Strangeness in Quark Matter 2019 Bari

Roy Glauber: in Memoriam

The Glauber-Model in High Energy Nucleus-Nucleus Collisions

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GOETHE UNIVERSITÄT FRANKFURT AM MAIN

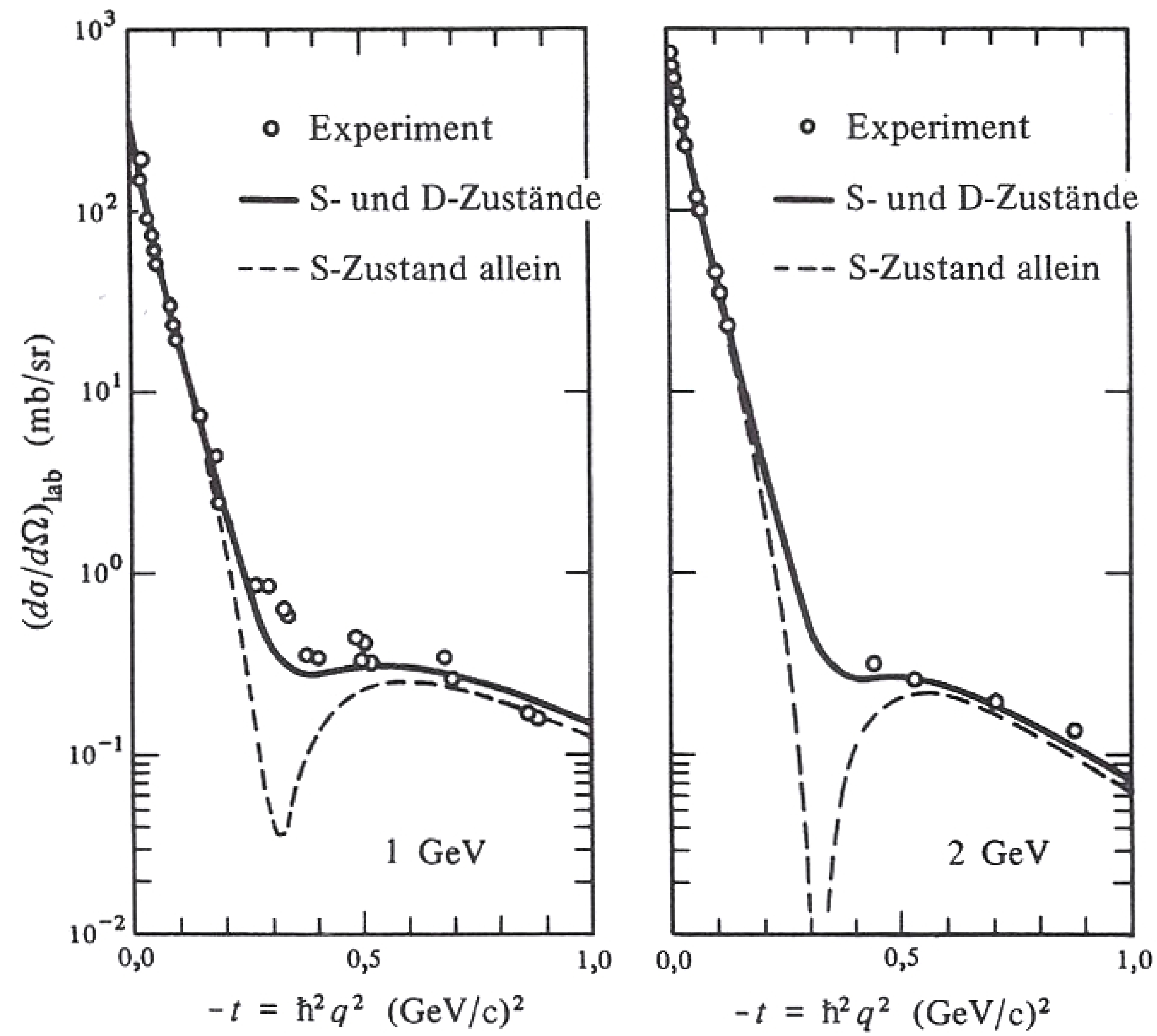
Roy Glauber

- born Sept. 1, 1925 New York
- 1941 undergrad. Harvard
- 1943 Manhattan Project
- 1949 PhD. with J. Schwinger Harvard
- 1976 Professor at Harvard
  - Quantum Electrodyn. of interacting light and matter
  - Quantum optics
  - High energy Hadron-Nucleus Collisions
- 2005 Nobel Prize
- He died on Dec. 26, 2018

Roy Glauber (Nobel Prize, 2005)

Fraunhofer Diffraction Scattering in pA and AA Collisions

- An “optical” view of hadron scattering
- Nucleons at high E are essentially undeflected because $p_{long} >> p_t$
- like light “rays”
- Along their linear trajectories they add up the phase shifts from successive scattering encounters
- They cast a shadow, like X-Ray pictures: **Eikons**



V. Franco and R. Glauber, PRL 22 (1996) 370

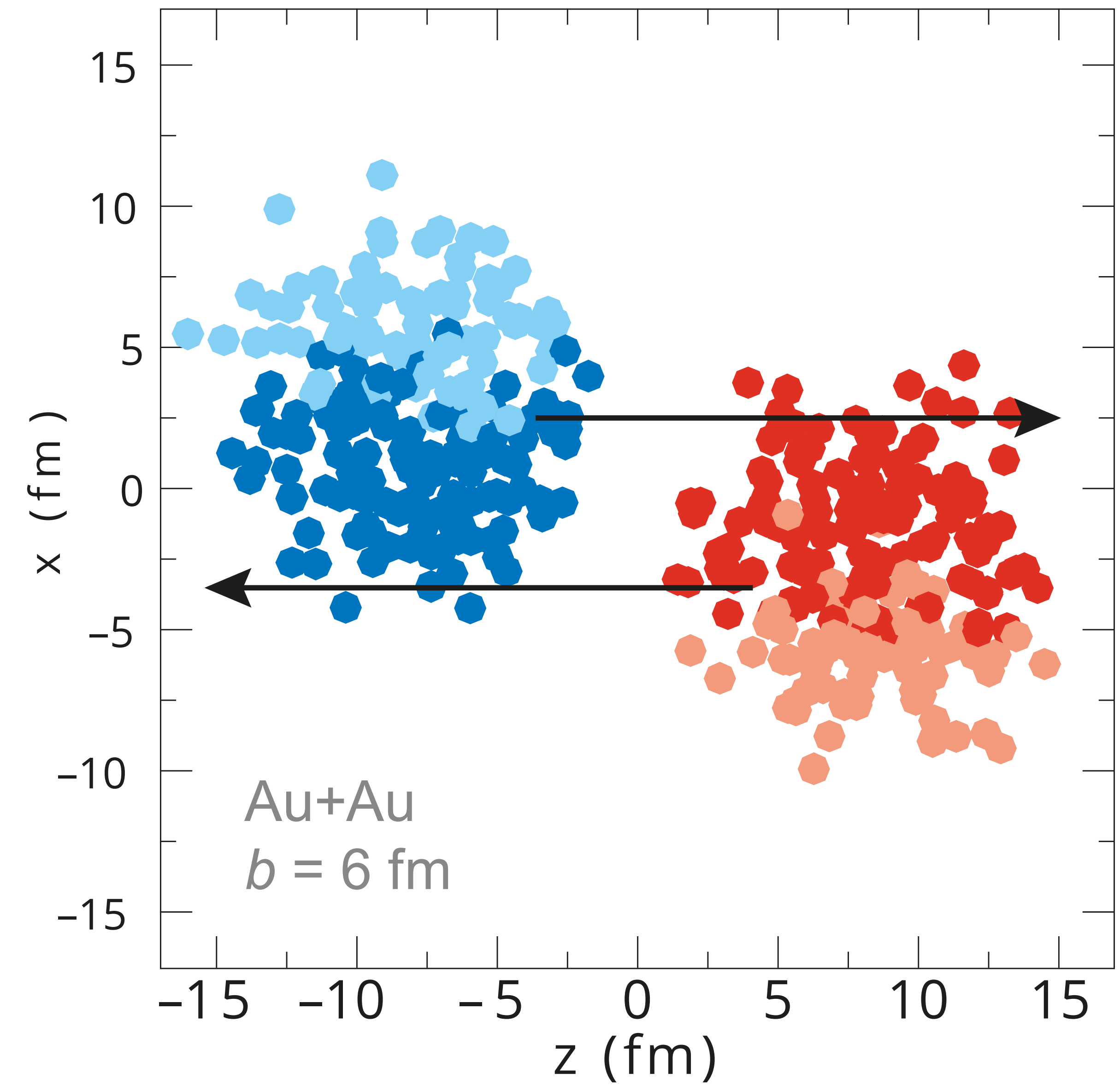
Participant and Collision-Number

The hypothesis of independent linear trajectories of the constituent nucleons of target and projectile nuclei makes it possible to simply count the number of participating nucleons and the number of N-N collisions in dependence on the basic input N-N cross section.

The collision geometry: target mass **A** and projectile mass **B** and impact parameter **b**

$$\{A, B, b, \sigma_{NN}\} \Leftrightarrow N_{part}, N_{coll}$$

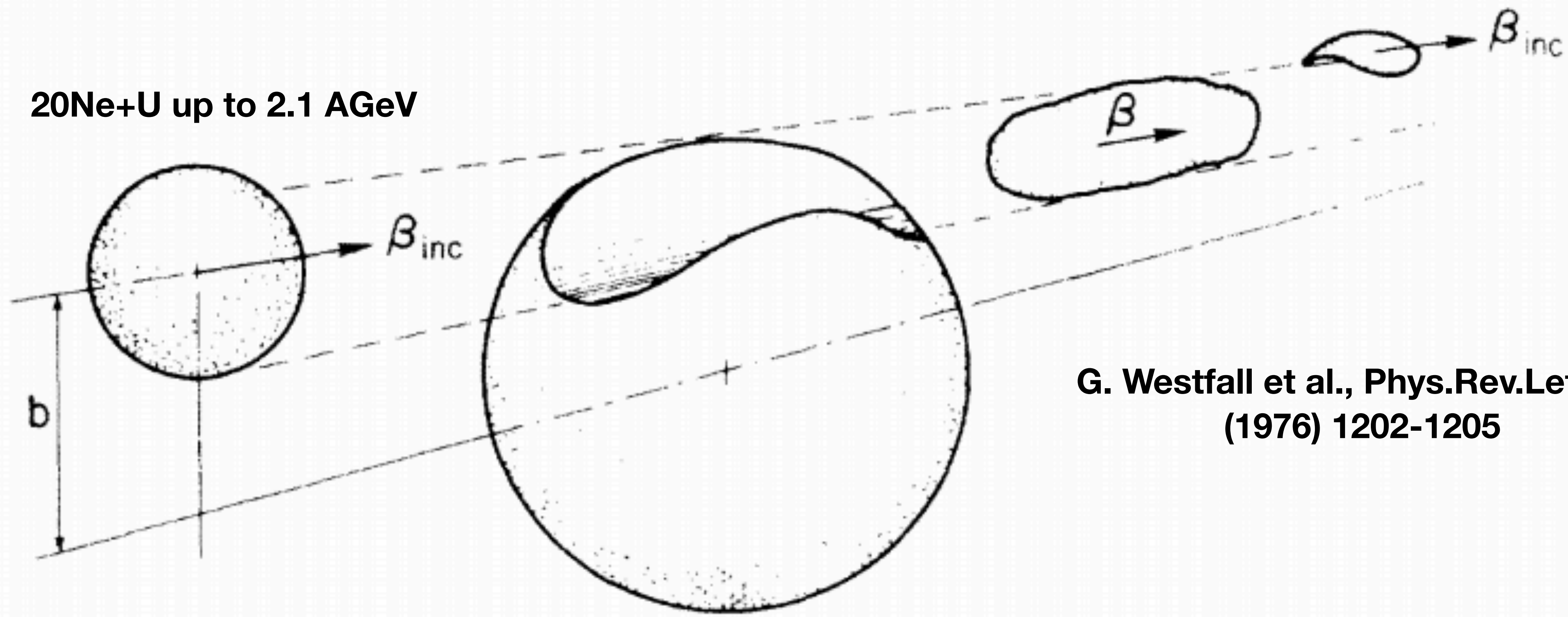
$$\Rightarrow \sigma_{AB,tot}$$



R. Glauber, High Energy Coll. Theory, Lectures in Theor. Phys, Interscience NY (1959)

M. Miller, K. Reygers, S. Sanders, P. Steinberg
Glauber modeling in high energy nuclear collisions, Ann.Rev.Nucl.Part.Sci. 57 (2007) 205

Bevalac Physics: Carved-out Fireballs



G. Westfall et al., Phys.Rev.Lett. 37 (1976) 1202-1205

FIG. 1. A neon nucleus is incident on the uranium nucleus with a velocity β_{inc} in the laboratory frame and impact parameter b. The swept-out nucleons from the projectile and target are called the fireball, and their center of mass has the velocity β in the laboratory frame.

- Geometric Picture: W. Swiatecki
  E_{lab}, N_{partA}, N_{partB} ➜ E_{cm} and $N_{fireball}$
  Abrasion-Ablation model

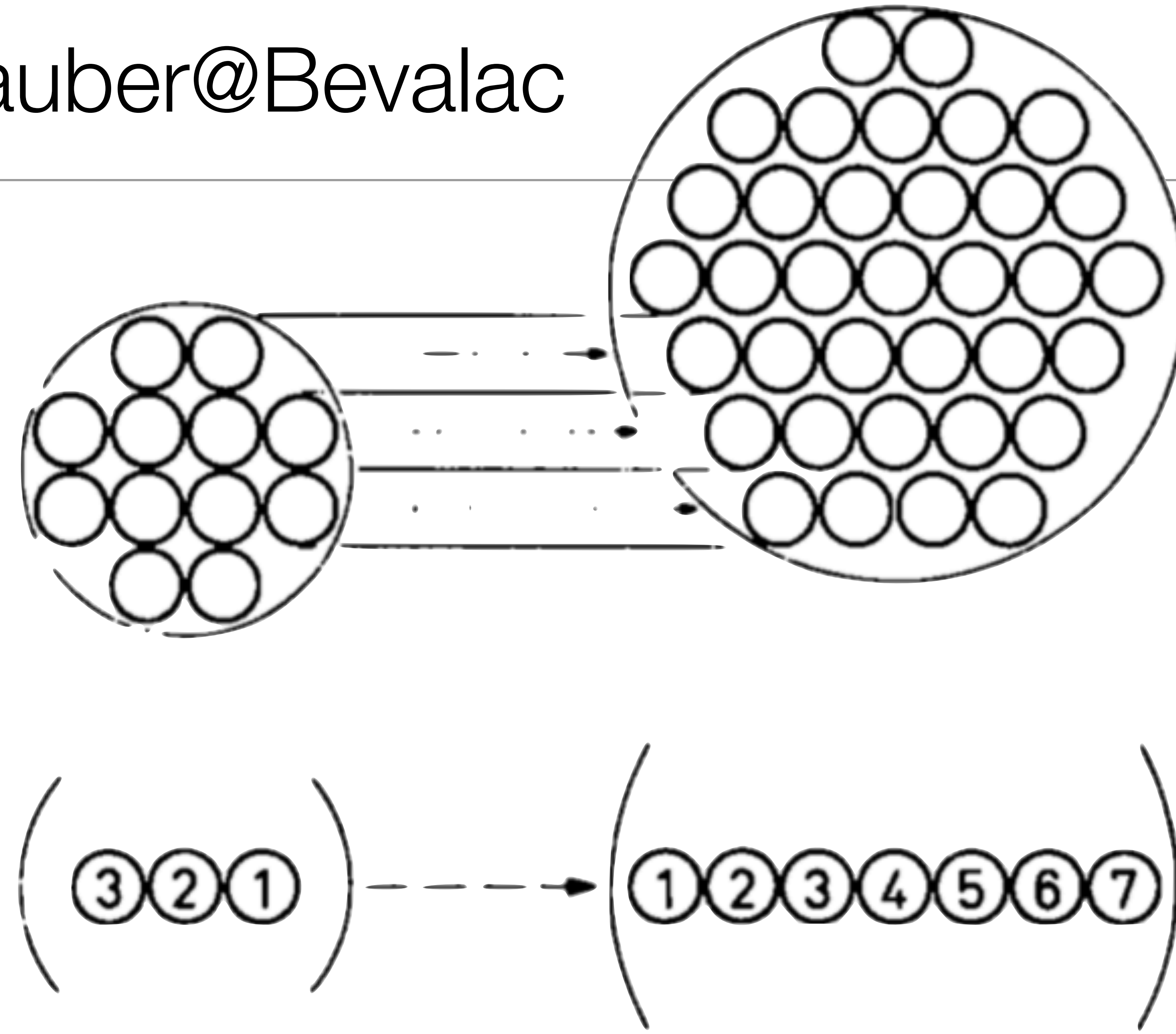
+

- Thermal equilibrium a la Hagedorn

➡ Hadron Spectra

Rows on Rows: Glauber@Bevalac

Note: In collisions of A<B the dynamics and composition of the fireball depend critically on impact parameter **b**



J. Hüfner and J. Knoll,
Nuclear Physics A290 (1977) 460

Fig. 2. "Rows on rows". An illustration of the one-dimensional cascade model. Projectile and target are decomposed into rows of nucleons (in beam direction). Only corresponding rows on the same straight line scatter by each other. For instance, projectile nucleon 1 scatters by target nucleons 1 to 7, then projectile nucleon 2 scatters by target nucleons 1 to 7, etc. Interactions among projectile and among target nucleons are excluded.

Difficulty with very Asymmetric Collisions-Systems

⚠ Watch out in p+A, d+A etc.!

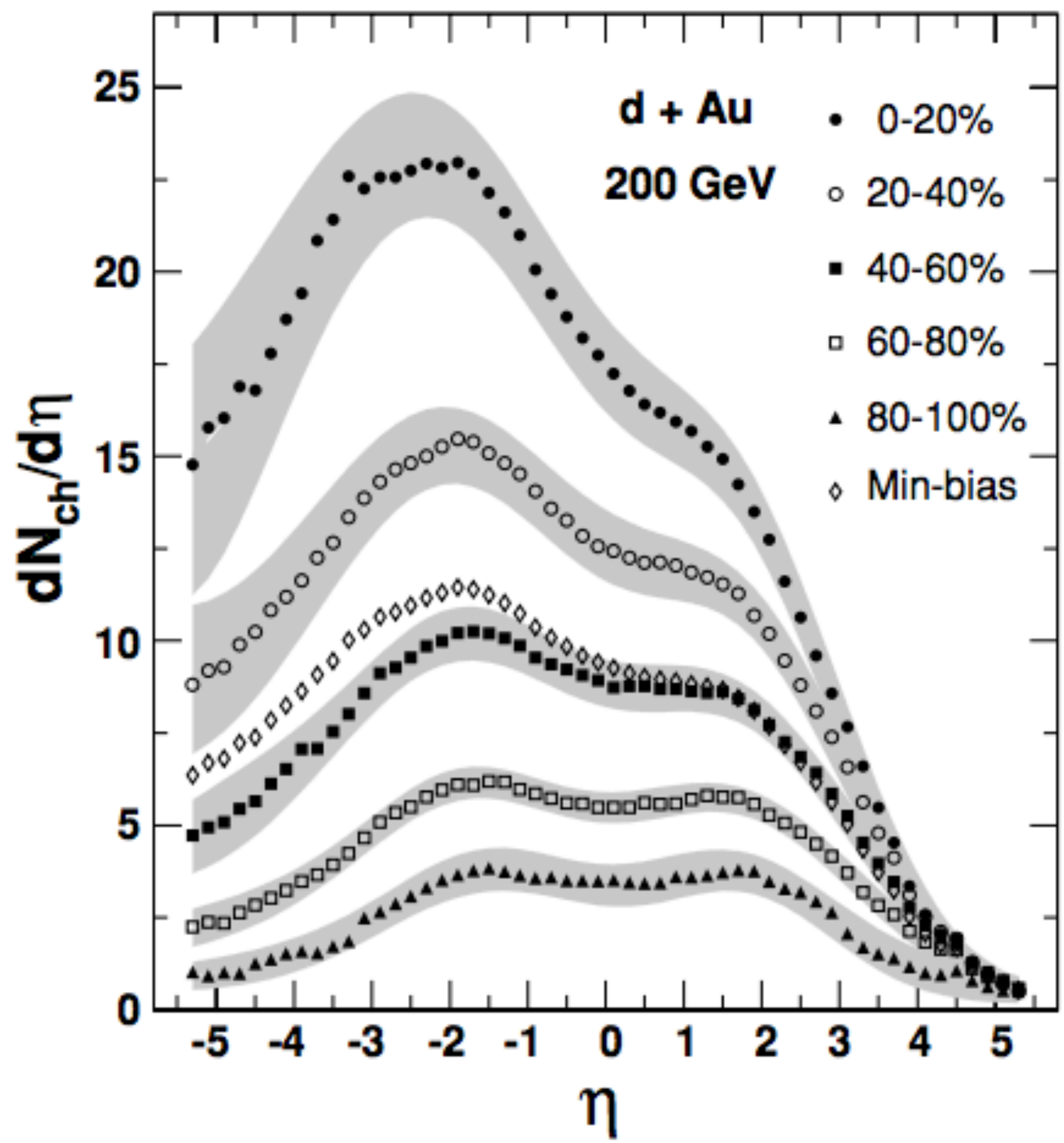
the effective CM-System of soft production falls significantly below y_{mid} of hard production!

$\Delta y_{mid} \approx 2$ depending of impact parameter

This explains the preference for equal mass systems:

U+U at Bevalac, Pb+Pb at SPS, Au+Au at AGS

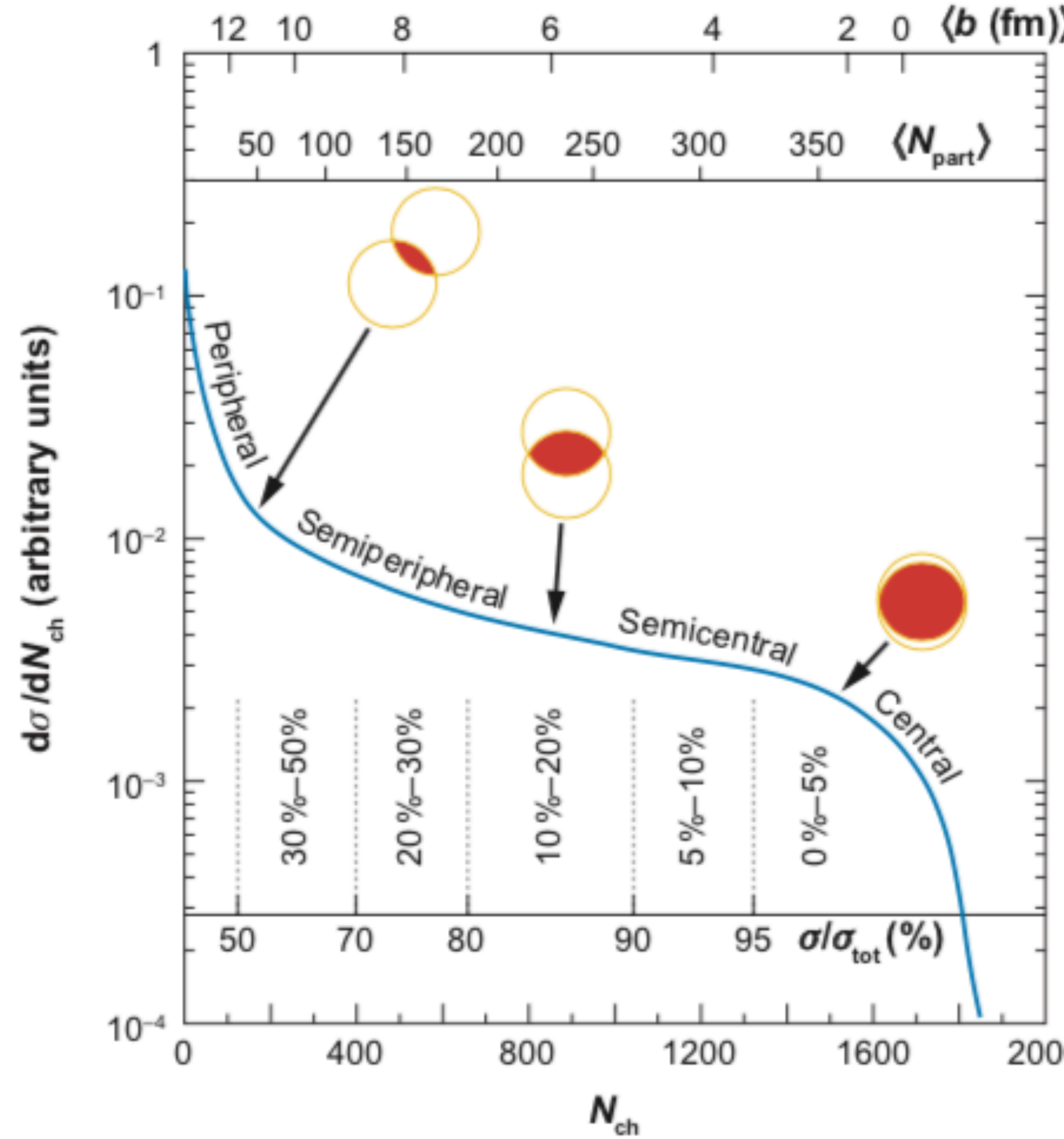
P. Steinberg, arXiv:nucl-ex/0703002



Back et al. (PHOBOS), Phys.Rev. C72 (2005) 031901

The <b> windows from <N_{ch}> windows

- Experiment determines average N_{ch} in windows of centrality
- Modeling of connection between N_{ch} and N_{part}
- All the rest follows from the Glauber Model



M. Miller et al., Ann.Rev.Nucl.Part.Sci. 57 (2007) 205

The Nuclear Modification Factor

Hypothesis:

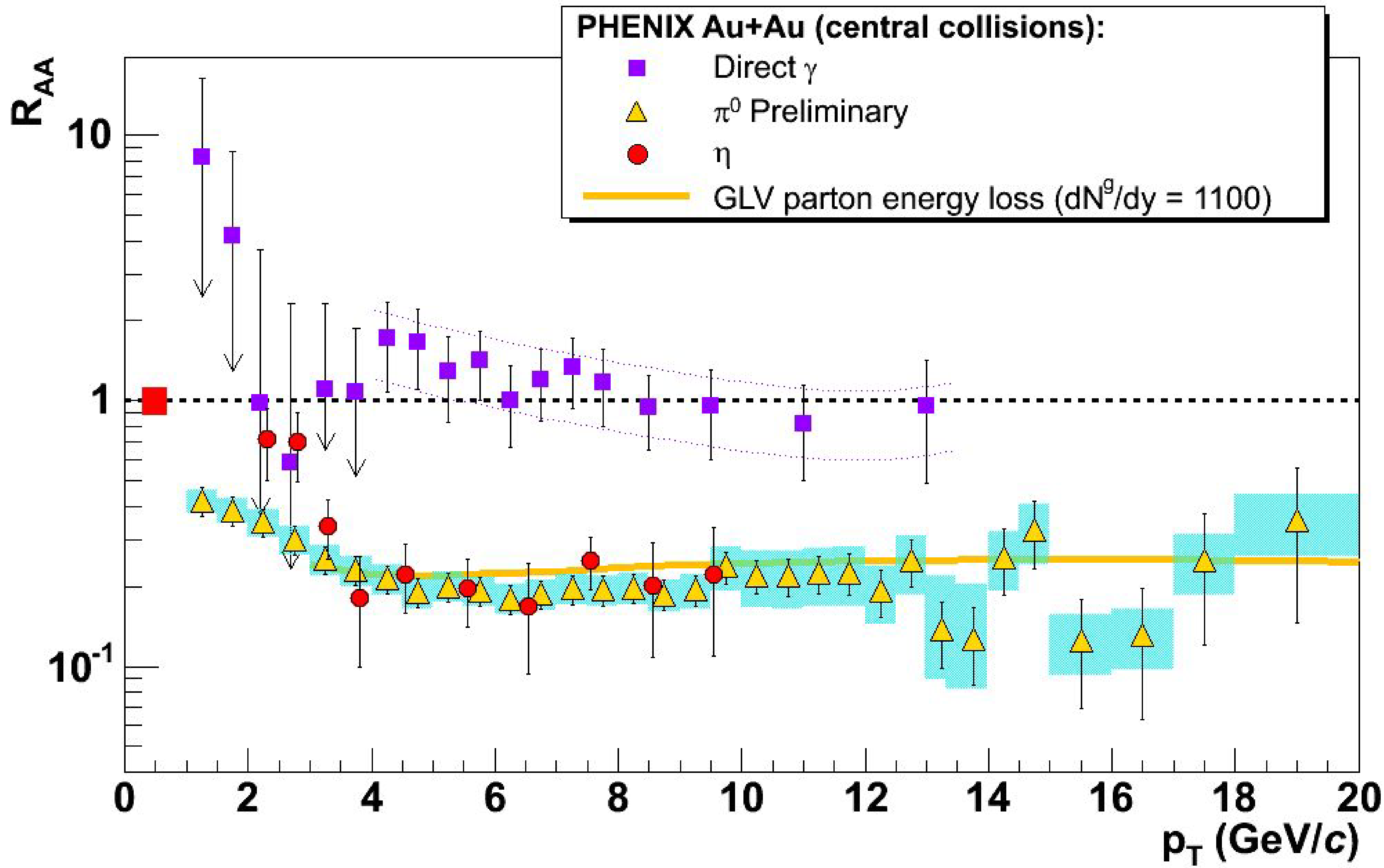
- High p_t “hard” hadrons result from primordial leading partons produced in hard collisions
- Upon penetration of the co-traveling QCD medium they suffer suppression
- Hadron suppression at high p_t
- This determines the QCD transport Coefficient $\hat{q} = \langle q_T^2 \rangle / \lambda$

Define

$$R_{AA} = \frac{d\sigma_{AA \to h}/d^3p}{N_{coll}(AA, b)\, d\sigma_{pp \to h}/d^3p}$$

$R_{AA} = 1$ if A+A is a simple scaling of p+p

Hadron suppression

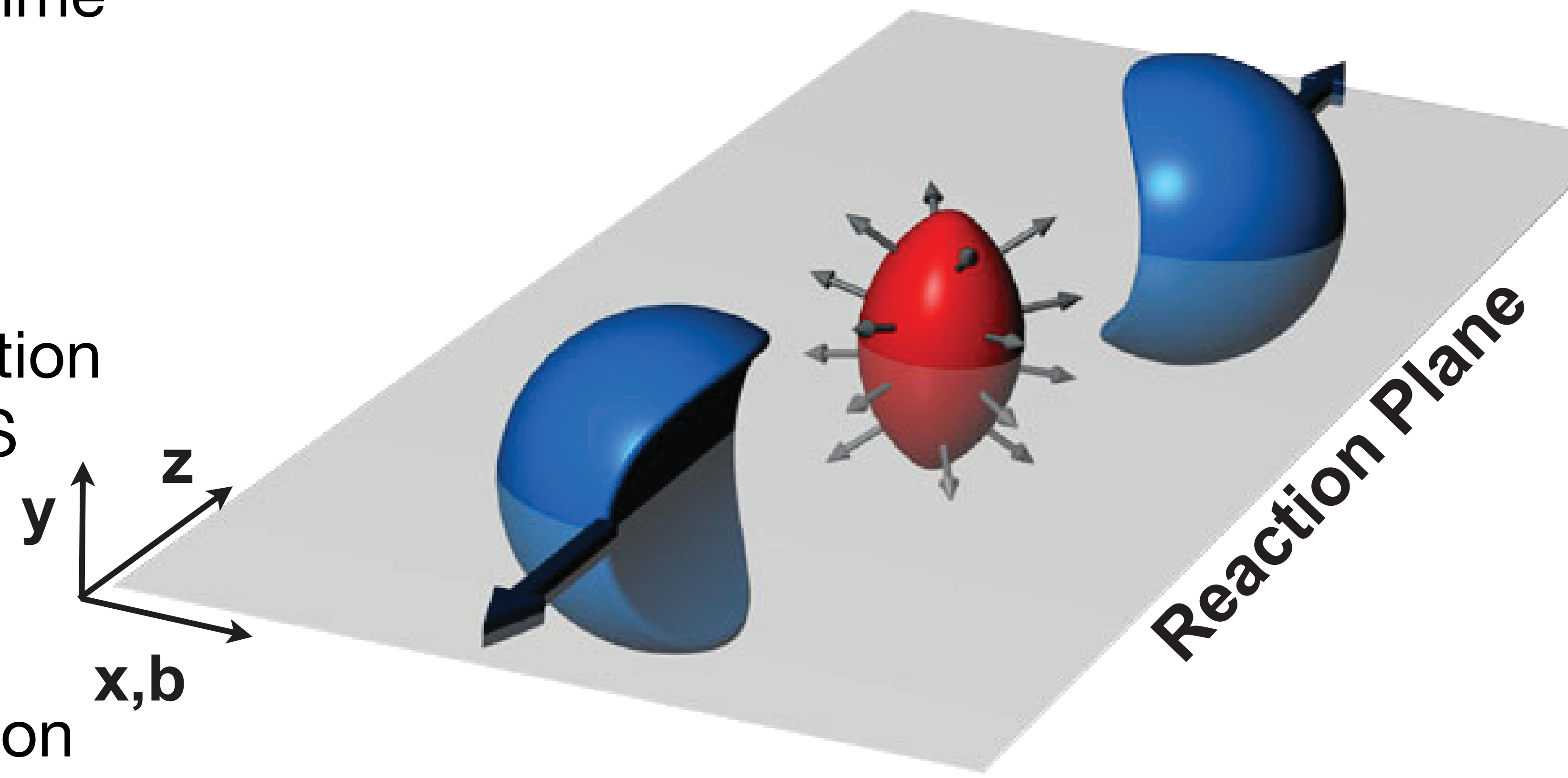


Elliptic Flow Initialisation

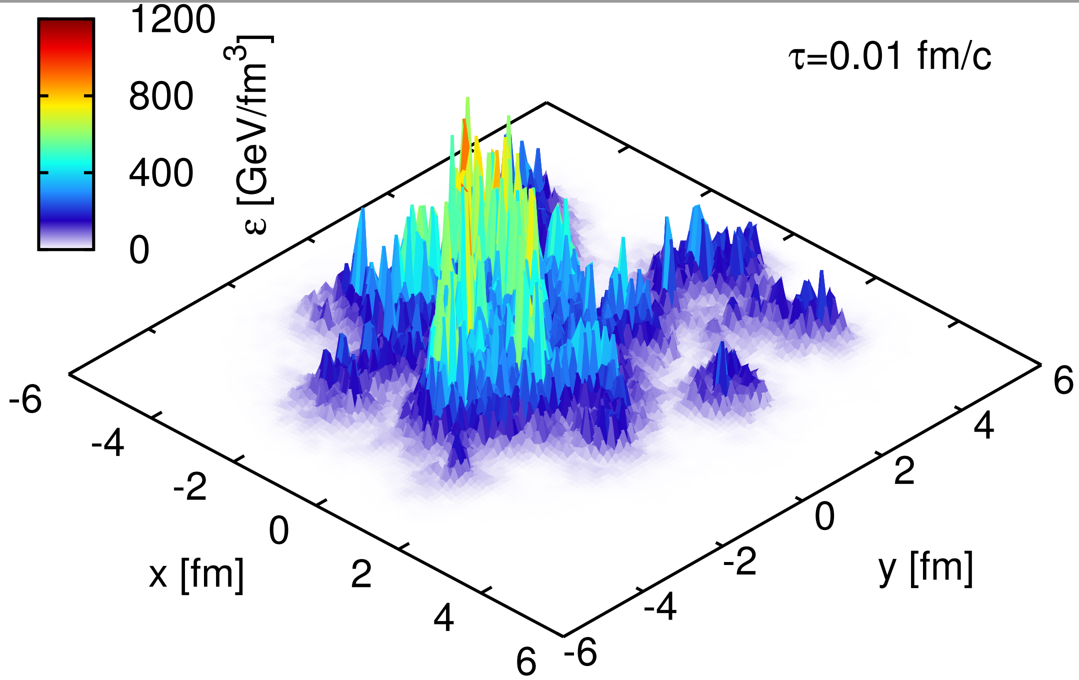
- At RHIC and LHC this picture is semi-realistic because the resolution of the primordial time scale is Δt < 0.1 fm/c
- Very high shutter speed!
- Good primordial time resolution unlike at SPS and RHIC BES
- Observation of the initial anisotropy in the final momentum space depends on the amount of viscous damping during hydro-transport.

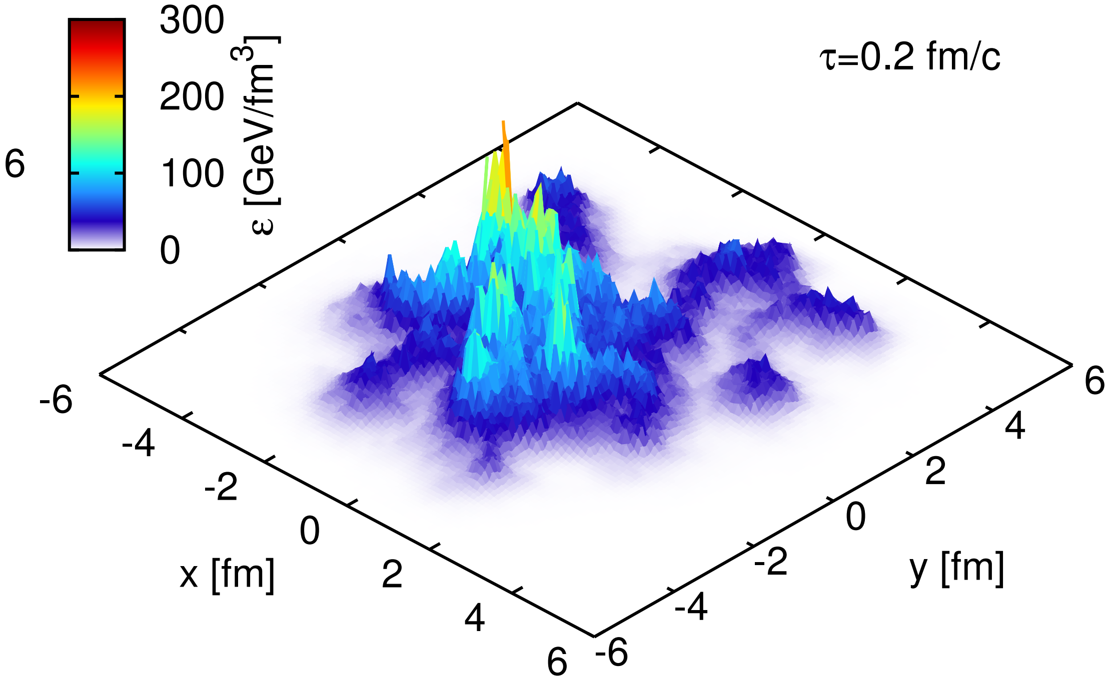
  Quantified by **η/s**

Clearly a “Glauber Picture”

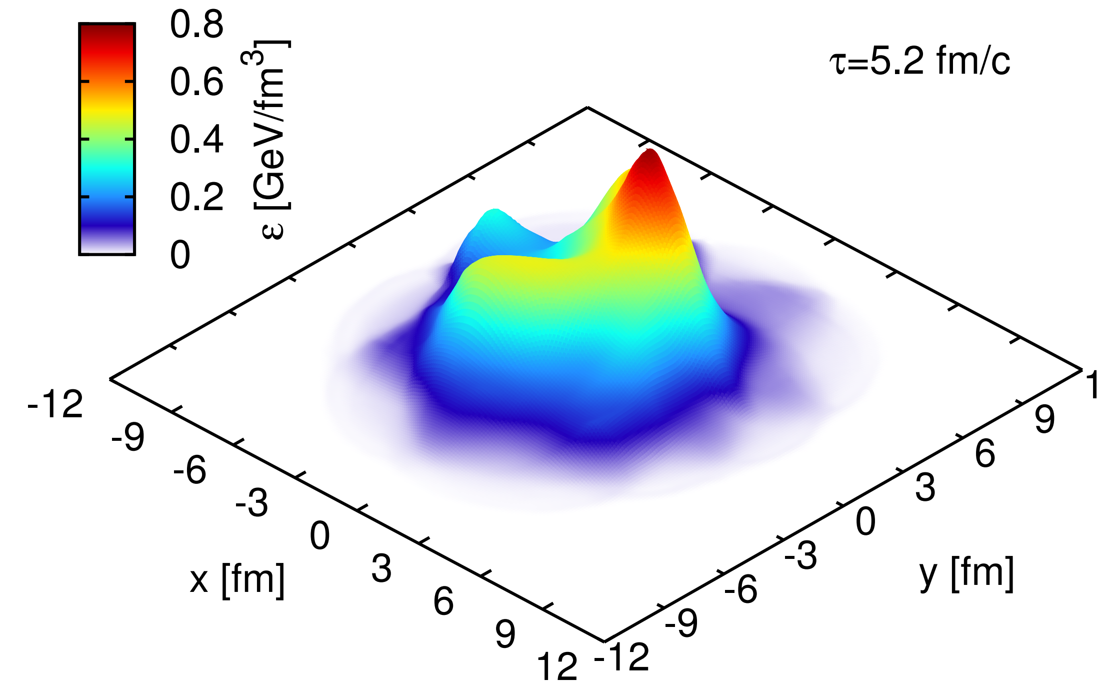


Single Event Analysis





- 3 transverse density profiles at 0.01, 0.2 and 5.2 fm/c
- Falling energy density scales!
- Smoothening by η/s = 0.12
- Events show structure beyond present v_n analysis



Summary

"Glauber Tomography"-Results

q̂ and η/s anti-correlated:

$$\eta/s = \text{const. } T^3/\hat{q}$$

emerging at RHIC and LHC

PHYSICAL REVIEW VOLUME 100, NUMBER 1 OCTOBER 1, 1955

Cross Sections in Deuterium at High Energies

R. J. GLAUBER
Lyman Laboratory of Physics, Harvard University, Cambridge, Massachusetts

(Received May 27, 1955)

Recent measurements at high energies indicate that the total cross sections for collisions of both nucleons and π mesons with deuterons are noticeably smaller than the sums of the corresponding cross sections for free neutrons and protons. A formalism for calculating the cross sections of the deuteron is developed, based on the assumption that the interactions of the incident particle with the neutron and proton may individually be treated by the general methods of diffraction theory. The nonadditivity of the free-particle cross sections is shown to be due largely to "eclipses" in which either the neutron or the proton lies in the shadow cast by the other, an effect in which quantum mechanical diffraction plays an important role. Simple representations of the high-energy interactions and the ground-state wave function of the deuteron are found to lead to cross-section defects of the magnitude observed.