Analysis of Bose-Einstein correlation data in Pb+Pb collisions at CERN SPS energies

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- **BudaLund analitical hydro formulas for observables**
- **Fits to NA49 data of 20, 30, 40, 80, 158 AGeV energies**
- **Results**
- **Conclusion**

The BudaLund fluid model

- **Observables**

$$\mathbf{N_1}(p) = \int d^4x\, S(x,p)$$

$$C(Q,p) = 1 + \left|\frac{\widetilde{S}(Q,p)}{\widetilde{S}(0,p)}\right|^2 = 1 + \lambda_* \left|\frac{\widetilde{S}_c(Q,p)}{\widetilde{S}_c(0,p)}\right|^2$$

$$S(x,p) = S_c(x,p) + S_h(x,p)$$

$$\mathbf{N_1}(p) = \frac{1}{\sqrt{\lambda_*}} \int d^4x\, S_c(x,p)$$

The BudaLund fluid model

- **A general form**

$$S(x,p)\,d^4x = f(x,p)\,p_\mu\,d\sigma^\mu(x)$$

- **With probability distribution for fluids**

$$S(x,p)\,d^4x = \frac{g}{(2\pi)^3}\,\frac{p_\mu\,d\sigma^\mu(x)}{\exp\left(\dfrac{p_\mu u^\mu(x)}{T(x)} - \dfrac{\mu(x)}{T(x)}\right) + s_q}$$

The BudaLund fluid model

- **Buda-Lund solutions of the 5 differential fluid equations:**

$$d^4\sigma(x) = u(x)H(\tau)d^4x$$

$$u(x) = (\gamma, \sinh\eta_x, \sinh\eta_y, \sinh\eta_z)$$

$$\frac{\mu(x)}{T(x)} = \frac{\mu_0}{T_0} - s$$

$$\frac{1}{T(x)} = \frac{1}{T_0}\left(1 + \frac{T_0 - T_s}{T_s}s\right)\left(1 + \frac{(T_0 - T_e)}{T_e}\frac{(\tau - \tau_0)^2}{2\Delta\tau^2}\right)$$

The BudaLund fluid model

- **Where (in case of axial symmetry):**

$$H(\tau) = \frac{1}{(2\pi\Delta\tau^2)^{1/2}} \exp\left(-\frac{(\tau-\tau_0)^2}{2\Delta\tau^2}\right)$$

$$s = \frac{r_t^2}{(2R_G^2)} + \frac{(\eta - y_0)^2}{2\Delta\eta^2}$$

$$\sinh(\eta_t) = \frac{\langle u_t \rangle r_t}{R_G} \quad (= H_t r_t ; H_t : \textit{transverse Hubble constant})$$

The BudaLund fluid model

- **Final form of Invariant Momentum Distribution:**

$$N(\mathbf{p}) = \frac{g}{(2\pi)^3}\,\overline{E}\,\overline{V}\,\overline{C}\exp\left(-\frac{p\cdot u(\overline{x}) - \mu(\overline{x})}{T(\overline{x})}\right)$$

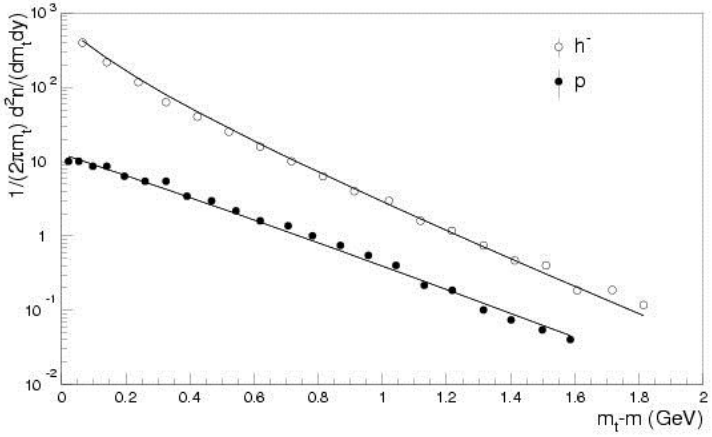
$$\overline{E} = m_t \cosh(\overline{\eta})$$

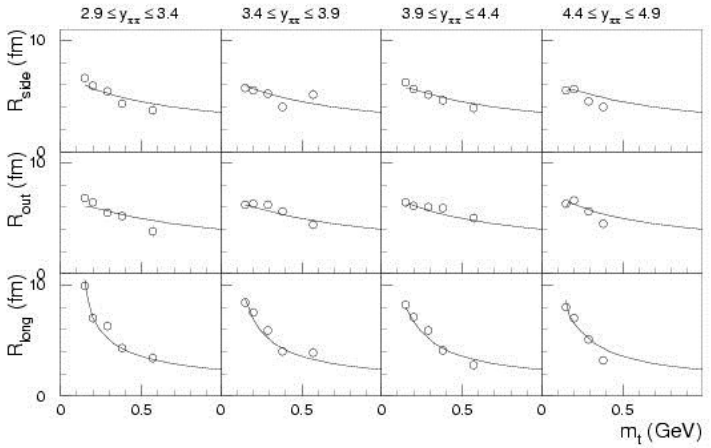
$$\overline{V} = 2\pi^{(3/2)}\,\overline{R}_{par}\,\overline{R}_{tr}{}^2\,\overline{\Delta\tau}\,\frac{\overline{\Delta\tau}}{\Delta\tau}$$

$$\overline{C} = \frac{1}{\sqrt{\lambda_*}}\exp\left(\frac{\overline{\Delta\eta}^2}{2}\right)$$

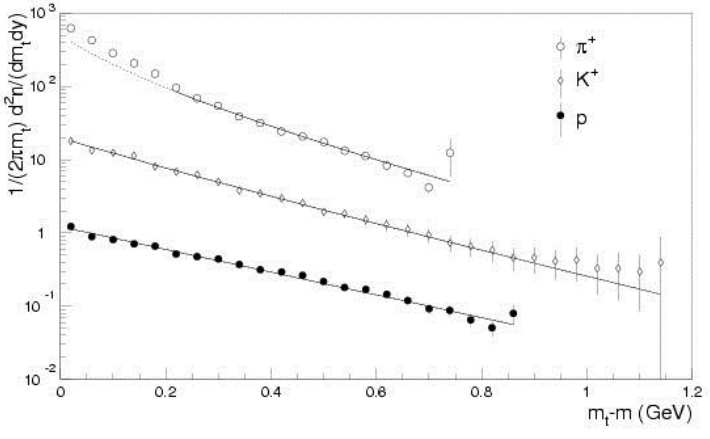
BudaLund old fits to old SPS Pb+Pb

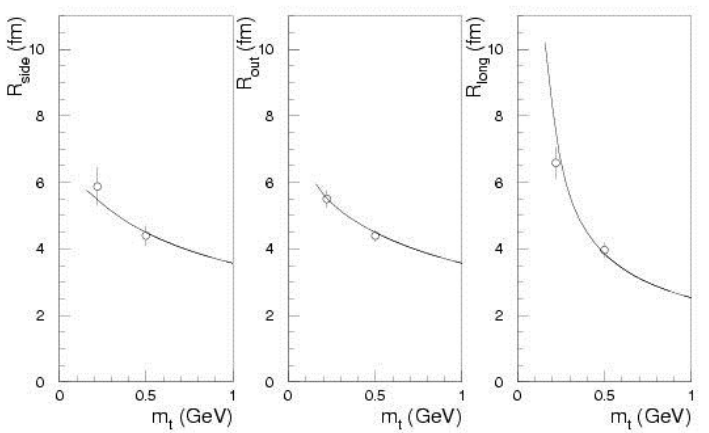
NA49





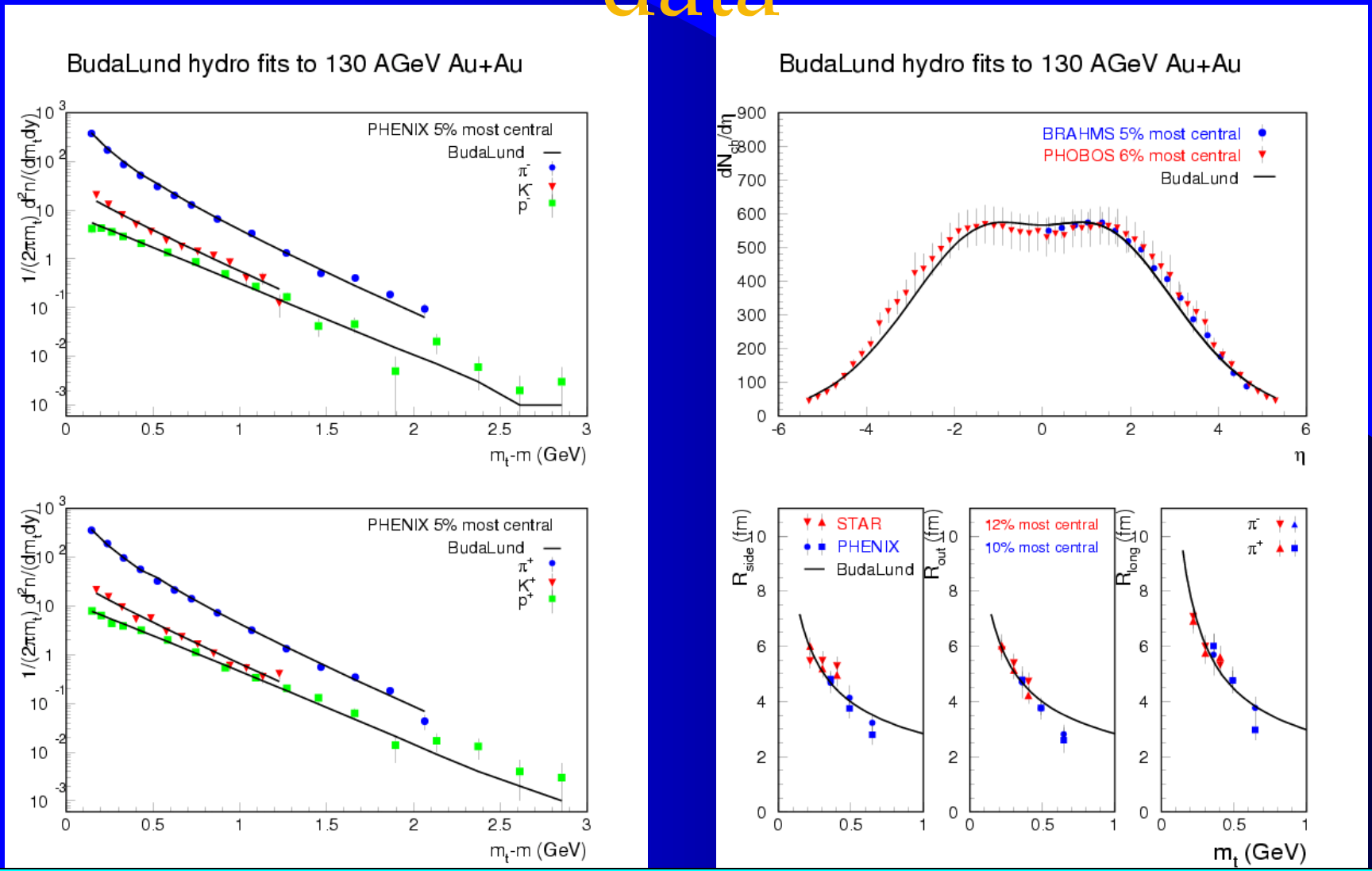
NA44





A. Ster, T.Csörgő, B. Lörstad , Nucl.Phys. A661 (1999) 419-422, nucl-th/9907338

BudaLund fits to RHIC Au+Au data



A. Ster, et al., Acta Phys.Polon. B35 (2004) 191-196, nucl-th/0311102

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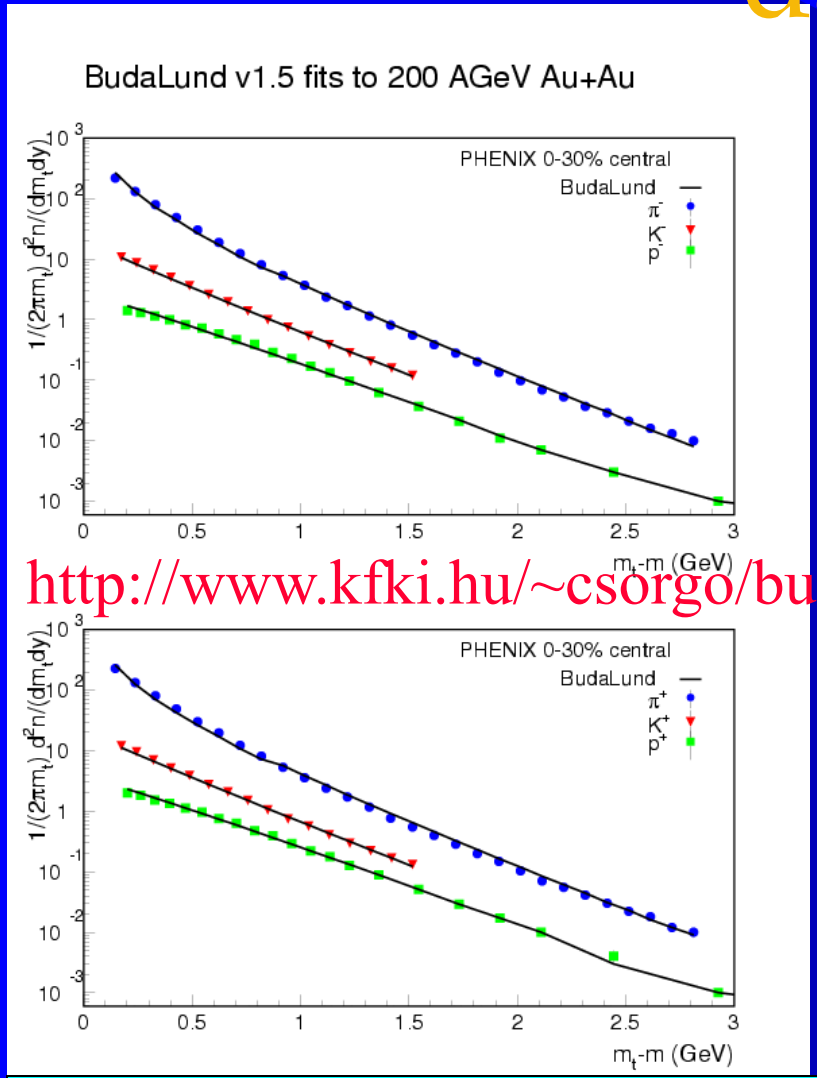
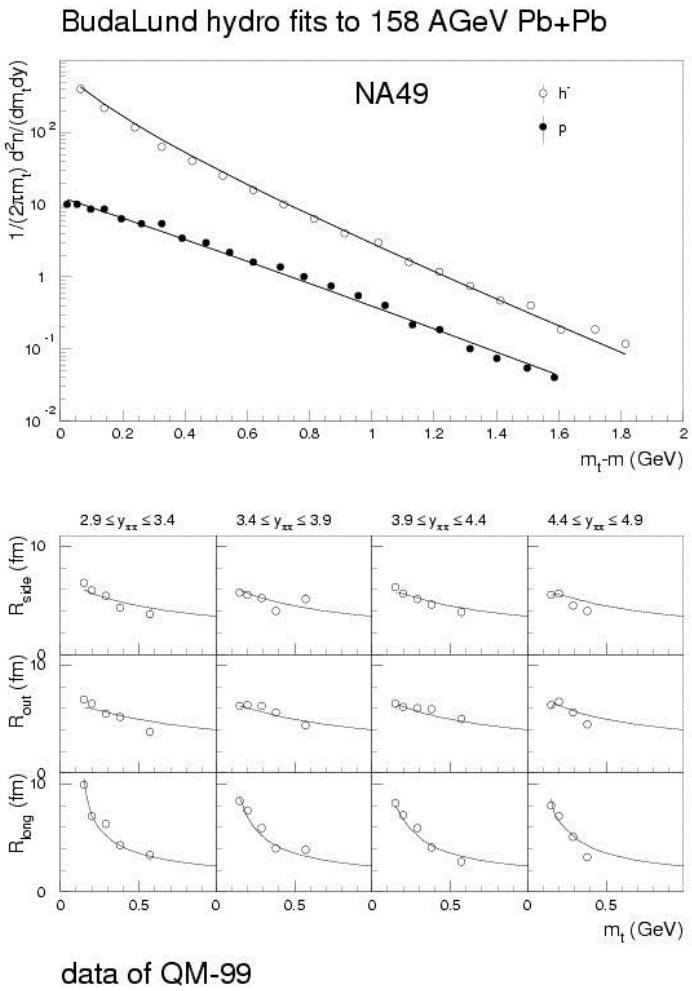


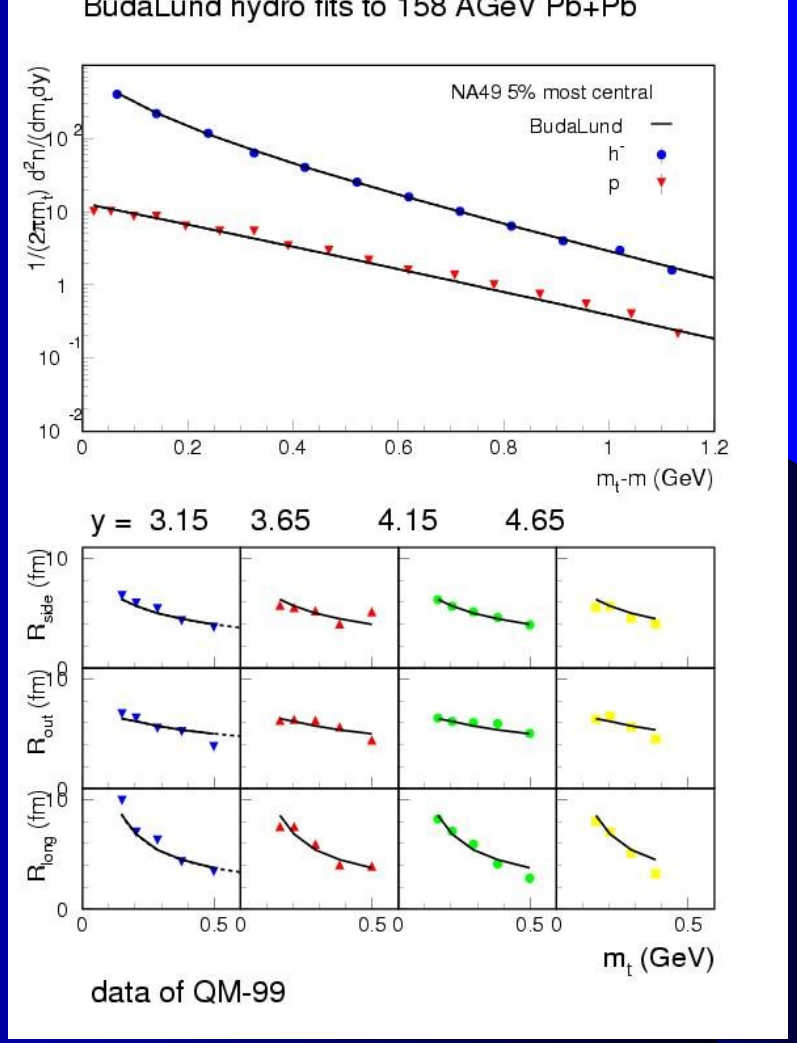
http://www.kfki.hu/~csorgo/budalund/budalund1.5.qm04.tar.gz

M. Csanád, et al., J.Phys.G30: S1079-S1082, 2004, nucl-th/0403074

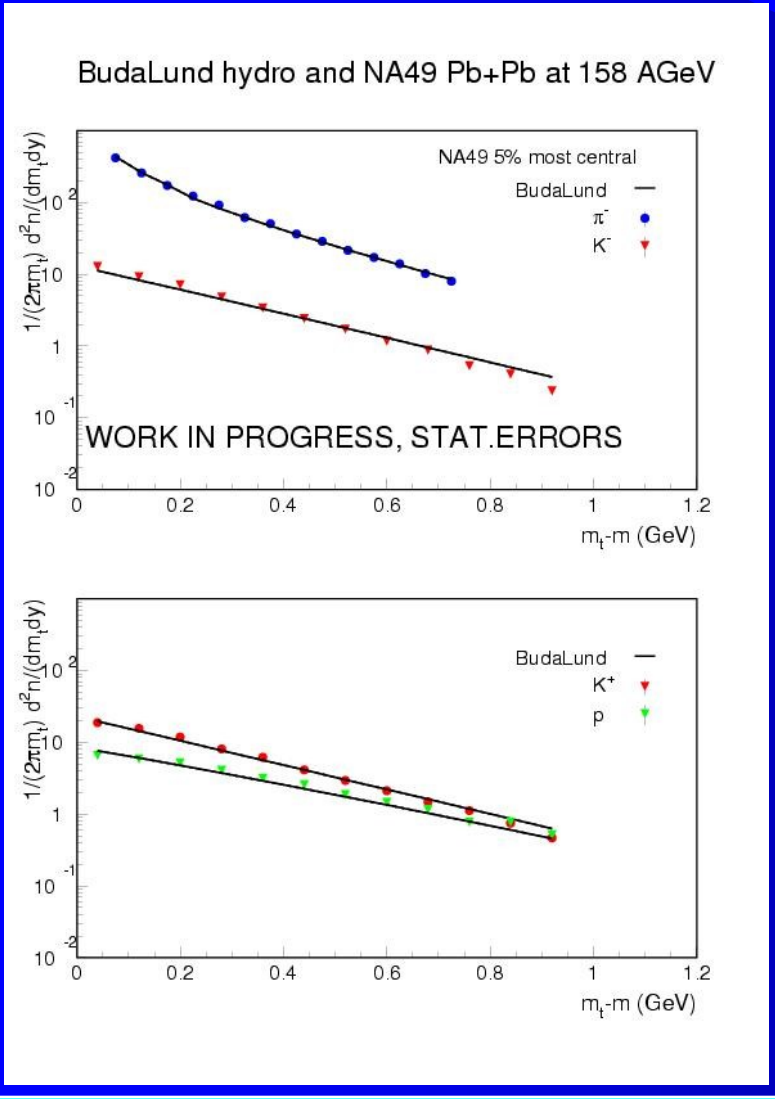
BudaLund fits to old NA49 data

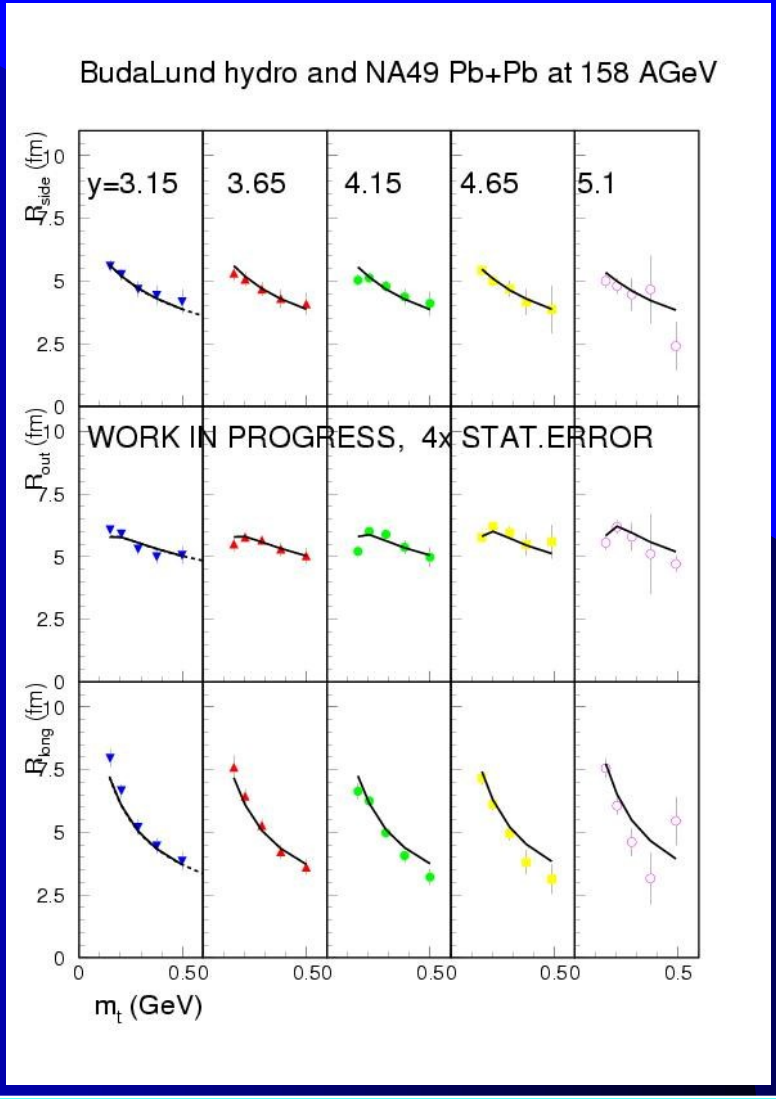


New code



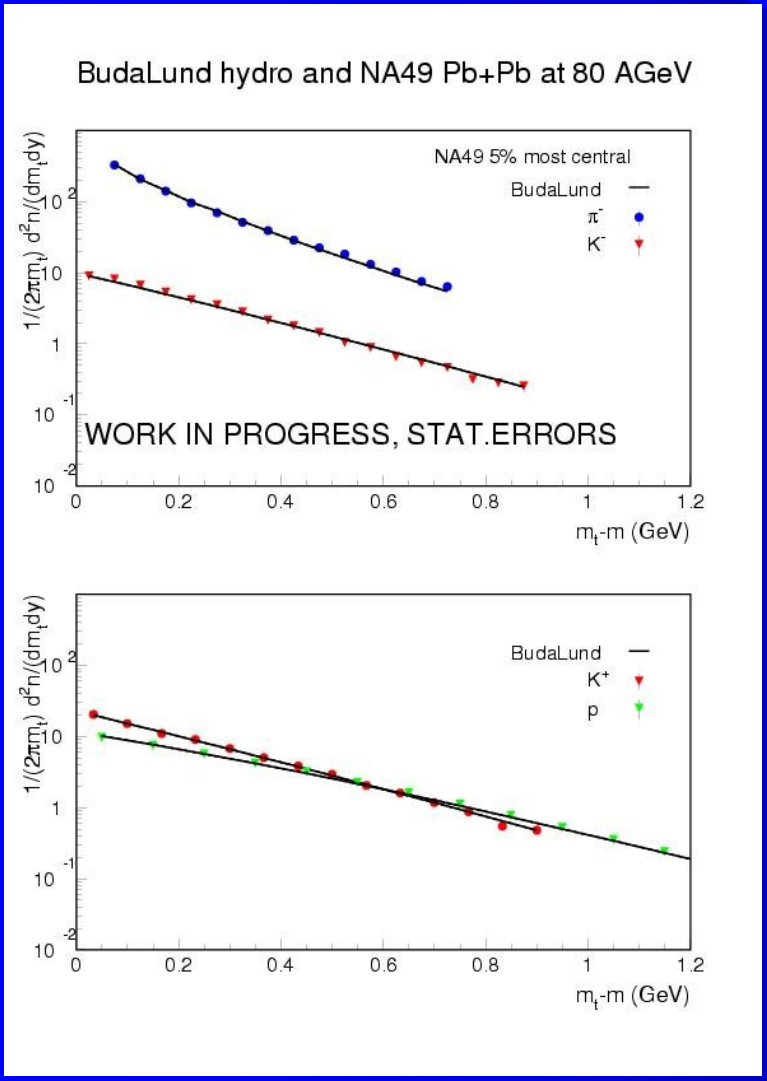
BudaLund fits to recent NA49 data

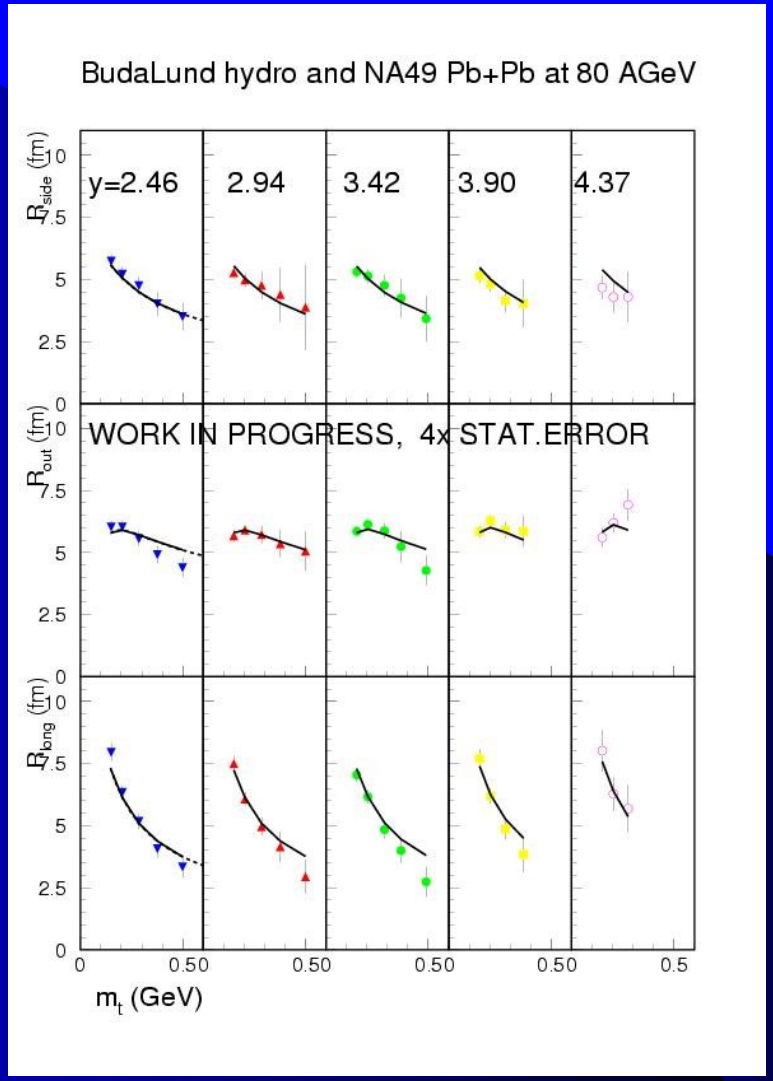




NA49 Collaboration (preliminary data), A. Ster, T. Csörgő and M. Csanád (work in progress)

BudaLund fits to recent NA49 data





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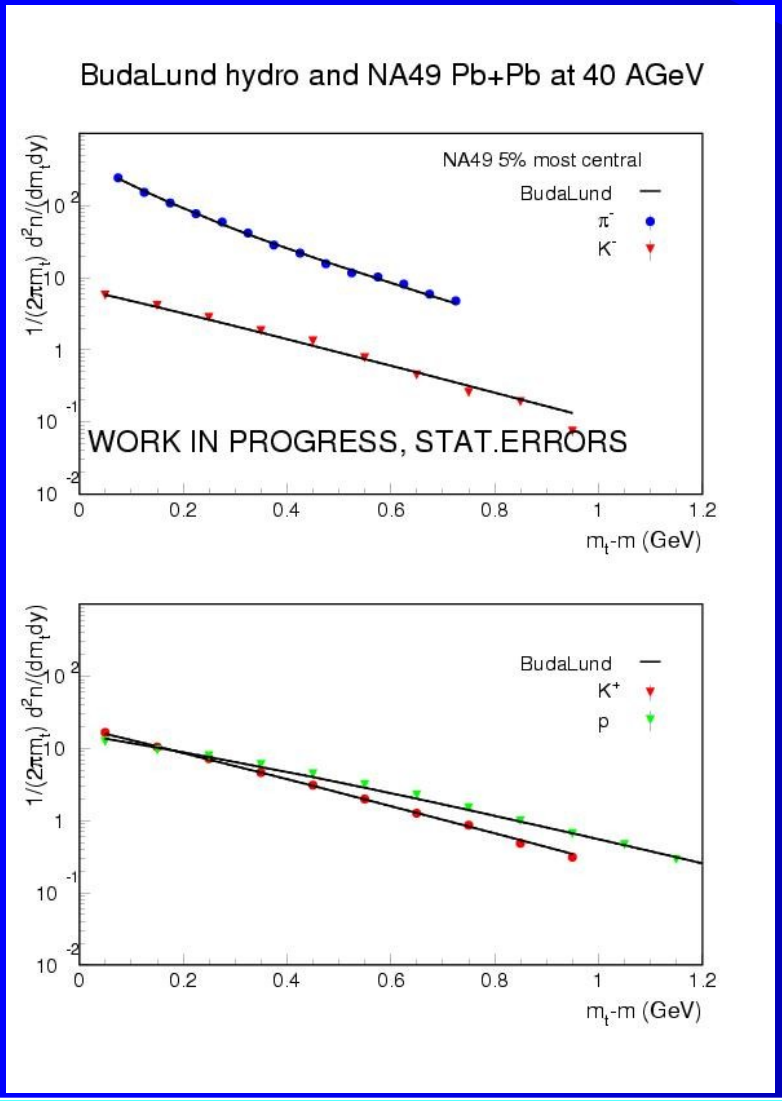

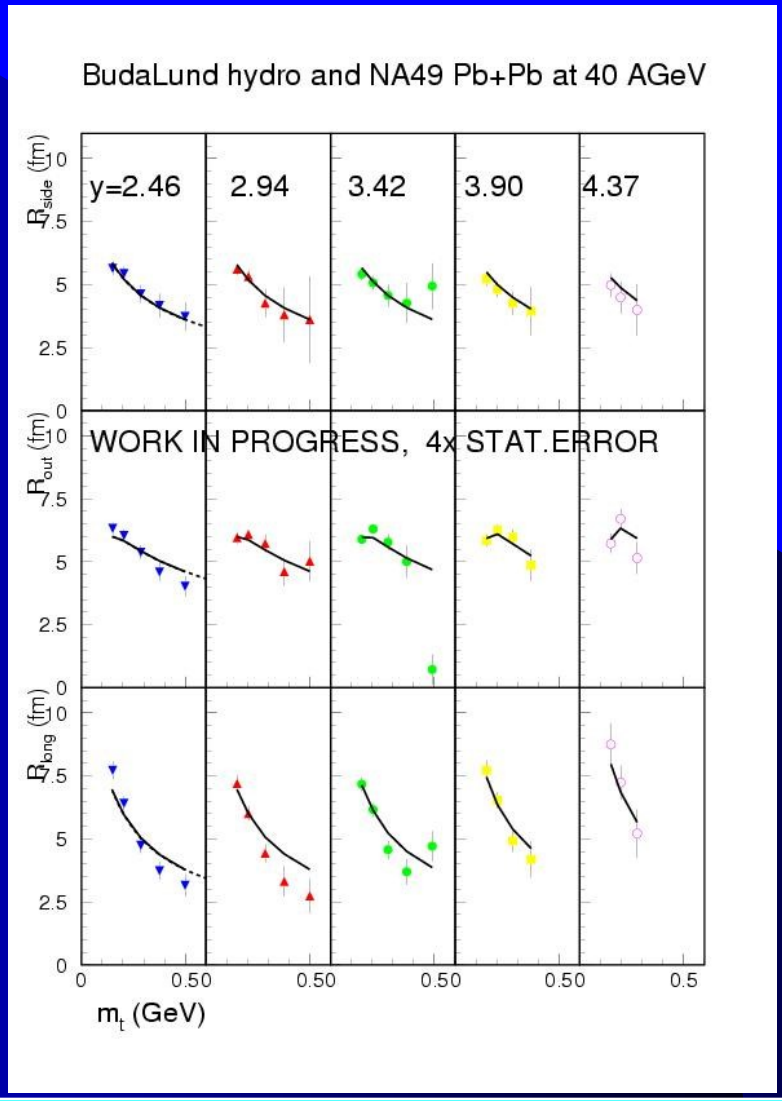

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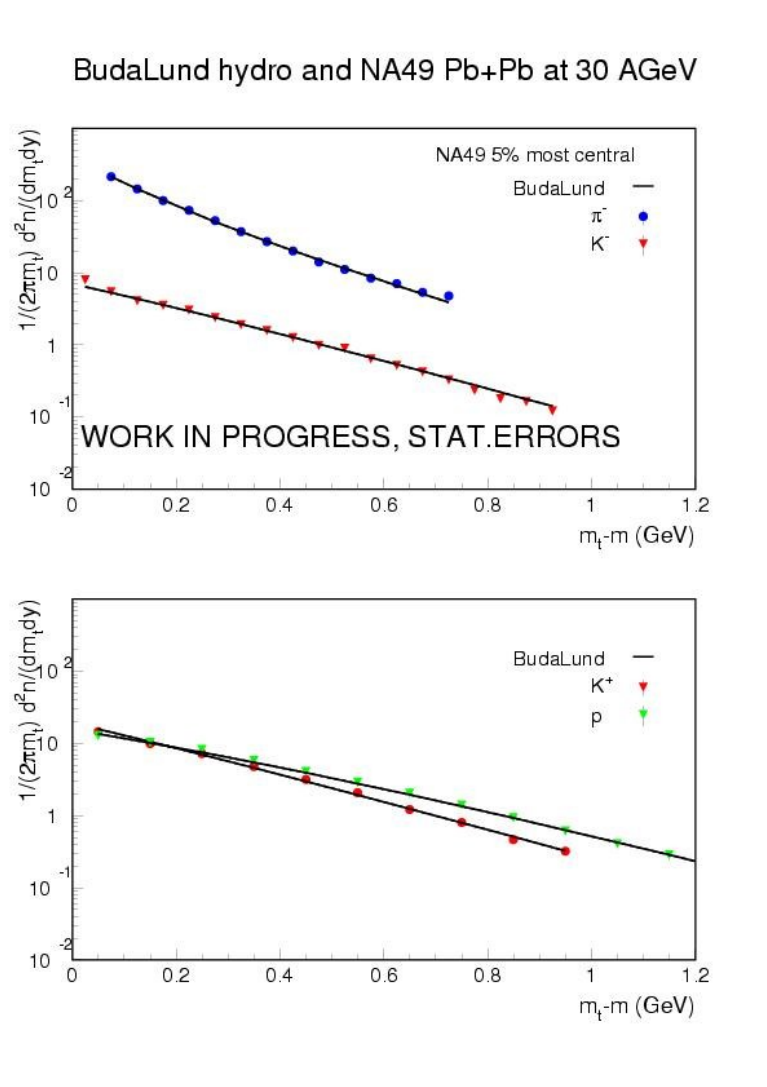

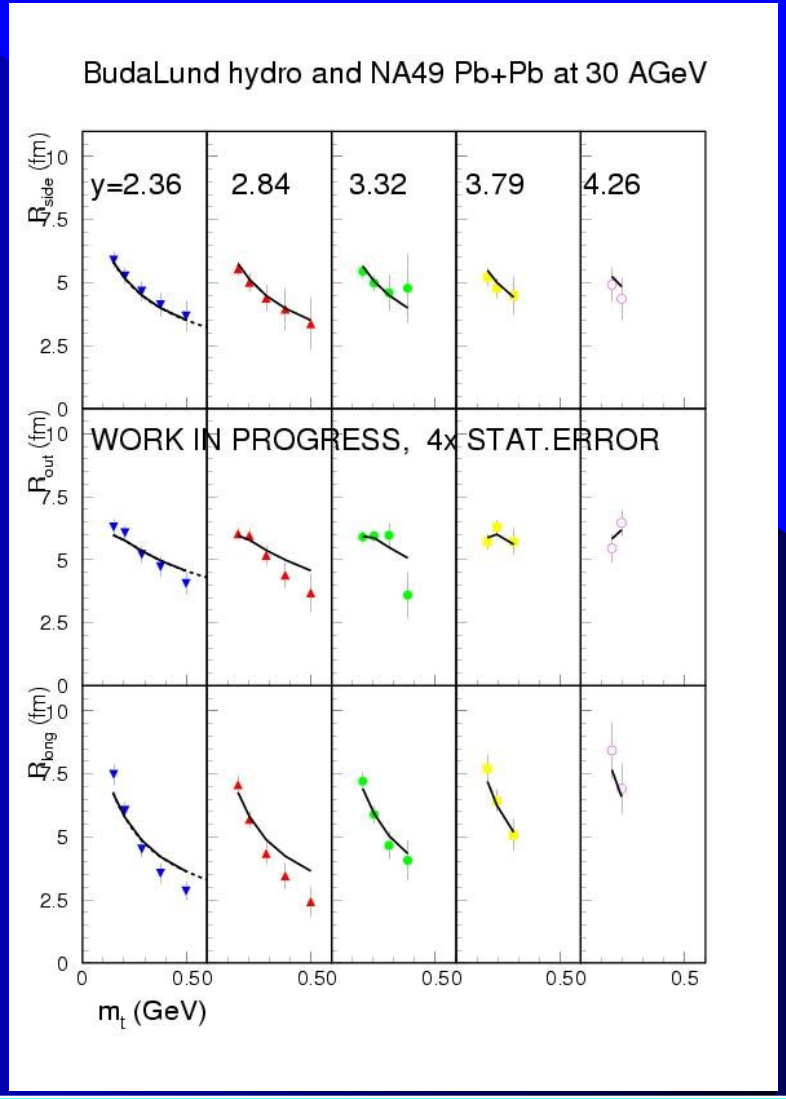

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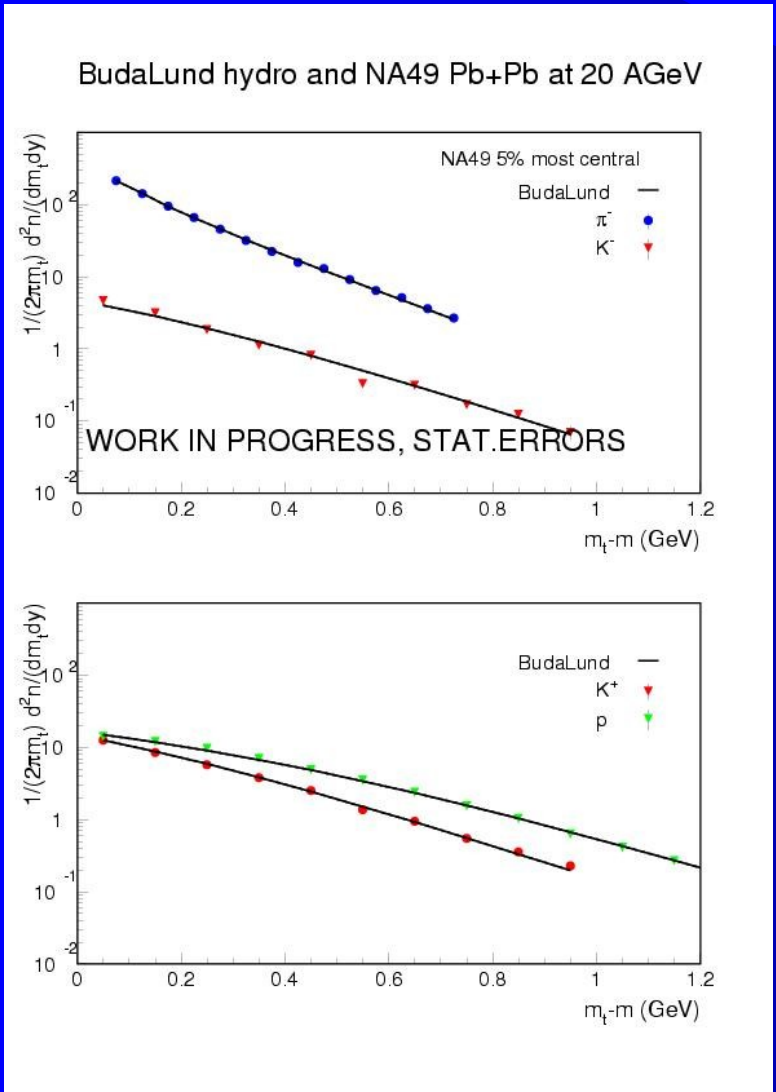
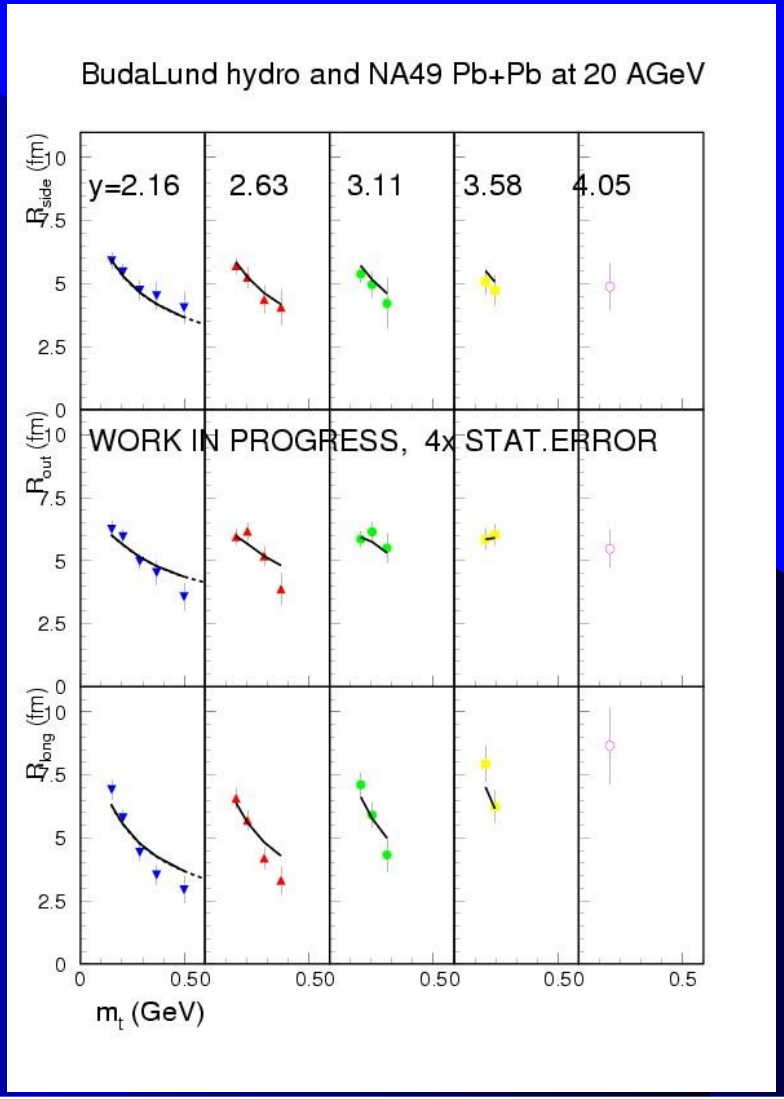


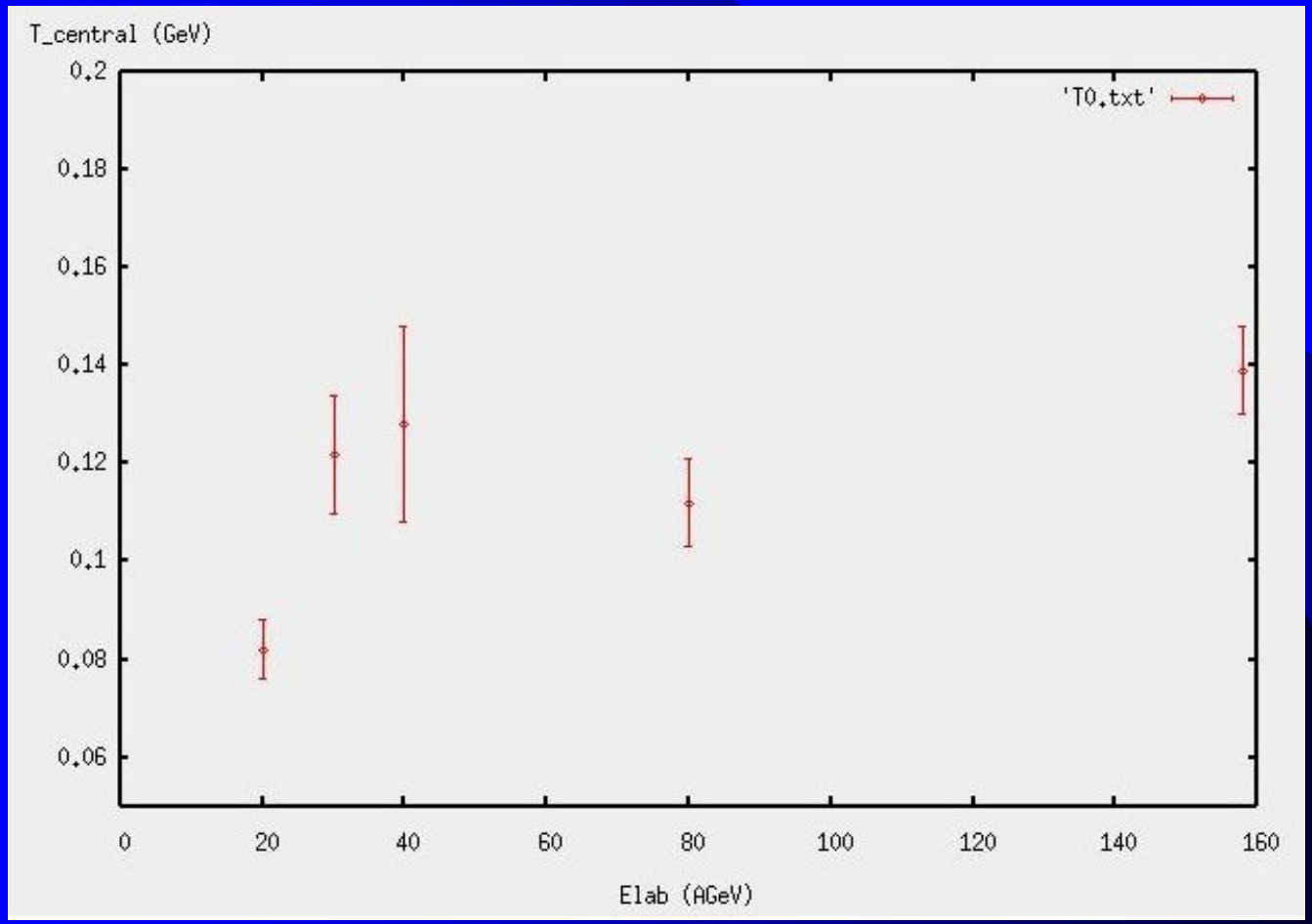


NA49 Collaboration (preliminary data), A. Ster, T. Csörgő and M. Csanád (work in progress)

Status of Buda-Lund fits to NA49 data

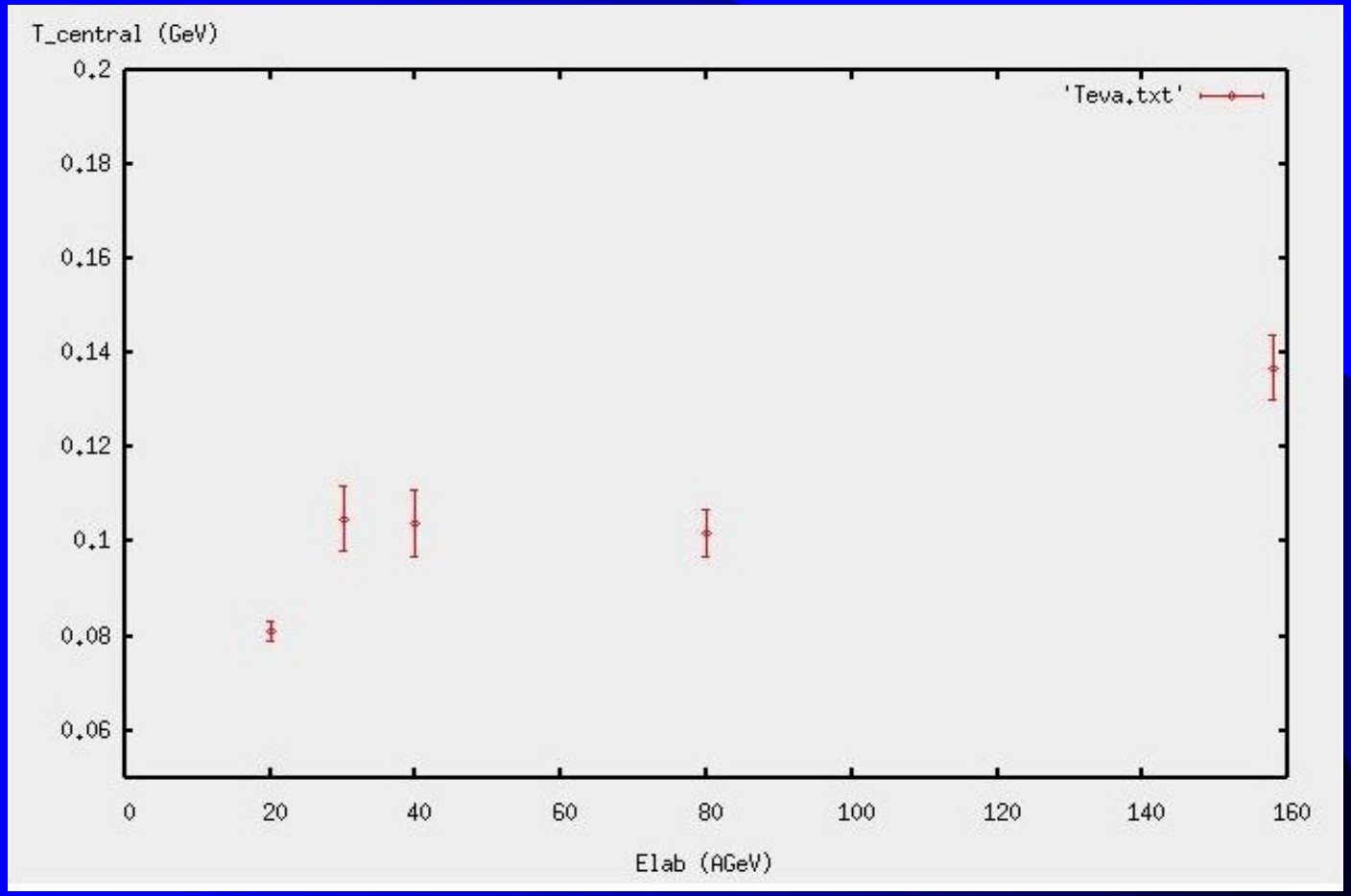
- **Old (Torino QM 1999) results reproduced**
- **Confidence level of the Torino QM 99 data fits is acceptable, CL > 0.1 %**
- **Conf. level of the new NA49 data with: stat errors of ~ 0.1 fm -> only CL < 0.1 %, not acceptable**
- **Good CL is obtained if error on radii x 4 tried**
- **All forthcoming numbers: work in progress**
- **Missing: dn/dy, $R_{outlong}$, hyperon spectra fits**

Buda-Lund, excitation function of central T from NA49 Pb+Pb



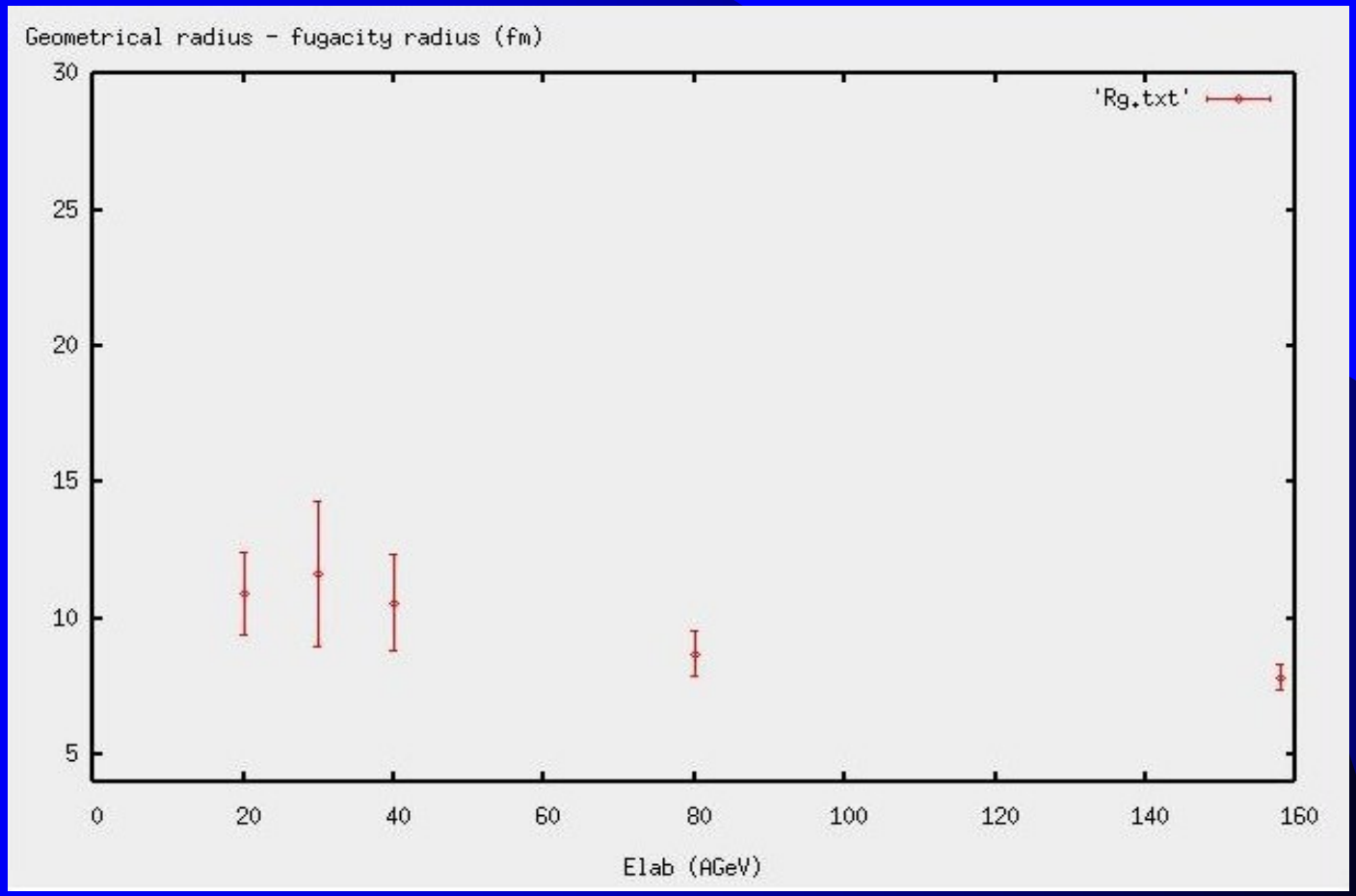
Central temperature increases with increasing bombarding energy

Buda-Lund, excitation function of T(post evap) from NA49 Pb+Pb



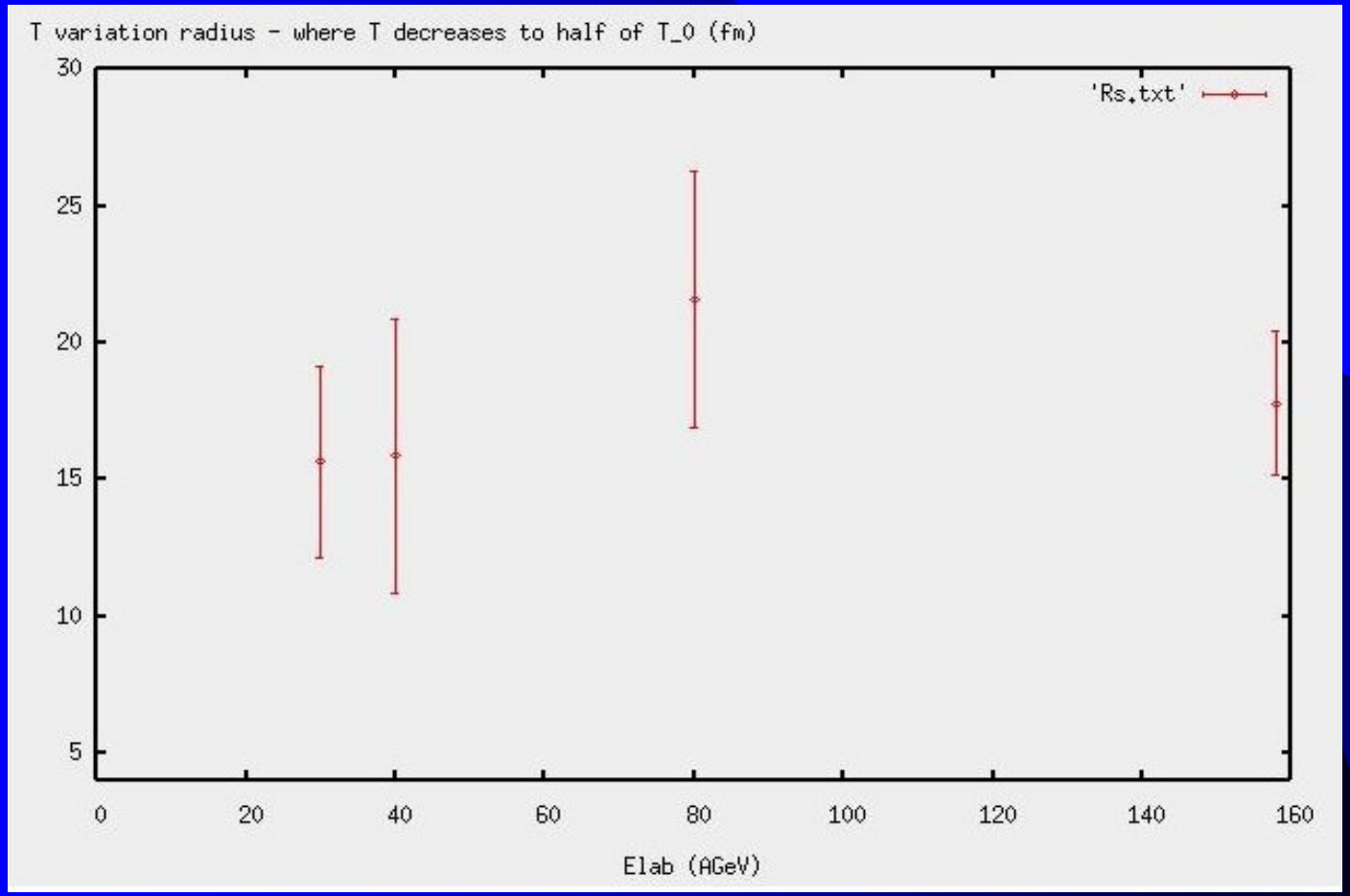
Post-evaporation temperature increases also with increasing E, similar to central T.

Buda-Lund, excitation function of geometrical radius from NA49 Pb+Pb



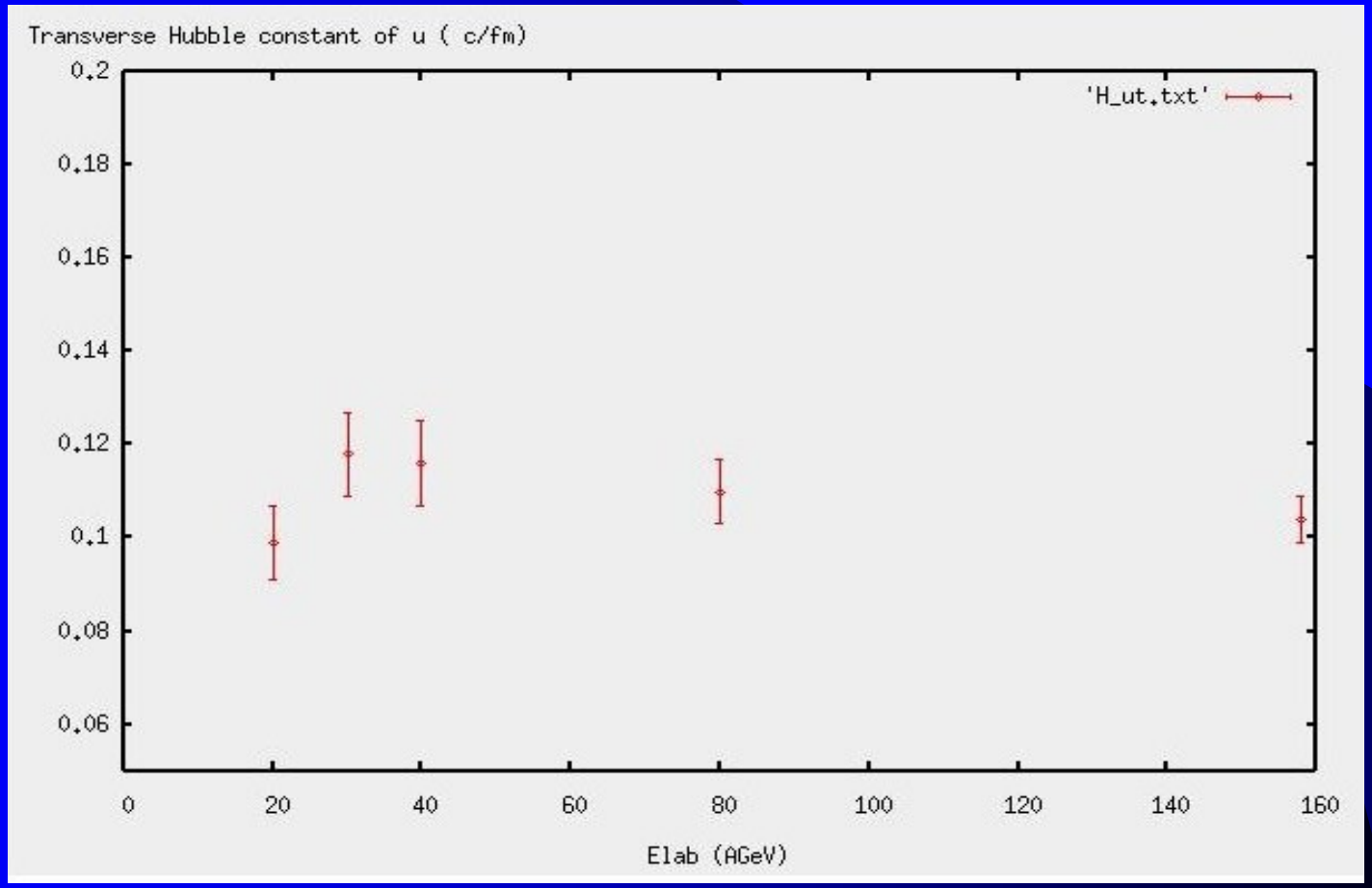
Geometrical size decreases or nearly flat with increasing Elab!

Buda-Lund, excitation function of R_s, $T(R_s) = T_0/2$ from NA49 Pb+Pb



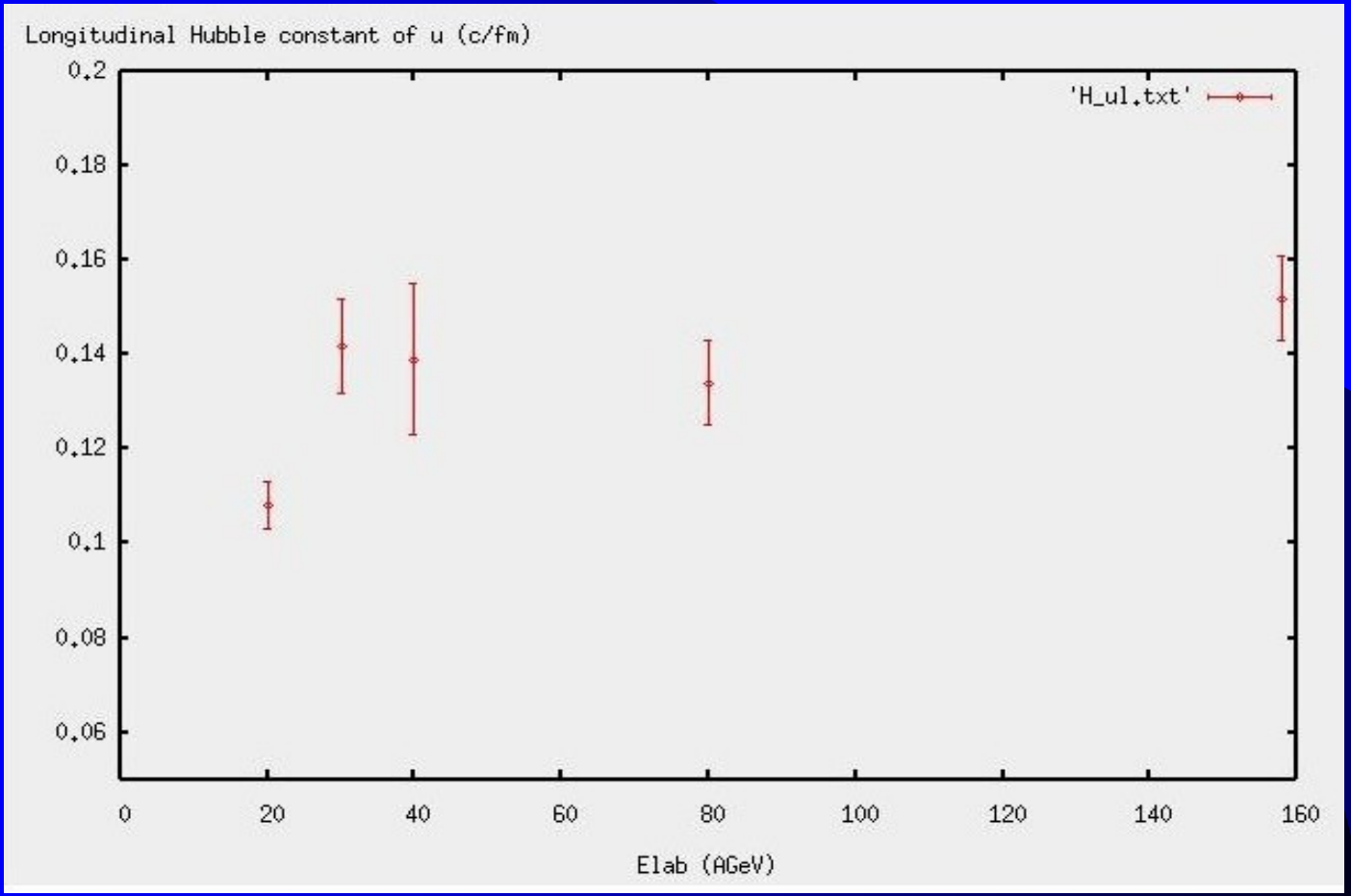
R_s is large: temperature is nearly constant in the transverse plane.

Buda-Lund, excitation function of Hubble constant H_{tr} from NA49 Pb+Pb



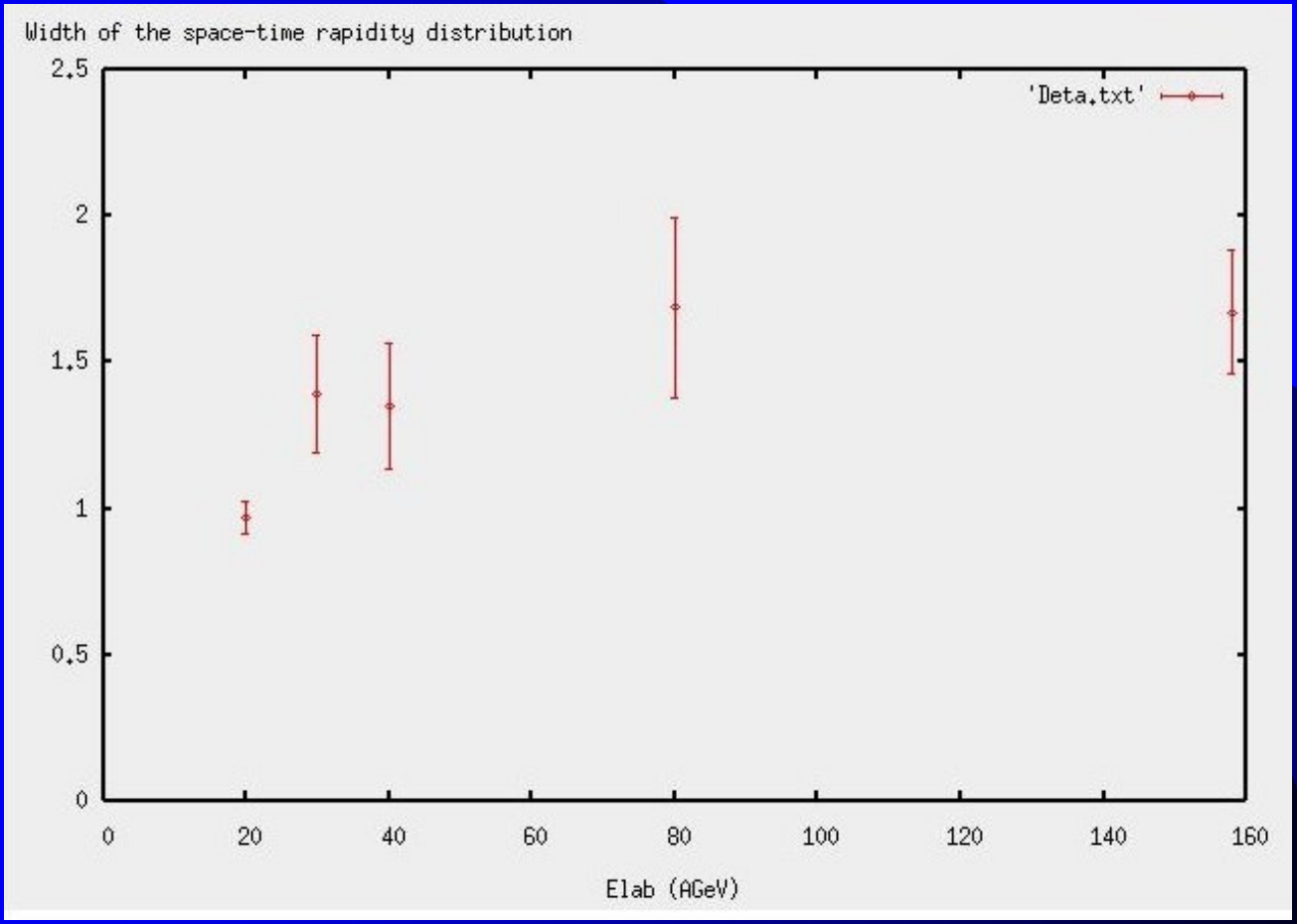
Transverse expansion rate nearly saturates. $H_{tr}= \langle u_t \rangle / R_g$

Buda-Lund, excitation function of Hubble constant H_{long} from NA49 Pb+Pb



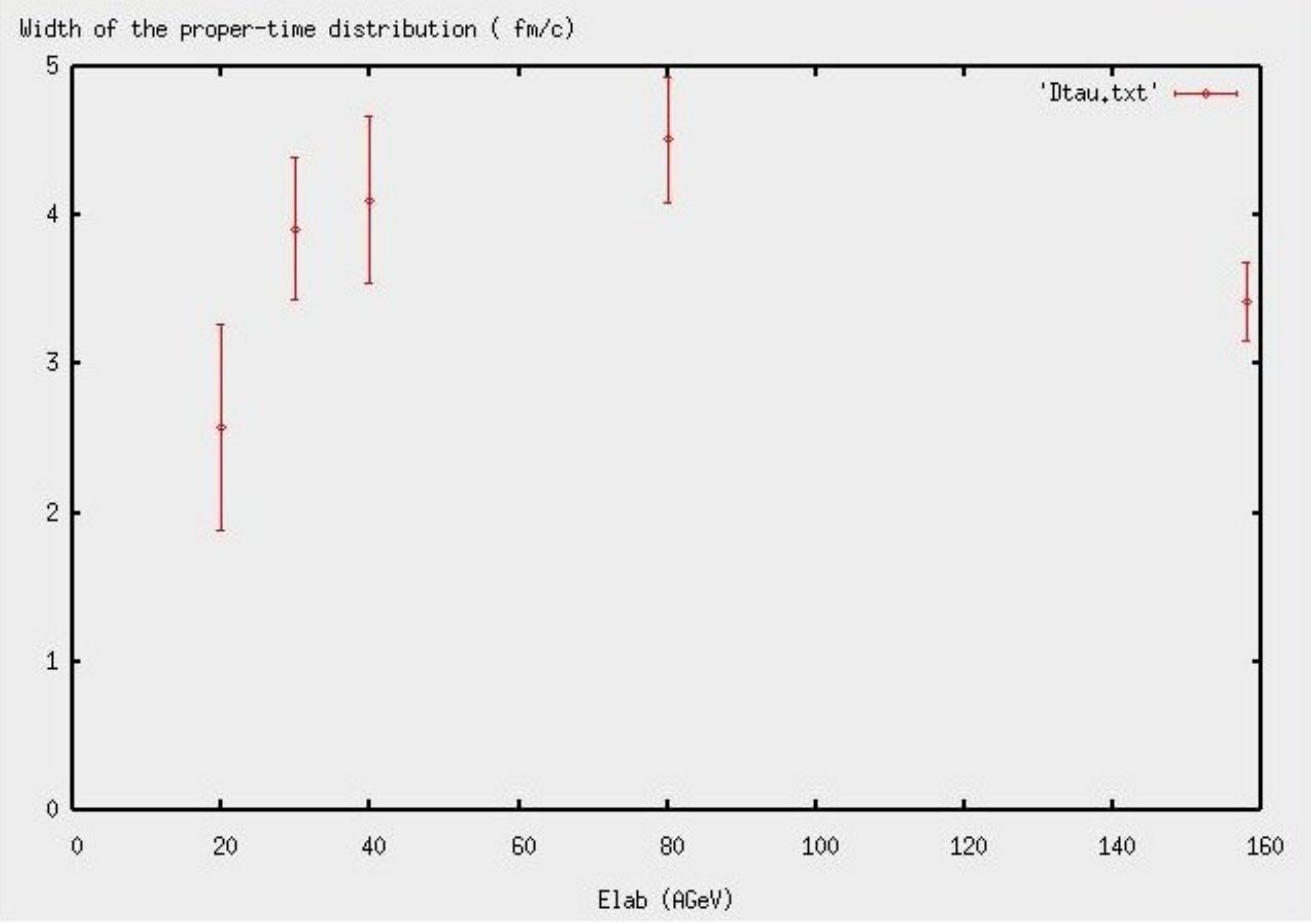
Longitudinal expansion rate slightly increases. $H_{long} = 1/\tau_0$

Buda-Lund, excitation function of $\Delta\eta$ from NA49 Pb+Pb



Longitudinal extension slightly increases.

Buda-Lund, excitation function of $\Delta\tau$ from NA49 Pb+Pb



Emission time width fluctuates within errors .

BudaLund fit results of NA49 data

BudaLund parameters	158 AGeV	80 AGeV	40 AGeV	30 AGeV	20 AGeV
T_0 [MeV]	139 ± 9	112 ± 9	128 ± 20	122 ± 12	82 ± 6
T_e [MeV]	137 ± 7	102 ± 5	104 ± 7	105 ± 7	81 ± 2
H_t [c/fm]	0.10 ± 0.01	0.11 ± 0.01	0.12 ± 0.01	0.12 ± 0.01	0.10 ± 0.01
H_l [c/fm]	0.15 ± 0.01	0.13 ± 0.01	0.14 ± 0.02	0.14 ± 0.01	0.11 ± 0.01
R_G [fm]	7.8 ± 0.5	8.7 ± 0.8	10.6 ± 1.8	11.6 ± 2.7	10.9 ± 1.5
R_s [fm]	17.7 ± 2.6	21.5 ± 4.7	15.8 ± 5.0	15.6 ± 3.5	32.0 ± 5.9
$\Delta\tau$ [fm/c]	3.4 ± 0.3	4.5 ± 0.4	4.1 ± 0.6	3.9 ± 0.5	2.6 ± 0.7
$\Delta\eta$	1.7 ± 0.2	1.7 ± 0.3	1.4 ± 0.2	1.4 ± 0.2	1.0 ± 0.6
χ^2/NDF	151 /113	67 /115	153 /103	81 /103	66 /82

$$\langle u_t \rangle = H_t \cdot R_G$$

$$\tau_0 = 1/H_l$$

Analysis of NA49 prel. data

- **Torino QM 99 fit reanalized, CL > 0.1 %**
- **New NA49 data**
  - analysed with stat errors only, order of ~ 0.1 fm
  - only CL < 0.1 %, not acceptable
  - all fits look good but fits are only work in progress
  - Missing: dn/dy, $R_{outlong}$, hyperon spectra fits
- **Monotonic increase with energy: T_0, T_{evap}, $\Delta\eta$,**
- **Within errors, independent of energy: H_{tr}, H_{long}, R_g, R_s, $\Delta\tau$**
- **Temperature is ~ constant of (r,t) at freeze in Pb+Pb@CERN SPS**

Conclusions on NA49 prel. new data

- **Buda-Lund model describes single particle distributions, and HBT radii w/o HBT puzzle:**

  Pb+Pb @SPS,

  Elab = 20, 30, 40, 80, 158 AGeV

- **But the CL is good only on the previously published NA49 data, errors on new data stat only and very small (0.1 fm)**

- **$T_0 < T_c$ in h+p and Pb+Pb @SPS**

  $T_0 > T_c$ in p+p and Au+Au @RHIC ;

  IF T_c=172±3MeV