Nuclear shapes from energy density functional and heavy-ion collisions

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DE LA RECHERCHE À L'INDUSTRIE
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Introduction

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  ATLAS Collaboration, Report No. ATLAS-CONF-2021-001

  ATLAS Collaboration, arXiv:2205.00039

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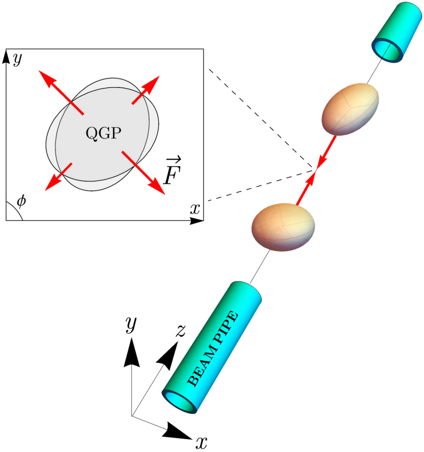
y
QGP
$\vec{F}$
ϕ
x
BEAM PIPE
y
z
x

Asymmetry in particle distribution: elliptic flow

- Distribution of detected hadrons can be expanded

$$dN/d\phi \propto 1 + 2 \sum_{n \geq 1} v_n \cos\left[n(\phi - \phi_n) \right]$$

where v_2 is the elliptic flow (quadrupole component)

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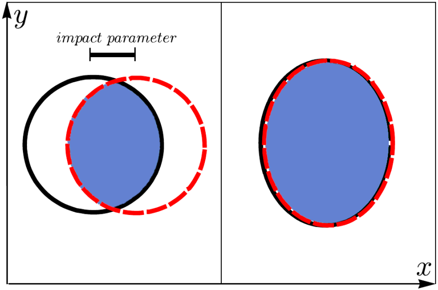
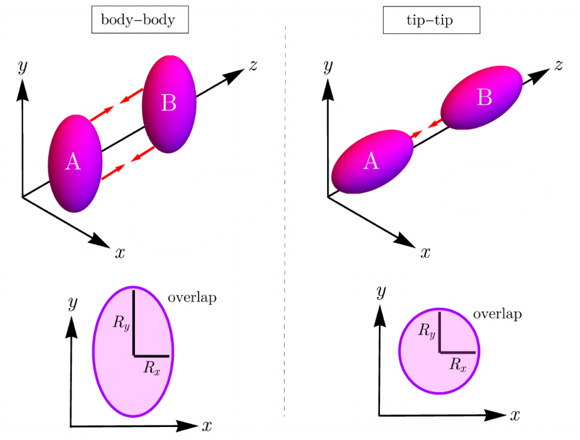
- Linked to geometric asymmetry of the initial condition



Courtesy of V. Somà

How to discern orientations in central collisions?



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Relation between the size of the system and $\langle p_t \rangle$

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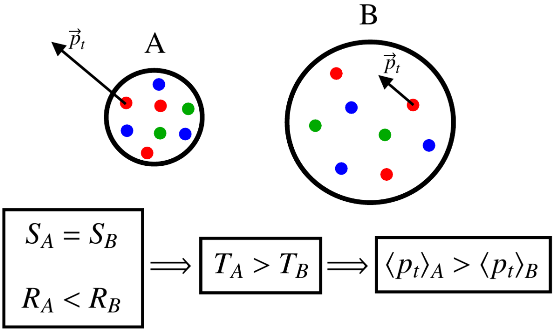

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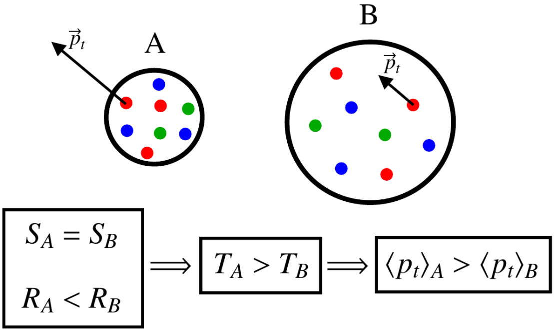

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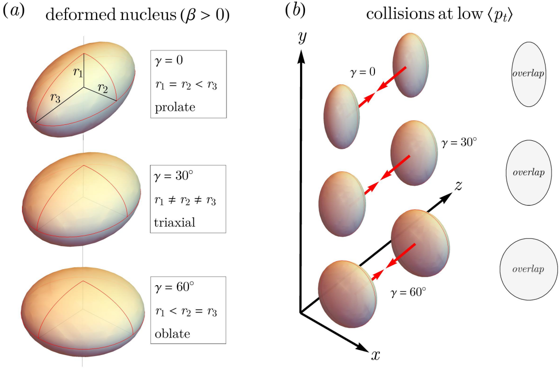
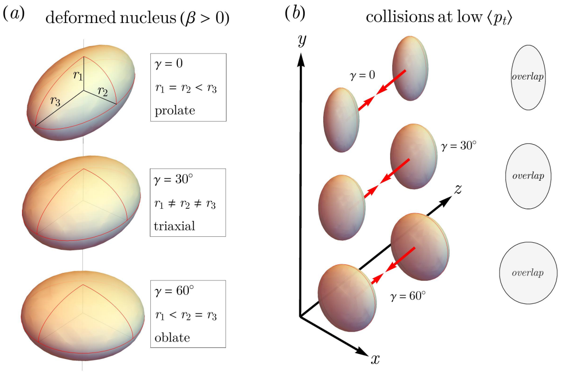
- $\langle p_t \rangle$ is the average transverse momentum of particles
- Looking at low $\langle p_t \rangle \Rightarrow$ looking at larger nuclear overlaps

Orientation at low $\langle p_t \rangle$



Orientation at low $\langle p_t \rangle$

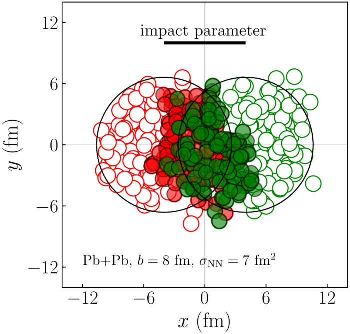


- Pearson correlation coefficient

$$\rho(v_2^2, \langle p_t \rangle) = \frac{\left\langle \delta v_2^2 \delta \langle p_t \rangle \right\rangle}{\sqrt{\left\langle \left(\delta v_2^2 \right)^2 \right\rangle \left\langle \left(\delta \langle p_t \rangle \right)^2 \right\rangle}}$$

where $\delta o = o - \langle o \rangle$

Modeling of the nuclei: Monte-Carlo Glauber



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- Nucleons sampled using Woods-Saxon density

$$\rho_{ws}(r,\theta,\varphi) = \rho_0 \left(1 + \exp\left[\frac{1}{a}\left(r - R(\theta,\varphi)\right)\right]\right)^{-1}$$

$$R(\theta,\varphi) = R_0 \left\{1 + \beta \left(\cos\gamma\, Y_{20}(\theta,\varphi) + \frac{1}{\sqrt{2}} \sin\gamma \left[Y_{22}(\theta,\varphi) + Y_{2-2}(\theta,\varphi)\right]\right)\right\}$$

Modeling of the nuclei: inputs from nuclear theory

- State-of-the-art multi-reference energy density functional calculations

- Variational calculations

$$\delta \frac{\langle \Psi | H | \Psi \rangle}{\langle \Psi | \Psi \rangle} = 0 \quad \text{with} \quad |\Psi\rangle = \sum_{(\beta_v, \gamma_v) K} f_{(\beta_v, \gamma_v) K} P^J_{MK} P^N P^Z | \Phi(\beta_v, \gamma_v) \rangle$$

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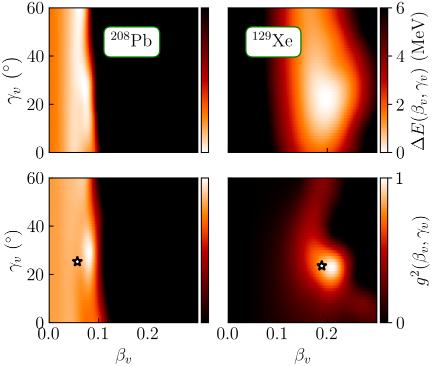
- Explore triaxial deformations (β_v, γ_v) through constrained minimizations

- Calculations performed on a 3d Cartesian mesh

- Skyrme-type SLyMR1 parametrization

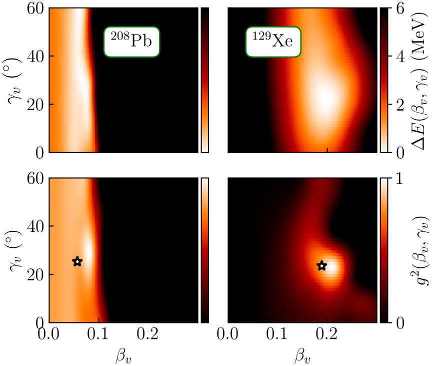
  Sadoudi *et al.*, Phys. Rev. C 88, 064326 (2013)

  Jodon, PhD thesis, Université Lyon 1 (2014)



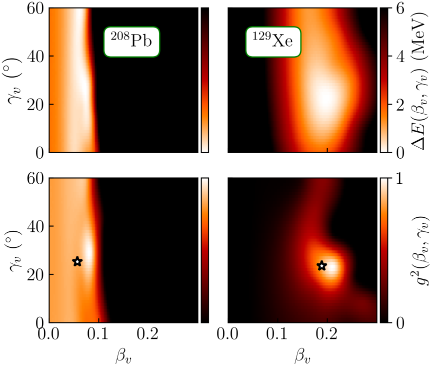
208Pb
129Xe
γv (°)
βv
0.0
0.1
0.2
0
20
40
60
ΔE(βv, γv) (MeV)
g2(βv, γv)
0
2
4
6
1

Modeling of the nuclei: inputs from nuclear theory



- Strategy

$$\begin{aligned}\bar{\beta}_v &= \sum_{(\beta_v,\gamma_v)} \beta_v\, g^2(\beta_v,\gamma_v) \\ \bar{\gamma}_v &= \sum_{(\beta_v,\gamma_v)} \gamma_v\, g^2(\beta_v,\gamma_v)\end{aligned} \rightarrow \text{ build } |\Phi(\bar{\beta}_v,\bar{\gamma}_v)\rangle \rightarrow \text{ fit WS parameters}$$



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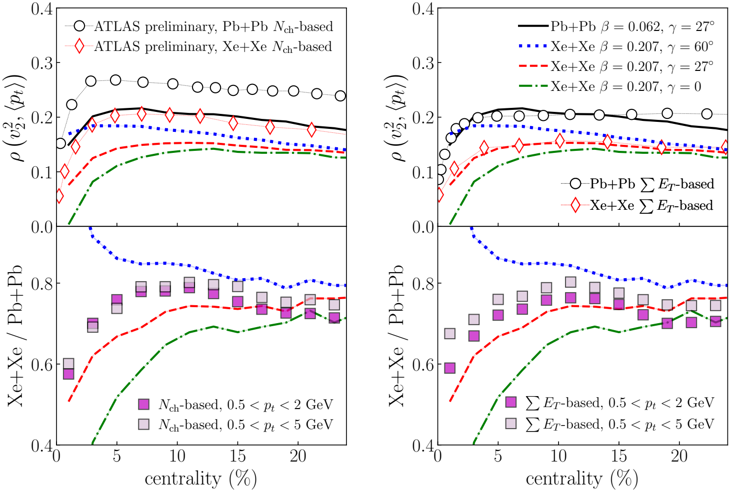
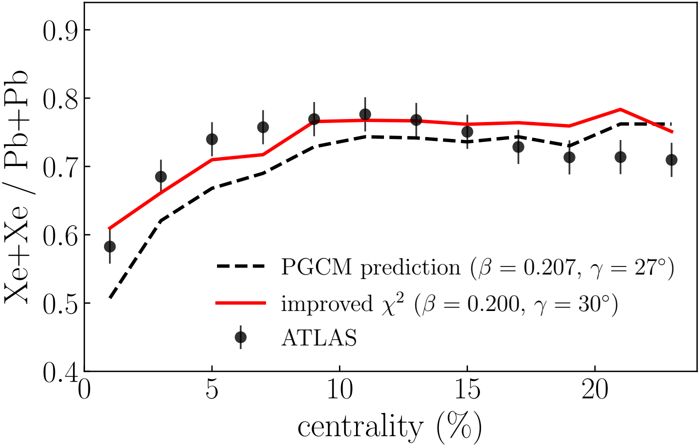
- Results for ^{208}Pb: $a = 0.537$ fm, $R_0 = 6.647$ fm, $\beta = 0.062$, $\gamma = 27.04°$
- Results for ^{129}Xe: $a = 0.492$ fm, $R_0 = 5.601$ fm, $\beta = 0.207$, $\gamma = 26.93°$

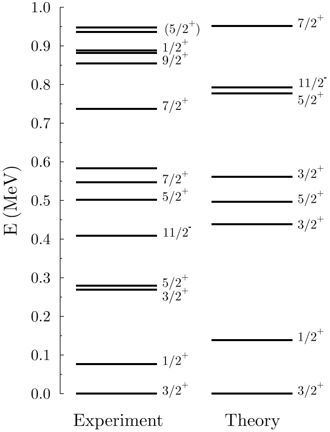
Analysis of LHC data

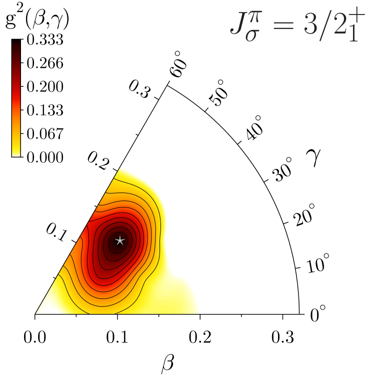


Best fit of LHC data



Preliminary results on ^{197}Au





Average def.: $\bar{\beta} = 0.13, \bar{\gamma} = 40°$

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