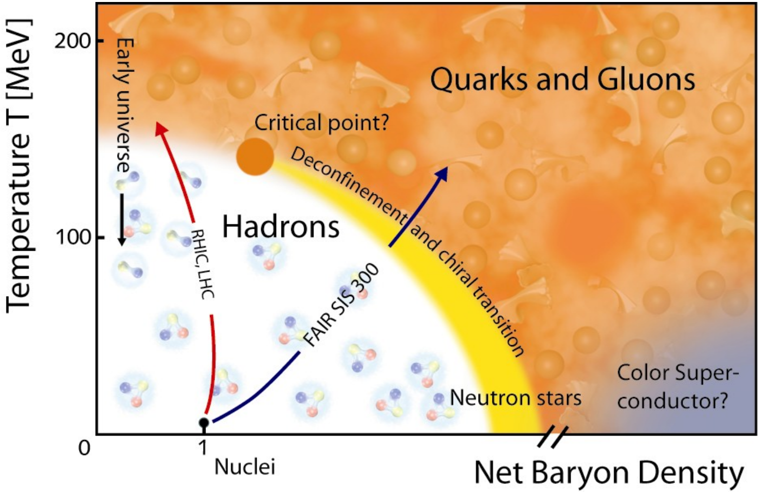
Implications of recent measurements in heavy-ion collisions

Matthew Luzum

Institut de physique théorique
CEA Saclay, France

Rencontres de Blois
31 May, 2012

Phases of the strong interactions

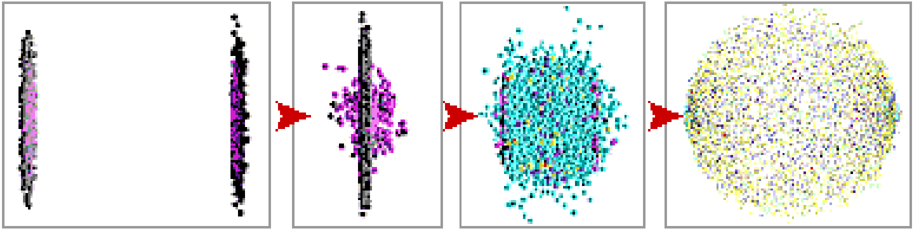


Deconfined Quark-Gluon Plasma at high T

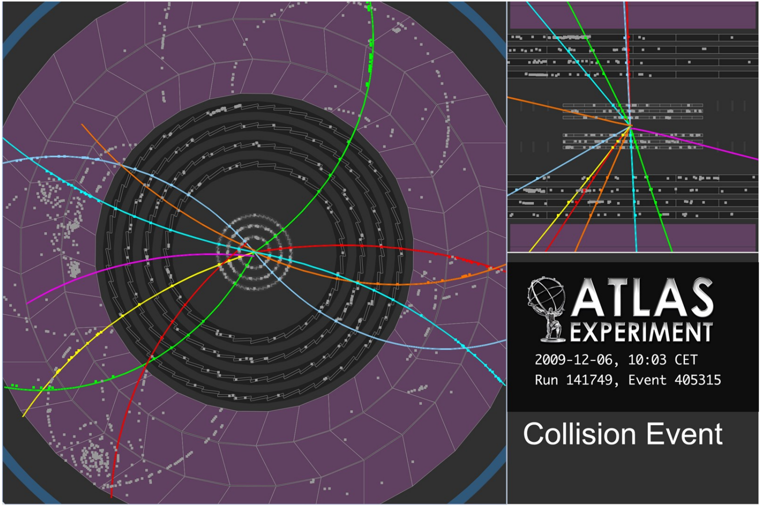
Creating a Quark Gluon Plasma

Highest-energy ion colliders:

- Relativistic Heavy Ion Collider (RHIC) at BNL *(since 2000)*
  $\rightarrow$ Au+Au at $\sqrt{s_{NN}} = 200$ GeV
- Large Hadron Collider (LHC) at CERN *(since 2010)*
  $\rightarrow$ Pb+Pb at $\sqrt{s_{NN}} = 2760$ GeV

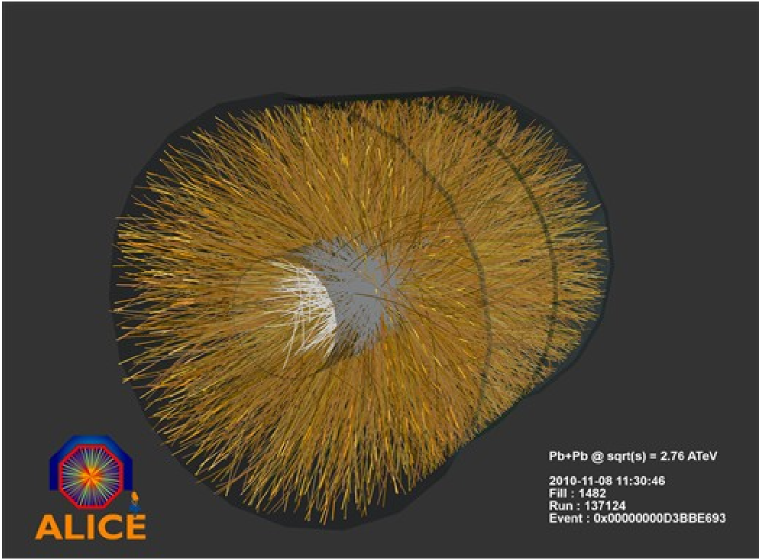


PROTON-PROTON COLLISION



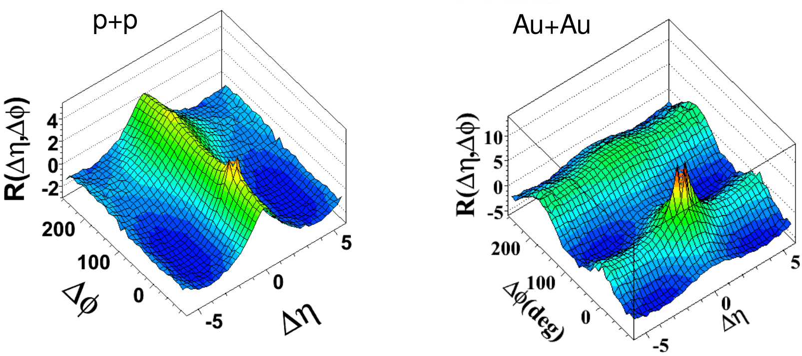
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

HEAVY-ION COLLISION



TWO-PARTICLE CORRELATIONS

Unique long-range correlations in heavy-ion collisions. . .



(PHOBOS, Phys.Rev. C81 (2010) 024904)

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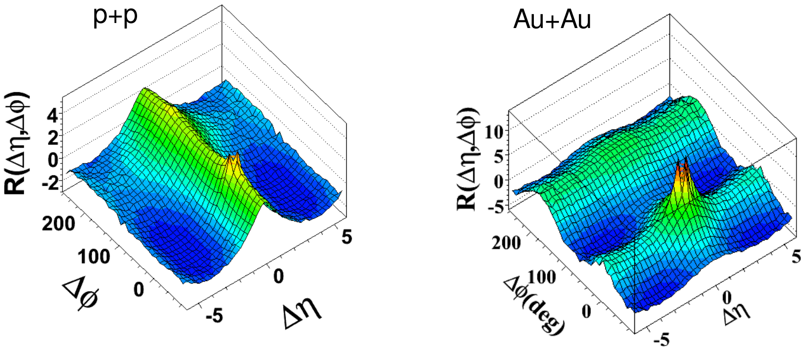

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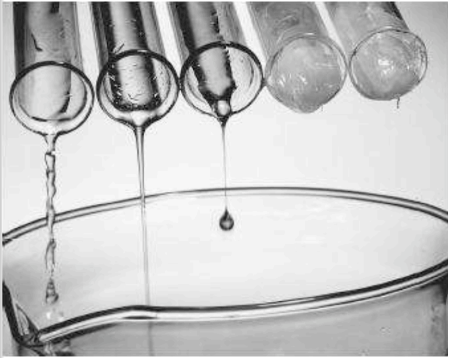
indicate strong collective behavior

Hydrodynamics

Hydrodynamics

- Universal description of system with large separation of scales (e.g., local thermal equilibrium)
- Valid if system is large enough/ interactions are strong enough
- Access to microscopic dynamics through transport coefficients, e.g., shear viscosity η
- (Compare to conjectured lower bound $\eta/s \geq 1/4\pi \simeq 0.08$)



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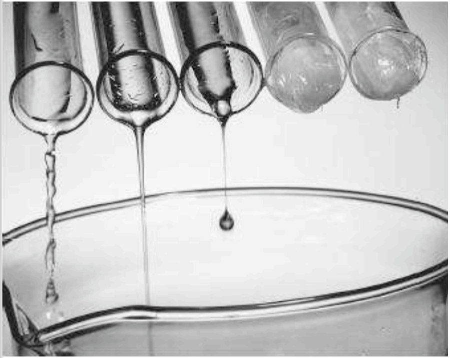

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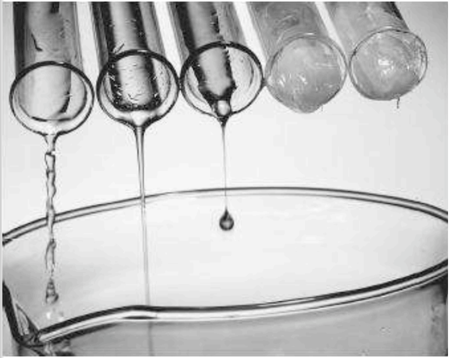

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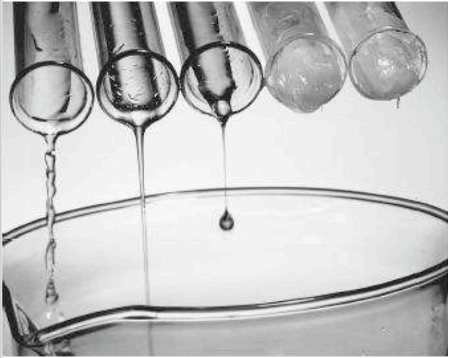
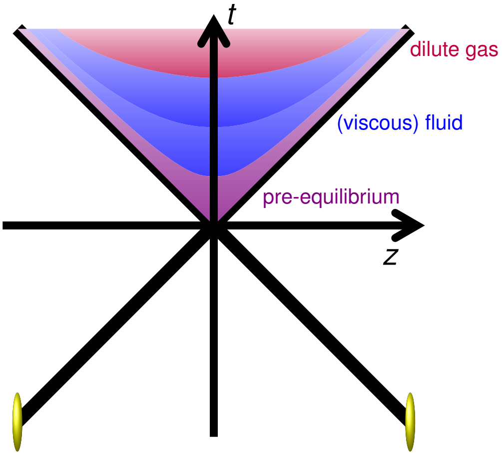


Collision Evolution



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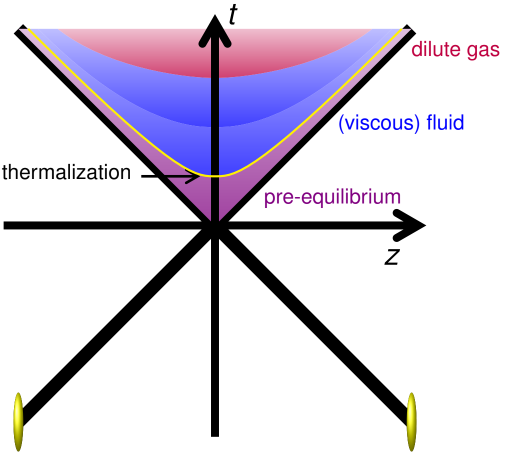
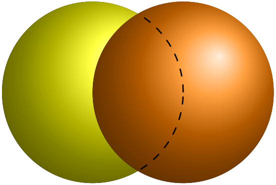


Well described by hydrodynamics, but sensitive to initial conditions (low-x nuclear wavefunction, soft particle production, thermalization. . .)

FLOW



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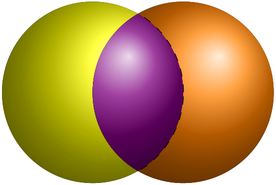

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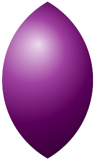

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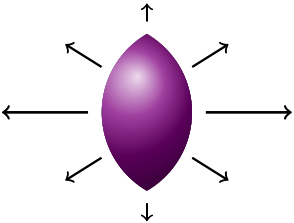

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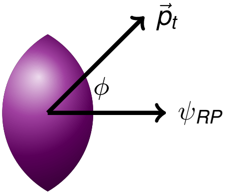

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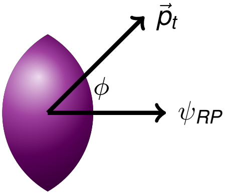

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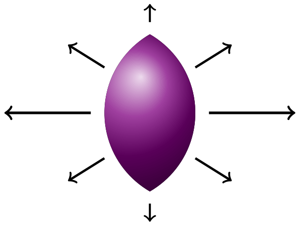

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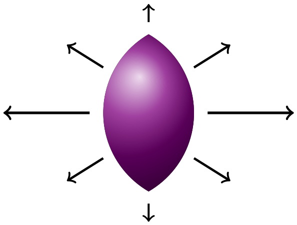

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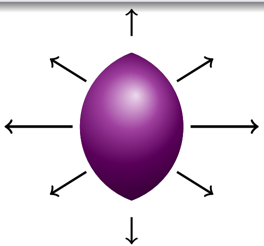

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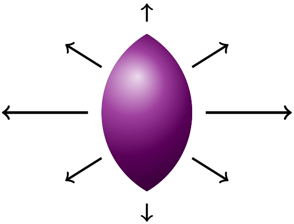

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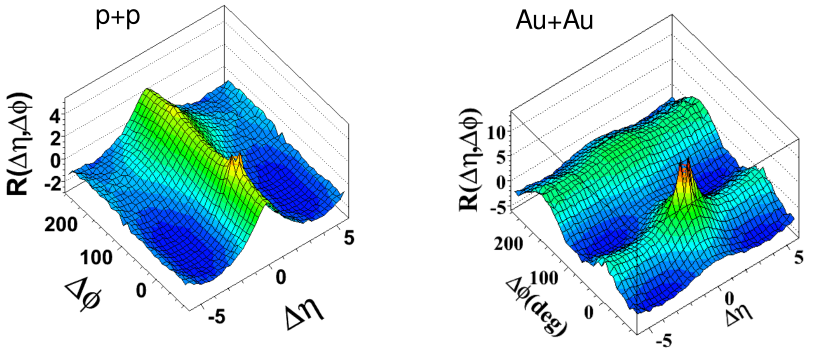

(PHOBOS, Phys.Rev. C81 (2010) 024904)

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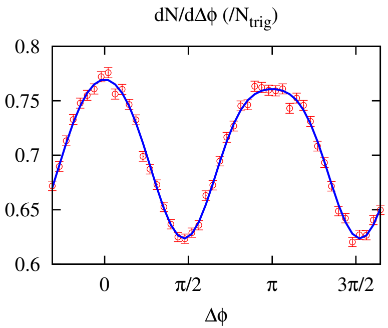

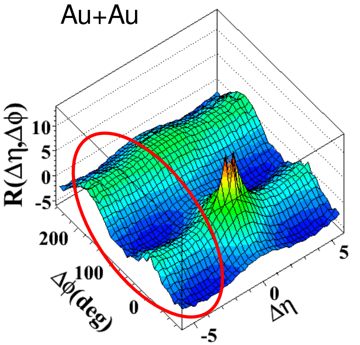

(STAR, arXiv:1010.0690)

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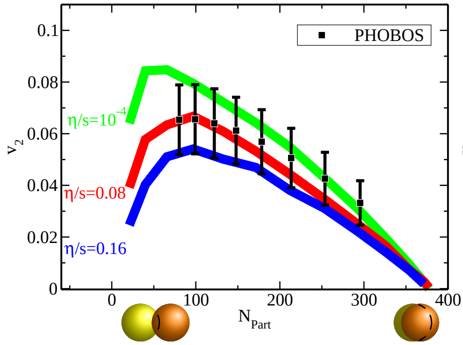
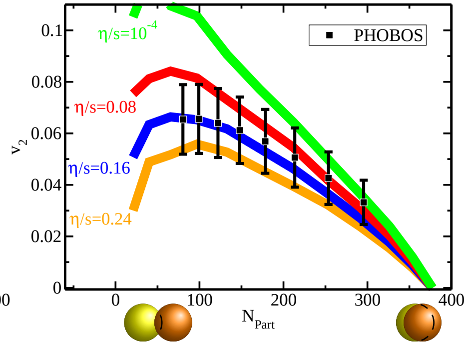
Elliptic Flow and viscosity

"Glauber" initial conditions



"CGC" initial conditions



(ML & Romatschke, Phys.Rev. C78 (2008) 034915)

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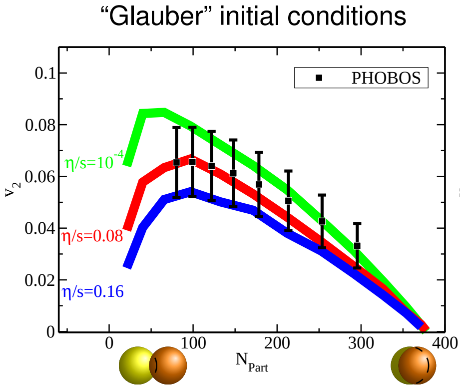

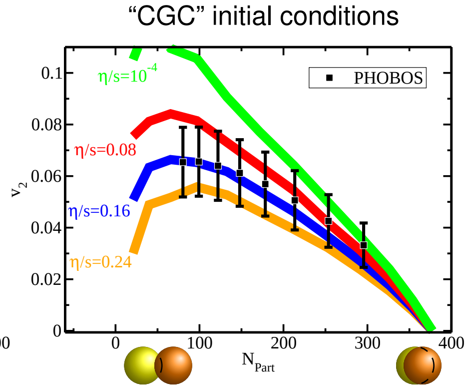

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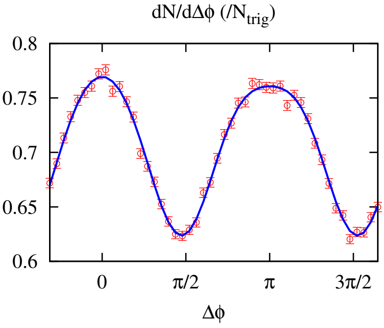

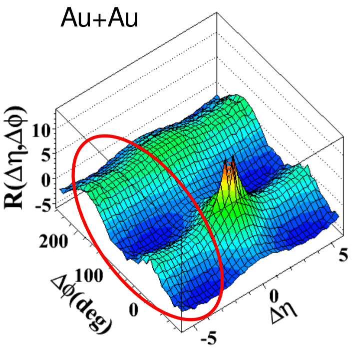

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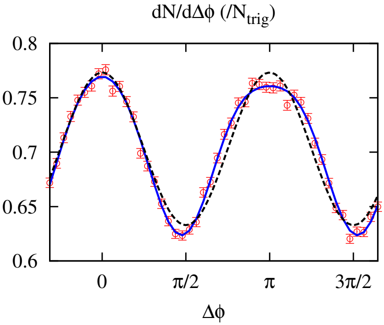

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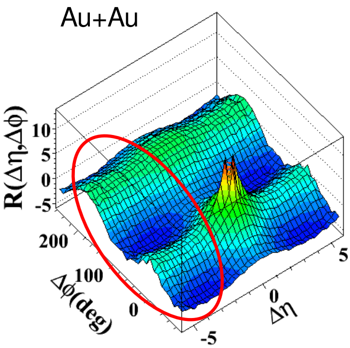

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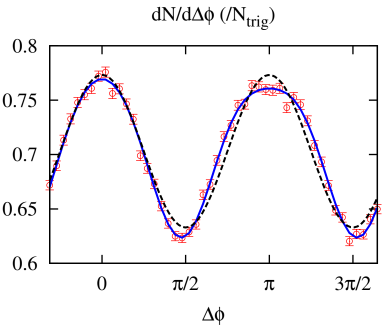

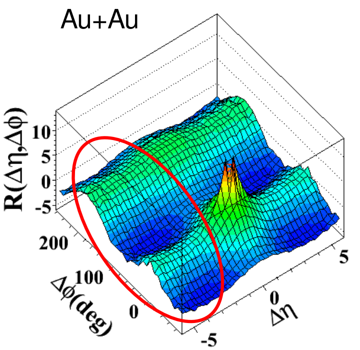

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. . . can be entirely explained by collective flow:

Flow fluctuations

$$\frac{dN}{d\phi} \propto 1 + 2v_2 \cos 2\phi + 2v_4 \cos 4\phi + \ldots$$

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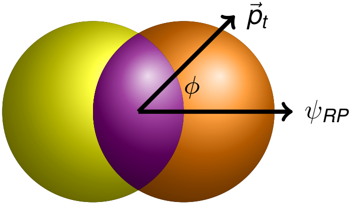

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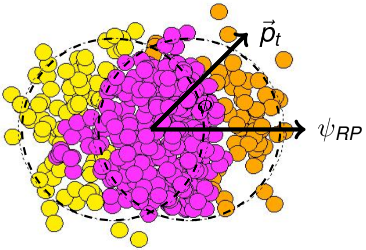

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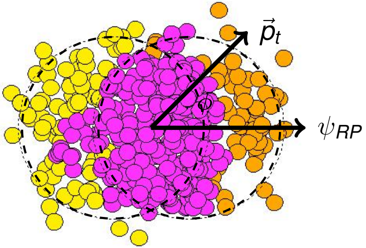

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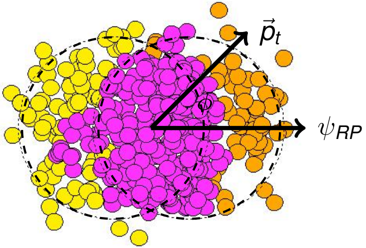

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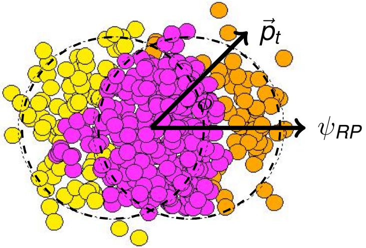

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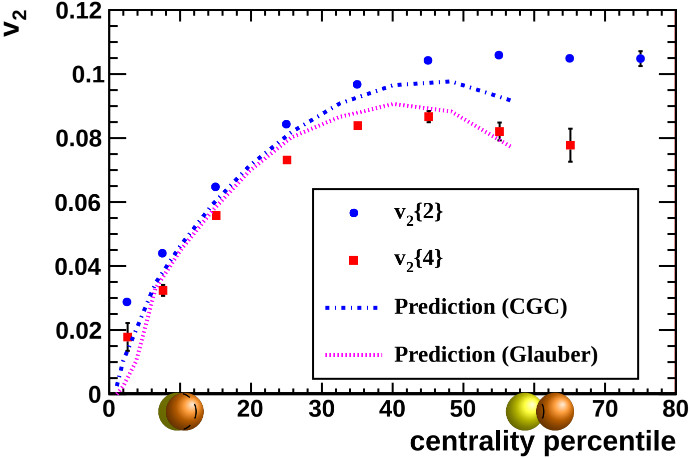
RECENT RESULTS: ELLIPTIC FLOW AT LHC

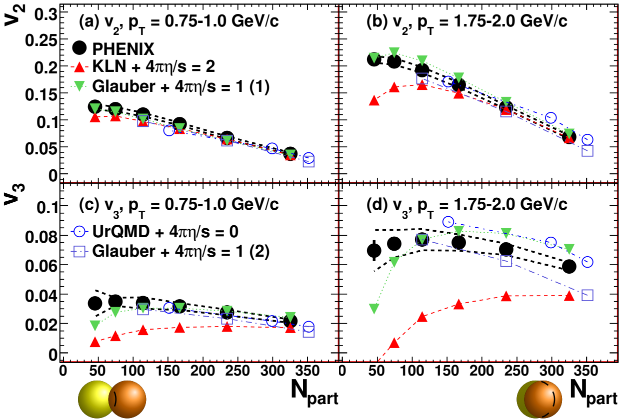
Hydro calculations correctly predicted flow at LHC:



(ML, Phys.Rev. C83 (2011) 044911)

RECENT RESULTS: v_n

Combining observables constrains theory



(PHENIX , Phys.Rev.Lett. 107 (2011) 252301)

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Many brand new data still waiting for thorough study:

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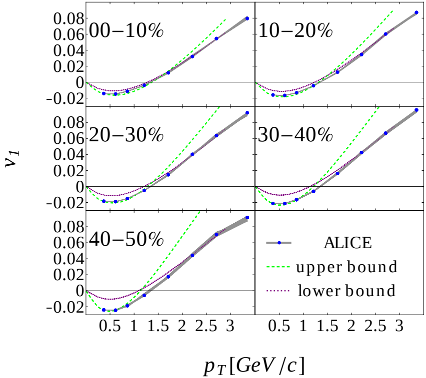

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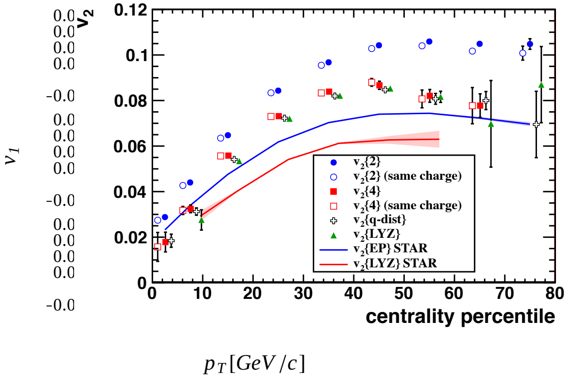

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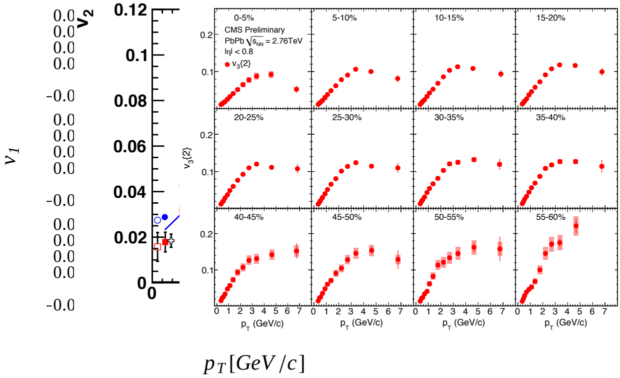

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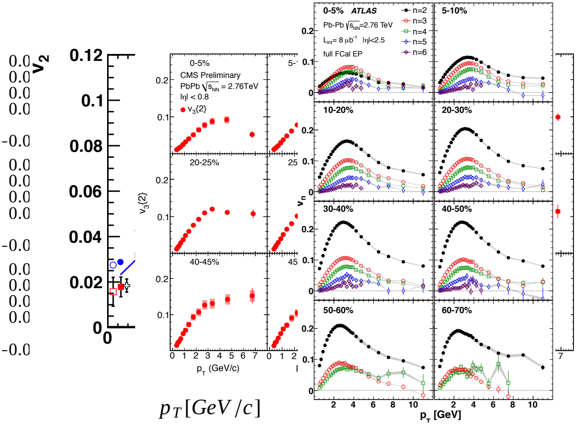

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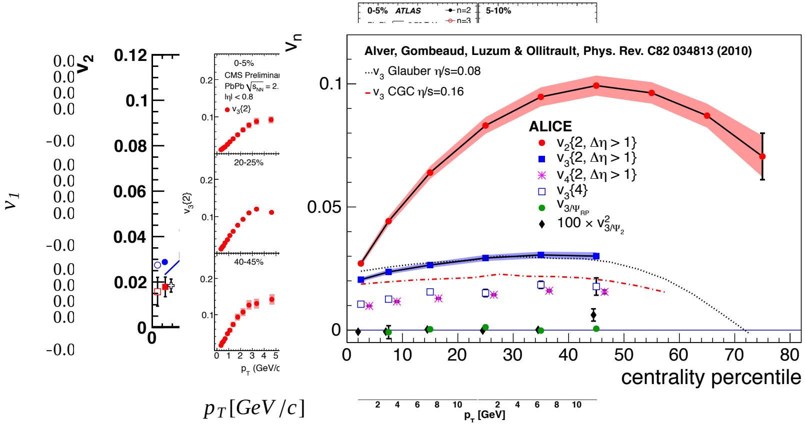

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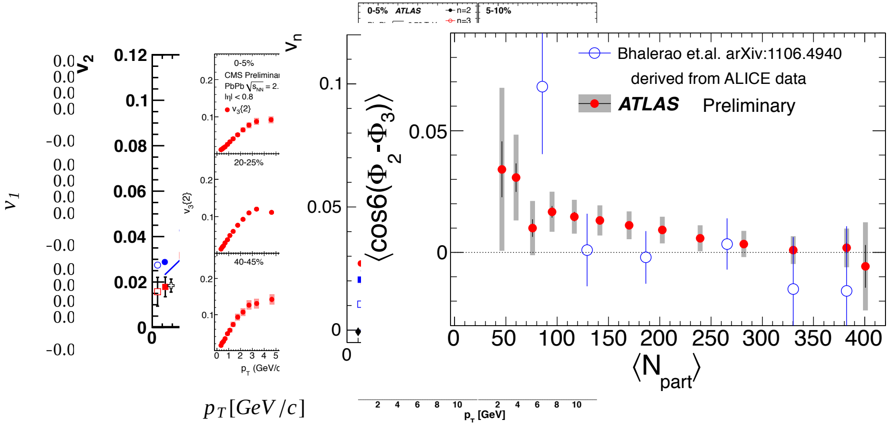

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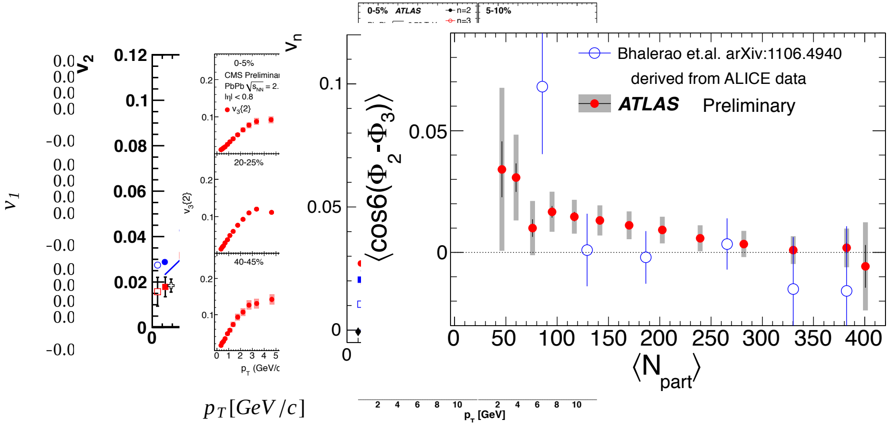

(and some still to be measured)

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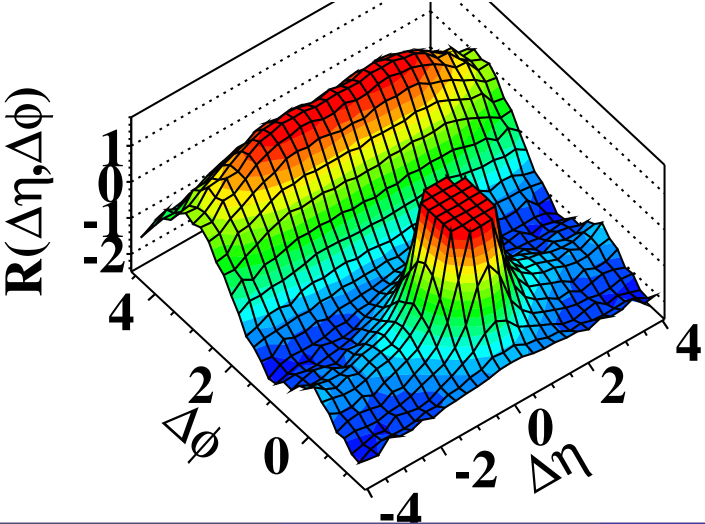
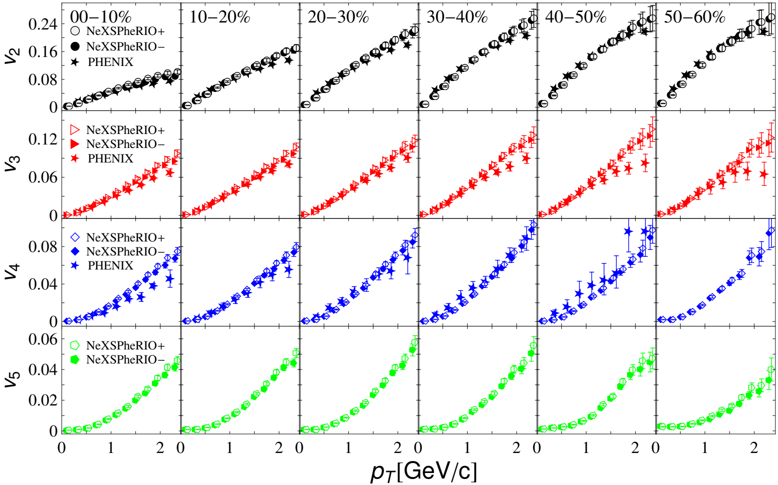
CMS PP RIDGE

(d) CMS N ≥ 110, 1.0GeV/c<p_T<3.0GeV/c



RECENT RESULTS

Hydrodynamic calculation can reproduce two-particle correlation:



(Gardim, Grassi, ML, Ollitrault, arXiv:1203.2882)

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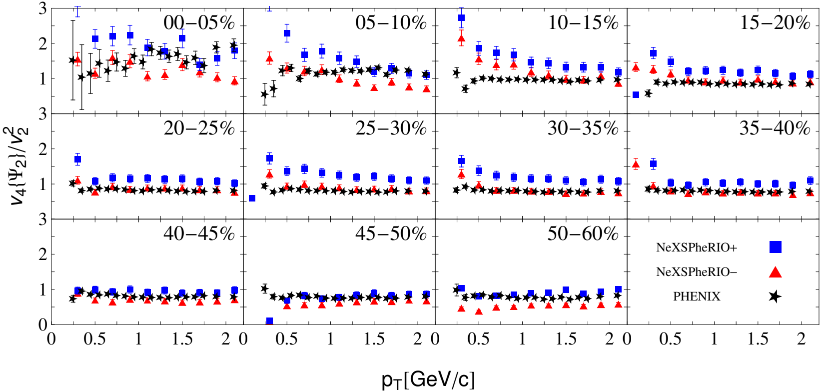

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