Recoil Distance Lifetime Measurement of ^{38}Si and Implementation of Active Target Technique

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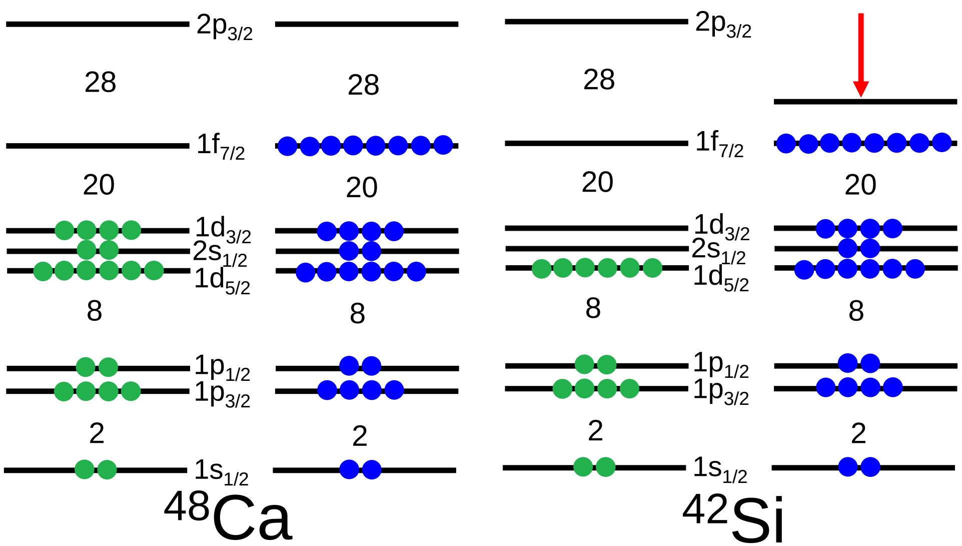
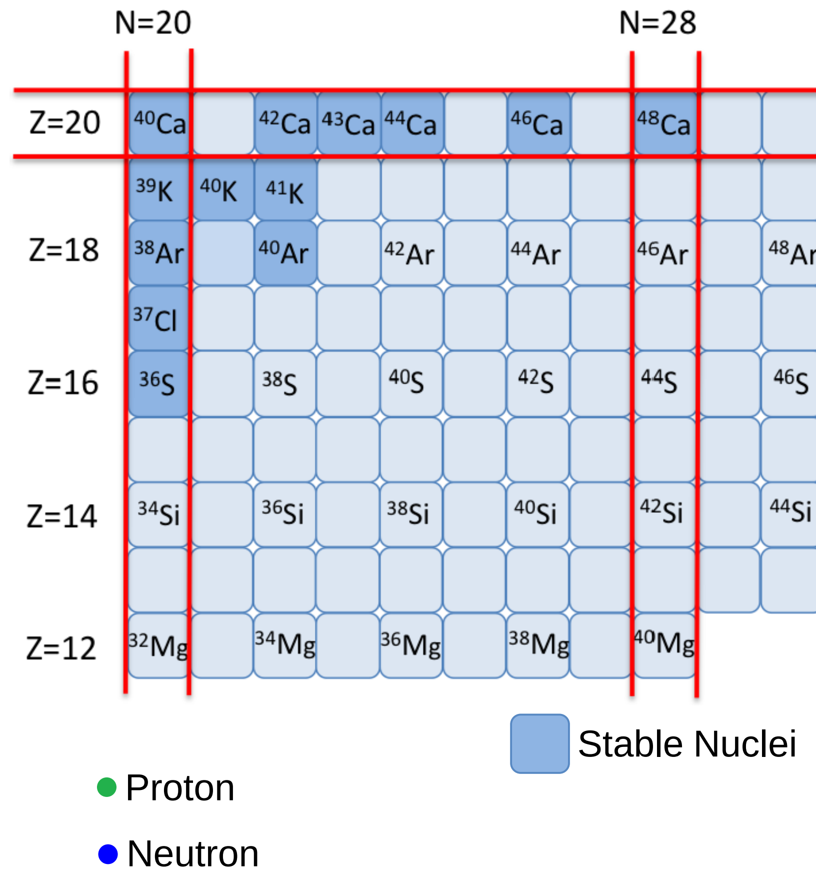
Outline

- Physics Background and Motivation for ^{38}Si
- Experimental set up and Method
- Preliminary ^{38}Si Lifetime Data
- Discussion of ^{38}Si Results
- Active Target Implementation

Shell Evolution from Mg→Ca

- Neutron rich nuclei
- Magic Numbers 20 and 28 [1],[2]
  - Persistent in ^{40,48}Ca, ^{34}Si
  - Absent in ^{32,40}Mg, ^{42}Si
- Island of inversion [3],[4]
  - Magicity disappears





[1] T. Otsuka et al. Phys. Rev. Lett. 87, 082502
[2] O. Sorlin and M-G Porquet 2014 Phys. Scr. 2013 014003
[3] E. K. Warburton et al. Phys. Rev. C. 41, 1147 (1990)
[4] B.A. Brown Physics 3,104 (2010)

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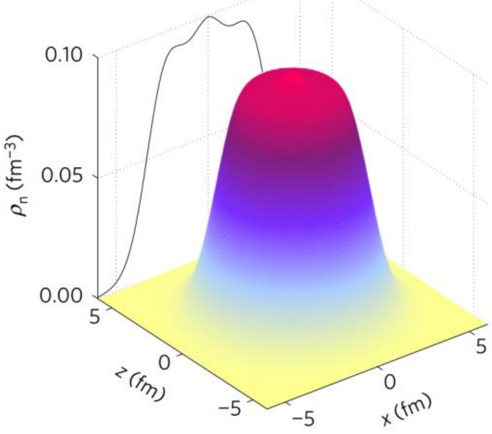
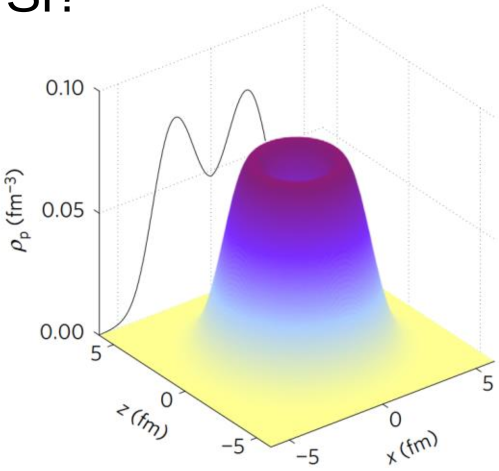
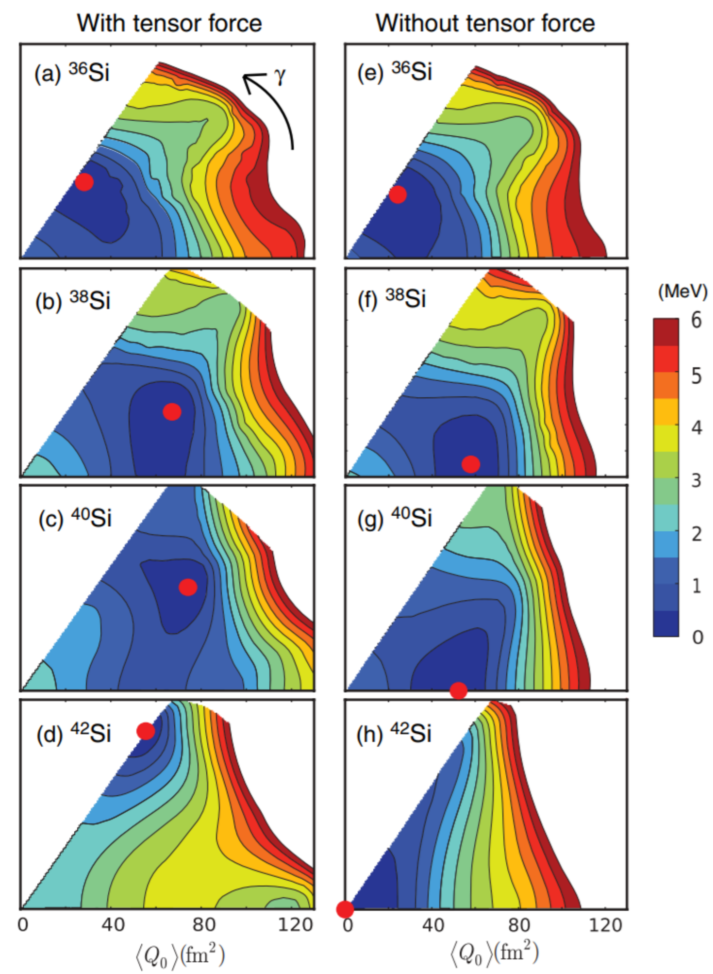
Shape Evolution Near ^{38}Si

- Si isotopes N=20-28
  - Shell evolution
  - ^{34}Si is closed shell
  - No N=28 shell at ^{42}Si [1]
- Triaxial deformation [2]
- Cross shell excitations [3]
  - Between $1f_{7/2}$ and $2p_{3/2}$
- Bubble Structure in ^{34}Si
  - Persists in neutron rich Si?





Potential Energy Surface



[1] B. Bastin et al, PRL 99, 022503 (2007)
[2] Y. Utsuka et al. Phys. Rev. C 051301(R)(2012)
[3] S. R. Stroberg et al. Phys. Rev. C 91, 041302 (R) (2015)
[4] T. Otsuka et al. Phys. Rev. Lett. 87, 082502
[5] A. Mutschler et al. Nature Physics 13, 152-156 (2017)

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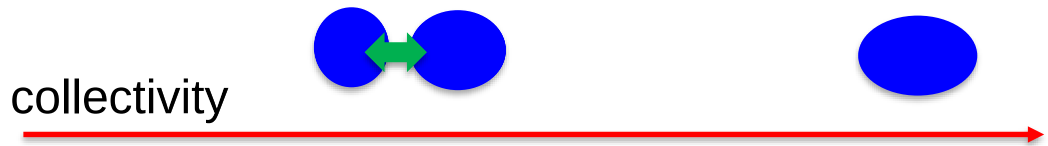
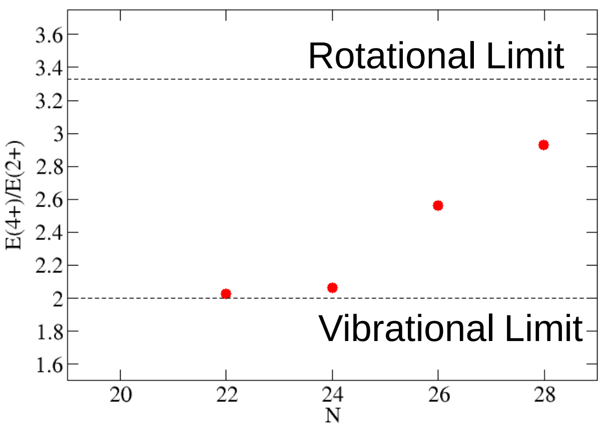
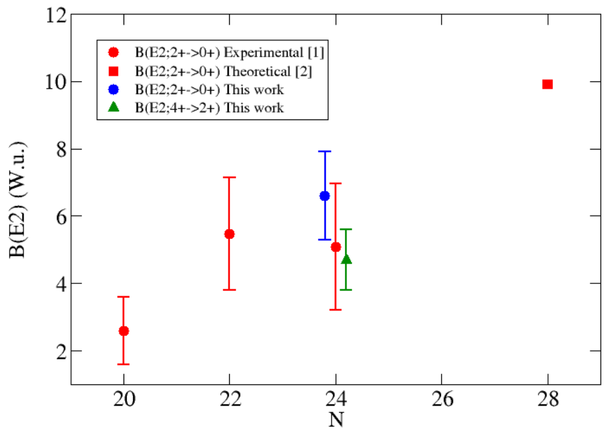
Collectivity in ^{38}Si

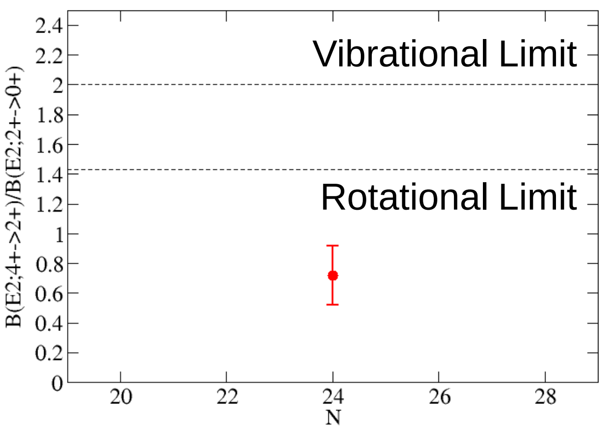
- ^{38}Si
  - Collective nature
  - Turning point
  - Vibrational → Deformed
  - B(E2) transition strength measurement
    - » Hint at shell configuration
    - » Intruder $p_{3/2}$
    - » Information on (4^+_2) state



	Vibrational	Triaxial (γ=30°)[4]	Deformed
$E(4^+)/E(2^+)$	2	2.67	3.3
$\frac{B(E2;4^+\rightarrow2^+)}{B(E2;2^+\rightarrow0^+)}$	2	1.39	1.43

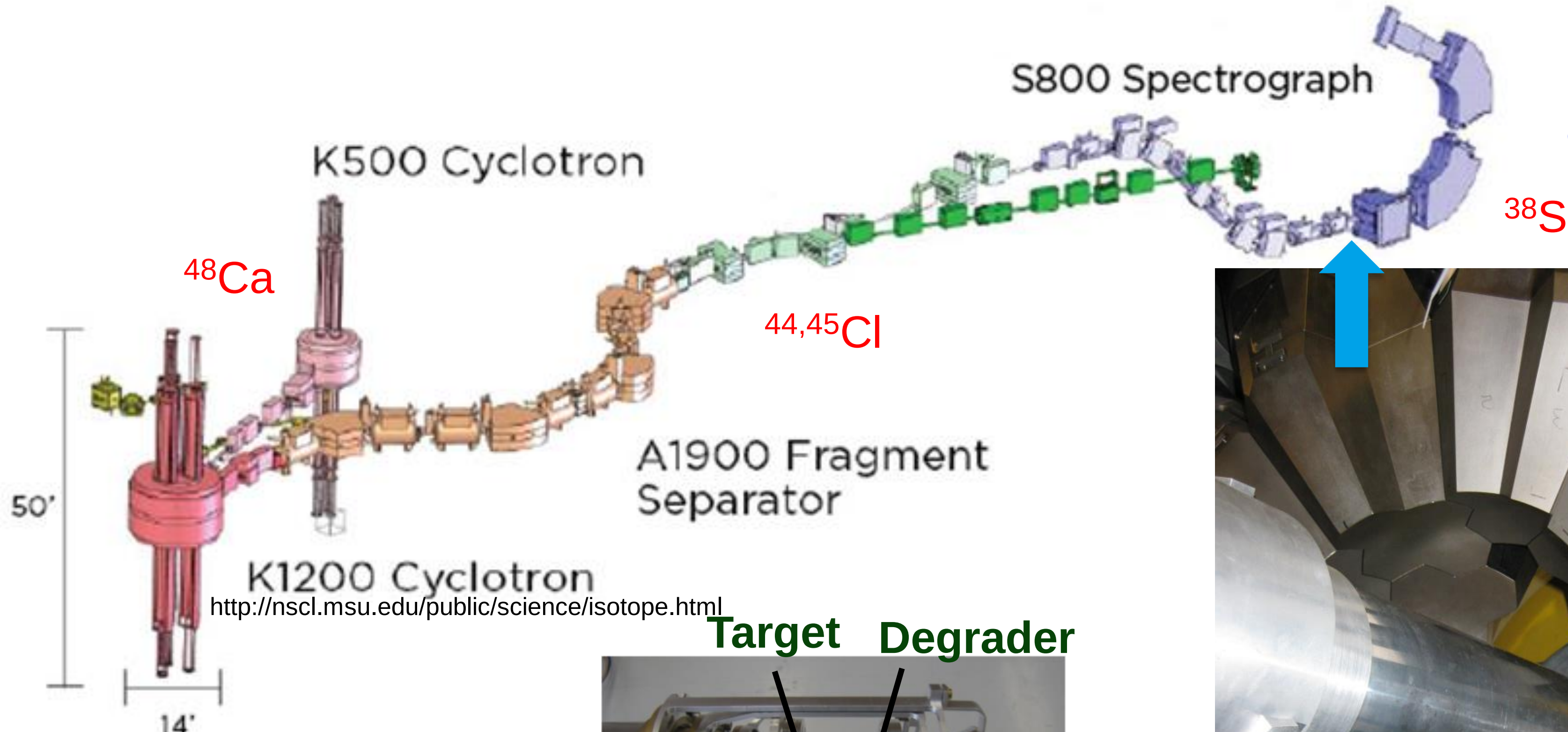




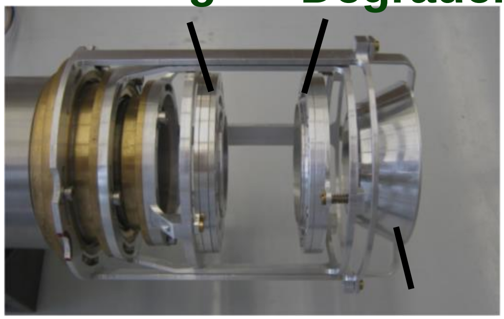


[1] R. W. Ibbotson et al, Phys. Rev. Lett. 80, 2081 (1998)
[2] F. Nowacki and A. Poves, Phys. Rev. C. 79, 014310 (2009)
[3] S. Takeuchi et al. PRL 109, 182501 (2012)
[4] W. T. Chou et al. Phys. Rev. C 47,157 (1993)

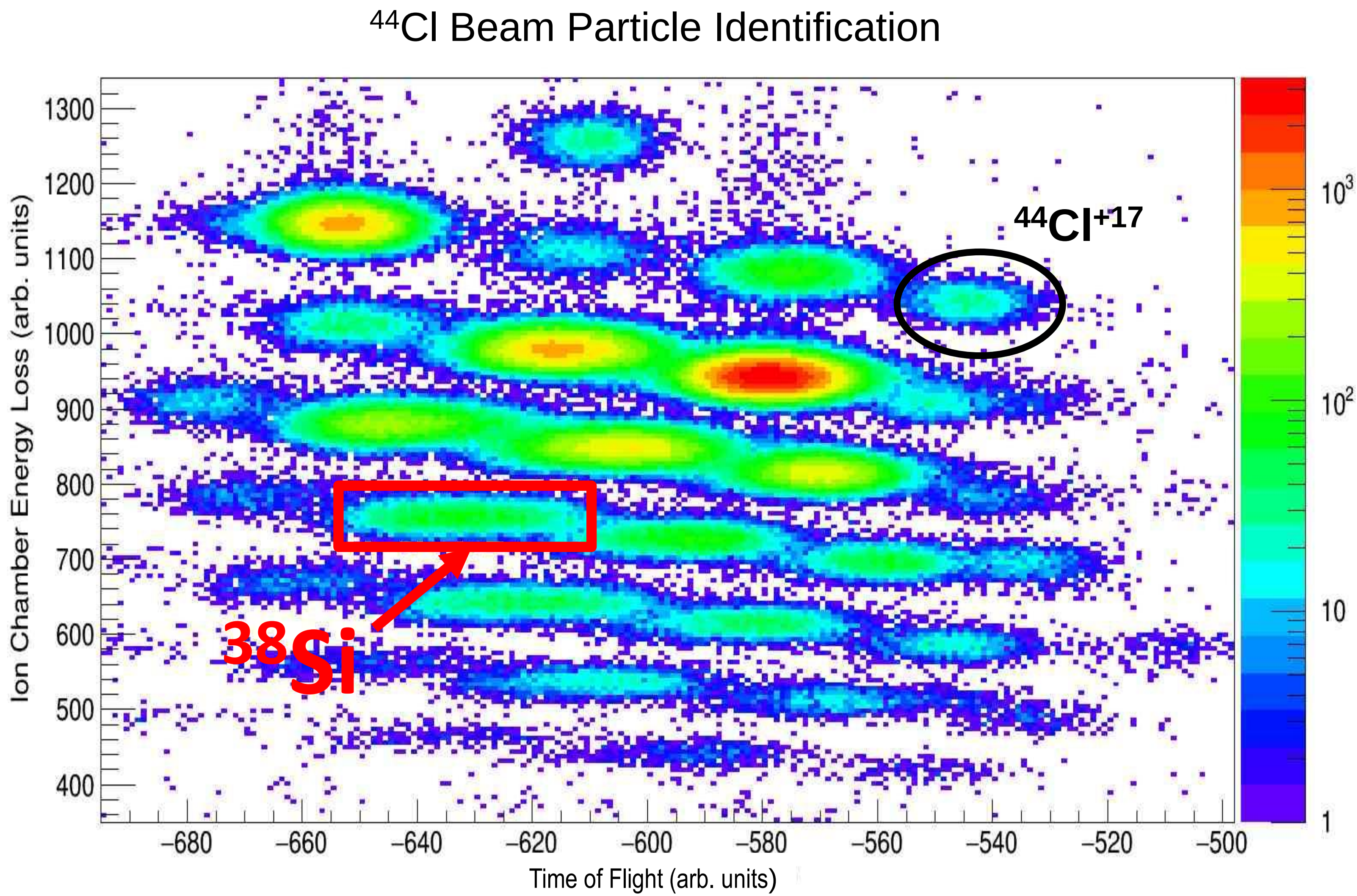
Experimental Setup



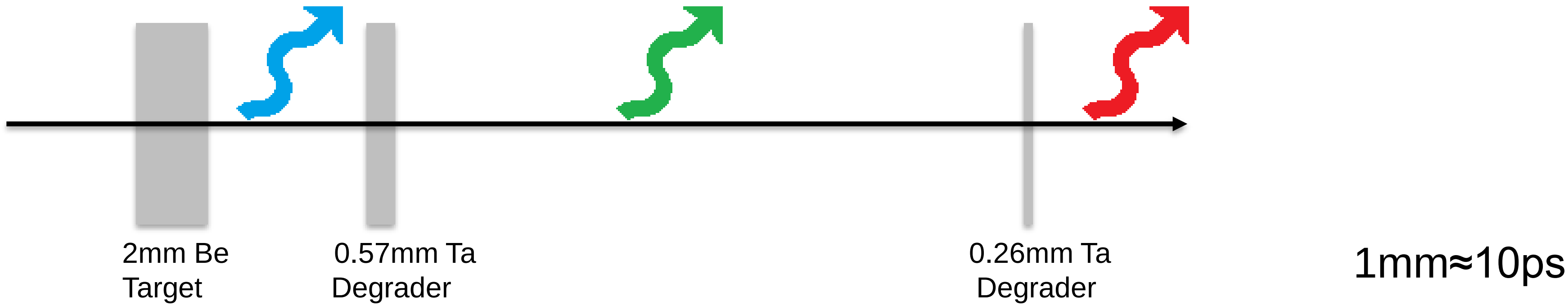
- Two Reactions
  - $^{44}Cl + ^{9}Be \rightarrow ^{38}Si$
  - $^{45}Cl + ^{9}Be \rightarrow ^{38}Si$



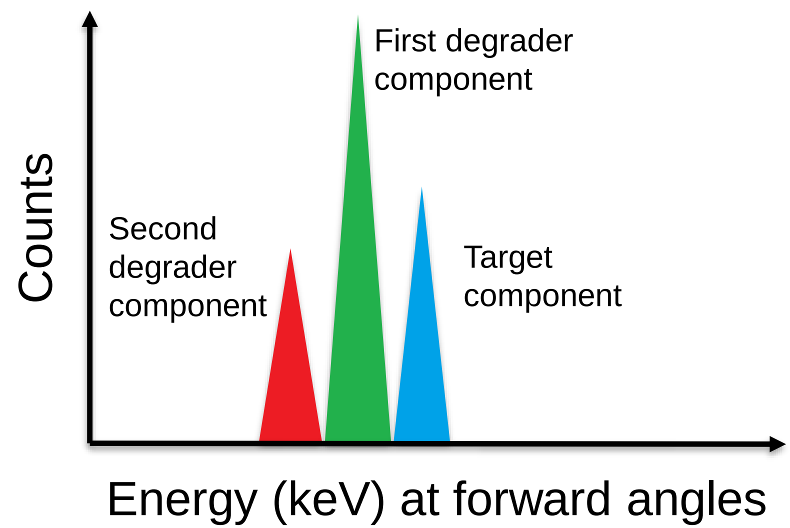
S800 Particle Identification



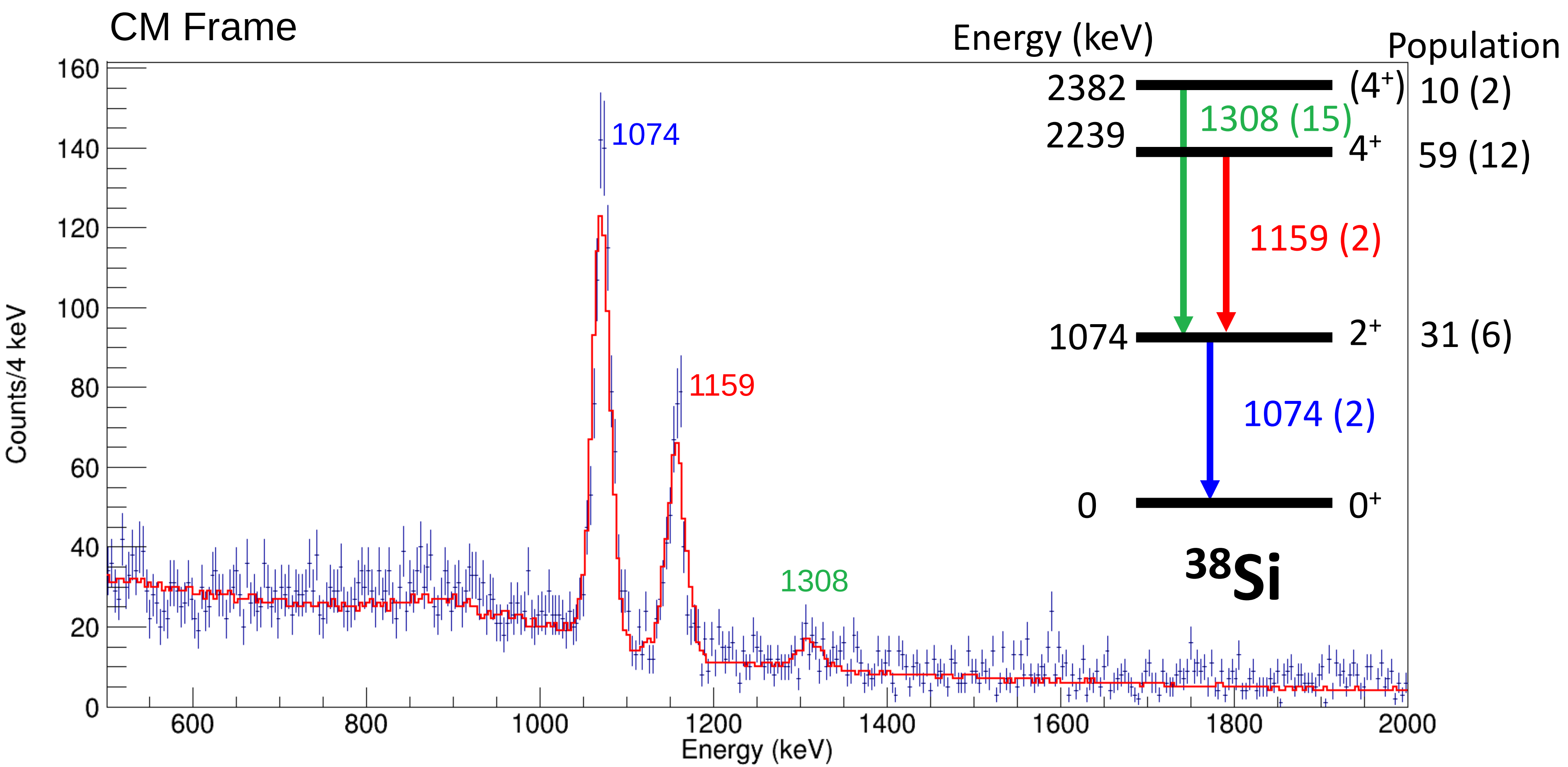
Recoil Distance Method



- Doppler-shift correction
  - Each β → peak
  - Peak height → # decays
  - Relative height give lifetime information
- Advantages
  - Model independent B(E2) measurement
  - 1 ns to 10 ps lifetime range
- Disadvantages
  - Multiple distance measurements
  - Reactions in degrader foils

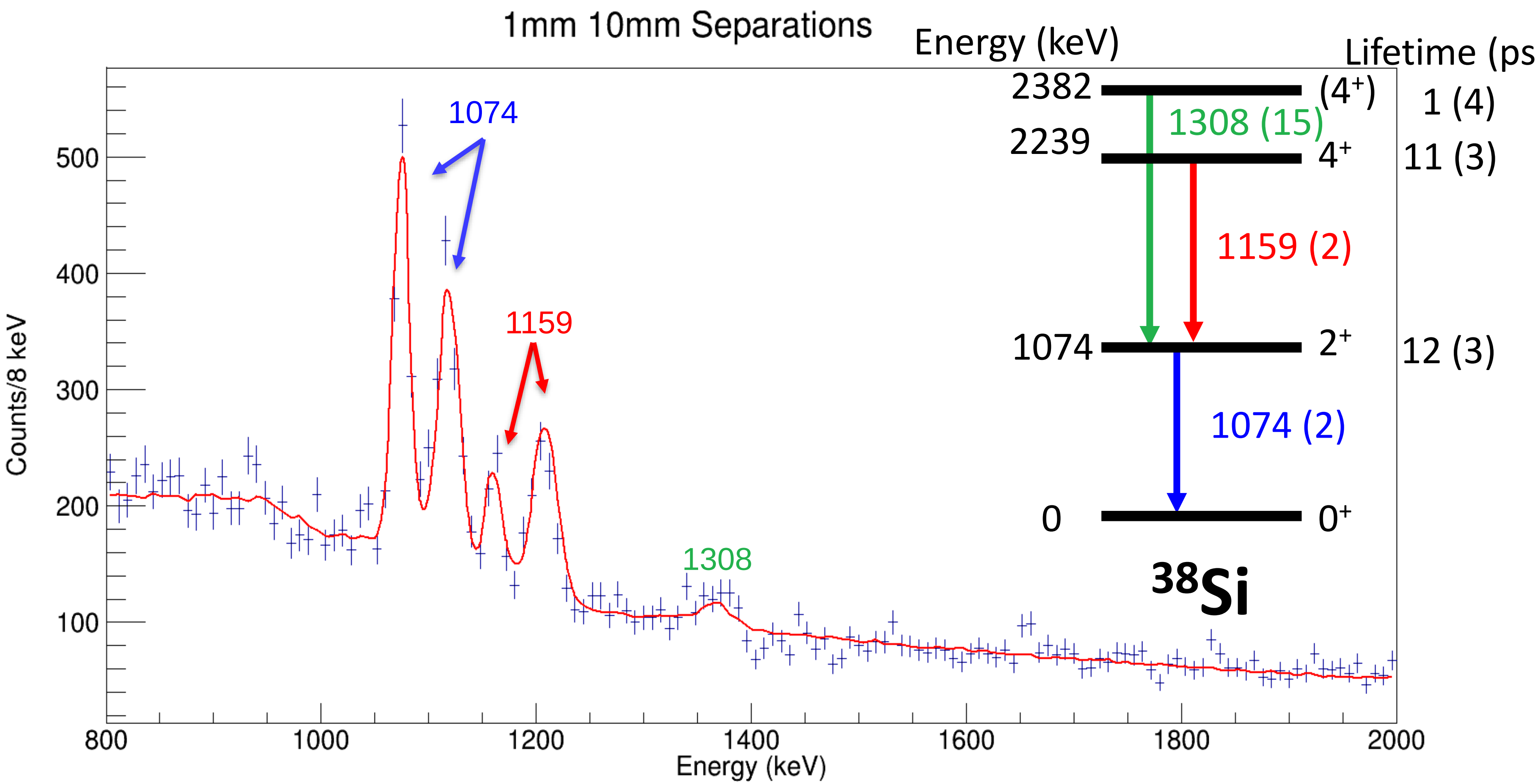


Target Only Data



[1] K. Steiger et al. Euro Phys J.A (2015) 51:117

Three Foil Data



[1] K. Steiger et al. Euro Phys J.A (2015) 51:117

B(E2) from Preliminary Lifetimes

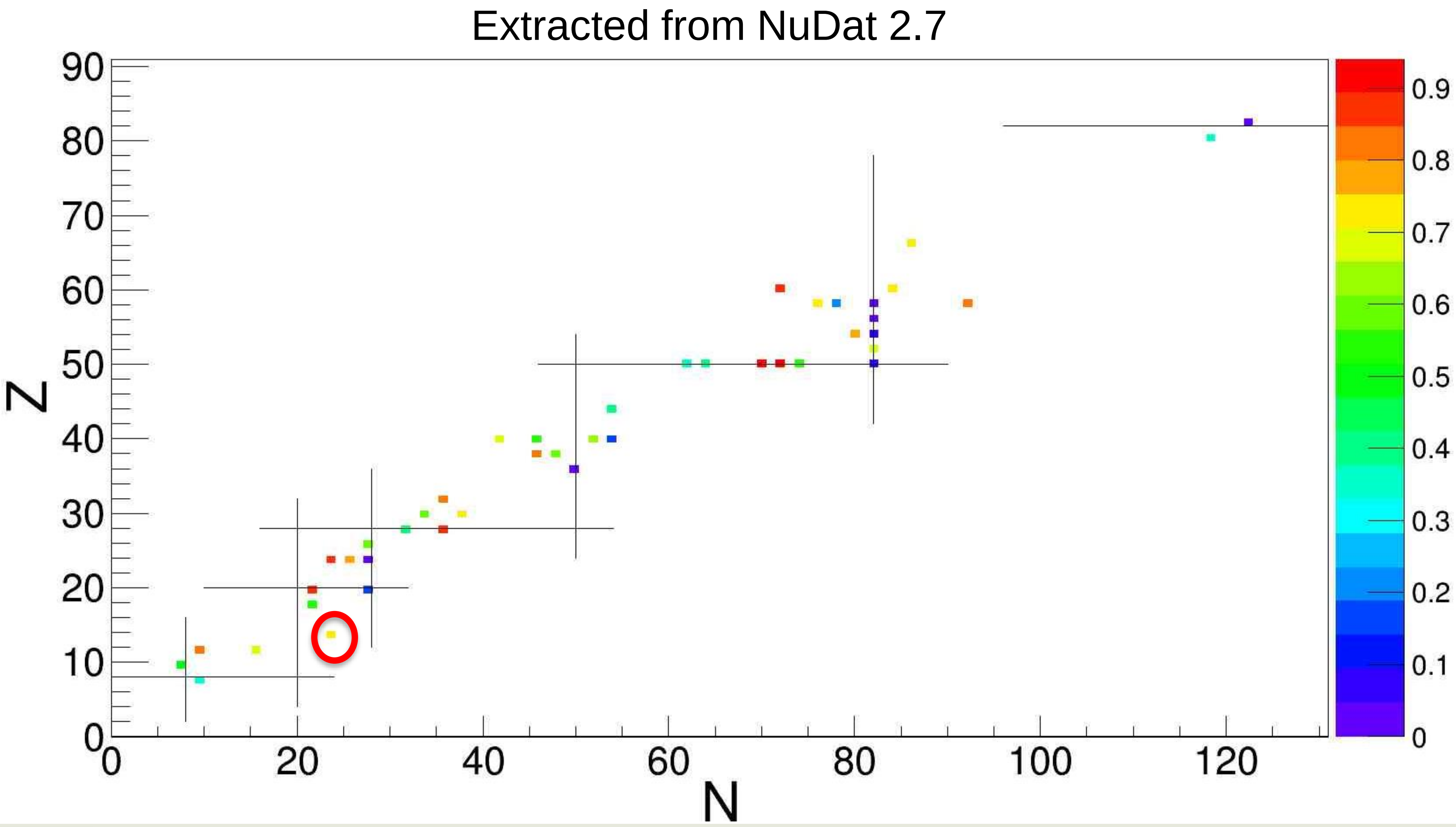
Transition	Energy (keV)	Lifetime (ps)	B(E2↓) (e^2fm^4)	Previous B(E2↓) (e^2fm^4)	Energy Ratio	B(E2) Ratio
$2^+ \to 0^+$	1074(2)	12 (3)	50 (10)	39 (14)[1]	---	---
$4^+ \to 2^+$	1159(2)	11 (3)	36 (7)	---	2.08	0.72
$(4^+) \to 2^+$ $(2^+) \to 2^+$	1308(15)	1 (4)	>44 B(M1):>5.2×10^{-3}	---	2.20	

	Vibrational	Triaxial (γ=30°)[2]	Deformed
$E(4^+)/E(2^+)$	2	2.67	3.3
$\frac{B(E2;4^+ \to 2^+)}{B(E2;2^+ \to 0^+)}$	2	1.39	1.43

* Assuming pure M1 transition

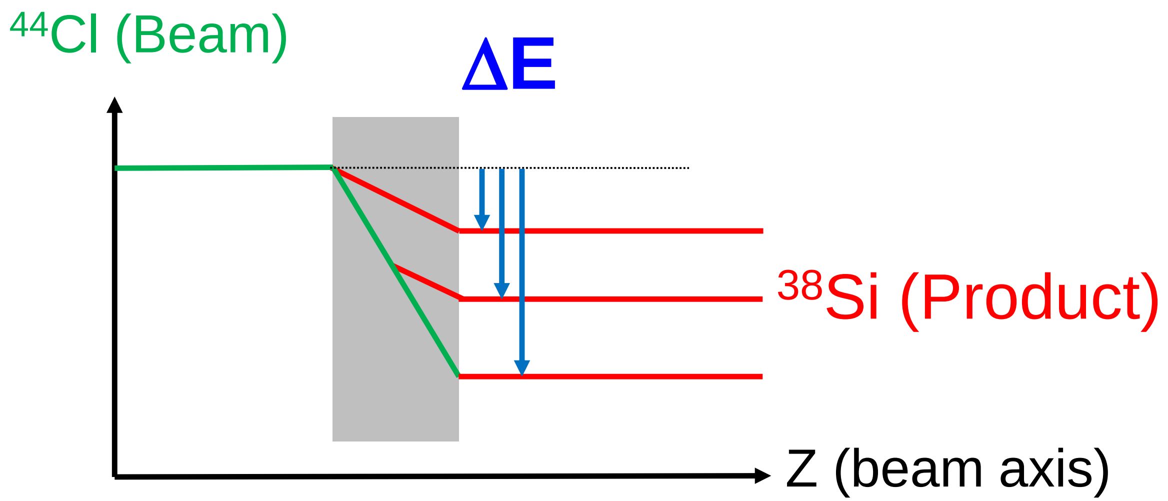
[1] R. W. Ibbotson et al, Phys. Rev. Lett. 80, 2081 (1998)
[2] W. T. Chou et al, Phys. Rev. C 47,157 (1993)

Isotopes with B(E2) Ratio less than 1

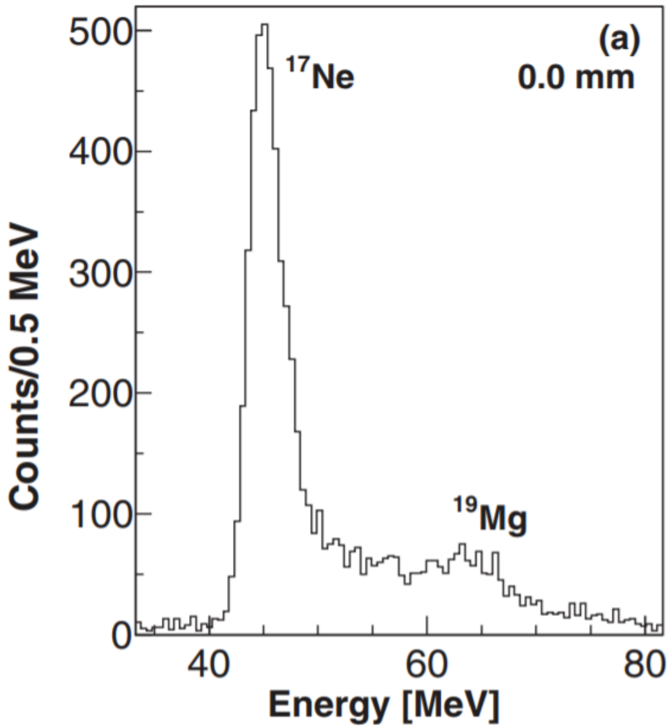


Jun Chen, Private Communication

Active Target



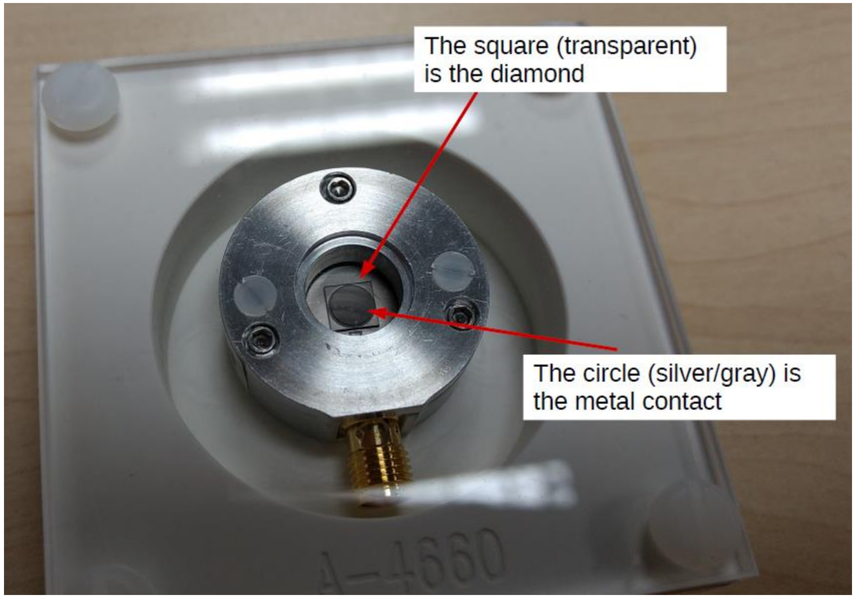
- Track reaction point in target
  - Better Doppler-shift corrections
  - Reduce degrader background
  - Increased sensitivity
    - » Short lifetimes, < a few ps



[1] P. Voss et al. Phys. Rev. C 90, 014301 (2014)

Diamond Active Target

- Diamond detector
  - Radiation hard
  - 1% energy resolution
  - 500 μm thick
  - 4.5 mm x 4.5 mm
  - Use in place of target foil



- Next Steps
  - Diamond Detector
    - » Beam test with heavy ions
    - » Characterize

Summary

- For the nuclei in the region around N=20 to 28, there is an evolution of shape and structure due to the change in nuclear shell structure far from stability.
- The Si isotopic chain is expected to show a variety of collectivity as predicted by most recent shell model calculations.
- The change in collectivity can be seen in B(E2) ratios resulting from deformations due to cross shell excitations.
- ^{38}Si is of particular importance as the turning point between vibrational and rotational collective pictures.
- Preliminary lifetimes for the first three transitions in ^{38}Si have been determined.
- A diamond active target will be implemented to improve sensitivity of future lifetime measurements.

Thanks and Questions

- Lifetime Group: Hiro Iwasaki, John Ash, Rob Elder, Tea Mijatovic
- Collaborators: Nobuyuki Kobayashi, Hye Young Lee, Kenneth Whitmore, Charles Loelius, Jun Chen, Daniel Bazin, Alfred Dewald, Alexandra Gade, Dirk Weisshaar, Peter Bender, Joe Belarge, Eric Lunderberg, Brandon Elman, Brenden Longfellow, Thoryn Haylett, Michael Mathy, Sebastian Heil
- NSSC
- Questions?

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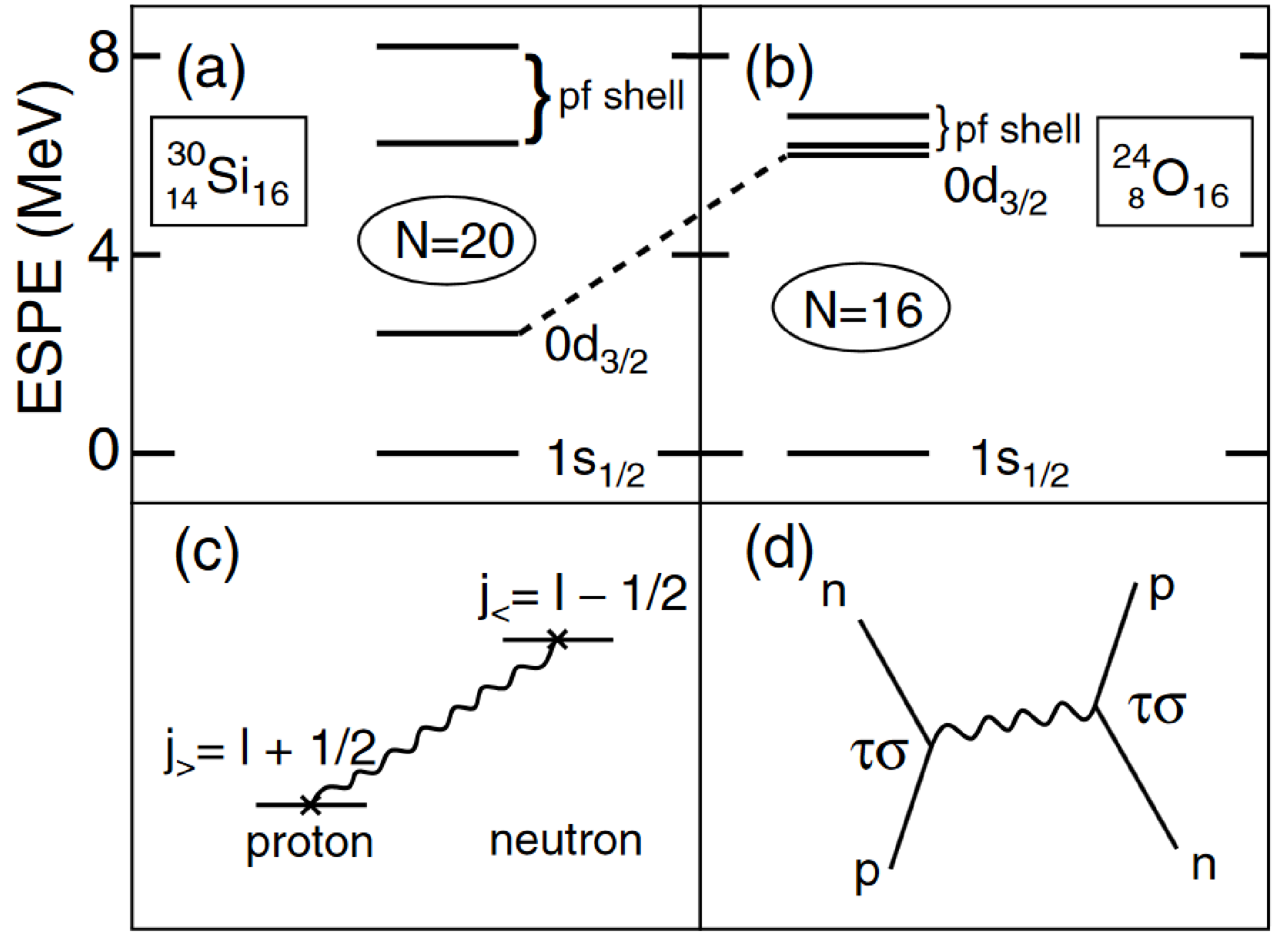
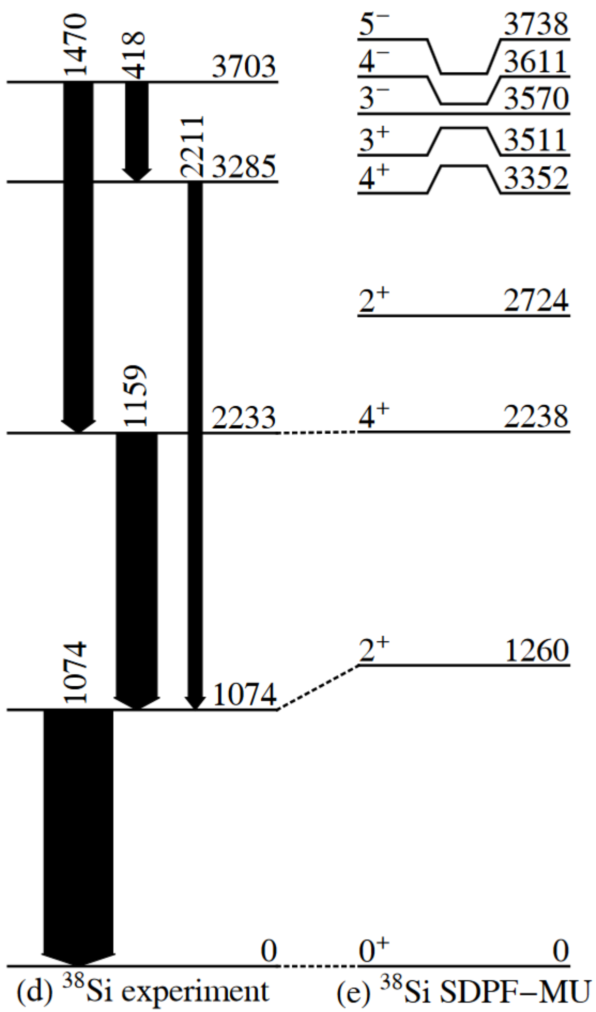


[1] T. Otsuka et al. Phys. Rev. Lett. **87**, 082502 (2001)

Previous Measurements

- Coulomb excitation (1998) [1]
  - E(2⁺)=1084 (20) keV,
  - B(E2↑) of 193 (71) e^2fm^4
- Inelastic proton scattering (2007) [2]
  - Three gamma peaks in spectrum
  - Two candidates for the 4⁺ state
- Multinucleon removal (2012) [3]
  - E(2⁺)= 1071 (12), E((4⁺))= 2239 (22), E((4⁺))= 2355 (26) keV
- Beta decay (2015) [4]
  - E(2⁺)=1074 (2), E(4⁺)=2233 (2) keV
  - Suggested the lower state as 4⁺
- No lifetimes measured previously
- J^π at 2355 keV not confirmed



[1] R. W. Ibbotson et al, Phys. Rev. Lett. 80, 2081 (1998)
[2] C. M. Campbell et al, Phys. Rev. B 4, 652 (2007)
[3] S. Takeuchi et al. Phys. Rev. Lett. 109, 182501 (2012)
[4] K. Steiger et al, Eur. Phys. J. A (2015) 51:117
[5] Y. Utsuno et al Prog.Theor.Phys.(Kyoto),Suppl. 196, 304 (2012)

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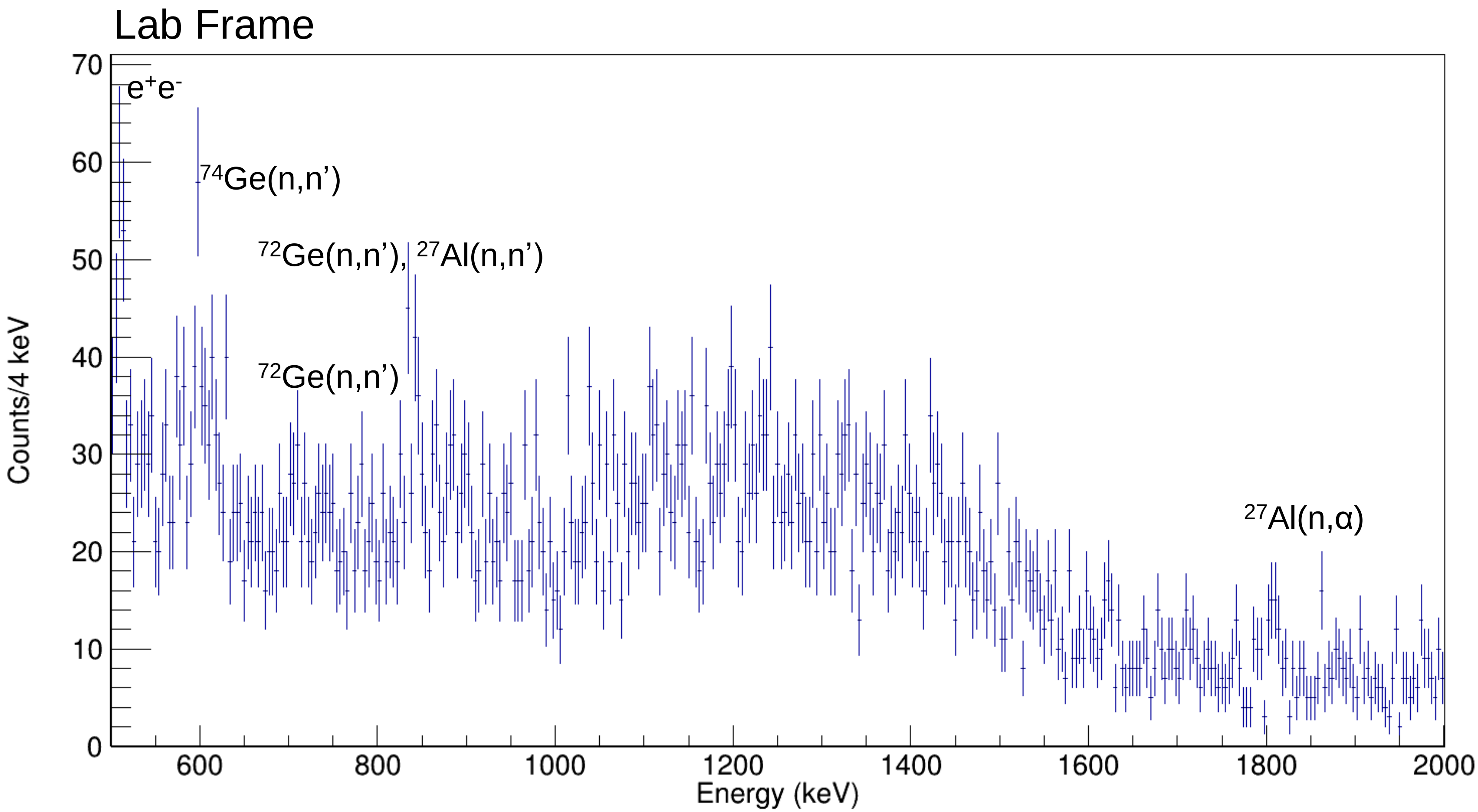
Target Only Data



Three Foil Data

Ratio Tgt/deg = 1.5

Cl45 Beam, 25mm 25mm Separations