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The decay spectroscopy program with the 8π spectrometer at TRIUMF: lessons learned and future plans

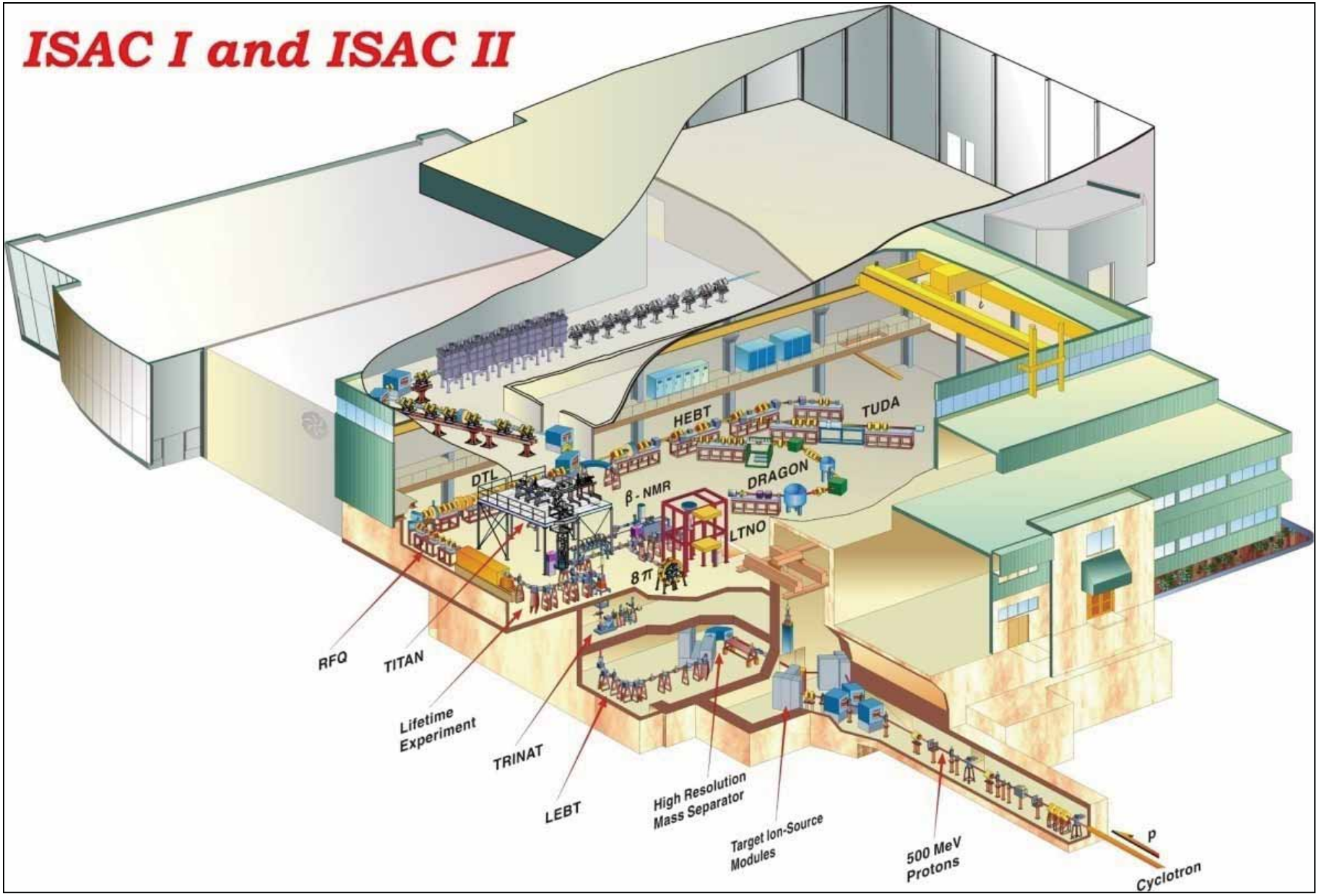
Paul Garrett

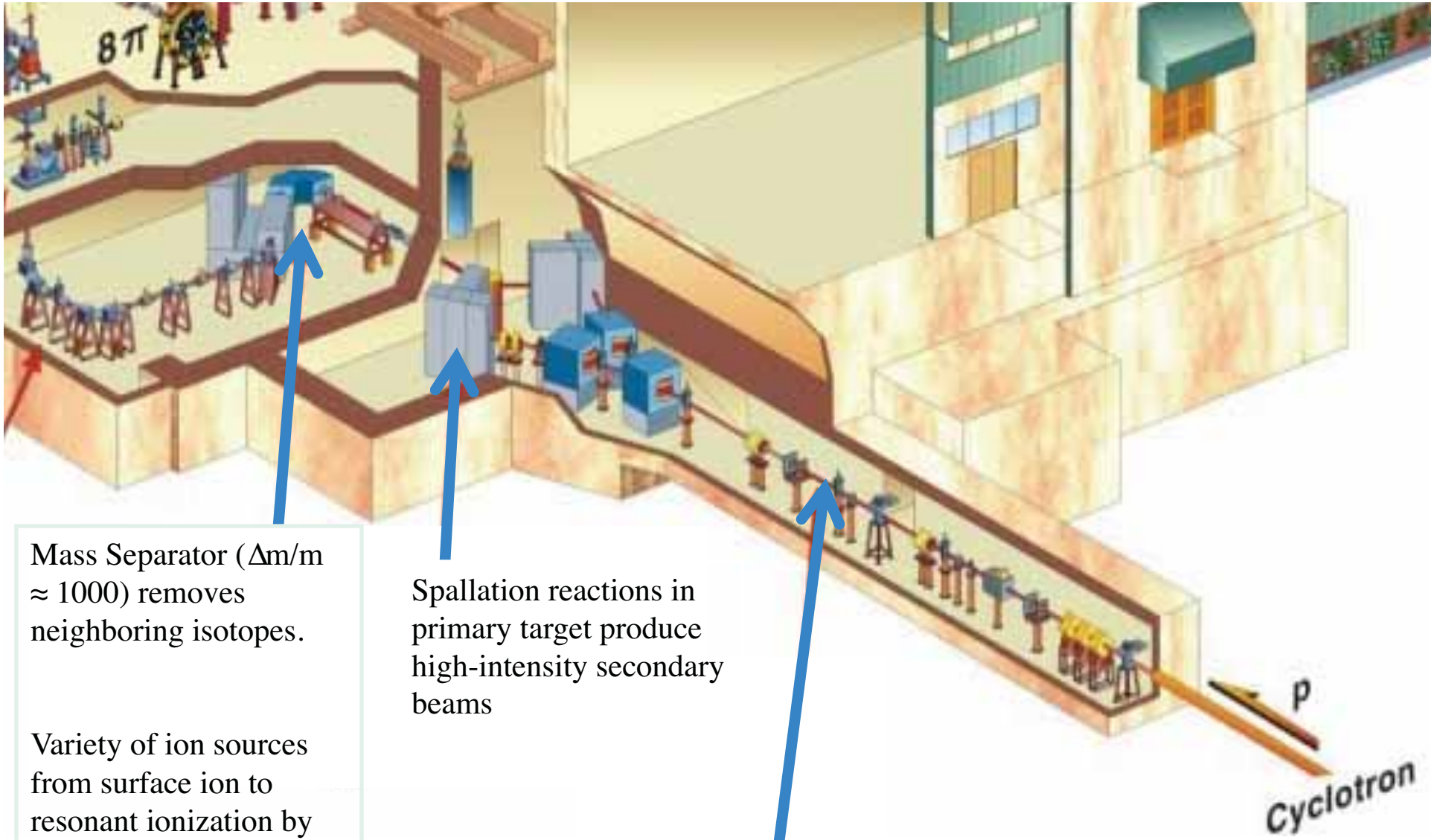
University of Guelph

for the 8π collaboration

AFC workshop
ANL Apr. 14 – 16, 2011

ISAC I and ISAC II





Mass Separator ($\Delta m/m \approx 1000$) removes neighboring isotopes.

Variety of ion sources from surface ion to resonant ionization by laser

Spallation reactions in primary target produce high-intensity secondary beams

Up to 100 μA, 500 MeV proton beams from the TRIUMF main cyclotron impinge on the primary target.

The 8π spectrometer – a versatile tool for nuclear physics

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8π Spectrometer at ISAC

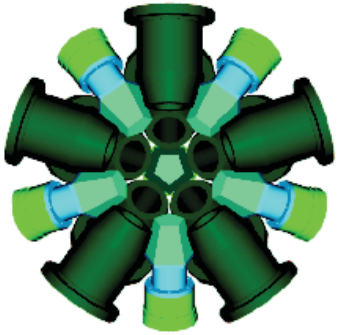
20 Compton-Suppressed HPGe detectors

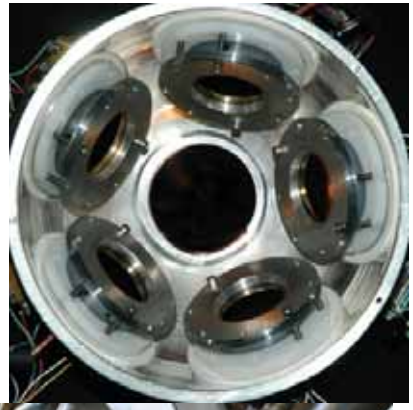
and 10 BaF2 detectors for γ-ray detection

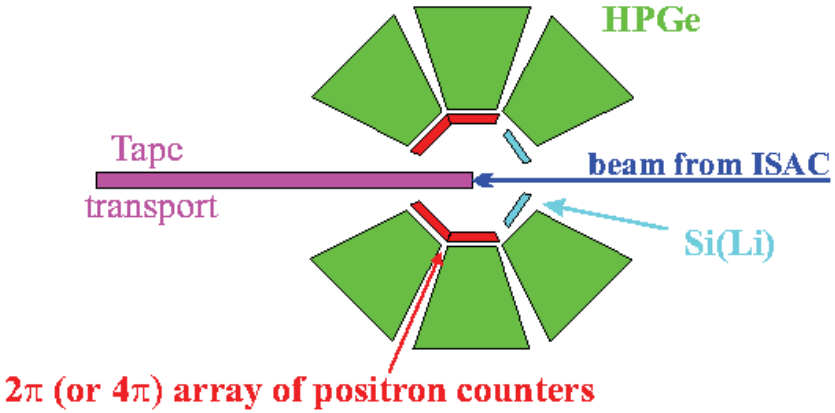
20 plastic scintillators for β detection

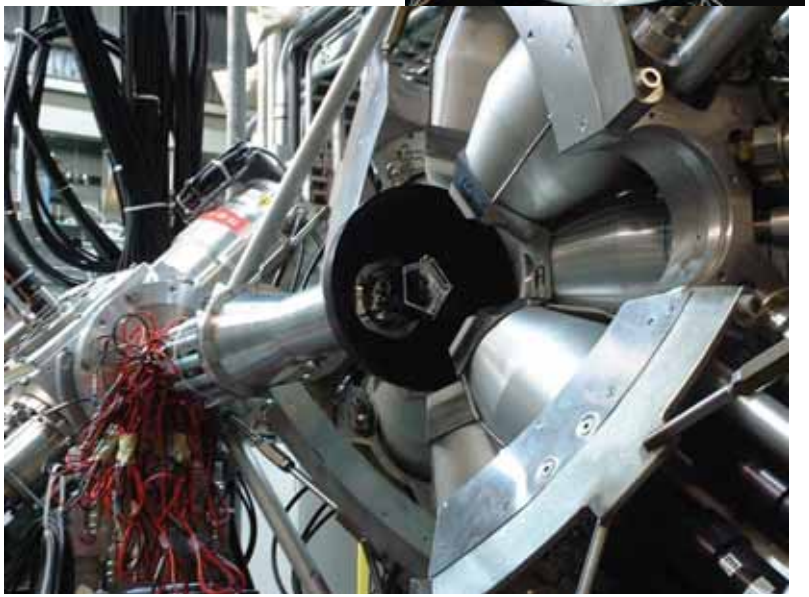
5 Si(Li) detectors for conversion electron spectroscopy

Fast, in-vacuum tape transport system









Auxiliary detectors as important for decay spectroscopy as in-beam spectroscopy – ***8π uses auxiliaries for every experiment performed***

Moving tape collector for transport of activity – our most important auxiliary device

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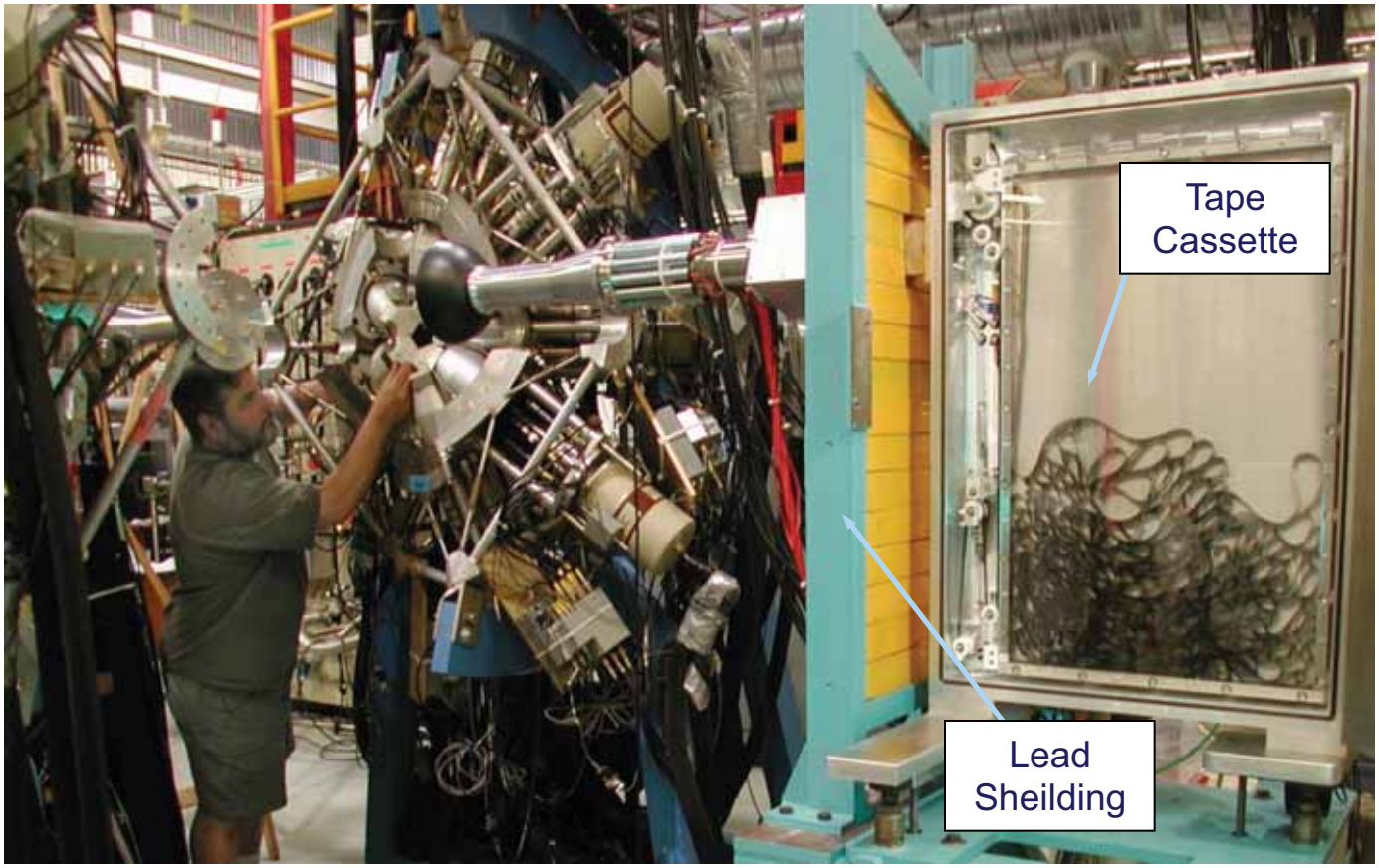
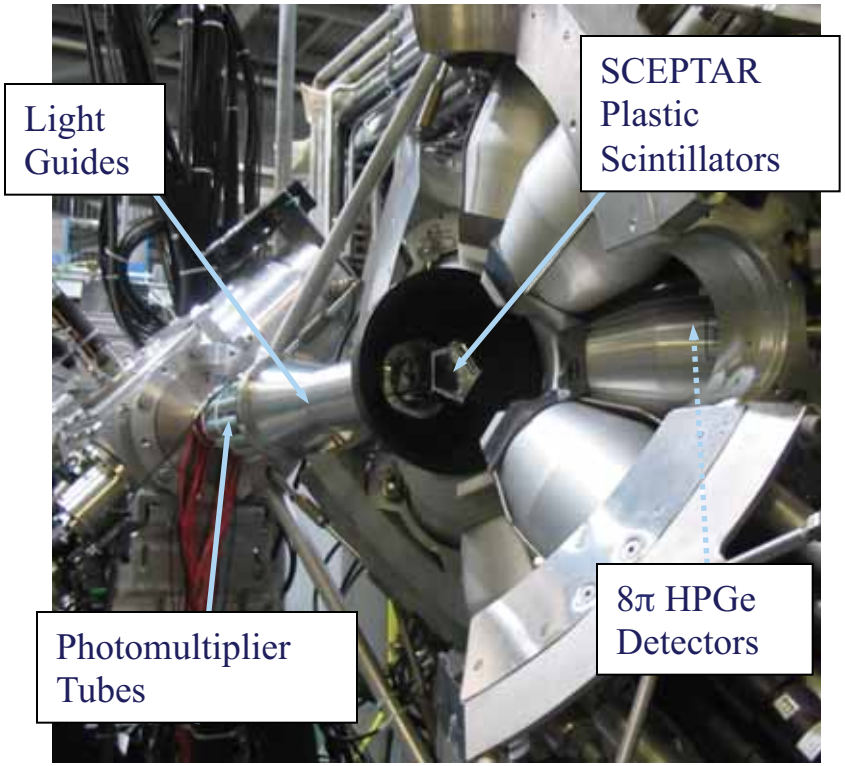
- Beam implanted onto a moving tape at center of array
  - Allows for movement of long-lived activity out of focus of spectrometer
- Tape speeds, dwell times, etc., variable
- Control of beam kicker tightly coupled – beam collection time variable (down to ~ 100ms)

- Tape transport very flexible: can be motionless, or operated in continuous motion
- Disadvantage: study of long-lived activity in presence of intense, short-lived isobar

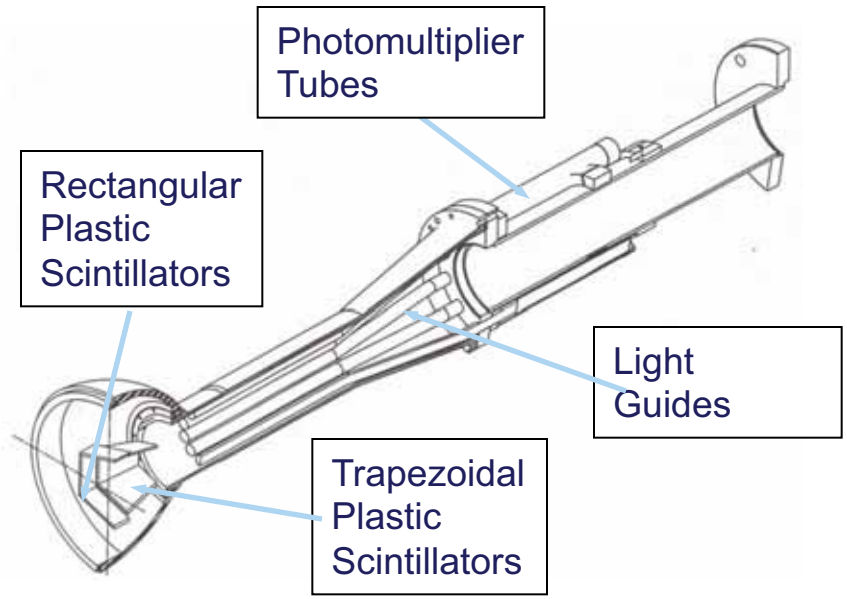


Built by E. Zganjar, LSU

SCEPTAR and the 8π spectrometer



- SCEPTAR divided into two hemispheres.
- Each half contains 10 thin (~1.6 mm) plastic scintillator panels.
- 10 panels arranged in two pentagonal rings.



- 1-to-1 correspondence between the SCEPTAR detectors and the Ge detectors allows to veto event that arises from high-energy β particles that reach Ge detector

Example of low beam-rate experiment – ^{32}Na decay

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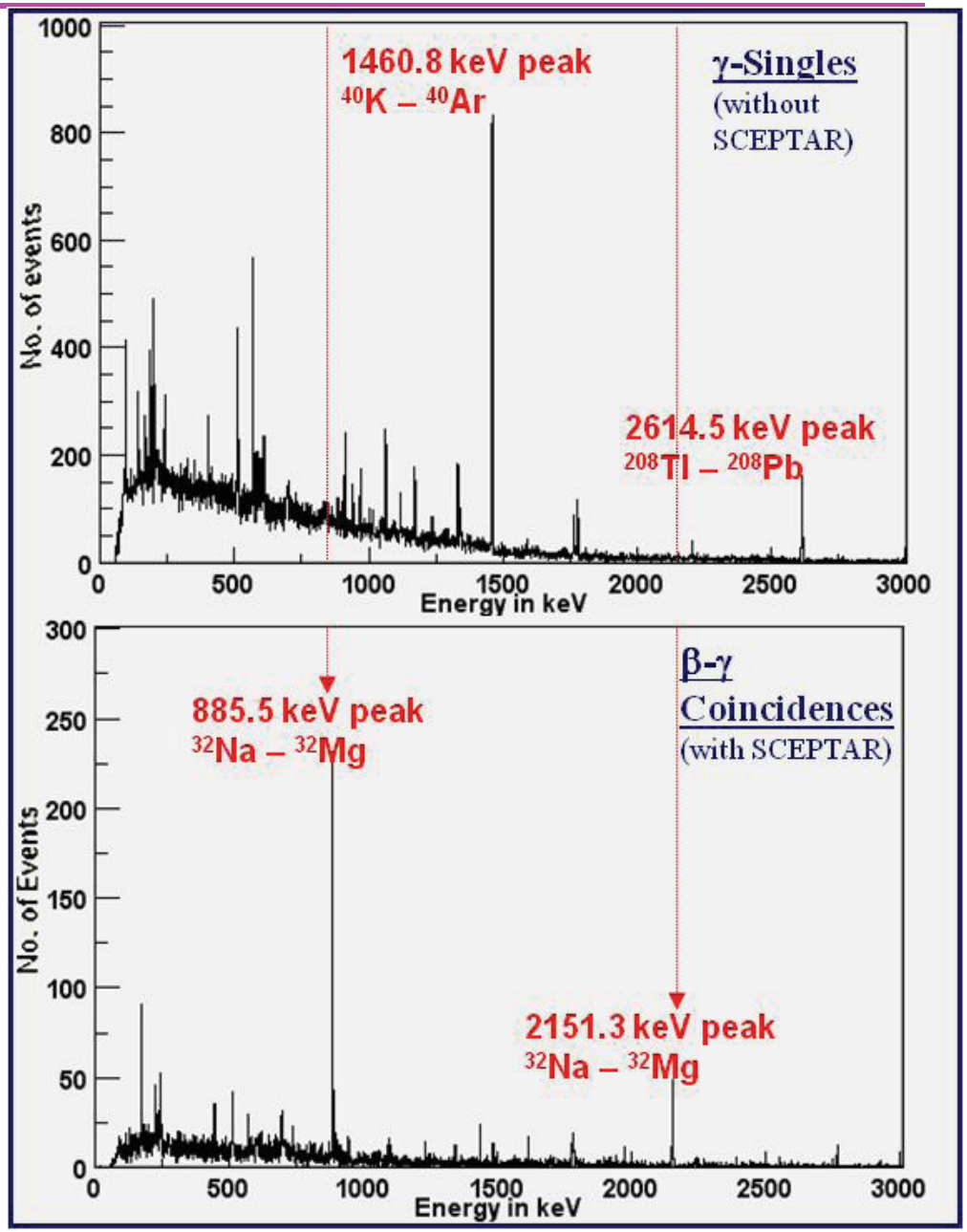
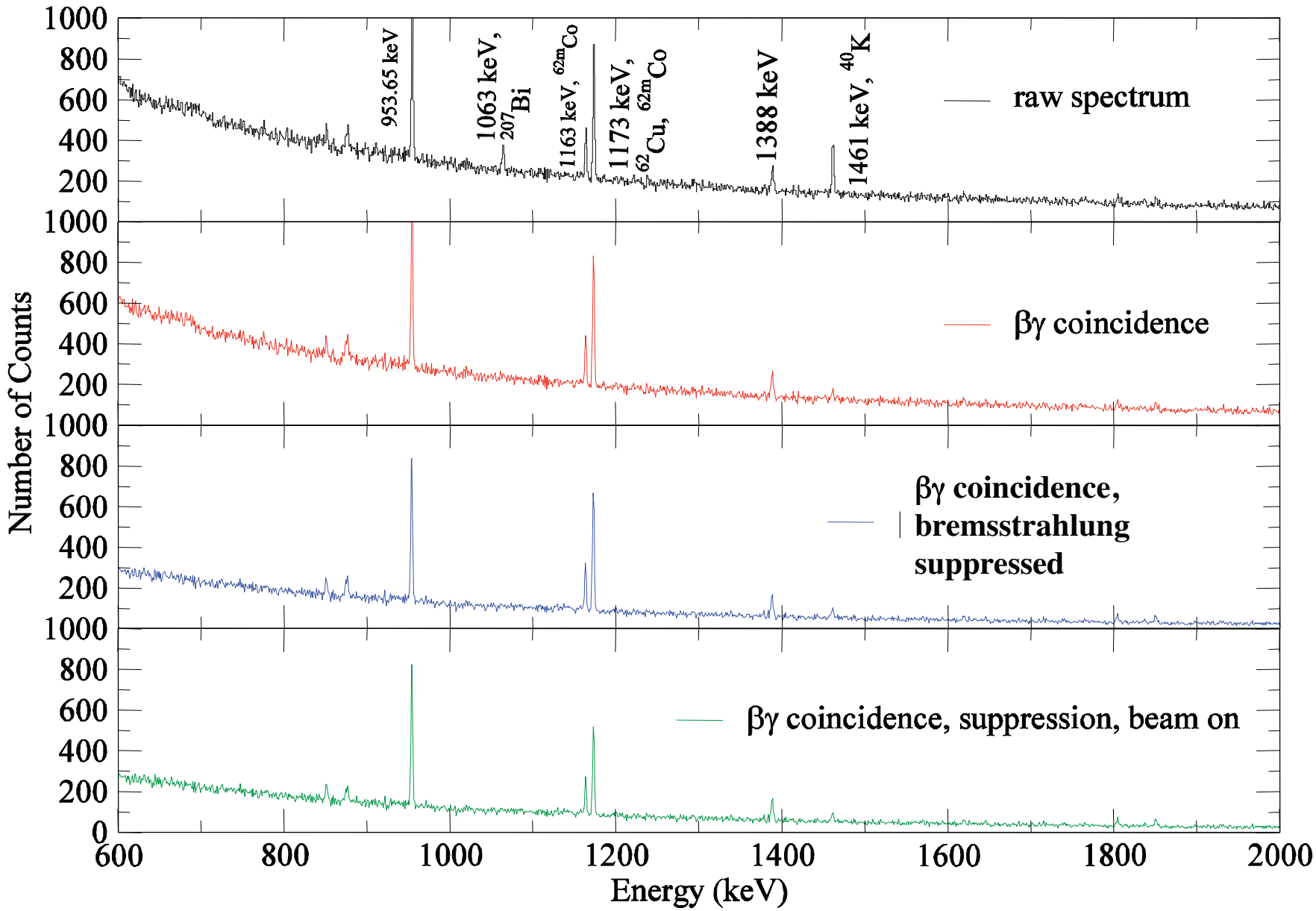
- ^{32}Na decay investigated as a means to study the excited nuclear states of ^{32}Mg (Z=12, N=20).
- ^{32}Na beam rate at ~2 ions/s
- β-γ coincidences measured with 8π and SCEPTAR.
- Reduce background and allow weak ^{32}Na decay spectrum to be measured.
- Spectroscopy impossible without β tagging



C.M. Mattoon et al., PRC 75, 017302 (2007)

Improvement in γ signal quality with β tagging with SCEPTAR – ^{62}Ga decay



PACES – 5 Si detectors inside target chamber for conversion electron detection

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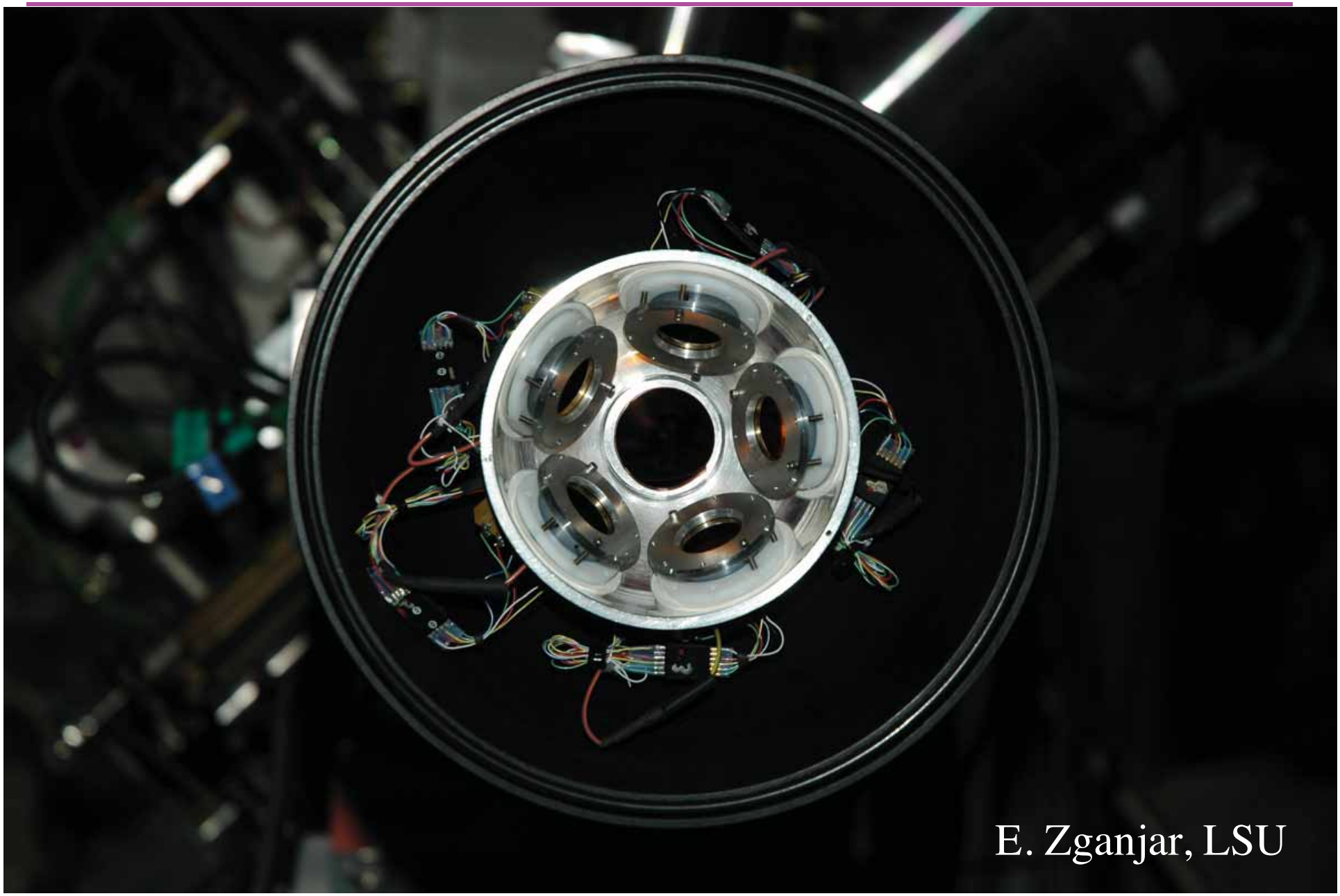

E. Zganjar, LSU

Discovery of new isomer in ^{174}Tm

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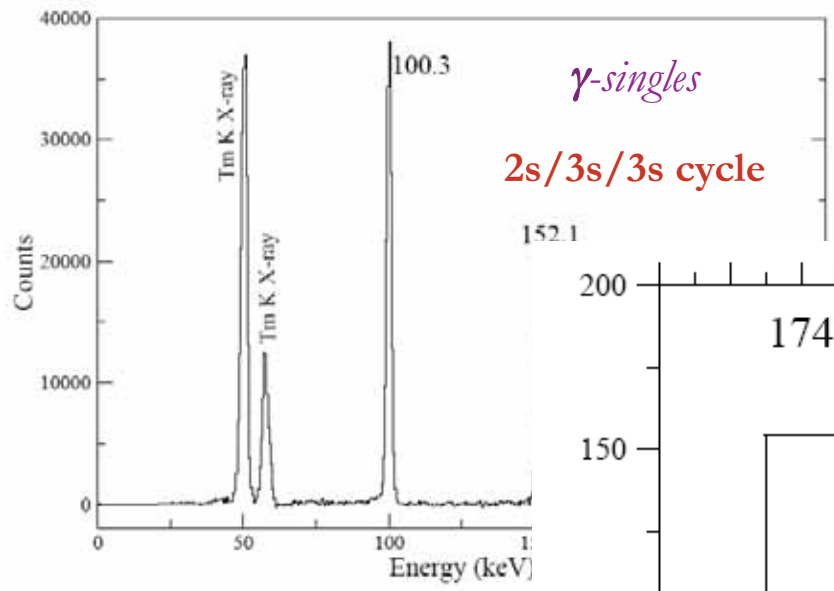
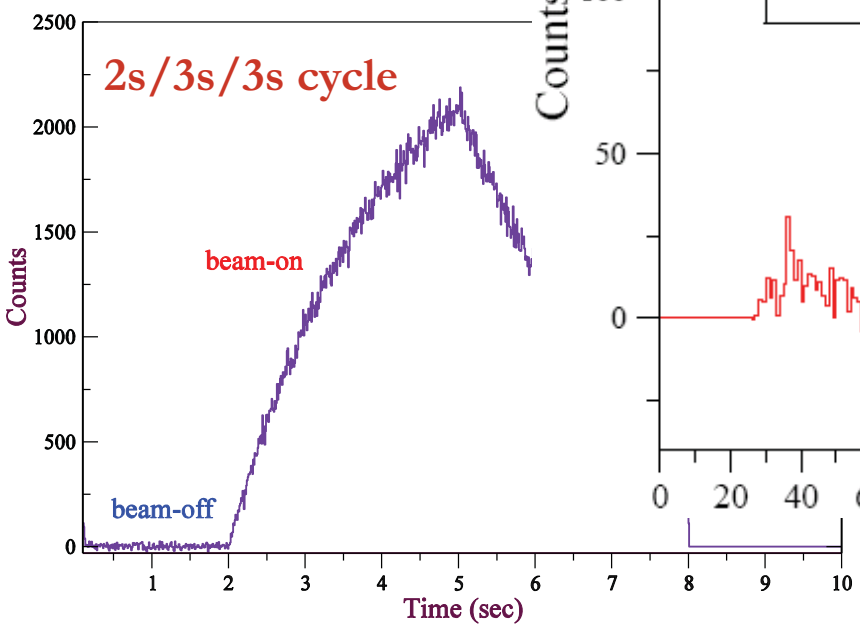
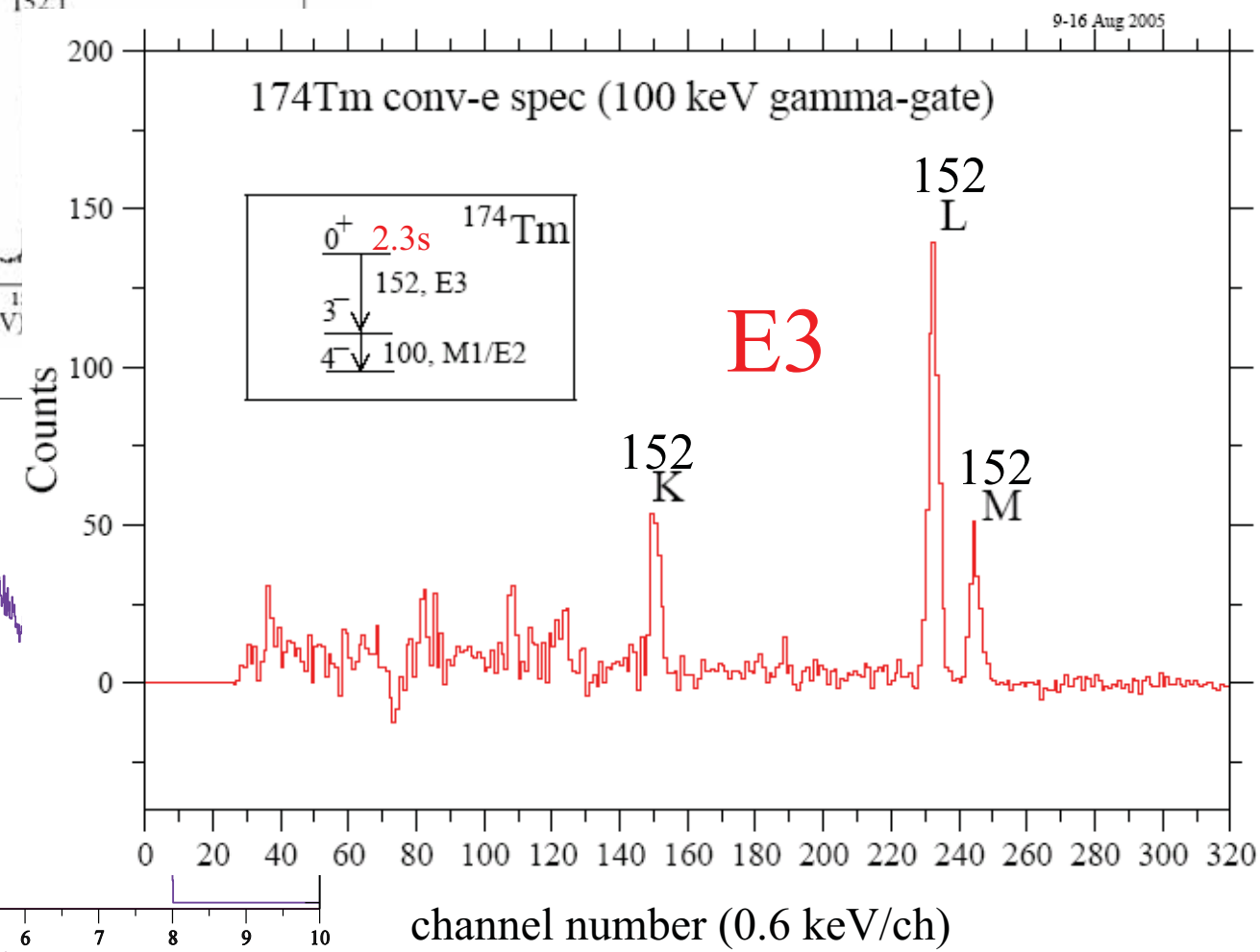
R.S. Charkrawarthy et al., PRC 72, 024306 (2006)







Data from PACES in rare-earth nuclei

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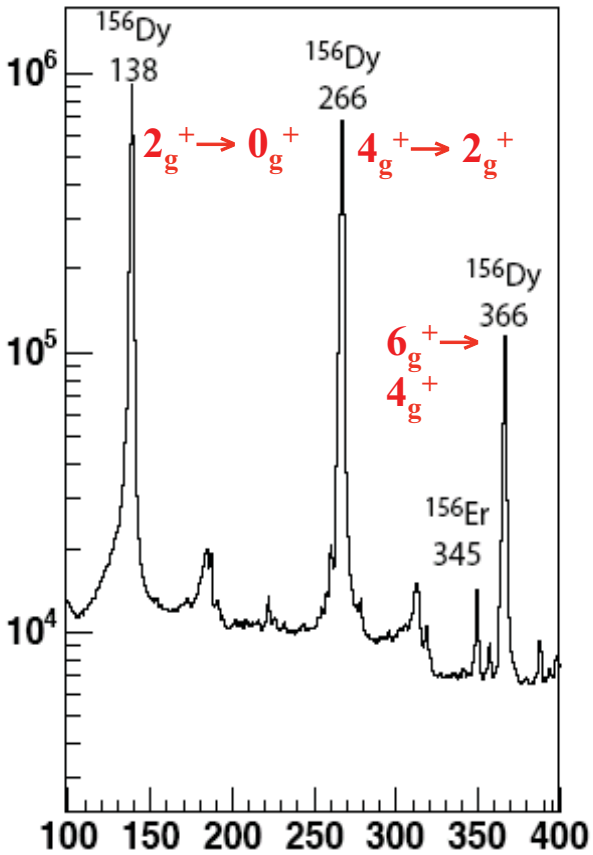
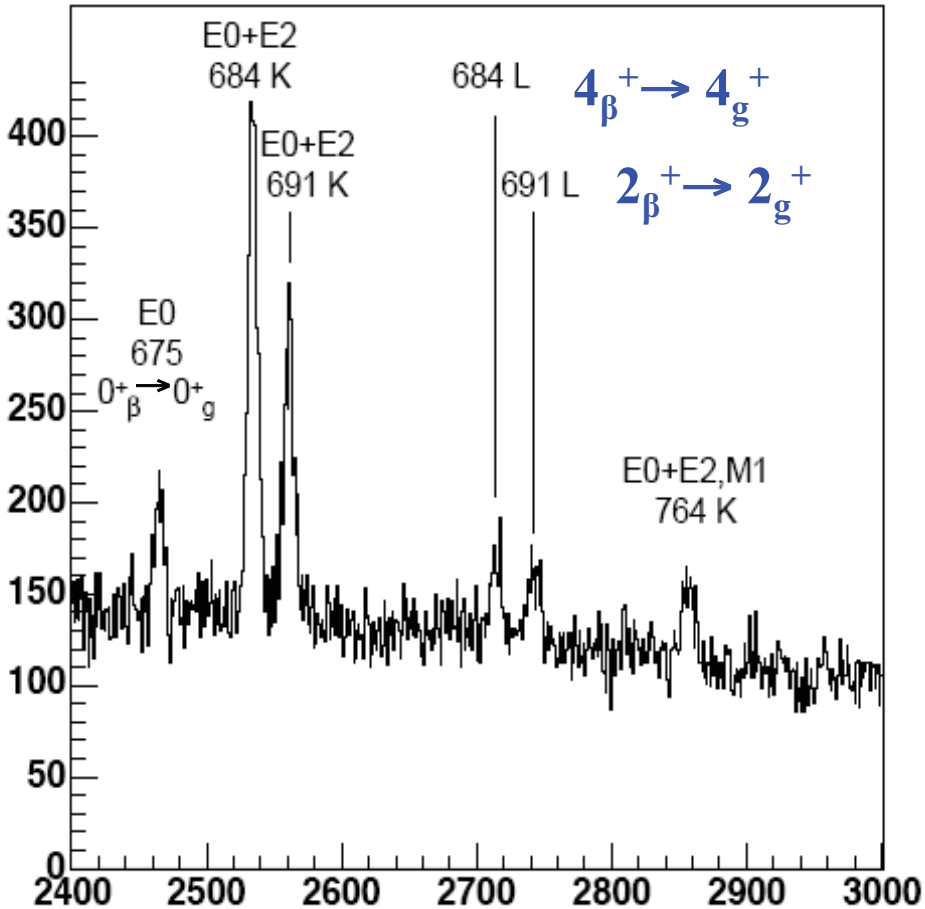
- *E*0 transitions are vital to substantiate claims of shape co-existence
- Most cases require high-statistics to extract accurately (unless $0^+ \rightarrow 0^+$ additional components of *M1*, *E2* need to be accounted for)





DANTE array for fast timing

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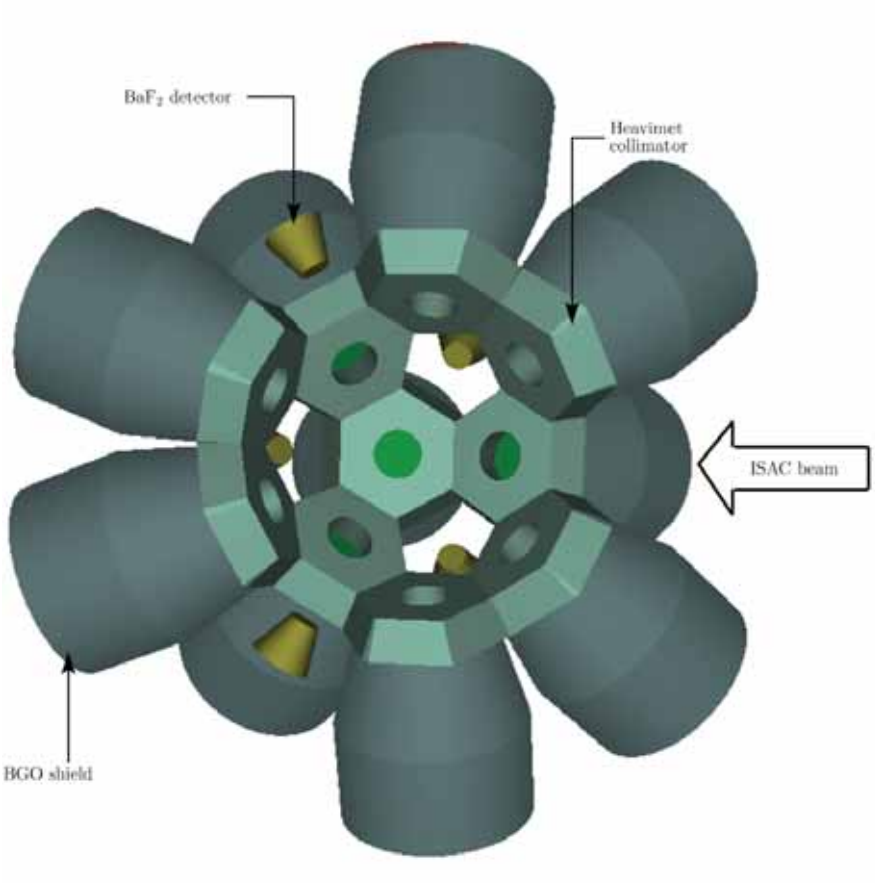
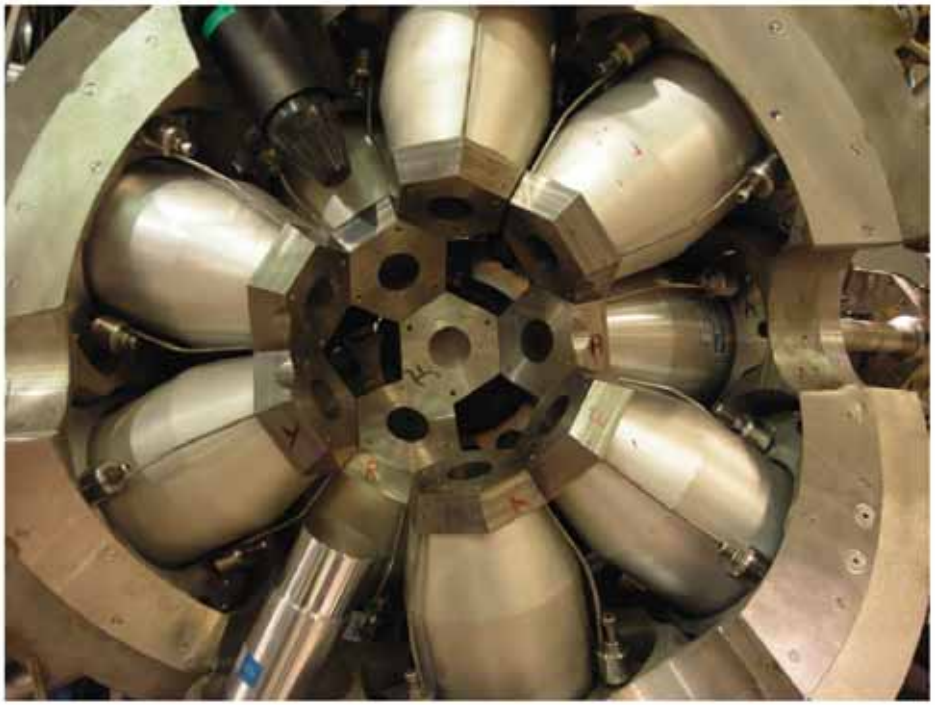
- 10 BaF_2 detectors for fast timing measurements
- In process of replacing with $LaBr_3$





First tests with DANTE installed in 8π array

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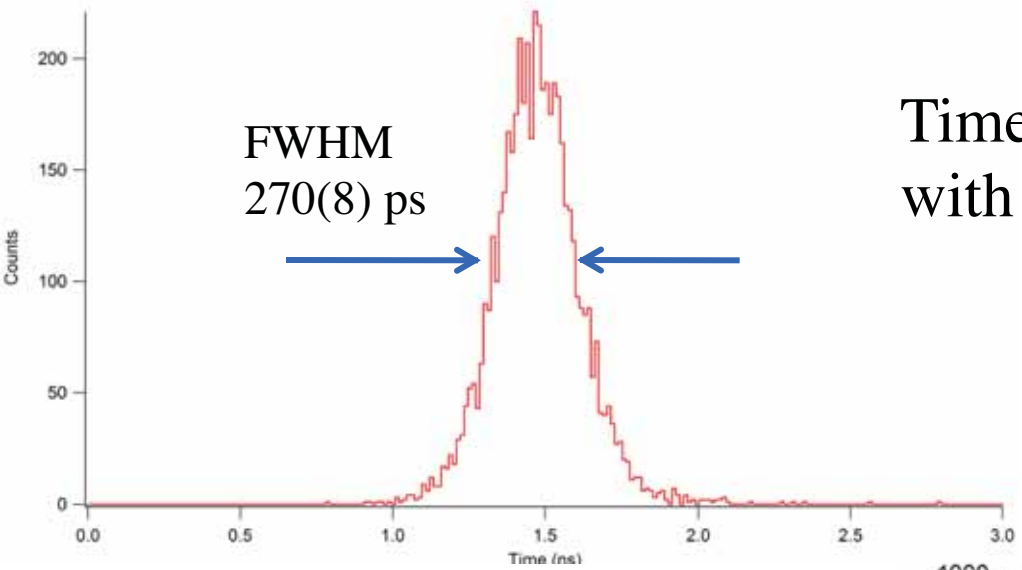
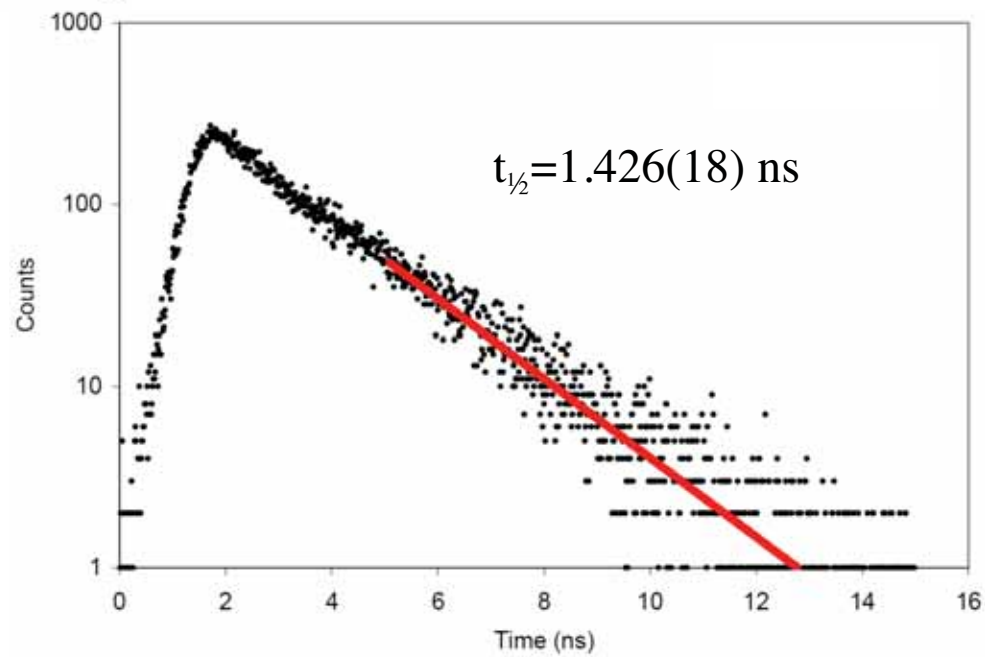


Time response measured with ^{60}Co

Time measurement of 2^+ state in ^{152}Sm (^{152}Eu decay)

Issue: detector-to-detector scattering across array



Results from ^{112}Ag β^- and ^{112}In β^+/EC decay experiment

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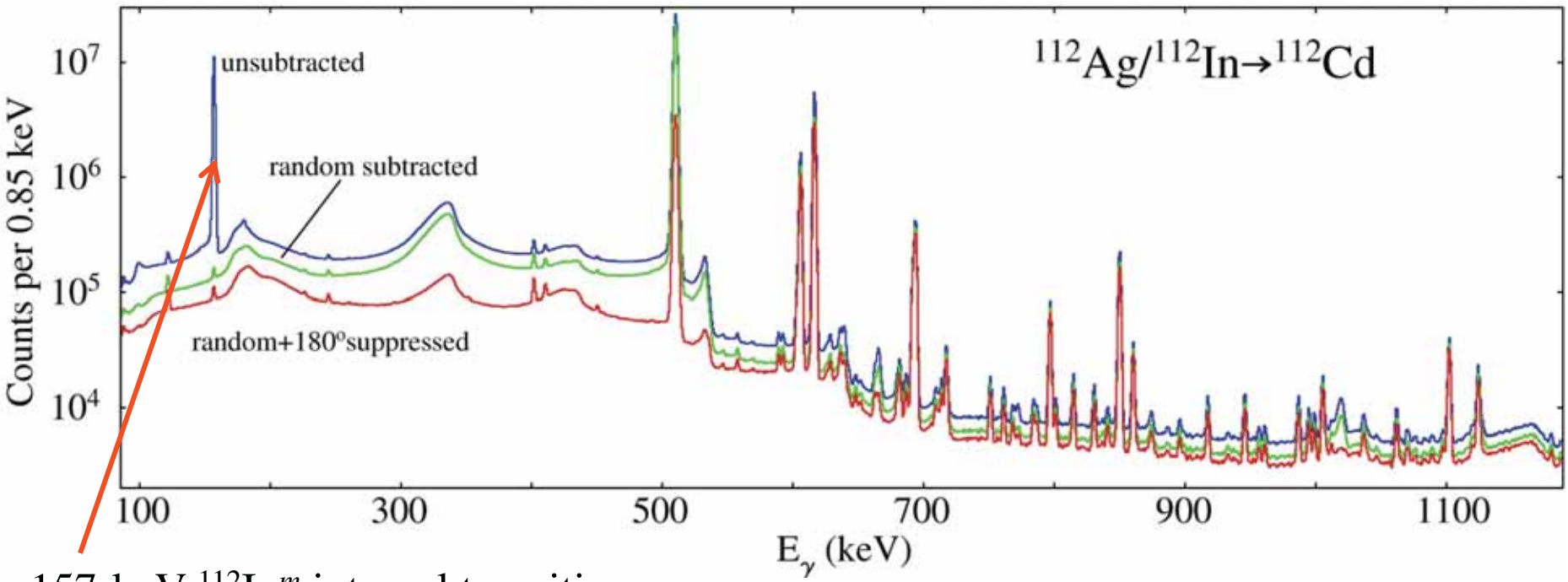
- **$\gamma\gamma$-matrix projection**
  - **200×10^6 prompt events, 100×10^6 events random subtracted, 48×10^6 events 180° suppressed**



157-keV ^{112}In^m internal transition

Important to have sufficiently wide coincidence window to properly account for time-randoms

Issues to consider

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- **Tape collector with variable beam-spill control is vital**
  - **Flexibility with deposit either internal or external of array is highly desirable**
- **High-throughput DAQ**
- **Auxiliary detectors to increase range of physics**
  - **Si for conversion e^- for multipolarities**
    - **Need LN2 cooling – restrictive geometry**
    - **e^- need unobstructed path to Si**
    - **Si count rates quickly become limiting factor – segmentation**
  - **Introduction of fast-timing detectors like $LaBr_3$**
- **Measurement of angular correlations**
  - **Complements e^- for multipolarities, spin sequences**
  - **Many (perhaps *most*) previous γ branching ratios wrong**
    - **Singles problematic, coincidences affected by angular correlations**

Future at TRIUMF – GRIFFIN

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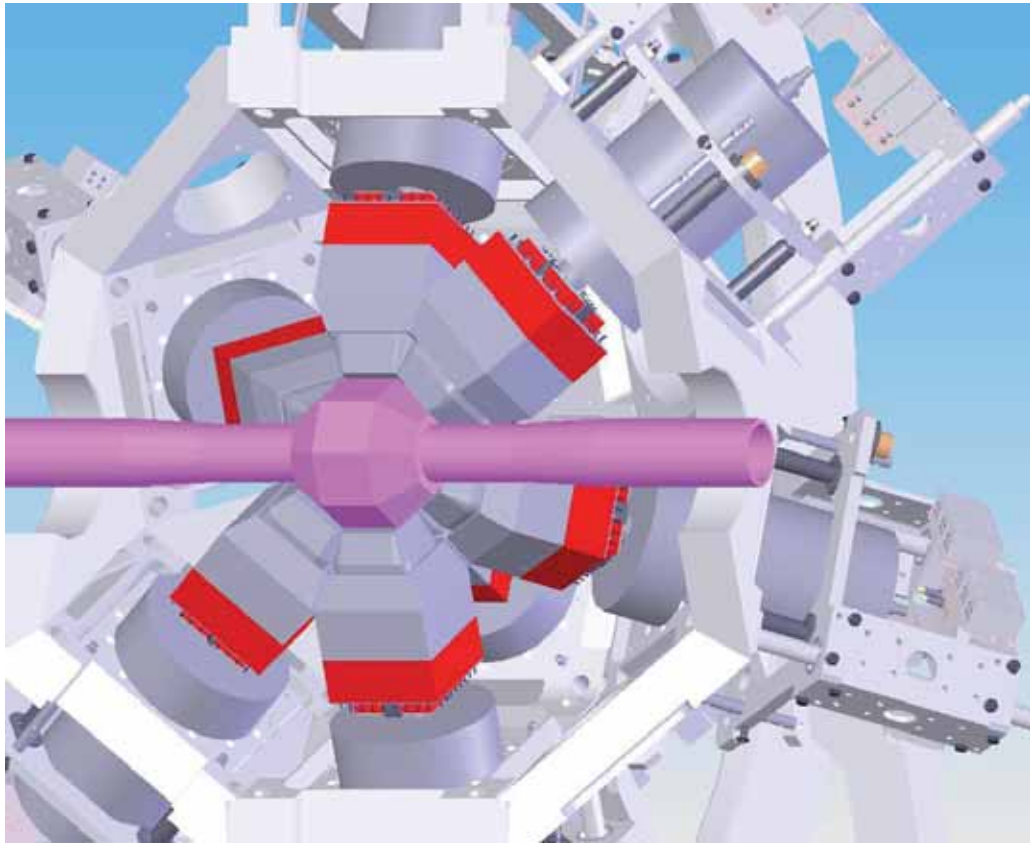
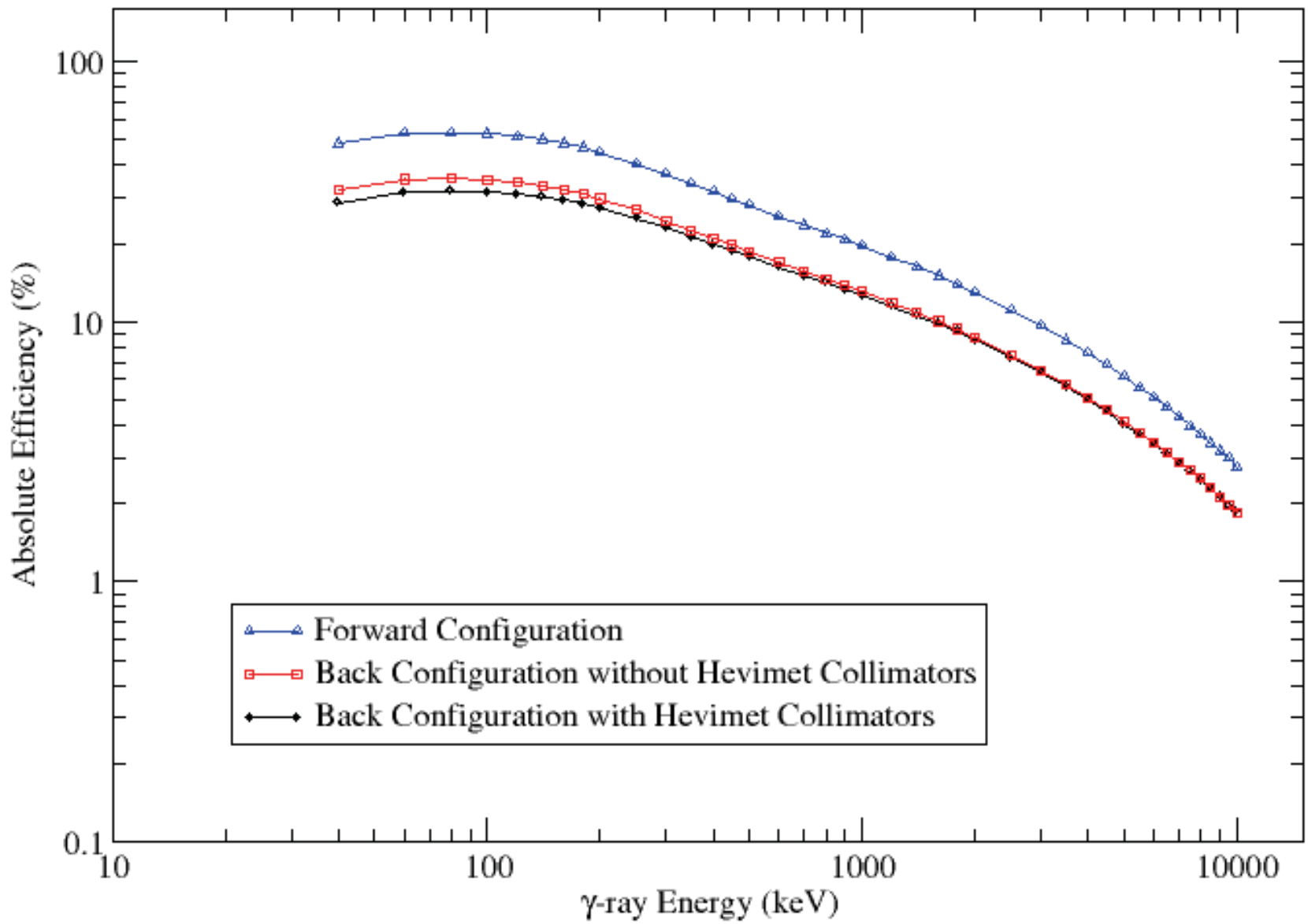
***G**amma-**R**ay **I**nfrastructure **F**or **F**undamental **I**nvestigations of **N**uclei*

- **Phase I fully funded**
  - **16 large-volume unsegmented clover detectors (40% crystals – 220% with addback)**
  - **Support structure, new beam line, etc.**
  - **Digital DAQ – triggerless with aim to write 300 MB/s (~1 MHz event rate)**
- **Phase II will complete array with BGO shields**
- **Commission 2014**

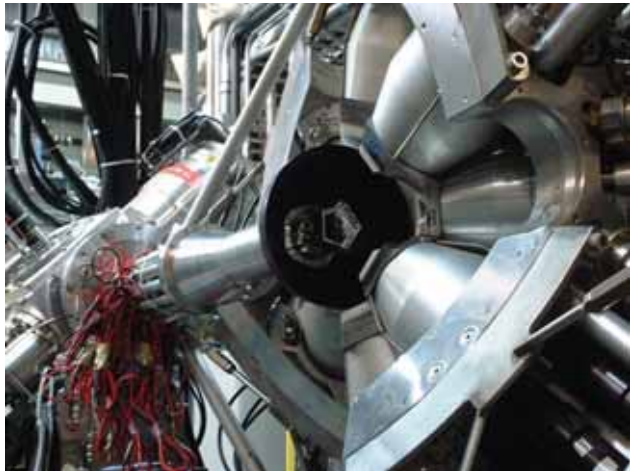


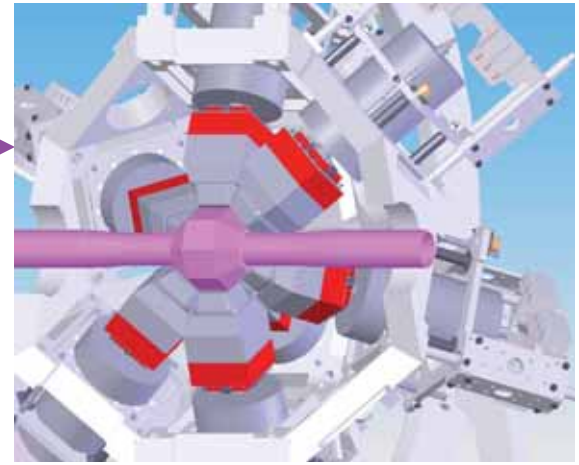
GRIFFIN Efficiency

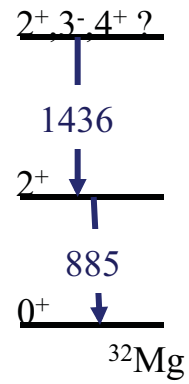


Example: β decay of $^{32}Na \rightarrow {}^{32}Mg$

Efficiency increase: $\dfrac{\varepsilon_{\gamma\gamma}^{GRIFFIN}}{\varepsilon_{\gamma\gamma}^{8\pi}} \sim 300$

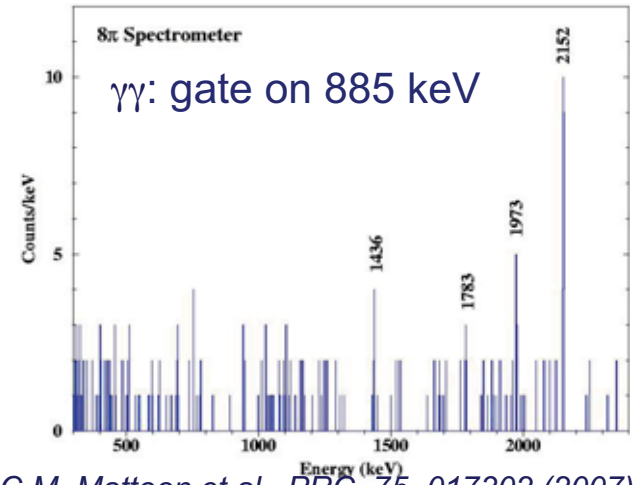


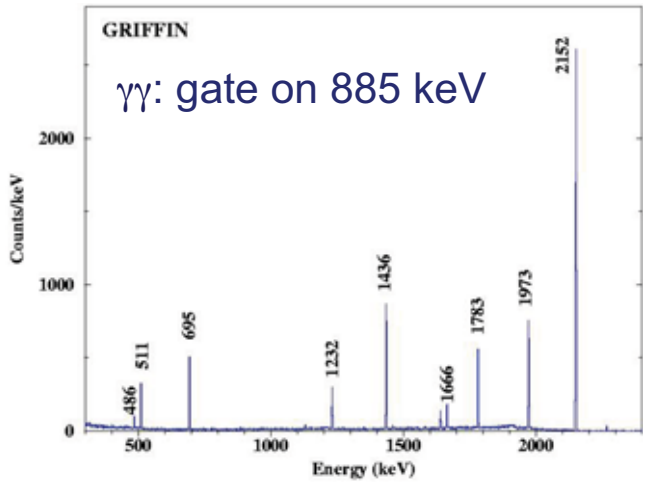


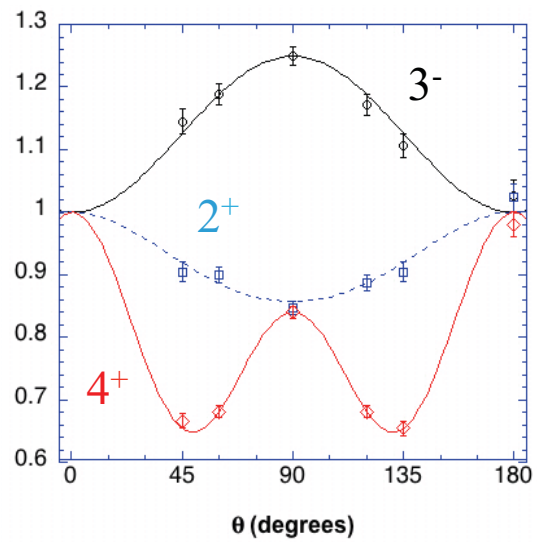


8π, ^{32}Na @ 2 ions/s

GRIFFIN

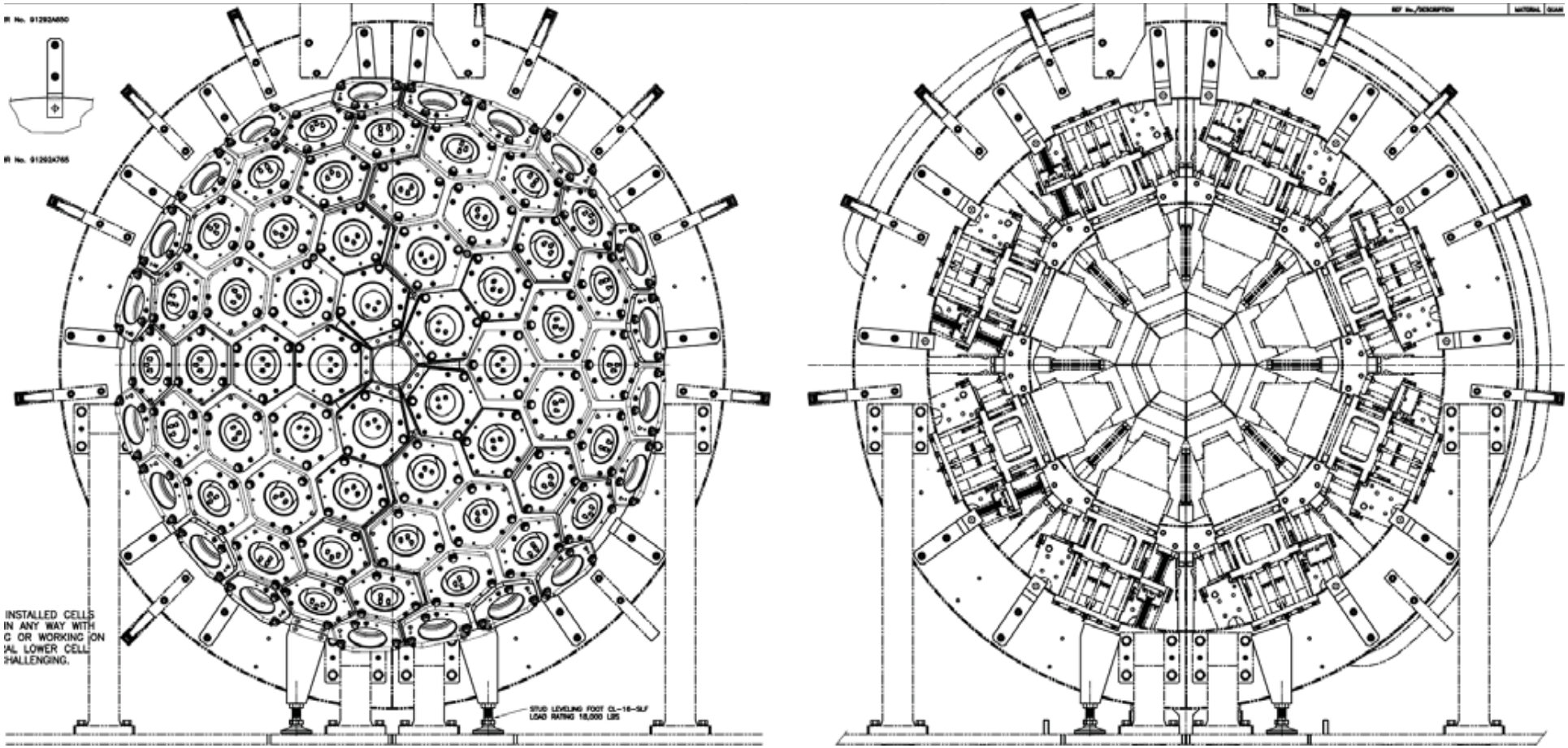






C.M. Mattoon et al., PRC. 75, 017302 (2007)

Enabling β-delayed *n* measurements



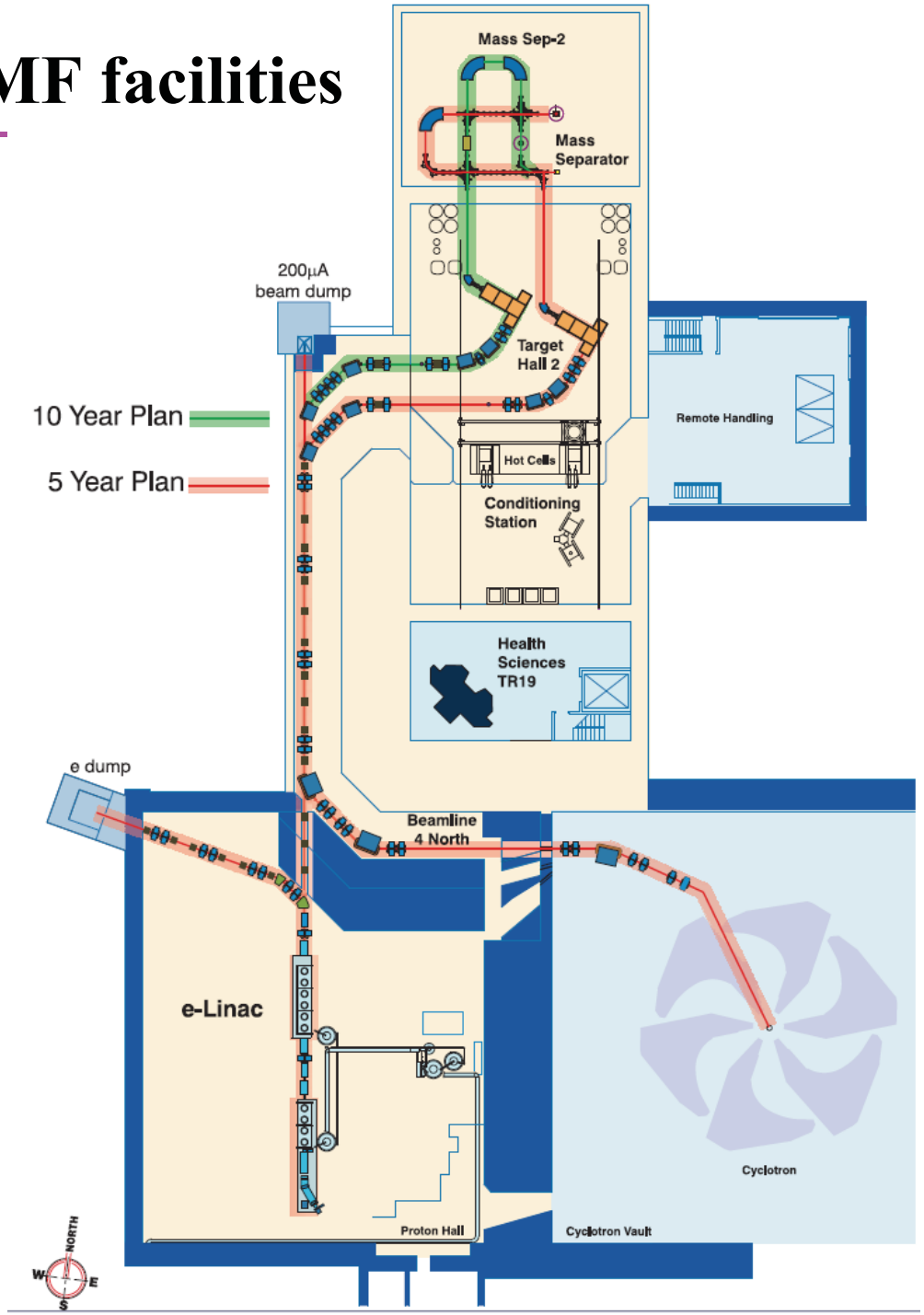
- **DESCANT – 1.1π sr deuterated scintillator neutron detector array being designed to be mounted to TIGRESS and GRIFFIN**
- **E_n from ~100 keV to 10 MeV**

ARIEL upgrade of TRIUMF facilities

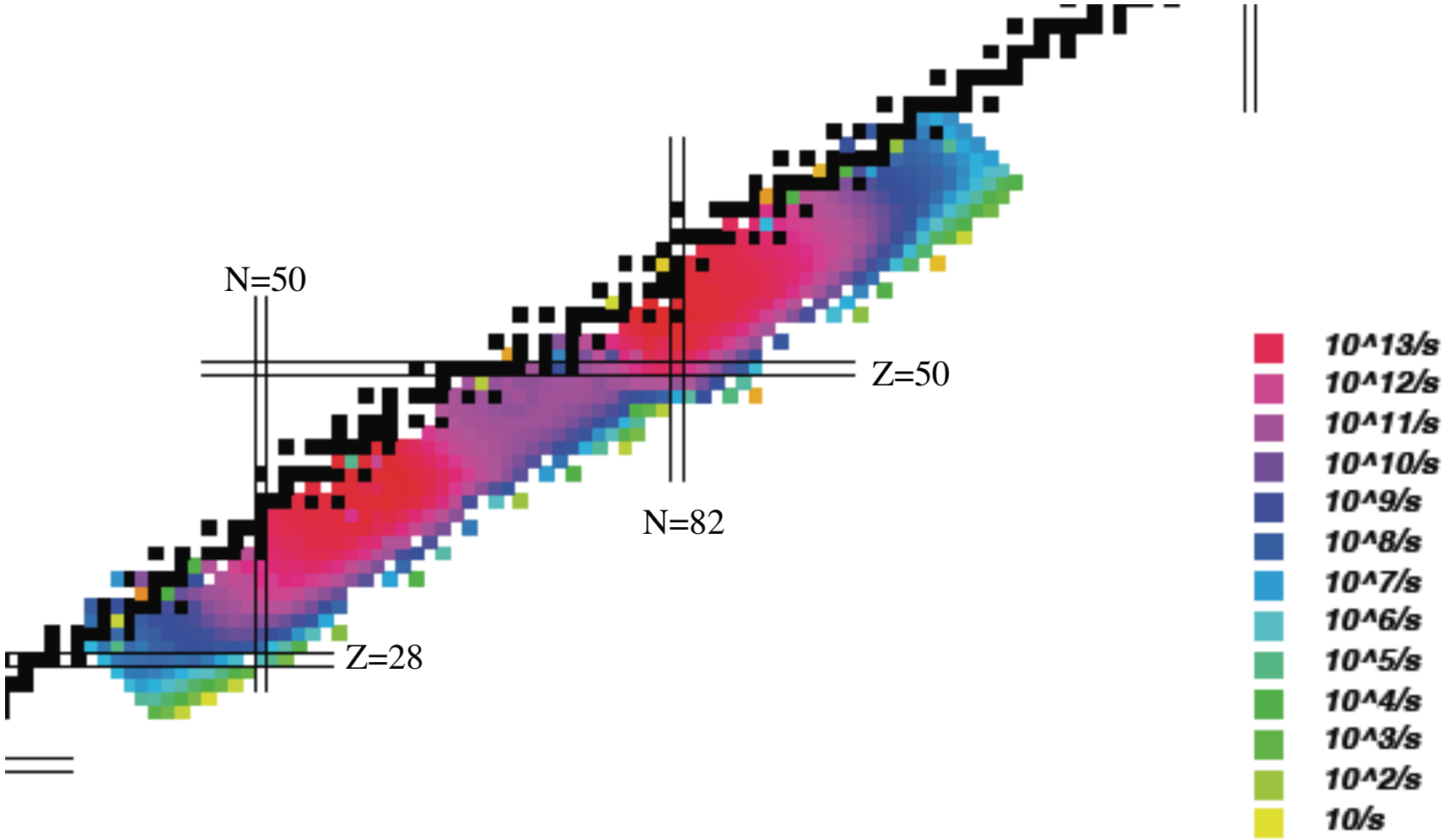
- **TRIUMF plans include development of new 50 MeV 500 kW e-LINAC, *ARIEL*, as photo-fission driver**
  - **25 MeV, 50kW by 2013, 100 kW by 2015**
  - **50 MeV, 100 kW by 2017, 500 kW by 2020**

- **Positive funding decision by Canadian Fund for Innovation (CFI) + BC provincial support (~ $63M)**

Funding for target station, mass separator, beam transport, etc., must await next 5 year budget cycle beginning 2015

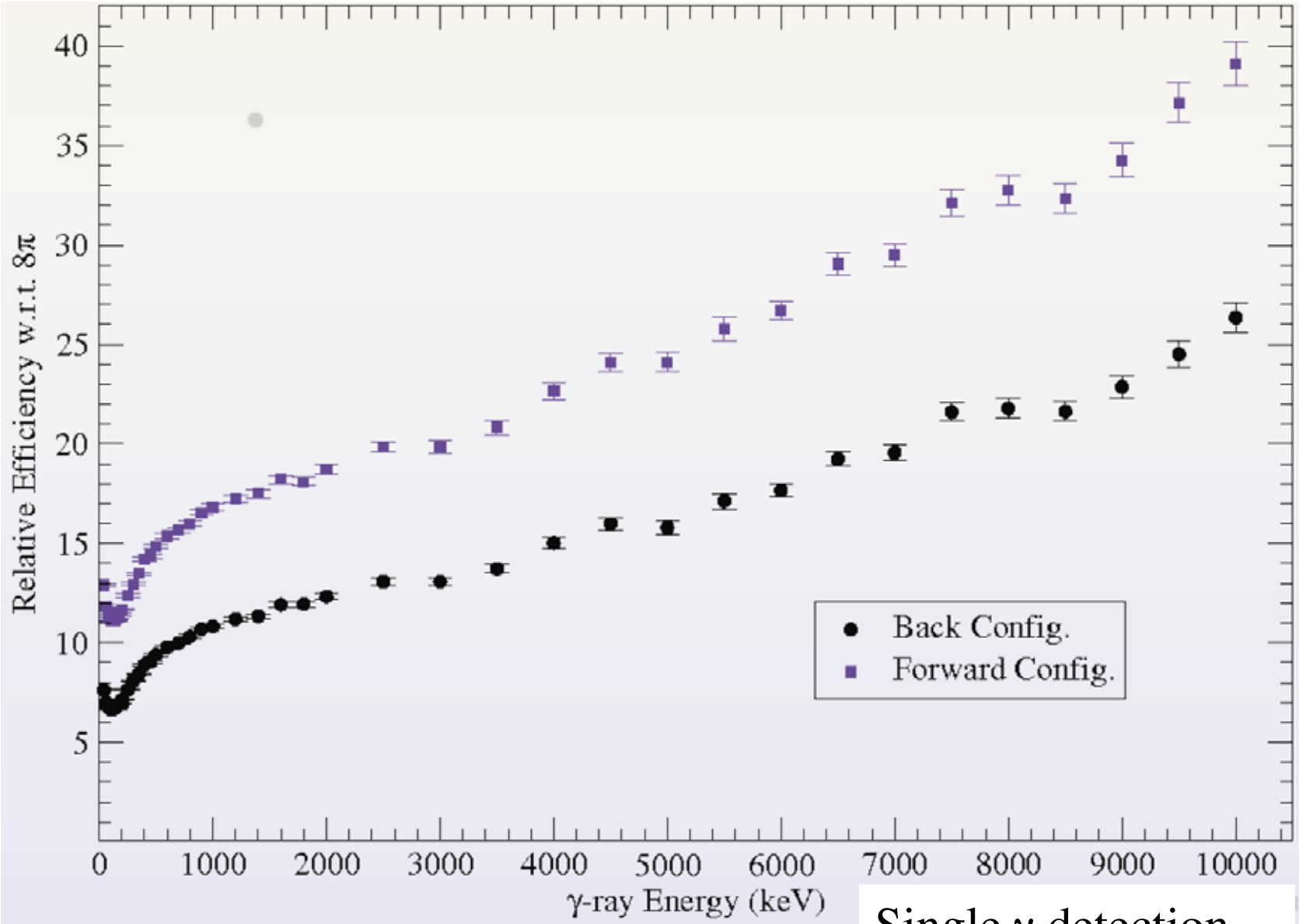


Calculated in-target production 50 MeV, 100 kW



GRIFFIN + ARIEL and p-induced spallation on actinide target will enable far-reaching science program for decades

Comparison of GRIFFIN efficiency *vs* 8π



Single γ detection

^{11}Li decay at ISAC with the 8π+SCEPTAR

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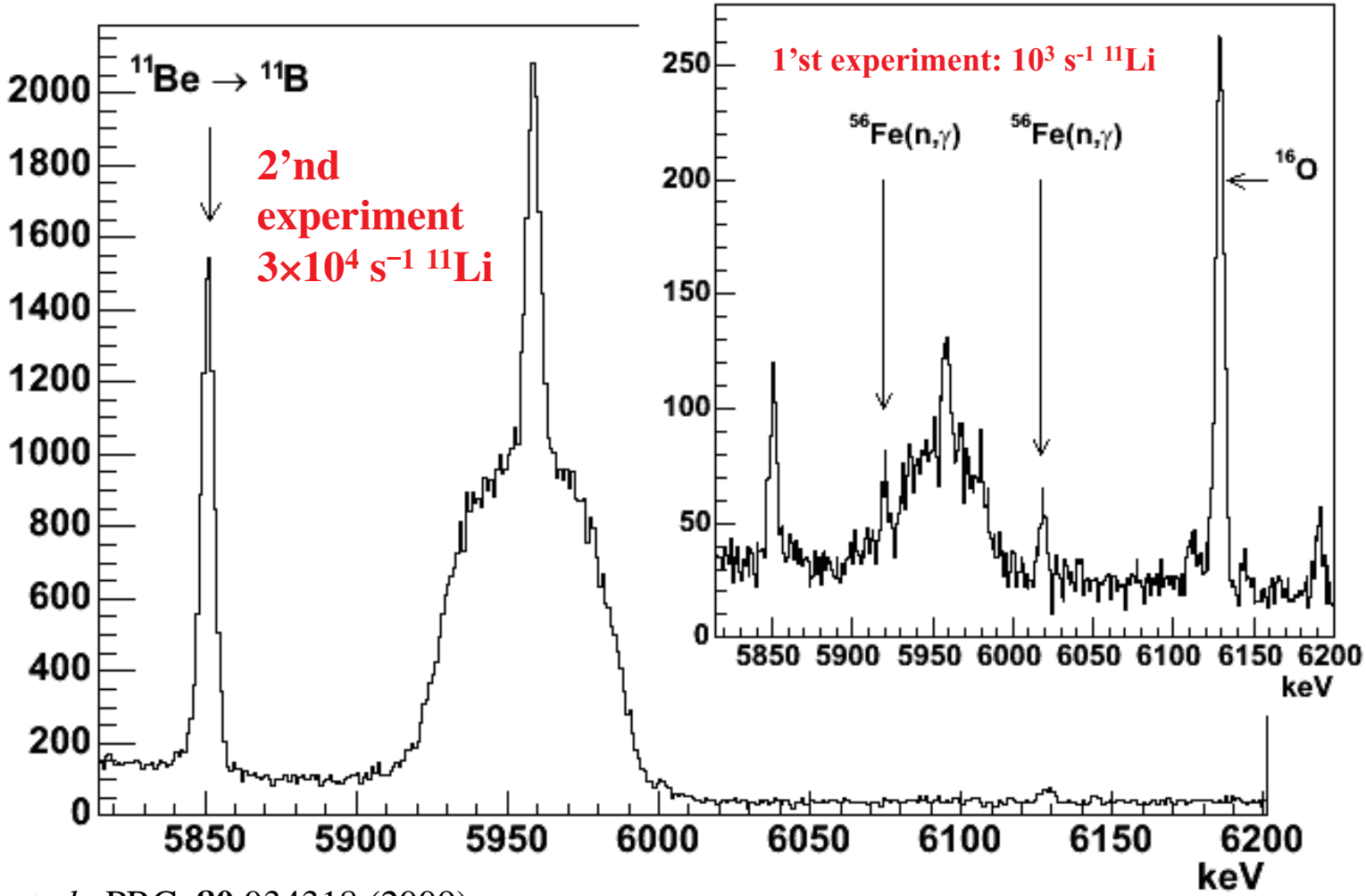
- β−γ coincidences:
  - Reduced background from room decays and induced reactions
- Increased signal to background ratio, better quality lineshape



Mattoon *et al*., PRC, **80** 034318 (2009)

PACES with the 8π

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