Dynamic isovector reorientation of deuteron as a probe to nuclear symmetry energy

Li Ou (欧立)[1] Zhigang Xiao (肖志刚)[2]

[1]Guangxi Normal University, China

[2]Tsinghua University, China

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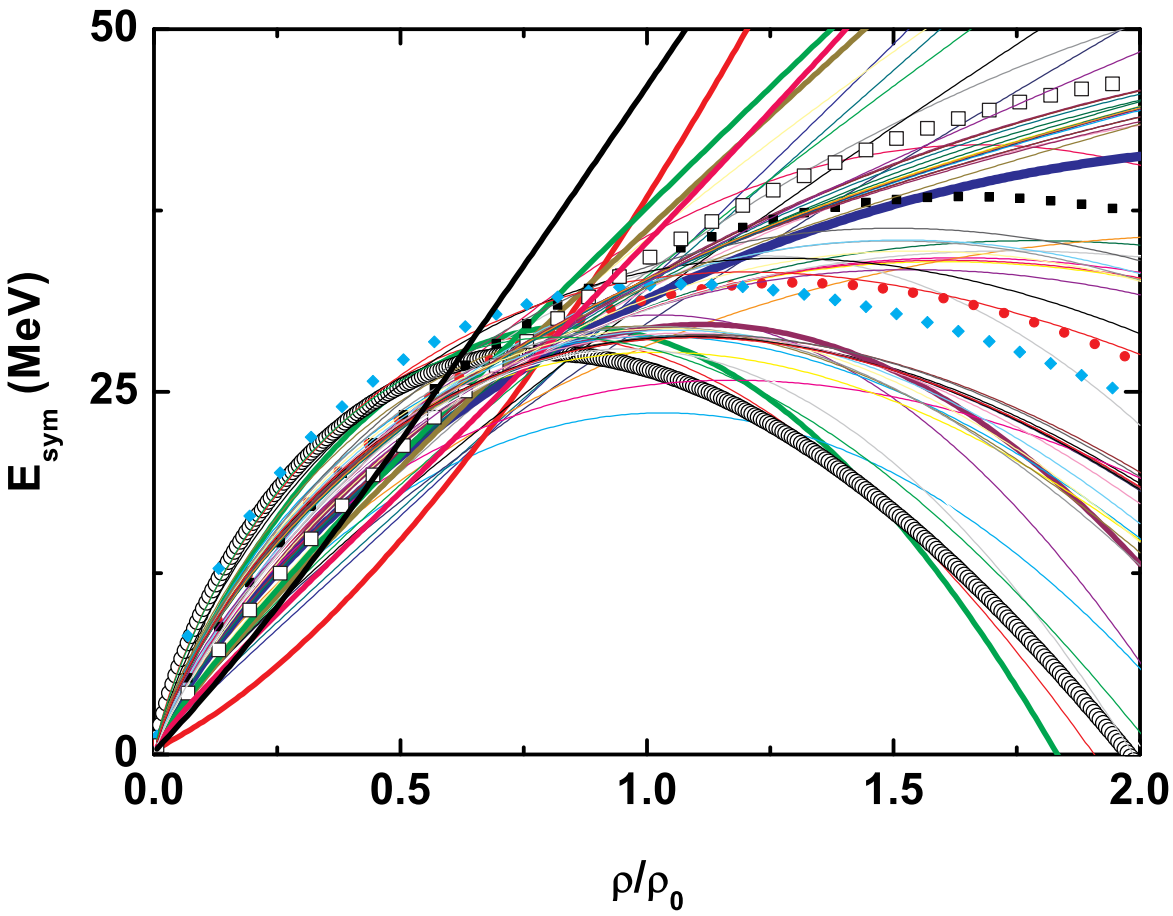
Outline

Outline

What? Why? Where?

Every audience here Know!

Aim of this work



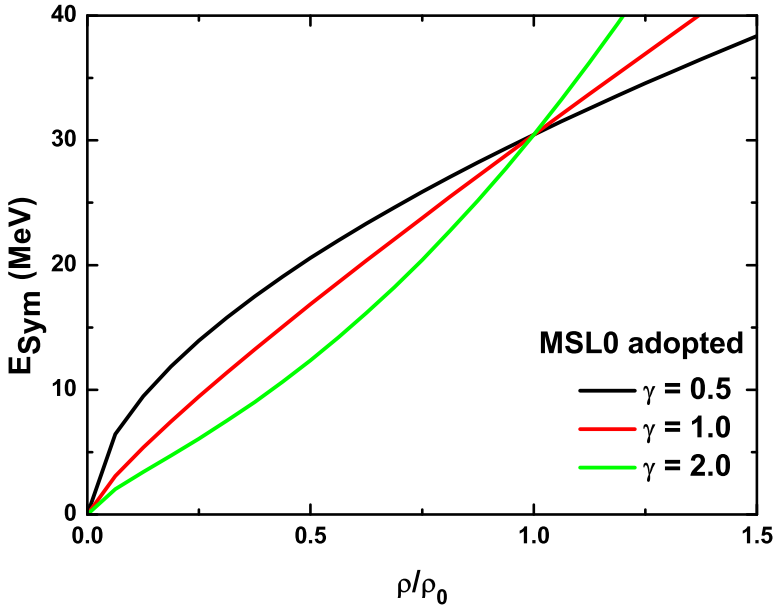
For constraint of $E_{\rm sym}$ by HIC, accurate information at low density is helpful to reduce $E_{\rm sym}$ uncertainty at high density!

Tool: ImQMD model, $E_{\rm sym}$ in ImQMD

$$\dot{r}_i = \frac{\partial H}{\partial p_i}, \quad \dot{p}_i = -\frac{\partial H}{\partial r_i}$$

$$H = T + U_{\rm loc} + U_{\rm Coul}$$

$$U_{\rm loc} = \int V_{\rm loc} dr$$



$$E_{\rm sym}(\rho) = \frac{C_{\rm s,k}}{2}\left(\frac{\rho}{\rho_0}\right)^{2/3} + \frac{C_{\rm s,p}}{2}\left(\frac{\rho}{\rho_0}\right)^{\gamma}$$

2-body | 3-body | surface

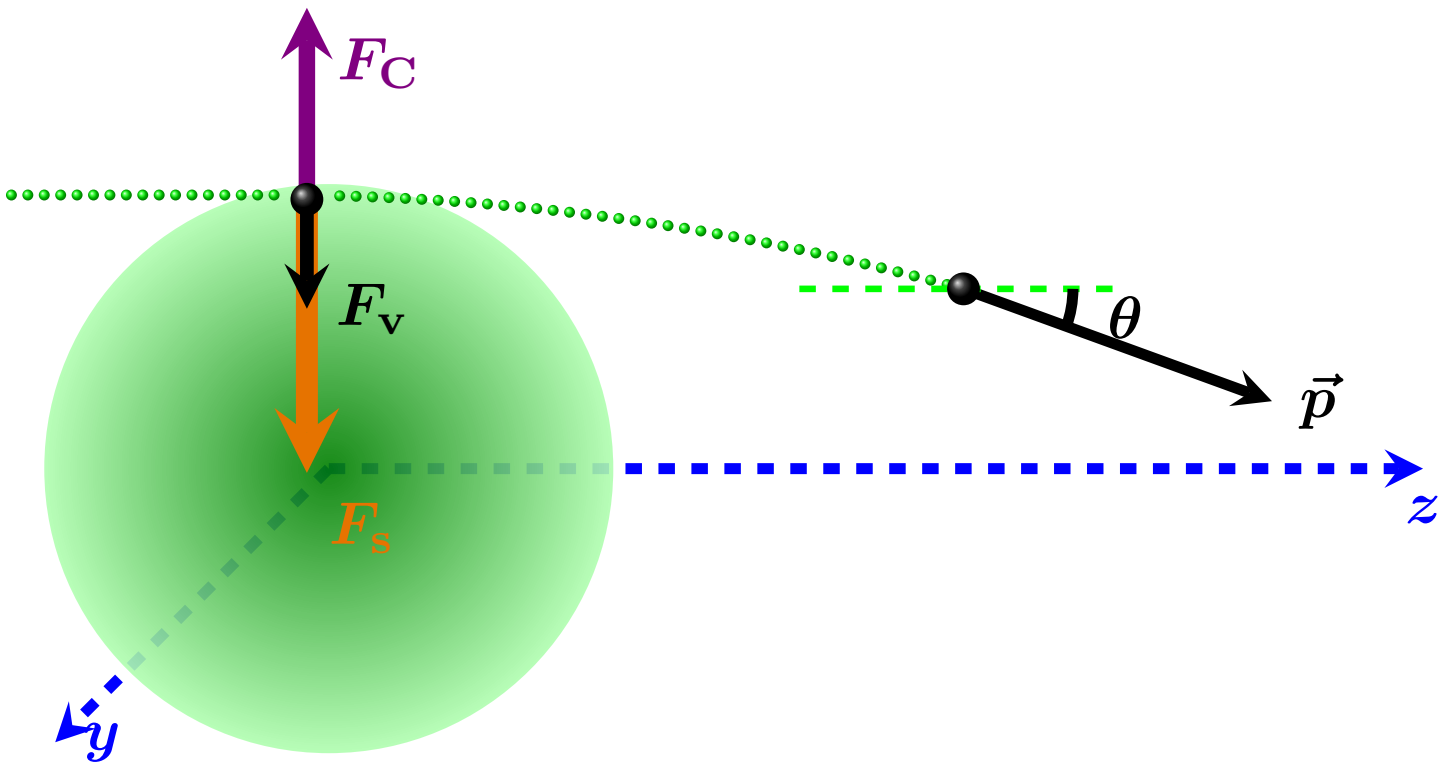
$$V_{\rm loc}(\rho) = \frac{\alpha}{2}\frac{\rho^2}{\rho_0} + \frac{\beta}{\gamma+1}\frac{\rho^{\gamma+1}}{\rho_0^{\gamma}} + \frac{g_{\rm sur}}{2\rho_0}(\nabla\rho)^2$$

$$+\frac{g_{\rm sur,iso}}{\rho_0}[\nabla(\rho_{\rm n}-\rho_{\rm p})]^2 + \frac{C_{\rm s}}{2}\left(\frac{\rho}{\rho_0}\right)^{\gamma}\rho\delta^2 + g_{\rho\tau}\frac{\rho^{8/3}}{\rho_0^{5/3}}.$$

surface symmetry | symmetry | $\rho\tau$ term

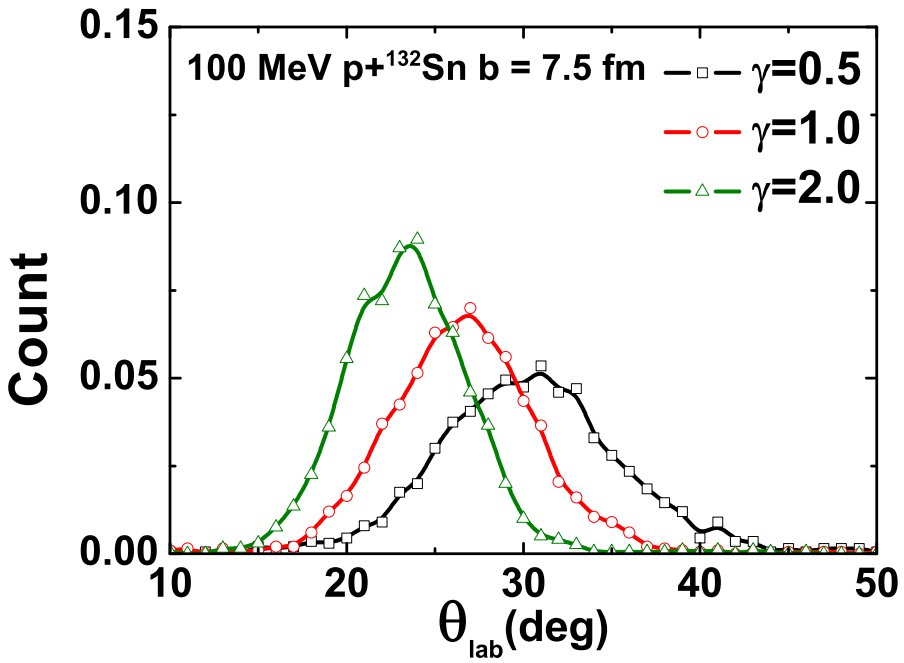
Outline

Nucleon scattering reaction



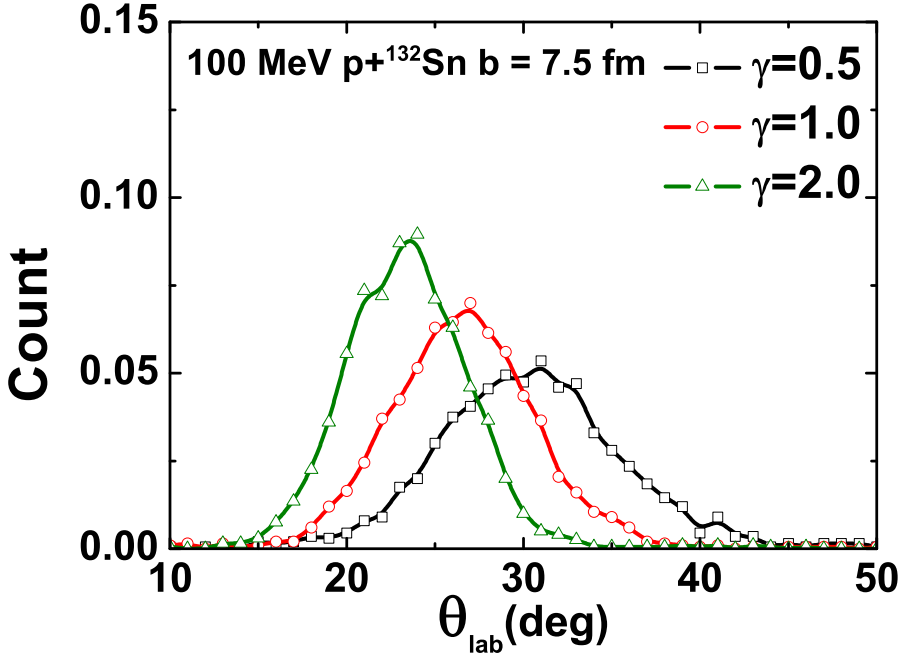
θ is larger for proton undergoing stronger symmetry potential!

Angular distribution for elastic scattering nucleon can be an observable for E_{sym}.



p+^{132}Sn.

Li Ou *et.al* **PRC78, 044609 (2008)**



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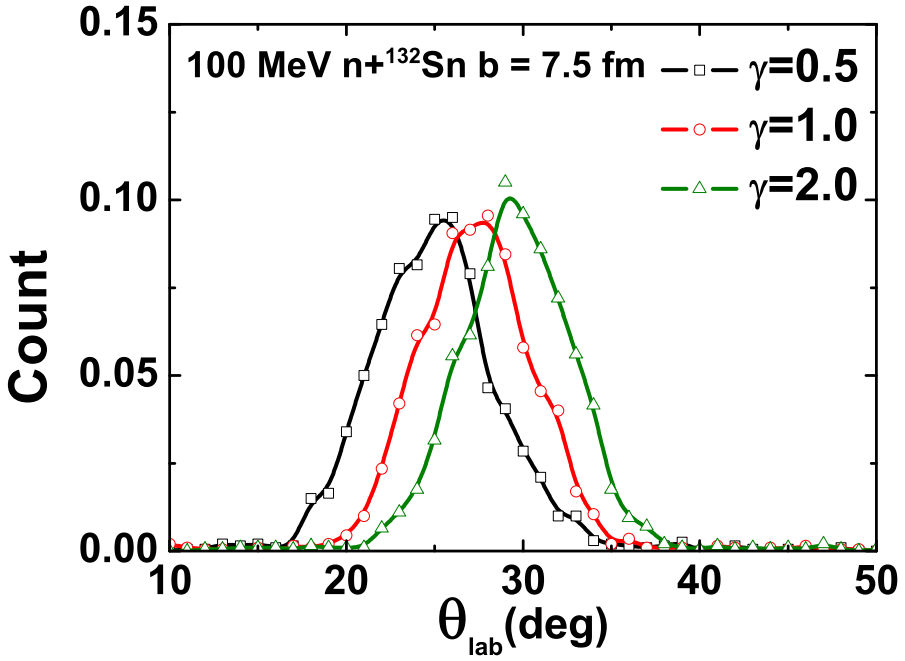

n+^{132}Sn.

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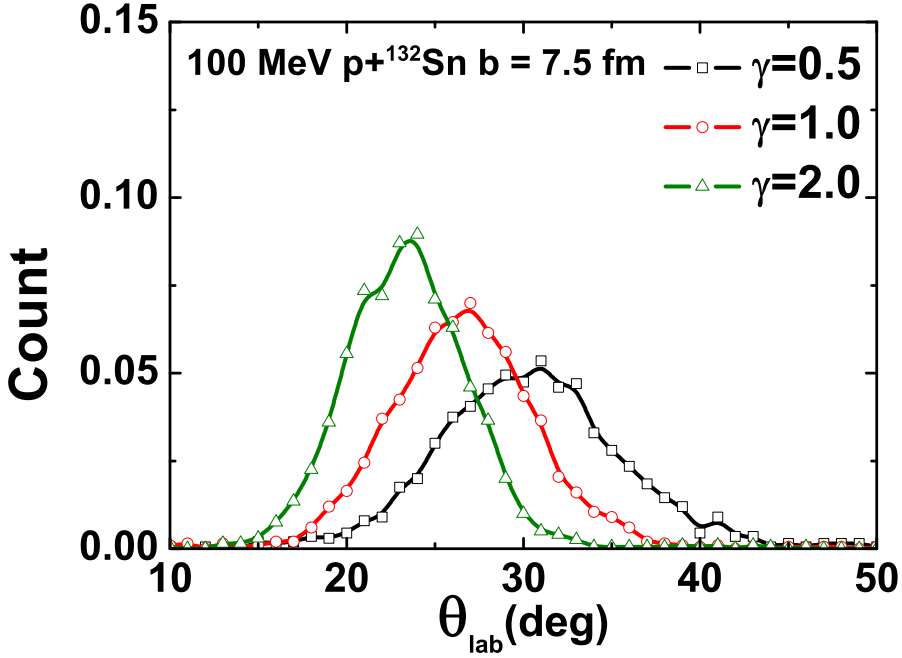

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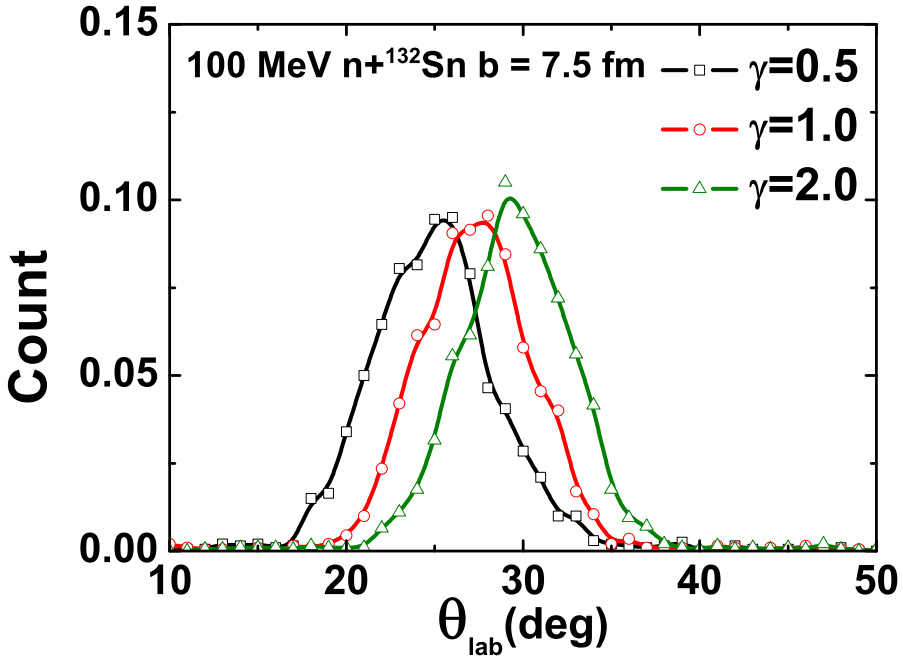

n+^{132}Sn.

$$\Delta\theta = \theta_p - \theta_n = \begin{cases} 5.5^\circ, & \gamma = 0.5, \quad \text{soft} \\ 0.5^\circ, & \gamma = 1.0, \quad \text{linear} \\ -6.6^\circ, & \gamma = 2.0, \quad \text{stiff} \end{cases}$$

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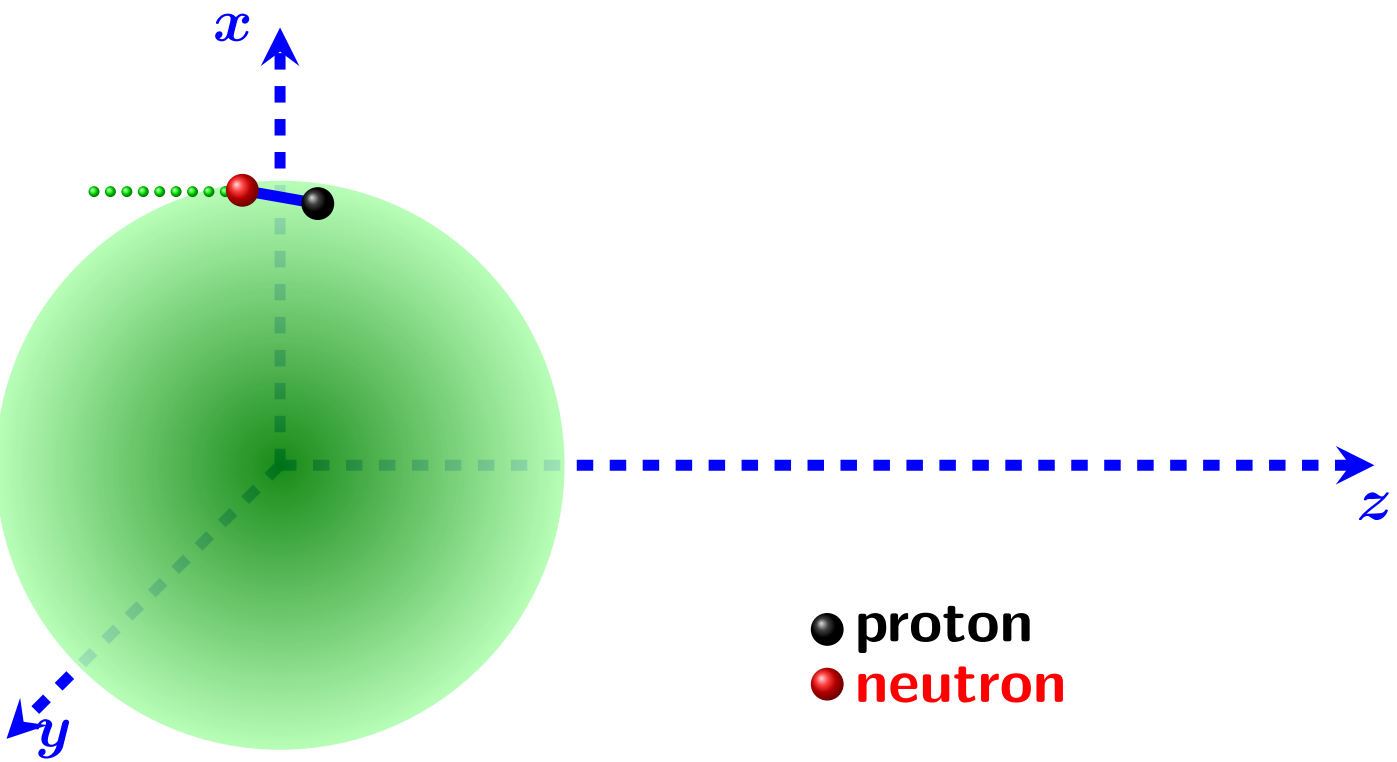
Deuteron breakup reaction



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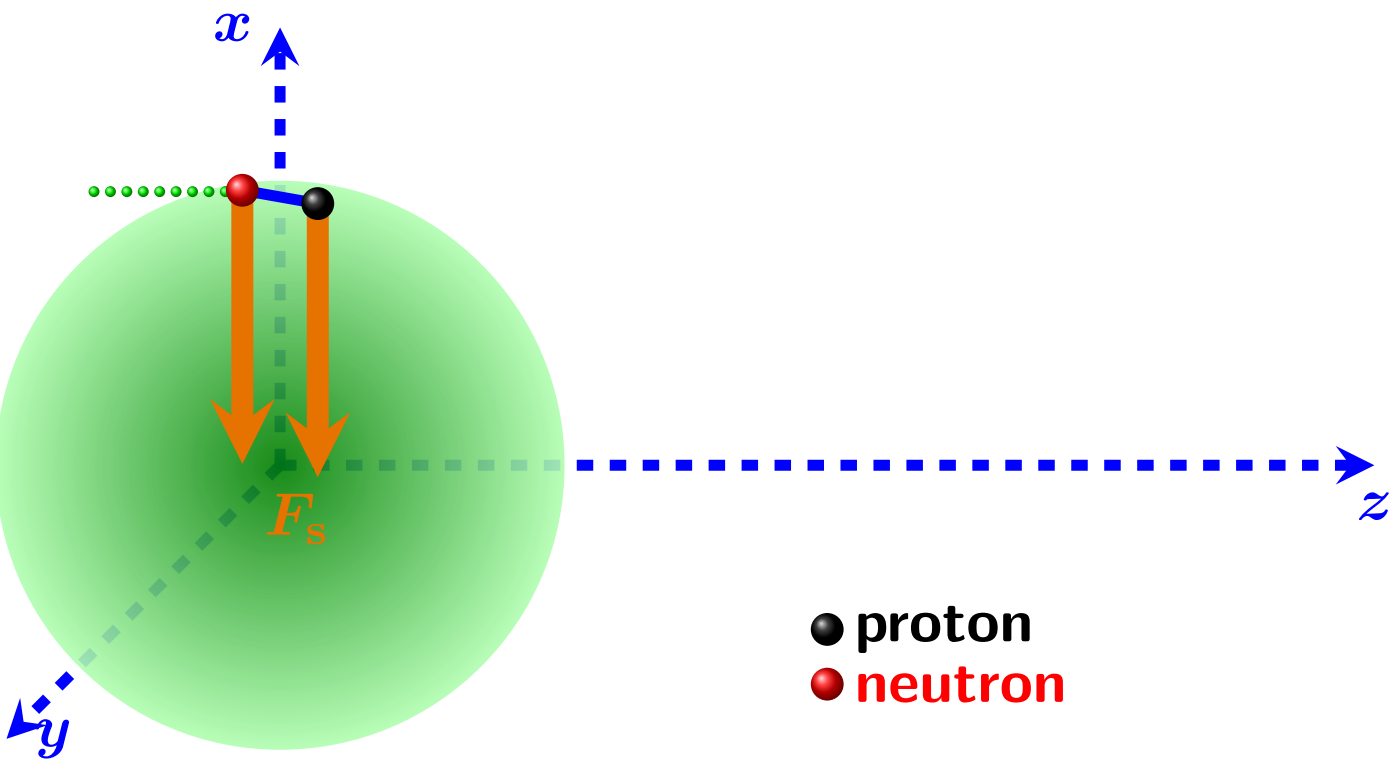
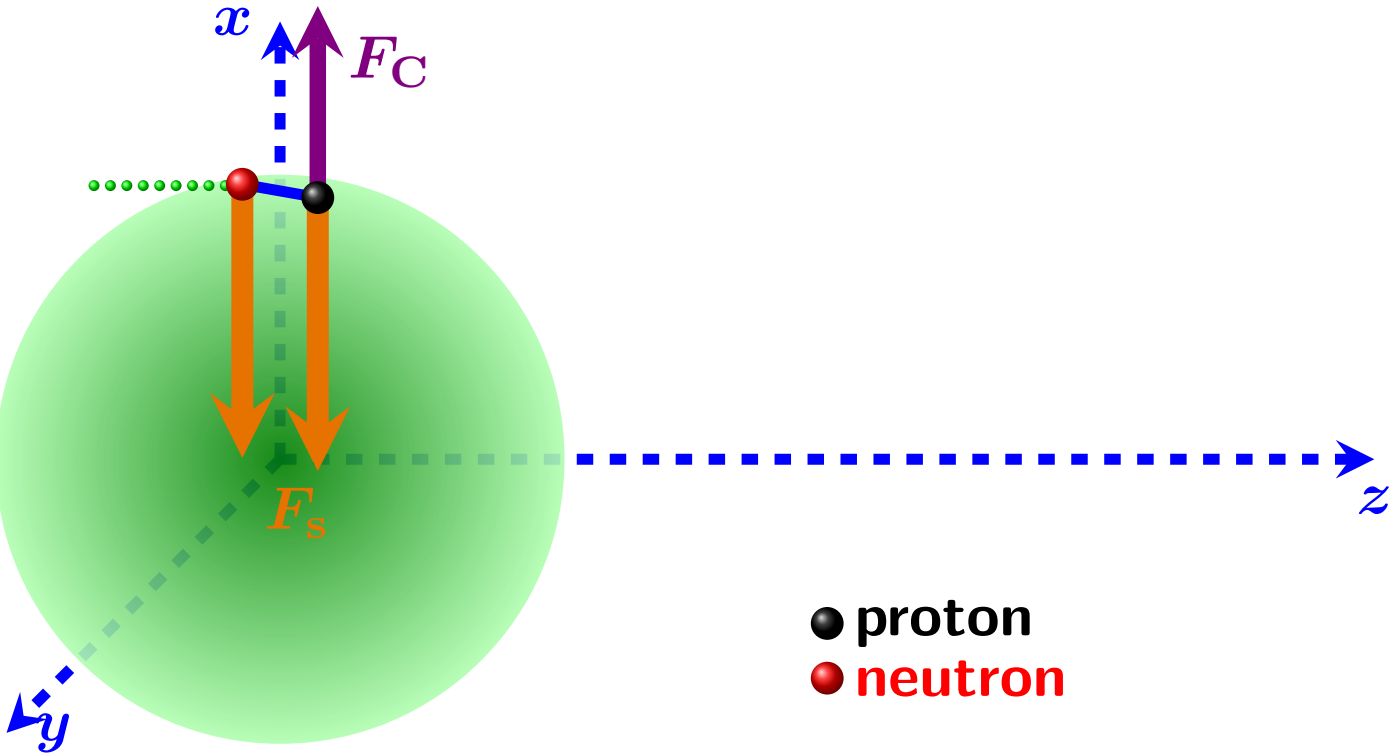


F_s from isoscale potential, deflexion;

Deuteron breakup reaction



F_s from isoscale potential, deflexion;

F_{Coul} from Coulomb potential, anticlockwise;

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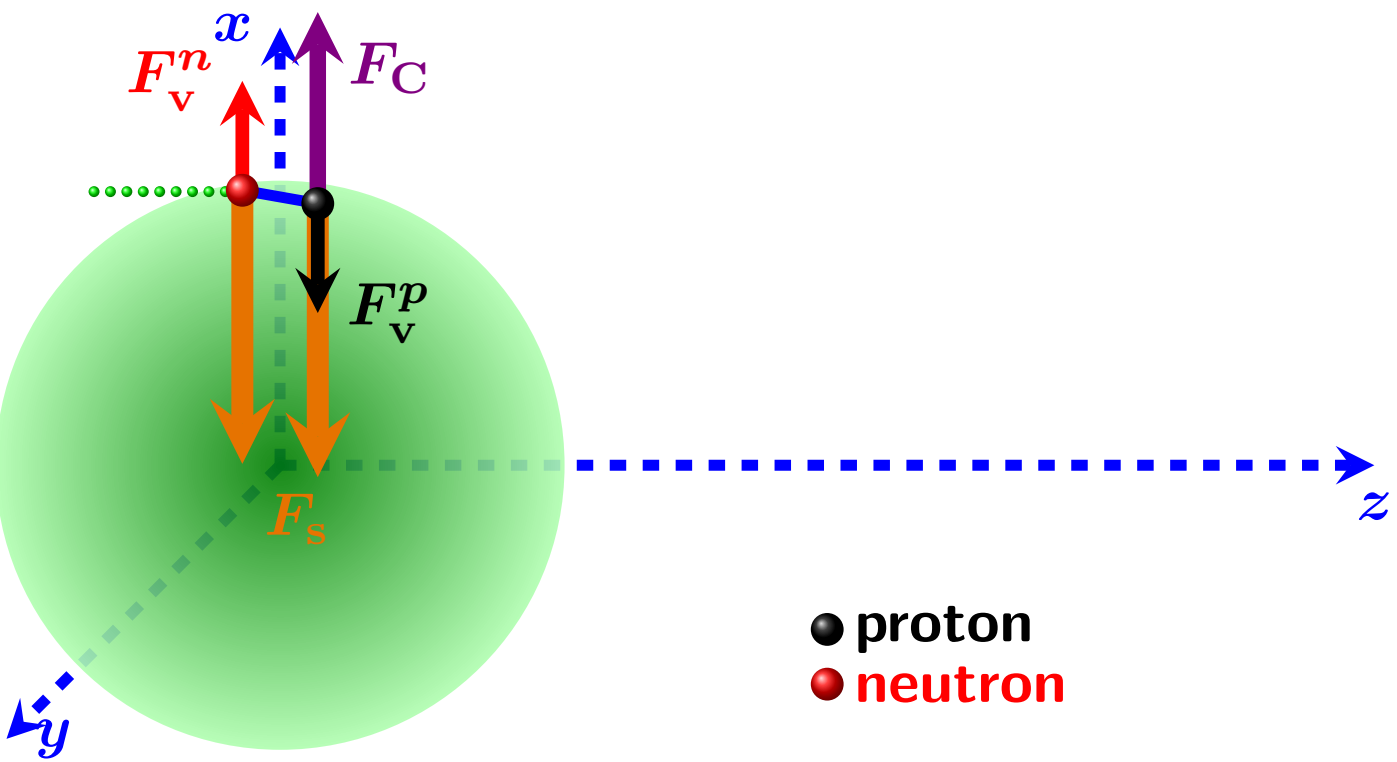


F_s from isoscale potential, deflexion;

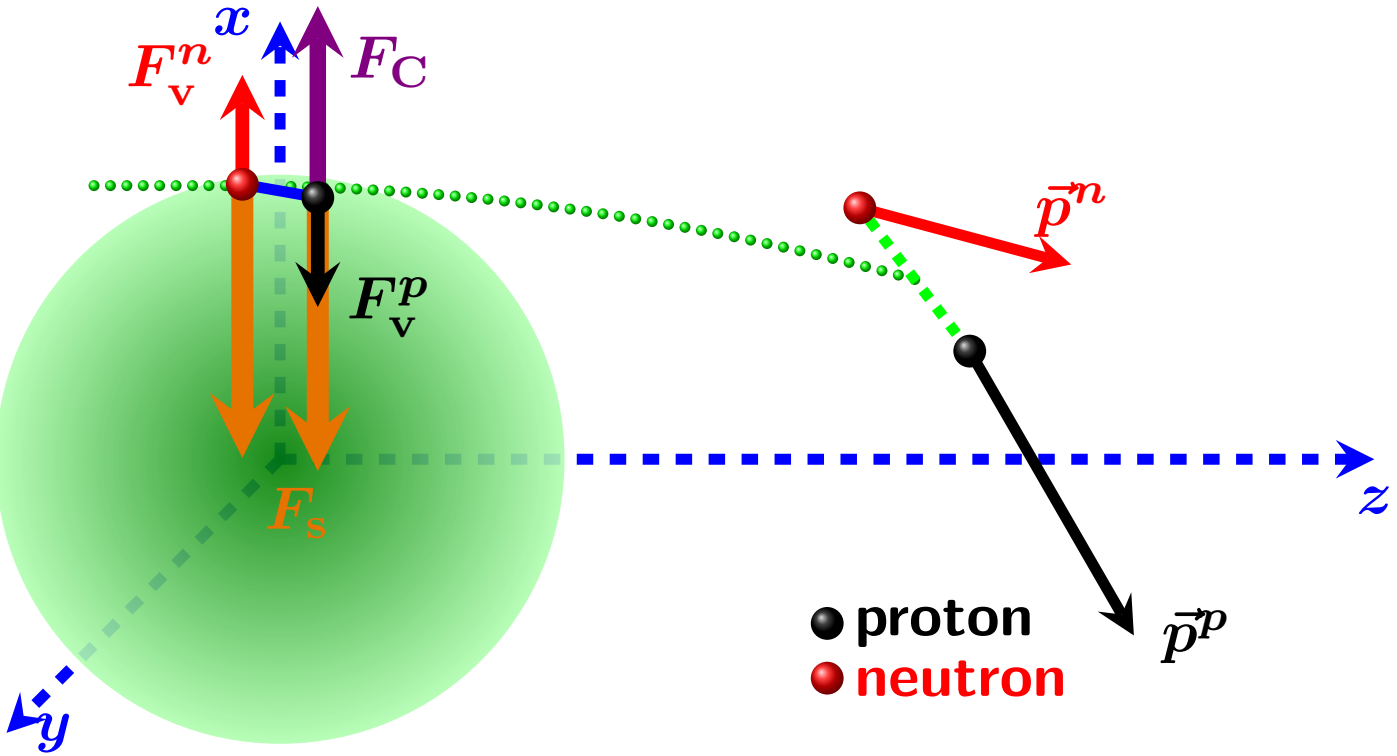
F_{Coul} from Coulomb potential, anticlockwise;

F_{v}^{p} on proton from isovector potential;

clockwise

F_{v}^{n} on neutron from isovector potential;

Deuteron breakup reaction



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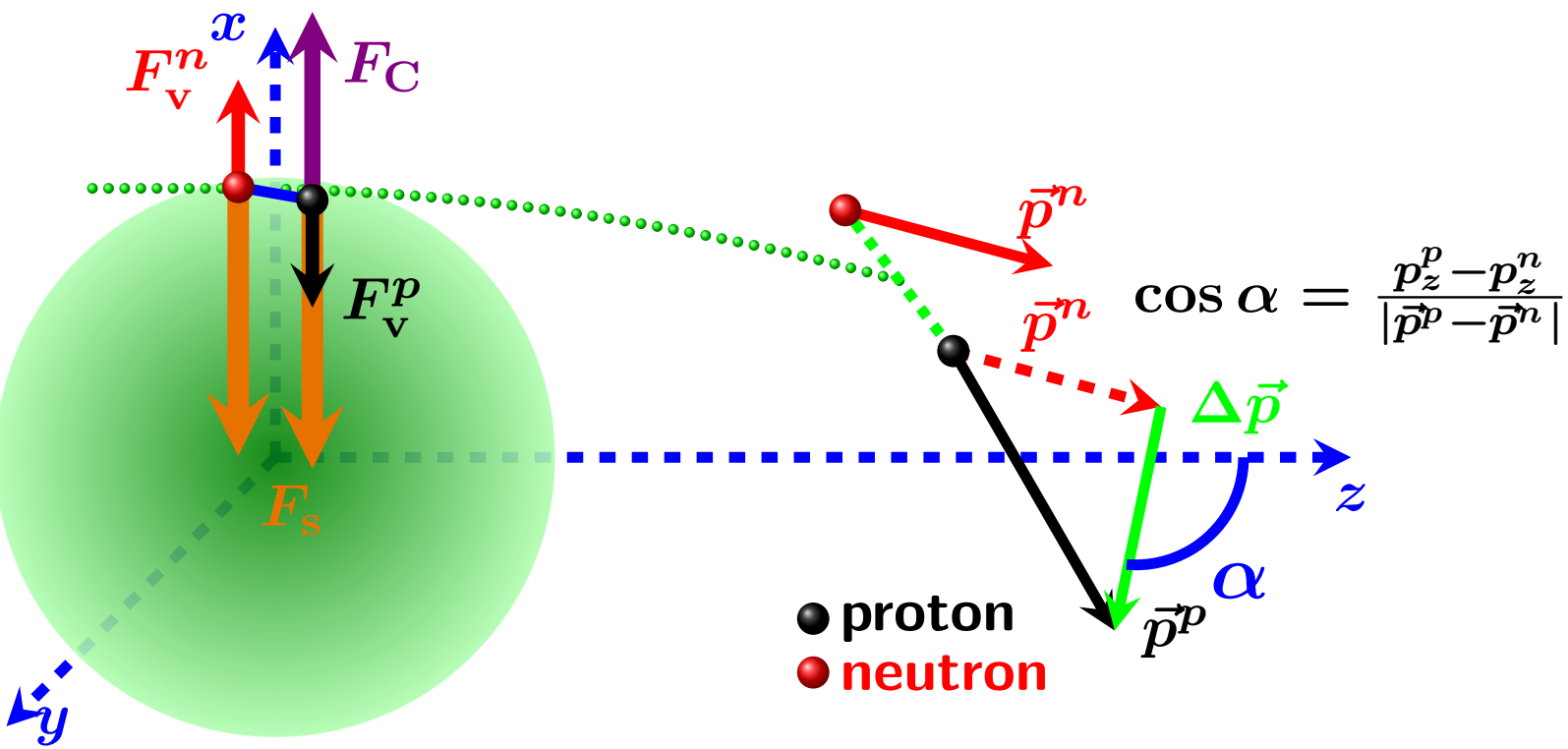

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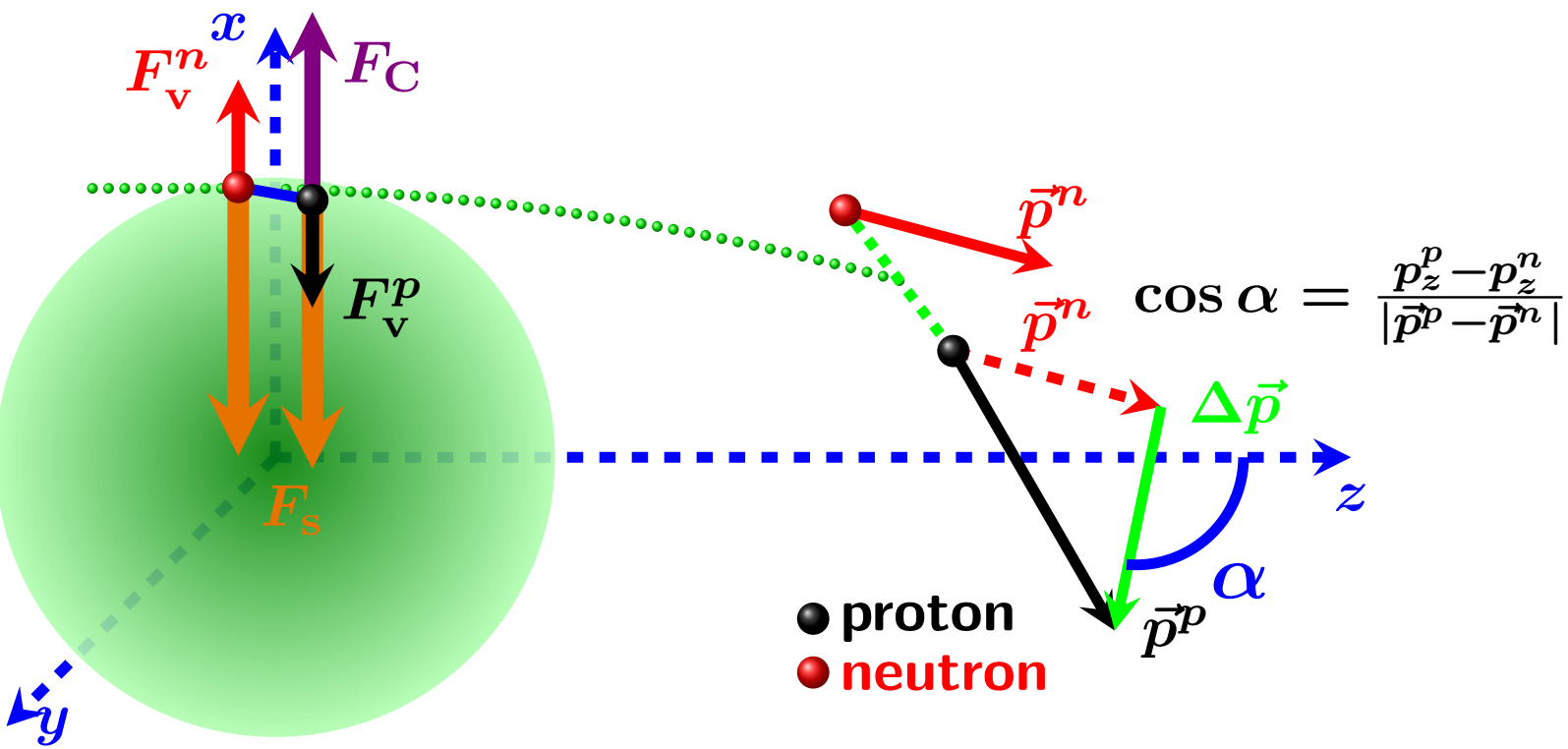

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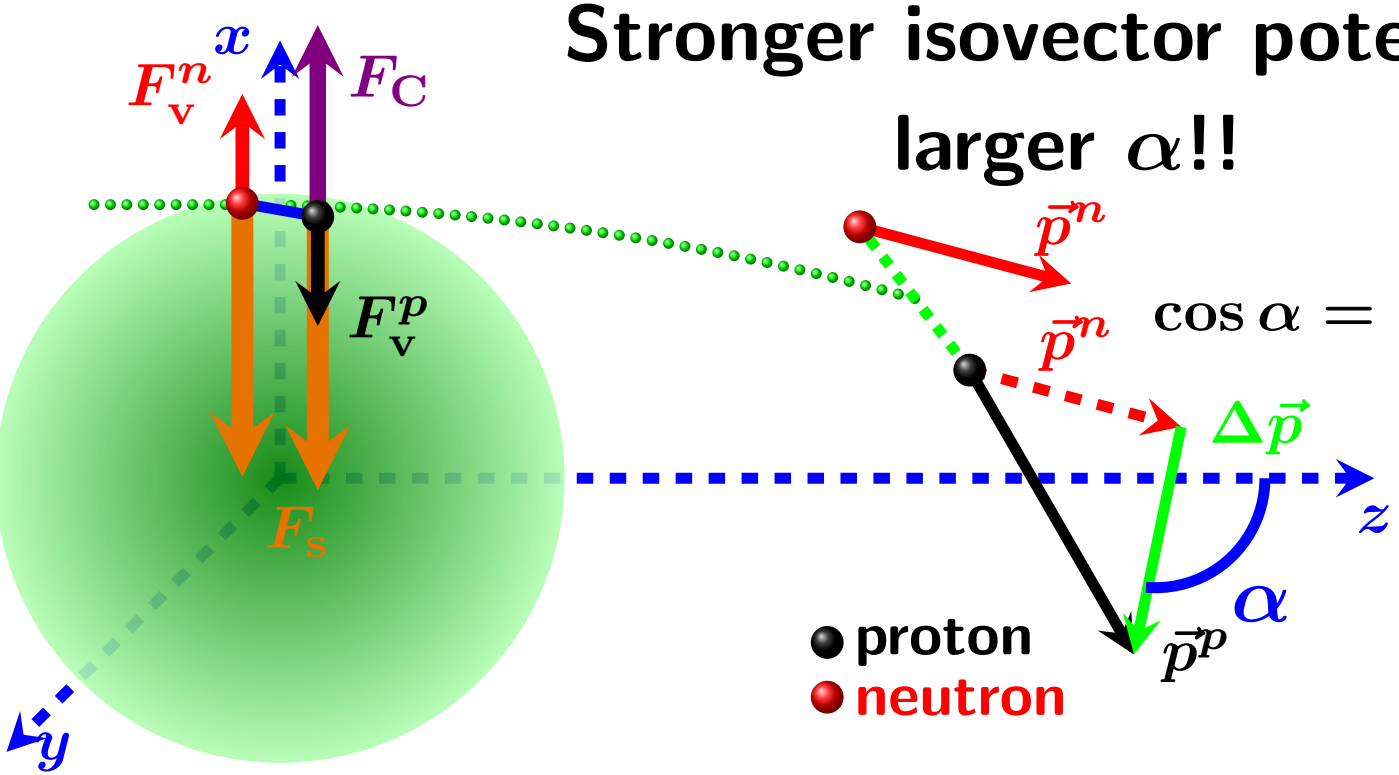


Stronger isovector potential

larger α!!

$$\cos\alpha = \frac{p_z^p - p_z^n}{|\vec{p}^p - \vec{p}^n|}$$

F_s **from isoscale potential, deflexion;**

$F_{\rm Coul}$ **from Coulomb potential, anticlockwise;**

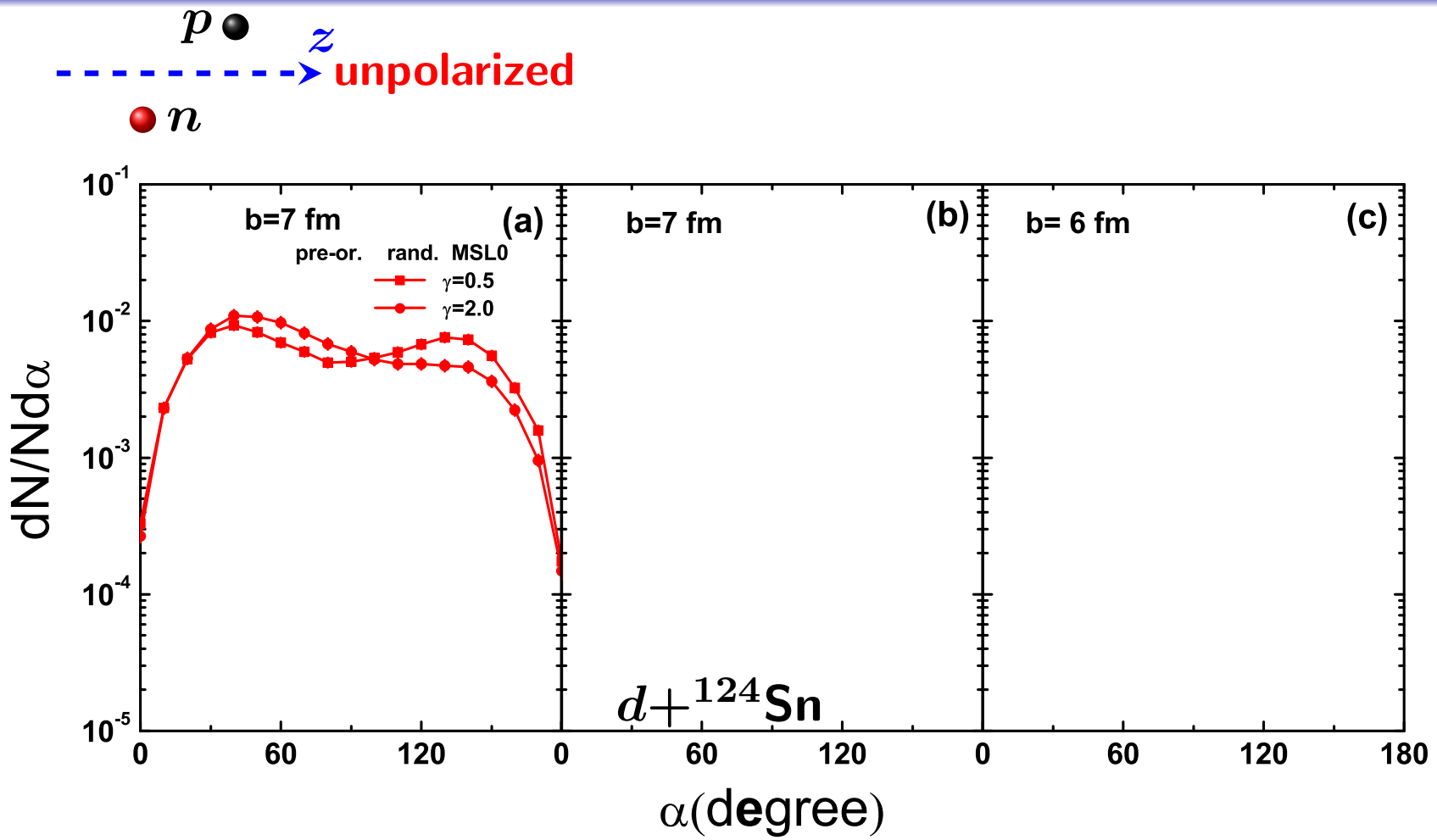
$F_{\rm v}^p$ **on proton from isovector potential;**

$F_{\rm v}^n$ **on neutron from isovector potential;**

clockwise

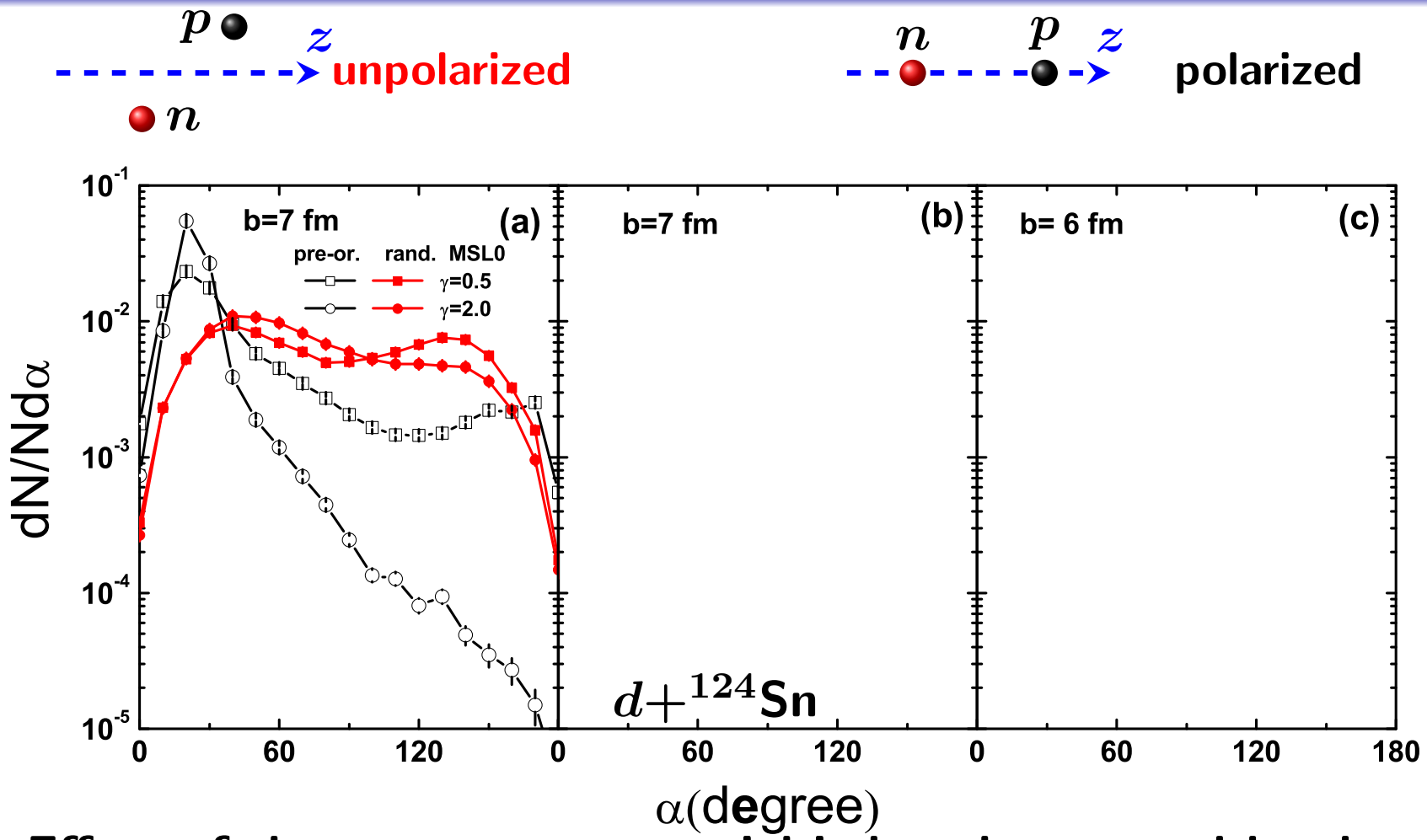
Outline

Isospin effect on reorientation of deuteron



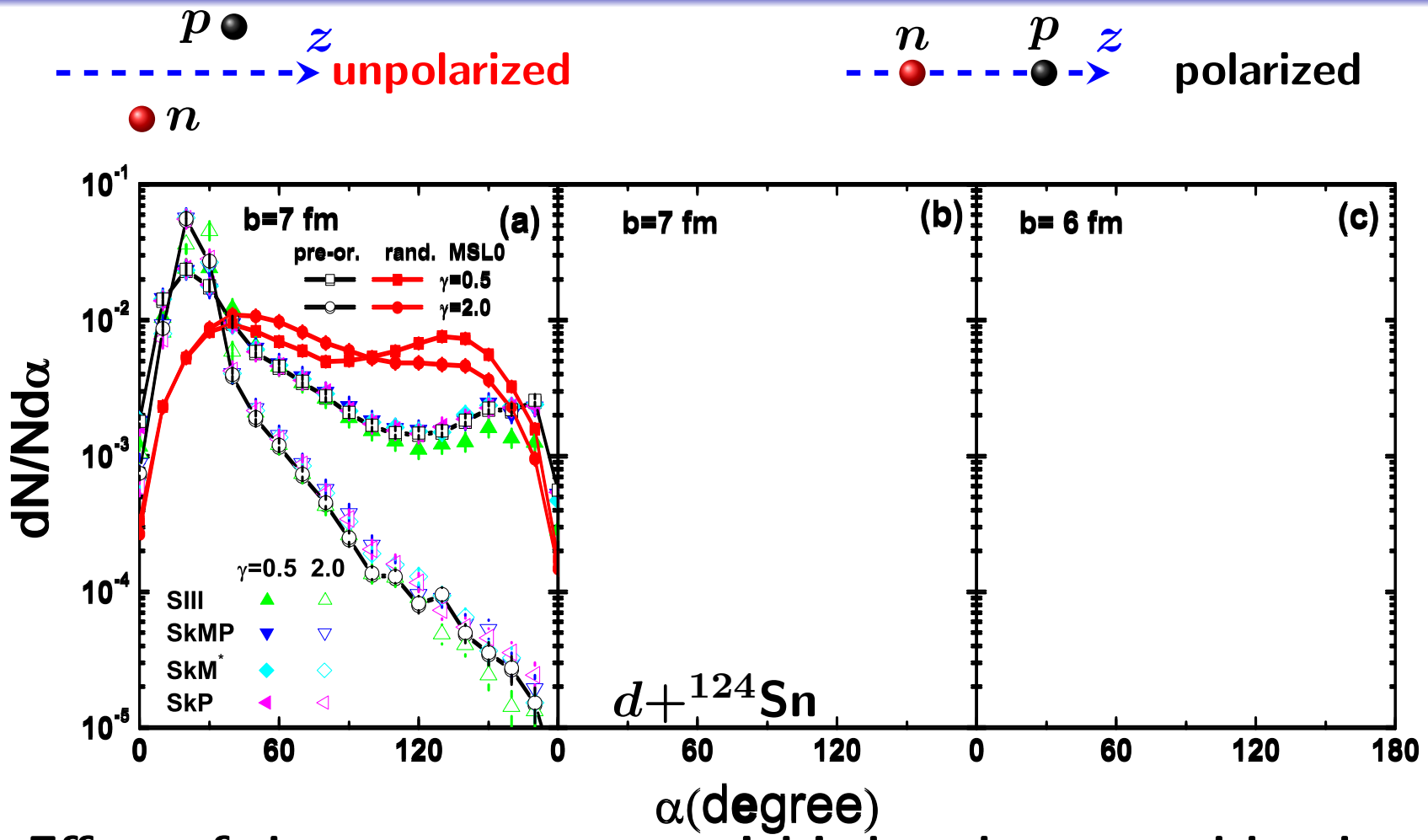
- **Effect of the symmetry potential is largely smeared by the random initial orientation of the incident deuteron.**

Isospin effect on reorientation of deuteron



- **Effect of the symmetry potential is largely smeared by the random initial orientation of the incident deuteron.**
- **Effect is more clear with polarized deuteron.**

Isospin effect on reorientation of deuteron



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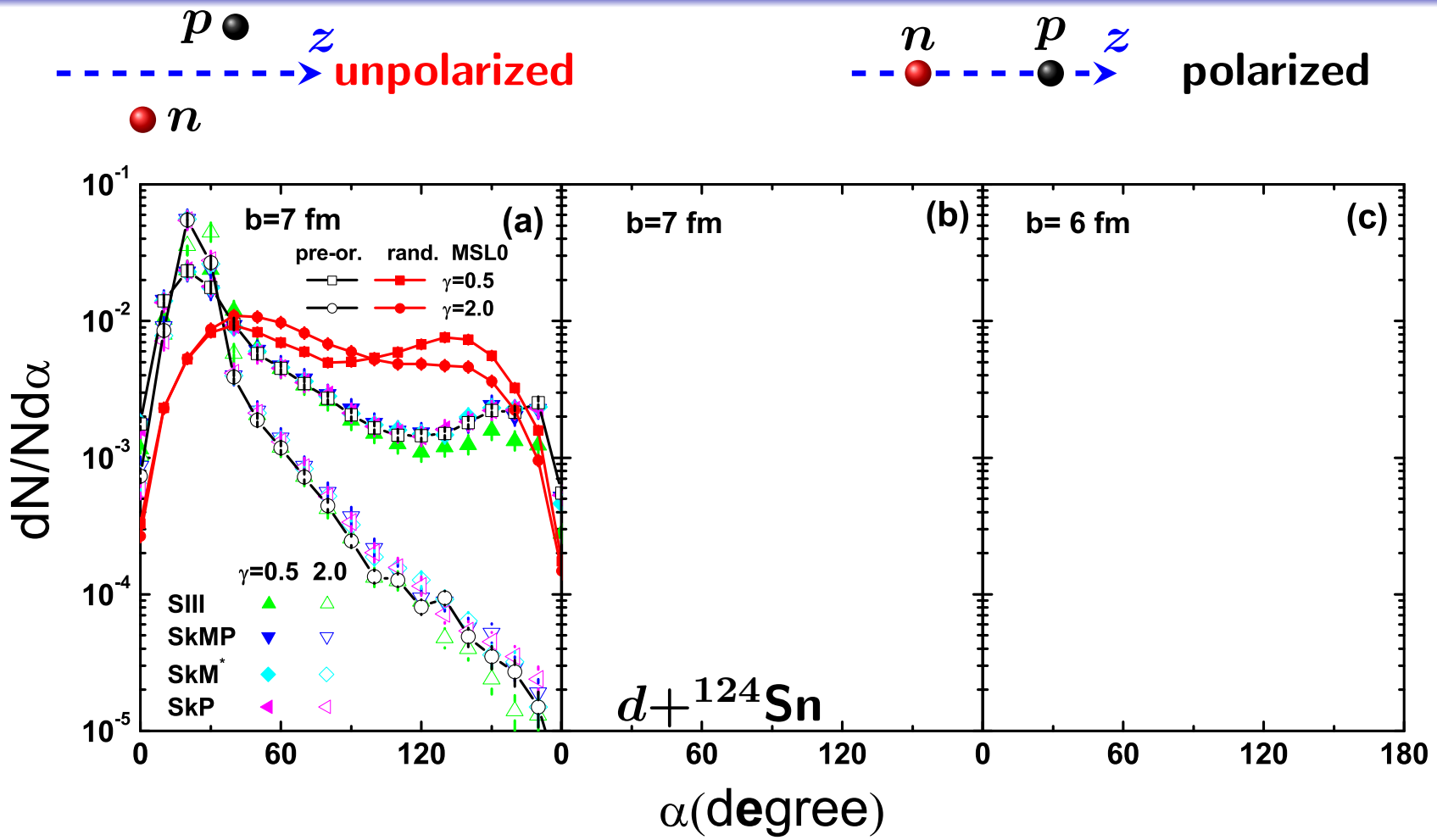
- α distribution is robust against isoscaler part of EOS.

Isospin effect on reorientation of deuteron



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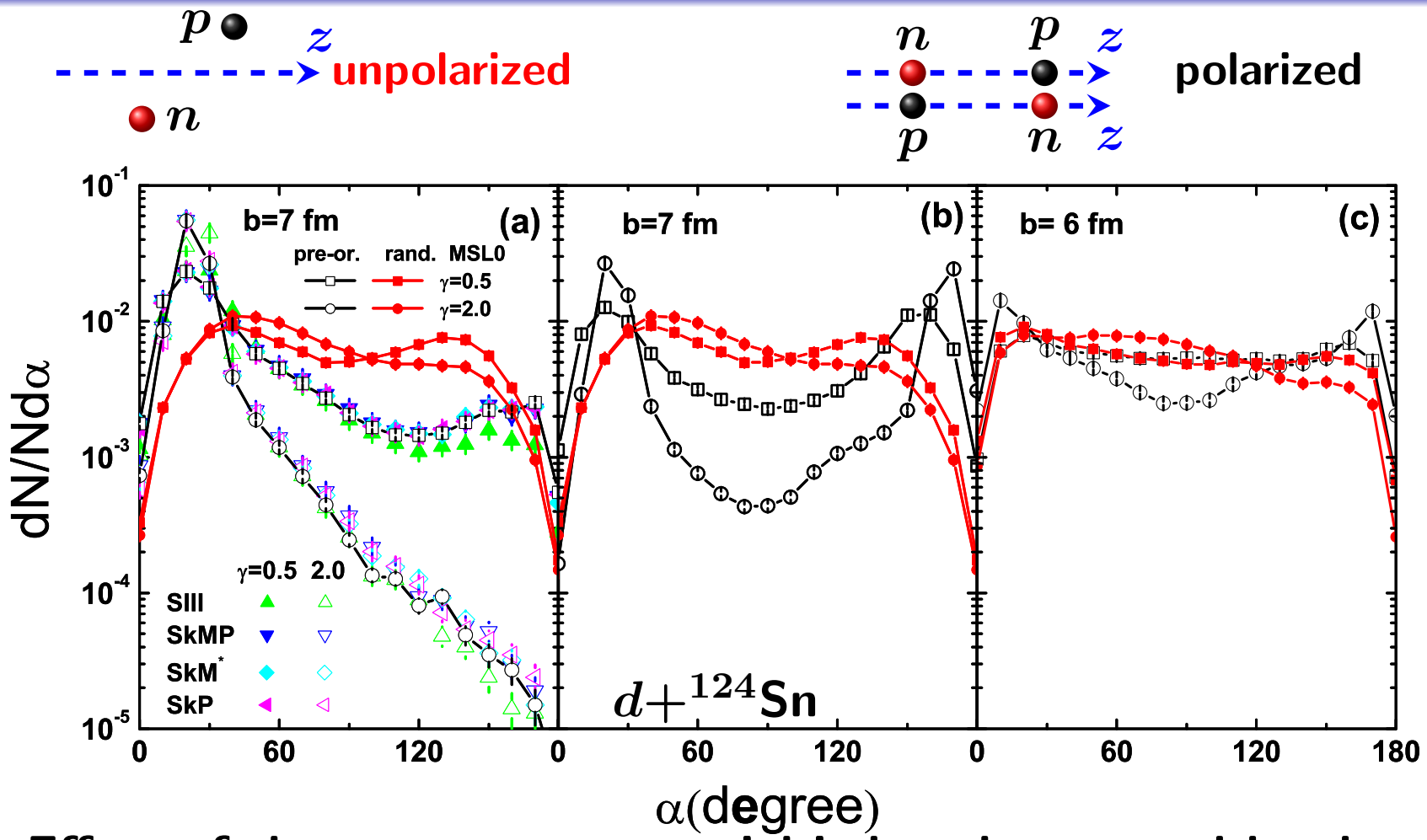
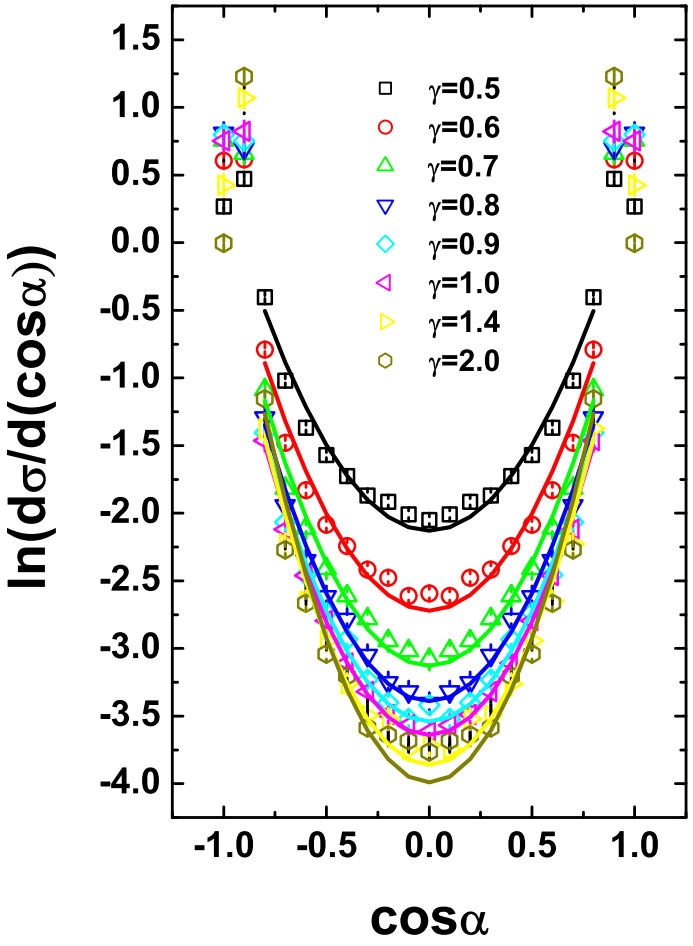
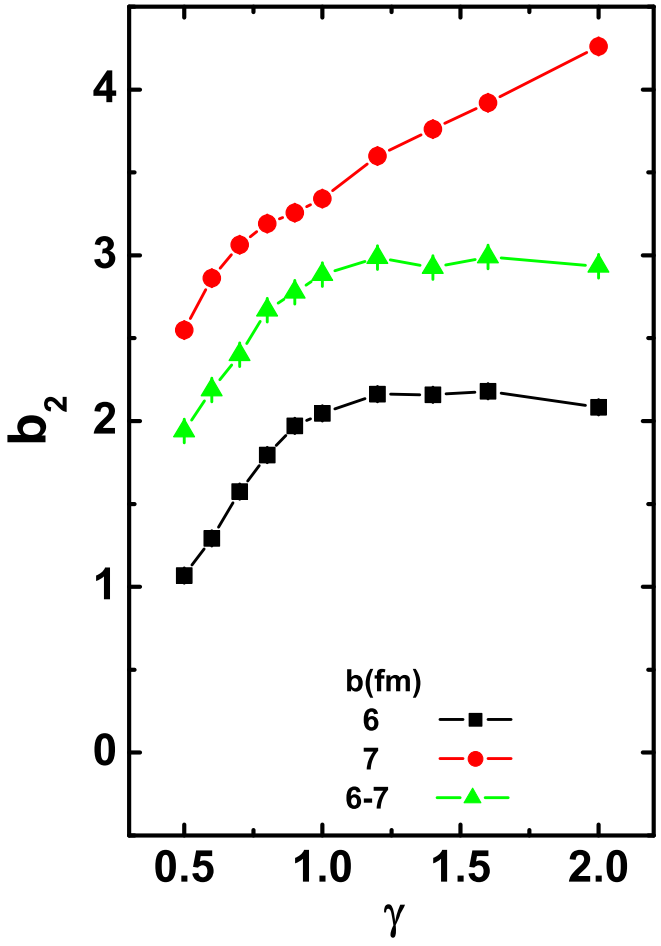


- **Effect of the symmetry potential is largely smeared by the random initial orientation of the incident deuteron.**
- **Effect is more clear with polarized deuteron.**
- **α distribution is robust against isoscaler part of EOS.**
- **α distribution is nearly symmetric.**

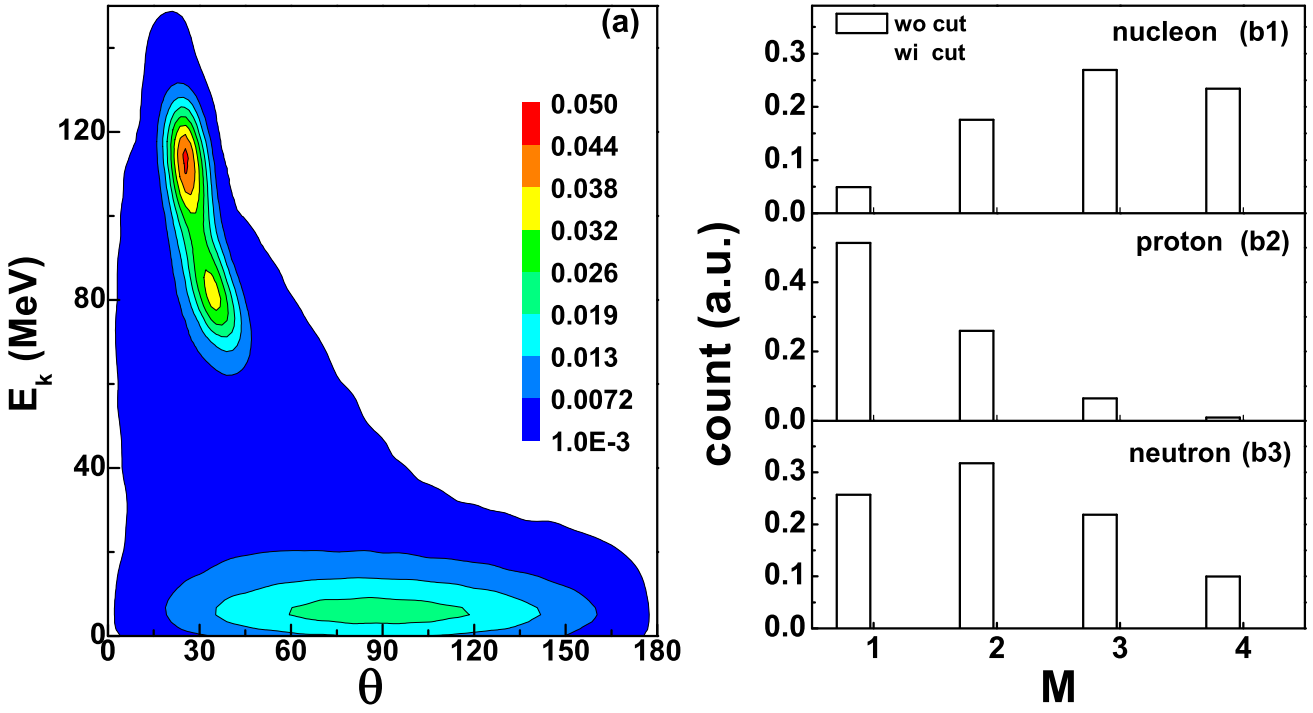




$$\ln\left[d\sigma/d\left(\cos\alpha\right)\right] = b_0 + b_2\cos^2\alpha$$

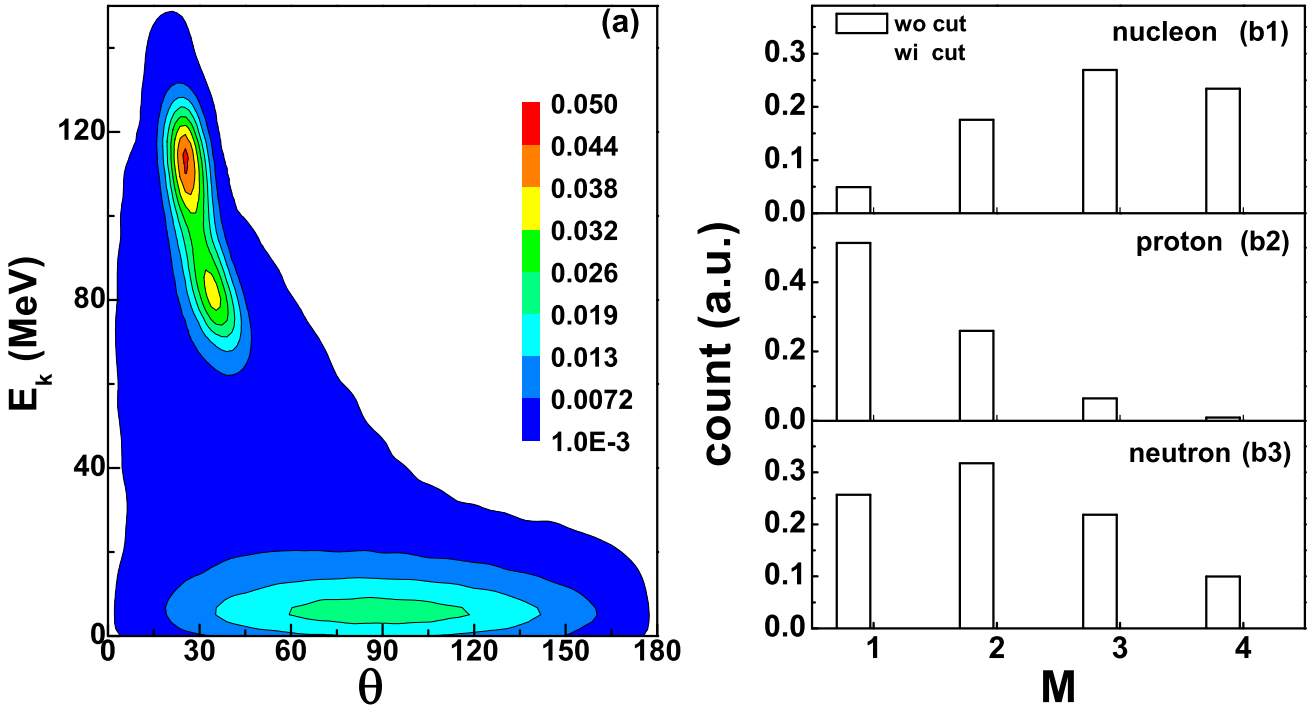
Quadratic coefficient b_2 increases significantly with γ, can be a sensitive observable to constrain $E_{\rm sym}$.

Experimental identification



- **Nucleons from projectile or target can be distinguished by θ-E_{k} correlation. Two components are evidently separated.**

Experimental identification



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- $M_{\mathrm{p}} = M_{\mathrm{n}} = 1$. **Most of spallation events can be excluded.**

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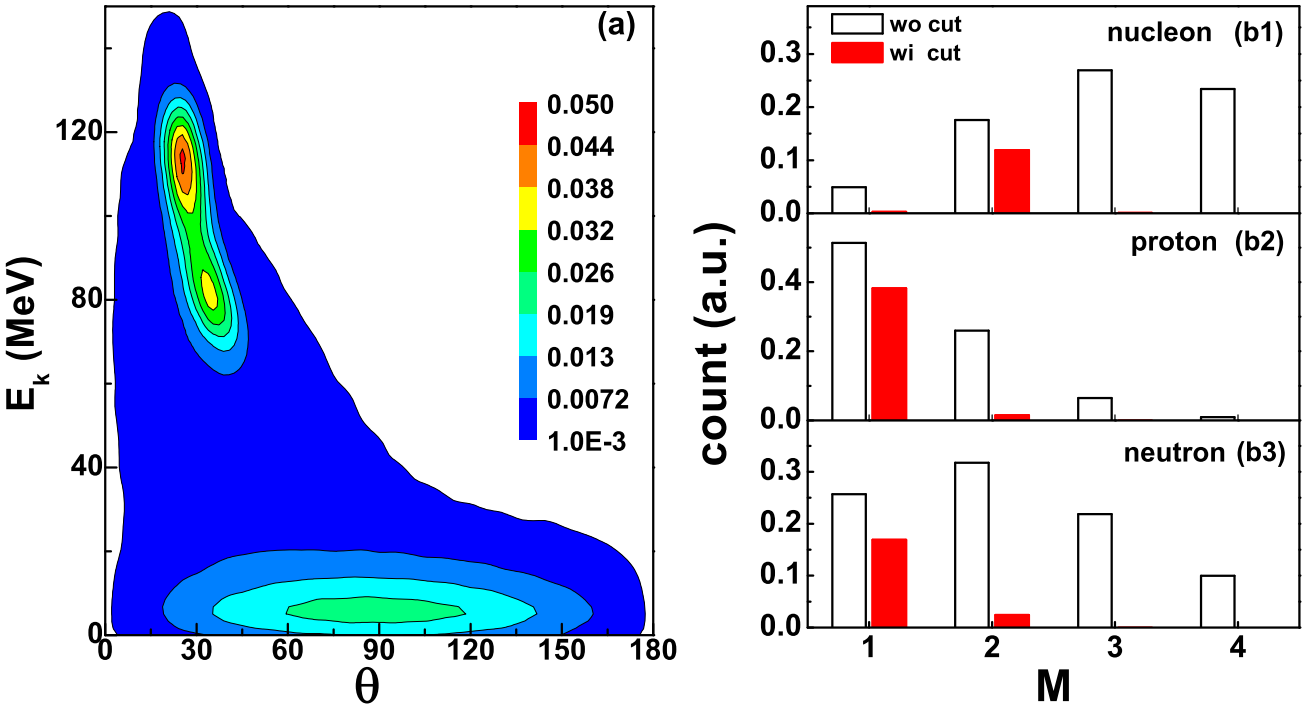

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- $M_{\mathrm{p}} = M_{\mathrm{n}} = 1$. Most of spallation events can be excluded.
- With energy cut $E_{\mathrm{k}} \geqslant 50$ MeV, breakup events caused by collision can be excluded.

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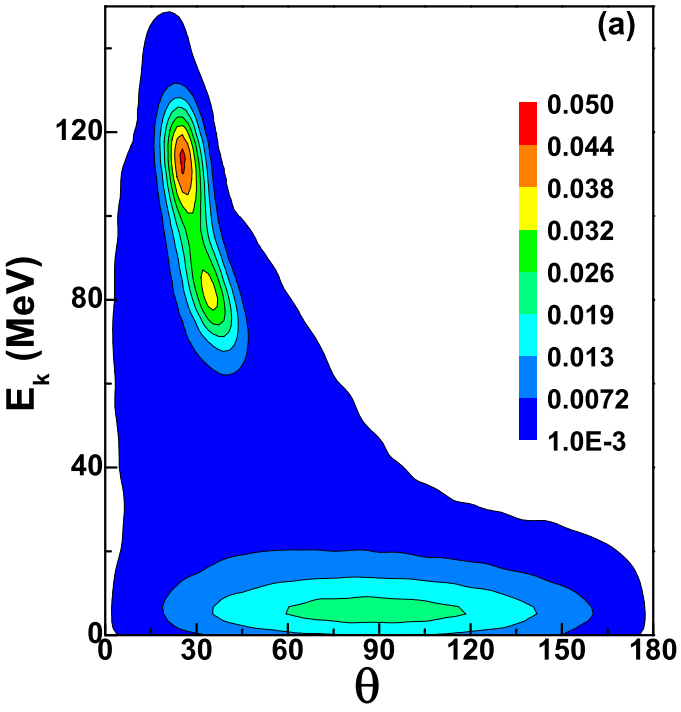

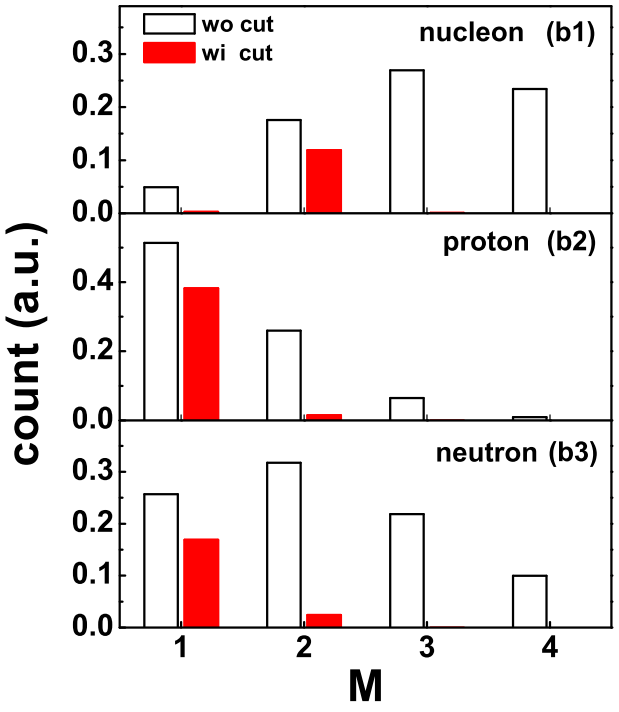

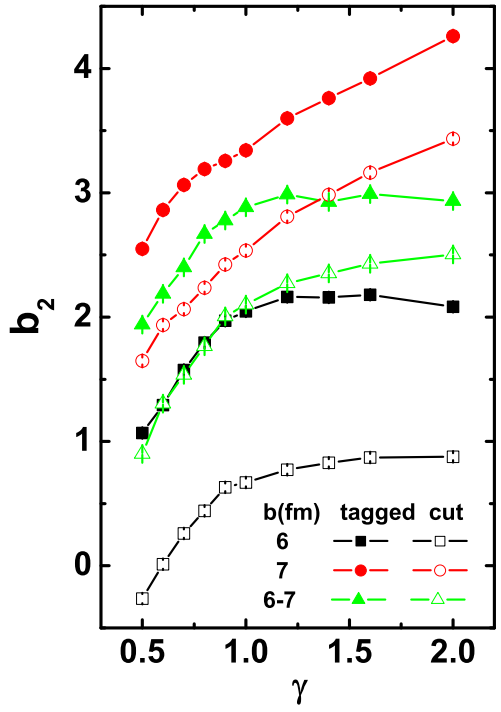

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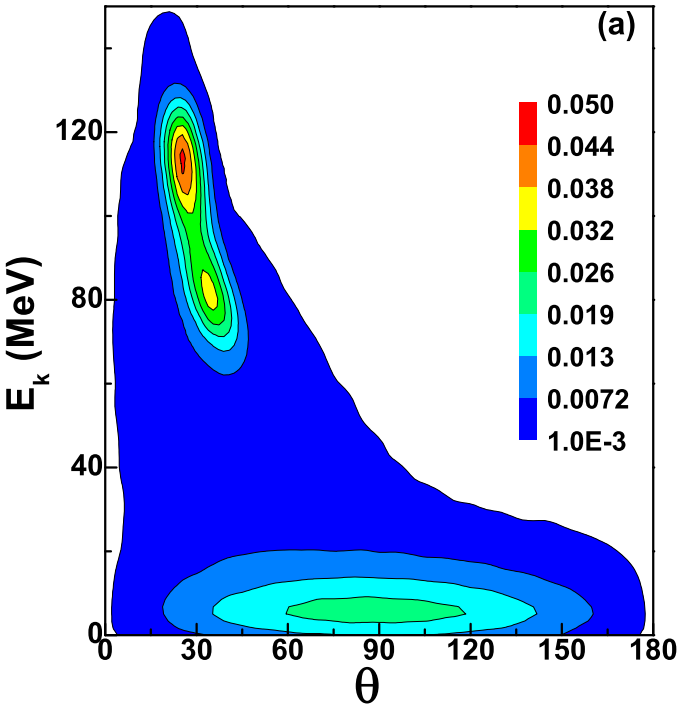

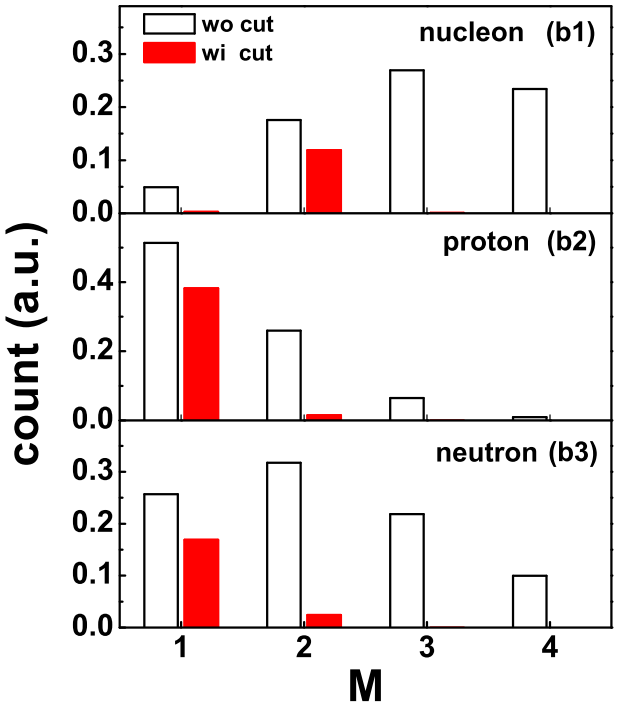

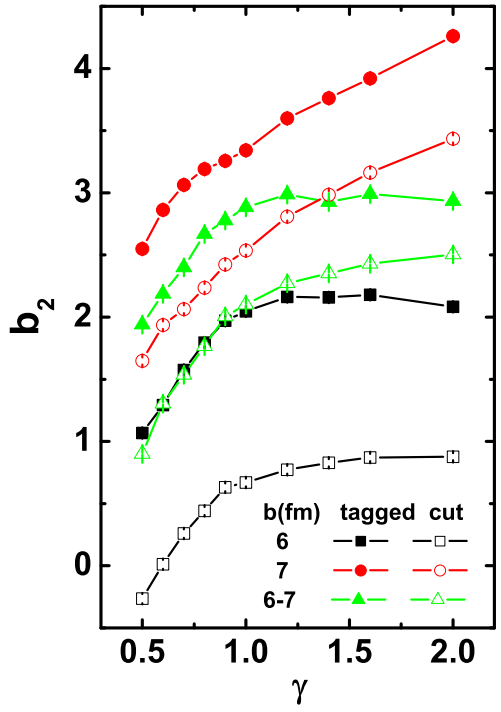

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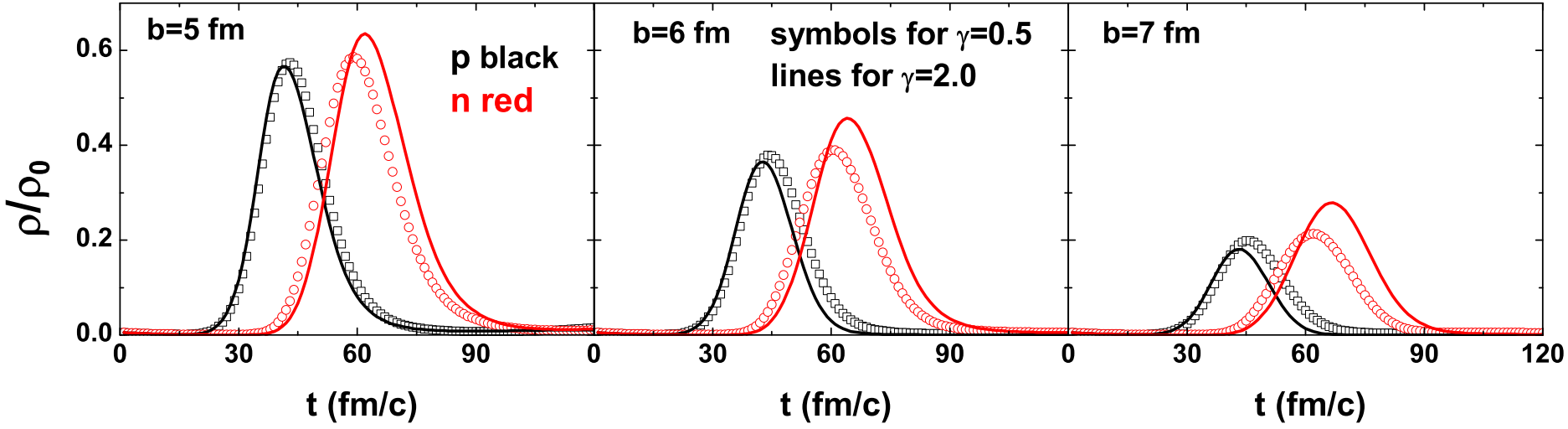
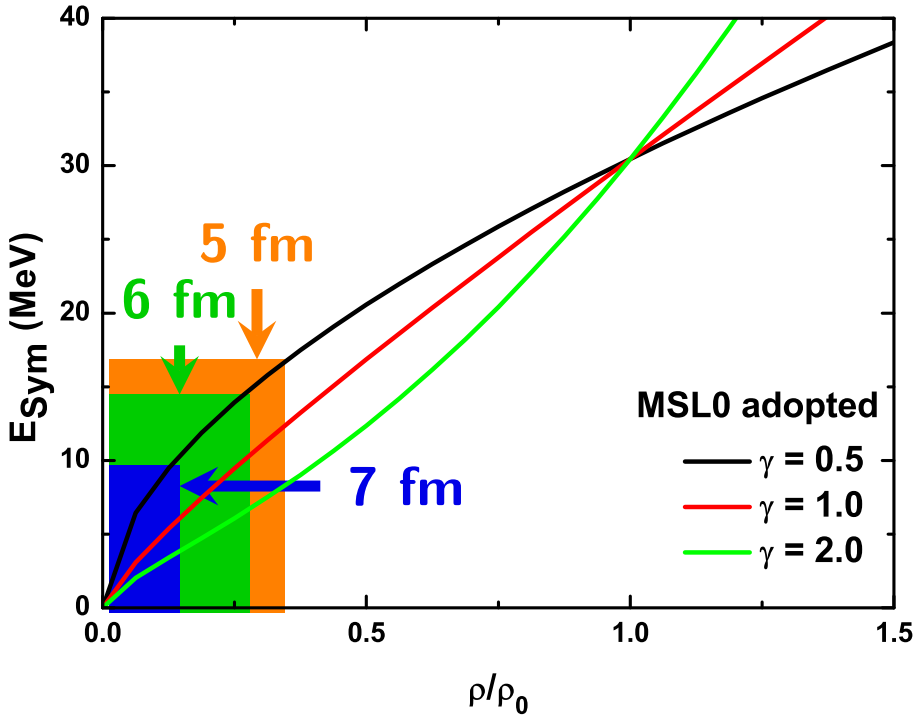
- With energy cut $E_{\rm k} \geqslant 50$ MeV, breakup events caused by collision can be excluded.
- Sensitivity represented by the slope of b_2 on $E_{\rm sym}$ is maintained.

Character





- E_{sym} below $0.5\rho_0$ can be obtained by this method.
- More sensitive and clear than HIC observables because the influence of collision can be easily excluded.

Outline

Summary

- **Within ImQMD framework, the reorientation effect of deuteron attributed to isovector interaction in the nuclear field of heavy target nuclei has been investigated for the first time.**
- **The correlation angle of nucleons from breakup polarized deuteron, depends sensitively on the isovector potential but insensitively on the isoscaler potential and the effective mass.**
- **In terms of sensitivity and cleanness, the breakup reactions induced by polarized deuteron beam at about 100 MeV/u provide a more stringent constraint to the symmetry energy at subsaturation densities.**

Thank you for your attention!