EURISOL User Group

TRIUMF/ISAC Present Status and Future Perspectives

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TRIUMF
CANADA'S NATIONAL LABORATORY FOR
PARTICLE AND NUCLEAR PHYSICS
LABORATOIRE NATIONAL CANADIEN
POUR LA RECHERCHE EN PHYSIQUE NUCLÉAIRE
ET EN PHYSIQUE DES PARTICULES

Conseil national
de recherches Canada
National Research
Council Canada
Canada

TRIUMF

TRIUMF site plan

Owned and operated as a joint venture by a consortium of Canadian universities via a contribution through the National Research Council of Canada

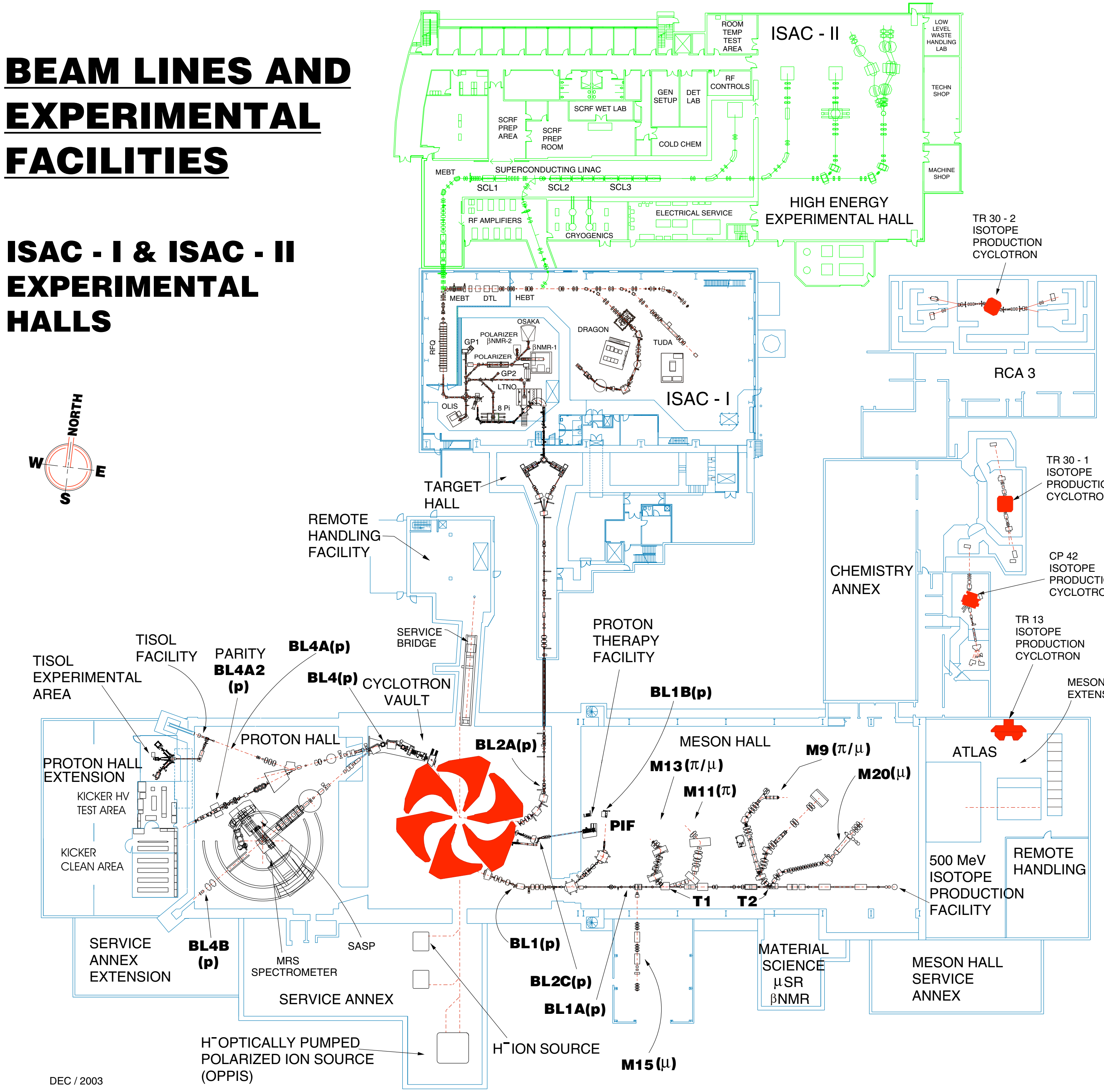
500 MeV H^- cyclotron

Capable of four independent users

1. 150 µA for µSR
2. 100 µA for ISAC facility
3. 80 µA for nuclear medicine isotopes production
4. Proton therapy (I ~ nA)
5. Proton hall not receiving beam in the moment, 200 µA are available.

BEAM LINES AND EXPERIMENTAL FACILITIES

ISAC - I & ISAC - II EXPERIMENTAL HALLS



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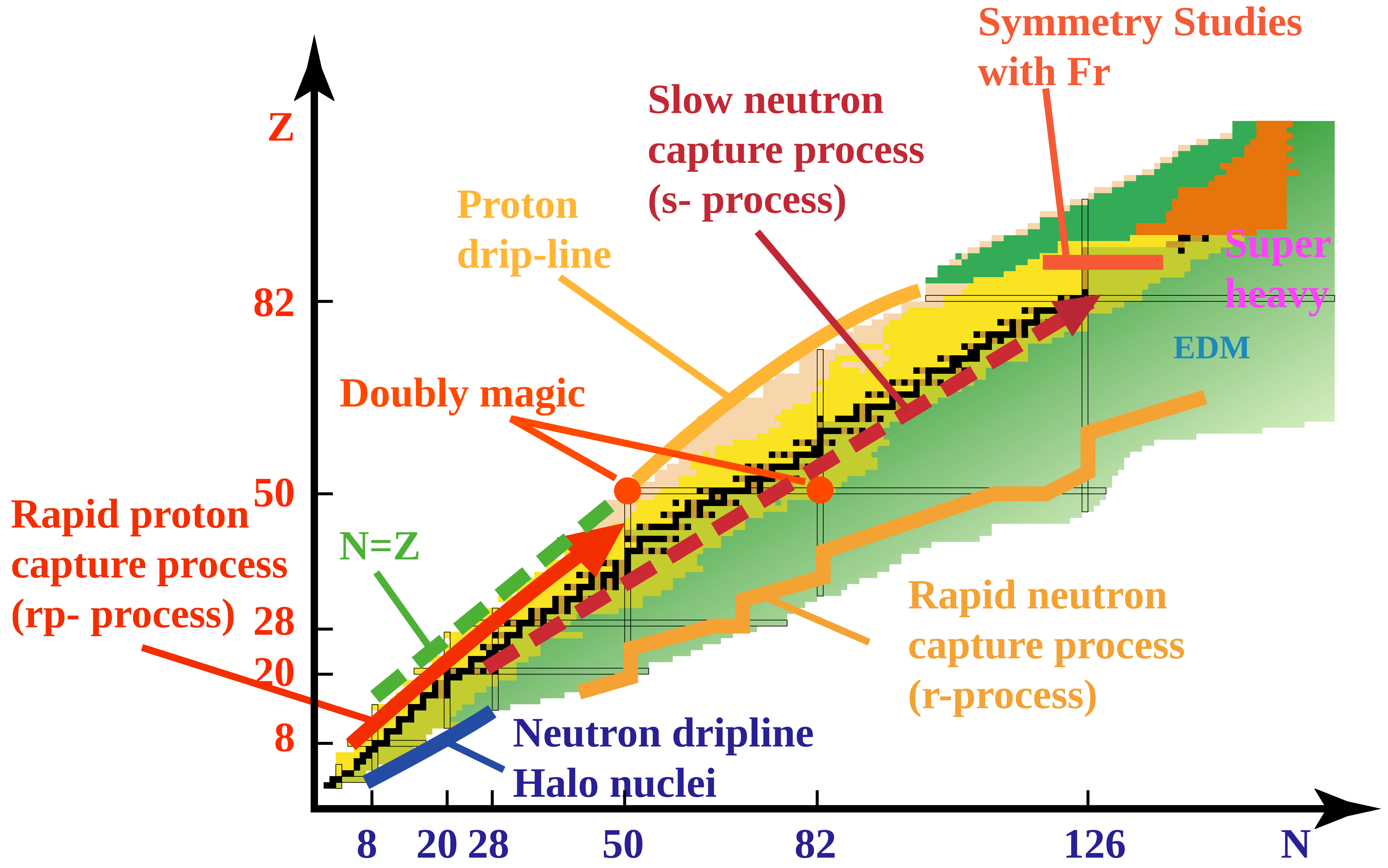
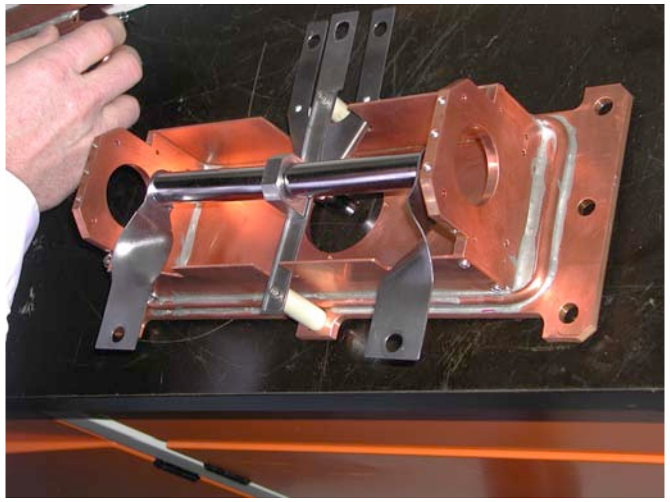
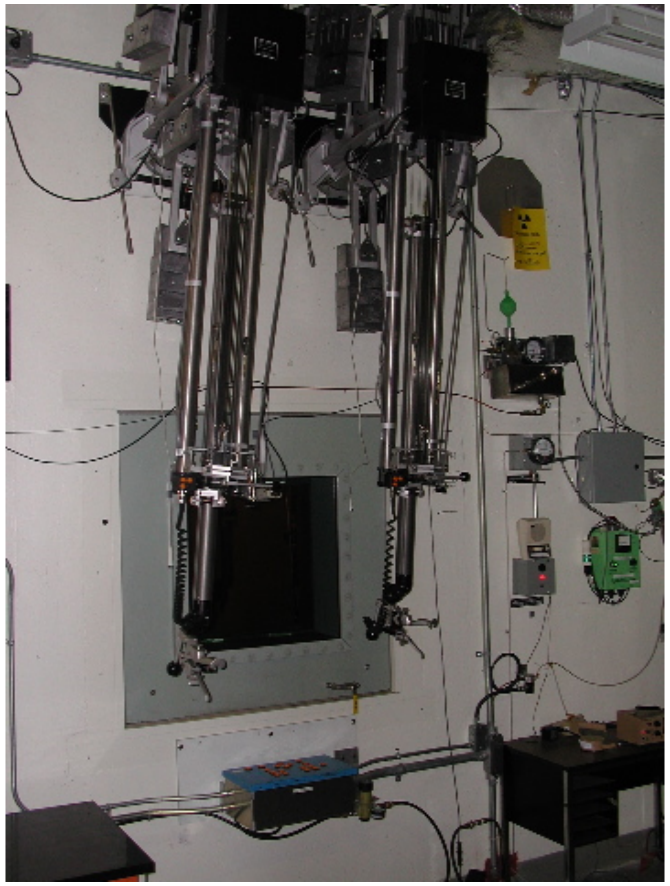
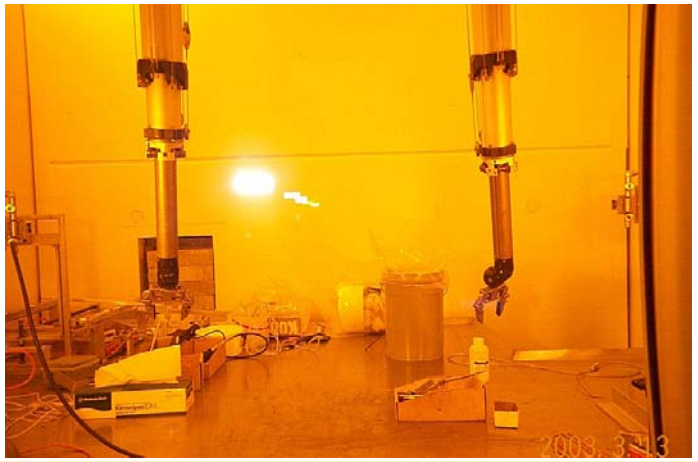
Physics at ISAC



ISAC Facility



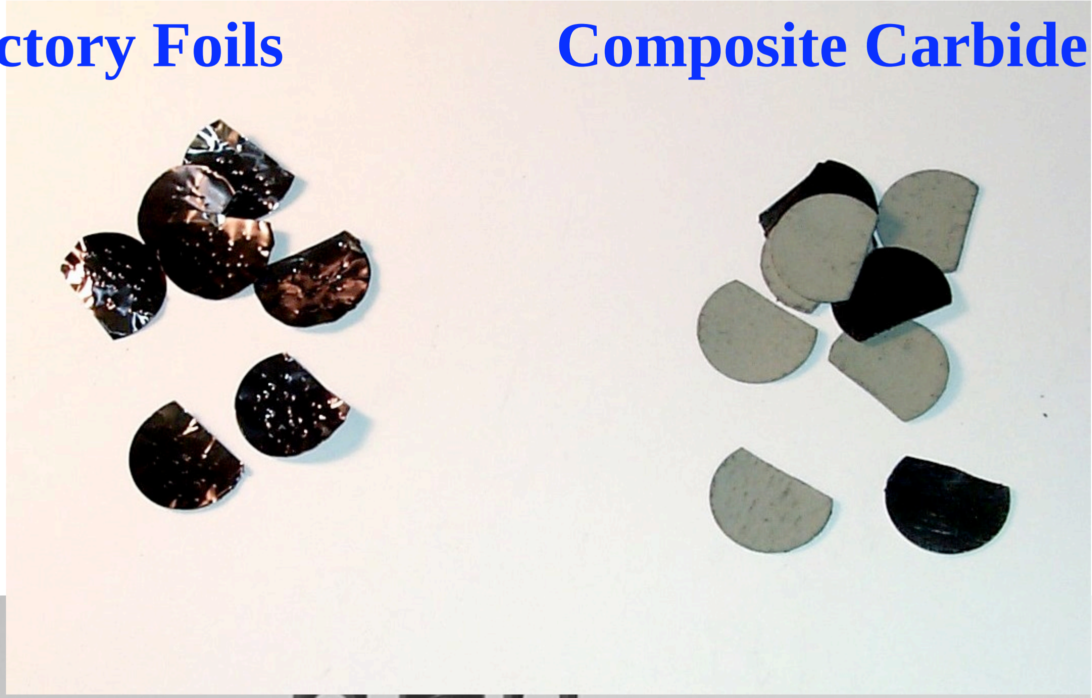




- Driver: H^- Cyclotron
- Operate in CW mode
- Proton Energy : 500 MeV
- Target station used modular approach that permits to operate at 100 μA.
- Target change in a hot-cell using manipulator.
- Minimization of the waste material.

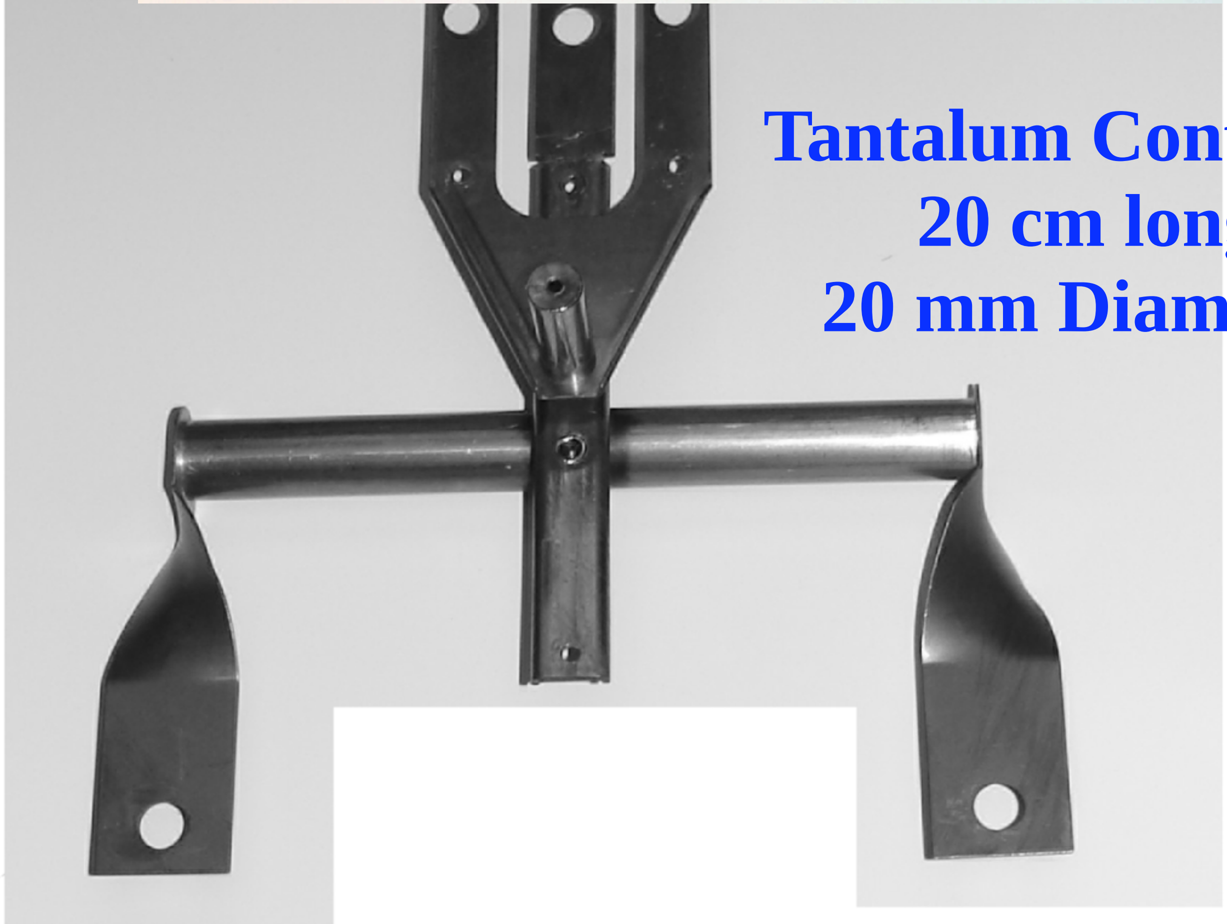
ISOL Target Development

- Target used at ISAC, refractory metals, Ta, Nb, ...
- Foils of thin layers of refractory carbides (SiC, TiC, ZrC, LaC_2 ~ 0.1 mm thick) deposited on flexible exfoliated graphite sheet
- Development of the composite foil technique has allowed carbide target operation with up to 100 µA proton beam.



Refractory Foils

Composite Carbide Foils



Tantalum Container
20 cm long
20 mm Diameter

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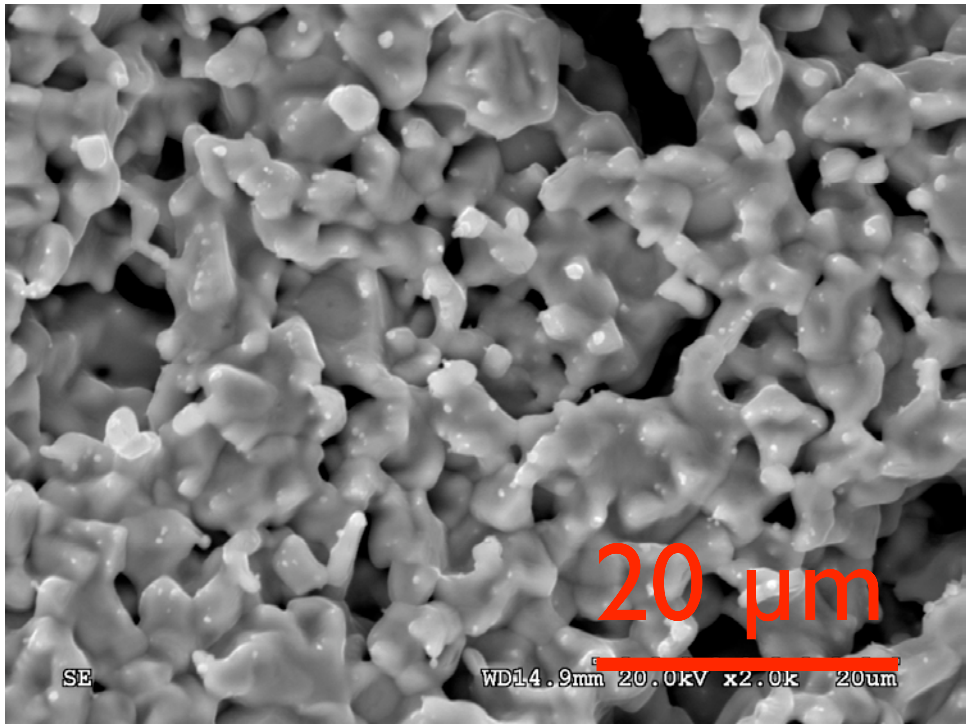
Composite Targets

- **To dissipate the power for the composite carbide target we developed a new technique. Using a slip cast method, the carbide target material is bounded onto an exfoliated graphite foil(0,13 mm thick).**
- **The target is then cut out of the cast and inserted into the Tantalum target container.**

Slip cast onto exfoliated graphite foil (0.13 mm thick)

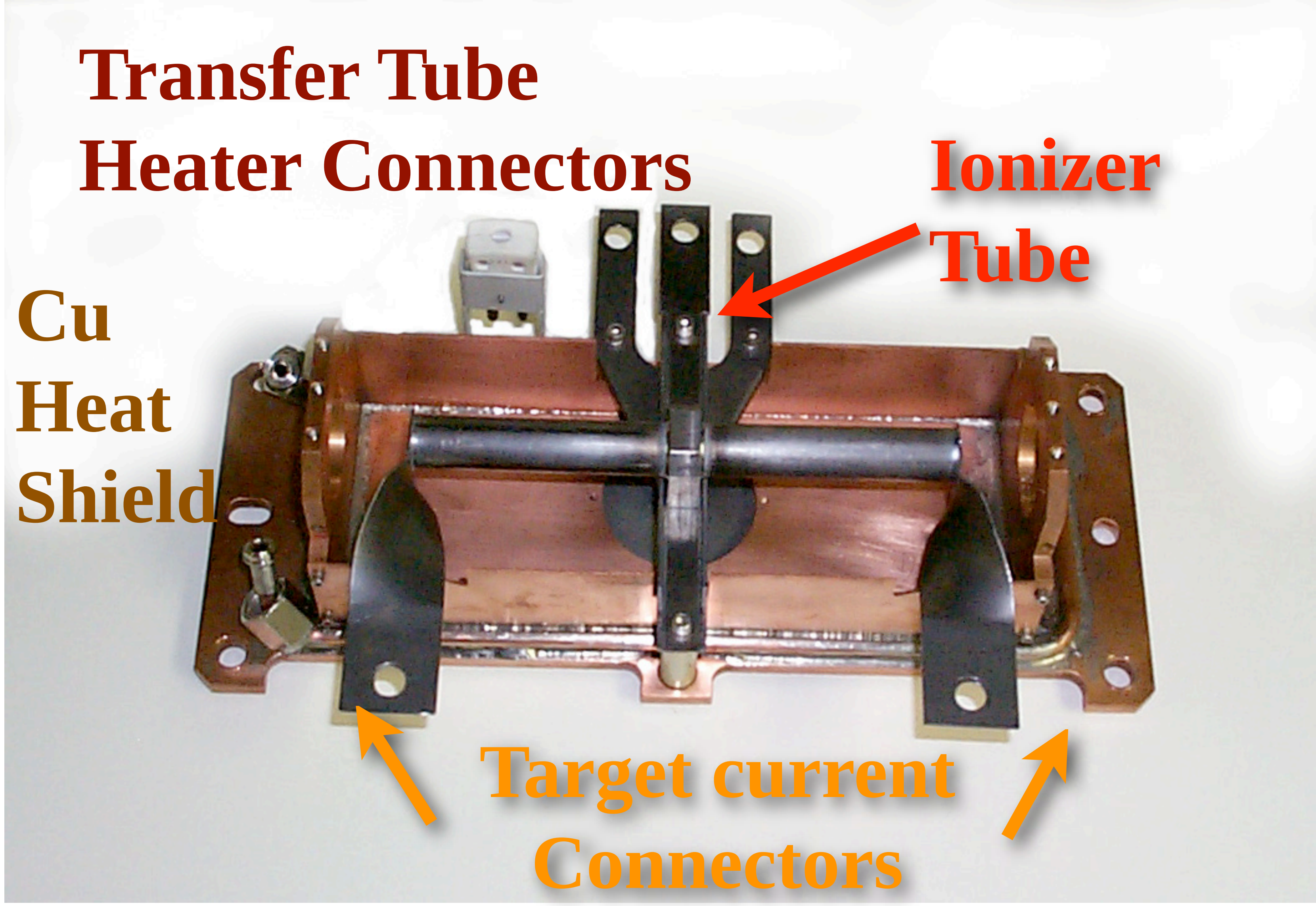


Electron Scan of the LaC_2 after slip cast and sintering at 1600 ºC.

HPT development

- Even though the ISAC facility has been designed for 100 µA, at the beginning (1998) it was not possible to operate the target with more than 1-3 µA.
- In 1999 a Nb foil target was operated with 10 µA.
- In 2000 both the Ta and Nb target were operated with 20 µA, and a SiC made from pressed powder into pellets was operated with 10 µA.
- In 2001 the proton beam intensity was raised to 40 µA on Ta and SiC/graphite composite target. This was obtained by removing all the thermal heat shield around the target and by reducing the target heating, while maintaining the target central temperature at the same value.

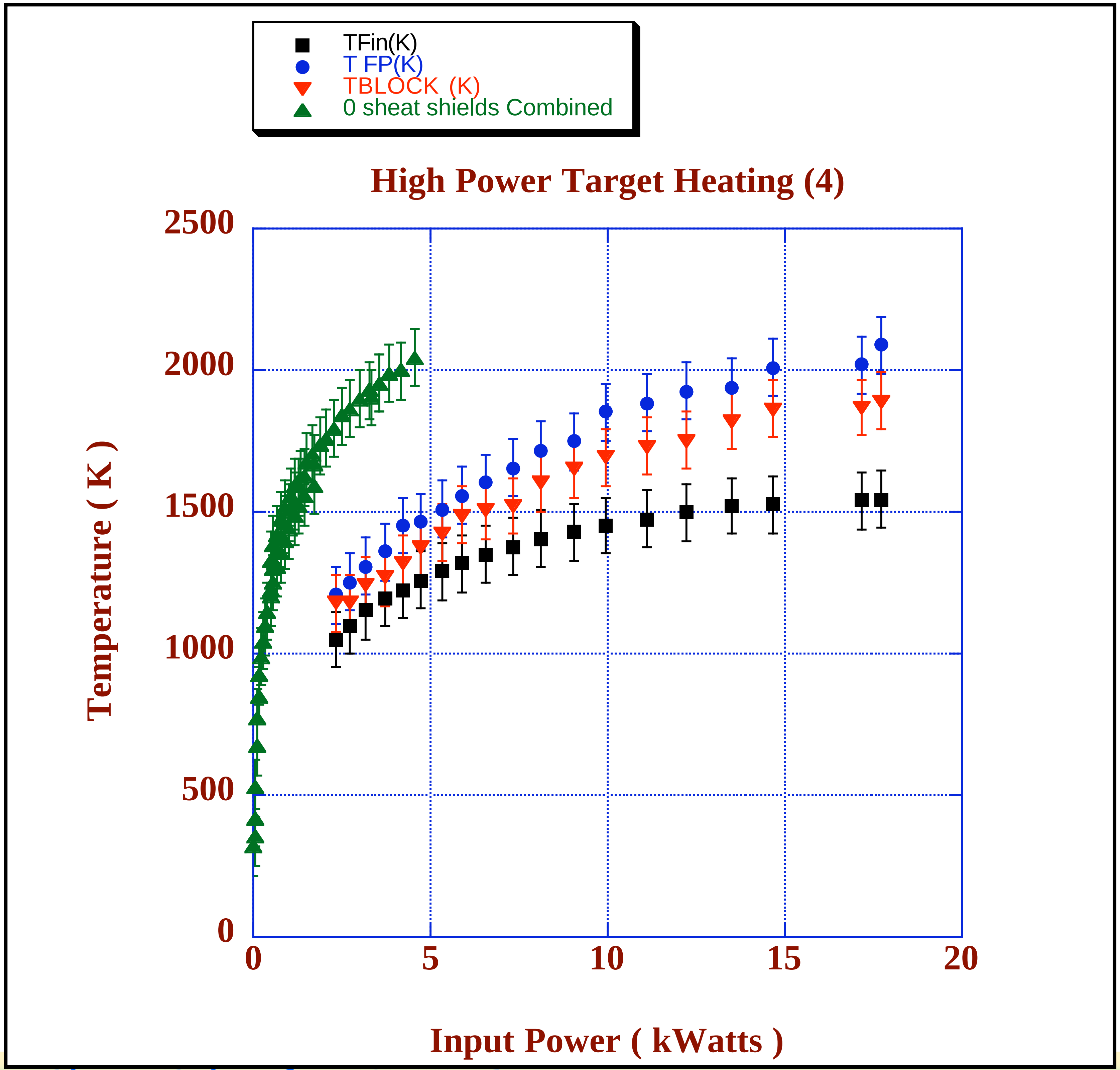
ISAC Target



Initial Design can only dissipate 4-7 kW in the target.

- **With this target design we can go as high as 40 µA.**
- **To go beyond this limit we have to add more effective cooling.**
- **We developed our own radiative cooling target by adding fins to the tantalum target container.**

High Power Target



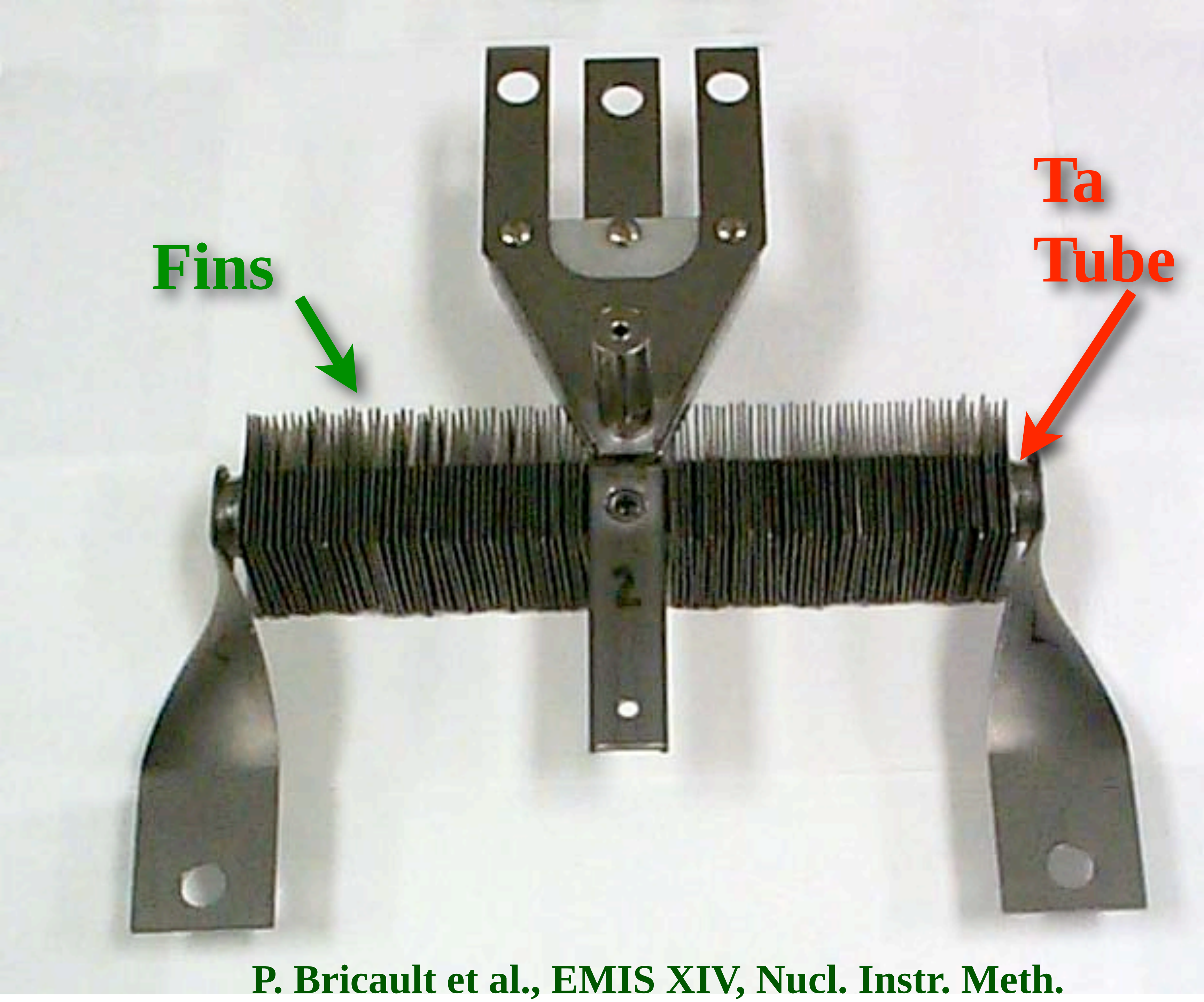
Improve the cooling by adding fins onto the target container. Emissivity: 0,92.

We demonstrated that a target equipped with fins can dissipate up to 18 kW using electron bombardment .

High Power Target

Contrary to other designs we can use any target material, refractory metals or composite carbides or oxides, inside the Ta target container.

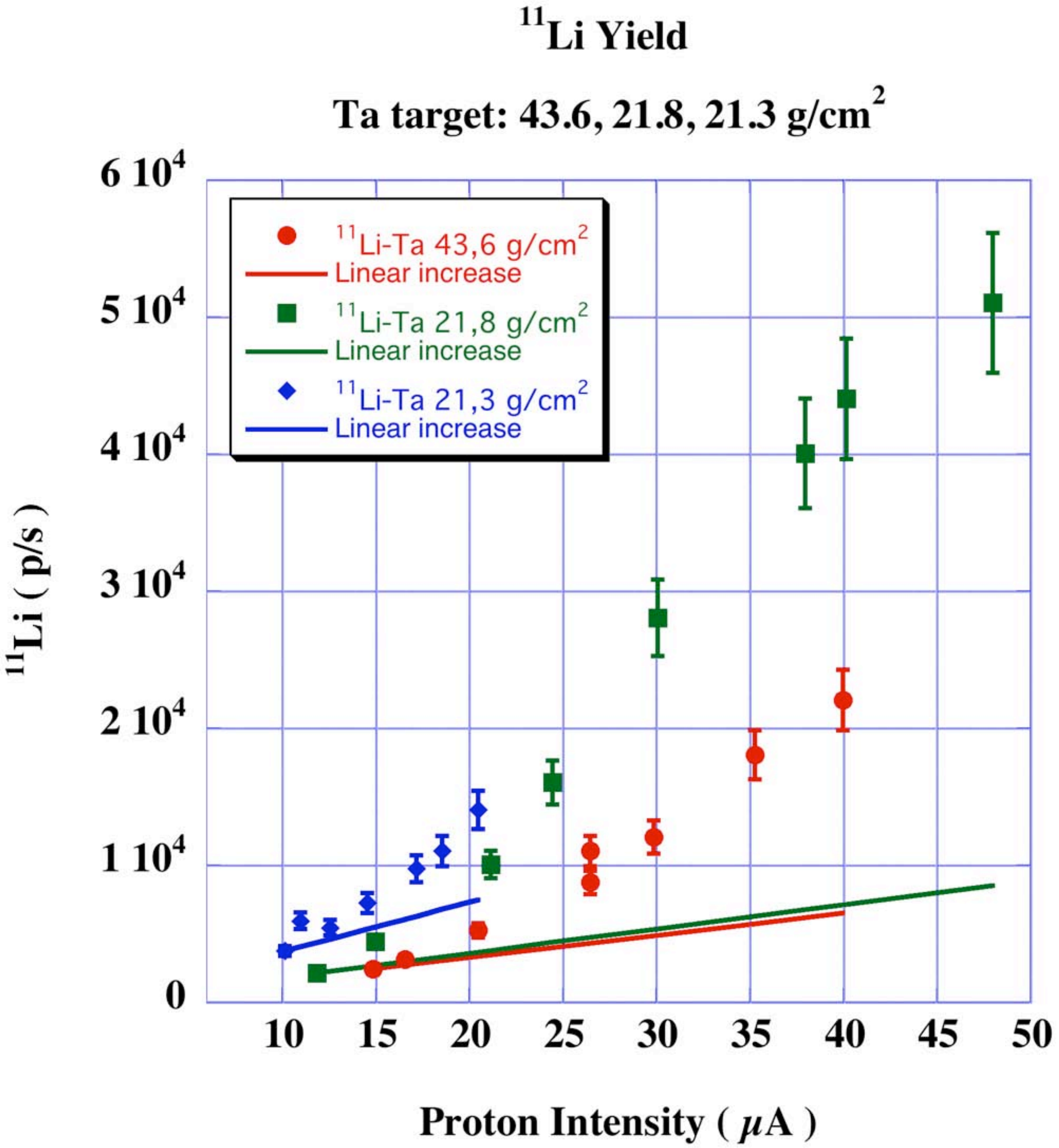
We demonstrated the operation of our HPT at 100µA level for a 500 MeV proton beam.



P. Bricault et al., EMIS XIV, Nucl. Instr. Meth.

Non-Linear Yield vs Φ

- Evidence of Radiation Enhanced Diffusion with the increase of the proton flux density.
- This allow us to have very high yield of short-lived elements.
- Release less sensitive to diffusion in the crystal.



^{A}Li charge radius

Nuclear Charge Radius of Lithium-11 3

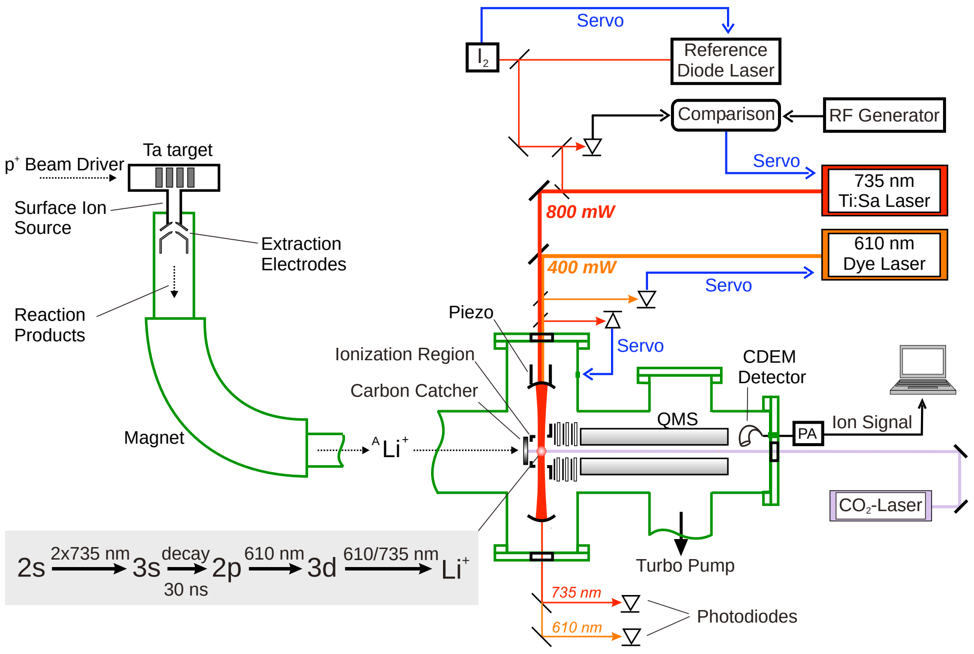


Figure 1. Experimental setup for the resonance ionization of lithium.

6 R. Sánchez *et al.*

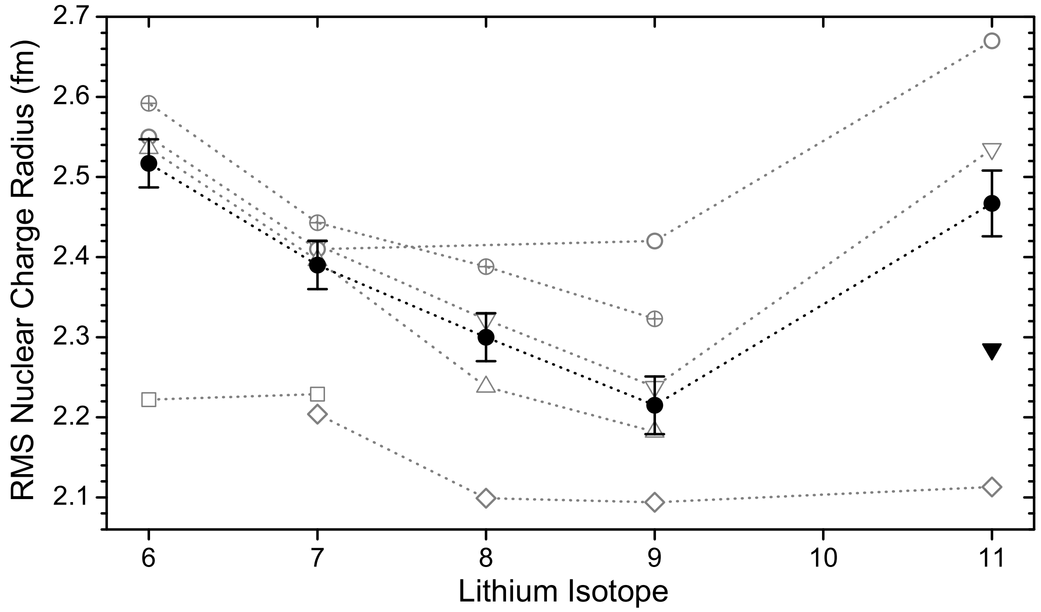


Figure 3. Root-mean-square nuclear charge radii of the lithium isotopes: ···●··· this work, ···□··· *ab-initio* no-Core Shell Model [9], ···◇··· Large-Basis Shell Model [8], ···△··· Greens-Function Monte-Carlo Model [10, 11], ···▽··· (▼) Stochastic Variational Multi-Cluster Model [12, 13], ···⊕··· Fermionic Molecular Dynamics Model [14], ···○··· Dynamic Correlation Model [15].

Nuclear Charge Radii of 9,11L: The Influence of Halo Neutrons
R. Sánchez, W. Nörtershäuser, G. Ewald, D. Albers, J. Behr, P. Bricault, B. A. Bushaw, A. Dax, J. Dilling, M. Dombsky, G. W. F. Drake, S. Götte, R. Kirchner, H.-J. Kluge, Th. Kühl, J. Lassen, C. D. P. Levy, M. R. Pearson, E. J. Prime, V. Ryjkov, A. Wojtaszek, Z.-C. Yan, and C. Zimmermann
Physical Review Letters 96, 033002 (2006)

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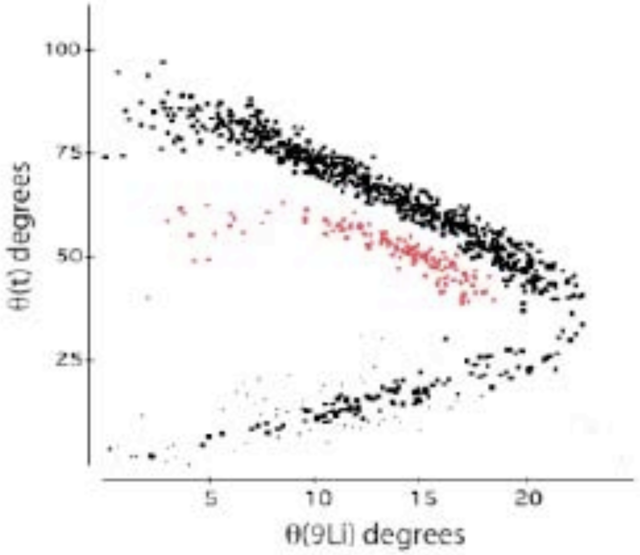
MAYA at TRIUMF

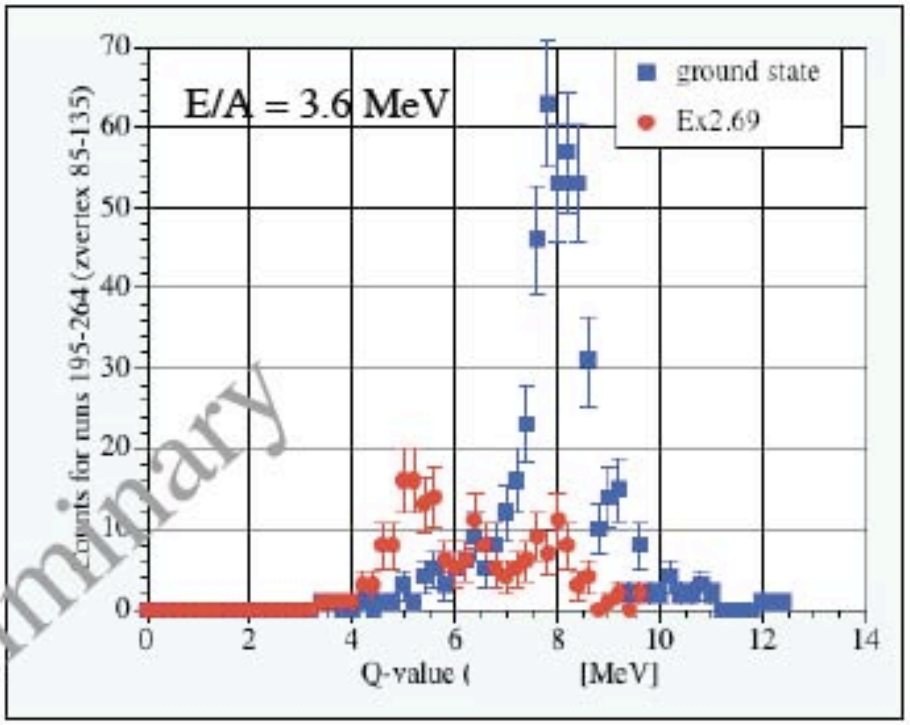
The p(^{11}Li,t)^{9}Li reaction

H. Savajols (GANIL) & I. Tanihata (ANL)

- The most sensitive tool to probe neutron correlation
- TRIUMF is the only facility in the world capable of studying this

Active target Maya from GANIL





Preliminary

Interesting observation of ^{9}Li in excited ($1/2^{-}$) state

High precision superallowed *ft*

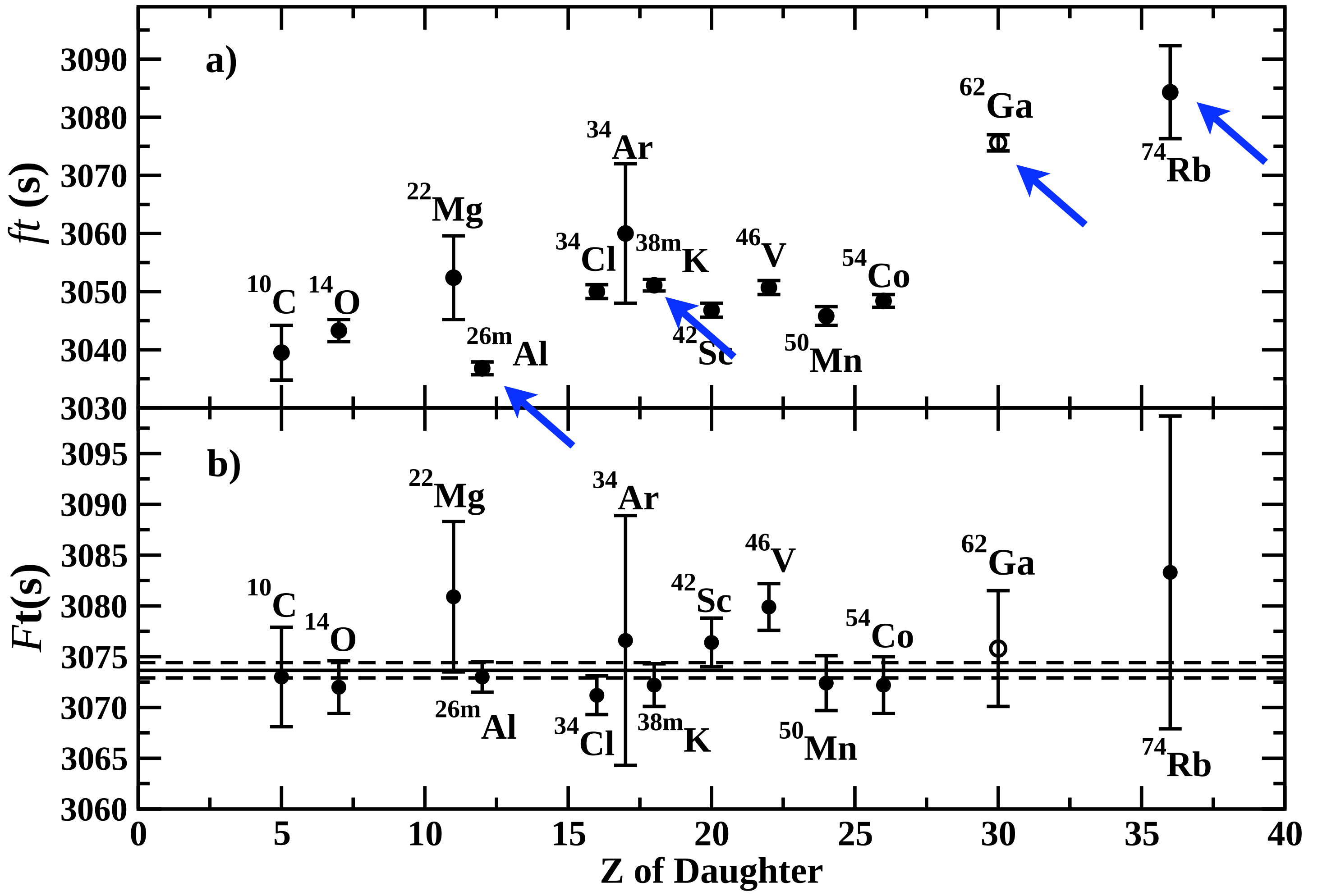


FIG. 3: The 13 precision superallowed (a) ft and (b) $\mathcal{F}t$-values. The average $\overline{\mathcal{F}t}$ = 3073.66(75) s in (b) is obtained from the 12 values (solid circles) given in Table 1 of Ref. [5], while the open circle for ^{62}Ga is from the present work.

Precision Branching Ratio Measurement for the Superallowed $^{+}$ Emitter ^{62}Ga and Isospin-Symmetry-Breaking Corrections in *A*62 Nuclei

B. Hyland,[1] C. E. Svensson,[1] G. C. Ball,[2] J. R. Leslie,[3] T. Achtzehn,[2] D. Albers,[2] C. Andreoiu,[1] P. Bricault,[2] R. Churchman,[2] D. Cross,[4] M. Dombsky,[2] P. Finlay,[1] P. E. Garrett,[1,2] C. Geppert,[5] G. F. Grinyer,[1] G. Hackman,[2] V. Hanemaayer,[2] J. Lassen,[2] J. P. Lavoie,[6] D. Melconian,[2,4] A. C. Morton,[2] C. J. Pearson,[2] M. R. Pearson,[2] A. A. Phillips,[1] M. A. Schumaker,[1] M. B. Smith,[2] I. S. Towner,[3] J. J. Valiente-Dobón,[1] K. Wendt,[5] and E. F. Zganjar[7], Phys. Rev. Lett. 97, 102501 (2006)

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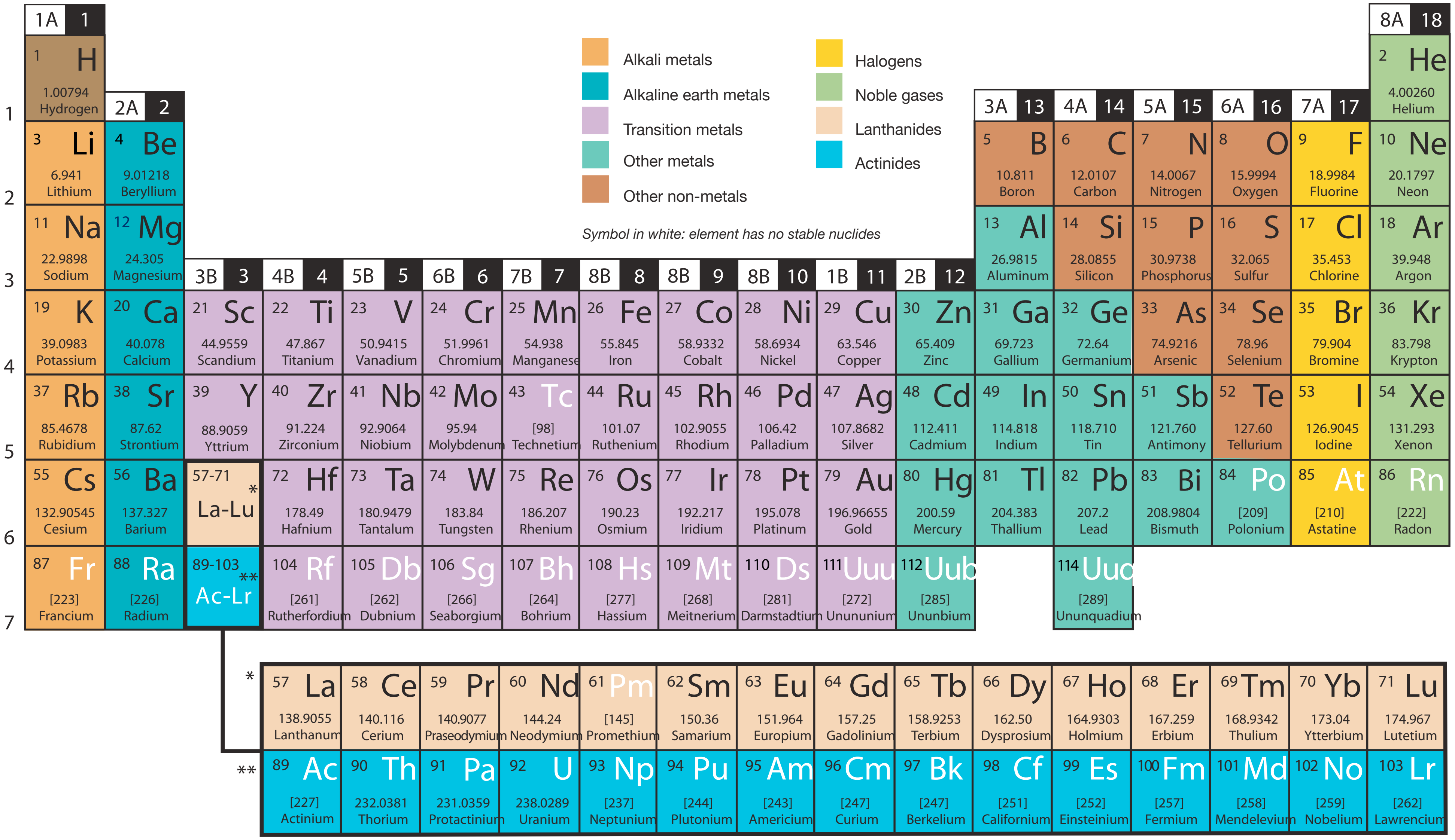
Ion Sources Development

- **The requirement for an ISOL ion source diverge from to a certain degree from the ones for an off-line ion source;**
  - **Because the production rate is somehow limited, We need highly efficient ion source,**
  - **Ionization efficiency most be independent of the pressure fluctuation,**
  - **Ion source free of instabilities in order to prevent reduction of the mass resolving power,**
  - **Has to operate in high radiation field and at high temperature to avoid condensable element to stick on the walls,**
  - **Maintenance free and long life-time,**
  - **Small size to avoid large nuclear waste inventory.**

Ion Source Development at ISAC



🟧 Alkali metals
🟦 Alkaline earth metals
🟪 Transition metals
🟩 Other metals
🟫 Other non-metals
🟨 Halogens
🟩 Noble gases
🟧 Lanthanides
🟦 Actinides

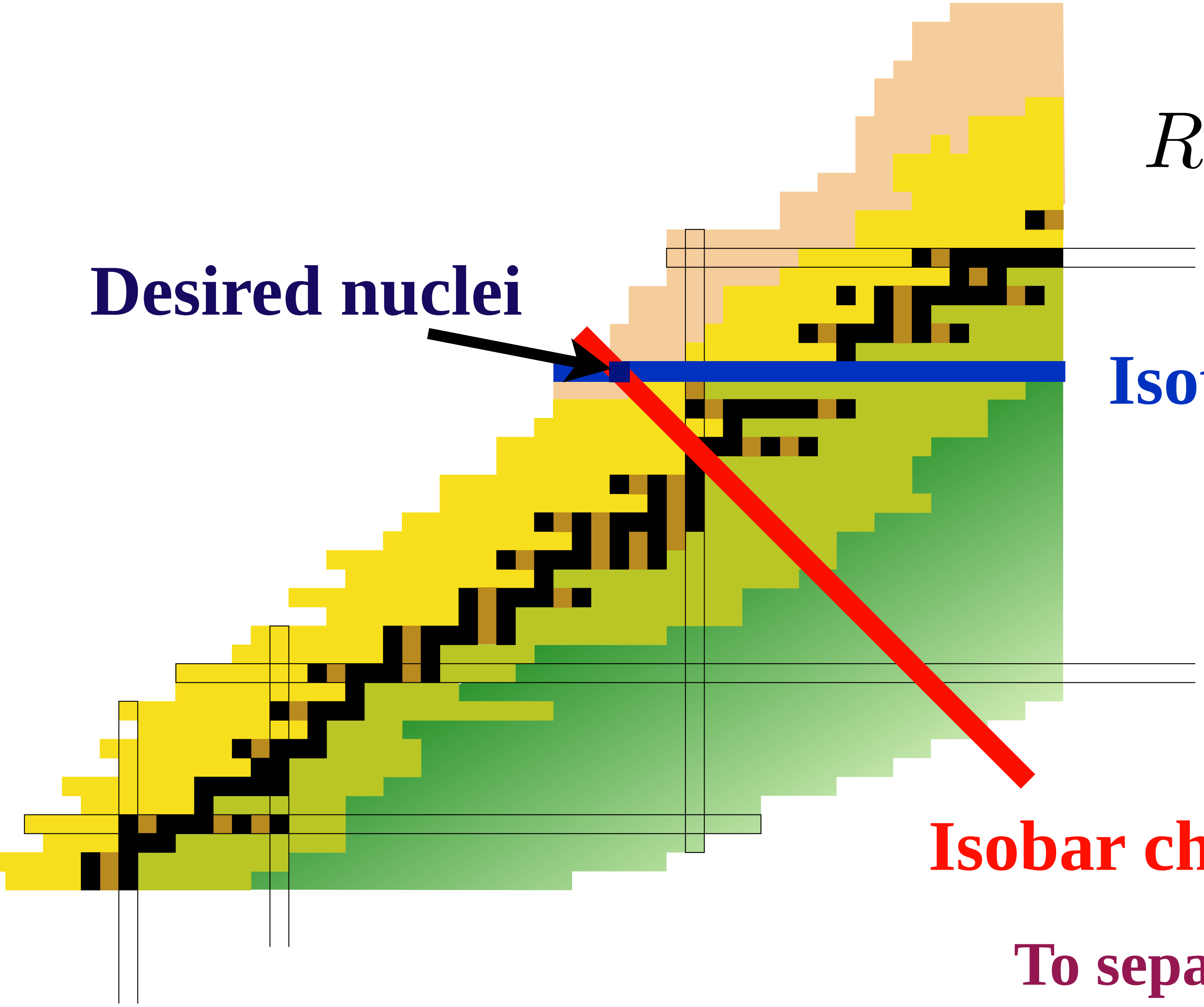
Symbol in white: element has no stable nuclides

	1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 H 1.00794 Hydrogen																	2 He 4.00260 Helium
2	3 Li 6.941 Lithium	4 Be 9.01218 Beryllium											5 B 10.811 Boron	6 C 12.0107 Carbon	7 N 14.0067 Nitrogen	8 O 15.9994 Oxygen	9 F 18.9984 Fluorine	10 Ne 20.1797 Neon
3	11 Na 22.9898 Sodium	12 Mg 24.305 Magnesium											13 Al 26.9815 Aluminum	14 Si 28.0855 Silicon	15 P 30.9738 Phosphorus	16 S 32.065 Sulfur	17 Cl 35.453 Chlorine	18 Ar 39.948 Argon
4	19 K 39.0983 Potassium	20 Ca 40.078 Calcium	21 Sc 44.9559 Scandium	22 Ti 47.867 Titanium	23 V 50.9415 Vanadium	24 Cr 51.9961 Chromium	25 Mn 54.938 Manganese	26 Fe 55.845 Iron	27 Co 58.9332 Cobalt	28 Ni 58.6934 Nickel	29 Cu 63.546 Copper	30 Zn 65.409 Zinc	31 Ga 69.723 Gallium	32 Ge 72.64 Germanium	33 As 74.9216 Arsenic	34 Se 78.96 Selenium	35 Br 79.904 Bromine	36 Kr 83.798 Krypton
5	37 Rb 85.4678 Rubidium	38 Sr 87.62 Strontium	39 Y 88.9059 Yttrium	40 Zr 91.224 Zirconium	41 Nb 92.9064 Niobium	42 Mo 95.94 Molybdenum	43 Tc [98] Technetium	44 Ru 101.07 Ruthenium	45 Rh 102.9055 Rhodium	46 Pd 106.42 Palladium	47 Ag 107.8682 Silver	48 Cd 112.411 Cadmium	49 In 114.818 Indium	50 Sn 118.710 Tin	51 Sb 121.760 Antimony	52 Te 127.60 Tellurium	53 I 126.9045 Iodine	54 Xe 131.293 Xenon
6	55 Cs 132.90545 Cesium	56 Ba 137.327 Barium	57-71 * La-Lu	72 Hf 178.49 Hafnium	73 Ta 180.9479 Tantalum	74 W 183.84 Tungsten	75 Re 186.207 Rhenium	76 Os 190.23 Osmium	77 Ir 192.217 Iridium	78 Pt 195.078 Platinum	79 Au 196.96655 Gold	80 Hg 200.59 Mercury	81 Tl 204.383 Thallium	82 Pb 207.2 Lead	83 Bi 208.9804 Bismuth	84 Po [209] Polonium	85 At [210] Astatine	86 Rn [222] Radon
7	87 Fr [223] Francium	88 Ra [226] Radium	89-103 ** Ac-Lr	104 Rf [261] Rutherfordium	105 Db [262] Dubnium	106 Sg [266] Seaborgium	107 Bh [264] Bohrium	108 Hs [277] Hassium	109 Mt [268] Meitnerium	110 Ds [281] Darmstadtium	111 Uuu [272] Unununium	112 Uub [285] Ununbium		114 Uuq [289] Ununquadium				

*	57 La 138.9055 Lanthanum	58 Ce 140.116 Cerium	59 Pr 140.9077 Praseodymium	60 Nd 144.24 Neodymium	61 Pm [145] Promethium	62 Sm 150.36 Samarium	63 Eu 151.964 Europium	64 Gd 157.25 Gadolinium	65 Tb 158.9253 Terbium	66 Dy 162.50 Dysprosium	67 Ho 164.9303 Holmium	68 Er 167.259 Erbium	69 Tm 168.9342 Thulium	70 Yb 173.04 Ytterbium	71 Lu 174.967 Lutetium
**	89 Ac [227] Actinium	90 Th 232.0381 Thorium	91 Pa 231.0359 Protactinium	92 U 238.0289 Uranium	93 Np [237] Neptunium	94 Pu [244] Plutonium	95 Am [243] Americium	96 Cm [247] Curium	97 Bk [247] Berkelium	98 Cf [251] Californium	99 Es [252] Einsteinium	100 Fm [257] Fermium	101 Md [258] Mendelevium	102 No [259] Nobelium	103 Lr [262] Lawrencium

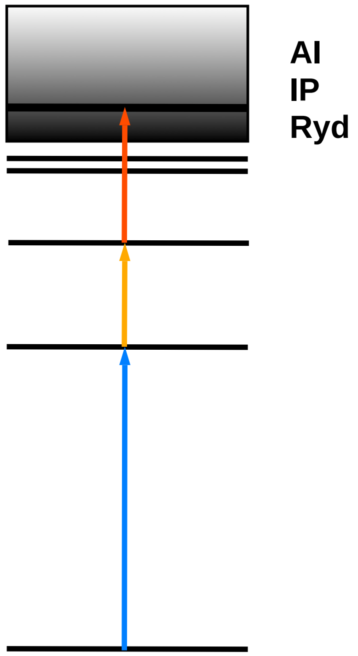
Laser Ion Source

Advantage in RIB production using Resonant Laser Ion Source (RLIS)



$$R = \frac{m}{\delta m} = \frac{A}{1}$$

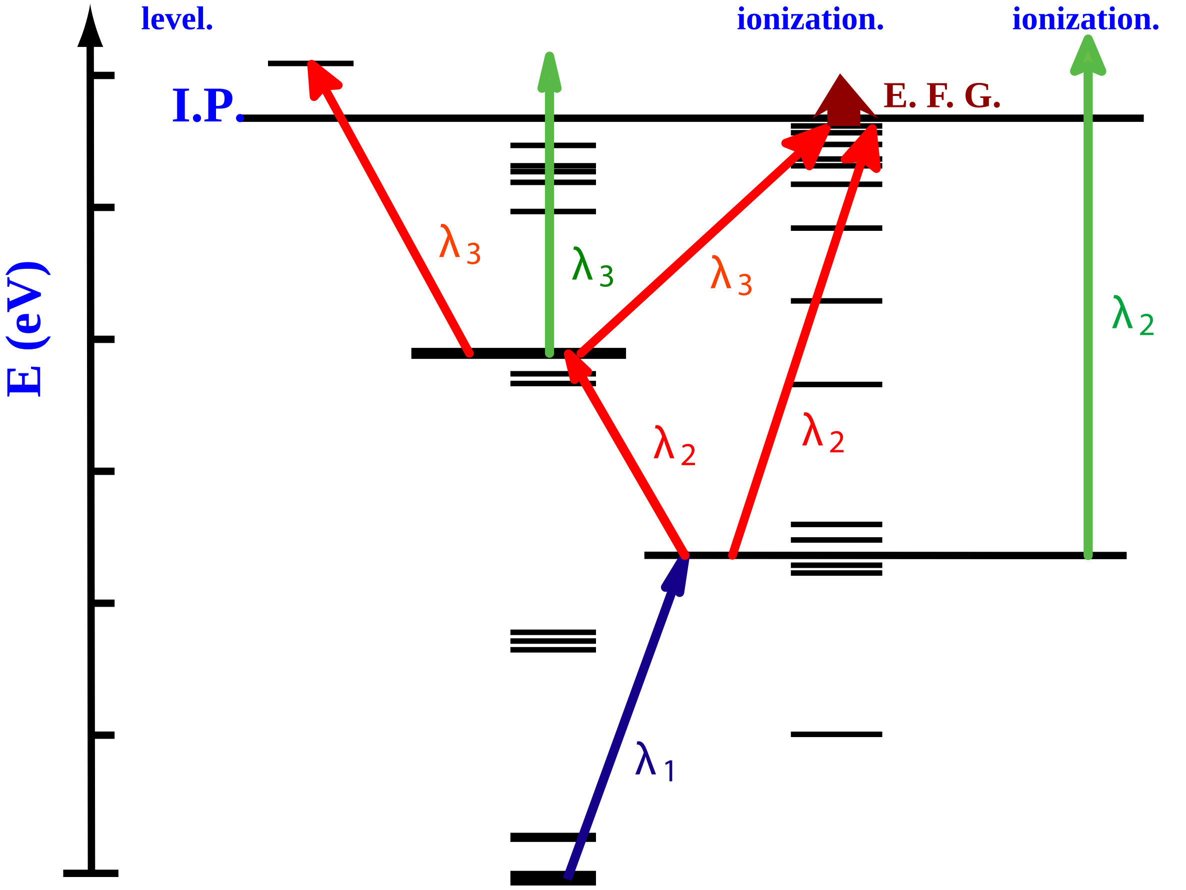
Resonant Ionization LIS
-> element selective
-> isobar free beams

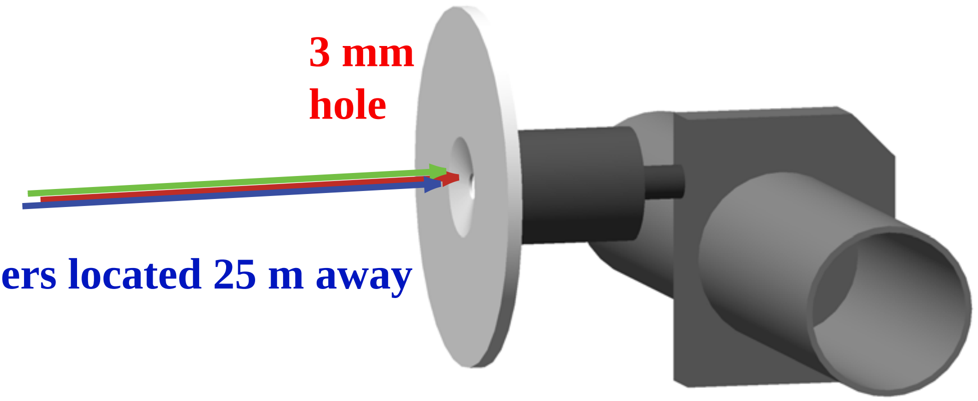


To separate isobars for different mass region;
A~ 60 => R = 20 000 to 25 000 at least!
A ~ 120 => R = 30 000 to 60 000 at least!

Resonant Laser Ion Source

Principle of the Resonance Laser Ion Source (RLIS)

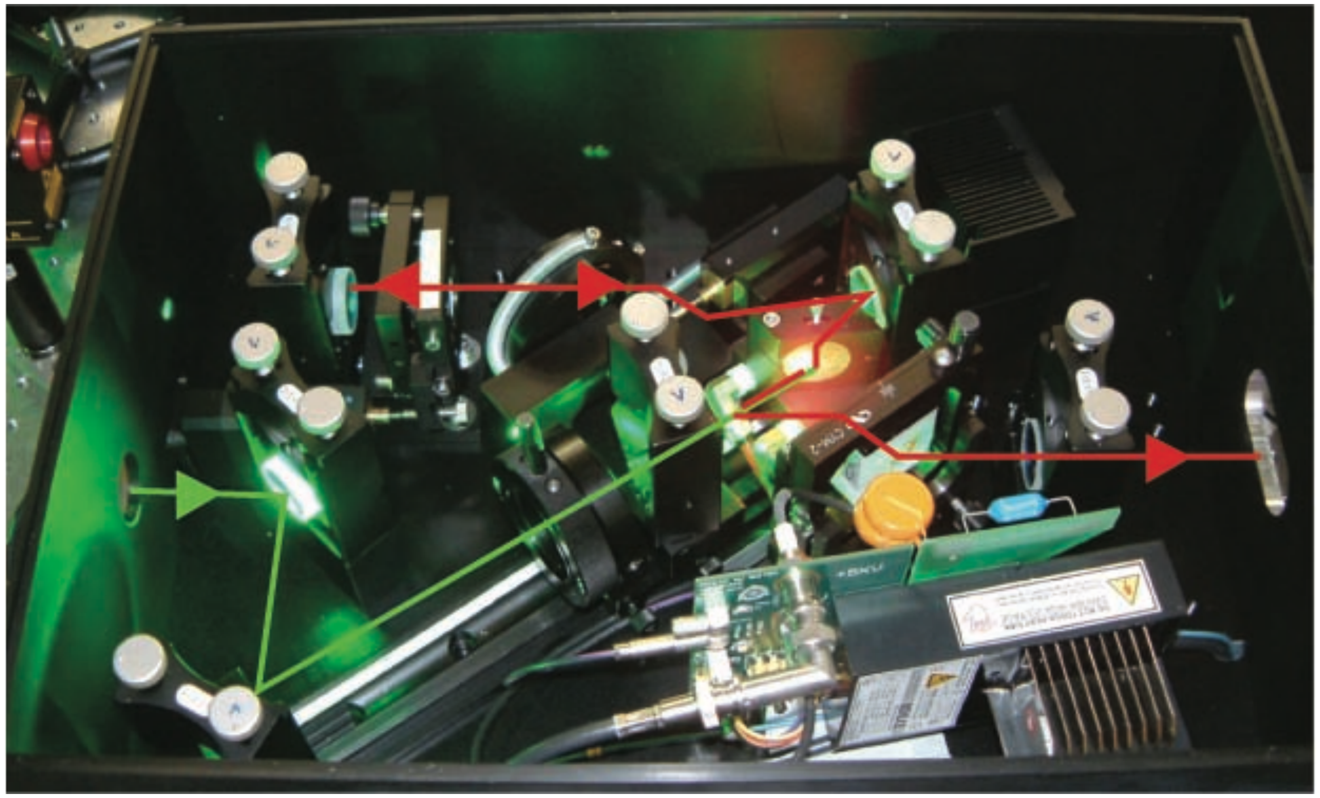


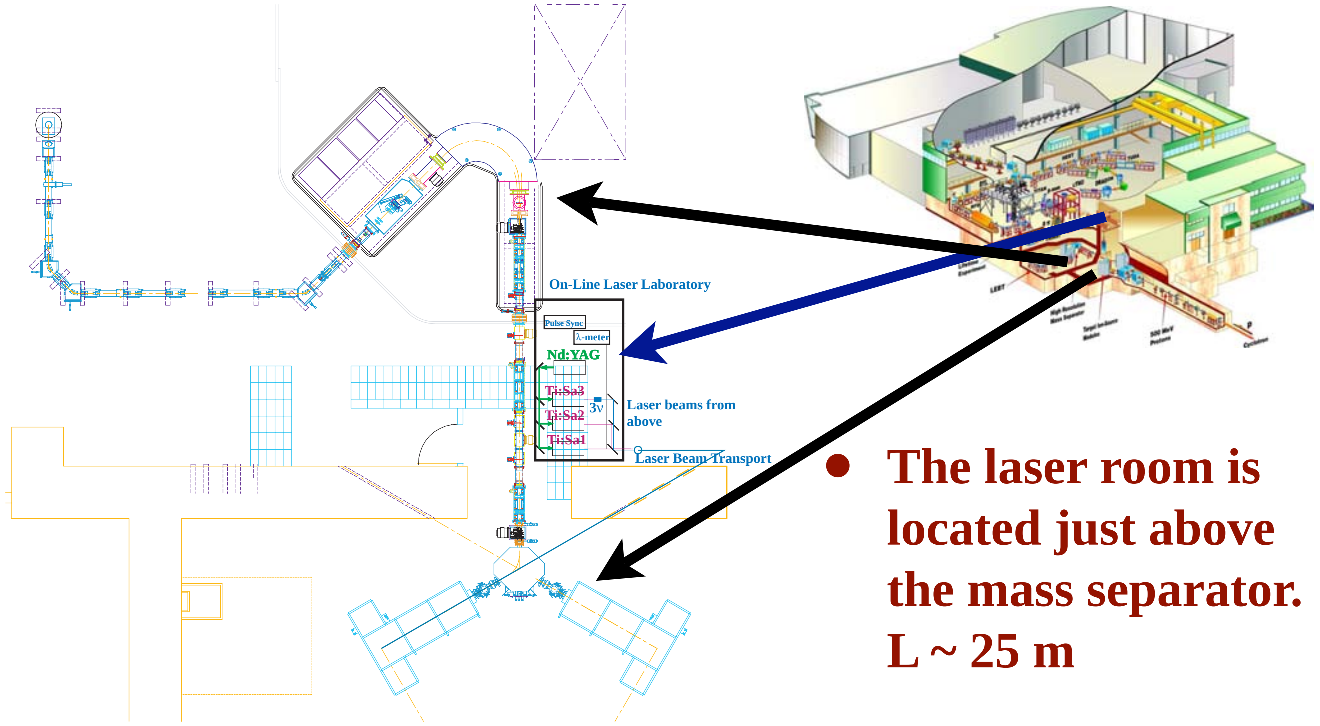


- **Laser requirements**
  - **Laser must be applicable to a wide range of elements**
  - **For selectivity at least two resonant steps are required and third one is even better.**
  - **High repetition rate to ensure that the atom sees at least one laser pulse while traveling inside the transfer tube.**
  - **Need to focus the laser beams into a 3 mm diameter hole, ~ 25 m away**
    - **Good laser beams quality is required.**
    - **Large optics elements.**
  - **Need to synchronize the laser pulse such they arrive at the same time inside the transfer tube.**

TRIUMF Ti:Sa Laser

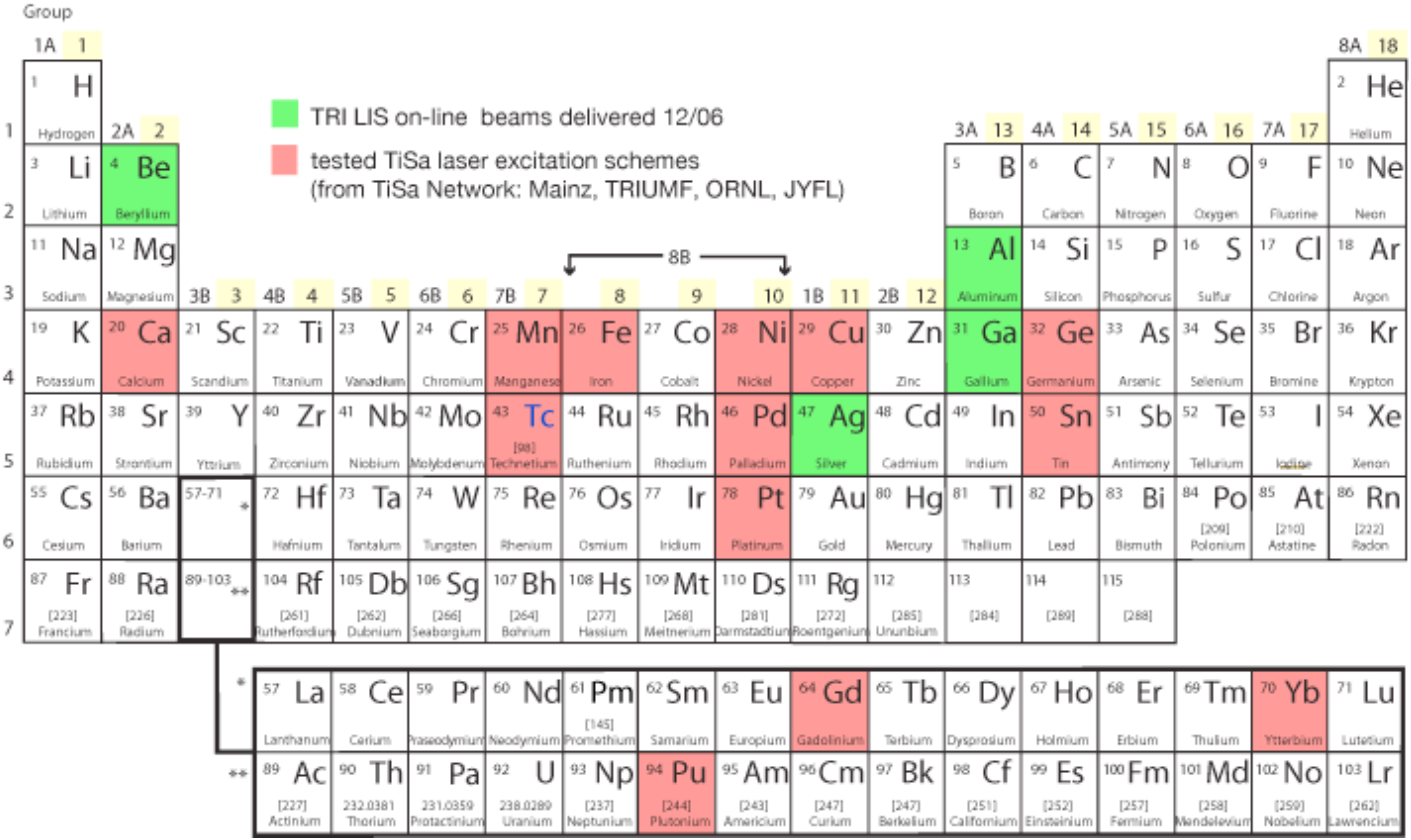
- **We built our Ti:Sa laser using U. Mainz design.** J.H. Yi et al, Japanese Journal of Applied Physics Part 1, Vol 42, Issue 8, p. 5066-5070 (2003)
  - **We simplify the design to make fabrication more cost effective using CNC machining.**
  - **Improve cooling, better thermal stability**
- **We upgrade the laser system by double side pumping.**
  - **More than double the output power.**





- The laser room is located just above the mass separator. L ~ 25 m

Laser Ion Source



🟩 TRI LIS on-line beams delivered 12/06

🟥 tested TiSa laser excitation schemes
(from TiSa Network: Mainz, TRIUMF, ORNL, JYFL)

Group

	1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	9	10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 H Hydrogen																	2 He Helium
2	3 Li Lithium	🟩 4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
3	11 Na Sodium	12 Mg Magnesium											🟩 13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
4	19 K Potassium	🟥 20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	🟥 25 Mn Manganese	🟥 26 Fe Iron	27 Co Cobalt	🟥 28 Ni Nickel	🟥 29 Cu Copper	30 Zn Zinc	🟩 31 Ga Gallium	🟥 32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
5	37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	🟥 43 Tc [98] Technetium	44 Ru Ruthenium	45 Rh Rhodium	🟥 46 Pd Palladium	🟩 47 Ag Silver	48 Cd Cadmium	49 In Indium	🟥 50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
6	55 Cs Cesium	56 Ba Barium	57-71 *	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	🟥 78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po [209] Polonium	85 At [210] Astatine	86 Rn [222] Radon
7	87 Fr [223] Francium	88 Ra [226] Radium	89-103 **	104 Rf [261] Rutherfordium	105 Db [262] Dubnium	106 Sg [266] Seaborgium	107 Bh [264] Bohrium	108 Hs [277] Hassium	109 Mt [268] Meitnerium	110 Ds [281] Darmstadtium	111 Rg [272] Roentgenium	112 [285] Ununbium	113 [284]	114 [289]	115 [288]			

*	57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm [145] Promethium	62 Sm Samarium	63 Eu Europium	🟥 64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	🟥 70 Yb Ytterbium	71 Lu Lutetium
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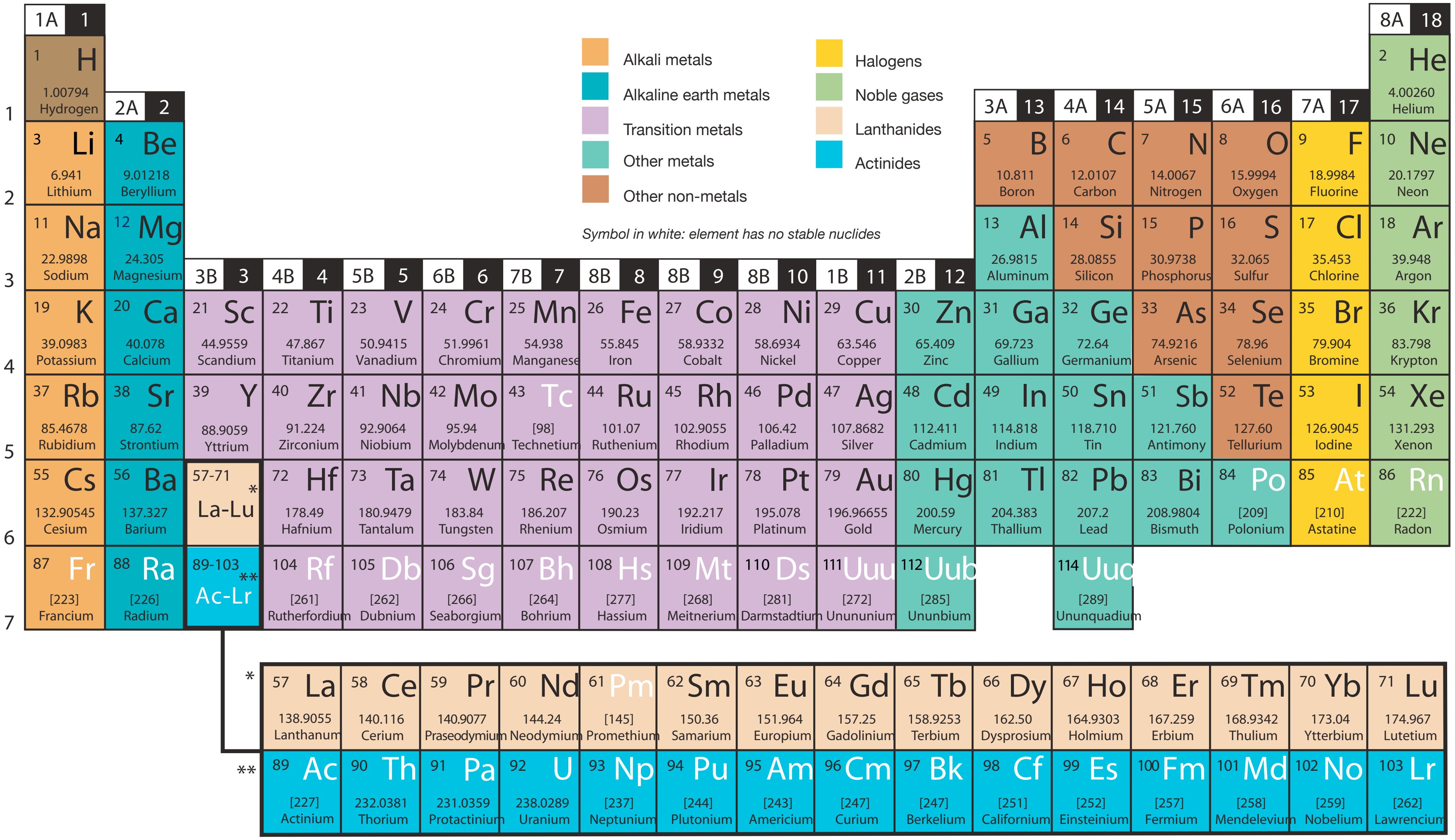
Ion Source Development at ISAC



- 🟧 Alkali metals
- 🟦 Alkaline earth metals
- 🟪 Transition metals
- 🟩 Other metals
- 🟫 Other non-metals
- 🟨 Halogens
- 🟩 Noble gases
- 🟧 Lanthanides
- 🟦 Actinides

Symbol in white: element has no stable nuclides

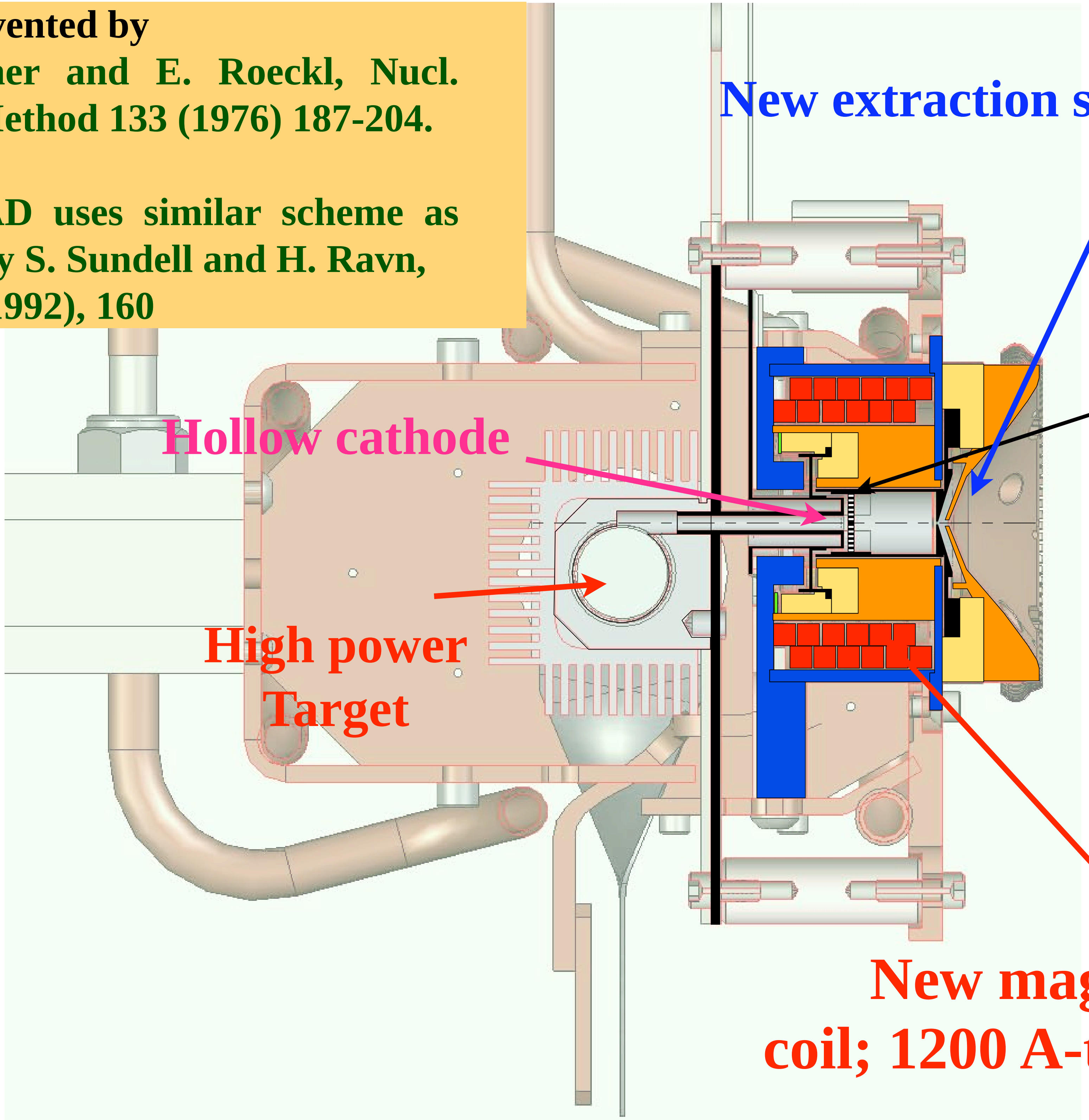
	1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 H 1.00794 Hydrogen																	2 He 4.00260 Helium
2	3 Li 6.941 Lithium	4 Be 9.01218 Beryllium											5 B 10.811 Boron	6 C 12.0107 Carbon	7 N 14.0067 Nitrogen	8 O 15.9994 Oxygen	9 F 18.9984 Fluorine	10 Ne 20.1797 Neon
3	11 Na 22.9898 Sodium	12 Mg 24.305 Magnesium											13 Al 26.9815 Aluminum	14 Si 28.0855 Silicon	15 P 30.9738 Phosphorus	16 S 32.065 Sulfur	17 Cl 35.453 Chlorine	18 Ar 39.948 Argon
4	19 K 39.0983 Potassium	20 Ca 40.078 Calcium	21 Sc 44.9559 Scandium	22 Ti 47.867 Titanium	23 V 50.9415 Vanadium	24 Cr 51.9961 Chromium	25 Mn 54.938 Manganese	26 Fe 55.845 Iron	27 Co 58.9332 Cobalt	28 Ni 58.6934 Nickel	29 Cu 63.546 Copper	30 Zn 65.409 Zinc	31 Ga 69.723 Gallium	32 Ge 72.64 Germanium	33 As 74.9216 Arsenic	34 Se 78.96 Selenium	35 Br 79.904 Bromine	36 Kr 83.798 Krypton
5	37 Rb 85.4678 Rubidium	38 Sr 87.62 Strontium	39 Y 88.9059 Yttrium	40 Zr 91.224 Zirconium	41 Nb 92.9064 Niobium	42 Mo 95.94 Molybdenum	43 Tc [98] Technetium	44 Ru 101.07 Ruthenium	45 Rh 102.9055 Rhodium	46 Pd 106.42 Palladium	47 Ag 107.8682 Silver	48 Cd 112.411 Cadmium	49 In 114.818 Indium	50 Sn 118.710 Tin	51 Sb 121.760 Antimony	52 Te 127.60 Tellurium	53 I 126.9045 Iodine	54 Xe 131.293 Xenon
6	55 Cs 132.90545 Cesium	56 Ba 137.327 Barium	57-71 * La-Lu	72 Hf 178.49 Hafnium	73 Ta 180.9479 Tantalum	74 W 183.84 Tungsten	75 Re 186.207 Rhenium	76 Os 190.23 Osmium	77 Ir 192.217 Iridium	78 Pt 195.078 Platinum	79 Au 196.96655 Gold	80 Hg 200.59 Mercury	81 Tl 204.383 Thallium	82 Pb 207.2 Lead	83 Bi 208.9804 Bismuth	84 Po [209] Polonium	85 At [210] Astatine	86 Rn [222] Radon
7	87 Fr [223] Francium	88 Ra [226] Radium	89-103 ** Ac-Lr	104 Rf [261] Rutherfordium	105 Db [262] Dubnium	106 Sg [266] Seaborgium	107 Bh [264] Bohrium	108 Hs [277] Hassium	109 Mt [268] Meitnerium	110 Ds [281] Darmstadtium	111 Uuu [272] Unununium	112 Uub [285] Ununbium		114 Uuq [289] Ununquadium				

*	57 La 138.9055 Lanthanum	58 Ce 140.116 Cerium	59 Pr 140.9077 Praseodymium	60 Nd 144.24 Neodymium	61 Pm [145] Promethium	62 Sm 150.36 Samarium	63 Eu 151.964 Europium	64 Gd 157.25 Gadolinium	65 Tb 158.9253 Terbium	66 Dy 162.50 Dysprosium	67 Ho 164.9303 Holmium	68 Er 167.259 Erbium	69 Tm 168.9342 Thulium	70 Yb 173.04 Ytterbium	71 Lu 174.967 Lutetium
**	89 Ac [227] Actinium	90 Th 232.0381 Thorium	91 Pa 231.0359 Protactinium	92 U 238.0289 Uranium	93 Np [237] Neptunium	94 Pu [244] Plutonium	95 Am [243] Americium	96 Cm [247] Curium	97 Bk [247] Berkelium	98 Cf [251] Californium	99 Es [252] Einsteinium	100 Fm [257] Fermium	101 Md [258] Mendelevium	102 No [259] Nobelium	103 Lr [262] Lawrencium

FEBIAD-Mk-XI

FEBIAD invented by
R. Kirchner and E. Roeckl, Nucl. Instr. and Method 133 (1976) 187-204.

Our FEBIAD uses similar scheme as developed by S. Sundell and H. Ravn, NIM, B70 (1992), 160



New extraction system

Hollow cathode

High power Target

New magnetic coil; 1200 A-t=> 500 G

grid

12,7 mm diameter Ta,
1 mm thick

FEBIAD-Mk-XI

FEBIAD invented by
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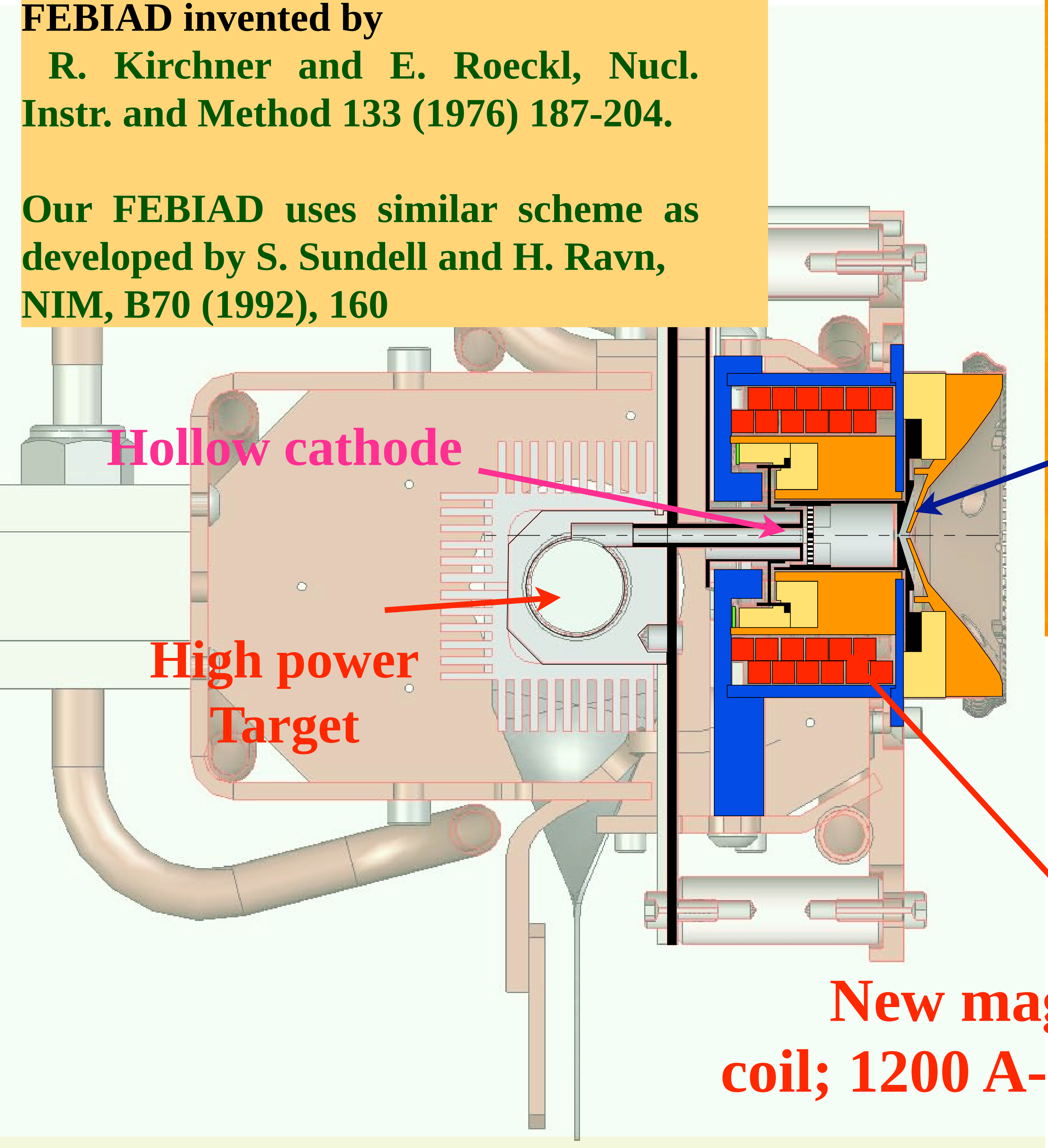

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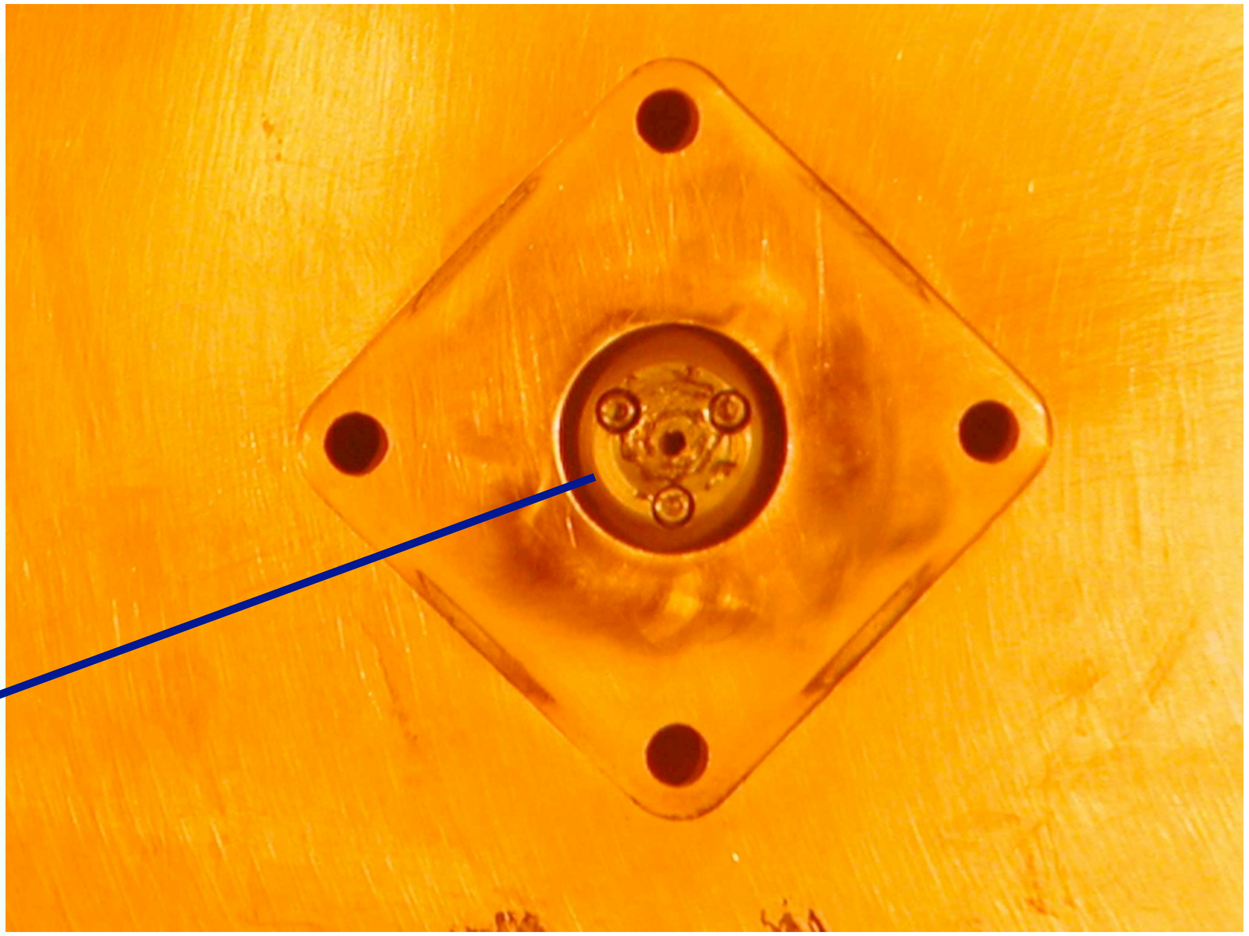
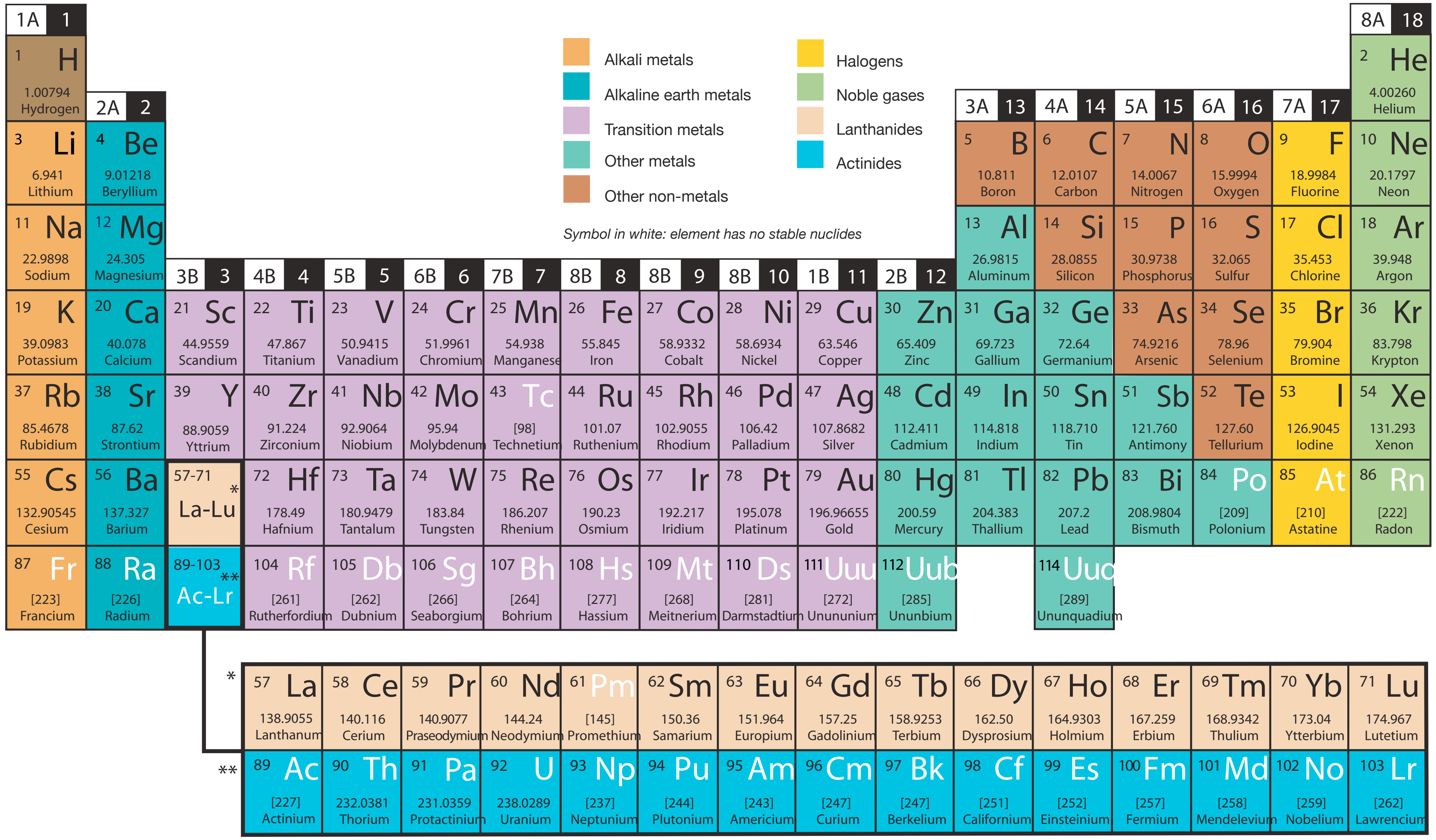


The extraction electrode after run.
New extraction system
Fresh electrode with new tartget/ion source assembly

Ion Source Development at ISAC



- 🟧 Alkali metals
- 🟦 Alkaline earth metals
- 🟪 Transition metals
- 🟩 Other metals
- 🟫 Other non-metals
- 🟨 Halogens
- 🟩 Noble gases
- 🟧 Lanthanides
- 🟦 Actinides

Symbol in white: element has no stable nuclides

	1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 H 1.00794 Hydrogen																	2 He 4.00260 Helium
2	3 Li 6.941 Lithium	4 Be 9.01218 Beryllium											5 B 10.811 Boron	6 C 12.0107 Carbon	7 N 14.0067 Nitrogen	8 O 15.9994 Oxygen	9 F 18.9984 Fluorine	10 Ne 20.1797 Neon
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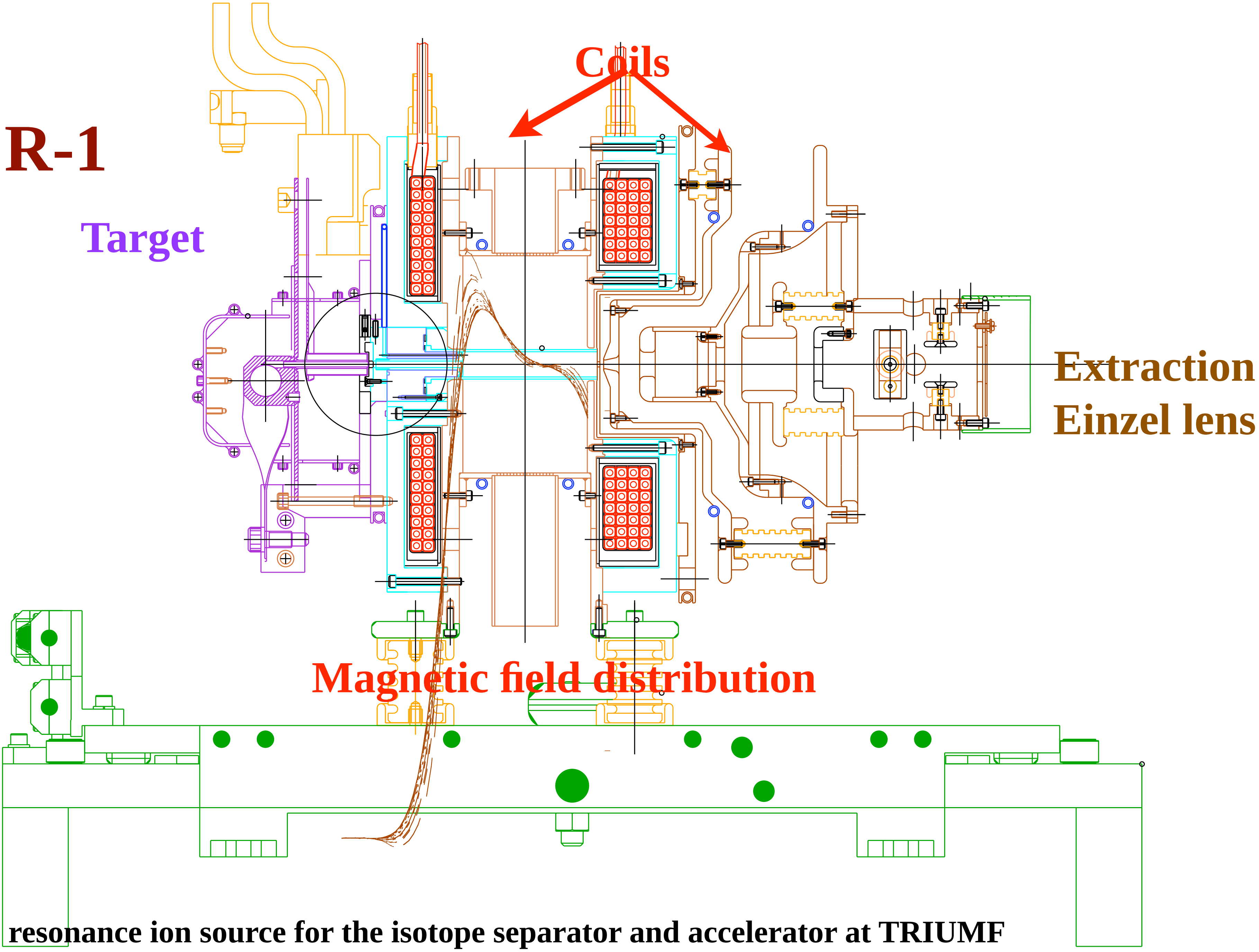
Electron Cyclotron Resonance Ion Source

TRIUMF ECR-1

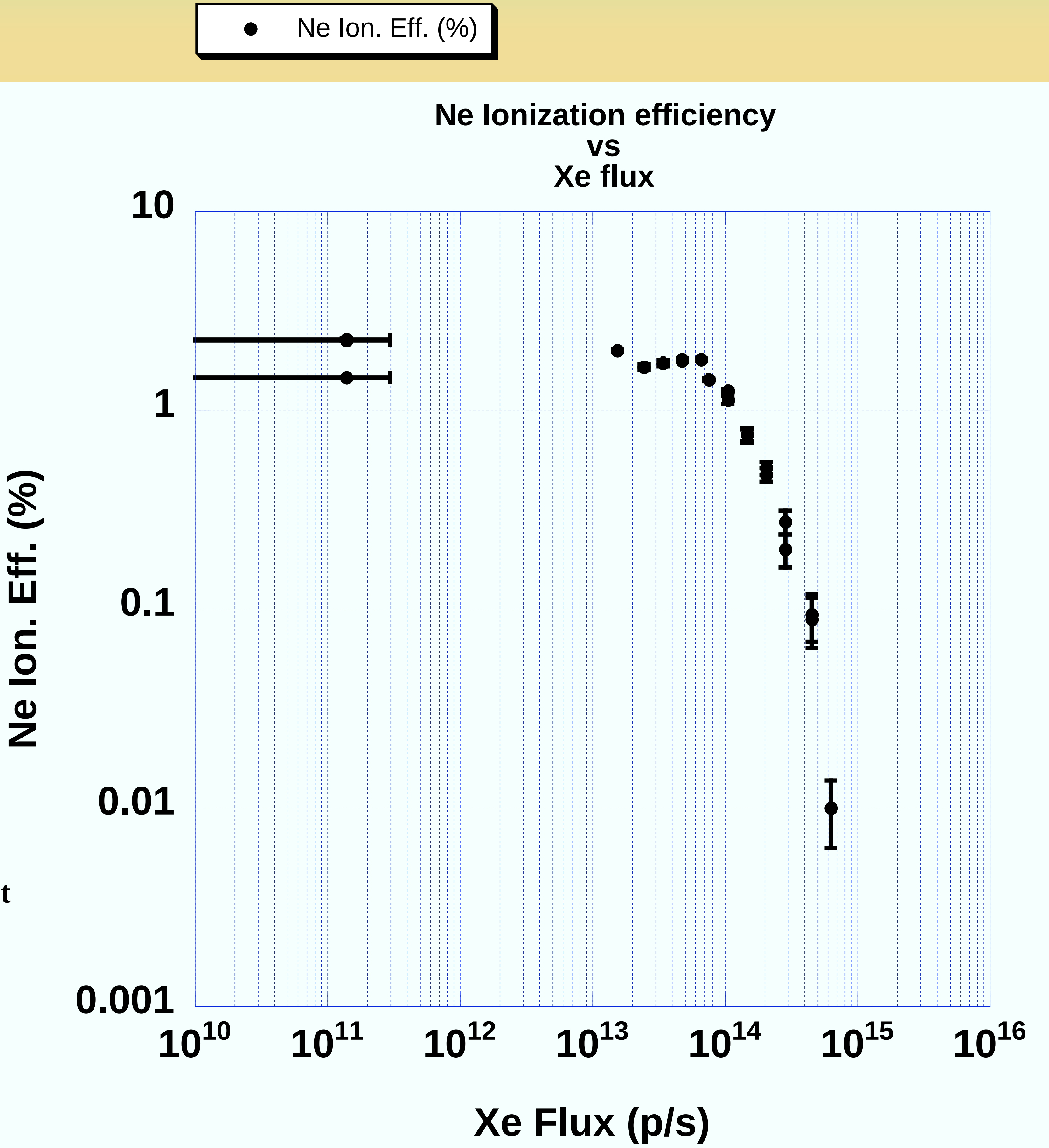


Design of an electron cyclotron resonance ion source for the isotope separator and accelerator at TRIUMF

D. Yuan, K. Jayamanna, M. Dombsky, D. Louie, S. Kadantsev, R. Keitel, T. Kuo, M. McDonald, M. Olivo, and P. Schmor
Rev. Sci. Instrum. 71, 643 (2000)

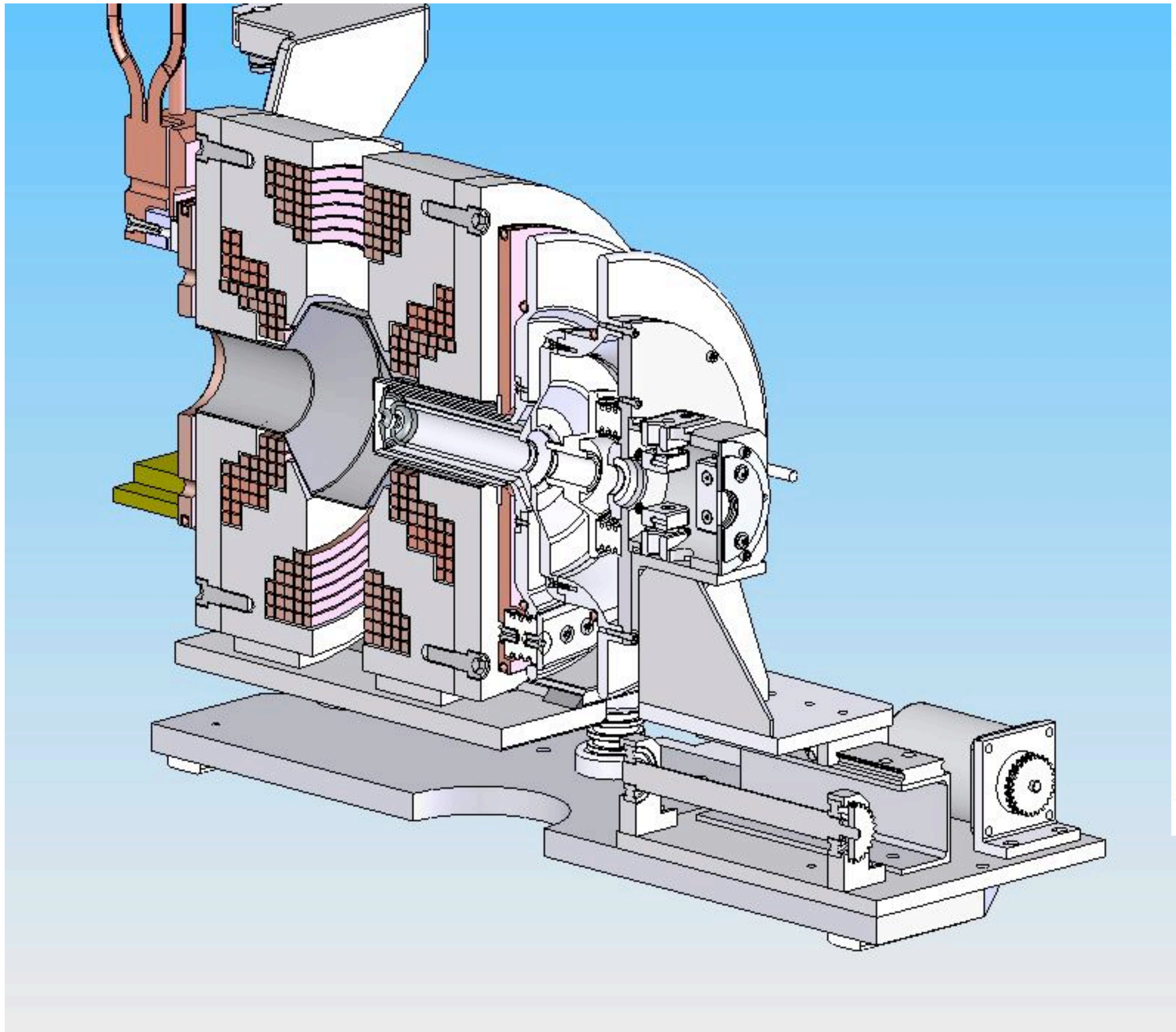
Ne ionization efficiency versus the Xe flux injected into the ECR-1.

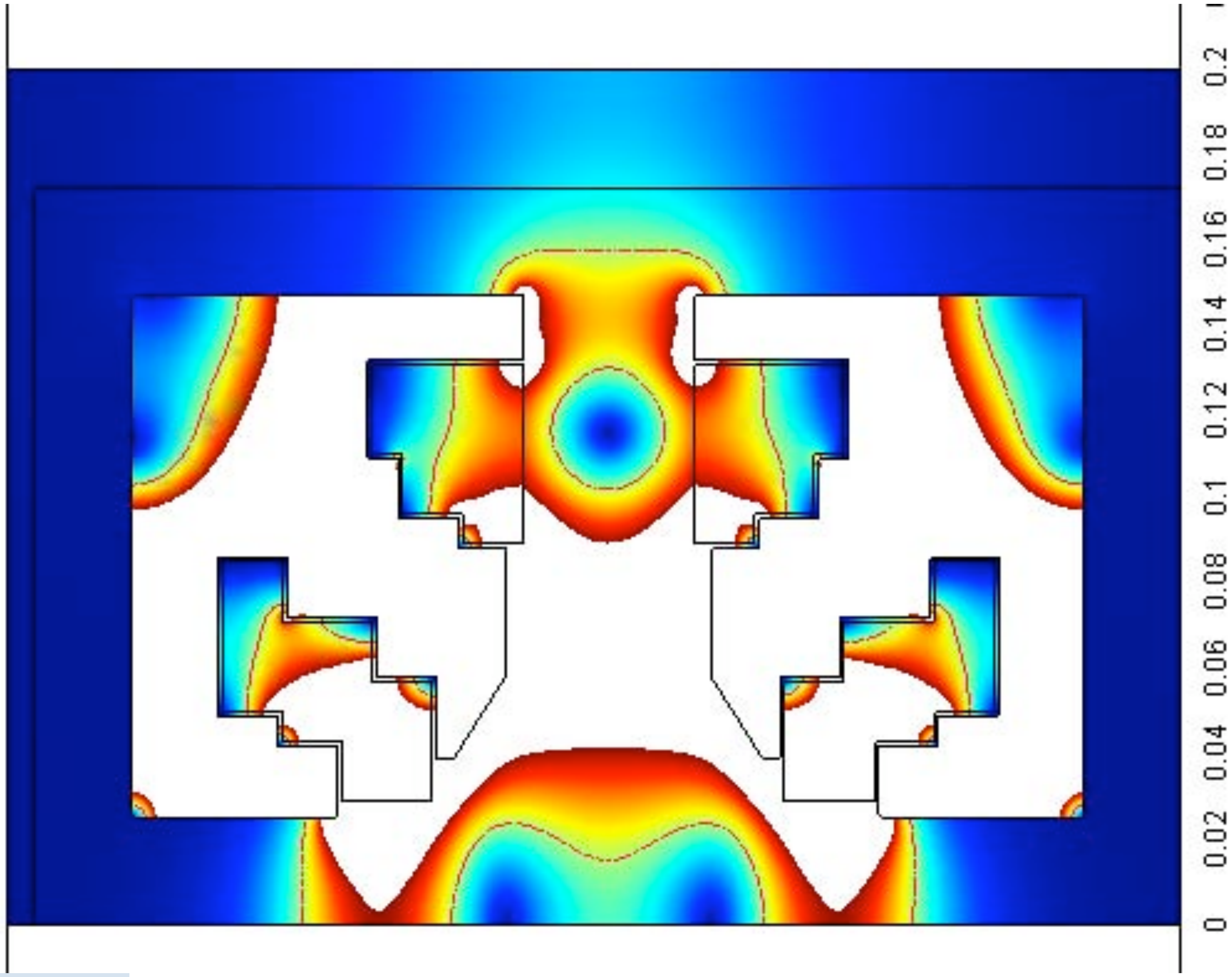
Gas flux found to be incompatible with on-line operation.



Recent Results with the 2.45 GHZ ECRIS at TRIUMF-ISAC.
Bricault, Pierre; Jayamanna, Keerthi; Yuan, Dick He Ling; Olivo, Miguel; Schmor, Paul.
AIP Conference Proceedings, 2005, Vol. 749 Issue 1, p143-146

New ECR Ion Source



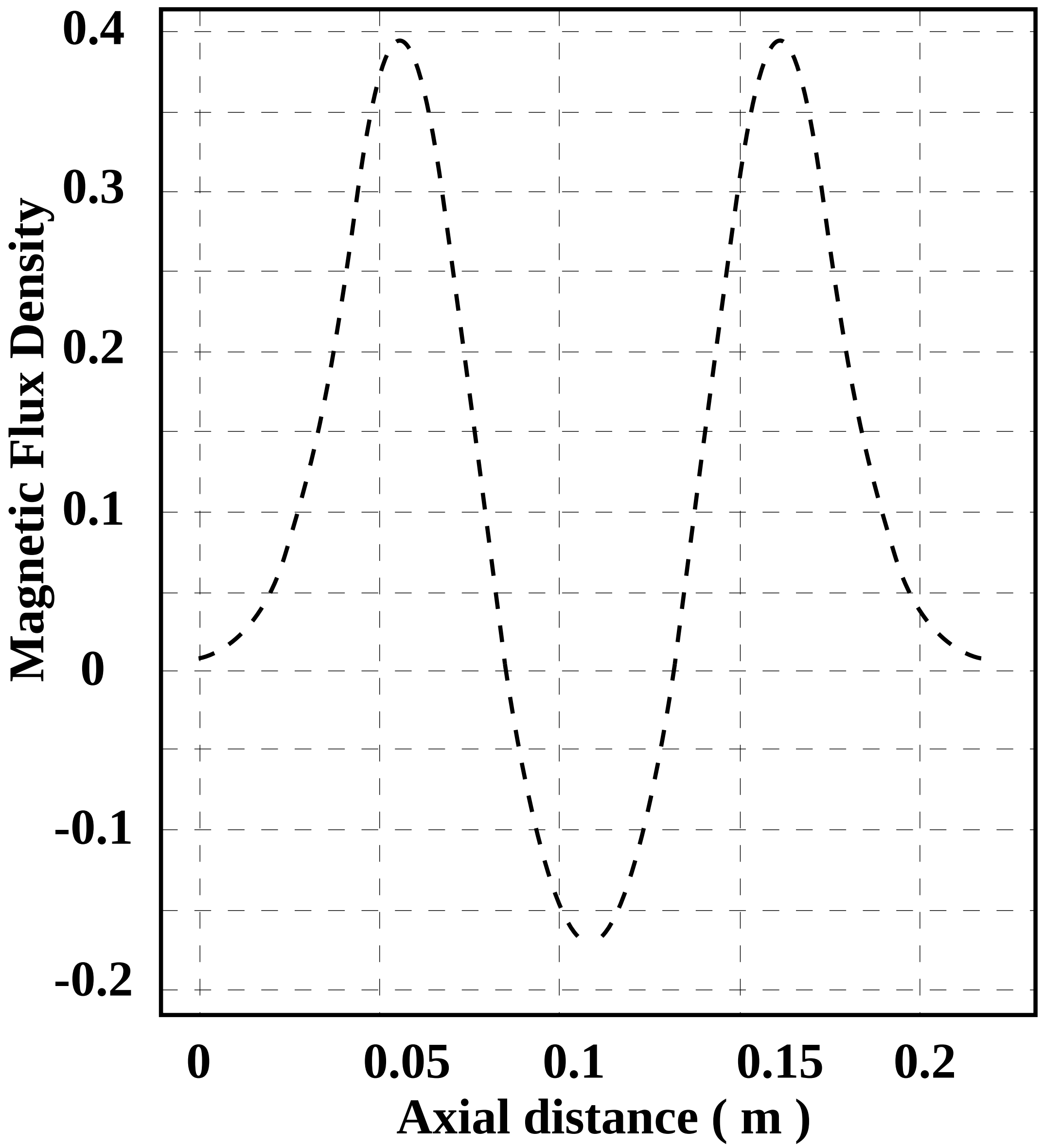


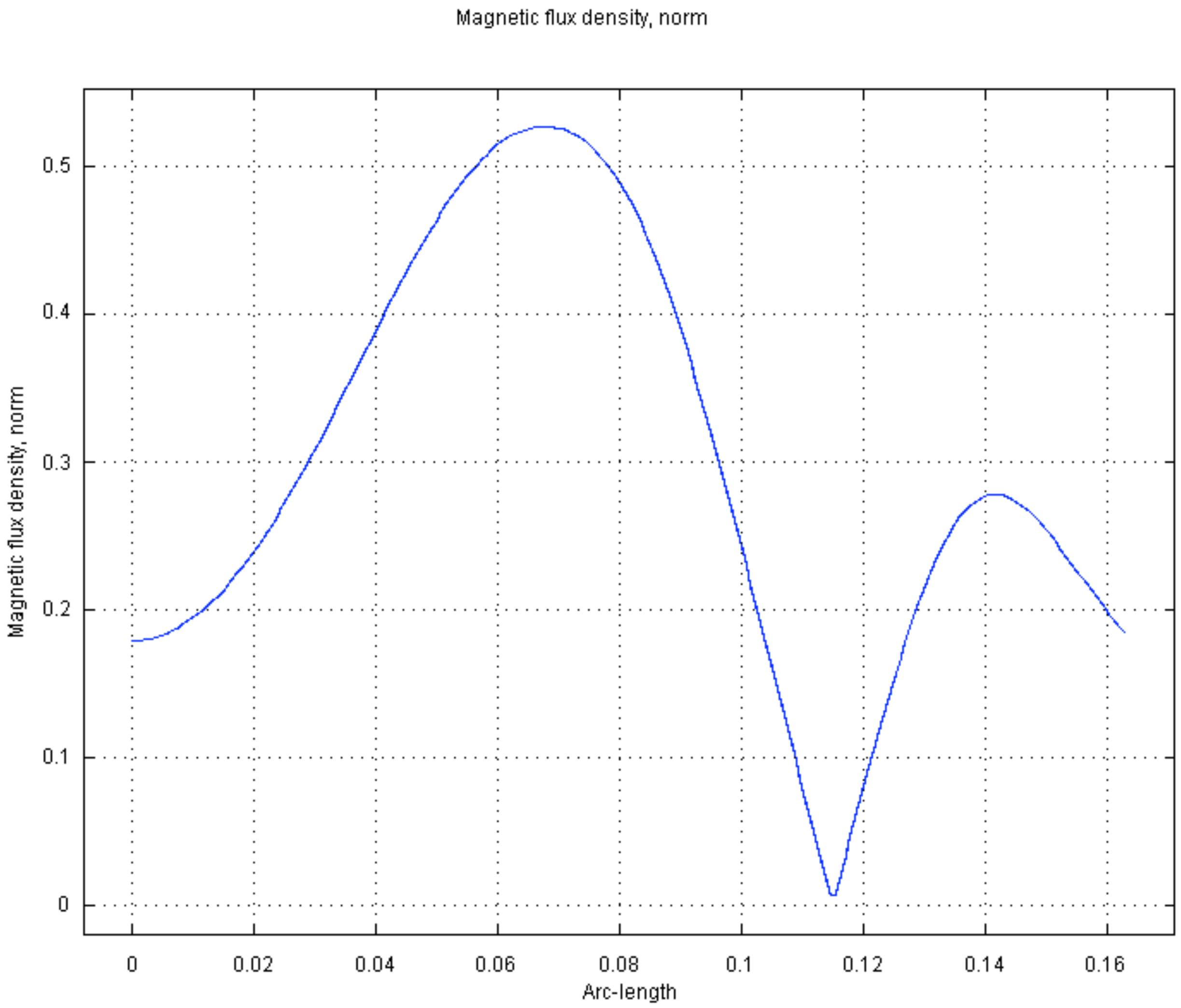
- **MISTIC new ECR ion source, Collaboration between GANIL and TRIUMF,**
- **ECR with longitudinal and radial magnetic confinement.**
- **Operates at 3 - 6 GHz, N. Lecesne, P. Bricault-TRI-DN-05-23.**

New ECR Ion Source

Axial magnetic field

Radial magnetic field

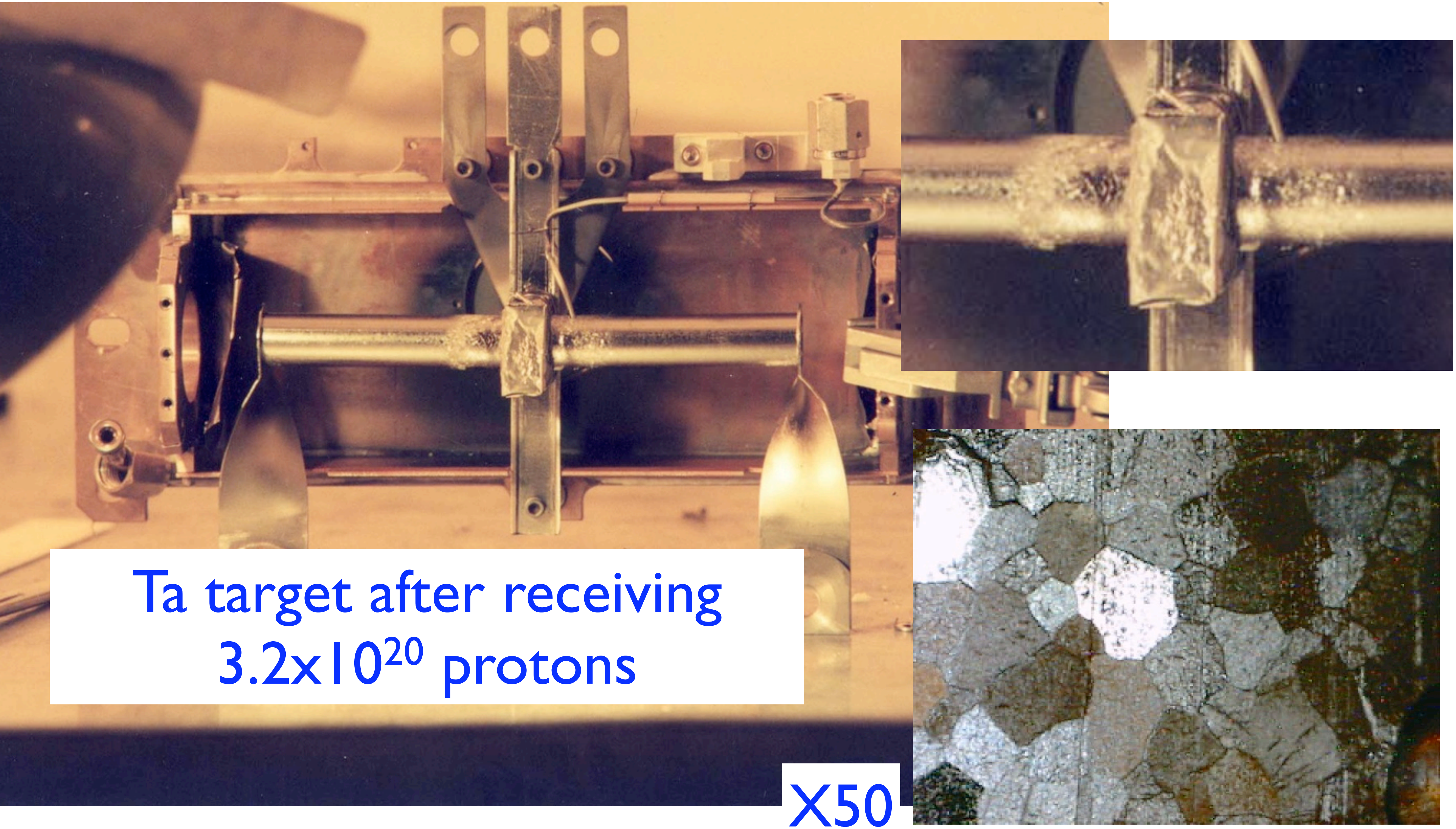




N. Lecesne, P. Bricault-TRI-DN-05-23.

Better electron confinement will yield to better on-line ionization efficiency

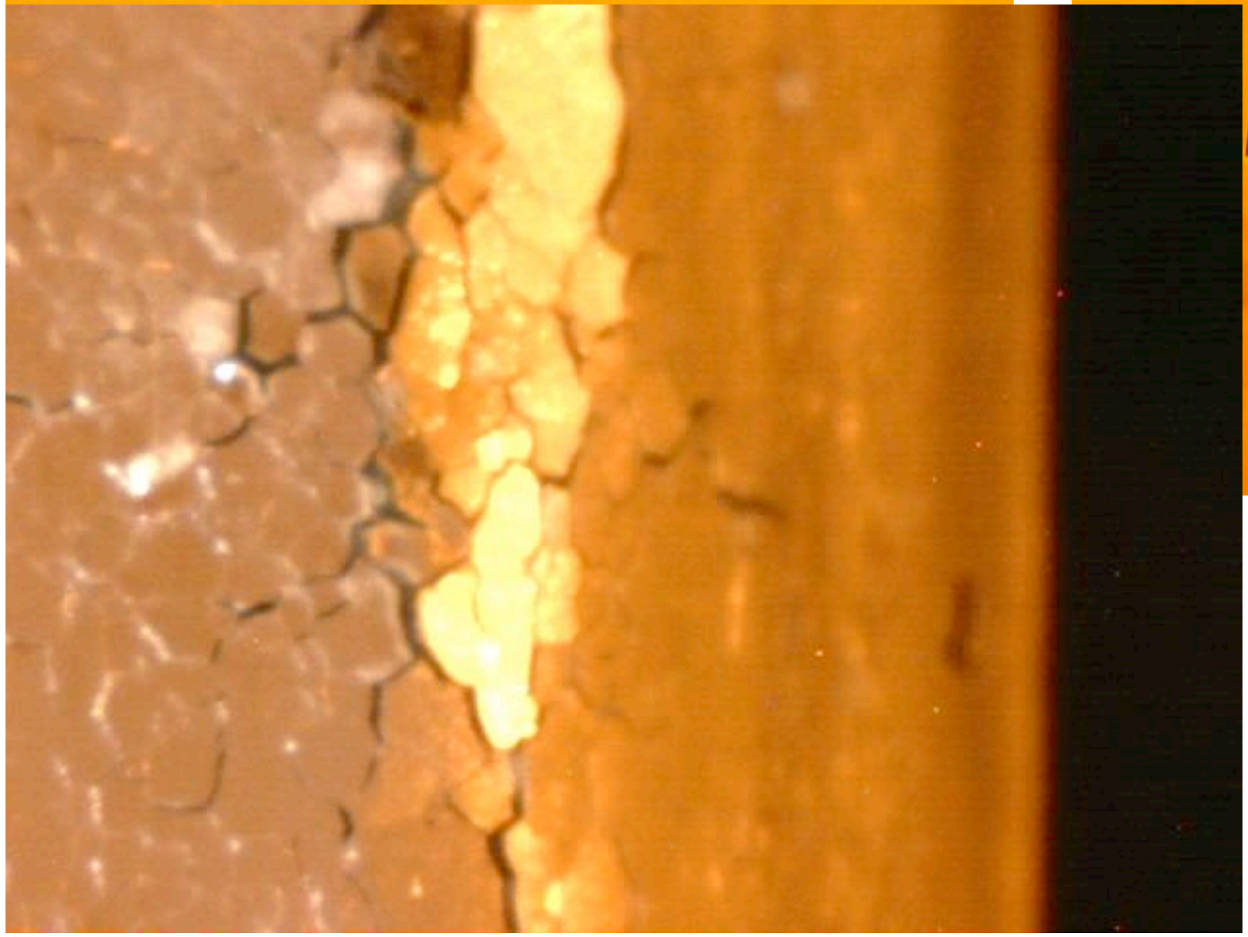
Radiation damage



Ta target after receiving $3.2\text{x}10^{20}$ protons

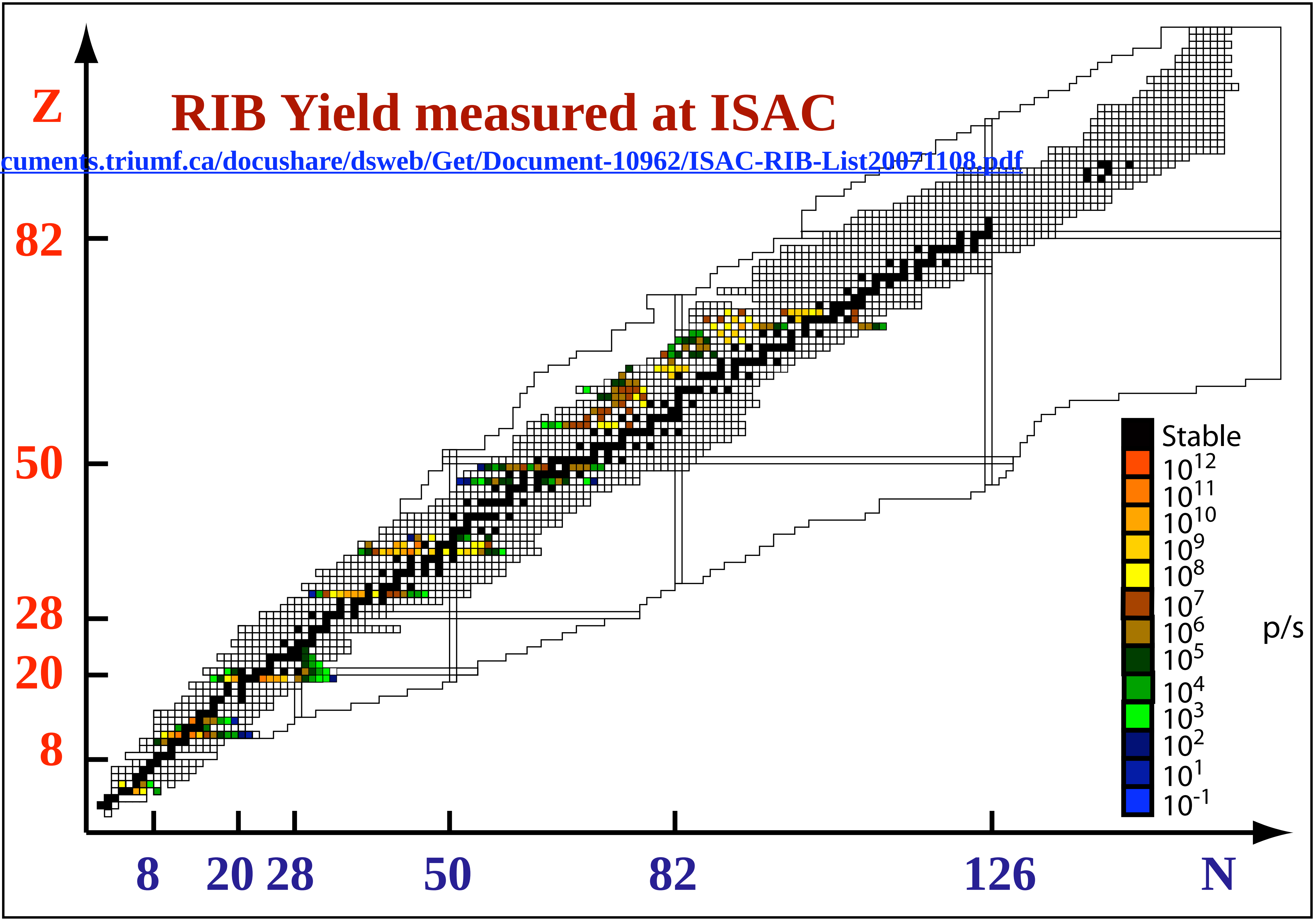
X50

Radiation damage



Target container damage leads to reduced yield!
Cannot operate the target for long period!

ISAC Measured RIB



TRIUMF

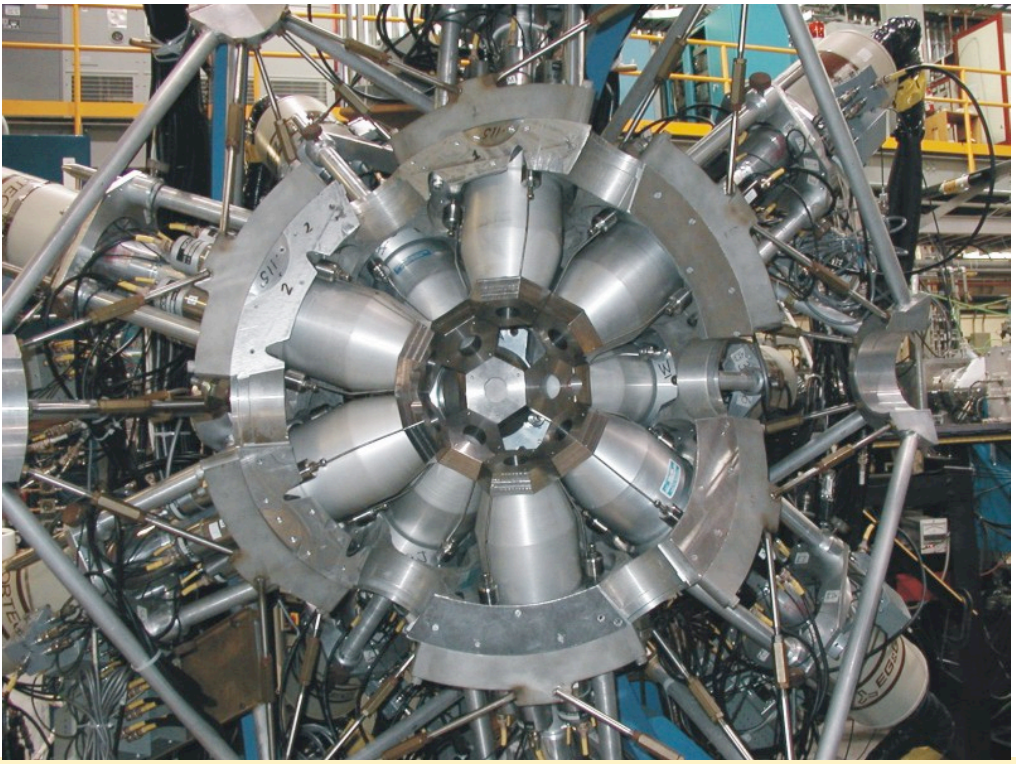
ISAC Facility

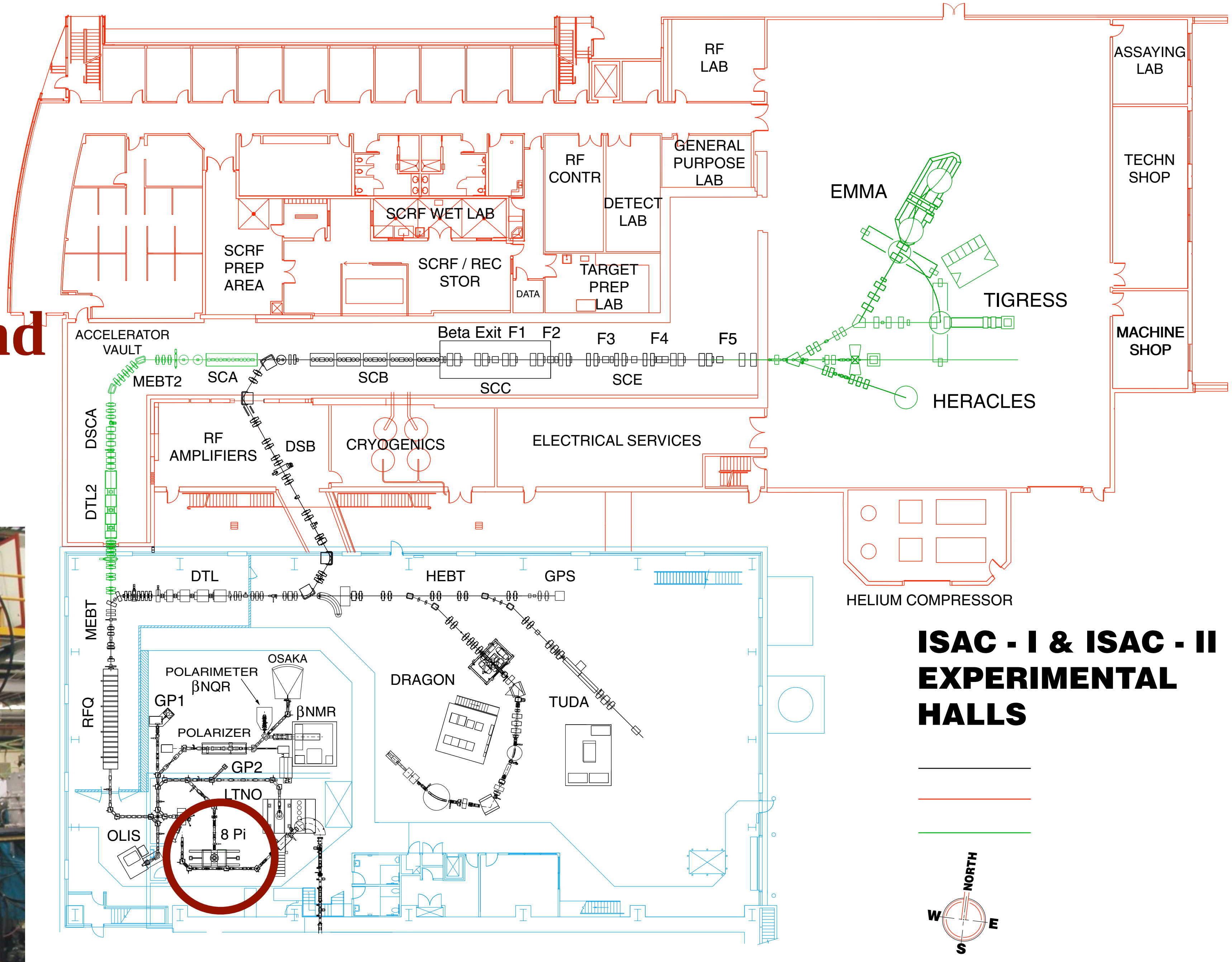
8π

γ-array

- 20 HP Ge Detectors
- 20 Plastic Scintillators
- Tape system

=> High precision $T_{1/2}$ and Branching Ratio measurements.



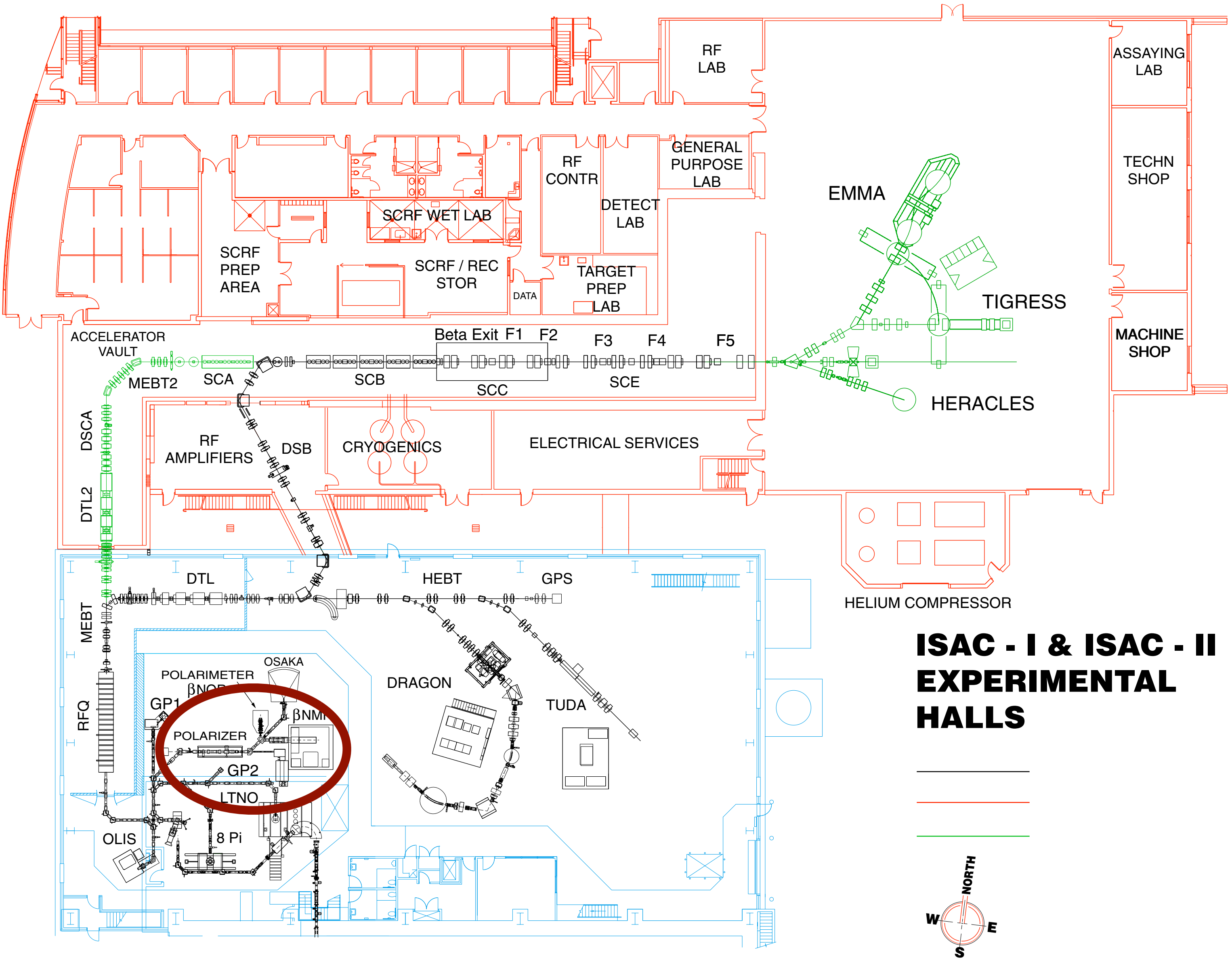


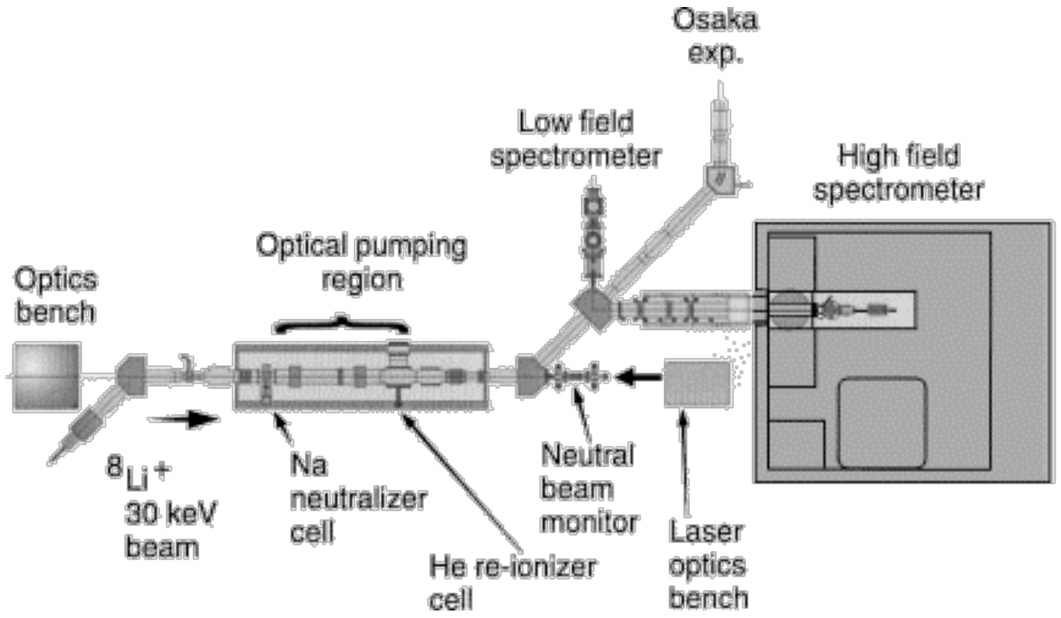
TRIUMF

ISAC Facility

Polarized Beams

- Neutralization Na cell
- Co-linear laser beams
- He gas cell ionizer
  - βNMR, high B field (8 T)
  - βNQR, low B field
  - β decay of polarized beams, ^{A}Li, ^{A}Na, ^{A}Be, ...

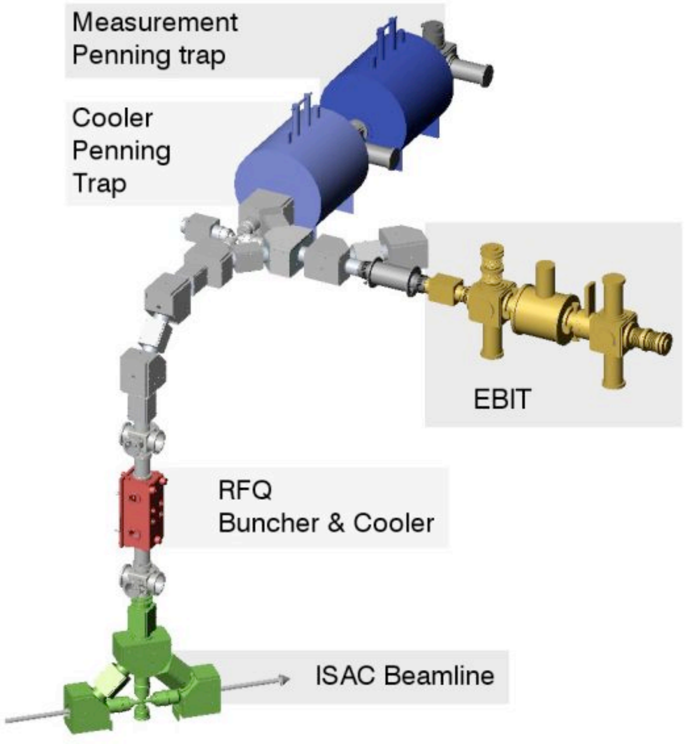


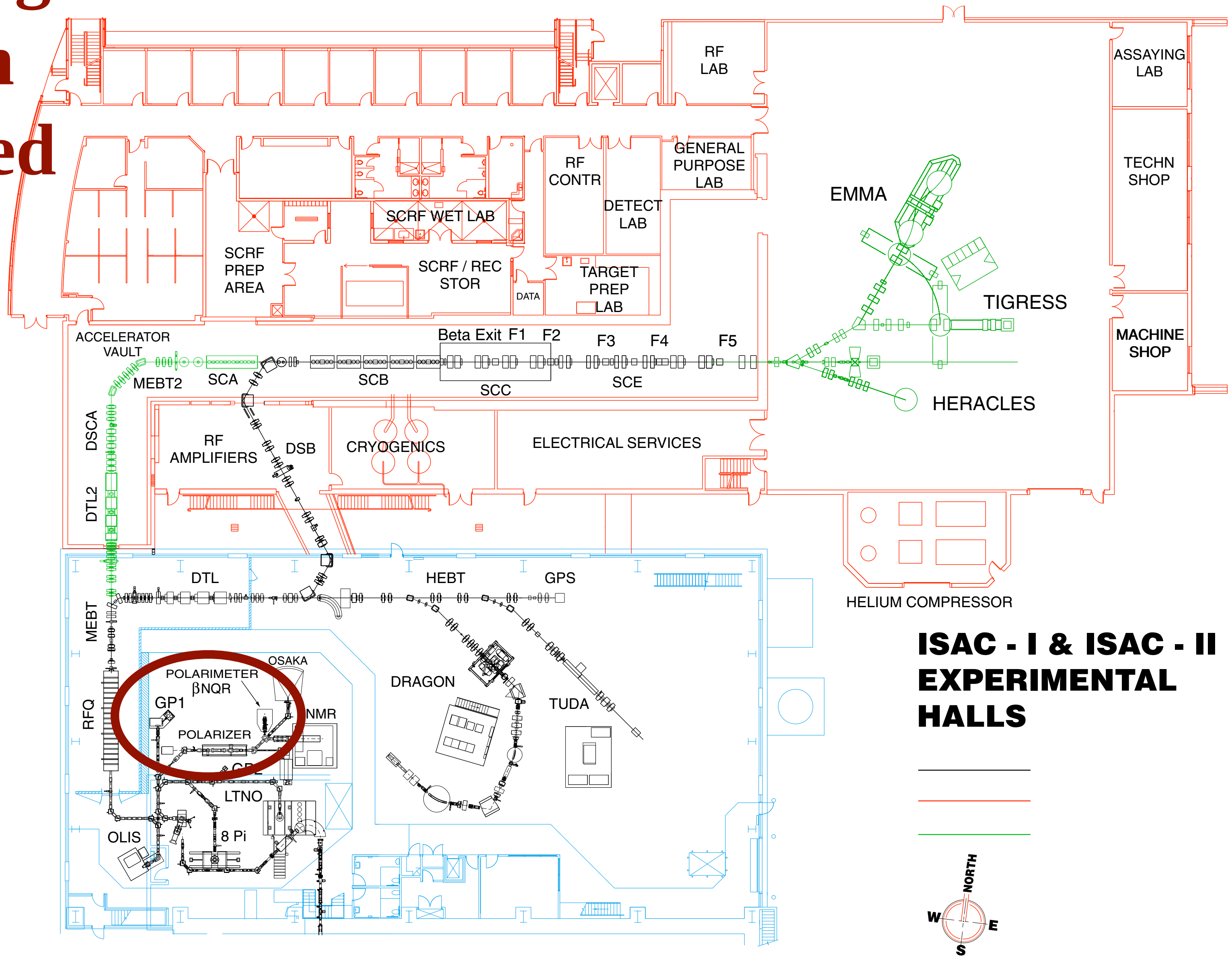


ISAC Facility

TITAN

It utilizes an EBIT charge state booster and a Penning trap to measure mass with high accuracy of short lived exotic ions.





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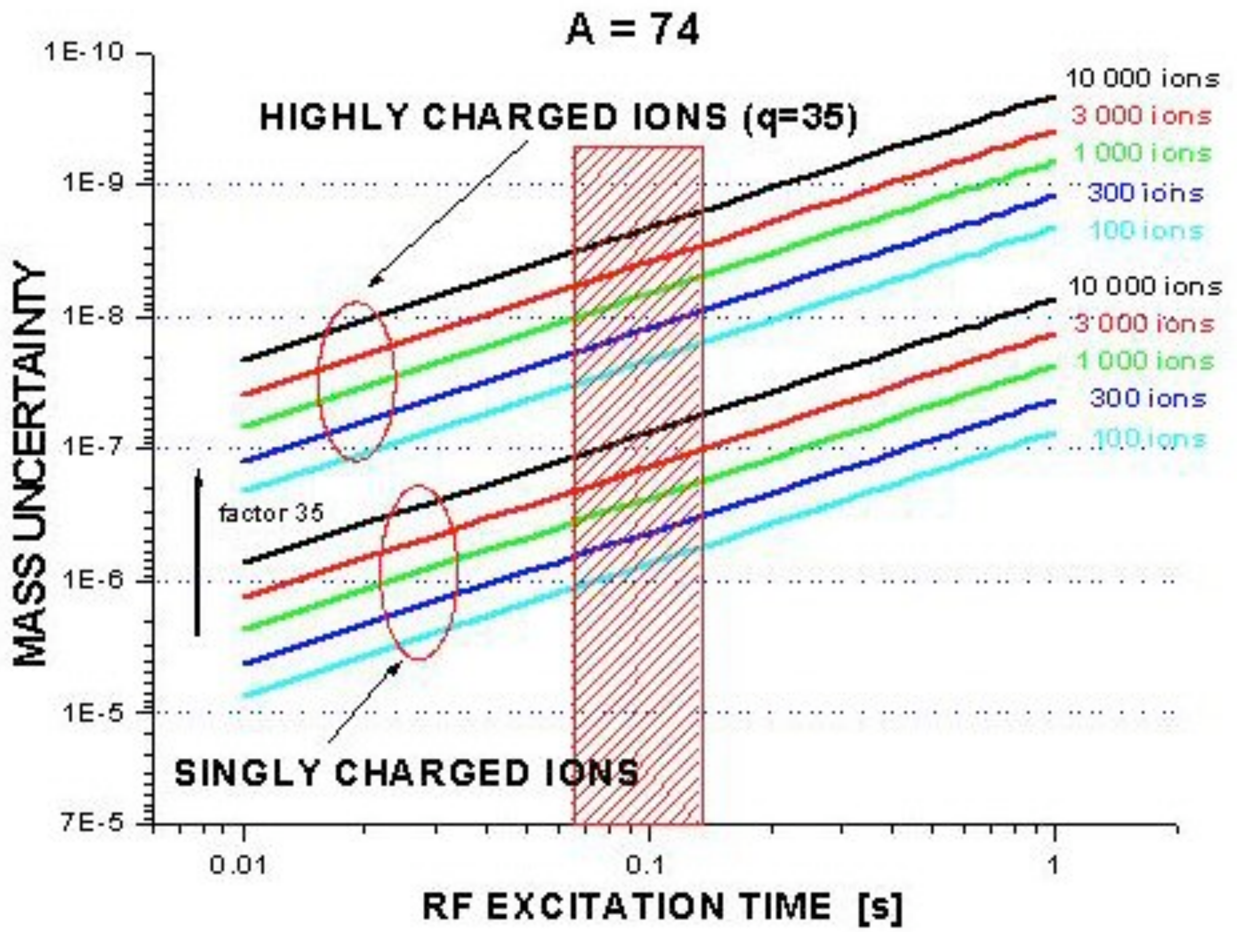
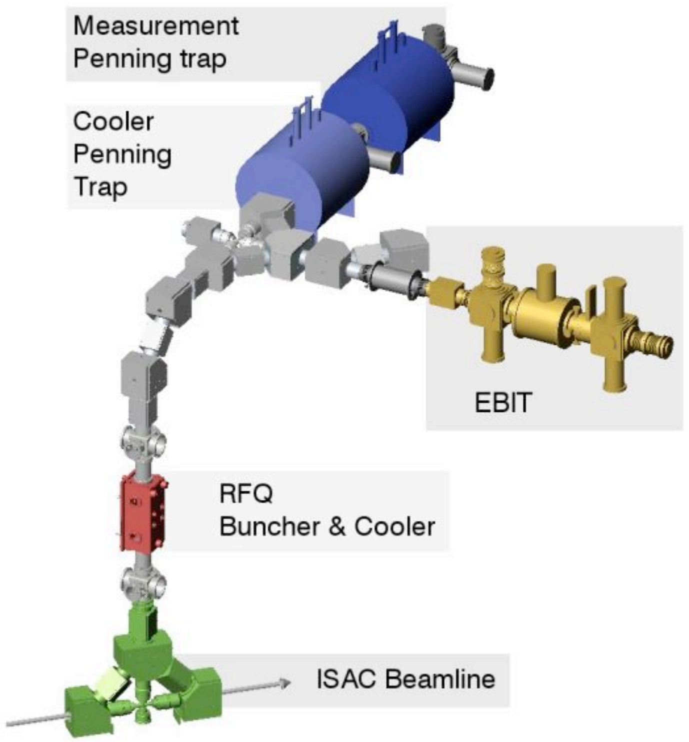
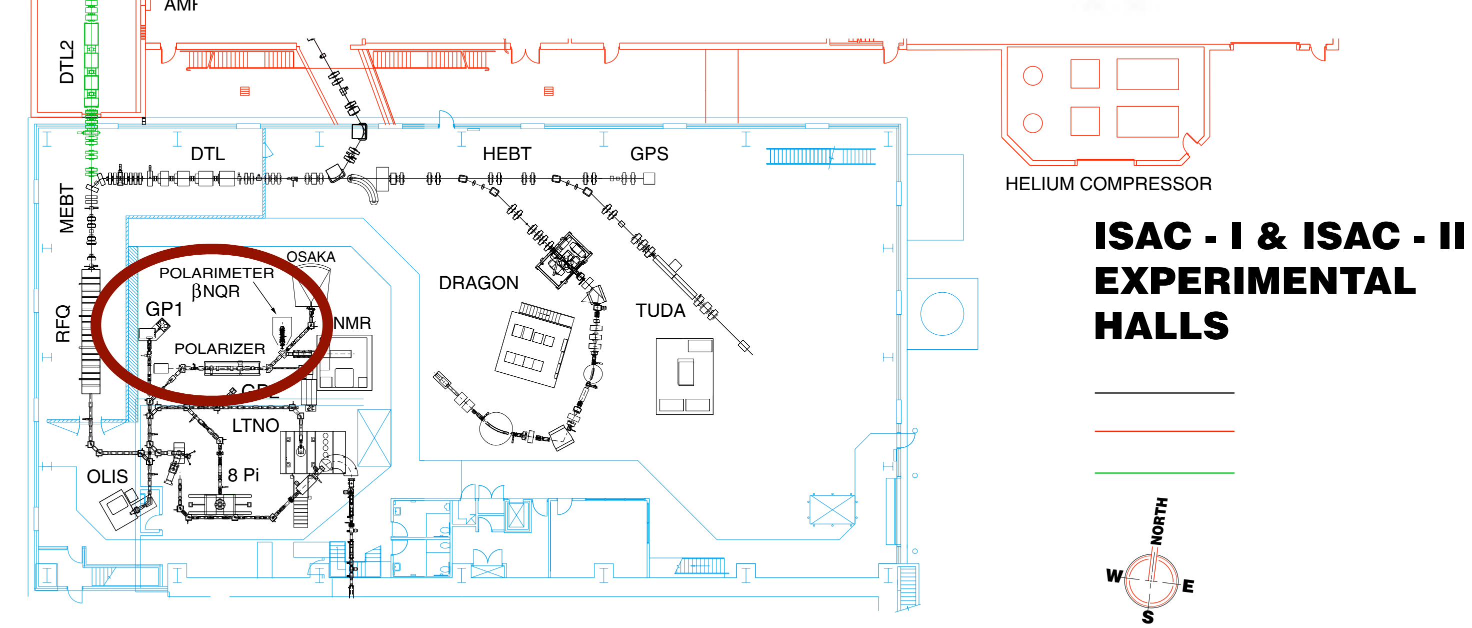


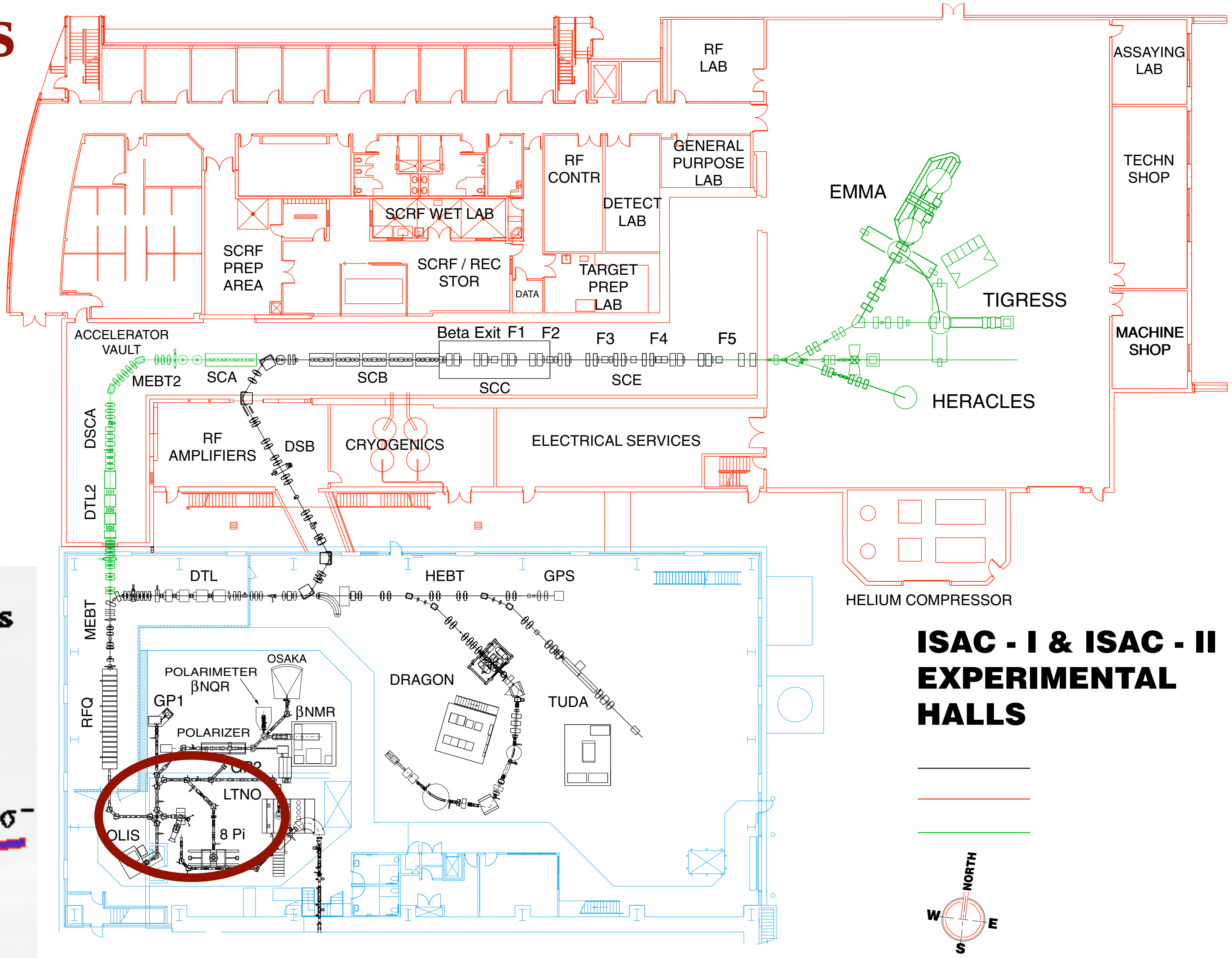


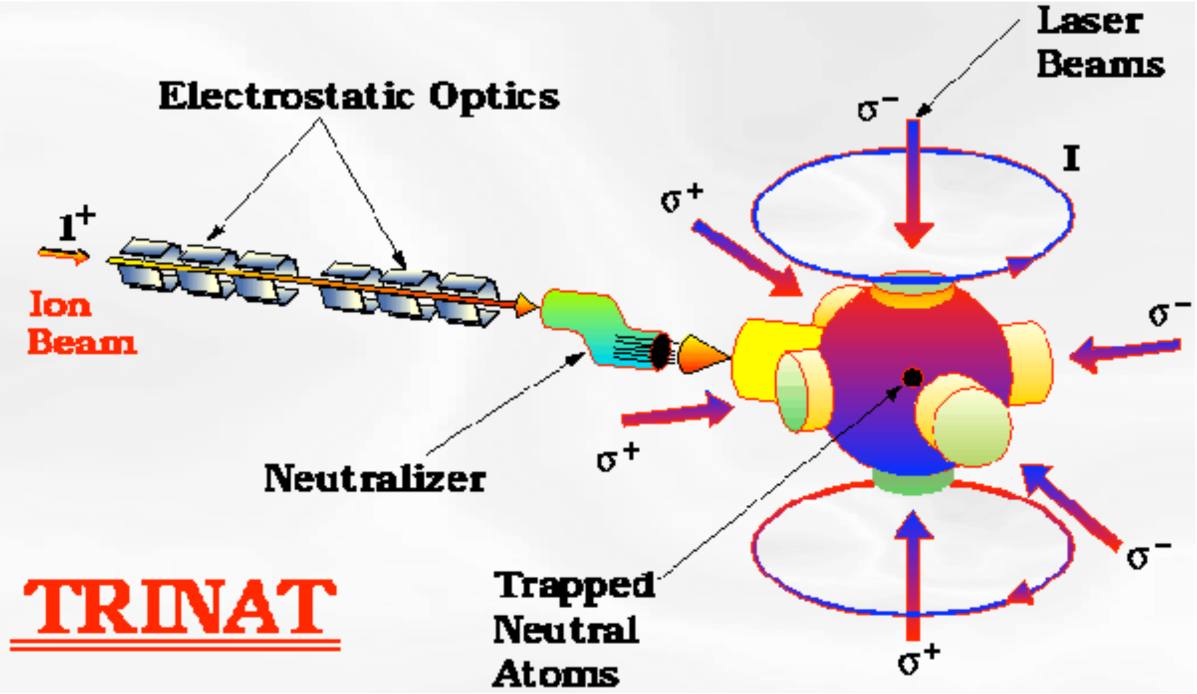


ISAC Facility

TRINAT

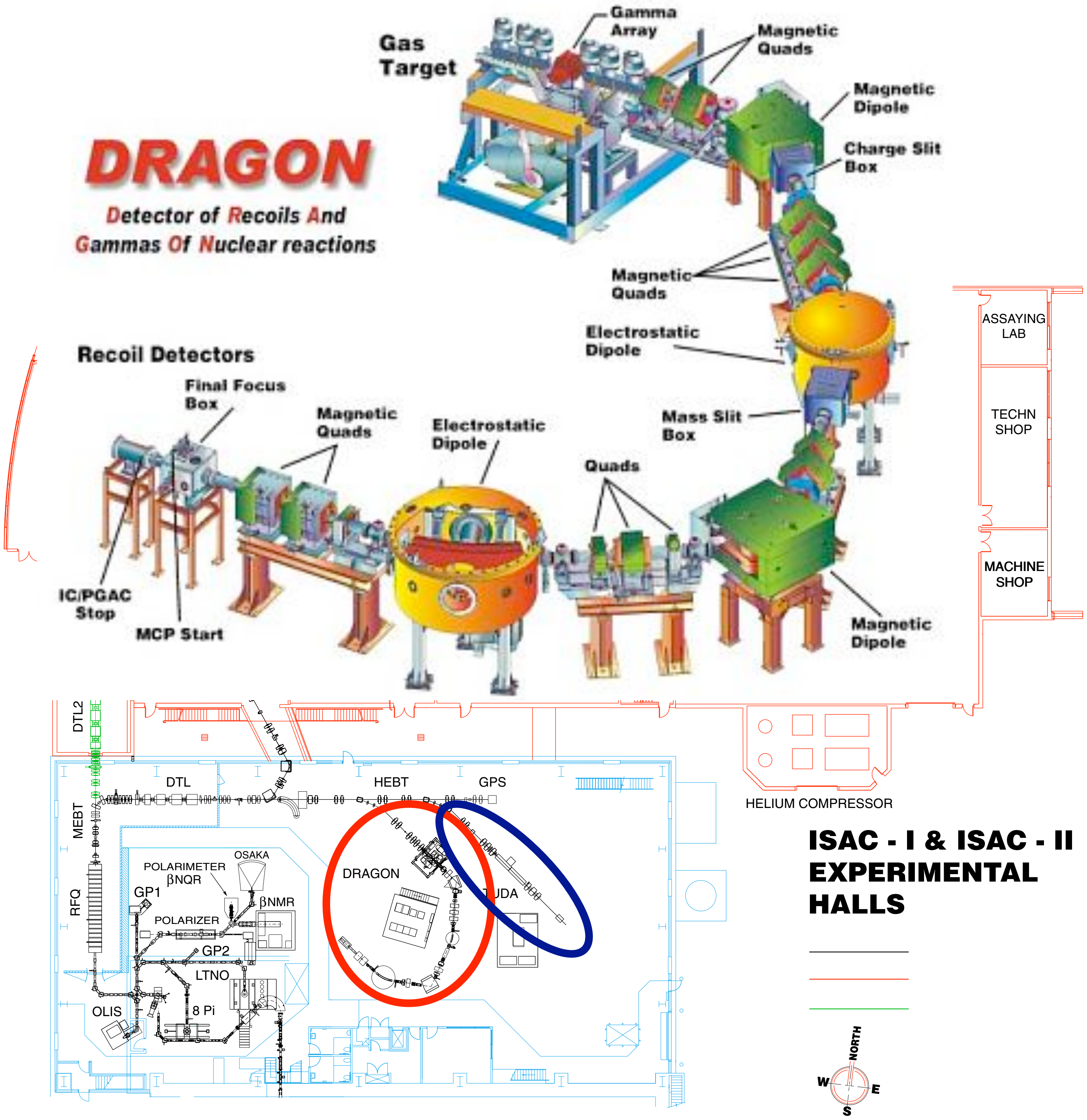
The TRINAT facility utilizes neutral atoms, cooled and trapped by laser beams to perform β-ν correlation measurements.



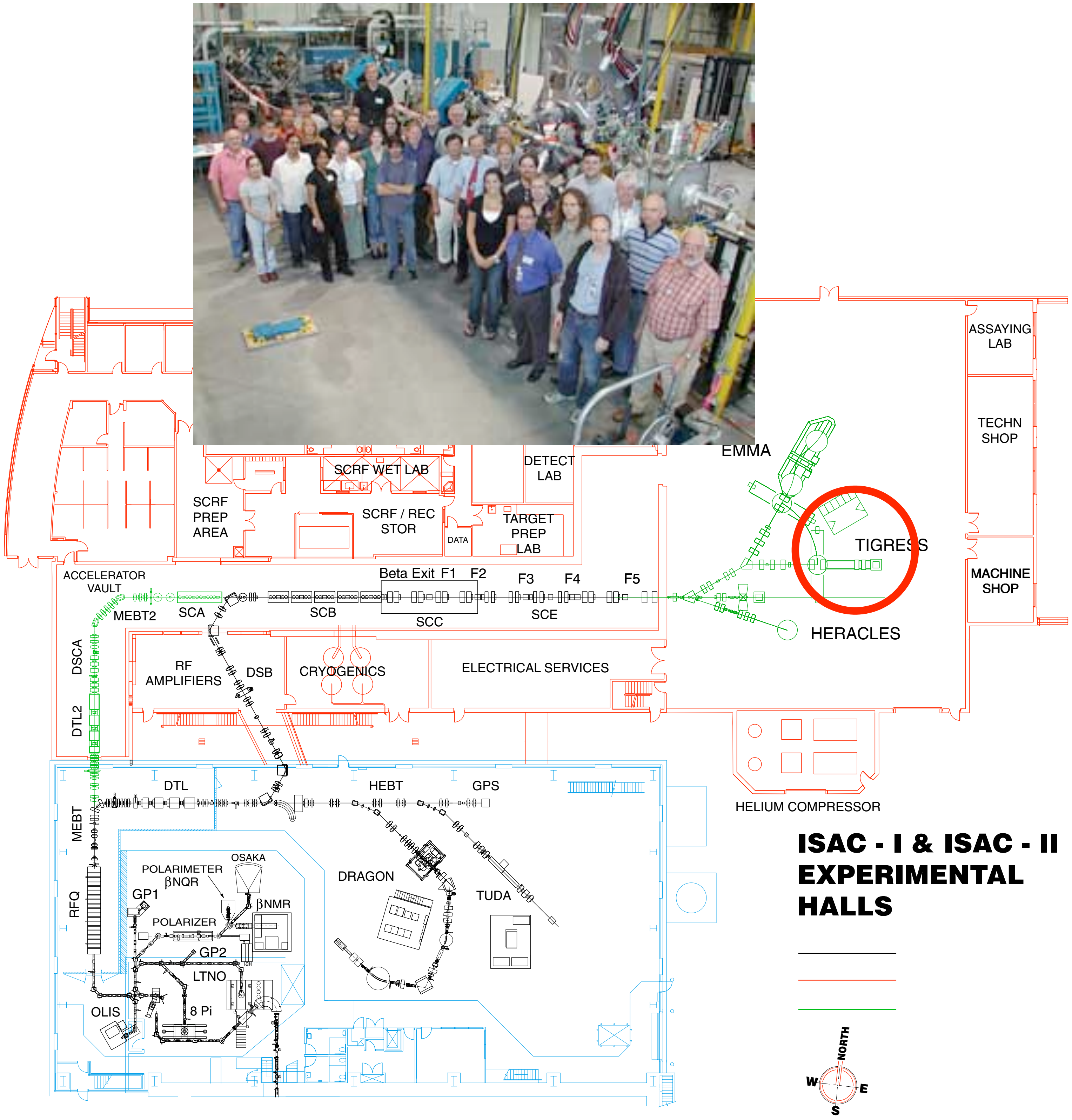


ISAC Facility

- Nuclear astrophysics
  - DRAGON
    - Windowless gas target
    - γ- array detector
    - E-B recoil spectrometer
    - Rejection ~ 10^{-15}.
  - TUDA
    - Large Si Array

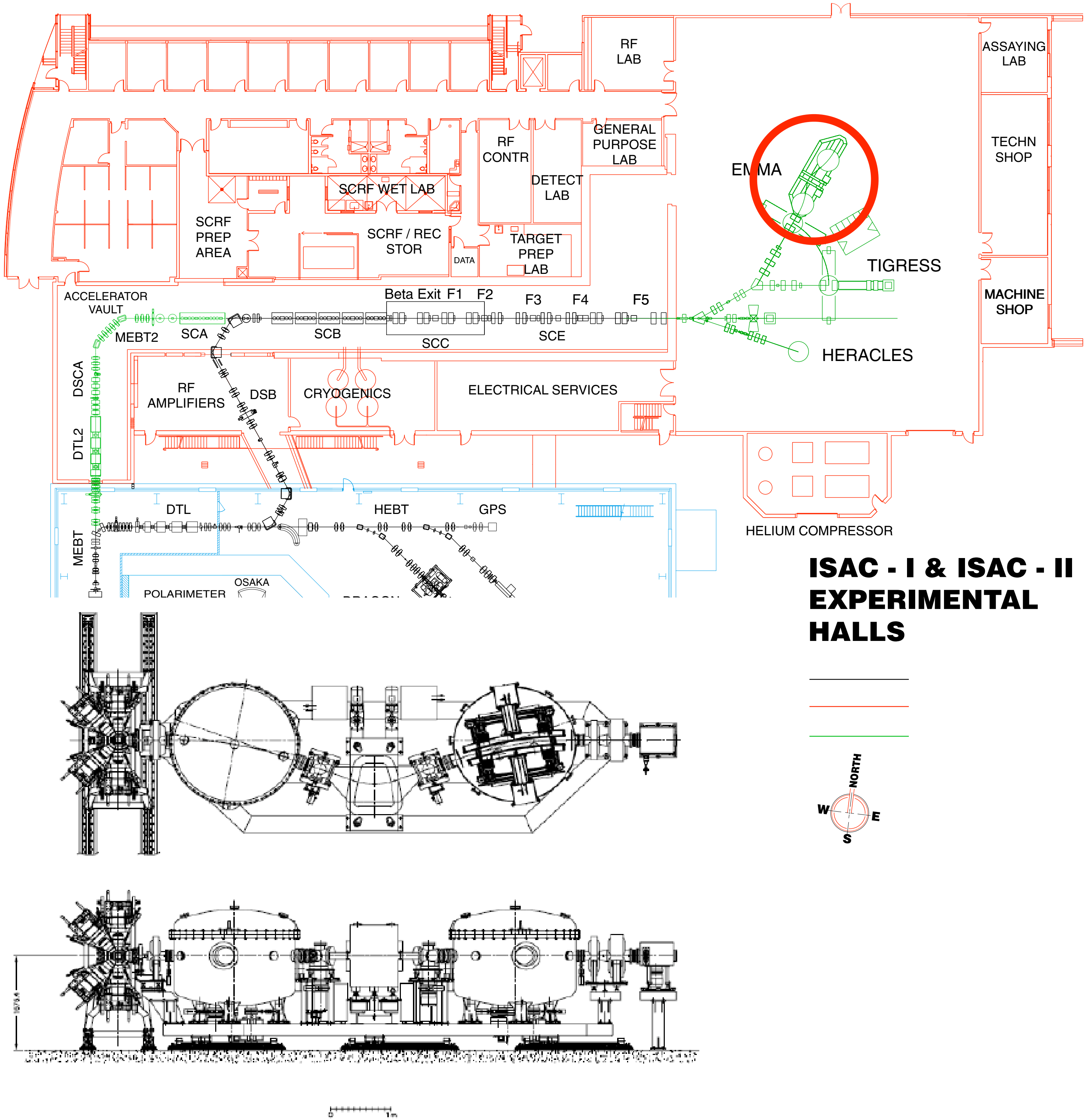


ISAC Facility



- Nuclear Structure
  - TIGRESS
    - γ- array detector
    - 12 Ge clovers
    - Large Si Array

ISAC Facility



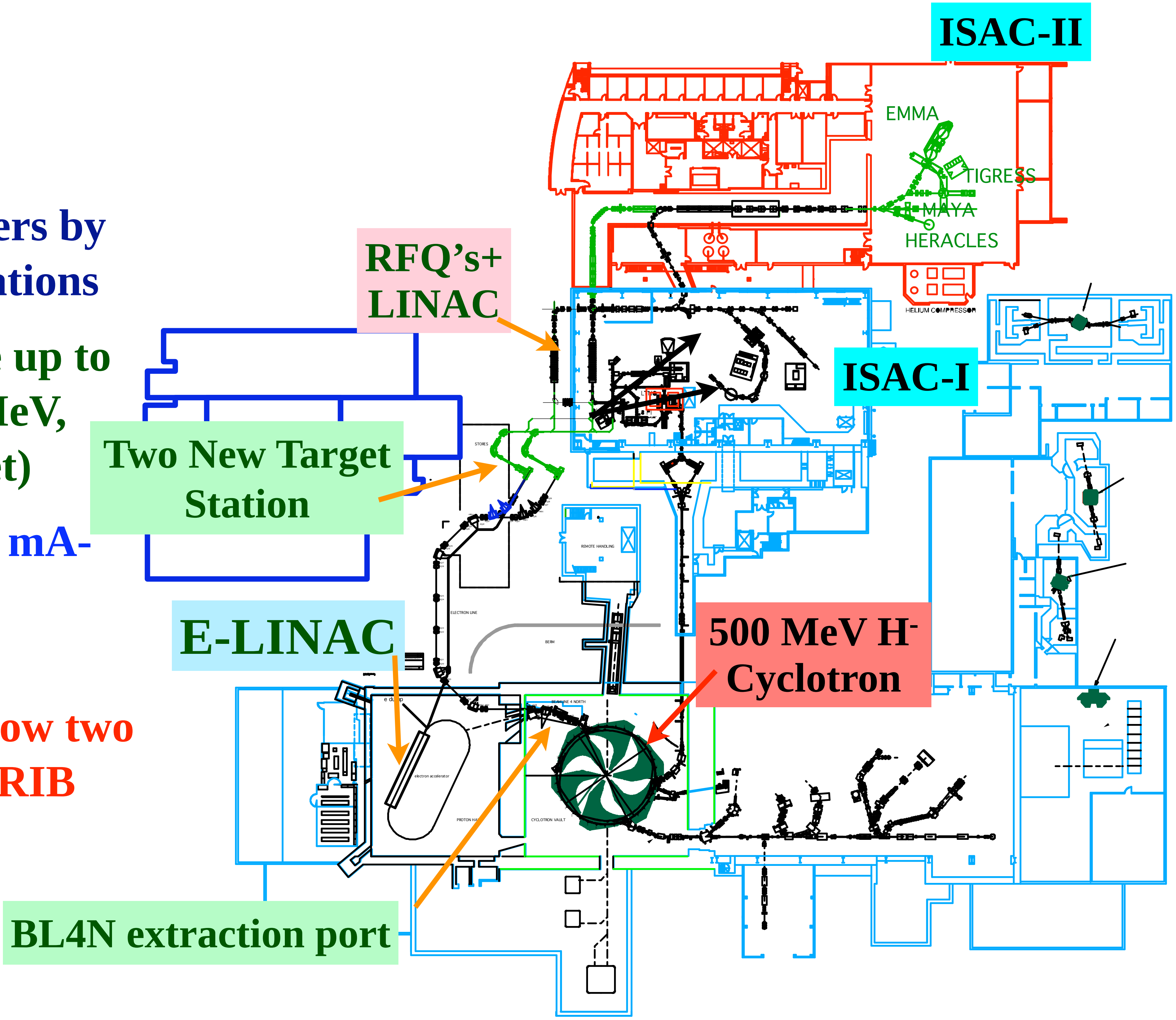
- **EMMA**
  - **Electro Magnetic Mass Analyzer**
  - **Can combine TIGRESS and recoil mass spectrometer**

Future perspectives

- TRIUMF wants to increase the number of experiments at ISAC.
  - Provide two accelerated Radioactive Ion Beams at the simultaneously:
    - A second RFQ in parallel with the actual RFQ injector.
    - A Low ß SC QWR LINAC to match ISAC-II SC LINAC
  - Proposal for the next 5-YP (2010-2015) to build two new target stations for:
    - up to 400 μA proton beam at 500 MeV; (200 kW),
    - 1 MW-class electron driver (20 mA at 50 MeV) for Uranium photo-fission.

Future perspectives

- **Provide more beam to users by adding two new target stations**
  - **Use of BL4 can provide up to 400 µA proton at 500 MeV, (200 kW beam on target)**
  - **Add a SC e-LINAC, 20 mA-50 MeV, (1 MW),**
- **Second front end for the accelerator system will allow two simultaneous accelerated RIB for physics.**



ISAC-II

RFQ's+ LINAC

ISAC-I

Two New Target Station

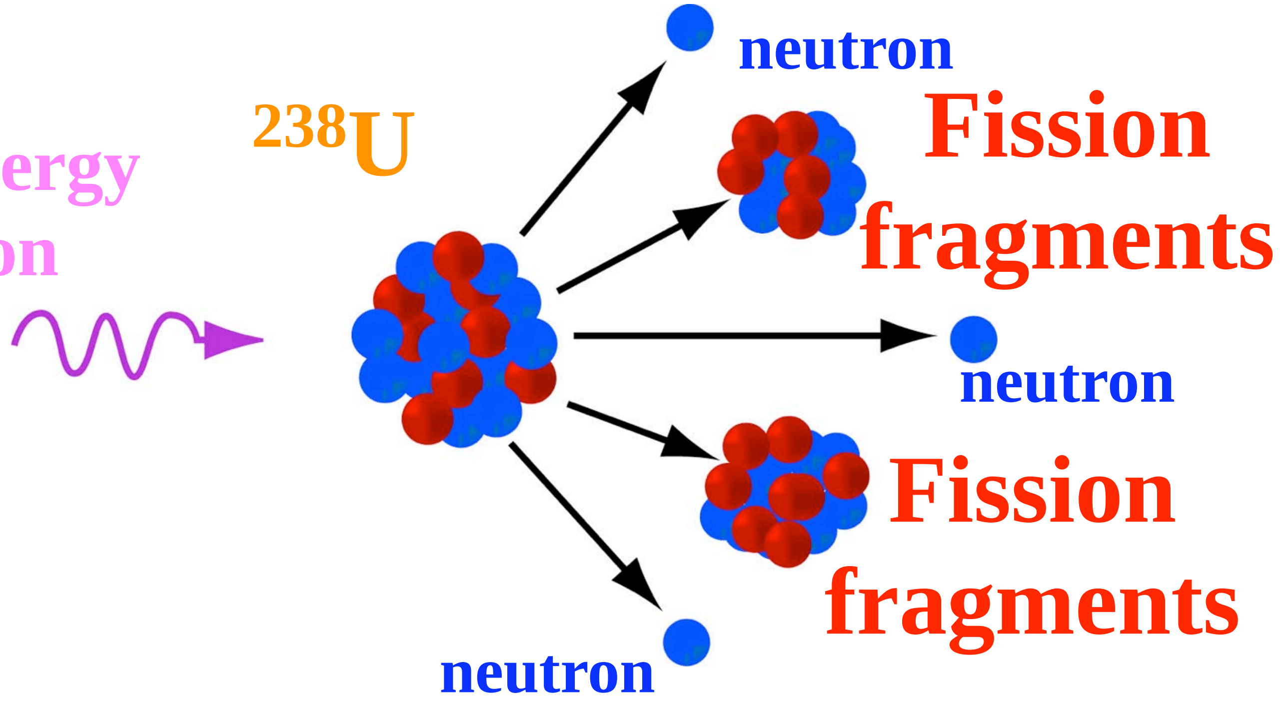
E-LINAC

500 MeV H$^-$ Cyclotron

BL4N extraction port

Photofission

- **Fission can be induced by photons exciting the giant dipolar resonance (GDR) of the nucleus. This process is called photofission.**
- **Proposed by W. Diamond and Y. Oganessian as a mean to produce Radioactive Ion Beam.**
- **^{91}Kr production rate provides a reference point between Diamond's estimate and meaurements at Alto using LIL (LEPP Injector Linac at Orsay)**



High energy Photon

^{238}U

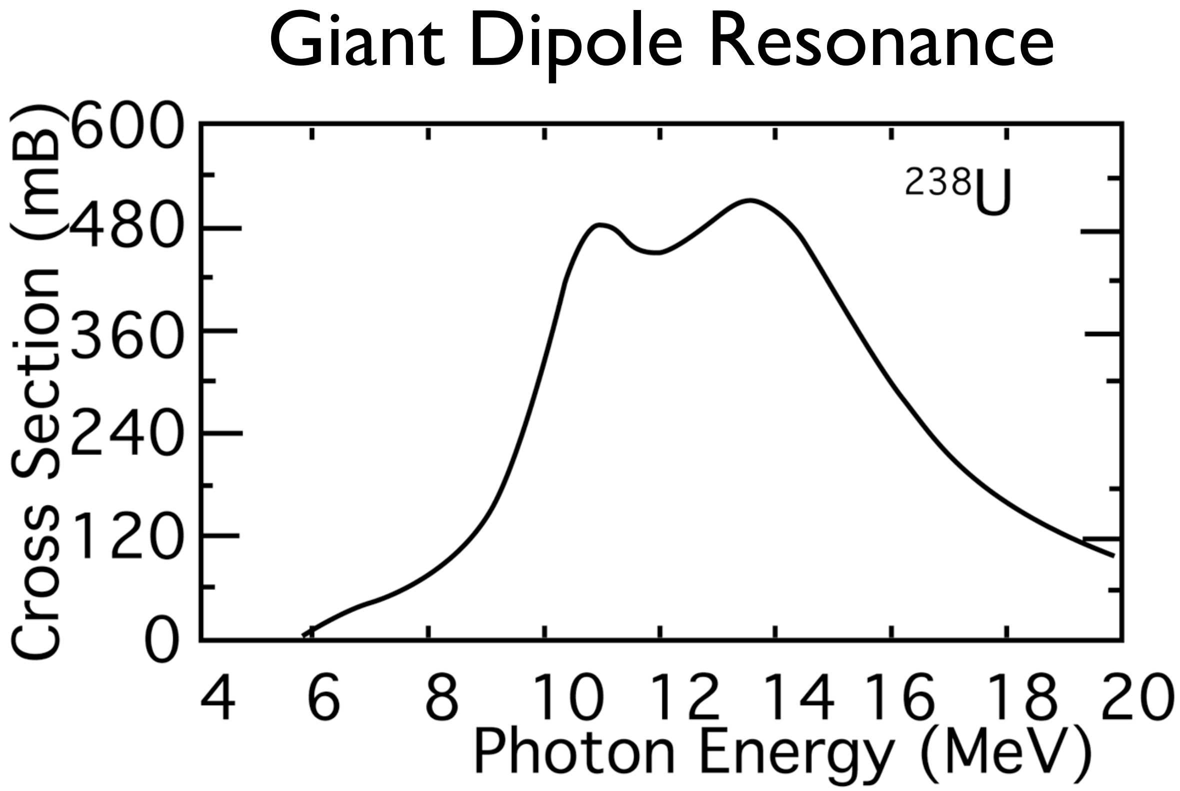
neutron

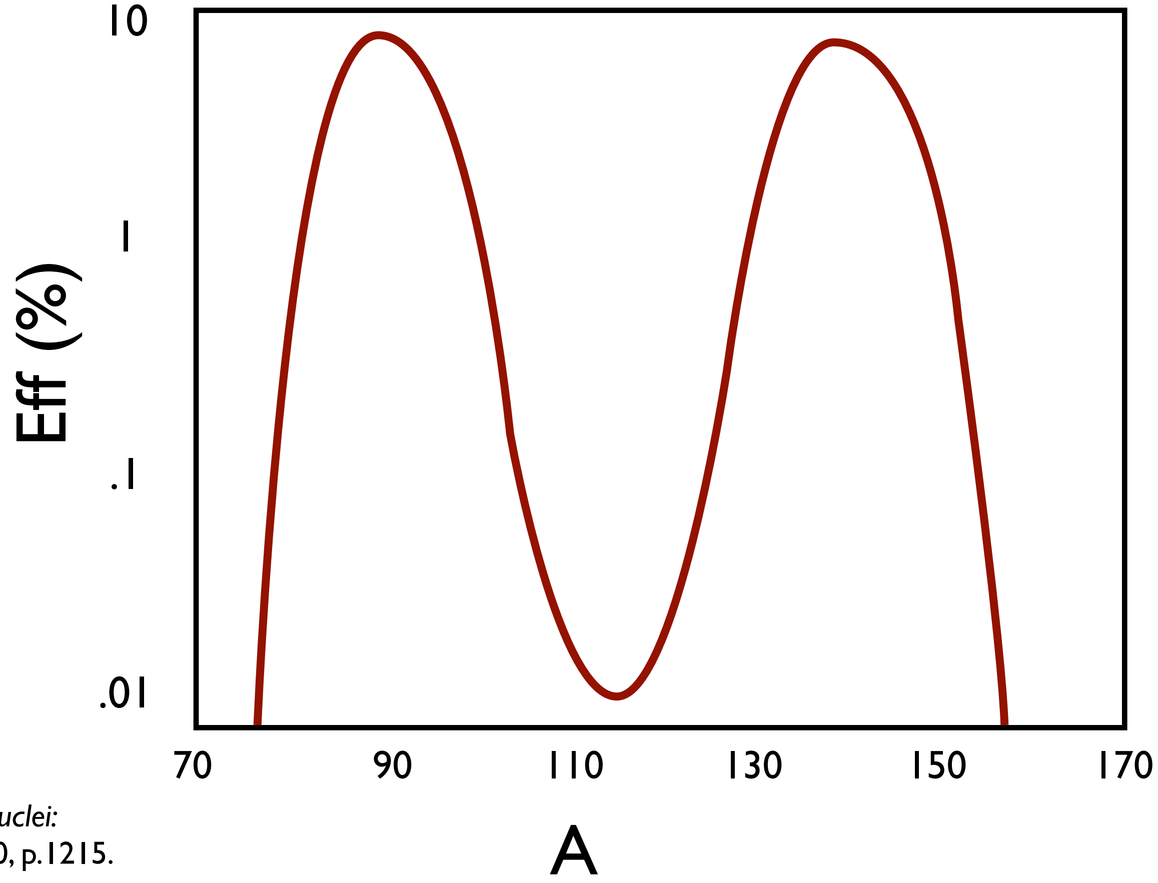
Fission fragments

neutron

Fission fragments

neutron



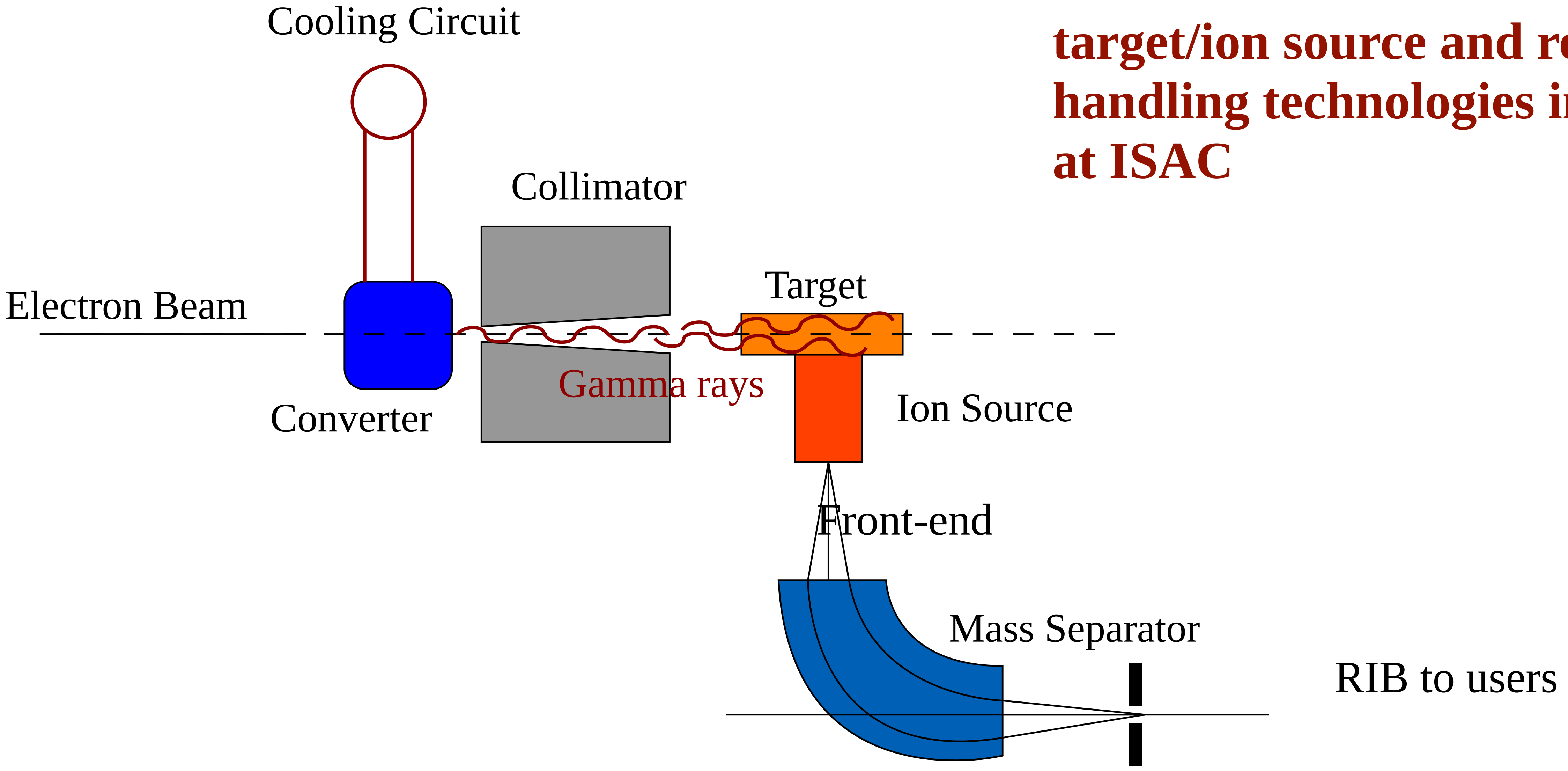


J. T. Caldwell, E. J. Dowdy, B.L. Berman, R.A. Alvarez and P. Meyer, "*Giant Resonance for the actinide nuclei: photoneutron and photofission cross section for ^{235}U, ^{236}U, ^{238}U and ^{232}Th*", Phys. Rev. C, vol. 21, April 1980, p.1215.

Basic Parameters

Item	Value	Units
Electron energy	**50**	**MeV**
Total power	**0,5**	**MW**
Electron current	**0,01**	**Ampère**
Target, UC_2	**50**	**g/cm^2**

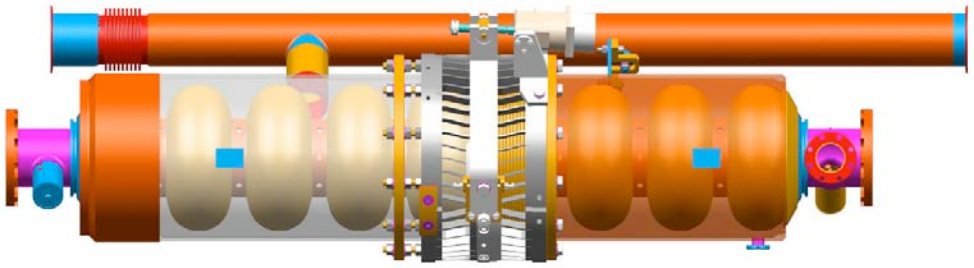
- **A 500 kW electron beam could produce 10^{14} fissions/s from a ^{238}U target, leading to copious neutron-rich isotopes.**
- **We will utilize the same target/ion source and remote handling technologies in use at ISAC**

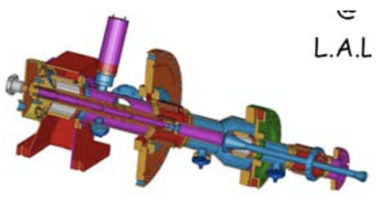


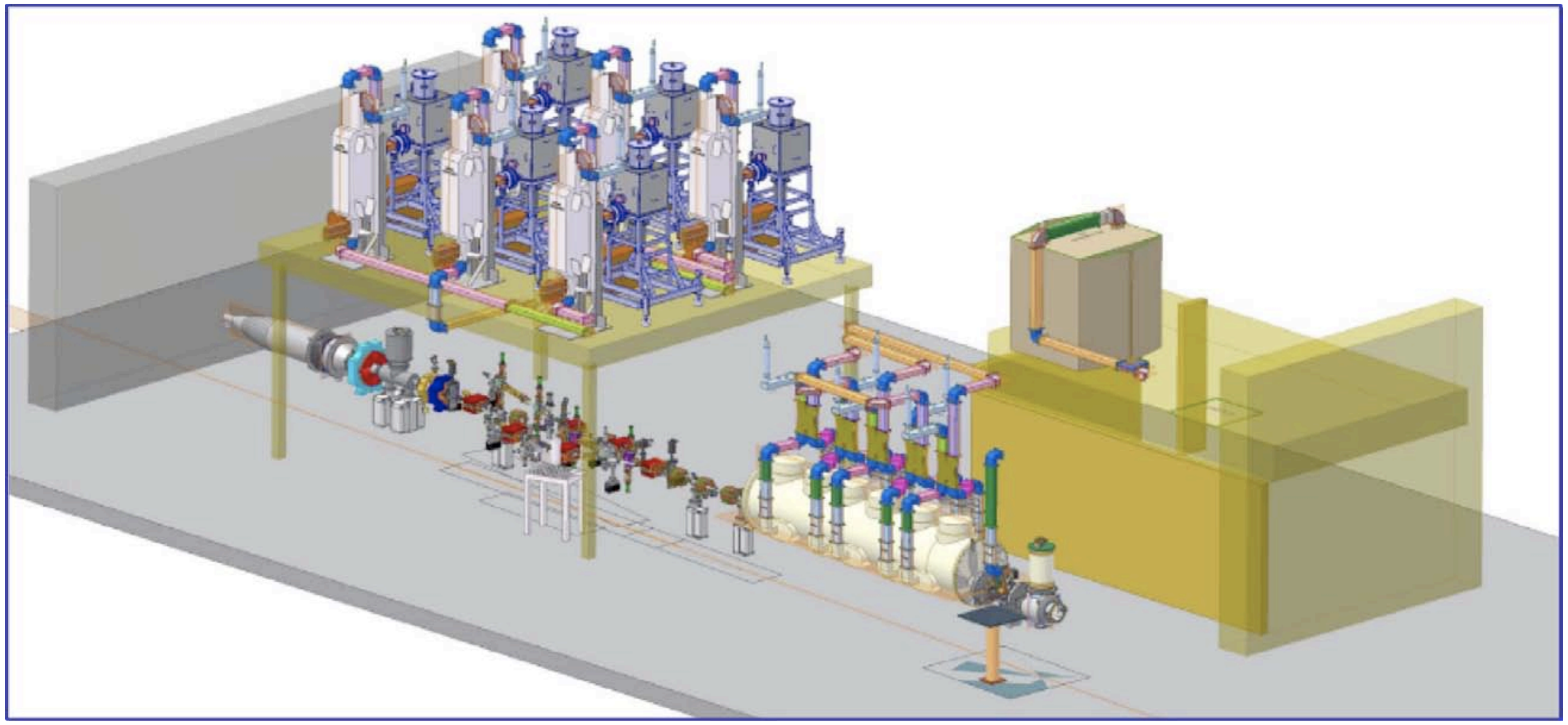
eLINAC

L-band SCRF technology provides cost effective approach to MW-class fission driver.

There are cell, cavity, input coupler, HOM damper, tuner, klystron, IOT, cryostat and BPM designs all pre-existing – eliminates substantial R&D & cost.







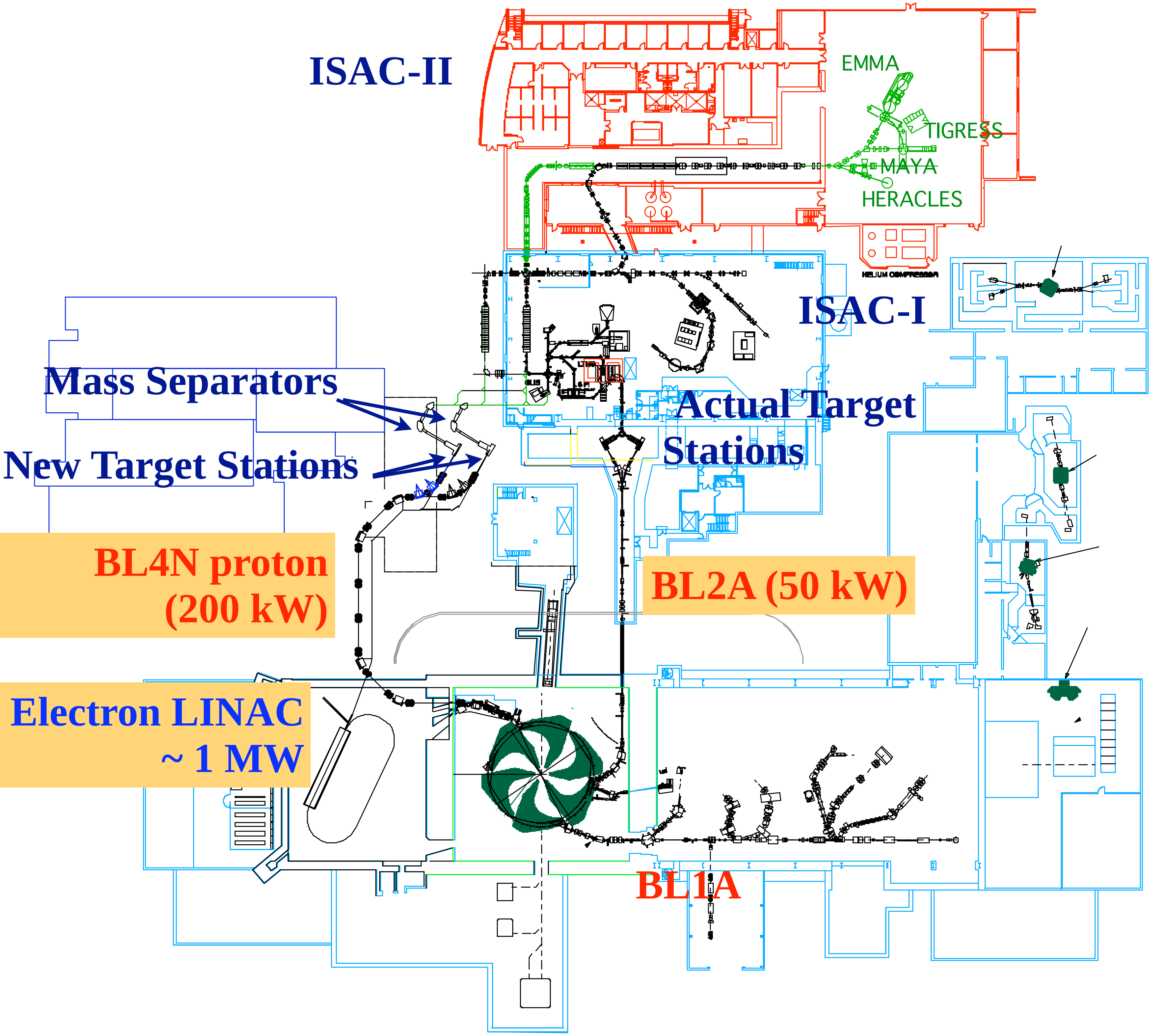
TRIUMF

Summary

- Development of high power target allow us to operate routinely at 70-80 µA. Next year with the new rotating proton beam device we will operate 100 µA.
- A program to equip the TRIUMF-ISAC RIB facility with ion sources that can efficiently ionize nearly all elements is underway
  - Resonant Laser Ion Source is quite advanced,
    - New generation of Ti:Sa solid state lasers.
  - FEBIAD ion source is being developed on-line. New design will incorporate a new radiation hard coil.
  - ECR (MISTIC) prototype is ready for tests,
- ISAC-II superconducting LINAC is in the commissioning phase. We reached accelerating field gradient larger than the expected one; 7.5 MV/m.
- New ISAC-II facilities, TIGRESS (γ spectrometer) commissioned and EMMA (recoil mass separator has been funded).
- Next 5-year plan propose to equip ISAC facility with new target stations to allow 3 simultaneous RIB to experiments.

TRIUMF

Summary



- Three Radioactive Ion Beams at the same time
  - One form BL2A
  - Two from BL4N
    - Electron for photo-fission
    - proton