Faziaconfronti:
test of the symmetry energy recipes included in AMD comparing different datasets of FAZIA

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Motivations of the analysis

- The isospin transport can be used as a probe of the stiffness of the symmetry energy
- The isotopic composition of the primary ejectiles should depend on the stiffness of the symmetry energy
- Isospin diffusion and drift are expected:

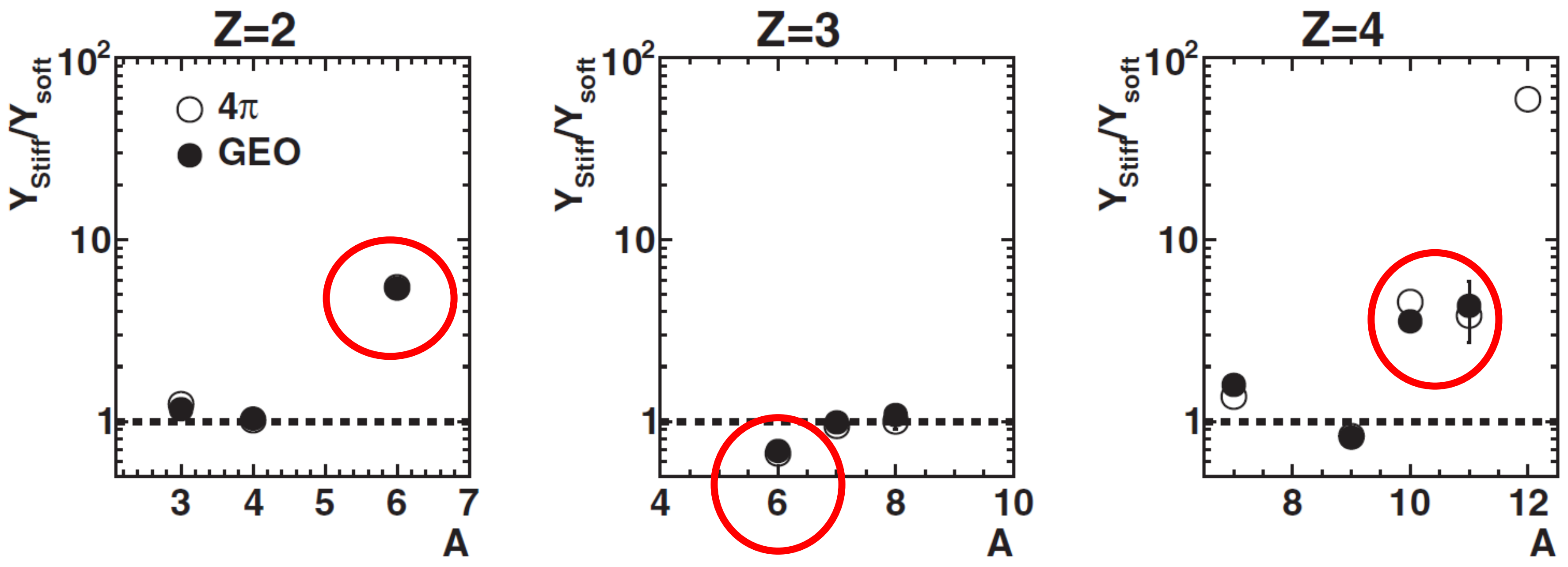
$$j_n - j_p \propto S(\rho)\nabla I + \frac{\partial S(\rho)}{\partial \rho} I \nabla \rho \qquad I = \frac{N-Z}{A}$$

- Isospin drift is in particular expected if there is a density gradient, e.g. in the neck zone, supposed to be at smaller density than QP/QT
- For midvelocity emitted IMF, which should be produced in the neck region, the N/Z should be higher when the symmetry energy is stiff (the higher the symmetry energy the more symmetric the isotopic composition of the ejectiles because the symmetry energy tends to make N=Z)
- The isotopic composition may be blurred by the secondary decay, for example because of the side feeding process

Motivations of the analysis: **the ISOFAZIA case**

The best possibility to discriminate between stiff and soft symmetry energy (in the framework of the AMD model) seems to come from the most exotic light fragments

AMD+GEMINI++



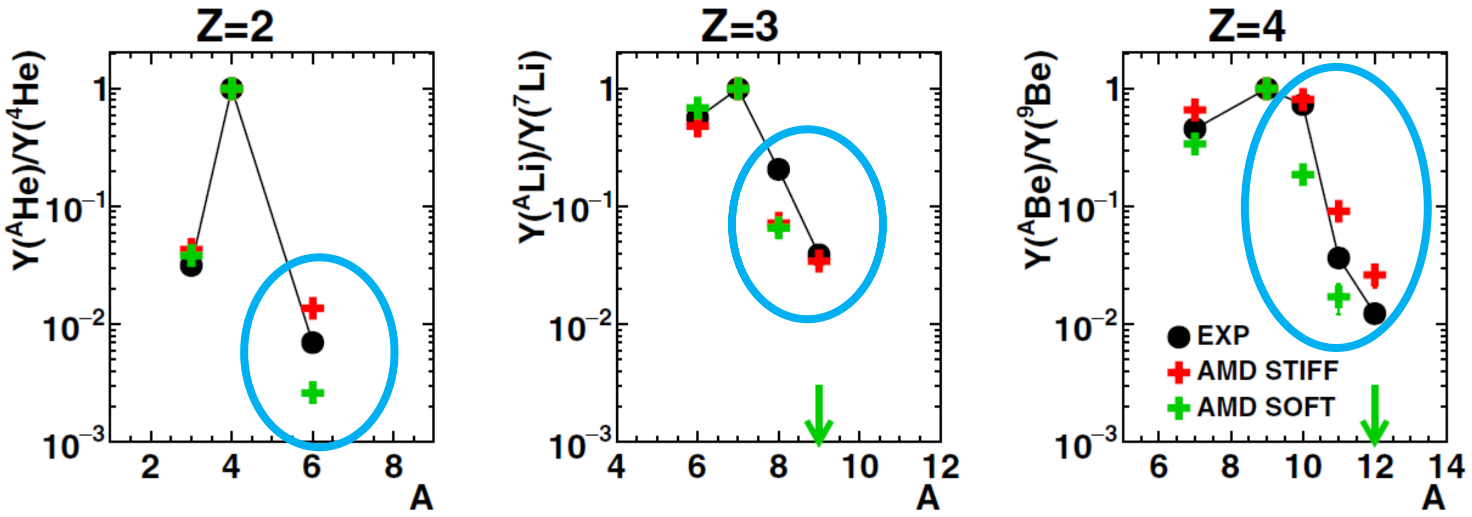
The most exotic fragments seem to keep track of stiffness of the symmetry energy

They are less affected by side feeding

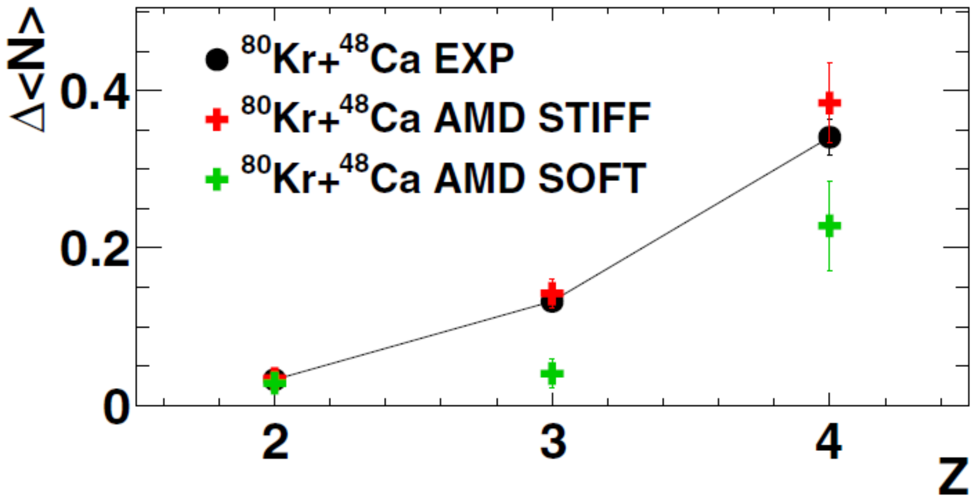
Ratio of the yields obtained with stiff and soft parametrization

S.Piantelli et al., PRC 103 (2021) 014603

Hints towards a stiff symmetry energy from the yields of the most exotic light ejectiles



ISOFAZIA



Also the average backward-forward (with respect to the QP) neutron number gives the same hint

S.Piantelli et al., PRC 103 (2021) 014603

FAZIACONFRONTI: the goals of the analysis

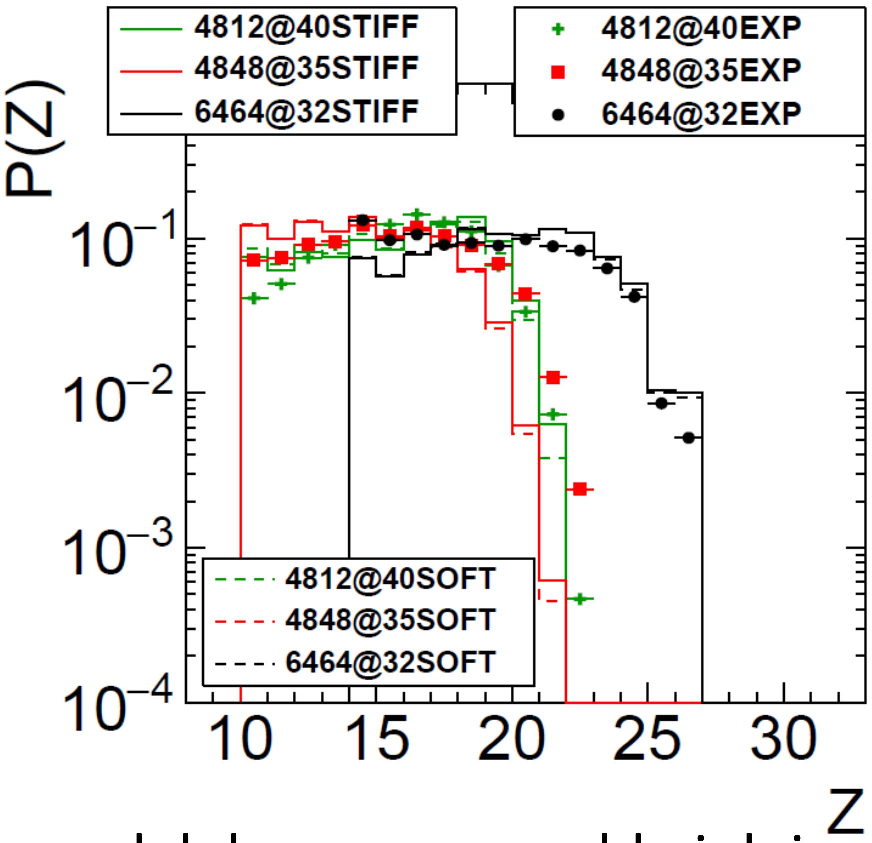
- The idea is to compare the isotopic composition of midvelocity emitted fragments with the prediction of AMD + GEMINI++ in three different systems:
  - ^{48}Ca+^{48}Ca@35AMeV FAZIASYM – 4 blocks in wall configuration
  - ^{64}Ni+^{64}Ni@32AMeV E789 – INDRA FAZIA
  - ^{48}Ca+^{12}C@40AMeV FAZIAPRE – 6 blocks
- CaCa and NiNi are symmetric systems => the isospin diffusion should be reduced
- They are neutron rich systems => there is room for the formation of many exotic fragments which could keep a signature of the symmetry energy
- CaC is a benchmark because in this very asymmetric system there is no room for the formation of the neck => no isospin drift
- Caveat: ^{48}Ca+^{12}C is not the best of the benchmarks because N/Z of projectile and target is different.
- ^{40}Ca+^{12}C would be better but:
  - The system at 40AMeV is not ready for the analysis
  - But then we should move to the neutron poor side: we should use ^{40}Ca+^{40}Ca and ^{58}Ni+^{58}Ni => less room for the formation of neutron rich fragments
  - In ^{40}Ca+^{40}Ca, which is a N=Z system, there is no drift
- The evolution of the midvelocity isotopic composition can be followed as a function of the centrality if the reduced momentum is used as impact parameter estimate (not possible for the CaC but possible for both NiNi and CaCa even if CaCa has a much smaller geometrical coverage)

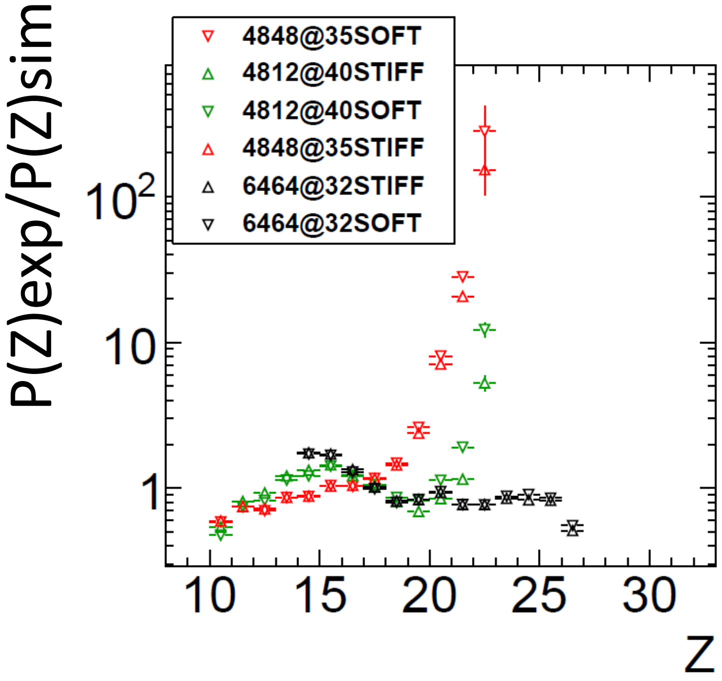
Preliminary results

Charge distribution of the biggest fragment of the event forward emitted in the C.M.

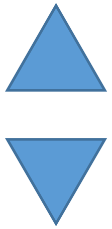
Only events where only 1 forward emitted big fragment with $Z>Z_{Proj}/2$ are accepted

For CaCa and NiNi the big fragment is the QP
For CaC it might be also the incomplete fusion source





Yield exp/yield model



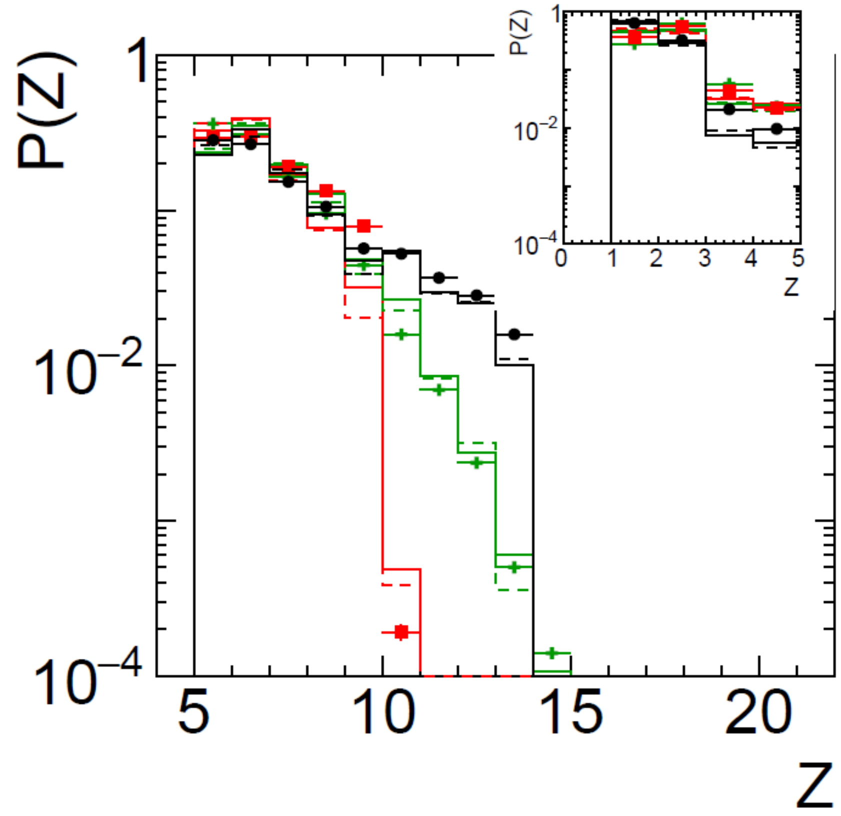
STIFF

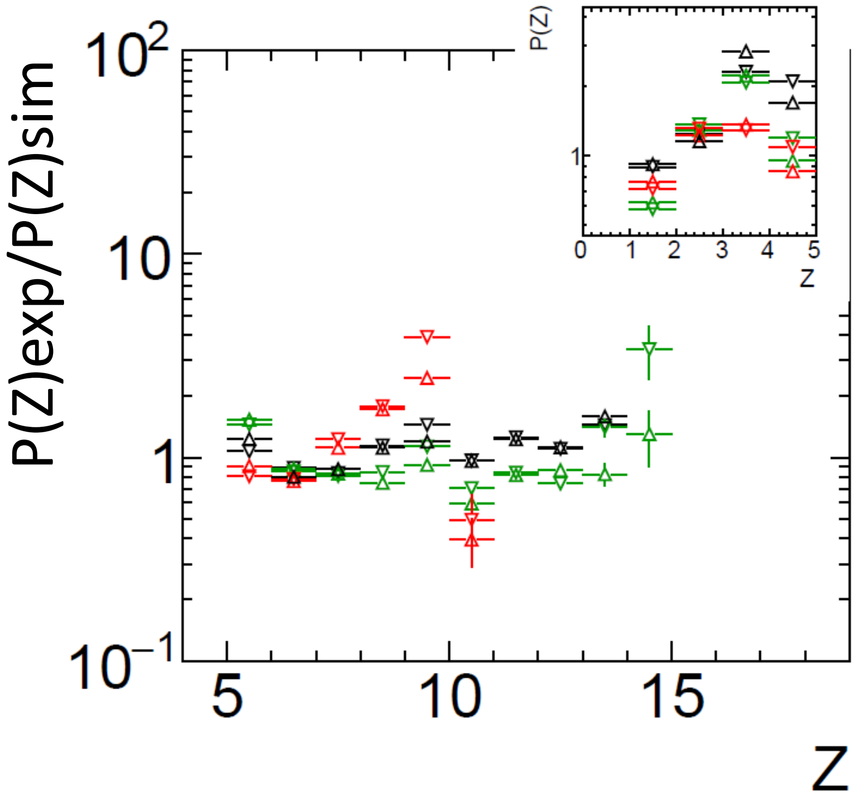
SOFT

The model does a reasonable job in repoducing the experimental data, with some difficulties close to the elastic region especially for CaCa

No significant differences between stiff and soft predictions: reasonable, inclusive data in terms of N/Z

The accompanying ejectiles





Exp yields/Model yields

STIFF

SOFT

In this set of ejectiles also fragments belonging to the QP breakup class as defined in other analysis are included

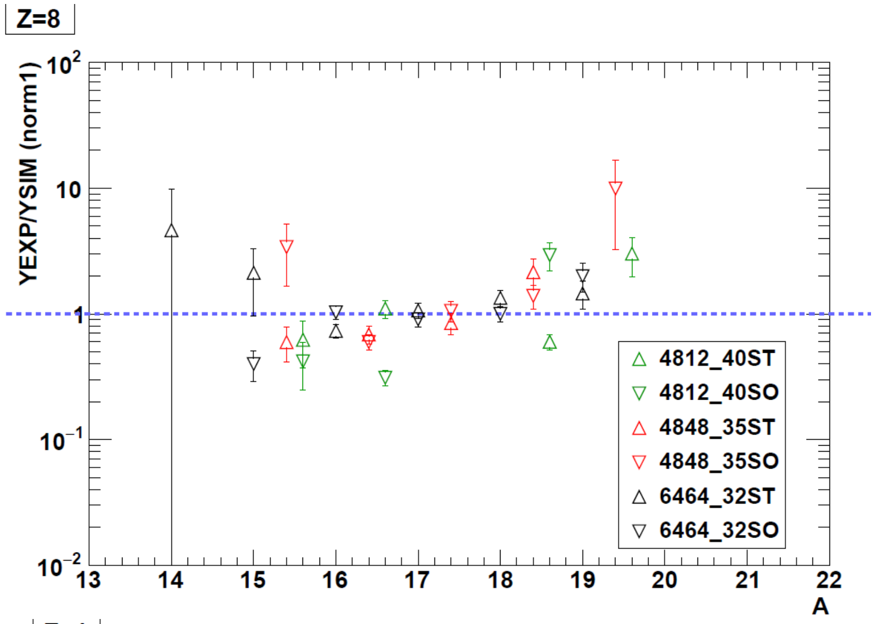
No significant difference between stiff and soft

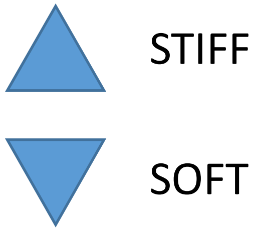
The model does a good job in reproducing the data

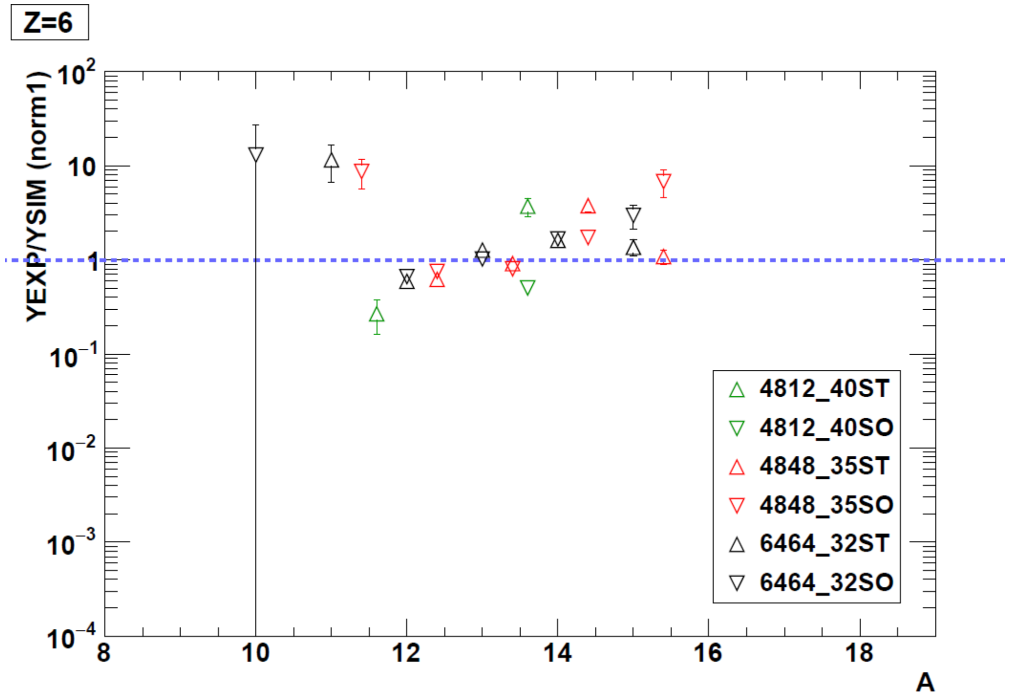
Work in progress: isotopic composition of midvelocity fragments

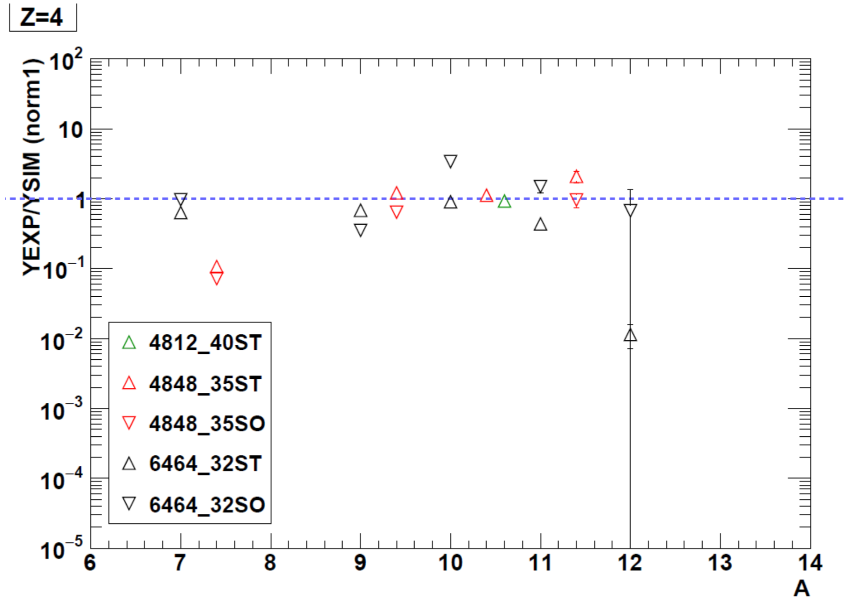
Fragments backward emitted with respect to the big one (QP for NiNi and CaCa)

Subtraction of the forward emission









Chisquare to evaluate the best agreement between stiff and soft

Z=8

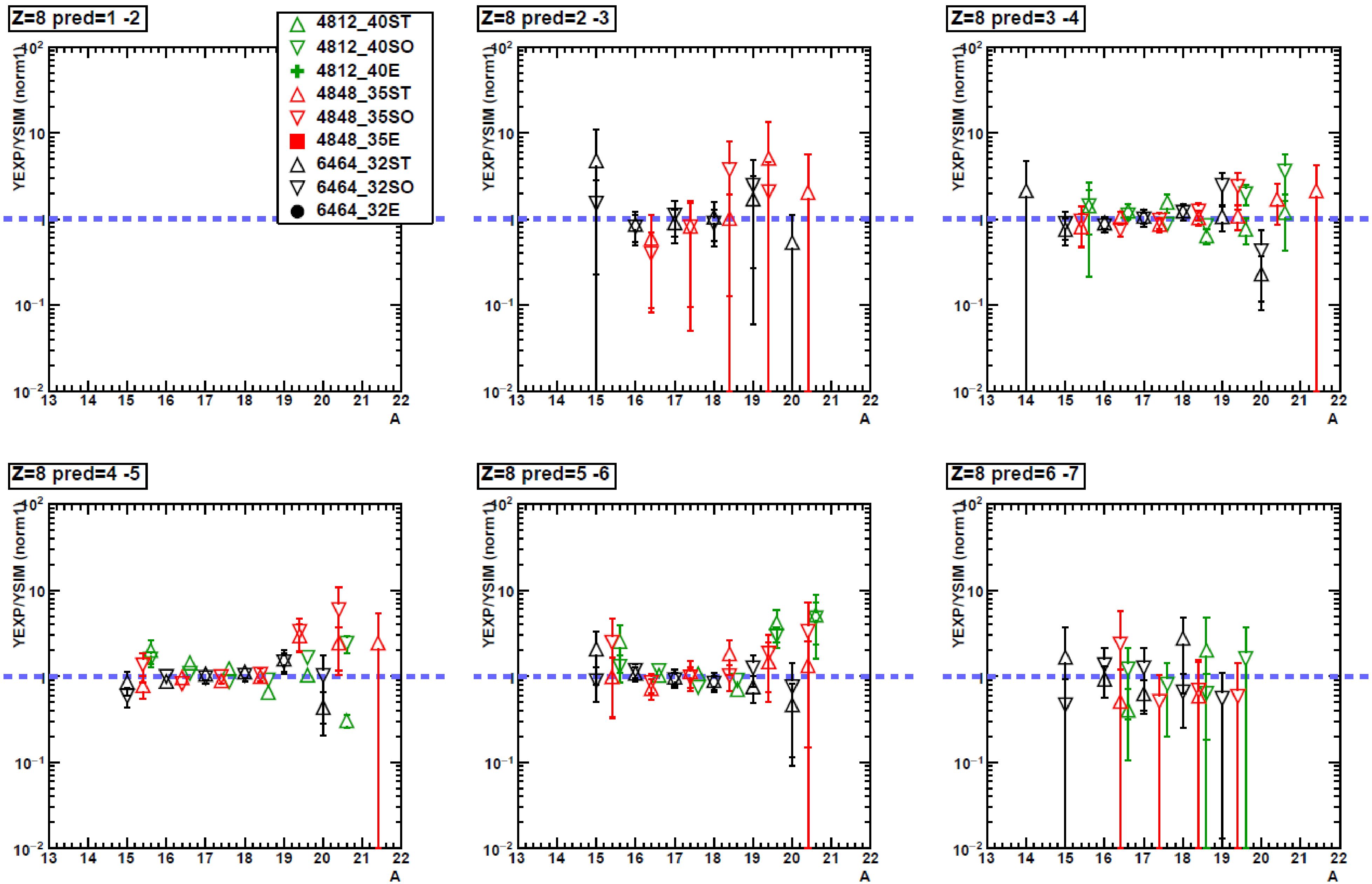
CaC STIFF 7.5 SOFT 85.3

CaCa STIFF 4.3 SOFT 5.6

NiNi STIFF 2.6 SOFT 6.8

Slightly better agreement with stiff

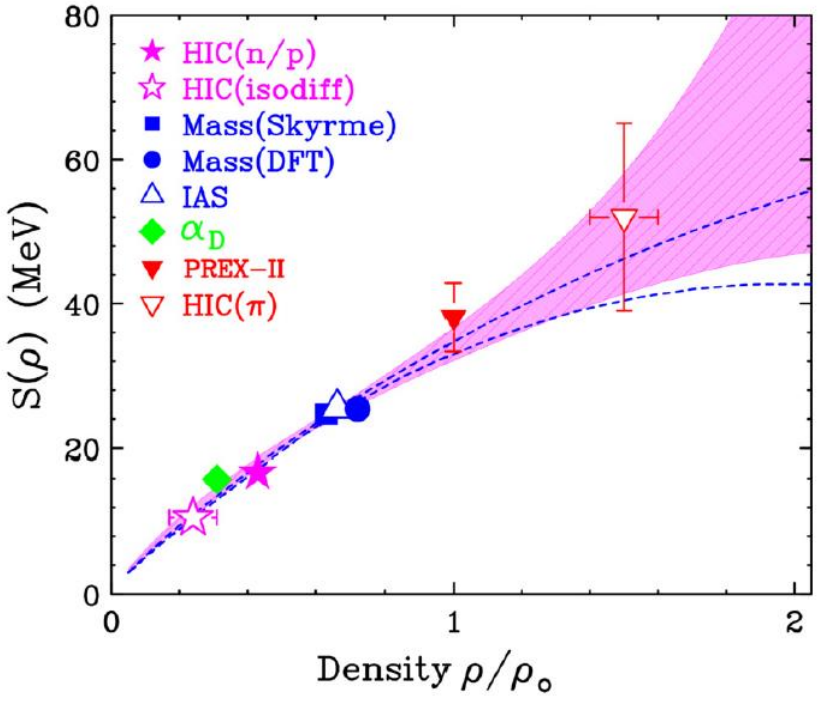
Work in progress: evolution with the centrality (p_{red})



Conclusions and perspectives

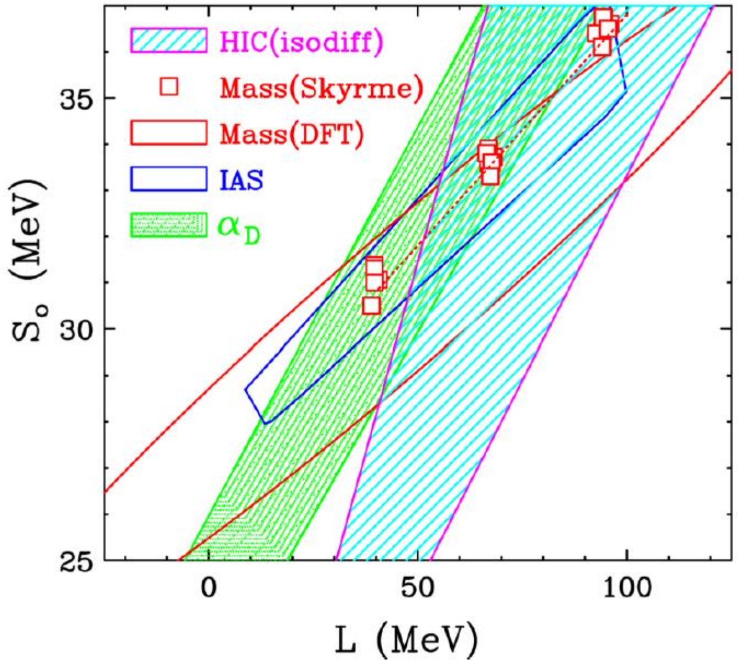
- The analysis is still in progress, results are very preliminary
- The model does a reasonable job in reproducing the isotopic composition of the midvelocity fragments

Is it possible to put a FAZIA point on the plot by Lynch et al., PLB 830(2022)137098 on the symmetry energy?



My answer is maybe NO, because to me it is difficult to establish the proper ρ value on the x axis, since the system explores a (wide) range of ρ during the collision

…but it should be possible to put a point on the plot



$$e_{\rm iv} = E_{\rm sym} + L_{\rm sym} x + \frac{1}{2} K_{\rm sym} x^2 + \frac{1}{3!} Q_{\rm sym} x^3 + \frac{1}{4!} Z_{\rm sym} x^4 + \cdots ,$$

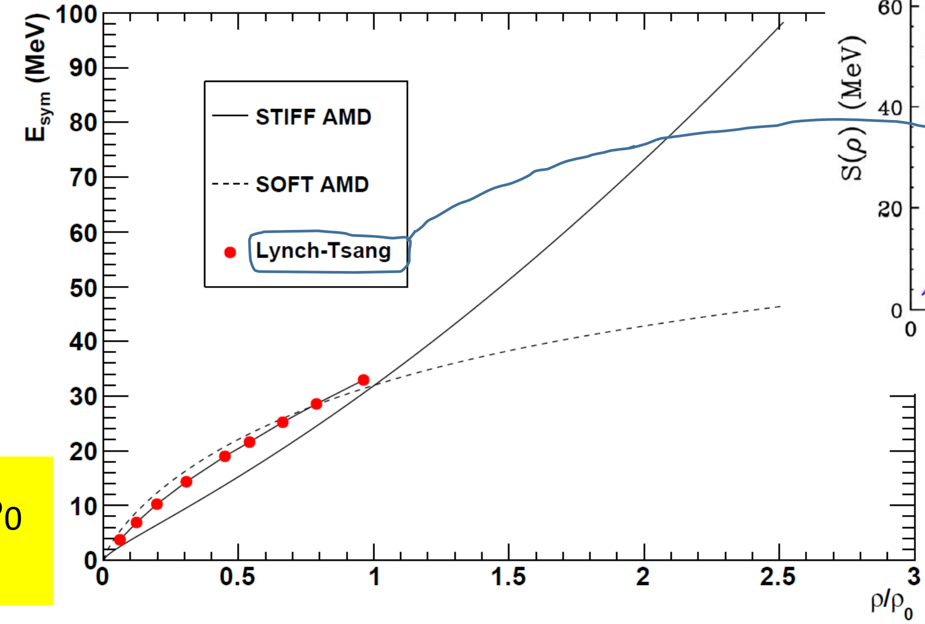
$$x = (n_0 - n_{sat})/3n_0$$

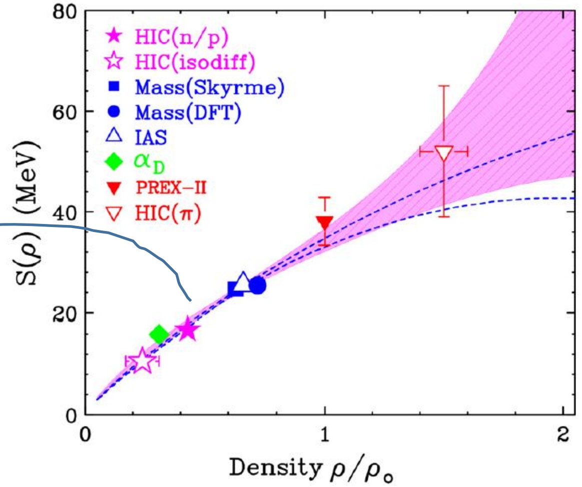
$$n_0 = n_n + n_p$$

Parameters of the Taylor expansion of the symmetry energy as a function of the density

Note that AMD does not provide the possibility to modify L and S_0 as one wants

There are two functions for the symmetry energy, a stiff one and a soft one (with the soft one agreeing quite well with the one proposed in Lynch et al., PLB 830(2022)137098)





From these functions it is possible to extract L and S_0

S_0=32MeV L_{stiff}=108MeV; L_{soft}=46 MeV

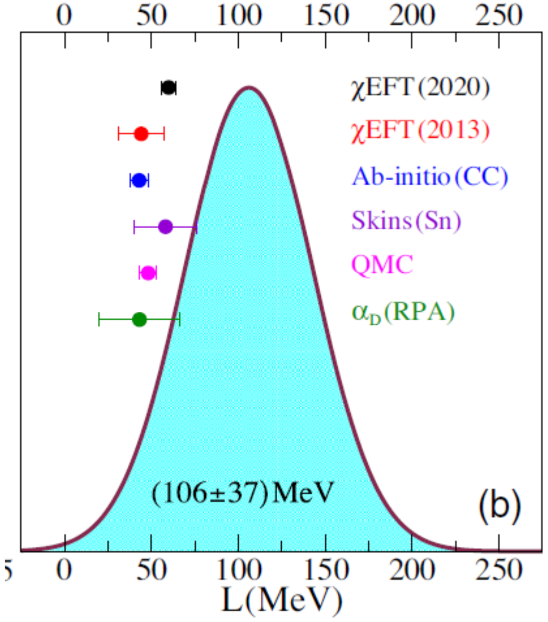
Conclusions and perspectives

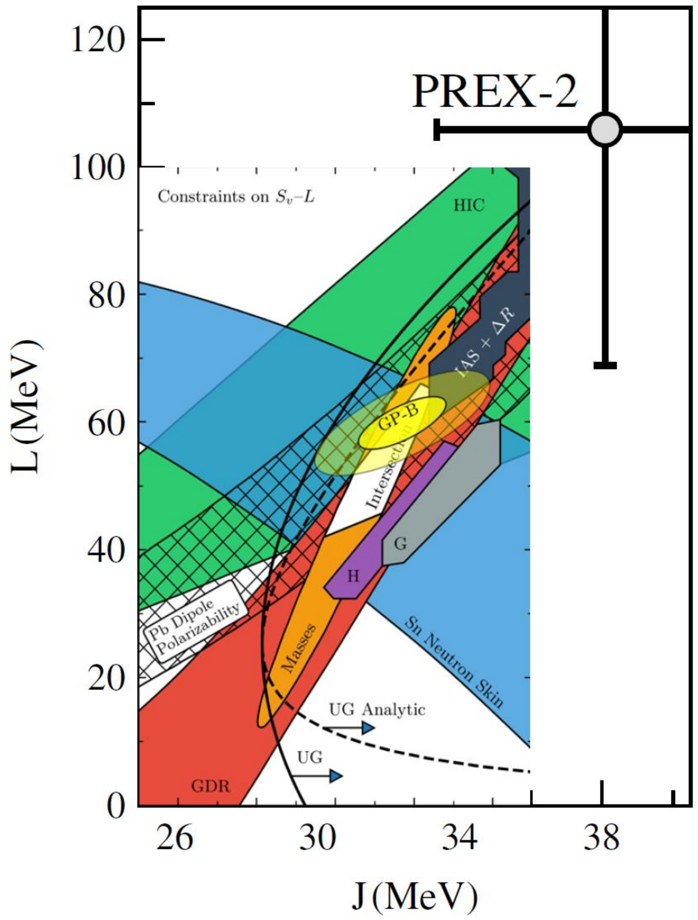
- In the preliminary experimental results there is not an abyssal difference between stiff (L=108 MeV) and soft (L=46MeV), although a χ^2 calculation seems to suggest a weak trend towards stiff symmetry energy (necessary to verify if this remains true for all the Z and all the centralities).

Is it the stiff value L=108 MeV too big with respect to the general consensus? Maybe, but…

….there is PREX-2 measuring the skin thickness of ^{208}Pb, which gives L=106 MeV

Reed et al., PRL 126(2021)172503





Conclusions and perspectives

- There is not a very big difference between $^{48}Ca+^{12}C$ (where the neck is not expected) and the other two systems where the neck should form. Is the diffusion doing the same job in this case?
- It is important to test if the trend towards stiff symmetry energy persists even if the afterburner is changed (e.g. Gemini fortran90).