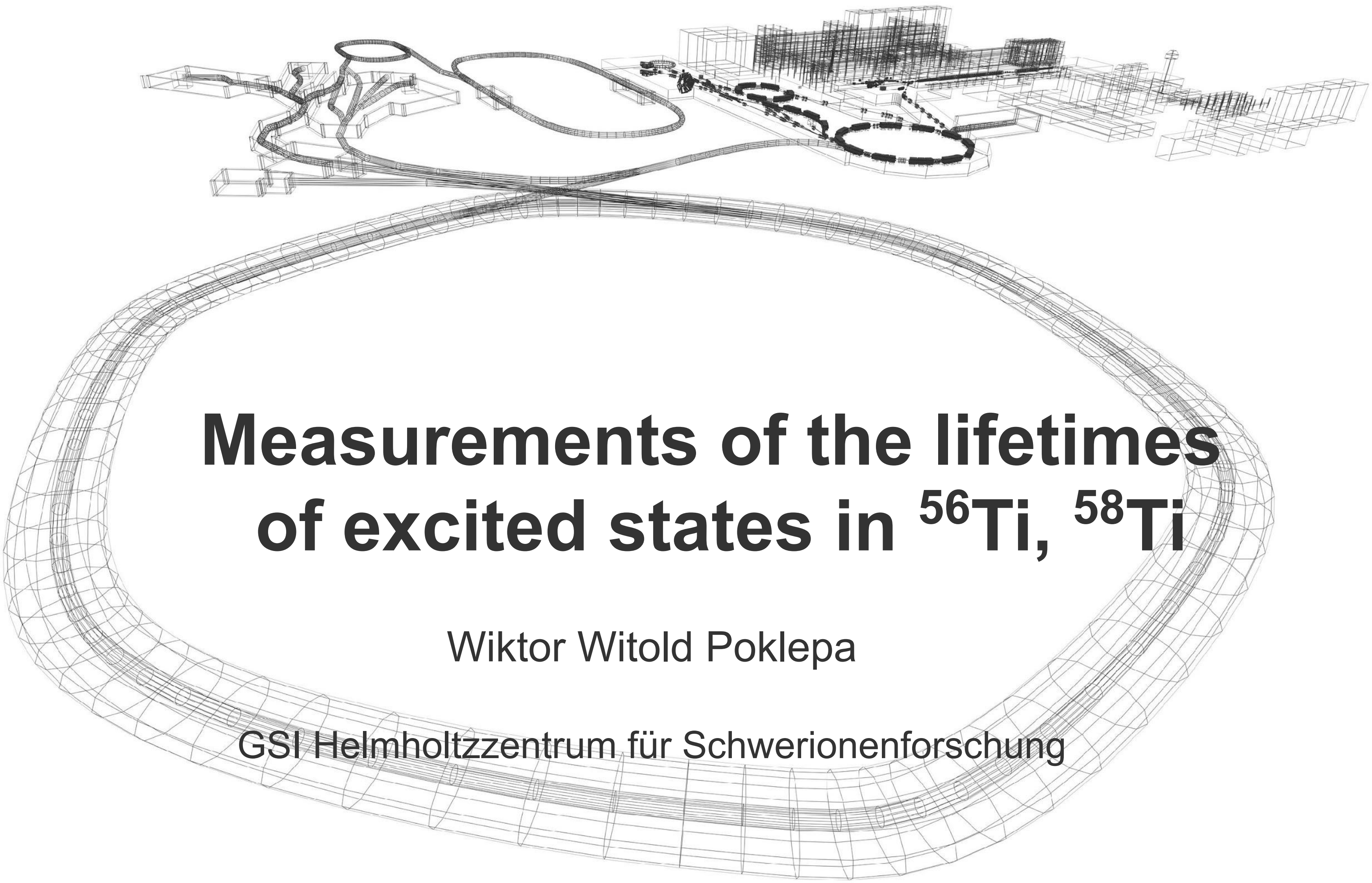
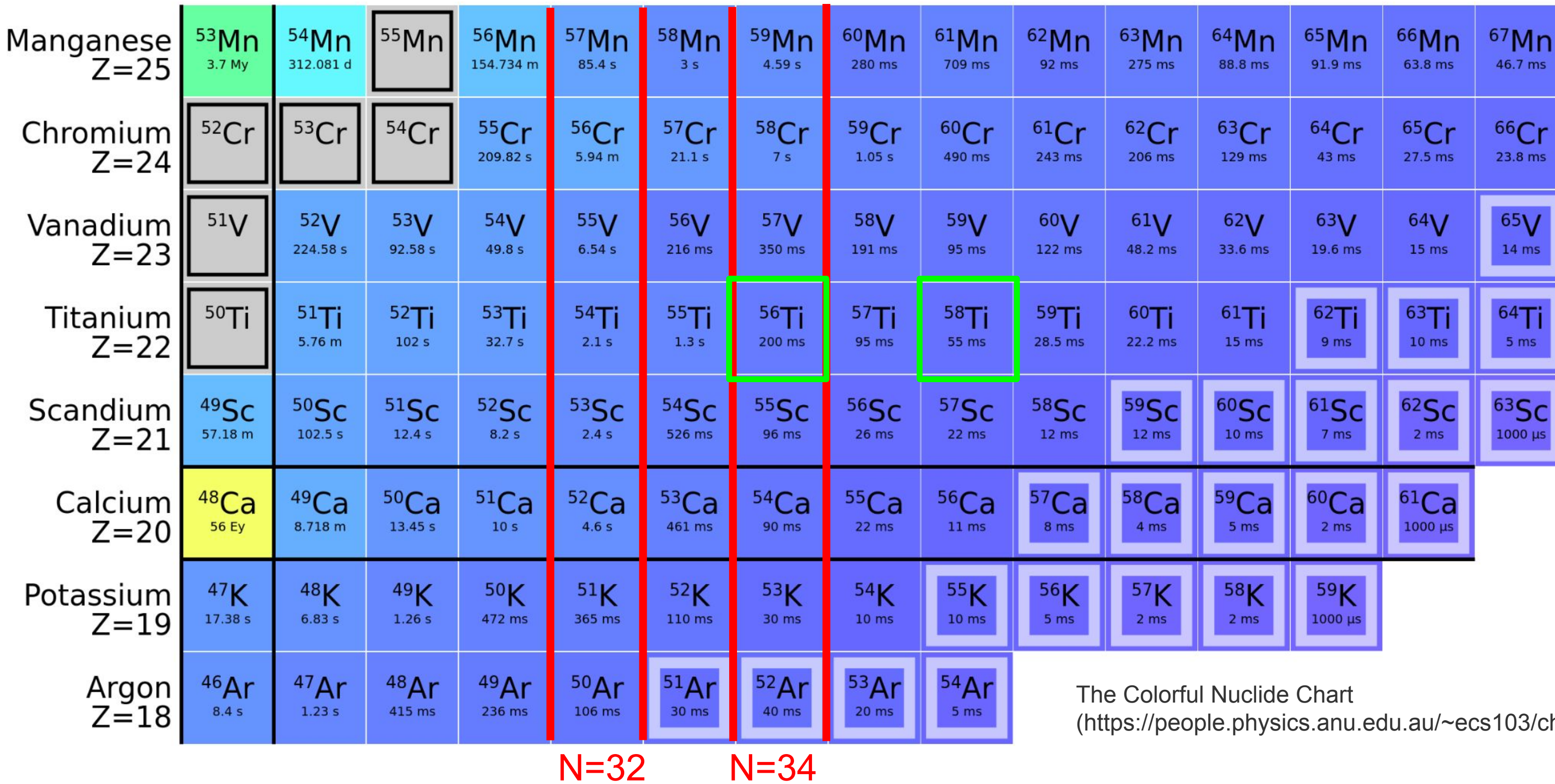


Measurements of the lifetimes of excited states in ^{56}Ti, ^{58}Ti

Wiktor Witold Poklepa

GSI Helmholtzzentrum für Schwerionenforschung

Motivation

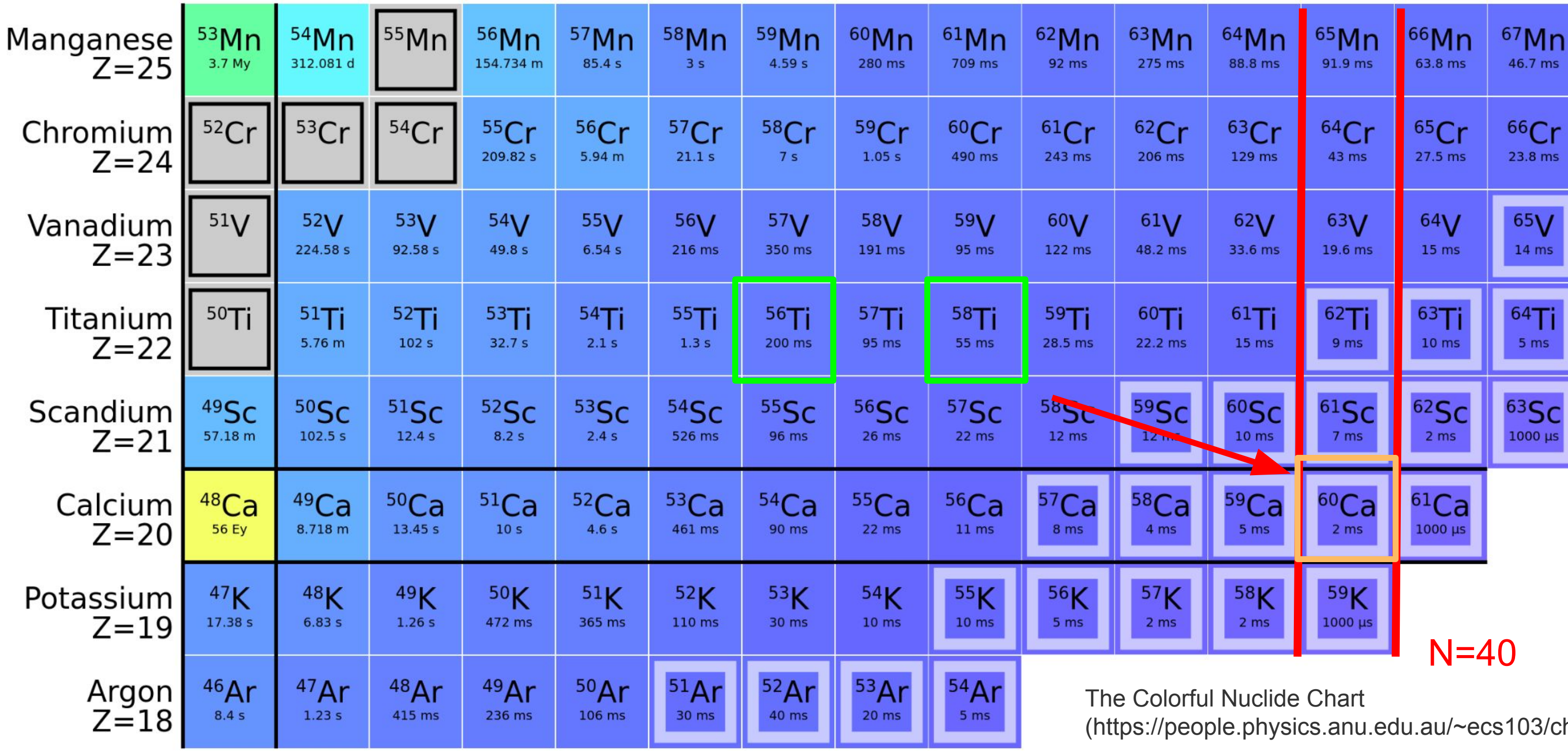


The Colorful Nuclide Chart
(https://people.physics.anu.edu.au/~ecs103/chart/)

- Validity of the neutron magic numbers N = 32,34

D.-C. Dinca et al., Phys. Rev. C 71 (2005), 041302(R) , D. Steppenbeck et al., Nature vol 502 (2013)

Motivation



The Colorful Nuclide Chart
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- Validity of the neutron magic numbers N = 32,34

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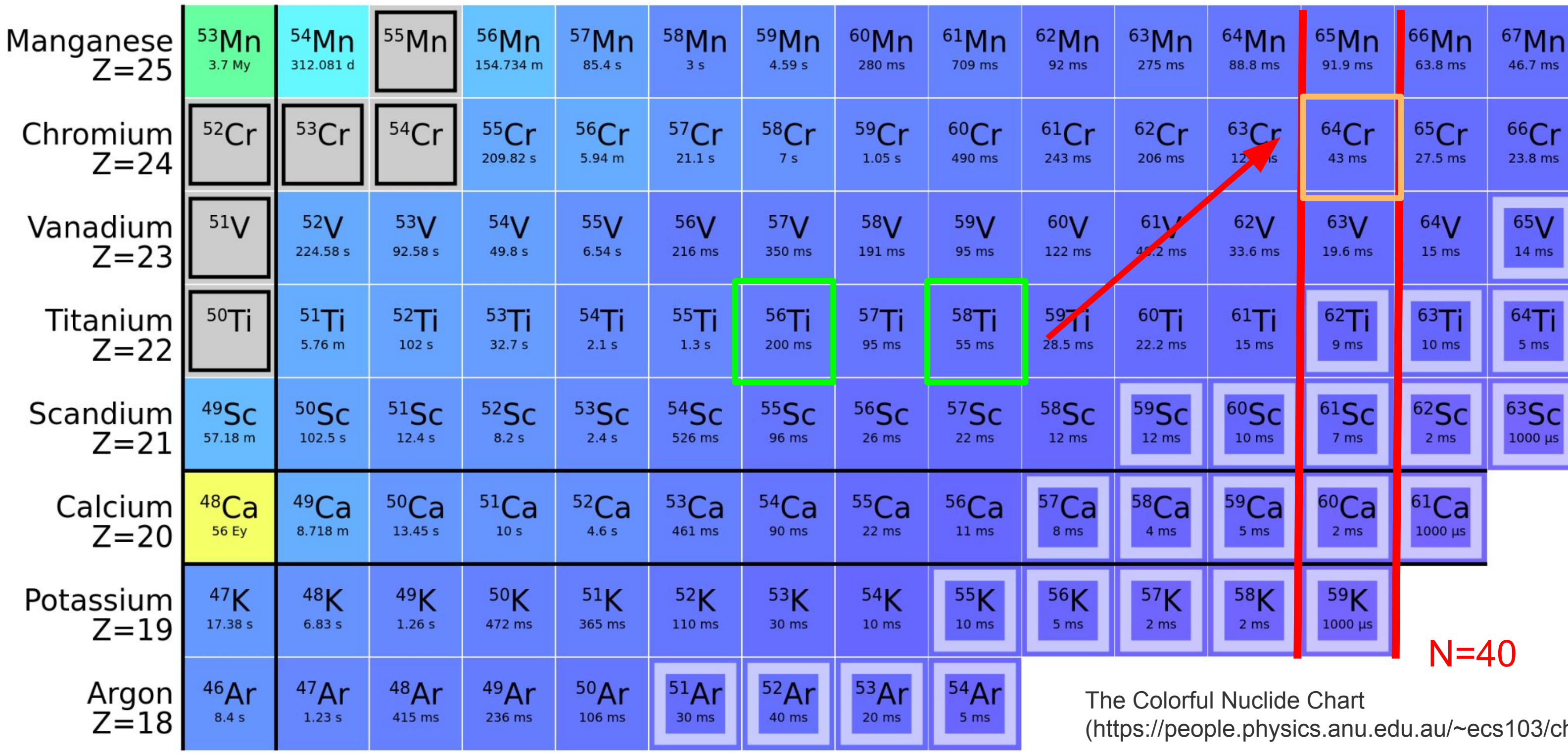
- Probing the nuclear structure towards N=40 ^{60}Ca

  A. Gade et al., Phys. Rev. Lett. 112 (2014), 112503

Motivation



The Colorful Nuclide Chart
(https://people.physics.anu.edu.au/~ecs103/chart/)

- Validity of the neutron magic numbers N = 32,34

  D.-C. Dinca et al., Phys. Rev. C 71 (2005), 041302(R) , D. Steppenbeck et al., Nature vol 502 (2013)

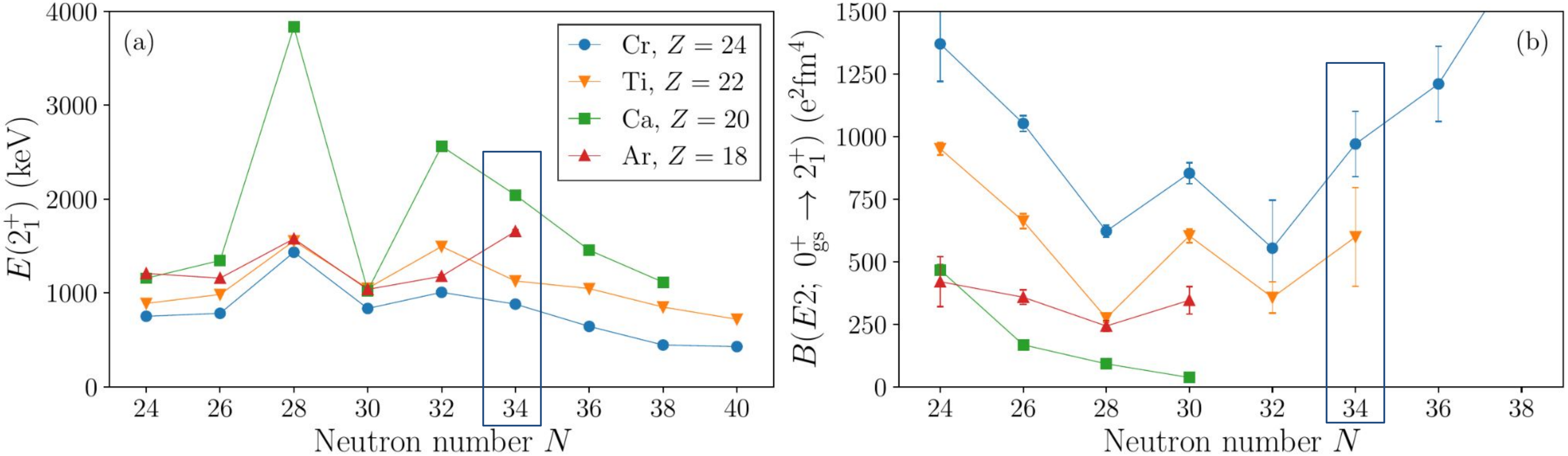
- Probing the nuclear structure towards N=40 ^{60}Ca

  A. Gade et al., Phys. Rev. Lett. 112 (2014), 112503

- Approaching the island of inversion around ^{64}Cr

  S.M. Lenzi et al., Phys. Rev. C 82 (2010) 054301

The N = 32,34 sub-shell closures



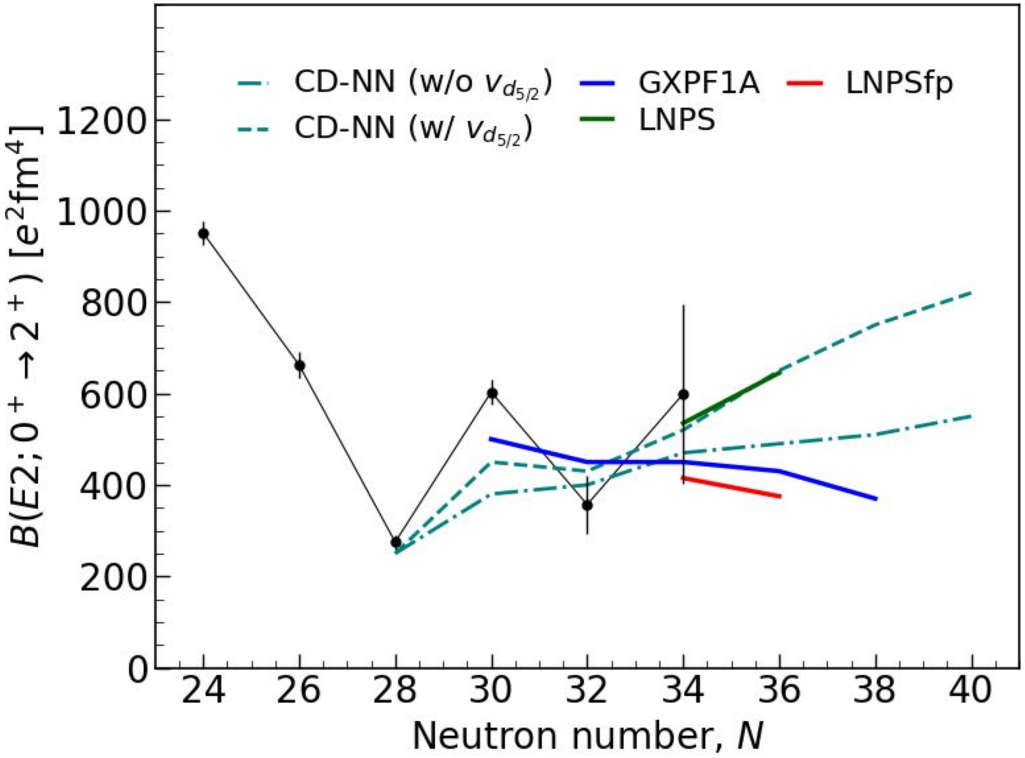
- No sign of shell closure for ^{56}Ti
- The B(E2) value involves big uncertainty
- E(2^+) values established up to N = 40 for Ti isotopes

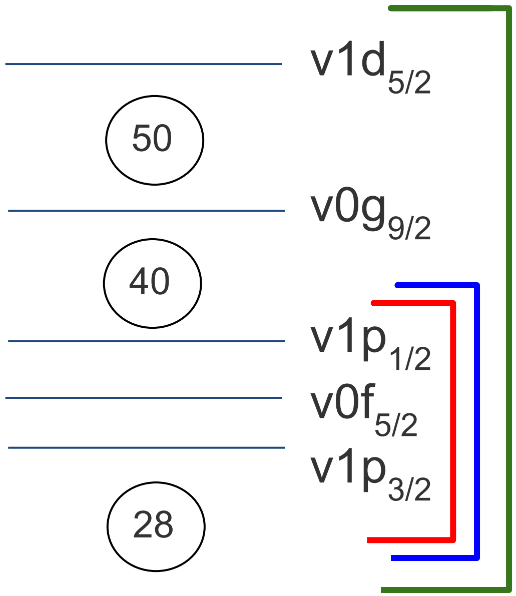
M.L. Cortes et al., Phys. Rev. Lett B 800 (2020) 135071

Approaching the ^{64}Cr IoI

- Island of inversion is a region where the deformed intruder states are energetically favored giving rise to collectivity
- Indications that ^{59}Ti and ^{61}Ti belong to the Island of Inversion

K. Wimmer et al., Phys. Lett. B 792 (2019) 16-20



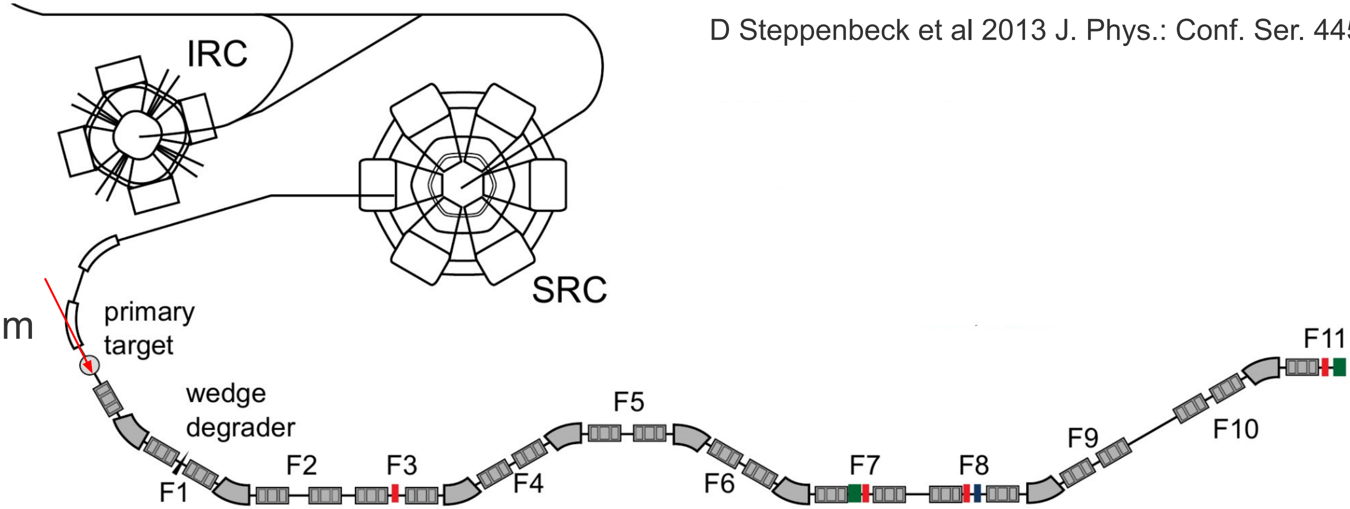


S.M. Lenzi et al., Phys. Rev. C 82 (2010) 054301
L. Coraggio et al., Phys. Rev. C 89 (2014) 024319

BigRIPS & ZeroDegree

D Steppenbeck et al 2013 J. Phys.: Conf. Ser. 445 012012

^{70}Zn
345 AMeV
primary beam



BigRIPS & ZeroDegree

D Steppenbeck et al 2013 J. Phys.: Conf. Ser. 445 012012

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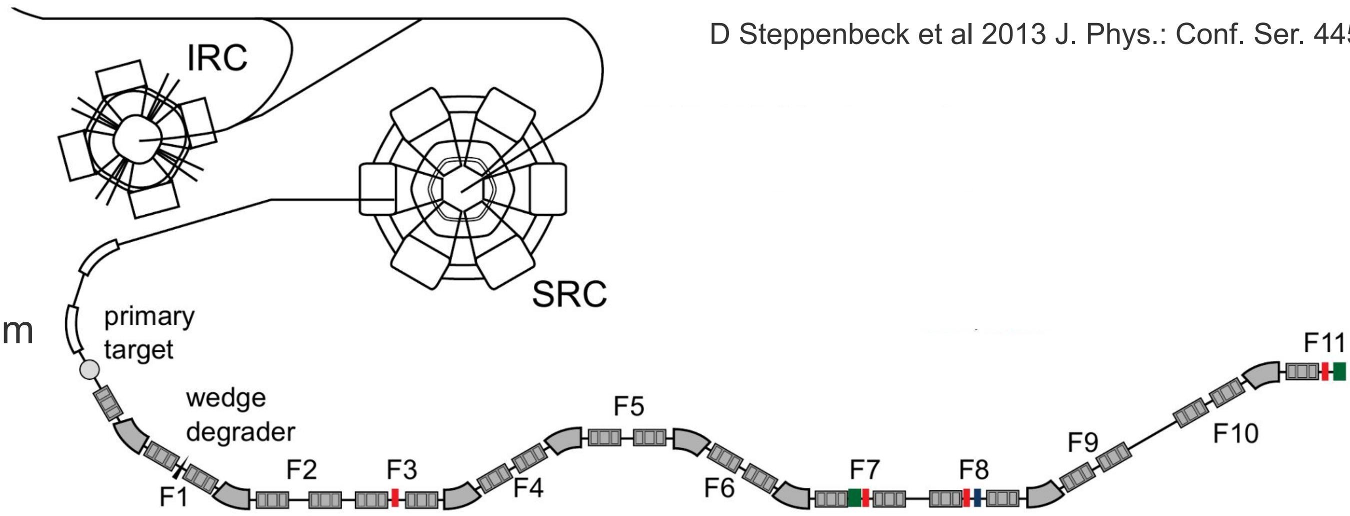


$$\mathrm{TOF} = \frac{L}{\beta c}$$

BR

BigRIPS identification by:
ΔE, TOF, Bρ

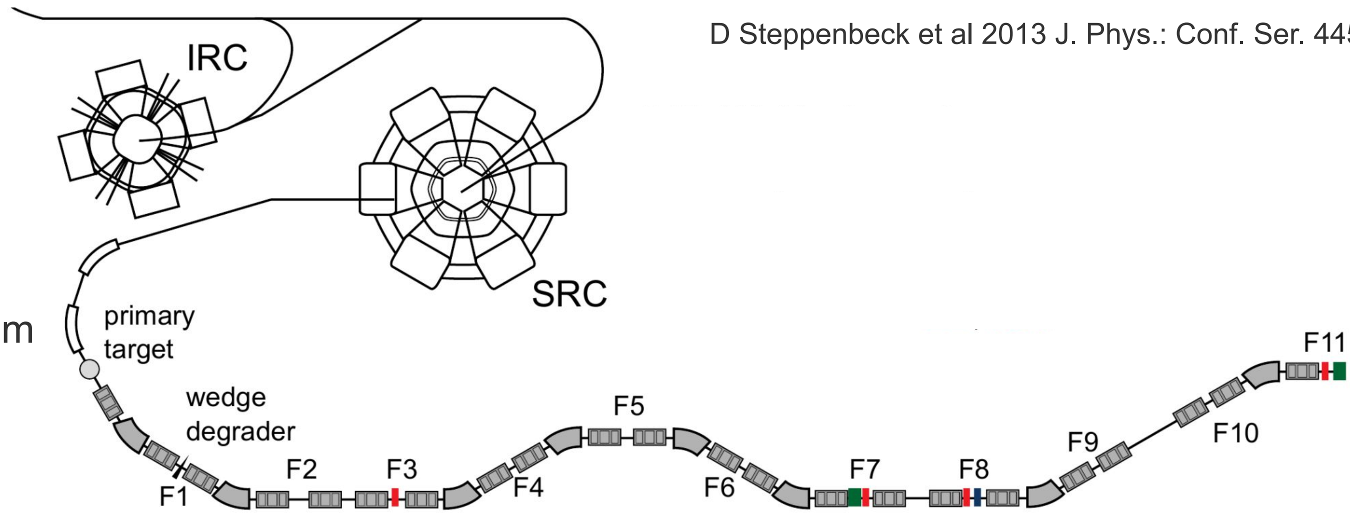
$$\frac{A}{Q} = \frac{B\rho}{\beta\gamma}\frac{c}{m_u},$$

$$\frac{dE}{dx} = \frac{4\pi e^4 Z^2}{m_e v^2} Nz \left[\ln\frac{2m_e v^2}{I} - \ln(1-\beta^2) - \beta^2\right]$$

BigRIPS & ZeroDegree

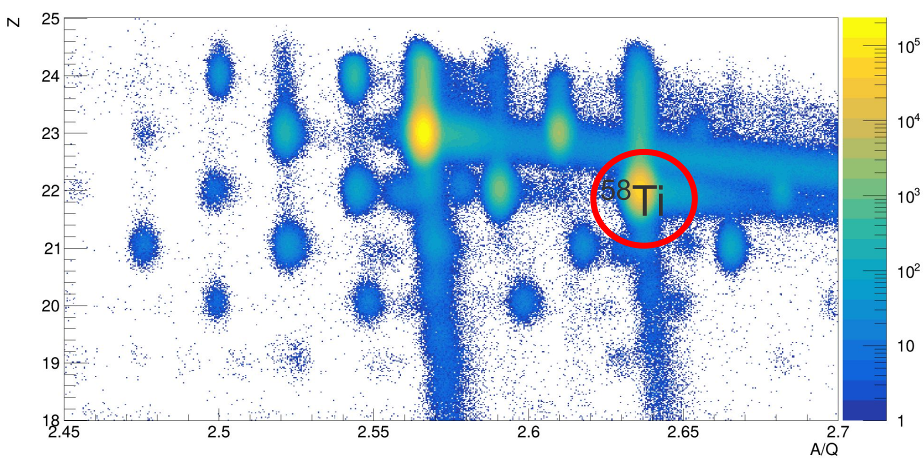
D Steppenbeck et al 2013 J. Phys.: Conf. Ser. 445 012012

^{70}Zn
345 AMeV
primary beam



BR

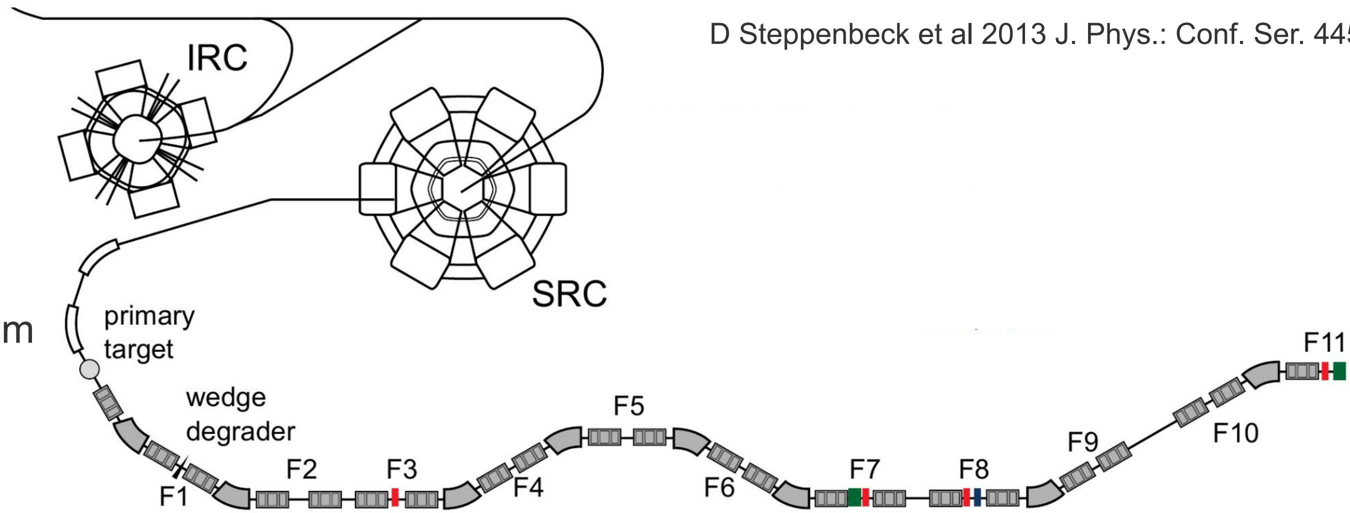
BigRIPS identification by:
ΔE, TOF, Bρ



BigRIPS & ZeroDegree

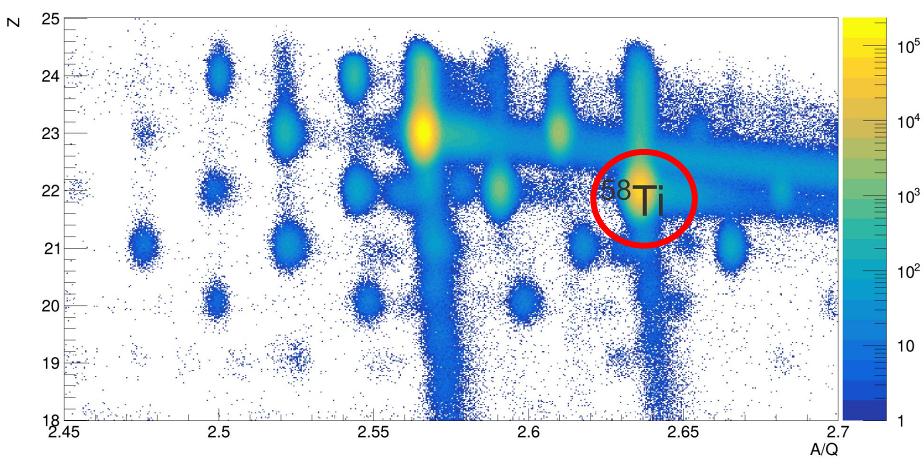
D Steppenbeck et al 2013 J. Phys.: Conf. Ser. 445 012012

^{70}Zn
345 AMeV
primary beam



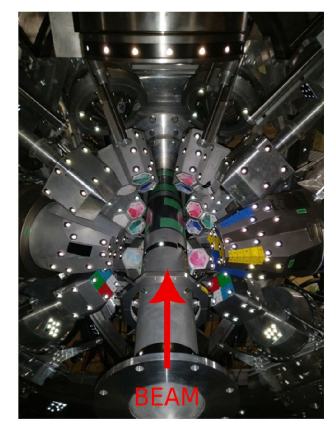
BR

BigRIPS identification by:
ΔE, TOF, Bρ



Secondary target
(Be or Au)
Nucleon
Knockout
Reactions,
Coulomb
Excitation

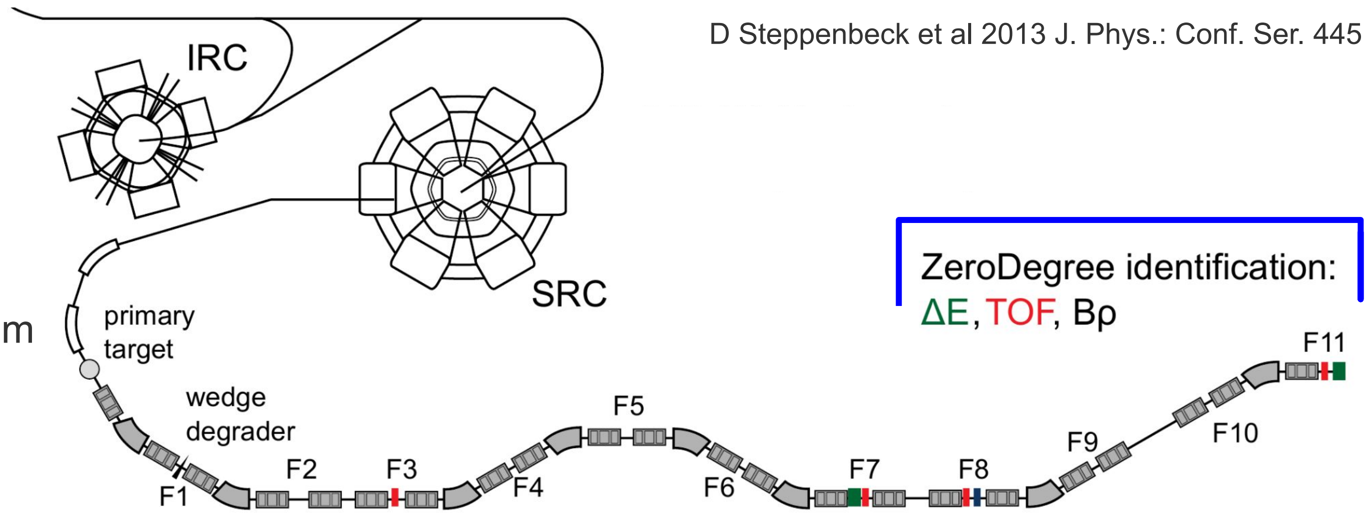
HPGe HiCARI
array for gamma
detection



BigRIPS & ZeroDegree

D Steppenbeck et al 2013 J. Phys.: Conf. Ser. 445 012012

^{70}Zn
345 AMeV
primary beam

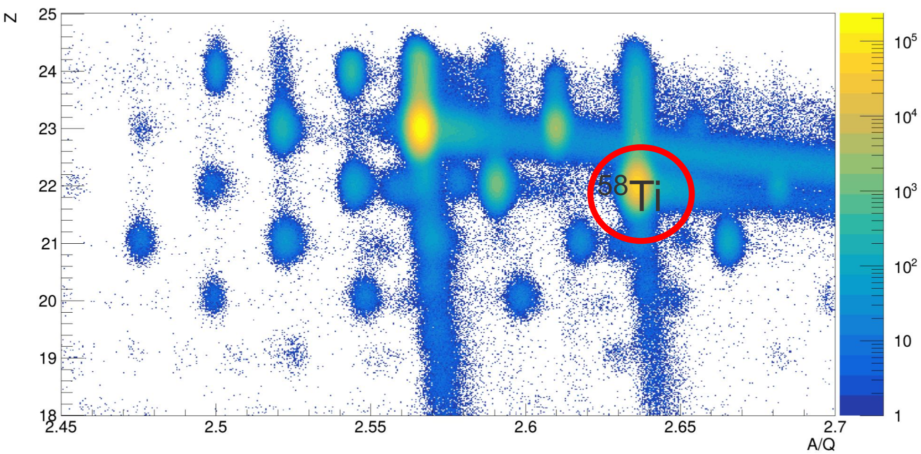


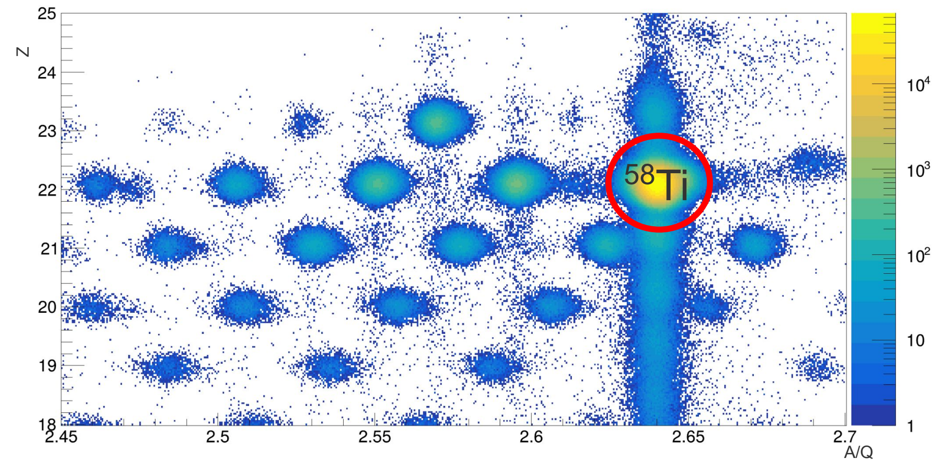
ZeroDegree identification:
ΔE, TOF, Bρ

ZD

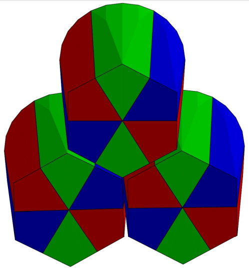
BR

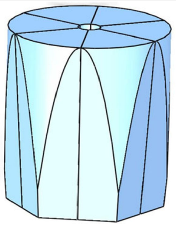
BigRIPS identification by:
ΔE, TOF, Bρ



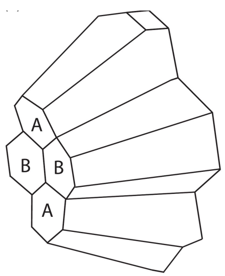


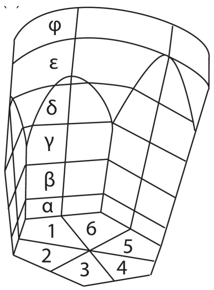
HiCARI @ F8 focal plane



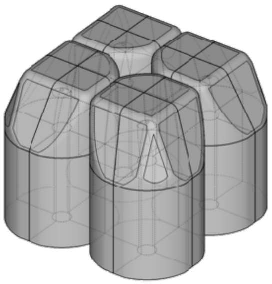


- 6 Miniball triple-cluster from Europe





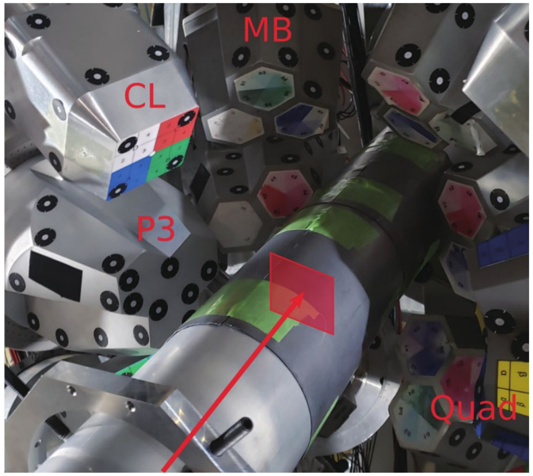
- RCNP quad (GRETA-type, Japan)
- LBNL triple (GRETA-type, USA)



- 4 Super-Clovers from IBS (Korea)
- 4 Clovers from IMP Lanzhou (China)

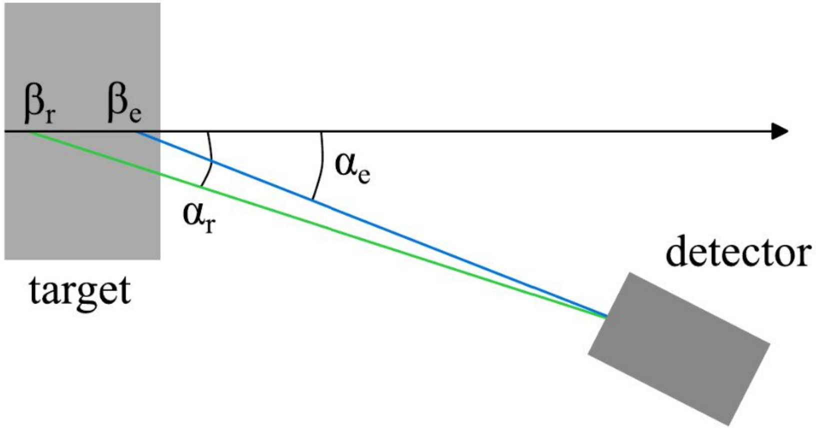
- GRETA-type electronics and DAQ (RCNP, ANL, LBNL, U Tokyo)

funding: JSPS KAKENHI Grant No.
19H00679, RIKEN, RCNP

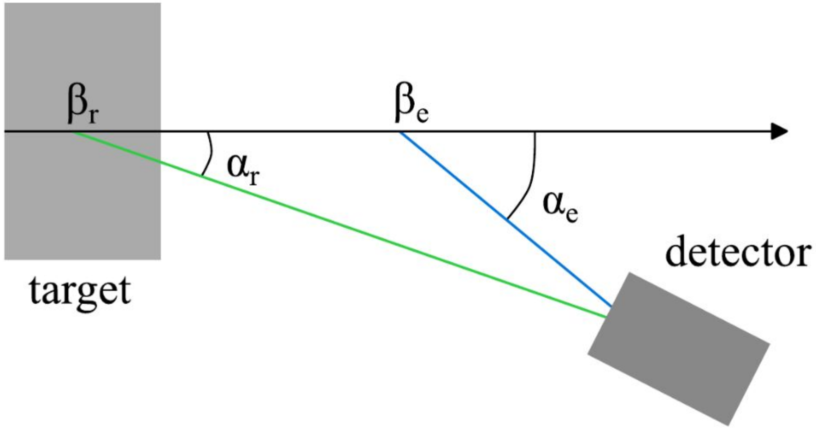


K.Wimmer, et. al., RIKEN Accel. Prog. Rep. 54 (2021)

P. Doornenbal et al., Nucl. Instrum. Meth. A 613, 218 (2010)

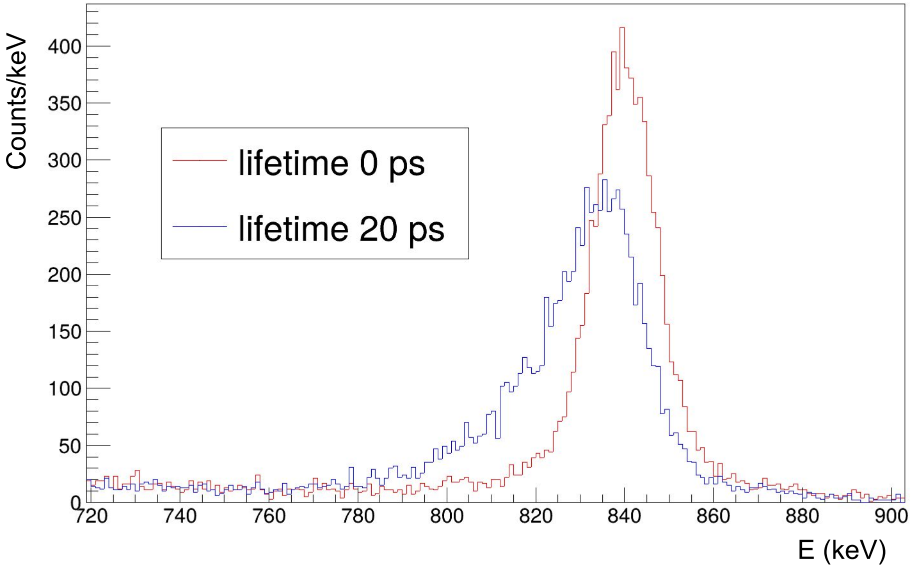


M.A. Bentley, G. Benzoni, K. Wimmer Eur. Phys. J. A (2023) 59:172

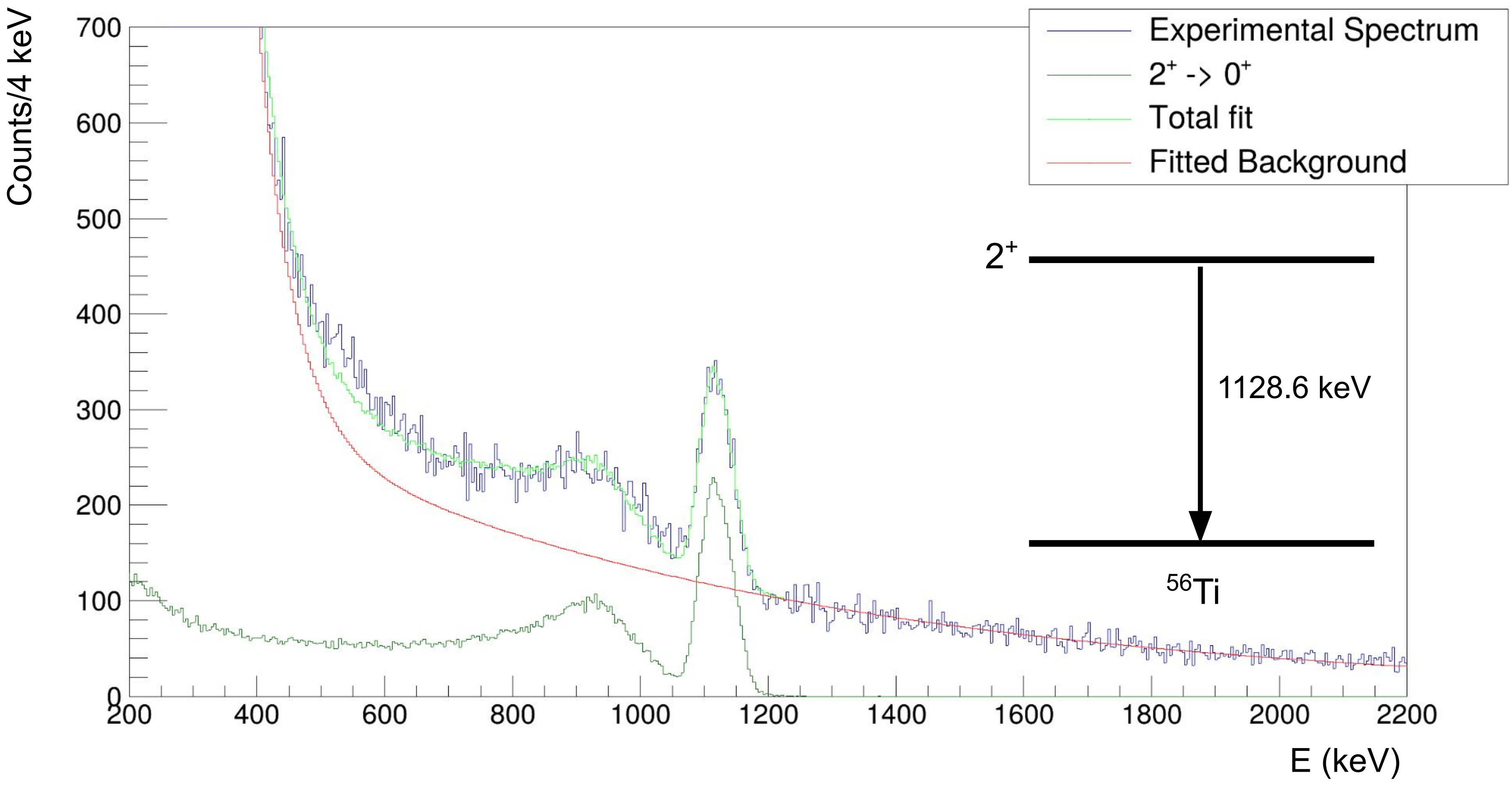


- Lifetime measurements based on the in-flight Doppler shift lineshape analysis

$$E_{lab} = E_0 \cdot \frac{\sqrt{1-\beta^2}}{1-\beta cos\alpha}$$



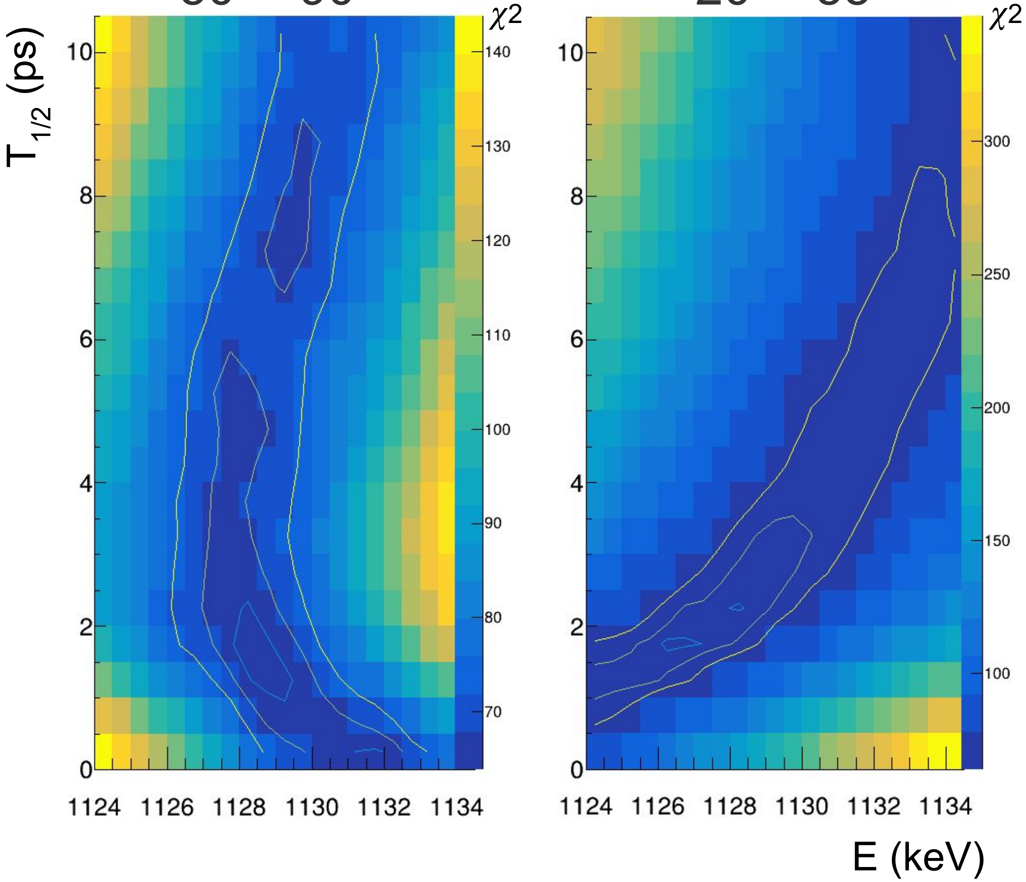
Results ^{56}Ti coulex on gold



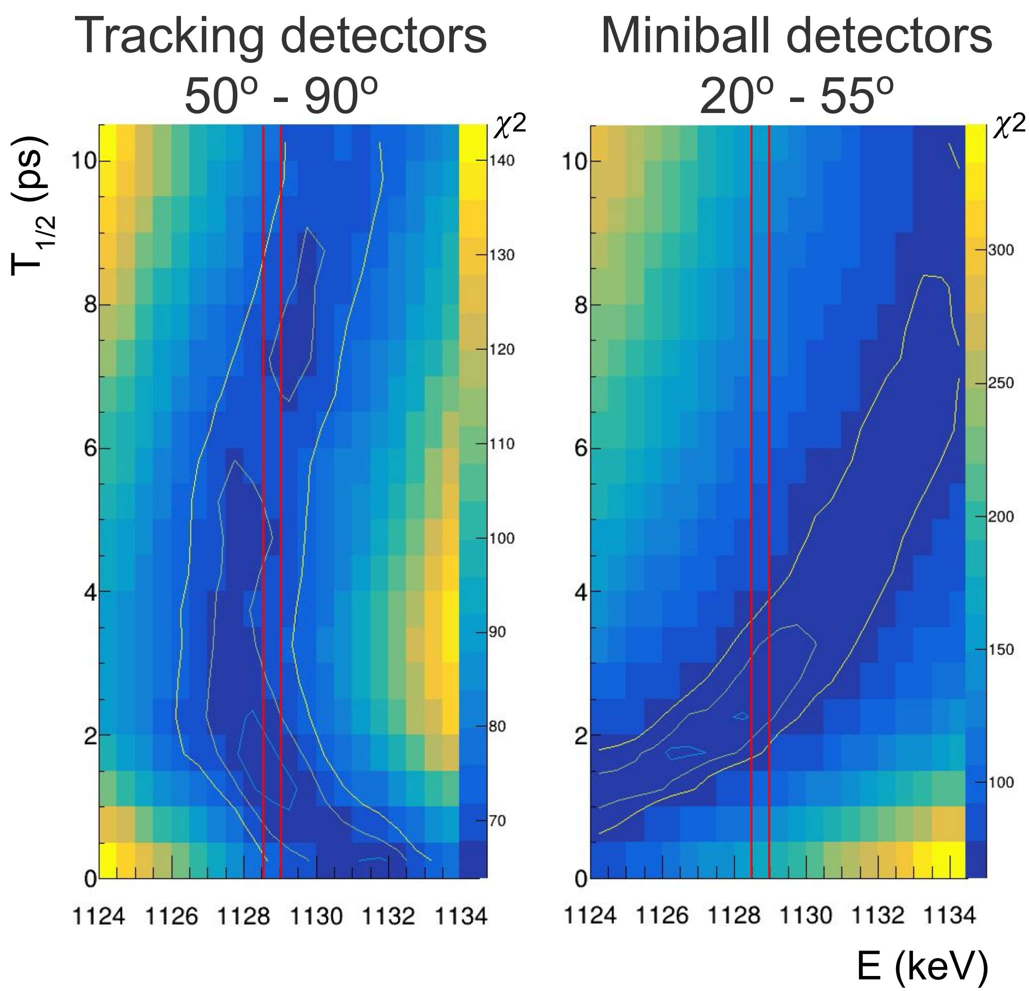
Results ^{56}Ti coulex on gold

Tracking detectors
$50^o - 90^o$

Miniball detectors
$20^o - 55^o$

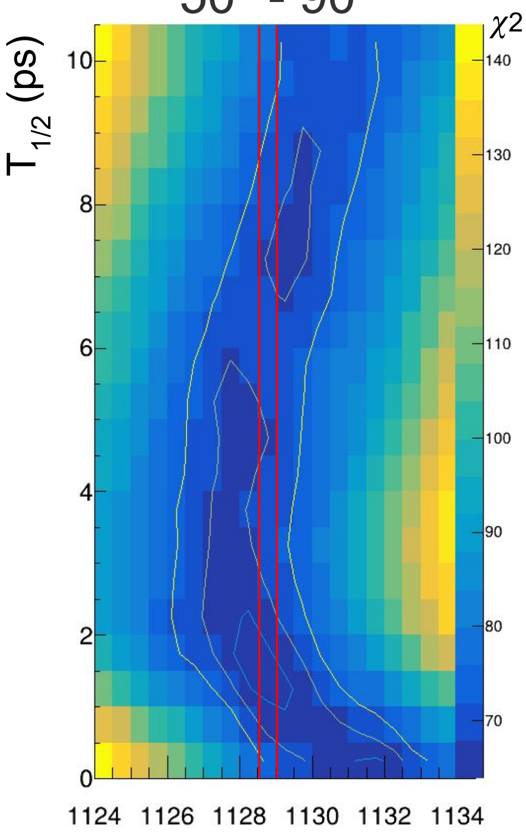


Results ^{56}Ti coulex on gold

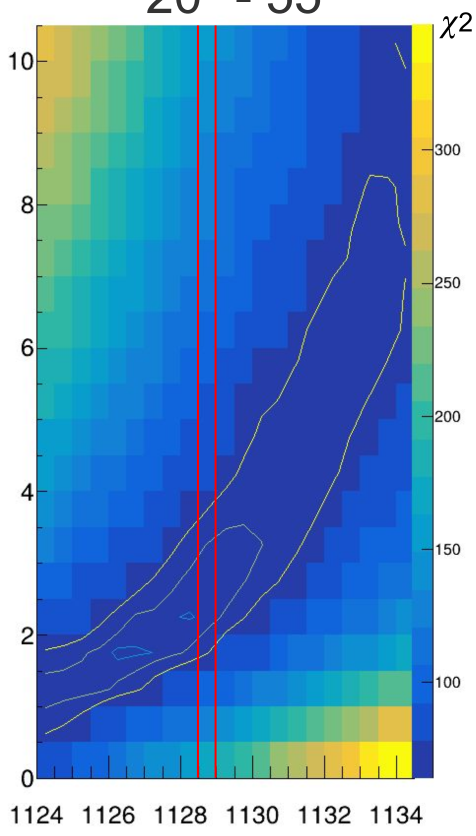


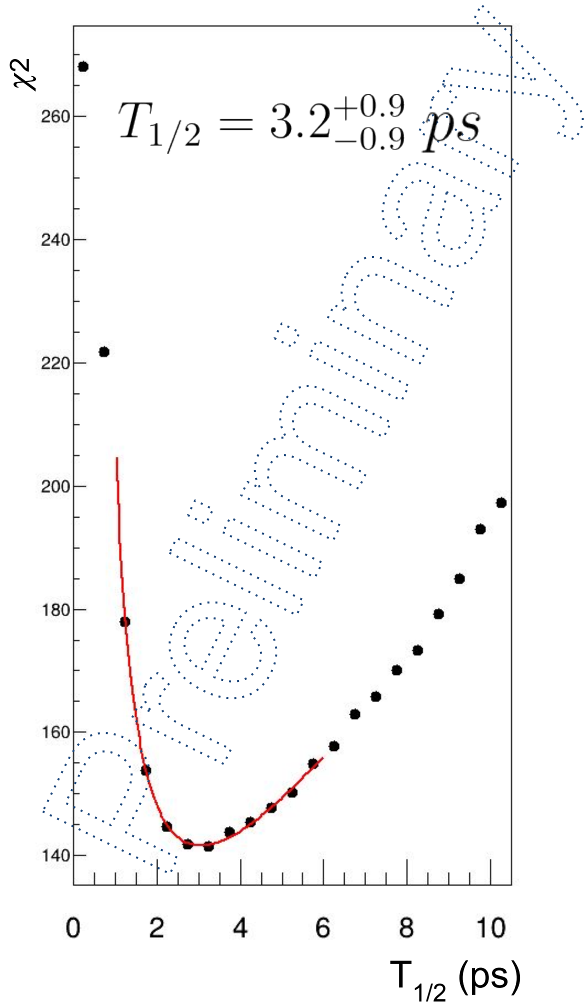
Results ^{56}Ti coulex on gold

Tracking detectors
50° - 90°

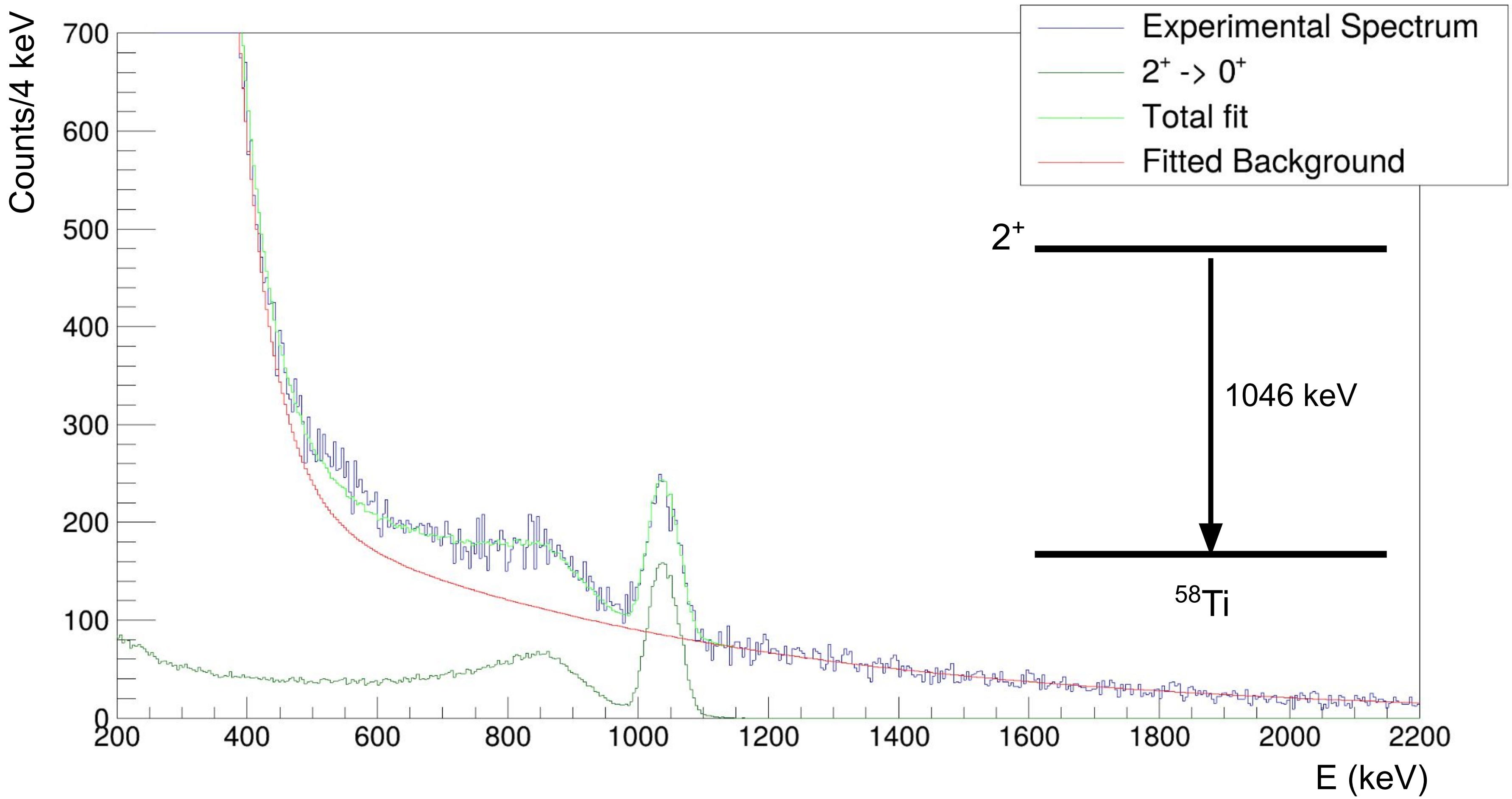


Miniball detectors
20° - 55°



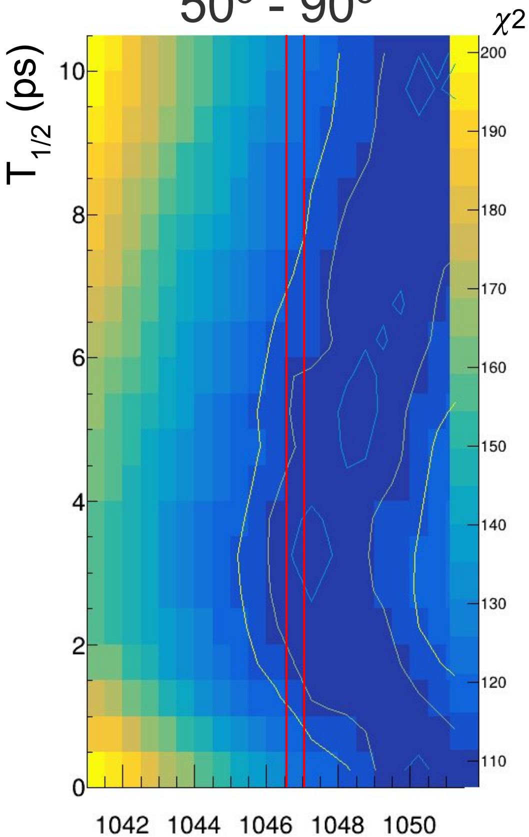


Results ^{58}Ti coulex on gold

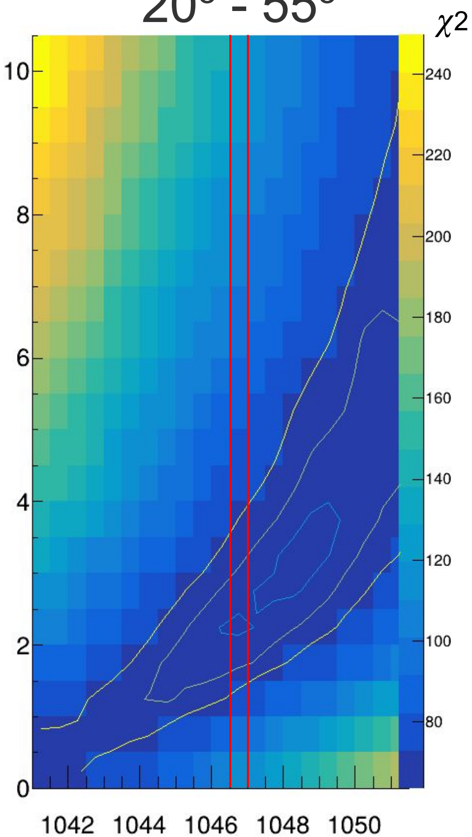


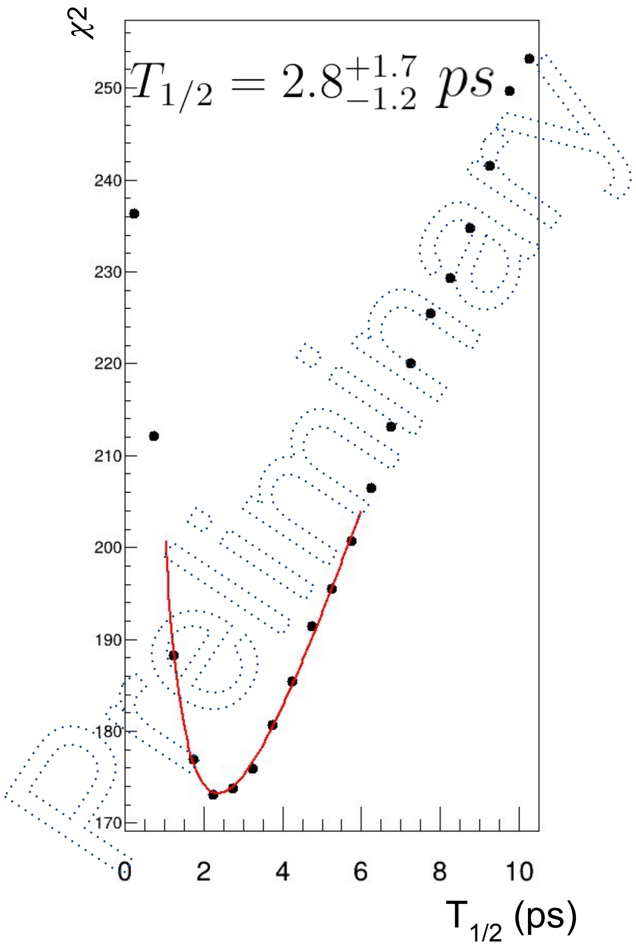
Results ^{58}Ti coulex on gold

Tracking detectors
50º - 90º

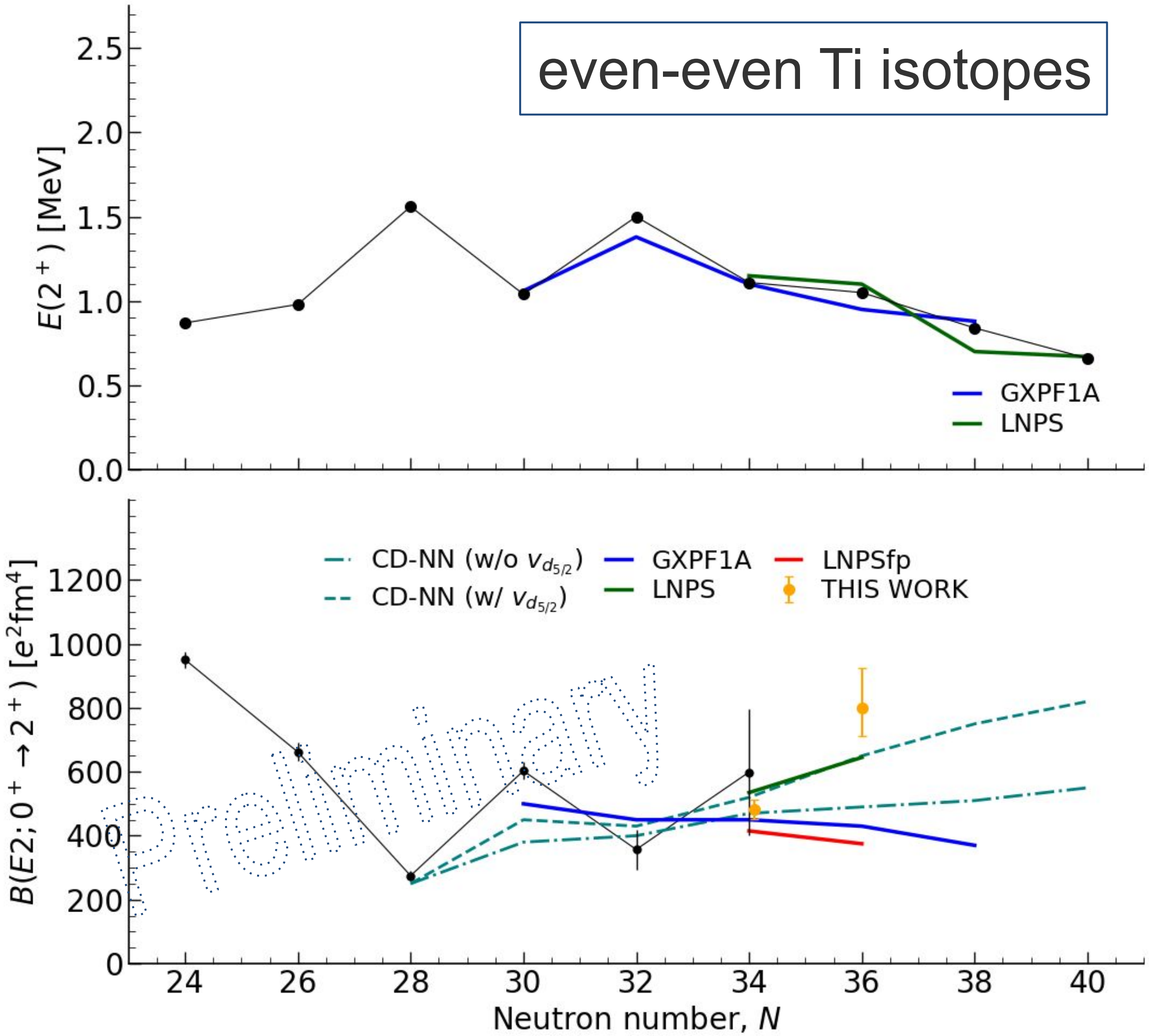


Miniball detectors
20º - 55º





Conclusions



Summary and outlook

- The experiment was conducted at RIBF, the Coulomb excitation channel was studied
- Lifetimes of the first 2^+ states were measured for ^{56}Ti and ^{58}Ti
- The extracted high B(E2) value for the ^{58}Ti nucleus suggests increased collectivity
- Next steps include extracting the B(E2) from the coulomb excitation cross sections

Acknowledgements

HiCARI & Miniball collaborations

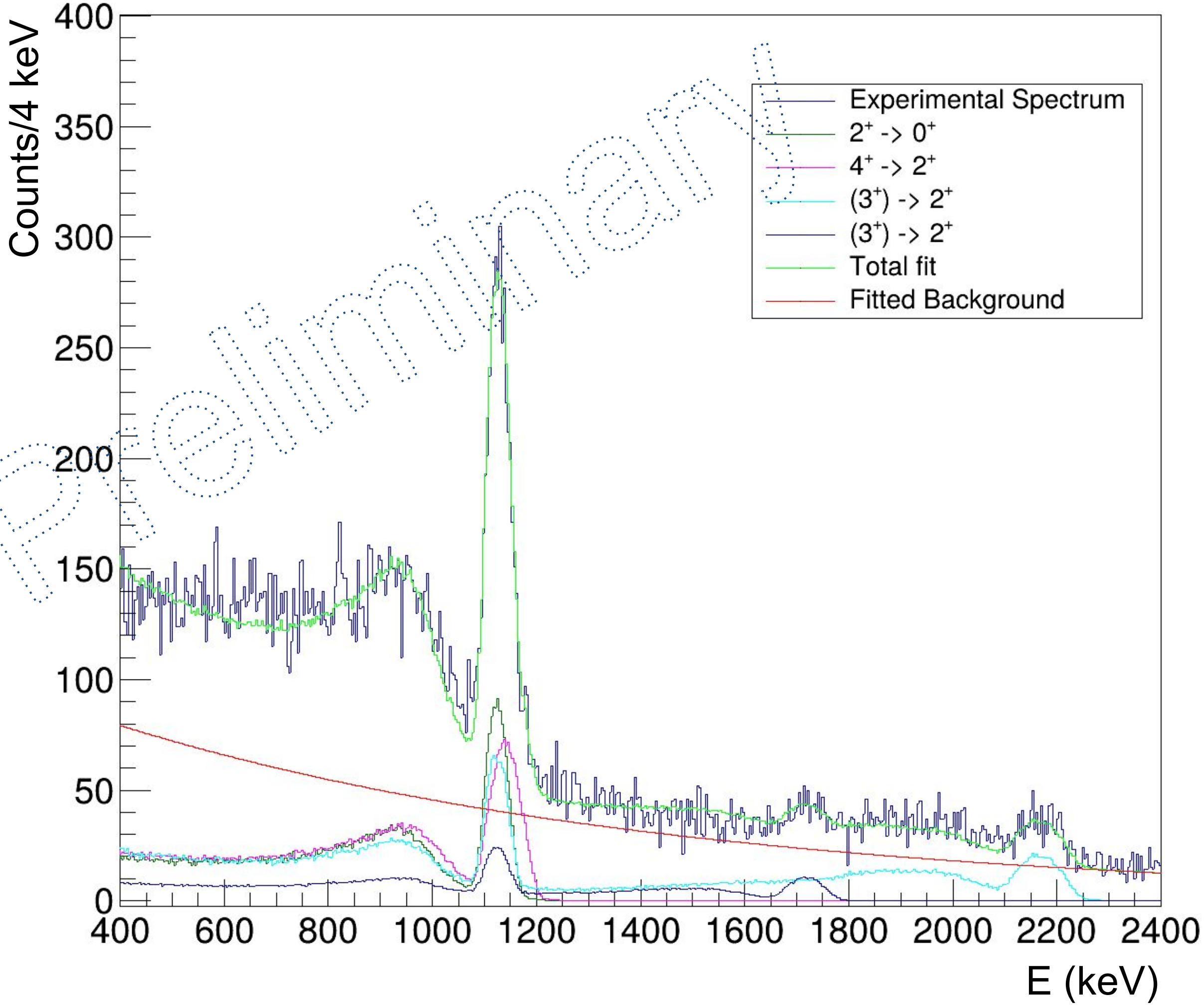
K. Wimmer, M. Reece, M. Mikołajczuk, J. Kim,
M. Armstrong, N. Aoi, H. Baba, F. Browne, C. Campbell,
Z. Chen, H. Crawford, H. de Witte, P.Doornenbal,
C. Fransen, H. Hess, S. Iwazaki, A. Kohda, T. Koiwai,
B. Mauss, B. Moon, P. Reiter, D. Suzuki, N. Warr,
Y. Yamamoto

Thank you for your attention!

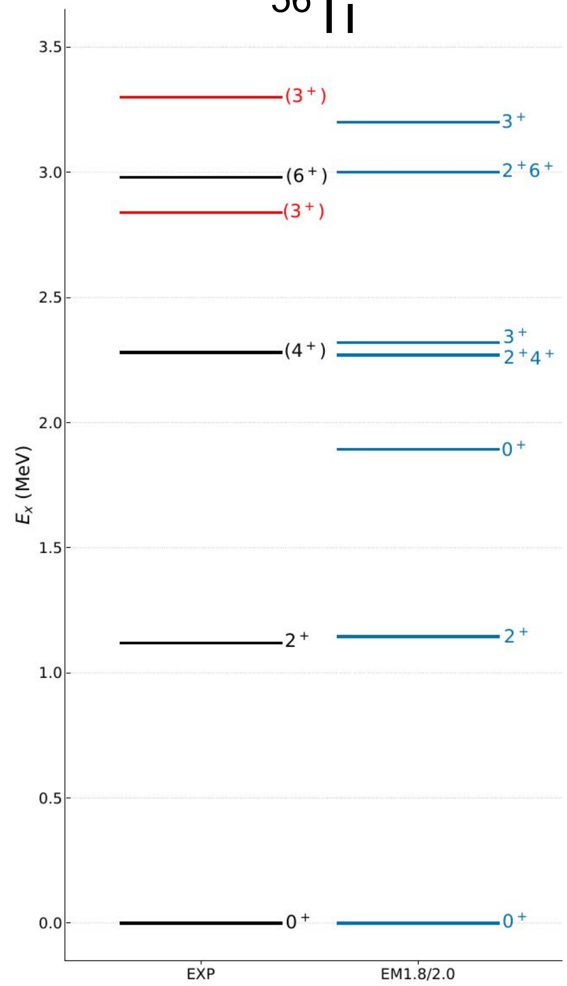
Backup slides

Outlook: Be target data and Coulomb deformation length extraction

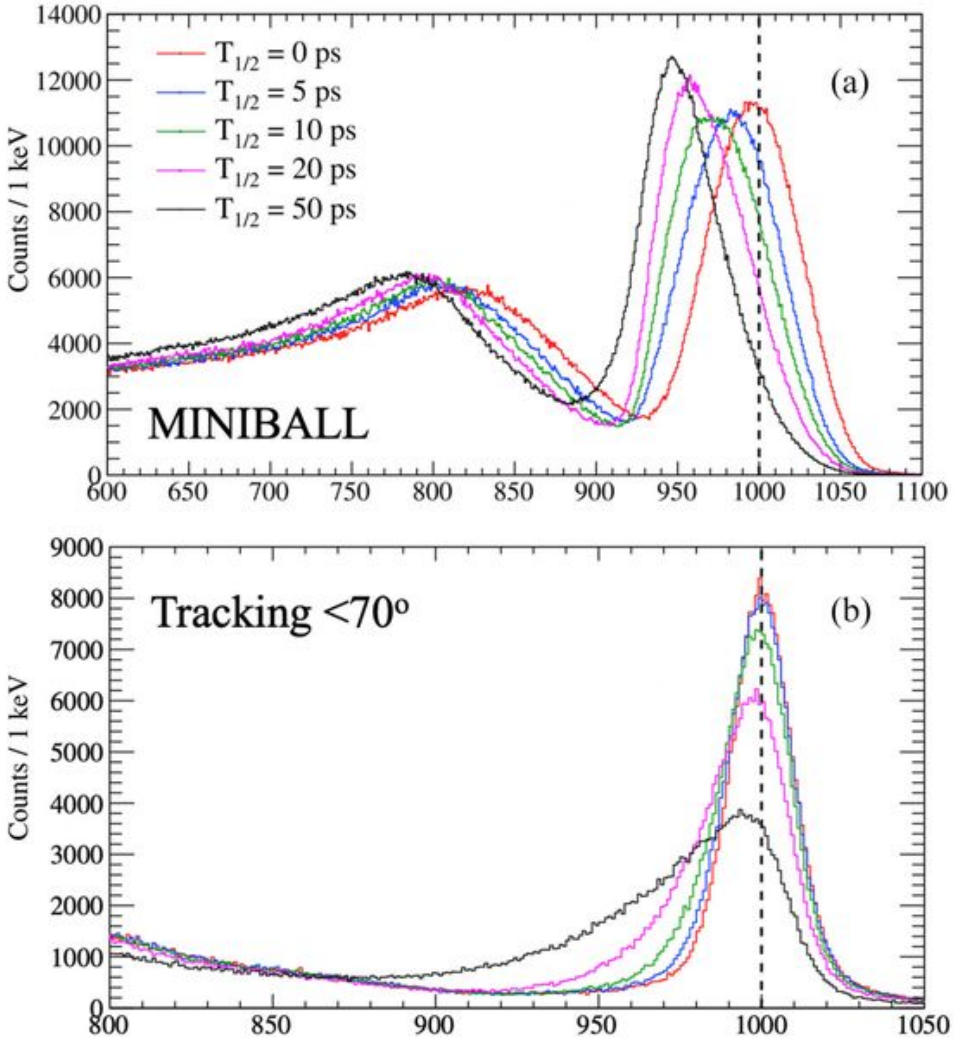
^{56}Ti inelastic scattering on beryllium



^{56}Ti

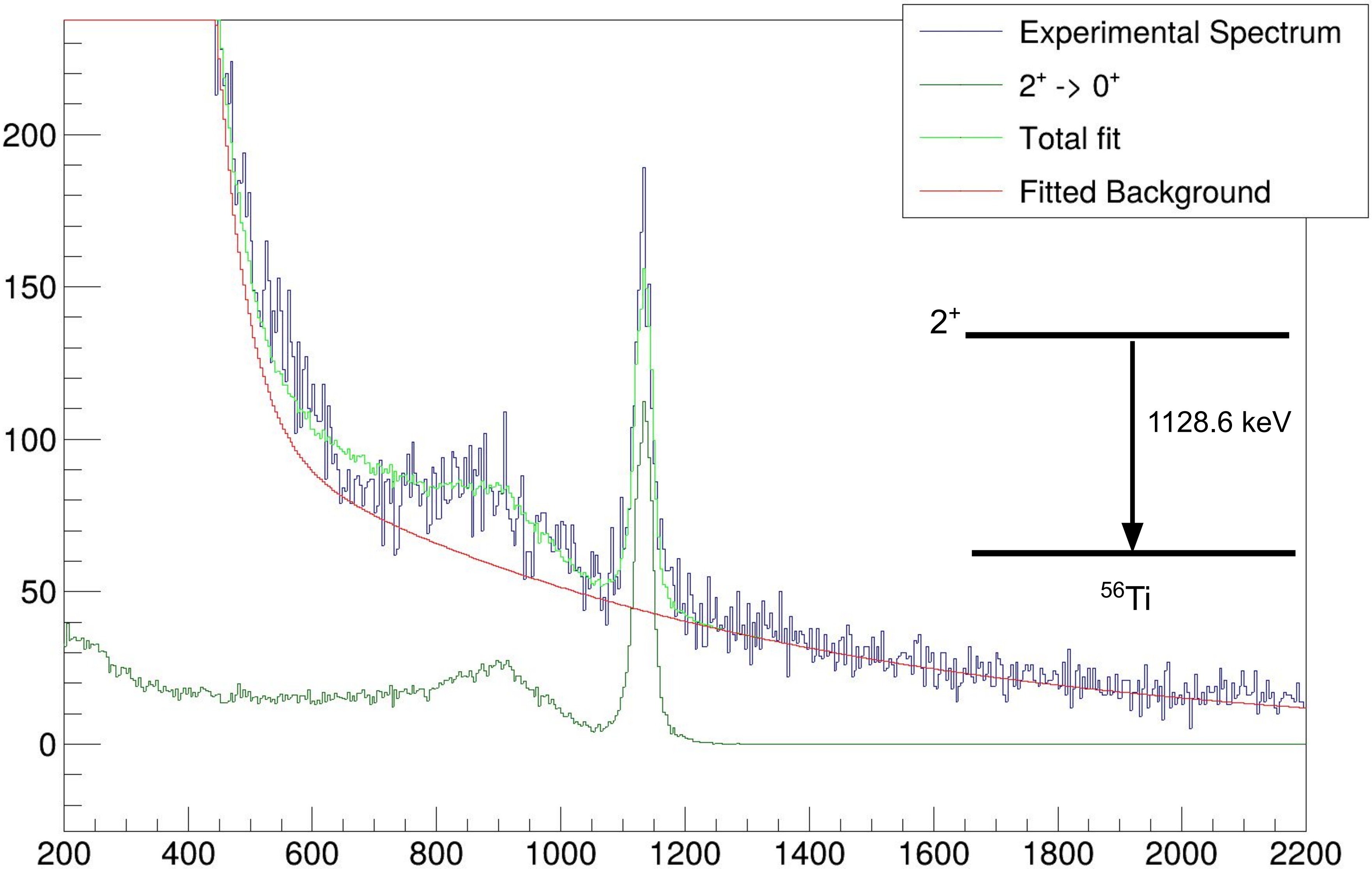


Lineshape for different detector groups

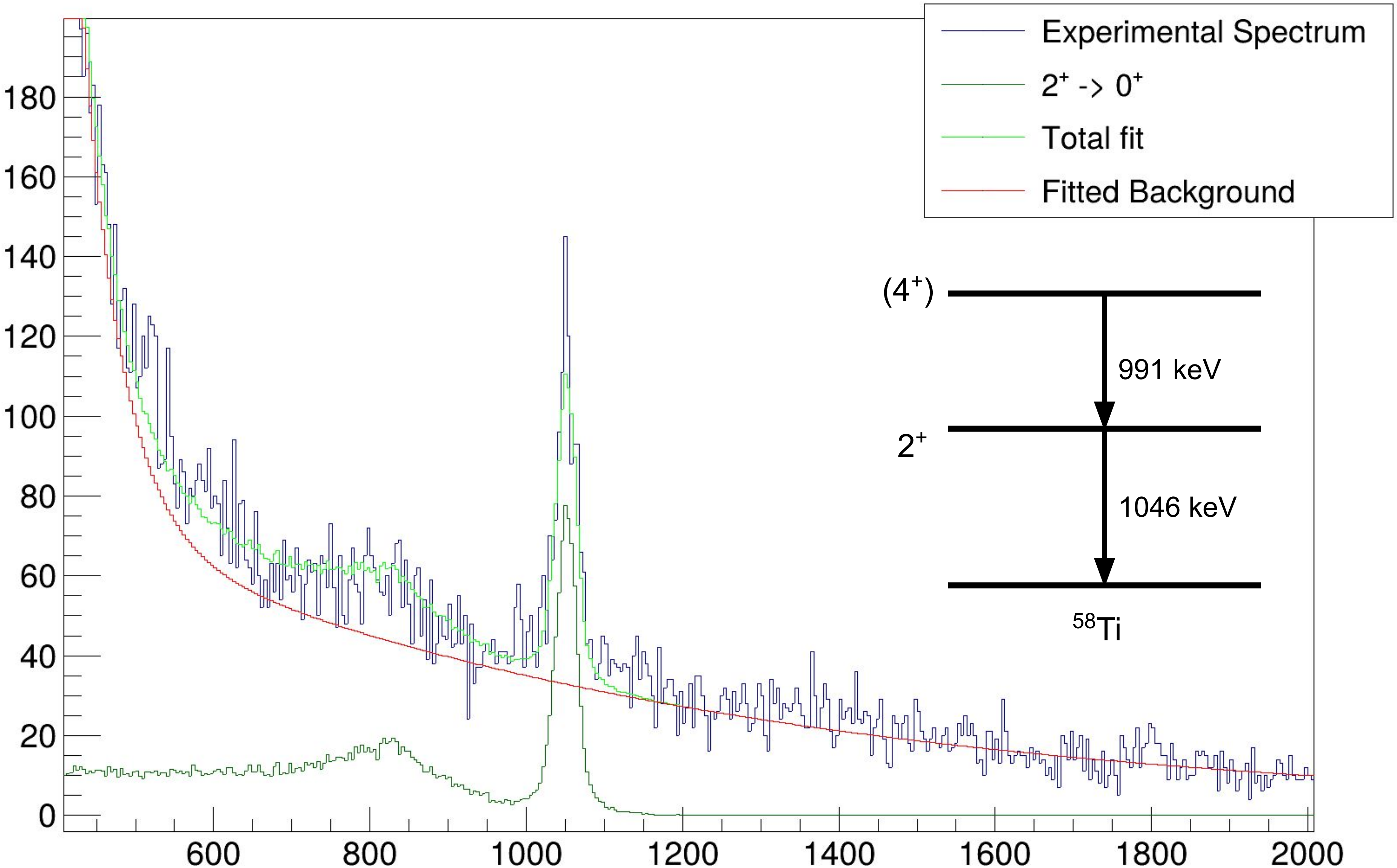


J.Acosta et.al., PHYSICAL REVIEW C 111, 064316 (2025)

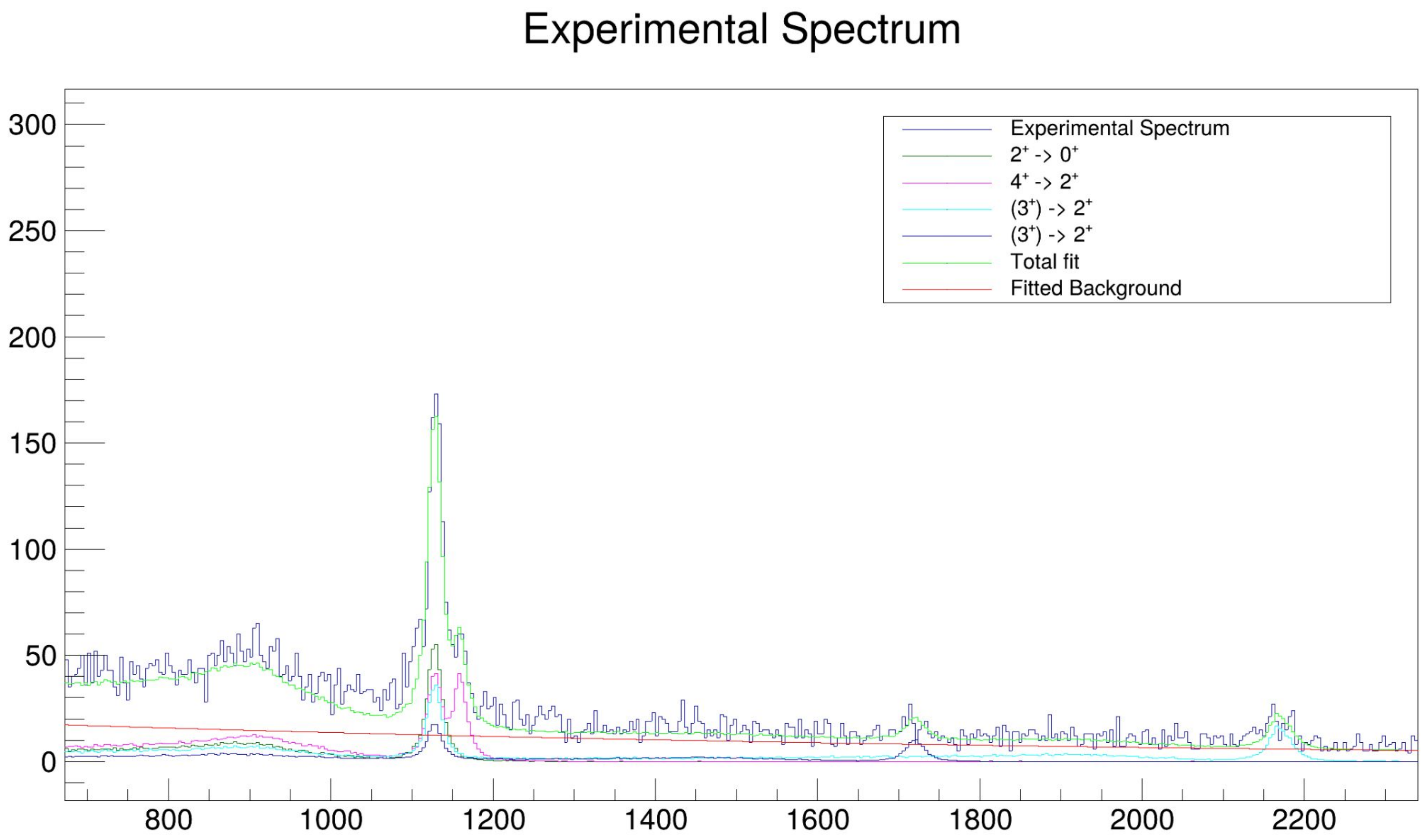
Tracking 56Ti



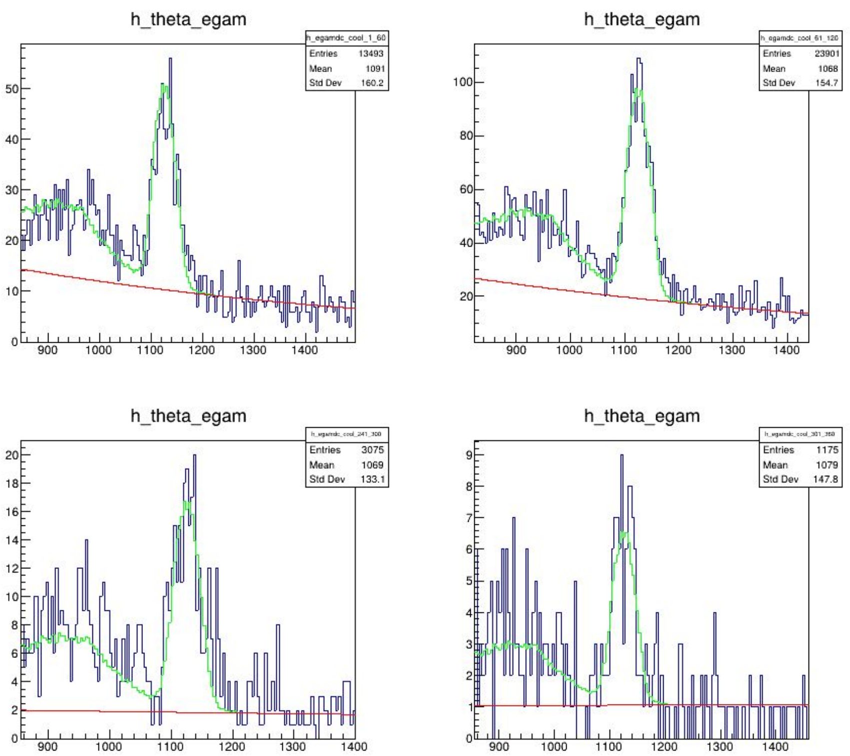
Tracking 58Ti



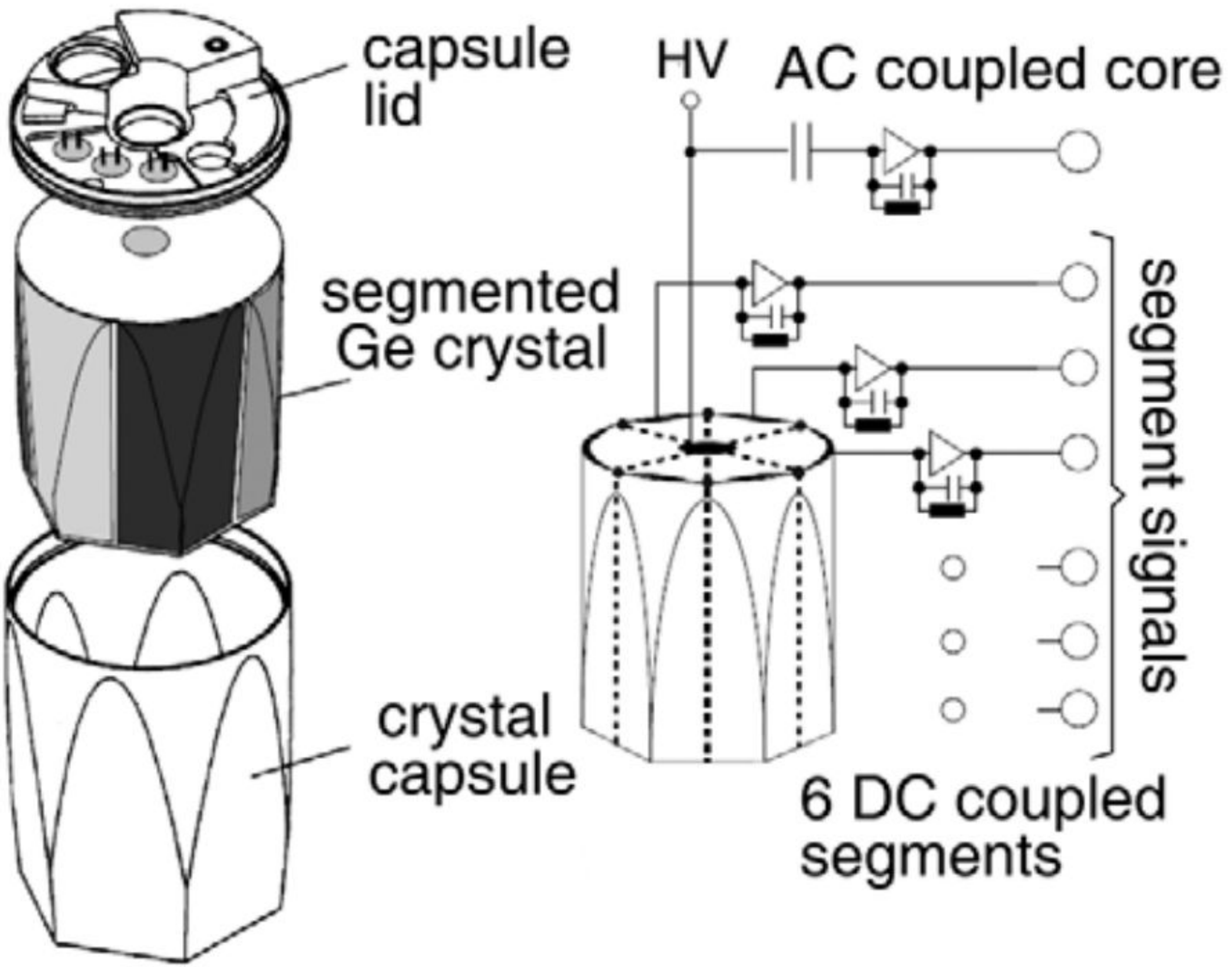
56Be coulex


Experimental Spectrum
300
250
200
150
100
50
0
800
1000
1200
1400
1600
1800
2000
2200
Experimental Spectrum
2+ -> 0+
4+ -> 2+
(3+) -> 2+
(3+) -> 2+
Total fit
Fitted Background

Angle group fits



Miniball



capsule lid
segmented Ge crystal
crystal capsule
HV
AC coupled core
segment signals
6 DC coupled segments

Gretina

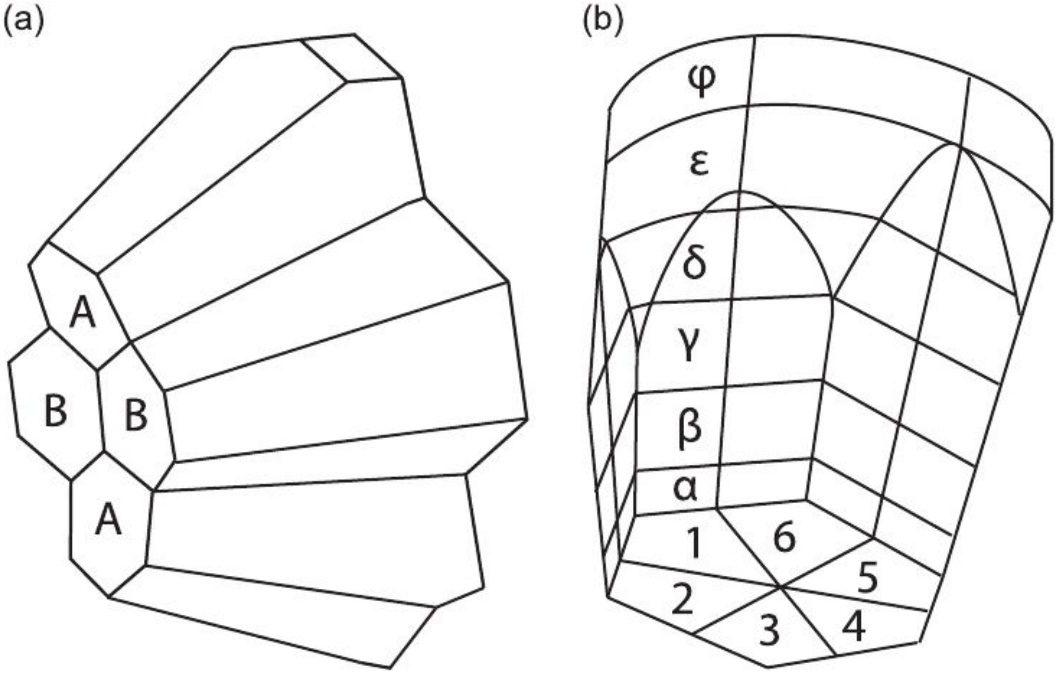
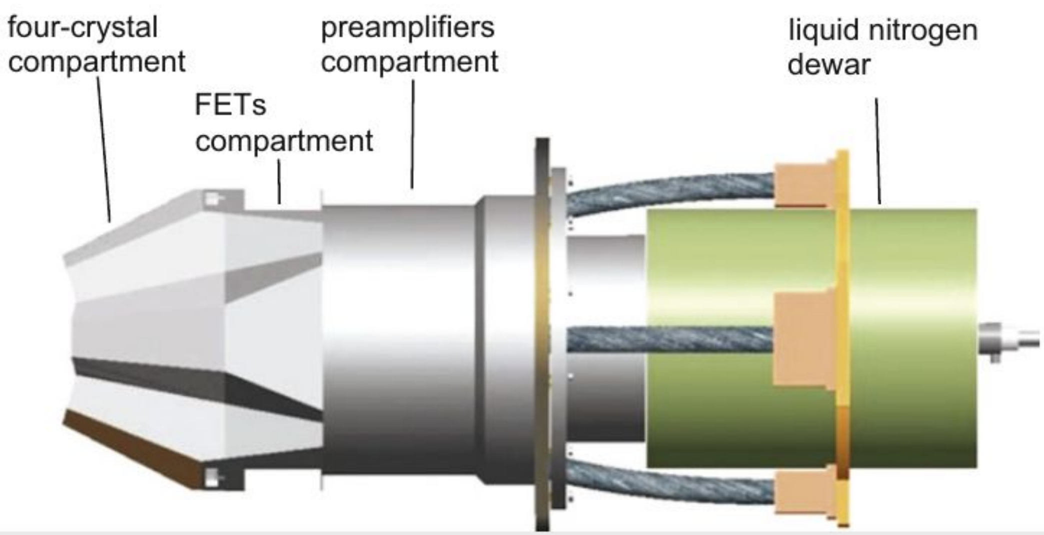
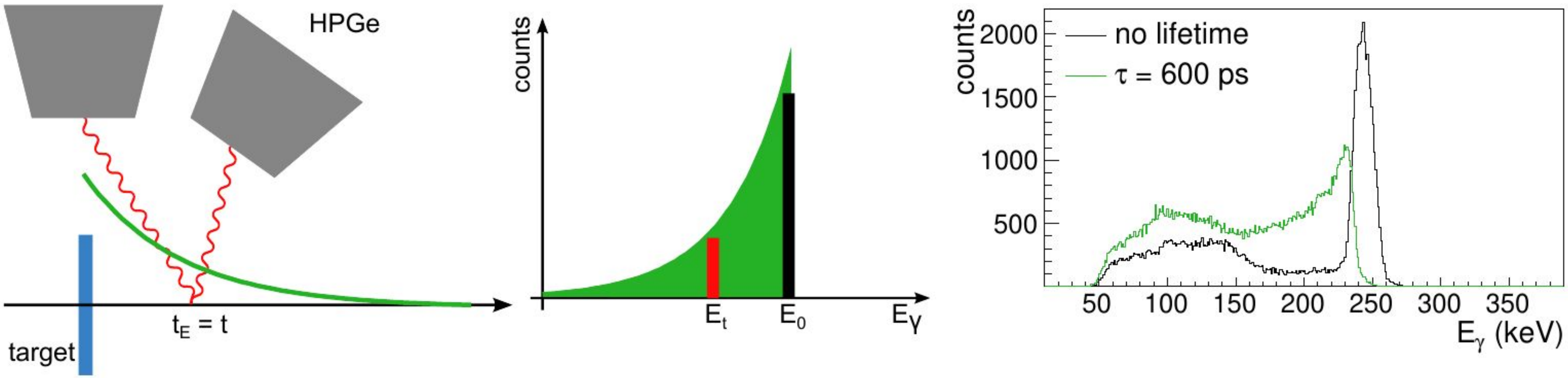


Fig. 3. Schematic drawing of (a) four crystals packed in one module, two A-type crystals and two B-type crystals and (b) an individual crystal showing the electrical segmentation of its outer contact.



Lineshape analysis



K.Wimmer, private communications

PID Analysis

First steps of the Particle Identification (PID) :

- Background cuts :
  - Remove the pile up events in the MUSIC detectors
  - Cuts on the PPAC Tsum signal
  - Plastic detector cuts - they should follow the relation

$$T_R - T_L = A log\frac{q_L}{q_R}$$

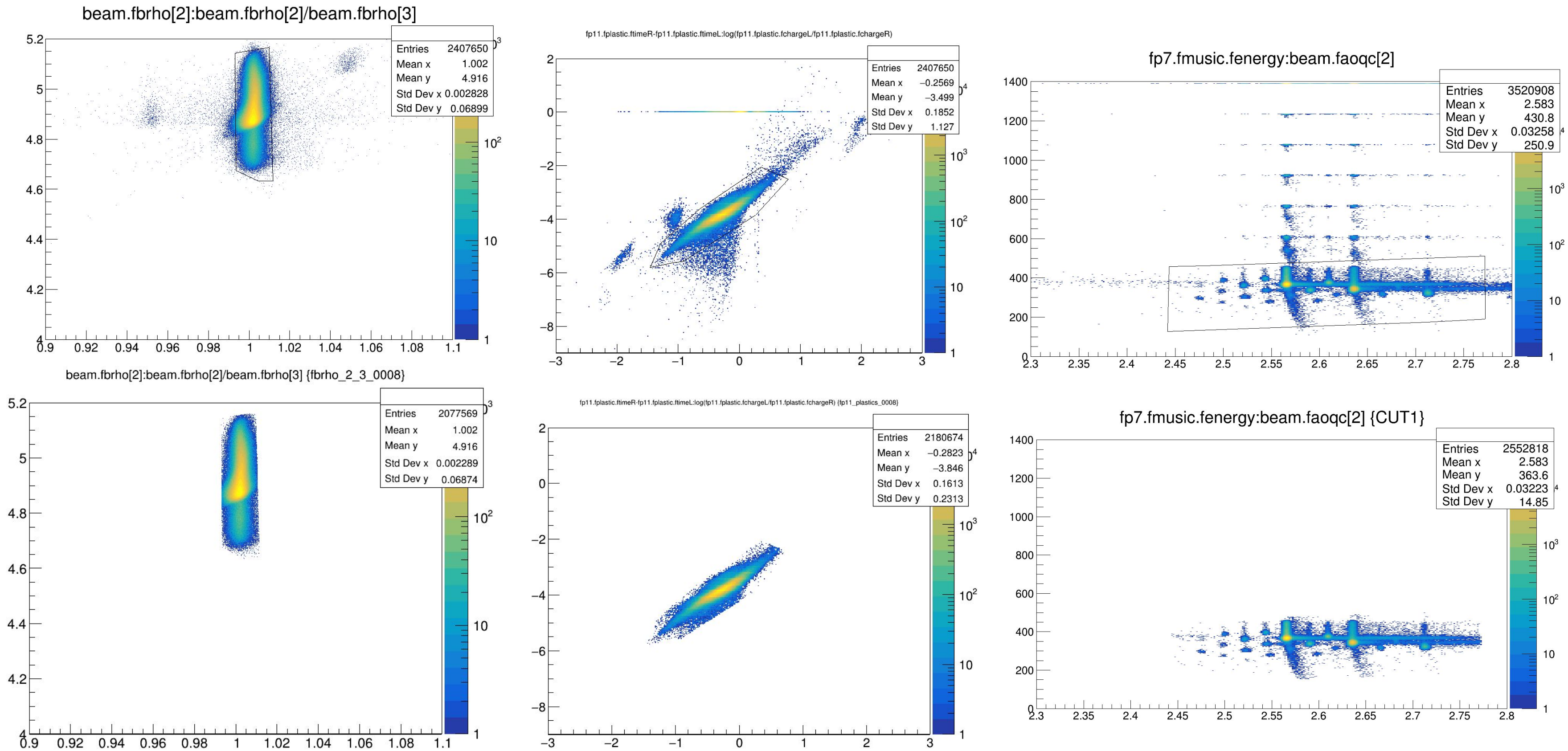
  - Remove the changing charge states by looking at the Bρ ratio between different parts of BigRIPS and ZeroDegree

- Corrections (TOF, A/Q)

PID Analysis

First steps of the Particle Identification (PID) :

- Background cuts (charge states, correlations in plastic detectors, pile up events in MUSIC detectors)
- Corrections (TOF, A/Q)



Plastic vs MUSIC