Collectivity in medium mass self-conjugate nuclei

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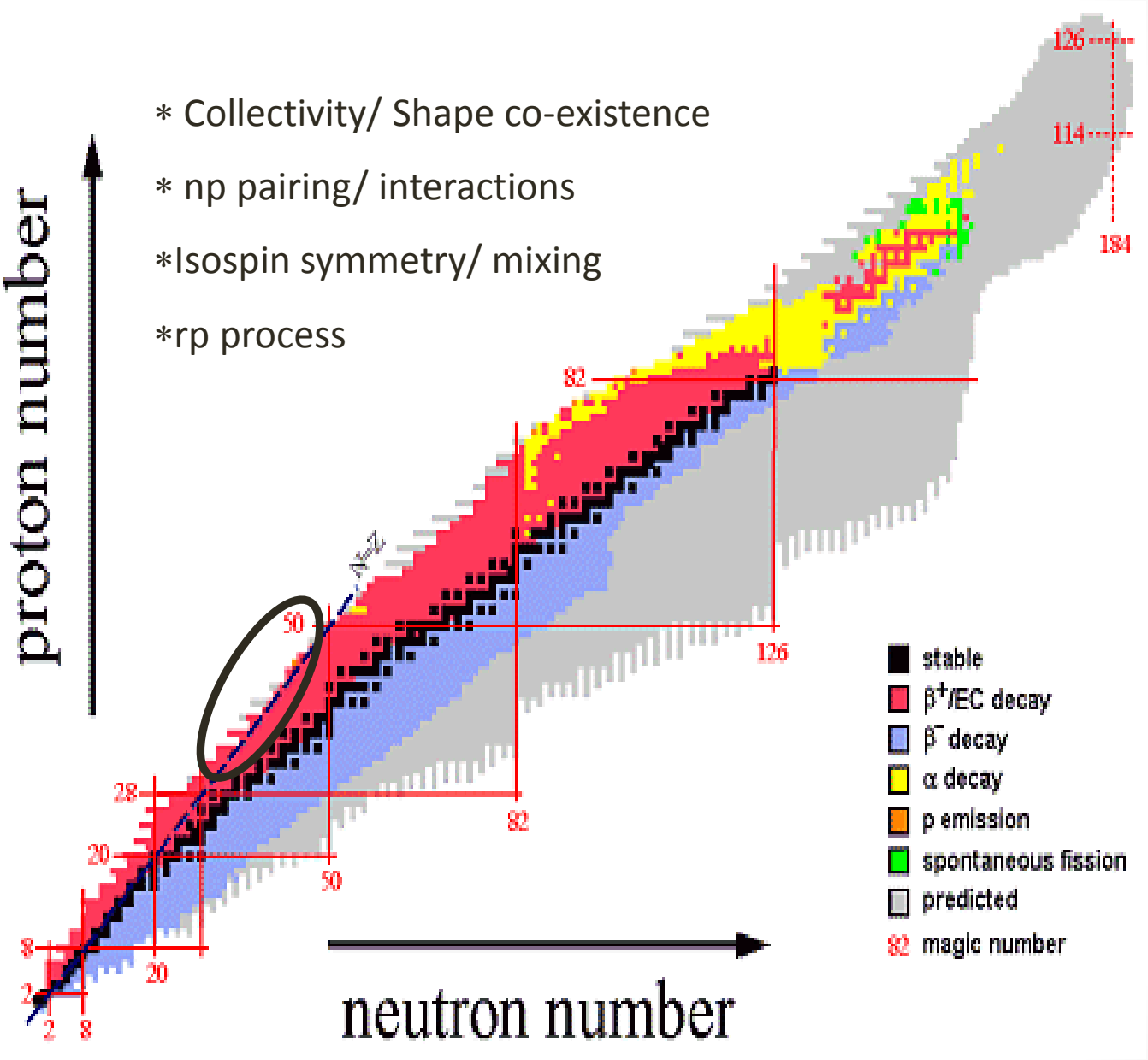
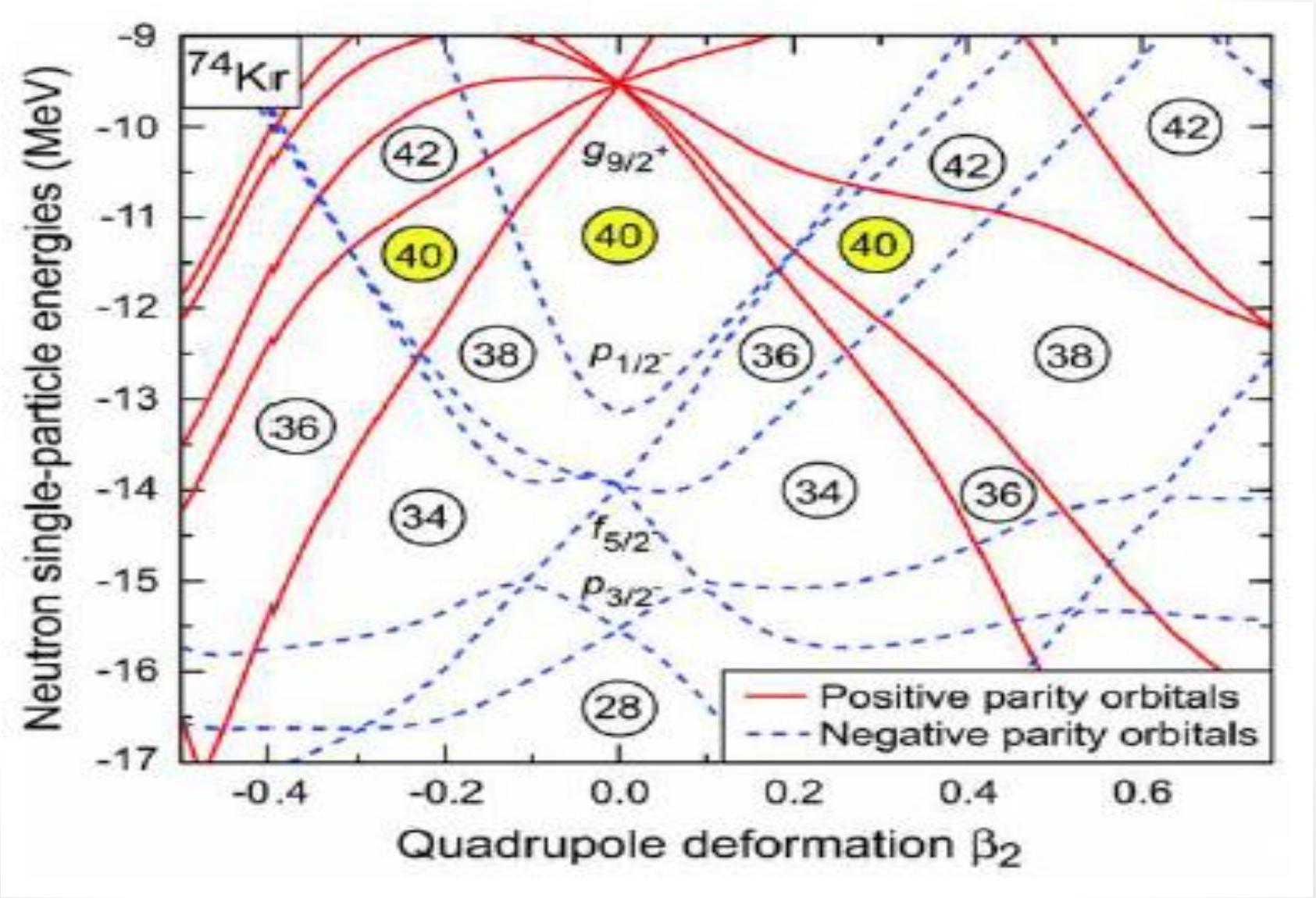
Overview

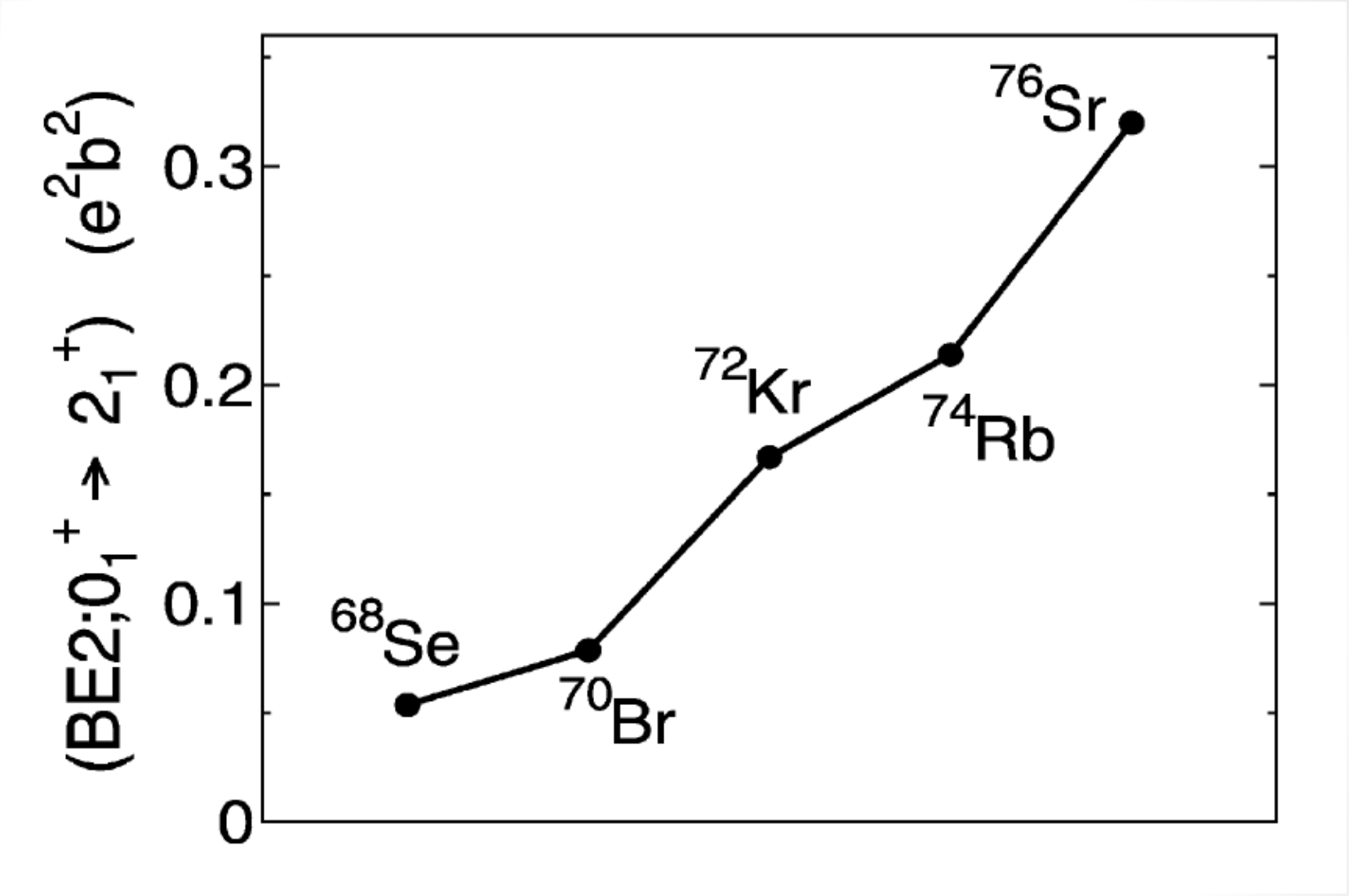
- Physics interest in the N=Z mass ~70 region.
- The Recoil Distance Doppler Shift technique for studying excited-state lifetimes.
- The NSCL facility.
- Data analysis.
- Preliminary results.
- Discussions and further work.

* Collectivity/ Shape co-existence
* np pairing/ interactions
*Isospin symmetry/ mixing
*rp process



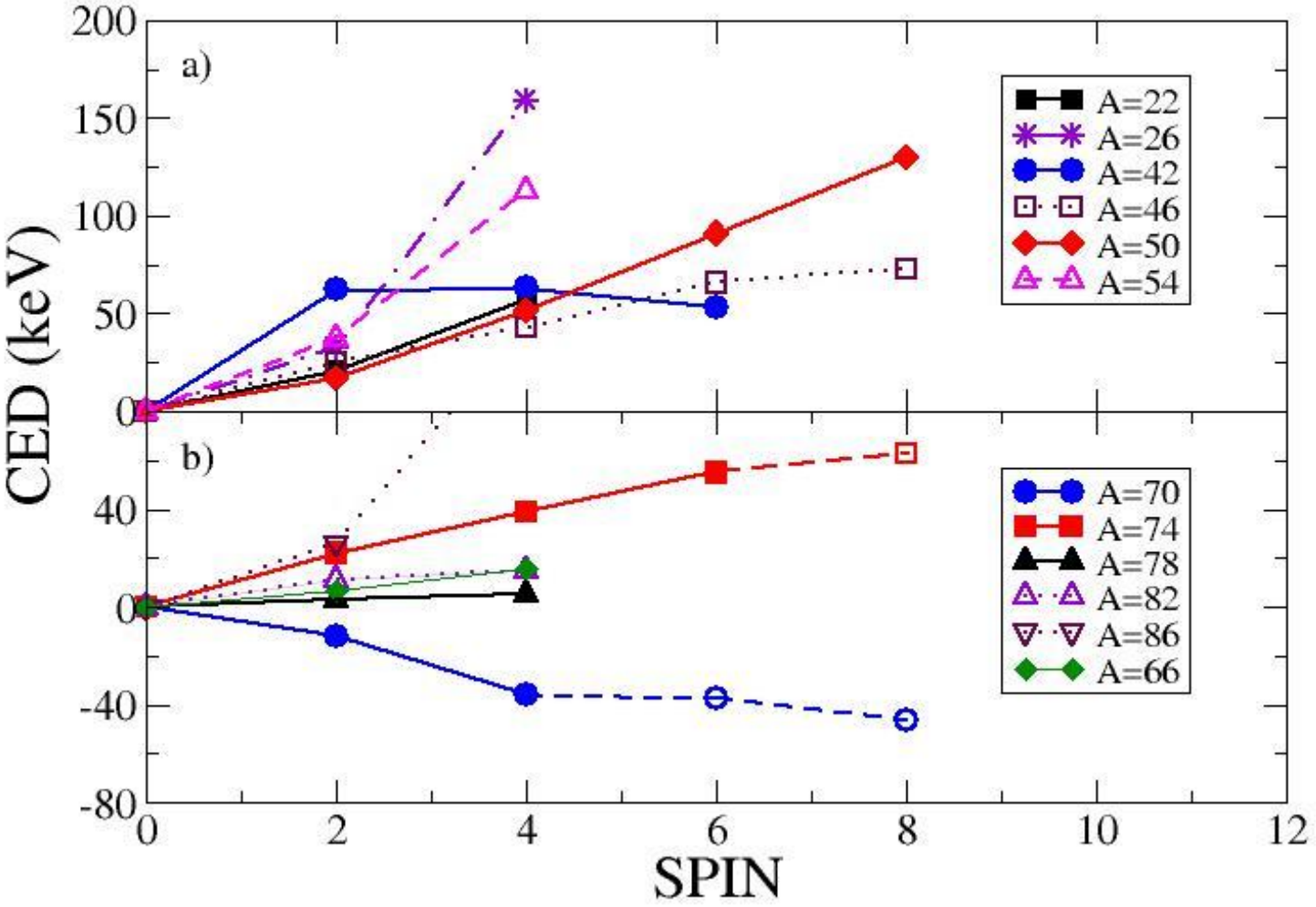
Collectivity in medium-mass nuclei





M. Hasegawa *et al.*, Phys Lett B 656 (2007) 51-55

Coulomb energy differences



A study of ^{70}Br and ^{70}Se

- Performed at the NSCL facility at Michigan State University.
- Fragmentation, and subsequent nucleon knockout, for the first time in this region.
- S800 and SeGA.
- Recoil Distance Doppler Shift (RDDS) technique.

A. Deward *et al.,* Prog. Part. Nucl. Phys. **67**, 786 (2012)

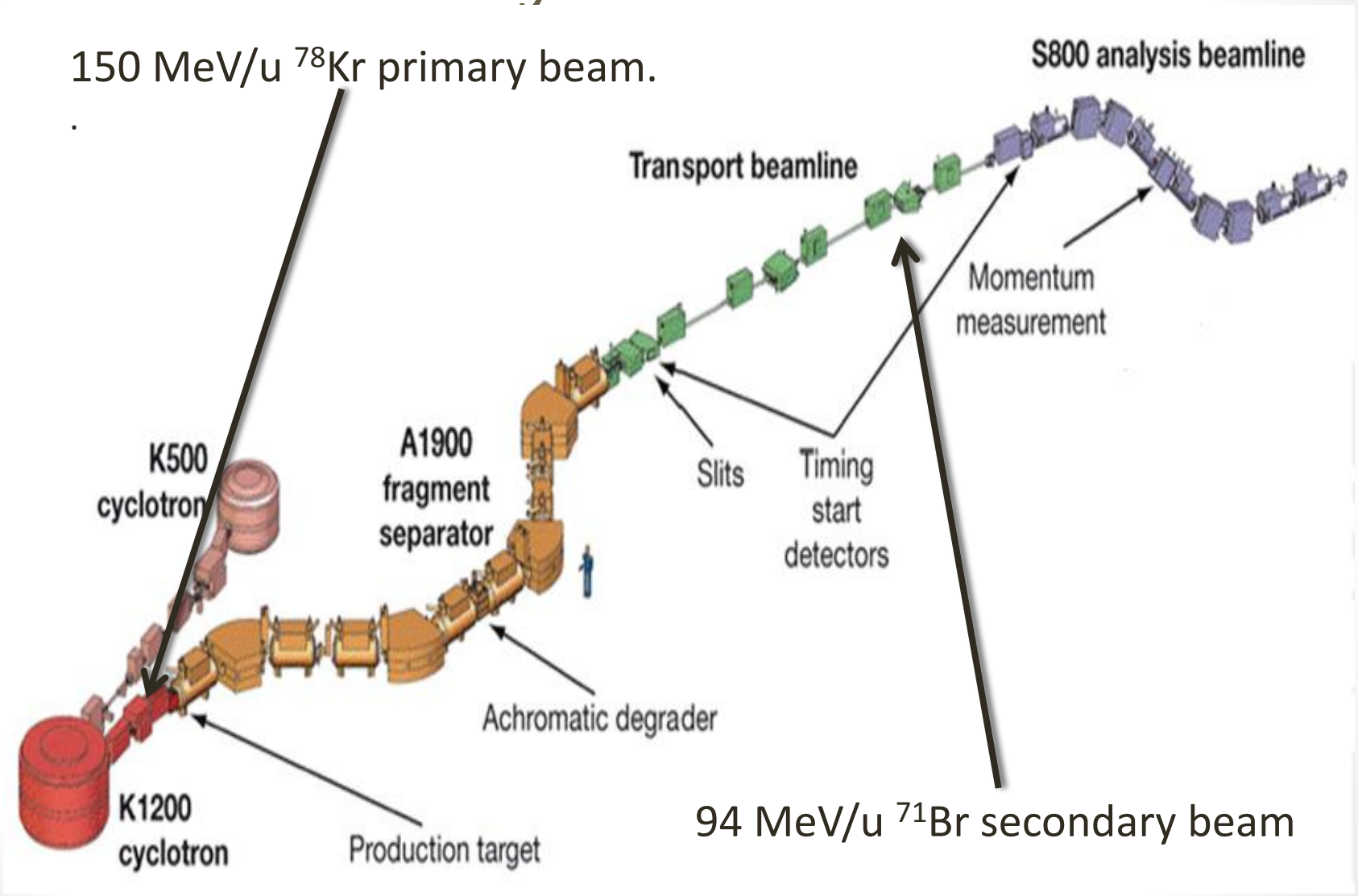
- Commissioning of new plunger device, TRIPLEX.
- Measurement of the lifetime of the first excited 2^+ state and other low lying excited states in ^{70}Br for the first time.
- Re-measurement of the ^{70}Se 2^+ excited state in the same set-up, to confirm literature result (3.2(2) ps).

J. Ljungvall *et al.* PRL **100**, 102502 (2008)

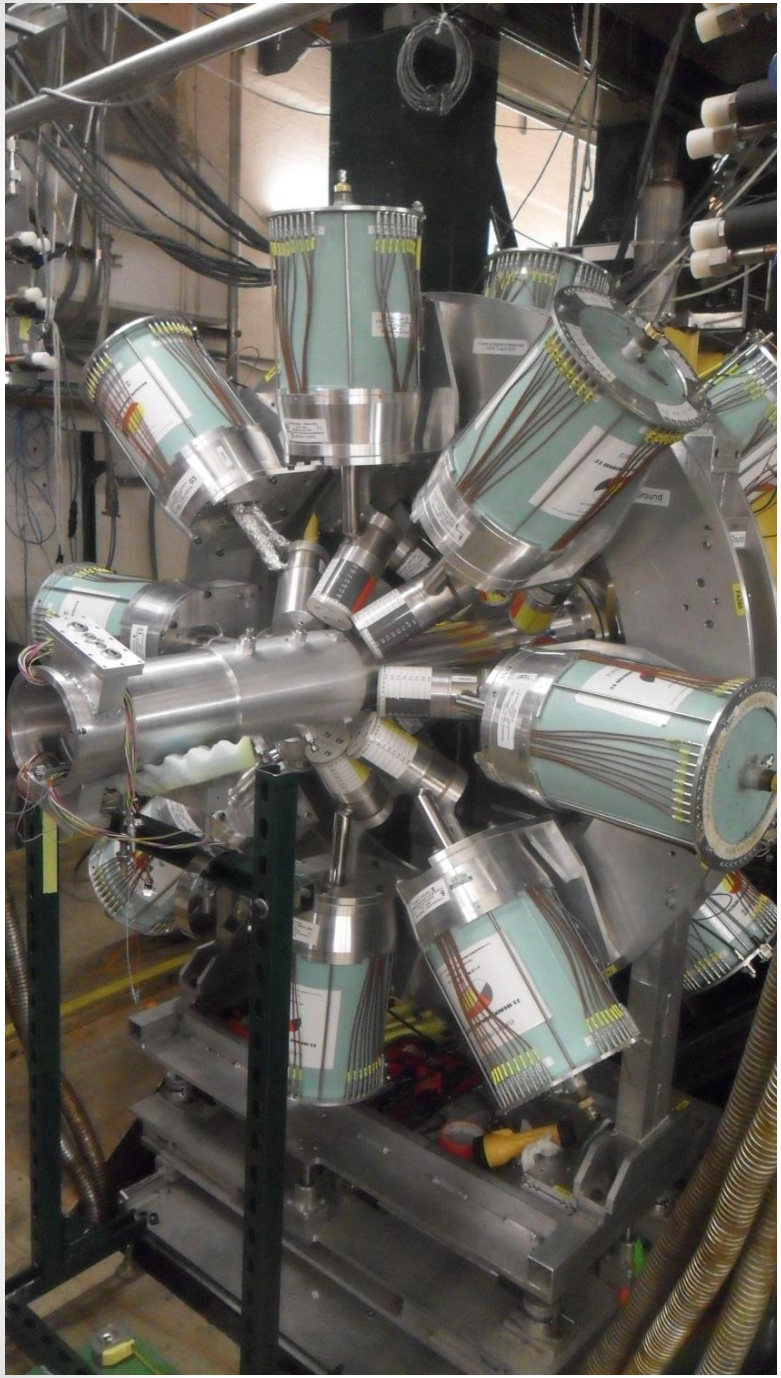
- Search for the previously unidentified 1^+ excited state in ^{70}Br.

NSCL Facility

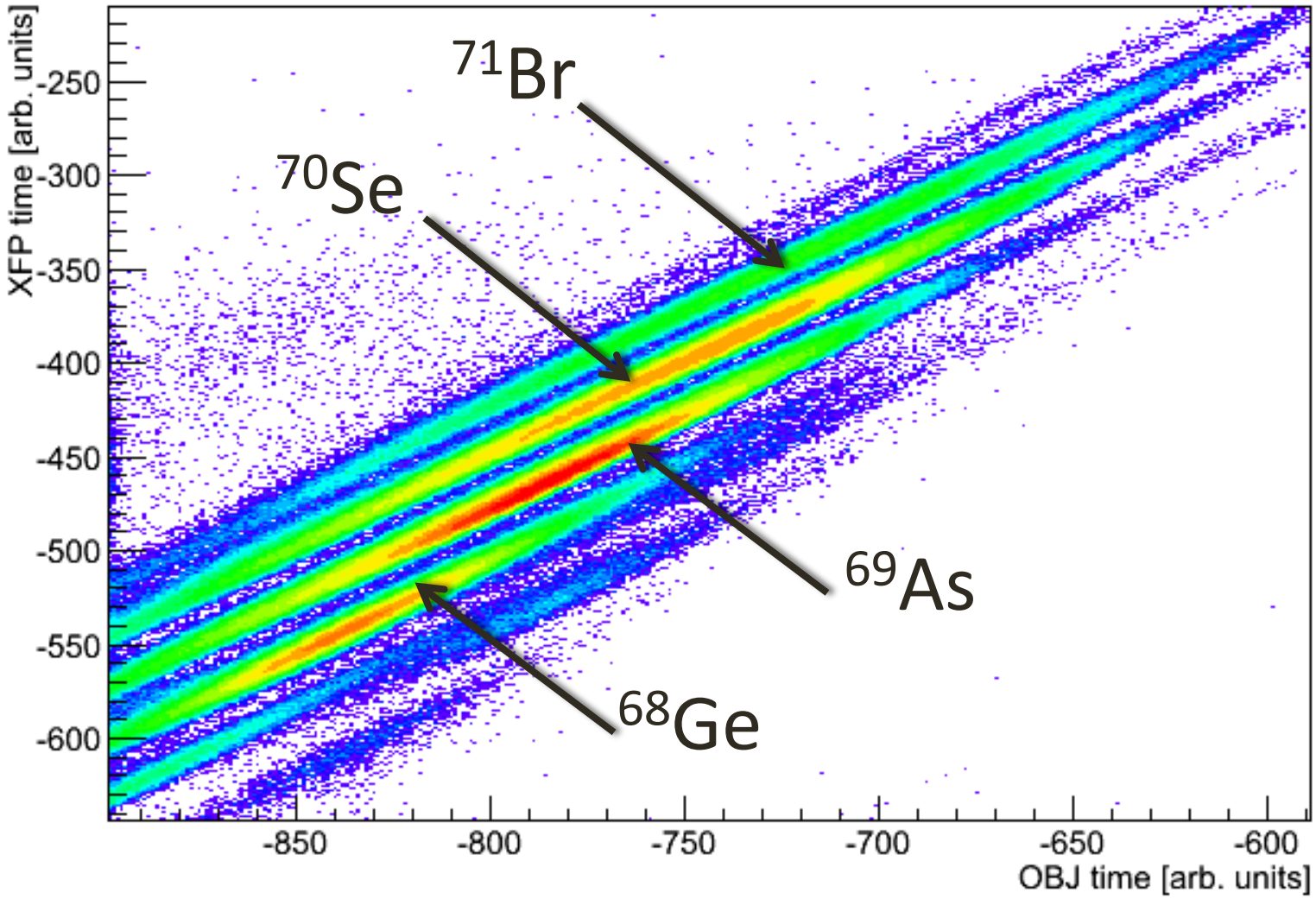
150 MeV/u ^{78}Kr primary beam.

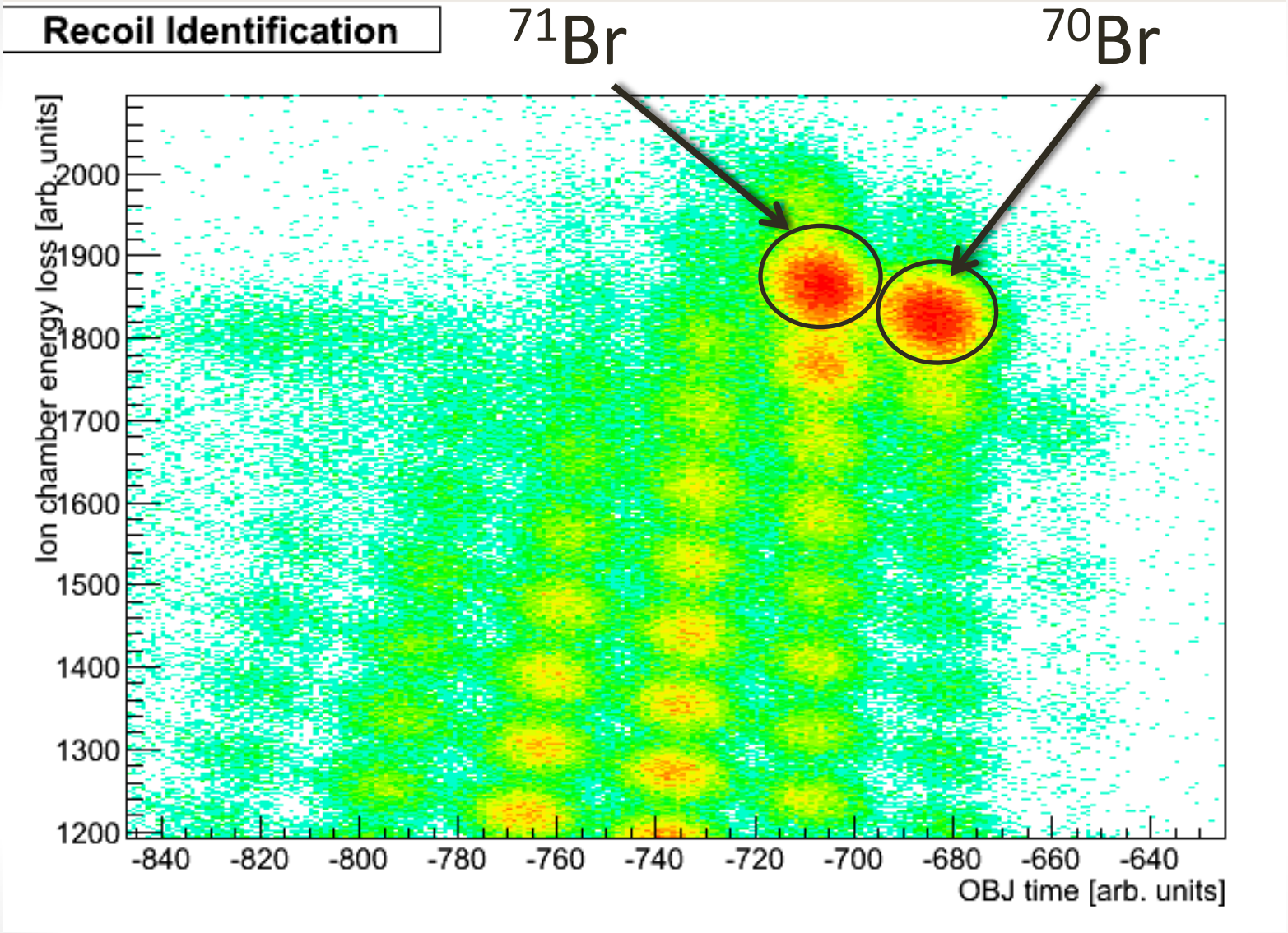


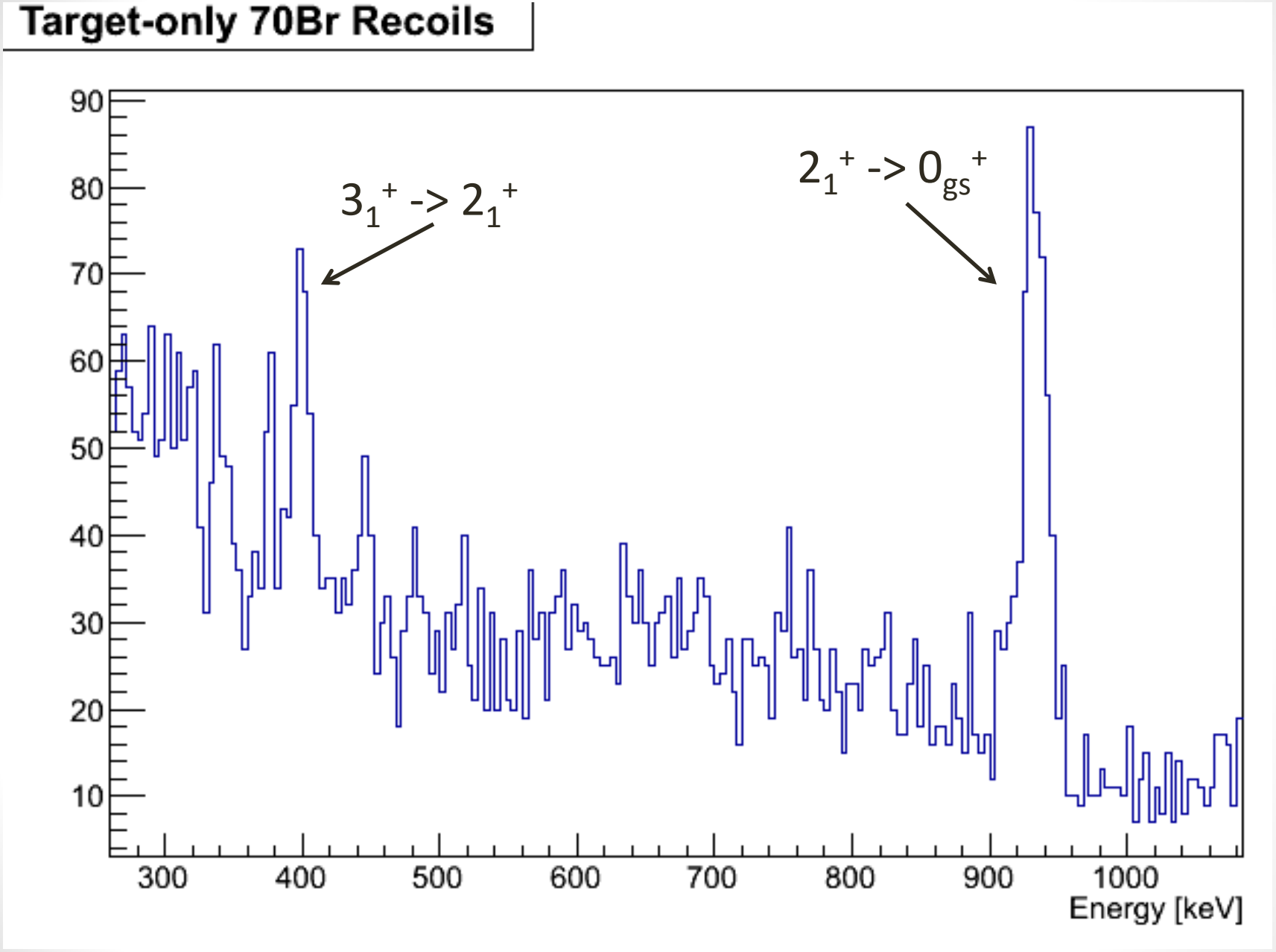
94 MeV/u ^{71}Br secondary beam



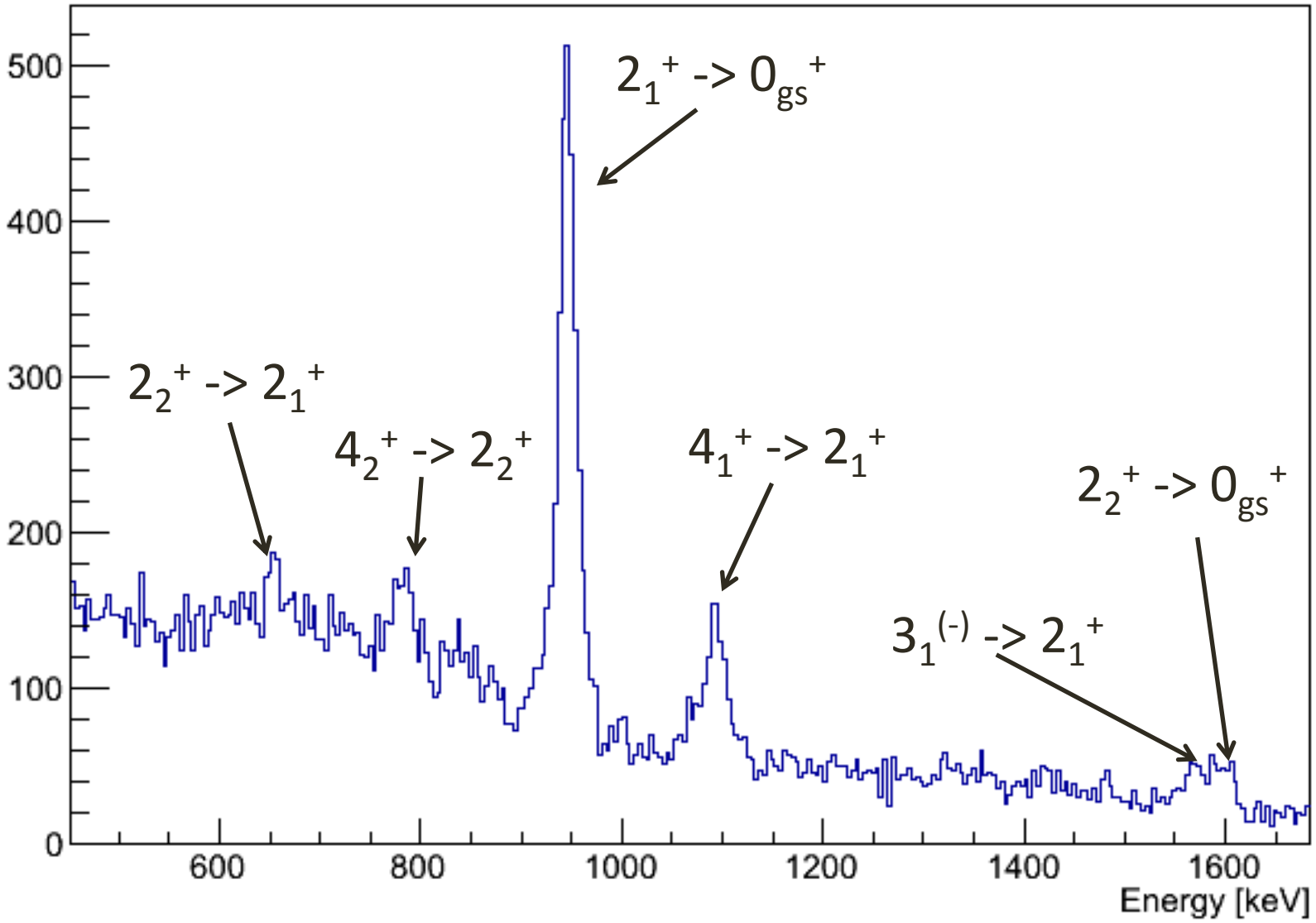
Secondary Beam Identification



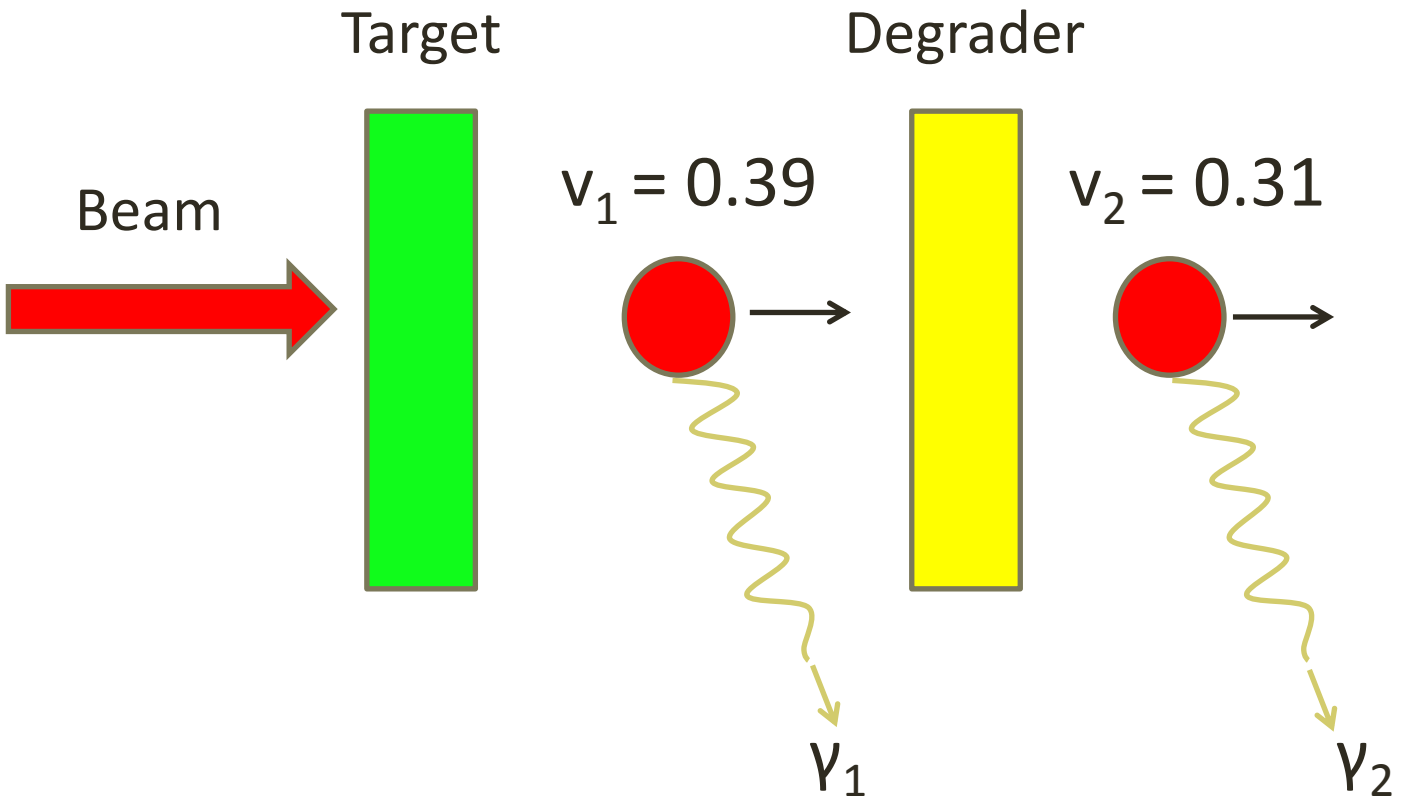

Recoil Identification
^{71}Br
^{70}Br
Ion chamber energy loss [arb. units]
2000
1900
1800
1700
1600
1500
1400
1300
1200
-840
-820
-800
-780
-760
-740
-720
-700
-680
-660
-640
OBJ time [arb. units]

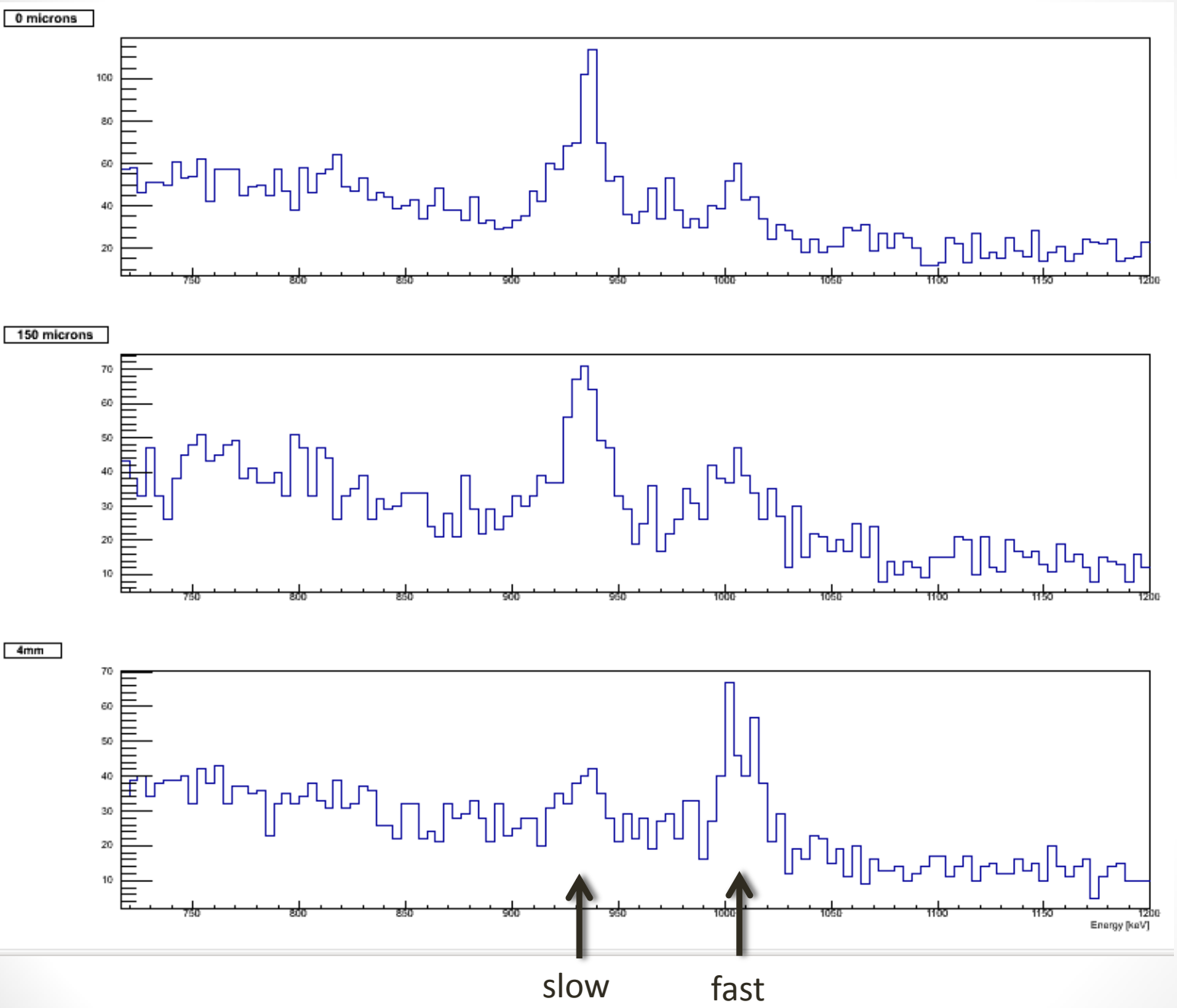

Target-only 70Br Recoils
$3_1^+ \rightarrow 2_1^+$
$2_1^+ \rightarrow 0_{gs}^+$
90
80
70
60
50
40
30
20
10
300
400
500
600
700
800
900
1000
Energy [keV]

Target-only 70Se Recoils



RDDS technique

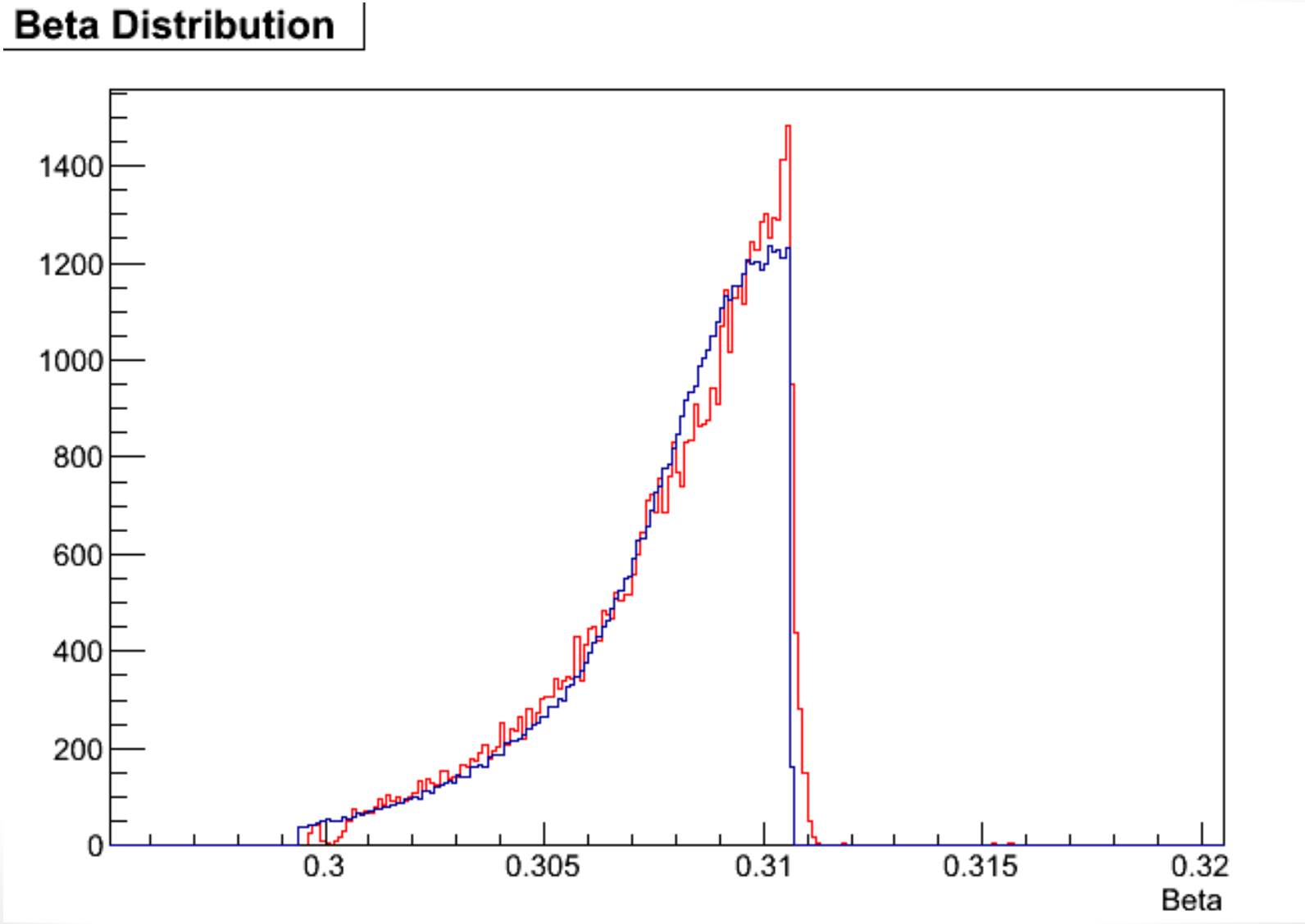



0 microns
150 microns
4mm
slow
fast
Energy [keV]

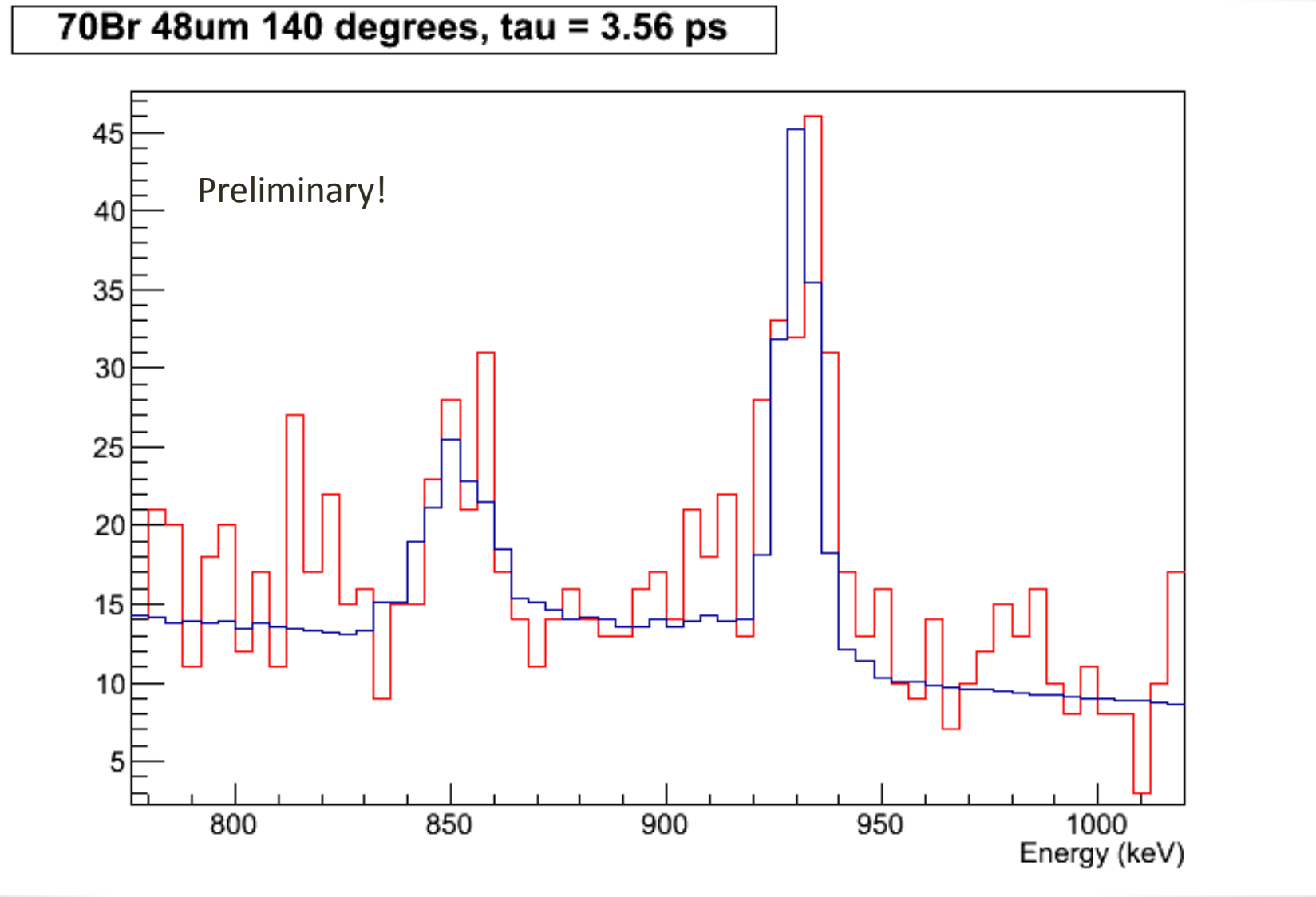
Extracting lifetimes

- Use of GEANT4 simulation package G4LifeTime developed at NSCL.
- Can use experimental particle spectra to match incoming beam and outgoing recoil characteristics.
- Can accurately replicate the positions of SeGA detectors.
- Can be fit to experimental gamma spectra with a variable lifetime.
- Lifetime deduced by a chi-squared fit.

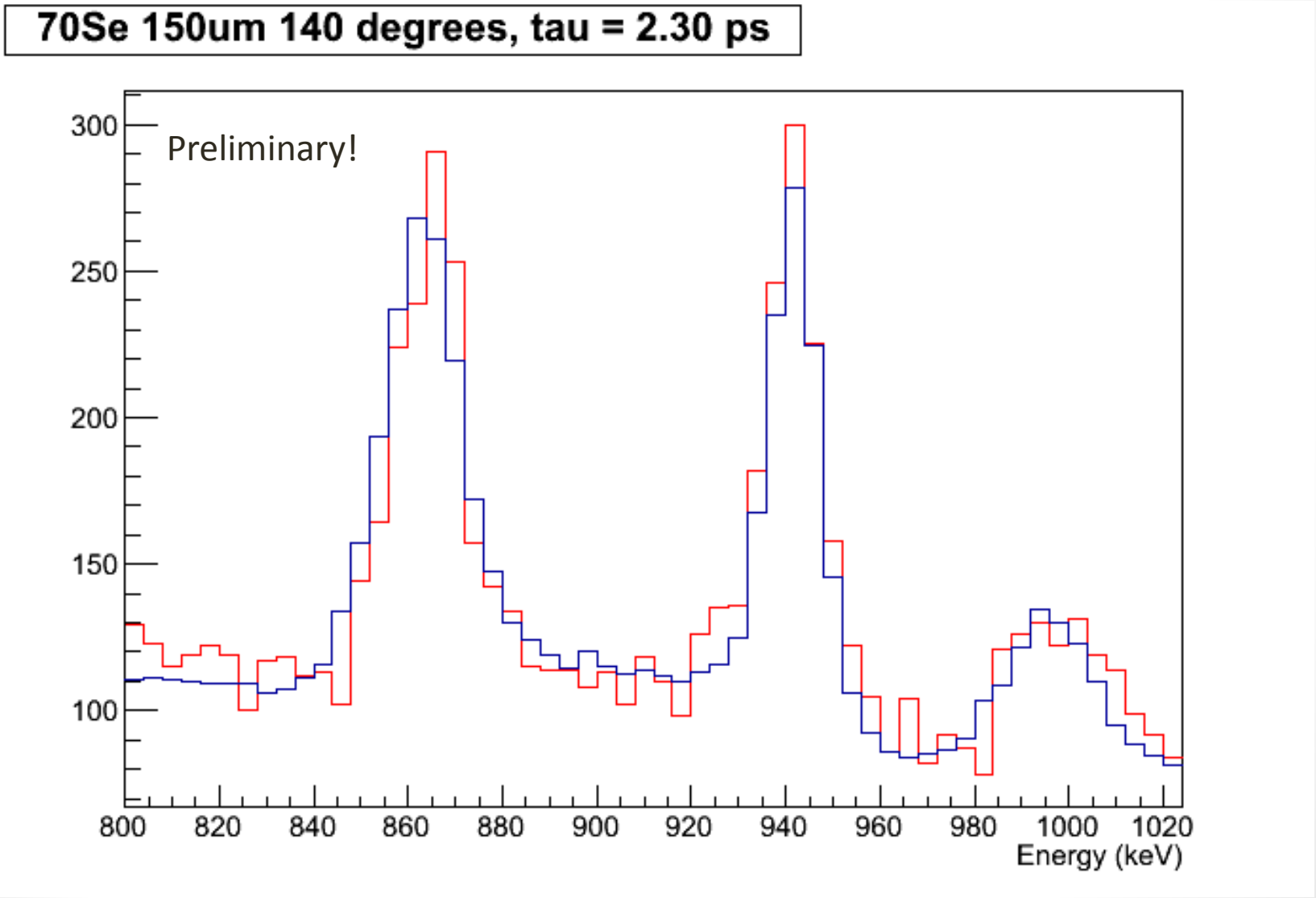
Matching the particle spectra



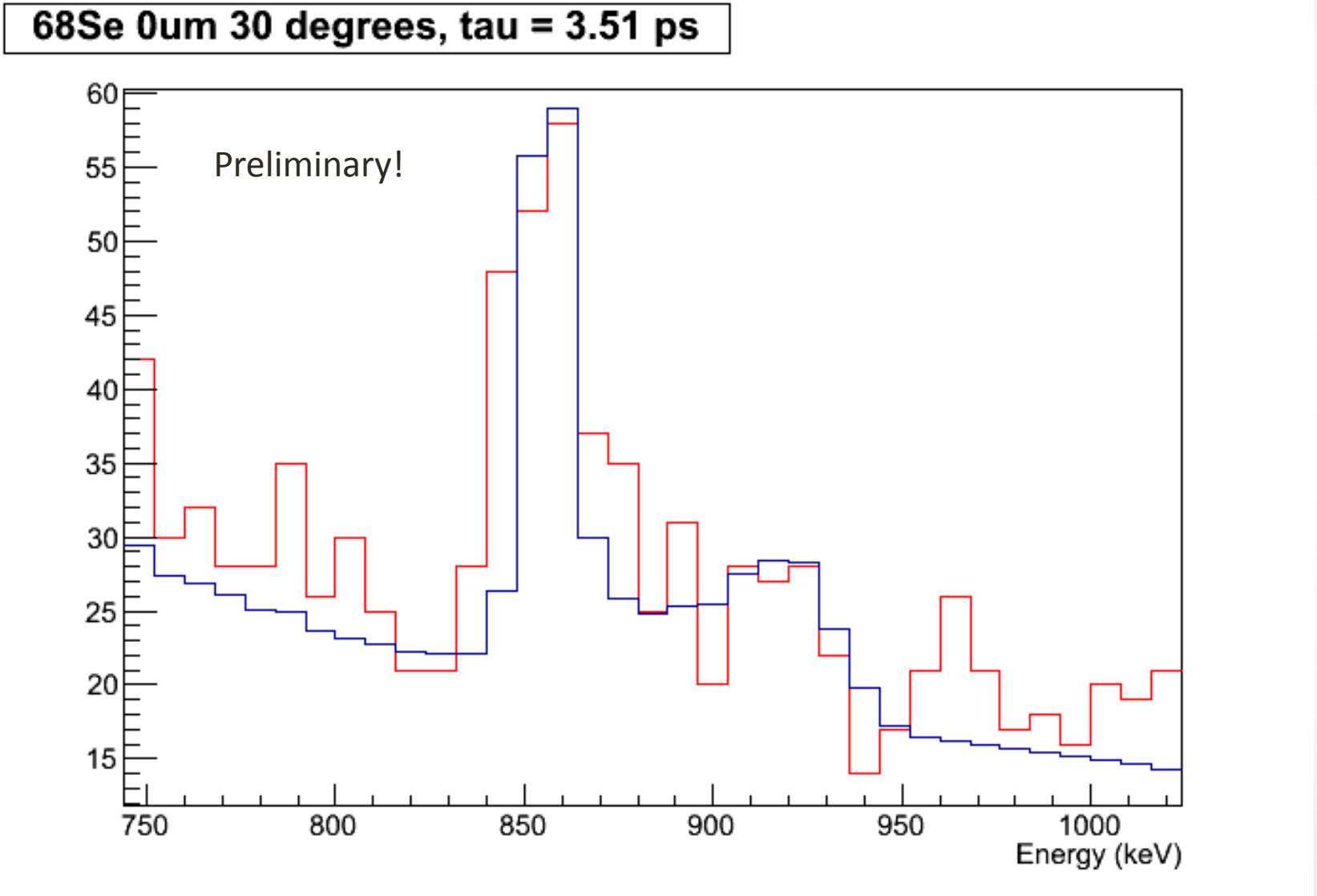
Matching the gamma spectra



Matching the gamma spectra



Matching the gamma spectra



Lifetime Results

- Very preliminary! Systematic errors still exist.

Nucleus	State	Energy of transition (keV)	Lifetime (ps) [lit] [2]	Lifetime (ps) [this work]
70Br	3+	403	-	75(15)
70Br	2+	934	-	3.56(17)
70Se	2+	945	3.2(2)	2.30(5)
68Se	2+	854	-	3.51(38)

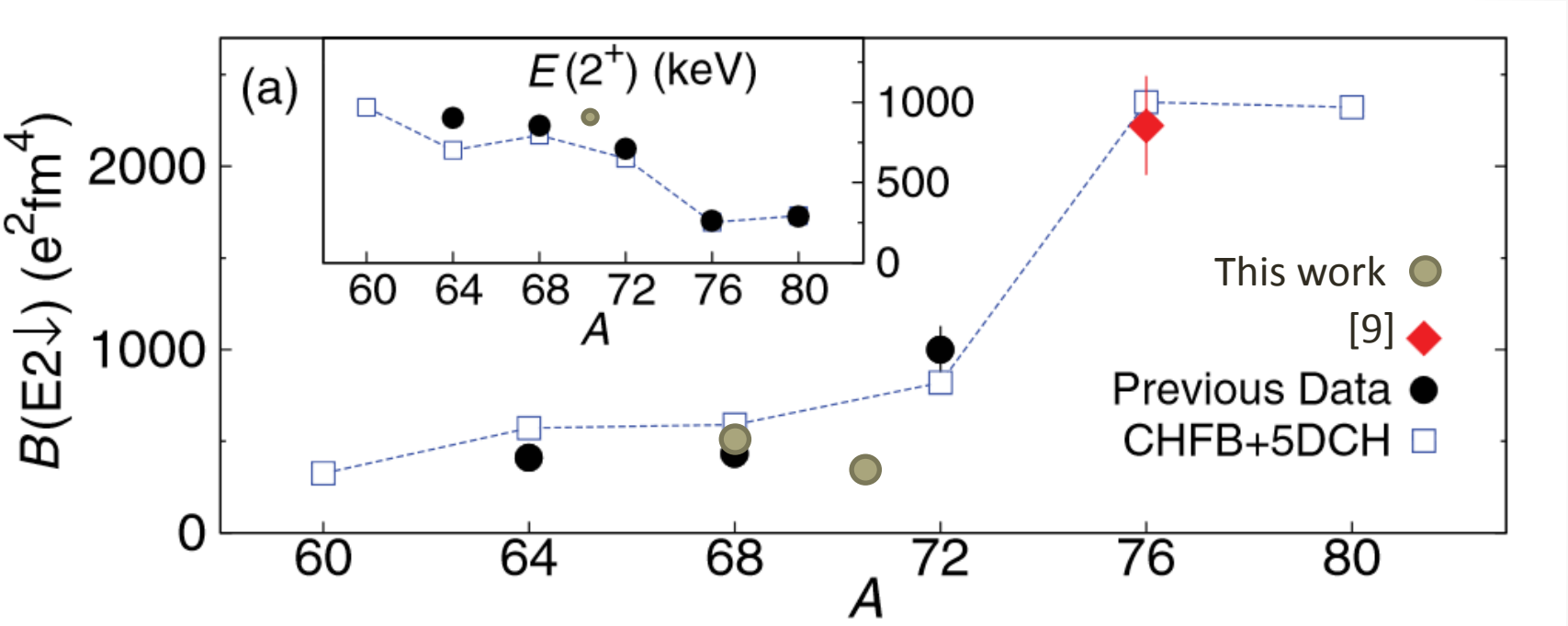
B(E2)s and B(M1)

- Very preliminary! Systematic errors still exist.

Nucleus	State	Transition Energy (keV)	B(E2) [lit] (e^2fm^4) [2,3]	B(E2) this work (e^2fm^4)	$B(E2)_{sp}$ this work (W.u.)
70Br	2+	934	-	323(16)	18.8(9)
70Se	2+	945	342(19)	472(10)	27.5(6)
68Se	2+	854	432(58)	513(56)	31.1(34)

- Assuming same shape for isobars (shell model), B(E2) (and hence lifetime) difference expected to be ~6% due to the difference in level energies (E_γ^5).
- Excited VAMPIR results produce different shapes in ground states.

Nucleus	State	Transition Energy (keV)	B(M1) theory	B(M1) this work (μ_N^2)	$B(M1)_{sp}$ this work (μ_N^2)
70Br	3+	403	-	0.011(2)	0.006(1)



[9] A. Lemasson *et al.,* Phys. Rev. C **85**, 0413039(R) (2012)

Quasi-deuteron configurations?

Constructive/destructive interference of spin and orbital parts of ΔT=1 M1 transitions.

$$Core^{even-even} \otimes \left(j_p \otimes j_n\right)_{J,T}$$

Quasi… $j = l + 1/2$ $B(M1; 0^+ \rightarrow 1^+) = \frac{3}{4\pi}\frac{j+1}{j}(l + 4.706)^2\mu_N^2$

Nonquasi… $j = l - 1/2$ $B(M1; 0^+ \rightarrow 1^+) = \frac{3}{4\pi}\frac{j+1}{j}(l - 3.706)^2\mu_N^2$

- Hindered 3^+ suggests nonquasi-deuteron configuration.
- Suggests that the components of the 3^+ are predominantly $(f_{5/2})^2$ configuration, $j = l - 1/2$.

Summary and Outlook

- Commissioning run of new plunger device for exotic beams.
- First case of population of nucleon knockout in the region.
- First measurement of low-lying excited state lifetimes in ^{70}Br.
- Preliminary analysis suggests a strongly hindered B(M1) in ^{70}Br.
- Suggestion of different lifetimes for first excited states in ^{70}Br and ^{70}Se.
- A non-observation of the 1^+ excited state.
- ^{68}Se excited state lifetime obtained.
- Unobserved side-feeding must be correctly accounted for.
- Systematic errors still exist in the data. Lifetimes quoted are possibly marginally underestimated.
- There is potential for lifetime study of other nuclei in the data, and also potential for new spectroscopy in some nuclei.

Collaborators

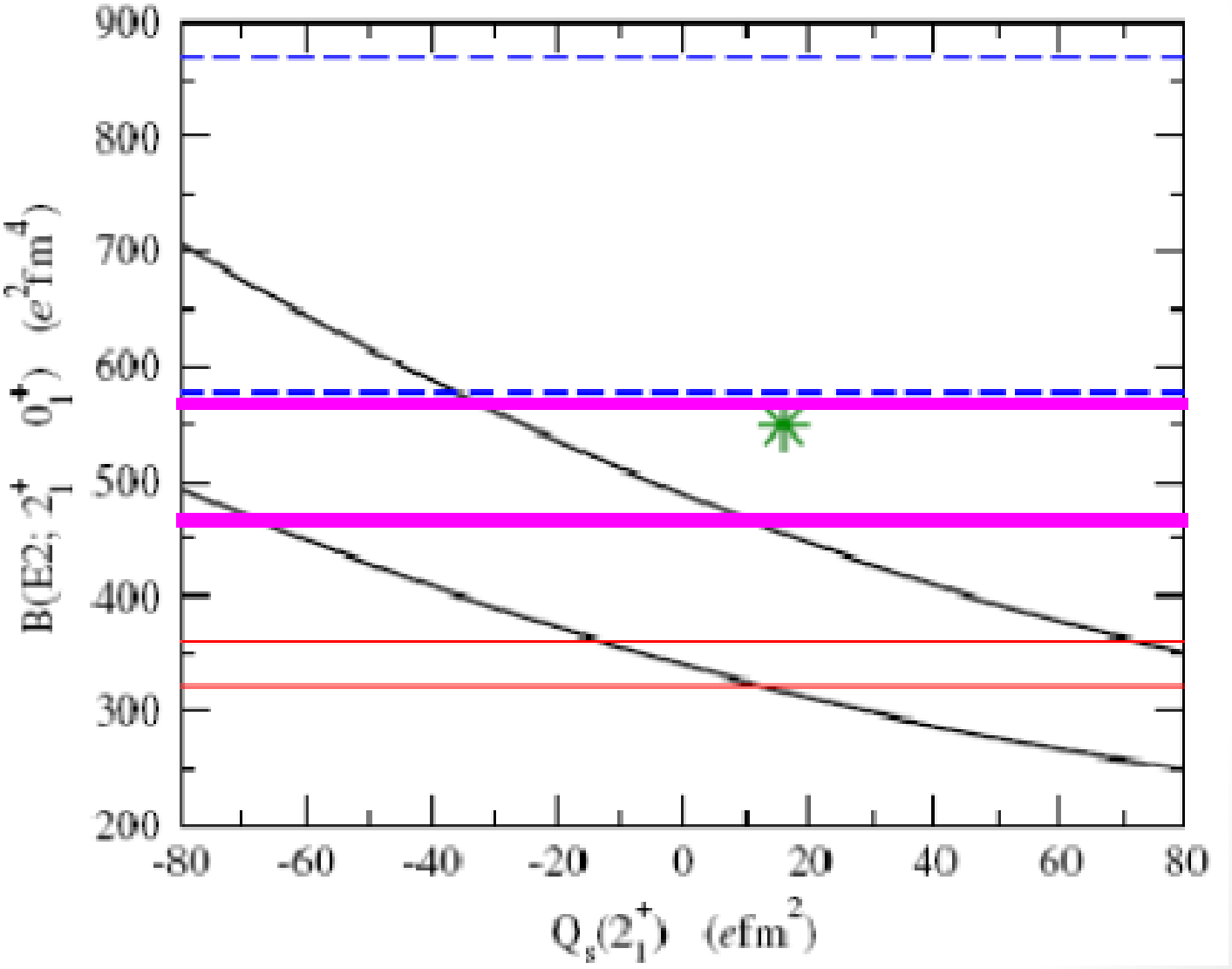
- University of York
  M. Bentley, P. Davies, J. Henderson, D. Jenkins, B.S. Nara Singh, I. Paterson, R. Wadsworth.
- NSCL
  H. Iwasaki, A. Lemasson, A. Gade, D. Bazin, D. Weisshar, K. Wimmer, J. Berryman.
- IKP-Koeln
  A. Dewald, M. Hackstein, T. Braunroth, T. Pissulla, C. Fransen.
- LNL
  G. deAngelis.
- UT
  D. Miller.

References

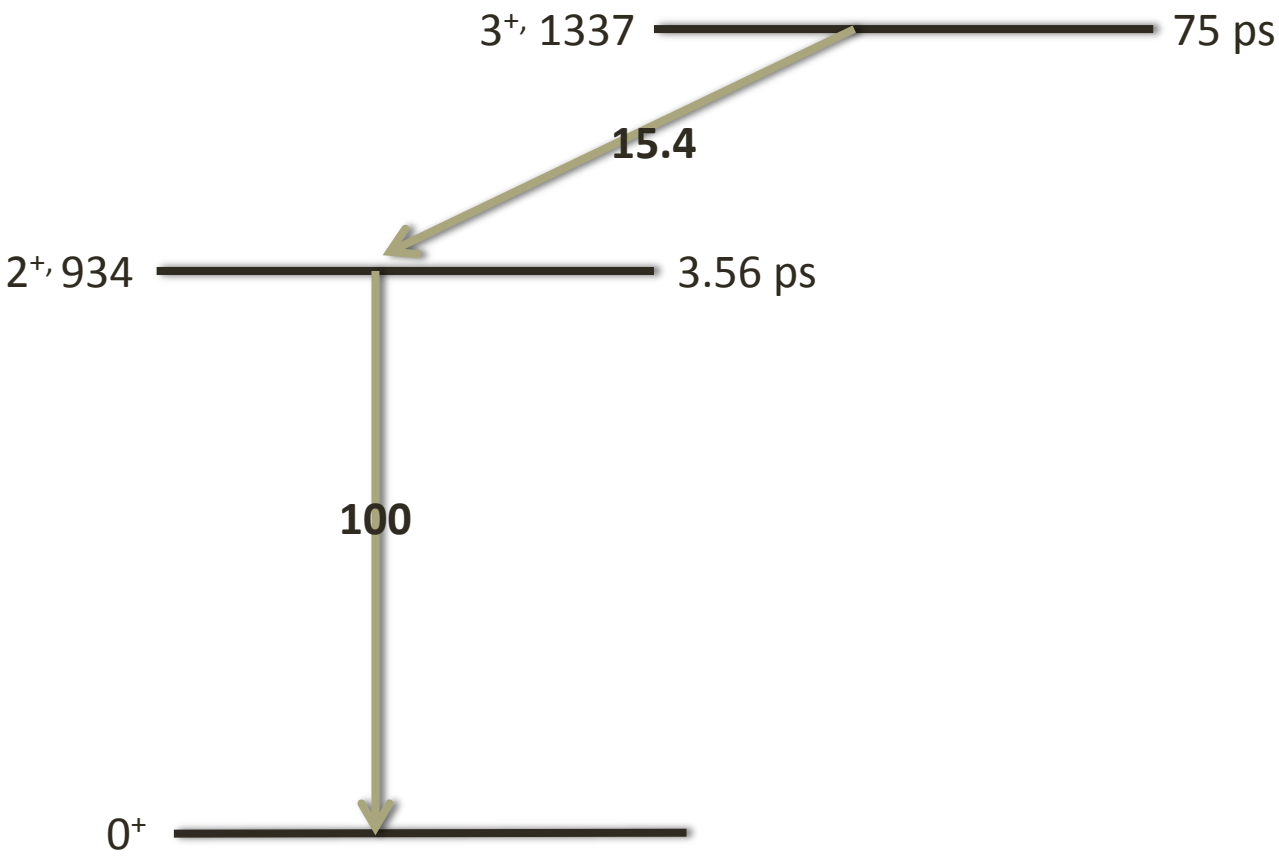
- [1] A. Deward *et al.,* Prog. Part. Nucl. Phys. **67**, 786 (2012)
- [2] A. Obertelli *et al.,* Phys. Rev. C **80**, 031304(R) (2009)
- [3] J. Ljungvall *et al.* Phys. Rev. Lett. **100**, 102502 (2008)
- [4] K. Starosta *et al.,* Phys. Rev. Lett .**99**, 042503 (2007)
- [5] A. Gade *et al,* Phys. Rev. Lett. **95**, 022502 (2005)
- [6] M. Hasegawa *et al.,* Phys. Lett. B **656**, 51 (2007)
- [7] B.S. Nara Singh *et al.,* Phys. Rev. C **75**, 061301(R) (2007)
- [8] D. Jenkins *et al.*, Phys. Rev. C **65**, 064307 (2002)
- [9] A. Lemasson *et al.,* Phys. Rev. C **85**, 0413039(R) (2012)

Thank you for listening

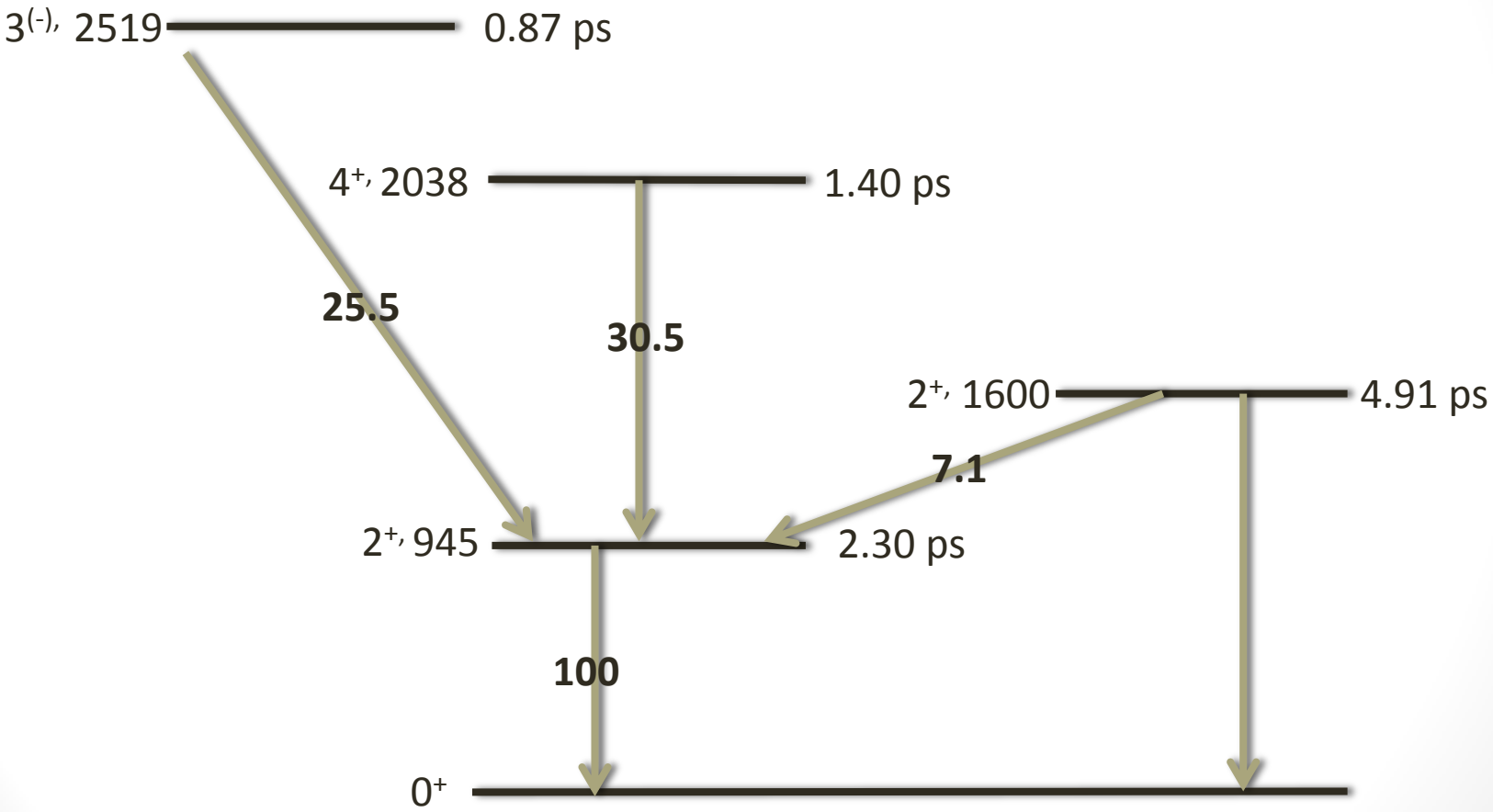
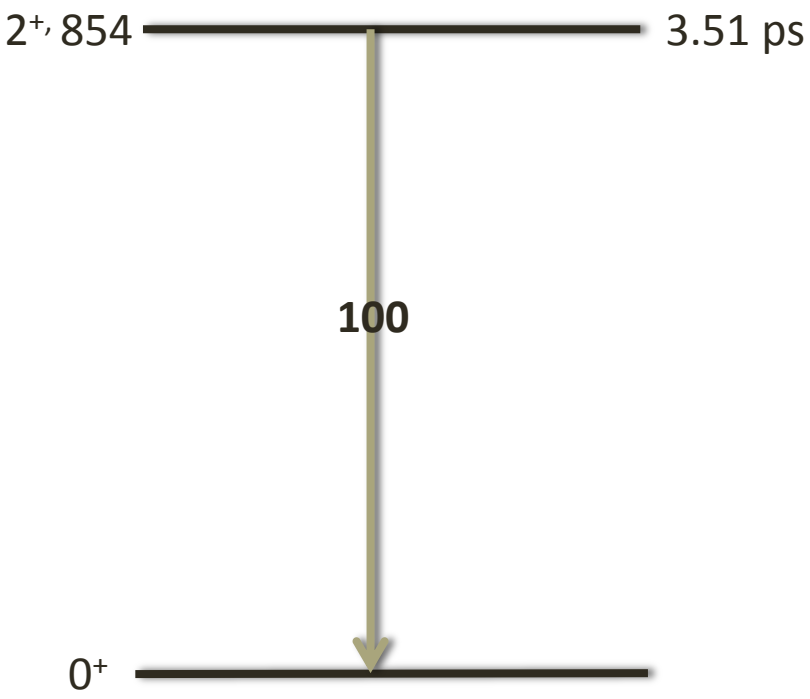
The ^{70}Se discrepency



^{70}Br feeding history



^{70}Se feeding history



^{68}Se feeding history