R-process experiments at fragment separator facilities

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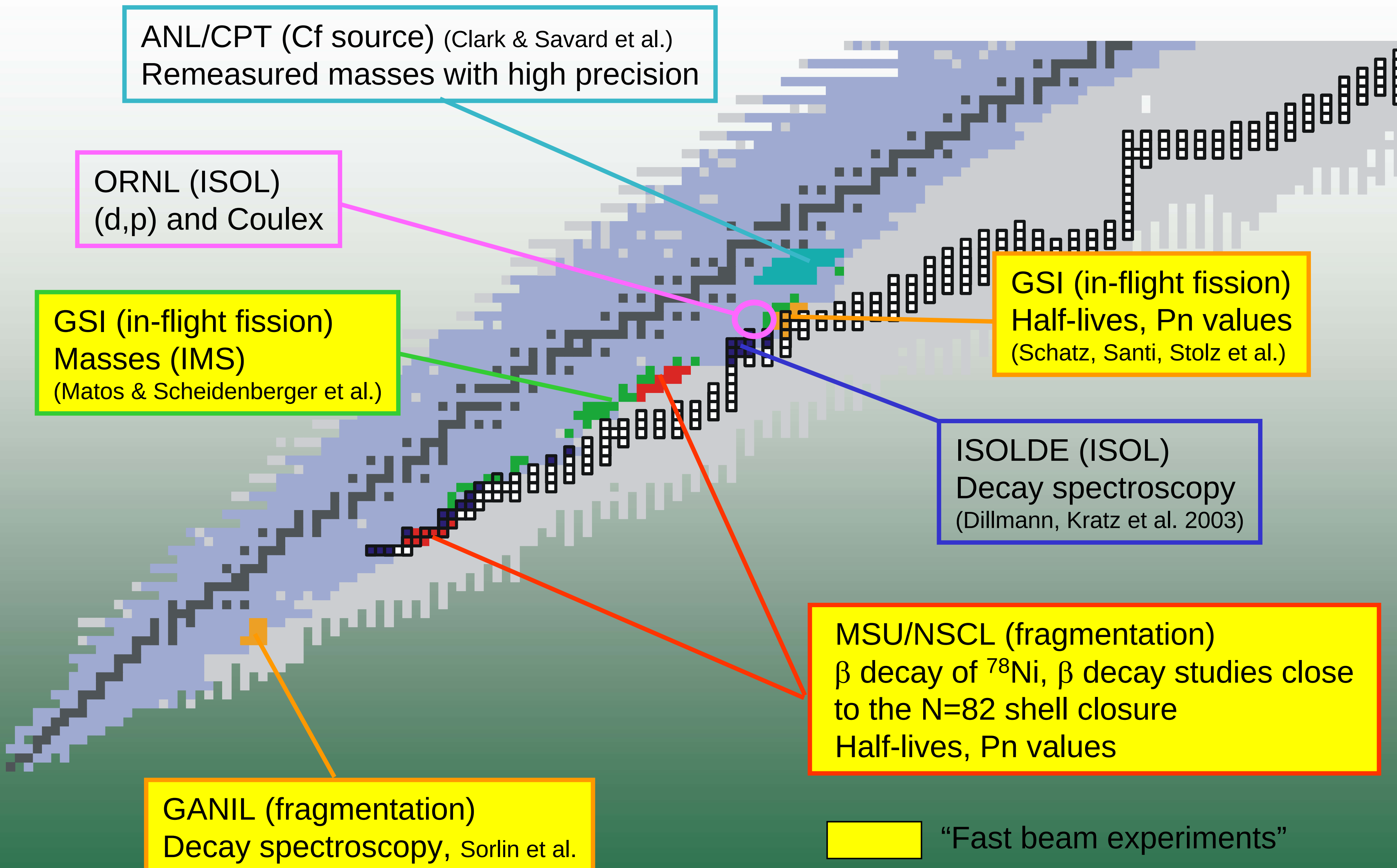

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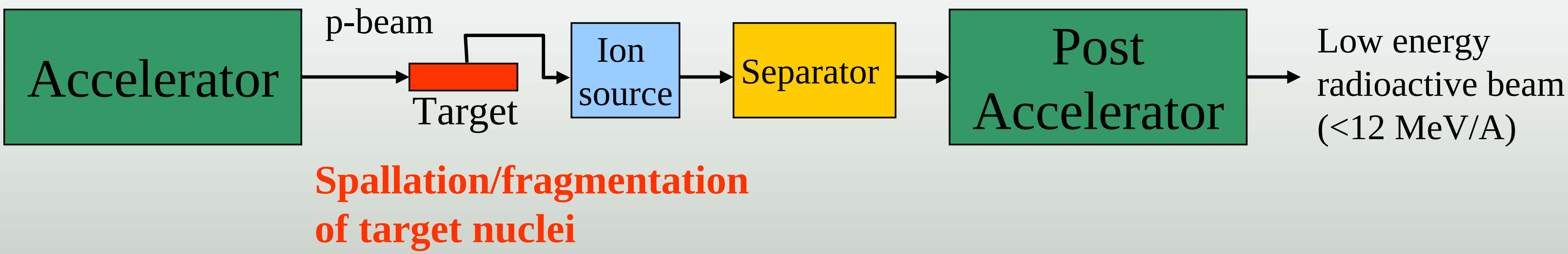
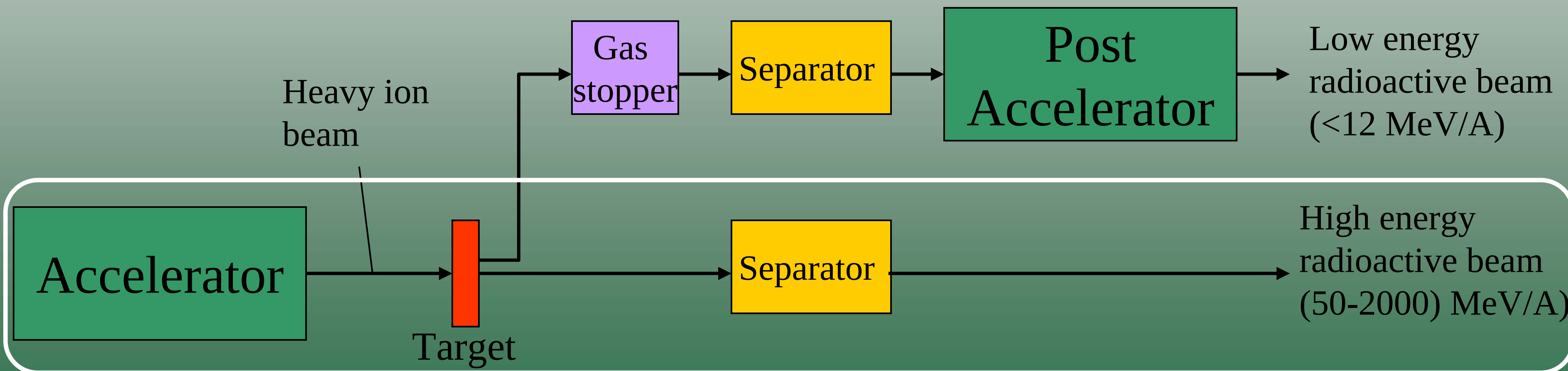
Production of radioactive beams

ISOL (ISOLDE, ISAC, Oak Ridge, Louvain-la-Neuve, …):



Fragmentation (NSCL, GSI, RIKEN, GANIL, …):



Fast beams from fragmentation

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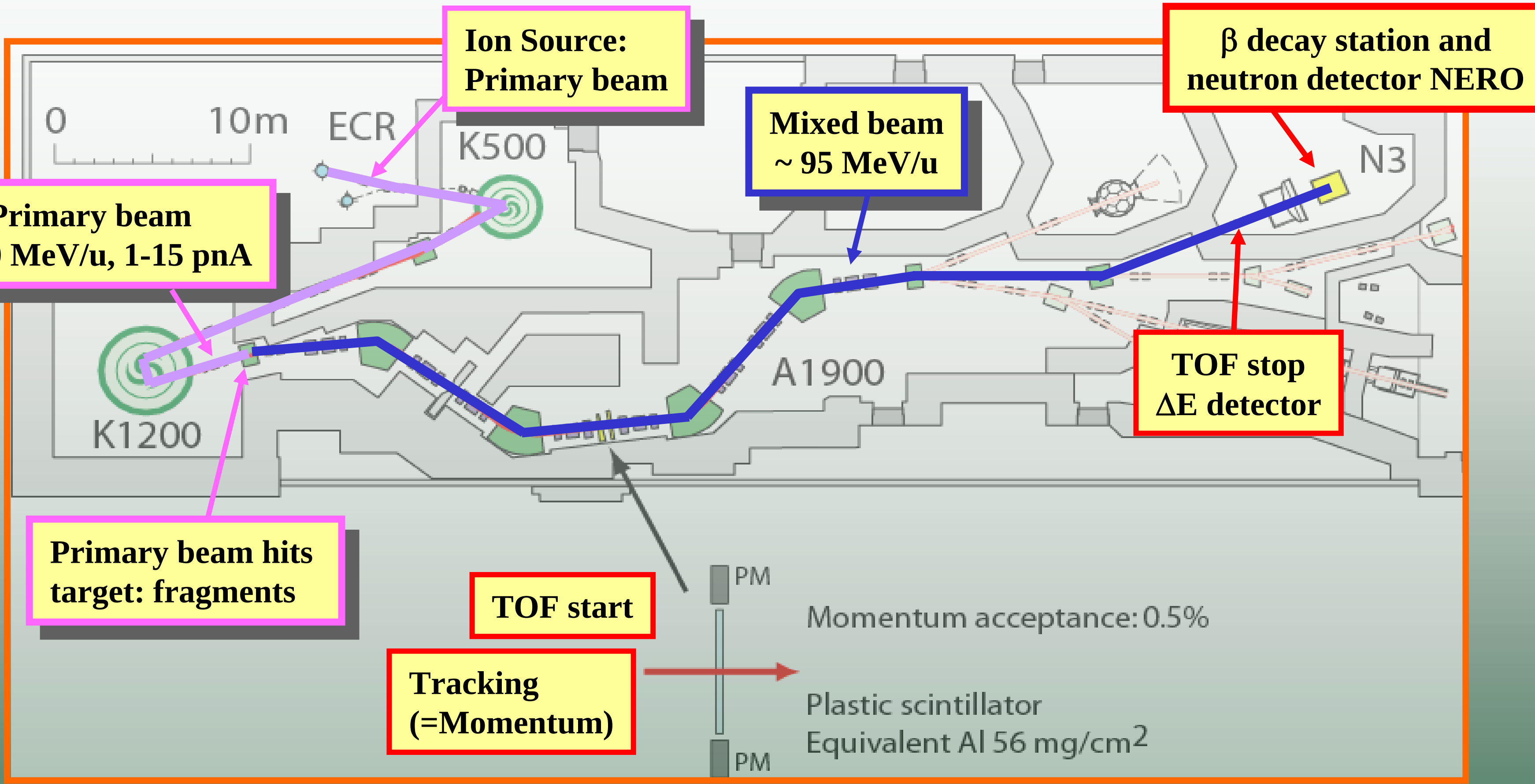
NSCL Coupled Cyclotron Facility



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Summary features of fast beams from fragmentation

Fast beams from fragmentation complement other techniques and they have these particular features :

- High selectivity even with mixed (“cocktail”) beams because due to its high energy, relevant particle properties can be detected (TOF, energy losses …)
- Fast beam – negligible decay losses (~100 nanoseconds..)
- Production of broad range of rare isotope beams with a single primary beam

Typical beam energies: 50-1000 MeV/nucleon
Typical new rare isotope beams can be produced within ~ 1h

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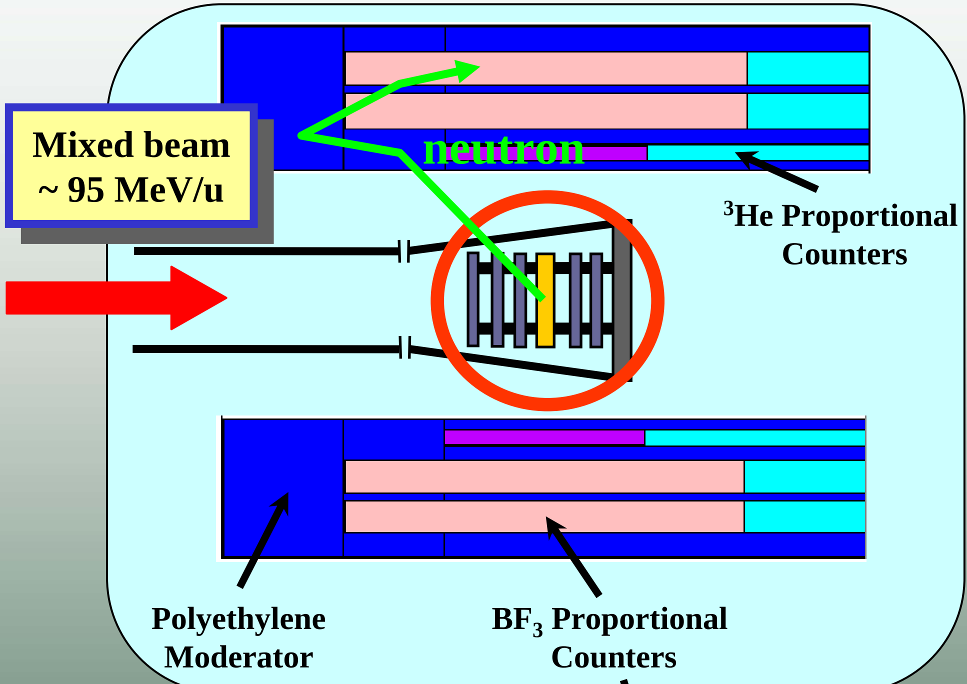
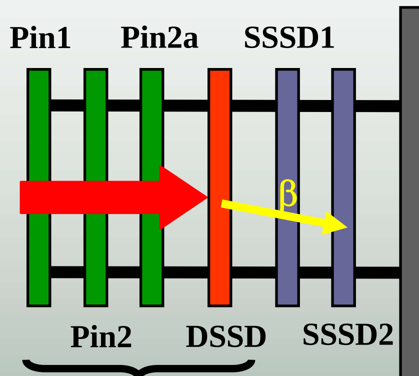
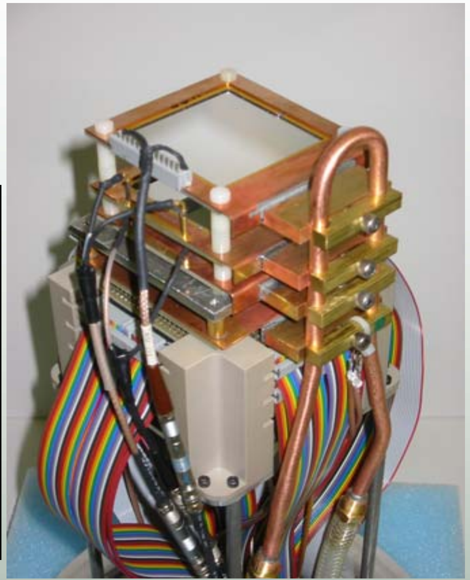
Implant and decay station: β decay studies

β decay station and neutron detector NERO





TKE = Pin1+Pin2+Pin2a+DSSD

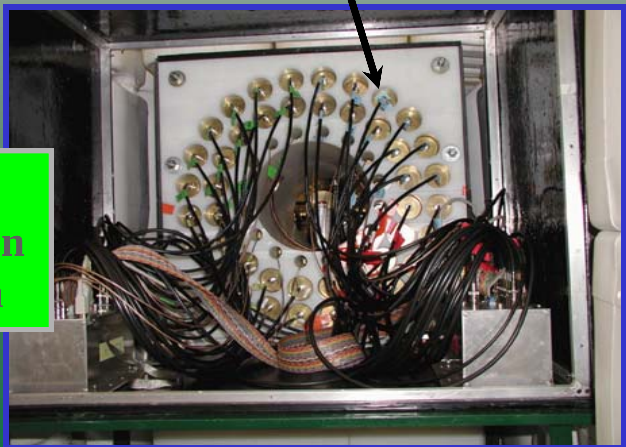


Implant and β decay detector

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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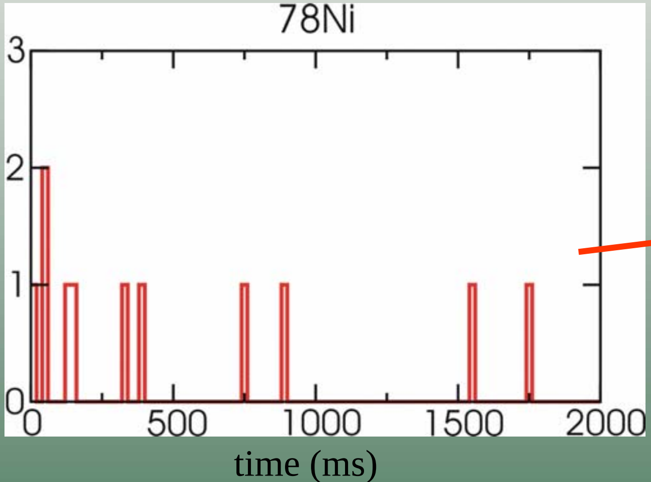
Exp. 02028: β Decay Half-life of ^{78}Ni

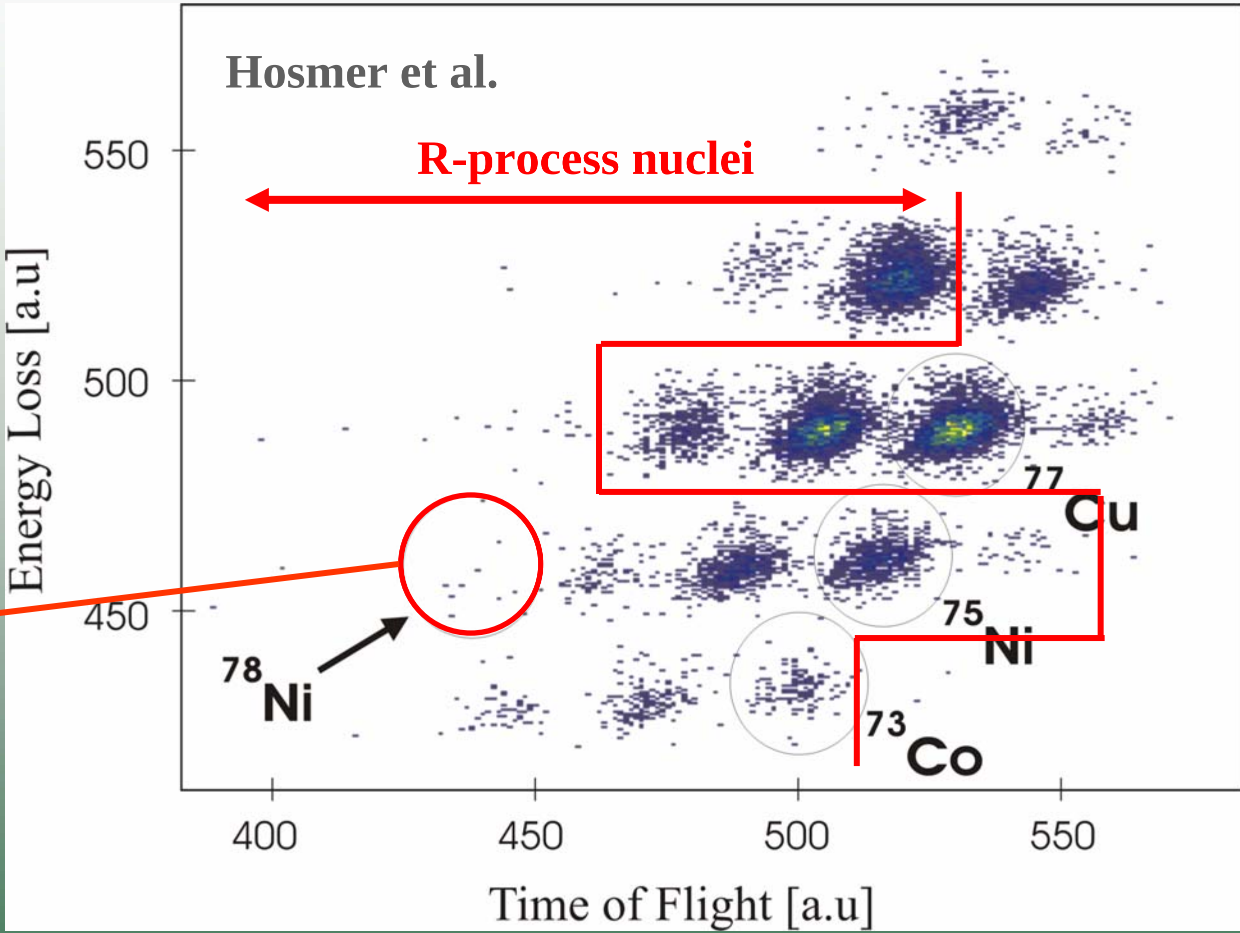
Measured $t_{1/2}$ of $^{75-78}$Ni

Total ^{78}Ni yield: 11 events in 104 h



Half-lives are important r-process inputs, affecting abundances and time scales.

Particle Identification



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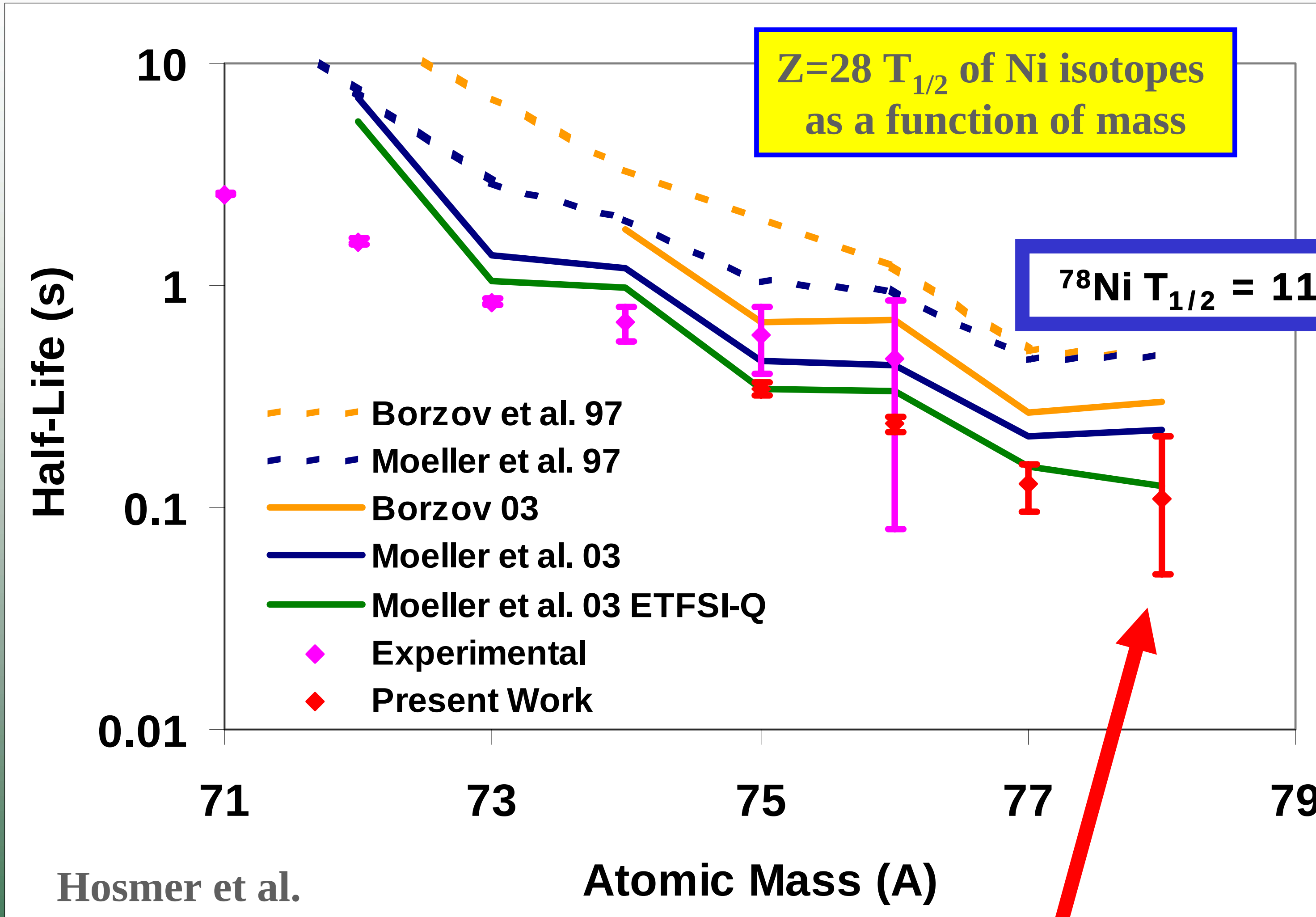

^{78}Ni $T_{1/2} = 110^{+100}_{-60}$ ms

^{78}Ni: relatively short $T_{1/2}$

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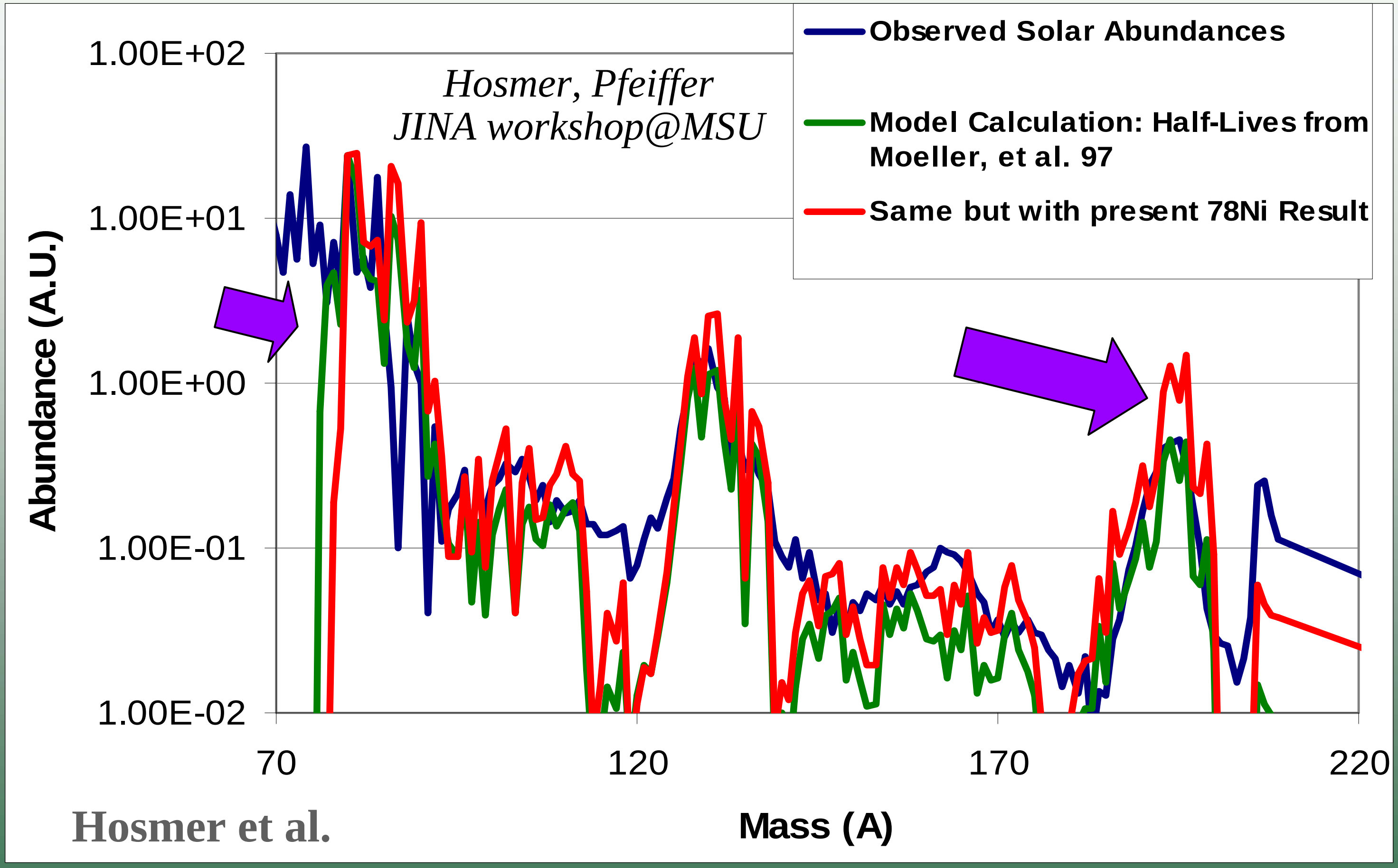
Exp. 02028: β Decay Half-life of ^{78}Ni

Shorter $T_{1/2}$ of a waiting point → Acceleration of r-process



Acceleration of process means more material reaches higher mass.

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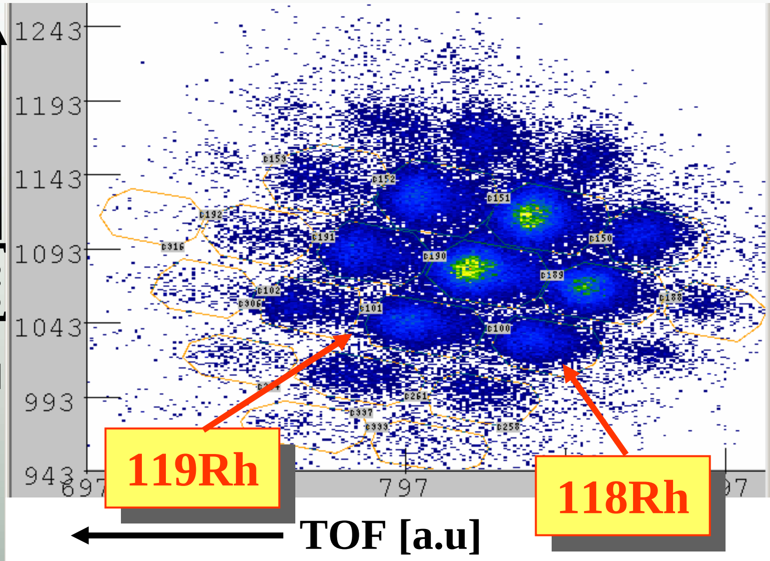
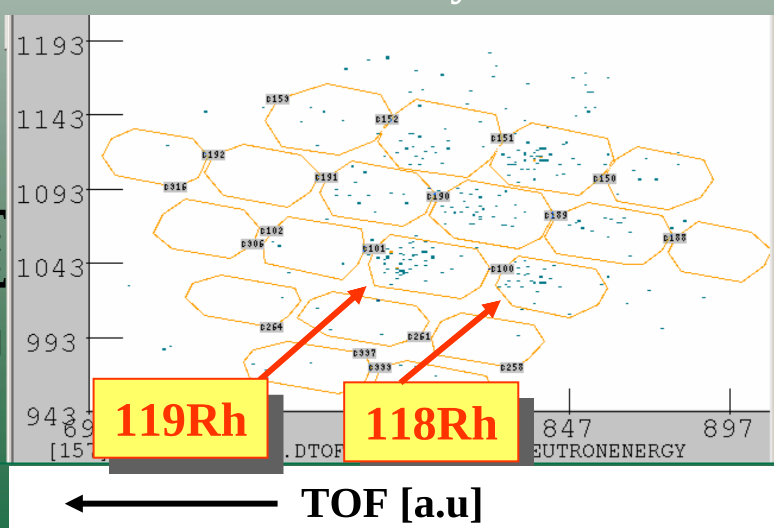
Exp. 02032 : β-Decay Studies Near the N=82 Shell Closure

Particle ID: decays



Particle ID: decay-neutron



Z \ N	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 0.172	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 0.92	Pd120 [illegible]	Pd121	Pd122	Pd123	Pd124	Pd125	Pd126	Pd127	Pd128	Pd129
Rh (45)	Rh115 0.99	Rh116 0.68	Rh117 0.44	Rh118	Rh119	Rh120	Rh121	Rh122	Rh123	Rh124	Rh125	Rh126	Rh127	Rh128
Ru (44)	Ru114 0.53	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

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

r-process

Preliminary
Montes et al.

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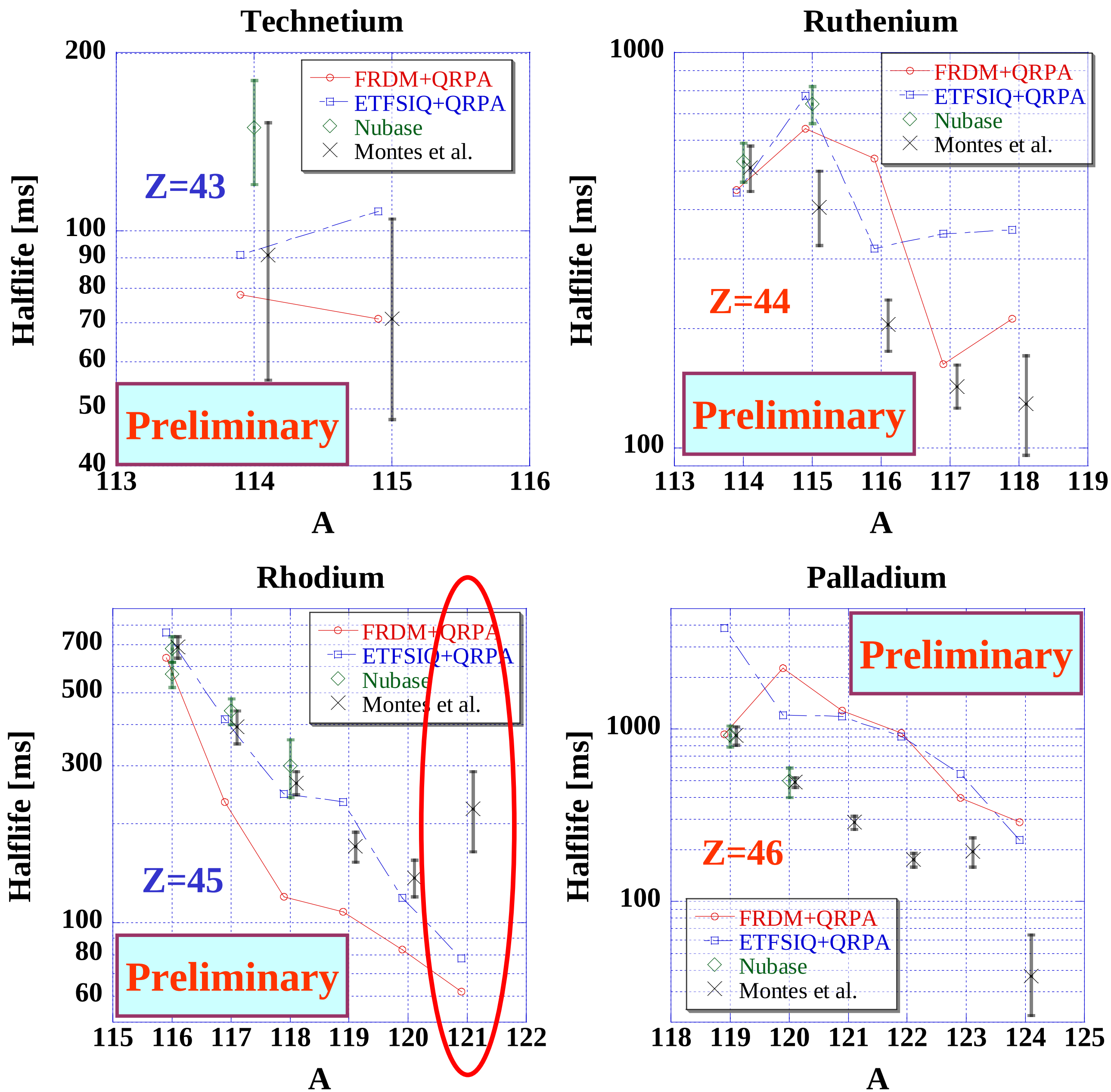
Exp. 02032 : β-Decay Studies Near the N=82 Shell Closure



Our $T_{1/2}$ contribution

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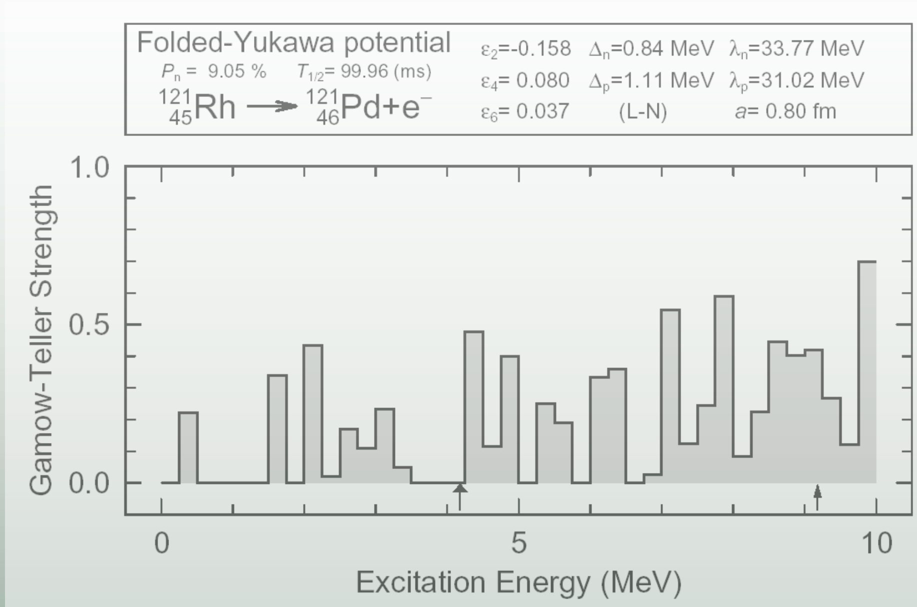
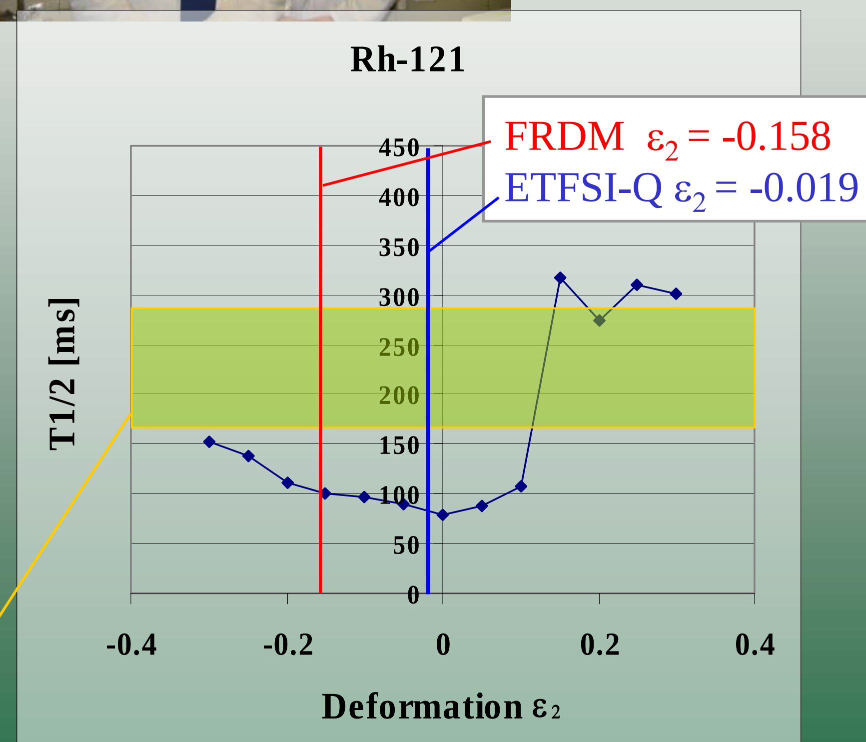


Montes,Pfeiffer,Kratz
Mainz/JINA

Q, Sn from Audi et al., Nucl. Phys. A729 (2003)

Ruthenium: Lower $T_{1/2}$ than predicted
Rhodium : Higher $T_{1/2}$ values than predicted
Palladium: Lower $T_{1/2}$ values than predicted



Experimental result

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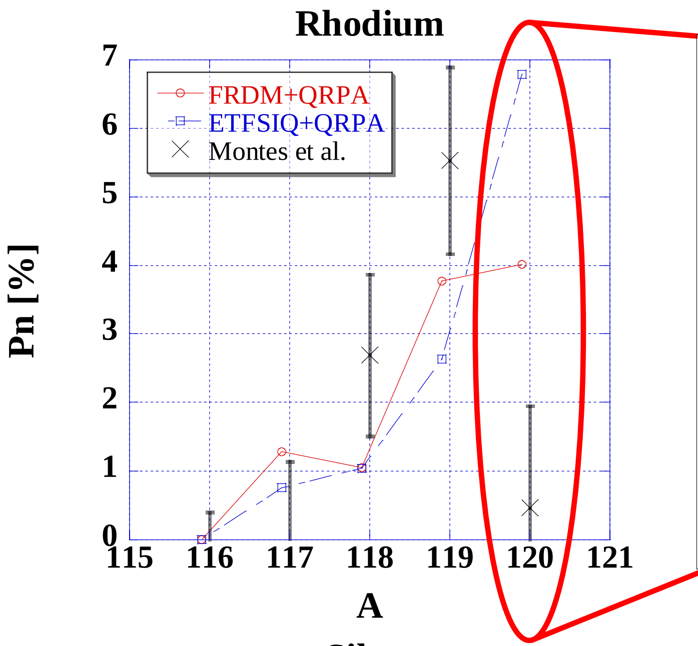
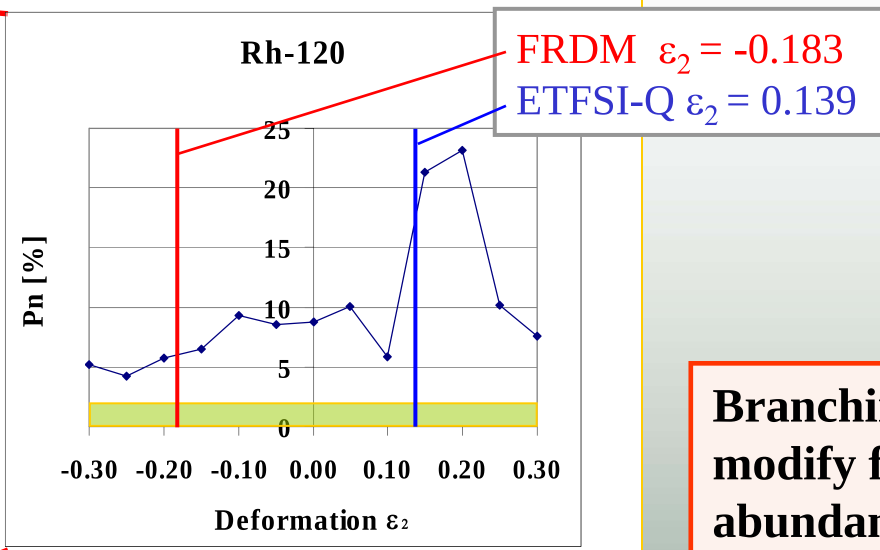
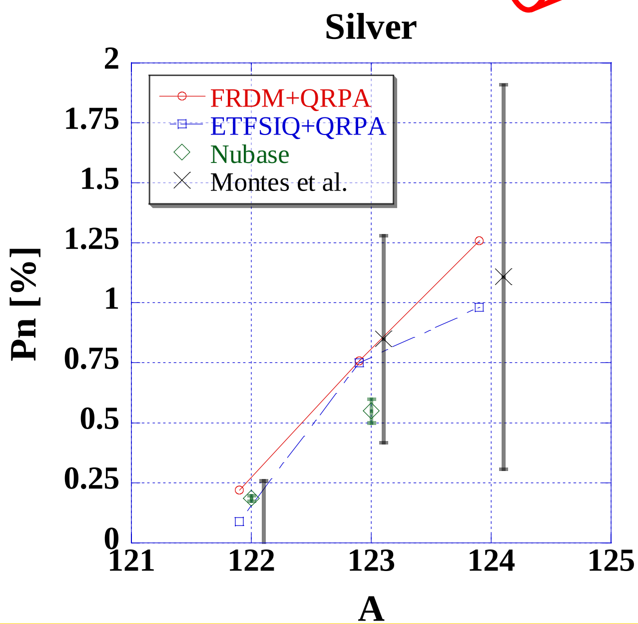




Montes,Pfeiffer,Kratz
Mainz/JINA



Preliminary

Deformation alone is not enough…
S.p. energy levels?
Q and Sn values?

Montes et al.

Branchings modify final abundance before freezeout

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

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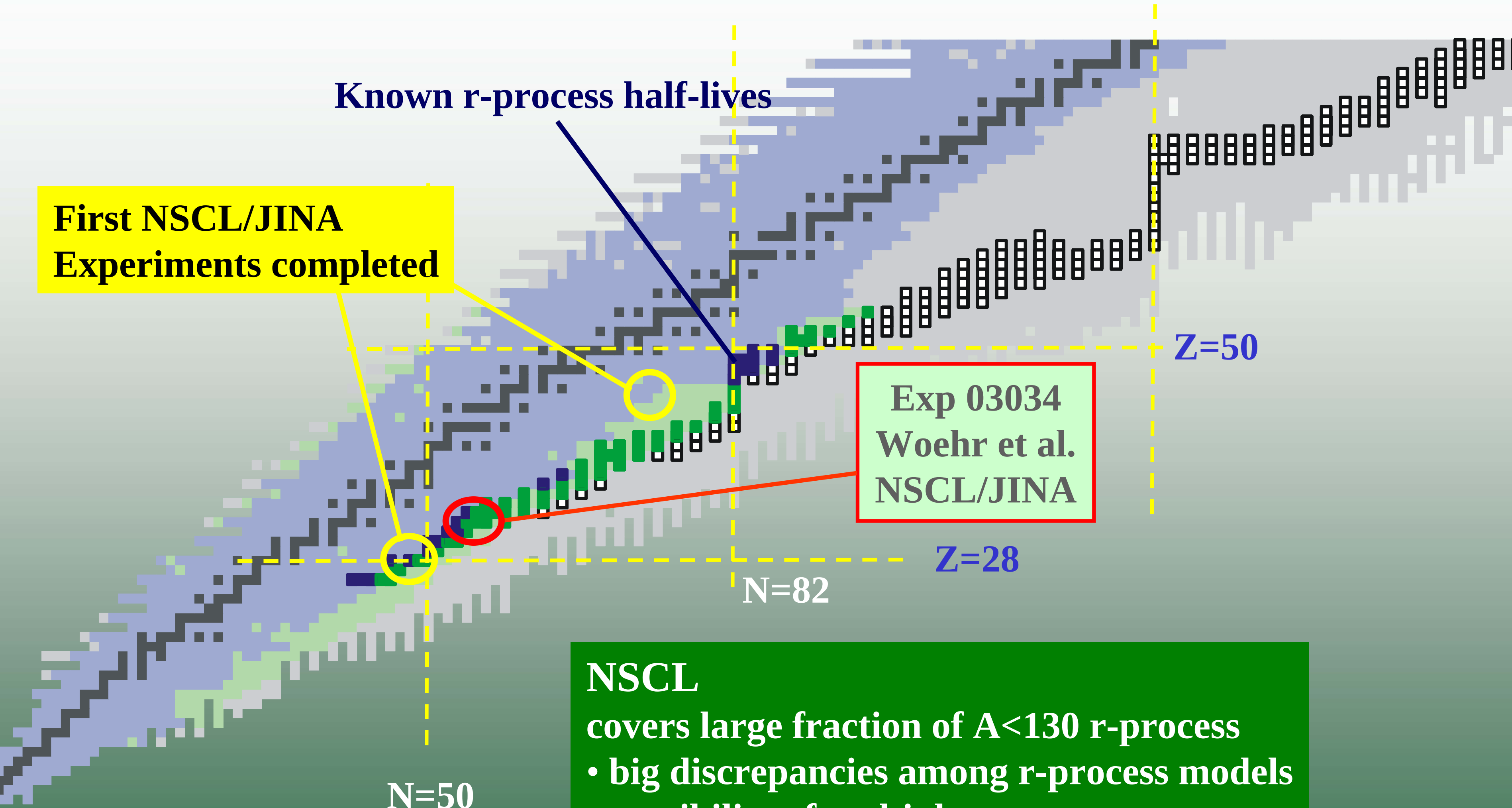
NSCL reach



NSCL
covers large fraction of A<130 r-process
- **big discrepancies among r-process models**
- **possibility of multiple r-processes**

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R-process collaboration

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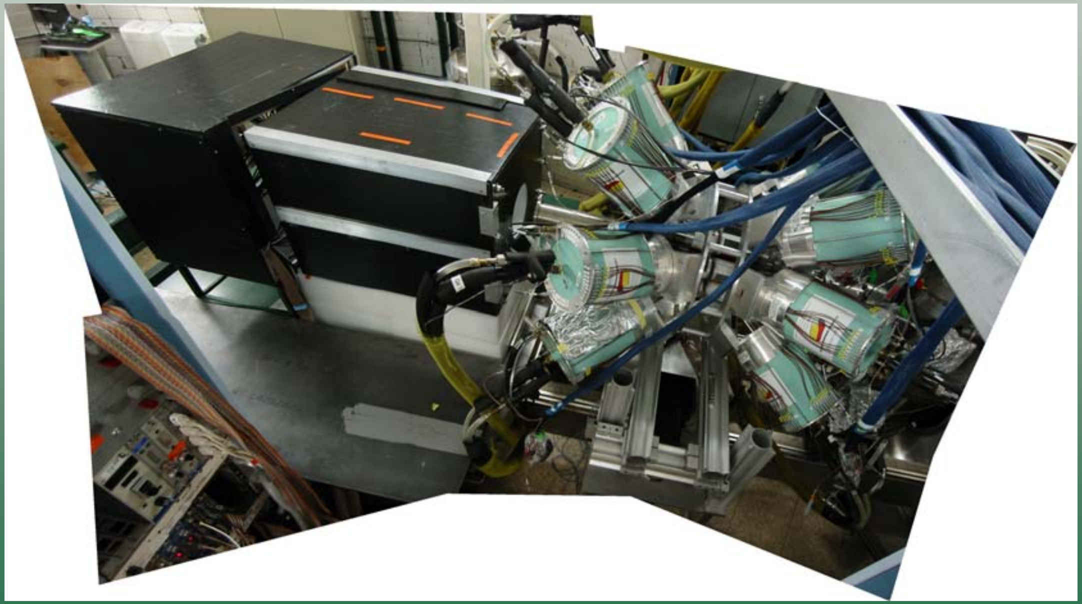

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