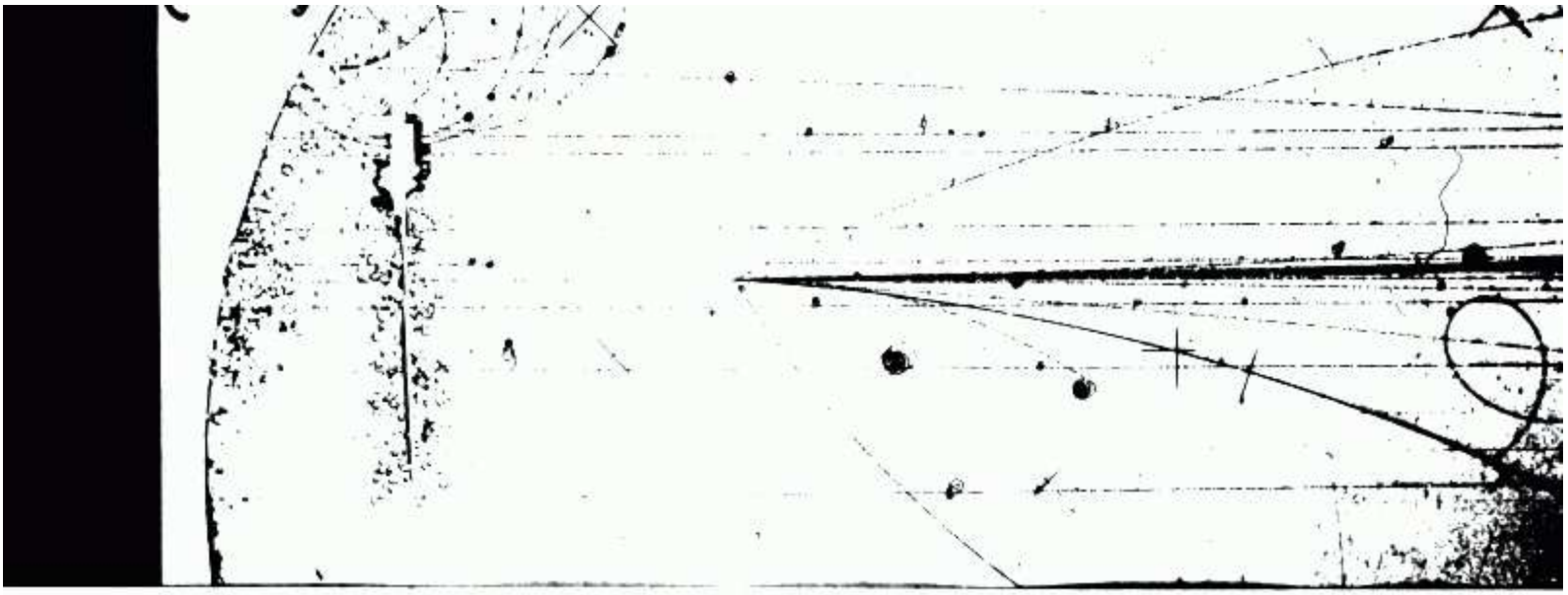
Wit Busza

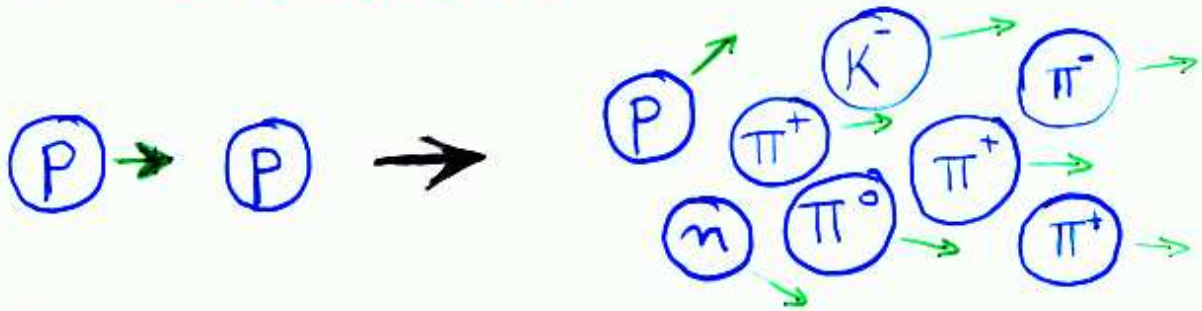
Goldhaber Symposium

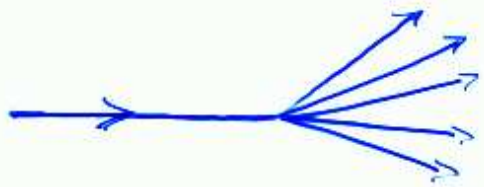
October 7, 2001

COLLIDING NUCLEI AT ULTRA RELATIVISTIC VELOCITIES

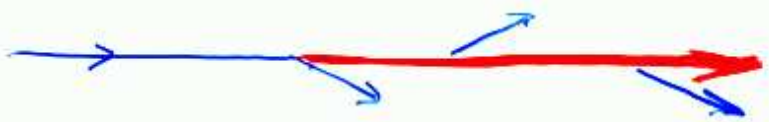


PP COLLISION @ 100 GeV



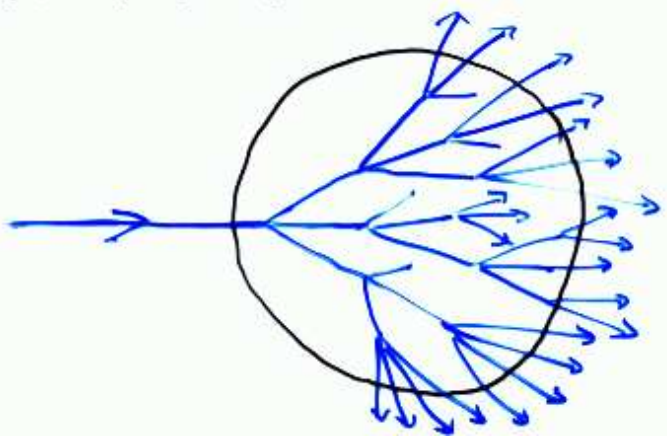


?

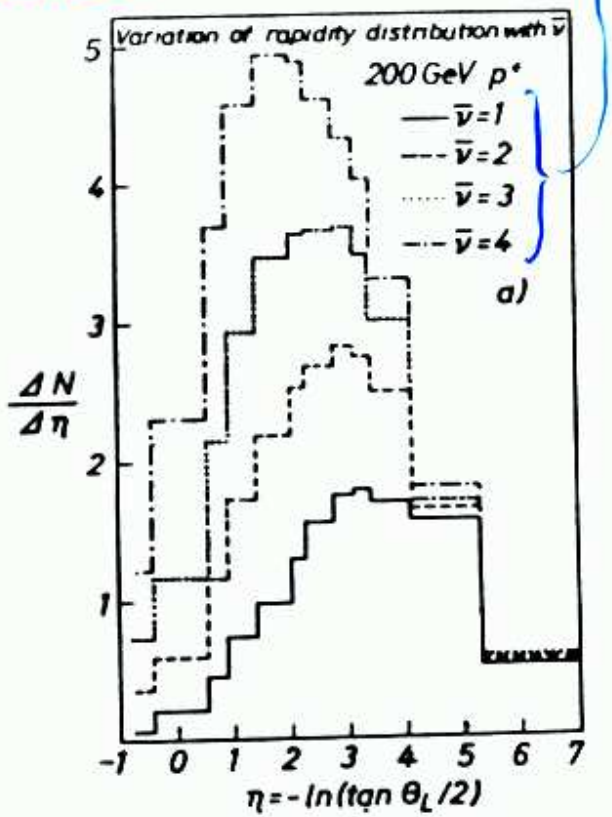


?

COLLISION INSIDE A NUCLEUS SHOULD RESOLVE THE ISSUE :



OF PARTICLES



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

(# OF NUCLEONS HIT BY INCIDENT PROTON)

"RELATIVISTIC" VELOCITY

RAPIDITY y

OR

PSEUDORAPIDITY η

GALILEAN TRANSFORMATION:

$$V = V_1 + V_2$$

RELATIVISTIC TRANSFORMATION

$$V \neq V_1 + V_2$$

BUT $y = y_1 + y_2$

WHERE $y \equiv \tanh^{-1} \frac{v}{c}$ (c = SPEED OF LIGHT)

↑ "RAPIDITY"

& $\eta \approx y$ CALLED "PSEUDORAPIDITY"

$$\eta \equiv -\ln \tan \frac{\theta}{2}$$

A Picture of Multiple-Meson Production*

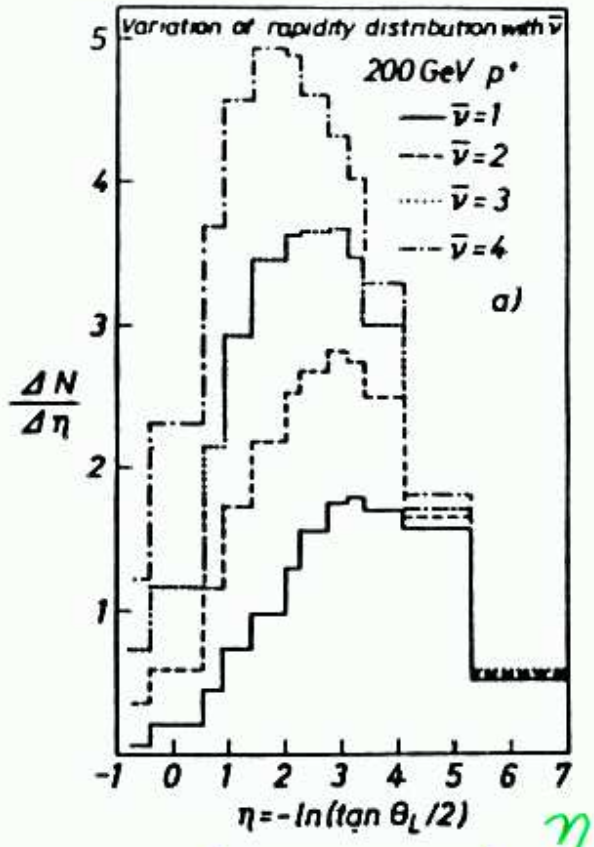
PRL

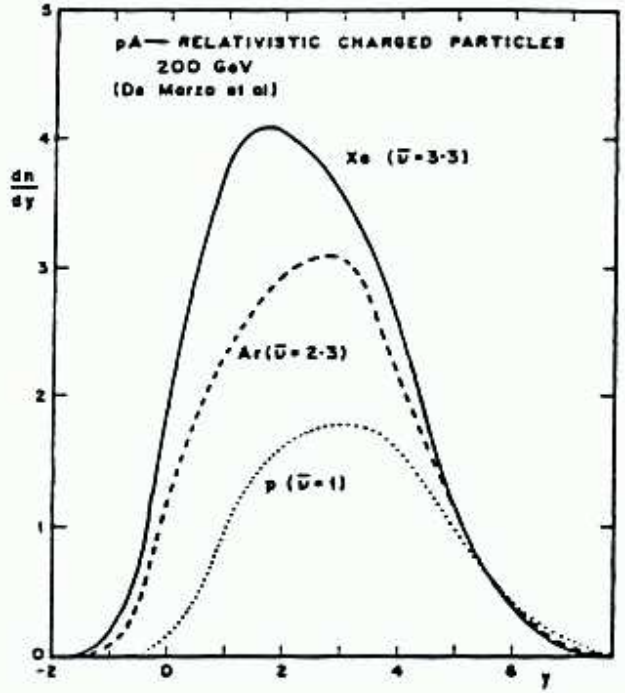
Alfred S. Goldhaber
Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11790
(Received 15 April 1974)

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 :

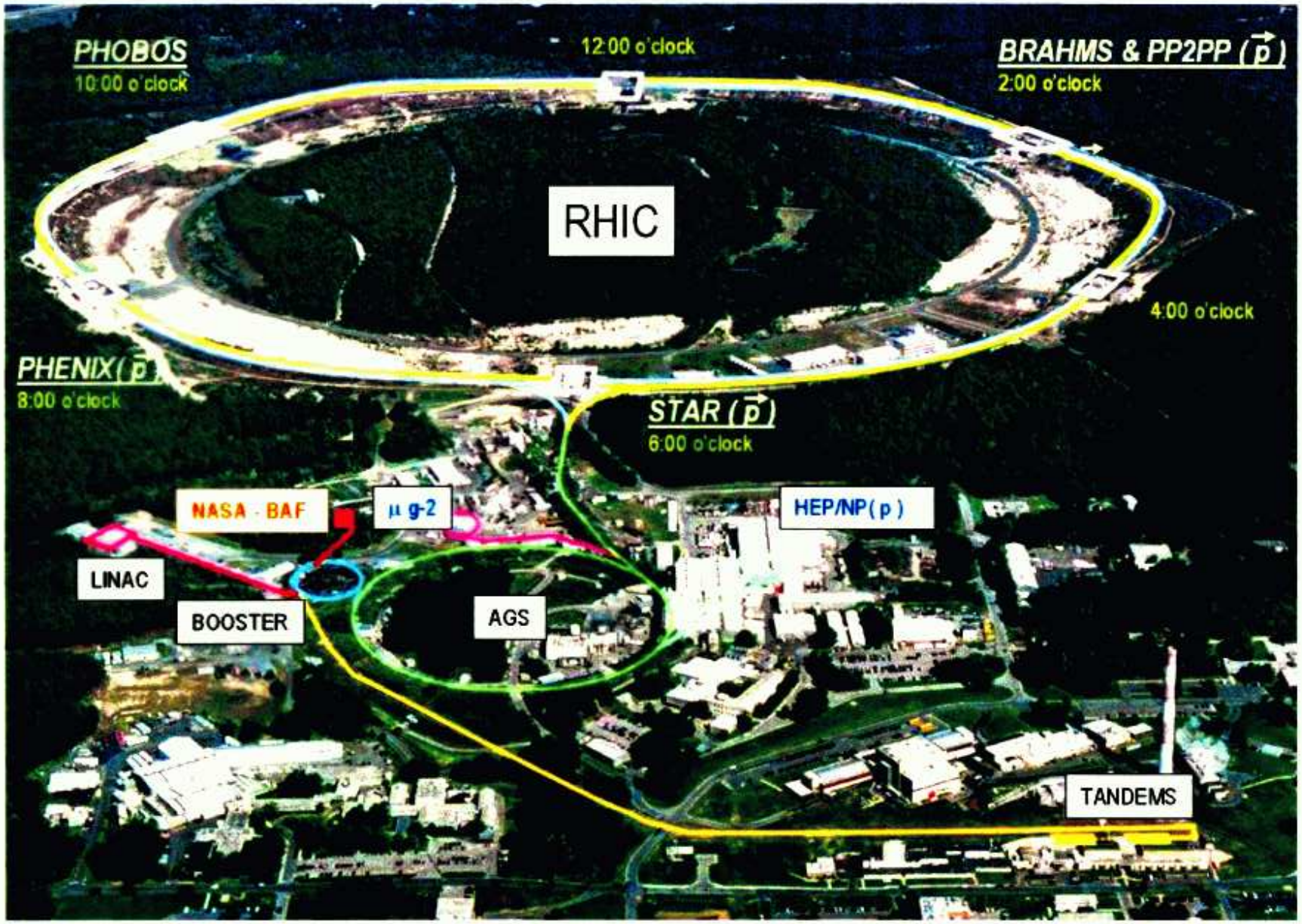
LOOK IN REST FRAME OF PRODUCED PARTICLE



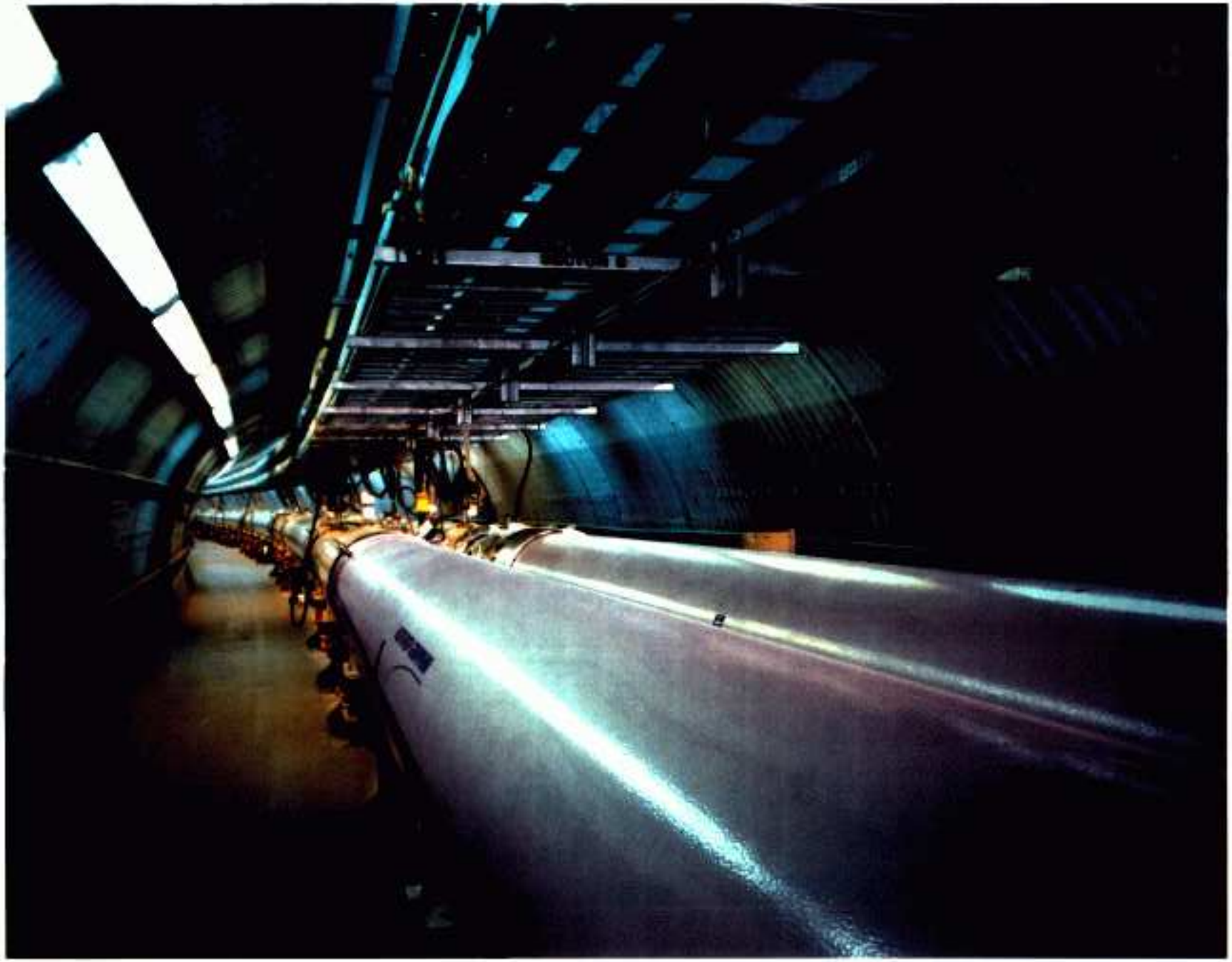


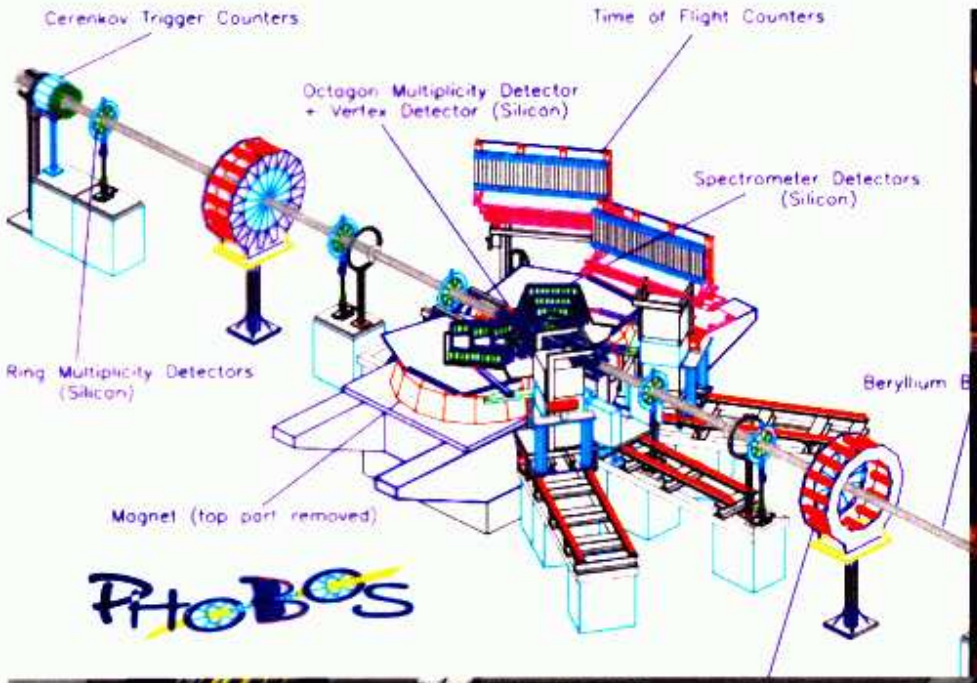
Y

η

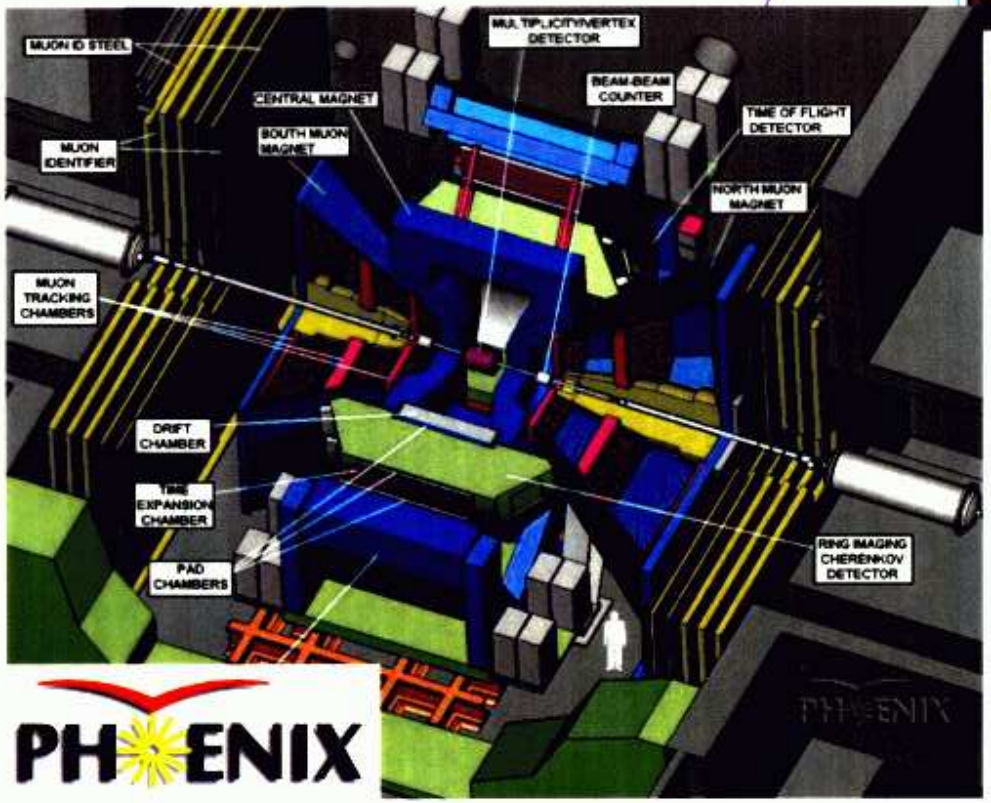

PHOBOS
10:00 o'clock
12:00 o'clock
BRAHMS & PP2PP ($\vec{p}$)
2:00 o'clock
RHIC
4:00 o'clock
PHENIX ($\vec{p}$)
8:00 o'clock
STAR ($\vec{p}$)
6:00 o'clock
NASA - BAF
μ g-2
HEP/NP (p)
LINAC
BOOSTER
AGS
TANDEMS

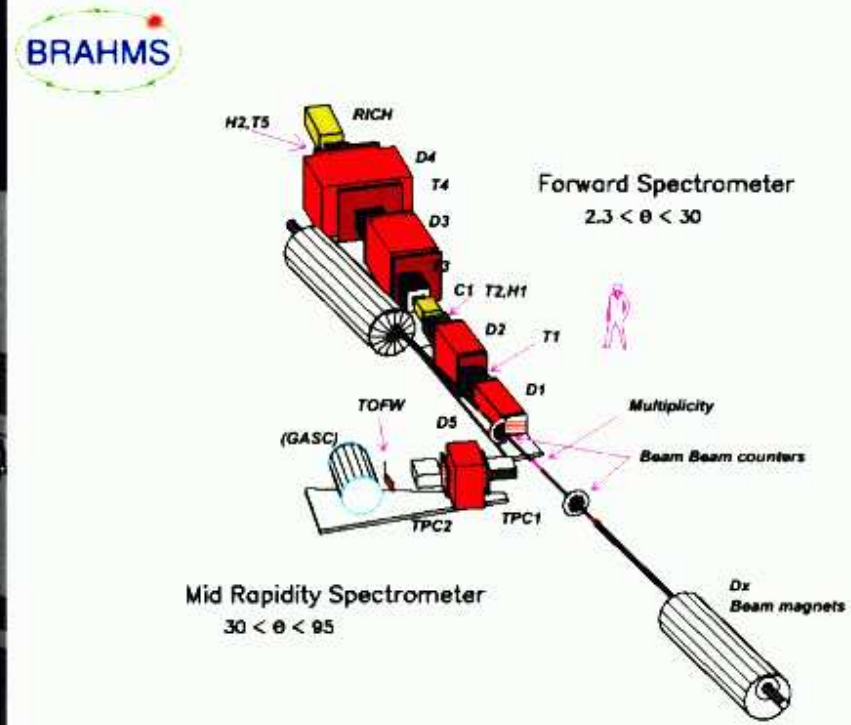
D0230298

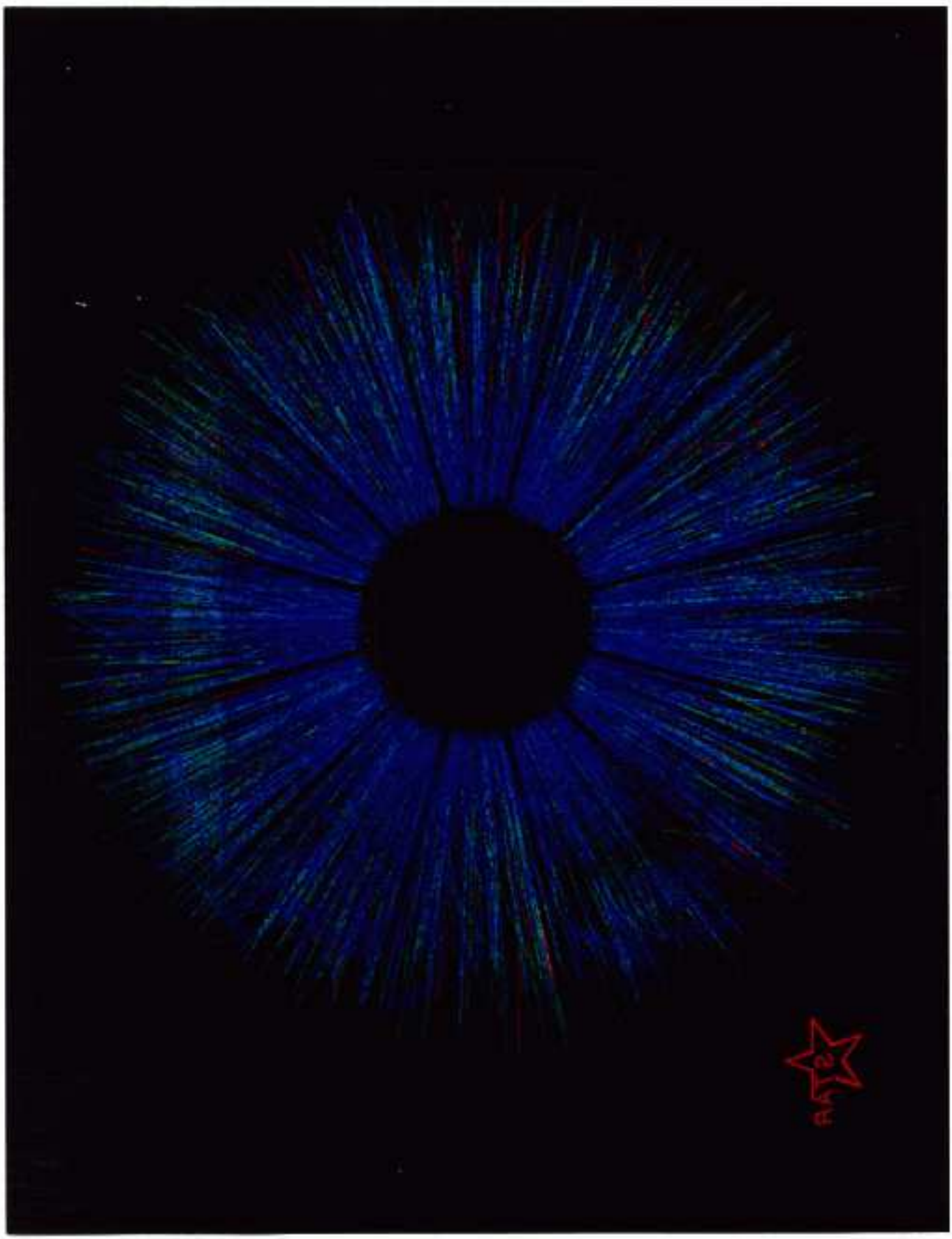



Cerenkov Trigger Counters
Time of Flight Counters
Octagon Multiplicity Detector
+ Vertex Detector (Silicon)
Spectrometer Detectors
(Silicon)
Ring Multiplicity Detectors
(Silicon)
Beryllium B
Magnet (top part removed)
PHOBOS

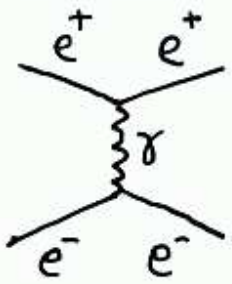
STAR


MUON ID STEEL
MULTIPLICITY/VERTEX DETECTOR
BEAM-BEAM COUNTER
CENTRAL MAGNET
TIME OF FLIGHT DETECTOR
SOUTH MUON MAGNET
MUON IDENTIFIER
NORTH MUON MAGNET
MUON TRACKING CHAMBERS
DRIFT CHAMBER
TIME EXPANSION CHAMBER
PAD CHAMBERS
RING IMAGING CHERENKOV DETECTOR
PHENIX


BRAHMS
H2,T5
RICH
D4
T4
D3
C1
T2,H1
D2
T1
D1
TOFW
D5
(GASC)
Multiplicity
Beam Beam counters
TPC2
TPC1
Dx
Beam magnets
Forward Spectrometer
2.3 < θ < 30
Mid Rapidity Spectrometer
30 < θ < 95

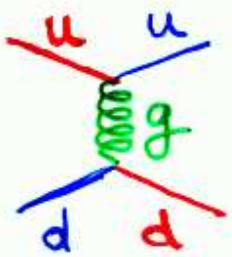


QED



→ atoms
molecules
gases
liquids
solids
lasers
superconductivity
⋮

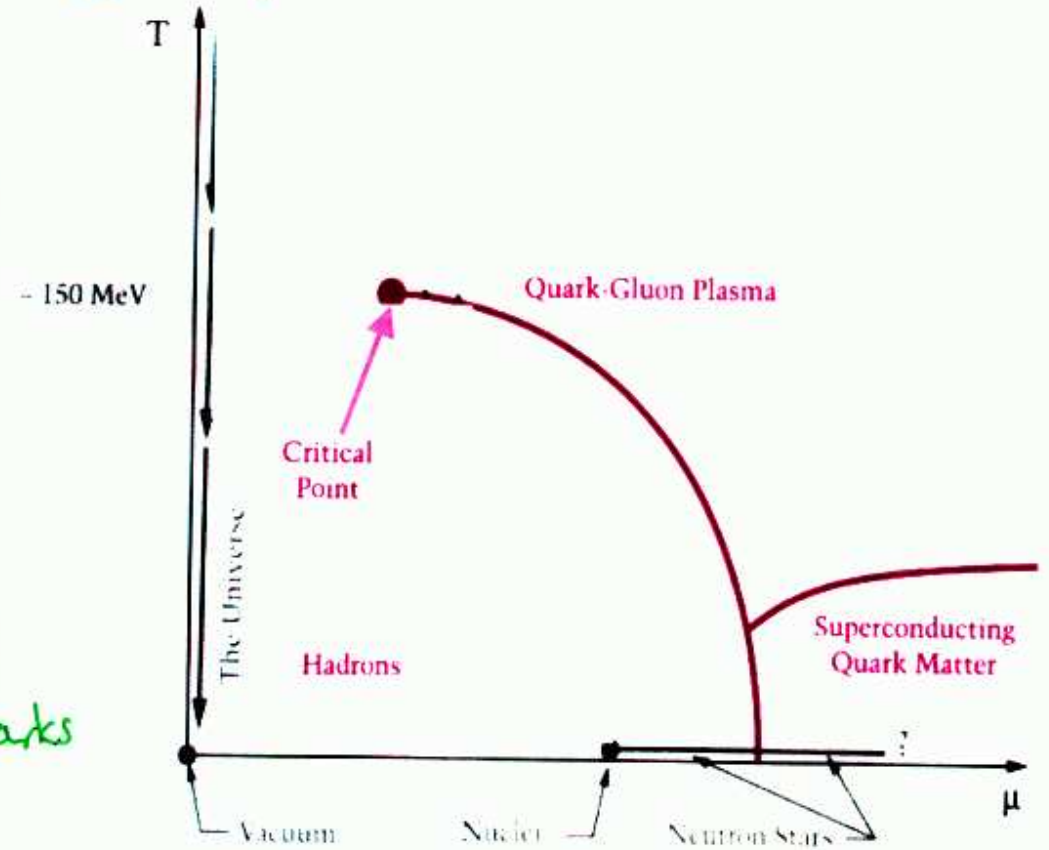
QCD



+

→ a very interesting vacuum
confinement of quarks
protons
pions
nuclei
⋮

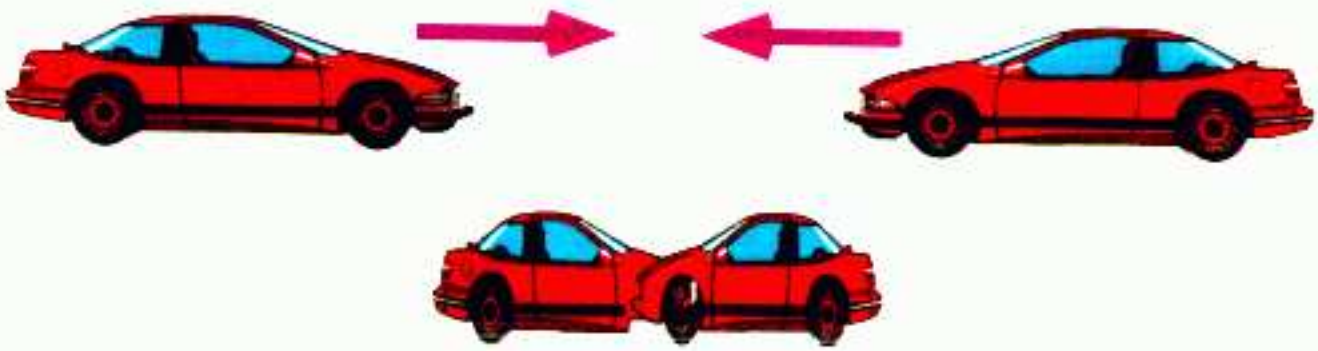
TEMPERATURE
OR
Energy Density

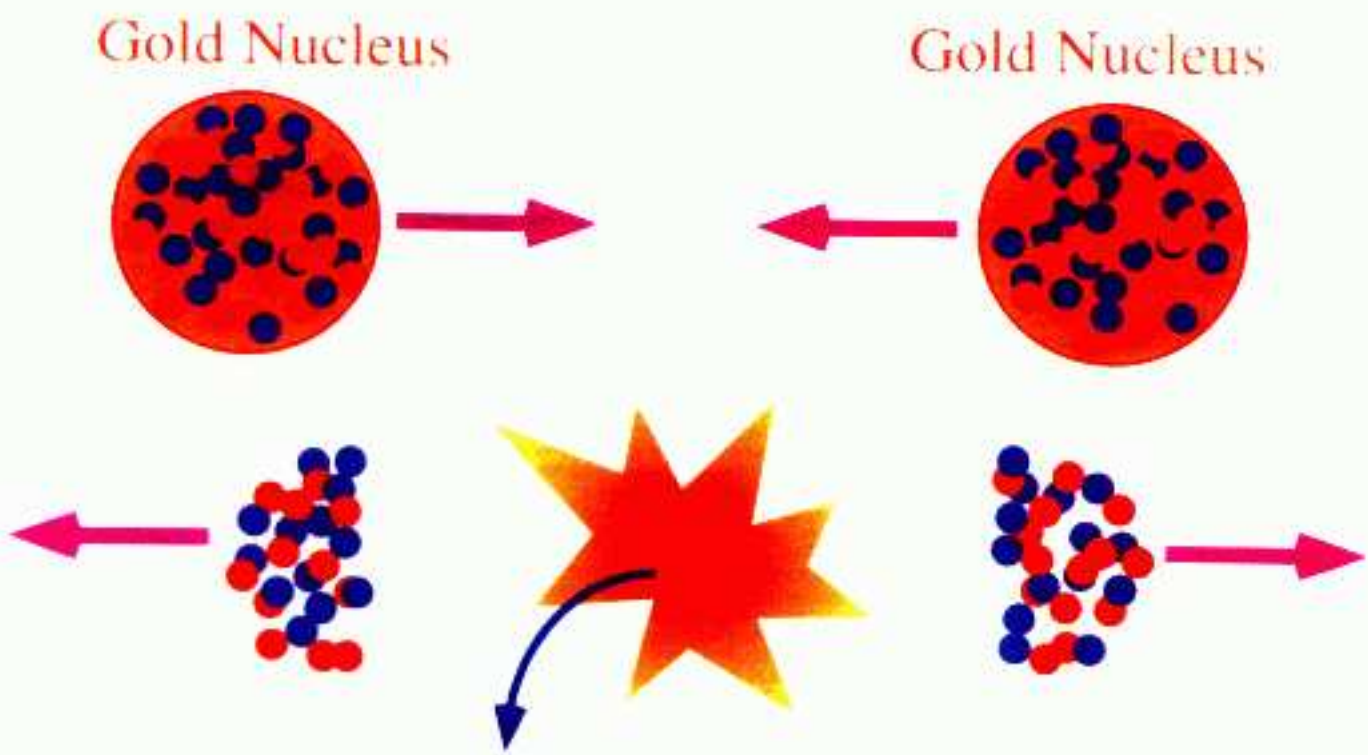


Baryon Density

(MATTER DENSITY)

Creating High Energy Density through Colliding Nuclei

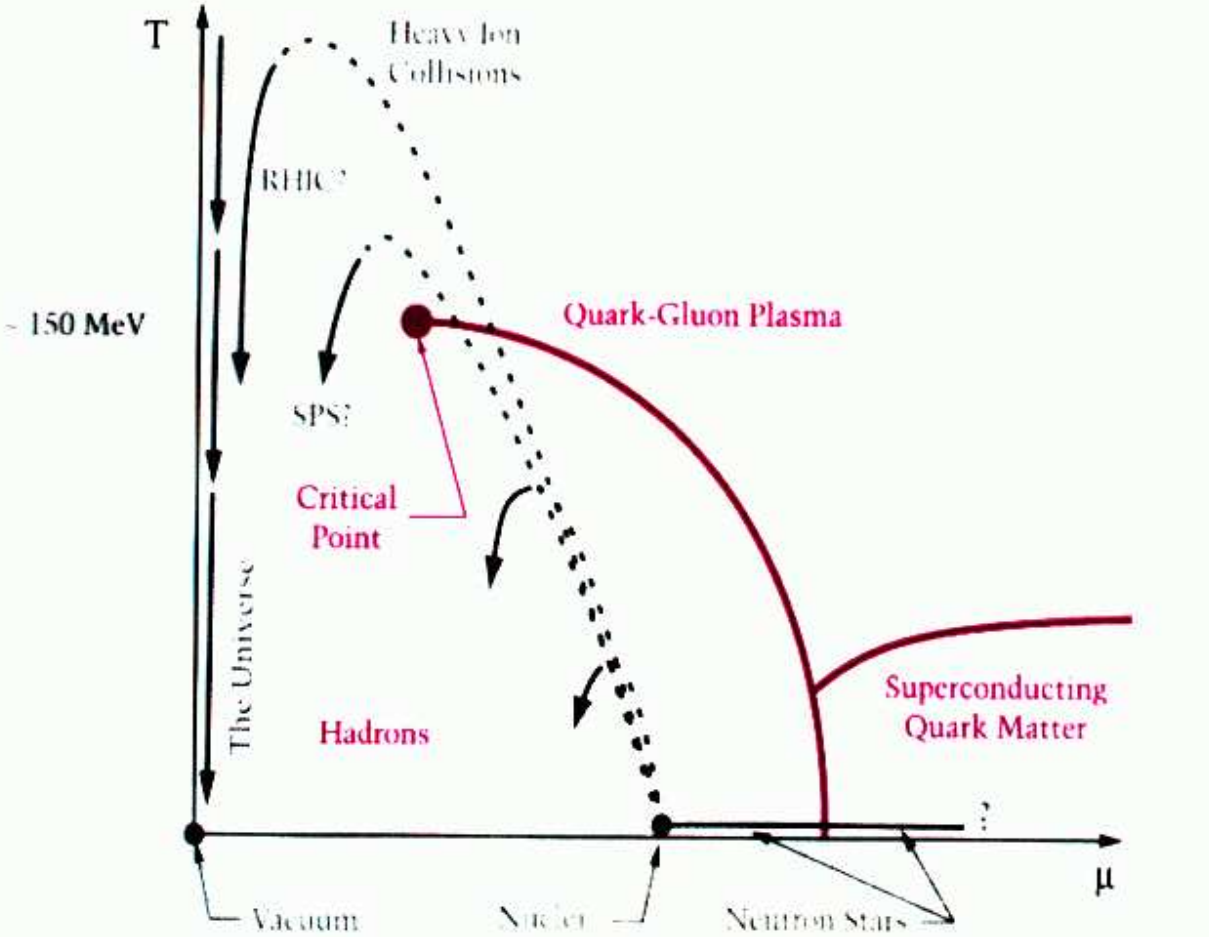




Energy density greater than that inside a proton, similar to that of the universe at a millionth of a second after the Big Bang... called the

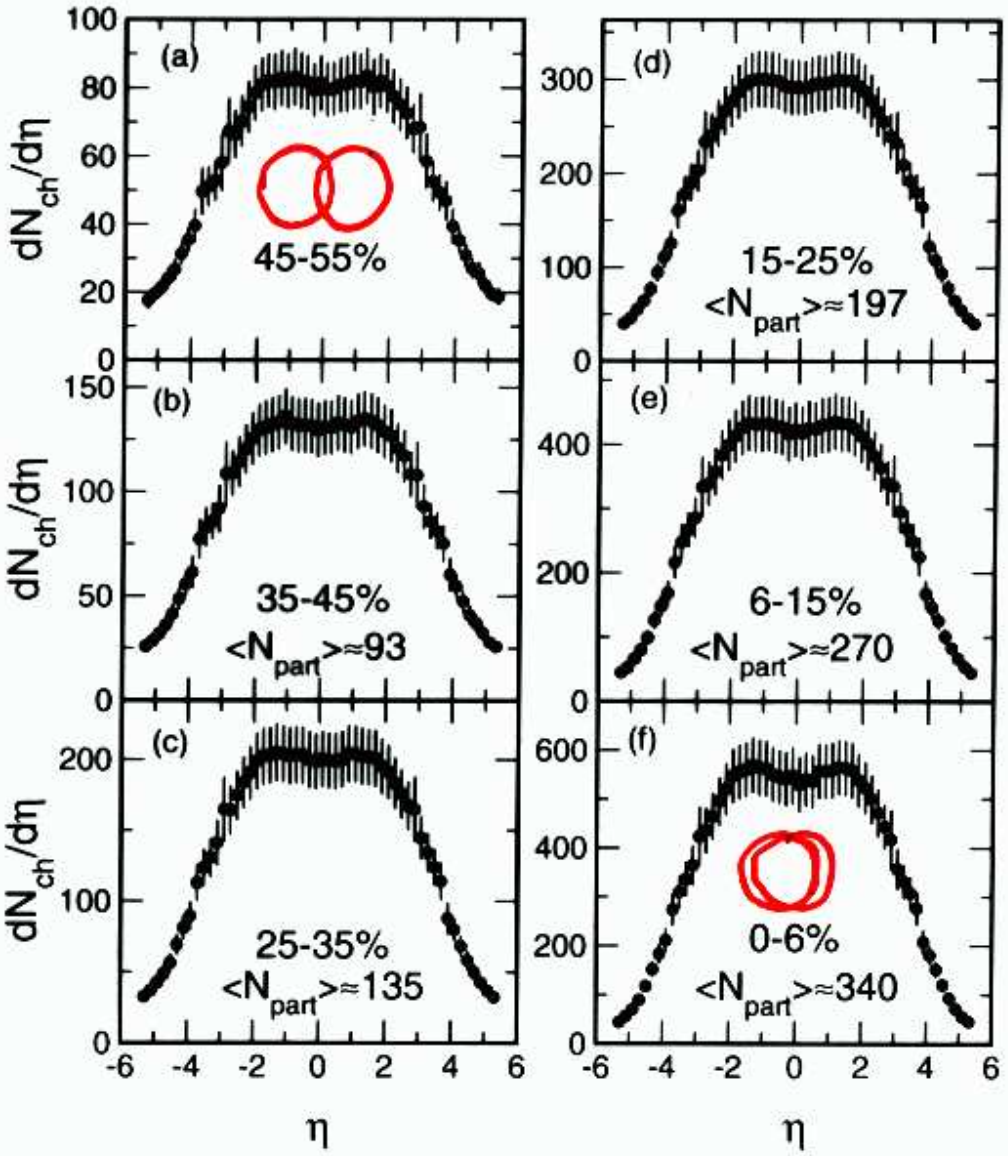
QUARK GLUON PLASMA

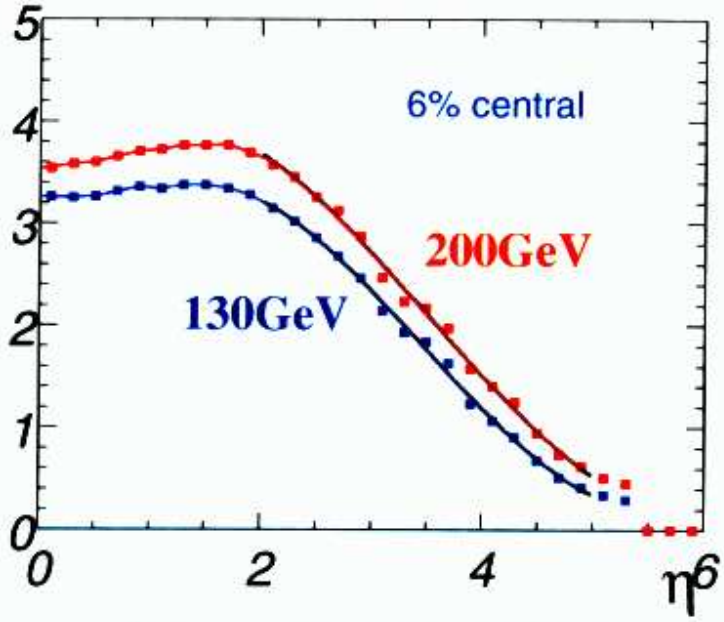
Temperature or Energy Density



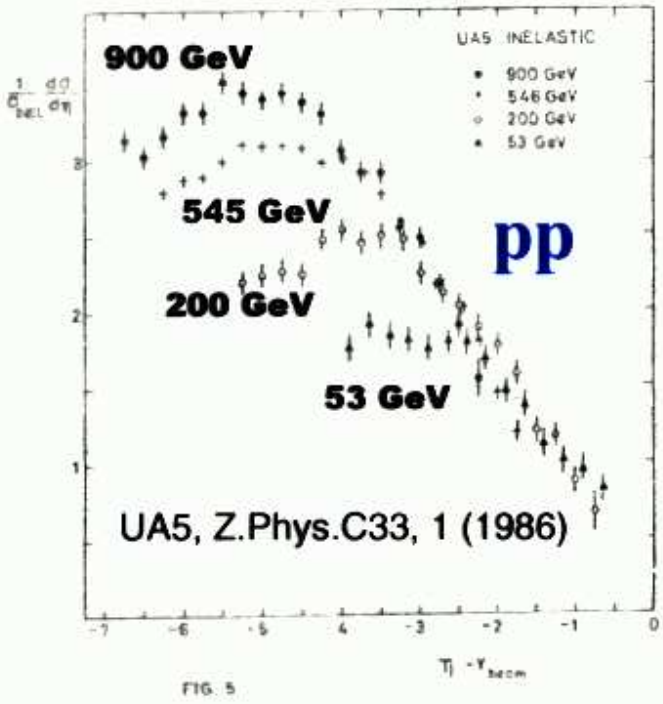
Baryon or Matter Density

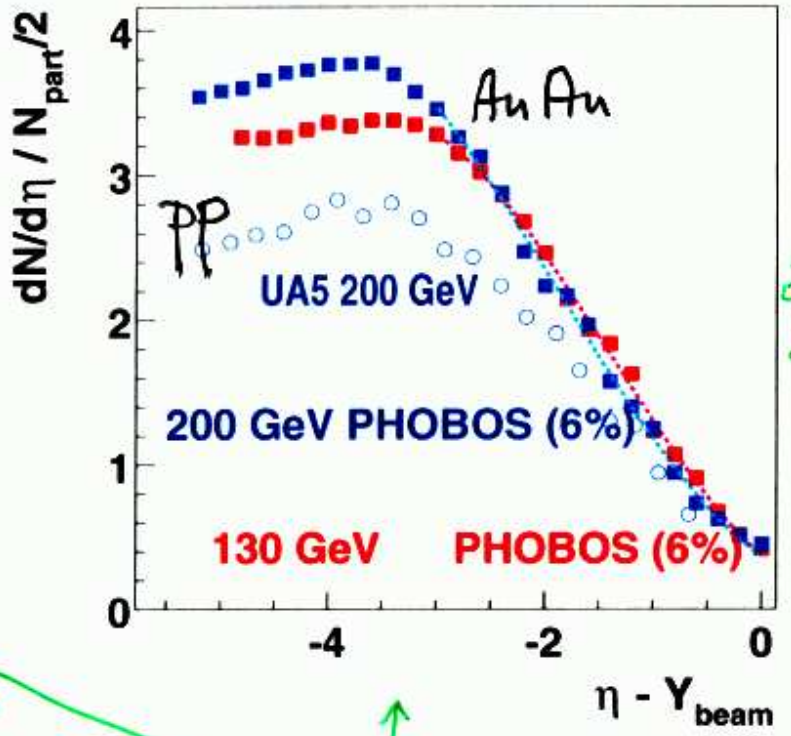
AuAu 130GeV

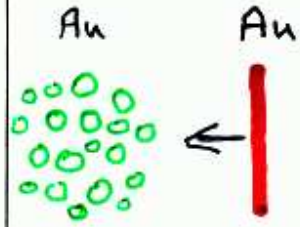




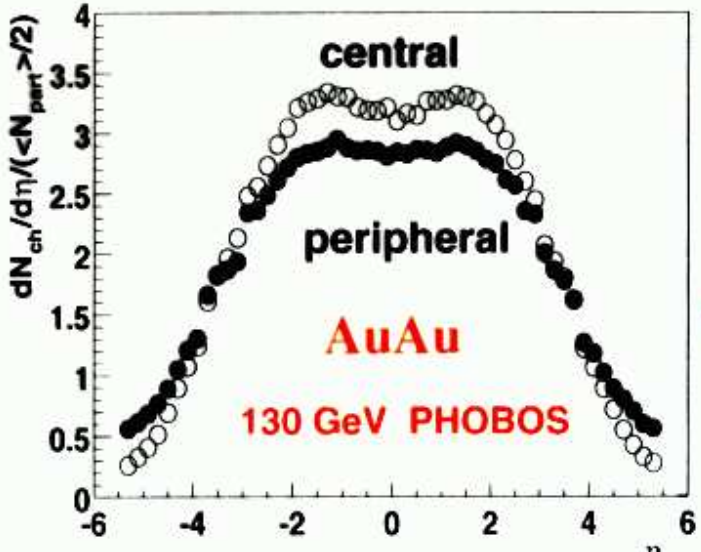
"RELATIVISTIC" VELOCITY
PSEUDORAPIDITY



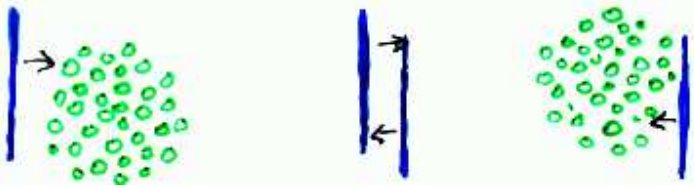




PLOTTED IN REST FRAME OF ONE NUCLEUS



PLOTTED IN CM REST FRAME



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NUCLEAR STOPPING POWER

Wit BUSZA
Physics Department and Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

and

Alfred S. GOLDHABER
Institute for Theoretical Physics, State University of New York at Stony Brook, Stony Brook, Long Island, NY 11794, USA

pp. 235–238

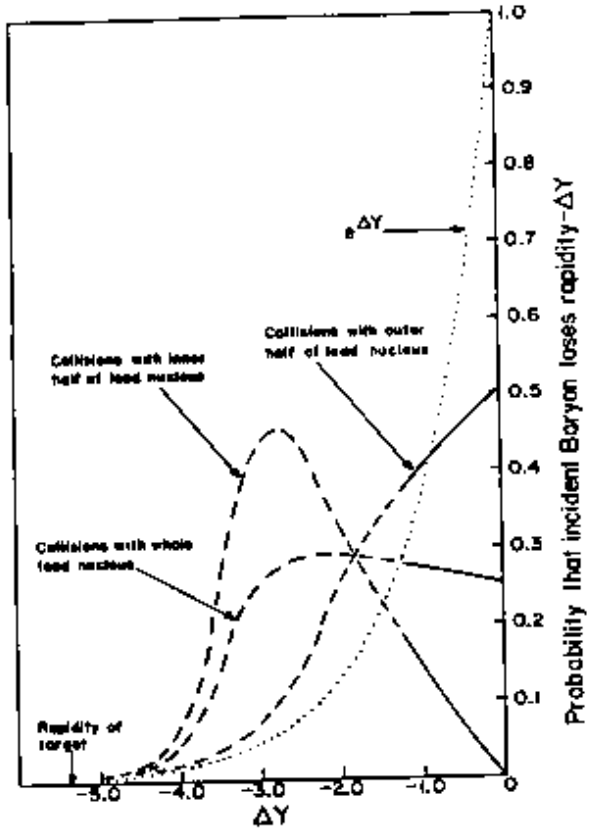
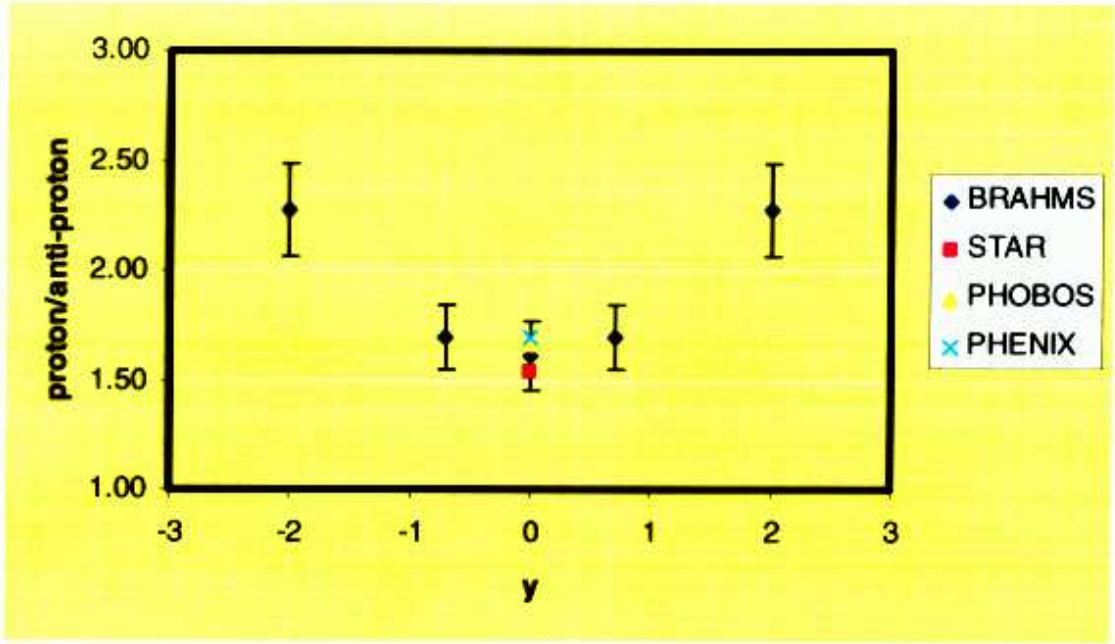
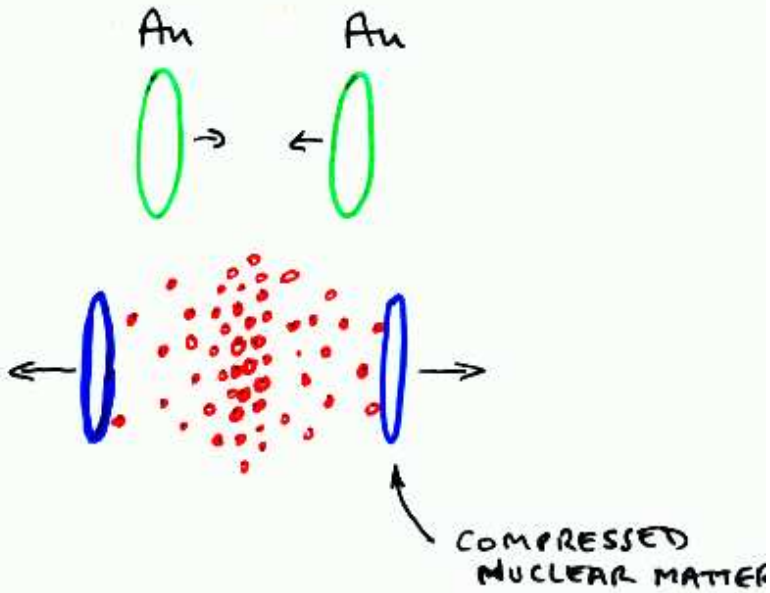
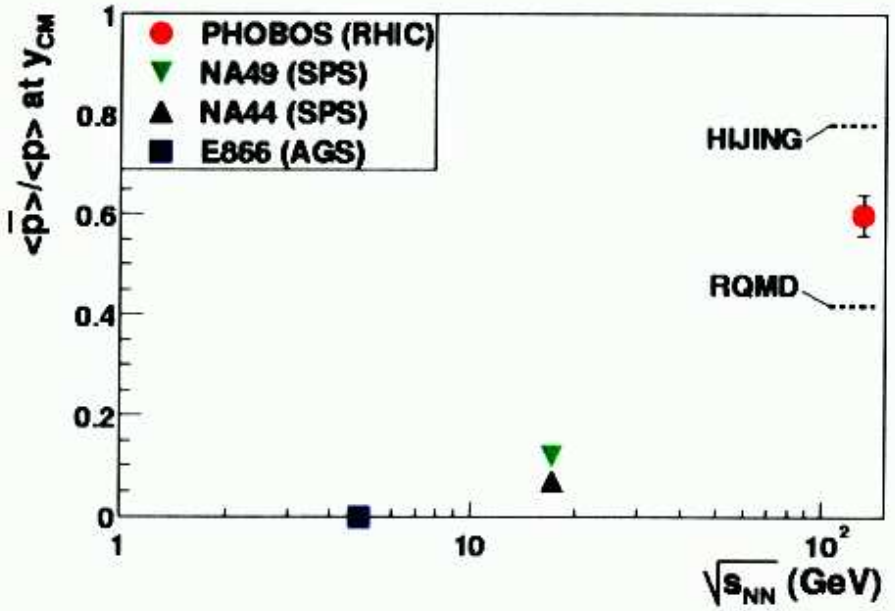
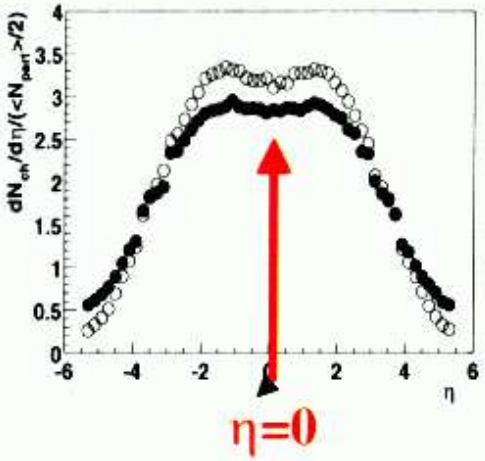


Fig. 3. Extrapolated probability distributions for rapidity loss of protons striking lead nuclei. The dashed lines are the extrapolated portions. The constraint that the normalized total, central, and peripheral inclusive cross sections should all be smooth makes the extrapolations nearly unique.

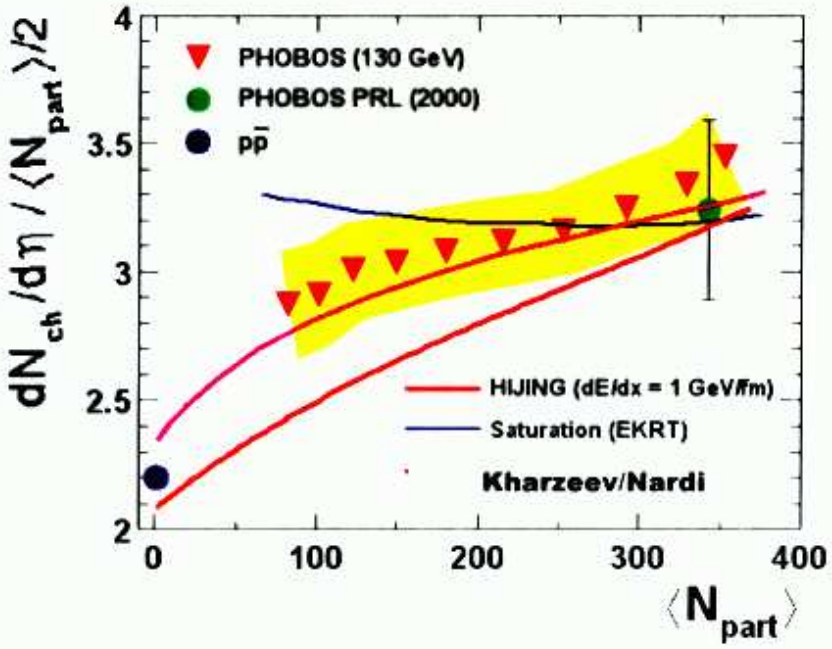

3.00
2.50
2.00
1.50
1.00
proton/anti-proton
-3
-2
-1
0
1
2
3
y
BRAHMS
STAR
PHOBOS
PHENIX


Au
Au
COMPRESSED
NUCLEAR MATTER

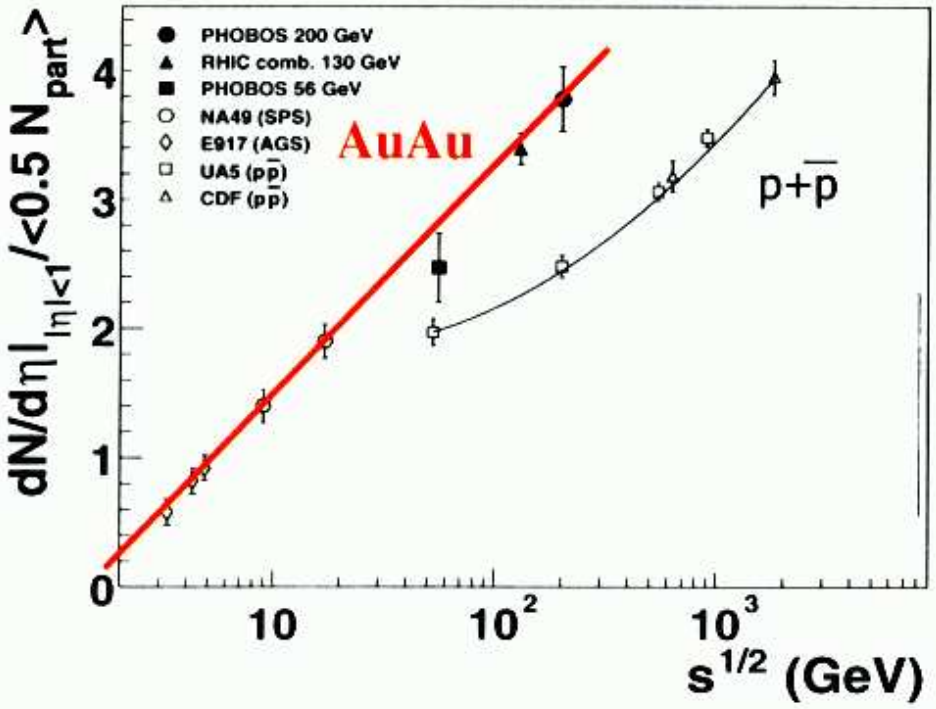

PHOBOS (RHIC)
NA49 (SPS)
NA44 (SPS)
E866 (AGS)
HIJING
RQMD
<p̄>/<p> at y_CM
1
0.8
0.6
0.4
0.2
0
1
10
10^2
√s_NN (GeV)



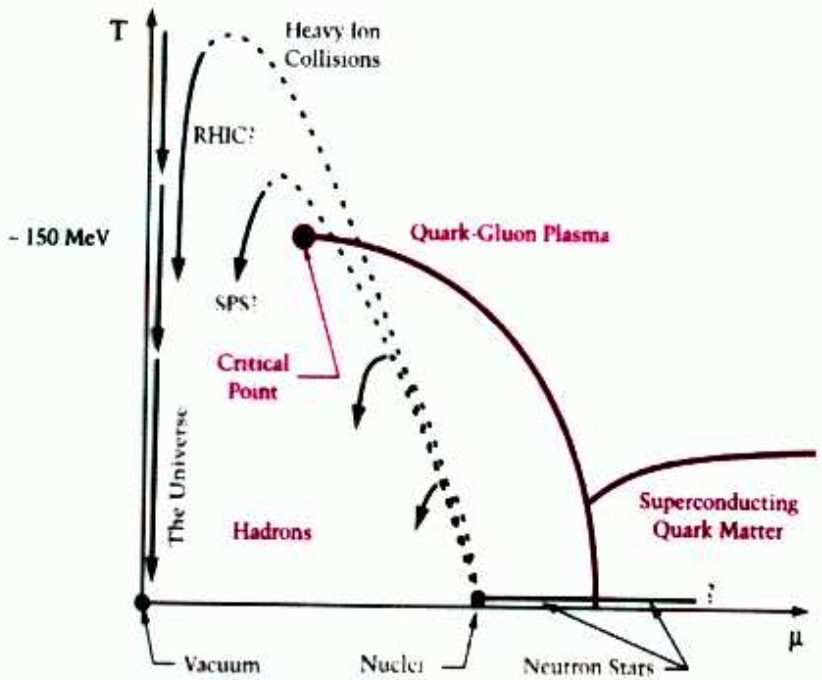
Centrality Dependence at η=0 130 GeV

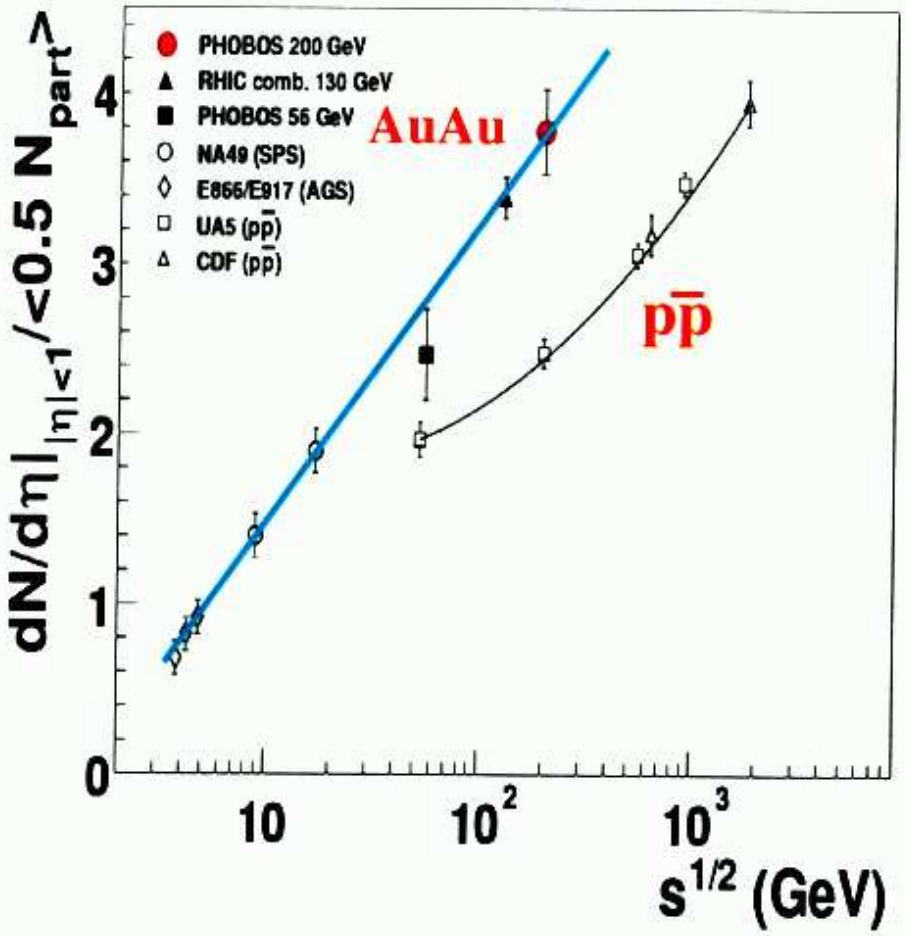


Multiplicity at η≈0 vs Energy



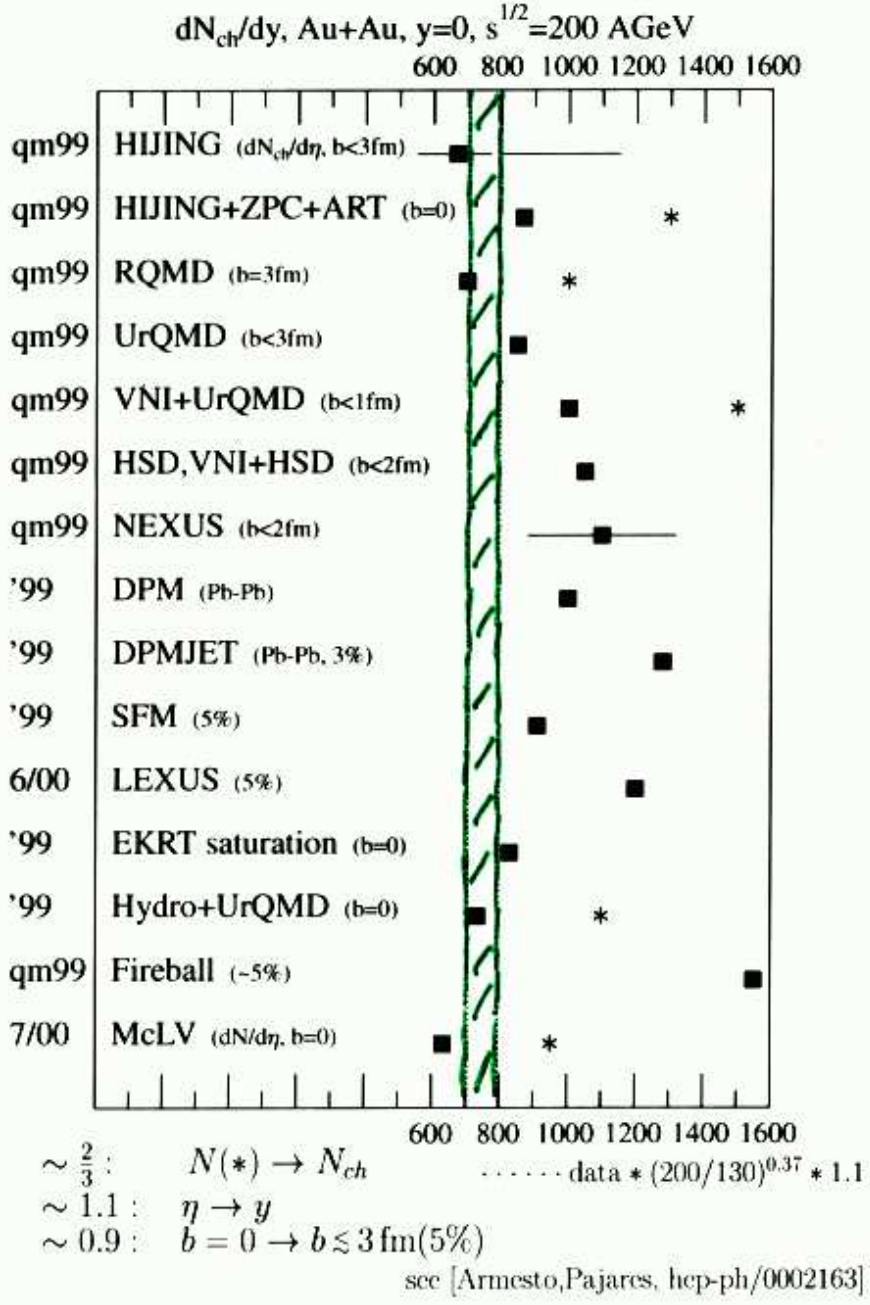
Energy Density or Temperature





Baryon Density

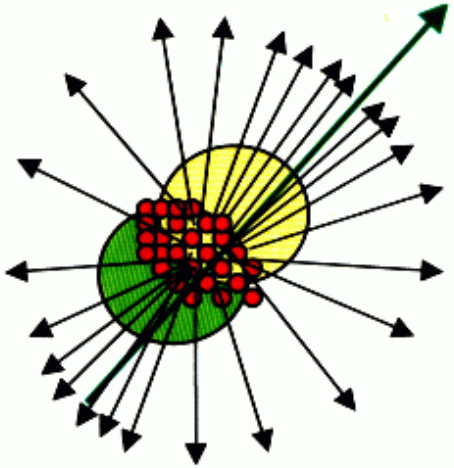
Predictions:

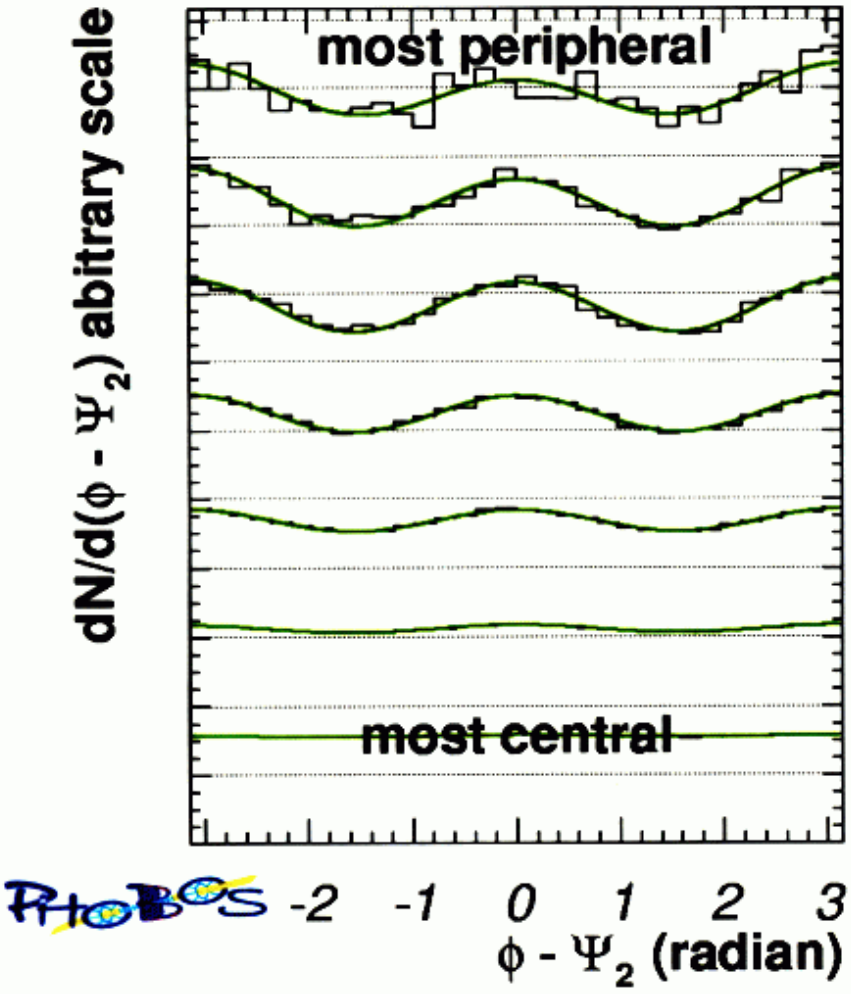


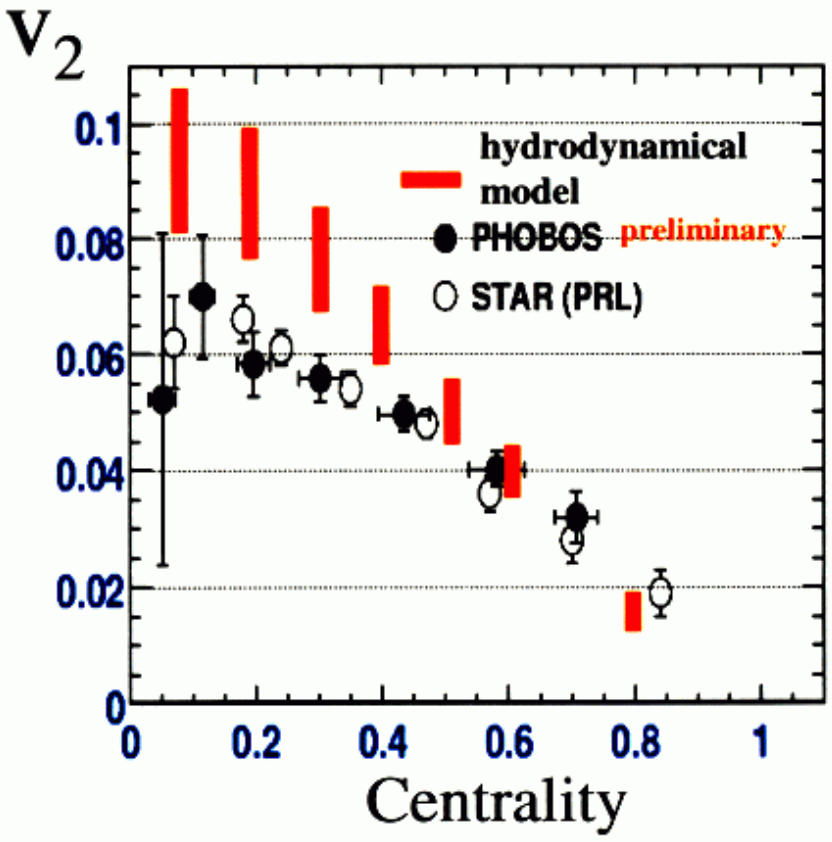
see [Armesto,Pajares, hep-ph/0002163]

Elliptic Flow

NEAR $y = 0$







×3 AGS
50% MORE THAN AT SPS

m_T Spectra

BOLTZMANN DISTRIBUTION:

$$\frac{dN}{m_T^{\frac{3}{2}} dm_T} \sim e^{-m_T/T}$$

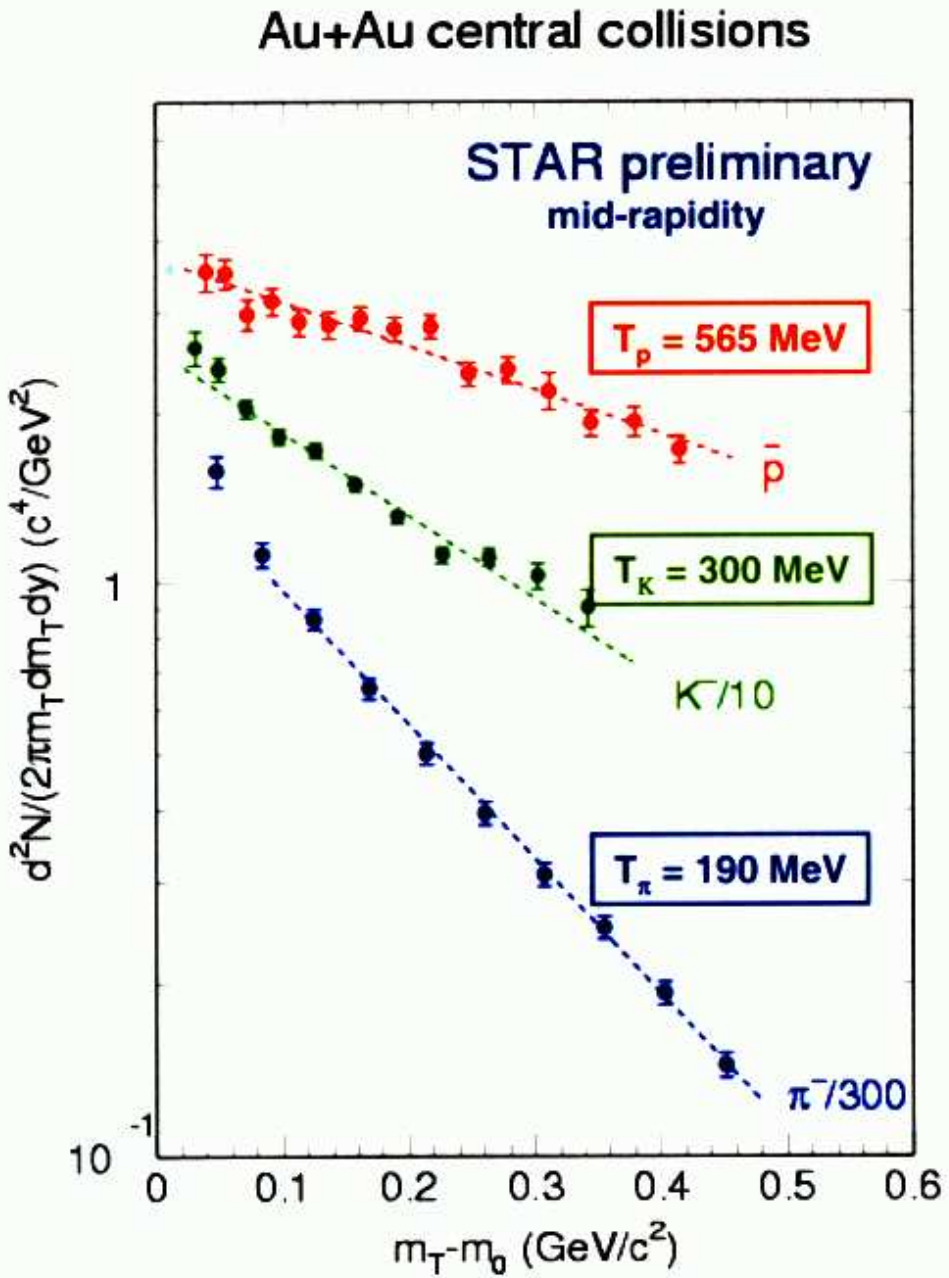
∴ SLOPES SHOULD BE THE SAME

RESULTS SUGGEST

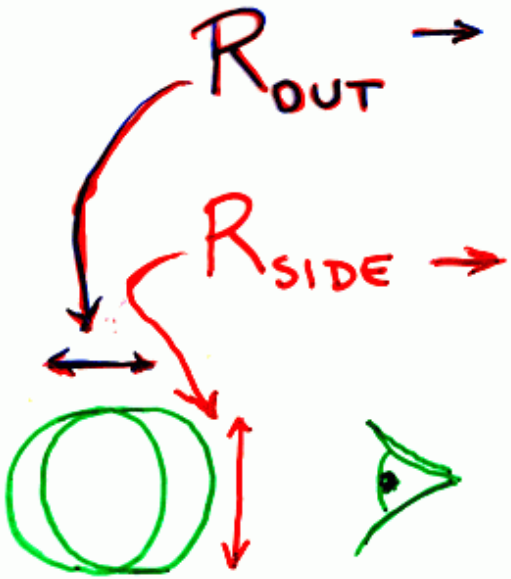
RADIAL VELOCITY OF SYSTEM $> 0.5c$!

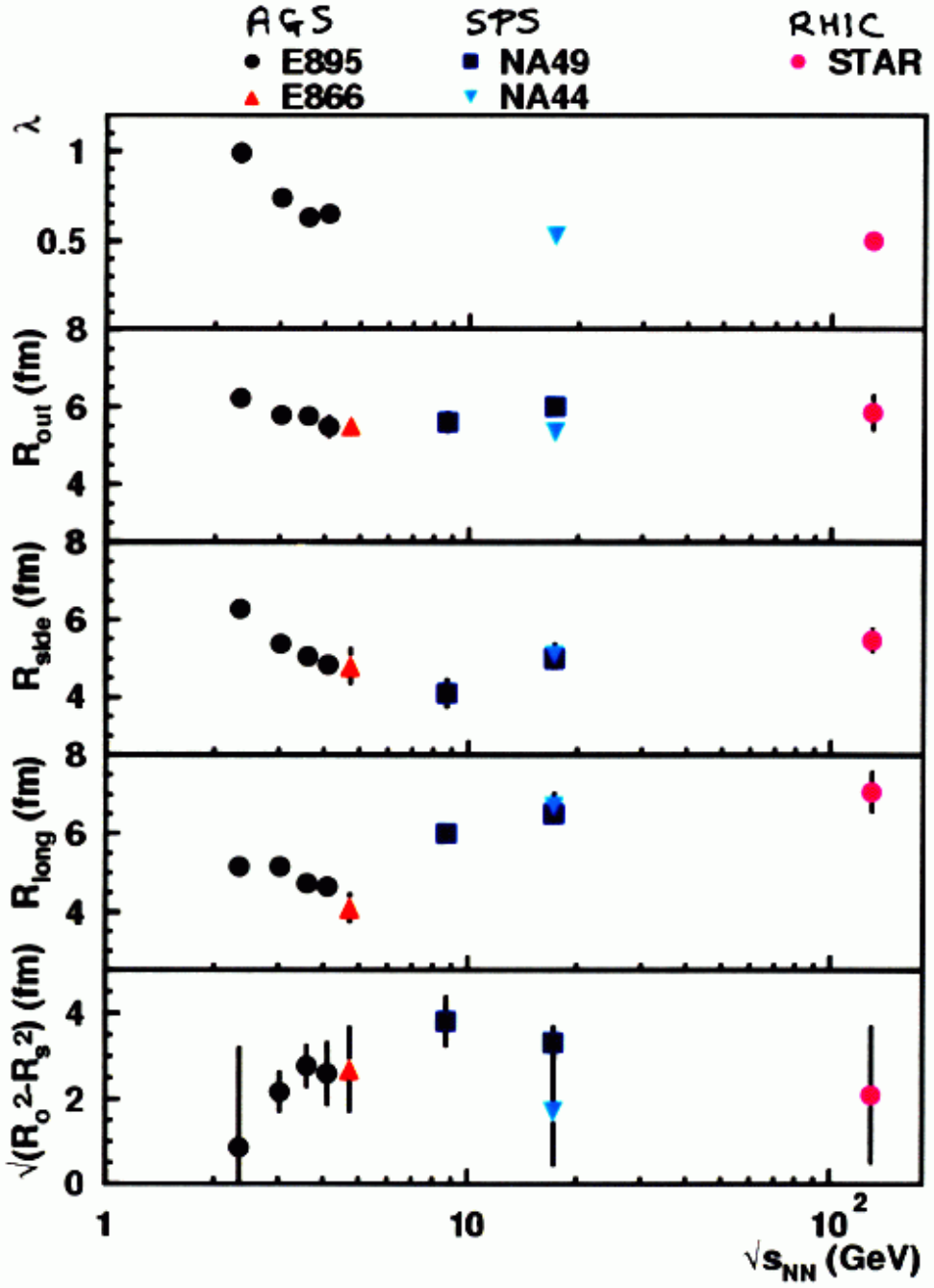
(ALREADY SEEN @ SPS)

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

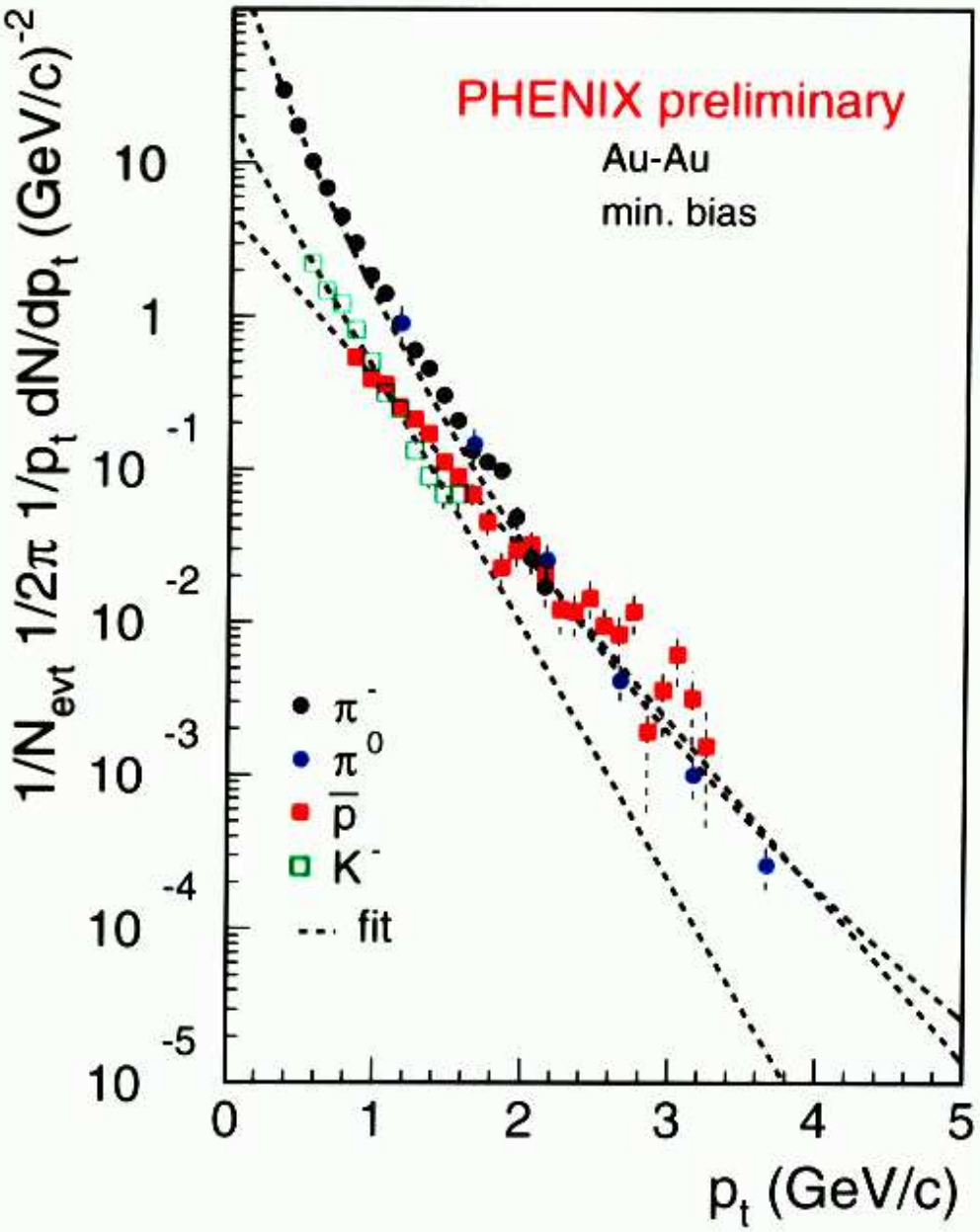


The HBT Excitation function



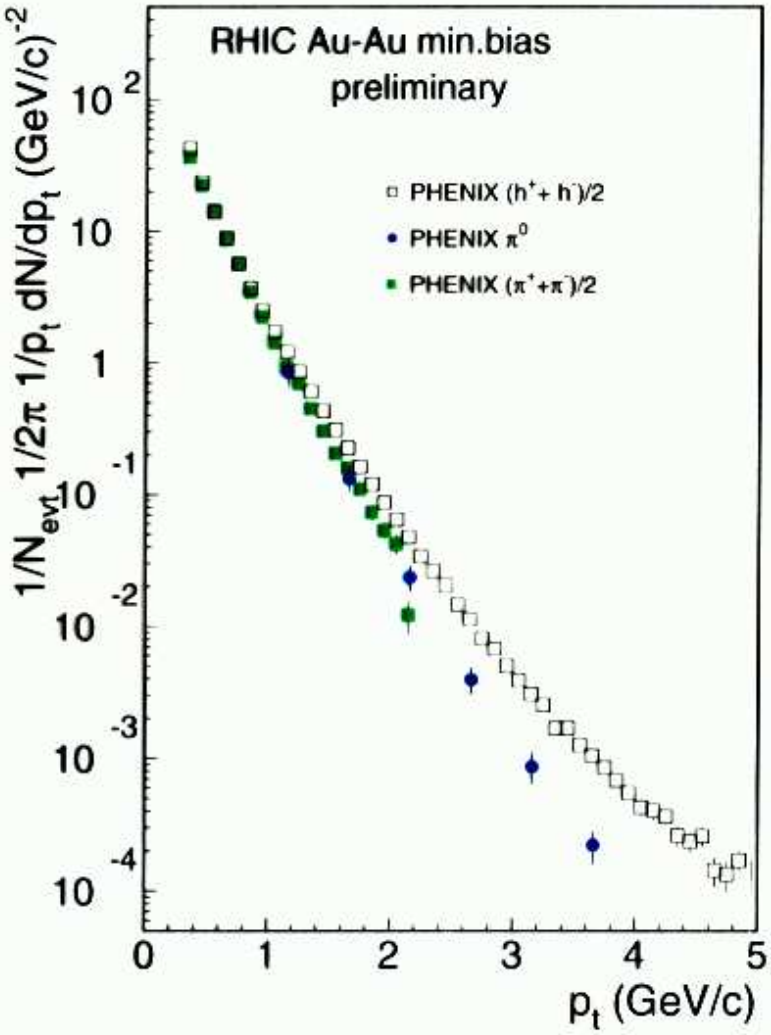


STAR
Preliminary

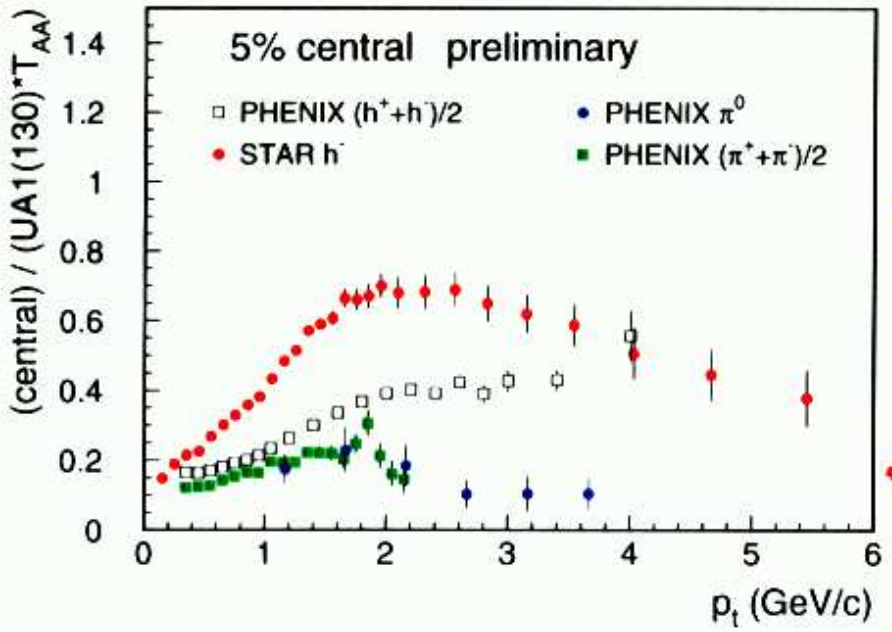


$\bar{p} > \pi$
@ $p_t > 2$ GeV/c !

Jet quenching



Comparison of central AuAu to pp

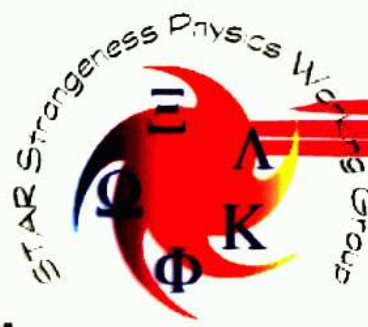


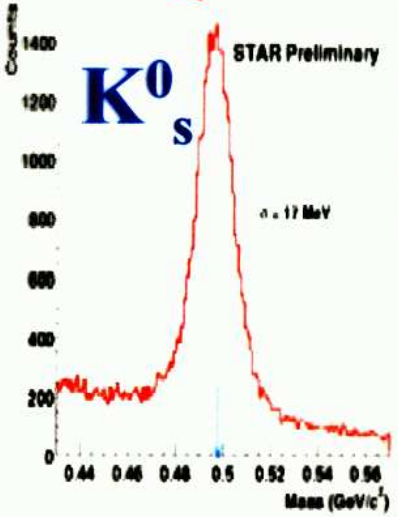
← hard processes

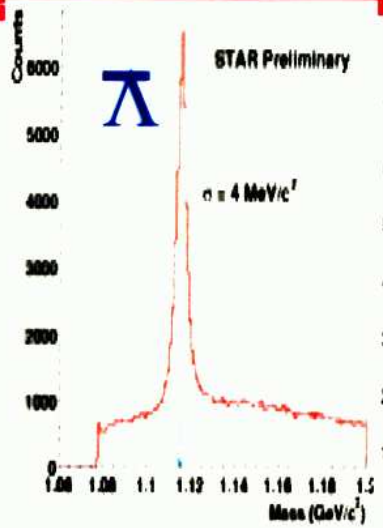
← soft processes

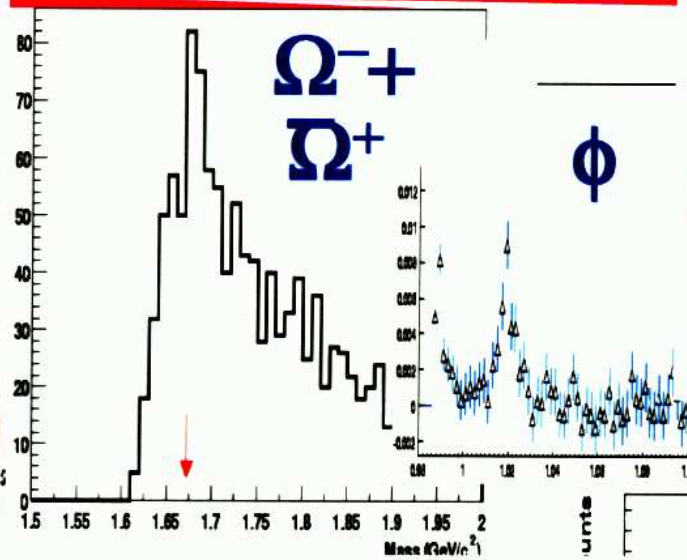
Data from Drees QM01

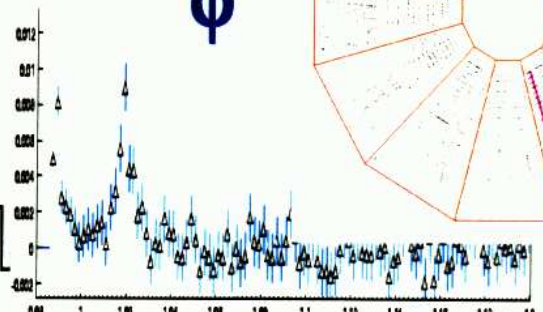
STAR STRANGENESS! (Preliminary)

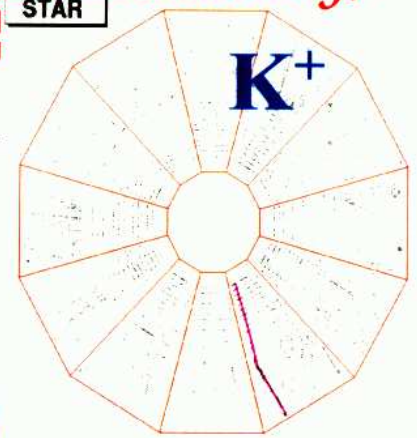


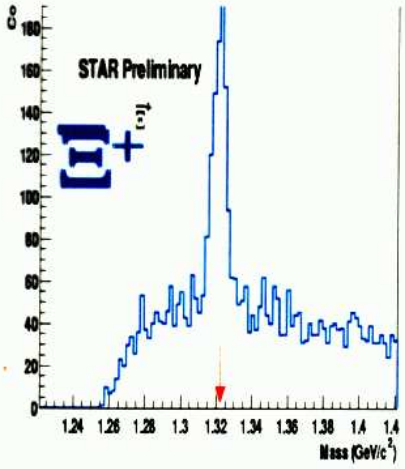


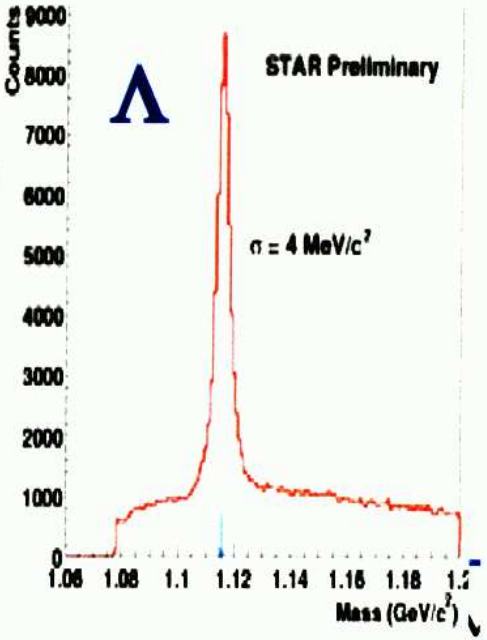


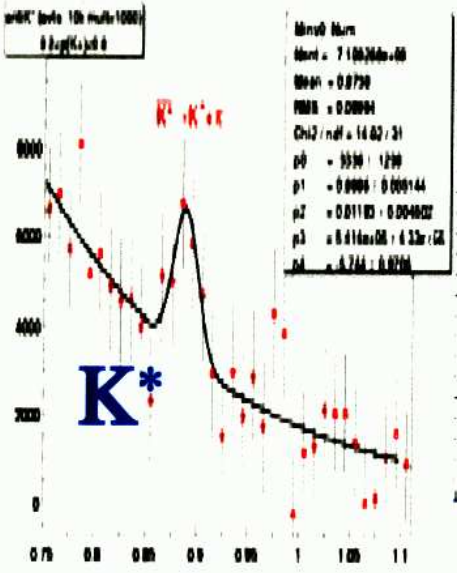


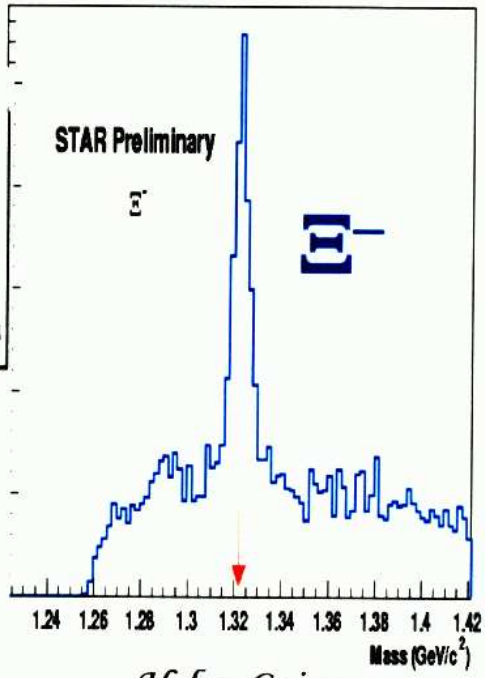




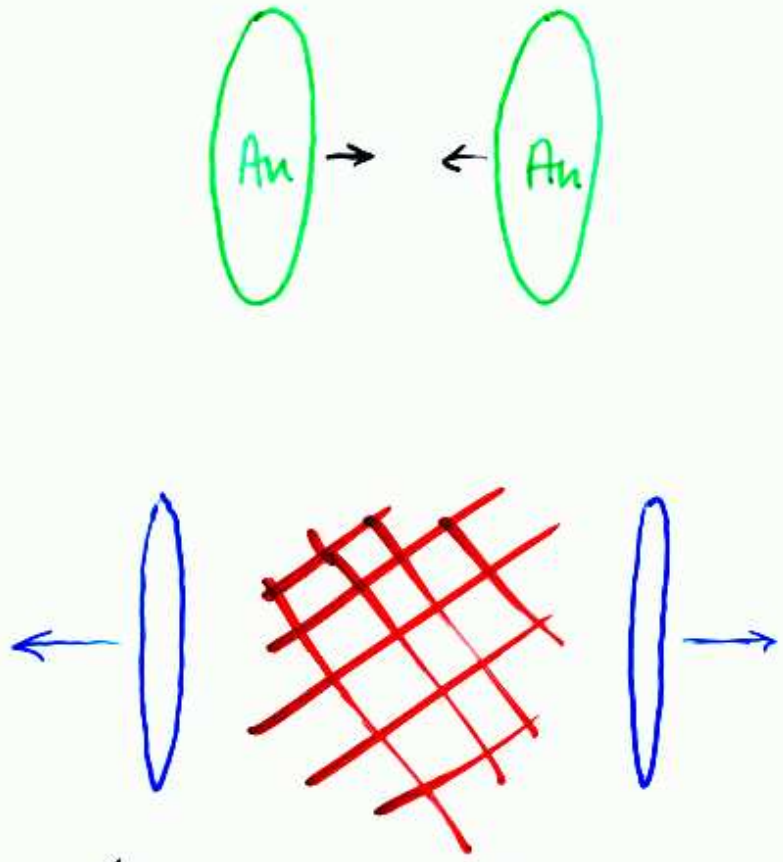








Helen Caines



FRAGMENTATION AS YOU WOULD EXPECT FROM pp & pA

ENERGY DENSITY INCREASES SMOOTHLY WITH ENERGY

AT RHIC $\gg 1\,\mathrm{GeV/fm^3}$

WITH HIGH PRESSURE

So Fred, what's going on?