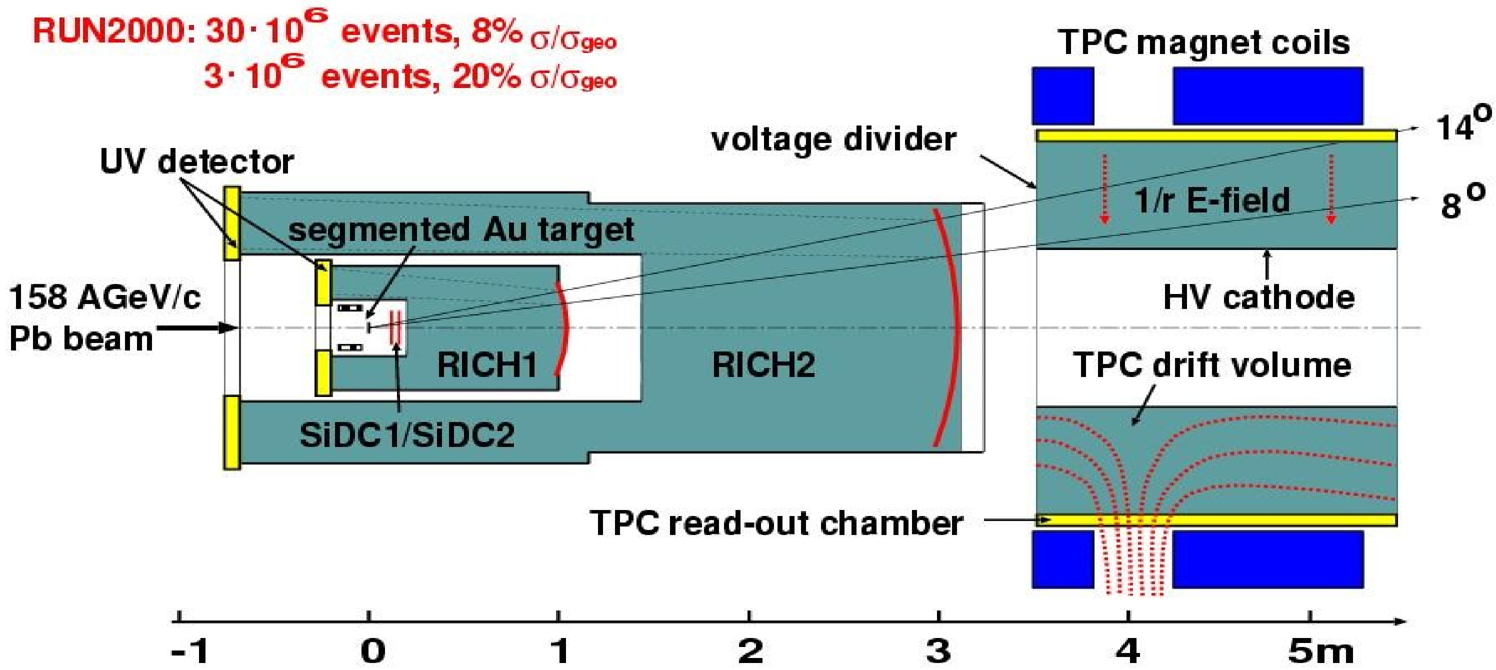
Hydro, blast, and CERES

Dariusz Miskowiec, GSI Darmstadt

- hydro vs. CERES
- blast vs. CERES
- blast vs. hydro

CERES

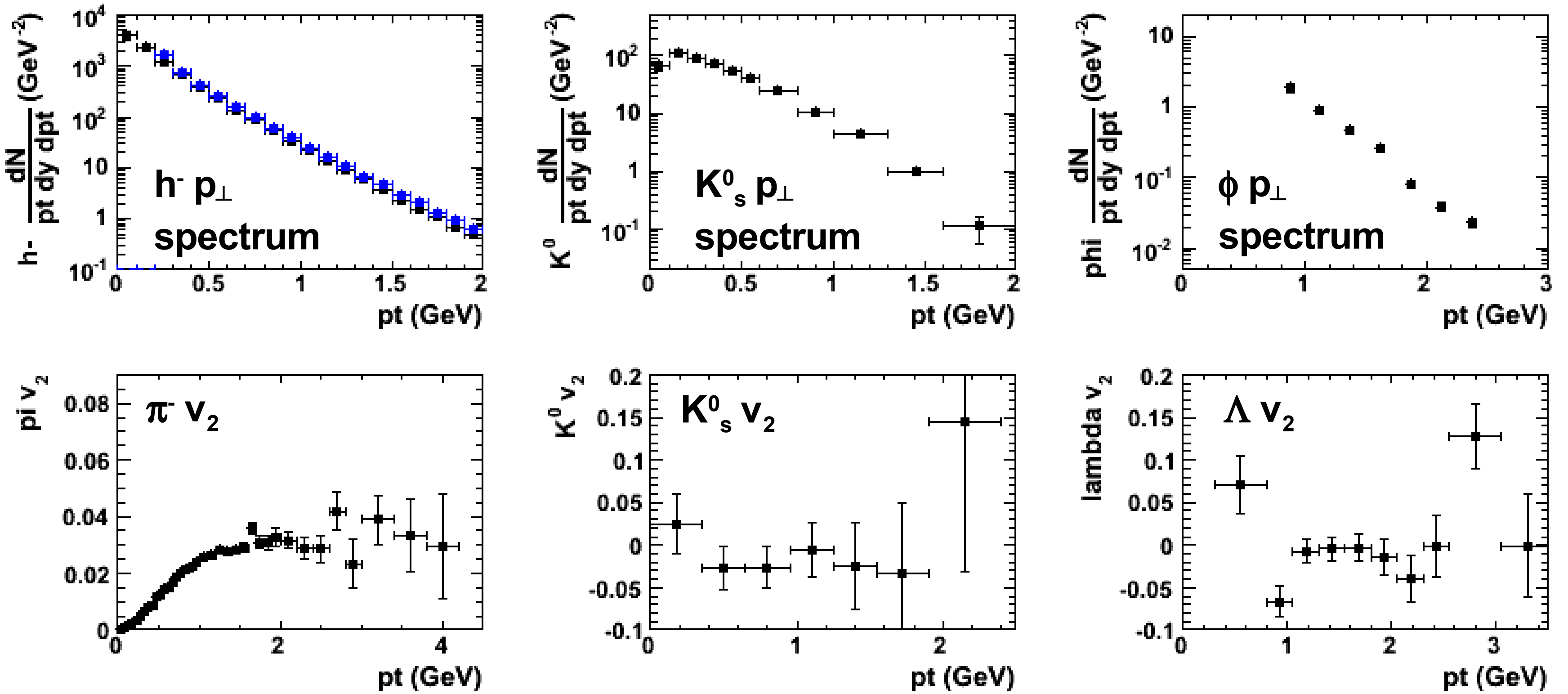


Pb+Au at 158 AGeV 7% central

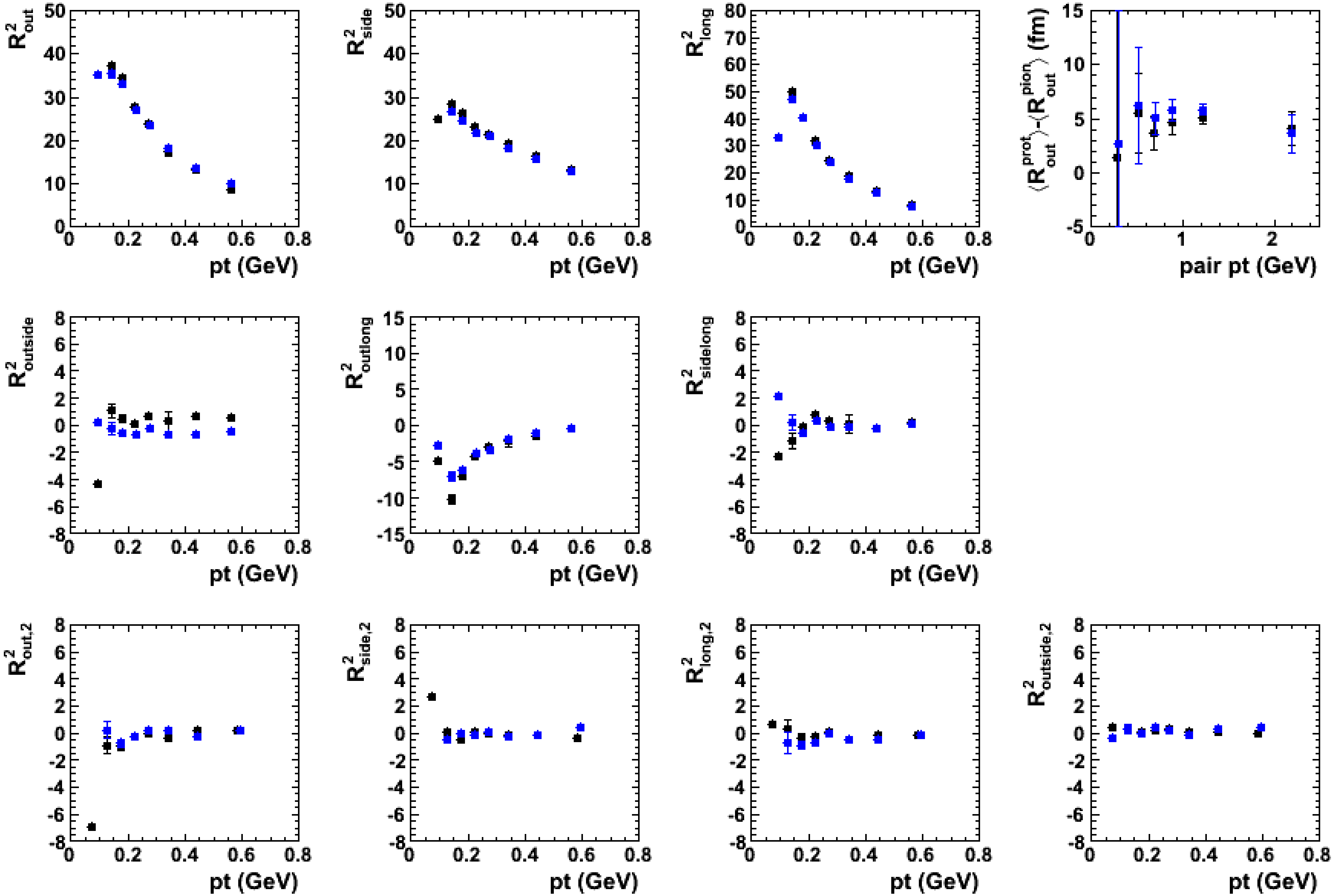
CERES build and upgraded for leptons; but also good for...

pt spectra, elliptic flow, two-particle correlations of hadrons

CERES pt spectra and elliptic flow



CERES two-particle correlations



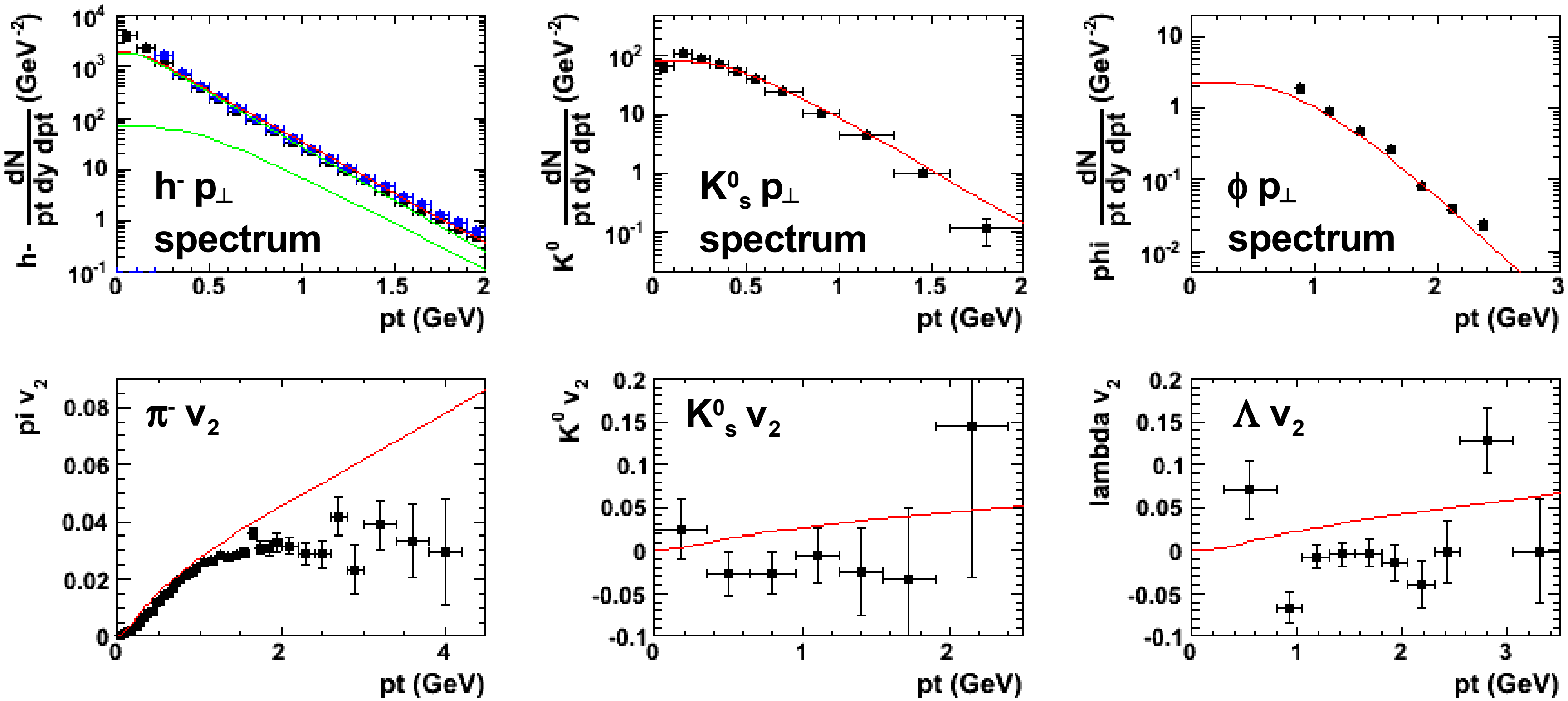
Hydro

- Pasi Huovinen, calculation of Au+Pb at 158 A GeV, b=2.6 fm
- hydrodynamical model, see e.g. nucl-th/0305064
- freeze-out at a fixed energy density (similar to fixed temp)

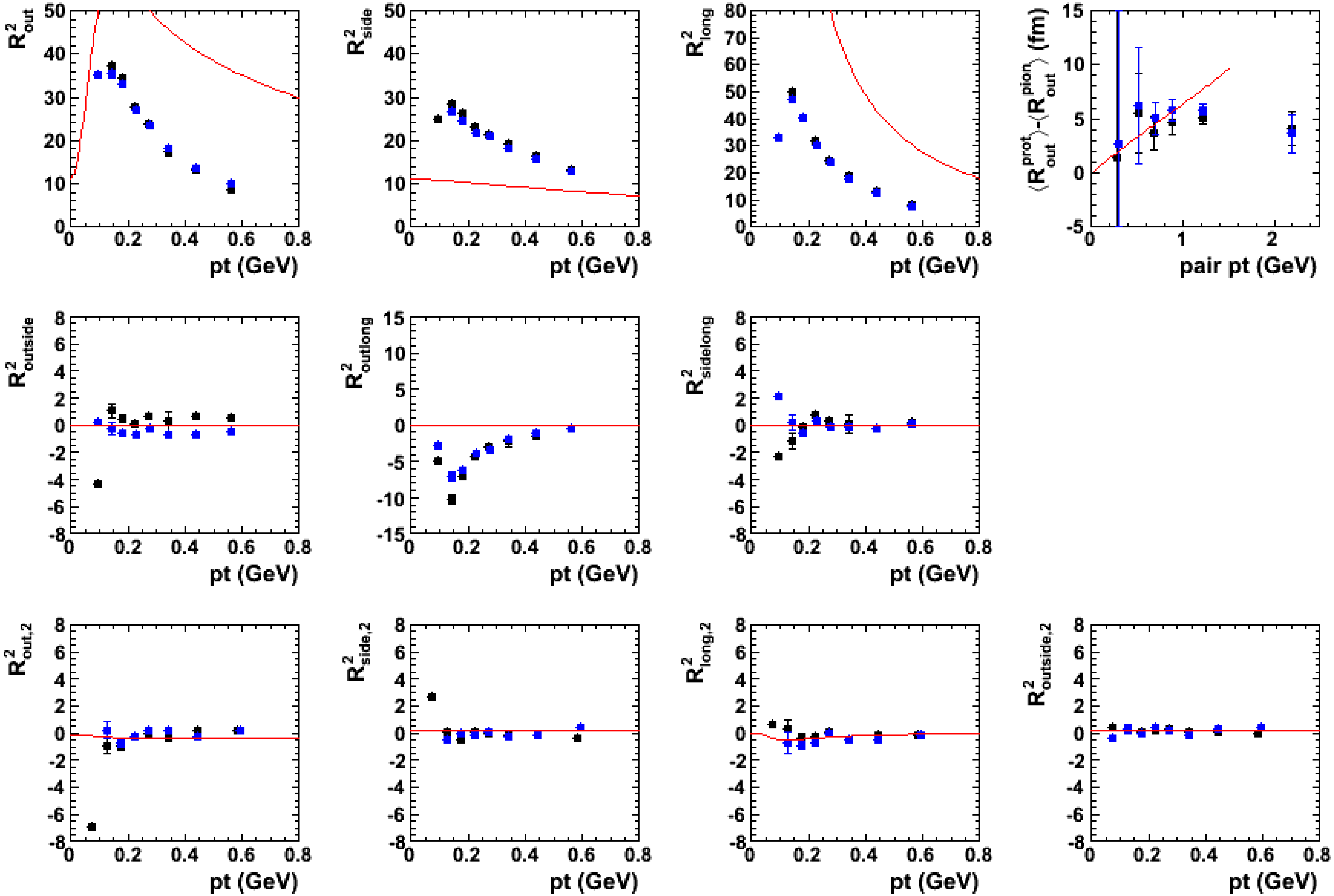
two sets of results:

- T=160 MeV (like at chemical freeze-out)
- T=120 MeV (like at kinetic freeze-out)

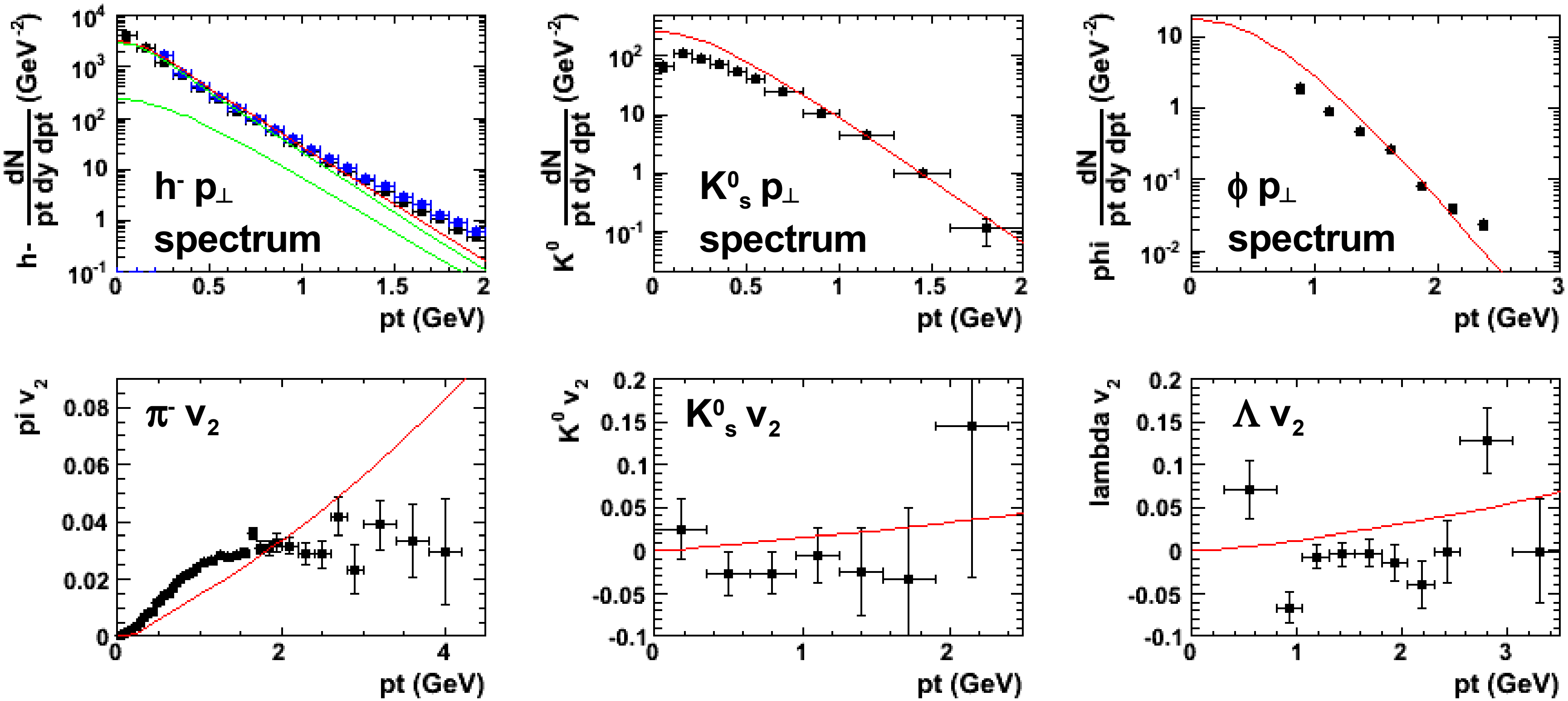
hydro T=120 MeV (lines) and CERES (points)



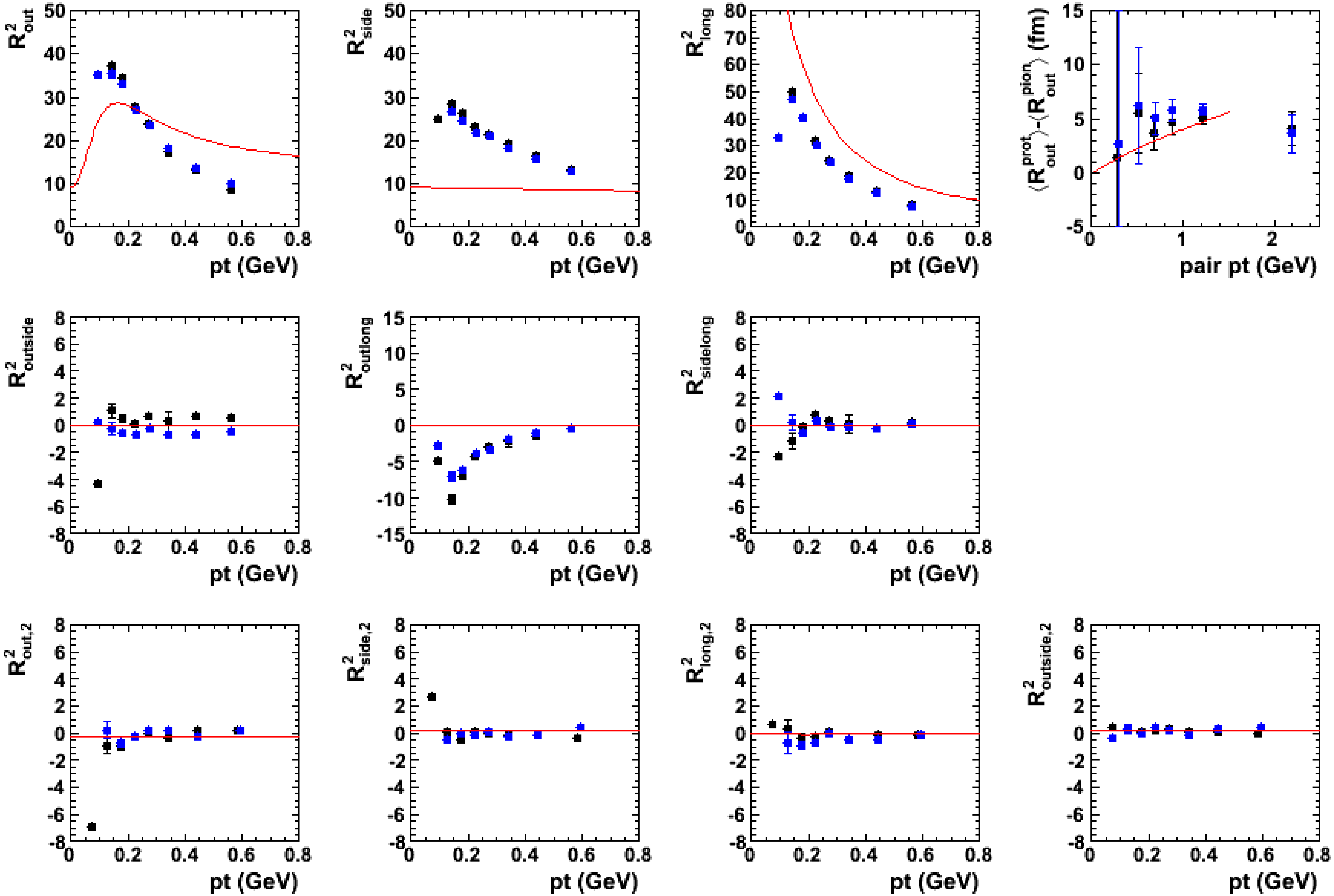
hydro T=120 MeV (lines) and CERES (points)



hydro T=160 MeV (lines) and CERES (points)



hydro T=160 MeV (lines) and CERES (points)



puzzle

hydro

~~RHIC~~ HBT puzzle

Blast wave model

Retière, Lisa, PRC 70(2004)044907

analytic hydro-inspired 8-d emission function

$$S(x,K) = m_T \cosh(\eta - Y)\, \Omega(r,\phi_S)\, e^{\frac{-(\tau-\tau_0)^2}{2\Delta\tau^2}} \frac{1}{e^{K\cdot u/T} \pm 1}$$

with the space profile

$$\Omega(r,\phi_S) = \Omega(\tilde{r}) = \frac{1}{1+e^{(\tilde{r}-1)/a}}$$

and the normalized elliptic radius

$$\tilde{r}(r,\phi_S) = \sqrt{\frac{(r\cos(\phi_S))^2}{R_x^2} + \frac{(r\sin(\phi_S))^2}{R_y^2}}$$

and the flow four-velocity

$$u = u_\mu(x,\rho_0,\rho_2)$$

Blast wave model

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with the space profile

$$\Omega(r,\phi_S) = \Omega(\tilde{r}) = \frac{1}{1+e^{(\tilde{r}-1)/a}}$$

space-time dependence

and the normalized elliptic radius

$$\tilde{r}(r,\phi_S) = \sqrt{\frac{(r\cos(\phi_S))^2}{R_x^2} + \frac{(r\sin(\phi_S))^2}{R_y^2}}$$

and the flow four-velocity

$$u = u_\mu(x, \rho_0, \rho_2)$$

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with the space profile

$$\Omega(r,\phi_S) = \Omega(\tilde{r}) = \frac{1}{1+e^{(\tilde{r}-1)/a}}$$

four-momentum dependence

and the normalized elliptic radius

$$\tilde{r}(r,\phi_S) = \sqrt{\frac{(r\cos(\phi_S))^2}{R_x^2} + \frac{(r\sin(\phi_S))^2}{R_y^2}}$$

and the flow four-velocity

$$u = u_\mu(x,\rho_0,\rho_2)$$

Blast wave model

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with the space profile

$$\Omega(r,\phi_S) = \Omega(\tilde{r}) = \frac{1}{1+e^{(\tilde{r}-1)/a}}$$

parameters

and the normalized elliptic radius

$$\tilde{r}(r,\phi_S) = \sqrt{\frac{(r\cos(\phi_S))^2}{R_x^2} + \frac{(r\sin(\phi_S))^2}{R_y^2}}$$

and the flow four-velocity

$$u = u_\mu(x, \rho_0, \rho_2)$$

Blast wave model

Retière, Lisa, PRC 70(2004)044907

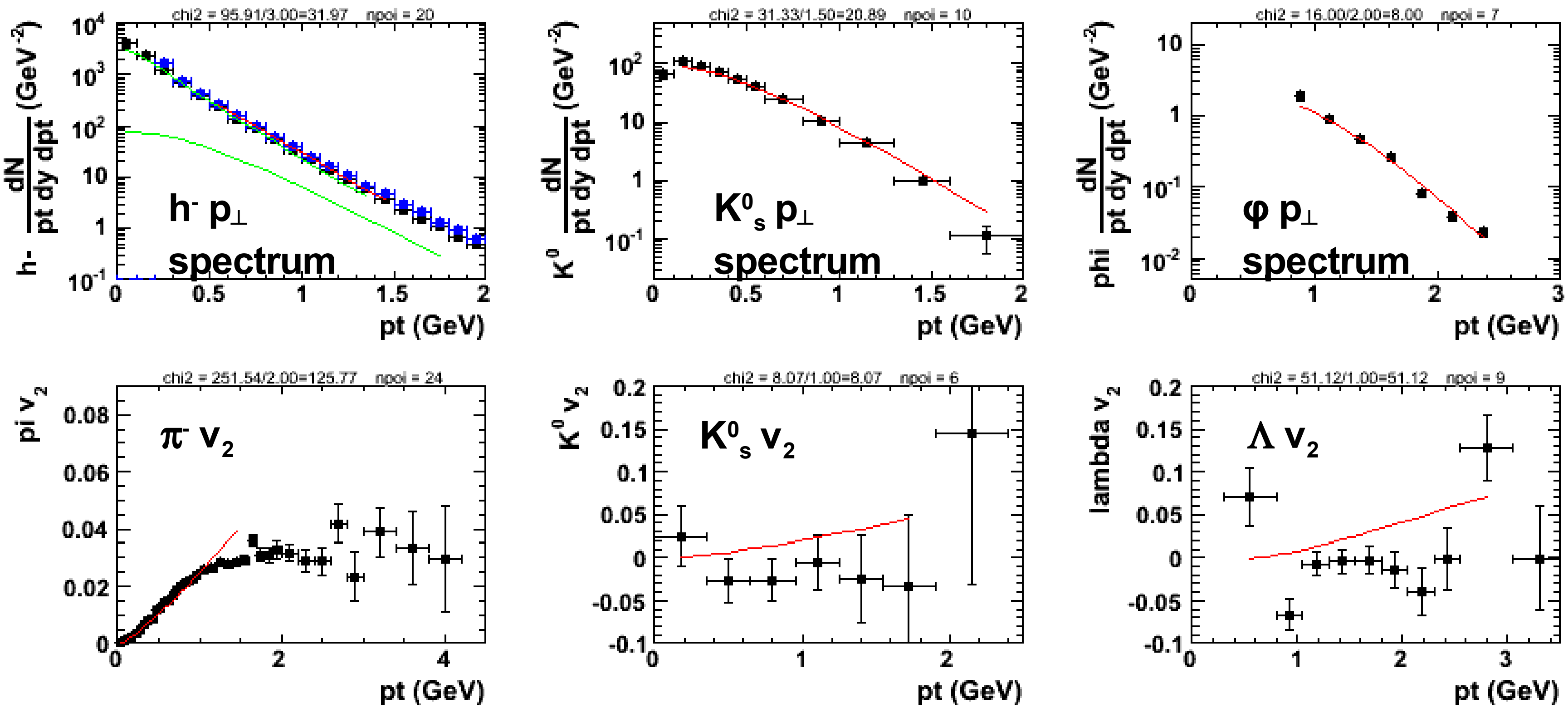
analytic hydro-inspired 8-d emission function

$$S(x,K) = m_T \cosh(\eta - Y)\,\Omega(r,\phi_S)\, e^{\frac{-(\tau-\tau_0)^2}{2\Delta\tau^2}}\, \frac{1}{e^{K\cdot u/T} \pm 1}$$

by semi-analytic integration gives

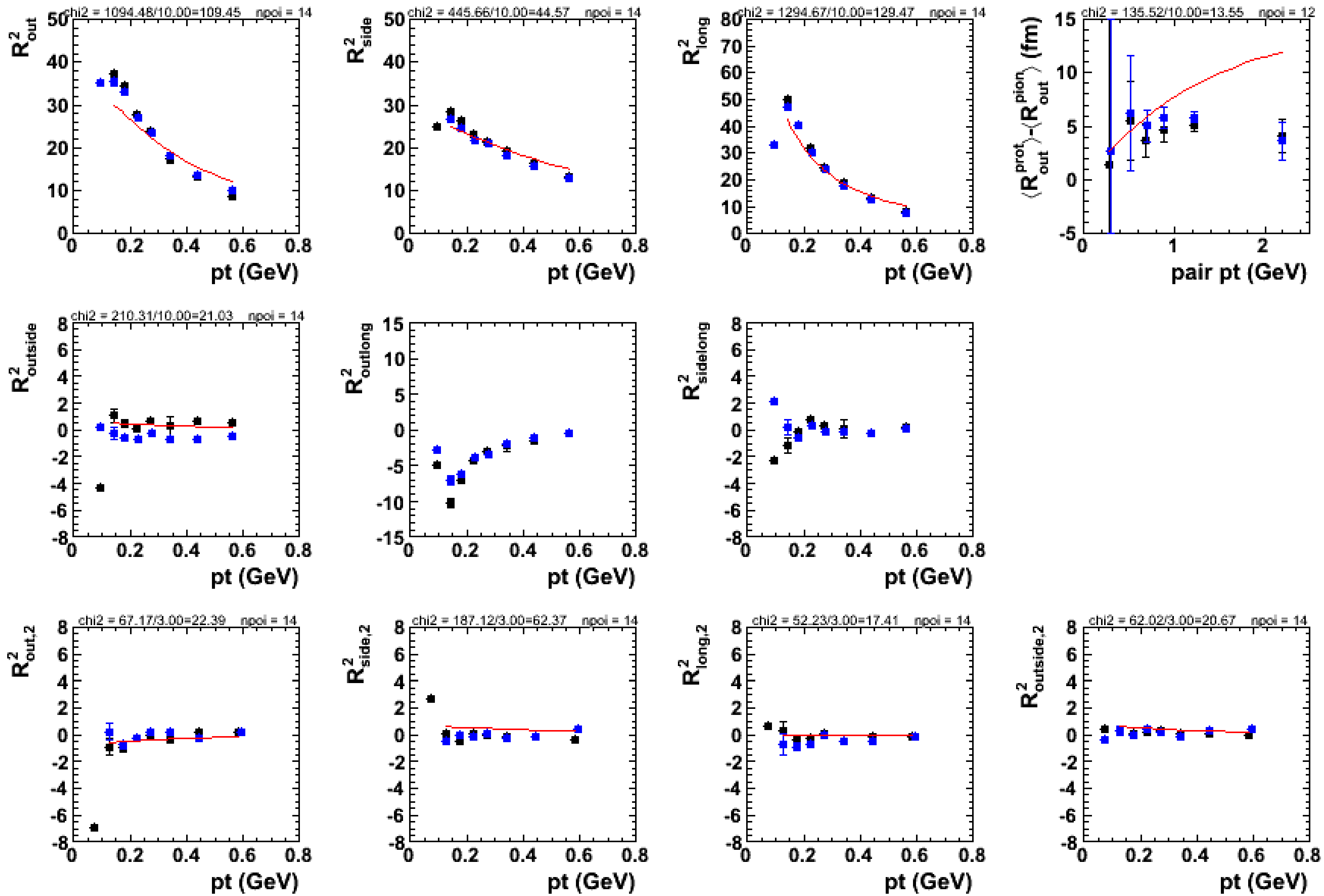
- **pt-spectra**
- **elliptic flow**
- **HBT radii (including their reaction-plane dependence)**
- **non-identical particle correlations**

blast T=100 MeV (lines) and CERES (points)

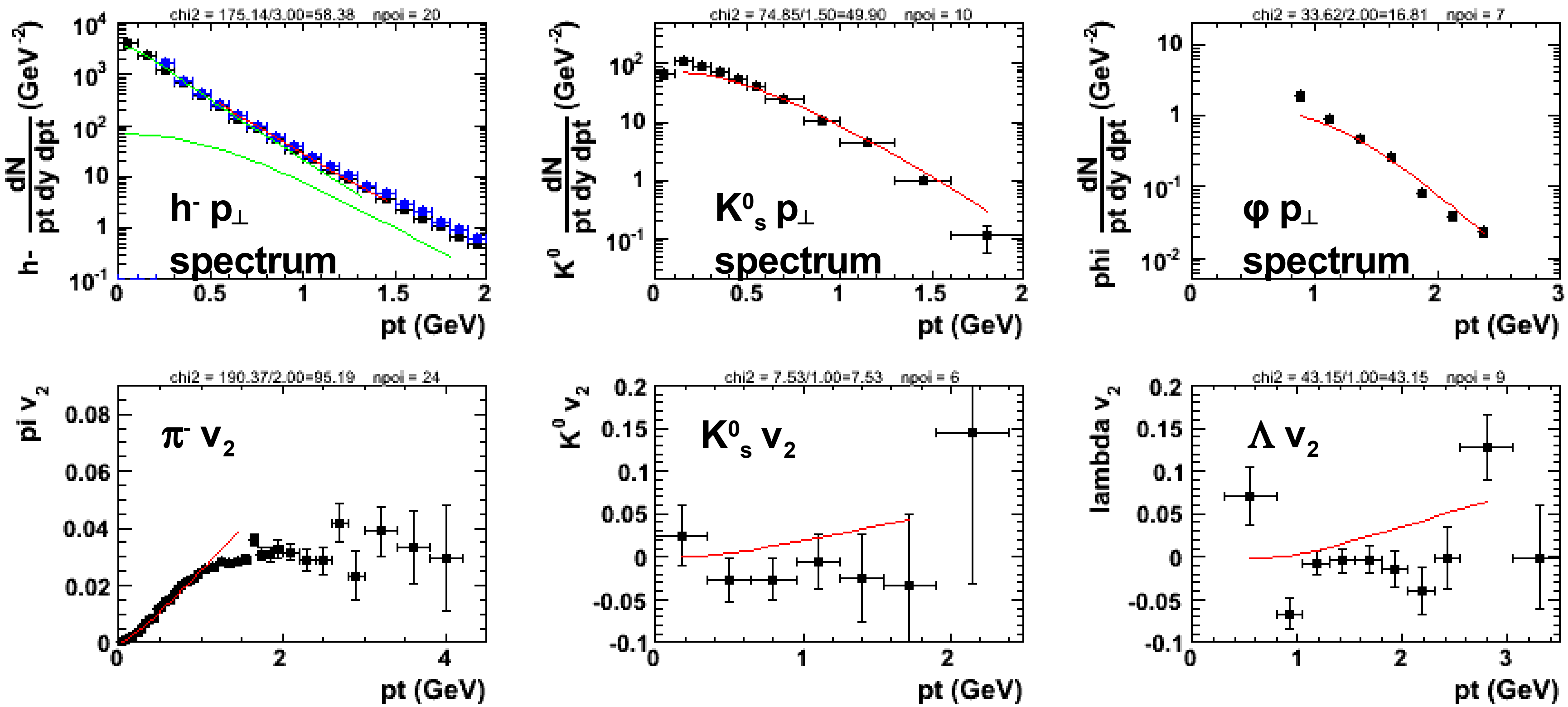


other->fPim = 152.7
other->fKa0 = 18.44
other->fPhi = 1.451
blast->fT = 0.100
blast->fRho0 = 0.87
blast->fRho2 = 0.016
blast->fRx = 11.26
blast->fRy = 11.42
blast->fAs = 0.010
blast->fTau0 = 7.37
blast->fDtau = 1.55

blast T=100 MeV (lines) and CERES (points)

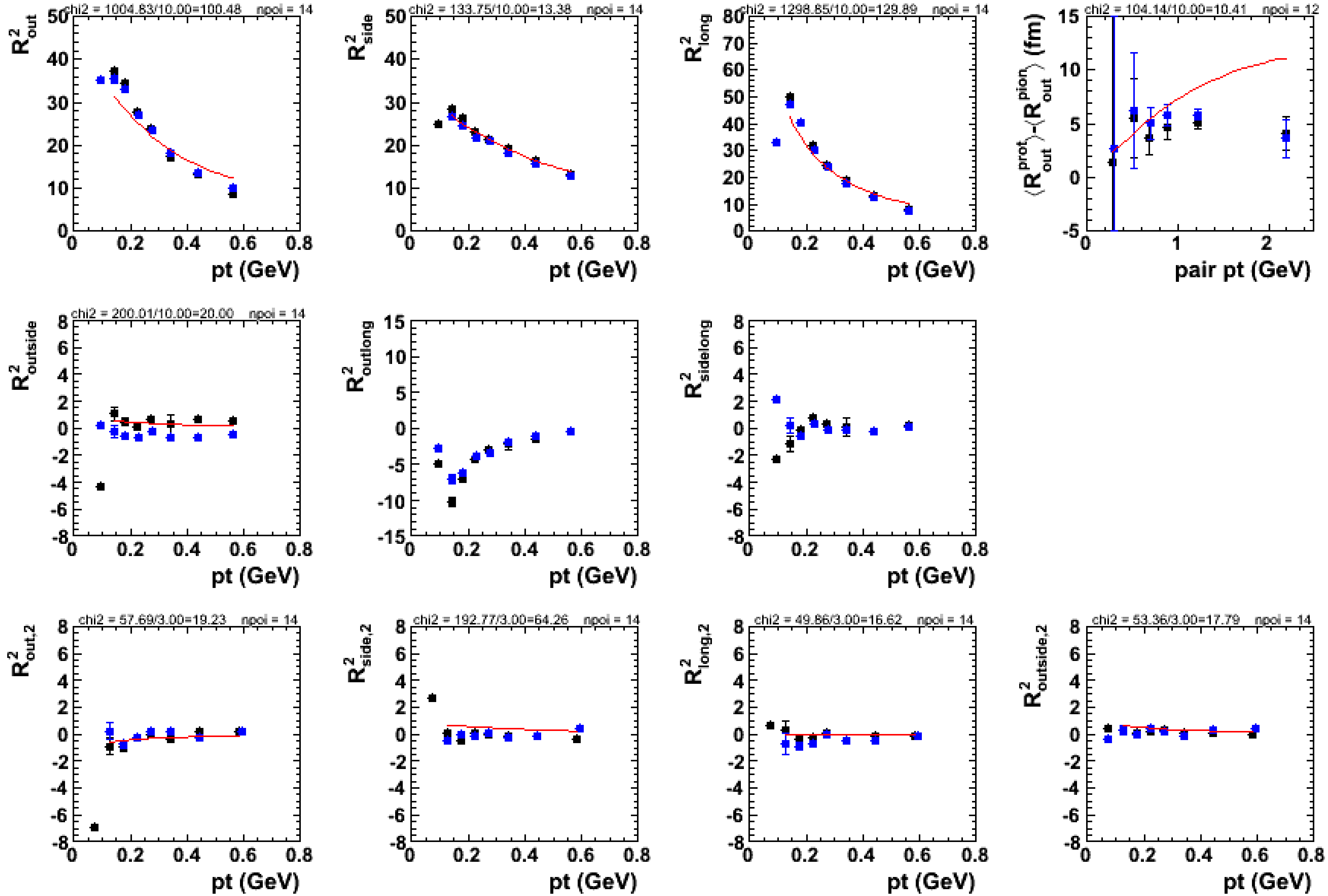


blast T=80 MeV (lines) and CERES (points)

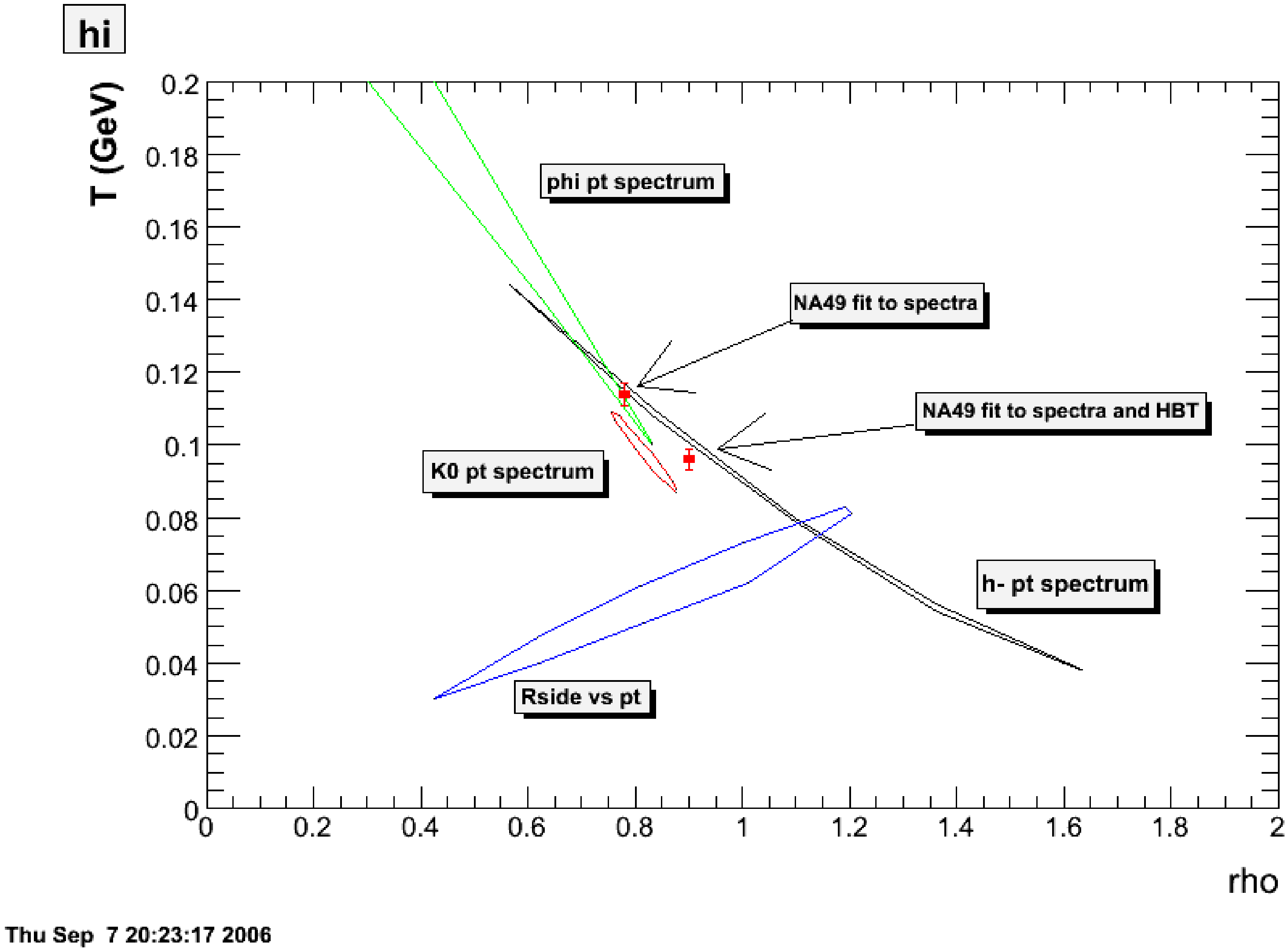


other->fPim = 165.0
other->fKa0 = 17.39
other->fPhi = 1.117
blast->fT = 0.080
blast->fRho0 = 1.02
blast->fRho2 = 0.014
blast->fRx = 12.62
blast->fRy = 12.79
blast->fAs = 0.010
blast->fTau0 = 8.69
blast->fDtau = 2.03

blast T=80 MeV (lines) and CERES (points)



T - ρ contours


hi
T (GeV)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
rho
phi pt spectrum
NA49 fit to spectra
NA49 fit to spectra and HBT
K0 pt spectrum
h- pt spectrum
Rside vs pt
Thu Sep 7 20:23:17 2006

blast vs. hydro

Use blast to understand what is wrong in hydro:

- **blast is hydro inspired and has 8 free parameters**

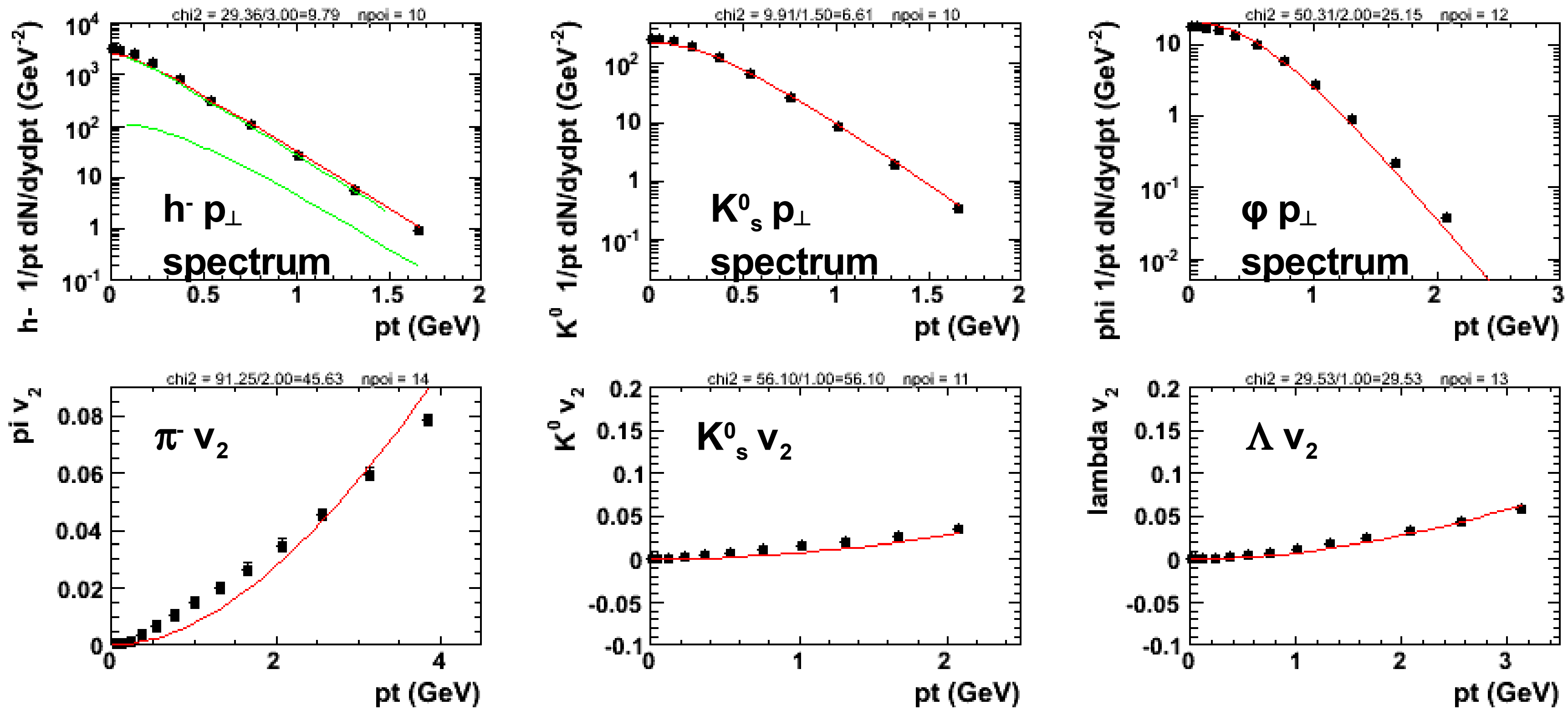
  → true hydro source must be a special case of blast source

- **fit CERES by blast and fit hydro by blast and compare the resulting parameters**

- **identify THE parameter which is different**

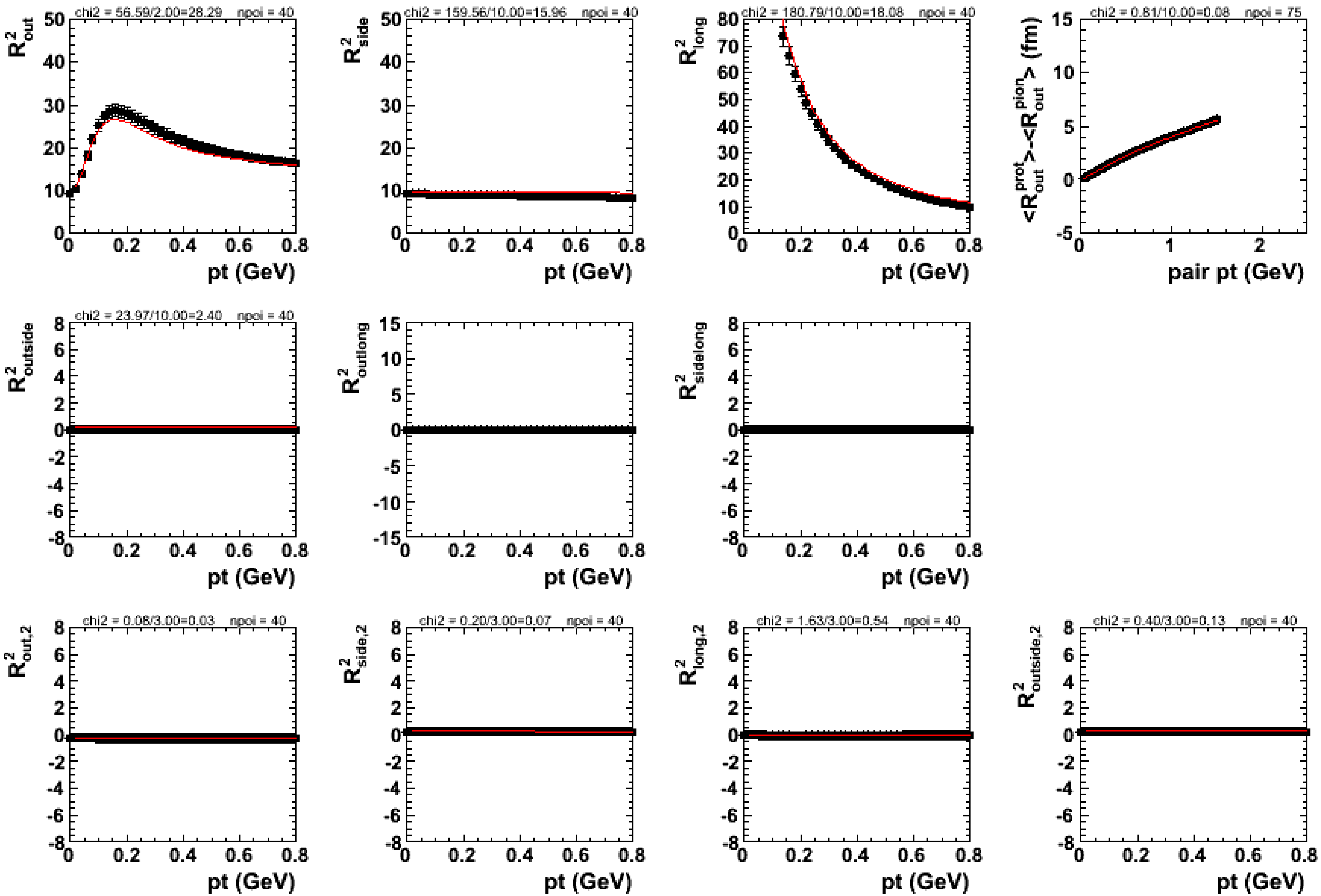
  → this is what needs to be fixed in hydro

blast (lines) and hydro 160 MeV (points)

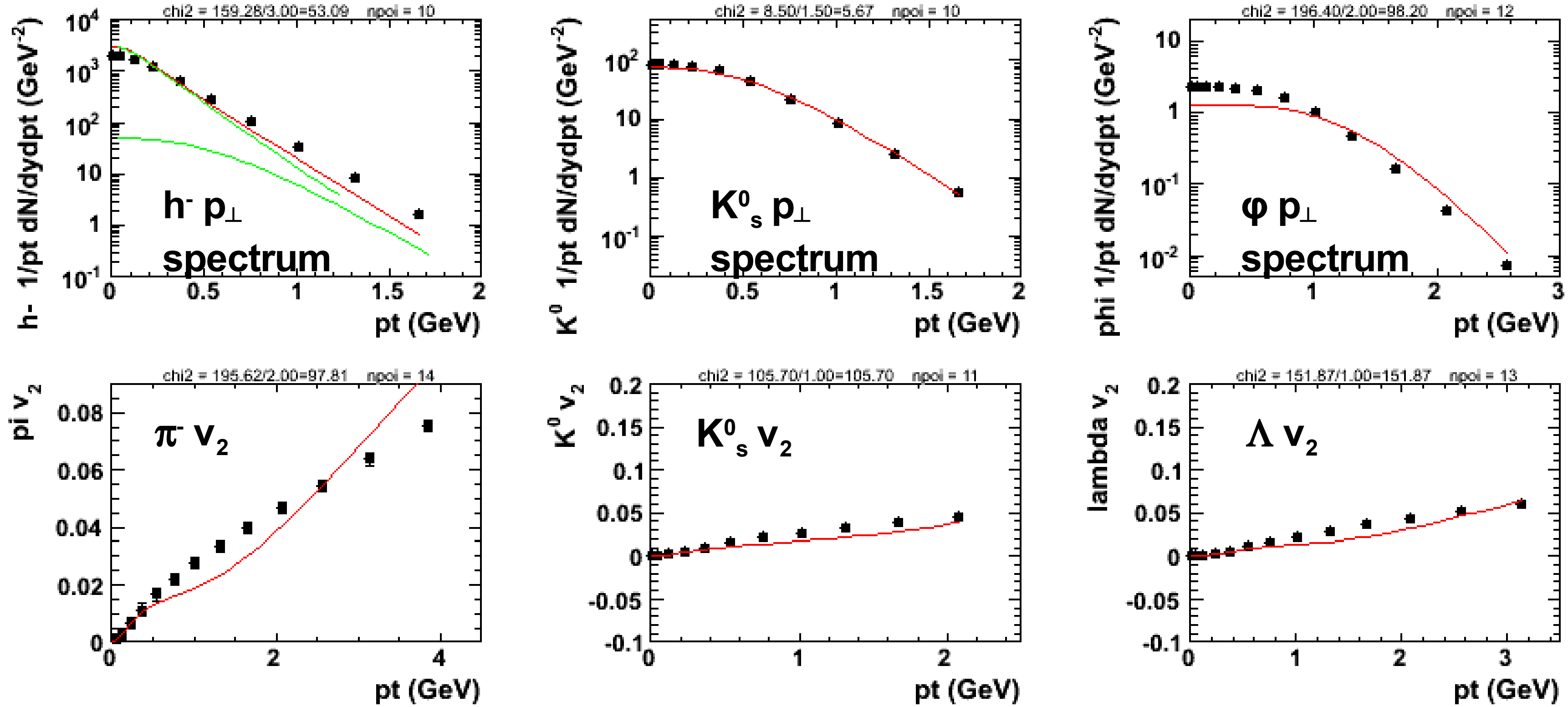


other->fPim = 155.5
other->fKa0 = 30.95
other->fPhi = 4.806
blast->fT = 0.174
blast->fRho0 = 0.15
blast->fRho2 = 0.026
blast->fRx = 6.22
blast->fRy = 6.30
blast->fAs = 0.010
blast->fTau0 = 4.57
blast->fDtau = 2.56

blast (lines) and hydro 160 MeV (points)

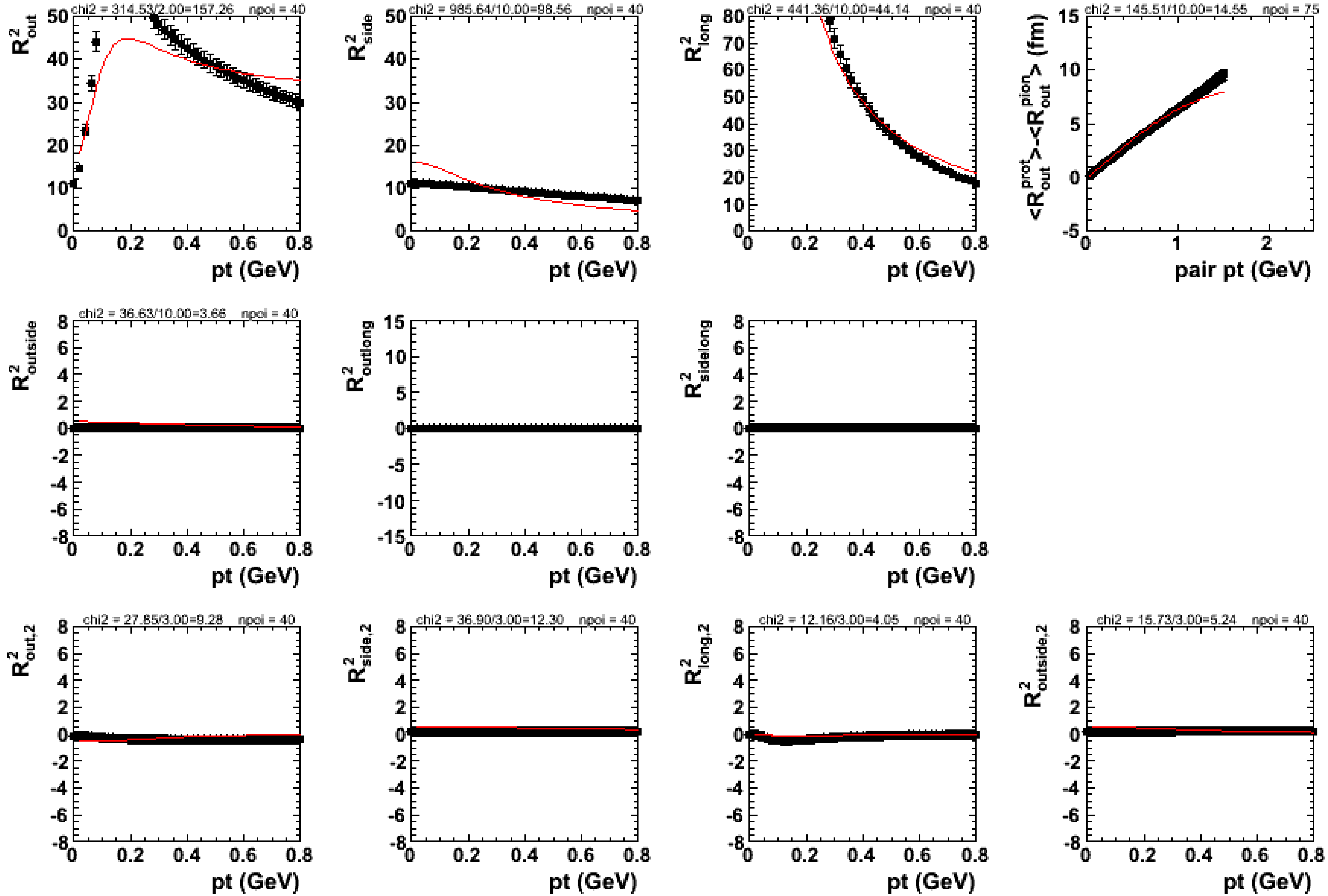


blast (lines) and hydro 120 MeV (points)



other->fPim = 129.6
other->fKa0 = 19.10
other->fPhi = 1.164
blast->fT = 0.070
blast->fRho0 = 1.07
blast->fRho2 = 0.001
blast->fRx = 9.23
blast->fRy = 9.53
blast->fAs = 0.010
blast->fTau0 = 14.73
blast->fDtau = 6.13

blast (lines) and hydro 120 MeV (points)



blast vs. hydro

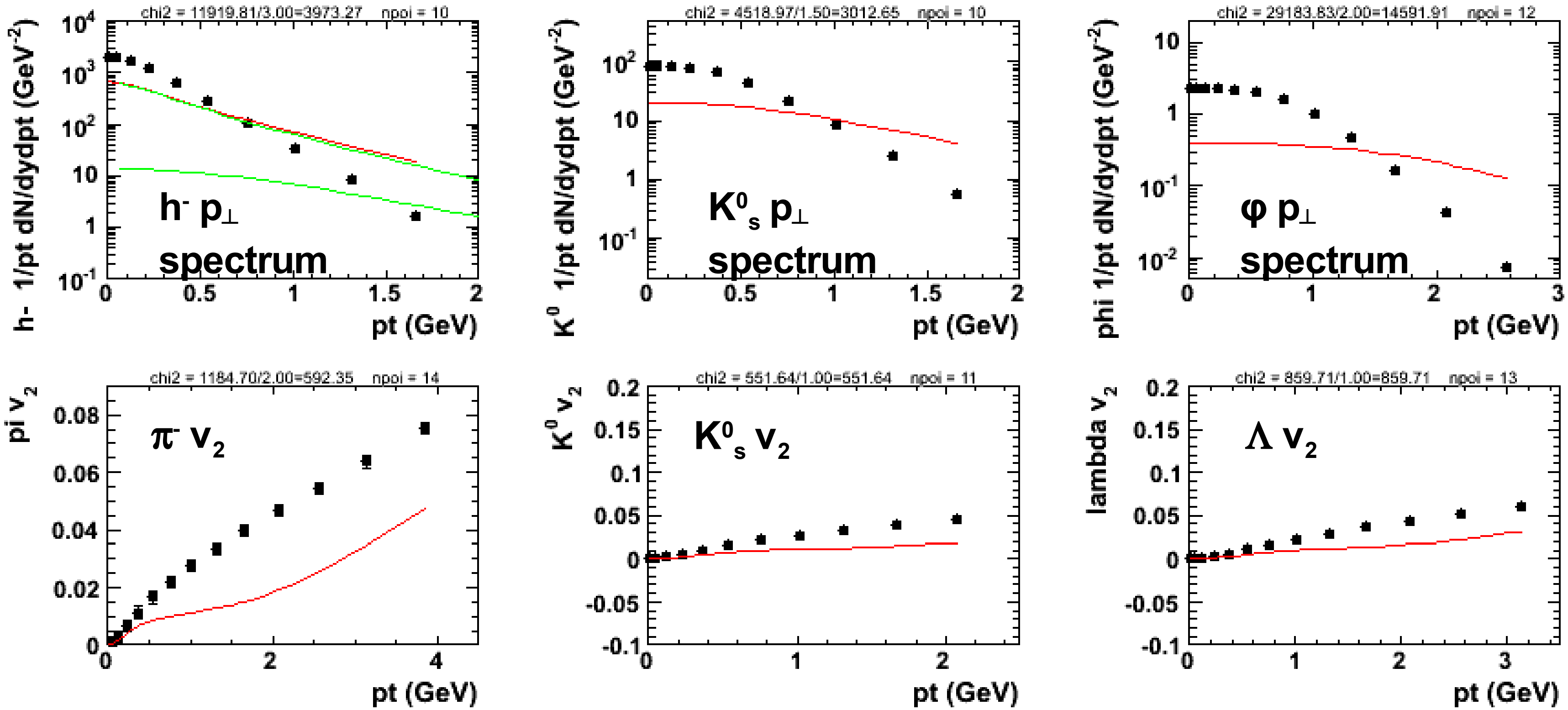
Use blast to understand what is wrong in hydro:

- **blast is hydro inspired and has 8 free parameters**
  → true hydro source must be a special case of blast source

- **fit CERES by blast and fit hydro by blast and compare the resulting parameters**

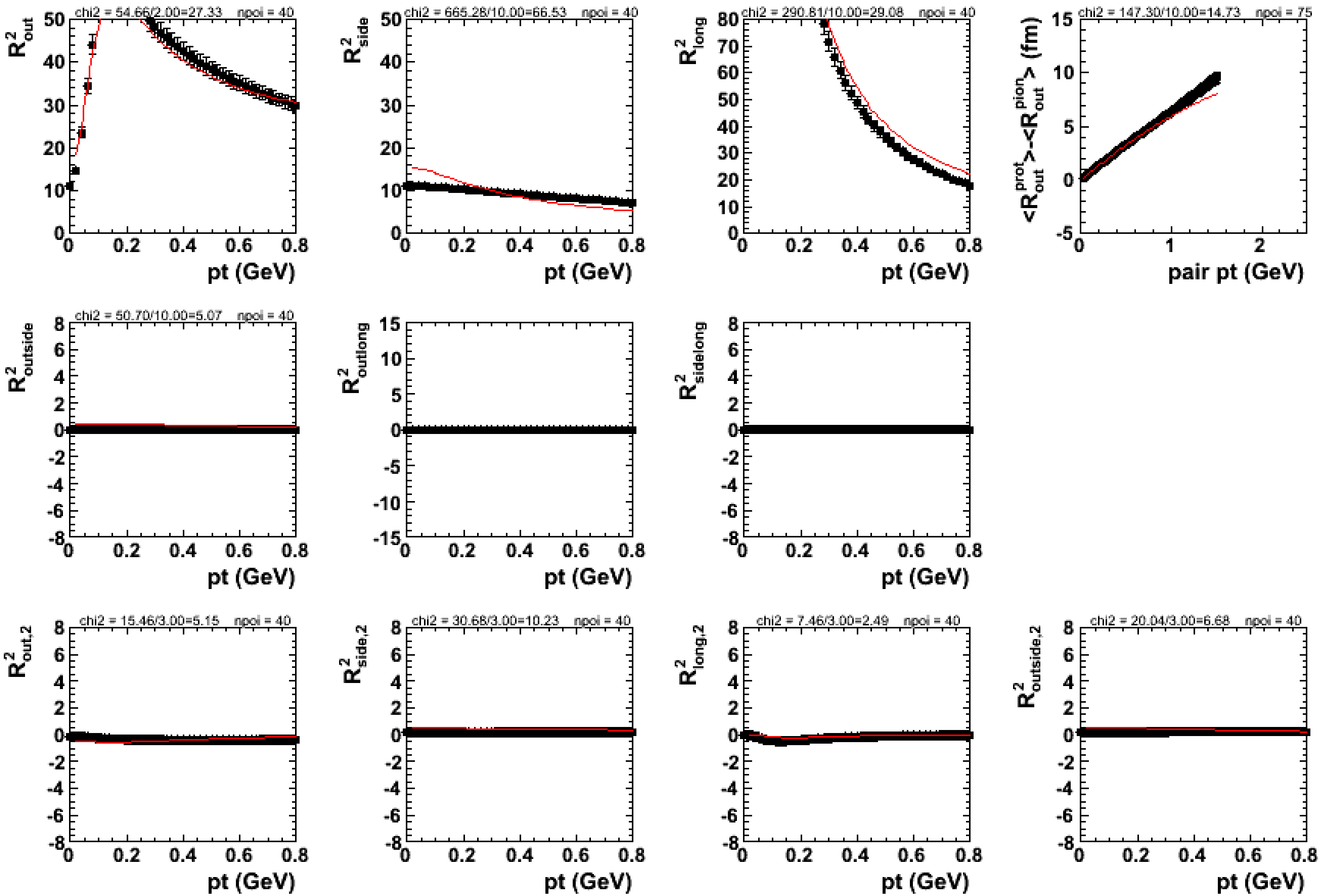
- **identify THE parameter which is different**
  → this is what needs to be fixed in hydro

blast only HBT (lines) and hydro 120 MeV (points)

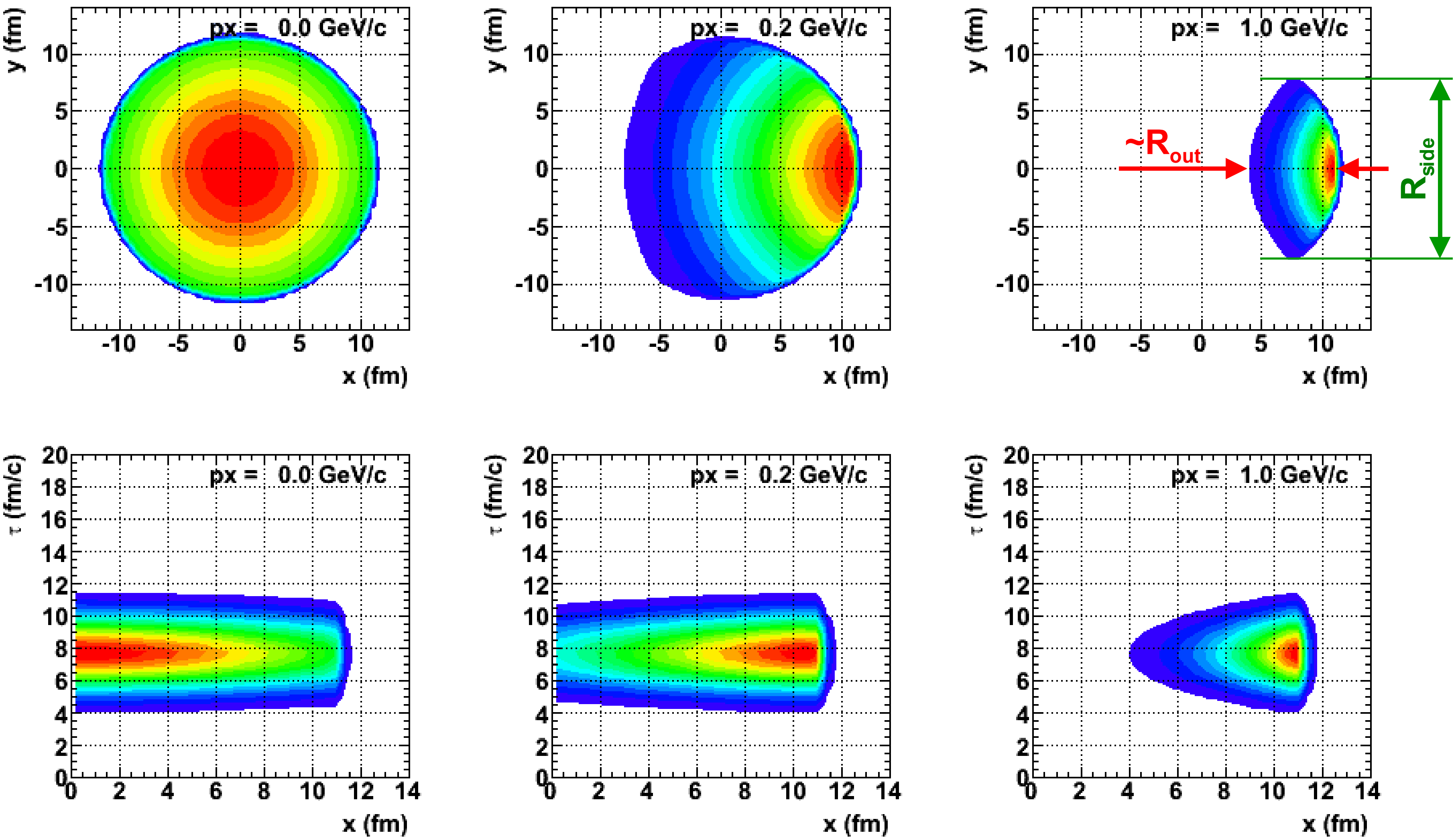


other->fPim = 129.6
other->fKa0 = 19.10
other->fPhi = 1.164
blast->fT = 0.139
blast->fRho0 = 1.59
blast->fRho2 = 0.001
blast->fRx = 9.68
blast->fRy = 9.98
blast->fAs = 0.010
blast->fTau0 = 10.11
blast->fDtau = 5.84

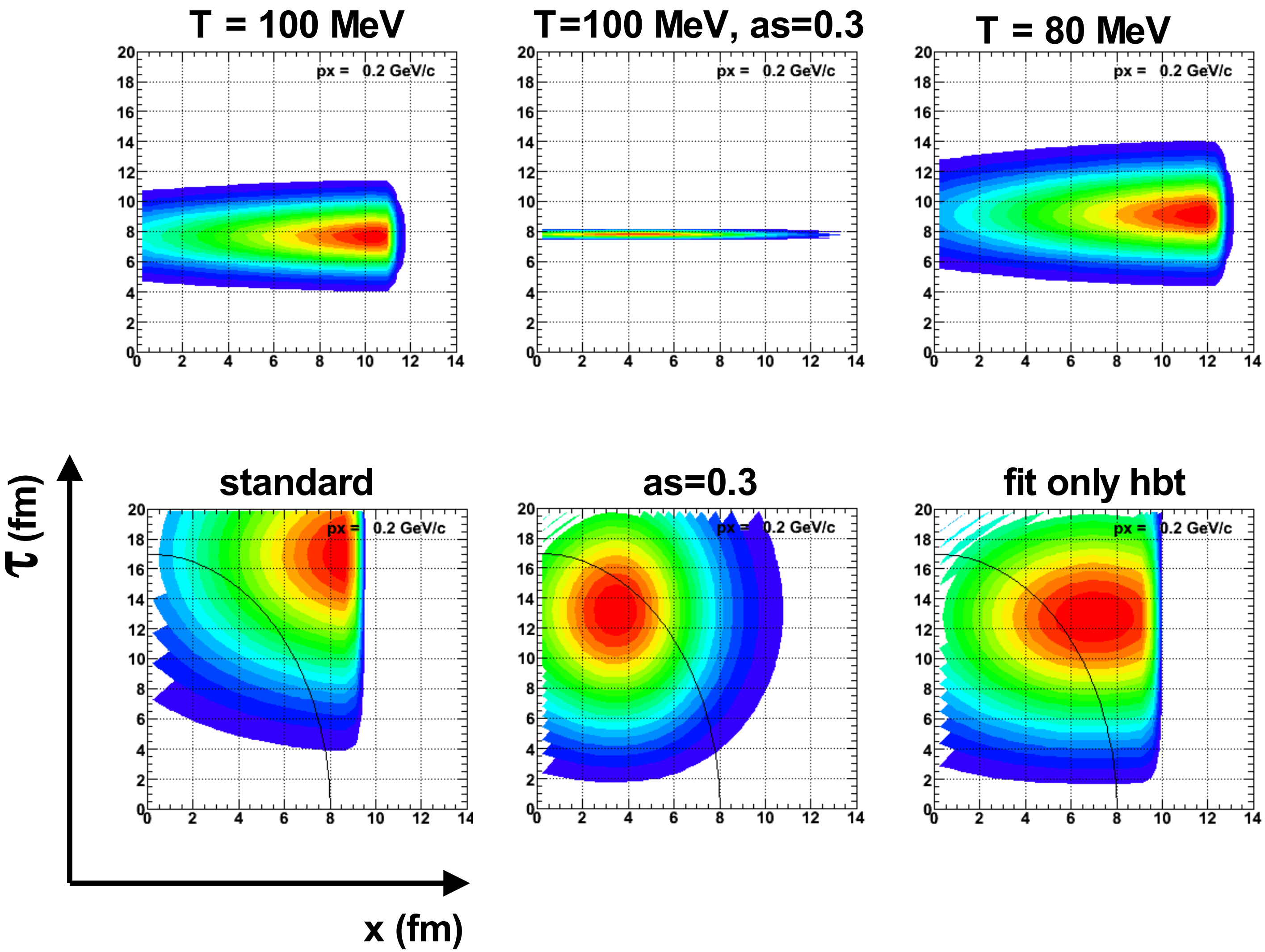
blast only HBT (lines) and hydro 120 MeV (points)



blast - source shape



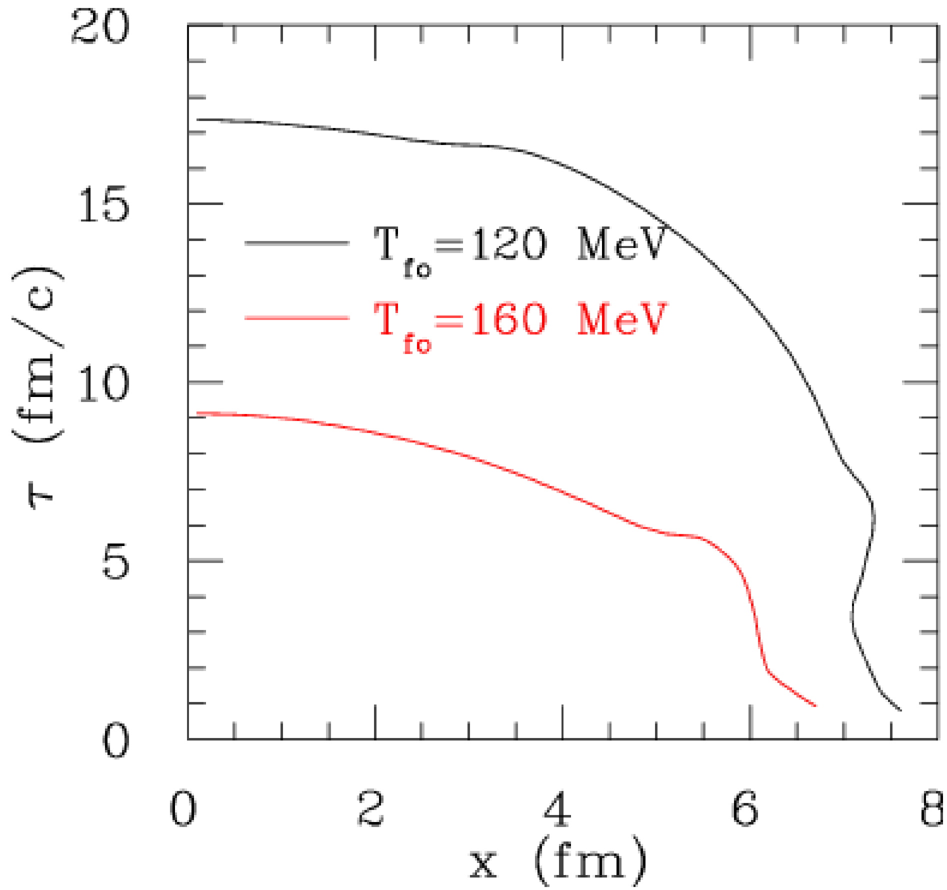
fitted blast source shapes



fit to CERES data

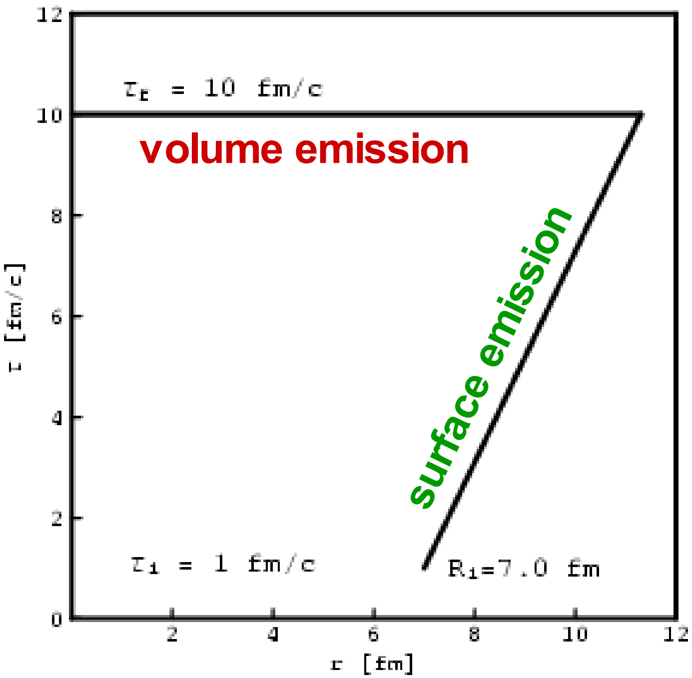
"fit" to hydro
120 MeV

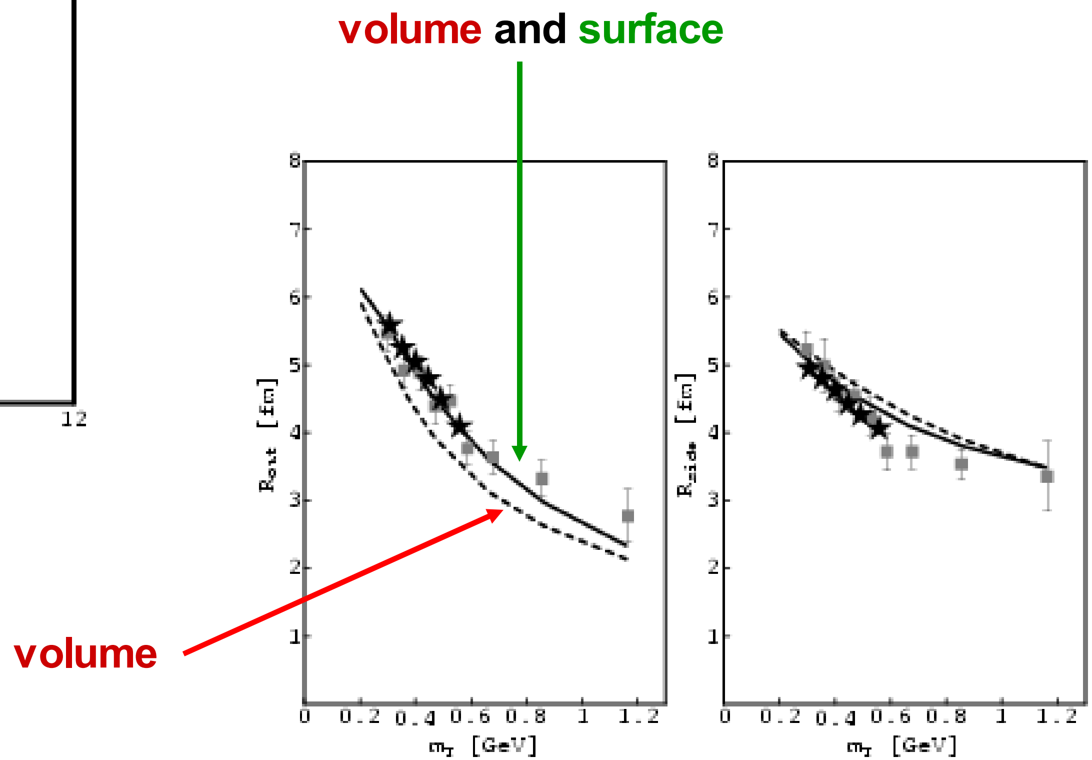
hydro source shape



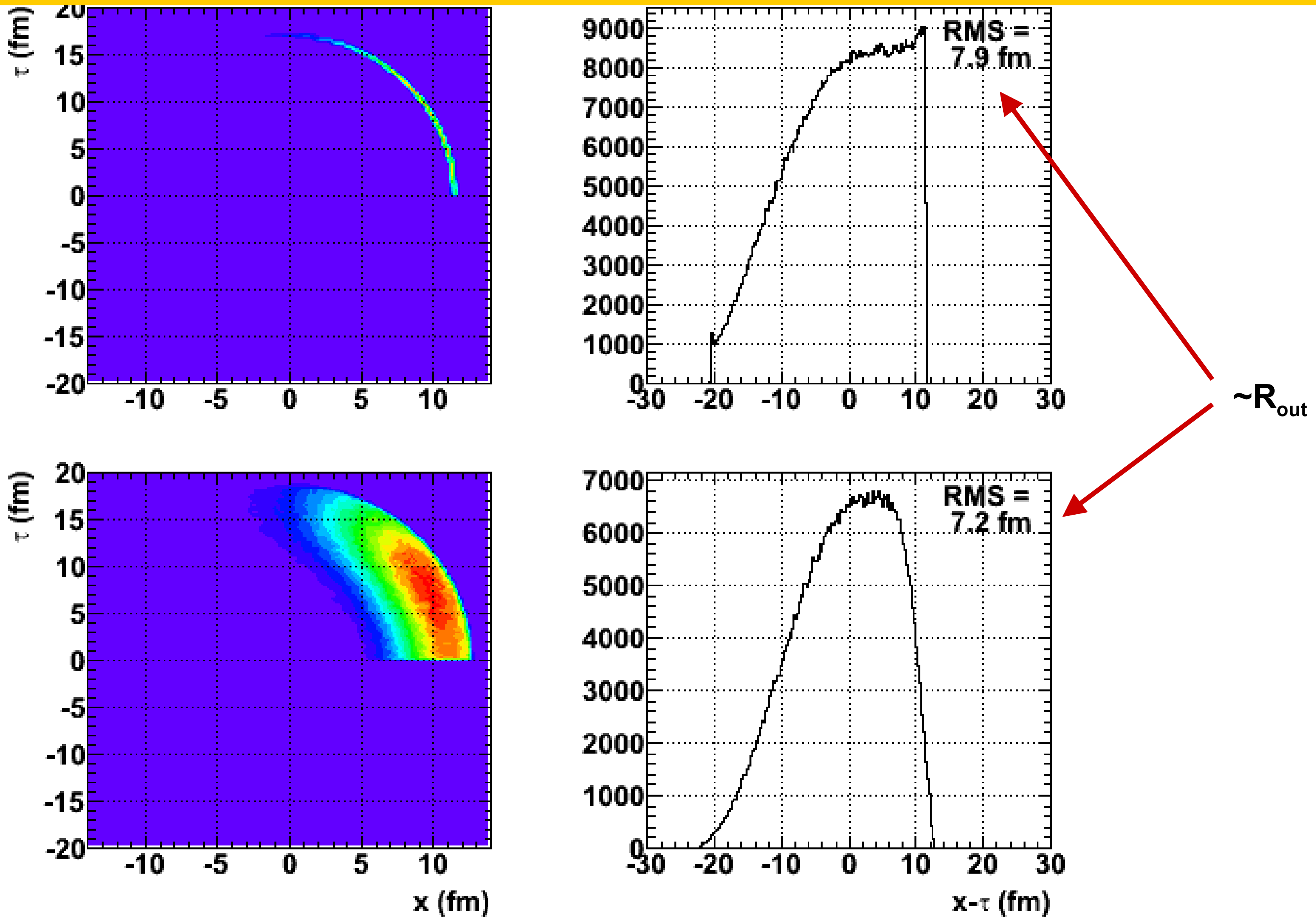
Sinyukov's blast

Phys.Rev. C73 (2006) 024903
pi- pi- from PHENIX and STAR





hydro, why is R_{out} so large and R_{side} so small: freeze-out surface too thin?

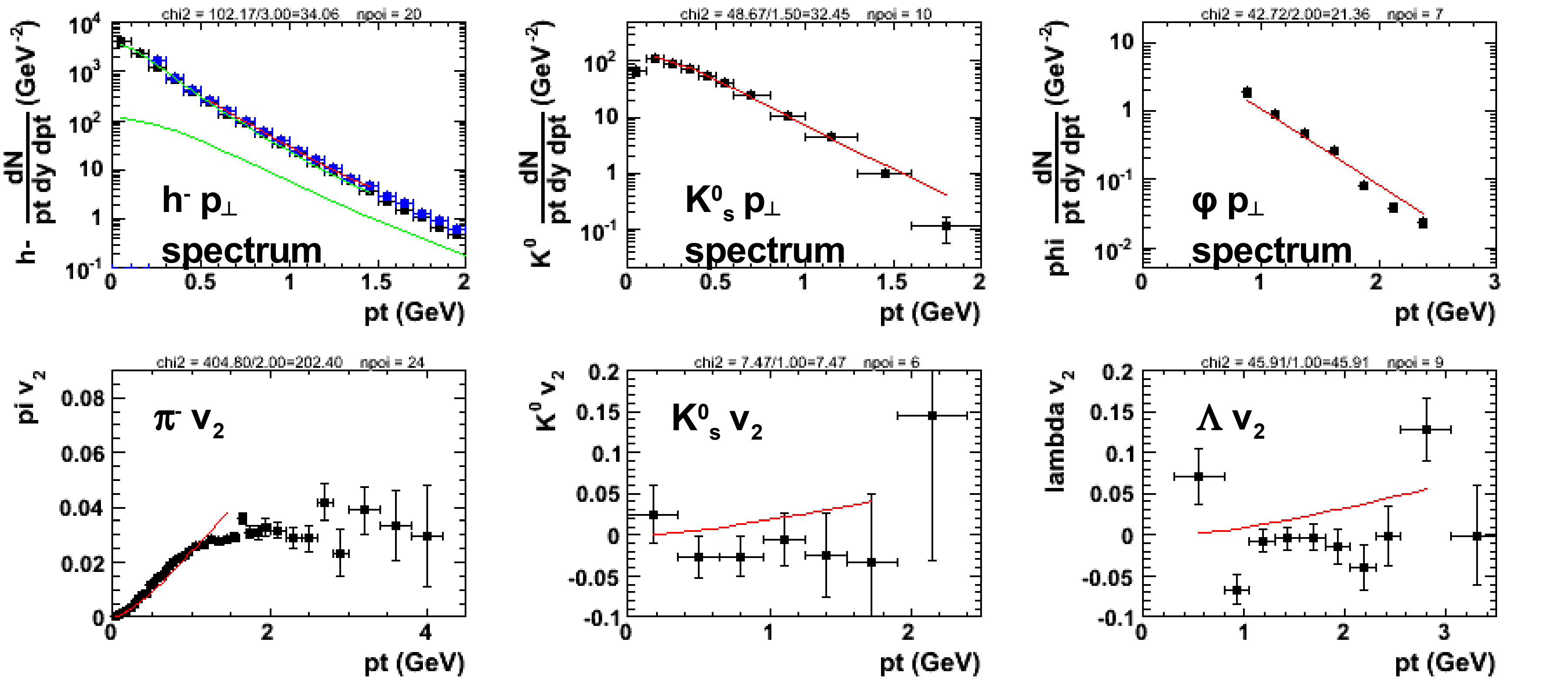


summary

- blast fits CERES data reasonably well
  (in spite of the lacking resonances, lacking surface emission...)
- hydro fits CERES spectra and flow but not HBT radii
- blast is qualitatively different from hydro (even if "inspired" by it)
- troubles with hydro may have to do with the freeze-out hypersurface moving inward (Pasi Huovinen)
- ... combined with its unrealistic small thickness?

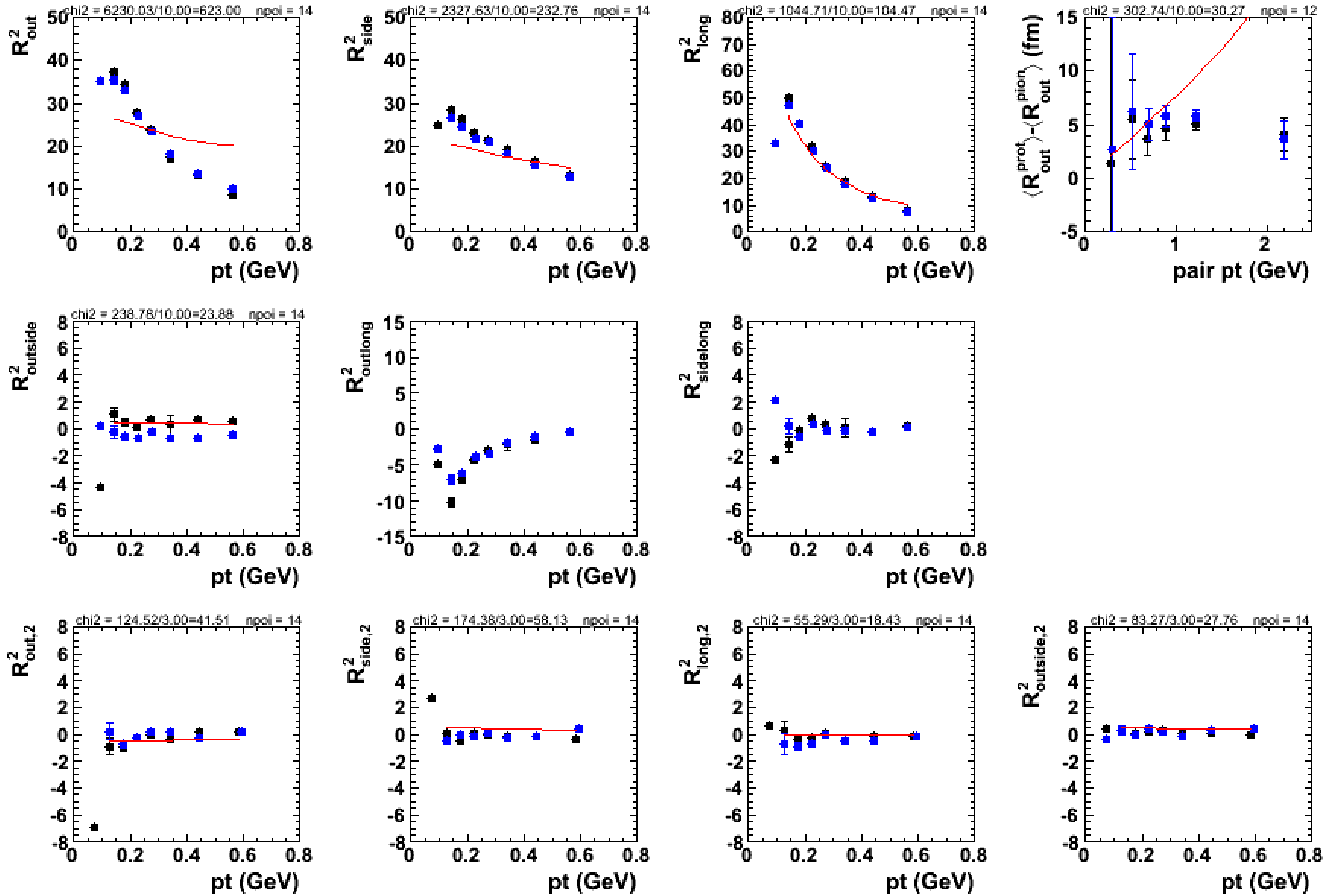
backup slides

blast T=100 MeV as=0.3 (lines) and CERES (points)

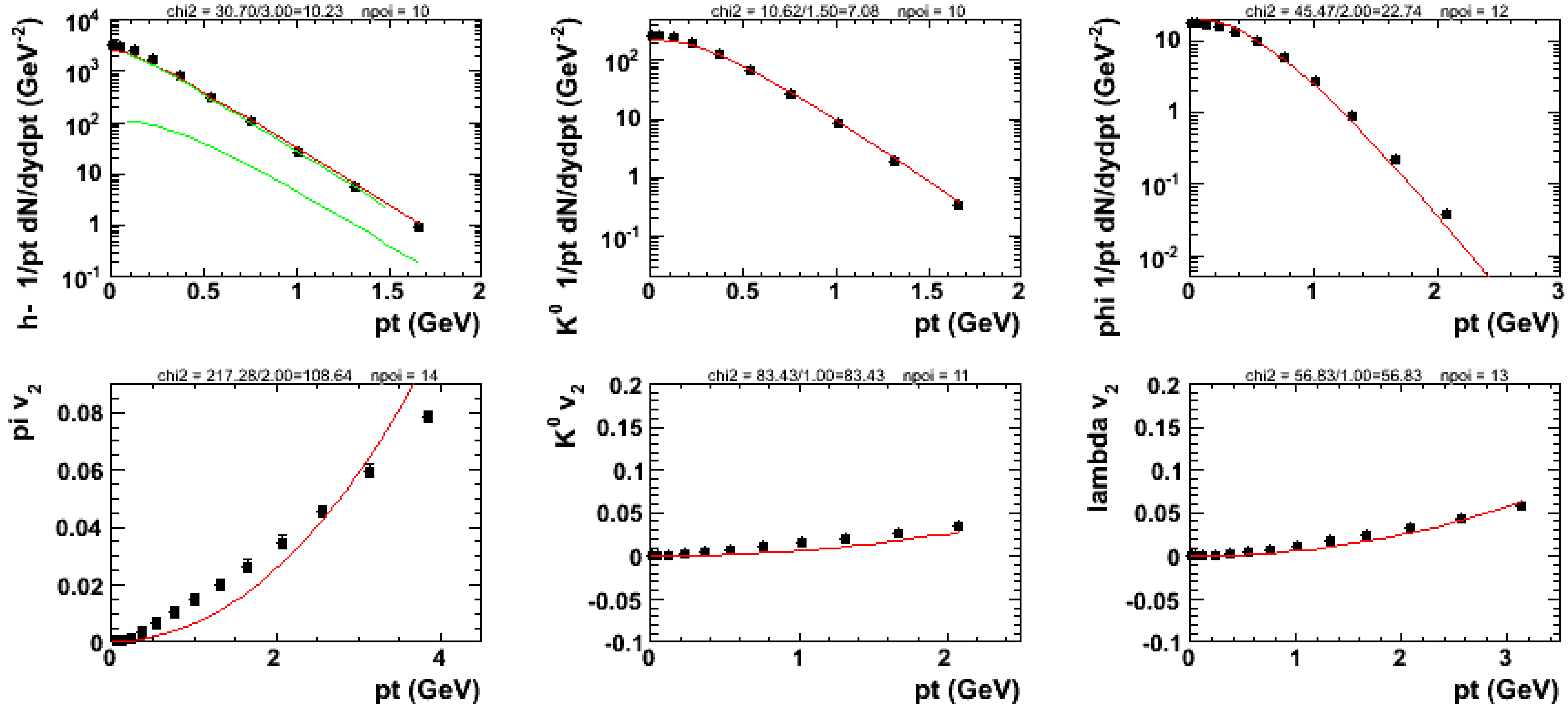


other->fPim = 169.6
other->fKa0 = 19.57
other->fPhi = 1.710
blast->fT = 0.100
blast->fRho0 = 0.52
blast->fRho2 = 0.009
blast->fRx = 6.96
blast->fRy = 7.07
blast->fAs = 0.300
blast->fTau0 = 7.65
blast->fDtau = 0.02

blast T=100 MeV as=0.3 (lines) and CERES (points)

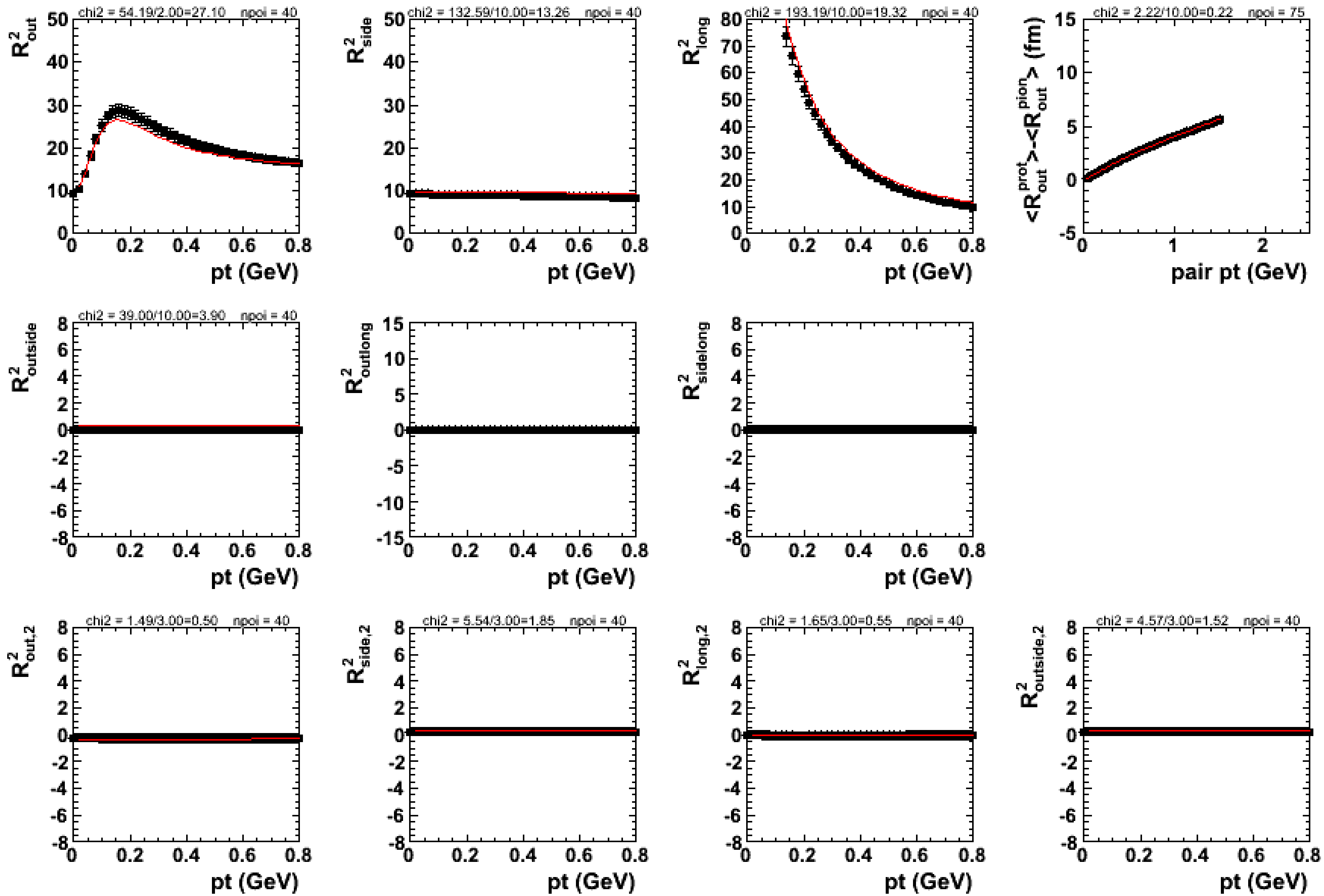


blast as=0.3 (lines) and hydro 160 MeV (points)

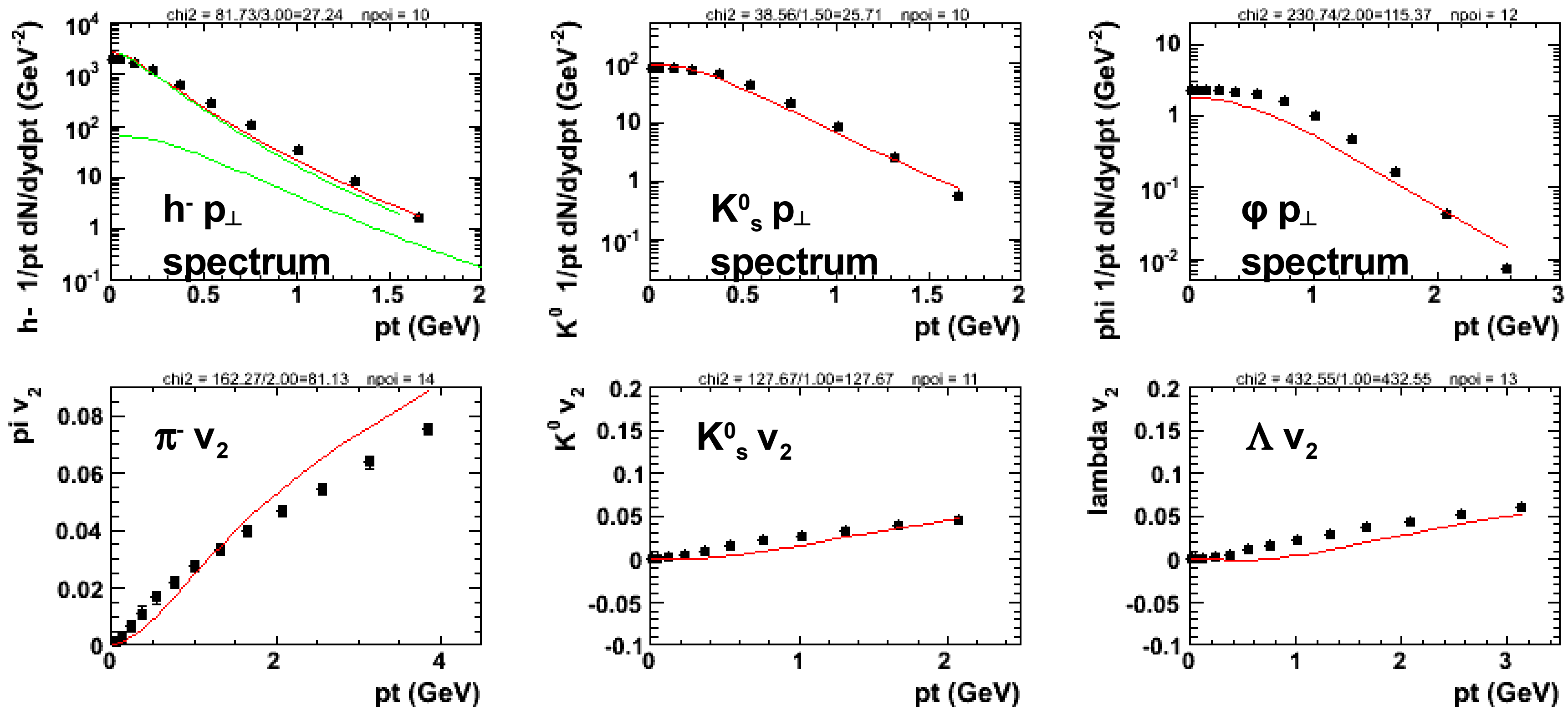


other->fPim = 156.0
other->fKa0 = 30.85
other->fPhi = 4.775
blast->fT = 0.174
blast->fRho0 = 0.10
blast->fRho2 = 0.012
blast->fRx = 3.97
blast->fRy = 4.10
blast->fAs = 0.300
blast->fTau0 = 4.78
blast->fDtau = 2.44

blast as=0.3 (lines) and hydro 160 MeV (points)

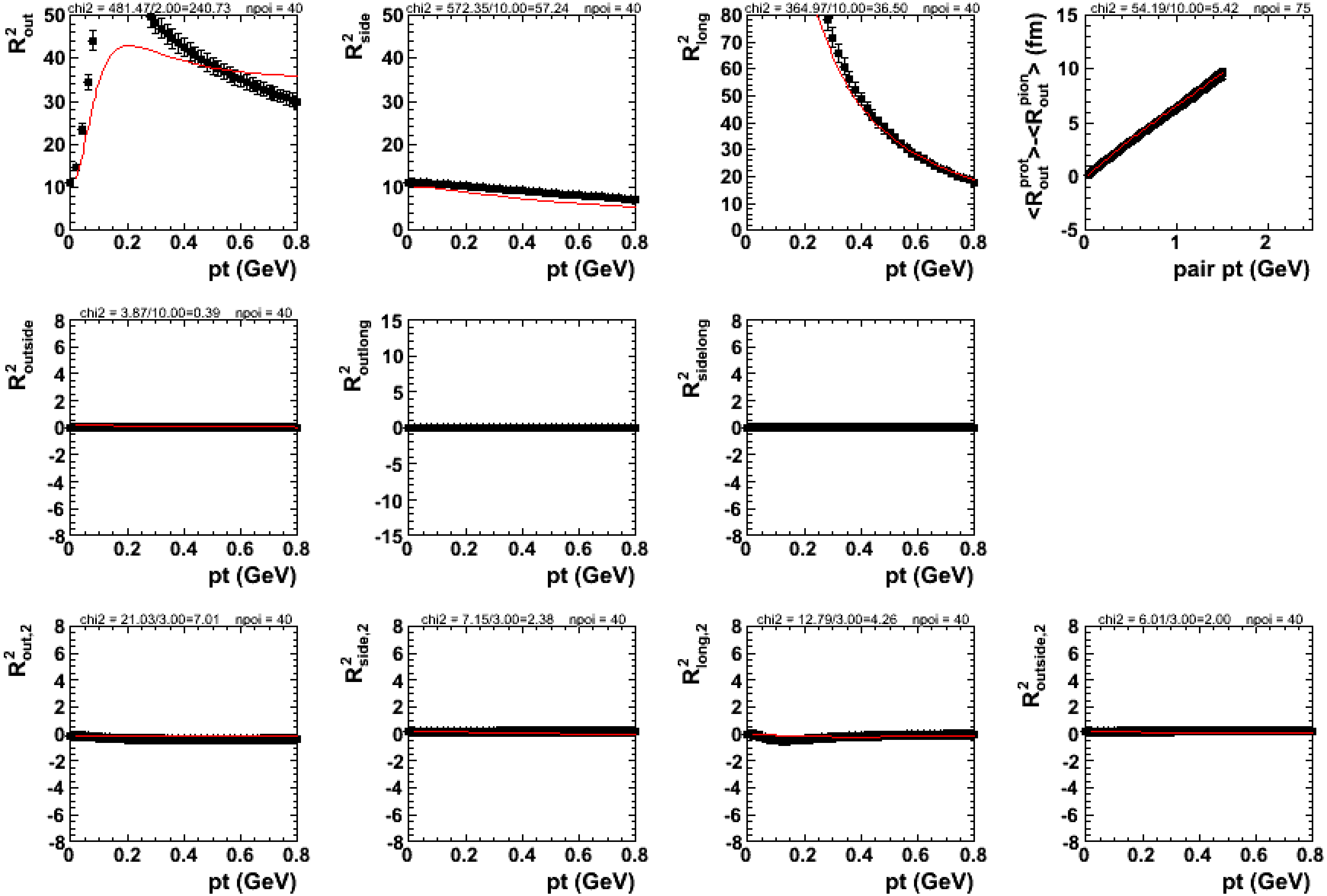


blast as=0.3 (lines) and hydro 120 MeV (points)



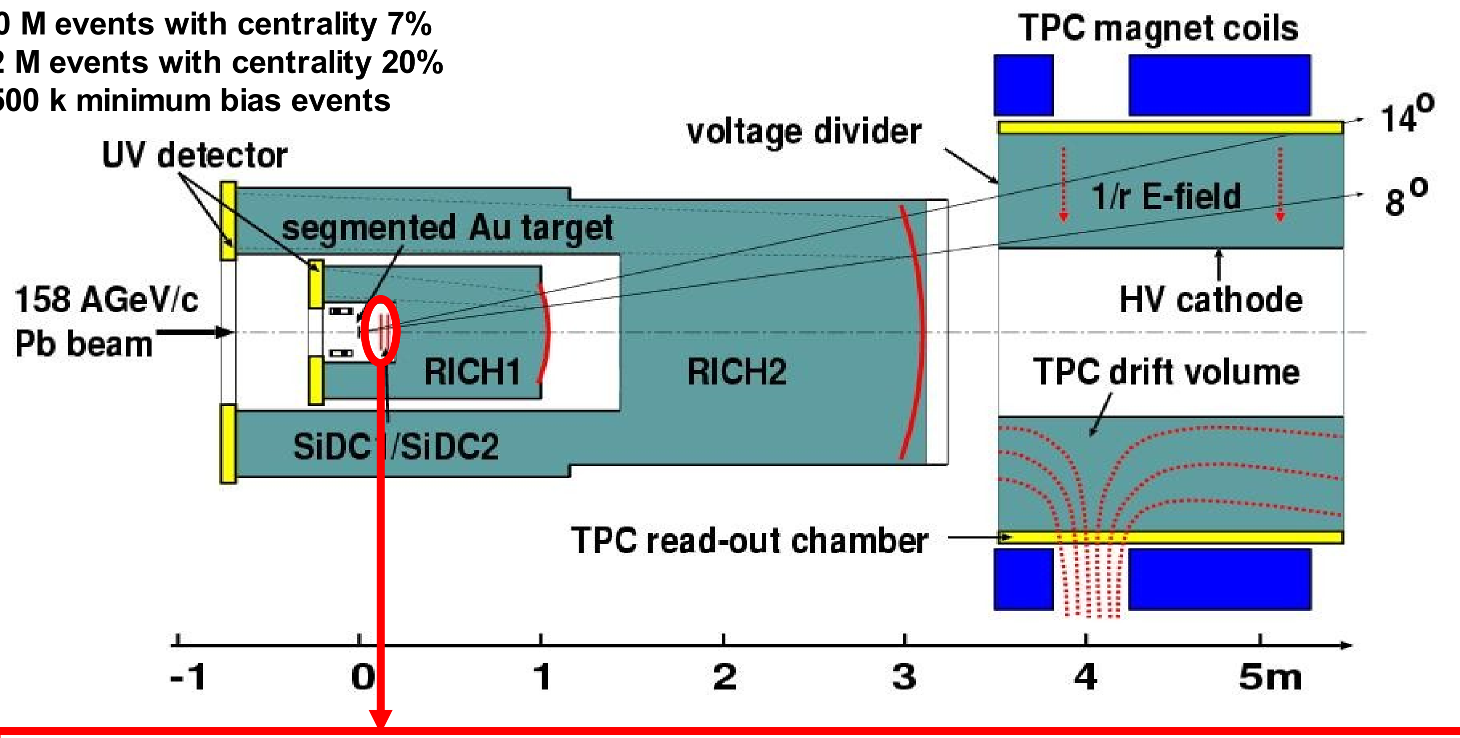
other->fPim = 113.7
other->fKa0 = 16.43
other->fPhi = 0.842
blast->fT = 0.089
blast->fRho0 = 0.60
blast->fRho2 = 0.011
blast->fRx = 5.06
blast->fRy = 5.09
blast->fAs = 0.300
blast->fTau0 = 10.46
blast->fDtau = 5.98

blast as=0.3 (lines) and hydro 120 MeV (points)

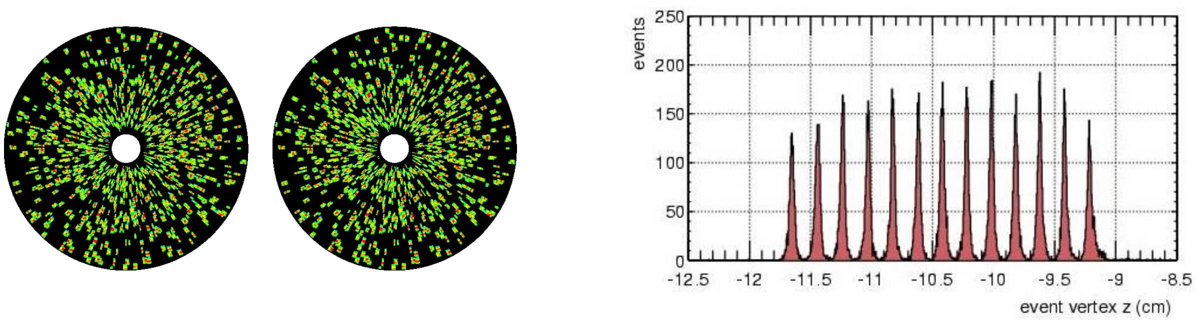


setup with TPC: 1999 and 2000

run 2000: 30 M events with centrality 7%
2 M events with centrality 20%
500 k minimum bias events



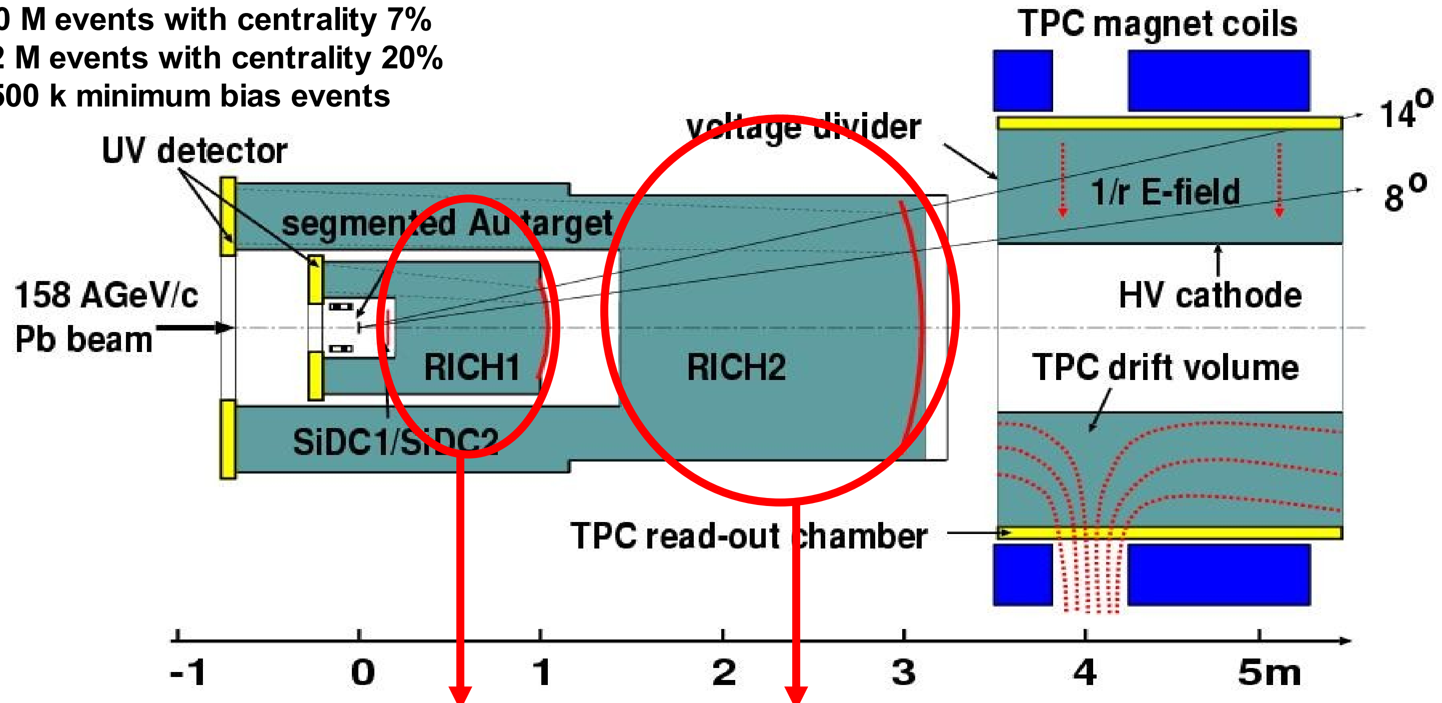
SD: event vertex, track vertex and angle

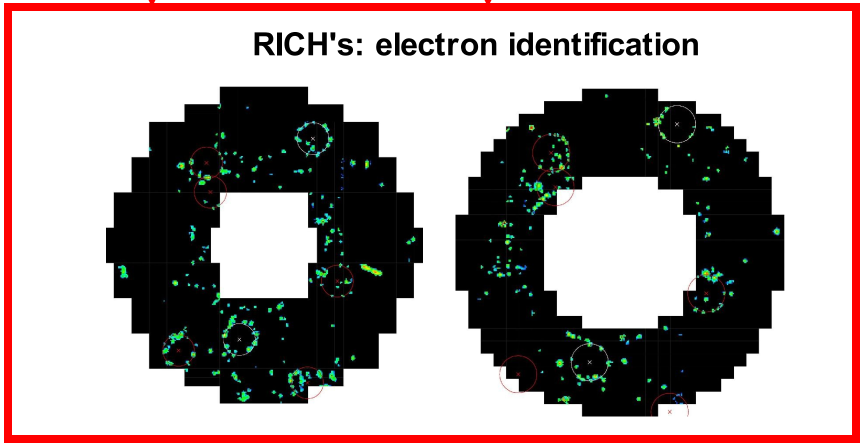


event Δz = 0.2 mm
track $\Delta\theta$ = 0.2 mrad
$\Delta\varphi$ = 2 mrad

setup with TPC: 1999 and 2000

run 2000: 30 M events with centrality 7%
2 M events with centrality 20%
500 k minimum bias events





setup with TPC: 1999 and 2000

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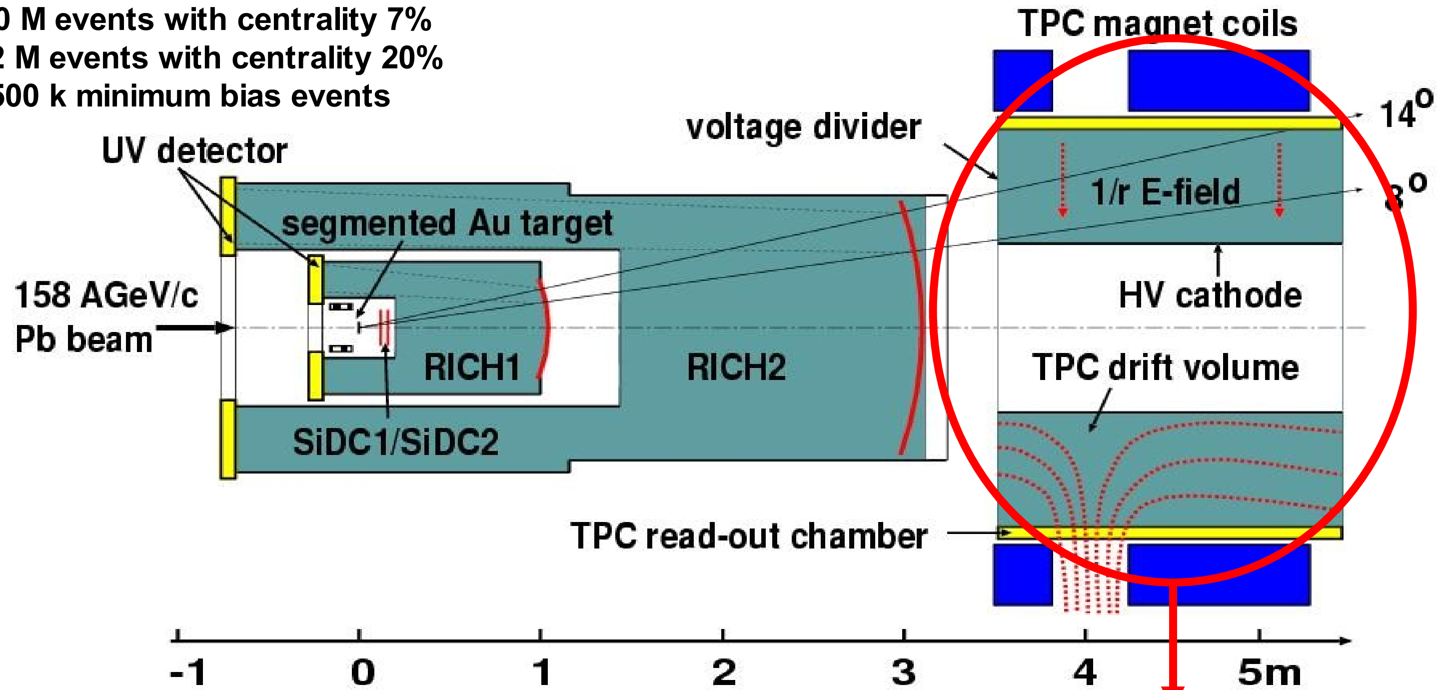
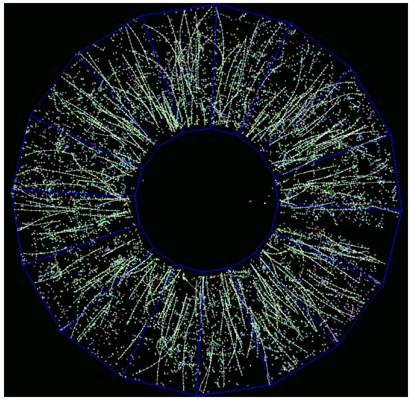
500 k minimum bias events



radial drift TPC: momentum and energy loss

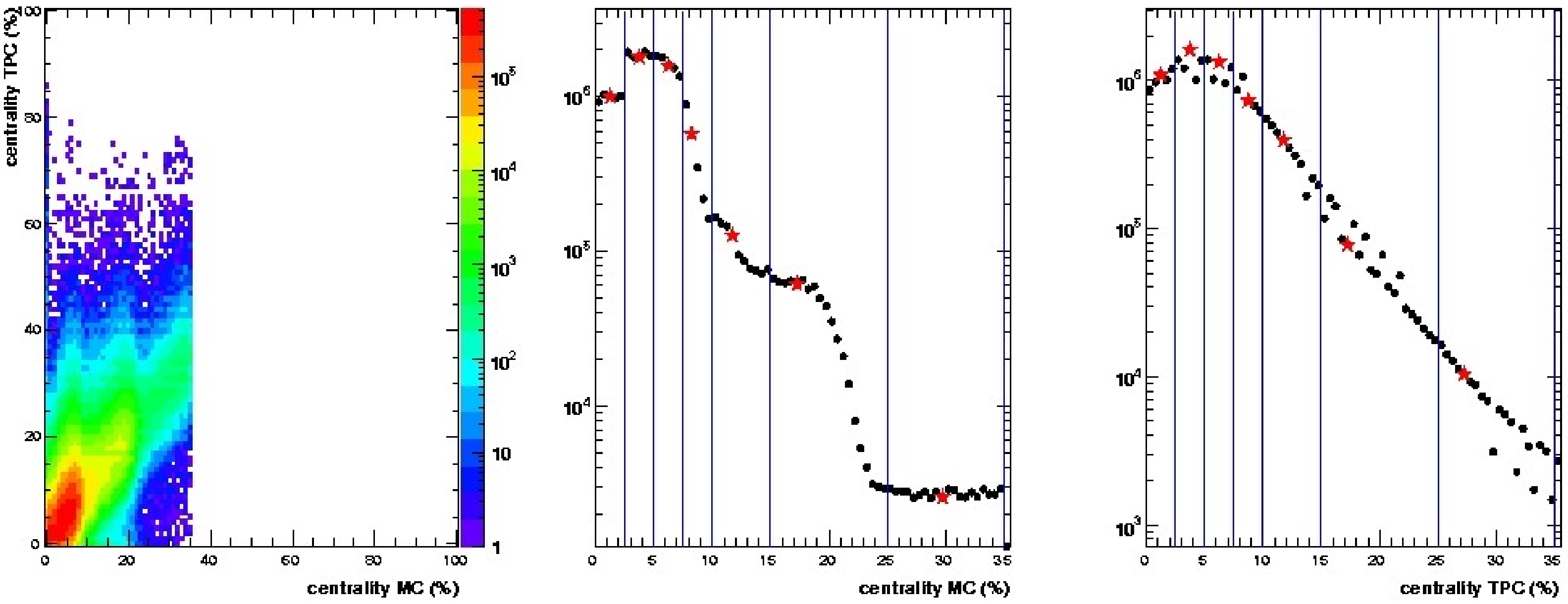


$\Delta p/p = 2\% \oplus 1\% * p/GeV$

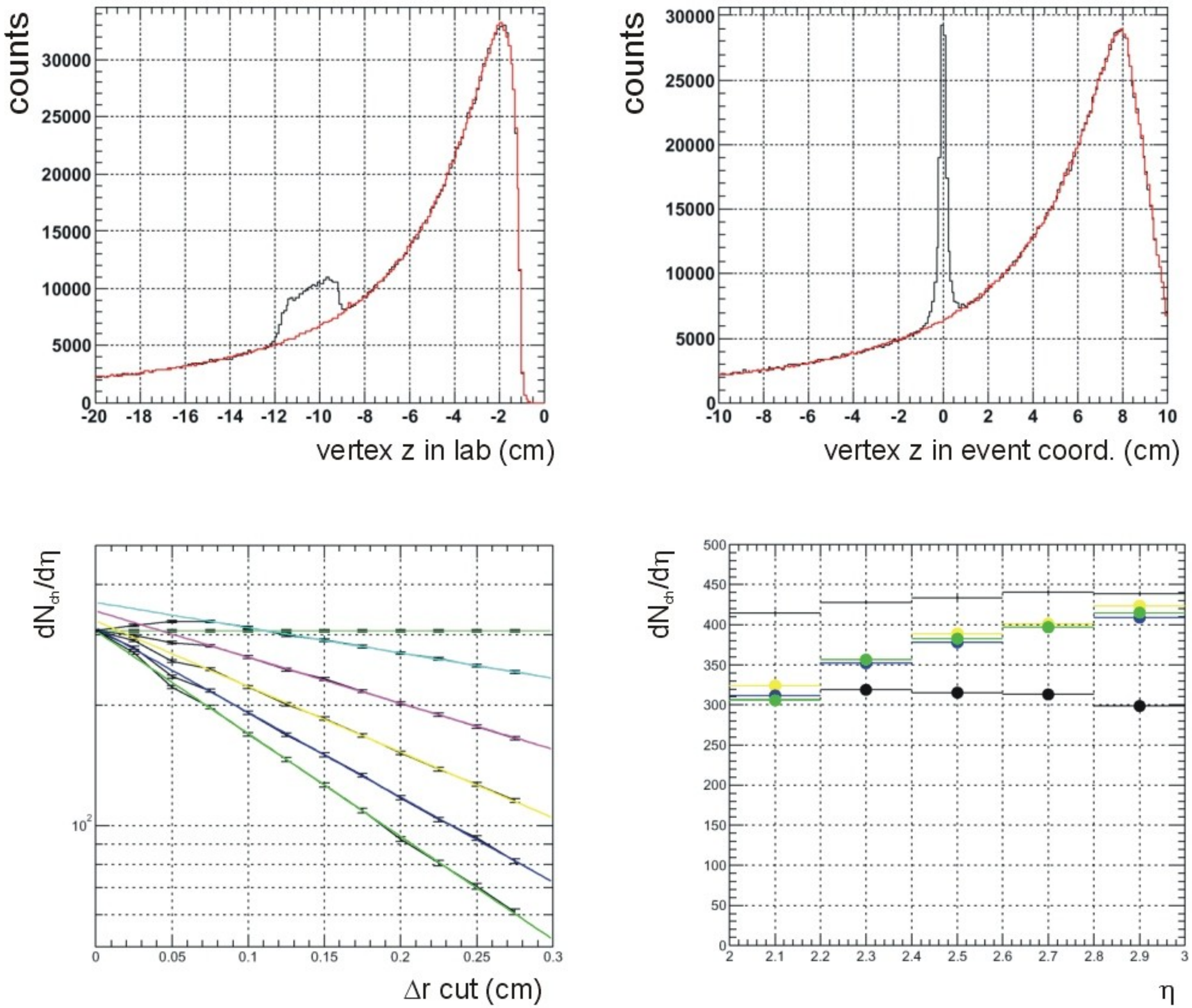
$\Delta m/m$ = 3.8 % for ϕ

$\Delta(dE/dx)/(dE/dx)$ = 10%

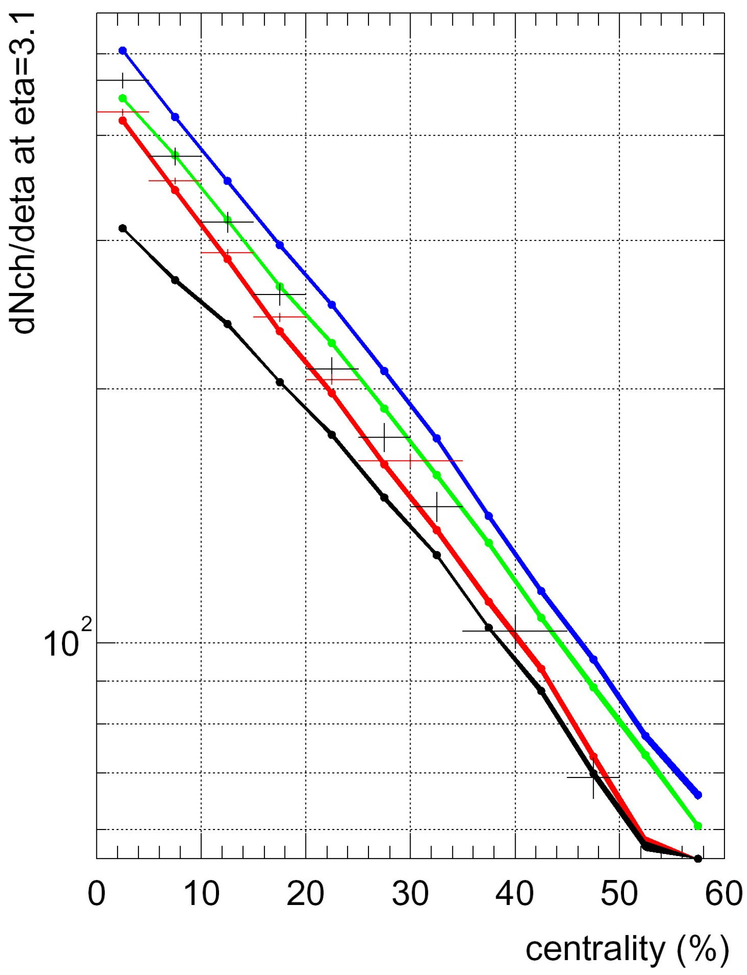
centrality of the analyzed data set

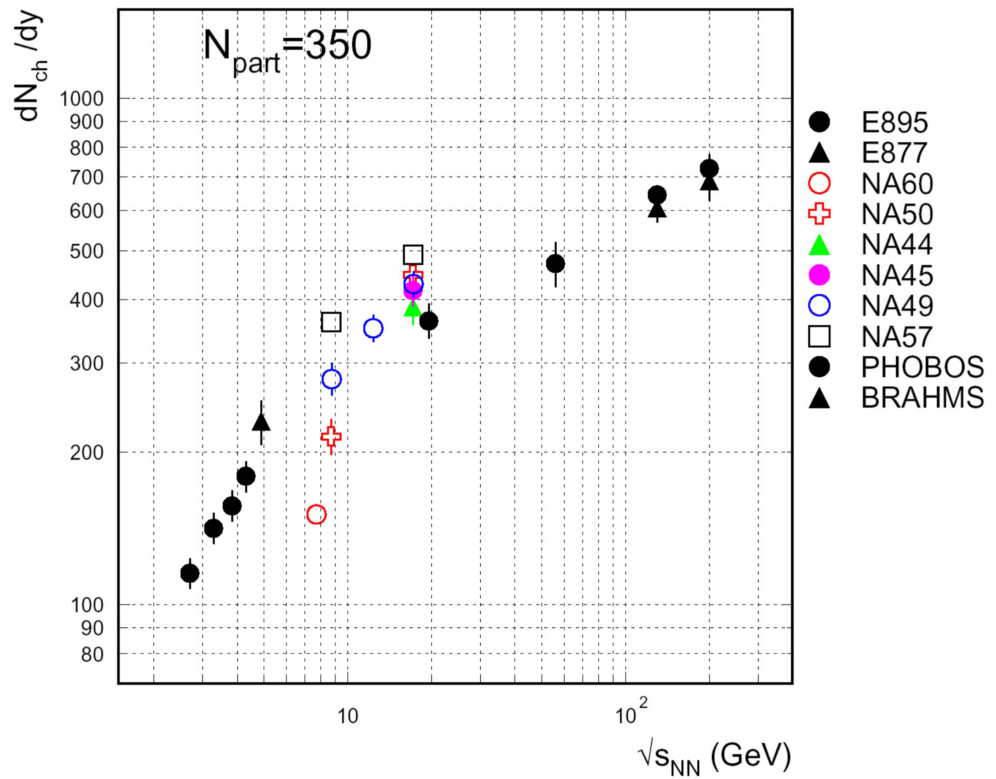


Absolute multiplicity of charged particles



Absolute multiplicity of charged particles





dNch/dy = 1.025 dNch/dη applied at SPS
dNch/dy = 1.1 dNch/dη applied at RHIC

Fitting R_{side} and Δx

$$R_{side}(p_\perp) = \frac{R_G}{\sqrt{1+\frac{m_\perp \eta_f^{\;2}}{T}}}$$

$$m_\perp = \sqrt{m_\pi + \left(\frac{P_\perp}{2}\right)^2}$$

U. Heinz, many many papers

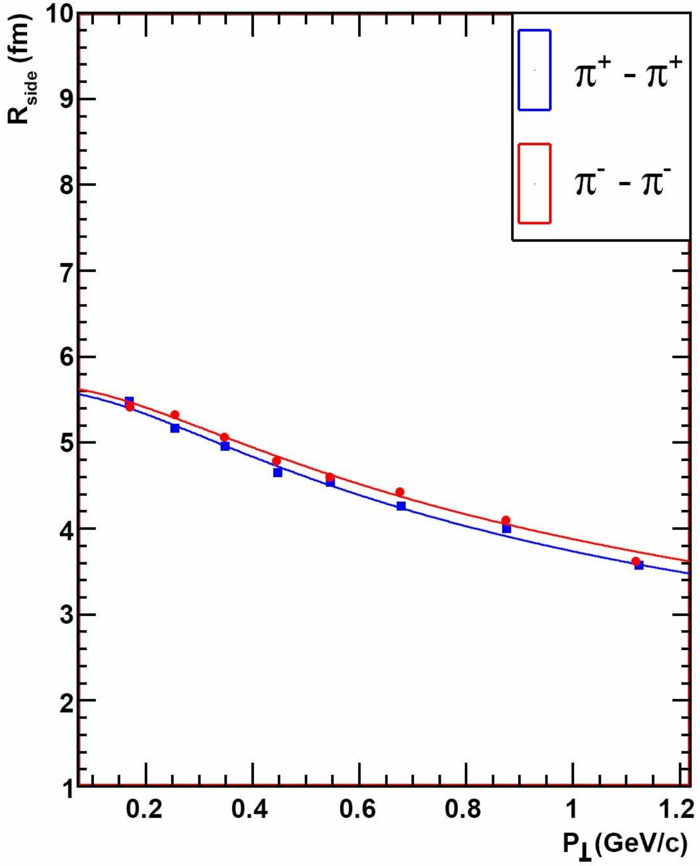
$$\langle \Delta x \rangle = \frac{R_G \, \beta_\perp \, \beta_0}{\beta_0^{\;2} + \frac{T}{m_\perp}}$$

$$m_\perp = \sqrt{m_\perp^{\;1} \, m_\perp^{\;2}}$$

$$\eta_f = \frac{1}{2}\log\frac{1+\beta_0}{1-\beta_0}$$

$$\beta_\perp = \frac{1}{\sqrt{1+\left(\frac{m_\pi + m_p}{P_\perp}\right)^2}}$$

R. Lednicky, nucl-th/0305027, based on Akkelin, Sinyukov Z.Phys.C 72(1996)501



R_{side} dominates the fit
Δx agrees reasonably well
→ all flow?