

Single-particle structure of neutron-rich copper

Direct reactions and spectroscopy with hydrogen targets:
past 10 years at RIBF and future prospects
York, August 2023

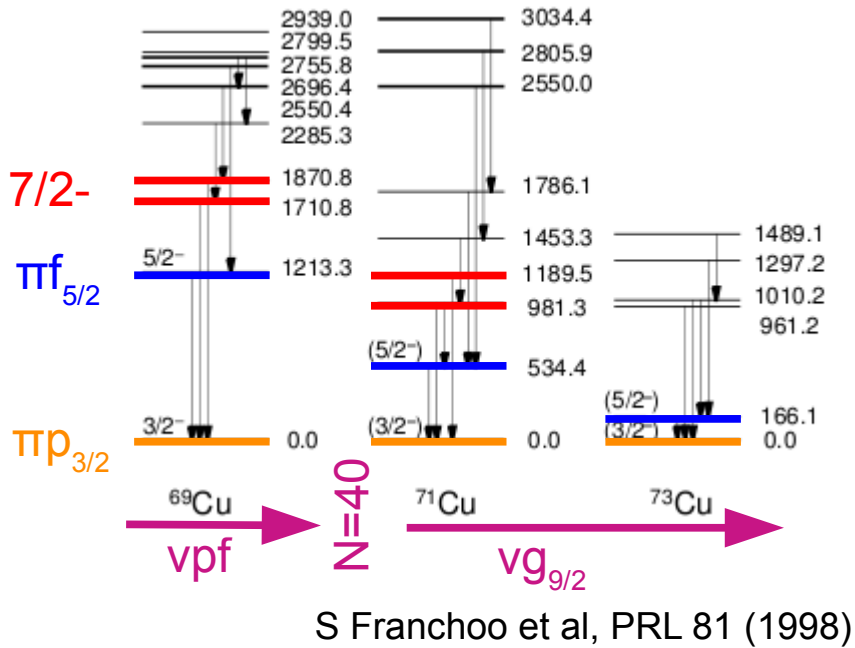
S Franchou

IJC, Orsay, France

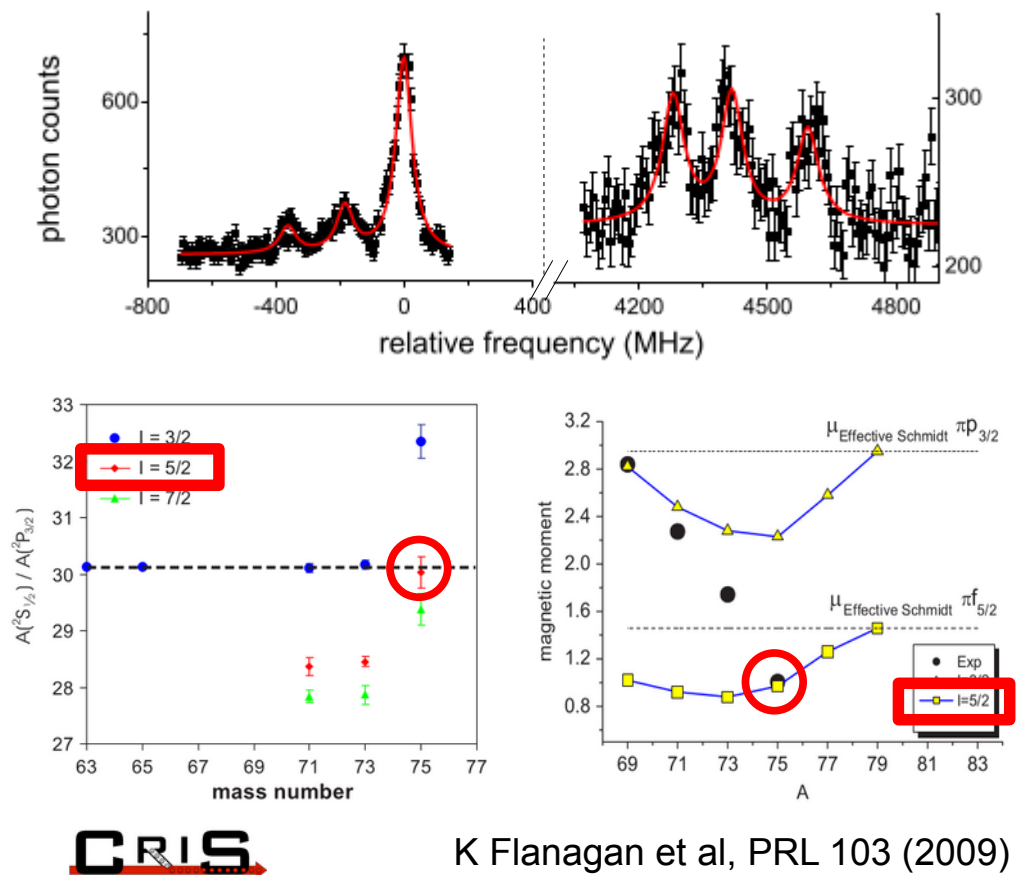


Monopole migration in neutron-rich copper

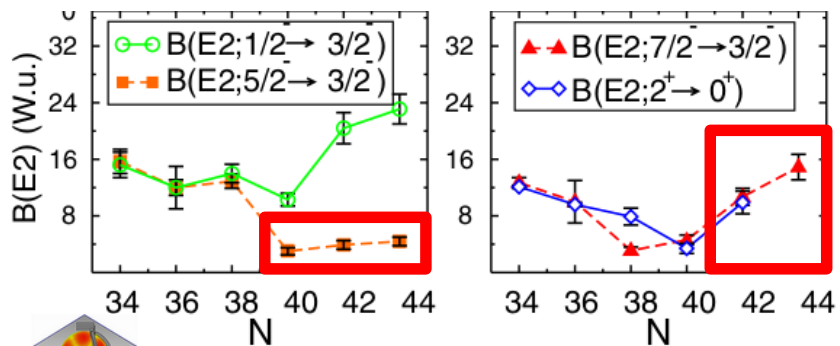
β decay into $^{69,71,73}\text{Cu}$ at Lisol



laser spectroscopy of ^{75}Cu at Cris Isolde

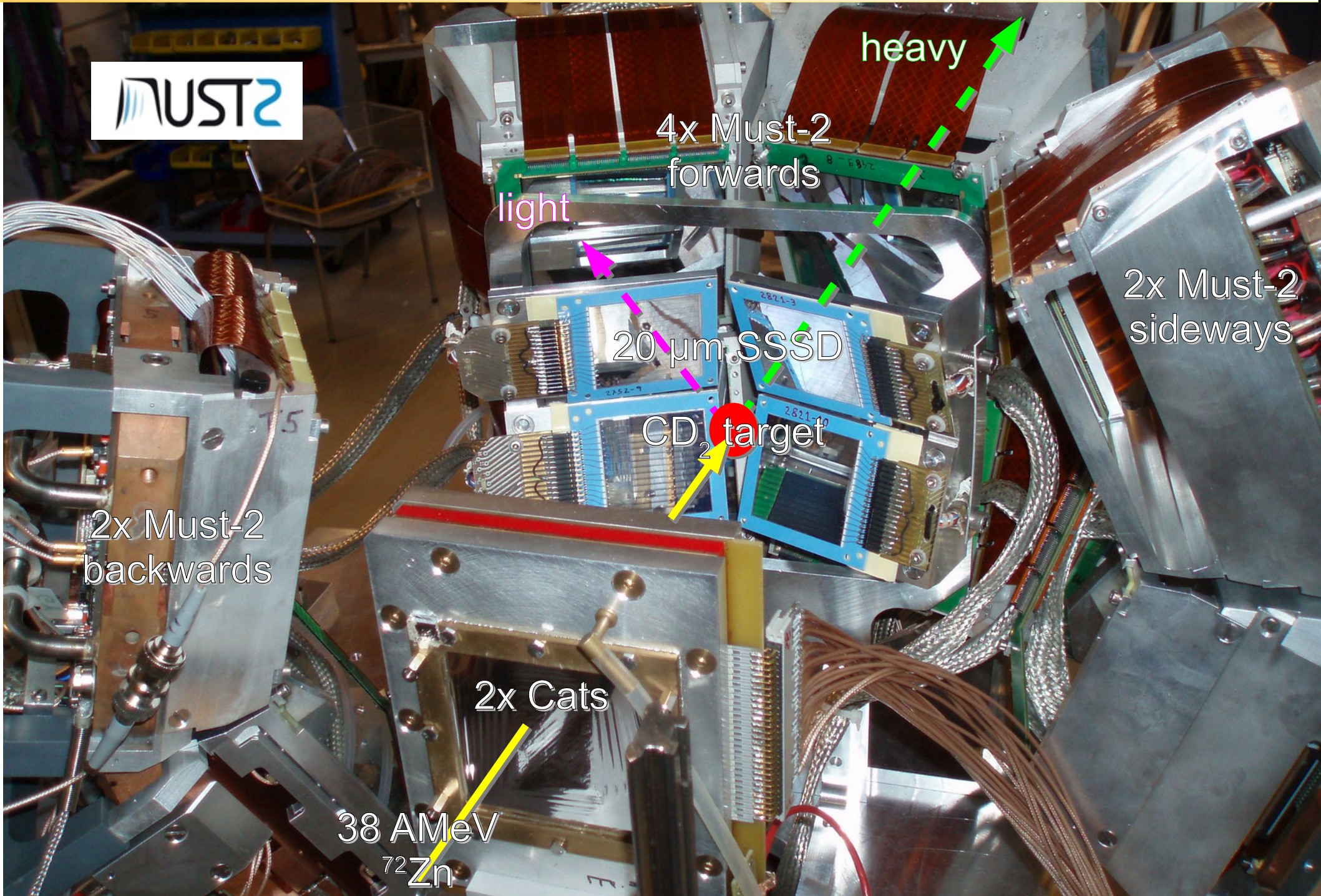


Coulomb excitation at Rex Isolde



- $\pi f_{5/2}$ single-particle nature from Coulex
- $\pi f_{5/2}$ becomes ground state in ^{75}Cu
- related to $\ell-1/2 \pi f_{5/2} \leftrightarrow \ell+1/2 \nu g_{9/2}$ interaction?
- Coulex leaves one candidate for $\ell+1/2 \pi f_{7/2}$!

Proton pick-up into ^{71}Cu at Ganil



heavy

4x Must-2
forwards

light

20 μm SSSD

CD_2 target

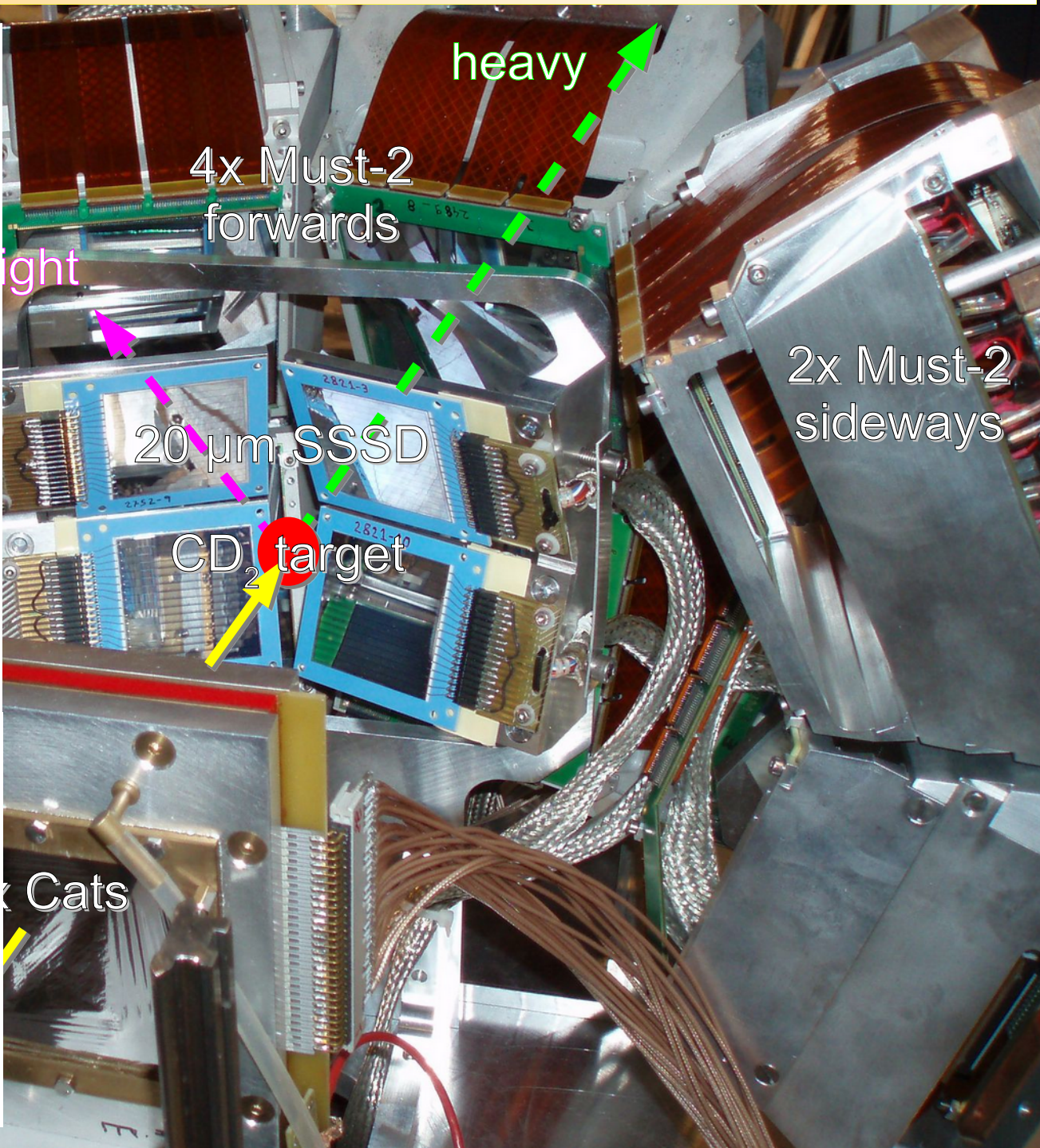
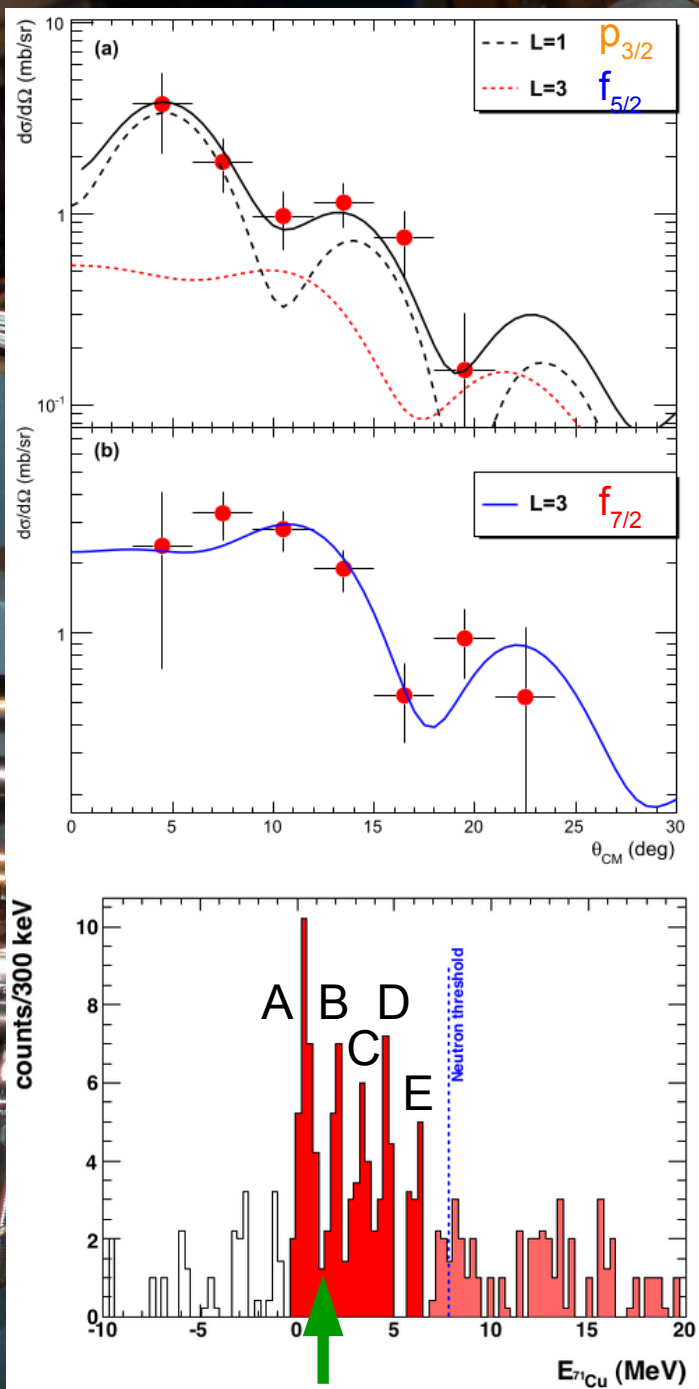
2x Must-2
sideways

2x Must-2
backwards

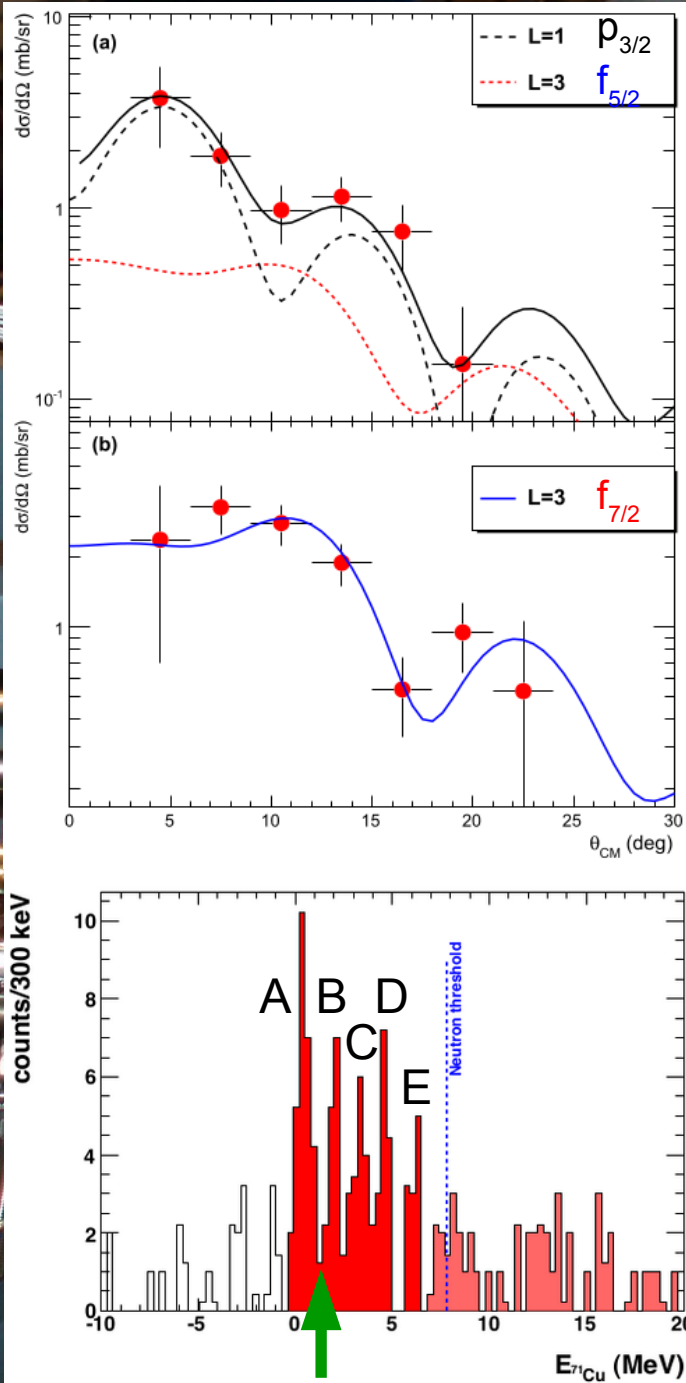
2x Cats

38 A MeV
 ^{72}Zn

Proton pick-up into ^{71}Cu at Ganil



Proton pick-up into ^{71}Cu at Ganil



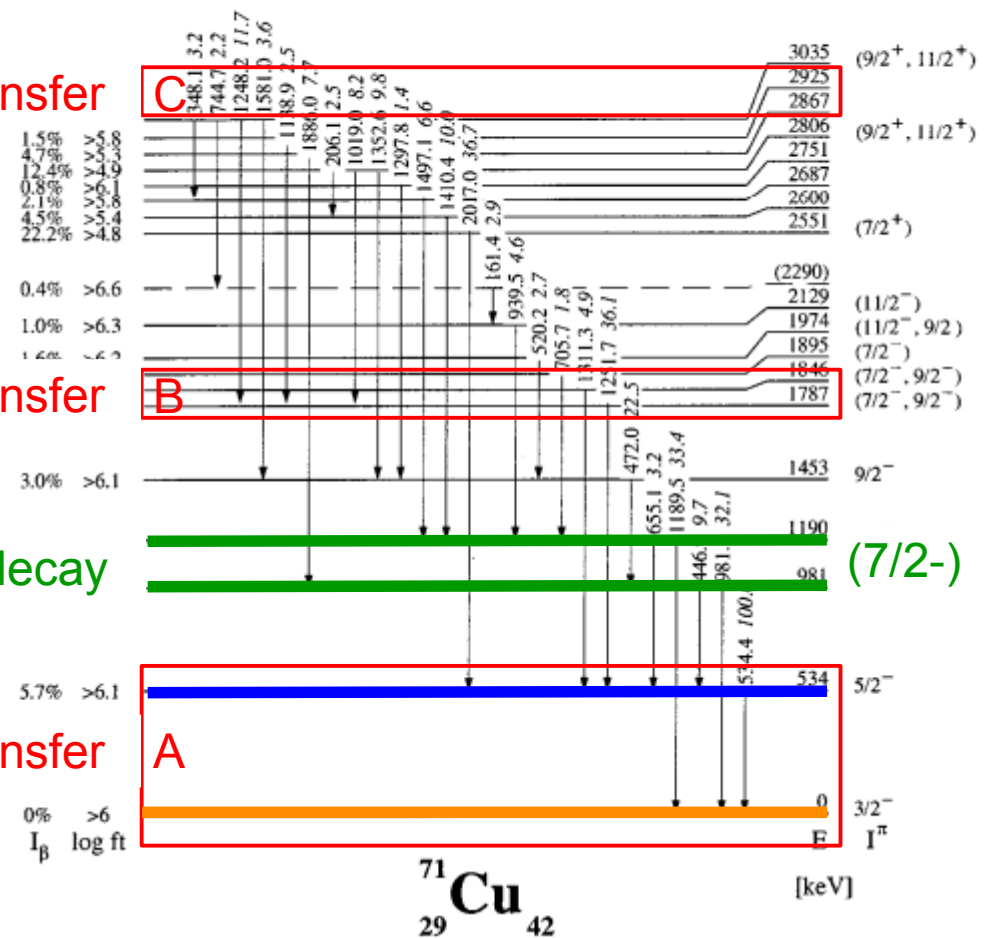
transfer **D**

transfer **C**

transfer **B**

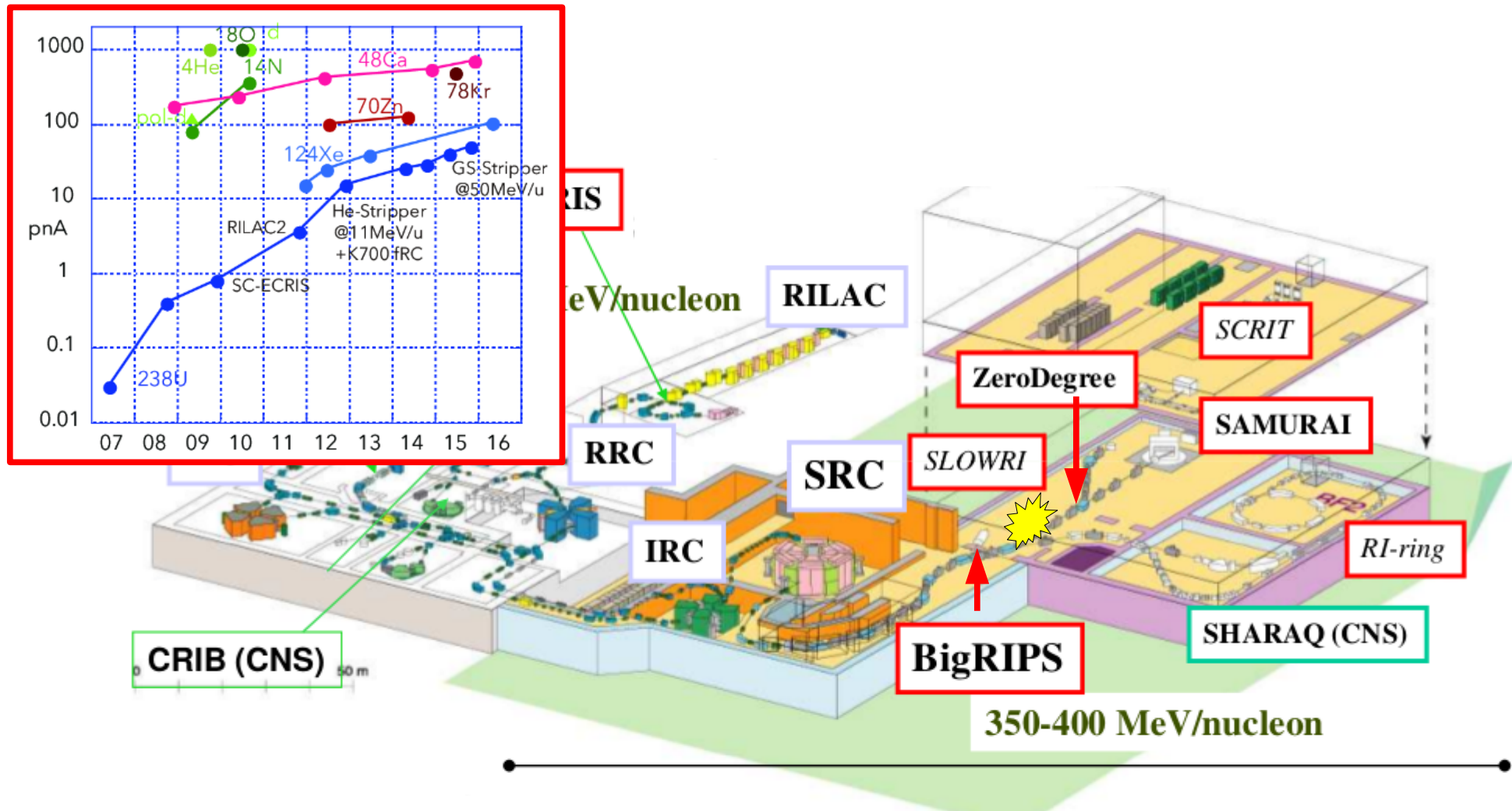
β decay

transfer **A**



P Morfouace et al, PLB 751, 306 (2015)

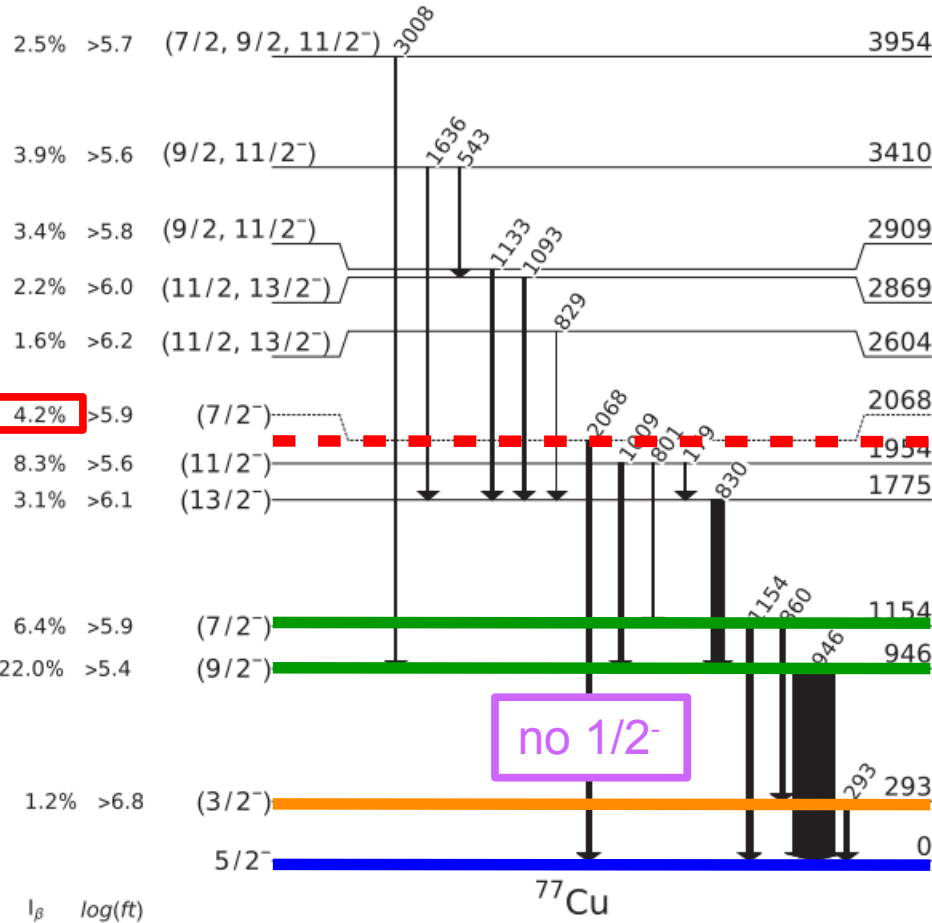
RIKEN RI Beam Factory (RIBF)



Intense (80 kW max.) H.I. beams (up to U) of 345 A MeV at SRC
Fast RI beams by projectile fragmentation and U-fission at BigRIPS

$\beta\gamma$ spectroscopy of ^{77}Cu at Riken

^{77}Ni $158.9(42)$ ms $Q_{\beta^-} = 11.765(526)$ MeV



$\pi f_{7/2}^{-1}?$

4.2%

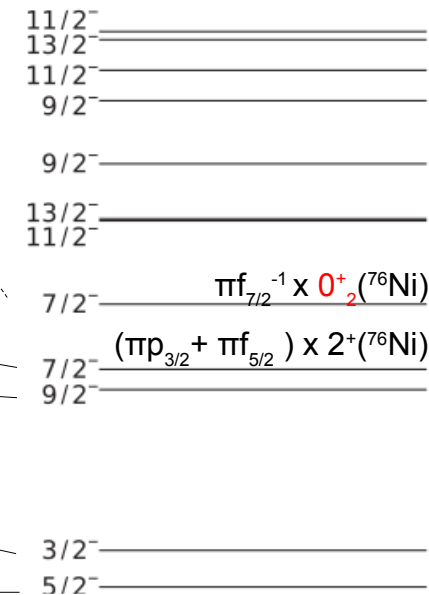
$\pi p_{3/2} \times 2^+?$

$\pi f_{5/2} \times 2^+?$

$\pi p_{3/2}$

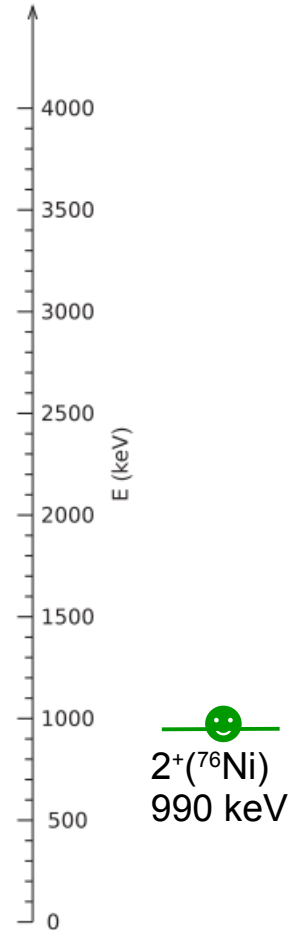
$\pi f_{5/2}$

no $1/2^-$



MCSM

Tsunoda & Otsuka

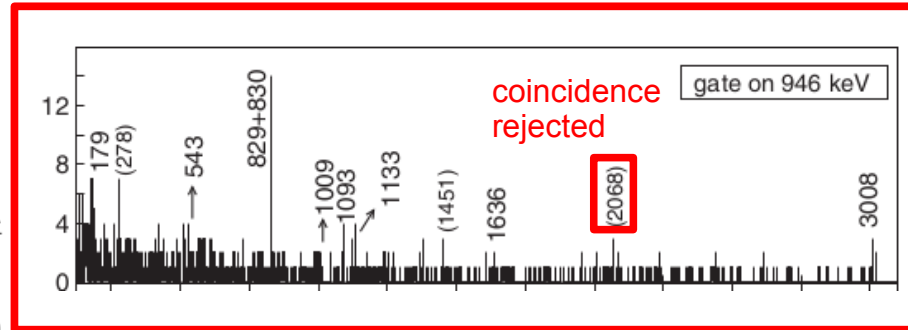
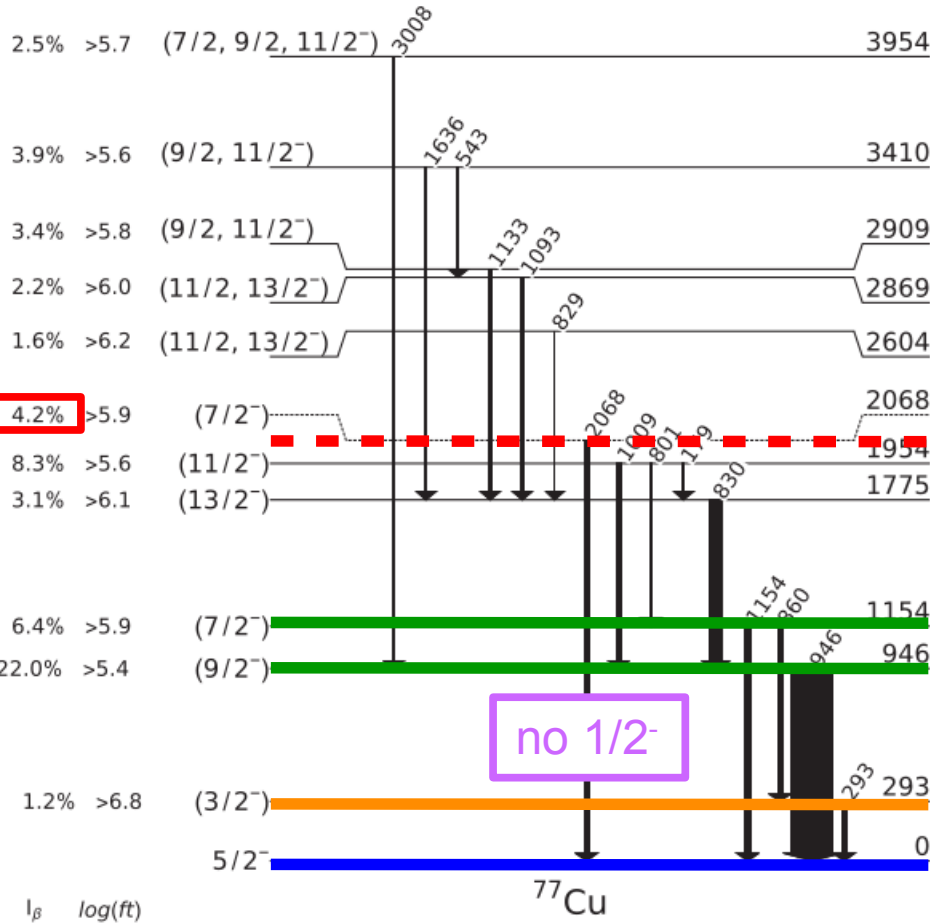


- 10 pA ^{235}U at 345 AMeV on ^9Be
- fission fragments separated in Bigrips + Zerodegree
- Wasabi + Eurica



$\beta\gamma$ spectroscopy of ^{77}Cu at Riken

^{77}Ni $158.9(42)$ ms $Q_{\beta^-} = 11.765(526)$ MeV



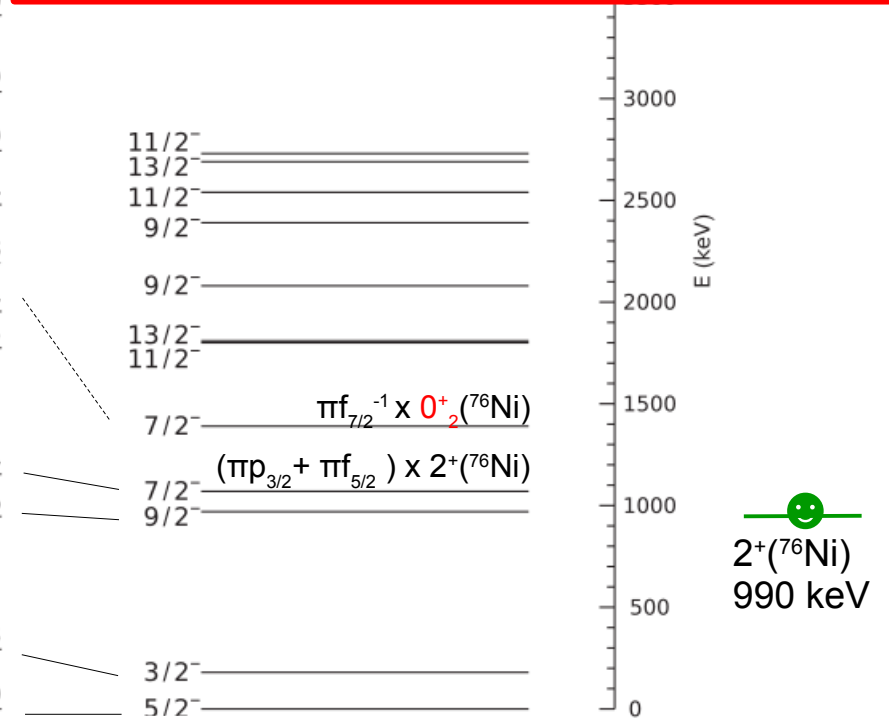
$\pi f_{7/2}^{-1}?$

$\pi p_{3/2} \times 2^+?$

$\pi f_{5/2} \times 2^+?$

$\pi p_{3/2}$

$\pi f_{5/2}$

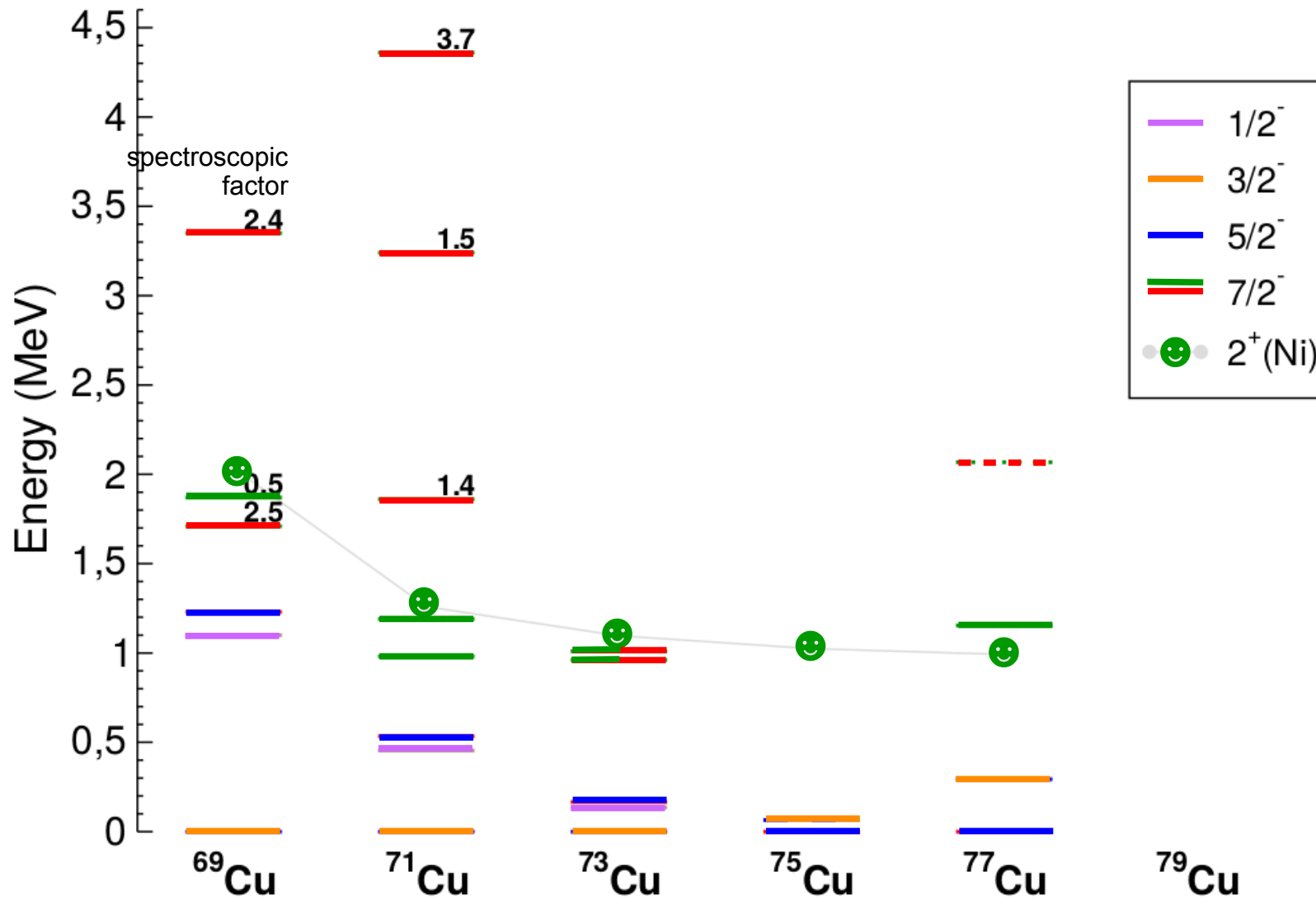


MCSM
Tsunoda & Otsuka

- 10 pA ^{235}U at 345 AMeV on ^9Be
- fission fragments separated in Bigrips + Zerodegree
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$\beta\gamma$ spectroscopy of ^{77}Cu at Riken



γ spectroscopy of ^{79}Cu at Riken



270 A MeV
 ^{80}Zn

Dali-2

p

p

Minos TPC
LH₂ target

A Obertelli et al, EPJ A 50 (2014)

Dali-2

S Takeuchi et al, NIM A 763 (2014)

heavy

spokespersons
P Doornenbal & A Obertelli

γ spectroscopy of ^{79}Cu at Riken

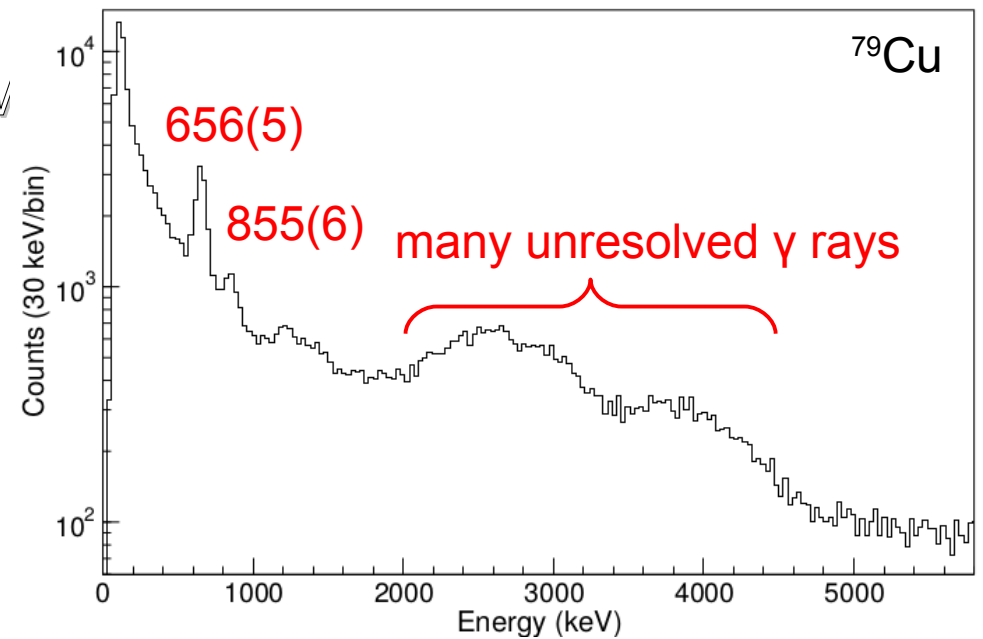
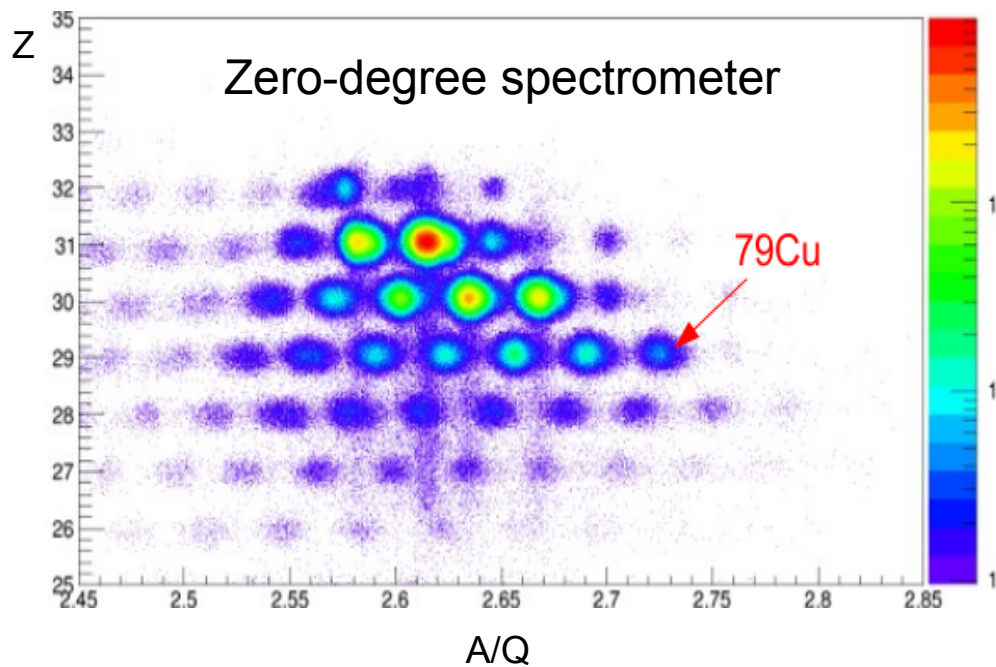


270 A MeV
 ^{80}Zn

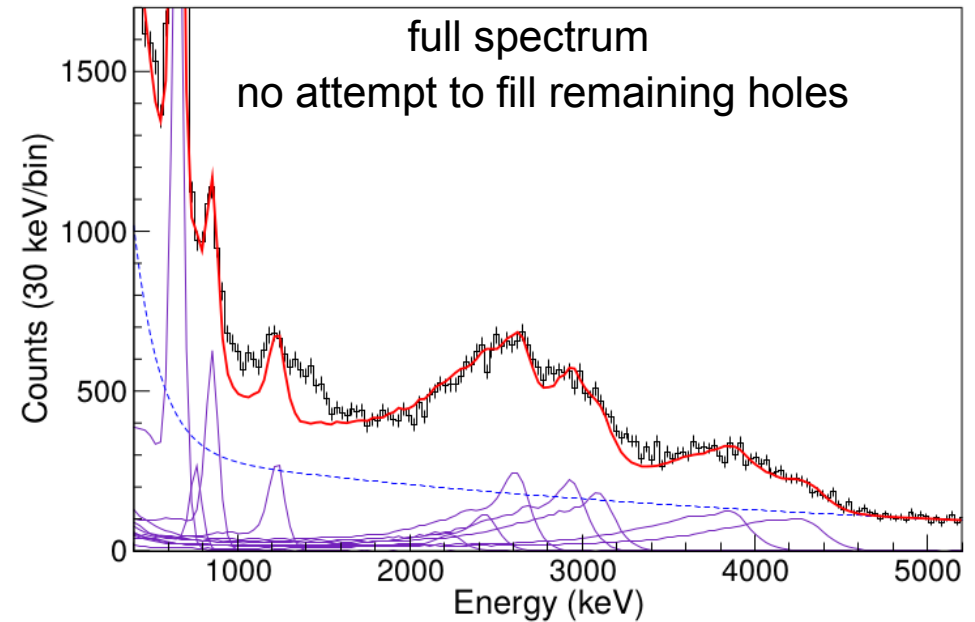
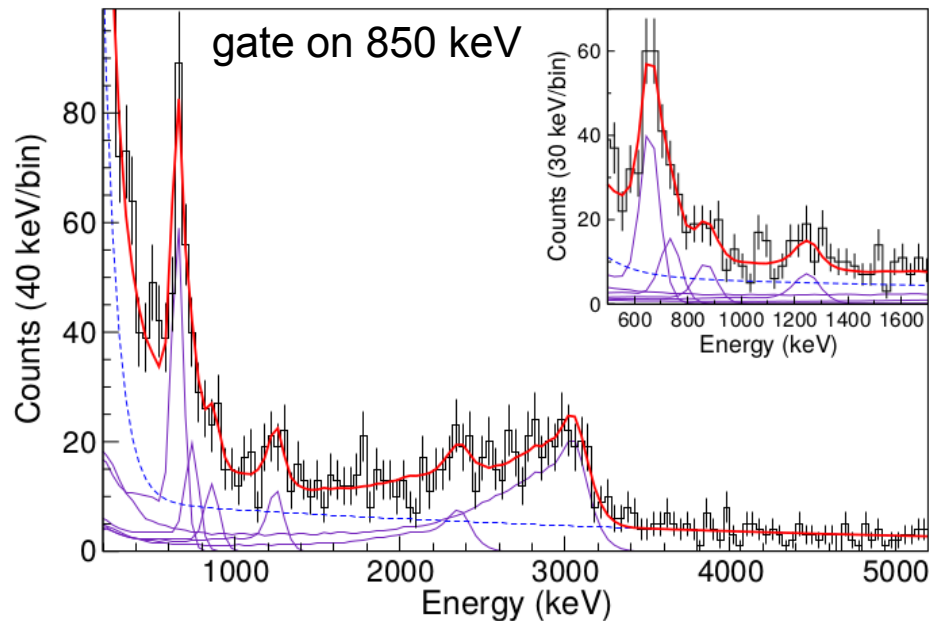
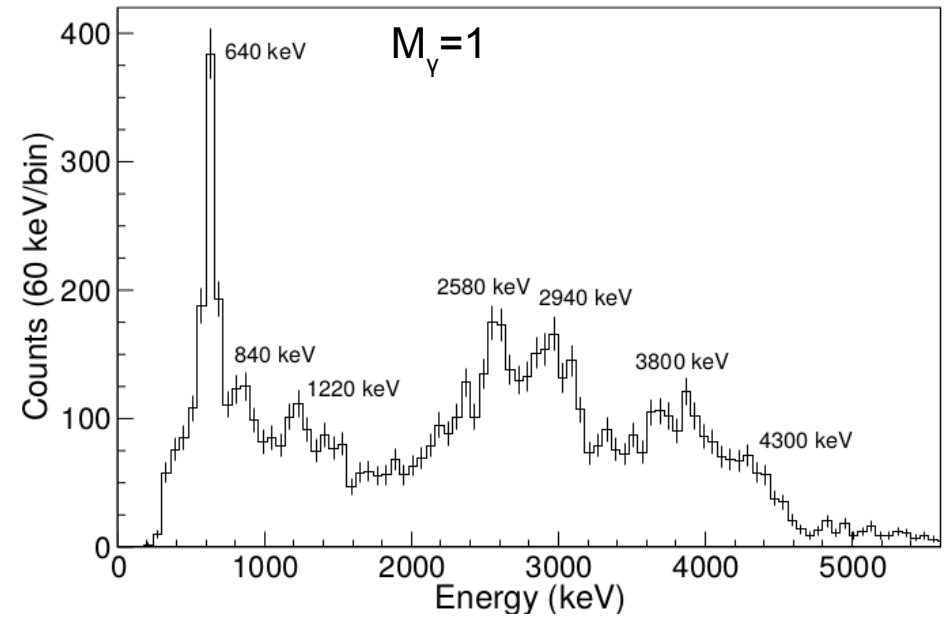
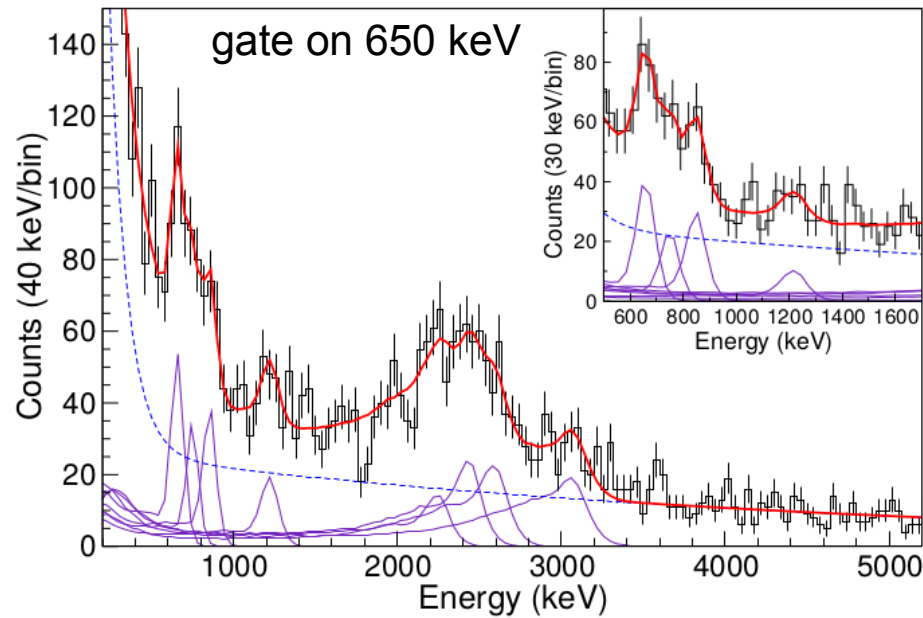
Dali-2

p

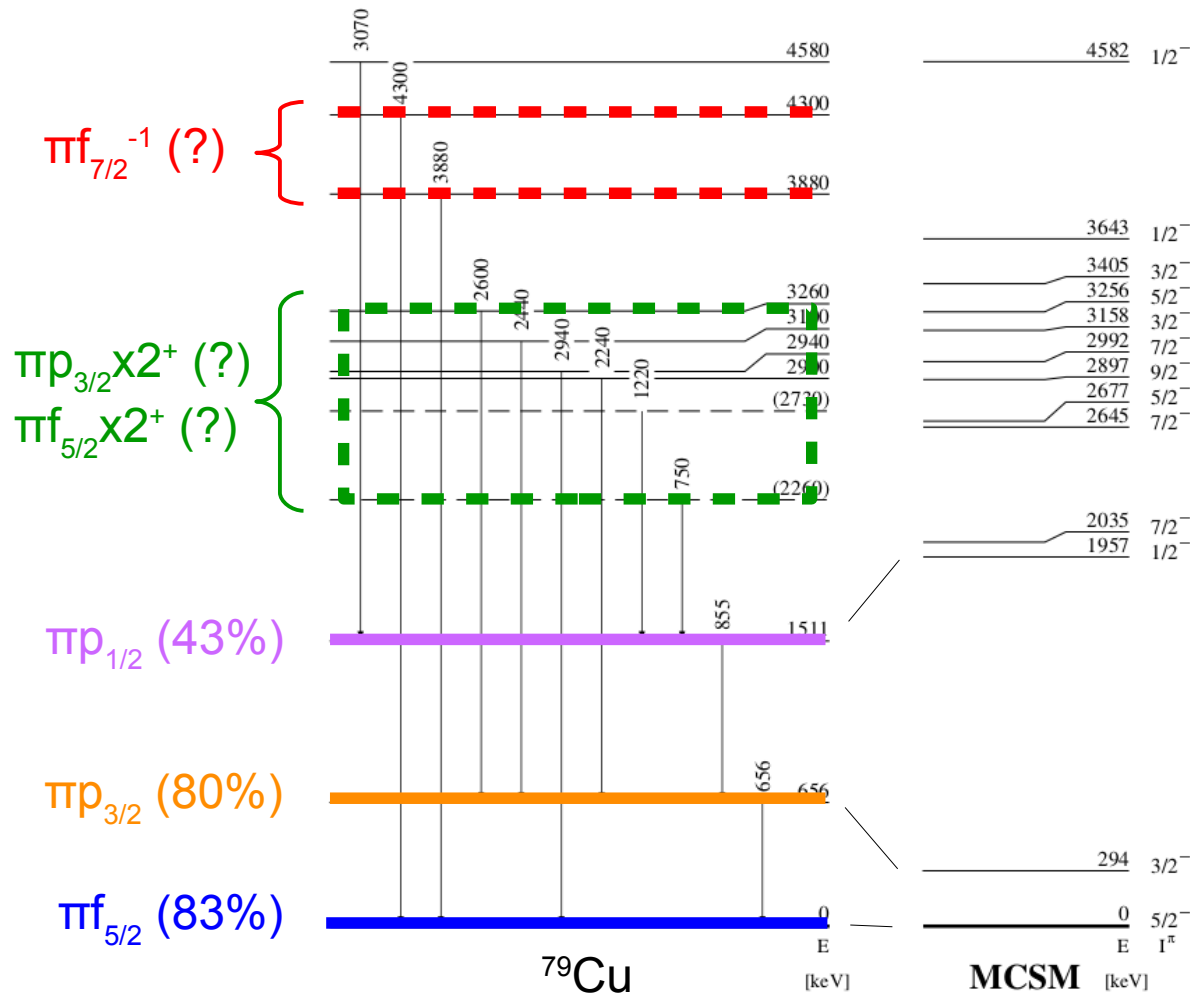
p



identify transitions from $\gamma\gamma$ coincidences or $M_{\gamma}=1$



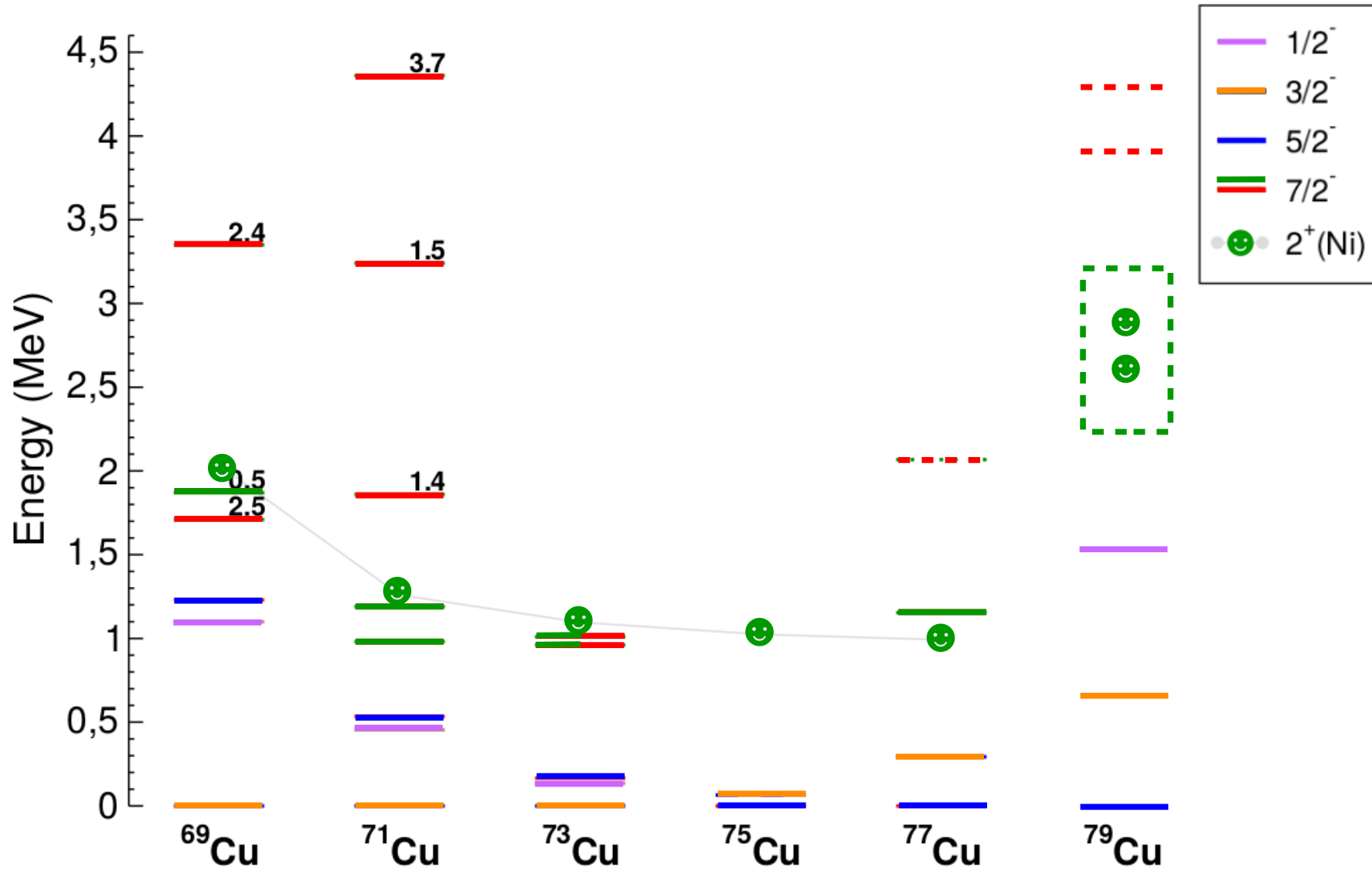
γ spectroscopy of ^{79}Cu at Riken



A3DA
Y Tsunoda, T Otsuka

- fair agreement with MCSM
- $\pi p_{1/2}$ at 1.5 MeV from absence of direct feeding
- multiplet allows for estimation of $2^+(^{78}\text{Ni})$
- $\pi f_{7/2}$ hole fragmented at 4 MeV ?

γ spectroscopy of ^{79}Cu at Riken



γ spectroscopy of ^{79}Cu at Riken



4x Superclover

Quad

P3

265 AMeV
 ^{80}Zn

heavy

Be target

4x Miniball

construction proposal
P Doornenbal & K Wimmer

spokespersons
R Taniuchi, SF & D Suzuki

γ spectroscopy of ^{79}Cu at Riken



4x Superclover

$^{80}\text{Zn}(^9\text{Be},X)^{79}\text{Cu}$ γ -ray spectra all detectors

