



Update on TRIUMF

Nigel Smith,
Executive Director & CEO

CINP-IPP Joint Session
2024-05-30



What is TRIUMF?

TRIUMF is Canada's particle accelerator centre. We are a world-class hub of research, education, and innovation that is home to ~600 staff and students.

Founded in 1968 by the University of British Columbia, Simon Fraser University, and the University of Victoria, **TRIUMF is a national asset**, driving research locally, nationally, and connecting Canadian researchers to the world.



Research Program

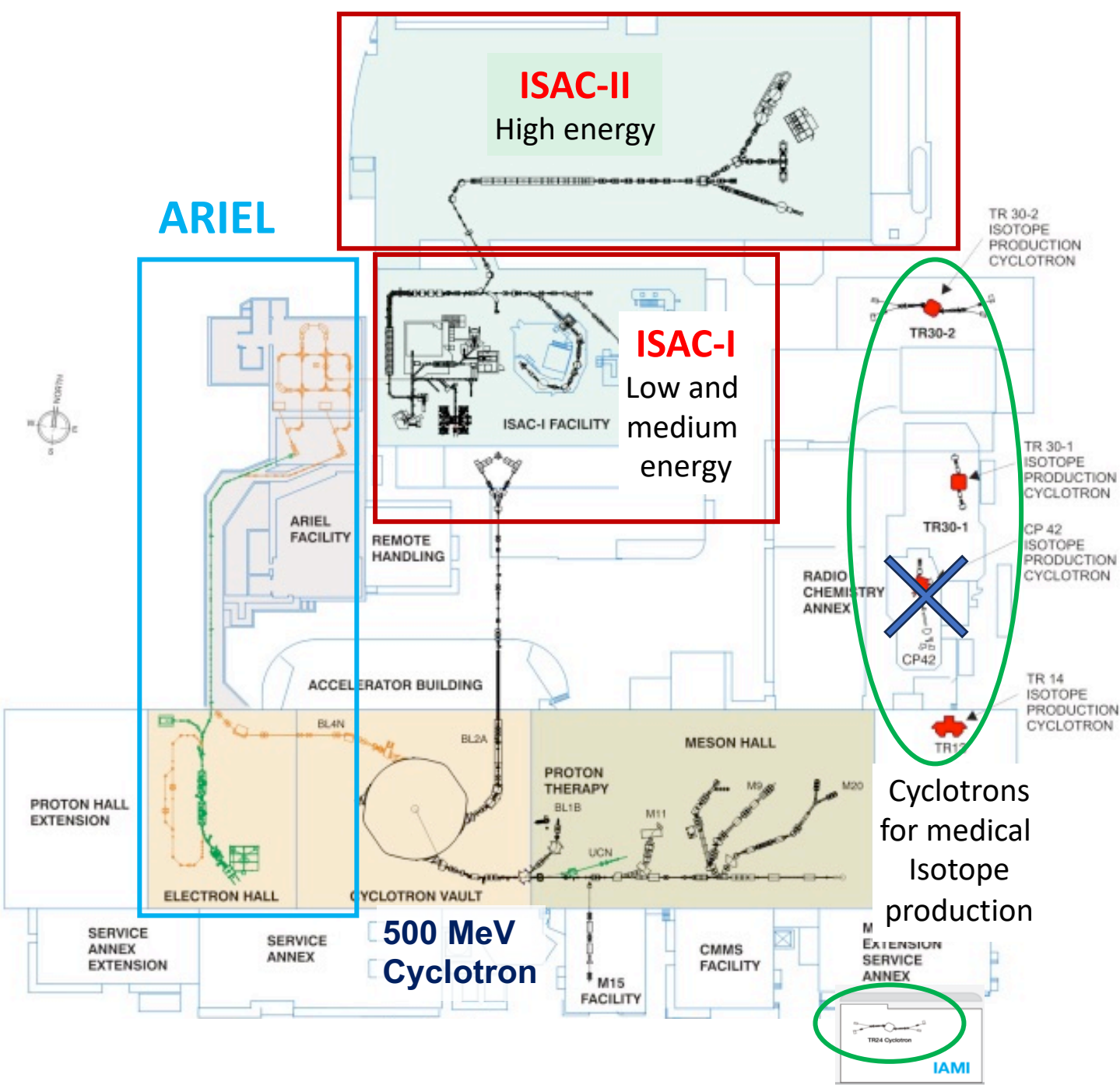
TRIUMF's work **addresses the most compelling challenges in contemporary science** and connects fundamental scientific research through to commercialisation.

TRIUMF is a hub of excellence centred on a **core of expertise in accelerator technology, detector development and isotope research.**

Our science programme has been articulated in a 20-year vision, outlining where we and our community would like to take the facility in the next two decades



TRIUMF accelerator complex



Primary beam driver:
Cyclotron, 500 MeV, H⁻
Produces rare isotopes, neutrons and muons!

Isotope Separator and Accelerator facility -
ISAC

Isotope Separator Online (ISOL) facility
ISAC-I: Normal conducting-linac, 0.15-1.5 MeV/u
ISAC-II: Superconducting-linac, 5-15 MeV/u

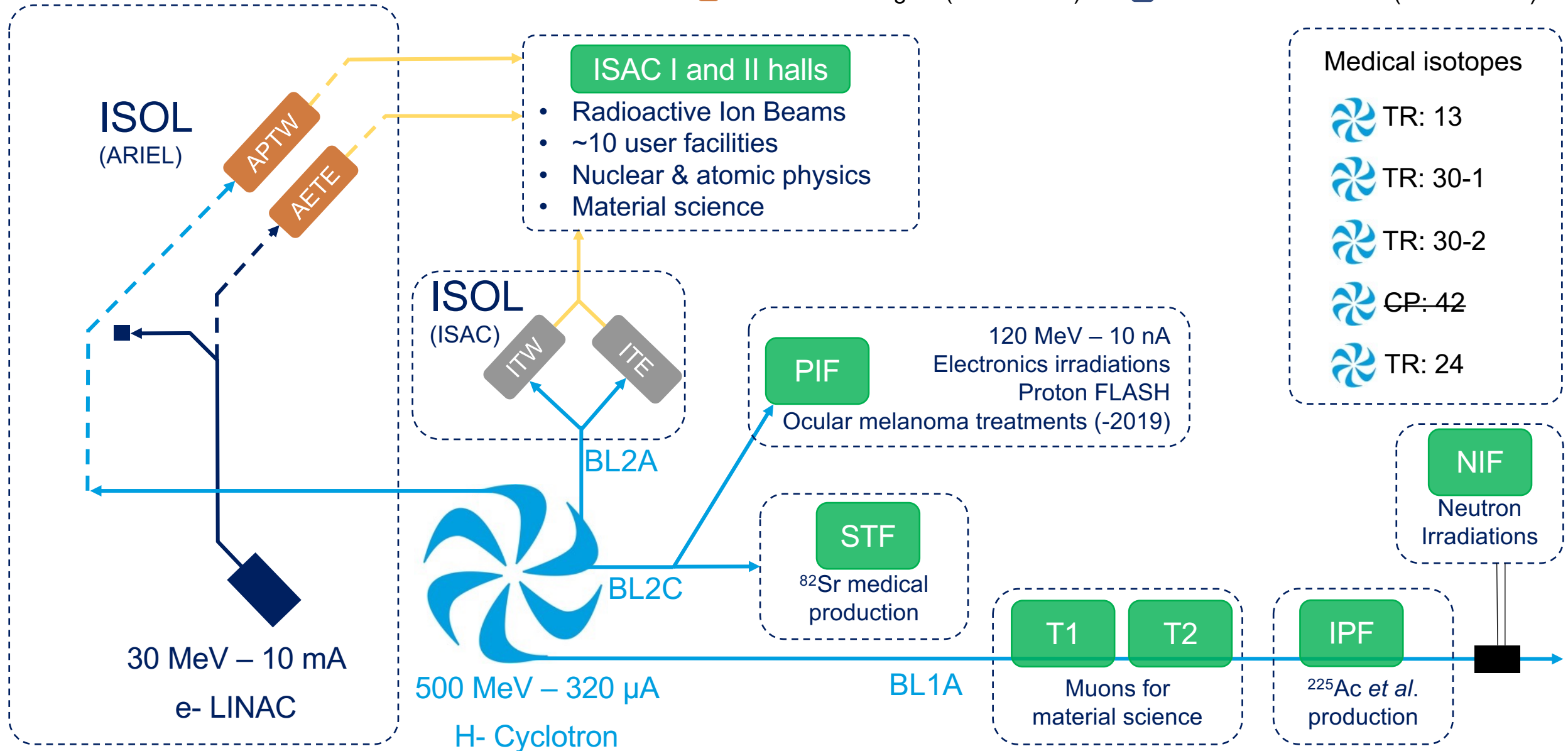
Advanced Rare Isotope Laboratory - **ARIEL**

Superconducting electron linac
30 MeV, 10 mA, cw

4 Cyclotrons for medical isotope production
(Including a TR24 in the Institute for advanced Medical
Isotope – IAMI)

Accelerators & Facilities

- User facilities
- ISAC ISOL targets (since 2000s)
- ARIEL ISOL targets (from ~2025)
- Cyclotron & beamlines (since ~1975)
- RIB lines
- E-linac and beamline (since ~2013)



Science Highlights in appendix

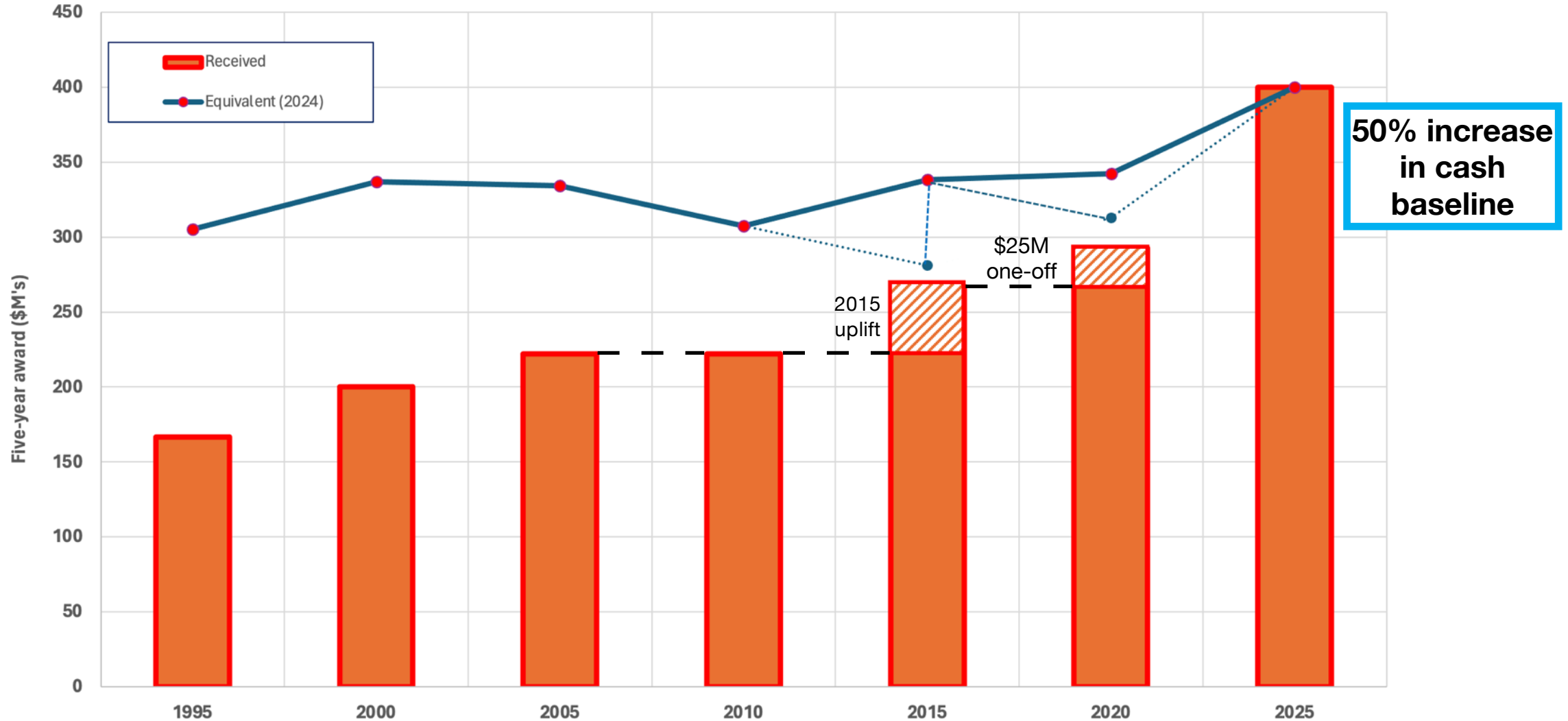
Focus on budget update

Budget 2024 Outcome - Result

- “To advance the next generation of cutting-edge research, Budget 2024 proposes major research and science infrastructure investments, including: **\$399.8 million over five years**, starting in 2025-26, to support TRIUMF, Canada’s sub-atomic physics research laboratory, located on the University of British Columbia’s Vancouver campus. This investment will upgrade infrastructure at the world’s largest cyclotron particle accelerator, positioning TRIUMF, and the partnering Canadian research universities, at the forefront of physics research and enabling new medical breakthroughs and treatments, from drug development to cancer therapy.”
- We have confirmed with NRC and ISED that there is no ring-fencing or other restrictions that exist on how we use the funds (cf \$25M projects in current award)
- A **fabulous** result as we have secured a 50% increase in baseline operations during times of incredible fiscal pressure, yet I need to dampen expectations as we didn’t get the full request which will have implications on our programme

Budget 2024 Outcome - Context

TRIUMF Funding levels (5-year awards)



Budget 2024 Outcome - Request ⁹

- TRIUMF is at a critical moment in its life cycle as a major research facility; the lab faces a critical inflection point as it balances the demands of aging legacy infrastructure while seeking to complete and operate new world-class facilities.

Five core themes of the request:

1. Delivering new infrastructure for science impact
2. Ensuring operational excellence
3. Training the diverse talent of tomorrow
4. Refurbishing legacy facilities
5. Evolving TRIUMF's program towards the future

	Funding Level			
	≤ 300	350	400	450
Operational excellence	Yellow	Green	Green	Green
IAMI	Orange	Light Green	Green	Green
Facility utilization	Orange	Yellow	Light Green	Green
Domestic research ecosystem	Red-Orange	Yellow	Light Green	Green
Site maintenance	Red	Orange	Yellow	Green
Talent and training	Red	Orange	Yellow	Green
Major deferred maintenance (BL1A/substation)	Red	Orange	Yellow	Green
Innovation & commercialization	Red	Orange	Yellow	Green
International research ecosystem	Red	Orange	Yellow	Green
ARIEL completion	Red	Orange	Yellow	Green
ARIEL operations	Red	Orange	Orange	Green

Heat map visualizing various funding-level scenarios, including those of reduced funding from the \$450M request

Budget 2024 - Outcomes

- We have given the government some indication of what we can achieve at this level within the request in terms of infrastructure completion, HQP training, international and national science leadership, etc.
- Within the Request for Support, the \$400M scenario was framed as (in comparison to the \$450M request) a “Loss of Opportunity”:
 - ARIEL construction is slowed and operations of ARIEL and IAMI are delayed, resulting in the loss of first-mover advantage against international competition in key research and technology areas
 - Increased risk of infrastructure failure due to reduced investment in deferred maintenance
 - Decreased science output with internal resources and staff reorganised to fill operational requirements
- Now we know the budget outcome we will need to look at potential options at this level, balancing the direction from government (if any), the requirements of the lab, and the desires of our stakeholders
 - We have some flexibility in how we frame the next five year programme
- Process will lead to a funded five-year plan that TRIUMF can be judged against - this is going to be critical for the transition to a new funding structure.

Budget 2024 - Outcomes

- Some of the areas that we have viewed as essential components of the next five-year planning (the “rocks”) have been agreed with the Board. Some were driven by the Board expectations
- **Compensation plans:** we aim to deliver the market median as a target salary for all staff by the end of the next five-year plan, with evaluations of market every three or four years.
- **Deferred maintenance:** an essential component of the request and discussions with government. We have an aging core infrastructure and need to invest heavily in securing future operations
 - Can we use CFI IF process (there is a new “core facilities” stream) to augment budget?
- **Operational Excellence** is a cornerstone of the request. Funding "Weft and Warp" as a response to CNSC reports, developing research security, safety, programme management, ...
- These components form the basis of the award, as re-affirmed by statements from the PM. So we need to deliver on these...

Budget 2024 Outcomes¹²

- Overall, this outcome will allow us to stabilise TRIUMF and consolidate on the currently planned operations, infrastructure and programme
 - Want to continue to focus on completion of ARIEL and IAMI as major objectives, can we advance their operations from the submitted scenario?
- We still have one year to run on the current five-year plan, and will be guiding the organisation to the new plan over the next year
 - This means things will remain very tight over this year, but we have the confidence that the next five years have increased operational support
- Over the next few years, we will have the ability to seize opportunities that may arise, with the major objective to ensure TRIUMF is operating at maximum efficiency and efficacy
- *Basically, this budget secures the future operations of TRIUMF*

Budget 2024 Outcomes - MRF

- There is no specific text around the Major Research Facility (MRF) framework in the Budget 2024, however many of the components are clearly being lined up to move towards this structure:
 - Additional support to MRF to get them to the 2029/30 timeframe
 - Capstone organisation to help advance *internationally collaborative, mission driven and multidisciplinary research*
 - Strategic advisory bodies
- We will continue to engage with ISED and CFI as the MRF process unfolds. There may be additional detail in the Fall Economic Statement, or in the Budget Act itself

5-year plan process timeline

14

- Three streams of input and process we need to coordinate and manage:
 - Governance chains
 - Board of Governors, Science Council, Members' Council (AGM)
 - Government
 - NRC Contribution agreement discussions, ACOT
 - Community
 - Science Council, Science Week, TUEC/TUG meetings
- Basically need scenarios articulated by June, input over July/August, finalised by September for approval in October
 - NRC cash flow and documentation needs to be with TB by mid-July (within \$5M p.a.)

Four Key Priorities for 2024

- *Development of budget following \$399.8M budget outcome*
 - ✓ • Understanding of any restrictions on use of funds, or expectations from federal government
 - Completion of potential scenarios within this budget envelope, for discussion with stakeholders
 - Board oversight: June review of plans, September endorsement of final plan to move to MC/AGM
- *Development and finalisation of contribution agreement with NRC to allow funds to flow*
 - Currently in discussion with NRC. Needs full completion by 2024 TRIUMF AGM
- *Initiation of “Weft and Warp”*
 - Project definition underway
 - Completion of discovery through 2024; iterations of planning and implementation
- *Development and release of next five-year plan (aligned with budget)*
 - Community consultation through summer (Science Week)

Weft and Warp (noun)¹⁶

- The essential foundation of an organization (from weaving)
- We are re-weaving the fabric of the laboratory systems to head towards operational excellence
- This will be a programme of work, with projects running asynchronously



D. Preddy

▶ **the warp** [S] • FABRICS & FASHION • specialized



the threads that go along the length of a piece of cloth or a loom (= a special frame for making cloth)

Compare

the weft specialized

the weft

noun [S] • FABRICS & FASHION • specialized

UK /weft/ US /weft/

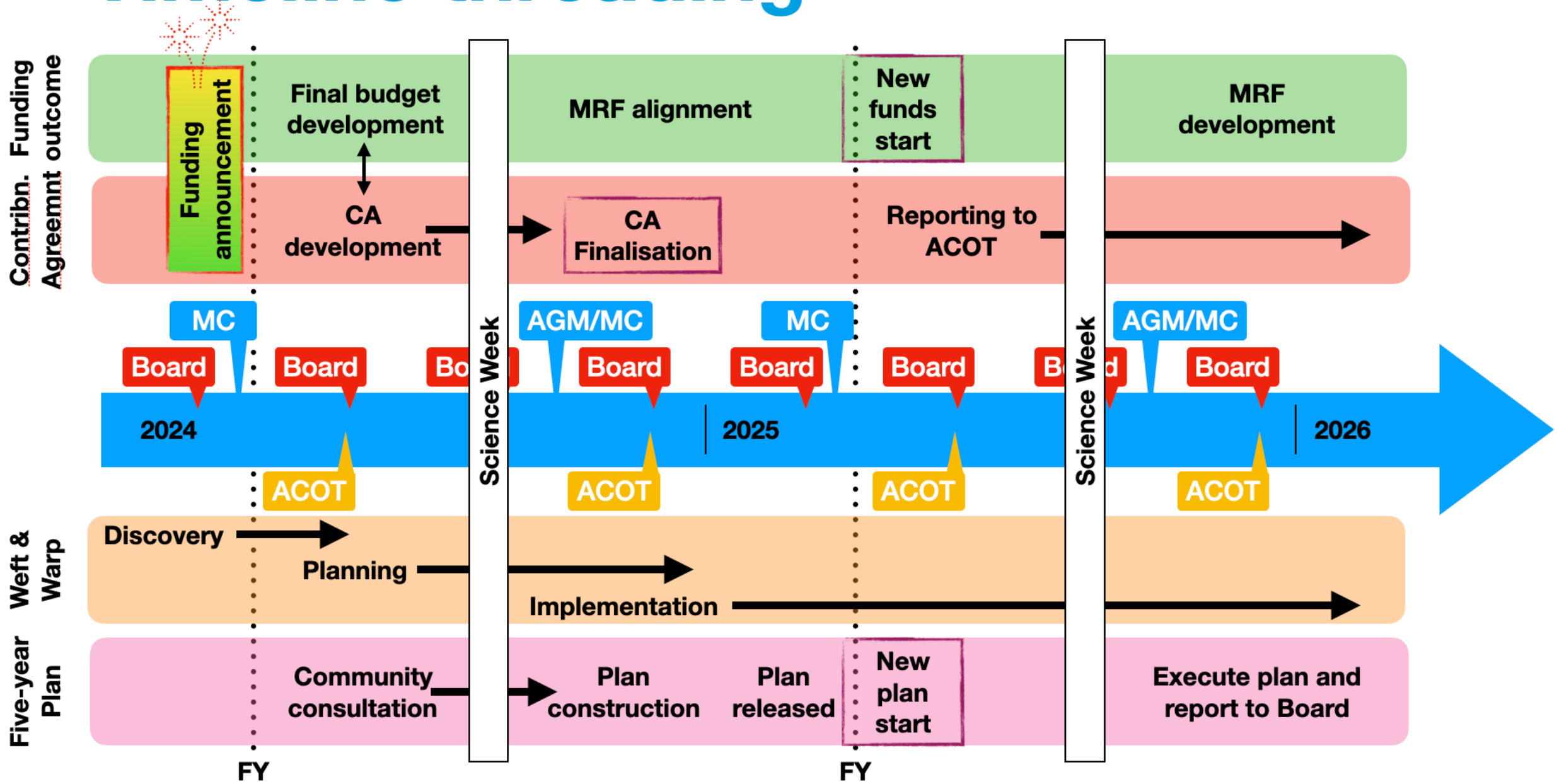
Add to word list

the threads that go across the length of a piece of cloth or a loom (= a special frame for making cloth)

Compare

warp noun

Timeline threading





Thank You!

Merci!

www.triumf.ca

@TRIUMFLab

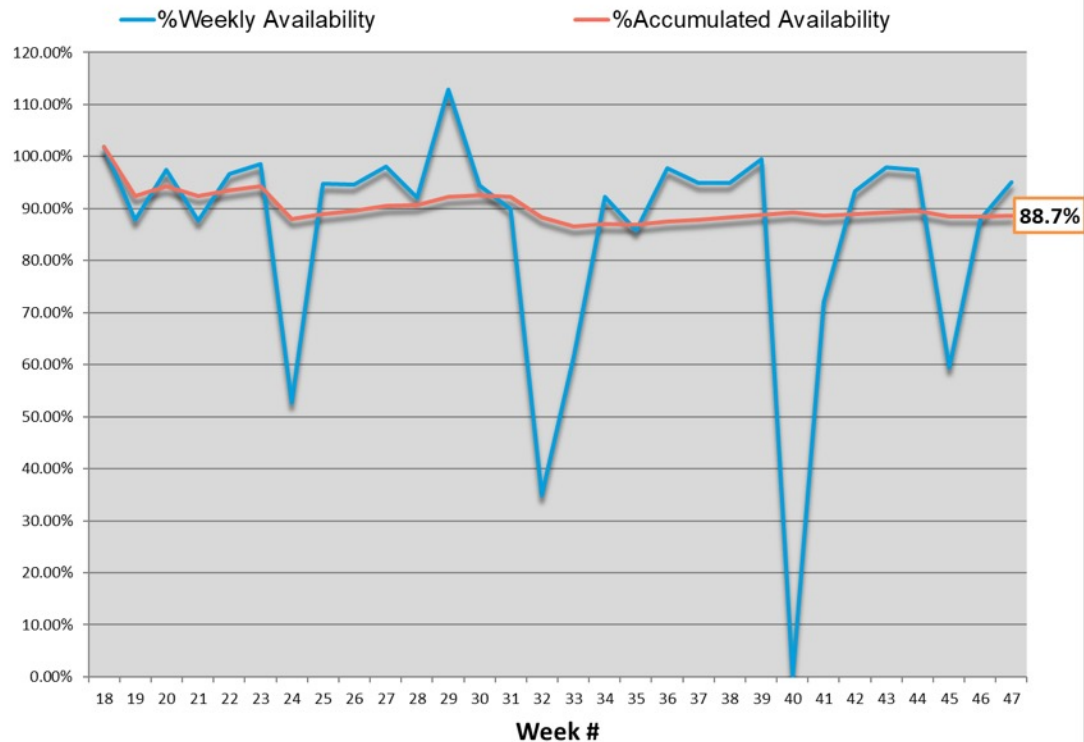


2023 Annual Retrospective – Scientific Progress

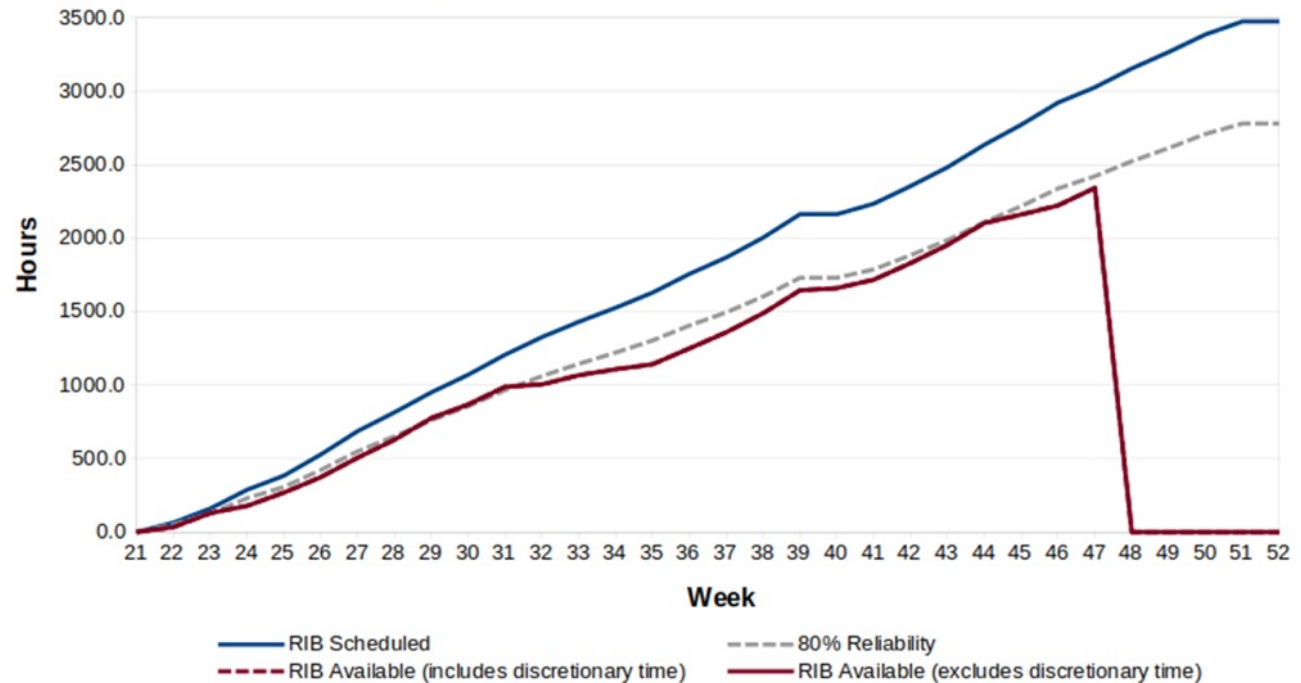
Operations

Thanks to Operations, Technical Groups, Service Groups, maintenance and SAS coordinators for delivering beam to users and maintaining infrastructure.

2023 Cyclotron Availability (%)

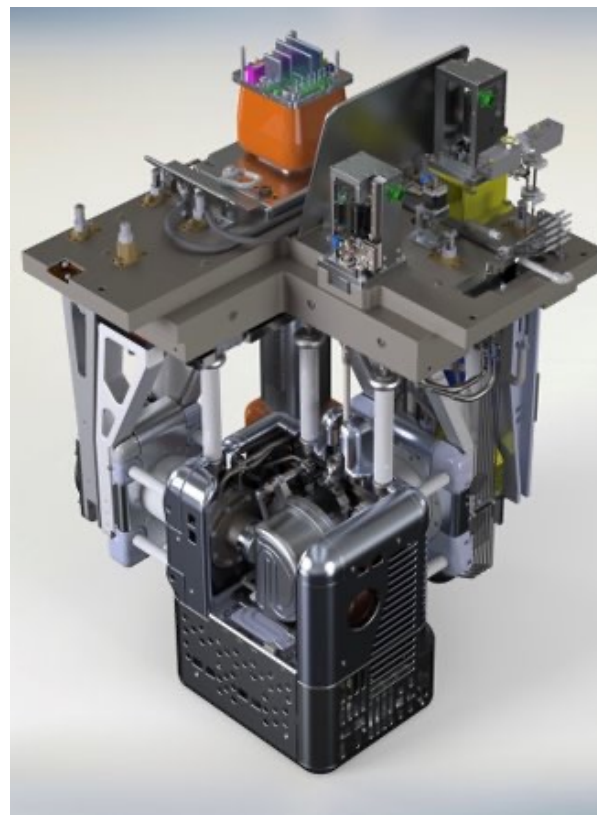


ISAC RIB Availability - Schedule 144 (2023) Experiments and Development



Progress on ARIEL - 2023

- Bottom-up cost and schedule review completed
- Beam extracted into BL4N
- Target module design complete
- Target hall shielding 85% design complete, 65% installation complete
- Hot cell (largest single capital invest) installation completed
- First RIB module dogleg completed



Target module design completion Hot cell completed



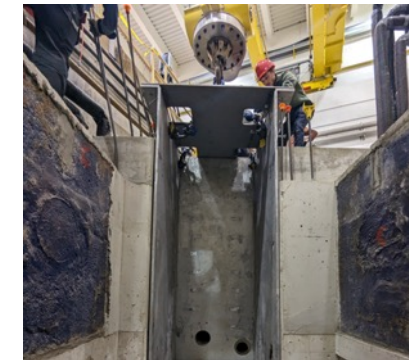
RIB module dogleg



BL4N vault installation



Target hall shielding

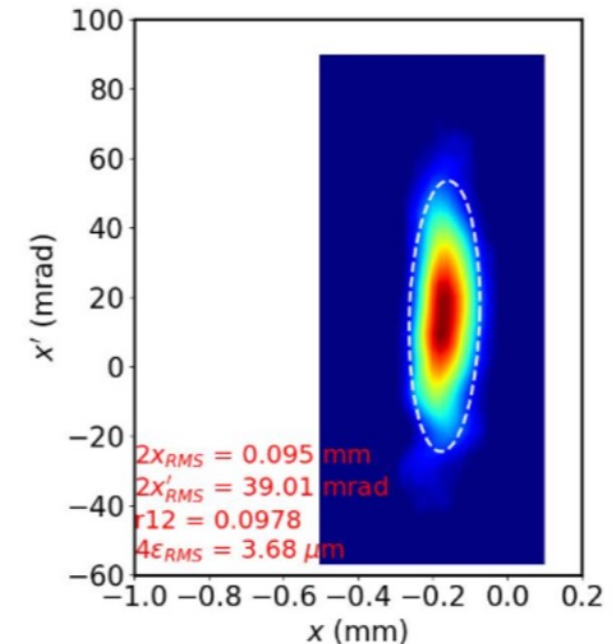
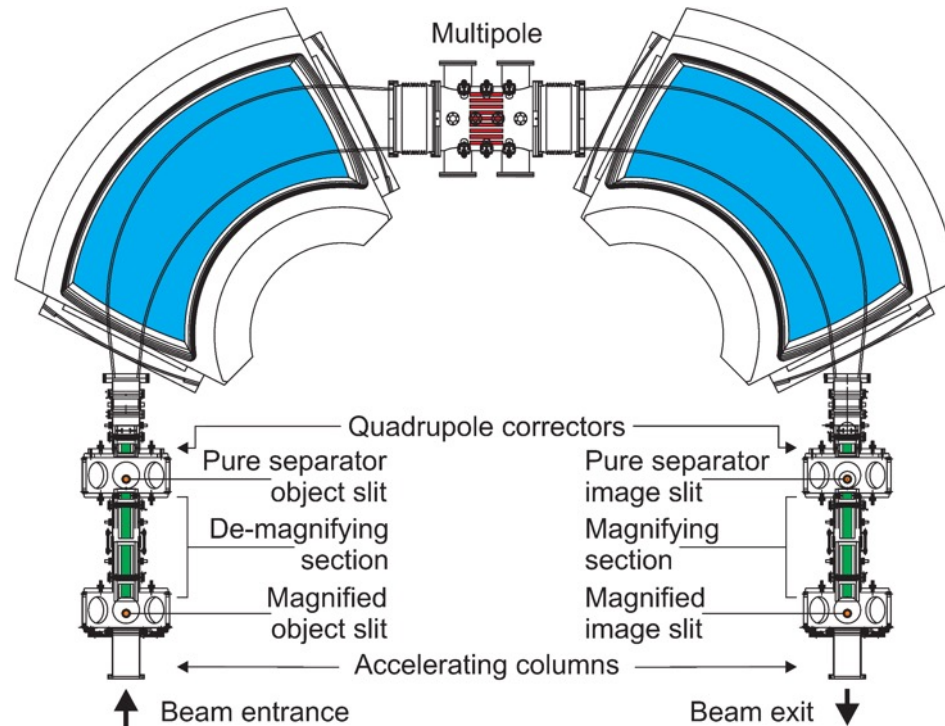
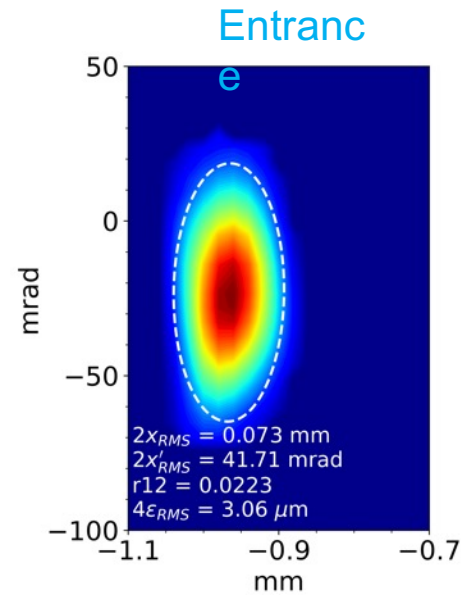
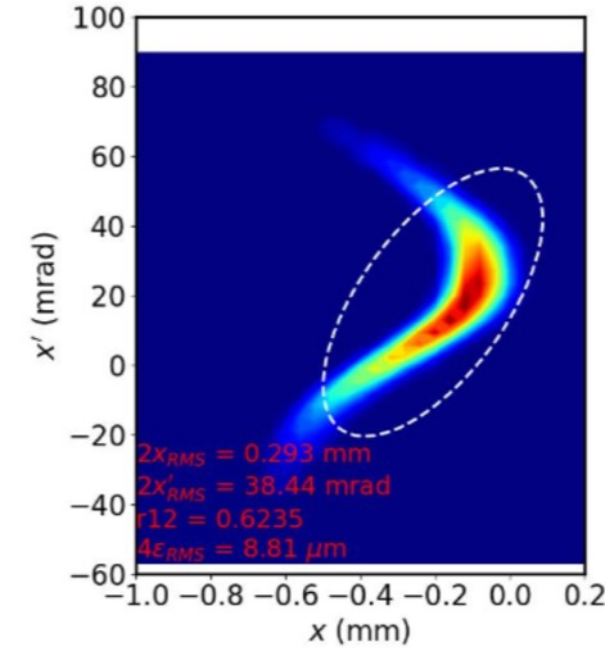


High Resolution Spectrometer (CANREB)

- Two 90-degree dipole design
- Electrostatic Multi-pole corrector between dipoles
- $\Delta M/M = 1/13000$ resolution tune demonstrated with high transmission – world leading performance



High resolution and high transmission

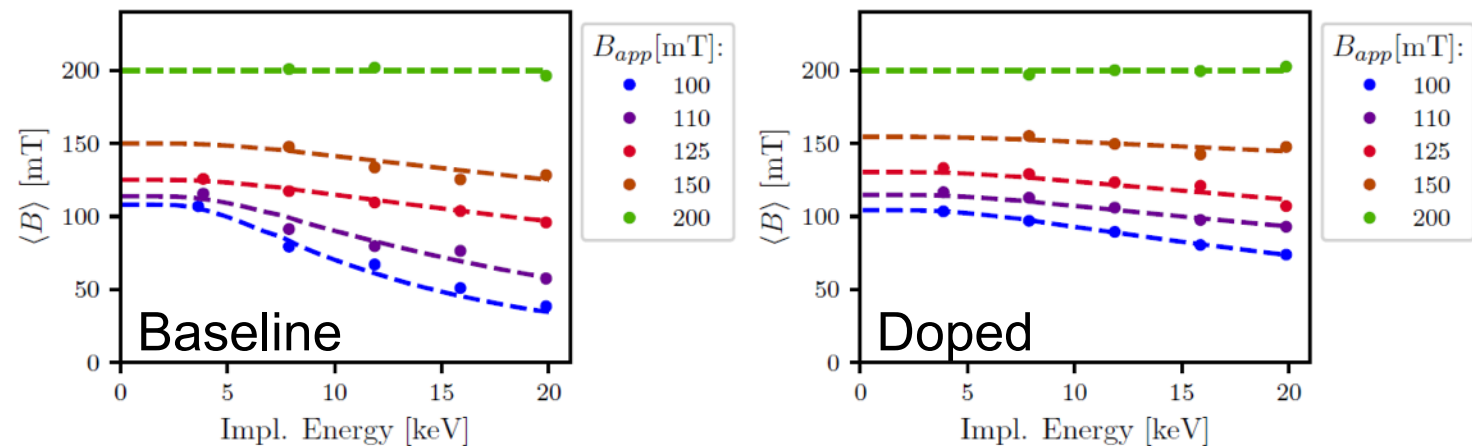


New ' β -SRF' Facility First Results

- New beamline extension installed at β -NMR facility for SRF materials characterization
- Unique facility in the world for depth profiling materials in parallel magnetic fields up to 200mT – SRF regime – critical field of Nb
- Collaboration between SRF group, Beam physics and CMMS

First results show Meissner screening in two samples (baseline and doped) as a function of applied field:

- Clear difference in screening profile between the two samples
- Clear breakdown of Meissner screening with applied field



First paper Feb. 2023 'Editor's pick'

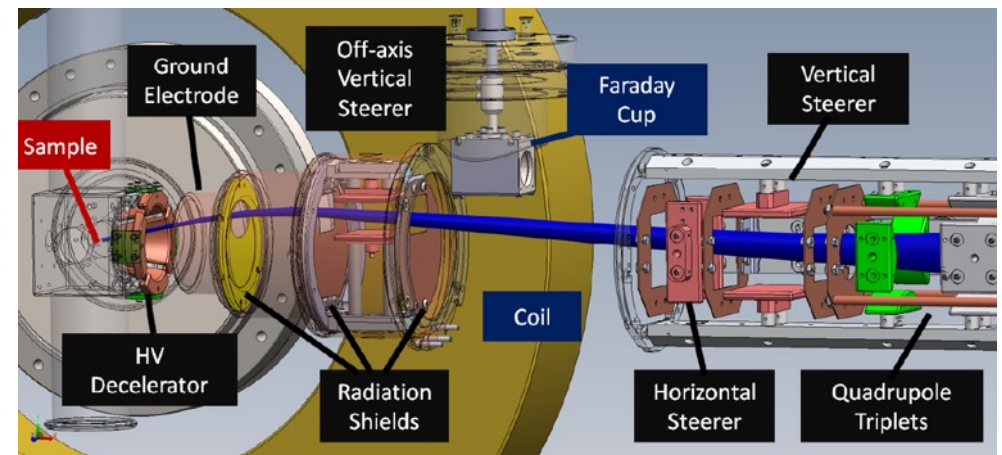
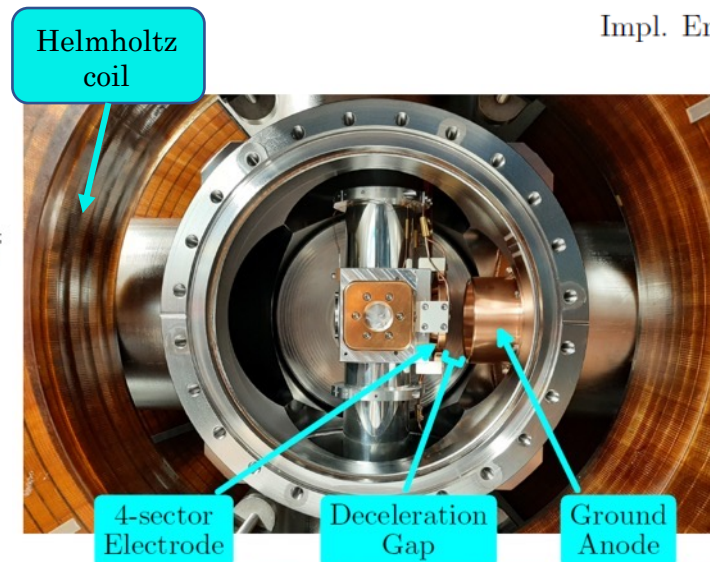
RESEARCH ARTICLE | FEBRUARY 10 2023

A new high parallel-field spectrometer at TRIUMF's β -NMR facility

Edward Thoeng ; Ryan M. L. McFadden ; Suresh Saminathan ; Gerald D. Morris ; Philipp Kolb ; Ben Matheson ; Md Asaduzzaman ; Richard Baartman ; Sarah R. Dunsiger ; Derek Fujimoto ; Tobias Junginger ; Victoria L. Kamer ; Spencer Kiy ; Ruohong Li ; Monika Stachura ; John O. Ticknor ; Robert F. Kiefl ; W. Andrew MacFarlane ; Robert E. Laxdal

Edward was recognized at SRF2023 with the Early Career Presenter Award.

2024-05-30



- TRIUMF and VECC (Kolkata) have had an active collaboration since 2008
- As part of the collaboration TRIUMF has completed and shipped three major deliverables to India in 2023
 - SRF QWR cryomodule – shipped January 2023
 - TISA Front end – prototype ARIEL target module – May 2023
 - RIE – radioactive ion extraction beamline – Nov. 2023



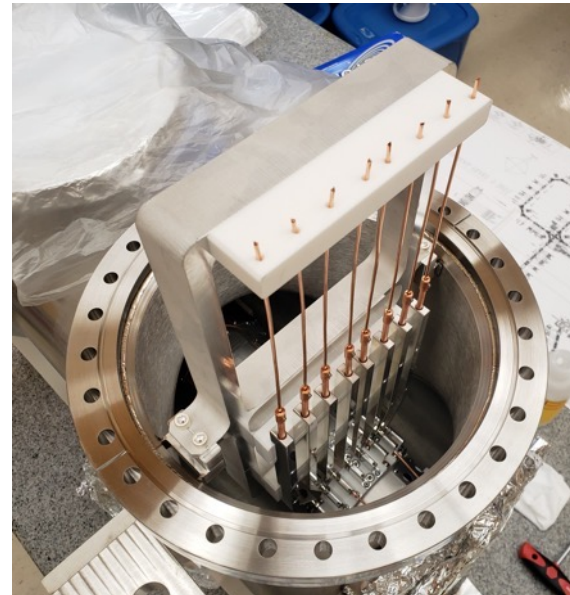
Quarter-Wave Resonator
Heavy Ion Cryomodule



TISA Front end



RIB module - HV feed lines

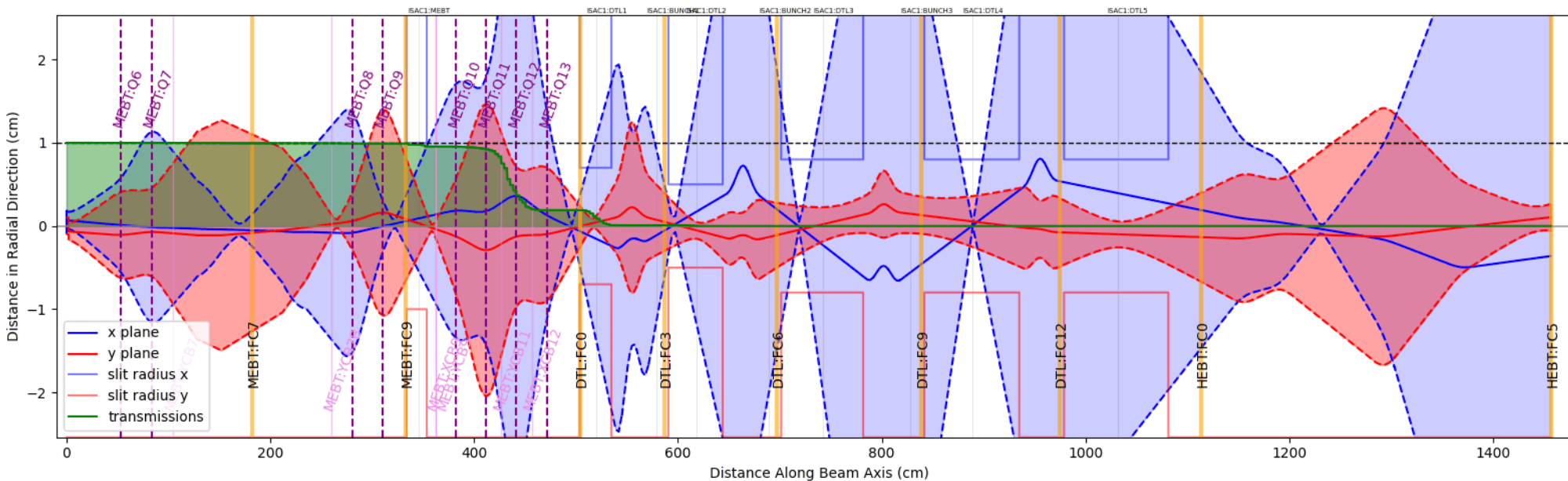
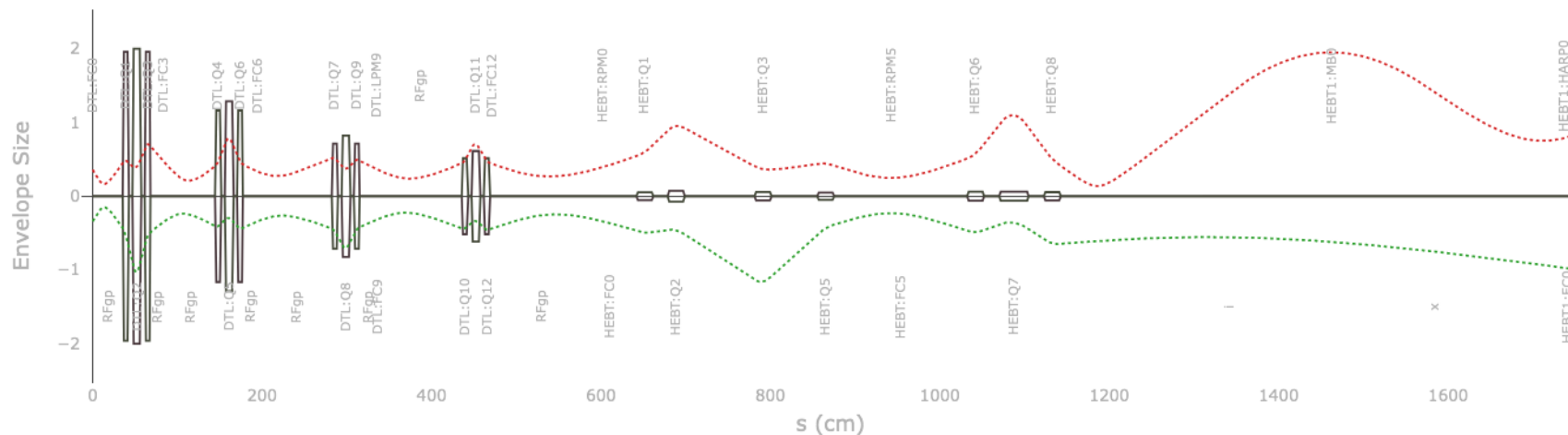


RIB beamline pre-separator



Advanced beam tuning test at ISAC

- Model Coupled Accelerator Tuning (MCAT) – new tool for tuning in ISAC
→ ready for transfer to RIB Operations
- Developing tools to significantly reduce manual tuning.
- Machine learning efforts: Bayesian optimization being developed in ISAC (example ISAC-I MEBT tuning)



STEP: 0
 'MEBT:Q6': 9.75
 'MEBT:Q7': 14.44
 'MEBT:Q8': 17.94
 'MEBT:Q9': 23.43
 'MEBT:Q10': 8.95
 'MEBT:Q11': 21.43
 'MEBT:Q12': 21.86
 'MEBT:Q13': 12.01
 TRANSMISSION: 0.0

ALPHA Update

- First scientific result from **ALPHA-g!**
 - 17/71 authors are TRIUMF-affiliated, including 3 graduate students.
 - This publication made headlines all over the world.
- **ALPHA-2** run ended
 - Successful spectroscopy campaigns, aided by Be⁺-assisted antihydrogen production and laser cooling.
- **HAICU**, the Canadian project to support antihydrogen research
 - Ongoing optimization of the hydrogen trap design.
 - Hydrogen decelerator from UBC is near completion and will be delivered to TRIUMF.

Article

Observation of the effect of gravity on the motion of antimatter


<https://doi.org/10.1038/s41586-023-06527-1>

Received: 6 May 2023

Accepted: 9 August 2023

Published online: 27 September 2023

Open access

 Check for updates

E. K. Anderson¹, C. J. Baker², W. Bertsche^{3,4}, N. M. Bhatt², G. Bonomi⁵, A. Capra⁶, I. Carli⁶, C. L. Cesar⁷, M. Charlton², A. Christensen⁸, R. Collister^{6,9}, A. Cridland Mathad², D. Duque Quiceno^{6,9}, S. Eriksson², A. Evans^{6,9}, N. Evetts⁹, S. Fabbri^{3,10}, J. Fajans^{8,10}, A. Ferwerda¹¹, T. Friesen¹², M. C. Fujiwara¹, D. R. Gill⁶, L. M. Golino², M. B. Gomes Gonçalves², P. Grandemange⁶, P. Granum¹, J. S. Hangst^{1,10}, M. E. Hayden¹³, D. Hodgkinson^{3,8}, E. D. Hunter⁶, C. A. Isaac², A. J. U. Jimenez⁶, M. A. Johnson^{3,4}, J. M. Jones², S. A. Jones¹⁴, S. Jonsell¹⁵, A. Khramov^{6,16}, N. Madsen², L. Martin⁶, N. Massacret⁶, D. Maxwell², J. T. K. McKenna^{1,3}, S. Menary¹¹, T. Momose^{6,9,17}, M. Mostamand^{6,17}, P. S. Mullan^{2,18}, J. Nauta², K. Olchanski⁶, A. N. Oliveira¹, J. Peszka^{2,18}, A. Powell¹², C. Ø. Rasmussen¹⁹, F. Robicheaux²⁰, R. L. Sacramento⁷, M. Sameed^{13,21}, E. Sarid^{22,23}, J. Schoonwater², D. M. Silveira⁷, J. Singh³, G. Smith^{6,19}, C. So⁶, S. Stracka²⁴, G. Stutter^{1,25}, T. D. Tharp²⁶, K. A. Thompson², R. I. Thompson^{6,12}, E. Thorpe-Woods², C. Torkzaban⁸, M. Urioni⁵, P. Woosaree¹² & J. S. Wurtele⁸

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Science

Scientists drop antimatter to see if it falls

Antimatter is influenced by gravity just like matter, ALPHA-g experiment finds

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Science

Scientists get closer to solving mystery of antimatter

© 27 September

rs démontrent que l'antimatière pas vers le haut

observé, pour la première fois, le comportement d'antiatomes en vue pour attirer les masses de matière ordinaire entre elles, n'est ière.

september 27

 ALJAZEERA

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EXPLAINER

Features | Science and Technology

Gravity test: Antimatter falls down, but where did it all go?

From Star Trek to PET scans, antimatter has thrilled and worried humankind. Now, scientists have resolved a key mystery.

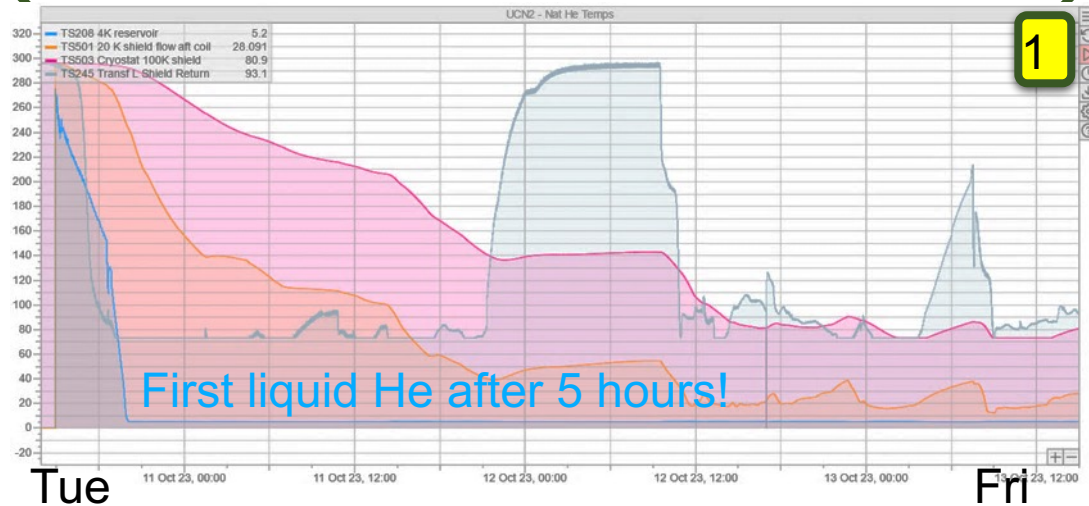
Source



TUCAN
TRIUMF Ultra Cold
Advanced Neutron source

EDM update

- Successful Phase 2A cooldown (4.2 K) **1** Oct 10 to 13
 - Cryostat, He return system, slow control and liquefier performed well! No cold leaks. **Big milestone!**
 - Thanks to everybody involved!
- Good meeting with Jon Aro from CNSC on Oct 17. Received initial feedback on safety analysis report. Just minor comments.
- Great meeting with TSBC on Oct 23: go ahead for manufacturing tail section at TRIUMF!
- Now pushing for Phase 2B cooldown (1.5 K) before liquefier repair (Dec)



- MSR installation almost complete, 5/5 layers installed **2** shielding factor measurement shows a deficit... investigating.
- B0 coil production has started **3**
- Gate 2/3 review happening in November
- Nov 5-9 nEDM 2023 workshop in Santa Fe with many TUCAN participants: <https://web.cvent.com/event/ab450600-c4ab-40c9-9935-0b54734ddaa0>



- Silicon photo-multiplier performances enable reaching nEXO target energy resolution
 - Hamamatsu (HPK)
 - Fondazione Bruno Kessler (FBK)
- Wide range of operation voltage acceptable
- Extensive multi-institutions campaign led by TRIUMF



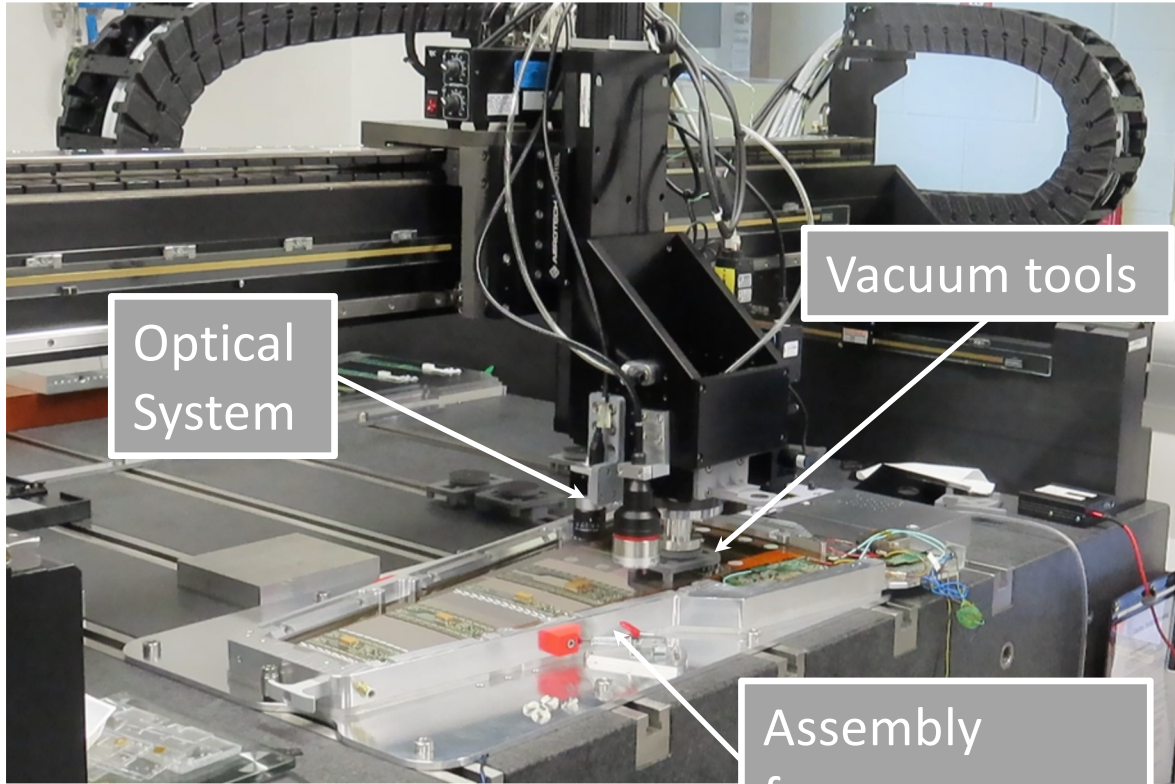
Performance of novel VUV-sensitive Silicon Photo-Multipliers for nEXO

[G. Gallina](#) ✉, [Y. Guan](#), [F. Retiere](#), [G. Cao](#) ✉, [A. Bolotnikov](#), [I. Kotov](#), [S. Rescia](#), [A. K. Soma](#), [T. Tsang](#), [L. Darroch](#), [T. Brunner](#), [J. Bolster](#), [J. R. Cohen](#), [T. Pinto Franco](#), [W. C. Gillis](#), [H. Peltz Smalley](#), [S. Thibado](#), [A. Pocar](#), [A. Bhat](#), [A. Jamil](#), [D. C. Moore](#), [G. Adhikari](#), [S. Al Kharusi](#), [E. Angelico](#), ... [T. Ziegler](#)

[+ Show authors](#)

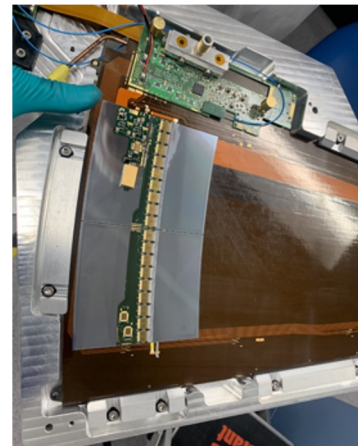
The European Physical Journal C **82**, Article number: 1125 (2022) | [Cite this article](#)

Calculations based on measured SiPM performances

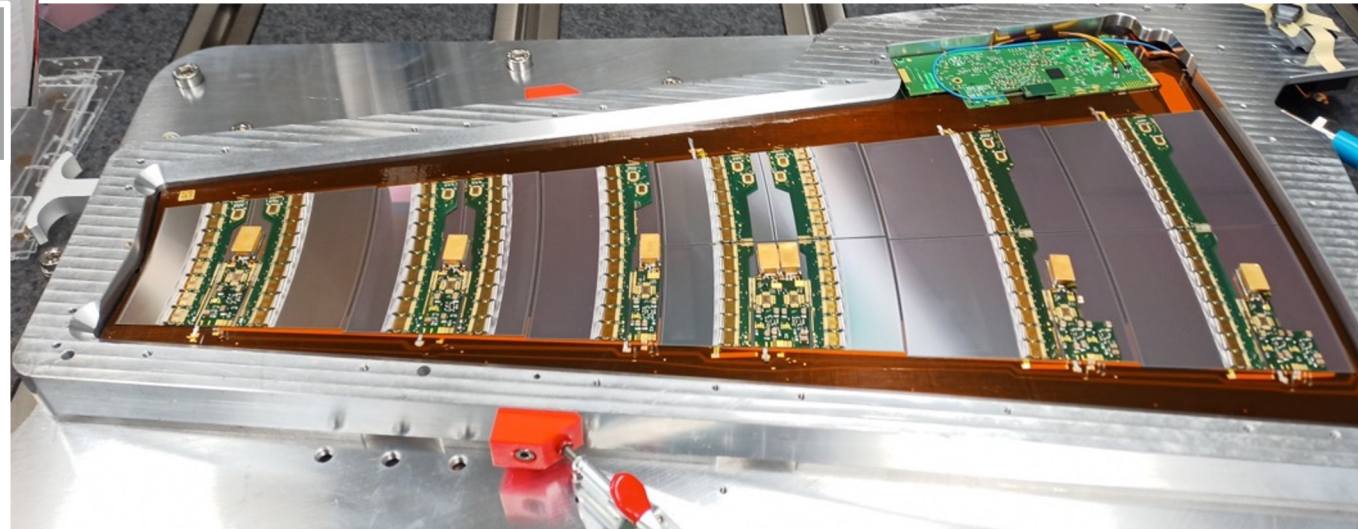


ITk Petal assembly milestone

- Assembly of three petals recently
- First Pre-Production A (PPA) petal in ATLAS
- Vancouver/Canada is first ITk EC site to qualify
 - Automated loading using robotic gantry
 - All placements within specification $\pm 50\mu\text{m}$
 - Exercised full Canadian production workflow
 - Assembly of first PPB petal in preparation



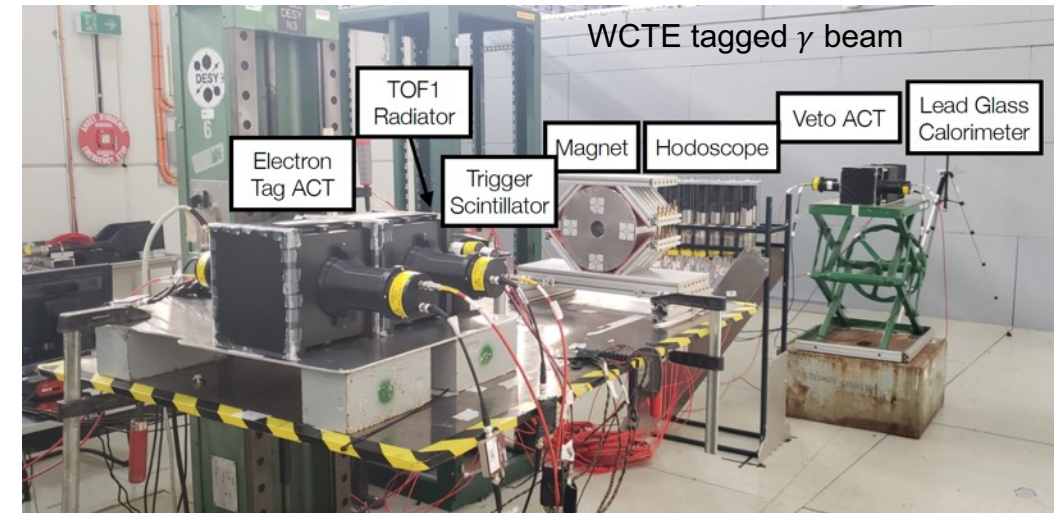
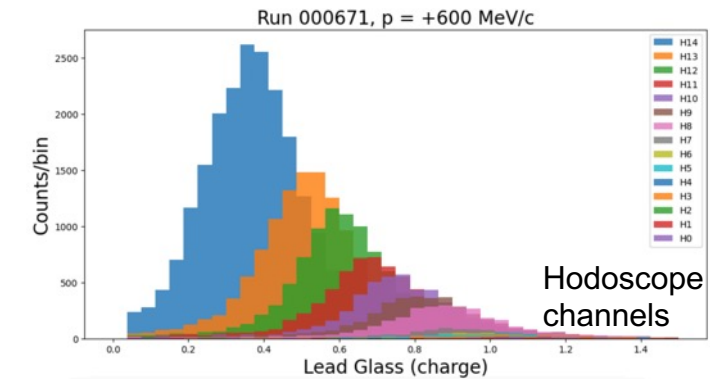
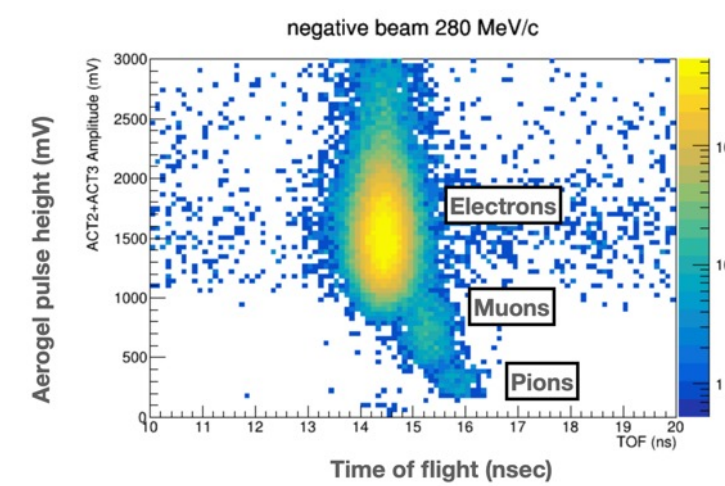
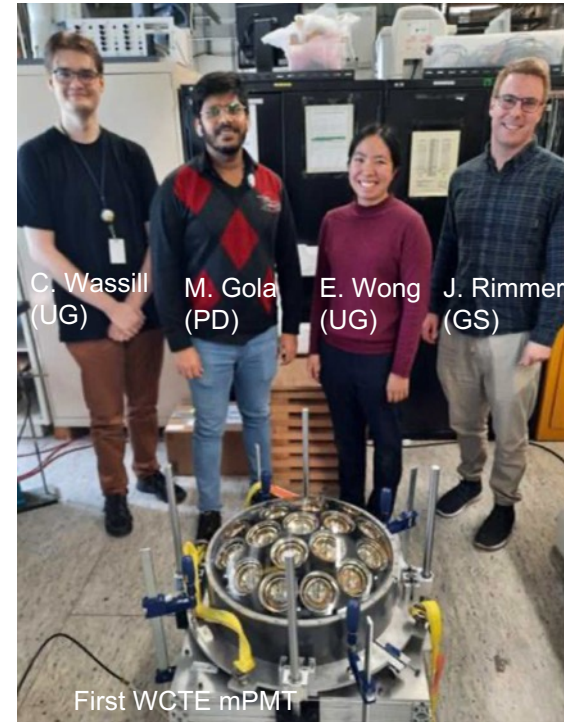
- Single module PPB petal assembled at special request
- Sent to DESY for system test Preparation and readout (FELIX) development at NIKHEF



T2K and Hyper-K

WCTE Water Cherenkov Test Experiment and IWCD Intermediate Water Cherenkov Detector

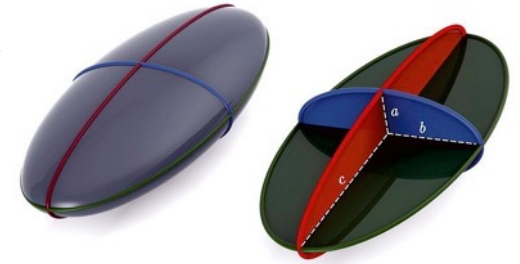
- TRIUMF continues to play a leading role in mPMT and calibration systems for IWCD and WCTE
 - WCTE mPMT production has commenced
- WCTE scheduled to take data in Aug. 2024
 - Schedule delayed by a few months due to the need for tank redesign
 - Additional tests of 8 mPMTs and calibration source deployment system at CERN planned in Feb. 2024
 - Successful beam test at CERN T9 in July 2023 demonstrated the performance of the beam monitors and beam statistics
 - Upgrades for 2024 planned
 - 3 publications expected
 - PD Laurence Cook software/analysis convener



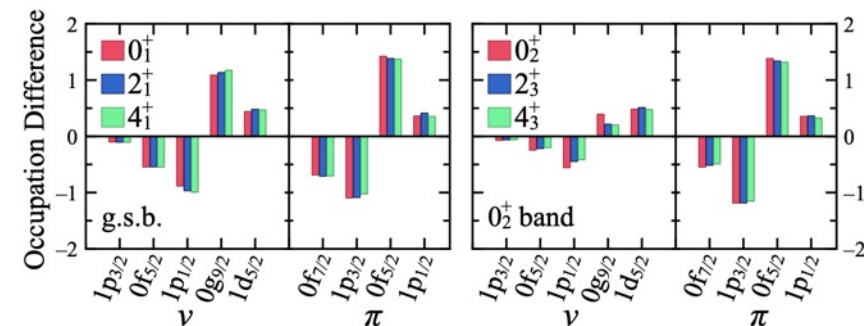
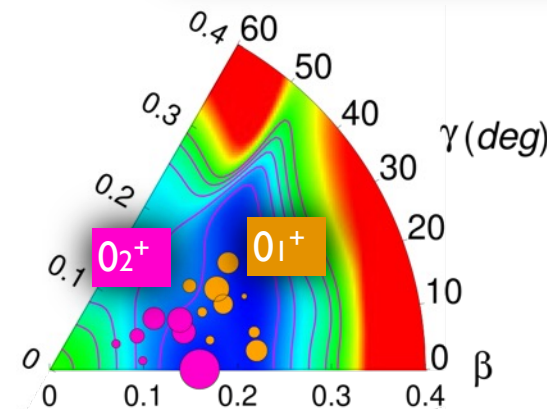
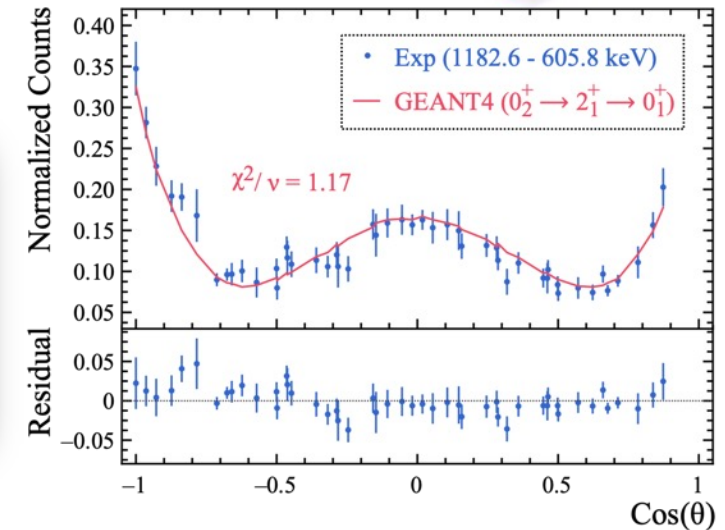
First Evidence of Axial Shape Asymmetry and Configuration Coexistence in ^{74}Zn : Suggestion for a Northern Extension of the N = 40 Island of Inversion

M. Rocchini, P.E. Garrett, M. Zielińska, S.M. Lenzi, D.D. Dao, F. Nowacki, et al., *Phys. Rev. Lett.* 130, 122502 (2023).

- ^{74}Zn investigated at GRIFFIN following ^{74}Cu β decay
- γ - γ angular correlation analysis \Rightarrow Firm spin assignments for 2_2^+ , 3_1^+ , 0_2^+ , 2_3^+ states
- Two new transitions observed $\Rightarrow 2_3^+ \rightarrow 0_2^+$ and $2_3^+ \rightarrow 4_1^+$
- From measured γ -ray branching and $E2/M1$ mixing ratios for transitions de-exciting the 2_2^+ , 3_1^+ , 2_3^+ states \Rightarrow Relative $B(E2)$ values
- A rotational-like structure appears at low energy in ^{74}Zn
- New microscopic Large-Scale Shell-Model calculations
 - Shapes of individual states
 - Wave-function compositions
- The ground state is found to have enhanced axial shape asymmetry (triaxiality)
- Configuration-coexisting 0_2^+ state



A shore of the N = 40 “island of inversion” appears to manifest above Z = 26, previously thought as its northern limit in the chart of the nuclides



SONIK@DRAGON – $^3\text{He} + ^4\text{He}$ elastic scattering

Elastic scattering of $^3\text{He} + ^4\text{He}$ with SONIK

S. N. Paneru,^{1,*} C. R. Brune,¹ D. Connolly,² D. Odell,¹ M. Poudel,¹ D. R. Phillips,¹ J. Karpesky,³ B. Davids,^{2,4} C. Ruiz,² A. Lennarz,² U. Greife,³ M. Alcorta,² R. Giri,¹ M. Lovely,³ M. Bowry,² M. Delgado,^{2,5} N. E. Esker,² A. Garnsworthy,² C. Seeman,² P. Machule,² J. Fallis,⁶ A. A. Chen,⁷ F. Laddaran,⁸ A. Firmino,⁹ and C. Weinerman¹⁰

¹Department of Physics & Astronomy, Ohio University, Athens, Ohio 45701, USA

²TRIUMF, Vancouver, British Columbia, Canada

³Department of Physics, Colorado School of Mines, Golden, Colorado 80401, USA

⁴Physics Department, Simon Fraser University, Burnaby, BC, Canada

⁵Instituto de Física Teórica IFT-UAM/CSIC, Madrid, Spain

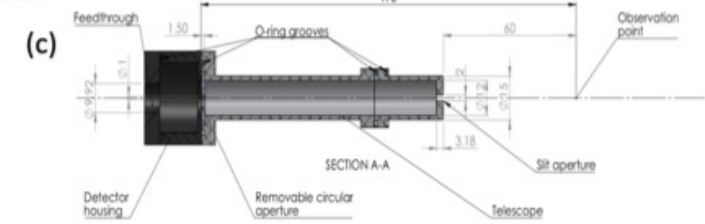
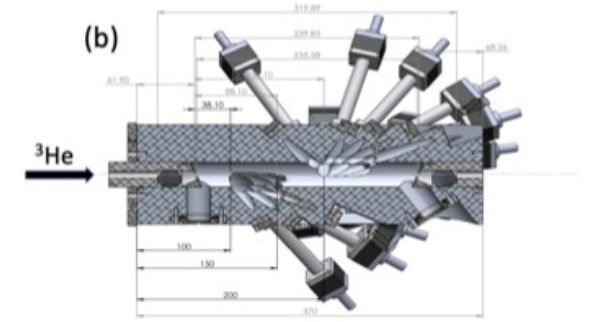
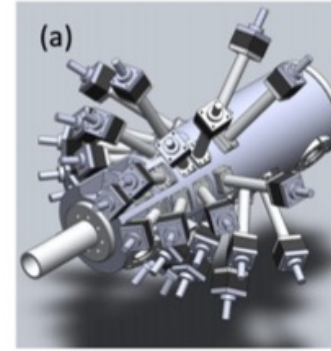
⁶North Island College, British Columbia, Canada

⁷McMaster University, Ontario, Canada

⁸University of British Columbia, British Columbia, Canada

⁹University of Alberta, Edmonton, Alberta, Canada

¹⁰McGill University, Montreal, Quebec, Canada

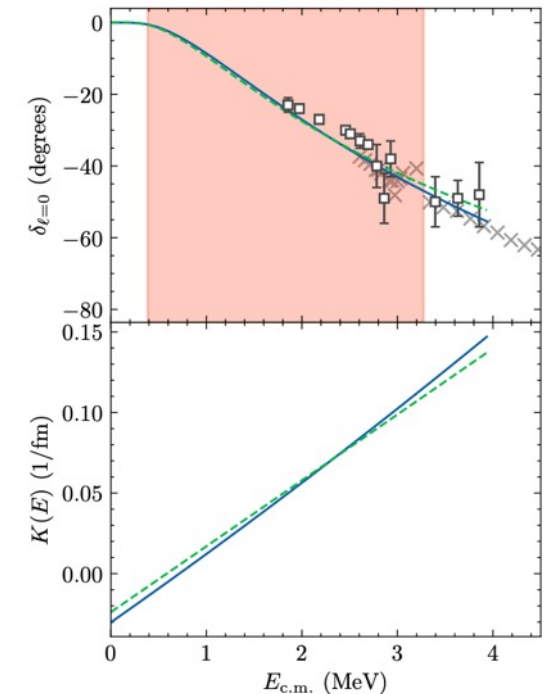
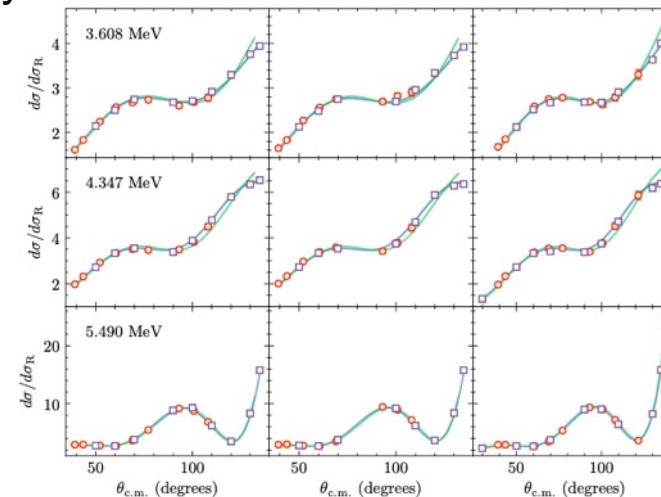
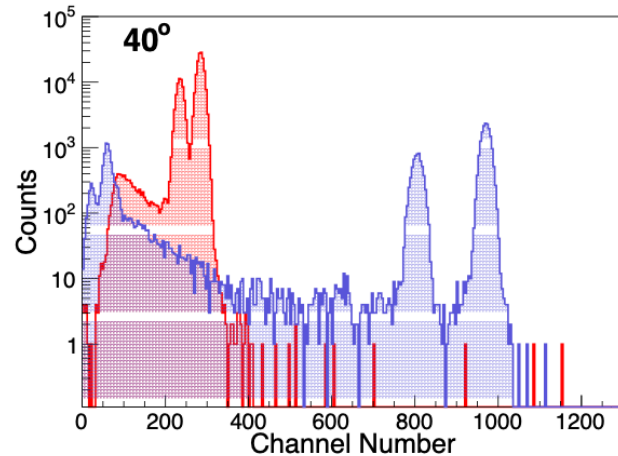


Accepted for Publication in Physical Review C October 2023.

Data from SONIK@DRAGON

Precision scattering \rightarrow extraction of low energy scattering parameters critical for Big Bang Nucleosynthesis & Solar Neutrino Production

Analysis using R-Matrix and Halo Effective Field Theory





Measuring neutron capture cross sections of radioactive nuclei

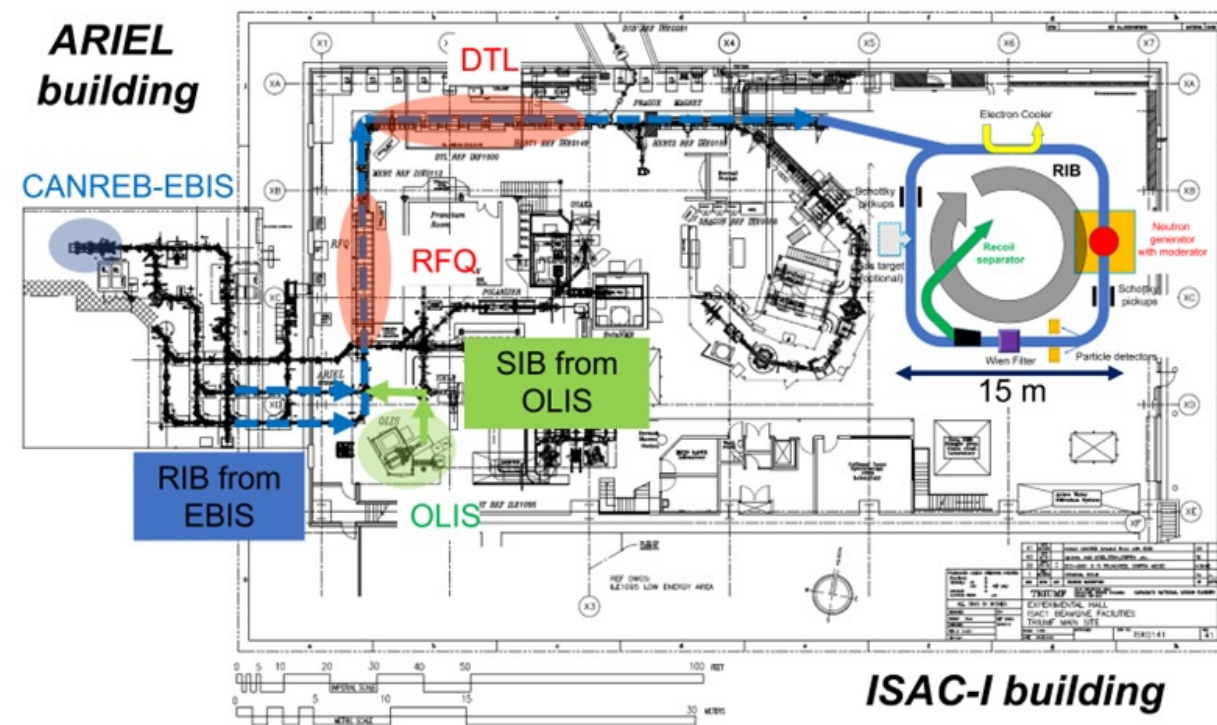
From activations at the FZK Van de Graaff to direct neutron captures in inverse kinematics with a storage ring at TRIUMF

Iris Dillmann^{1,2,a}, Oliver Kester^{1,2}, Richard Baartman^{1,2}, Alan Chen³, Tobias Junginger^{1,2}, Falk Herwig², Dobrin Kaltchev¹, Annika Lennarz^{1,3}, Thomas Planche^{1,2}, Chris Ruiz^{1,2}, Nicole Vassh¹

¹ TRIUMF, Vancouver, BC V6T 2A3, Canada

² Department of Physics and Astronomy, University of Victoria, Victoria, BC V8P 5C2, Canada

³ Department of Physics and Astronomy, McMaster University, Hamilton, ON L8S 4M1, Canada



Recent Theory Papers

How long does the hydrogen atom live?

David McKeen^{1,*} and Maxim Pospelov^{2,3,†}

¹TRIUMF, 4004 Wesbrook Mall, Vancouver, BC V6T 2A3, Canada

²School of Physics and Astronomy, University of Minnesota, Minneapolis, MN 55455, USA

³William I. Fine Theoretical Physics Institute, School of Physics and Astronomy, University of Minnesota, Minneapolis, MN 55455, USA

Universe, accepted

PHYSICAL REVIEW LETTERS **131**, 011005 (2023)

Dark Matter Annihilation inside Large-Volume Neutrino Detectors

David McKeen^{1,*}, David E. Morrissey^{1,†}, Maxim Pospelov^{2,3,‡}, Harikrishnan Ramani^{4,§} and Anupam Ray^{5,2,||}

PHYSICAL REVIEW LETTERS **131**, 022502 (2023)

Isomeric Excitation Energy for ⁹⁹In^m from Mass Spectrometry Reveals Constant Trend Next to Doubly Magic ¹⁰⁰Sn

L. Nies^{1,2,*}, D. Atanasov^{1,†}, M. Athanasakis-Kaklamanakis^{1,3}, M. Au^{1,4}, K. Blaum⁵, J. Dobaczewski^{6,7}, B. S. Hu⁸, J. D. Holt^{8,9}, J. Karthein¹⁰, I. Kulikov¹¹, Yu. A. Litvinov^{11,12}, D. Lunney¹³, V. Manea¹³, T. Miyagi^{14,12,5}, M. Mougeot^{1,5,‡}, L. Schweikhard², A. Schwenk^{14,12,5}, K. Sieja¹⁵ and F. Wienholtz¹⁴

PHYSICAL REVIEW LETTERS **130**, 242501 (2023)

Featured in Physics

Microsecond Isomer at the *N*=20 Island of Shape Inversion Observed at FRIB

T. J. Gray¹, J. M. Allmond¹, Z. Xu², T. T. King¹, R. S. Lubna³, H. L. Crawford⁴, V. Tripathi⁵, B. P. Crider⁶, R. Grzywacz^{2,1}, S. N. Liddick^{3,7}, A. O. Macchiavelli¹, T. Miyagi^{8,9}, A. Poves¹⁰, A. Andalib^{3,11}, E. Argo^{3,11}, C. Benetti⁵, S. Bhattacharya⁵, C. M. Campbell⁴, M. P. Carpenter¹², J. Chan², A. Chester³, J. Christie², B. R. Clark⁶, I. Cox², A. A. Doetsch^{3,11}, J. Dopfer^{3,11}, J. G. Duarte¹³, P. Fallon⁶, A. Frotscher⁶, T. Gaballah⁶, J. T. Harke¹³, J. Heideman², H. Huegen², J. D. Holt^{14,15}, R. Jain^{3,11}, N. Kitamura², K. Kolos¹³, F. G. Kondev¹², A. Laminack¹, B. Longfellow¹³, S. Luitel⁶, M. Madurga², R. Mahajan³, M. J. Mogannam^{3,7}, C. Morse¹⁶, S. Neupane², A. Nowicki², T. H. Ogunbaku^{6,3}, W.-J. Ong¹³, C. Porzio⁴, C. J. Prokop¹⁷, B. C. Rasco¹, E. K. Ronning^{3,7}, E. Rubino³, T. J. Ruland¹⁸, K. P. Rykaczewski¹, L. Schaedig^{3,11}, D. Seweryniak¹², K. Siegl², M. Singh², A. E. Stuchbery¹⁹, S. L. Tabor⁵, T. L. Tang⁵, T. Wheeler^{3,11}, J. A. Winger⁶ and J. L. Wood²⁰

Element abundance patterns in stars indicate fission of nuclei heavier than uranium

Ian U. Roederer^{1,*†}, Nicole Vassh², Erika M. Holmbeck³, Matthew R. Mumpower^{4,5},
Rebecca Surman⁶, John J. Cowan⁷, Timothy C. Beers⁶, Rana Ezzeddine⁸, Anna Frebel^{9,10},
Terese T. Hansen¹¹, Vinicius M. Placco¹², Charli M. Sakari¹³

¹Department of Astronomy, University of Michigan; Ann Arbor, MI 48109, USA.

²TRIUMF (Tri-University Meson Facility), Vancouver, BC V6T 2A3, Canada.

Science, accepted

Physics Letters B 845 (2023) 138156



Contents lists available at ScienceDirect

Physics Letters B

journal homepage: www.elsevier.com/locate/physletb



Ab initio informed evaluation of the radiative capture of protons on ⁷Be

K. Kravvaris^{a,*}, P. Navrátil^b, S. Quaglioni^a, C. Hebborn^{c,a}, G. Hupin^d



Physics Letters B 843 (2023) 138025



Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/physletb



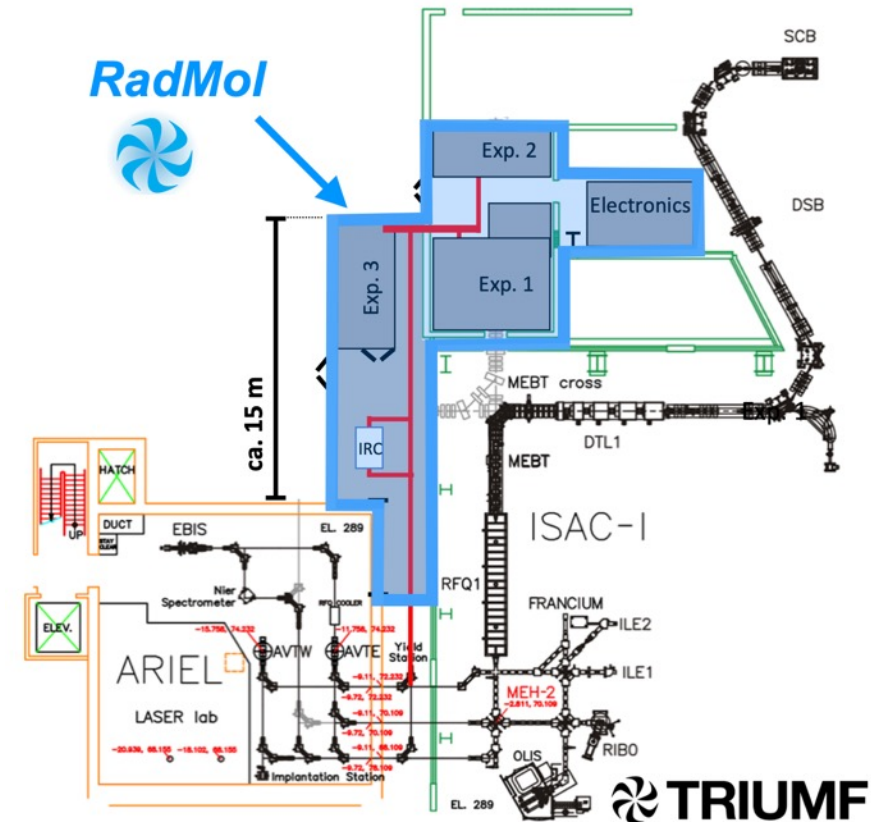
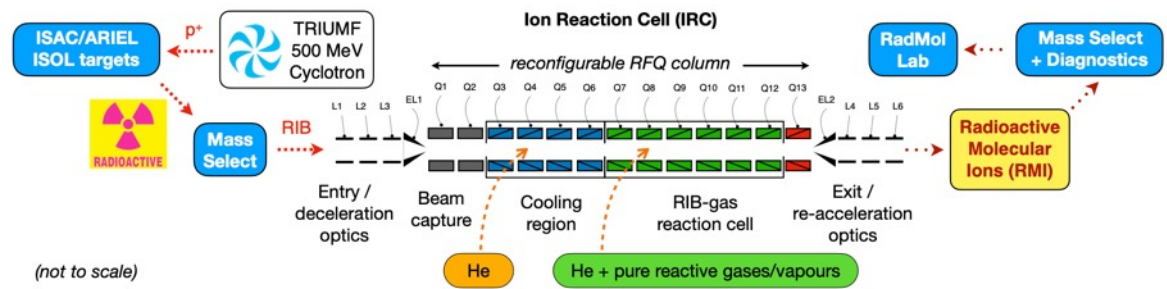
Level structures of ^{56,58}Ca cast doubt on a doubly magic ⁶⁰Ca

S. Chen^{a,b,c,*}, F. Browne^b, P. Doornenbal^b, J. Lee^a, A. Obertelli^{d,e,b}, Y. Tsunoda^f, T. Otsuka^{b,g,h}, Y. Chazonoⁱ, G. Hagen^{n,j}, J.D. Holt^{k,l}, G.R. Jansen^{m,n}, K. Ogata^{l,o}, N. Shimizu^f, Y. Utsuno^{h,i}, K. Yoshida^b, N.L. Achouri^p, H. Baba^b, D. Calvet^e, F. Château^e, N. Chiga^b, A. Corsi^e, M.L. Cortés^b, A. Delbart^e, J.-M. Geller^e, A. Giganon^e, A. Gillibert^e, C. Hilaire^e, T. Isobe^b, T. Kobayashi^q, Y. Kubota^{b,i}, V. Lapoux^e, H.N. Liu^{e,d,r}, T. Motobayashi^b, I. Murray^{s,b}, H. Otsu^b, V. Panin^b, N. Paul^{e,t}, W. Rodriguez^{b,u,v}, H. Sakurai^{b,g}, M. Sasano^b, D. Steppenbeck^b, L. Stuhl^{f,w,x}, Y.L. Sun^{e,d}, Y. Togano^y, T. Uesaka^b, K. Wimmer^{g,b}, K. Yoneda^b, O. Aktas^t, T. Aumann^{d,z}, L.X. Chung^{aa}, F. Flavigny^s, S. Franchoo^s, I. Gasparic^{ab,d,b}, R.-B. Gerst^{ac}, J. Gibelin^p, K.I. Hahn^{ad,x}, D. Kim^{ad,b,x}, T. Koiwai^g, Y. Kondo^{ae}, P. Koseoglou^{d,z}, C. Lehr^d, B.D. Linh^{aa,af}, T. Lokotko^a, M. MacCormick^s, K. Moschner^{ac}, T. Nakamura^{ae}, S.Y. Park^{ad,x}, D. Rossi^d, E. Sahin^{ag}, P.-A. Söderström^d, D. Sohler^w, S. Takeuchi^{ae}, H. Törnqvist^{d,z}, V. Vaquero^{ah}, V. Wagner^d, S. Wang^{ai}, V. Werner^d, X. Xu^a, H. Yamada^{ae}, D. Yan^{ai}, Z. Yang^b, M. Yasuda^{ae}, L. Zanetti^d



Opportunities with Radioactive Molecules review paper

- Nuclear experimentalist and theorists contributed to a review paper on opportunities for fundamental physics research with radioactive molecules
 - Five co-authors from TRIUMF



Opportunities for Fundamental Physics Research with Radioactive Molecules

7 February 2023

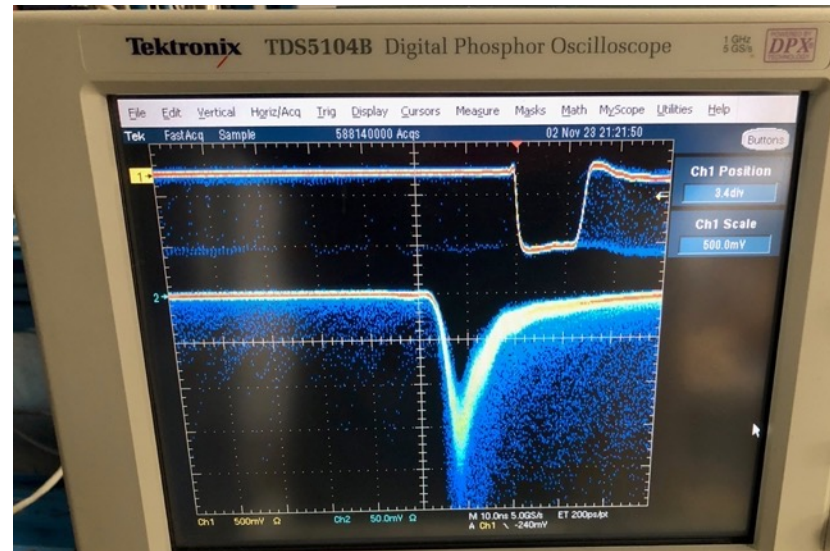
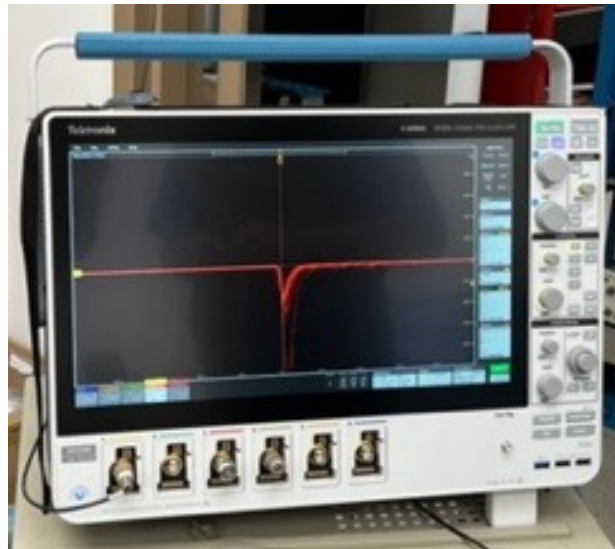
arXiv:2302.02165

M9A has been safely delivered and is doing well !

First (muon ?) beam observed
Aug. 31, 2023 5:45 p.m.
... as verified by an
indisputable independent
witness; aka Nigel Smith

A genuine M9A
muon beam trace,
right now in M9A

... and the beam rate
achieved to date



... but in reality, it was a
positron beam that was
penetrating a closed gate
value at the end of the
beamline

>1.2 E6 μ^+ /sec

>4 times the rate of M20 or M15*

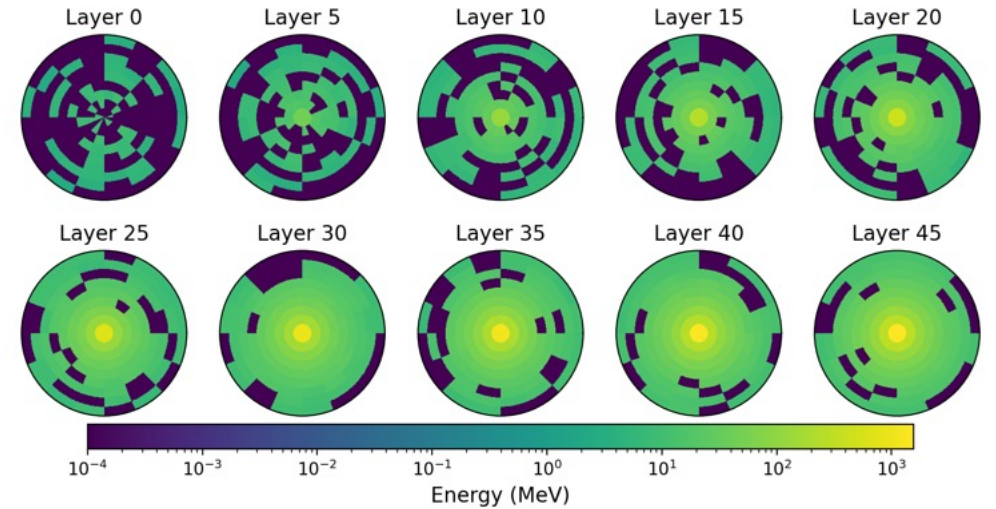
*in its currently degraded (but soon to be rejuvenated) state

Scientific Computing: Machine Learning and Quantum Computing

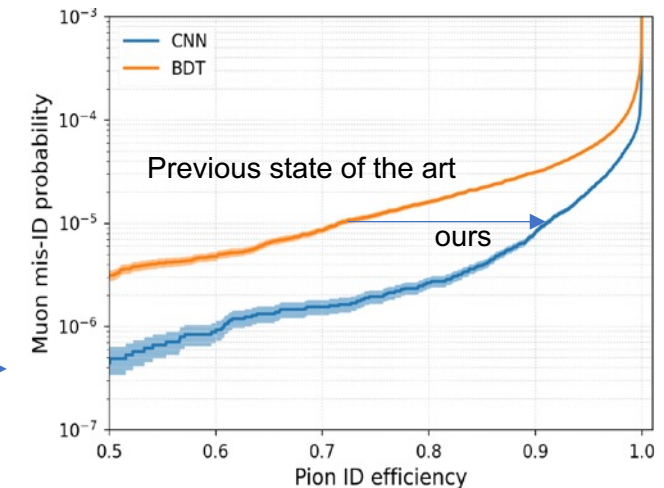
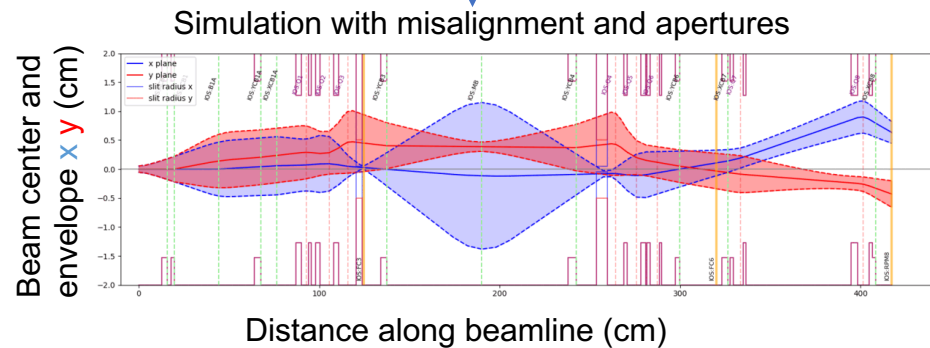
- Quantum – Assisted ML calorimeter simulation for ATLAS @ HL-LHC:

- D-Wave quantum annealer as a sampler within a deep generative network
- NRC Applied Quantum Computing Challenge program
 - M. Swiatlowski, W. Fedorko *et al.* (Perimeter, UBC, SFU, Virginia)
 - Use D-Wave quantum annealer
 - \$400k – includes postdoc funding

Full depth calorimeter simulation using Pegasus D-Wave QPU



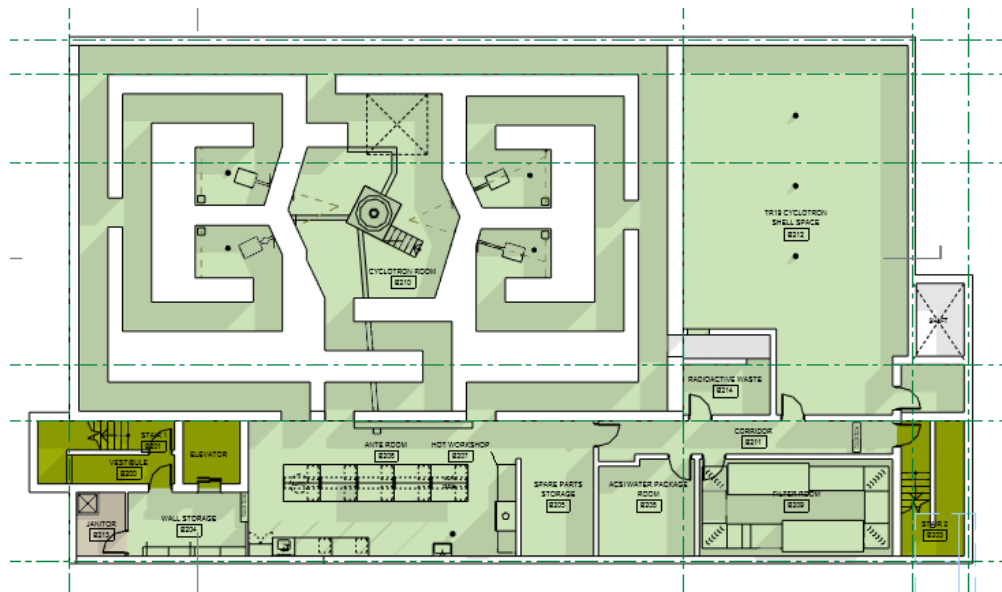
- AI tuning of TRIUMF beamlines
 - Tuning for RIB beamlines (ISAC I) being developed
 - Simulation + Physical beamlines
- Multiple projects for
 - ATLAS
 - Water Cherenkov experiments
 - ALPHA
 - NA62 (accepted JHEP)



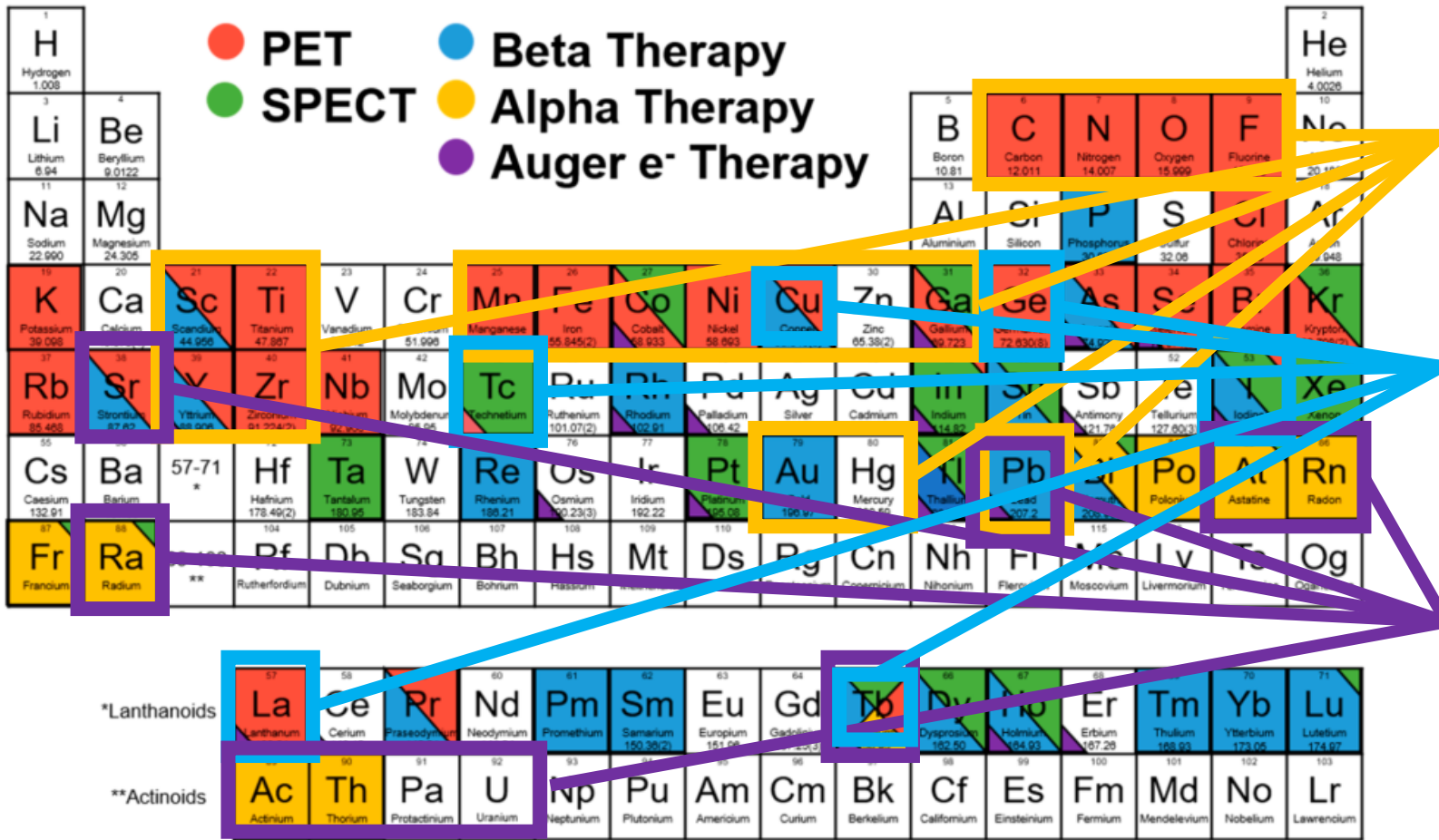
IAMI (P442)



- includes P471, P550, P527
 - Construction substantially complete
 - BC Provincial Health Authority will be placing 2nd cyclotron in facility; additional lab space to support expanding provincial PET program
 - Additional funding requests continue in discussion with provincial funding ministries
 - If all remaining funding materializes, expect operations to commence in 2025



Continued Focus on Radiometals



TR13 MeV

- Legacy machine operating at ideal energy for many isotopes

24 MeV

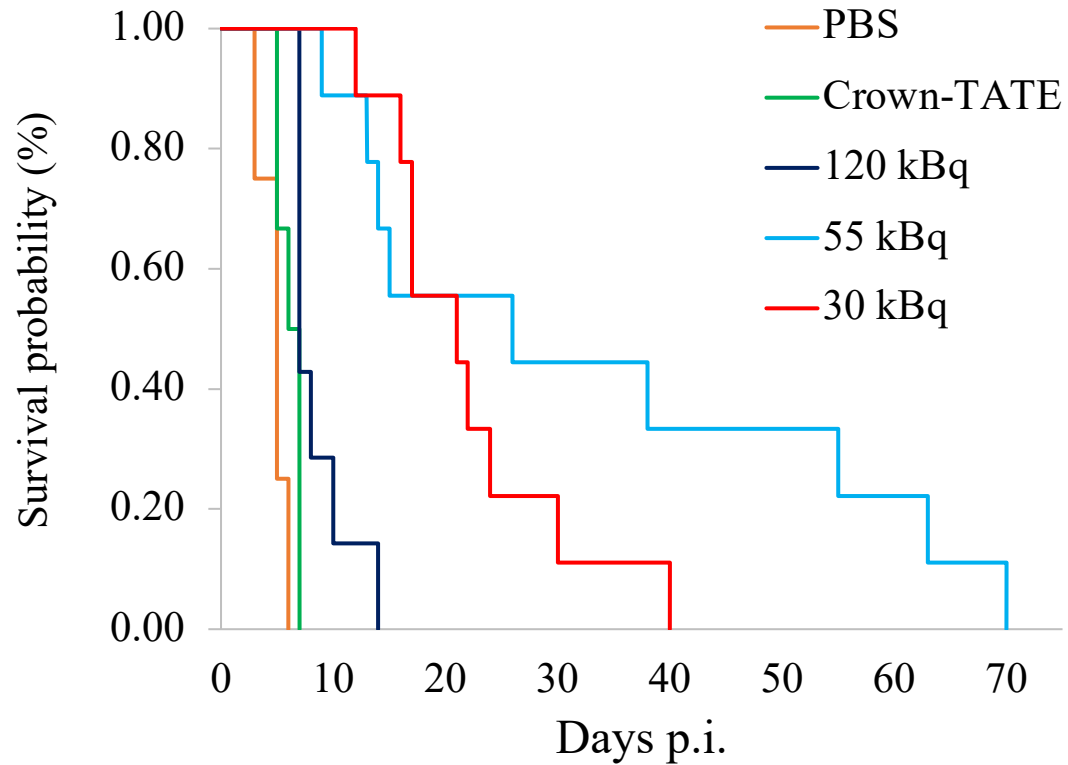
- Modern, high-intensity machine that expands on TRIUMF's radionuclide repertoire

520 MeV (IPF, ISAC)

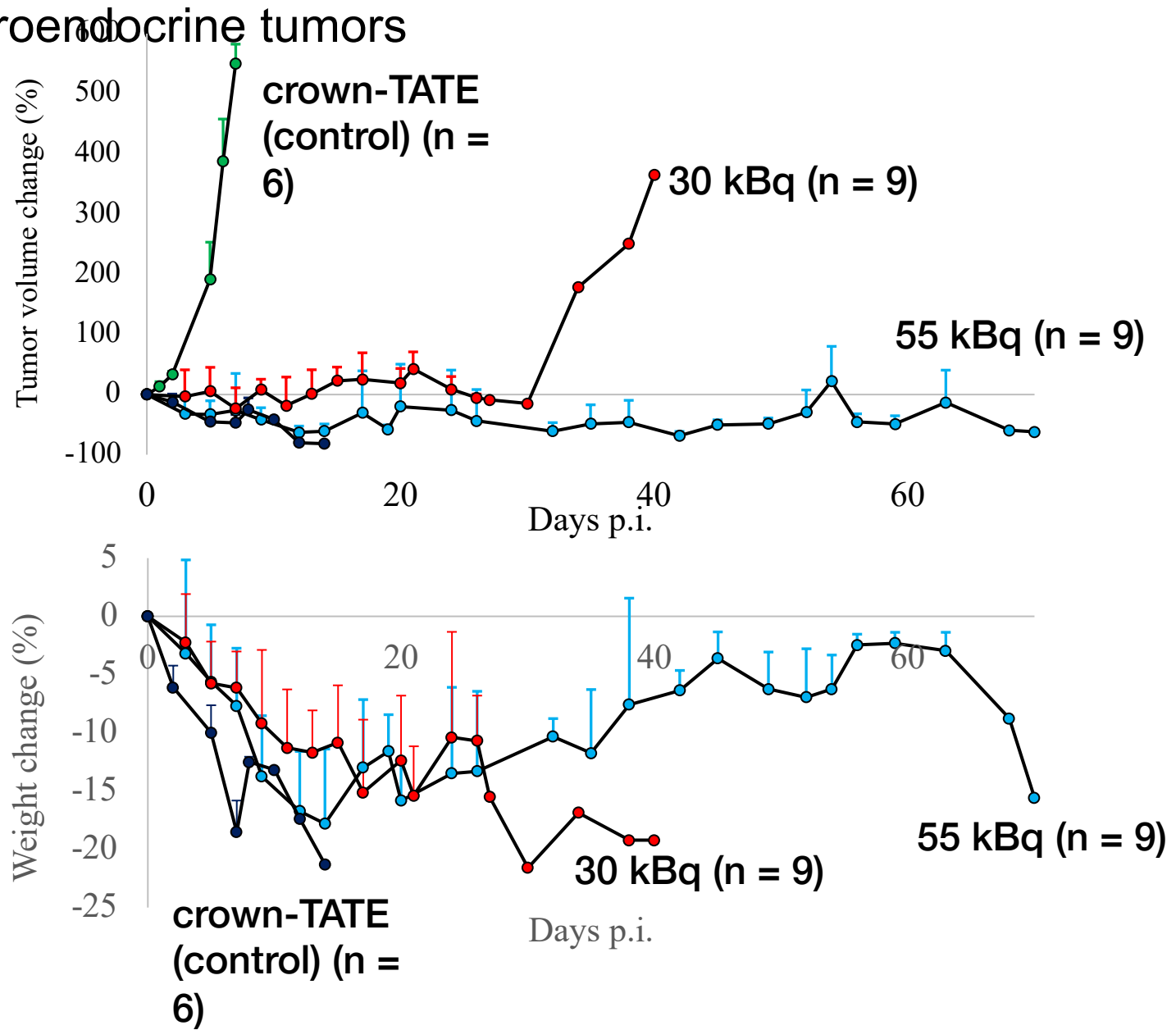
- Globally unique machine that provides access to equally unique radionuclides, applications

Pre-clinical Therapy studies:

$[^{225}\text{Ac}]$ Ac-crown-TATE for treating neuroendocrine tumors

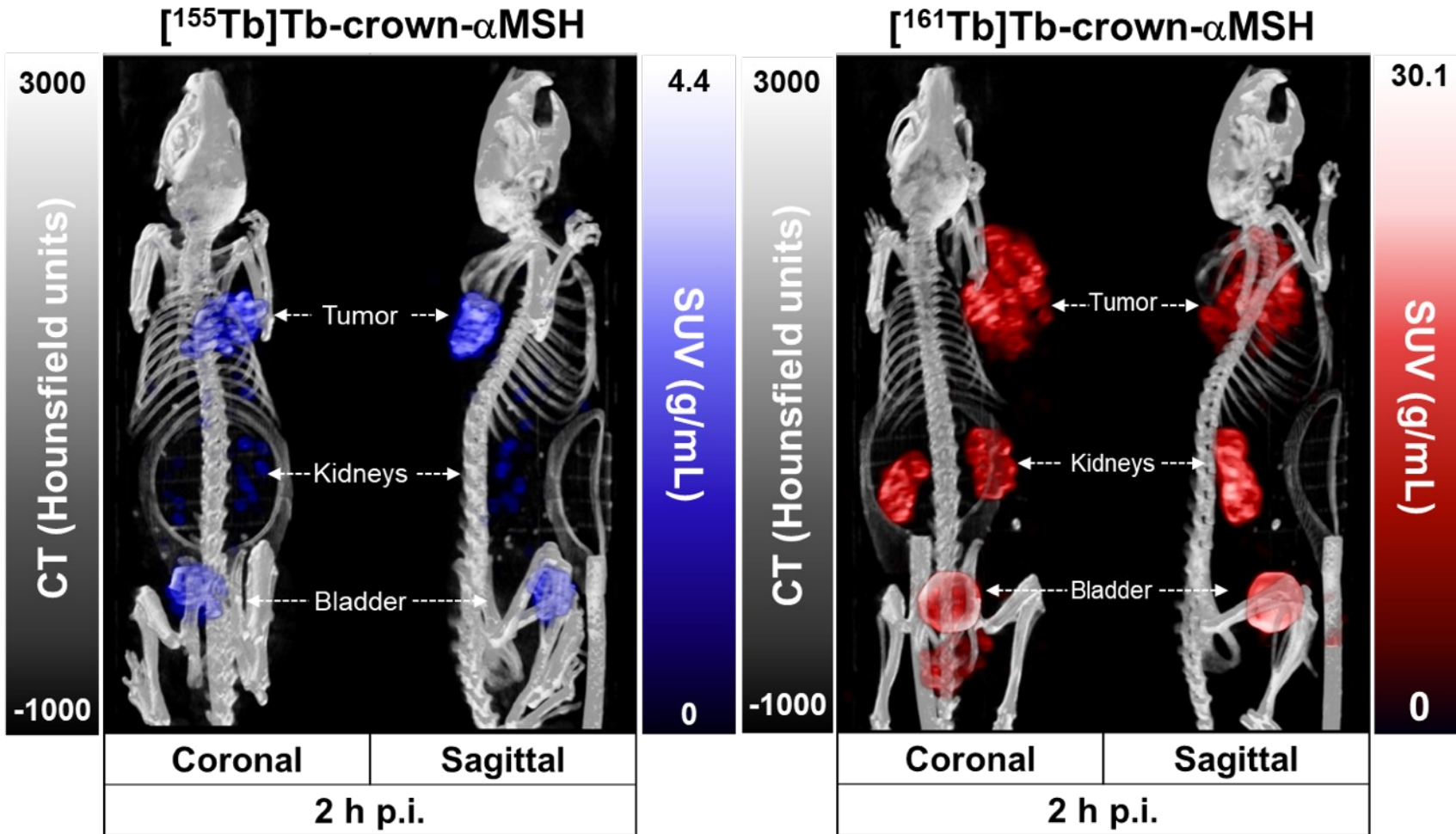


AR42J tumour bearing mice treated with 30 or 55 kBq of $[^{225}\text{Ac}]$ Ac-crown-TATE survived longer



Isotopes from ISAC:

[^{155/161}Tb]Tb-crown-αMSH biodistribution and imaging*

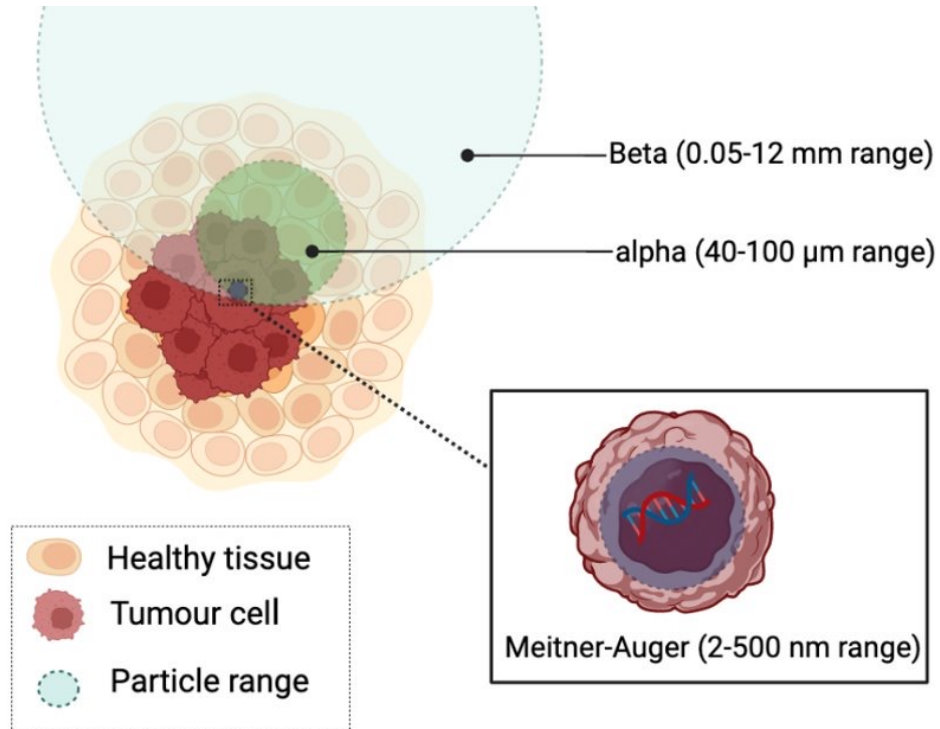


- High contrast images
- Good tumour uptake
- Low injected dose

SPECT/CT MIP at 2 h post-injection of [¹⁵⁵Tb]Tb-crown-αMSH (~196 kBq/subject, 21.7 MBq/nmol); and [¹⁶¹Tb]Tb-crown-αMSH (~3.30 MBq/subject, 39.6 MBq/nmol) in mice bearing melanoma tumors.

*¹⁶¹Tb sourced externally

Radionuclide Therapy is not limited to alpha-, beta- emitters



Potential Auger-emitters:

$^{58\text{m}}\text{Co}$

^{71}Ge

^{103}Pd

$^{103\text{m}}\text{Rh}$

^{161}Tb

^{165}Er

^{191}Os

^{239}Np

...

- Continued pursuit of:
 - Novel production methods
 - Separation chemistry
 - Chelate chemistry
 - Applications

Current focus:

119

Sb

antimony

165

Er

erbium

197

Hg

mercury

NFRF-Transformation: Rare Isotopes to Transform Cancer



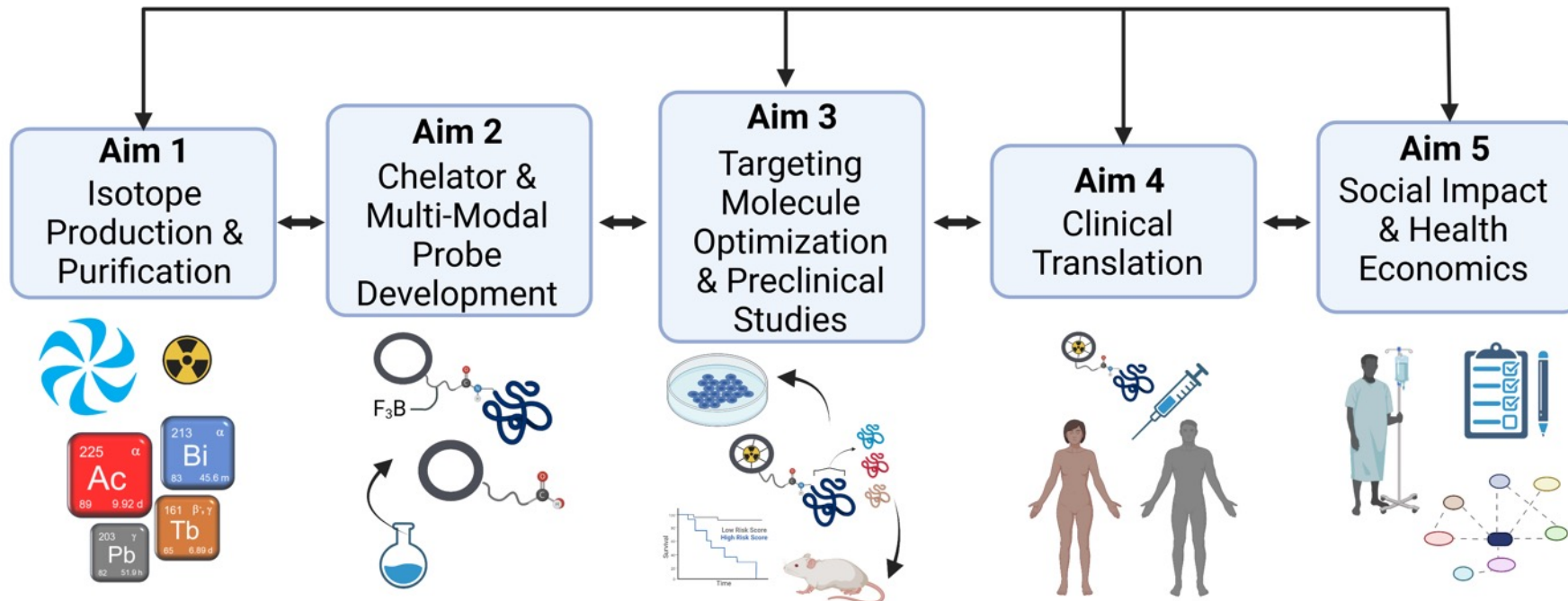
New Frontiers in Research Fund
Fonds **Nouvelles frontières** en recherche

\$23.7 mil over 6 years

NPI: Bénard (UBC/BC Cancer)

Co-PI: Ramogida (SFU/TRIUMF)

TRIUMF Team: Hoehr, Radchenko, Schaffer, Yang



500 MeV Isotope Production: $^{232}\text{Th}(p,x)$

Production campaigns:

- 2016: Effort started
- 2020 Irradiations: 3 targets for a total of 6,320 μAh
- 2021 Irradiations: 5 targets for a total of 28,900 μAh
- 2022 Irradiations: 4 targets for a total of 42,500 μAh

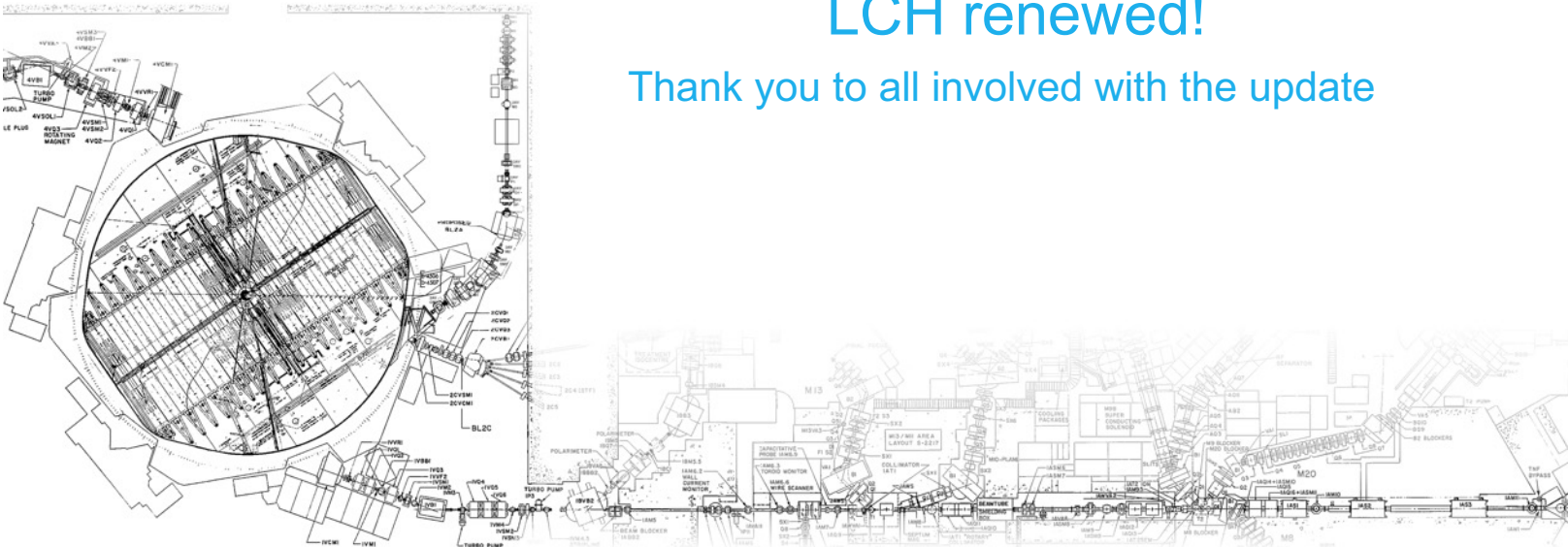
Isolated (decay corrected):

>12 GBq of ^{225}Ac (containing $\sim 0.16\%$ ^{227}Ac); and
1.4 GBq of Ra-225 for generators (no ^{227}Ac detected)

2023 campaign: underway (important for 2024 effort)

LCH renewed!

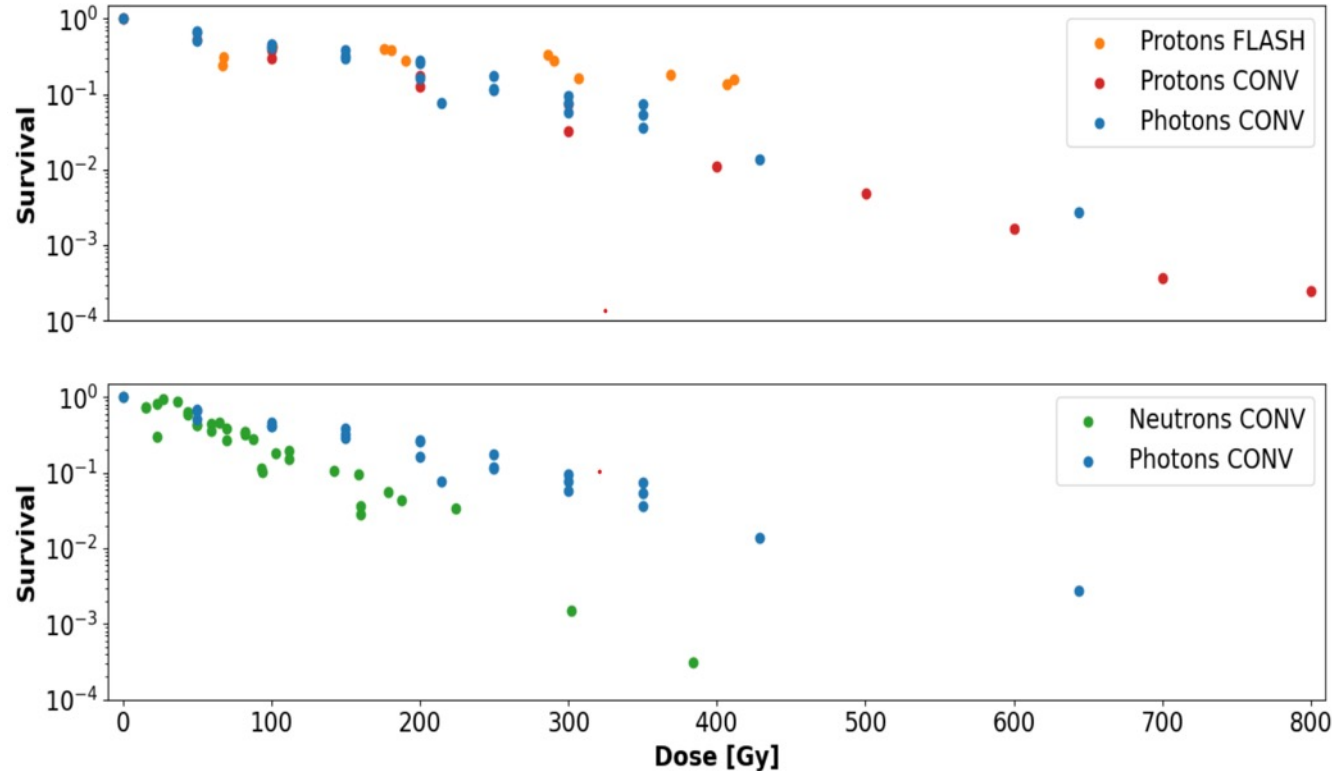
Thank you to all involved with the update



Proton (and photon) FLASH at TRIUMF

Continue building on decades of proton therapy experience at TRIUMF

FLASH: Ultra-high dose rate (> 40 Gy/s) irradiations may maintain tumor cell killing but improve healthy tissue sparing due to lower killing of healthy cells than at conventional radiotherapy dose rates



Preliminary findings:

- Confirmation of the clinical assumption of 10% higher cell killing by protons compared to photons
- For protons: Potential observation of the FLASH effect (lower cell killing at ultra-high dose rates)

\$35M Canadian Medical Isotope Ecosystem Funded by federal government

Next steps

- Call for proposals for new \$5M Fund announced Nov 2023 to fund new projects
- First close for Call – Jan 31, 2024
- Awards announced – March 31, 2024
- Collaboration and Networking Events Calendar in process



Strategic Innovation Fund

From: [Innovation, Science and Economic Development Canada](#)



A simpler, more flexible tool to grow Canada's economy



www.cmie.ca

First Cancer Patients get TRIUMF-produced Ac-225

Trial Condition(s):
Metastatic castration-resistant prostate cancer

A study to learn how safe the study treatment actinium-225-macropa-pelgifatamab (BAY3546828) is, how it affects the body, how it moves into, through and out of the body, and about its anticancer activity in men with advanced metastatic castration-resistant prostate cancer (mCRPC)

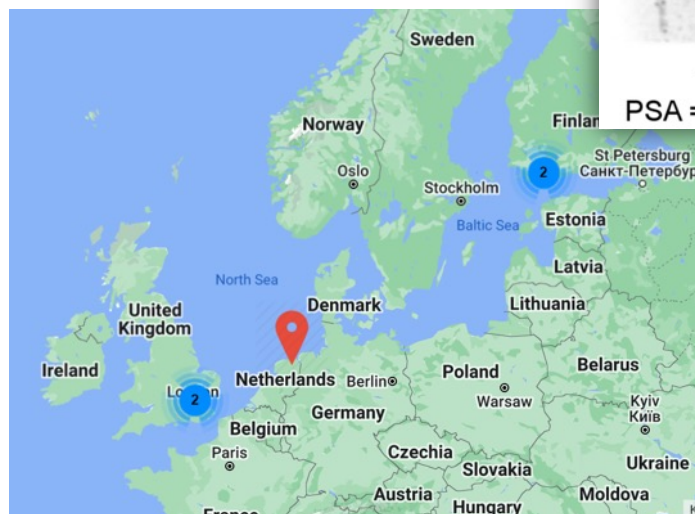
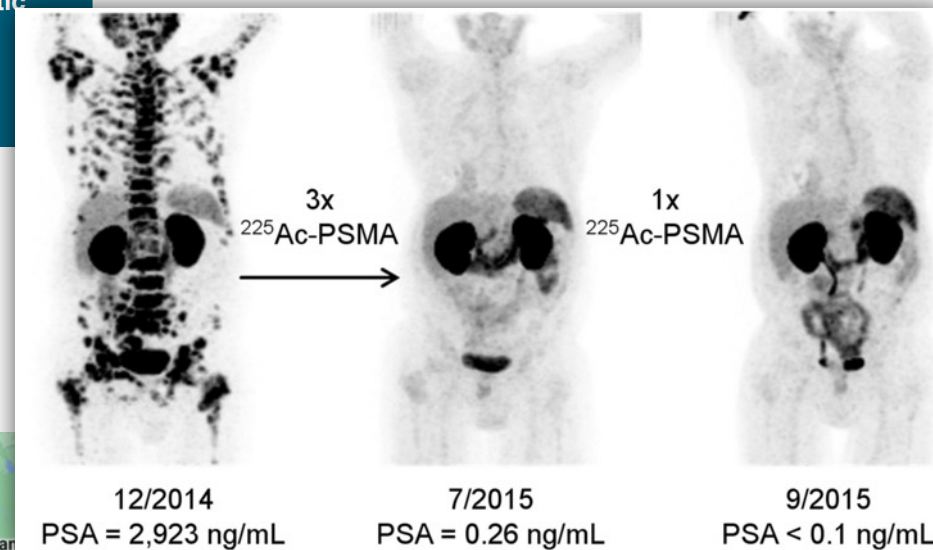
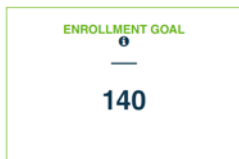
Bayer Identifier: **i**
22143

ClinicalTrials.gov Identifier: **i**
[NCT06052306](https://clinicaltrials.gov/ct2/show/study/NCT06052306)

EudraCT Number: **i**
Not Available

EU CT Number: **i**
2022-502623-22-00

Trial Summary



CLINICAL TRIALS
EXPLORER