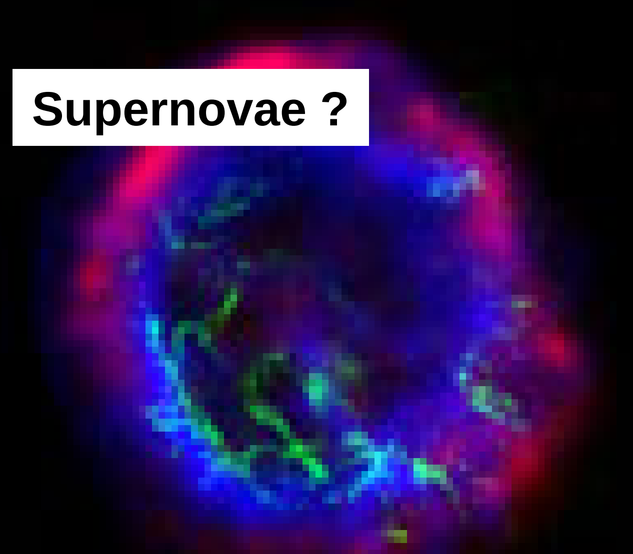
r (apid neutron capture) process

Produces ~half of elements > Fe (for example most of Au, Pt, U, …)

Open questions:

- **What is the site of the r-process ?**
  (Supernovae ? Neutron star mergers ? γ-ray bursts ? …)
- **Is there more than one r-process ?**
- **Can the r-process tell us about physics at extreme astrophysical conditions ?**



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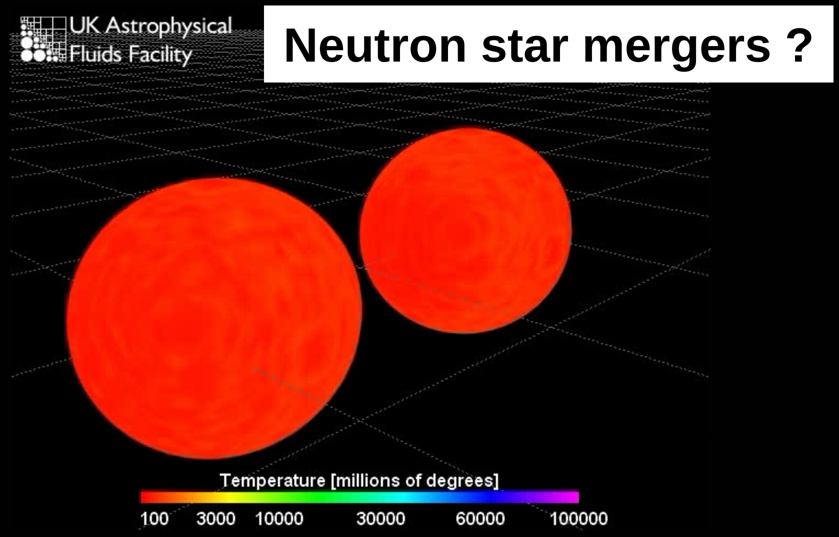
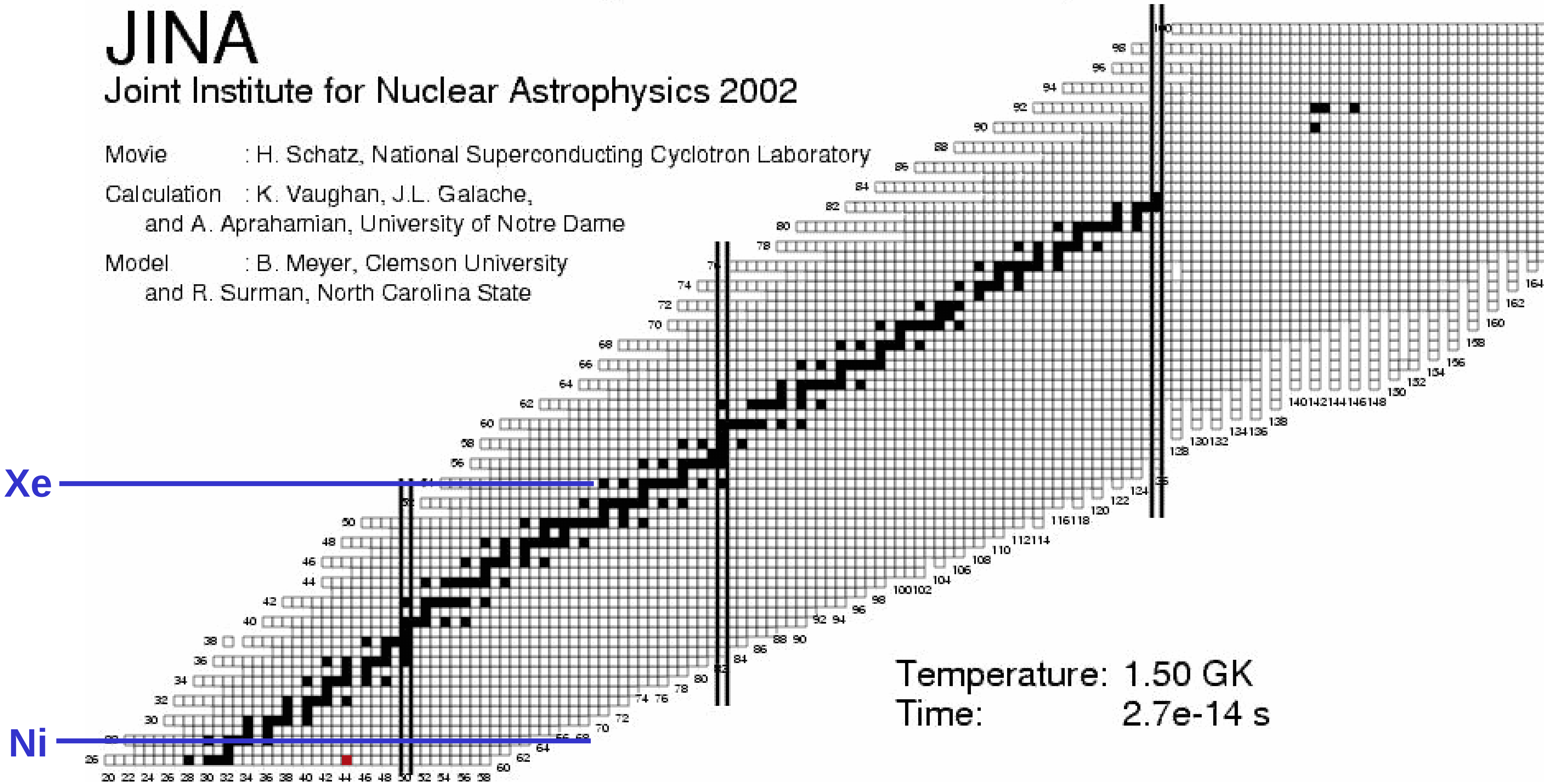


Nucleosynthesis in the r-process



<u>Need nuclear physics</u>

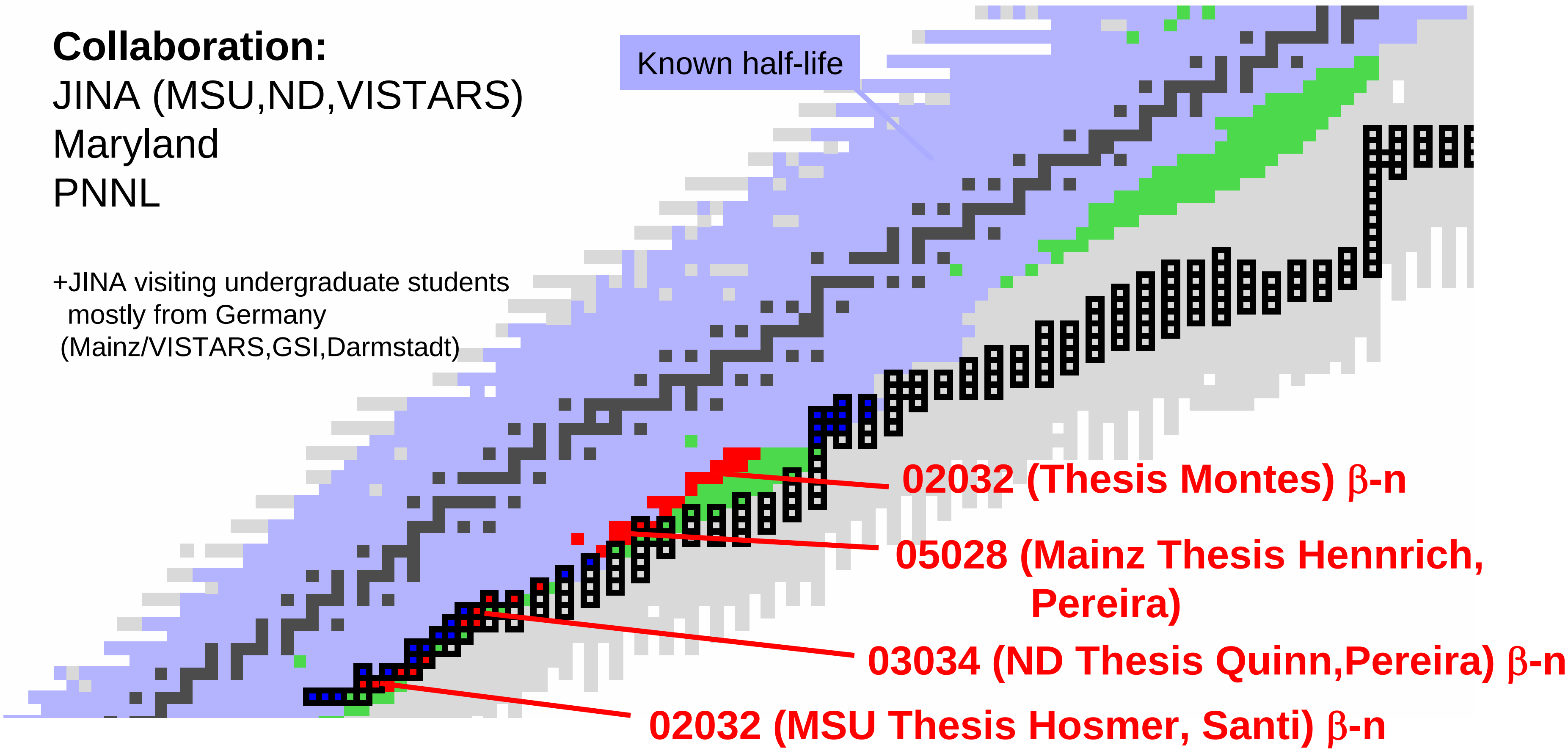
→ To extract astrophysical information from observed final abundances (guide search for site, constrain physics of site ?)

→ To disentangle different r-processes (what does each process make ?)

r-process experiments at the NSCL

Collaboration:
JINA (MSU,ND,VISTARS)
Maryland
PNNL

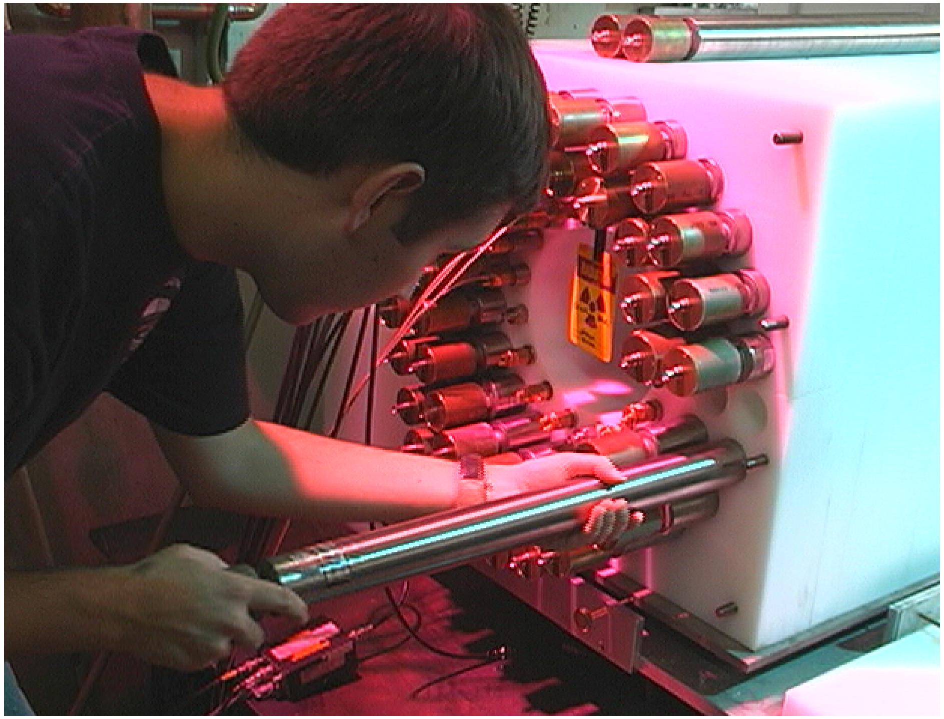
+JINA visiting undergraduate students
mostly from Germany
(Mainz/VISTARS,GSI,Darmstadt)



NSCL has unique capabilities in reaching the r-process below N=82

→ This is where more than one r-process could contribute
→ Testbed for shell effects (probably fast freezeout – sensitivity !)
→ Site specific signatures: α-rich freezeout contribution, ν-effects, …)
→ GOAL: reliable modeling of pattern for various r-processes for A<130

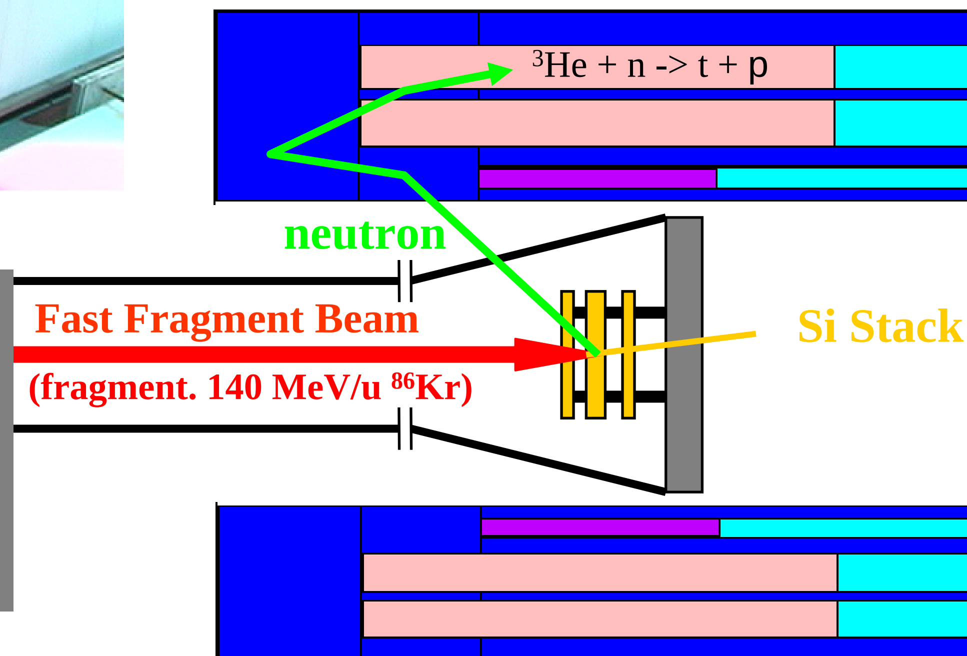
First experiment: r-process in the Ni region (Hosmer et al.)



<u>Measure:</u>

- β-decay half-lives
- Branchings for β-delayed n-emission

New NSCL/JINA Neutron detector NERO counters: Mainz, PNNL, calibration: ND

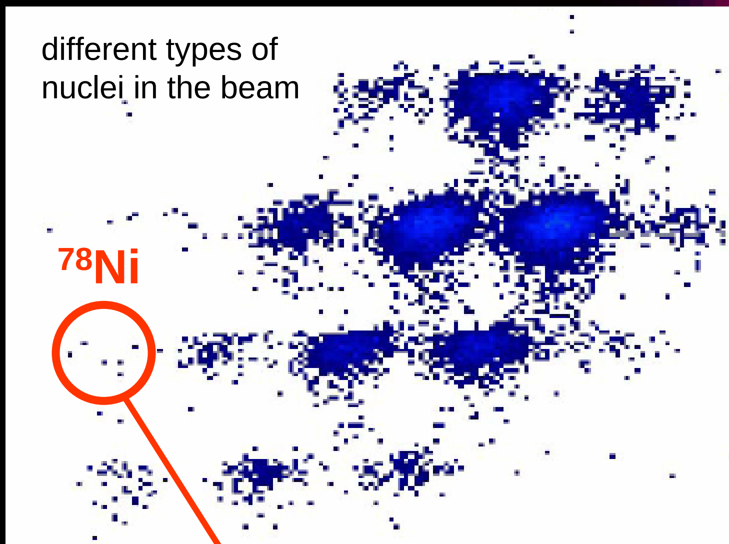


Detect:

- Particle type (TOF, dE, p)
- Implantation time and location
- β-emission time and location
- Neutron-β coincidences

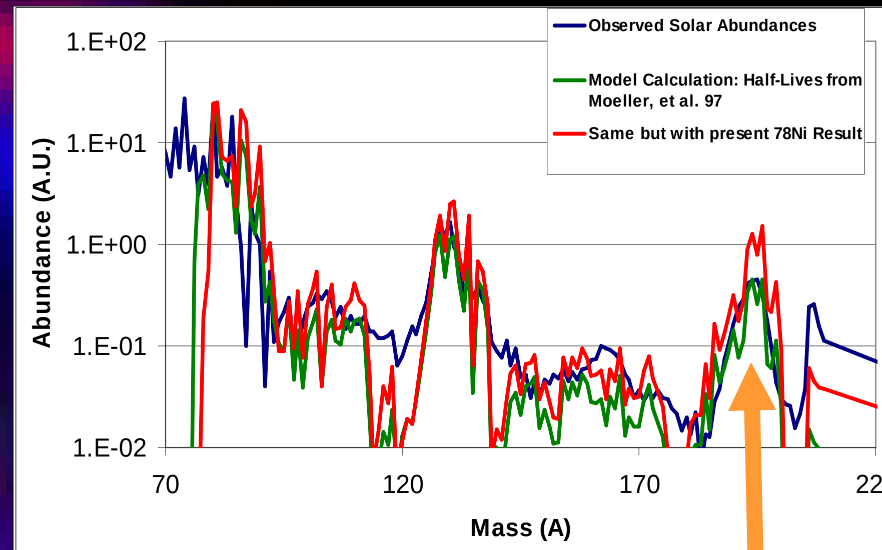
Half-life of ^{78}Ni

Particle identification in rare isotope beam from NSCL at Michigan State University



Measured half-life of ^{78}Ni with 11 events
This is the most neutron rich of the 10 possible classical doubly-magic nuclei in nature.

Model calculation for synthesis of heavy elements during the r-process in supernova explosions
JINA student exchange with VISTARS/ r-process school



models produce excess of heavy elements with new shorter 78Ni half-life

→ need to readjust conditions in model

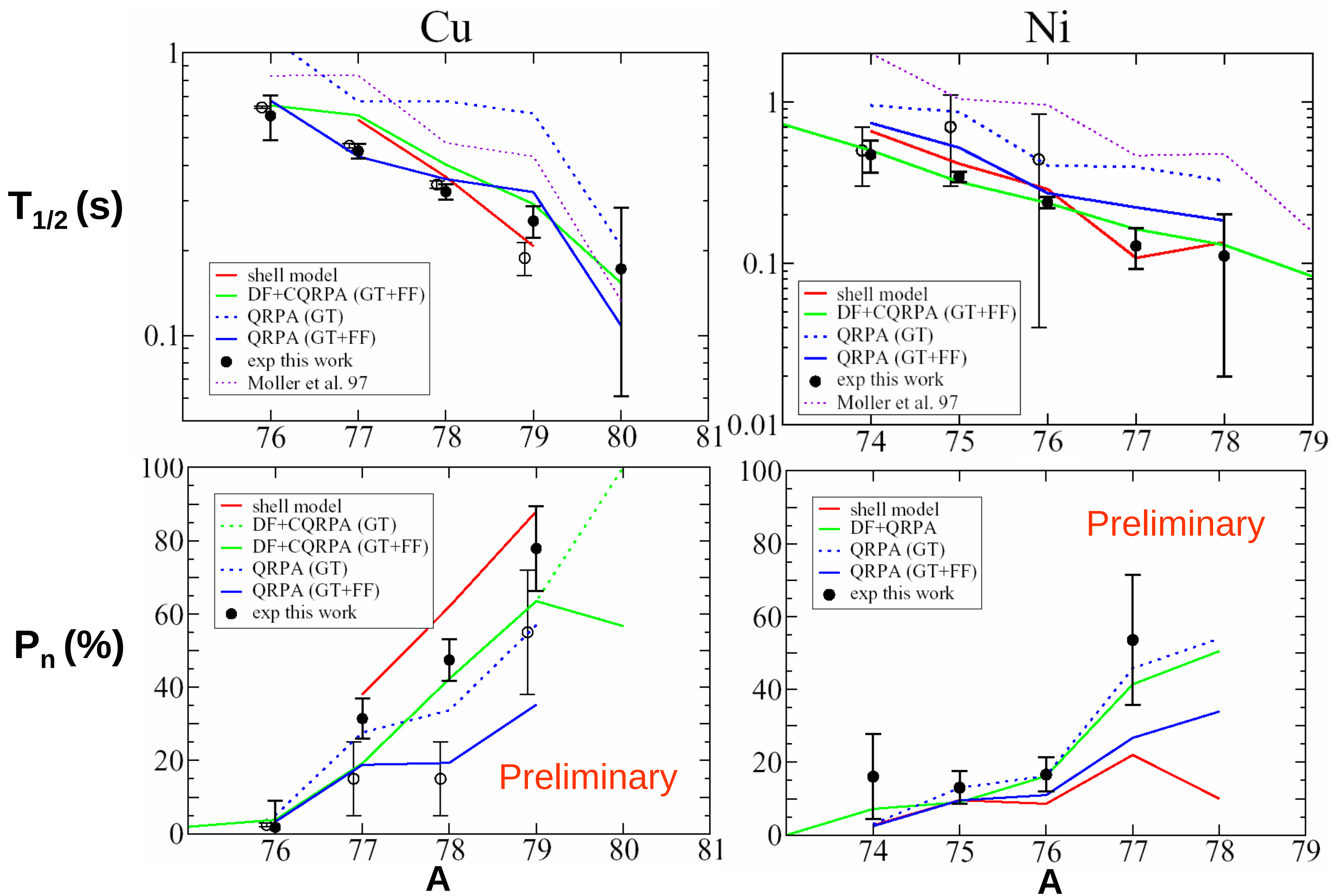
Result: 110 $^{+100}_{-60}$ ms

P. Hosmer et al. PRL 94 (2005) 112501

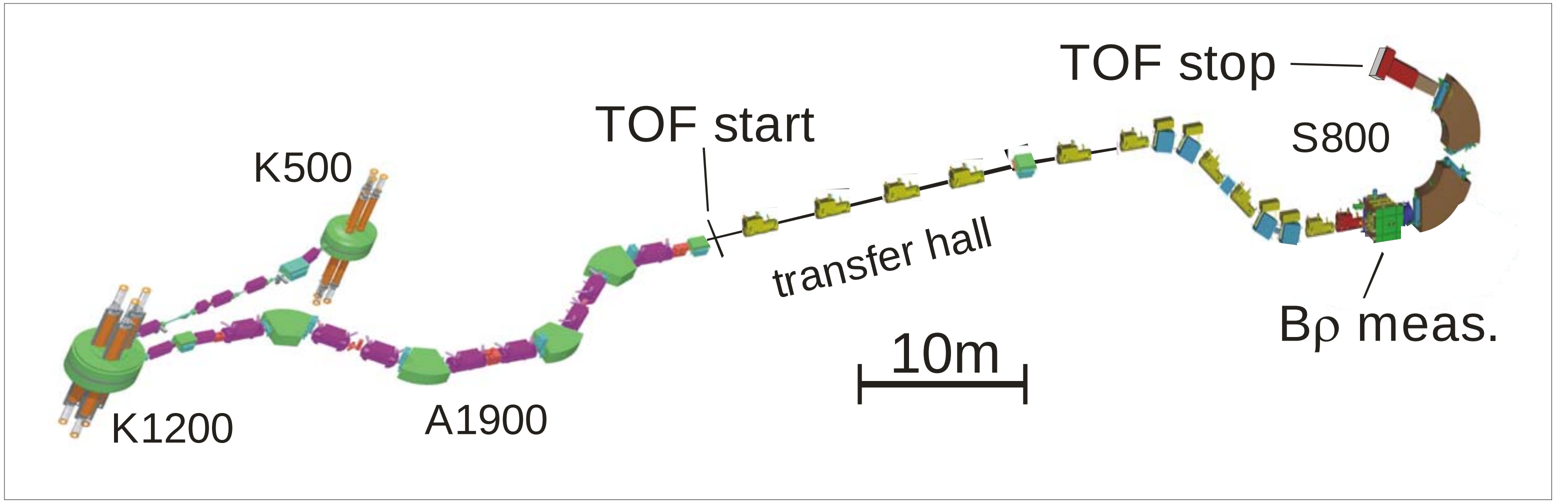
Thesis: P. Hosmer

Results (Hosmer et al.)

DF+CQRPA Borzov et al. 2005, QRPA: Moller et al. 2003, Shell model: Lisetzky & Brown 2005

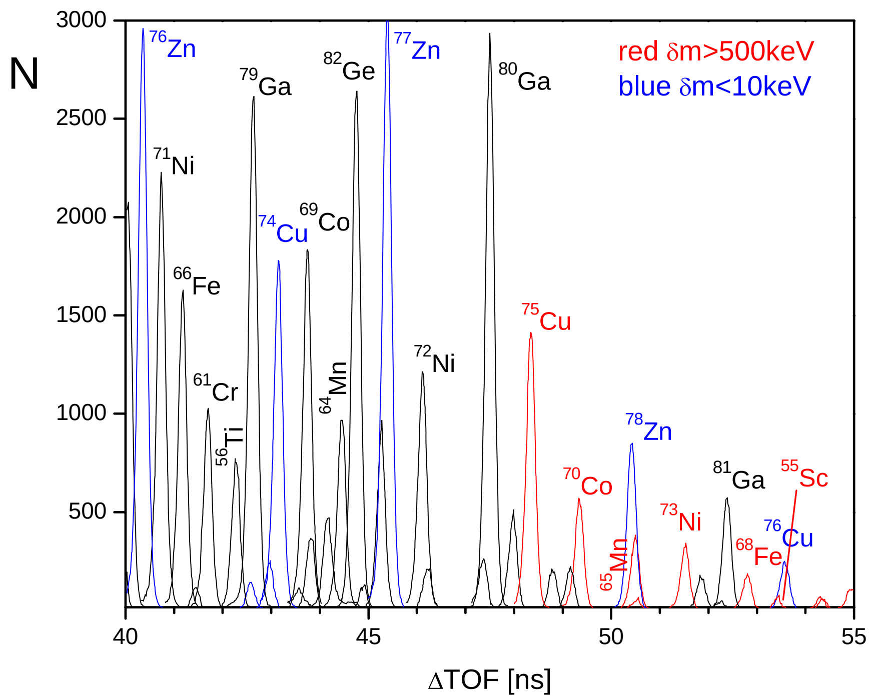


TOF Mass measurements (Matos, Estrade)



First experiment Feb 2006
Preliminary data

$$\frac{m_0}{q}\gamma = B\rho\,\frac{t}{l}.$$



Summary

- Experiments at NSCL (and GSI) are an important part of the JINA r-process program

- JINA:
  - driver in forming multi-institutional collaboration and student exchange
  - equipment collaboration
  - student training in modeling and astro theory

  → rapid interpretation and implementation of data in r-process codes

- part of a larger JINA framework of modeling of various r-processes and s-process, observations, stable beam s-process experiments, nuclear theory efforts

- Goal: understand origin of heavy elements A=80-130 → disentangle various processes and test models with experimental nuclear data (error bars !)
  → fully interpret observations

- also relevant for neutron star crust modeling (nuclear physics needs emerging)