INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

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SCHOOL ON
NON-ACCELERATOR PHYSICS
25 April - 6 May 1988

PARTICLE PHYSICS WITH BALLOONS SATELLITES AND SPACE STATIONS (4)

by

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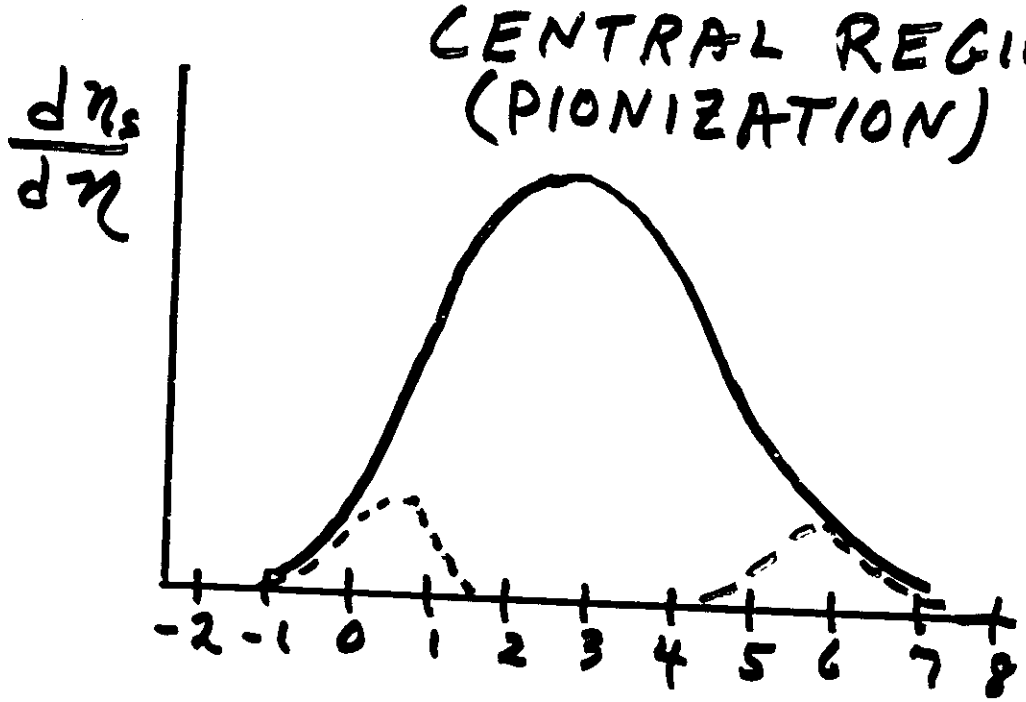
PSEUDO-

RAPIDITY DISTRIBUTIONS

$$\eta = -\ln \tan \theta/2$$



TARGET FRAGMENTATION REGION

PROJECTILE FRAGMENTATION REGION

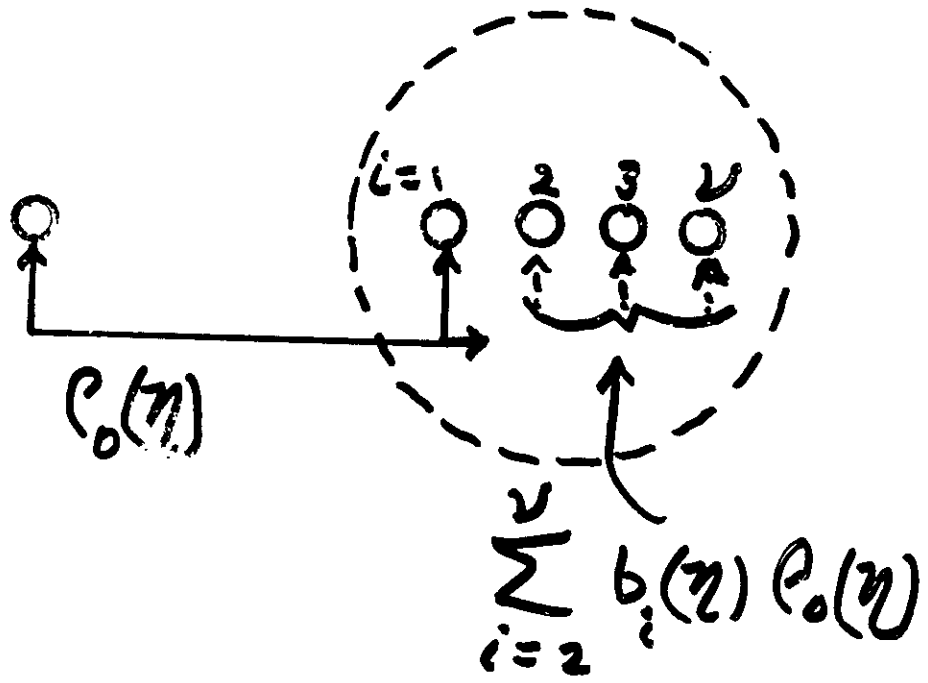
EMULSION TERMINOLOGY:

PROJECTILE + TARGET $\rightarrow n_s + N_h$

$N_h = N_b + N_g$ REFLECTS $\rightarrow$ NUCLEAR TARGET RESPONSE

DIRECT STUDIES OF N-N AND h-A INTERACTIONS

GIVES FOLLOWING PICTURE FOR h-A COLLISIONS



RAPIDITY DENSITY $\rho(\eta) = \frac{1}{\sigma}\frac{d\sigma}{d\eta}$

OR PSEUDO-RAPIDITY, η

$\eta = -\ln \tan \theta/2$

$$\rho(\eta) = \underset{i=1}{\rho_0(\eta)} + \sum_{i>1} b_i(\eta)\,\rho_0(\eta)$$

WE CAN
EXTRAPOLATE h-A PICTURE
TO B-A COLLISIONS,
USING LINEAR SUPER POSITION.

IF DATA AGREES WITH SUCH
EXTRAPOLATION, THEN STUDY
OF B-A COLLISIONS NOT
INTERESTING.

BUT, DEVIATIONS TELL US
THAT THE NUCLEAR
ENVIRONMENT IS IMPORTANT!

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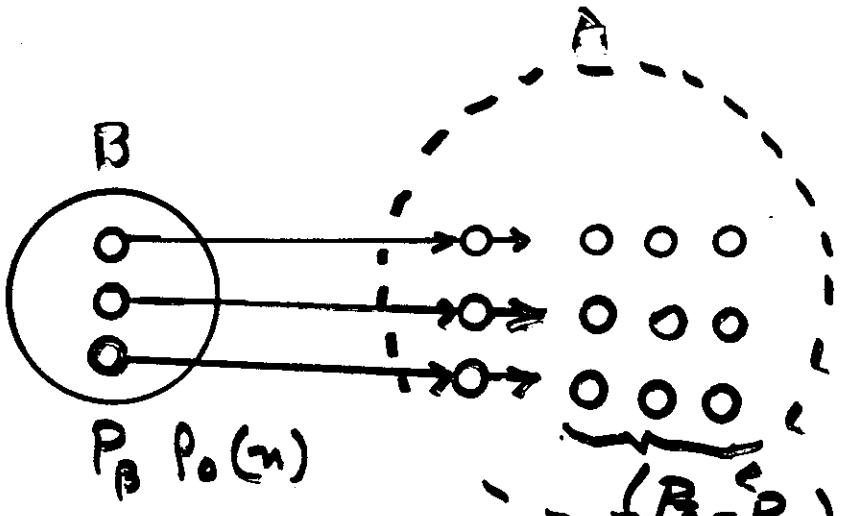
* SUPERPOSITION OF N-N OR
h-A COLLISIONS SUPPLIES
THE NORM TO TEST MODELS
FOR B-A COLLISIONS.

EXISTING DATA FOR B-A COLLISIONS TOO POOR TO CHOOSE BETWEEN DETAILS OF MODELS!

BUT SIMPLE PICTURE FOR B-A COLLISIONS (B<A)



P_B WOUNDED NUCLEONS IN PROJECTILE

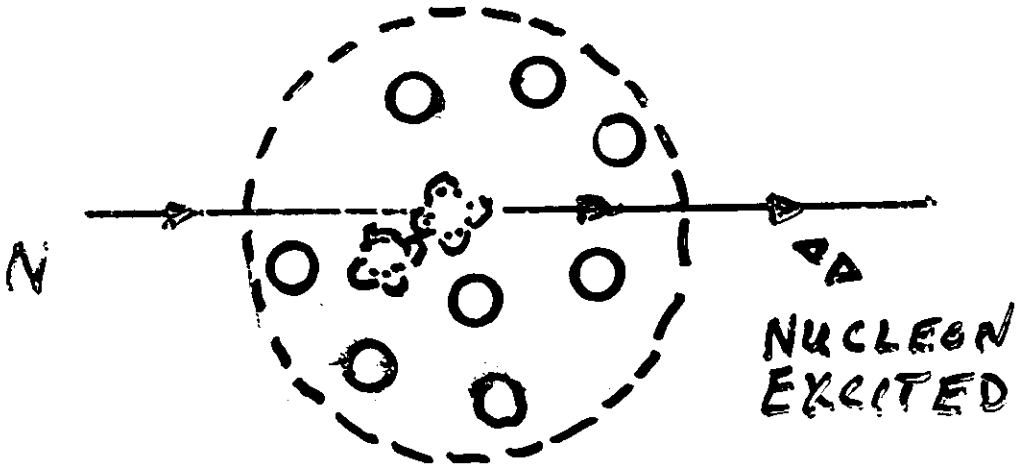
P_A WOUNDED NUCLEONS IN TARGET

$$P(n) = P_B P_0(n) + (P_A - P_B)\, b(n) P_0(n)$$

IF ALL NUCLEONS WOUNDED

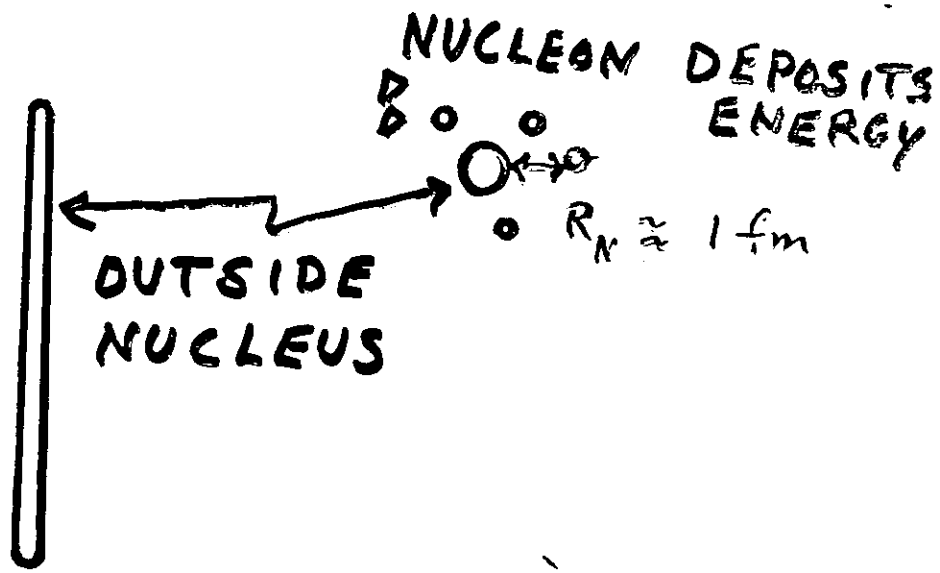
$$P(n)_{MAX} = B P_0(n) + (A - B)\, b(n) P_0(n)$$

NUCLEON - NUCLEUS :



TARGET FRAME

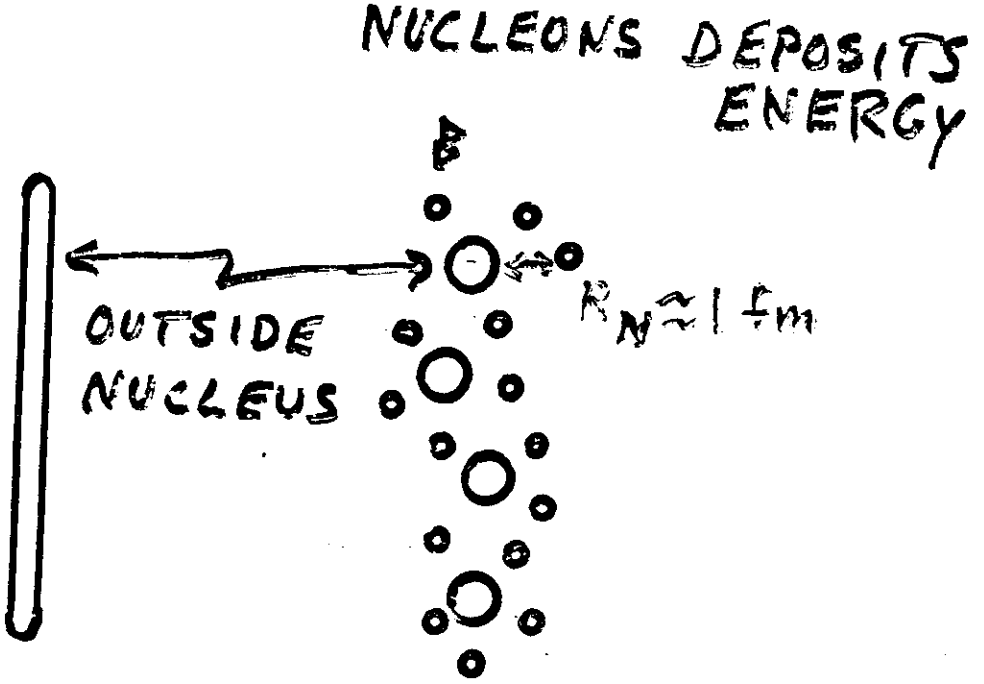
NUCLEAR TRANSPARANCY



PROJECTILE FRAME

(LORENTZ CONTRACTION $\Rightarrow t_{FORMATION} >> t_{TRANSIT}$)

NUCLEUS - NUCLEUS :



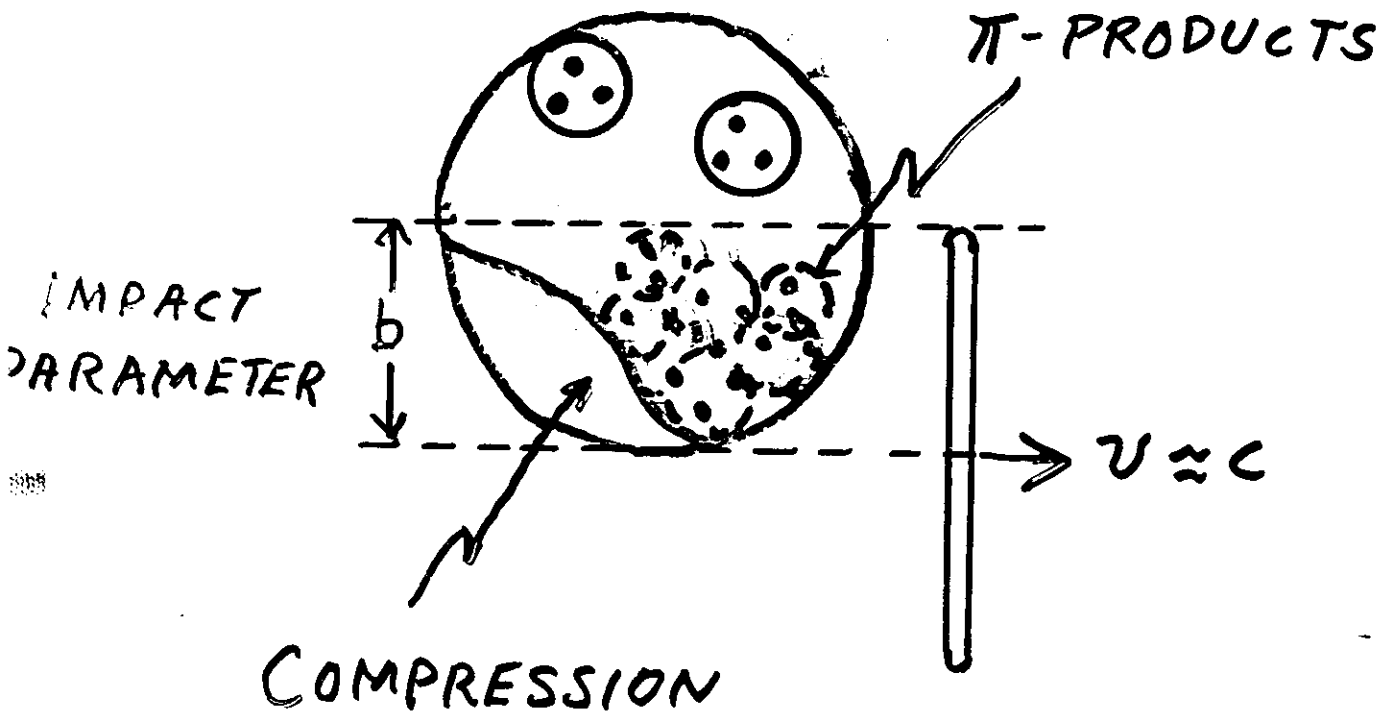
PROJECTILE FRAME

EXPECTED REASON FOR DEVIATION FROM SUPERPOSITION MODELS

MANY EXCITED NUCLEONS CAN RESCATTER OFF EACH OTHER

⇒ POSSIBLY HOT DENSE FIREBALL VIA PARTICLE PRODUCTION

HEATING BY DIRECT COMPRESSION:



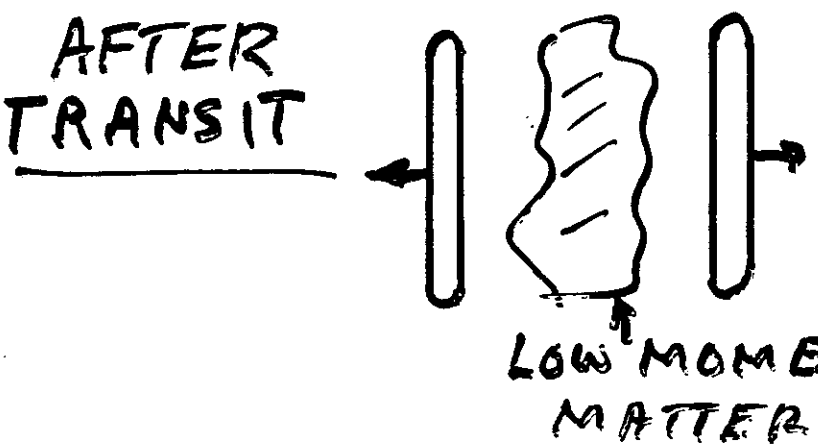
THE "WOUNDED" PART OF TARGET IS HEATED BY COMPRESSION IN ADDITION TO HEATING SUPPLIED BY PARTICLE PRODUCTION.

IN COLLISIONS OF TWO HEAVY IONS

SAME HEATING PROCESS IN BOTH PROJECTILE AND TARGET

IF THERE IS ABUNDANT PROD. OF SLOW (IN C.M.S.) PIONS WHEN TWO HEAVY NUCLEI COLLIDE,

A PHASE TRANSITION MAY RESULT FROM ENERGY LEFT BEHIND IN REGION CONNECTING THE SEPARATING NUCLEI



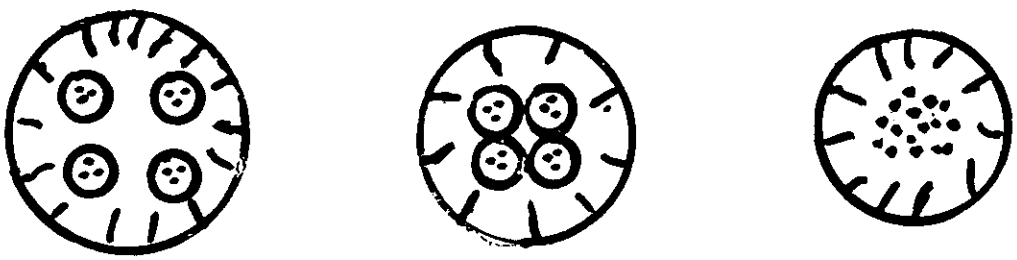
BIG QUESTION: IS ENERGY DENSITY SUFFICIENT TO FORM QUARK-GLUON PLASMA ?

USING QCD ONE CAN HOPE TO COMPUTE CRITICAL DENSITY, ρ_c, WHEN MATTER SHIFTS FROM HADRON TO QUARK PHASE

VARIOUS ESTIMATES STARTING AT A FEW TIMES THE DENSITY OF COLD NUCLEAR MATTER, ρ_0.

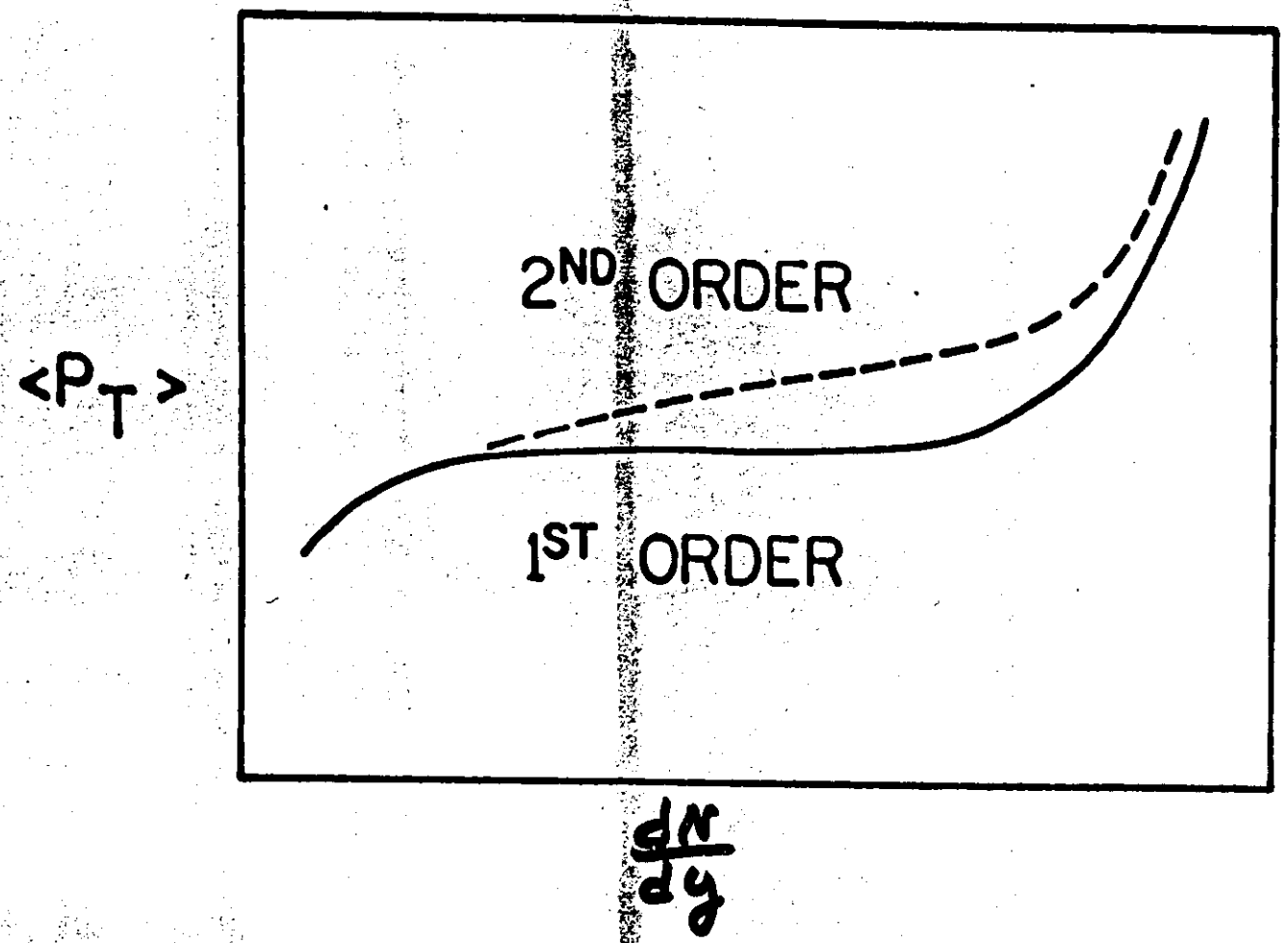
$(\rho_c \geq$ SEVERAL $\cdot \rho_0)$

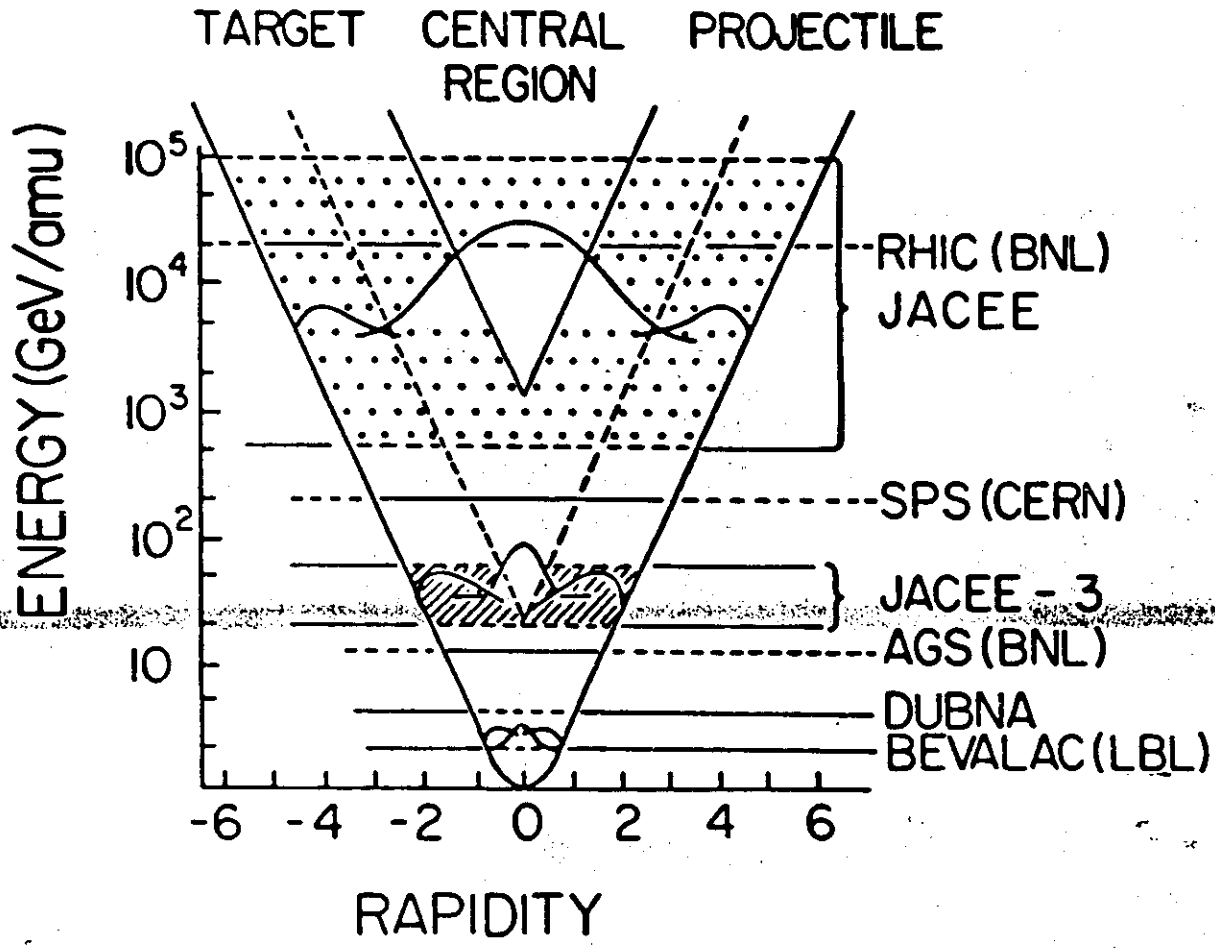
(PERHAPS $\rho_c \gtrsim 1\ GeV/fm^3$)



NUCLEAR MATTER | CRITICAL DENSITY | QUARK MATTER

INCREASING DENSITY

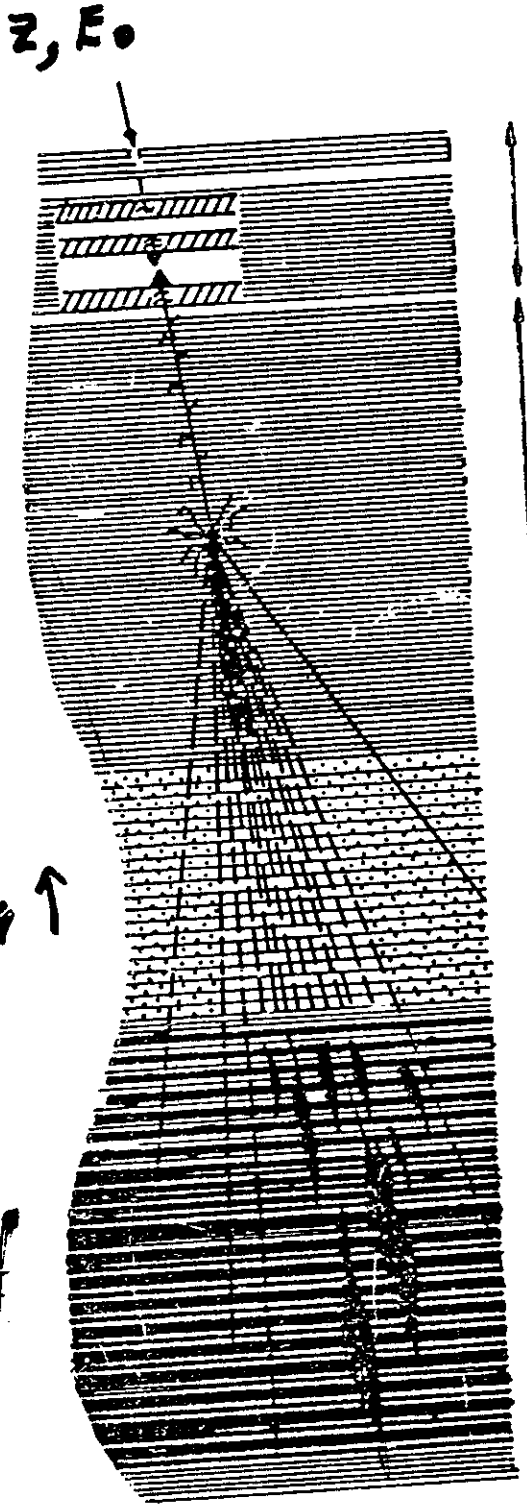

$\langle P_T \rangle$
2ND ORDER
1ST ORDER
$\frac{dN}{dy}$


TARGET
CENTRAL REGION
PROJECTILE
ENERGY (GeV/amu)
10^5
10^4
10^3
10^2
10
RHIC (BNL)
JACEE
SPS (CERN)
JACEE - 3
AGS (BNL)
DUBNA
BEVALAC (LBL)
-6 -4 -2 0 2 4 6
RAPIDITY

VERTICAL STACK-UP

("HIGH ENERGY JACEE")

~ 300 layers



CHARGE DETECTOR
- Thick Emul. 200 - 400 μm
- CR-39
- CN

TARGET (LOW Z - ACRYLIC) (HIGH Z - Fe)
- Thin Emul. 50 - 75 μm
- CR-39

SPACER
- Honey-comb Paper
- Thin Emul. (few)

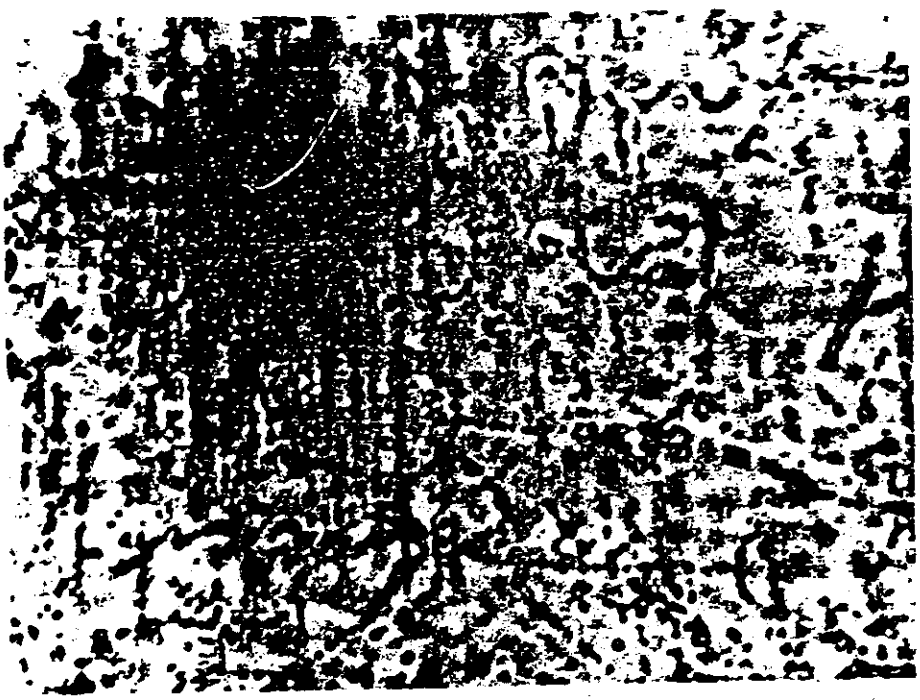
CALORIMETER (HIGH Z - LEAD)
- Thin Emul.
- X-Ray Film
- Lead Sheets 1 mm, 2.5 mm

7 X_0

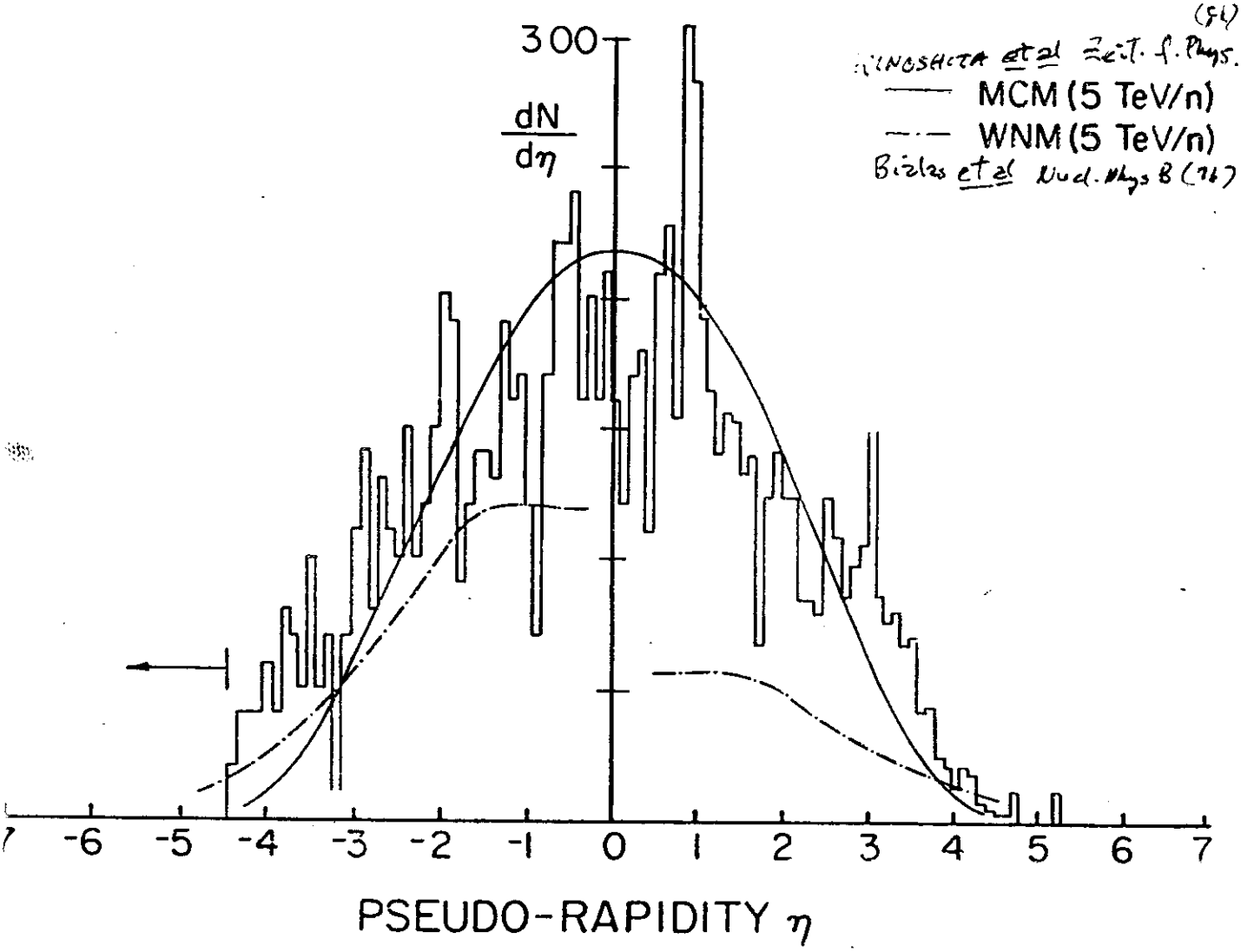
JACEE Balloon Flights

Flight	Date	Launch Site	Residual Altitude (g/cm^2)	Time (hrs)	Area (m^2)
JACEE-0	5/79	Sanriku (Japan)	8.0	29.0	0.20
JACEE-1	9/79	Palestine (USA)	3.7	26.5	0.80
JACEE-2	10/80	Palestine (USA)	4.0	29.6	0.80
JACEE-3	6/82	Greenville (USA)	5.0	39.0	0.25
JACEE-4	9/83	Palestine (USA)	4.5	59.5	0.80
JACEE-5	10/84	Palestine (USA)	5.0	15.0	0.80
JACEE-6	5/86	Palestine (USA)	5.0	30.0	0.80
JACEE-7	1/87	Australia-Paraguay	5.0	150	0.60
JACEE-8	2/88	Australia-Brazil	5.0	100	0.60

800 μm
BASE PLATE



Si + AgBr → $S N_h$ + 1010 ± 30 N_{ch} + 7(70)γ
(4 TeV/nucl)

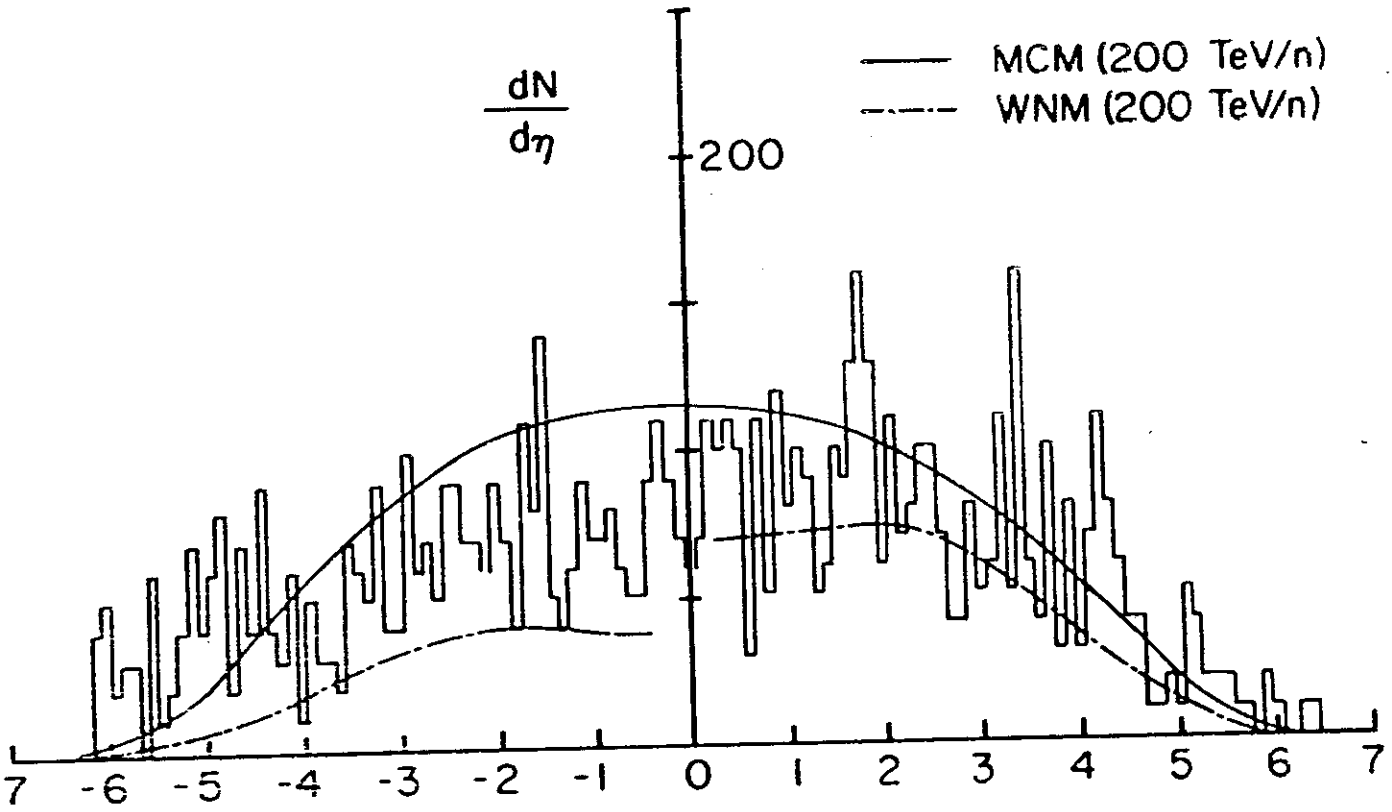


ACRYLIC !!

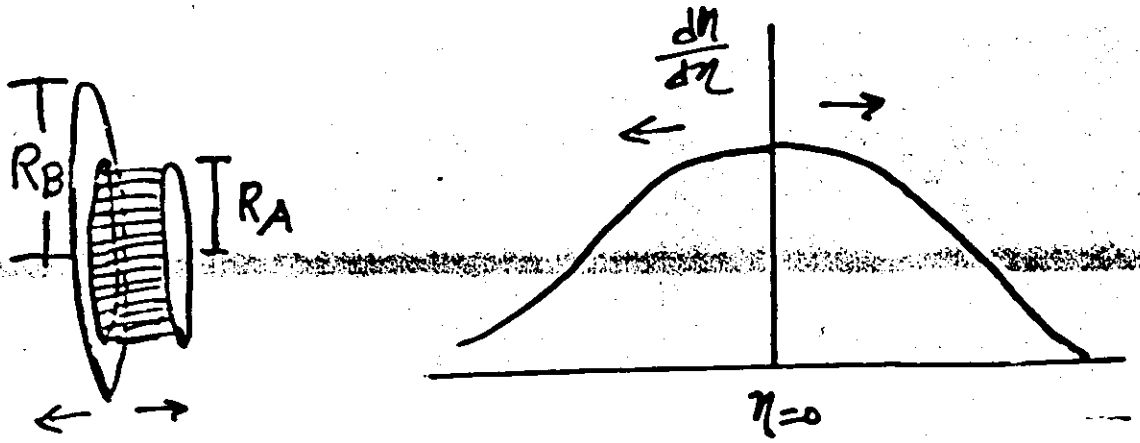
$Ca + C \rightarrow He + 760 \pm 30 N_{ch} + > 300\ \gamma$

$E_0 \simeq 2.6 \times 10^{15}$ eV

Highest energy event ever observed "directly"



ESTIMATE OF THE ENERGY DENSITY
FROM PSEUDO RAPIDITY DISTRIBUTIONS
[CENTRAL RAPIDITY DENSITY]
BJORKEN FORMULA

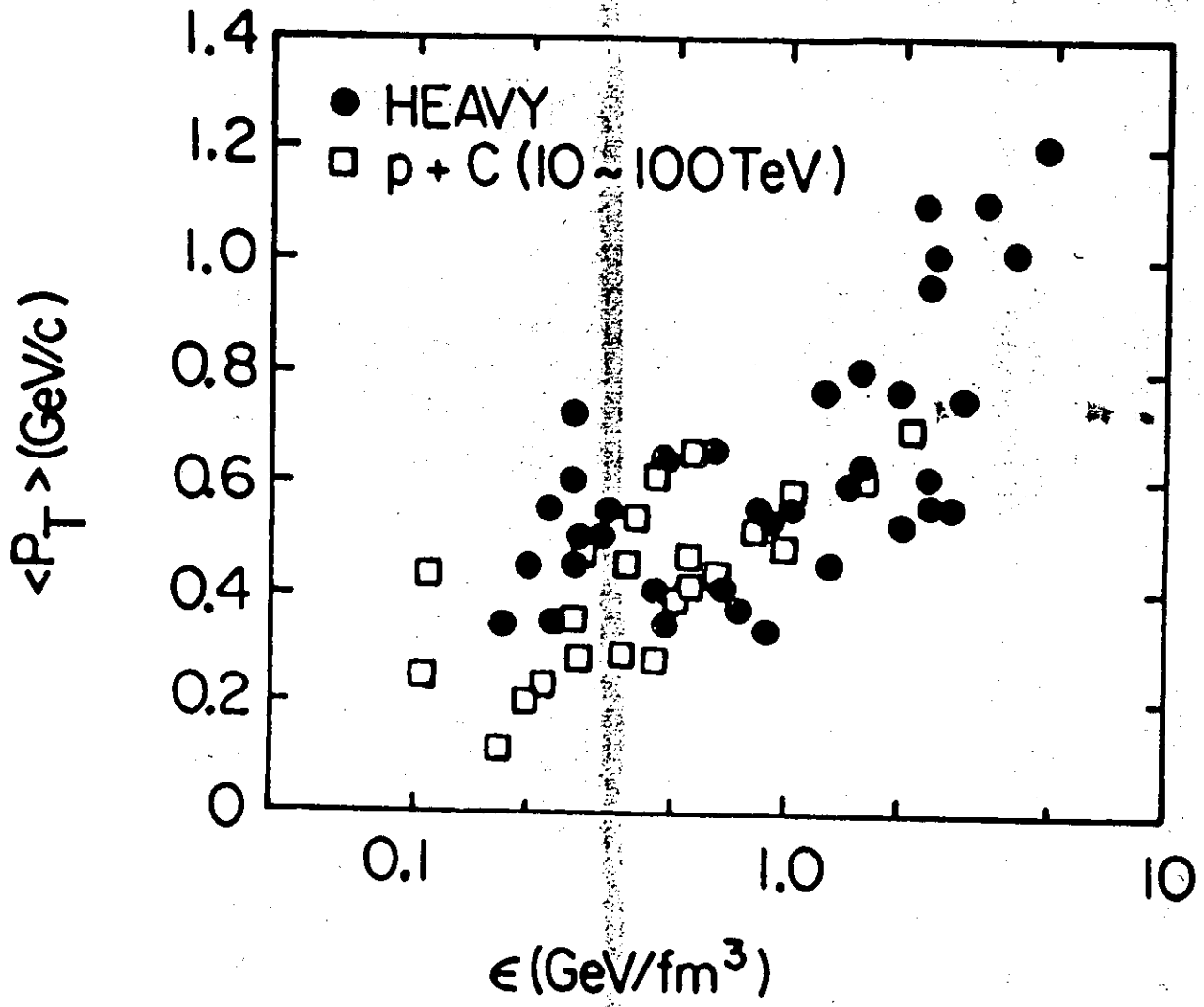


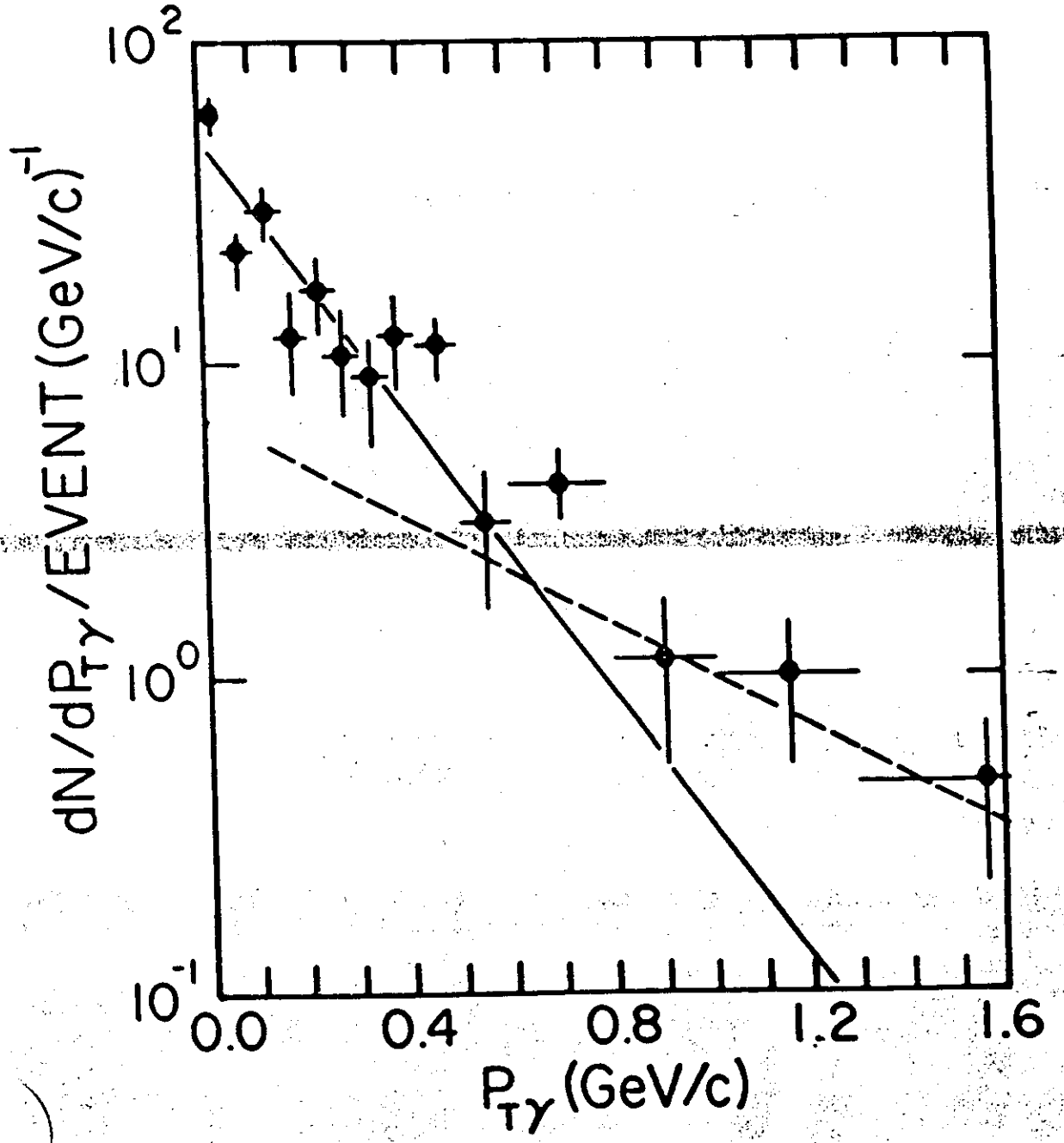
$$\underline{\epsilon} = \langle \sqrt{p^2+m^2} \rangle \; \tfrac{3}{2} \frac{dn}{d\eta} \Big/ \pi R_A^2 \, t$$

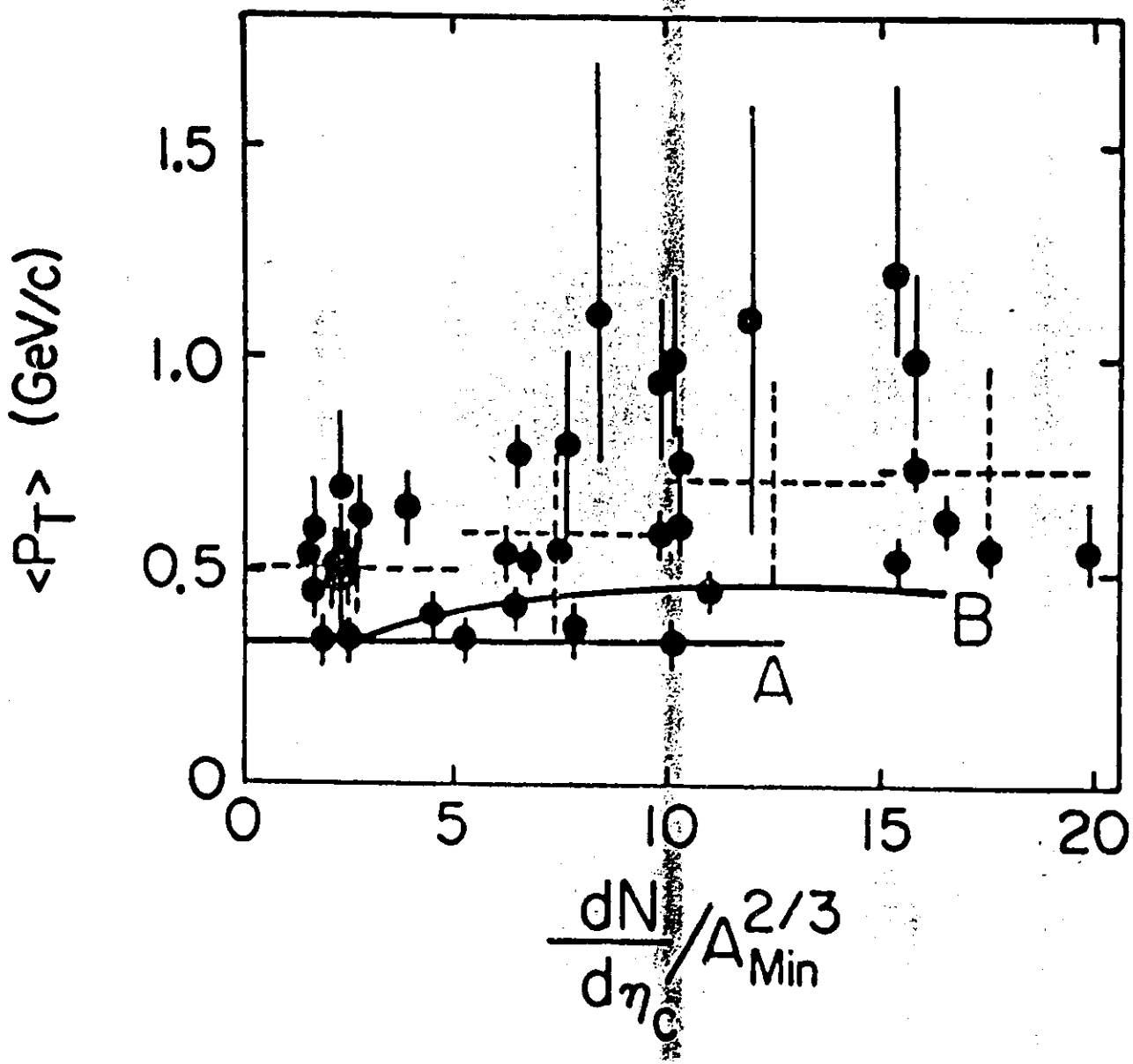
$$\geq \sqrt{\langle p_T^2 \rangle + m^2} \; \tfrac{3}{2} \frac{dn}{d\eta} \Big/ \pi R_A^2 \, t$$

High Energy Central Collision Candidates ($N_{ch} > 400$)

A + B	E_o (TeV/amu)	N_{ch}	$dN/d\eta_c$	$\langle P_T \rangle$ (GeV/c)	ϵ (GeV/fm^3)
Ca + C	100.0	760 ± 30	81 ± 8	0.53 ± 0.04	2.0
Si + Em	4.1	1010 ± 30	183 ± 10	$0.55^{+0.12}_{-0.05}$	2.7
V + Pb	1.5	1050^{+300}_{-50}	258 ± 12	0.55 ± 0.05	2.5
Ti + Pb	1.0	416	139 ± 8	$1.00^{+0.2}_{-0.15}$	2.4
Ca + Pb	1.8	452	100 ± 16	$1.1^{+1.0}_{-0.35}$	2.2
Ca + Pb	0.5	670 ± 40	142 ± 8	1.1 ± 0.5	3.3
Si + Pb	4.0	790^{+40}_{-25}	147 ± 8	$1.0^{+0.2}_{-0.15}$	3.8
C + Pb	71.5	400^{+15}_{-30}	81 ± 7	>1.2	4.5


HEAVY
p + C (10 ~ 100TeV)
<P_T> (GeV/c)
ε (GeV/fm³)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0.1
1.0
10


10^2
10^1
10^0
10^{-1}
$dN/dP_{T\gamma}$ / EVENT (GeV/c)$^{-1}$
0.0
0.4
0.8
1.2
1.6
$P_{T\gamma}$ (GeV/c)


1.5
1.0
0.5
0
0
5
10
15
20
<PT> (GeV/c)
dN/dηc / A^2/3 Min
A
B