Experiment and ImQMD model comparison using $^{129,124}Xe + ^{124,112}Sn$@ 100AMeV collisions

Korea-China joint workshop for rare isotope physics

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Nuclear symmetry energy

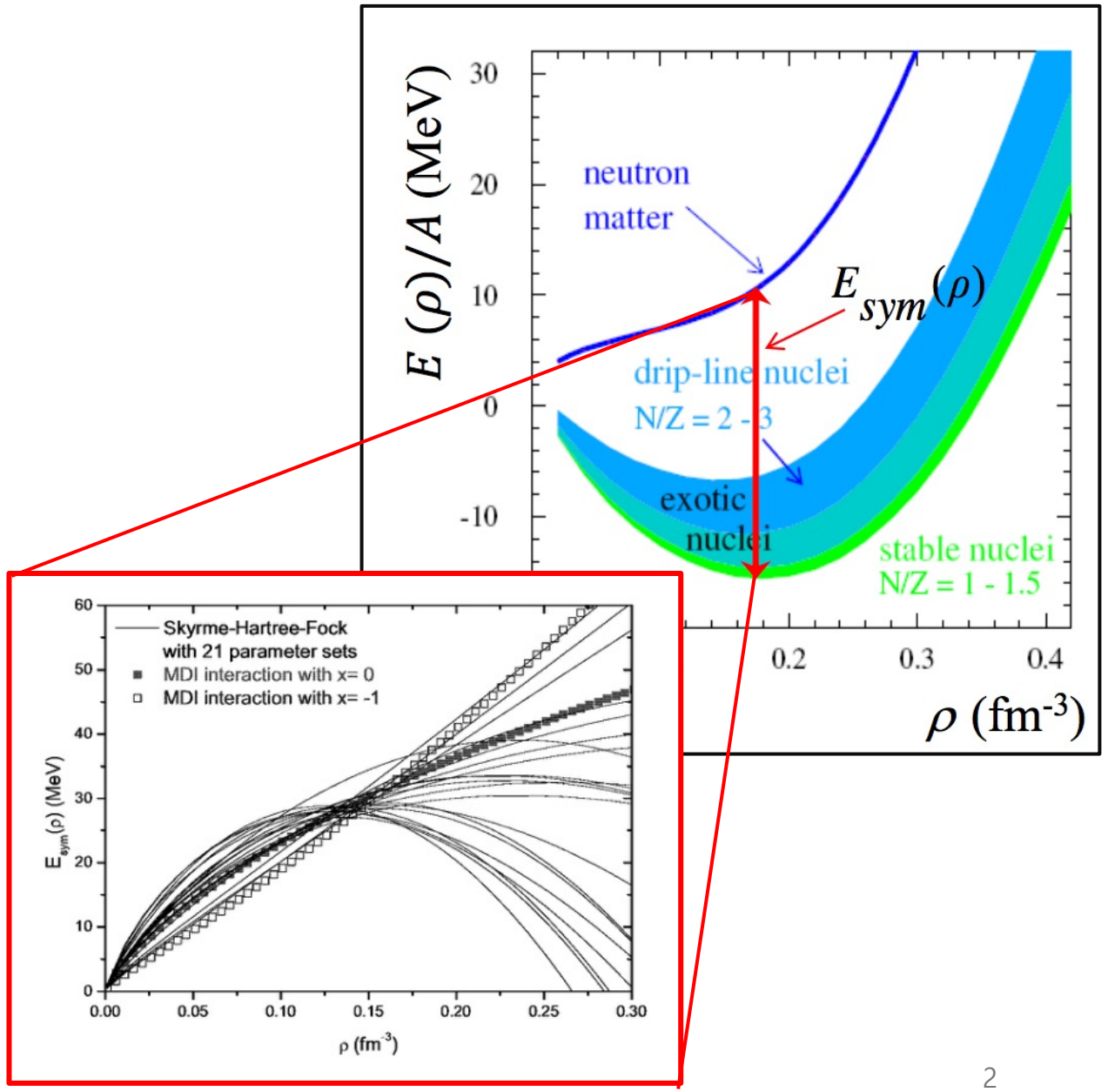
Nuclear Equation of State(NEoS)

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

$$\text{where}, \delta = \frac{\rho_n - \rho_p}{\rho}$$

$$E_{sym}(\rho) = E_{sym}(\rho_0)\left(\frac{\rho}{\rho_0}\right)^{\gamma}$$

$$= S + \frac{L_{sym}}{3}\left(\frac{\rho-\rho_0}{\rho_0}\right) + \frac{K_{sym}}{18}\left(\frac{\rho-\rho_0}{\rho_0}\right)^2 \cdots$$



$R_{n/p}$ Slope

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Thermodynamic picture of primary fragment yield

$$Y_{pri}(N,Z,T) \simeq \frac{VA^{3/2}}{\lambda_T^3}\omega(N,Z,T)\exp\left[\frac{E_B(N,Z)+N\mu_n+Z\mu_p}{T}\right]$$

$$Y(N,Z,T) = f(N,Z,T)Y_{pri}(N,Z,T)$$

1) $R_{\mathrm{n/p}} = \dfrac{Y(\mathrm{n})}{Y(\mathrm{p})} \propto \exp\left(\dfrac{\mu_{\mathrm{n}}-\mu_{\mathrm{p}}}{T}\right) = \exp\left(\dfrac{2V_{sym}\delta}{T}\right)$

2) $V_{sym}(p) = V_{sym}^0 + \dfrac{\partial V_{sym}}{\partial p^2}p^2 \ldots$

3) $\Delta m^*_{\mathrm{np}} \approx -\left(\dfrac{m^*}{m}\right)^2 4m\delta\dfrac{\partial V_{sym}}{\partial p^2}$

1) + 2) + 3) →

$$R_{\mathrm{n/p}} \approx \exp\left(\frac{2V_{sym}^0\delta}{T}\right)\exp\left(-\frac{\lambda\left(\frac{m^*}{m}\right)^2\Delta m^*_{\mathrm{np}}}{T}(E_k/A)\right)$$

$$\boldsymbol{S_{n/p} = \frac{\partial \ln R_{n/p}}{\partial E_k/A} \propto -\frac{\lambda}{T}\left(\frac{m}{m^*}\right)^2 \Delta m^*_{np}}$$

$$\mathbf{DR(n/p) = R_{n/p}^{higher\ N/Z} / R_{n/p}^{lower\ N/Z}}$$

$$Y_{C.I.n(p)} = \frac{dM_{n(p)\ C.I.}}{dE_{c.m.}dy_{c.m.}} = \sum_{N,Z} N(Z)\frac{dM(N,Z)}{d(E/A)_{c.m.}dy_{c.m.}}$$

Analysis condition and Experiment

- **INDRA 4th campaign at GSI (1998-1999)**
  (INDRA-ALADIN collaboration)

$^{129,124}_{54}\mathrm{Xe} + {}^{124,112}_{50}\mathrm{Sn}$ @ 100AMeV

- **No neutron detection :**
  C.I. using $2 \leq A \leq 4$

- **Bayesian estimation method**

	IW1
et_{12} [MeV]	750~1050
b_0	0.21~0.42

- **Rapidity selection :**
  $-0.4 < \mathrm{y}_0^{\mathrm{cm}} < 0.4$

ImQMD(+ GEMINI++) with Skyrme parameter

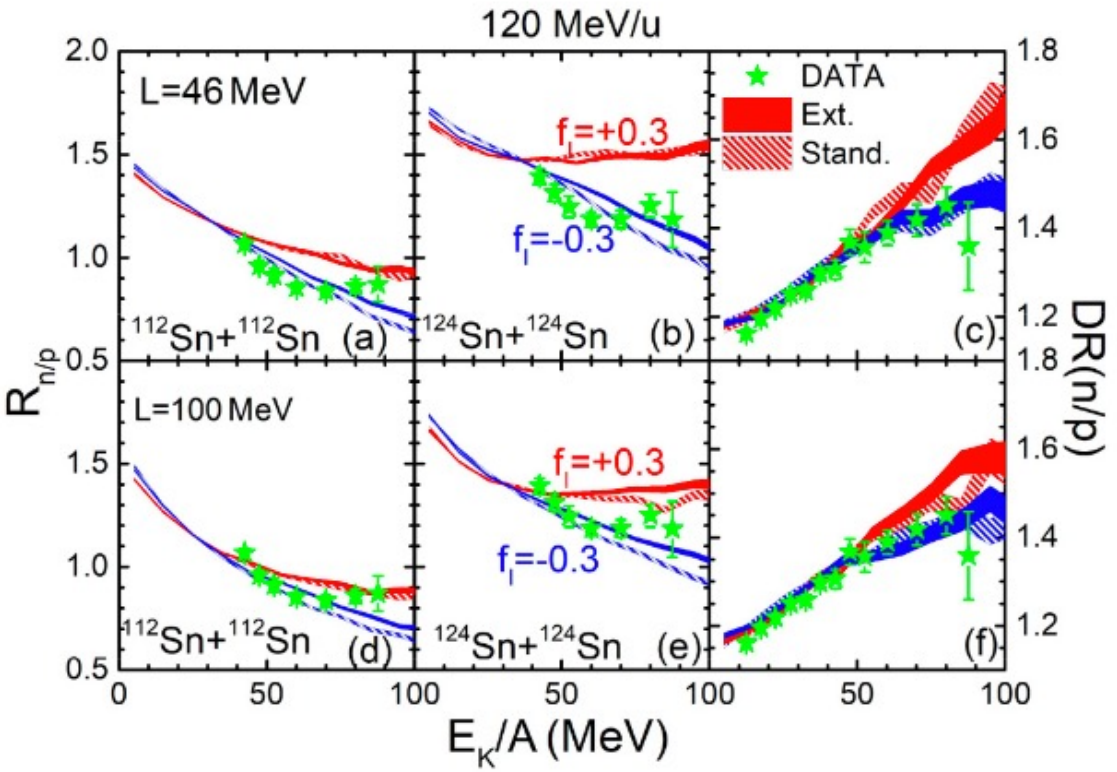
Para	ρ_0	E_0	K_0	S_0	L
SLy4	0.160	-15.97	230	32	46
SkM*	0.160	-15.77	217	30	46

	K_{sym}	m^*/m	m_n^*/m	m_p^*/m
SLy4	-120	0.69	0.68	0.71
SkM*	-156	0.79	0.82	0.76

- 5 discrete b_0 are chosen for time efficiency. (0.1, 0.2, 0.3, 0.4 and 0.5)≈ IW1
- About 10^6 events for each b_0

$^{112}Sn + ^{112}Sn$, $^{124}Sn + ^{124}Sn$ @ 120 MeV/u

$\left(N/Z_{sys} \sim 1.24, 1.48\right)$, C.I. $(1 \le A \le 4)$



Red(f_I: 0.3) : $m_n^* < m_p^*$ Blue(f_I: −0.3) : $m_n^* > m_p^*$

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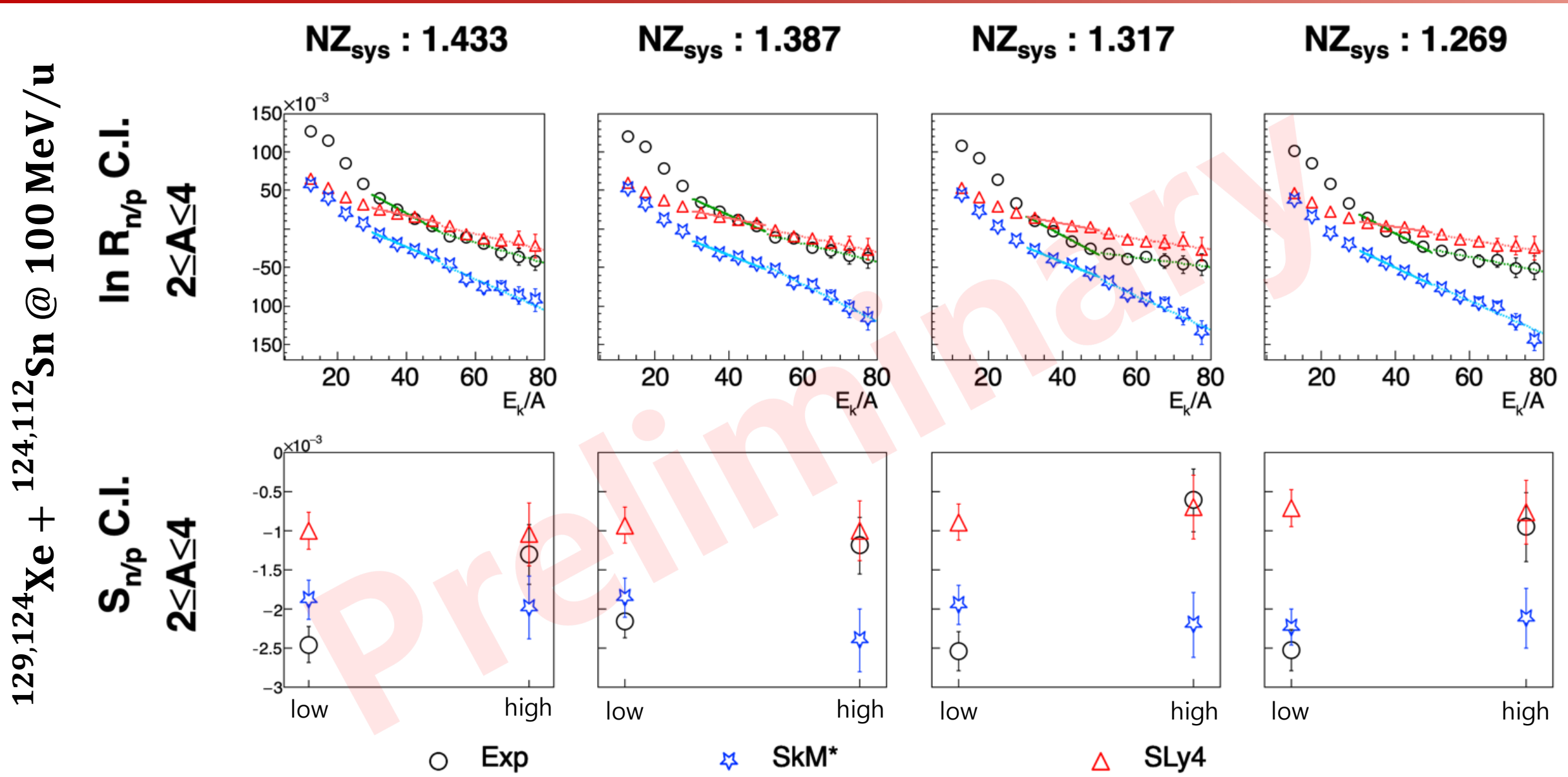
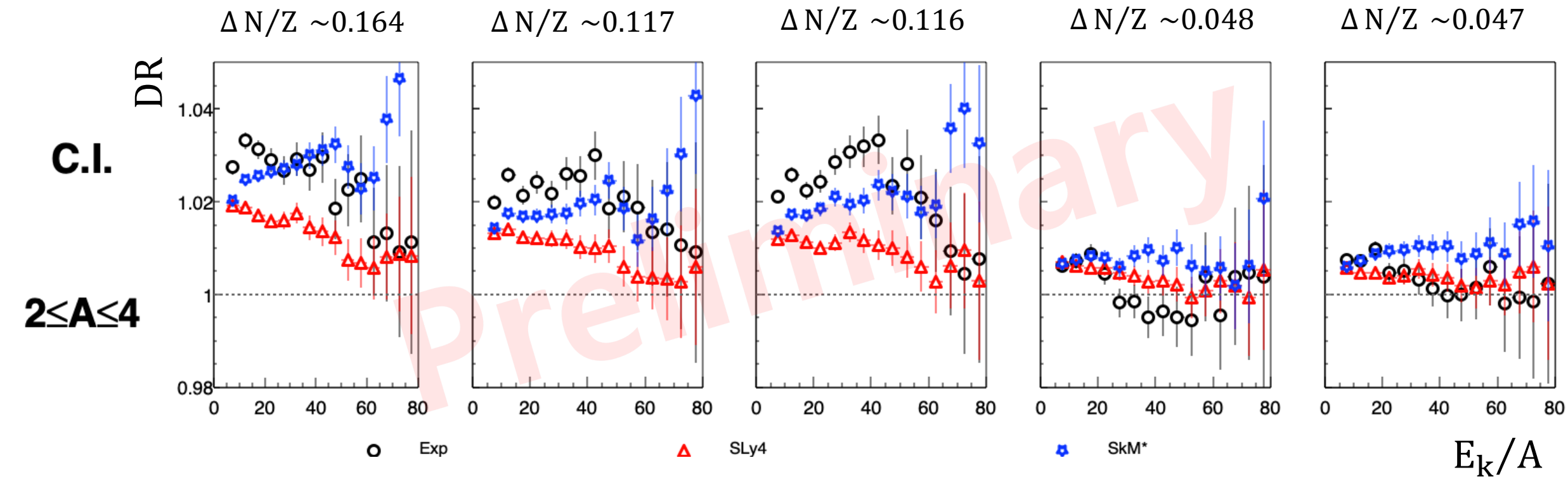
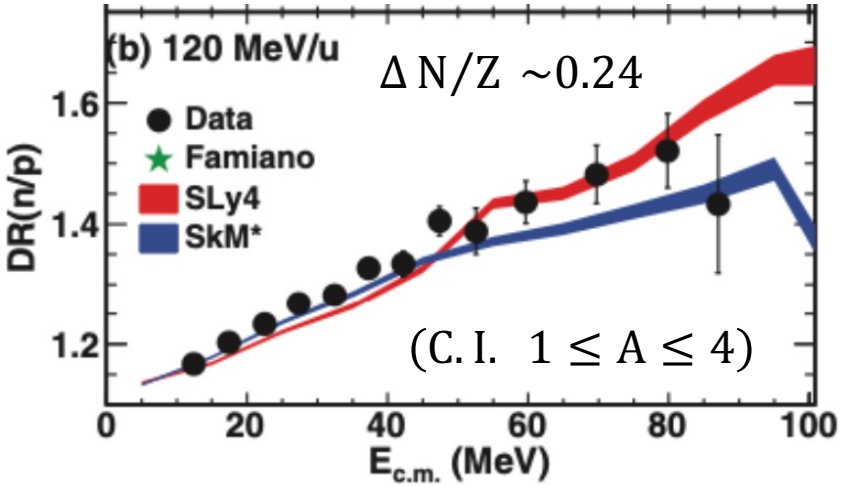
Analysis results

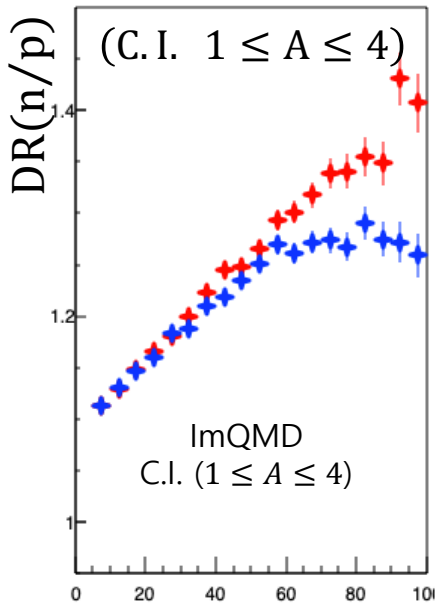


low : $30 < E_k/A < 50$MeV high : $50 < E_k/A < 80$MeV





PHYSICAL REVIEW C 94, 011601(R) (2016)



- Mass splitting studies using $S_{n/p}$ of yield ratio is consistent with previous studies.
- Different energy dependency and relatively scale of two parameter sets are related to absence of free nucleons.

Summary

1. To study symmetry energy, $S_{n/p}$ and $\mathrm{DR}(n/p)$ from experimental and ImQMD calculation are compared.

2. Like previous study, $S_{n/p}$ well reflects effective mass splitting even free nucleons are excluded.

3. $\mathrm{DR}(n/p)$ seems less sensitive to effective mass splitting than $S_{n/p}$.

4. Discussion of the analysis results is currently ongoing.

Thank you!

GANIL

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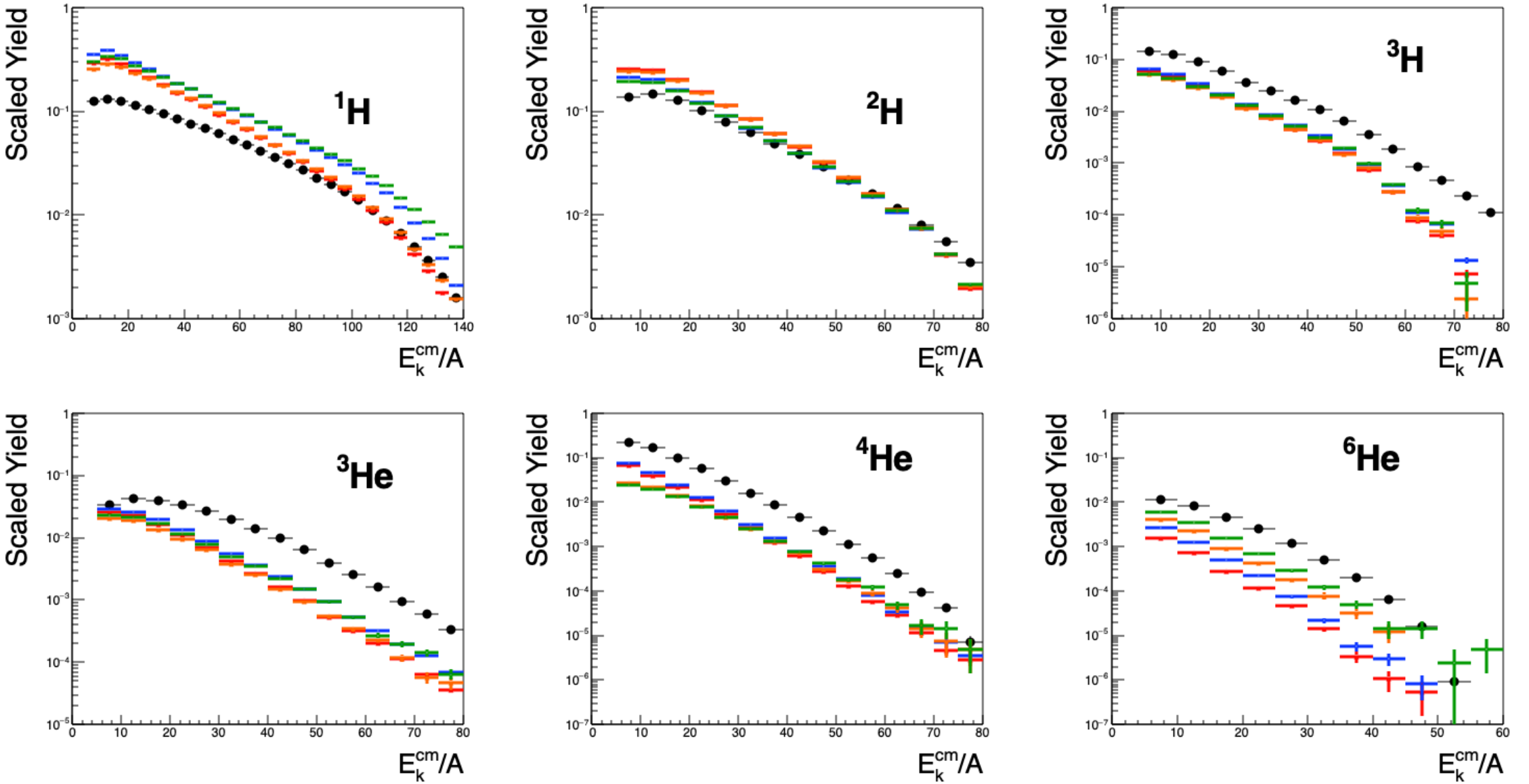
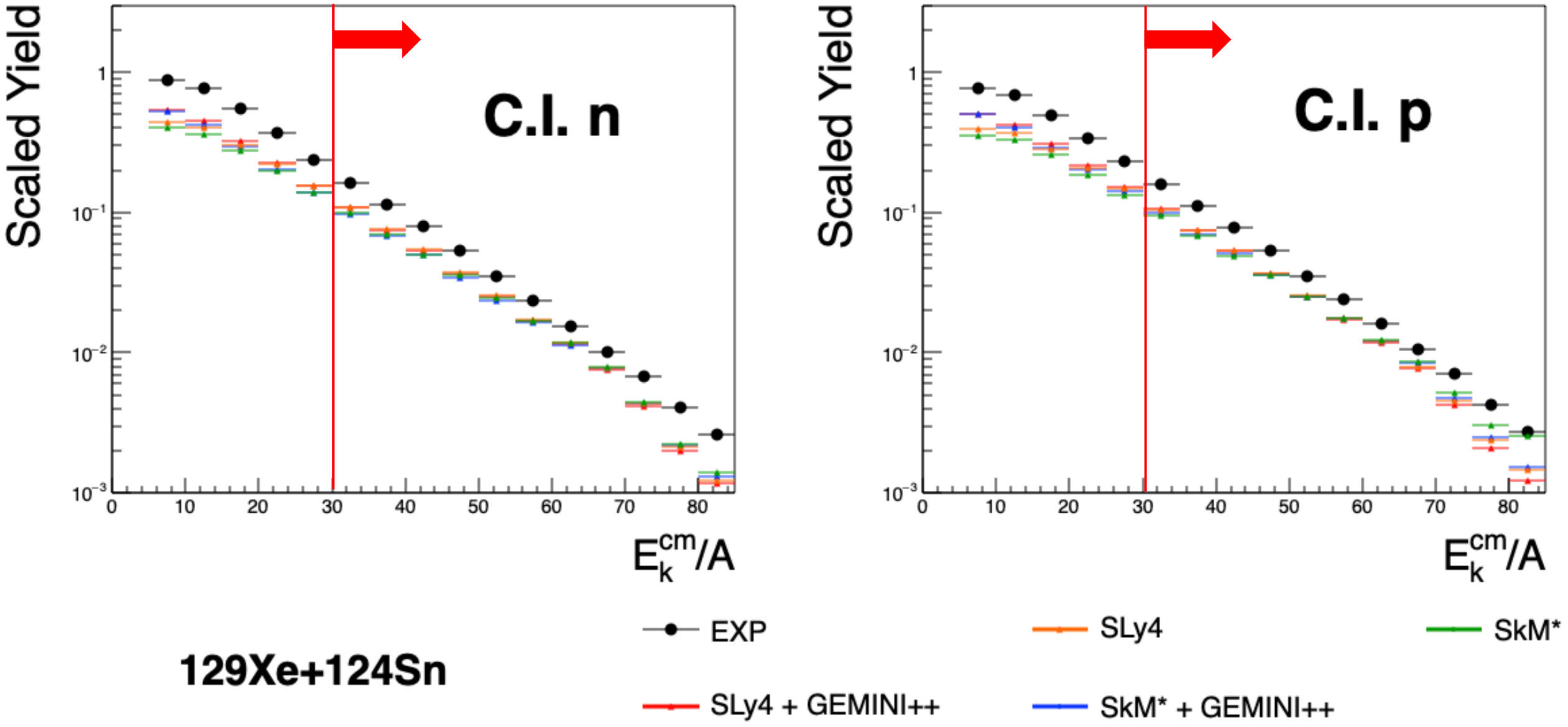

Scaled Yield
^{1}H
^{2}H
^{3}H
^{3}He
^{4}He
^{6}He
E_k^{cm}/A
EXP
SLy4
SkM*
SLy4 + GEMINI++
SkM* + GEMINI++

129Xe+124Sn



C.I. using $2 \leq A \leq 4$