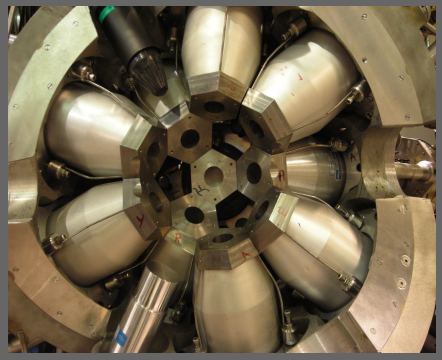
TRIUMF

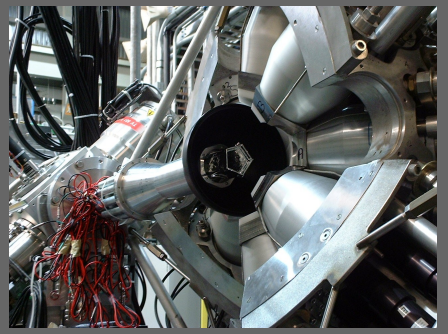
Canada's National Laboratory for Particle and Nuclear Physics
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

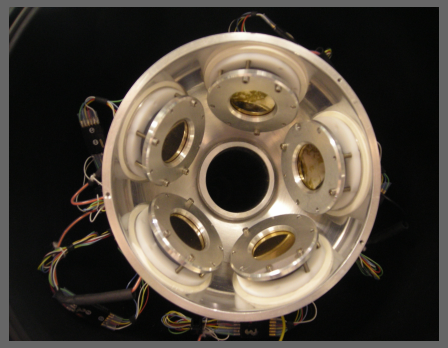
Present and Future Decay Spectroscopy at TRIUMF-ISAC

The 8pi Spectrometer

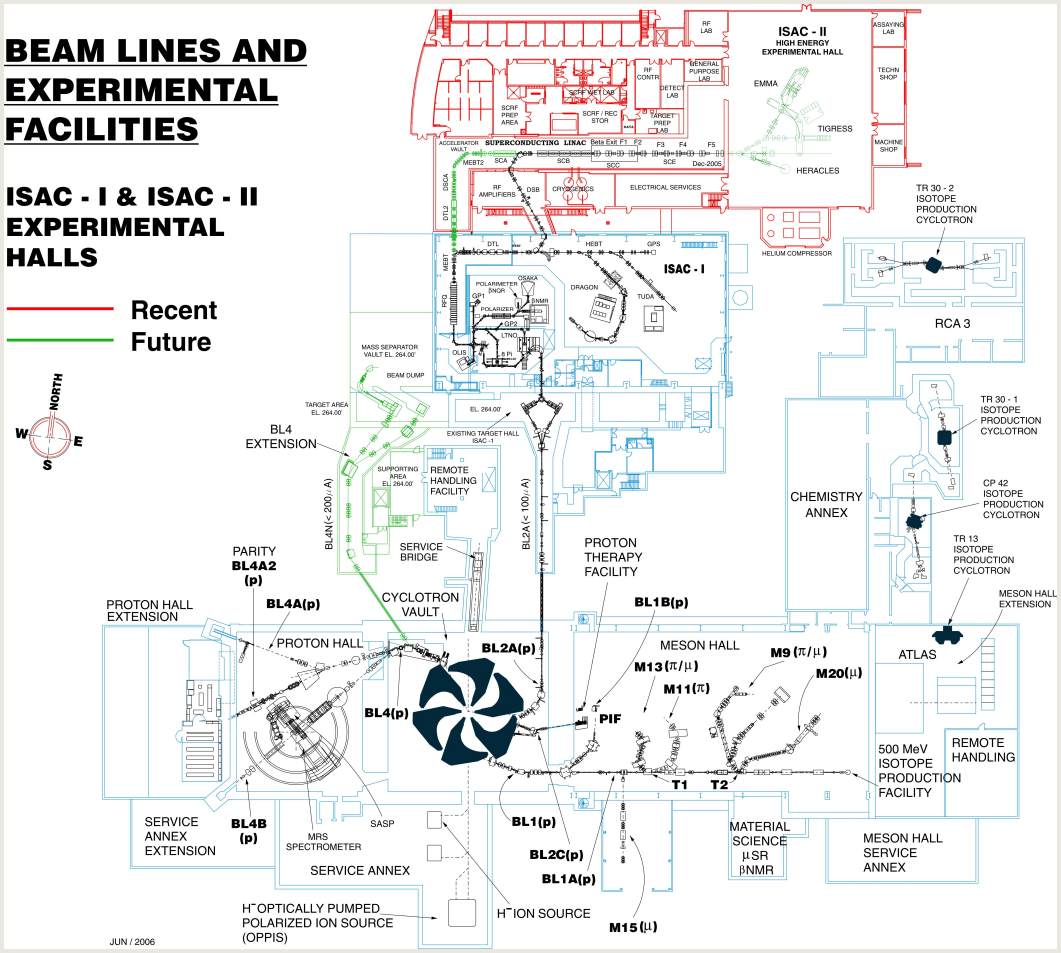
Adam Garnsworthy | Research Scientist | **TRIUMF**







Isotope Separator and ACcelerator

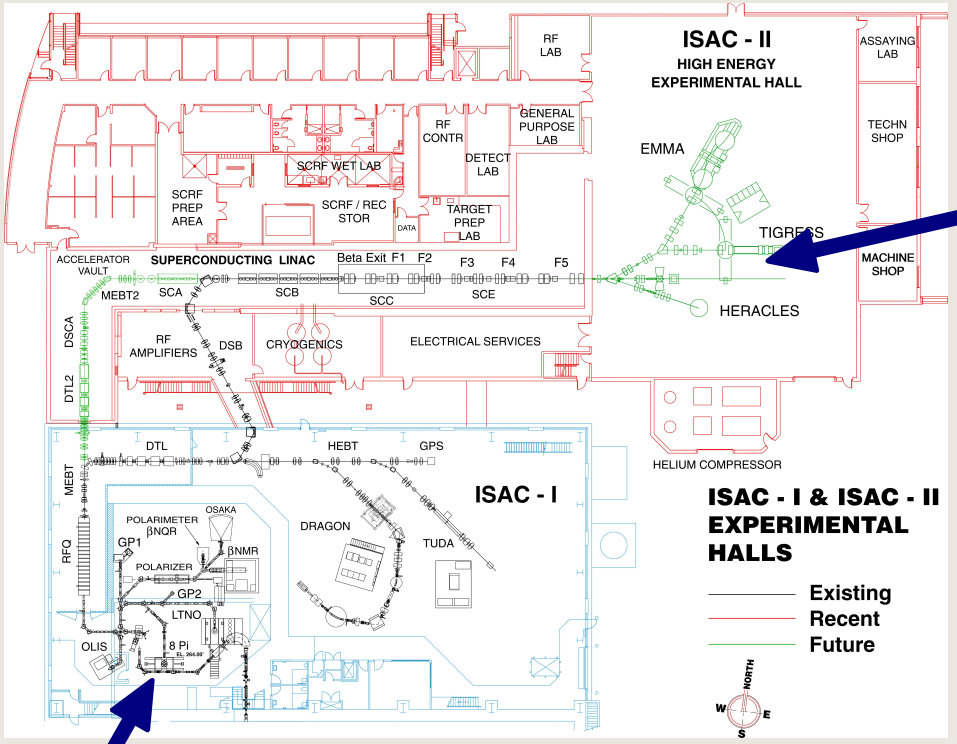


Cyclotron Driver: <100μA, 500MeV protons

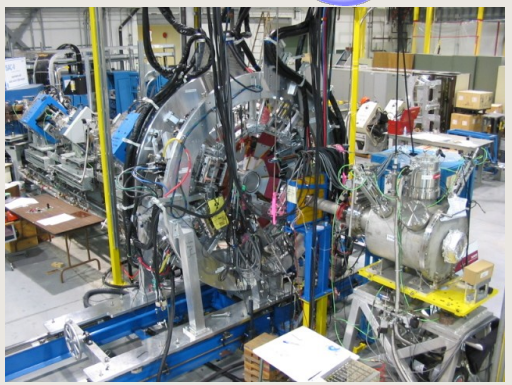
SiC, Nb, ZrC, Ta, UC Targets Surface, FEBIAD, TRILIS ion sources

ISACII SC LINAC <10MeV/u

Gamma-Ray Spectroscopy at ISAC

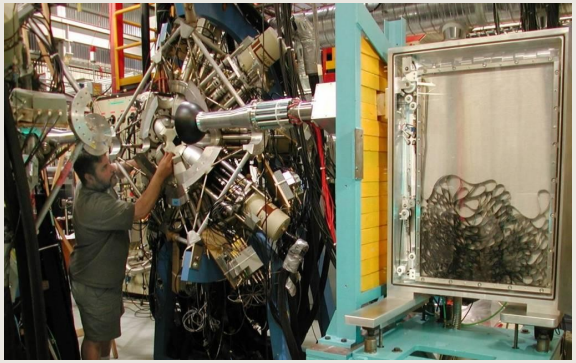


TIGRESS

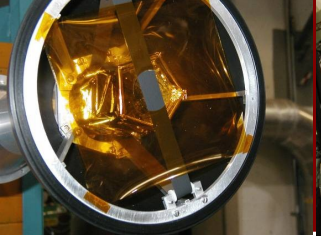
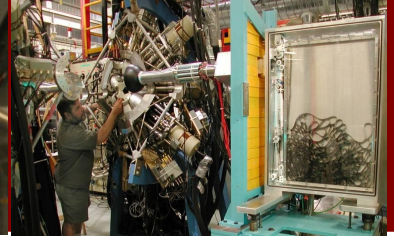


Nuclear Reactions

8π



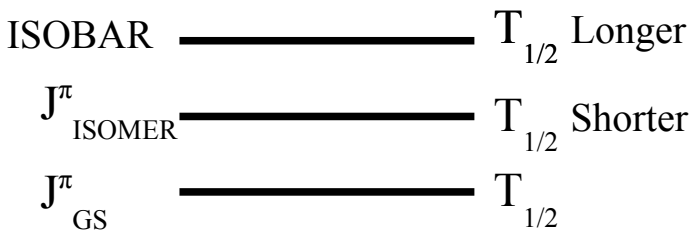
Nuclear Decay

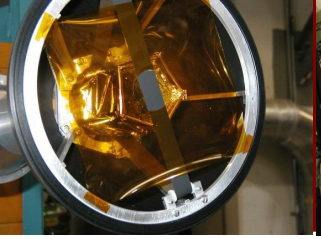
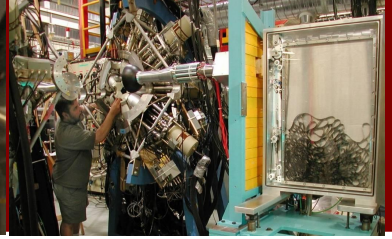



The 8pi Spectrometer at TRIUMF
Sensitive Decay Spectroscopy

Fast, in-vacuum tape system

Enhances decay of interest



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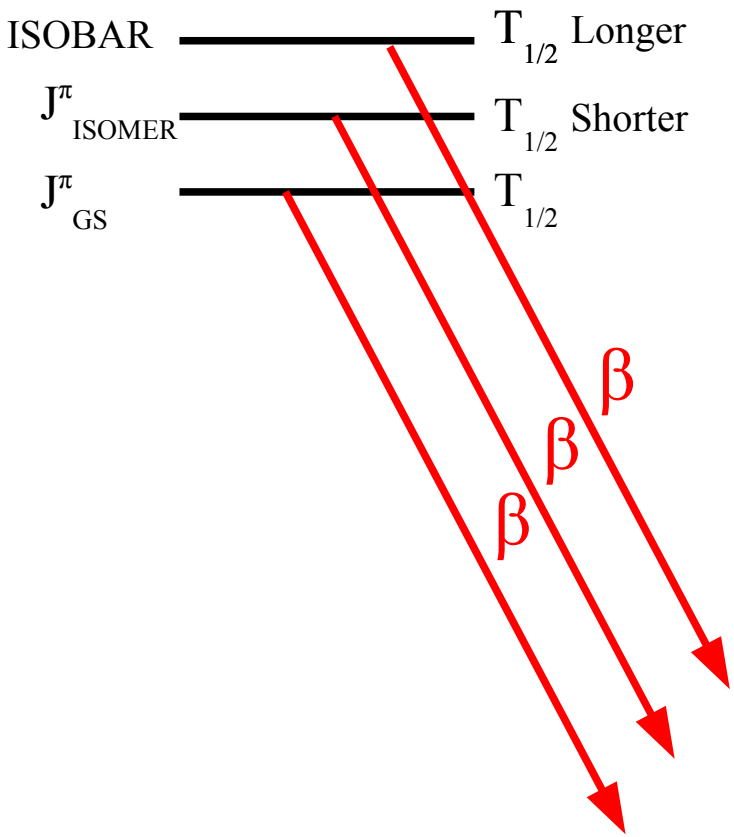

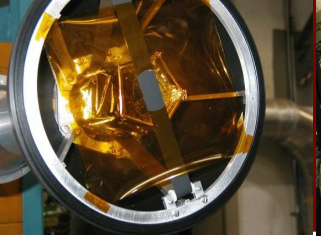
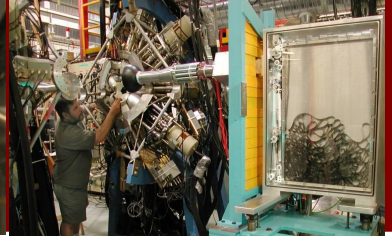

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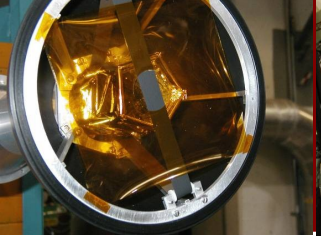
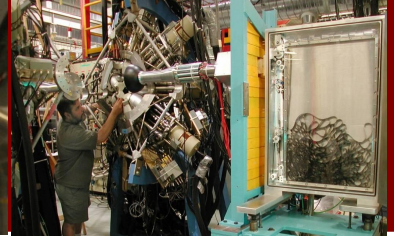
SCEPTAR: 10+10 plastic scintillators

Detects beta decays and determines branching ratios





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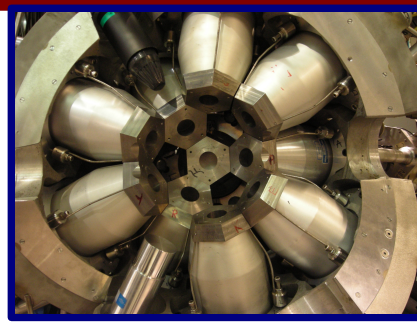
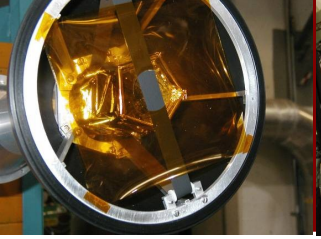
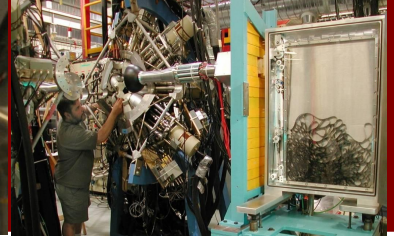
Detects beta decays and determines branching ratios

8pi Ge: 20 Compton-Suppressed HpGe

Detects gamma rays and determines branching ratios, multipolarities and mixing ratios



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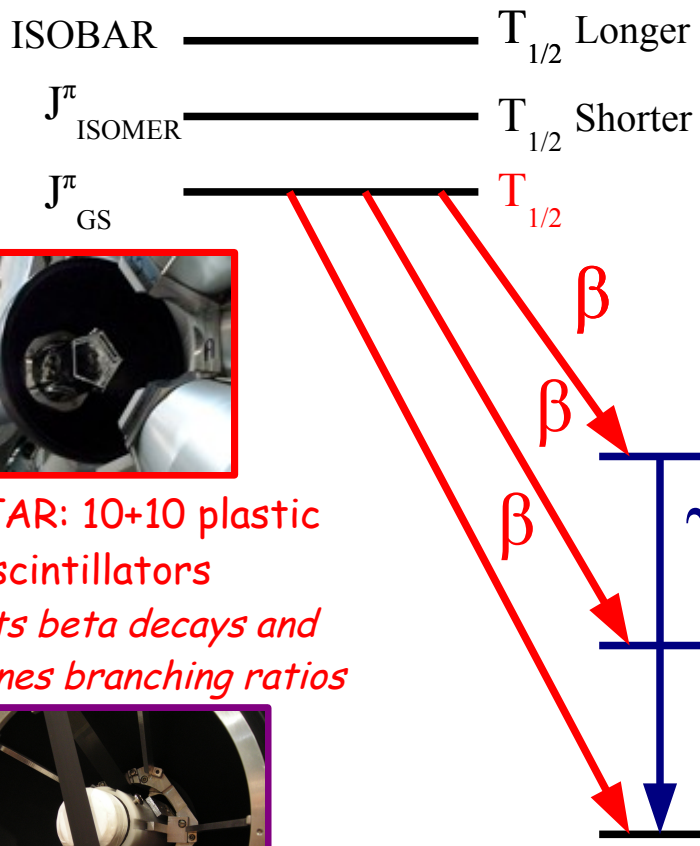

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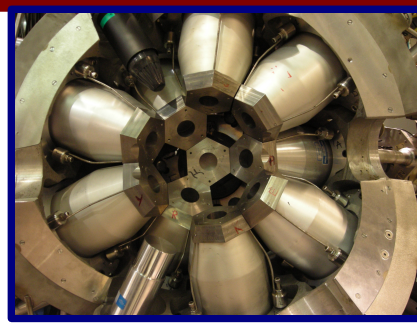
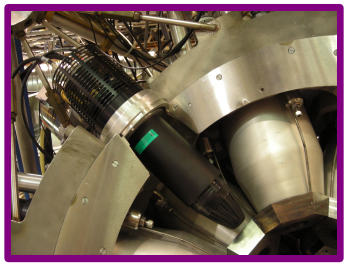


DANTE: 10 BaF_2/$LaBr_3$

Fast-timing of photons to measure level lifetimes



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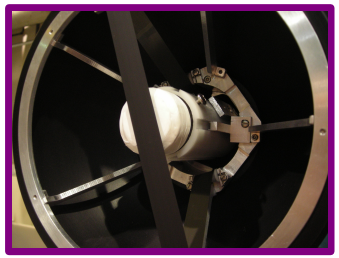
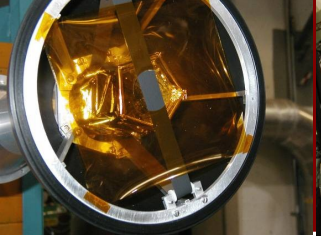
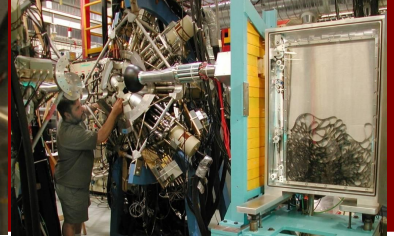


Zero-Degree Fast scintillator

Fast-timing signal for betas

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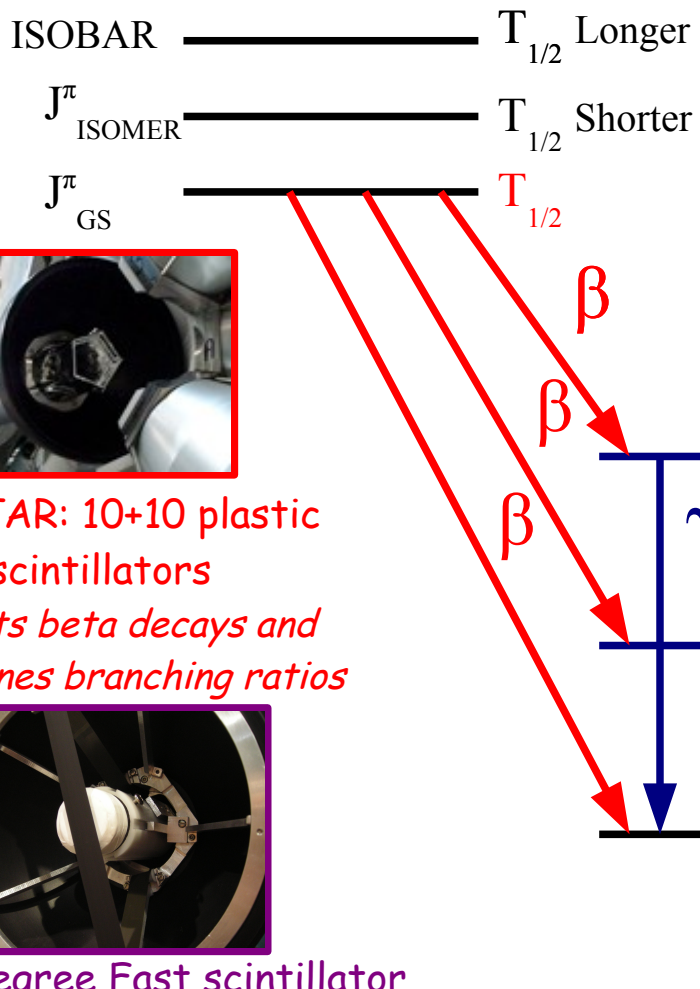
Enhances decay of interest



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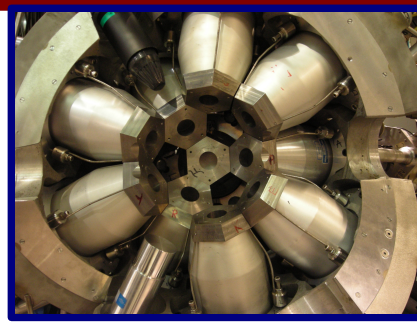

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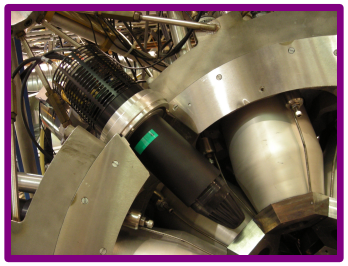

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PACES: 5 Cooled Si(Li)s

Detects Internal Conversion Electrons and alphas/protons

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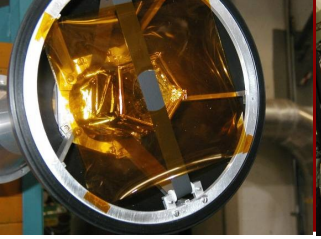

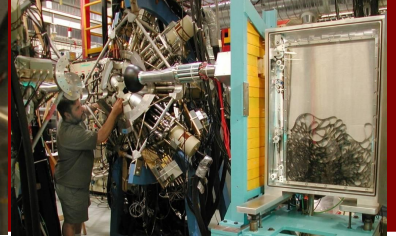

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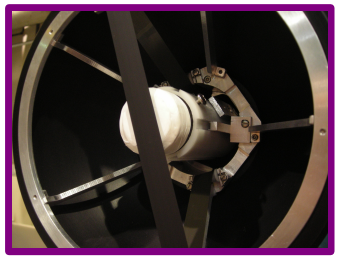


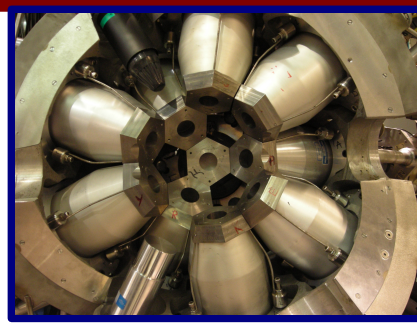
Zero-Degree Fast scintillator

Fast-timing signal for betas

Sensitive station for studying radioactive decay

8pi Ge: 20 Compton-Suppressed HpGe

Detect gamma rays and determines branching ratios, multipolarities and mixing ratios



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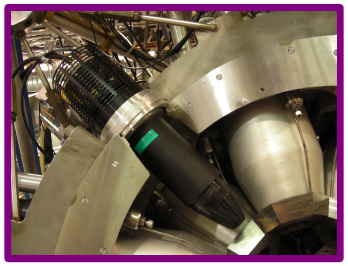

PACES: 5 Cooled Si(Li)s

Detects Internal Conversion Electrons and alphas/protons

The 8pi Data Acquisition System

Mostly analogue with digitization done in FERA modules – A versatile system

- Super-allowed decay studies
  - Precision measurements demanding high accountability in the DAQ and understanding of detector responses

- Nuclear Structure and Astrophysics
  - Demands large through-put of DAQ and fast recovery of detectors

8pi Experiments in 2009 and 2010

Nuclear Structure:

Shape Coexistence in Neutron-rich Sr isotopes, (Garnsworthy), Dec 2010

Search for Octupole Deformation in n-rich Rn isotopes (Svensson/Chupp/Tardif), Dec 2010

S1215 Characterization of shape coexistence near N = 40, ^{78}Kr (Kulp), Nov 2009

Source Characterization of shape coexistence near N = 90 (Kulp), Oct 2009

S984 Fast lifetimes and nuclear structure below N = 82, ^{112}Cd (Garrett), Apr 2009

Nuclear Astrophysics:

S1007 Equilibrium of ^{115}Cd^{m} During the s-process (Sumithrarachchi/Triambak), Apr 2010

Fundamental Symmetries:

S823 Pure Fermi Decay of N=Z, ^{74}Rb (Ball), Nov 2010

S1140 Precision Half-life measurement of ^{14}O and ^{15}O (Grinyer), Sept 2010

S1192 Precision Branching Ratio and $T_{1/2}$ of ^{19}Ne decay (Triambak), May 2009

8pi Experiments in 2009 and 2010

Nuclear Structure: **Excellent performance from UC_x Actinide Target**

Shape Coexistence in Neutron-rich Sr isotopes, (Garnsworthy), Dec 2010

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V_{ud} : The Responsibility of Low-Energy Nuclear Physics

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

phase space (Q-value)

half-life, branching ratio

$$ft = \frac{K}{|M_{fi}|^2 g^2}$$

constants

Weak coupling strength

matrix element

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

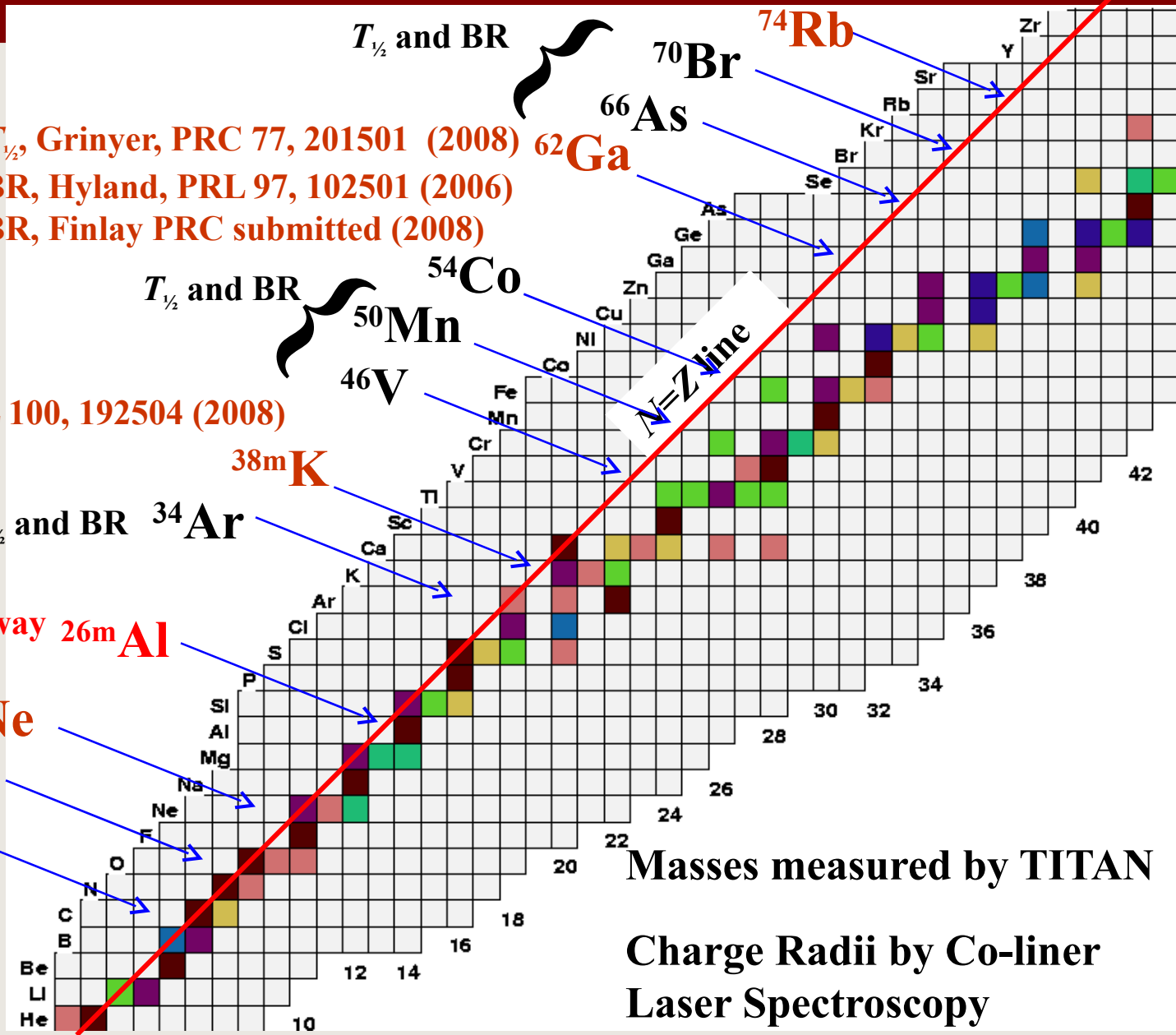
$$|M_{fi}|^2 = (T - T_Z)(T + T_Z + 1) = 2 \quad \text{(for T=1)}$$

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

Vector coupling constant $\rightarrow$ $G_V^2 = \frac{K}{2\,ft}$ $\qquad$ $|V_{ud}| = G_V / G_F$ $\leftarrow$ Fermi coupling constant

Superallowed Studies at ISAC

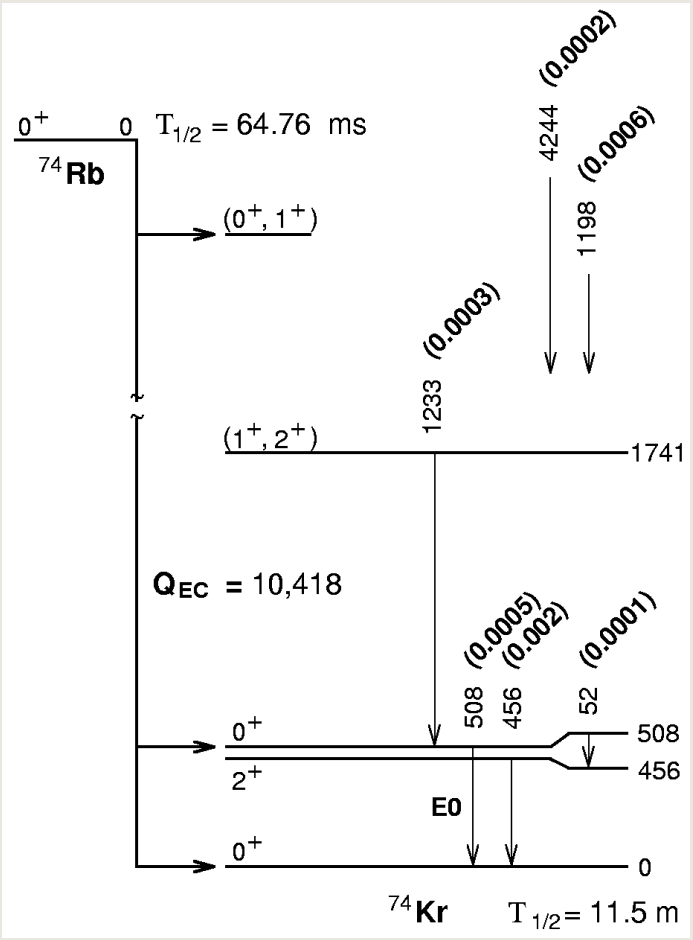
BR, G.C. Ball *et al*, PRL 86 1454 (2001)



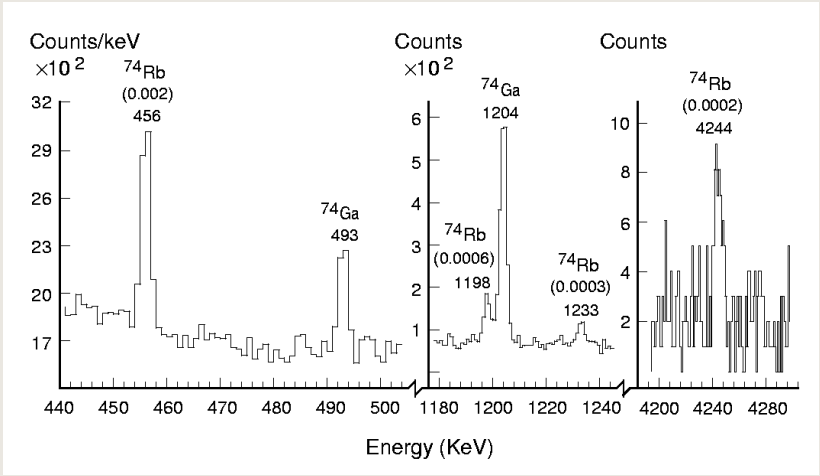
^{74}Rb Results from 2001

G.C. Ball *et al*, PRL 86 1454 (2001)

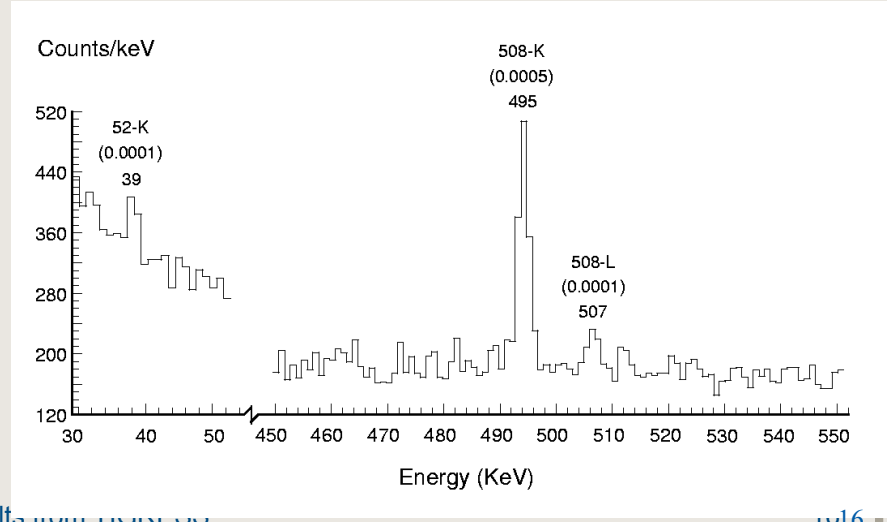
Original BR measurement at ISAC



Gamma-Ray Spectrum (1 HPGe detector)



Conversion Electron Spectrum



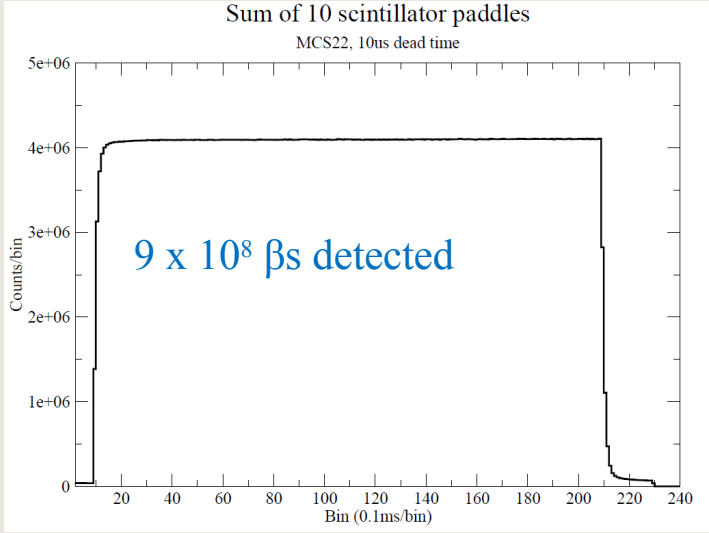
BR = 99.5(1)% Piechaczek *et al* Phys Rev C67 052305(R) 2003

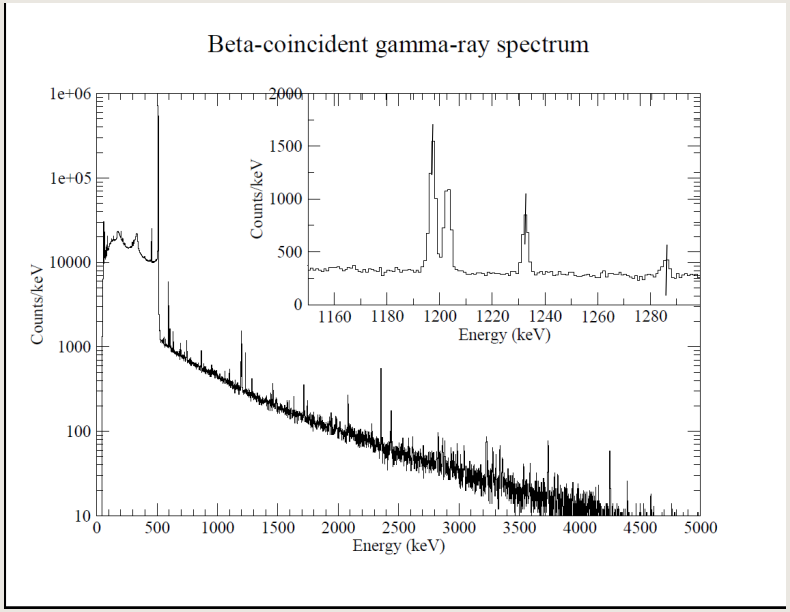
^{74}Rb Branching ratio Measurement using the 8π spectrometer, Nov 2010

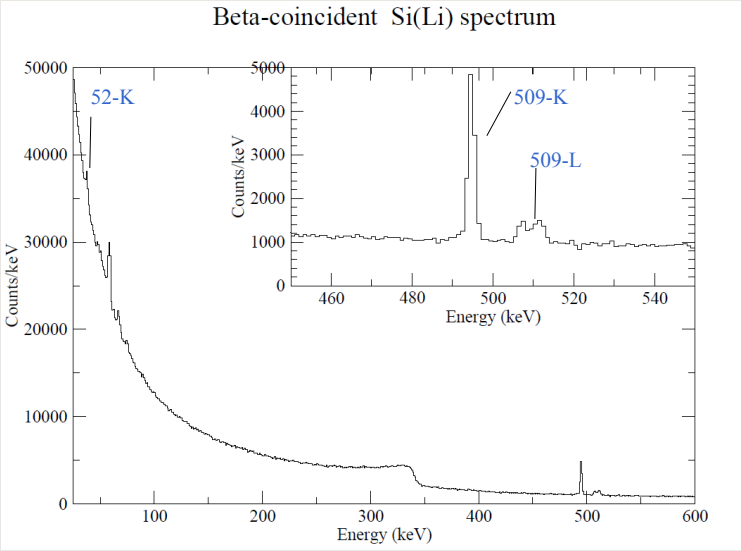
Goal: reduce uncertainty in BR by factor of 3

20 Compton-suppressed HpGe
10 plastic scintillators
5 LN_2-cooled Si(Li)

100 μA of 500MeV protons on High-power Nb
~10000 ^{74}Rb
^{74}Rb/^{74}Ga ratio increased ~150
mass difference : 1/4500

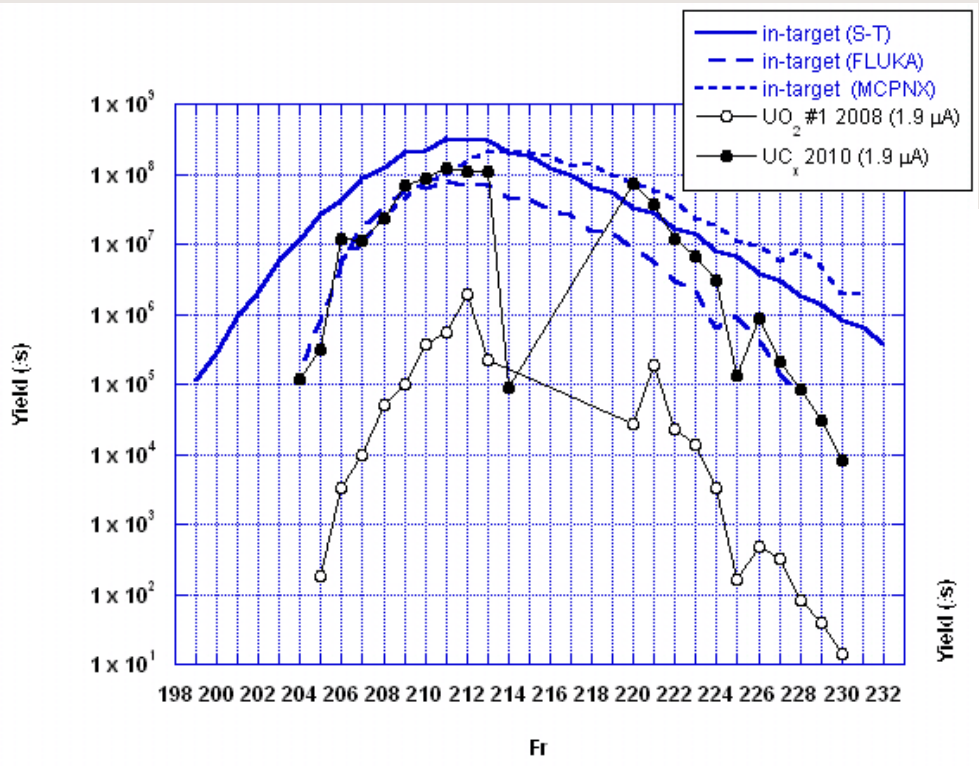


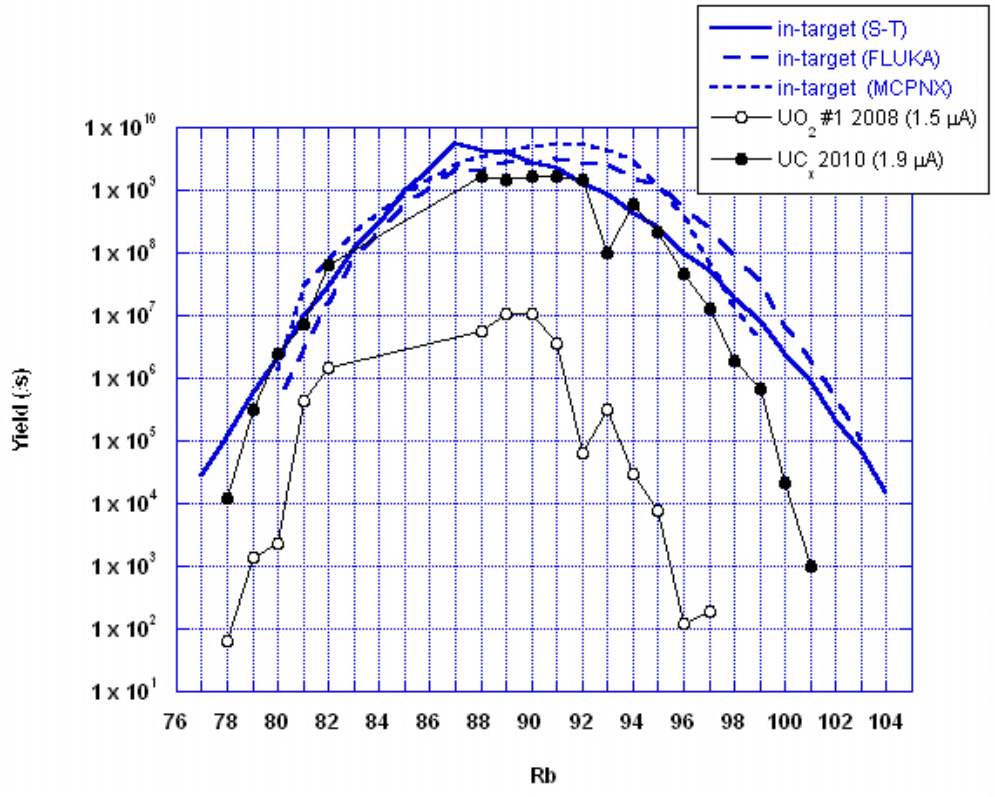




UCx Target Run – December 2010

Excellent performance from first UCx target with surface ion source





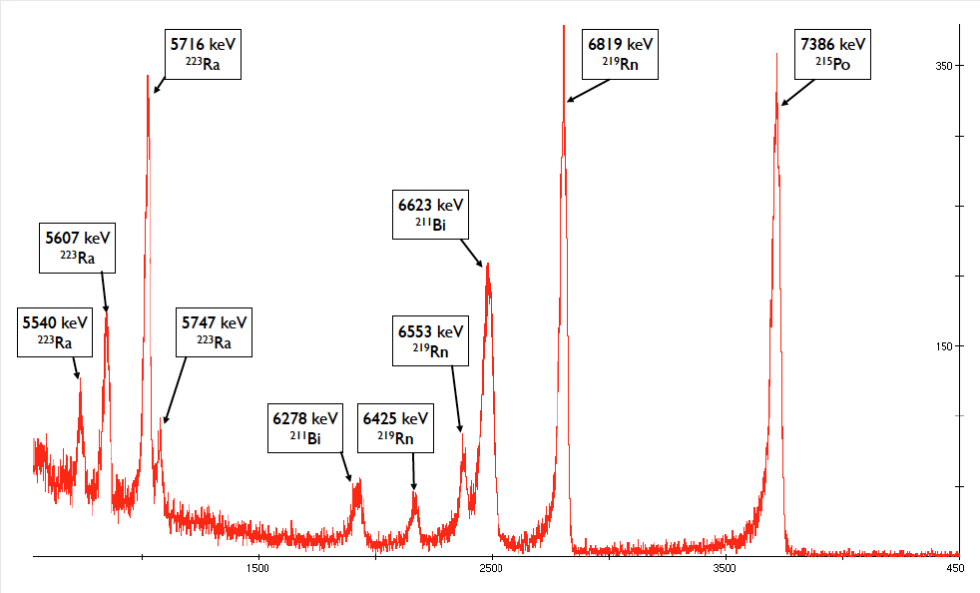
UCx Target Run – December 2010

Towards the structure of neutron-rich Rn
199, 218, 219, 221, 223At
At Laser-ionized. Ra and Fr surface

Five LN_2-cooled, 200mm^2 Si(Li)

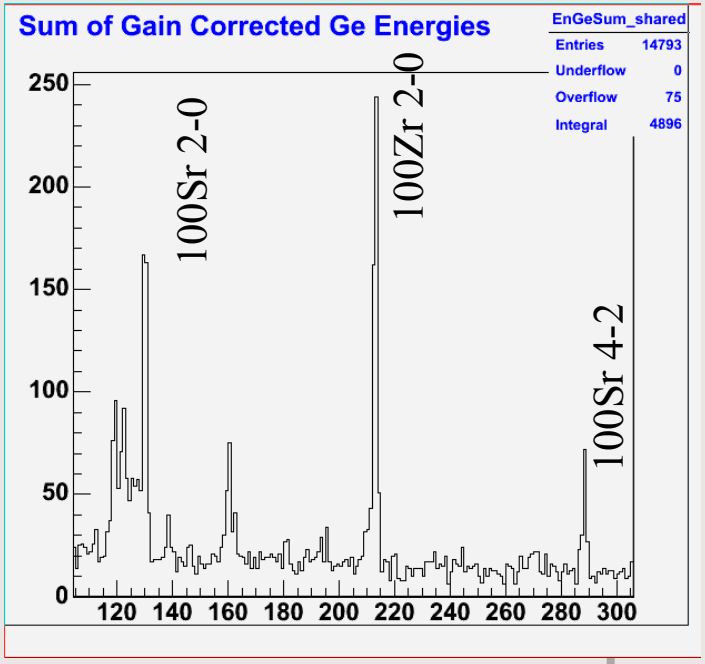
Record a high-gain and low-gain signal for both e^- and α,p

7.4% solid angle coverage



Shape transition and coexistence at *N*=60
96, 98, 100, 102Rb

Measure E0 strengths to determine mixing



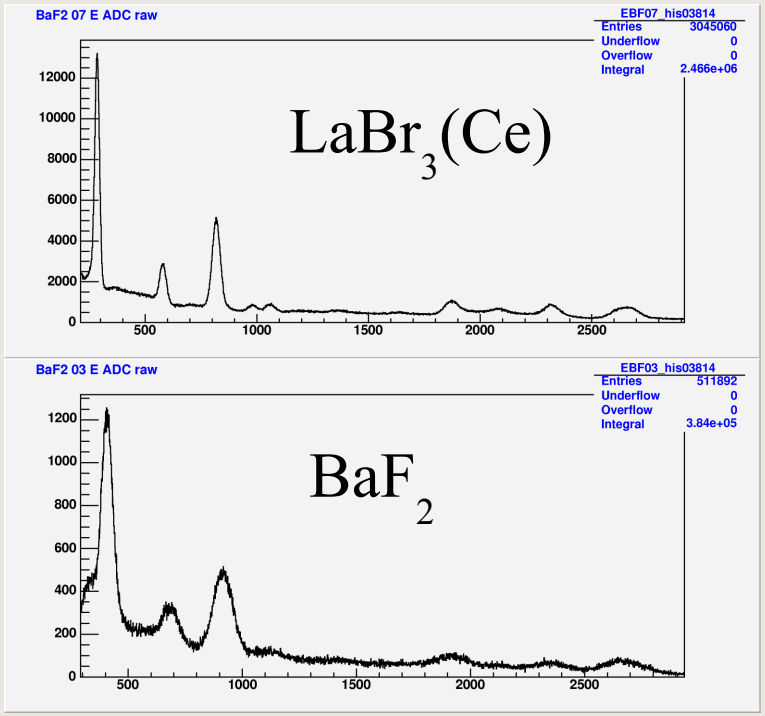
Hardware Developments

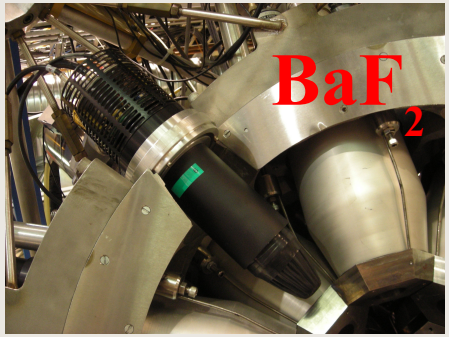
2010 – Fast-timing, $LaBr_3$

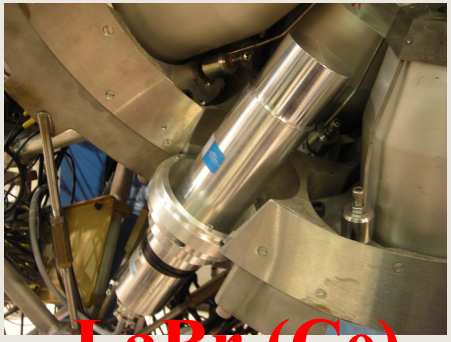
2015 – Ge Efficiency, GRIFFIN

GRIFFIN – Neutron Array, DESCANT (2012)

Increasing Sensitivity for Fast-Timing







Fast-timing allows the determination of transition rates

Replacing BaF2 scintillators with $LaBr_3(Ce)$

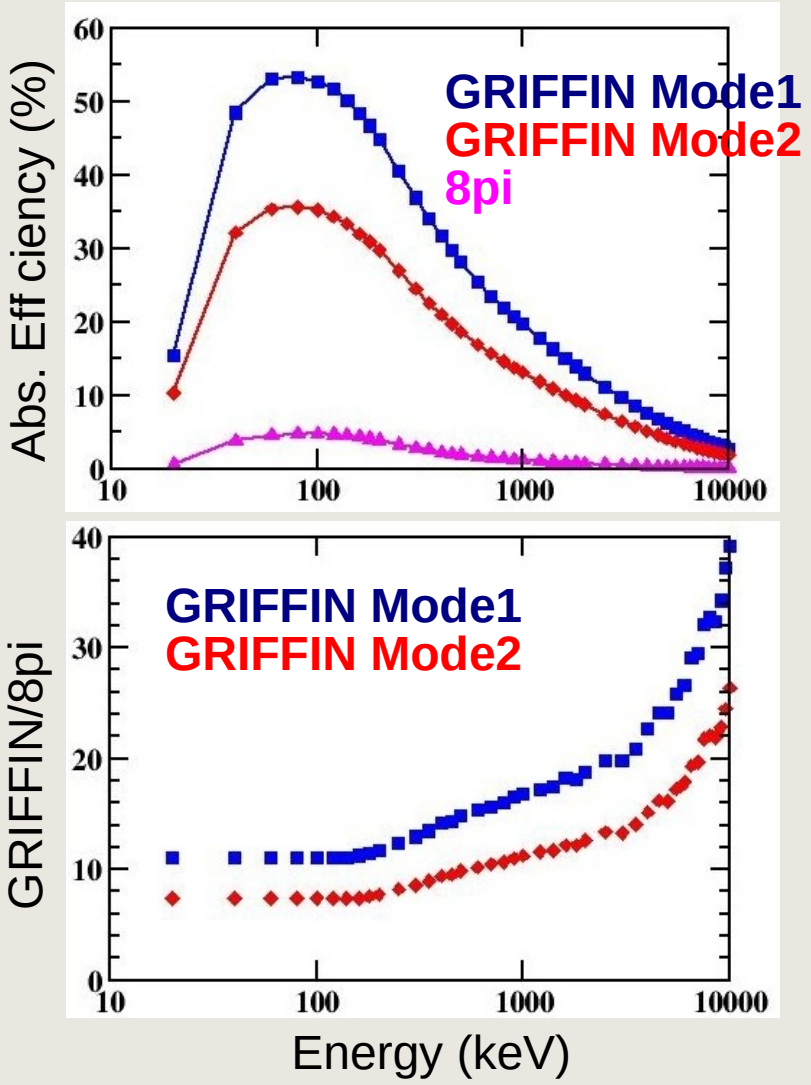
Superior Energy resolution (x3) and efficiency (x2)

1 tested in April 2010,

5 more now purchased and passed acceptance testing

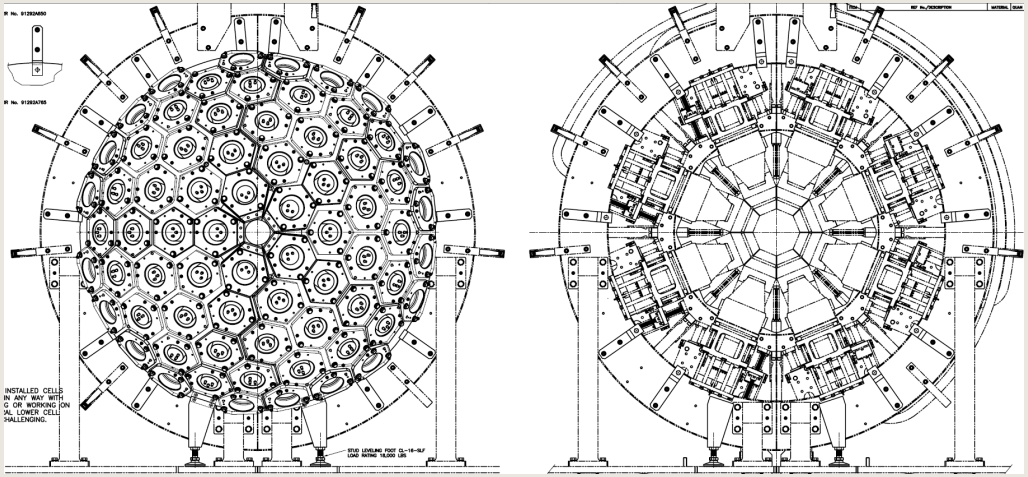
Gamma-Ray Infrastructure For Fundamental Investigations of Nuclei

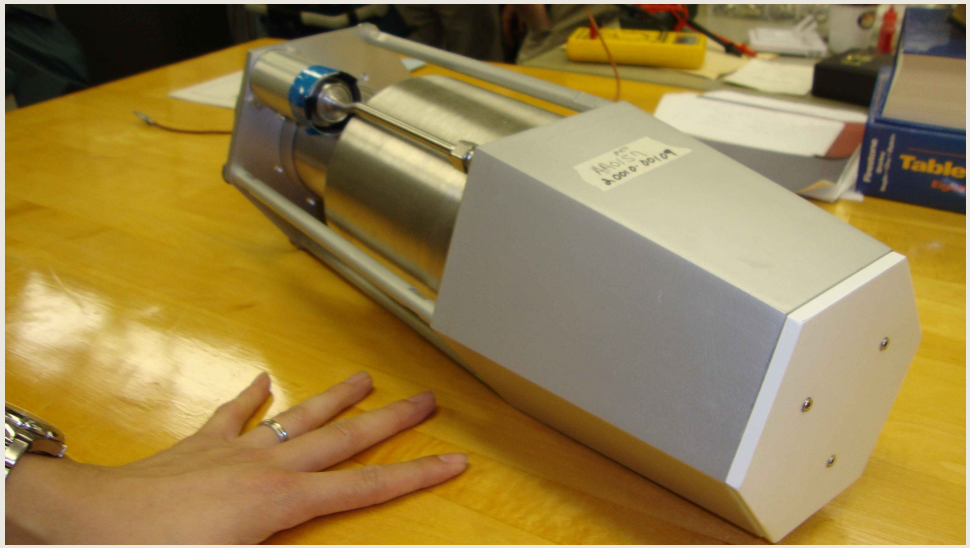
- **GRIFFIN** will upgrade the 8pi Ge to 16 fully-suppressed Clovers
- 300-fold increase in gamma-gamma efficiency
- High-rate digital DAQ
- 8pi requires >1 ion/s
  GRIFFIN can study >0.01ions/s
- Make use of all existing and future ancillaries



DEuterated SCintillator Array for Neutron Tagging

- DESCANT
- 70 element Neutron array
- Deuterated scintillators
- Custom digital DAQ with 1GHz sampling
- Couples directly to TIGRESS or GRIFFIN frame





Summary

- 8pi Spectrometer working well at ISAC
- Beginning to exploit the use of actinide targets and beams
- Future plans for upgrading the Ge efficiency and combining a neutron tagging array
- Facility upgrades
  - Increased beamtime from multiple frontends
  - E-linac for photofission

Acknowledgements and Thanks

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Randy Churchman, Chris Pearson, Steve Yates,
Nico Orce, Smarajit Triambak, Scott Williams,
Eric Tardiff, Jackie Glister, and all the 8pi Collaborations

Positions Available – Join the team!

TRIUMF is located in beautiful Vancouver, BC

- 2 yr Postdoc position working on TIGRESS
- 2yr Postdoc position working on SPICE
- Advanced Postdoc (5 years) working on Digital Data Acquisition
- Sabbatical opportunities

Thank You!

Merci!

Contact TRIUMF :
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S1007: Equilibrium of $^{115}Cd^{m}$ During the *s*-process

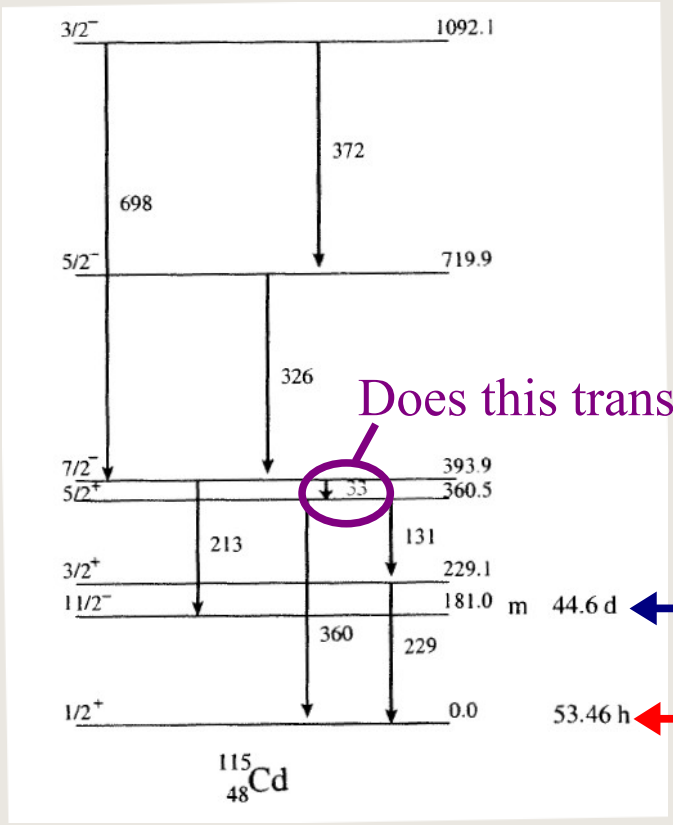
Sumithrarachchi/Triambak

Understanding the abundance of ^{116}Cd – contributions from the *r* and *s*-processes

^{116}Cd from *s*-process only through $^{115}Cd^{m}$

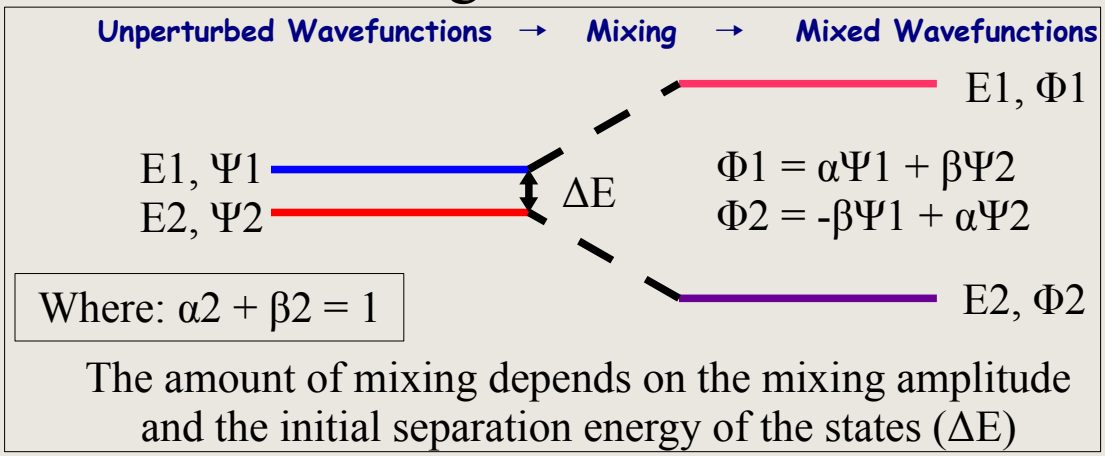
Search for gateway states which will link the isomer to the ground state through (γ,γ')

Experiment was cut short otherwise could have done detailed spectroscopy of ^{115}Cd



E0 Transitions provide structure insight

Two-State Mixing between levels of same spin/parity



For a transition between these states the $E0$ strength, $\rho_{if} = \frac{\langle \Phi_1 | \mathrm{m}(E0) | \Phi_2 \rangle}{eR^2}$

where e = electric charge
and $R = 1.2A^{\frac{1}{3}} fm$ and

$\langle \Phi_1 | \mathrm{m}(E0) | \Phi_2 \rangle \simeq \alpha\beta\Delta\langle r^2 \rangle$

Mixing between structures will *modify all observables* and disguise the true unperturbed configurations

Mixing must be understood to characterize the underlying structure

E0 strengths can reveal mixing parameters and unperturbed energy spacings