ICHEP 2000
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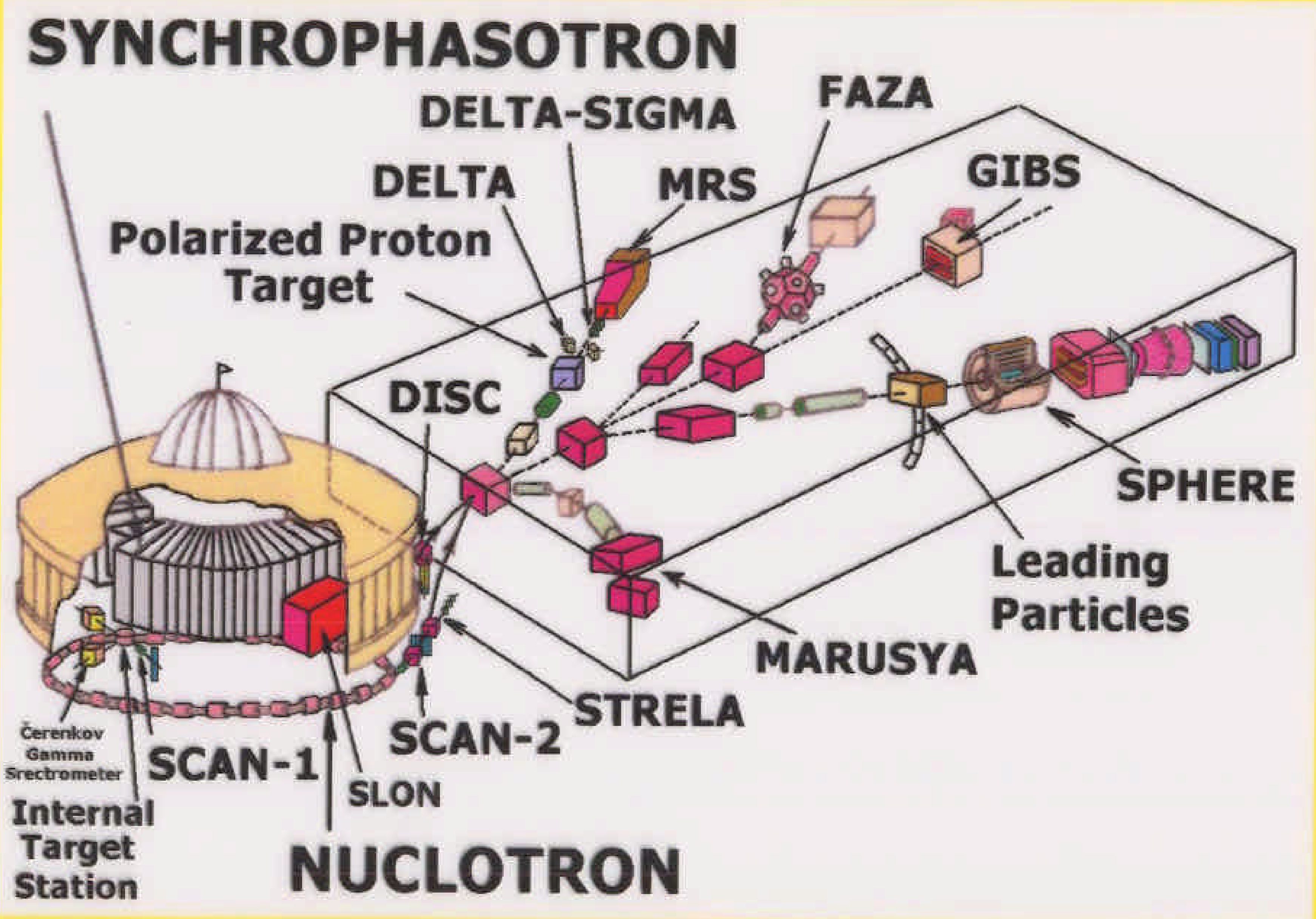
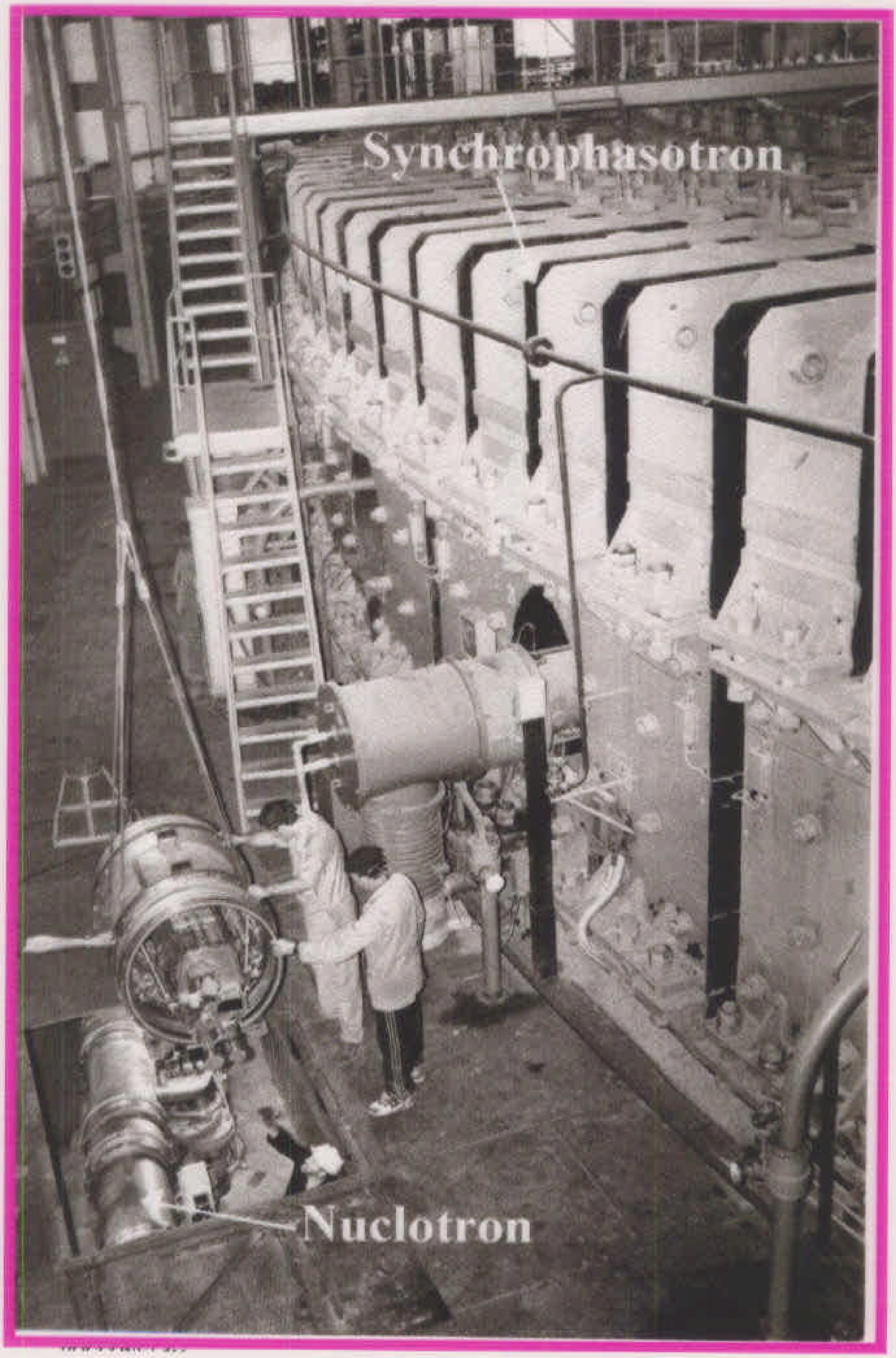
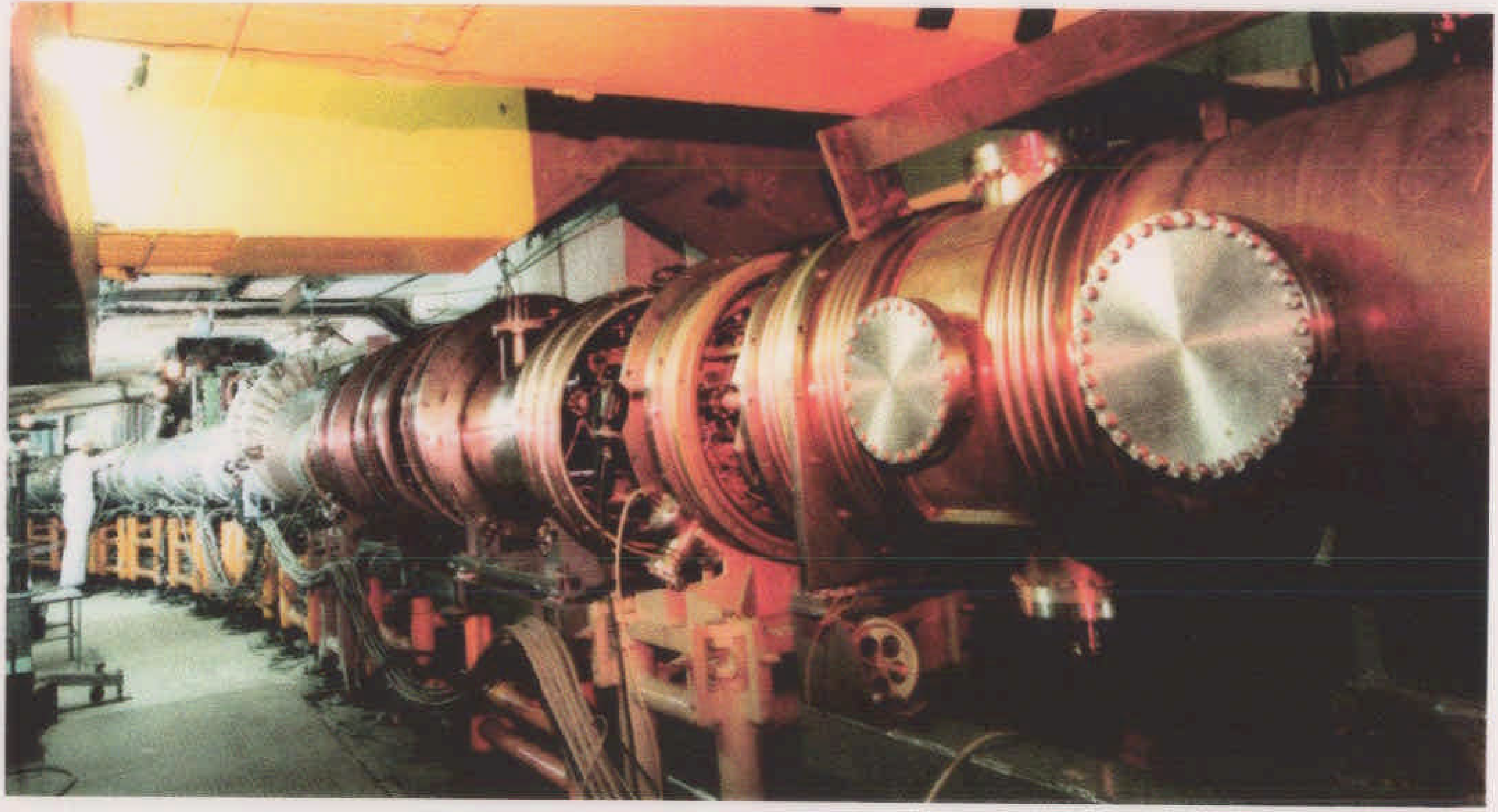
(July27 - August 2, 2000 at International House, Osaka)

Parallel Session PA-04c
A.Malakhov
Laboratory of High Energies
Joint Institute for Nuclear Research, Dubna
e-mail: malakhov@lhe.jinr.ru

New Results in Relativistic Nuclear Physics at JINR (Dubna)

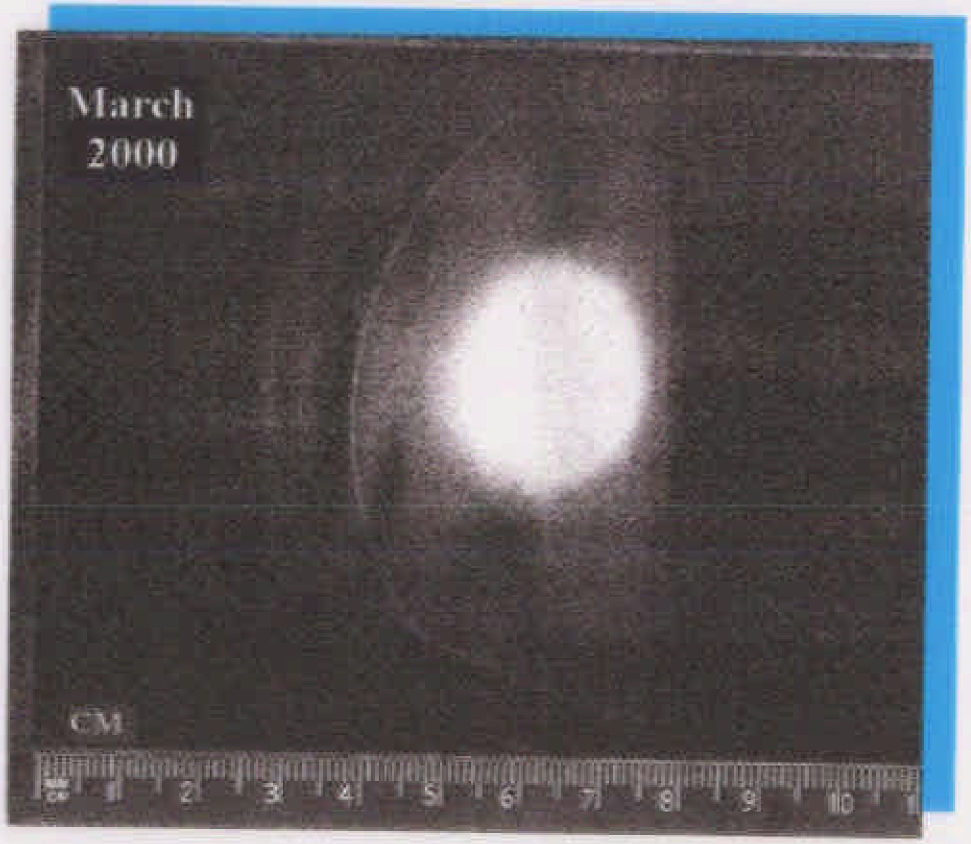

SYNCHROPHASOTRON
DELTA-SIGMA
FAZA
DELTA
MRS
GIBS
Polarized Proton Target
DISC
SPHERE
Leading Particles
MARUSYA
STRELA
SCAN-2
Čerenkov Gamma Srectrometer
SCAN-1
SLON
Internal Target Station
NUCLOTRON


Synchrophasotron
Nuclotron



The Beam Extraction System at the Nuclotron

NUCLOTRON EXTRACTED BEAM

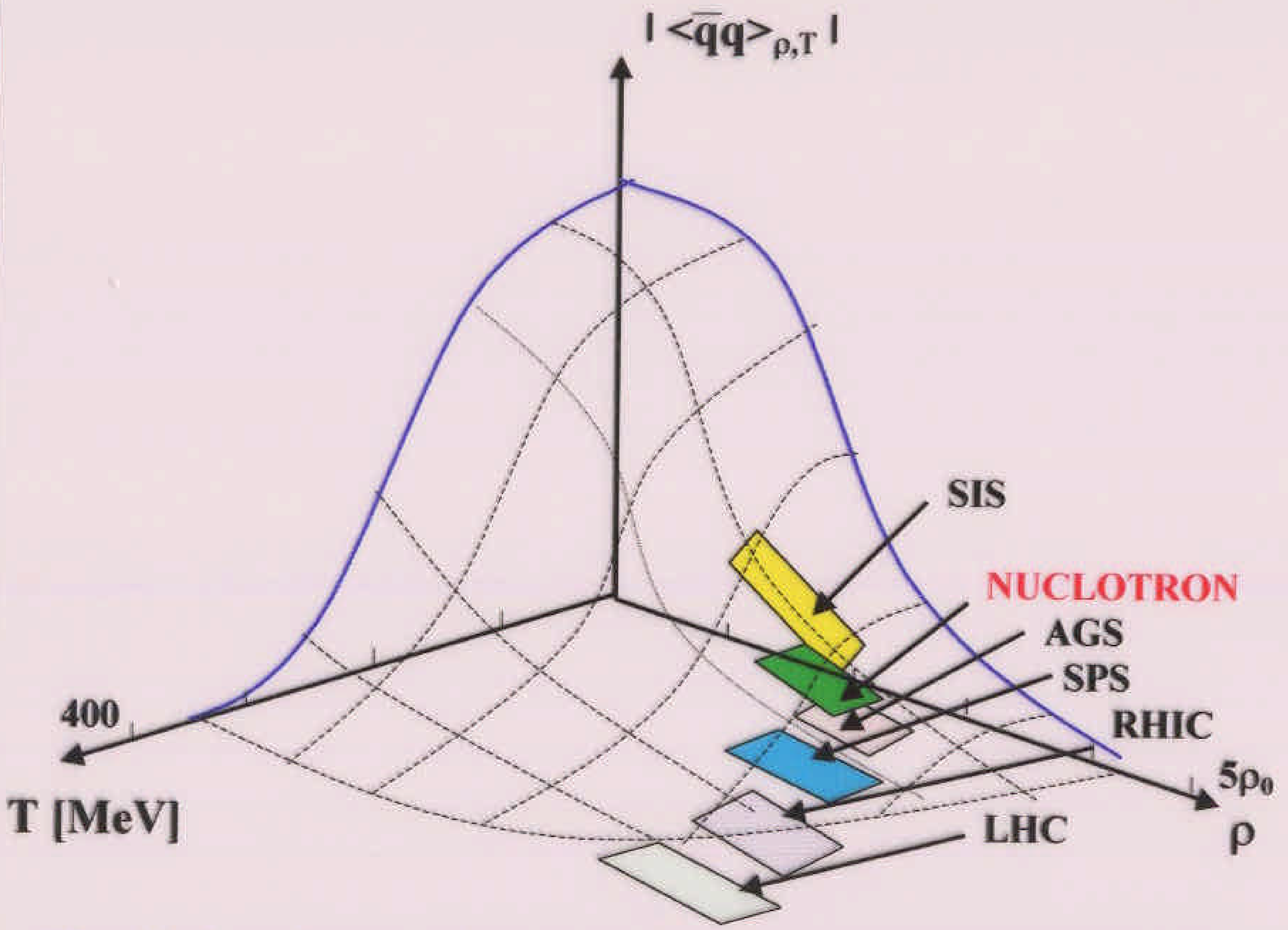


Deuterons

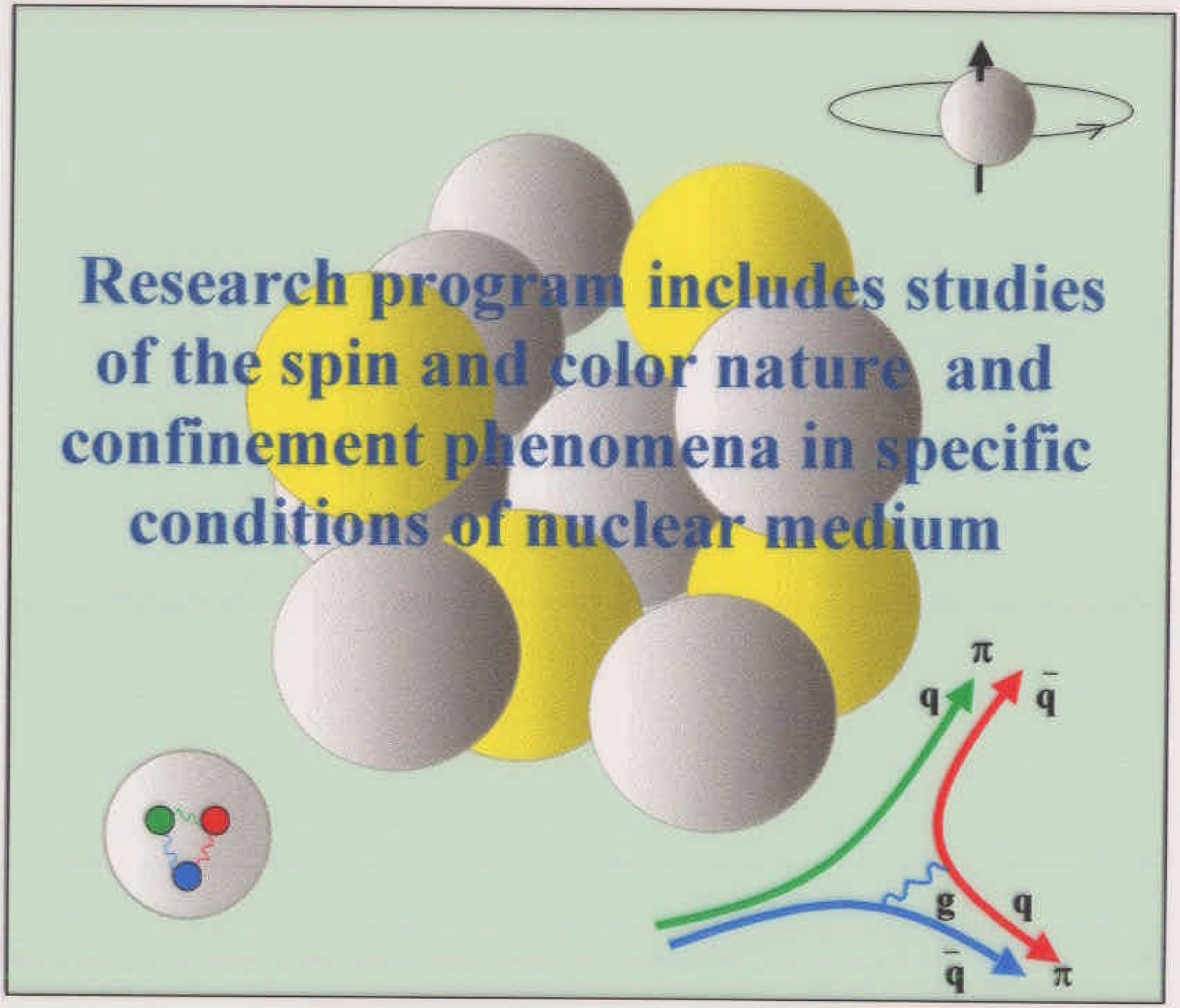
$P = 4.5$ GeV/c

$I = 10^9$ d/cycle

Beam	Intensity (particles per cycle)		
	Synchro-phasotron	Nuclotron	
		availabl	have to be
p	$4\cdot10^{12}$	$2\cdot10^{10}$	10^{13}
n (secondary)	10^{10}		10^{13}
n↑ (secondary)	10^{6}		10^{11}
d	10^{12}	$5\cdot10^{10}$	10^{13}
d↑	10^{9}	$3\cdot10^{8}$	$5\cdot10^{10}$
t (secondary)	10^{9}	$4\cdot10^{5}$	10^{10}
^{3}He (secondary)	$2\cdot10^{10}$		$5\cdot10^{11}$
^{4}He	$5\cdot10^{10}$	$8\cdot10^{8}$	$2\cdot10^{12}$
^{7}Li	$2\cdot10^{9}$		$5\cdot10^{12}$
^{12}C	10^{9}	10^{8}	$2\cdot10^{12}$
^{16}O	$5\cdot10^{7}$		10^{10}
^{20}Ne	10^{4}		$5\cdot10^{9}$
^{24}Mg	$5\cdot10^{6}$		$5\cdot10^{11}$
^{28}Si	$3\cdot10^{4}$		10^{10}
^{32}S	10^{3}		10^{10}
^{40}Ar	-		$2\cdot10^{9}$
^{56}Fe	-		10^{11}
^{84}Kr	-	10^{3}	$5\cdot10^{8}$
^{96}Mo	-		10^{10}
^{131}Xe	-		$2\cdot10^{8}$
^{181}Ta	-		10^{8}
^{209}Bi	-		10^{8}
^{238}U	-		10^{8}
Energy	4.5 A·GeV	5.2 A·GeV	6 A·GeV

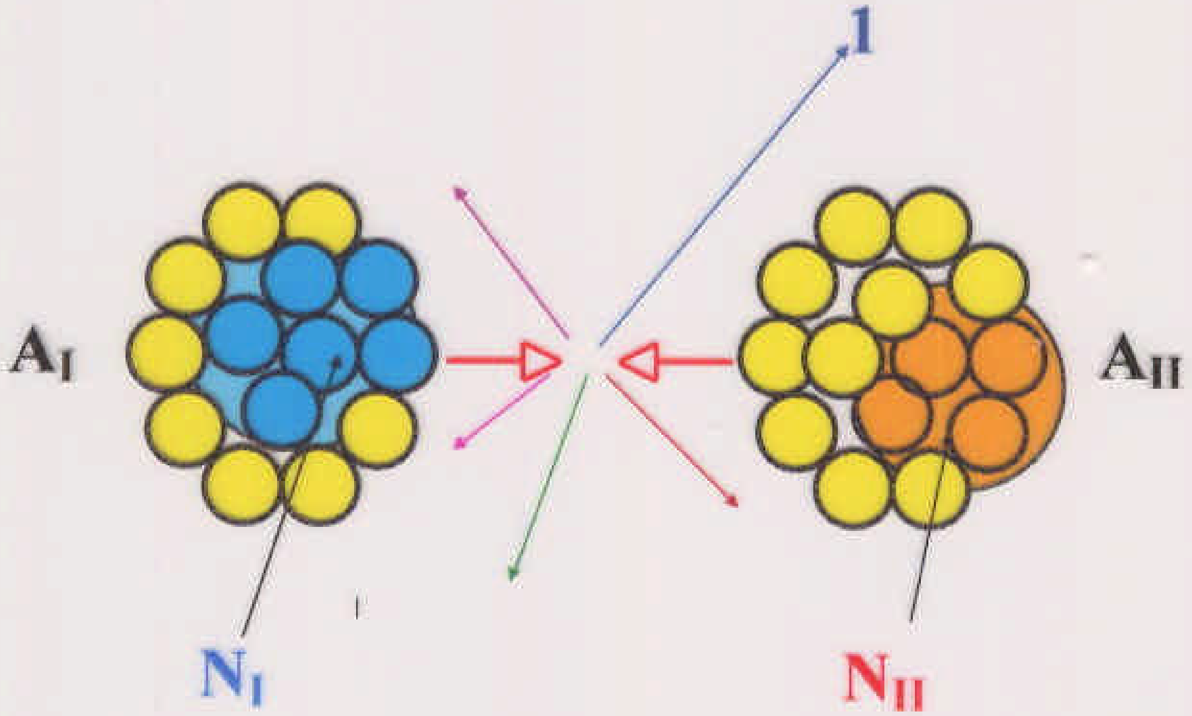


The chiral condensate calculated within the Nambu Jona-Lasinio model as a function of temperature and baryon density


Research program includes studies of the spin and color nature and confinement phenomena in specific conditions of nuclear medium
π
q
q̄
g
q
q̄
π

Cumulative effect

$$I + II \rightarrow 1 + \ldots$$



$N_{I,II} > 1 \leftarrow$ ***CUMULATIVE region***

$A + B \rightarrow \pi + X$

The total 4-momentum conservation:

$$x_A p_A + p_B = p_\pi + p_X$$

$$p_X^2 = M_X^2 \geq (x_A m_N + m_N)^2$$

$$(x_A p_A + p_B - p_\pi)^2 \leq (x_A m_N + m_N)^2$$

$$\Downarrow$$

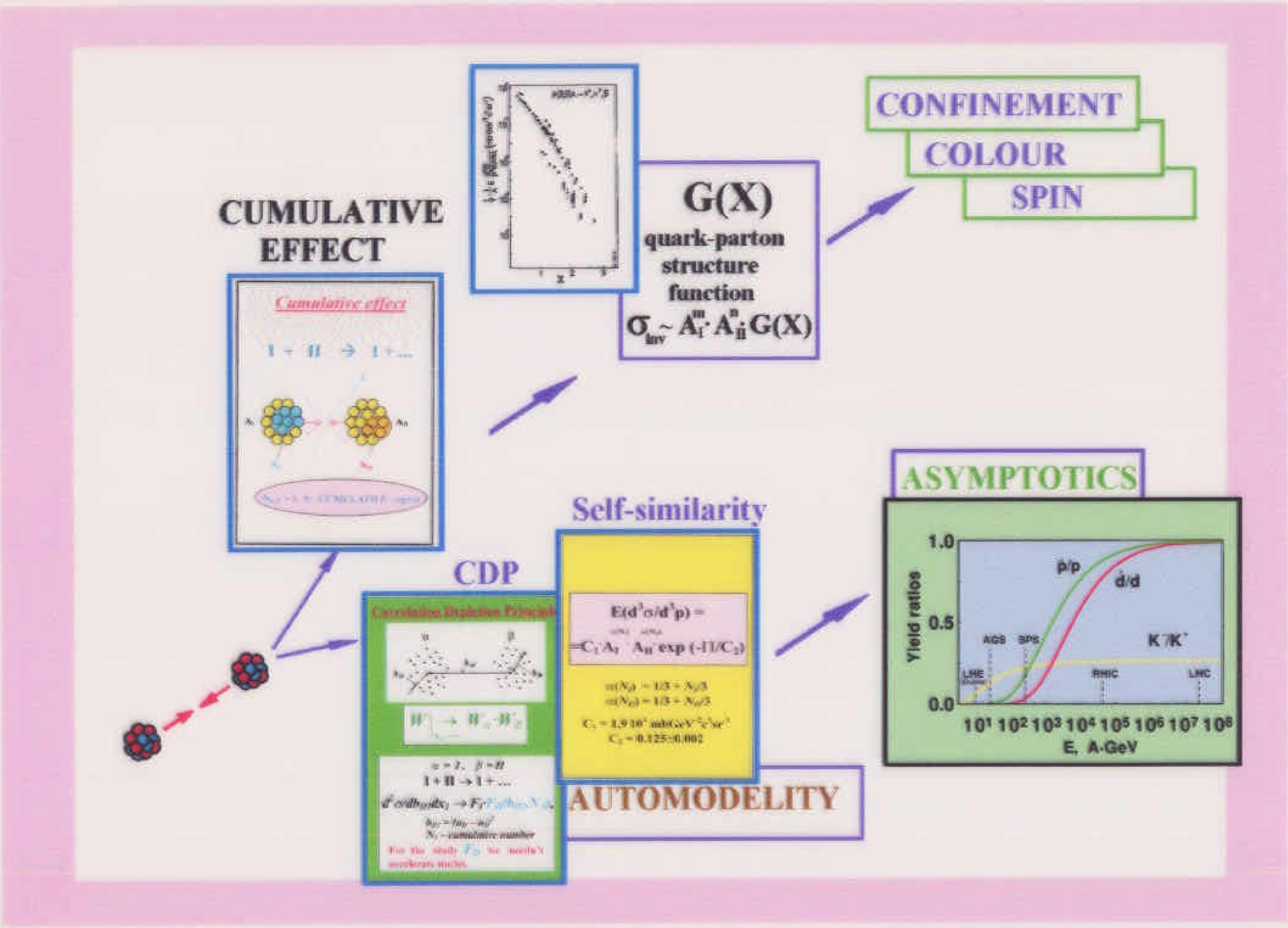
$$\frac{(p_B p_\pi) - m_\pi^2/2}{(p_A p_B) - m_N^2 - (p_A p_\pi)} \leq x_A$$

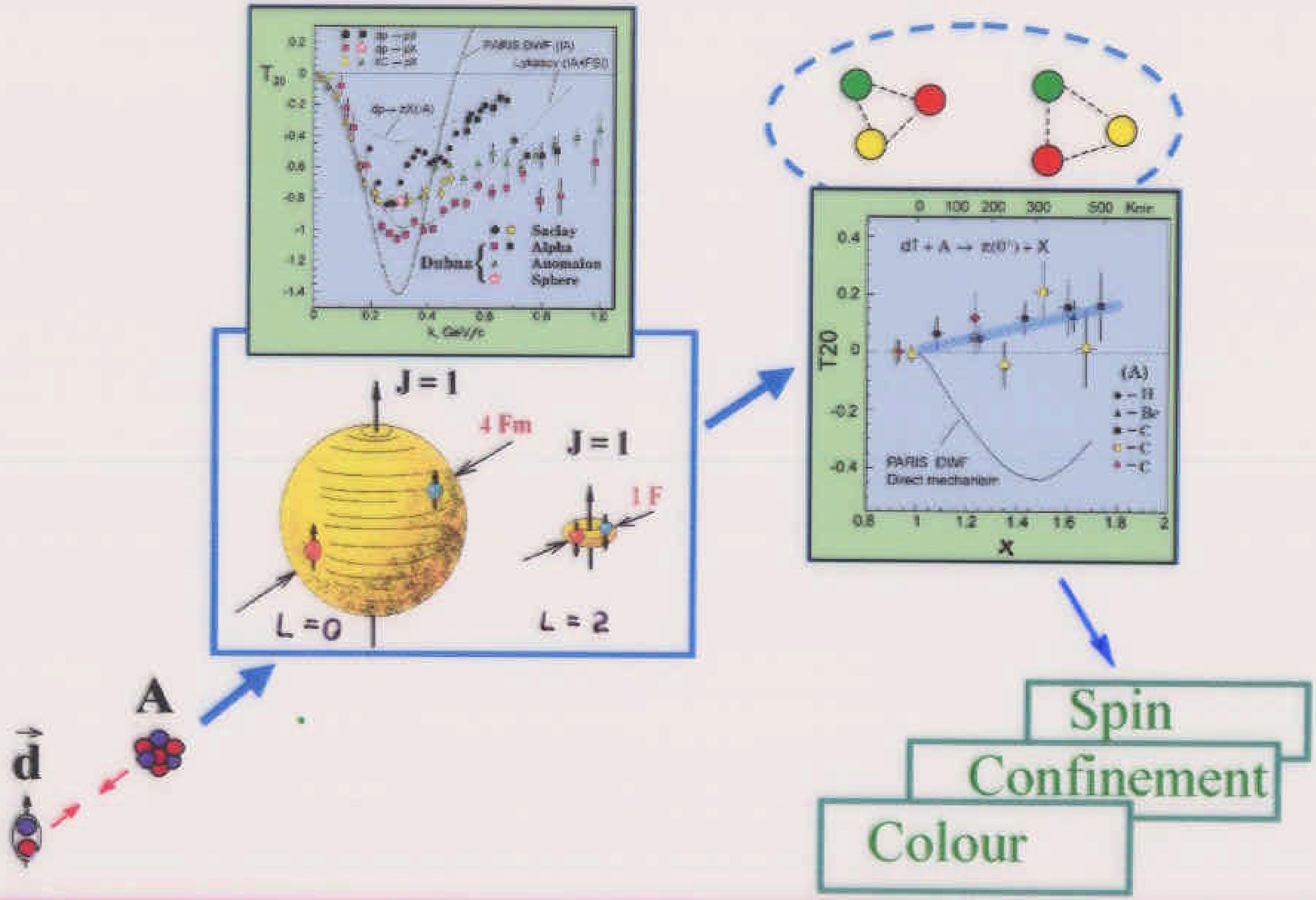
$$x_C \rightarrow \min x_A$$

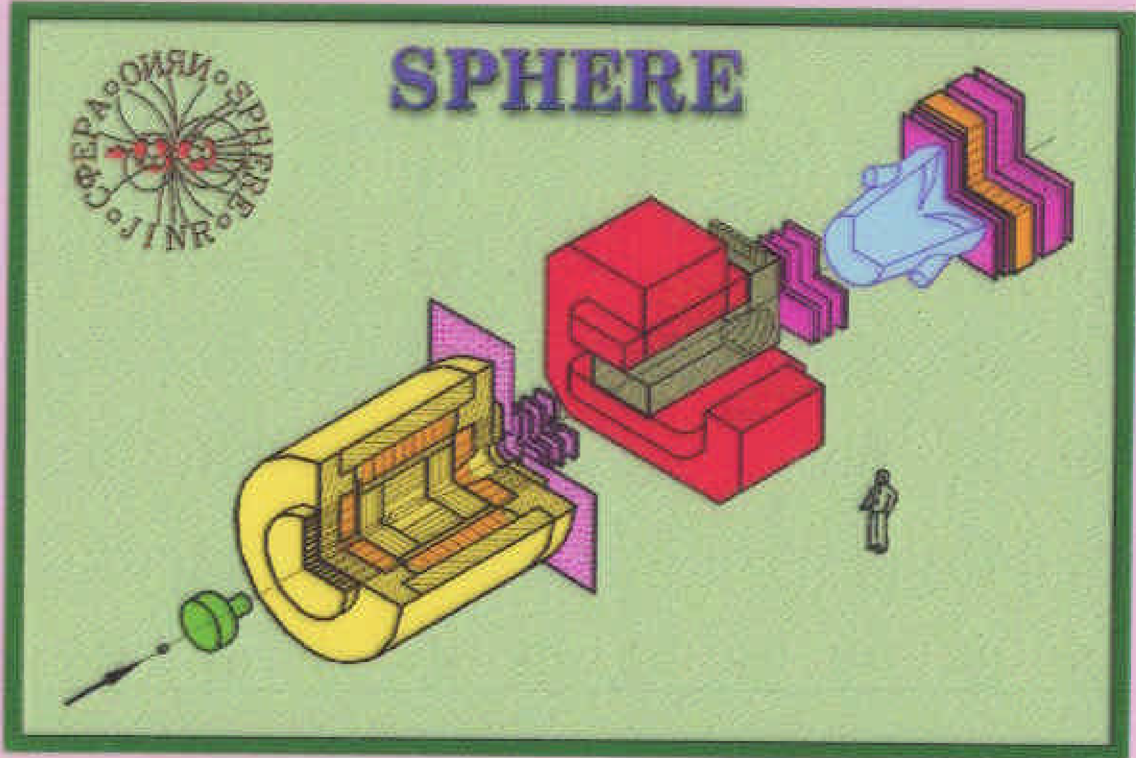
x_C corresponds to the minimum mass (in nucleon mass units) of part of the projectile nucleus involved in the reaction

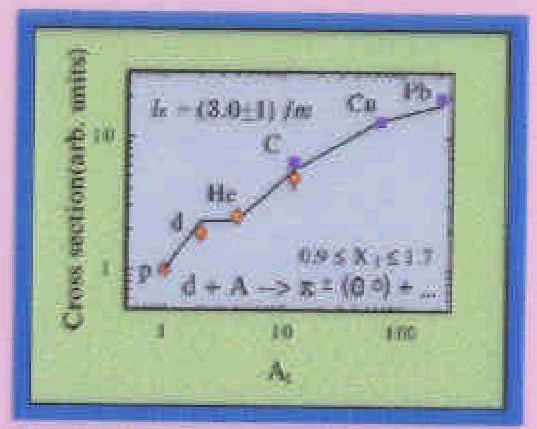
$$\boxed{x_C = \frac{(p_B p_\pi) - m_\pi^2/2}{(p_A p_B) - m_N^2 - (p_A p_\pi)}}$$

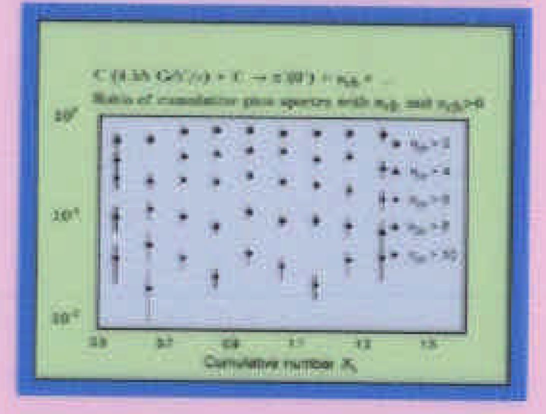
$x_C > 1 \Rightarrow$ cumulative region

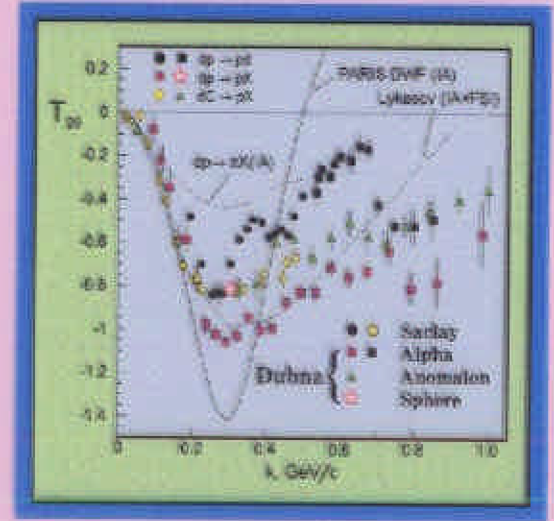

CUMULATIVE EFFECT
Cumulative effect
G(X)
quark-parton
structure
function
σ_inv ~ A_I^m · A_II^n G(X)
CONFINEMENT
COLOUR
SPIN
Self-similarity
E(d³σ/d³p) =
C₁ = 1.9·10⁴
C₂ = 0.125±0.002
CDP
Correlation Depletion Principle
I + II → I + ...
AUTOMODELITY
ASYMPTOTICS
Yield ratios
1.0
0.5
0.0
p̄/p
d̄/d
K⁻/K⁺
AGS
SPS
RHIC
LHC
10¹ 10² 10³ 10⁴ 10⁵ 10⁶ 10⁷ 10⁸
E, A·GeV

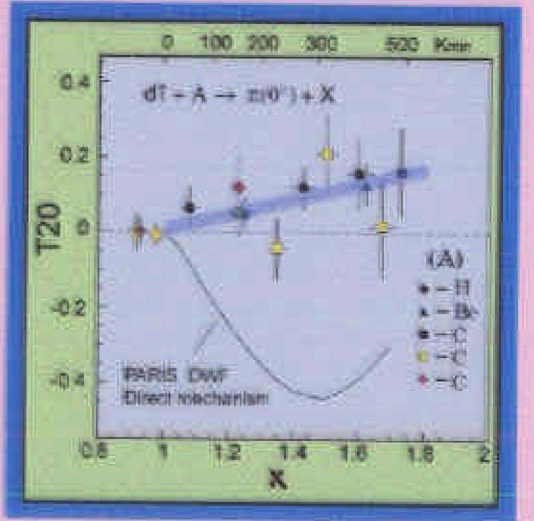

d
A
T20
dp → pX
dp → pX
dC → pX
PARIS DWF (IA)
Lykasov (IA+FSI)
dp → π(0)A
Saclay
Alpha
Anomalon
Sphere
Dubna
k, GeV/c
J = 1
4 Fm
J = 1
1 F
L = 0
L = 2
T20
0 100 200 300 500 Kπ
d↑ + A → π(0°) + X
PARIS DWF
Direct mechanism
(A)
– H
– Be
– C
– C
– C
x
Spin
Confinement
Colour

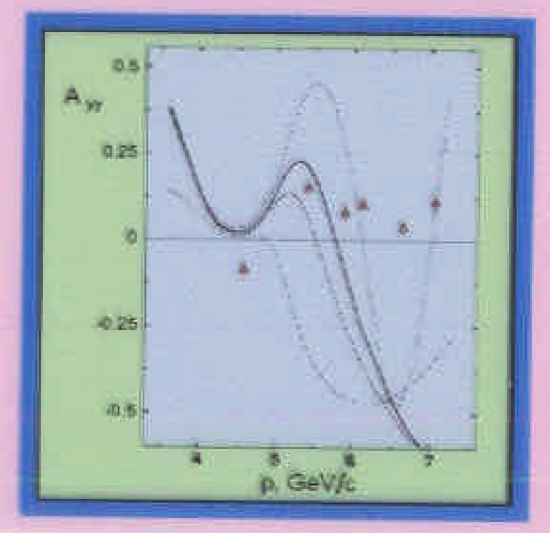

SPHERE
СФЕРА ОИЯИ SPHERE JINR

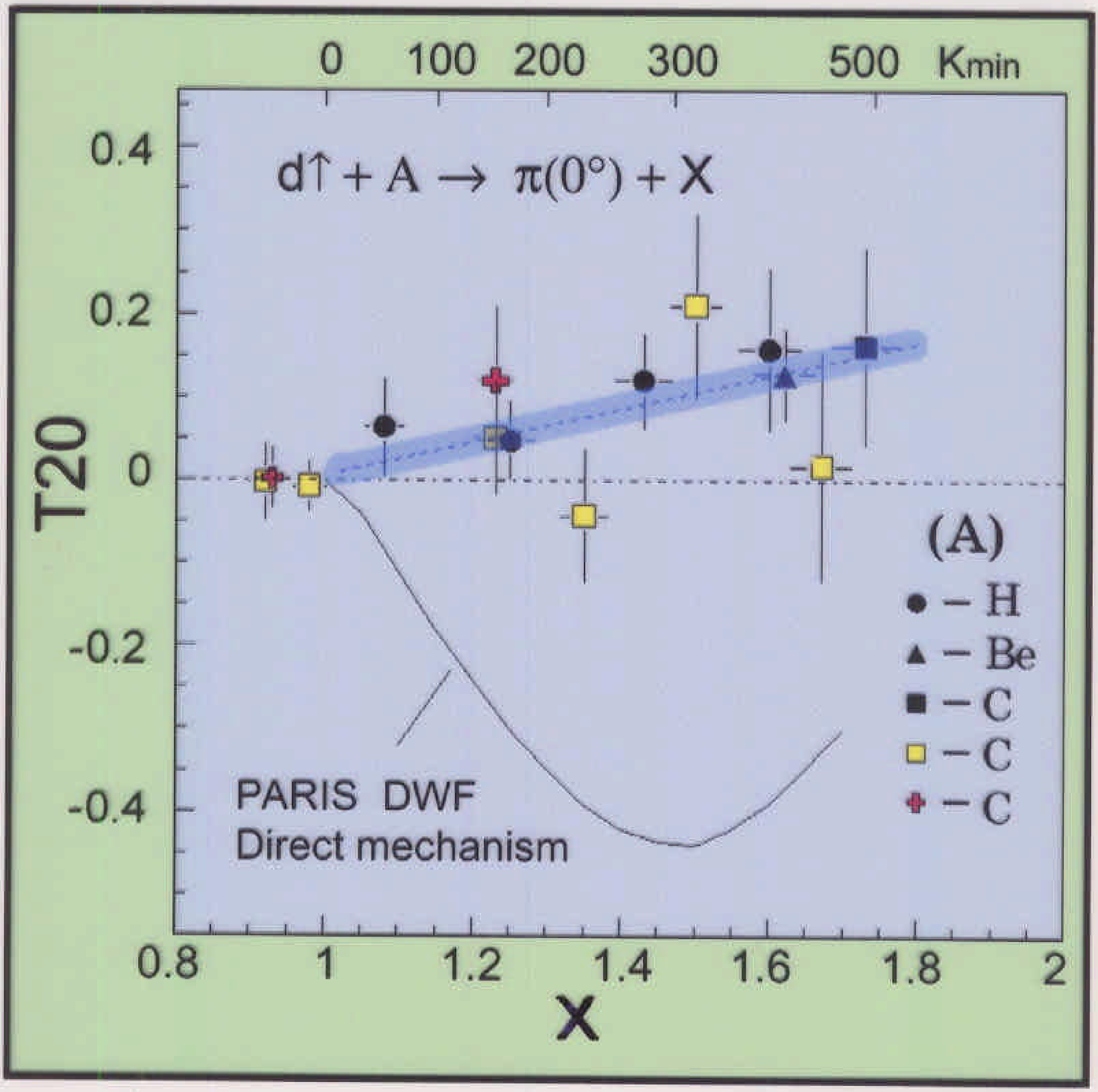

Cross section(arb. units)
Cu
Pb
C
He
d
p
0.9 ≤ X ≤ 1.7
d + A -> π ± (0 °) + ...
A


Cumulative number X

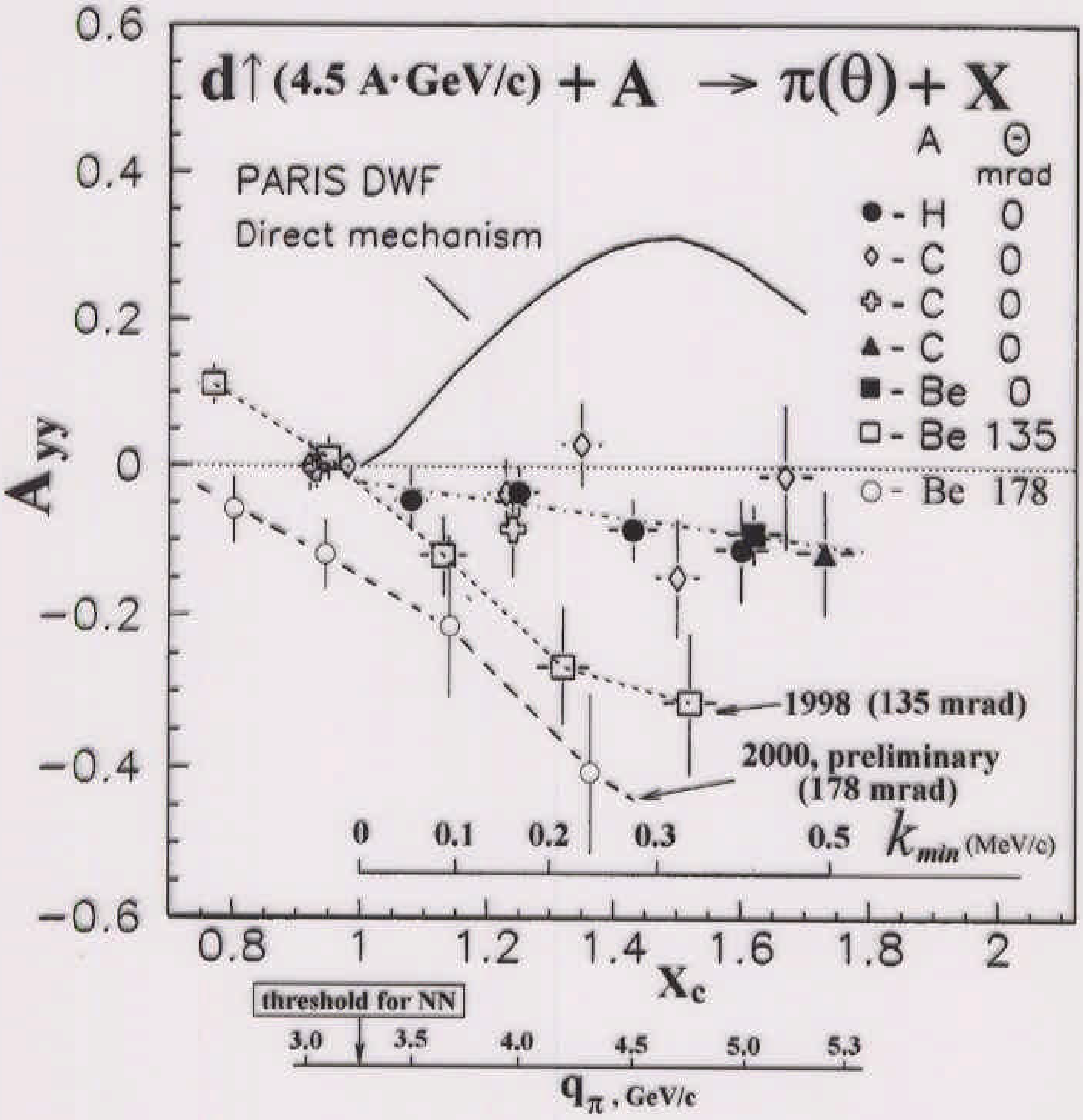

T20
PARIS DWF (A)
Saclay
Alpha
Anomalon
Sphere
Dubna
k, GeV/c


0 100 200 300 500 Kmr
T20
PARIS DWF
Direct mechanism
(A)
X


A yy
p, GeV/c


0 100 200 300 500 Kmin
0.4
0.2
0
-0.2
-0.4
T20
d↑ + A → π(0°) + X
(A)
● – H
▲ – Be
■ – C
□ – C
✚ – C
PARIS DWF
Direct mechanism
0.8 1 1.2 1.4 1.6 1.8 2
X

$$\sigma\uparrow(\Theta)=\sigma(\Theta)[1+\tfrac{3}{2}p_zA_y(\Theta)+\tfrac{1}{2}p_{zz}A_{yy}(\Theta)]$$



Typical values of vector and tensor deuteron beam polarizations are $p_Z^{\pm} = \pm 0.5$ and $p_{ZZ}^{\pm} = \pm 0.7$.

$$\sigma^{+} = \sigma^{0}\left(1 + \frac{3}{2}p_z^{+}A_y + \frac{1}{2}p_{zz}^{+}A_{yy}\right),$$
$$\sigma^{-} = \sigma^{0}\left(1 + \frac{3}{2}p_z^{-}A_y + \frac{1}{2}p_{zz}^{-}A_{yy}\right),$$

$$A_{yy} = 2\left[\frac{p_z^{-}}{p_z^{-}p_{zz}^{+} - p_z^{+}p_{zz}^{-}}\left(\frac{n^{+}}{n^{0}} - 1\right) - \frac{p_z^{+}}{p_z^{-}p_{zz}^{+} - p_z^{+}p_{zz}^{-}}\left(\frac{n^{-}}{n^{0}} - 1\right)\right],$$
$$A_y = -\frac{2}{3}\left[\frac{p_{zz}^{-}}{p_z^{-}p_{zz}^{+} - p_z^{+}p_{zz}^{-}}\left(\frac{n^{+}}{n^{0}} - 1\right) - \frac{p_{zz}^{+}}{p_z^{-}p_{zz}^{+} - p_z^{+}p_{zz}^{-}}\left(\frac{n^{-}}{n^{0}} - 1\right)\right]$$

$$A_{yy} = -\sqrt{2}[(1/2)T_{20} + \sqrt{(3/2)}T_{22}]$$

$$T_{20} = \frac{2\sqrt{2}\,(n^{+} - n^{-})}{(n^{+}p_{zz}^{-} - n^{-}p_{zz}^{+})}$$

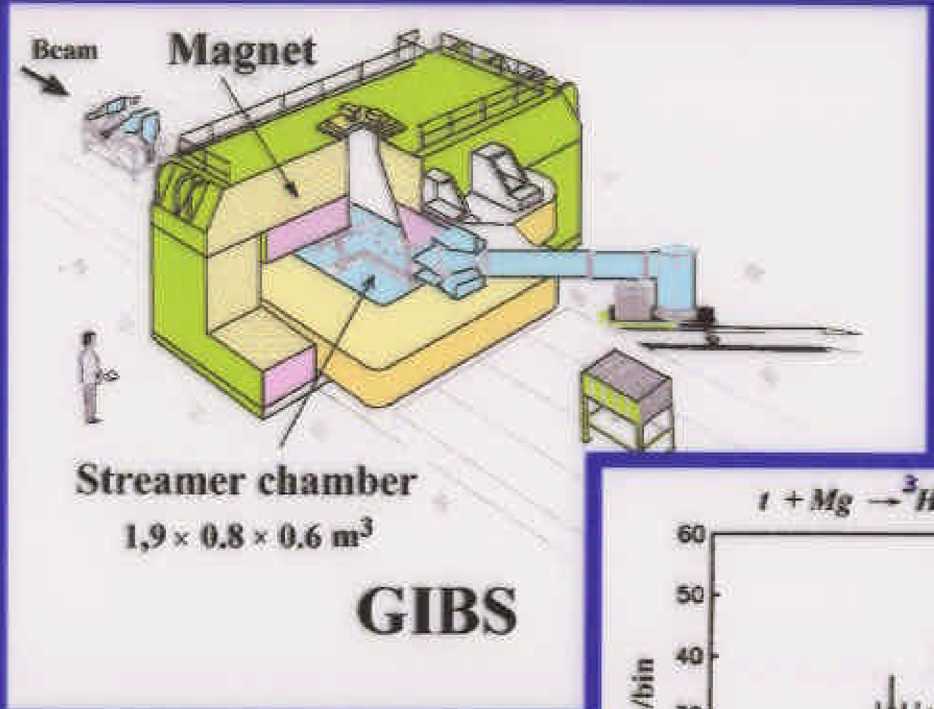
At a zero angle $T_{20} = -\sqrt{2}\,A_{yy}$

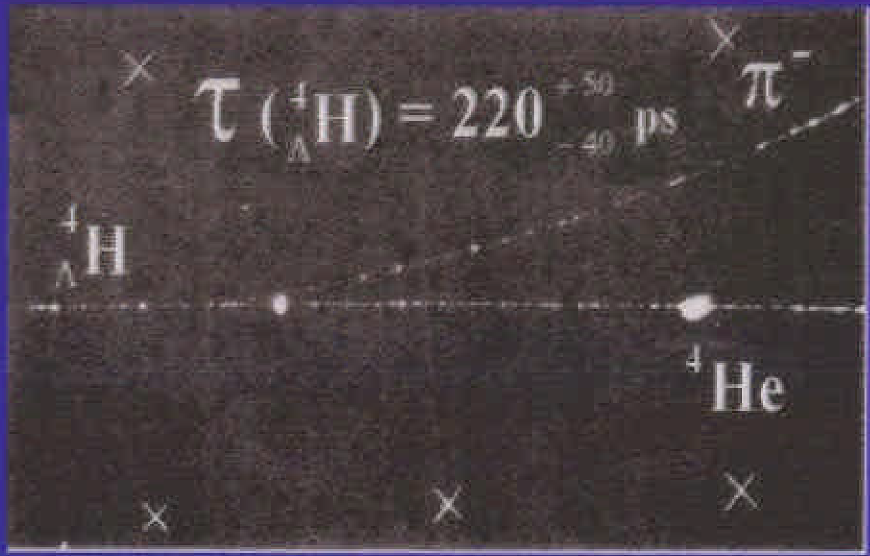
$$T_{20} = \frac{1}{\sqrt{2}} \; \frac{2\sqrt{2}\, v(q)w(q) - w(q)^2}{v(q)^2 + w(q)^2},$$

where *v* and *w* are the S- and D-wave components in DWF

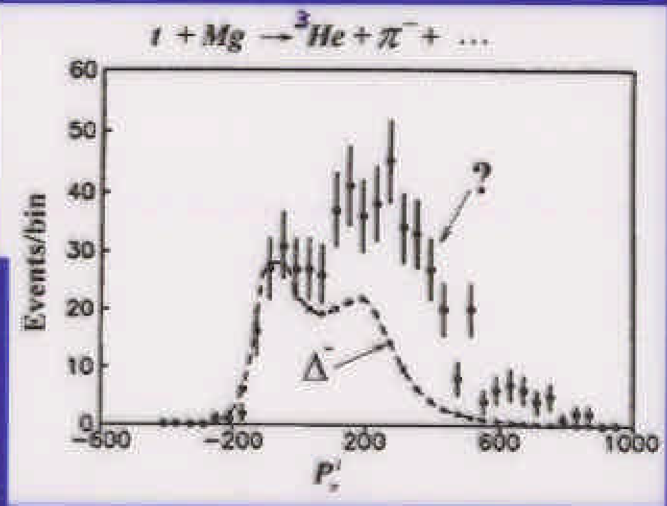
$$T_{20} = \frac{2\sqrt{2}\,(n^{+} - n^{-})}{(n^{+}p_{zz}^{-} - n^{-}p_{zz}^{+})},$$

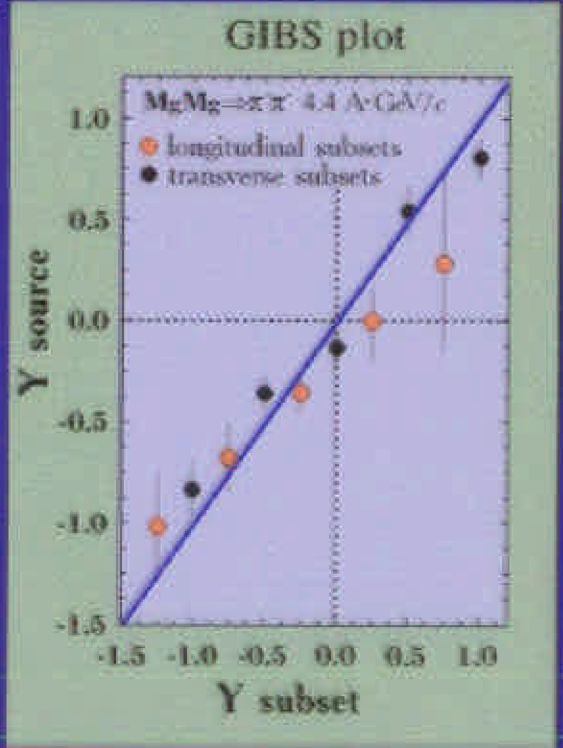
where n^{+} (n^{-}) is the pion yield for the deuterons having the tensor polarization p_{zz}^{+}(p_{zz}^{-})


Beam
Magnet
Streamer chamber
1,9 × 0.8 × 0.6 m³
GIBS

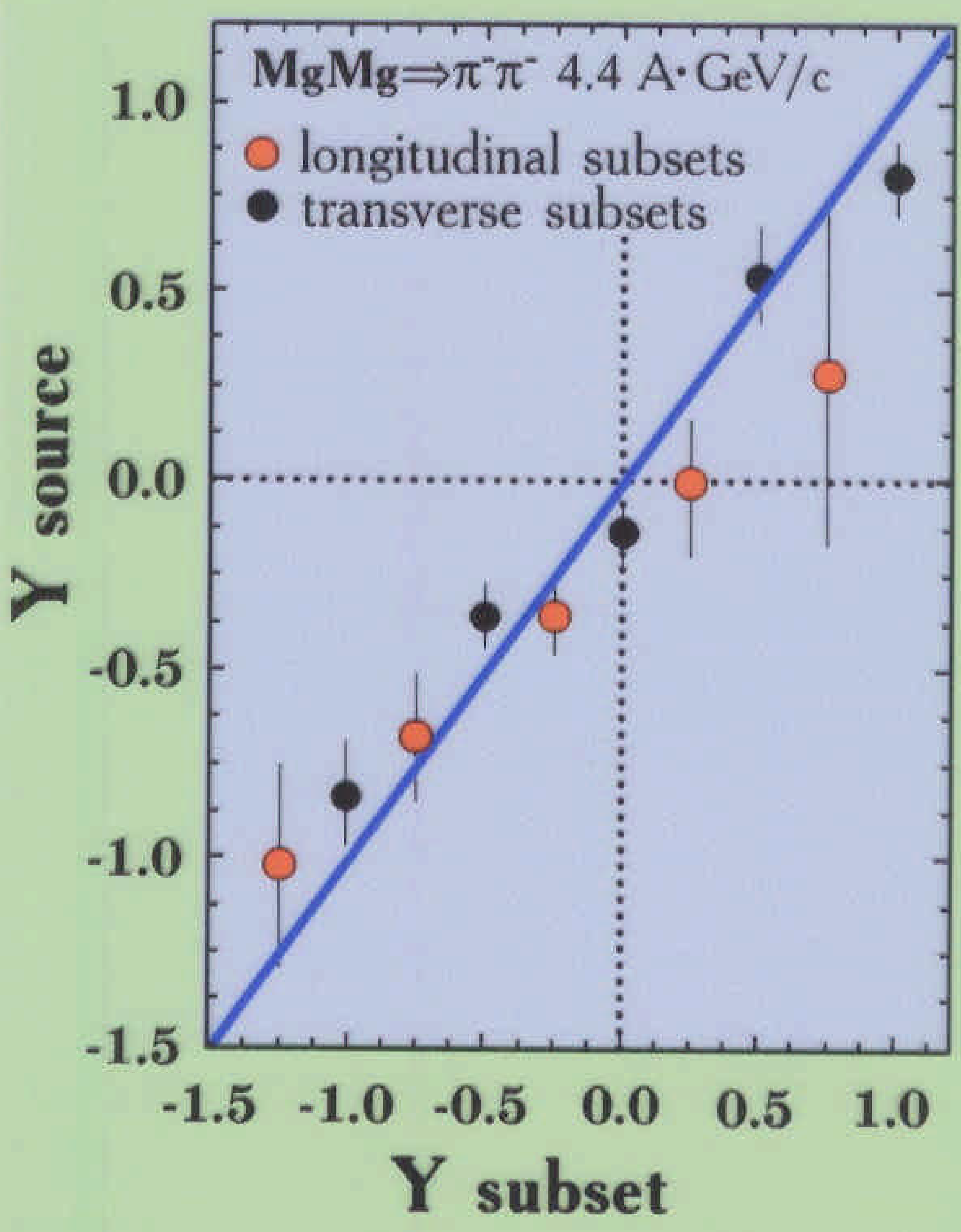

τ(ΛH) = 220 +50 −40 ps
π⁻
ΛH
He


O + Pb , 4.5 A·GeV

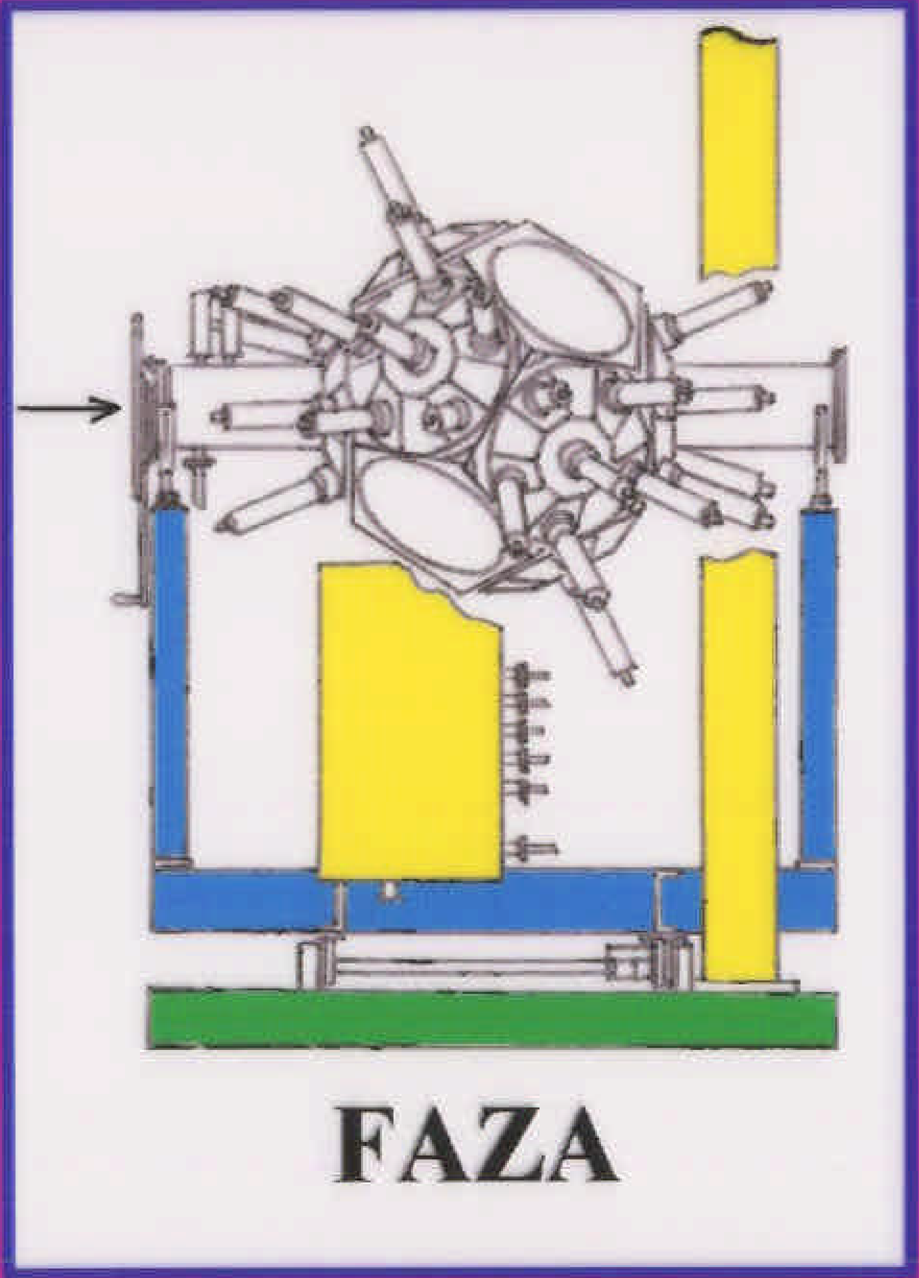

t + Mg → ³He + π⁻ + …
Events/bin
Δ⁻
?
P′z

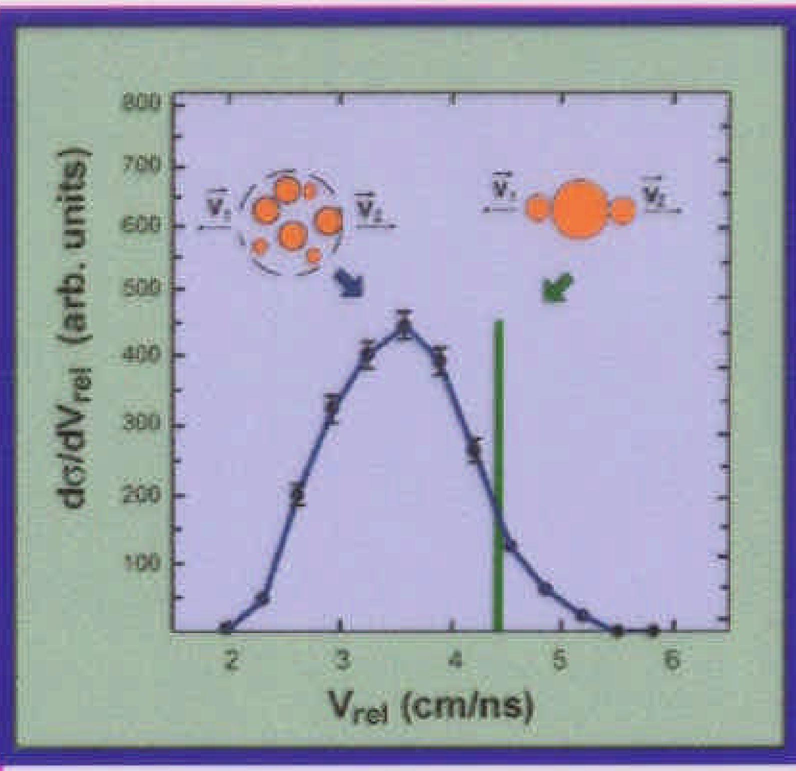

GIBS plot
MgMg⇒π⁻π⁻ 4.4 A·GeV/c
longitudinal subsets
transverse subsets
Y source
Y subset

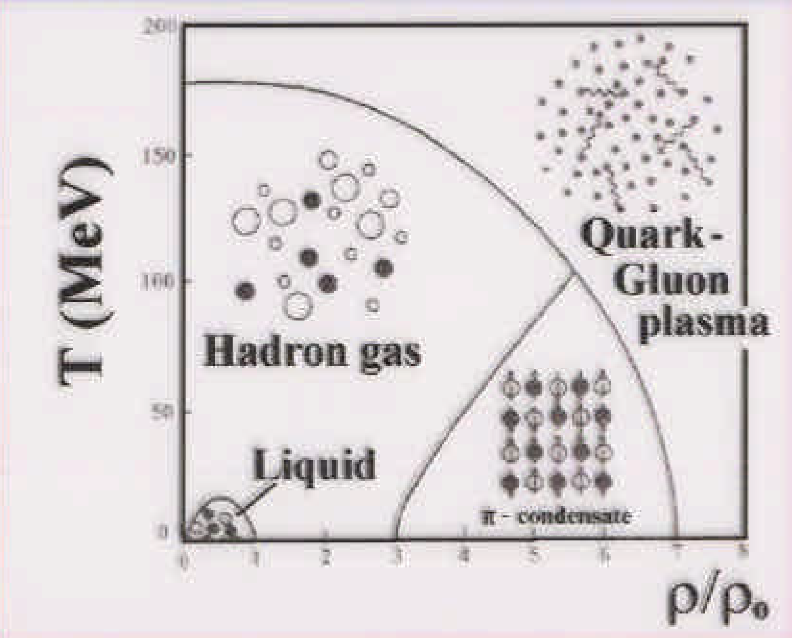
GIBS plot



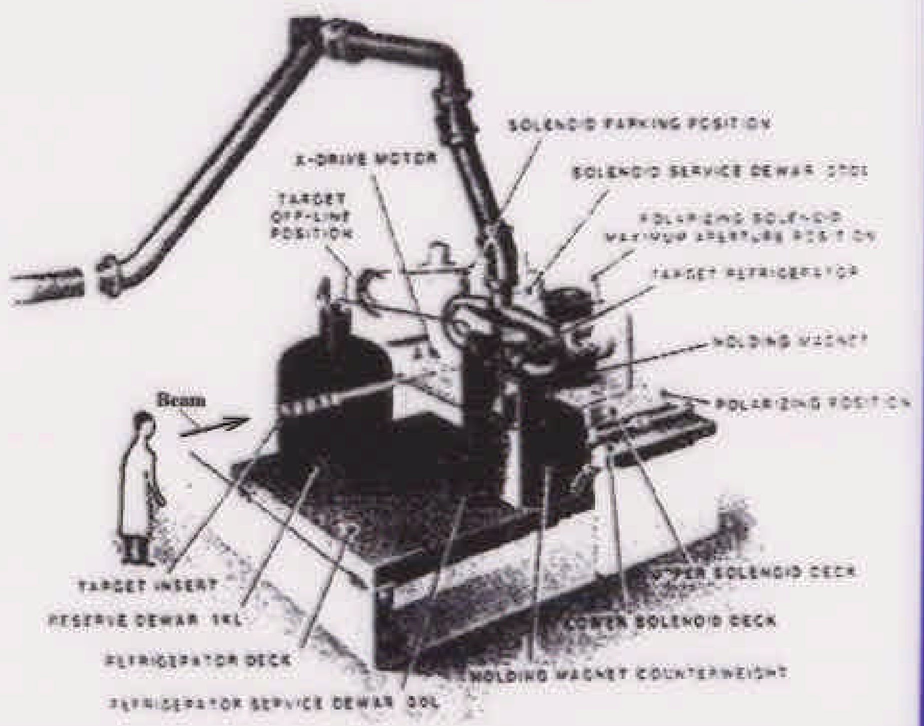
MgMg⇒π⁻π⁻ 4.4 A·GeV/c
longitudinal subsets
transverse subsets
Y source
1.0
0.5
0.0
-0.5
-1.0
-1.5
-1.5
-1.0
-0.5
0.0
0.5
1.0
Y subset

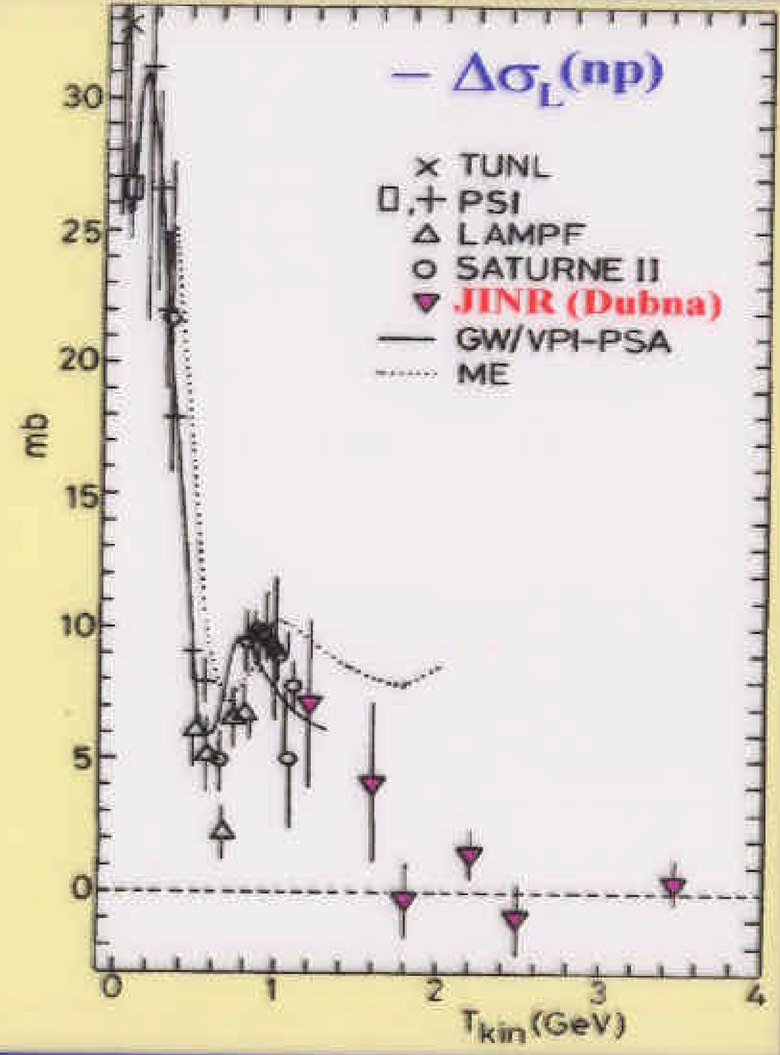

FAZA


dσ/dV$_{rel}$ (arb. units)
800
700
600
500
400
300
200
100
2
3
4
5
6
V$_{rel}$ (cm/ns)

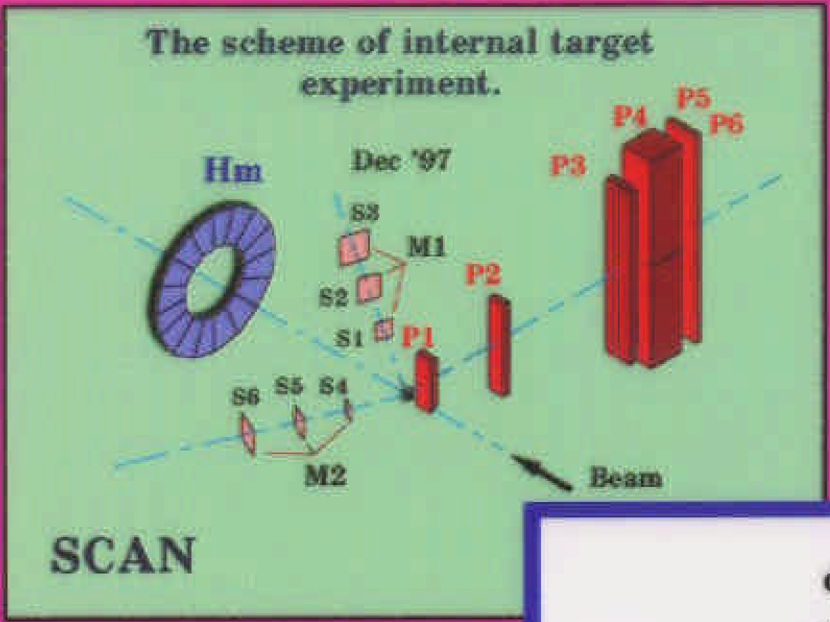

T (MeV)
200
150
100
50
0
Quark-
Gluon
plasma
Hadron gas
Liquid
π - condensate
0
1
2
3
4
5
6
7
8
ρ/ρ₀

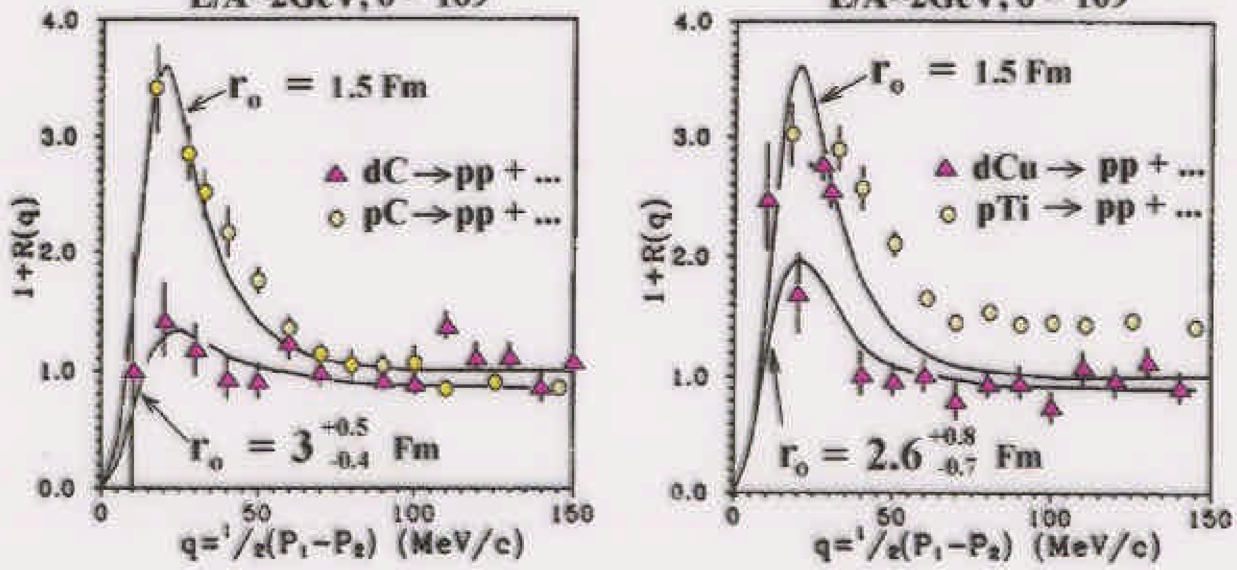
Proton Polarized Target



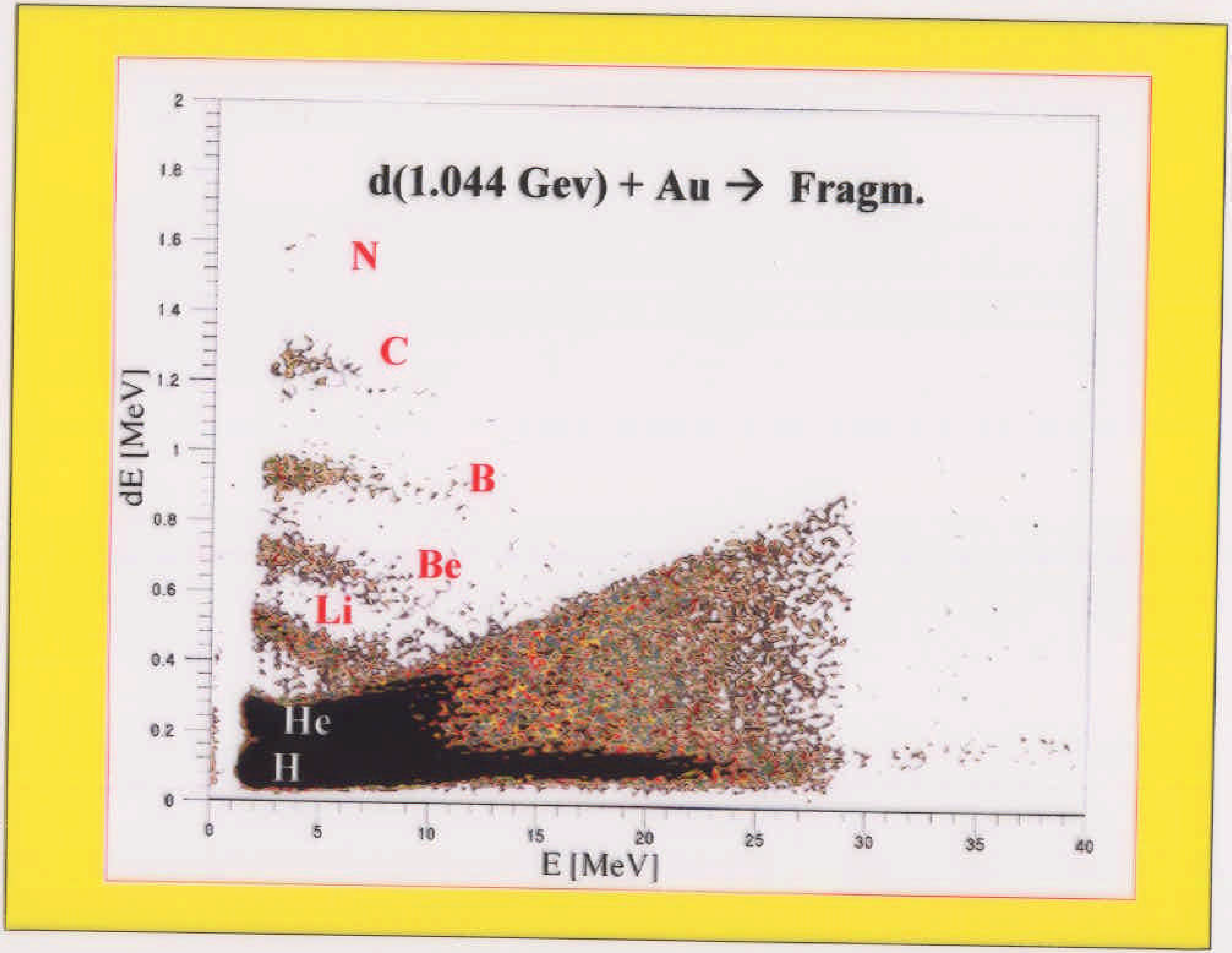


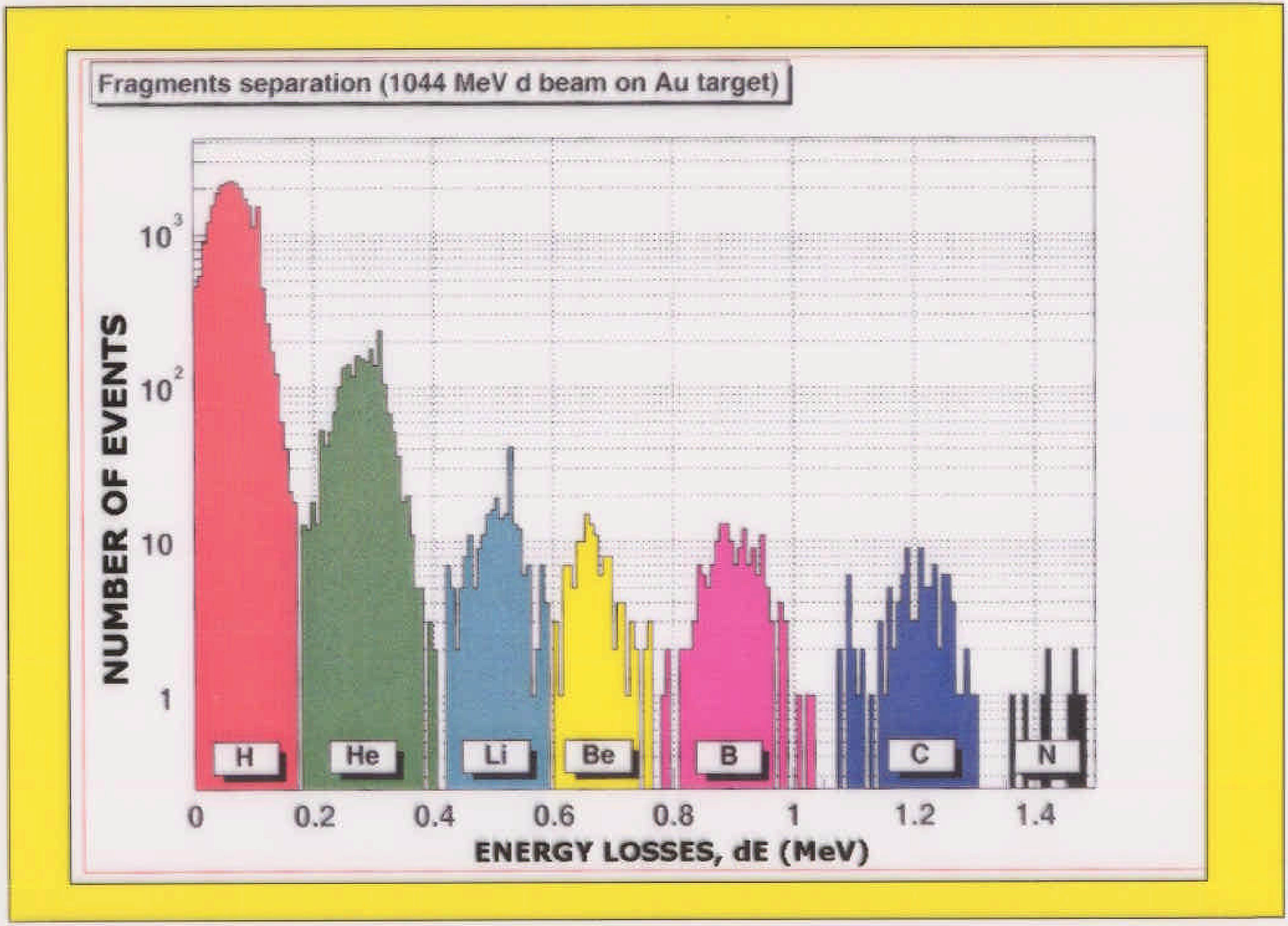
Nuclotron internal target experiment





Spectrometer of the Cumulative Hadrons at the Nuclotron
SCAN


d(1.044 Gev) + Au → Fragm.
dE [MeV]
E [MeV]
N
C
B
Be
Li
He
H
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
5
10
15
20
25
30
35
40


Fragments separation (1044 MeV d beam on Au target)
NUMBER OF EVENTS
10^3
10^2
10
1
H
He
Li
Be
B
C
N
0
0.2
0.4
0.6
0.8
1
1.2
1.4
ENERGY LOSSES, dE (MeV)

$$E\cdot(d^3\sigma/d^3p) =$$

$$= C_1 \cdot A_I^{\alpha(N_I)} \cdot A_{II}^{\alpha(N_{II})} \cdot \exp\left(-\Pi/C_2\right)$$

$$\alpha(N_I) = 1/3 + N_I/3$$

$$\alpha(N_{II}) = 1/3 + N_{II}/3$$

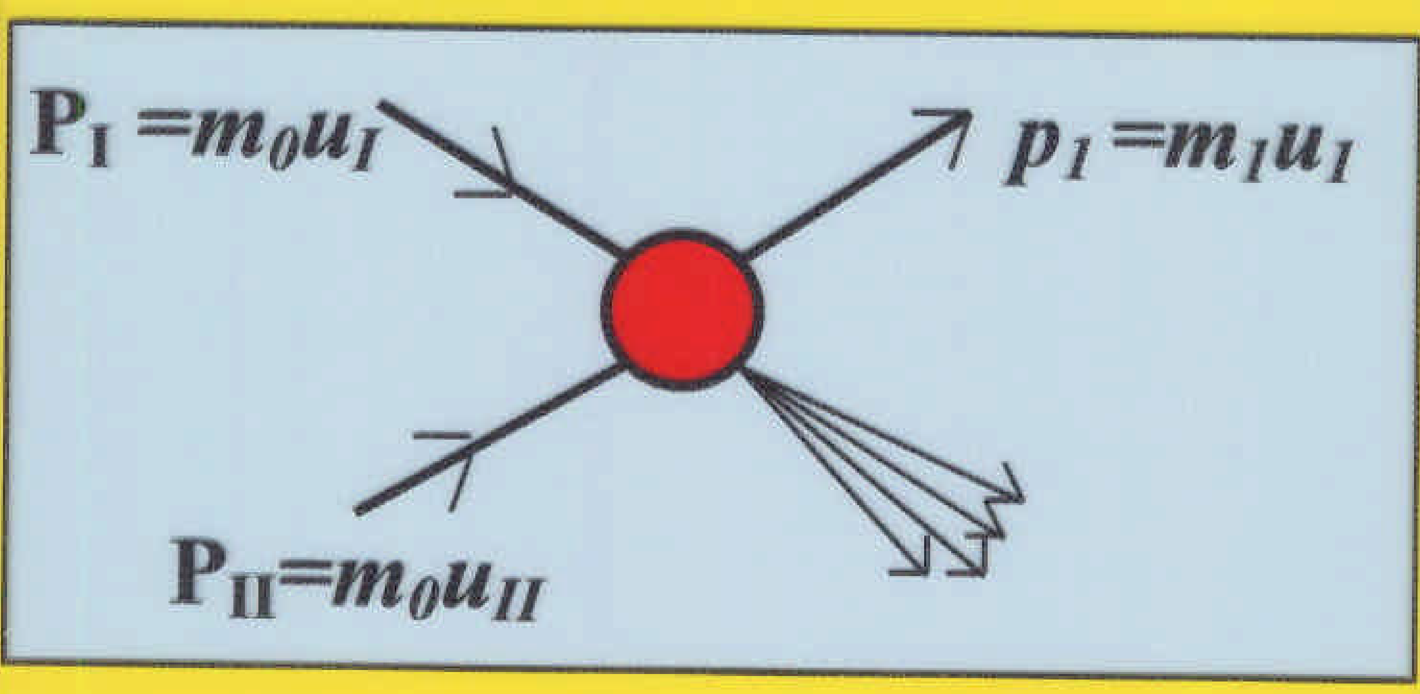
$$C_1 = 1{,}9 \cdot 10^4 \text{ mbGeV}^{-2}c^3\text{sr}^{-1}$$

$$C_2 = 0.125 \pm 0.002$$

$$\Pi = \min\left[{}^{1}/_{2}\sqrt{(u_{I}N_{I} + u_{II}\,N_{II})^{2}}\right]$$

Anton Baldin.
JINR Rapid Communications, No.4[78]-96, 1996, p.61.

$I + II \rightarrow 1 + \ldots$



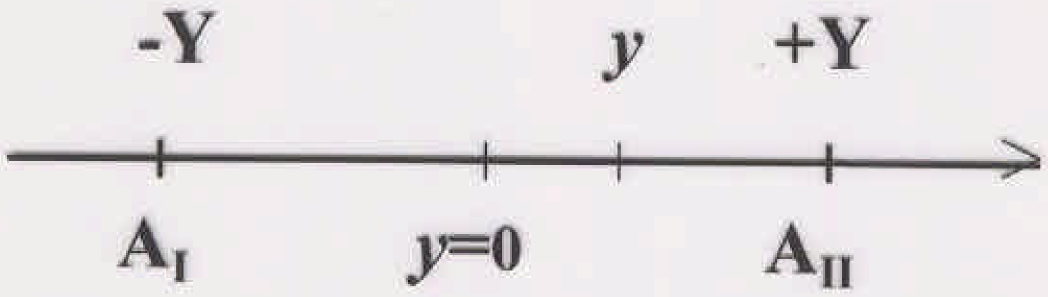
$$(N_I P_I + N_{II} P_{II} - p_1)^2 = \\ = (N_I m_0 + N_{II} m_0 + \Delta)^2$$

Δ is the mass of the particle providing conservation of the barion number, strangeness and other quantum numbers

Π^{min} ➡ $\partial\Pi/\partial N_I = 0$; $\partial\Pi/\partial N_{II} = 0$

In central rapidity region ($y = 0$)

$$(u_1 u_I) = (u_1 u_{II})$$



$$N_I = N_{II} =$$
$$= N = [1+\sqrt{1+(\Phi_\delta/\Phi^2)}]\cdot\Phi,$$

where

$$\Phi=(1/m_0)\cdot[m_T \mathrm{ch}Y + \Delta]\cdot(1/2\mathrm{sh}^2 Y)$$

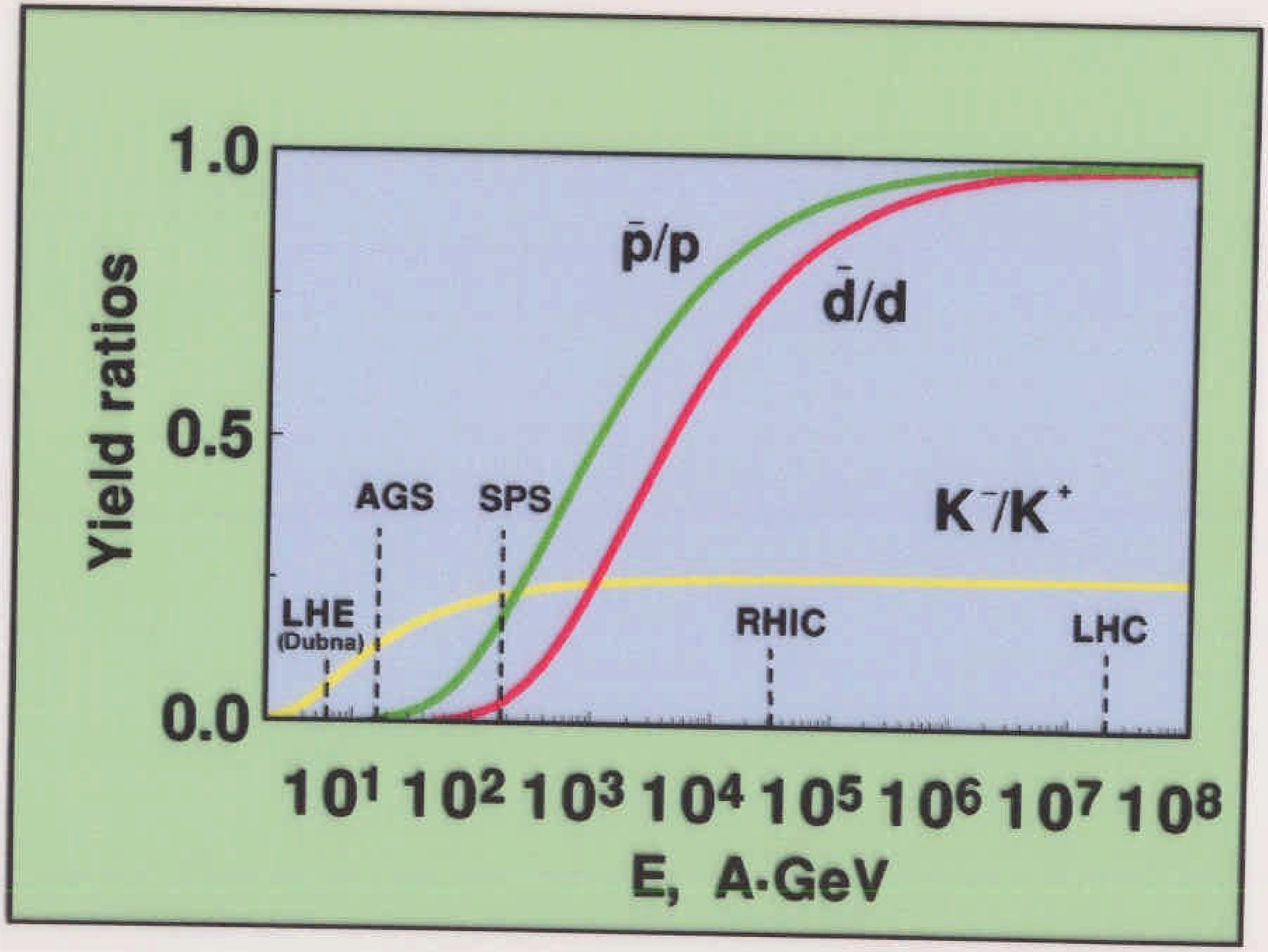
$$\Phi_\delta = (\Delta^2 - m_1^2)/(4m_0^2\mathrm{sh}^2 Y)$$

and

$$\Pi^{min} = N\cdot\mathrm{ch}Y$$

Ratios of the yields	$\bar{p}/p$	$\bar{d}/d$	K^-/K^+
Calculation (160 A·GeV) (the present report) (p_T=0)	**0,16**	**0,027**	**0,25**
NA52 (160 A· GeV)	**≈ 0,1**	**≈ 0,01**	**≈ 0,2**
NA44 (160 A· GeV)	**≈ 0,08**	**-**	**≈ 0,4**
Calculation (11 A· GeV) (the present report) (p_T=0)	**0,00039**	**-**	**0,11**
E866 (11 A· GeV)	**≈ 0,0003**	**-**	**≈ 0,2**

PREDICTIONS



References

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2. S.Afanasiev et al. Fragmentation of tensor polarized deuterons into cumulative pions. Physics Letters B 445 (1998) 14-19.
3. S.V.Afanasiev et al. Measurement of the tensor analyzing power A_{yy} in inclusive breakup of 9 GeV/c deuterons on carbon at large transverse momenta of protons. Physics Letters B 434 (1998) 21-27.
4. V.P.Ladygin et al. First results on the tensor analyzing power A_{yy} in deuteron inclusive breakup at large transverse momenta of protons. Few-Body System Suppl. 10, 451-454 (1999)
5. Yu.S.Anisimov et al. First results of study of transversal dimension of region of cumulative particles production in d + C and d + Cu reactions for energy 2 GeV/nucleon. JINR rapid Communications No.5(91)-98 (1998) 25-32.
6. M.Kh.Anikina et al. HBT measurement of the expansion velocity of pion production volume. Physics Letters B 397 (1997) 30-36.
7. V.A.Karnaukhov. Hot nuclei and liquid-gas phase transition in nuclear matter. Preprint JINR, P1-99-193 (1999).
8. V.I.Sharov et al. Measurements of the np total cross section difference $\Delta\sigma_L$ at 1.59, 1.79 and 2,20 GeV. Eur.Phys. J.C 13, 255-265 (2000).
9. A.M.Baldin, A.I.Malakhov. Relativistic multiparticle processes in the central rapidity region at asymptotically high energies. JINR rapid Communications No.1(87)-98 (1998) 5-12.
10. A.I.Malakhov. Relativistic multiparticle processes in the central rapidity region at asymptotically high energies in nuclear collisions. Proceedings of the 29th International Conference on High Energy Physics, Vancouver, Canada, 23-29 July 1998, World Scientific, V.II, 1497-1500.

Conclusions

In JINR (Dubna) we have

- the interesting research program with relativistic beams of
  - nuclei
  - polarized deuterons and neutrons
- the new perspectives of investigations with extracted nuclear beams of the Nuclotron