Lifetime measurement of the first 2^+ state in ^{112}Te

M. Doncel[(1)], T. Back[(1)], B. Cederwall [(1)],
D. Hodge[(2)], D. Cullen[(2)] *et al*
(1)The Royal Institute of Technology (KTH), Sweden
(2)Schuster Laboratory, University of Manchester, United Kingdom

Contents

ROYAL INSTITUTE OF TECHNOLOGY

Lifetime measurement in neutron-deficient Te isotopes

- ***Motivation, why Te isotopes?***
- ***Experimental details***
- ***The Recoil Distance Doppler Shift method (RDDS)***
- ***Data analysis***
- ***Experimental results***
- ***Conclusions***

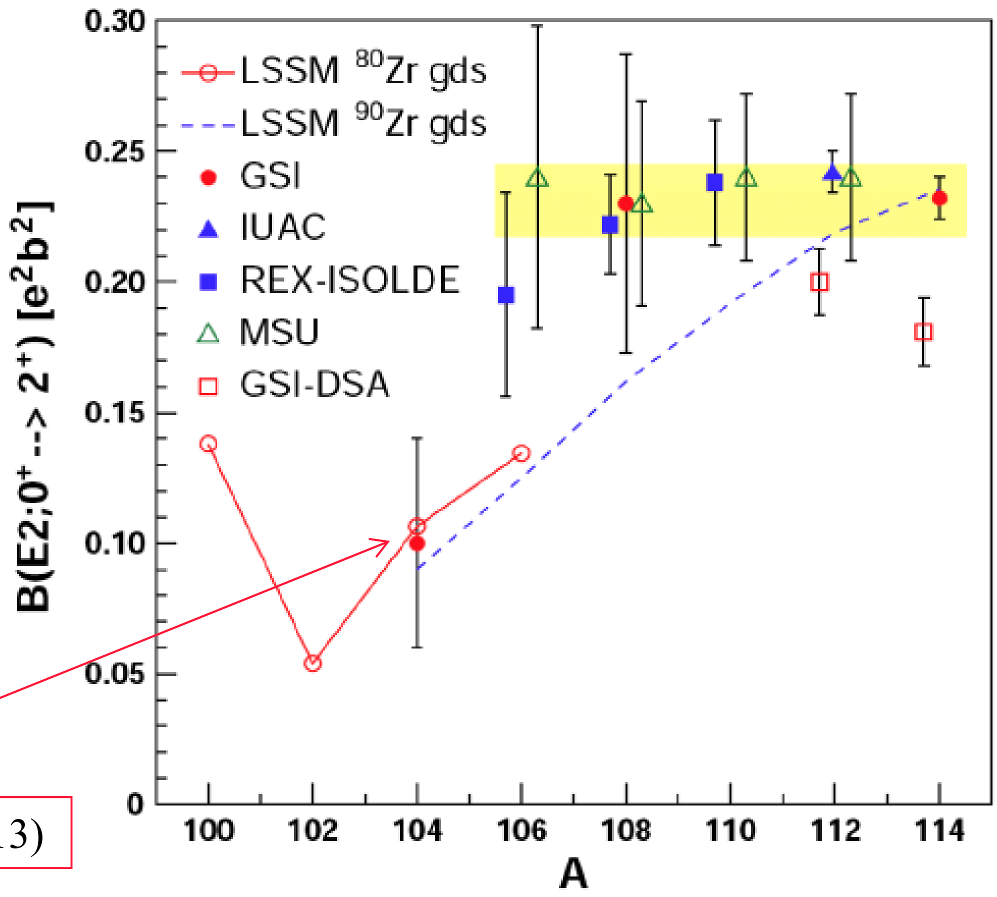
Why Te isotopes?

ROYAL INSTITUTE OF TECHNOLOGY

Evolution of the collectivity for nuclei approaching N=Z

Shell gap weakening??

Evolution of the collectivity in light Sn isotopes



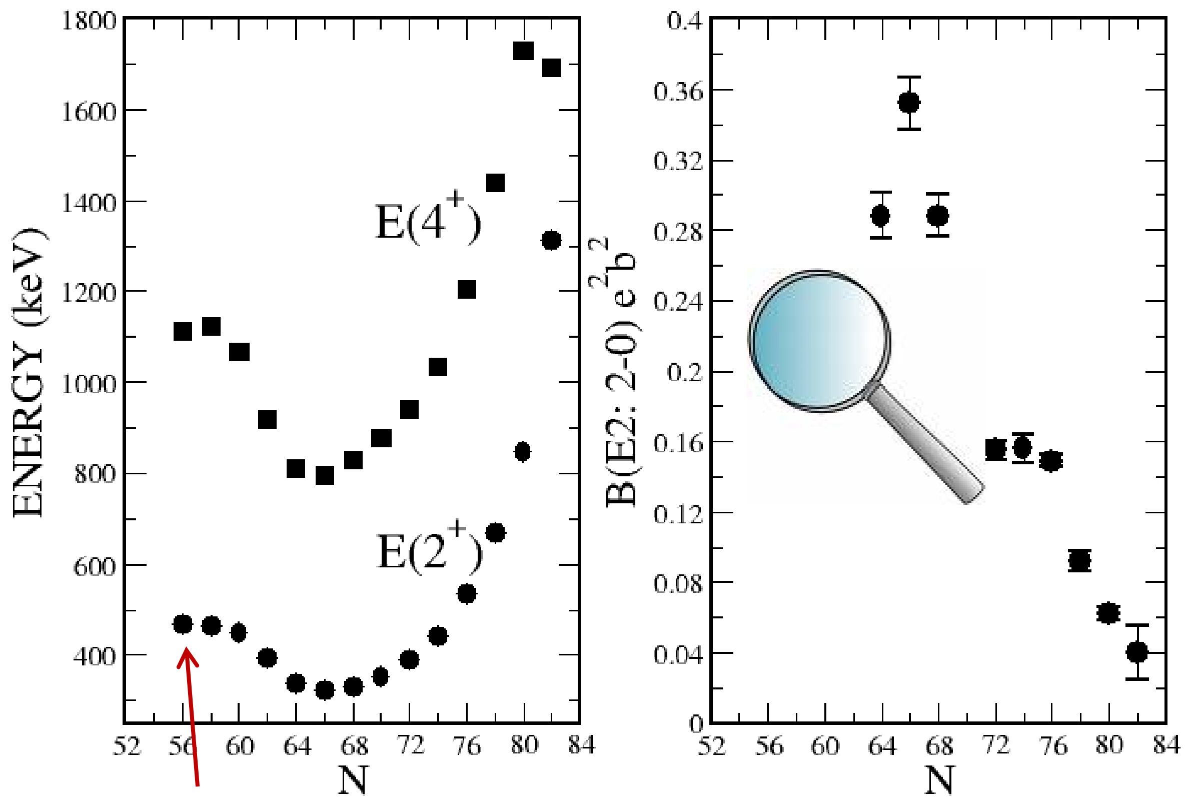
^{104}Sn, PRESPEC, Guastalla et al., PRL 110, (2013)

Why Te isotopes?

ROYAL INSTITUTE OF TECHNOLOGY

Evidence for enhanced collective strength in Te and Xe nuclei approaching N=Z

Xe experimental $E(2^+)$ and $B(E2; 2^+ \rightarrow 0^+)$ systematics



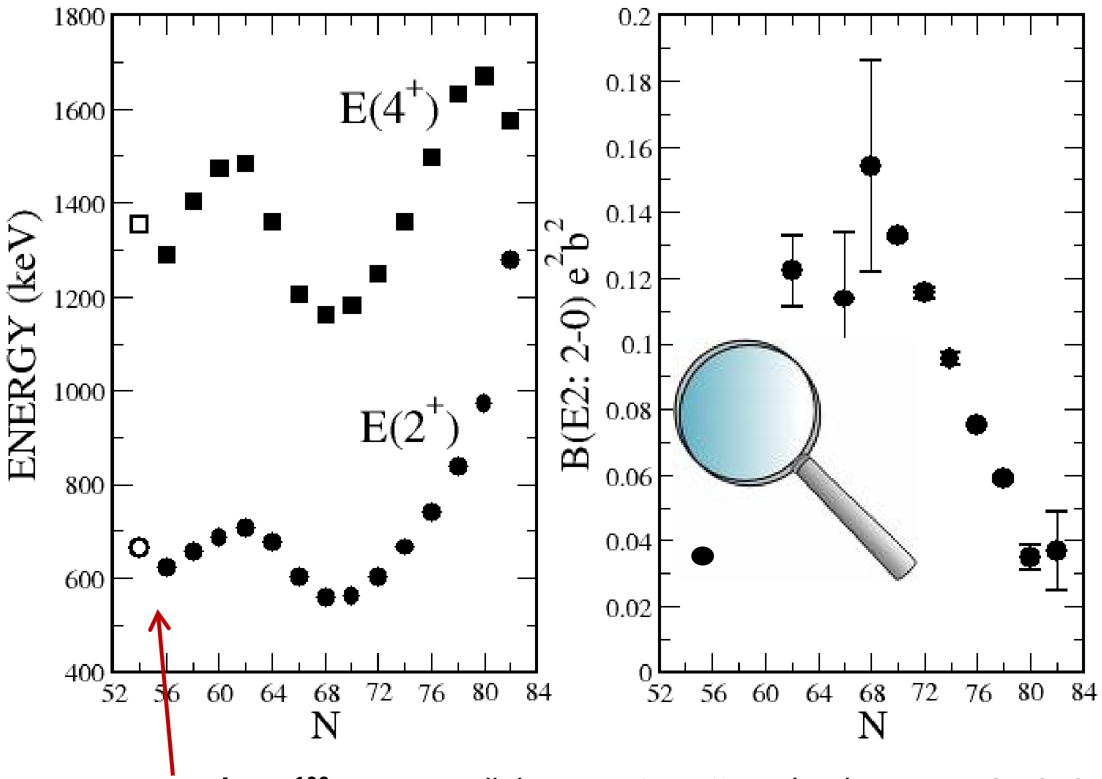
T_Z=1 nucleus ^{110}Xe; M. Sandzelius, B. Hadinia,, B. Cederwall *et al.*, Phys. Rev. Lett. 99, 022501 (2007)

Why Te isotopes?

ROYAL INSTITUTE OF TECHNOLOGY

Evidence for enhanced collective strength in Te and Xe nuclei approaching N=Z

Te experimental $E(2^+)$ and $B(E2; 2^+ \rightarrow 0^+)$ systematics



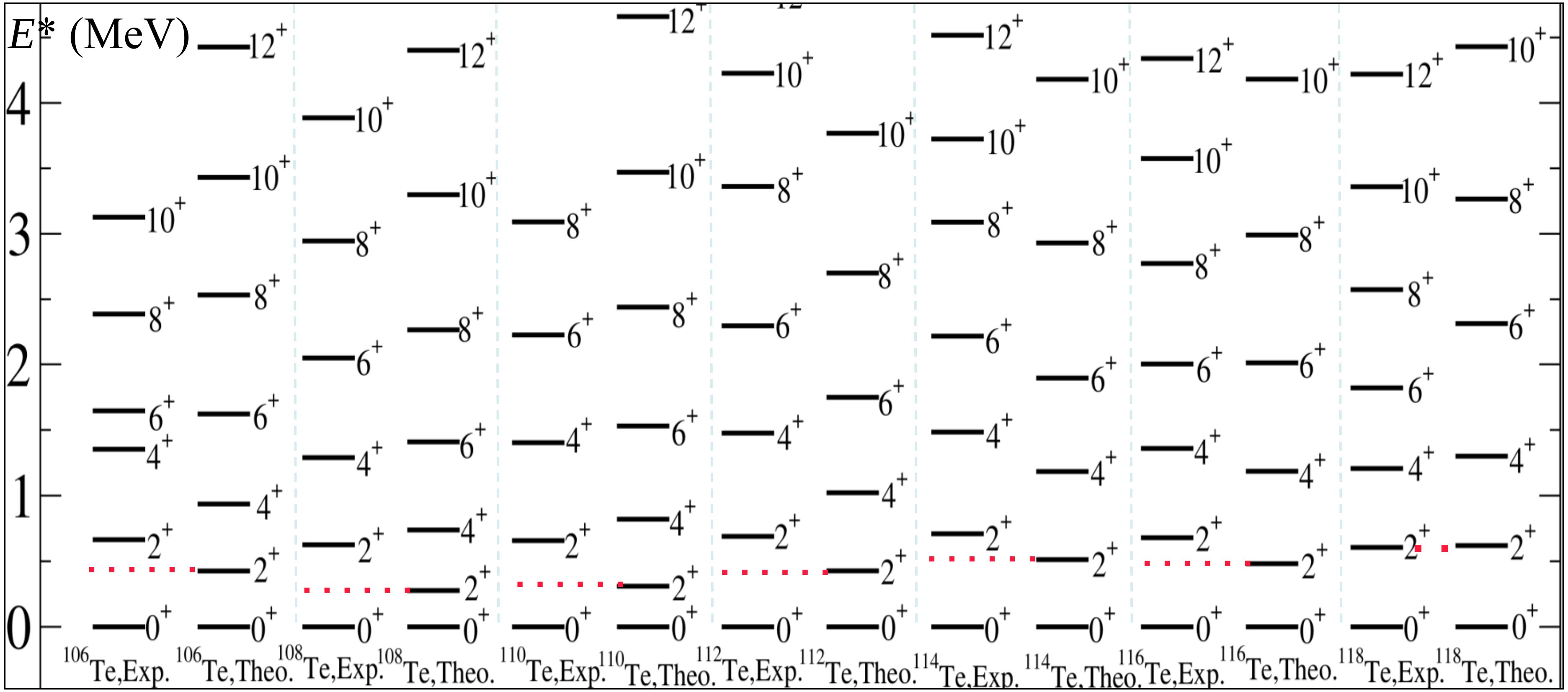
T_Z=1 nucleus ^{106}Te : B. Hadinia, B. Cederwall *et al.*, Phys. Rev. C 72, 041303 (2005)

Why Te isotopes?

ROYAL INSTITUTE OF TECHNOLOGY

LSSM calculations (C. Qi, R. Liotta *et al.*) for light Te isotopes indicate that configuration mixing due to the <u>monopole tensor force between primarily the $\pi 0g_{7/2}$ and $\nu 1d_{5/2}$ orbitals</u> can induce enhanced collectivity but significant inconsistencies remain (E* vs B(E2))

Need B(E2) data and calc. in larger model space!!!

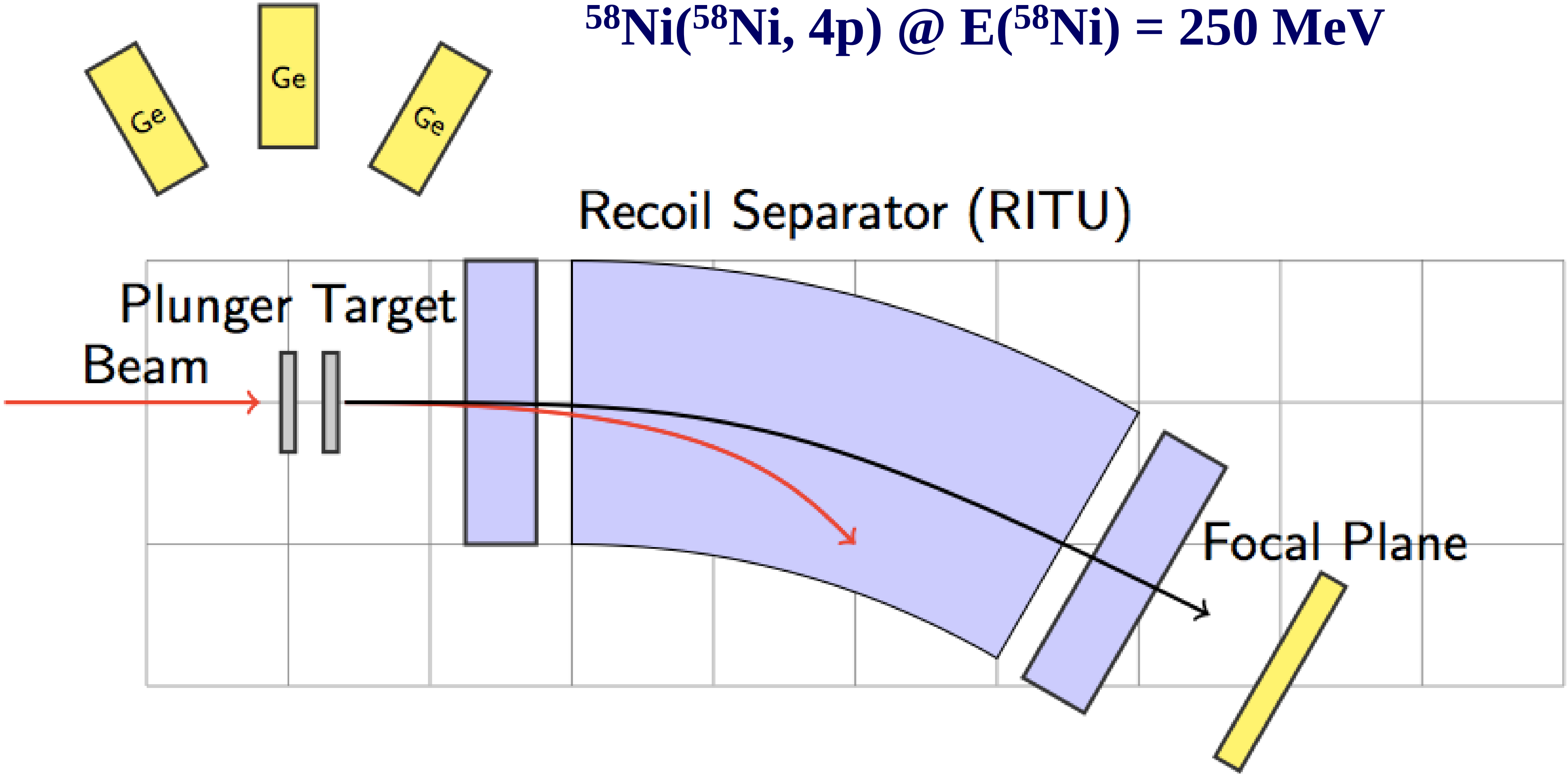


Experimental setup

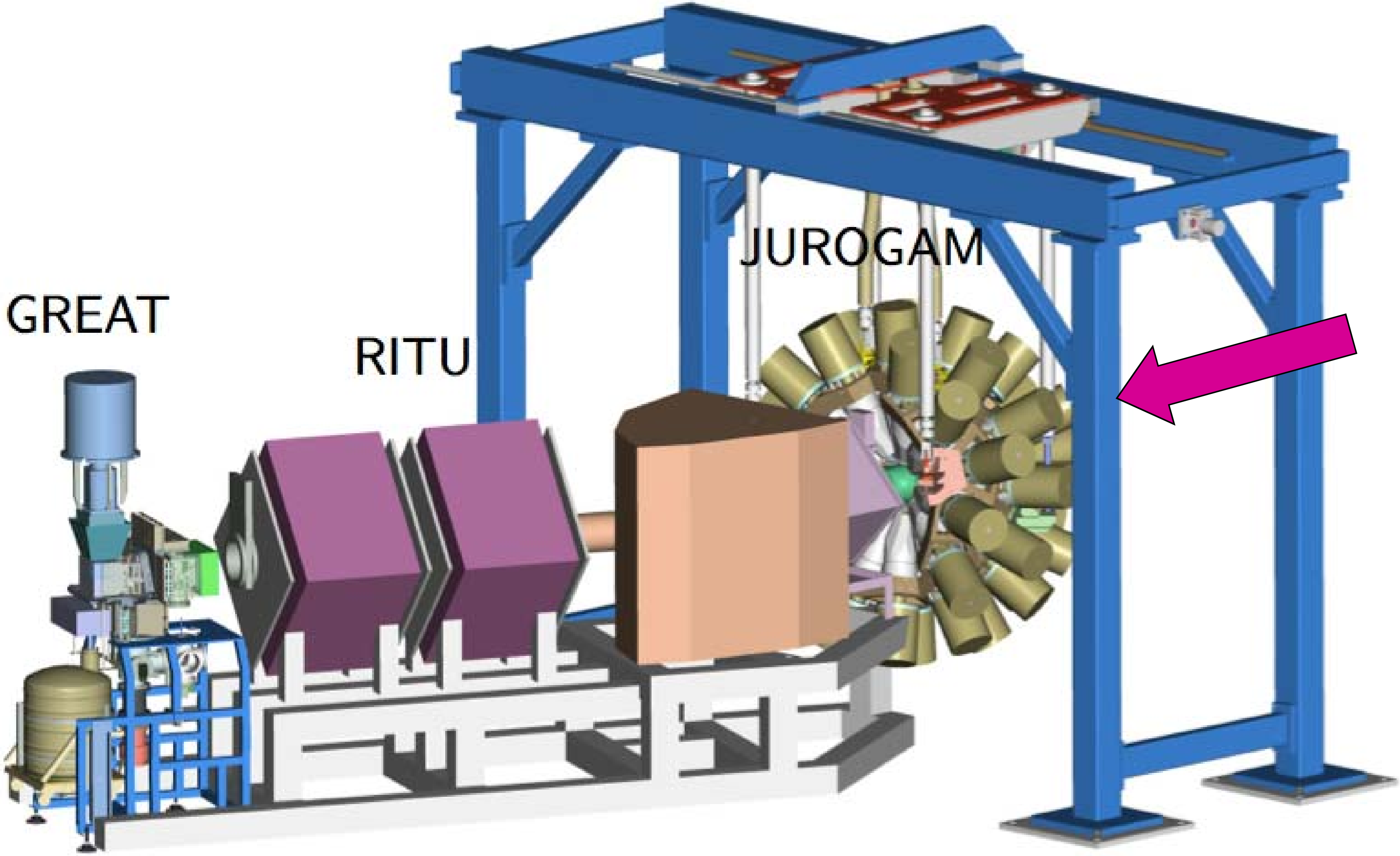
JUROGAM II coupled to RITU and GREAT + DPUNS plunger

Fusion-evaporation reaction

^{58}Ni(^{58}Ni, 4p) @ E(^{58}Ni) = 250 MeV



Experimental setup

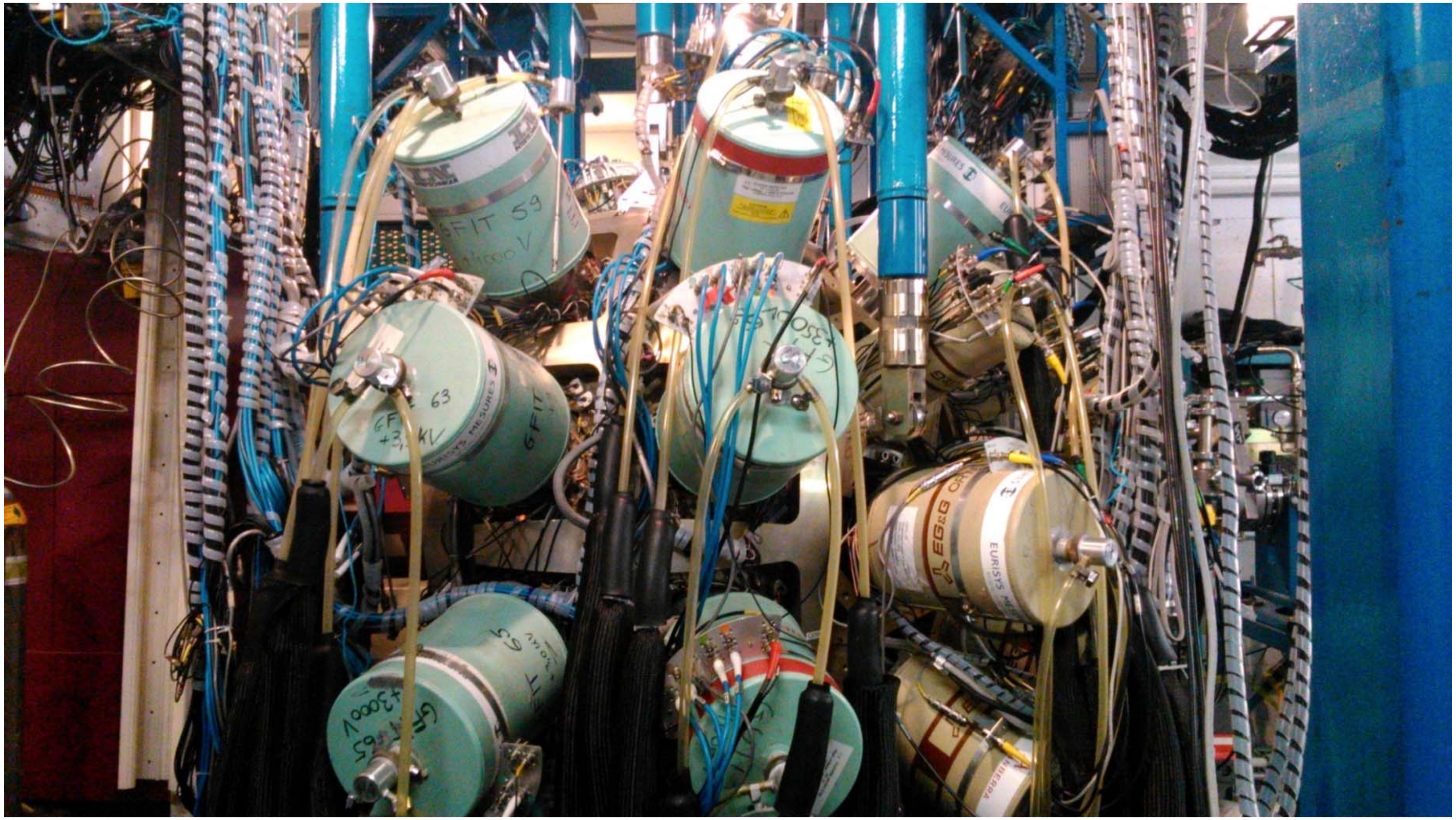


JURGOGAM II

KTH
VETENSKAP
OCH KONST
ROYAL INSTITUTE
OF TECHNOLOGY

39 HPGe detectors in 4 different rings (24 Clovers + 15 Ph-1 detectors)

Gamma efficiency at 1.3 MeV ~ 4%



JURGAM II

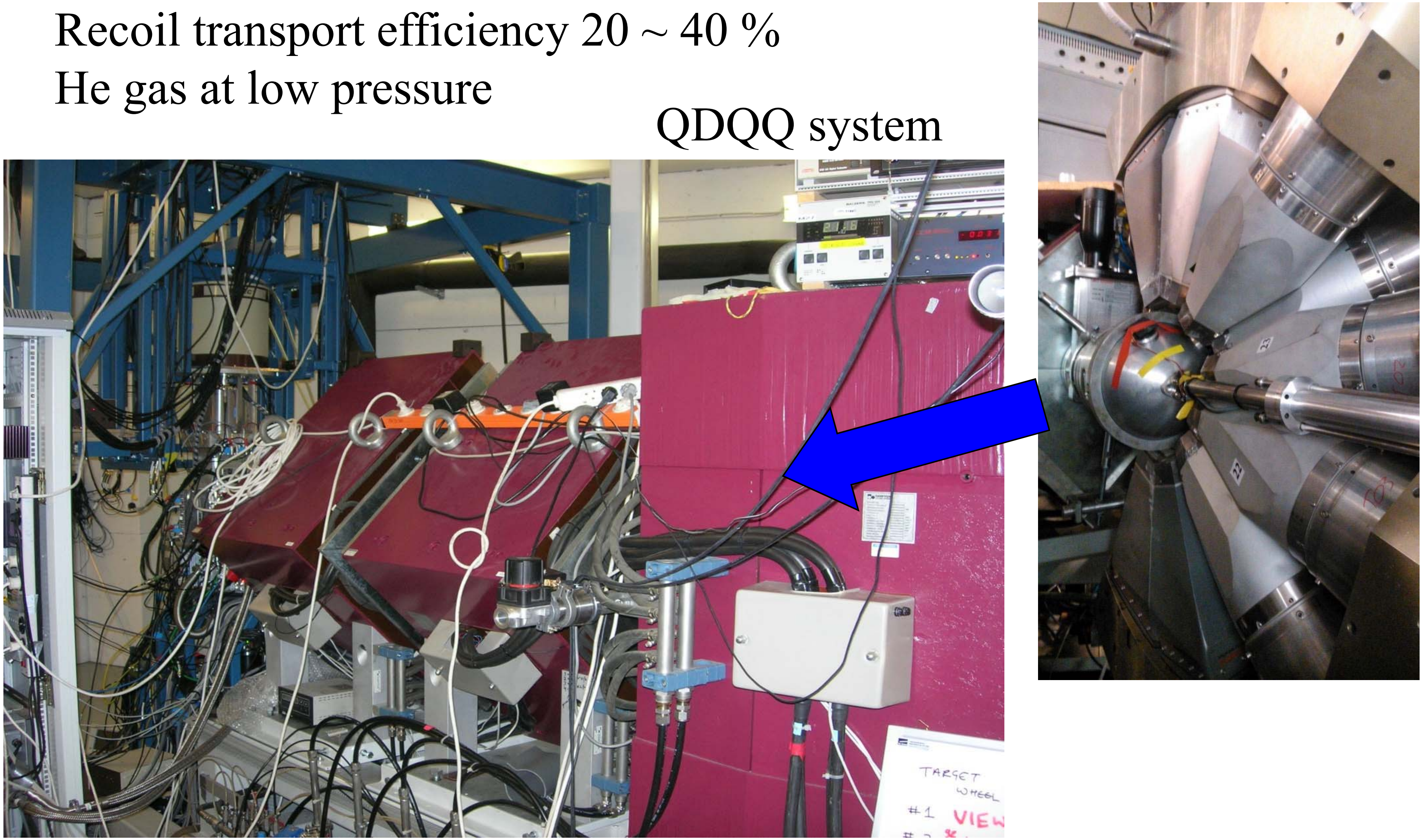
39 HPGe detectors in 4 different rings (24 Clovers + 15 Ph-1 detectors)

Gamma efficiency at 1.3 MeV ~ 4%

RITU (Recoil Ion Transport Unit)

Recoil transport efficiency 20 ~ 40 %
He gas at low pressure

QDQQ system



GREAT (Gamma Recoil Electron Alpha Tagging)

ROYAL INSTITUTE OF TECHNOLOGY

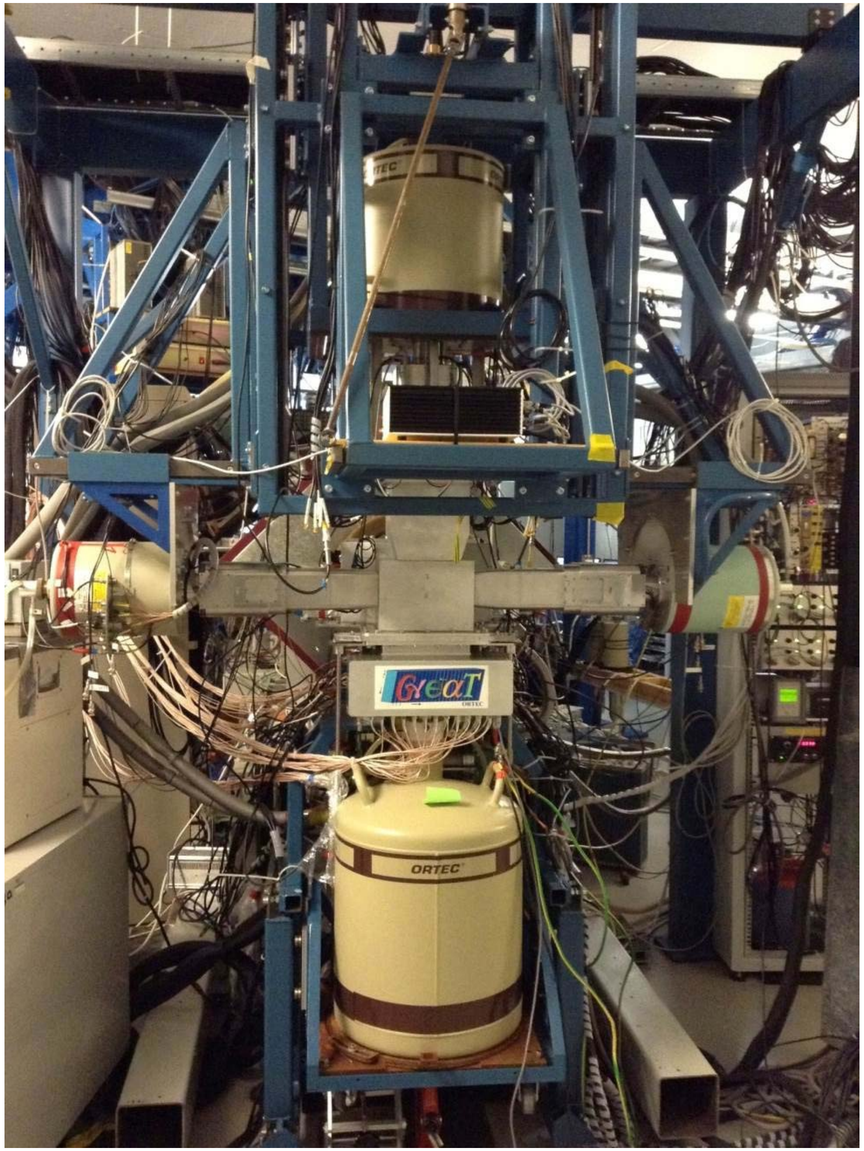
2 DSSD: 60*40 mm^2
4800 pixels
Rate up to 5 kHz

Multiwire proportional counter (MWPC)

Array of 28 Si-PIN photodiodes

Planar Ge strip detector (X-rays,β)

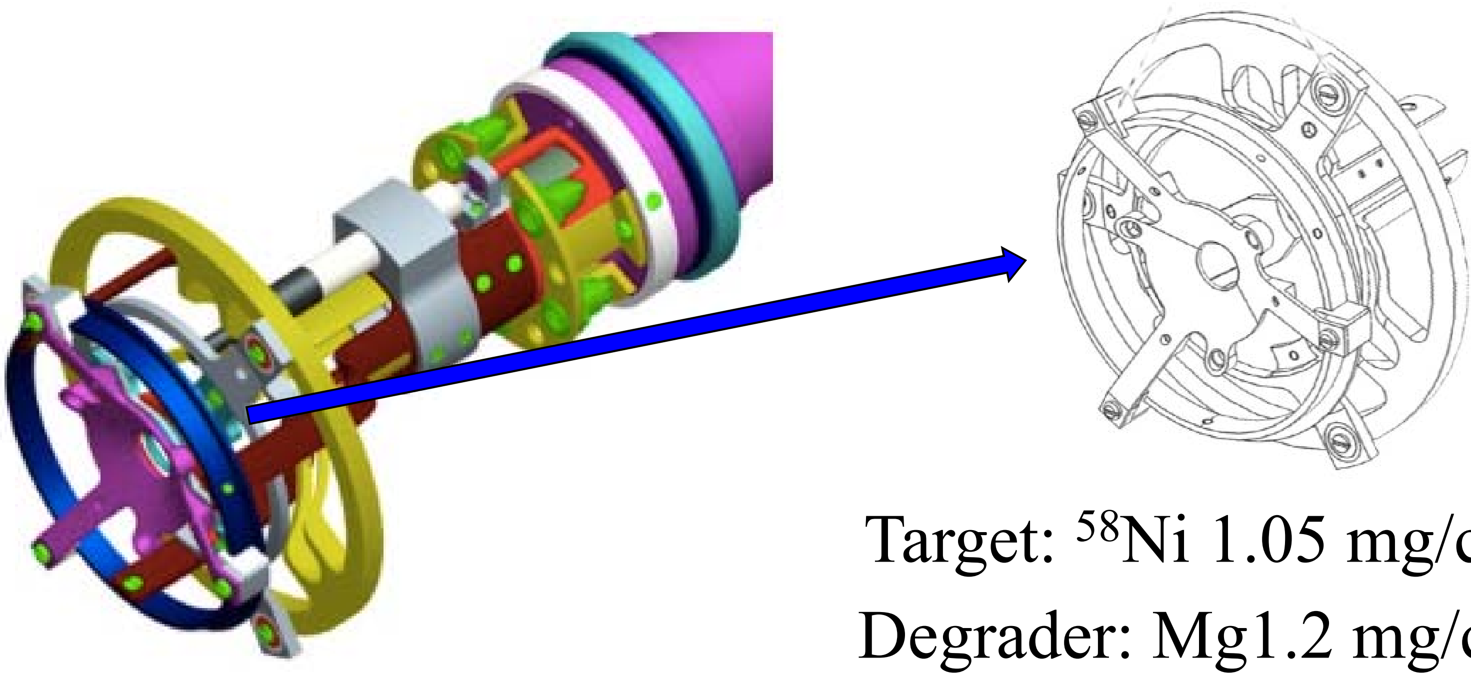
3 Segmented Ge Clover (γ decay)



DPUNS (Differential Plunger for Unbound Nuclear States)

Differential plunger device to measure lifetimes of nuclear states beyond the proton drip line developed by the University of Manchester

M. J. Taylor et al., NIMA 707, 143 (2013)

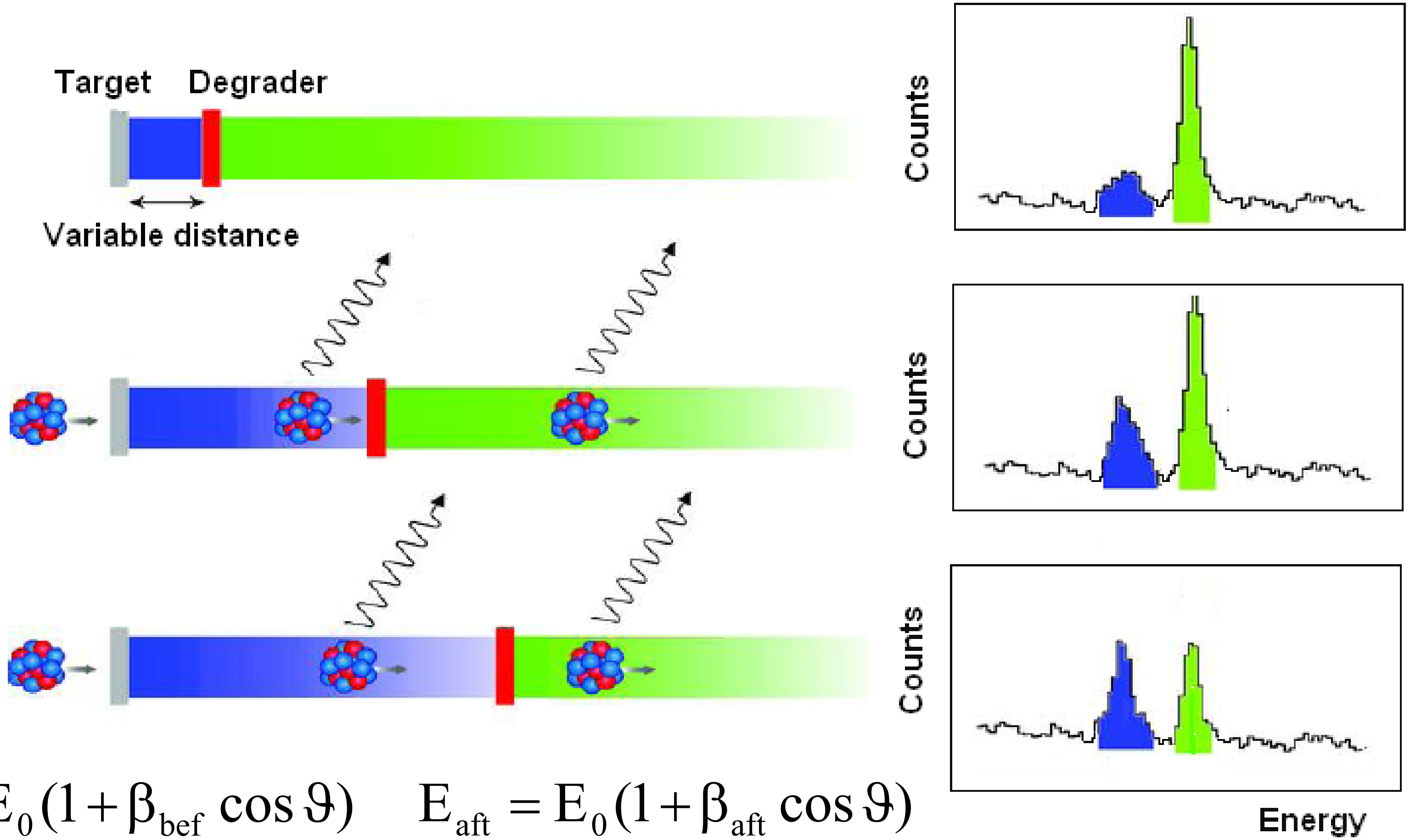


Target: ^{58}Ni 1.05 mg/cm^2

Degrader: Mg1.2 mg/cm^2

Distance range: 5 – 1000 μm

Recoil Distance Doppler Shift Method (RDDS)



$$E_{bef} = E_0(1+\beta_{bef}\cos\vartheta) \qquad E_{aft} = E_0(1+\beta_{aft}\cos\vartheta)$$

Only the Ph-1 detectors placed in rings at 134° and 158° are used for the lifetime determination!

Recoil Distance Doppler Shift Method (RDDS)

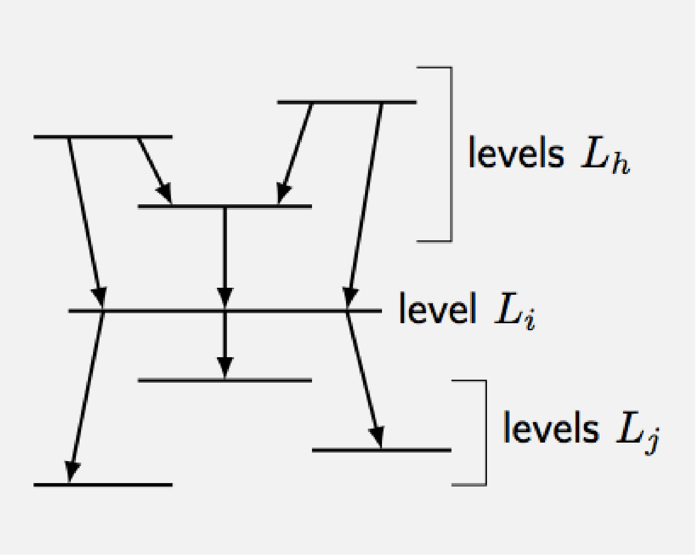
ROYAL INSTITUTE OF TECHNOLOGY

Differential Decay Curve Method (DDCM)

(A. Dewald et al., Z.Phys.A **334** (1989))

The numbers $n_i(t)$, of nuclei in state L_i, etc, at time t, obeys:

$$\frac{\mathrm{d}n_i(t)}{\mathrm{d}t} = -\lambda_i n_i(t) + \sum_h \lambda_h n_h(t) b_{hi}$$



We define the *decay function*, R:

$$R_{ij}(t) = \lambda_i b_{ij} \int_t^{\infty} n_i(t)\mathrm{d}t$$

$$\frac{\mathrm{d}R_{ij}(t)}{\mathrm{d}t} = -\lambda_i \left[R_{ij}(t) - b_{ij} \sum_h R_{hi}(t) \right]$$

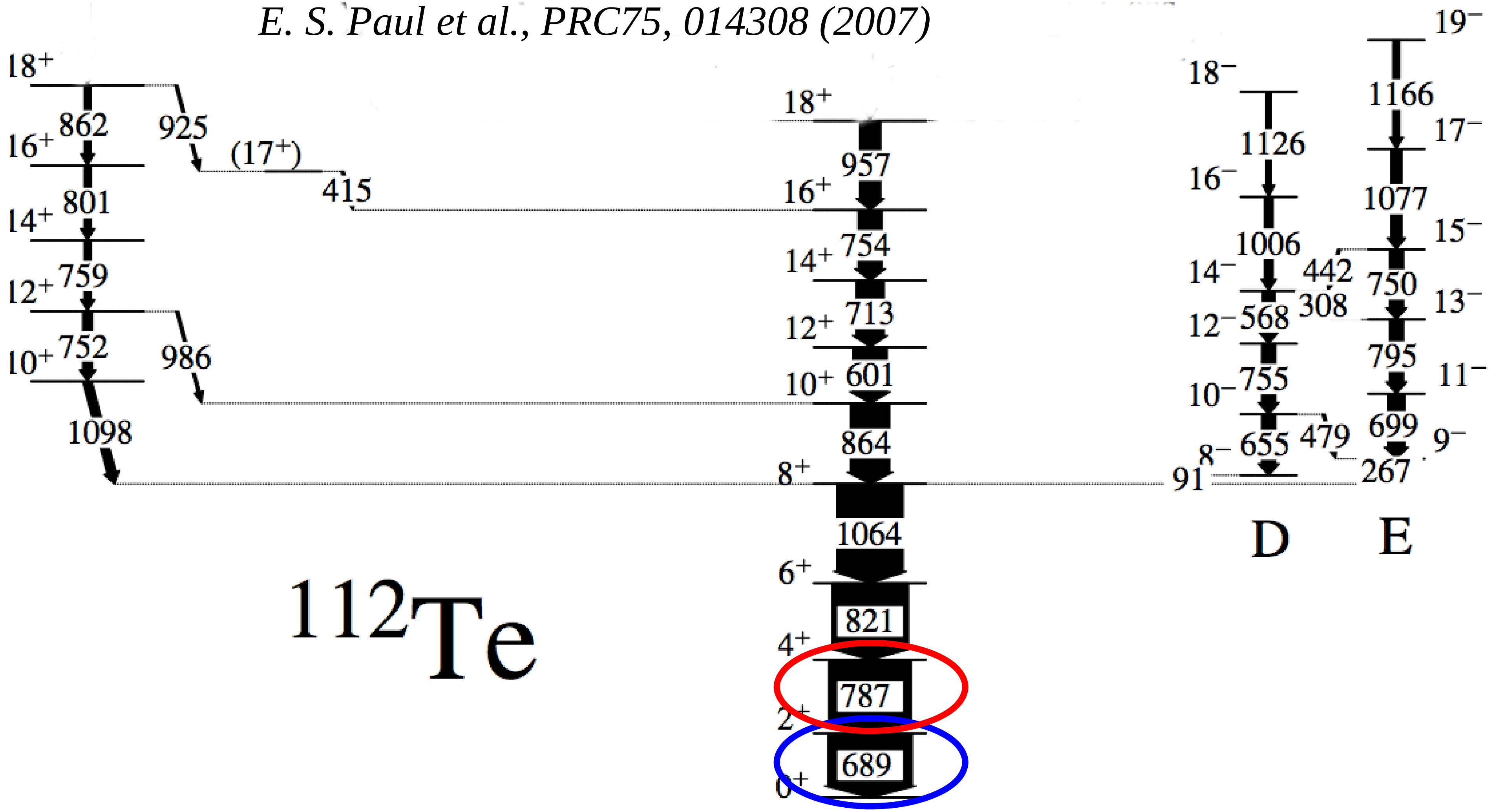
Using $t = x/v$, we can write:

$$Q_{ij}(x) = \frac{R_{ij}(x)}{R_{ij}(0)} = \frac{I^u_{ij}(x)}{I^u_{ij}(x) + I^s_{ij}(x)}$$

$$\tau_i(d) = -\frac{Q_{ij}(d) - b_{ij} \sum_h \left[\frac{J_{hi}}{J_{ij}}\right] Q_{hi}(d)}{v \left[\frac{\mathrm{d}Q_{ij}(d)}{\mathrm{d}x}\right]}$$

Lifetime of the 2^{+} state in ^{112}Te

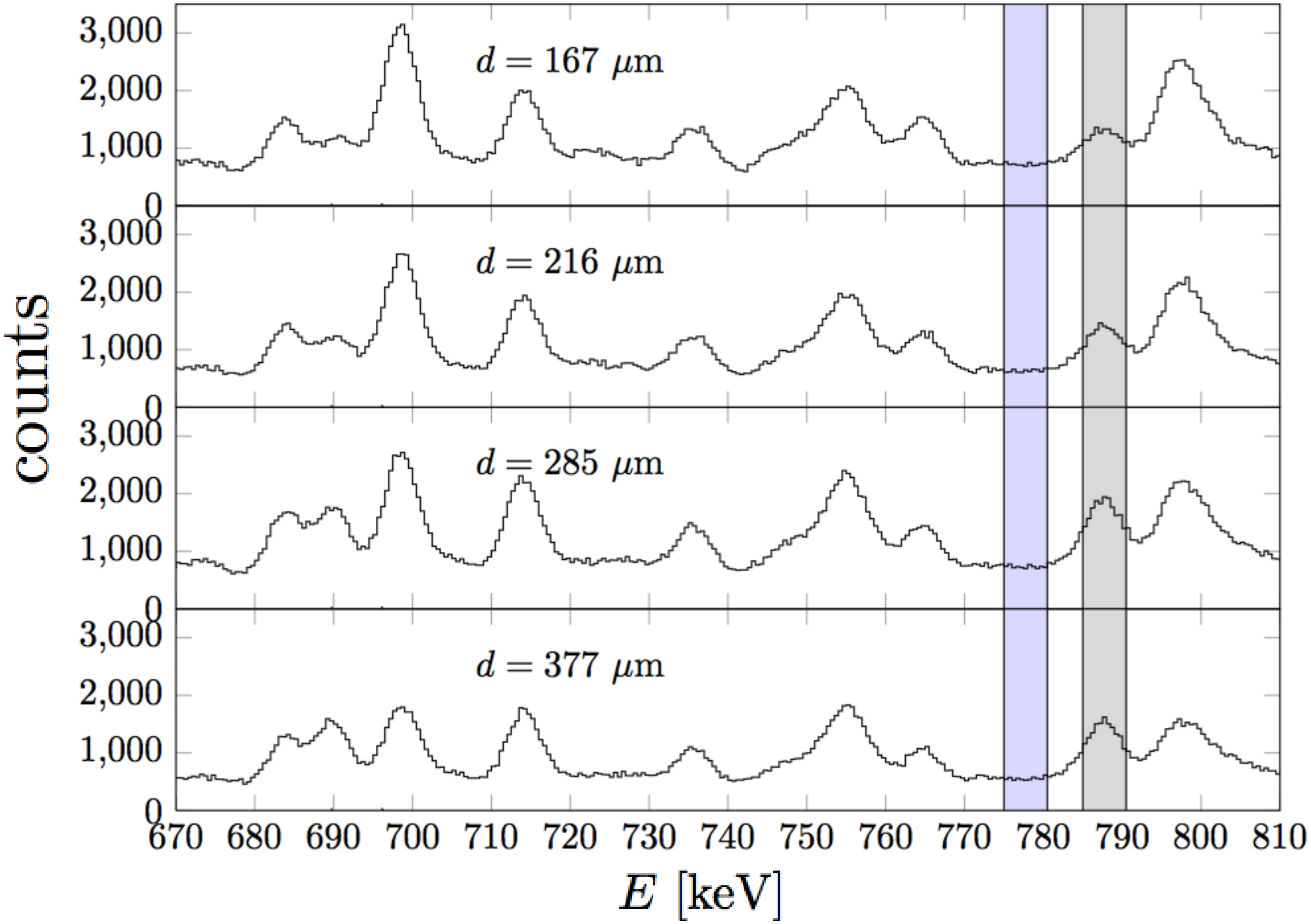
E. S. Paul et al., PRC75, 014308 (2007)



Gate in the 4^{+} state (red) to look at the lifetime of the 2^{+} state (blue)

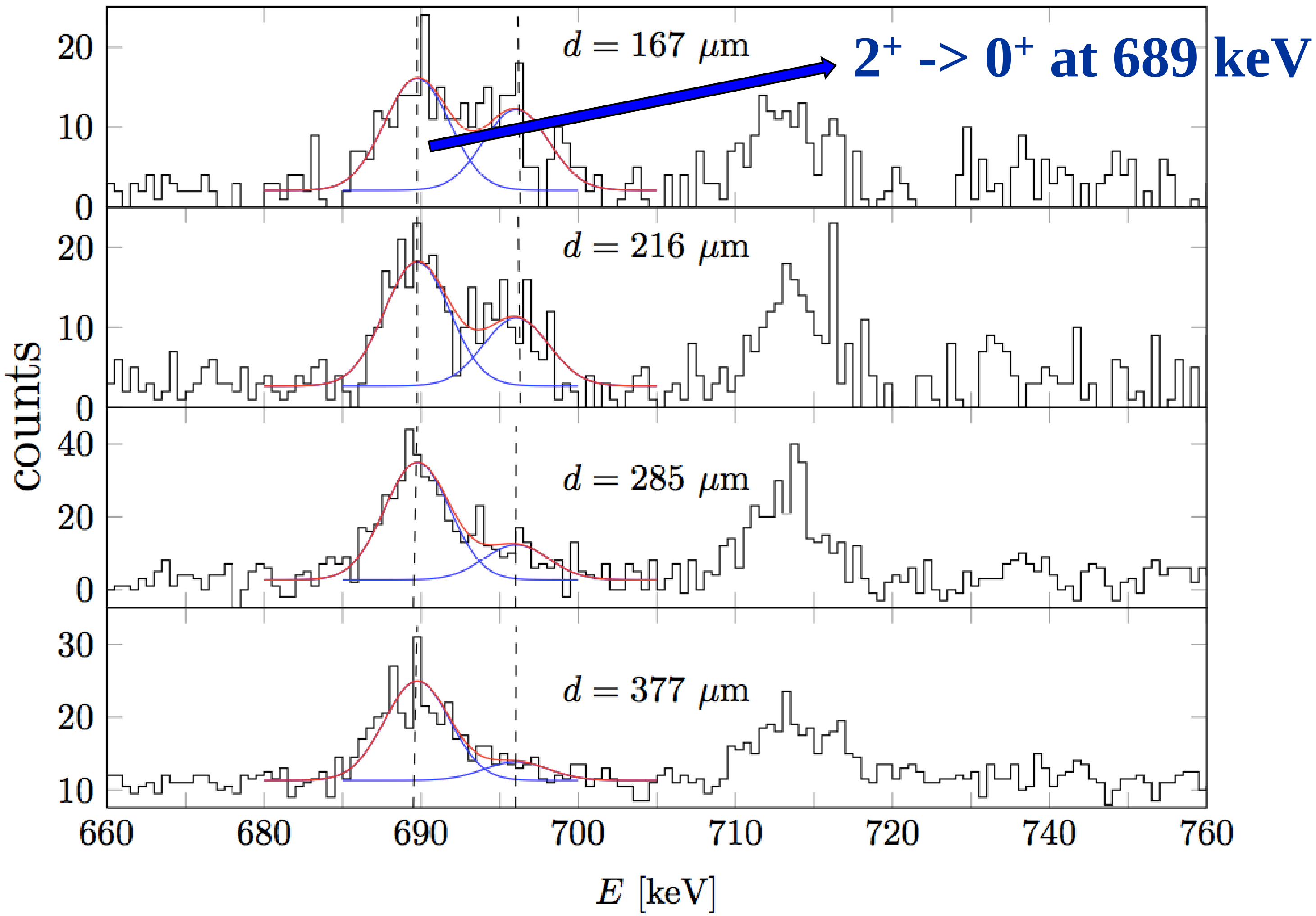
Data analysis

ROYAL INSTITUTE OF TECHNOLOGY



Projections of the γ-γ Ring1 & Ring2 matrix for the sensitivity region
(In grey the 4^+ gate and in blue the background gate)

Data analysis

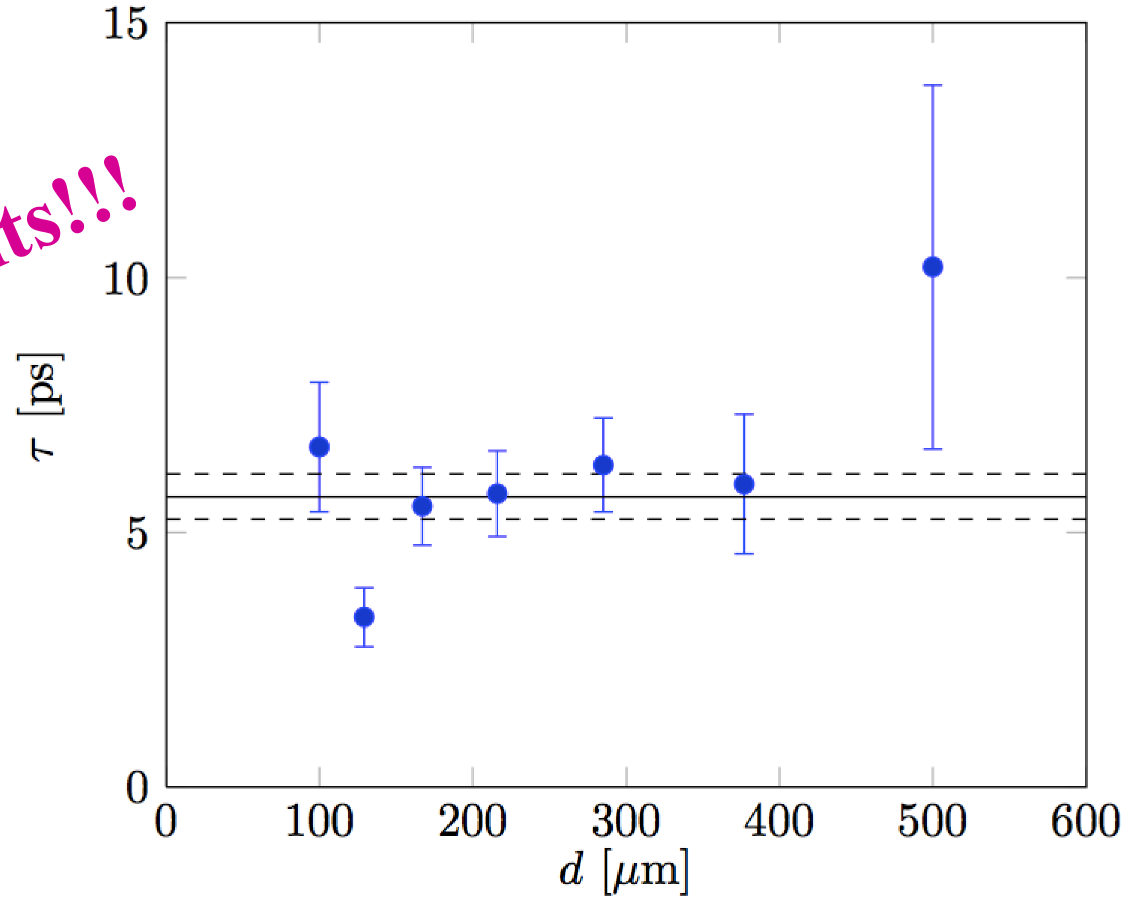


Doppler shift for the 2^+ -> 0^+ transition in the sensitivity region

Experimental results: ^{112}Te

ROYAL INSTITUTE OF TECHNOLOGY

Preliminary results!!!



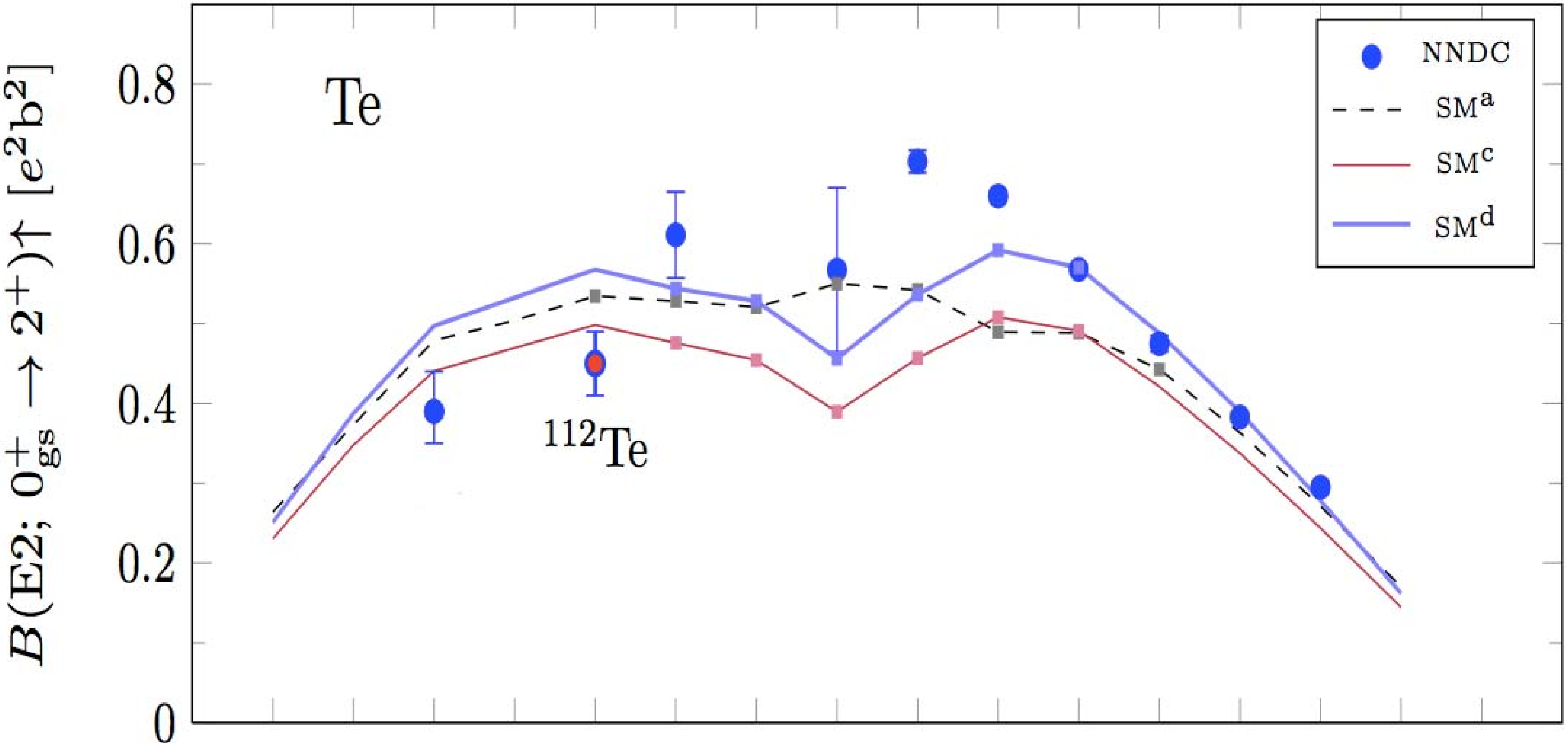
$\tau = 5.7 \pm 0.4$ ps

$B(E2; 0+ \rightarrow 2+) = 0.46 \pm 0.04\ e^2b^2$

Shell model calculations

ROYAL INSTITUTE OF TECHNOLOGY

^{112}Te full valence space considered for π and ν ($g_{7/2}$, $d_{5/2}$, $d_{3/2}$, $s_{1/2}$ and $h_{11/2}$)



SM^a: CQ, 2011 with old interaction and s.p.e. of Banu, $\varepsilon_p = 0.8, \varepsilon_p = 1.5$

SM^c: CQ, 2014, new interaction, $\varepsilon_p = 0.8, \varepsilon_p = 1.5$

SM^d: CQ, 2014, new interaction, $\varepsilon_p = 0.9, \varepsilon_p = 1.5$

Conclusions

ROYAL INSTITUTE OF TECHNOLOGY

The lifetime of the 2^+ state at 689 keV of the ^{112}Te isotope has been measured using the JUROGAM II array coupled to the RITU spectrometer and the DPUNS plunger setup through the Recoil Distance Doppler Shift method.

The measured value for the reduced transition probability is in good agreement with the shell-model theoretical calculations in the very large *gdsh* valence space.

Thank you!!

M. Doncel[1], T. Back[1], B. Cederwall[1], C. Qi[1], R. Liotta[1], D. Hodge[2], D. Cullen[2], M. J. Taylor[2], M. G. Procter[2], J. Pakarinen[3], T. Grahn[3], P. T. Greenlees[3], K. Auranen[3], U. Jakobsson[3], R. Julin[3], S. Juutinen[3], A. Herzáñ[3], J. Konki[3], M. Leino[3], J. Partanen[3], P. Peura[3], P. Rahkila[3], P. Ruotsalainen[3], M. Sandzelius[3], J. Sarén[3], J. Sorri[3], S. Stolze[3], and J. Uusitalo[3]

[1] The Royal Institute of Technology (KTH), Sweden

[2] Schuster Laboratory, University of Manchester, United Kingdom

[3] Department of Physics, University of Jyväskylä, Finland