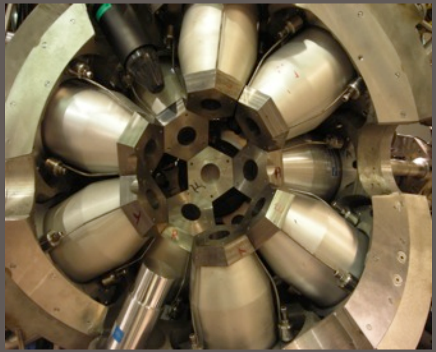
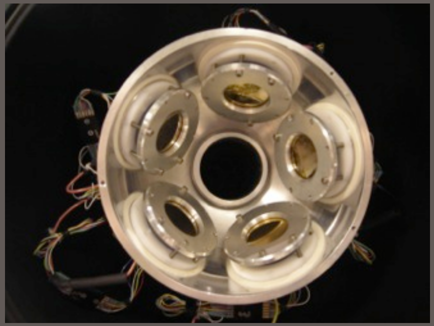
TRIUMF

Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

Exotic nuclei studied with the 8pi spectrometer at TRIUMF

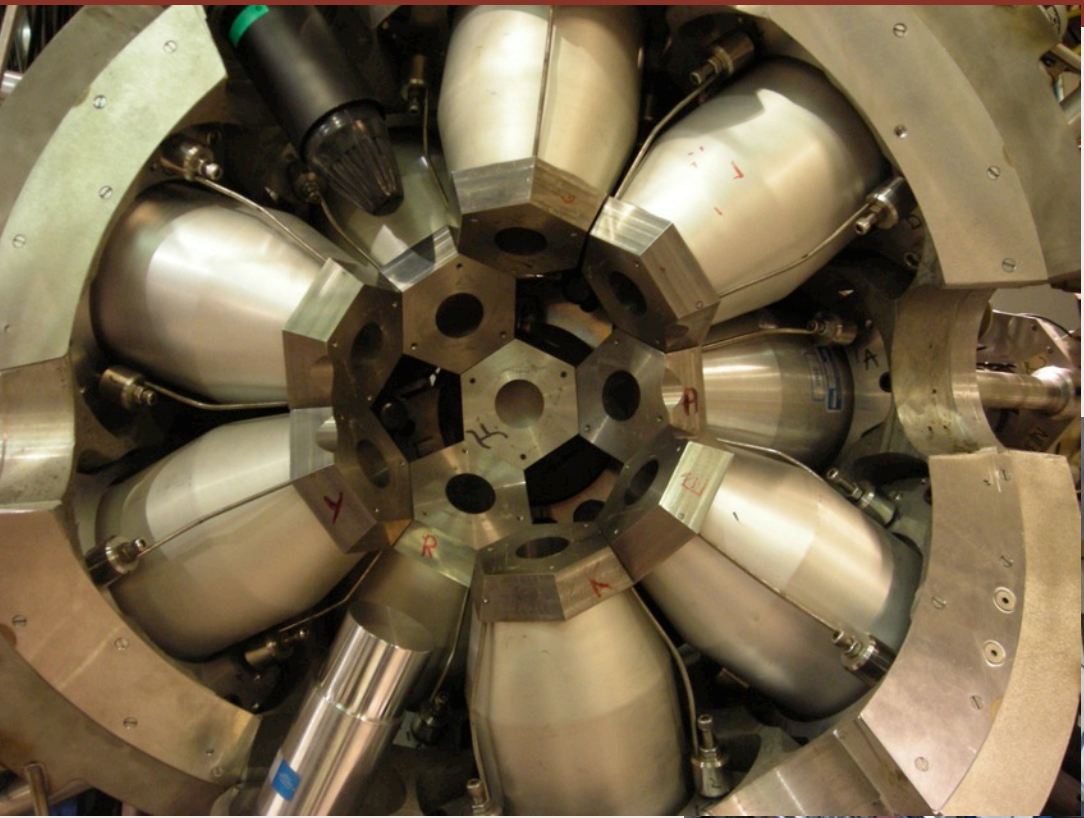
Adam Garnsworthy | Research Scientist | TRIUMF
On behalf of the 8pi collaboration



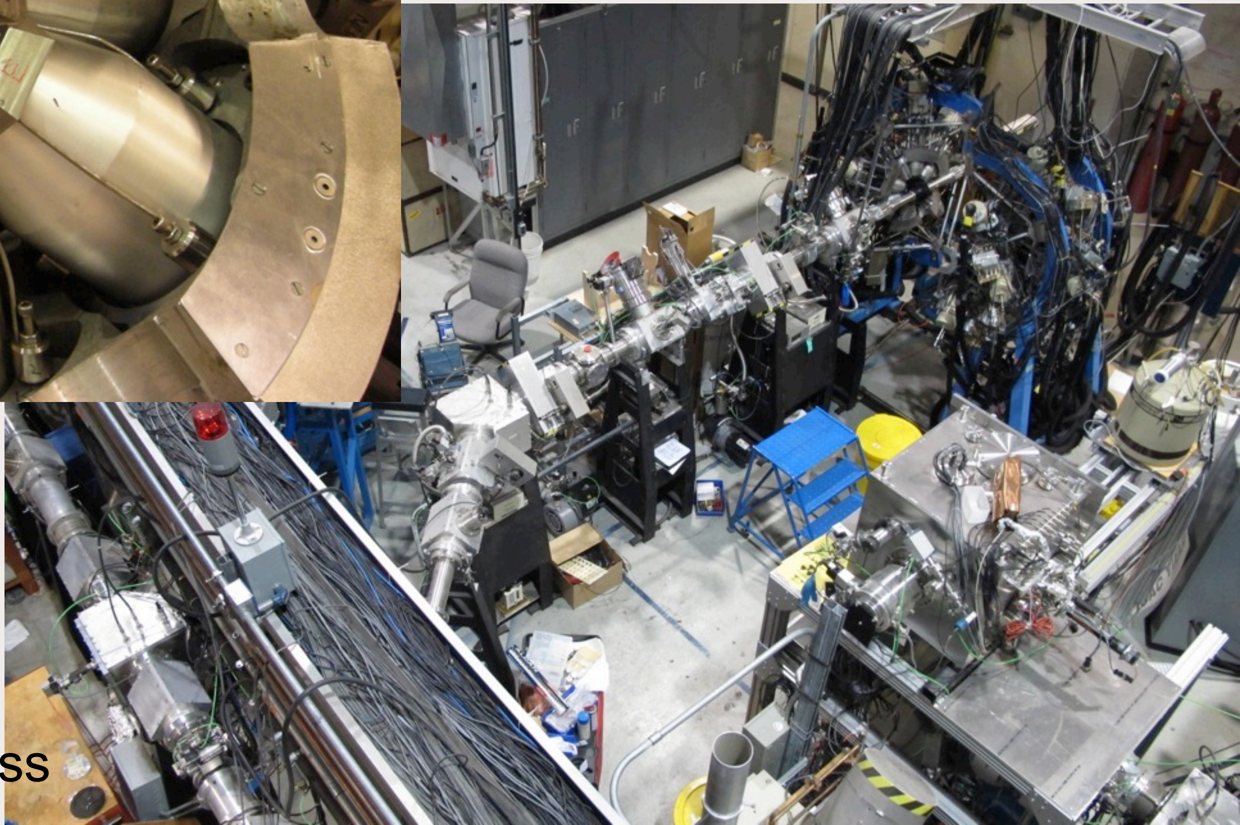


TRIUMF

The 8π Spectrometer at TRIUMF-ISAC



Performed decay spectroscopy at TRIUMF-ISAC-I from Feb 2002 to Dec 2013



Researchers from 24 institutions from 8 countries.

>25 post-docs,
5PhD, 12MSc, 1MPhys
12 Grad. Students in progress

The 8π Spectrometer at TRIUMF-ISAC

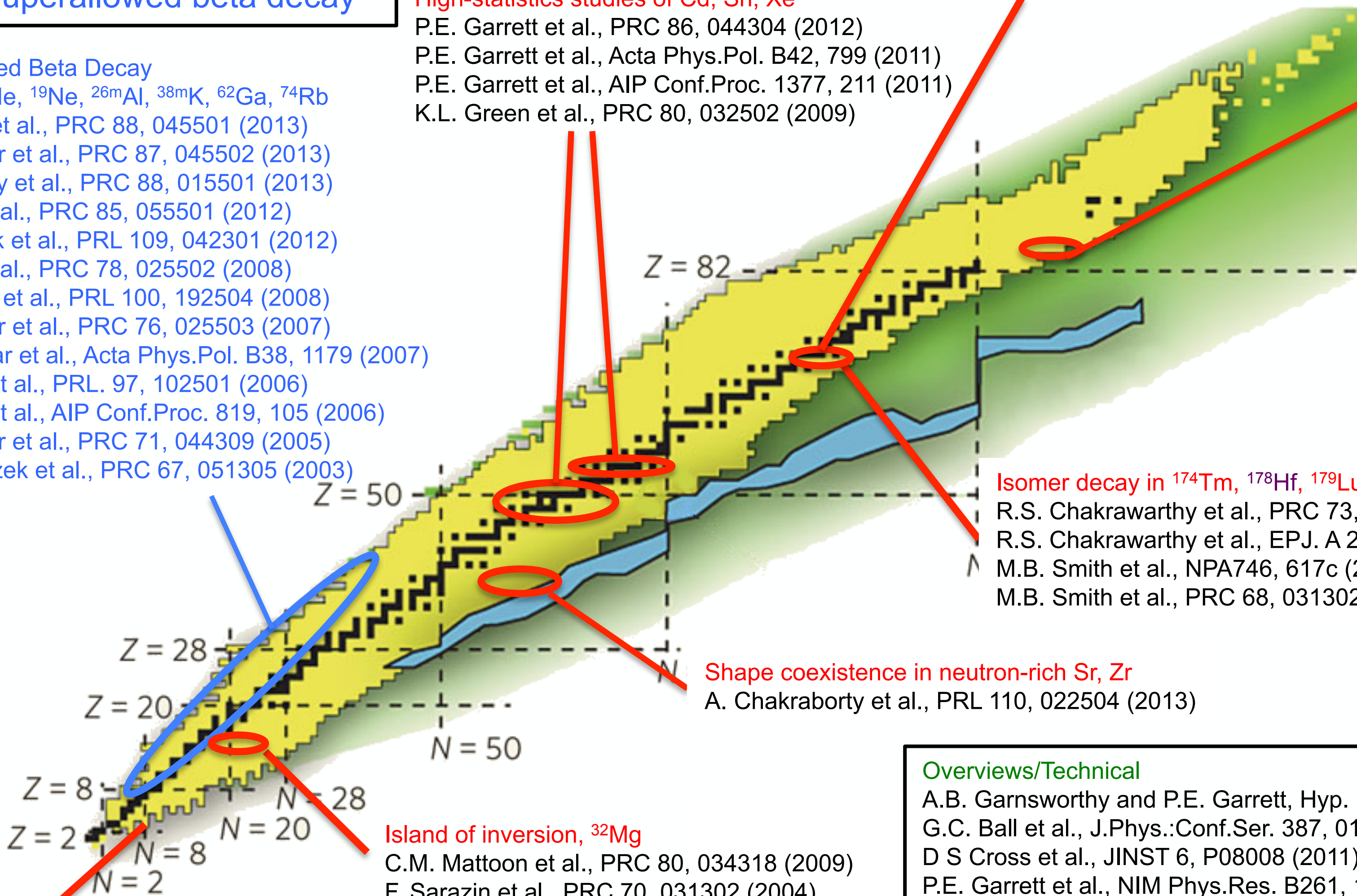
32 publications including 4 PRLs
19 on Nuclear Structure
13 on Superallowed beta decay

Superallowed Beta Decay
^{10}C, ^{14}O, ^{18}Ne, ^{19}Ne, ^{26m}Al, ^{38m}K, ^{62}Ga, ^{74}Rb
R. Dunlop et al., PRC 88, 045501 (2013)
G.F. Grinyer et al., PRC 87, 045502 (2013)
A.T. Laffoley et al., PRC 88, 015501 (2013)
P. Finlay et al., PRC 85, 055501 (2012)
S. Triambak et al., PRL 109, 042301 (2012)
P. Finlay et al., PRC 78, 025502 (2008)
K.G. Leach et al., PRL 100, 192504 (2008)
G.F. Grinyer et al., PRC 76, 025503 (2007)
E.F. Zganyar et al., Acta Phys.Pol. B38, 1179 (2007)
B. Hyland et al., PRL. 97, 102501 (2006)
B. Hyland et al., AIP Conf.Proc. 819, 105 (2006)
G.F. Grinyer et al., PRC 71, 044309 (2005)
A. Piechaczek et al., PRC 67, 051305 (2003)

Half Life of geochronometer, ^{176}Lu
G.F. Grinyer et al., PRC 67, 014302 (2003)

High-statistics studies of Cd, Sn, Xe
P.E. Garrett et al., PRC 86, 044304 (2012)
P.E. Garrett et al., Acta Phys.Pol. B42, 799 (2011)
P.E. Garrett et al., AIP Conf.Proc. 1377, 211 (2011)
K.L. Green et al., PRC 80, 032502 (2009)

Structure of $^{219-223}$Rn towards a RnEDM search



Isomer decay in ^{174}Tm, ^{178}Hf, ^{179}Lu
R.S. Chakrawarthy et al., PRC 73, 024306 (2006)
R.S. Chakrawarthy et al., EPJ. A 25, S1, 125 (2005)
M.B. Smith et al., NPA746, 617c (2004)
M.B. Smith et al., PRC 68, 031302 (2003)

Shape coexistence in neutron-rich Sr, Zr
A. Chakraborty et al., PRL 110, 022504 (2013)

Island of inversion, ^{32}Mg
C.M. Mattoon et al., PRC 80, 034318 (2009)
F. Sarazin et al., PRC 70, 031302 (2004)

^{11}Li beta-delayed neutron emission
C.M. Mattoon et al., PRC 75, 017302 (2007)

Overviews/Technical
A.B. Garnsworthy and P.E. Garrett, Hyp. Int. 225, 121 (2014)
G.C. Ball et al., J.Phys.:Conf.Ser. 387, 012014 (2012)
D S Cross et al., JINST 6, P08008 (2011)
P.E. Garrett et al., NIM Phys.Res. B261, 1084 (2007)
G.C. Ball et al., J.Phys.(London) G31, S1491 (2005)
S.J. Williams et al., J.Phys.(London) G31, S1979 (2005)

8π: Results with long-lived sources

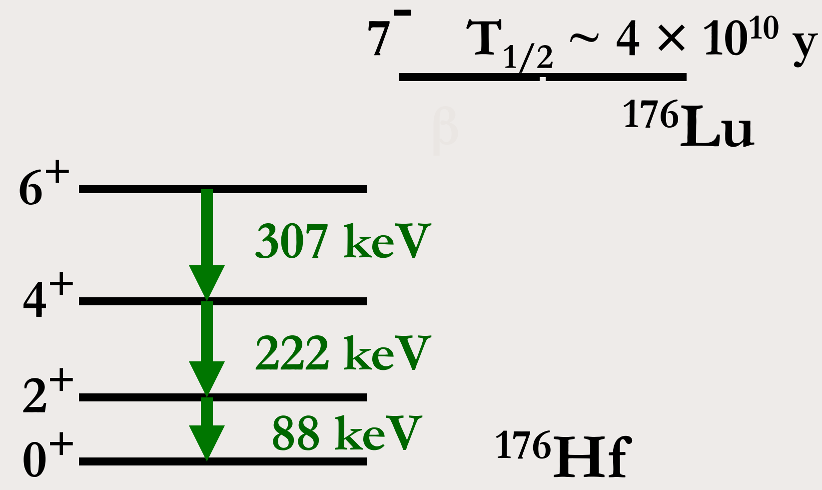
<u>The Half-Life of ^{176}Lu by a γ – γ Coincidence Technique:</u>

$T_{1/2}$ = 40.8 ± 0.3 billion years

Used as a geochronometer with Lu/Hf abundance ratios.

Experiment: February 2002

Published: *G.F. Grinyer et al., Phys. Rev. C 67, 014302 (2003)*



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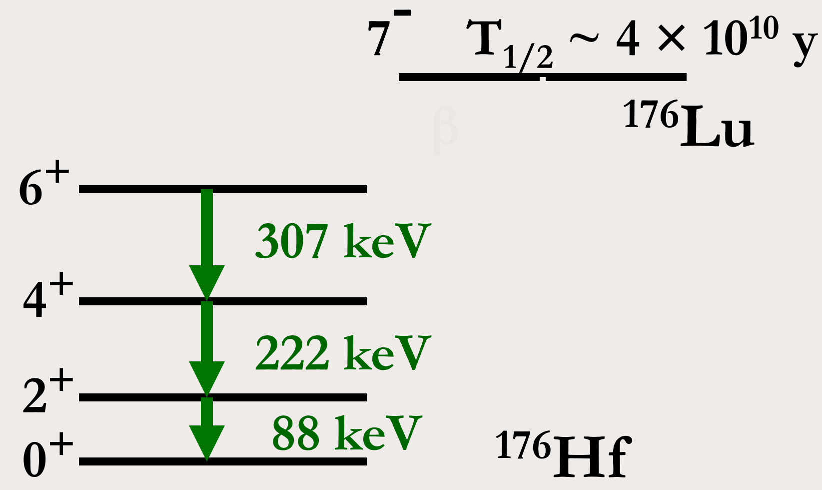


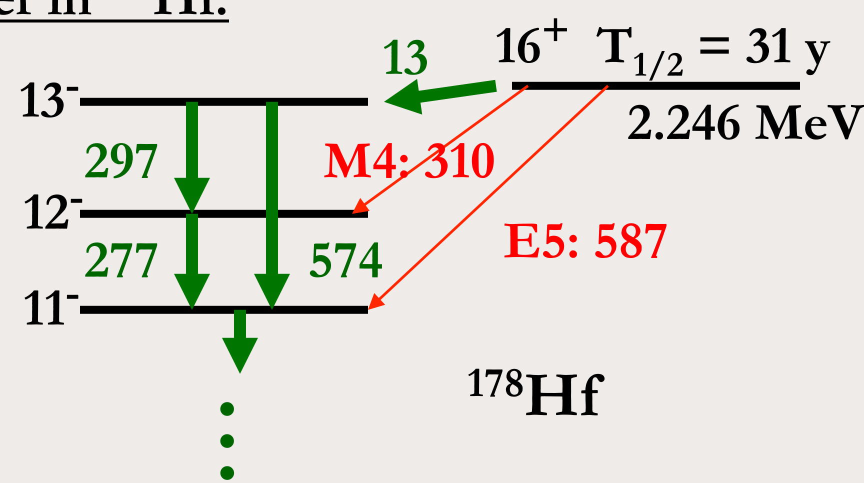
<u>Gamma Decay of the 31-year K^{π} = 16^{+} Isomer in ^{178}Hf:</u>

First observation of M4 and E5 decay of a high-K isomer

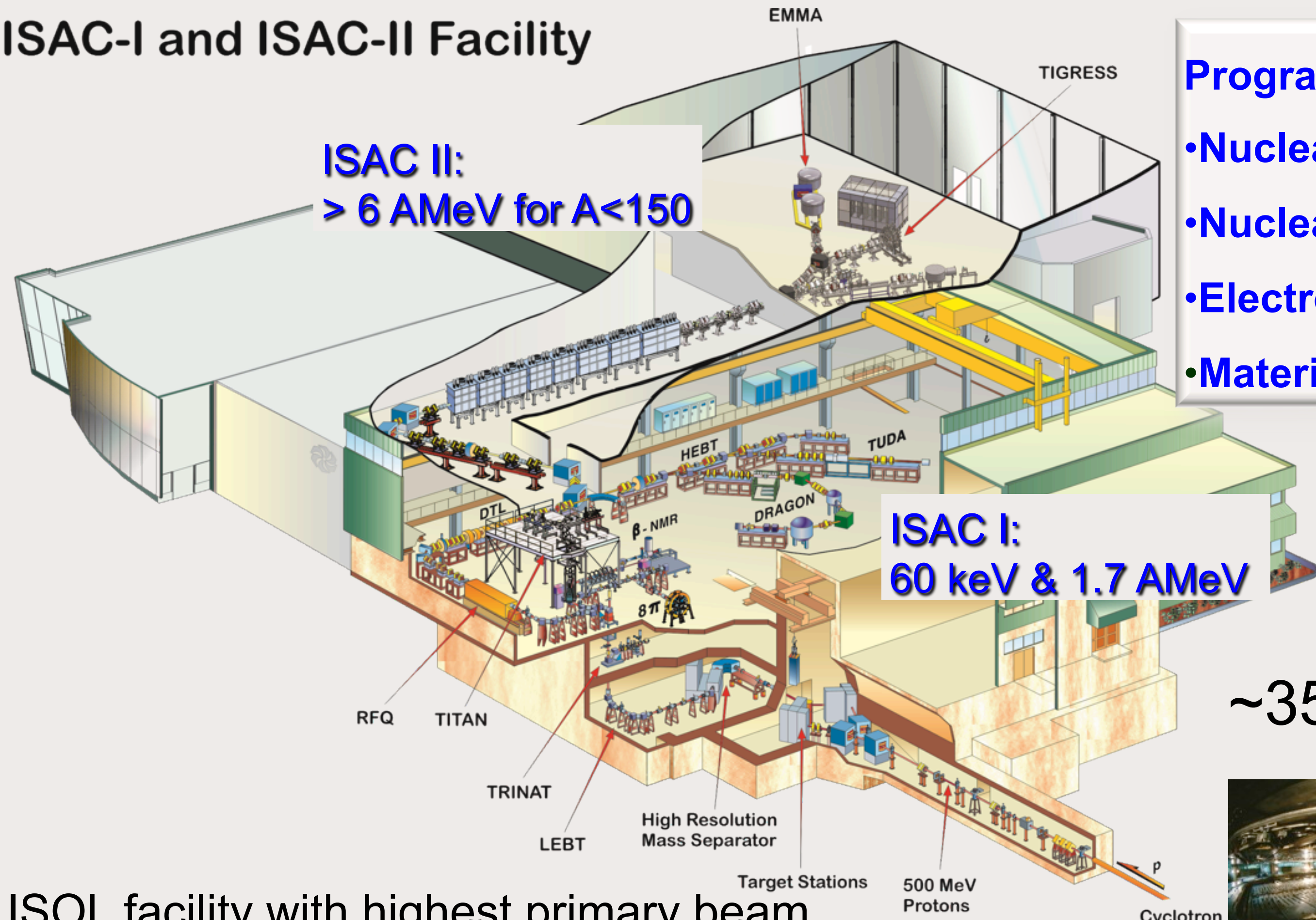
- reduced K hindrances ~ 100

Experiment: December 2002

Published: *M.B. Smith et al., Phys. Rev. C 68, 031302(R) (2003).*



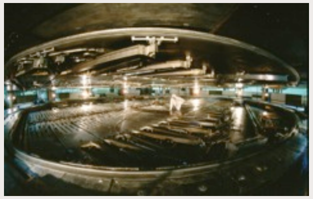
ISAC rare isotope facility



Programs in

- **Nuclear Structure & Dynamics**
- **Nuclear Astrophysics**
- **Electroweak Interaction Studies**
- **Material Science**

~3500 RIB hours /yr



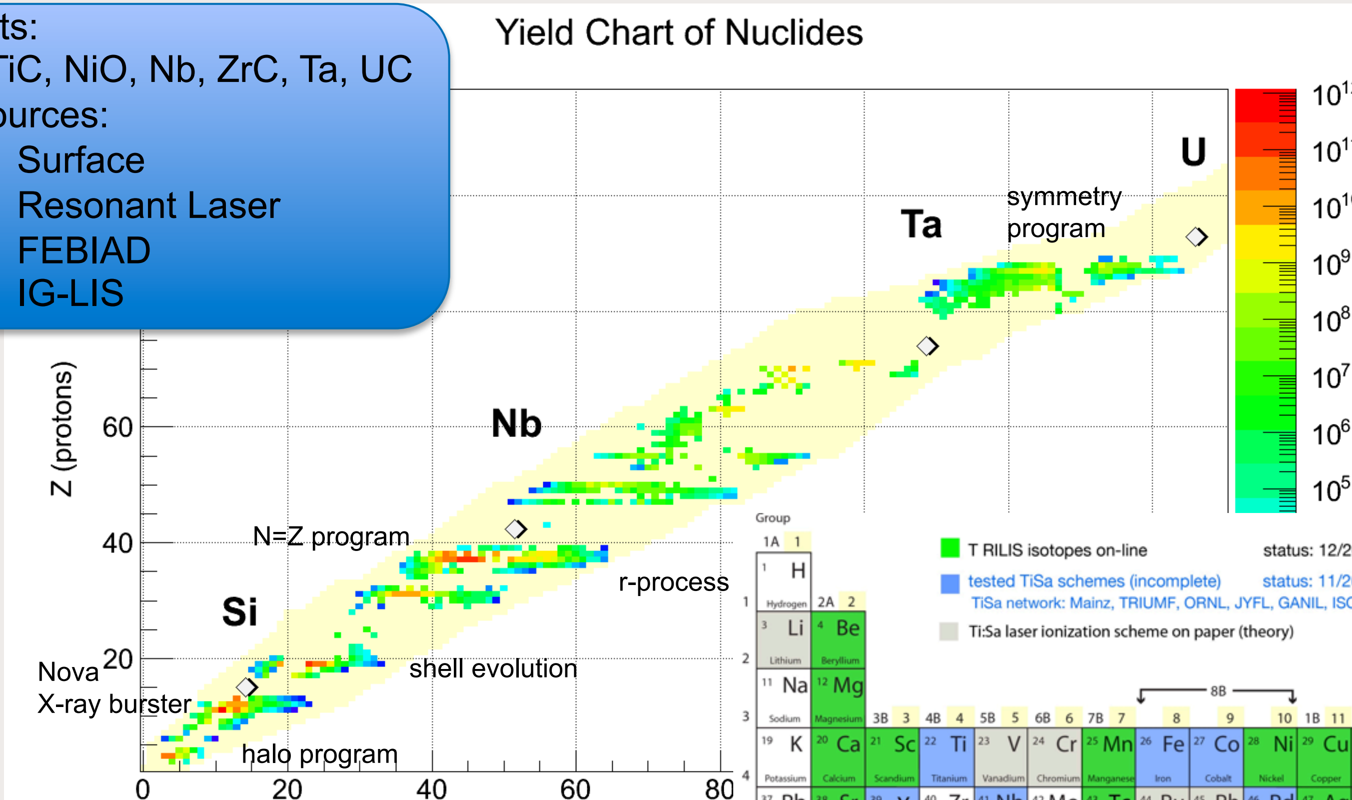
ISOL facility with highest primary beam intensity (100 μA, 500 MeV protons)

target materials: Si, Ti, Zr, Nb, Ta, U

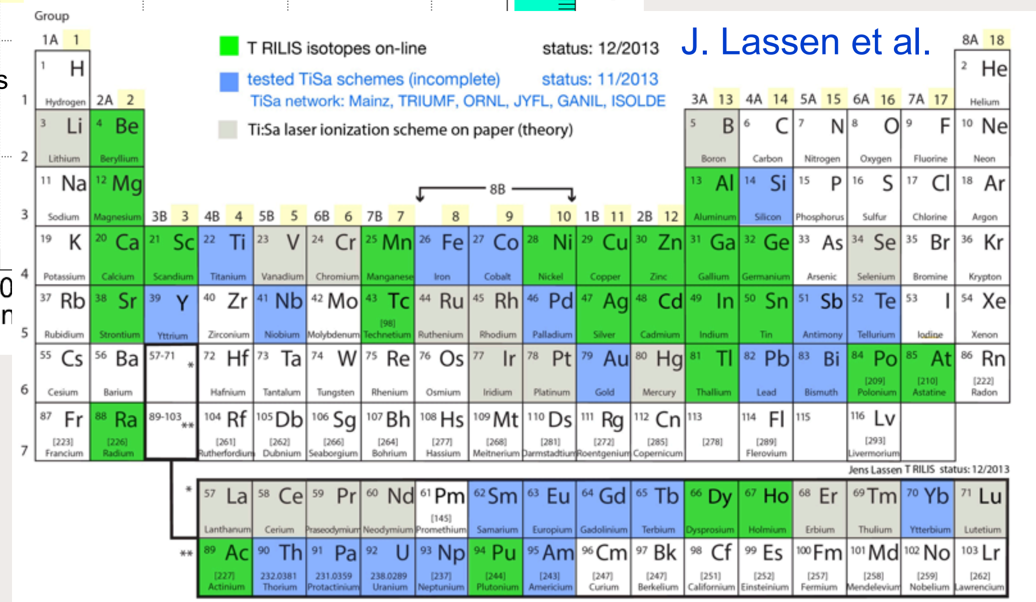
TRIUMF

ISAC isotopes

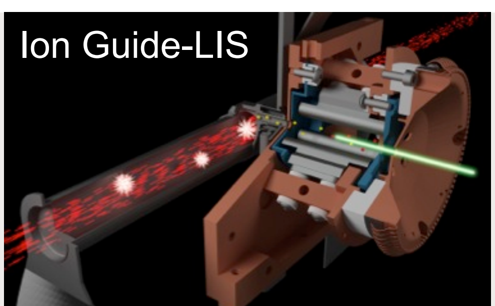
Targets:
SiC, TiC, NiO, Nb, ZrC, Ta, UC
Ion sources:
- Surface
- Resonant Laser
- FEBIAD
- IG-LIS



P. Kunz et al.



J. Lassen et al.

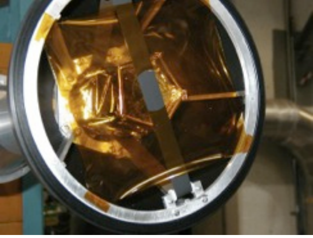
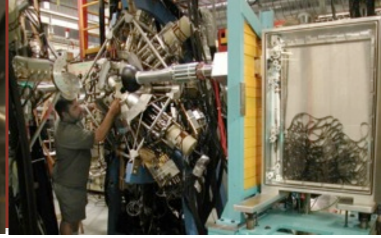


The 8pi Spectrometer at TRIUMF
Sensitive Decay Spectroscopy

ISOBAR

J^{π}_{ISOMER}

J^{π}_{GS}

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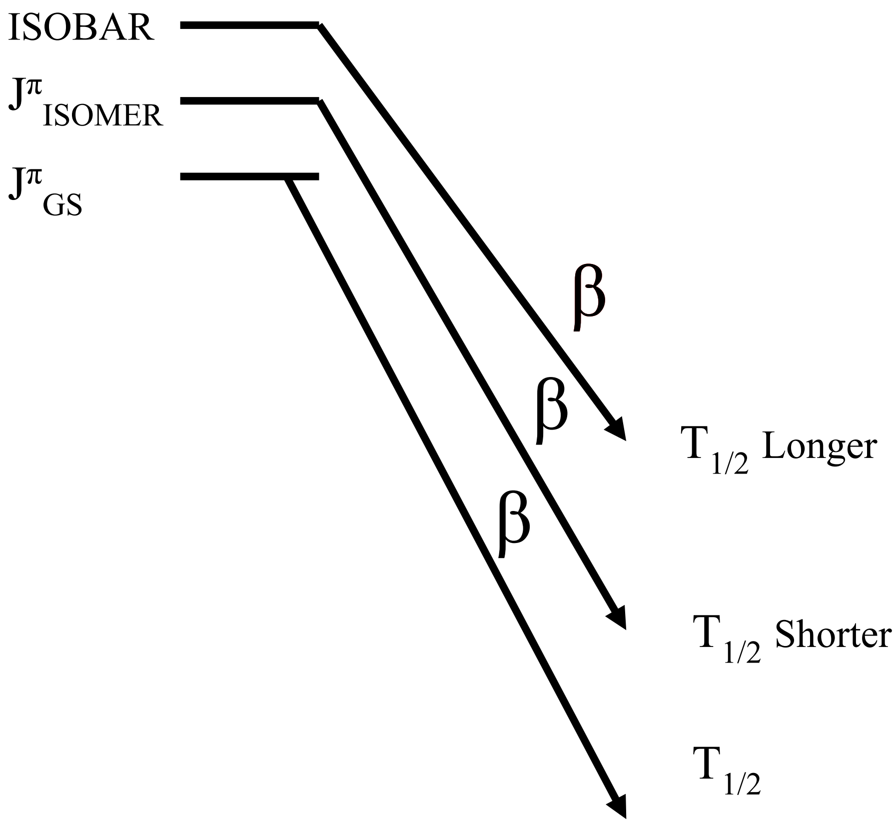
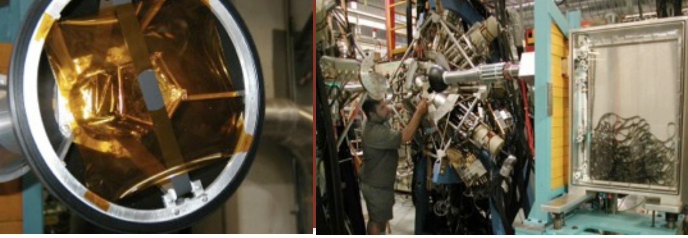
Fast, in-vacuum tape system
Enhances decay of interest





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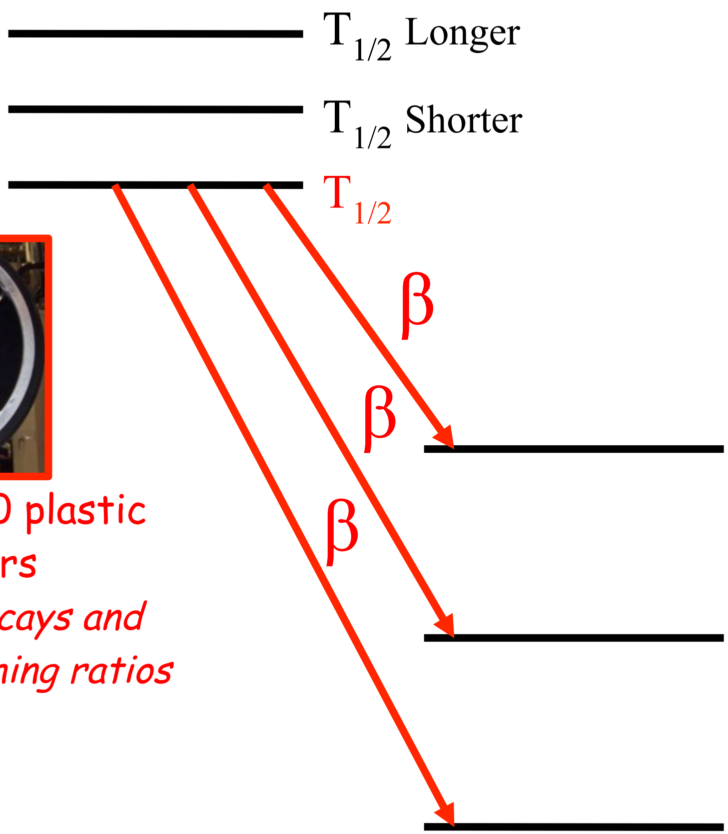
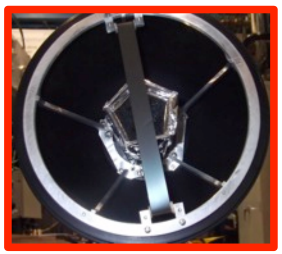
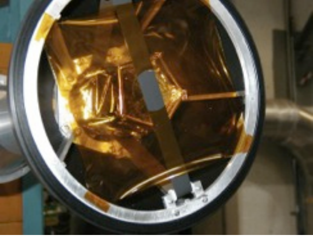
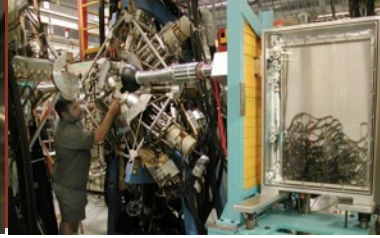




SCEPTAR: 10+10 plastic scintillators
Detects beta decays and determines branching ratios





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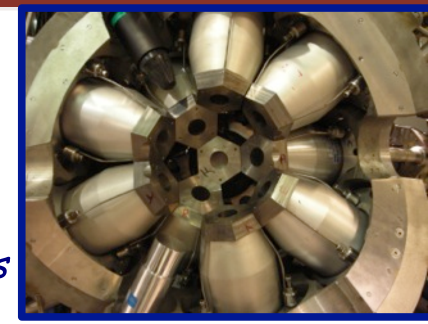
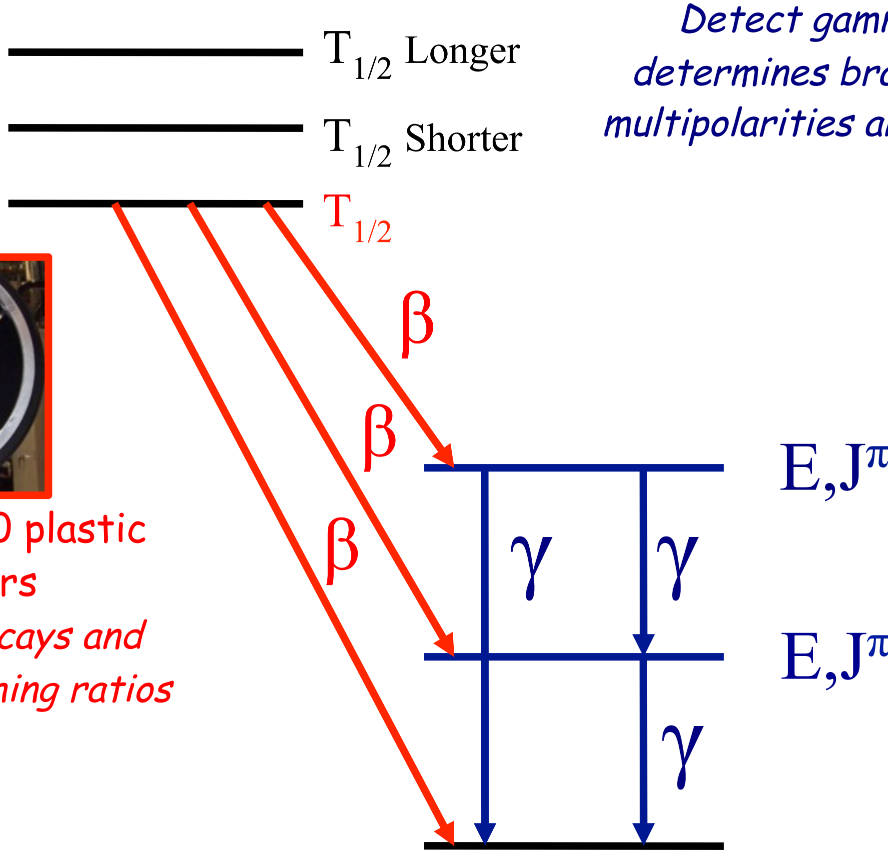
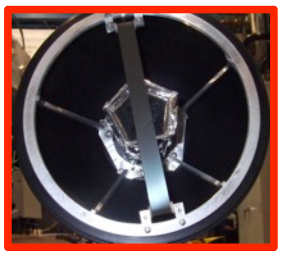
8pi Ge: 20 Compton-Suppressed HpGe
Detect gamma rays and determines branching ratios, multipolarities and mixing ratios

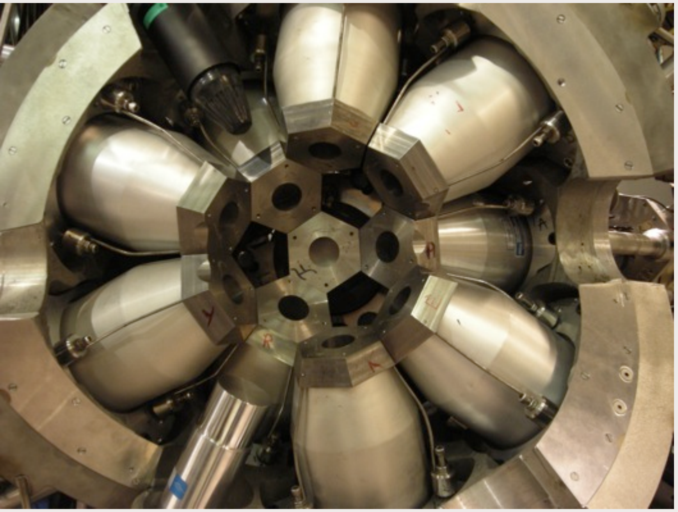






SCEPTAR: 10+10 plastic scintillators
Detects beta decays and determines branching ratios

8pi HPGe Detectors



Twenty Compton-Suppressed coaxial HPGe

Each has 20% relative efficiency, ~1% array total

1.8-2.2keV FWHM at 1.3MeV

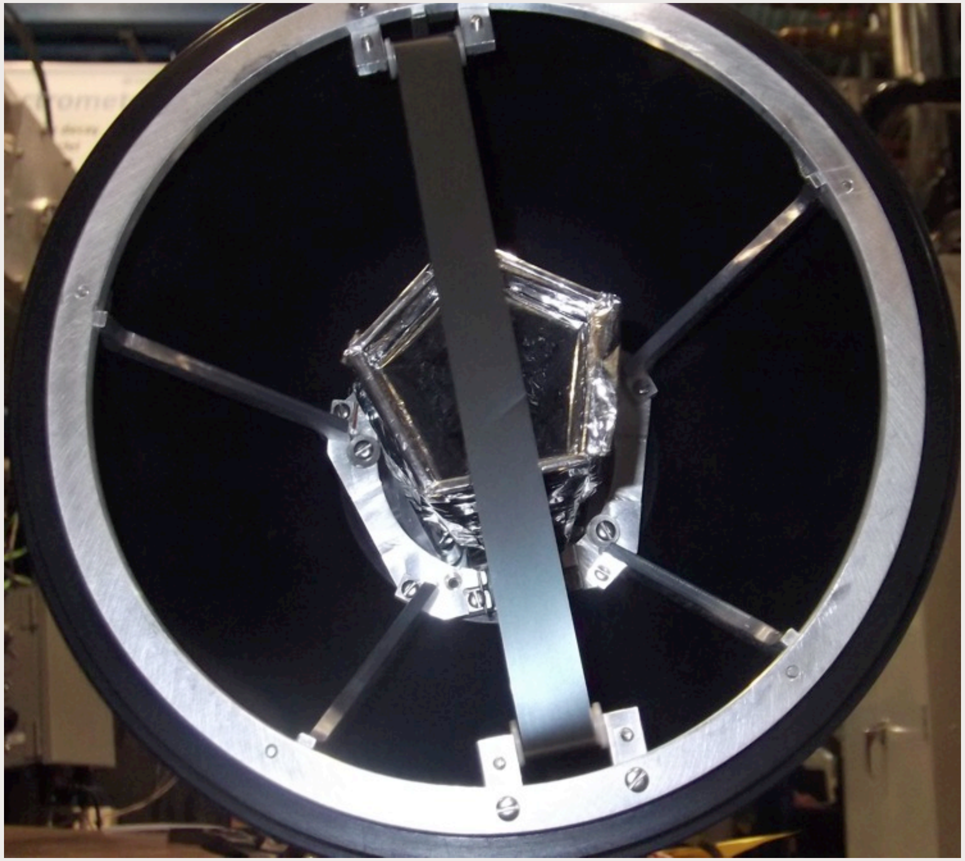
Thin Be front windows and delrin vacuum chamber to increase low-energy efficiency

Delrin absorbers to reduce Bremsstrahlung photons from high-energy beta particles

Excellent arrangement for angular distribution measurements

SCEPTAR

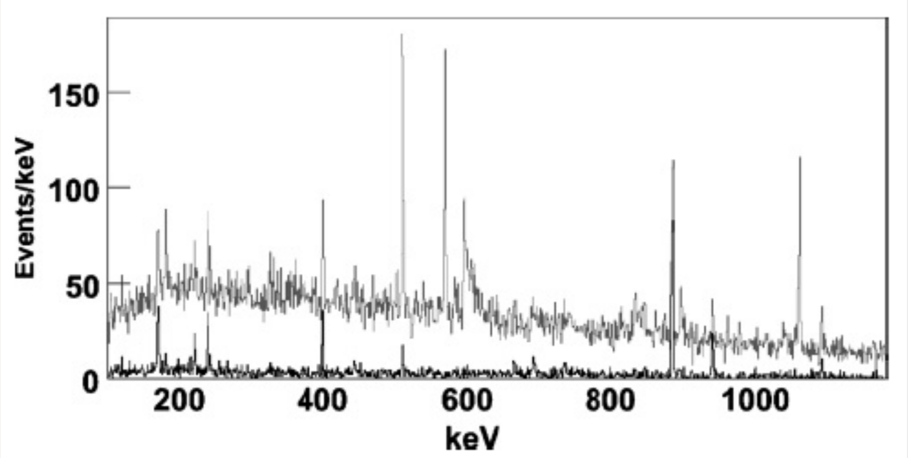
SCintillating Electron-Positron Tagging ARray



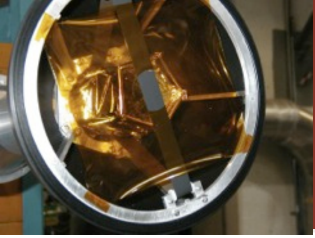
-Two hemispheres of 10 plastic scintillators

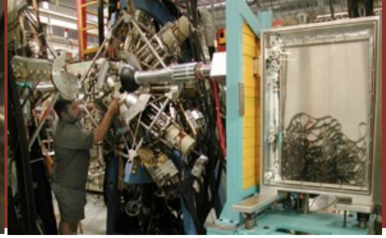
-Detect beta particles with ~80% solid angle coverage

-One-to-one correspondence with the HpGe



C.M.Mattoon et al., PRC75, 017302 (2007)





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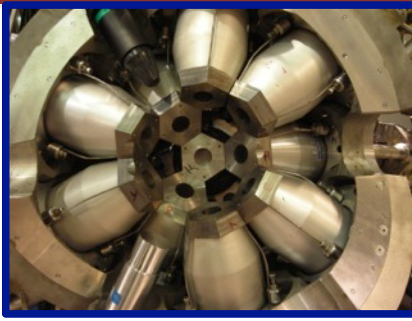
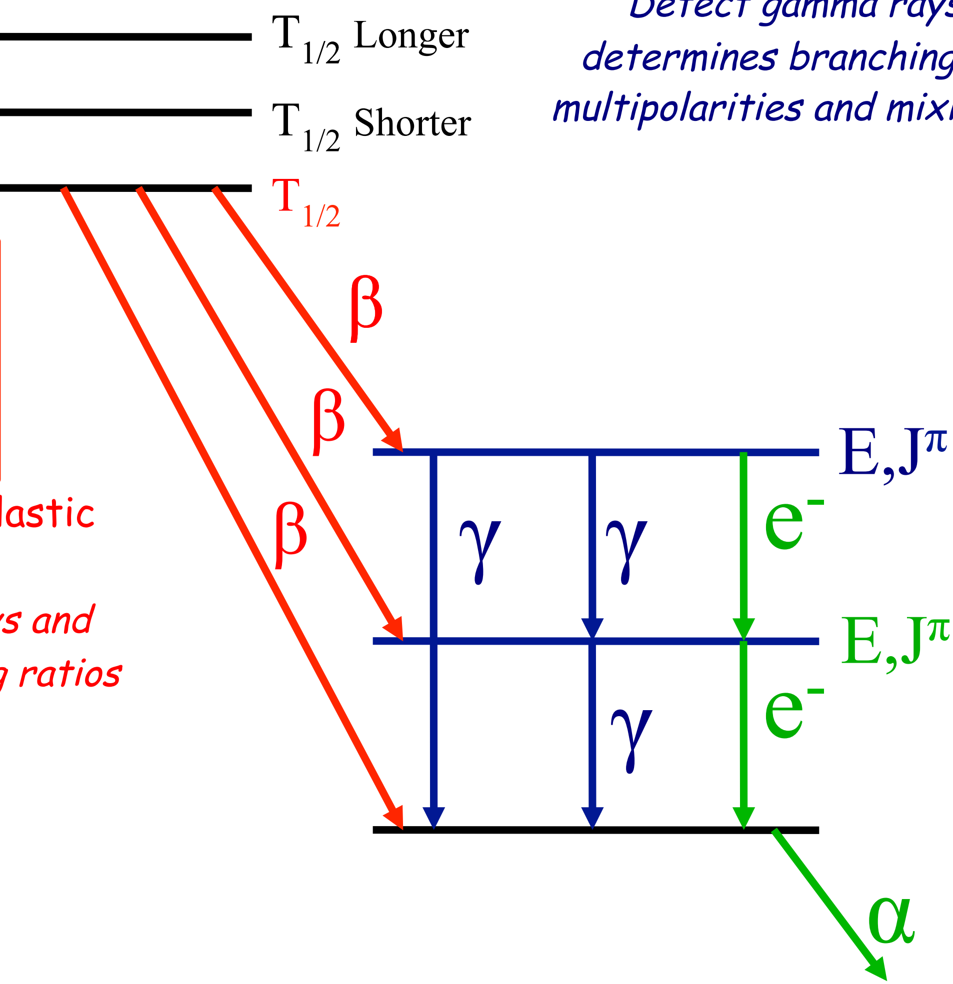
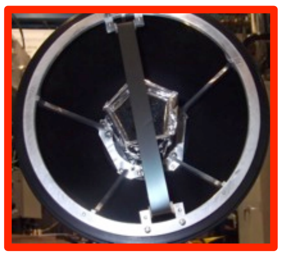
8pi Ge: 20 Compton-Suppressed HpGe
Detect gamma rays and determines branching ratios, multipolarities and mixing ratios





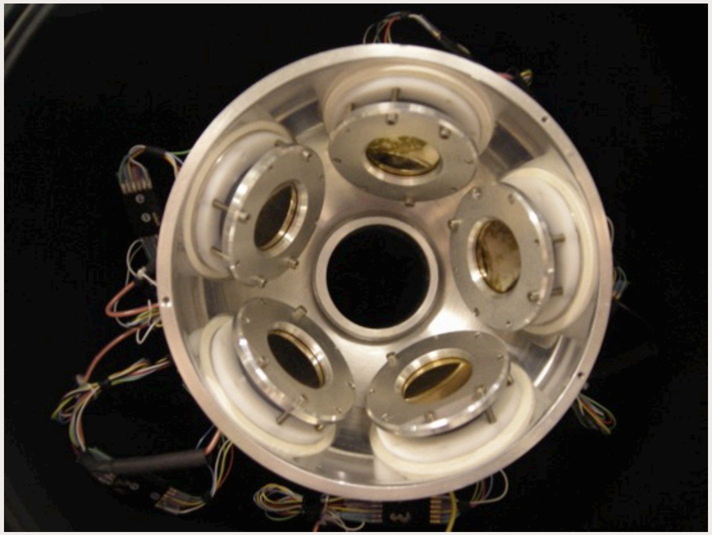


SCEPTAR: 10+10 plastic scintillators
Detects beta decays and determines branching ratios

PACES: 5 Cooled Si(Li)s
Detects Internal Conversion Electrons and alphas/protons

PACES

Pentagonal Array for Conversion Electron Spectroscopy

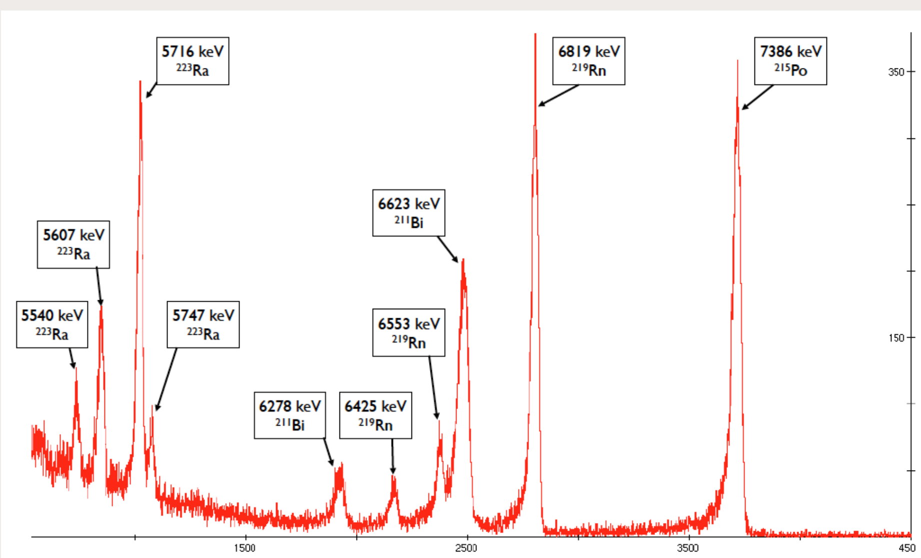


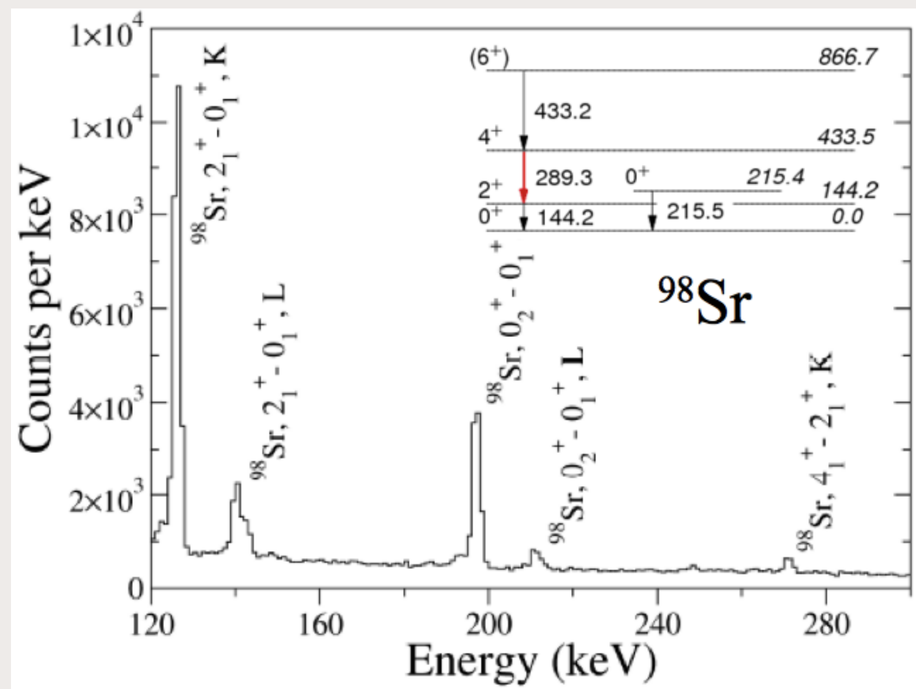
Five 5mm thick, 200mm^2 Si(Li)

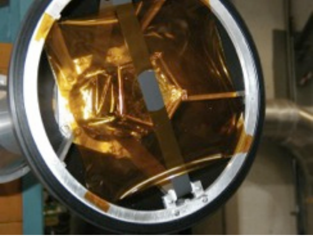
LN_2-cooled Si diode and FET

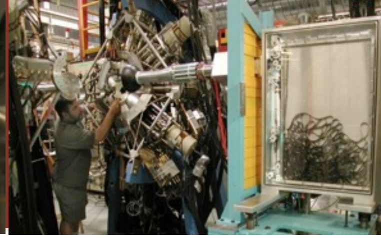
Solid angle coverage: 1.4% each, 7% total

~2keV resolution for electrons
Dual-Gain data readout – electron, alpha









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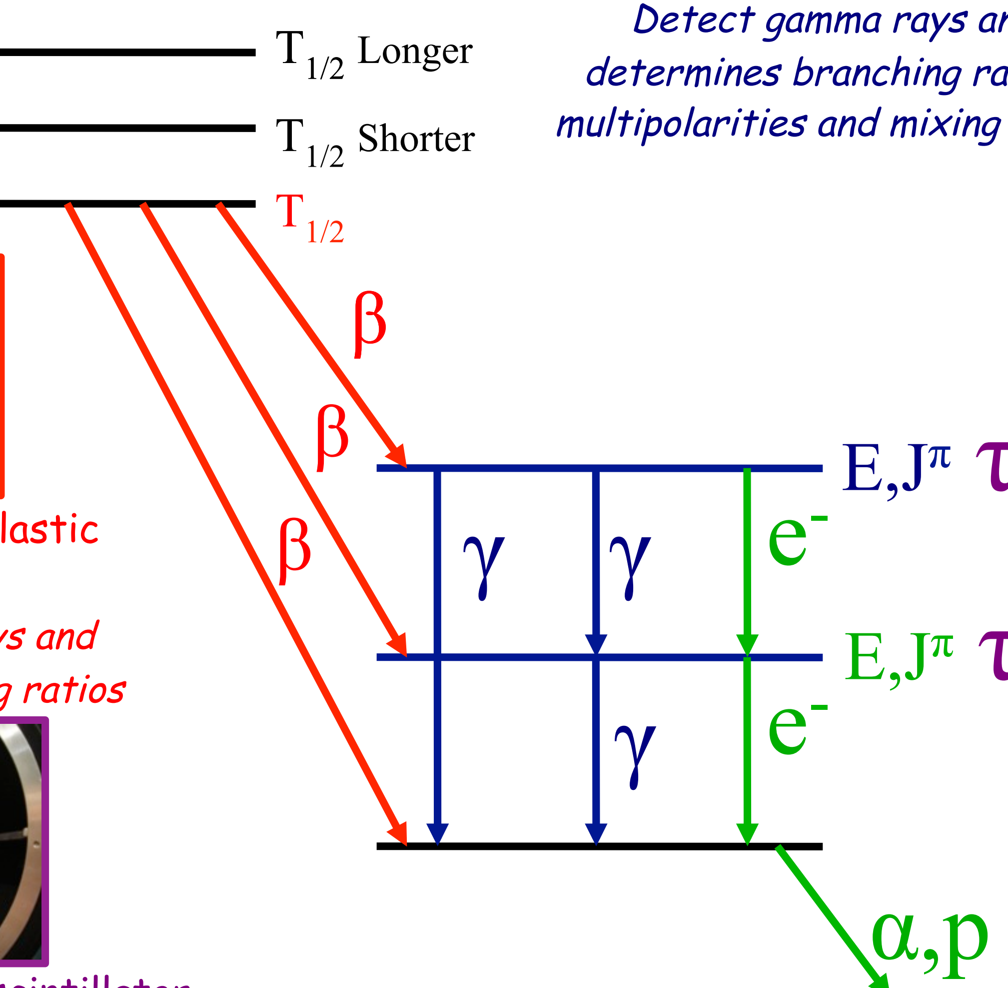

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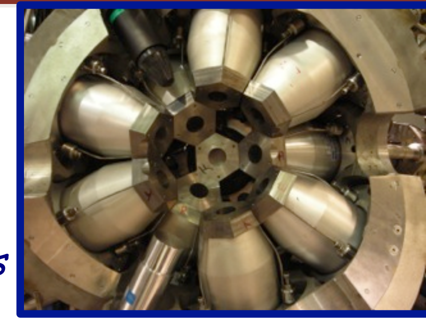

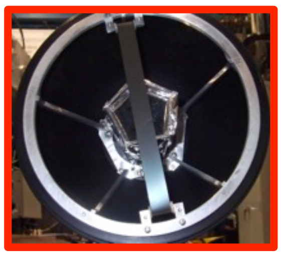

SCEPTAR: 10+10 plastic scintillators
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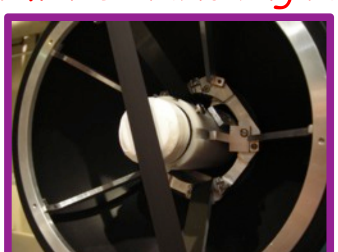
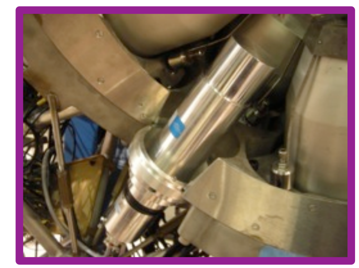
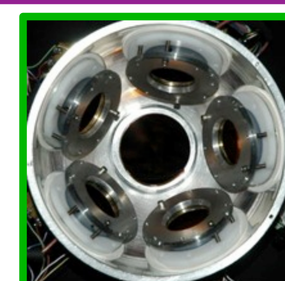


Zero-Degree Fast scintillator
Fast-timing signal for betas

DANTE: 10 $BaF_2/LaBr_3$
Fast-timing of photons to measure level lifetimes





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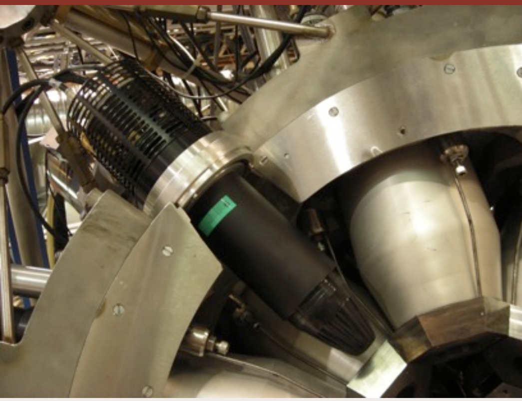
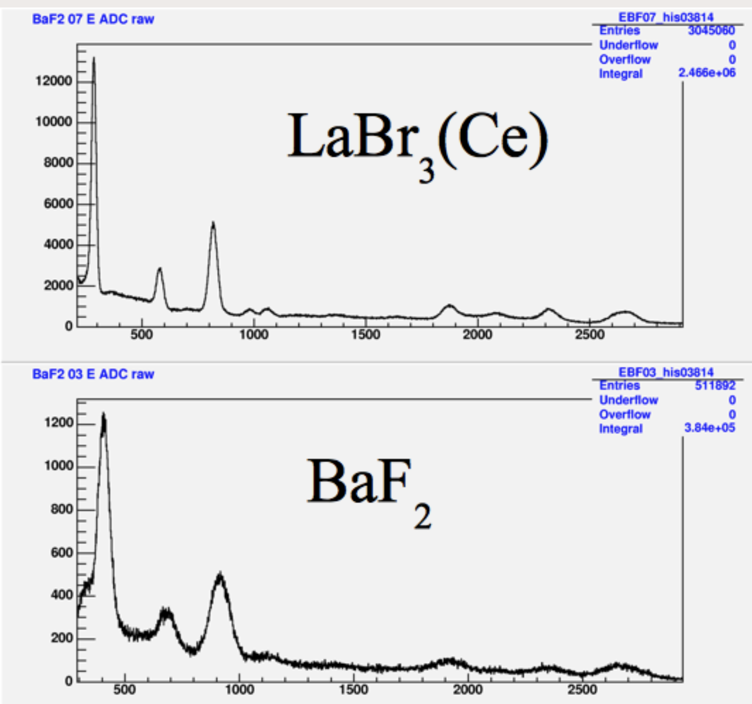
DANTE

Di-pentagonal Array for Nuclear Timing Experiments



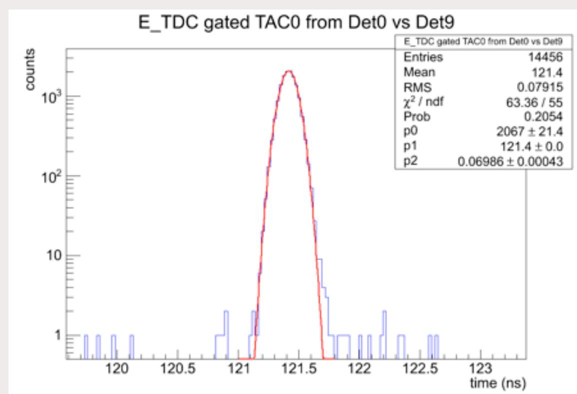
Fast-timing allows the determination of transition rates

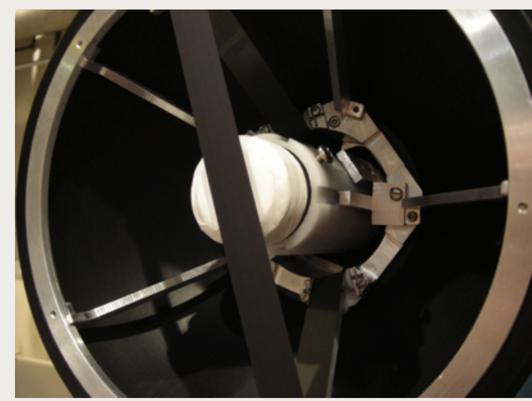
-BaF_2, truncated cone;
base 4cm, front 2cm, length 3cm
-$LaBr_3$(Ce) 2"x2" cylinder



Superior Energy resolution (x3) and efficiency (x2)

LaBr-LaBr FWHM = 165(1) ps





Fast Zero-degree scintillator for β-γ timing. BC422Q = 0.7ns

D.Cross et al., JINST 06, P08008 (2011)

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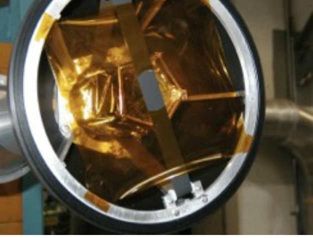

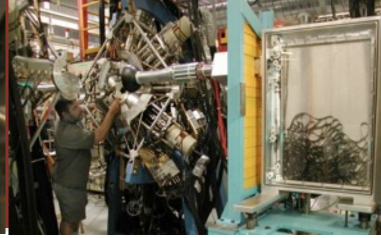

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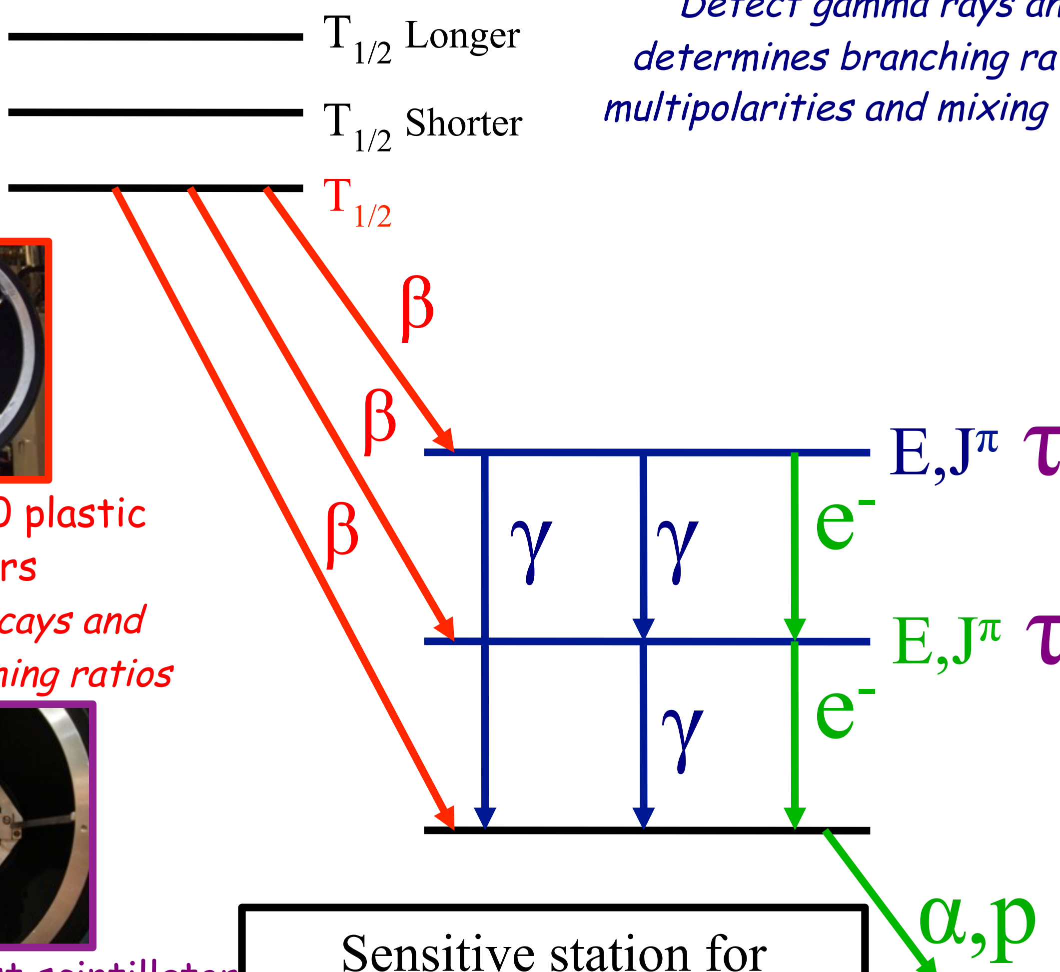

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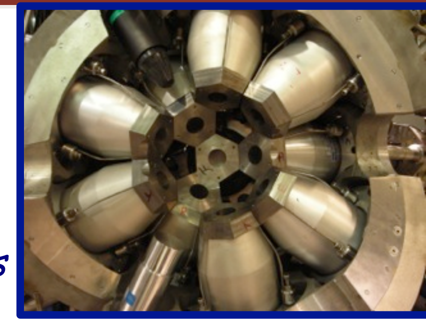

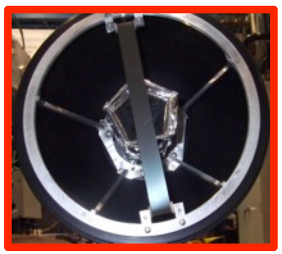

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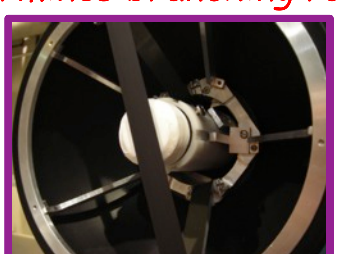

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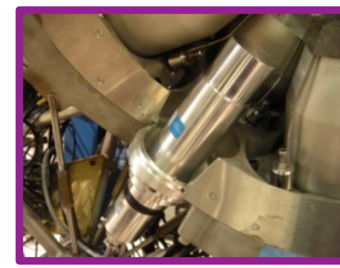
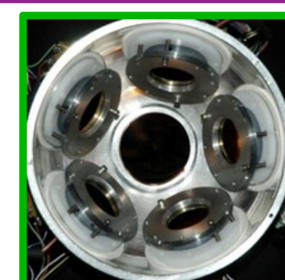
DANTE: 10 $BaF_2/LaBr_3$
Fast-timing of photons to measure level lifetimes





PACES: 5 Cooled Si(Li)s
Detects Internal Conversion Electrons and alphas/protons

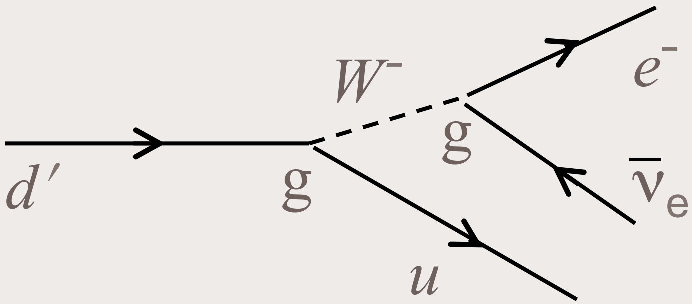
Sensitive station for studying radioactive decay

TRIUMF

The Cabibbo-Kobayashi-Maskawa (CKM) matrix

- The CKM matrix plays a central role in the Standard Model

→ and underpins all quark flavour-changing interactions:
weak interaction eigenstates ≠ quark mass eigenstates



$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$$|d'\rangle = V_{ud}|d\rangle + V_{us}|s\rangle + V_{ub}|b\rangle$$

- In the Standard Model the CKM describes a unitary transformation.

$$V_{ud}^2 + V_{us}^2 + V_{ub}^2 = 1$$

The first row of the CKM matrix provides, by far, the most demanding experimental test of this unitarity condition.

TRIUMF

V_{ud} from Superallowed Fermi β Decay

To first order, β decay ft values can be expressed as:

phase space (Q-value) → constants

half-life, branching ratio → Weak coupling strength

$$f\,t = \frac{K}{|M_{fi}|^2\, g^2}$$

↑ matrix element

For the special case of $0^+ \rightarrow 0^+$ (pure Fermi) β decays between isobaric analogue states (superallowed) the matrix element is that of an isospin ladder operator:

$$|M_{fi}|^2 = (T - T_Z)(T + T_Z + 1) = 2 \quad \text{(for T=1)}$$

Strategy: Measure superallowed ft-values, deduce G_V and V_{ud}:

Vector coupling constant → $G_V^2 = \dfrac{K}{2\,ft}$

$|V_{ud}| = G_V / G_F$ ← Fermi coupling constant

Superallowed β Decay Studies at ISAC

$T_{1/2}$, G.C. Ball *et al*, PRL 86 1454 (2001)
BR, A. Piechaczek et al, PRC 67, 051305 (2003)
BR, R. Dunlop et al, PRC 88, 045501 (2013)
Q: S. Ettenauer et al., PRL 107, 272501 (2011)
CR: E. Mané et al, PRL 107, 212502 (2011)

T$_{½}$, G.F. Grinyer, PRC 77, 201501 (2008)
BR, B.H. Hyland, PRL 97, 102501 (2006)
BR, P. Finlay PRC 78, 044321 (2008)

T$_{½}$ and BR

BR, K.G. Leach et al., PRL 100, 192504 (2008)
$T_{1/2}$, G.C. Ball *et al*, PRC 82, 045501 (2010)

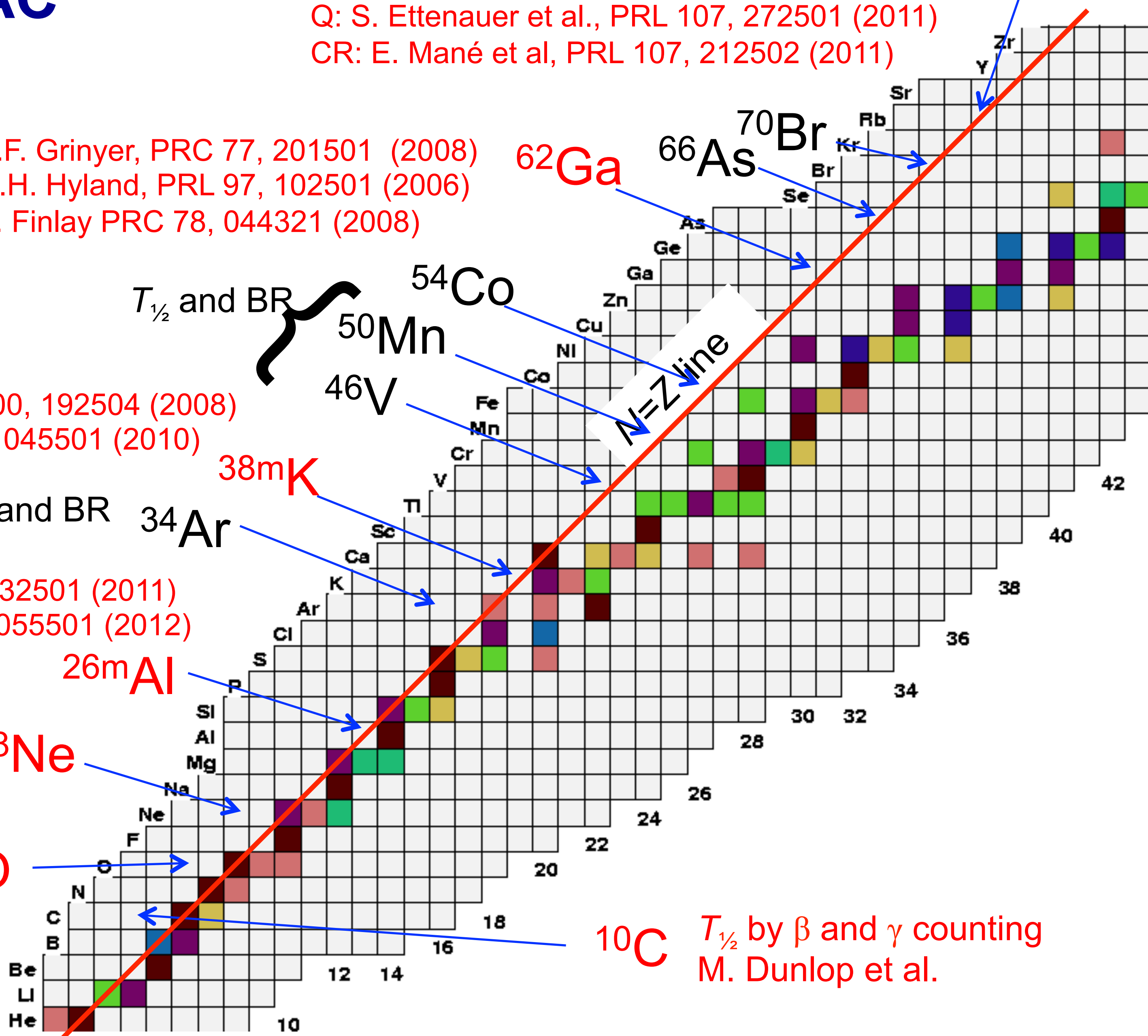
T$_{½}$ and BR

T$_{½}$ P. Finlay et al, PRL 106, 032501 (2011)
BR, P. Finlay et al, PRC 85, 055501 (2012)

T$_{½}$, G.F. Grinyer et al,
PRC 76, 025503 (2007)
PRC 87, 045502 (2013)

T$_{½}$, A.T. Laffoley et al,
PRC 88, 015501 (2013)

T$_{½}$ by β and γ counting
M. Dunlop et al.

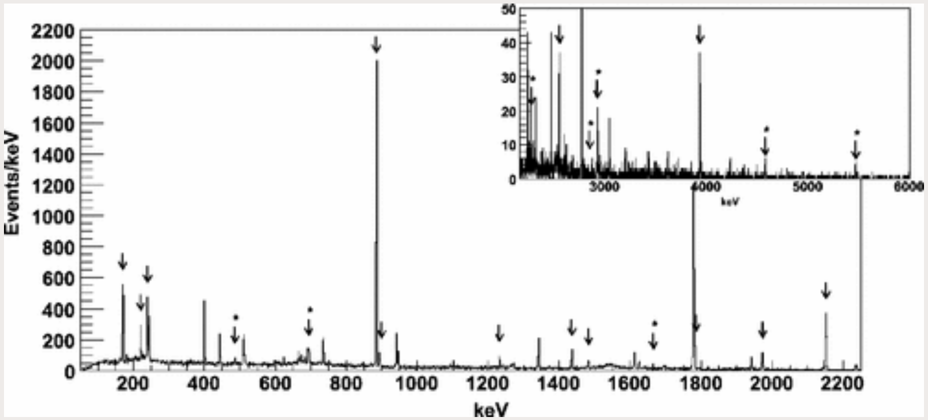


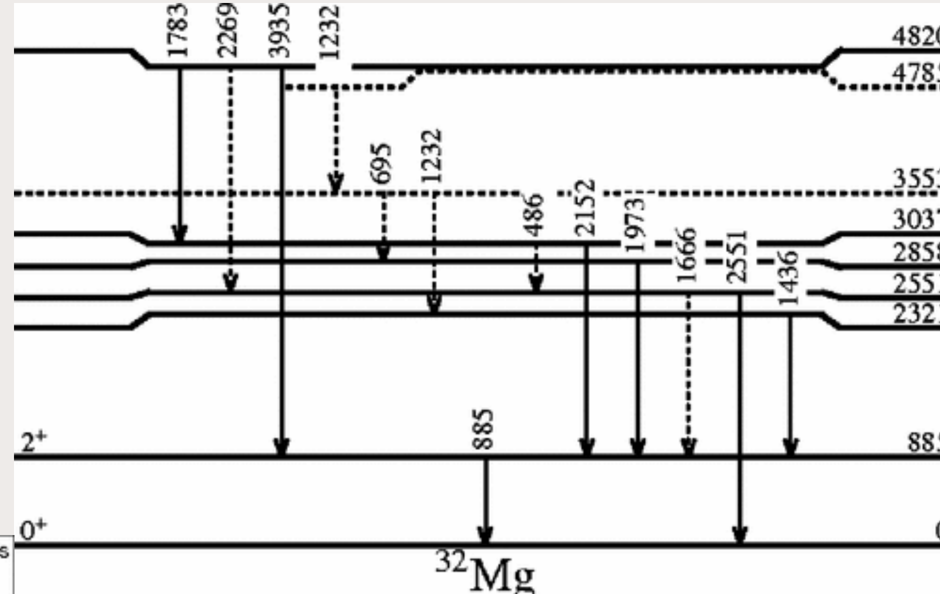
TRIUMF

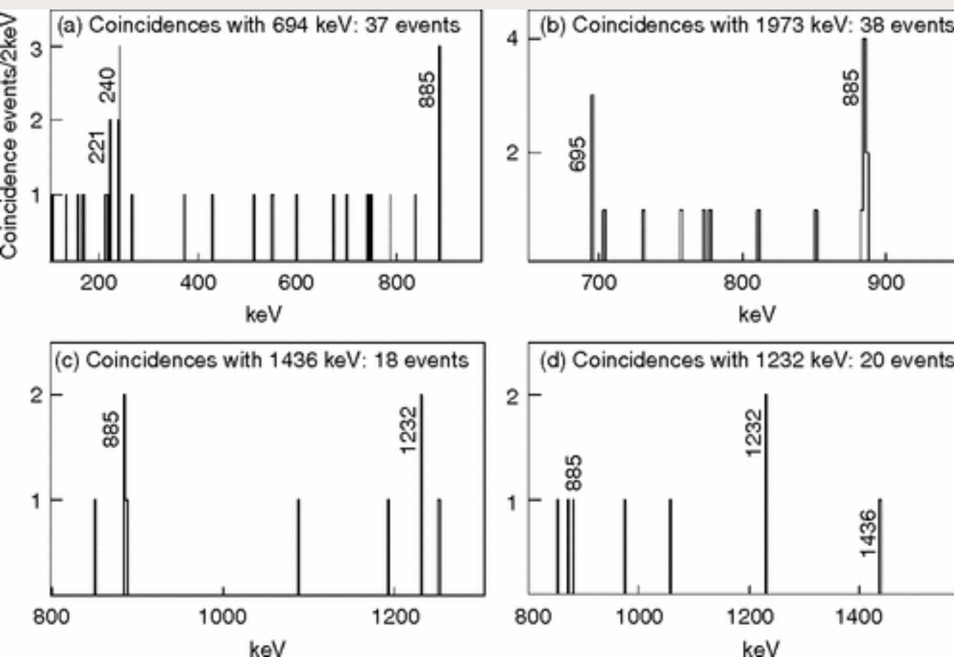
Nuclear Structure Studies with the 8pi Spectrometer

Beam Intensity	Beam Species	
2-3 pps	^{32}Na	Build level scheme with gamma-gamma coincidences
6 pps	^{102}Sr	
10^4 pps	^{11}Li	
10^5 pps	^{174m}Tm	
10^6 pps	^{94}Y/Sr/Rb	Identity weak branches, angular correlations
10^6 pps	^{98}Y/Sr/Rb	
10^7 pps	^{179m}Lu	
10^9 pps	^{110,112,116}In, ^{110,112}Ag ^{124}Cs	Identity very weak branches

Island of Inversion – Level scheme of ^{32}Mg



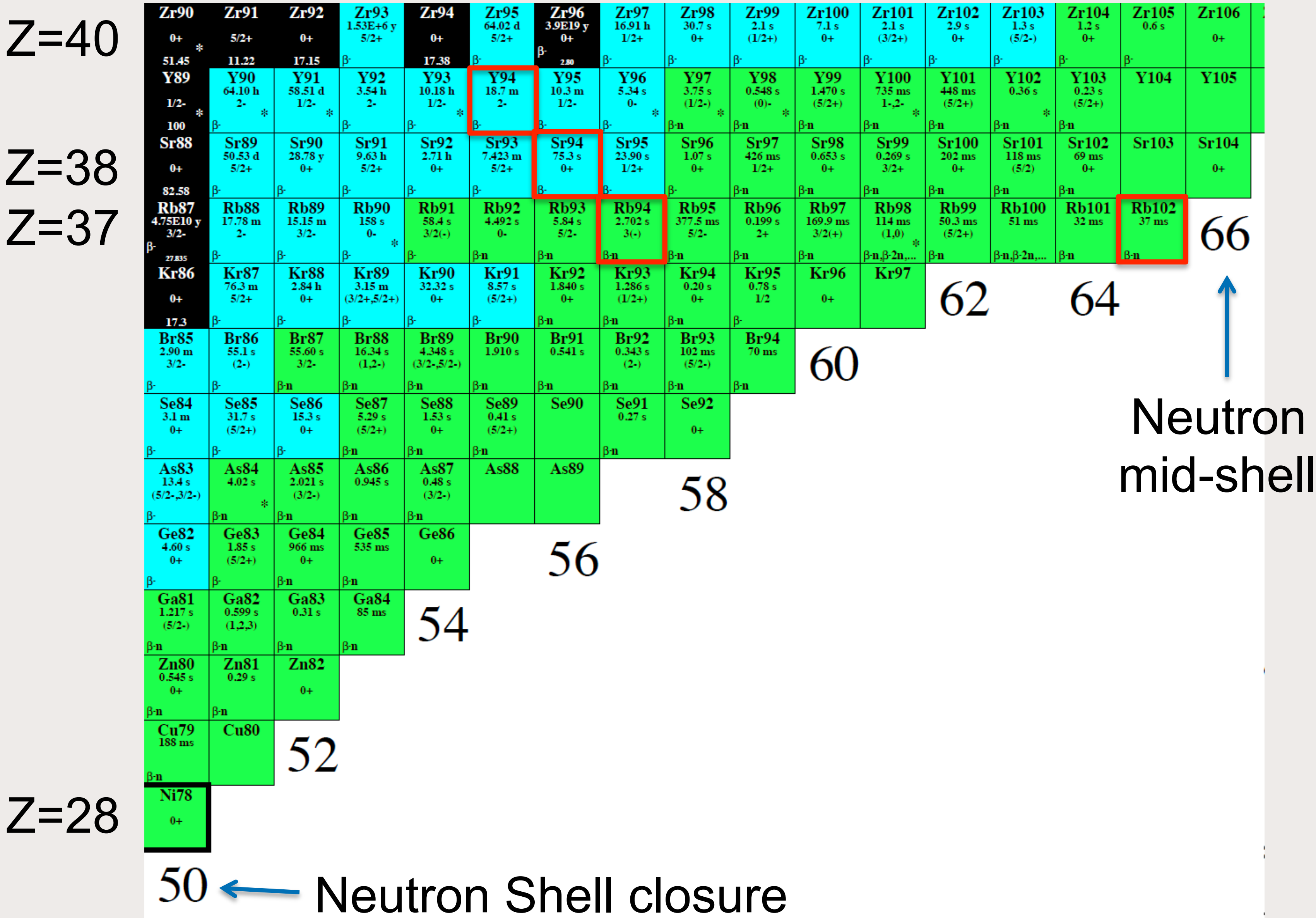




- Beam of ^{32}Na at 2-3 pps
- Built level scheme from coincidences, new levels identified
- Spin assignments not possible

C.M. Mattoon *et al.*, Phys. Rev. C 75, 017302 (2007)

Neutron-Rich Rb Isotopes



TRIUMF

Decay of ^{102}Rb

Z.M. Wang *et al., to be published*

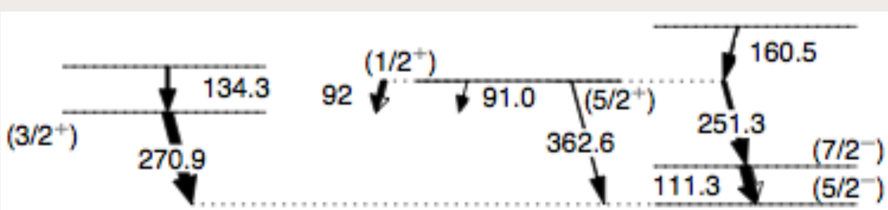
^{102}Rb beam at 6 pps

^{101}Sr populated in beta-delayed neutron emission

Level scheme consistent with previous beta-decay study

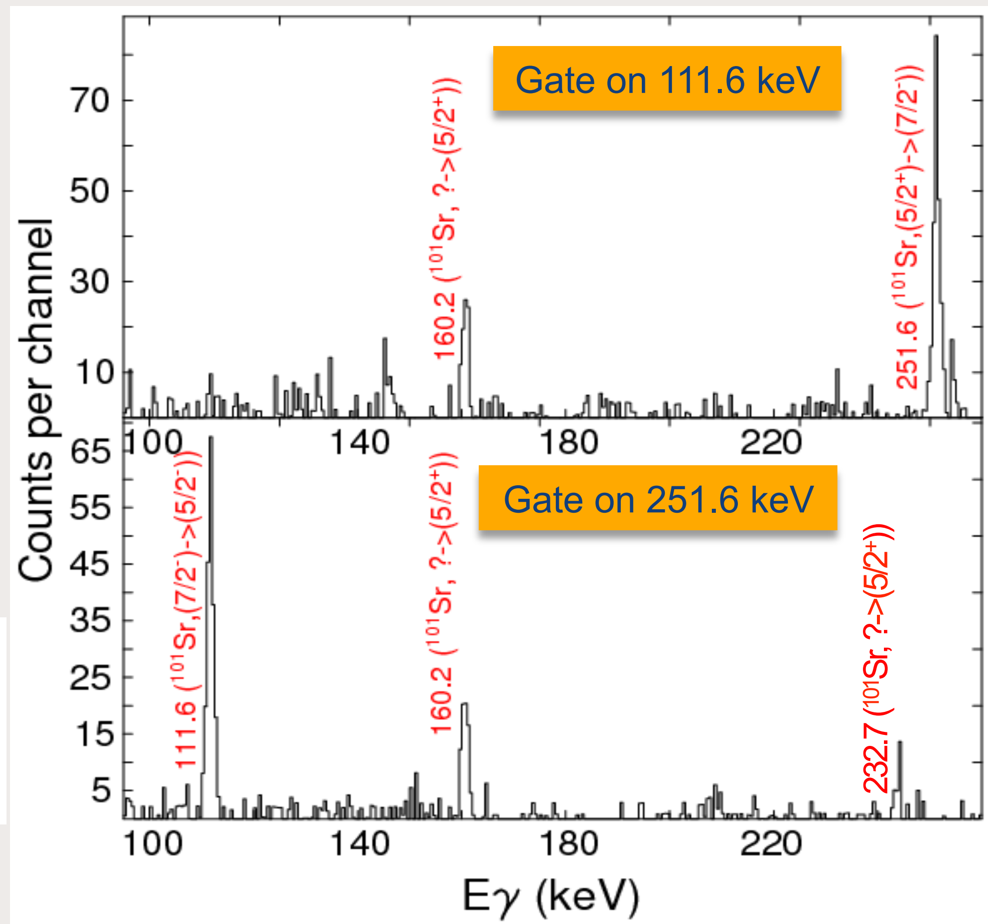
Lhersonneau *et al.*, Z. Phys. A 351, 357 (1995).

Confirmed tentative 134, 161keV transitions



$^{102}Rb \rightarrow ^{101}Sr$

Gamma-gamma coincidence



Decay of ^{102}Rb

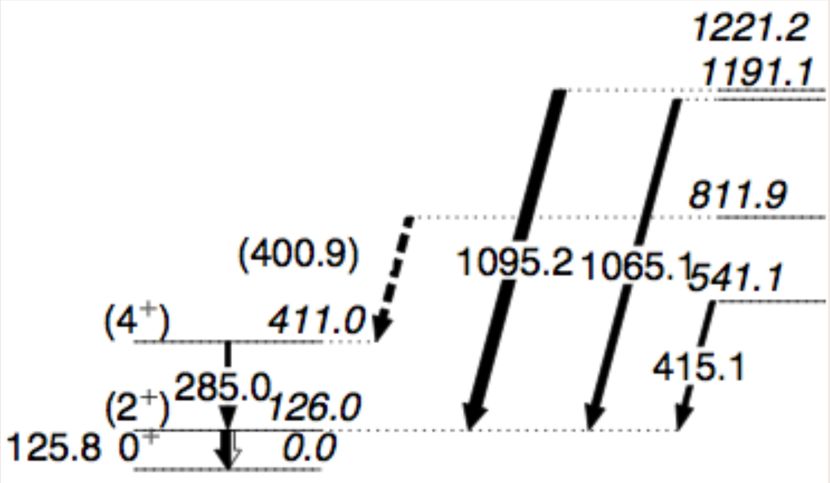
Z.M. Wang *et al., to be published*

^{102}Sr populated in beta-decay

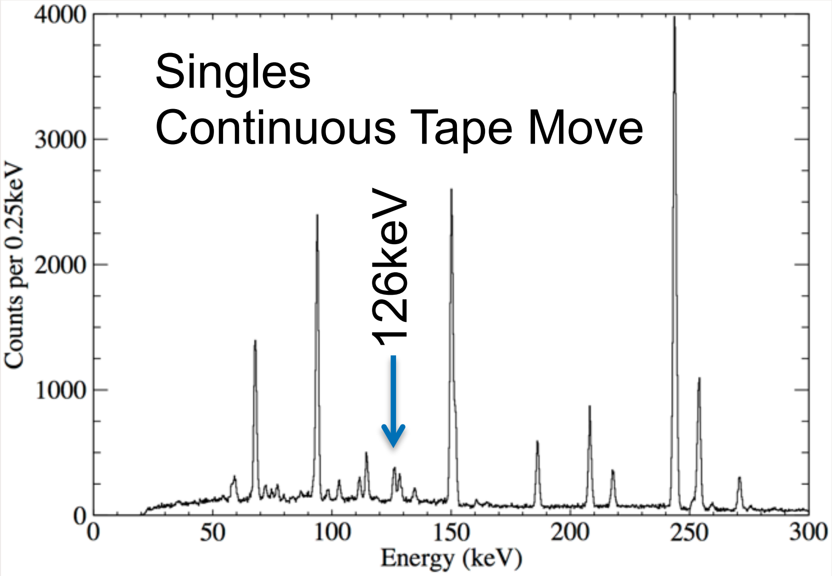
Previously only 126keV known

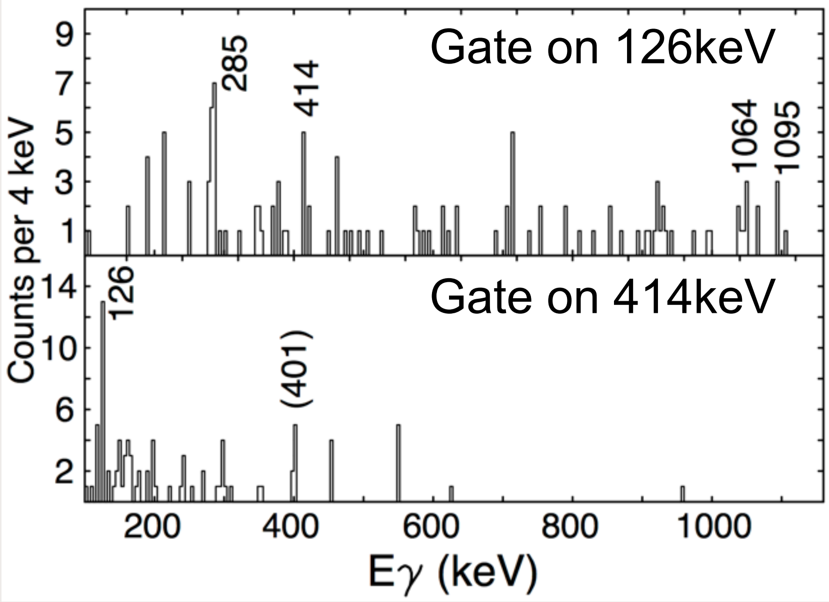
Lhersonneau *et al.*, Z. Phys. A 351, 357 (1995).

E(4+)/E(2+) = 3.26

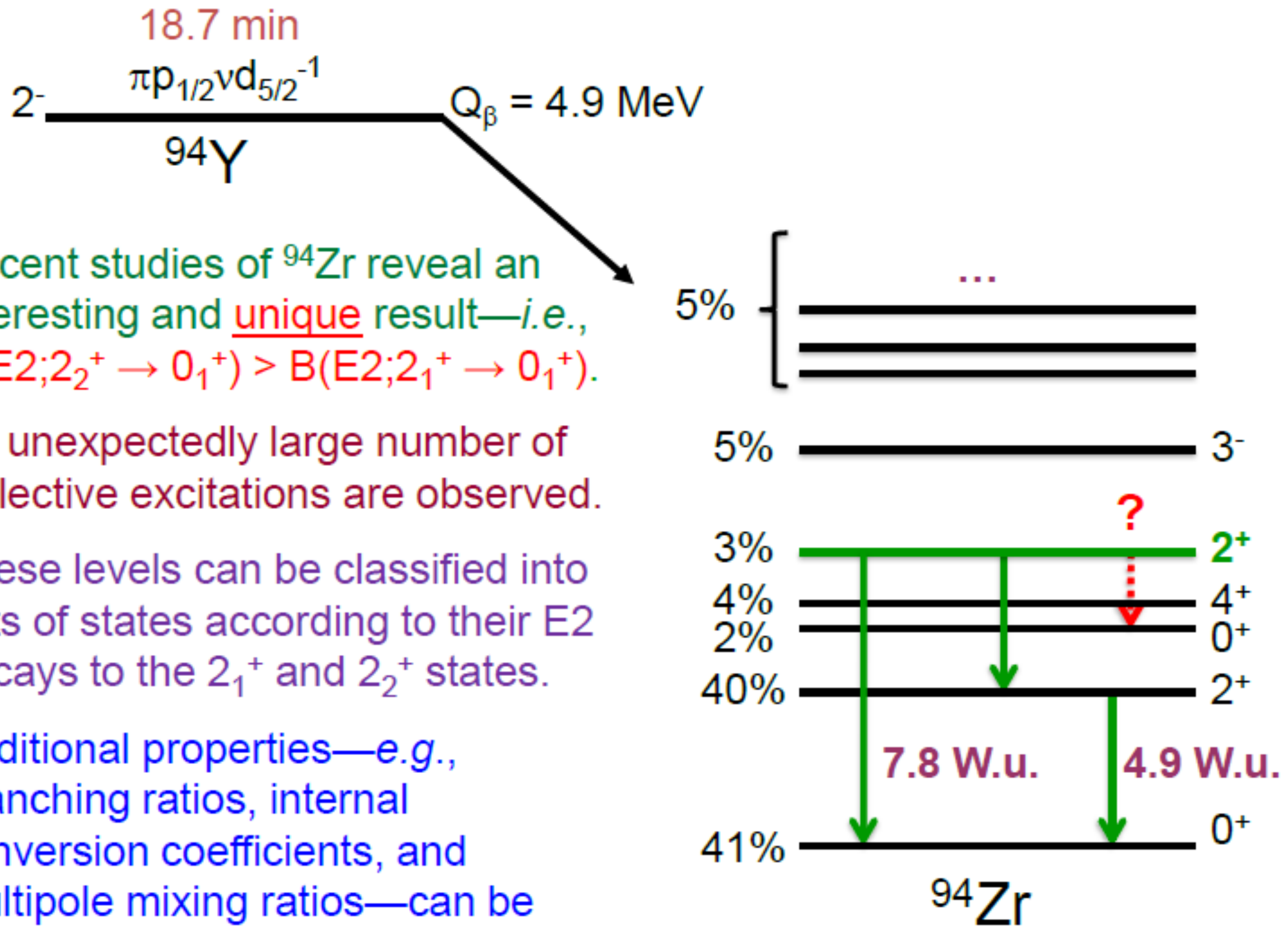


^{102}Rb → ^{102}Sr



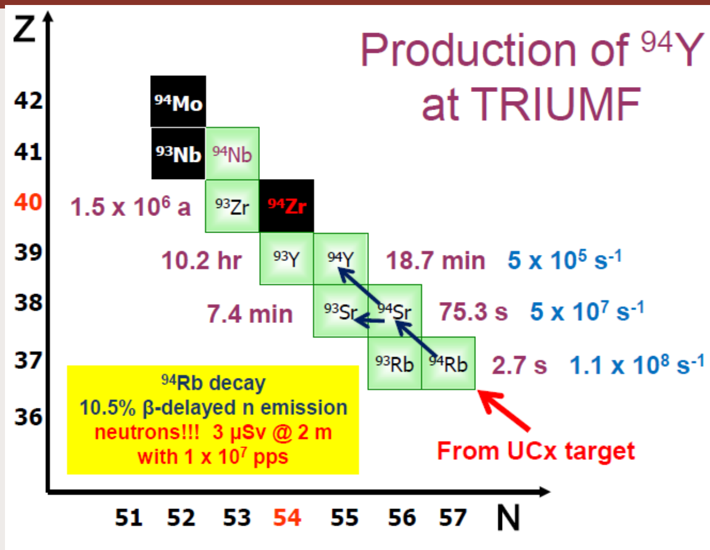


β-decay of ^{94}Y: the anomalous structure of ^{94}Zr: *Yates et al Aug 2011*

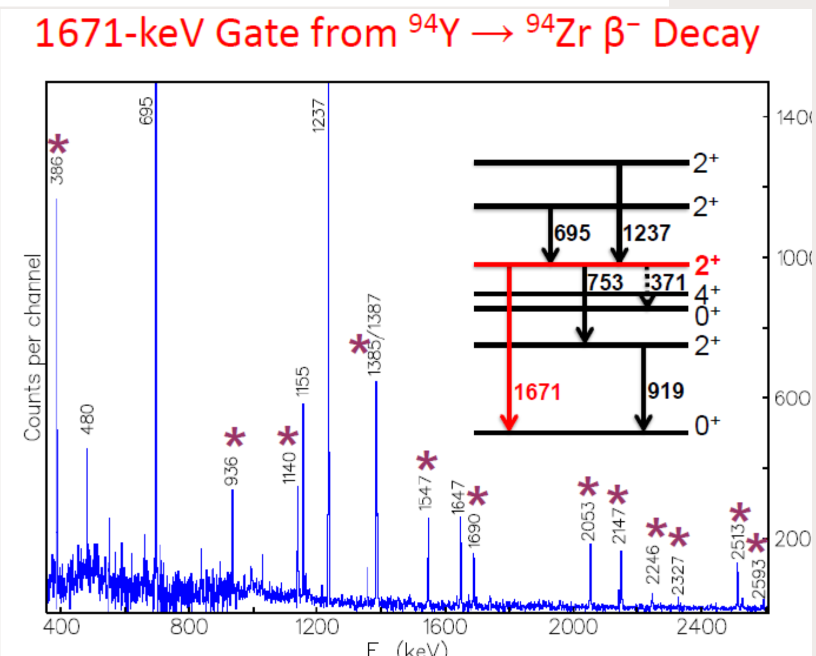


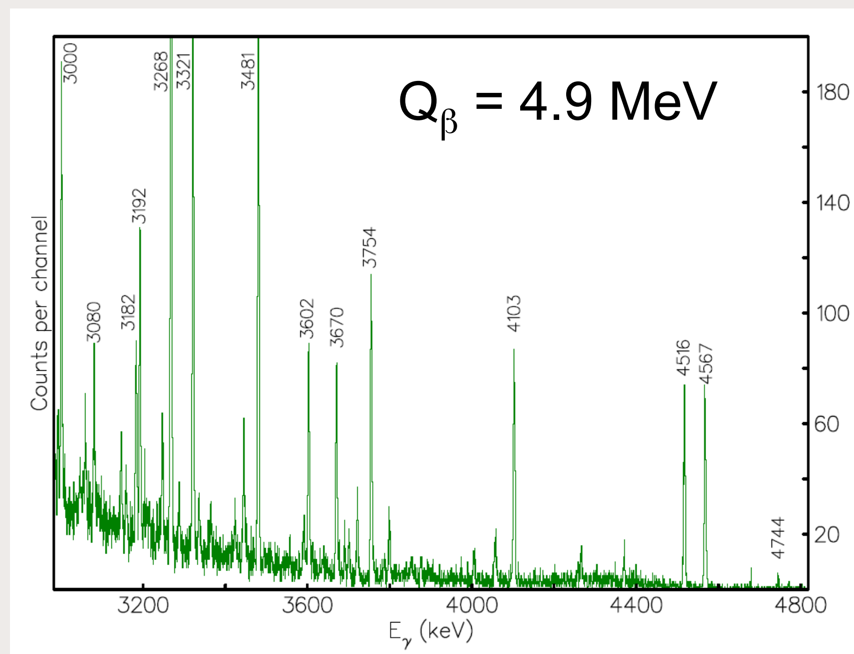
- Recent studies of ^{94}Zr reveal an interesting and unique result—*i.e.*, $B(E2;2_2^+ \rightarrow 0_1^+) > B(E2;2_1^+ \rightarrow 0_1^+)$.
- An unexpectedly large number of collective excitations are observed.
- These levels can be classified into sets of states according to their E2 decays to the 2_1^+ and 2_2^+ states.
- Additional properties—*e.g.*, branching ratios, internal conversion coefficients, and multipole mixing ratios—can be measured with the 8π and the auxiliary detection systems.

the anomalous structure of ^{94}Zr

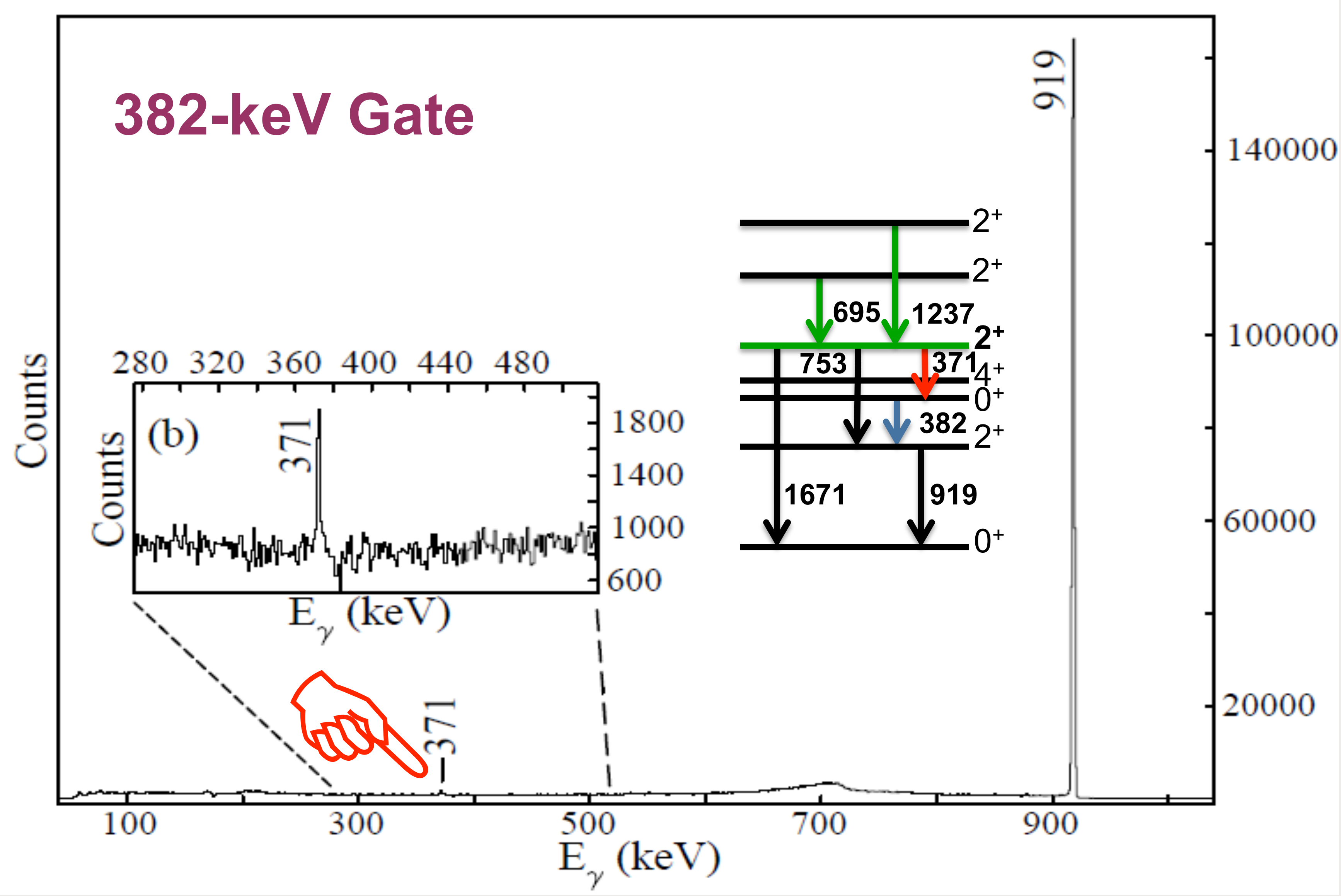


- high- statistics γ-γ data set enables search for weak transitions
- gamma rays from high lying states near Qβ were observed
- large number of new transitions populating the second 2+ level

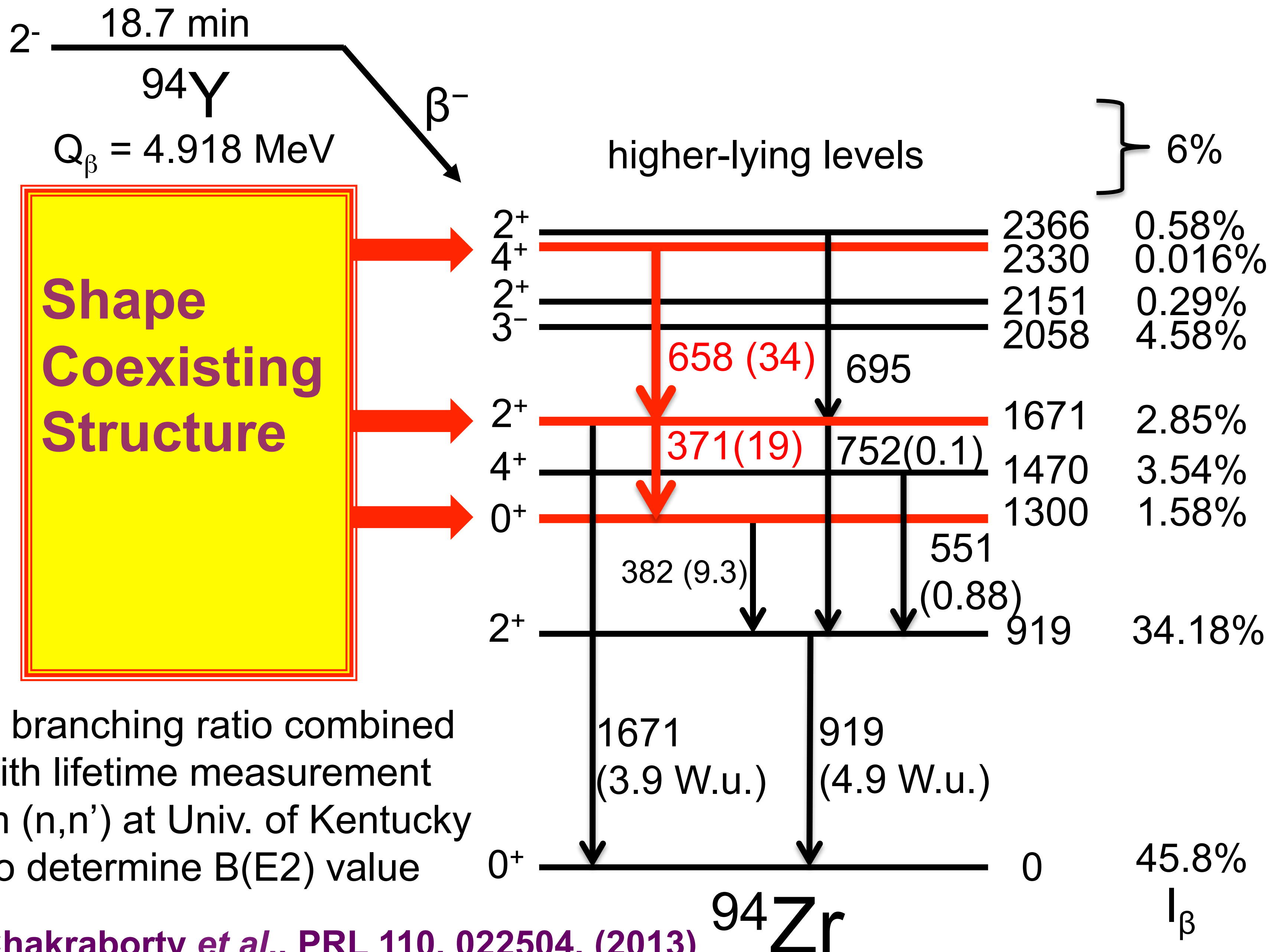




the anomalous structure of ^{94}Zr



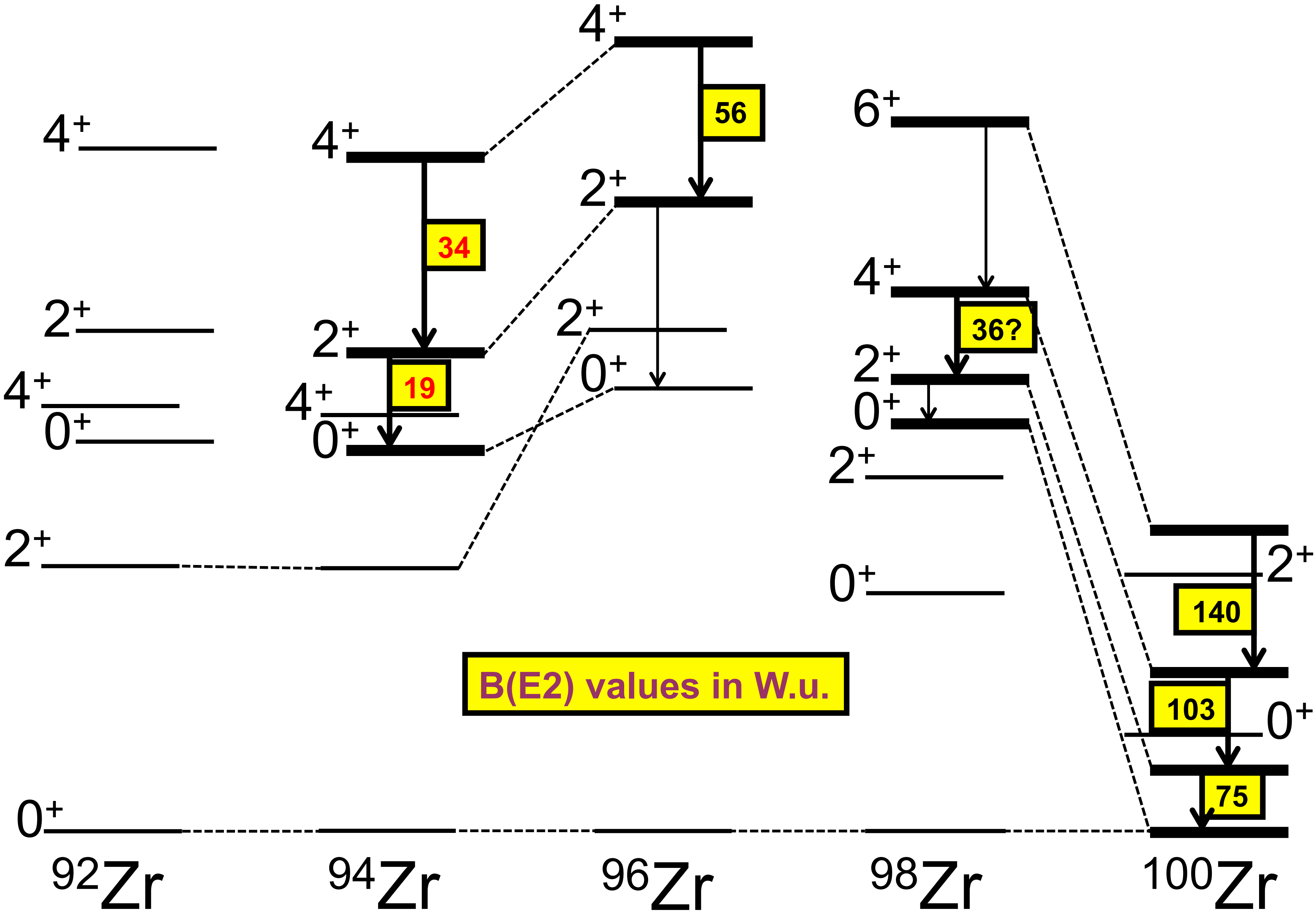
Coexisting structures in ^{94}Zr



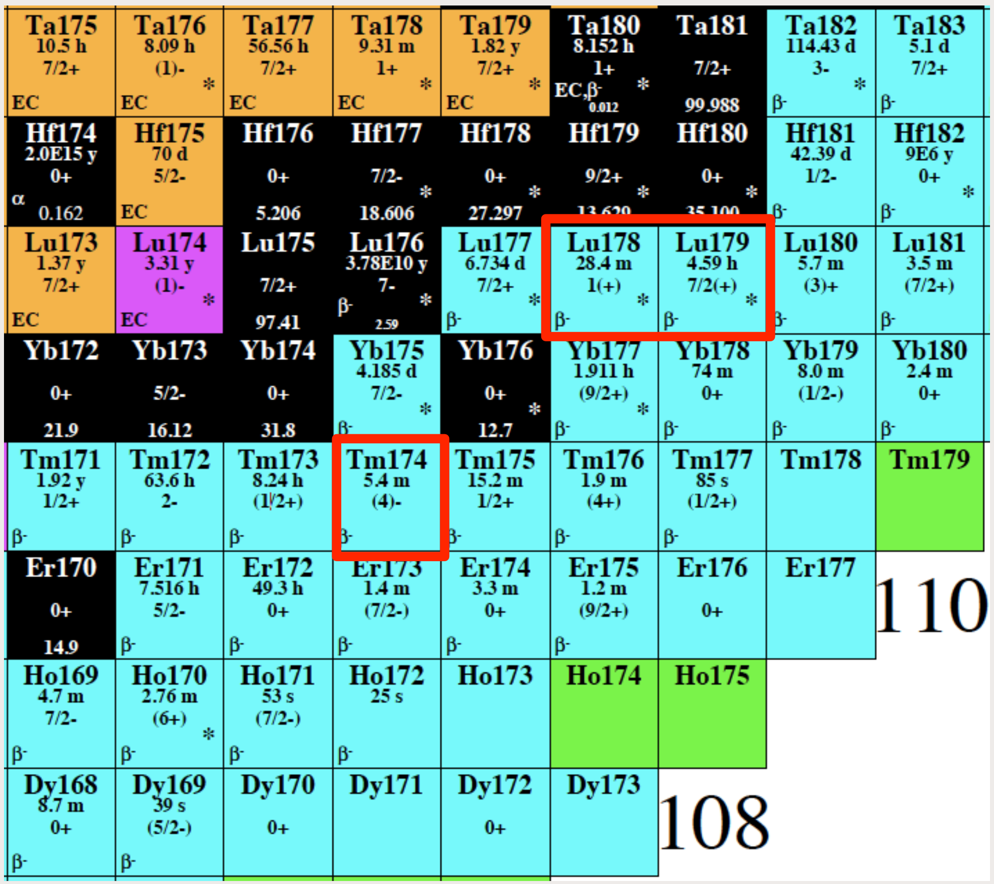
8pi branching ratio combined with lifetime measurement from (n,n') at Univ. of Kentucky to determine B(E2) value

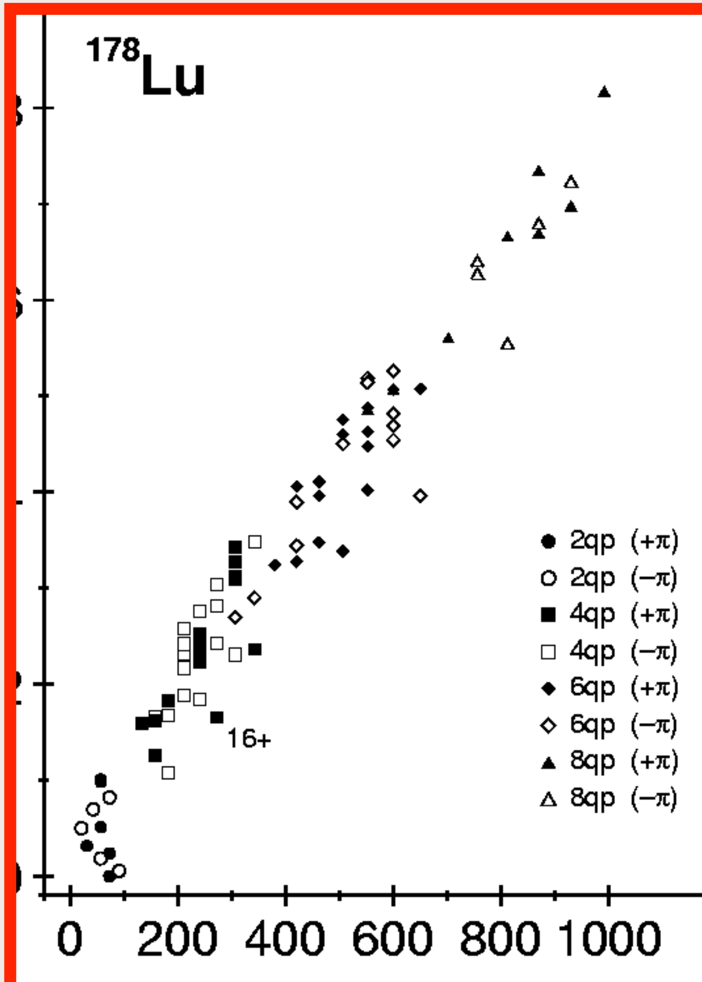
A. Chakraborty *et al.*, PRL 110, 022504, (2013)

Coexisting Structures in ^{94}Zr



Search for high-*K* isomers





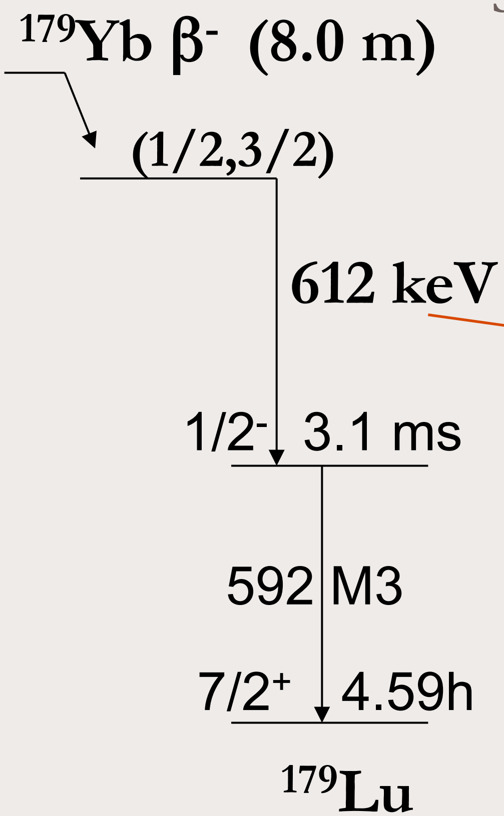
500 MeV protons on Ta ISOL target with surface ion source

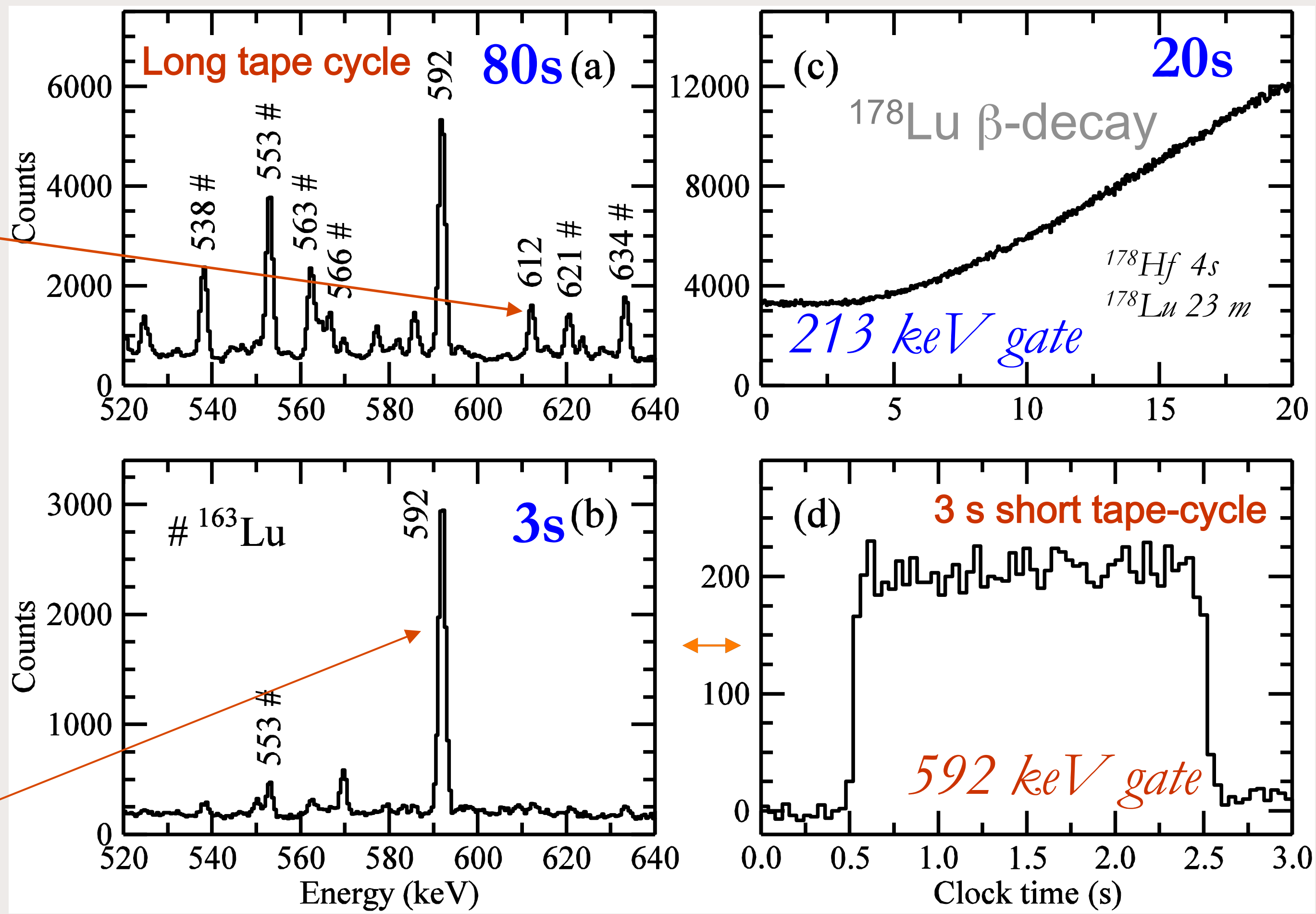
Suggested isomers in both ^{178}Lu and ^{179}Lu (high *K*, low E_x)

Possible $T_{1/2}$'s of ms to 500s

3.1 ms ^{179}Lu isomer beam

Surprise: Fast diffusion of Lu from the target, a new record for ISAC

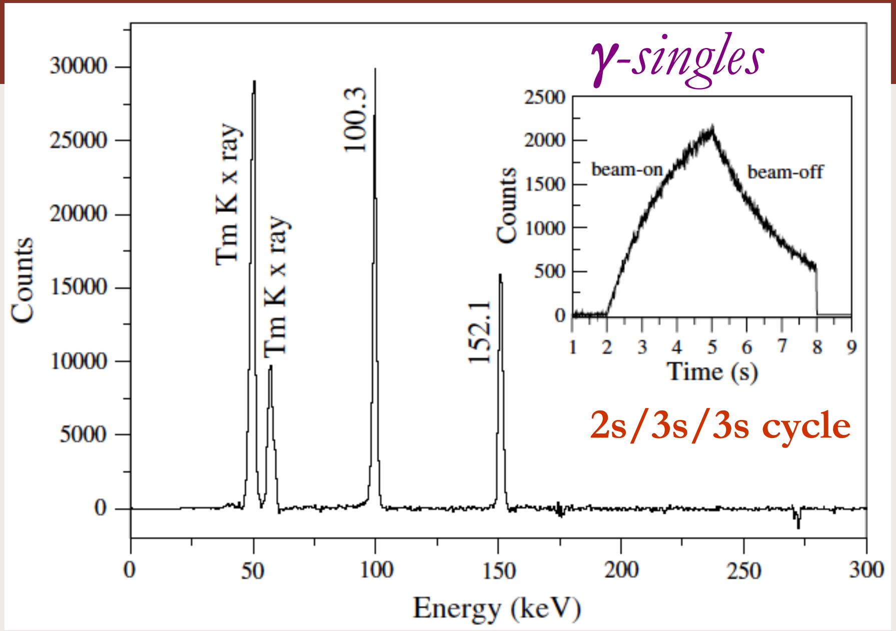




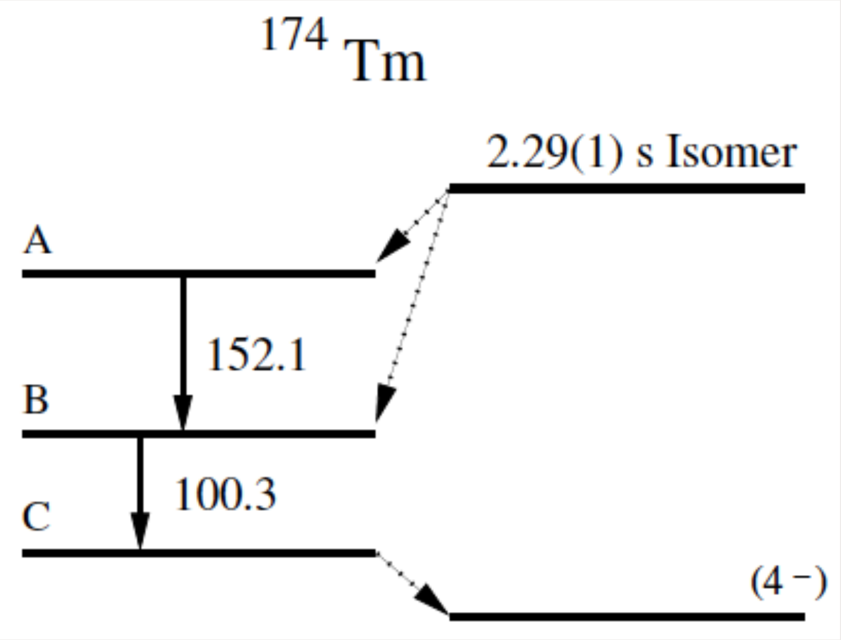
Activity vs Clock consistent with its population directly from the ion-source

Smith, Walker, Chakrawarthy et al. Nuc. Phys. A 746, 617c (2004)

Previously unidentified Isomer in ^{174}Tm

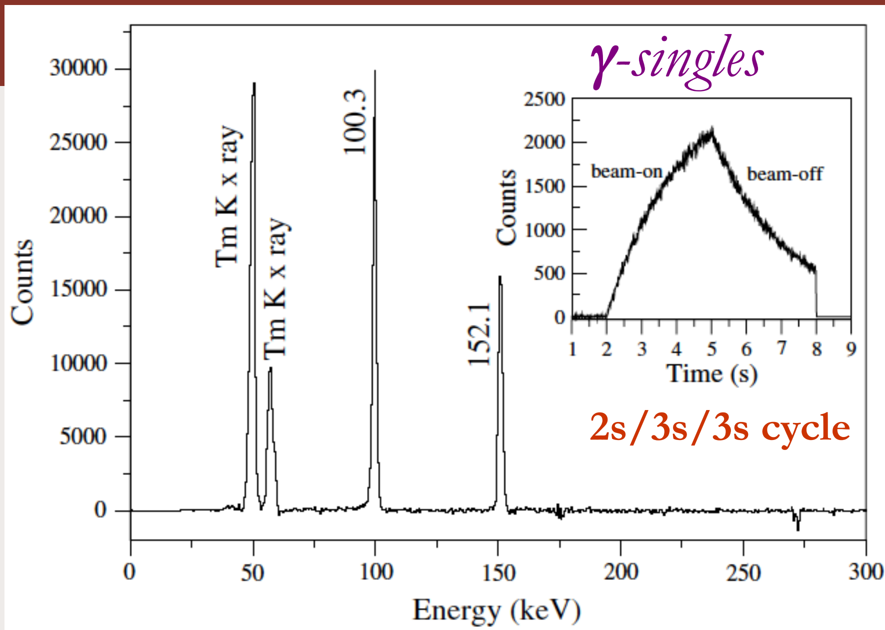


A=174 beam mainly Lu (142 d/3yr) and some Tm GS (5.4 m).

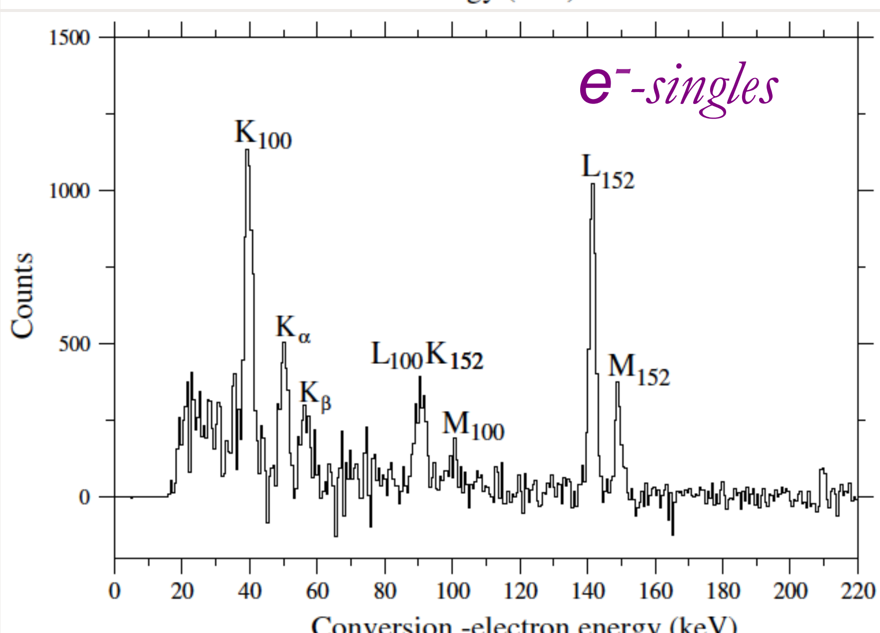


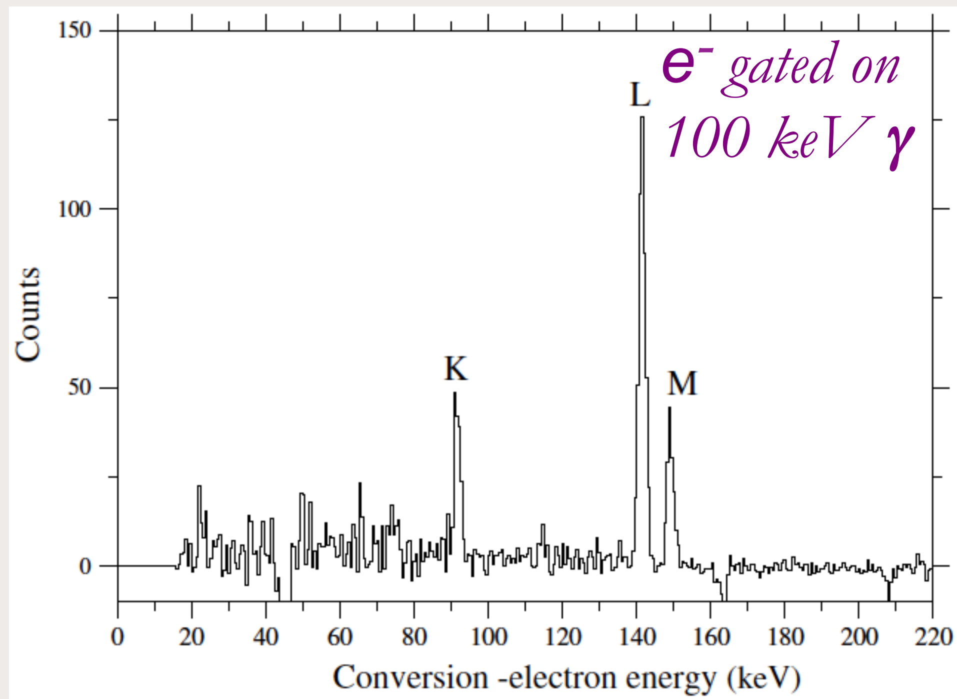
R.S. Chakrawarthy et al., Phys.Rev. C 73, 024306 (2006)
R.S. Chakrawarthy et al., Eur.Phys.J. A 25, Sup. 1, 125 (2005)

Previously unidentified Isomer in ^{174}Tm



A=174 beam mainly Lu (142 d/3yr) and some Tm GS (5.4 m).



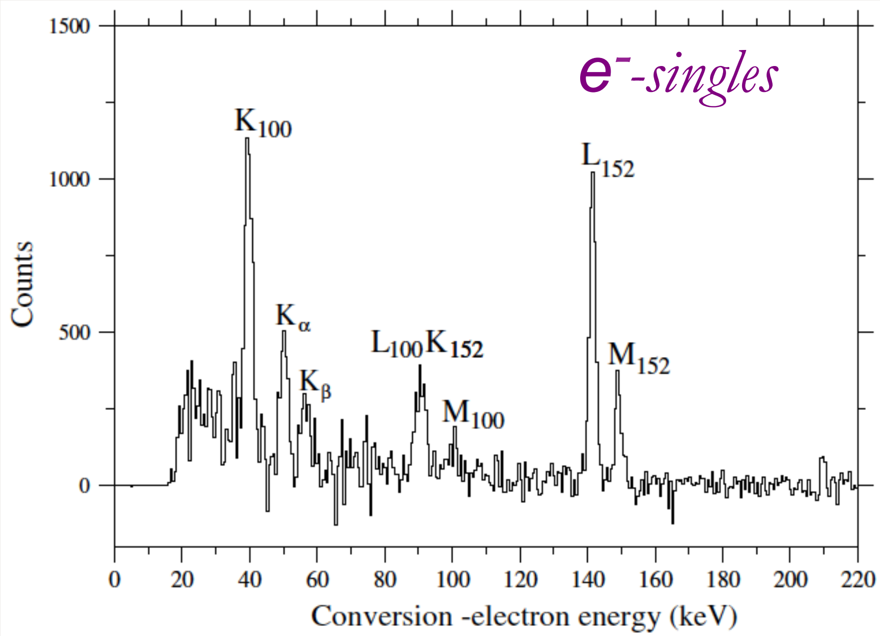


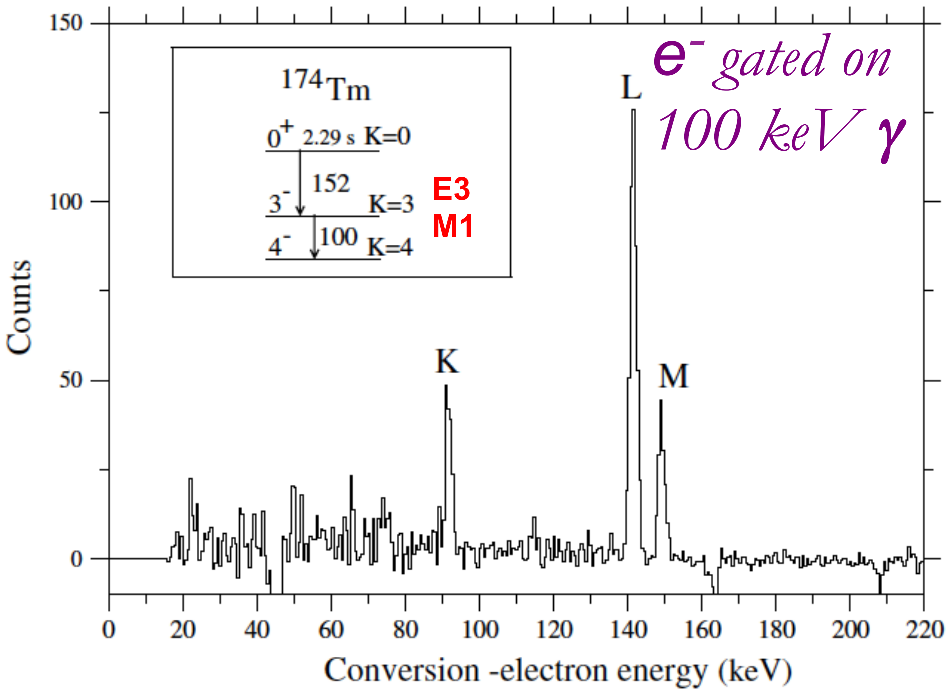
R.S. Chakrawarthy et al., Phys.Rev. C 73, 024306 (2006)
R.S. Chakrawarthy et al., Eur.Phys.J. A 25, Sup. 1, 125 (2005)

Previously unidentified Isomer in ^{174}Tm

E_γ (keV)	Expt. ICC	Theo. ICC
152.1	α_K 1.13 ± 0.06	α_K (*E3*) 1.18
	α_L 3.31 ± 0.48	α_L (*E3*) 4.10
	α_M 1.10 ± 0.12	α_M (*E3*) 0.99
100.3	α_K 3.10 ± 0.01	α_K (*M1*) 2.66
	α_L 0.45 ± 0.10	α_L (*M1*) 0.40
	α_M 0.14 ± 0.03	α_M (*M1*) 0.09

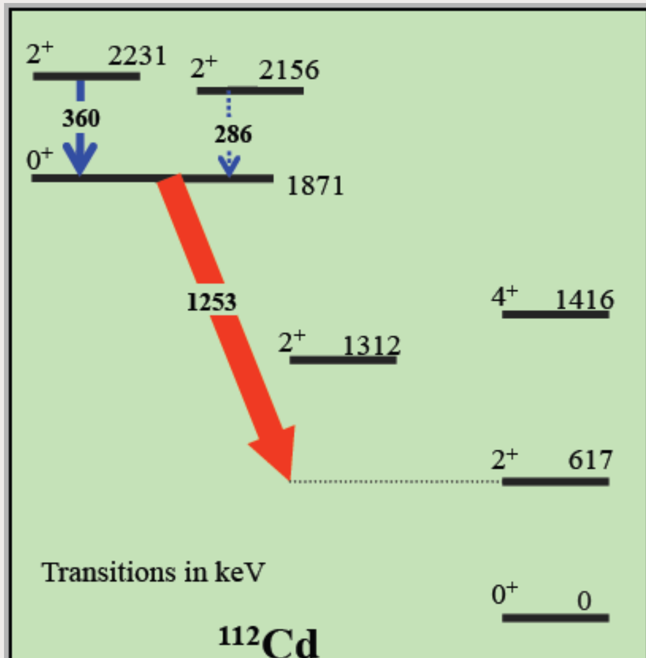
A=174 beam mainly Lu (142 d/3yr) and some Tm GS (5.4 m).

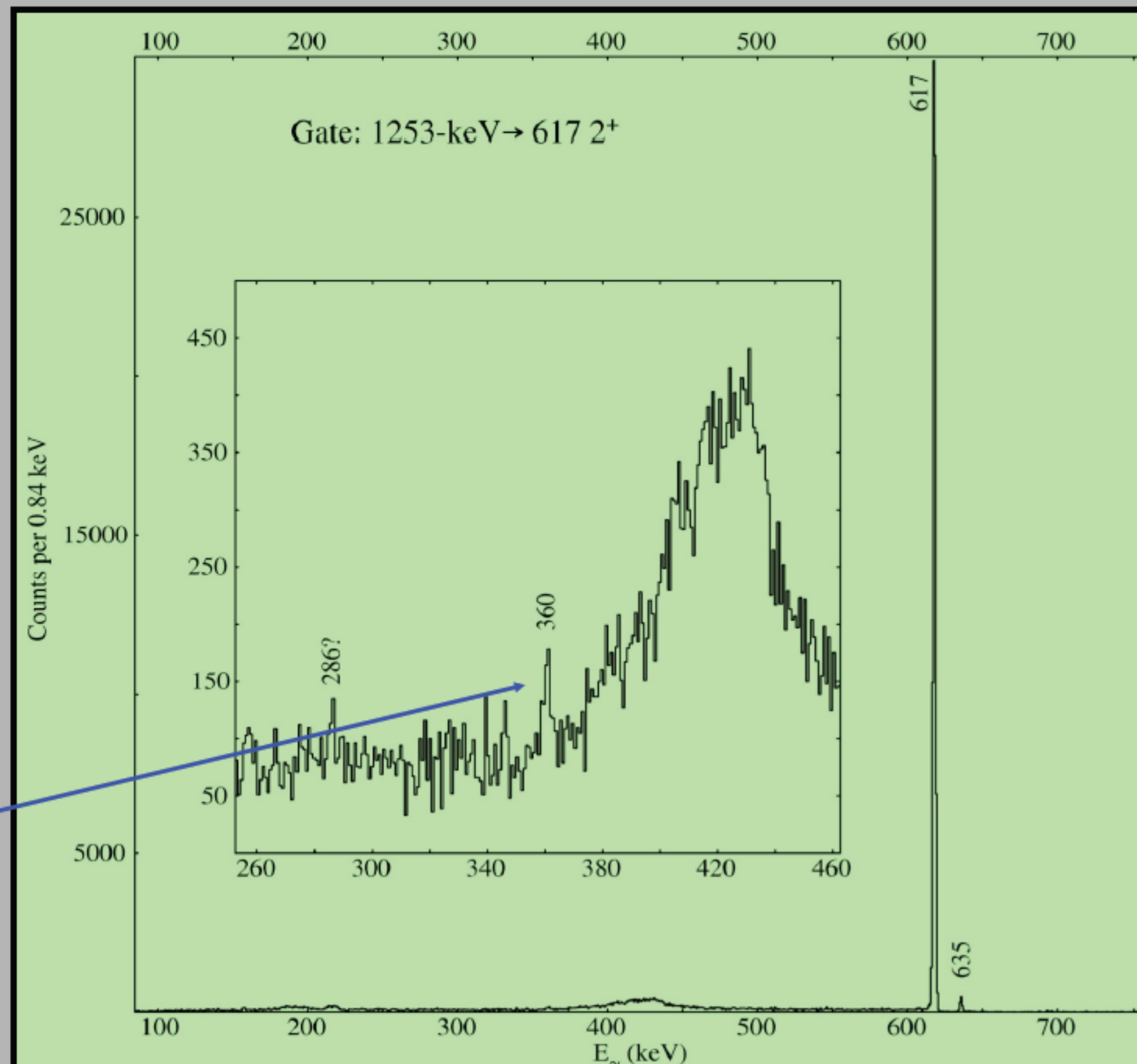




R.S. Chakrawarthy et al., Phys.Rev. C 73, 024306 (2006)
R.S. Chakrawarthy et al., Eur.Phys.J. A 25, Sup. 1, 125 (2005)

Nuclear Structure from High-Statistics Beta-Decay





5×10^{-4} γ branch from 2231-keV level

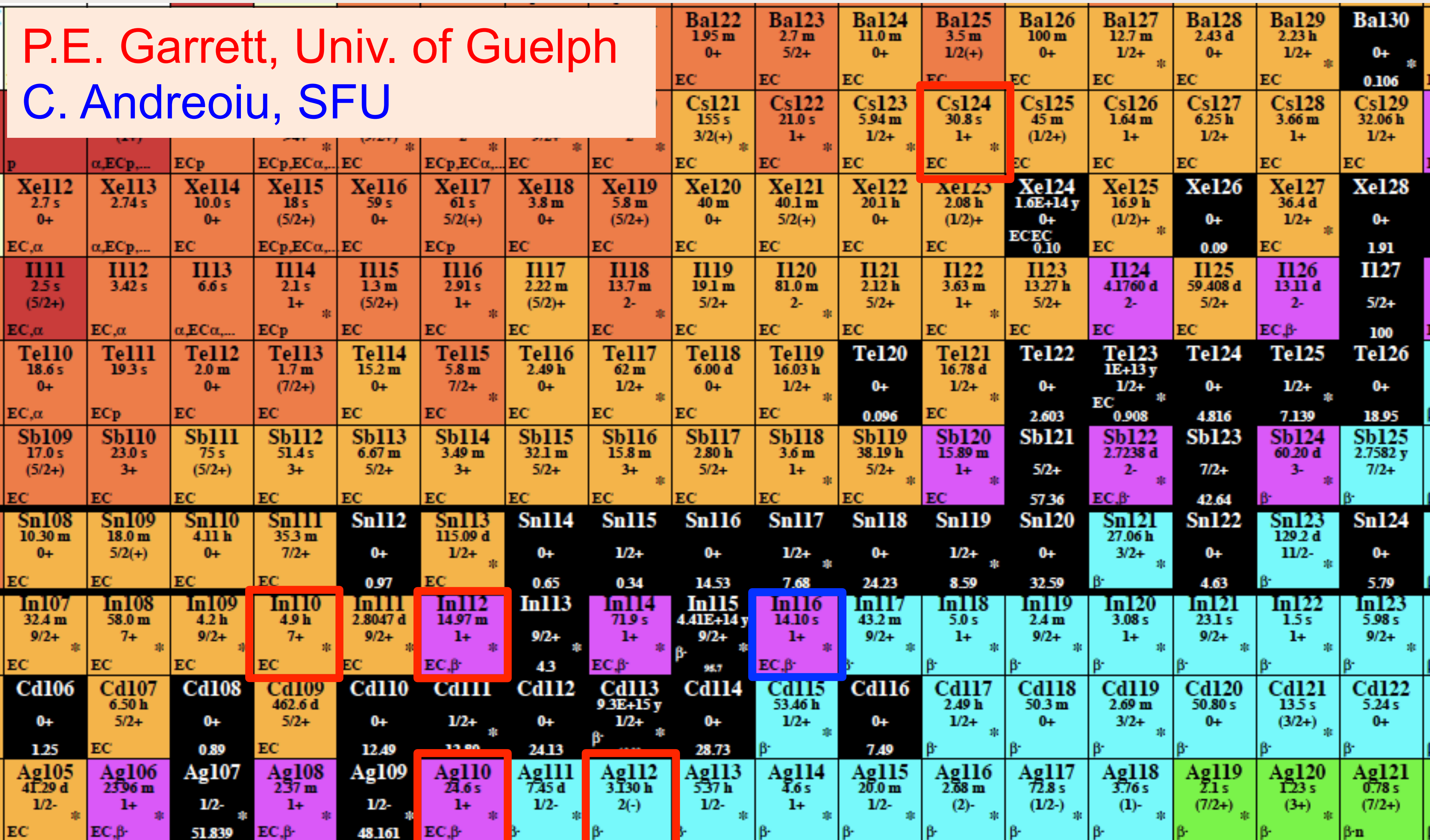
$I_\gamma(360) \approx 10^{-6}$ of $I_\gamma(617\text{-keV}, 2^+\rightarrow0^+)$

P.E. Garrett et al., Phys.Rev. C 86, 044304 (2012)

TRIUMF

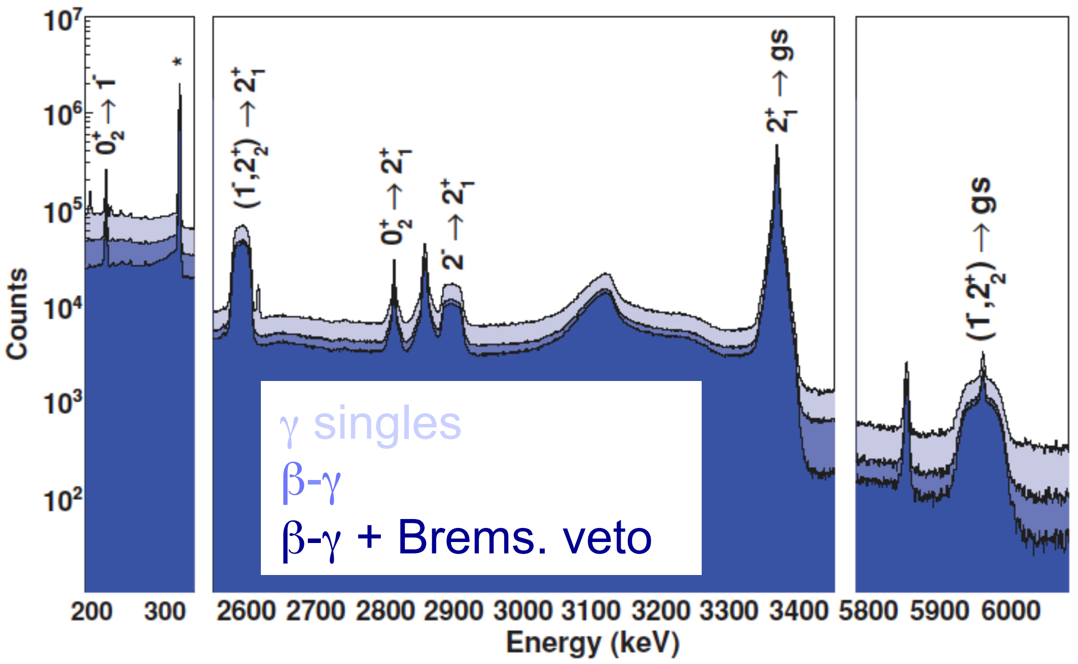
Nuclear Structure from High-Statistics Beta-Decay

P.E. Garrett, Univ. of Guelph
C. Andreoiu, SFU



Study of the β-decay of ^{11}Li:

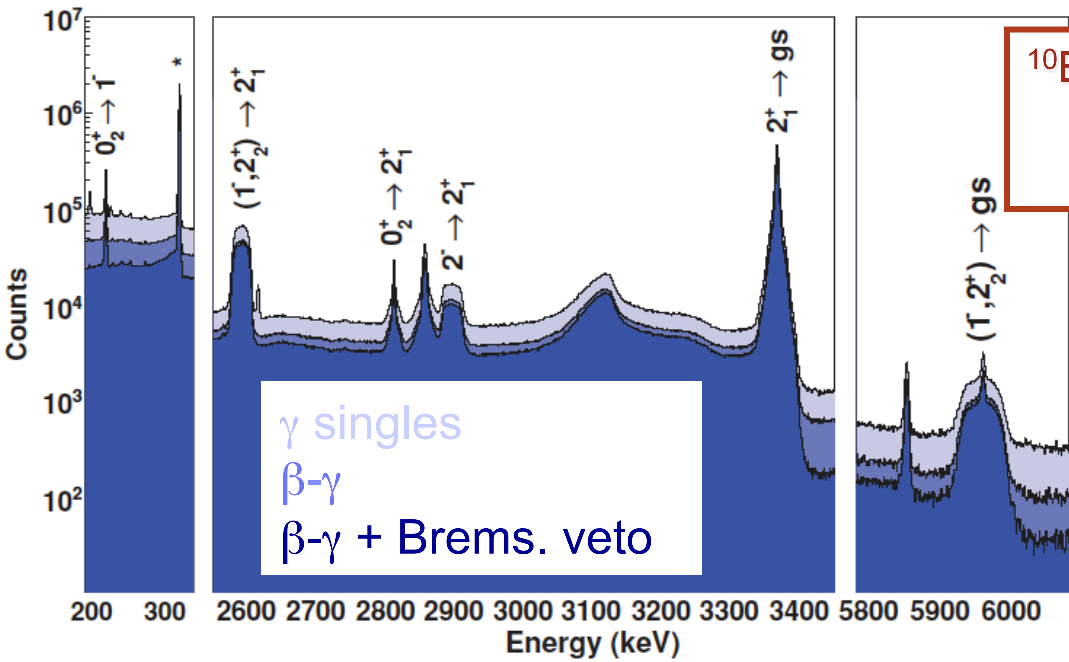
A Neutron Spectroscopy Experiment Without Neutron Detectors



C.M. Mattoon et al., Phys.Rev. C 80, 034318 (2009)
F.Sarazin et al., Phys. Rev. C70 (2004) 31302(R)

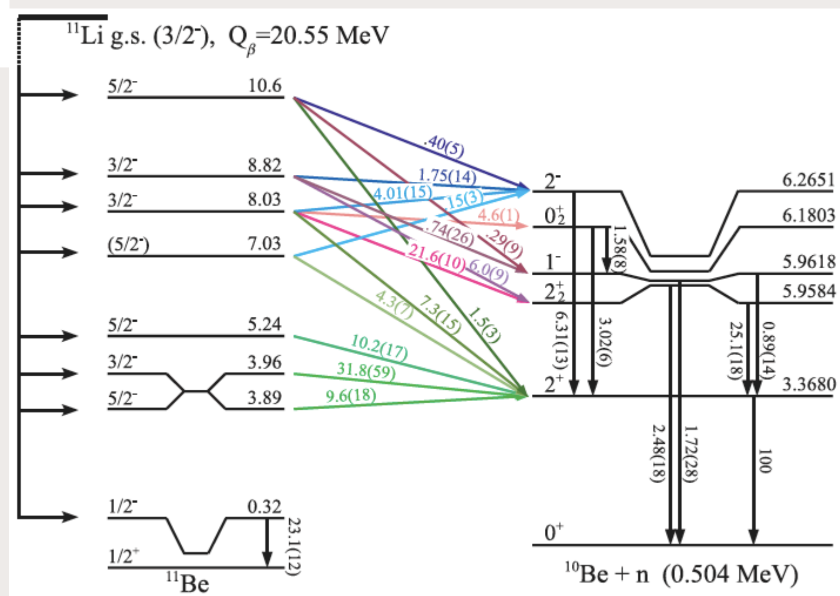
Study of the β-decay of ^{11}Li:

A Neutron Spectroscopy Experiment Without Neutron Detectors



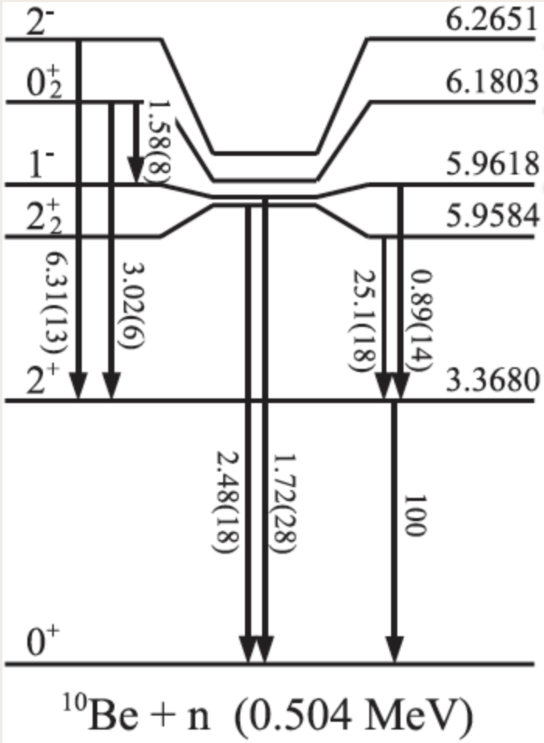
^{10}Be γ-peaks are Doppler Broadened
Lineshape = f(Lifetime, Neutron Energy)
Max. Width = f(Neutron Energy)

-Lineshape analysis by Monte Carlo simulation
- Resolution on the neutron energies (~50keV) comparable to Direct Time-Of-Flight Neutron Spectroscopy Experiments



C.M. Mattoon et al., Phys.Rev. C 80, 034318 (2009)
F.Sarazin et al., Phys. Rev. C70 (2004) 31302(R)

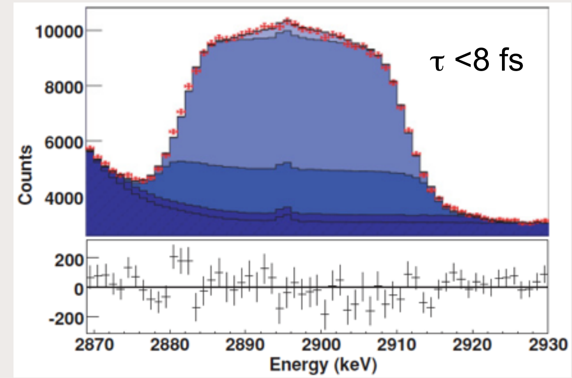
Monte-Carlo Lineshape Analysis

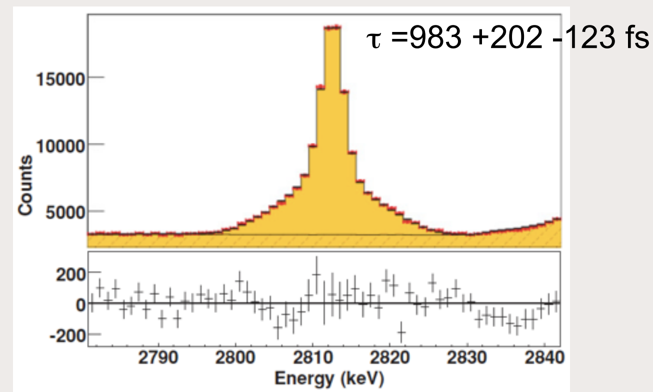


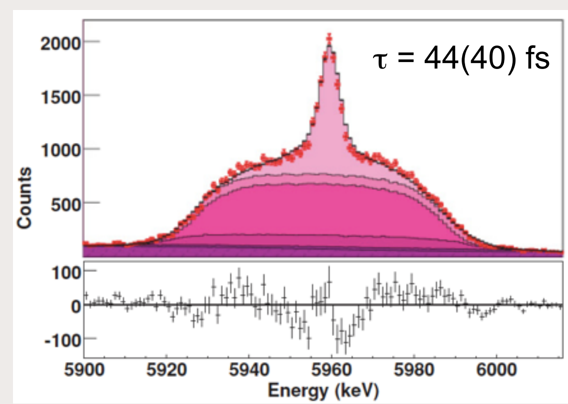
J^π	This work	Fynbo [4]	Sarazin [5]	Tilley [37]
2_2^+	$61.4^{+8.0}_{-6.2}$	>35	60(10)	<55
1^-	44(40)	230(90)	[a]	–
0_2^+	983^{+202}_{-123}	760(170)	870(175)	760^{280}_{210}
2^-	<8	160(40)	85(12)	–

[a]Less than a few hundred fs.

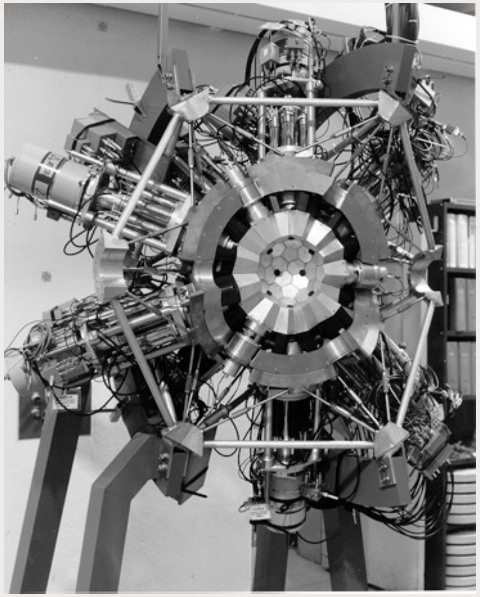
C.M. Mattoon et al., Phys.Rev. C 80, 034318 (2009)
F.Sarazin et al., Phys. Rev. C70 (2004) 31302(R)







The Future…
8pi Spectrometer at Simon Fraser University



K. Starosta and C. Andreoiu

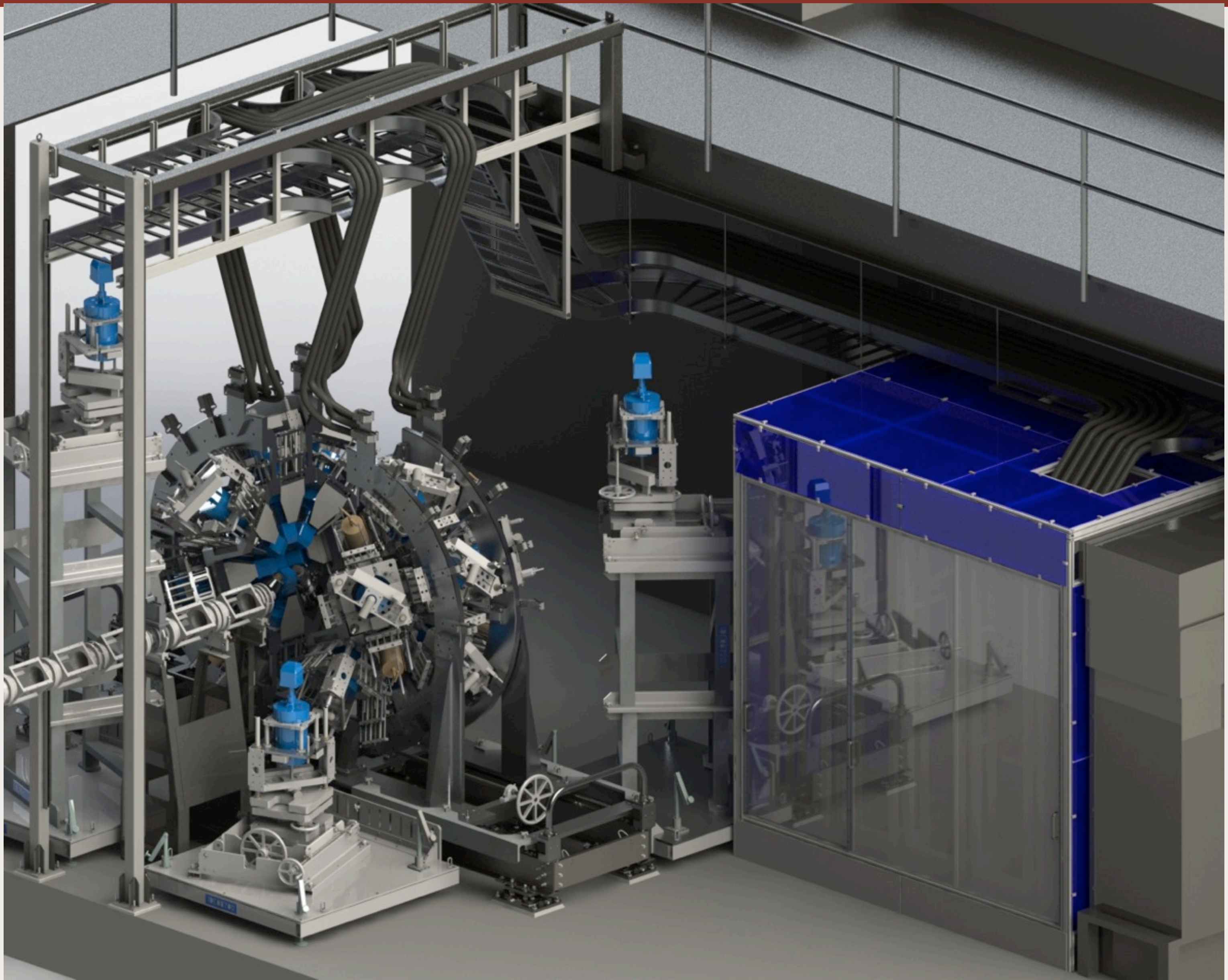
Full 8pi spectrometer using 20 HPGe and 4π BGO filter

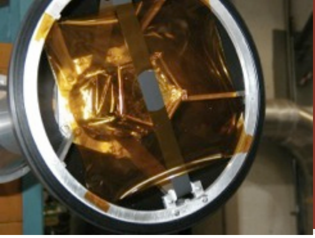
Digital DAQ system

Neutron-induced fission studies using neutron generator located one floor below in shielded vault

Study properties of neutron-rich nuclei

The Future…
GRIFFIN Spectrometer at ISAC



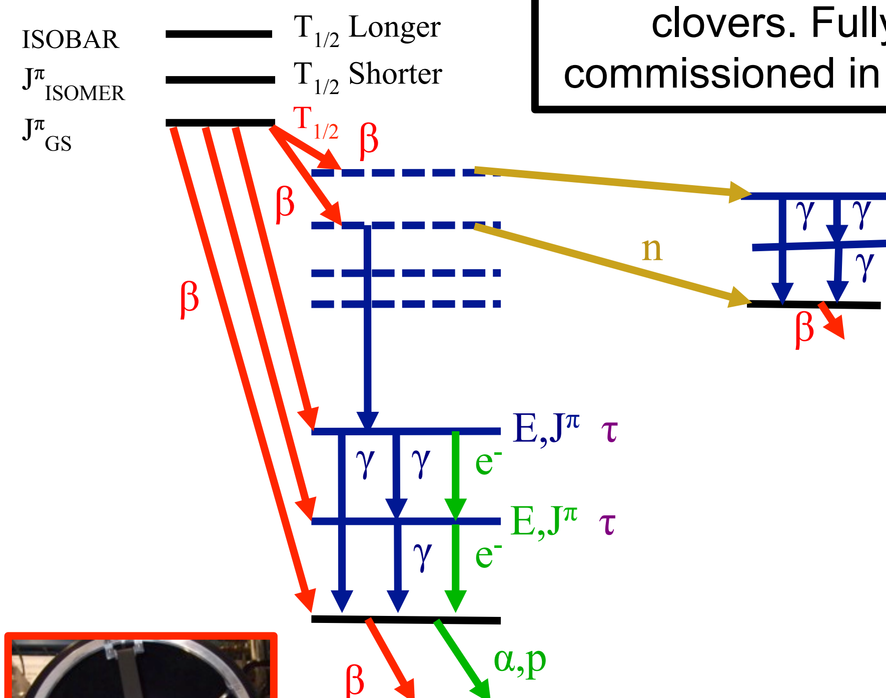


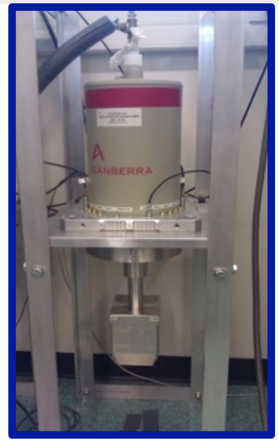
New GRIFFIN Facility at TRIUMF
Sensitive Decay Spectroscopy

GRIFFIN

Fast, in-vacuum tape system
Enhances decay of interest

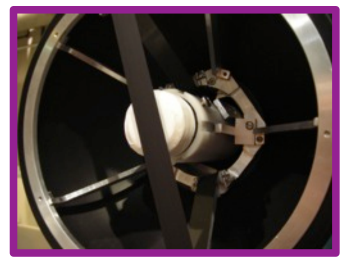
Initial operation in fall 2014 with 12 clovers. Fully commissioned in 2015

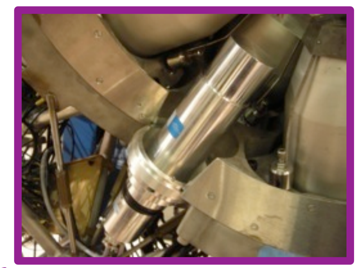




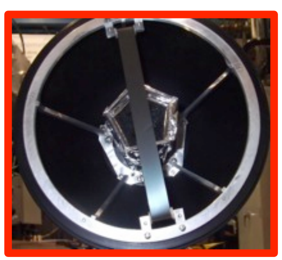
HPGe: 16 Clovers
Detect gamma rays and determines branching ratios, multipolarities and mixing ratios

$LaBr_3$: 8 $LaBr_3$
Fast-timing of photons to measure level lifetimes



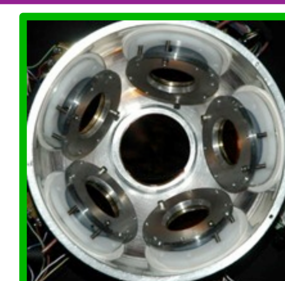


Zero-Degree Fast scintillator
Fast-timing signal for betas



SCEPTAR: 10+10 plastic scintillators
Detects beta decays and determines branching ratios

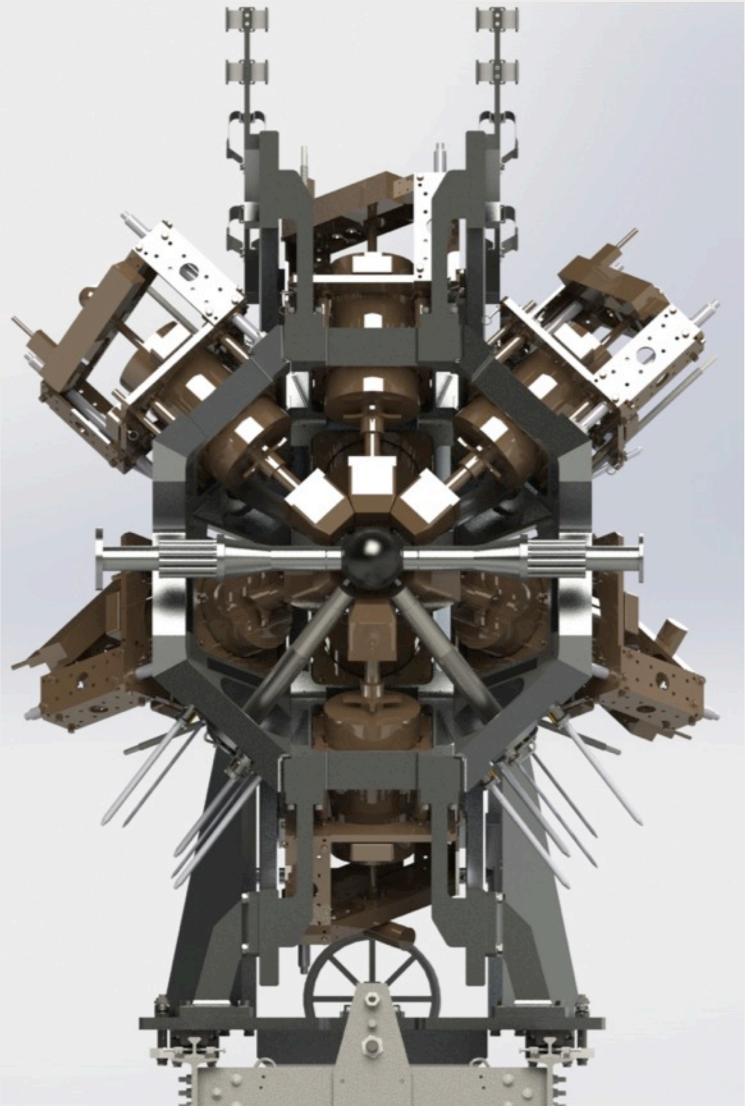
Neutron-Arrays: DESCANT or VANDLE
Detects neutrons to measure beta-delayed neutron branching ratios

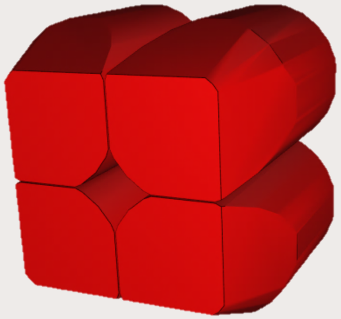


PACES: 5 Cooled Si(Li)s
Detects Internal Conversion Electrons and alphas/protons

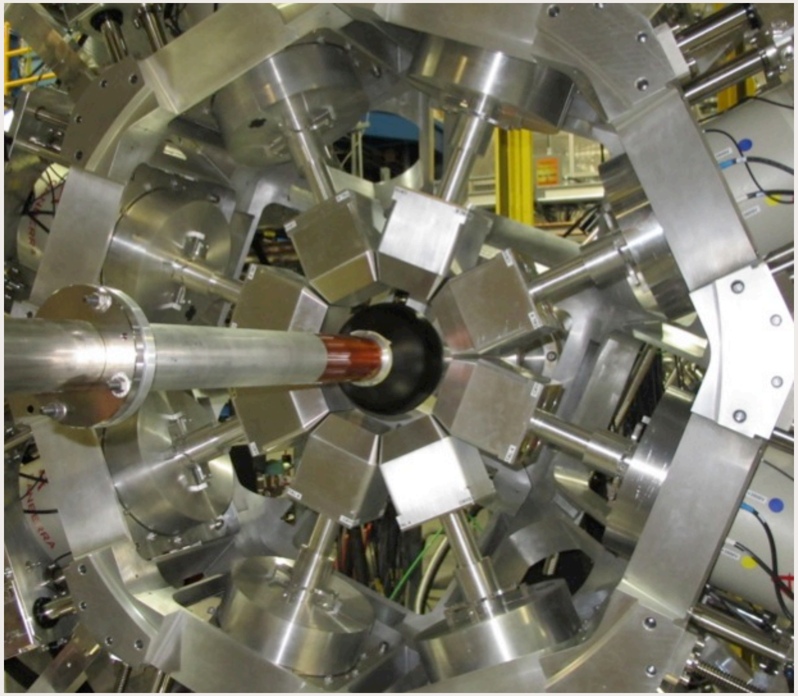
GRIFFIN HPGe Clover Detectors

An array of 16 large-volume HPGe Clover detectors



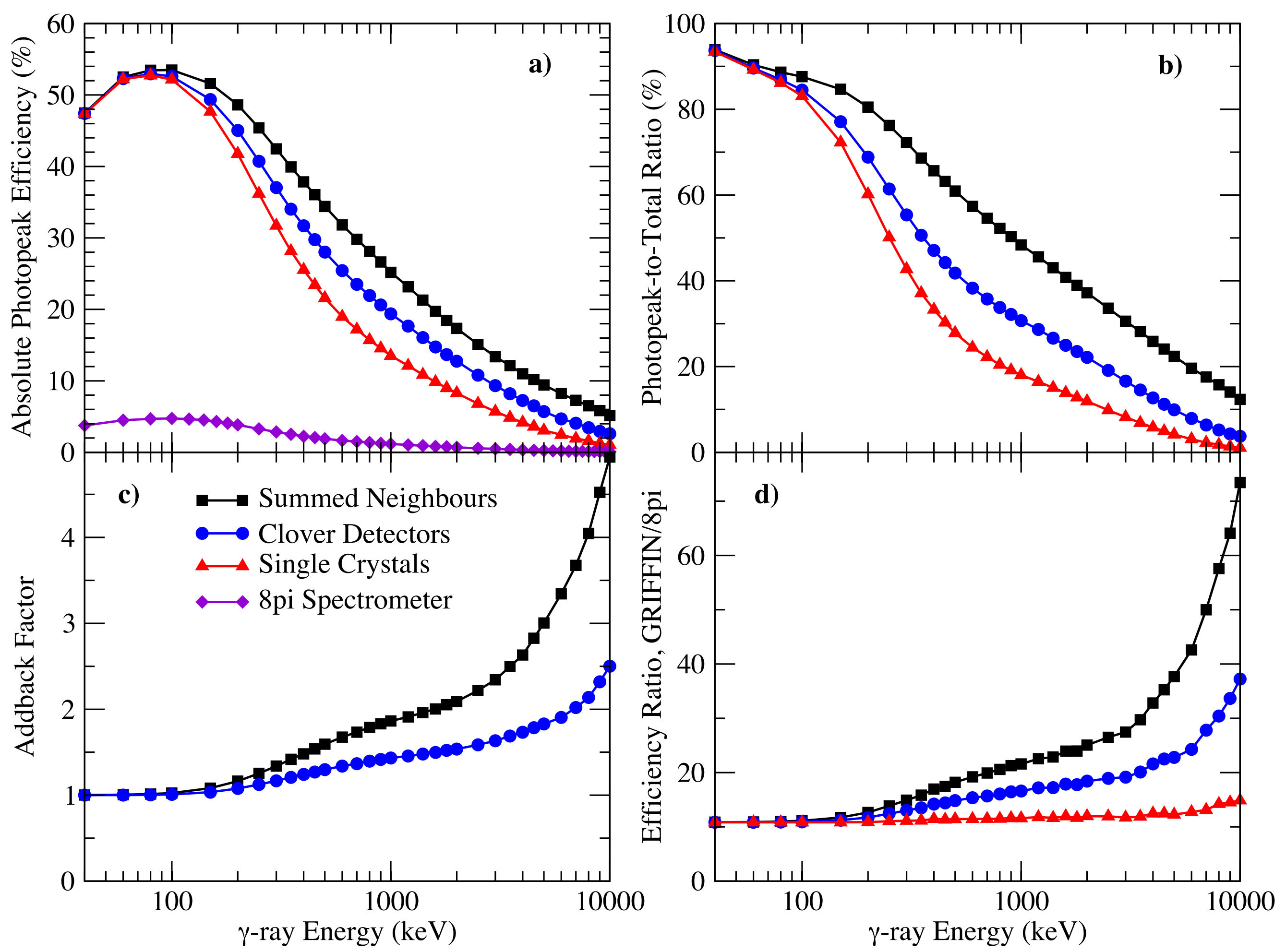


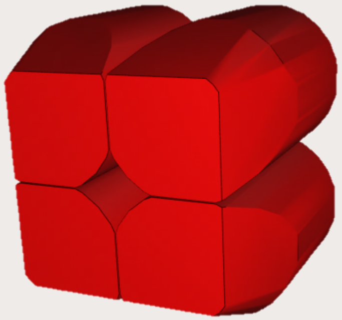
60mm diameter,
tapered crystals.
≥90mm length



GRIFFIN HPGe Clover Detectors

An array of 16 HPGe Clover detectors





60mm diameter, tapered crystals. ≥90mm length

Resolution (FWHM):
≤2.2 keV @ 1.3 MeV
≤1.3 keV @ 122 keV

Rel. Eff. @ 1.3 MeV
Crystal ≥38%
Clover ≥215%

Timing ≤6ns

GRIFFIN HPGe Clover Detectors

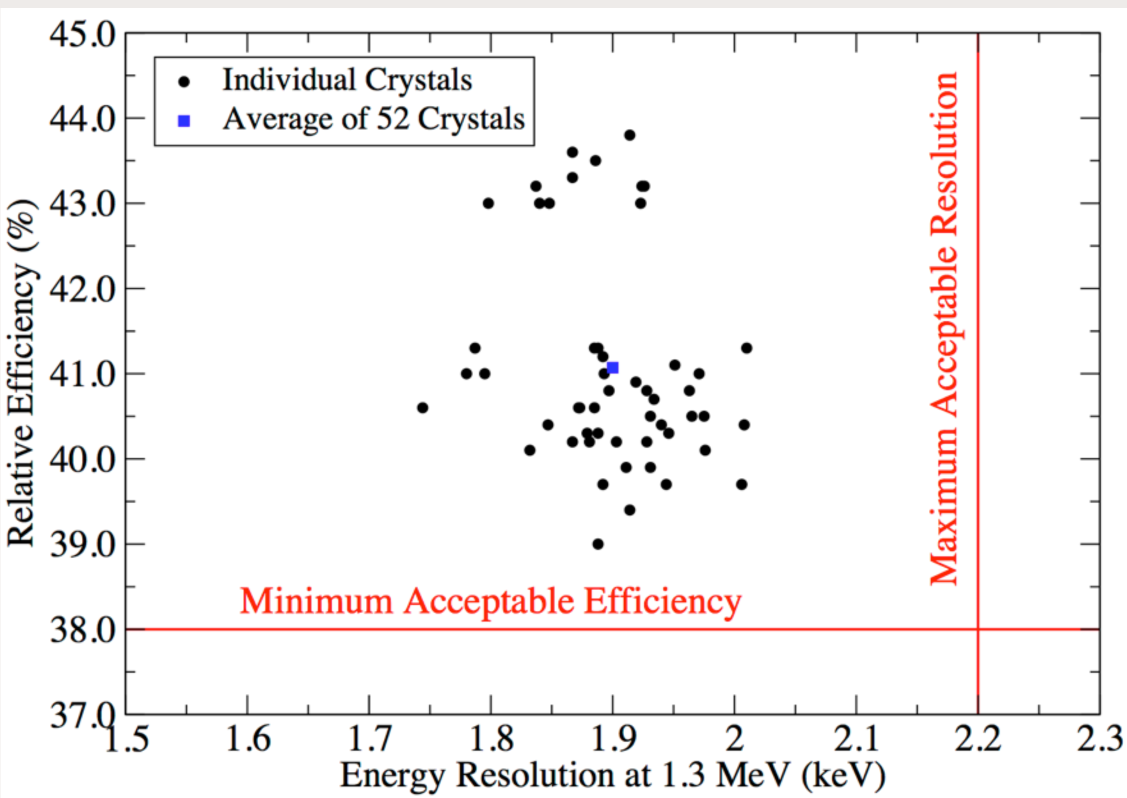
Thirteen of sixteen GRIFFIN clovers fully accepted

Average Performance of first 52 crystals:

Energy resolution@ 121keV = 1.11keV

Energy resolution@ 1.3MeV = 1.90keV

Photo-peak Rel. Eff. @ 1.3MeV = 41.07%



Testing performed at SFU

Dec 2012	4 Accepted
April 2013	8 Accepted
Jan 2014	9 Accepted
May 2014	13 Accepted
April 2015	*16 Accepted*
May 2015	*Complete*

TRIUMF

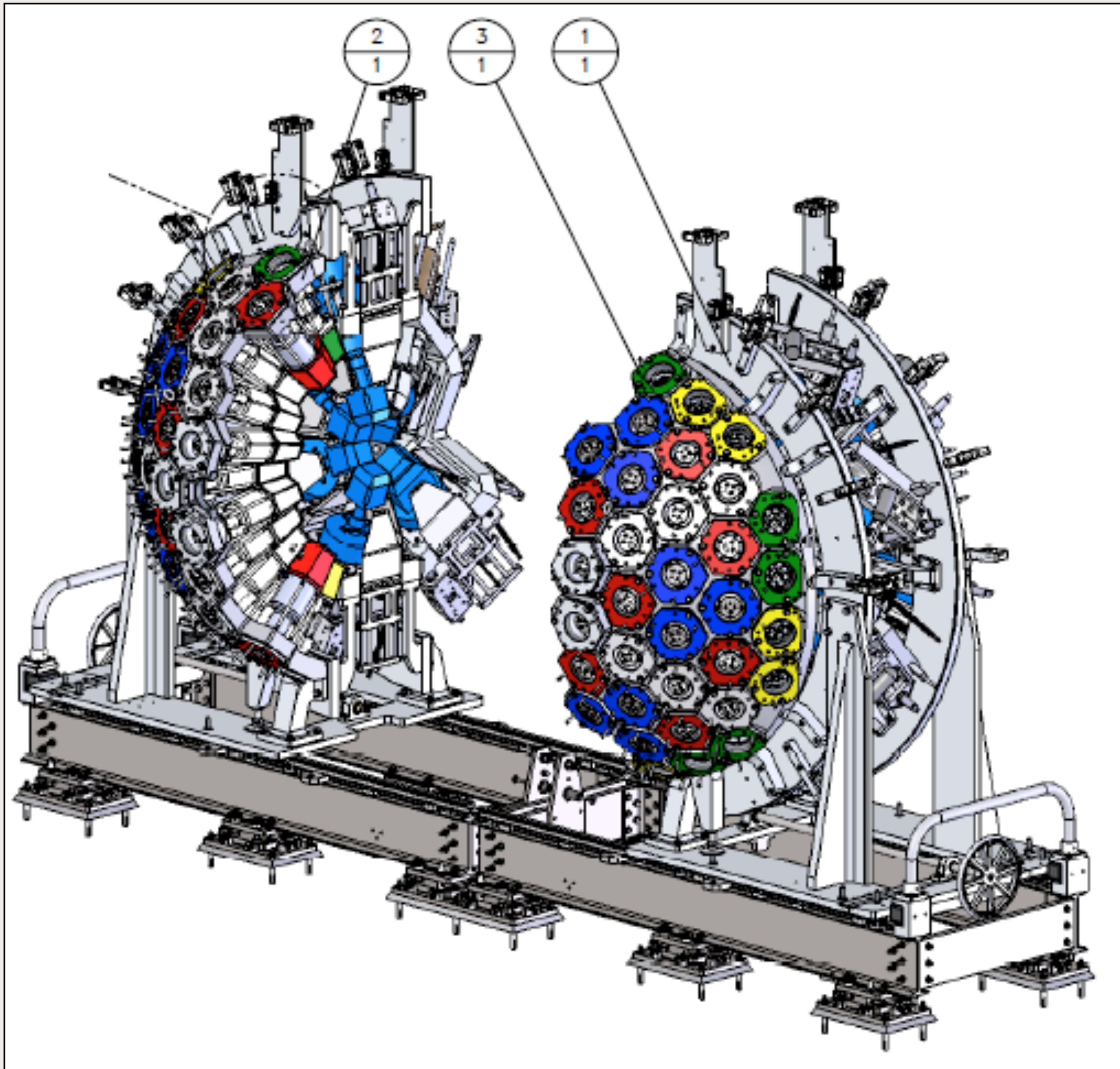
See talk by Vinzenz Bildstein, Fri 2pm, Session 32

GRIFFIN+DESCANT

70 element array of deuterated scintillator for neutron time-of-flight

DESCANT has 27% neutron efficiency with 12 HPGe Clovers

Uses GRIF-4G digitizers

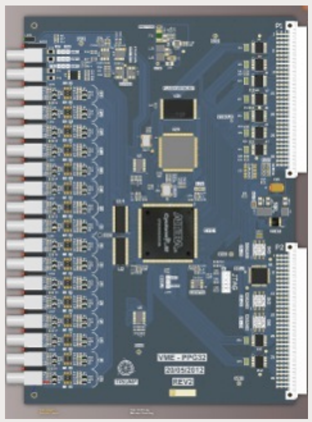


GRIFFIN DAQ System

Custom Digital Electronics Modules designed and built by Universite de Montreal and TRIUMF

Programmable Logic Pulse Generator

32 Channels
NIM or TTL



Clock Distribution Module

10MHz Atomic Clock
Low-jitter fan-out to all modules

GRIF-16 Module

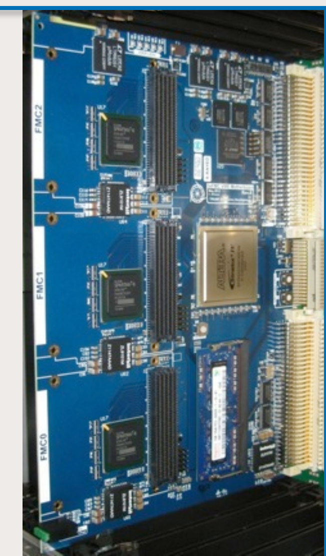
16 chans
100MHz,
14bit

GRIF-4G Module

4 chans
1GHz,
14bit

Master and Collector Module

650MB/s link to each digitizer
2GB RAM with peak transfer of 8.5Gb/s.



GRIFFIN DAQ System

Custom Digital Electronics Modules designed and built by Universite de Montreal and TRIUMF

High data through-put:

Each crystal running at 50kHz

300MB/s of filtered data, 1TB per hour

≈ 5×10^9 gamma-gamma coincidences/hour

…to enable ultra-high-statistics studies

High accountability:

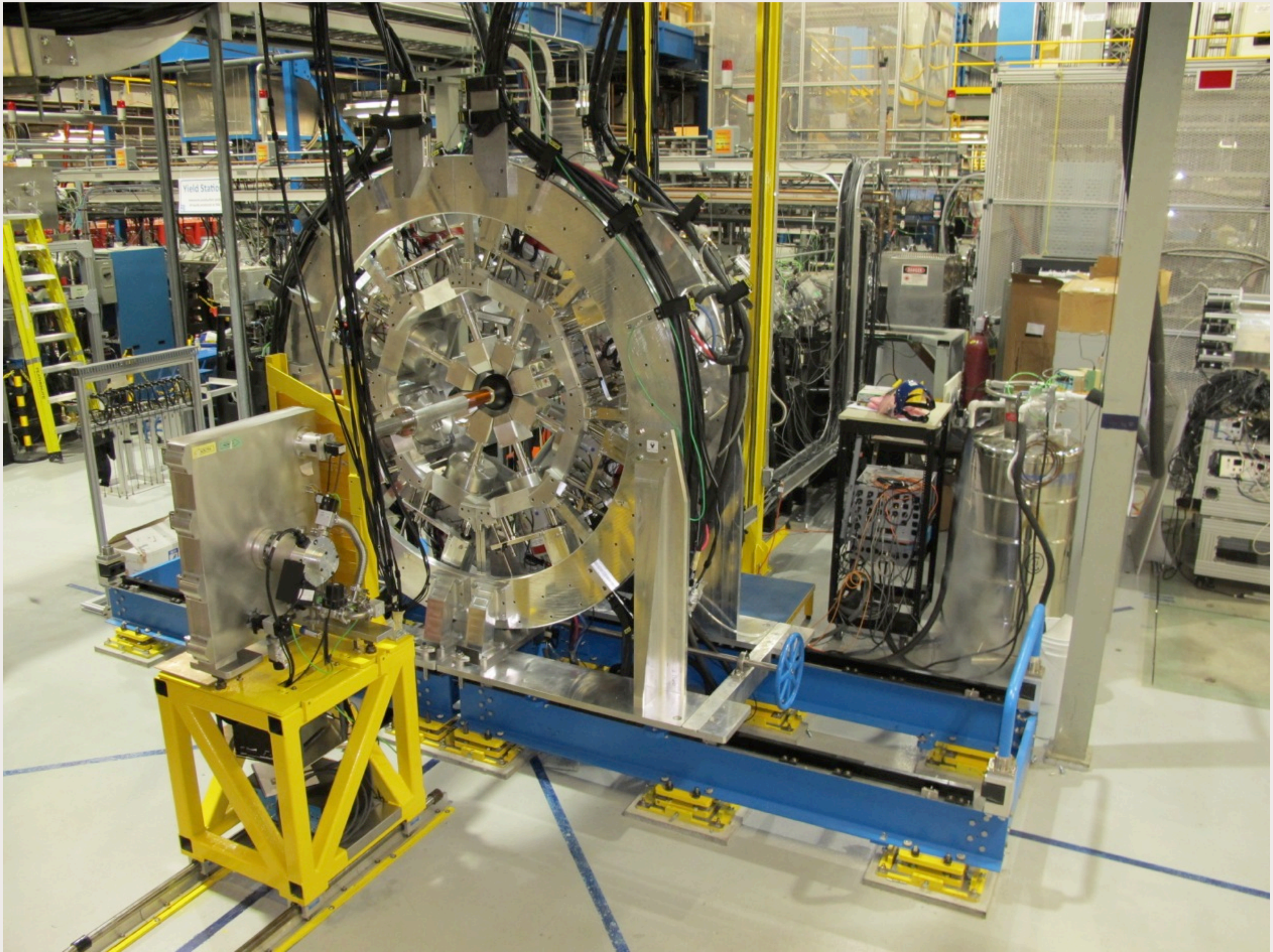
Accurate deadtime knowledge

Pile-up handling

Event traceability from threshold crossing to disk

…to enable high-precision half-life/BR measurements

GRIFFIN Installation - July 4th



TRIUMF

Acknowledgements

G.C. Ball, R.S. Chakrawarthy, G. Hackman, M.B. Smith, S.J. Williams (TRIUMF)

V. Bildstein, R. Dunlop, P. Finlay, P.E. Garrett, K.L. Green, G.F. Grinyer, B. Hyland, A.T. Laffoley, K.G. Leach, C.E. Svensson, S. Triambak (University of Guelph)

C.M. Mattoon, F. Sarazin (Colorado School of Mines)

J.L. Wood (Georgia Institute of Technology)

A. Piechaczek, E.F. Zganyar (Louisiana State University)

C. Andreoiu, D.S. Cross (SFU)

A. Chakraborty, S.W. Yates (University of Kentucky)

P.M. Walker (University of Surrey)

Plus many other students and post docs

The 8π Spectrometer at TRIUMF-ISAC

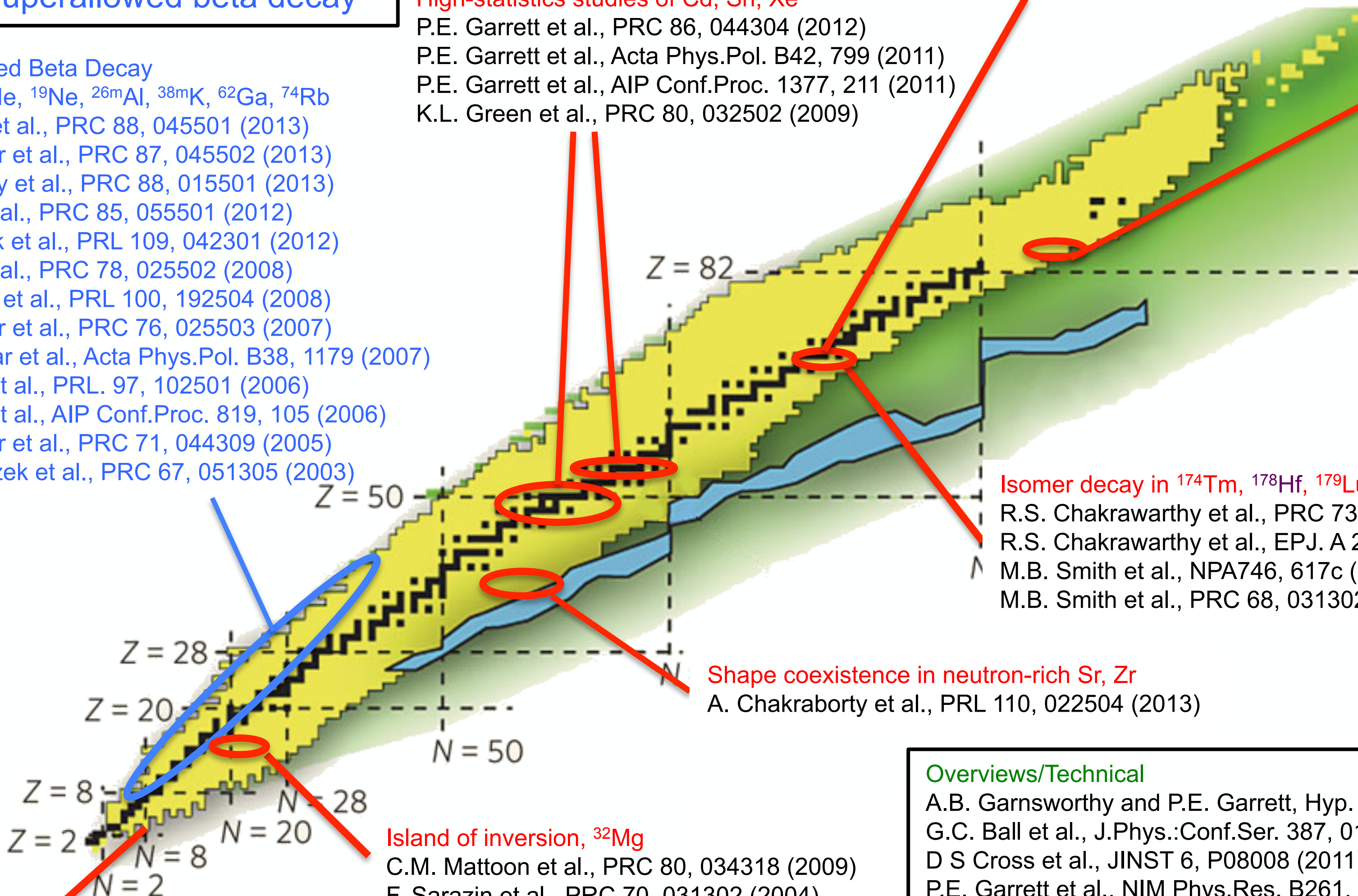
32 publications including 4 PRLs
19 on Nuclear Structure
13 on Superallowed beta decay

Superallowed Beta Decay
^{10}C, ^{14}O, ^{18}Ne, ^{19}Ne, ^{26m}Al, ^{38m}K, ^{62}Ga, ^{74}Rb
R. Dunlop et al., PRC 88, 045501 (2013)
G.F. Grinyer et al., PRC 87, 045502 (2013)
A.T. Laffoley et al., PRC 88, 015501 (2013)
P. Finlay et al., PRC 85, 055501 (2012)
S. Triambak et al., PRL 109, 042301 (2012)
P. Finlay et al., PRC 78, 025502 (2008)
K.G. Leach et al., PRL 100, 192504 (2008)
G.F. Grinyer et al., PRC 76, 025503 (2007)
E.F. Zganyar et al., Acta Phys.Pol. B38, 1179 (2007)
B. Hyland et al., PRL. 97, 102501 (2006)
B. Hyland et al., AIP Conf.Proc. 819, 105 (2006)
G.F. Grinyer et al., PRC 71, 044309 (2005)
A. Piechaczek et al., PRC 67, 051305 (2003)

High-statistics studies of Cd, Sn, Xe
P.E. Garrett et al., PRC 86, 044304 (2012)
P.E. Garrett et al., Acta Phys.Pol. B42, 799 (2011)
P.E. Garrett et al., AIP Conf.Proc. 1377, 211 (2011)
K.L. Green et al., PRC 80, 032502 (2009)

Half Life of geochronometer, ^{176}Lu
G.F. Grinyer et al., PRC 67, 014302 (2003)

Structure of $^{219-223}$Rn towards a RnEDM search



Isomer decay in ^{174}Tm, ^{178}Hf, ^{179}Lu
R.S. Chakrawarthy et al., PRC 73, 024306 (2006)
R.S. Chakrawarthy et al., EPJ. A 25, S1, 125 (2005)
M.B. Smith et al., NPA746, 617c (2004)
M.B. Smith et al., PRC 68, 031302 (2003)

Shape coexistence in neutron-rich Sr, Zr
A. Chakraborty et al., PRL 110, 022504 (2013)

Island of inversion, ^{32}Mg
C.M. Mattoon et al., PRC 80, 034318 (2009)
F. Sarazin et al., PRC 70, 031302 (2004)

^{11}Li beta-delayed neutron emission
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A.B. Garnsworthy and P.E. Garrett, Hyp. Int. 225, 121 (2014)
G.C. Ball et al., J.Phys.:Conf.Ser. 387, 012014 (2012)
D S Cross et al., JINST 6, P08008 (2011)
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G.C. Ball et al., J.Phys.(London) G31, S1491 (2005)
S.J. Williams et al., J.Phys.(London) G31, S1979 (2005)

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A. Chakraborty et al., Phys.Rev.Lett. 110, 022504 (2013)
R. Dunlop et al., Phys.Rev. C 88, 045501 (2013)
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E.F. Zganyar et al., Acta Phys.Pol. B38, 1179 (2007)
R.S. Chakrawarthy et al., Phys.Rev. C 73, 024306 (2006)
B. Hyland et al., Phys.Rev.Lett. 97, 102501 (2006)
B. Hyland et al., AIP Conf.Proc. 819, 105 (2006)
G.C. Ball et al., J.Phys.(London) G31, S1491 (2005)
R.S. Chakrawarthy et al., Eur.Phys.J. A 25, Sup. 1, 125 (2005)
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S.J. Williams et al., J.Phys.(London) G31, S1979 (2005)
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M.B. Smith et al., Phys.Rev. C 68, 031302 (2003)

8pi operated at TRIUMF-ISAC-I from 2000 to 2013

32 publications including 4 PRLs

19 Nuclear Structure (Black)
13 Superallowed beta decay (Blue)

Researchers from 24 institutions from 8 countries.

25 post-docs,
5PhD, 12MSc, 1MPhys

12 Grad. Students in progress so more publications still to come…

The 8π Spectrometer at TRIUMF-ISAC