TRIUMF

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

THE TRIUMF-ISAC RADIOACTIVE ION BEAM (RIB) FACILITY: RECENT HIGHLIGHTS AND FUTURE PLANS

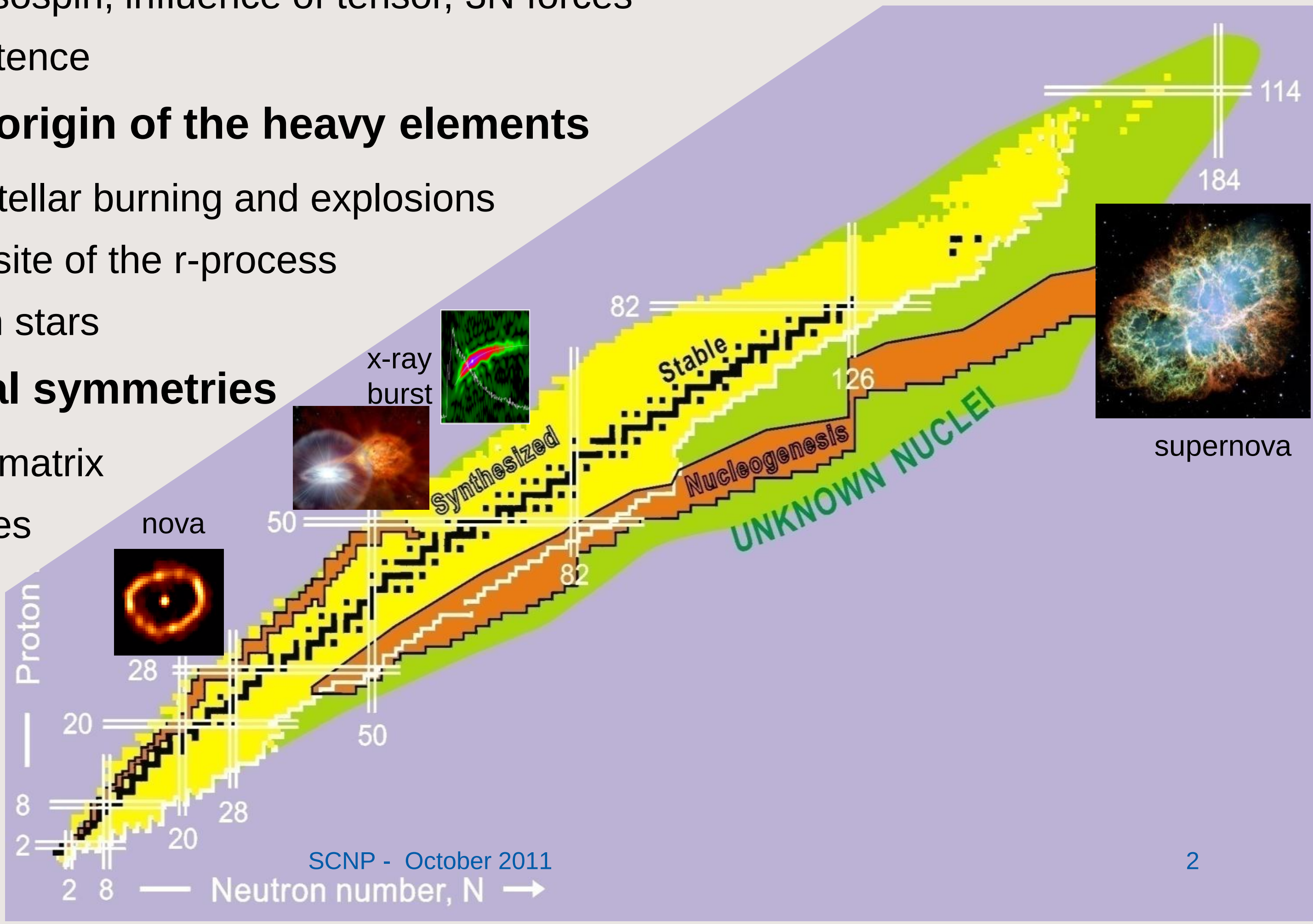
ISOLDE Workshop 2011

December 7, 2011

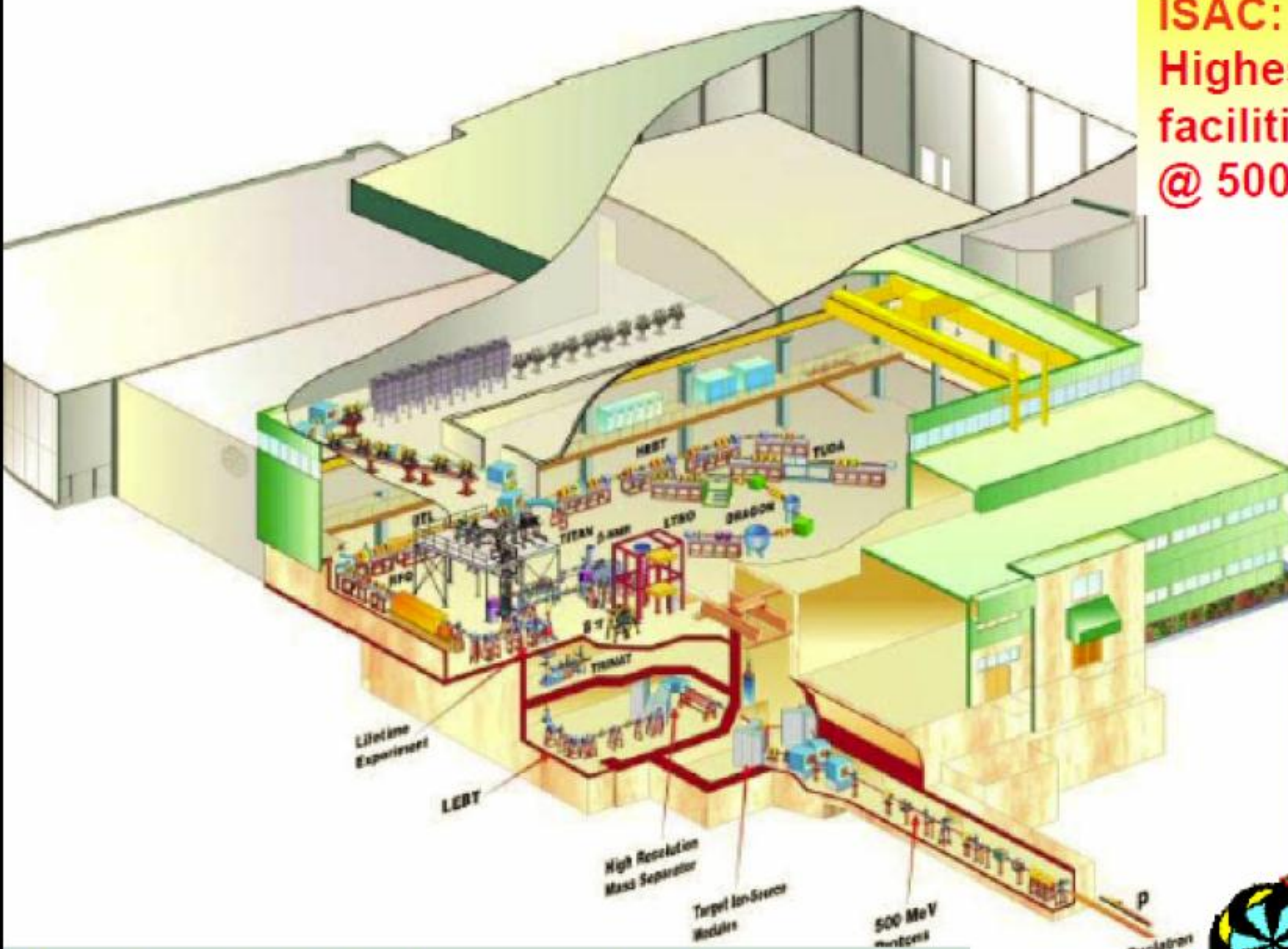
Gordon Ball TRIUMF

Rare Isotope Beam Science

- **Developing a unified theory of nuclei and hadronic matter**
  - precision tests of ab-initio theory,
  - shell evolution with isospin, influence of tensor, 3N forces
  - limits of nuclear existence
- **Understanding the origin of the heavy elements**
  - crucial reactions in stellar burning and explosions
  - identifying path and site of the r-process
  - properties of neutron stars
- **Testing fundamental symmetries**
  - unitarity of the CKM matrix
  - Parity violation studies
  - EDM searches
  - double beta decay



ISAC @ TRIUMF



ISAC:
Highest power for On-Line facilities, we go up to 100μA @ 500MeV DC proton

ISAC has 3 exper. areas:

- Low energy (60keV)
- ISAC I (up 1.8 MeV/u)
- ISAC II (up to 16MeV/u, presently upgraded)

Suite of experimental stations:

- TRINAT, Beta-NMR, 8pi, tape-station, TITAN, Co-linear laser spec, polarised beam line, etc
- DRAGON, TUDA, TACTIC, GPS,
- TIGRESS, EMMA (2011), HERACLES

Target material for beam production includes U (UO and UC license)
Ion sources: surface, laser, FEBIAD, ECR (test)
TRIUMF part of collaborations for target and ion source R&D

Actinide target development

- Tests in 2008 and 2009 with UO_2 surface and FEBIAD ion source
- License to run with U targets at < 2μA for 1000 μA hr approved Nov 2009
- Development and characterization of UC_X target material in 2010

Dec 2010: UC_x with surface /TRILIS ion source

- Yield measurements Na,K,Rb,At,Fr,Ra leading to several experiments:
  - laser ionization of $^{199,217-218,223}$At ,first measurement of isotope shifts
  - β-decay studies of $^{221-225}$At with 8π, a precursor to Rn EDM
  - β-decay of neutron-rich $^{94-102}$Rb: shape coexistence at N=60
  - mass measurement with TITAN for neutron-rich $^{94-98}$Rb/Sr isotopes
  - collinear laser spectroscopy of cooled and bunched Fr: A<209
  - long-lived ^{225}Ra source for off-line setup of Fr atom trap

License to operation with U targets at 10μA for 5000 μA hr Nov 28, 2011

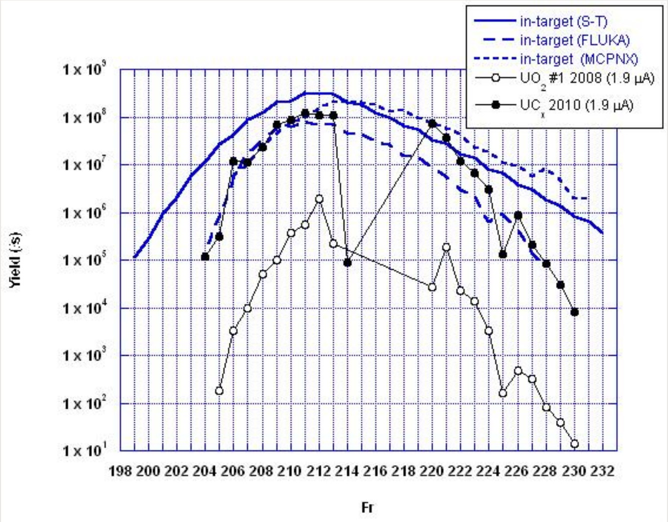
First UCx at 10 μA started running Dec 1. Expected increase in yields observed

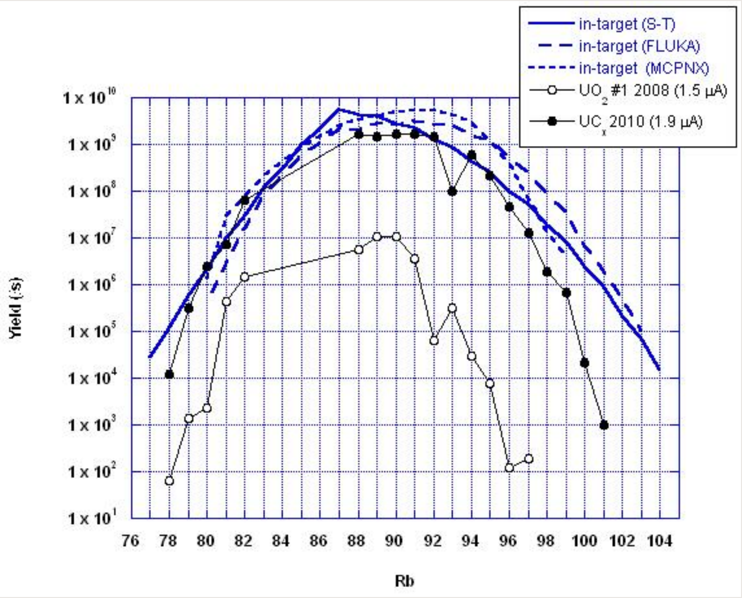
TRIUMF

Fr and Rb yields measured from UC_x target Dec 2010

Yields are more than sufficient for the Fr program:

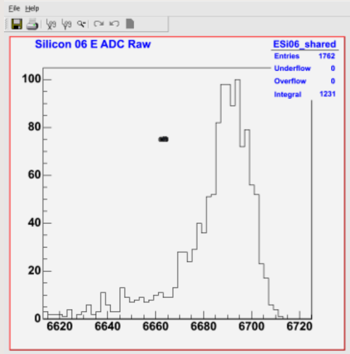
- Collinear laser spectroscopy
- Anapole moment and atomic PNC

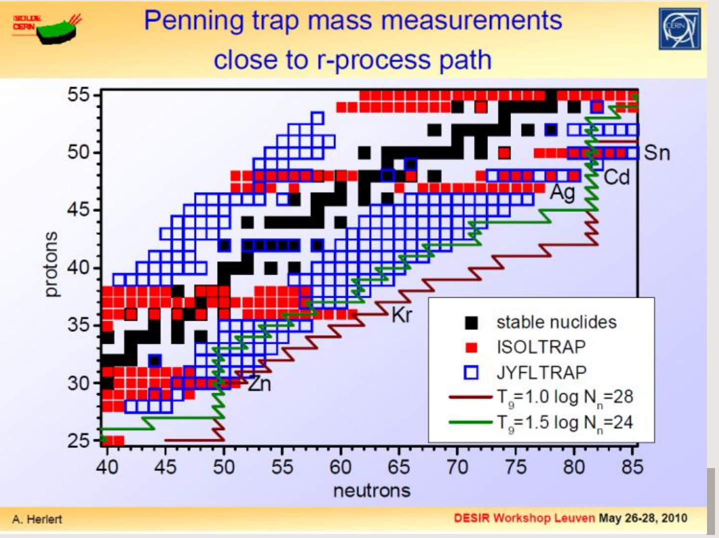




Alpha decay of laser ionized ^{199}At detected in 8π SiLi array PACES

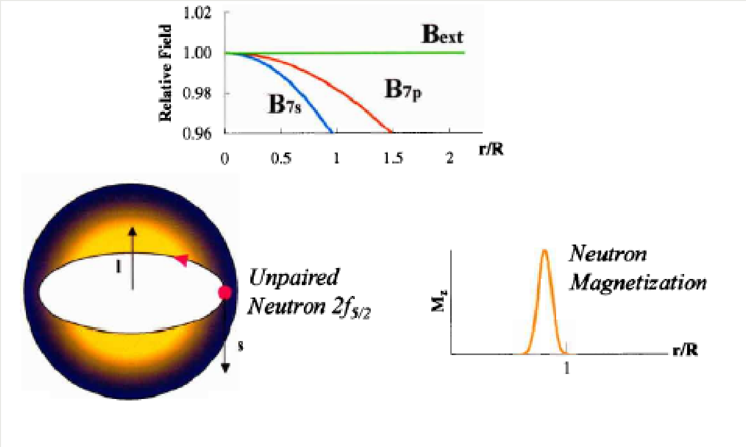
Dec 10,2010





Physics with francium at TRIUMF

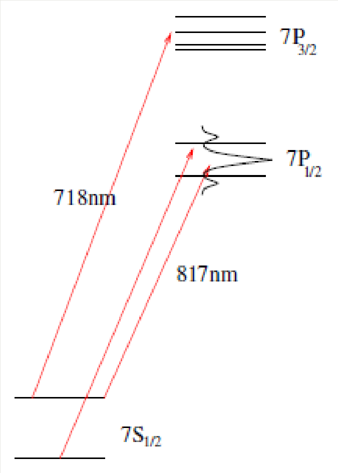
- Francium is the heaviest simple atom making it an ideal laboratory for many fundamental tests
- A programme of experiments is approved at TRIUMF including Weak Nucleon-Nucleon Interactions by Parity non-conservation and Spectroscopy of the 7s - 8s transition
- First experiment *Hyperfine anomaly measurements in neutron deficient Fr isotopes* getting a handle on the nuclear magnetisation distribution.



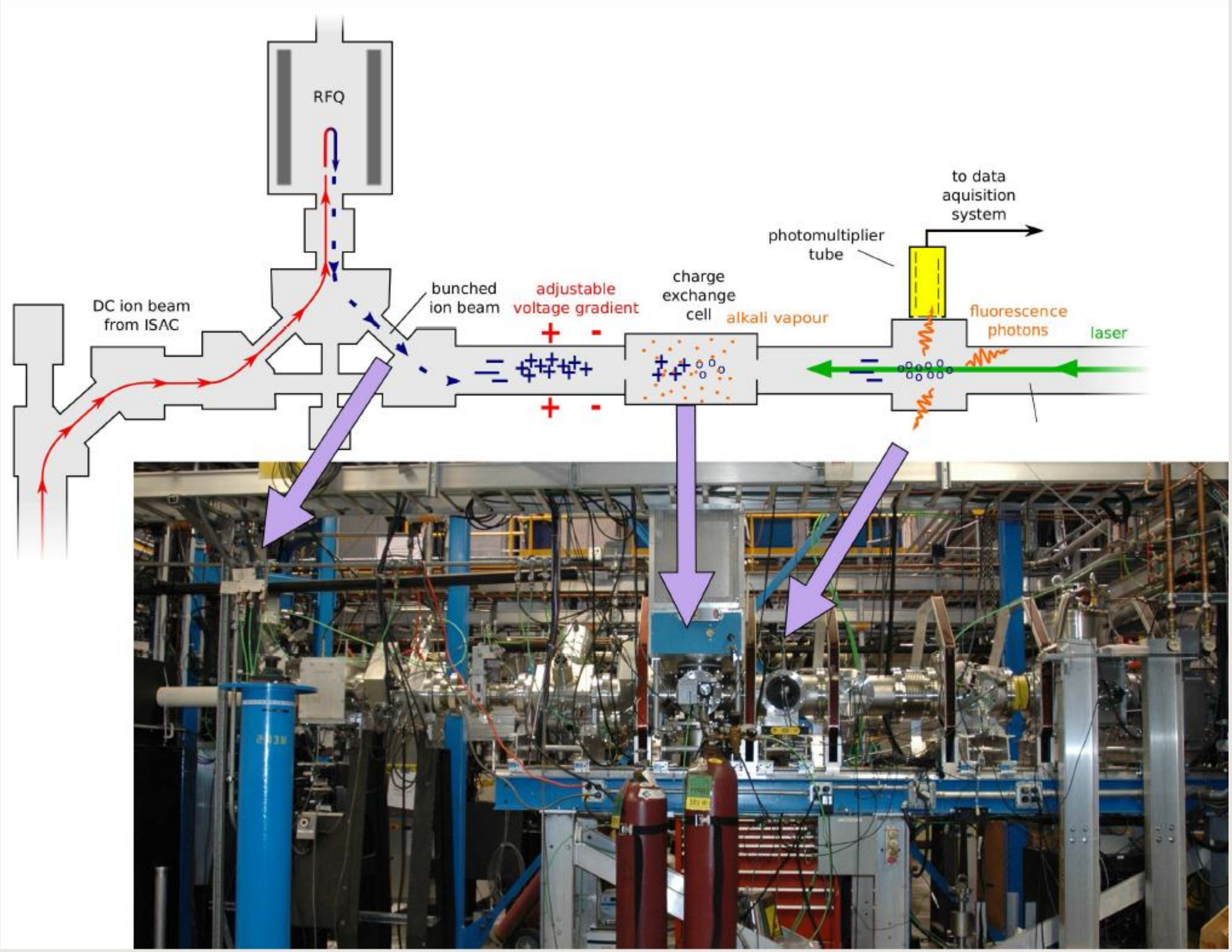
The valence neutron within Francium provides localised magnetism due to it's spin

High precision measurements of the atomic hyperfine structure use the atomic electrons to probe this effect.
Firstly measurements of the atomic $S_{1/2}$ state using collinear laser spectroscopy

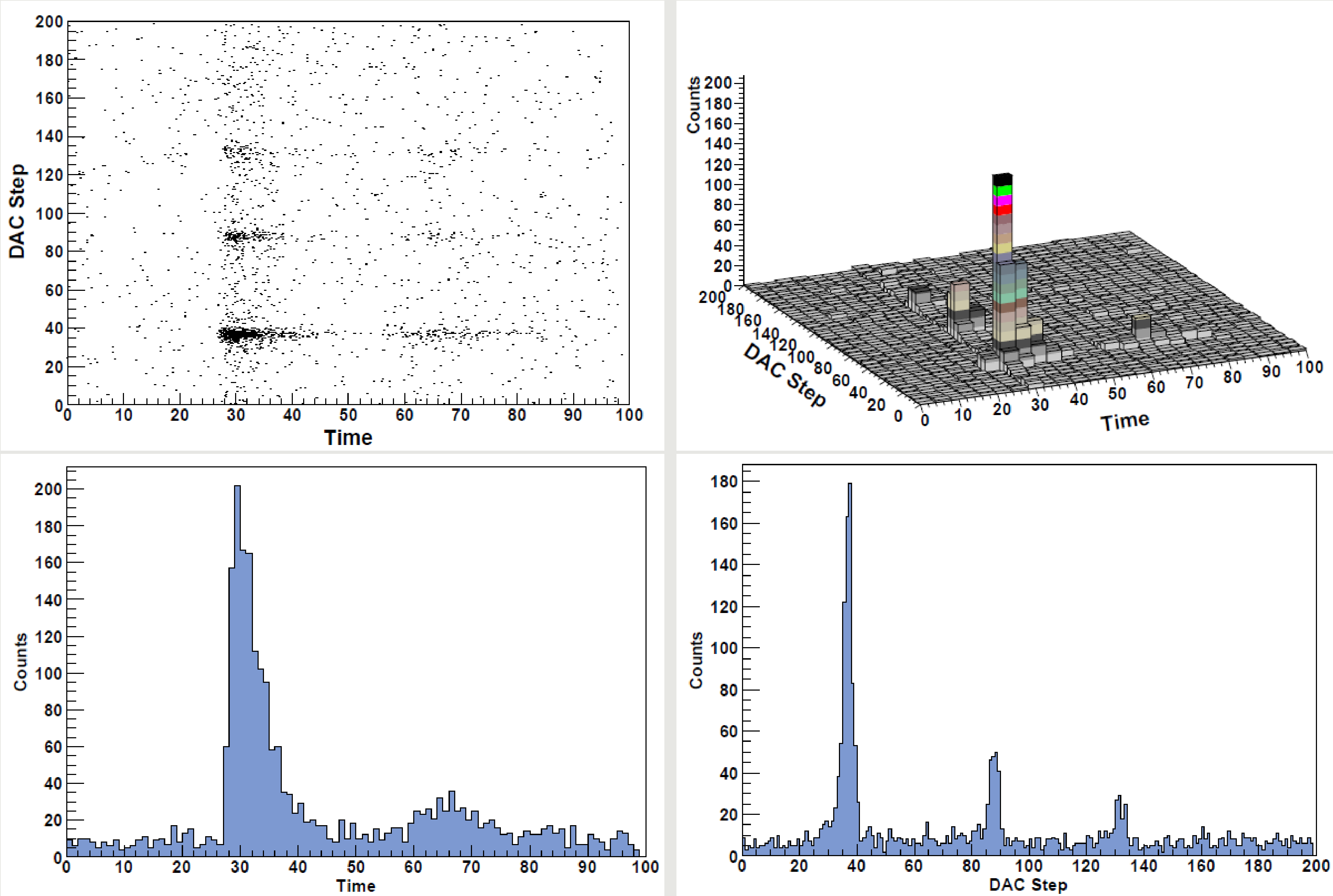
Followed by spectroscopy on a sample of atoms trapped within a Magneto-optical trap.



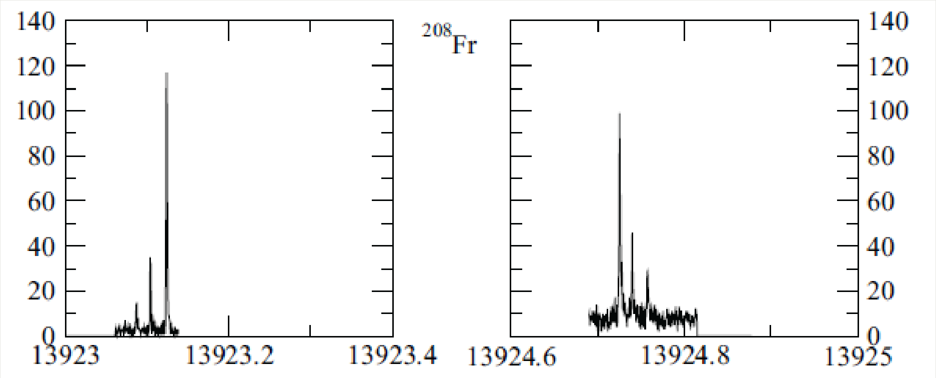
Collinear Laser Spectroscopy with cooled bunched beams

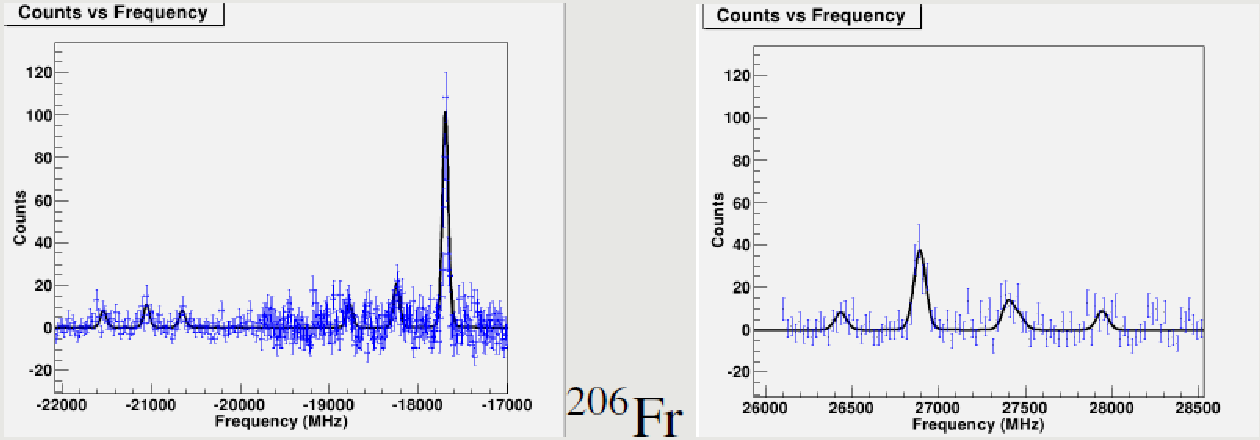


An MCS based DAQ System
for laser spectroscopy



First results

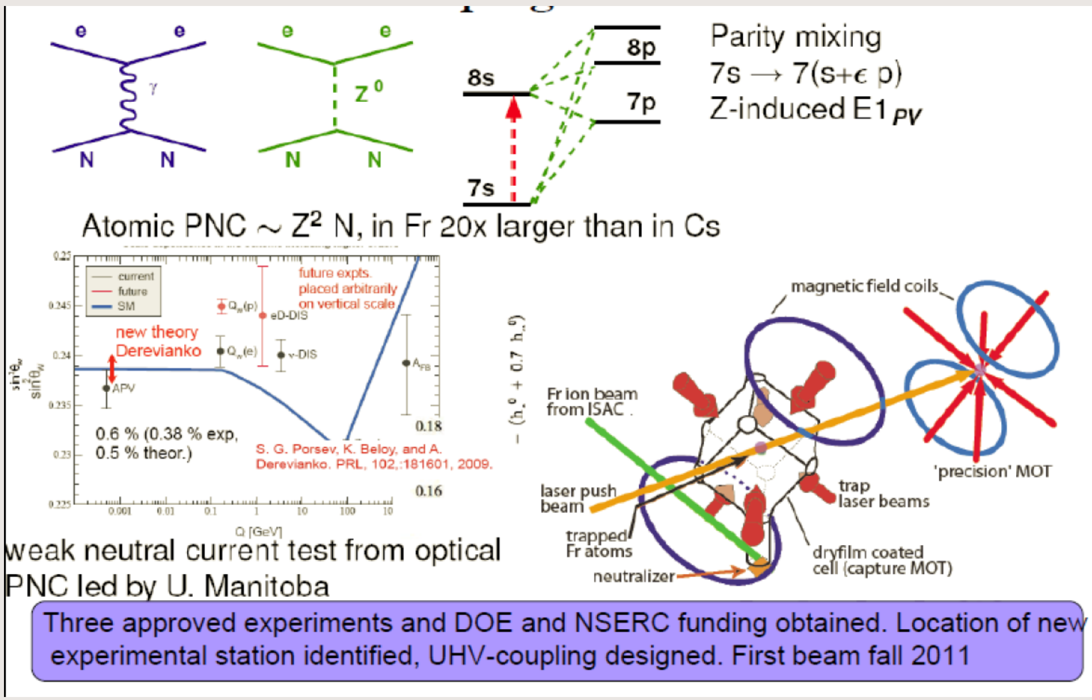




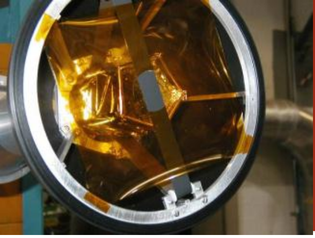
- ^{208}Fr used as a frequency reference
- ^{206}Fr new measurement
- Confirms at least one nuclear isomer in ^{206}Fr
- First collinear laser spectroscopy on Fr.
- Data will provide ground state moments, spin and RMS charge radii of ^{206}Fr and ^{206m}Fr

Fr PNC program at ISAC

Next steps: Trap Fr in MOT laser trap and prepare for PNC



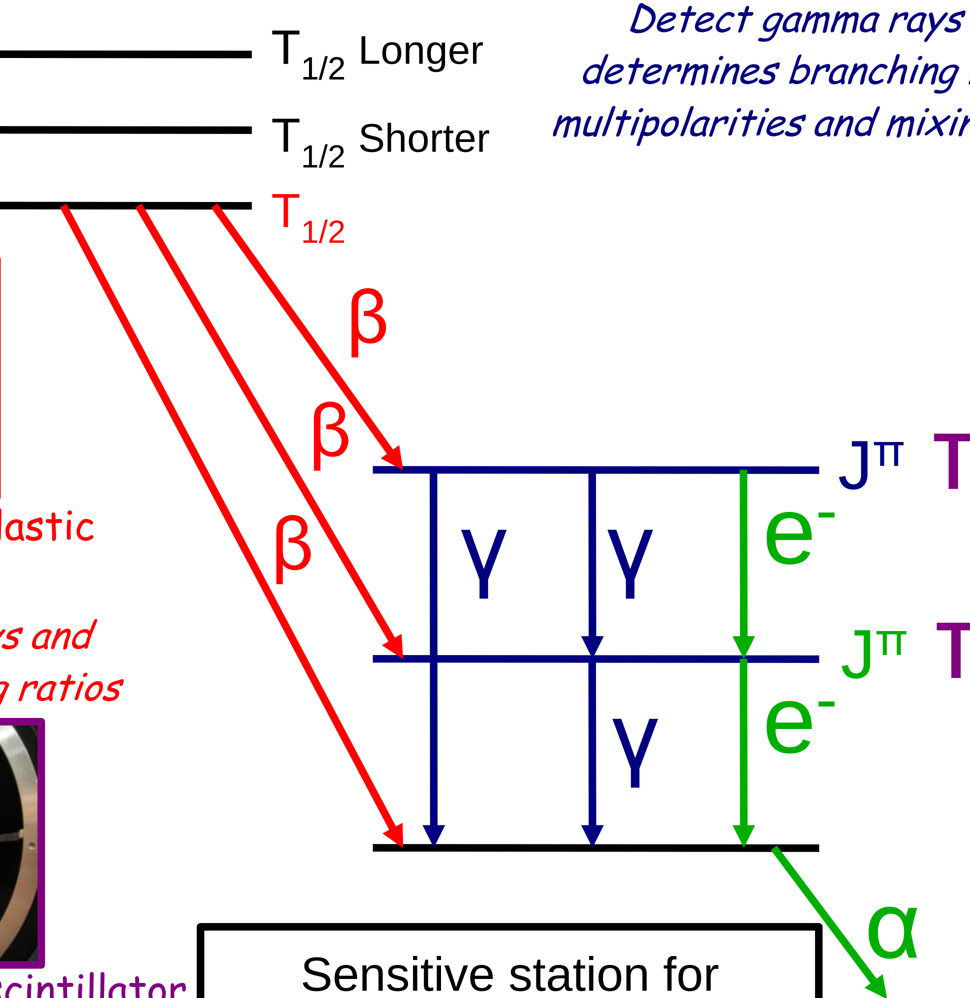
New fully shielded (E&M) laser room now installed (University of Maryland-DOE funded including laser equipment)



The 8pi Spectrometer at TRIUMF
Sensitive Decay Spectroscopy

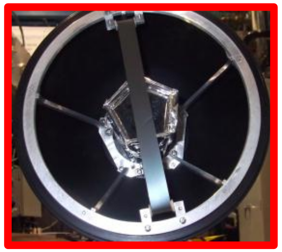
Fast, in-vacuum tape system

Enhances decay of interest



8pi Ge: 20 Compton-Suppressed HpGe

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

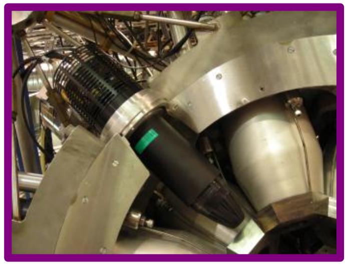


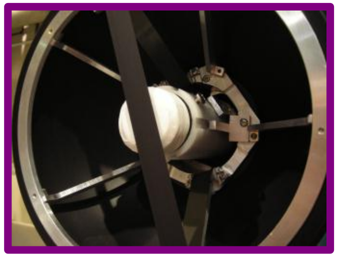
SCEPTAR: 10+10 plastic scintillators

Detects beta decays and determines branching ratios

DANTE: 10 $BaF_2/LaBr_3$

Fast-timing of photons to measure level lifetimes





Zero-Degree Fast scintillator

Fast-timing signal for betas

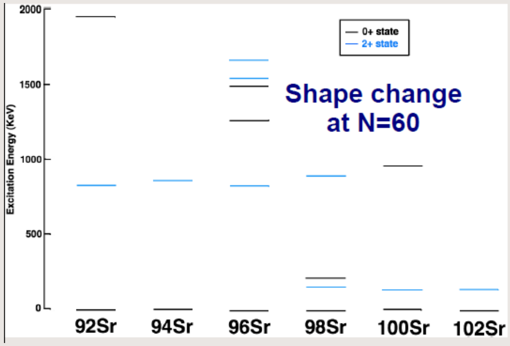
Sensitive station for studying radioactive decay

PACES: 5 Cooled Si(Li)s

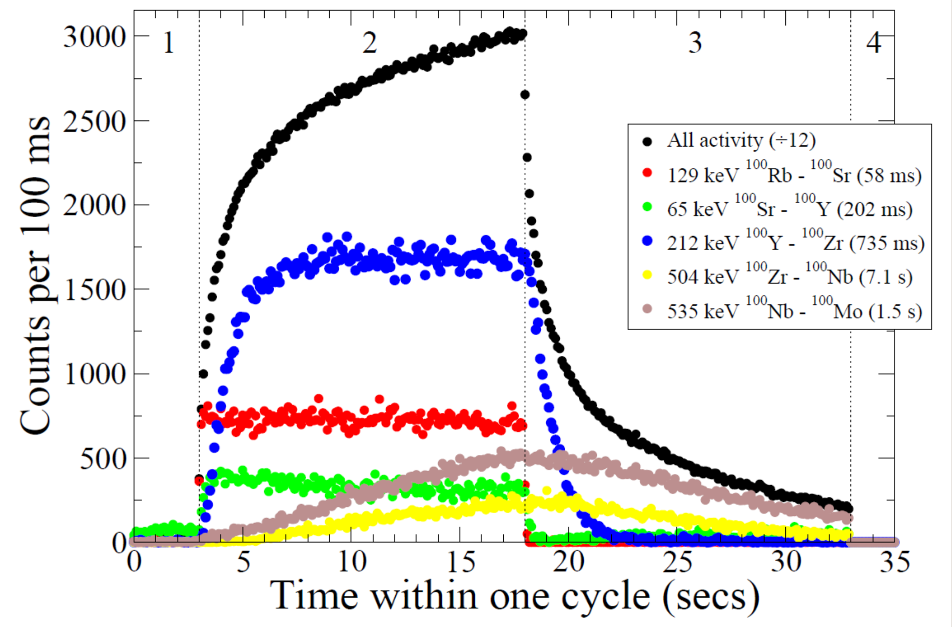
Detects Internal Conversion Electrons and alphas/protons

Shape transition and coexistence at *N*=60: Structure of ^{96,98,100,102}Sr from decay of Rb beams

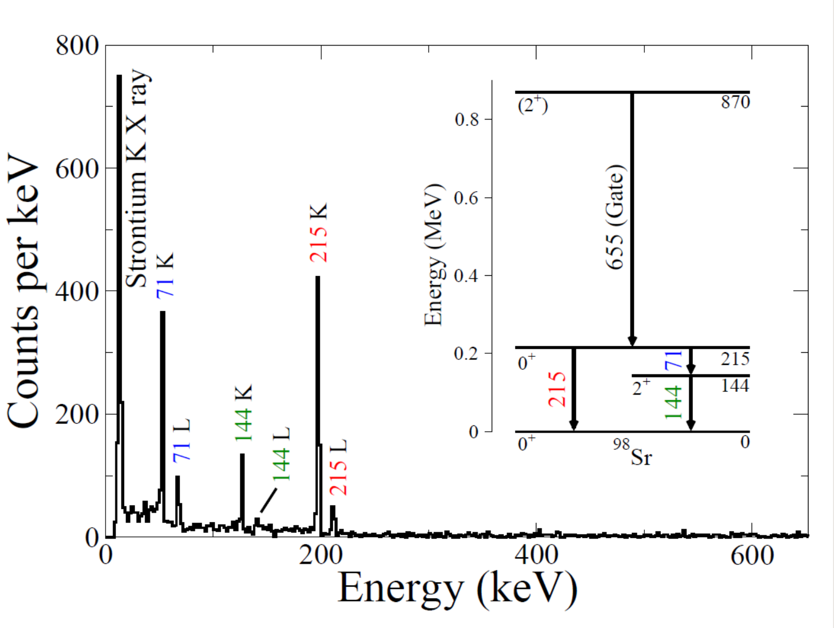
Measurement of E0 transition strengths can provide insight into the nature of, and mixing between, the underlying configurations



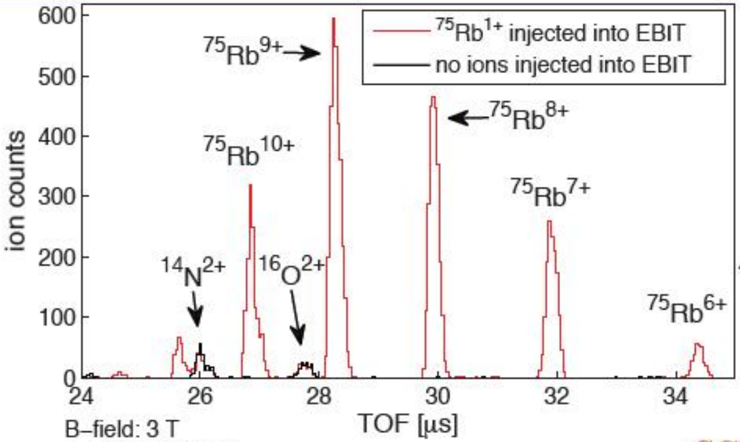
Using implantation/decay cycle times to identify gamma transitions in isobaric decay chain



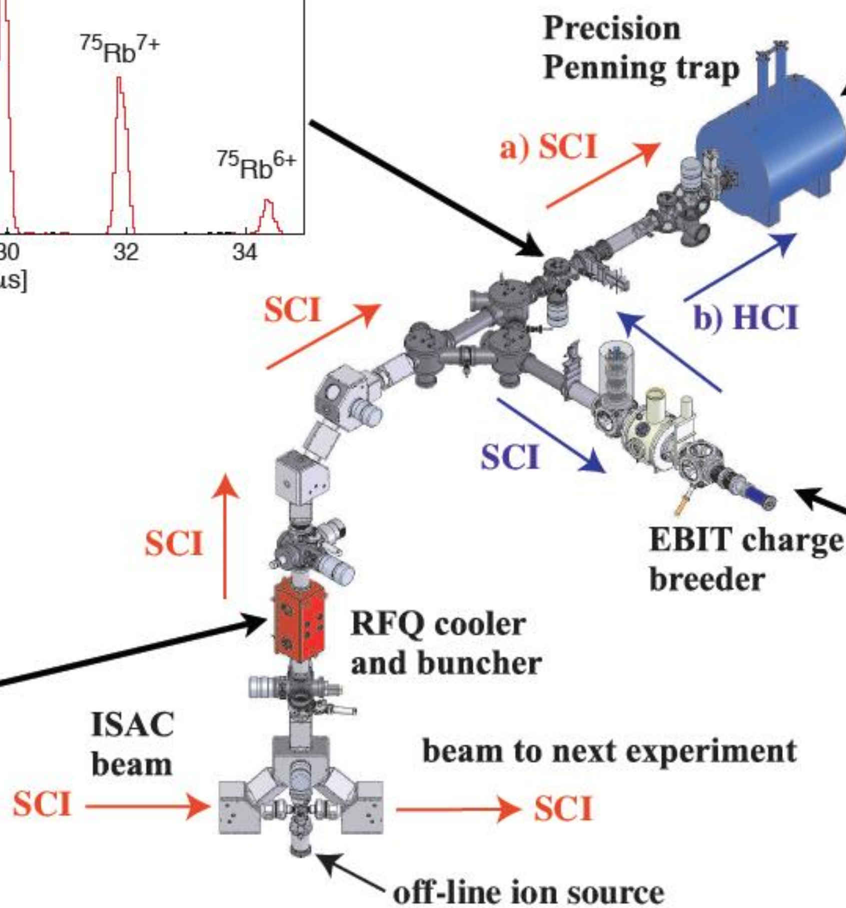
Gamma gated conversion electron spectrum for ^{98}Sr



TITAN @ TRIUMF



B–field: 3 T
e–current: 10 mA
charge breeding time: 35 ms
extraction time: 800 ns
500 ion shots



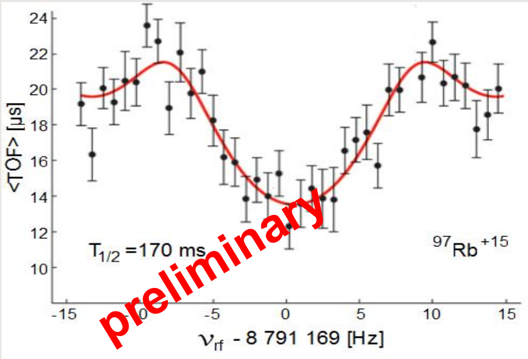
$$\frac{\delta m}{m} \propto \frac{m}{q}\frac{1}{BTN^{1/2}}$$

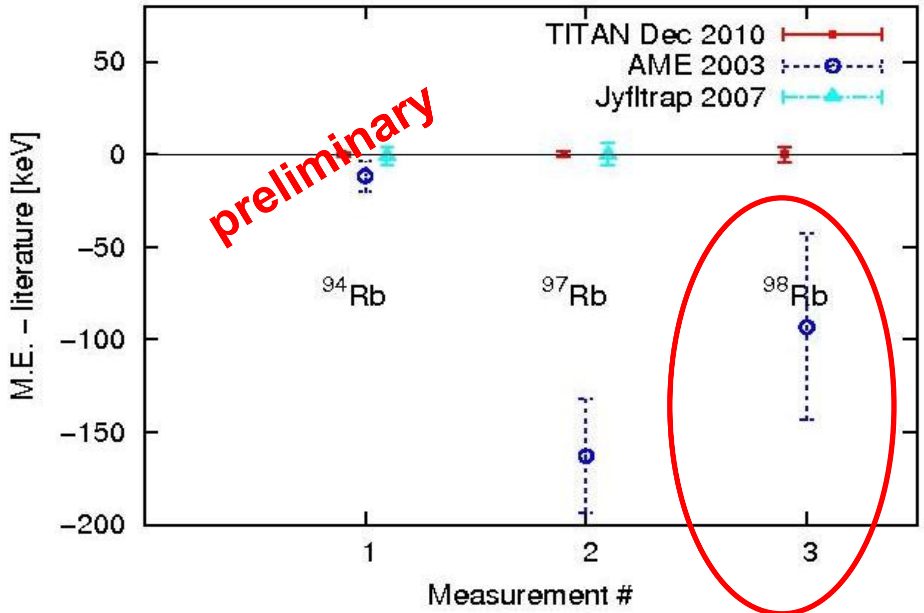
mass measurement for nuclear astrophysics of n-rich ^{94,97,98}Rb and ^{94,97,98,99}Sr

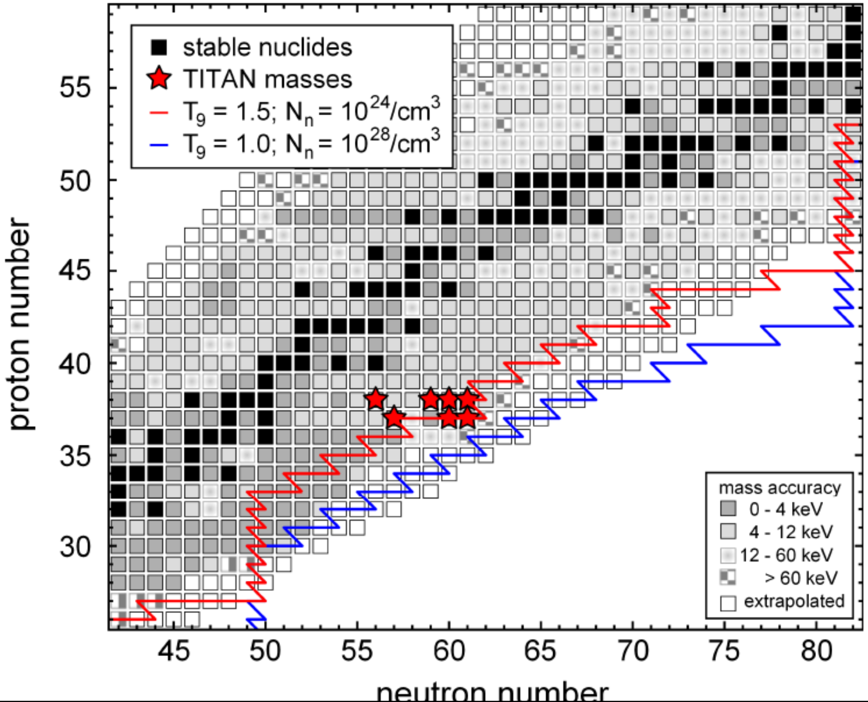
- First time online mass measurement in Penning trap at this high charge state q=+15.

- First direct mass measurement of ^{98}Rb
- Uncertainties reduced of all other masses (^{94,97,98}Rb and ^{94,97,98}Sr)

V.V. Simon et al. in prep for PRC







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Evolution to neutron-rich calcium isotopes

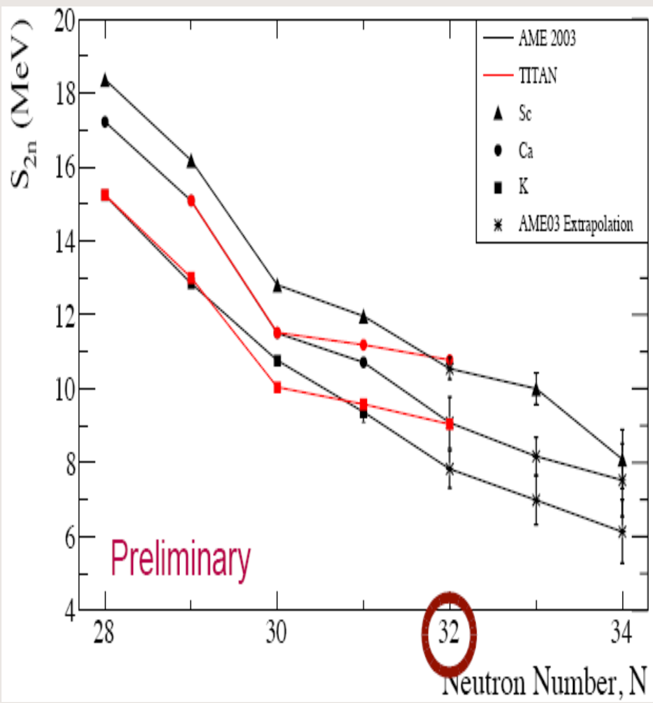
New mass measurements for Ca (Summer/ Fall 2011)

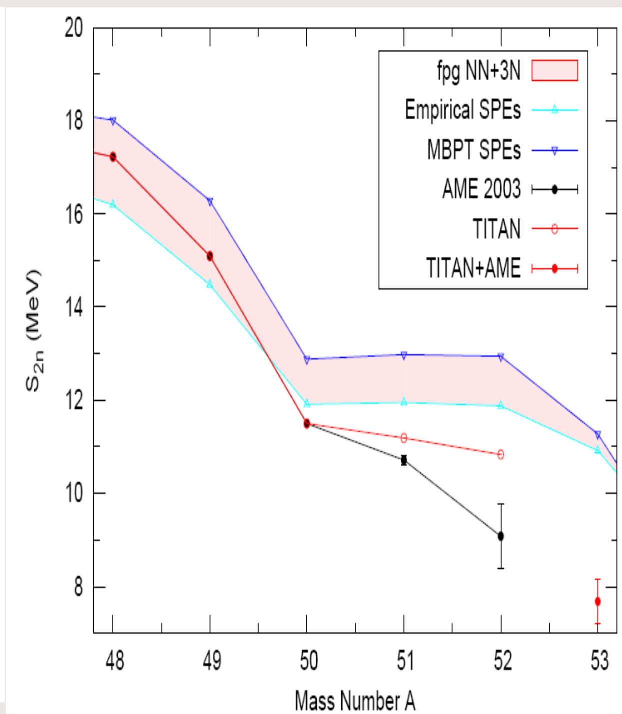
Reached up to Ca-52, K-51 and found ~ 2 MeV deviation;

AND, new calculations show:

repulsive 3N contributions key for calcium ground-state energies

Holt, Menendez, Schwenk et al.,





possible to extend with UCx
Run planned 14-16 Dec 2011

behavior of S_{2n} and Δ_n agrees with NN+3N calculations

A. Gallant et al., in prep. for PRL

TRIUMF

Vud: the responsibility of low-energy nuclear physics

High precision measurements of superallowed β-emitter ^{74}Rb

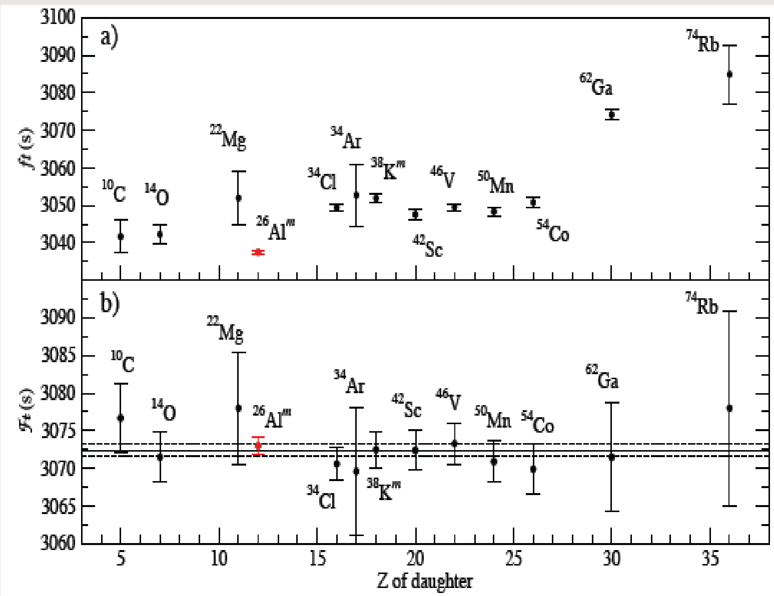
In Nov 2010 three experiments focused on the study of β-emitter ^{74}Rb ($T_{1/2}$=65 ms)

(1) a high precision measurement of the mass of $^{74}Rb^{8+}$ with TITAN and HCIs

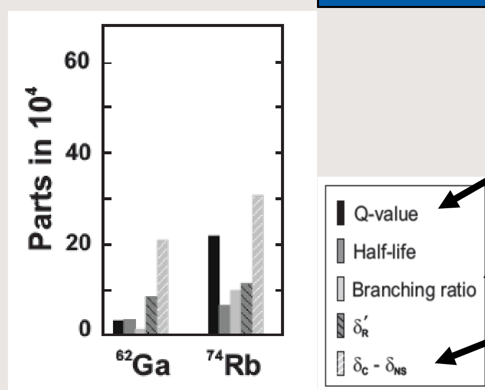
(2) a high precision branching ratio measurement using the 8π spectrometer

(3) a measurement of the charge radius of ^{74}Rb using collinear laser spectroscopy on cooled and bunched beams from the TITAN RFQ: to reduce the theoretical uncertainty in the nuclear structure correction δC

ISAC with 100μA p-beam on Nb target. Separator with R=4500



P. Finlay et al., PRL 106, 032501 (2011)



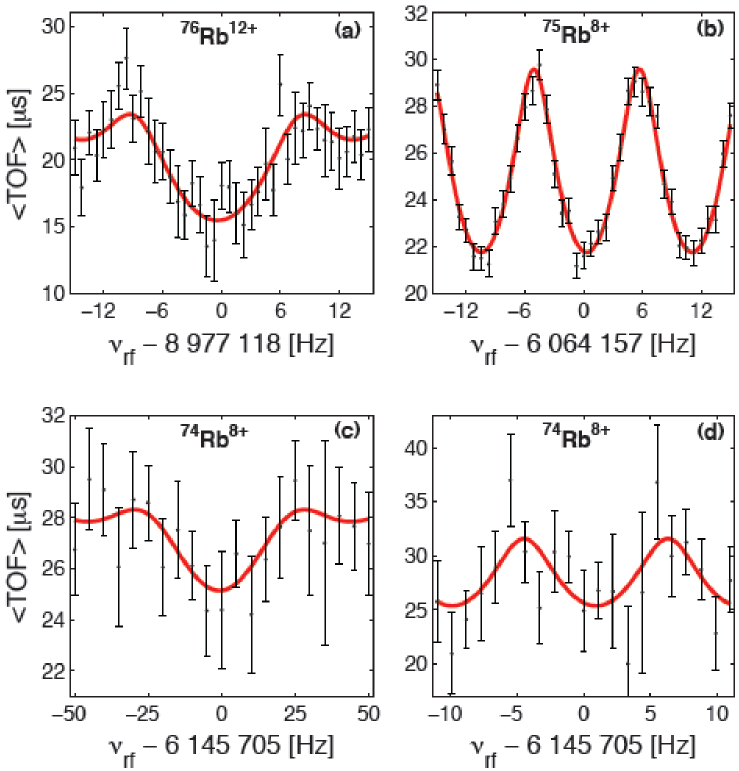
T&H PRC 79, 055502 (2009)

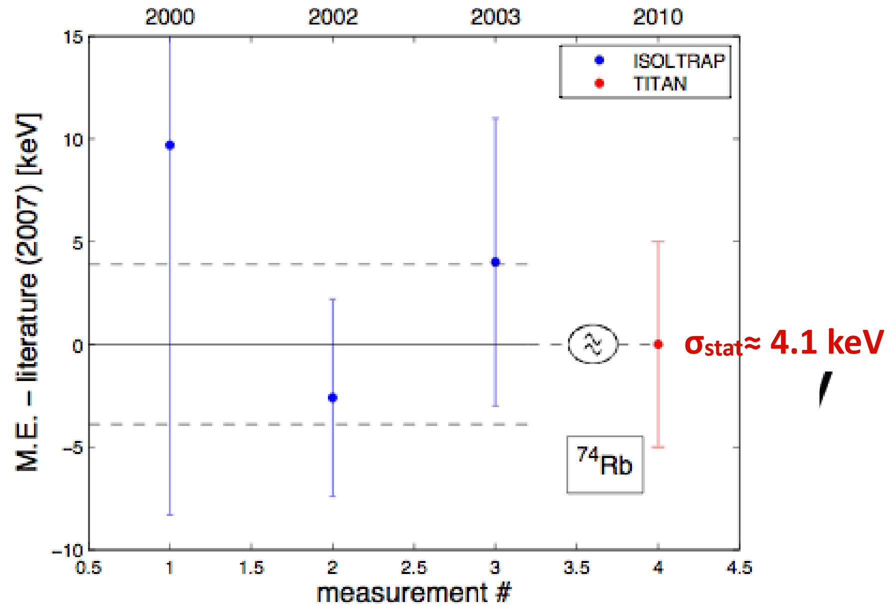
For (1)

For (2)

For (3)

mass measurement of $^{74-76}Rb^{8-12+}$





Factor of 100 increase in precision possible

HCI
during this beamtime demonstrated
up to q=12+

Ramsey excitation:

- 2 excitation pulses
- improves precision by a factor 2 - 3

$$\frac{\delta m}{m} \propto \frac{m}{q} \frac{1}{BTN^{1/2}}$$

compared to conventional method: improvement by factor >24

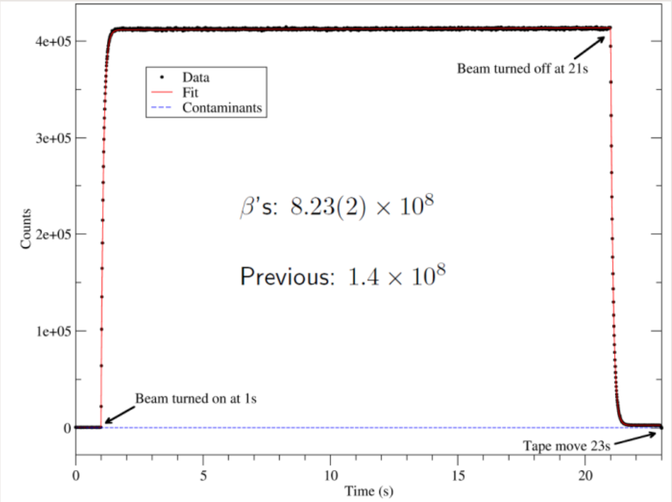
S. Ettenauer et al., accepted for publication in PRL arXiv:1109.3494

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

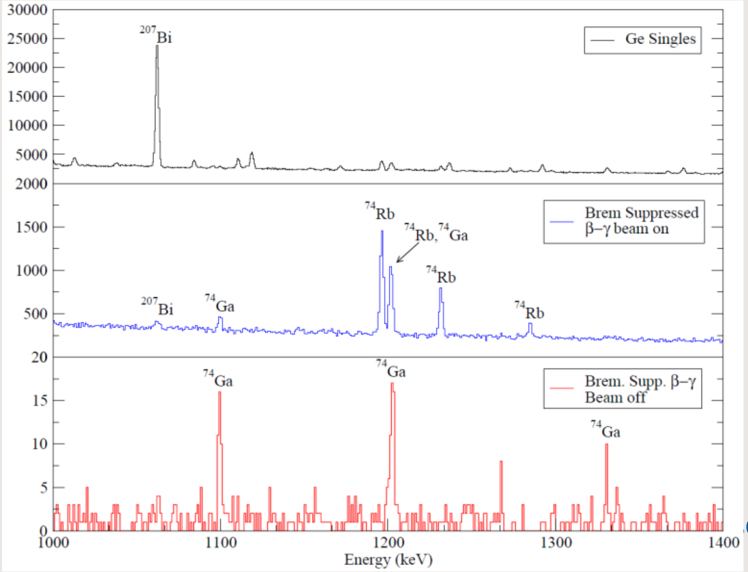
Goal: reduce uncertainty in BR by factor of 3

• previous value 0.5 +/- 0.1 % obtained using only one HPGe detector and two Si(Li) counters

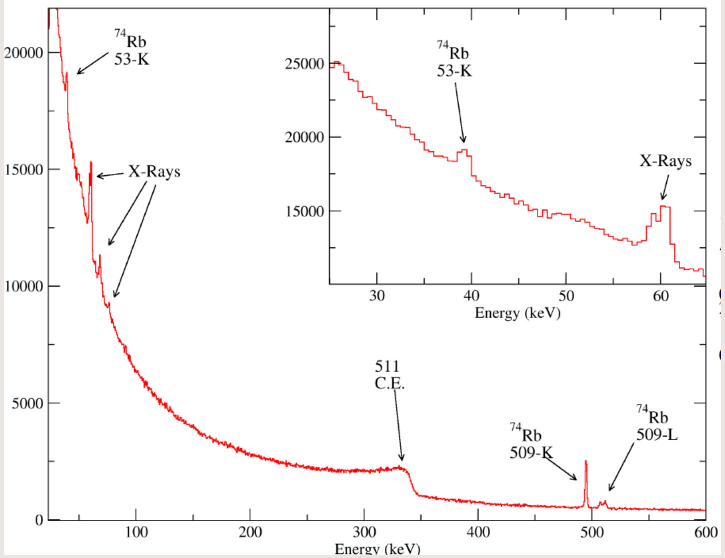
Data obtained in Nov2010 with HP Ta and 100uA
• ~ 10000/s ^{74}Rb
• ^{74}Rb/^{74}Ga ratio increased by ~ 150



beta-coincident gamma-ray spectra

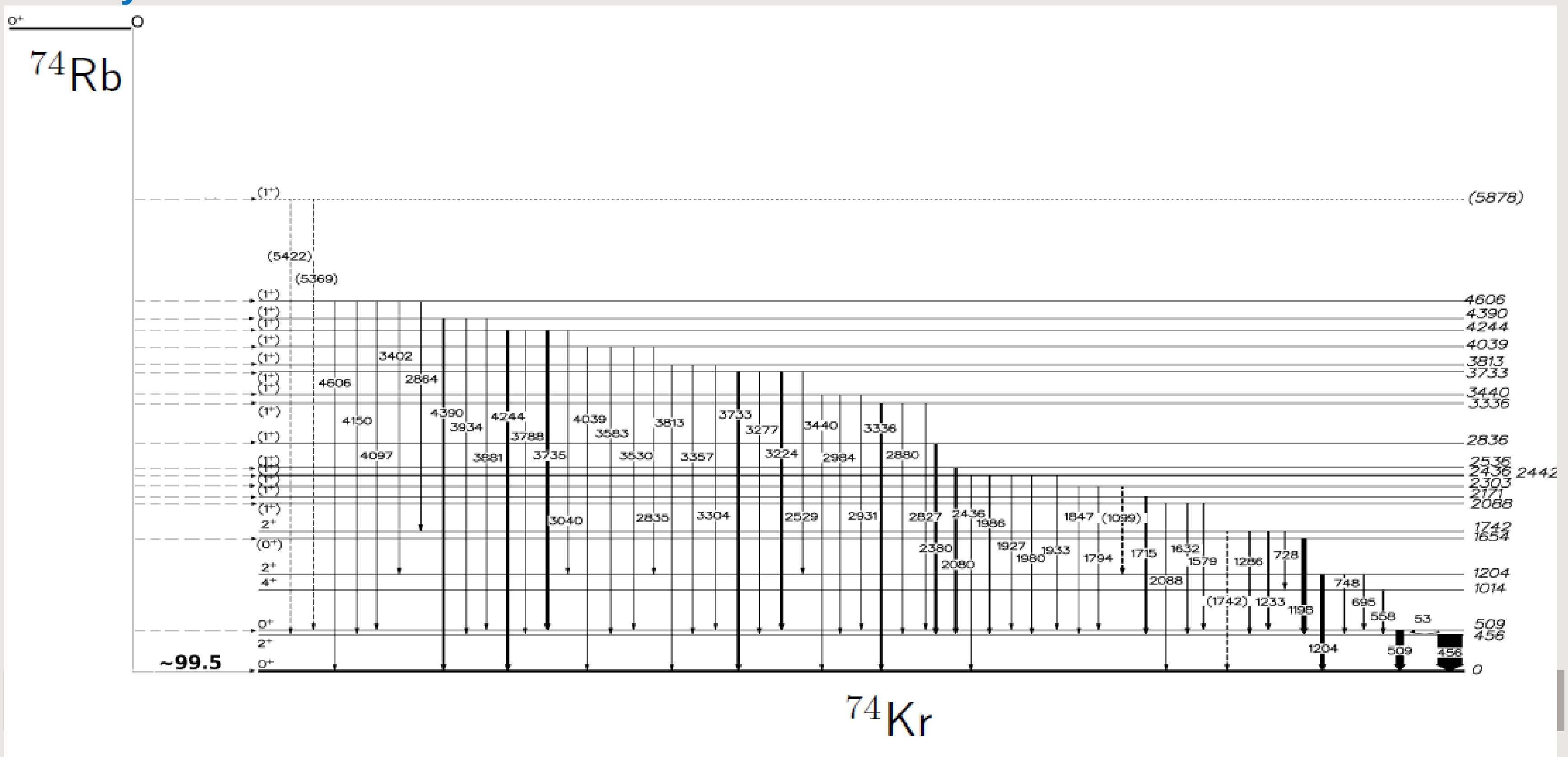


beta-coincident Si(Li) spectrum



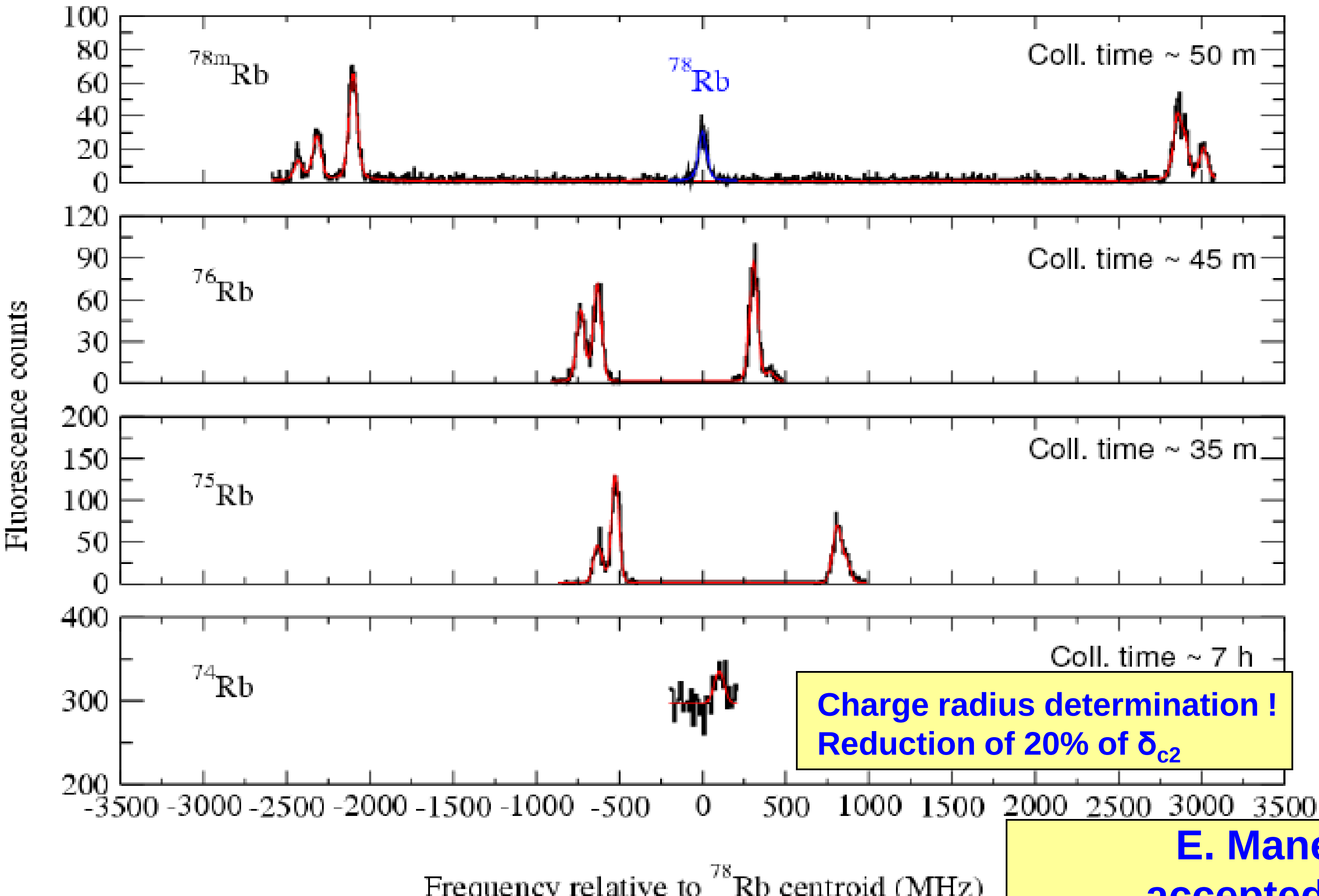
^{74}Rb Branching ratio Measurement using the 8π spectrometer

- High Q-value leads to feeding of many high-lying 1+ levels
- The low-lying 2+ and 0+ levels act as collector states and enable a measure of total decay strength
- Present experiment confirmed previous decay scheme
- 47 new transitions and 14 new levels were identified.
- comparison with theory for estimate of unobserved gs decay strength should lead to 0.03% uncertainty in BR



Determination of the charge radius of ^{74}Rb through collinear laser spectroscopy of cooled bunched beams

TITAN/Laser-spectroscopy: TRIUMF, McGill, Manchester UK



Yields

^{74}Rb - 1.7e4/s

^{75}Rb – 2.1e6/s

^{76}Rb – 9e7/s

^{78}Rb - 2.1e9/s

^{78m}Rb - 4.4e9/s

Charge radius determination !
Reduction of 20% of δ_{c2}

E. Mane et al.
accepted at PRL

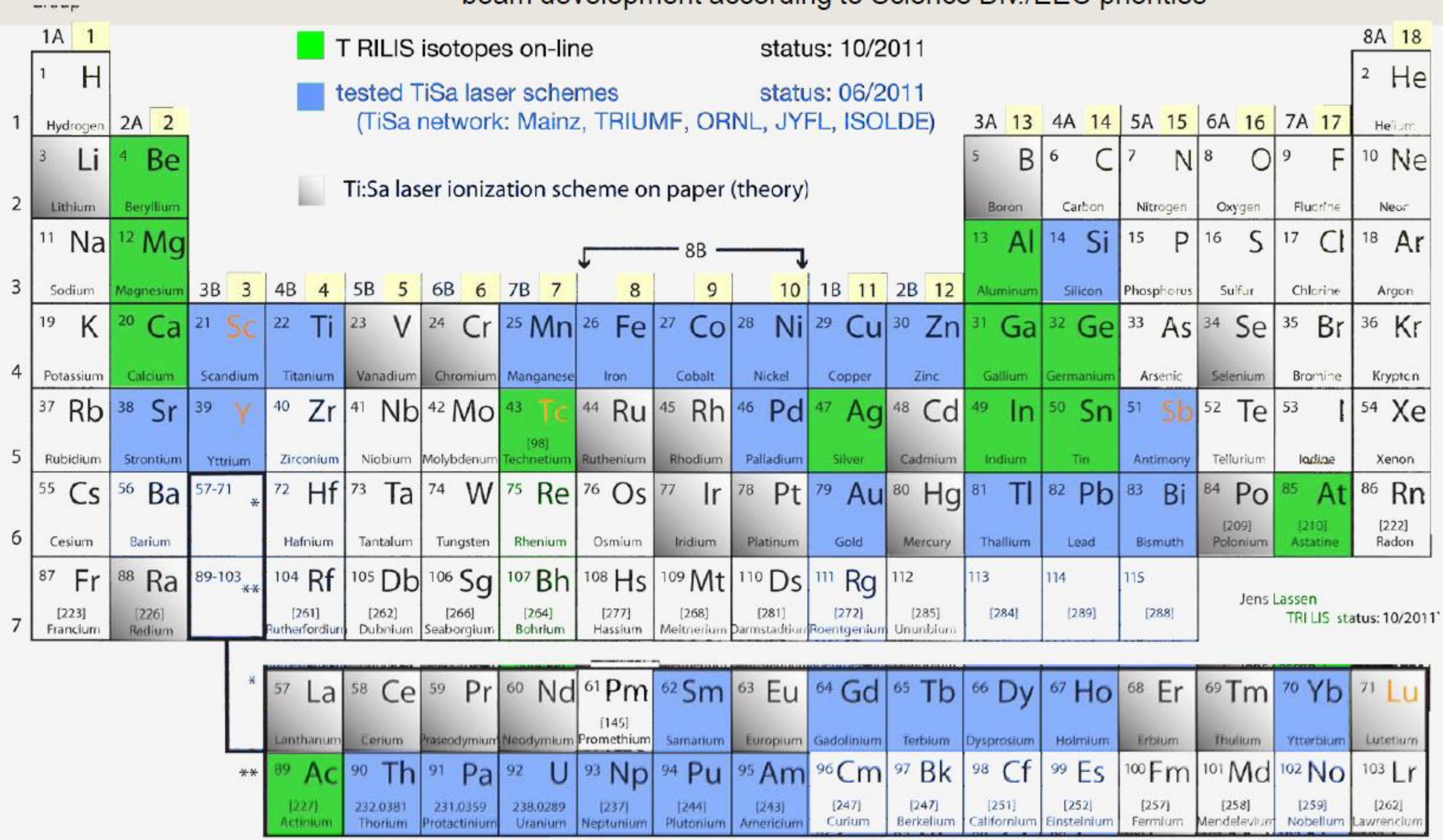
TRILIS beam development new beams in 2011: Ca,Tc, Ge, In, At, and Ac

(first beam 12/2004)

TiSa based LIS turned "35 (+) elements" developed
now at par with dye-laser based RILIS

TRIUMF-ISAC yield database: http://www.triumf.info/facility/research_fac/yield.php

beam development according to Science Div./EEC priorities

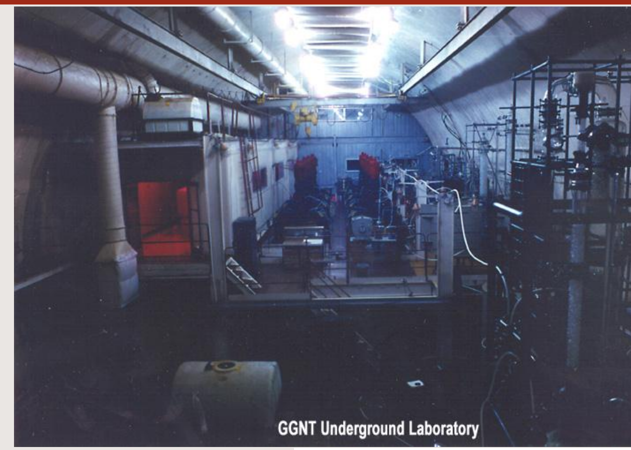


neutrino experiments: SAGE & GALLEX

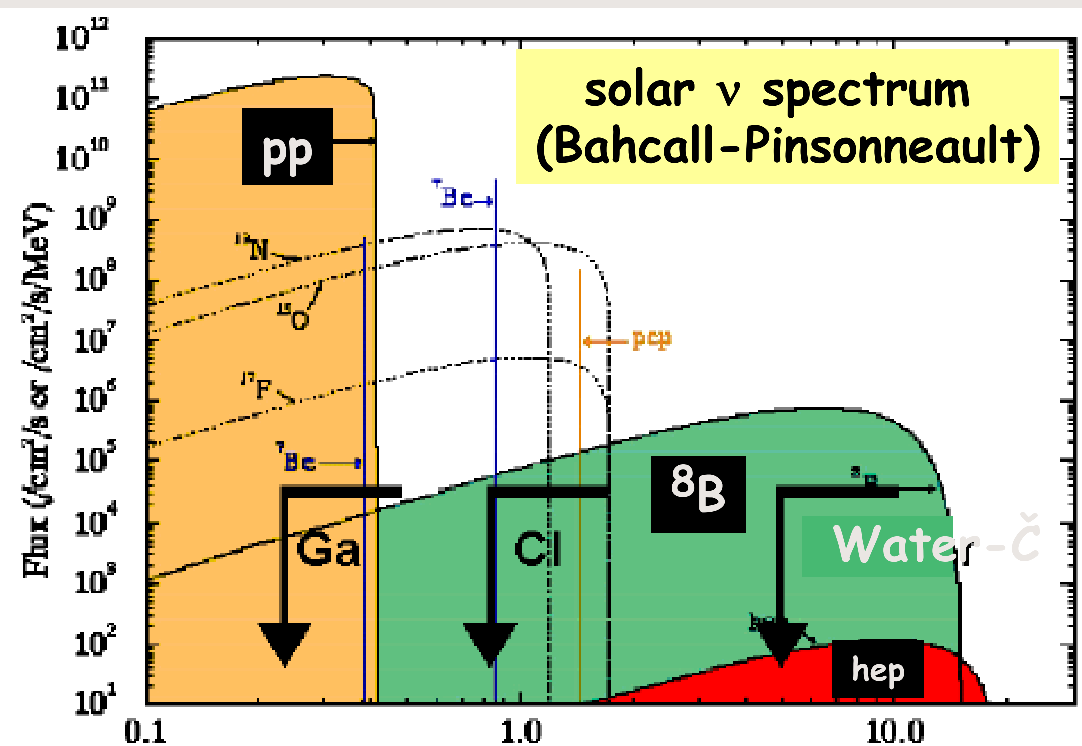
$^{71}Ga\ (\nu_e, e-)^{71}Ge$

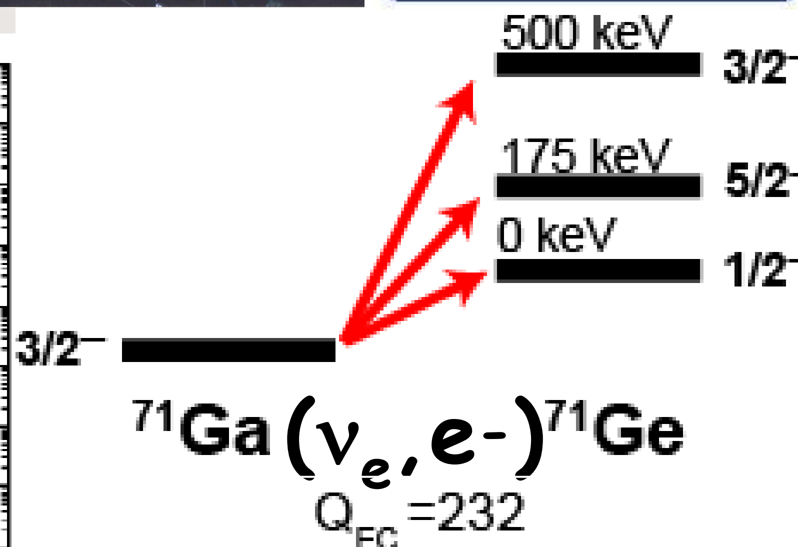
Q=232 (0.4)keV

Expected rate: ~ 74.6 SNU
SAGE/GALLEX: 66.1 ± 3.1 SNU



GALLEX
Gallium Experiment at Gran Sasso
INTERNATIONAL SOLAR NEUTRINO RESEARCH COLLABORATION

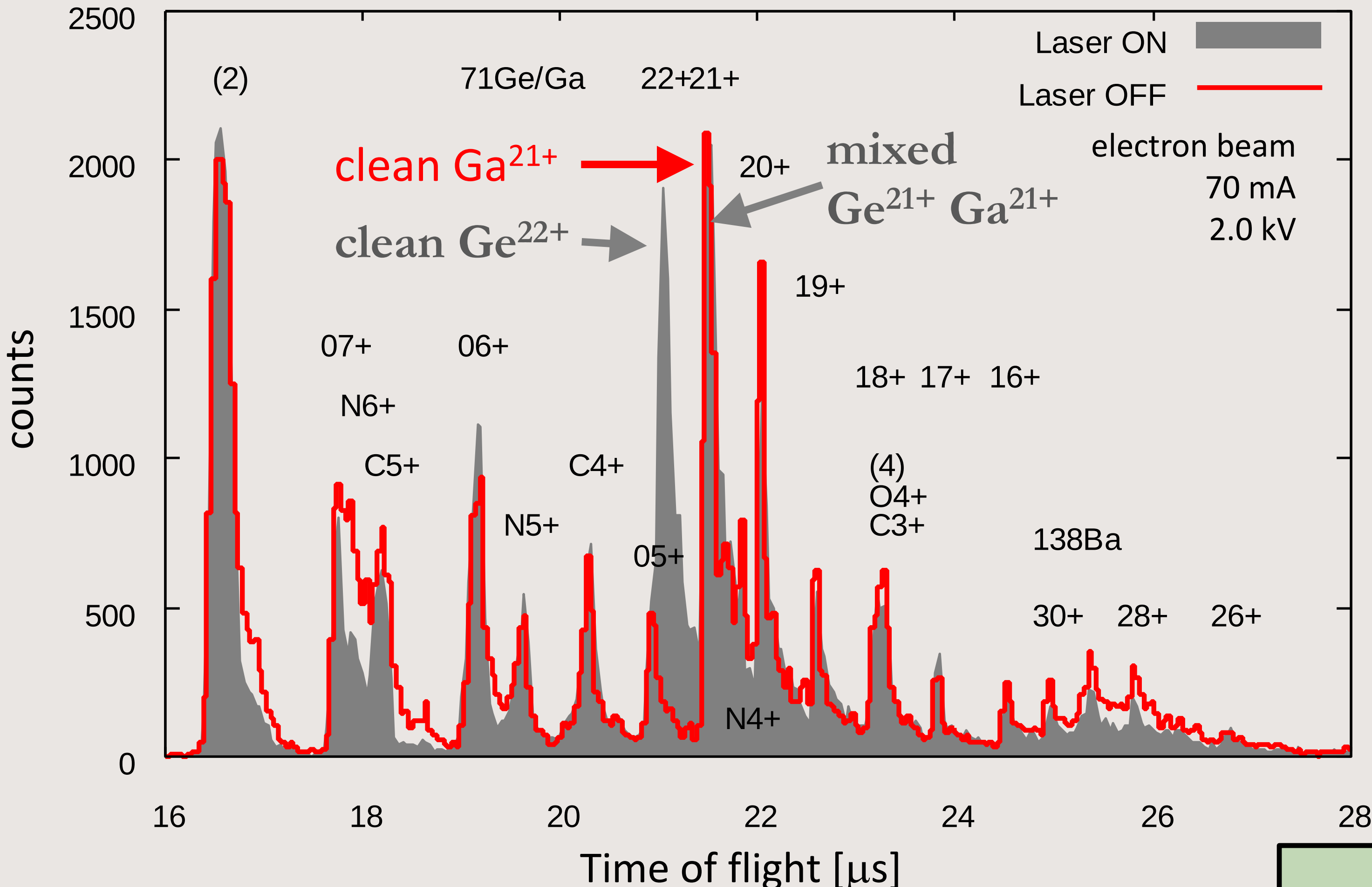




Difference due to wrong Q-value? Check needed!

^{71}Ge-^{71}Ga both from ISAC

Isobaric separation by charge breeding to atomic shell closures



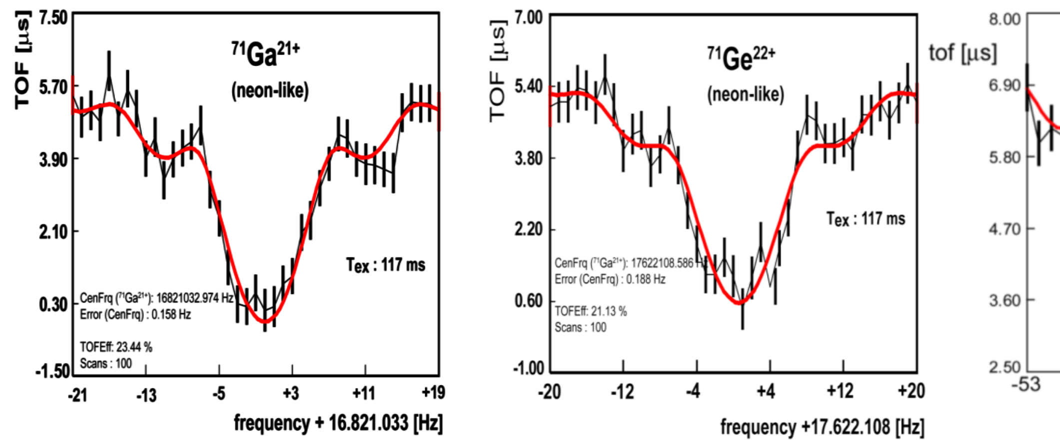
Ge delivery from ISAC required Laser Ionization

→ clean $^{71}Ga^{21}$ if Laser OFF (Ga produced through surface ionization)

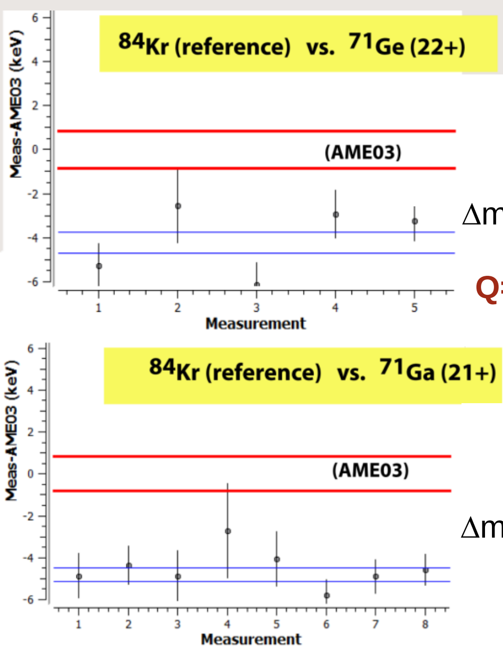
→ clean $^{71}Ge^{22}$ if Laser ON (Ga not breeded to q=22+)

Special Thanks to Jens Lassen & the TRILIS team

Separation of isobars by use of threshold charge breeding: Z of Ge and Ga is different and e-binding is Z-dependent (both Ne-like)



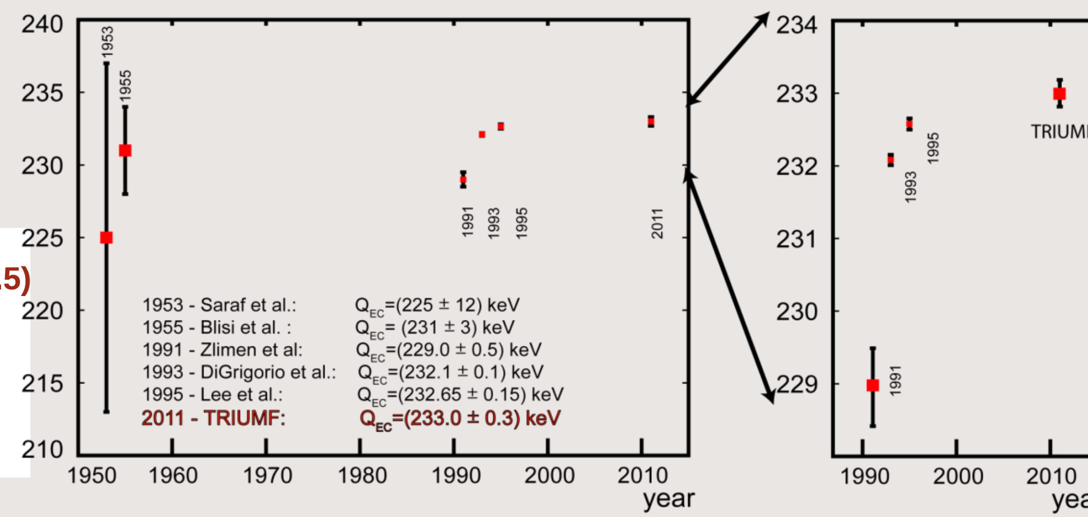
Q-value confirmed:
Need different explanation for ν–disagreement!
Frekers et al., prep for PRL



Δm~0.5keV

Q=233keV(~0.5)

Δm~0.5keV

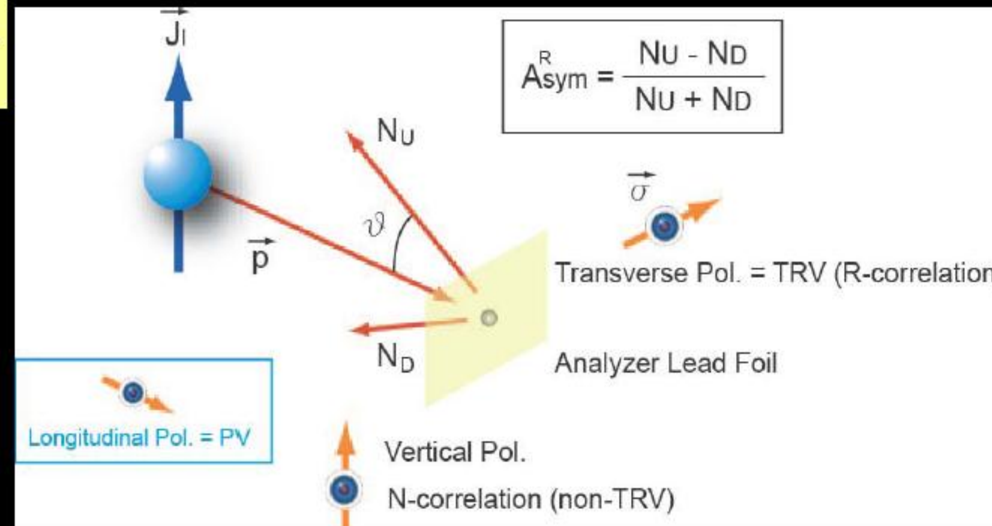


ISAC S1183 MTV (Mott Poralimetry for T-Violation Experiment)

Jiro Murata (Rikkyo-U, JAPAN) 2009 ~

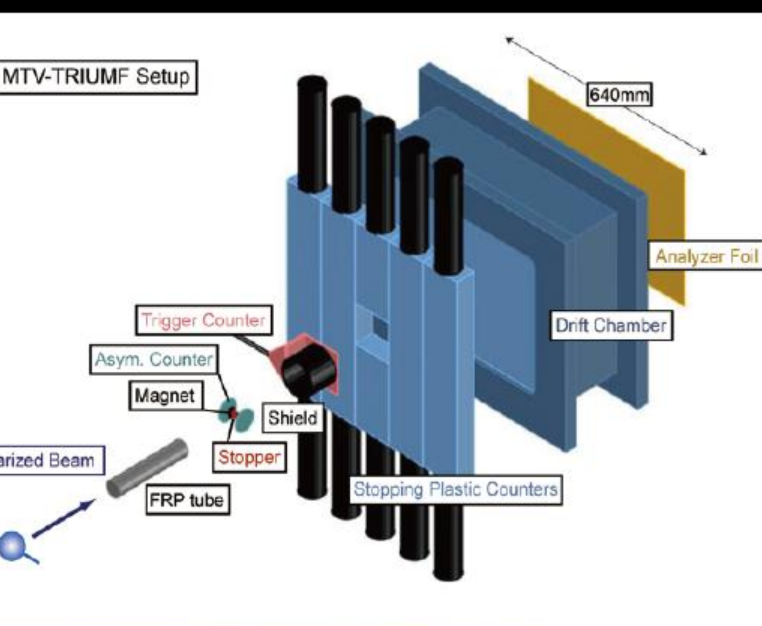
***R*-Correlation (PV & TRV) in 8Li beta decay**

$$R\vec{\sigma}\cdot\frac{<\vec{J}>}{J}\times\frac{\vec{p}_e}{E_e}$$

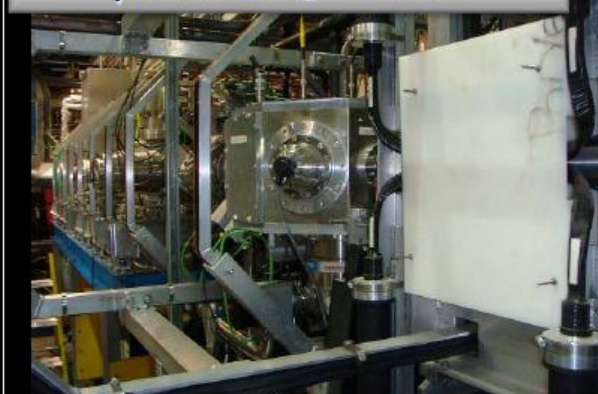


Searching non-zero Electron Transverse Polarization using Mott Scattering Analyzing Power

Started at KEK-TRIAC (2008)
Moved to ISAC (2009)
Physics Run (2010)



pol 8Li @ ISAC



28keV @ 10^7pps

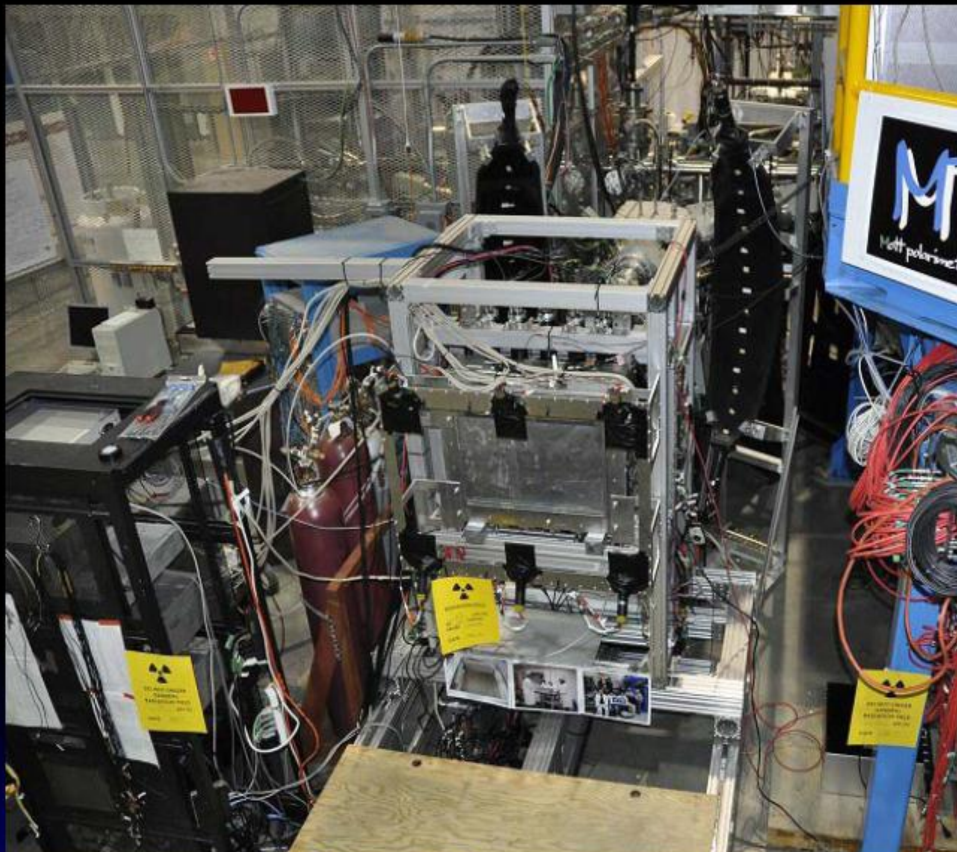
80% polarization

Al 10um @500Gauss

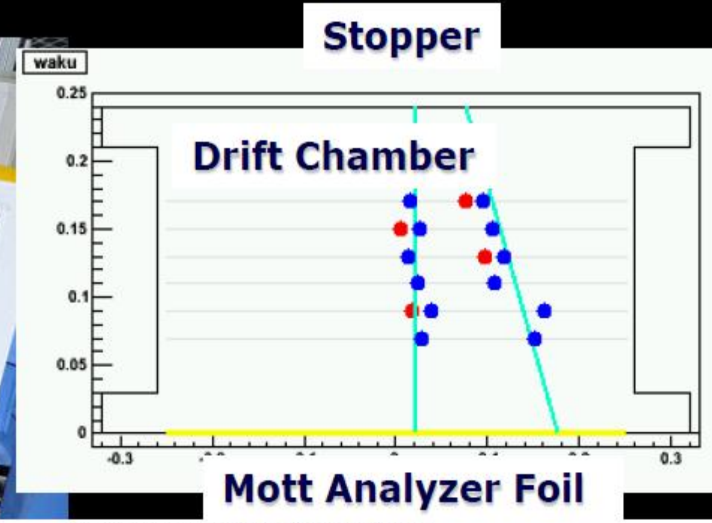
Collinear Laser Optical Pumping

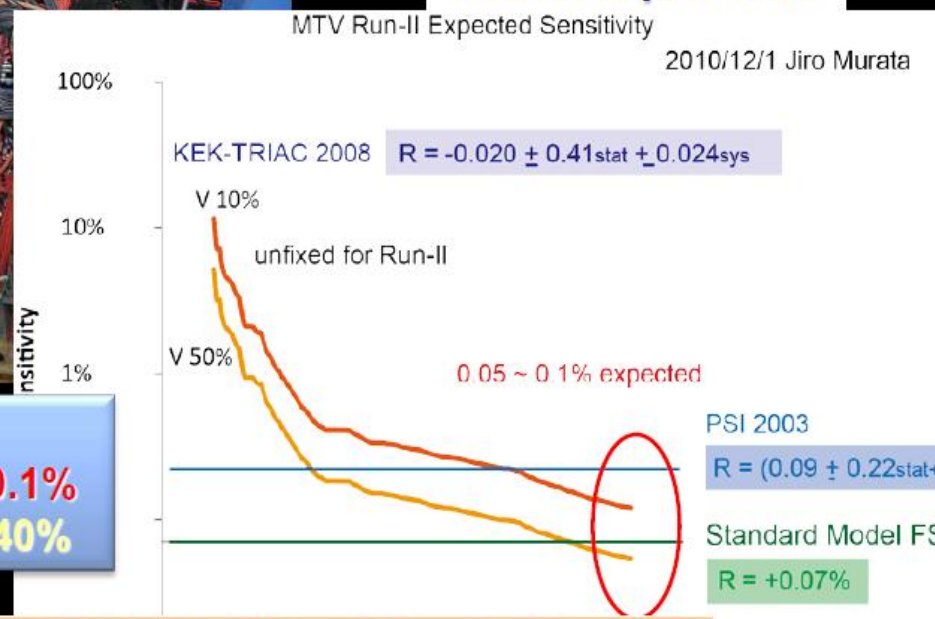
P. Levy 2003

MTV Run-II : First Physics Run 2010



1 week data production in Nov. 2010
First Physics Run 430M V-tracks :R-precision~0.1%
KEK-TRIAC (2008) 0.6M V-tracks : R-precision ~40%





Highest Statistical Precision Achieved !!

Systematic Study is undergoing to for the publicatior

Beta-NMR Facilities at ISAC-1

β-NMR facilities at ISAC-I are optimized for studies in condensed matter physics, extracting information via the anisotropic beta-decay of spin-polarized radioactive ions (*i.e.*, ^{8}Li) implanted into materials.

Variable energy and stopping range (2 -500nm) : **Depth-resolved probe of magnetism,** and more generally, able to study *any* phenomena at surfaces of bulk materials and within thin film structures which affect the polarization of the implanted probe. (superconductivity, disordered & dynamic magnetism, structure, transport...)

Two spectrometers are capable of :

- High field Nuclear Magnetic Resonance, H_0 = 0.1 ~ 9T (currently to ~45MHz for ^{8}Li)
- Low-field NMR and zero-field Nuclear Quadrupole Resonance, H_0 = 0 ~ 0.022T
- Energy range 0.1 ~ 30keV at sample surface, with beam spot <3mm diameter.
- Temperature range currently 3 ~ 300K (extended range 0.3 ~ 500K planned.)

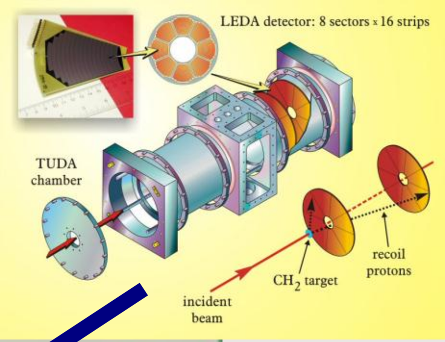
Types of measurements:

- NMR and NQR in CW or modulated RF magnetic field,
- Measurement of spin-lattice relaxation rate $1/T_1$ with pulsed beams.

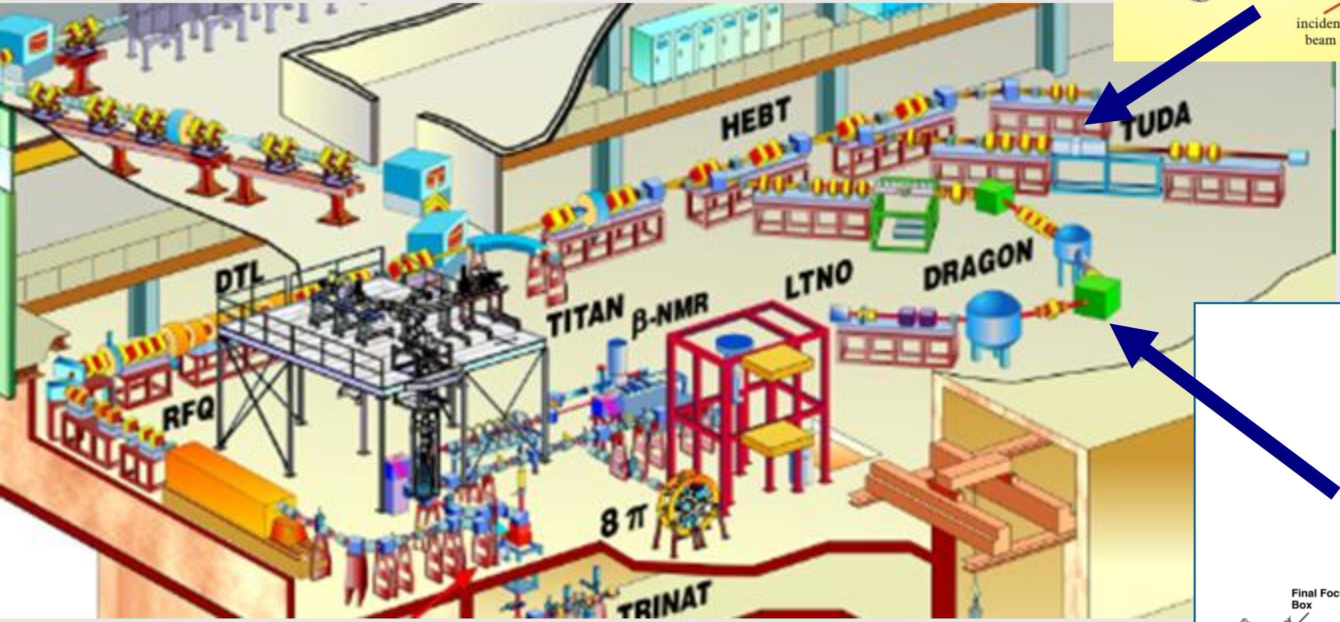
Independent variables: Temperature, beam energy, applied DC and RF magnetic fields, material composition, orientation...

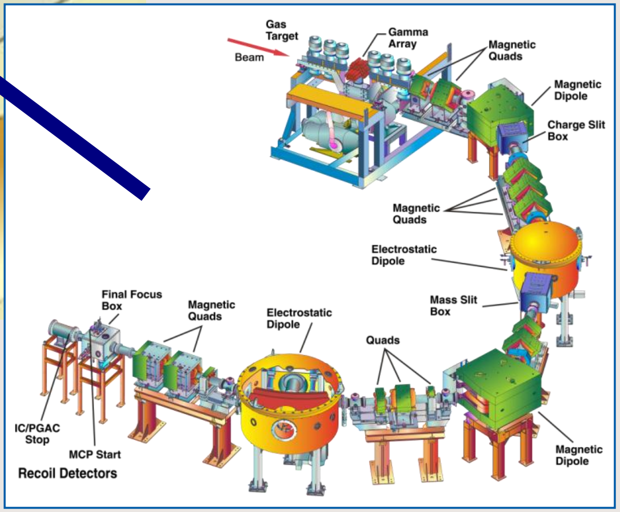
Nuclear astrophysics facilities in ISAC-I

medium energy
~ 0.15 -1.7 AMeV



TUDA
Astrophysical charged particle reactions





DRAGON
Astrophysical capture reactions

Novae observables: the $^{18}F(p,\alpha)^{15}O$ reaction

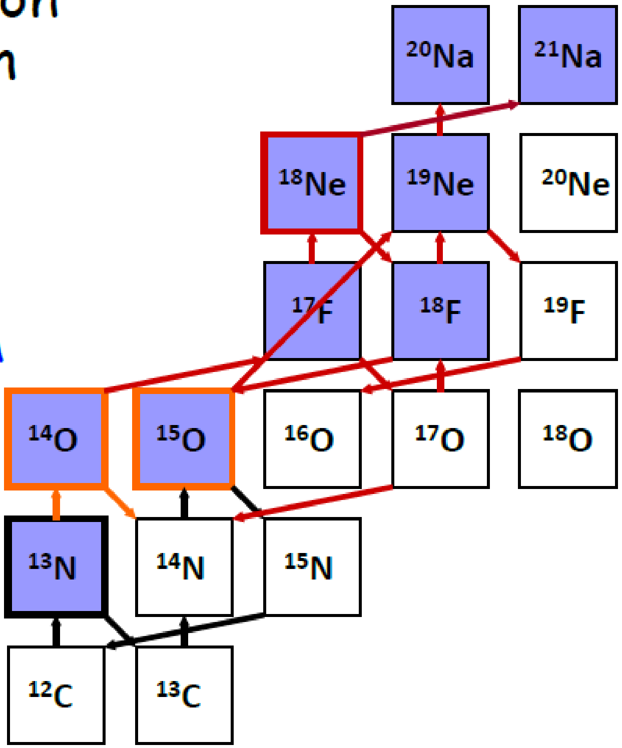
THE UNIVERSITY *of York*

- Observation of γ-ray emission from novae gives information on explosion conditions
- γ-ray flux dominated by decay of ^{18}F
- Final abundance of ^{18}F depends on rates of production/destruction processes

➢ Production – decay of ^{18}Ne and $^{17}O(p,\gamma)^{18}F$ (DRAGON U. Hager)

➢ Destruction – $^{18}F(p,\alpha)^{15}O$ (TUDA A. Laird and A. Murphy) and $^{18}F(p,\gamma)^{19}Ne$ (DRAGON A. Laird and C. Ruiz)

Data taken Nov 2011

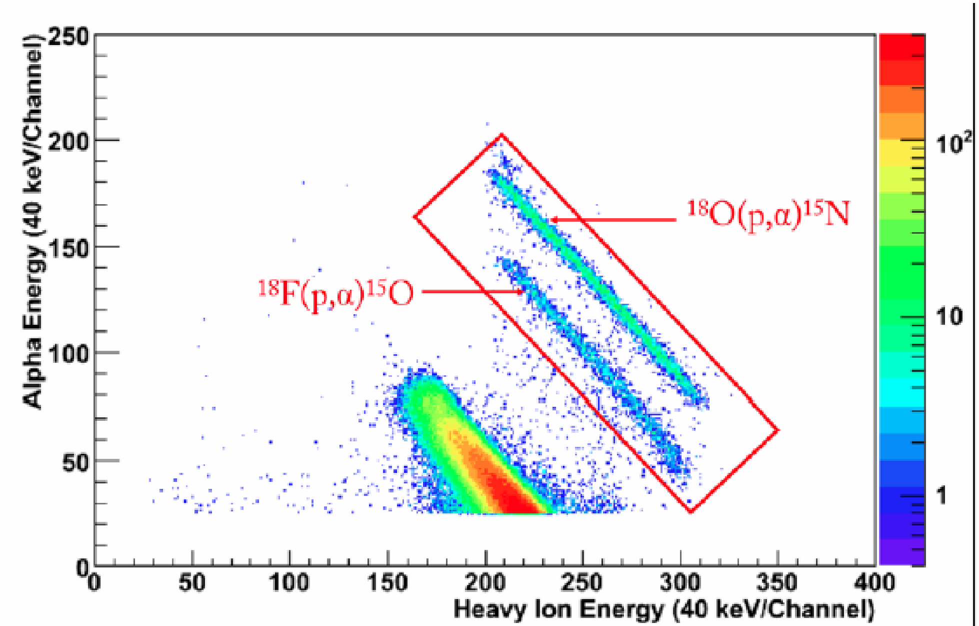


$^{18}F(p,a)^{15}O$ dominates the destruction rate of ^{18}F

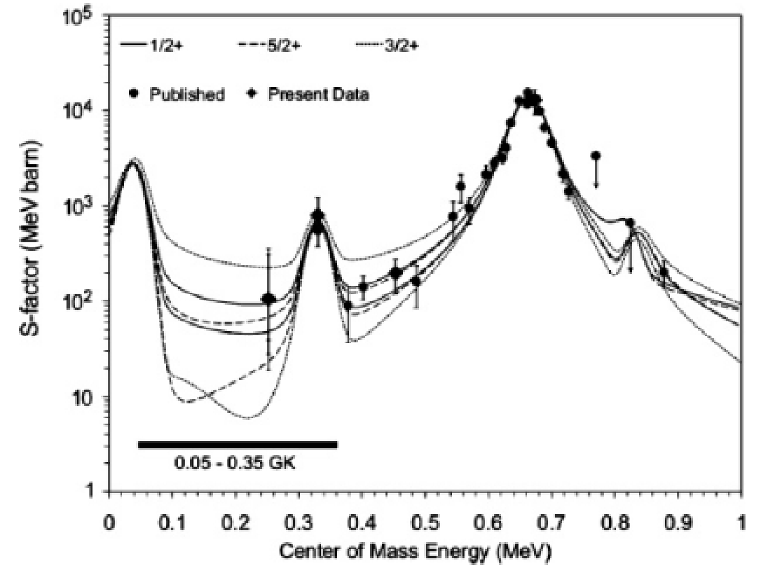
Abundances of ^{16}O (maybe), ^{18}O and ^{19}F also influenced

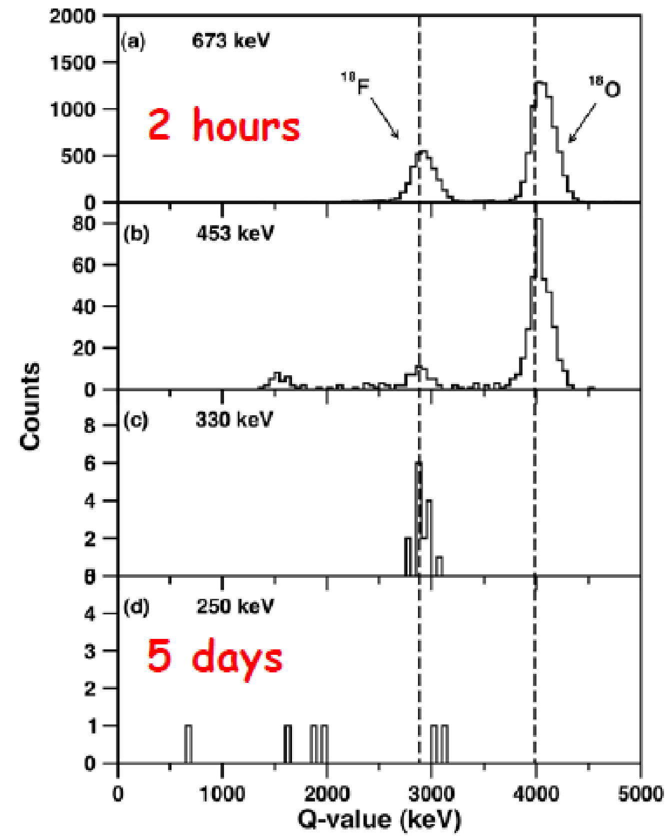
The $^{18}F(p,\alpha)^{15}O$ Data

- ^{18}F beam (5×10^6 pps) on CH_2 target
- Coincident detection of α and ^{15}O



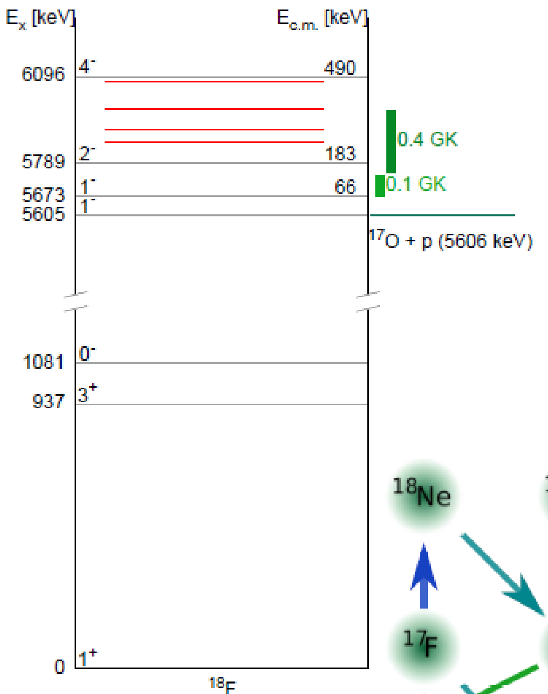
- Gate on energy-energy
- Gate on ϕ correlation
- Gate on θ correlation

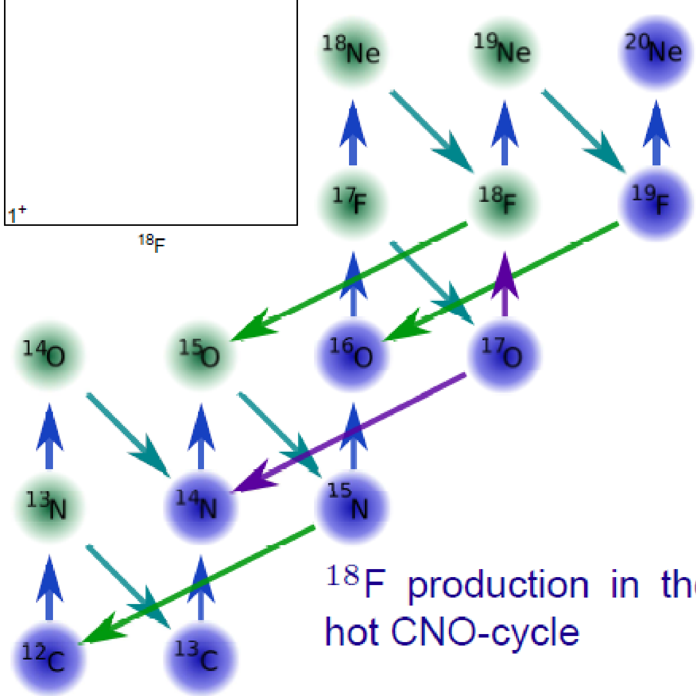




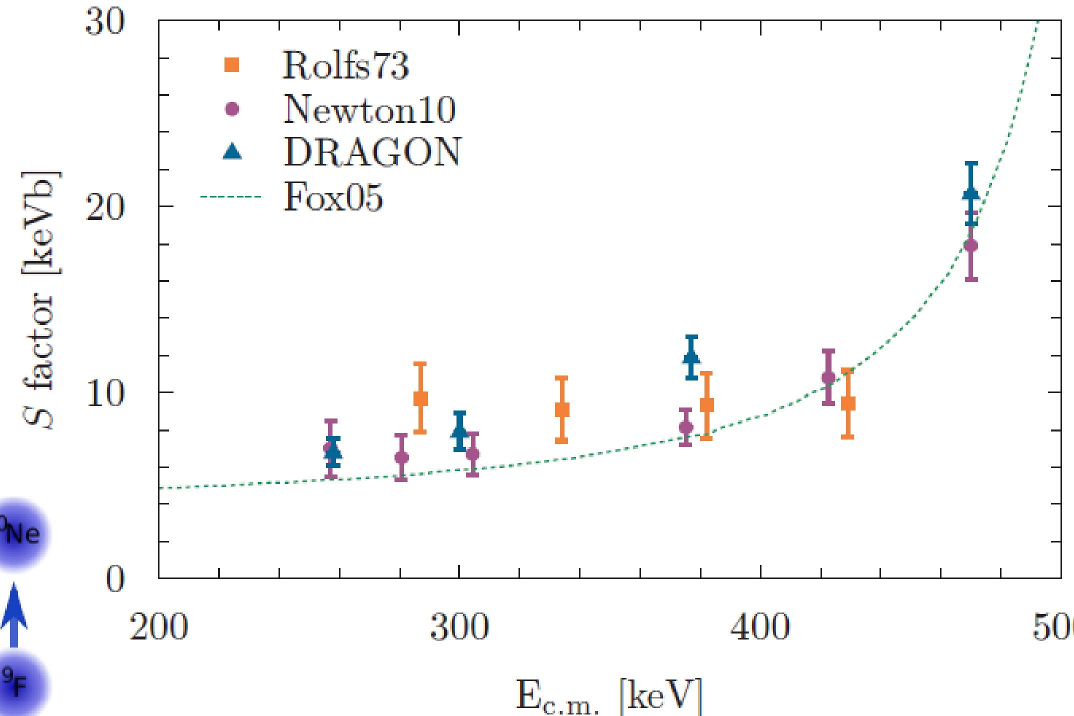
Beer et al., PRC(R) 83 042801 (2011)

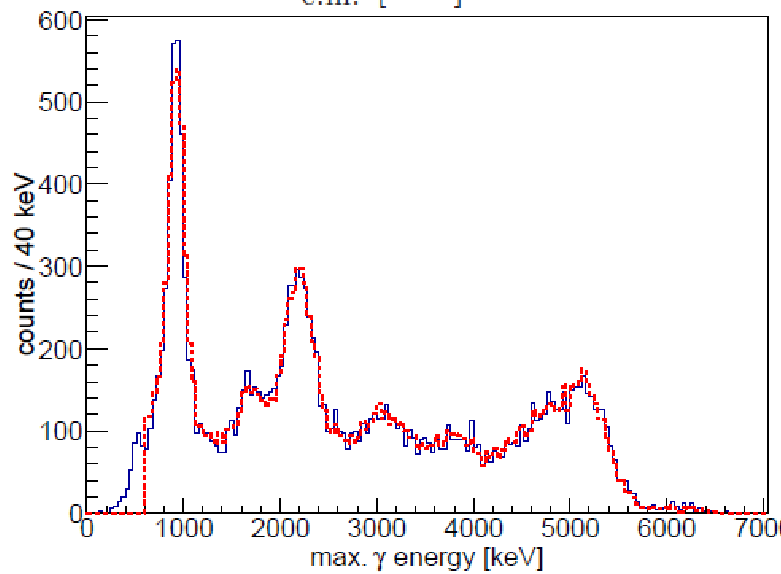
$^{17}O(p,\gamma)^{18}F$ at DRAGON





^{18}F production in the hot CNO-cycle

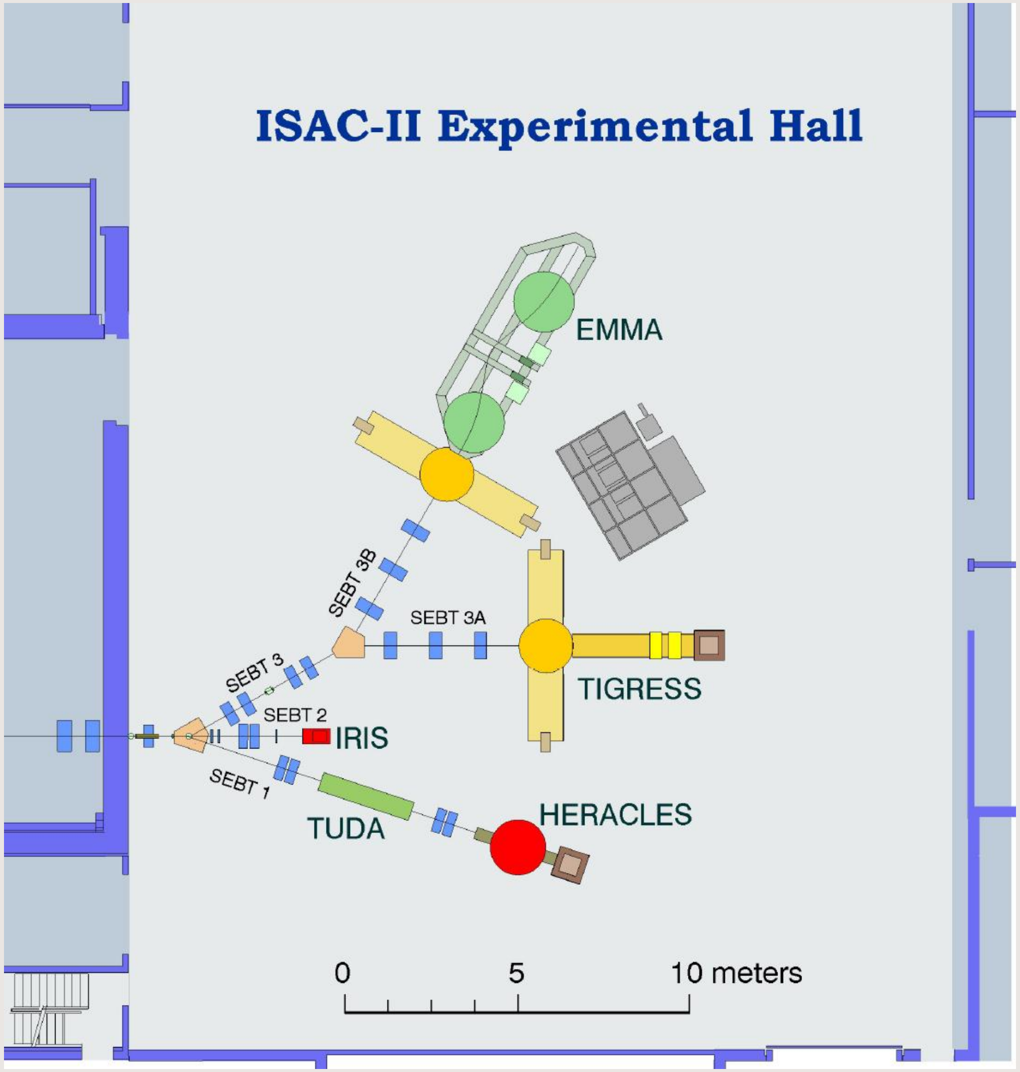




U. Hager et al. *Submitted to Phys. Rev. C.*

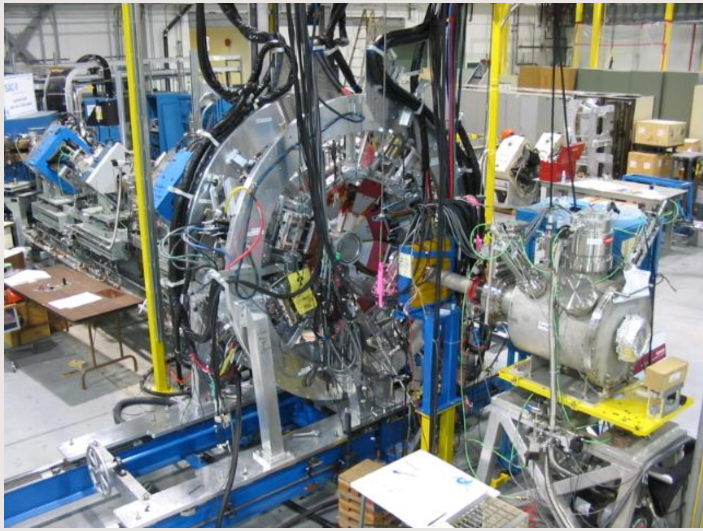
ISAC-II science program

- First experiment with MAYA in fall 2006
- TIGRESS commissioned in summer 2007
- TUDA moved to ISAC-II in spring 2009
- SEBT 1 to HERACLE completed and commissioned in Nov 2010.
- High-beta cavities provided 12 A MeV ^{20}Ne beam to HERACLES in Dec 2010.
- IRIS to be commissioned in spring 2012
- SEBT 3B to EMMA to be built in fiscal 2012
- EMMA to be commissioned in 2013
- A > 30 RIBs available in 2012-3



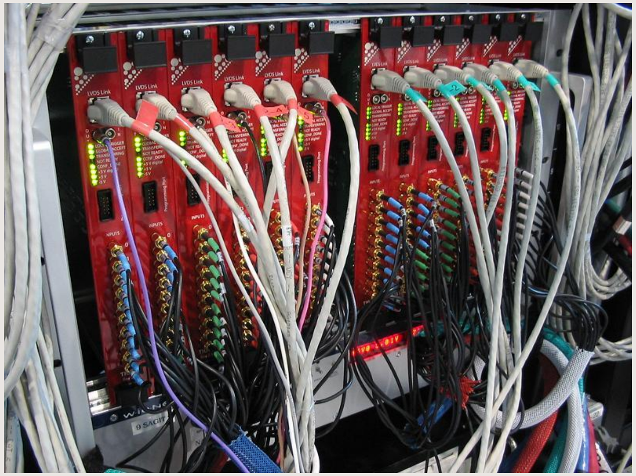
TIGRESS γ-ray Spectrometer

- An array of up to 16 highly-segmented high efficiency HPGe clover detectors
- Reconfigurable Compton suppression shields
- Fully operational digital acquisition system
- Position sensitivity of first interaction for Doppler correction



- A variety of auxiliary detectors available or under construction including:

  -charged particle detector arrays : BAMBINO and SHARC
  - neutron Array DESCANT (2012)
  - electron spectrometer SPICE (2012)
  - Plunger TIP (2012)
  - CSI Array (2012)
  - Bragg Detector (2014)
  - Recoil separator EMMA (2013)



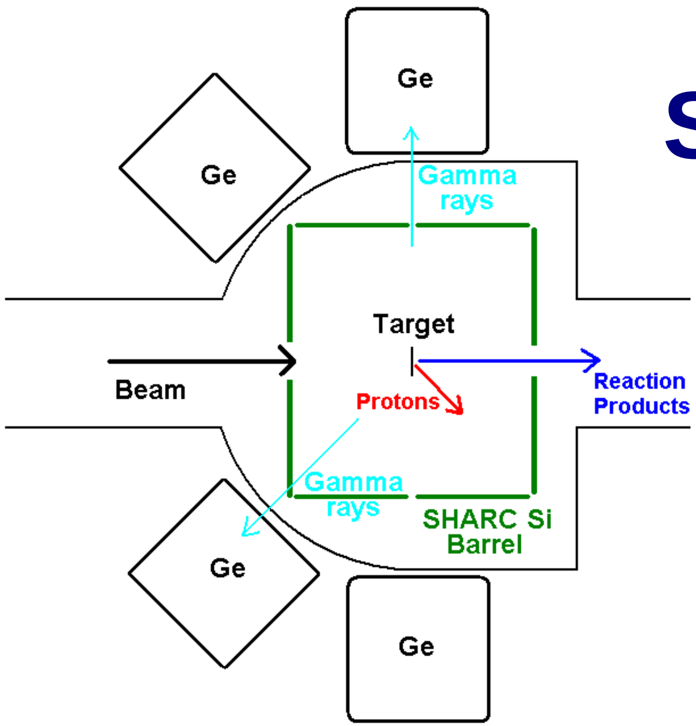
University of York, UK
Colorado School of Mines, USA
Louisiana State University, USA
TRIUMF

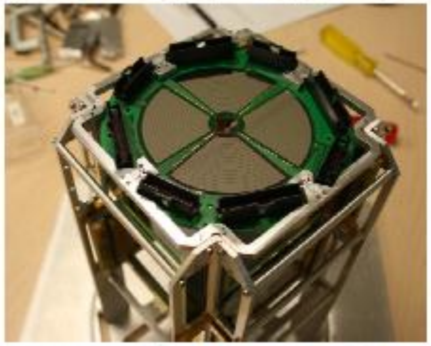
Silicon Highly-segmented Array for Reactions and Coulex

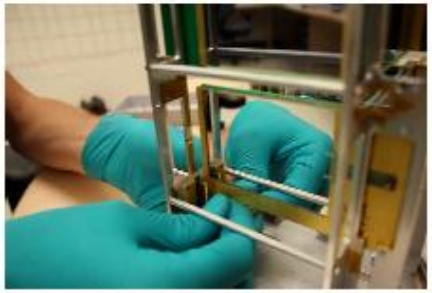
Close to 4π solid angle coverage of silicon

Excellent energy (25keV) and angular (0.9-1.5º) resolution

SHARC



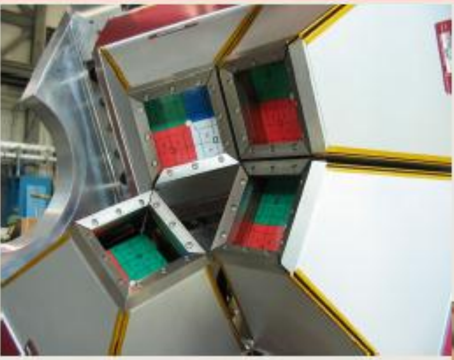




Optimized for transfer and Coulomb excitation studies for Nuclear Structure and Nuclear Astrophysics

TRIUMF

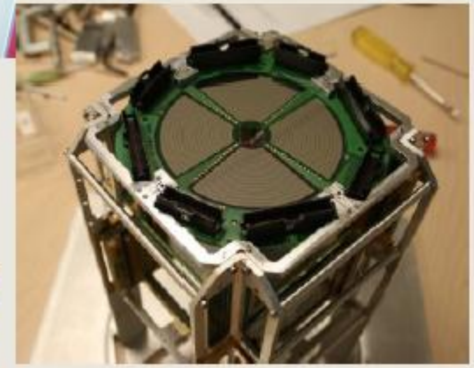
TIGRESS+SHARC Experiments in 2010



11 TIGRESS Clovers

New TIG64 modules for Silicon signals

4π highly-segmented silicon barrel



ISAC II High-Beta Cavities >5MeV/u

Nuclear Structure:

S1201 July 6He@5MeV/u Sarazin – Benchmarking (^{6}He,^{4}He) against (t,p)
S1212 Oct 26Mg@8MeV/u Williams – Characterizing Collectivity in the Island of Inversion

Nuclear Astrophysics:

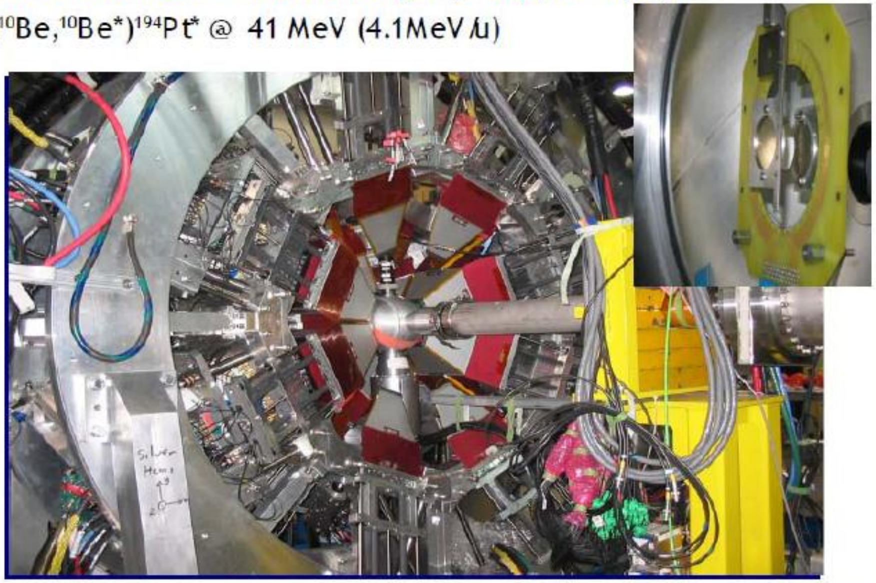
S900 June 15N@5MeV/u Fulton/Diget - A Determination of the α+^{15}O Radiative Capture Rate by a Measurement of the ^{15}O(^{6}Li,d)^{19}Ne Reaction
S1213 Oct 20Na@6MeV/u Blackmon/Diget - Probing Astrophysical Nuclear Processes with (^{20}Na,^{6}Li)

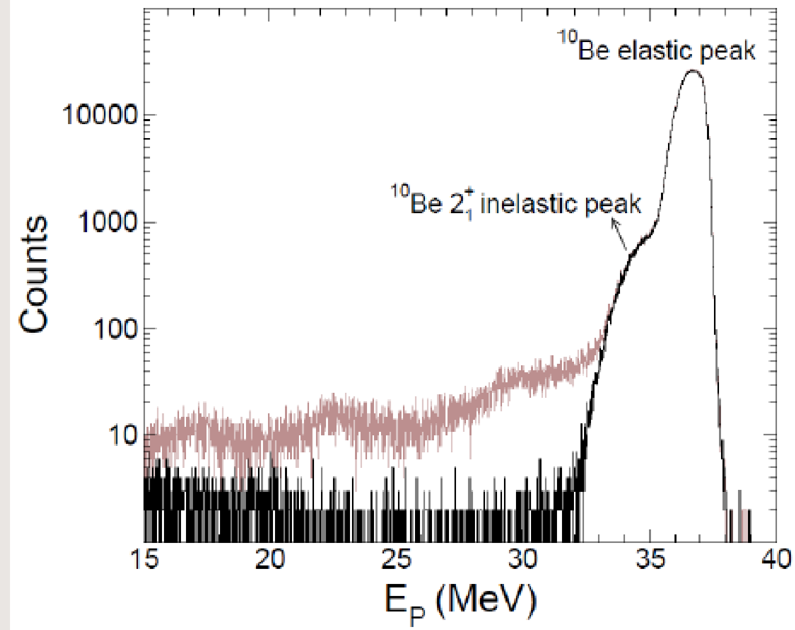
TRIUMF

Testing *Ab Inito* calculations of light nuclei: Coulomb excitation of ^{10}Be

8 TIGRESS Clovers + BAMBINO [30°, 60°] (S3 Style)

$^{194}Pt(^{10}Be,^{10}Be^*)^{194}Pt^*$ @ 41 MeV (4.1MeV/u)

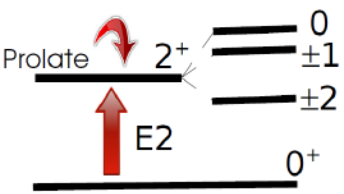


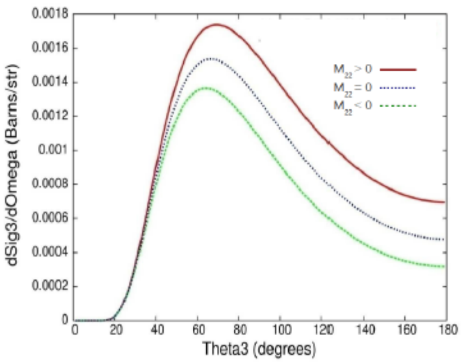


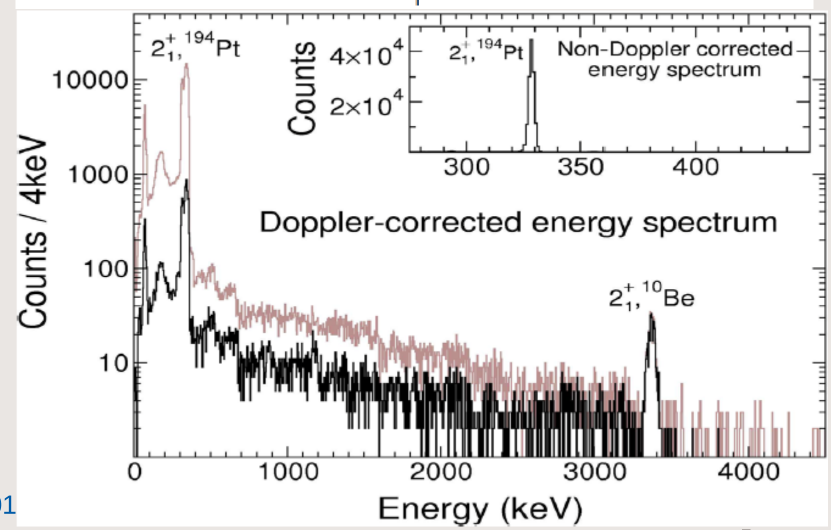
(2nd order effect in Coulomb excitation)

$$\sigma_{E2} = \sigma_R[k_1(\theta_{CM},\xi)B(E2)\,(\,1 + k_2(\theta_{CM},\xi)\;Q_S(2_1^+)\,)]$$

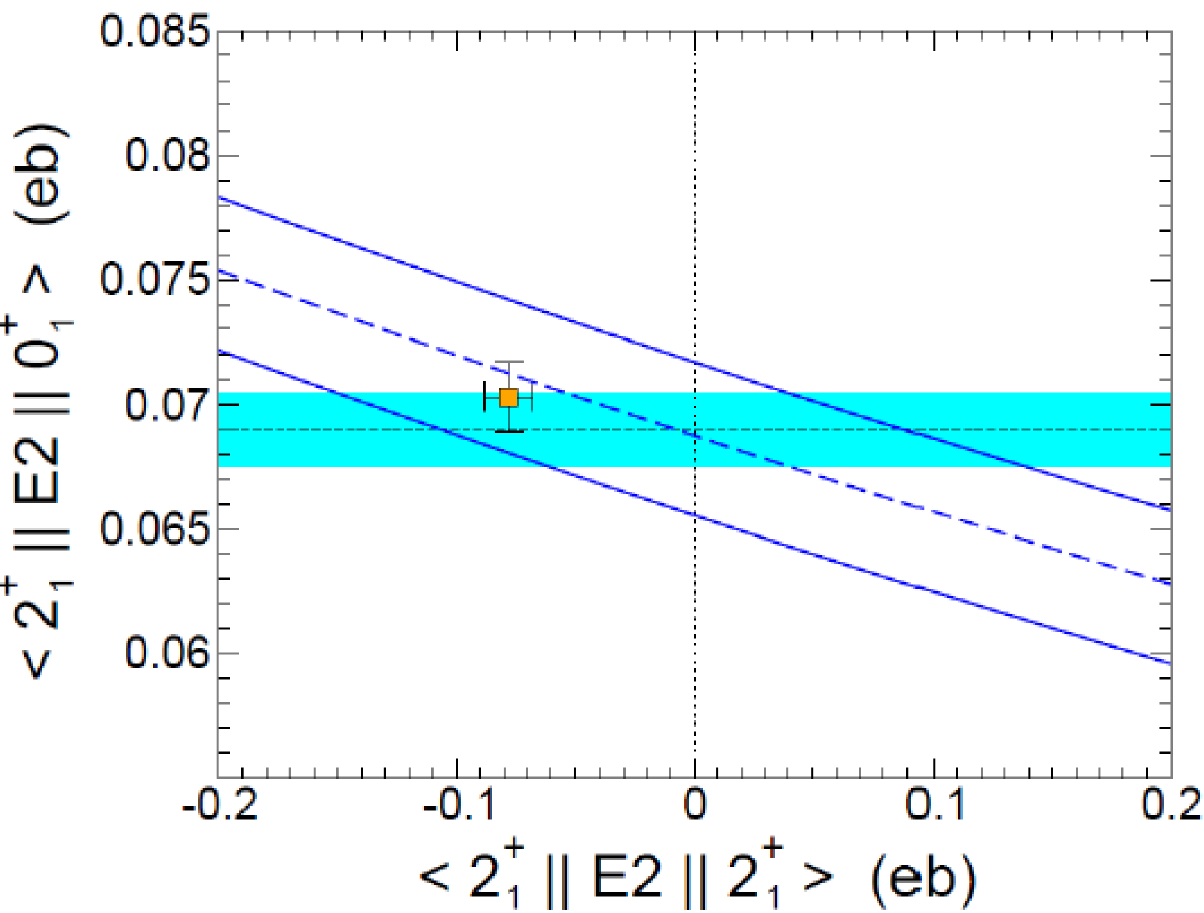
Both projectile and target experience strong time-dependent field gradients







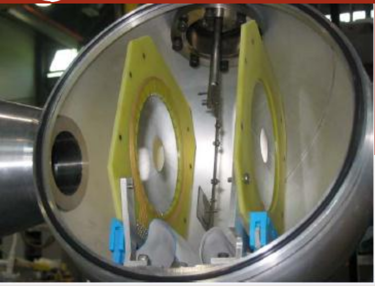
variation of $<2_1^+||E2||0_1^+>$ as a function of $< 2_1^+||E2||2_1^+>$ for ^{10}Be, 3.368 MeV state



preliminary results

- The diagonal band corresponds to the 1σ limits of the ratio of the integrated experimental yields from 30-60 degrees
- the (blue) band corresponds to the value of the transitional matrix element obtained from a weighted average of 3 previous lifetime measurements
- the (square) data point is the value predicted in NCSM with the CD Bonn 2000 two body potential
- better statistics required to definitely determine the sign of Qs(2+)

TRIUMF



Coulomb Excitation of ^{11}Be on ^{196}Pt
First TIGRESS Experiment to use 12 detectors

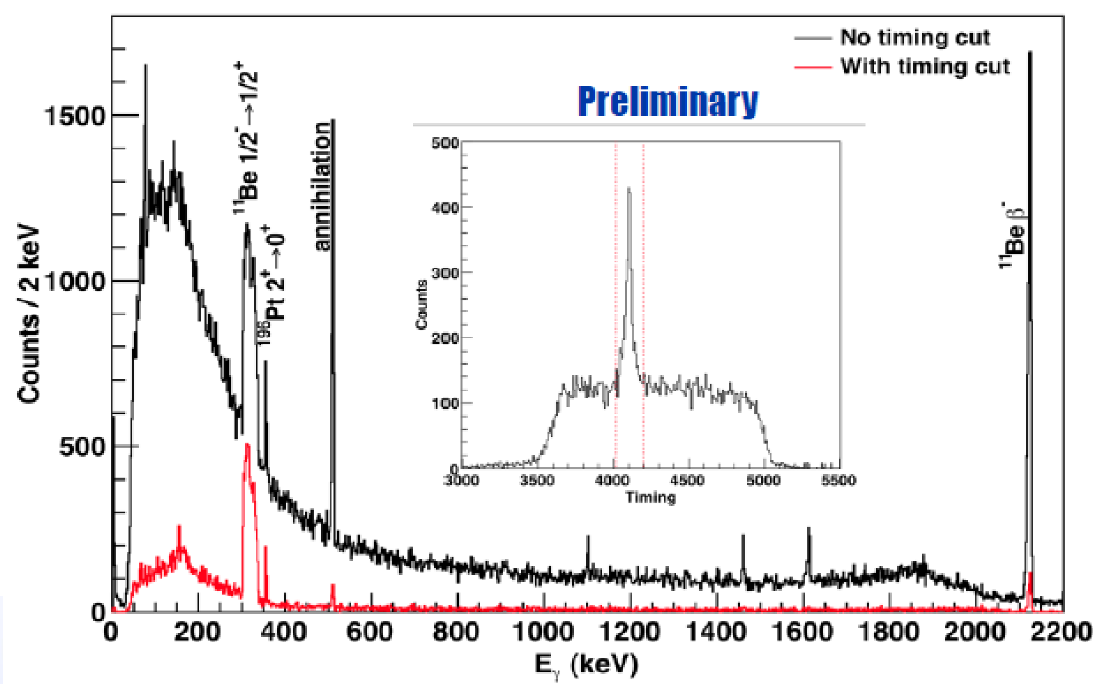
The one neutron halo nucleus ^{11}Be has the strongest *E1* strength known between bound states

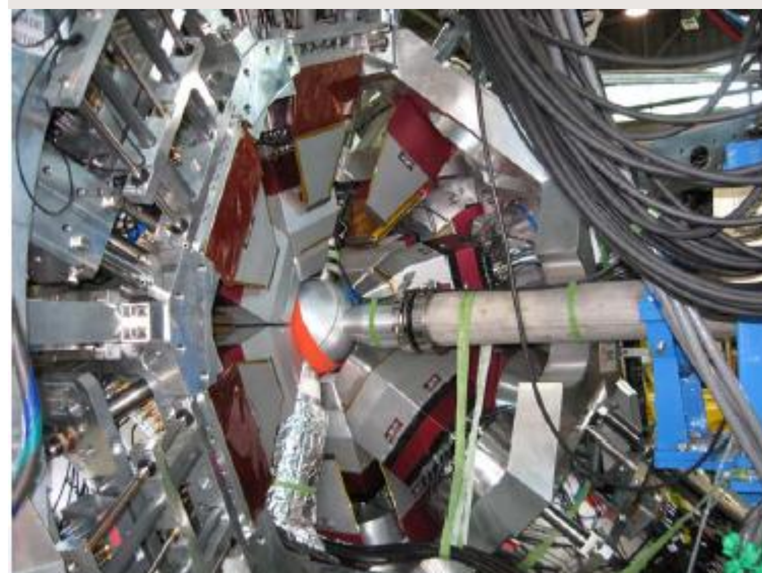
Strong soft-E1 transition strength to the continuum peaks at~0.8 MeV and the energy weighted E1 strength up to 4 MeV exhaust 70% of the cluster sum rule.

Measured Coulex on ^{196}Pt at bombarding energies of 19, 23 and 42 MeV at 10^6 pps to determine the *E1* strength to the bound state and continuum to 5%

Comparison to *ab inito* no-core shell model + resonating group method

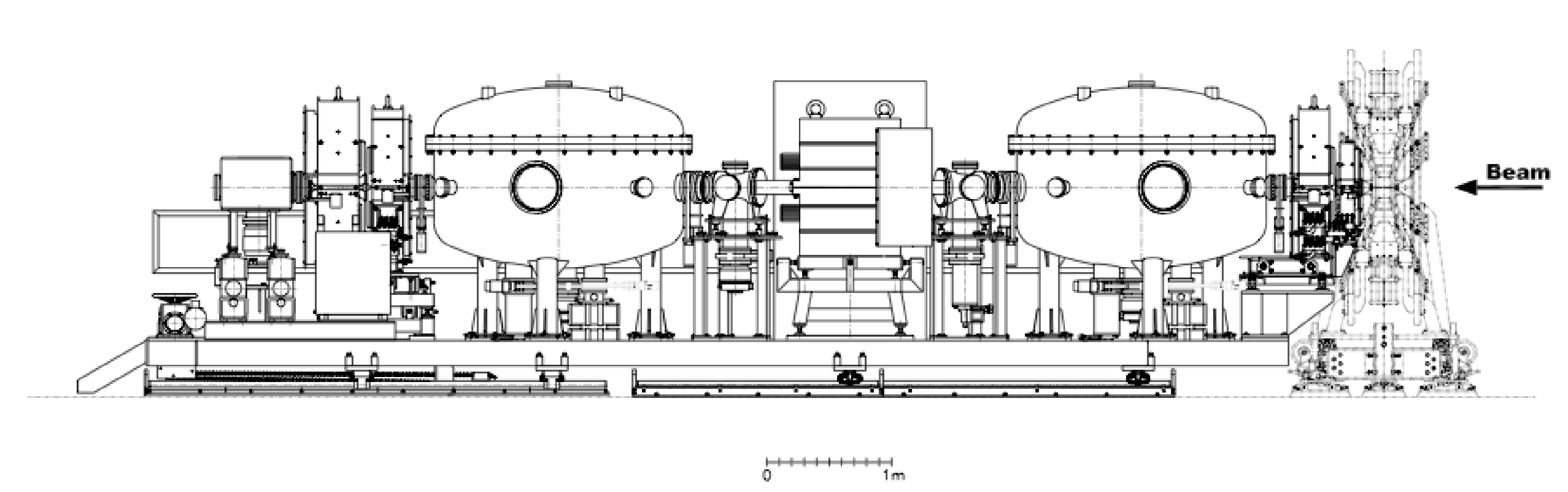
(Navratil et al)





TRIUMF

EMMA: ElectroMagnetic Mass Analyzer



Recoil Mass Spectrometer for ISAC-II

Length = 9 m; 1st order mass resolving power = 500

Solid angle: ± 4° by ± 4° = 20 msr

M/q acceptance = ± 4%; Energy acceptance = ± 20%

±350 kV TRIUMF-engineered high voltage power supplies built and tested

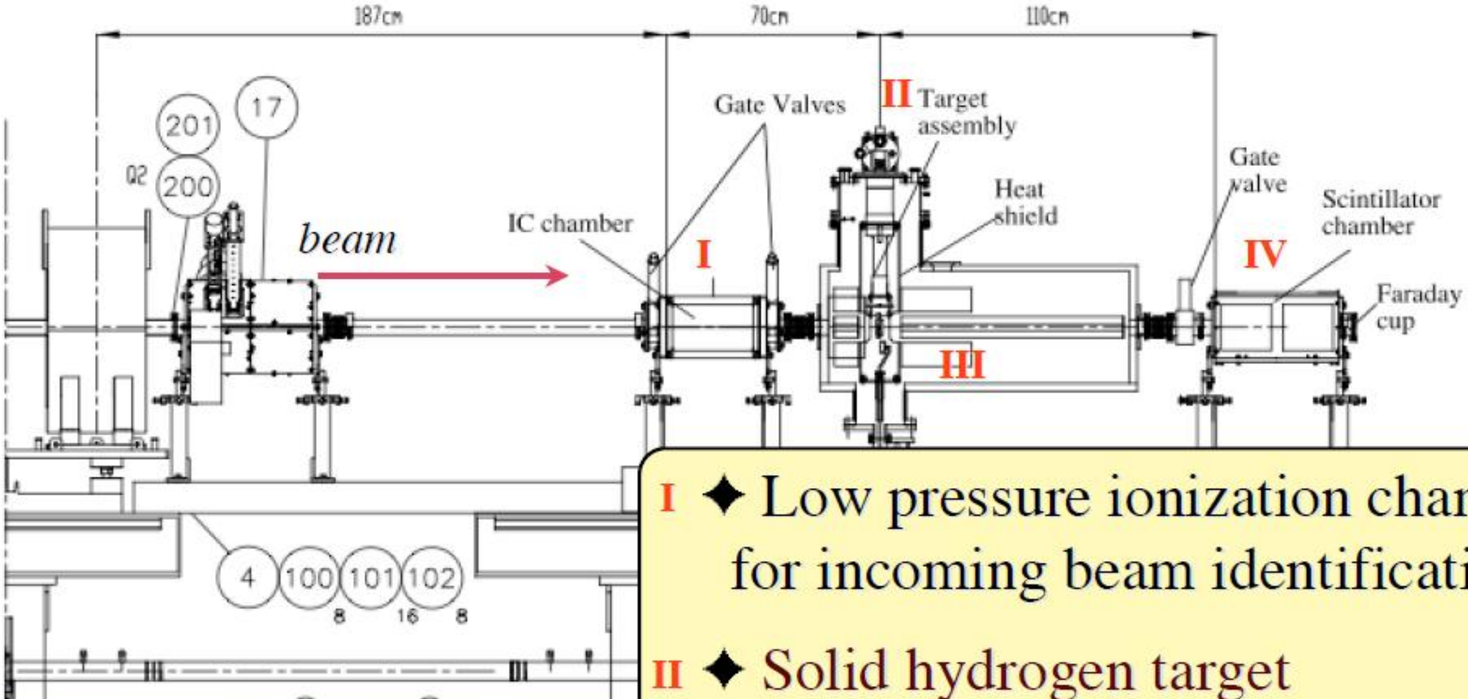
Electromagnetic elements under construction by Bruker Biospin,

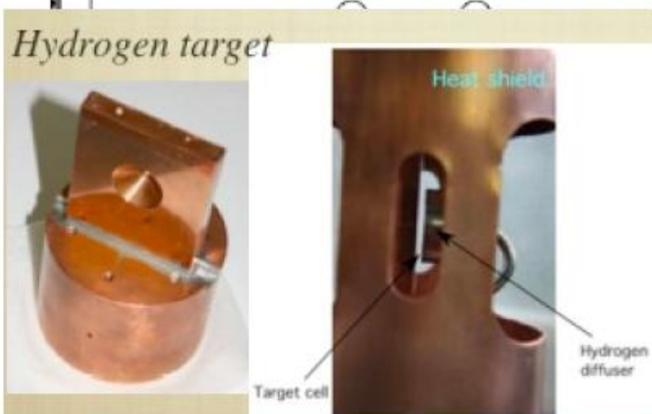
Delivery expected in 2012

Commissioning complete in 2013

IRIS : A new facility for direct nuclear reactions at ISAC

TRIUMF — Saint Mary's University — RCNP, Osaka, Japan

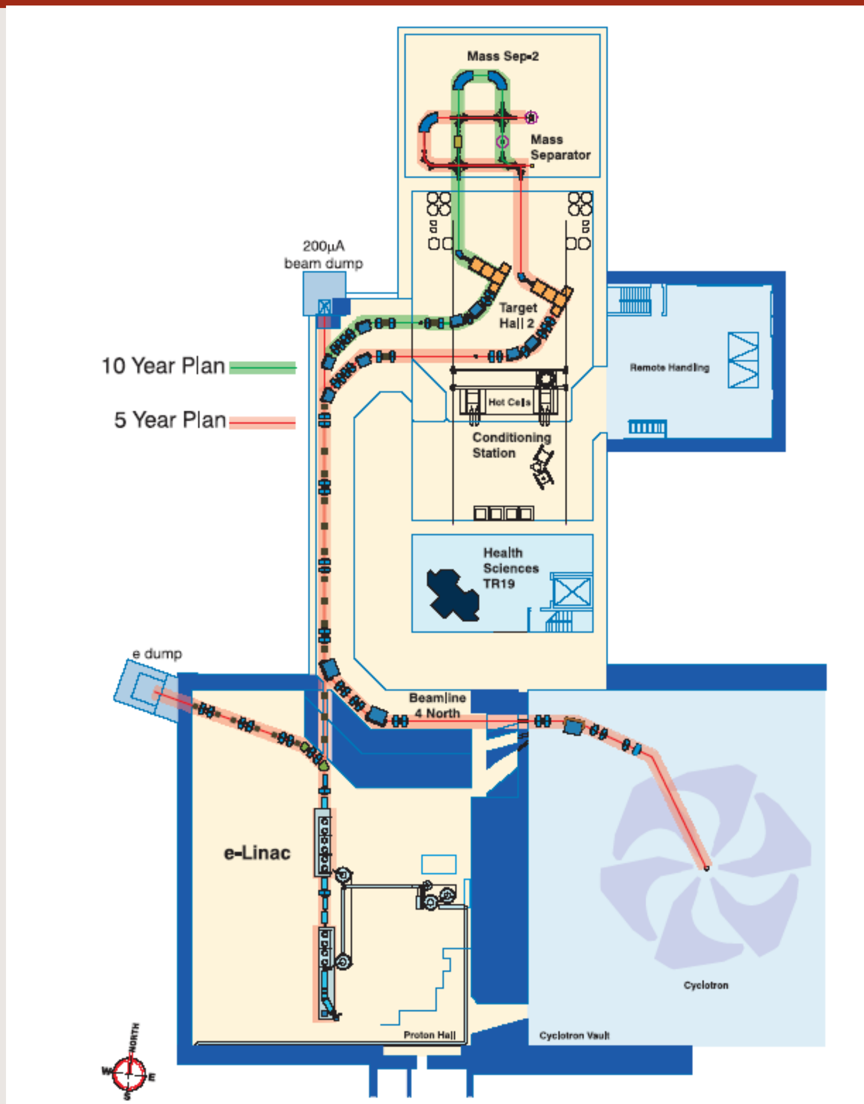




- I ✦ Low pressure ionization chamber for incoming beam identification
- II ✦ Solid hydrogen target
- III ✦ Si-CsI array for reaction product tagging.
- IV ✦ Radiation hard scintillator for beam counting

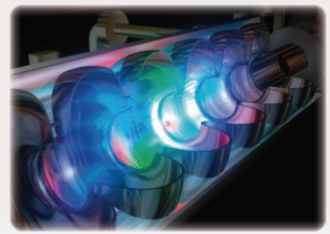
Commissioning in 2012

Advanced Rare Isotope Laboratory



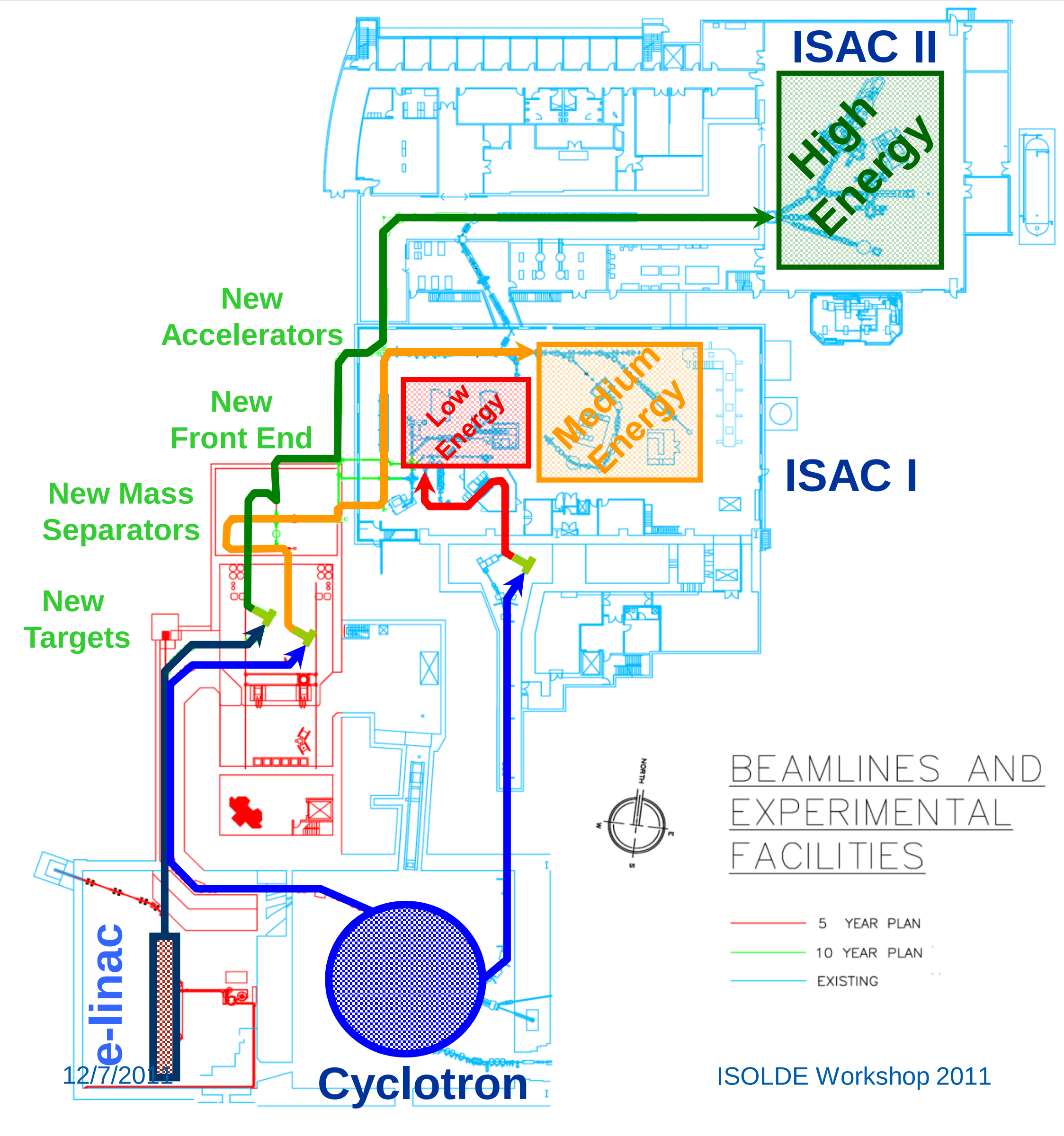
TRIUMF **ARIEL**

ADVANCED RARE ISOTOPE LABORATORY



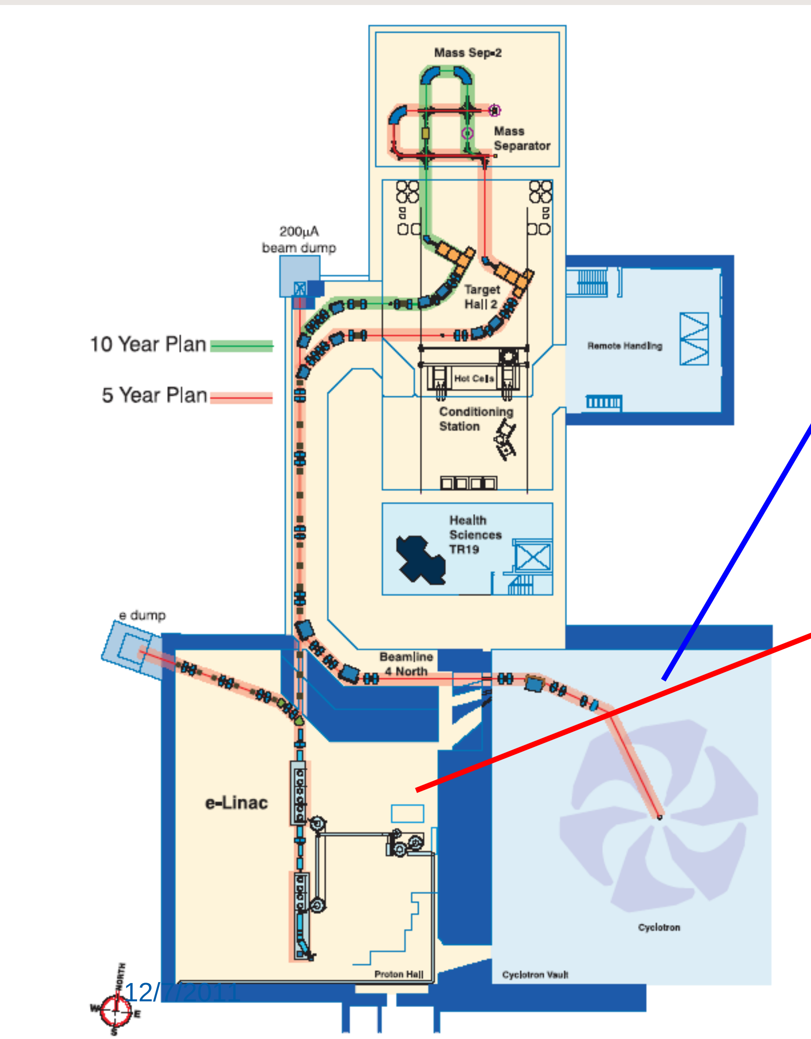
ARIEL is a new underground beam tunnel surrounding a next-generation linear accelerator – an e-linac, led by the University of Victoria. The project will allow TRIUMF to develop technology to advance Canada's supply of critical medical isotopes, capitalize on existing investments, and broaden its research capabilities in particle physics, nuclear physics, nuclear medicine, and materials science.

ARIEL Project 10-Year Plan: Motivation



- expand RIB program with:
  - three simultaneous beams
  - increased number of hours delivered per year
  - new beam species
  - enable long beam times (nucl. astro, fund. symm.)
  - increased beam development capabilities
- New electron linac driver for photo-fission
- New proton beamline
- New target stations and front end
- staged installation

ARIEL science reach



New proton spallation beam line on UC

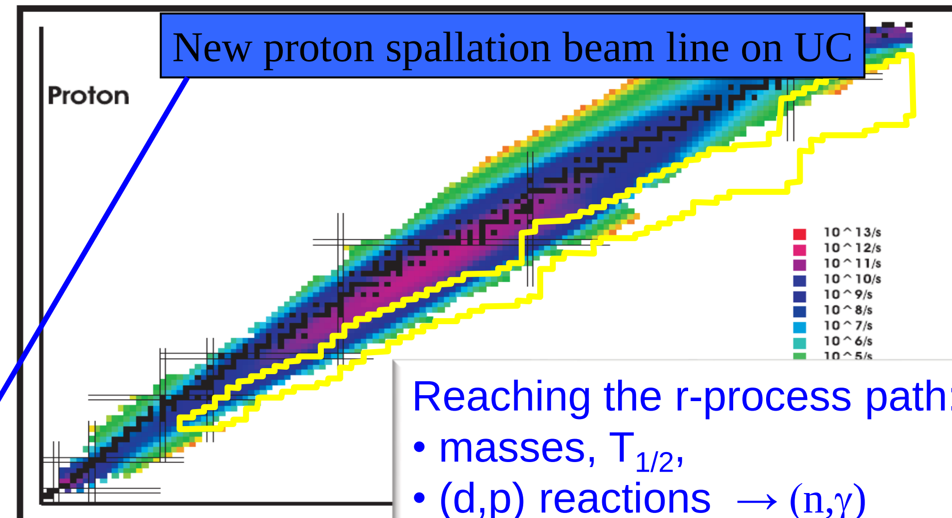


Figure 7: Production yield in target assuming

Reaching the r-process path:

- masses, $T_{1/2}$,
- (d,p) reactions $\rightarrow$ (n,γ)
- decay spectroscopy

Photo-fission on U-target

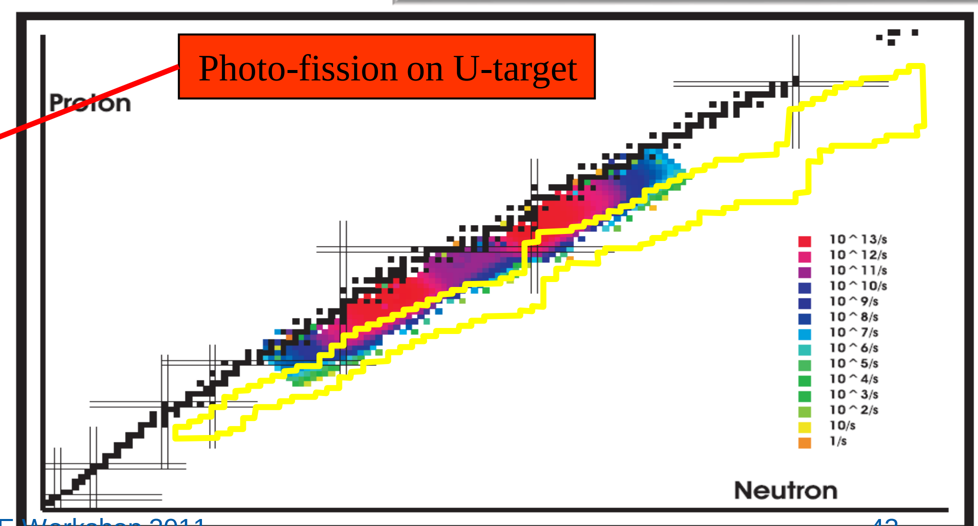
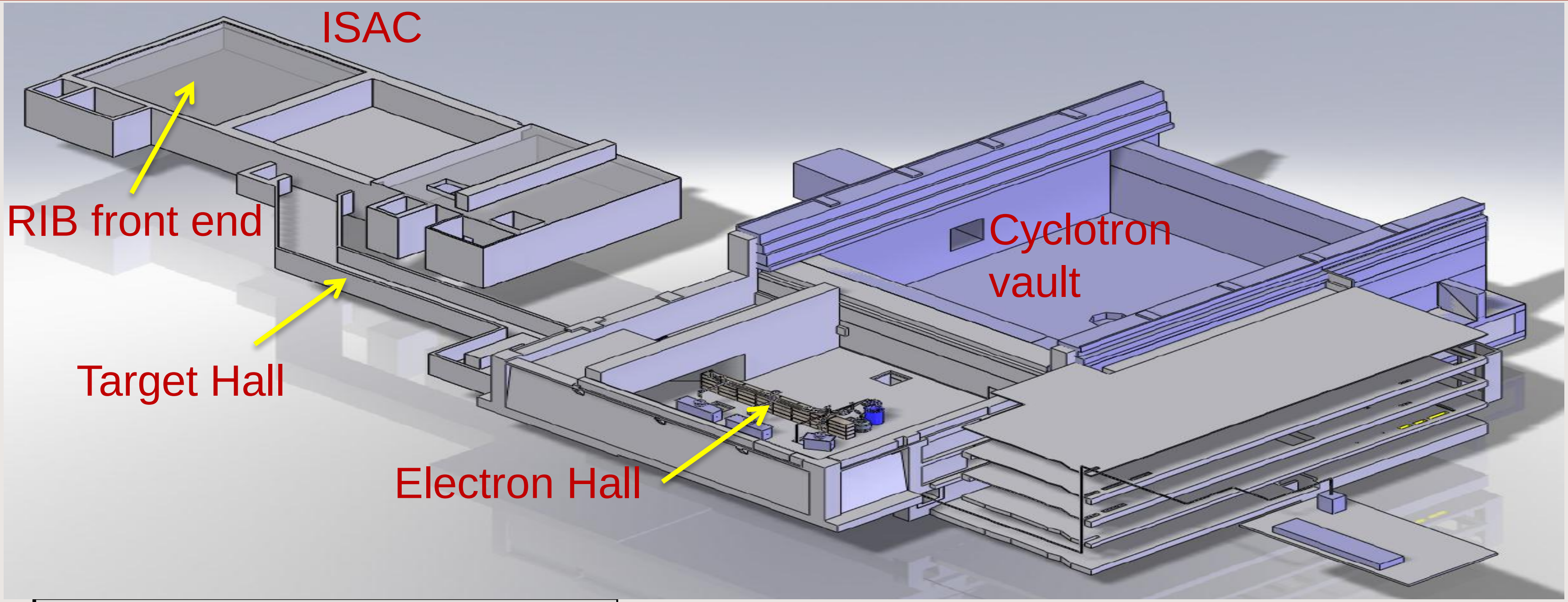


Figure 8: Production in target assuming 4.6x10[13] photo-fission induced into a 15 g/cm[2] UC_X target.

ARIEL CF Schedule



Design – **12** months

Oct 1, 2010

Design Consultants Selected

Tender

Aug 2011

Excavation

Oct 2011

Jan 31 2012

Electron Hall occupancy

Tender

Oct 2011

Main ARIEL Construction – 16 months

Dec 2011

Sep 2012

March 31, 2013

Summary

- many world class experimental facilities in operation or under development at ISAC to address key questions in
  nuclear structure, nuclear astrophysics, fundamental symmetries and material science
- Availability of n-rich beams from UCx target has started new era for ISAC experiments, highest production yields with 10 μA protons
- beam development remain crucial to remain competitive
  - ***photo fission of U will yield intense neutron-rich beams with significantly reduced isobaric contaminants***
- ARIEL will provide RIBs for two and eventually three users, simultaneously, to exploit the scientific potential of ISAC

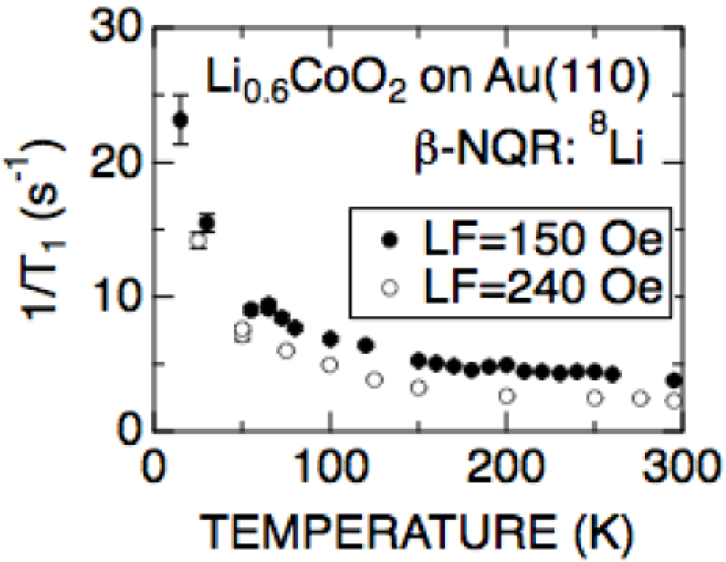
A special thanks to those who contributed to this presentation

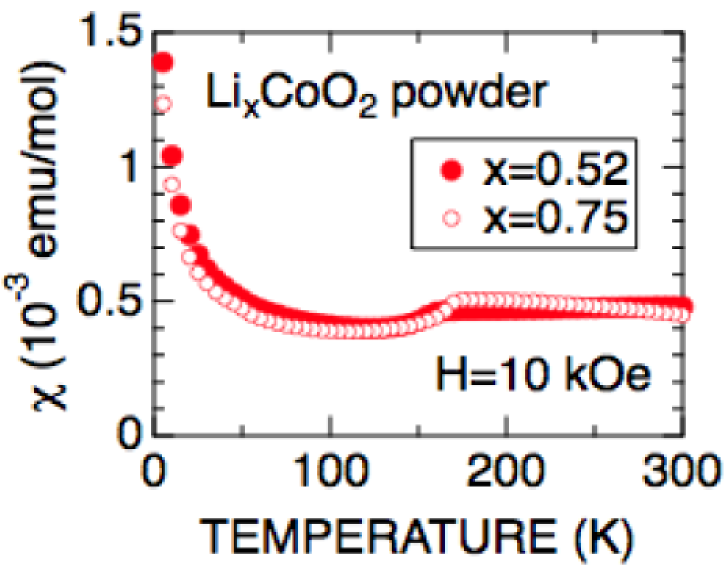
Thank you!

Merci!

M1306: ^{8}Li β-NMR of Li-battery material; $Li_{0.6}CoO_2$

Jun Sugiyama, Toyota CRDL



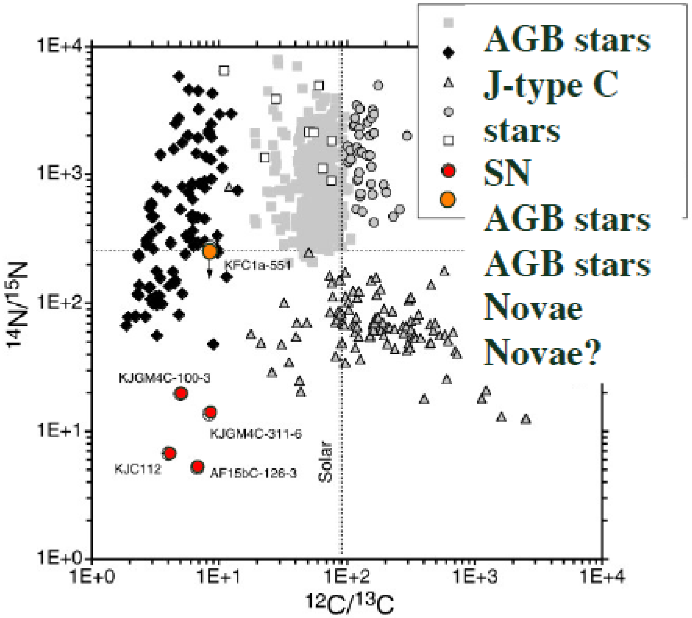


- In October 2011, we attempted to measure a Li diffusive behavior in the Li-deficient $Li_{0.6}CoO_2$ epitaxial film on an Au substrate by a β-NMR technique in order to clarify the change in Li diffusion coefficient (D_{Li}) at the interface between electrode and electrolyte in a solid-state battery.

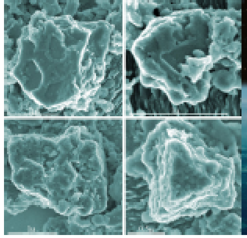
- For this film, Li ions are expected to start to diffuse above 150 K, based on susceptibility (χ), NMR, and μSR measurements.

- Even in the highest longitudinal field achievable (240 Oe) with the β-NQR apparatus, the spin-lattice relaxation rate (T_1^{-1}) still shows a Curie-Weiss behavior (at top left) as in the case for susceptibility measurements χ(T) (bottom left).

- In order to decouple the electronic contribution to T_1^{-1}, we plan to measure β-NMR spectra in 2012 with the high field apparatus.

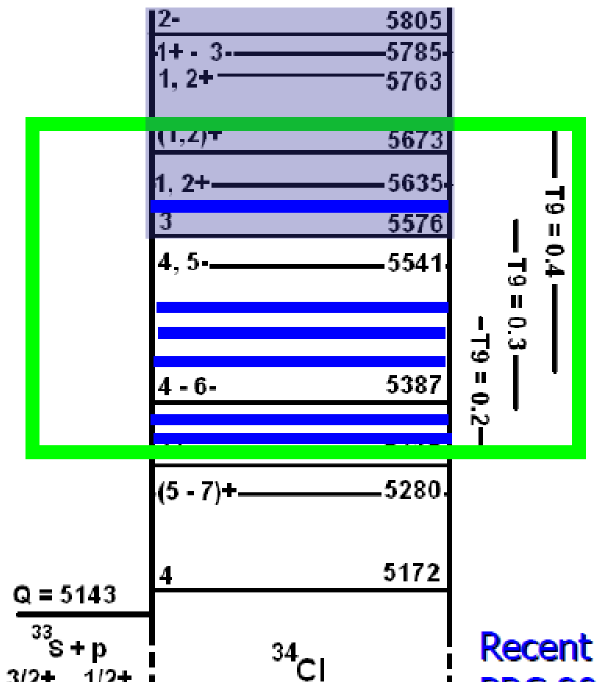


$^{33}S(p,\gamma)^{34}Cl$



Motivation:

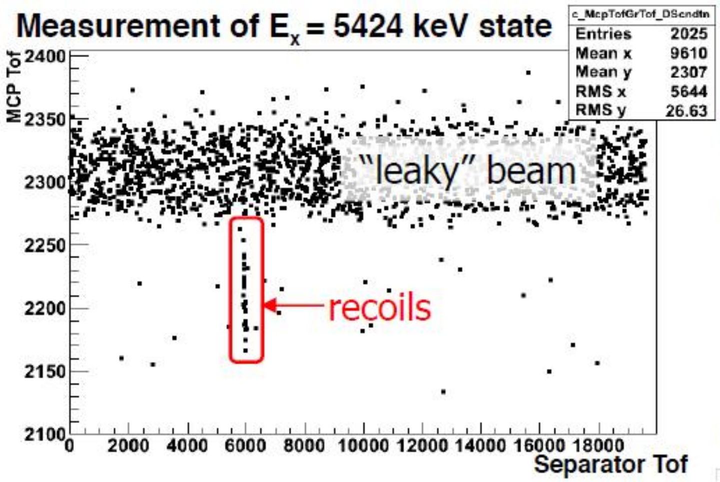
- ^{33}S abundance in pre-solar grains could indicate nova origin.
- ^{34m}Cl is a potential target for γ-telescopes



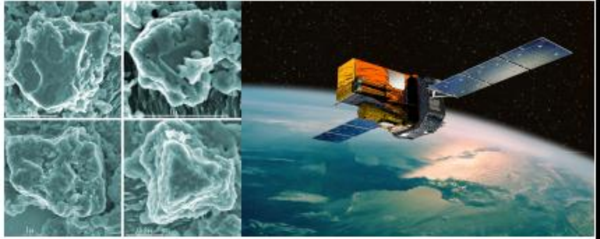
DRAGON experiment:

- Confirm two lowest energy $\omega\gamma$ literature values
- Measure / set upper limits for $\omega\gamma$ of the other unmeasured states within the Gamow window (0.2 - 0.4 GK)

Recent work by A. Parikh et al. using $^{34}S(^{3}He,t)^{34}Cl$
PRC 80, 015802 (2009)

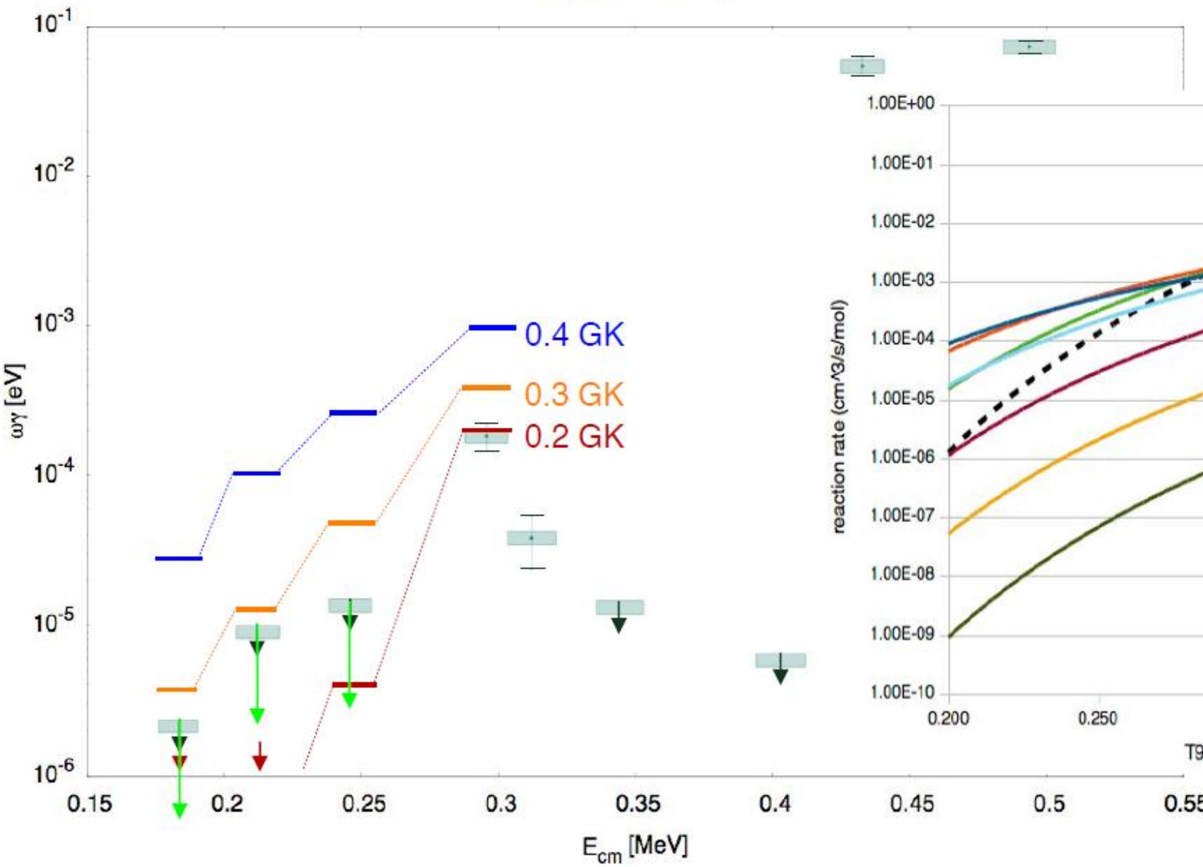


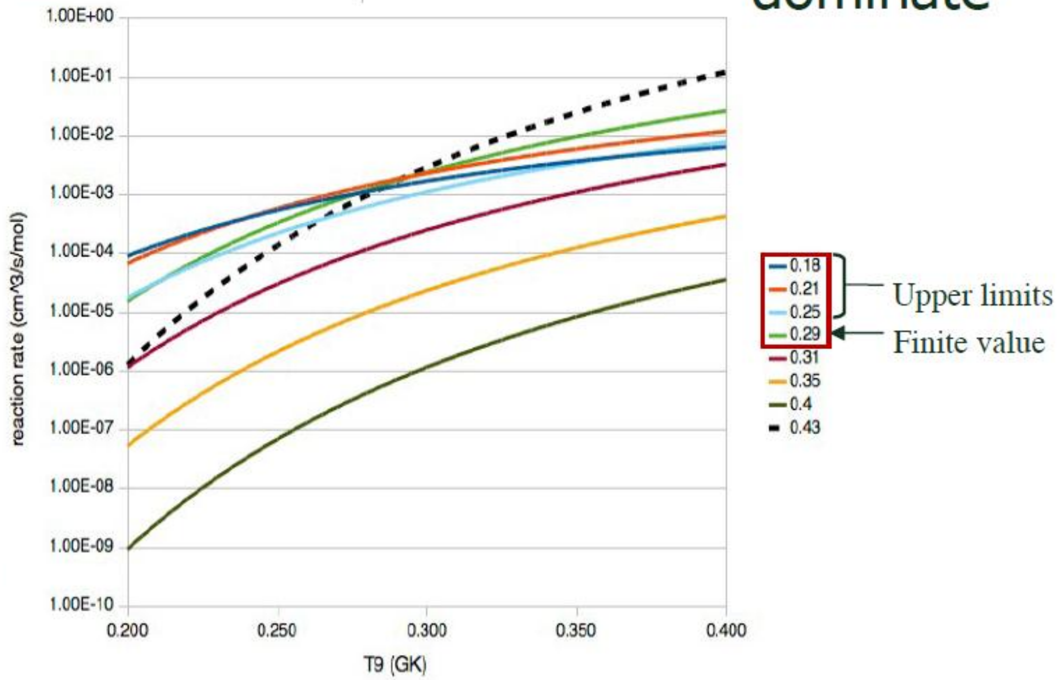
$^{33}S(p,\gamma)^{34}Cl$



Conclusions:

- At ≥ 0.3 GK the $^{33}S(p,\gamma)^{34}Cl$ reaction will continue to be dominated by the E_x = 5576 keV state.
- At ≤ 0.2 GK the state around E_x = 5436 keV will most likely dominate

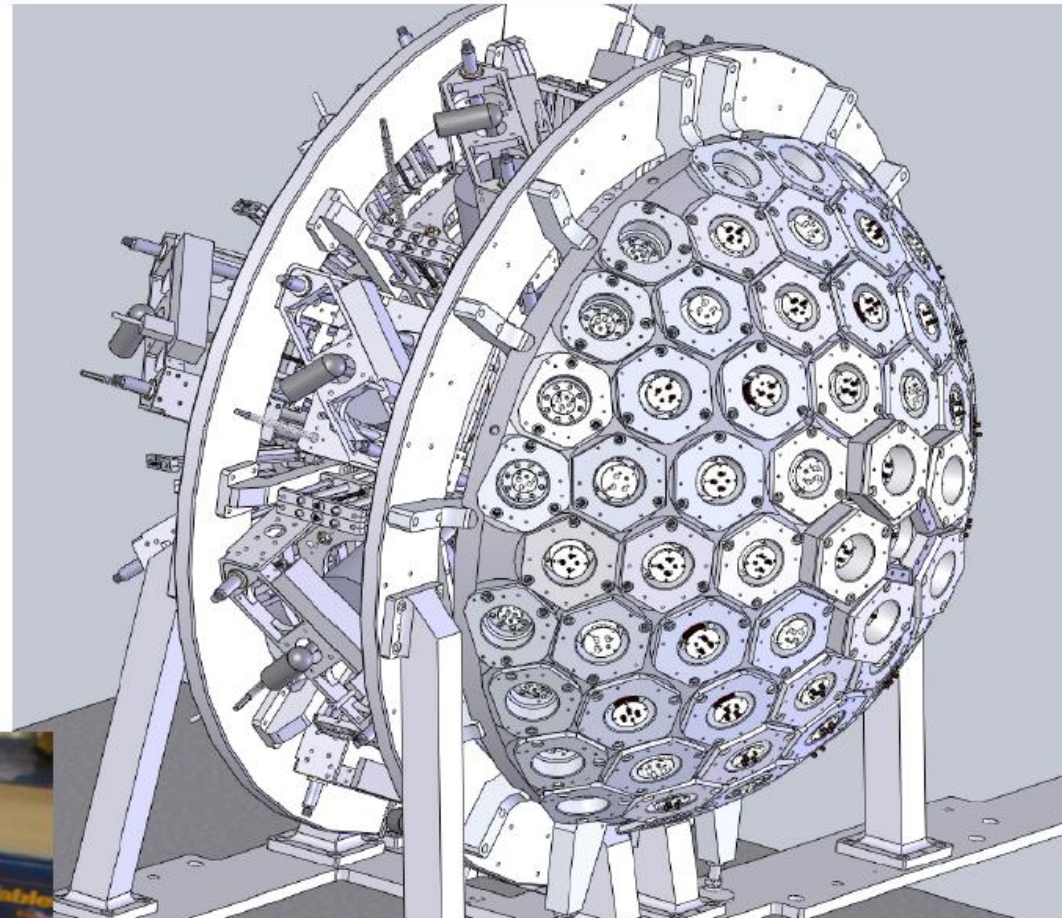


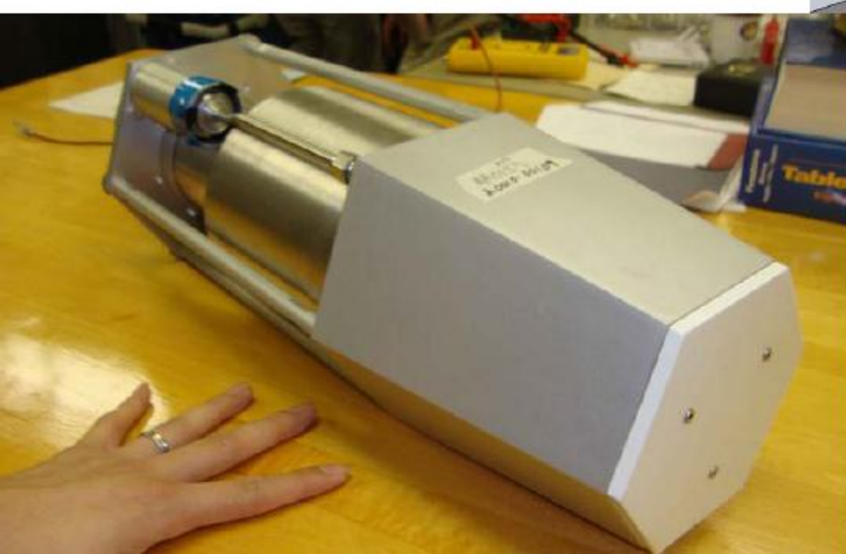


DESCANT array for neutron detection

UNIVERSITY of GUELPH

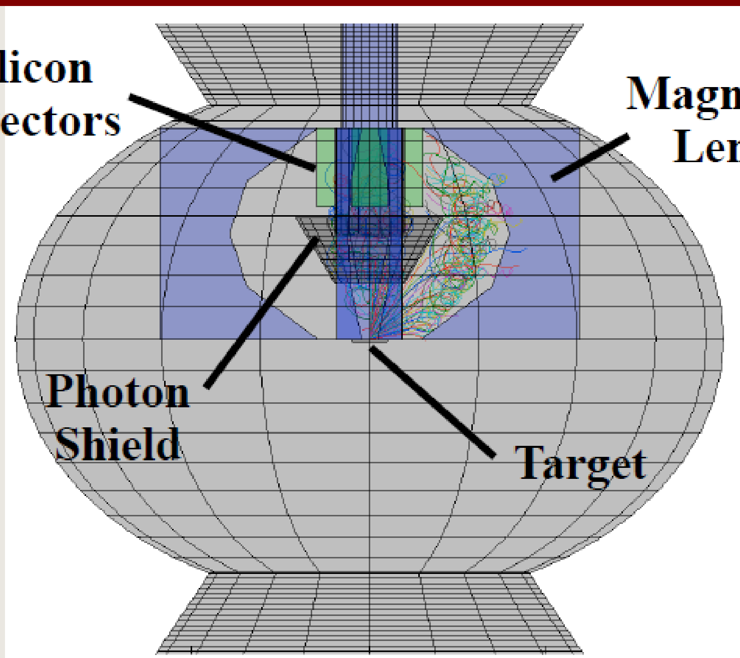
- **New array of neutron detectors based on deuterated liquid scintillator**
- **Designed to couple to TIGRESS for fusion evaporation studies, and GRIFFIN for β-delayed neutrons**
- **Commissioning 2012**



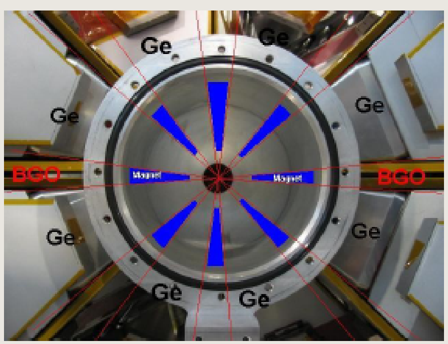


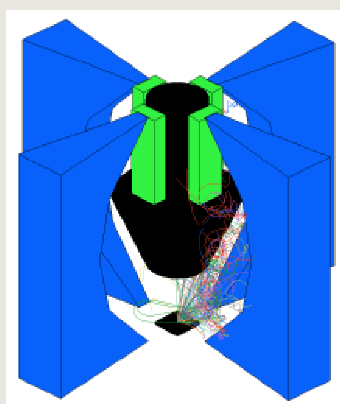
Liquid scintillator detector cans 15 cm deep. 70 ~hexagonal detectors, removable inner rigs to allow for downstream auxiliaries

SPICE
SPectrometer for Internal Conversion Electrons



Concept Design



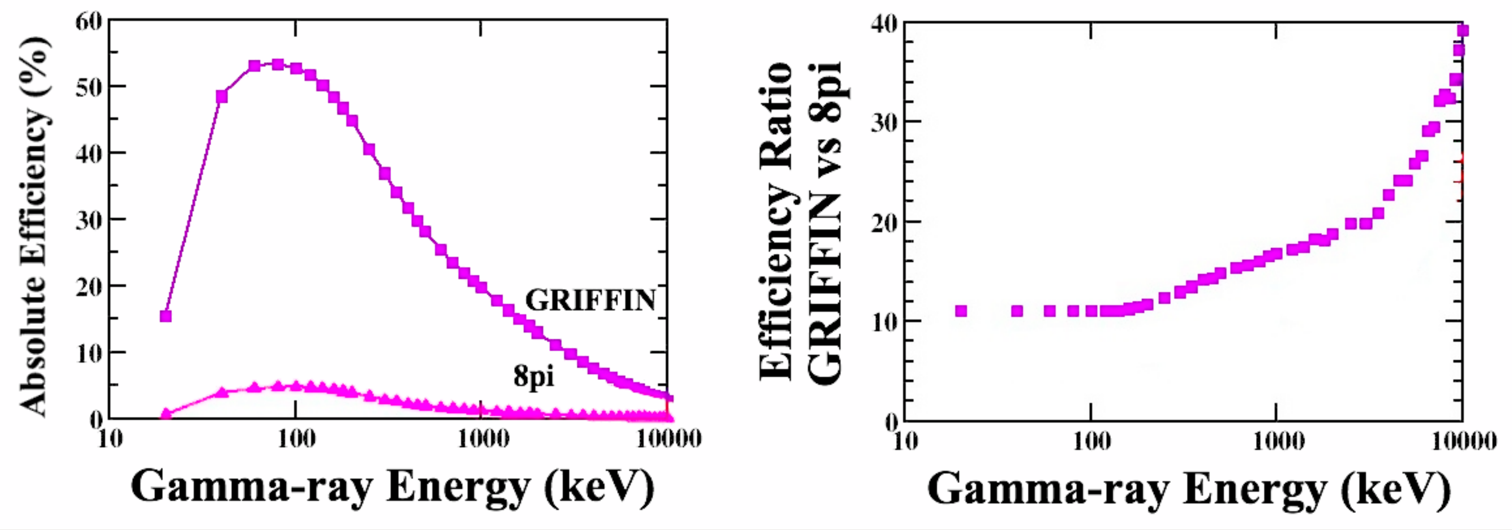


- Couples to 16 TIGRESS Clovers for gamma-electron coincidences (Plus other ancillaries)
- Backward angle geometry and Delrin vacuum chamber for background suppression
- High efficiency for electrons 100keV to 4MeV
- High granularity for electron-electron coincidences

TRIUMF

GRIFFIN installation in 2014

Upgrade the 8pi to 16 HPGe Clover detectors and high-rate digital DAQ

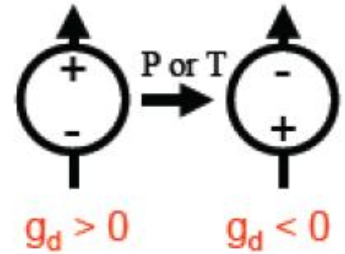


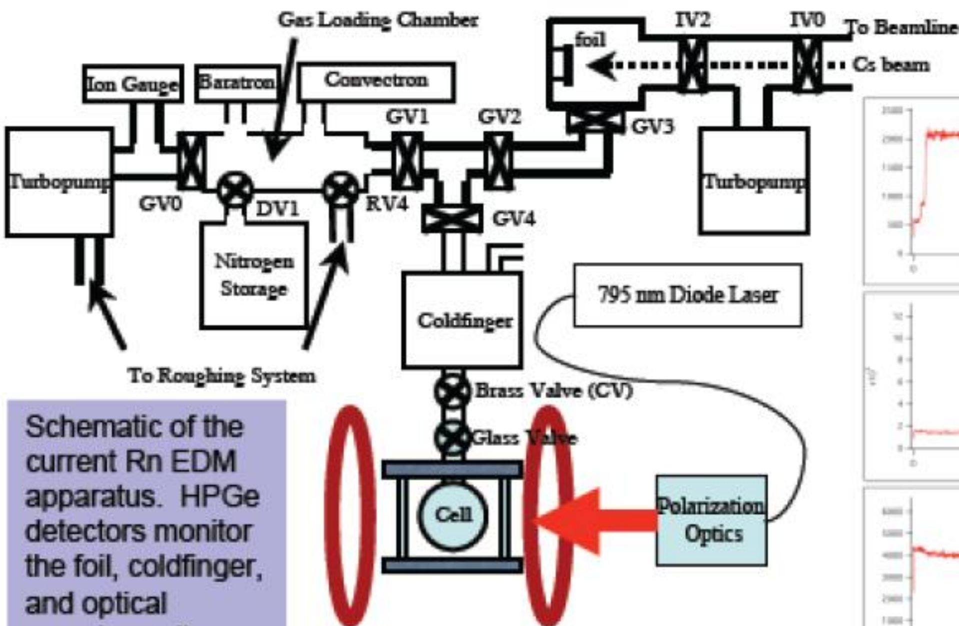
8pi: 1% efficiency at 1.3MeV, GRIFFIN: 17% efficiency at 1.3MeV
8pi: Study beams of >1pps, GRIFFIN: Study beams of >0.01pps
SCEPTAR: 80% solid angle coverage
PACES: 7% solid angle coverage
DANTE: Lifetime sensitivity down to ~100picoseconds
DESCANT: neutron array 25% solid angle coverage

Radon EDM

- A permanent electric dipole moment (EDM) would violate CP symmetry.
- Any measurement above SM background indicates new physics (e.g. SUSY, LR, etc.) → explain the matter-antimatter asymmetry in the universe.
- Sensitivity enhancement due to nuclear octupole deformation: a factor of 400-600 relative to ^{199}Hg, the current most-precise atomic EDM measurement.

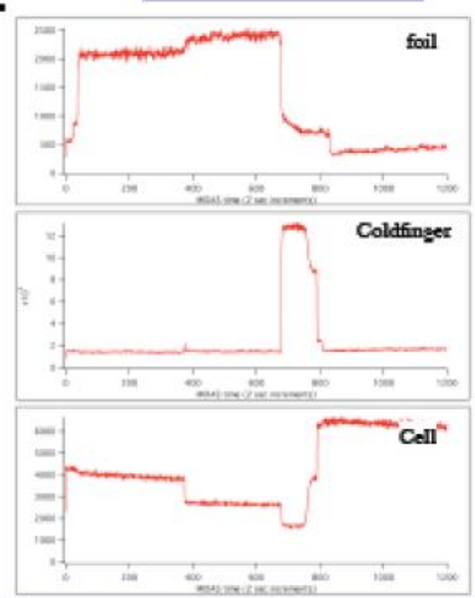
$$\langle \mathbf{d}_{atom} \rangle = g_d \langle \mathbf{J} \rangle$$





Schematic of the current Rn EDM apparatus. HPGe detectors monitor the foil, coldfinger, and optical pumping cell.

Transfer activity from foil to cell.



Induce polarized Rn atoms to precess around a small B-field and a large E parallel or antiparallel to B. Use radiation anisotropies to measure the precession frequency.

$$\hbar\omega_{\pm} = 2\mu B \pm 2dE$$

$$d = \frac{\hbar\Delta\omega}{4E}$$

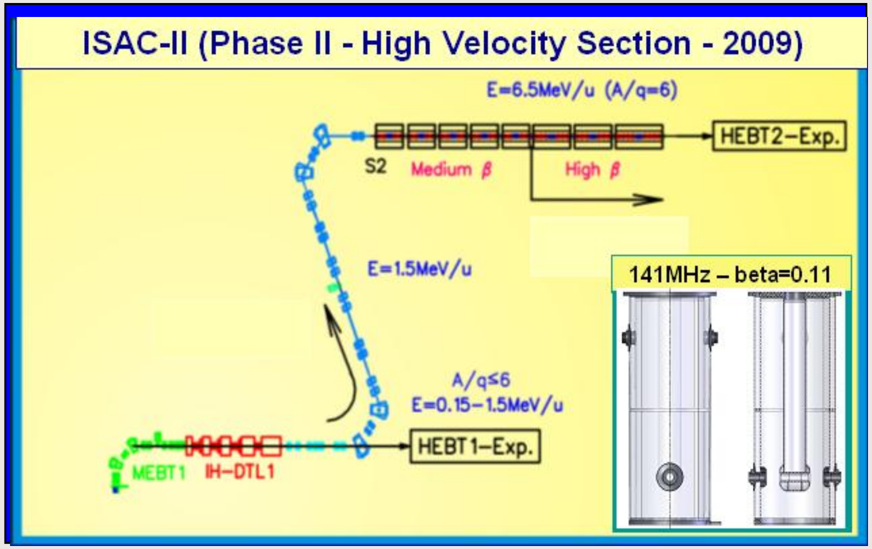
Currently developing the gas transfer, polarization, and detection apparatus using isotopes of xenon from a cesium beam. Radon production requires an actinide target.

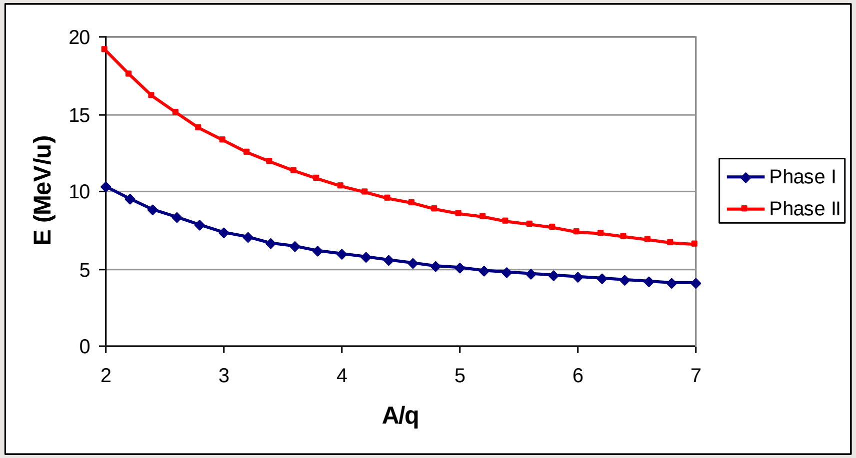
SFU

UNIVERSITY of GUELPH

ISAC-II Super Conducting LINAC

- ISAC-II goal is to boost the energy of the heavy ions above the Coulomb barrier for all masses
- Phase I section (20MV) commissioned in 2006
- Phase II upgrade – commissioned in spring 2010 added 20MV of voltage gain for a total of 40MV

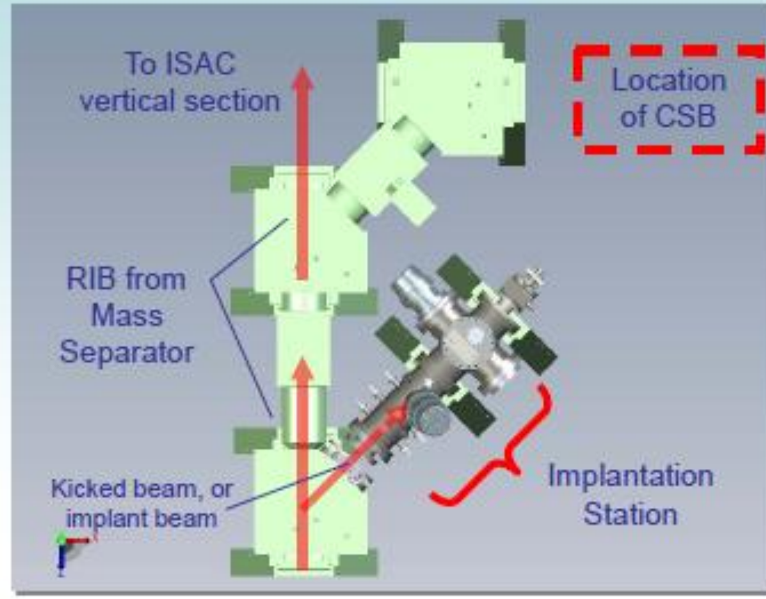




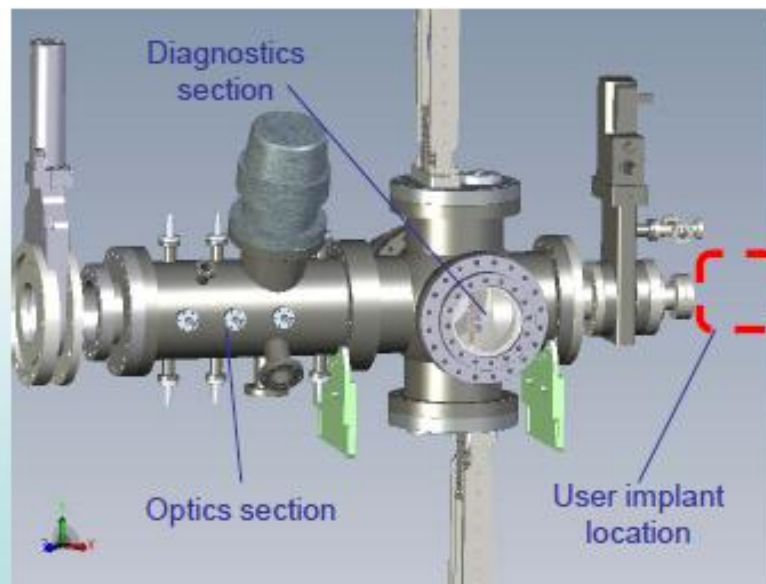
TRIUMF

ISAC Implantation Station

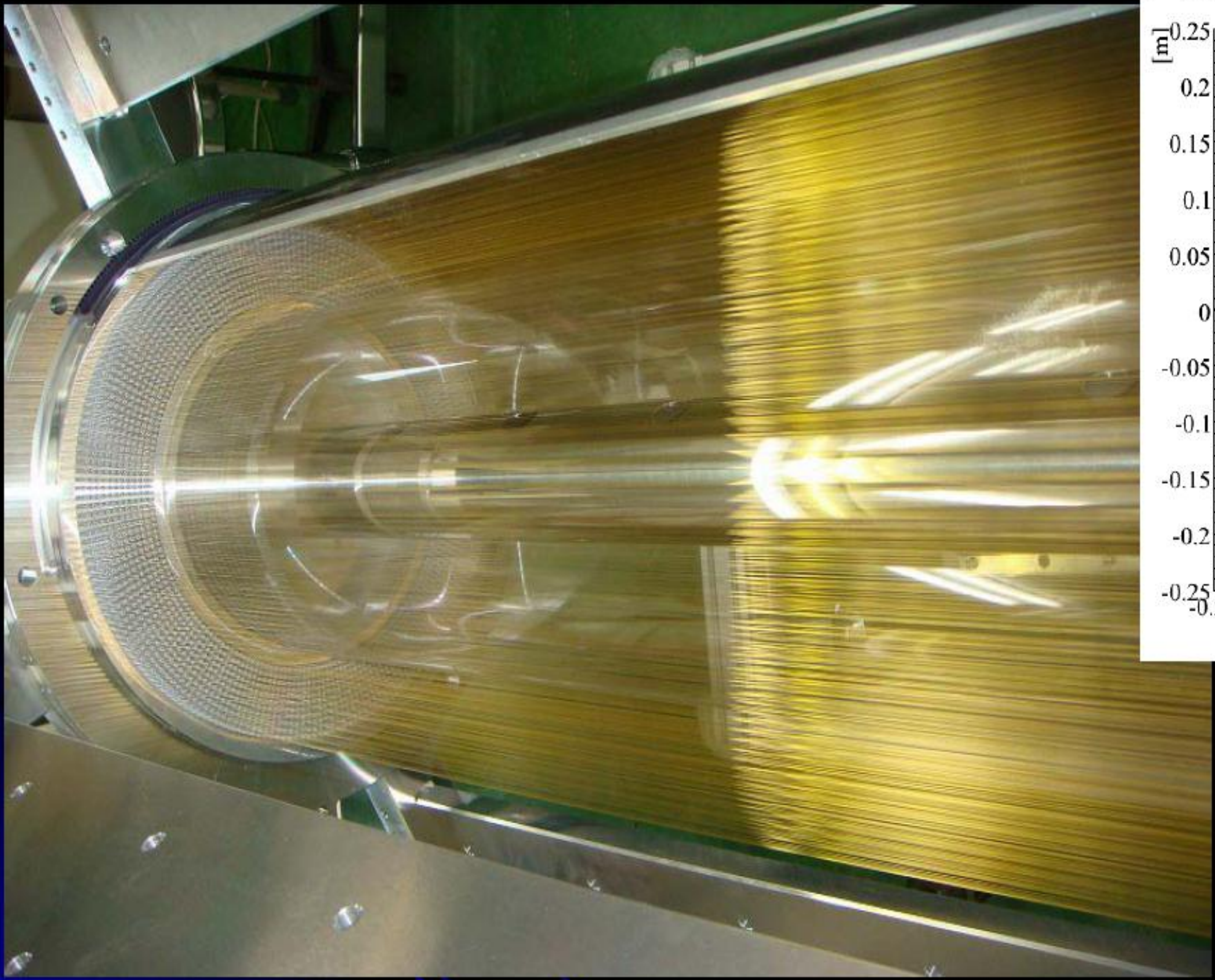
- Fabrication of high-quality long-lived targets (e.g. ^{22}Na, ^{26}Al)
- Replace existing *collection station* in ISAC MSR
- Raster optics
- UHV system
- User facility - each implantation treated as an experiment, EEC approval and safety review required
- Optimizes implant efficiency, improves diagnostics, reduces contact with contamination, simplifies implant procedures

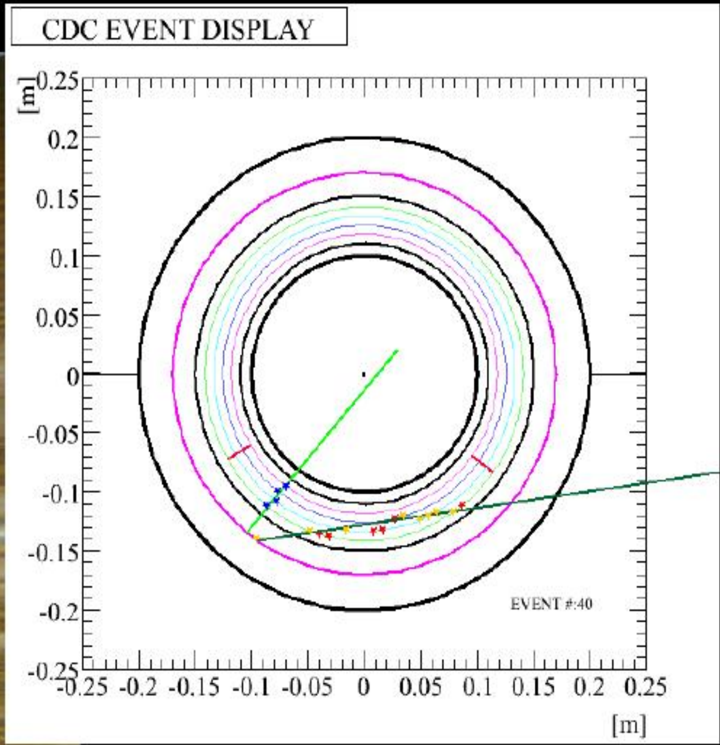


- Science Division budget (~$60k) + some controls financed by Controls Group
- Clean assembly on bench, early 2011
- Installation and alignment spring 2011
- Commissioning aimed for late April 2011
- Possible implantation May 2011??



MTV Future : CDC





Beam Test 2011 Nov.
V-track events recorded

Start Physics Run from 2012

Cylindrical Drift Chamber commissioned 2011

Systematics Reduction from Detector Symmetry