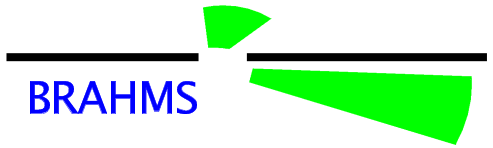
Towards Matter-Antimatter Balance at RHIC

Antiparticle-to-particle ratios measured by BRAHMS



Claus Ekman Jørgensen
Niels Bohr Institute

14th Nordic Meeting on Intermediate and High Energy Nuclar Physics
Gräftåvallen, January 5-10, 2002

The BRAHMS Collaboration

I.G. Bearden[7], D. Beavis[1], C. Besliu[10], Y. Blyakhman[6], J.Brzychczyk[4], B. Budick[6], H. Bøggild[7] ,C. Chasman[1], C. H. Christensen[7], P. Christiansen[7],J.Cibor[4], R.Debbe[1], J. J. Gaardhøje[7],M. Germinario[7] ,K. Grotowski[4] , K. Hagel[8], O. Hansen[7], A.K. Holme[12], H. Ito[11], E. Jacobsen[7], A. Jipa[10], J. I. Jordre[10], F. Jundt[2], C.E.Jørgensen[7], T. Keutgen[9], E. J. Kim[5], T. Kozik[3], T.M.Larsen[12], J. H. Lee[1], Y. K.Lee[5], G. Løvhøjden[2], Z. Majka[3], A. Makeev[8], B. McBreen[1], M. Murray[8], J. Natowitz[8], B.S.Nielsen[7], K. Olchanski[1], D. Ouerdane[7], R.Planeta[4], F. Rami[2], D. Roehrich[9], B. H. Samset[12], S. J. Sanders[11], I. S. Sgura[10], R.A.Sheetz[1], Z.Sosin[3], P. Staszel[7], T.S. Tveter[12], F.Videbæk[1], R. Wada[8] and A.Wieloch[3]

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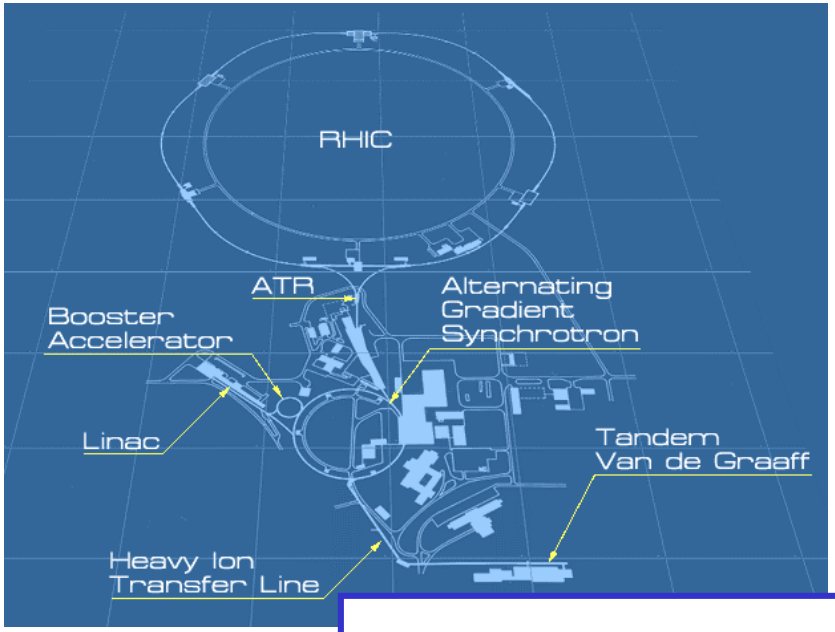
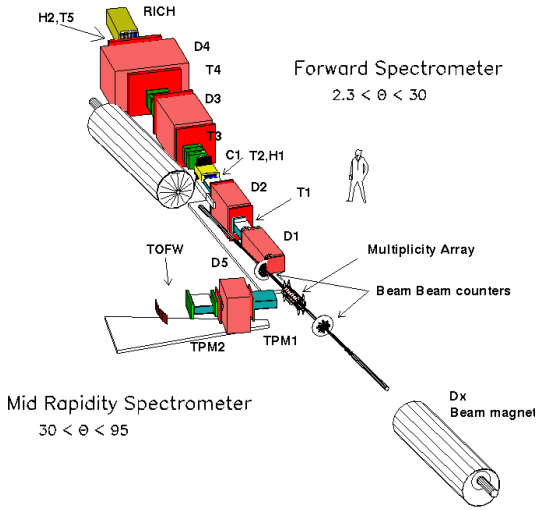
[3]Jagiellonian University, Cracow, Poland, [4]Institute of Nuclear Physics, Cracow, Poland
[5]Johns Hopkins University, Baltimore, USA, [6]New York University, USA
[7]Niels Bohr Institute, Blegdamsvej 17, University of Copenhagen, Denmark
[8]Texas A&M University, College Station. USA, [9]University of Bergen, Norway
[10]University of Bucharest, Romania, [11]University of Kansas, Lawrence,USA
[12] University of Oslo Norway

The Relativistic Heavy Ion Collider



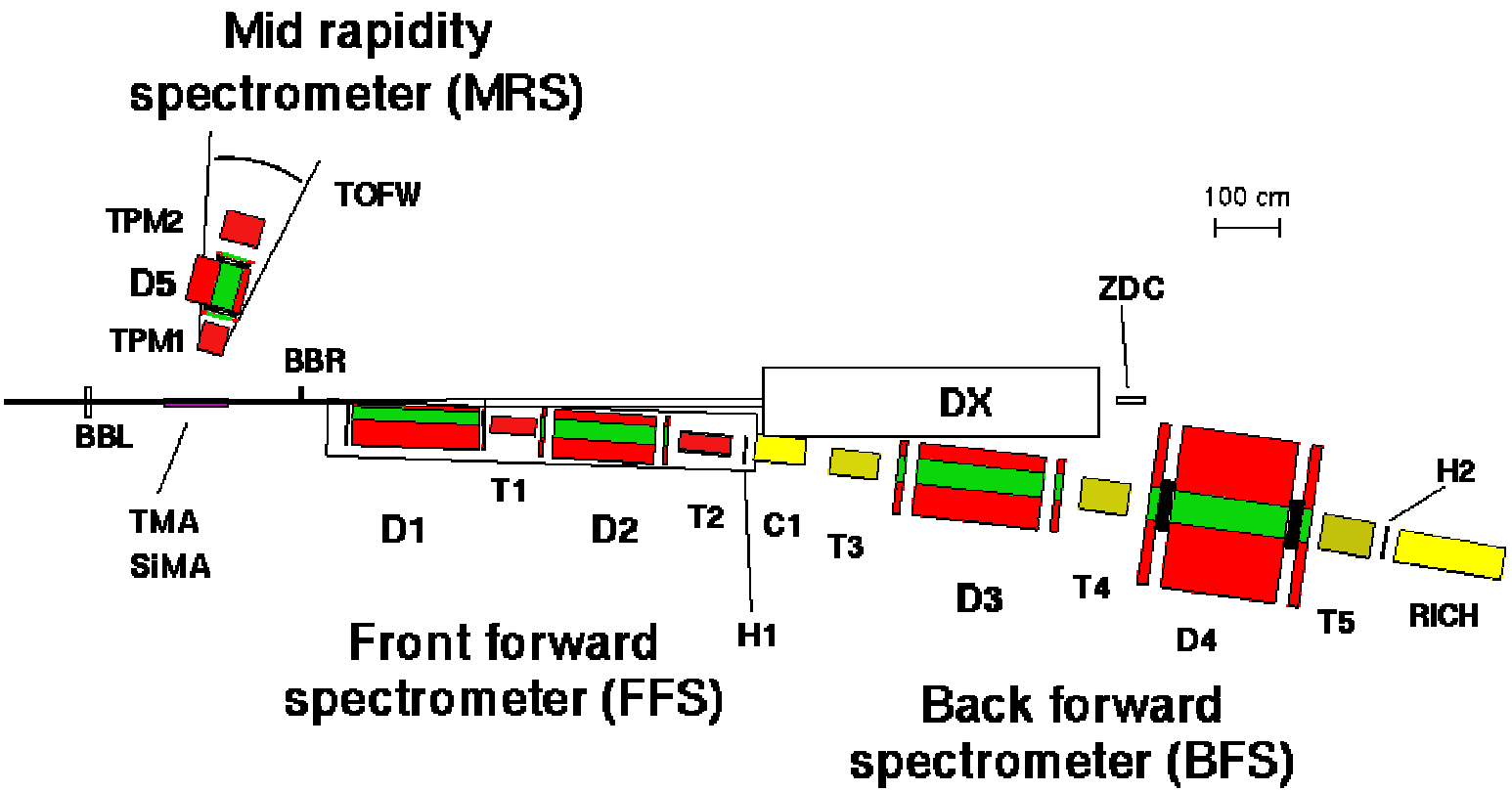


Au+Au at $\sqrt{s_{NN}} = 200\,\mathrm{GeV}$

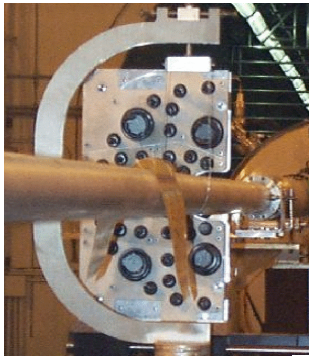
Physics running July 7 to November 26

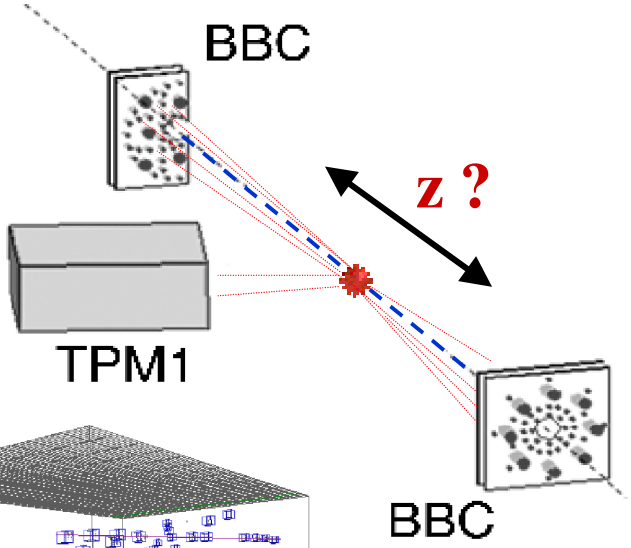
> 15 G events recorded with BRAHMS

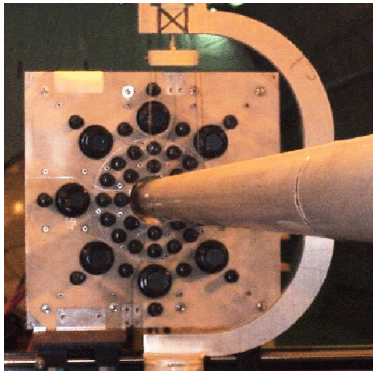
The BRAHMS Experiment

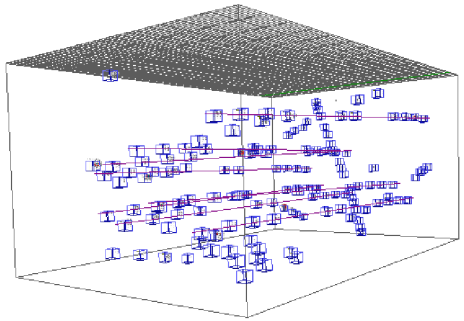


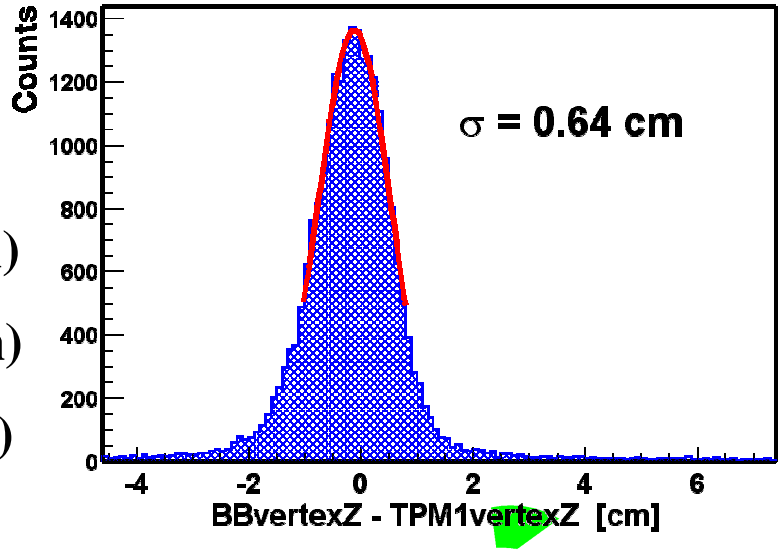
Determination of Collision Vertex







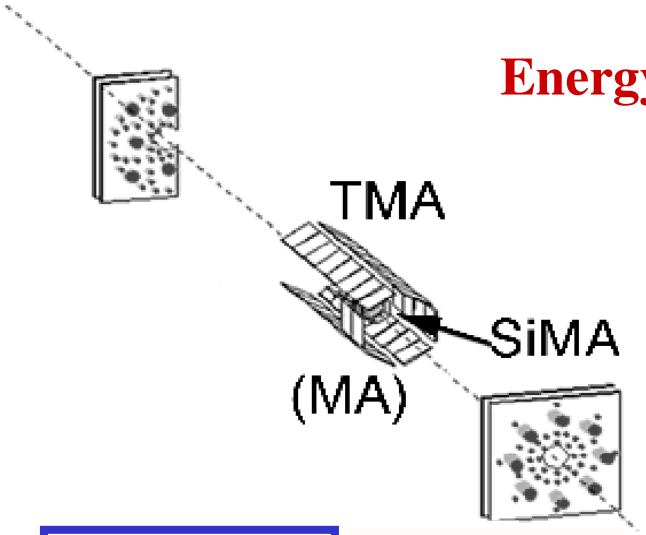


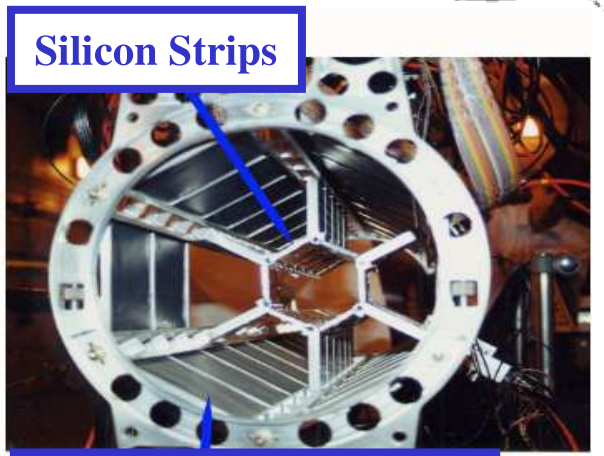


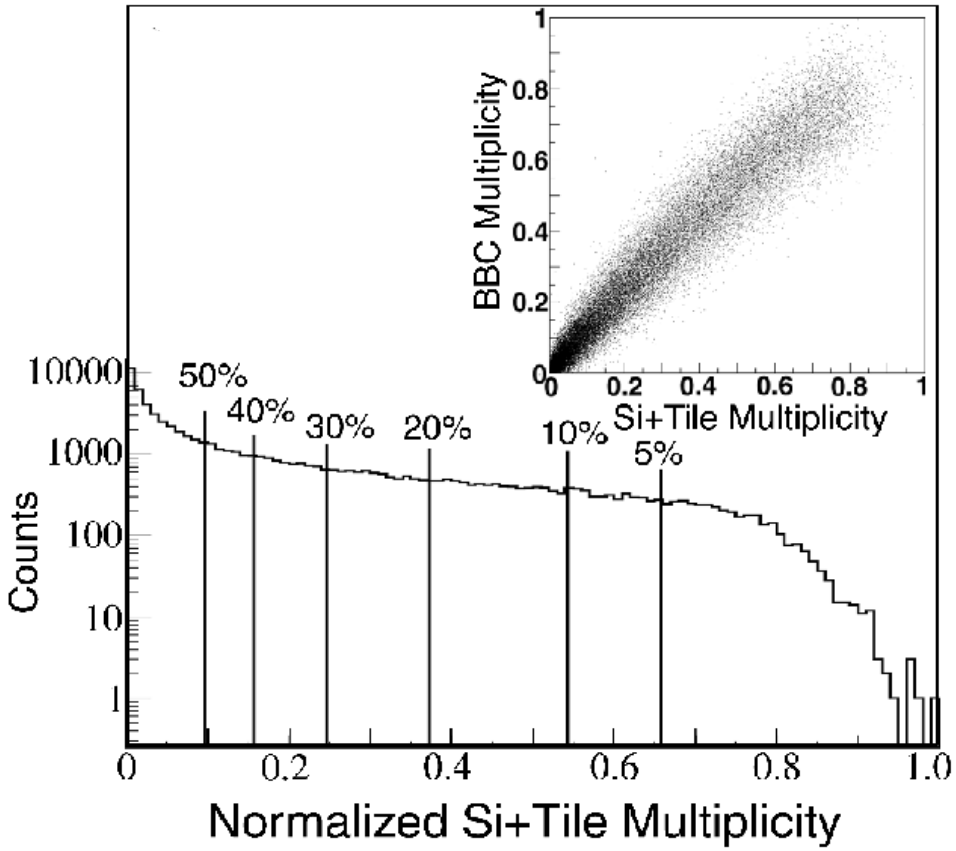
- **Δt in BBC measurements (σ ≤ 0.7 cm)**
- **Δt in ZDC measurements (σ ≤ 3.5 cm)**
- **Combining hits in TPM1 (σ ≤ 0.2 cm)**

Determination of Collision Centrality

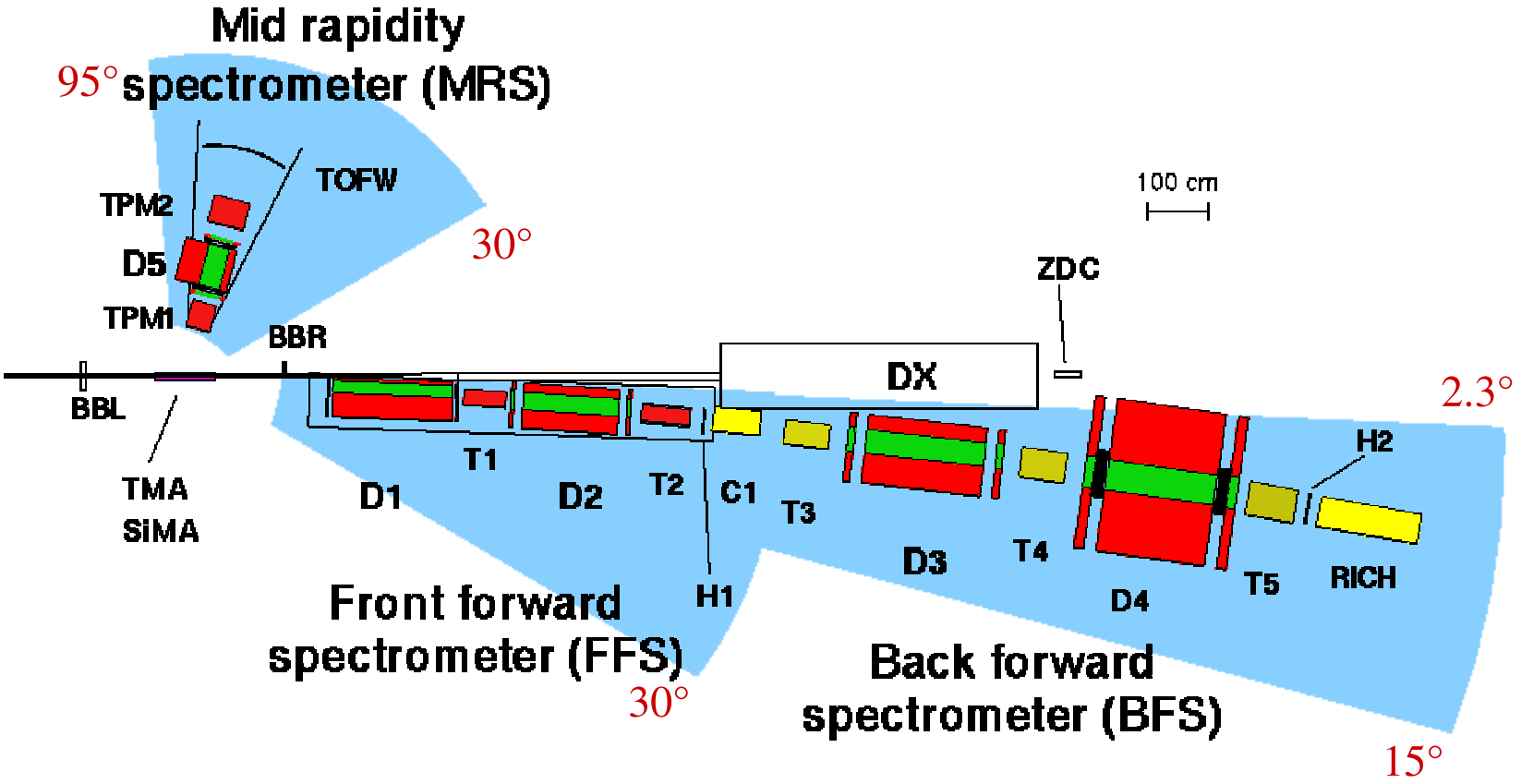
Energy deposit → Multiplicity → Centrality







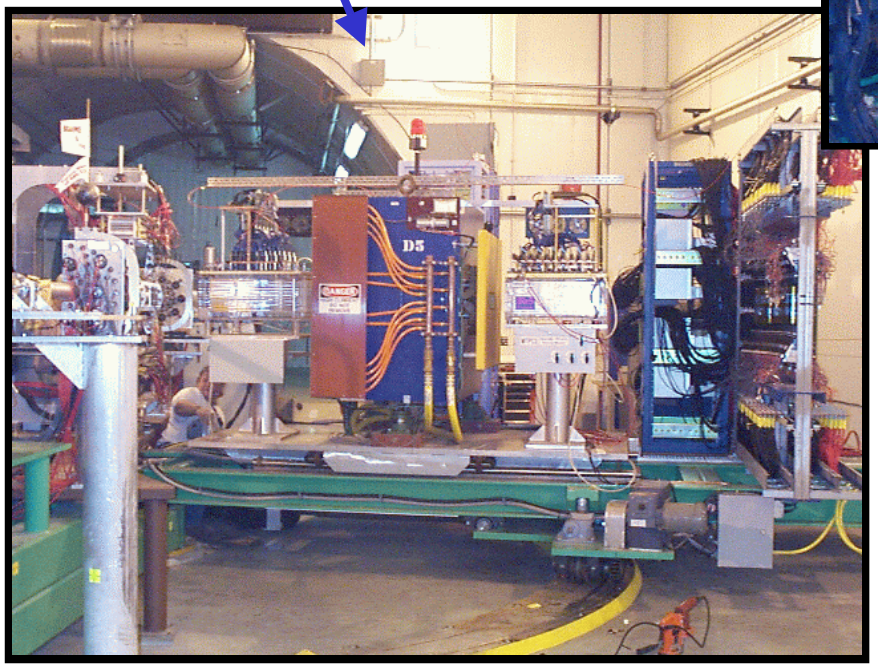
The BRAHMS Experiment

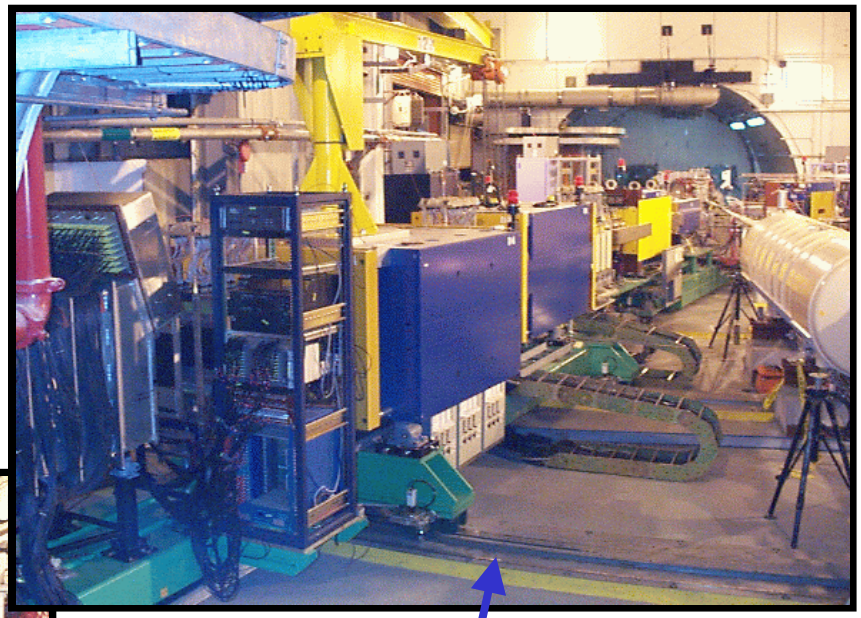


MRS

- 2 Time Projection Chambers
- 1 Dipole Magnet
- 1 Time-of-flight wall

30-90 degree rotation



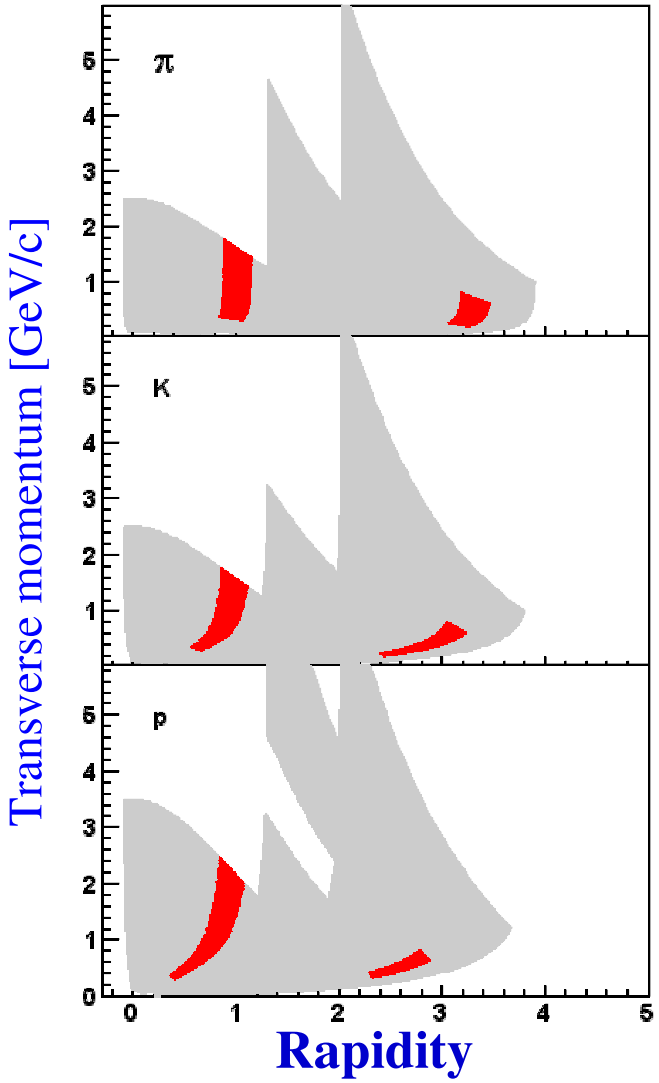


FS

- 2 Time Projection Chambers
- 3 Drift Chambers
- 4 Dipole Magnets
- 2 Time-of-flight wall
- 2 Cherenkov Detectors

2.3-30 degree rotation

BRAHMS Acceptance

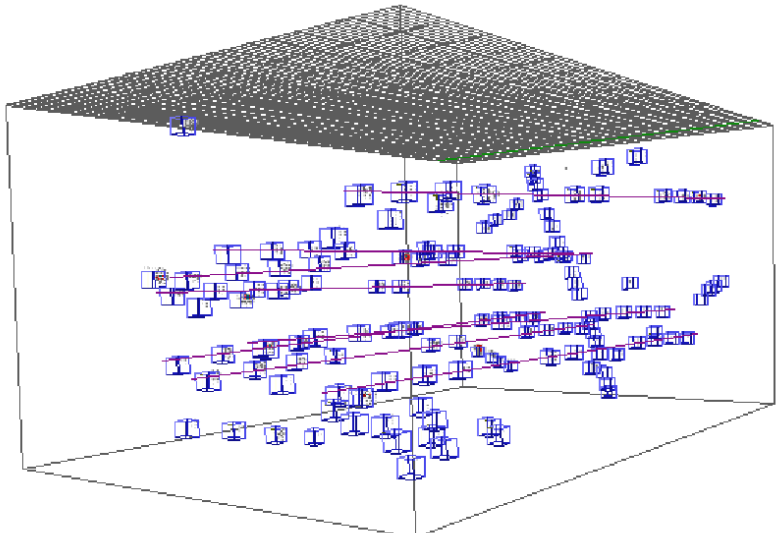


PID over a broad range of rapidity and transverse momentum.

- PID in MRS via TOFW
- PID in FS via TOF1, C1, TOF2 and RICH

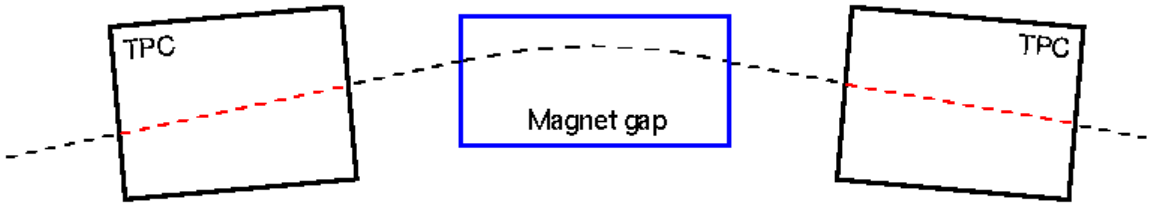
One setting:
MRS at 40 deg.
FS at 4 deg.

Tracking in the Spectrometers

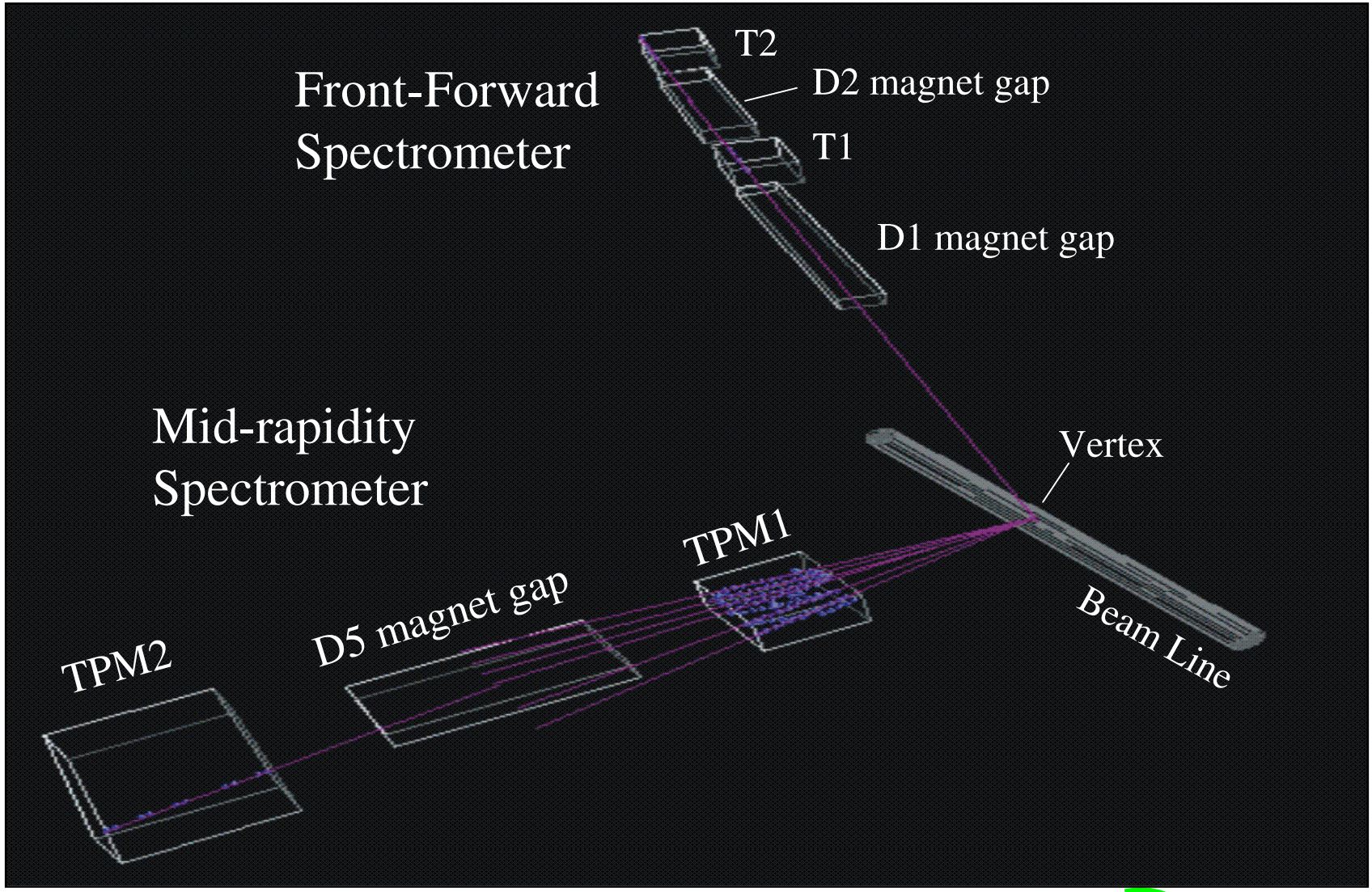


Track reconstructed in Tracking Chambers

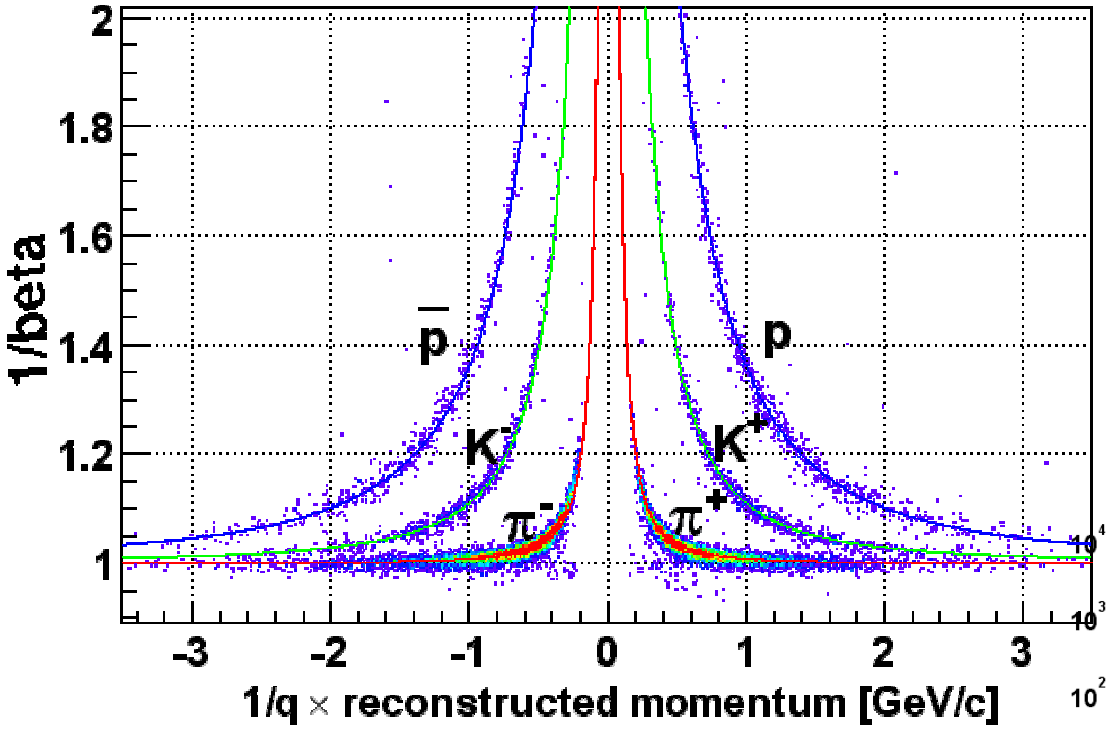
Matched in the magnet gap

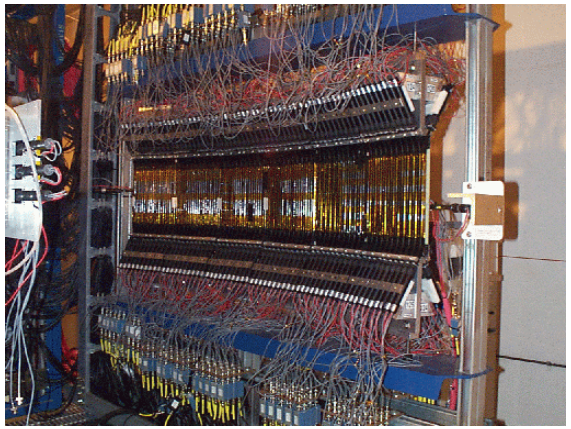


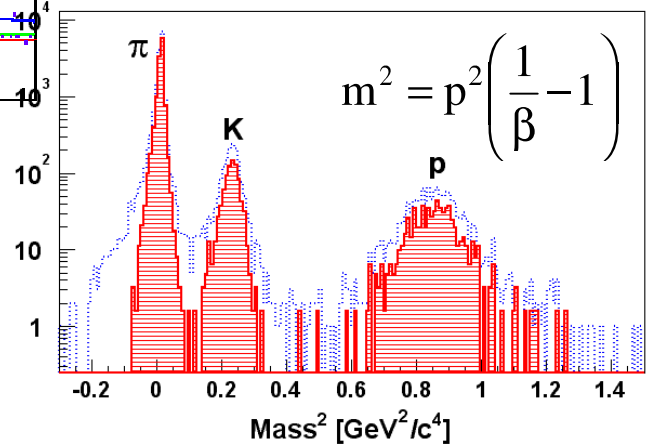
Bending of tracks ⇒ momentum of particles


Front-Forward
Spectrometer
T2
D2 magnet gap
T1
D1 magnet gap
Mid-rapidity
Spectrometer
Vertex
TPM1
D5 magnet gap
TPM2
Beam Line

Time-of-flight Wall TOFW





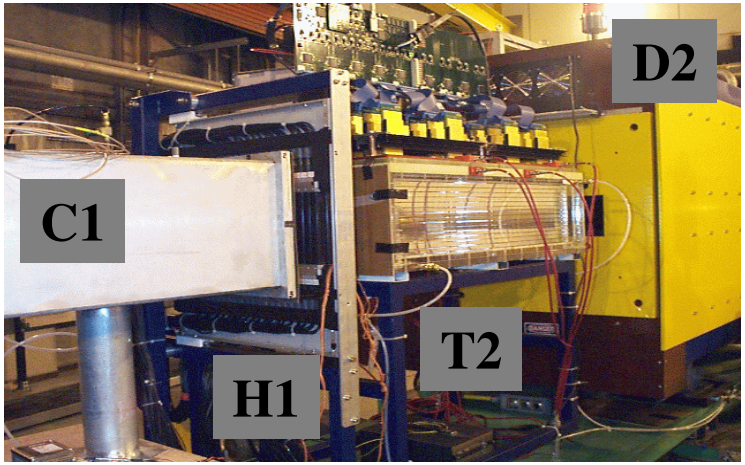


125 scintillator slats

TOF resolution σ ≈ 100 ps

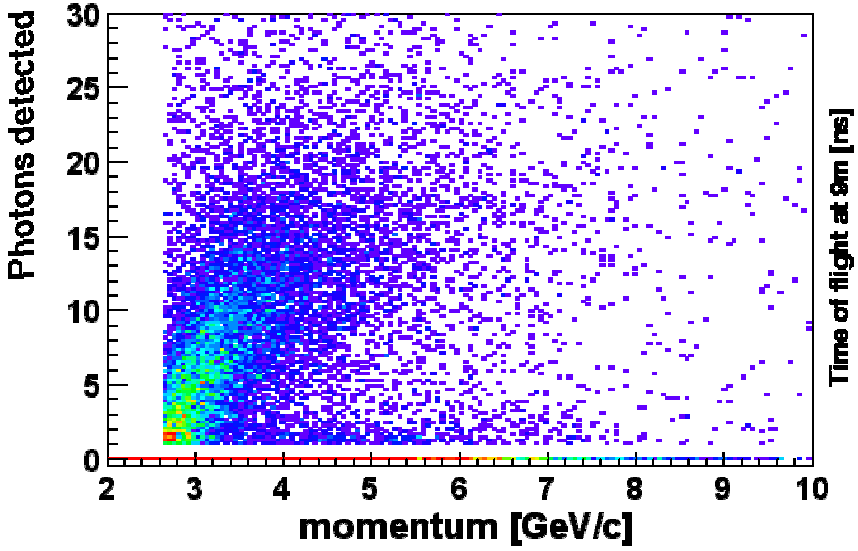
π/K separation up to ≈ 2 GeV/c

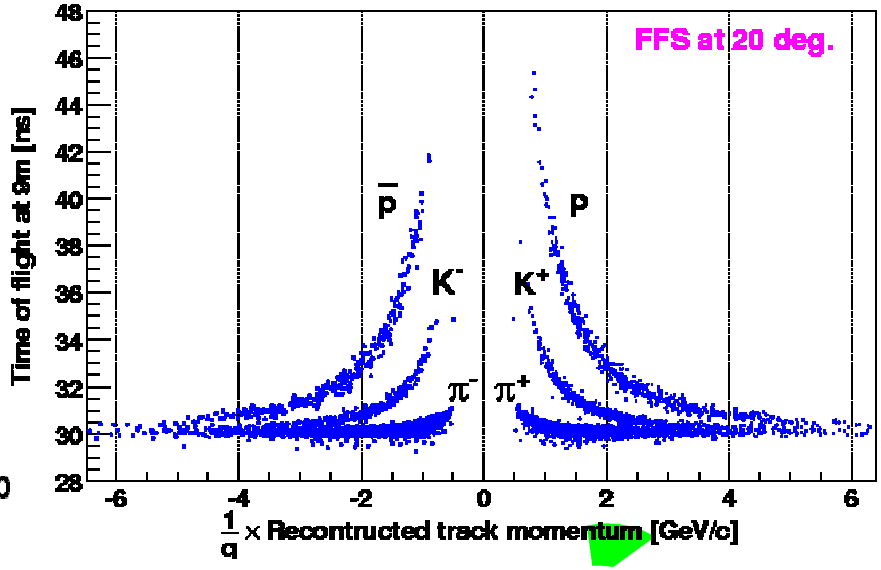
PID in the front-forward spectrometer



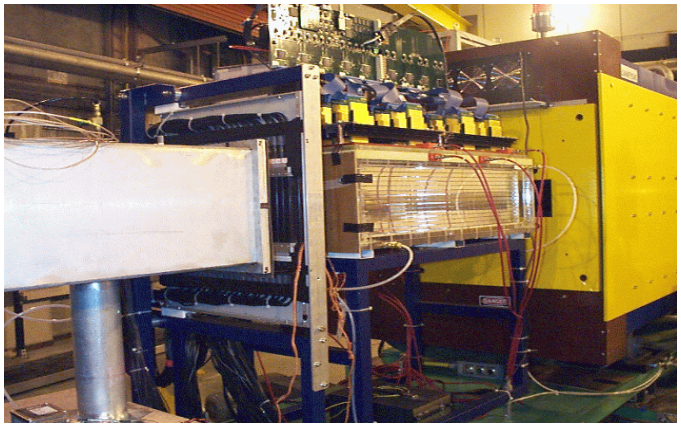
Time-of-flight wall H1
(40 slats - resolution σ ≈ 65 ps)

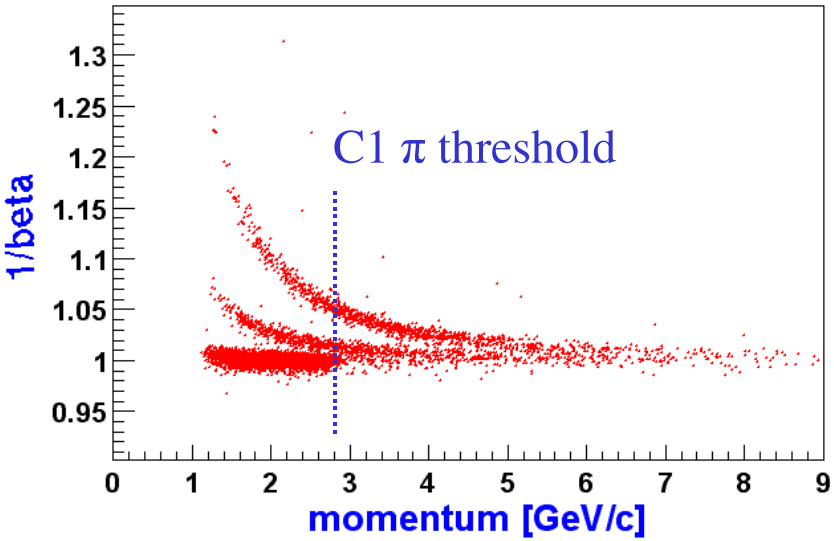
Threshold Cherenkov C1
(pion p threshold ≈ 2.7 GeV/c)

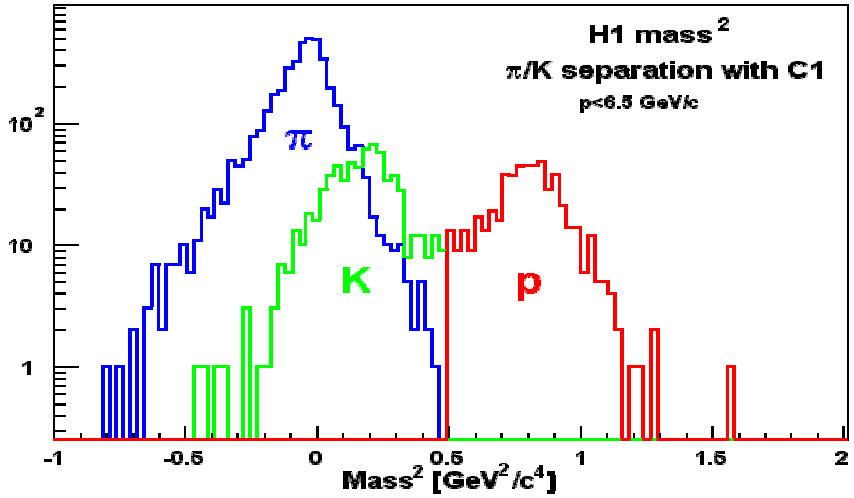




PID in the front-forward spectrometer

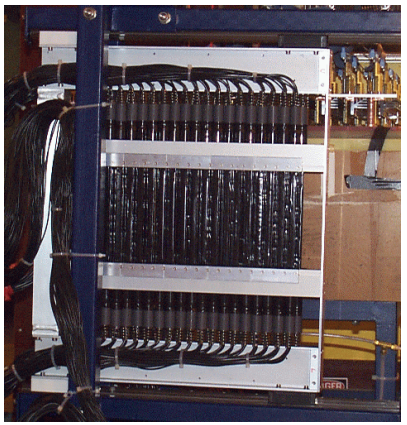


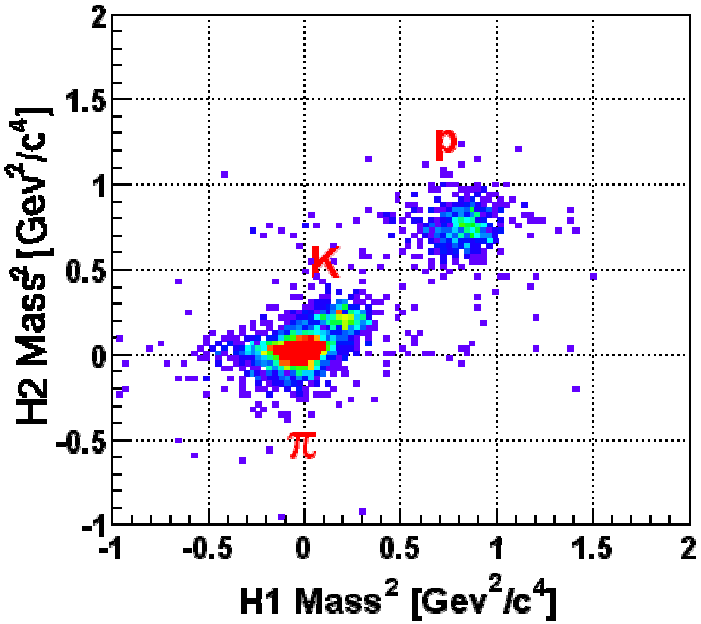


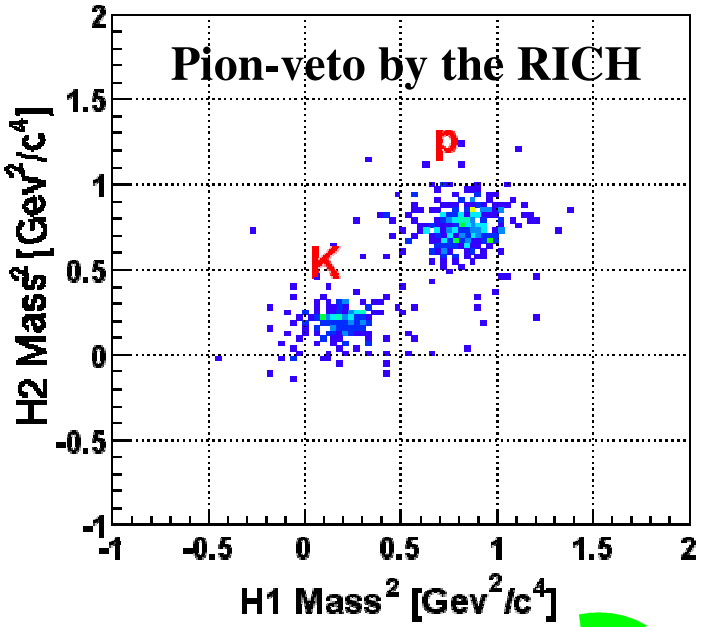


Time-of-flight wall H2

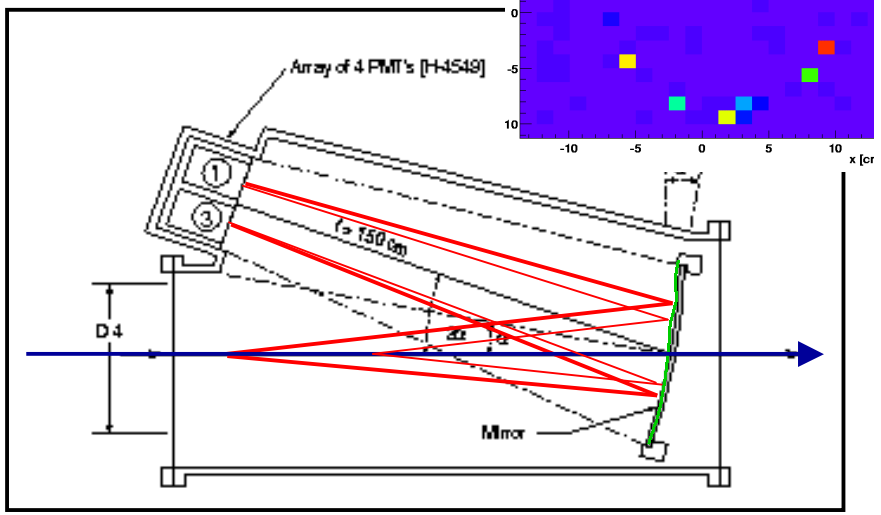
32 scintillator slats
18 meter from nominal vertex
TOF resolution σ ≈ 80 ps

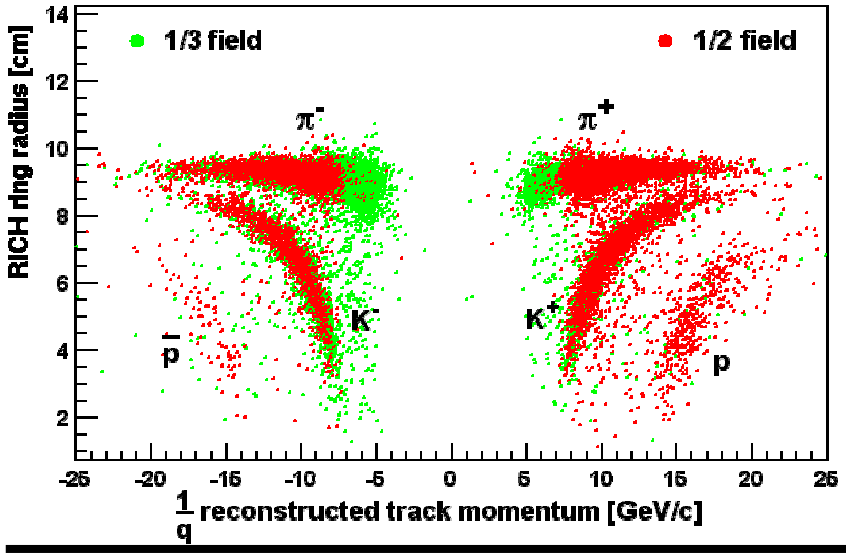


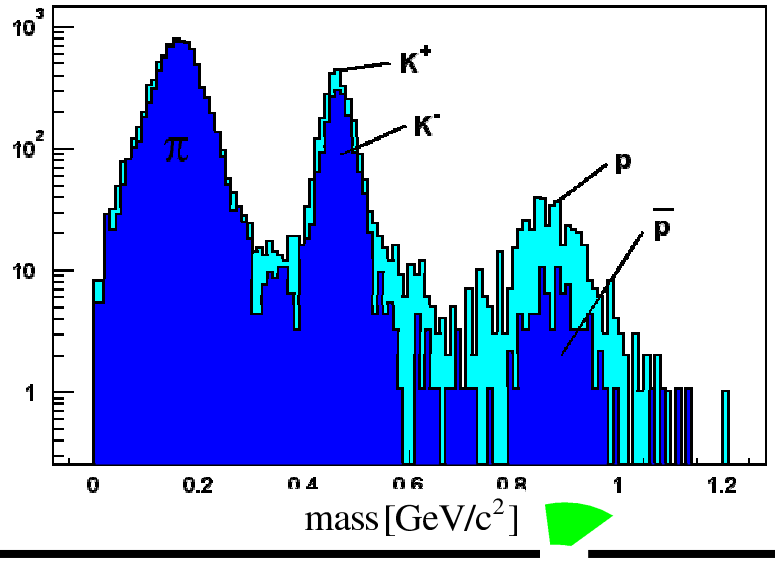




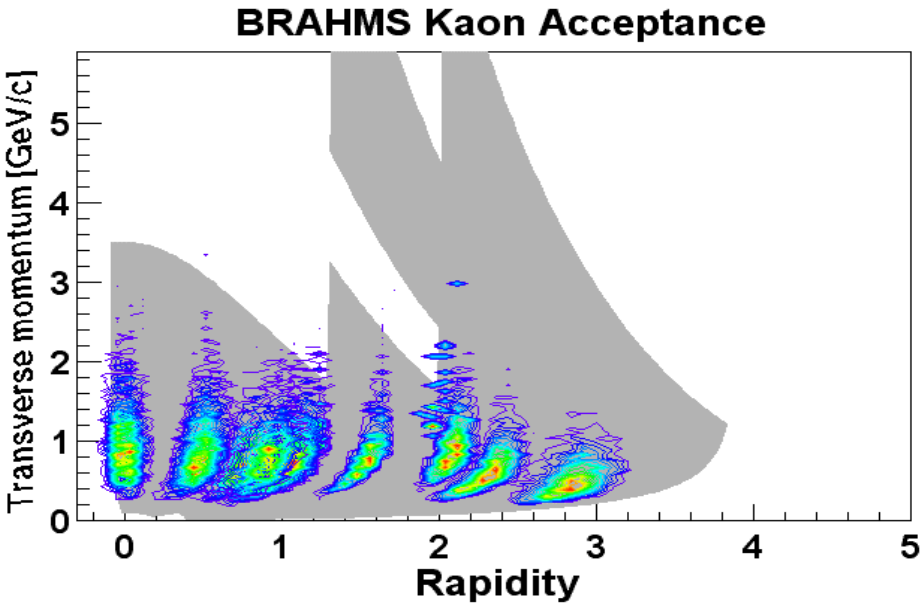
Ring Image Cherenkov

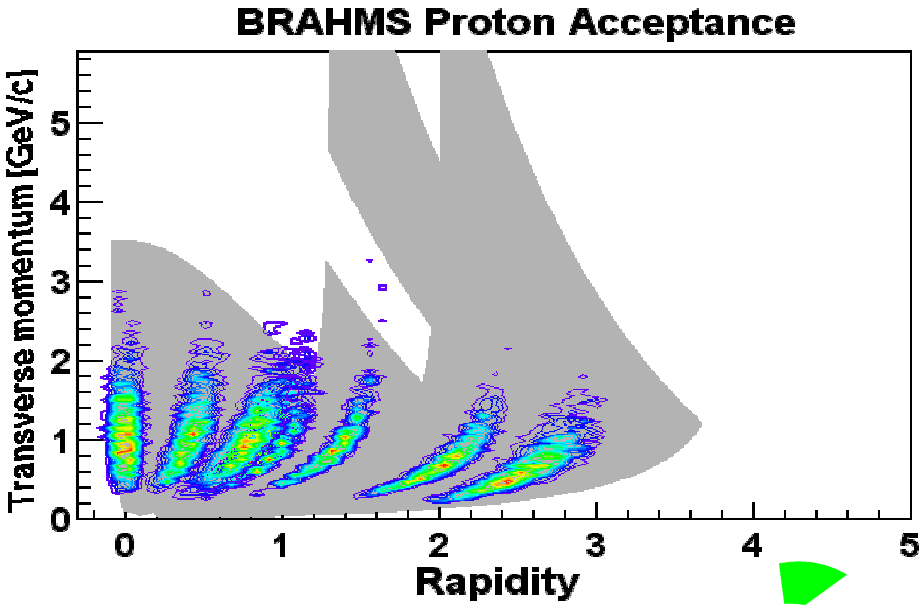






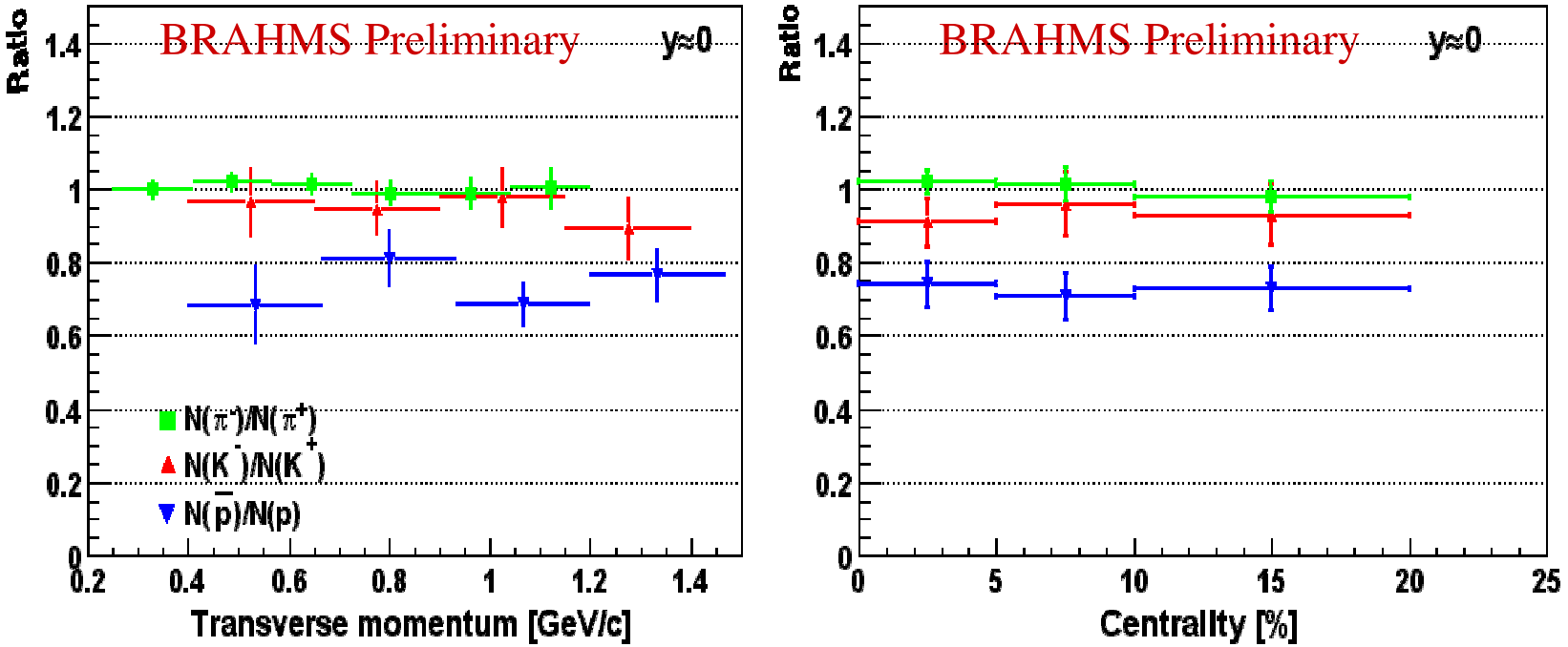
BRAHMS Acceptance for Kaons and Protons





Ratios vs Pt and centrality

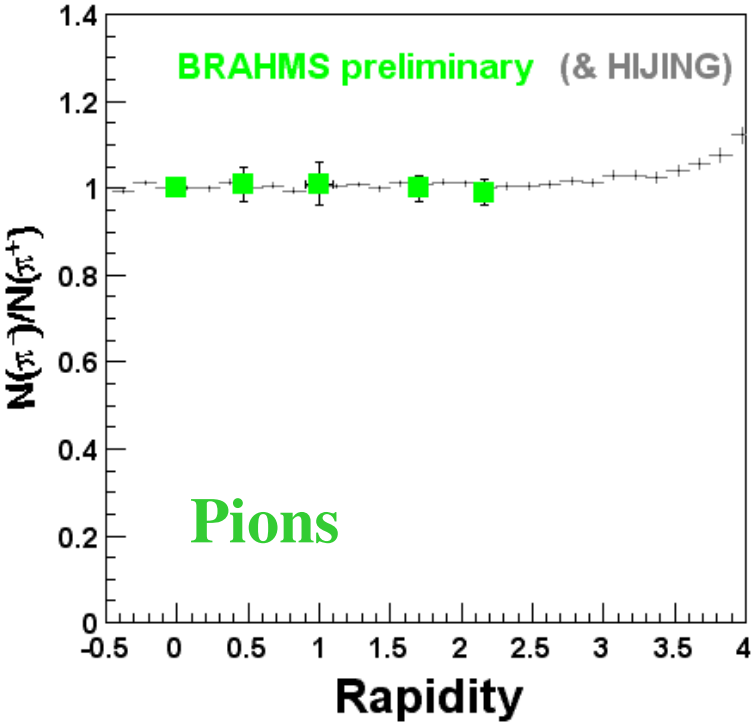
$\sqrt{s_{NN}} = 200\,\mathrm{GeV}$

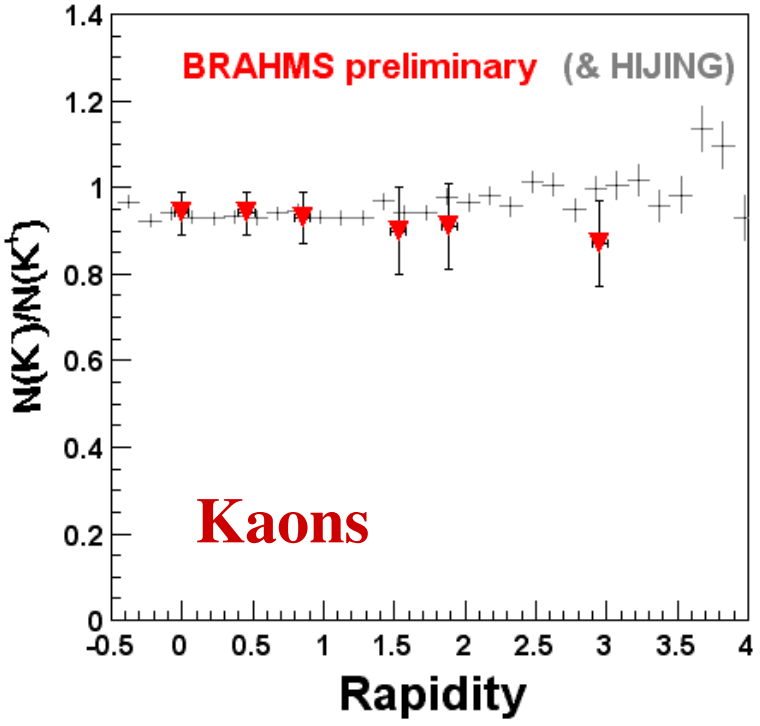


No sign of Pt or centrality dependence

Rapidity dependence – pions and kaons

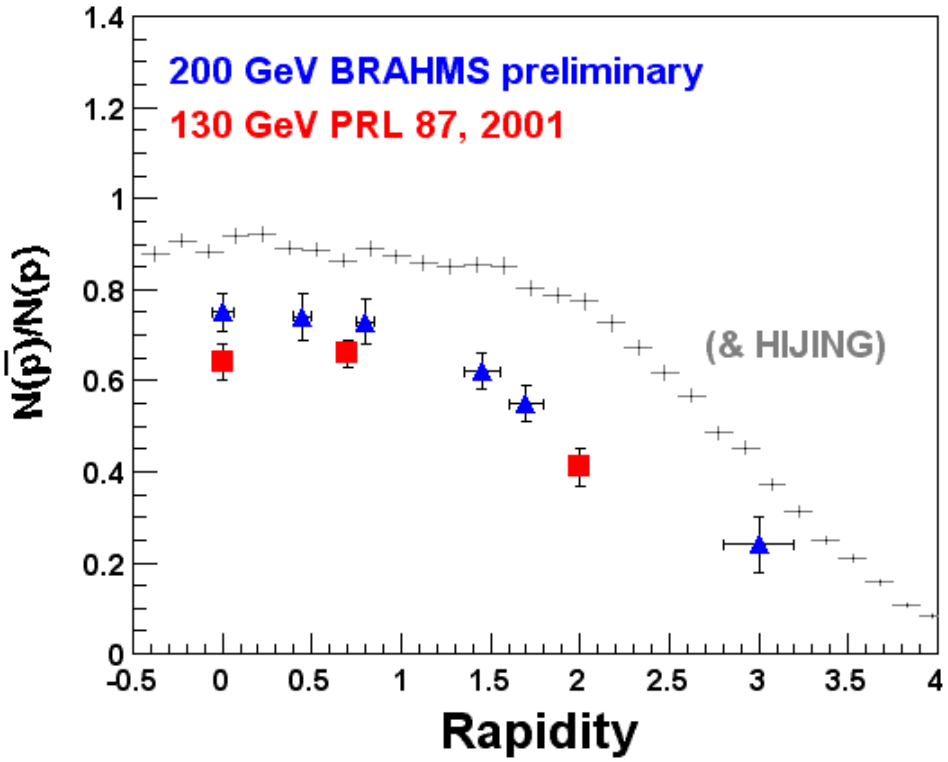
$\sqrt{s_{NN}} = 200\,\mathrm{GeV}$





Rapidity dependence – proton ratio

$$\sqrt{s_{NN}} = 200\,\text{GeV}$$

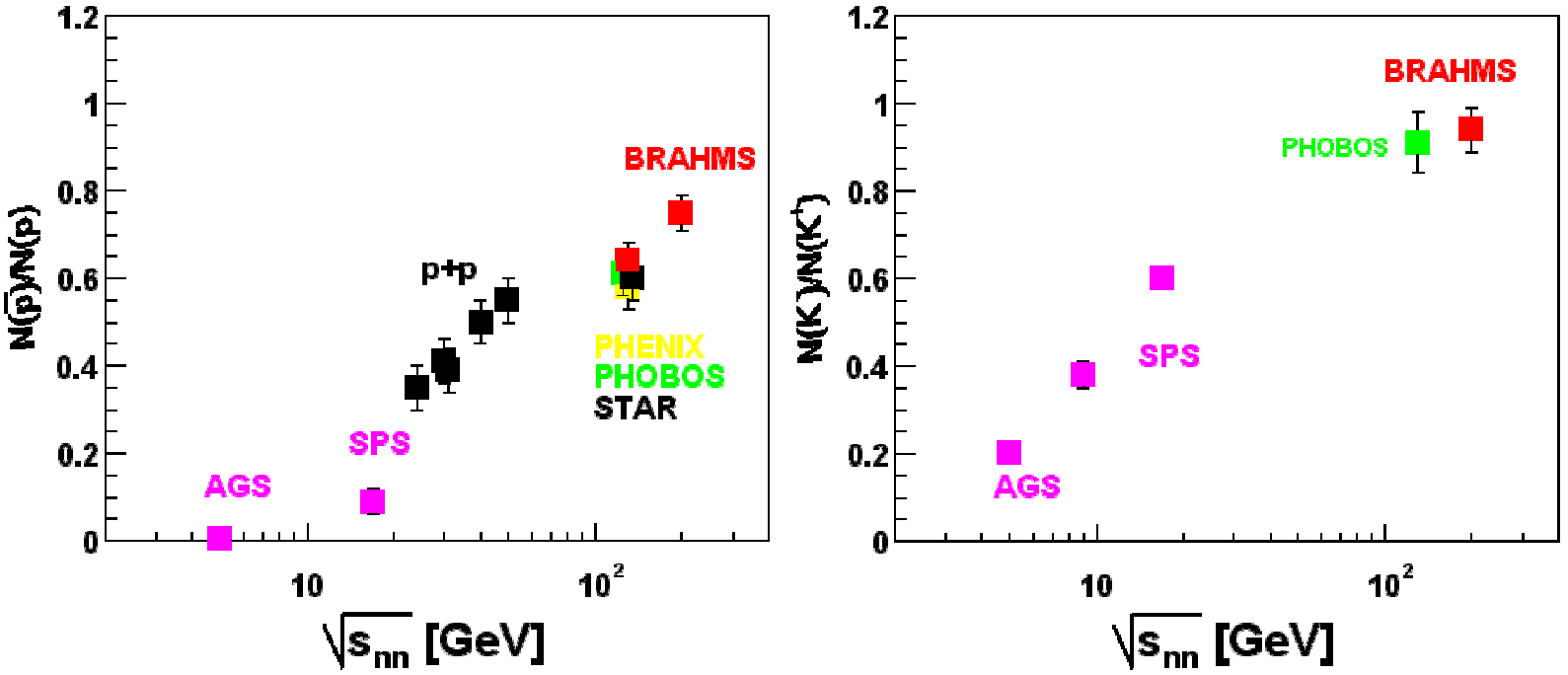


Baryon number transport … or pair production?

$$\frac{N(\bar{p})}{N(p)} = \frac{N(\bar{p}_p)}{N(p_p) + N(p_i)}$$

We need the yields!

Energy Systematics (y=0)



- towards matter-antimatter balance….

Net protons at midrapidity

	$N(p)$	$N(\bar{p})$	$N(p) - N(\bar{p})$
$\sqrt{s_{NN}} = 17$ GeV	31	5	26*
$\sqrt{s_{NN}} = 130$ GeV	40	26	14*
$\sqrt{s_{NN}} = 200$ GeV	(39)	(30)	(9)*

* NA49 QM99 & PRL82 (1999)

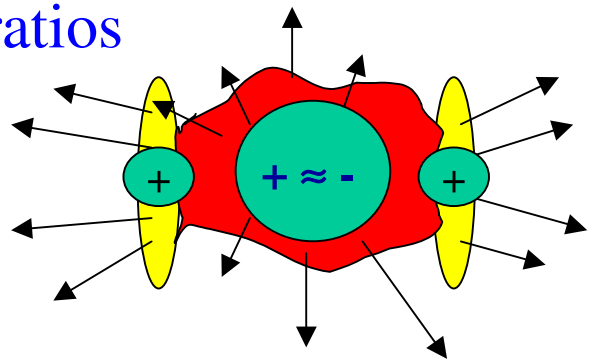
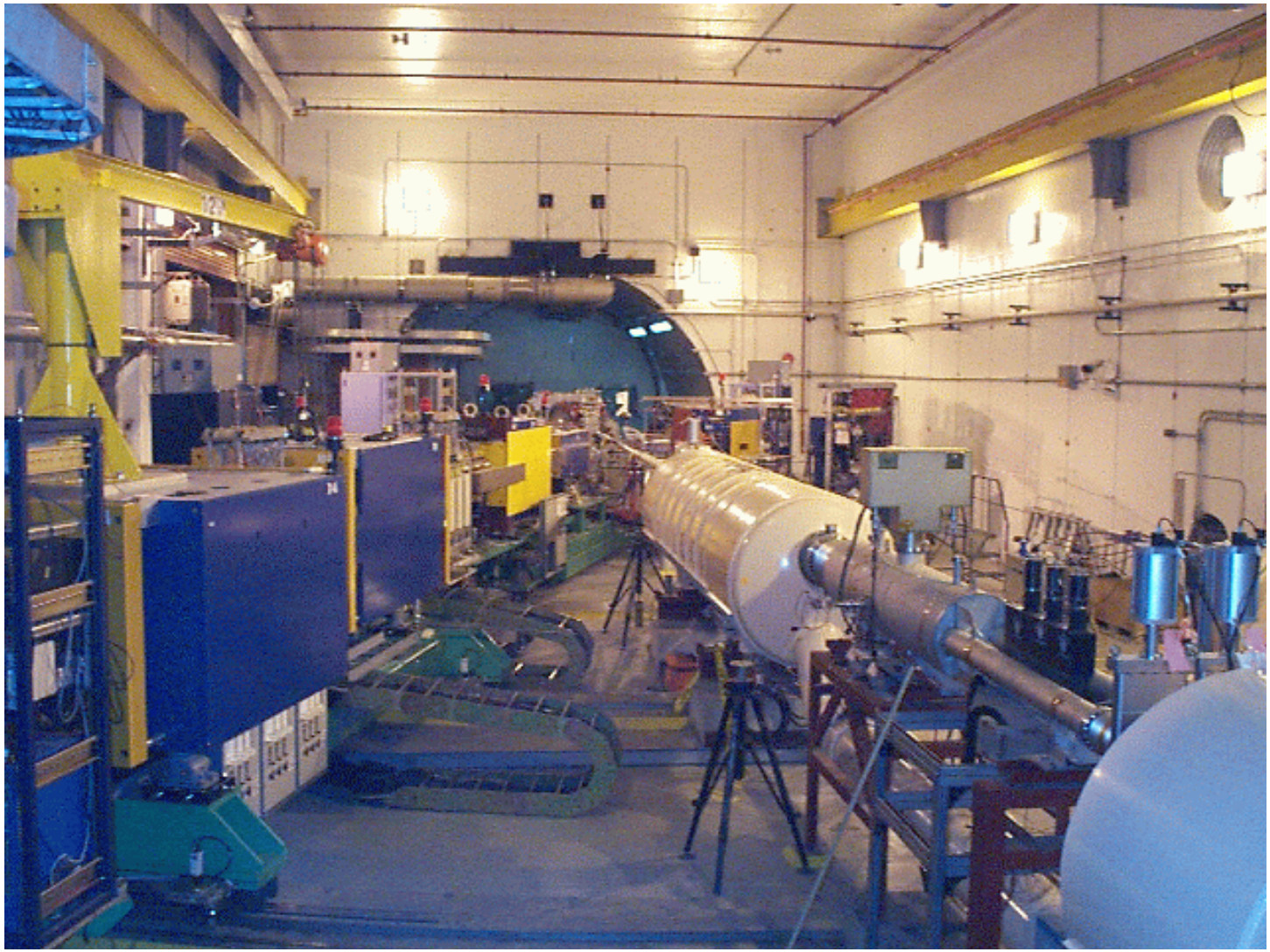
* STAR PRL87 (2001)

$$\frac{N(\bar{p})}{N(p)} = \frac{N(\bar{p}_p)}{N(p_p) + N(p_i)}$$

* Assuming 14% more p and $\bar{p}$ (like dN/dη, BRAHMS sub to PRL dec.2001) and $N(\bar{p})/N(p) = 0.75$.

Antiparticle-to-particle ratios in Au+Au at $\sqrt{s_{NN}} = 200$ GeV

- Measured $N(\bar{p})/N(p)$, $N(K^-)/N(K^+)$ and $N(\pi^-)/N(\pi^+)$
  - for p and K this is the highest so far observed in HI collisions
- Ratios nearly independent of Pt and centrality
- Strong energy dependence of p and k ratios
  (towards matter-antimatter balance at RHIC)
- Strong rapidity dependence of p ratio
  - consistent with high transparency scenario
    (but Bjorken limit not reached)



- Present models does not reproduce RHIC data