TRIUMF

Canada's National Laboratory for Particle and Nuclear Physics

Science Goals and Priorities

Adam Garnsworthy

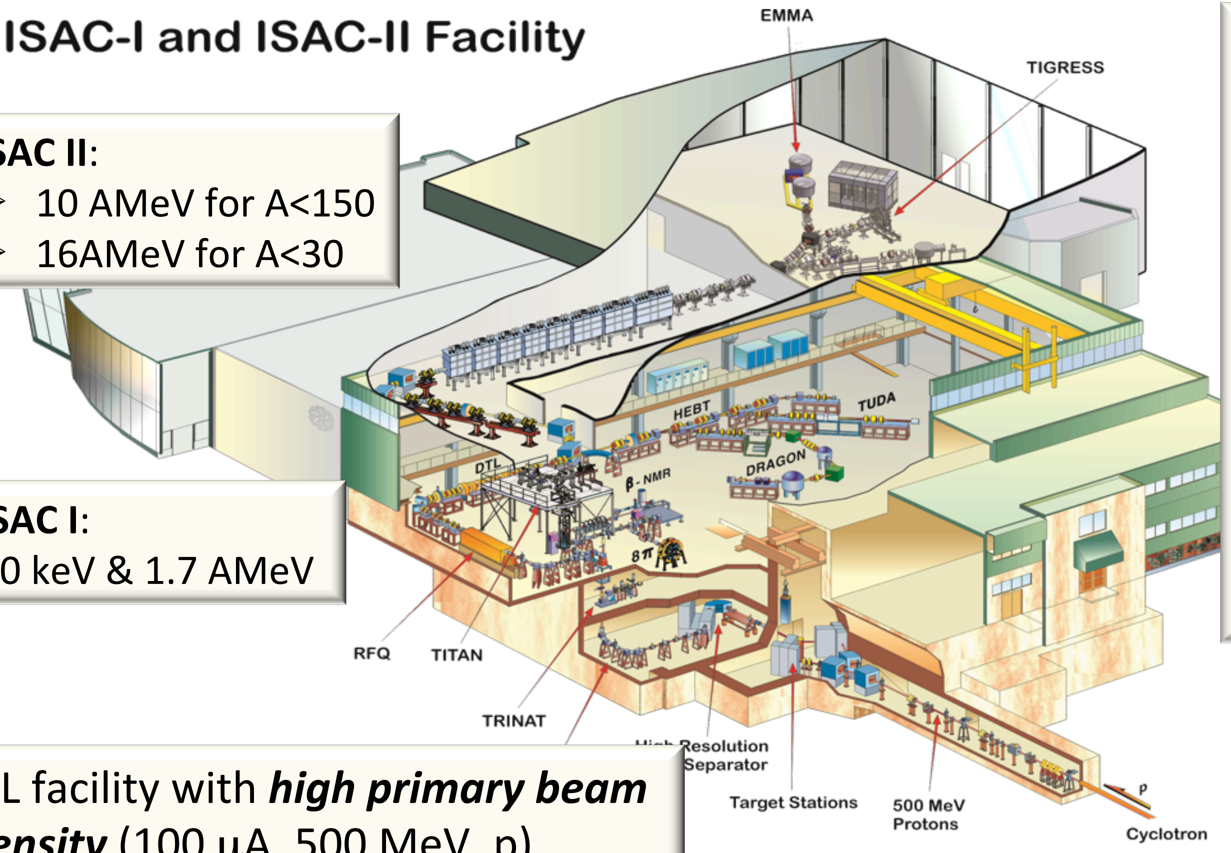
ARIEL Principal Scientist and TRIUMF Research Scientist

January 11th 2017

ARIEL Town Hall Meeting

Vancouver, BC, Canada

ISAC rare isotope facility



ISAC II:

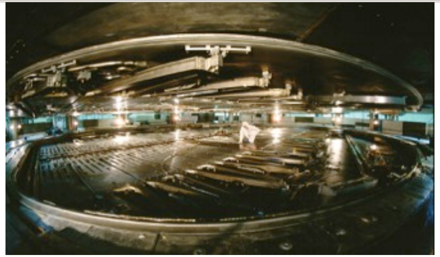
- 10 AMeV for A<150
- 16AMeV for A<30

ISAC I:
60 keV & 1.7 AMeV

ISOL facility with ***high primary beam intensity*** (100 μA, 500 MeV, p)
Delivering RIBs since 1999.

Programs in

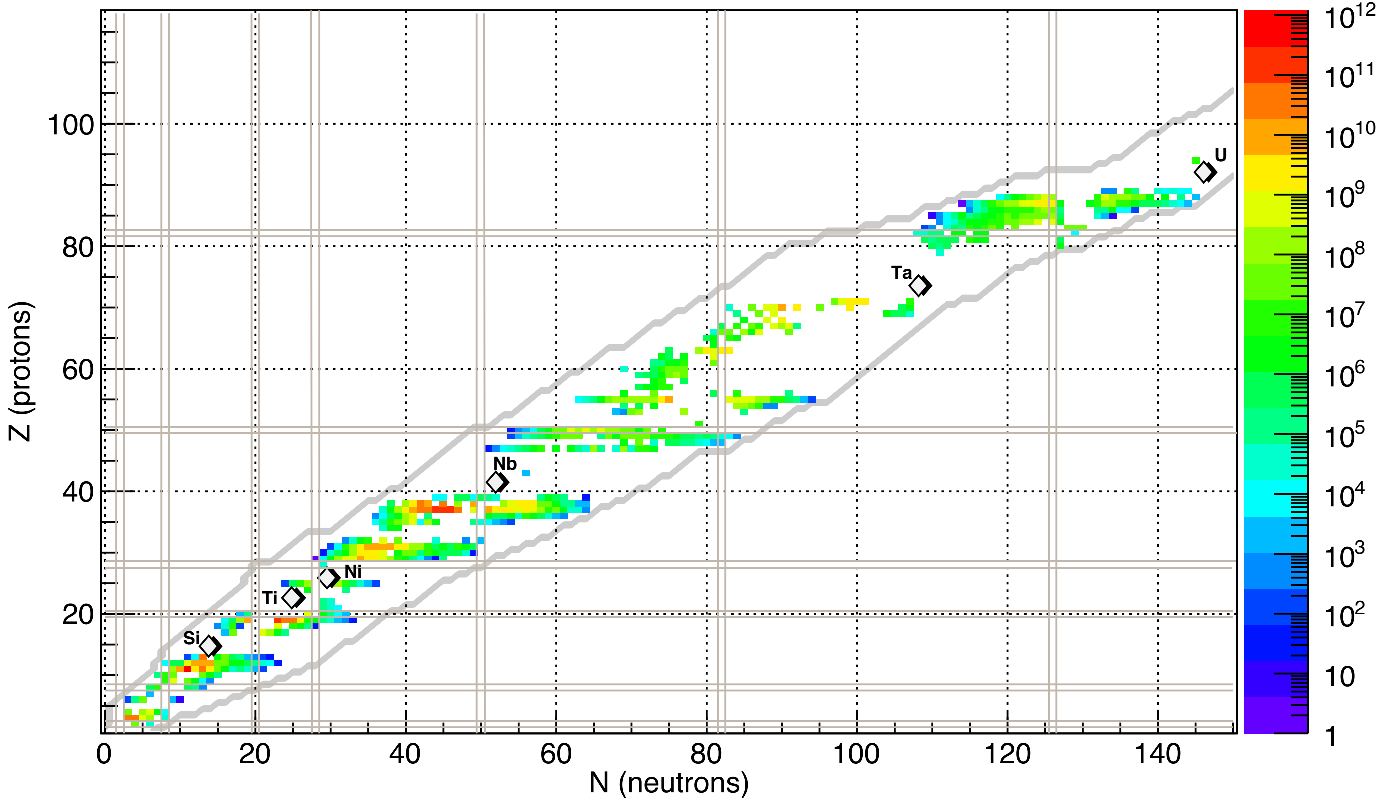
- Nuclear Structure & Dynamics
- Nuclear Astrophysics
- Electroweak Interaction Studies
- Material Science
- 18 permanent experiments

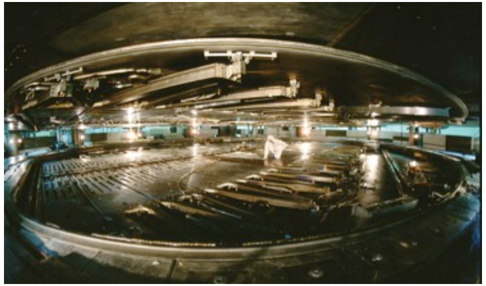


TRIUMF

ISAC rare isotope facility

Isotopes delivered at ISAC (P.Kunz, Updated June 2016)



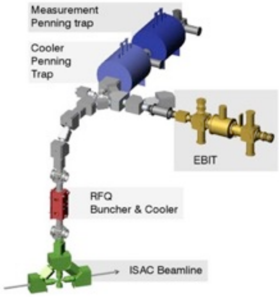


Target materials:
SiC, TiC, NiO, Nb, ZrC, Ta, U

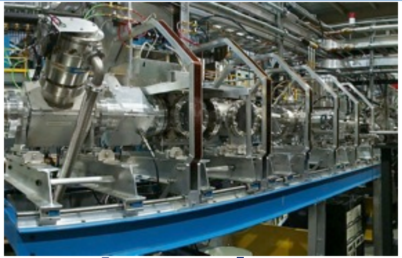
Ion sources:
Surface, FEBIAD, IG-LIS

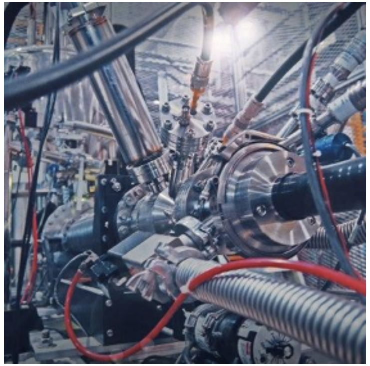
ISAC experimental areas

Low energy RIBs
< 60 keV

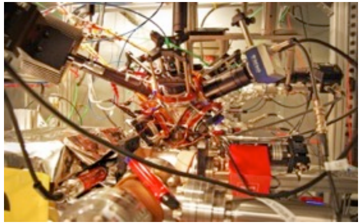


TITAN
Penning Traps
(masses,
in-trap decay)



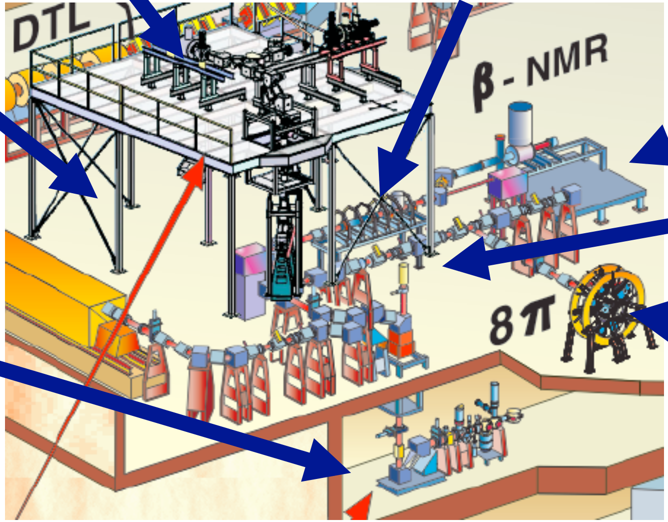


FRANCIUM MOT
(PNC, anapole moment)

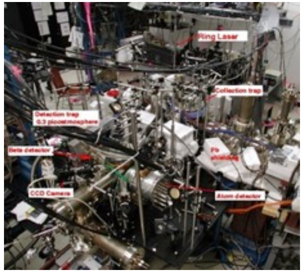


Polarizer beamline
Laser spectroscopy, MTV
CPT test, betaNMR

Beta-NMR
Material science

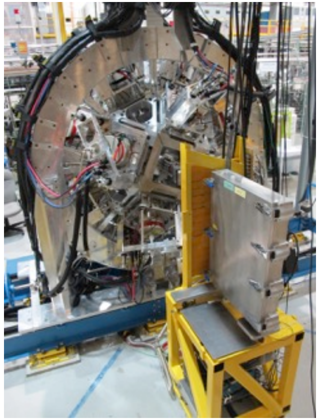


TRINAT
Neutral Atom Trap
(βν-neutrino correlations)



GPS
Beta counter
(superallowed
decays)

GRIFFIN
Gamma & Electron
spectrometer
(decay spectroscopy,
superallowed decays)

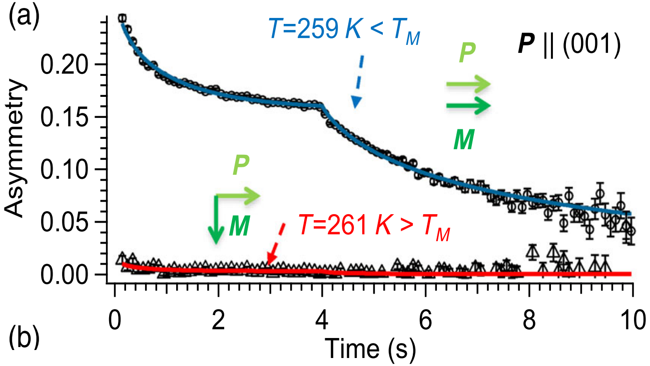


β-NMR Investigation of the Depth-Dependent Magnetic Properties of an Antiferromagnetic Surface

PRL **116**, 106103 (2016) PHYSICAL REVIEW LETTERS week ending 11 March 2016

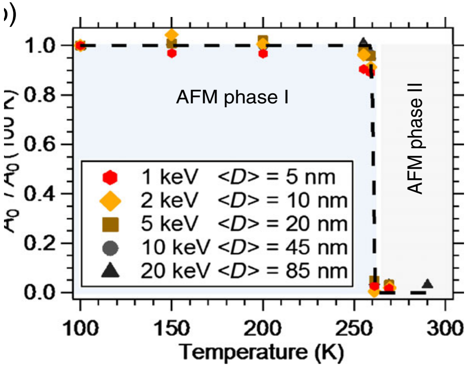
D. L. Cortie, T. Buck, M. H. Dehn, V. L. Karner, R. F. Kiefl, C. D. P. Levy, R. M. L. McFadden, G. D. Morris, I. McKenzie, M. R. Pearson, X. L. Wang, and W. A. MacFarlane

(a)

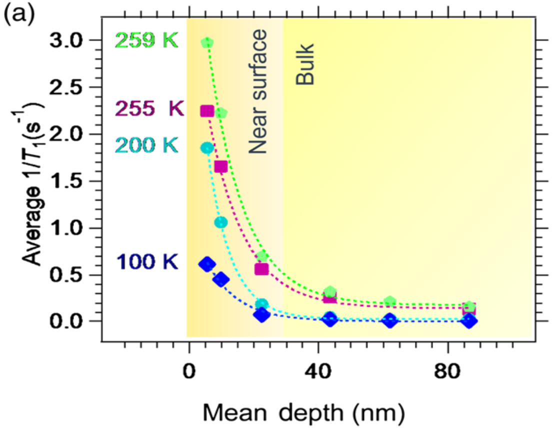


β-NMR was used to study the depth dependence of the Morin spin reorientation transition in α-Fe_2O_3 (hematite). The surface-localized dynamics decay towards the bulk with a characteristic length of 11 nm, indicating the presence of soft surface magnons.

(b)

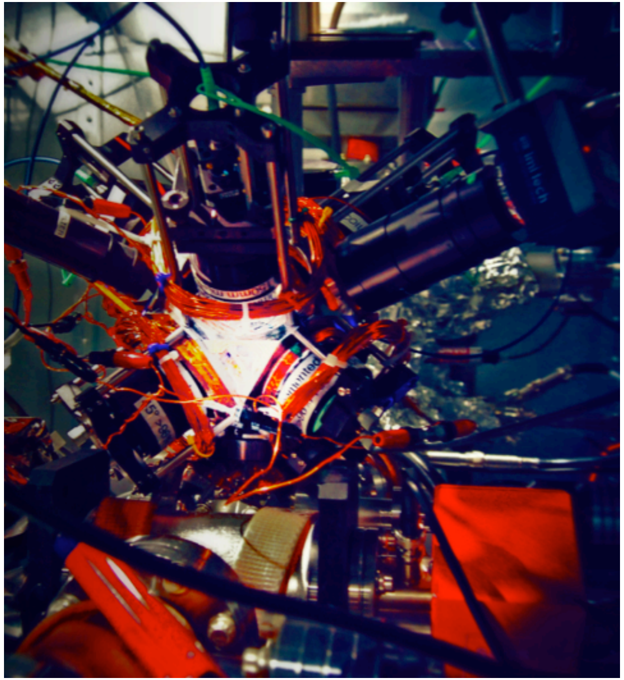


(a)



PRL 115, 042501 (2015) PHYSICAL REVIEW LETTERS week ending 24 JULY 2015

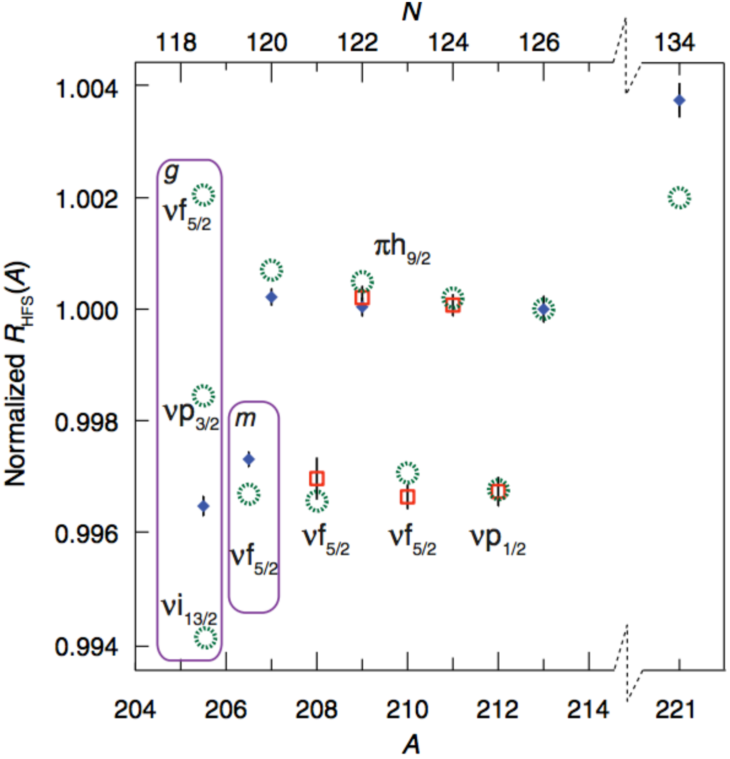
Hyperfine Anomalies in Fr: Boundaries of the Spherical Single Particle Model



Goal is the measure parity-violating anapole moments.

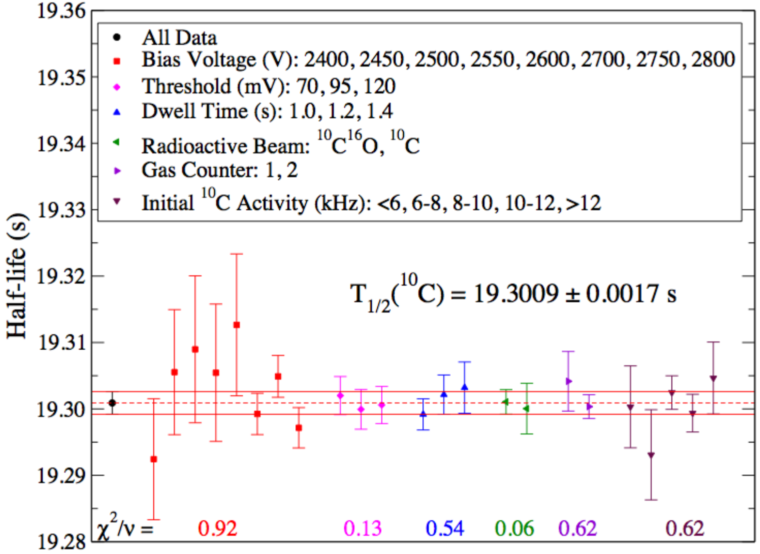
Essential to understand all nuclear contributions, such as finite magnetic and charge distributions.

Hyperfine splitting of $7P_{1/2}$ state in Fr isotopes.



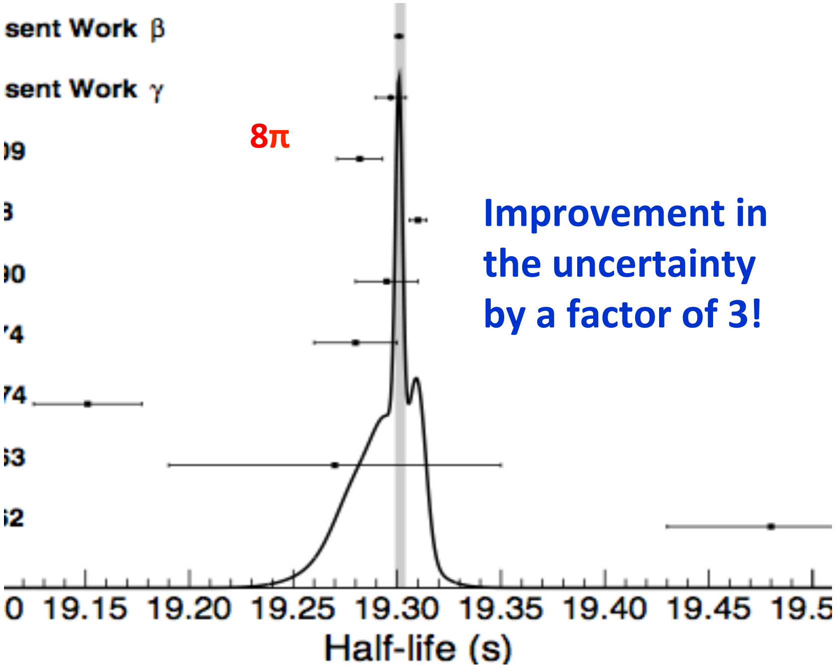
High-precision half-life of ^{10}C: β-counting at GPS

β-counting systematics



$T_{1/2,\beta}(^{10}C) = 19.3009 \pm 0.0017$ s

The most precise (0.009%) superallowed $T_{1/2}$ reported to date!

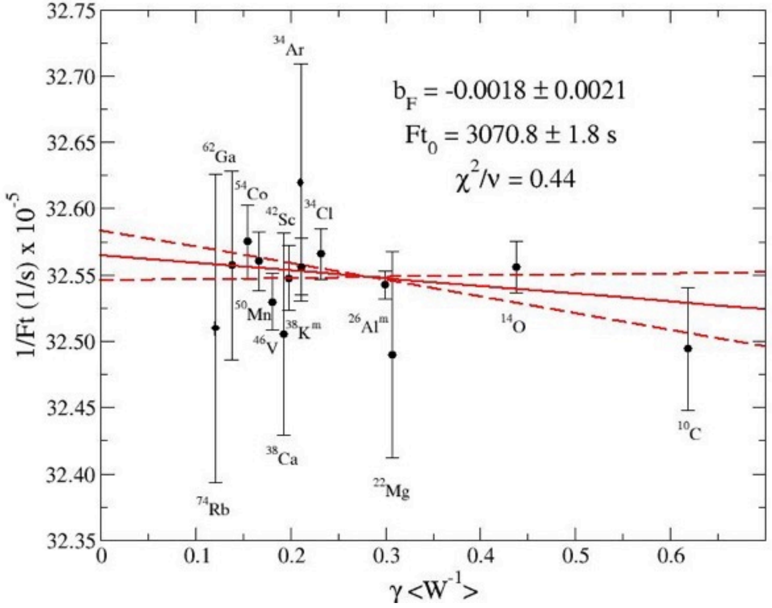


Improvement in the uncertainty by a factor of 3!

M.R. Dunlop et al., Phys. Rev. Lett. 116, 172501 (2016)

Updated Scalar Current Limits from the World Superallowed β Decay Data: b_F = -0.0018 (21)

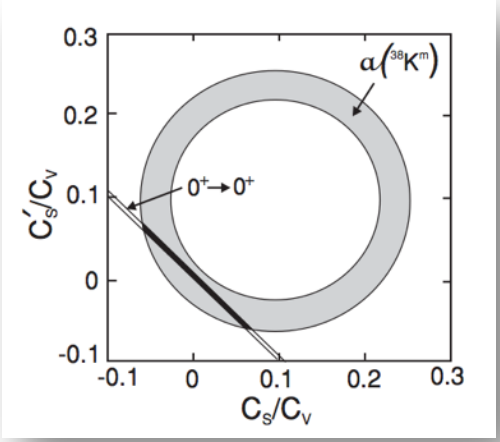
$C_S/C_V = -b_F/2 = +0.0009 \pm 0.0011$ (for $C_S = C_S'$)



M.R. Dunlop et al., Phys. Rev. Lett. 116, 172501 (2016)

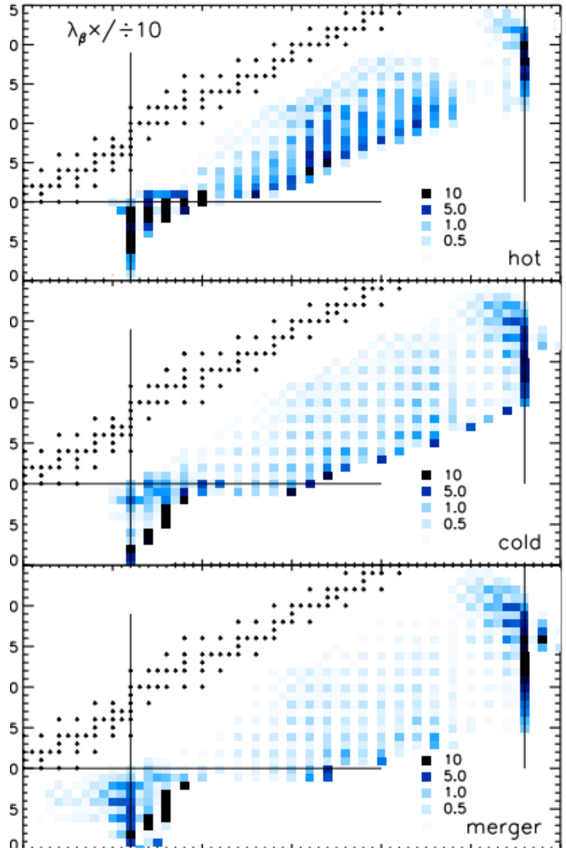
For a general C_S and C_S', the β−ν angular correlation coefficient from ^{38m}K decay provides an independent constraint:

$-0.065 \leq C_S/C_V, \; C_S'/C_V \leq 0.065$



A. Gorelov et al., Phys. Rev. Lett. 94, 142501 (2005)

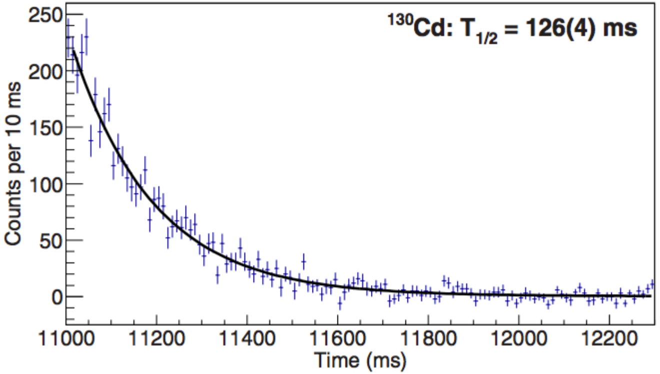
GRIFFIN: ^{128,129,130}Cd β-decay

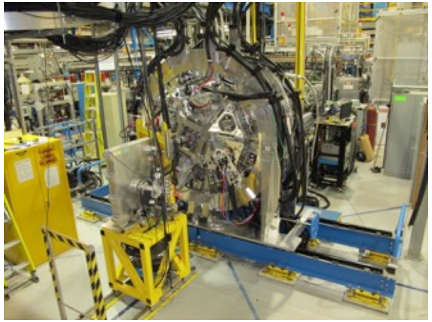


PHYSICAL REVIEW C **93**, 062801(R) (2016)

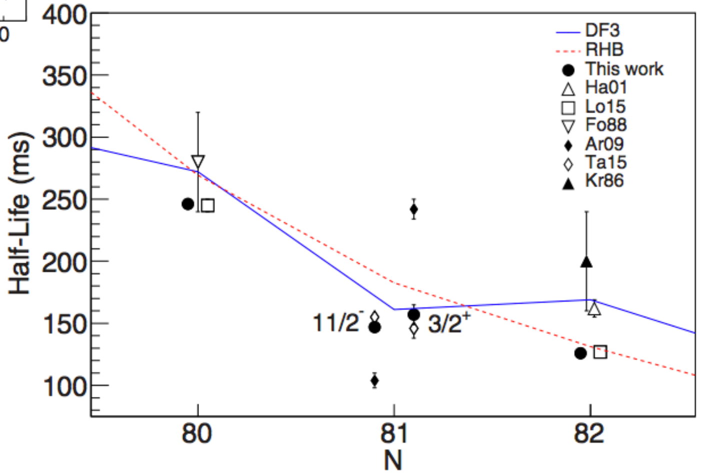
RAPID COMMUNICATIONS

Half-lives of neutron-rich $^{128–130}$Cd





Measurement of decay half lives and properties are important for astrophysical r-process calculations

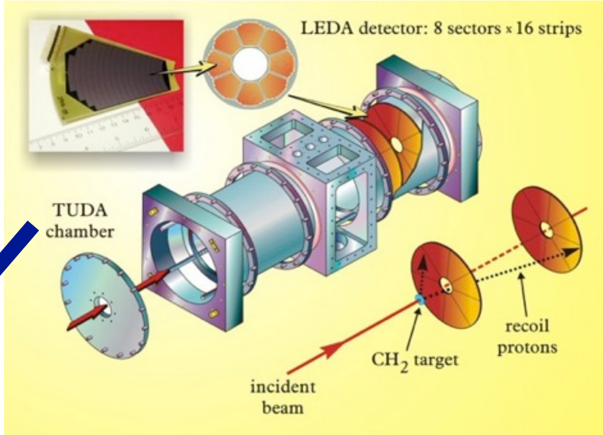


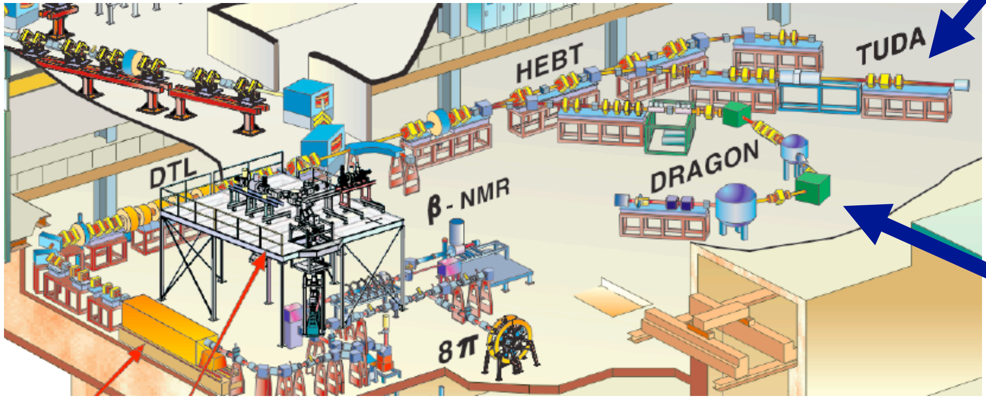
G. Lorusso et al. PRL 114 192501 (2015)
M. Mumpower *et al.*, Prog.Part.Nucl.Phys. 86, 86 (2016)

ISAC experimental areas

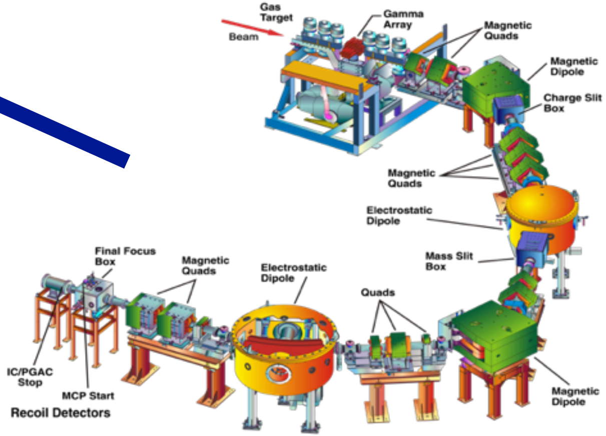
Medium energy RIBs
~ 0.15 -1.7 AMeV

TUDA
Astrophysical charged particle reactions



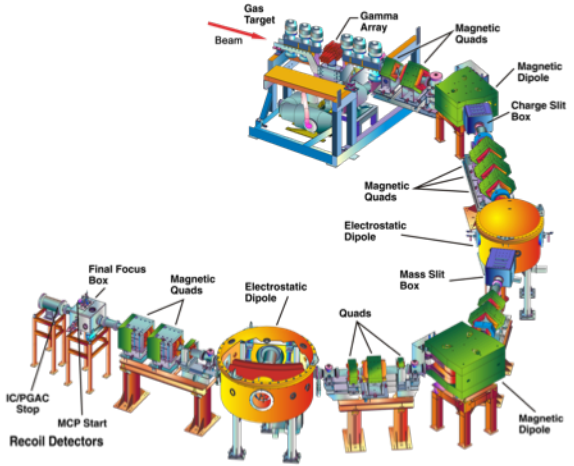


DRAGON
Astrophysical capture reactions



Successful program at DRAGON

TRIUMF



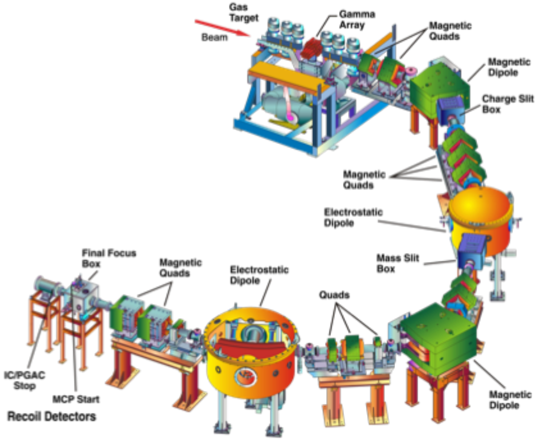
Reaction	Motivation	Intensity (s^{-1})	Purity (beam:cont.)
^{21}Na(p,γ)^{22}Mg	1.275 MeV line emission in ONe novae	5×10^{9}	100%
^{12}C(α,γ)^{16}O	Helium burning in red giants	6×10^{11}	
^{26g}Al(p,γ)^{27}Si	Nova contribution to galactic ^{26}Al	3×10^{9}	30,000:1
^{12}C(^{12}C$,\gamma$)^{24}Mg	Nuclear cluster models	3×10^{11}	
^{40}Ca(α,γ)^{44}Ti	Production of ^{44}Ti in SNII	3×10^{11}	10,000:1 – 200:1
^{23}Mg(p,γ)^{24}Al	1.275 MeV line emission in ONe novae	5×10^{7}	1:20 – 1:1,000
^{17}O(α,γ)^{21}Ne	Neutron poison in massive stars	1×10^{12}	
^{18}F(p,γ)^{19}Ne	511 keV line emission in ONe novae	2×10^{6}	100:1
^{33}S(p,γ)^{34}Cl	S isotopic ratios in nova grains	1×10^{10}	
^{16}O(α,γ)^{20}Ne	Stellar helium burning	1×10^{12}	
^{17}O(p,γ)^{18}F	Explosive hydrogen burning in novae	1×10^{12}	
^{3}He(α,γ)^{7}Be	Solar neutrino spectrum	5×10^{11}	
^{58}Ni(p,γ)^{59}Cu	High mass tests (p-process, XRB)	6×10^{9}	
^{26m}Al(p,γ)^{27}Si	SNII contribution to galactic ^{26}Al	2×10^{5}	1:10,000
^{38}K(p,γ)^{39}Ca	Ca/K/Ar production in novae	2×10^{7}	1:1
^{19}Ne(p,γ)^{20}Na	^{19}F abundance in nova ejecta	2×10^{7}	1:1 to 4:1
^{22}Ne(p,γ)^{23}Na	NeNa cycle; explosive H burning in classical novae	2×10^{12}	

7 RIB
10 Stable beam

DRAGON: ^{38}K(p,γ)^{39}Ca

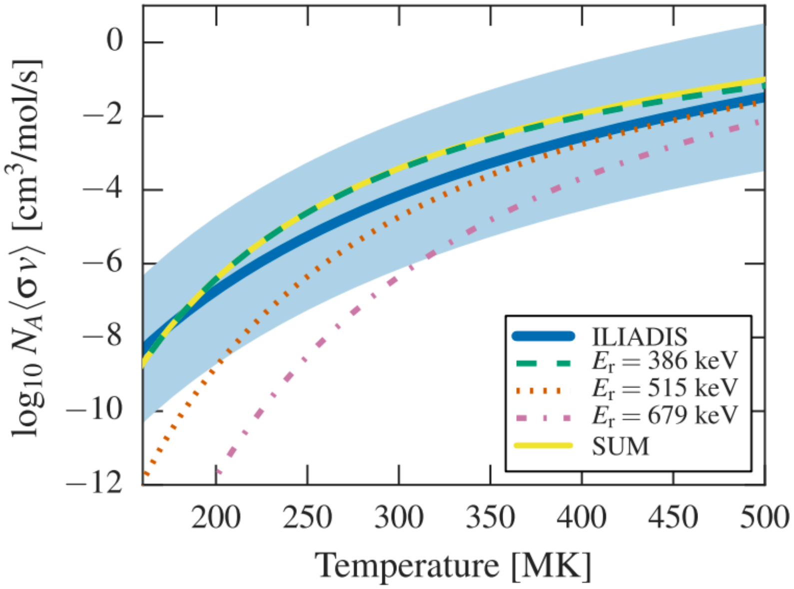
PRL **116**, 132701 (2016) PHYSICAL REVIEW LETTERS week ending 1 APRIL 2016

Direct Measurement of the Astrophysical ^{38}K(p,γ)^{39}Ca Reaction and Its Influence on the Production of Nuclides toward the End Point of Nova Nucleosynthesis



First experimental measurement of this reaction rate.

Constrains the rate of ^{38}K(p,γ)^{39}Ca in ONe nova and significantly reduces uncertainty in ^{38}Ar and ^{40}Ca abundances.



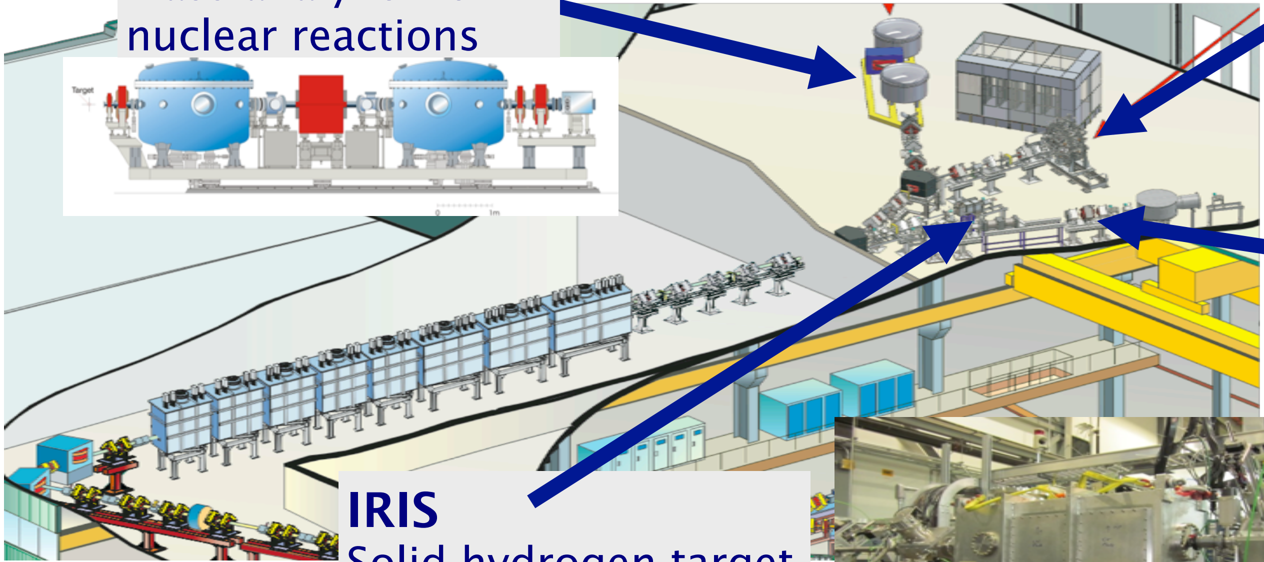
First charge-bred beam to DRAGON. Heaviest RIB direct radiative capture measurement.

ISAC experimental areas

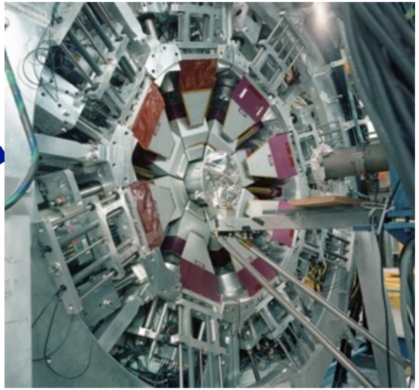
High-energy RIBs
> 6 AMeV

TIGRESS + **auxiliary detectors**

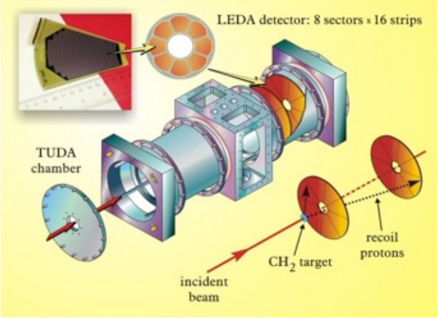
HPGe γ–ray spectrometer
in–beam spectroscopy of nuclear reactions



EMMA (2016)
Mass analyzer for nuclear reactions



TUDA
Scattering array for direct reactions



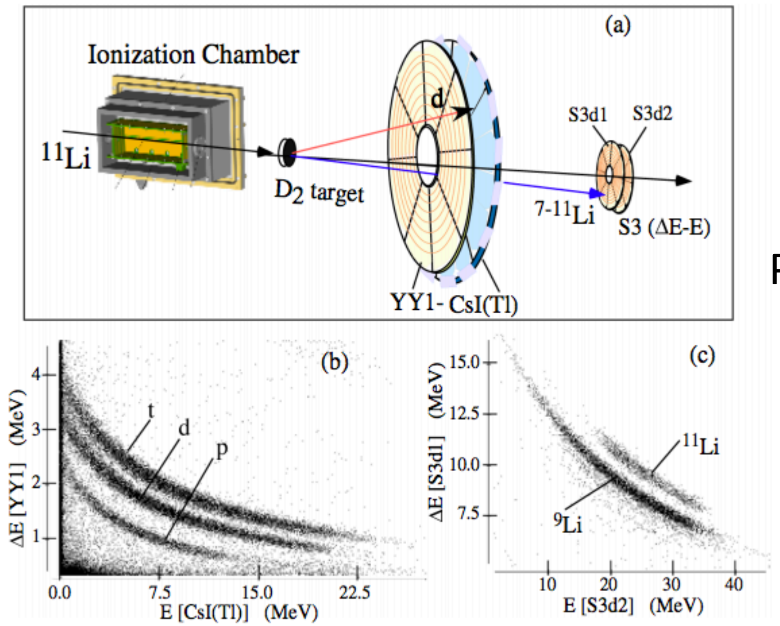
IRIS
Solid hydrogen target for direct nuclear reactions

IRIS: d(^{11}Li,d')^{11}Li'

PRL 114, 192502 (2015) PHYSICAL REVIEW LETTERS week ending 15 MAY 2015

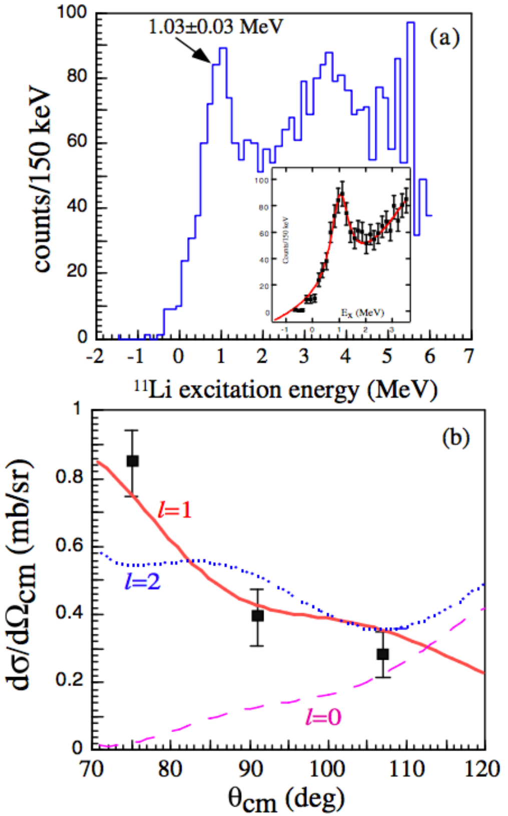
Evidence of Soft Dipole Resonance in ^{11}Li with Isoscalar Character

R. Kanungo, A. Sanetullaev *et al.*



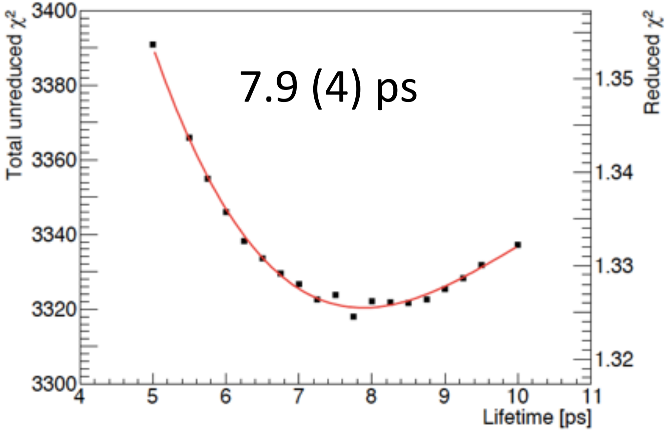
First evidence of a dipole resonance in ^{11}Li having an isoscaler character.

Provides stringent tests of *ab initio* theories and nuclear forces.

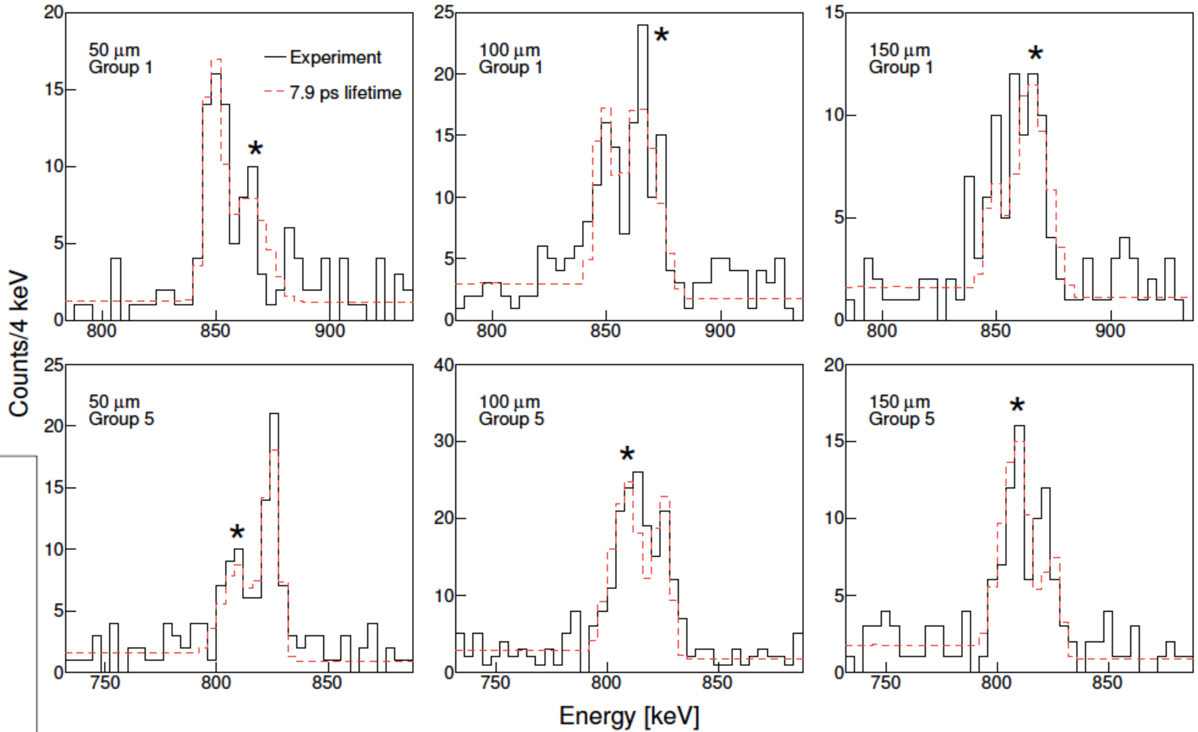


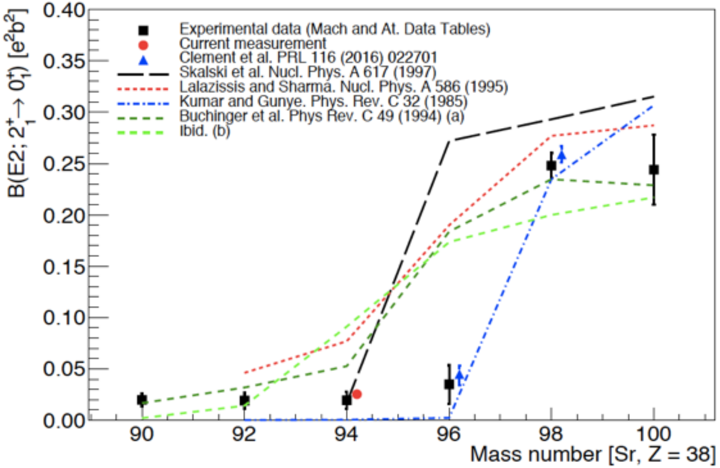
TRIUMF

TIGRESS Integrated Plunger



First 2^+ state populated in unsafe Coulex of ^{94}Sr beam

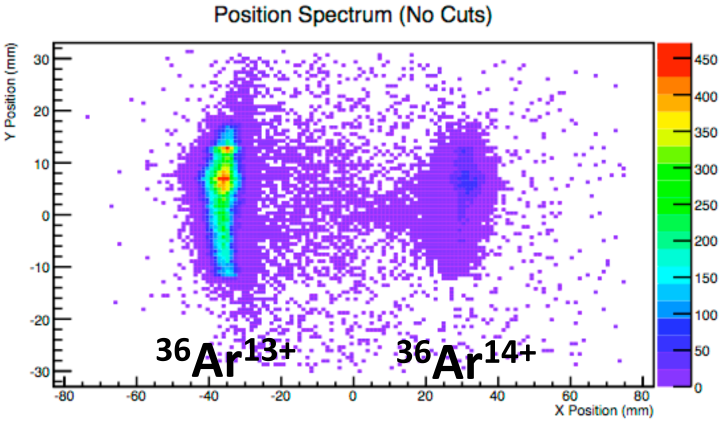


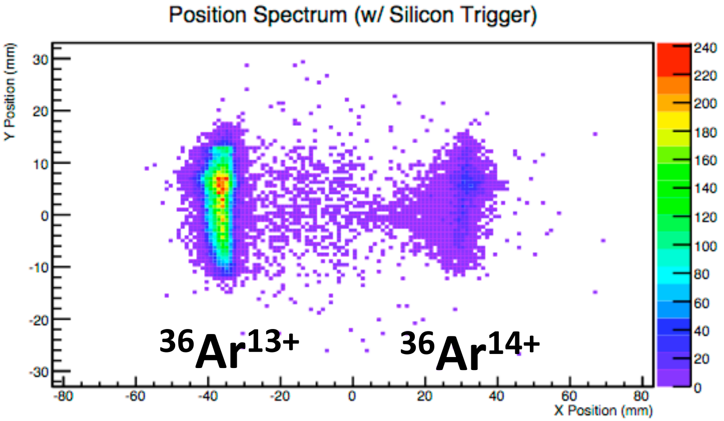


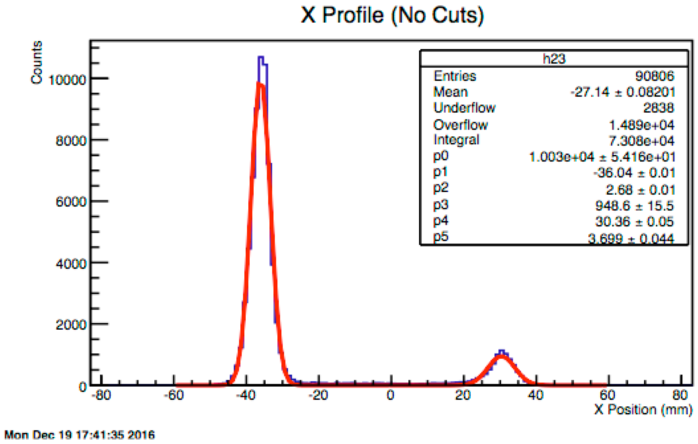
- Improves uncertainty in the *B(E2)* value from 40% to <6%.
- Confirms sudden onset of deformation in ground-state structure. *Submitted to PRL.*

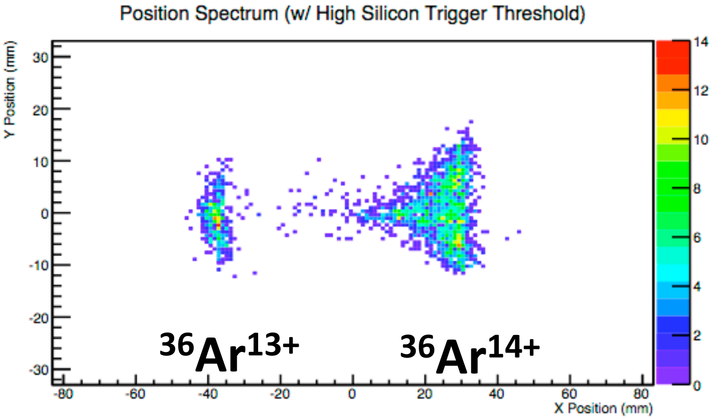
TRIUMF

EMMA has been commissioned!



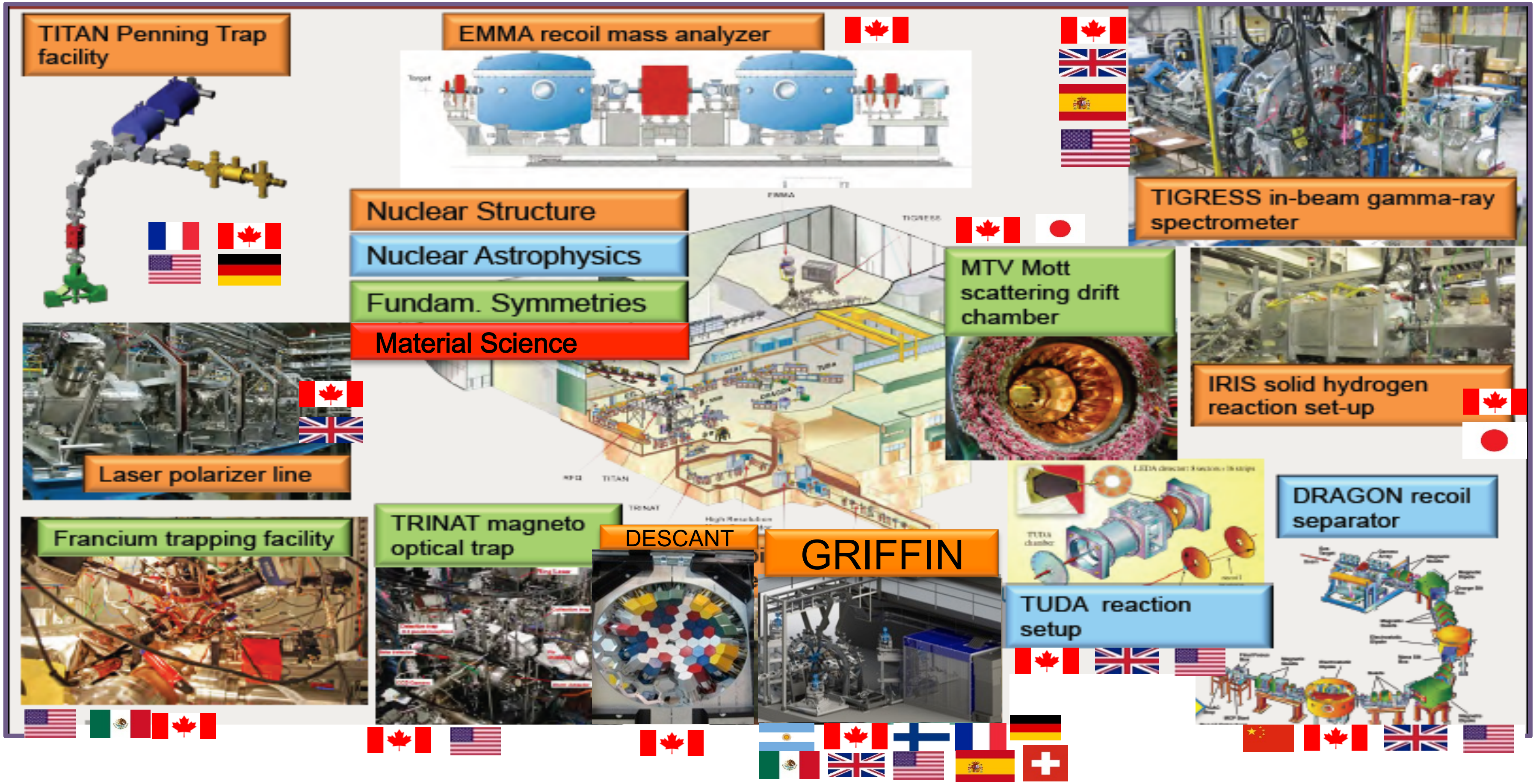






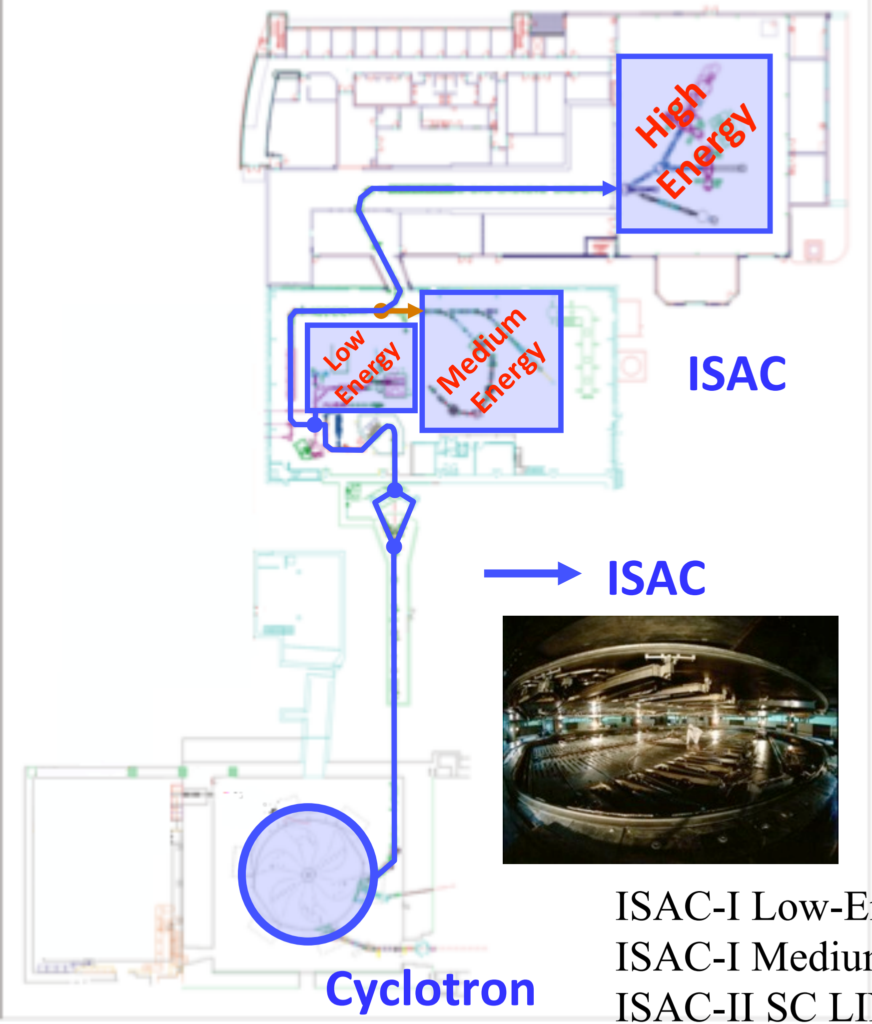
Beam suppression $>10^{12}$

Experimental facilities and programs of ISAC



TRIUMF-ISAC

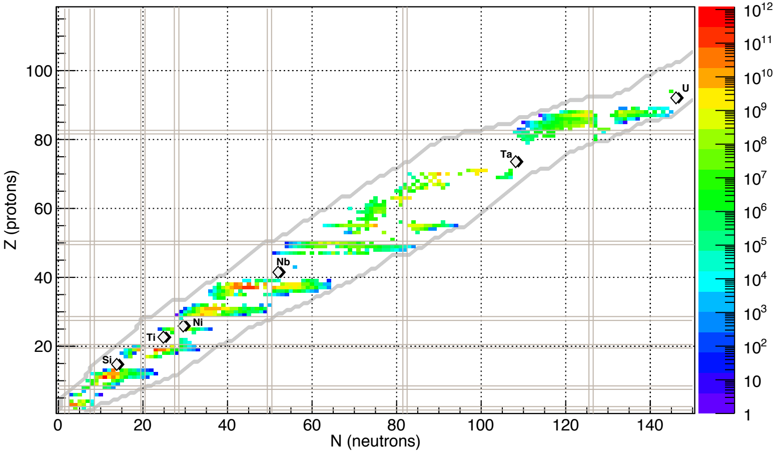
Isotope Separator and ACcelerator



1 RIB delivery to experiments

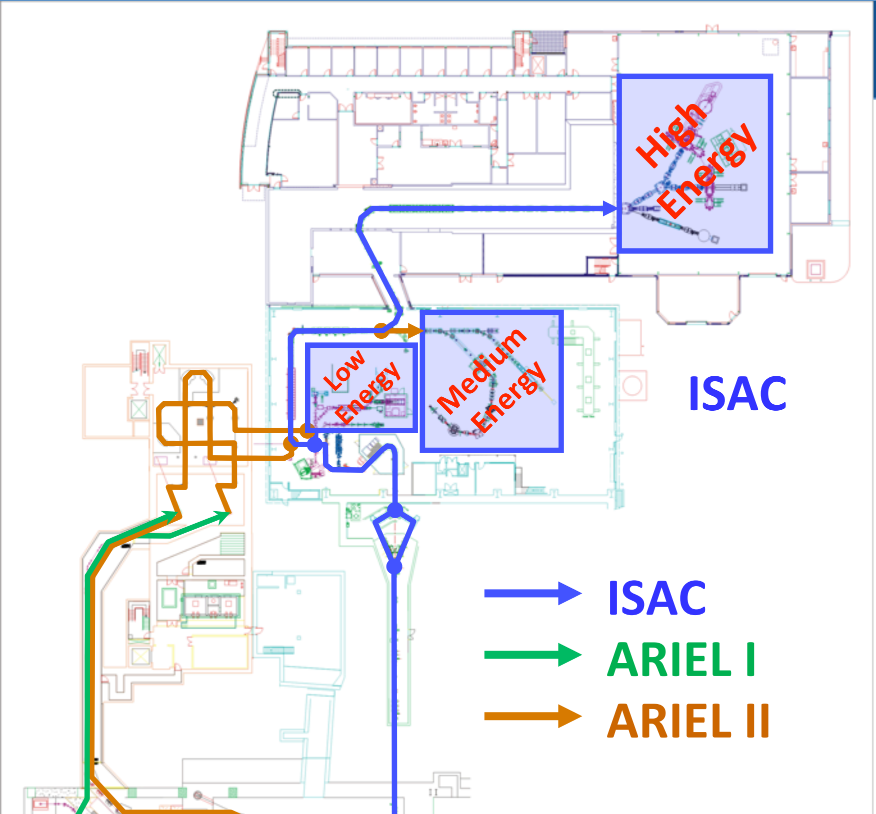
500MeV p^+ at 100μA on ISOL target

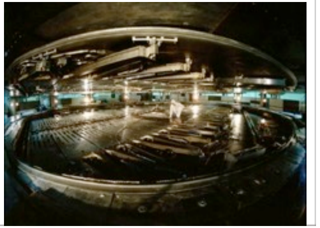
SiC, NiO, Nb, ZrC, Ta, UC_x Targets
Surface, FEBIAD, IG-LIS ion sources



ISAC-I Low-Energy <60keV — Ground state + decay, material science
ISAC-I Medium E <1.5MeV/u — Astrophysics
ISAC-II SC LINAC <10MeV/u — Nuclear reactions and structure

TRIUMF-ARIEL





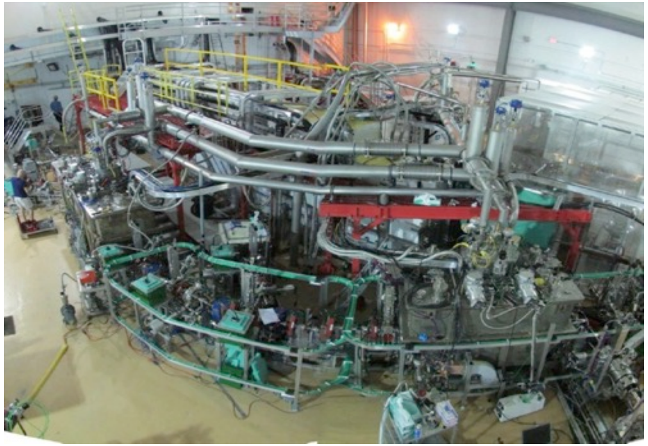
Advanced Rare-IsotopE Laboratory

1 RIB ➔ 3 simultaneous RIBs

ARIEL Project:

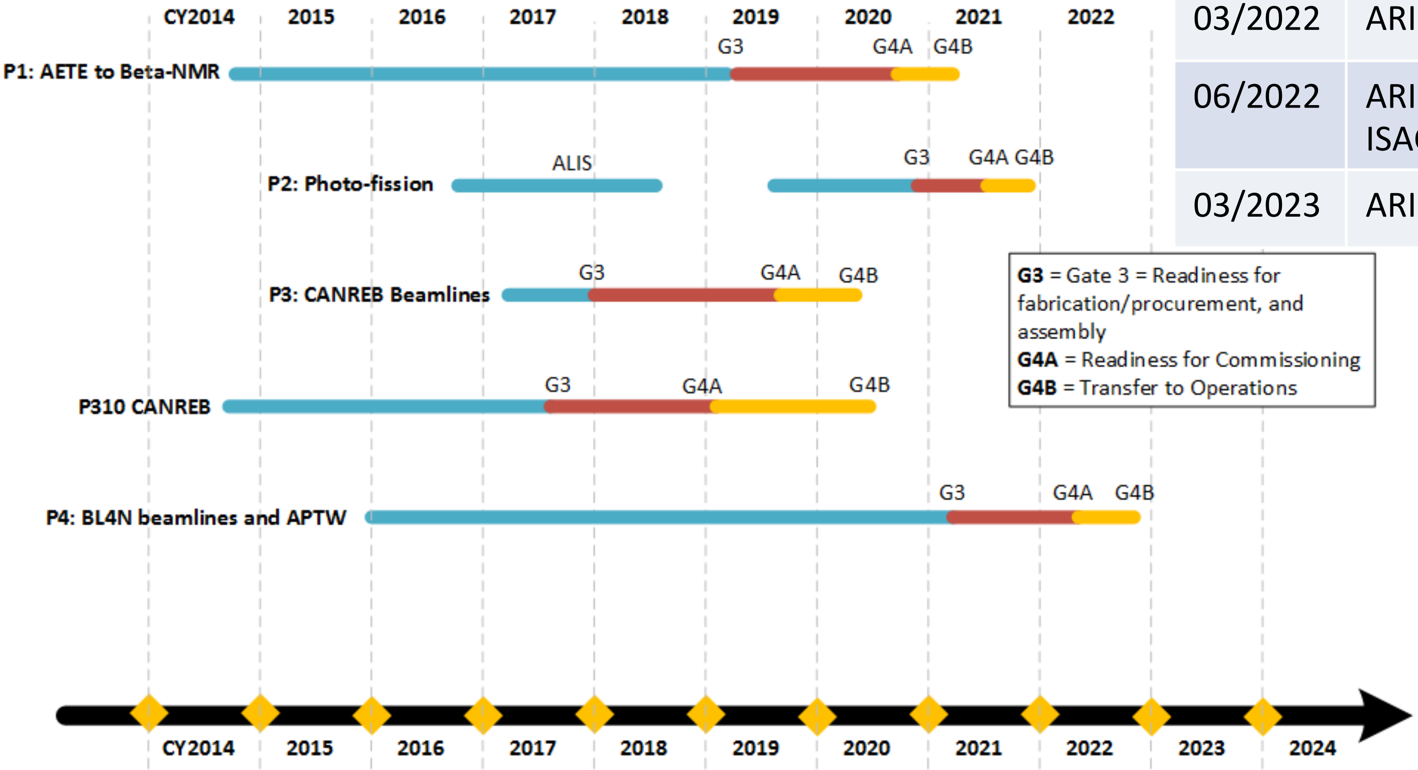
- new electron linac driver for photo-fission
- new proton beamline
- new target stations and front end

E-linac and electron beamline
Sept. 2014



ARIEL Completion to Science

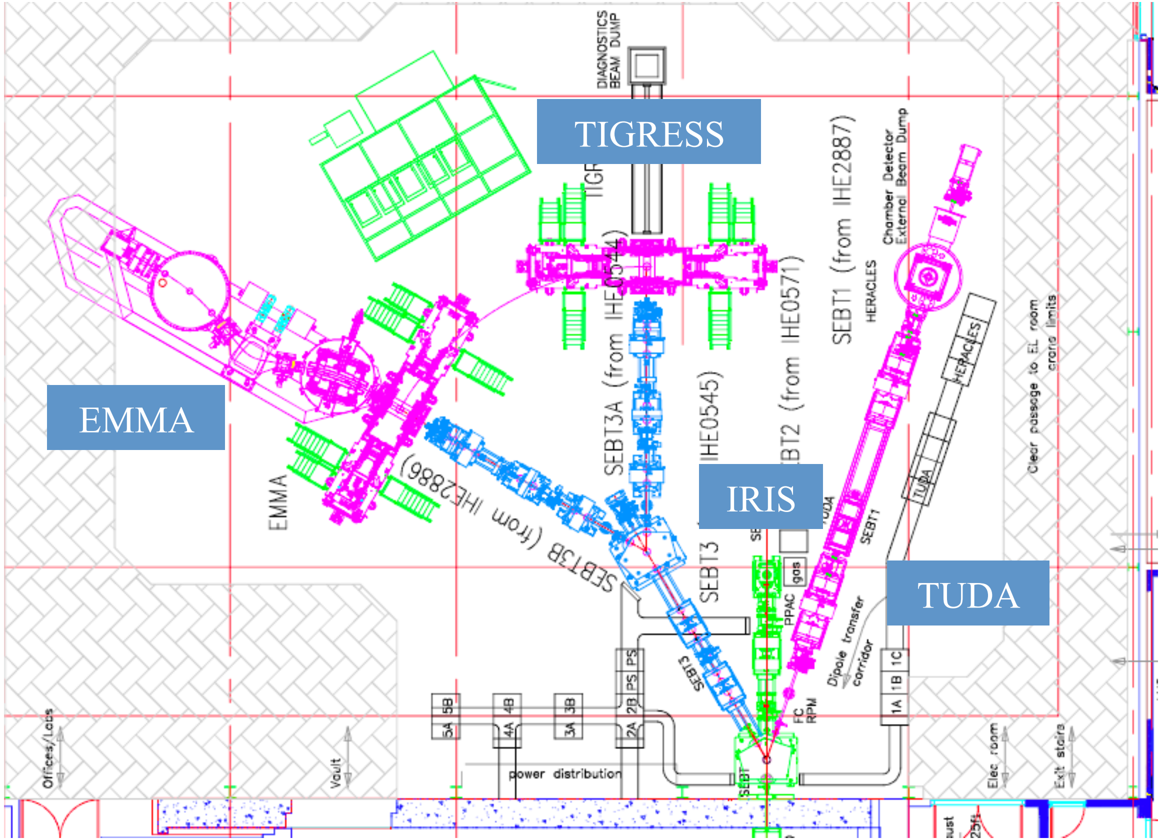
1999	Low-energy ISAC beams
10/2020	ISAC-CANREB-ISAC beams
03/2022	ARIEL beam to β-NMR
06/2022	ARIEL photo-fission beams to ISAC
03/2023	ARIEL spallation beams to ISAC



G3 = Gate 3 = Readiness for fabrication/procurement, and assembly
G4A = Readiness for Commissioning
G4B = Transfer to Operations

ISAC-CANREB-ISAC beams

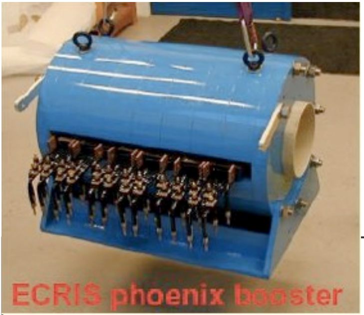
- Impact on accelerated beam program, primarily ISAC-II

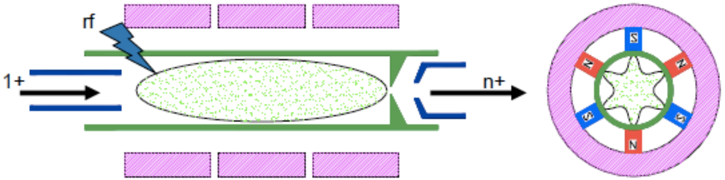


EMMA
IRIS
TIGRESS
TUDA-II

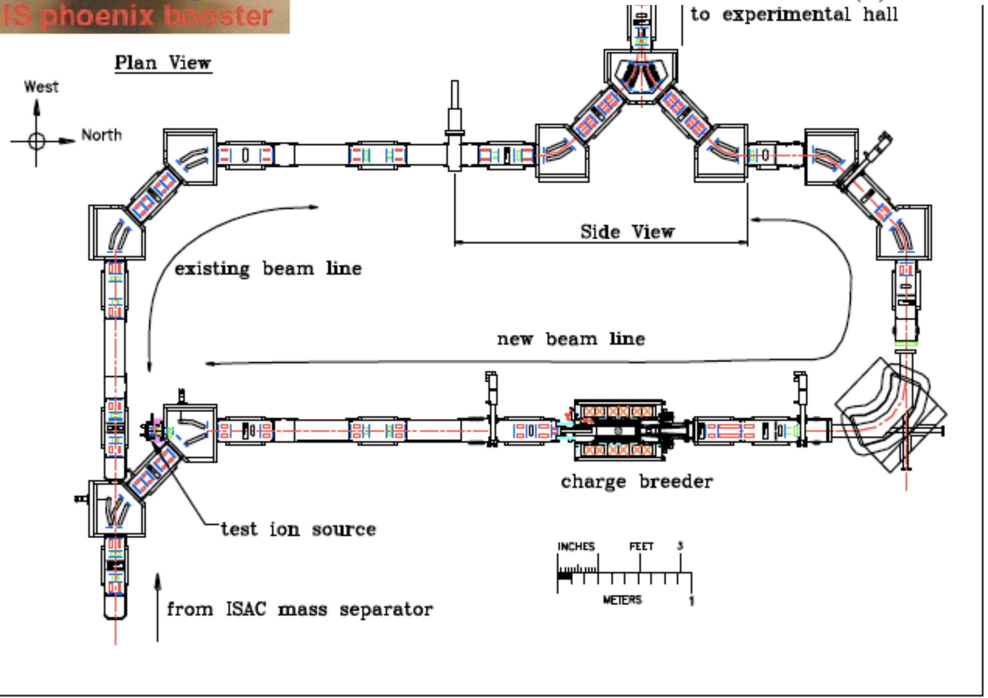
DRAGON
TUDA-I

ISAC-CANREB-ISAC beams





$$\omega_{rf} = \omega_c = \frac{q}{m(E)} B$$



Existing ISAC ECR CSB:

Modified 14.5 GHz PHOENIX ECR ion source from Pantechnik

Inject 1+ ions, extract n+ ions

Reduces A/q from <238 to <30 (7) for acceptance into RFQ (MEBT)

Advantages:
- Continuous output (DC beam)
- High intensity capability
- No pre-bunching/cooling required

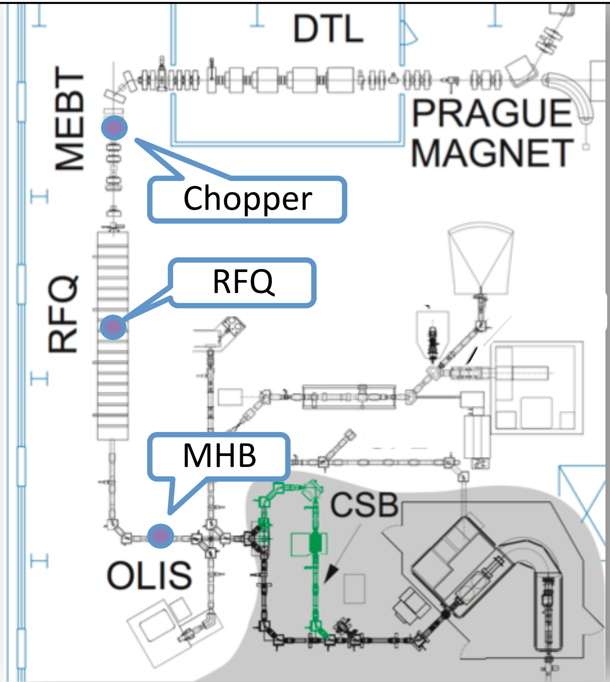
Issues:
- Efficiency <5%
- Stable backgrounds at all A/q

TRIUMF

ISAC-CANREB-ISAC beams

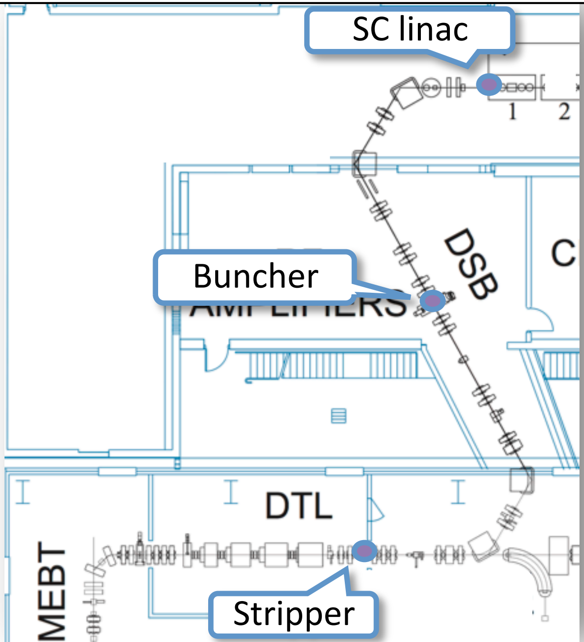
Stage 1:
CSB-LEBT-RFQ-MEBT-DTL

- Time-of-flight separation in LEBT
- Pre-buncher phase used to tune for selection
- Prague Diagnostic station used for setup
- Theoretical: 1/1000 resolution in A/q

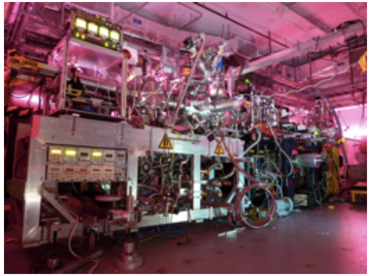


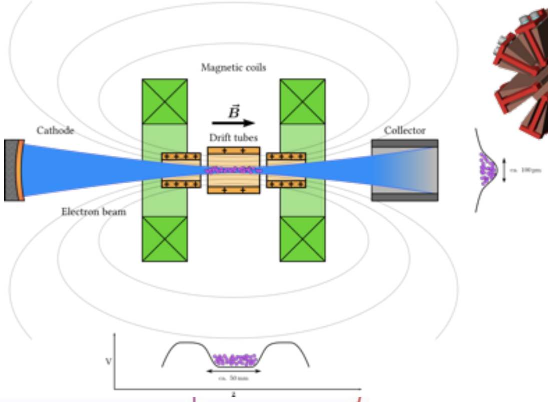
Stage 2 (**NOT ALWAYS REQUIRED**):
DSB-SCLINAC-SEBT-Experiment

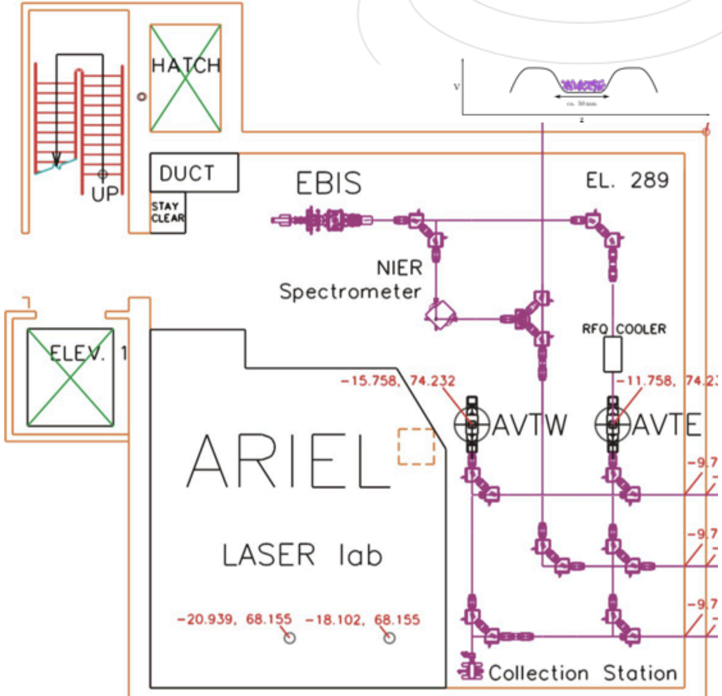
- Stripping foil at 1.5MeV/u
- Change in A/q and differential TOF
- DSB slits used for selection
- TBragg detector used for setup
- Theoretical: 1/800 resolution in A/q



ISAC-CANREB-ISAC beams







Future CANREB EBIS CSB:

Electron-Beam Ion Source built at Max-Plank Institute for Nuclear Physics, Heidelberg

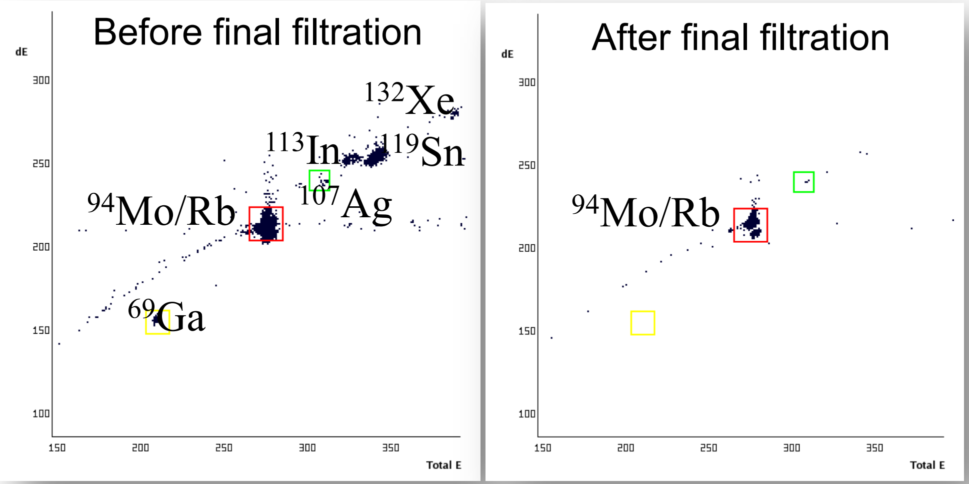
Inject cooled, bunched 1+ ions, extract bunched n+ ions

Reduces A/q from <238 to <30 (7) for acceptance into RFQ (MEBT)

Advantages:
-High Efficiency 10-20%
-High-purity beams

Issues:
-Need cooled and bunched injection
-Pulsed beam extraction

ISAC-CANREB-ISAC beams



Factor ~100 increase in charge-bred beam intensities.

Opportunities for the accelerated beam program

- Coulex: B(E2) ➔ Quadrupole moment
- Transfer reactions become feasible in some cases where they were not before
- Transfer: state identification ➔ precision

Call to Users:
What are the first experiments, science goals and priorities with CANREB charge-bred beams?

ARIEL beam to β-NMR

In-target production rates [1 $kW^{-1} \cdot s^{-1}$]:

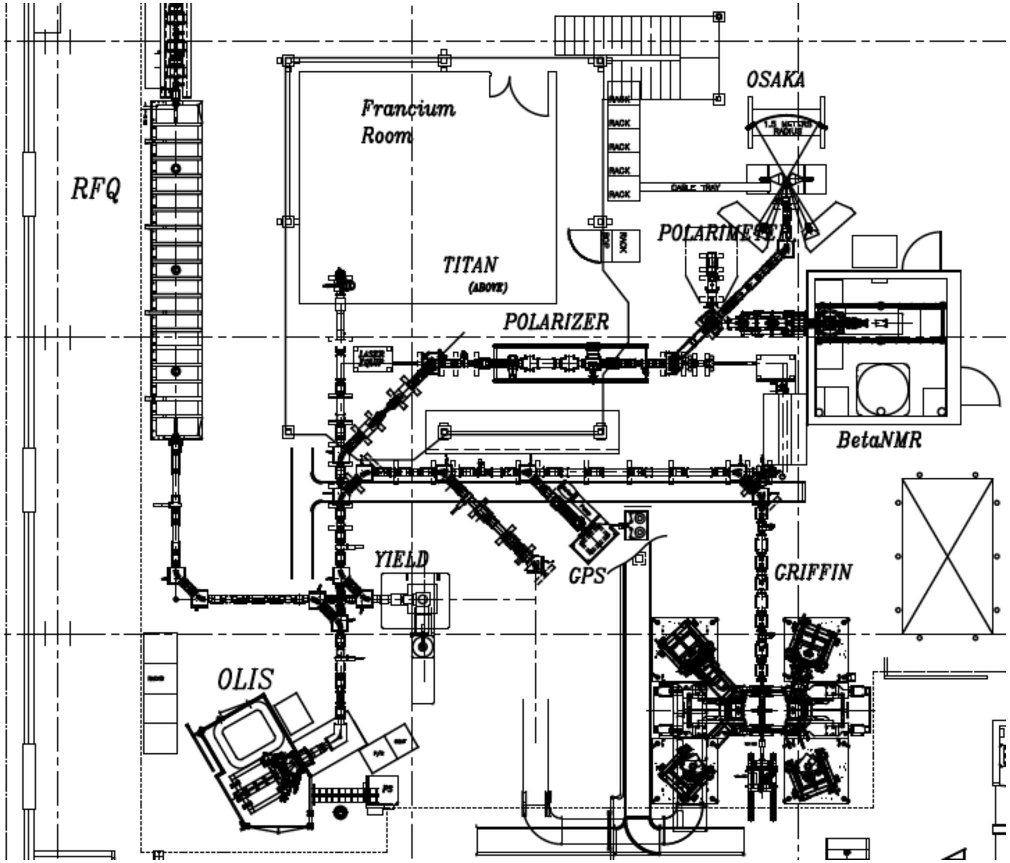
from BeO: ^{8}Li: $5 \cdot 10^{9}$ pps

- β-NMR currently ~6 weeks of ISAC schedule ➔ ~3 months of ARIEL beam
- This will not happen instantly. Access still required in ARIEL target hall for installation work

- Low-energy area is poorly laid out. When delivering to β-NMR from ARIEL:
  - cannot deliver to TITAN, Co-liner Laser Spec., OSAKA, MTV

- Increase in beam availability to β-NMR, GRIFFIN, GPS, Francium, DRAGON, ISAC-II

ARIEL beam to β-NMR

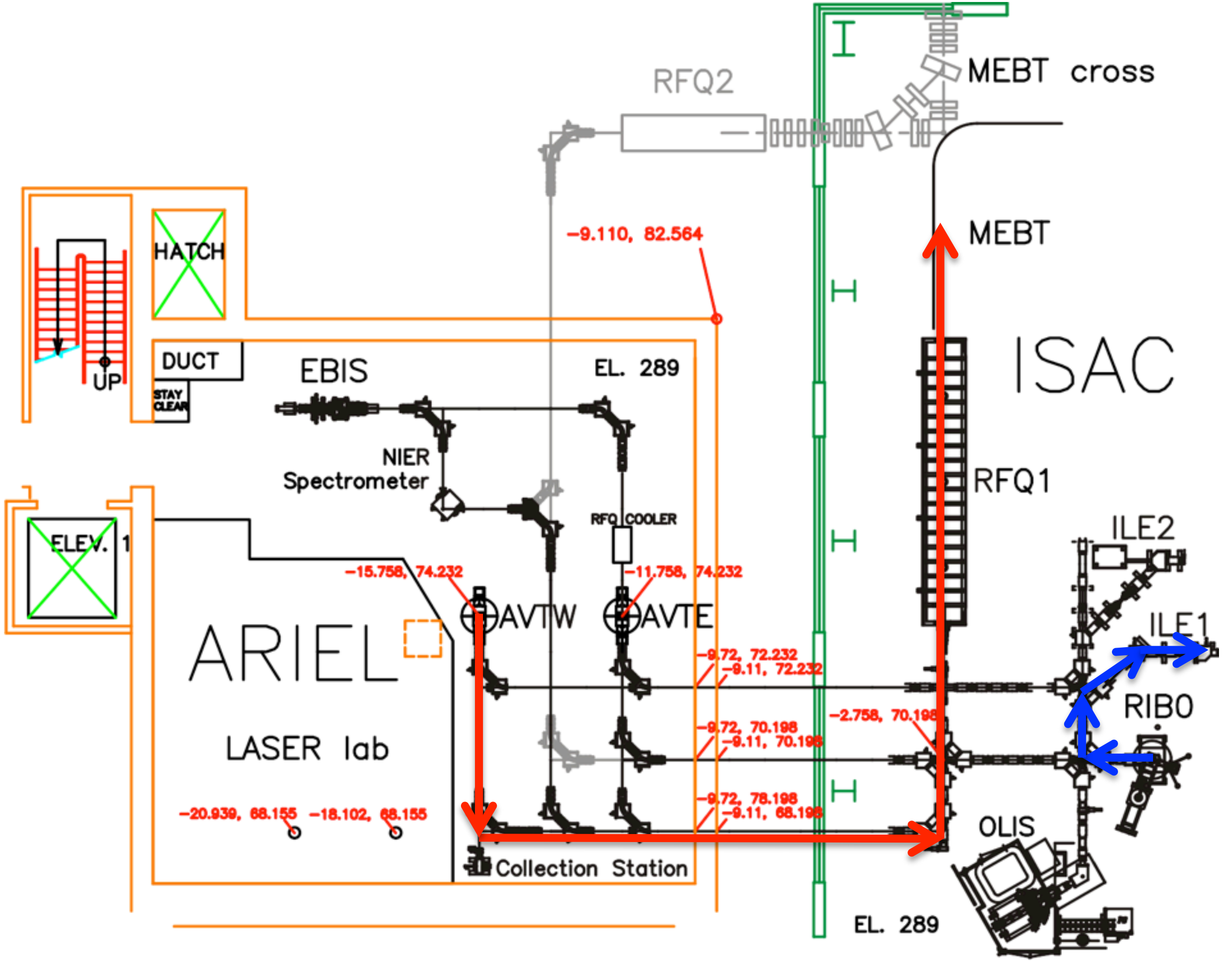


- Low-energy area is poorly laid out.

When delivering to β-NMR from ARIEL:

- cannot deliver to TITAN, Co-liner Laser Spec., OSAKA, MTV

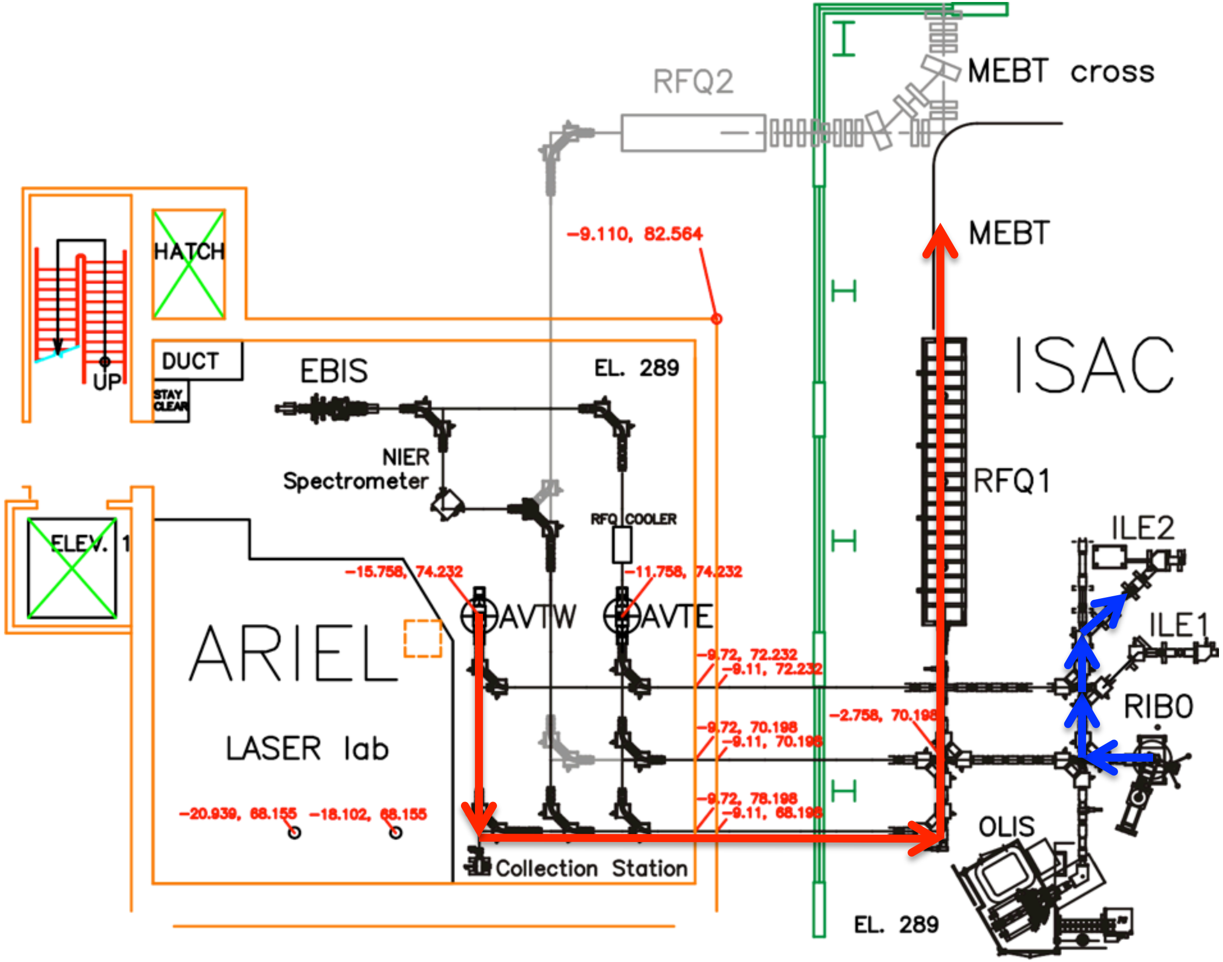
ISAC and ARIEL Beam Delivery



ISAC – LEBT
GPS, GRIFFIN

ARIEL – MEBT/SEBT
DRAGON, TUDA-I
EMMA, IRIS,
TIGRESS, TUDA-II

ISAC and ARIEL Beam Delivery



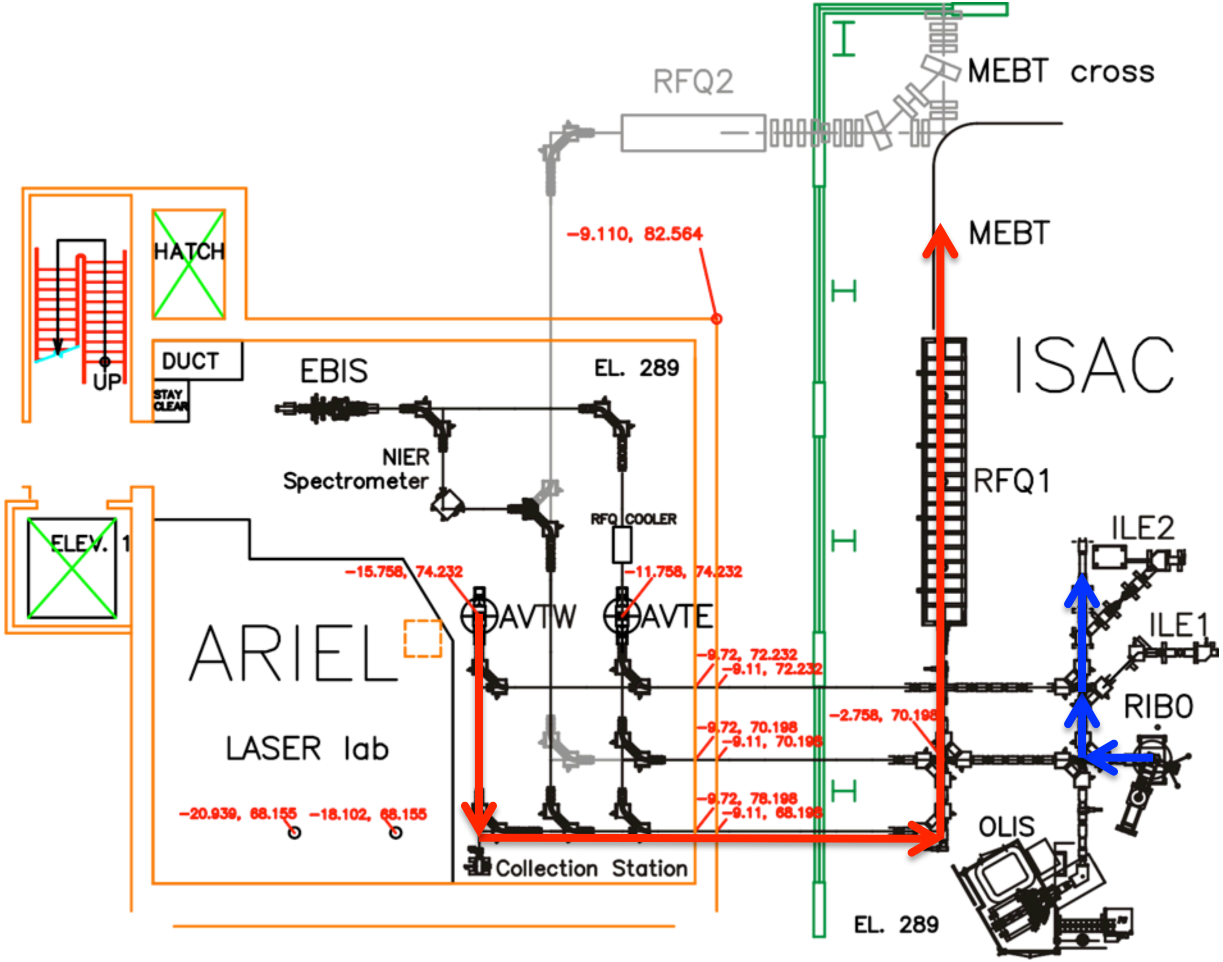
ISAC – LEBT

TITAN, Laser Spec., beta-NMR, OSAKA, MTV

ARIEL – MEBT/SEBT

DRAGON, TUDA-I
EMMA, IRIS,
TIGRESS, TUDA-II

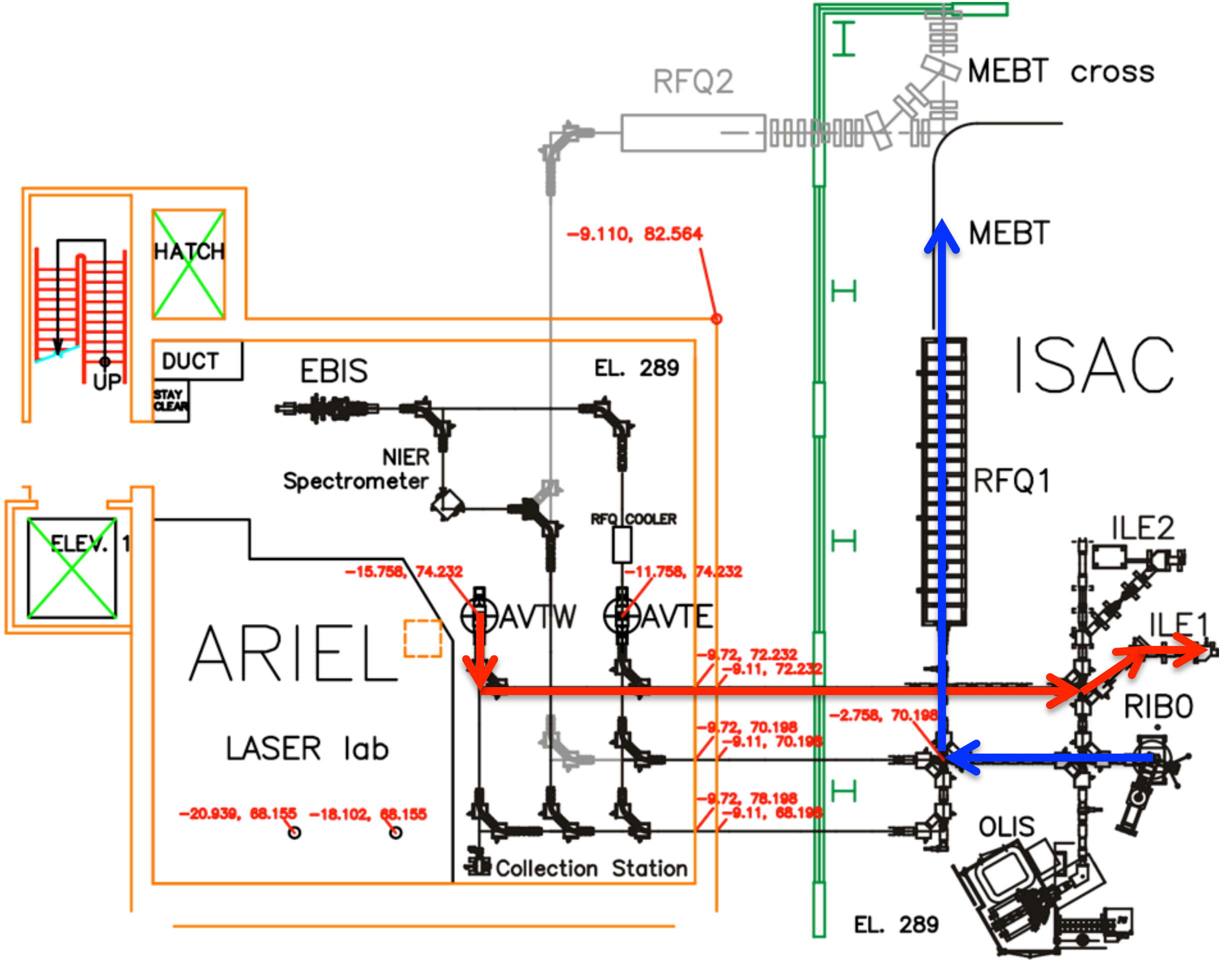
ISAC and ARIEL Beam Delivery



ISAC – LEBT
Francium

ARIEL – MEBT/SEBT
DRAGON, TUDA-I
EMMA, IRIS,
TIGRESS, TUDA-II

ISAC and ARIEL Beam Delivery



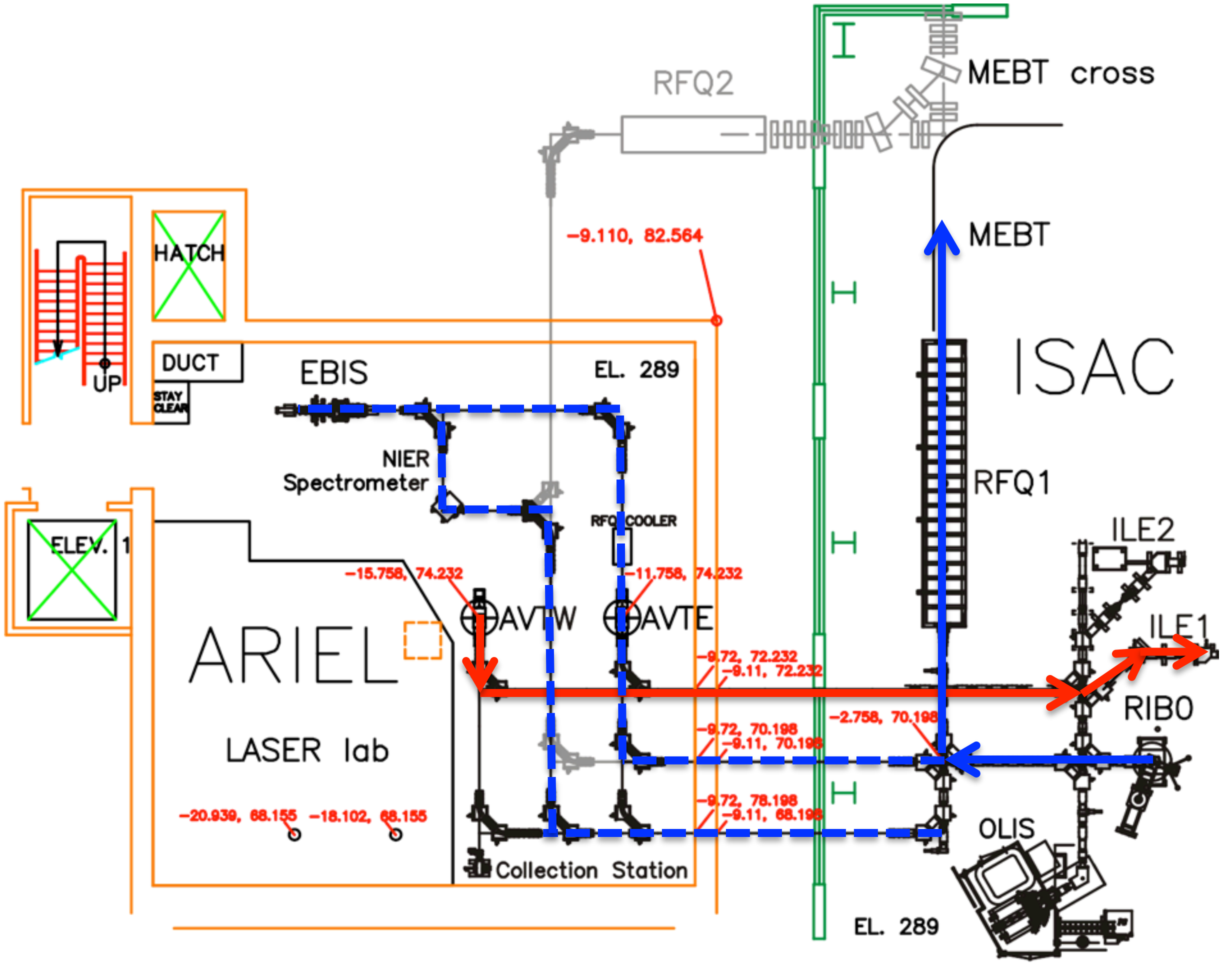
ISAC – LEBT

DRAGON, TUDA-I
EMMA, IRIS,
TIGRESS, TUDA-II

ARIEL – LEBT

GPS, GRIFFIN

ISAC and ARIEL Beam Delivery



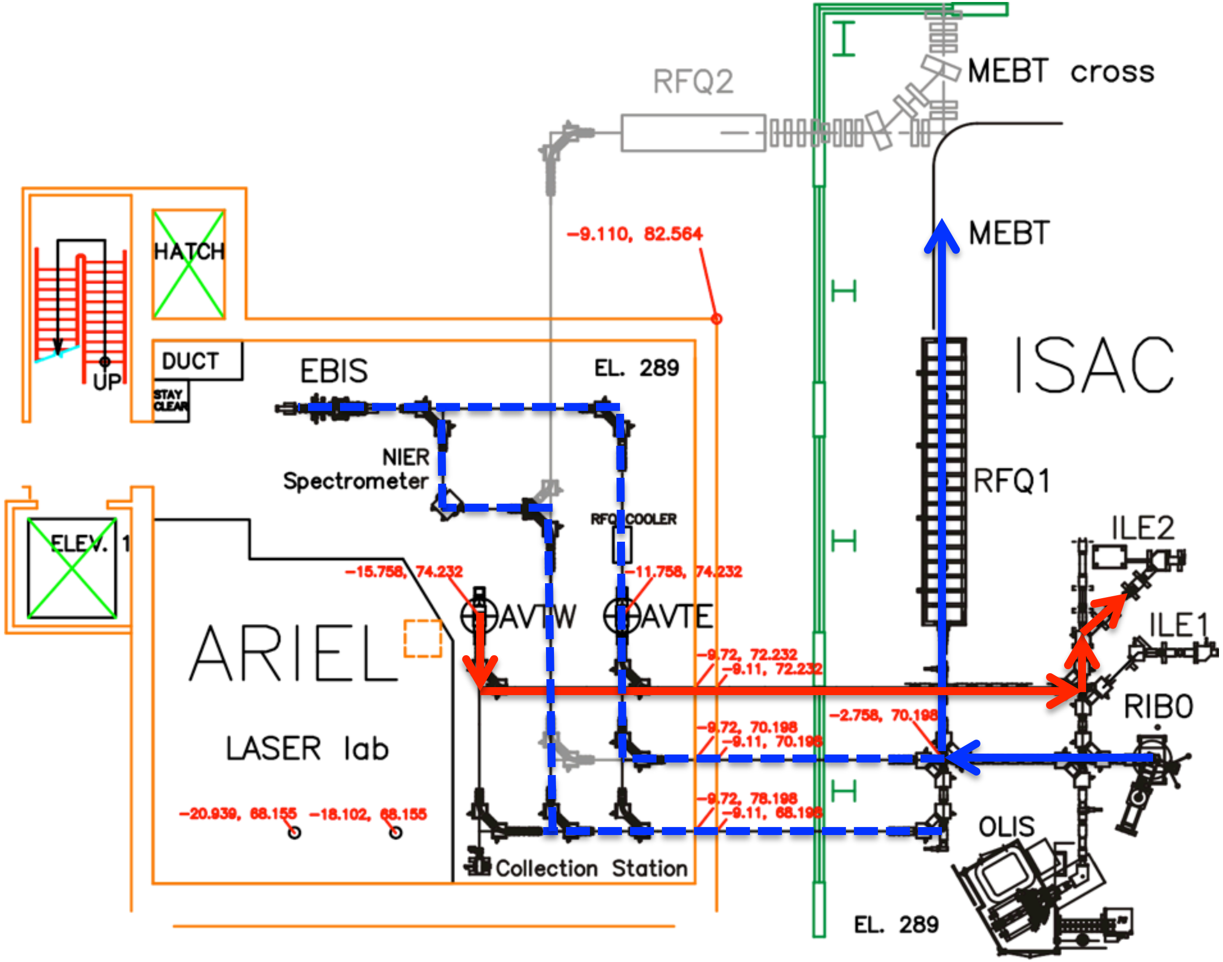
ISAC – LEBT

DRAGON, TUDA-I
EMMA, IRIS,
TIGRESS, TUDA-II

ARIEL – LEBT

GPS, GRIFFIN

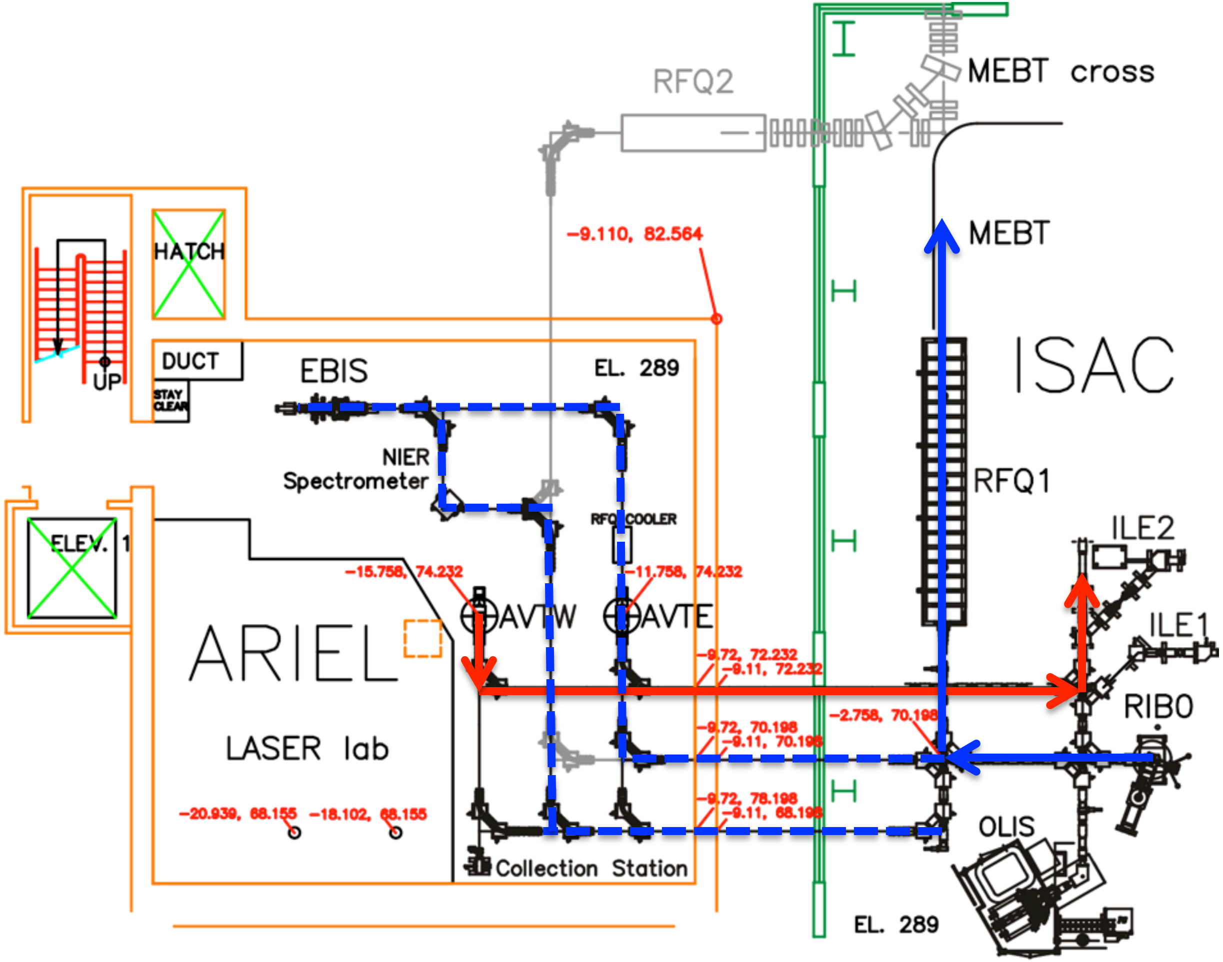
ISAC and ARIEL Beam Delivery



ISAC – LEBT
DRAGON, TUDA-I
EMMA, IRIS,
TIGRESS, TUDA-II

ARIEL – LEBT
TITAN, Laser Spec.,
beta-NMR, OSAKA, MTV

ISAC and ARIEL Beam Delivery



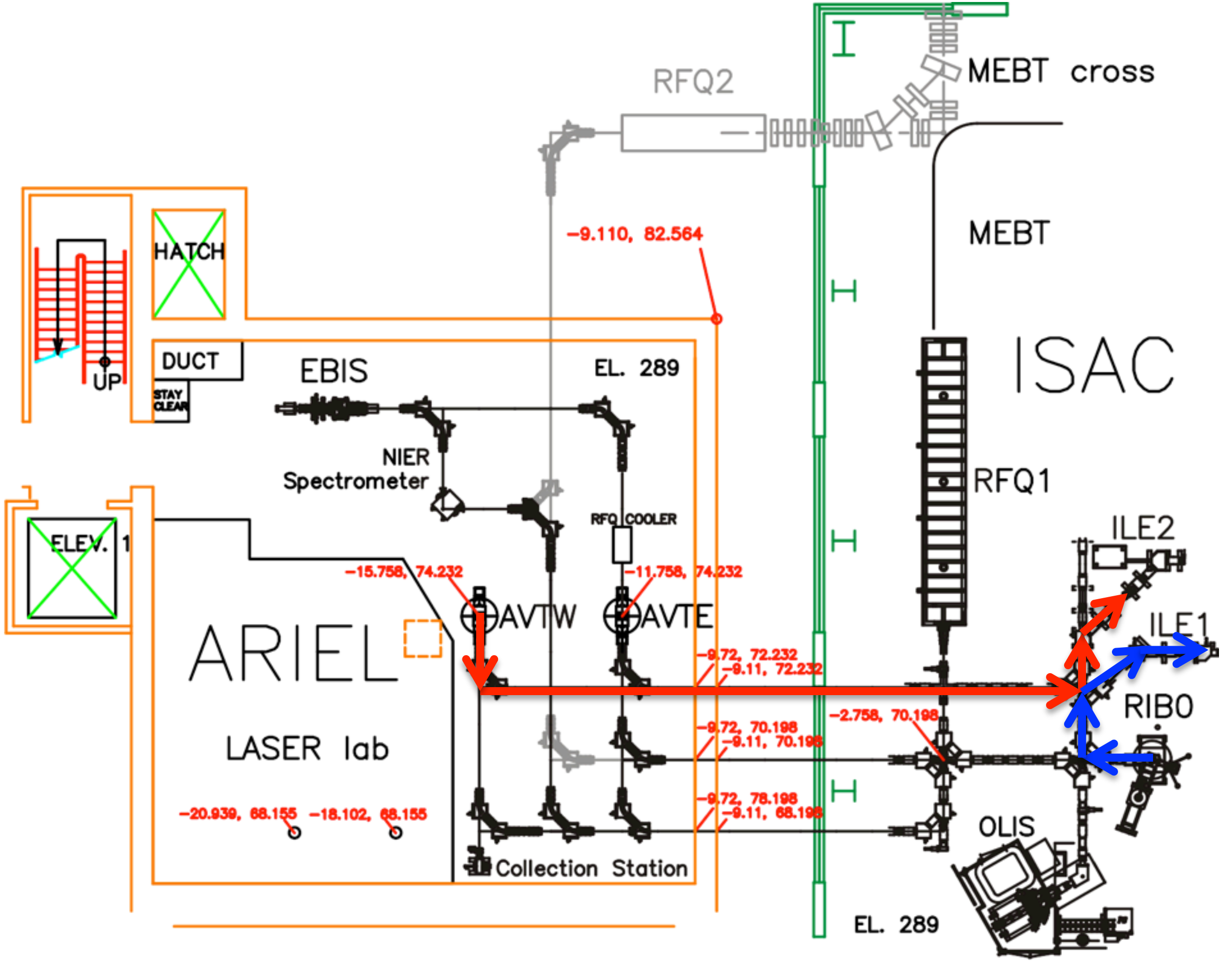
ISAC – LEBT

DRAGON, TUDA-I
EMMA, IRIS,
TIGRESS, TUDA-II

ARIEL – LEBT

Francium

ISAC and ARIEL Beam Delivery



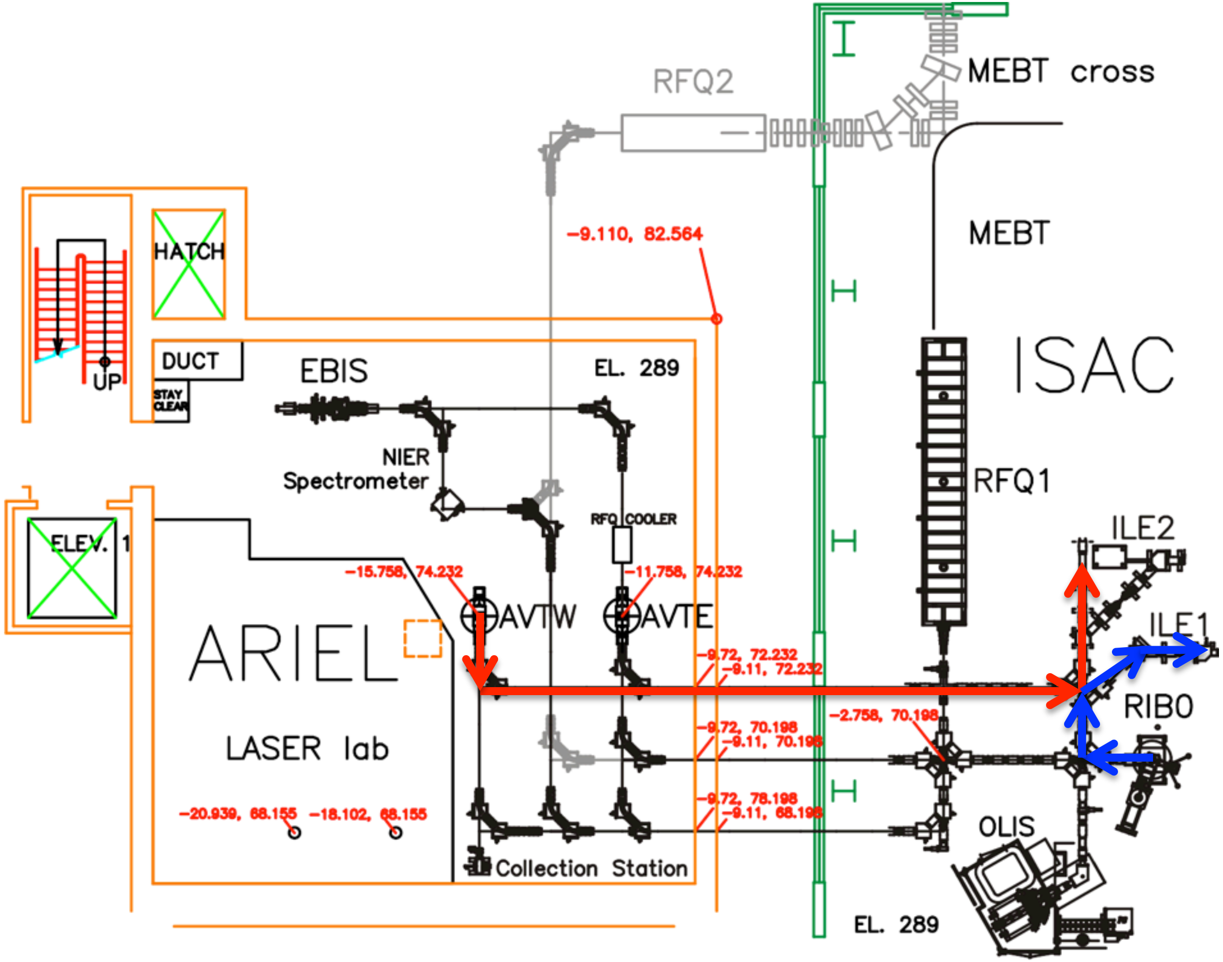
ISAC – LEBT

GPS, GRIFFIN

ARIEL – LEBT

TITAN, Laser Spec., beta-NMR, OSAKA, MTV

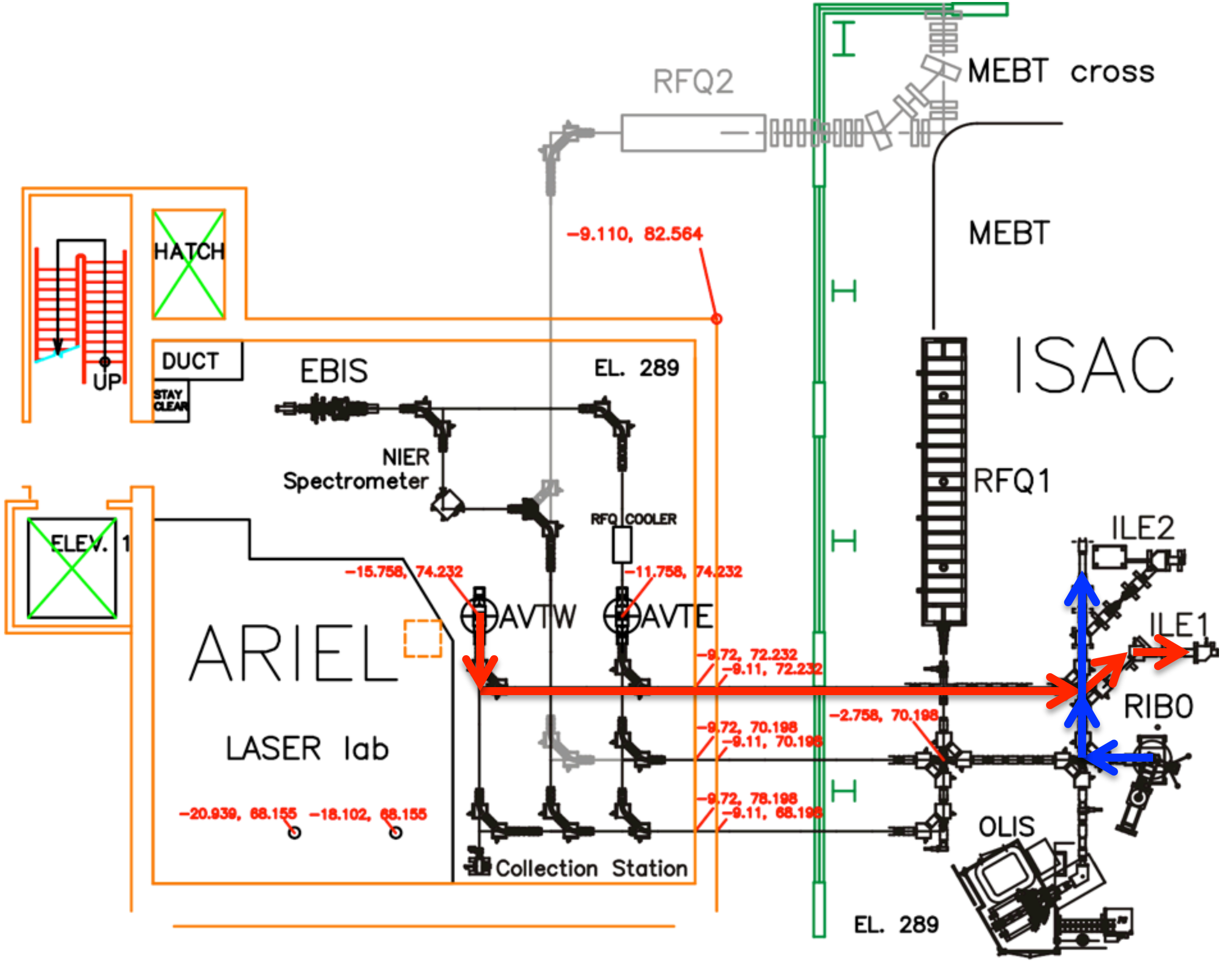
ISAC and ARIEL Beam Delivery



ISAC – LEBT
GPS, GRIFFIN

ARIEL – LEBT
Francium

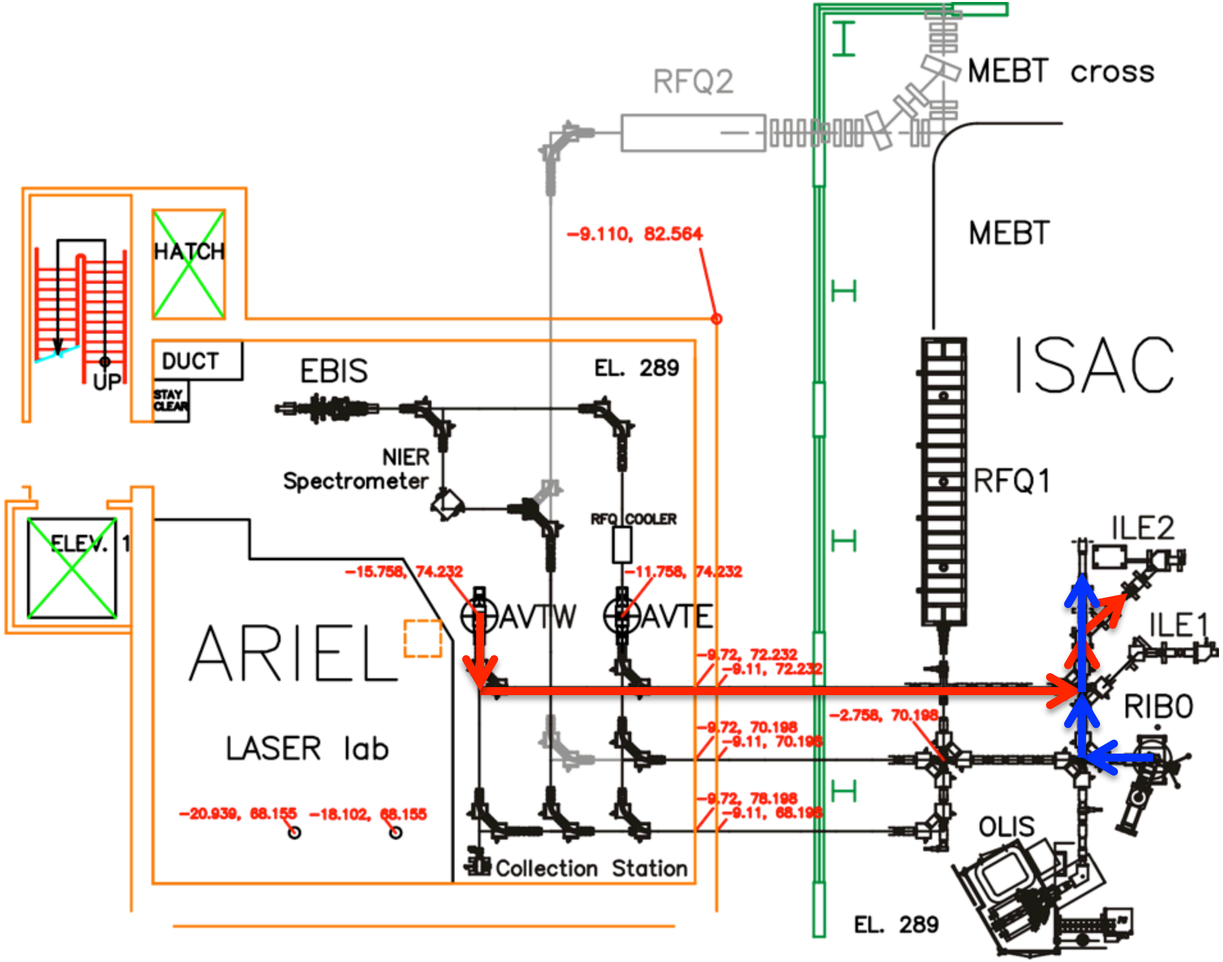
ISAC and ARIEL Beam Delivery



ISAC – LEBT
Francium

ARIEL – LEBT
GPS, GRIFFIN

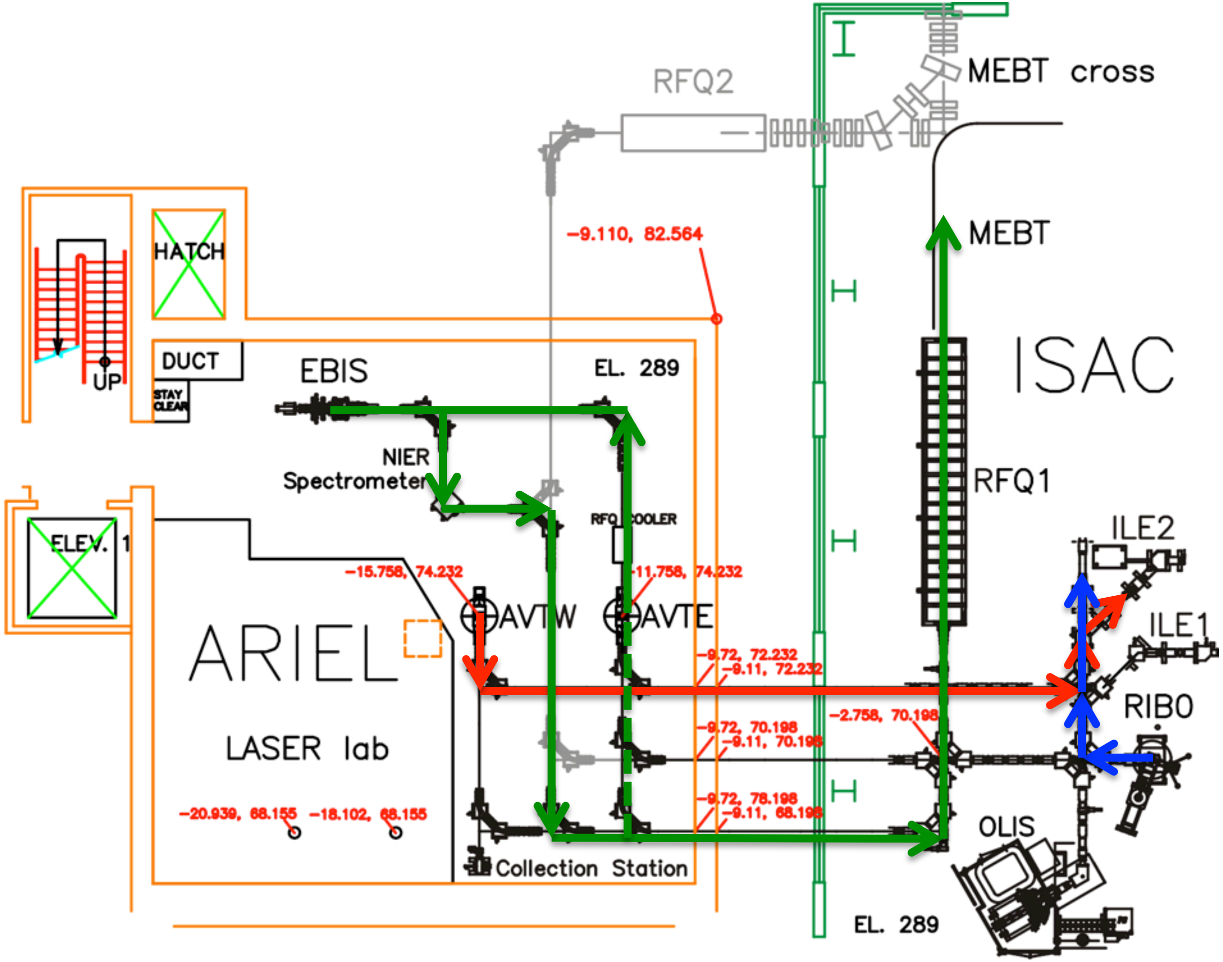
ISAC and ARIEL Beam Delivery



ISAC – LEBT
Francium

ARIEL – LEBT
TITAN, Laser Spec., beta-NMR, OSAKA, MTV

ISAC and ARIEL Beam Delivery

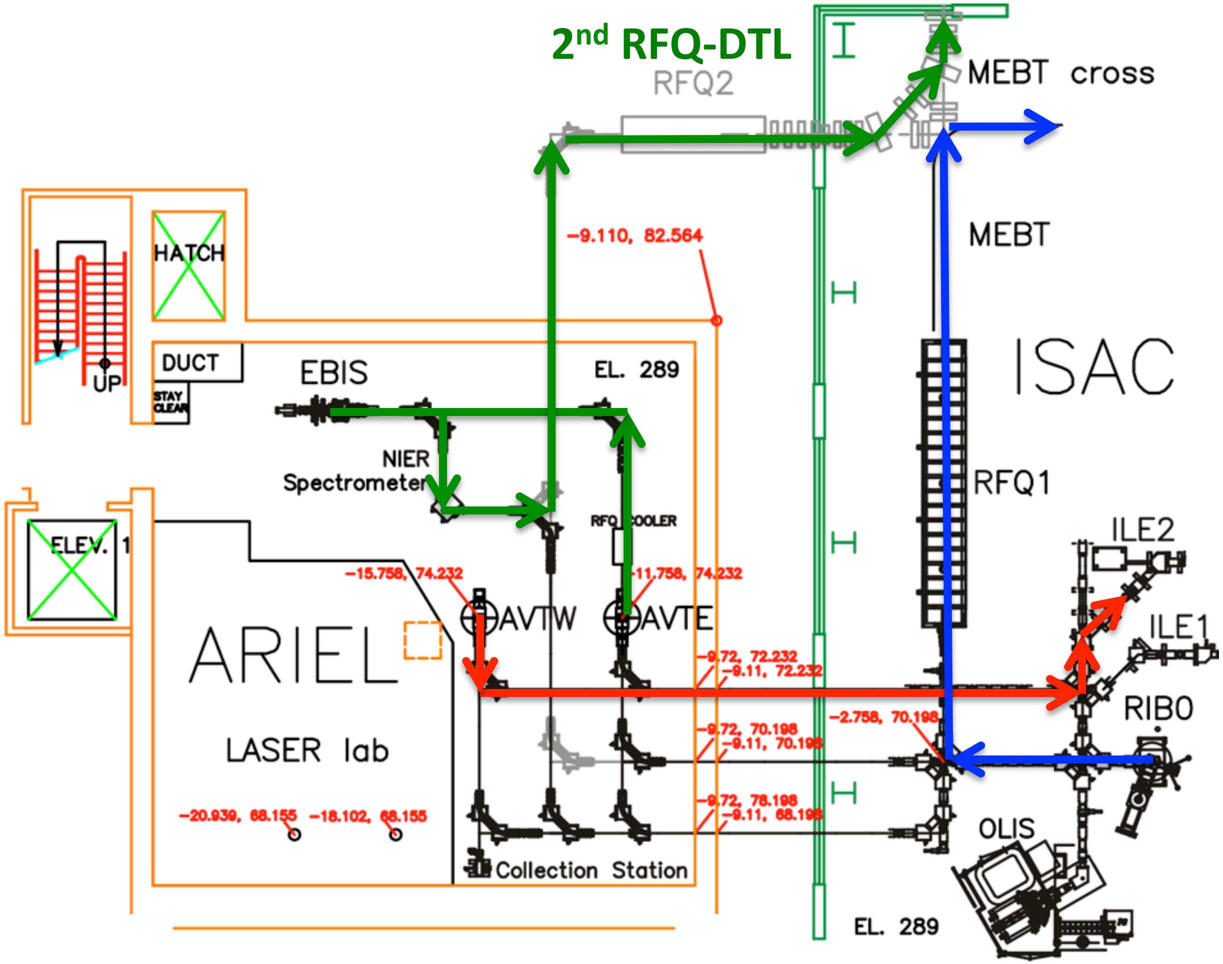


ISAC – LEBT
Francium

ARIEL – LEBT
TITAN, Laser Spec., beta-NMR, OSAKA, MTV

ARIEL – MEBT/SEBT
DRAGON, TUDA-I
EMMA, IRIS,
TIGRESS, TUDA-II

ISAC and ARIEL Beam Delivery



ISAC – MEBT
DRAGON, TUDA-I

ARIEL – LEBT
TITAN, Laser Spec., beta-NMR, OSAKA, MTV

ARIEL –SEBT
EMMA, IRIS, TIGRESS, TUDA-II

ARIEL beam to β-NMR

In-target production rates [1 $kW^{-1} \cdot s^{-1}$]:

from BeO: ^{8}Li: $5 \cdot 10^{9}$ pps

- β-NMR currently ~6 weeks of ISAC schedule ➔ ~3 months of ARIEL beam
- This will not happen instantly. Access still required in ARIEL target hall for installation work

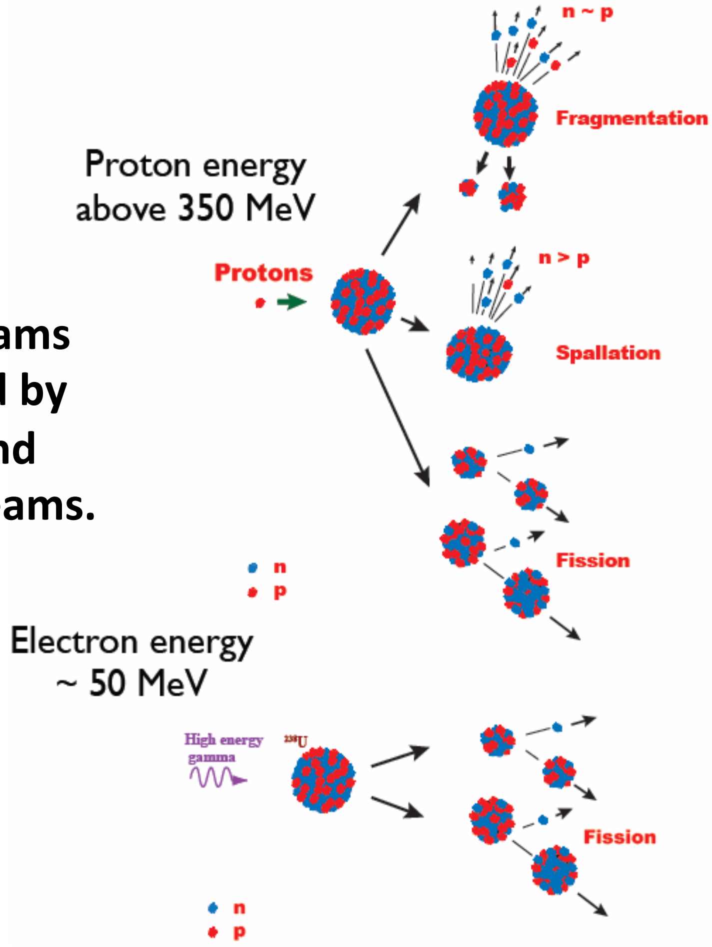
- Low-energy area is poorly laid out. When delivering to β-NMR from ARIEL:
  - cannot deliver to TITAN, Co-liner Laser Spec., OSAKA, MTV

- Increase in beam availability to β-NMR, GRIFFIN, GPS, Francium, DRAGON, ISAC-II

Call to Users:
What are the first experiments, science goals and priorities for material science with β-NMR?

ARIEL photo-fission beams to ISAC

Rare-isotope beams will be produced by from proton and electron driver beams.



500MeV Protons on UCx

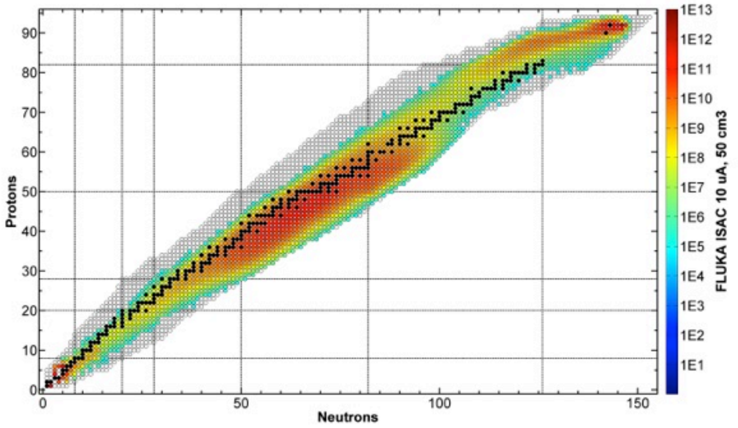
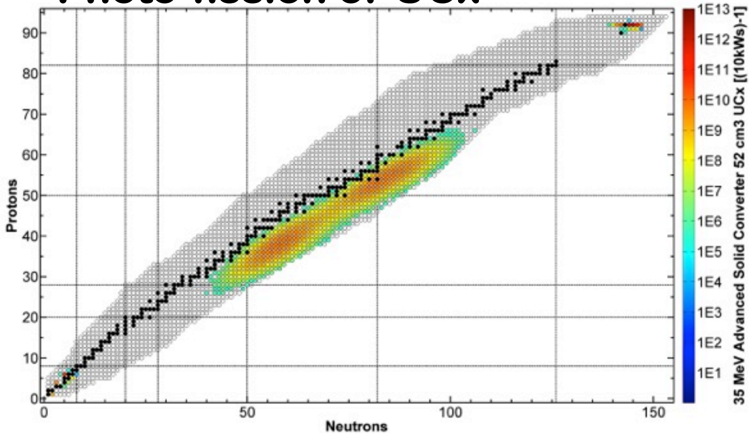


Photo-fission of UCx



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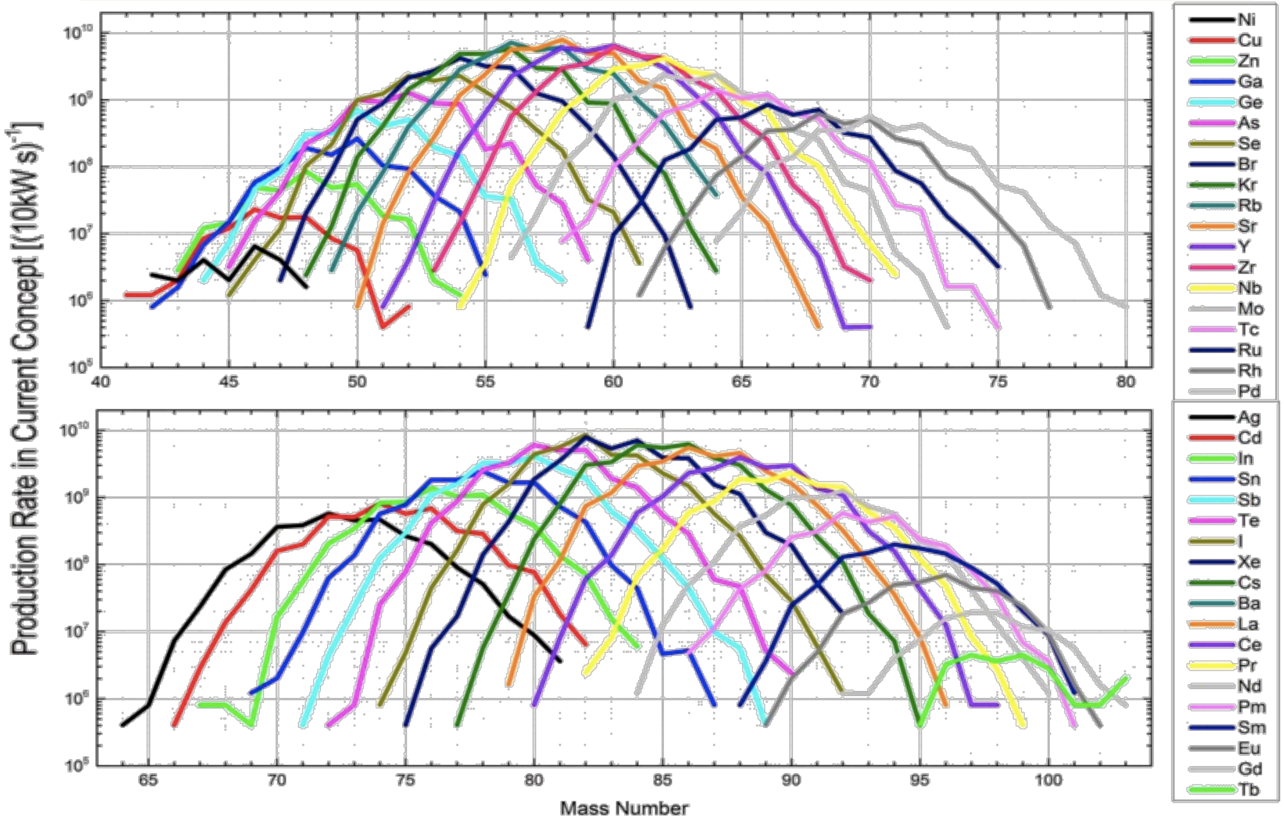
FLUKA Production Map from 35 MeV Electrons

ARIEL Current Concept Design In-Target Production Yields [10 $kW^{-1} \cdot s^{-1}$]



FLUKA: A. Gottberg (TRIUMF and results verified independently with GEANT4 (Marla Cervantes Smith, University of Victoria)

In-target production rates [10 $kW^{-1} \cdot s^{-1}$]:

from BeO:

^{8}Li: $5 \cdot 10^{10}$

from UC_x:

^{78}Ni: $1 \cdot 10^{5}$

^{98}Kr: $8 \cdot 10^{7}$

^{100}Rb: $1 \cdot 10^{8}$

^{98}Sr: $5 \cdot 10^{9}$

^{132}Sn: $5 \cdot 10^{8}$

^{146}Xe: $2 \cdot 10^{7}$

^{144}Ba: $5 \cdot 10^{9}$

^{150}Cs: $4 \cdot 10^{5}$

500MeV Protons on UC_x:

^{78}Ni: $2 \cdot 10^{6}$

^{98}Kr: $1 \cdot 10^{8}$

^{100}Rb: $9 \cdot 10^{7}$

^{98}Sr: $1 \cdot 10^{10}$

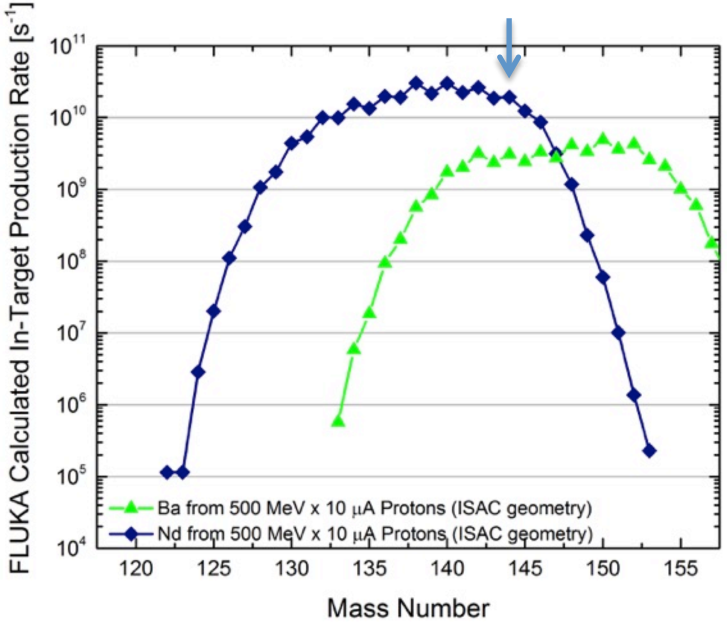
^{132}Sn: $5 \cdot 10^{9}$

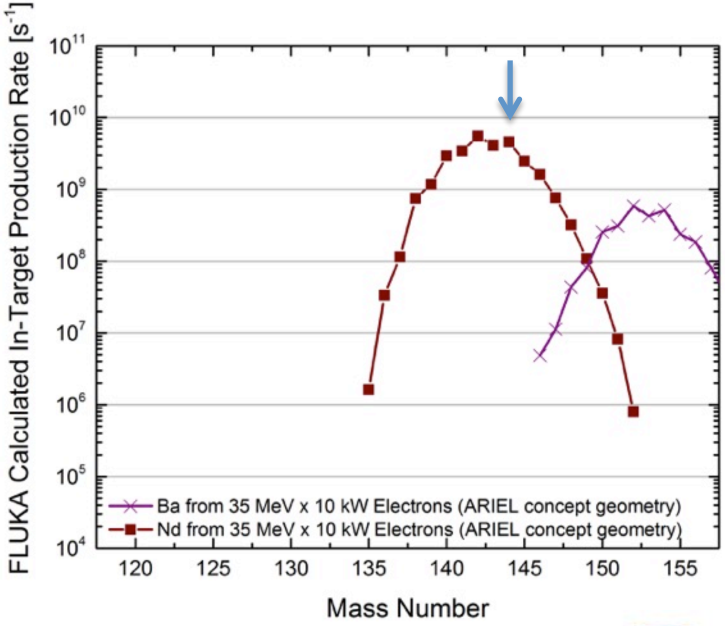
^{146}Xe: $1 \cdot 10^{7}$

^{144}Ba: $2 \cdot 10^{10}$

^{150}Cs: $5 \cdot 10^{5}$

ARIEL photo-fission beams to ISAC

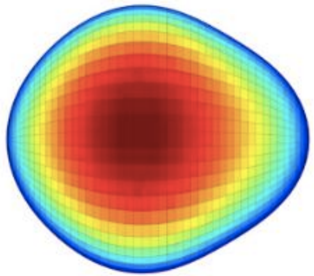




^{144}Ba is doubly-magic for octupole deformation; Z=56, N=88.

500MeV protons: 2×10^{10} with 3×10^{9} Nd (and Ce, Pr, Pm, Sm, Eu, Gd etc)

10kW electrons: 5×10^{9} with zero Nd



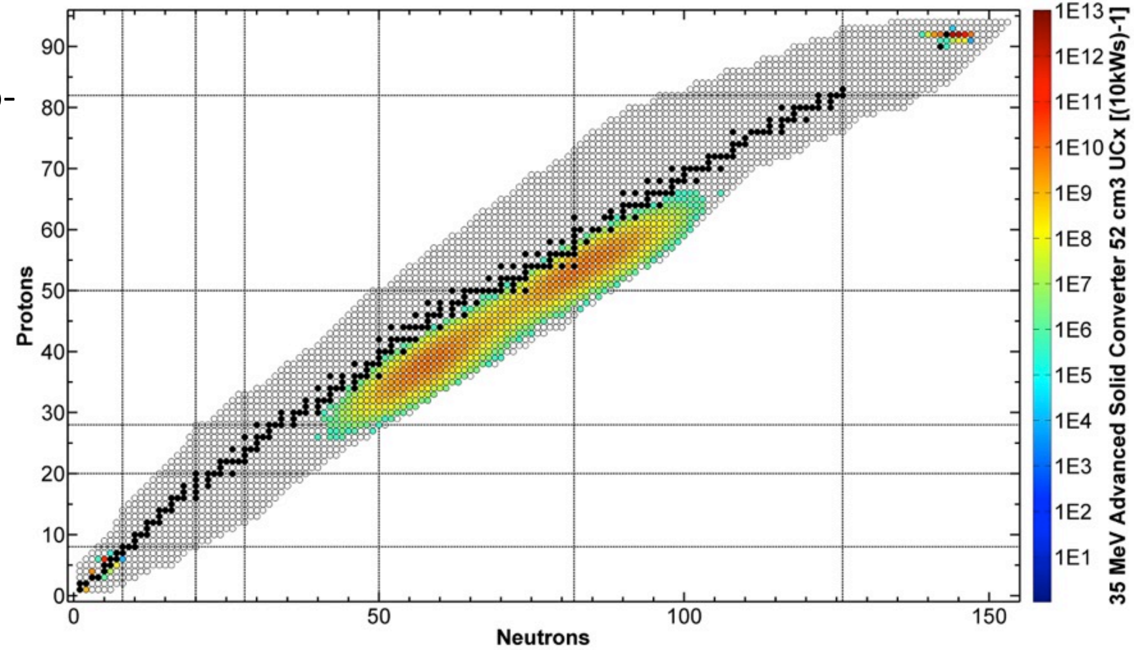
ARIEL photo-fission beams to ISAC

- Beams from electron-induced photo-fission of UC_x
- Intense, clean neutron-rich beams

- Lots of interesting physics:

r-process, shell structure, quadrupole deformation, collectivity, Octupole deformation, phase transitions

Photo-fission of UCx



Call to Users:
What are the first experiments, science goals and priorities with beams from photo-fission?

ARIEL spallation beams to ISAC

- More beamtime availability with 3 simultaneous beams.
- More time available for beam development activities.

- Astrophysics – longer beamtimes means more precision and more complete studies
- Fundamental symmetries – longer beamtimes enable precision measurements

- Opportunities limited without a Medium Resolution Separator (MRS), in most cases only 2 beams can be utilized simultaneously. IG-LIS beams may be ok.
- Opportunities limited by only one RFQ-DTL, can only deliver to either medium or high-energy area.

- Longer beamtimes means more precision and more complete studies

$^{21}Na(p,\gamma)^{22}Mg$

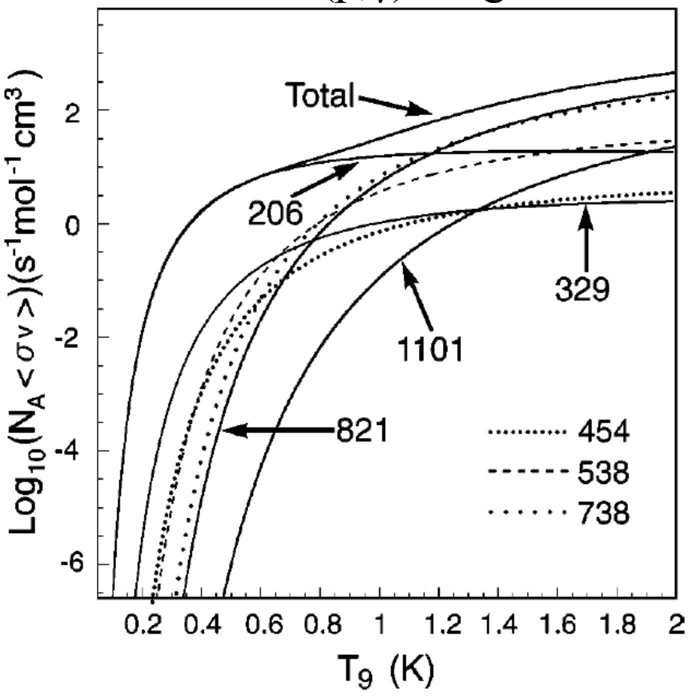


TABLE I. $^{21}Na(p,\gamma)^{22}Mg$ resonance strengths and energies.

E_x (MeV)	$E_{c.m.}$ (keV)	Γ (keV)	$\omega\gamma$ (meV)
5.714	205.7±0.5		1.03±0.21
5.837	329		⩽0.29
5.962	454±5		0.86±0.29
6.046	538±13		11.5±1.36
6.246	738.4±1.0		219±25
6.329	821.3±0.9	16.1±2.8	556±77
6.609	1101.1±2.5	30.1±6.5	368±62

Limited beamtime usually results in only the strongest resonances being studied introducing significant uncertainty to the final reaction rate calculations.

J.M. D'Auria *et al.*, PRC 69, 065803 (2004).

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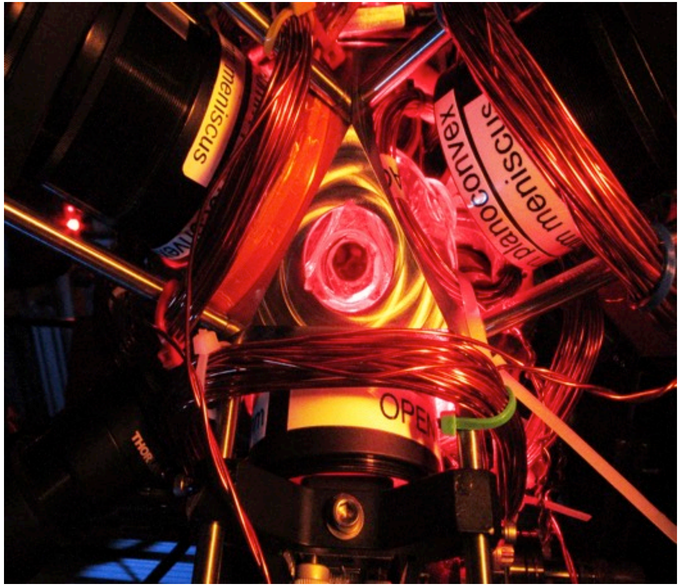
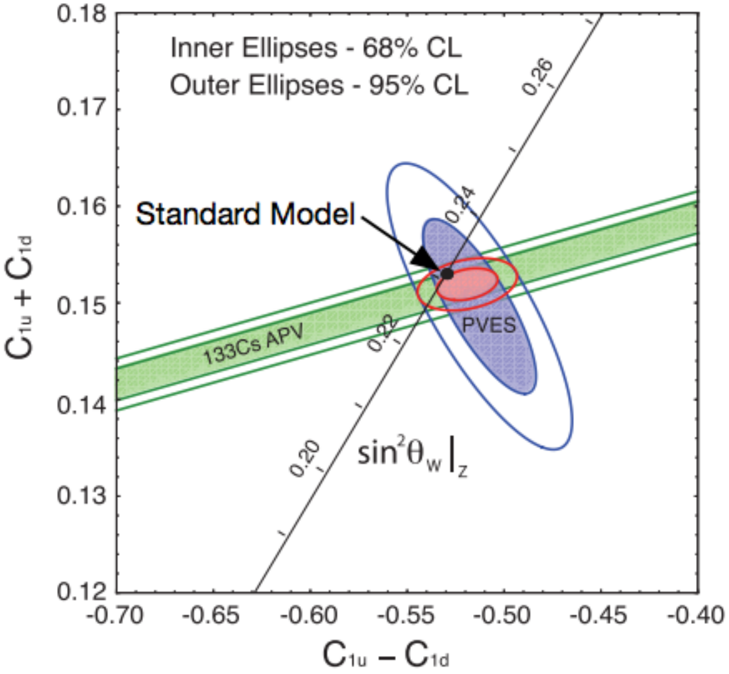
Precision Measurements

- Longer beamtimes enables time-consuming precision measurements





Atomic Parity Violation measurements in Fr to put constraints on weak electron-quark couplings.

Androic *et al.*, PRL 111, 141803 (2013).

ARIEL spallation beams to ISAC

- More beamtime availability with 3 simultaneous beams.
- More time available for beam development activities.

- Astrophysics – longer beamtimes means more precision and more complete studies
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- Opportunities limited without a MRS, in most cases only 2 beams can be utilized simultaneously unless IG-LIS is used.
- Opportunities limited by only one RFQ-DTL, can only deliver to medium or high-energy area.

Call to Users:
What are the first experiments, science goals and priorities when 3 simultaneous beams are available?

Potential upgrades and new installations

- Medium-Resolution Separator
- 2^{nd} RFQ-DTL accelerator path
- New ISAC frontend
- 50MeV eLINAC
- 500kW converter development
- Re-circulation ring
- …

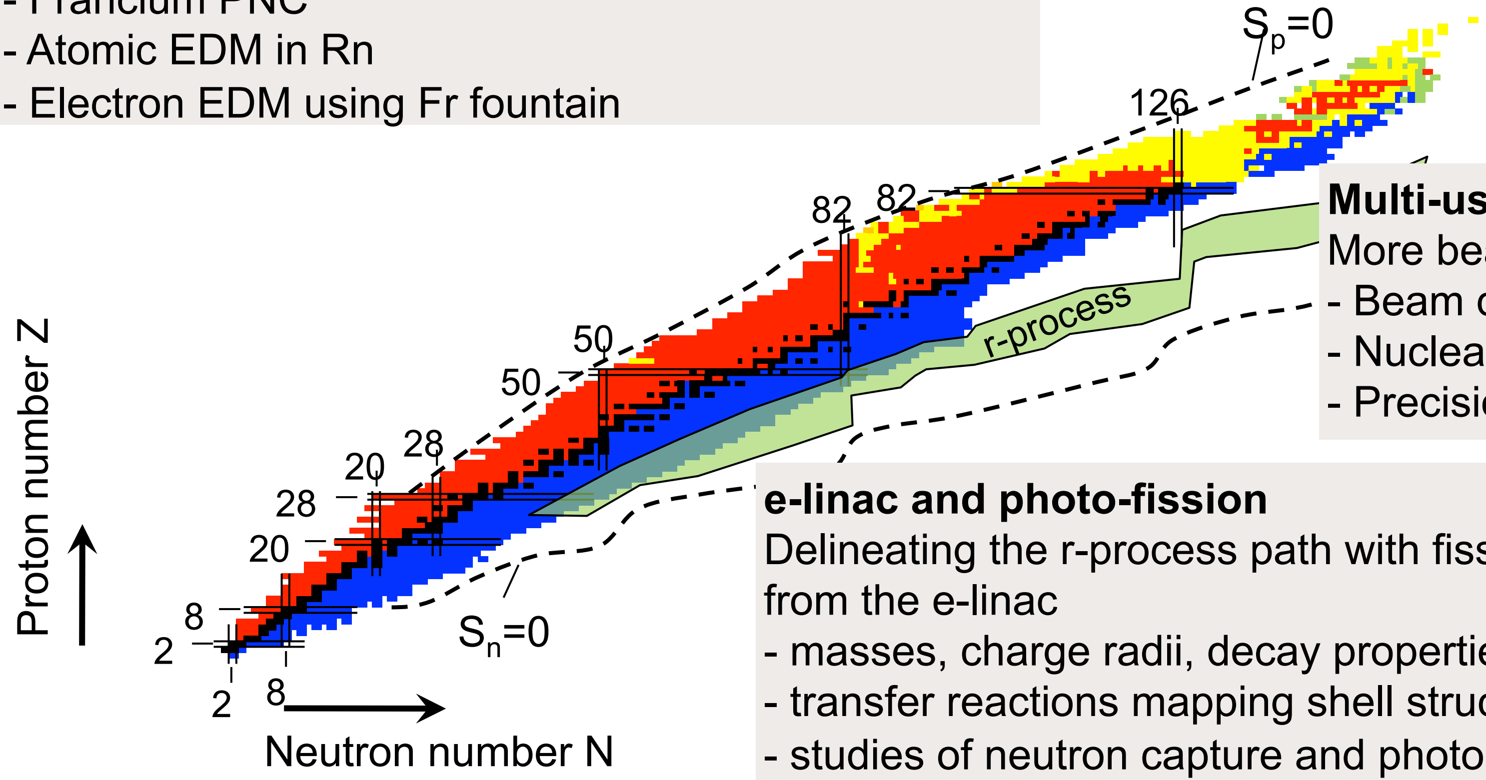
- Storage ring
- HELIOS-type device
- Total-Absorption Spectrometer
- …

User consultation in the summer as part of next TRIUMF 5-year planning process. Starting thinking about this.

The Future: Science enabled by ARIEL

Actinide proton beam-line:
High intensity, clean beams for electroweak precision experiments using hundreds of days of beam per year
- Francium PNC
- Atomic EDM in Rn
- Electron EDM using Fr fountain

TRIUMF ARIEL
ADVANCED RARE ISOTOPE LABORATORY



Multi-user operations:
More beam time for
- Beam development
- Nuclear astrophysics
- Precision experiments

e-linac and photo-fission
Delineating the r-process path with fission fragment beams from the e-linac
- masses, charge radii, decay properties
- transfer reactions mapping shell structure
- studies of neutron capture and photo dissociation rates

Science Goals and Priorities

Call to Users:

Please help define the science goals and priorities for the different stages of ARIEL:

- **More intense, cleaner accelerated beams from ISAC-CANREB-ISAC,**
- **Increase in polarized Li beam availability to beta-NMR, OSAKA, MTV**
- **Beams from electron-induced Photo-fission of UC_x,**
- **when 3 simultaneous beams are available.**

What are the priorities for future upgrades and installations?

Any other suggestions please.

Canada's national laboratory for particle and nuclear physics

Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

Thank you!
Merci!

TRIUMF: Alberta | British Columbia | Calgary | Carleton | Guelph | McGill | Manitoba | McMaster | Montréal | Northern British Columbia | Queen's | Regina | Saint Mary's | Simon Fraser | Toronto | Victoria | Western | Winnipeg | York

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