β-decay measurements of r-process nuclei

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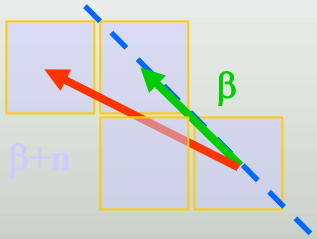
Supernova 1994D in NGC 4526

Nuclear physics in the r-process

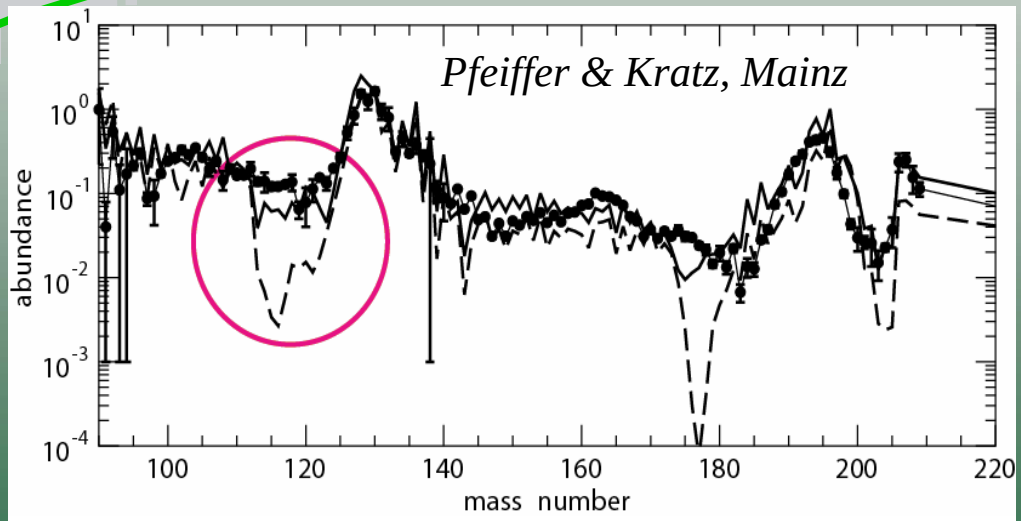
Fission rates and distributions

β-delayed n-emission branchings
(final abundances)



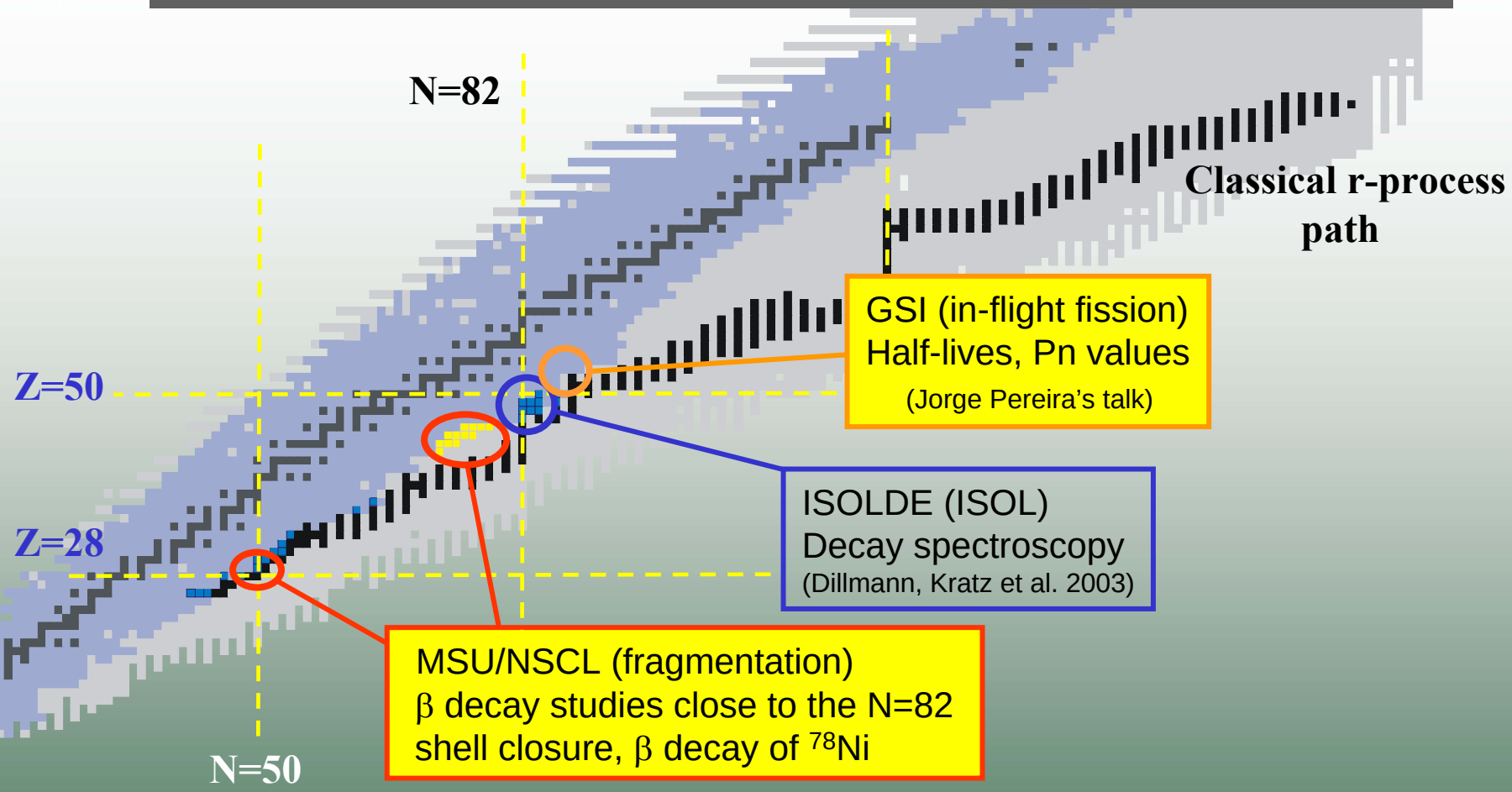
β-decay half-lives
(abundances and
process speed)

Masses (Sn)
(location of the path)



Solar r-process abundances (dots) and abundances using the classical r-process model based on the ETFSI-Q (solid line) mass model and ETFSI-1 (dashed line) mass model

β-decay measurements of r-process nuclei



- Only experimental information available for a few isotopes at the N=50 and N=82 shell closure
- So far, we need to rely heavily on theoretical calculations:

QRPA + Mass models (FRDM, ETFSI)

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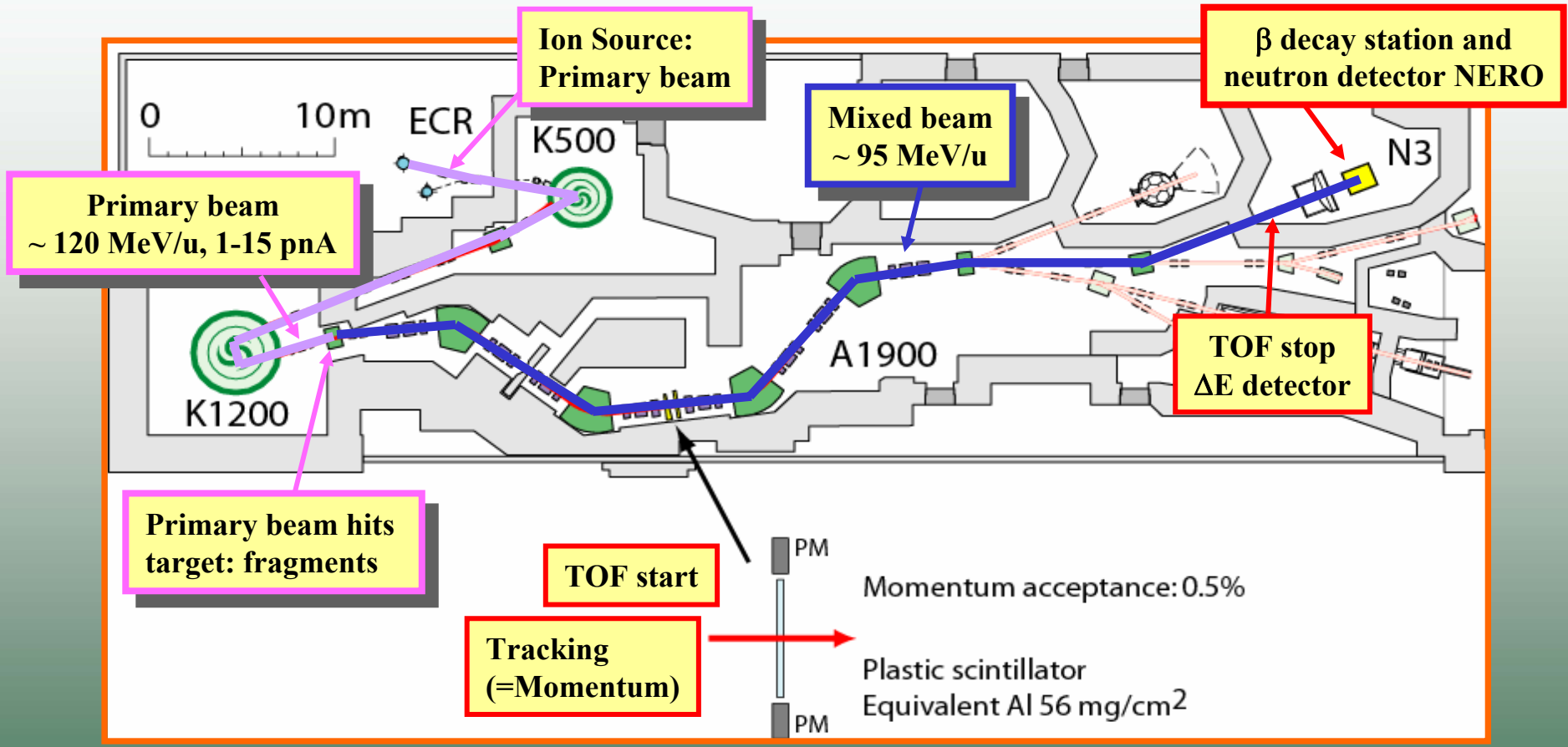
NSCL Coupled Cyclotron Facility



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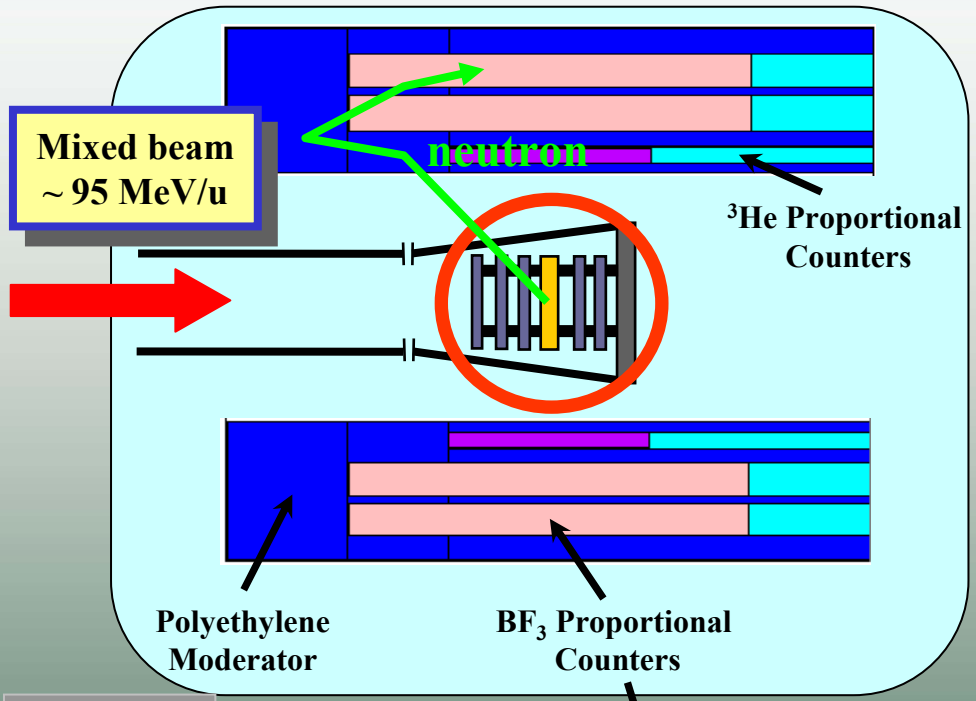
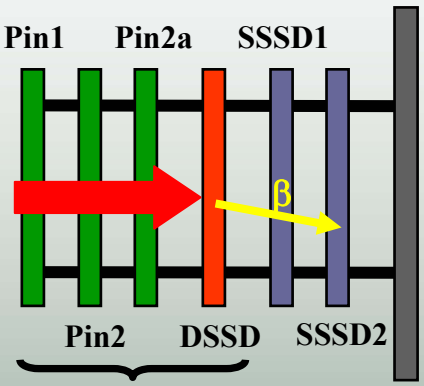
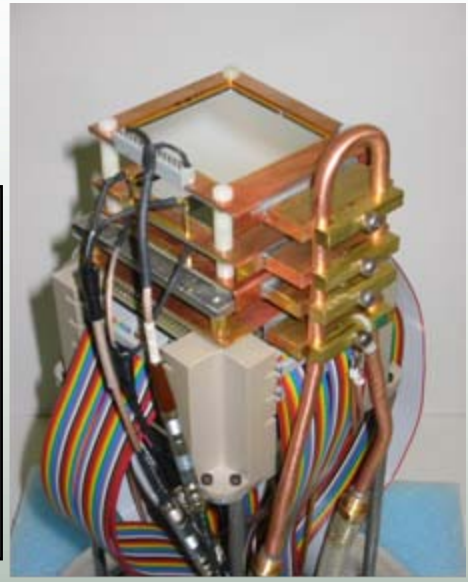
Implant and decay station: β decay studies

β decay station and neutron detector NERO





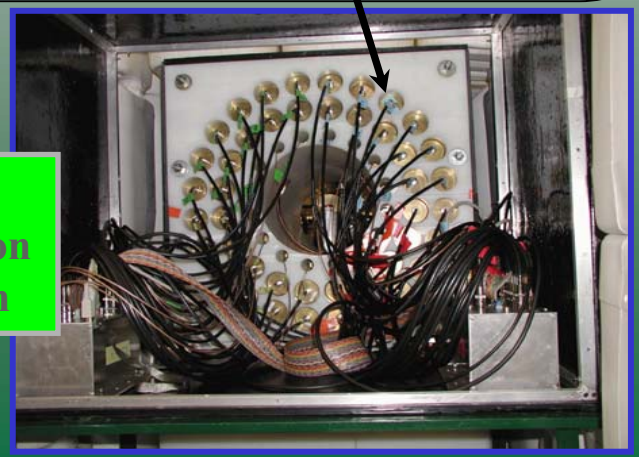
TKE = Pin1+Pin2+Pin2a+DSSD



Implant and β decay detector

Half-lives $T_{1/2}$

Neutron detector



β-delayed neutron emission probabilities Pn

Neutron Emission Ratio Observer (NERO):
- 60 counters total (16 ^{3}He , 44 BF_3)
- 60 cm x 60 cm x 80 cm polyethylene block
- Efficiency ~40%

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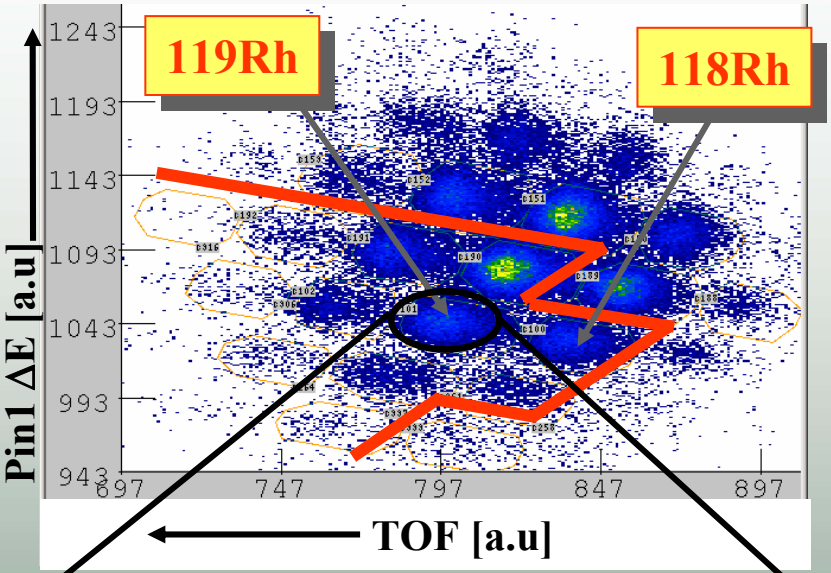
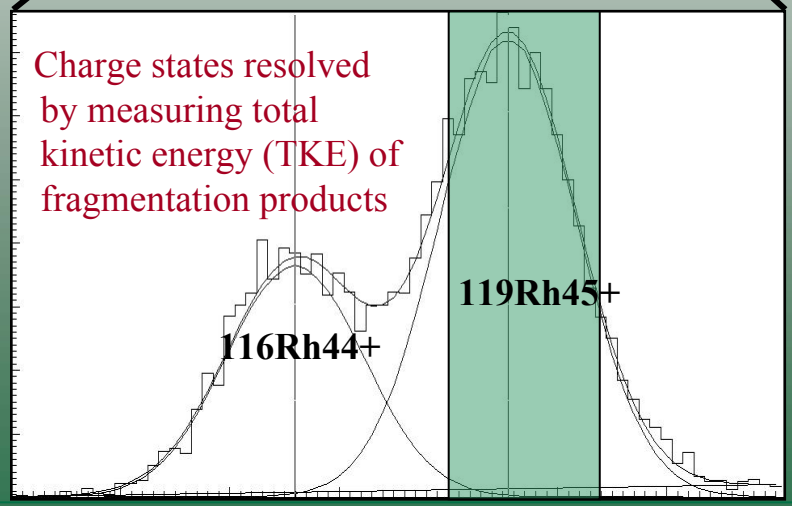
β-Decay Studies Near the N=82 Shell Closure

Particle ID: decays





	70	71	72	73	74	75	76	77	78	79	80	81	82	83
Sn (50)	Sn120	Sn121 >99	Sn122	Sn123 >99	Sn124	Sn125 >99	Sn126 >99	Sn127 >99	Sn128 >99	Sn129 >99	Sn130 >99	Sn131 56.00	Sn132 39.70	Sn133 1.45
In (49)	In119 >99	In120 3.08	In121 23.10	In122 1.50	In123 5.98	In124 3.11	In125 2.36	In126 1.60	In127 1.09	In128 0.84	In129 0.61	In130 0.32	In131 0.28	In132 0.201
Cd (48)	Cd118 >99	Cd119 >99	Cd120 50.80	Cd121 13.50	Cd122 5.24	Cd123 2.10	Cd124 1.25	Cd125 0.65	Cd126 0.506	Cd127 0.37	Cd128 0.34	Cd129 0.27	Cd130 0.20	Cd131 0.18
Ag (47)	Ag117 72.80	Ag118 3.76	Ag119 2.10	Ag120 1.23	Ag121 0.78	Ag122 0.52	Ag123 0.293	Ag124 0.1[illegible]	Ag125 0.166	Ag126 0.107	Ag127 0.079	Ag128 0.058	Ag129 0.046	Ag130
Pd (46)	Pd116 11.80	Pd117 4.30	Pd118 1.90	Pd119 0.9[illegible]	Pd120 0.[illegible]	Pd121	Pd122	Pd123	Pd124	Pd125	Pd126	Pd127	Pd128	Pd129
Rh (45)	Rh115 0.99	Rh116 0.6[illegible]	Rh117 0.44	Rh118	Rh119	Rh120	Rh121	Rh122	Rh123	Rh124	Rh125	Rh126	Rh127	Rh128
Ru (44)	Ru114 0.5[illegible]	Ru115 0.74	Ru116	Ru117	Ru118	Ru119	Ru120	Ru121	Ru122	Ru123	Ru124	Ru125	Ru126	Ru127
Tc (43)	Tc113 0.17	Tc114 0.15	Tc115	Tc116	Tc117	Tc118	Tc119	Tc120	Tc121	Tc122	Tc123	Tc124	Tc125	Tc126
Mo (42)	Mo112	Mo113	Mo114	Mo115	Mo116	Mo117	Mo118	Mo119	Mo120	Mo121	Mo122	Mo123	Mo124	Mo125
Nb (41)	Nb111	Nb112	Nb113	Nb114	Nb115	Nb116	Nb117	Nb118	Nb119	Nb120	Nb121	Nb122	Nb123	Nb124
Zr (40)	Zr110	Zr111	Zr112	Zr113	Zr114	Zr115	Zr116	Zr117	Zr118	Zr119	Zr120	Zr121	Zr122	Zr123

r-process

- New $T_{1/2}$
- Improved $T_{1/2}$
- New P_n

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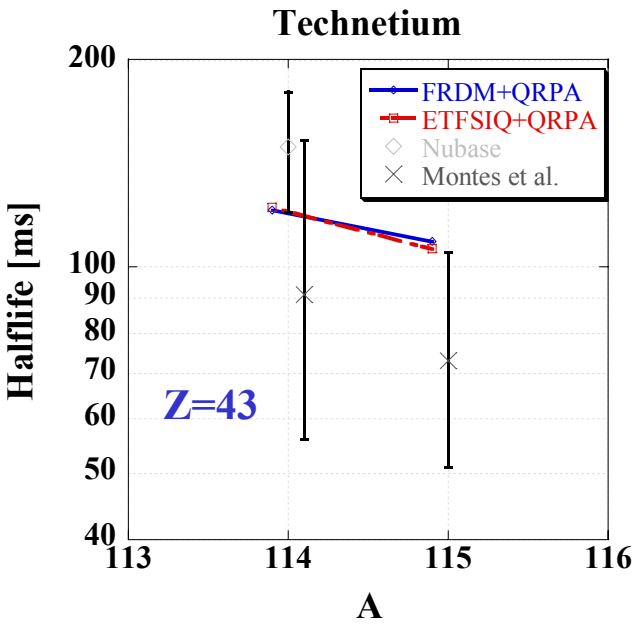
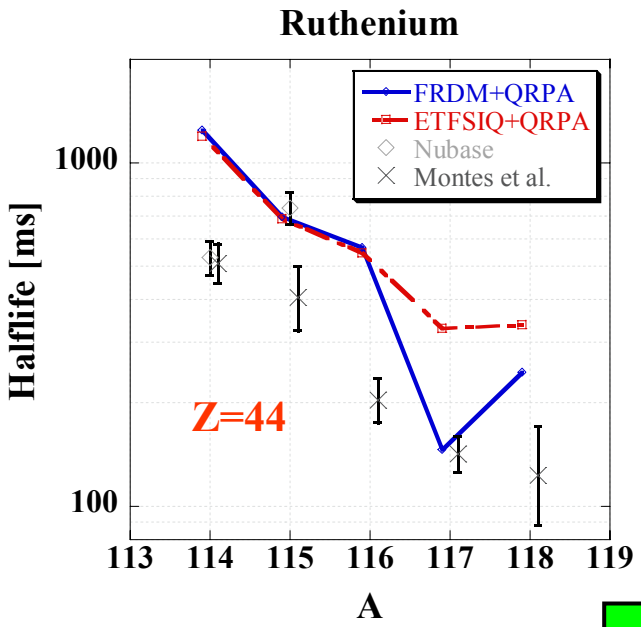
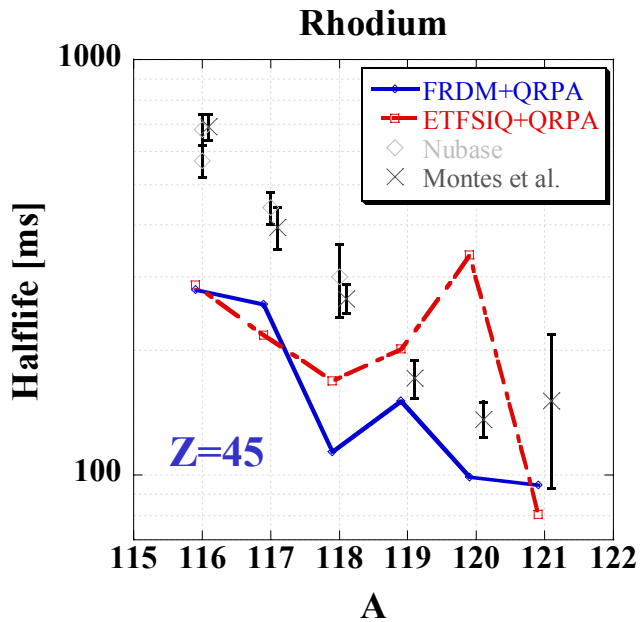
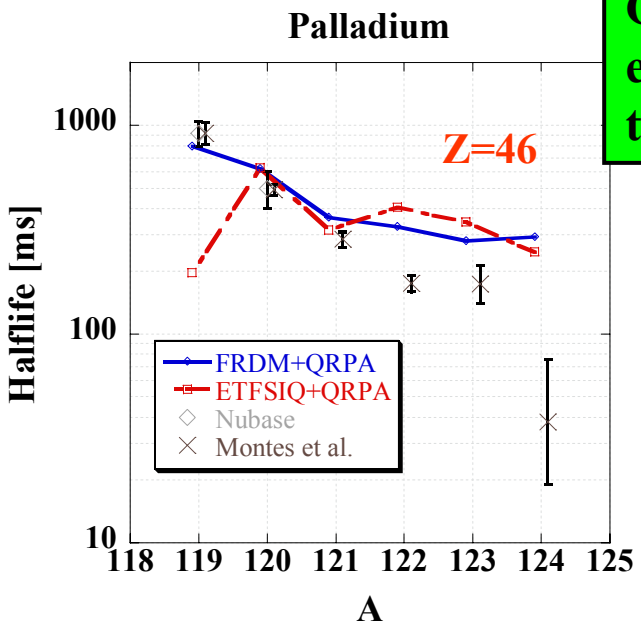
β-Decay Studies Near the N=82 Shell Closure









Our $T_{1/2}$ contribution

Good agreement between experimental and theoretical values

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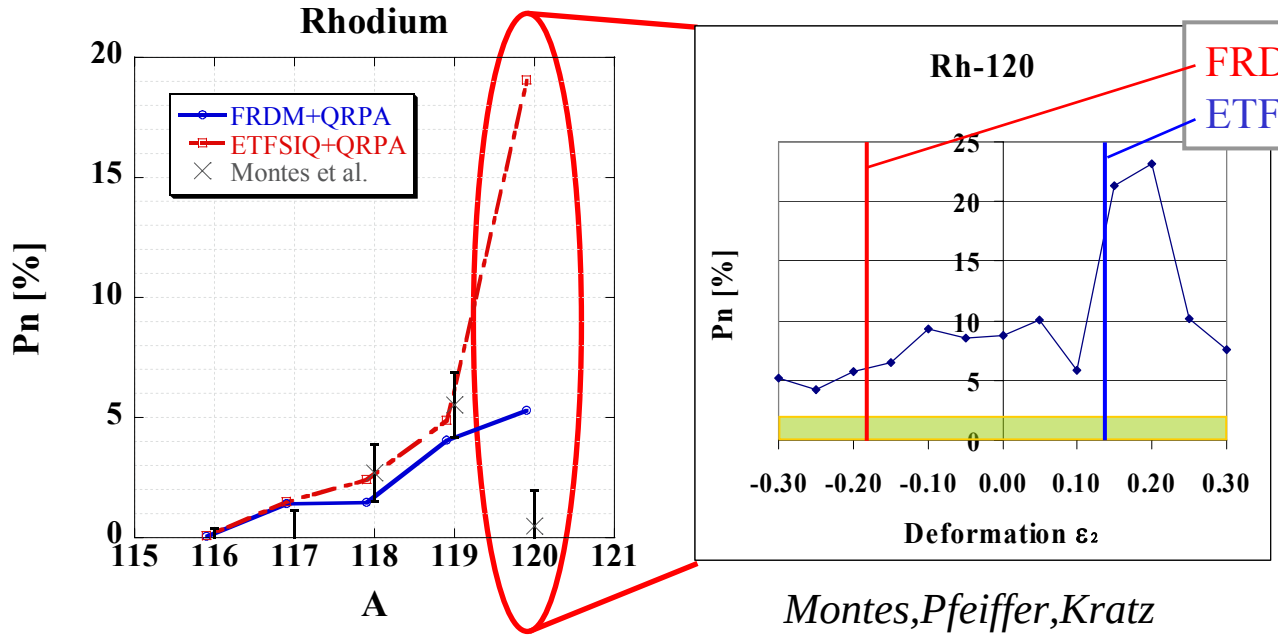


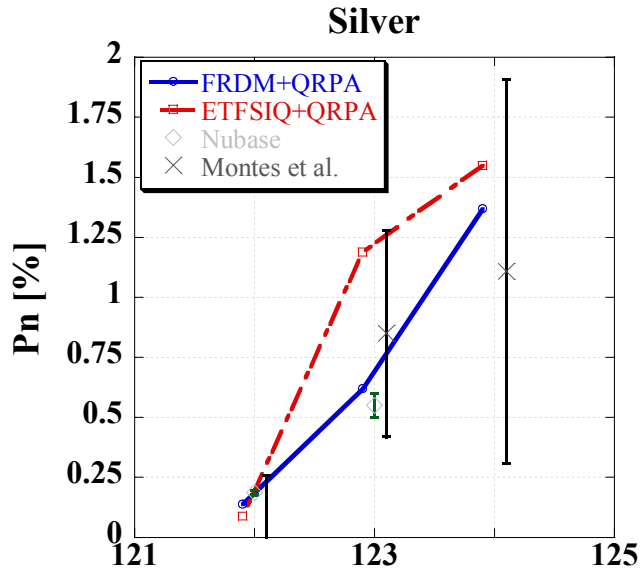
FRDM $\varepsilon_2 = -0.183$

ETFSI-Q $\varepsilon_2 = 0.139$

Montes,Pfeiffer,Kratz
Mainz/JINA

Good agreement between experimental and theoretical values

Only surprise ^{120}Rh



$T_{1/2}$ and Pn <u>rough</u> indicators of nuclear structure …

Deformation and Q value alone are not enough…
s.p. energy levels?
Sn values?

Montes et al.

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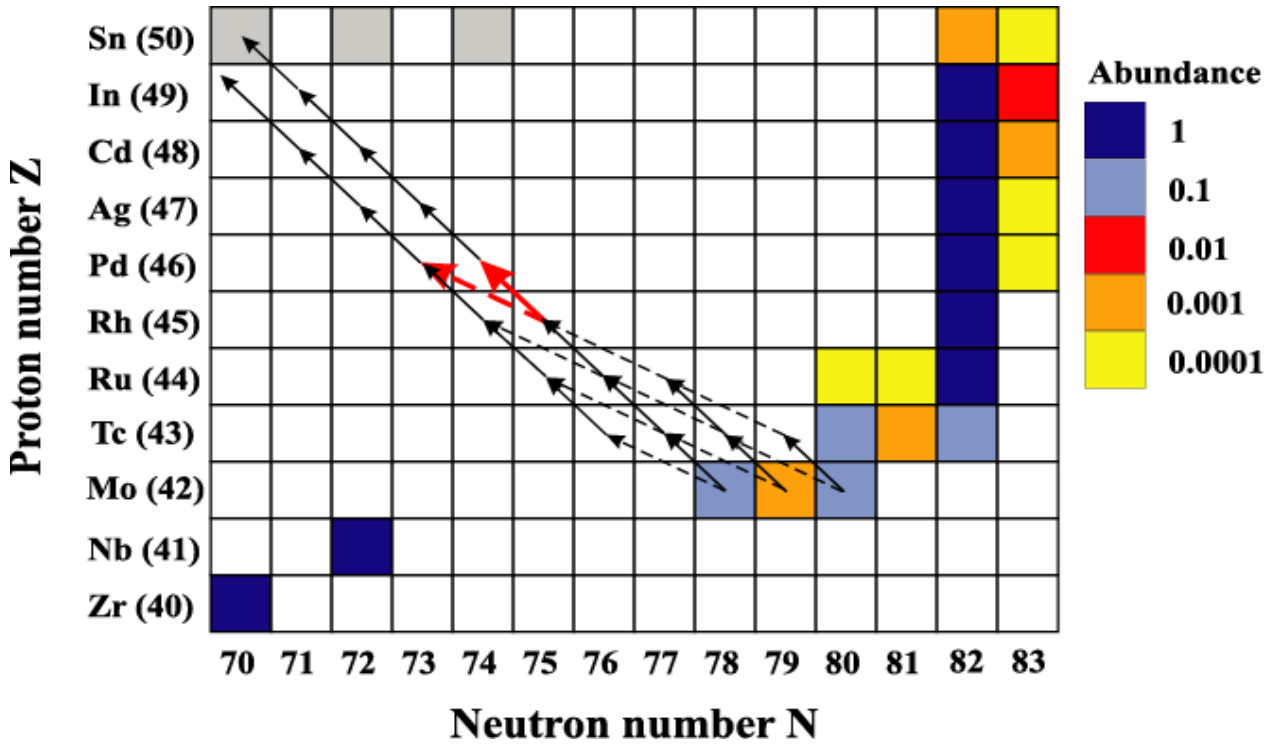
β-Decay Studies Near the N=82 Shell Closure

Calculated isotopic abundances just before freezeout



Branchings modify final abundance before freezeout

Abundance ratio $^{120}Sn/^{119}Sn$ is increased by 60% but…..

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Summary

- Nuclear physics is needed to make full use of astronomical observations and to experimentally constrain r-process models
- Experimental nuclear data (and good theoretical models) are needed
- Good agreement between predictions and experimental values (less than a factor of 3) in this mass region
- Except ^{120}Rh P_n value: not explained by quadrupole deformation or mass uncertainty. Incorrect placement of the dominant GT feeding ($\nu g_{7/2} \rightarrow \pi g_{9/2}$)
- Effect in the r-process? Isotopic ratio ^{120}Sn/^{119}Sn

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β-decay measurements of r-process nuclei

Collaboration

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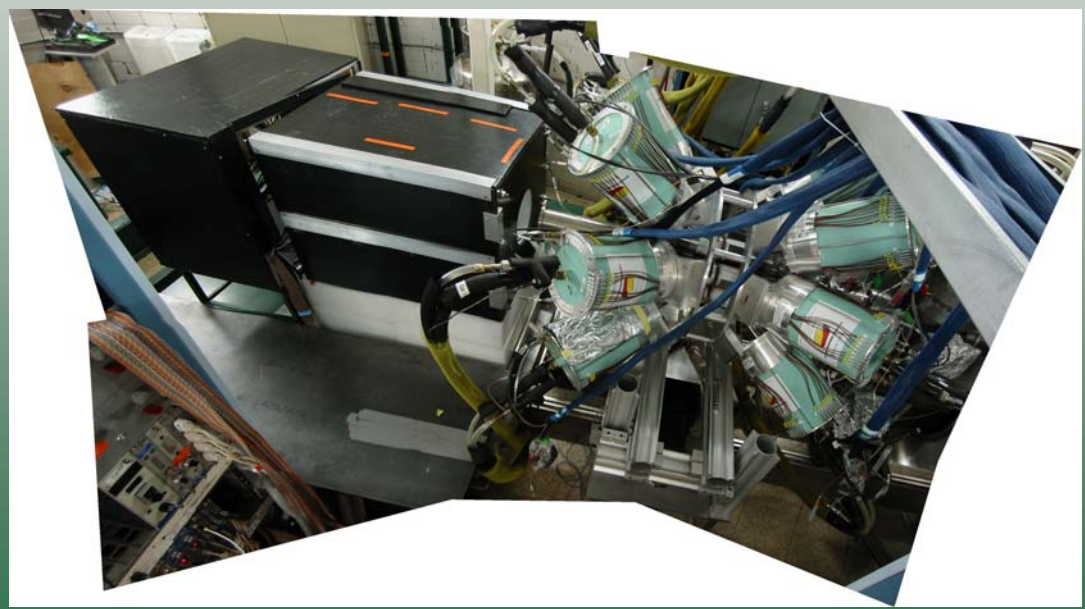

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β-Decay Studies Near the N=82 Shell Closure

Over-prediction of the experimental $T_{1/2}$ for N≥74 Pd isotopes…
Uncertainty in the input parameters???

1. **ε_2 does not explain it..**
2. **An increase in the Q_β value better reproduce the experimental results..**

- **Large Q_b value ^{130}Cd decay best reproduced by mass models with N=82 shell quenching (Dillmann et al. PRL 91 (2003) 162503)**
- **Systematic Variation of $E(2^+)$ for ^{120}Pd: hints to the absence of shell quenching (Walters et al. Phys. Rev. C (2004) 034314)**

$T_{1/2}$ and Pn rough indicators of nuclear structure …

Increase in Q_β consistent with a weakening of the neutron shell-closure seen by N≥74 Pd but…..

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