Experimental inputs for supernova dynamics

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LIA COSMA

Type II Supernovae

- Supernova explosion occurs via core-collapse in very massive stars ($M>8M_{sun}$)
- Shock front is stalled unless revived by extra neutrino emission
  - Critically depends on **electron capture** during collapse e+p->n+ν
- Ejecta might be seeds for r-process if matter is sufficiently n-rich
  - Critically depends on the global proton fraction and on the **composition of matter** at the neutrinosphere
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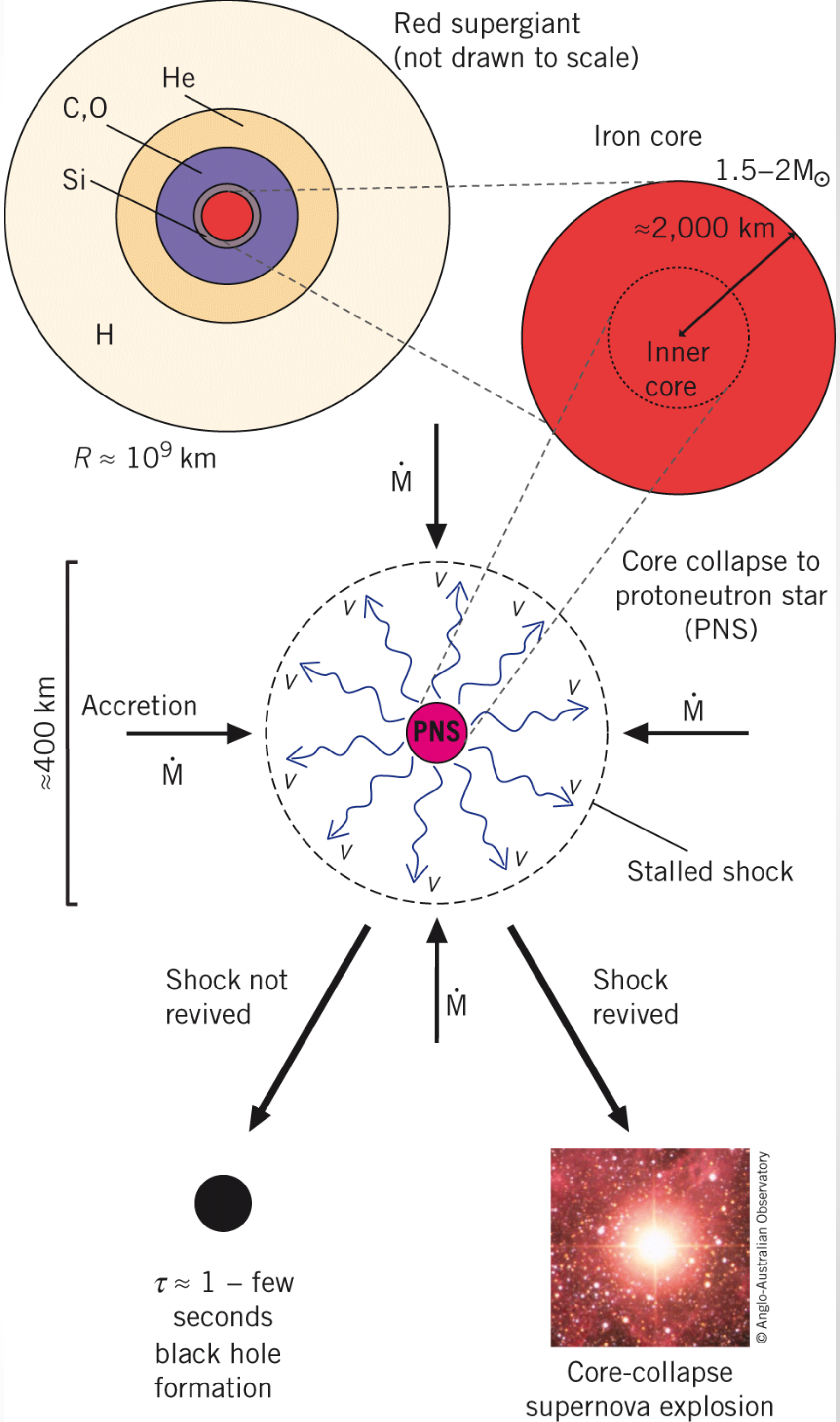
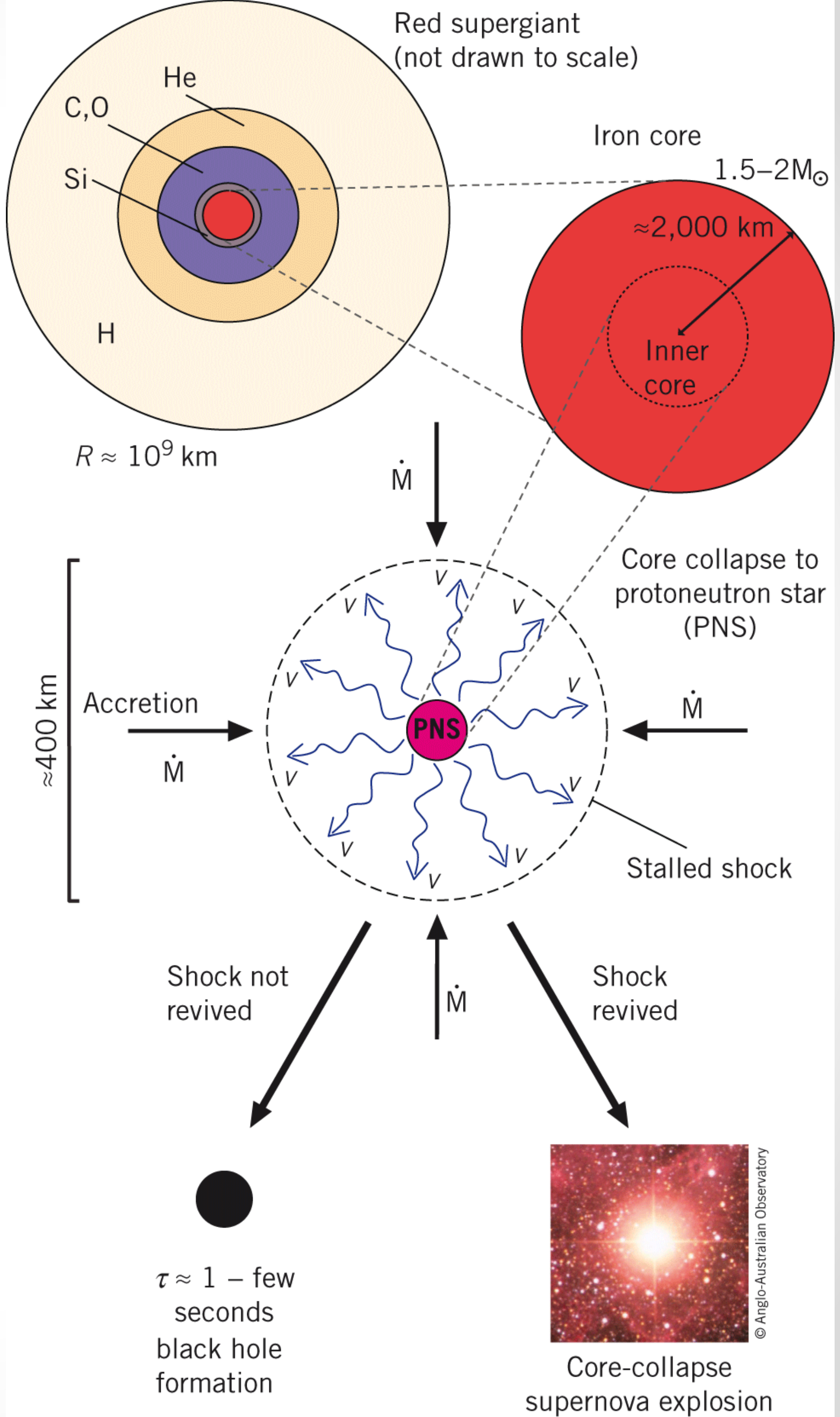


Type II Supernovae

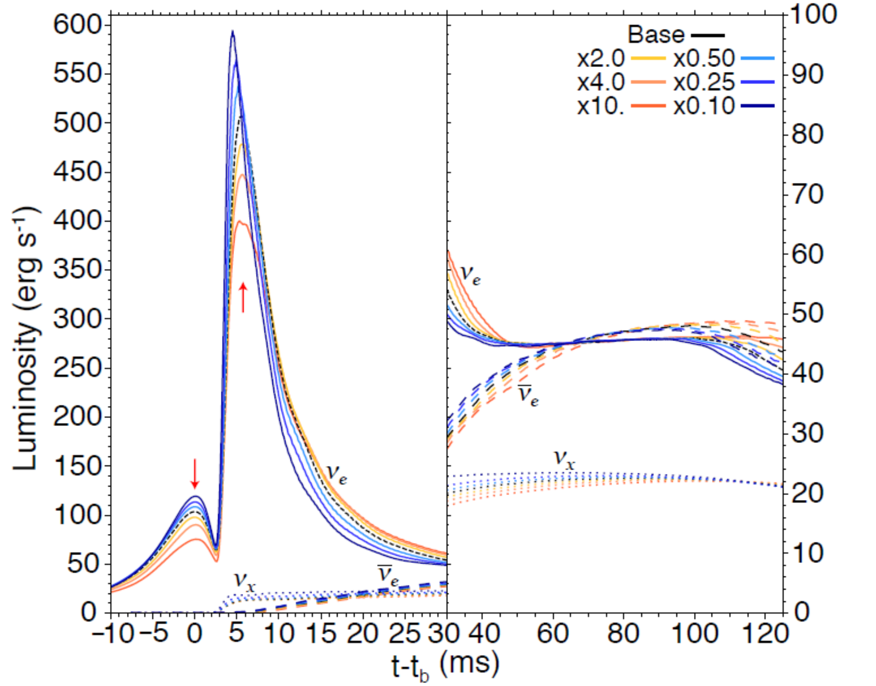
Our LIA project:

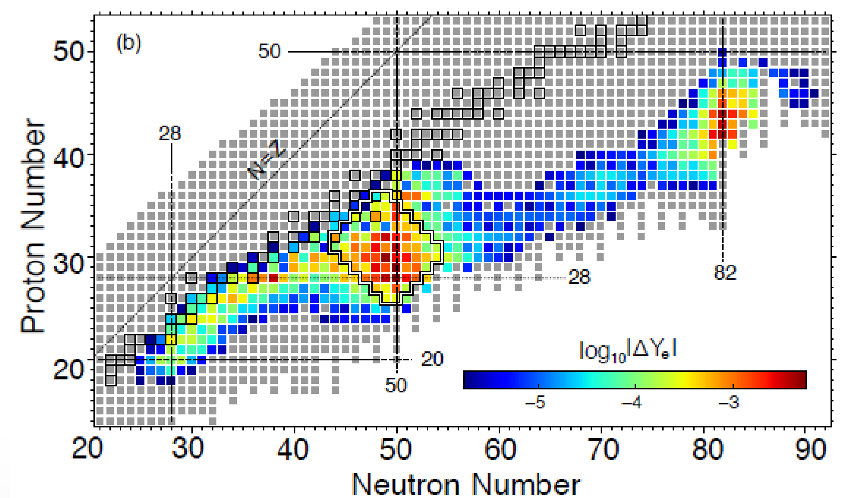
- study **e-capture rates (I) and matter composition (II)** within a model including realistic nuclear inputs
- Identify key nuclear observables
- Stimulate experiments and provide theoretical simulations and interpretations



(1) Electron capture during core collapse

- The supernova evolution and ν luminosity crucially depends on the e-capture rate.
- The main nuclei involved are very neutron rich isotopes around the N=50 and N=82 magic numbers
- Their **mass** and **e-capture probability** govern the global deleptonization rate

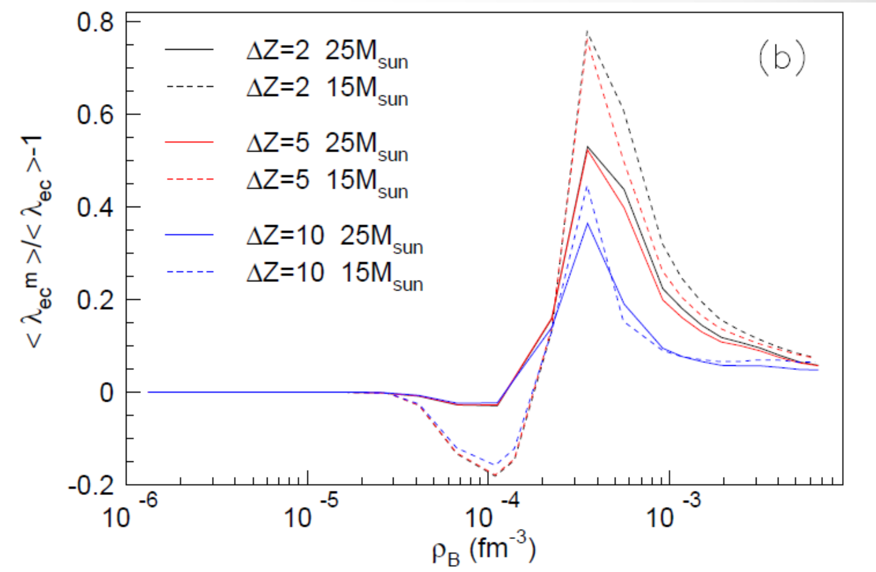




- C.Sullivan 2016

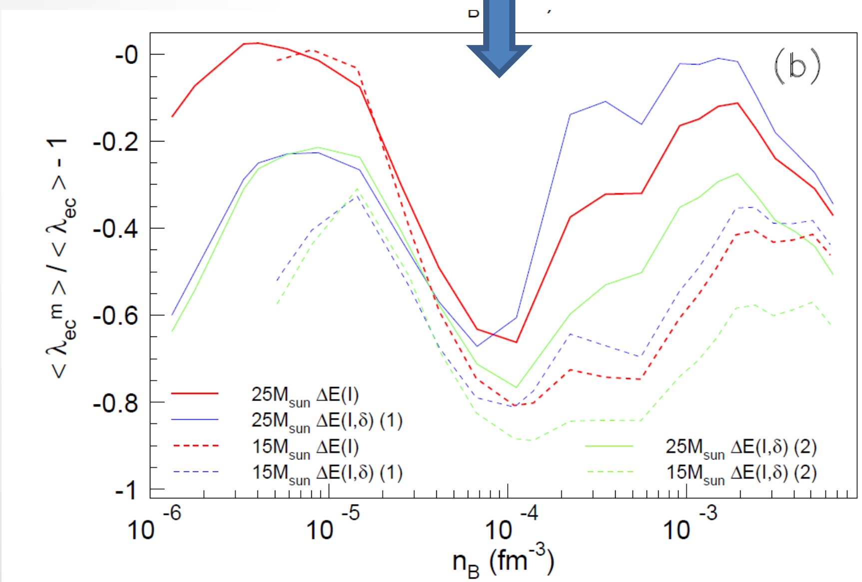
(1) Electron capture during core collapse

- **Effect of the mass**



A.Raduta 2016

- **Effect of the capture rate**



A.Raduta 2017

These are only sensitivity studies. The final answer can only come from measurements around N=50 and N=82

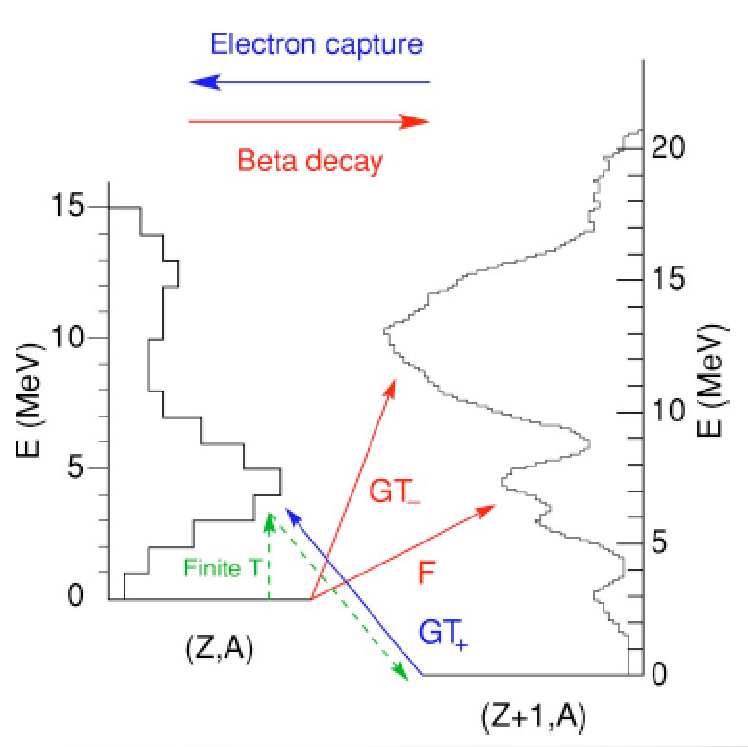
(1) Electron capture during core collapse

- I-220 JYFL proposal (B.Bastin, A.Kankainen) "Mass measurements in the vicinity of 78Ni to constraint core collapse supernovae models and to study the N=50 and Z=28 shell" to be run in 2017
  - High precision mass measurement for 5 new isotopes around Z=28 N=50
- E-capture rates on these same exotic nuclei can be deduced from the inverse β decay process
  - GT strength measurement
  - Study in progress ......

Phase space factor

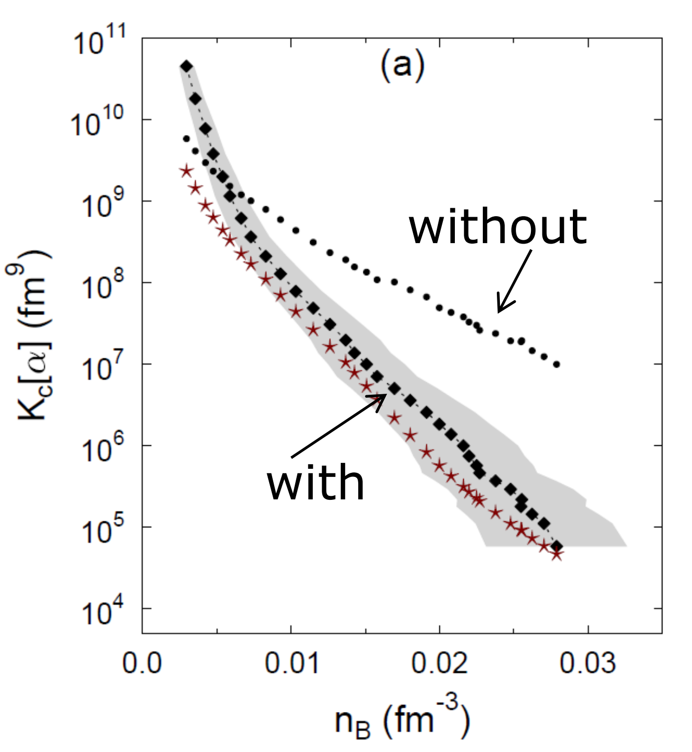
$$\lambda = \ln 2 \sum_j \frac{f_j(T, \rho, U_F)}{(ft)_j},$$

Transition rate



(2) Matter composition at the ν–sphere

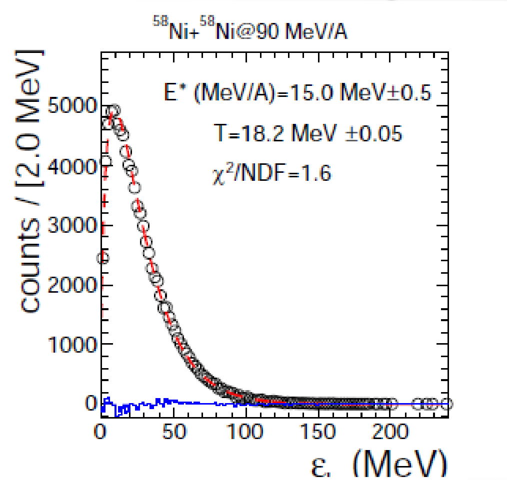
- The possibility of generating a strong r-process in SN explosions depends on the initial proton fraction and matter composition
- In turn, this depends on the in-medium modification of nuclear masses
- Exp.study requires many light nuclei at low ρ and finite T => vaporization data
- Present data (Texas A&M)
    - One single data set
    - Symmetric N~Z system only
    - No verification of equilibrium
    - T and ρ from theoretical model

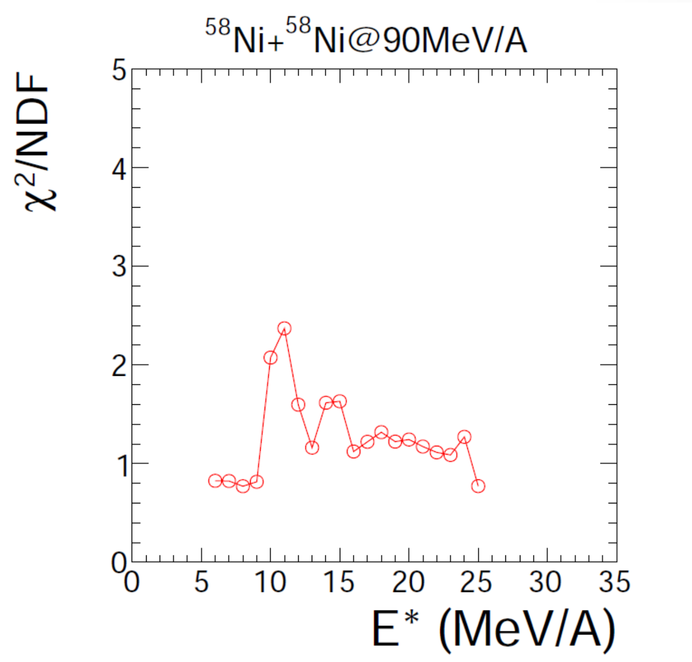


(2) Matter composition at the ν–sphere

Analysis of INDRA data
Ni+Ni 90 A.MeV

- Temperature from particle spectra

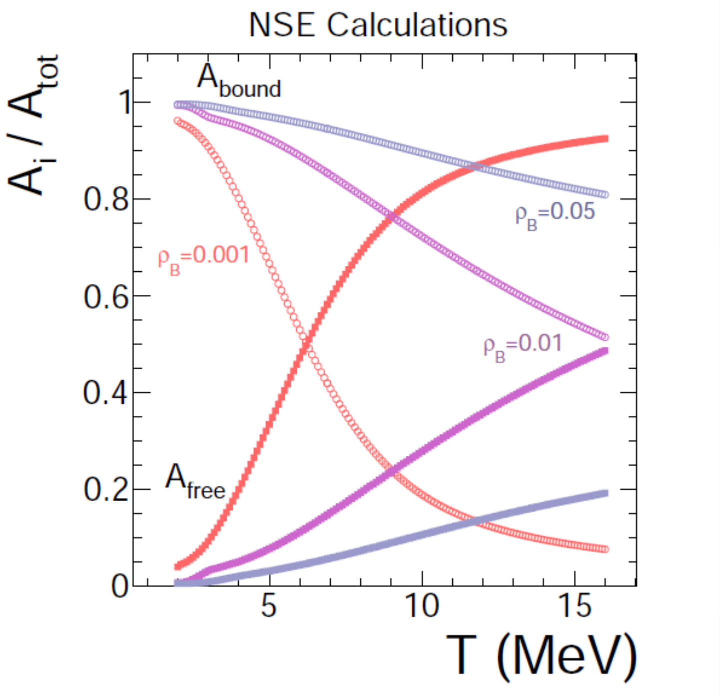




(2) Matter composition at the ν–sphere

Analysis of INDRA data
Ni+Ni 90 A.MeV

- Temperature from particle spectra
- Density from bound particle fraction

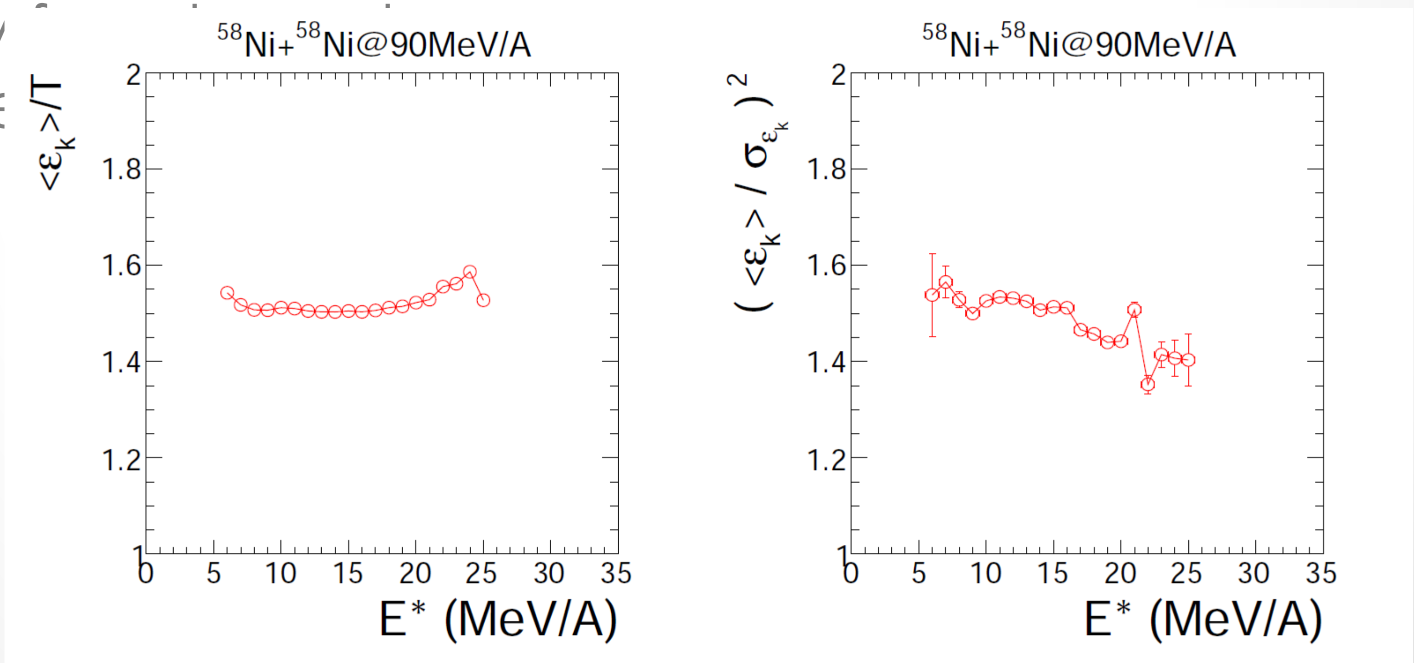


(2) Matter composition at the ν–sphere

Analysis of INDRA data
Ni+Ni 90 A.MeV

- Temperature from particle spectra
- Density
  particle

- No deviation of equilibrium up to second moments



(2) Matter composition at the ν–sphere

Analysis of INDRA data Ni+Ni 90 A.MeV

- Temperature from particle spectra
- Density from bound particle fraction

- No deviation of equilibrium up to second moments

- Analysis in progress
- Proposition of a FAZIA@GANIL LoI (E.Bonnet) to extend to asymmetric nuclei

Conclusions

- The understanding of core collapse supernova dynamics and explosive nucleosynthesis requires a realistic nuclear modelling including key inputs from experimental data on n-rich nuclei
- Our contribution:
  - A microscopic EoS model including the full distribution of nuclear species
  - LoI FAZIA@GANIL =>2016
  - Mass measurement at IGISOL (n-rich Fe and Co isotopes) =>2017
  - Analysis of INDRA vaporization data =>now
  - GT strenght proposal to extract e-capture rates =>in progress