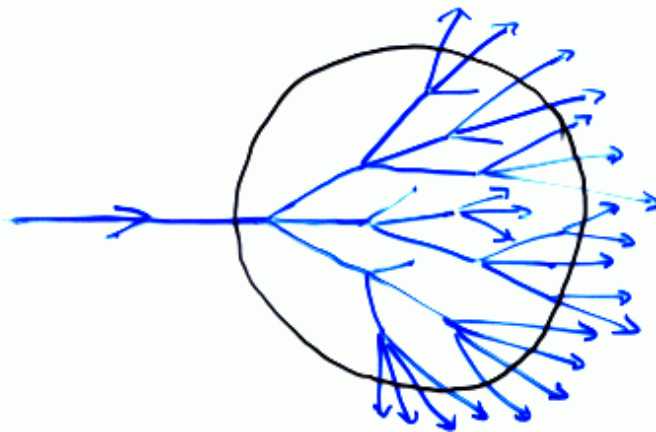


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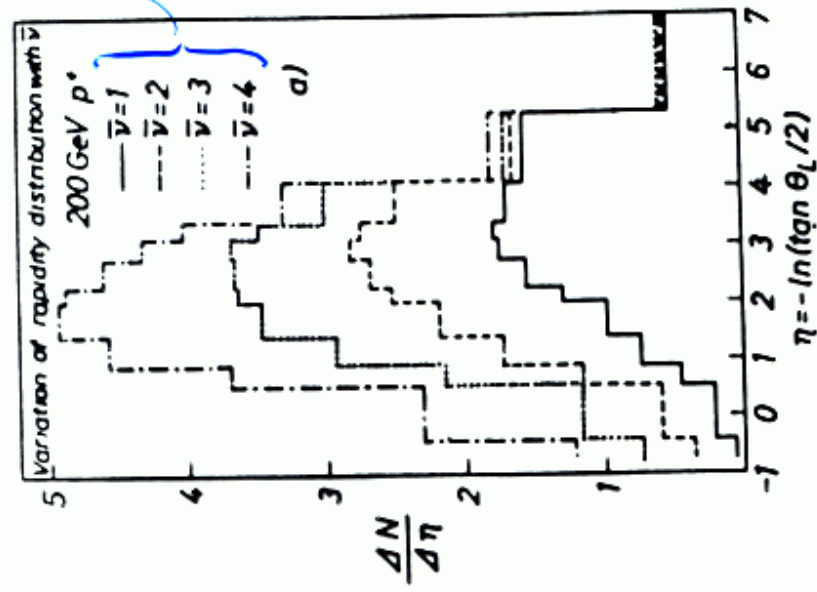
COLLISION INSIDE A NUCLEUS SHOULD RESOLVE THE ISSUE :



DIFFERENT NUMBER OF
"PARTICIPATING NUCLEONS", N_{PART}
MEASURED BY THICKNESS OF
THE NUCLEUS

(# OF NUCLEONS HIT BY
INCIDENT PROTON)

OF
PARTICLES



GALILEAN TRANSFORMATION :

$$V = V_1 + V_2$$

RELATIVISTIC TRANSFORMATION

$$V \neq V_1 + V_2$$

BUT $\gamma = \gamma_1 + \gamma_2$

WHERE $\gamma \equiv \tanh^{-1} \frac{v}{c}$

C = SPEED
OF
LIGHT

↑
"RAPIDITY"

& $\eta \approx \gamma$ CALLED "PSEUDORAPIDITY"
 $\eta \equiv -\ln \tan \frac{\theta}{2}$

"RELATIVISTIC" VELOCITY
RAPIDITY γ
OR

PSEUDORAPIDITY η

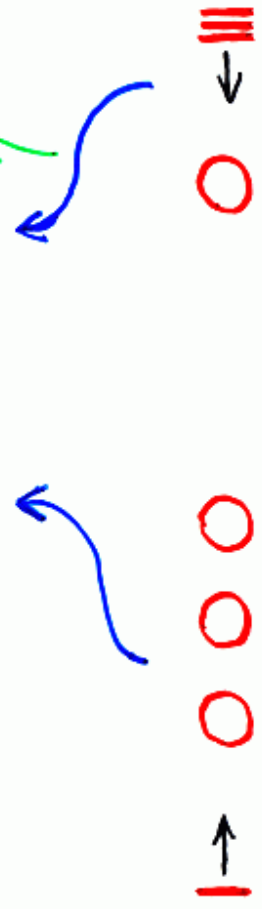
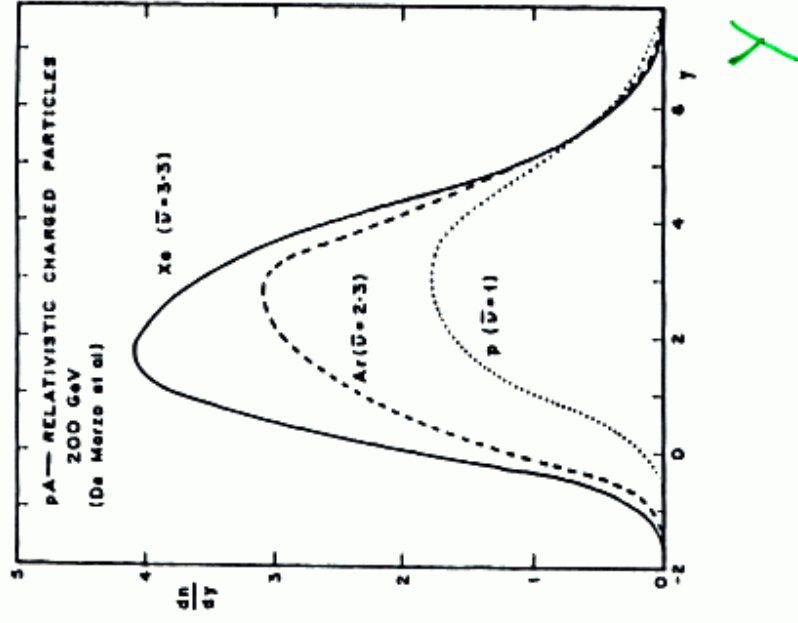
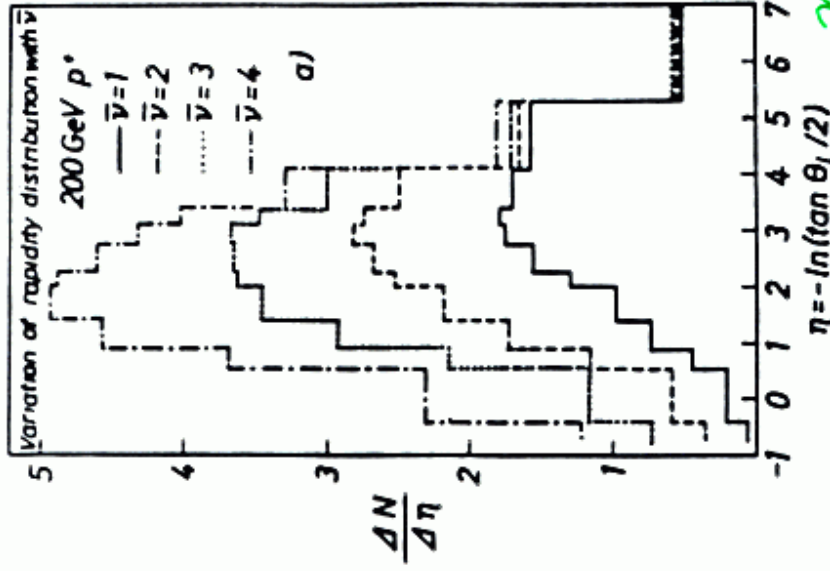
Alfred S. Goldhaber

Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11790
(Received 15 April 1974)

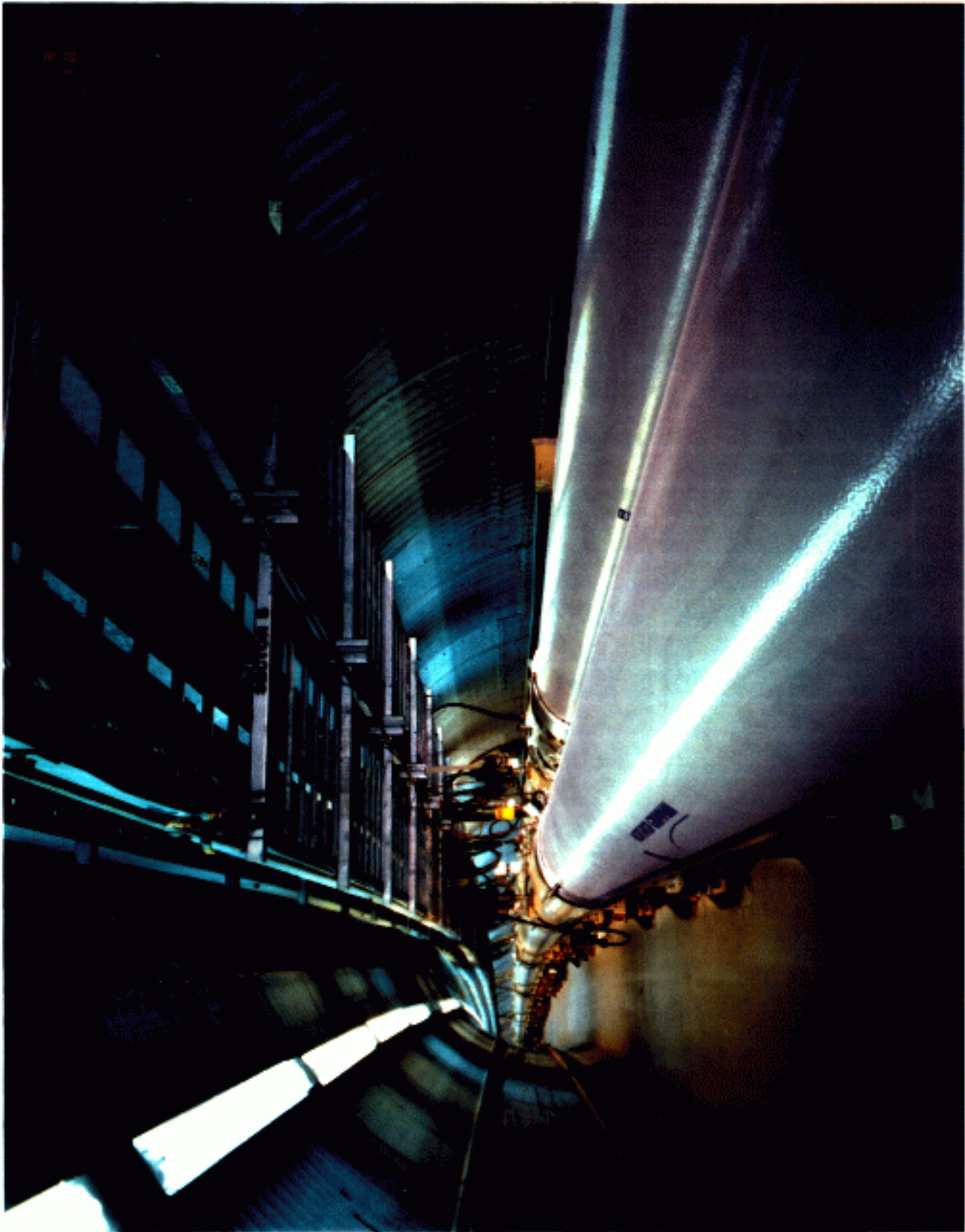
High-energy hadron-hadron collisions are viewed as proceeding by a strong short-range "quark-quark" interaction, generating a "spark" in the form of a self-interacting meson field, which yields observable mesons only after the incident particles have passed. This picture leads to the possibility of rare events with high multiplicity. There is a definite contradiction to Gottfried's recent model of multiple production in *nuclei*, but little practical distinction for beams below 1 TeV.

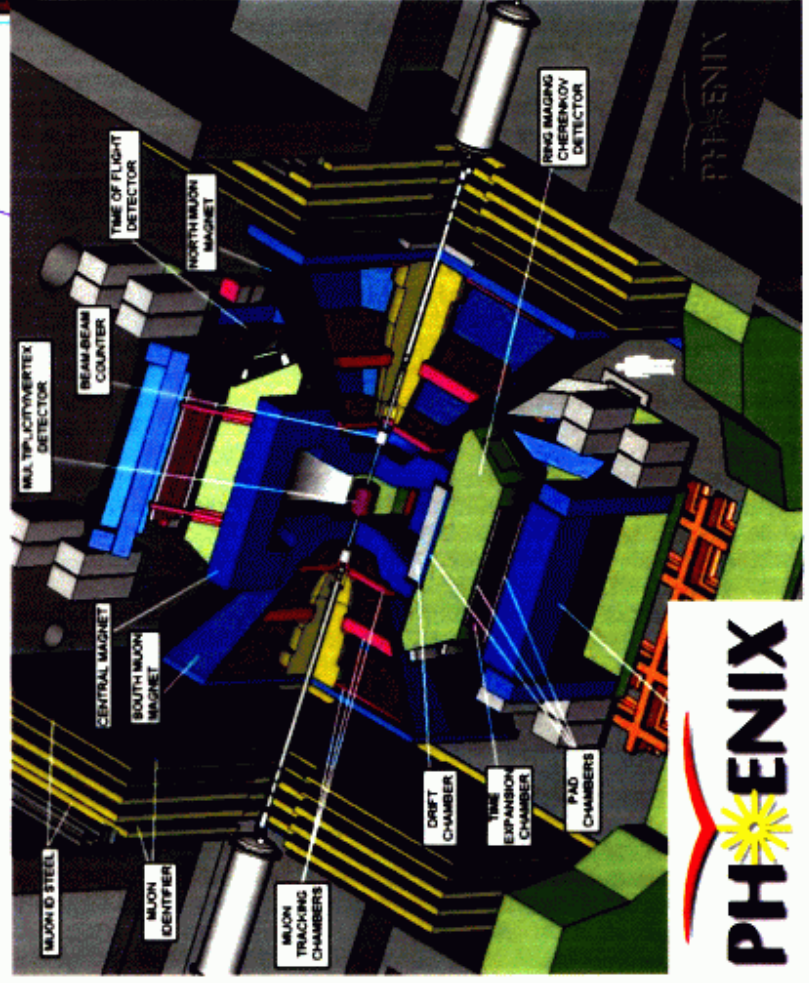
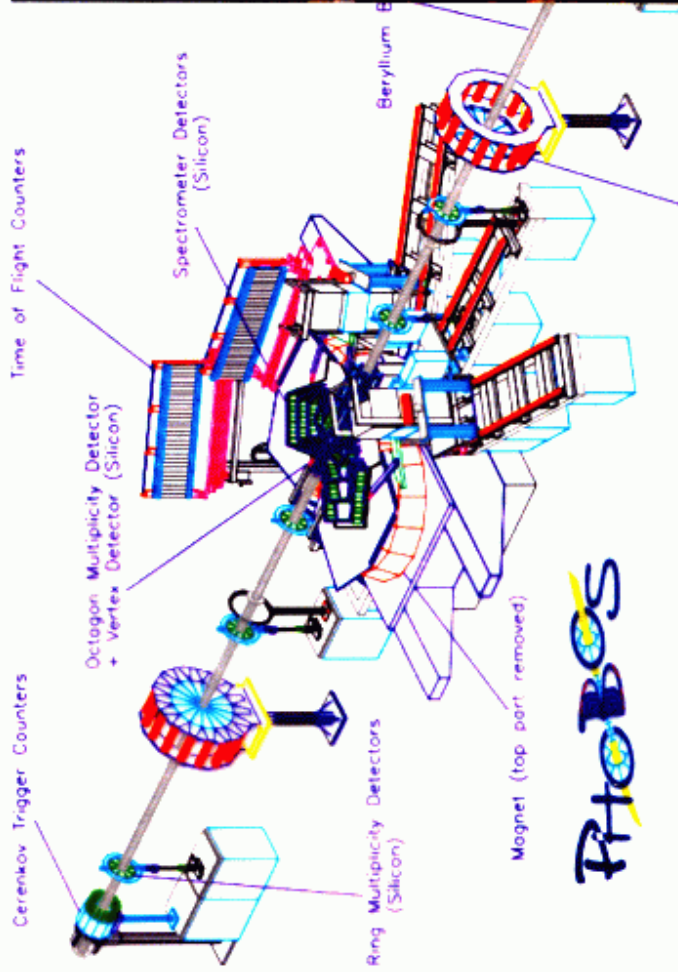
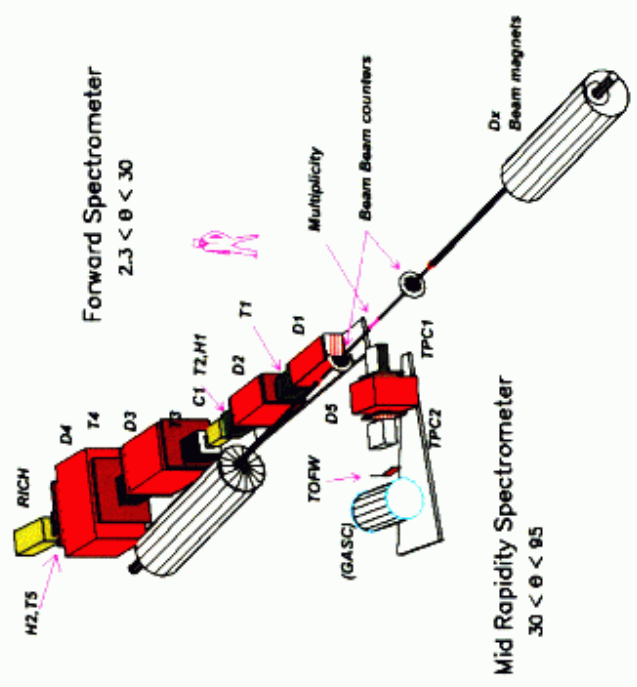
MESSAGE:

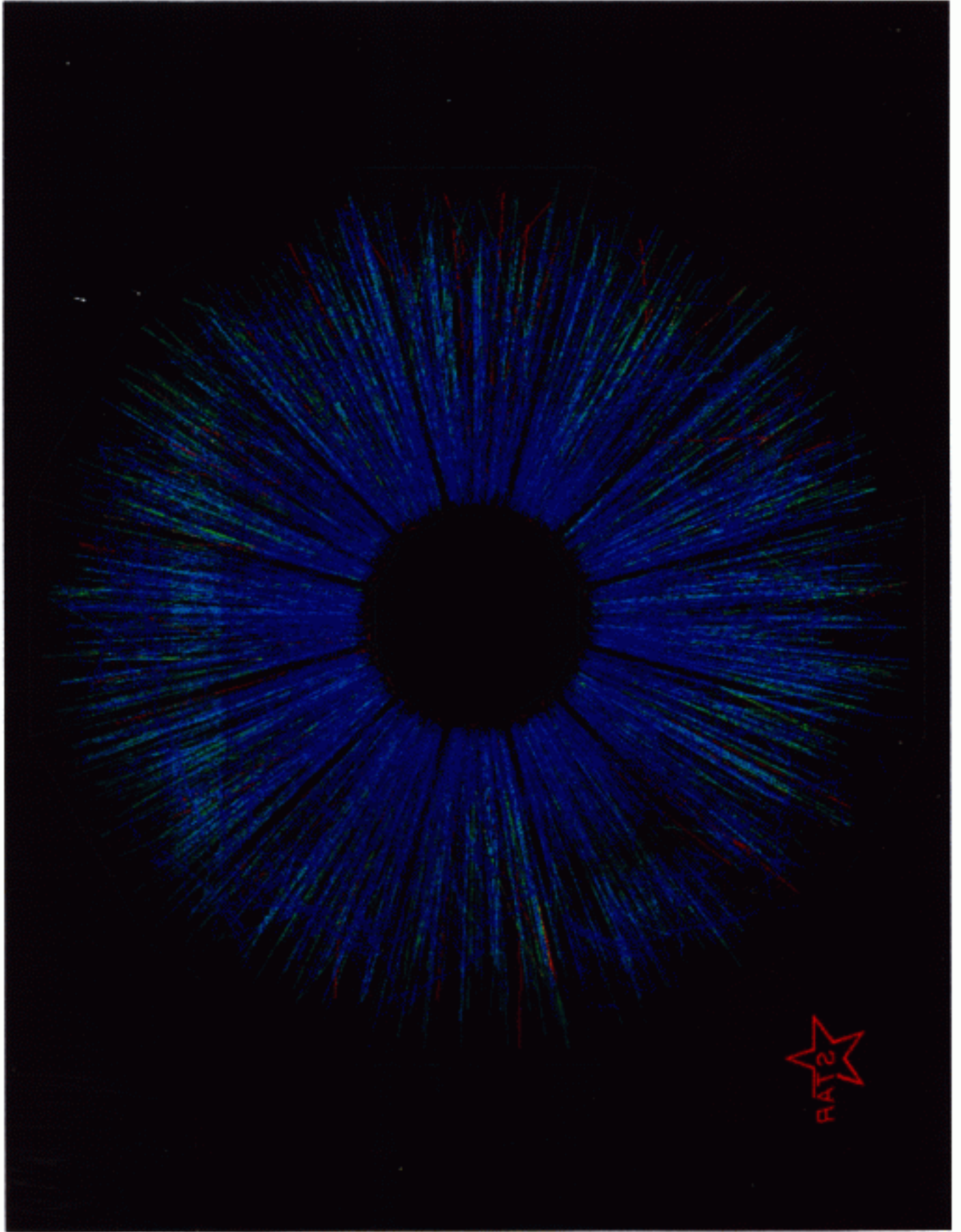
LOOK IN REST FRAME
OF PRODUCED PARTICLE

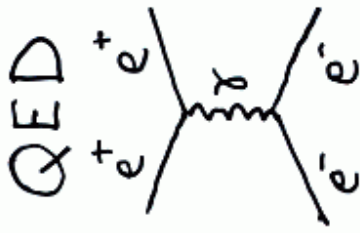








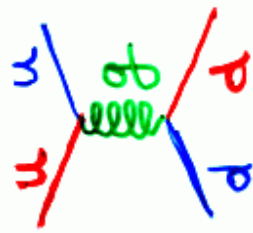




atoms
molecules
gases
liquids
solids
lasers
superconductivity
...



QCD



+

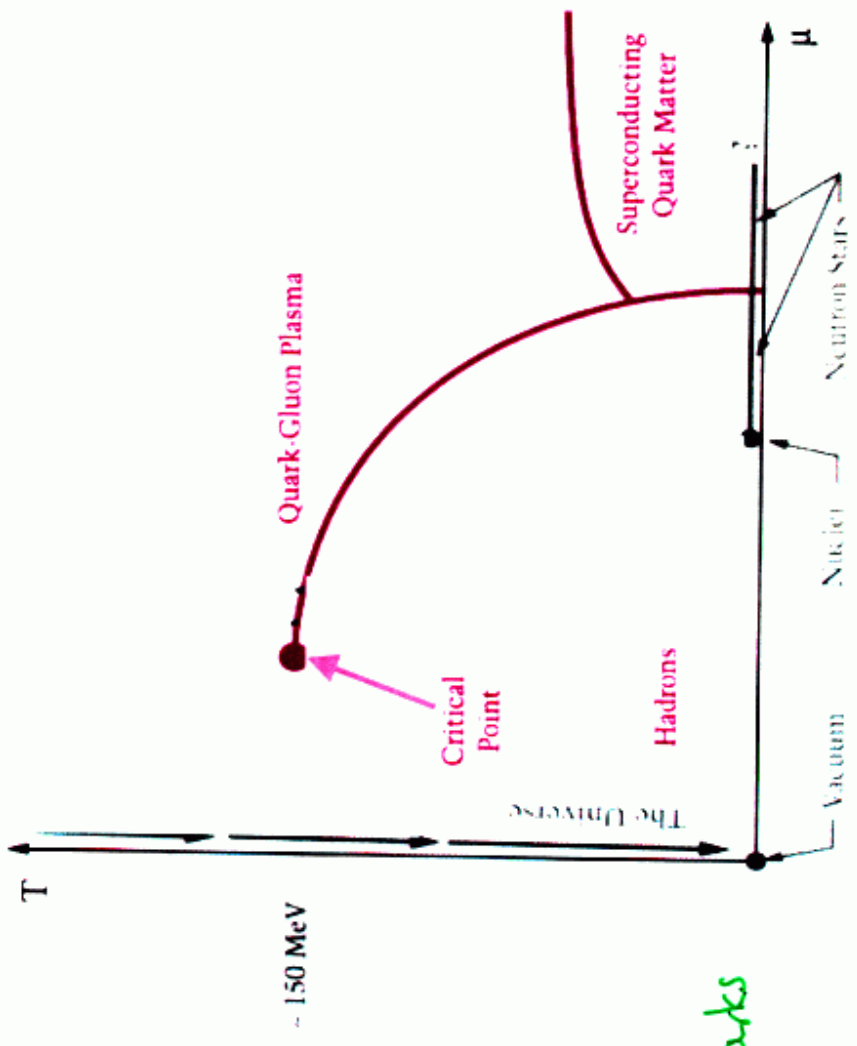
gluons
free quarks

a very interesting vacuum
confinement of quarks
protons
pions
nuclei
...



TEMPERATURE OR

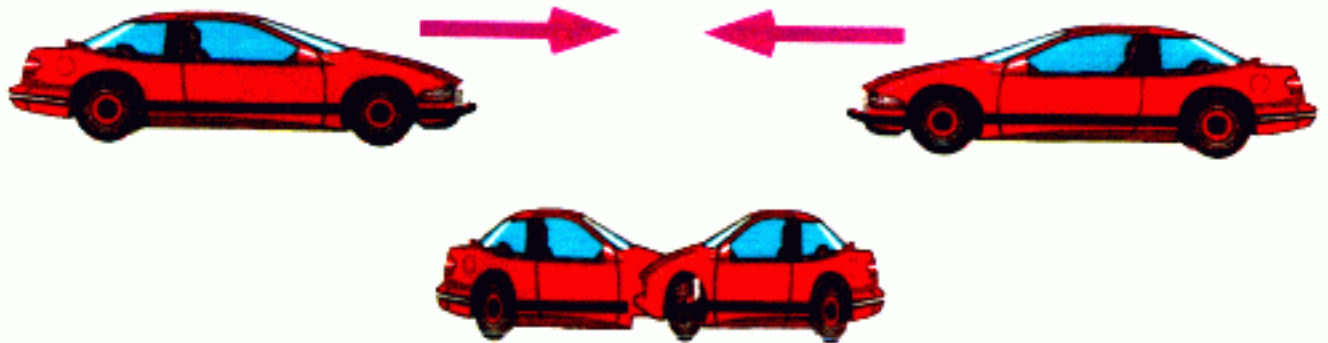
Energy Density



Baryon Density

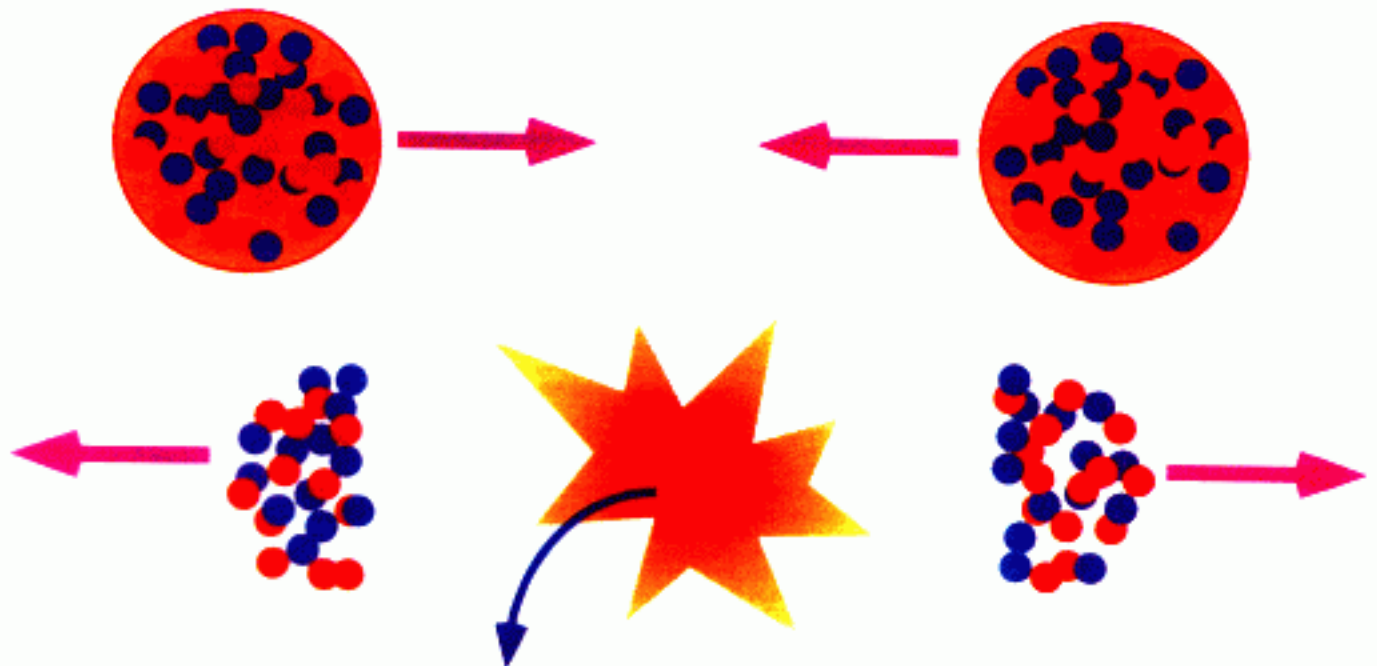
(MATTER DENSITY)

Creating High Energy Density through Colliding Nuclei



Gold Nucleus

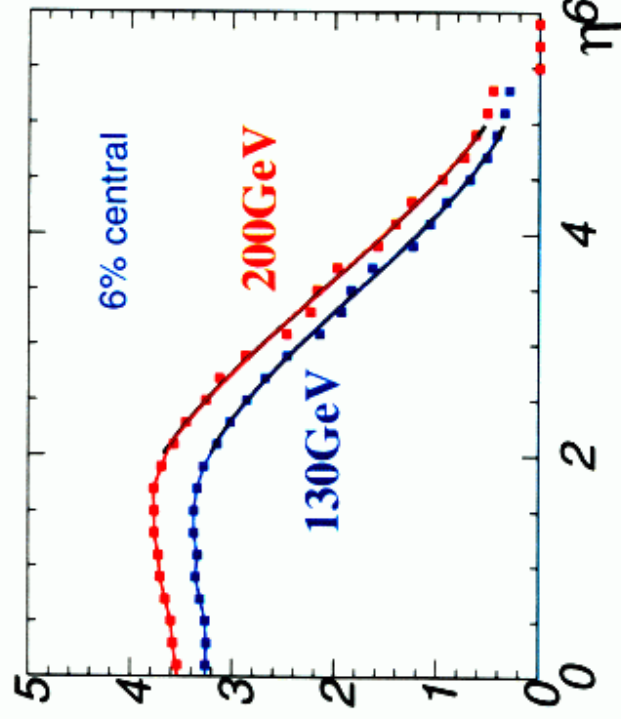
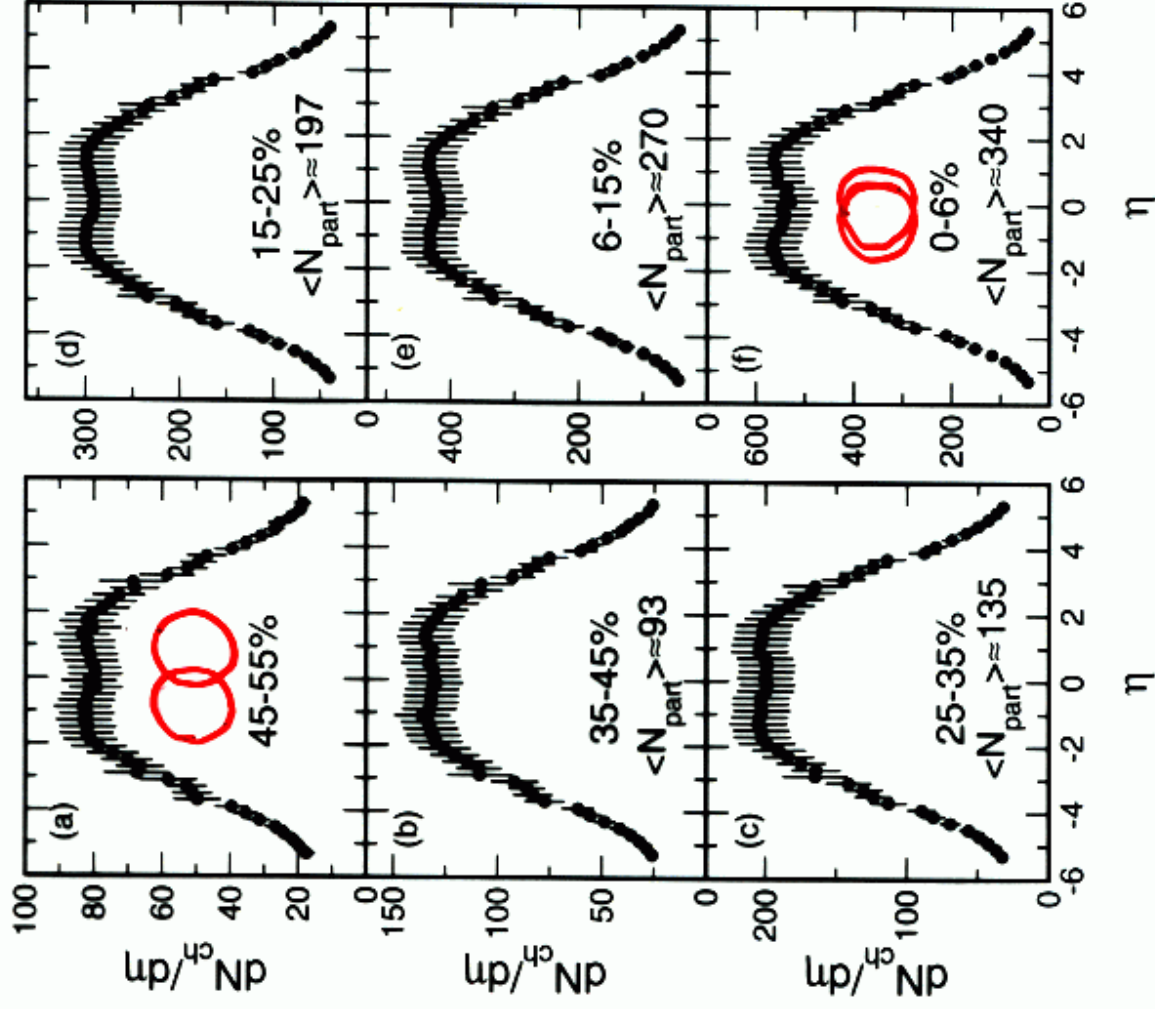
Gold Nucleus



Energy density greater than that inside a proton,
similar to that of the universe at a millionth
of a second after the Big Bang... called the

QUARK GLUON PLASMA

AuAu 130GeV



"RELATIVISTIC" VELOCITY
PSEUDORAPIDITY

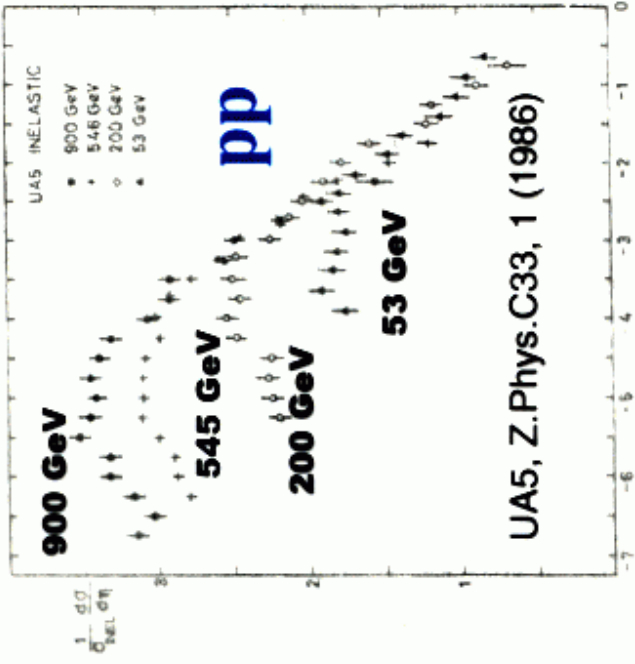
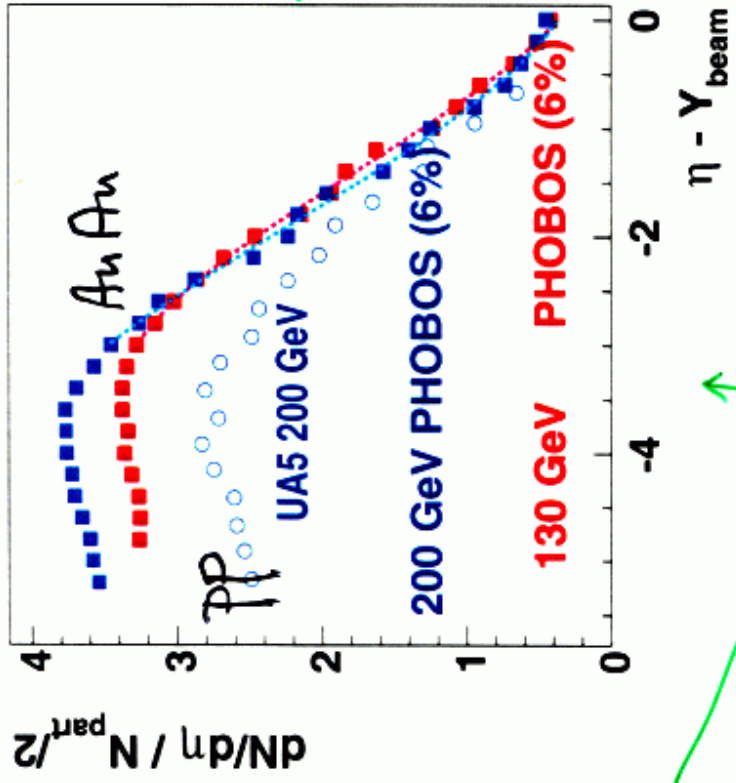
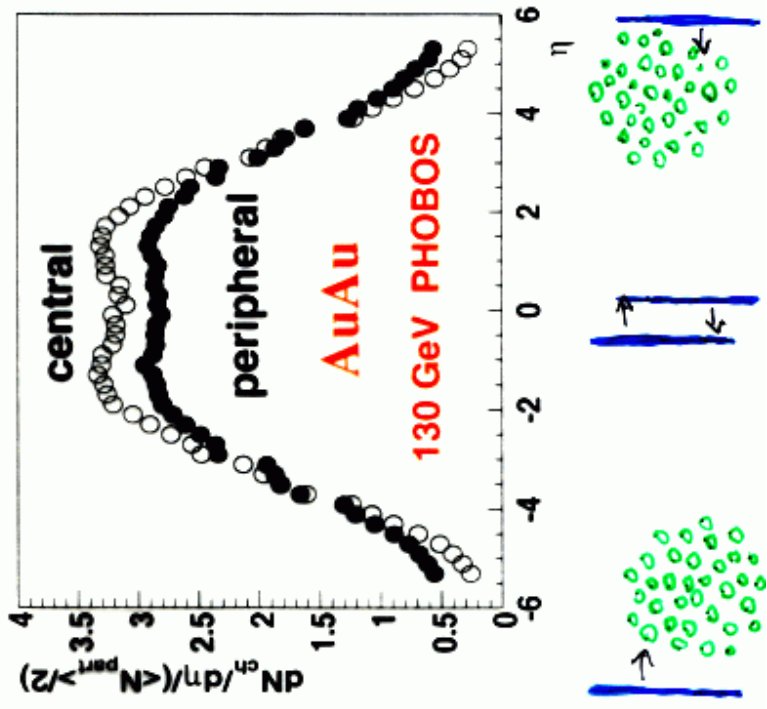


FIG. 5



↑ PLOTTED IN REST FRAME OF ONE NUCLEUS

← PLOTTED IN CM REST FRAME

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NUCLEAR STOPPING POWER

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*Institute for Theoretical Physics, State University of New York at Stony Brook,
Stony Brook, Long Island, NY 11794, USA*

pp. 235-238

17 May 1984

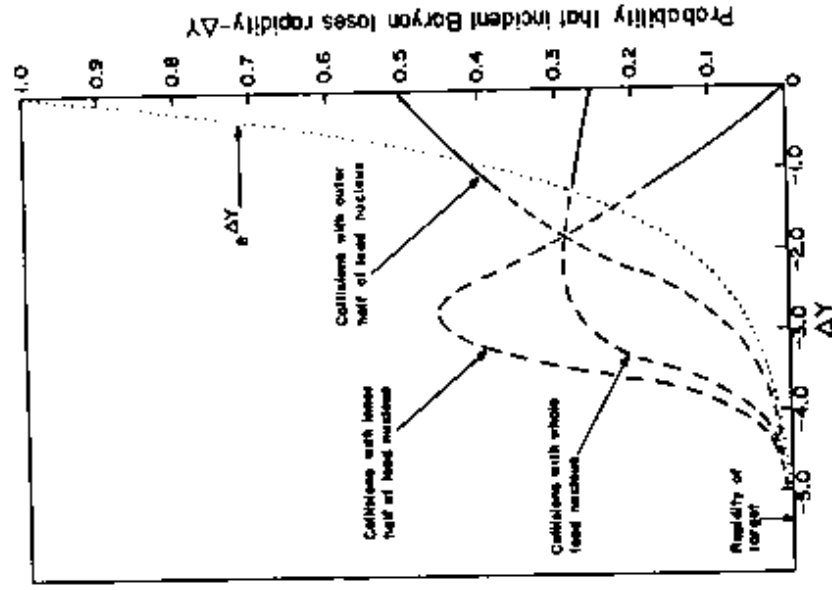
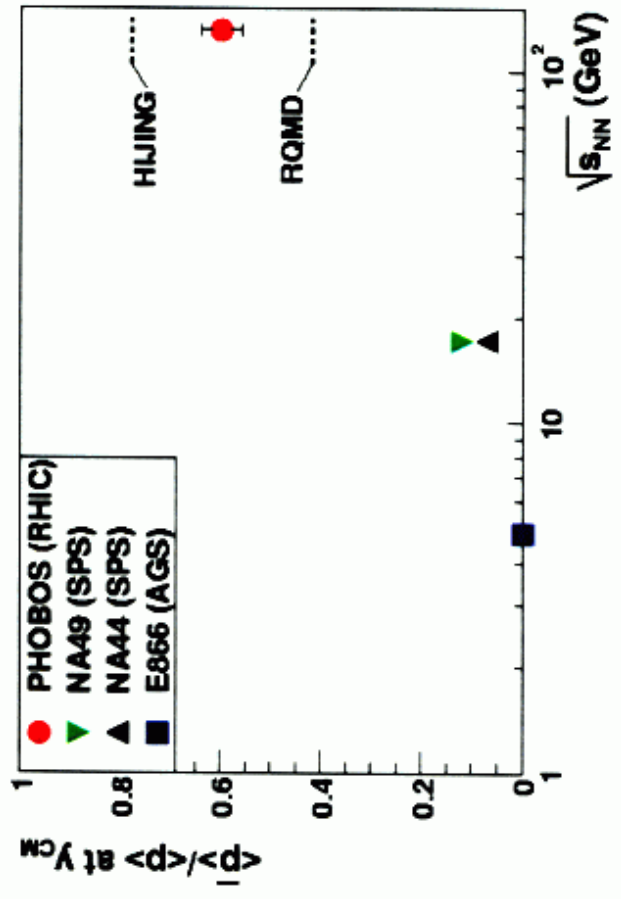
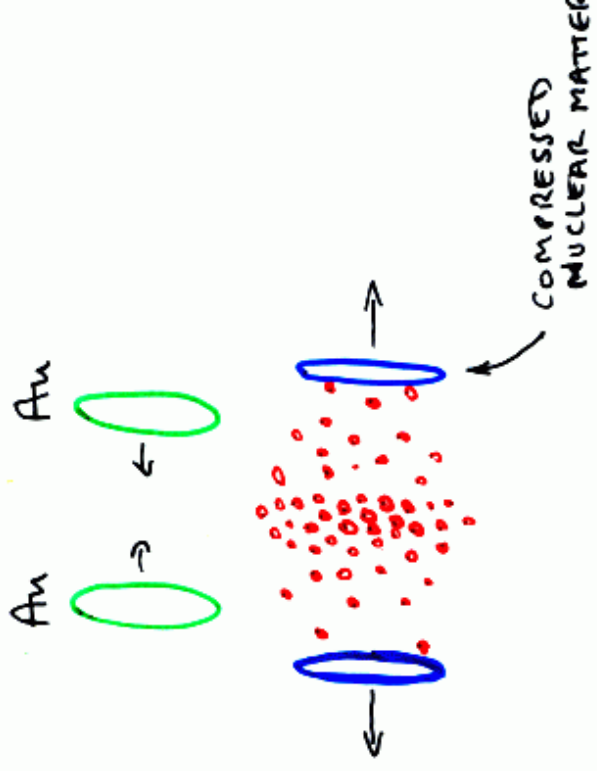
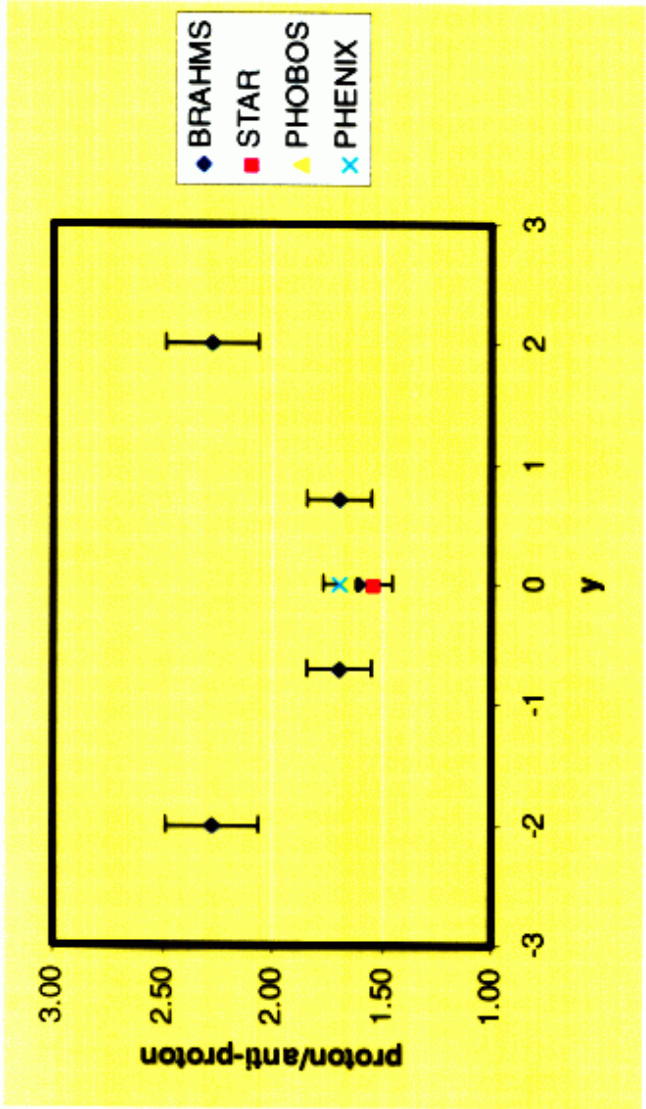
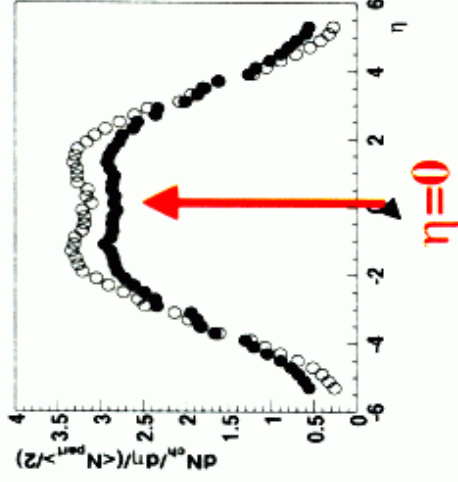
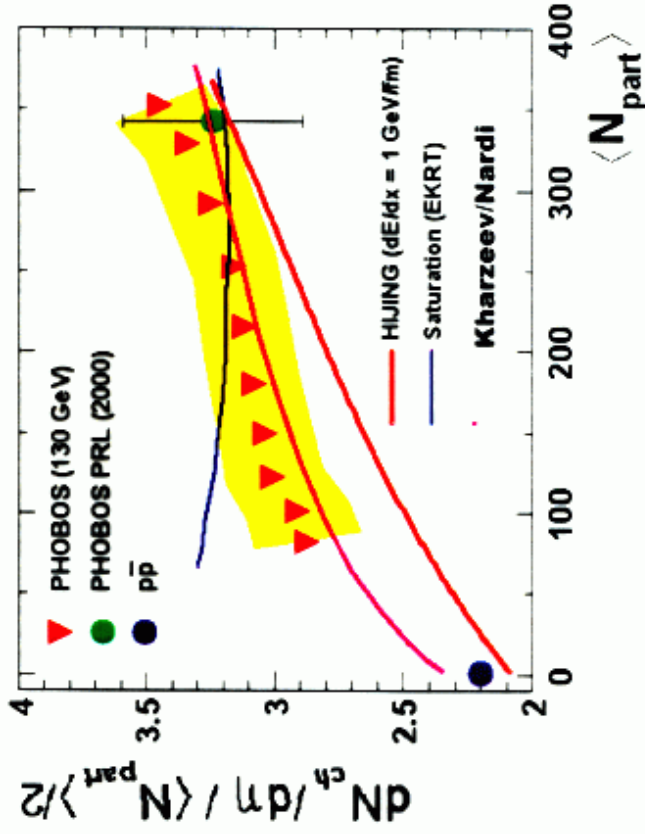


Fig. 3. Extrapolated probability distributions for rapidity loss of protons striking lead nuclei. The dashed lines are the extrapolated portions. The constraint that the normalized total, central, and peripheral inclusive cross sections should all be smooth makes the extrapolations nearly unique.

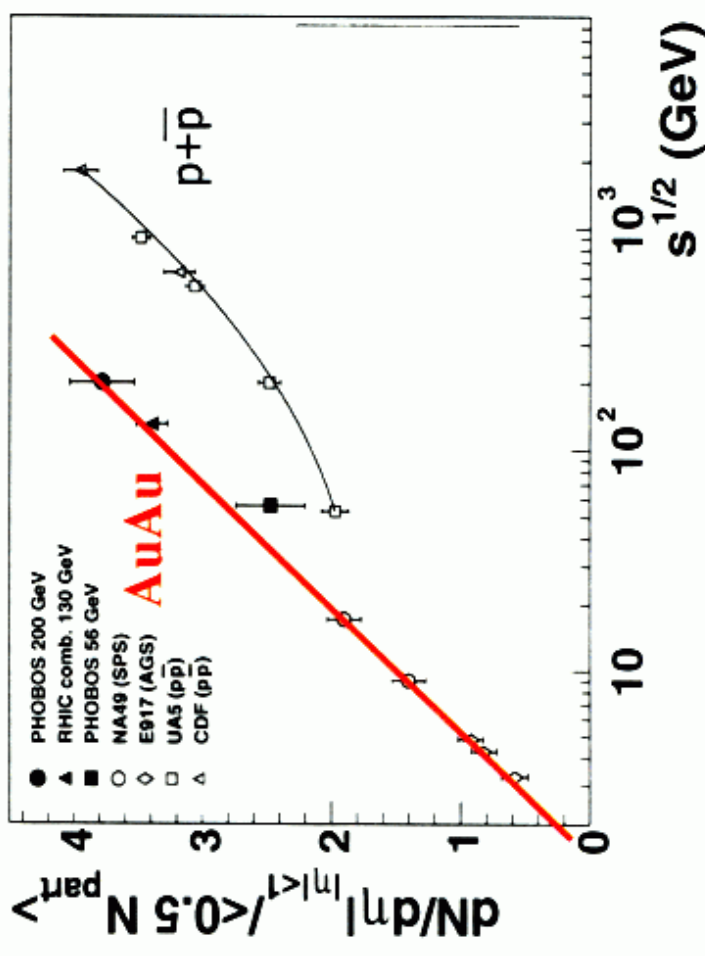




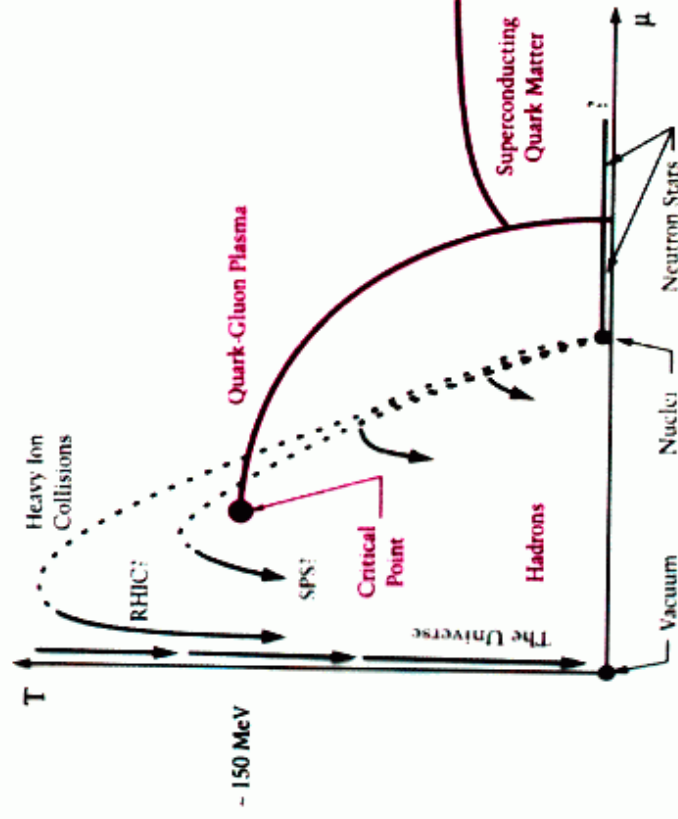
Centrality Dependence at $\eta=0$ 130 GeV



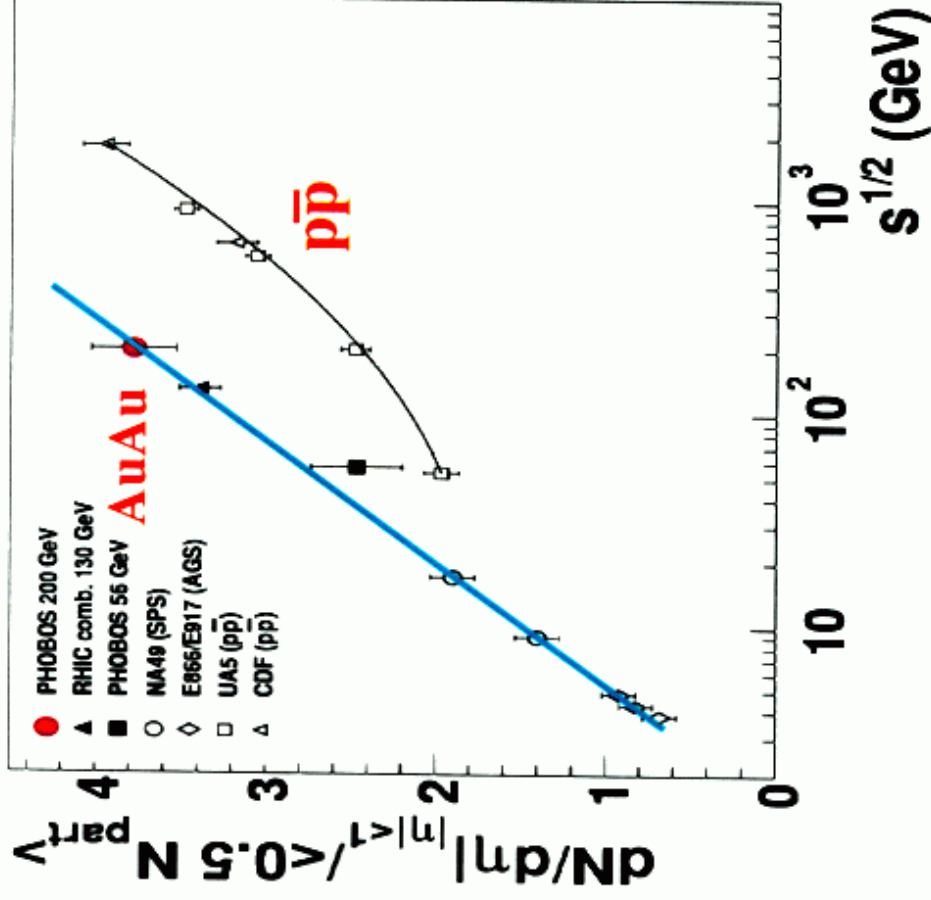
Multiplicity at $\eta \approx 0$ vs Energy



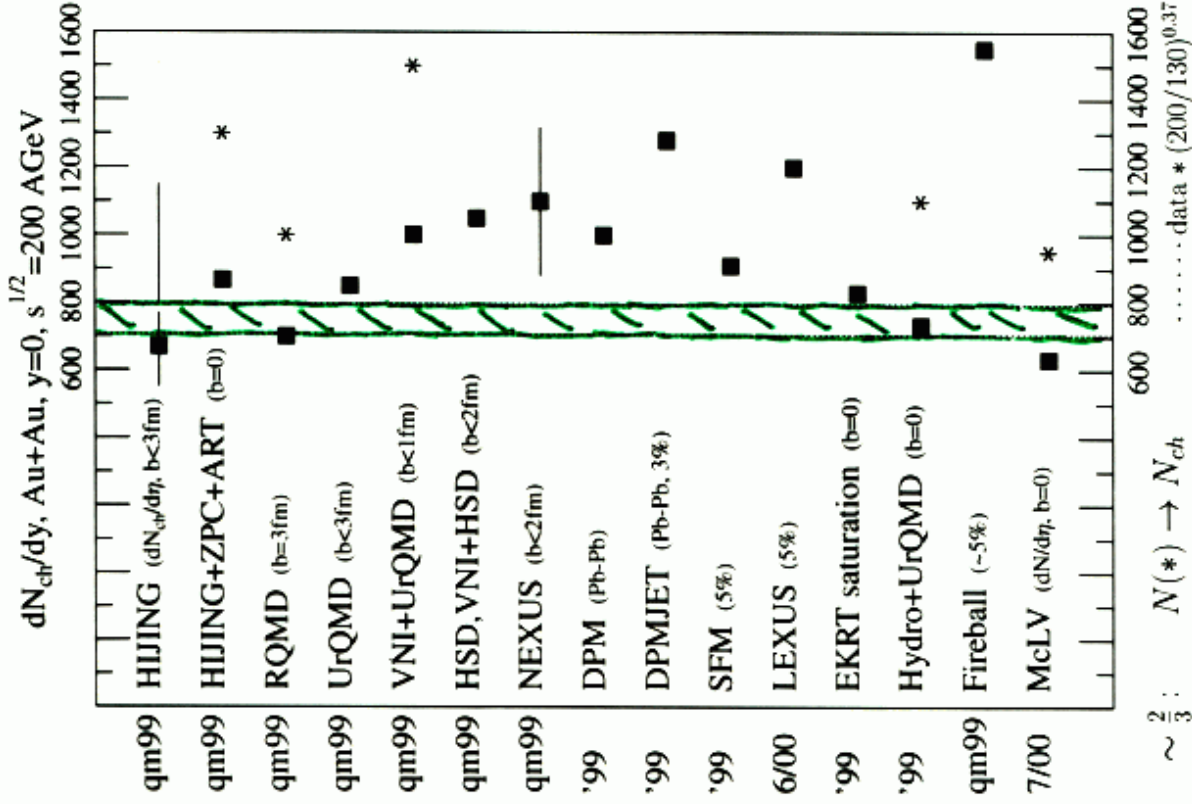
Energy Density or Temperature



Baryon Density



Predictions:



$\sim \frac{2}{3} : N(*) \rightarrow N_{ch}$

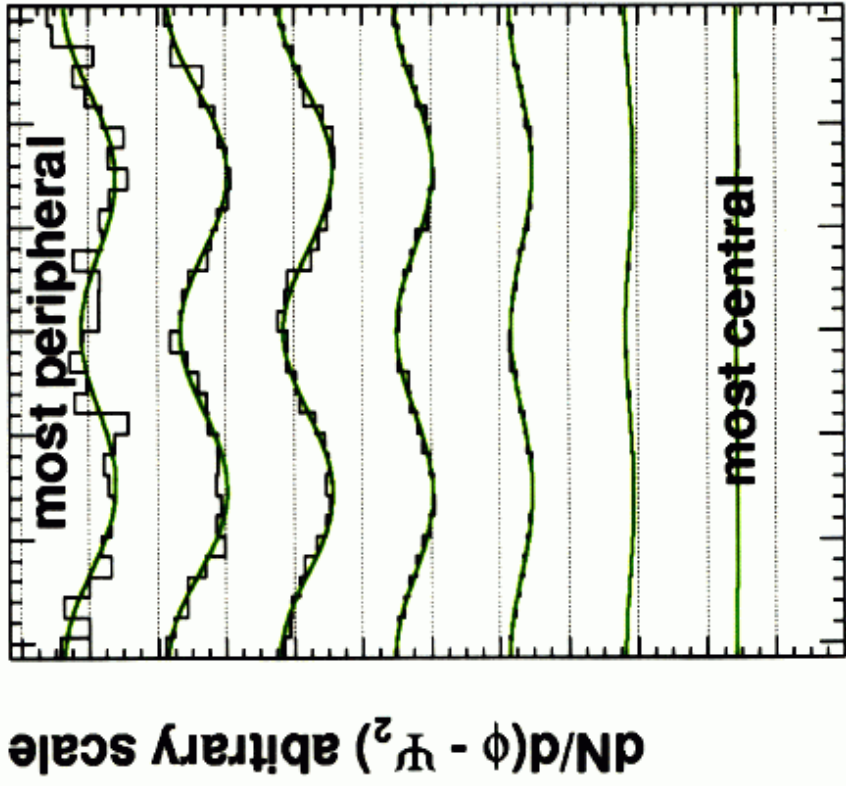
$\sim 1.1 : \eta \rightarrow y$

$\sim 0.9 : b = 0 \rightarrow b \lesssim 3 \text{ fm}(5\%)$

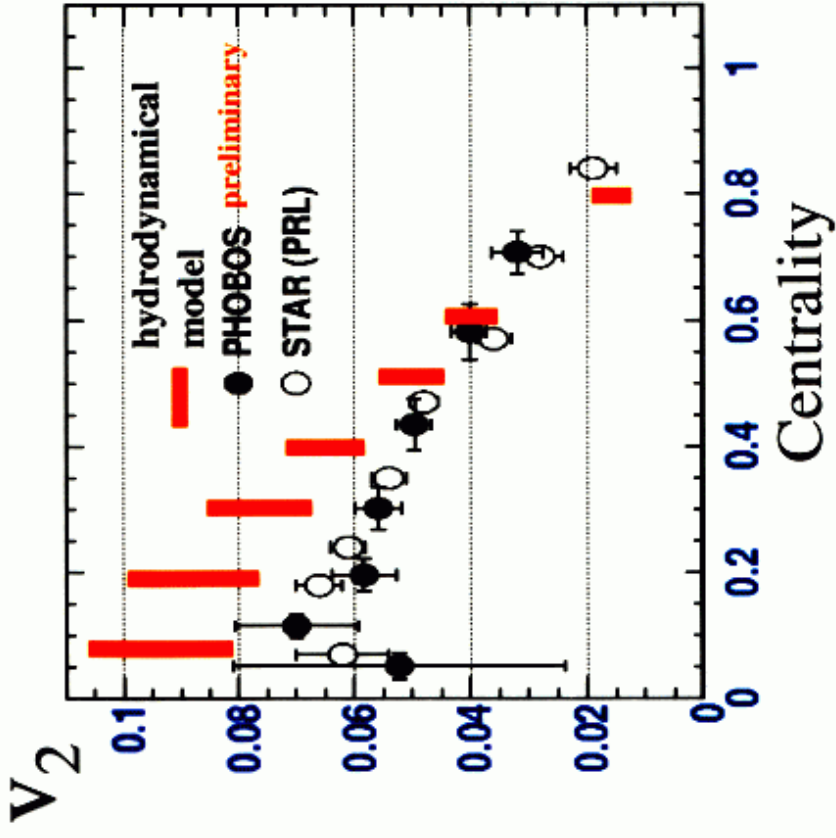
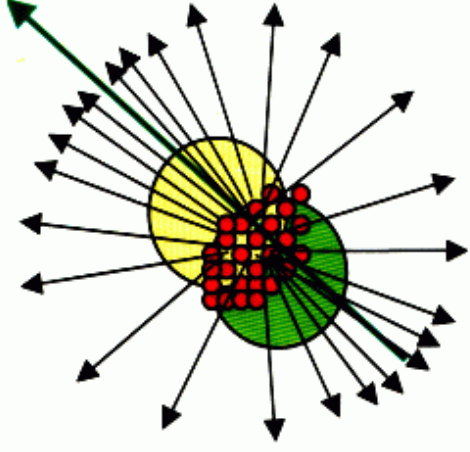
see [Arnesato, Pajares, hep-ph/0002163]

Elliptic Flow

NEAR $y = 0$



PHOBOS -2 -1 0 1 2 3
 $\phi - \Psi_2$ (radian)



X3 AGS
 50% MORE
 THAN AT
 SPS



m_T Spectra

BOLTZMANN DISTRIBUTION:

$$\frac{dN}{m_T^2 dm_T} \sim e^{-m_T/T}$$

∴ SLOPES SHOULD BE THE SAME

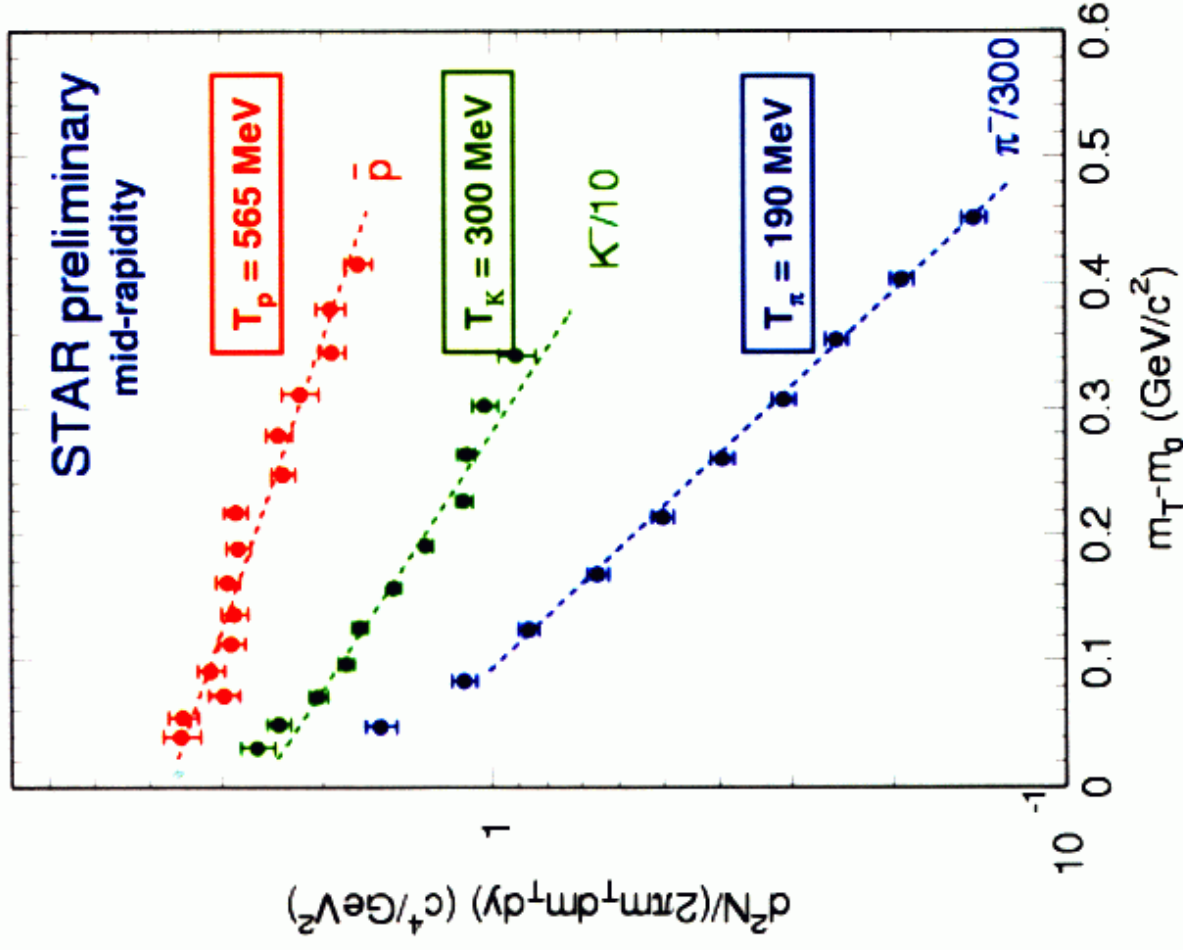
RESULTS SUGGEST

RADIAL VELOCITY OF SYSTEM $> 0.5c$!

(ALREADY SEEN @ SPS)

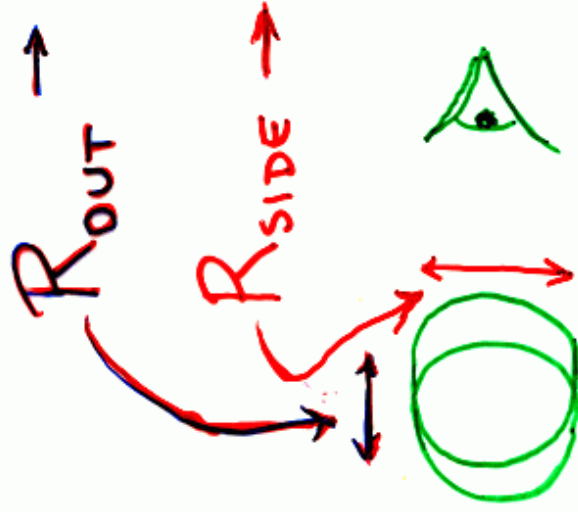
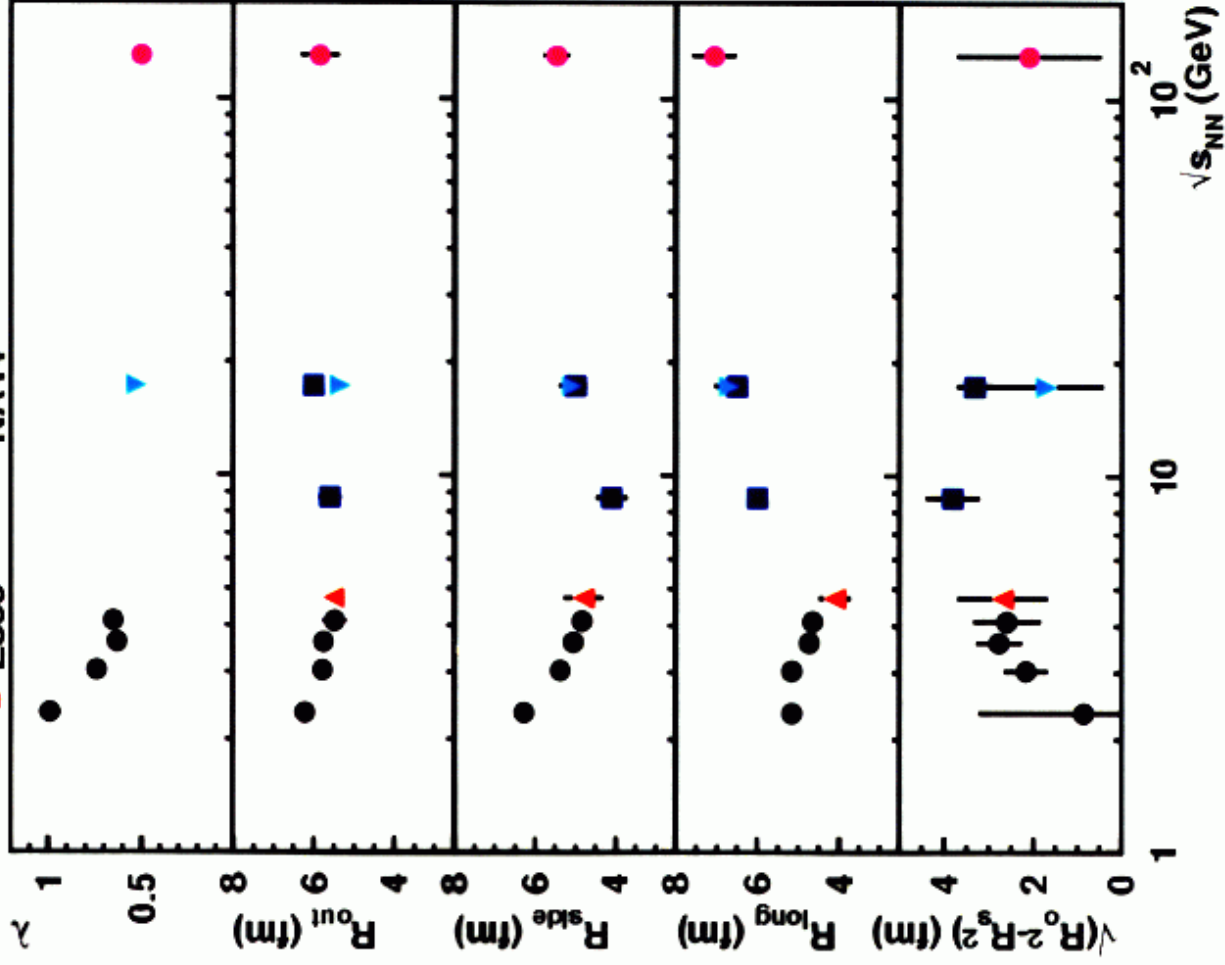
$$m_T^2 \equiv m_0^2 + P_T^2$$

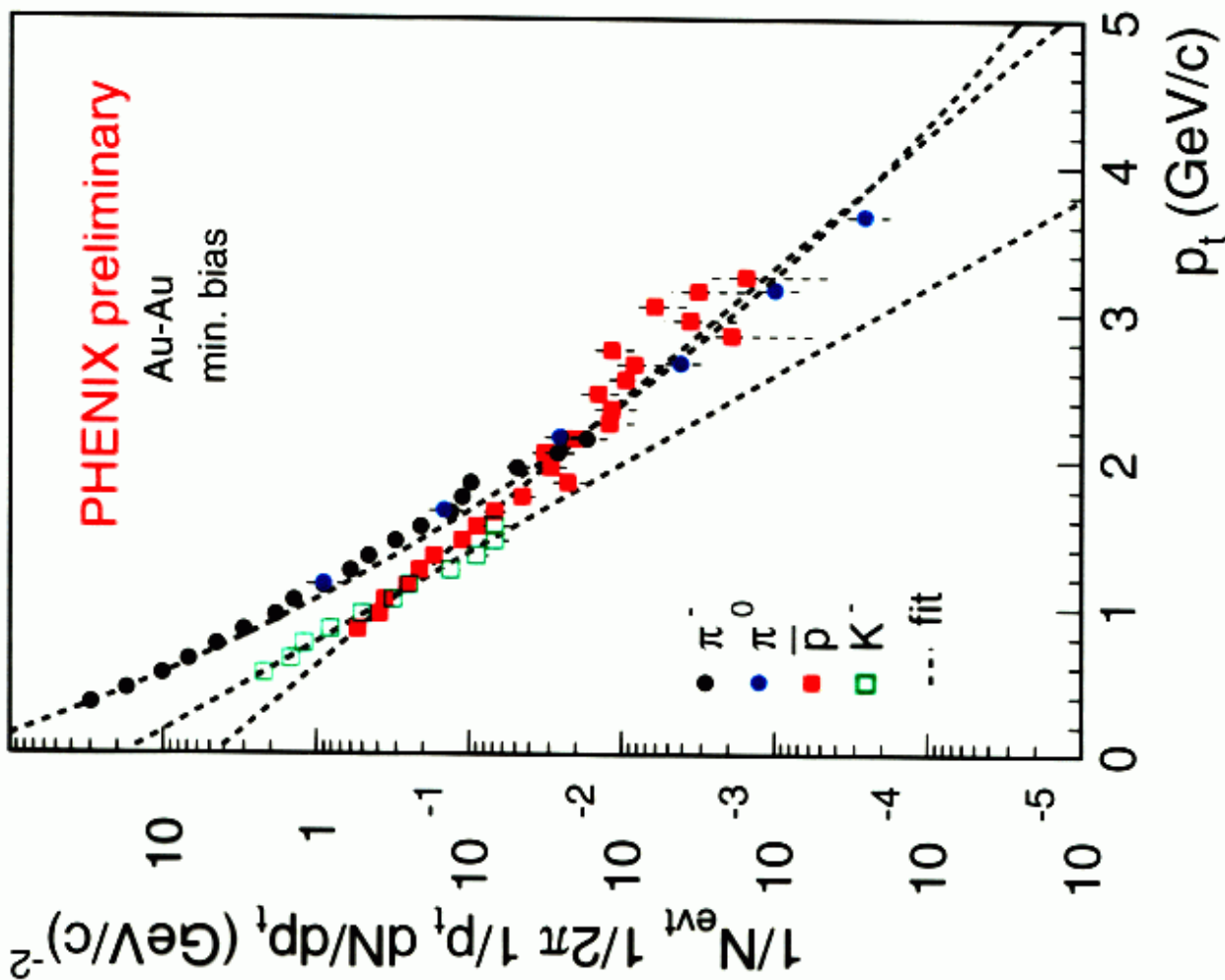
Au+Au central collisions



The HBT Excitation function

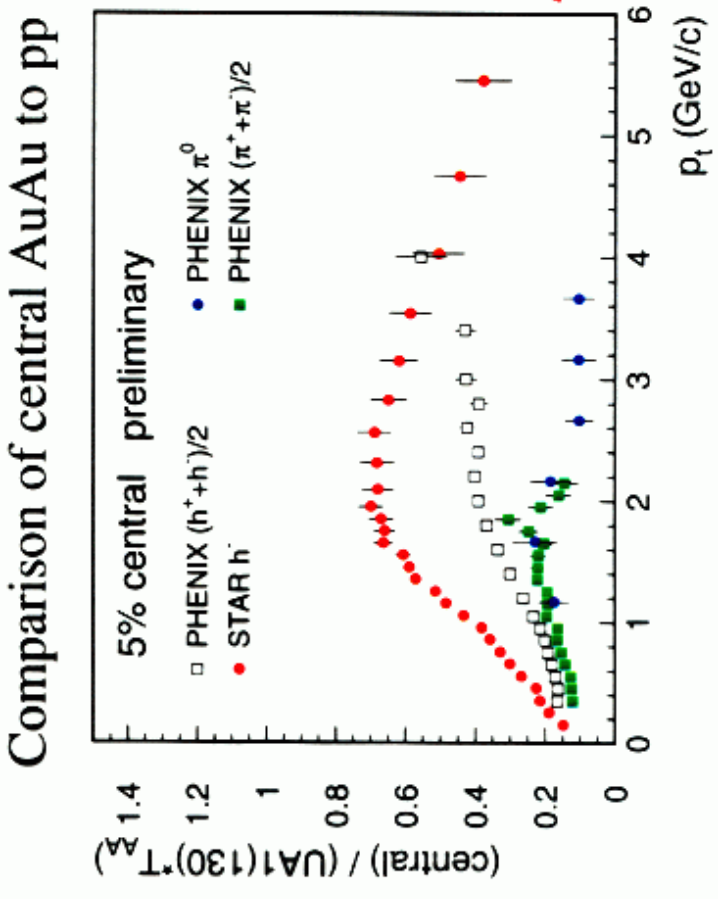
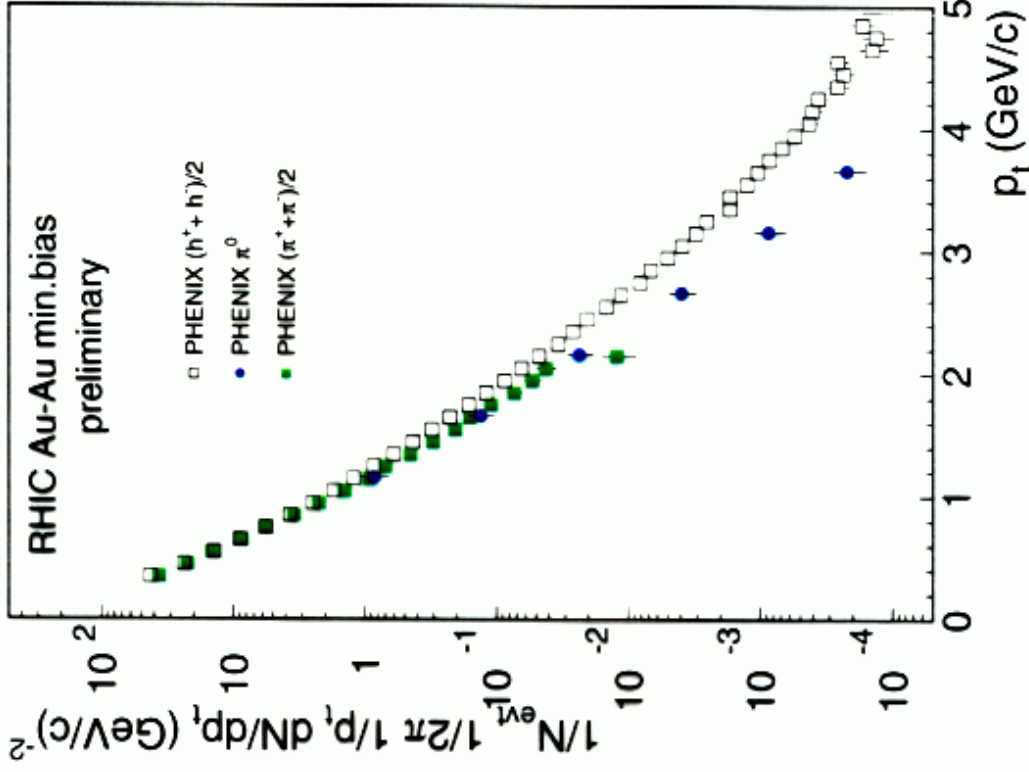
STAR
Preliminary





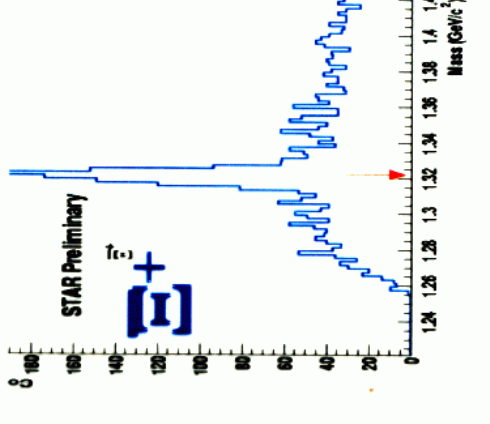
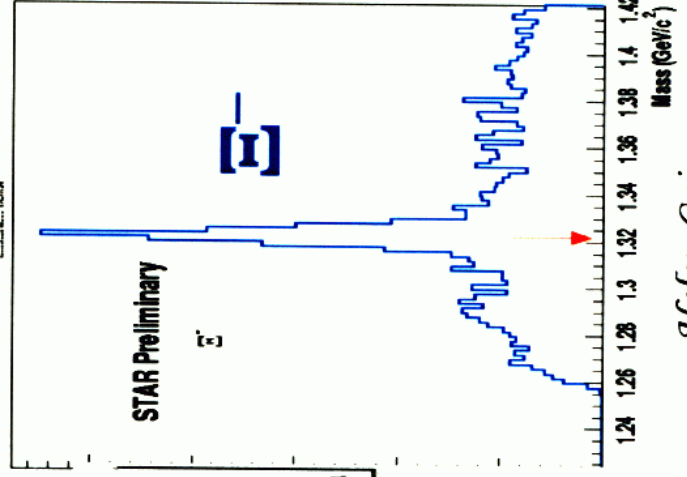
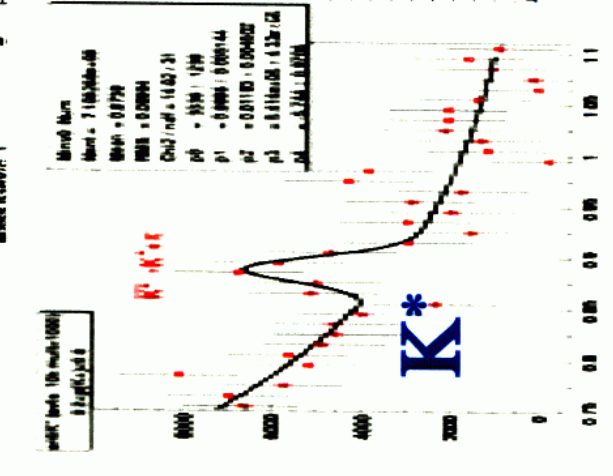
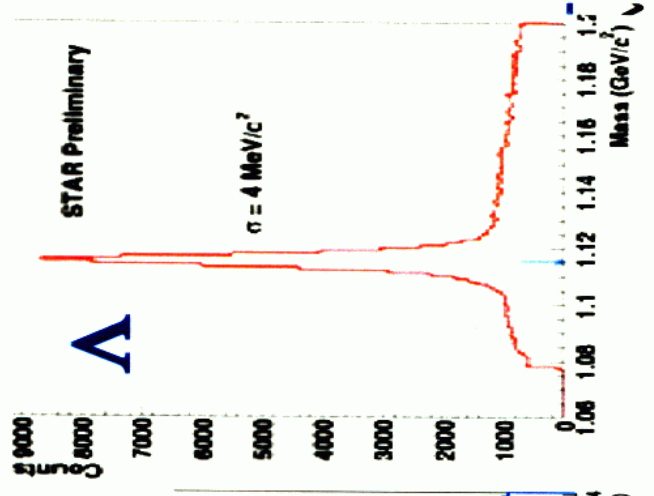
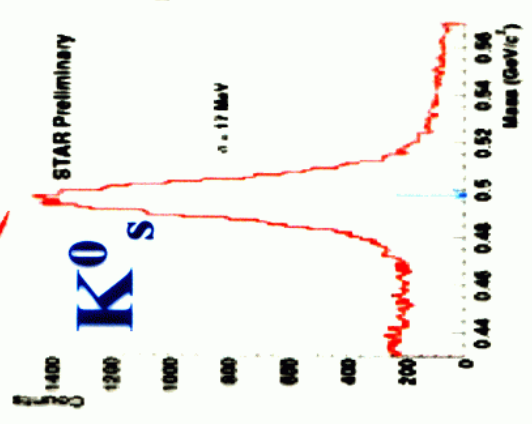
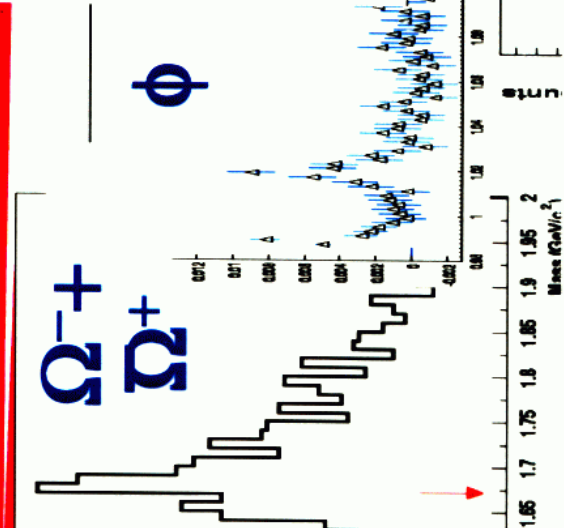
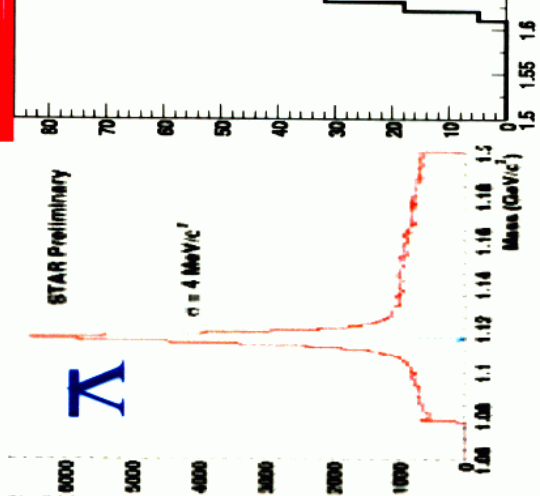
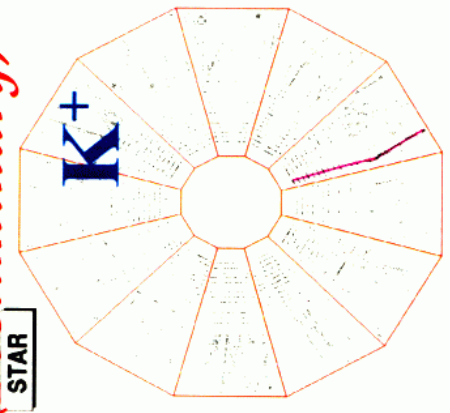
P > π
@ p_t > 2 GeV/c !

Jet quenching

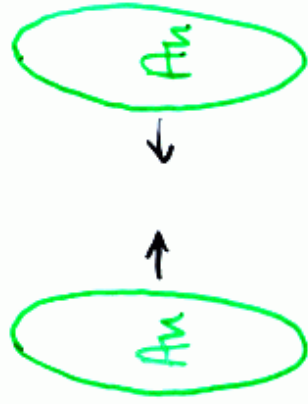


Data from Drees QM01

STAR STRANGENESS! (Preliminary)



Helen Caines



ENERGY DENSITY
 INCREASES SMOOTHLY
 WITH ENERGY
 AT RHIC $\gg 1 \text{ GeV}/\text{fm}^3$
 WITH HIGH PRESSURE

FRAGMENTATION
 AS YOU WOULD
 EXPECT FROM PP
 & pA

So Fred, what's going on?