Be+Be and Be+p collisions at SPS energies

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Ideas and methods developed with

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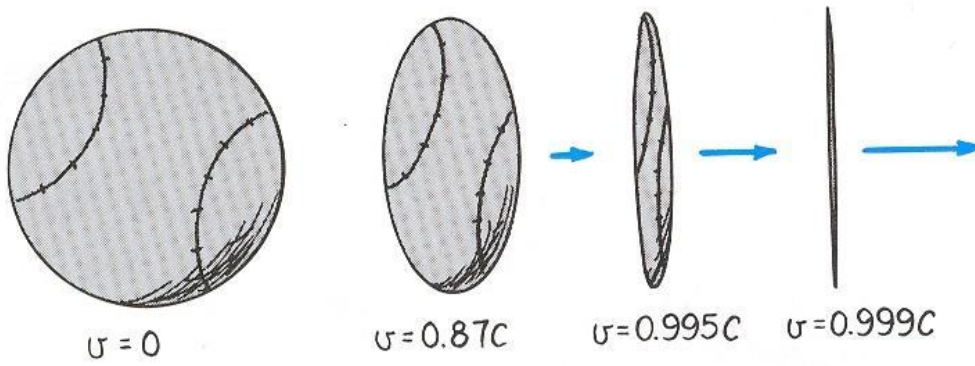
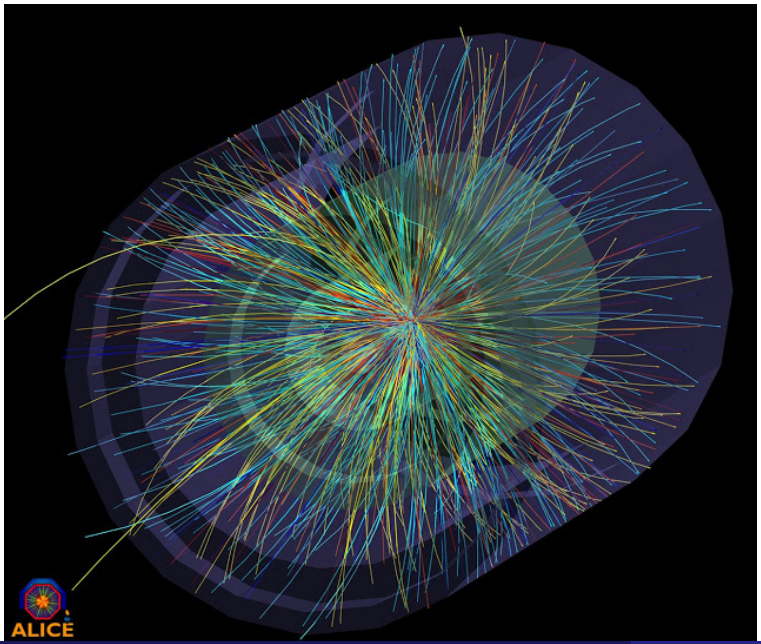
Ultra-relativistic nuclear collisions and the ground state

- Lorentz contraction
- Collision: essentially instantaneous passage, snapshot of a frozen configuration
- Reduction of the ground-state wave function of the nucleus **(like measurement)**

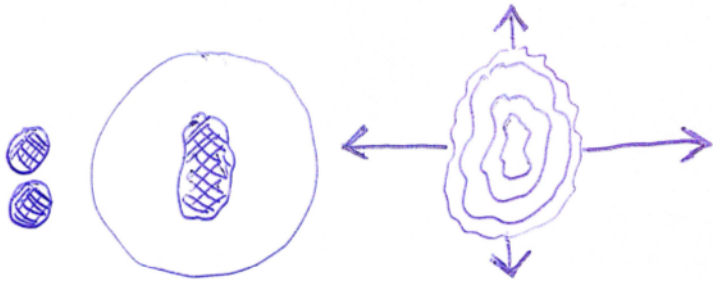




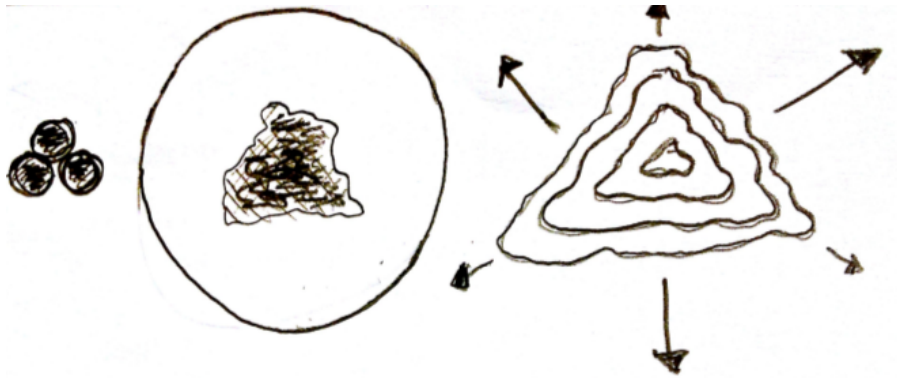
- "Development": detection of particles
- Different paradigm that in low-energy nuclear experiment (no slow reactions, cascades, ...)

Throwing dumbbells or triangles against a wall

asymmetry of shape $\rightarrow$ asymmetry of initial fireball $\rightarrow$
$\rightarrow$ hydro or transport $\rightarrow$ collective harmonic flow



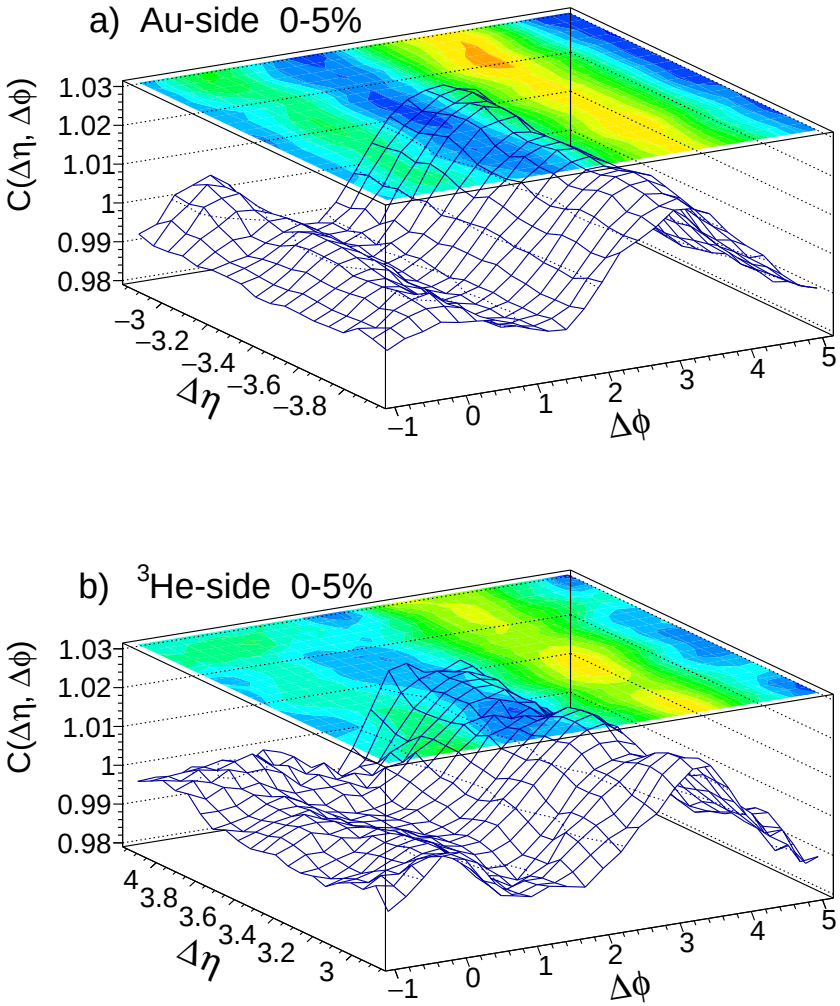
d, Be

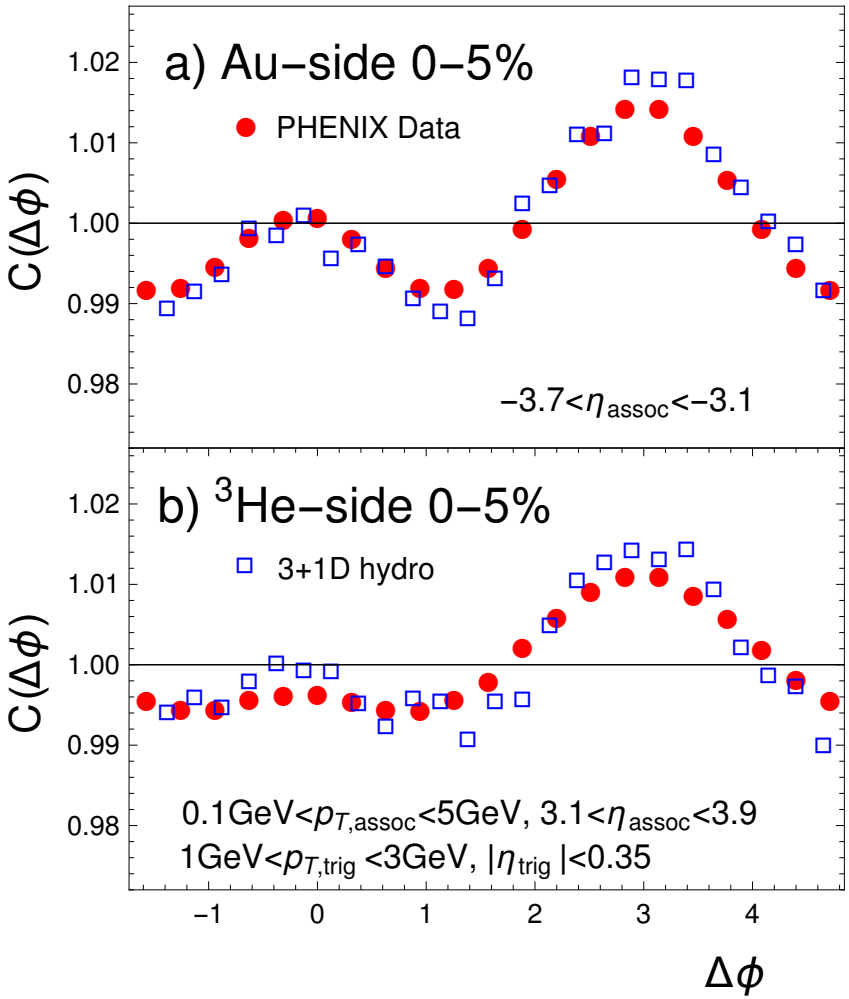


^{3}He, ^{12}C

[more details in WB & Enrique Ruiz Arriola, PRL 112 (2014) 112501
Piotr Bożek, WB, ERA & Maciej Rybczyński, PRC 90 (2014) 064902]

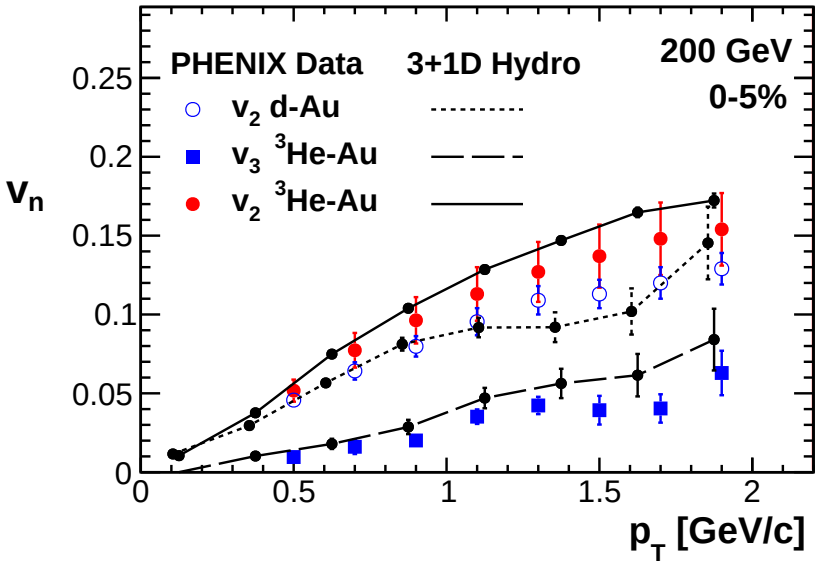
Some results for ^{3}He-Au

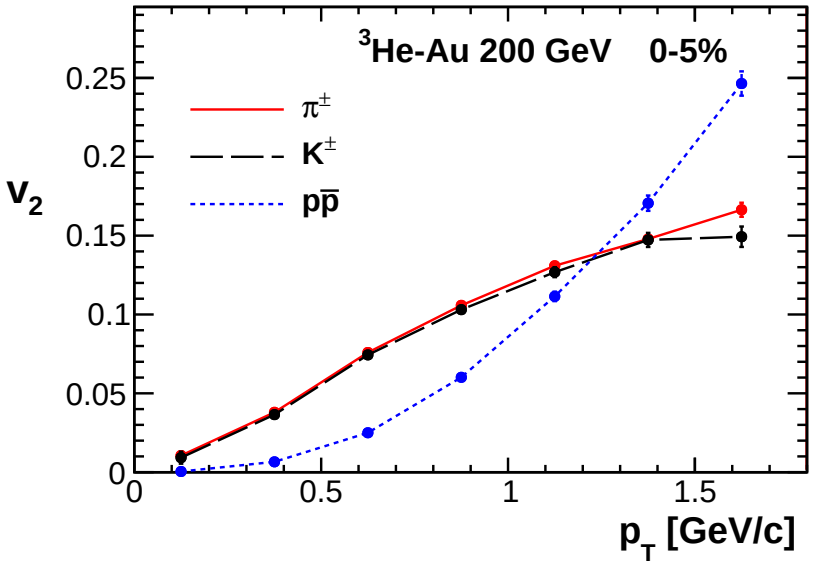




(seen on both pseudorapidity sides)

Flow in ^{3}He-Au

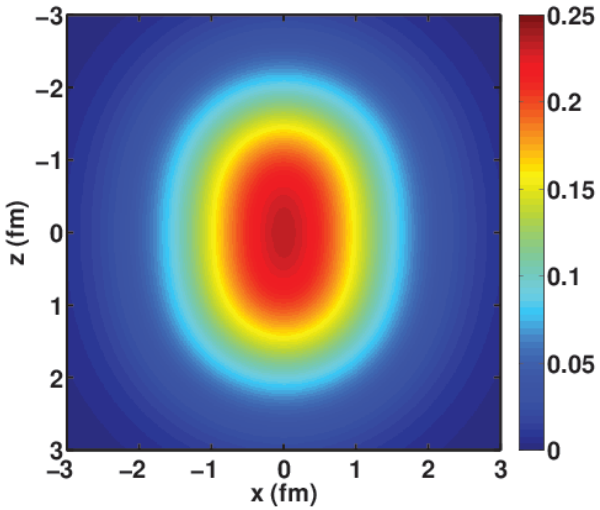




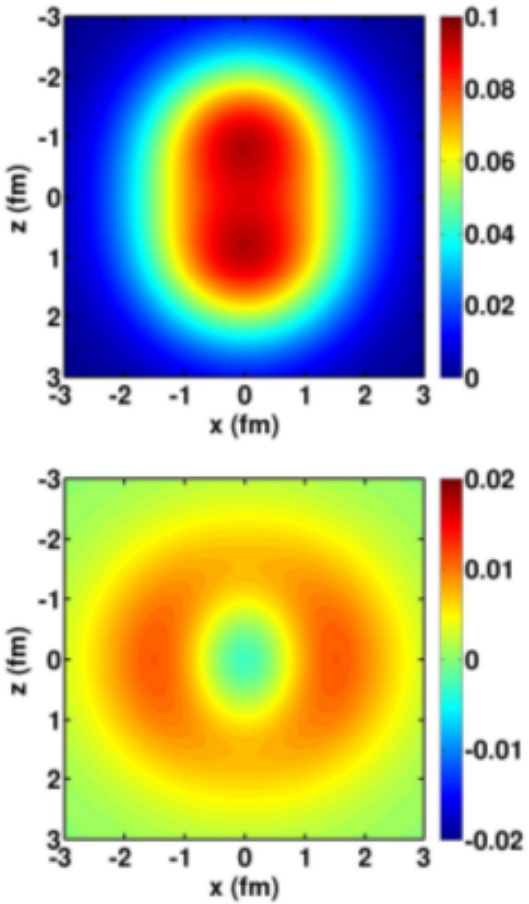
(mass ordering visible)

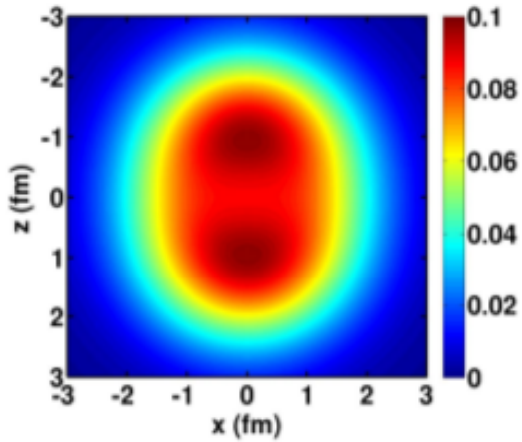
[Bożek & WB, arXiv:1503.00468]

No-core shell model ^{7}Be and ^{9}Be



^{7}Be $(p+n)$



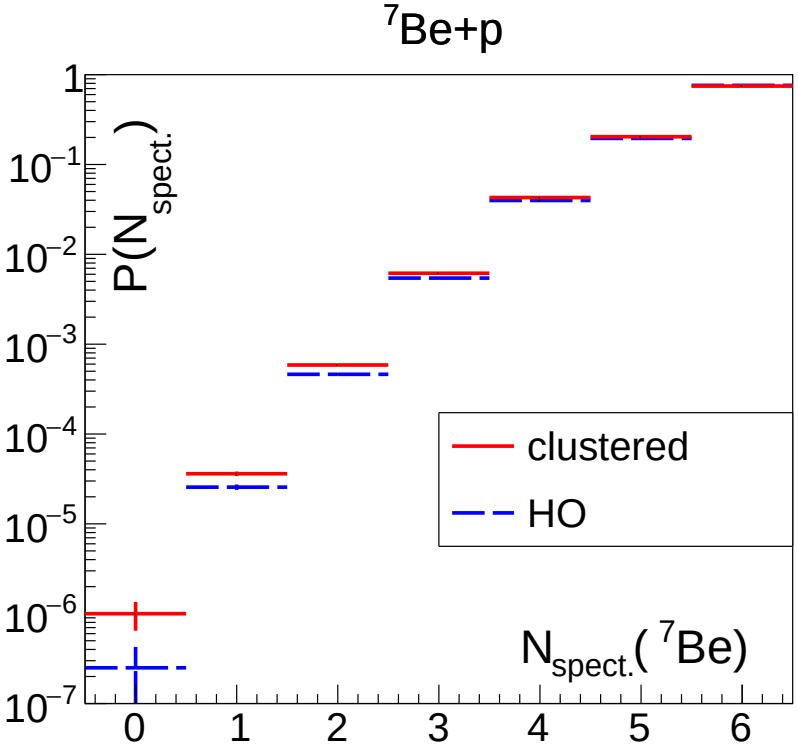


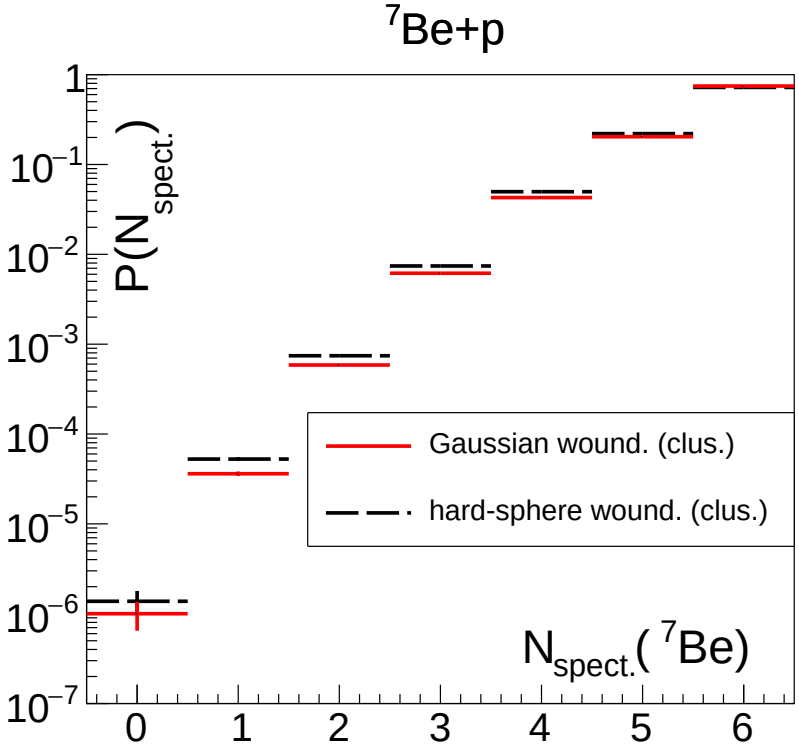
^{9}Be $\begin{pmatrix} p & n \\ n-p & \end{pmatrix}$

[Robert Chase Cockrell, PhD Thesis, Iowa State U.]

Be+p – reversed spallation

[all simulations with GLISSANDO 2 with $\sigma_{NN}^{\mathrm{inel}} = 32$ mb]





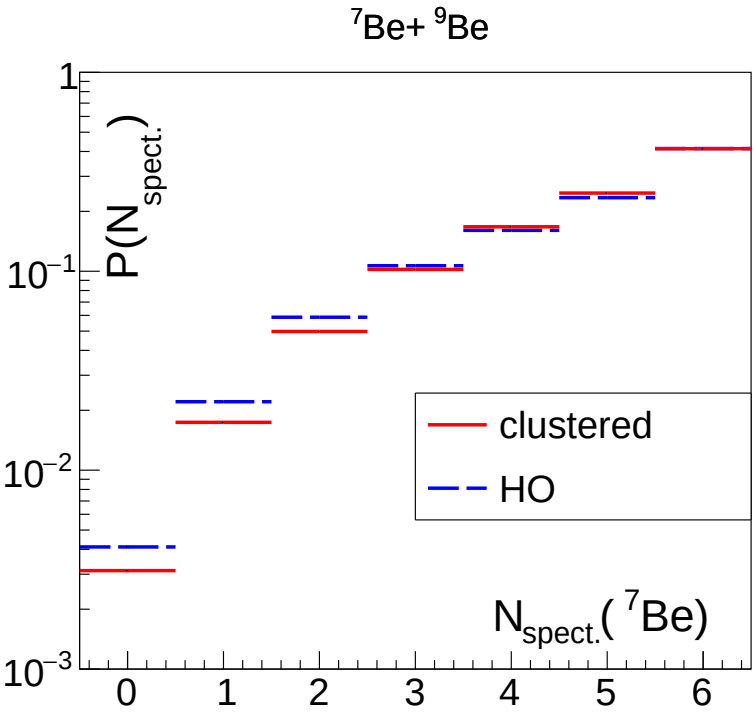
- clustered wave function leads to higher chance of wounding more nucleons compared to HO wave function
- sensitivity to the (Glauber) production model

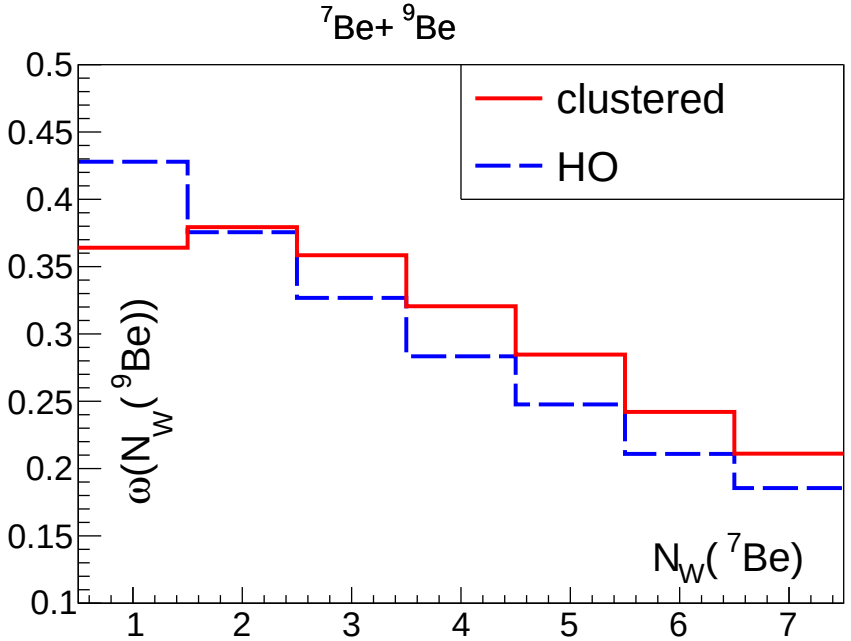
Fragments

GLISSANDO 2:

In Be+p reactions 50% of events preserve the ^{4}He cluster (none of nucleons in it is hit by the incident proton) and 40% preserve the ^{3}He cluster

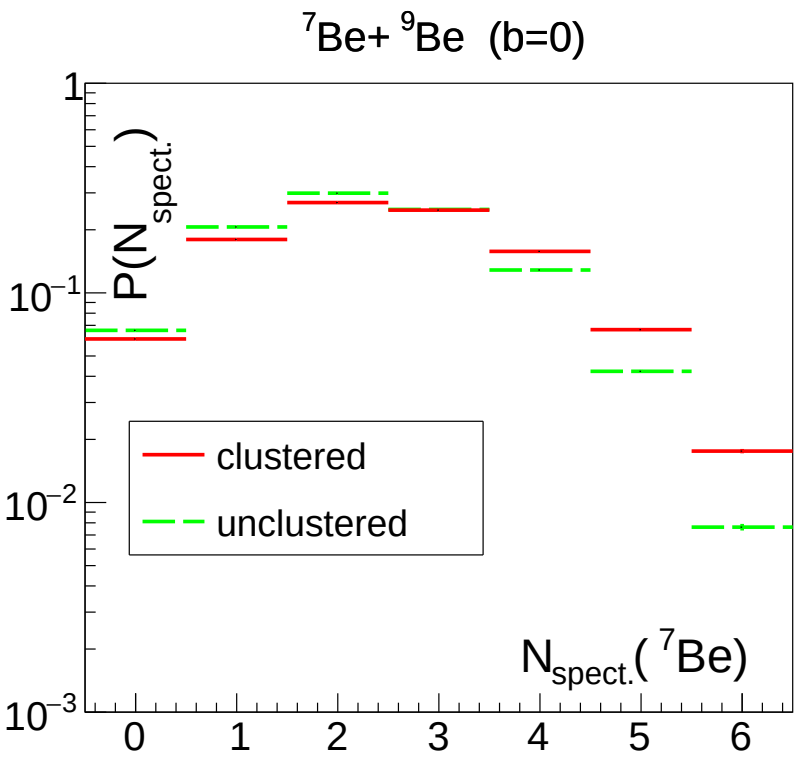
^{7}Be+^{9}Be

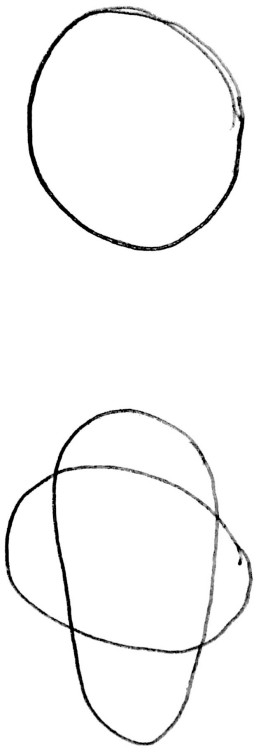




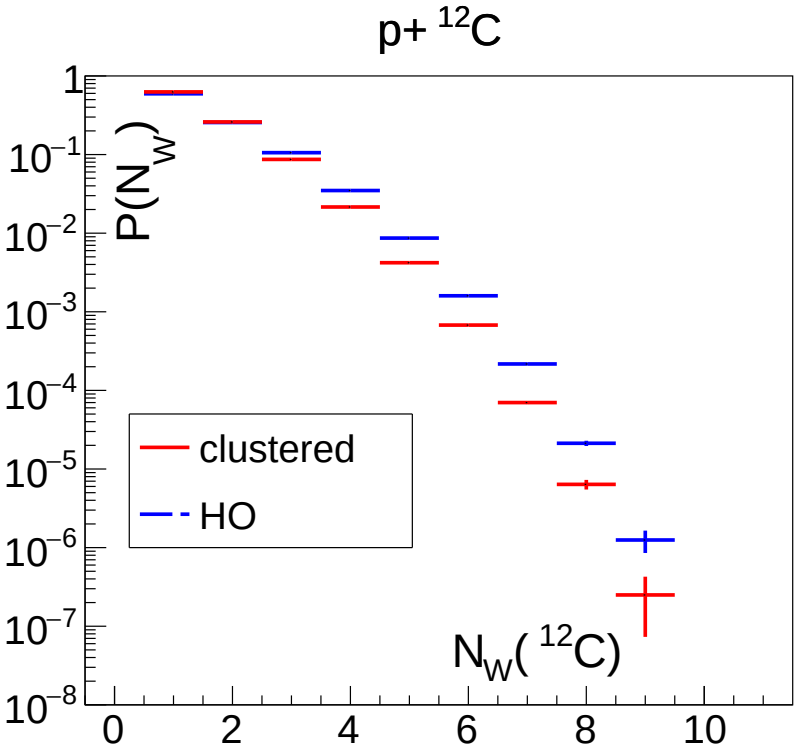
fluctuations increased by clusterization

To understand: ^{7}Be+^{9}Be at $b = 0$





p+C



$\sigma^{\text{inel}}_{p+C} = 253$ mb (clustered)

$\sigma^{\text{inel}}_{p+C} = 238$ mb (HO)

$\sigma^{\text{inel}}_{p+C} = (257.2 \pm 1.9 \pm 8.9)$ mb (NA61 secret, M. Posiadała)

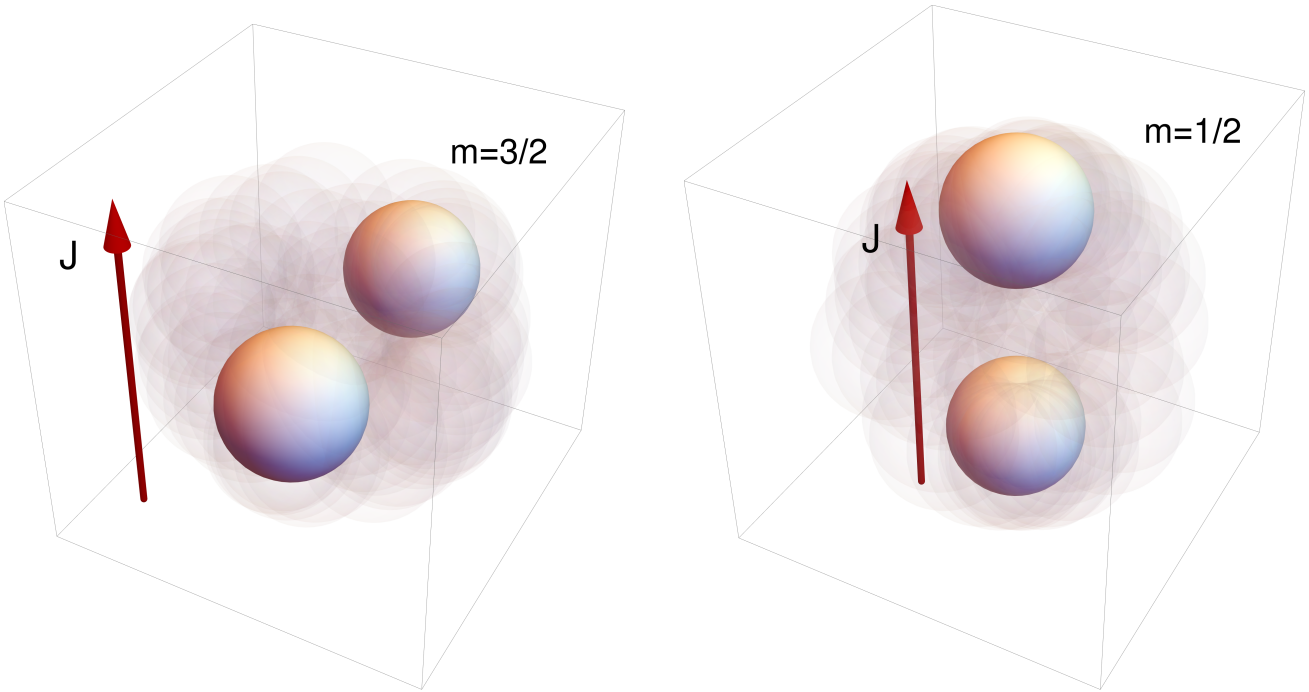
Making ^{7}Be of good quantum numbers

$^7\text{Be} = {}^4\text{He} + {}^3\text{He}$ (treated as elementary)

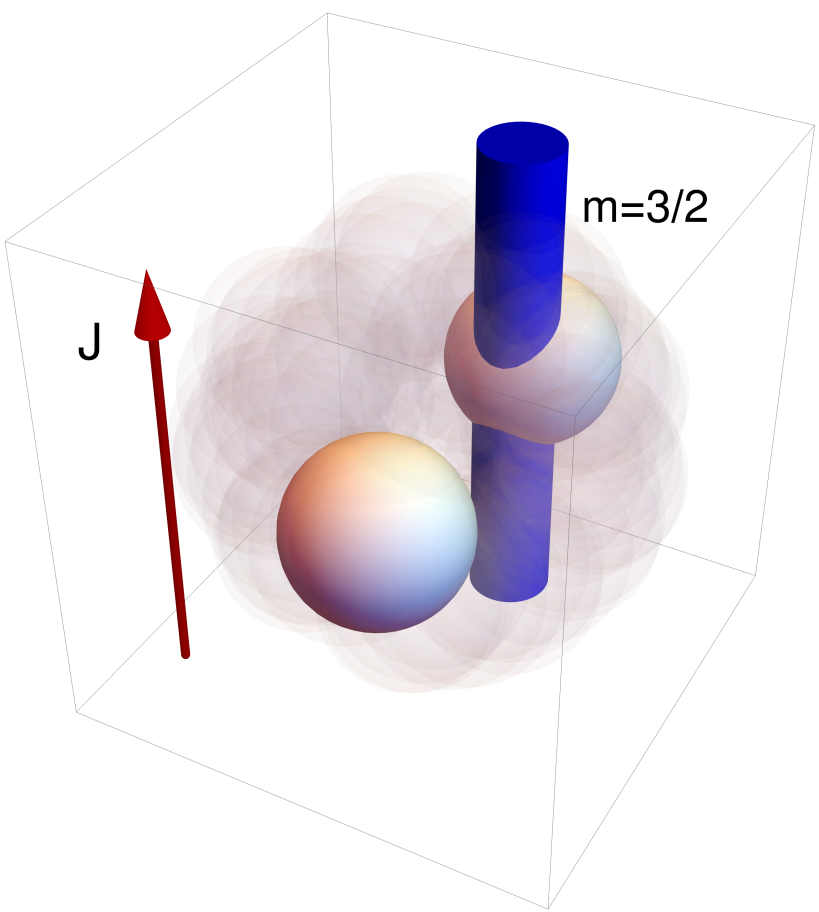
$\frac{3}{2}^- = 0^+ + \frac{1}{2}^+ + 1^-$ (orbital motion of ^{4}He and ^{3}He)

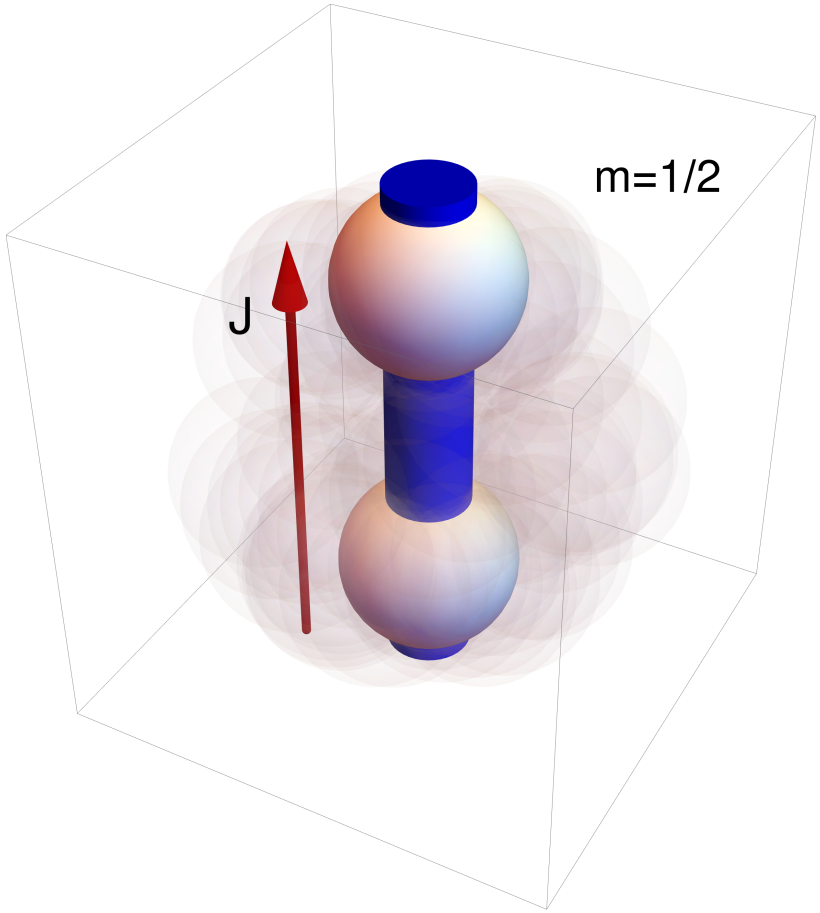
$|\frac{3}{2}, m = \frac{3}{2}\rangle = |\frac{1}{2}, \frac{1}{2}\rangle \otimes |1, 1\rangle$

$|\frac{3}{2}, m = \frac{1}{2}\rangle = \sqrt{\frac{2}{3}}|\frac{1}{2}, \frac{1}{2}\rangle \otimes |1, 0\rangle + \sqrt{\frac{1}{3}}|\frac{1}{2}, -\frac{1}{2}\rangle \otimes |1, 1\rangle$



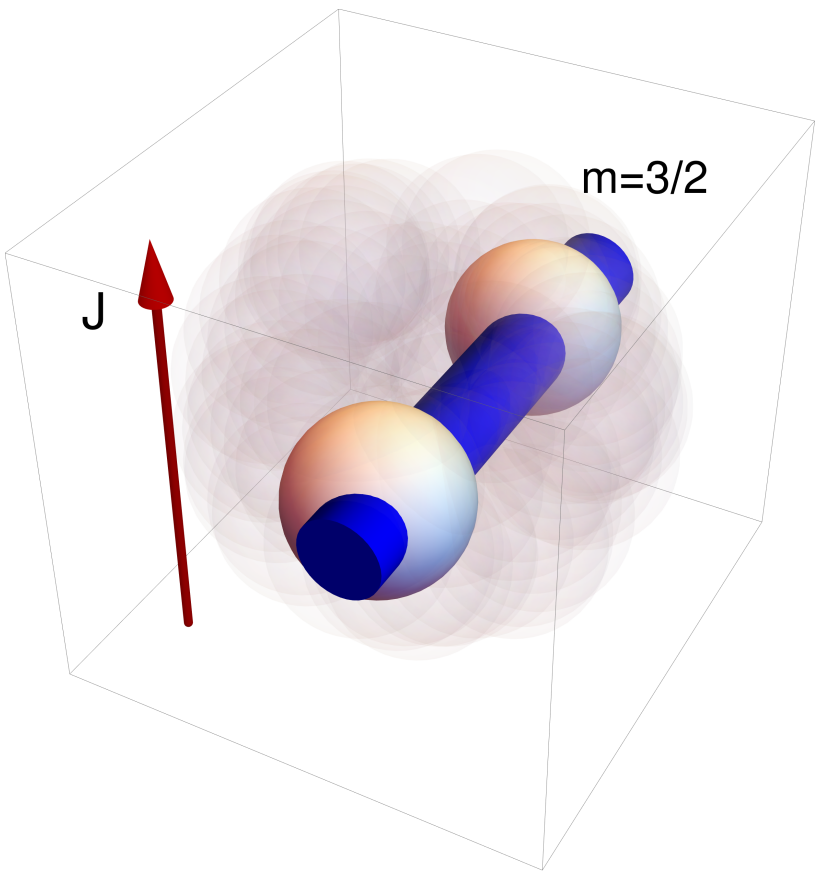
$J \parallel z$

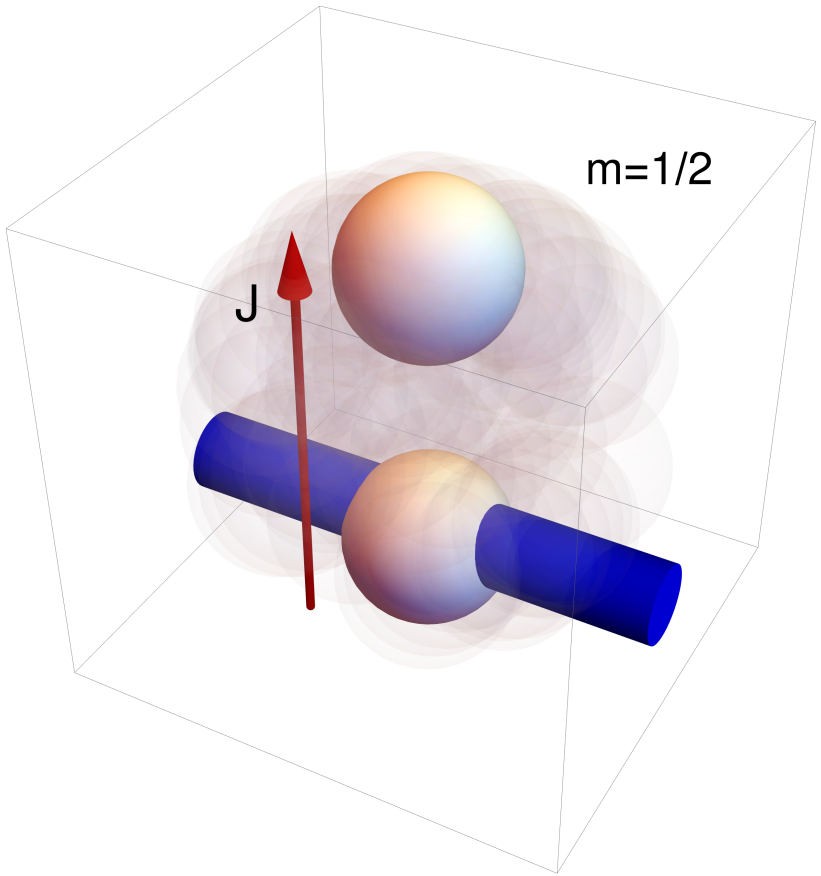




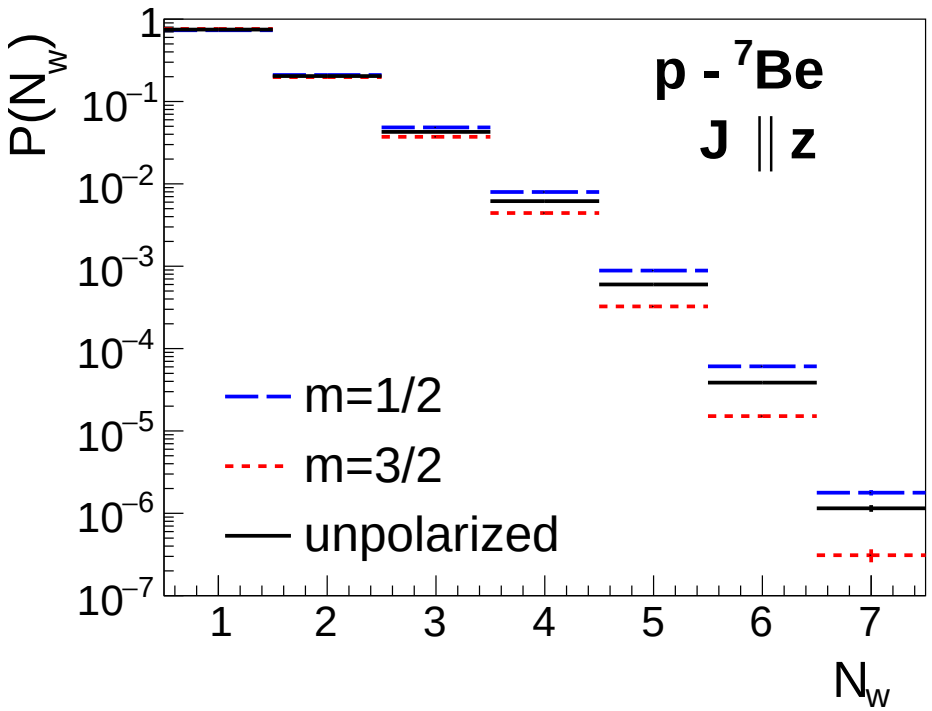
(radius of the cylinder corresponds to the NN wounding cross section)

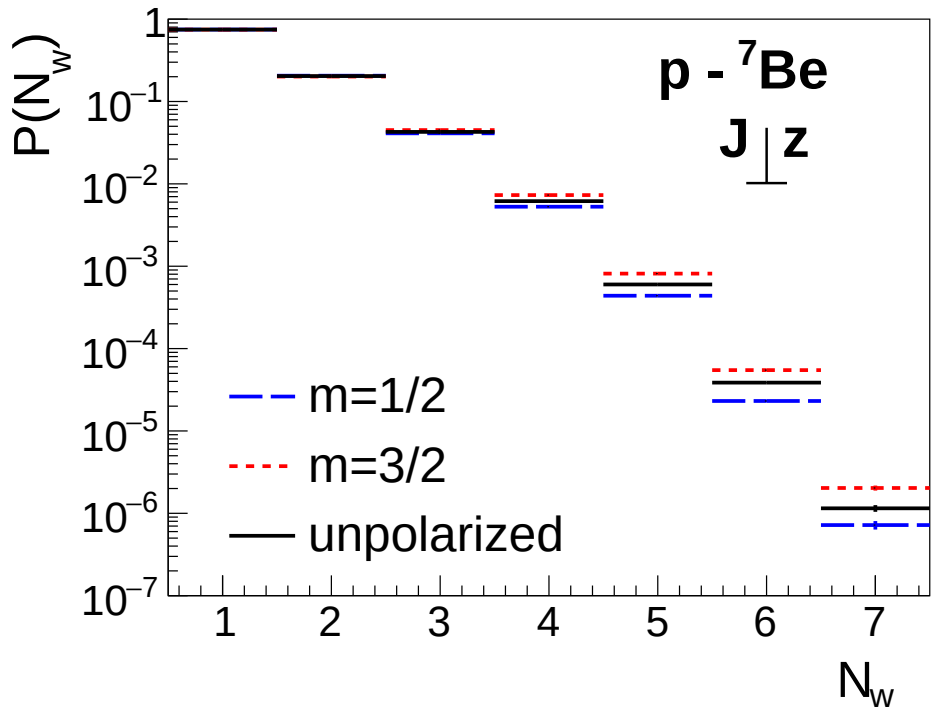
$J \perp z$





Results for p – polarized ^{7}Be





Conclusions

New way of looking at the ground state nuclear structure by taking the "high-energy" snap shots

- Small on large (d-Au, ^{3}He-Au, Be+Pb, C+Pb): harmonic flow detects intrinsic shape
- Small on small – sensitivity to the wave functions (Be+Be) in spectator distributions, fluctuations, ...
- Small on proton - new field of reversed spallation
- Polarized beams would offer more precise insight into clusterization. Some remnant polarization from inhomogeneous magnetic field affects the results