Polarization effects in deuteron-induced reactions

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Outline

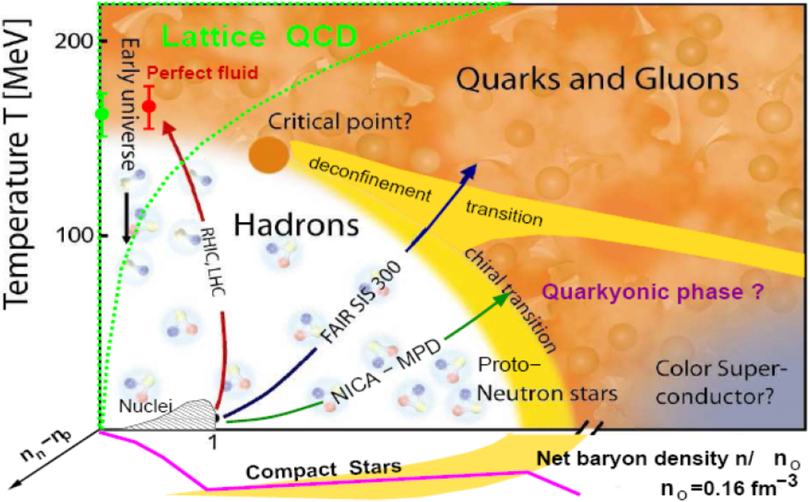
Outline

1. Motivation
2. Model
3. Results and discussion
4. Summary

Nuclear Matter Equation of State

Equation of State(EOS)

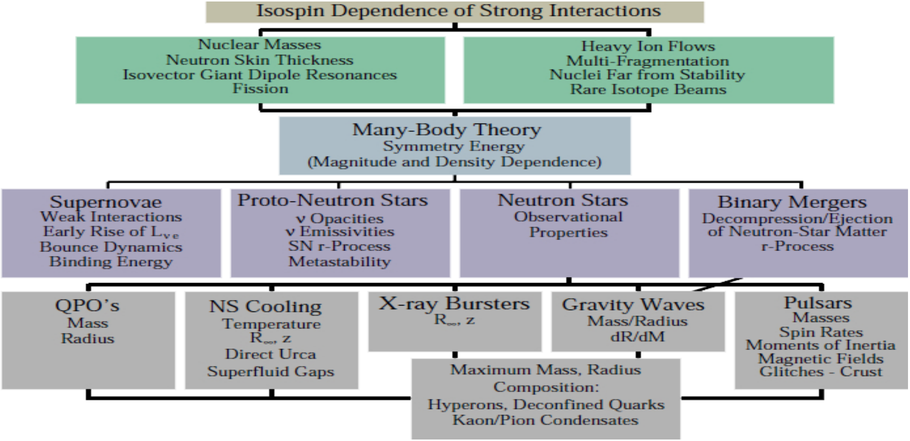
The energy of per nucleon in a nuclear matter $E(\rho, \delta, T)$**.**



What & Why Symmetry Energy

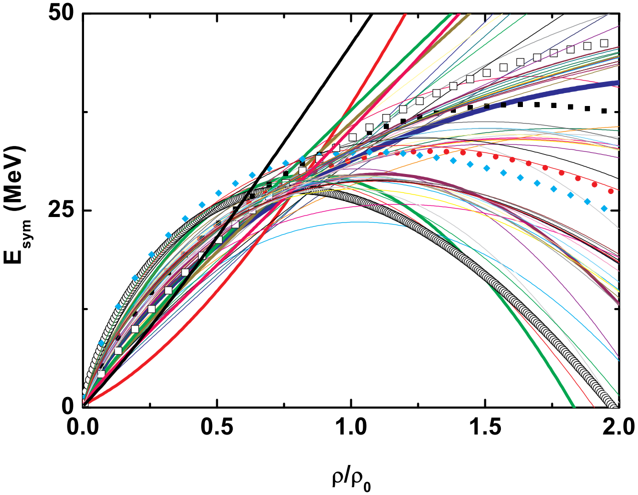
Symmetry Energy

$$E(\rho,\delta) = E(\rho,0) + E_{\text{sym}}(\rho)\delta^2 + \mathcal{O}(\delta^4)$$
$$E_{\text{sym}}(\rho) = E(\rho,\delta=1) - E(\rho,\delta=0)$$



A. Steiner, M. Prakash, J. Lattimer and P. Ellis, Phys. Rep. 411, 325 (2005).

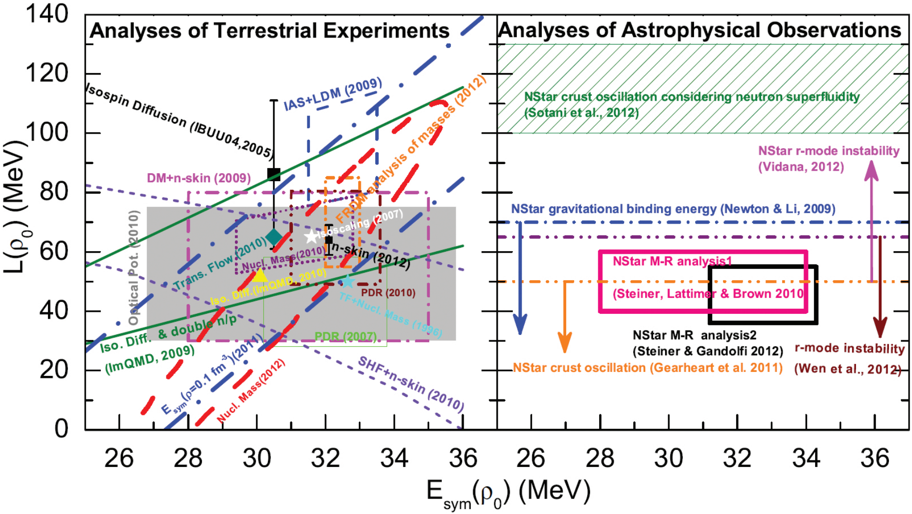
E_{sym} vs ρ is unclear



There is great uncertainty at super-high and sub-saturation density.

Need to be constrained by experiment!

Current constraints on $E_{\rm sym}(\rho)$



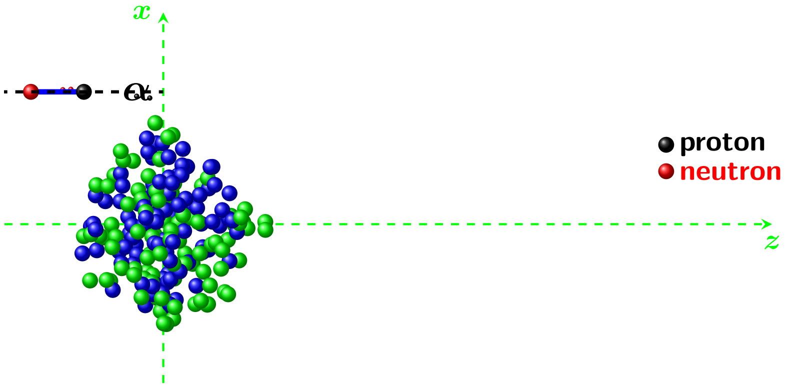
B.A. Li, L.W. Chen, F.J. Fattoyev, W.G. Newton, and C. Xu, arXiv:1212.1178

$E_{\rm sym}(\rho_0) = 32.5 \pm 2.5$ MeV $L = 55 \pm 25$ MeV

$E_{\rm sym}(\rho) = E_{\rm sym}(\rho_0)\,(\rho/\rho_0)^\gamma$ with $\gamma = 0.9 \pm 0.4$

Outline

Method



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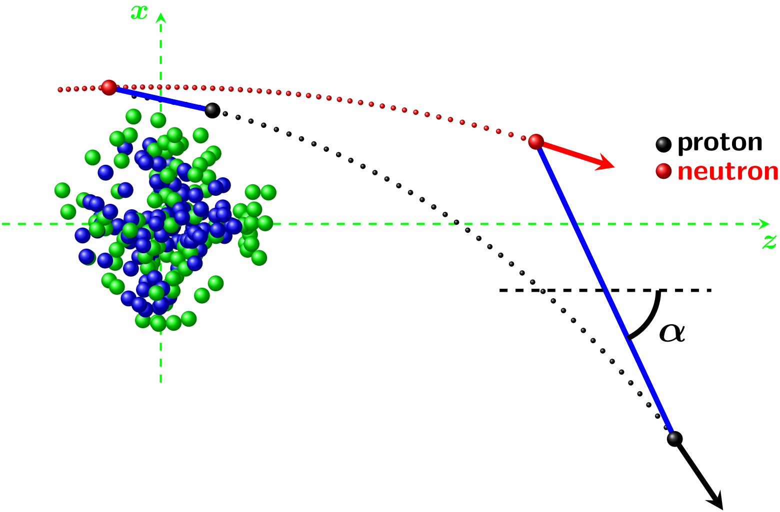

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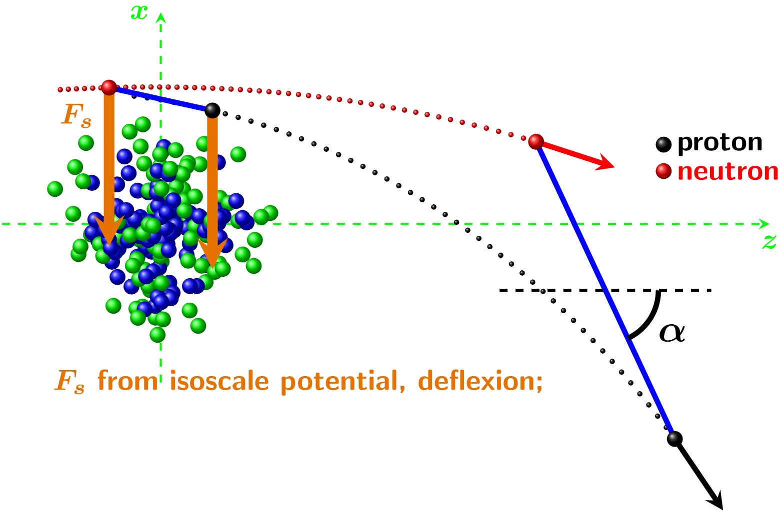
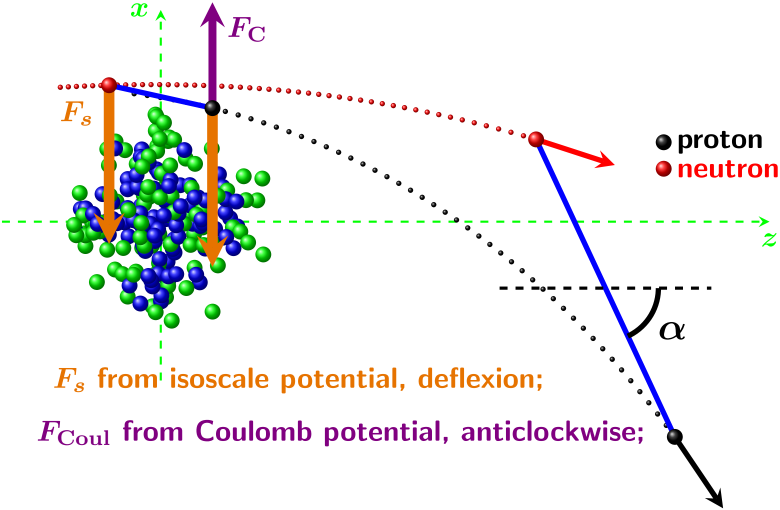


F_s from isoscale potential, deflexion;

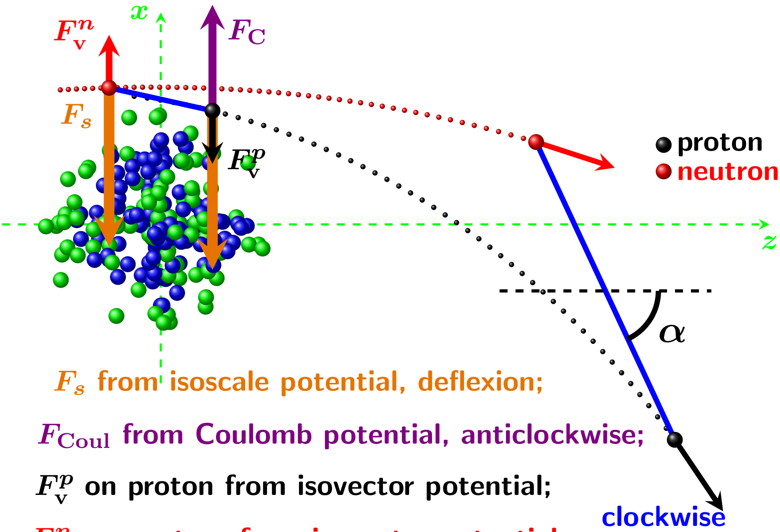
Method



F_s from isoscale potential, deflexion;

F_{Coul} from Coulomb potential, anticlockwise;

Method



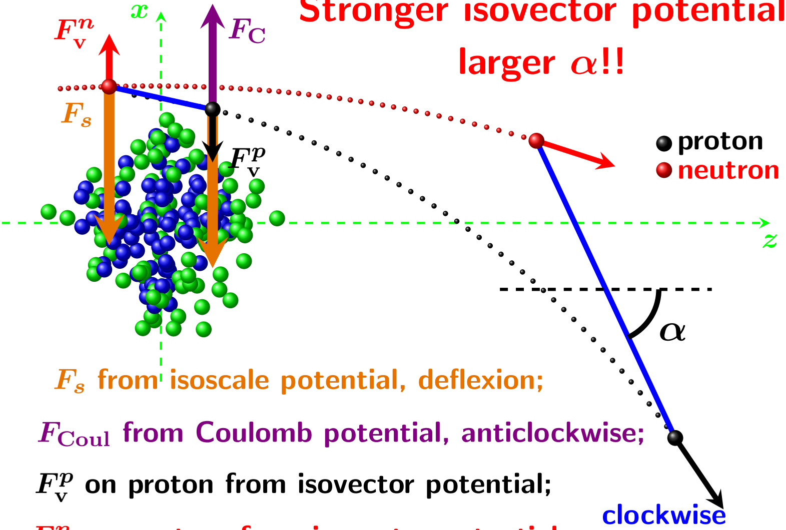
F_s from isoscale potential, deflexion;

F_{Coul} from Coulomb potential, anticlockwise;

F_v^p on proton from isovector potential;

F_v^n on neutron from isovector potential;

Stronger isovector potential larger α!!



F_s from isoscale potential, deflexion;

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F_v^p on proton from isovector potential;

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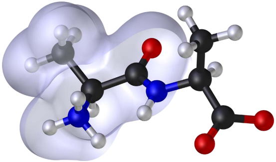
Tool: ImQMD model

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

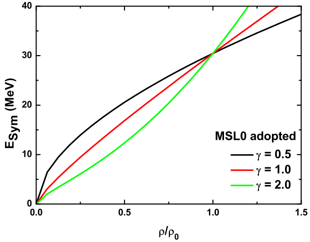
$$H = T + U_{\mathrm{loc}} + U_{\mathrm{Coul}}$$



$$U_{\mathrm{Coul}} = \frac{1}{2}\int \rho_p(r)\frac{e^2}{|r-r'|}\rho_p(r')drdr'.$$

$$T = \sum_i T_i = \sum_i \frac{p_i^2}{2m},$$

$$U_{\mathrm{loc}} = \int V_{\mathrm{loc}}dr,$$



2-body | 3-body | surface

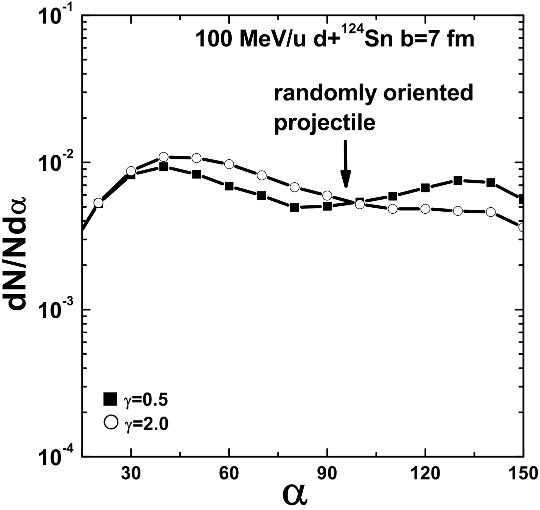
$$V_{\mathrm{loc}}(\rho) = \frac{\alpha}{2}\frac{\rho^2}{\rho_0} + \frac{\beta}{\gamma+1}\frac{\rho^{\gamma+1}}{\rho_0^{\gamma}} + \frac{g_{\mathrm{sur}}}{2\rho_0}(\nabla\rho)^2$$

$$+\frac{g_{\mathrm{sur,iso}}}{\rho_0}[\nabla(\rho_n - \rho_p)]^2 + \frac{C_s}{2}\left(\frac{\rho}{\rho_0}\right)^{\gamma+1}\delta^2 + g_{\rho\tau}\frac{\rho^{8/3}}{\rho_0^{5/3}}.$$

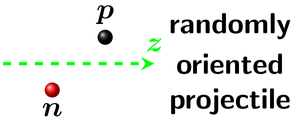
surface symmetry | symmetry | $\rho\tau$ term

Outline

Isospin effect on polarization

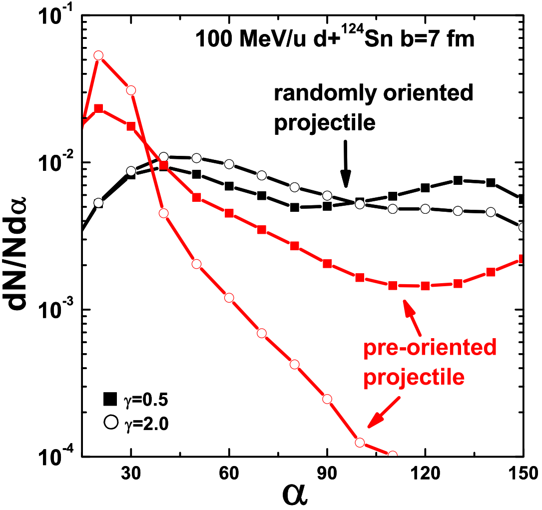


$$\cos\alpha = \frac{p_z^p - p_z^n}{|\vec{p}^p - \vec{p}^n|}$$



- Symmetry potential has effect on polarization angle.

Isospin effect on polarization



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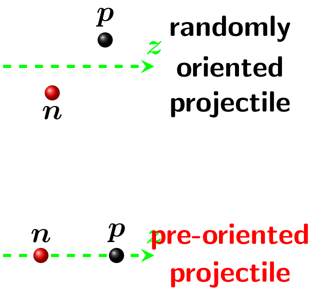
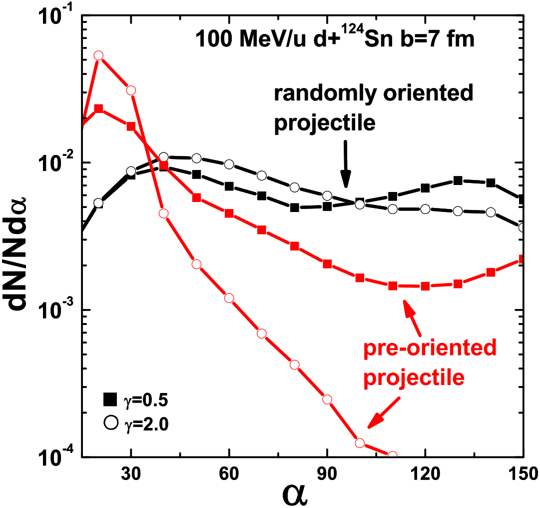


- Symmetry potential has effect on polarization angle.
- Effect is more clear on pre-oriented projectile.

Isospin effect on polarization



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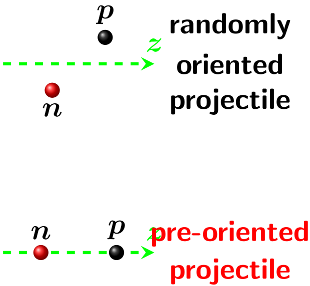
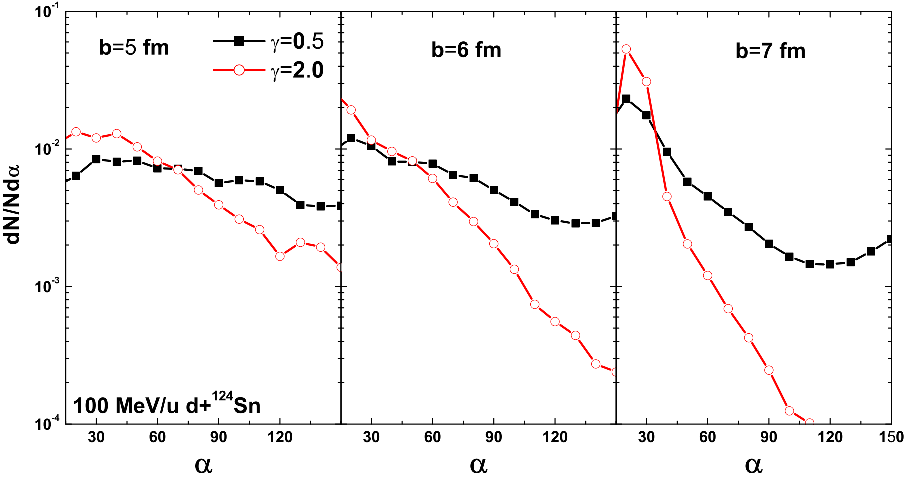


- Symmetry potential has effect on polarization angle.
- Effect is more clear on pre-oriented projectile.
- Polarization direction is changed more with stronger symmetry potential ($\gamma = 0.5$).

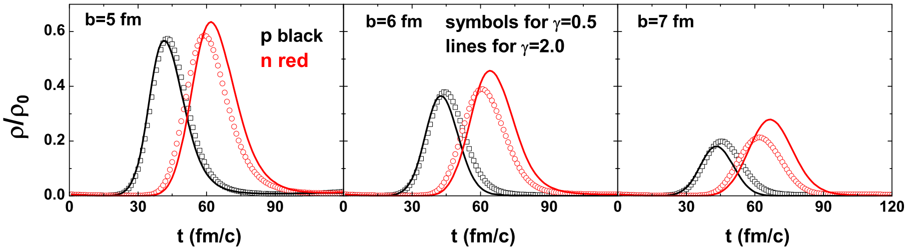
Impact parameter dependence

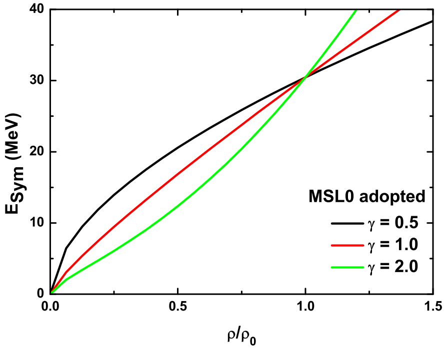


With impact parameter decreases, the isospin effect becomes more and more weak.

- **Asymmetry degree becomes smaller and smaller;**
- **Too strong isoscale potential weakens isospin effect.**

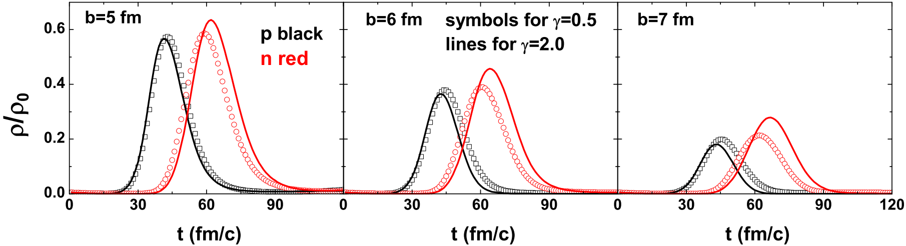
Clear density range

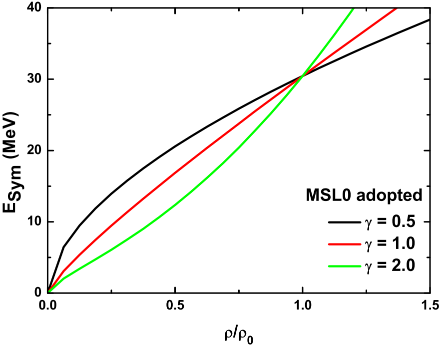




- **HIC, difficult to exclude collision events and distinguish the density.**

Clear density range





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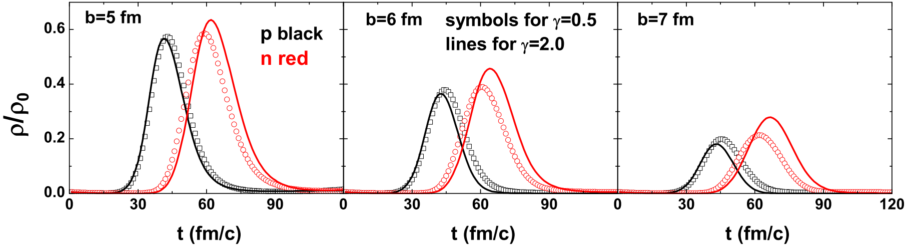
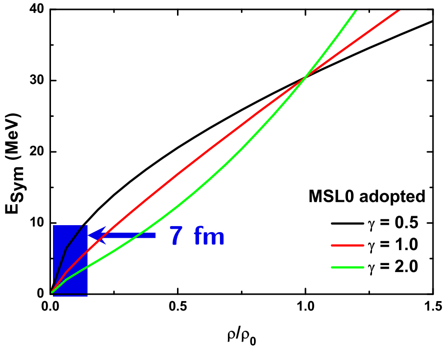
- **Deuteron breakup reaction, no collision and clear density range.**

Clear density range





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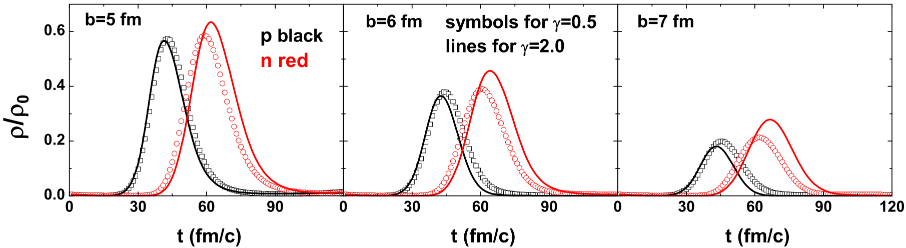
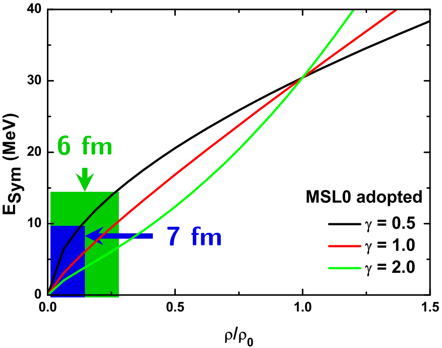
Clear density range





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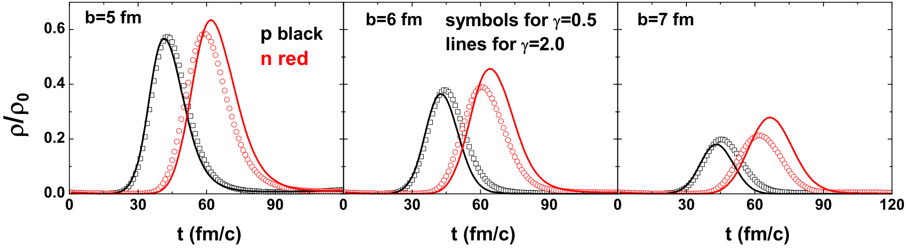

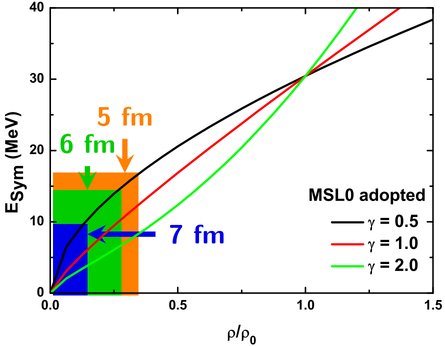

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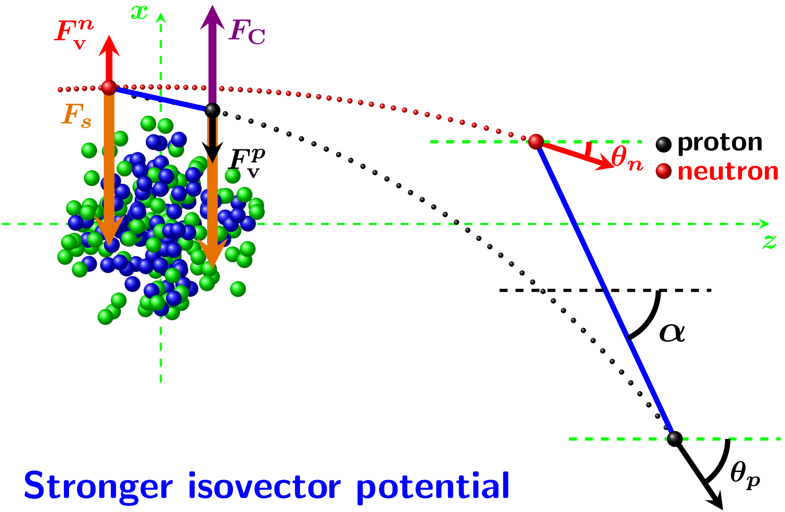
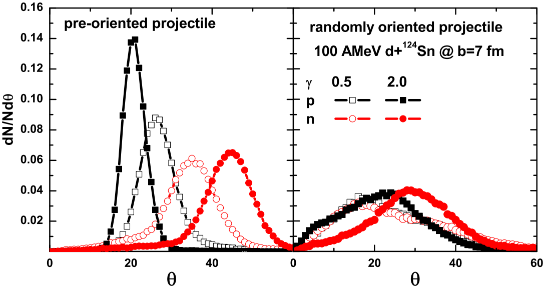
Angle distribution



Stronger isovector potential

larger θ_p! smaller θ_n!

Angle distribution



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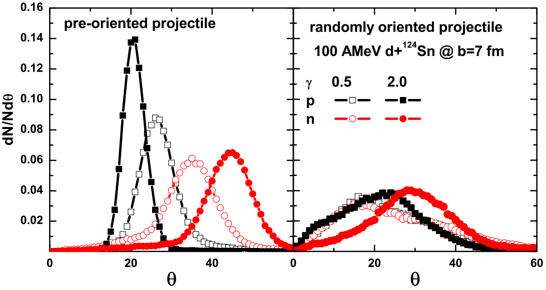

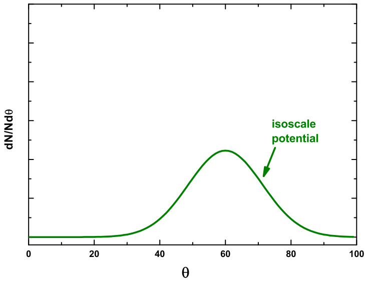

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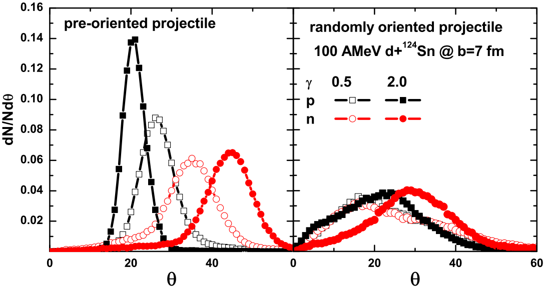

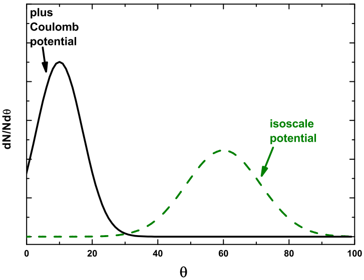

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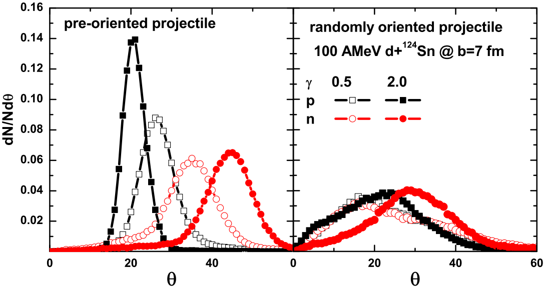

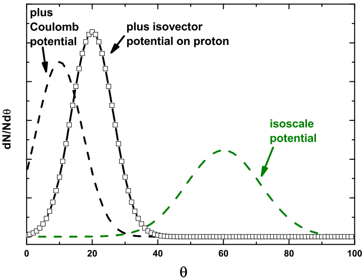

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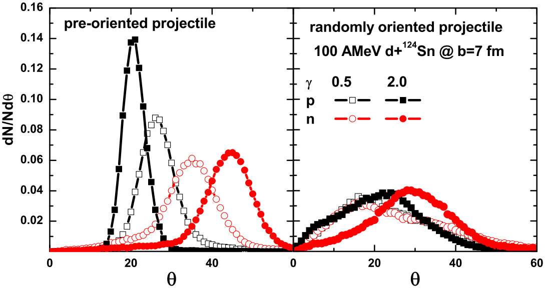

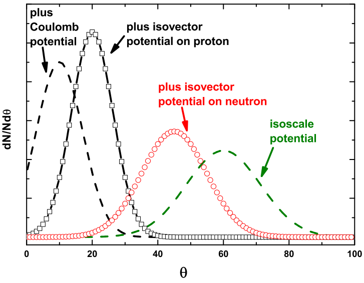

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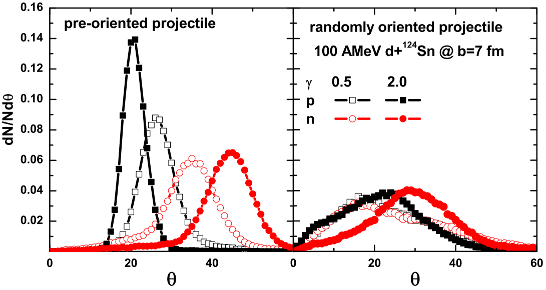
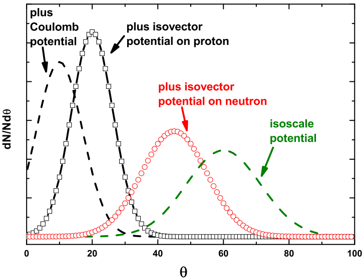
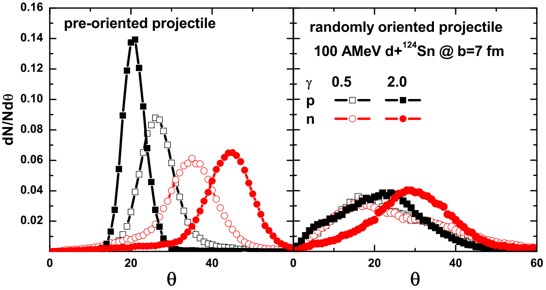
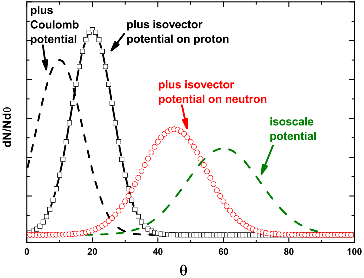




- **Strong symmetry potential, peak closes to each other;**

Angle distribution





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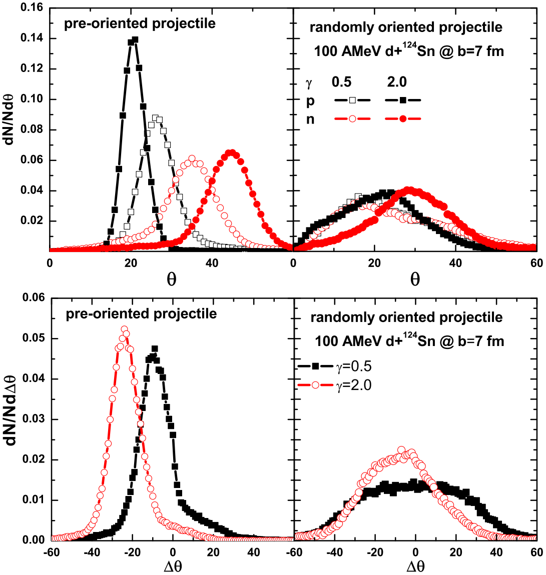
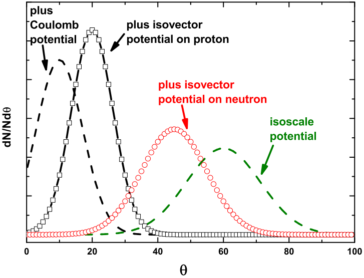
- **Difference vanishes for randomly oriented projectile.**

Angle distribution





- **Strong symmetry potential, peak closes to each other;**
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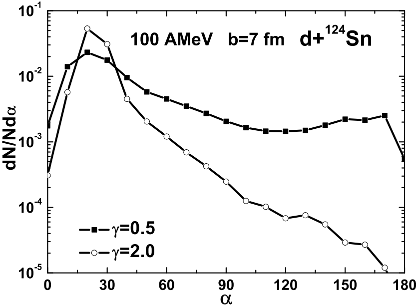
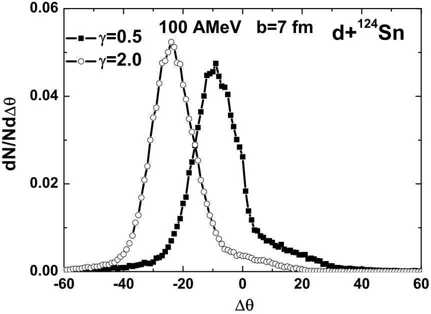
Polarization direction





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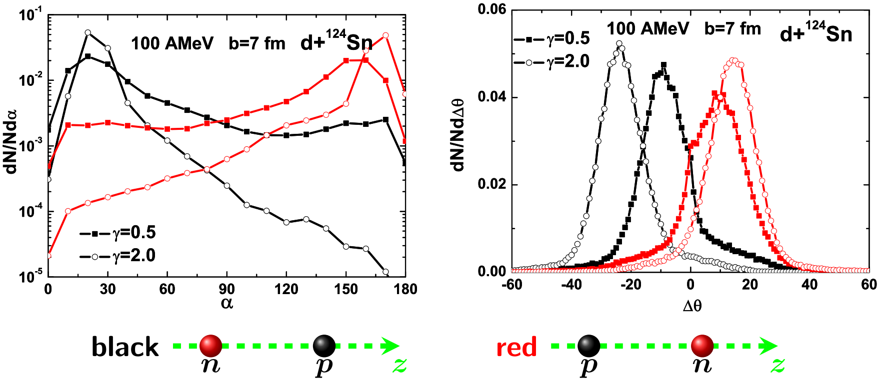
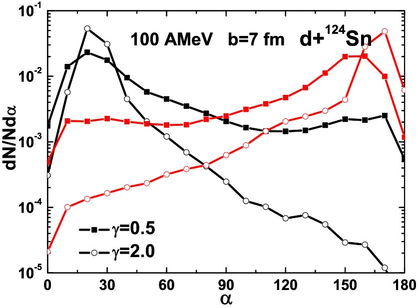
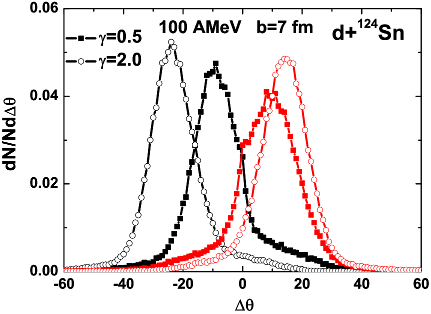


- **There is also clear (but smaller) isospin effect if pre-oriented direction is reversed.**

Polarization direction





black

red

- **There is also clear (but smaller) isospin effect if pre-oriented direction is reversed.**
- **One possible reason is that the sequence of proton and neutron enter the meanfield is reversed.**

Outline

Summary

1. **Polarization effect of deuteron due to isovector interaction in the nuclear potential of heavy target is investigated within ImQMD framework.**
2. **Because of simple and clear reaction mechanism, pre-oriented deuteron-induced reaction provide a very clean probe to detect the density dependence of symmetry energy.**

Thanks!