Event Anisotropy in Au+Au Collisions at RHIC

Raimond Snellings (LBNL)

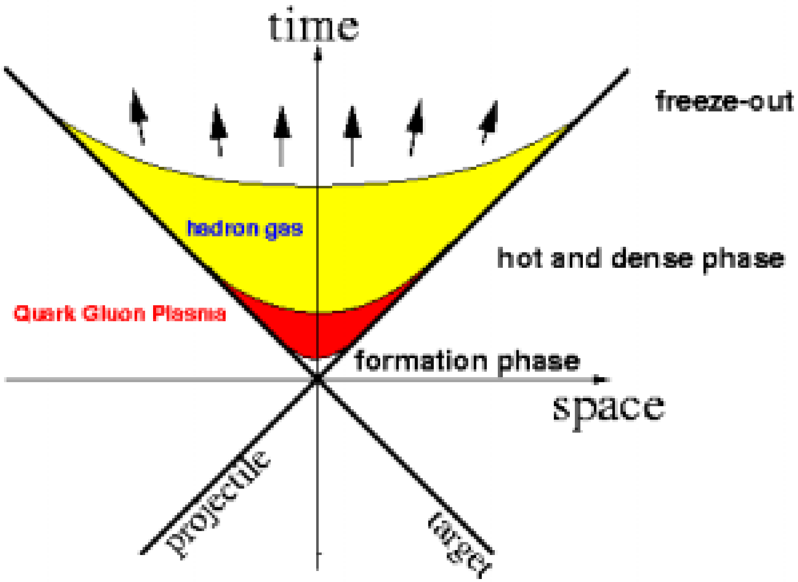
For the STAR Collaboration

Overview

- Introduction
- First elliptic flow measurement at RHIC
  - Elliptic flow versus centrality
  - Elliptic flow for identified particles versus p_t
- Elliptic "flow" for charged particles with a $p_t > 2$ GeV/c
- Summary

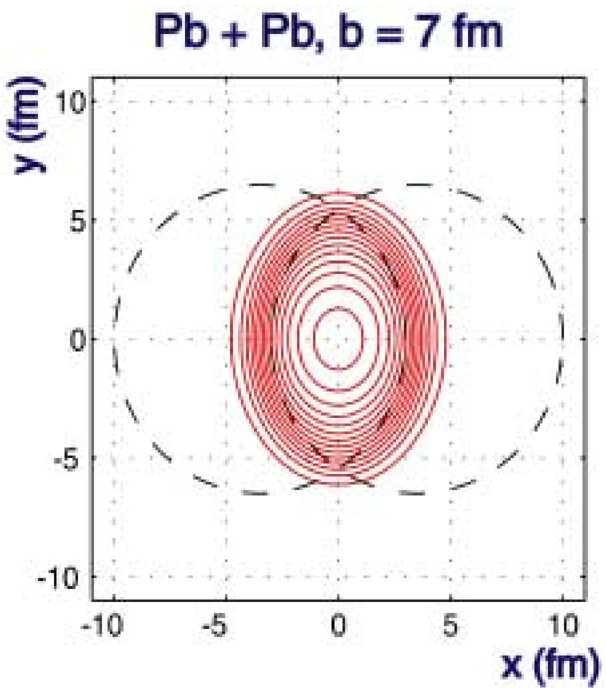
Why Heavy-Ion Collisions?
Why Elliptic Flow Measurements?

- Study the bulk properties of matter far from the ground state ("parton" matter)
- The pressure - The pressure gradient generates collective motion (flow)
  - Central collisions: radial flow
  - Peripheral collisions: radial flow and anisotropic flow

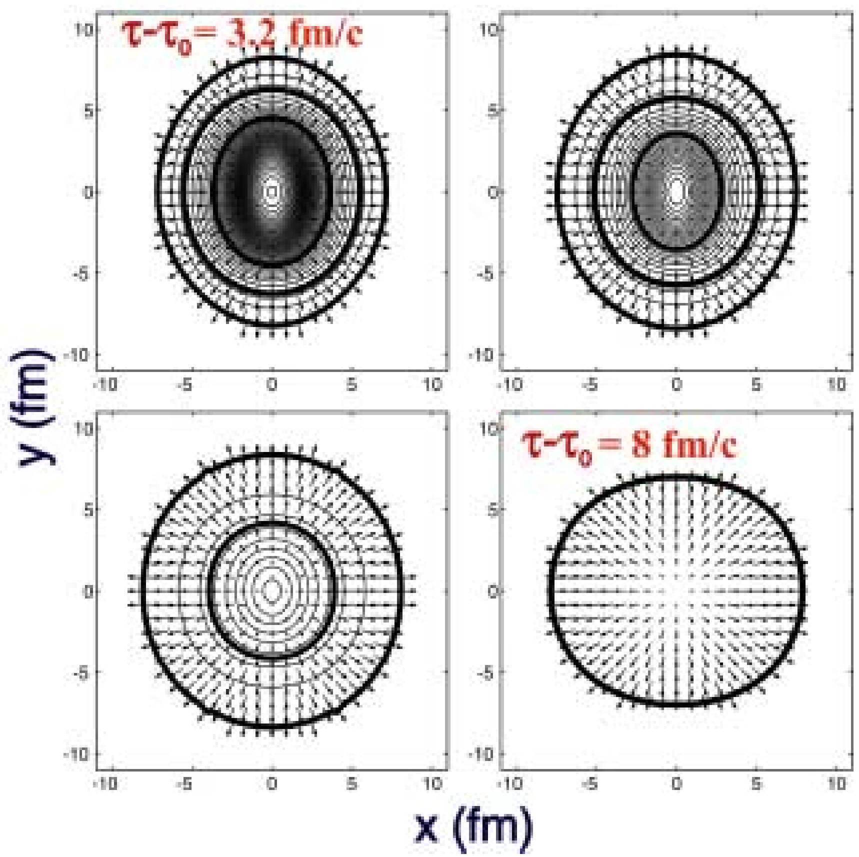


A Hydro Calculation of Elliptic Flow

P. Kolb, J. Sollfrank, and U. Heinz

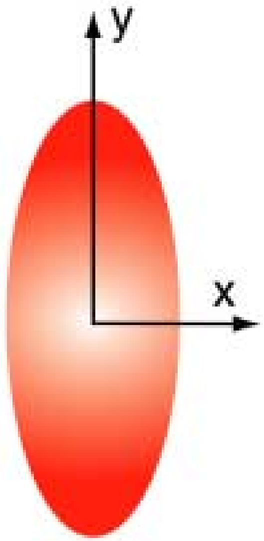


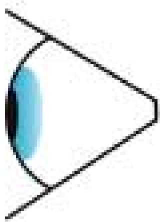
Equal energy density lines

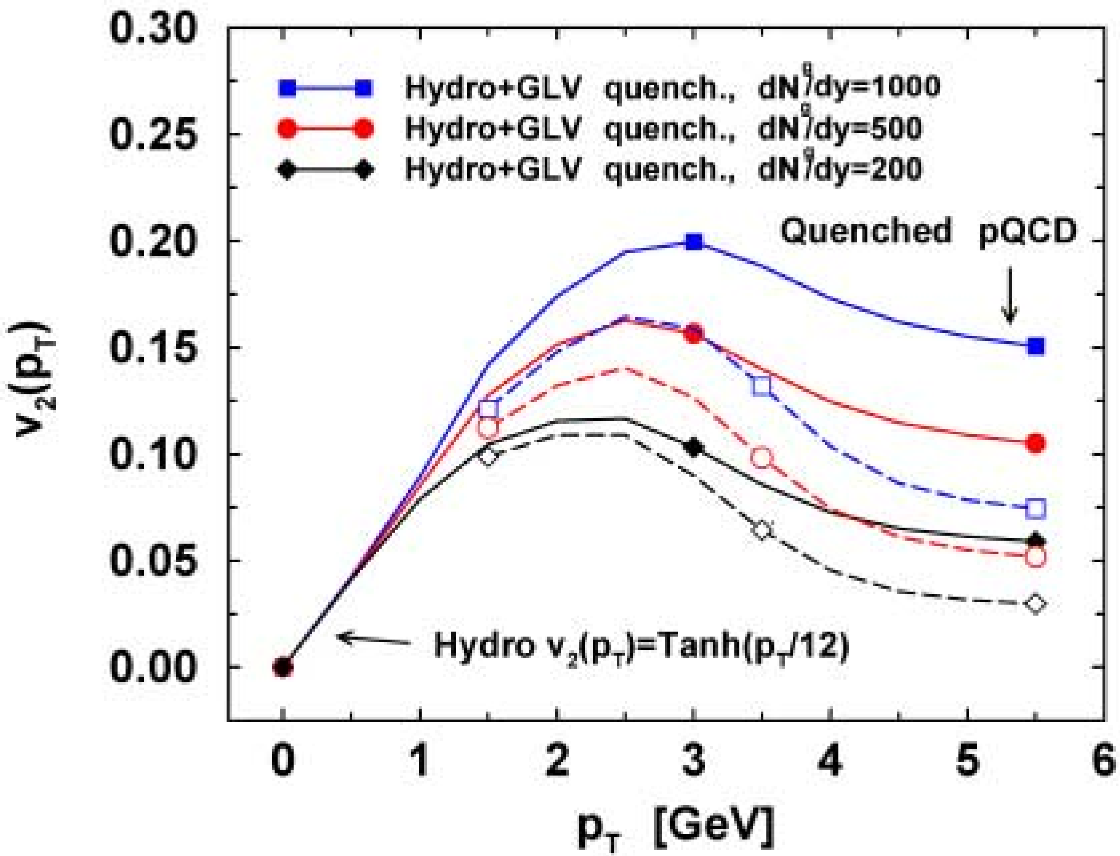


$v_2(p_t)$ for high p_t particles

M. Gyulassy, I. Vitev and X.N. Wang, nucl-th/00012092



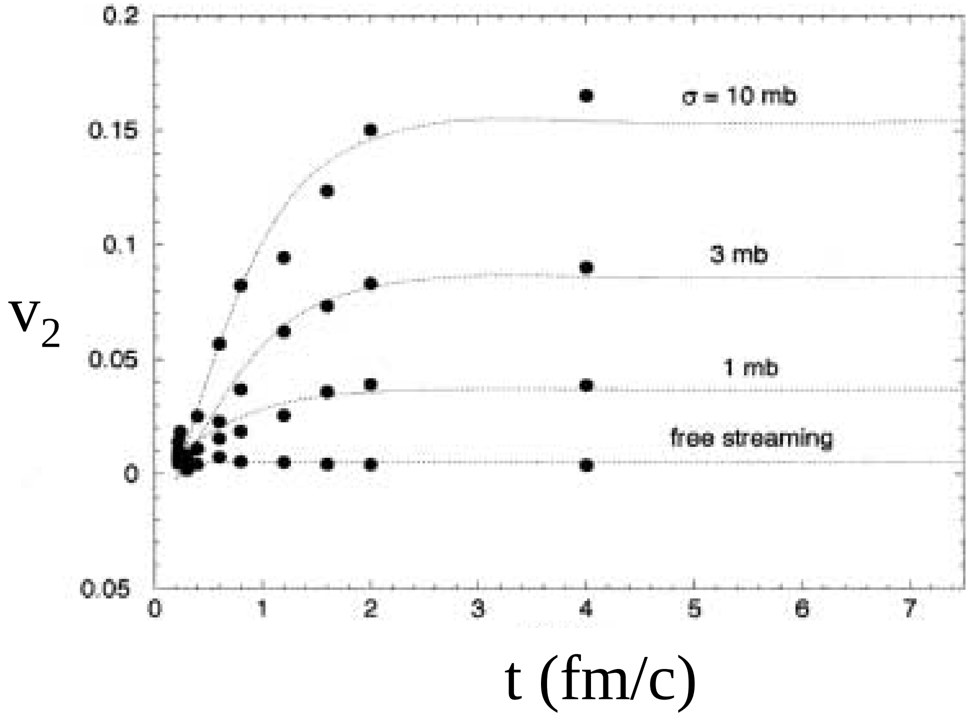




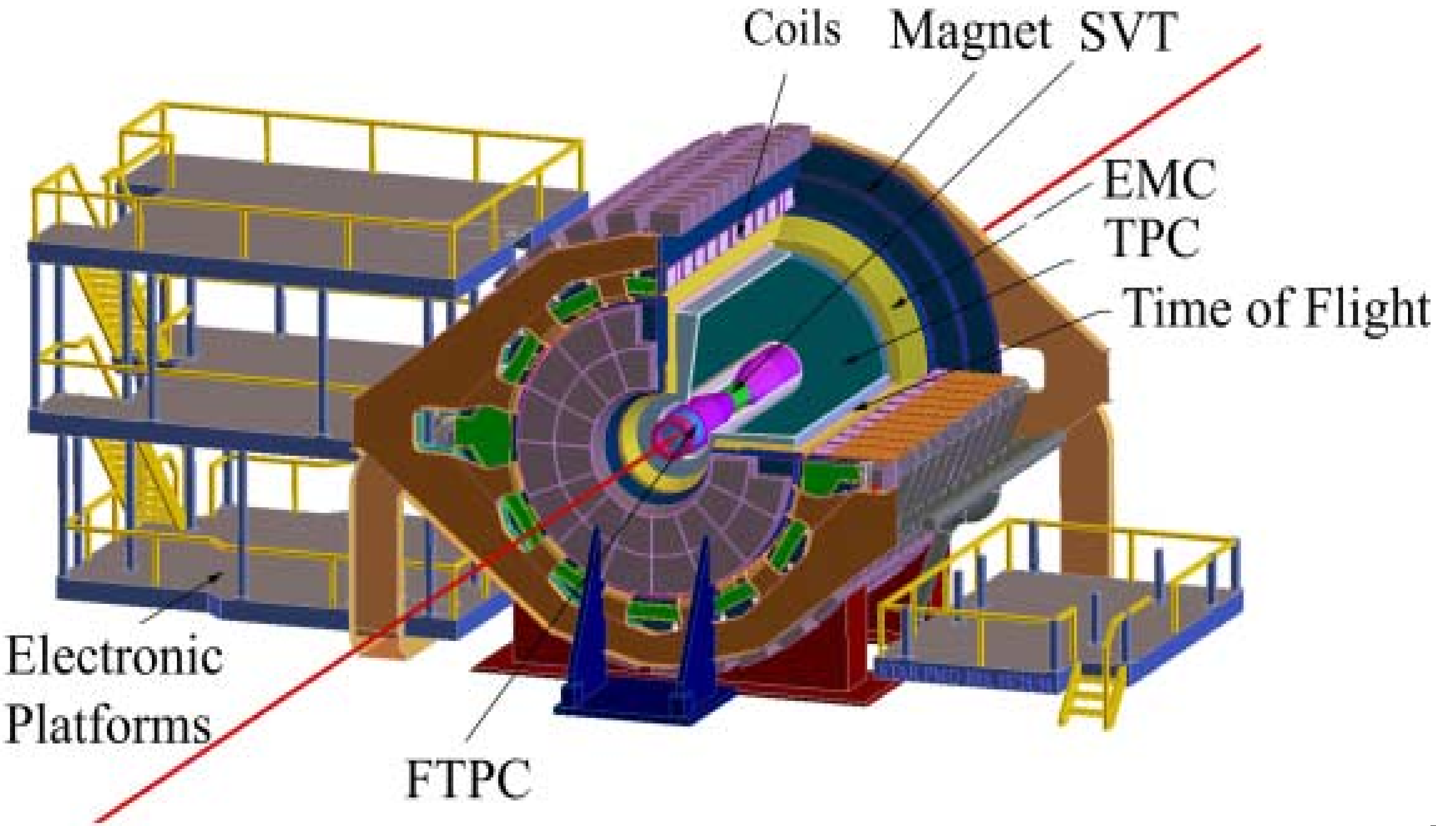
Summary (elliptic flow)

- Rescattering
  - Converts space anisotropy to momentum anisotropy
- Becomes more spherical
  - Self-quenching
    - ✓ thermalization at Early time

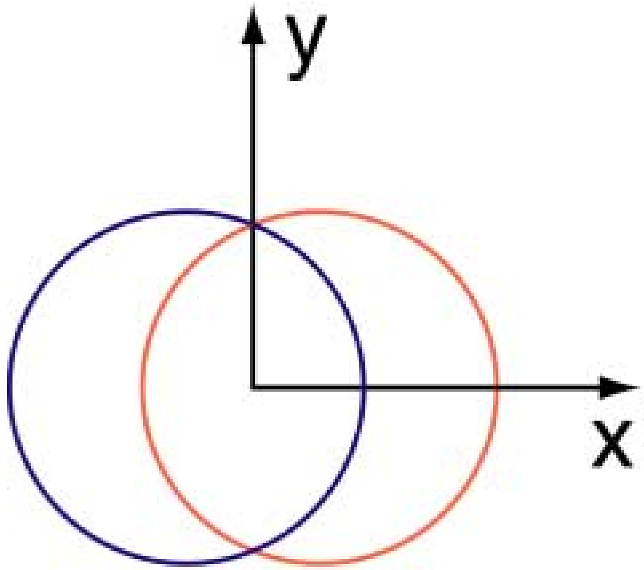
Zhang, Gyulassy, Ko, PL B455 (1999) 45

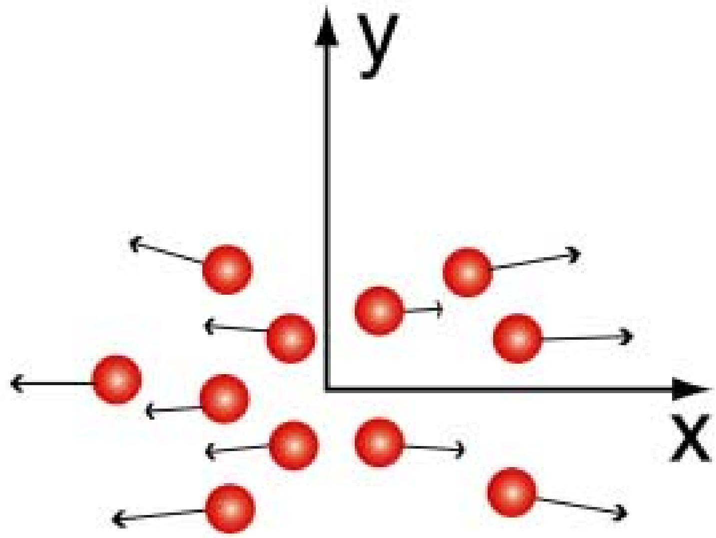


The STAR Detector at RHIC



A schematic view of v_2





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

P. Jacobs and G. Cooper, nucl-ex/0008015

$$v_2 = \langle \cos 2\phi \rangle$$

$$\phi = \mathrm{atan}\frac{p_y}{p_x}$$

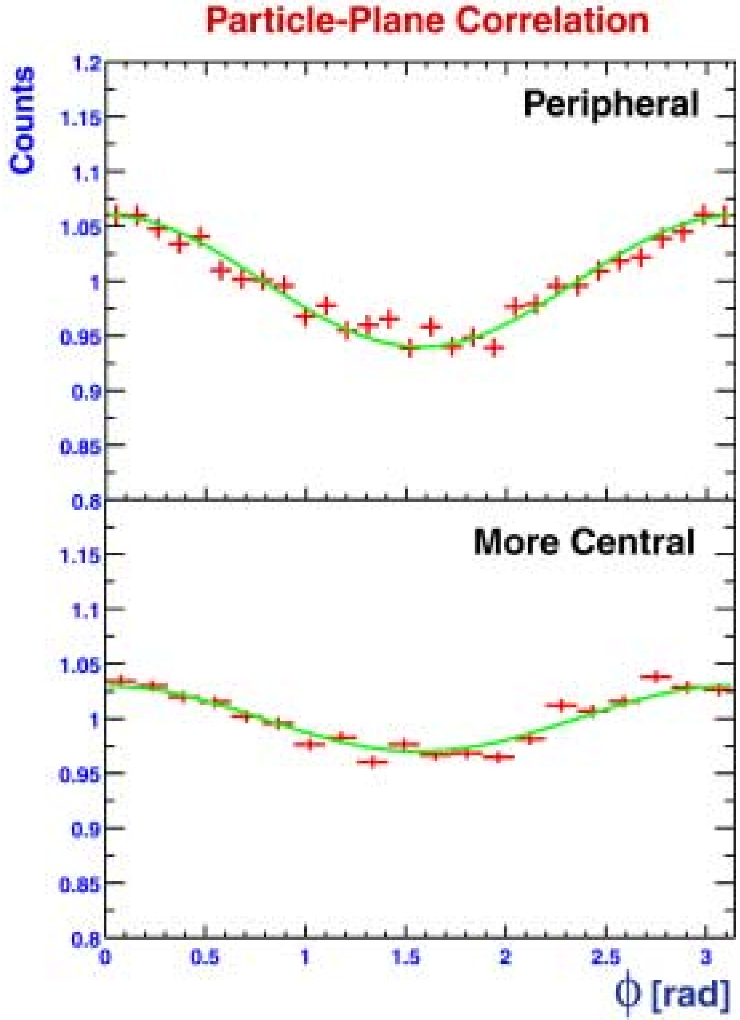
Almond shape overlap region in coordinate space

Momentum space

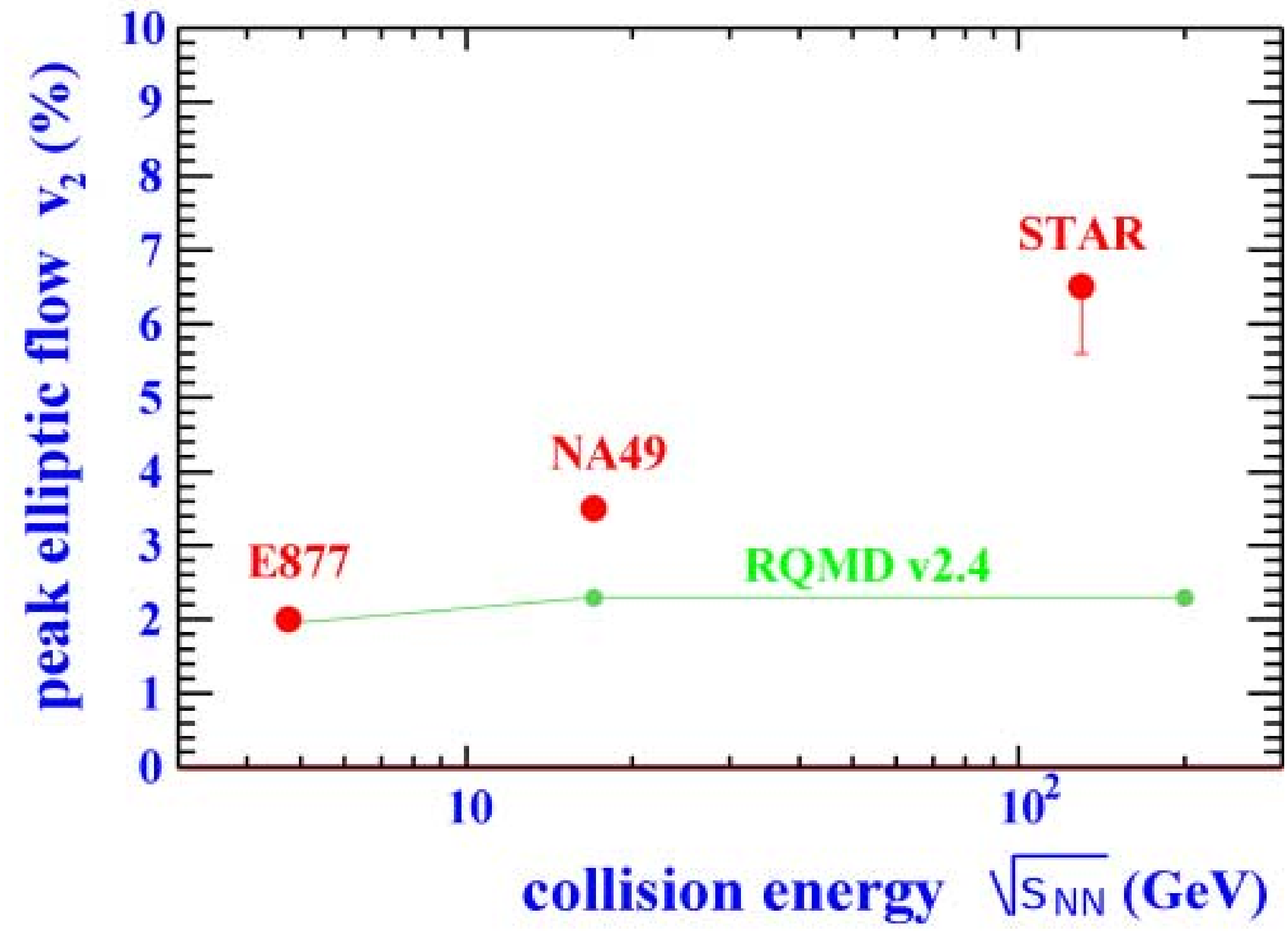
Azimuthal-angle distribution versus reaction plane

- v_2 increases from central to peripheral collisions

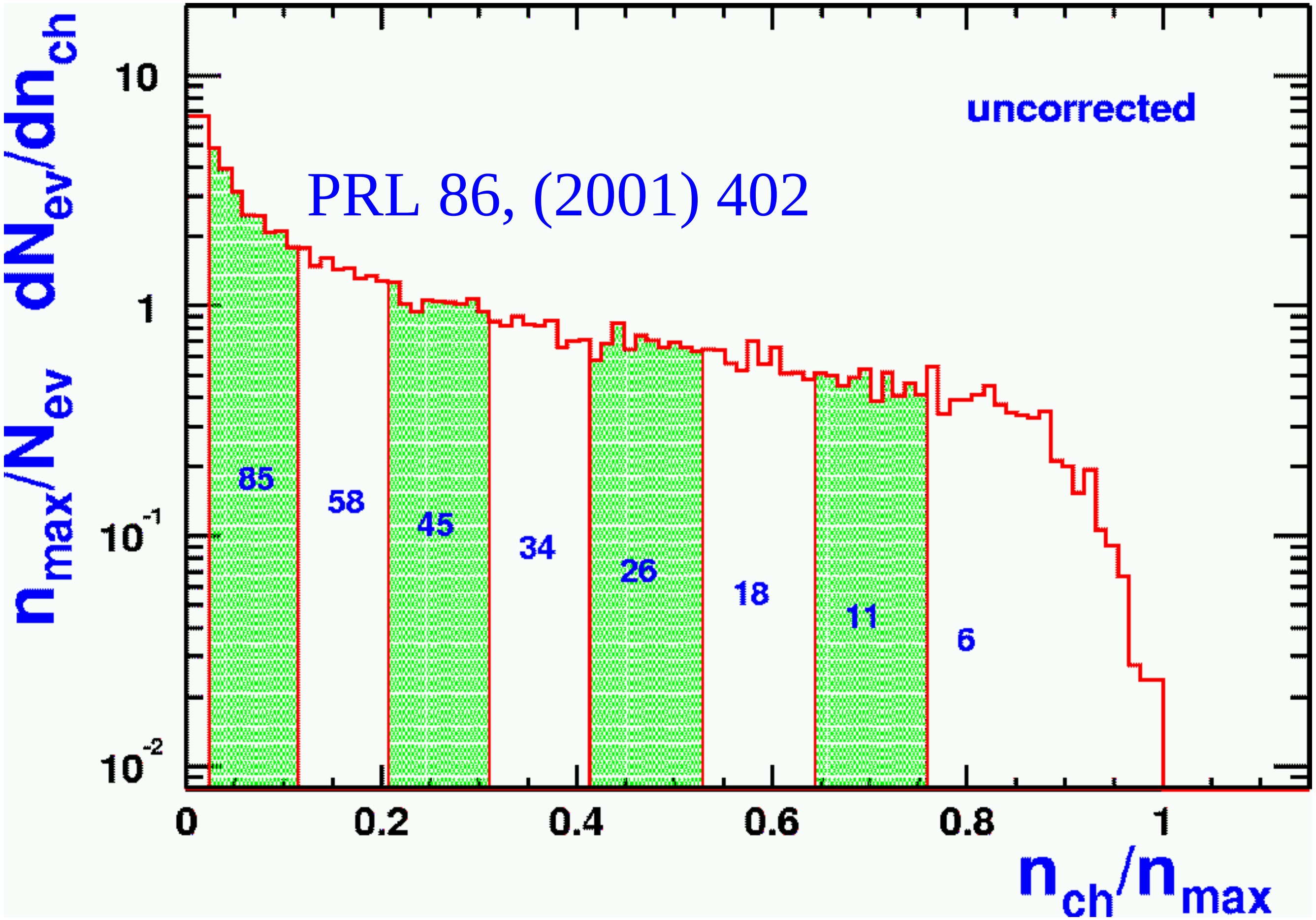
$$v_2 = \langle \cos 2\phi \rangle$$



Excitation function



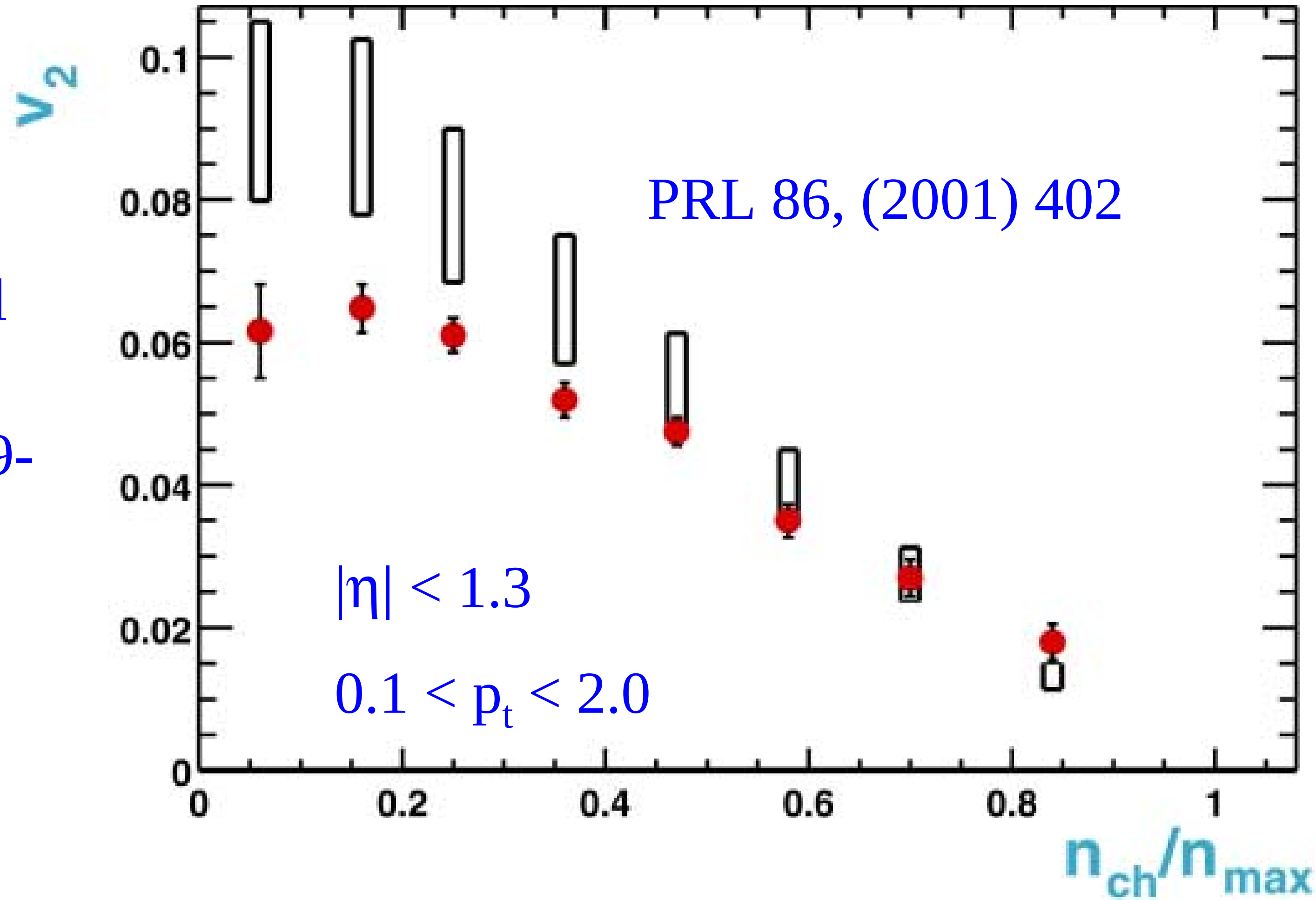
Centrality Selection



n_{ch} = primary tracks in $|\eta| < 0.75$

Charged particle v_2 versus centrality

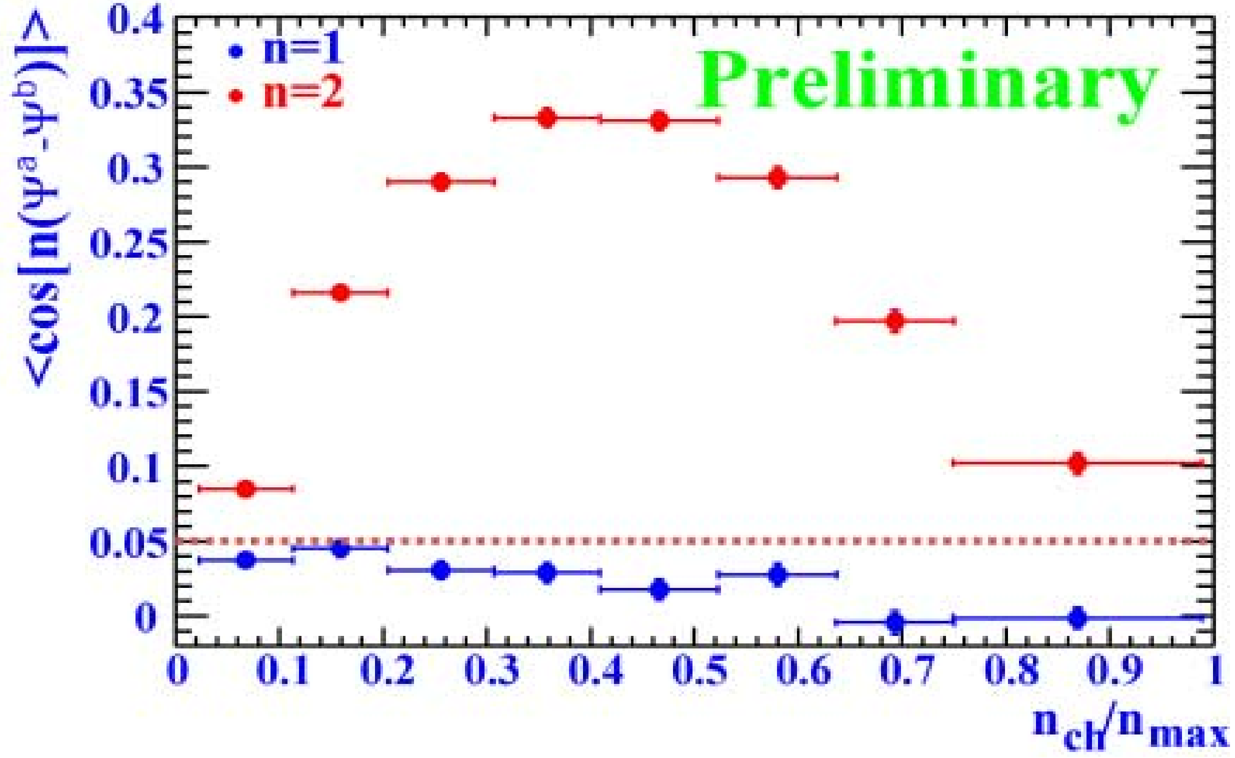
- Boxes show "initial spatial anisotropy" ε scaled by 0.19-0.25



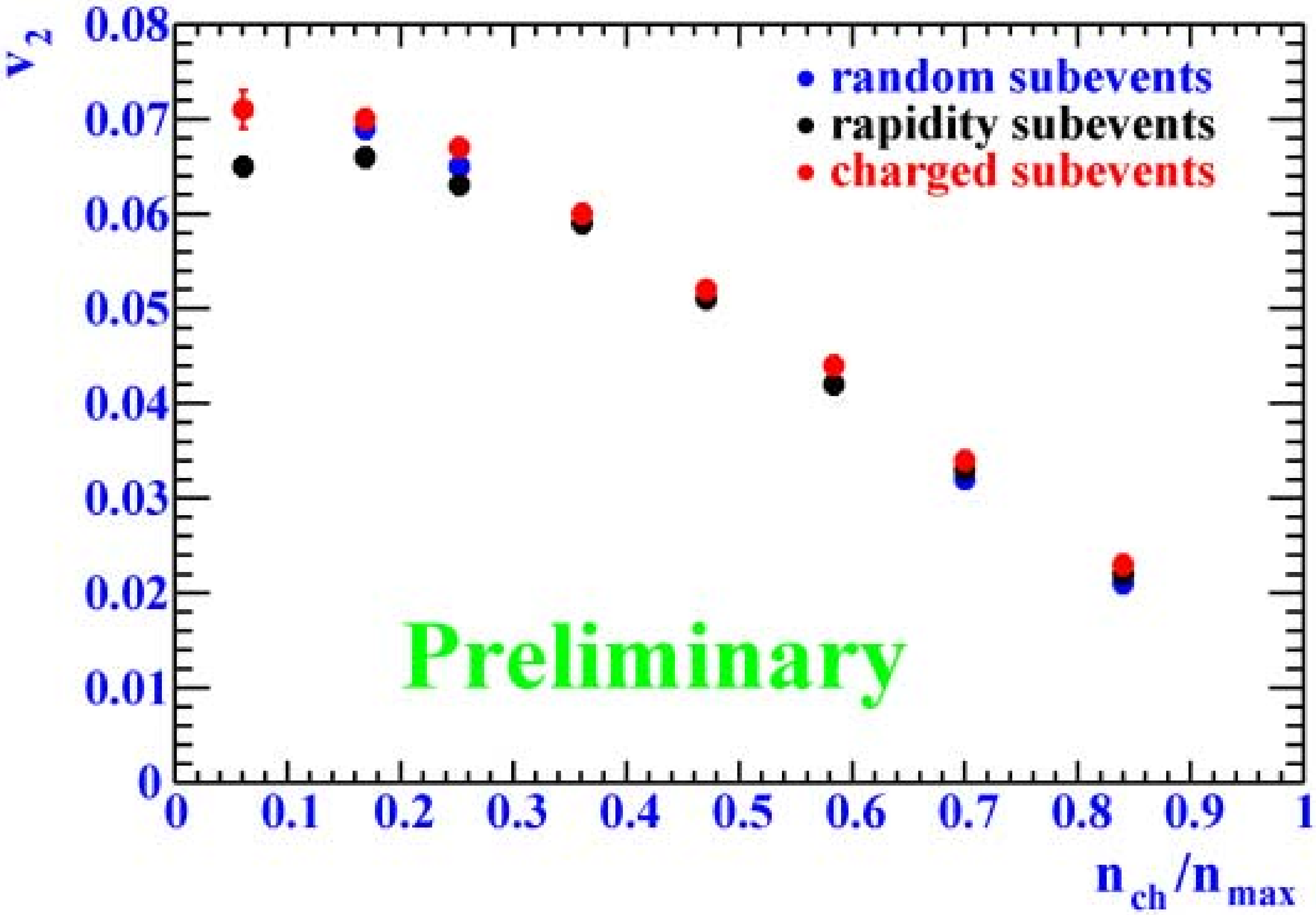
Sub Event Correlation

$$\Psi_2^{A,B} = \frac{1}{2}\mathrm{Tan}^{-1}\left(\frac{\sum_i w_i \cdot \sin(2\phi_i)}{\sum_i w_i \cdot \cos(2\phi_i)}\right)$$

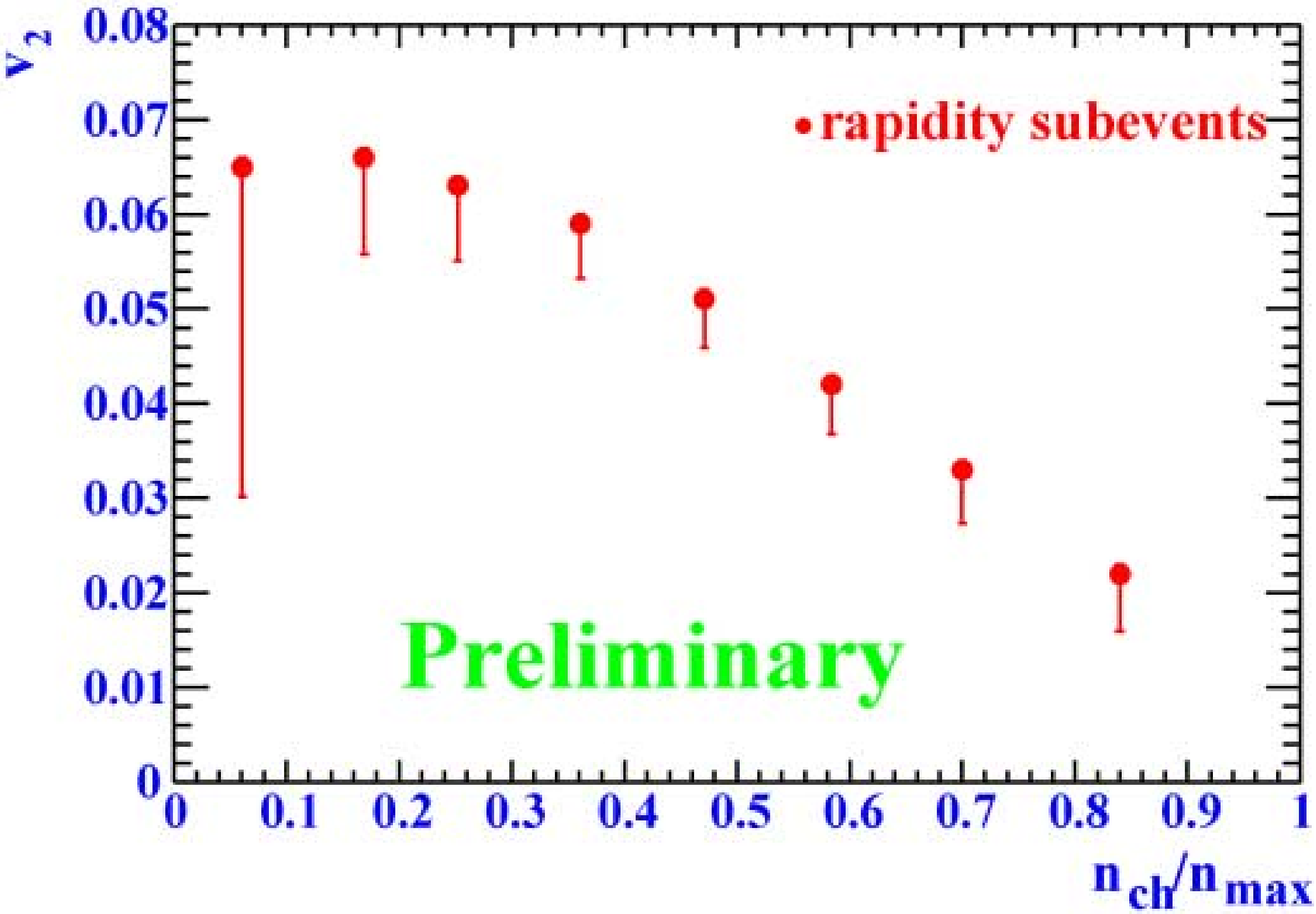
- Non-Flow Effects
  - Momentum conservation
  - HBT, Coulomb (final state)
  - Resonance decays
  - Jets



Different “sub event” methods



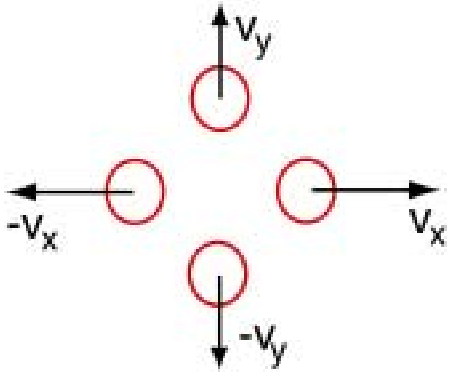
Systematic errors



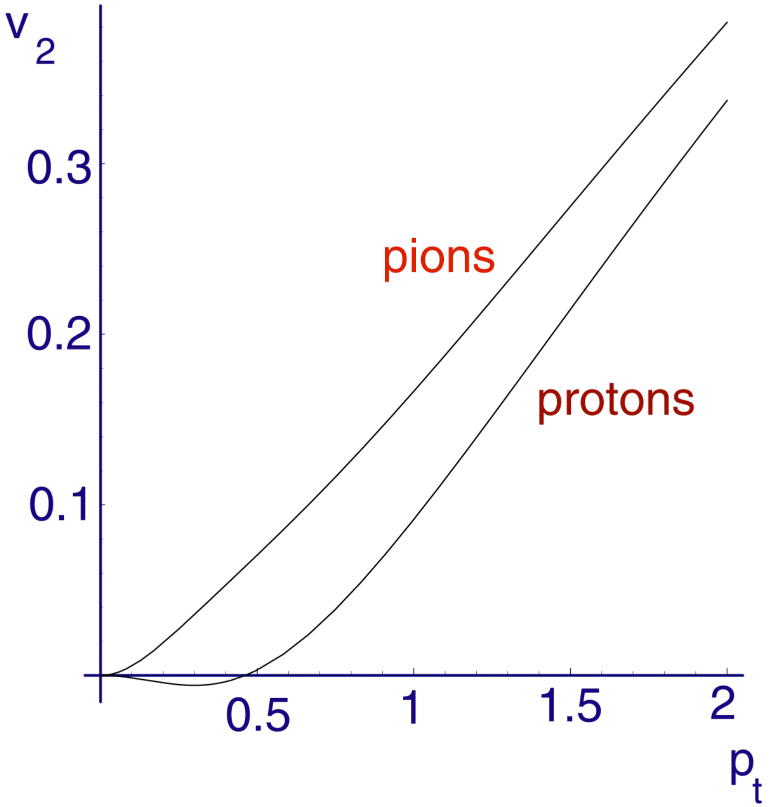
$v_2(p_t)$ for a thermal source

Pasi Huovinen

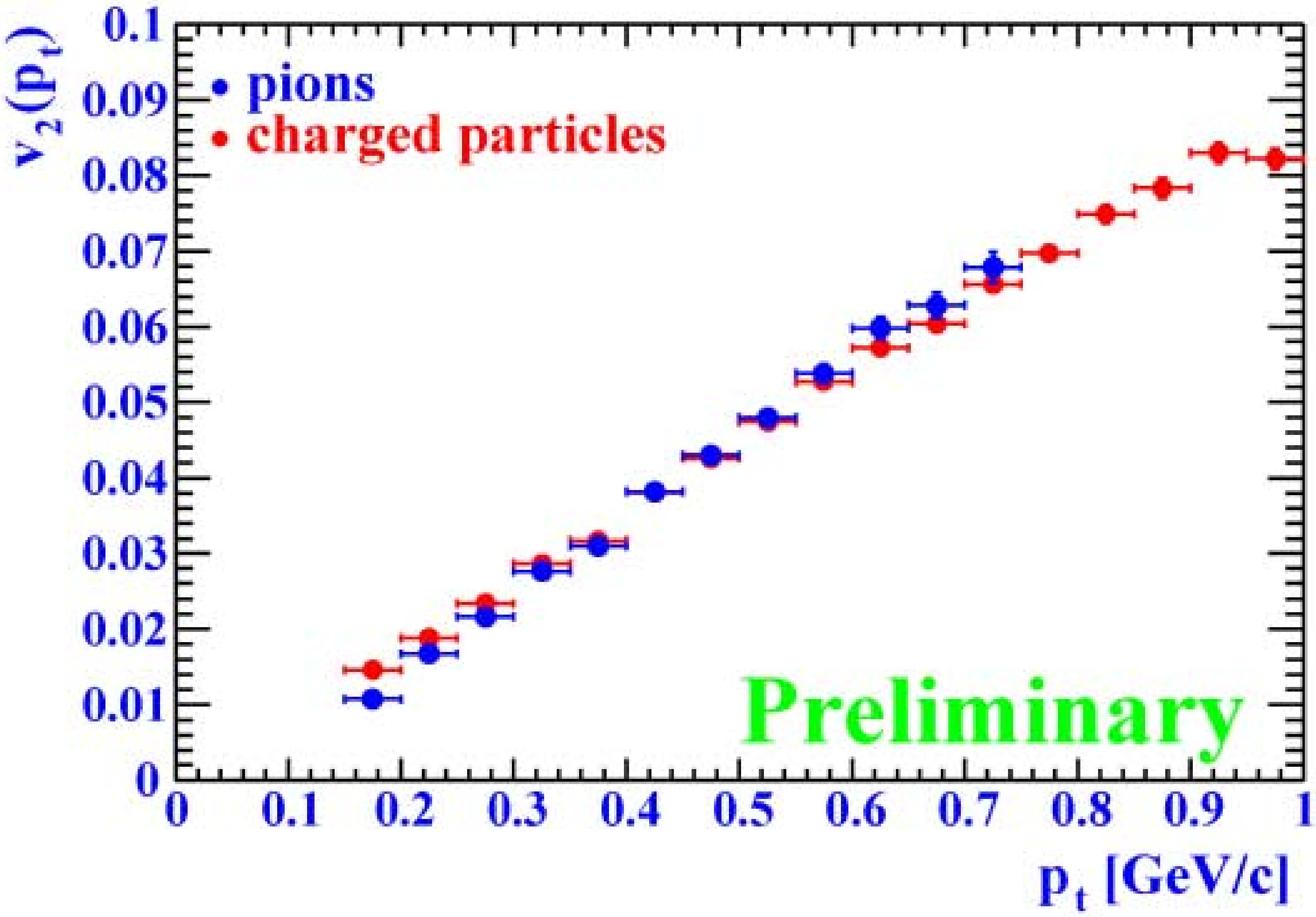
Simple thermal source



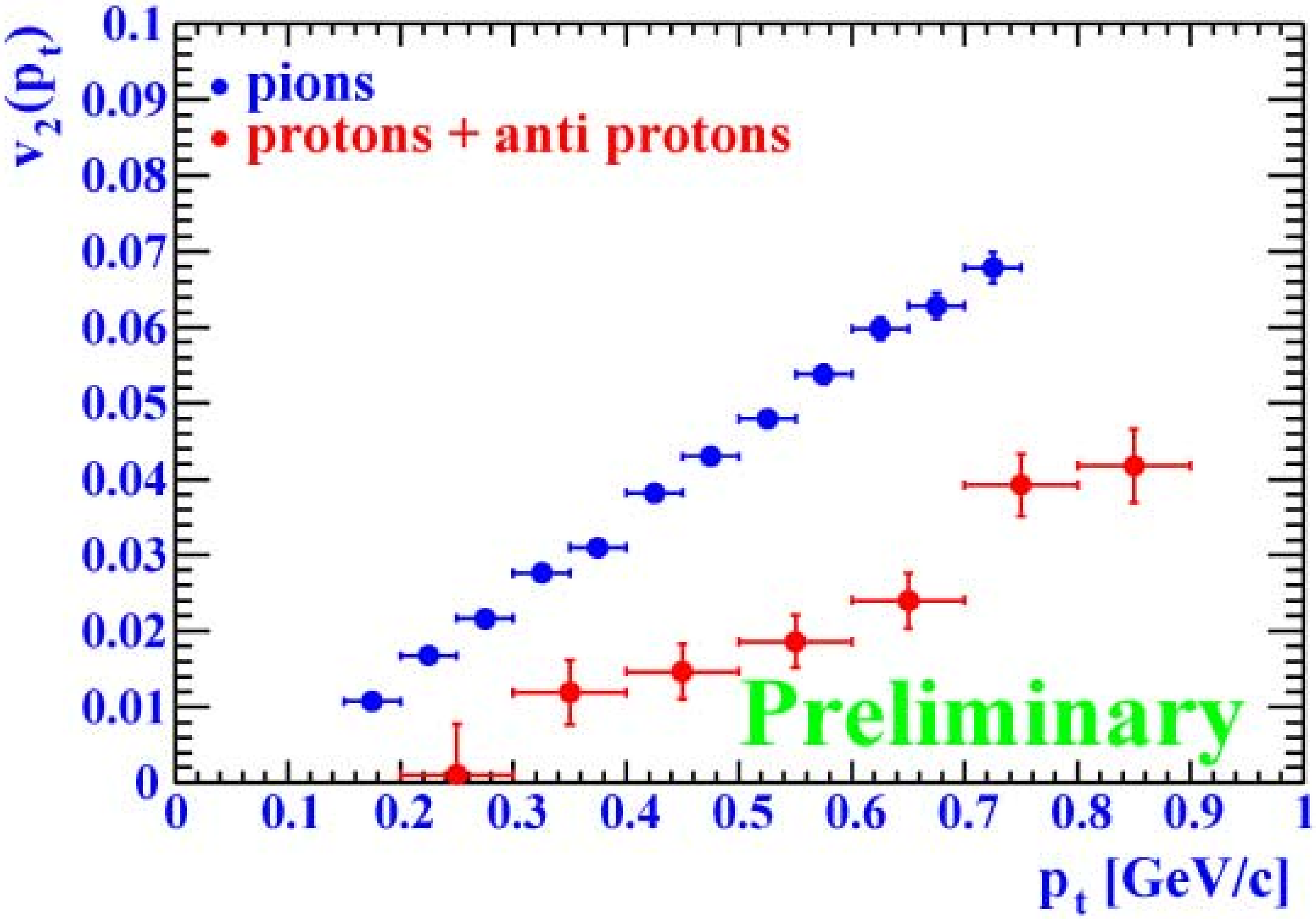
$$v_2(m) = \frac{C_1 - e^{\lambda\sqrt{m^2+p^2}} C_2}{C_3 + e^{\lambda\sqrt{m^2+p^2}} C_4}$$



Charged particle and charged pion $v_2(p_t)$ (minimum bias)

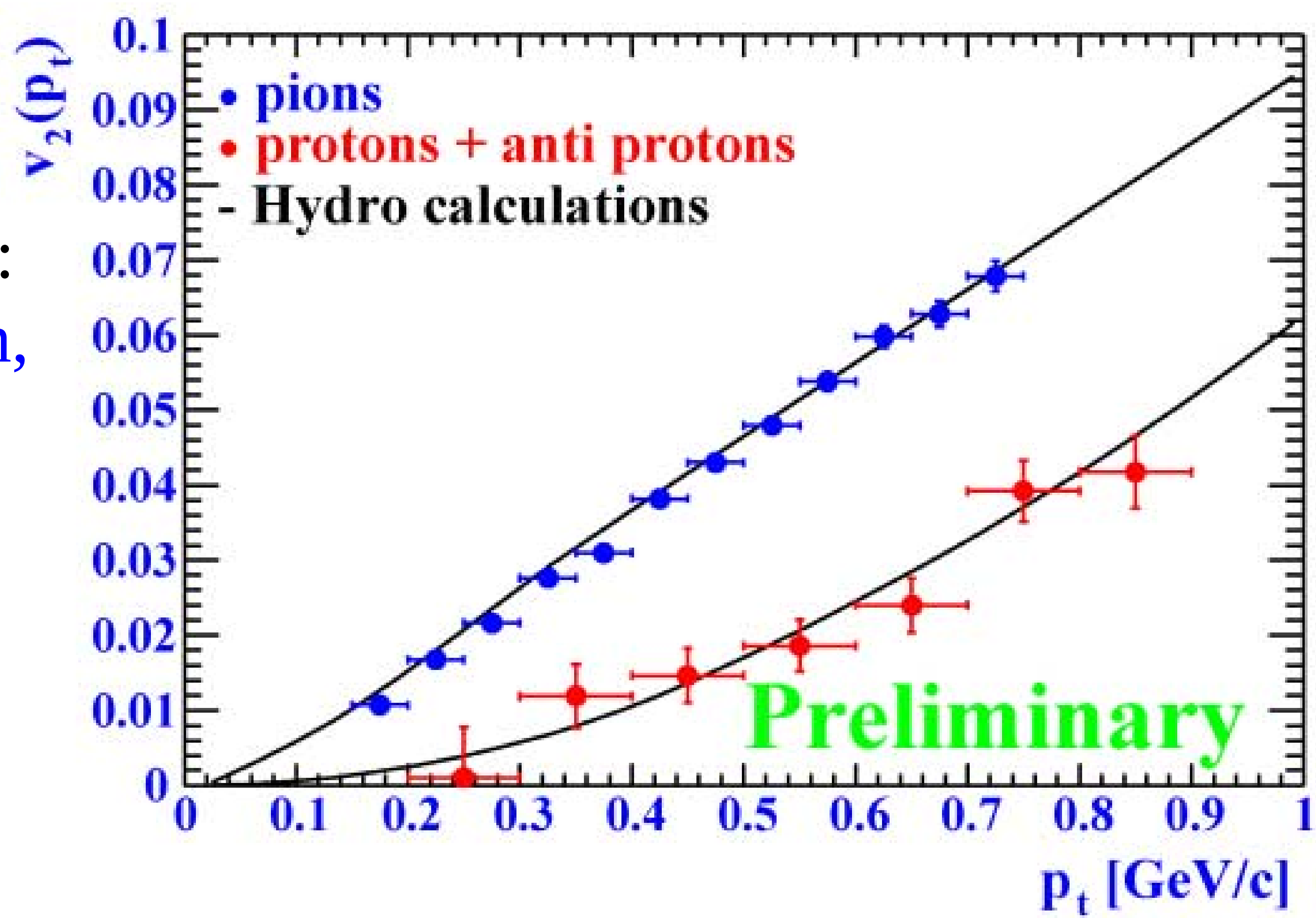


Charged pion and proton + anti proton $v_2(p_t)$ (minimum bias)

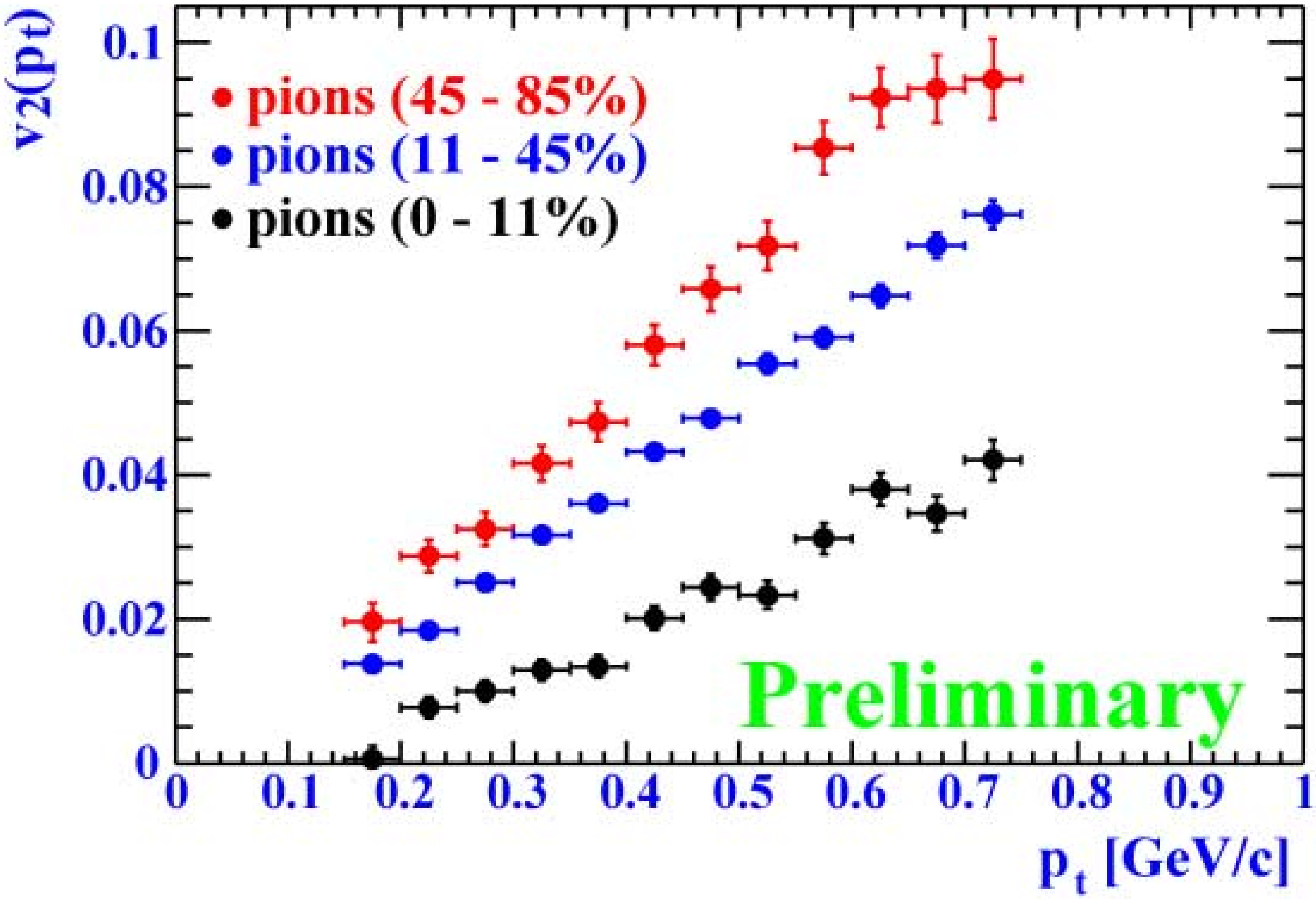


A Hydro view of the world

- Hydro calculations: P. Huovinen, P. Kolb and U. Heinz

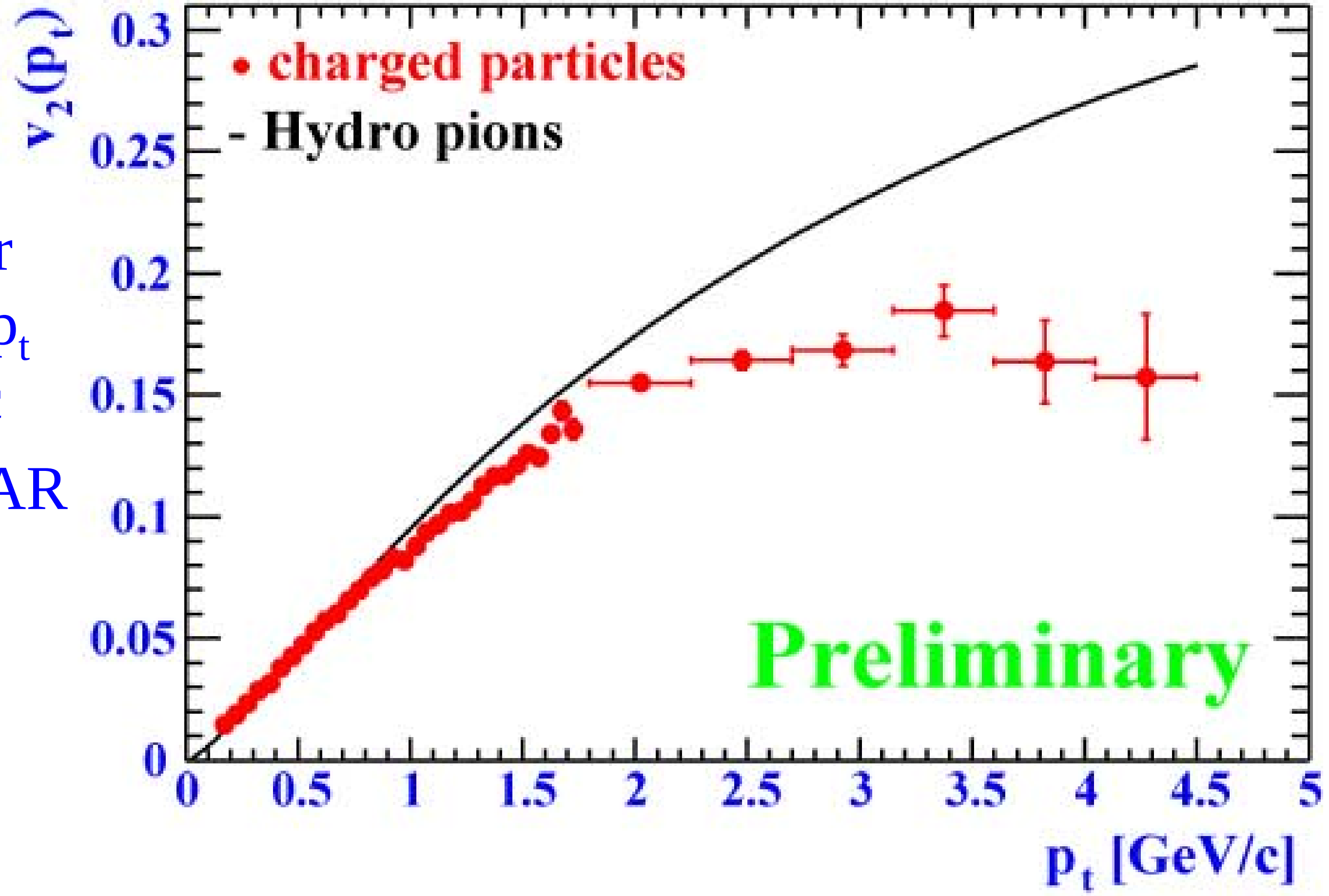


Charged pion $v_2(p_t)$ for different centralities



Charged particle anisotropy $0 < p_t < 4.5$ GeV/c

- Only statistical errors
- Systematic error 10% - 20% for p_t = 2 – 4.5 GeV/c
- More in the STAR high-pt talk (James Dunlop, PS2, this afternoon)



Summary

- Mass dependence of $v_2(p_t)$ shows a behavior in agreement with hydro calculations
- Large v_2 is an indication of early thermalization
- First time in Heavy-Ion Collisions a system created which at low p_t is in quantitative agreement with hydrodynamic model predictions for v_2 for mid-central collisions
- Around $p_t > 2$ GeV/c the data starts to deviate from hydro. However, v_2 stays large.

The STAR Collaboration

Brazil: Universidade de Sao Paolo

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England: University of Birmingham

France: Institut de Recherches Subatomiques Strasbourg, SUBATECH - Nantes

Germany: Max Planck Institute – Munich, University of Frankfurt

Poland: Warsaw University, Warsaw University of Technology

Spokesperson: John Harris

Institutions: 36
Collaborators: 415
Students: ~50

Russia: MEPHI – Moscow, LPP/LHE JINR–Dubna, IHEP-Protvino

U.S. Labs: Argonne, Lawrence Berkeley National Lab, Brookhaven National Lab

U.S. Universities: Arkansas, UC Berkeley, UC Davis, UCLA, Carnegie Mellon, Creighton, Indiana, Kent State, MSU, CCNY, Ohio State, Penn State, Purdue, Rice, Texas A&M, UT Austin, Washington, Wayne State, Yale