Simulations of Pion Productions with pBUU

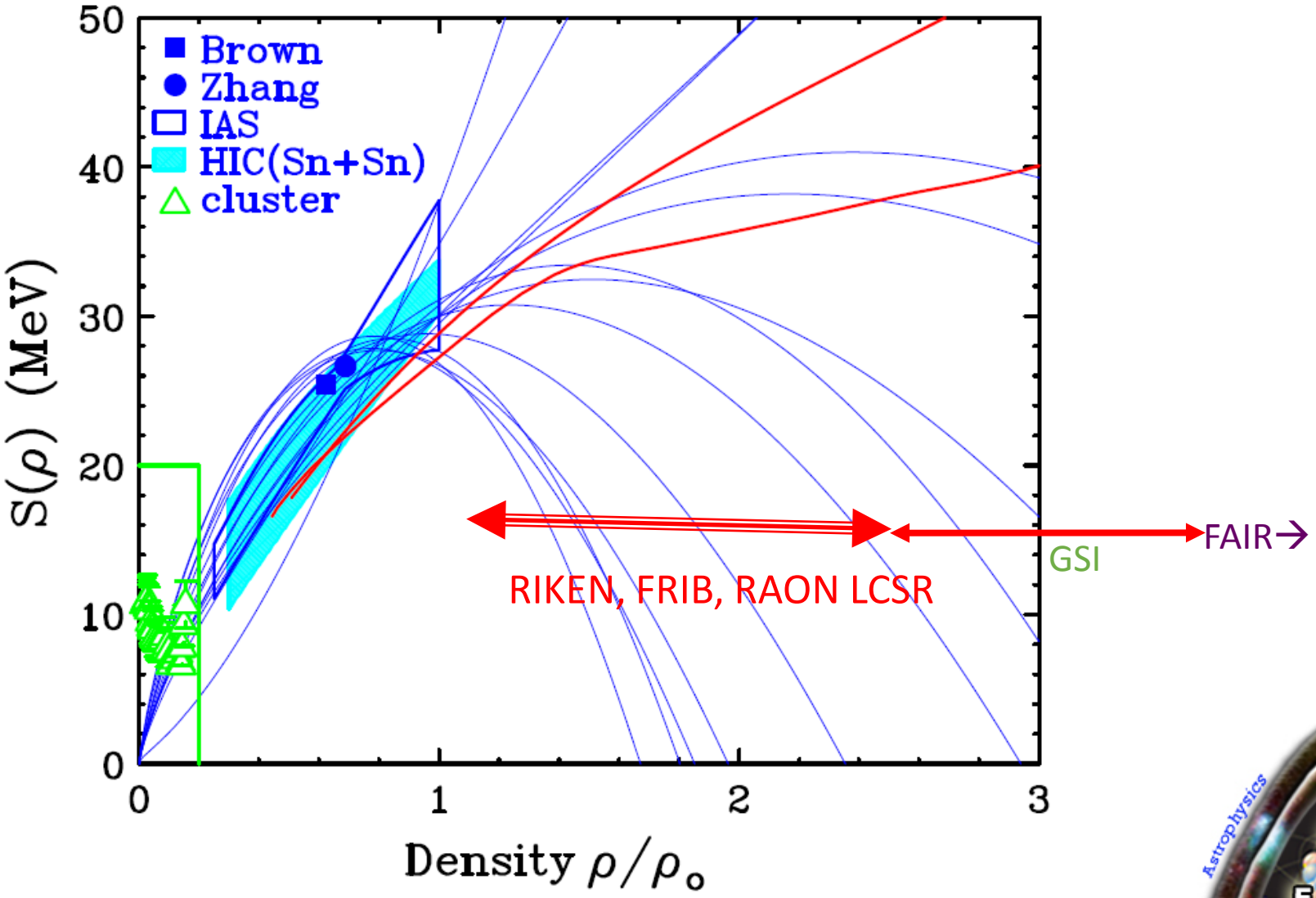
Betty Tsang for SπRIT Collaboration

NSCL

Justin Estee
Jun Hong
Hananiel Setiawan
MengBo Chen
Jon Barney

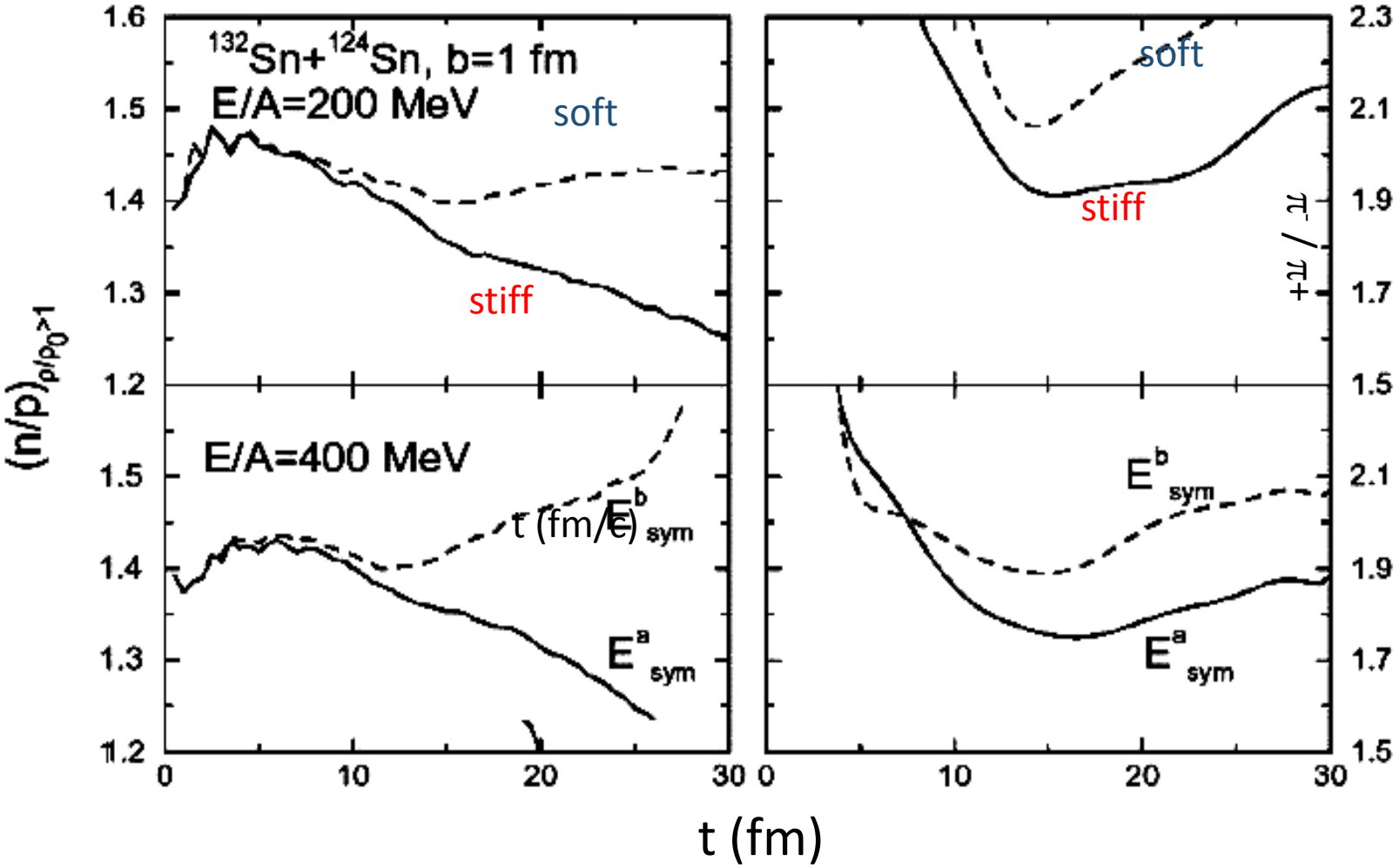
FRIB

Symmetry Energy Project



Pion production and Symmetry Energy

Beyond integrated yields



Delta resonance reactions

$$pp \rightarrow \Delta^{++} \rightarrow pn\pi^+$$

$$nn \rightarrow \Delta^{o} \rightarrow pn\pi^-$$

…ect.

$$\pi^-/\pi^+ \approx (\rho/\rho_0)^2$$

Li et al., Nucl.Phys. A734 (2004) 593.

Systems Simulated with pBUU

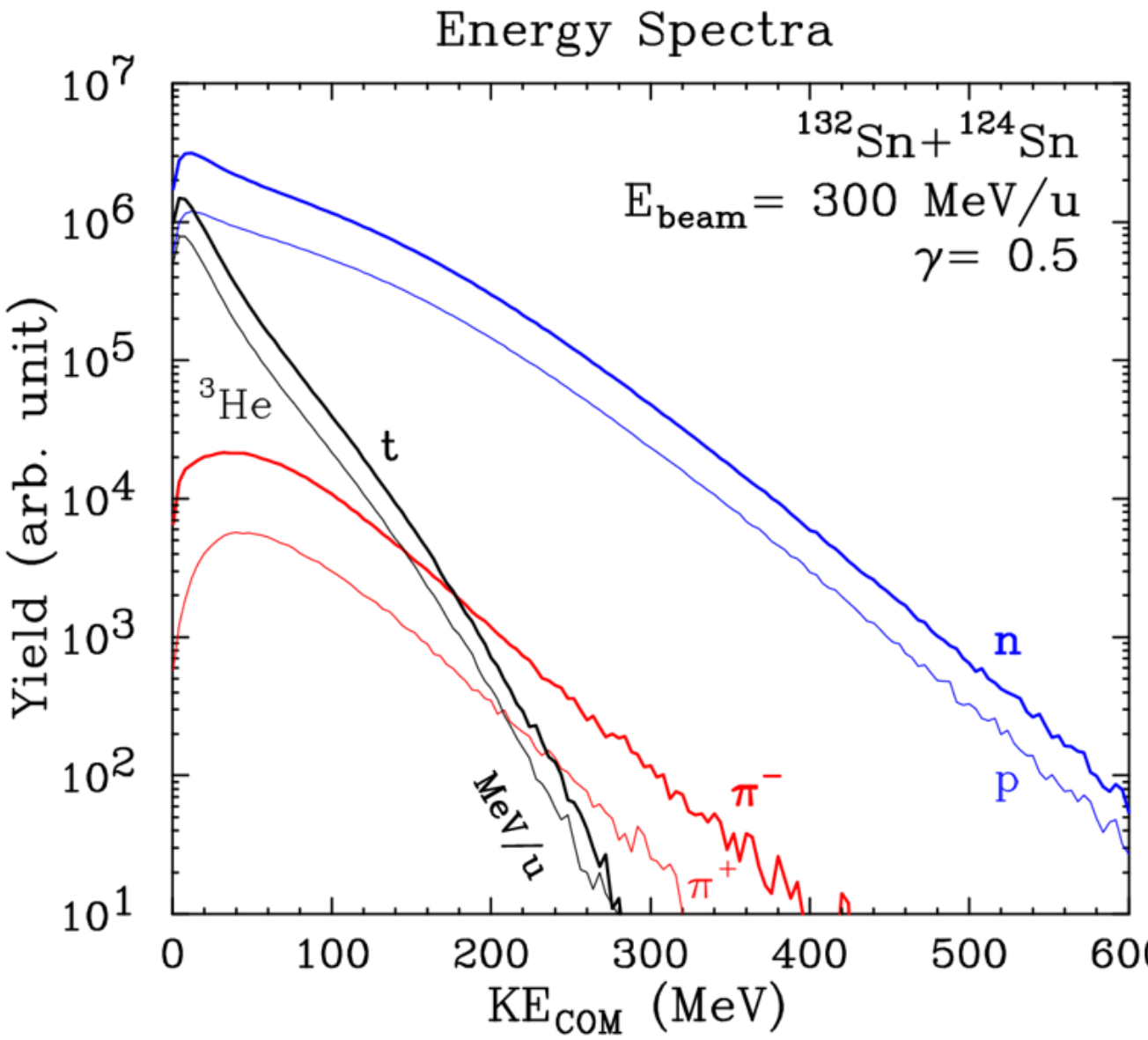
Project	Target	MeV/u	b	γ
Sn132	Sn124	300	3	0.5
Sn132	Sn124	300	3	1.8
Sn108	Sn112	300	3	0.5
Sn108	Sn112	300	3	1.8
Sn132	Sn124	200	3	0.5
Sn132	Sn124	200	3	1.8
Sn108	Sn112	200	3	0.5
Sn108	Sn112	200	3	1.8
Ca48	Sn124	300	1	0.5
Ca48	Sn124	300	1	1.8
Ca40	Sn112	300	1	0.5
Ca40	Sn112	300	1	1.8

MSU students

Justin Estee
Jun Hong
Hananiel Setiawan
MengBo Chen
Jon Barney

Systems Simulations with pBUU

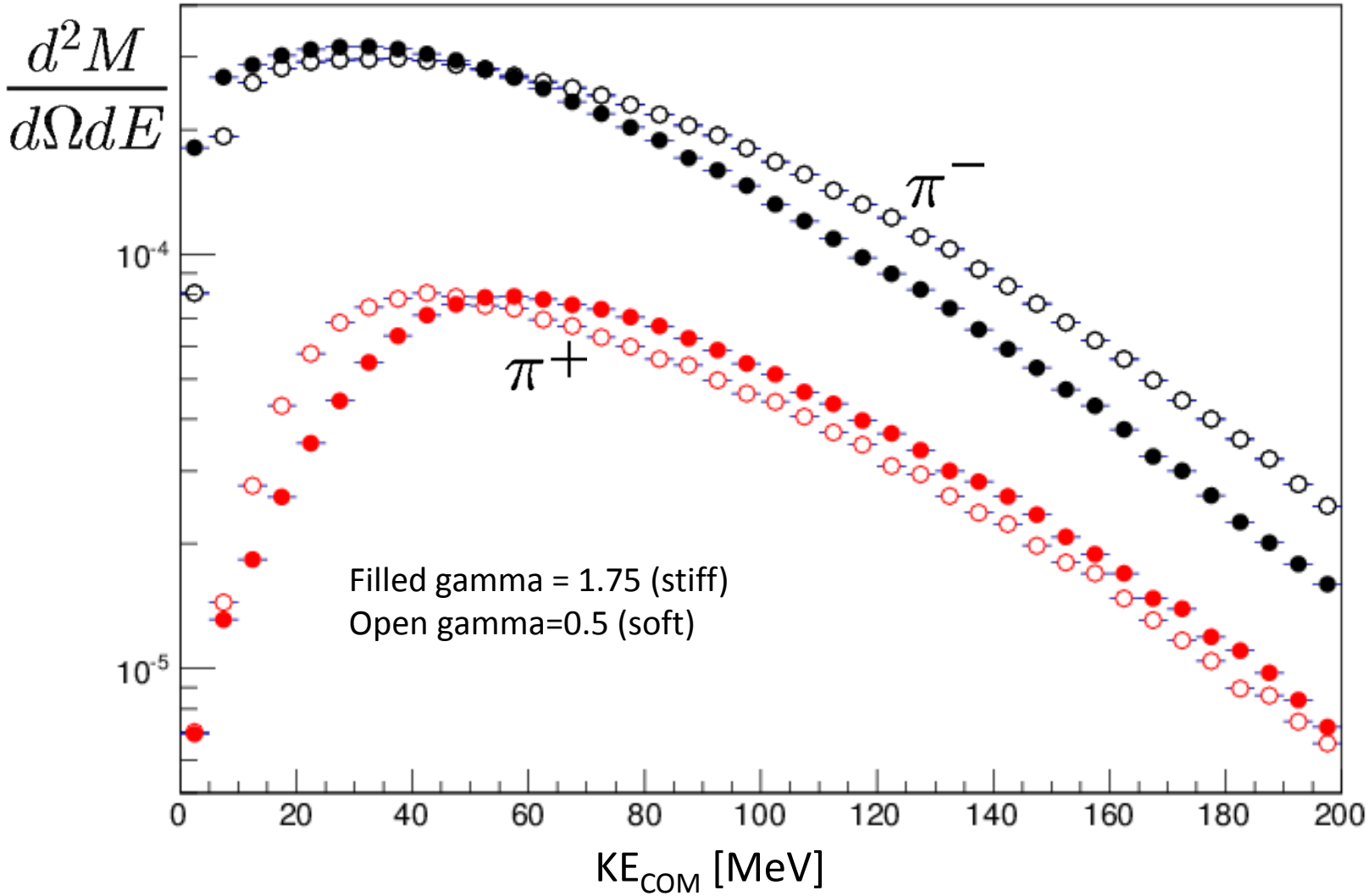
Project	Target	MeV/u	b	γ
Sn132	Sn124	300	3	0.5
Sn132	Sn124	300	3	1.8
Sn108	Sn112	300	3	0.5
Sn108	Sn112	300	3	1.8
Sn132	Sn124	200	3	0.5
Sn132	Sn124	200	3	1.8
Sn108	Sn112	200	3	0.5
Sn108	Sn112	200	3	1.8
Ca48	Sn124	300	1	0.5
Ca48	Sn124	300	1	1.8
Ca40	Sn112	300	1	0.5
Ca40	Sn112	300	1	1.8



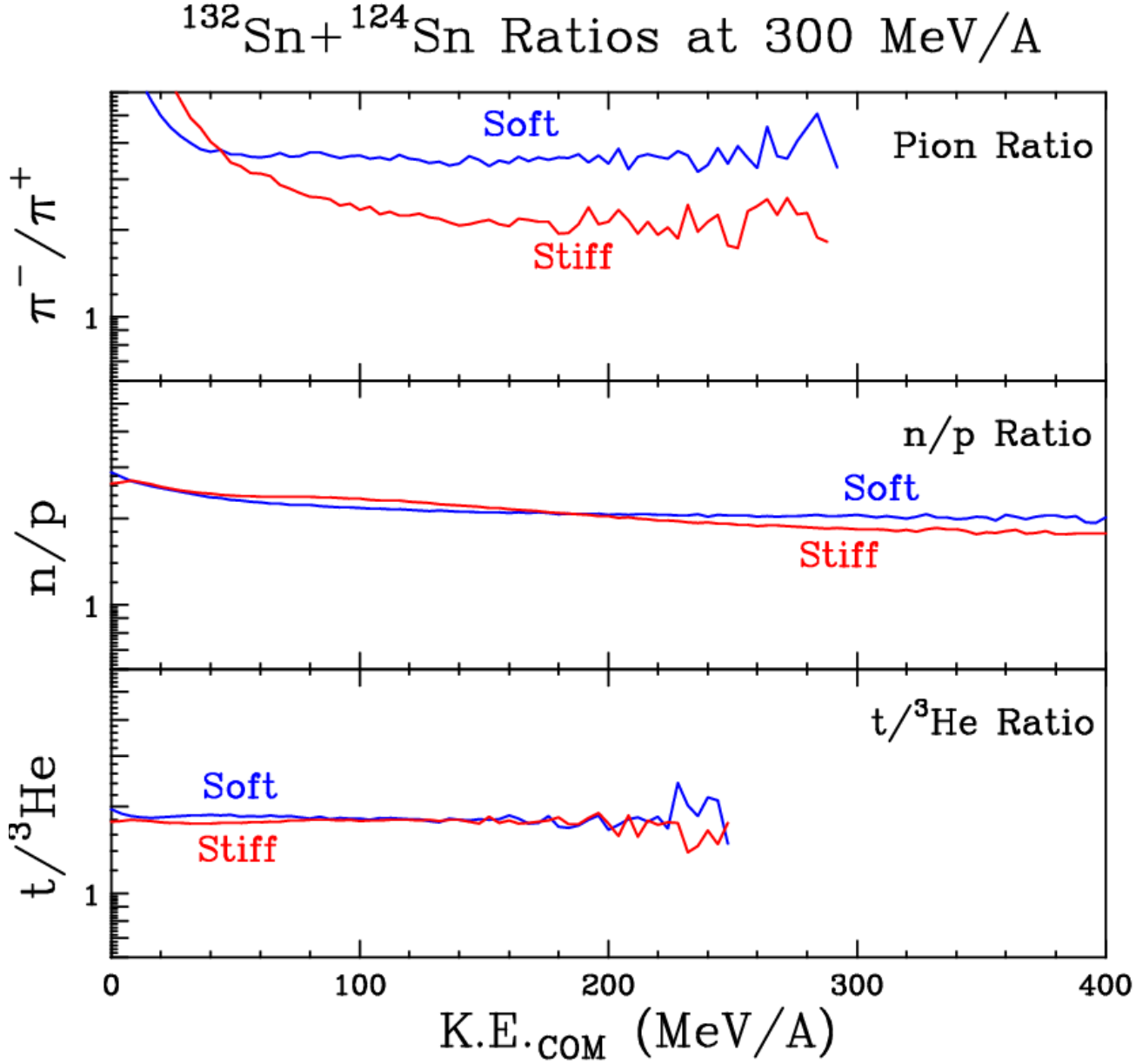
Integrated yield is not enough, we need Spectra

π - & π + spectra; $^{132}Sn+^{124}Sn$ and b=3fm

- Difference in π^- & π^+, due to resonance model
- Stiffer symmetry energy, $\gamma = 1.75$, tends to expel neutrons more than $\gamma = .5$
- π^+ peak at ~ 50 MeV represents Coulomb peak.



Multiplet Observables to study Symmetry Energy at $\rho >> \rho_0$



$$\frac{E}{A}(\rho,\alpha) = \frac{E}{A}(\rho,0) + S(\rho)(\alpha^2 - O(\alpha^4))$$

$$\alpha = \frac{\rho_n - \rho_p}{\rho_n + \rho_p}$$

$$S(\rho) = S_{kin}(\rho_0)(\frac{\rho}{\rho_0})^{\frac{2}{3}} + S_{\text{int}}(\rho_0)(\frac{\rho}{\rho_0})^{\gamma}$$

Pion ratios have the largest sensitivities to the symmetry energy parameter γ

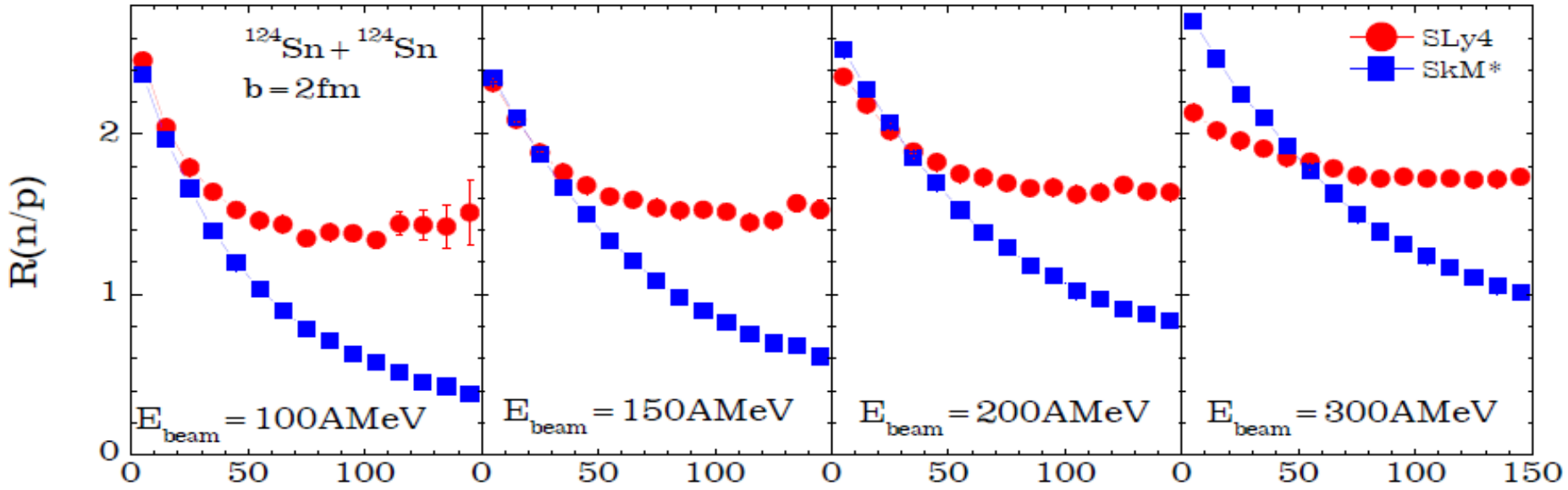
γ=0.5 soft; γ=0.5 stiff

Nucleon Effective Masses: Effects in pion ratios?

$S(\rho)=12.7(\rho/\rho_o)^{2/3} + 19(\rho/\rho_o)^{\gamma_i}$ + mean field in ImQMD05

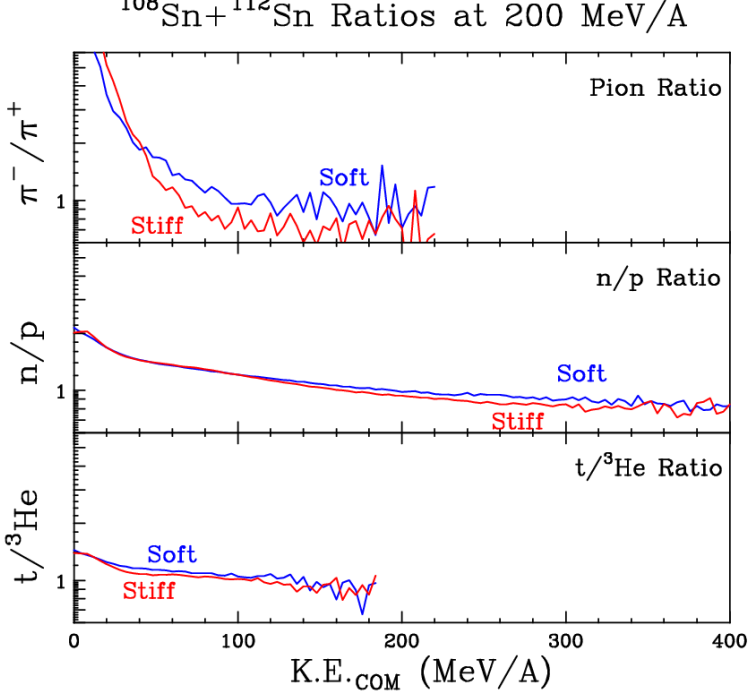
ImQMD05_sky: incorporate Skyrme interactions

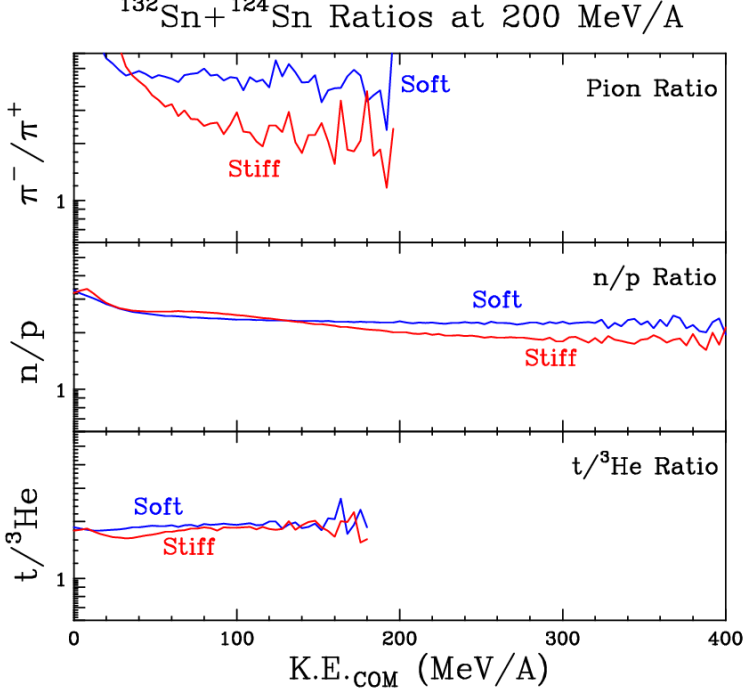
Skyrme	S0(MeV)	L (MeV)	m_n^*/m_n	m_p^*/m_p
SLy4	32	46	0.68	0.71
SkM*	30	46	0.82	0.76
NRAPR	33	60	0.69	
Gs	31	93	0.81	0.76
SkI2	33	104	0.66	0.7



E/A

200 MeV

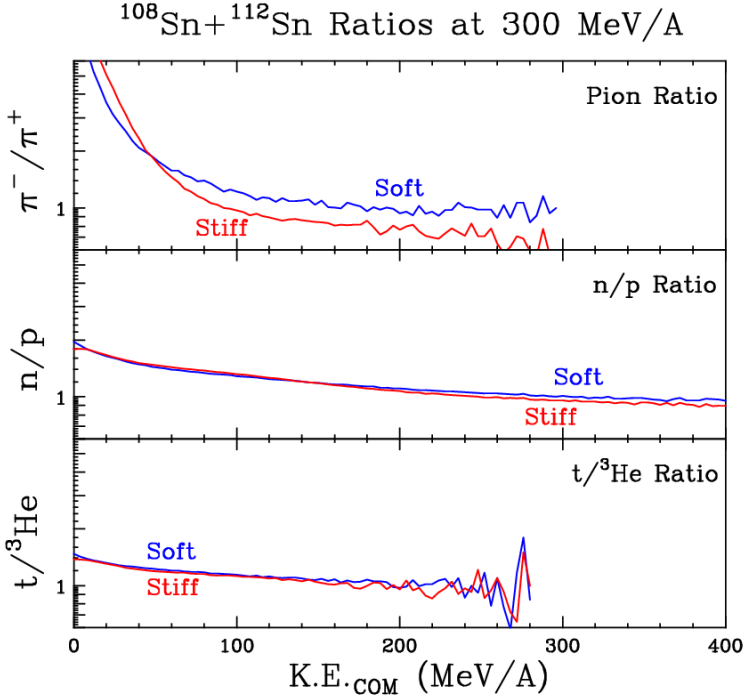


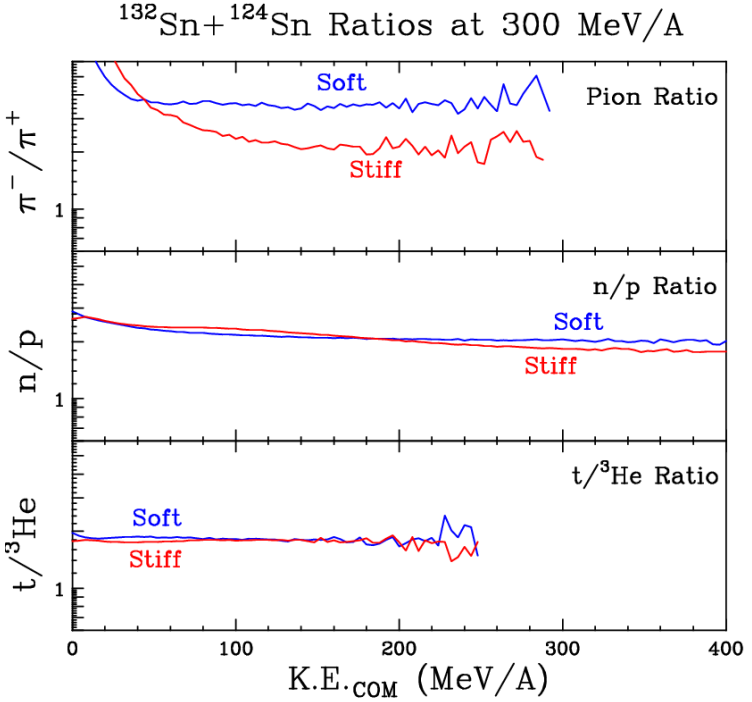


Larger effects for more neutron-rich systems.

Larger effects at E/A=200 MeV but production cross-sections are lower.

300 MeV





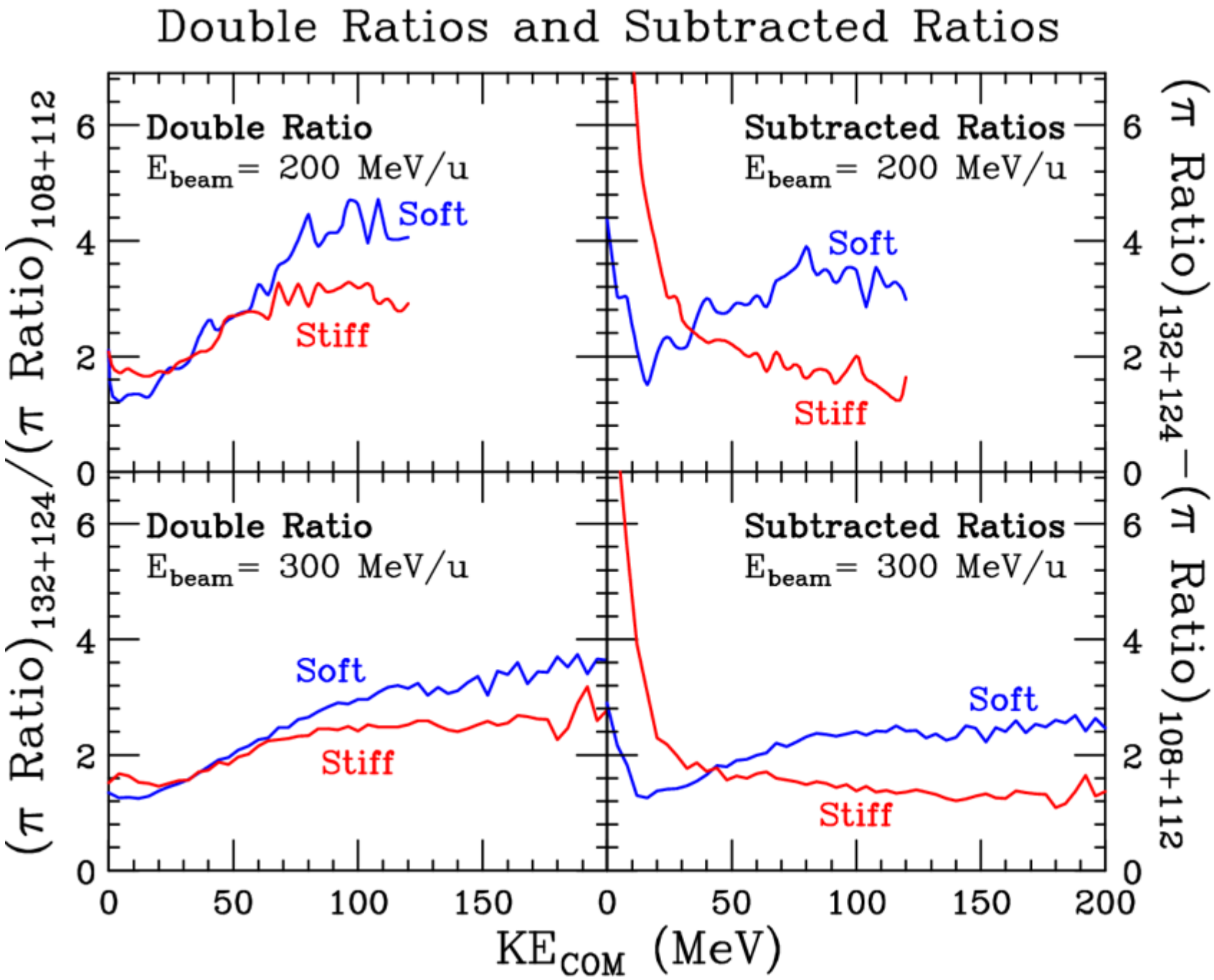
First experiment: 132Sn+124Sn at E/A=300 MeV

2nd experiment: 108Sn+112Sn at E/A=300 MeV to cancel out systematic errors

E/A

200 MeV

300 MeV



Larger effects at E/A=200 MeV but production cross-sections are lower.

Lower energy region in different spectra maybe sensitive to Coulomb and Optical potentials in pion scattering

Discussions

Outstanding Issues in Model comparisons & model development

Cross-sections (To validate models?)

-- existing data? additional pion data?

Differences in code predictions on symmetry energy

Influence of effective mass splitting in pion productions

Clustering effects on pion production

Importance of Asymmetric systems to constraint other transport parameters: σ_{NN}; effective masses?

…

Suggestions for upcoming SπRIT experiments

- ✓How about the determination of the reaction plane and impact parameter?
- ✓How about the systematic and statistic errors?

① n/p, π^-/π^+ , $^3H/^3He$, v_1, and v_2? (*multi-observables*)

② y and p_t distributions; y-p_t- correlated distribution? (*window-cut sensitivity*)

③ To reconstruct Δ? (*high density SE, and a better after-burner*)

Discussions

Outstanding Issues in Model comparisons & model development

1.Effects of in-medium delta potential.

2.Are there any experimental observables that can are model independent? Or at least give a clear signal that is independent of how theory might treat pions.

3.Are there any theoretical error estimates on pion ratio predictions?