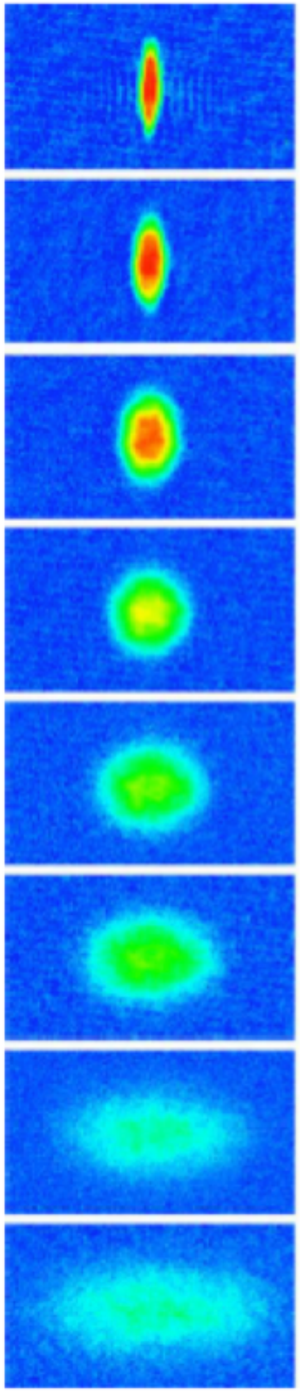


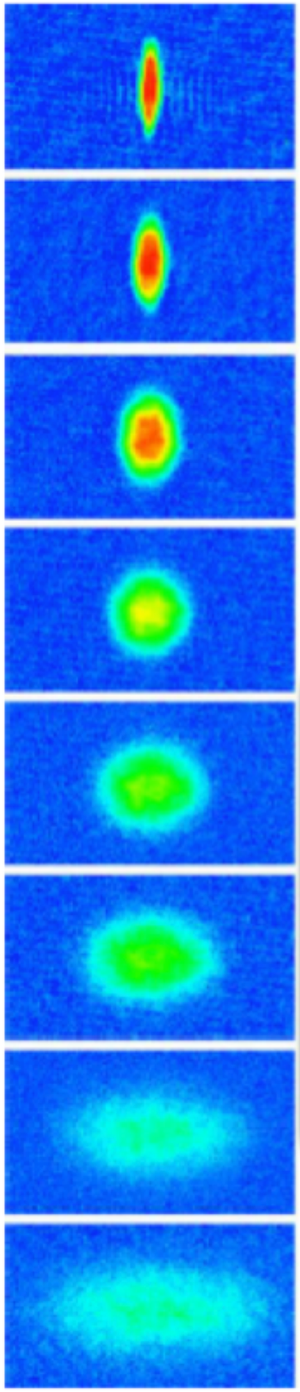
azimuthally-sensitive femtoscopy in the STAR energy scan program

an update

Mike Lisa

Ohio State University

In collaboration with: E. Mount (OSU), E. Frodermann (U. Minn), G. Graef, M. Mitrovski, H. Petersen, M. Bleicher (Frankfurt)



azimuthally-sensitive femtoscopy in the STAR energy scan program

A warm welcome, c/o Kyrill

- **Conclusion 1:** 25 years of NOT very successful searches for QGP evidence that we are missing a few key elements which do not allow us to formulate some convincing signals.
- **Conclusion 2:** the low energy programs will hardly be successful, even if they ``discover some irregularities'', since without theoretical back up they will convince no one!

Outline

- **connections**
  - laser-induced micro-explosions
  - RHIC-induced femto-explosions
  - cold atomic gases
- **azimuthally-sensitive HBT (asHBT)**
  - what is measured
  - what it measures
  - what's been measured
  - what needs to be measured
- **estimating shapes** – simple formulae versus full simulation
- **model calculations and sensitivity to physics**
  - hydrodynamics
  - cascade transport
  - hydro + cascade hybrid
- **summary**, what's to come

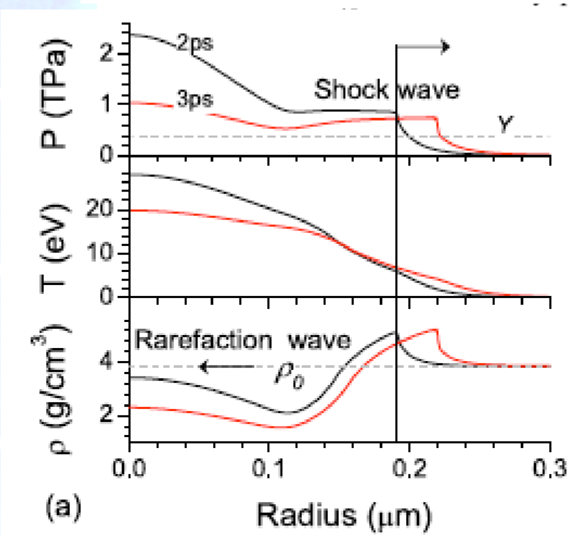
PRL **96**, 166101 (2006) PHYSICAL REVIEW LETTERS week ending 28 APRIL 2006

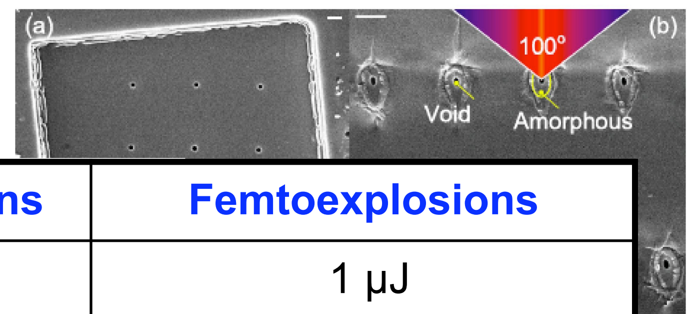
Laser-Induced Microexplosion Confined in the Bulk of a Sapphire Crystal: Evidence of Multimegabar Pressures

S. Juodkazis,[1] K. Nishimura,[1] S. Tanaka,[1] H. Misawa,[1] E. G. Gamaly,[2] B. Luther-Davies,[2]

Extremely high pressures (~10 TPa) and temperatures (5×10^5 K) have been produced using a single laser pulse (100 nJ, 800 nm, 200 fs) focused inside a sapphire crystal. The laser pulse creates an intensity over 10^{14} W/cm^2 converting material within the absorbing volume of ~0.2 μm^3 into plasma in a few fs. A pressure of ~10 TPa, far exceeding the strength of any material, is created generating strong shock and rarefaction waves. This results in the formation of a nanovoid surrounded by a shell of shock-affected material inside undamaged crystal. Analysis of the size of the void and the shock-affected zone versus the deposited energy shows that the experimental results can be understood on the basis of conservation laws and be modeled by plasma hydrodynamics. Matter subjected to record heating and cooling rates of 10^{18} K/s can, thus, be studied in a well-controlled laboratory environment.

studied in a well-controlled laboratory environment.





	Microexplosions	Femtoexplosions
√s	0.1 μJ	1 μJ
ε	10^{17} J/m^3	5 GeV/fm^3 = 10^{36} J/m^3
T	10^6 K	200 MeV = 10^{12} K
rate	10^{18} K/sec	10^{35} K/s

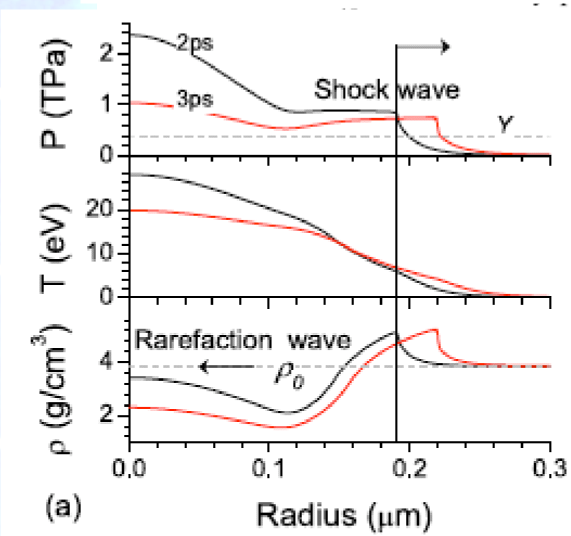
PRL 96, 166101 (2006) PHYSICAL REVIEW LETTERS week ending 28 APRIL 2006

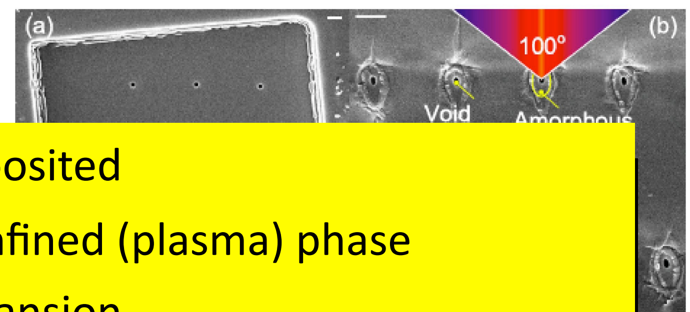
Laser-Induced Microexplosion Confined in the Bulk of a Sapphire Crystal: Evidence of Multimegabar Pressures

S. Juodkazis,[1] K. Nishimura,[1] S. Tanaka,[1] H. Misawa,[1] E. G. Gamaly,[2] B. Luther-Davies,[2]

Extremely high pressures (~10 TPa) and temperatures (5×10^5 K) have been produced using a single laser pulse (100 nJ, 800 nm, 200 fs) focused inside a sapphire crystal. The laser pulse creates an intensity over 10^{14} W/cm^2 converting material within the absorbing volume of ~0.2 μm^3 into plasma in a few fs. A pressure of ~10 TPa, far exceeding the strength of any material, is created generating strong shock and rarefaction waves. This results in the formation of a nanovoid surrounded by a shell of shock-affected material inside undamaged crystal. Analysis of the size of the void and the shock-affected zone versus the deposited energy shows that the experimental results can be understood on the basis of conservation laws and be modeled by **plasma hydrodynamics**. Matter subjected to record heating and cooling rates of 10^{18} K/s can, thus, be studied in a well-controlled laboratory environment.

studied in a well-controlled laboratory environment.





- energy quickly deposited
- transition to deconfined (plasma) phase
- hydrodynamic expansion
- cool back to confined (atomic) phase

PRL 96, 166101 (2006) PHYSICAL REVIEW LETTERS week ending 28 APRIL 2006

Laser-Induced Microexplosion Confined in the Bulk of a Sapphire Crystal: Evidence of Multimegabar Pressures

PHYSICAL REVIEW B 76, 024101 (2007)

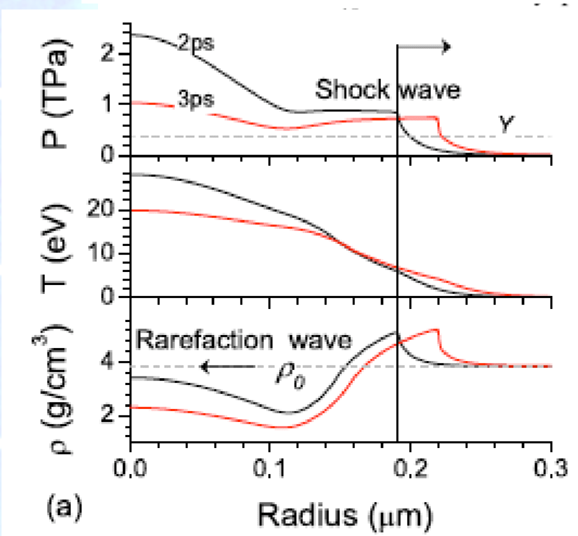
Model and numerical simulations of the propagation and absorption of a short laser pulse in a transparent dielectric material: Blast-wave launch and cavity formation

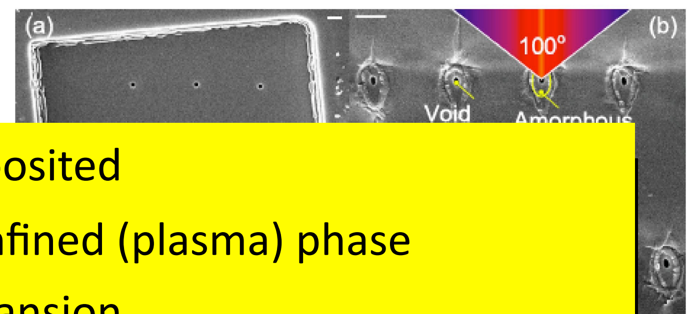
Ludovic Hallo,[1,*] Antoine Bourgeade,[2] Vladimir T. Tikhonchuk,[1] Candice Mezel,[1] and Jérome Breil[1]
[1]Université Bordeaux 1, CNRS, CEA, UMR 5107, 33405 Talence Cedex, France
[2]CEA-CESTA, BP 1, 33114 Le Barp, France

(Received 30 March 2007; published 2 July 2007)

of a nanovoid surrounded by a shell of shock-affected material inside undamaged crystal. Analysis of the size of the void and the shock-affected zone versus the deposited energy shows that the experimental results can be understood on the basis of conservation laws and be modeled by **plasma hydrodynamics**. Matter subjected to record heating and cooling rates of 10^{18} K/s can, thus, be studied in a well-controlled laboratory environment.

studied in a well-controlled laboratory environment.





- energy quickly deposited
- transition to deconfined (plasma) phase
- hydrodynamic expansion
- cool back to confined (atomic) phase

PRL 96, 166101 (2006) PHYSICAL REVIEW LETTERS week ending 28 APRIL 2006

Appl Phys A (2008) 92: 837–841
DOI 10.1007/s00339-008-4580-5
Applied Physics A
Materials Science & Processing

Formation of nanocavities in dielectrics: influence of equation of state

L. Hallo · A. Bourgeade · C. Mézel · G. Travaillé ·
D. Hébert · B. Chimier · G. Schurtz · V.T. Tikhonchuk

Published online: 28 Ma

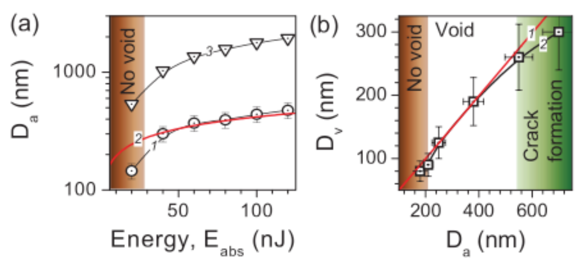


FIG. 3 (color). (a) The diameter (1) and length (3) of the amorphous region vs the absorbed pulse energy, E_{abs}. The voids were 20 μm beneath the surface. Curve (2) plotted by Eq. (1) with l_a = 80 nm. (b) Dependence of the void diameter on the diameter of amorphous part: (1) theory by Eq. (2) with δ = 1.14; (2) experiment.

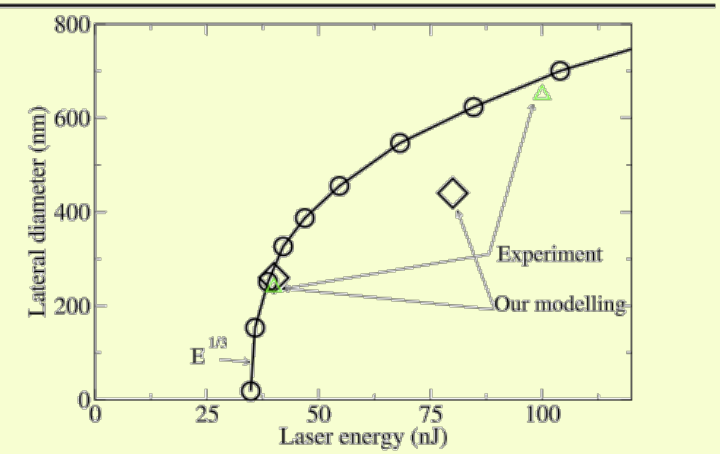
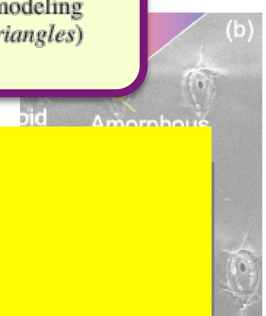


Fig. 9 Cavity diameter on the laser energy in silica, simple modeling (*circles*) [2], IL0005 EOS (*diamond shapes*) and experiment (*triangles*)

...data should allow a tuning of equations of state in ... main of extreme parameters

Table 1 SESAME 7387, QEOS and home-made IL type EOS parameters

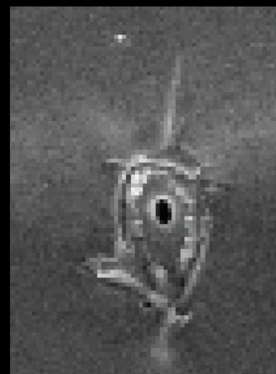
EOS name	G	E_{sub} (MJ/kg)
QEOS	1.5	≈0.01
SESAME 7387	0.65	10
IL0005	0.03	17
IL0006	0.03	28
IL0007	0.03	8



- energy quickly deposited
- transition to deconfined (plasma) phase
- hydrodynamic expansion
- cool back to confined (atomic) phase
- probe **EoS** under extreme conditions (**√s dep.**)

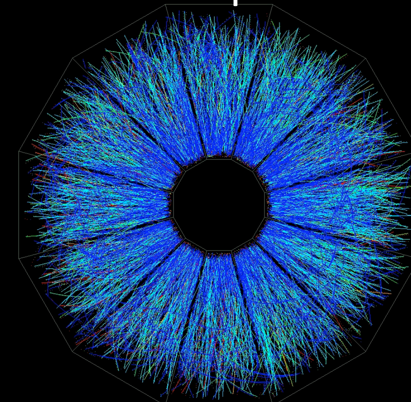
PRL 96, 166101 (2006) PHYSICAL REVIEW LETTERS week ending 28 APRIL 2006
Appl Phys A (2008) 92: 837–841
Applied Physics A

Microexplosion



measure geometry
infer momentum

Femtoexplosion



measure momentum
infer geometry

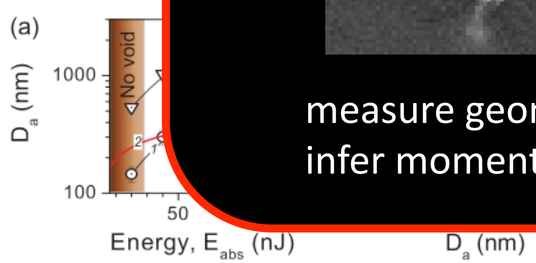


FIG. 3 (color). (a) The diameter (1) and length (3) of the amorphous region vs the absorbed pulse energy, E_{abs}. The voids were 20 μm beneath the surface. Curve (2) plotted by Eq. (1) with l_a = 80 nm. (b) Dependence of the void diameter on the diameter of amorphous part: (1) theory by Eq. (2) with δ = 1.14; (2) experiment.

main of extreme parameters

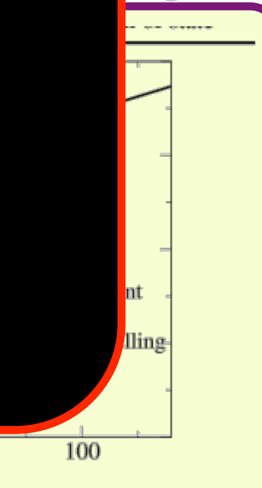


Fig. 9 Cavity diameter on the laser energy in silica, simple modeling (*circles*) [2], IL0005 EOS (*diamond shapes*) and experiment (*triangles*)

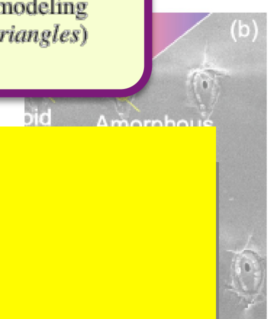
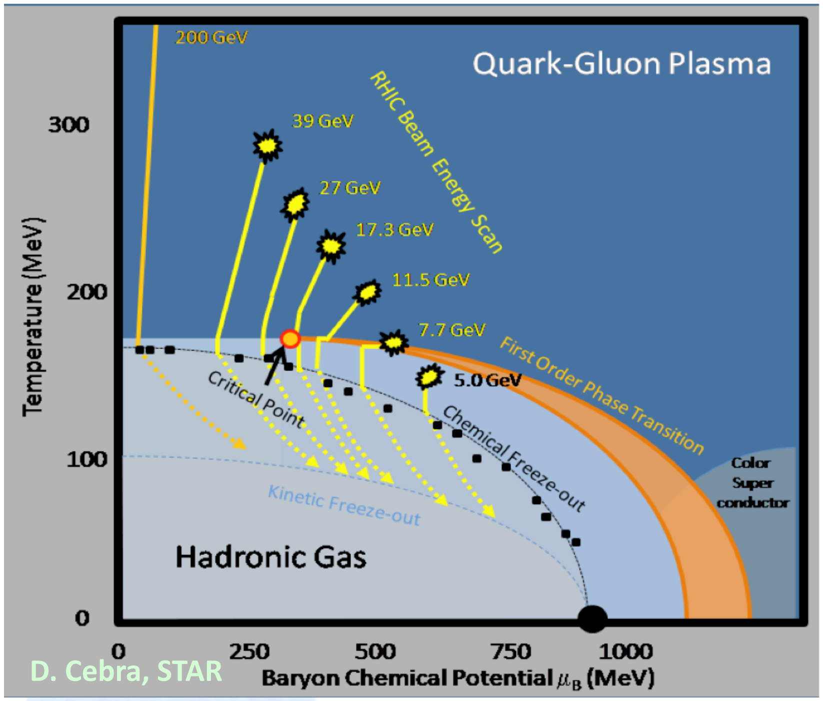


Table 1 SESAME 7387, QEOS and home-made IL type EOS parameters

EOS name	G	E_{sub} (MJ/kg)
QEOS	1.5	≈0.01
SESAME 7387	0.65	10
IL0005	0.03	17
IL0006	0.03	28
IL0007	0.03	8

- energy quickly deposited
- transition to deconfined (plasma) phase
- hydrodynamic expansion
- cool back to confined (atomic) phase
- probe **EoS** under extreme conditions (**√s dep.**)
- examine final shape/size of system



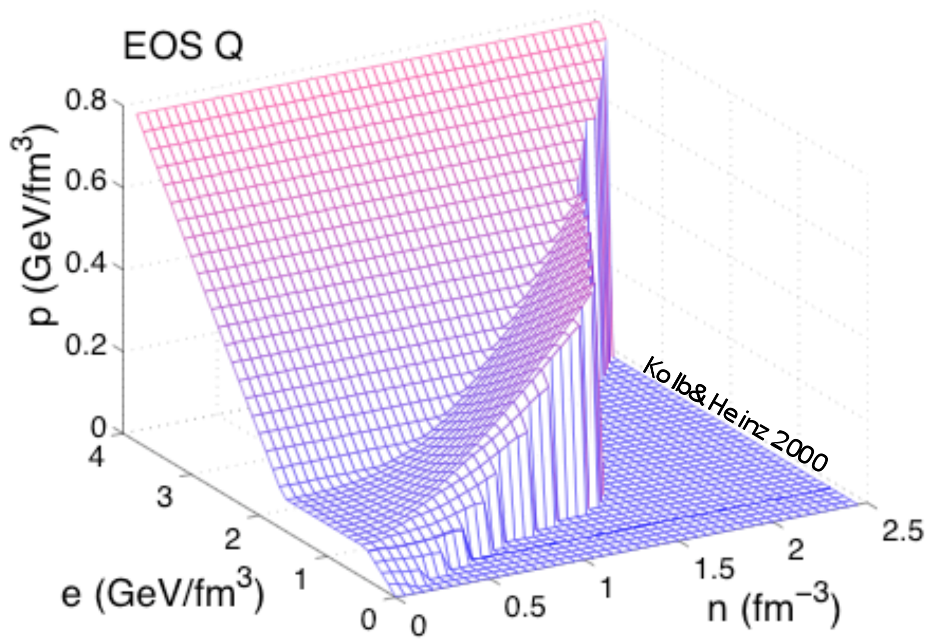
RHIC energy scan: √s=7-40 GeV (2010~2012 (?))

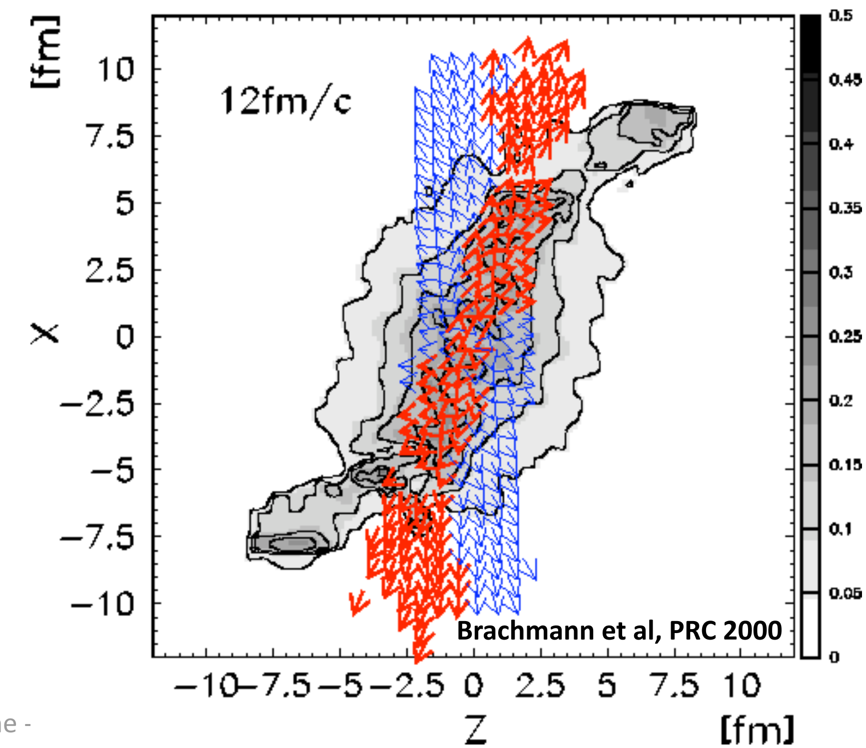
Probe QCD phase diagram via

- statistics/fluctuations

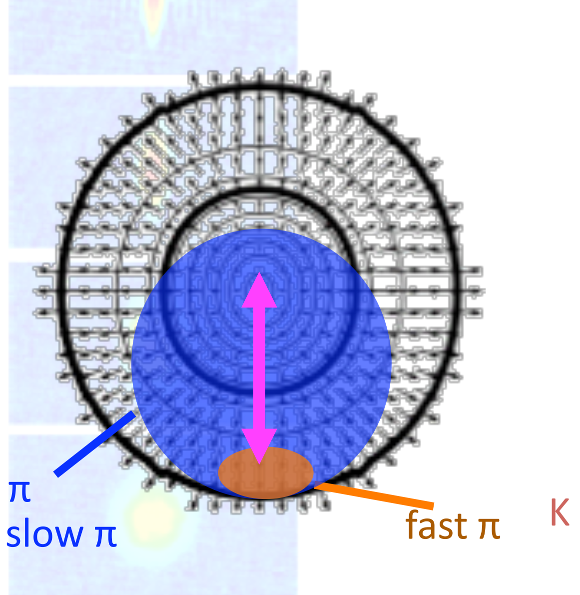
✓ dynamic system response

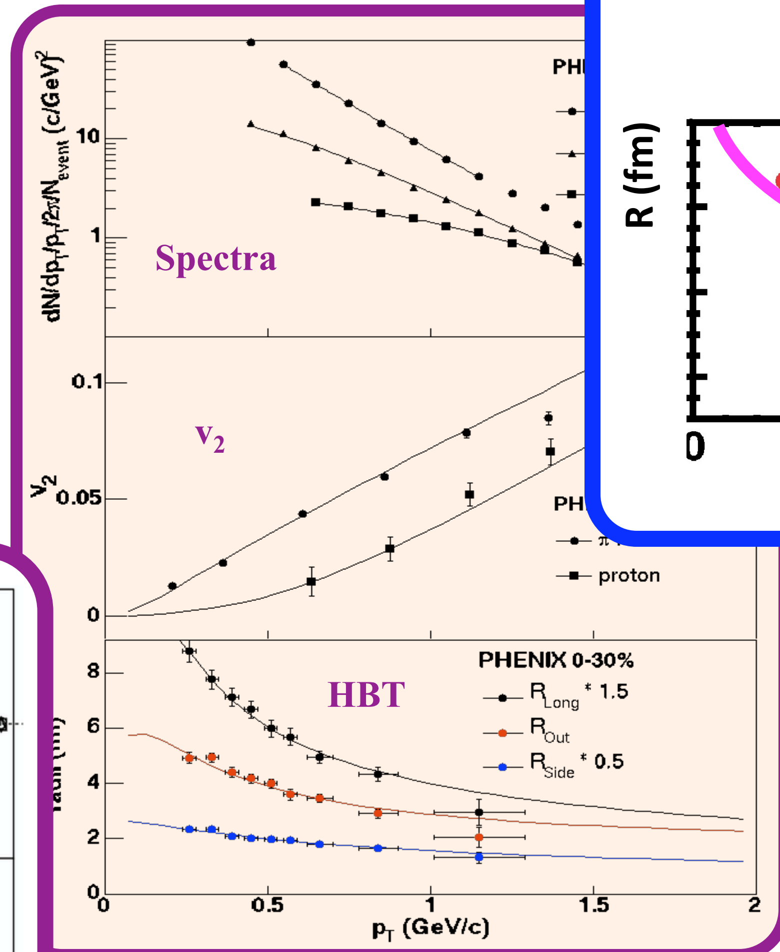
  - transport models (phase structure in EoS)
  - bulk collectivity (low-p_T measurements)

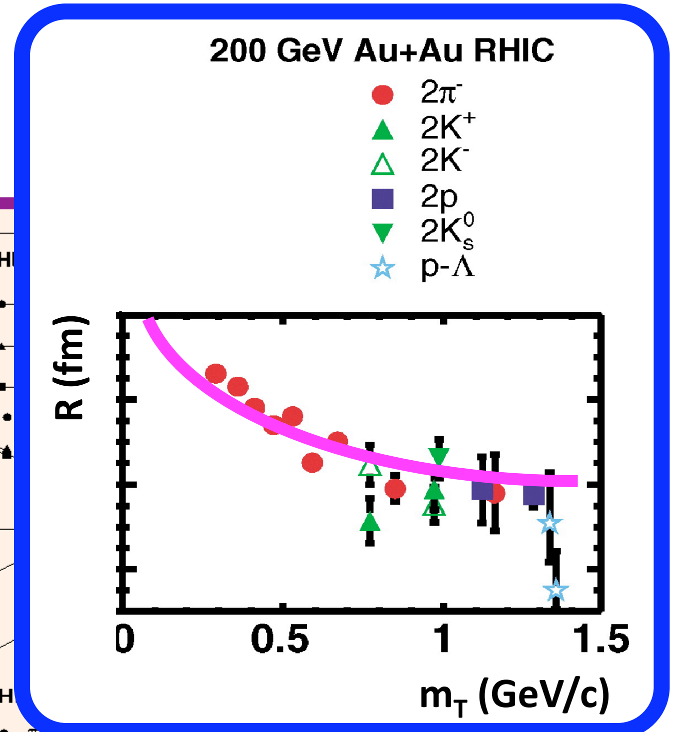


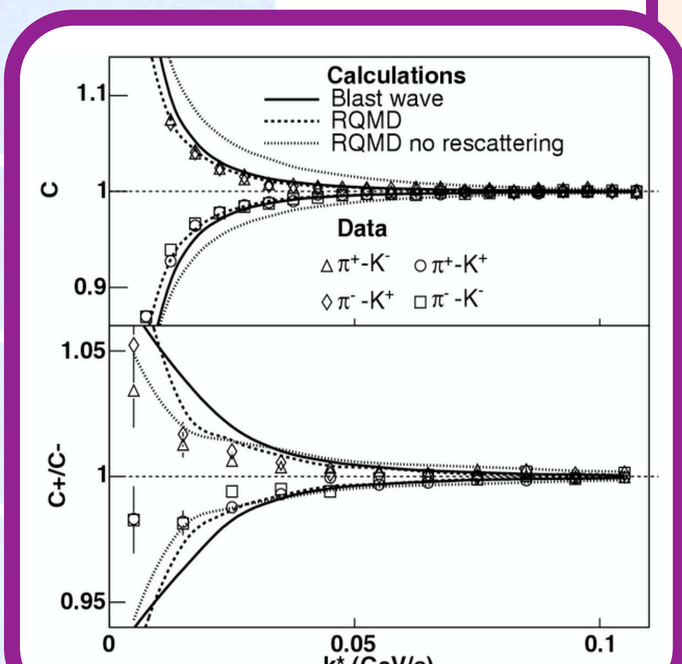


R(m_T) – spatial aspect of radial flow





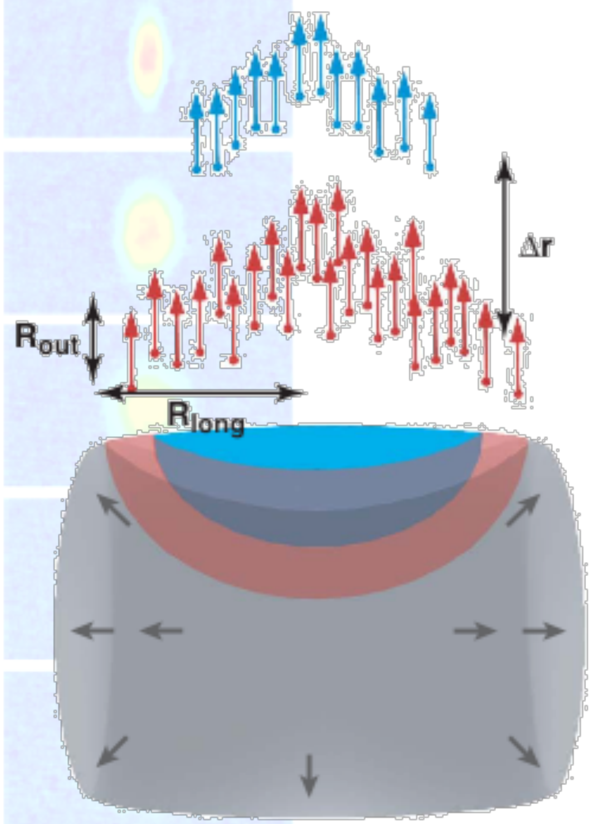


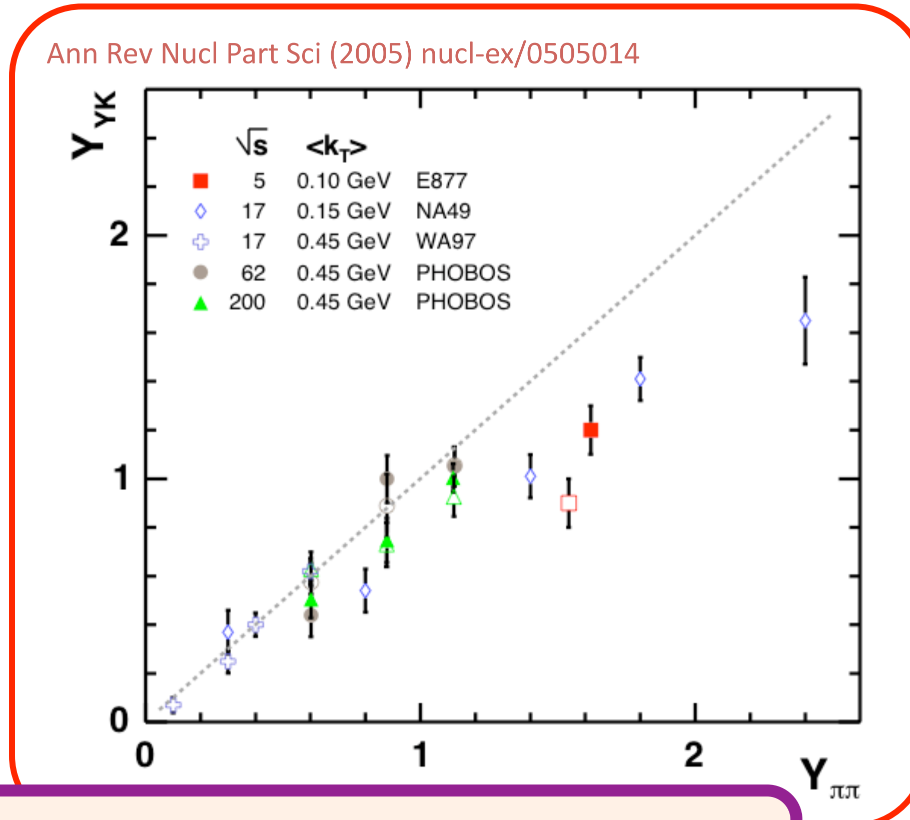


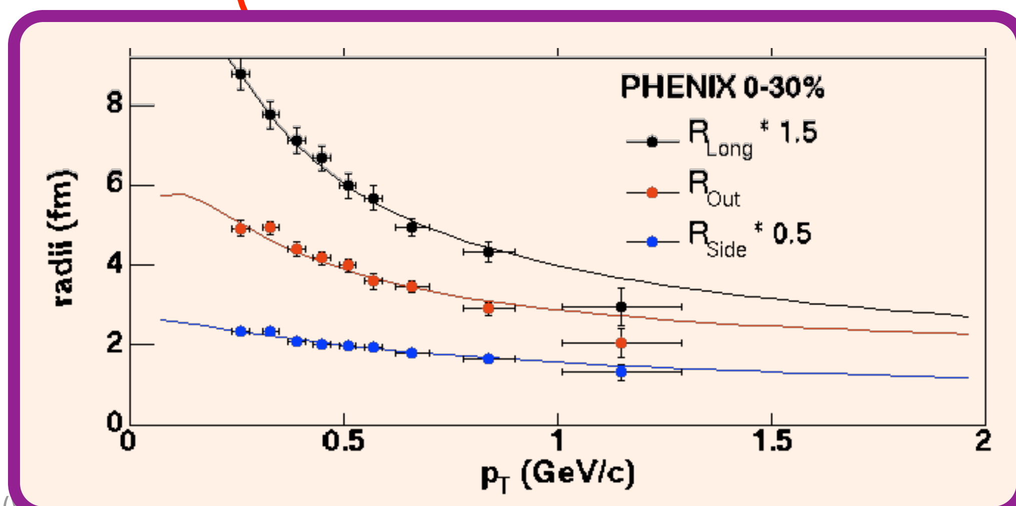
STAR PRL 91 262301 (2003)

(radial) space-momentum substructure mapped *in detail*

strong longitudinal flow (not necc B.I.)



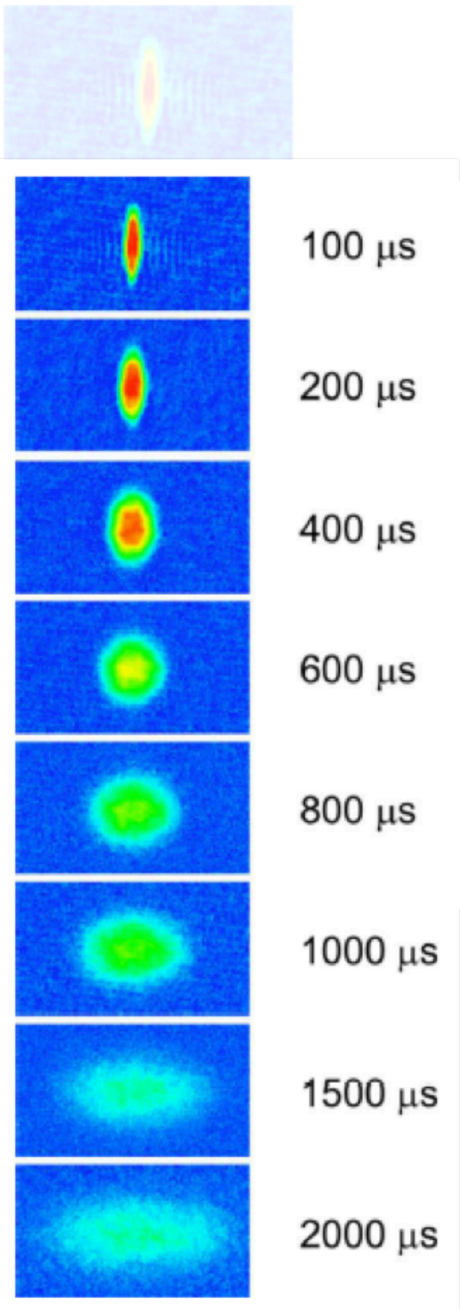




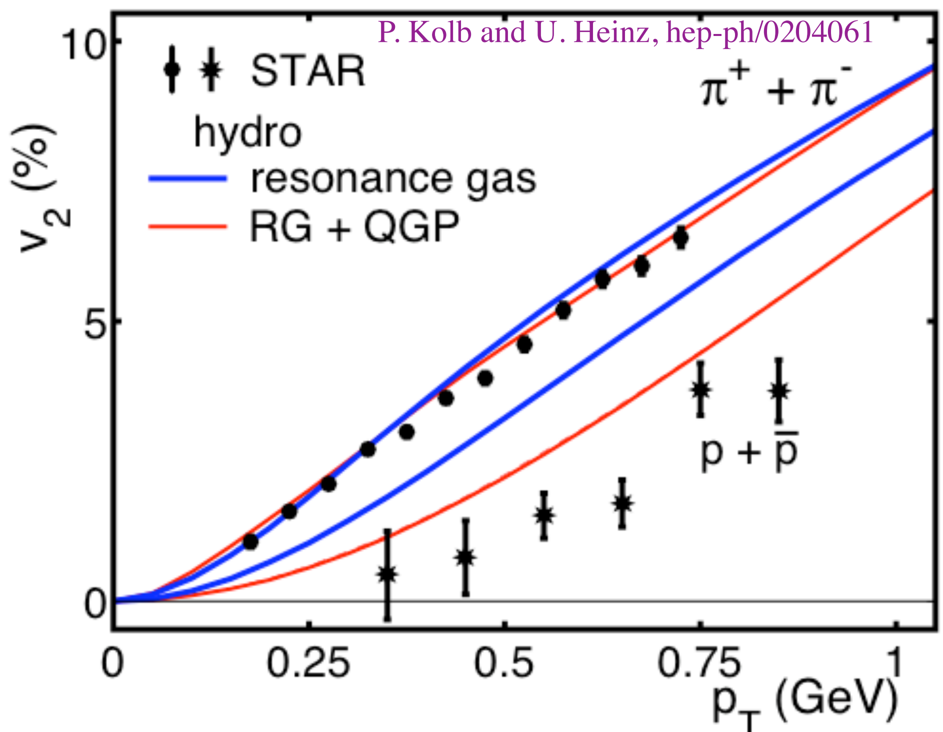
Also: $R_{ol}^2(y, p_T)$

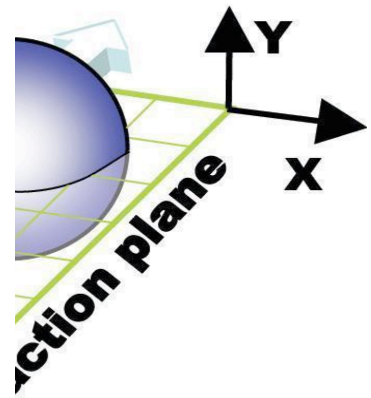
less attention to longitudinal d.o.f. in HBT

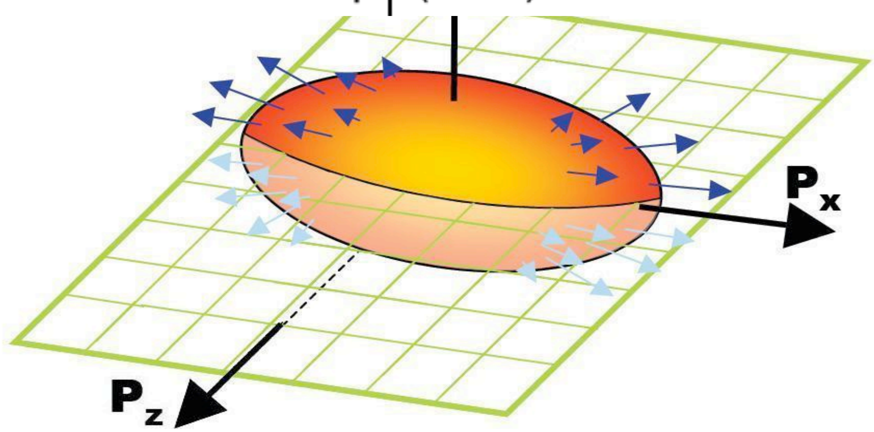
phi- the sexy direction



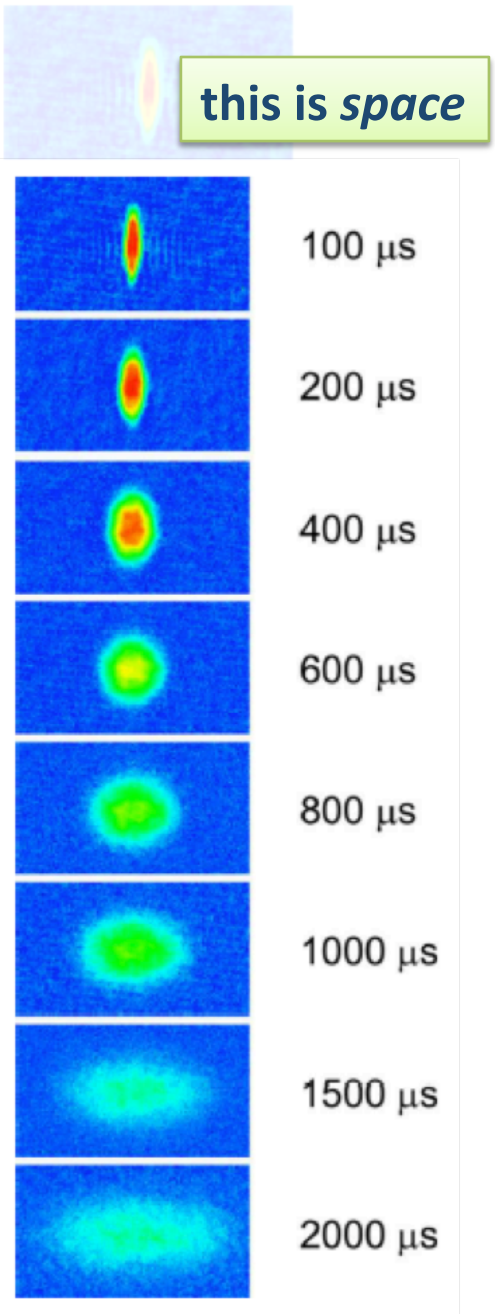
O'Hara et al, *Science* 2002



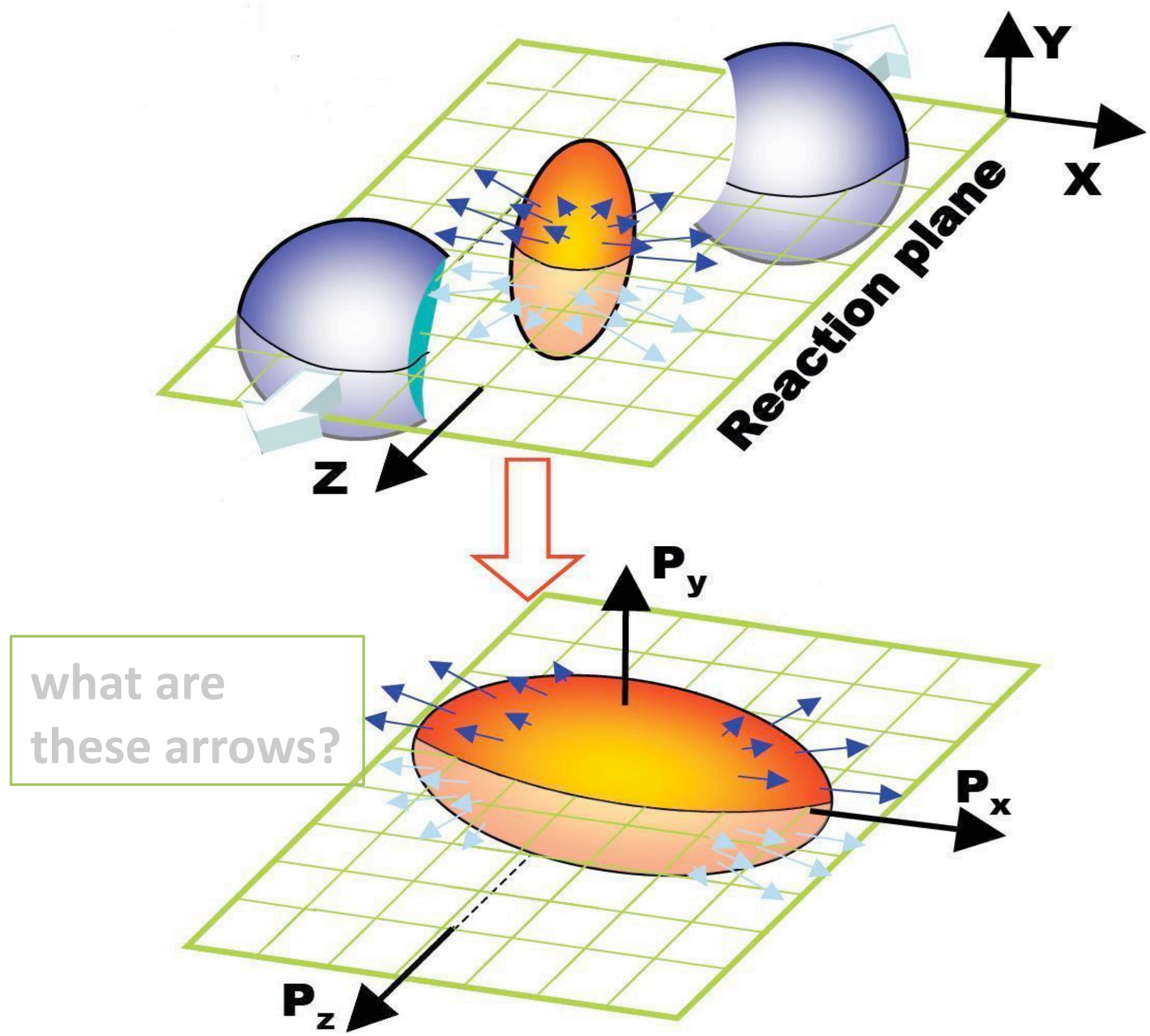




phi- the sexy direction

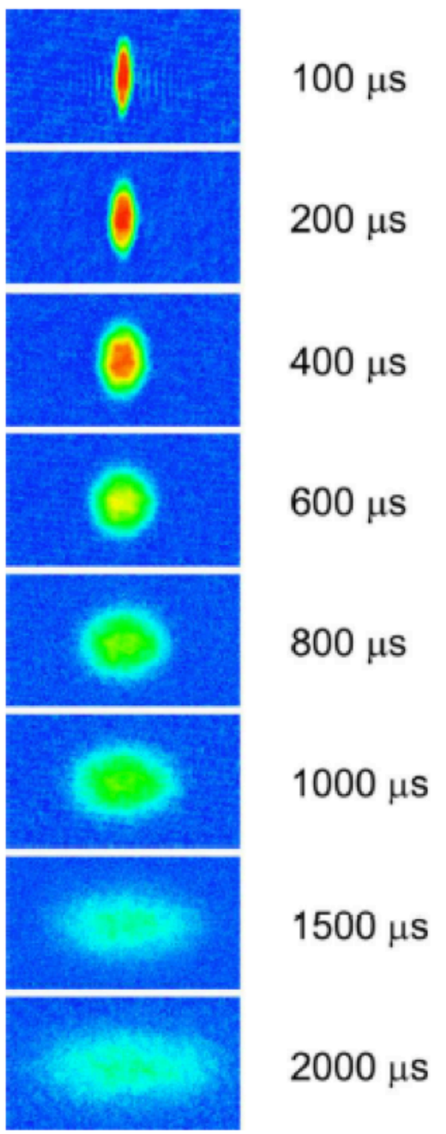


O'Hara et al, *Science* 2002



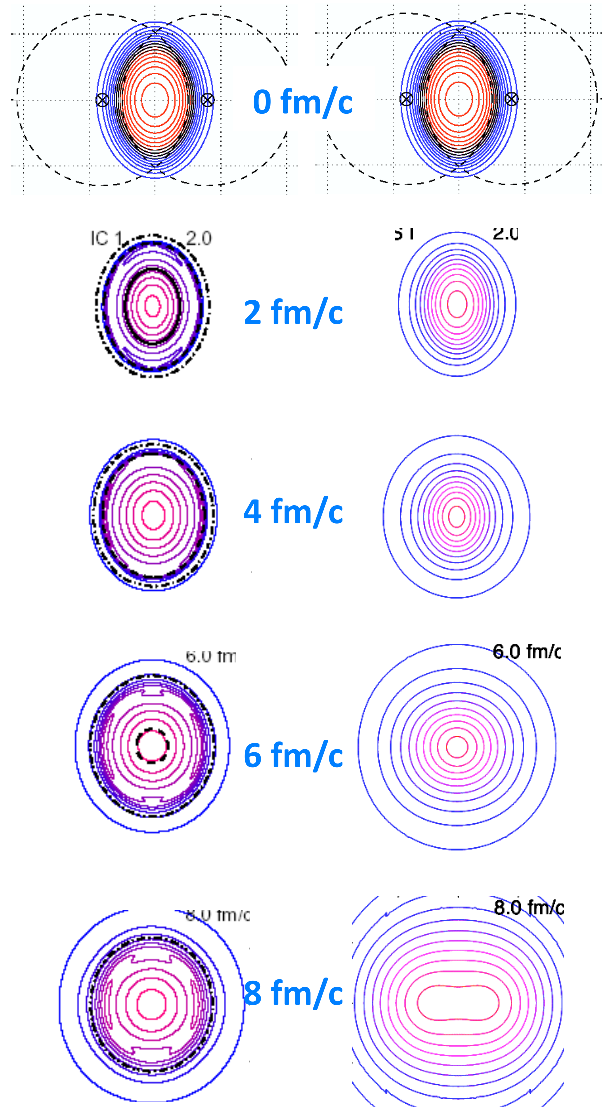
phi- the sexy direction

ultra-cold atoms



O'Hara et al, *Science* 2002

ultra-hot partons



EoS w/PT

EoS w/o PT

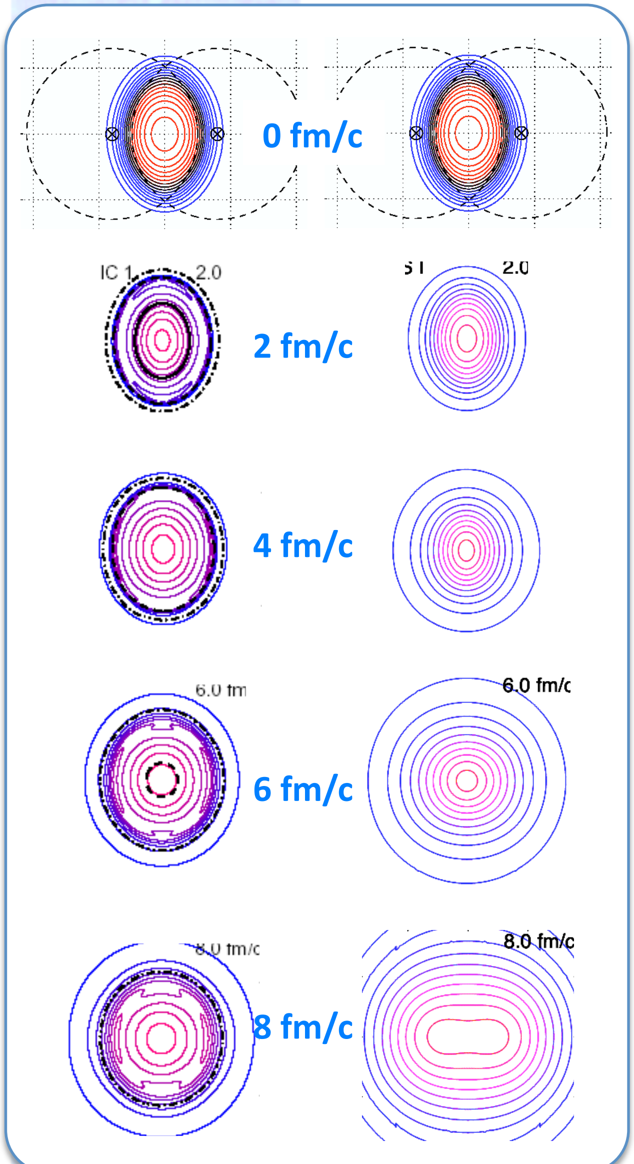
P Kolb, PhD 2002

evolution from initial "known" shape depends on

- pressure anisotropy ("stiffness")
- lifetime *

* O'Hara could *choose* when to destroy his system

phi- the sexy direction



evolution from initial "known" shape depends on

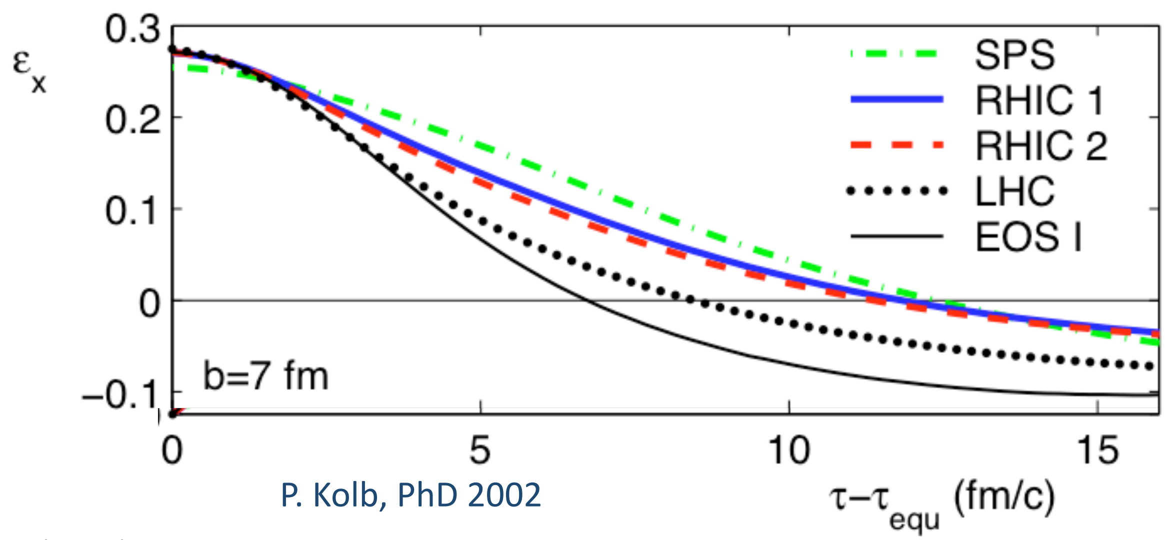
- pressure anisotropy ("stiffness")
- lifetime

Both are interesting!

We will measure a convolution over freezeout

- model needed

$$\varepsilon \equiv \frac{\langle y^2 \rangle - \langle x^2 \rangle}{\langle y^2 \rangle + \langle x^2 \rangle}$$

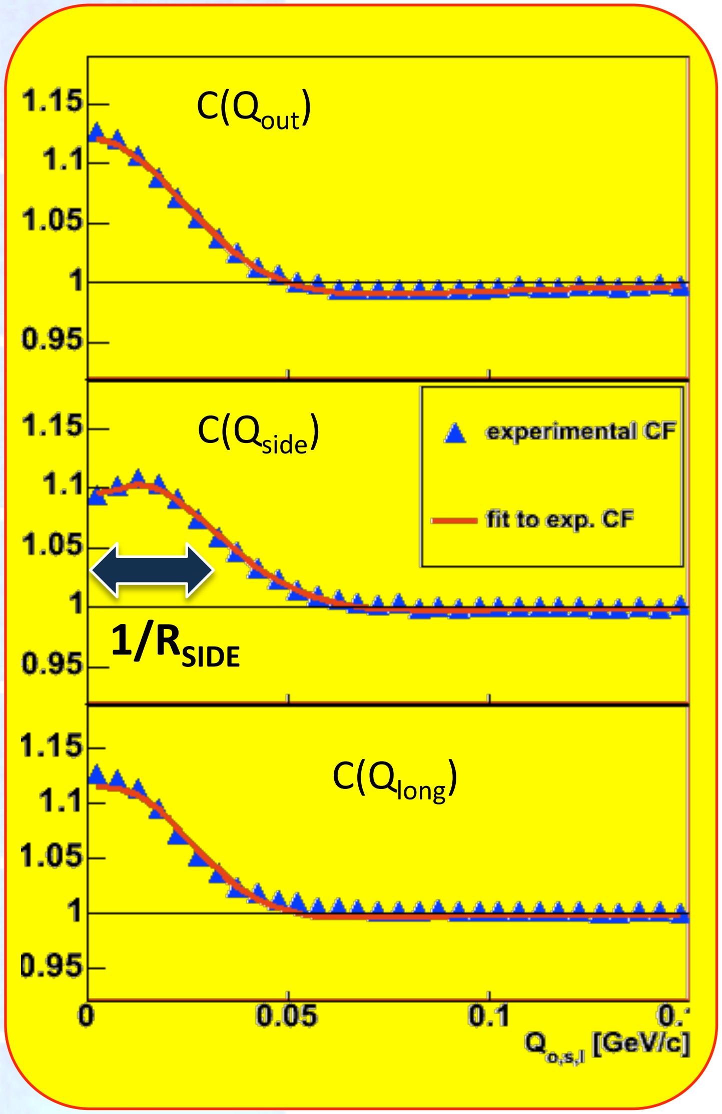


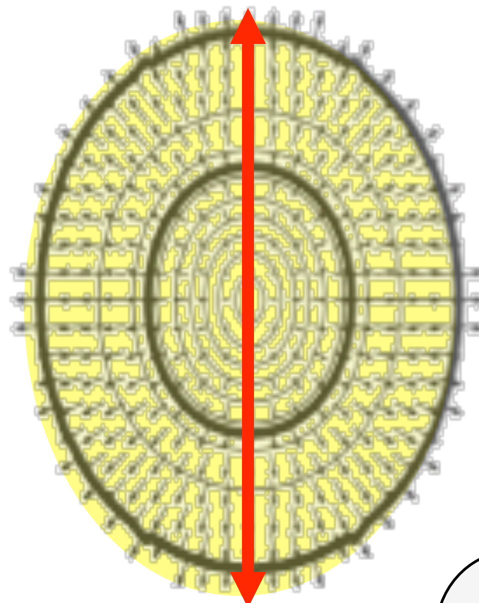
P. Kolb, PhD 2002

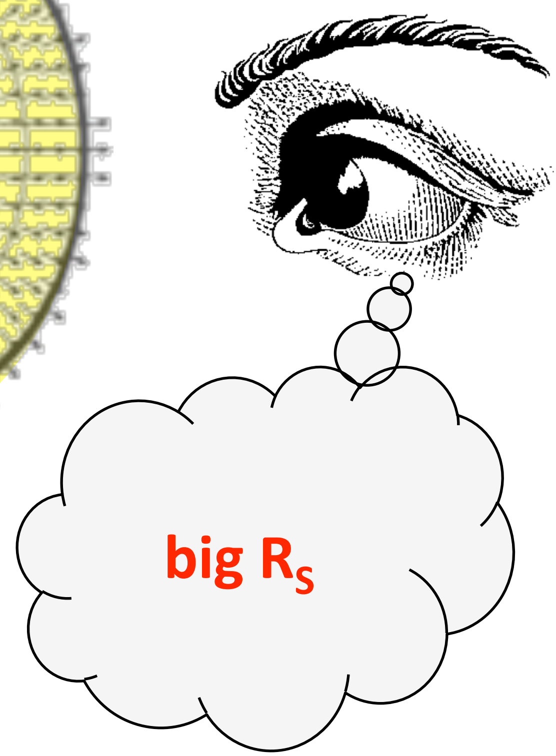
measuring lengths

$$C(\vec{q}) = N \cdot \left[1 + \lambda \cdot \left(K_{coul}(\vec{q}) \cdot \left\{ 1 + e^{-\left(q_o^2 R_o^2 + q_s^2 R_s^2 + q_l^2 R_l^2\right)} \right\} - 1 \right) \right]$$

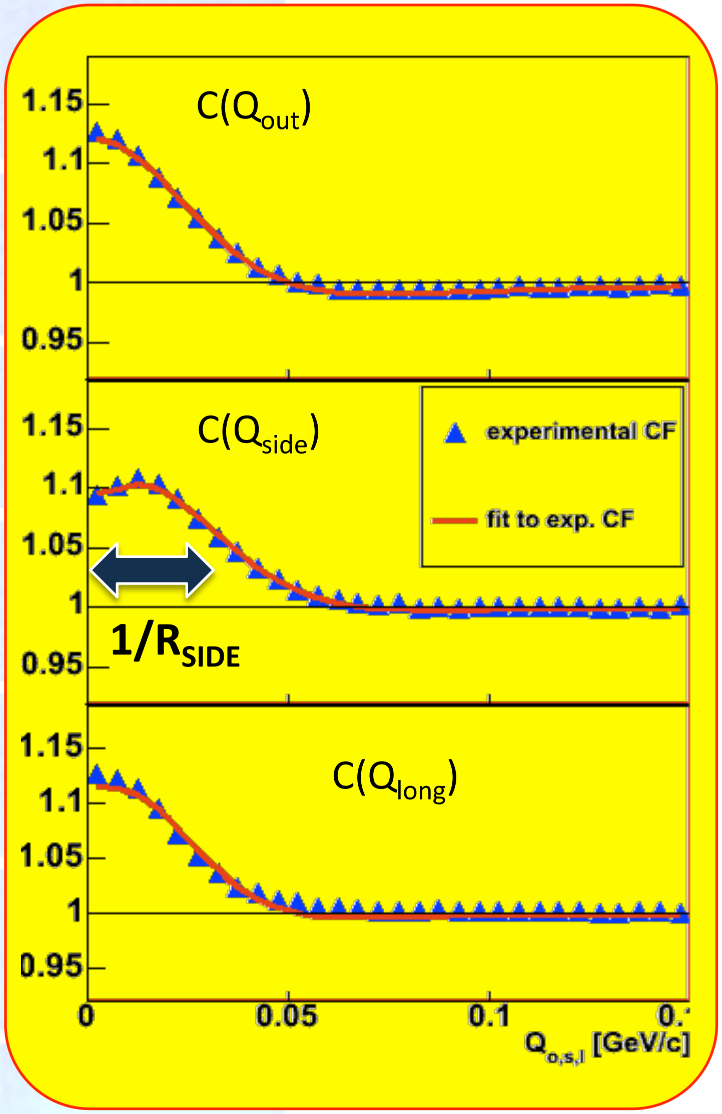
typical “Gaussian” fitting function

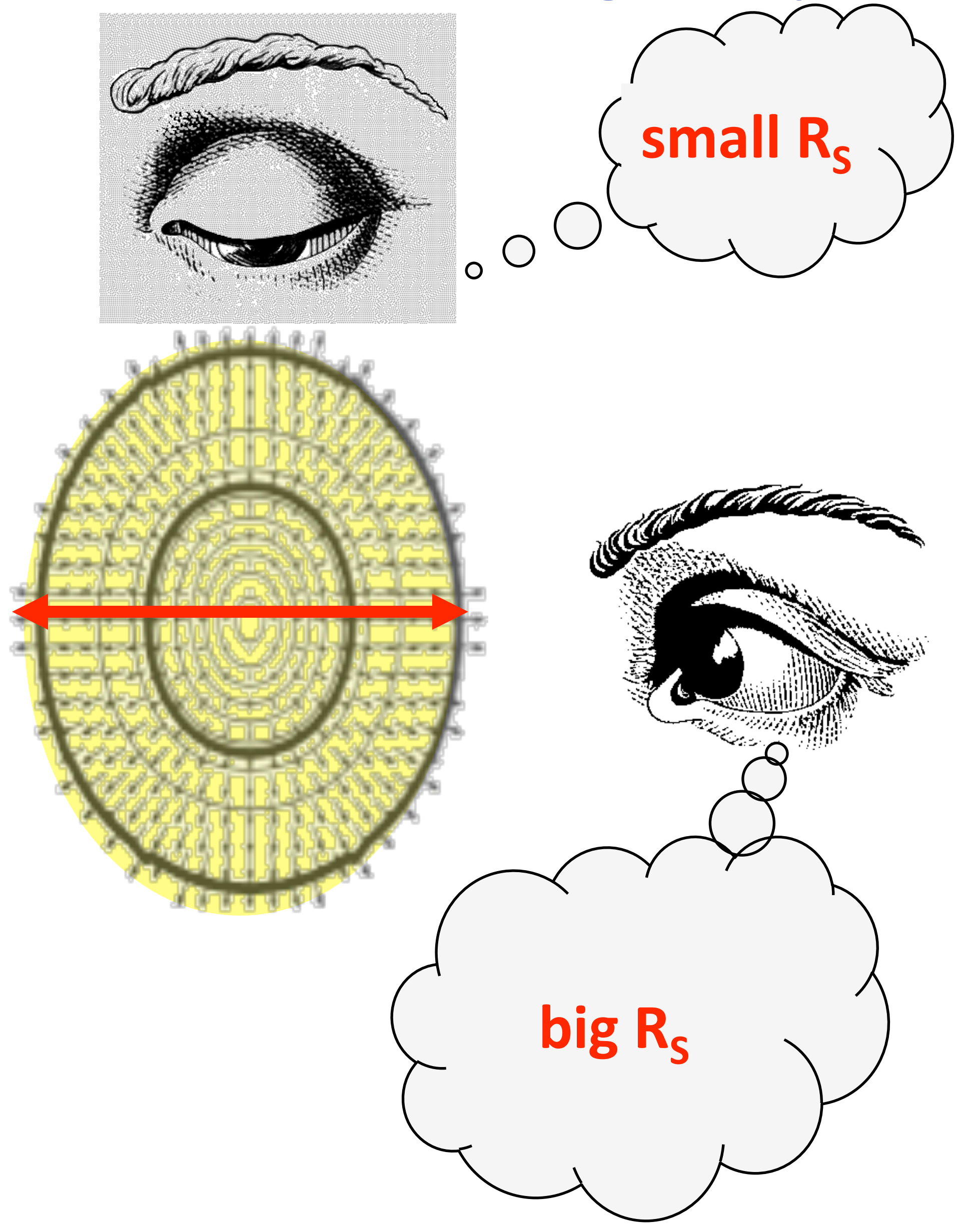




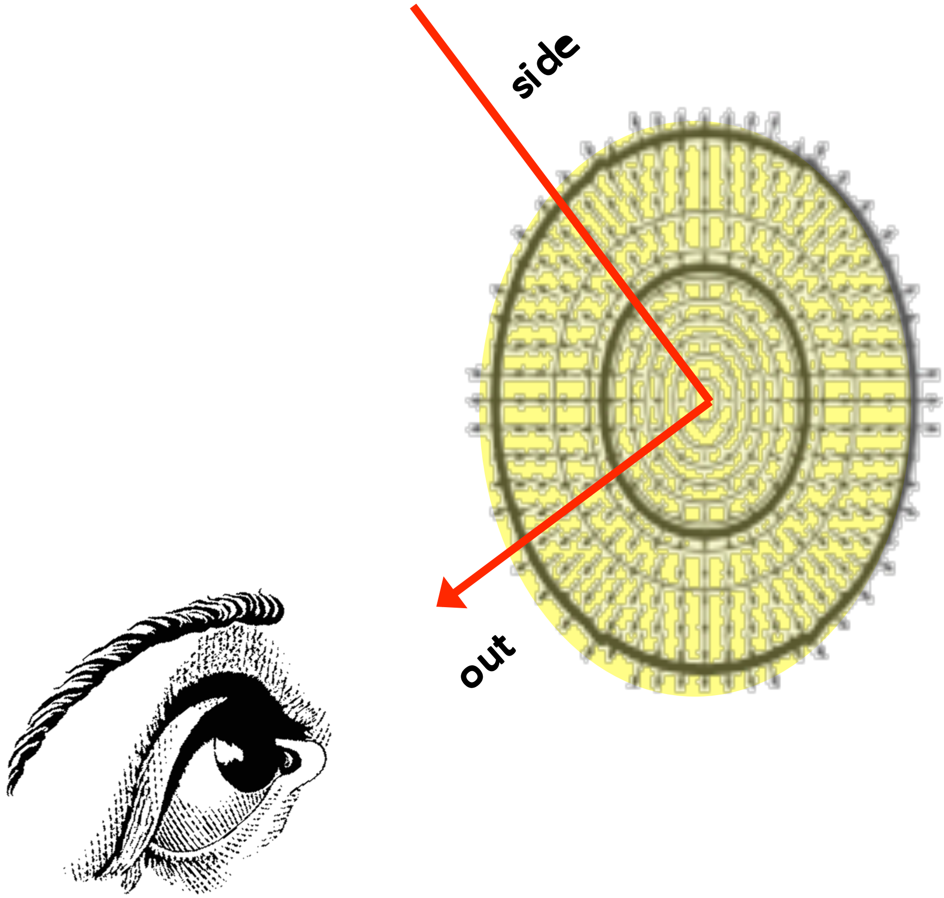


measuring shape





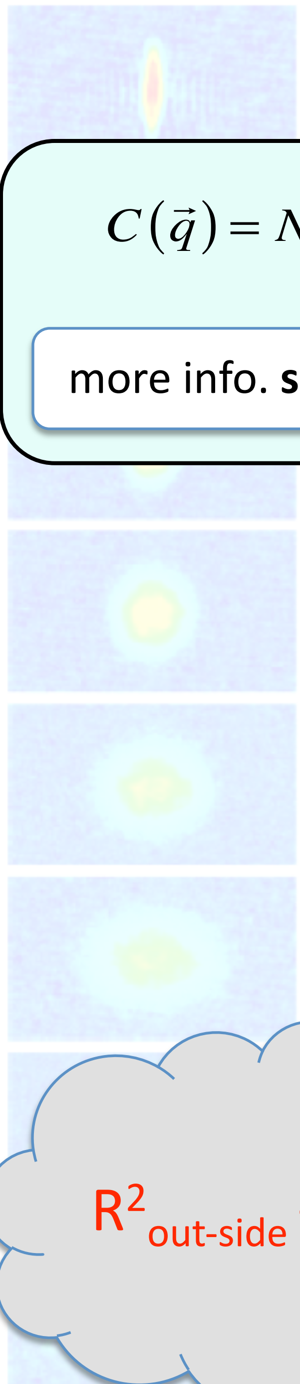
measuring shape

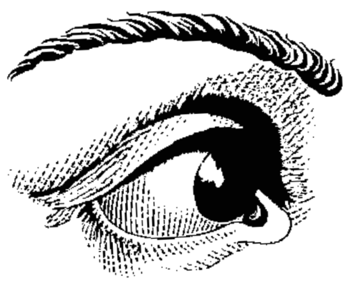


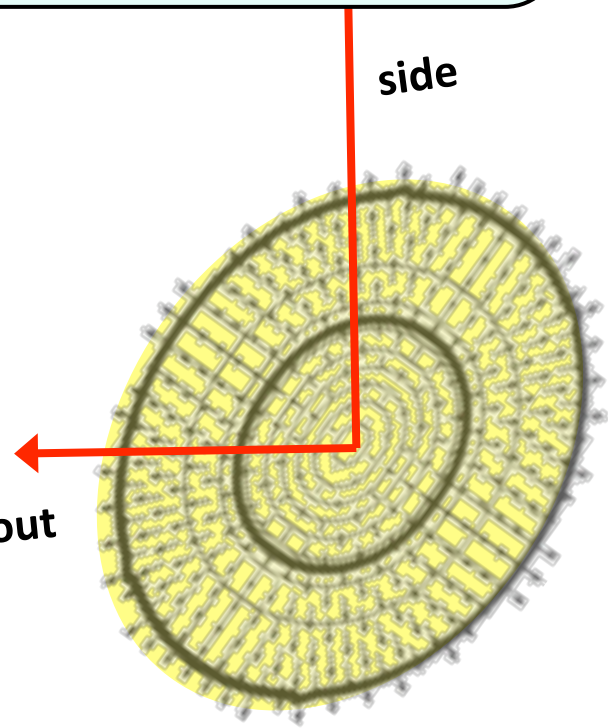
measuring shape

$$C(\vec{q}) = N \cdot \left[1 + \lambda \cdot \left(K_{coul}(\vec{q}) \cdot \left\{1 + \exp\left(-q_i q_j R_{ij}^2\right)\right\} - 1\right)\right]$$

more info. **six** “HBT radii” $R_o^2, R_s^2, R_l^2, R_{os}^2, R_{sl}^2, R_{ol}^2$





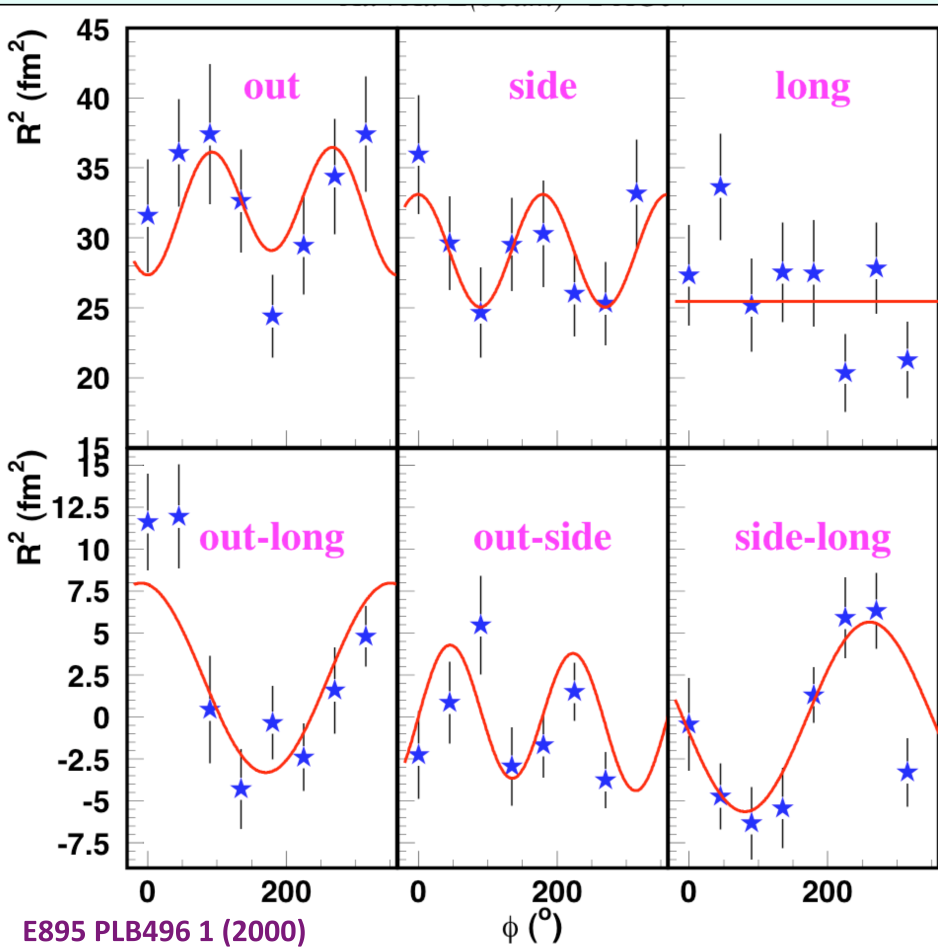


$R^2_{out\text{-}side} < 0$

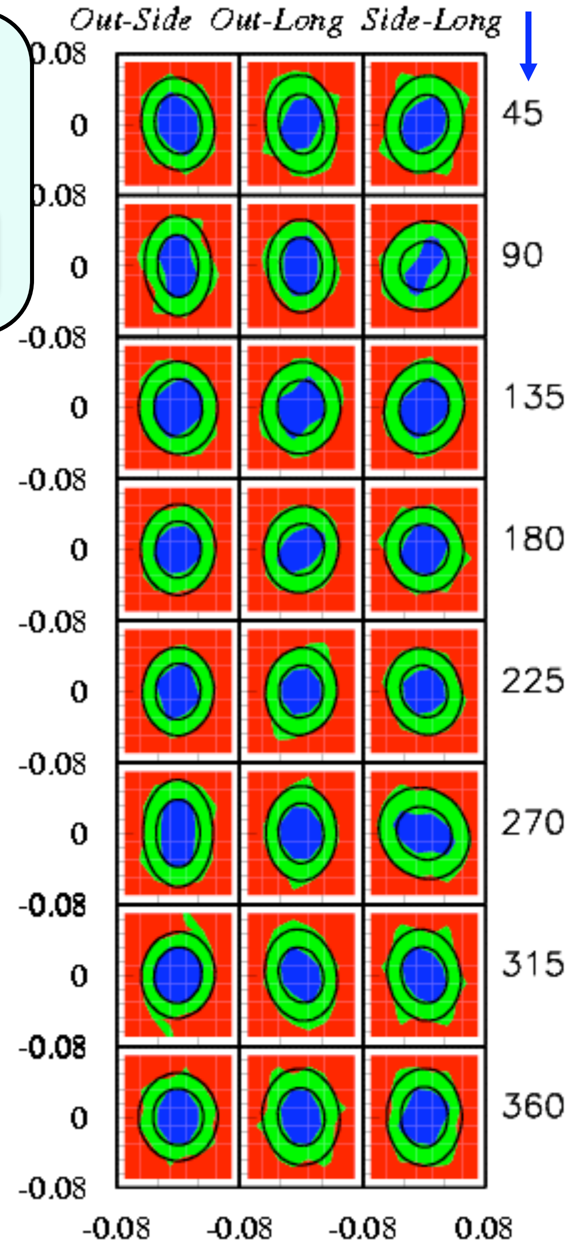
measuring shape

$$C(\vec{q}) = N \cdot \left[1 + \lambda \cdot \left(K_{coul}(\vec{q}) \cdot \left\{1 + \exp\left(-q_i q_j R_{ij}^2\right)\right\} - 1\right)\right]$$

more info. **six** “HBT radii” $R_o^2, R_s^2, R_l^2, R_{os}^2, R_{sl}^2, R_{ol}^2$



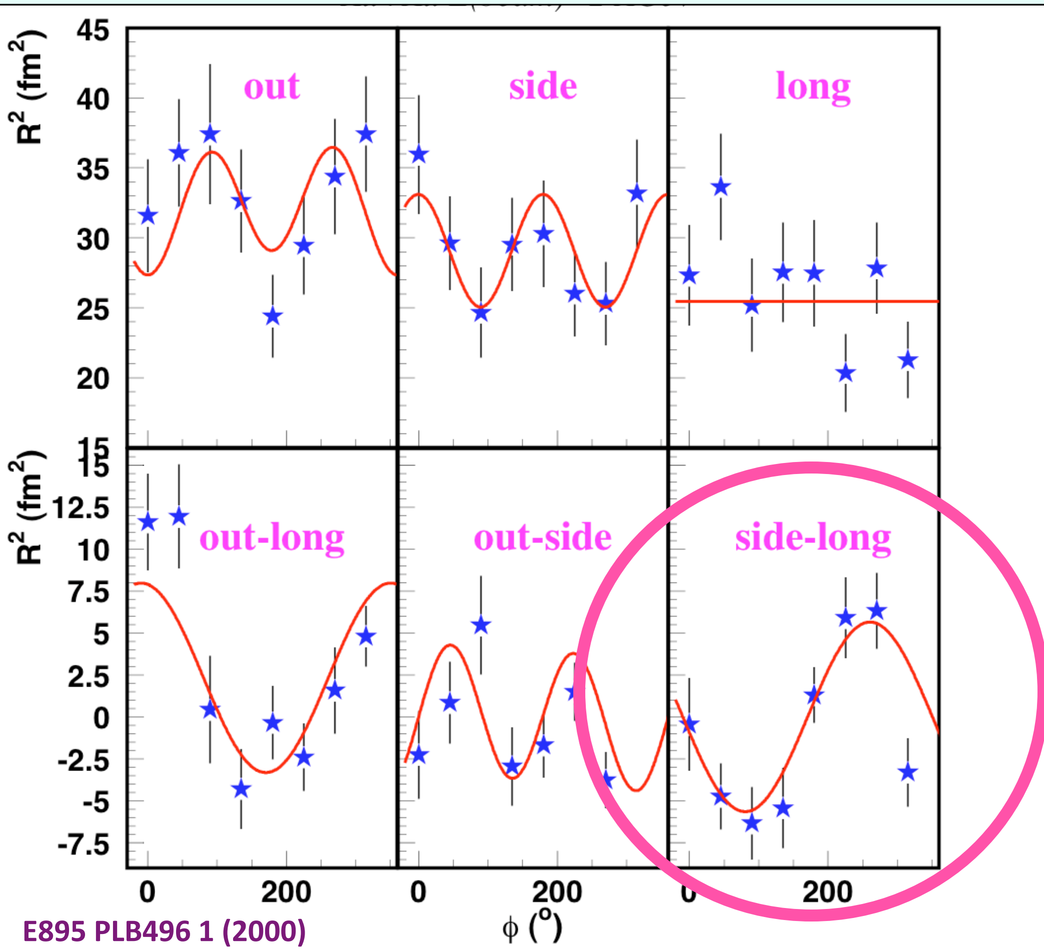
E895 PLB496 1 (2000)



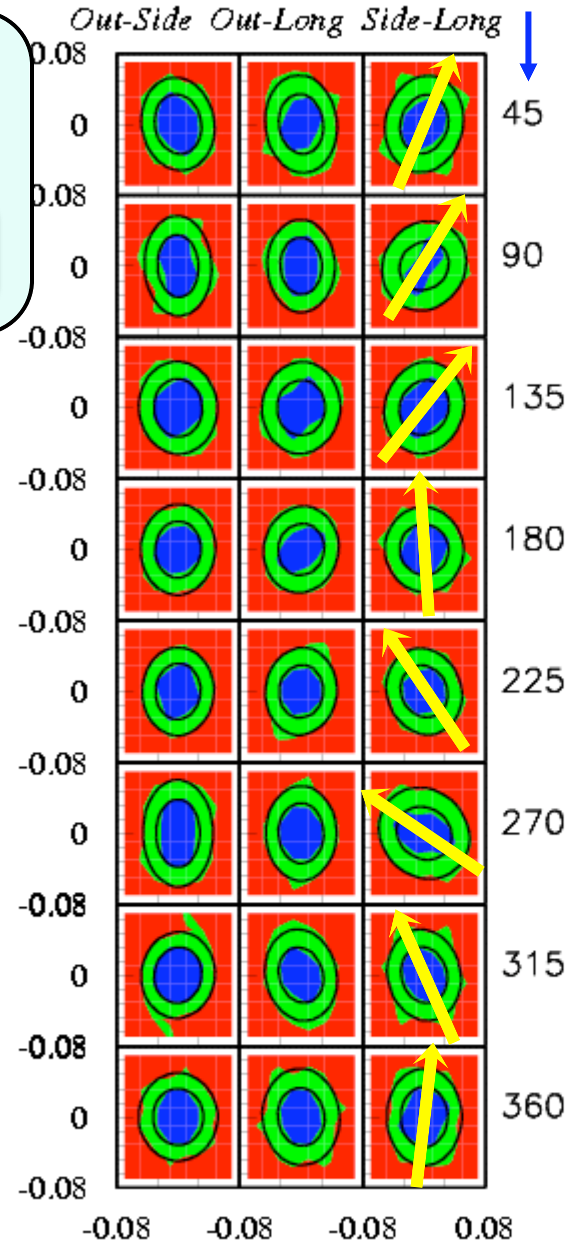
measuring shape

$$C(\vec{q}) = N \cdot \left[1 + \lambda \cdot \left(K_{coul}(\vec{q}) \cdot \left\{1 + \exp\left(-q_i q_j R_{ij}^2\right)\right\} - 1\right)\right]$$

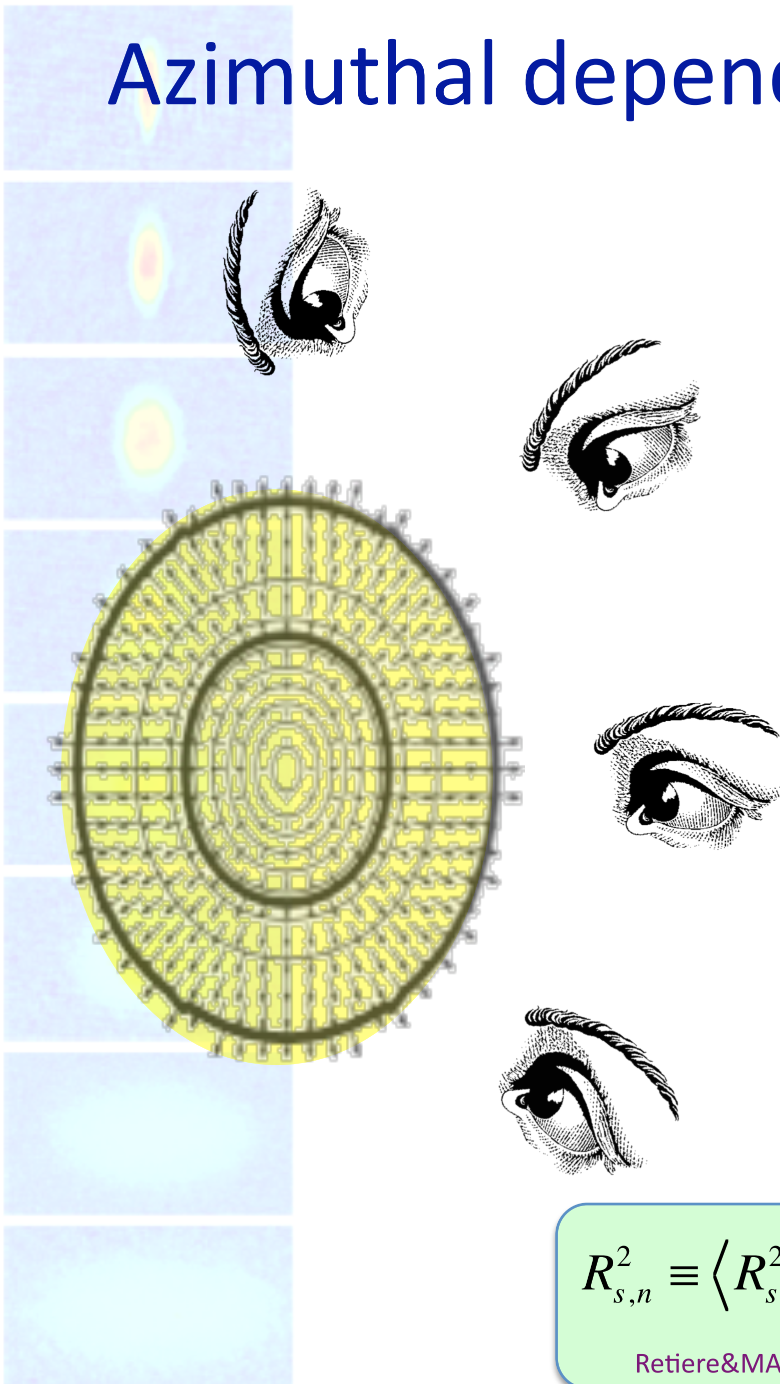
more info. **six** “HBT radii” $R_o^2, R_s^2, R_l^2, R_{os}^2, R_{sl}^2, R_{ol}^2$



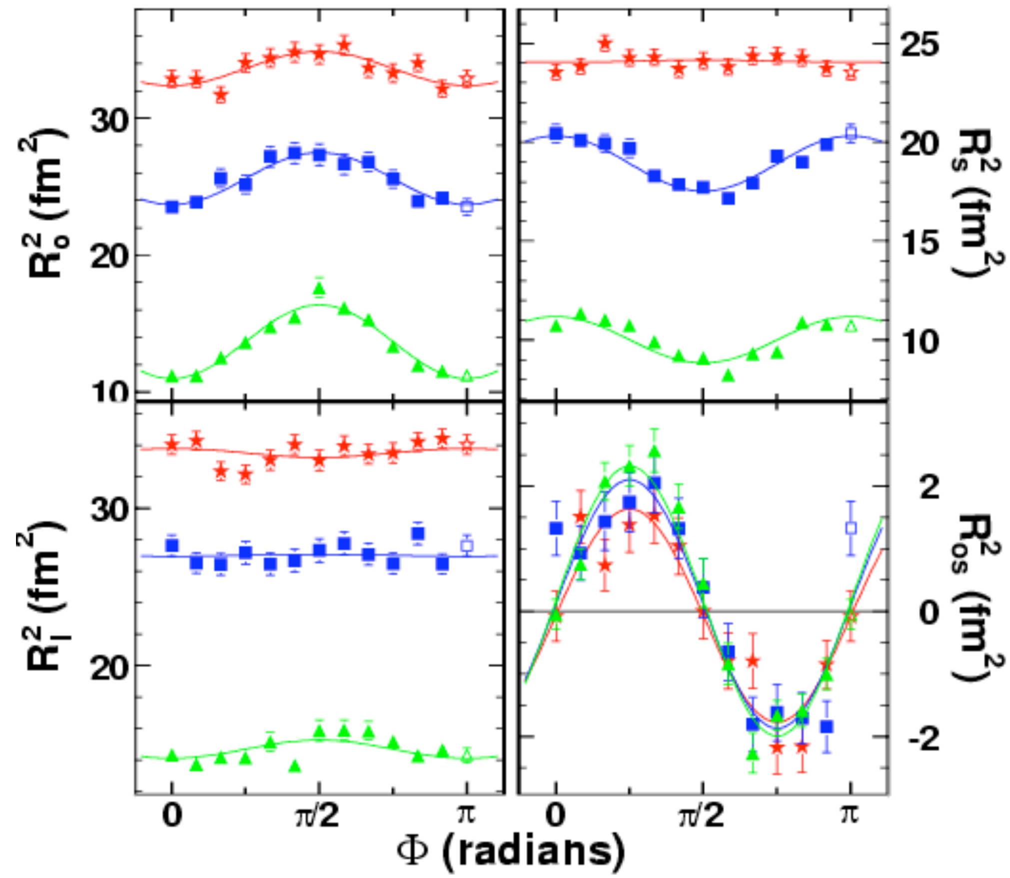
E895 PLB496 1 (2000)



Azimuthal dependence of HBT radii at RHIC



STAR, PRL93 012301 (2004)



$$R^2_{s,n} \equiv \left\langle R^2_s(\phi) \cdot \cos(n\phi) \right\rangle \qquad \varepsilon \approx 2\frac{R^2_{s,2}}{R^2_{s,0}} \approx 2\frac{R^2_{os,2}}{R^2_{s,0}} \approx -2\frac{R^2_{o,2}}{R^2_{s,0}}$$

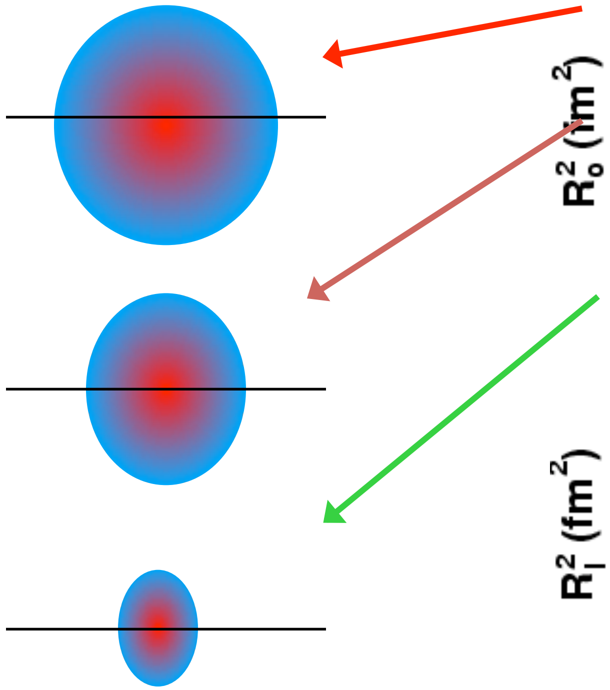
Retiere&MAL PRC70 (2004) 044907

expected systematics

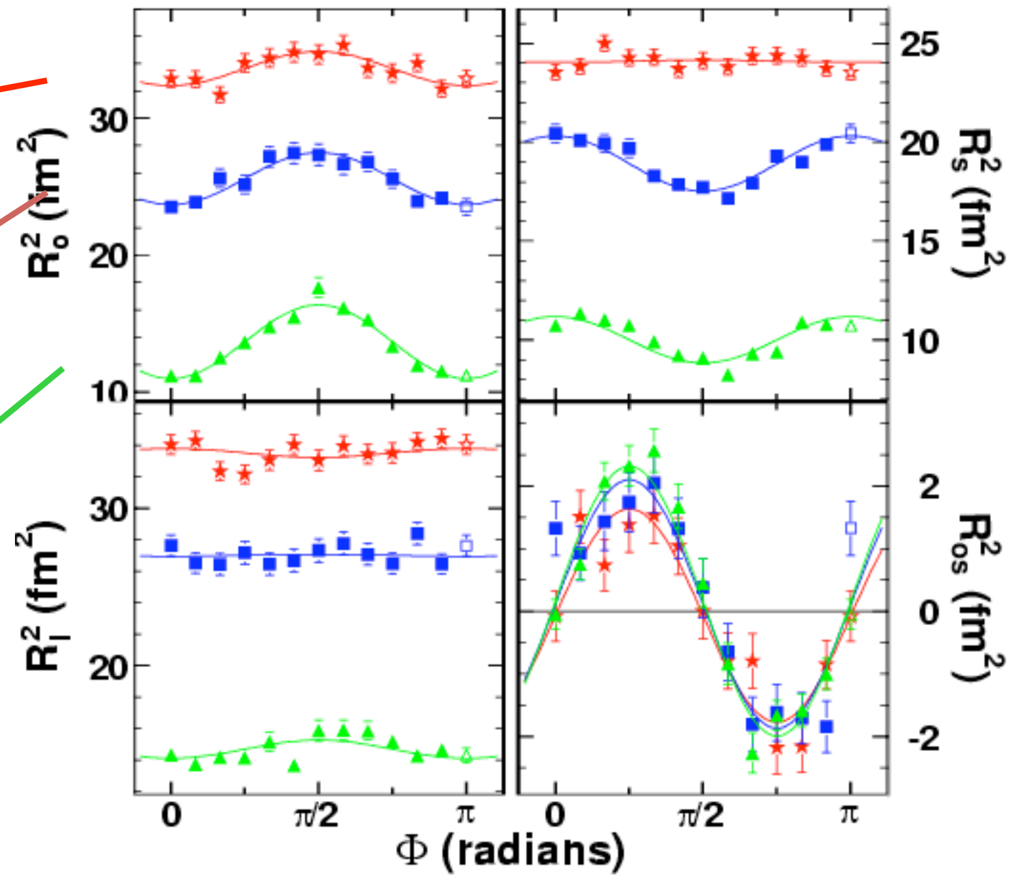
central collisions

mid-central collisions

peripheral collisions



STAR, PRL93 012301 (2004)

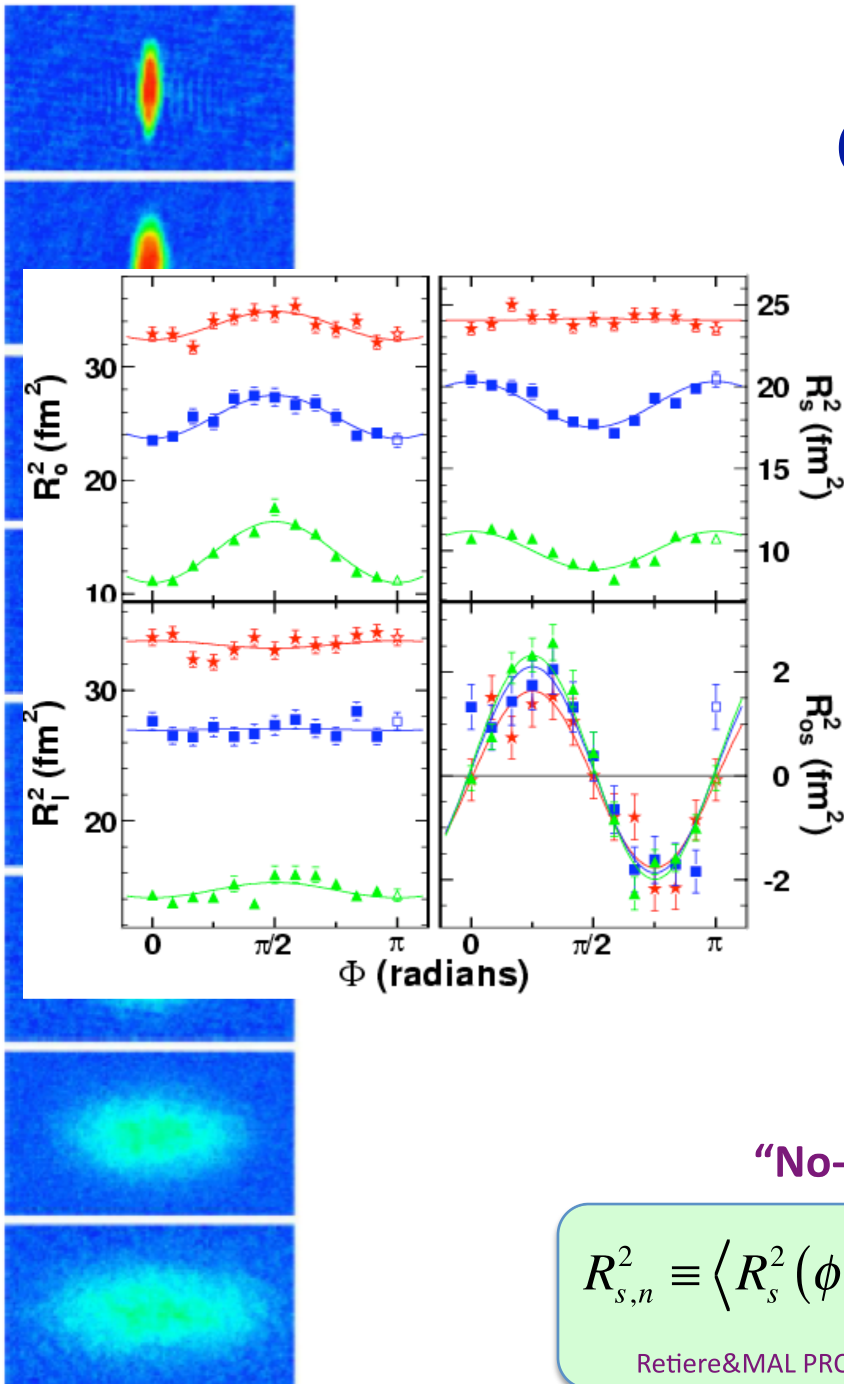


"No-flow formula" estimated good within ~ 30% (low pT)

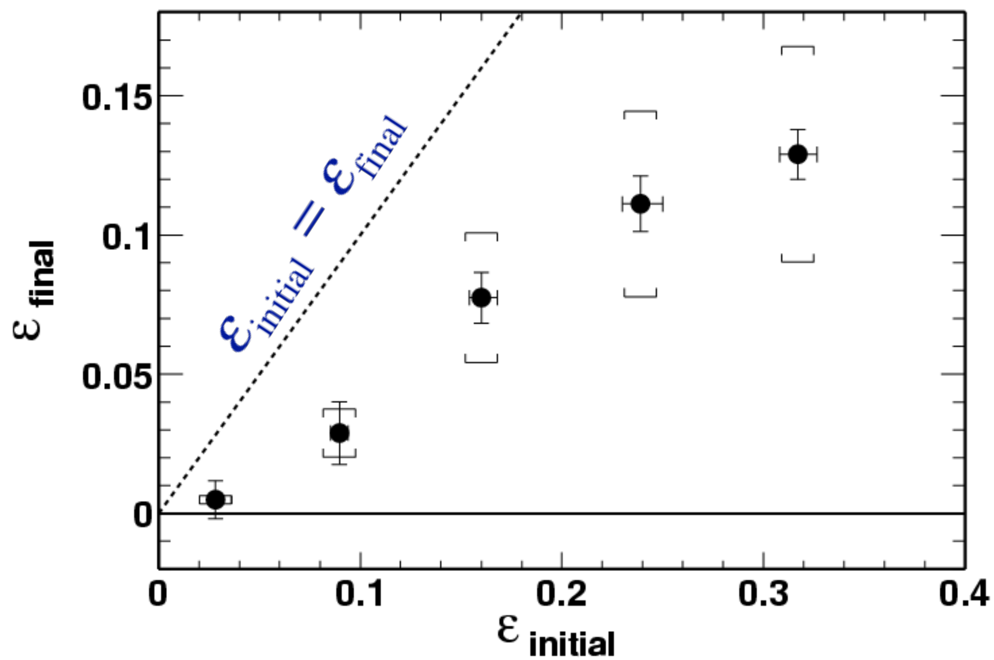
$$R^2_{s,n} \equiv \left\langle R_s^2(\phi)\cdot\cos(n\phi)\right\rangle \qquad \varepsilon \approx 2\frac{R^2_{s,2}}{R^2_{s,0}} \approx 2\frac{R^2_{os,2}}{R^2_{s,0}} \approx -2\frac{R^2_{o,2}}{R^2_{s,0}}$$

Retiere&MAL PRC70 (2004) 044907

“Spatial elliptic flow”: Centrality Evolution at RHIC



STAR PRL93 012301 (2004)



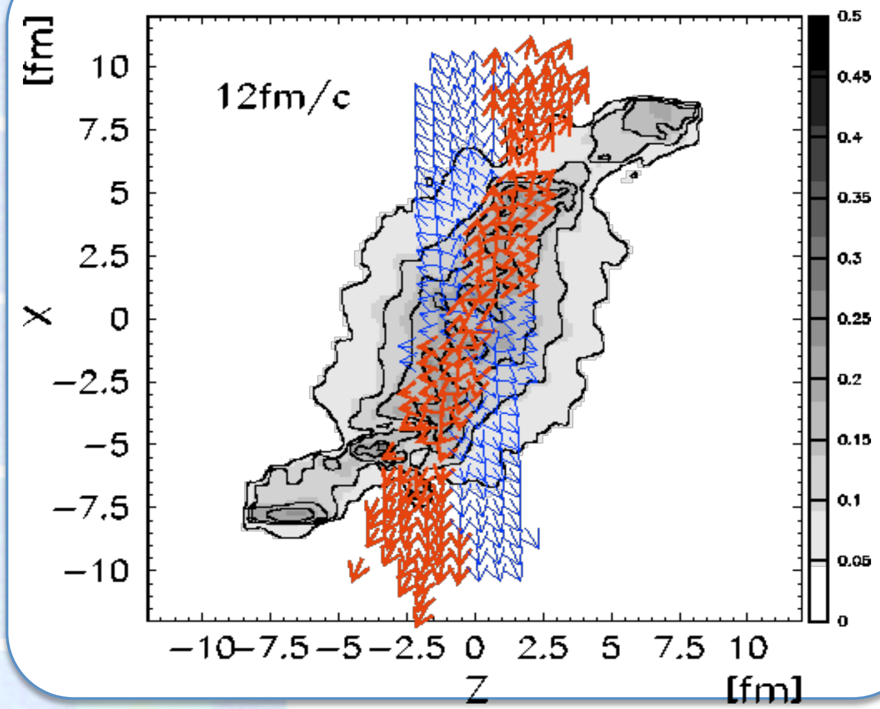
“No-flow formula” estimated good within ~ 30% (low pT)

$$R_{s,n}^2 \equiv \left\langle R_s^2(\phi)\cdot\cos(n\phi)\right\rangle \qquad \varepsilon \approx 2\frac{R_{s,2}^2}{R_{s,0}^2} \approx 2\frac{R_{os,2}^2}{R_{s,0}^2} \approx -2\frac{R_{o,2}^2}{R_{s,0}^2}$$

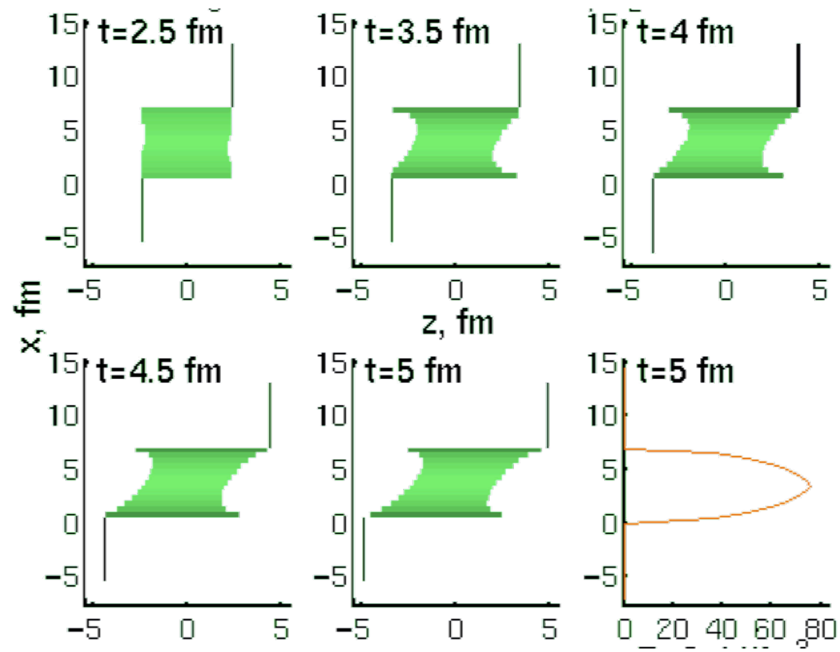
Retiere&MAL PRC70 (2004) 044907

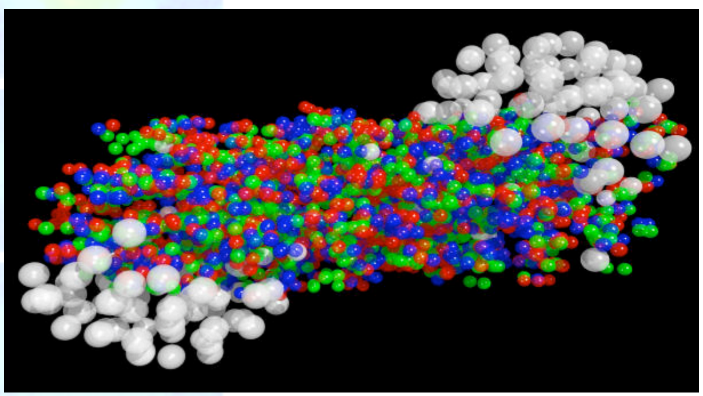
Effects of "spatial *directed* flow?"

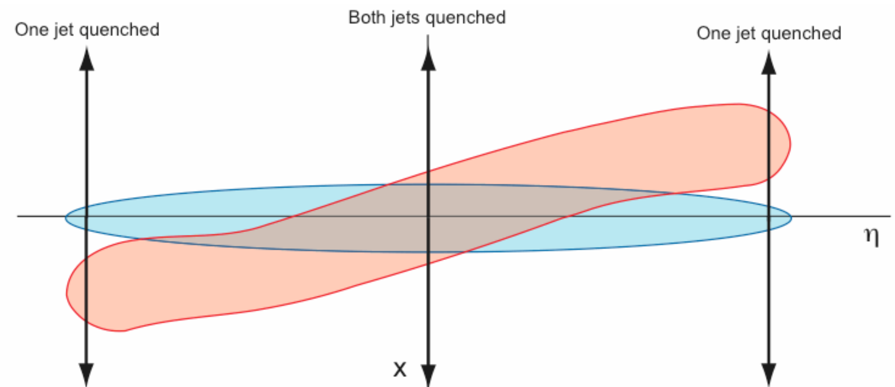
Brachmann et al, PRC 2000 – "flow vs anti-flow"



Csernai & Röhrich PLB 458(99)454 – "Third flow"

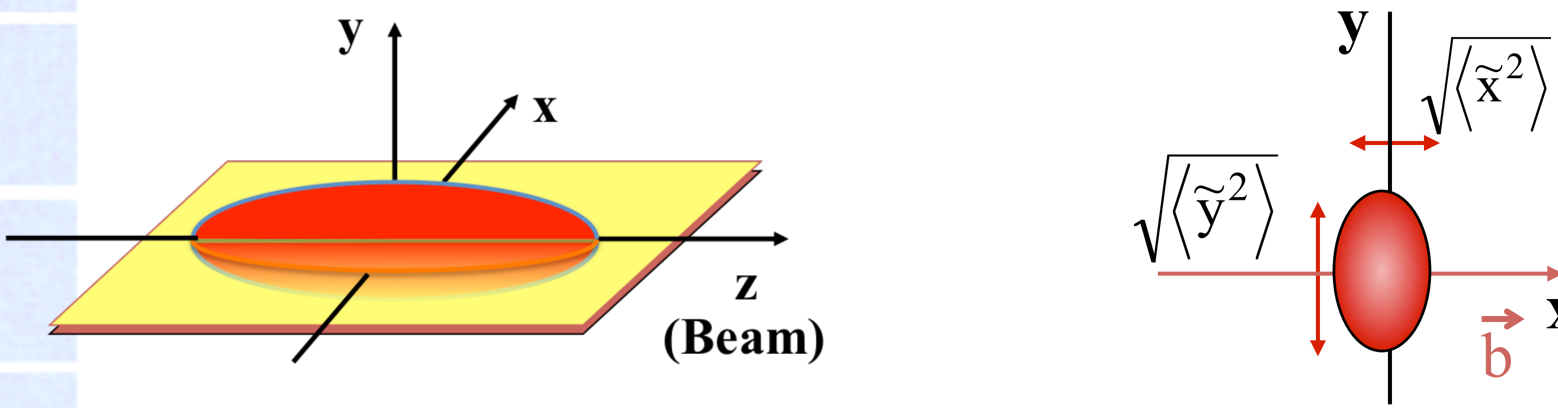




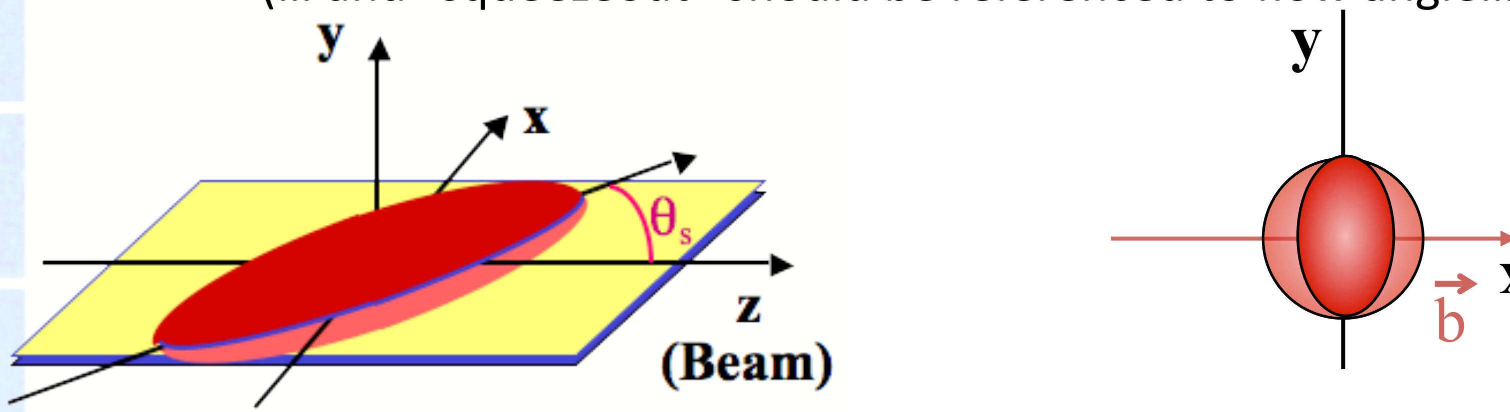


Adil & Gyulassy, PRC 2005 – "twisted sQGP"

Effects of "spatial *directed* flow?"



Tilt angle θ_s – analog of "flow angle"
(… and "squeezeout" should be referenced to flow angle…)



$$R^2_{s,n} \equiv \langle R^2_s(\phi) \cdot \cos(n\phi) \rangle \qquad \varepsilon \approx 2\frac{R^2_{s,2}}{R^2_{s,0}} \approx 2\frac{R^2_{os,2}}{R^2_{s,0}} \approx -2\frac{R^2_{o,2}}{R^2_{s,0}}$$

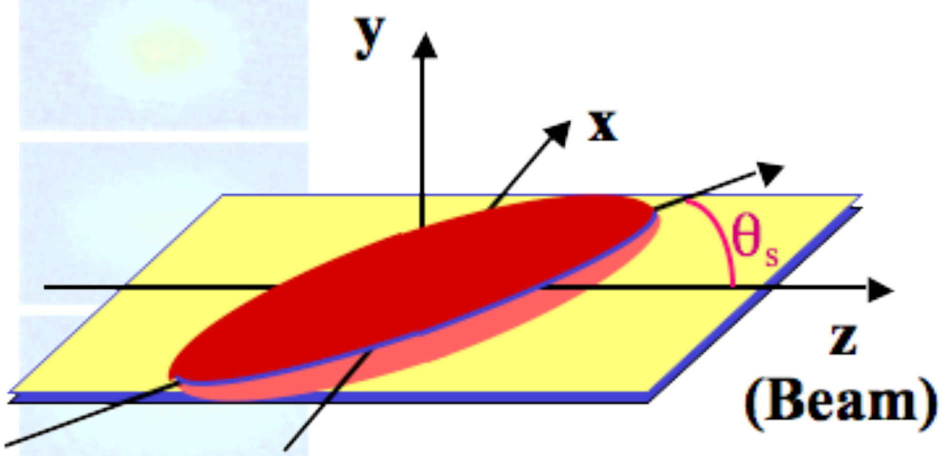
Retiere&MAL PRC70 (2004) 044907

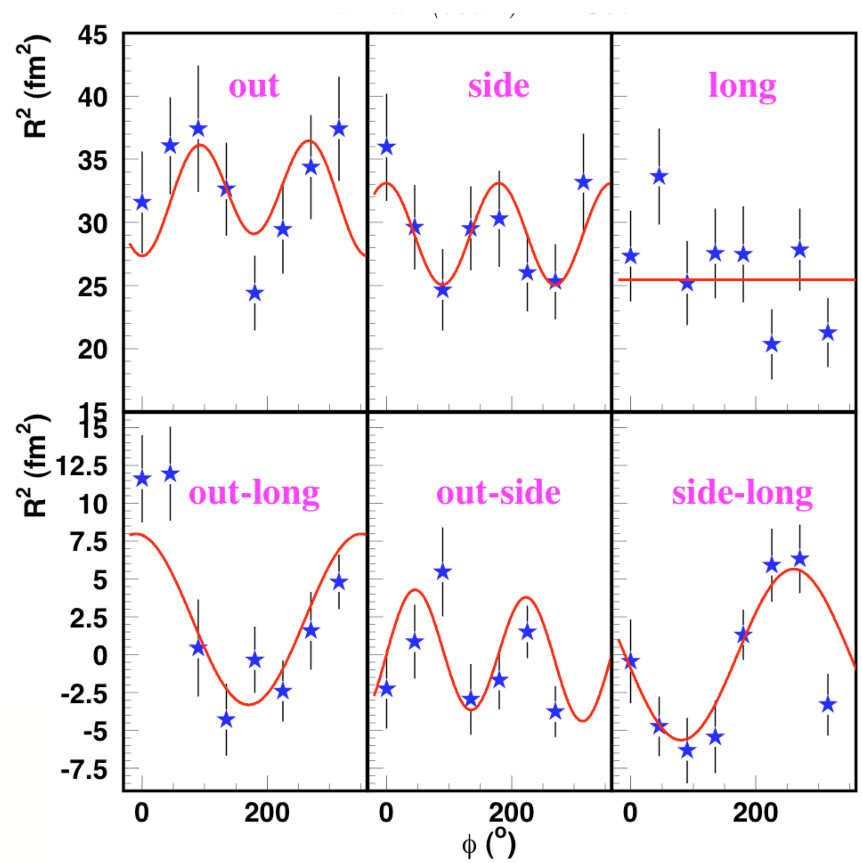
first-order oscillations reveal large tilts @ AGS

First-order R.P. needed

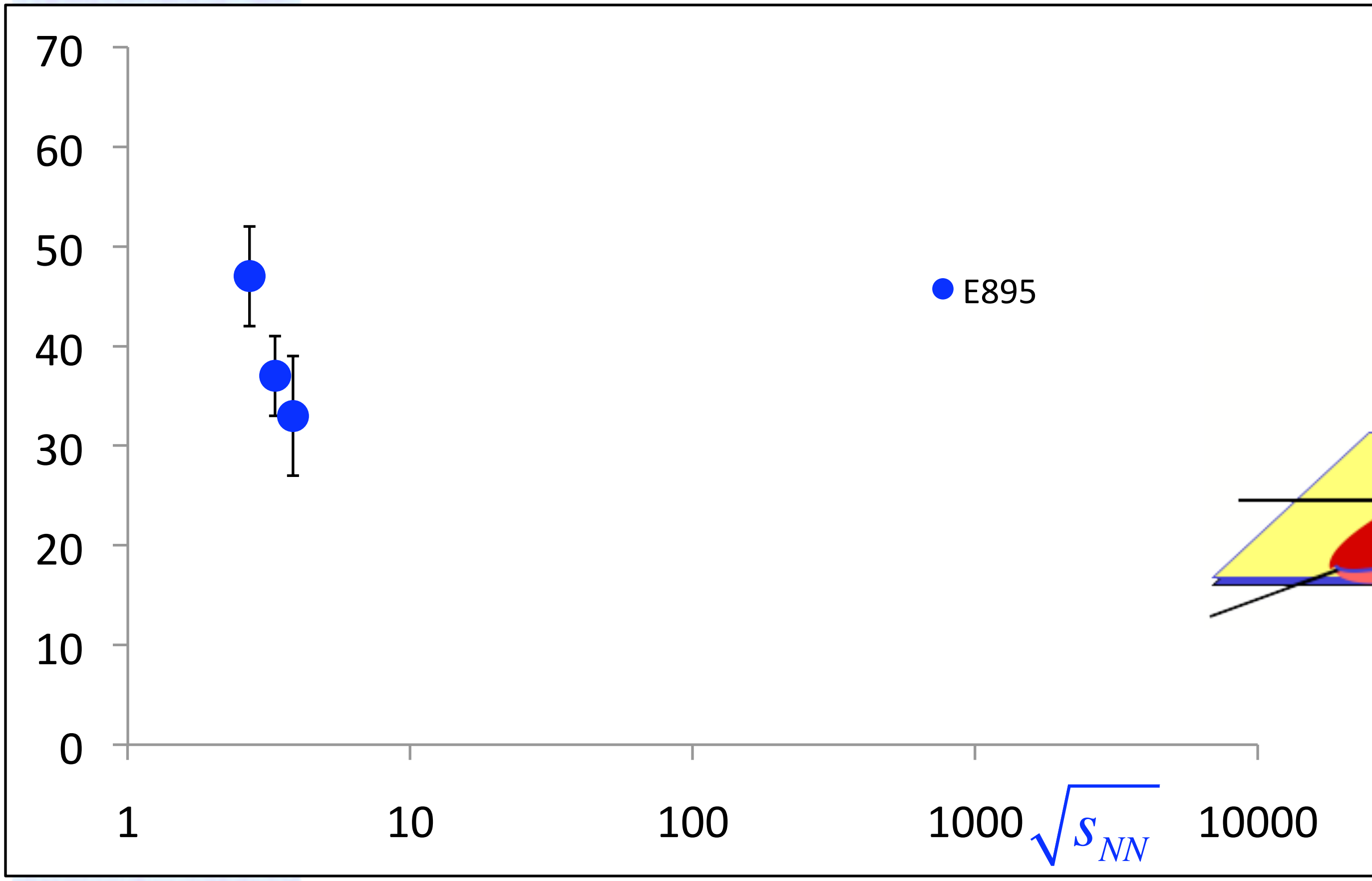
$$\theta_s = \frac{1}{2}\tan^{-1}\left(\frac{-4R^2_{sl,1}}{R^2_{l,0} - R^2_{s,0} + 2R^2_{s,2}}\right)$$

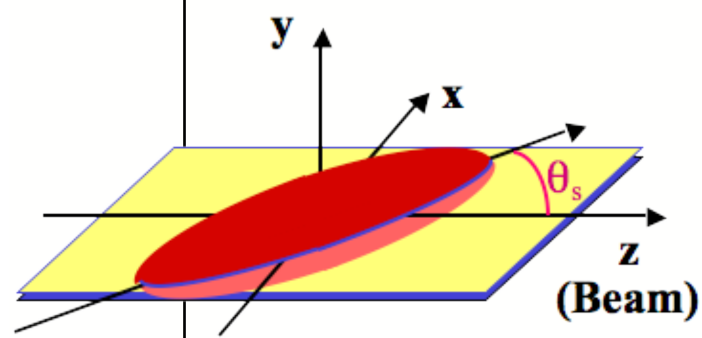
no-flow ellipsoid, LHW'00





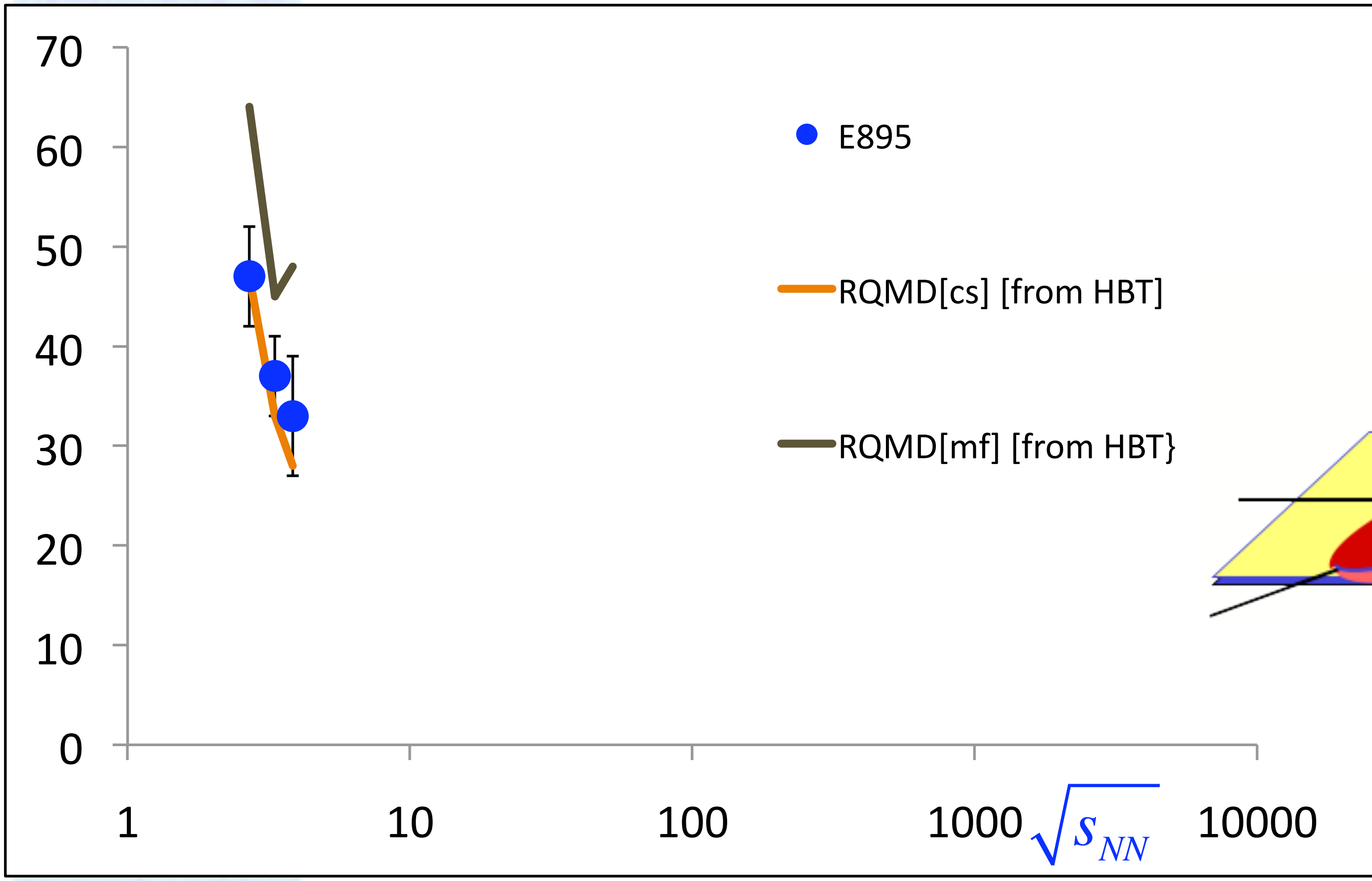
Tilt Angle

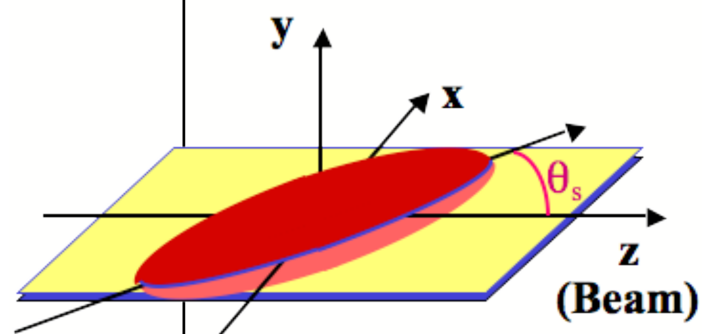




- Large tilts (compare θ_{flow}<1°)

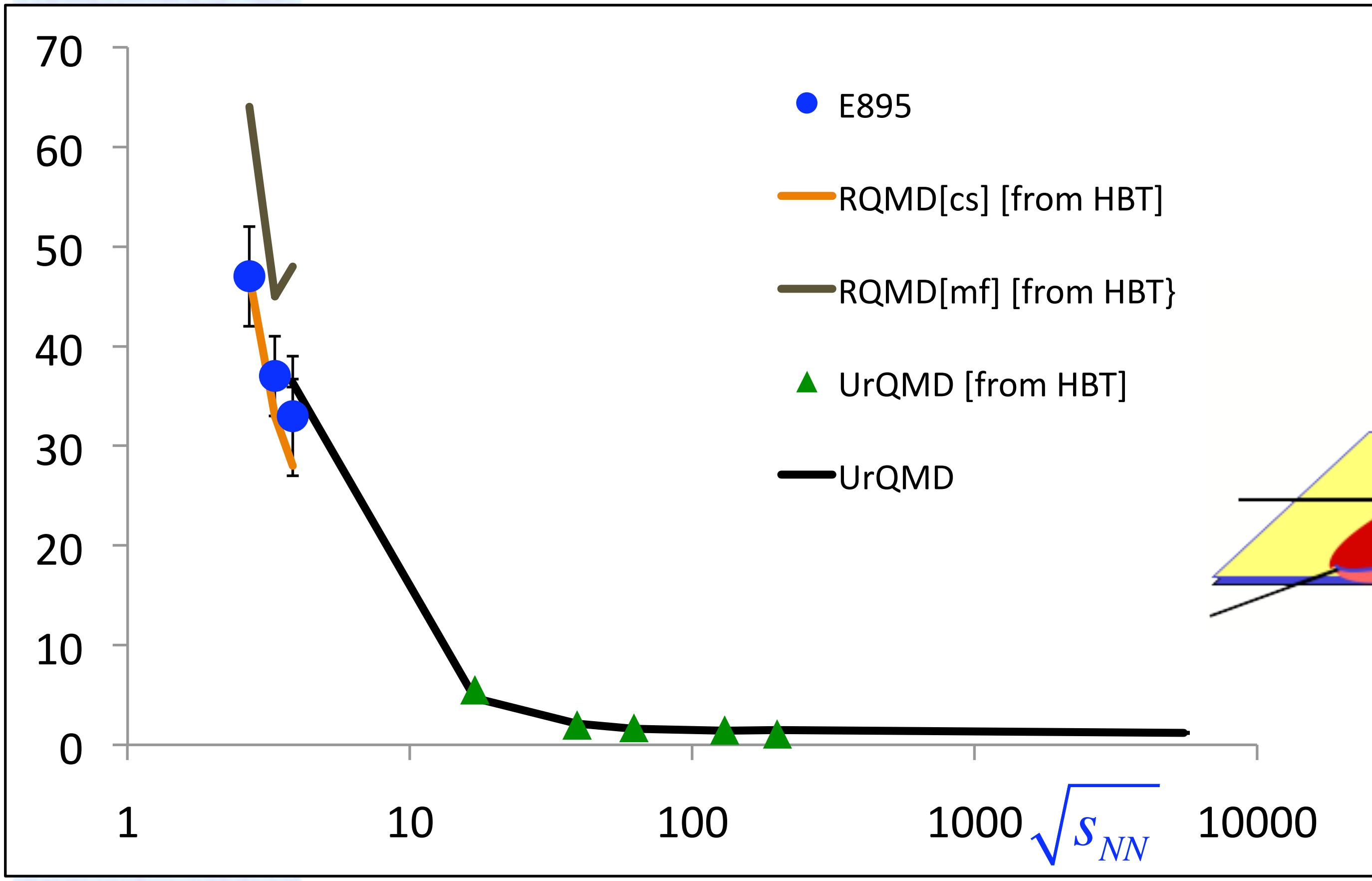
Tilt Angle

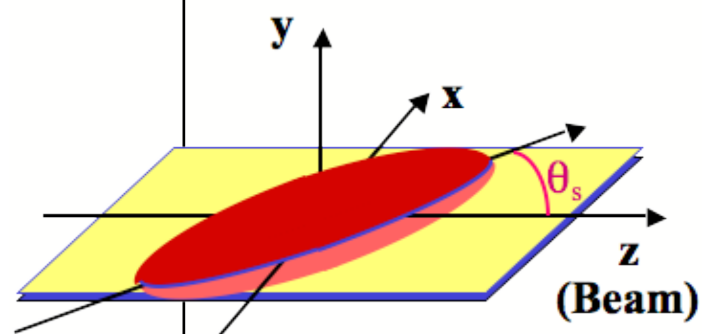




- Large tilts (compare θ_{flow}<1°)
- reproduced by transport calculations
- ✓ sensitive to medium response dynamics ("EoS")

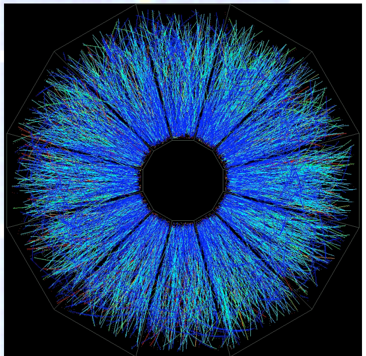
Tilt Angle

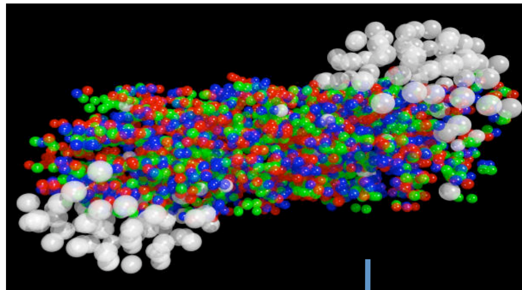




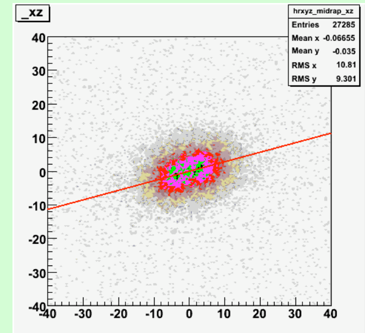
- Large tilts (compare θ_{flow}<1°)
- reproduced by transport calculations
- ✓ sensitive to medium response dynamics ("EoS")
- newer generation ~consistent with ancestor

Extracting shape information





The easy way

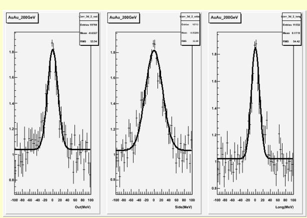


$$\rho(\vec{r}) \sim e^{-\frac{x\cdot\cos\theta_s - z\cdot\sin\theta_s}{2\sigma_x^2} - \frac{y^2}{2\sigma_y^2} - \frac{x\cdot\sin\theta_s + z\cdot\cos\theta_s}{2\sigma_z^2}}$$

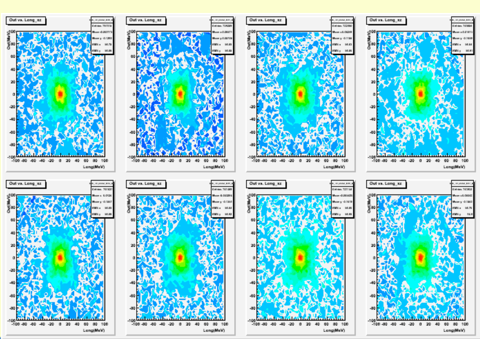
"CRAB, weighting"

$$C_{\vec{P}}^{ab}(\vec{q}) = \int d^3\vec{r}' \cdot S_{\vec{P}}^{ab}(\vec{r}') \cdot |\phi(\vec{q}',\vec{r}')|^2$$

8 (3D) corr. functions

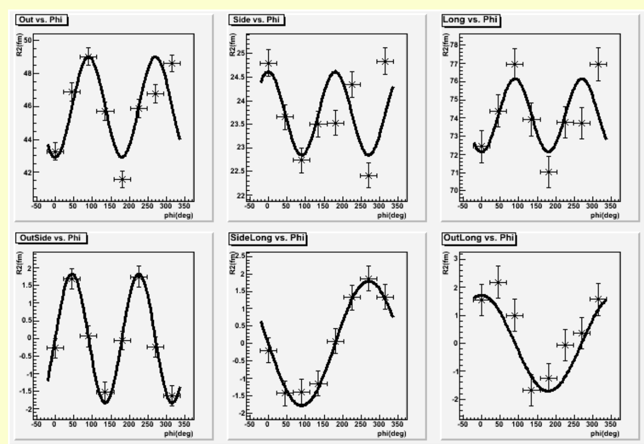


$$\phi_{pair} = 0, \frac{\pi}{4}, \frac{\pi}{2}, \frac{3\pi}{4}, \pi, \frac{5\pi}{4}, \frac{3\pi}{2}, \frac{7\pi}{4}$$



8 sets of 6 "HBT radii"

$$C^{fit}(\vec{q}) = 1 + \lambda \exp\left[-\sum_{i,j=o,s,l} q_i q_j R_{i,j}^2\right]$$



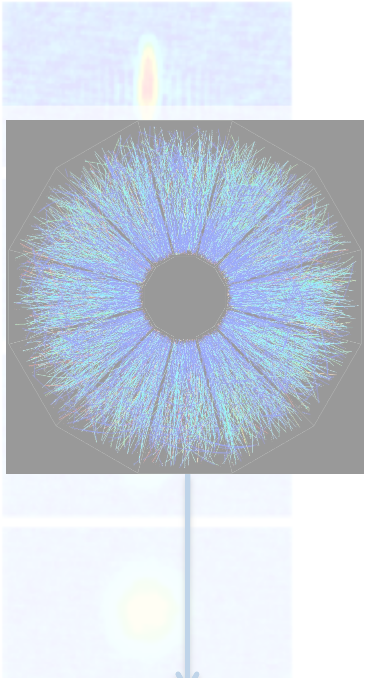
9(+) Fourier Coefficients

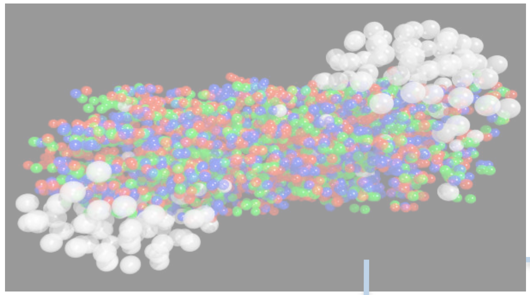
$$R_{ij,n}^2 = \left\langle R_{ij}^2(\phi) \begin{Bmatrix} \sin n\phi \\ \cos n\phi \end{Bmatrix} \right\rangle$$

$$\theta_s = \frac{1}{2}\tan^{-1}\left(\frac{-4R_{sl,1}^2}{R_{l,0}^2 - R_{s,0}^2 + 2R_{s,2}^2}\right)$$

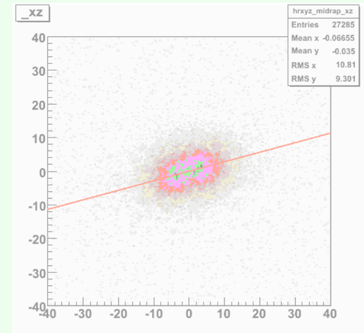
$$\varepsilon = 2\frac{R_{s,2}^2}{R_{s,0}^2}$$

Extracting shape information





The easy way

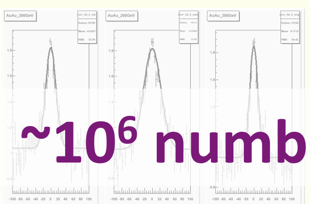


$$\rho(\vec{r}) \sim e^{-\frac{x\cdot\cos\theta_s - z\cdot\sin\theta_s}{2\sigma_x^2} - \frac{y^2}{2\sigma_y^2} - \frac{x\cdot\sin\theta_s + z\cdot\cos\theta_s}{2\sigma_z^2}}$$

"CRAB, weighting"

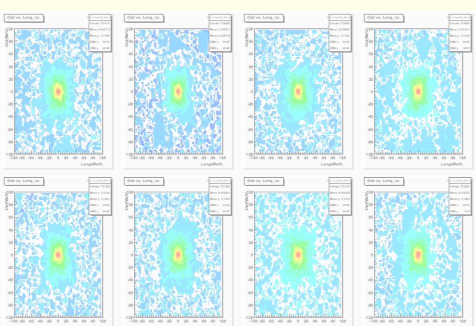
$$C_{\vec{P}}^{ab}(\vec{q}) = \int d^3\vec{r}' \cdot S_{\vec{P}}^{ab}(\vec{r}') \cdot \left|\phi(\vec{q}', \vec{r}')\right|^2$$

8 (3D) corr. functions



~10^6 numbers

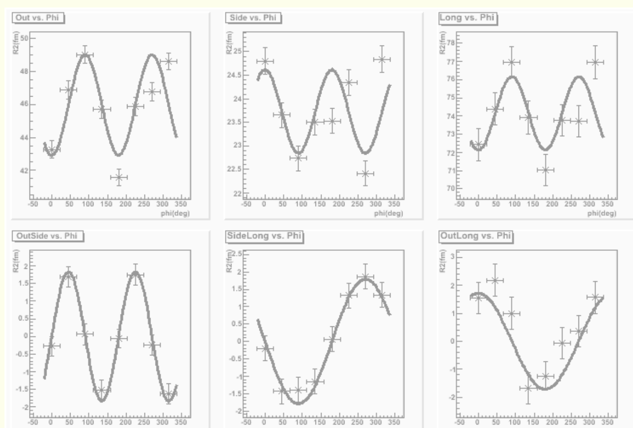
$$\phi_{pair} = 0, \frac{\pi}{4}, \frac{\pi}{2}, \frac{3\pi}{4}, \pi, \frac{5\pi}{4}, \frac{3\pi}{2}, \frac{7\pi}{4}$$



8 sets of 6 "HBT radii"

$$C^{fit}(\vec{q}) = 1 + \lambda \exp\left[-\sum q_i q_j R_{i,j}^2\right]$$

48 numbers



9(+) Fourier Coefficients

$$R_{ij,n}^2 = \left\langle R_{ij}^2(\phi) \begin{Bmatrix} \sin n\phi \\ \cos n\phi \end{Bmatrix} \right\rangle$$

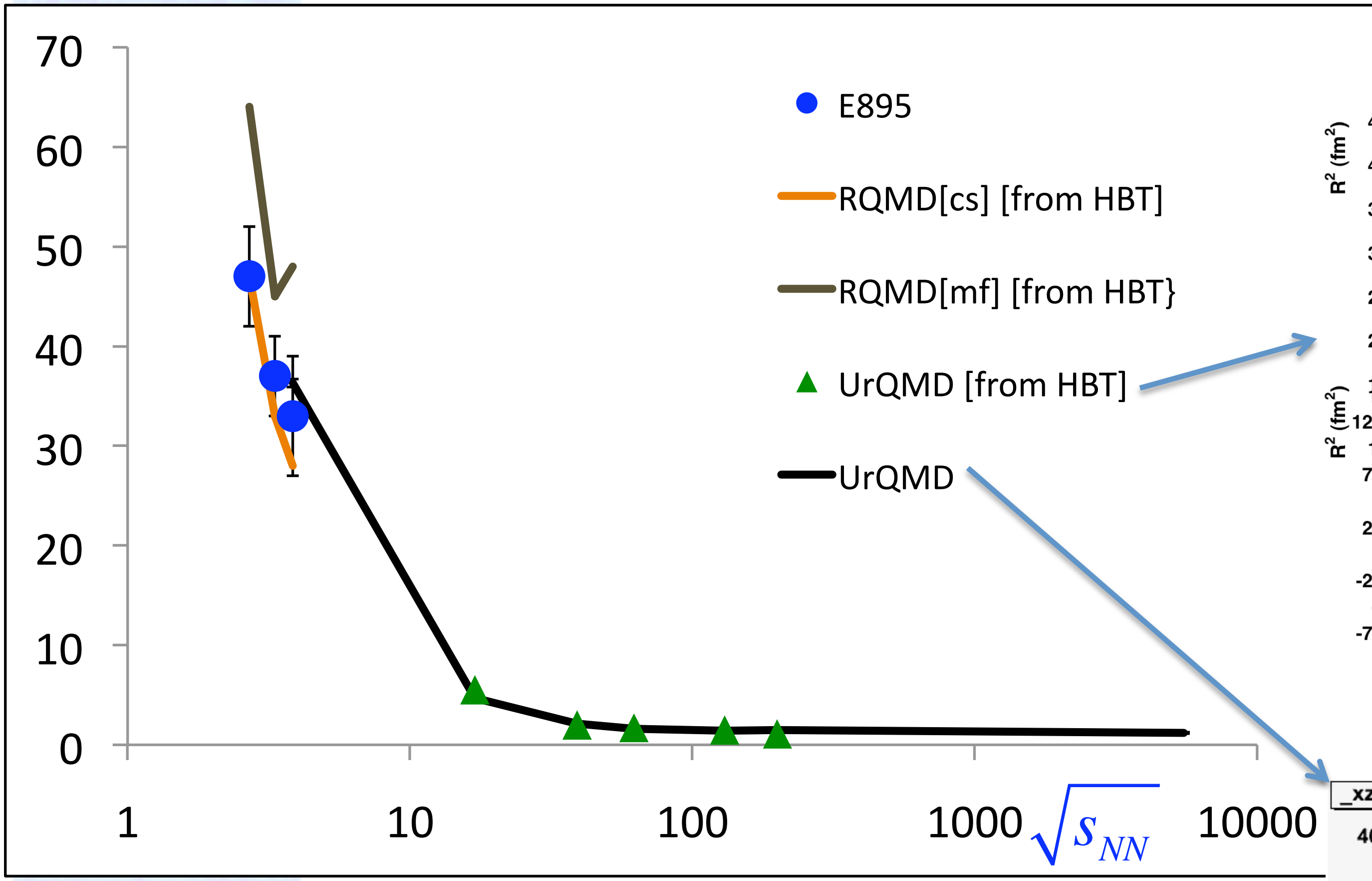
9 numbers

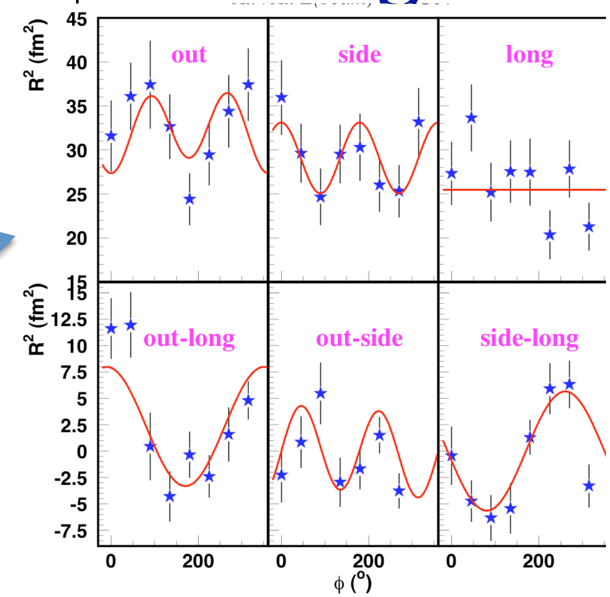
$$\theta_s = \frac{1}{2}\tan^{-1}\left(\frac{-4R_{sl,1}^2}{R_{l,0}^2 - R_{s,0}^2 + 2R_{s,2}^2}\right)$$

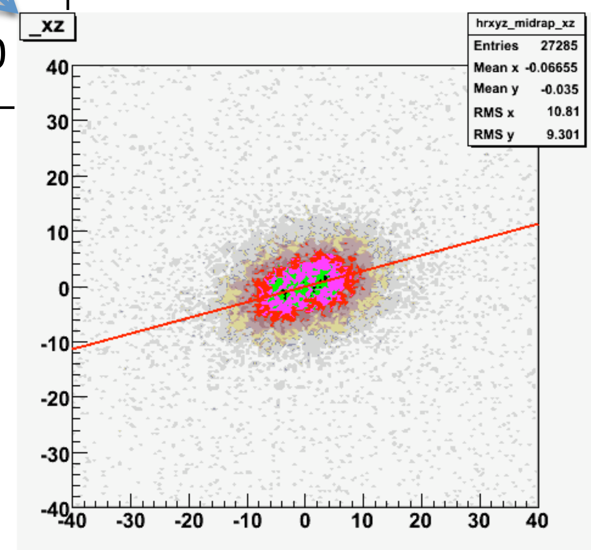
2 numbers

$$\varepsilon = 2\frac{R_{s,2}^2}{R_{s,0}^2}$$

Tilt Angle





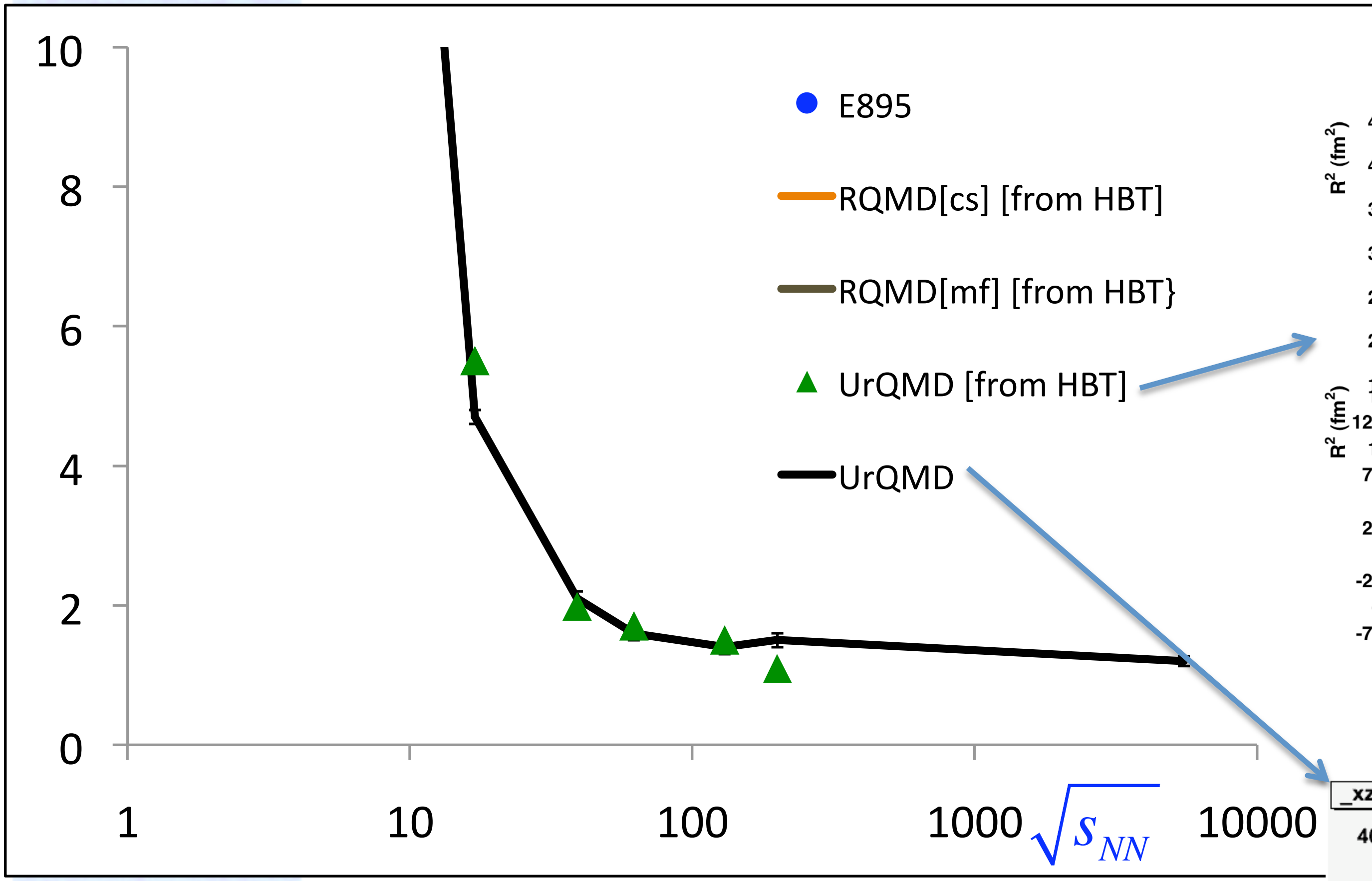


- Large tilts (compare θ_{flow}<1°)
- reproduced by transport calculations

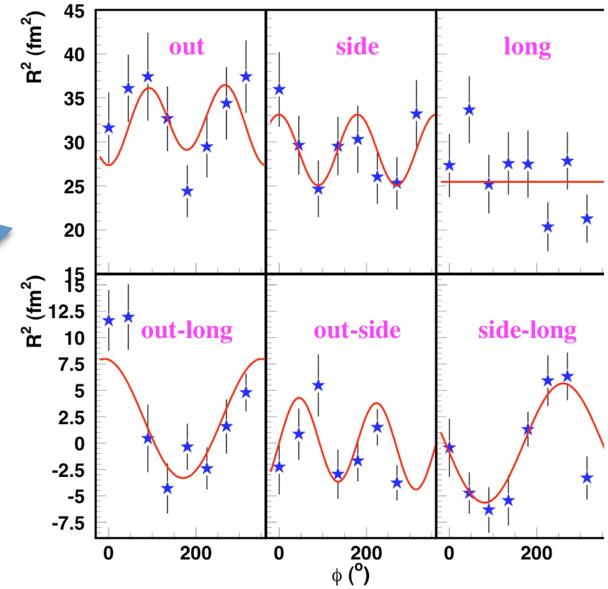
✓sensitive to medium response dynamics (“EoS”)

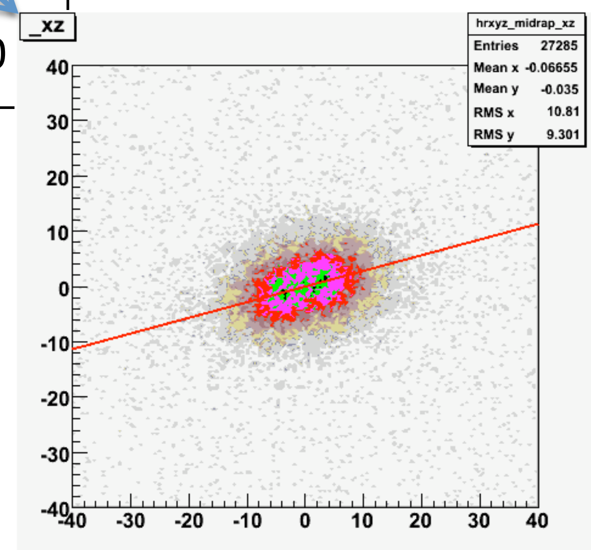
- newer generation ~consistent with ancestor

✓consistent tilt extracted by HBT radii or by space (nontrivial!)



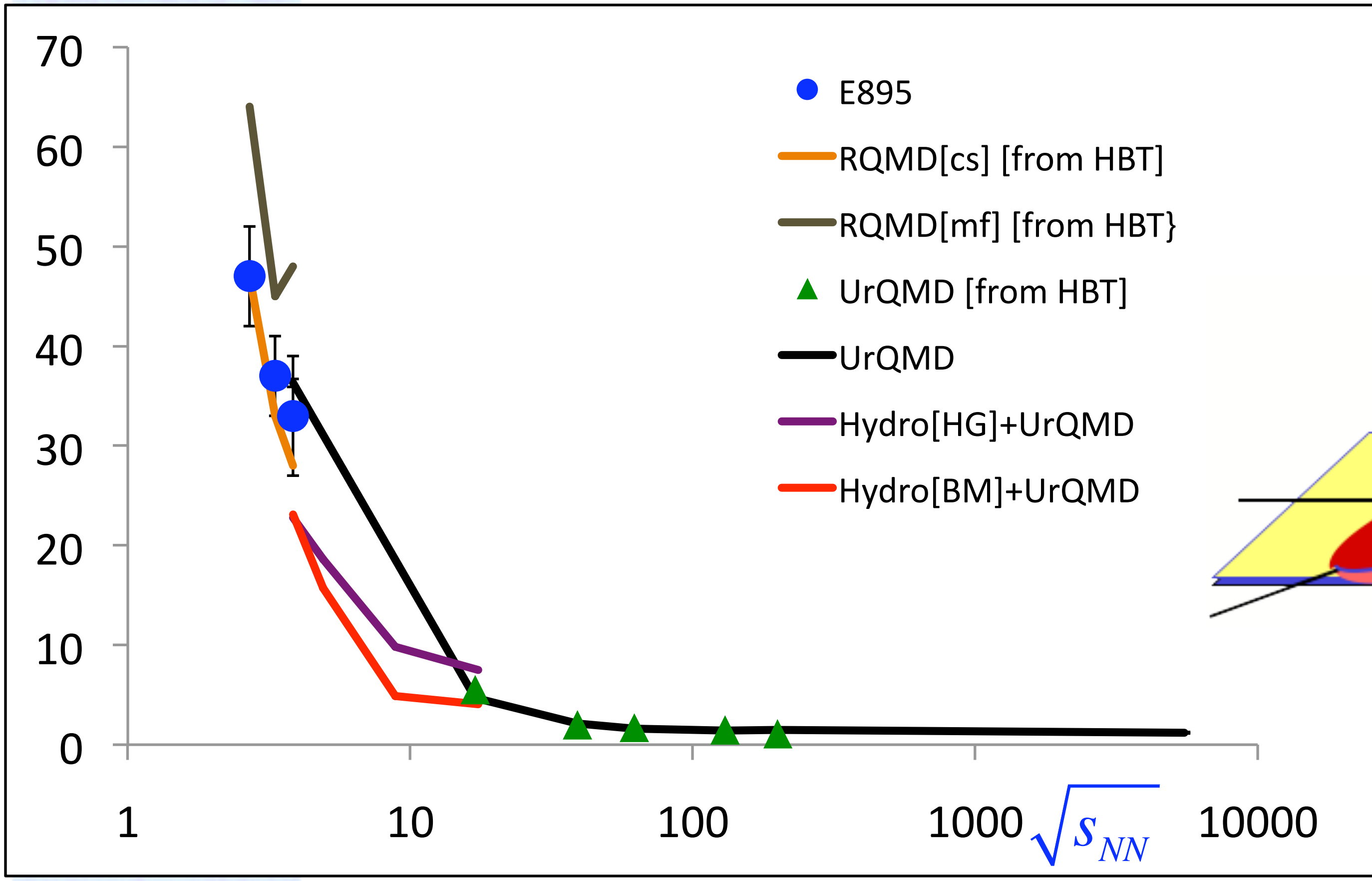
Blow-up

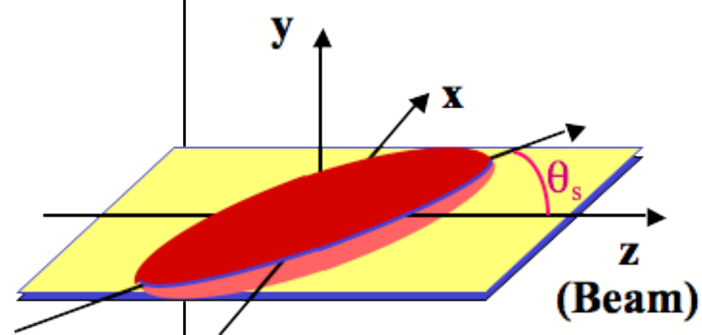




- Large tilts (compare θ_{flow}<1°)
- reproduced by transport calculations
- ✓ sensitive to medium response dynamics ("EoS")
- newer generation ~consistent with ancestor
- ✓ consistent tilt extracted by HBT radii or by space (nontrivial!)

Tilt Angle





- Large tilts (compare θ_{flow}<1°)
- reproduced by transport calculations
- ✓sensitive to medium response dynamics ("EoS")
- newer generation ~consistent with ancestor
- ✓consistent tilt extracted by HBT radii or by space (nontrivial!)
- sensitive to early (hydro) stage in hybrid models

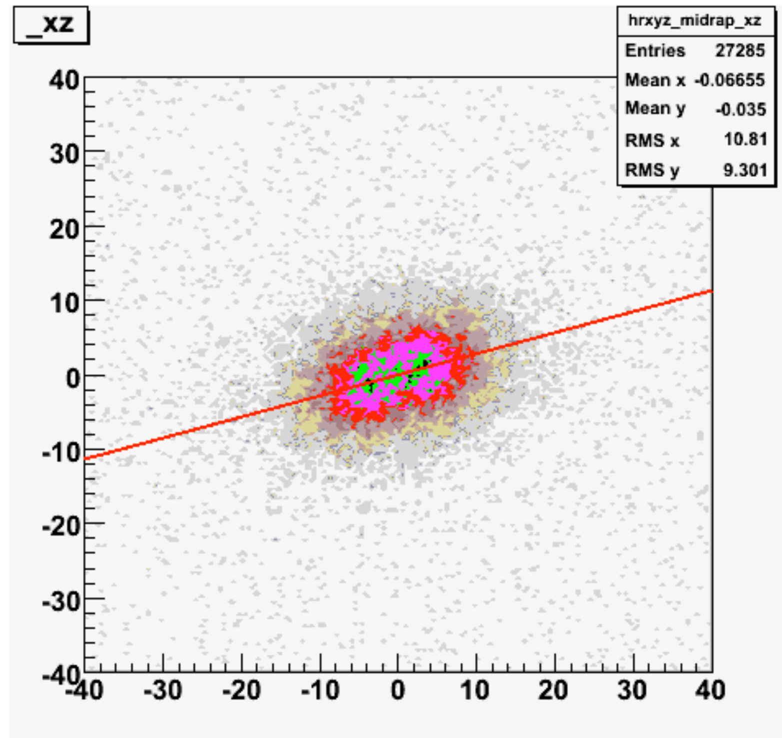
complications from large tilts?

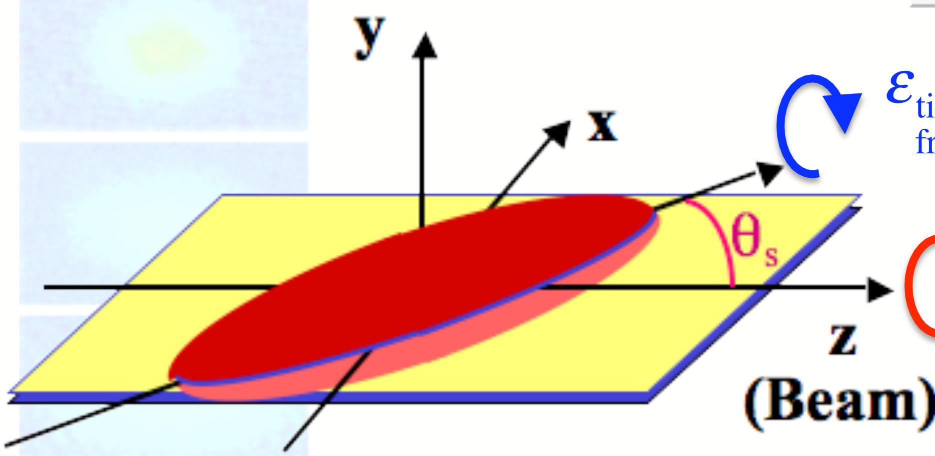
measurement:

UrQMD+hydro[BM]@ 3.8 GeV:

ε in non-natural frame significantly reduced from ε in natural (tilted) frame

affects CERES measurement?





$$\varepsilon_{\text{tilted frame}} = +0.04 \quad \text{(out-of-plane)}$$

$$\varepsilon_{\text{beam frame}} = -0.07 \quad \text{(in-plane)}$$

complications from large tilts?

measurement:

UrQMD+hydro[BM]@ 3.8 GeV:

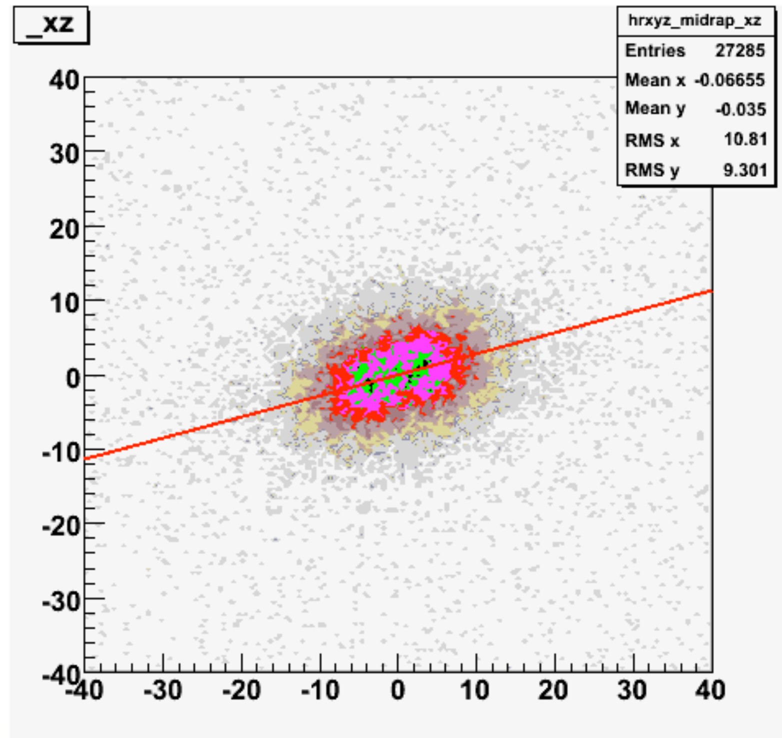
ε in non-natural frame significantly reduced from ε in natural (tilted) frame

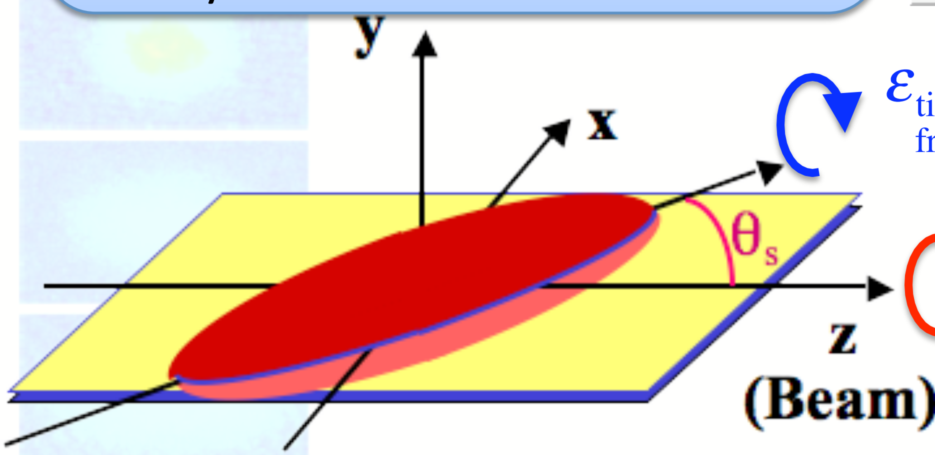
affects CERES measurement?

transport

Tilts are manifestly "boost variant," in *space* **even *at* y=0**

2D hydro codes?

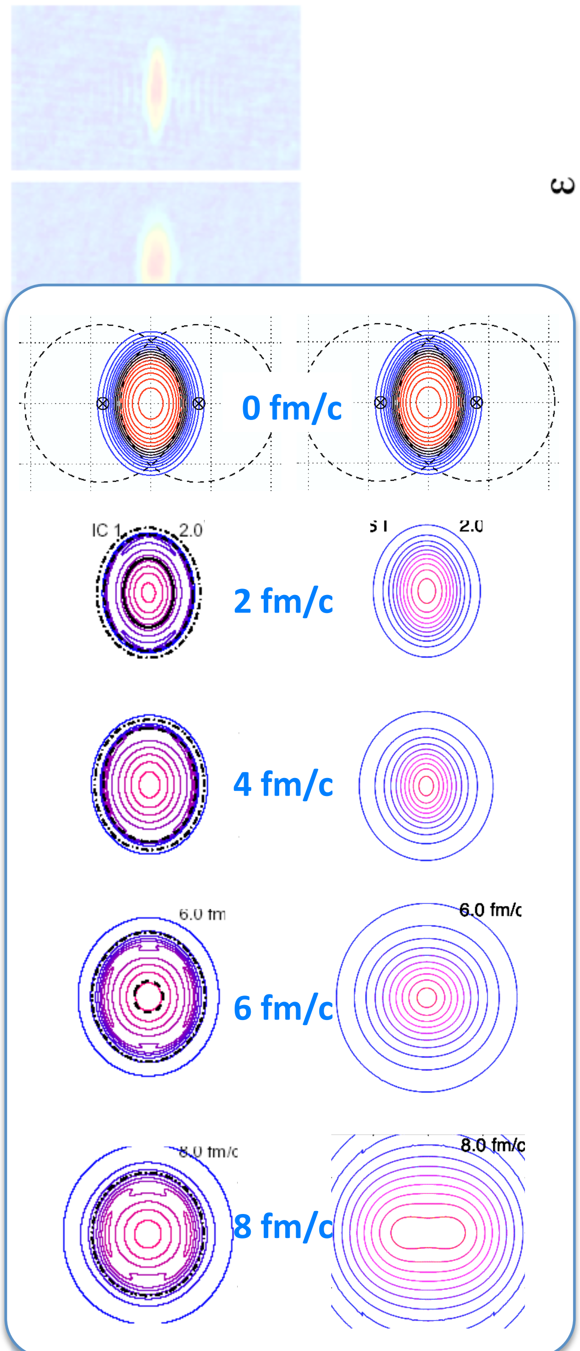


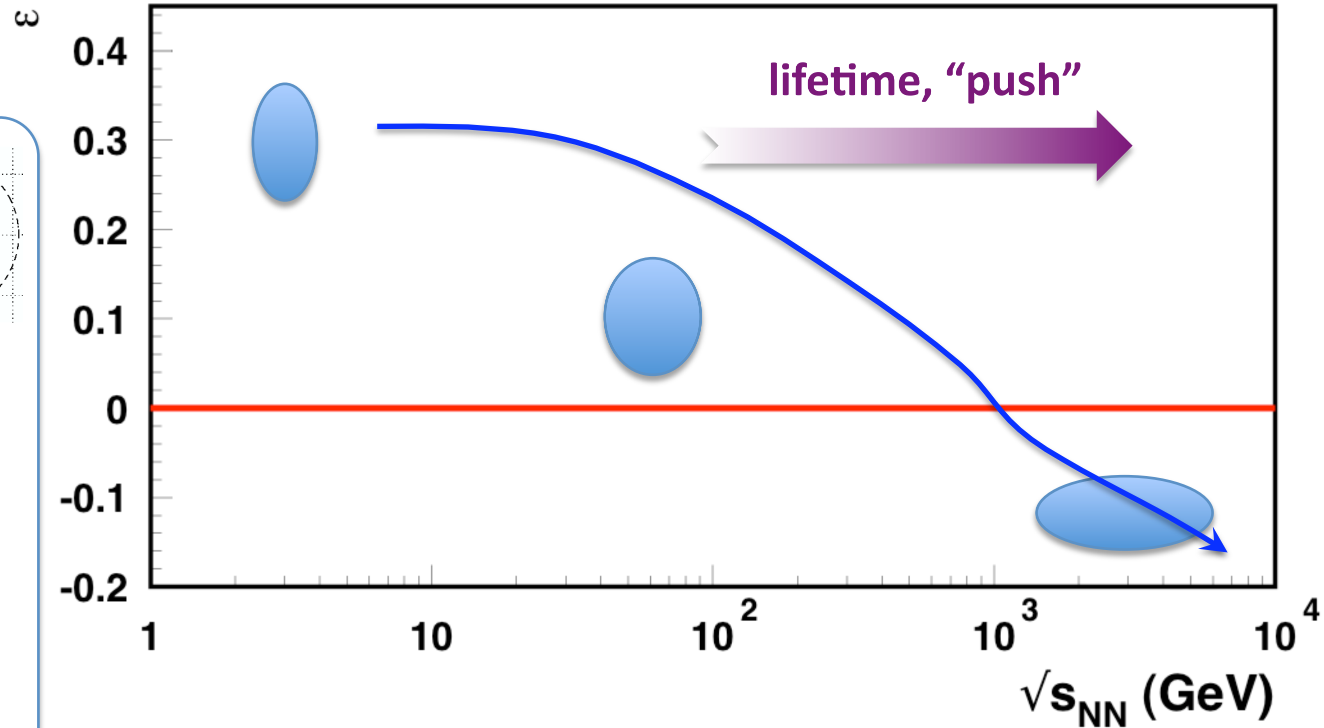


$\varepsilon_{\substack{\text{tilted}\\\text{frame}}} = +0.04$ (out-of-plane)

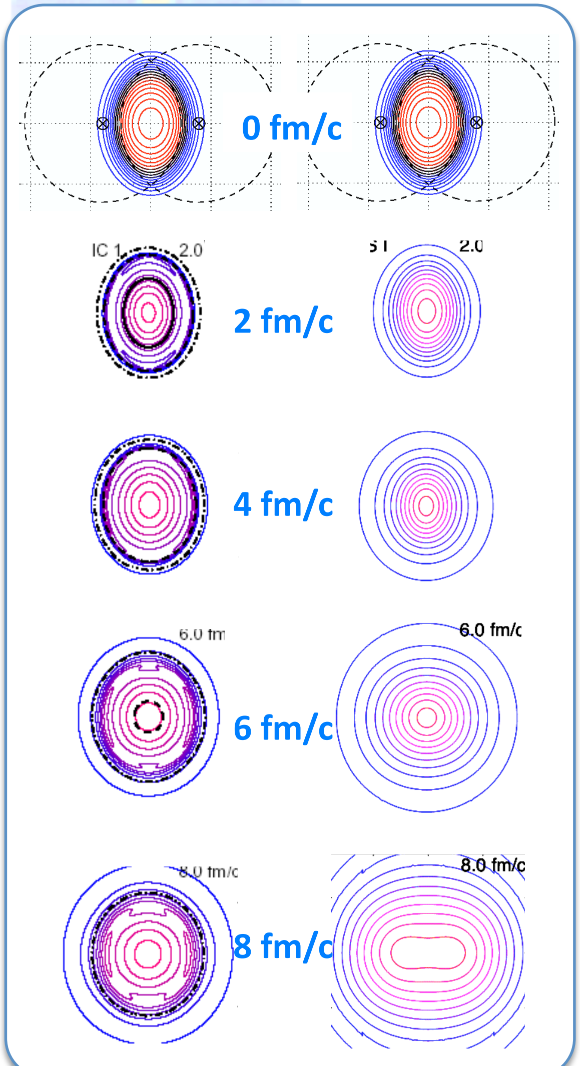
$\varepsilon_{\substack{\text{beam}\\\text{frame}}} = -0.07$ (in-plane)

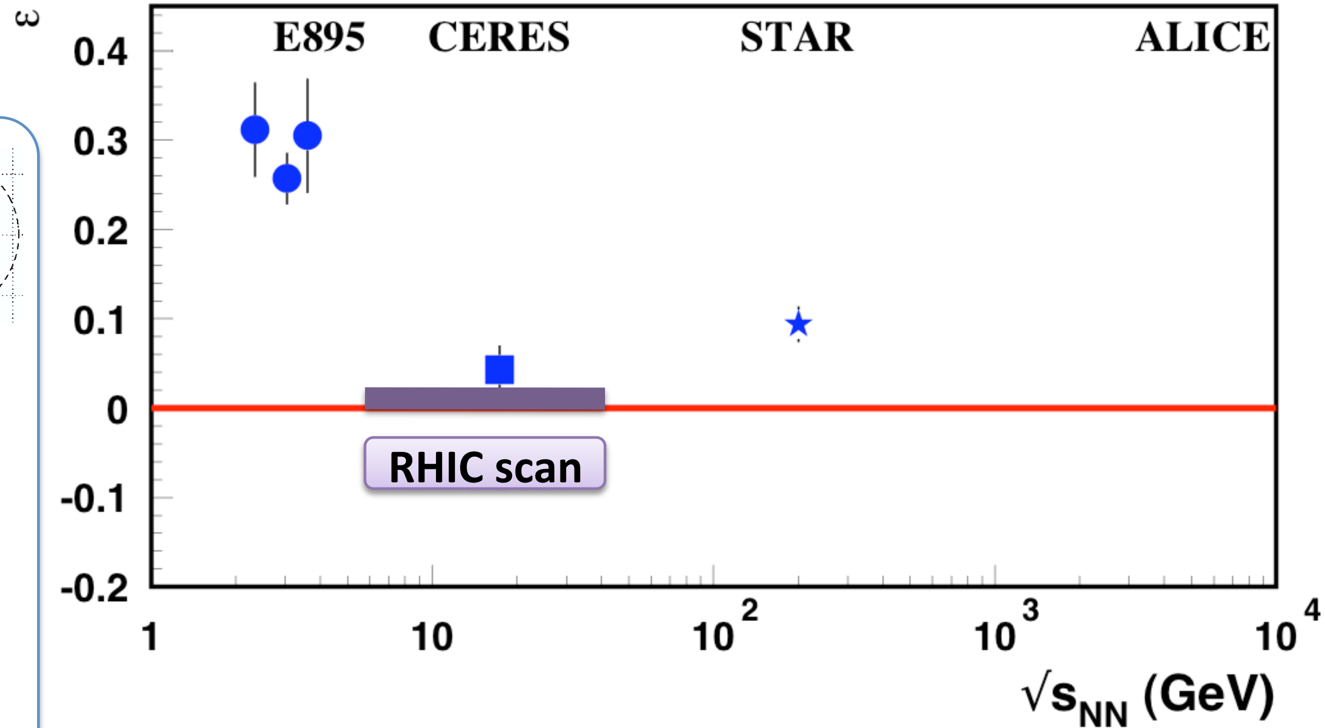
Generic expectation



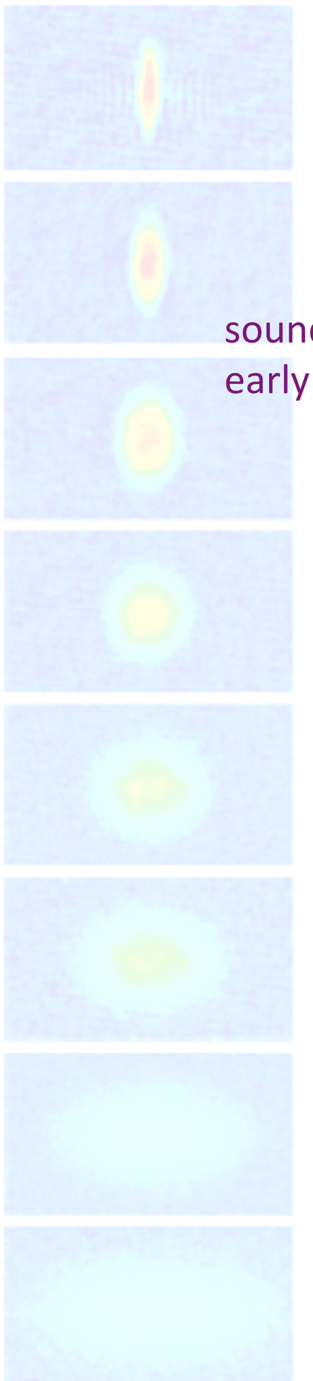


An excitation function begging for more



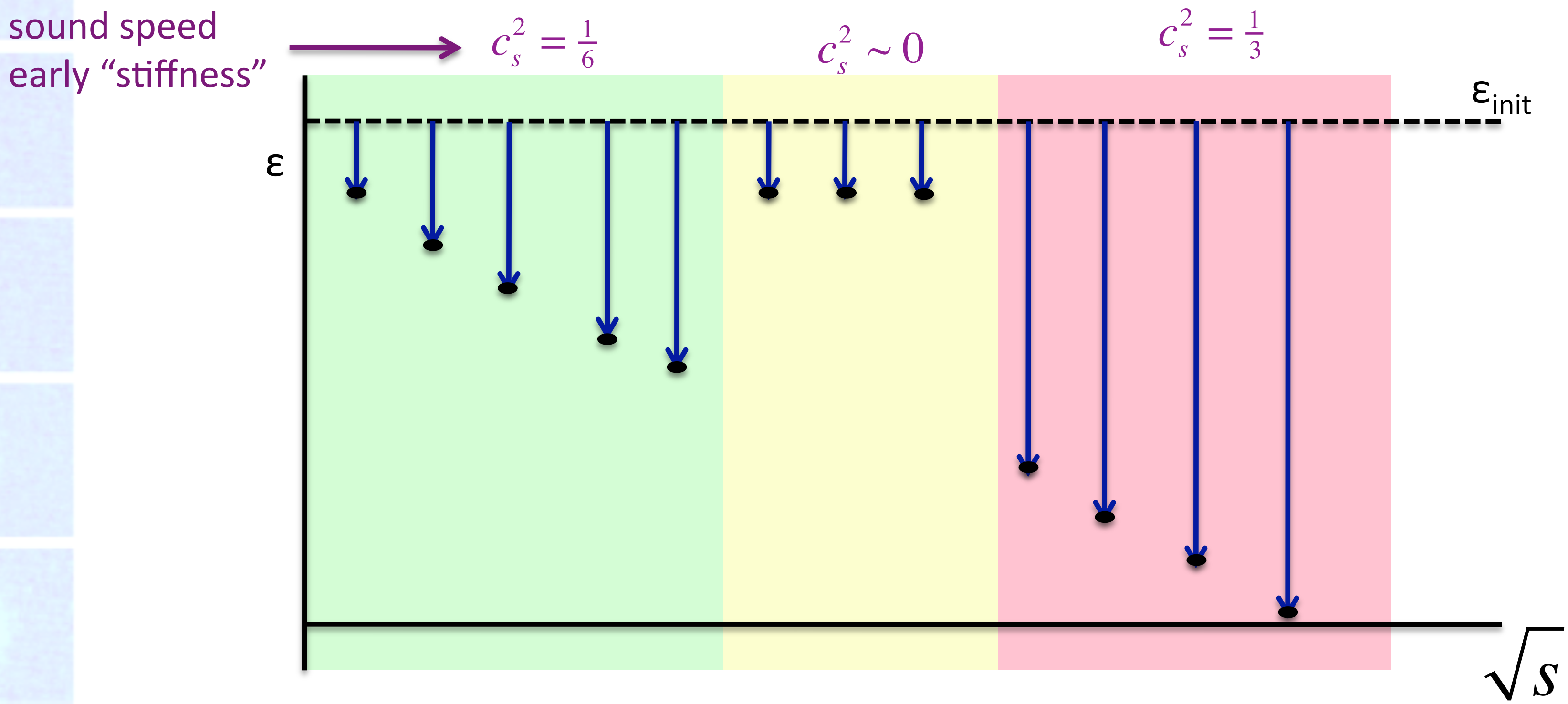


- non-monotonic excitation function of bulk observable?
  - interesting in proposed scan region
  - but: tilt issue – need 1st-order plane in scan!!



A pleasant daydream

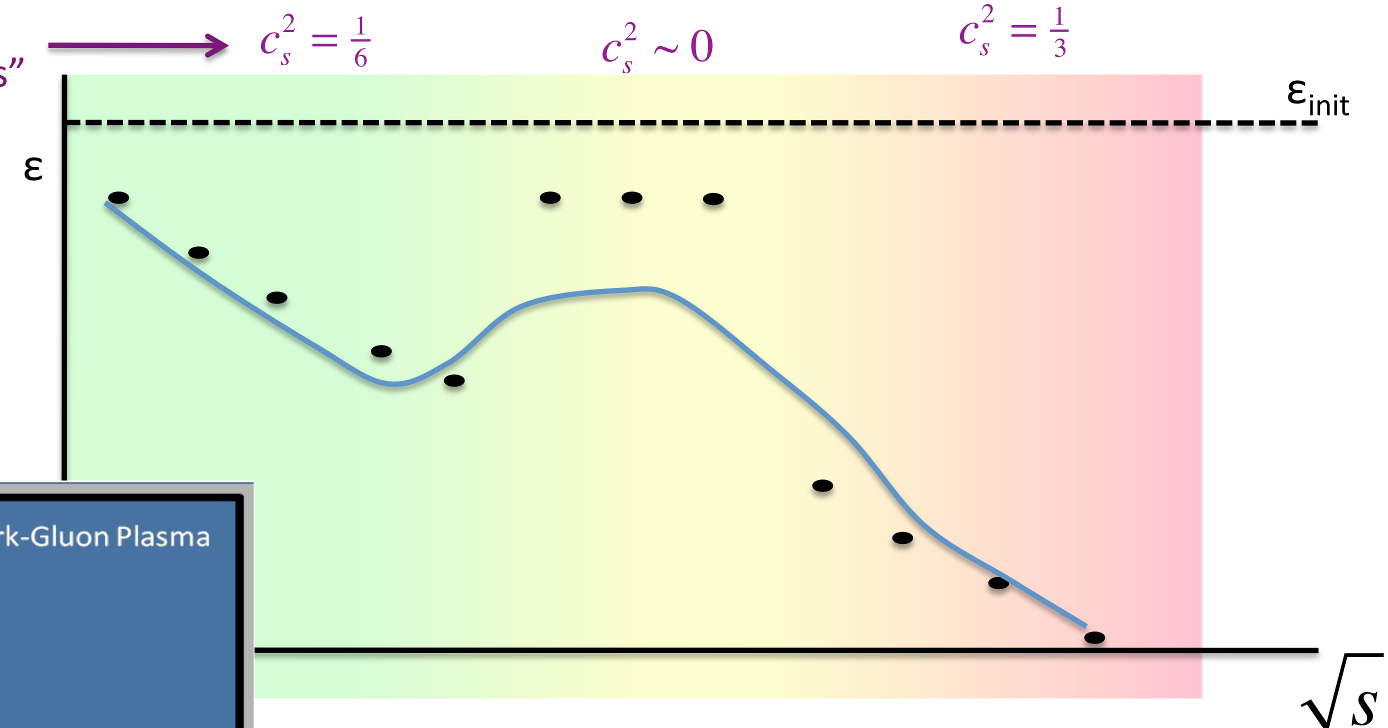
Focus on effect of EoS. Keep ε_{init} and effective lifetime fixed

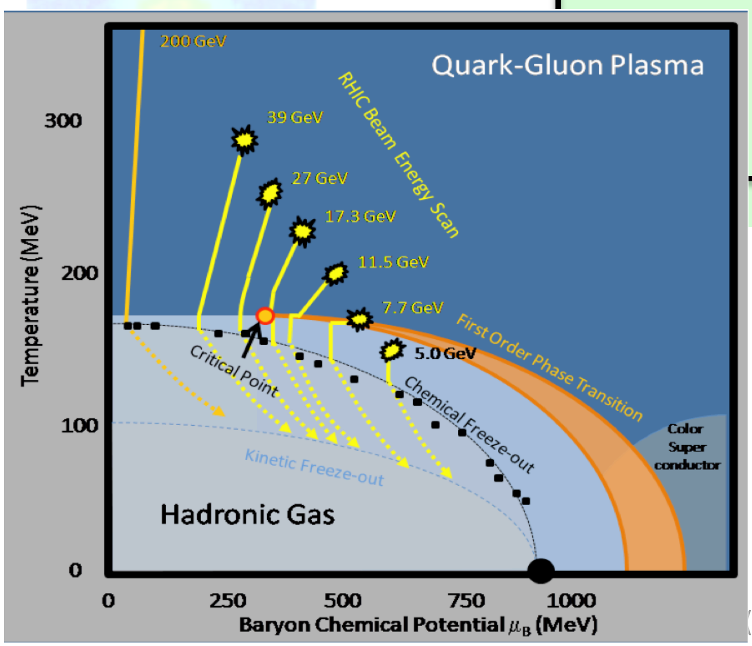


A pleasant daydream

Focus on effect of EoS. Keep ε_{init} and effective lifetime fixed

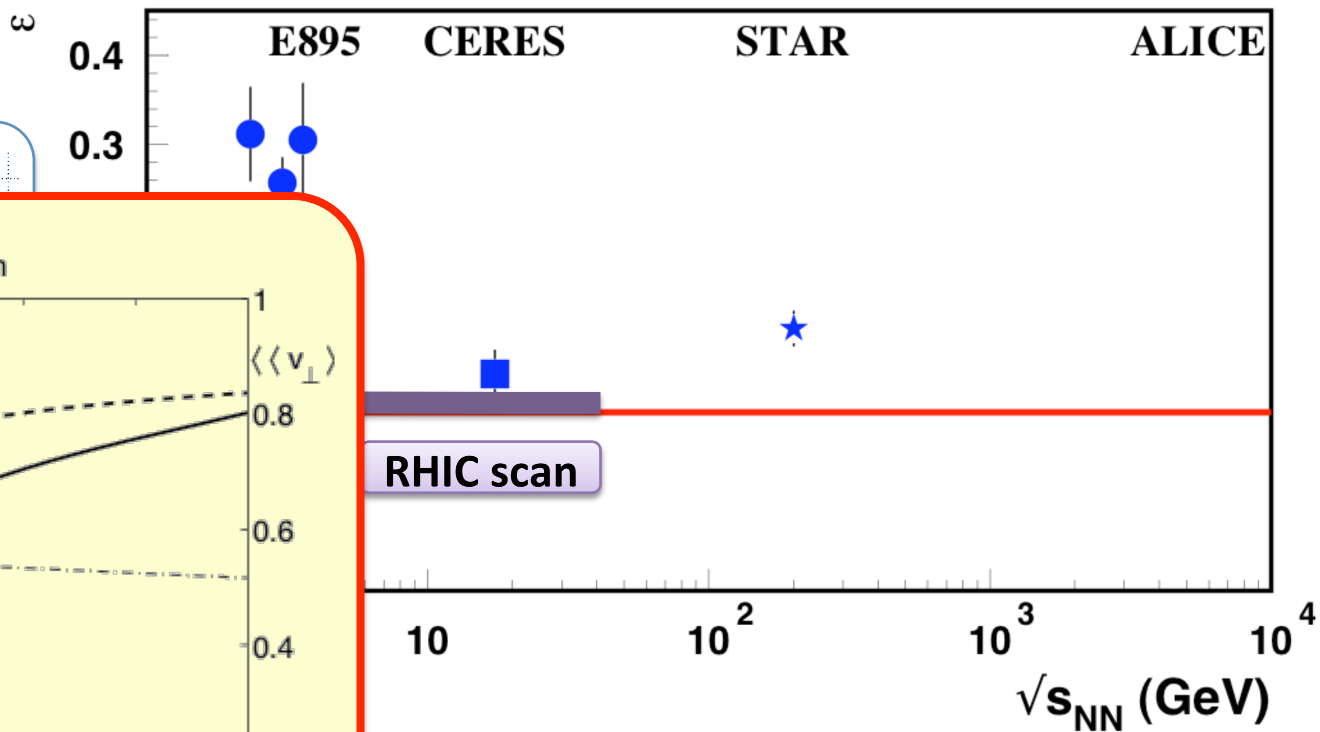
sound speed
early "stiffness"

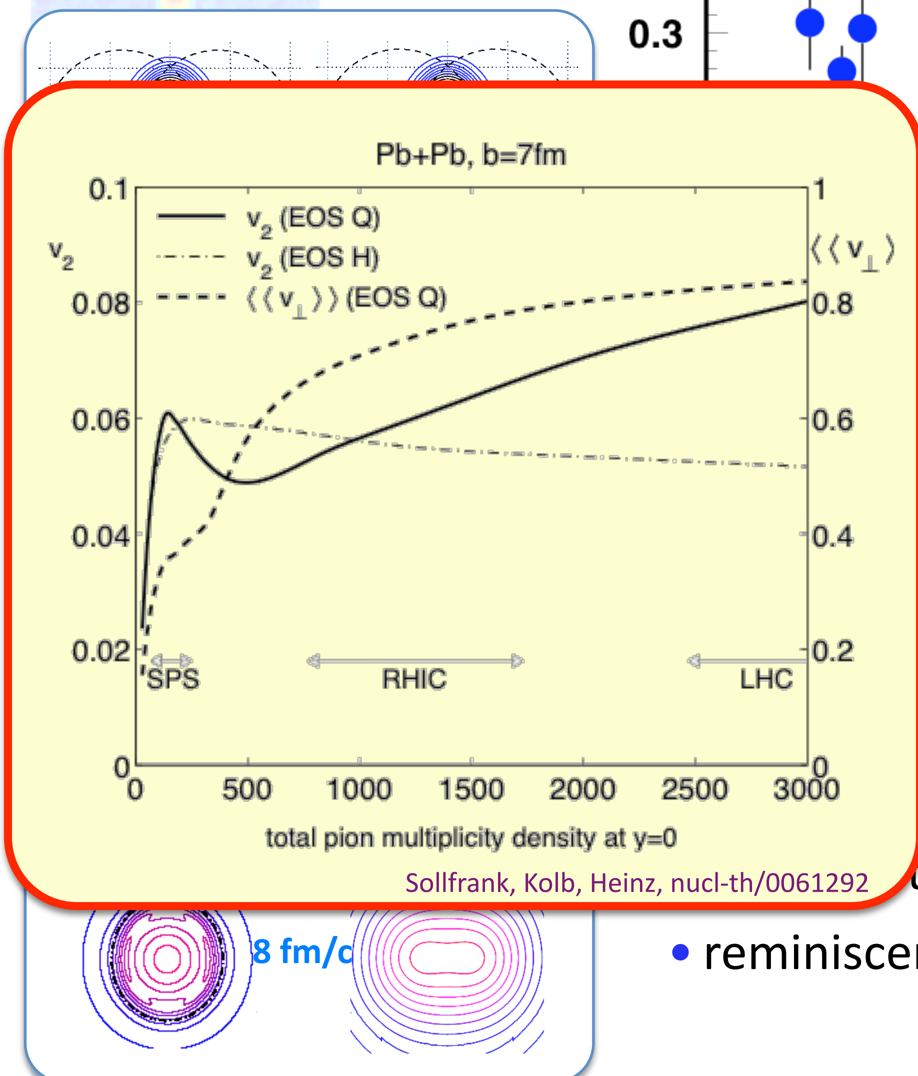




N.B.: seek $c_s^2 \approx 0$ at $\mu_B \neq 0$

An excitation function begging for more

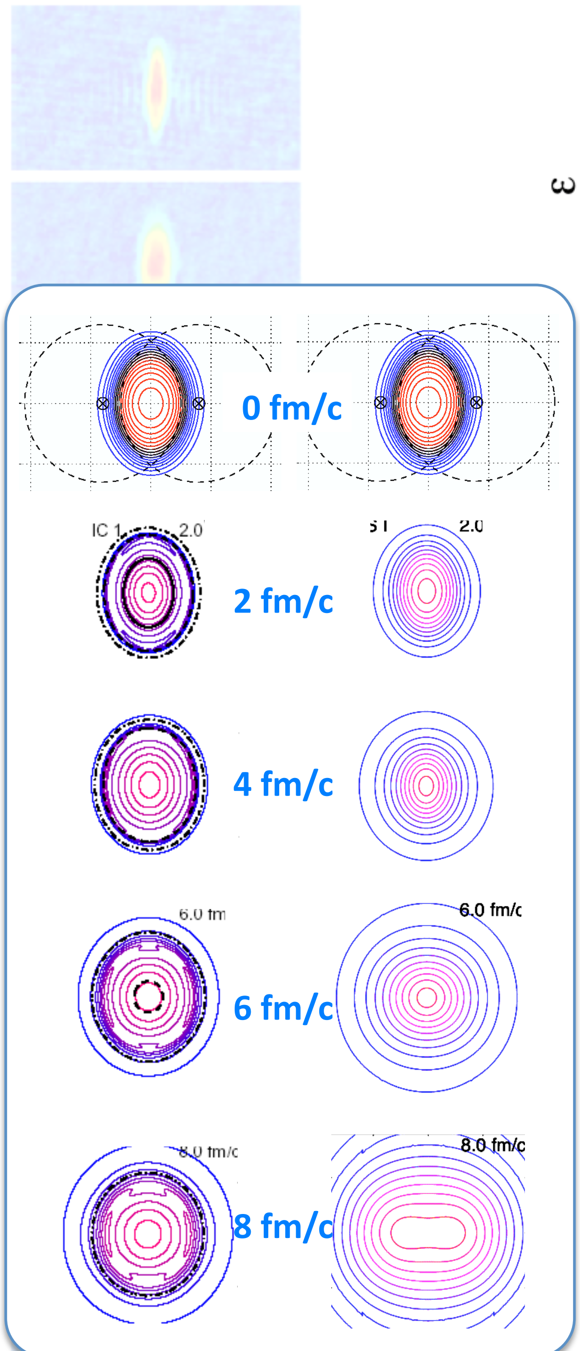


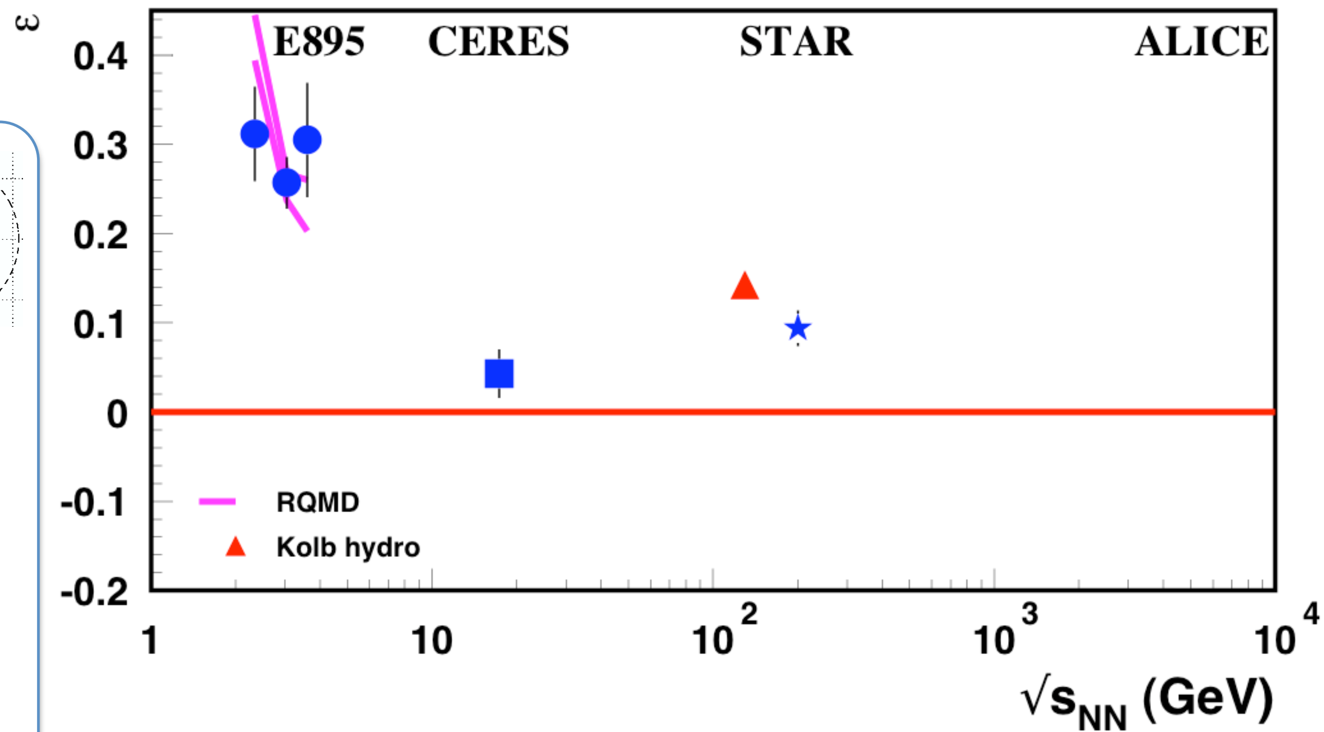


8 fm/c

- …tonic excitation function of bulk observable?
- …ting in proposed scan region
- …t issue – need 1st-order plane in scan!!
- reminiscent of (unobserved) non-monotonic v2(root(s))

Model comparisons

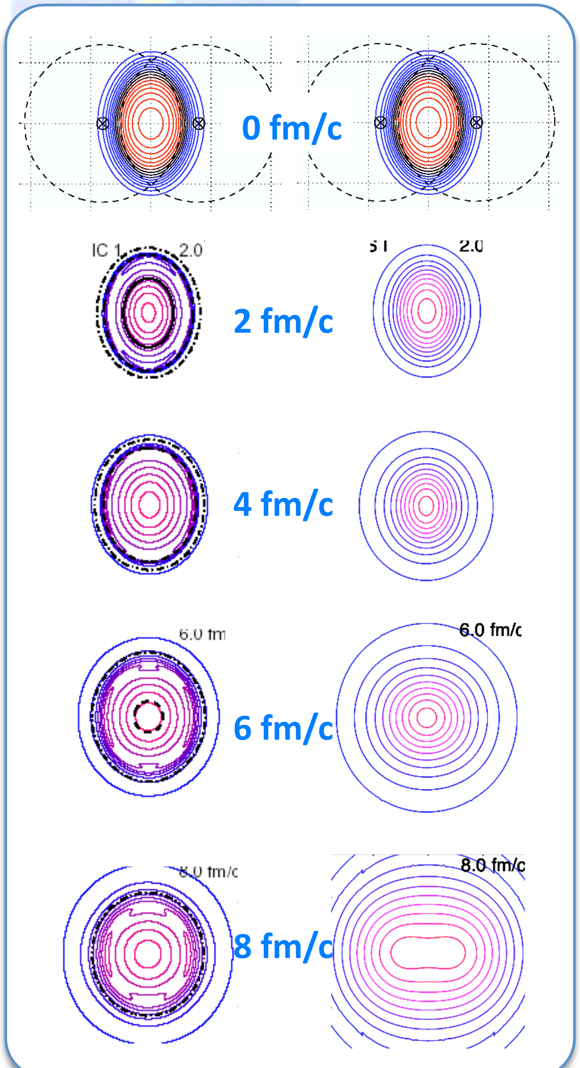


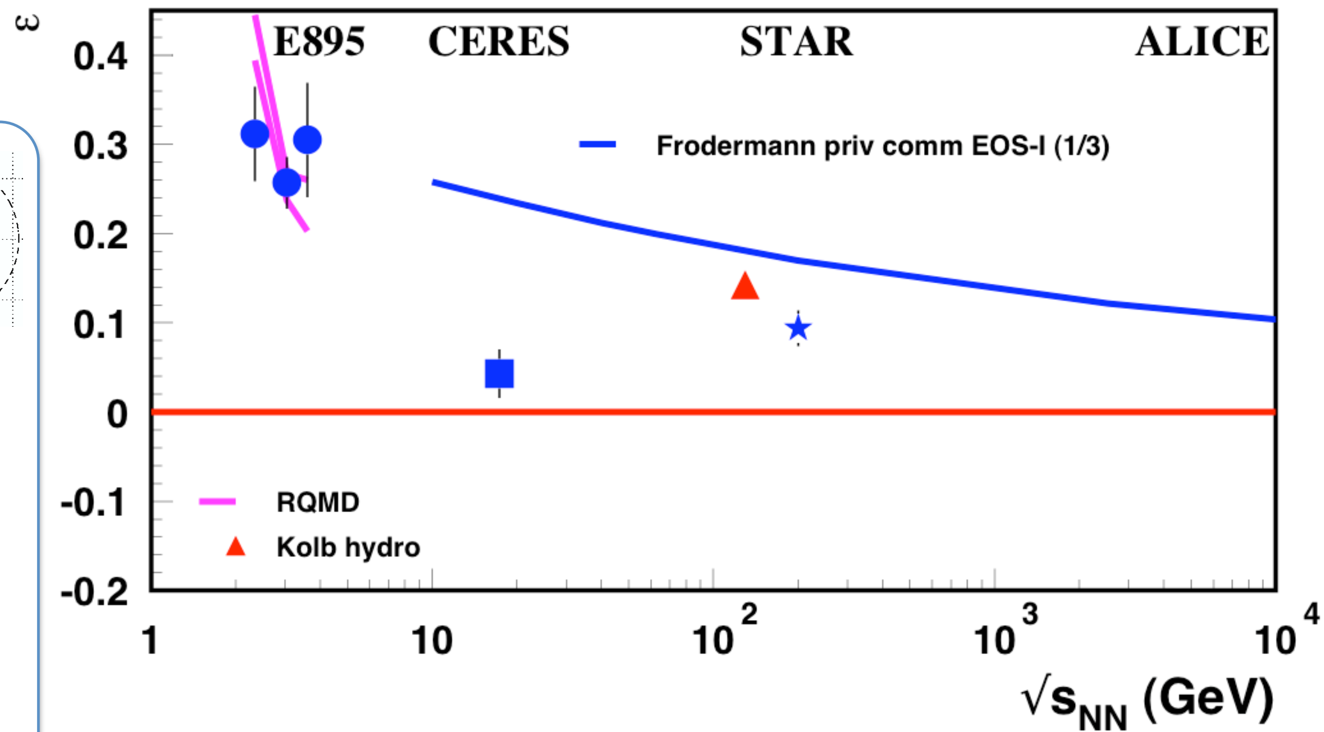


✓RQMD (not UrQMD) @ low energy

✓2D hydro of Kolb/Heinz @ RHIC

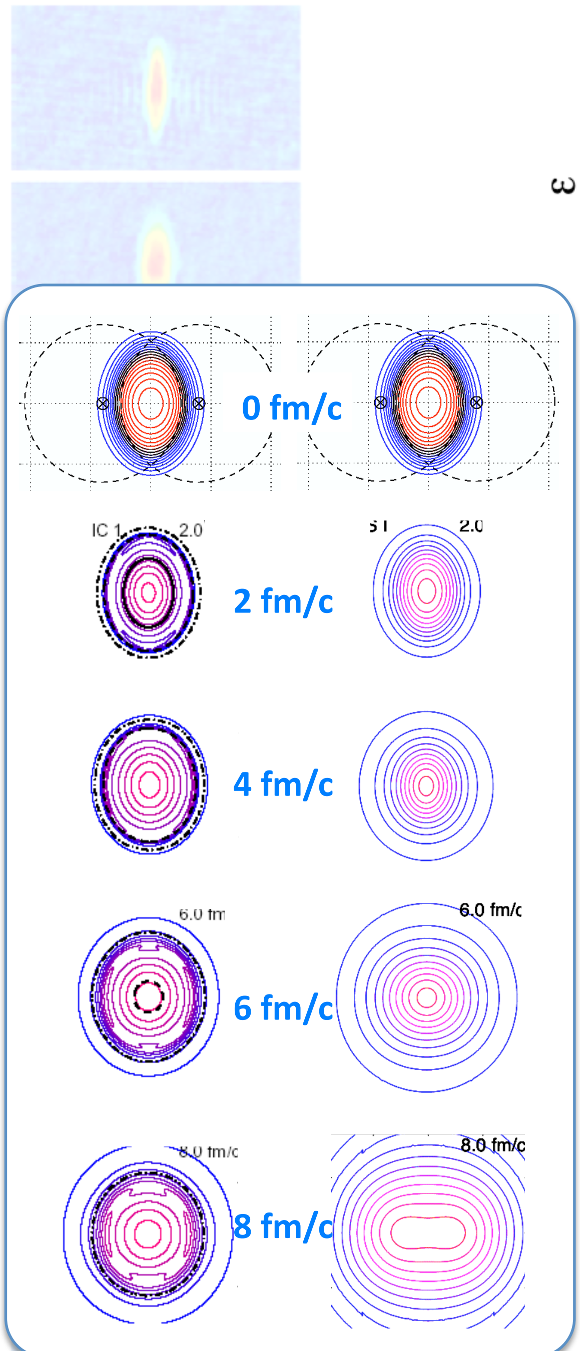
effect of EoS – 2D hydro

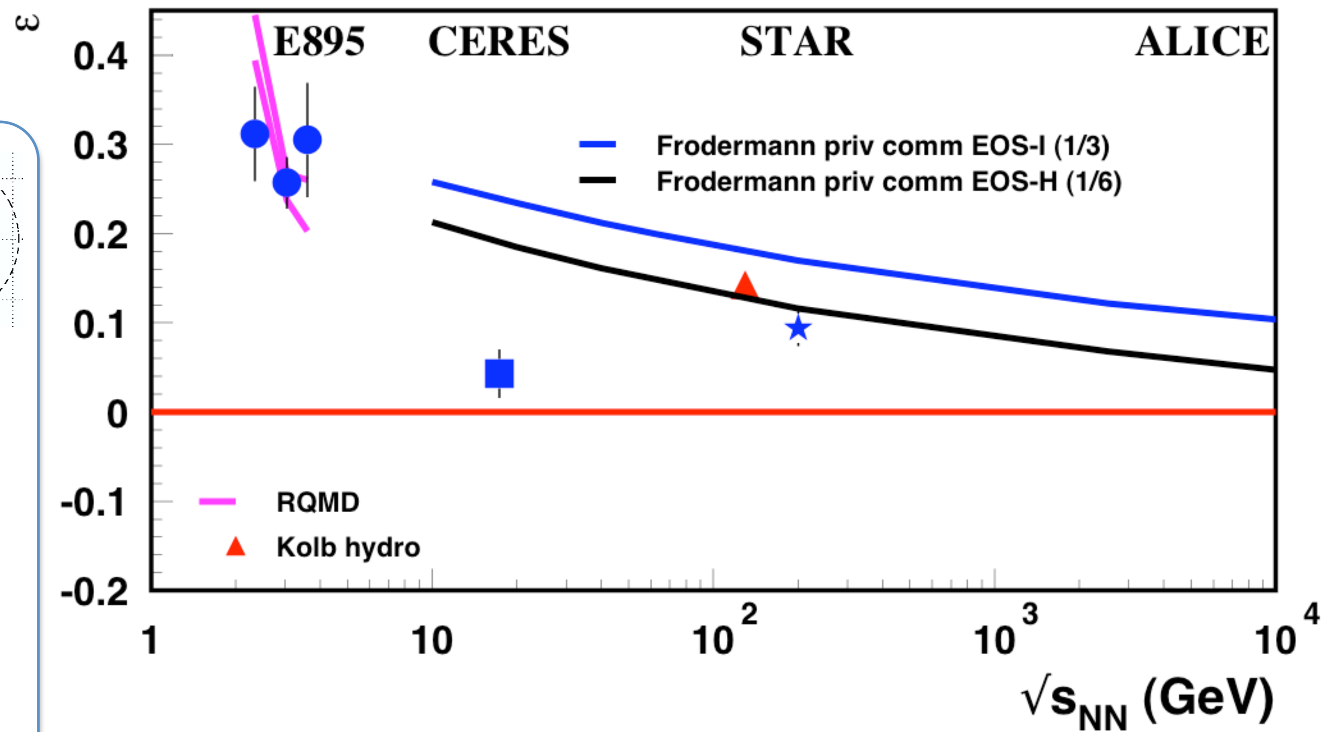




- ✓RQMD (not UrQMD) @ low energy
- ✓2D hydro of Kolb/Heinz @ RHIC
- scan with varying EoS 2D hydro

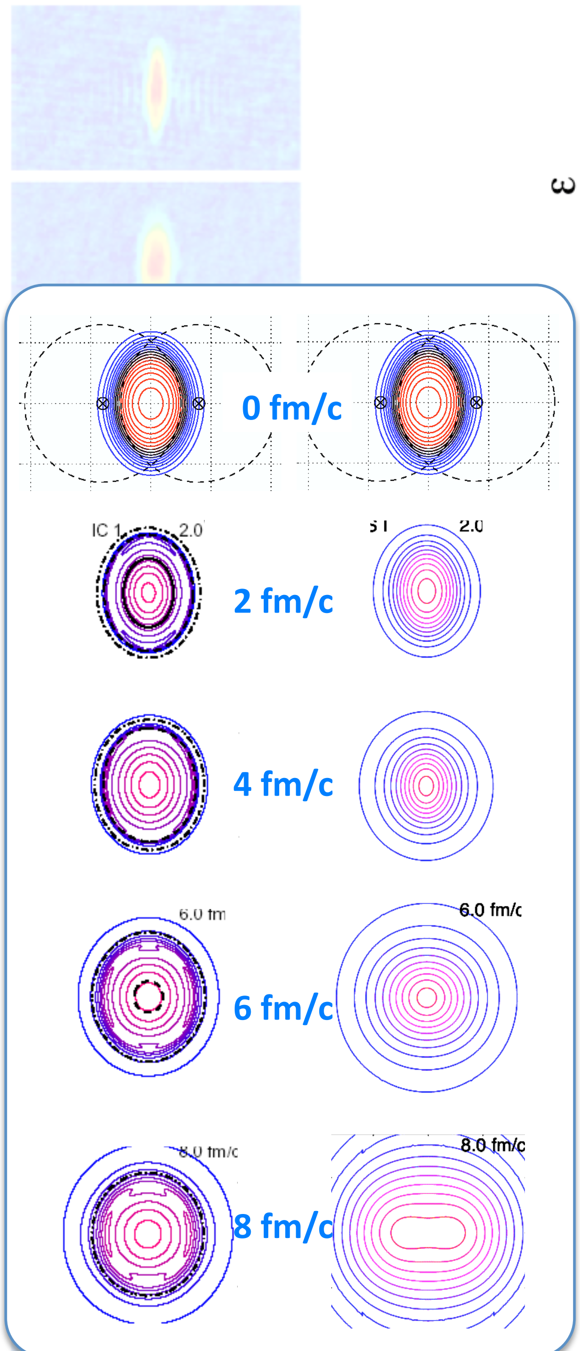
effect of EoS – 2D hydro

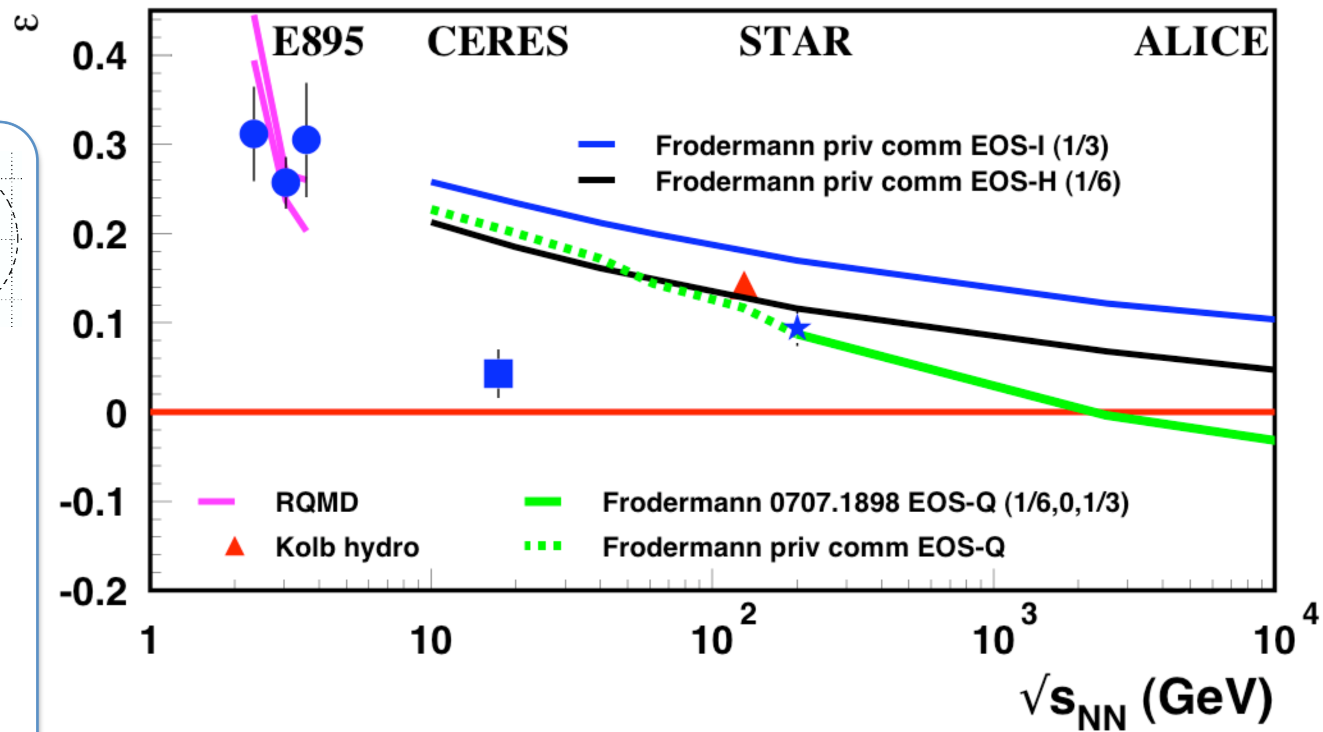




- ✓RQMD (not UrQMD) @ low energy
- ✓2D hydro of Kolb/Heinz @ RHIC
- scan with varying EoS 2D hydro

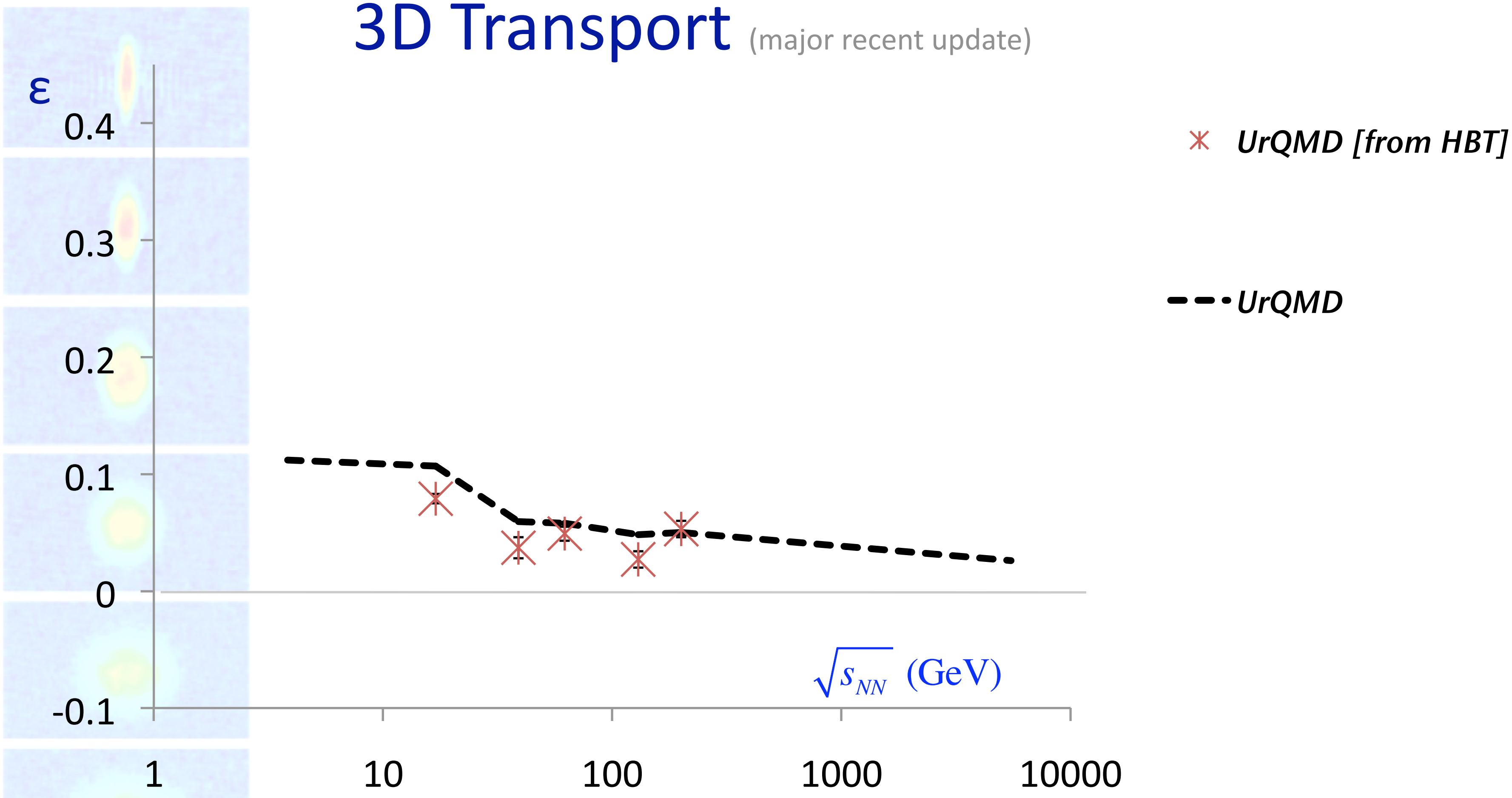
effect of EoS – 2D hydro



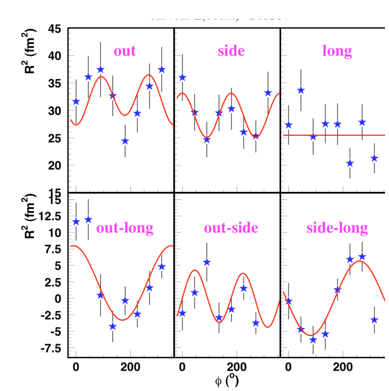


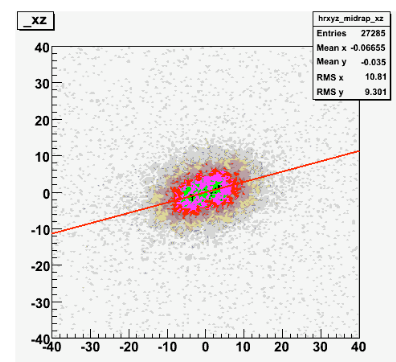
- ✓RQMD (not UrQMD) @ low energy
- ✓2D hydro of Kolb/Heinz @ RHIC
- scan with varying EoS 2D hydro
  - dependence on stiffness stresses lifetime
  - no non-monotonic behaviour predicted
  - **but**: 2D boost-invariant – no tilt

3D Transport (major recent update)

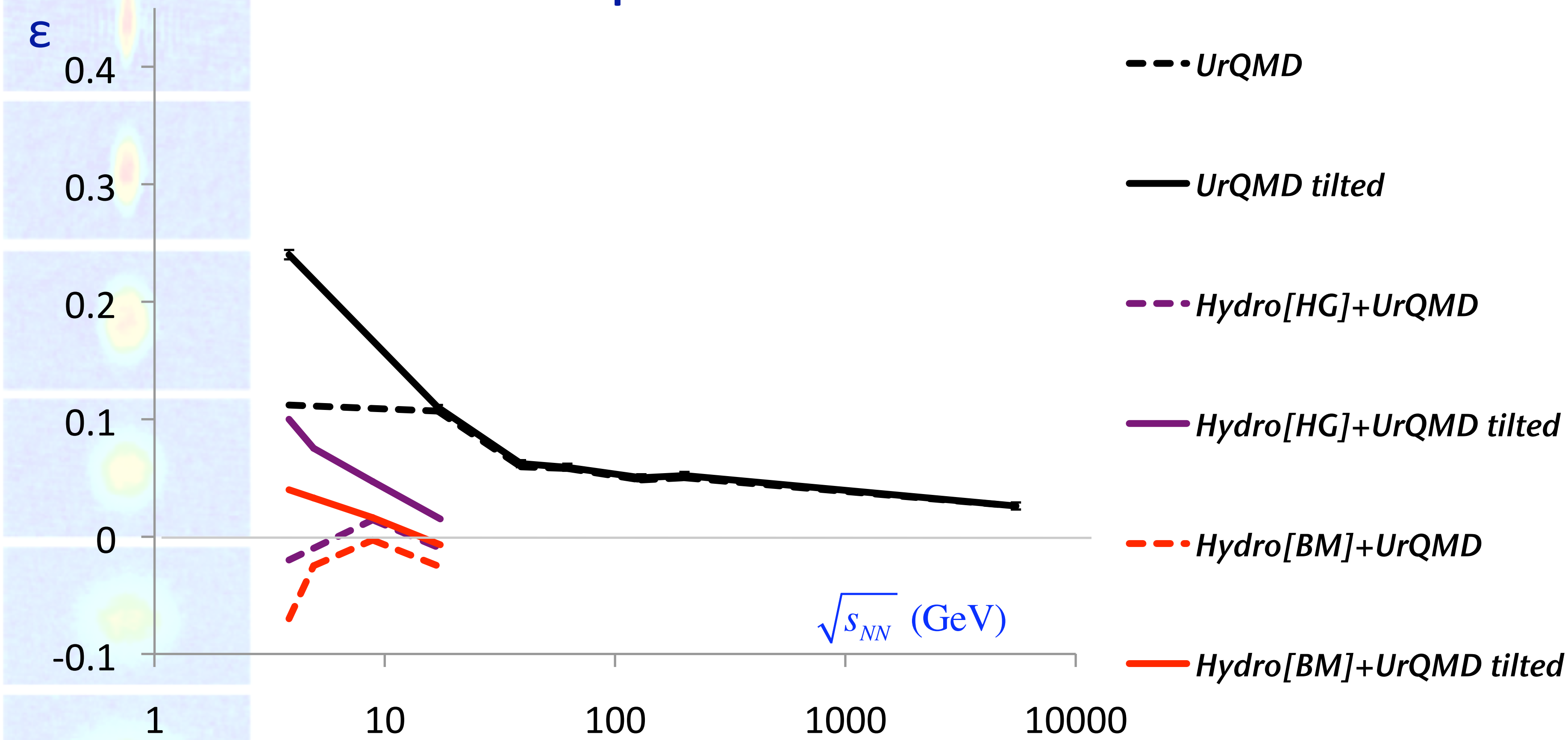


✓HBT ~ captures anisotropy in x,y,z



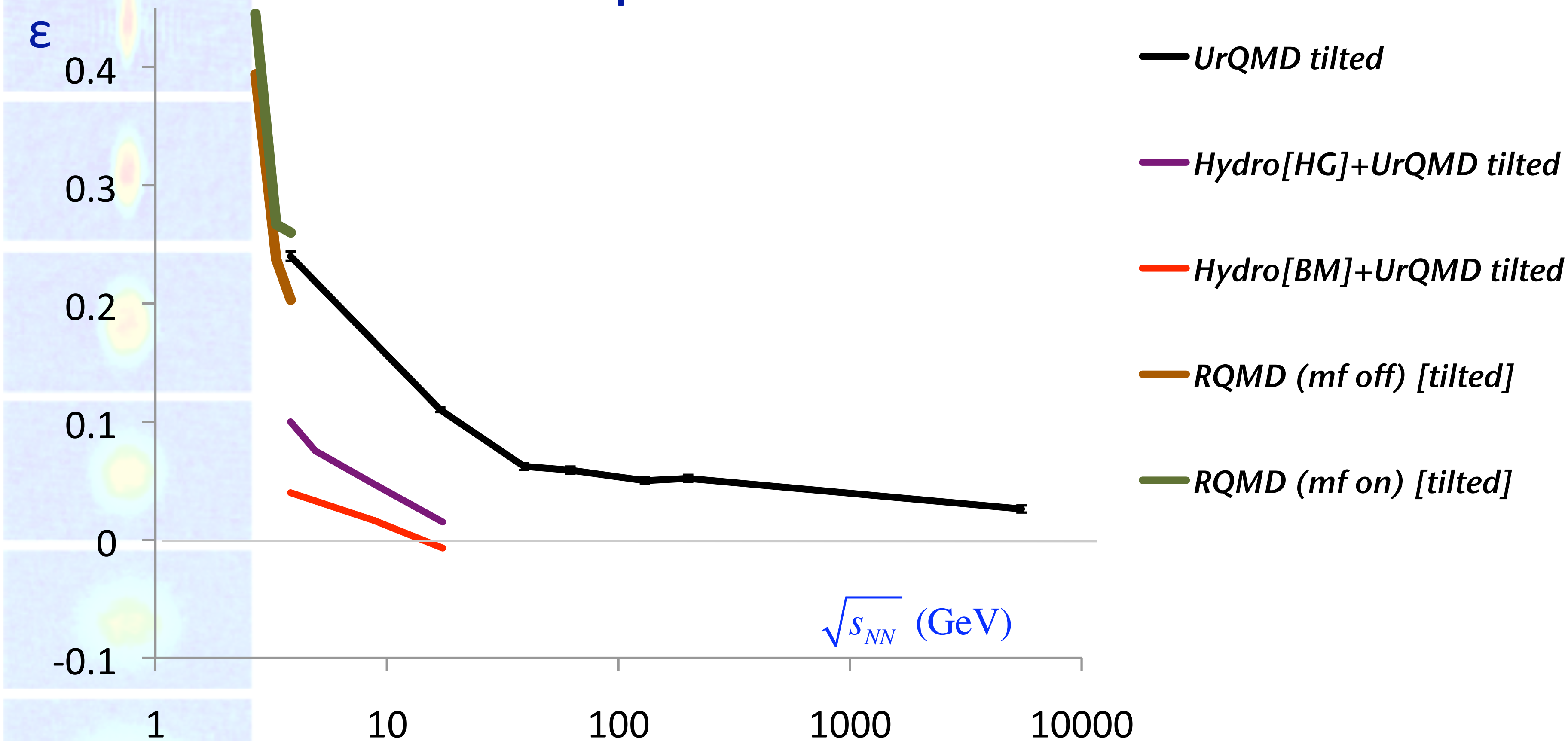


3D Transport (major recent update)



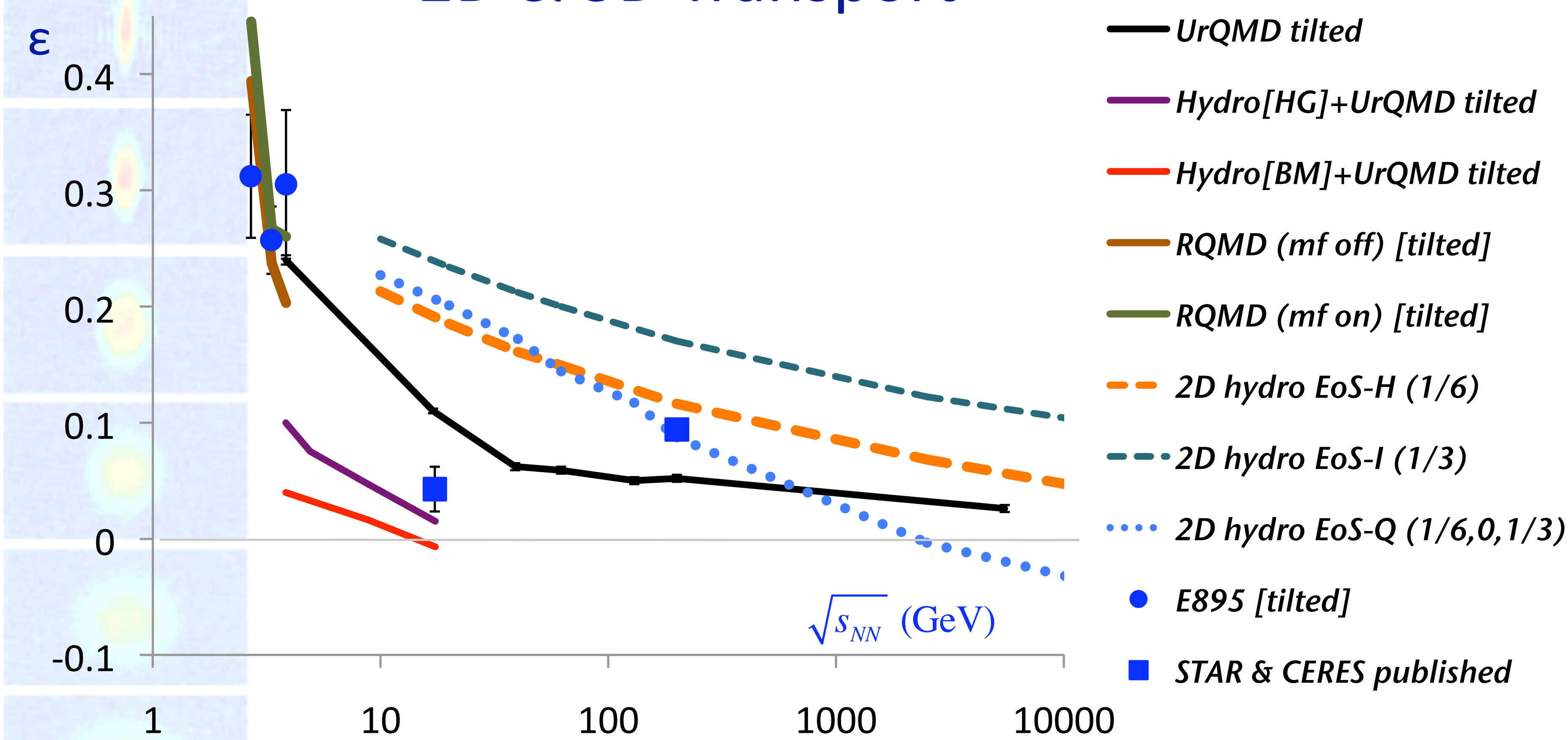
- ✓HBT ~ captures anisotropy in x,y,z
- ✓tilt only important at low energy
- ✓dependence on EoS – timescale effect

3D Transport (major recent update)



- ✓HBT ~ captures anisotropy in x,y,z
- ✓tilt only important at low energy
- ✓dependence on EoS – timescale effect
- ✓cascade code consistent with ancestor

2D & 3D Transport

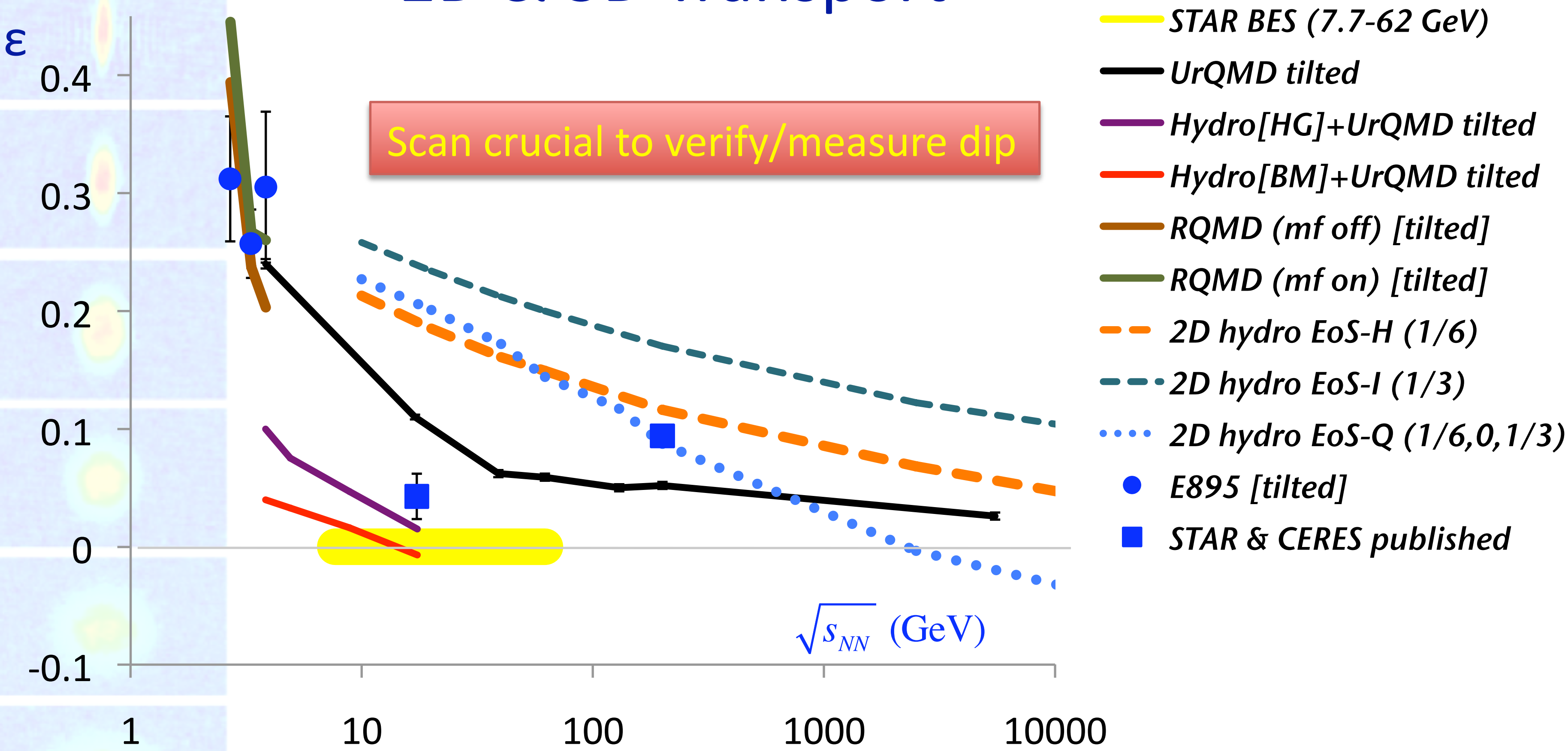


- ✓HBT ~ captures anisotropy in x,y,z
- ✓tilt only important at low energy
- ✓dependence on EoS – timescale effect
- ✓cascade code consistent with ancestor

- No model reproduces measured excitation fctn
  - agreement of **2D** hydro @ AGS surely coincidence
- No calculation displays non-monotonic behaviour
  - even 2D[EoS-Q] and 3D[BM]
  - timescale dominates in these models

see also Teaney, Lauret, & Shuryak nucl-th/0110037

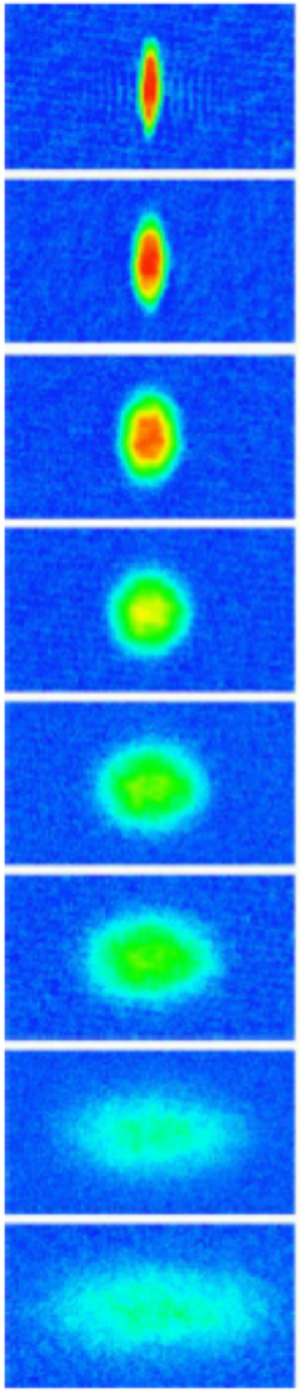
2D & 3D Transport



- ✓HBT ~ captures anisotropy in x,y,z
- ✓tilt only important at low energy
- ✓dependence on EoS – timescale effect
- ✓cascade code consistent with ancestor

- No model reproduces measured excitation fctn
  - agreement of **2D** hydro @ AGS surely coincidence
- No calculation displays non-monotonic behaviour
  - even 2D[EoS-Q] and 3D[BM]
  - timescale dominates in these models

see also **Teaney, Lauret, & Shuryak nucl-th/0110037**



Summary

- **p**-dep femtoscopy reveals flow-generated substructure
  - mT-dependence: radial flow
  - y-dependence: longitudinal flow
  - asHBT measures detailed spatial analogs of v1, v2

- bulk observable with
  - sensitive to EoS & dynamical time (& 3^{rd} flow component, softening?)
  - ‼ non-monotonic excitation fctn: interesting feature @ "interesting" $\sqrt{s}$

- true 3D, unified modeling important, to map out spatial dynamics

- 1^{st}-order R.P. necessary during RHIC energy scan

- Ongoing analyses – Chris Anson
  - 200 GeV Y4 – important consistency check
  - 62 GeV Y4 – first step in energy scan
  - 39 GeV – in progress
  - 7.7 GeV – in the queue