HIAF能区超子-核子相互作用和超核产生研究

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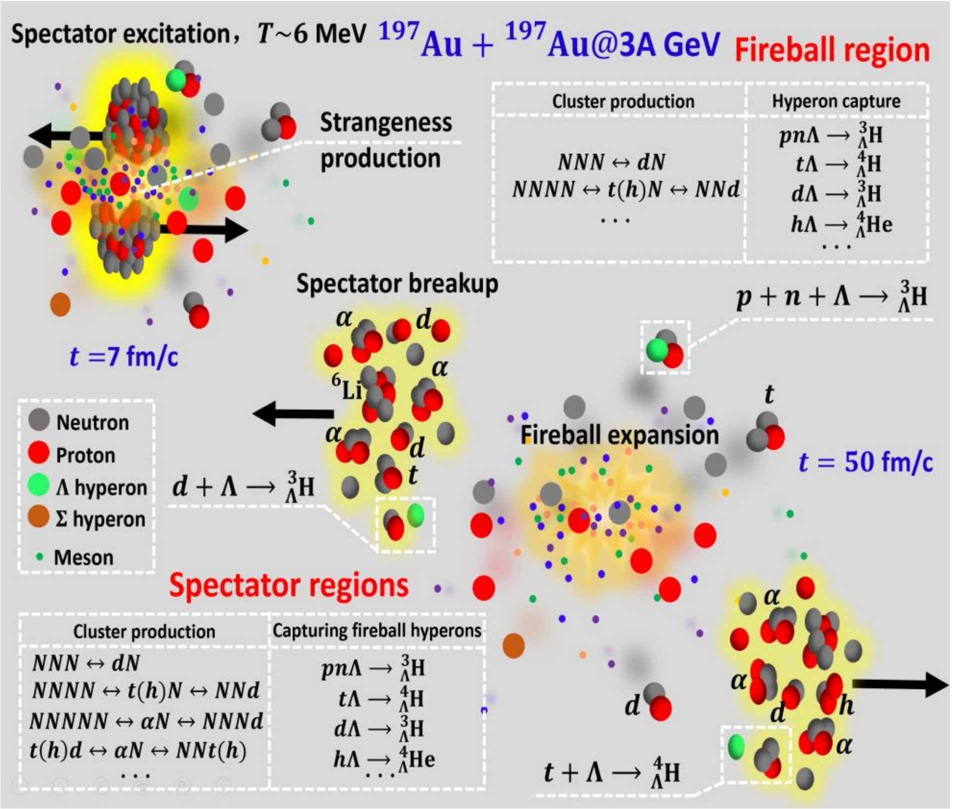
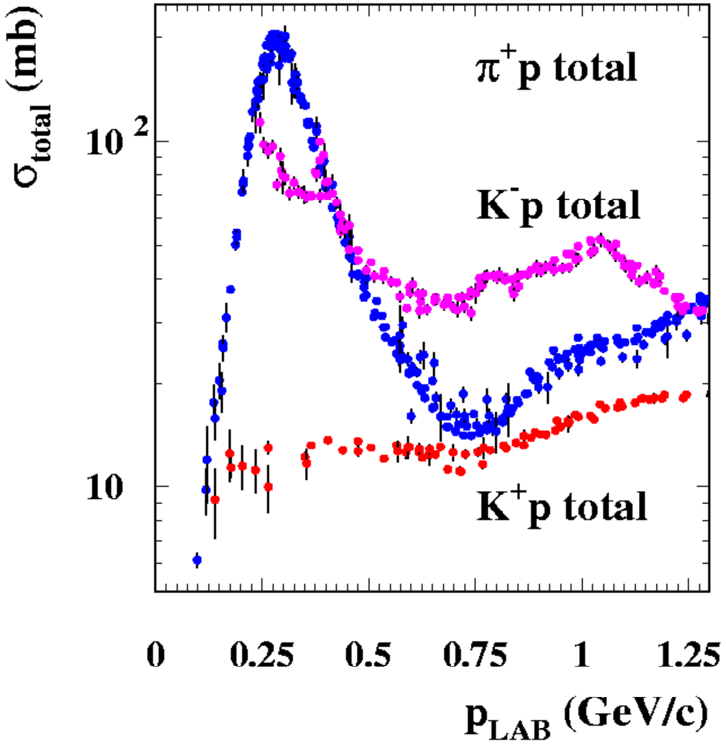
报告概要

- 超子-核子相互作用和超核物理研究进展
- **LQMD**输运模型
- 超子-核子相互作用和中子星物质性质
- 超核产生动力学研究
- **HIAF**装置π介子和反质子束流相关物理讨论
- 总结和展望



I. 超子–核子相互作用和超核物理研究进展

1. Strange particles production in hadron-hadron collisions

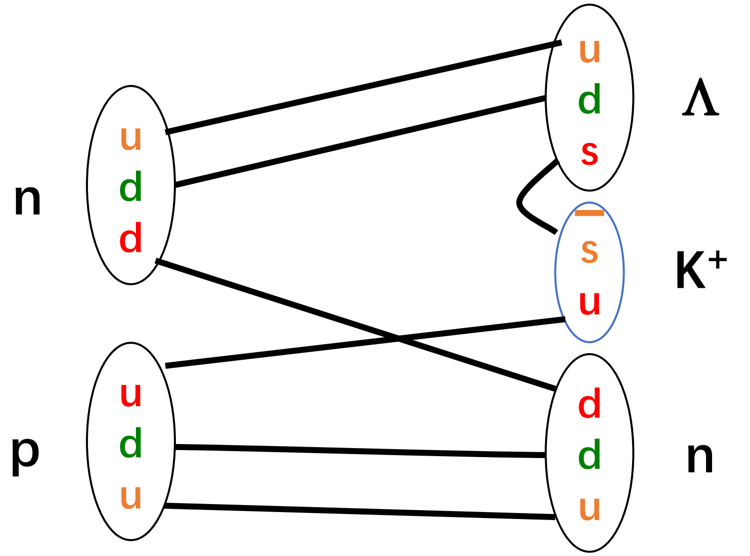


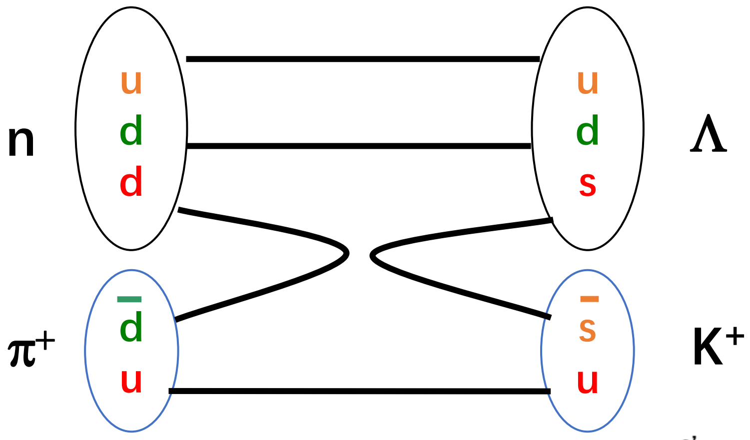
mean free path at ρ_0:

$\lambda(\pi) = 0.3$ fm

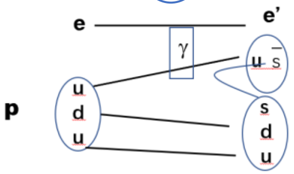
$\lambda(K^+) = 5$ fm

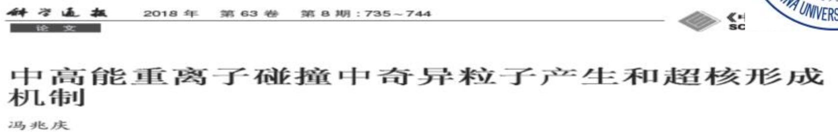
$\lambda(K^-) = 0.8$ fm





e+p → e′ + K⁺ + Λ

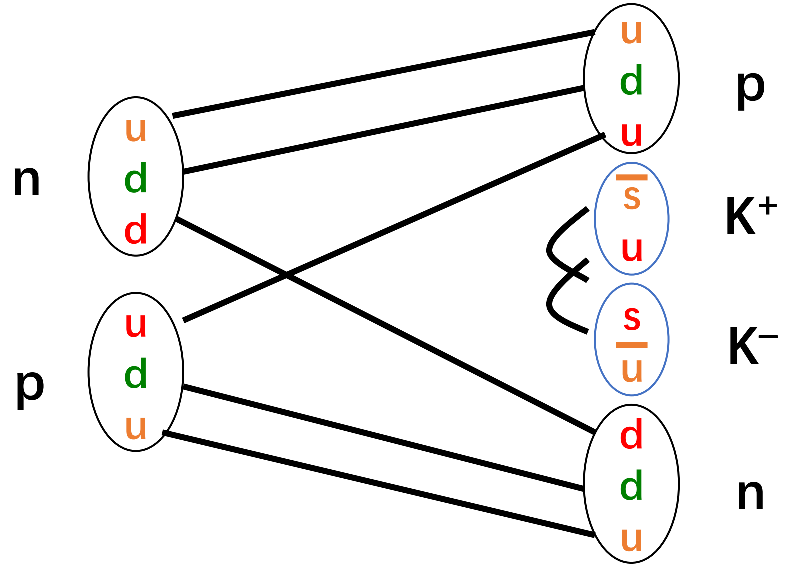


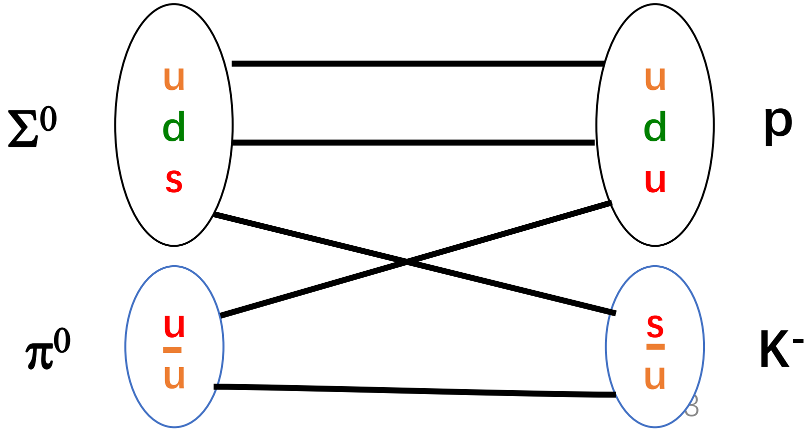

科学通报 2018 年 第 63 卷 第 8 期：735～744

论文

中高能重离子碰撞中奇异粒子产生和超核形成机制

冯兆庆



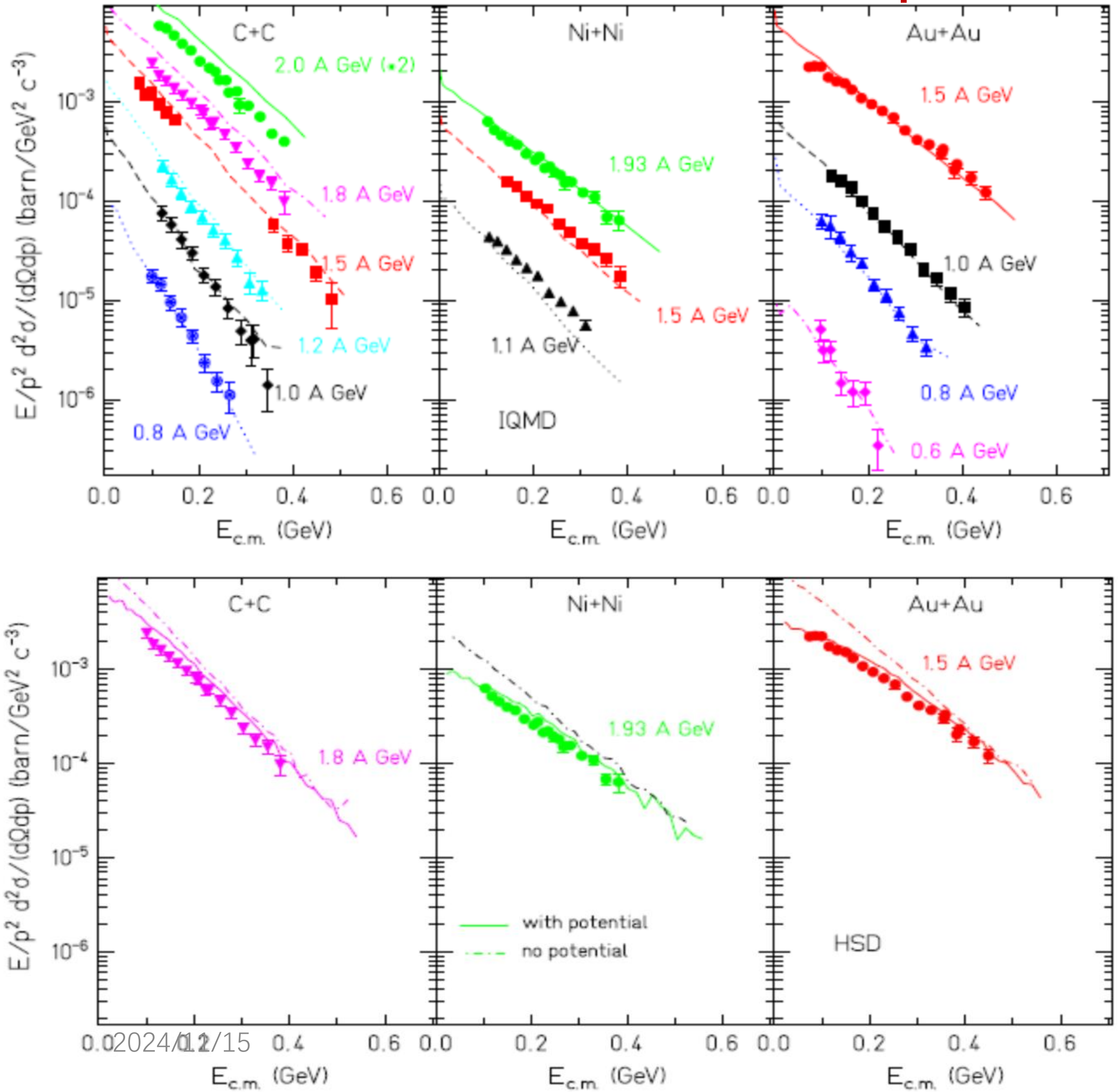


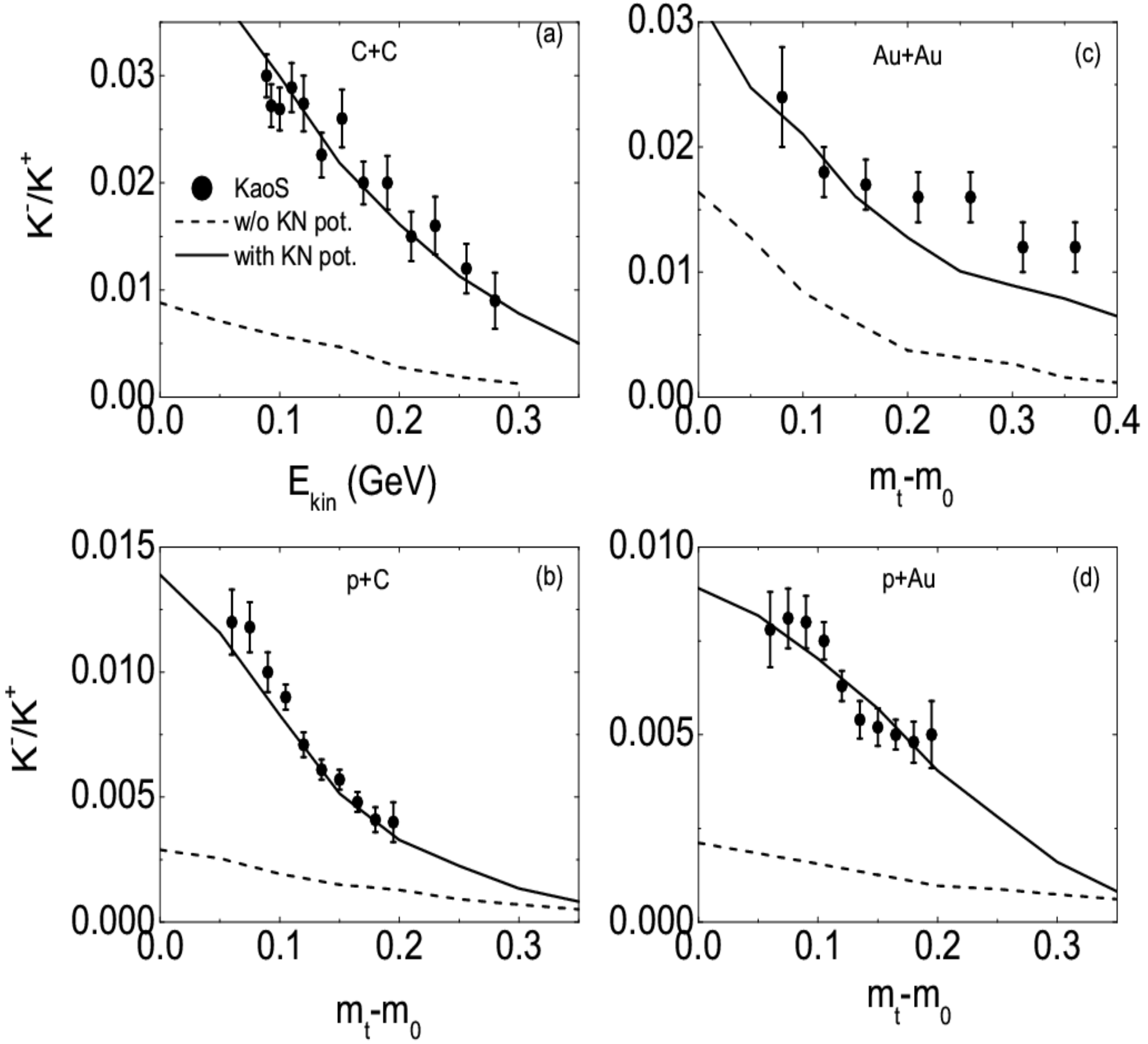
2. Strange particle production in HICs

Z. Q. Feng et al., Phys. Rev. C 90, 064604 (2014)

C. Hartnack et al. / Physics Reports 510 (2012) 119–200

K^+ production





$V_{K+}(\rho_0)$= 28 MeV, $V_{K-}(\rho_0)$= -100 MeV

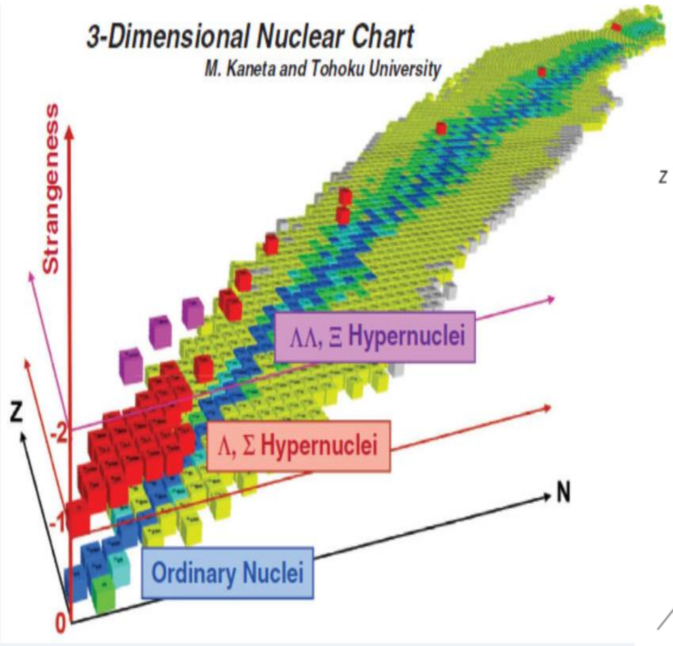
3. Hypernuclear production in HICs

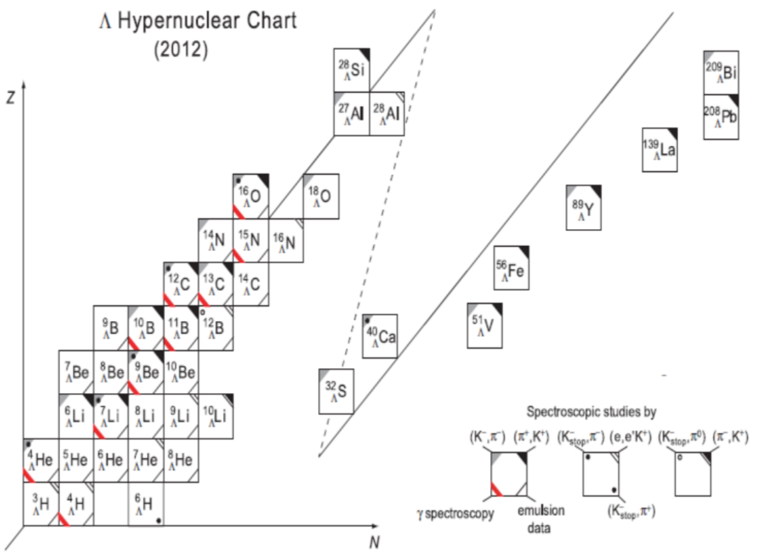
H. Tamura, *Prog. Theor. Exp. Phys*. (2012) 02B012

① Neutron-rich/proton-rich HN nuclei and spectroscopies

② Multistrangeness HN (S=-2) $_{\Lambda\Lambda}X$和$_{\Xi}X$

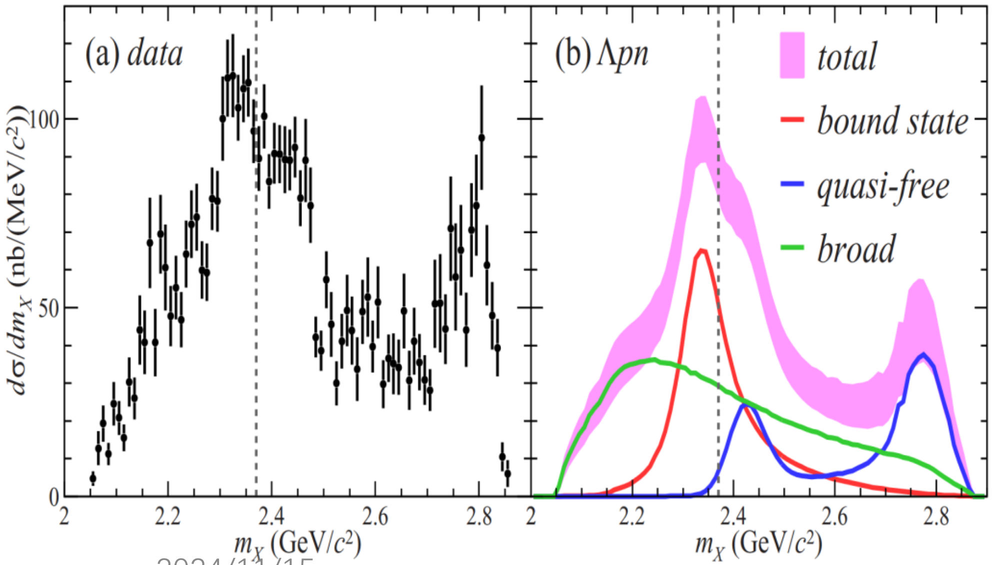
③ Interaction potentials of NΛ, NΞ NNΛ, etc

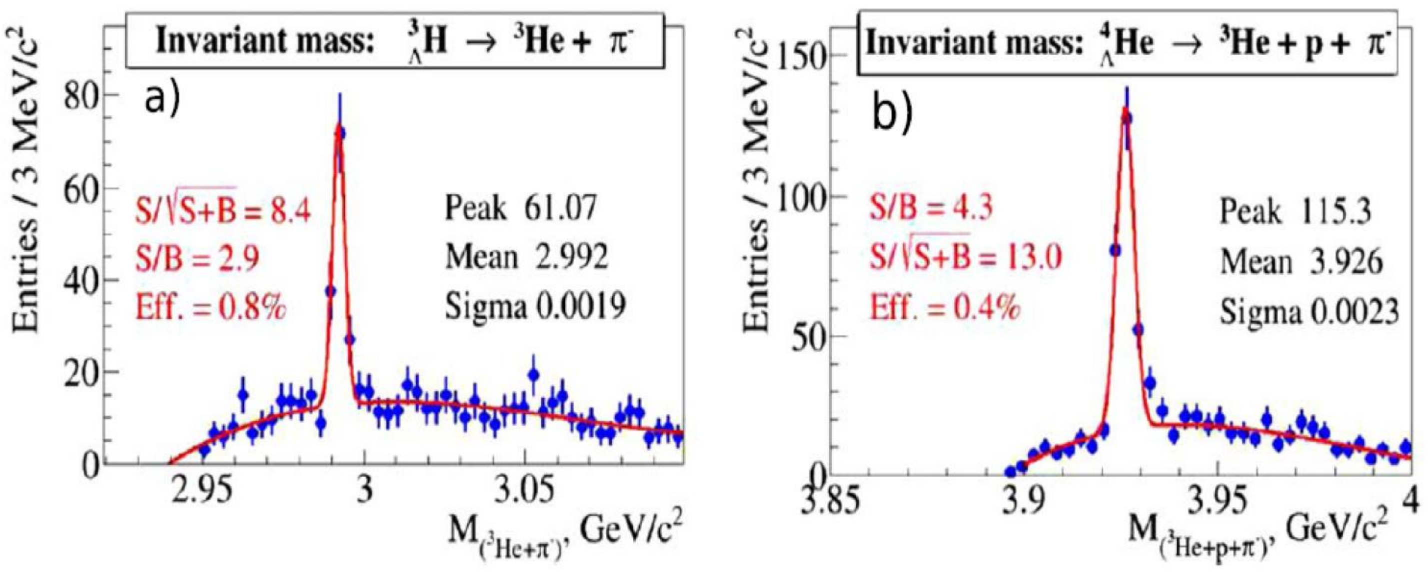




PHYSICAL REVIEW C **102**, 044002 (2020)

Observation of a $\overline{K}NN$ bound state in the ^{3}He(K^-, Λp)n reaction





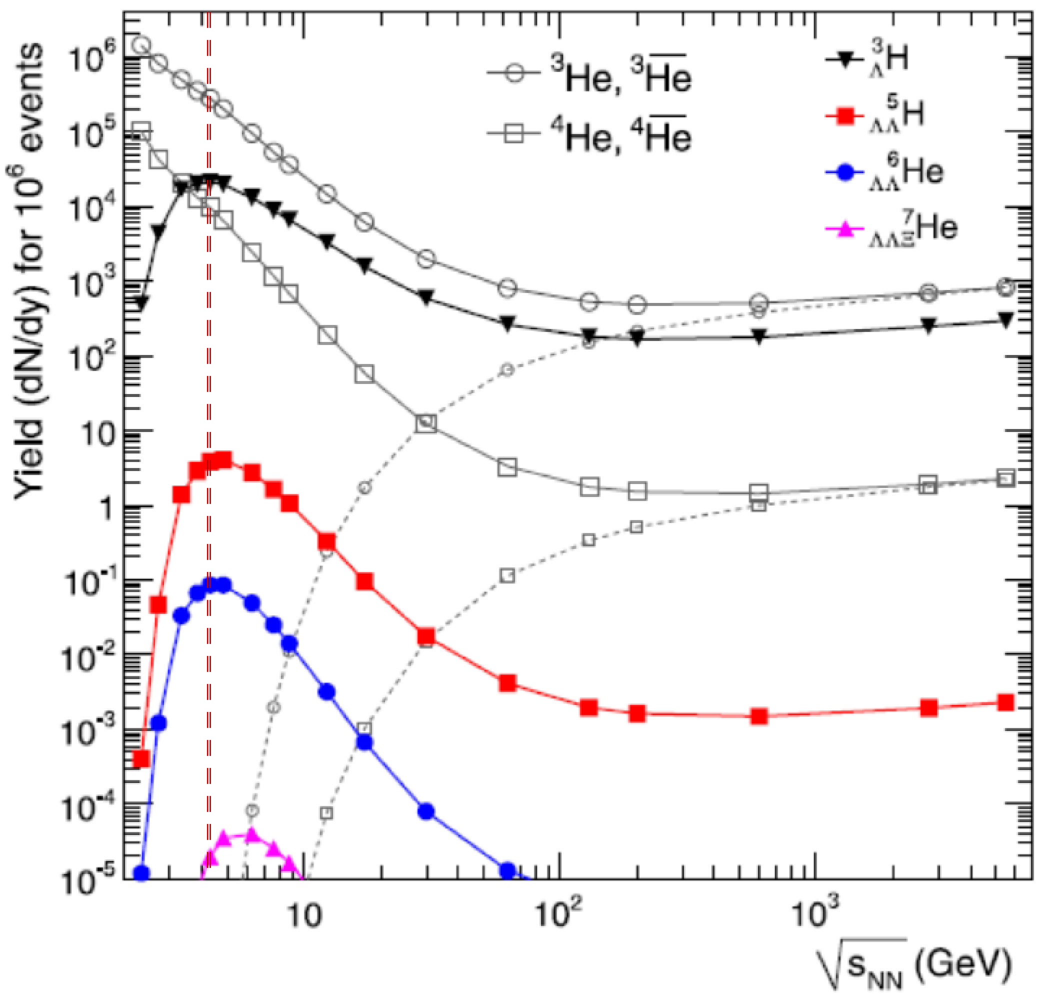
(Hyper-)cluster production in HICs-statistical approach

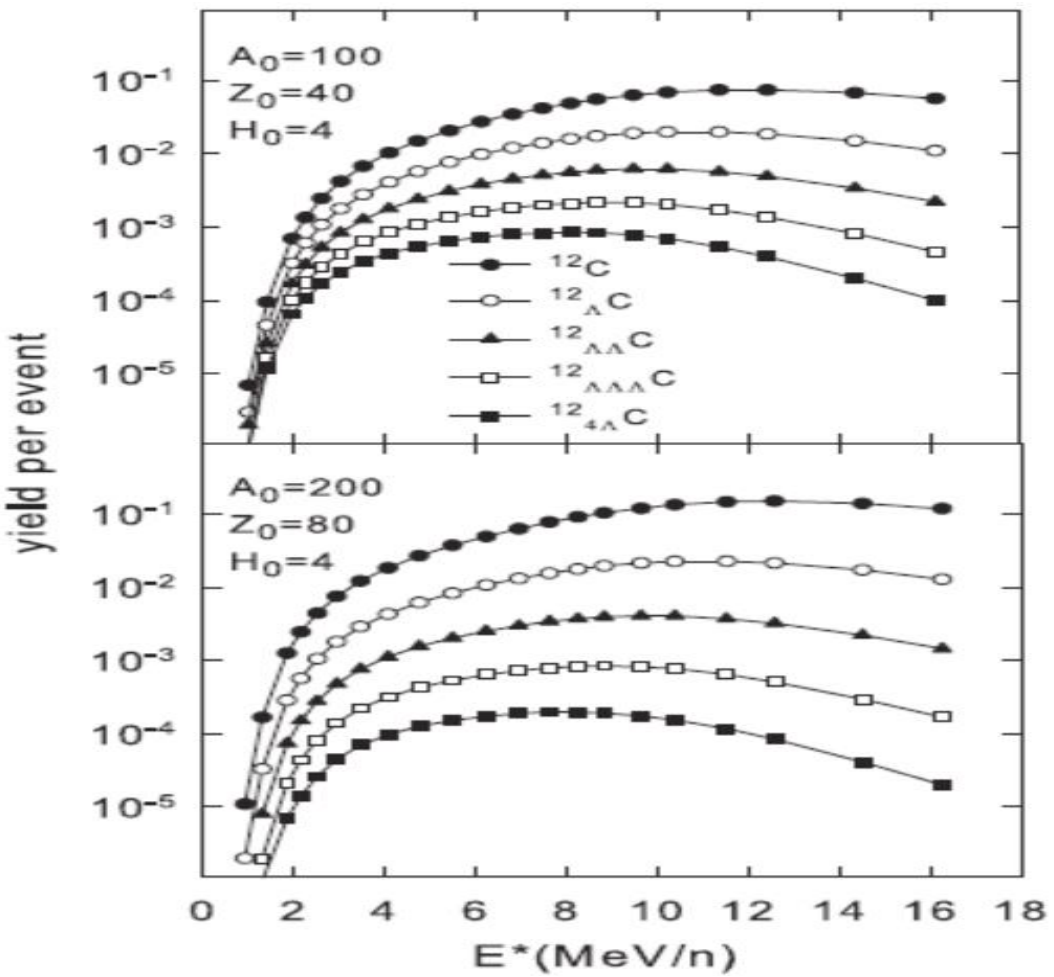
A. Andronic, P. Braun-Munzinger, J. Stachel, H. Stöcker, Physics Letters B 697 (2011) 203–207

N. Buyukcizmeci, R. Ogul, A. S. Botvina, M. Bleicher, Phys. Scr. 95 075311 (2020)

Pb+Pb

Statistical multifragmentation model (SMM)

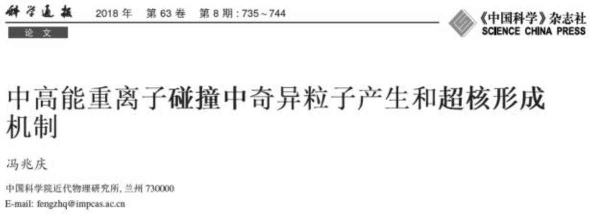




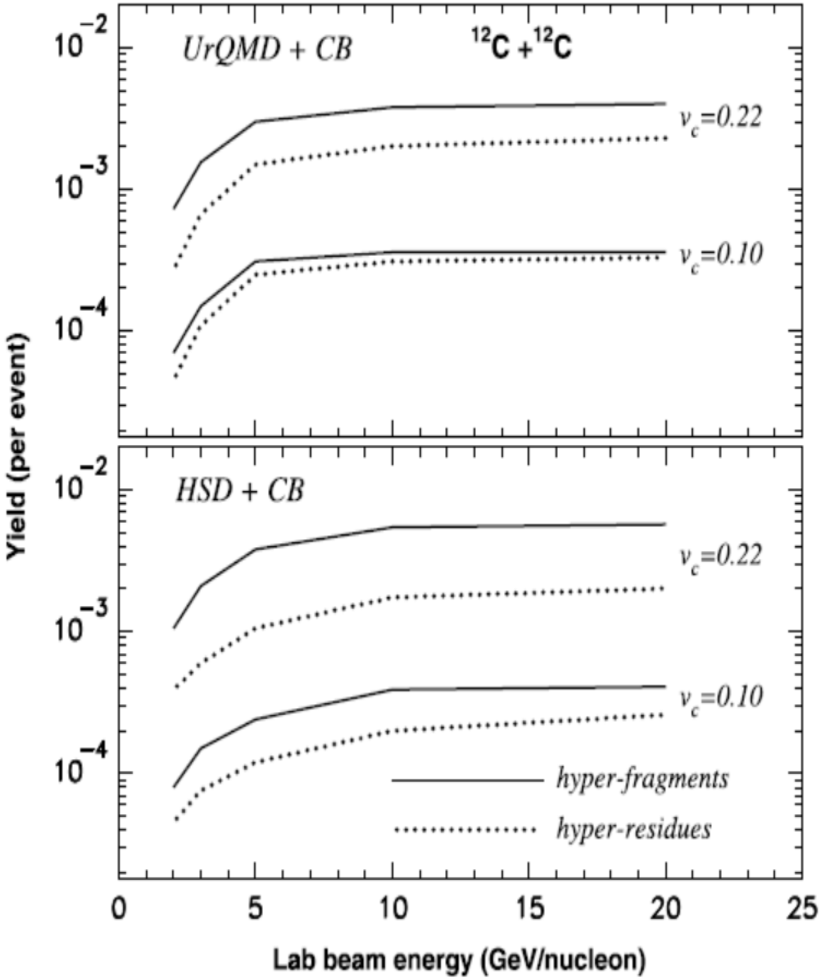
Transport model + coalescence approach

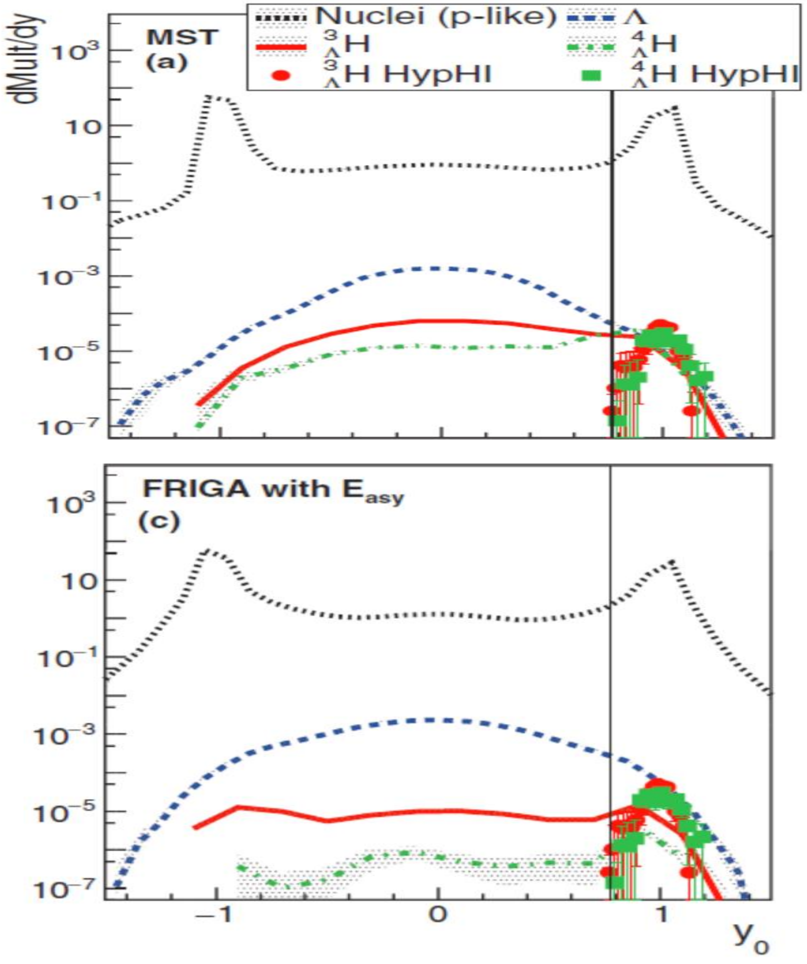
A.S. Botvina, J. Steinheimer, E.Bratkovskaya et al., Physics Letters B 742 (2015)7–14

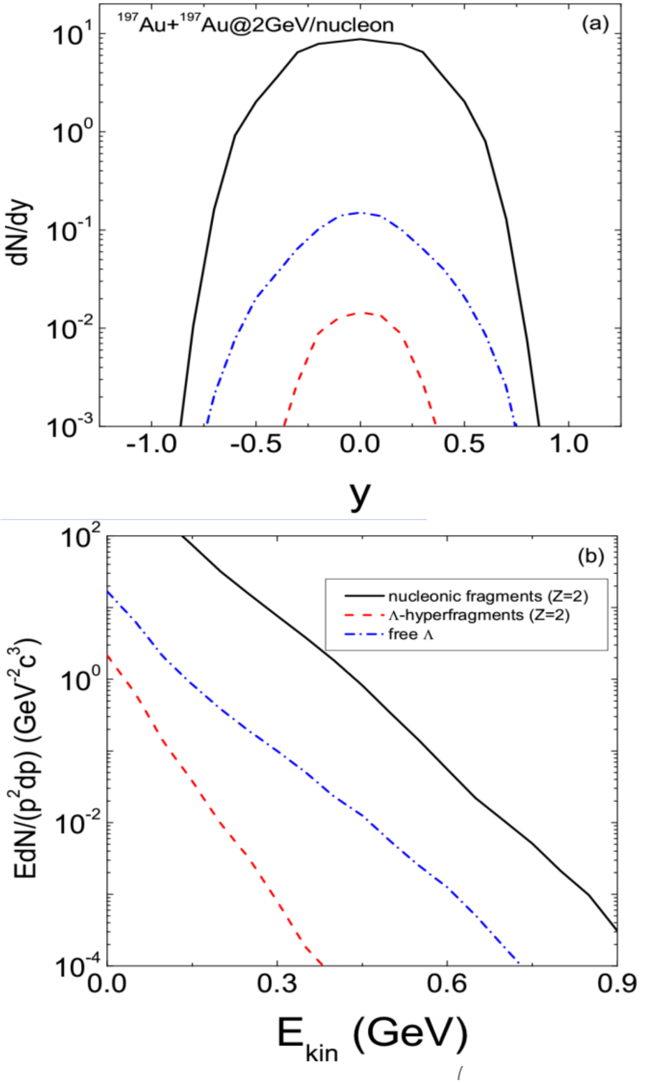
J. Aichelin, E. Bratkovskaya, A. Le Fèvre et al., Physical Review C 101, 044905 (2020)
A. Le Fèvre, J. Aichelin, C. Hartnack and Y. Leifels 100, Physical Review C 034904 (2019)



^{6}Li+^{12}C@2A GeV

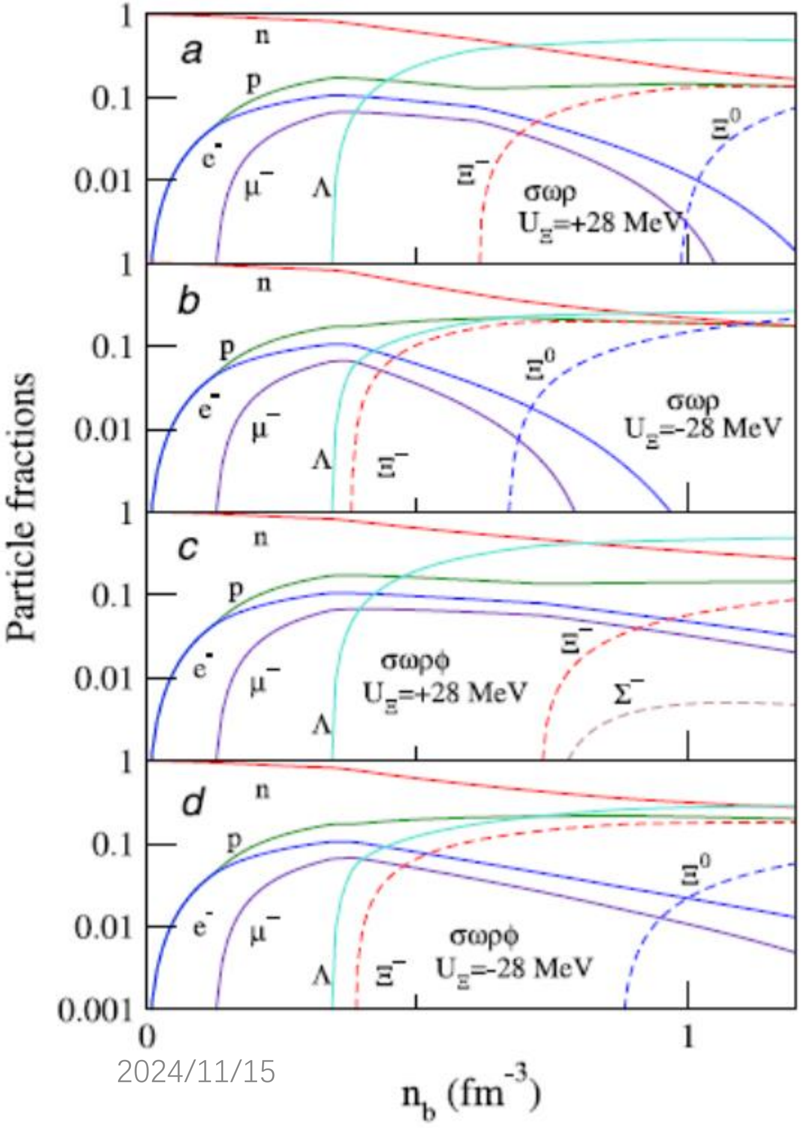


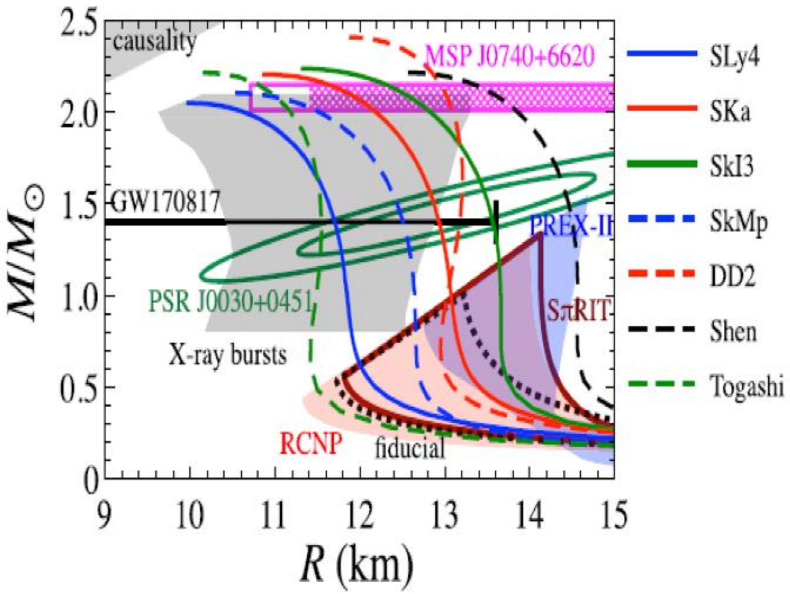


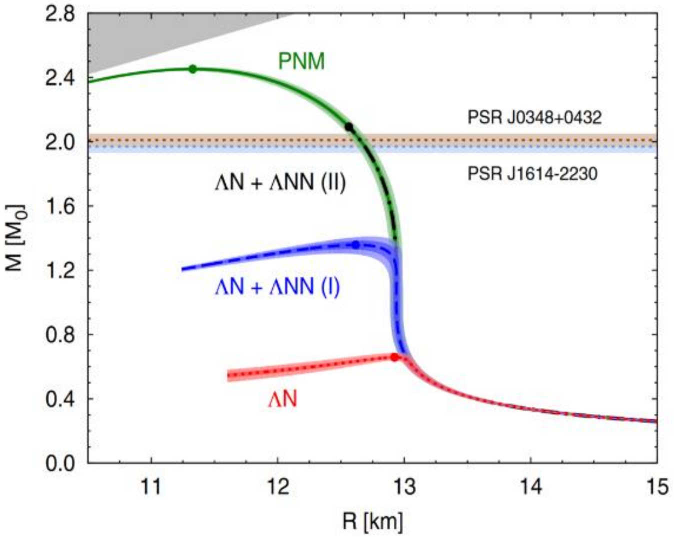


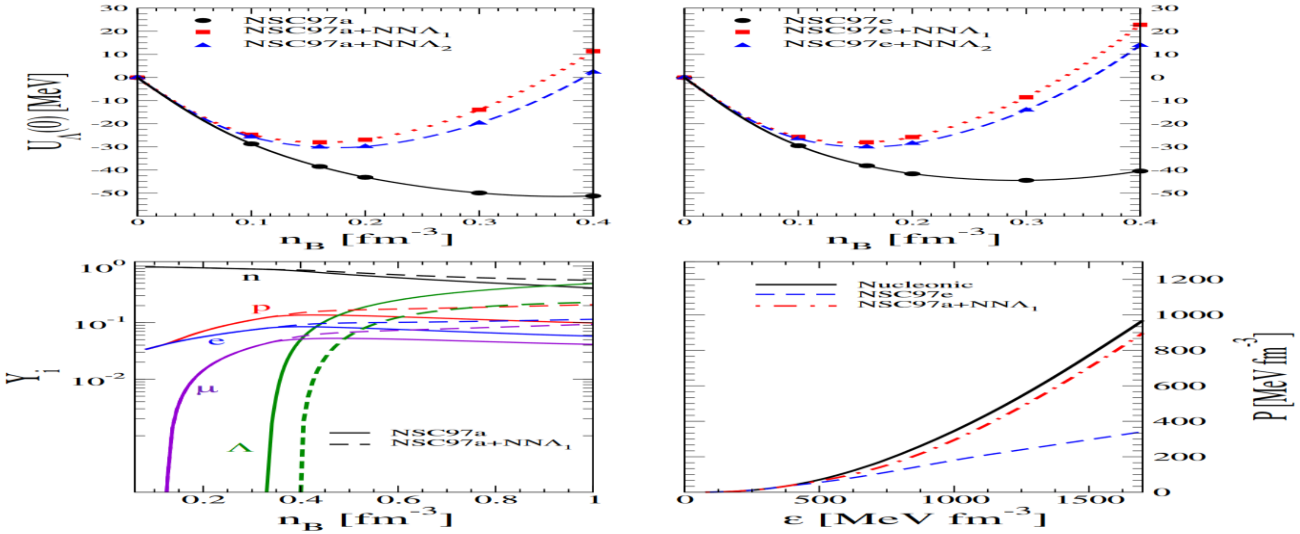
Hyperons in neutron stars (NS)

S. Weissenborn, D. Chatterjee, J. Schaffner-Bielich, Nucl. Phys. A 881, 62 (2012)
W. Z. Jiang, R. Y. Yang, and D. R. Zhang, Phys. Rev. C 87, 064314 (2013)
Diego Lonardoni, Alessandro Lovato, Stefano Gandolfi, and Francesco Pederiva, Phys. Rev. Lett. 114, 092301 (2015)





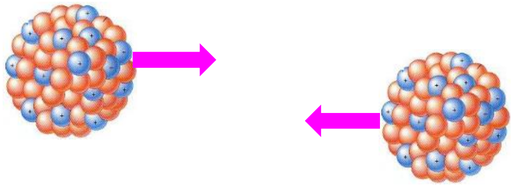




Lanzhou quantum molecular dynamics transport model (LQMD)

Heavy-ion collisions (5 MeV – 5 GeV/nucleon) and hadron induced reaction (p, $\bar{p}$, π, K, e, etc)

- **LQMD transport model** (Skyrme interaction, Walecka model with σ, ω, ρ, δ)
- **Neutron star equation of state** (nuclear symmetry energy at sub- and supra- saturation densities in HICs, isospin splitting of nucleon effective mass from HICs, particle production, 2-body and 3-body potential, multi-body correlation)
- **In-medium effects of hadrons** (optical potentials, energy conservation and in-medium effects, i.e., Δ(1232), N*(1440), N*(1535)), hyperons (Λ,Σ,Ξ) and mesons (π,K,η,ρ,ω,ϕ…))
- **Kinetic production of (hyper)clusters and nuclear fragmentation reactions** (production cross section, phase-space distribution, collective flows, cluster transportation, Mott effect, e.g., deuteron, triton, ^{3}He, α, $_{\Lambda(\Sigma)}X$, $_{\Lambda\Lambda}X$, $_{\Xi}X$, $_{\bar{\Lambda}}X$)
- **Nuclear fusion near Coulomb barrier energies** (barrier distribution, neck dynamics, fusion cross section etc)
- **Hadron induced nuclear reactions** (spallation reaction, physics at PANDA such as hypernuclear, neutron skin thickness etc)



1. Lanzhou quantum molecular dynamics transport model (LQMD-Skyrme)

PHYSICAL REVIEW C 84, 024610 (2011)

Momentum dependence of the symmetry potential and its influence on nuclear reactions

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$$H_B = \sum_i \sqrt{\mathbf{p}_i^2 + \mathbf{m}_i^2} + U_{\text{int}} + U_{\text{mom}}$$

$$U_{loc} = \int V_{loc}(\rho(\mathbf{r}))\, d\mathbf{r}$$

$$V_{loc}(\rho) = \frac{\alpha}{2}\frac{\rho^2}{\rho_0} + \frac{\beta}{1+\gamma}\frac{\rho^{1+\gamma}}{\rho_0^{\gamma}} + E_{sym}^{loc}(\rho)\rho\delta^2 + \frac{g_{sur}}{2\rho_0}(\nabla\rho)^2 + \frac{g_{sur}^{iso}}{2\rho_0}[\nabla(\rho_n - \rho_p)]^2,$$

Phys. Rev. C 84, 024610 (2011); 85, 014604 (2012)

$$U_{mom} = \frac{1}{2\rho_0}\sum_{i,j,j\neq i}\sum_{\tau,\tau'} C_{\tau,\tau'}\delta_{\tau,\tau_i}\delta_{\tau',\tau_j}\iiint d\mathbf{p}\, d\mathbf{p}'\, d\mathbf{r}\, f_i(\mathbf{r},\mathbf{p},t) \times [\ln(\epsilon(\mathbf{p}-\mathbf{p}')^2+1)]^2 f_j(\mathbf{r},\mathbf{p}',t).$$

$$E_{sym}(\rho) = \frac{1}{3}\frac{\hbar^2}{2m}\left(\frac{3}{2}\pi^2\rho\right)^{2/3} + E_{sym}^{loc}(\rho) + E_{sym}^{mom}(\rho).$$

C_{sym} = 38 MeV

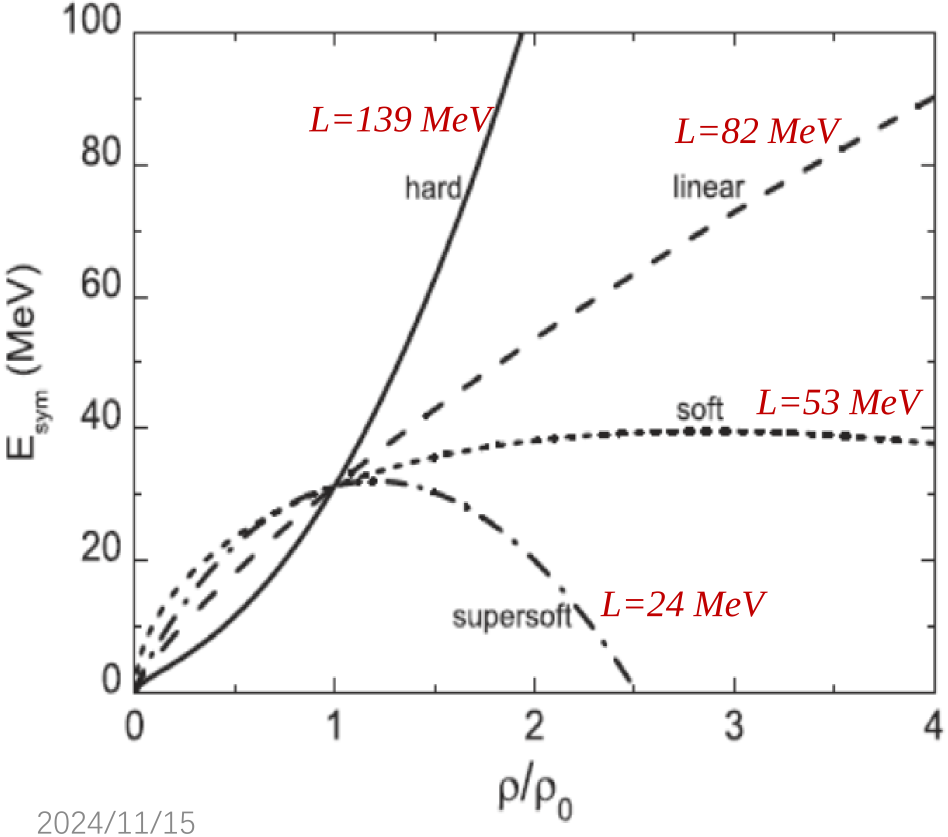
a_{sym} = 37.7 MeV

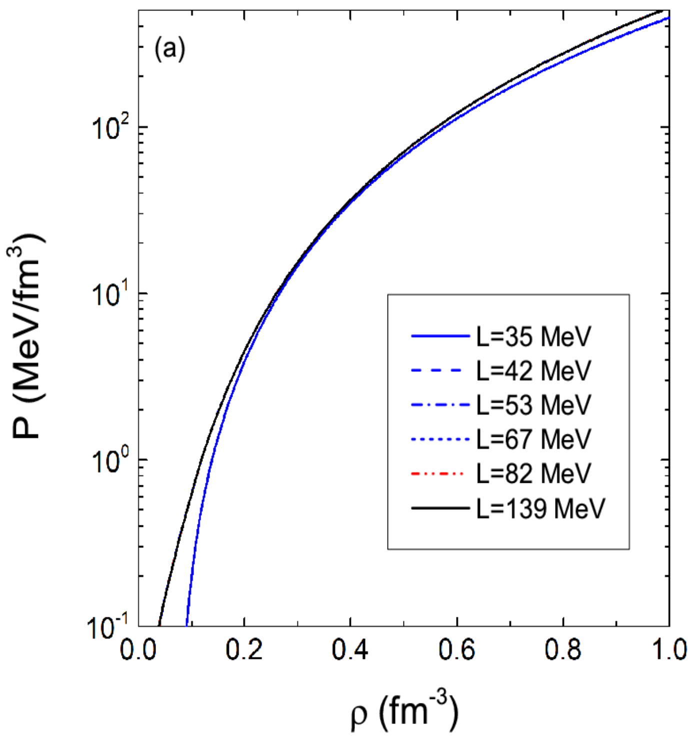
b_{sym} = -18.7 MeV

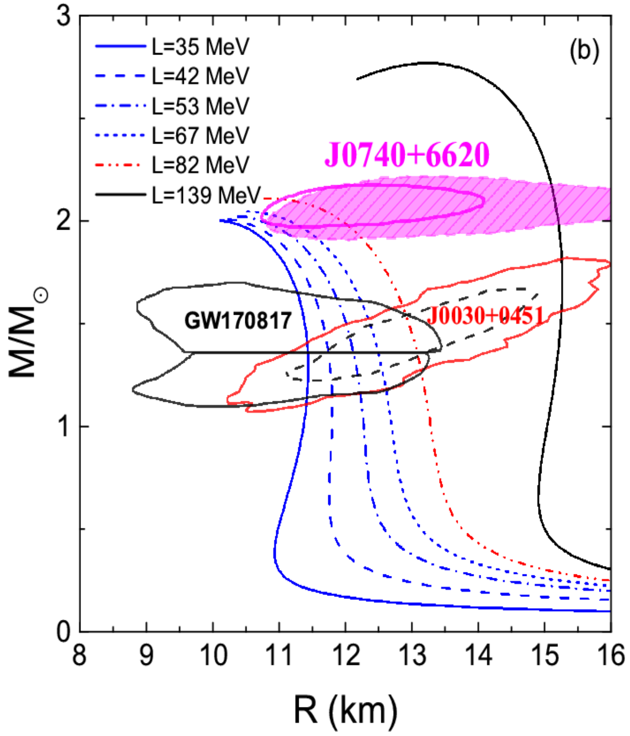
$$E_{sym}^{loc}(\rho) = \frac{1}{2}C_{sym}(\rho/\rho_0)^{\gamma_s} \qquad E_{sym}^{loc}(\rho) = a_{sym}(\rho/\rho_0) + b_{sym}(\rho/\rho_0)^2.$$

Table 1: The parameters and properties of isospin symmetric EoS used in the LQMD model at the density of 0.16 fm^{-3}.

Parameters	α (MeV)	β (MeV)	γ	C_{mom} (MeV)	ϵ (c^2/MeV^2)	m^*_∞/m	K_∞ (MeV)
PAR1	-215.7	142.4	1.322	1.76	5×10^{-4}	0.75	230
PAR2	-226.5	173.7	1.309	0.	0.	1.	230







2. Covariant energy-density functional (LQMD.RMF)

Si-Na Wei, Zhao-Qing Feng,
Nuclear Science and Techniques 35, 15 (2024)
arXiv:2302.09984

$$L = \bar{\psi}[i\gamma_\mu\partial^\mu - (M_N - g_\sigma\varphi - g_\delta\vec{\tau}\cdot\vec{\delta}) - g_\omega\gamma_\mu\omega^\mu - g_\rho\gamma_\mu\vec{\tau}\cdot\vec{b}^\mu]\psi$$
$$+\frac{1}{2}(\partial_\mu\varphi\partial^\mu\varphi - m_\sigma^2\varphi^2) - U(\varphi) + \frac{1}{2}(\partial_\mu\vec{\delta}\partial^\mu\vec{\delta} - m_\sigma^2\vec{\delta}^2)$$
$$+\frac{1}{2}m_\omega^2\omega_\mu\omega^\mu - \frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}m_\rho^2\vec{b}_\mu\vec{b}^\mu - \frac{1}{4}\vec{G}_{\mu\nu}\vec{G}^{\mu\nu}$$

$$F_{\mu\nu} = \partial_\mu\omega_\nu - \partial_\nu\omega_\mu,$$
$$G_{\mu\nu} = \partial_\mu\vec{b}_\nu - \partial_\nu\vec{b}_\mu,$$
$$U(\varphi) = \frac{g_2}{3}\varphi^3 + \frac{g_3}{4}\varphi^4$$

Energy density functional

$$\varepsilon = \sum_{i=n,p} 2\int\frac{d^3k}{(2\pi)^3}\sqrt{k^2 + M_i^{*2}} + \frac{1}{2}m_\sigma^2\varphi^2 + U(\varphi) + \frac{1}{2}m_\omega^2\omega_0^2 + \frac{1}{2}m_\rho^2 b_0^2 + \frac{1}{2}m_\delta^2\delta_3^2$$

Temporal evolution in phase space

$$\dot{\mathbf{x}} = \frac{\mathbf{p}_i^*}{p_0^*} + \sum_{i\neq j}^{N}\{\frac{g_v^2}{2m_v^2}z_j^{*\mu}u_{i,\mu}B_iB_j\frac{\partial\rho_{ij}}{\partial\mathbf{p}_i} + \frac{g_v^2}{2m_v^2}z_i^{*\mu}u_{j,\mu}B_iB_j\frac{\partial\rho_{ji}}{\partial\mathbf{p}_i} + \frac{g_v^2}{2m_v^2}z_j^{*\mu}\rho_{ji}B_iB_j\frac{\partial u_{i,\mu}}{\partial\mathbf{p}_i}$$
$$+z_j^{*\mu}\frac{B_iB_j\bar{g}_v^2}{2m_v^2}[\frac{\rho_{ij}}{1-p_{T,ij}^2/\Lambda_v^2}\frac{\partial u_{i,\mu}}{\partial\mathbf{p}_i} + \frac{u_{i,\mu}}{1-p_{T,ij}^2/\Lambda_v^2}\frac{\partial\rho_{ij}}{\partial\mathbf{p}_i} + u_{i,\mu}\rho_{ij}\frac{\partial[1/(1-p_{T,ij}^2/\Lambda_v^2)]}{\partial\mathbf{p}_i}]$$
$$+z_i^{*\mu}\frac{B_iB_j\bar{g}_v^2}{2m_v^2}[\frac{u_{j,\mu}}{1-p_{T,ji}^2/\Lambda_v^2}\frac{\partial\rho_{ji}}{\partial\mathbf{p}_i} + u_{j,\mu}\rho_{ji}\frac{\partial[1/(1-p_{T,ji}^2/\Lambda_v^2)]}{\partial\mathbf{p}_i}]$$
$$-\frac{m_j^*}{p_j^{*0}}\frac{\partial S_j}{\partial\mathbf{p}_i} - \frac{m_i^*}{p_i^{*0}}\frac{\partial S_i}{\partial\mathbf{p}_i}\},$$

$$\dot{\mathbf{p}} = -\sum_{i\neq j}^{N}\{\frac{g_v^2}{2m_v^2}z_j^{*\mu}u_{i,\mu}B_iB_j\frac{\partial\rho_{ij}}{\partial\mathbf{r}_i} + \frac{g_v^2}{2m_v^2}z_i^{*\mu}u_{j,\mu}B_iB_j\frac{\partial\rho_{ji}}{\partial\mathbf{r}_i}$$
$$+z_j^{*\mu}\frac{B_iB_j\bar{g}_v^2}{2m_v^2}\frac{u_{i,\mu}}{1-p_{T,ij}^2/\Lambda_v^2}\frac{\partial\rho_{ij}}{\partial\mathbf{r}_i}$$
$$+z_i^{*\mu}\frac{B_iB_j\bar{g}_v^2}{2m_v^2}\frac{u_{j,\mu}}{1-p_{T,ji}^2/\Lambda_v^2}\frac{\partial\rho_{ji}}{\partial\mathbf{r}_i}$$
$$-\frac{m_j^*}{p_j^{*0}}\frac{\partial S_j}{\partial\mathbf{r}_i} - \frac{m_i^*}{p_i^{*0}}\frac{\partial S_i}{\partial\mathbf{r}_i}\},$$

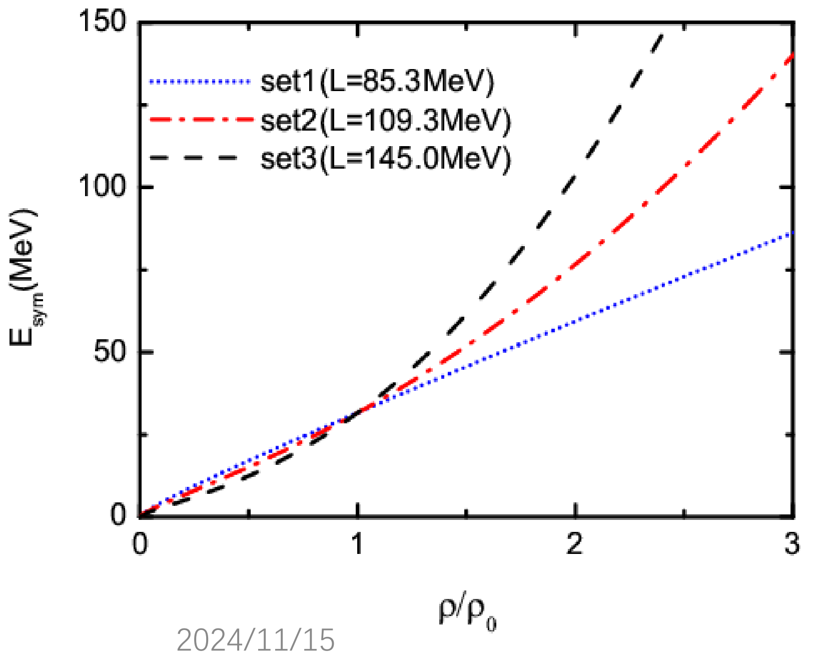
TABLE I: Parameter sets for RMF. The saturation density ρ_0 is set to be 0.16 fm^{-3}. The binding energy of saturation density is $E/A - M_N = -16$ MeV. The isoscalar-vector ω and isovector-vector ρ masses are fixed to their physical values, $m_\omega = 783$ MeV and $m_\rho = 763$ MeV. The remaining meson mass m_σ is set to be 550 MeV.

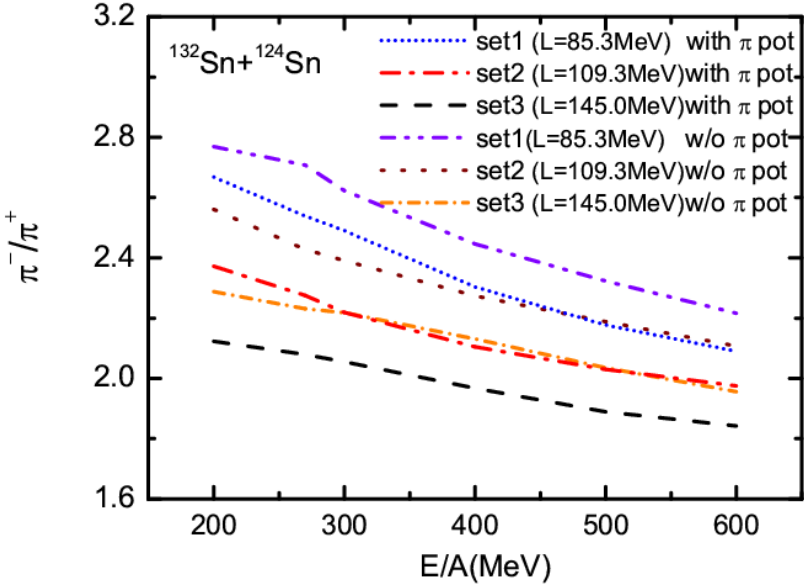
model	g_σ	g_ω	g_2 (fm^{-1})	g_3	g_ρ	g_δ	K (MeV)	$E_{sym}(\rho_0)$ (MeV)	L (ρ_0)(MeV)
set1	8.145	7.570	31.820	28.100	4.049	-	230	31.6	85.3
set2	8.145	7.570	31.820	28.100	8.673	5.347	230	31.6	109.3
set3	8.145	7.570	31.820	28.100	11.768	7.752	230	31.6	145.0

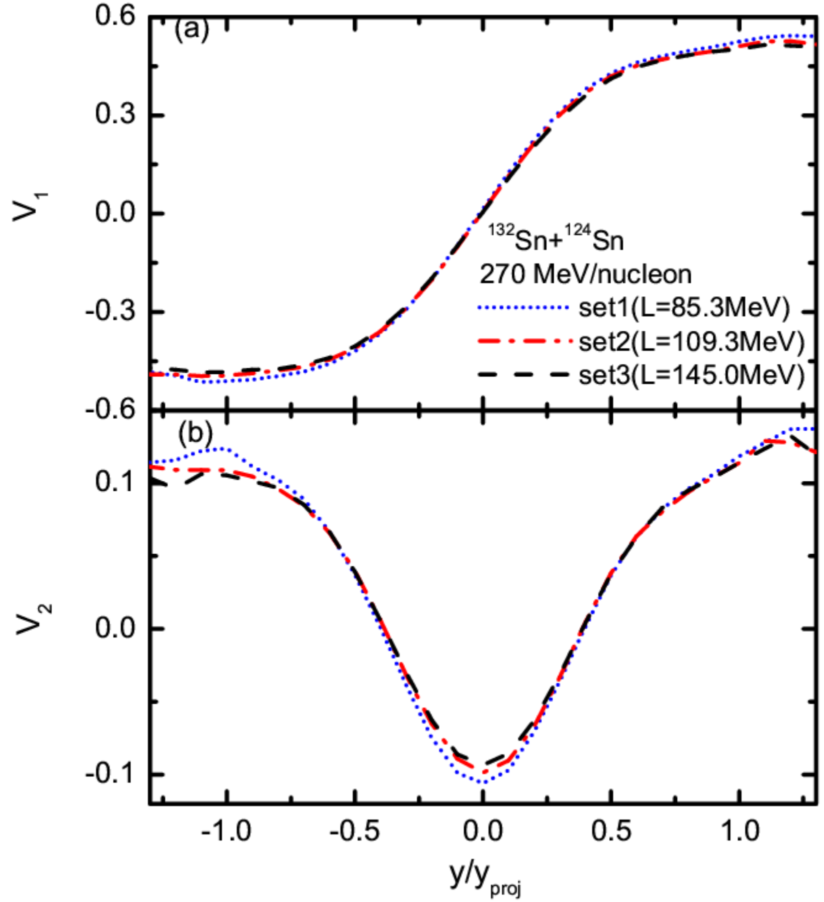
Symmetry energy

$$E_{sym} = \frac{1}{6}\frac{k_F^2}{E_F^*} + \frac{1}{2}\left[f_\rho - f_\delta\left(\frac{M^*}{E_F^*}\right)\right]\rho$$

$$f_{\rho,\delta} = g_{\rho,\delta}/m_{\rho,\delta}$$



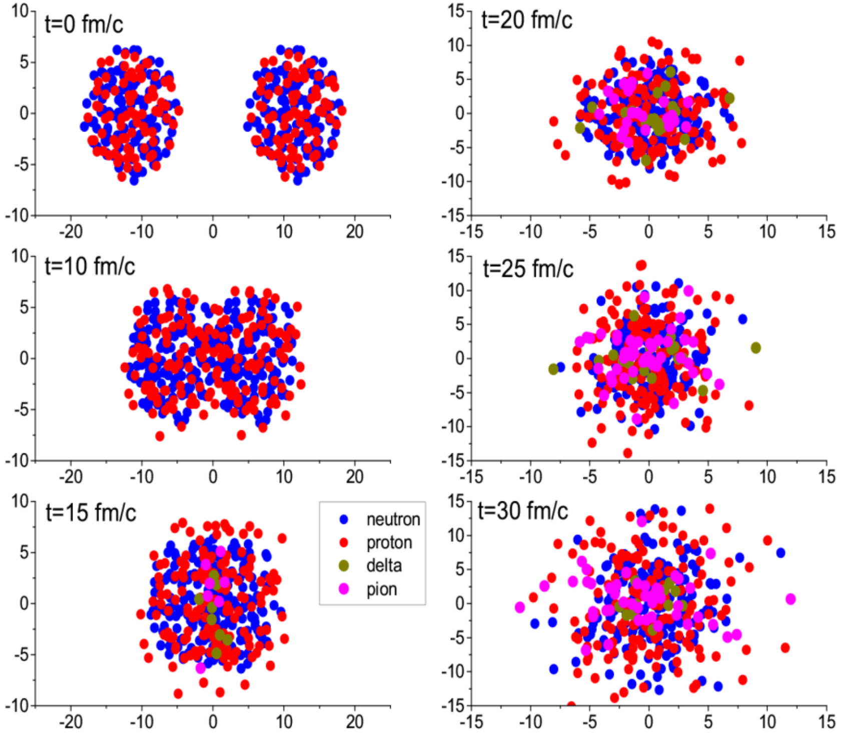




3. Particle production

π and resonances (Δ(1232), N*(1440), N*(1535), …) production:

$$NN \leftrightarrow N\Delta,\quad NN \leftrightarrow NN^*,\quad NN \leftrightarrow \Delta\Delta,\quad \Delta \leftrightarrow N\pi,$$
$$N^* \leftrightarrow N\pi,\quad NN \leftrightarrow NN\pi(s-state),\quad N^*(1535) \leftrightarrow N\eta$$



Collisions between resonances, NN*↔NΔ, NN*↔NN*

Strangeness channels:

$$BB \to BYK, BB \to BBK\overline{K}, B\pi(\eta) \to YK, YK \to B\pi,$$
$$B\pi \to NK\overline{K}, Y\pi \to B\overline{K},\quad B\overline{K} \to Y\pi,\quad YN \to \overline{K}NN,$$
$$BB \to B\Xi KK, \overline{K}B \leftrightarrow K\Xi, YY \leftrightarrow N\Xi, \overline{K}Y \leftrightarrow \pi\Xi.$$

Reaction channels with antiproton:

$$\bar{p}N \to \overline{N}N,\quad \overline{N}N \to \overline{N}N, \overline{N}N \to \overline{B}B, \overline{N}N \to \overline{Y}Y$$
$$\overline{N}N \to \text{annihilation}(\pi, \eta, \rho, \omega, K, \overline{K}, K^*, \overline{K}^*, \phi)$$

Statistical model with SU(3) symmetry for annihilation
(E.S. Golubeva et al., Nucl. Phys. A 537, 393 (1992))

The **PYTHIA** and **FRITIOF** code are used for baryon(meson)-baryon and antibaryon-baryon collisions at high invariant energies

III. 超子-核子相互作用和中子星物质性质

$$H_Y = \sum_{i=1}^{N_Y} V_i^{Coul} + V_{opt}^Y(\boldsymbol{p}_i, \rho_i) + \sqrt{\boldsymbol{p}_i^2 + m_Y^2}$$

$$V_{opt}^Y(\boldsymbol{p}_i, \rho_i) = \omega_Y(\boldsymbol{p}_i, \rho_i) - \sqrt{\boldsymbol{p}_i^2 + m_Y^2}$$

$$\omega_Y(\boldsymbol{p}_i, \rho_i) = \sqrt{(m_Y + \Sigma_S^Y)^2 + \mathbf{p}_i^2} + \Sigma_V^Y,$$

Phenomenological potential by fitting the results of chiral effective field theory

$$V_{opt}^{\Lambda}(\boldsymbol{p}_i, \rho_i) = V_a(\rho_i/\rho_0) + V_b(\rho_i/\rho_0)^2 + C_{mom}(\rho_i/\rho_0)\ln(\epsilon \boldsymbol{p}_i^2 + 1)$$

$$V_{opt}^{\Sigma}(\boldsymbol{p}_i, \rho_i) = V_0(\rho_i/\rho_0)^{\gamma_s} + V_1(\rho_n - \rho_p)t_\Sigma \rho_i^{\gamma_s -} + C_{mom}(\rho_i/\rho_0)\ln(\epsilon \boldsymbol{p}_i^2 + 1).$$

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Letter

Extracting the hyperon-nucleon interaction via collective flows in heavy-ion collisions

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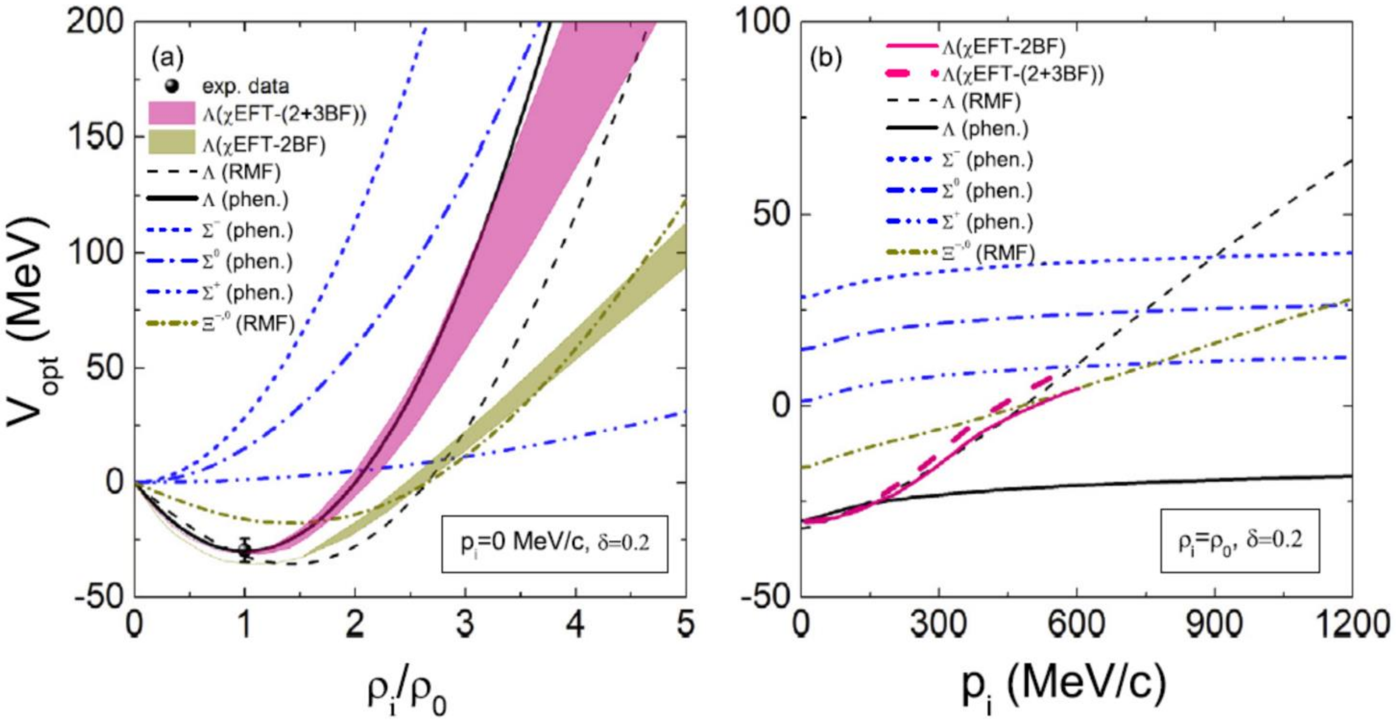
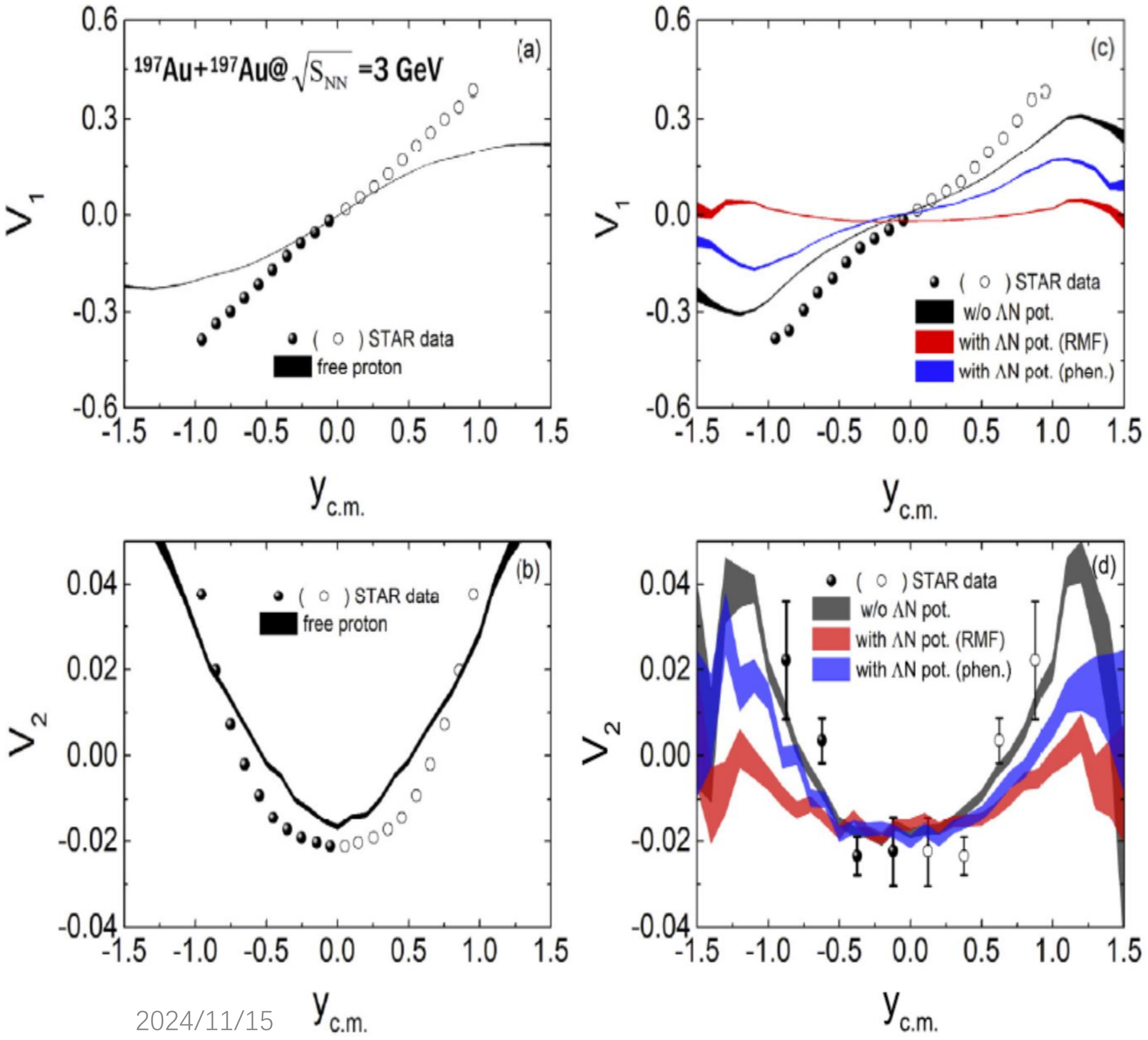
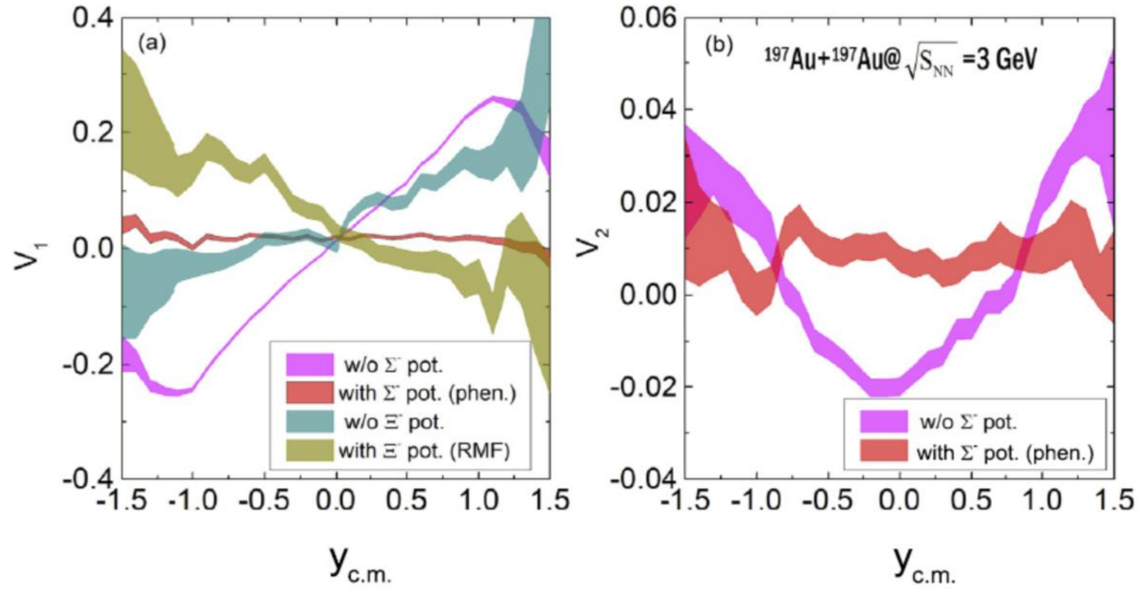
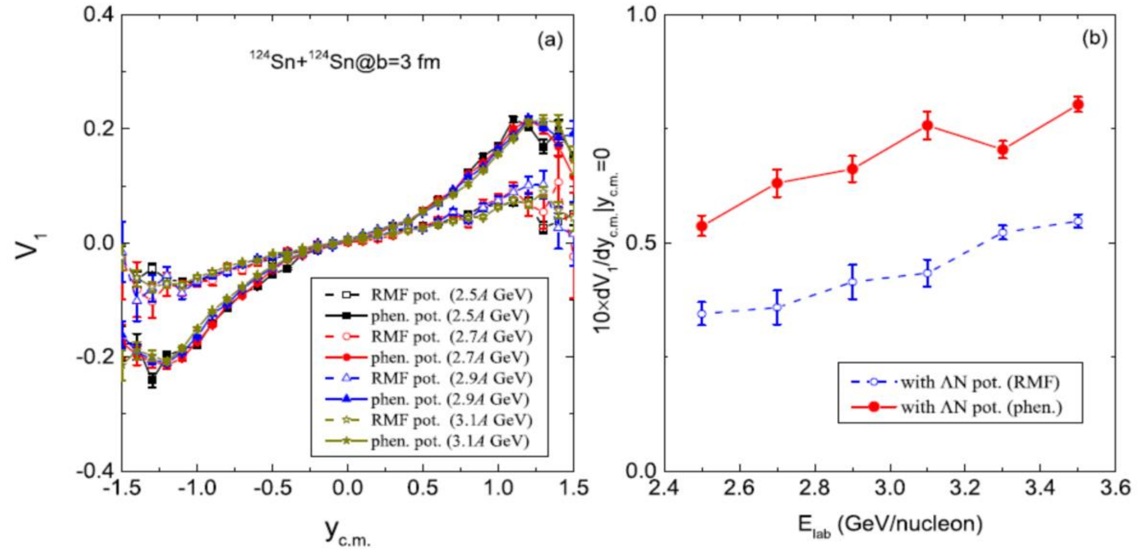


Extracting the hyperon-nucleon interaction via collective flows in heavy-ion collisions

Phys. Lett. B 851 (2024) 138580







The general flavor SU(3) symmetry

Phys. Lett. B 853 (2024) 138658

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Letter

Correlation of the hyperon potential stiffness with hyperon constituents in neutron stars and heavy-ion collisions

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LQMD.RMF

$$\mathcal{L}_{int} = \sum_B \bar{\psi}_B [g_{B\sigma}\sigma - \gamma_\mu (g_{B\omega}\omega^\mu + g_{B\phi}\phi^\mu + g_{B\rho}\vec{\tau}\cdot\vec{b}^\mu)$$

$$]\psi_B - \frac{1}{3}g_2\sigma^3 - \frac{1}{4}g_3\sigma^4,$$

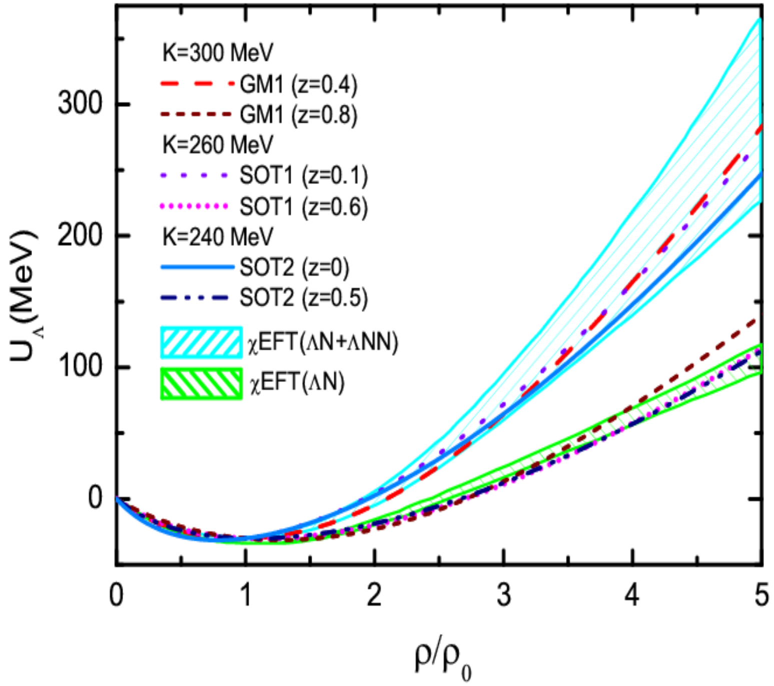
$$\frac{g_{\Lambda\omega}}{g_{N\omega}} = \frac{g_{\Sigma\omega}}{g_{N\omega}} = \frac{\sqrt{2}}{\sqrt{2}+\sqrt{3}z},$$

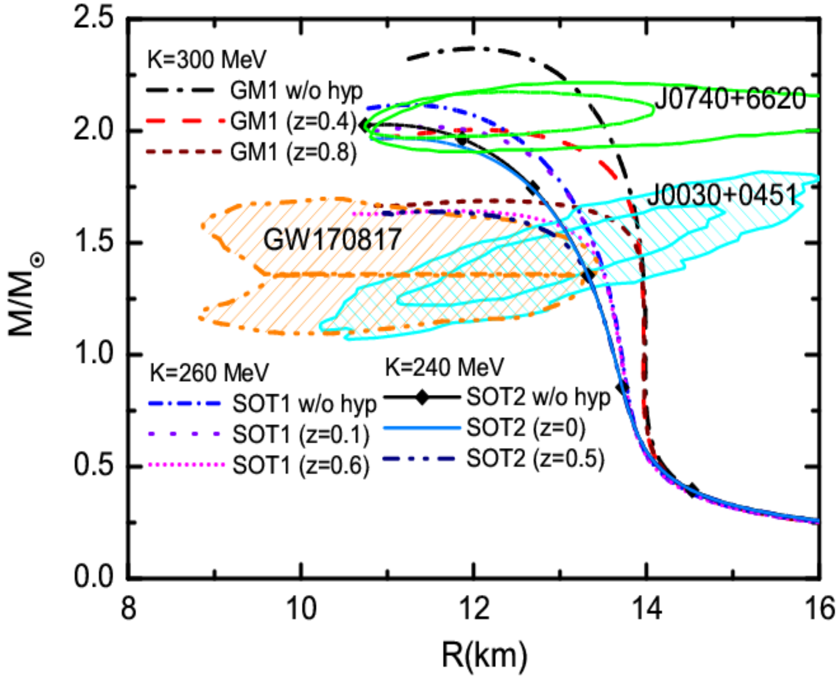
$$\frac{g_{\Lambda\phi}}{g_{N\omega}} = \frac{g_{\Sigma\phi}}{g_{N\omega}} = \frac{-1}{\sqrt{2}+\sqrt{3}z},$$

$$\frac{g_{\Xi\omega}}{g_{N\omega}} = \frac{\sqrt{2}-\sqrt{3}z}{\sqrt{2}+\sqrt{3}z},$$

$$\frac{g_{\Xi\phi}}{g_{N\omega}} = -\frac{1+\sqrt{6}z}{\sqrt{2}+\sqrt{3}z},$$

$$\frac{g_{N\phi}}{g_{N\omega}} = -\frac{\sqrt{6}z-1}{\sqrt{2}+\sqrt{3}z}.$$

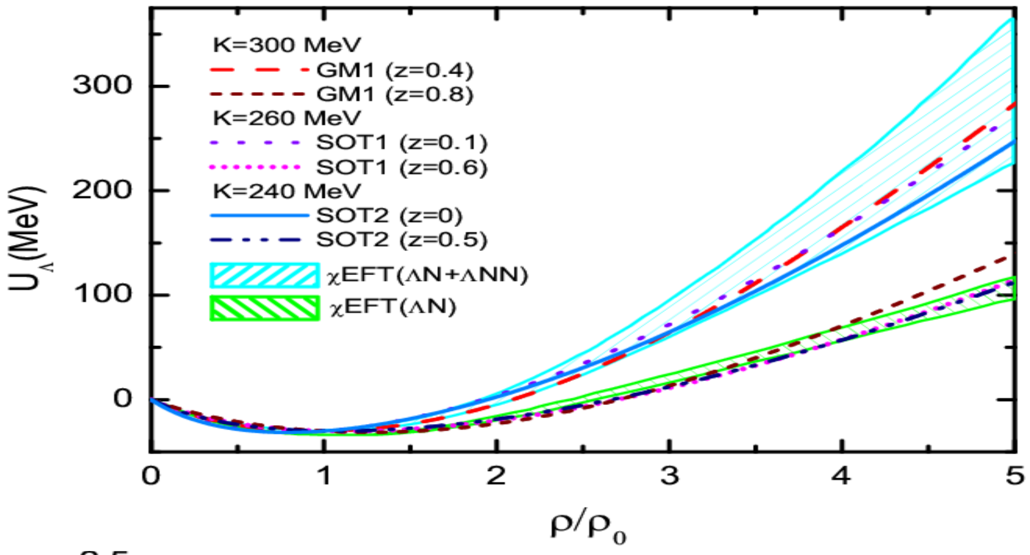


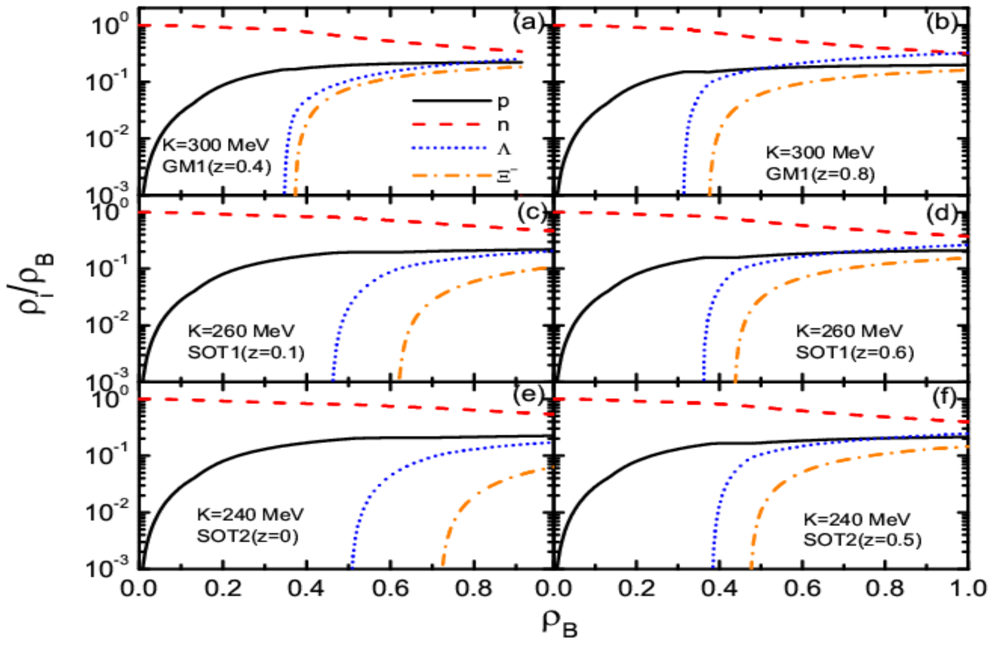


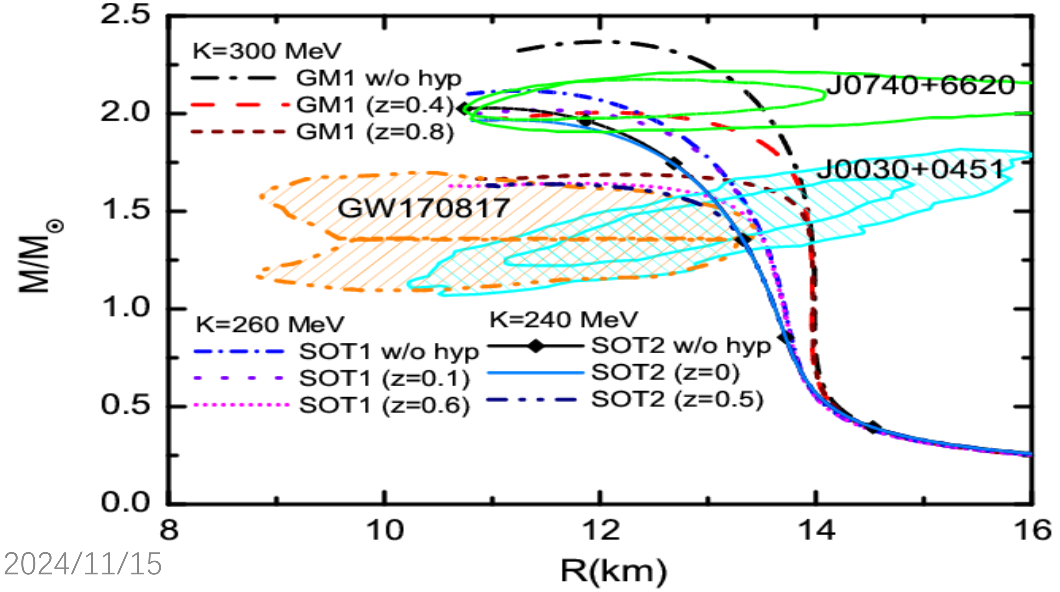
$$U_\Lambda(\rho_0) = -U_\Sigma(\rho_0) = -30\ \text{MeV},\ U_\Xi(\rho_0) = -14\ \text{MeV}$$

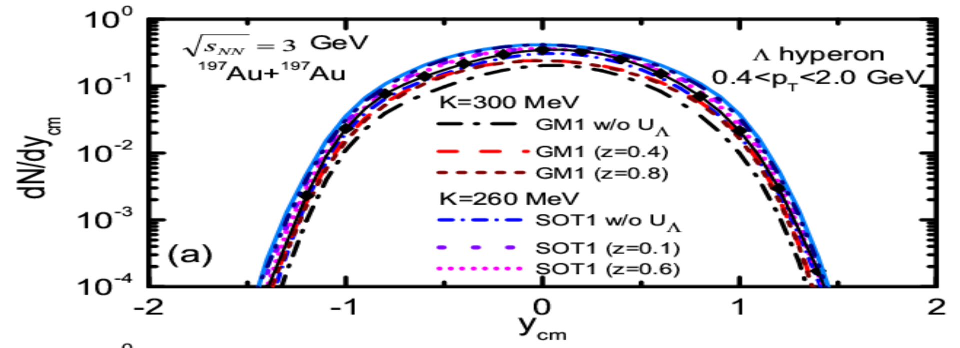
Correlation of the hyperon potential stiffness with hyperon constituents in neutron stars and heavy-ion collisions

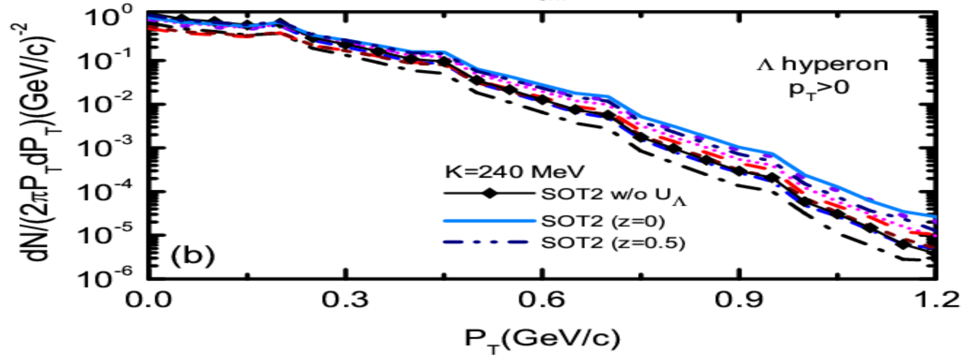
Si-Na Wei, ZQF, Wei-Zhou Jiang, PLB 853 (2024) 138658











High-density symmetry energy from hyperon production in heavy-ion collisions, Physics Letters B 846 (2023) 138180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Probing the high-density symmetry energy from subthreshold hyperon production in heavy-ion collisions

Zhao-Qing Feng
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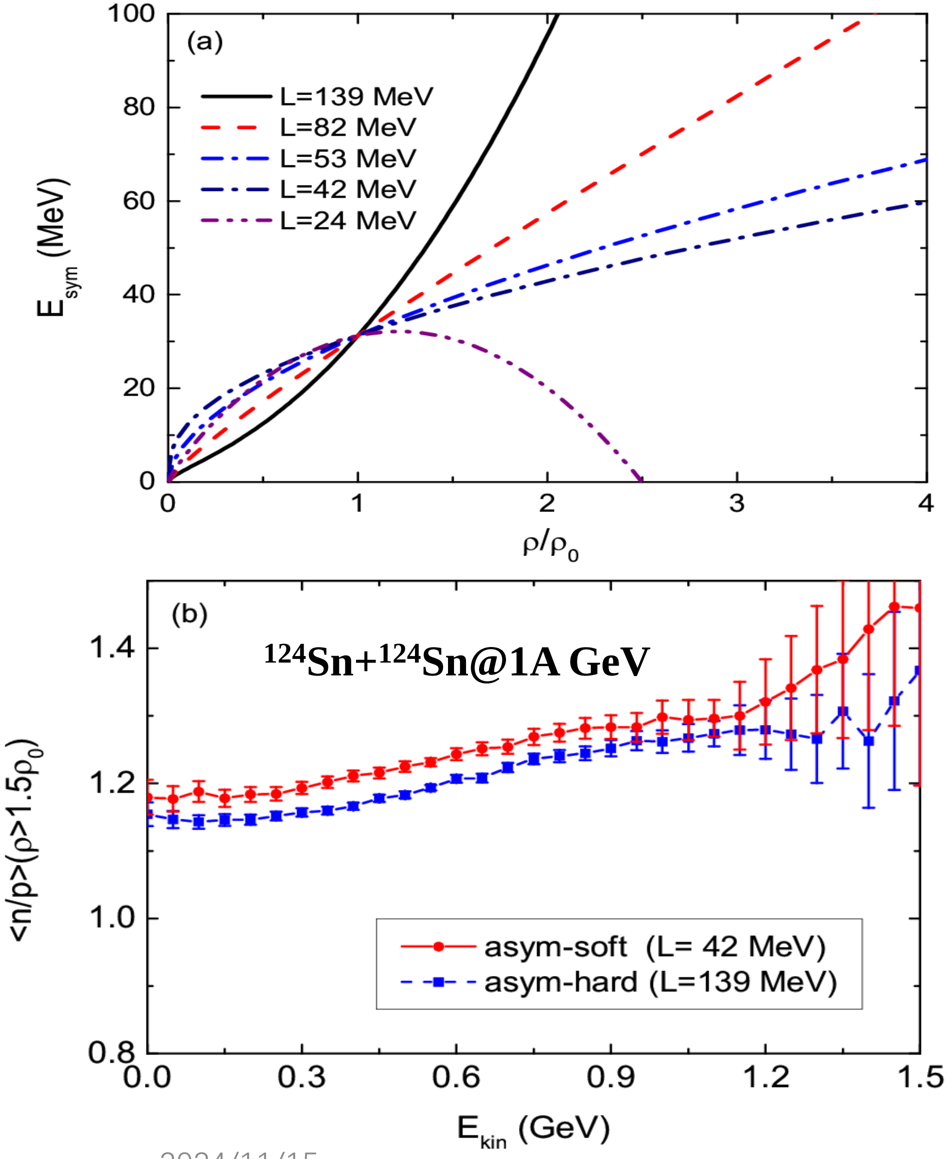
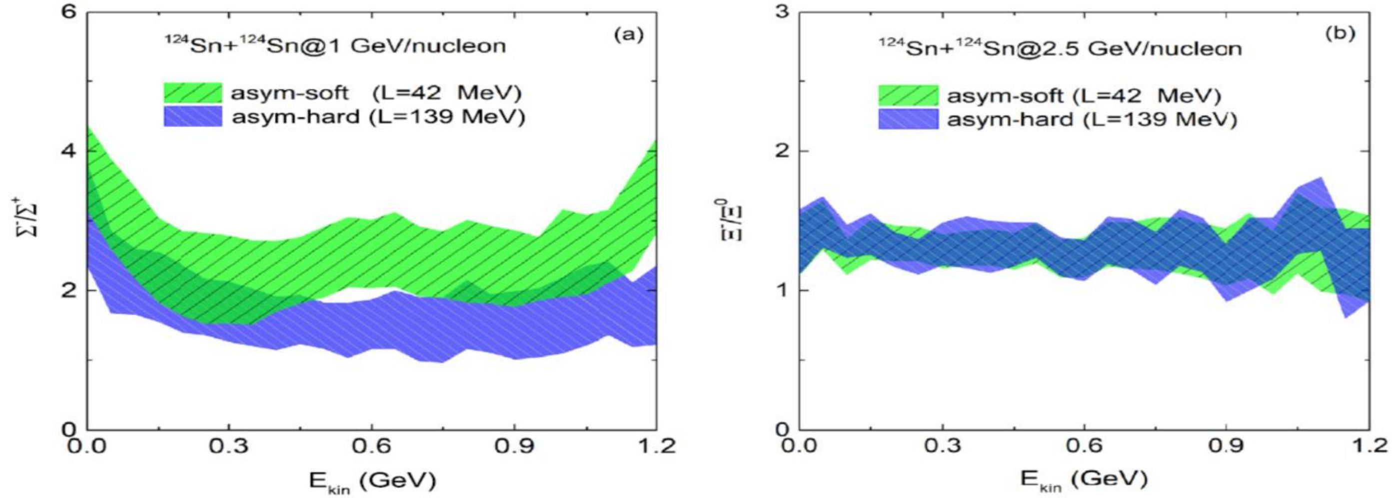
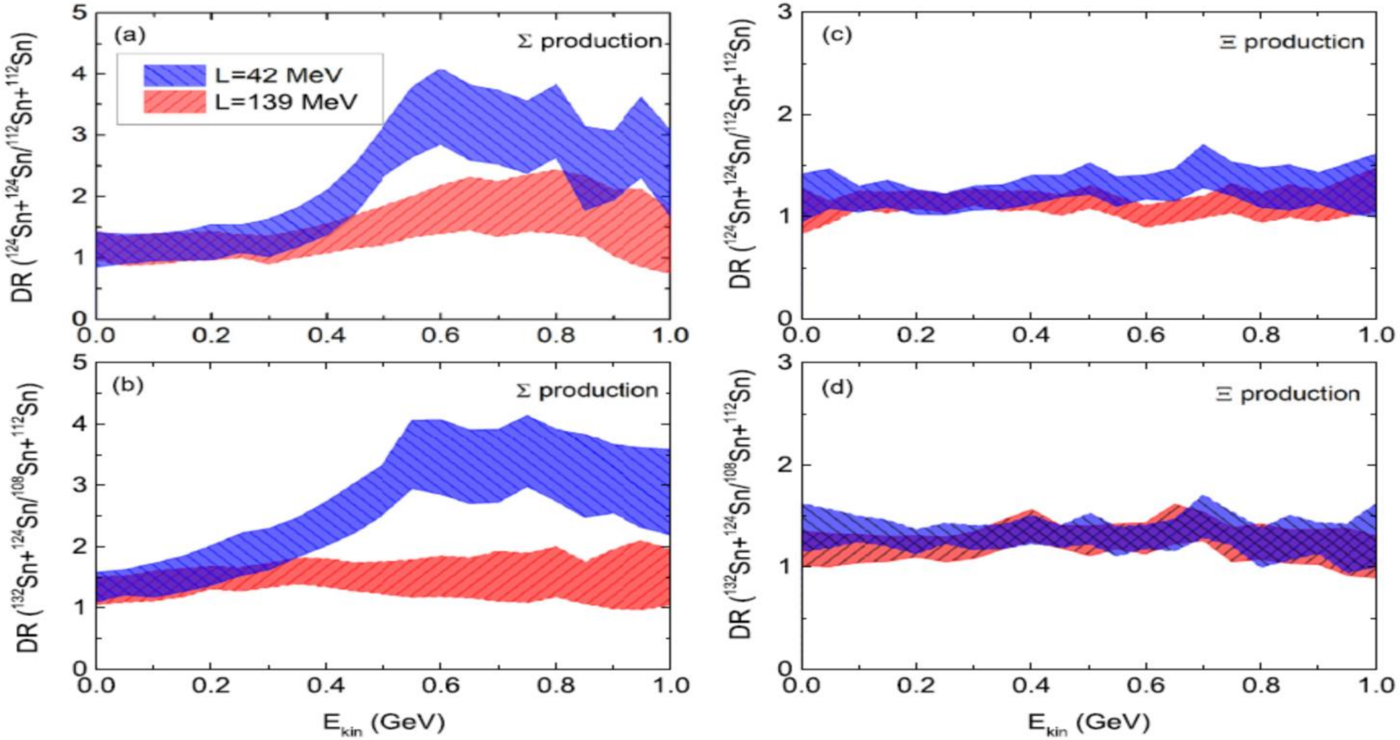




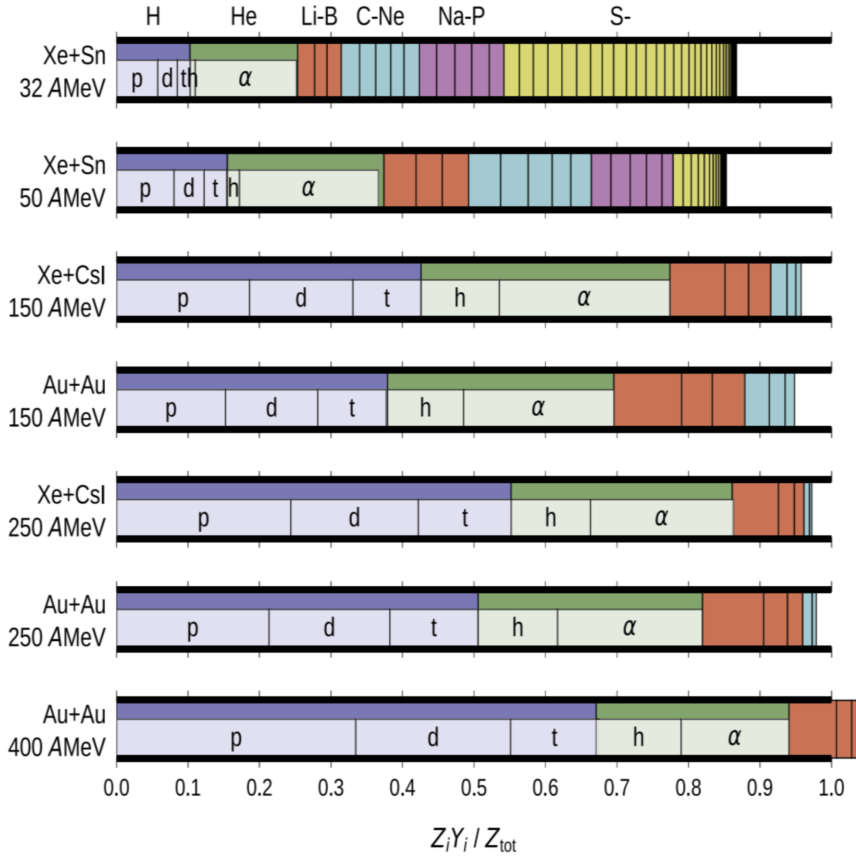


IV. 超核产生动力学研究

Kinetic approach for cluster production

P. Danielewicz, G. F. Bertsch, Nuclear Physics A 533 (1991) 712-748
Akira Ono, Prog. Part. Nucl. Phys. 105, 139-179 (2019)
R. Wang, Y. G. Ma, L. W. Chen et al., Phys. Rev. C 108, L031601 (2023)
Hui-Gan Cheng, Zhao-Qing Feng, Phys. Rev. C 109, L021602 (2024)

Year	models	Author(s)	Cluster(s)	Energy	Treatment(s)
1991	pBUU	P. Danielewicz et al.	d, t, h	fermi /intermediate energies	kinetic, Mott cut
2013	AMD-cluster	A. Ono	$2N, 3N, \alpha$	fermi /intermediate energies	kinetic, fermionic mean field
2021	SMASH	J. Staudenmaier et al.	d	GeV and higher	kinetic
2022	PHQMD	G. Coci et al.	d	GeV and higher	kinetic
2023	IBUU	R. Wang et al.	d, t, h, α	intermediate energies	kinetic, Mott cut
2023	LQMD	H. G. Cheng and Z. Q. Feng	d, t, h, α	fermi /intermediate energies	Kinetic, binding energy, Pauli effects



Clusters are produced by multinucleon or nucleon-cluster collisions

$$\frac{d\sigma}{d\Omega} = P(C_1 + C_2 \to C_3 + C_4) \times \frac{v_{\tilde{p}_{\rm rel}}}{v} \frac{\left|[\partial e(k)/\partial k]_{k=\tilde{p}_{\rm rel}}\right|}{\left|[\partial H(p_f)/\partial p_f]_{p_f=p_{\rm rel}}\right|} \frac{p_{\rm rel}^2}{\tilde{p}_{\rm rel}^2} \left[\frac{d\sigma_{\rm NN}}{d\Omega}\right]_{\tilde{p}_{\rm rel}}$$

$N_1+N_2 \leftrightarrow$ deuteron, $N_1+N_2+D_1 \rightarrow$ deuteron $+N'_1$, $N_1+N_2+N_3 \leftrightarrow$ triton (helium-3),

$N_1+N_2+N_3+D_1 \rightarrow$ triton (helium-3) $+N'_1$, $N_1+N_2+N_3+N_4 \leftrightarrow$ alpha

$p+\Lambda \leftrightarrow {}^2_\Lambda H$, $p+\Lambda+n \leftrightarrow {}^3_\Lambda H$, $p+\Lambda+n+n \leftrightarrow {}^4_\Lambda H$, $p+\Lambda+\Lambda \leftrightarrow {}^3_{\Lambda\Lambda} H$, $p+n+\Lambda+\Lambda \leftrightarrow {}^4_{\Lambda\Lambda} H$

…

PHYSICAL REVIEW C 109, L021602 (2024)
Letter

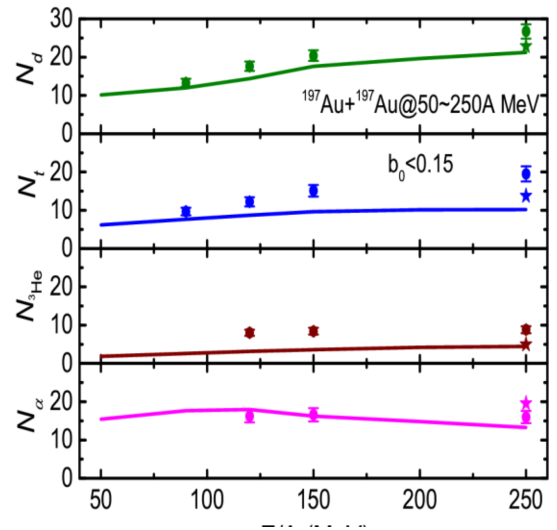
Novel approach to light-cluster production in heavy-ion collisions

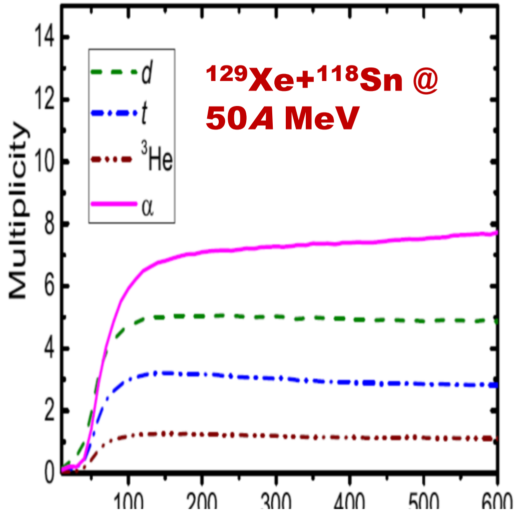
Hui-Gan Cheng and Zhao-Qing Feng
School of Physics and Optoelectronics, South China University of Technology, Guangzhou 510640, China

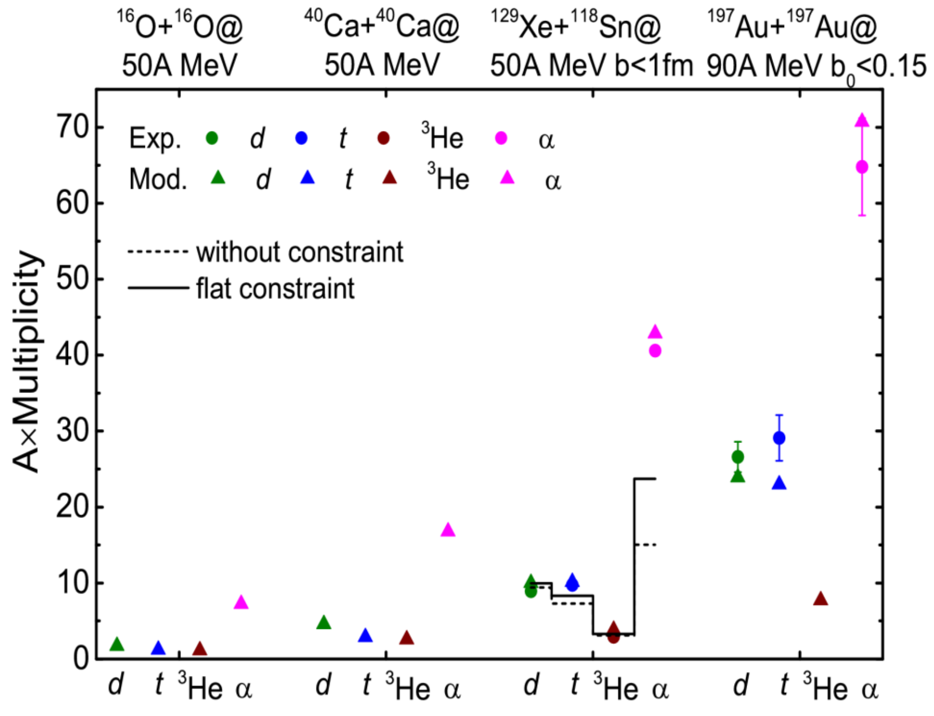
(Received 8 November 2023; accepted 25 January 2024; published 15 February 2024)

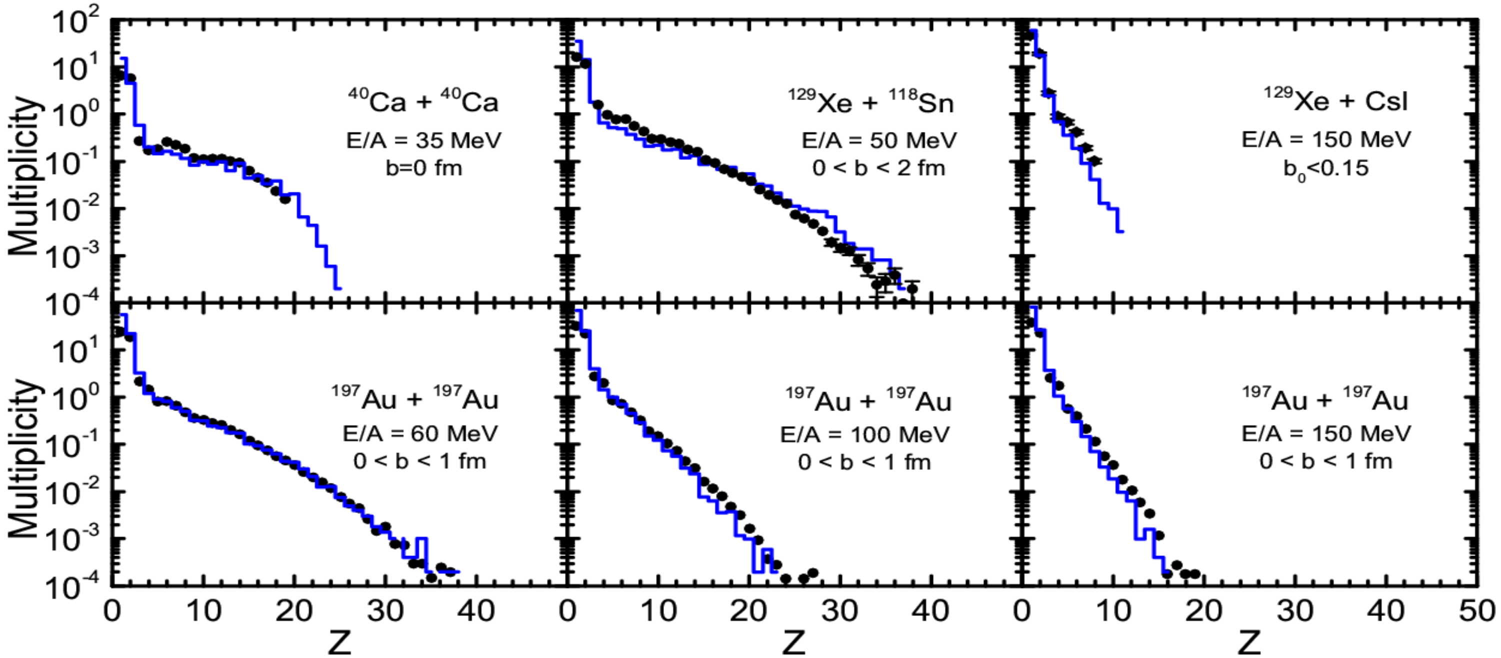
Kinetic approach for cluster production (LQMD.cluster)

$$
\begin{aligned}
H &= \sum_i \frac{\mathbf{p}_i^2}{2m} + \frac{\alpha}{2}\sum_{\substack{i,j\\ j\neq i}} \frac{\rho_{ij}}{\rho_0} + \frac{\beta}{1+\gamma}\sum_i \left(\sum_{j,j\neq i} \frac{\rho_{ij}}{\rho_0}\right)^{\gamma} \\
&+ \frac{C_{sym}}{2}\sum_{\substack{i,j\\ j\neq i}} t_{z_i} t_{z_j} \frac{\rho_{ij}}{\rho_0} + \frac{g_{\rm sur}}{2}\sum_{\substack{i,j\\ j\neq i}}{}' \left[\frac{3}{2L} - \left(\frac{\mathbf{r}_i - \mathbf{r}_j}{2L}\right)^2\right]\frac{\rho_{ij}}{\rho_0} \\
&+ \sum_i^{N_C} E^i_{\rm z.p.} + \sum_i^{N_d} V_{\rm corr} e^{-r_i^2/4L}
\end{aligned}
$$









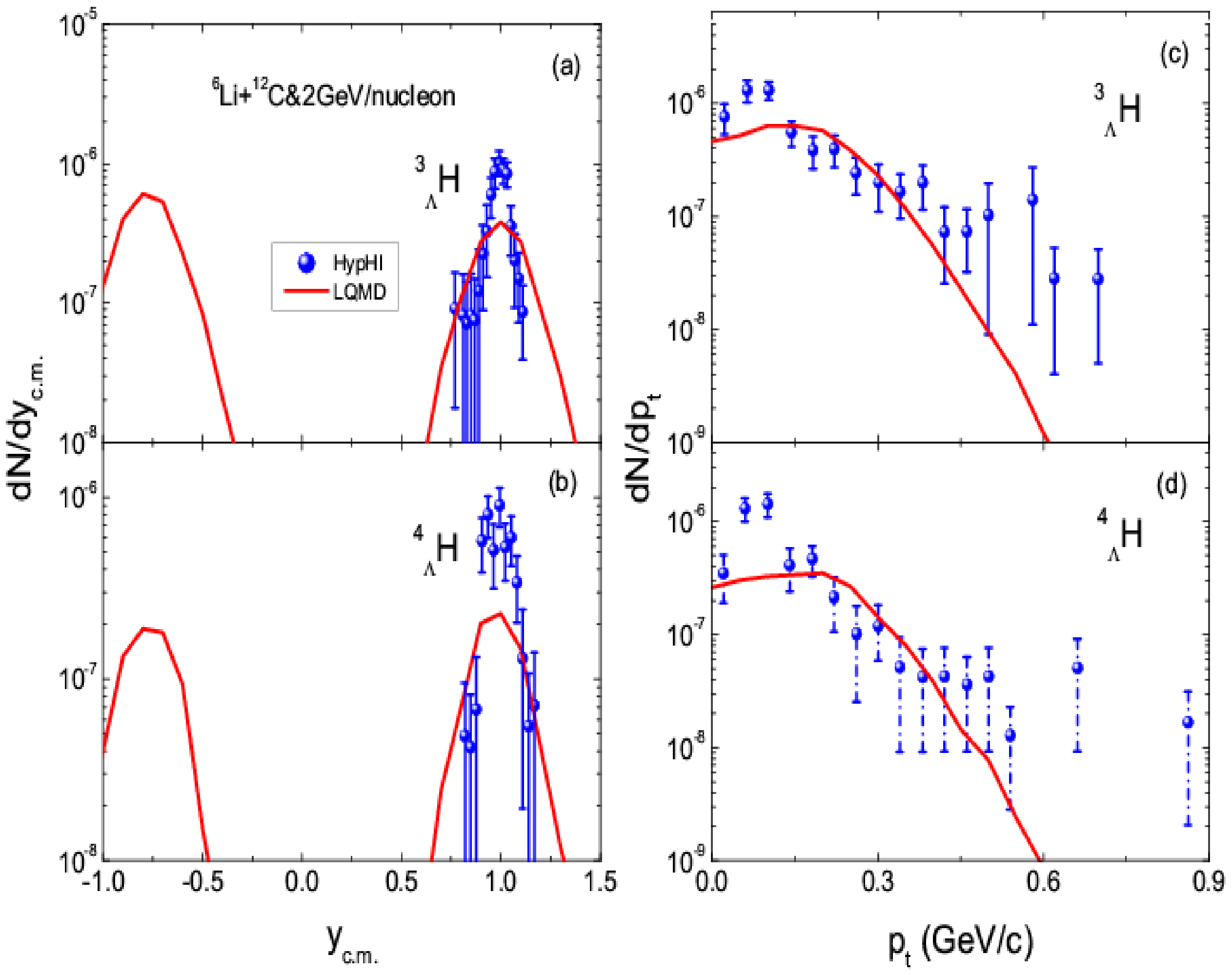
Hypernuclide production via HICs *(Wigner density approach)*

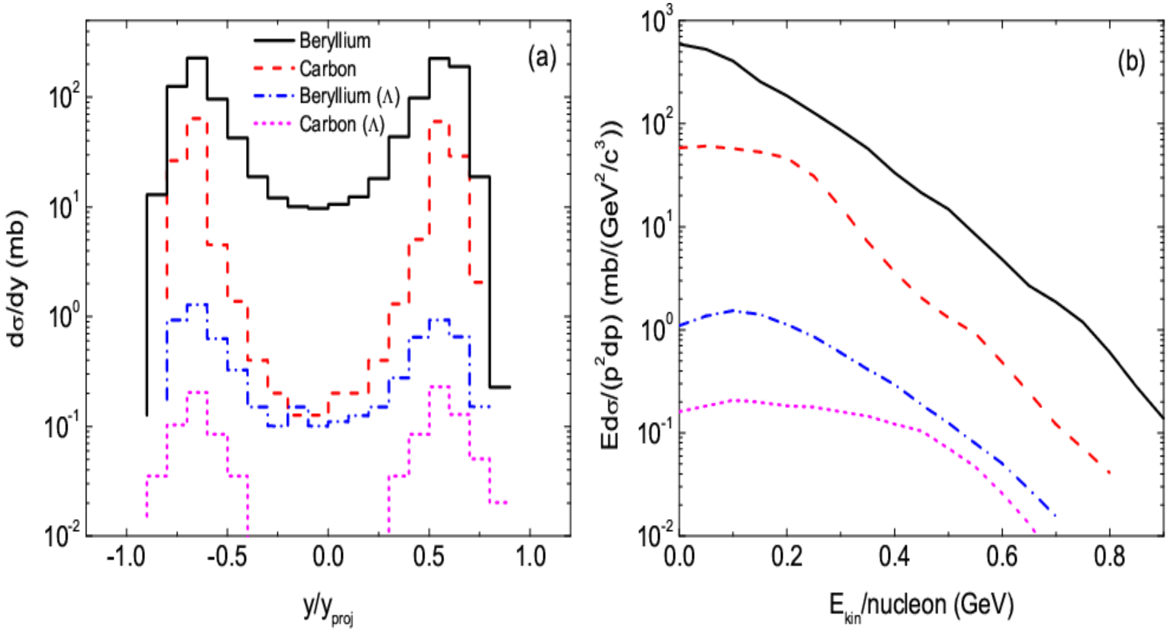
$^{124}Sn+^{124}Sn$@2*A* GeV

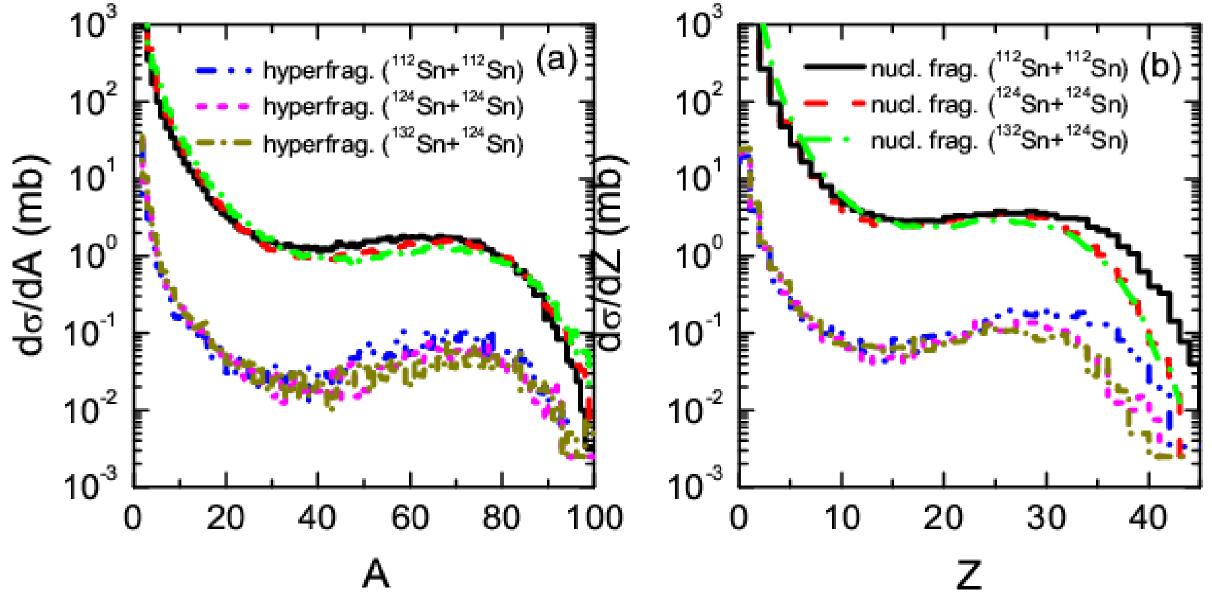
Z. Q. Feng, Phys. Rev. C 102, 044604 (2020)

Data: C. Rappold et al., (HypHI collaboration)

Phys. Lett. B 747, 129 (2015)

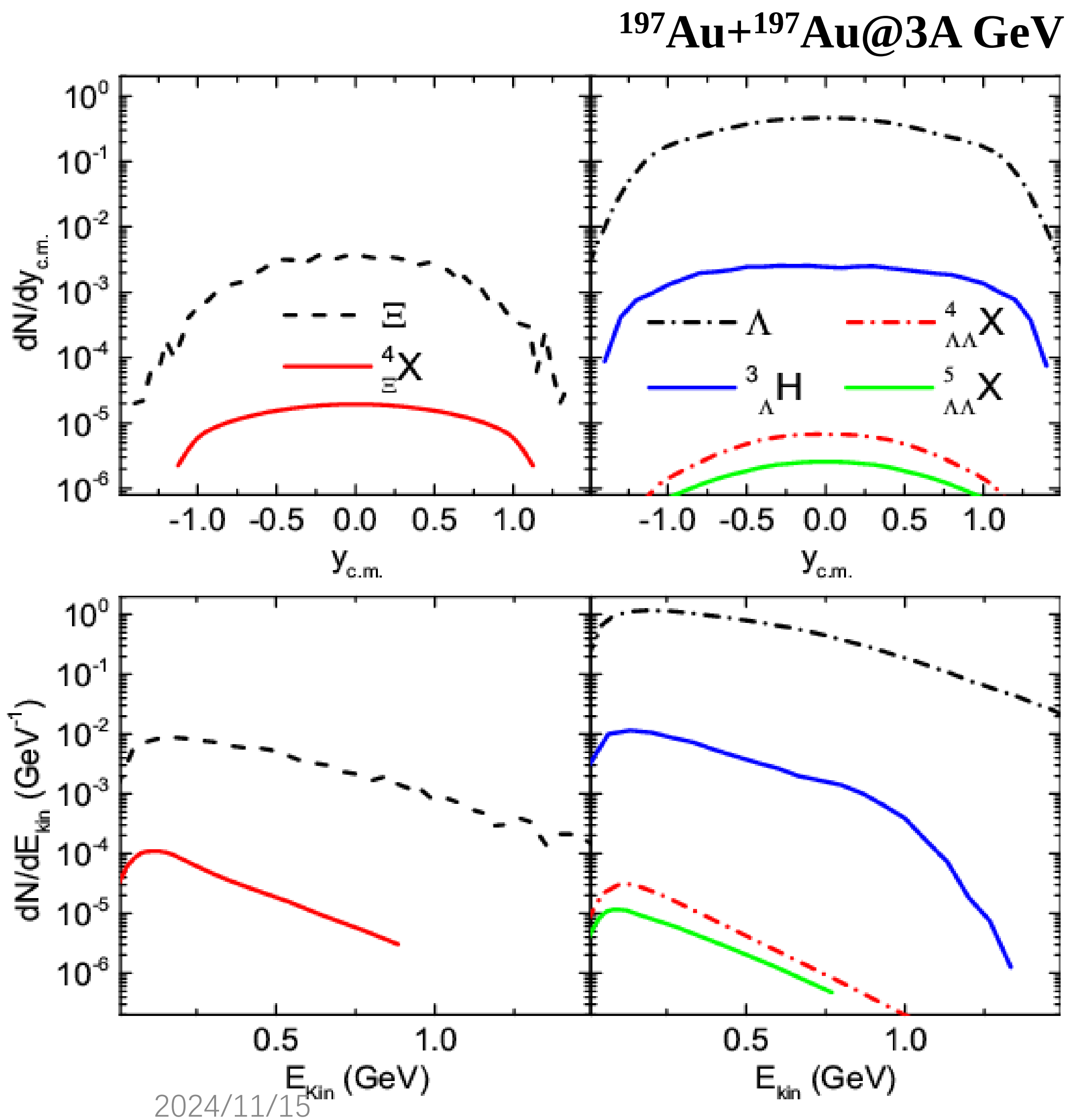


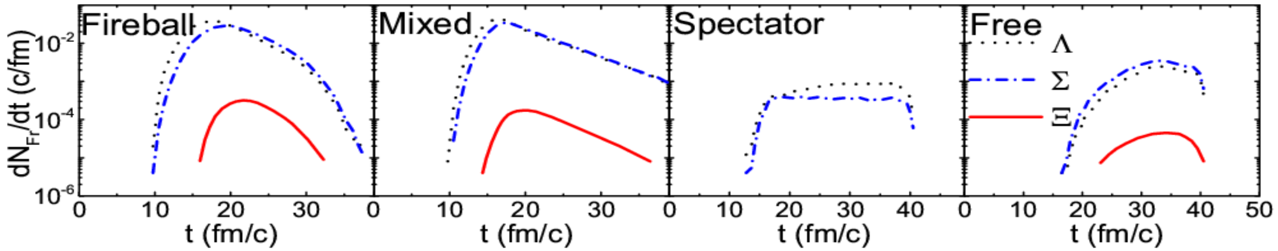




Multi-strangeness hypernuclide production

H.G. Cheng, Z. Q. Feng, Phys. Lett. B 824 (2022) 136849





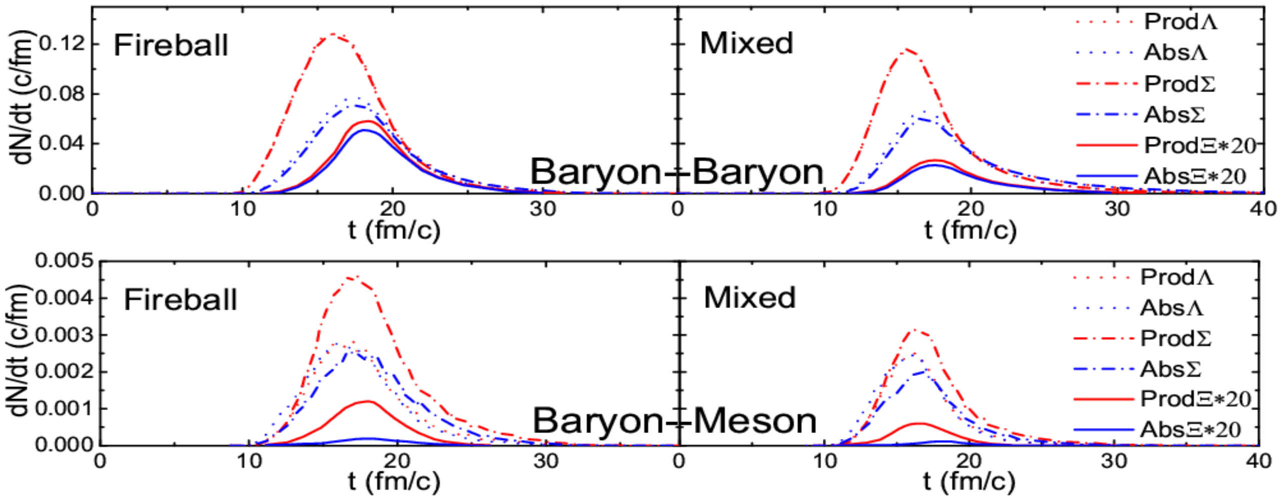


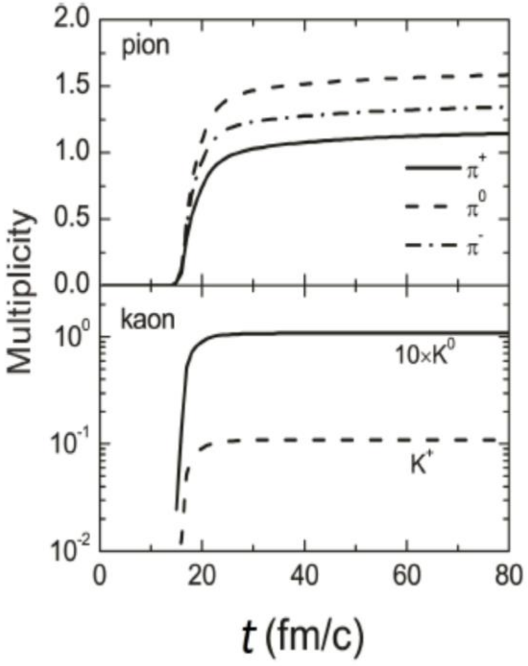
TABLE I. Comparison between cross sections of double lamda hypernuclei calculated with r_0 = 3.5 fm for Λ in ^{197}Au + ^{197}Au and ^{40}Ca + ^{40}Ca collisions at 3*A* GeV

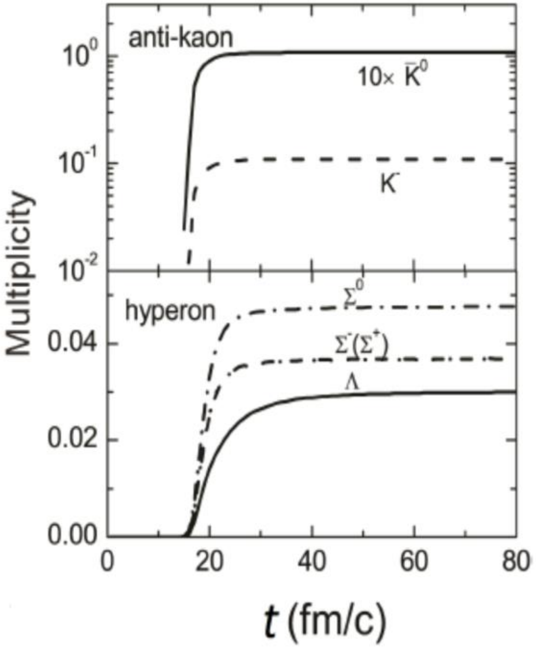
Hypernuclei	Cross sections (mb)	
	^{197}Au + ^{197}Au	^{40}Ca + ^{40}Ca
$^{4}_{\Lambda\Lambda}$H	2.6×10^{-2}	1.0×10^{-4}
$^{4}_{\Lambda\Lambda}$He	1.0×10^{-2}	$\sim 10^{-5}$
$^{5}_{\Lambda\Lambda}$H	5.9×10^{-3}	$\sim 10^{-5}$
$^{5}_{\Lambda\Lambda}$He	5.1×10^{-3}	$\sim 10^{-5}$
$^{5}_{\Lambda\Lambda}$Li	1.4×10^{-3}	$\sim 10^{-6}$
$^{6}_{\Lambda\Lambda}$He	2.2×10^{-3}	$\sim 10^{-6}$
$^{7}_{\Lambda\Lambda}$He	6.8×10^{-4}	$\lesssim 10^{-6}$

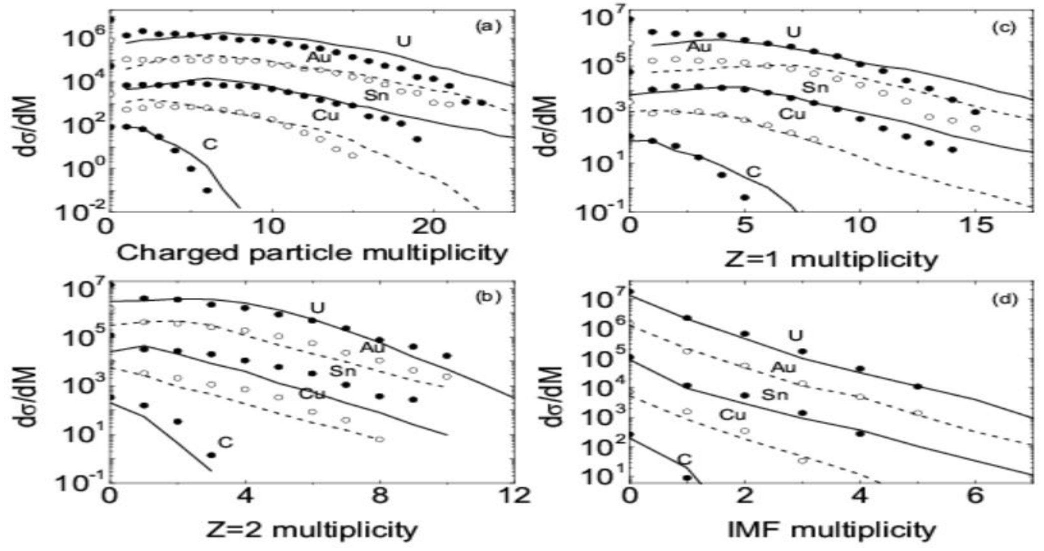
IV. HIAF装置π介子和反质子束流相关物理讨论

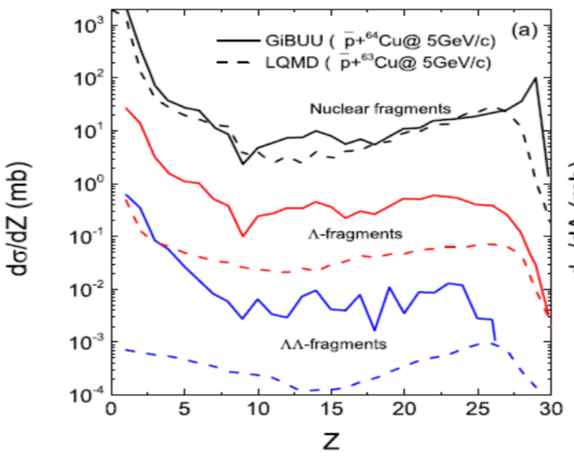
(Hyper) nuclear fragments with antiproton induced reactions

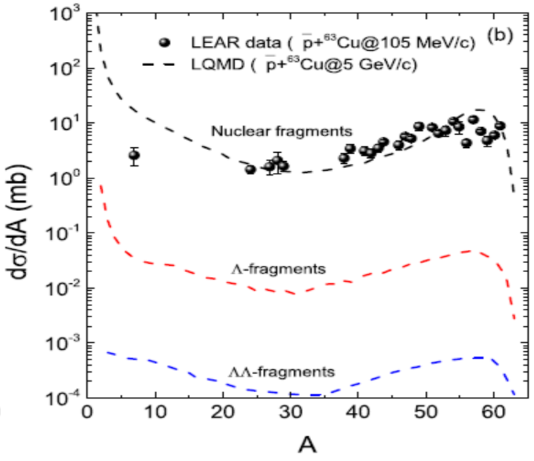
Zhao-Qing Feng, Physical Review C 101, 064601 (2020); 93, 041601(R) (2016)

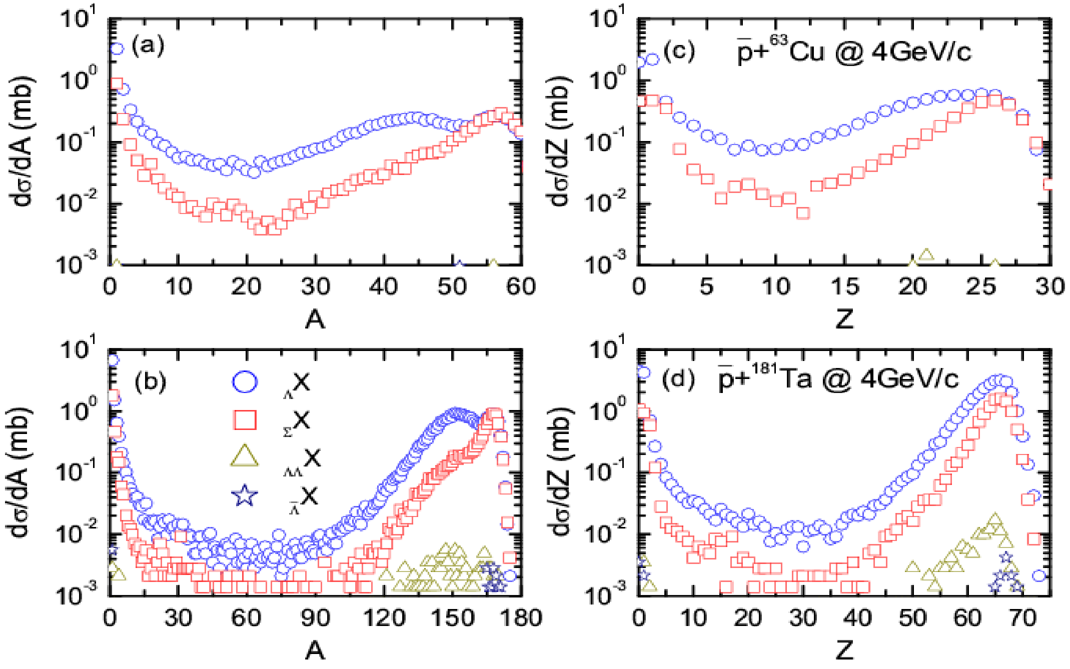












PHYSICAL REVIEW C **94**, 054617 (2016)

Nuclear fragmentation and charge-exchange reactions induced by pions in the Δ-resonance region

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(Received 5 September 2016; revised manuscript received 11 October 2016; published 18 November 2016)

The dynamics of the nuclear fragmentations and the charge exchange reactions in pion-nucleus collisions near the Δ(1232) resonance energies has been investigated within the Lanzhou quantum molecular dynamics transport model. An isospin-, momentum-, and density-dependent pion-nucleon potential is implemented in the model, which influences the pion dynamics, in particular the kinetic energy spectra, but weakly impacts the fragmentation mechanism. The absorption process in pion-nucleon collisions to form the Δ(1232) resonance dominates the heating mechanism of the target nucleus. The excitation energy transferred to the target nucleus increases with the pion kinetic energy and is similar for both π^-- and π^+-induced reactions. The magnitude of fragmentation of the target nucleus weakly depends on the pion energy. The isospin ratio in the pion double-charge exchange is influenced by the isospin ingredient of target nucleus.

DOI: 10.1103/PhysRevC.94.054617

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进 展 强流重离子加速器及其科学研究专题

基于HIAF集群的高强度缪子、反质子次级束产生及其物理研究展望

孙志宇[1,2*], 陈良文[1], 蔡汉杰[1], 李亮[3,4], 尤郑昀[5], 袁野[2,6], 王莹[5], 谢聚军[1,2], 冯兆庆[7], 王世陶[1,2]

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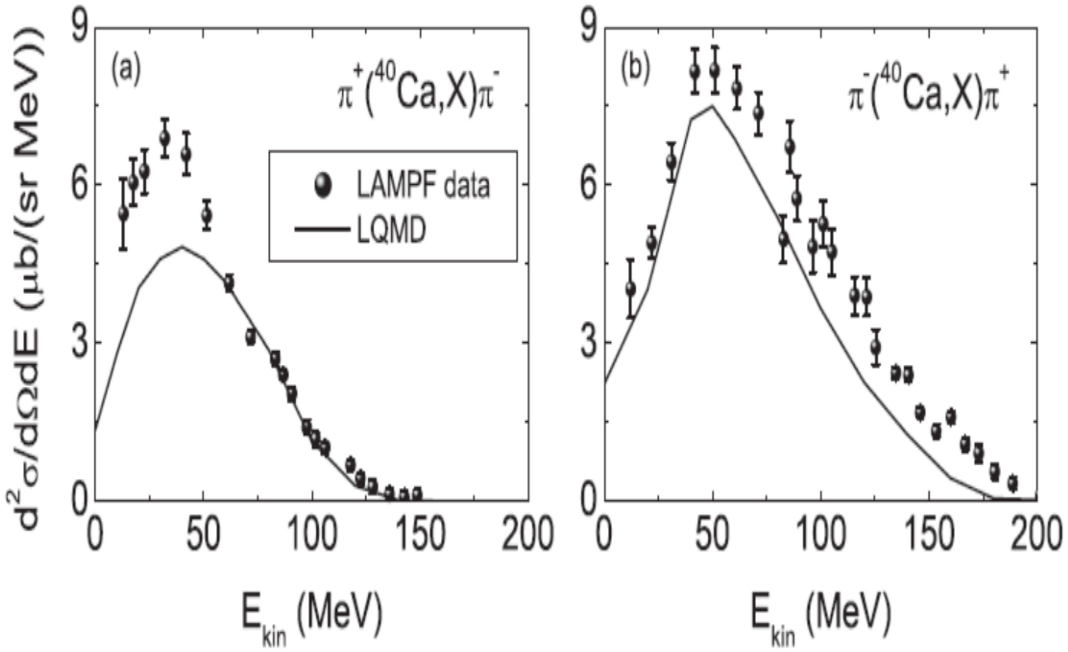
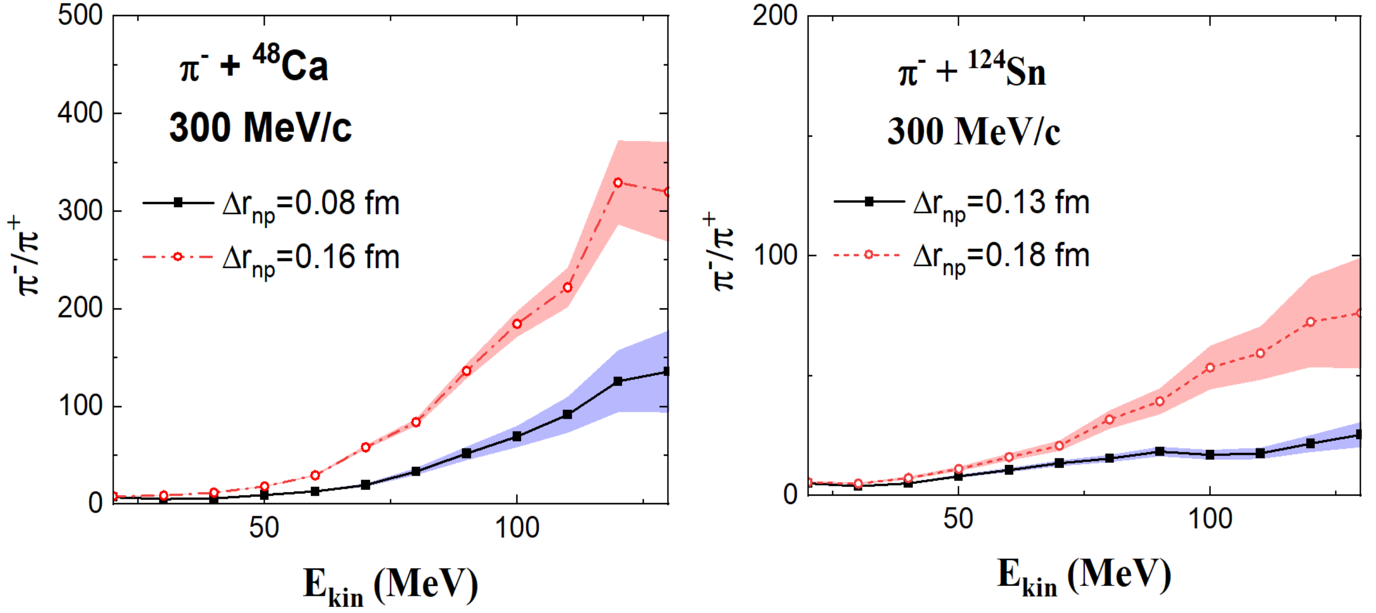
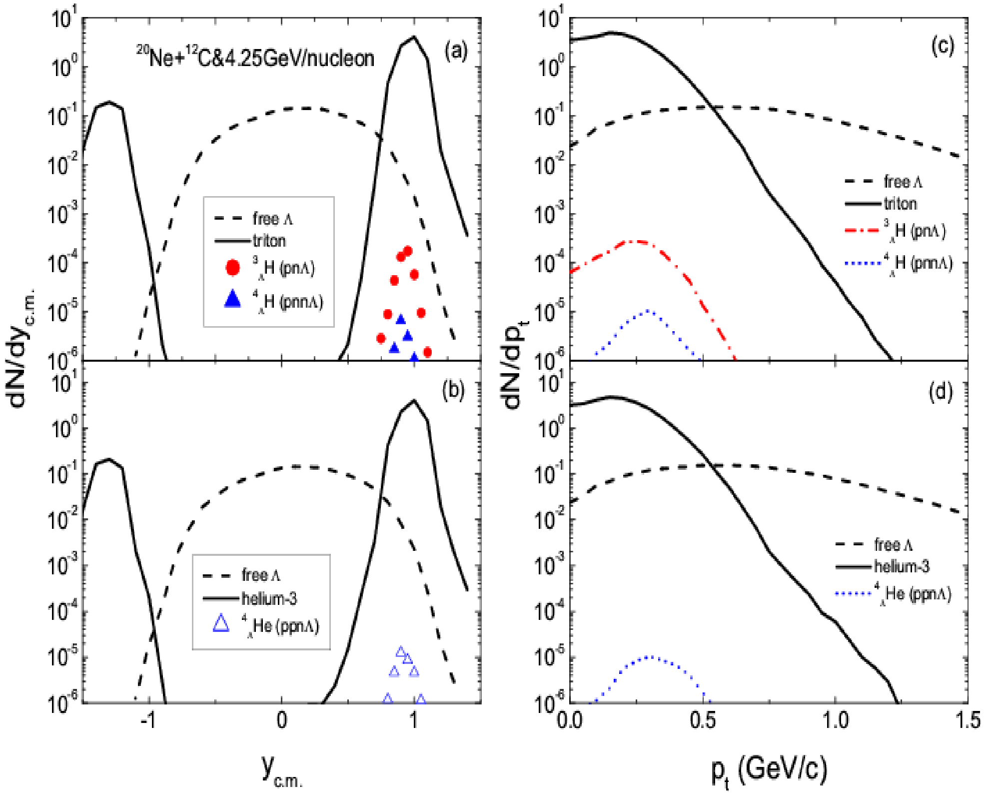
7. 华南理工大学物理与光电学院, 广州 510641
*联系人, E-mail: sunzhy@impcas.ac.cn





VI. 总结和展望

- ➢ The Extremely proton-rich/neutron-rich hypernuclides might be created via heavy-ion collisions at HIAF energies, e.g., $^{3}_{\Lambda}$H and $^{4}_{\Lambda}$H production in the reaction of ^{20}Ne+^{12}C at HIAF.
- ➢ The high-density symmetry probes single and double ratios of Σ^{-}/Σ^{+}(double ratio) via the isotopic reactions ^{112}Sn+^{112}Sn and ^{124}Sn+^{124}Sn, in particular above 0.4 GeV.
- ➢ The 3-body interaction potentials, e.g., ΛNN,ΣNN,ΞNN etc, might be constrained via heavy-ion collisions at HIAF.



- ➢ Antiproton and pion beams are being expected at the HIAF facility for hypernuclear physics, in-medium properties of hadrons, neutron-skin thickness, equation of state.

Thanks for your attention!