



EMBARKING ON A BRIGHT JOURNEY

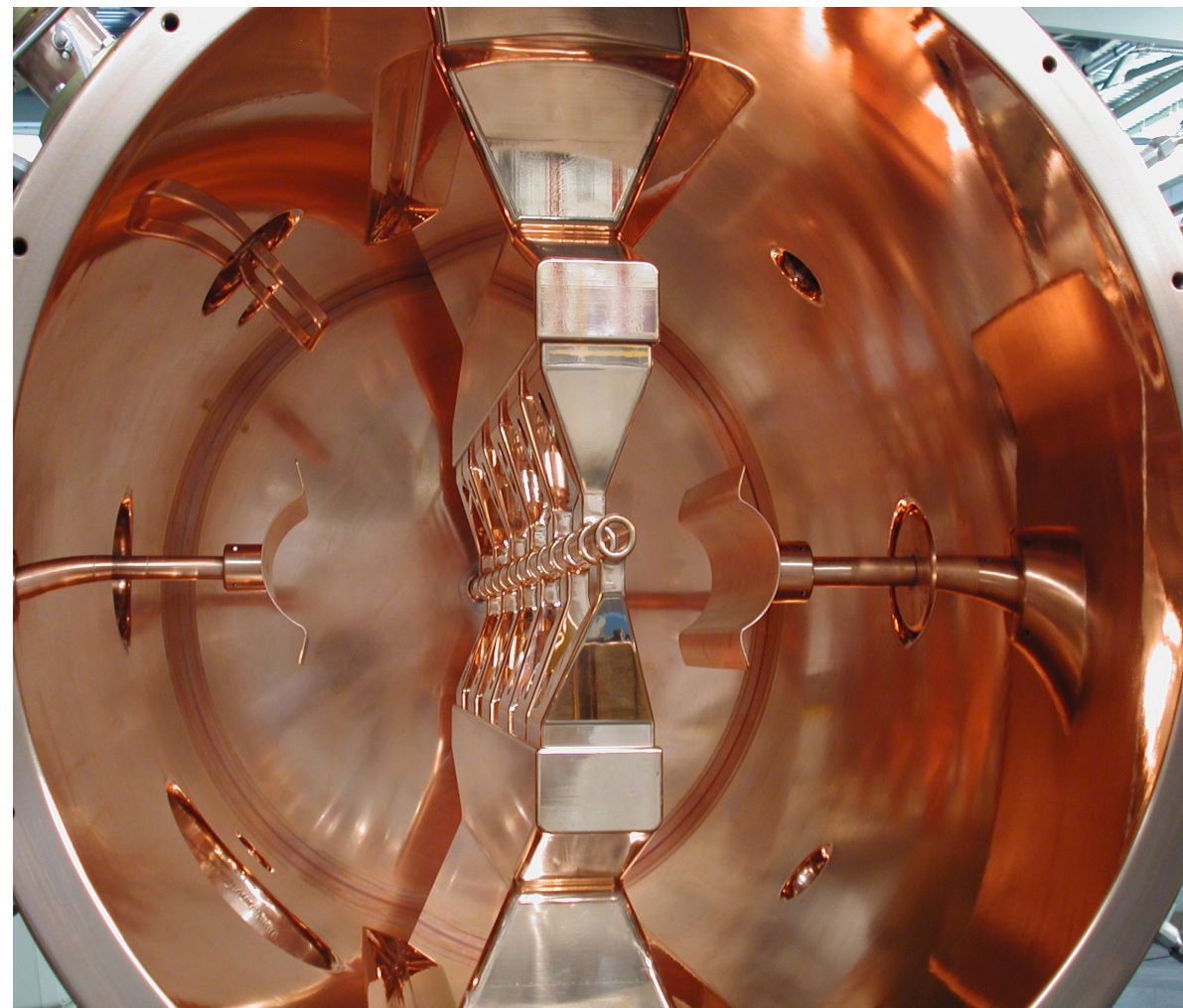
Five Year Plan 2025 – 2030

Physical Sciences Division

Petr Navratil

Interim Director, Physical Sciences

TRIUMF Science week
July 24, 2024

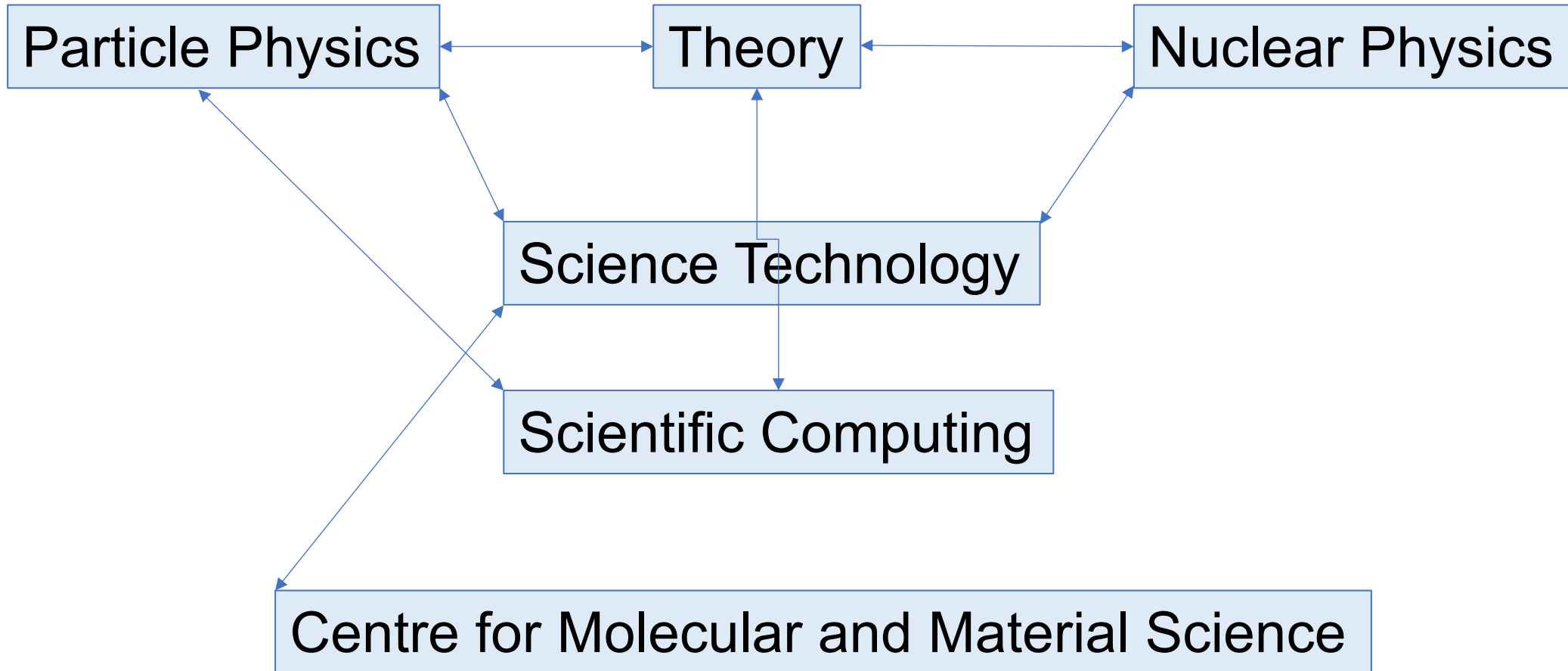


science
week / 24
July 22 - 26

Physical Sciences Division Mission Statement

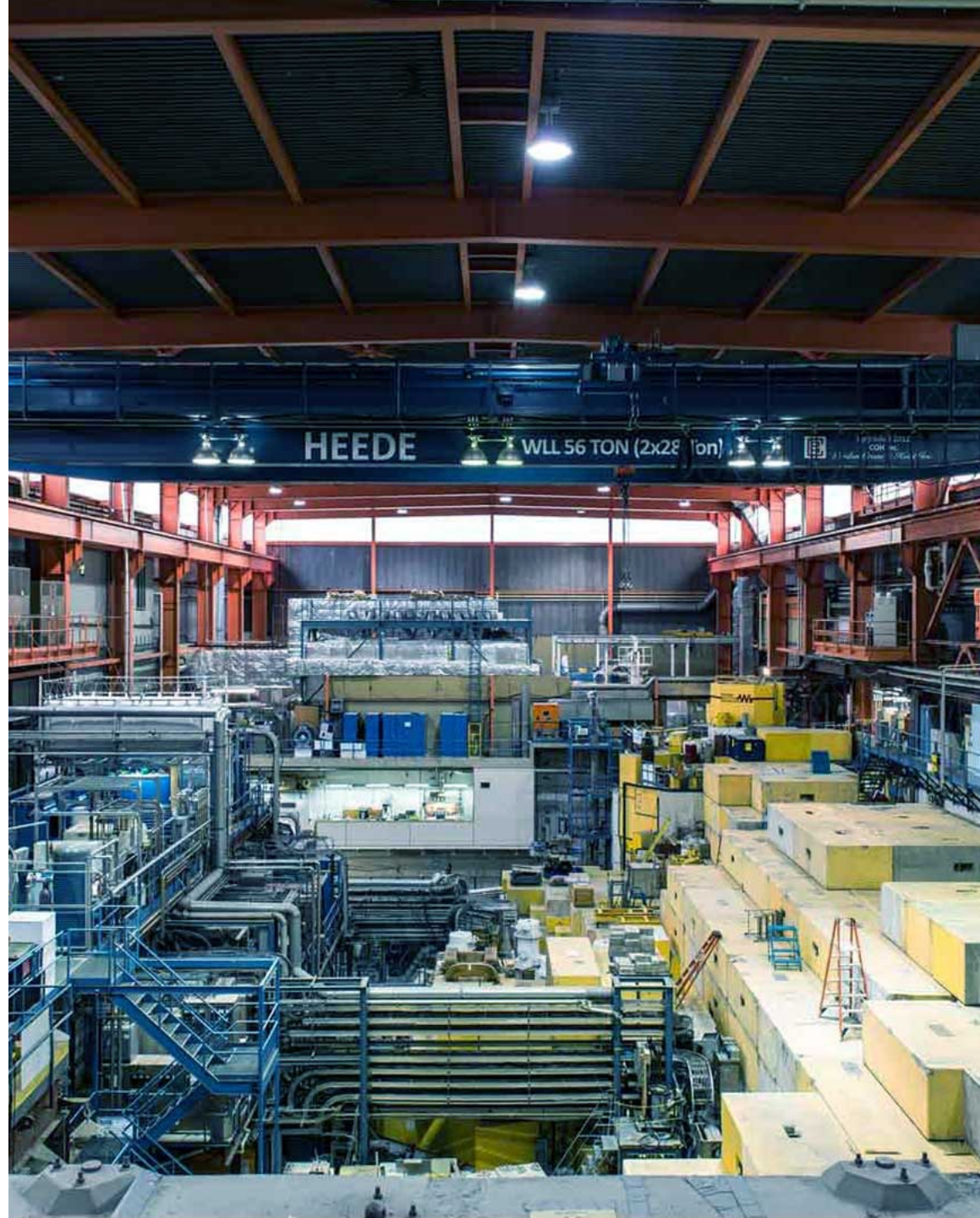
- To make discoveries, lead and contribute to research that address the most compelling questions in particle physics, nuclear physics, and materials science.
- To act as Canada's steward for the advancement of facilities, expertise, and technologies that enable outstanding science in those fields.
- To enhance connections to the Canadian and international communities.
- To train highly skilled personnel, transfer knowledge, inspire the public, and carry out research for the benefit of all Canadians.

Physical Sciences Division Departments



Physical Sciences Division planning process for 5YP 2025-2030

2024-07-23



5-year plan scenario considerations

More +ve	
Less +ve	
Less -ve	
More -ve	

	Scenarios		
	1 (Defer ARIEL/IAMI; 8-month cycle)	2 (Extended Shutdown)	3 (Delay ARIEL/IAMI; 6-month cycle)
Non-negotiable elements			
Compensation	✓	✓	✓
Deferred Maintenance	✓	✓	✓
Operational Excellence	✓	✓	✓
Considerations			
Position TRIUMF for next 5YP			
Maintain domestic scientific userbase / excellence			
Maintain international scientific userbase / excellence			
Talent Development (also 'compensation' above)			
Complete and operate ARIEL			
Complete and operate IAMI			
Complete BL1A Refurbishment			
Financially secure - operations & capacity			
Medical isotope production			
Manage reputation with users			
Maintain reputation with international collaborators			
Manage reputation with government			
Manage reputation with business partners			

PSD BAE retreat – May 24th, 2024

- Venue - Isabel MacInnes Ballroom, Walter Gage Residence, UBC
- 44 in-person participants that included PSD BAEs and P&S Scientists as well as BAEs from other divisions
 - Focus on the next five-year planning based on the \$400M budget
 - Discussions and development of the 5YP scenarios
 - Key presentations by Alex Gottberg on ARIEL completion timeline and Oliver Kester on BL1A renewal
 - All talks available at <https://indico.triumf.ca/event/540/timetable/#20240524>



Advisory Committee on TRIUMF (ACOT) Meeting

- June 10-12, 2024
 - In person
 - New chair
 - 5YP consultations
 - No parallel sessions
 - Student, postdoc, GAPS – poster session & stakeholder engagement session

DAY 1: Monday, June 10th, 2024

14:30 – 16:00 <i>(90 mins)</i>	<i>Committee Members & Observers</i> <i>Open to the Lab</i>	Plenary Session – Nigel Smith (MOB Auditorium) <ul style="list-style-type: none"> • Lab Overview • 5-Year plan / new funding
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DAY 2: Tuesday, Jun 11th, 2024

9:00 – 12:00 <i>(180 mins)</i>	<i>Committee Members & Observers</i> <i>Open to the Lab</i>	Serial Plenary with TRIUMF Science Leads (session order TBC) Life Sciences and IAMI (Paul Schaffer - remote): 9:00 am - 9:30 am Nuclear Physics (Chris Ruiz): 9:30 am - 10:00 am Theory (Petr Navratil): 10:00 am -10:30 am Particle Physics (Fabrice Retiere): 10:30 am – 11:00 am Material Science (Syd Kreitzman): 11:00 am - 11:30 am Accelerator and ARIEL (Alexander Gottberg): 11:30 am - 12:00 pm
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12:30 – 13:30 <i>(60 mins)</i>	<i>ACOT Members / Observers / TRIUMF Leadership / Invited Presenters</i>	Students Poster Session (Auditorium)
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Student and postdoc poster session:
20 posters, 12 from PSD



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Overall positive outcome

One of the top-level recommendations:
Complete and operate ARIEL and IAMI in the upcoming 5Y period

Student and postdoc poster session:
20 posters, 12 from PSD



2nd TRIUMF Quantum Workshop

June 24th, 2024 – Wesbrook Community Centre

- Following up on the successful 1st TRIUMF Quantum Strategy workshop held on March 11th

Goals:

- Formulate a quantum strategy for TRIUMF
 - What research at TRIUMF is aligned with Canada's National Quantum Strategy
 - What "quantum-enabled" science done at TRIUMF
 - Identify synergies among groups at TRIUMF on quantum-related activities
 - Future directions related to quantum science that TRIUMF should consider pursuing
-
- 25 participants - PSD BAEs and P&S scientists, TI representatives, and Nigel Smith
 - Presentations by CERN, U Sherbrook, UC Berkeley, U Waterloo scientists on their respective Quantum activities
 - TRIUMF's quantum strategy and quantum center discussions

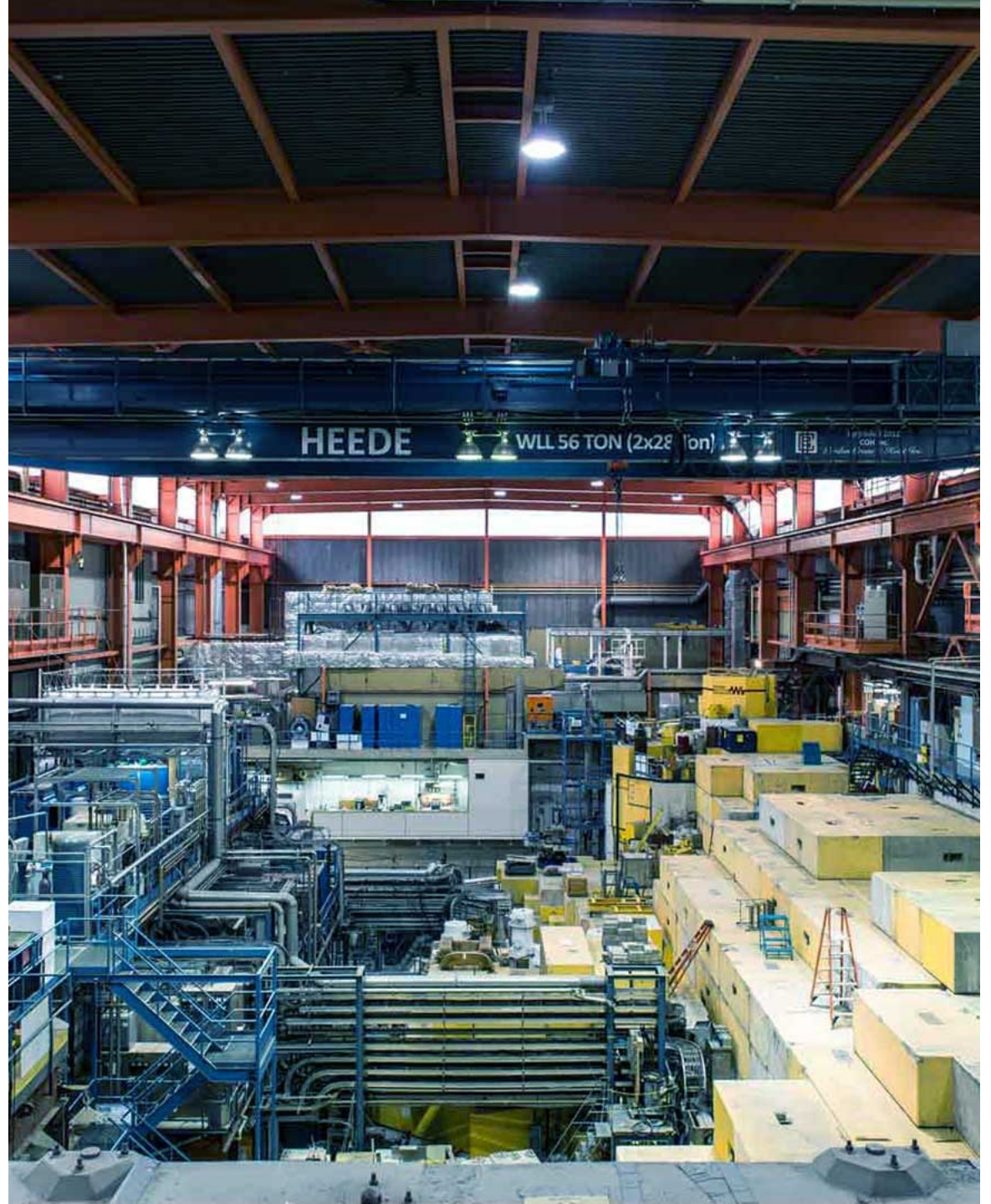


Presentations available at

https://triumfoffice365-my.sharepoint.com/:f/g/personal/lgorman_triumf_ca/EhlyOns-U0NAIhYjdsABrmoBoOSrc8uDgVOv0npGROvElw?e=vqGIA1

Impact of Shutdown Scenario on Physical Sciences Division activities

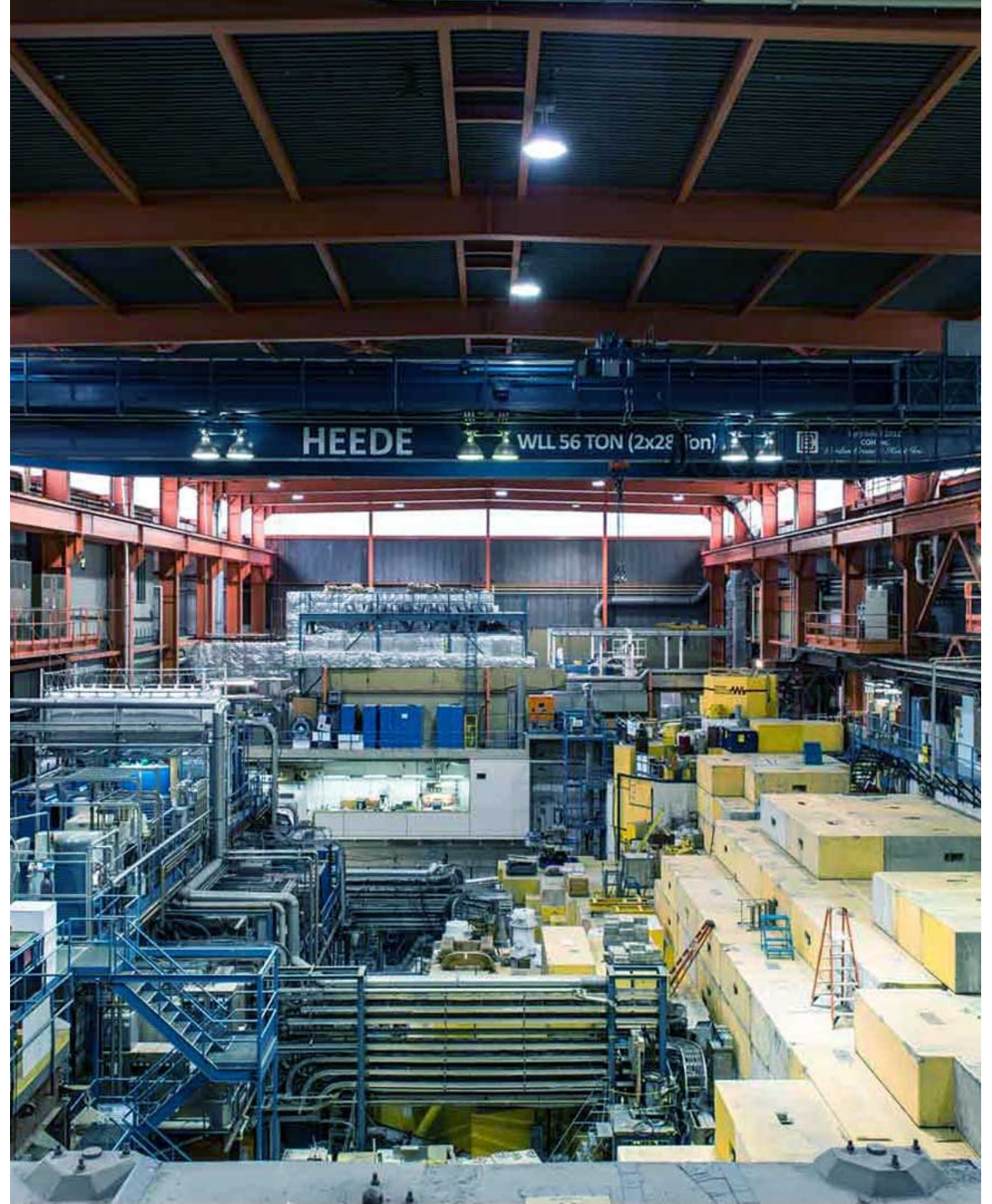
2024-07-23



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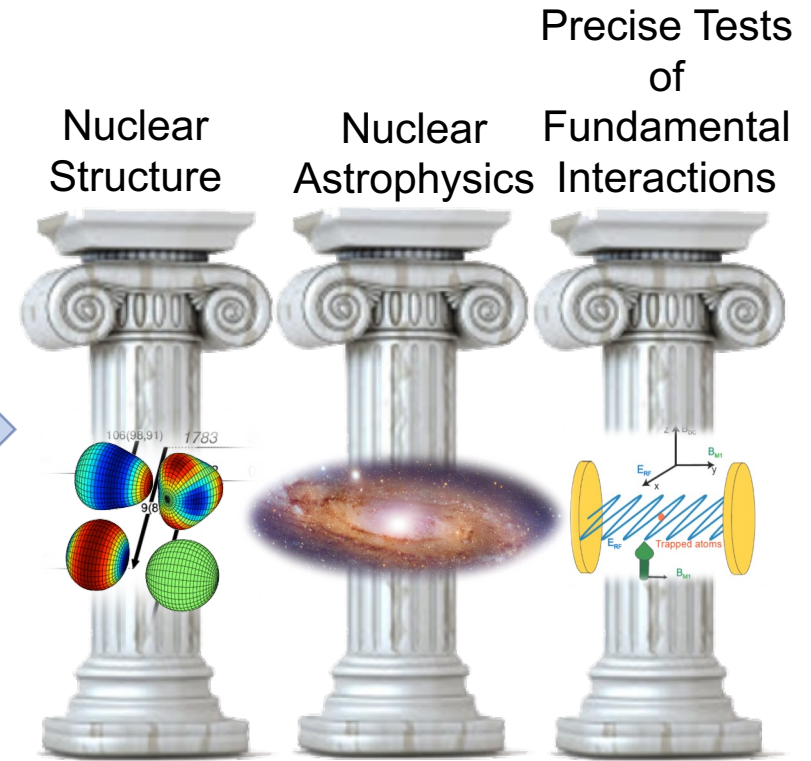
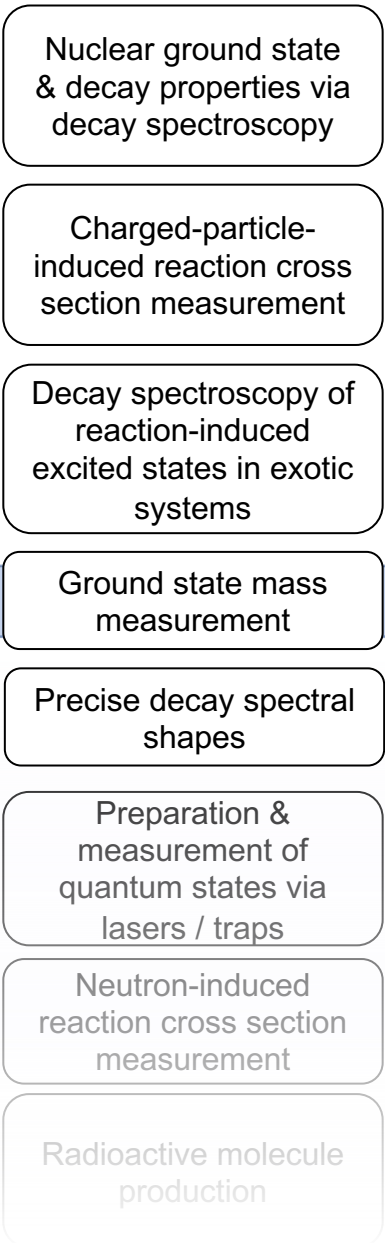
Nuclear Physics

2024-07-23



Nuclear Physics Facilities & Readiness

TRINAT	Precise, kinematically-complete measurements of beta-decay and associated parameters. Sensitive to time-reversal symmetry violation.
TITAN	Multi-instrument ion trap facility for masses & decay spectroscopy: MRTOF, MPET, EBIT: precision or coverage
FRANCIUM	Laser prepared Francium atoms probed towards Atomic Parity Violating signal
GRIFFIN / DESCANT	Decay spectrometer for gammas, betas, conversion electrons, neutrons
Polarizer / Laser-spec	Collinear laser spectroscopy for charge radii and nuclear moments. production of spin polarized isotopes for beta decay asymmetry experiments
DRAGON	Direct measurement of radiative proton & alpha capture reactions on exotic or stable isotopes
SONIK	Elastic scattering of radioactive nuclei → low energy scattering phase shifts
TUDA	Versatile direct & indirect charged particle reaction facility based around silicon arrays
DSL	Doppler-shift lifetimes facility for determination of excited state lifetimes
IRIS	Solid hydrogen or deuterium target scattering facility using CsI & Silicon arrays → extracting structure information from reactions using weak exotic beams
TIGRESS	In-Flight Gamma-Ray Spectroscopy following reactions induced on accelerated beams
EMMA	Recoil Spectrometer for detection & analysis of exotic reaction residues



Experimental Nuclear Physics Science Process

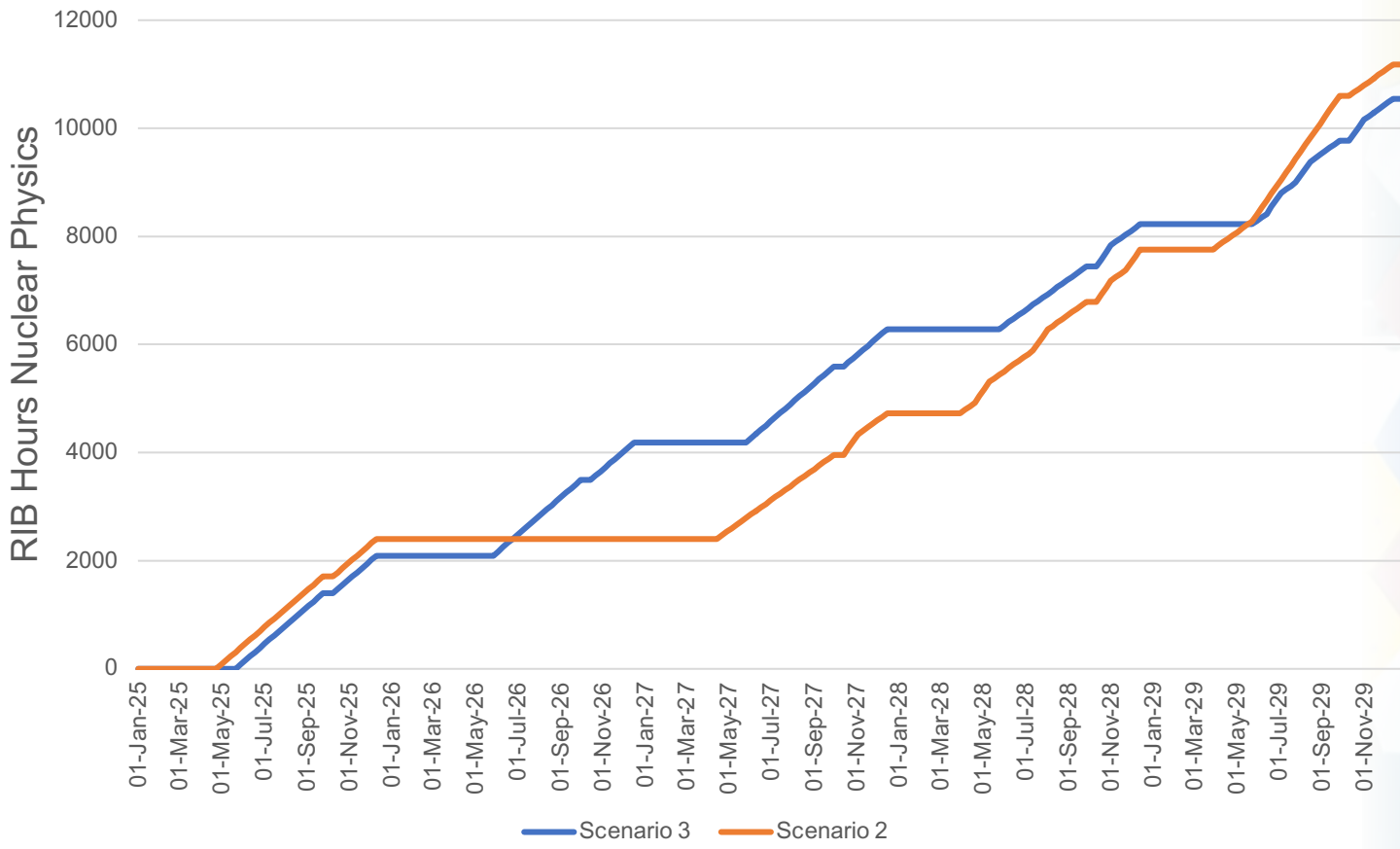
- In 2016/17 it was decided to grow the experiment *backlog* in anticipation of ARIEL era: goal was 2 years backlog
 - This gives **flexibility in scheduling** – many experiments per facility to choose from – more permutations of schedule to achieve efficiency
- EEC time window for expiring experiments was 2 years (M-priority expire automatically, H-priority can renew)
- 2018 began series of shorter beam schedules -> increased EEC time window to 3 years
- Current backlog is 788 shifts = 6,300 hours. At current rate would deplete that backlog by Fall 2027.
 - → ***We have a backlog suitable for the ARIEL era, but in an era of short ISAC-only running → Unsustainable***



ARIEL critical for the future of TRIUMF nuclear physics program

- More intense, cleaner neutron-rich beams, lying on or approaching *i*- and *r*-process paths
- Currently limited in science reach and volume by ***single RIB driver and beamline***
 - → ARIEL brings **independent RIB** beamlines
- **Eliminates competition** between Beam Development and running experiments
 - No longer need to sacrifice future beams and progress to satisfy “publications per year” output and HQP training
- **Removes pressure** to run many short-duration (usually low-E) experiments at the expense of long-duration experiments
 - Precision experiments lasting weeks to 1 month+ become feasible e.g. FRANCIUM PNC (more precisely “Francium on Tap”), DRAGON & TUDA “complete” direct measurements, BeEST Sterile neutrino experiment “SuperBeEST Phase”, enables the new RadMol program
 - Opens opportunity for more accelerated beam experiments: DRAGON/TUDA, EMMA, TIGRESS, IRIS, + *External Users*

Impact of Scenarios on Program



Scenario 2 – more RIB hours overall, new targets already in the upcoming 5Y period

Impact of Scenarios on Program

Category		Scenario 2 “2026 Shutdown”	Scenario 3 “Cut from 8 to 6 months/yr continues”
Scientific Productivity & Operation	RIB to NP experiments over 5 years	14,913 hours (105%) [about 8 experiments]	14,200 hours (100%)
	New Beams	Enhanced capability/independence of Beam Development post shutdown	Retain same slow pace of development
	Total Shutdown Time Over 5 years	127 weeks	126 weeks
	Distributions of Effort	Skewed towards latter half of 5YP	Uniformly distributed
	Diversity of Experiments	After shutdown, greater diversity & balance of accelerated & stopped beams	Deleterious to accelerated beam program
	Risk of Beam Delivery Failure / Disruption	Lesser after shutdown – greater reliability (*)	High, as present
Scientific Opportunity / Project Goals	Opportunity for Flagship Precision measurements	<ul style="list-style-type: none"> Compatible with BeEST timeline for Phase IV/SuperBeEST. FrPNC diverts to Rb for 1 y RadMol would need 2025 FrAg beamtime to fulfill Moore Foundation funding. TRINAT will divert to K metrology for r^2 	<ul style="list-style-type: none"> BeEST delayed until 29/30 FrPNC Fr once/year hamstrings progress RadMol FrAg spread out over 2025/26
TSOP07 – Experiment Management	EEC Quota & Backlog	Quota remains at 300 shifts/year	Reduce quota to ~220 shifts/year to reduce backlog
	EEC Frequency	Once in 2025, then pause until January 2027 (drop 3 meetings)	Reduce to once per year until 2028
	Beam Scheduling	Longer schedules (8-month) before & after shutdown = greater flexibility, more permutations	Restricted flexibility & diversity in each beam schedule (as current)
Maintenance, Repair, Operation & Upgrades	Machine Shop Availability	Machine Shop becomes available again for Operations jobs in 2027	Machine Shop becomes available again for Operations jobs in 2028
	Upgrades to facilities	Dedicated 16-month period to major experiment upgrades (but compete with ARIEL for resources)	Upgrades still compete with ARIEL and beamtime as status quo
Funding, People & Staffing	HQP Training	One year of postdoc/graduate training in experiments lost	Continuity for postdoc/graduate training in experiments
	NSERC Grant	One-third of an NSERC cycle no experiments	Continuity in funded activities
	Staffing Level	Critical to increase Tech support + Exp Program Coordinator to meet ARIEL	Limp along at same levels as current
International Reputation	External or New Users	Less opportunity for external or new users pre shutdown, but increased after – meets ISOLDE shutdown	Same opportunity for external or new users as current

Green = notable benefit
Red = Significant detriment

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Scenario 2 – HQP training in the shutdown year – focus on data analysis, experiment upgrades (not competing with ARIEL for resources)

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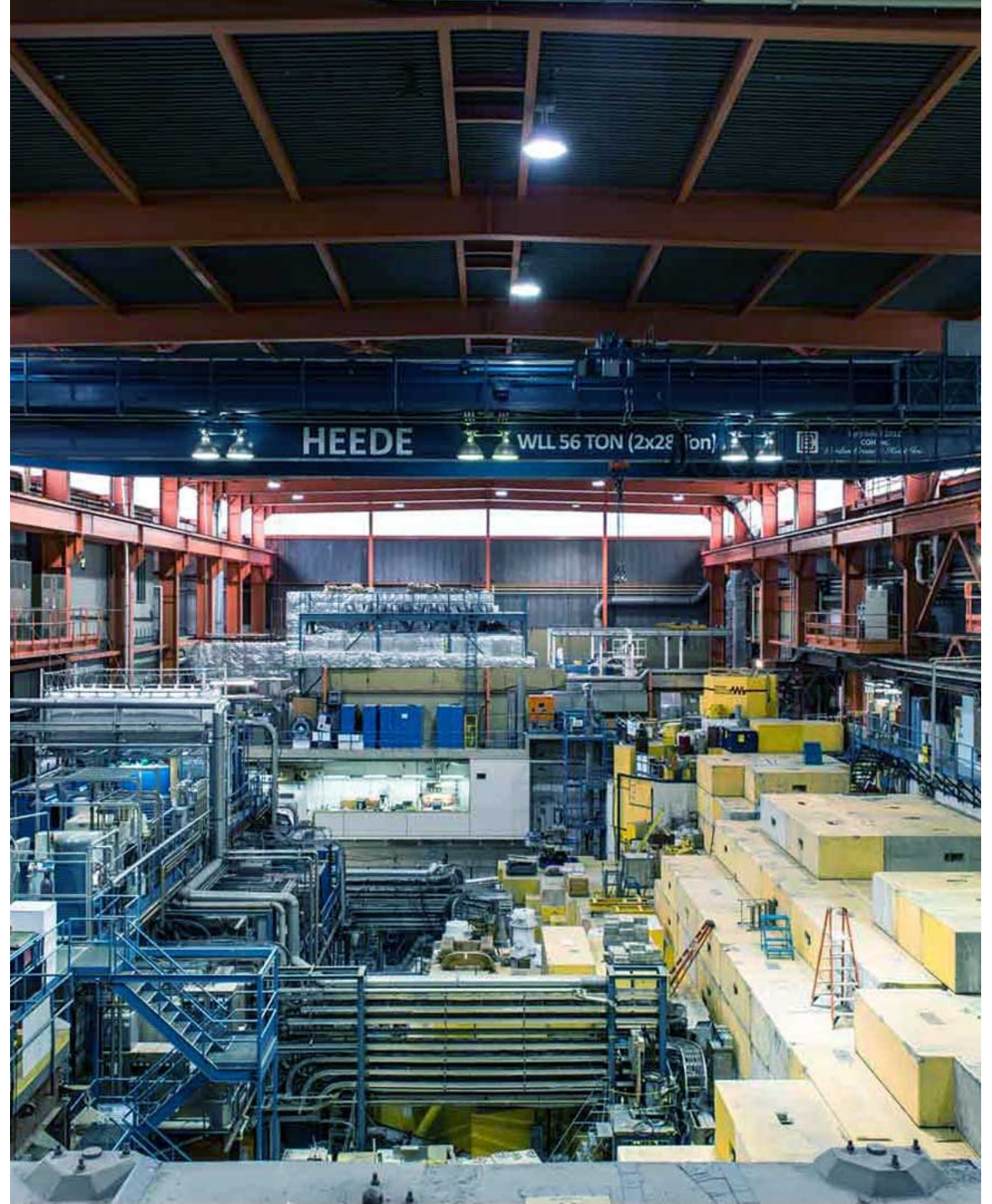
Scenario 2 – pause the NP-EEC after January 2025 meeting, for 3 meetings – restart in January 2027 with optimal 2-year backlog going forward
 Possibility to attract ISOLDE users during the CERN extended shutdown

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Impact of Shutdown Scenario on Physical Sciences Division activities

Particle Physics

2024-07-23



Particle Physics within the Physical Sciences Division

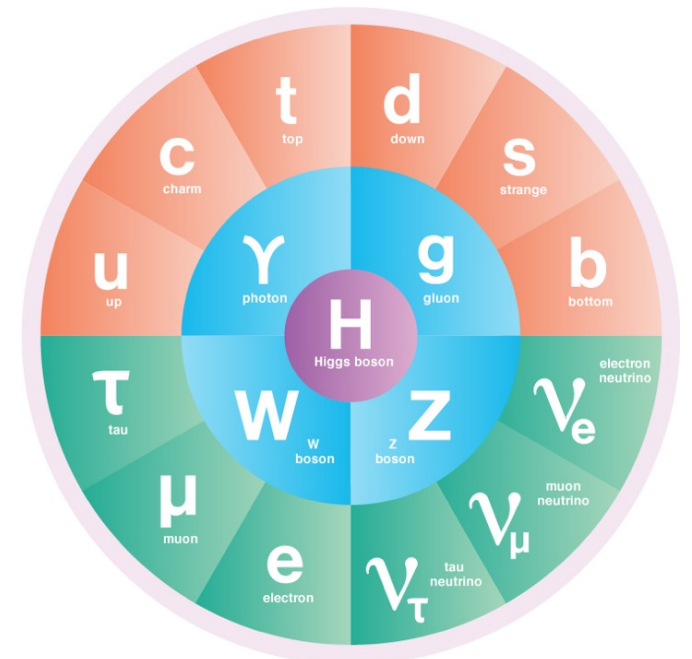
The departments of **Particle Physics, Science & Technology** and **Scientific Computing** address the areas:

- High Energy Frontier
- Neutrinos and Dark Matter
- Precision Tests of Fundamental Interactions



Lead in Scientific Discovery through focus projects

- Projects where we are involved in all areas
 - detector design/construction, operations, data analysis
- Ensure critical mass is established, maintain leadership in all areas
- Current experiments
 - ATLAS, T2K/Hyper-K, ALPHA, TUCAN, SuperCDMS
- New experiments expected to reach that point in the future
 - DarkLight, nEXO
 - HAICU (experimental space identified)
 - PIONEER



Exciting Science

- Particle Physics addresses many of the most compelling questions
 - Embedded in international collaborations
 - Growing onsite effort with new opportunities
- **Expect many exciting results from Particle Physics by 2030**
 - **ATLAS: Higgs boson potential, sensitivity to many new particles, precision measurements**
 - **Hyper-K: Probing CP violation in neutrino sector**
 - **UCN: World leading neutron EDM and neutron lifetime measurement**
 - **ALPHA: Precision anti-matter spectroscopy and effect of gravity on anti-matter**
 - **SuperCDMS & DarkSide 20k: Most sensitive Dark Matter results**
 - **DarkLight: Sensitivity to find X17 related boson**
 - **PIONEER: World's most precise e- μ universality test**

CFI Proposals

Successful in IF 2022/23:

- Hyper-K \$6.4M
 - 200 mPMTs, photogrammetry calibration and water quality monitoring equipment
- P-ONE \$5.9M (total project \$14.8M)
 - Six instrumented mooring lines for neutrino telescope at Ocean Network Canada (OCN)
- nEXO \$12M
 - Primarily for infrastructure at SNOLAB. Infrastructure at TRIUMF for photon detector characterization in liquid Xenon



5YP Scenarios

- Three 5YP scenarios have direct impact on Particle Physics program in particular for DarkLight and UCN

Scenario	Shutdown for a year to finish ARIEL construction	Business as usual 6 months shutdown – 6 months beam
Pros	<ul style="list-style-type: none"> Get ARIEL done quickly to free resources Hopefully able to install the re-circulation ring which would allow DarkLight to perform a 50 MeV experiment in 2027 	<ul style="list-style-type: none"> Will allow iterative operation mode of alternating testing with UCN, then adding components while optimizing operation and components offline
Cons	<ul style="list-style-type: none"> Delay important developments that require UCN production 	<ul style="list-style-type: none"> Delayed completion of ARIEL and impact on laboratory wide resources

UCN project in the shutdown scenario

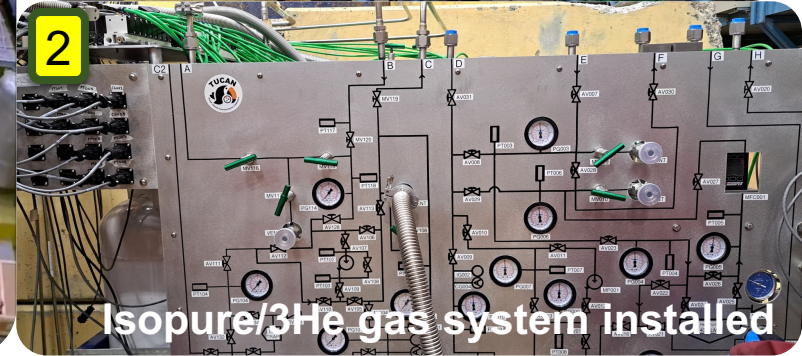
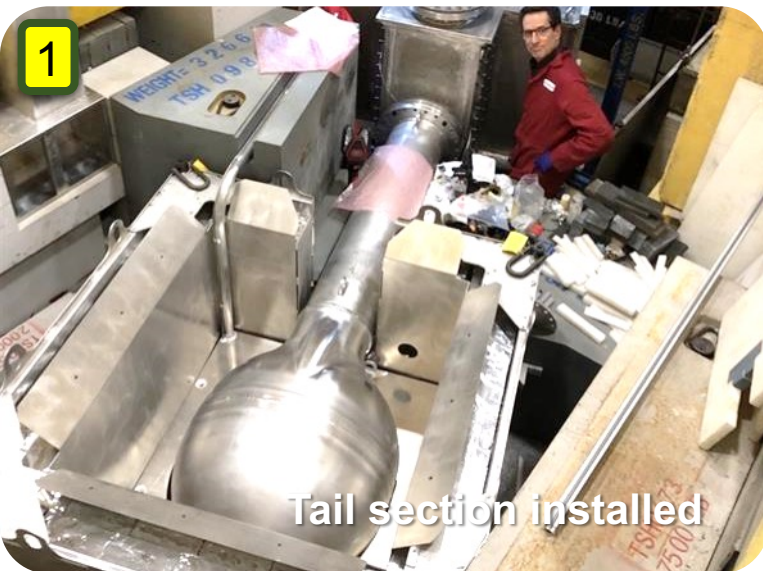
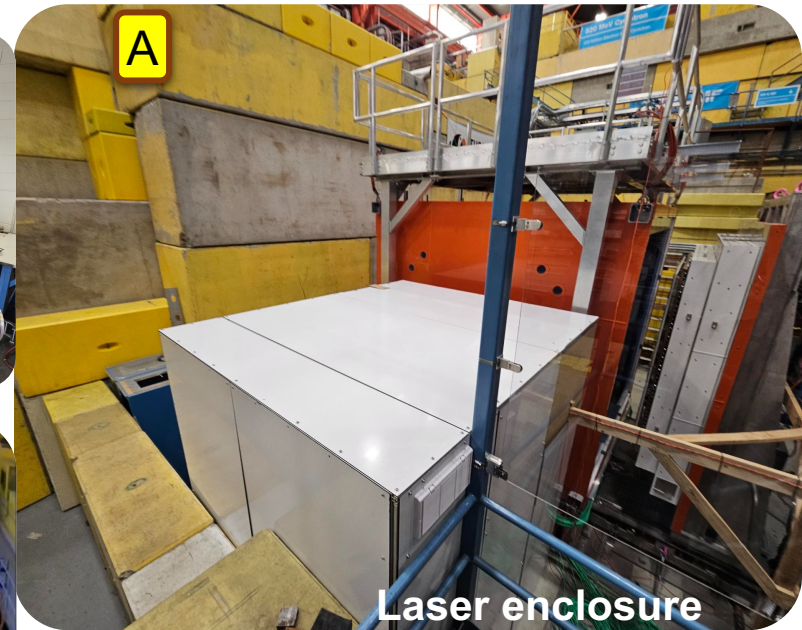
- UCN success depends on the timely refurbishment of the Beamline 1A
 - Enable UCN operation while other BL1A users running
 - Critical that the BL1A leak fix done during the shutdown
- Work planned during the shutdown
 - Laying the groundwork for a liquefier upgrade
 - Fixing shortcomings found in the source during the 2025 full runs with LD2
 - EDM experiment completion
 - Preparation work for a PENeLOPE run

All work done so that it does not compete with ARIEL for resources



- **Tail section** and moderators: installed! **1**
- **^3He gas system** installed and tested! **2**
- Performed **UCN source cooldown with ^3He**
 - Lowest temperature $T_{^3\text{He}} = 0.667 \text{ K}$
 - Simulated full beam heat $T_{^3\text{He}} = 0.84 \text{ K}$
 - Measured ^3He and ^4He boiling curves
- **Received CNSC licence** to commission BL1U to 40 μA
 - Beam was injected into BL1U up to 1 μA on June 28th
 - Completed north shielding wall **3**
 - Target cooling system reinstalled
- UCN production to start Sept 24!

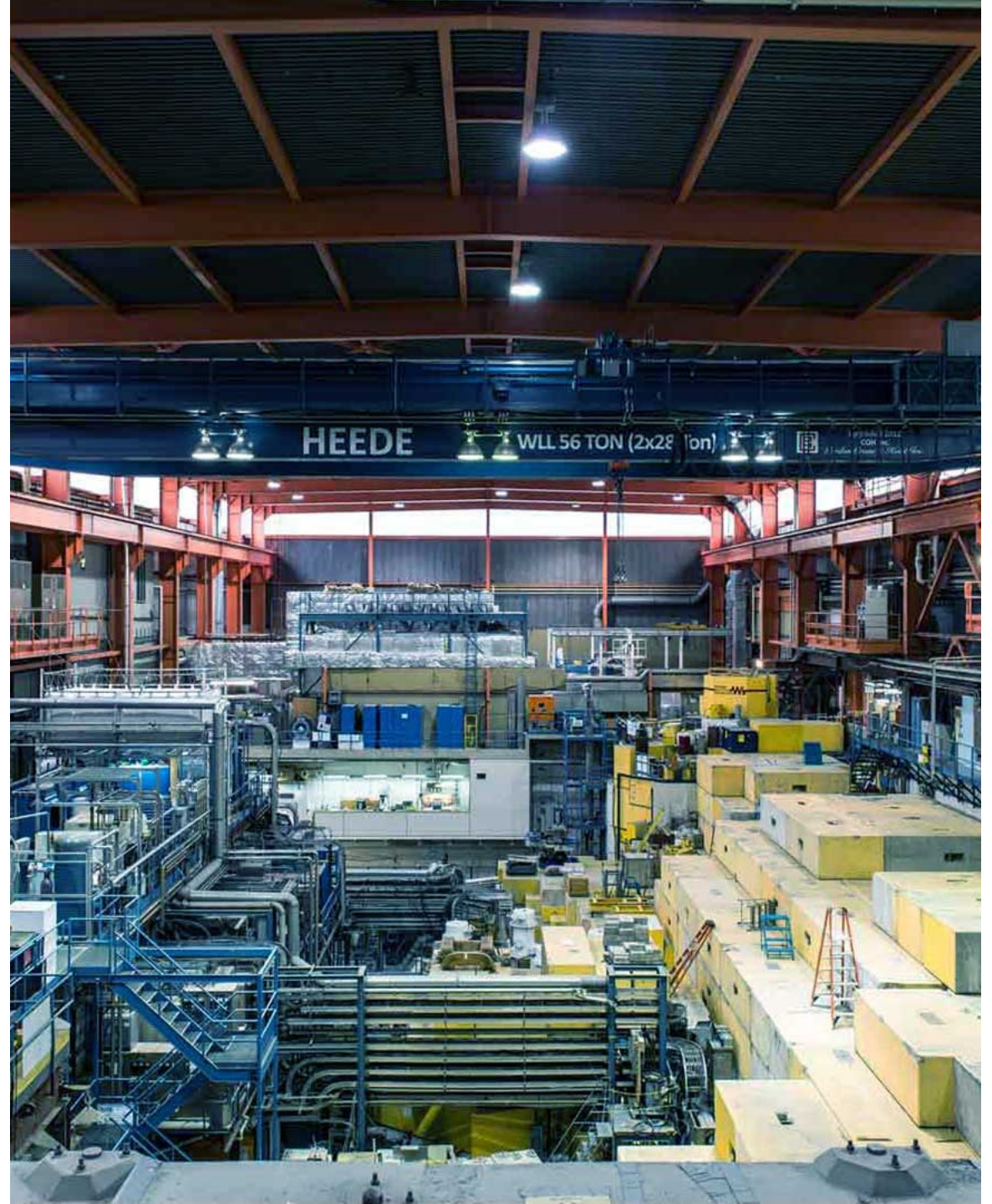
- Laser enclosure for (co-)magnetometers is being **A** completed.
- 5th mu metal layer will be installed in August.
- Holding field coil redesign restarted



Impact of Shutdown Scenario on Physical Sciences Division activities

Material and Molecular Science

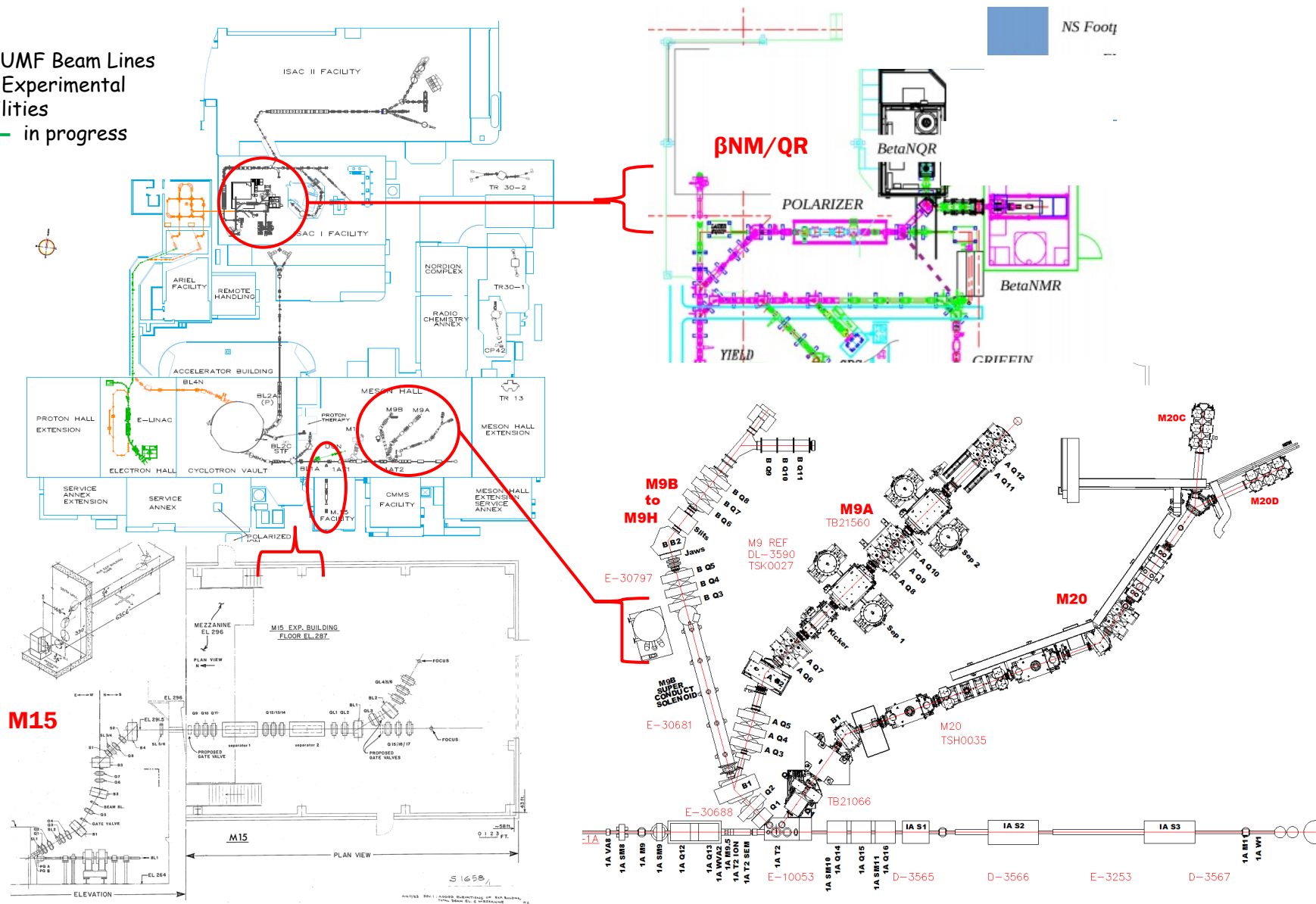
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TRIUMF CMMS Beamlines

TRIUMF Beam Lines
and Experimental
Facilities

— in progress



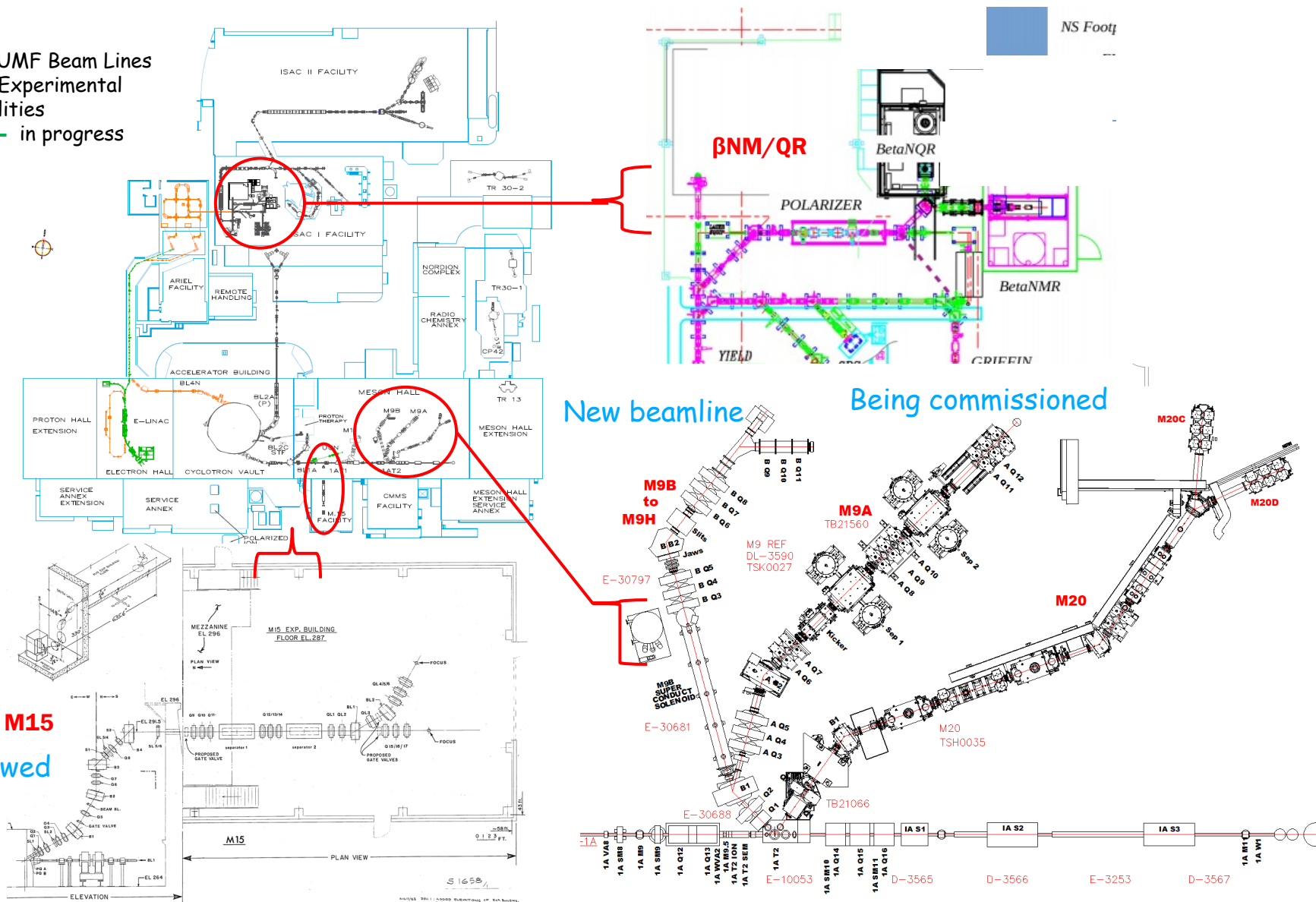
TRIUMF Centre for Molecular and Materials Science



TRIUMF CMMS Beamlines

TRIUMF Beam Lines and Experimental Facilities

— in progress



TRIUMF Centre for Molecular and Materials Science



CMMS Perspective & Challenge

- The addition of three BAE's to the group over the past several years has significantly increased the in-house TRIUMF impact in MMS research.
- The pending addition of M9A and **completing the M15 rejuvenation** will benefit the program by reducing the number of set-ups needed and providing the essential high luminosity surface muon beams for the user community.
- The design of the new M9H spin-rotated decay beam will deliver unique beams into the enclosed sample space of high-pressure cells over an unprecedented combination of temperatures (50mK-RT) and magnetic field (4T).
- New detector and DAQ technology will provide the high-quality spectrometers needed for the data complexities inherent in modern complex materials.
- The CMMS facility will try to increasingly migrate to liquid-cryogen free operations to protect its capacity to fully carry out its research mandate.
- **Managing personnel issues: Pending retirements and the support of additional research capacity given the imminent μ SR and future β NMR beams.**

TRIUMF's support for the CMMS and its commitment to BL1A will be a handsomely rewarded investment for its research scope on quantum materials and sustainability impacts.



CMMS - Shutdown Scenario

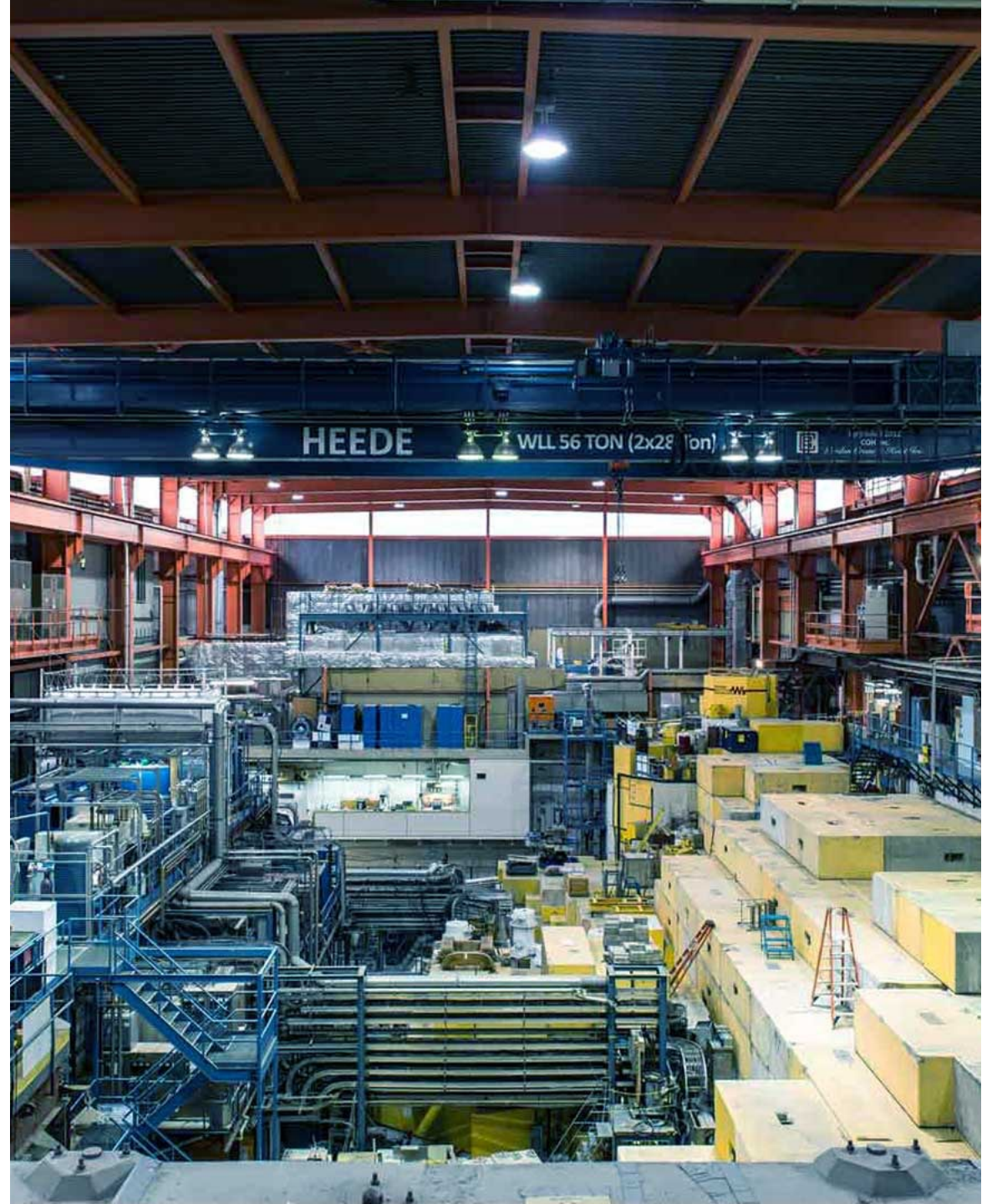
- Beamline 1A renewal is critical for the CMMS program
- It is crucial that essential beamline 1A renewal work is performed during the planned 2026 shutdown so that no further BL1A shutdown is needed, and the remaining work is performed during the regular shutdowns



Impact of Shutdown Scenario on Physical Sciences Division activities

Science Technology

2024-07-23



Science Technology department currently

- Currently focused on system level project delivery
- Minimum management resources
 - Limited transparency
 - Limited user engagement
- Minimum effort in technology development and tech transfer
 - Done on the side
- Major contribution to several CFI projects (ALPHA, DarkSide, nEXO, mPMT, P-ONE)
 - In general manpower expense charged to CFI
 - Sci Tech does not see any of these \$ but it helps offset some cost
 - We would like to see this contribution recognized and be part of the discussion for how to use this income

Possible evolution paths

- External funding from astro-particle physics is available
 - Secured: McDonald Institute (300+300k\$/y), SFU CERC (Darren Grant)
 - Applied for: CFI IF 2025 for the Innovation Driven Intelligent Detector, ID²
 - An instrumentation/detector center will happen in collaboration with SFU. The question is how broad/narrow its scope will be
 - Narrow scope would be High Energy and Astro-particle Detector (HEAD) center
- Expansion in green technologies is happening
 - Water analysis, Air analysis, Fusion reaction diagnostics
 - Possible other opportunities in health care, resource extraction,...
- TRIUMF can shape this more or less
 - TRIUMF could play a leading role and tap into this additional resources
 - It does not have to be expensive. Many funding sources possible

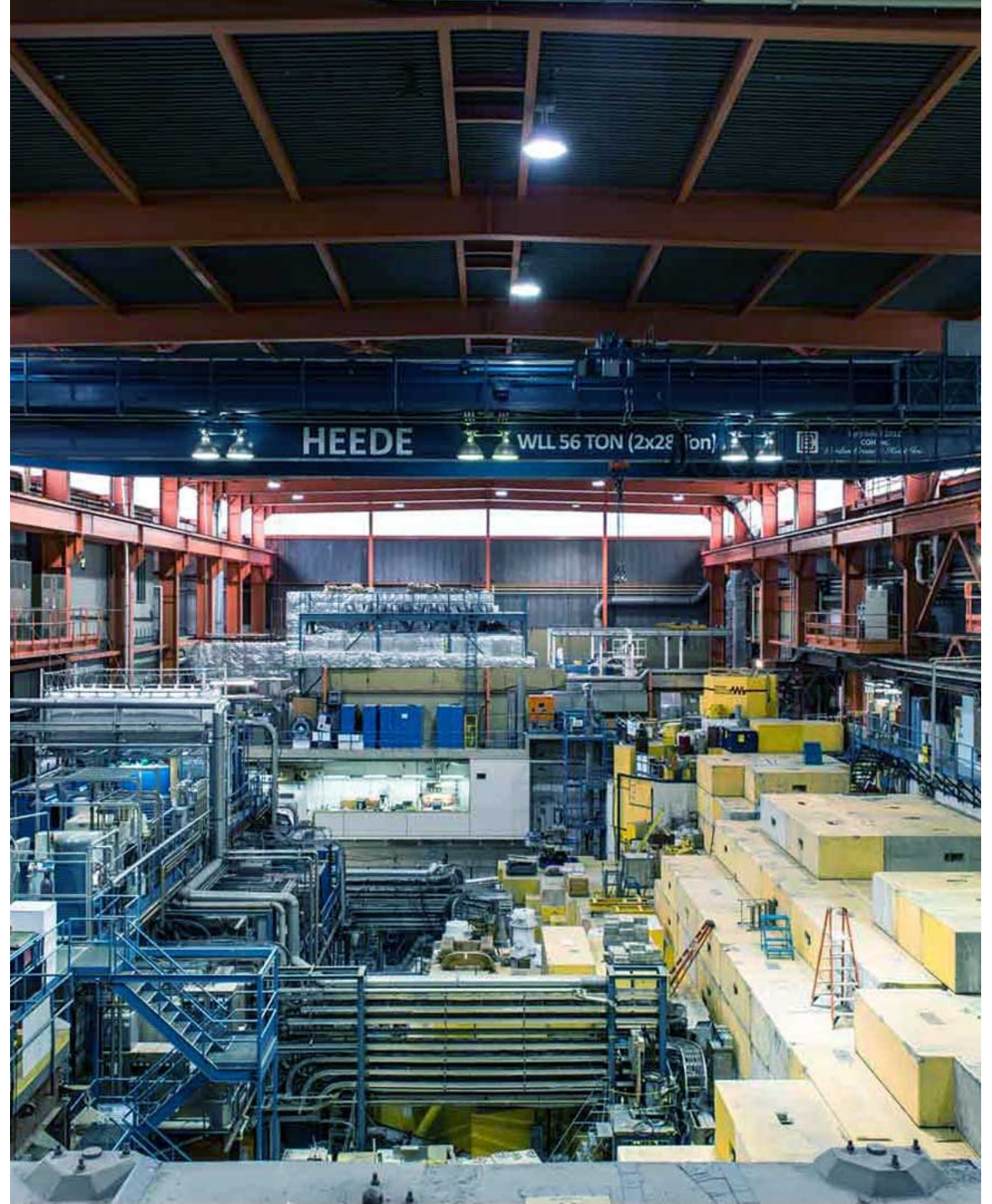
Science Technology – Shutdown Scenario

- Support for ARIEL completion in coordination with the ARIEL project leaders
- Support for other projects will continue although some reduction for small projects possible to balance the ARIEL needs

Impact of Shutdown Scenario on Physical Sciences Division activities

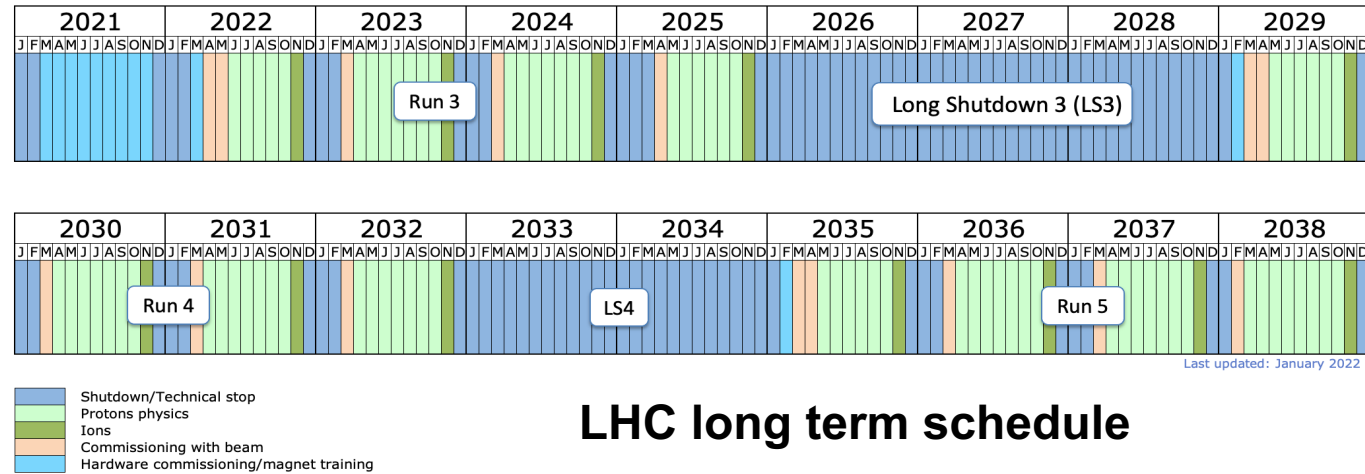
Scientific Computing

2024-07-23



ATLAS Tier-1 Centre & next 5YP

- Well established with ongoing 24/7 distributed computing operations and commitment.
- No additional personnel nor capital for infrastructure and equipment is being requested from TRIUMF in the next 5YP.
- Plan is for continuing 24/7 Tier-1 operations with existing TRIUMF staff complement.
- New CFI IF 2025 proposal in preparation:
 - hardware refresh and significant expansion for the HL-LHC.
 - personnel for software and computing R&D for the HL-LHC era.
 - Covers 2027-2031 time period (taking into account anticipated timeline for award finalization and in securing provincial matching funds).
 - Would bring infrastructure operating funds (IOF), primarily used for existing Tier-1 personnel (same as with prior CFI awards).
- In parallel to CFI preparations, there are ongoing discussions with the Digital Research Alliance of Canada for seeking either partial or full support during 2025-2030 period (their next funding cycle request to ISED is in preparation).



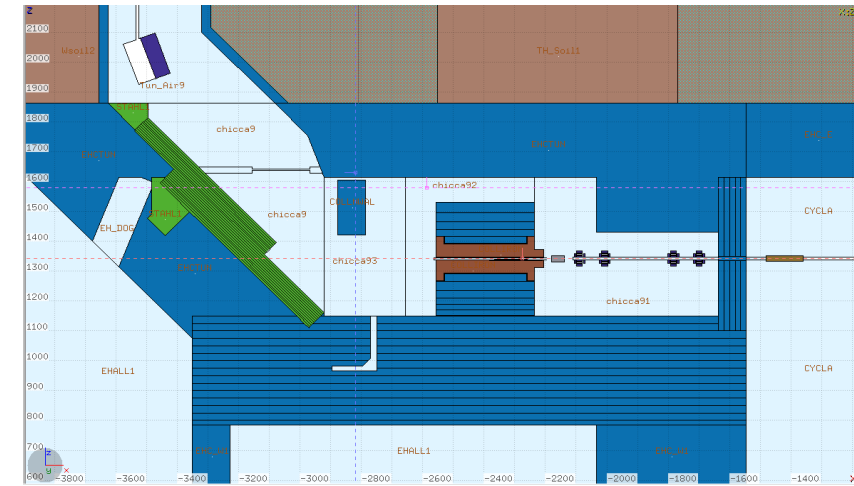
LHC long term schedule



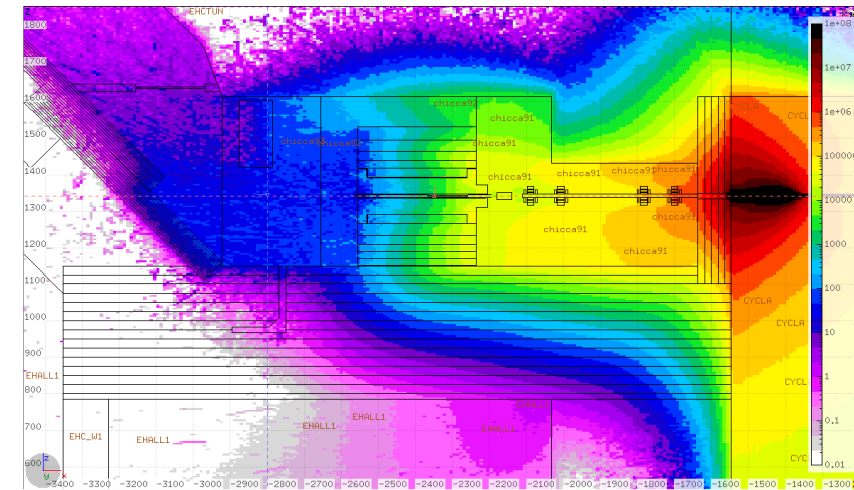
ARIEL support / FLUKA cluster

- Since early 2020, a significant portion of the old ATLAS Tier-1 centre capacity is being utilized for large FLUKA simulations campaigns:
 - 336 cores added to existing IS&T cluster via special network configuration (for security)
 - Crucial role in the design and construction of ARIEL shielding (time sensitive)
 - Typical simulation campaign lasts about 1 month when using 360 cores
- FLUKA cluster also used by PIF/NIF and other projects, like FLASH.

Shutdown Scenario – Ready to provide support for ARIEL completion if requested by the ARIEL project leaders



Geometry model of proton cave



Equivalent dose radiation map

Machine Learning & AI

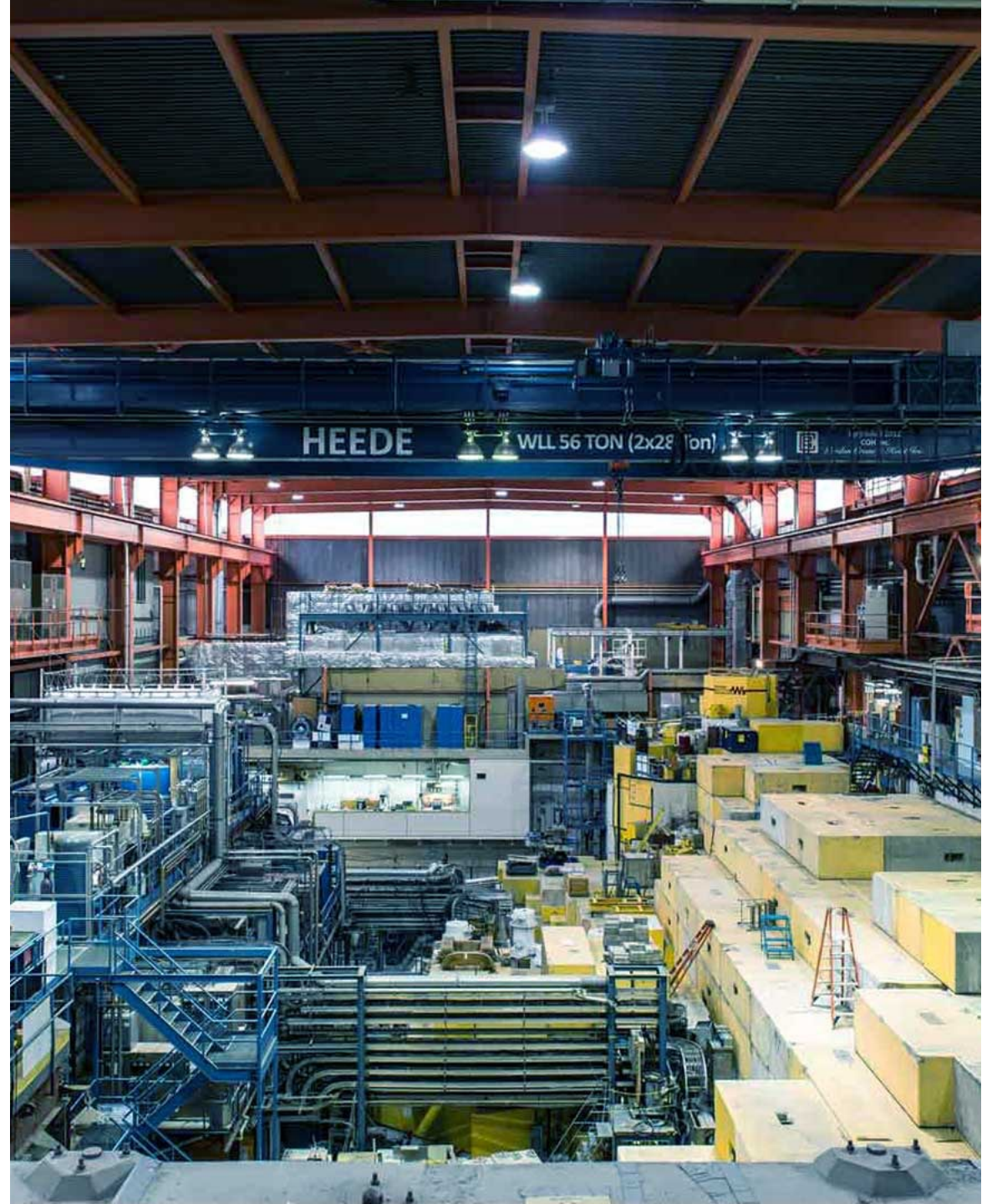
- Enhance collaboration between departments and divisions
- More talent-power and domain knowledge
 - Identify and execute ML applications across the scientific domains
- Infrastructure support
- HQP training
- Building and expanding on current success
- Aligned with 20-year vision

Shutdown Scenario – Ready to provide support for ARIEL completion if requested by the ARIEL project leaders

Impact of Shutdown Scenario on Physical Sciences Division activities

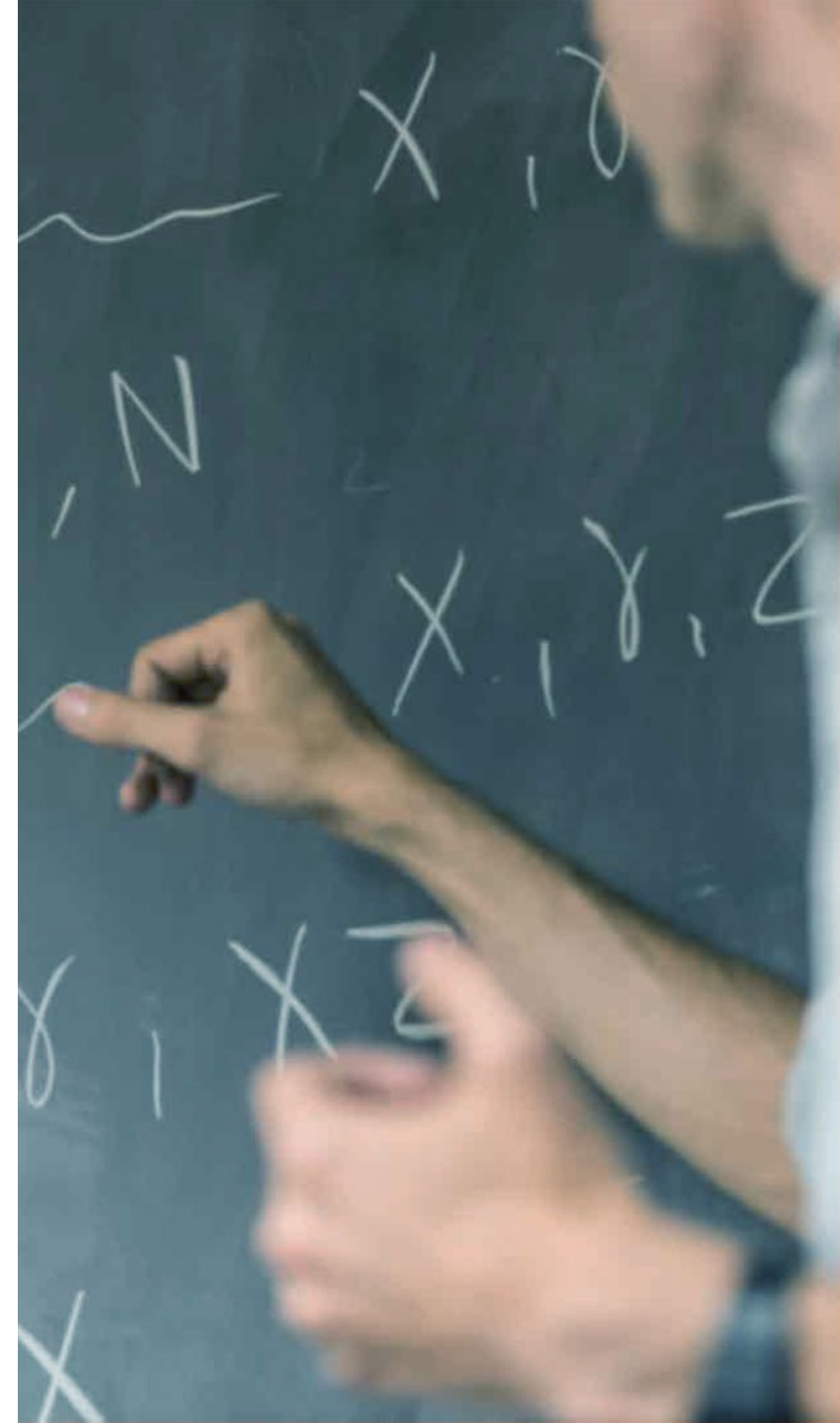
Theory

2024-07-23



Theory: Looking to the Future

- Theory Department helps to push the science that TRIUMF is interested in
 - Direct collaboration with TRIUMF experimentalists
 - Organizing workshops, seminars, colloquia that are of broad interest
 - Training HQP: PDFs, PhD, MS, co-op
 - Fostering a vibrant intellectual community
- Will continue to do so
- Shutdown Scenario – ready to go above and beyond as needed

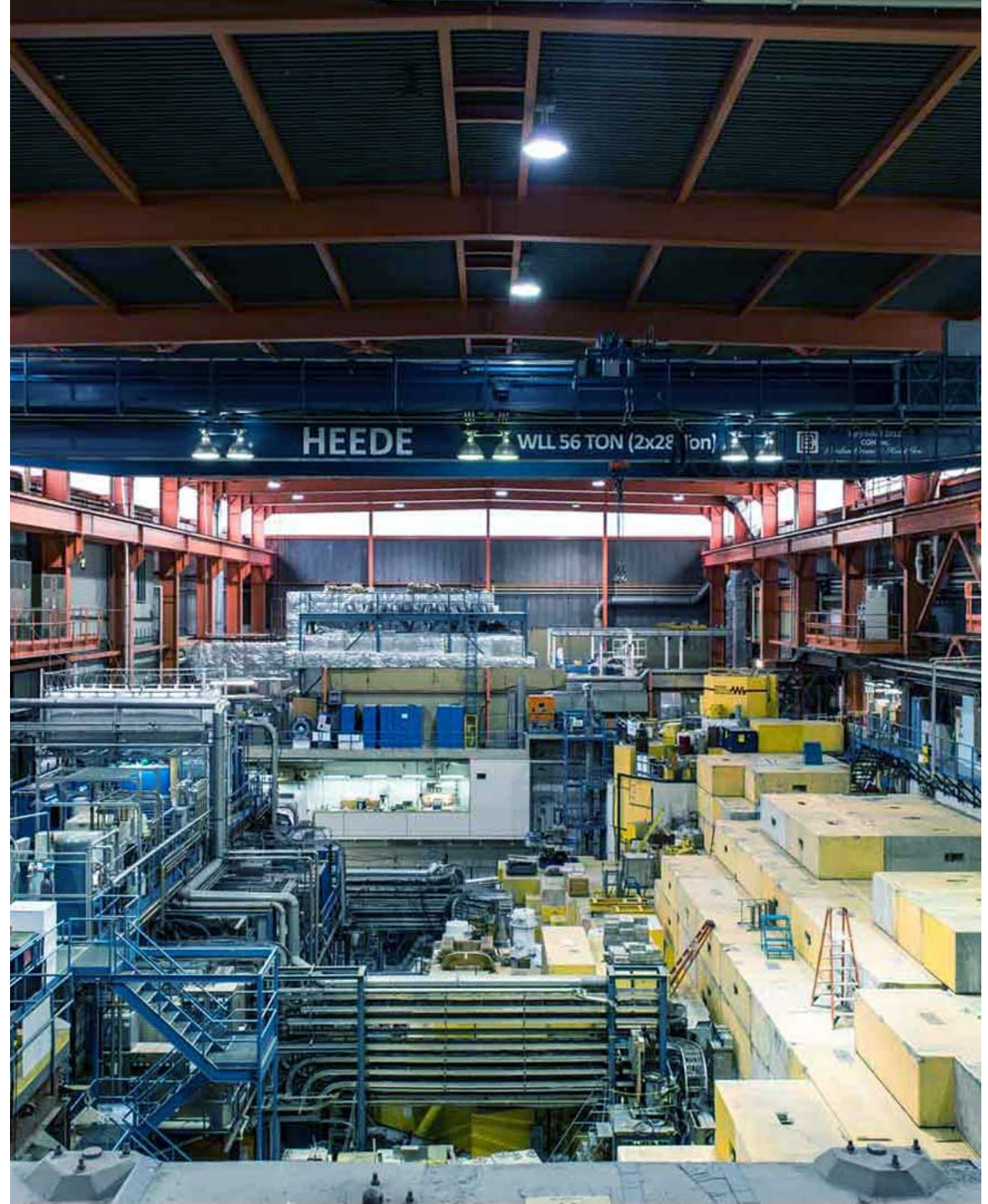


Exciting science results by 2030

New opportunities –

CFI IF 2025 projects

New projects to be done so that they does not compete with ARIEL for resources in the shutdown year



The CFI Innovation Fund (IF) 2025 competition

- TRIUMF received ten applications
 - ATLAS Tier-1 Centre and Distributed Computing at the LHC Energy Frontier Innovation Driven Integrated Detector (ID²) - [SFU cap \\$4M](#)
Harnessing the full capabilities of liquid Argon detection technology
 - nEXO: A Next-Generation Tonne-Scale Observatory for Neutrinoless Double Beta Decay
 - PIONEER – a next generation pion decay experiment
 - Precision Era in Matter-Antimatter Symmetry Test: Upgrade to the ALPHA Project at CERN
 - RadMol - A radioactive molecule lab for fundamental physics
 - TRIUMF electron linac based high intensity THz source. Stage 2
 - TUCAN EDM upgrade
 - SRF Accelerator technology for the Electron Ion Collider (EIC)
- TRIUMF Science Council reviewed the applications and submitted a report on March 18th, 2024
 - The main questions posed for this evaluation were:
 - Interest of TRIUMF in pursuing the proposed projects
 - Potential for scientific impact
 - Capacity and capability of the team
 - Benefit to TRIUMF's mission or infrastructure
 - Expense in terms of TRIUMF resources
- TRIUMF endorsement decisions still pending

New CFI IF 2025
Core Facilities Stream
announced:
TRIUMF beamline 1A renewal
project eligible;
Application submitted to UBC

New projects to be done so that
they does not compete with ARIEL
for resources in the shutdown year



nEXO for neutrinoless double beta decay

- A suite of CFI
 - CFI IF 2017 for noble liquid technology detection R&D infrastructure [Boulay]
 - Only 0.8M\$ at UBC/TRIUMF but enabled construction of 2 world class setups (VERA and MIEL) - Spent
 - CFI IF 2020 for photon detector solution [Kruecken]
 - 6.3M\$ at UBC for constructing SiPM mass testing infrastructure (clean room, probe station, upgrade of MIEL and VERA) – Being spent
 - CFI IF 2023 for many things mostly infrastructure at SNOLAB [Brunner]
 - 1.4 M\$ at UBC for upgrade of VERA to CLEAR for in liquid-Xenon optics characterization –Conditional pending movement by DOE on nEXO
 - CFI IF 2025 for many things mostly at SNOLAB [Brunner]
 - SiPM purchase and DAQ at UBC/TRIUMF

nEXO in CFI IF 2025

- SiPM purchase
 - Very little manpower need, IOF should cover needs
 - Use the IF 2020 infrastructure
- Data acquisition
 - Excellent match in expertise
 - Similar scope to DarkSide DAQ
 - Would use about 50% of the DAQ for a few years, 100% charged to CFI
 - Has brought TRIUMF visibility in the past

- No in-kind contribution requested from TRIUMF

University approved envelopes

McGill: \$3M

Queen's: \$2M

Carleton: \$1.5M

Windsor: \$100k

Sherbrooke: \$50k

UBC: \$2.5M

So far, the total university CFI cap: \$8.95M

PIONEER

NEXT-GENERATION RARE PION DECAY EXP.

Builds on TRIUMF leadership
in previous pion experiments

Strong international partners from diverse
backgrounds

- PIENU
- PEN/PiBeta
- MEG/MEGII
- Rare kaon decays
- low-energy stopped muon experiments
- $g - 2$
- high energy collider physics,
- neutrino physics



Approved by UBC with a CFI budget of \$3.51M
McGill approved \$300k

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PIONEER

CANADIAN INVOLVEMENT

Canadian group initiated the PIONEER project - approved with high priority at PSI in 2022

D. Bryman: former co-spokesperson

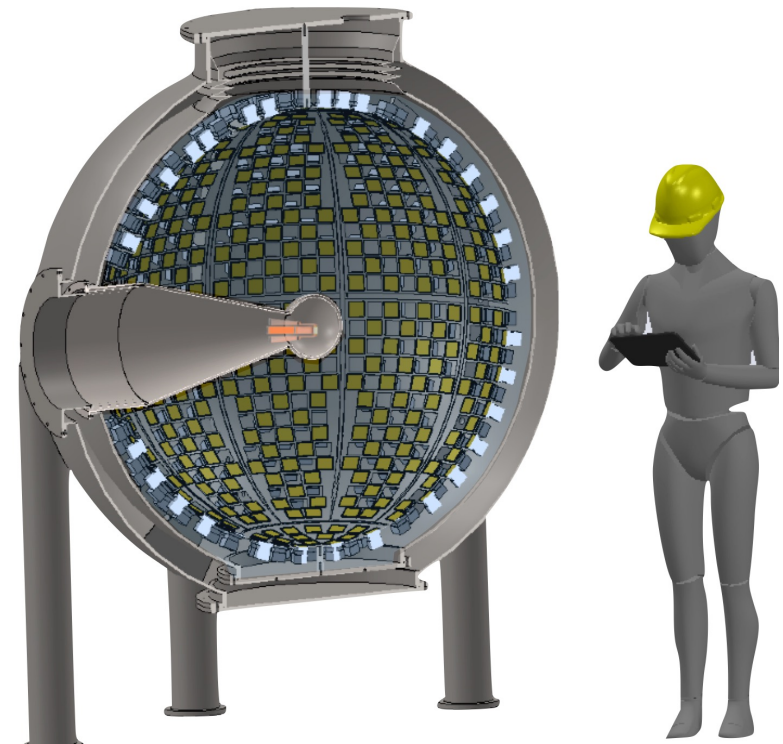
C. Malbrunot: deputy spokesperson

With experiment taking place at PSI, the Canadian group should provide intellectual leadership on detectors, simulation and data analysis.

Canadian group has taken on the “LXe calorimeter thread” (with participation of international collaborator, including Japanese colleagues from MEG - providing the in-kind)

The funds requested as part of CFI IF 2025 would provide crucial infrastructure for the construction of the PIONEER calorimeter - strong synergy with other TRIUMF-supported Nobel liquid experiments

Liquid Xenon technology –
synergy with nEXO



- CFI 2025: ALPHA Upgrade and R&D for quantum measurements
 - Modernization of aging equipment
 - Preparation for entirely new ways to do antimatter measurements: fountain, modularization
- IF 2028: HAICU@ALPHA
 - A major project, to build fountain at ALPHA@CERN
 - Upgrade HAICU infrastructure at TRIUMF
- TRIUMF FYP 2030–35
 - Quantum Physics with Antimatter: Fountain, Interferometer, Antihydrogen molecules, Optical trapping

Goal of ALPHA -
To make comparisons of hydrogen and antihydrogen at highest precision possible

Possible timeline

2024	2025	2026	2027	2028	2029	2030	2031	2032	2034
Run2		LS3	Run3						LS4?
CFI: ALPHA-g operation									
CFI: HAICU@Canada									
Application		CFI: ALPHA Upgrade							
			Application	CFI: HAICU@ALPHA					

Window of opportunities for upgrading obsolete equipment, incl. detector DAQ

Mostly Sci/Tech resources + Cryogenic engineering

- ALPHA/HAICU continues to push exciting antimatter science program well into 2030s
- CFI IF2025 will allow time-critical upgrades, but have limited impact on TRIUMF (DAQ, Cryo), though 2026 is a critical year (unless CERN LS3 is delayed)
- More significant (> \$20M) proposal is anticipated for IF2028 to realize an anti-atom interferometer at CERN
- Strong synergies with other activities (Quantum, detector, AI, laser, accelerator, cryo, vacuum, HiTc magnets etc)

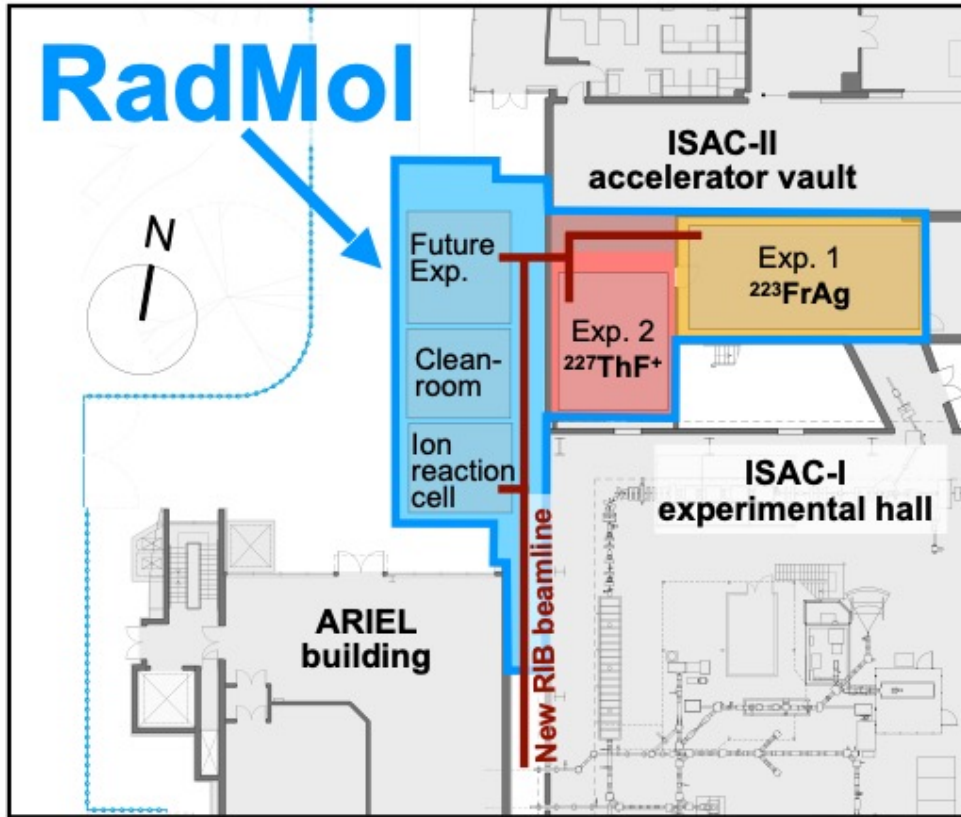
University of Calgary fully approved cap request of \$4M
UBC approved cap of \$2.03M

RadMol

A new opportunity enabled by ARIEL

a radioactive molecule lab for fundamental physics

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Goal:

- dedicated laboratory to study of radioactive molecules
- to host 3 experimental stations
- precision studies for searches for new physics
- Molecular EDM with unprecedented sensitivity to nuclear T-breaking Schiff moments
- provision for expansions into other fields

TRIUMF advantages:

- large variety in radioactive ion beams (RIB)
- high beamtime availability (3 independent RIBs)
- existing laboratory space for large, multi-station program

Current Canadian Team:

- 12 faculty and staff physicists

Status of submission:

Approved by UBC to go forward with \$3.6 M

University of Waterloo approved \$400k

University of Toronto and University of Manitoba decisions imminent

RadMol Collaboration:

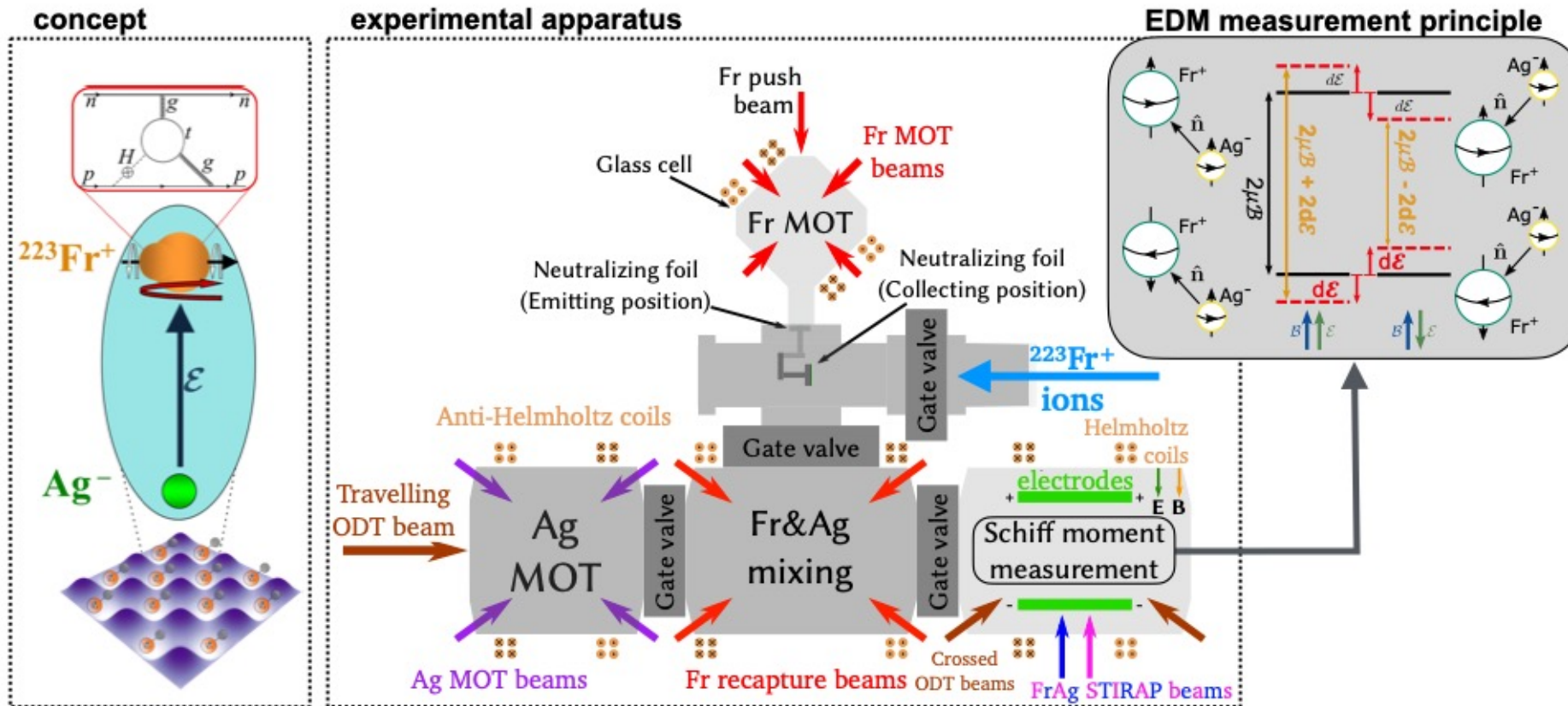


Depends on early completion of ARIEL

223FrAg experiment

A new opportunity enabled by ARIEL

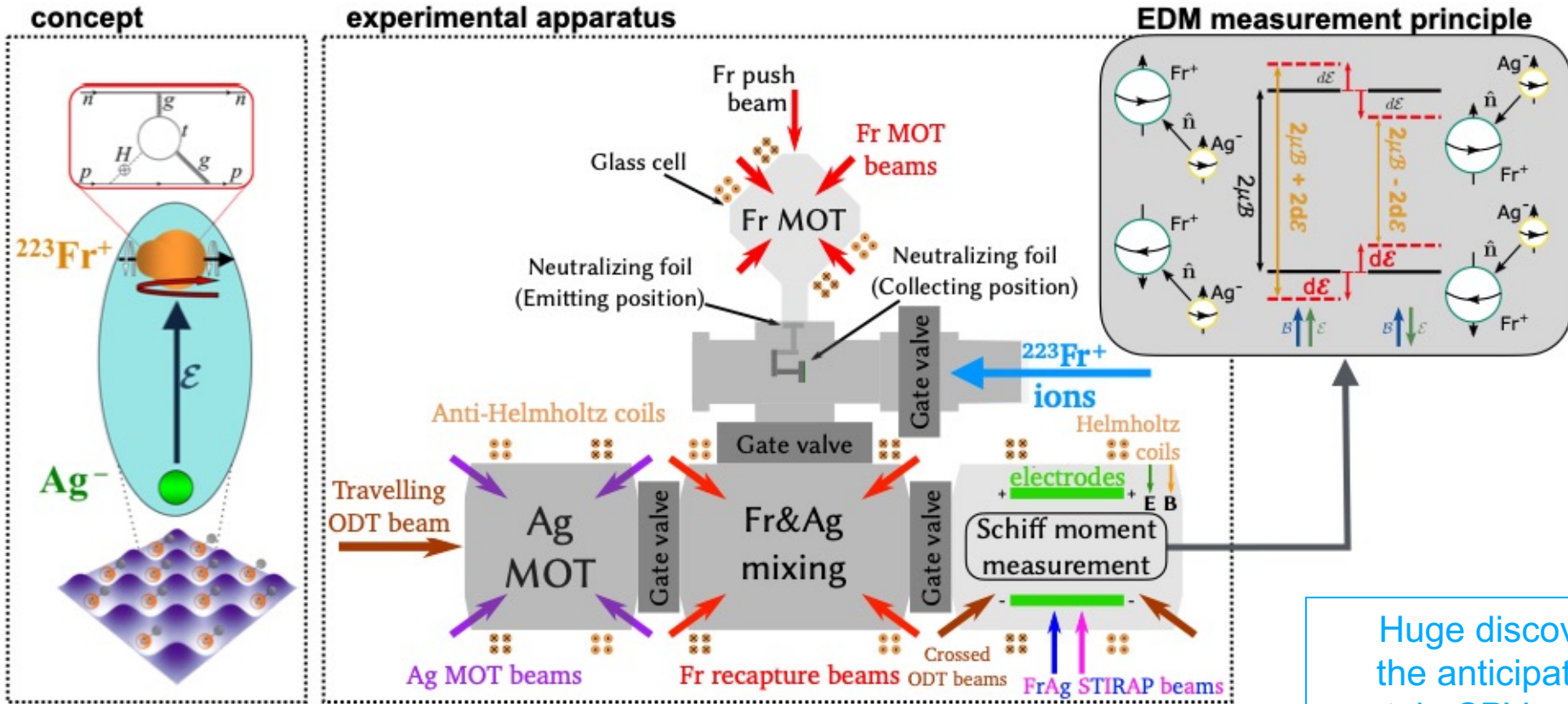
50



- led by Chicago (DeMille)
- benefits from Fr trapping knowhow at TRIUMF/Manitoba
- obtained 2.8 MUSD grant by Moore foundation (ca. 400 kCAD directly to TRIUMF)
- ^{223}Fr 's half-life 23 min: high-intensity online access + low-intensity offline source (^{227}Ac)

223FrAg experiment

A new opportunity enabled by ARIEL



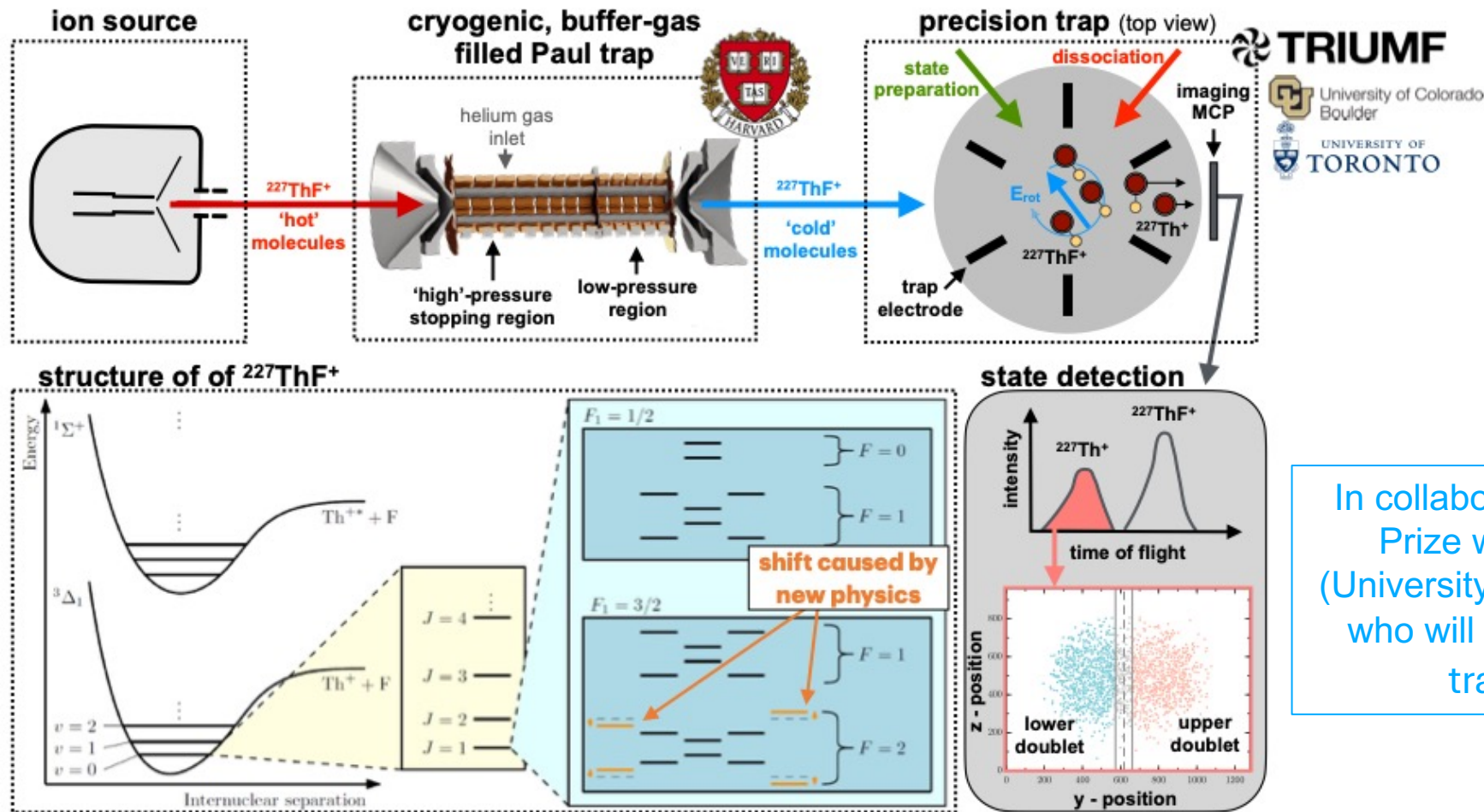
Huge discovery potential with the anticipated gain x1000 for certain CPV parameters compared to current "gold standard" of ¹⁹⁹Hg

- led by Chicago (DeMille)
- benefits from Fr trapping knowhow at TRIUMF/Manitoba
- obtained 2.8 MUSD grant by Moore foundation (ca. 400 kCAD directly to TRIUMF)
- ²²³Fr's half-life 23 min: high-intensity online access + low-intensity offline source (²²⁷Ac)

$^{227}\text{ThF}^+$ experiment

A new opportunity enabled by ARIEL

52



- experimental EDM techniques analogous to JILA electron EDM experiment
- molecular structure of $^{232}\text{ThF}^+$ known from spectroscopy at JILA
- access to ^{227}Th via ^{227}Ac sample from life sciences \Rightarrow strong inter-divisional effort
(Accelerator, Life Sciences, Physical Sciences)

In collaboration with the Nobel Prize winner Eric Cornell (University of Colorado Boulder) who will send his eEDM ion trap to TRIUMF

- The TRIUMF UltraCold Advanced Neutron (TUCAN) source is a **spallation-driven superfluid-helium, superthermal source**.
- Its goals are
 1. to provide record numbers of UCN to the TUCAN EDM experiment for a 10^{-27} e.cm search.
 2. to establish a UCN user facility at its second port.



C. Bidinosti², M. Bradley¹⁶, A. Brossard³, C. Davis³, D. Fujimoto³, M. Gericke⁴, P. Giampa³, R. Golub⁵, S. Hansen-Romu⁴, K. Hatanaka⁶, T. Hayamizu⁷, T. Higuchi⁸, G. Ichikawa⁹, S. Imajo¹⁰, A. Jaison¹¹, B. Jamieson², S. Kawasaki⁹, M. Kitaguchi¹², W. Klassen¹³, A. Konaka³, E. Korkmaz¹⁴, E. Korobkina⁵, M. Lavvaf⁴, L. Lee³, T. Lindner³, K. Madison¹³, Y. Makida⁹, R. Mammei², J. Mammei⁴, J. Martin², R. Matsumiya³, M. McCrea², E. Miller¹³, K. Mishima¹⁵, T. Momose¹³, T. Okamura⁹, H. Ong¹⁰, R. Picker³, D. Ramsay³, W. Schreyer³, H. Shimizu¹², S. Sidhu³, S. Stargardter⁴, I. Tanihata⁶, S. Vanbergen¹³, W. vanOers³, Y. Watanabe⁹, A. Zahra¹¹

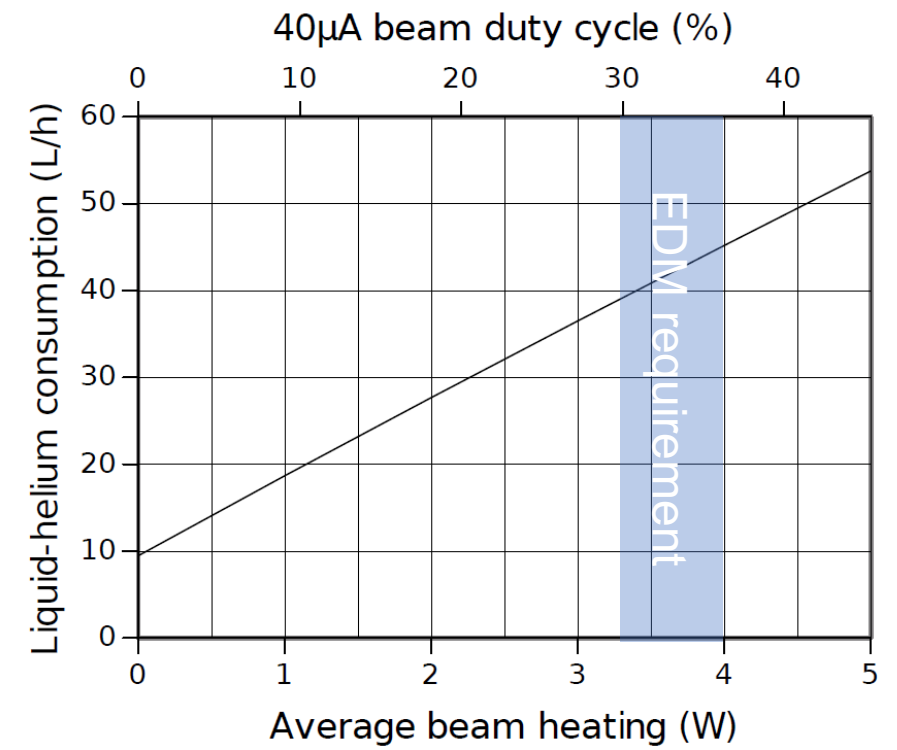
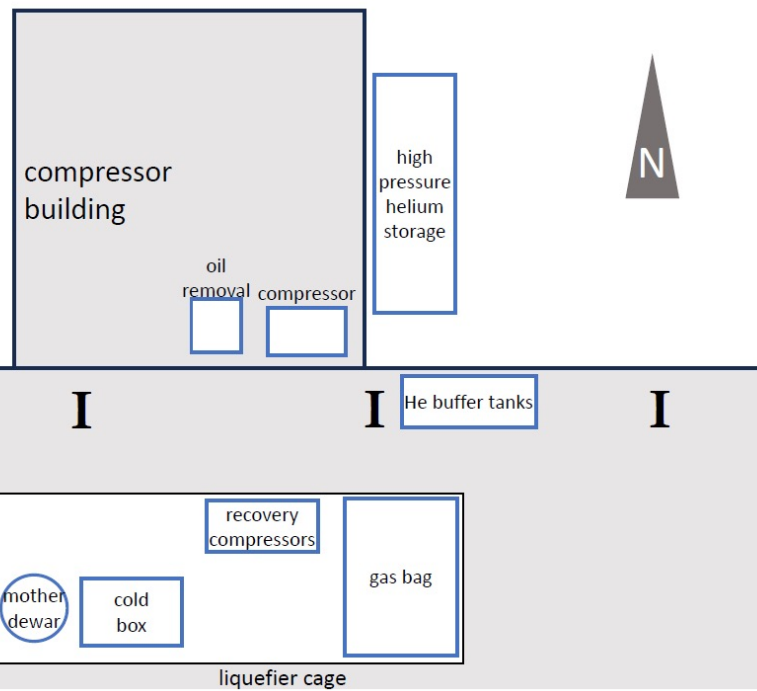
1 - Nagoya University, 2 - UW, Winnipeg, Canada, 3 - TRIUMF, Vancouver, Canada, 4 - UofM, Winnipeg, Canada, 5 - NCSU, Raleigh, NC, USA, 6 - RCNP, Osaka, Japan, 7 - RIKEN, 8 - KURNS, Kyoto University, Kyoto, Japan, 9 - KEK, Tsukuba, Japan, 10 - RCNP, Osaka University, 11 - University of Manitoba, 12 - Nagoya University, Nagoya, Japan, 13 - UBC, Vancouver, Canada, 14 - UNBC, Prince George, Canada, 15 - KEK, Tokai, Japan, 16 – University of Saskatchewan, Saskatoon, Canada

Liquefier upgrade

- The existing Meson hall liquefier provides only up to 55 l/h of liquid (currently only 30 to 40)
- This is **not enough** for the required beam duty cycle for collecting nEDM statistics



Current view of liquefier cage



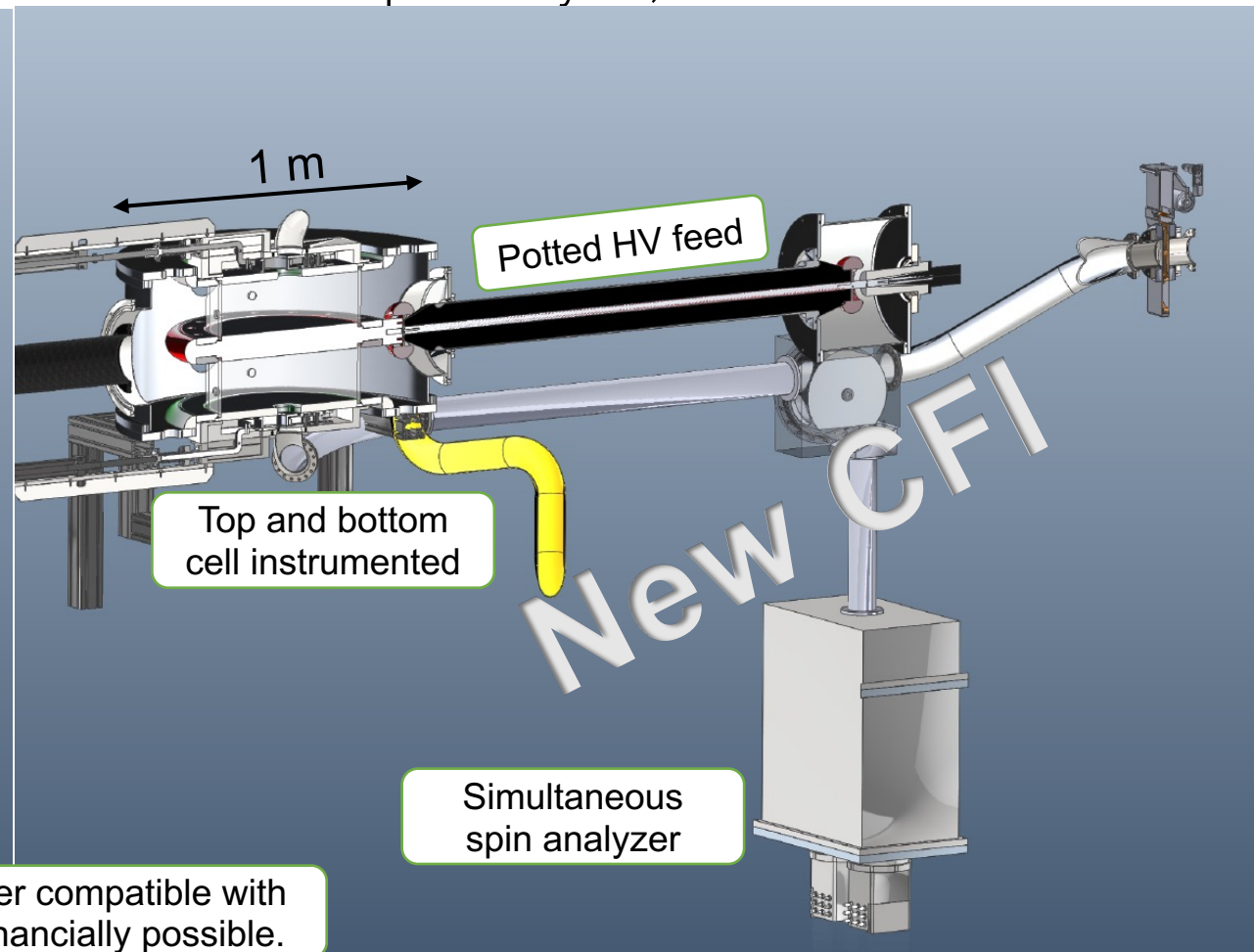
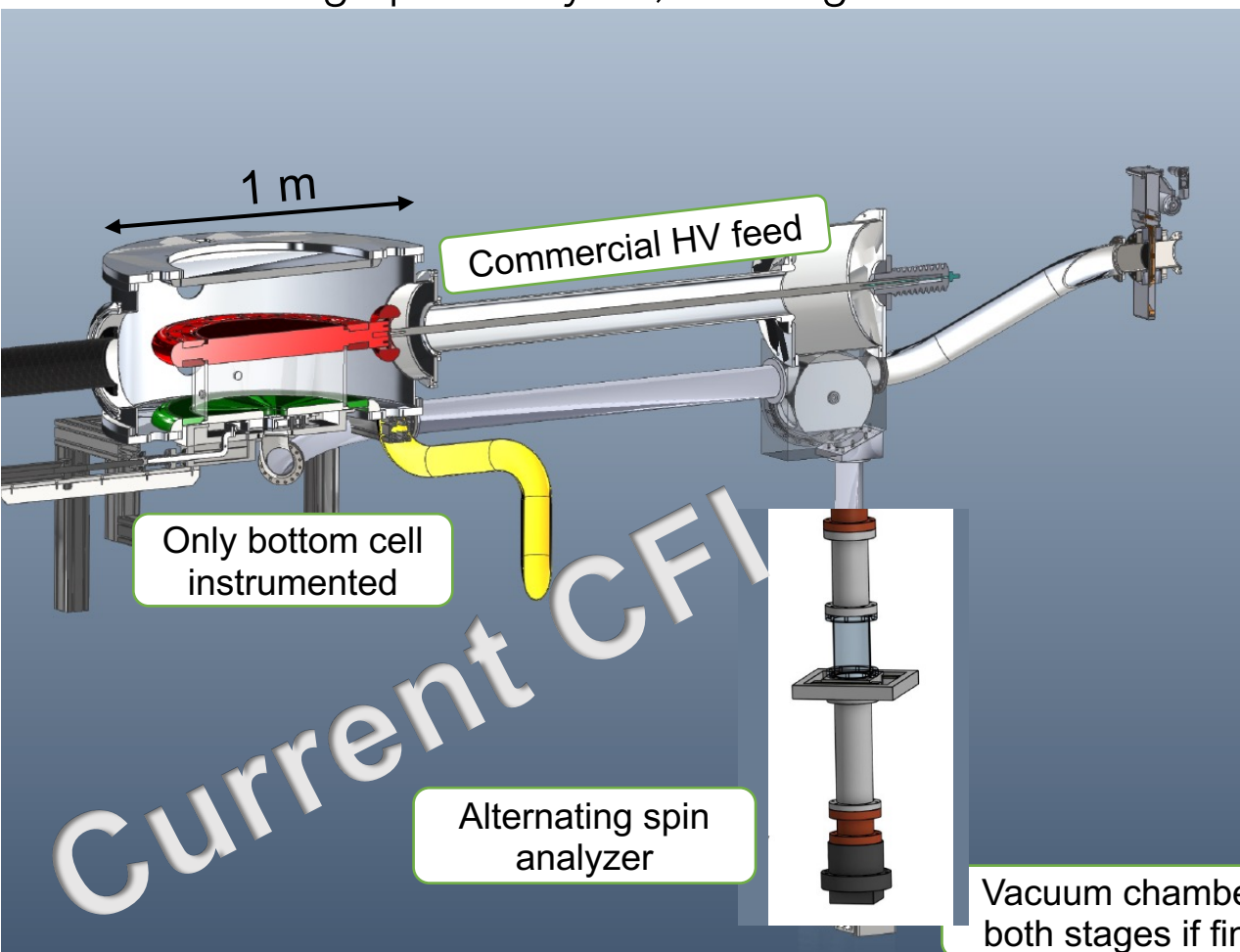
It became necessary to stage the EDM experiment due to budget constraints.

OC100

One experimental cell, 100 kV high voltage,
Alternating spin analyzer, existing EDM switch

2C200

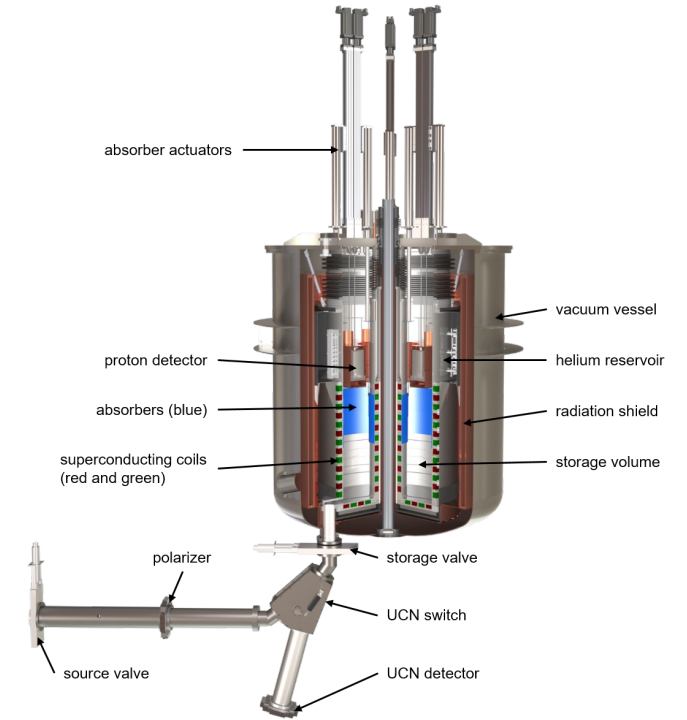
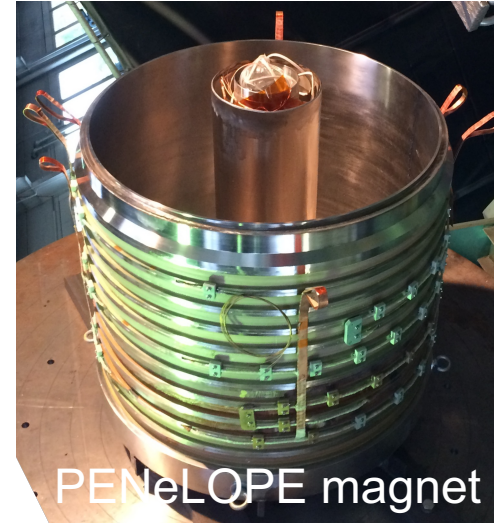
Two experimental cells, 200 kV high voltage,
simultaneous spin analyzer, new EDM switch



Vacuum chamber compatible with both stages if financially possible.

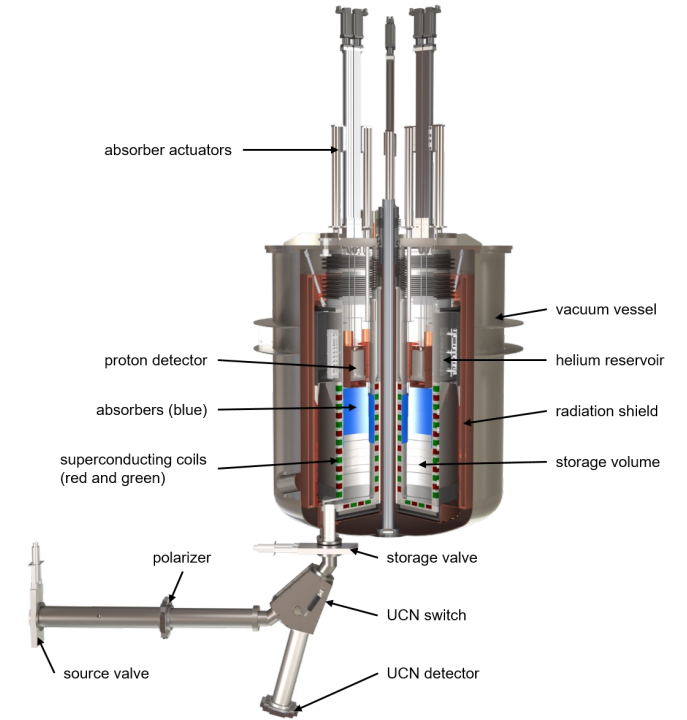
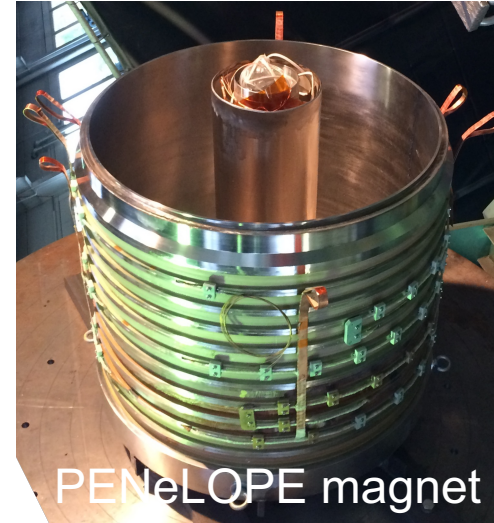
Exploiting 2nd port

- We're getting a complete **neutron lifetime experiment essentially for free**: PENeLOPE (Precision Experiment on the Neutron Lifetime Operation with Proton Extraction)
 - It requires **cryogenic infrastructure** (LHe and LN₂ and general services)
- ⇒ Expanding the fundamental neutron physics program at TRIUMF!



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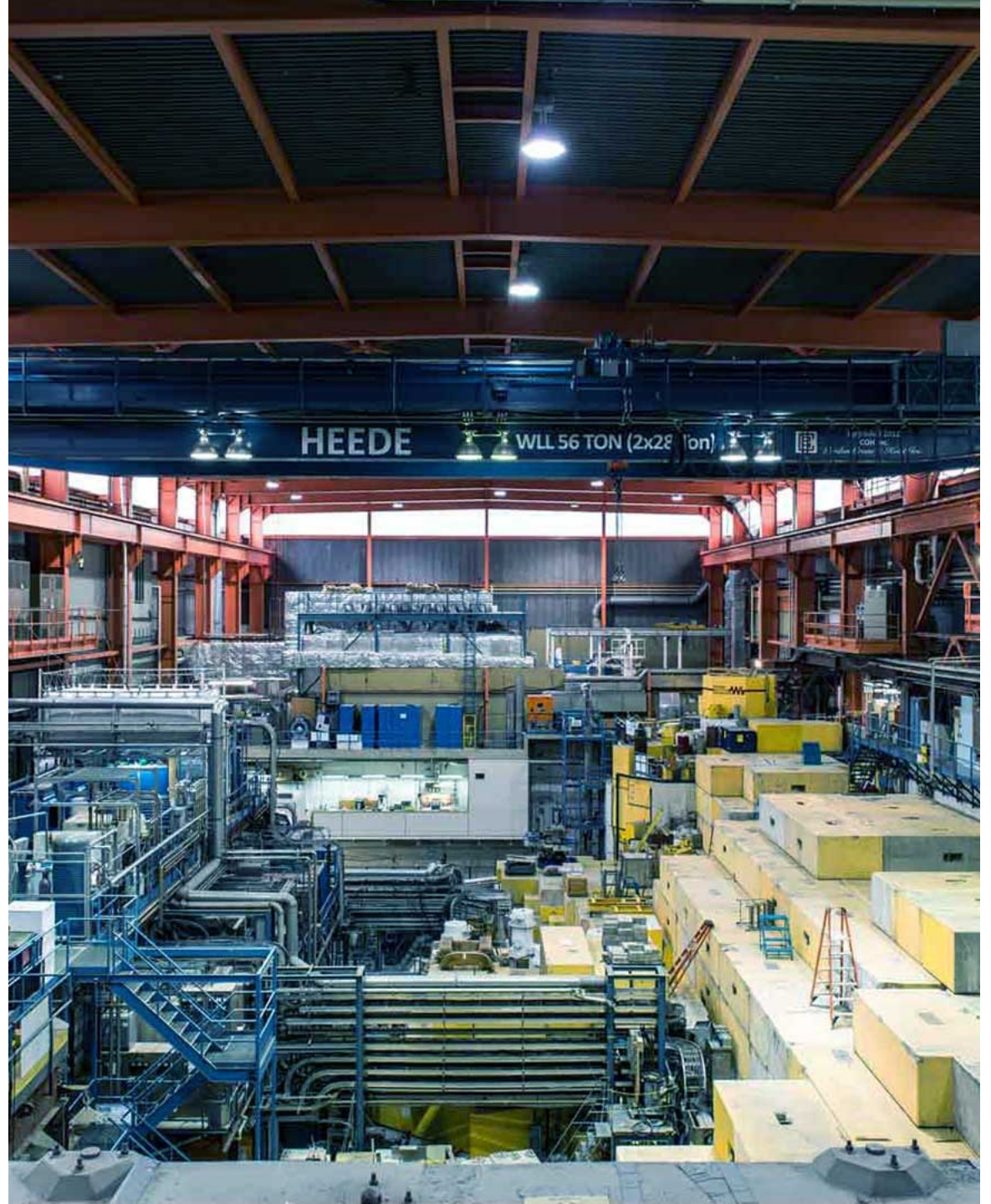
Status of submission:

TRIUMF TUCAN proposal will be **the only Stream 1 proposal** to be submitted by the University of Winnipeg, for the CFI IF 2025 competition. This means that the collaboration can use the full university cap and go beyond - \$4.43 M. Approved by UBC to go forward with \$4M. University of Manitoba cap contribution - \$0.5M



Summary & Outlook

2024-07-23



Summary

- It is the PSD highest priority to **complete and operate ARIEL** in the upcoming 5-year period
 - More beamtime for RIB experiments & beta NMR
 - Enable DarkLight experiment to start taking data, eventually at 50 MeV
 - Free resources for other projects
- **Renewal of the Beamline 1A** needs to be completed to a significant extent
 - Enable μ SR quantum material program on the new and refurbished beamlines
 - Enable UCN operation while other BL1A users running
- PSD scientists need to secure CFI IF 2025 funding
- A new opportunity enabled by ARIEL – RadMol program
 - Breakthrough discovery science

Discussions of the establishment of the Quantum & Instrumentation Center – see the presentation by Oliver Stelzer-Chilton in the afternoon

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The Extended Shutdown Scenario is the only option enabling these goals

Outlook

PSD scientists will deliver breakthrough science results, train numerous HQPs, and enable new technologies for societal benefits in the next five-year period

Thank you
Merci

