Proton and deuteron production at SPS energies

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for the NA49 collaboration

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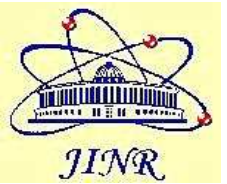
OUTLOOK



- Motivation
- NA49 Hadron Spectrometer
- PID and centrality selection
- p,d mid-rapidity m_t-spectra and yields
- Analysis of the p,d transverse mass distributions (energy and centrality dependence of $<m_t>$ and T)
- Coalescence, B_2 versus centrality, energy and m_t
- Summary

Motivation

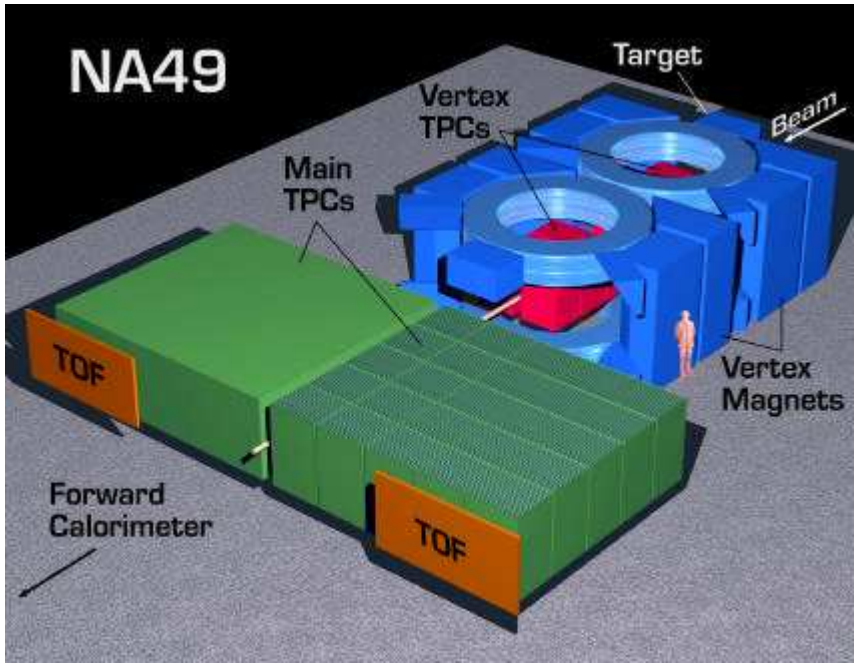
Aim: Study of nuclear matter at high temperature and density

Proton and deuteron production in A+A:

- **space-time structure of the freeze-out region**
- **collective effects in dense and hot nuclear matter**
- **reaction volume and freeze-out nucleon density**
- **final state interactions and nuclear cluster production mechanism**

S.Mrowczynski, Phys. Lett. B 277, 43 (1992)
R.Scheibl and U.Heinz, Phys. Rev. C 59, 1585 (1999)
A.Polleri et al., Phys. Lett. B 419, 19 (1998)

The NA49 spectrometer



Large acceptance: full forward hemisphere covered

Tracking: 4 TPC, $\delta p/p^2 = 3\ 10^{-5}$ (GeV/c) $^{-1}$

Particle ID:

dE/dx – $\sigma_E/E \cong 4\%$

TOF – $\sigma_T \cong 60$ ps

Centrality selection: ZDC

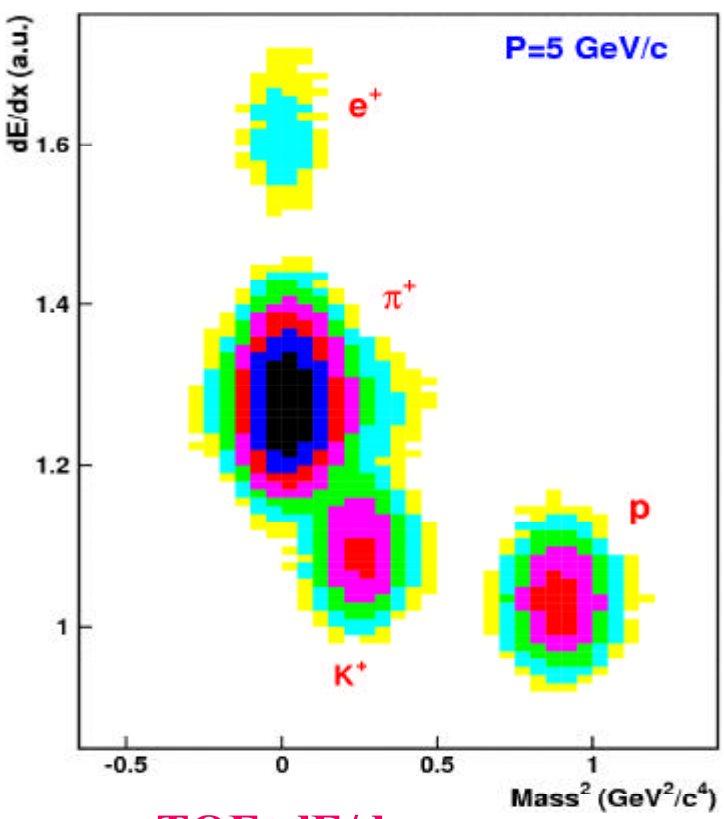
Data samples (for present study):

Pb+Pb 7% central @ 20,30,40,80 AGeV (400k events in each)

Pb+Pb 5% central @ 158 AGeV (400k events)

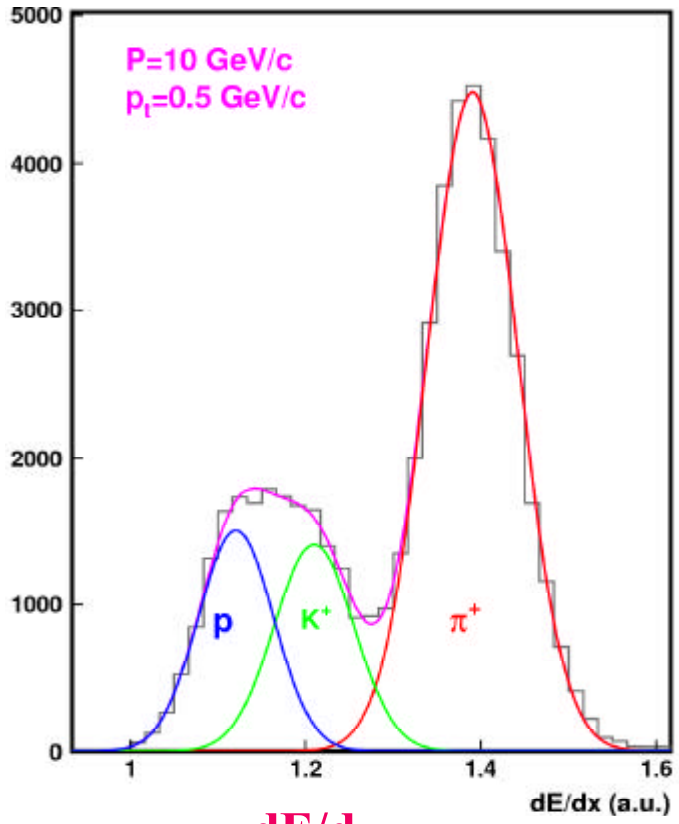
Pb+Pb min. bias @ 158 AGeV (700k events)

Particle Identification in NA49



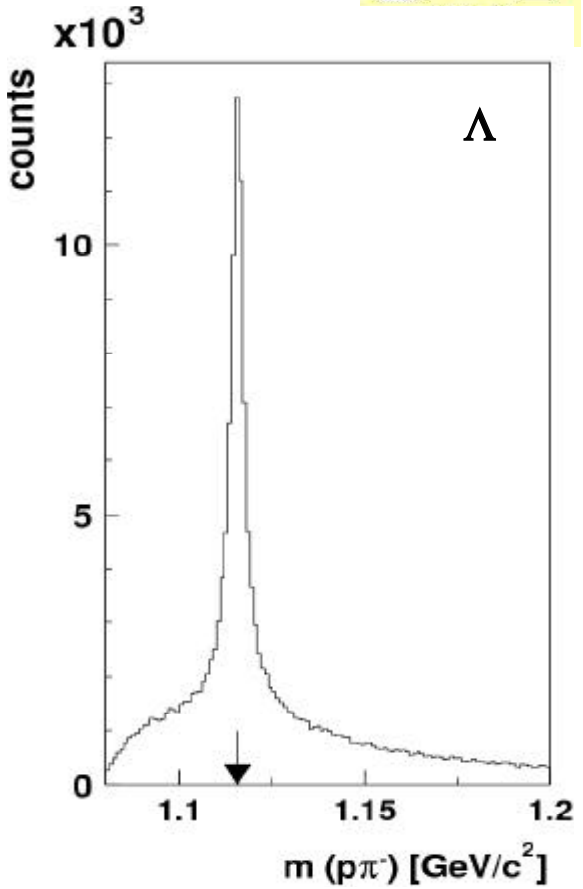
TOF+dE/dx

1 < P < 10 GeV/c



dE/dx

P > 5 GeV/c



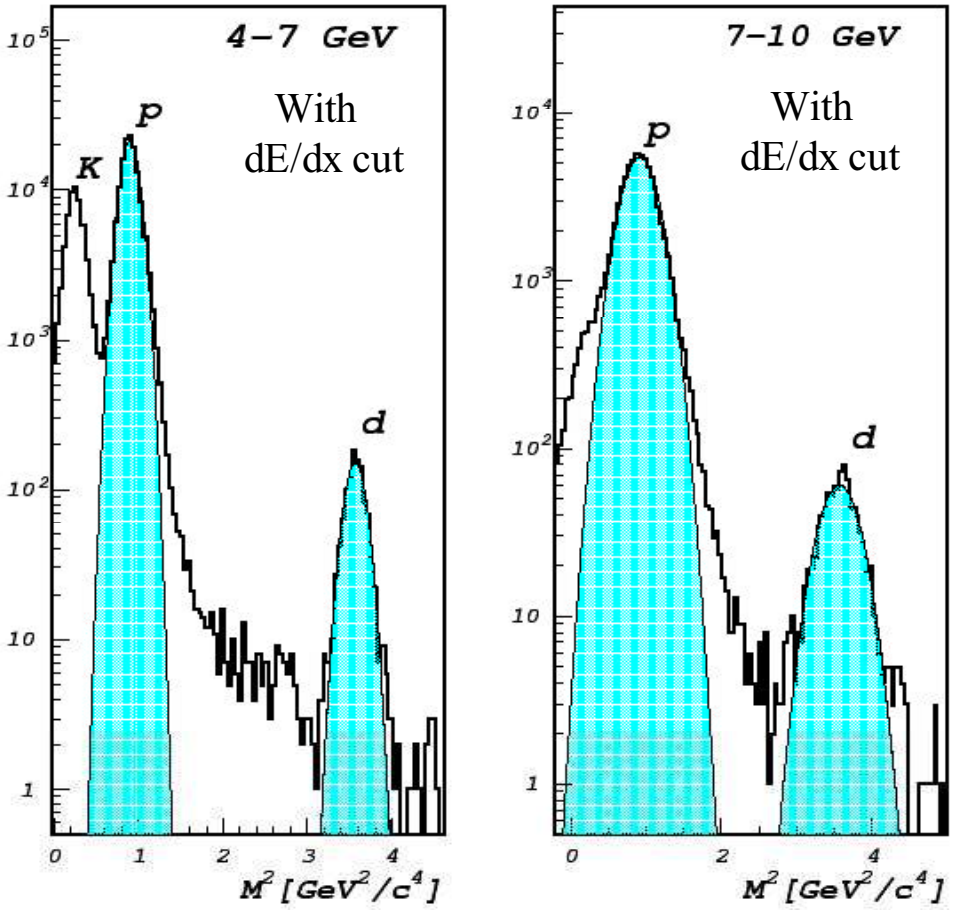
hyperons:

decay topology

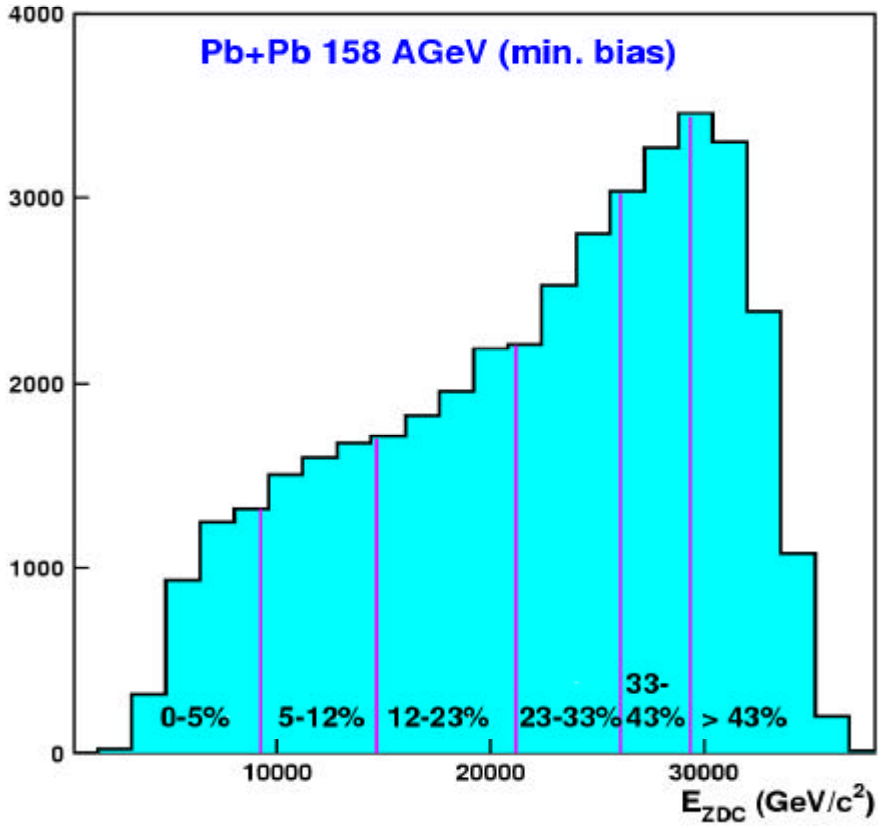
Corrections for geometrical acceptance, decay in flight, track quality cuts. Proton feeddown at 40-158 AGeV from NA49 data on Λ production, at 20 and 30 AGeV from VENUS.

TOF deuteron ID and centrality selection

NA49 p,d identification (TOF)

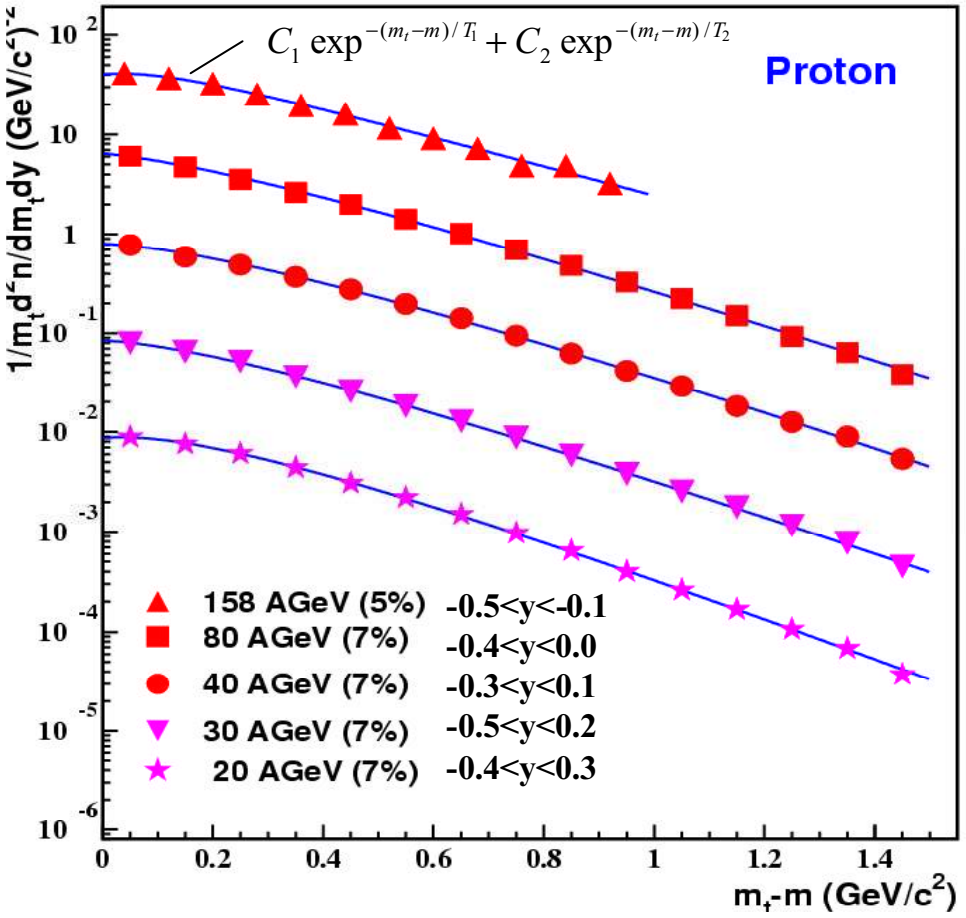


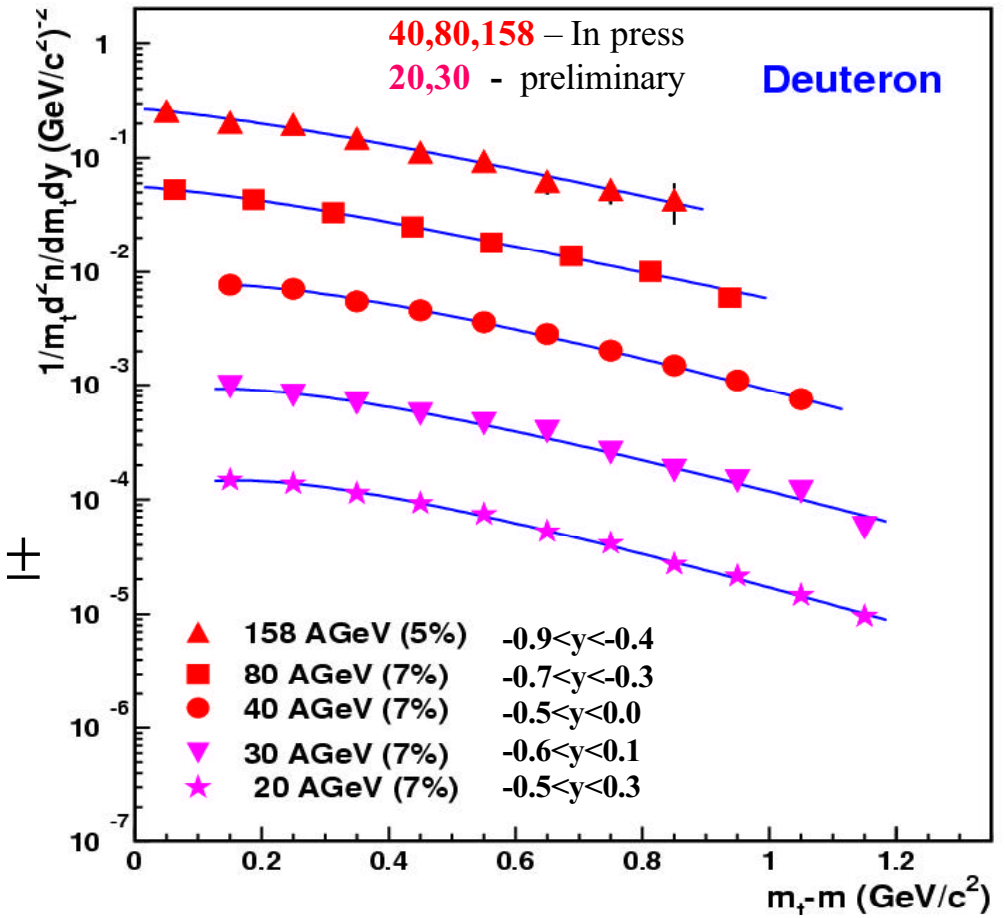
centrality selection



	central	⟷	peripheral
<N_{part}>	366		85
b (fm)	0-3.4		10-14

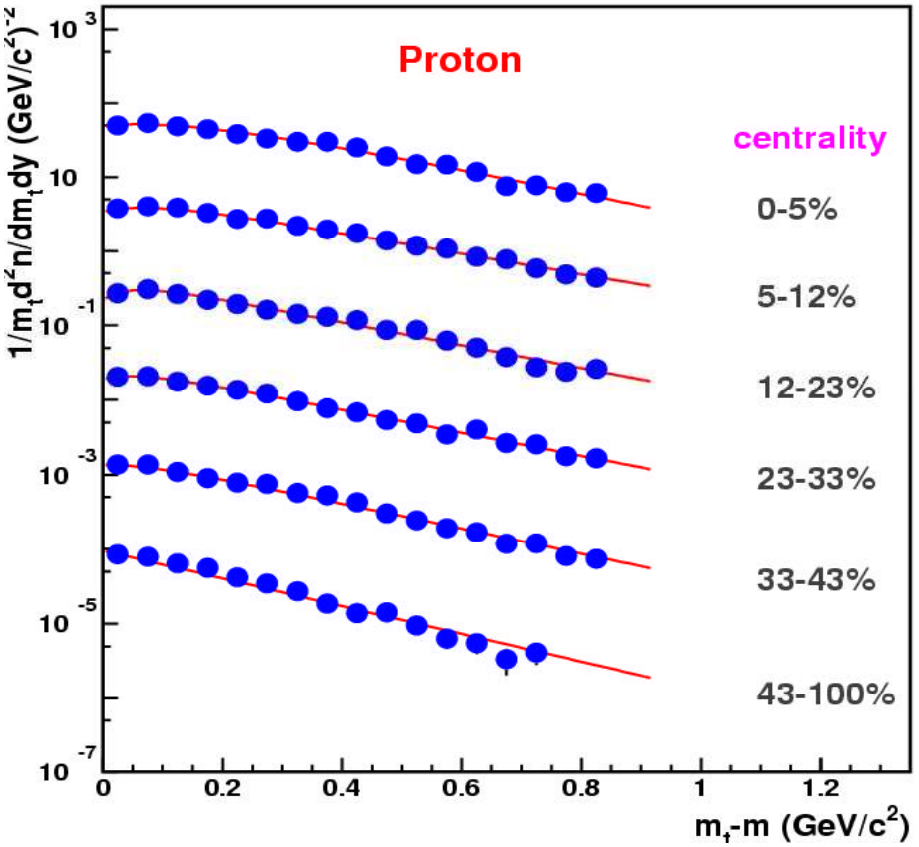
Mid-rapidity p,d m_t-spectra in central Pb+Pb @ 20-158 AGeV

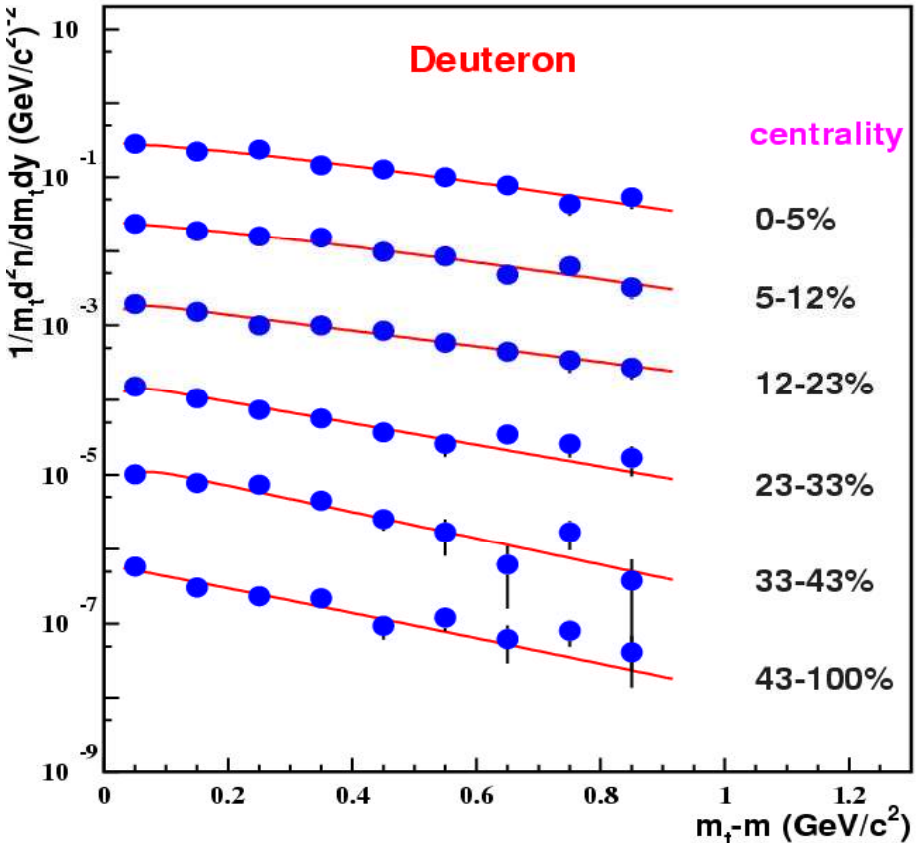




E_{beam}/A (GeV)	20	30	40	80	158
dn/dy (d)	2.11 ± 0.19	1.38 ± 0.15	1.02 ± 0.12	0.59 ± 0.08	0.33 ± 0.04
dn/dy (p)	45.0 ± 3.0	41.6 ± 3.0	41.3 ± 2.4	30.1 ± 2.0	29.6 ± 2.1

Centrality selected p,d m_t-spectra @ 158 AGeV

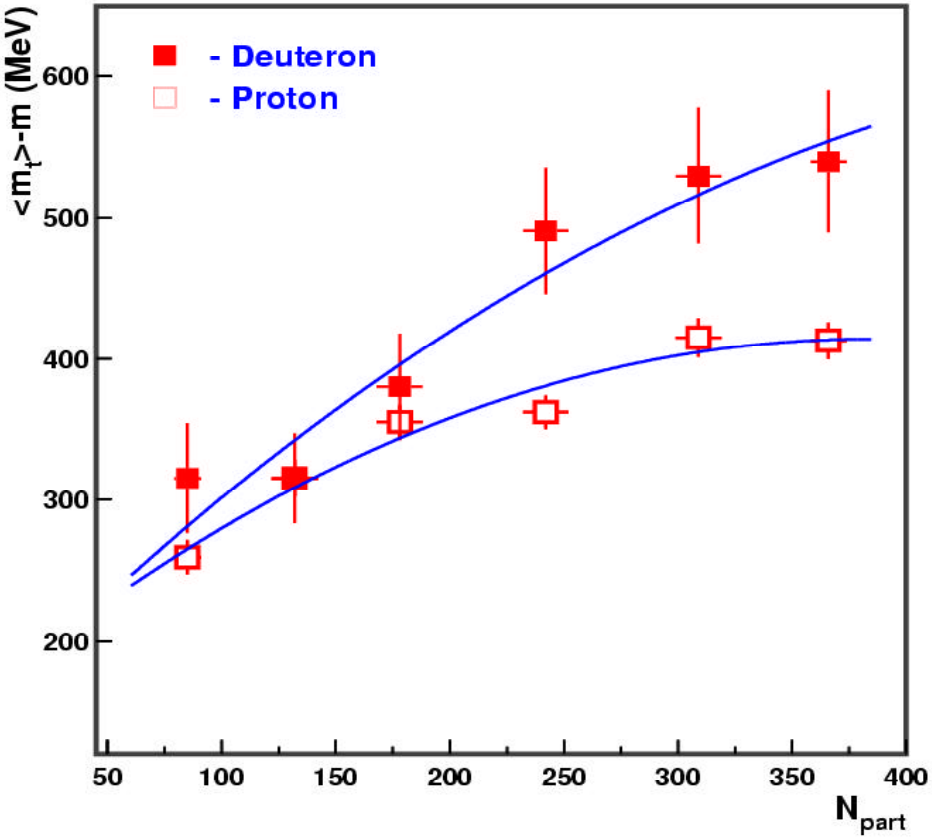


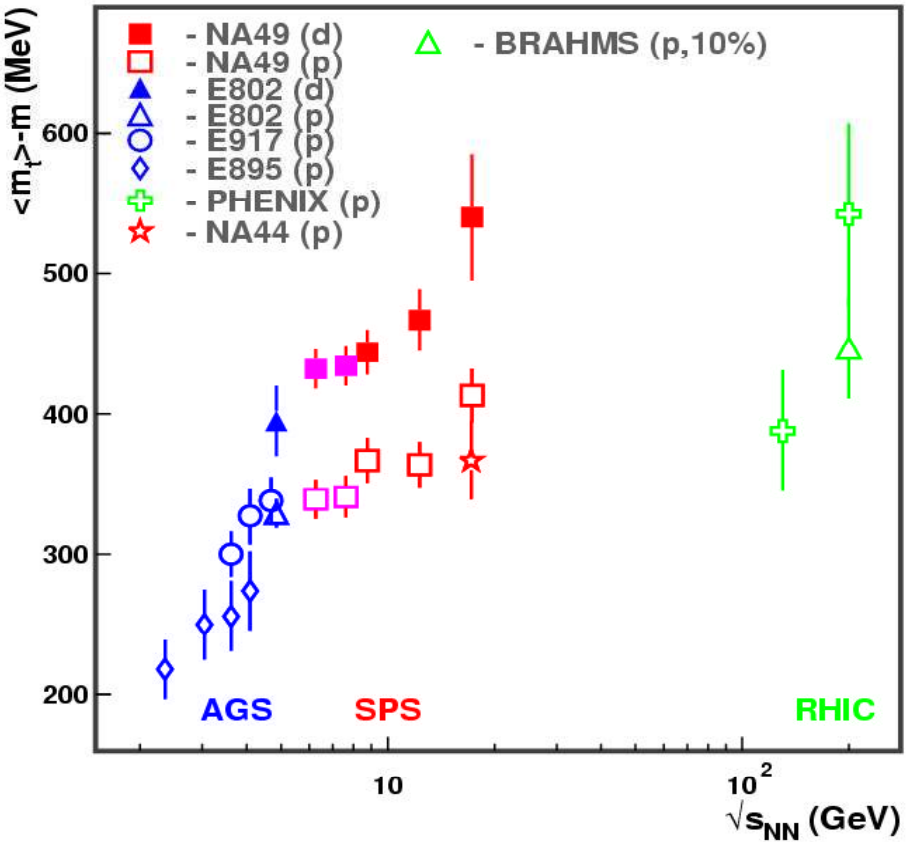


Centrality (%)	0-5	5-12	12-23	23-33	33-43	43-100
dn/dy (d)	$0.33 \pm .04$	$0.27 \pm .05$	$0.21 \pm .04$	$0.12 \pm .03$	$0.08 \pm .02$	$0.04 \pm .015$
dn/dy (p)	29.6 ± 2.1	22.2 ± 1.7	14.5 ± 1.5	$9.8 \pm 1.$	5.7 ± 0.7	2.9 ± 0.4

158 AGeV (Pb+Pb min. bias)

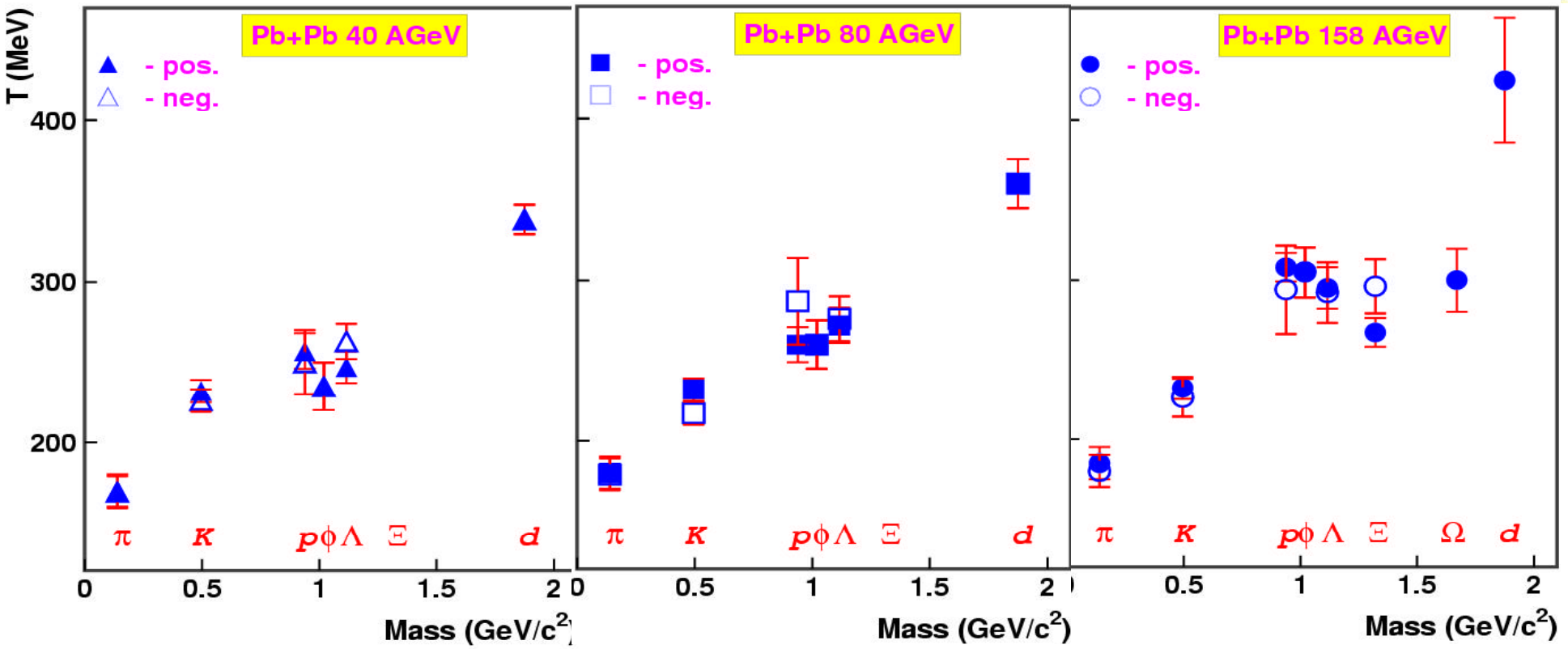
Central (Pb+Pb,Au+Au)





- $\langle m_t \rangle - m_d \gg \langle m_t \rangle - m_p$ in central A+A collisions at all energies
- $\langle m_t \rangle - m_d \approx \langle mt \rangle - m_p$ in peripheral collisions

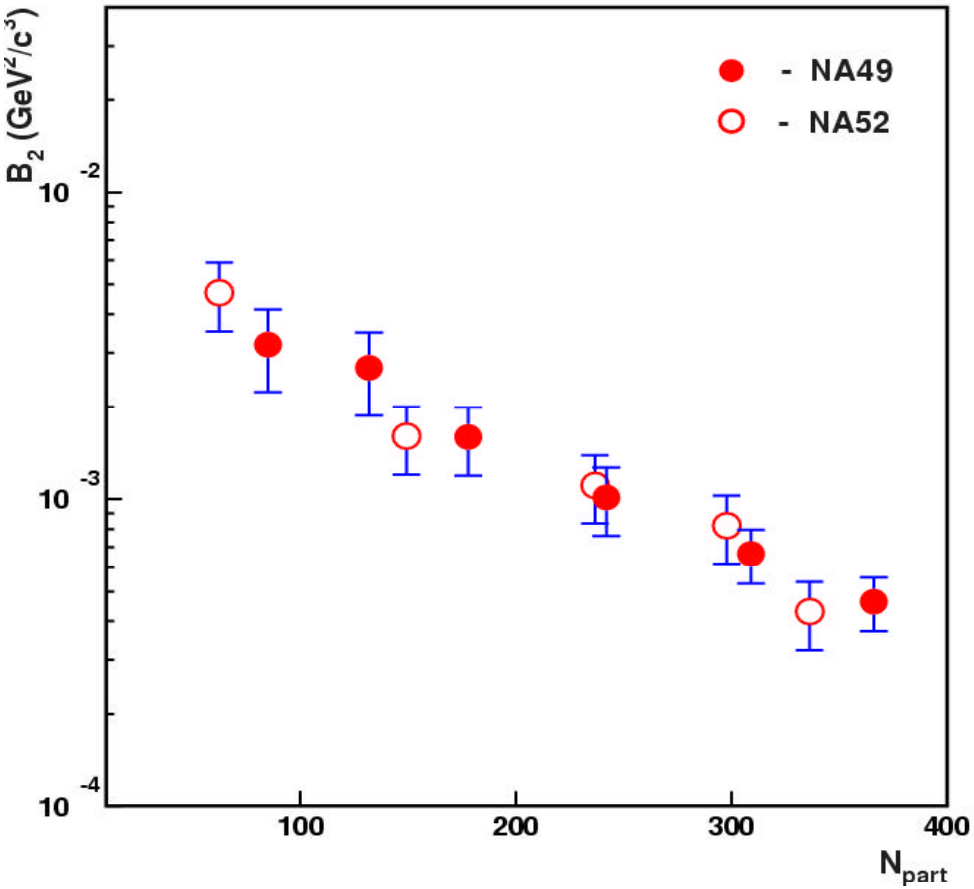
Inverse slope systematics from NA49 data



Slope parameter increases with increasing particle mass in central Pb+Pb collisions at all energies

Centrality dependence of the coalescence factor B_2

B_2 in Pb+Pb collisions (E=158 AGeV, p_t=0)

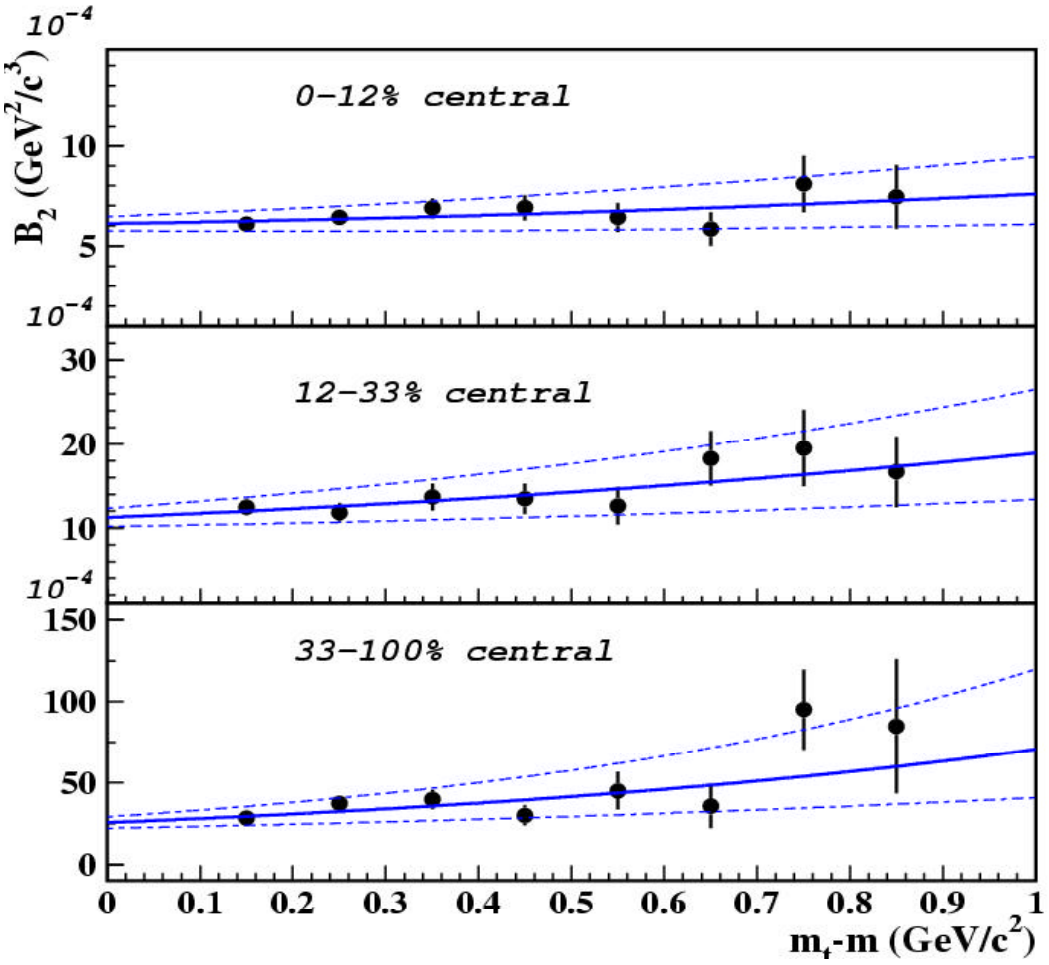


Coalescence model:

$$E_d \frac{d^3 N_d}{dp_d^3} = B_2 \left(E_p \frac{d^3 N_p}{dp_p^3} \right)^2, \qquad p_d = 2 \cdot p_p$$

B_2 decreases with increasing collision centrality

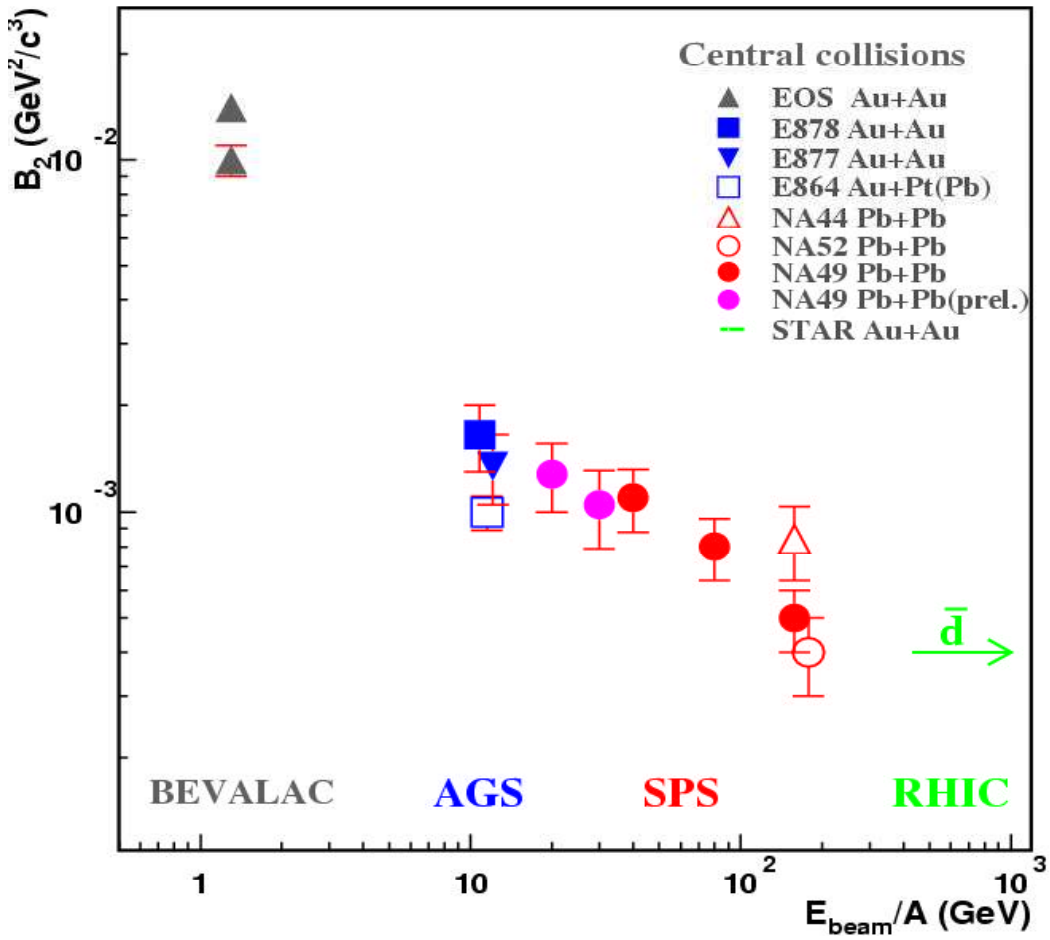
$B_2(m_t\text{-}m)$ @ 158 AGeV (min. bias)



$$B_2(m_t - m) \approx a \exp\left(b(m_t - m)\right)$$

- B_2 increses with m_t-m_d
- Effect also seen in peripheral collisions

B_2 energy dependence (Bevalac-AGS-SPS-RHIC)



B_2 decreases with energy (factor of 3 at SPS)

Summary

- p,d midrapidity transverse mass spectra measured by NA49 in Pb+Pb at 20,30,40,80 and 158 AGeV are presented

- m_t distributions of deuterons are harder then those of protons in central A+A collisions at all energies

- $\langle m_t \rangle - m_d$ is approaching $\langle m_t \rangle - m_p$ in the most peripheral collisions at 158 AGeV

- B_2 coalescence parameter at 158 AGeV exhibits strong centrality dependence and increases slowly with m_t

- B_2 decreses with increasing of energy

The NA49 collaboration

C.Alt, T.Anticic, B.Baatar, D.Barna, J.Bartke, M.Behler, L.Betev, H.Bialkowska, A.Billmeier, C.Blume, B.Boimska, M.Botje, J.Bracinik, R.Bramm, R.Brun, P.Buncic, V.Cerny, O.Chvala, J.G.Cramer, P.Csató, P.Dinkelaker, V.Eckardt, P.Filip, H.G.Fischer, Z.Fodor, P.Foka, P.Freund, V.Friese, J.Gál, M.Gazdzicki, G.Georgopoulos, E.Gladysz, S.Hegyi, C.Höhne, K.Kadija, A.Karev, S.Kniege, V.I.Kolesnikov, T.Kollegger, R.Korus, M.Kowalski, I.Kraus, M.Kreps, M. van Leeuwen, P.Lévai, A.I.Malakhov, C.Markert, B.W.Mayes, G.L.Melkumov, C.Meurer, A.Mischke, M.Mitrovski, J.Molnár, St.Mrówczynski, G.Pálla, A.D.Panagiotou, K.Perl, A.Petridis, M.Pikna, L.Pinsky, F.Pühlhofer, J.G.Reid, R.Renfordt, W.Retyk, C.Roland, G.Roland, M. Rybczynski, A.Rybicki, A.Sandoval, H.Sann, N.Schmitz, P.Seyboth, F.Siklér, B.Sitar, E.Skrzypczak, G.Stefanek, R.Stock, H.Ströbele, T.Susa, I.Szentpétery, J.Sziklai, T.A.Trainor, D.Varga, M.Vassiliou, G.I.Veres, G.Vesztergombi, D.Vranic, S.Wenig, A.Wetzler, Z.Wlodarczyk, I.K.Yoo, J.Zaranek, J.Zimányi

The estimation of a mean number of participants

In each centrality bin a direct estimate of the number of participating nucleons was made by estimated of the net barion number carried by produced particles.

$$(B - \bar{B}) = (p - \bar{p}) + (n - \bar{n}) + (Y - \bar{Y})$$

Averaging the results of several models and experimental data:

$$N_{part} = (1+\alpha)(p - \bar{p}) + 2\frac{1+\beta}{1+2\beta}\left(K^{+} - K^{-}\right)$$

$$where \qquad \alpha = (n - \bar{n})/(p - \bar{p}) \approx 1.07 \qquad \beta = (Y - \bar{Y})_{S=2}/(Y - \bar{Y})_{S=1} \approx 0.1$$

Bin	E/E_{beam}	$\sigma/\sigma_{tot}(\%)$	$\langle N_{part} \rangle$	$\langle N_w \rangle$	b (fm)
1	0-0.25	0-5	366 ±8	352	0-3.4
2	0.25-0.4	5-12	309 ±10	281	3.4-5.3
3	0.4-0.58	12-23	242 ±10	204	5.3-7.3
4	0.58-0.71	23-33	178 ±10	134	7.4-9.1
5	0.71-0.8	33-43	132 ±10	88	9.1-10.2
6	0.8-1.0	43-100	85 ±6	42	10.2-14.0