SFU

SIMON FRASER UNIVERSITY
ENGAGING THE WORLD

Decay Spectroscopy Experiments with GRIFFIN at ISAC-TRIUMF

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Simon Fraser University |
Burnaby, BC, Canada |

SSNET 2017 I Paris, France I November 6-10, 2017

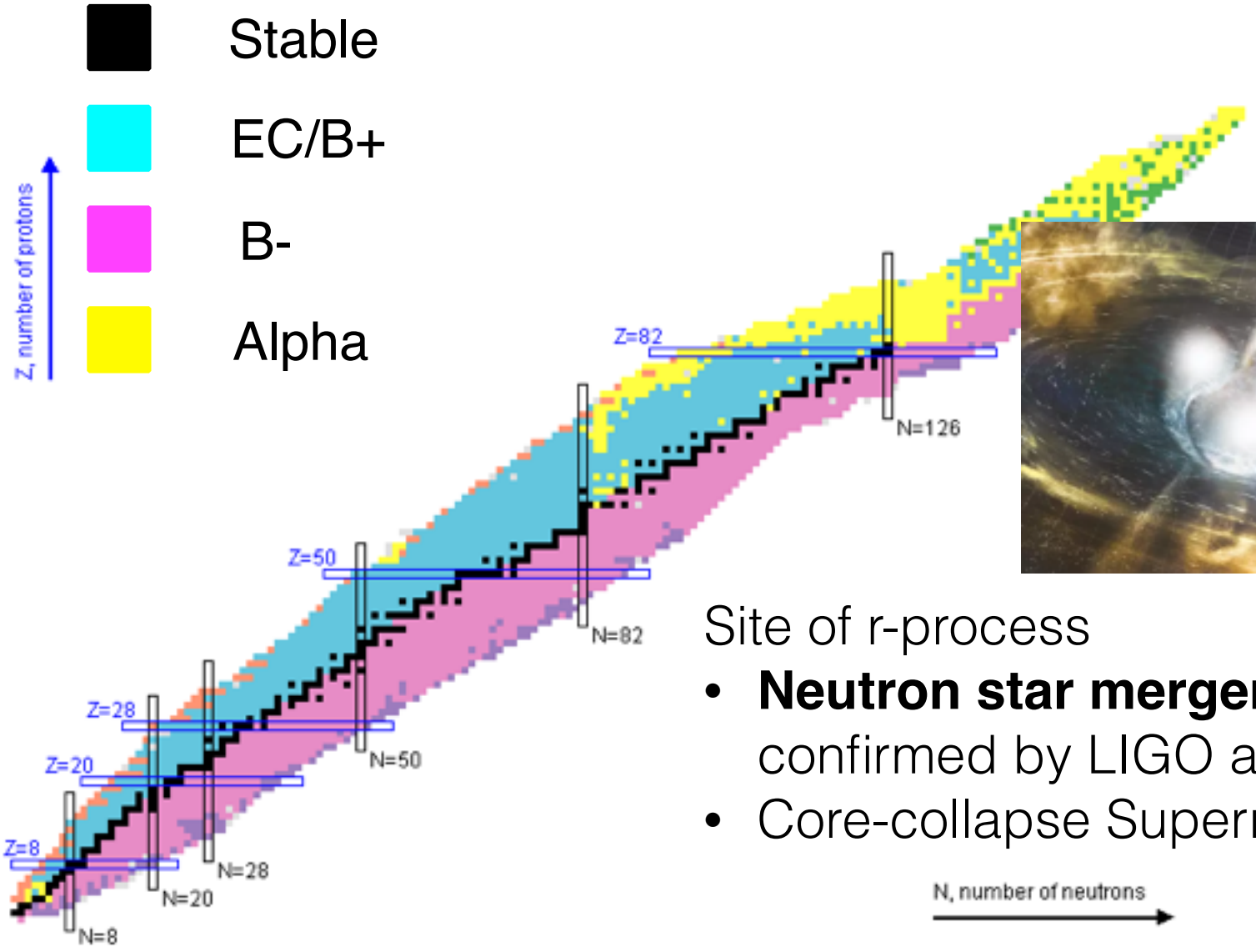
Location & Some History

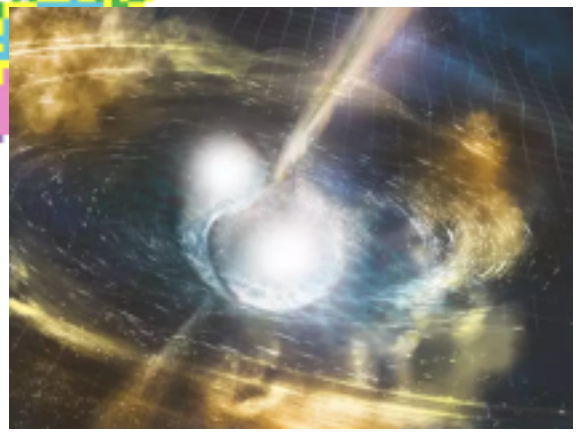
- **Tri-U**niversity **M**eson **F**acility (TRIUMF)
- 1968 Simon Fraser University, University of British Columbia and University of Victoria
- TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics
- Own and operated by a consortium of Canadian Universities

SFU
- **1965**
- **30,000 students**
- **6,500 faculty and staff**
- **130,000 alumni**
- **TISOL facility**

TISOL Facility, Prof. J. D'Auria, SFU

Structure and astrophysics

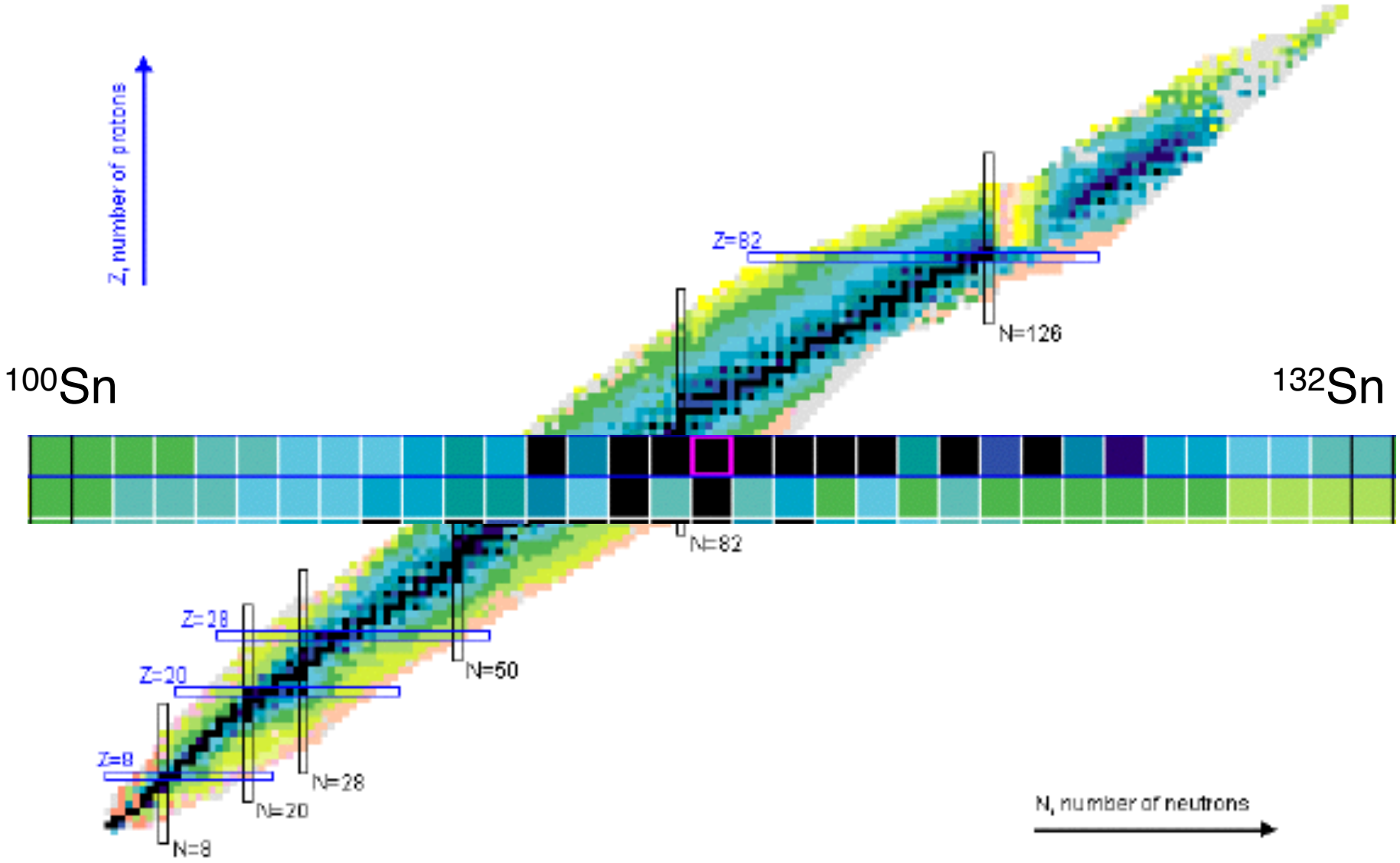




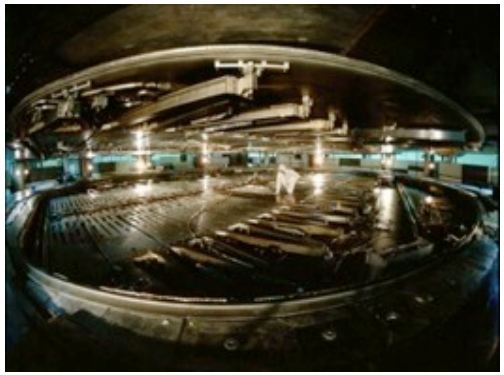
Site of r-process

- **Neutron star mergers** (Recently confirmed by LIGO and VIRGO)
- Core-collapse Supernovae

Magic Tin Nuclei

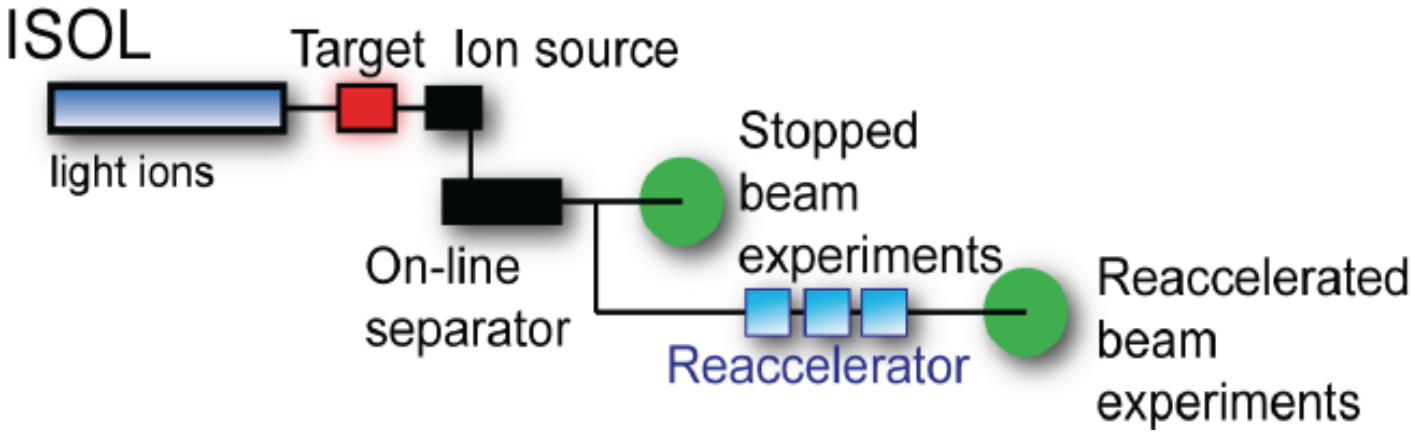


In-flight Separation On Line Technique for Radioactive Beam Production



Target materials:
SiC, TiC, NiO, Nb, ZrC, Ta, UCx
Ion sources:
Surface, FEBIAD, IG-LIS

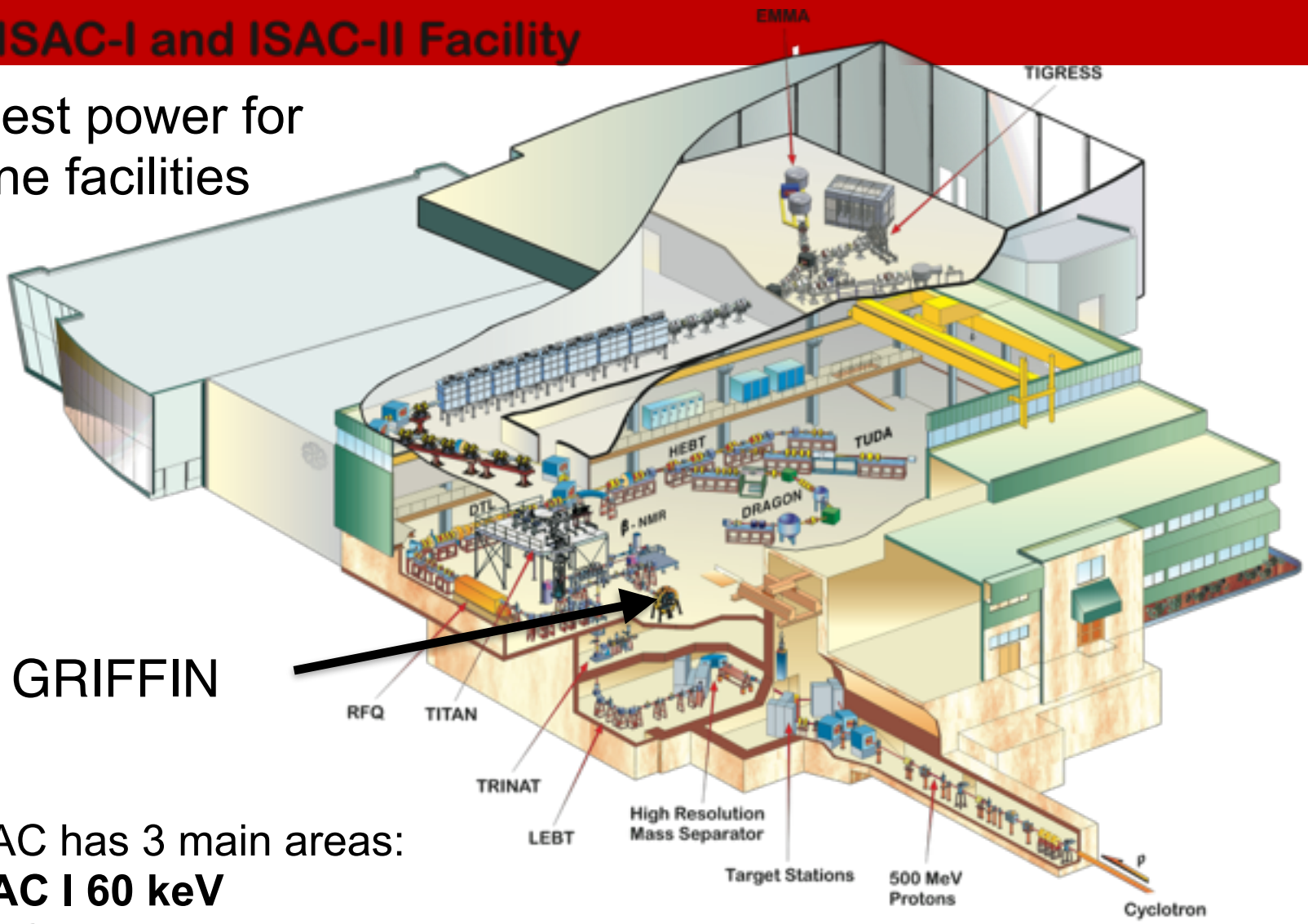
500 MeV p^+ at 100 μA on ISOL target



Isotope Separator and Accelerator (ISAC)

ISAC-I and ISAC-II Facility

Highest power for on-line facilities

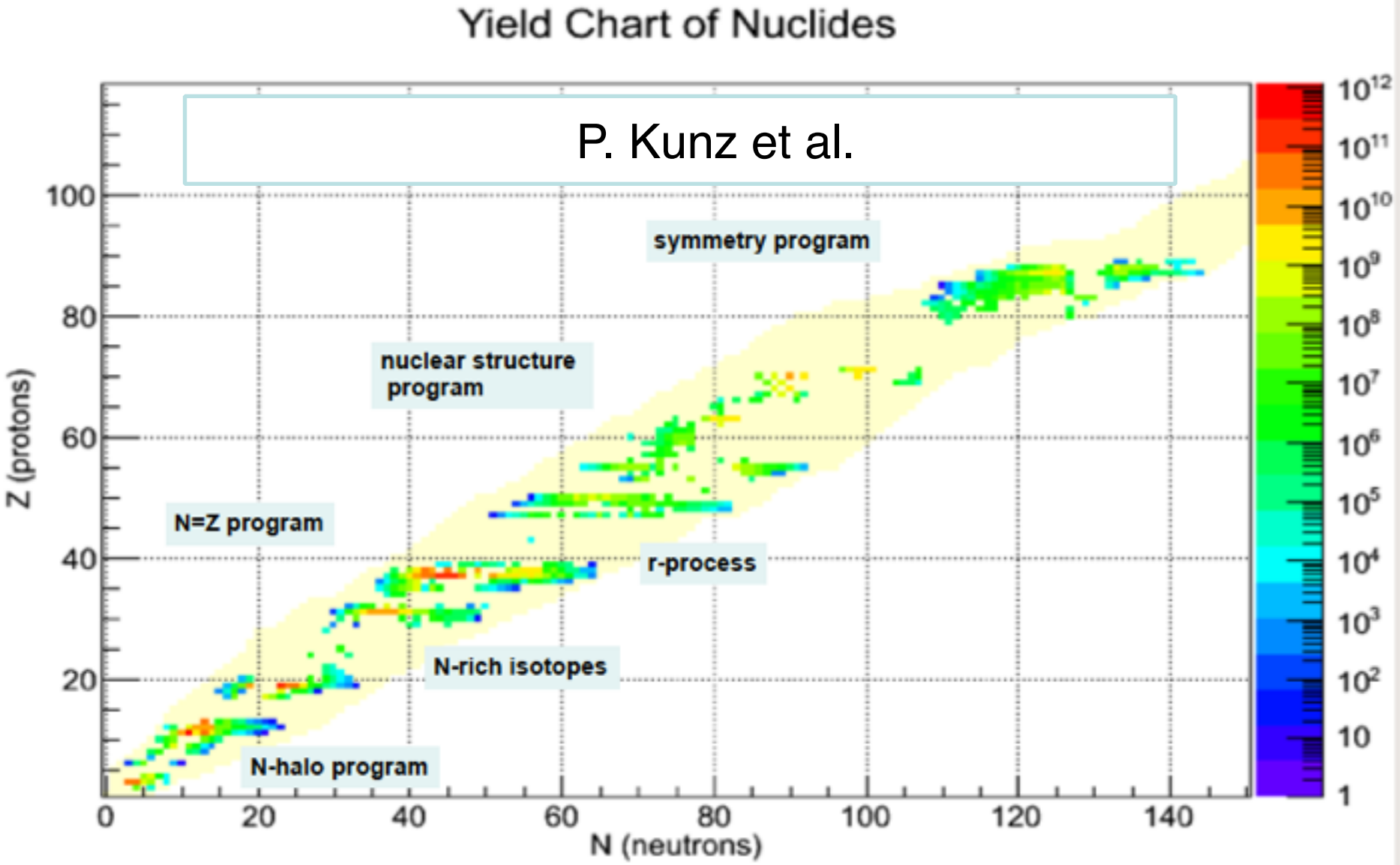


GRIFFIN

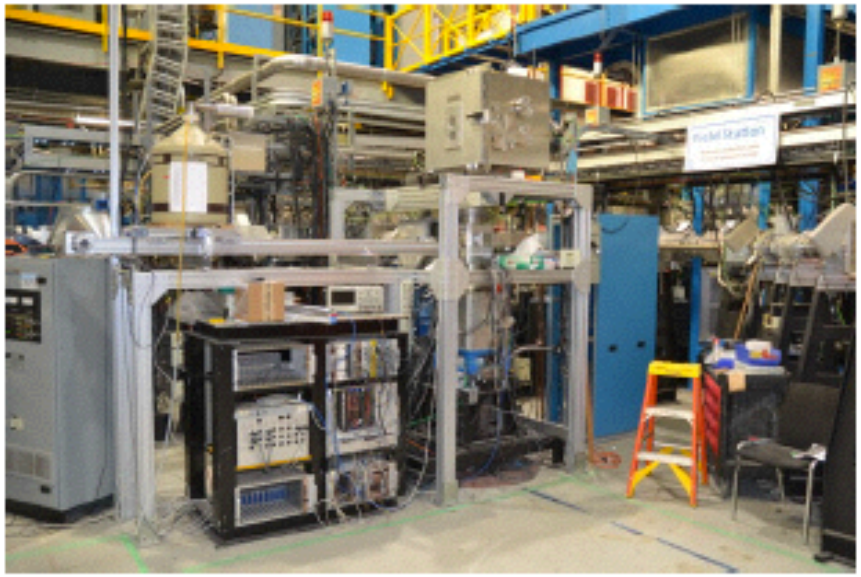
ISAC has 3 main areas:
ISAC I 60 keV
ISAC II 1.8 MeV·A
ISAC III > 6 MeV·A

TRIUMF

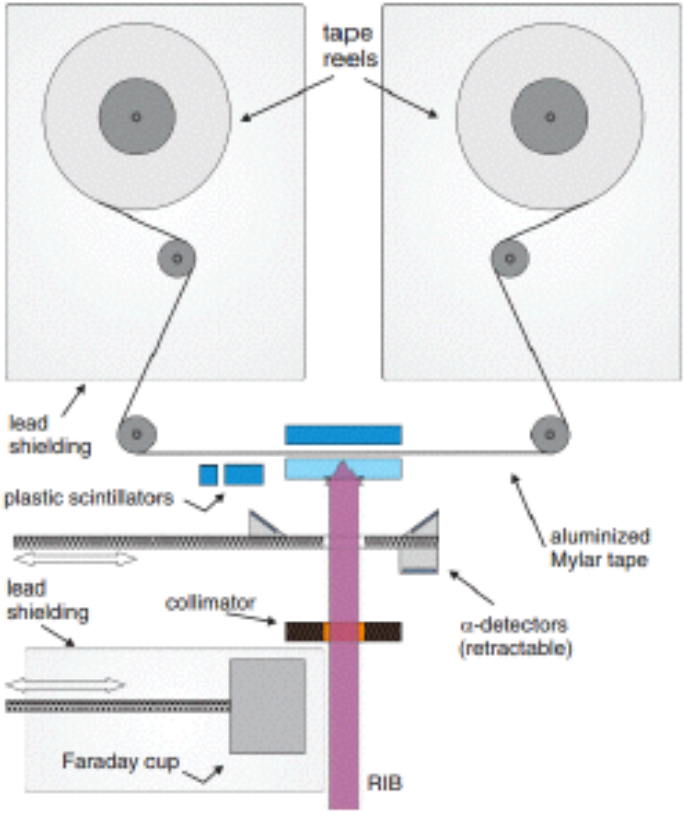
Isotopes delivered at ISAC



ISAC Yield Station



TRIUMF yield station

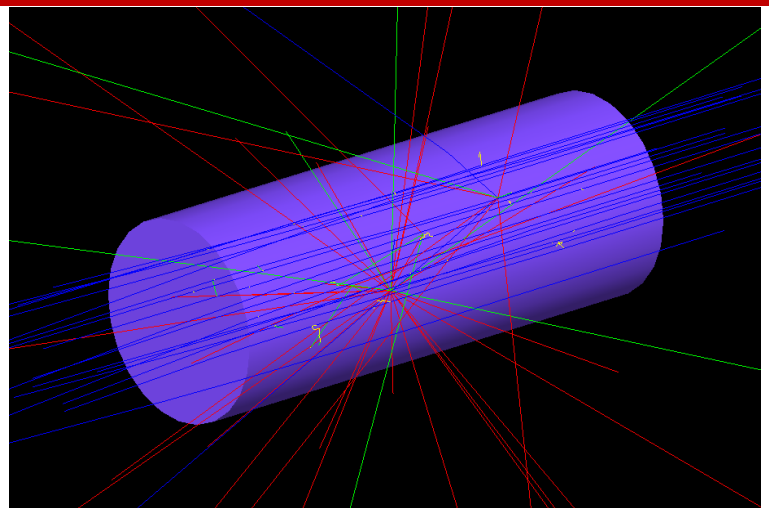


TRIUMF yield station schematic

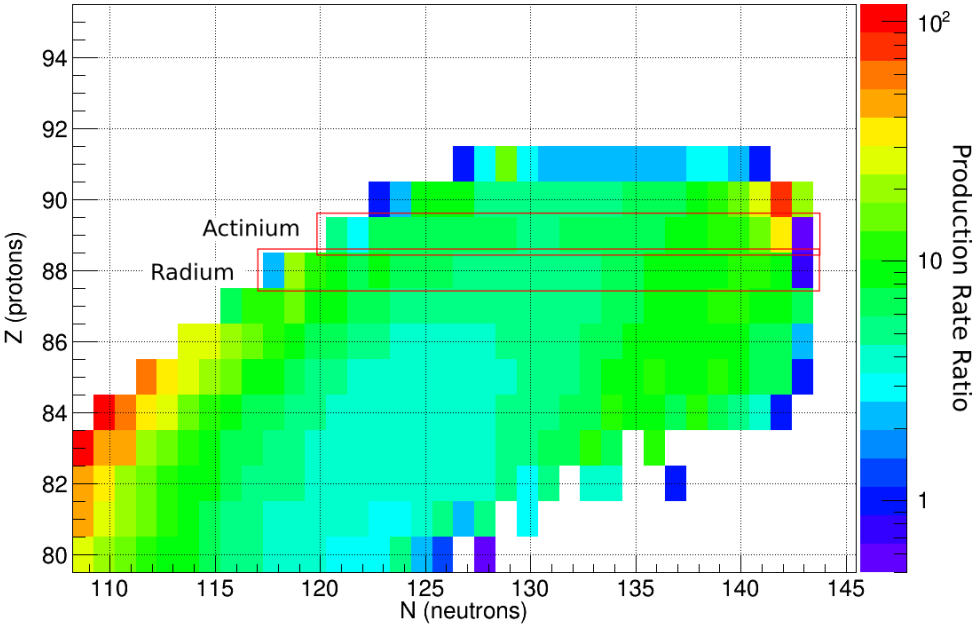
^{46}K Half-Life 96.303(79) s

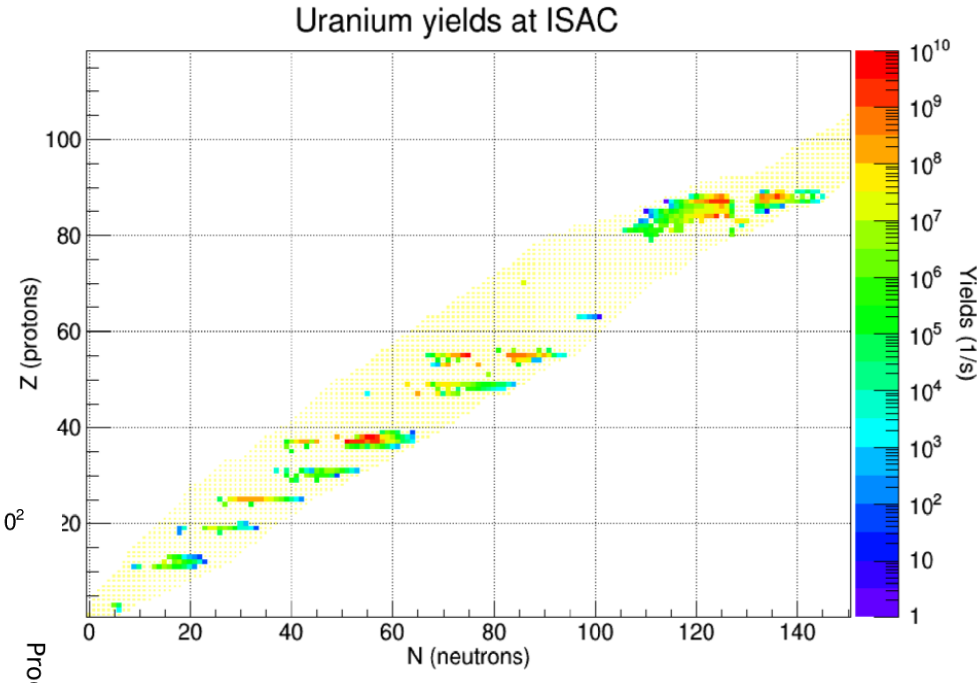
Kunz, P. Andreoiu, C. et al. Rev. Sci. Instrum. 85 (2014)

GEANT4 : Simulations for beam development



GEANT4 Target Simulation - Liege+ABLA - Thorium/Uranium - 480 MeV

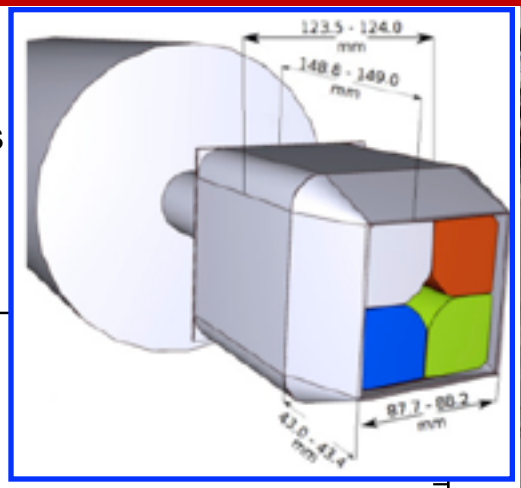


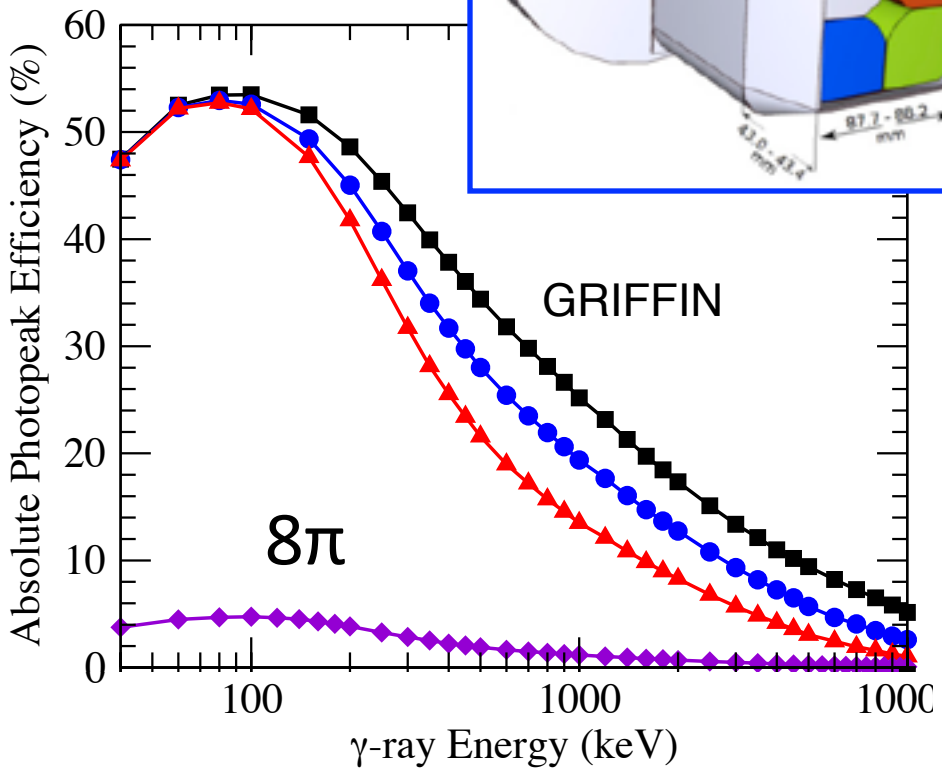


F. H. Garcia, C. Andreoiu and P. Kunz
NIMB 412 (Dec 2017) 174-179

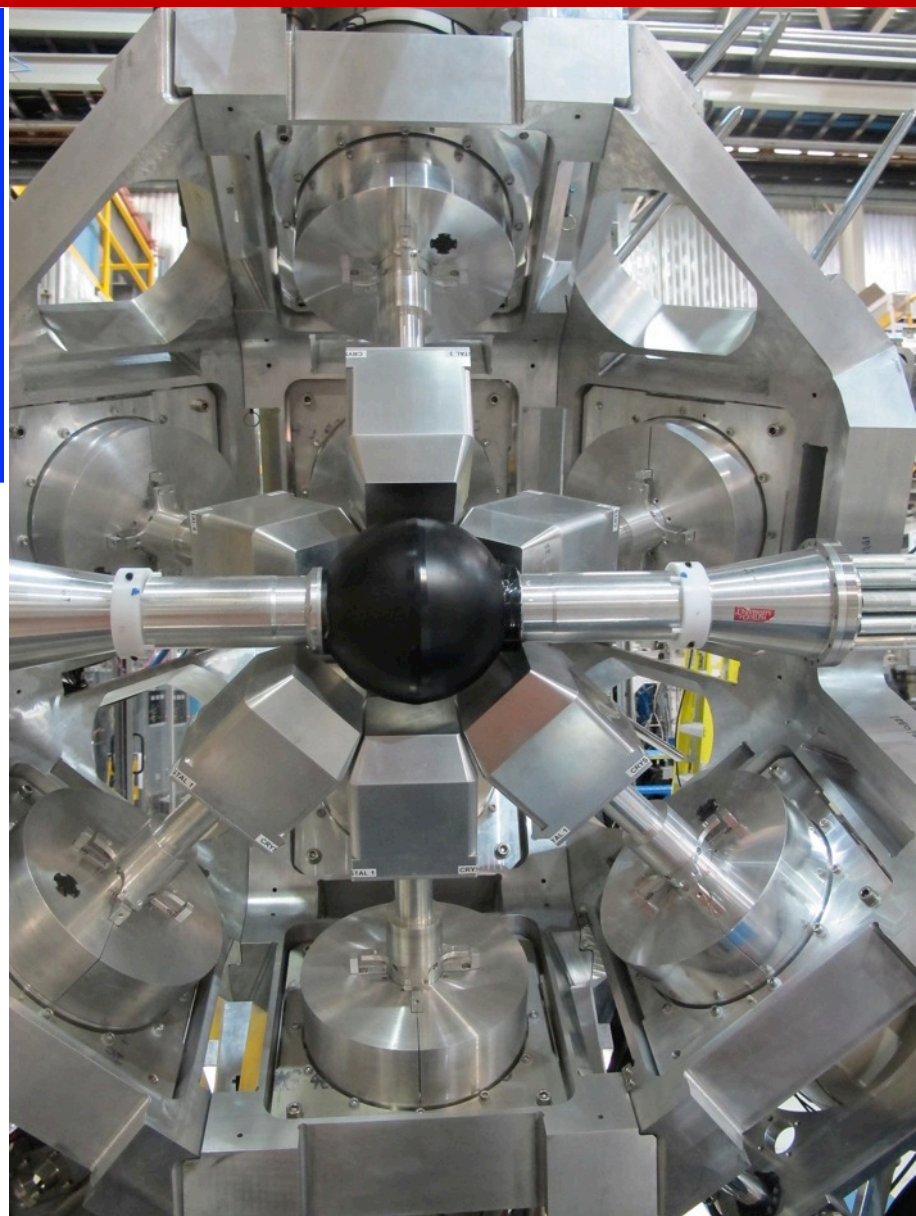
GRIFFIN - The Gamma-Ray Infrastructure For Fundamental Investigations of Nuclei

A close-packed array of
16 large-volume HPGe
Clover detectors, 64 crystals





4096 crystal pairs at 52 unique angles
for γ-γ angular correlations

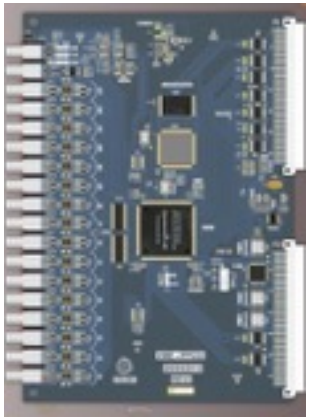


GRIFFIN Digital DAQ

Custom Digital Electronics designed and built at Université de Montreal and TRIUMF

Programmable Logic Pulse Generator

32 Channels NIM or TTL



Clock Distribution Module

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

300 MB/s of data to disk

GRIF-16 Module

16 chans
100 MHz,
14 bit

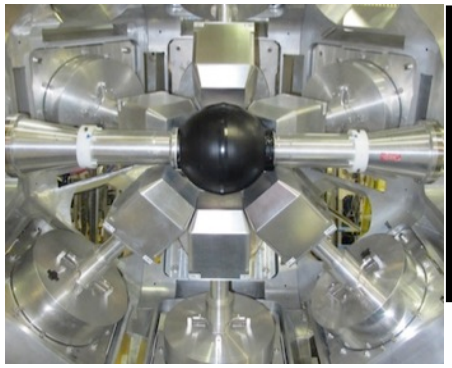
GRIF-4G Module

4 chans
1 GHz
14 bit

Master and Collector Module

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

GRIFFIN experiments and results



GRIFFIN is a powerful decay spectrometer for nuclear structure, astrophysics and fundamental interaction studies.
Commissioned Fall 2014.

2017
$^{188\text{-}200}$Tl: Development of collectivity in Hg isotopes

^{228,230}Fr: Probing Octupole deformation and collectivity in Radium isotopes. **2017**

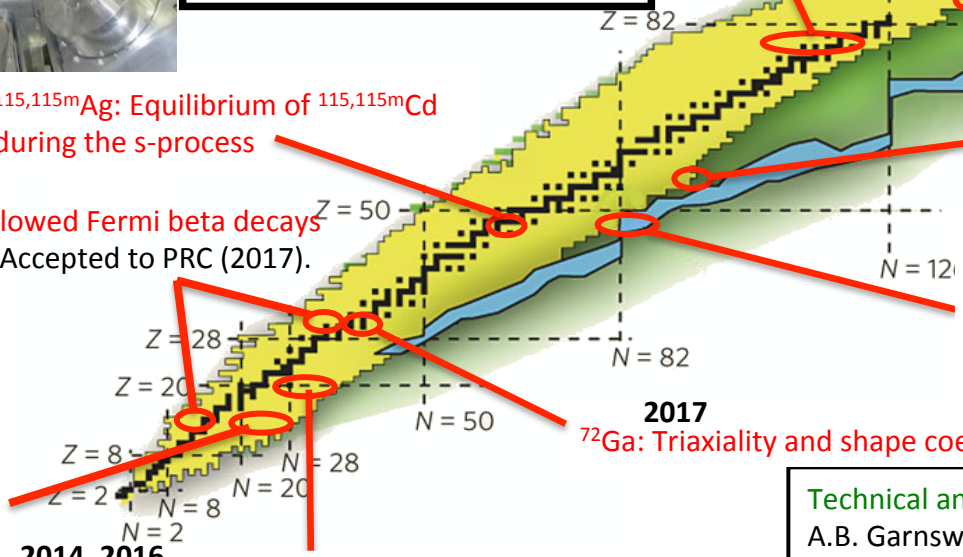
Calibrations and development with ^{9}Li, ^{26}Na, ^{66}Ga beams

2014 ^{115,115m}Ag: Equilibrium of ^{115,115m}Cd during the s-process

2016
^{145,146}Cs: β-delay neutron measurements with DESCANT, fast-timing with $LaBr_3$

2016
^{22}Mg, ^{62}Ga: Superallowed Fermi beta decays
M.R. Dunlop *et al.*, Accepted to PRC (2017).

2015, 2016
^{128,129,130,131,132}Cd, ^{129,130,131,132,133}In:
Nuclear structure and r-process nucleosynthesis at the N=82 shell closure
R. Dunlop *et al.*, PRC 93, 062801(R) (2016).



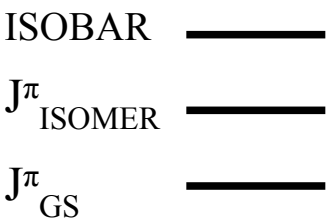
2017
^{72}Ga: Triaxiality and shape coexistence

2014, 2015
^{31,32}Na, ^{33,34,35}Mg:
Island of inversion

2014, 2016
^{46,47}K, ^{50}Ca: Single-particle and pair states near doubly-magic ^{48}Ca
A.B. Garnsworthy *et al.*, Accepted to PRC (2017).

Technical and Overview Publications
A.B. Garnsworthy *et al.*, NIM A 853, 85 (2017).
U. Rizwan *et al.*, NIM A 820, 126 (2016).
A.B. Garnsworthy, Acta Phys.Pol. B, 47, 713 (2016).
C.E. Svensson and A.B. Garnsworthy, Hyp. Int. 225, 127 (2014).

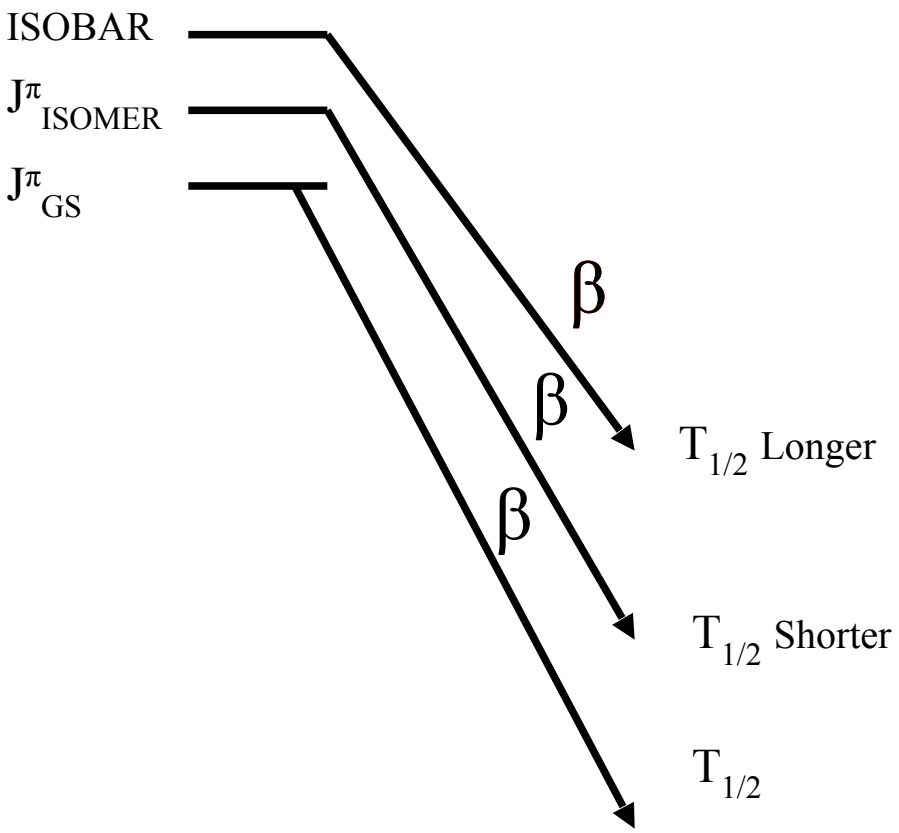
The GRIFFIN Spectrometer at TRIUMF
Sensitive Decay Spectroscopy



The GRIFFIN Spectrometer at TRIUMF
Sensitive Decay Spectroscopy

Fast, in-vacuum tape system

Enhances decay of interest



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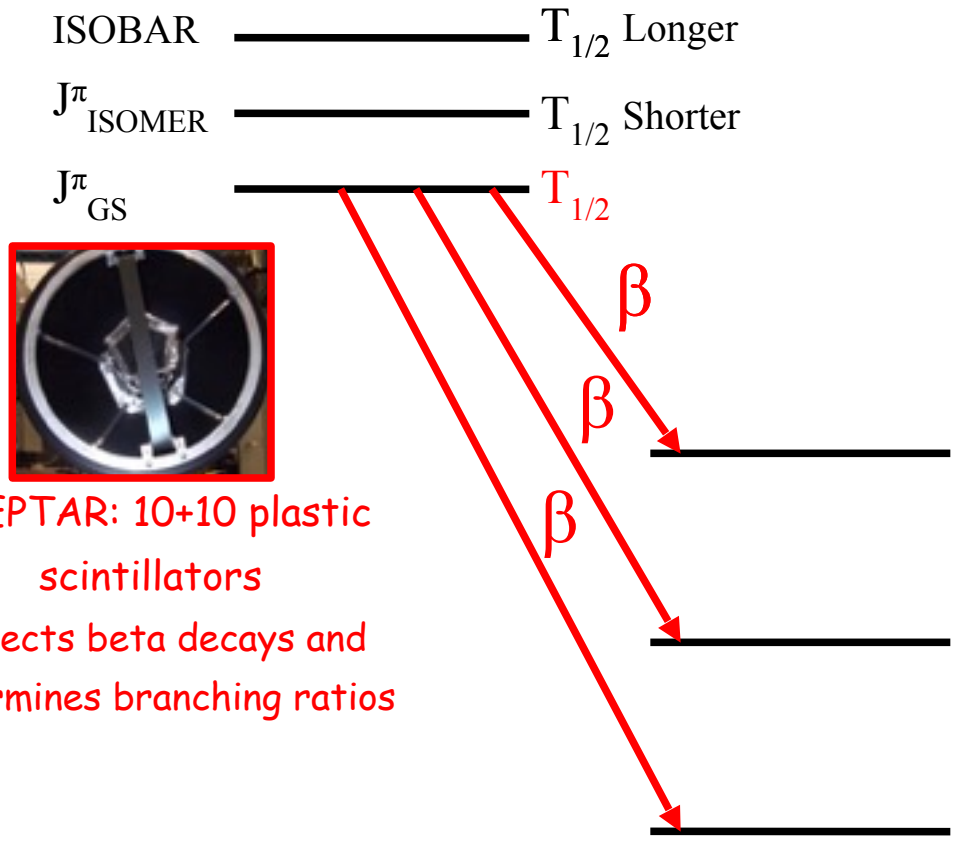

SCEPTAR: 10+10 plastic scintillators

Detects beta decays and determines branching ratios

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Sensitive Decay Spectroscopy

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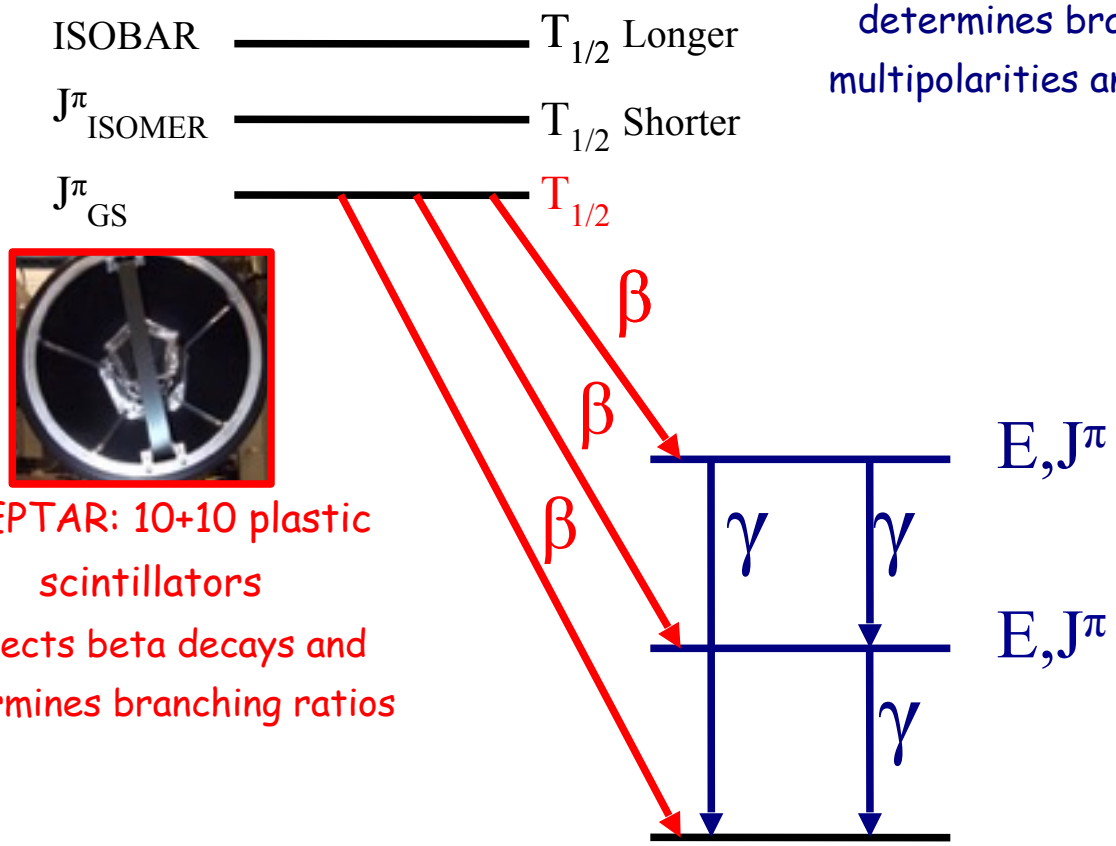
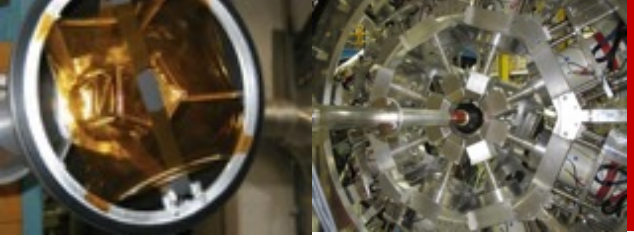


SCEPTAR: 10+10 plastic scintillators

Detects beta decays and determines branching ratios

GRIFFIN 16 HpGe Clovers

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



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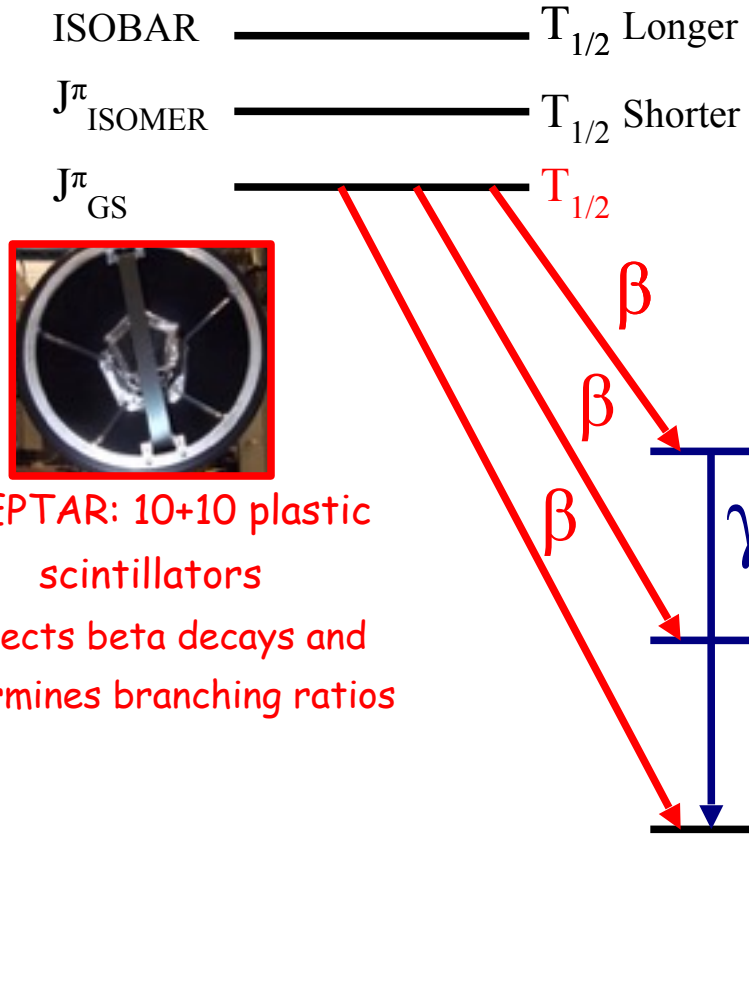

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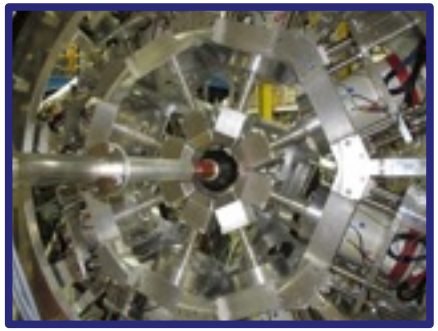


SCEPTAR: 10+10 plastic scintillators

Detects beta decays and determines branching ratios

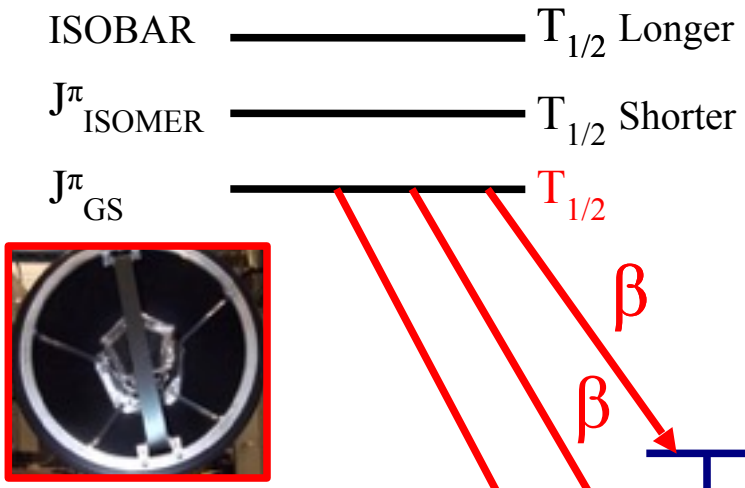
PACES: 5 Cooled Si(Li)s

Detects Internal Conversion Electrons and alphas/protons

The GRIFFIN Spectrometer at TRIUMF
Sensitive Decay Spectroscopy

Fast, in-vacuum tape system

Enhances decay of interest



SCEPTAR: 10+10 plastic scintillators

Detects beta decays and determines branching ratios

GRIFFIN 16 HpGe Clovers

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

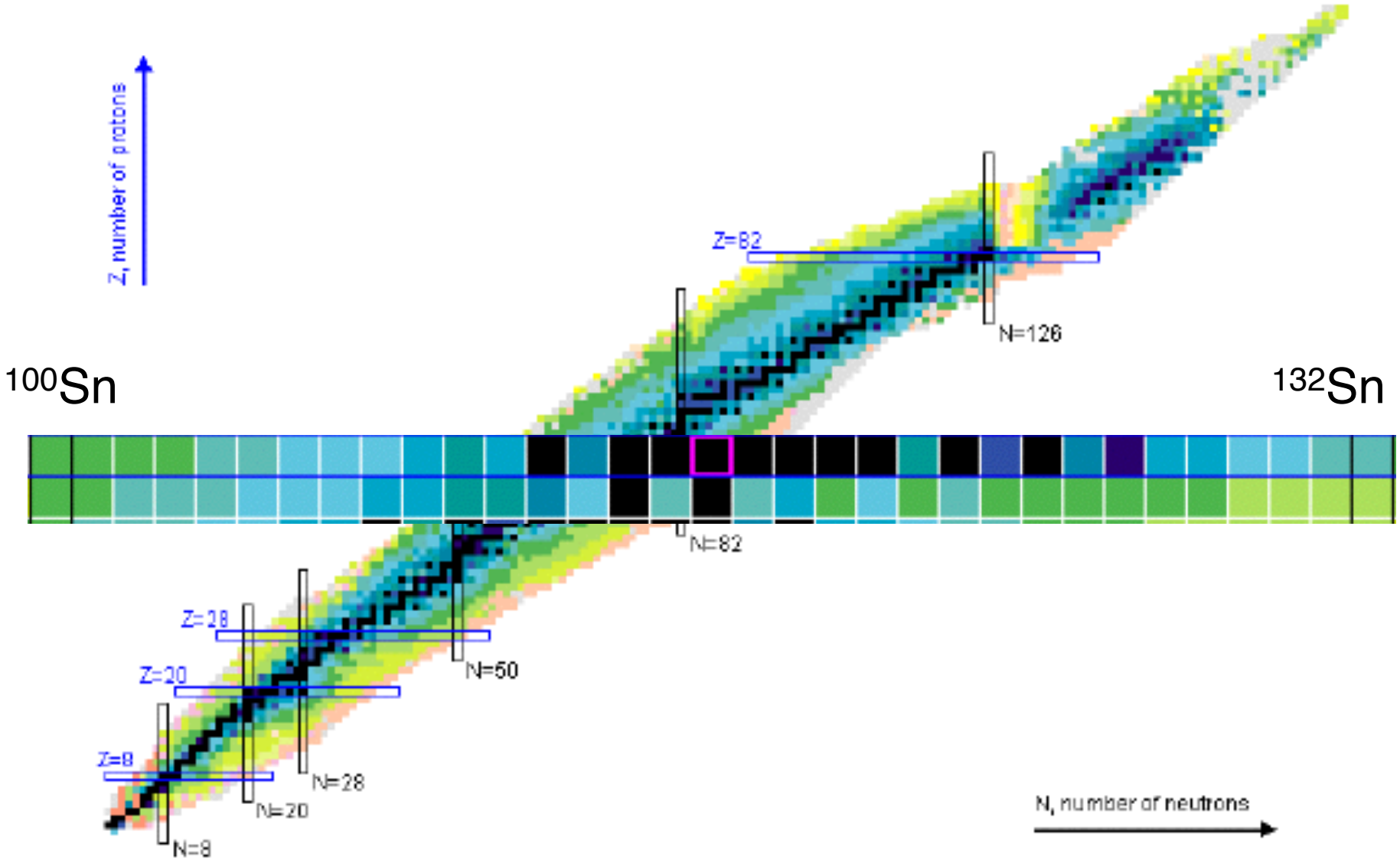
DANTE: 10 BaF_2/$LaBr_3$

Fast-timing of photons to measure level lifetimes

PACES: 5 Cooled Si(Li)s

Detects Internal Conversion Electrons and alphas/protons

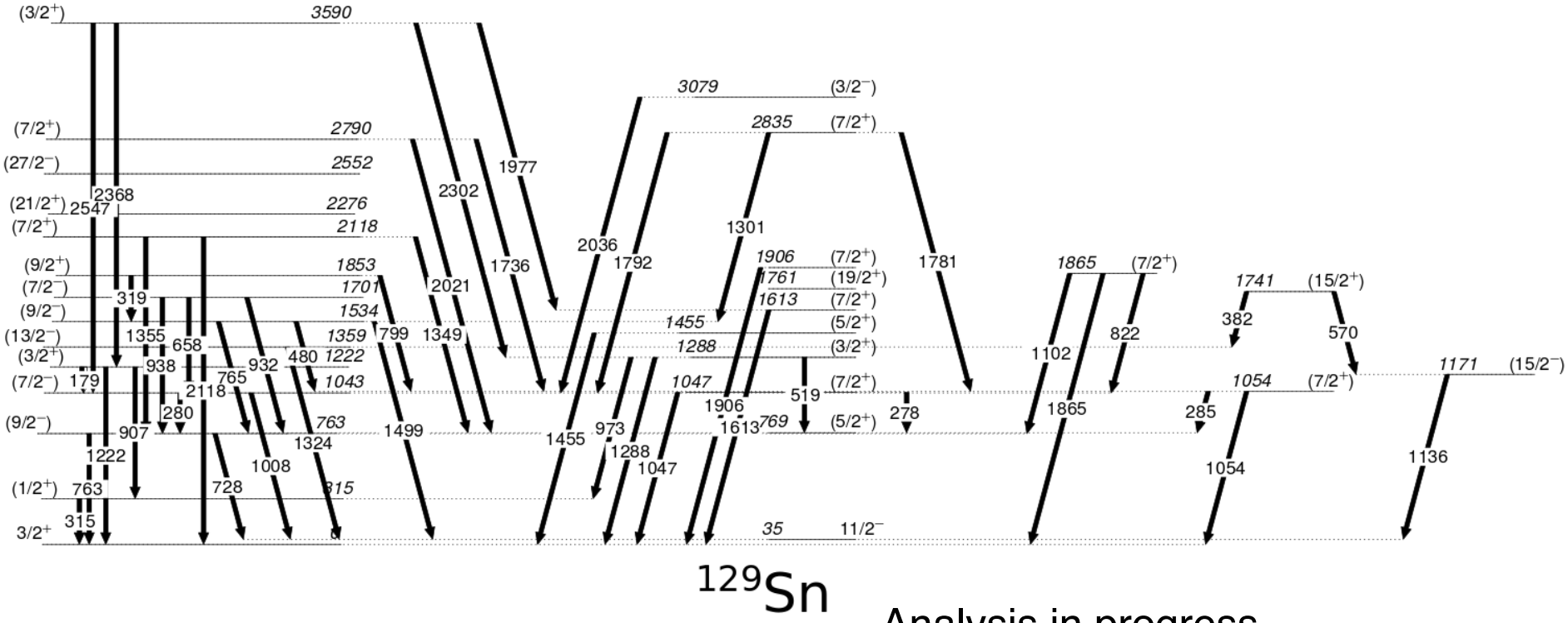
Magic Tin Nuclei



^{129}Sn

$$^{129}In \rightarrow {}^{129}Sn + \beta^- + \bar{\nu}_e \qquad Q_\beta = 7.77\ MeV$$

2700 pps; 3h



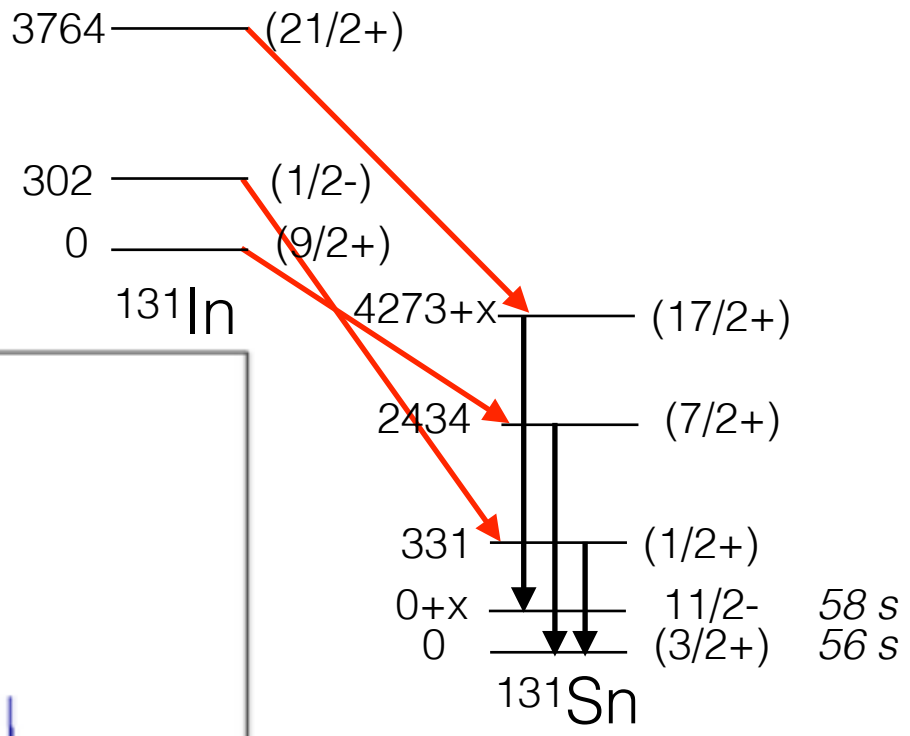
^{129}Sn

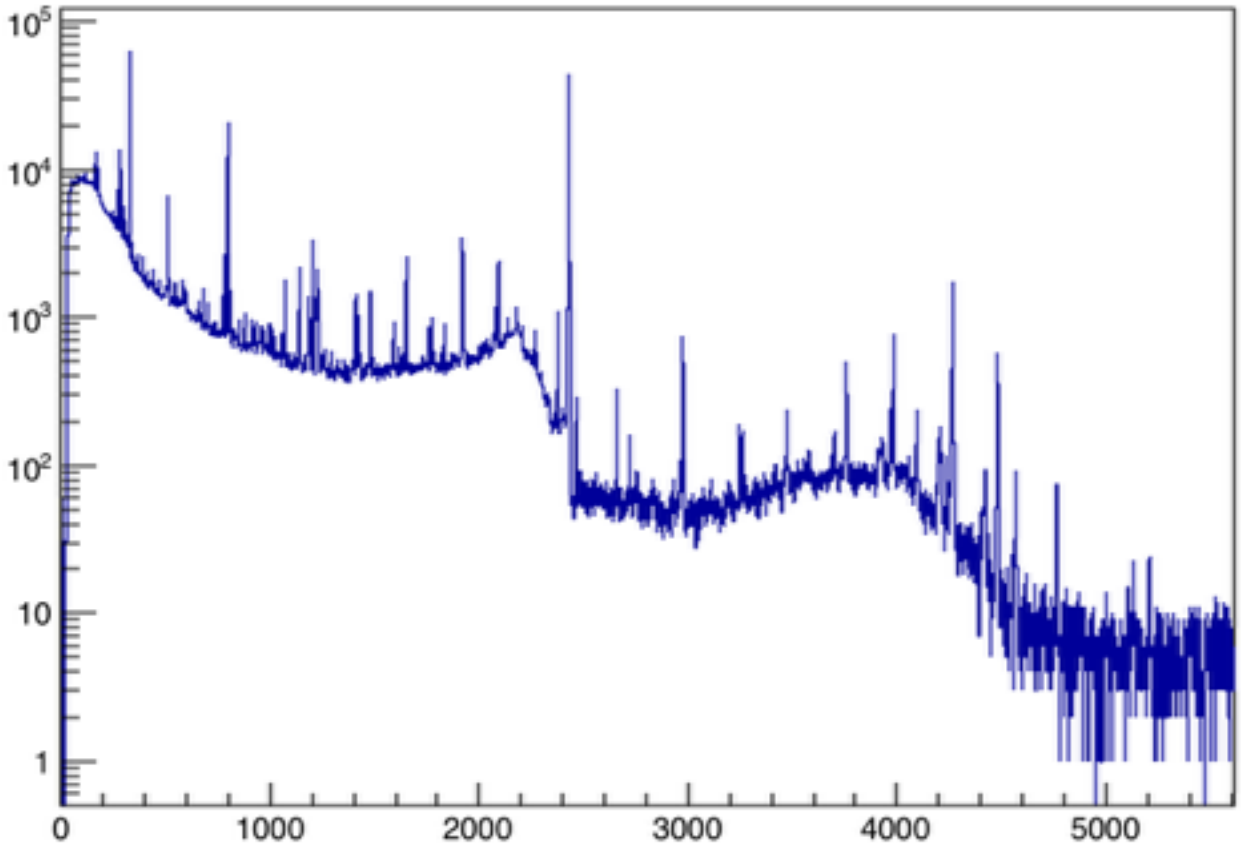
Analysis in progress

F.H. Garcia, Simon Fraser University

^{131}Sn γ-rays following ^{131}In Decay

- Delivered a mix of 3 beta-decaying states
- Each have very similar half-lives ~300 ms

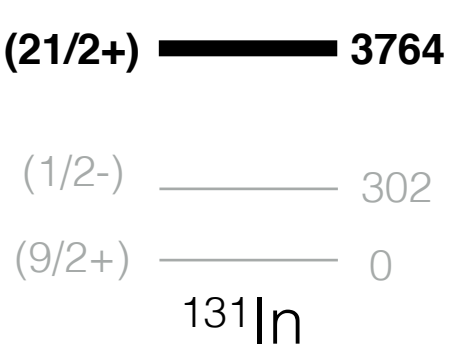




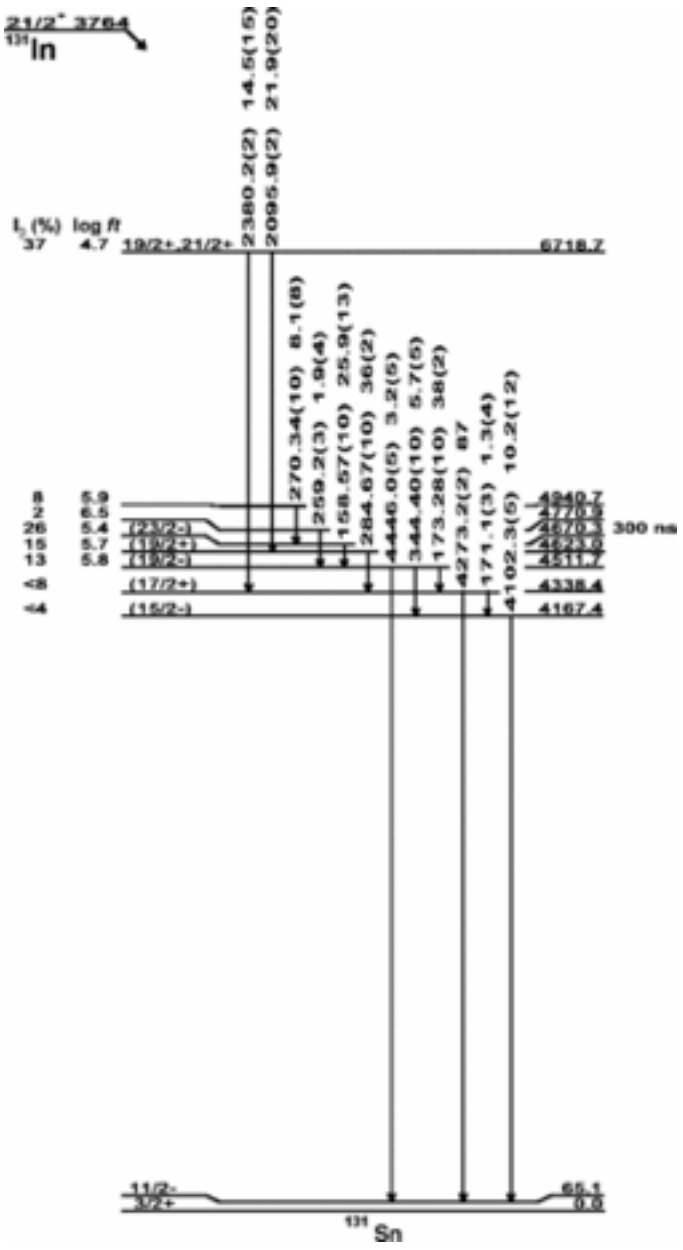
- Need to know level scheme well
- High resolution, high efficiency gamma-ray detection

R. Dunlop, Guelph

^{131}Sn γ-rays following High-spin ^{131}In Decay



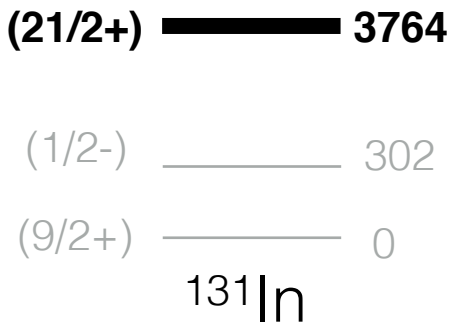
Gamma rays following beta decay of 3764 keV (21/2+) state



Previous work

Fogelberg *et al.* Phys. Rev. C **70**, 034312 (2004)

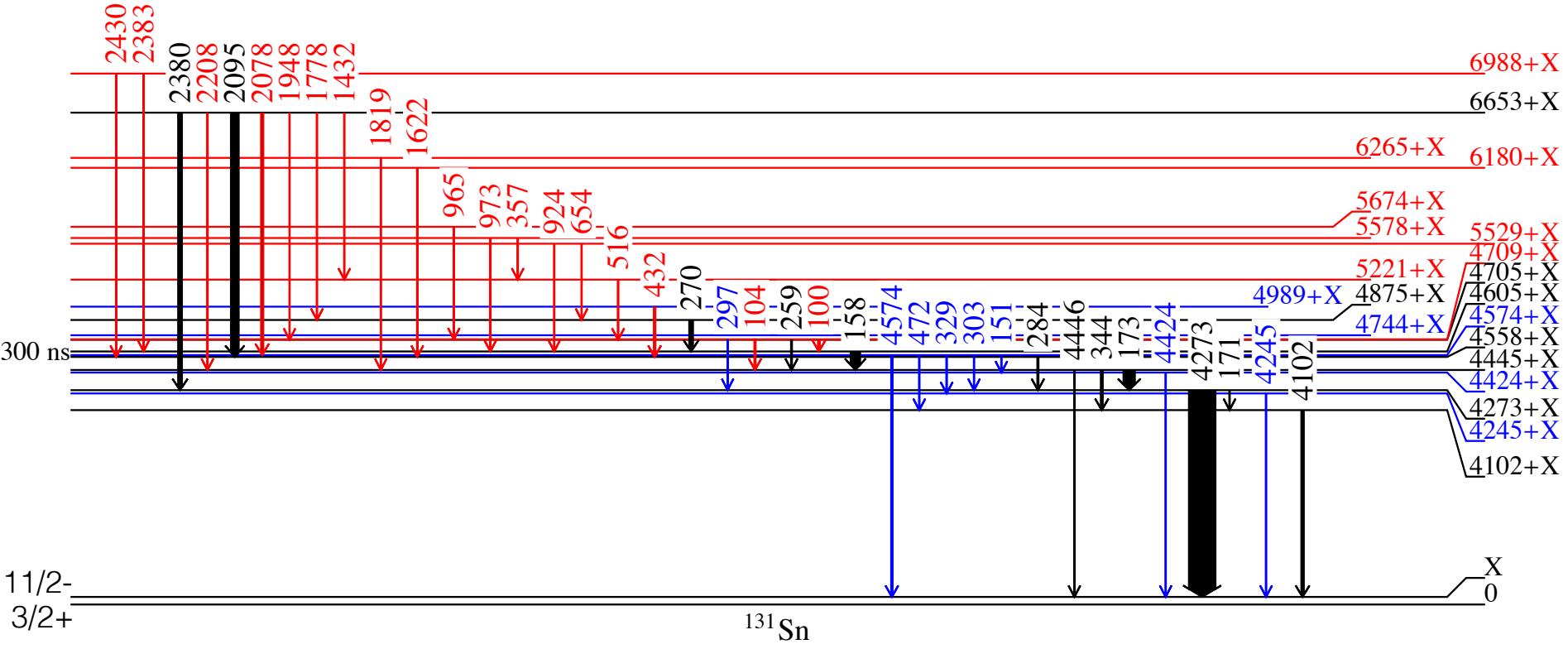
^{131}Sn γ-rays following High-spin ^{131}In Decay



Gamma rays following beta decay of 3764 keV (21/2+) state

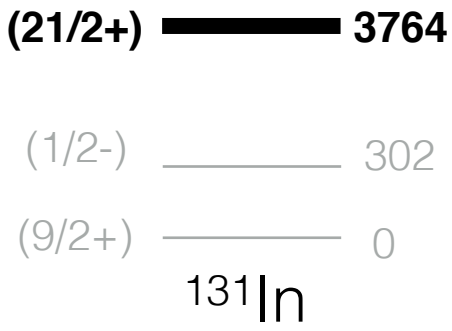
New: 8 Levels, 18 transitions

Prev. Fission: 6 Levels, 8 transitions



P. Bhattacharyya *et al.* PRL **87** 062502 (2001)

^{131}Sn γ-rays following High-spin ^{131}In Decay



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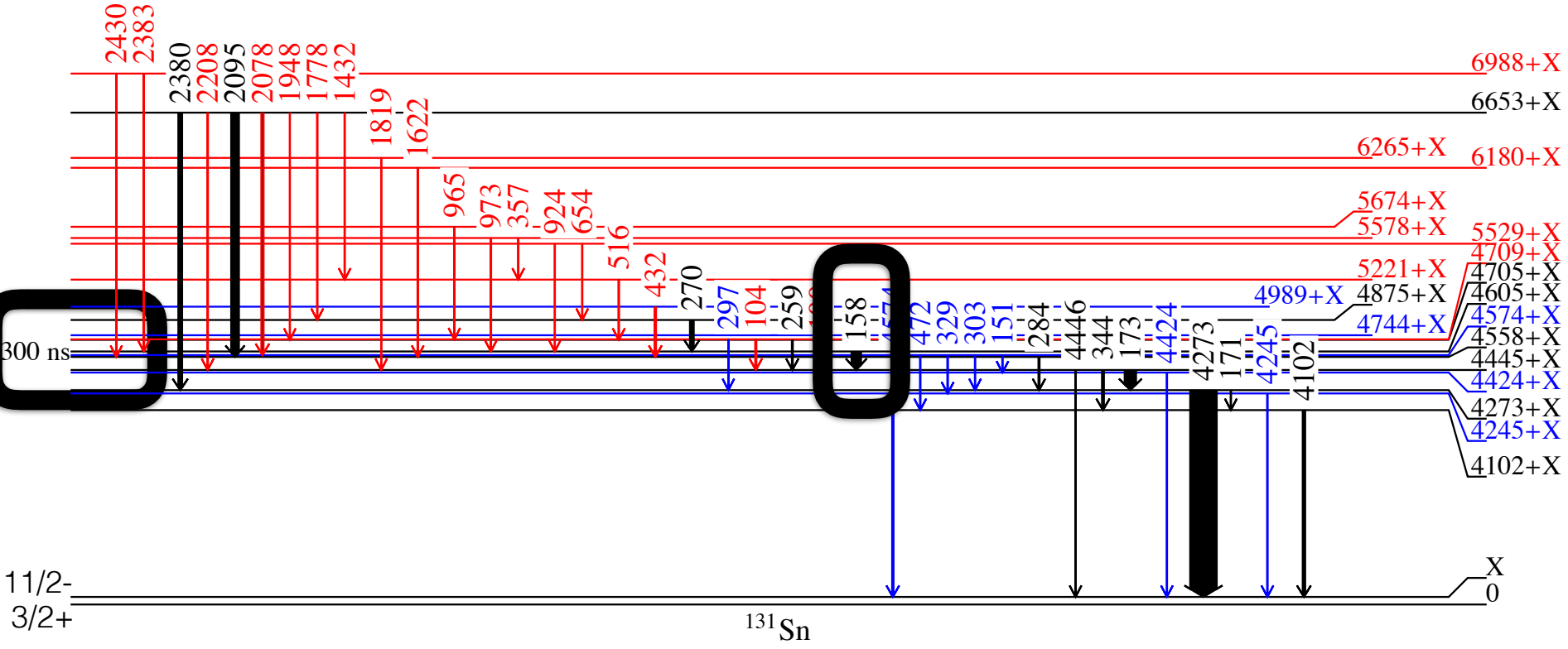
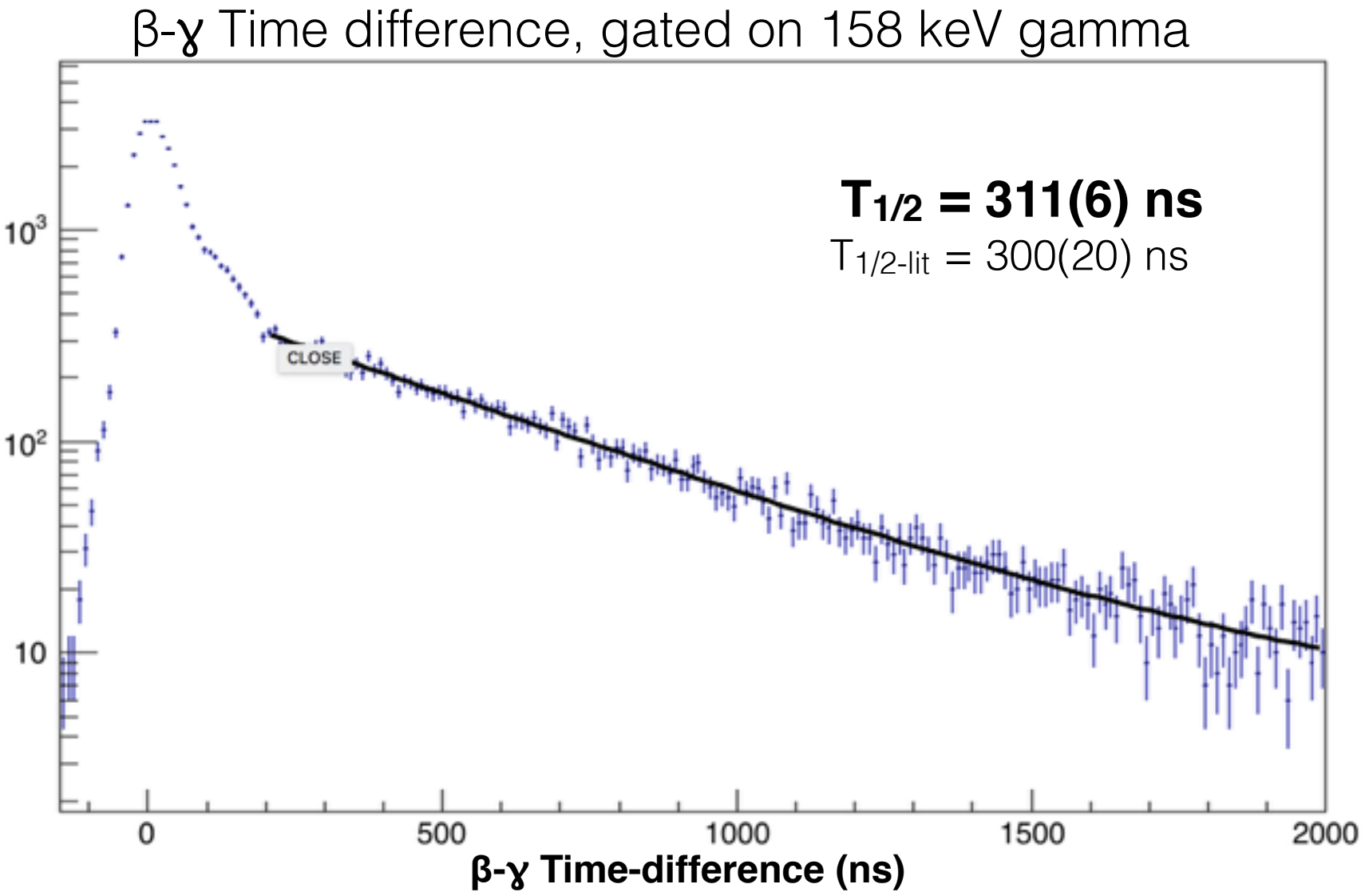


P. Bhattacharyya *et al.* PRL **87** 062502 (2001)

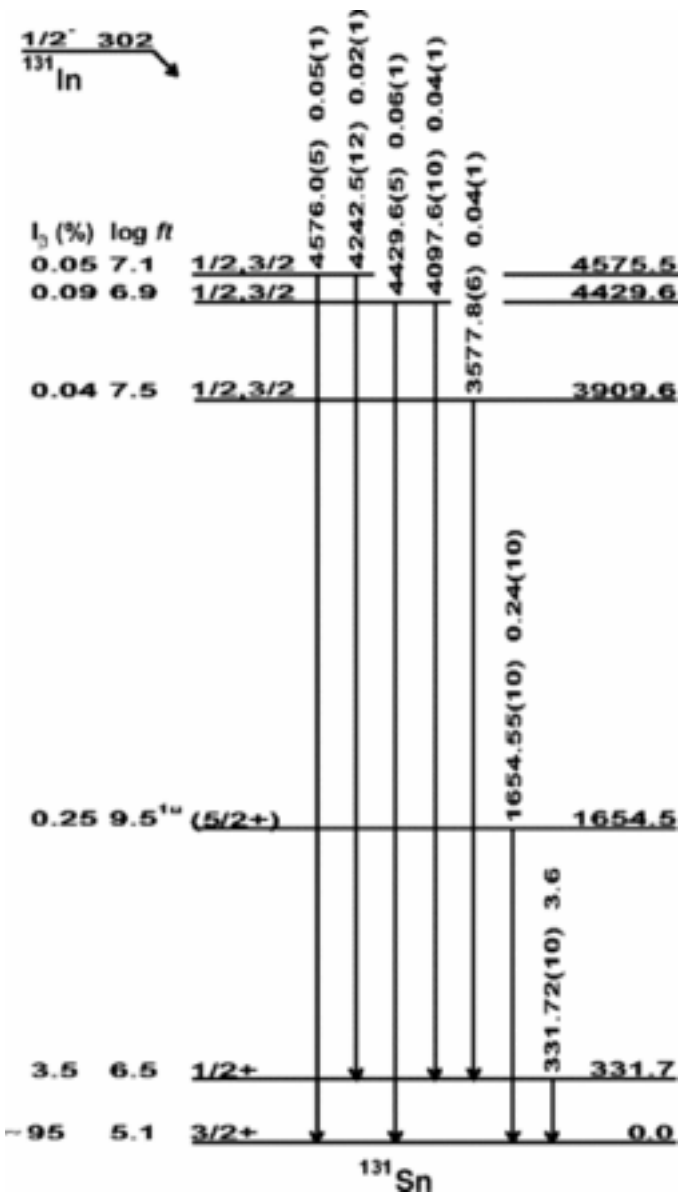
Isomer Half-life (4558+X keV)

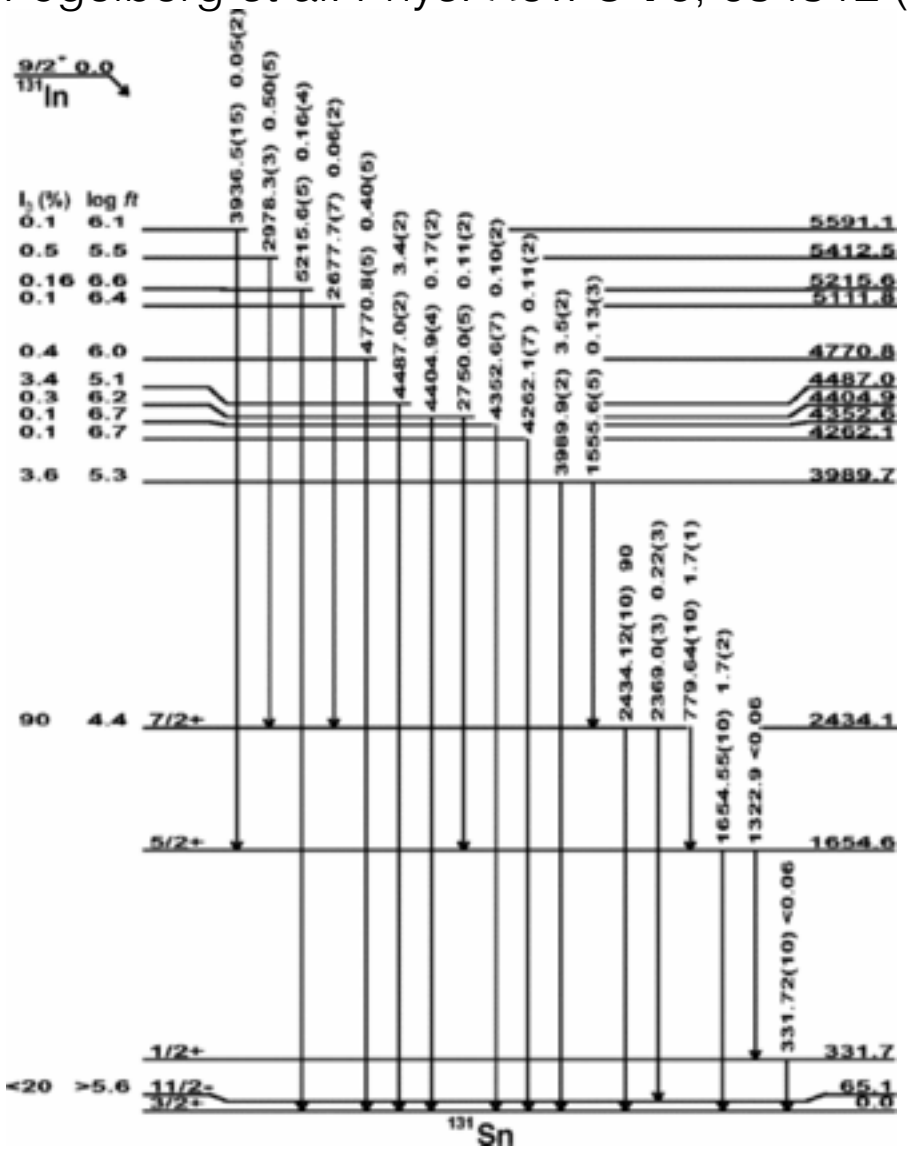


^{131}Sn γ-rays following Low-spin ^{131}In Decay

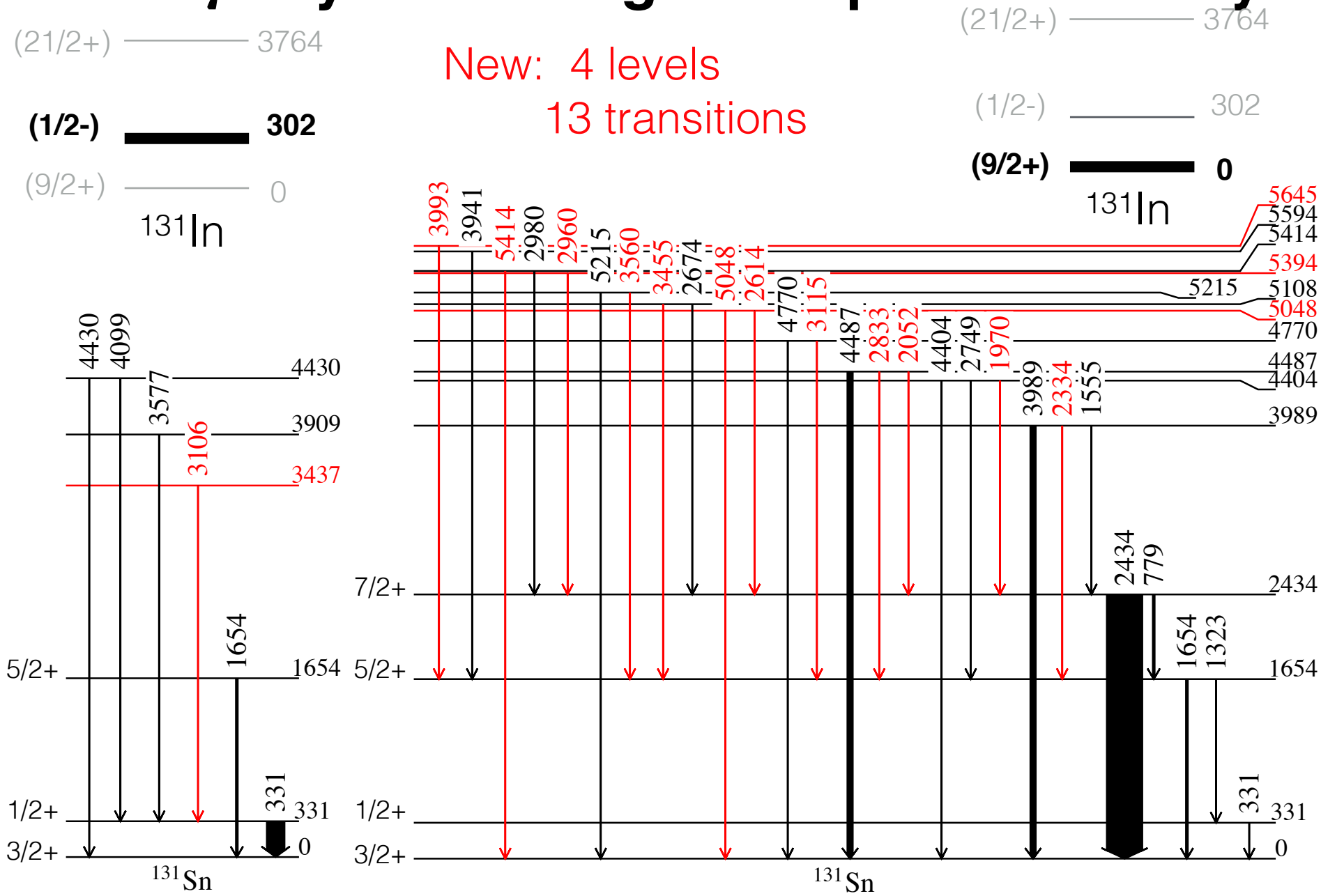
Previous work

Fogelberg *et al.* Phys. Rev. C **70**, 034312 (2004)

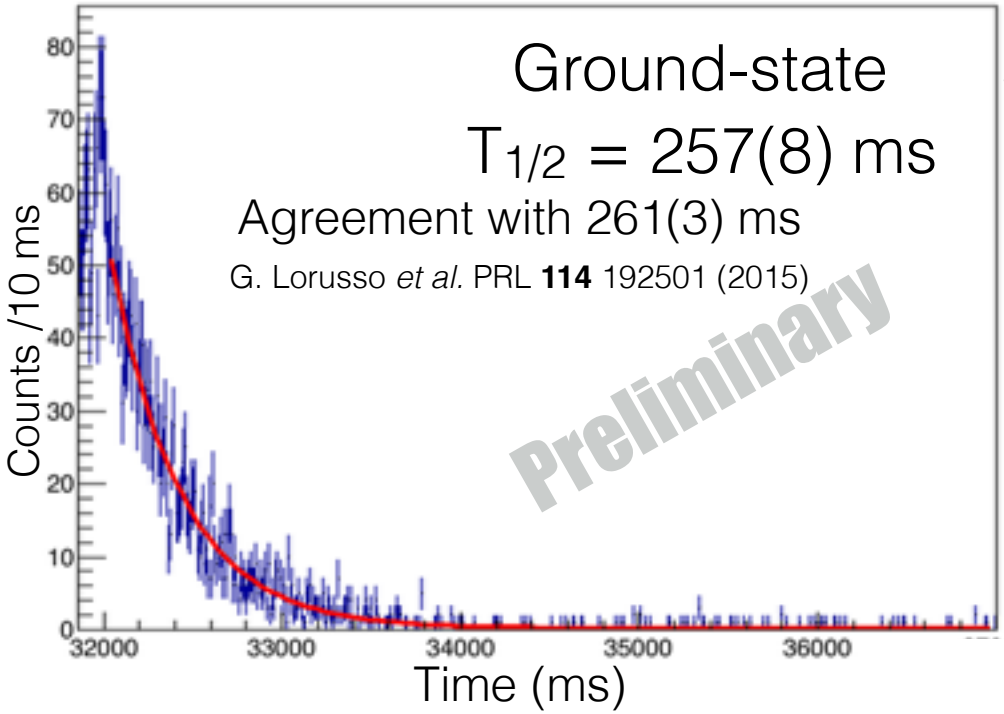


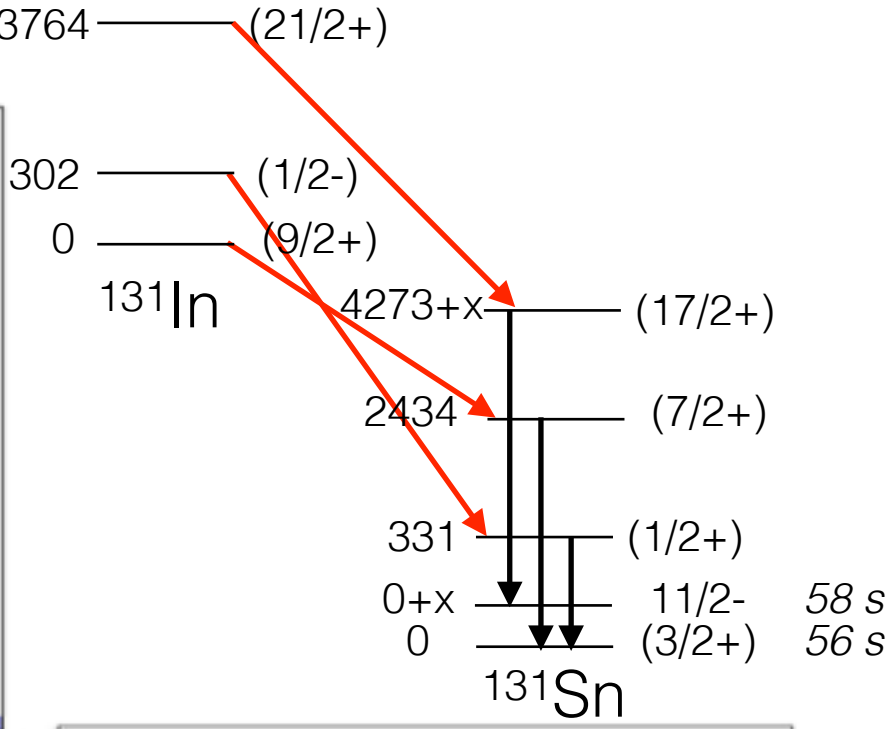


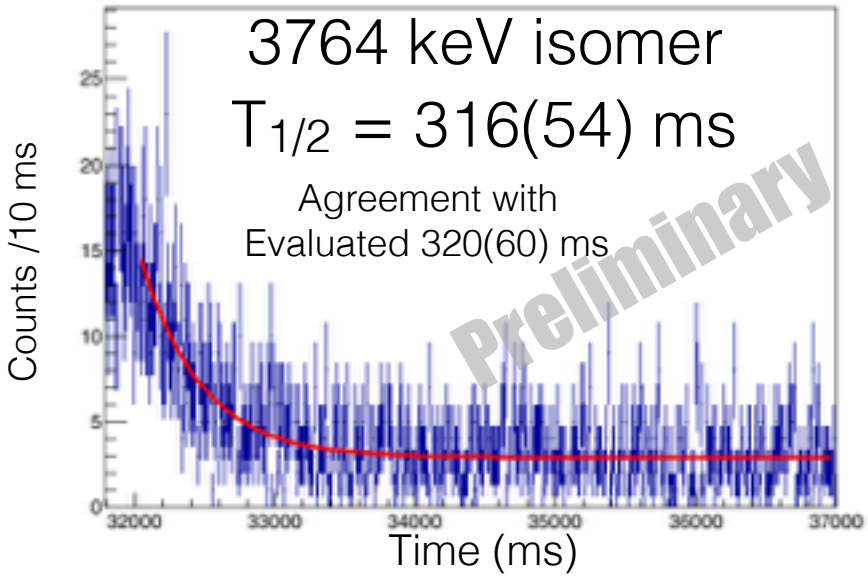
^{131}Sn γ-rays following Low-spin ^{131}In Decay

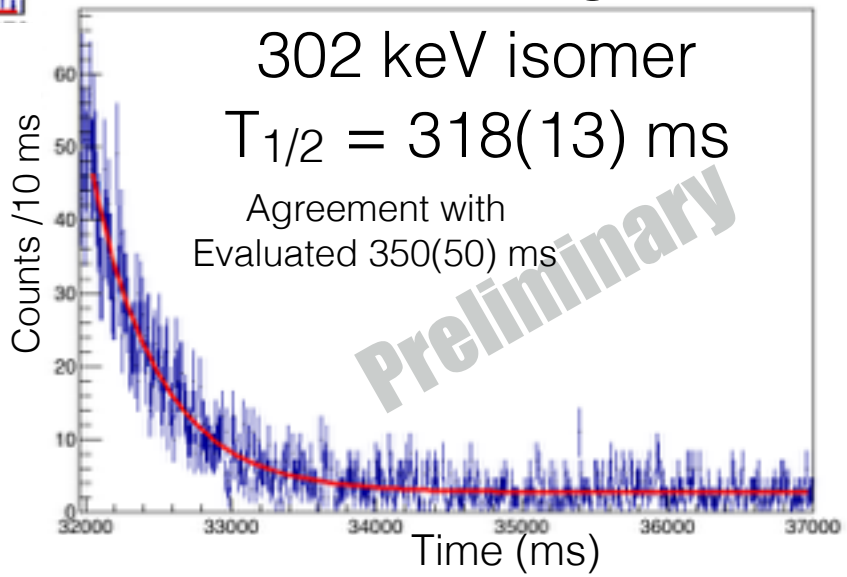


^{131}In Half-Life



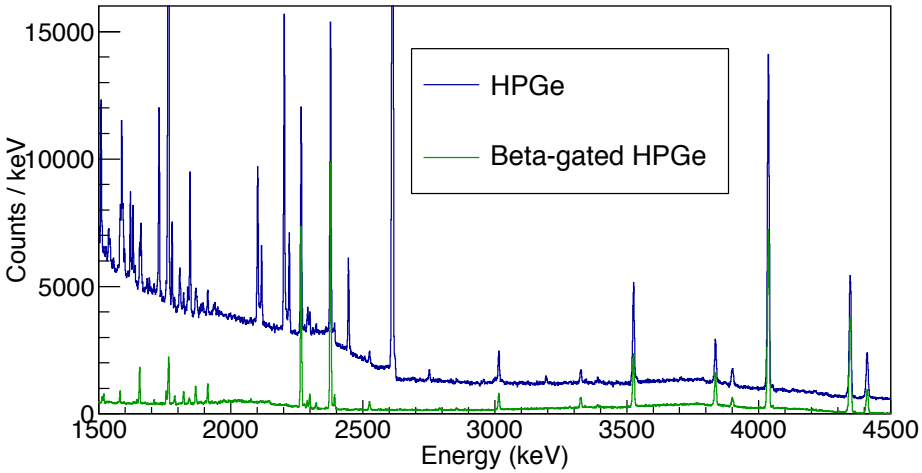


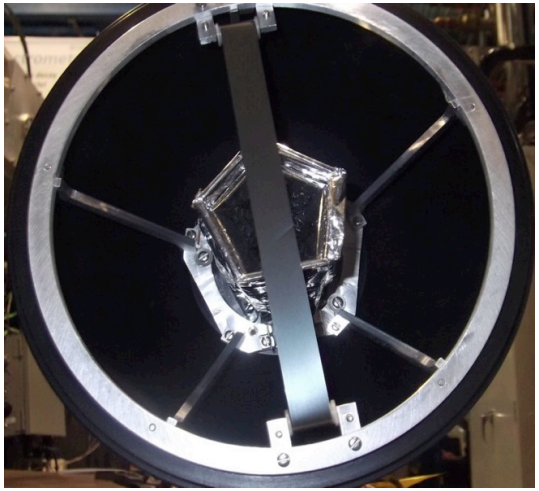


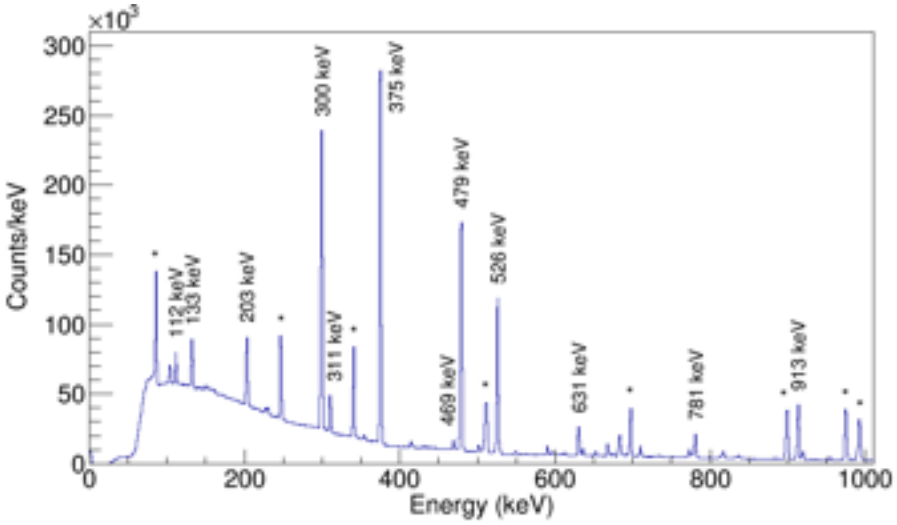


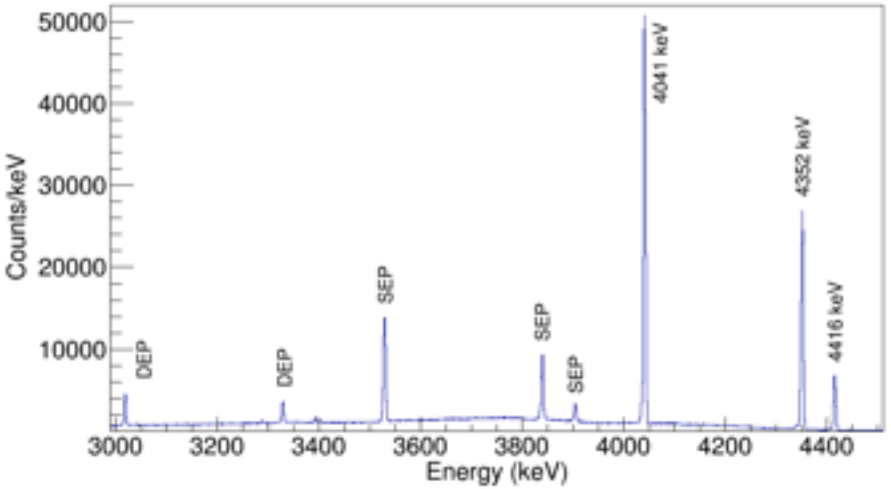
Predicted $T_{1/2}$ (192 ms) is small once scaled to correct ^{130}Cd half-life

^{132}In beta decay





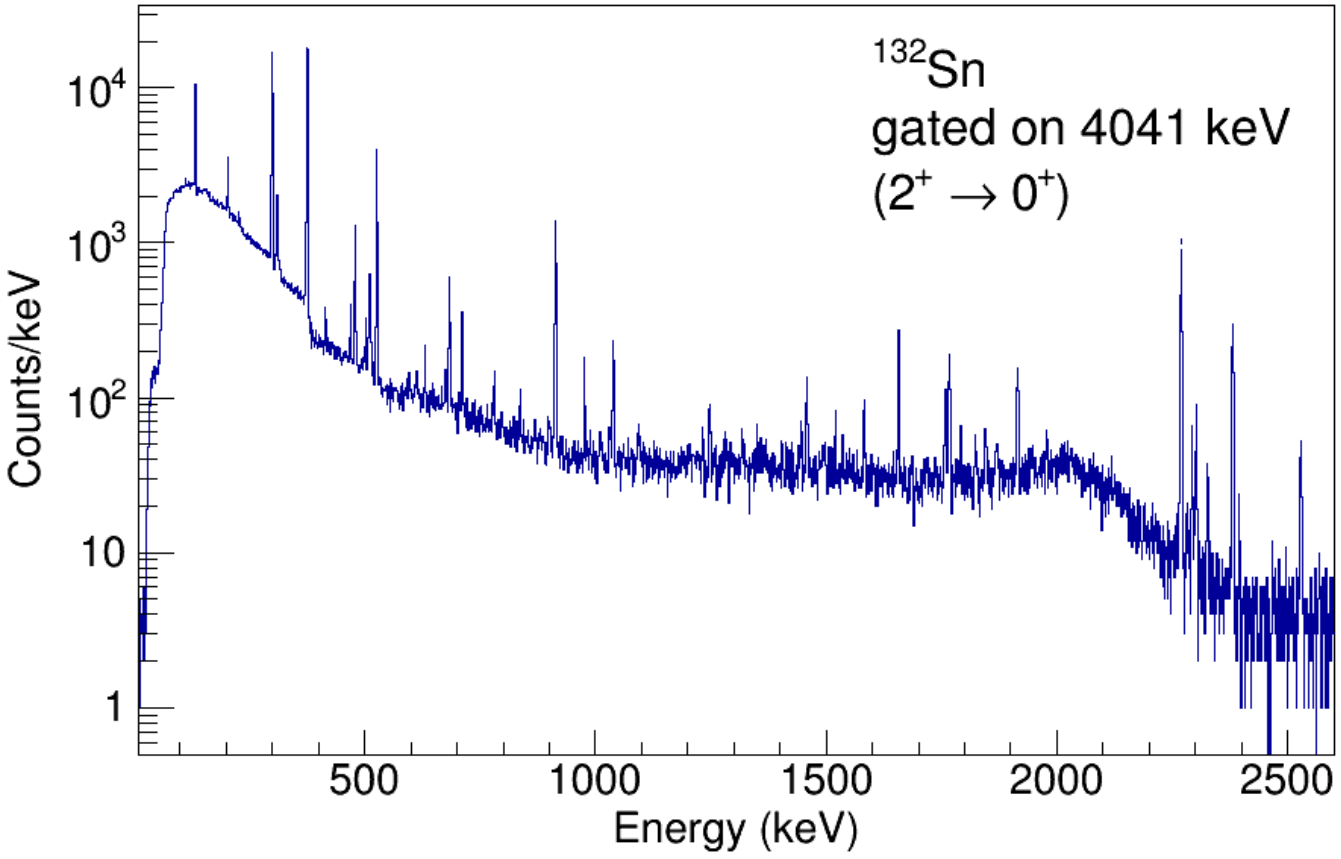




K. Whitmore, Simon Fraser University

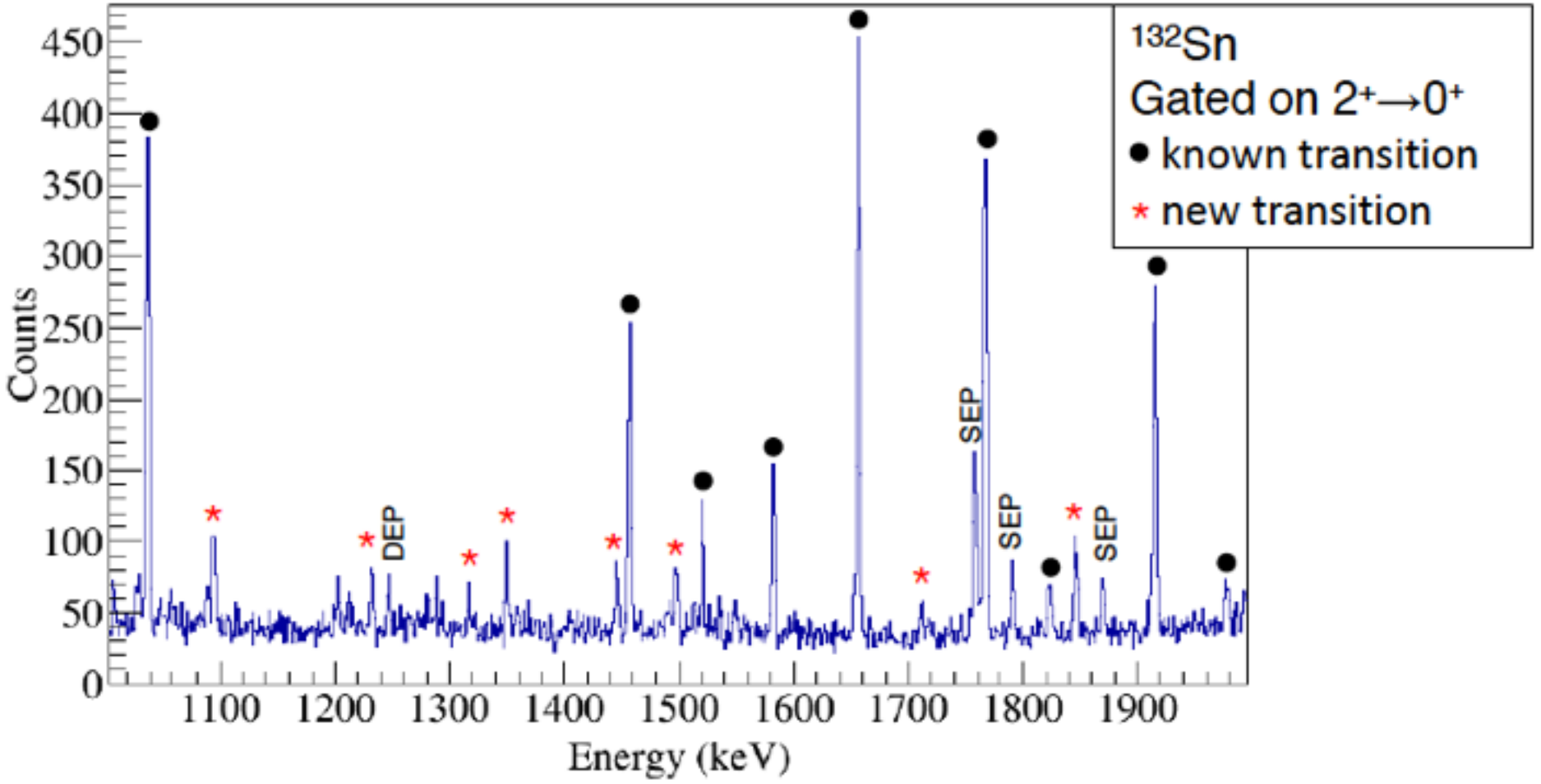
Detailed Spectroscopy of ^{132}Sn

70 pps ^{132}In; 62 h

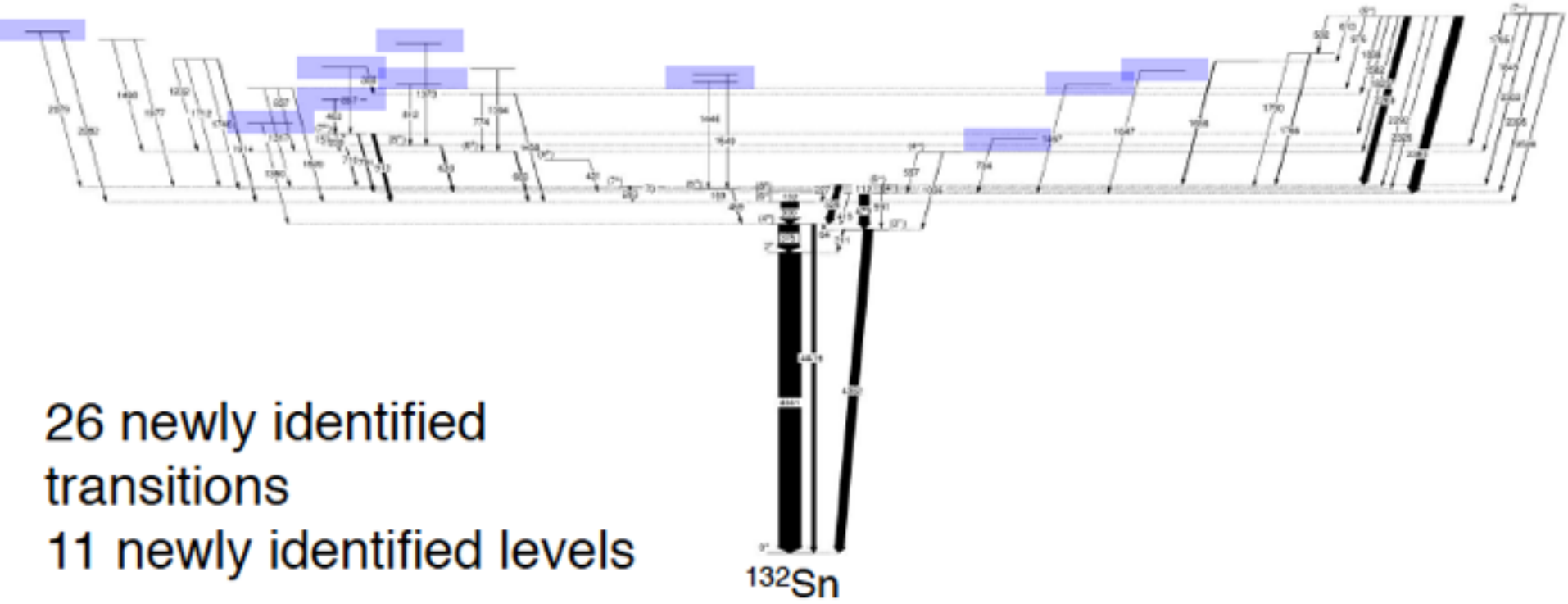


K. Whitmore, Simon Fraser University

New Transitions



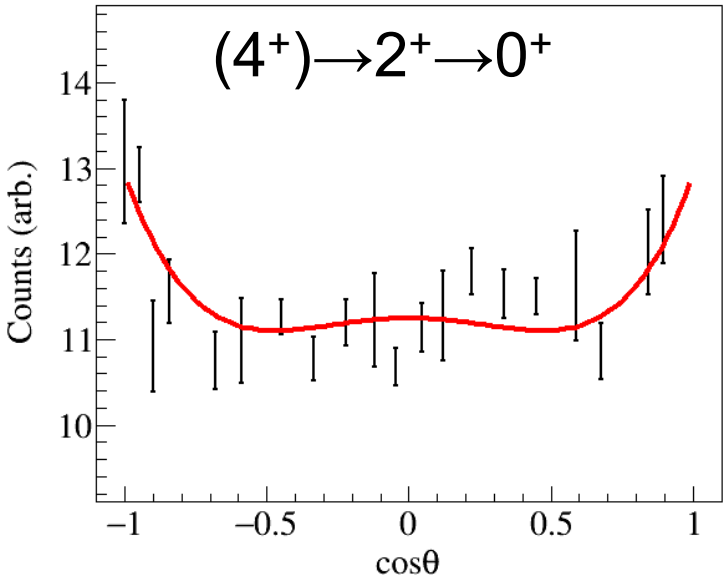
Level Scheme

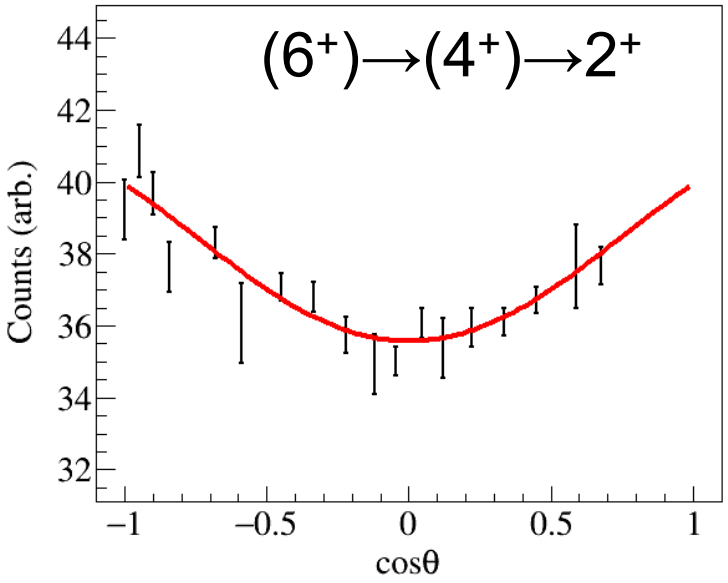


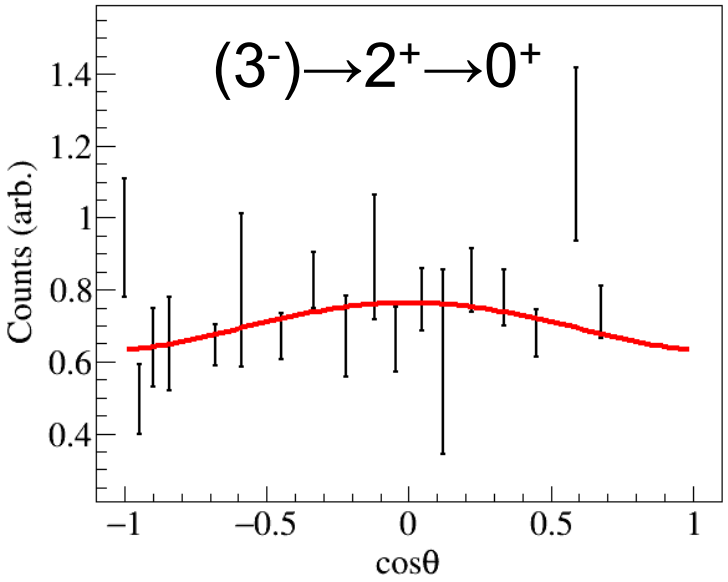
26 newly identified transitions
11 newly identified levels

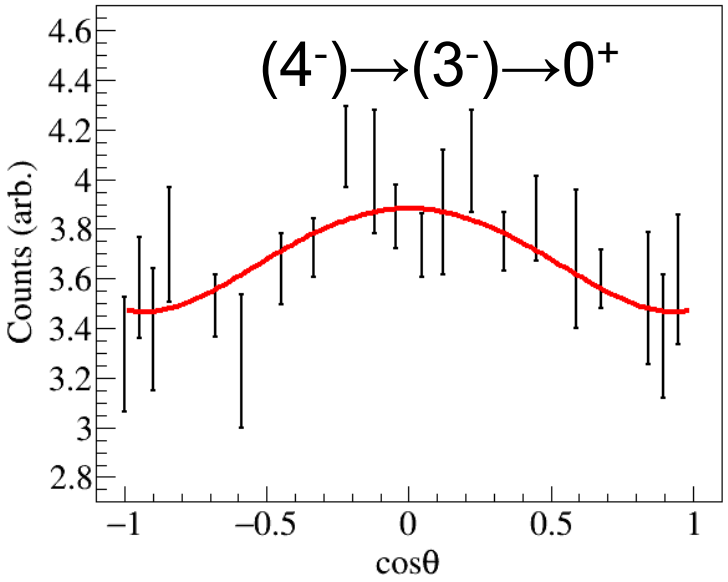
K. Whitmore, Simon Fraser University

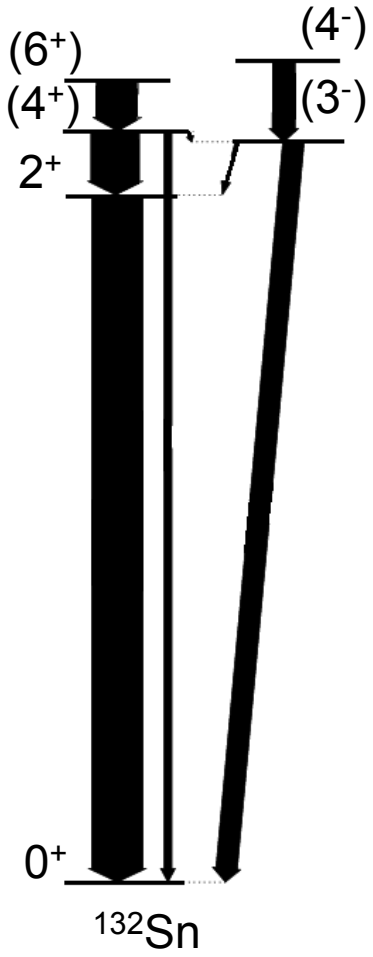
Spin Assignment







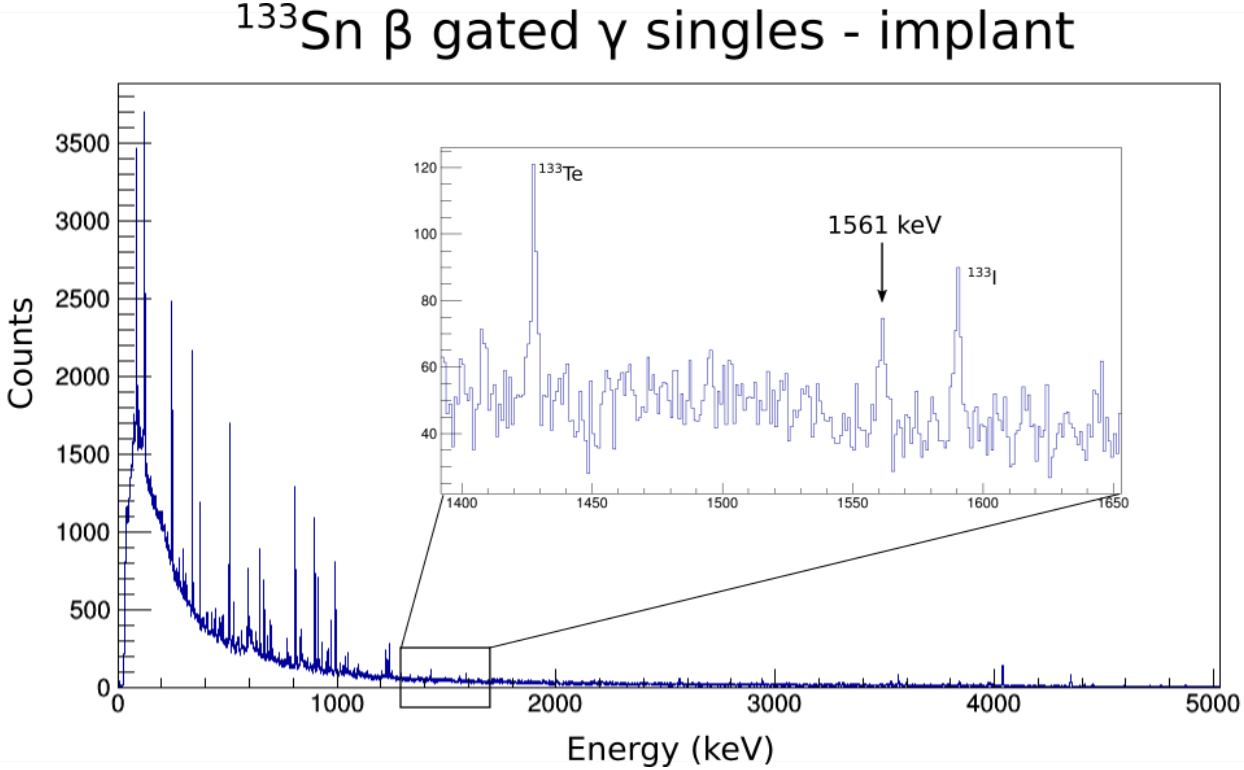


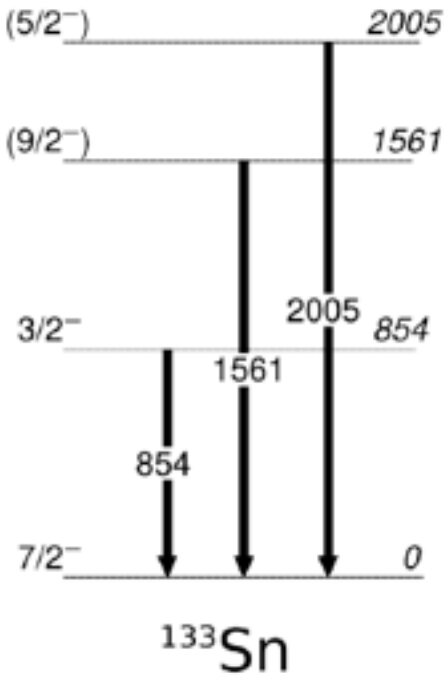


^{133}Sn

$$^{133}In \rightarrow {}^{133}Sn + \beta^- + \bar{\nu}_e \qquad Q_\beta = 13.4\ MeV$$

0.2 pps; 16 h





Ongoing analysis, F.H. Garcia, SFU

P. Hoff et al. PRL 77, 6 (1996)

Summary I

- Critical information on shell structure effects can be obtained from semi-magic nuclei close and far to stability, including angular correlations, polarity, lifetimes.

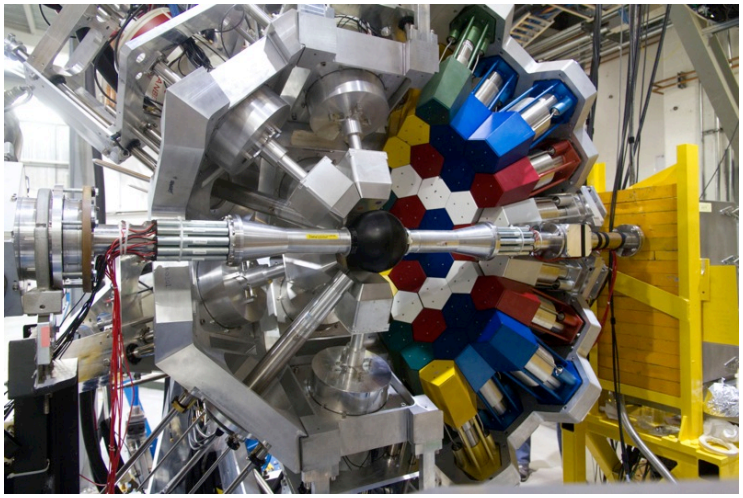
- Challenge and benchmark the nuclear models of structure and give hints about the nuclear interaction.

- GRIFFIN is a powerful tool for detailed decay studies.

- ARIEL - new driver; photo-fission; **neutron-rich factory**
    - new beam line, new target stations
    - increased beam time and research output

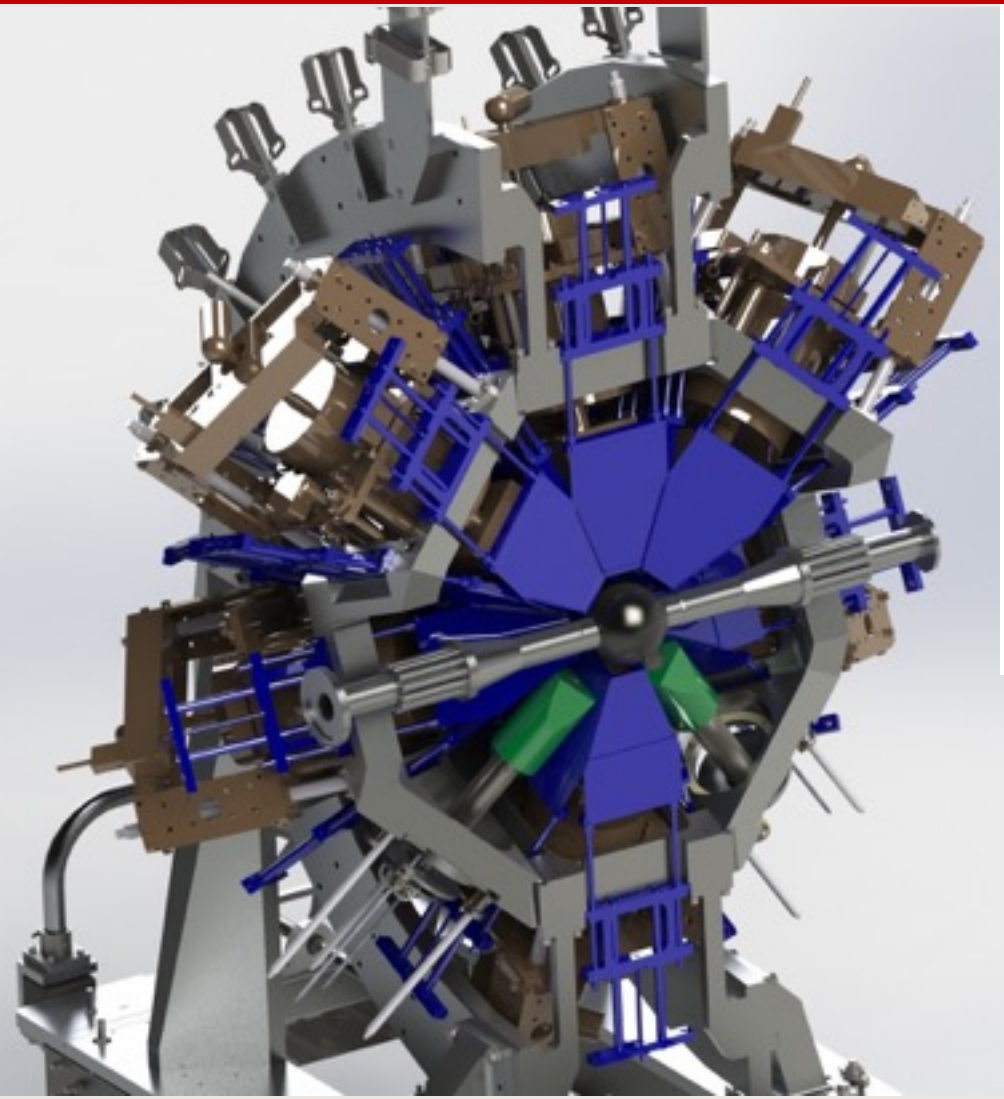
Summary II

GRIFFIN + DESCANT for beta-delayed neutron decays

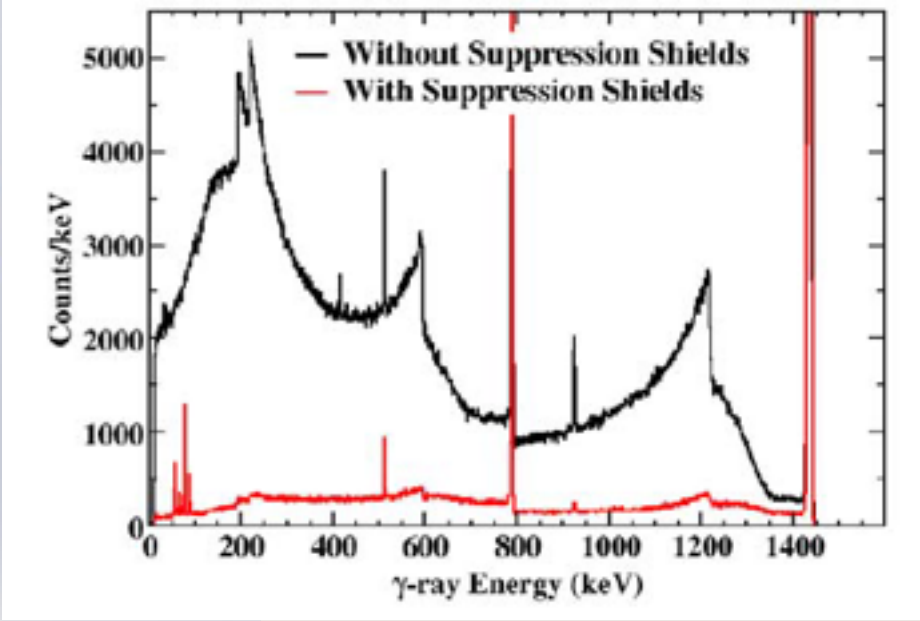


P. Garrett, University of Guelph

Summary III
Compton suppression shields for GRIFFIN



Guelph, SFU, TRIUMF



GEANT4-simulated GRIFFIN spectra without/with suppression shields

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Simon Fraser University, Canada

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Thank you ! Merci!