



Particle Physics

Oliver Stelzer-Chilton
ACOT Meeting, November 2024

Particle Physics within the Physical Sciences Division

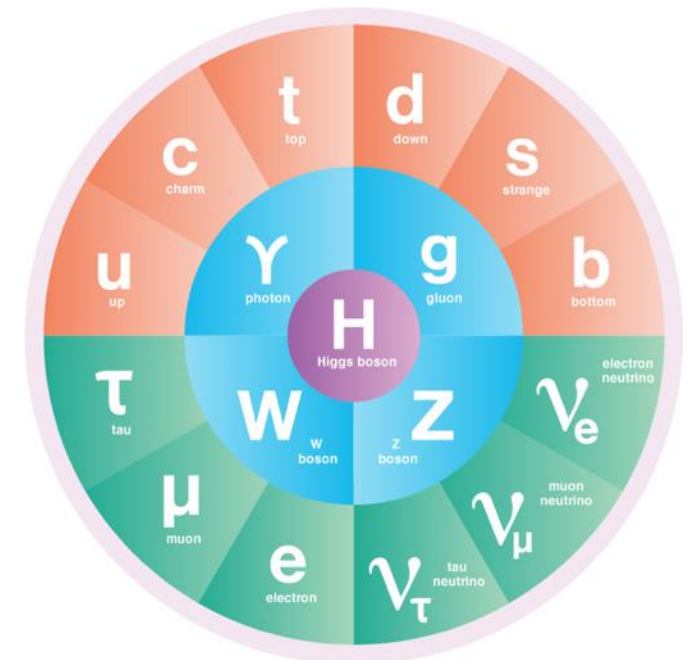
The departments of **Particle Physics, Science & Technology** and **Scientific Computing** address the areas:

- 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, PIONEER



Enable Particle Physics in Canada and Abroad

- TRIUMF is part of a **network of laboratories and partner institutions**
- Leverage TRIUMF key expertise in accelerator, computing, detector and DAQ technologies
 - Unique expertise in e.g. cryomodules, SiPM, TPC, gaseous detectors, DAQ, etc...
 - Support for Accelerator and Engineering, Science Technology and Computing are crucial
- **SNOLAB**: detector, facility and DAQ systems through Science and Technology involvement
 - > SuperCDMS, nEXO, ARGO, DEAP, SNO+
- **CERN**: In kind contributions to LHC and HL-LHC, share in detector upgrades -> ATLAS, ALPHA
 - > global detector R&D organization (DRD)
- **KEK/J-PARC**: beam monitoring accelerator contributions share in detector upgrades -> T2K/Hyper-K
- **PSI**: PIONEER
- **Gran Sasso**: DAQ systems, SiPM -> DarkSide
- Future involvement
 - Ocean Networks Canada: -> P-One
 - Future Collider



Particle Physics Department

Particle Physics – O. Stelzer-Chilton
Deputy – C. Malbrunot

I. Trigger	M. Vetterli (SFU)
O. Stelzer-Chilton	D. Gingrich (UofA)
M. Swiatlowski	P. Savard (UofT)
B. Stelzer (SFU)	G. Azuelos (UdeM, emeritus)
A. Konaka	D. Karlen (UVic)
M. Hartz (with IPMU)	X. Li
W. Rau (with MI).	J-M. Poutissou (emeritus)
K. Clark (with Queens, MI)	T. Brunner (McGill)
S. Yen (emeritus)	
M. Fujiwara	A. Capra
R. Picker	D. Gill (emeritus)
C. Malbrunot	R. Helmer (emeritus)
A. Olin (emeritus)	T. Numao (emeritus)

Affiliated Scientists

S. Bhadra (YorkU)
D. Bryman (UBC)
M. Hasinoff (UBC)
R. McPherson (UVic)
S. Oser (UBC)
T. Momose (UBC)
W. Van Oers (Manitoba)
R. Thompson (Calgary)
B. Pointon (BCIT)
M. Danninger (SFU)
P. De Perio (IPMU/Tokyo)
A. Khramov (BCIT)

*Monthly meetings inclusive to
Particle Physics,
Theory,
Science Technology
and Scientific Computing
department members*

*Dark Matter Forum Meetings
Science and Technology Seminars
Quantum Forum Seminars*

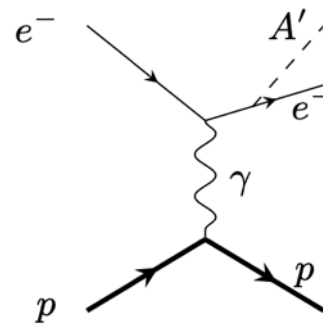
UCN Search

- Completed five candidates shortlist interviews – feedback collected by end of last week
 - Efrain Segarra, PSI Villigen
 - Marie Blatnik, Los Alamos
 - Skyler Degenkolb, U Heidelberg
 - Wolfgang Schreyer, Oak Ridge NL
 - Noah Yazdandoost, PSI Villigen

- Search committee
 - Chen-Yu Liu (chair), University of Illinois Urbana-Champaign
 - Brad Plaster, University of Kentucky
 - Jeff Martin, University of Winnipeg
 - Isabel Trigger, TRIUMF
 - Ruediger Picker, TRIUMF

Particle Physics - EEC

- Interest in carrying out more Particle Physics experiments onsite lead to the creation of the Particle Physics – Experiment Evaluation Committee (PP-EEC)
- Fifth PP-EEC to take place Thursday, January 13th
- EEC Committee:
 - Deborah Harris (York/FNAL) chair
 - Concettina Sfienti (Mainz)
 - Jan Friedrich (TU Munich)
 - Elise Novitski (UW)
 - Makoto Fujiwara (TRIUMF)
 - Dave McKeen (secretary)
 - OSC (ex officio)



$$R_{e/\mu} = \frac{\Gamma(\pi^+ \rightarrow e^+ \nu(\gamma))}{\Gamma(\pi^+ \rightarrow \mu^+ \nu(\gamma))}$$



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
 - Liquid Xenon detectors (TRIUMF part SiPM characterization)



IF 2025 Competition (university envelopes allocated and total)

- ATLAS-Tier-1: 9 ATLAS-Canada universities, \$5.3M request from CFI, \$13.2M total
- ALPHA-Next Gen: several ALPHA-Canada universities, \$6M request from CFI, \$15M total
- PIONEER: UBC and McGill, request from CFI \$3.8M, \$6.5M total
- TUCAN: U. Winnipeg, UBC, U. Manitoba, \$9.5M request from CFI, \$24M total
- nEXO: Carleton, McGill, Queen's, UBC, Sherbrooke, Windsor, \$9.2M request from CFI, \$23M total
- Liquid Ar for Dark Matter: Carleton
- CanFINDD: SFU, \$3M request from CFI, \$7.5M total

Connecting to the Community

- Summer Schools
- Workshops
- Conferences

Physics Potential of Future Colliders

18–20 Sept 2024
TRIUMF

Enter your search term

science week 2024
July 22 - 26

TRIUMF Princeton Physics SFU SIMON FRASER UNIVERSITY G S GRAN SAGGIO INSTITUTE S I

PD24

6th International Workshop on New Photon-Detectors
Simon Fraser University - Harbour Centre, Vancouver (CA)
Nov. 19-21, 2024

- Recent progress and new developments in photon-detectors such as SiPMs, MCPs, APDs, PMTs, Hybrid PMTs and digital photon-sensors
- Front-end, DAQ and trigger electronics
- Applications in particle and astroparticle physics, nuclear physics, nuclear medicine and industry

<p>International Advisory Committee</p> <p>G. Collazuol (Univ. of Padova) Y. Musienko (Univ. of Notre Dame, CERN) N. Otte (Georgia Institute of Technology) A. Para (FNAL) V. Puiil (JCLab, Orsay) A. Romano (Univ. of Birmingham) F. Sefkow (DESY) Q. Sen (HEP, CAS) T. Takeshita (Shinsu University) J.C. Vanel (LPICM, Ecole Polytechnique) M. Yokoyama (Univ. of Tokyo)</p>	<p>Organizing Committee</p> <p>F. Retiere (TRIUMF, Chair) G. Gallina (TRIUMF, Princeton Univ., Co-Chair) D. Grant (SFU) H. Lewis (TRIUMF) K. Raymond (TRIUMF) M. A. Sabia (TRIUMF, Sapienza) F. Shi (TRIUMF) R. Underwood (TRIUMF) P. Agnes (GSSI) P. Organtini (Princeton Univ.) A. Jamil (Princeton Univ.)</p>
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Abstract and Registration (Indico Page):

TRI-INSTITUTE SUMMER SCHOOL ON ELEMENTARY PARTICLES

PI · SNOLAB · TRIUMF

TRISEP

www.trisep.ca

DATE: JULY 8-19, 2024 | LOCATION: SNOLAB

SPEAKERS:
JOSEPH BRAMANTE, QUEEN'S UNIVERSITY
THOMAS BRUNNER, MCGILL UNIVERSITY
MIRIAM DIAMOND, UNIVERSITY OF TORONTO
SHOHINI GHOSE, WILFRID LAURIER UNIVERSITY
ZIQING HONG, UNIVERSITY OF TORONTO
BLAIR JAMIESON, UNIVERSITY OF WINNIPEG
MICHAEL KACAN, SLAC
KATIE MACK, PERIMETER INSTITUTE
SCOTT OSER, UNIVERSITY OF BRITISH COLUMBIA
STEPHEN SEKULA, SNOLAB/QUEEN'S UNIVERSITY
SARAH SHANDERA, PENNSYLVANIA STATE UNIVERSITY
DANIEL STOLARSKI, CARLETON UNIVERSITY
CHRIS THOME, NDSM UNIVERSITY
JEANNE WILSON, KING'S COLLEGE, LONDON

TOPICS:
STANDARD MODEL PHYSICS AND BEYOND
STATISTICS & COMPUTING FOR PARTICLE PHYSICS
DARK MATTER CANDIDATES AND DETECTION
NEUTRINOS PHYSICS
LONG BASELINE NEUTRINO MEASUREMENTS
NEUTRINOLESS DOUBLE BETA DECAY
FOCUSED LECTURES ON UNDERGROUND TOPICS

LOCAL ORGANIZING COMMITTEE:
ERICA BRUNELLE
ERICA CADEN
JODI COOLEY
JULIETTE DELOYE
BLAIRE FLYNN
SHAUN HALL
CHRISTINE KRAUS
SAMANTHA KUULA
RACHEL RICHARDSON
STEPHEN SEKULA

ADVISORY COMMITTEE:
CLIFF BURGESS, PERIMETER INSTITUTE & MCMMASTER
ERICA CADEN, SNOLAB
JETER HALL, SNOLAB
DAVID MORRISSEY, TRIUMF
OLIVER STELZER-CHILTON, TRIUMF

THE EARTH-HUMANITY COALITION

Discovery, accelerated

GRIDS2024

Graduate Instrumentation and Detector School

GRIDS2024

GRIDS2024 offers a diversified learning experience, combining lectures from leading experts with hands-on experience with typical detector and instrumentation technology.

Apply online - Open until March 15, 2024

Summary

- Many breakthrough results in Particle Physics expected over the next Five-Years
- We welcome the green light by the director to proceed with the replacement BAE hire for UCN
 - Short list interviews completed
 - Awaiting search committee report
- Impact of the 2026 shutdown on Particle Physics
 - Directly impacts on-site projects like TUCAN and DarkLight
 - Impacts through availability of resources on CFI projects especially new CFI proposals
 - Indirect impacts on Particle Physics projects through Science & Technology Department
- Quantum synergies with Nuclear Physics and CMMS
 - Had a fruitful visit by Quantum BC in August and were invited to their next general meeting
- Issues
 - Space remains a commodity (both office and research)

Agenda

- Particle Physics – Oliver Stelzer-Chilton (5+3)
- Scientific Computing – Reda Tafirout (7+3)
- Science & Technology – Pietro Giampa (15+5)

- Project updates
 - ATLAS – Max Swiatlowski (5+3)
 - T2K/Hyper-K – Akira Konaka (5+3)
 - TUCAN – Ruediger Picker (5+3)
 - ALPHA/ALPHA-G/HAICU – Andrea Capra (5+3)
 - SuperCDMS – Wolfgang Rau (3+2)
 - DarkLight – Kate Pachal (3+2)
 - PIONEER – Chloe Malbrunot (3+2)
 - nEXO – Chloe Malbrunot (3+2)

Thank you
Merci

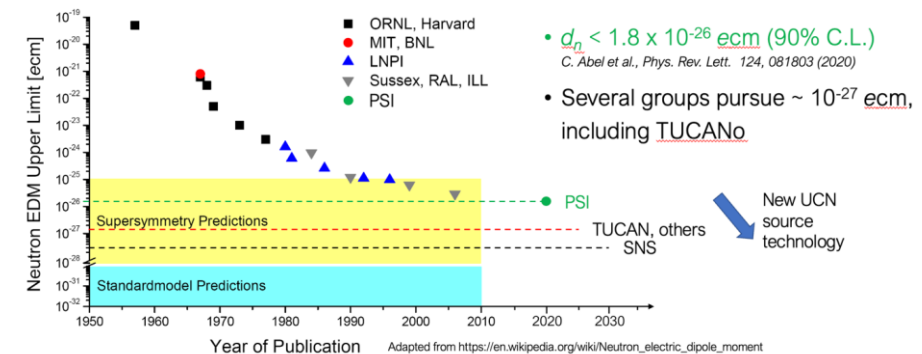
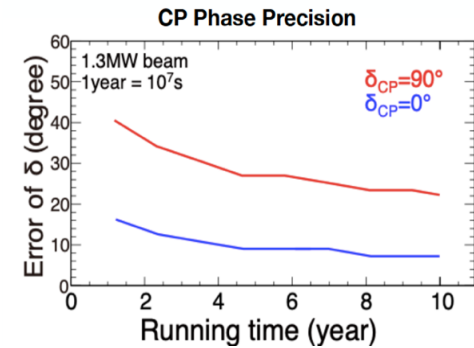
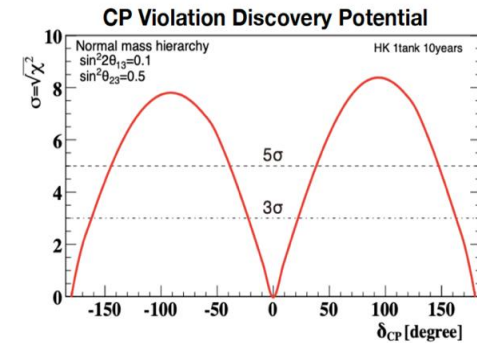
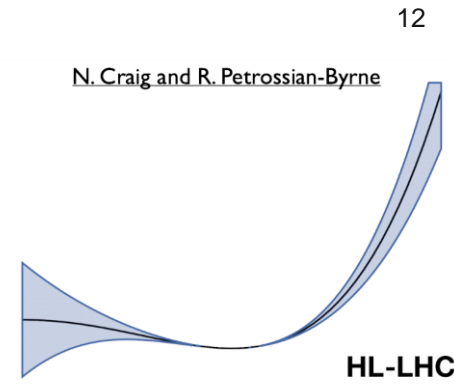
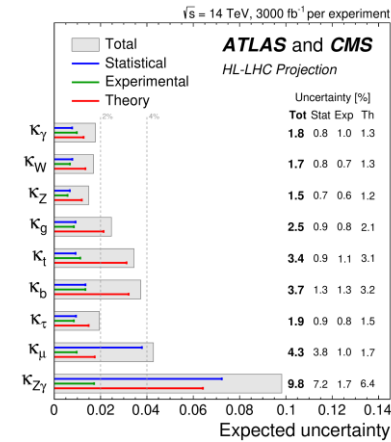
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Exciting Science in next 5 YP

- 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
 - ALPHA: Precision anti-matter spectroscopy and effect of gravity on anti-matter
 - SuperCDMS: Most sensitive Dark Matter results
 - DarkLight: Sensitivity to find new low mass dark boson
 - PIONEER: Towards the world's most precise e- μ universality test



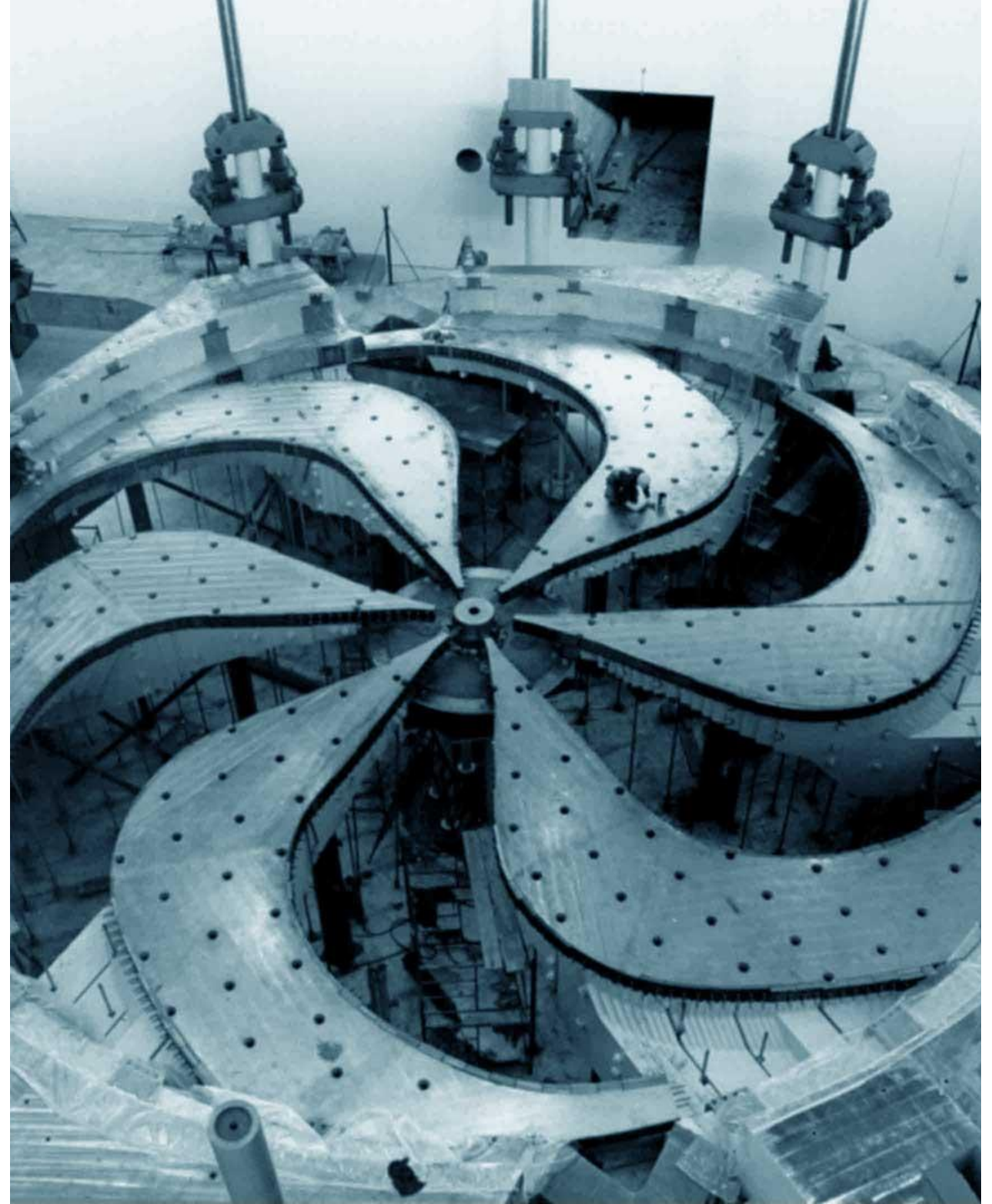
Scientific Computing

Status & Next 5YP

W. Fedorko, R. Tafirout

Scientific Computing Department

ACOT meeting, Fall 2024



Current Department Organization

- Common umbrella for existing activities:
 - Big data & Distributed Computing (ATLAS Tier-1) (R. Tafirout)
 - Machine Learning & Quantum Information Systems (W. Fedorko)
- Head / Deputy: R. Tafirout / W. Fedorko
 - Tier-1:

A. De Silva	X. Liu
R. Debhandari	D. Qing
F. Fernandez Galindo	Y. Shin
V. Kondratenko	A. Wong
 - QML: Javier Toledo (RA)

Affiliated Scientists:

C. Senko (Waterloo)

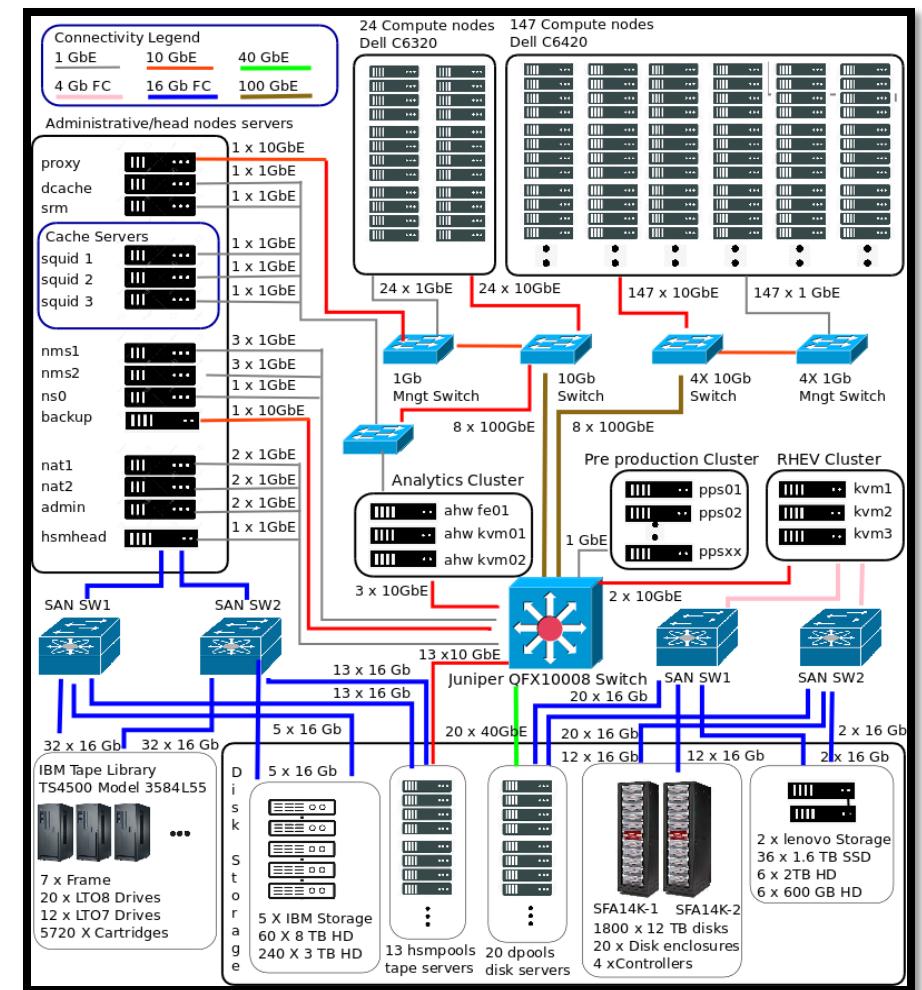
R. Islam (Waterloo)

P. Haljan (Simon Fraser)

J. Sirker (Manitoba)

ATLAS Tier-1 Centre & next 5YP

- Well established 24/7 distributed computing operations model with high availability & reliability:
 - data storage, data processing, simulations and user analysis in a highly secure environment
 - crucial user support for the entire collaboration
- Current capacity: ~9,000 cores ; 17 PB disk ; 45 PB tape
- Plan to continue Tier-1 operations in next 5YP with existing TRIUMF personnel complement
- New CFI IF 2025 funding proposal in preparation:
 - covers 2027-2031 period
 - \$5.3M from CFI (\$13.2M total project cost)
 - hardware expansion during LS3 & HL-LHC
 - personnel for computing R&D for HL-LHC
- Recently, secured crucial funding through special award of \$4.05M (from DRAC & BCKDF) to replace ageing equipment as bridging into next CFI:
 - active procurement process ongoing

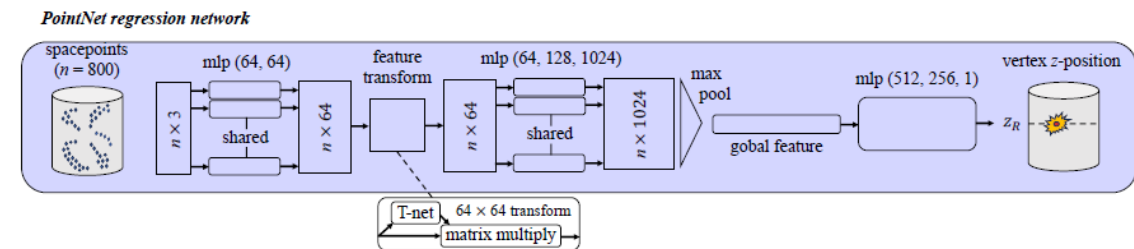
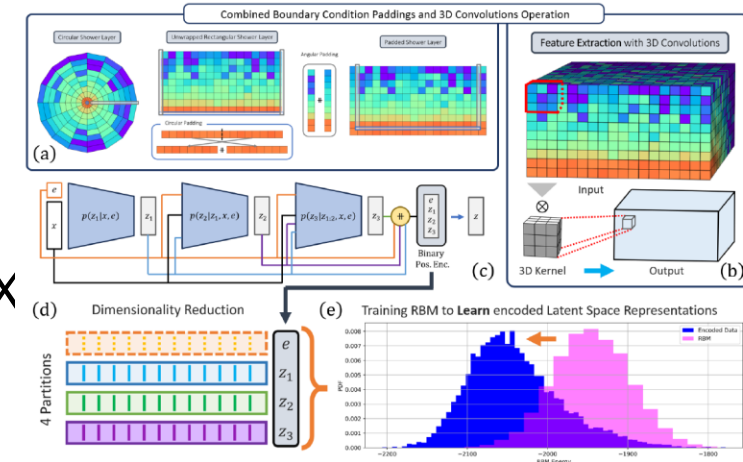


Digital Research
Alliance of Canada



Machine Learning and Quantum Computing Activities 1

- ML engagement recent since 2018
 - Part of the current TRIUMF strategic plan
- Supporting and driving multiple ML/QC aspects of projects:
 - ATLAS Quantum-Assisted ML
 - Accelerated calorimetric simulation: EPJC Letter accepted, PRX imminent, multiple conferences (IEEE, CHEP, NeurIPS)
 - Water Cherenkov HyperK/SuperK/WCTE/IWCD
 - Multiple threads centering on particle identification + reconstruction in Water Cherenkov detector
 - First look at real data with ML methods at SuperK
 - ATLAS Particle Flow
 - Improved calibration of calorimetric clusters
 - ATLAS Trigger/FPGA
 - Real time application of ML cluster calibration for Level 0 trigger for ATLAS @ HL-LHC
 - ALPHA
 - Reconstruction of annihilation vertex
 - Accepted at NeurIPS ML4PS, publication advanced draft
 - First look at data
 - NA62
 - CaloPID: Adopted, Published
 - RICHPID: In internal review



Machine Learning and Quantum Computing Activities 2

- Automated beam tuning with RIBs (ISAC I, B-NMR, DRAGON)
 - Aim automate beam steering with Bayesian Optimization in conjunction with Model Coupled Accelerator Tuning (MCAT) for optics.
 - On-going beam tests in ISAC MEBT HEBT and DRAGON
 - RSI in 2nd round of peer review. presented at IPAC
 - Plans to put tool in production before the long shutdown
- TIIGR w Life Sciences / SciTech
 - Aim to design detector for SPECT imaging for targeted alpha therapy with Ac^{225}
 - Initial detector design studies. Plans for ML image reconstruction and design optimization
 - Collaboration with Korean partners unfolding well.
- HQP support for all projects:
 - Postdocs, Grads, Coops/UG
 - MITACS
 - Capstone projects
 - Summer schools
 - Collaborations

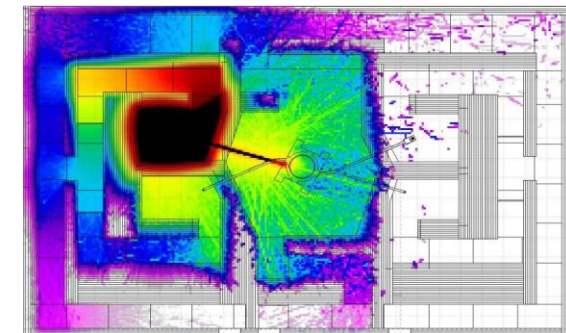
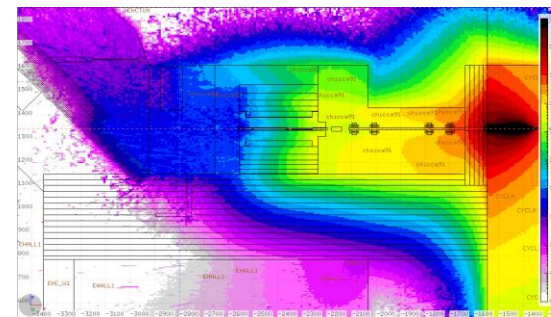
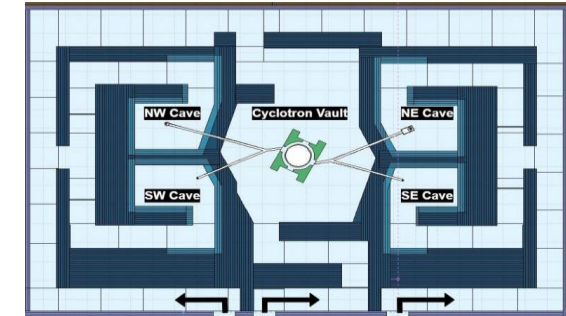
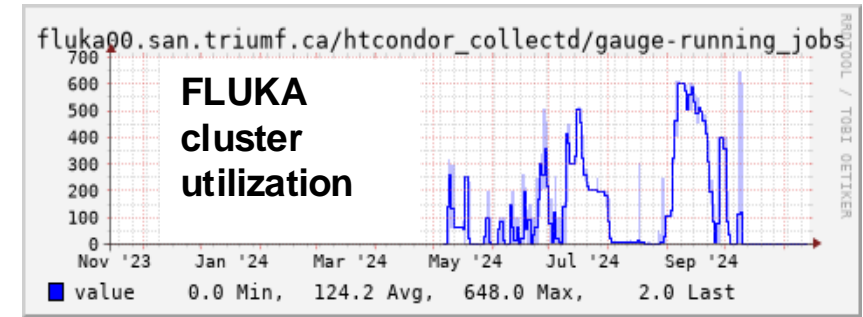


ML + QC projects 2025-30

- Continued support and leadership of existing ML & QC projects
- 5YP ARIEL Support:
 - Automatic beam tuning will support accepting beam from ARIEL into ISAC
 - Methods can be transferred to different beamline section
 - Relieve operators to manage x3 simultaneous beamlines
- Infrastructure:
 - In house rapid ML development machine(s) need periodic upgrades/replacement
 - Risk to program
 - 'Behind' state of the art
- 5YP alignment and risks
 - Extra personnel difficult under 5YP constraints
 - Additional 1 FTE ML-dedicated personnel would be needed for sustaining existing program + modest expansion
 - Nuclear Physics, Material Science, Life Sciences
 - Small likelihood of TIIGR getting delayed dependent on what personnel gets re-allocated

ARIEL & IAMI support / FLUKA cluster

- Since 2020, a significant portion of the old ATLAS Tier-1 centre capacity is being utilized for large FLUKA simulations campaigns:
 - 336 physical cores added to existing IS&T cluster via special network configuration (for security); jointly managed
 - crucial for ARIEL shielding design (time sensitive)
 - recent large simulation campaign for IAMI
- Cluster also used by PIF/NIF and other projects, like FLASH
- Additional features implemented since early 2024:
 - HTCondor batch system for efficient access
 - enhanced monitoring for cluster utilization
- CNSC approval received in May 2024 to operate the 500 MeV cyclotron with current BL4N shielding configuration.



ARIEL Proton Cave

IAMI TR24

Extra Material

CAM Initiative

- Project Driven by the Digital Research Alliance of Canada / Aim and scope:
 - The Controlled Access Management (CAM) for Research Data Initiative aims to enable collaboration between Canadian data repositories and research institutions to enhance research data management and research security.
- TRIUMF selected as partner organization along with other institutions (application made in 2023)
- There are monthly meetings with partner organization representatives
- TRIUMF is participating in two working groups:
 - Technology & Services
 - Data Governance & Data Stewardship
- Involvement from Scientific Computing and IS&T departments



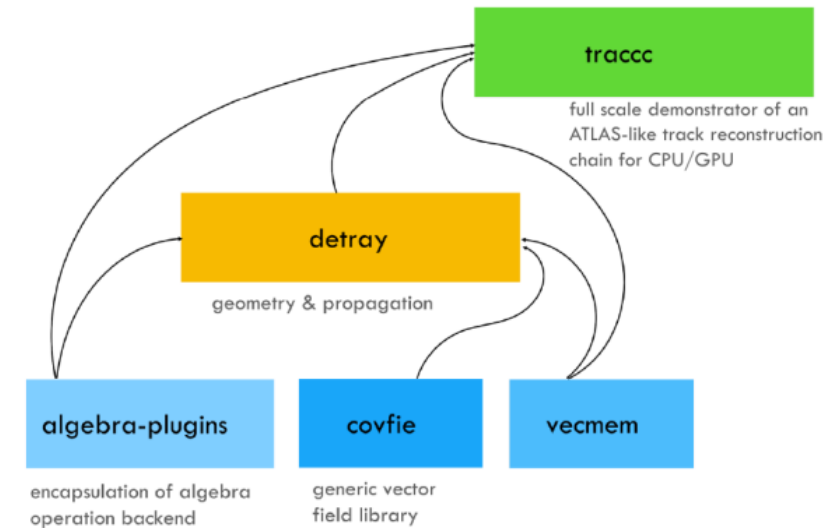
**Digital Research
Alliance** of Canada

**Alliance de recherche
numérique** du Canada

ATLAS Software & Computing Roadmap for the HL-LHC

- Roadmap has many components dealing with various topics & challenges:
 - Network infrastructure ready for Run 4
 - Detector Description, Simulation and Digitization projects
 - HL-LHC datasets replicas and versions management
 - Core Software and Heterogeneous Computing / Accelerators
 - etc.
- ATLAS Heterogeneous Computing & Accelerators Forum established recently
- To tackle the combinatorics in a high luminosity environment, investigate tracking on GPU. For this to succeed:
 - define a suitable Event Data Model,
 - develop a toolchain that supports e.g. CUDA kernels
 - provide GPU friendly implementations of the geometry and magnetic field.
- ATLAS Tier-1 CFI proposal (IF 2025) has capital provisions to hire additional personnel to work on software R&D for HL-LHC era.

ACTS - A Common Tracking Software



Science & Technology Department Update

ACOT November 2024

Pietro Giampa, TRIUMF

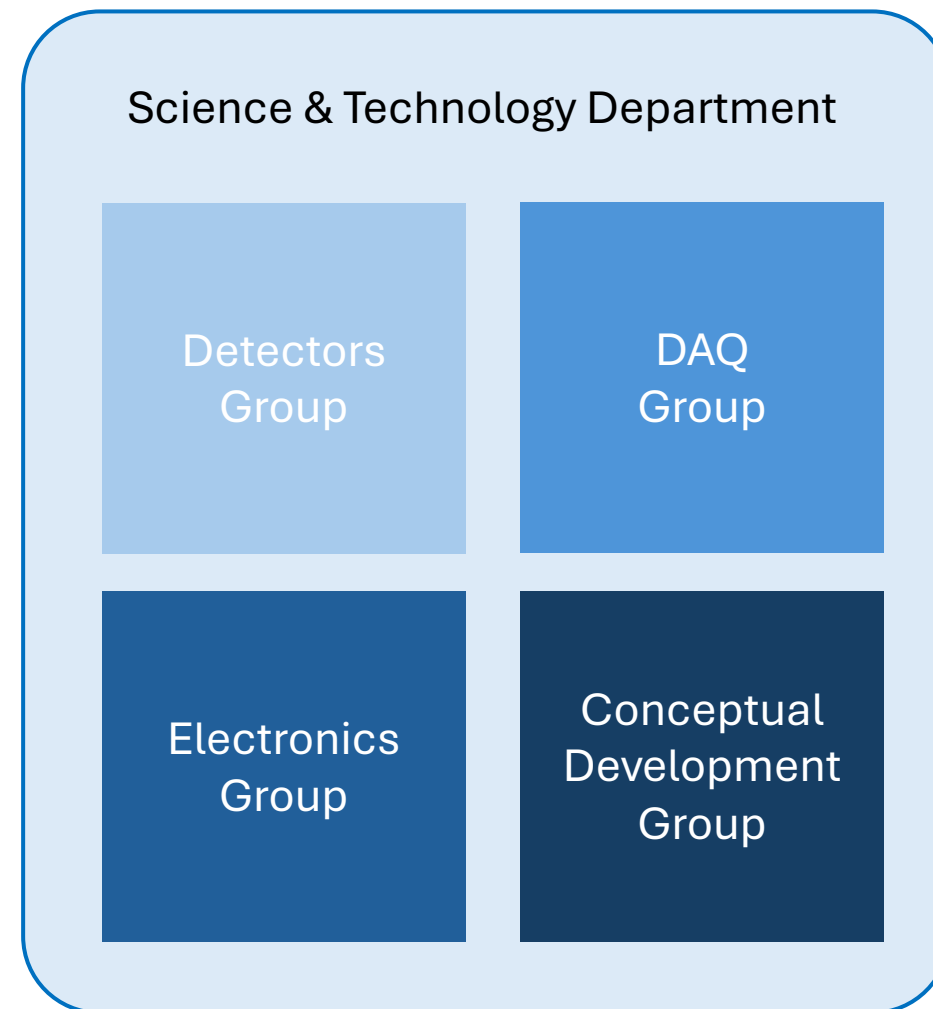


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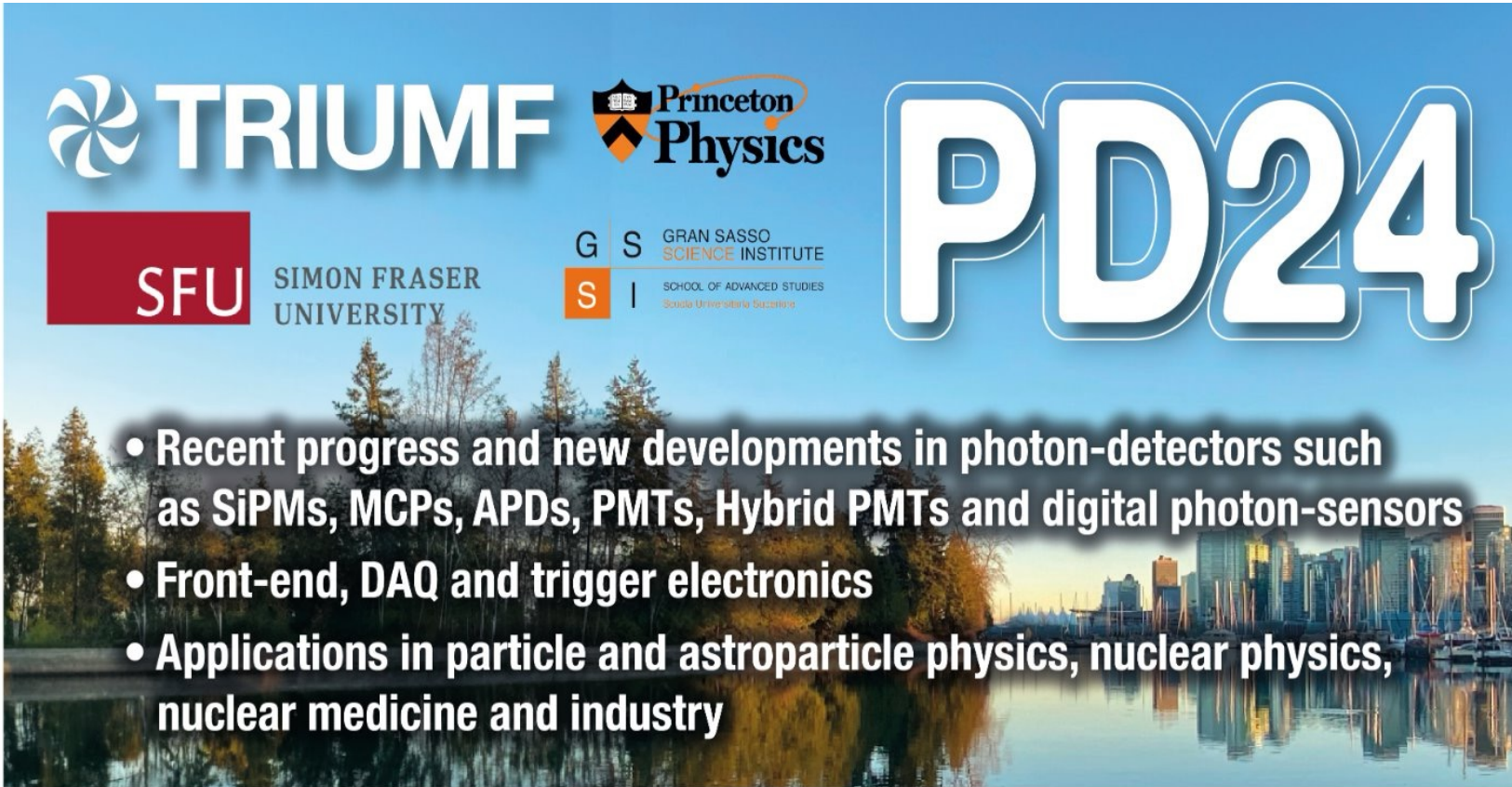
- Department Overview
- Integration with QRPP
- Projects Support Over the Last 2 QRPP Cycles
- Detector Group Highlights
- Electronics Group Highlights
- DAQ Group Highlights
- Conceptual Development Group Highlights
- Contributions to ARIEL
- New Technologies & Tech Transfer

Department Overview

- Enabling science and provide technical support for the programs at the laboratory. Strength in technical expertise and knowledge retention.
- Headed by F. Retiere. The department is subdivided in four major groups:
 - **Detectors Group**
(~8 people), lead by Philip Lu
 - **Data Acquisition (DAQ) Group**
(~4 people), *lead by Pierre Amaudruz*
 - **Electronics Group**
(~6 people), *lead by Daryl Bishop*
 - **Conceptual Development Group**
(~4 people), *lead by Nigel Hessey*
- Recent Departures: Chapman Lim (retirement), Bryerton Shaw (Electronics Group)



Department Overview



The banner features a scenic background of a city skyline reflected in water. At the top left, the TRIUMF logo is displayed in white. To its right is the Princeton Physics logo, which includes a shield icon. Below these are the logos for SFU (Simon Fraser University) and the Gran Sasso Science Institute (GSSI), which is associated with the School of Advanced Studies at the University of Perugia. The text 'PD24' is written in large, white, outlined letters on the right side. A list of topics is centered in the lower half of the banner.

- Recent progress and new developments in photon-detectors such as SiPMs, MCPs, APDs, PMTs, Hybrid PMTs and digital photon-sensors
- Front-end, DAQ and trigger electronics
- Applications in particle and astroparticle physics, nuclear physics, nuclear medicine and industry

The 6th International Workshop on new Photon-Detectors (PD24) will be held November 19-21, 2024 at Simon Fraser University, Harbour Centre in Vancouver, BC, Canada.

Integration with QRPP

- Over the past year the department has put a considerable effort in realignment with the QRPP system.
- Initiate communications with project leads ~1 month prior to the QRPP deadline, to engage in communication with group leaders and technical personnel.
- Department meets on the Friday after QRPP to go over all requests and confirm the resource loading.

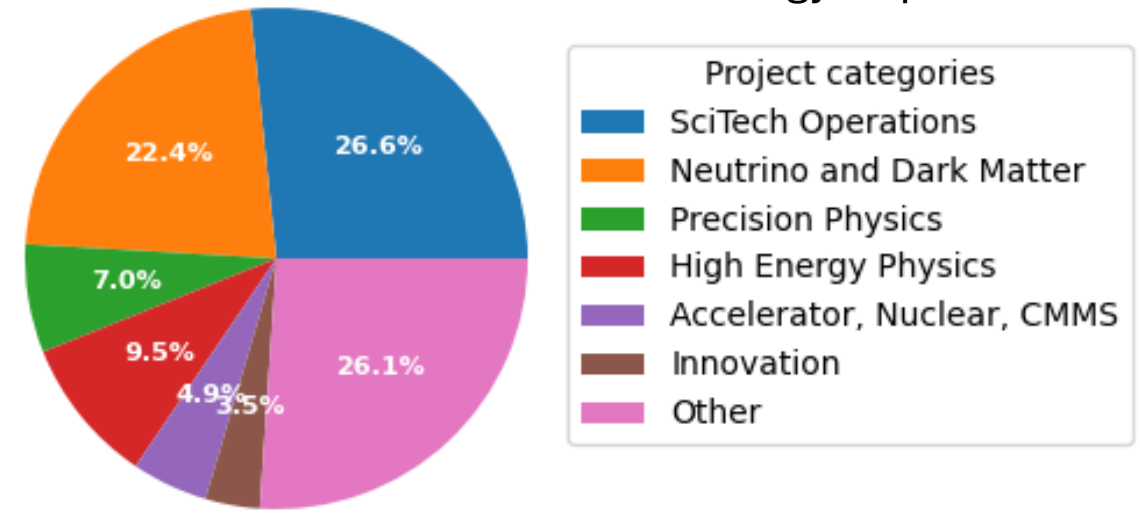
Project Number	Requested Support [FTE-Weeks / QRPP]	Effective Support [FTE-Weeks / QRPP]
DarkLight (PRJ-538)	5.6	5.9
HAICU (PRJ-552)	18.0	17.1
Hyper-K (PRJ-456-461-537)	26.5	24.3

Examples from July-Sep 24 QRPP Cycle

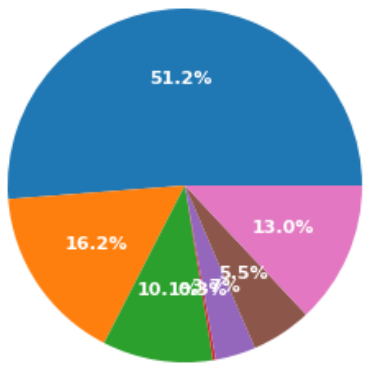
Project Support Over the Last Two QRPP Cycles

- July-Sep 2024 QRPP Cycle:
Supported 20 Projects, 71 Individual Tasks
- April – June 2024 QRPP Cycle:
Supported 20 Projects, 68 Individual Tasks

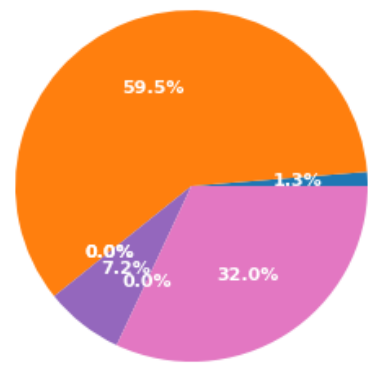
Science & Technology Department



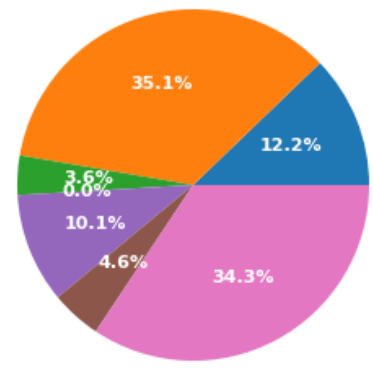
Detector Group



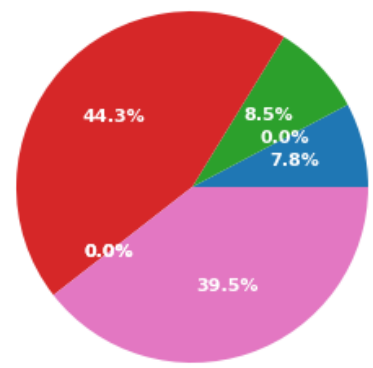
DAQ Group



Electronics Group



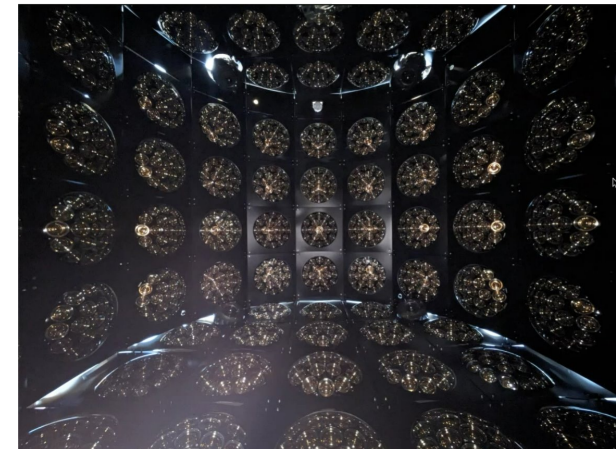
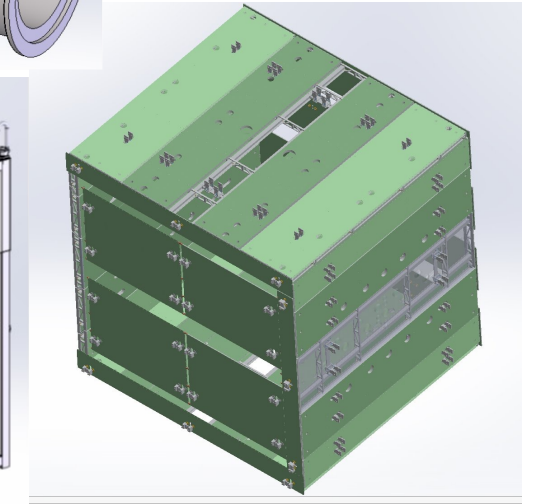
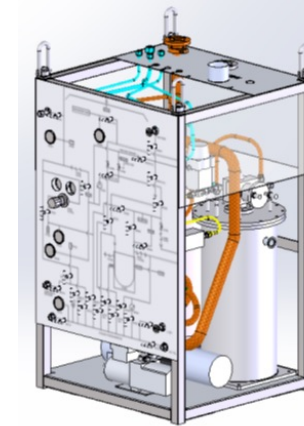
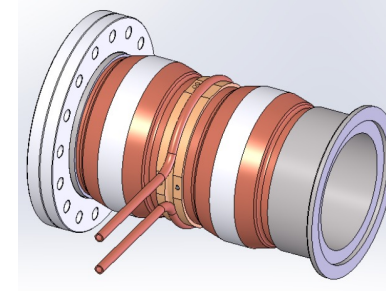
Conceptual Dev Group



Detector Group Highlights

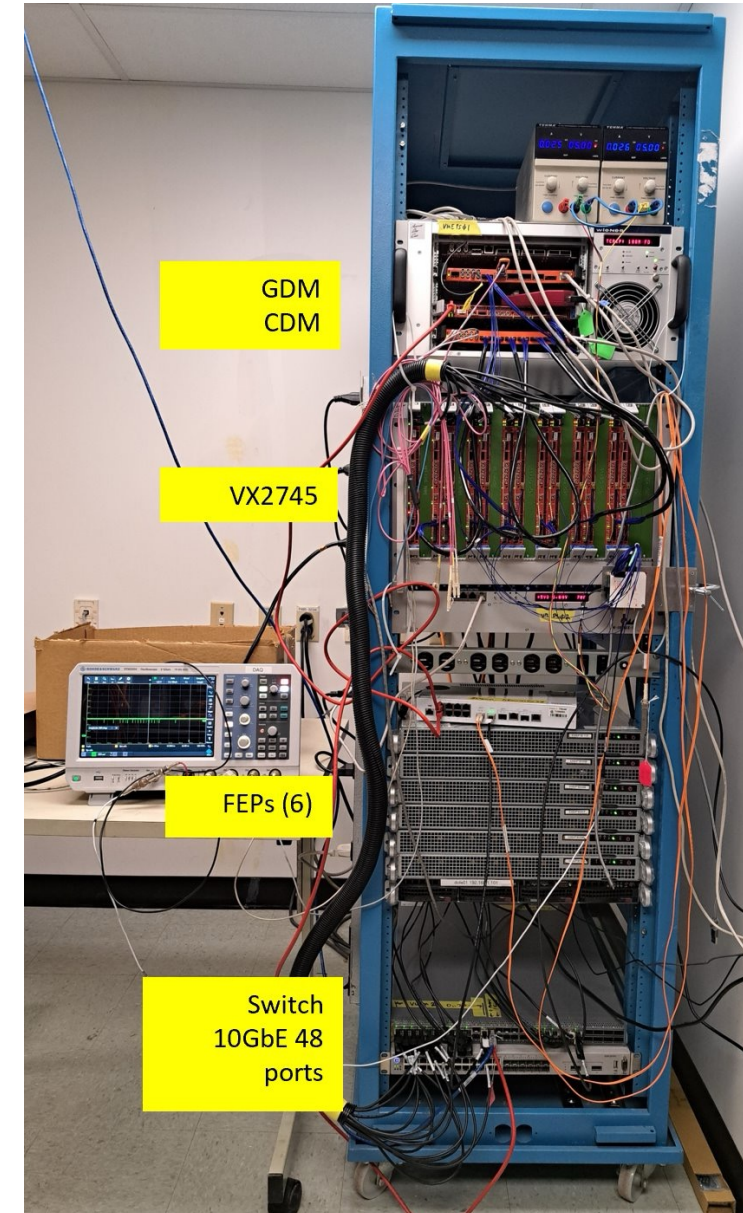
- Completed the TUCAN He3 Gas Handling Panels and continued the work on the B0 Coil.
- Continued to support nEXO & DarkLight.
- Renovation of the old compressor building to make space for HAICU.
- Supported IWCD: mPMT & Water Purity Monitor. Including trips to CERN by team members for installation and commissioning.

- Scintillator Shop Work (The limitation of only having one CNC mill remains the main bottleneck)



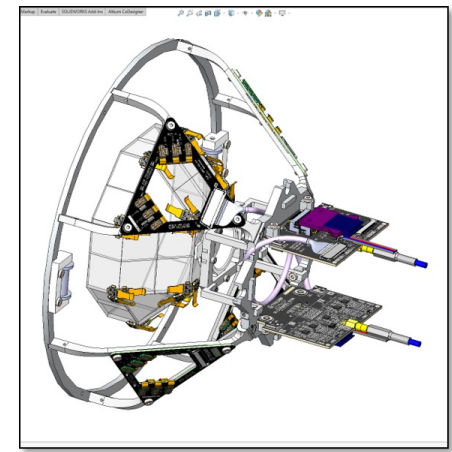
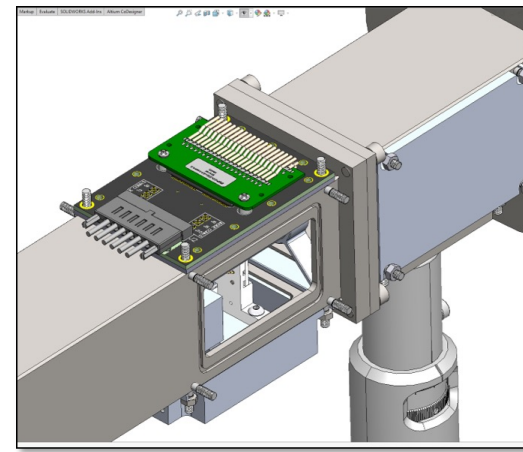
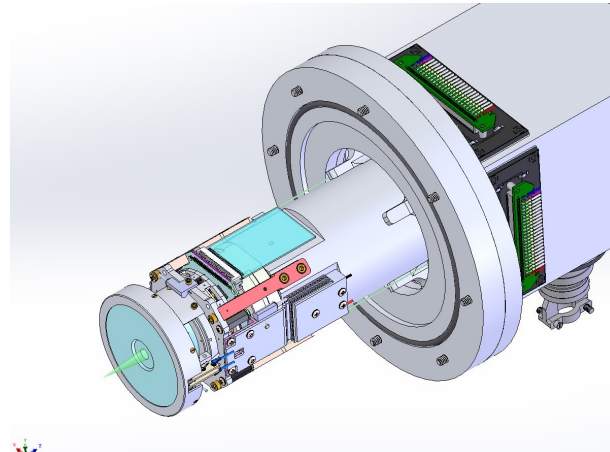
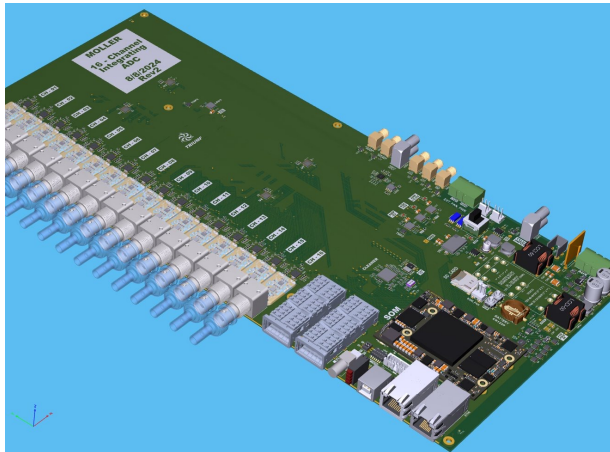
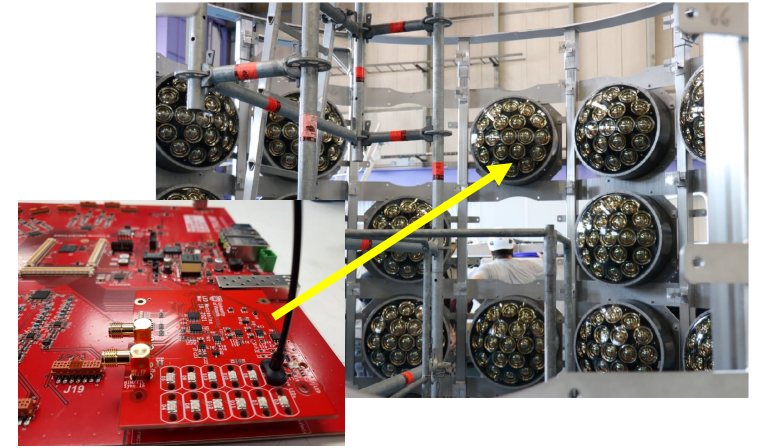
DAQ Group Highlights

- Continued the support of multiple programs (TUCAN, Hyper-K, DarkLight, P-ONE, GeneralFusion, PIONEER, DarkSide-20k ... and more).
- Highlight: DarkSide-20k
 - GDM-CDM - Clock and Trigger distribution
 - VX2745 CAEN digitizers running under 10gige network
 - Quadrant Setup at Triumf
- Thomas Lindner will be deputy group leader, as Pierre-Andre Amaudruz started his fellowship at LNGS (ITA).



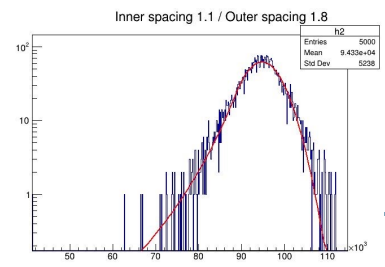
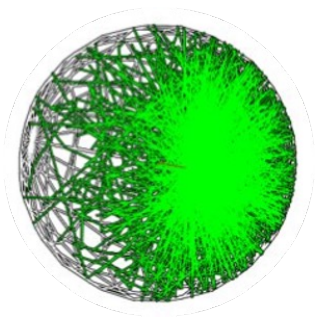
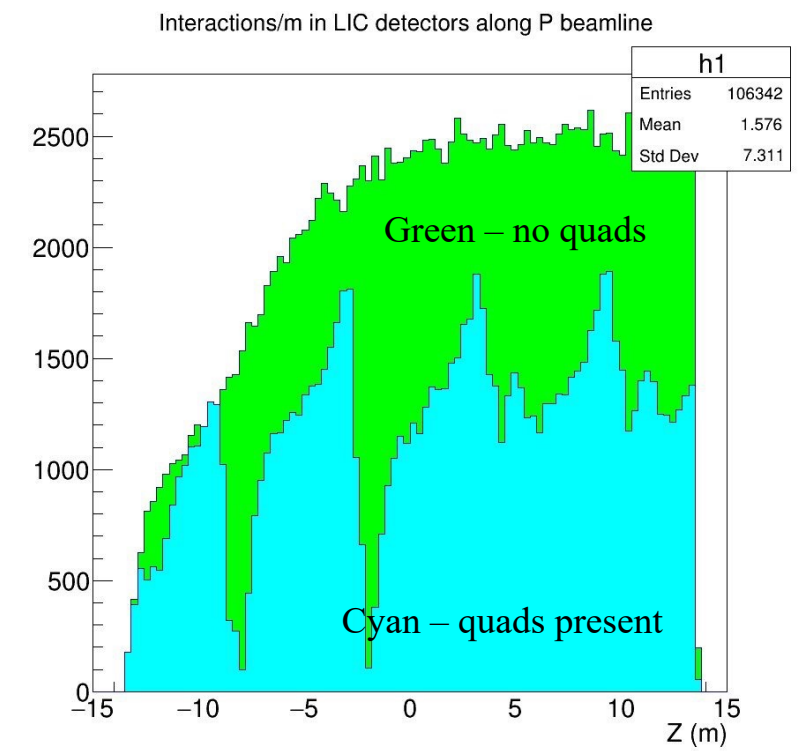
Electronics Group Highlights

- Development of the mPMT mainboard Rev2.
- Moller 16-Channel Integrating ADC
- CMMS NuTime SiPM Board, Sum and Feedthrough
- ARIES SiPM Electronics

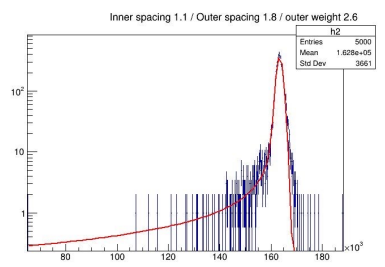


Conceptual Development Group Highlights

- PIONEER Simulations to Study of photo-sensor coverage and its effect on energy resolution in the spherical PIONEER geometry calorimeter (LXe).
- ARIEL's Machine Protection System Geant4 simulation of the **e** and **p** beamline failures with the added details of the focusing quads.
- TUCAN Cryostat Instrumentation Support.



Outer surface weighted by 2.6



Contributions to ARIEL

- Support of ARIEL is top priority priority, as we move into the shutdown period. This will impact the way Sci-Tech can support projects.
- Sci-Tech already supports different ARIEL tasks: panels design and construction, Raster magnet operation, and machine protection system simulations.
- Goal would be to identify self-contained projects where Sci-Tech groups can become owners and push over the goal line. Most effective operating way for this department. Preliminary discussions in early November, follow up by the whole team in mid-December.



New Technologies & Technology Transfer

Save the forest - Early forest fire detection

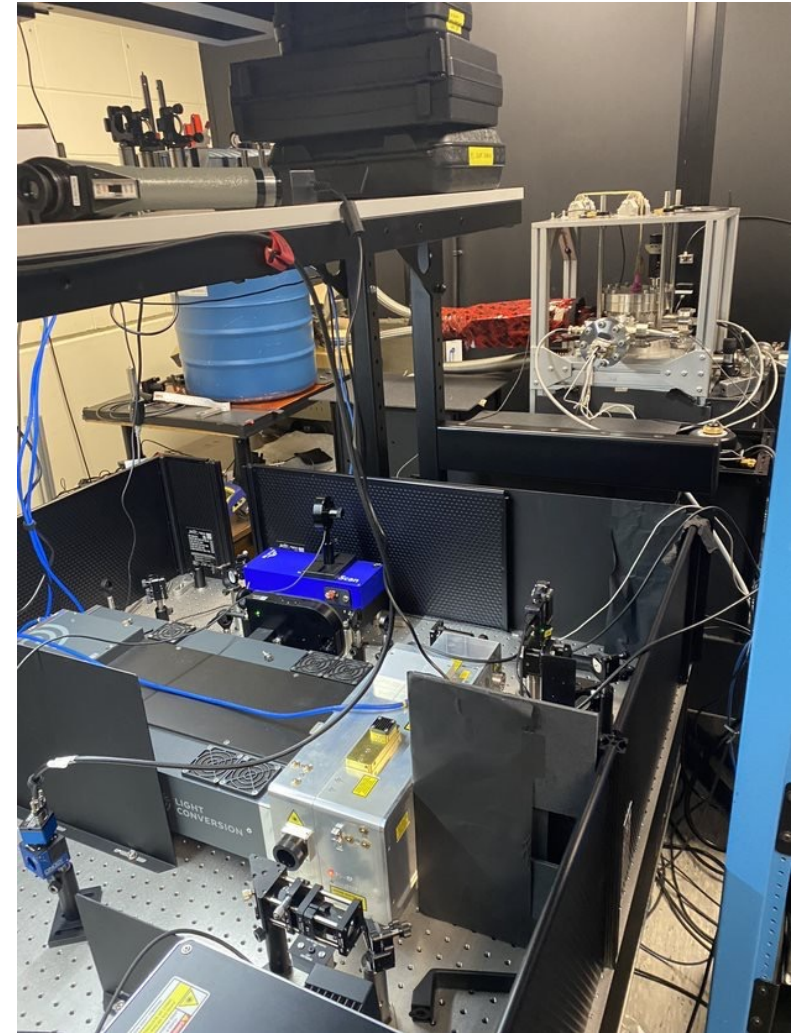
- *NFRF exploration submitted early November for identifying the optimum modality for early forest fire detection at the scale of BC (smoke, CO, static array, drones,...?)*
- *Canada/France/ Korea Eureka grant submitted with SenseNet for the development of a ultra-low power smoke detector with digital SiPM*

Save the whales - underwater depth detection using light rather than sound

- *Contract work with Envisioning Labs*
- *SiPM based LIDAR system*

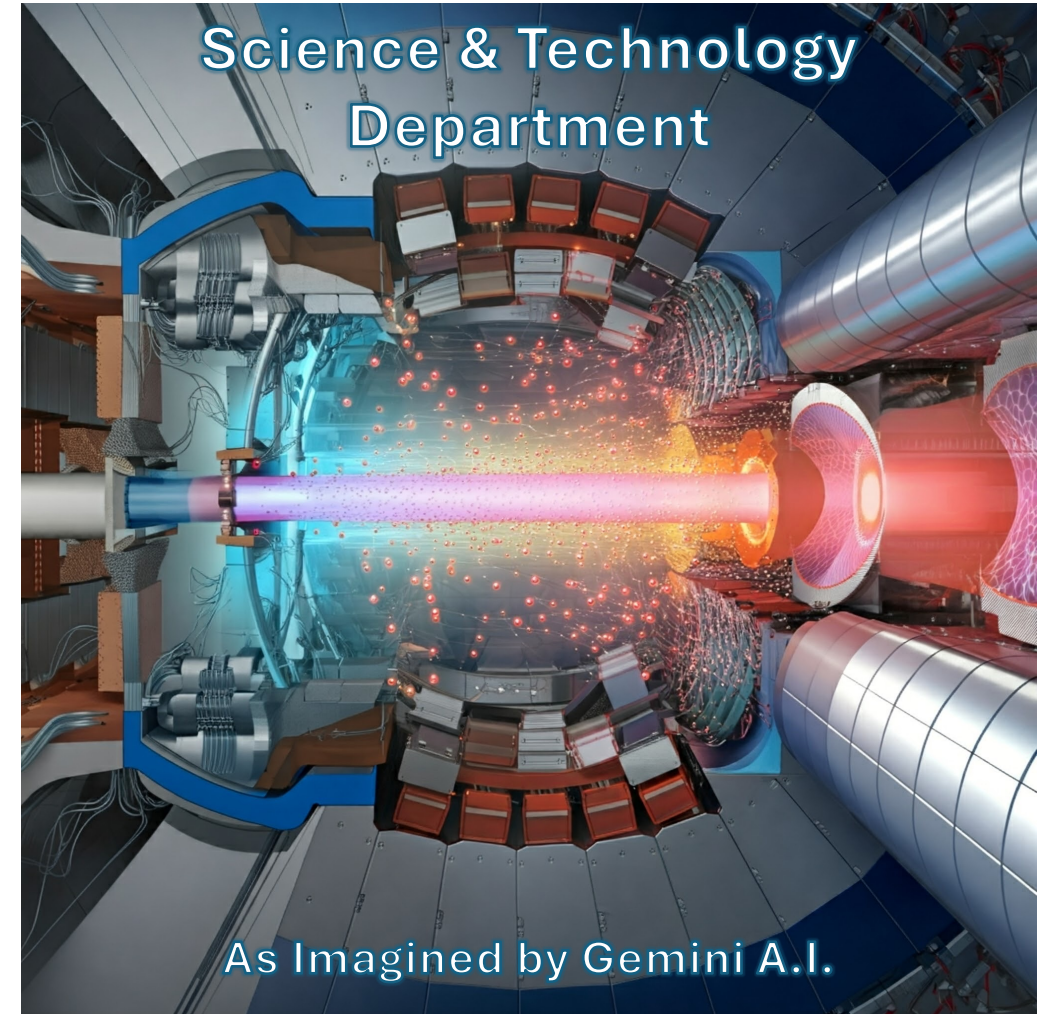
Clean energy – detecting the neutron produce by Fusion reaction

- *NSERC ALLIANCE with General Fusion*
- *Single photon timing resolution less than 100ps demonstrated*



Conclusions

- Sci-Tech continues to support a large fraction of the TRIUMF programs (~70 projects per QRPP cycle).
- Improving efficiency: our machine shop capabilities could be greatly improved with the addition of an extra CNC machine.
- We have started the process of coupling more and more with ARIEL. This work will impact how Sci-Tech can support projects during the shut down period (all hands-on deck).

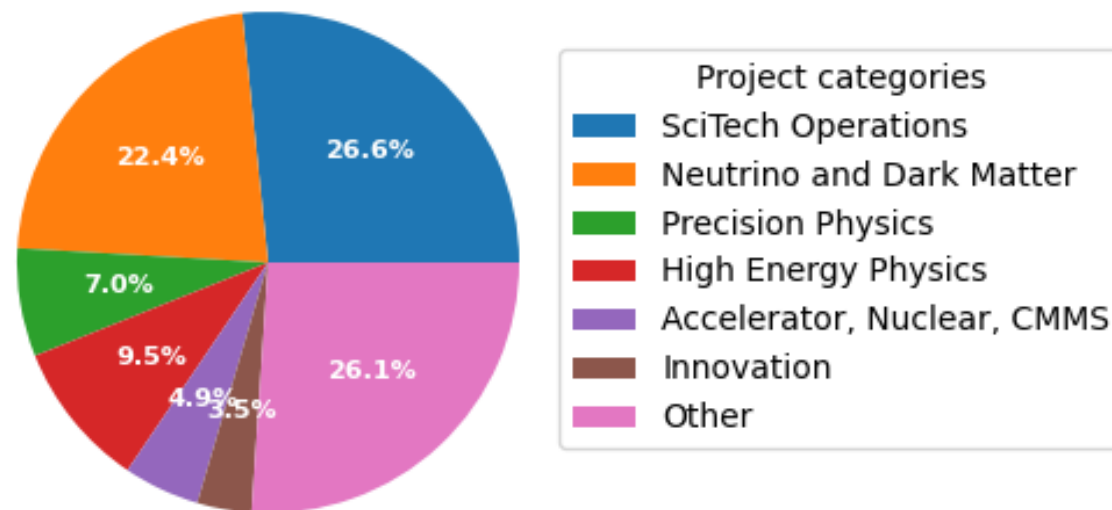


BACK UP SLIDES

Hours & Projects Breakdown

Total hours by project category:

SciTech Operations 4876.75
 Neutrino and Dark Matter 4108.25
 Precision Physics 1278.25
 High Energy Physics 1733.0
 Accelerator, Nuclear, CMMS 897.5
 Innovation 640.5
 Other 4769.25



SciTech Operations: O_30

Neutrino and Dark Matter: Hyper-K, nEXO, DarkSide-20k, Super-CDMS, P-ONE

Precision Physics: TUCAN, HAICU, PIONEER, DarkLight,

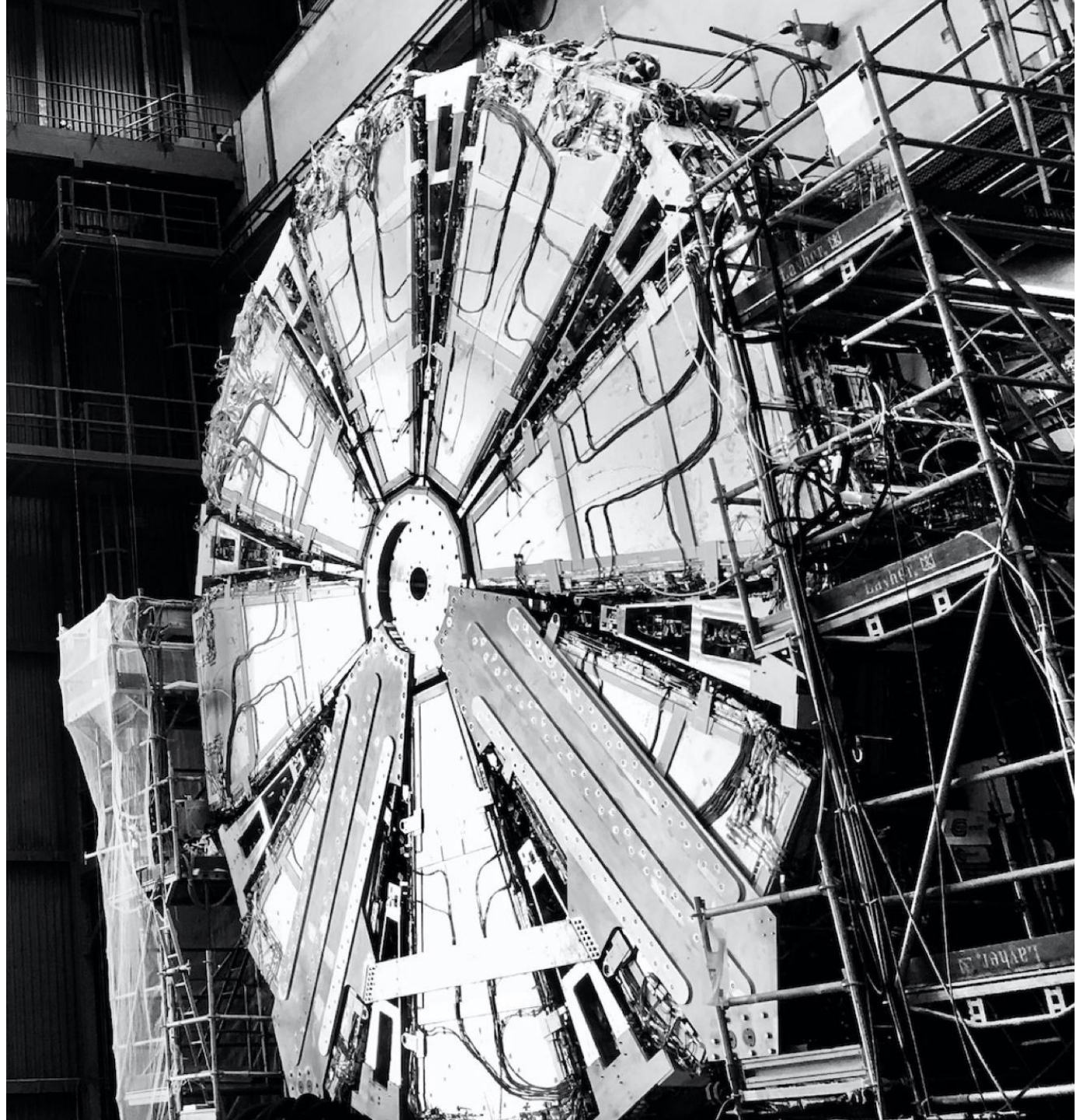
High Energy Physics: ATLAS

Accelerator, Nuclear, CMMS: NuTime, ARIEL, Moller, ISIS

Innovation: General Fusion, Water Purity Monitor

ATLAS Update

Max Swiatlowski, obo the ATLAS team



The TRIUMF ATLAS Group

BAE Scientists:

- Nigel Hessey
- Kate Pachal (adj. UBC)
- Oliver Stelzer-Chilton (adj. UBC)
- Reda Tafirout
- Maximilian Swiatlowski
- Isabel Trigger (adj. UVic)

University Joint Faculty

- Doug Gingrich (Alberta)
- Pierre Savard (Toronto)
- Bernd Stelzer (SFU)
- Mike Vetterli (SFU)

Affiliated Scientists

- Matthias Danninger (SFU)
- Rob McPherson (Victoria)

Detector Physicists

- Leonid Kurchaninov
- Luise Poley

Postdoctoral Fellows

- E. Filmer
- M. Basso
- D. Portillo (at CERN)
- E. Perez (at CERN)
- S. Tsigaridas (at CERN)
- M. Valente

Graduate Students

- R. Bate (UBC)
 - L. Brown (Victoria)
 - A. Bunka (UBC)
 - E. Carlson* (Victoria)
 - K. Leong (UBC)
 - C. McCracken (UBC)
 - S. Ramen (UBC)
- Plus 2-3 undergraduates throughout the year

- J.C. Rivera (Victoria)
- R. Salami (SFU)
- D. Sheppard (SFU)
- T. Saarinen (UBC)
- K. Usmanov (UBC)

Plus ~15 engineers, technicians, and Tier 1 computing personnel

* *Just graduated!* 🎓

The New “Small” Wheels: Upgraded Muon Detectors

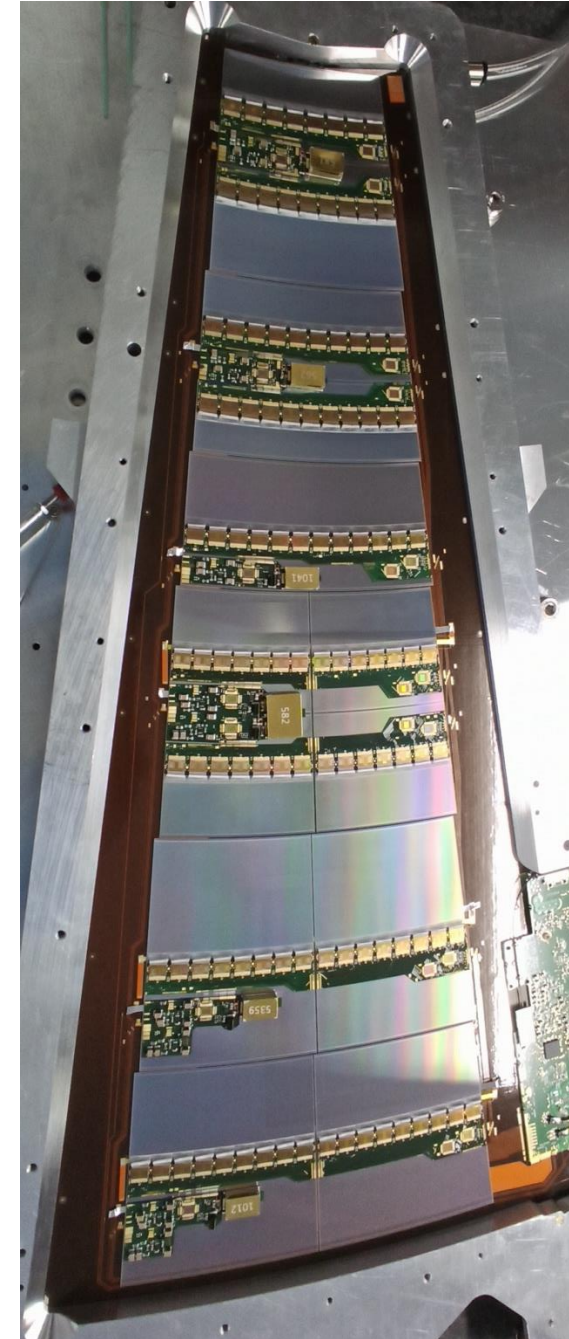
- Both wheels installed and operational since 2022
- First deployment in triggering: regularly participating in 2023 and 2024 triggering
- Current focus on high voltage failures during high lumi pp collisions: leading long-term GIF++ aging studies and investigations at CERN

- **5YP Goals: Continue NSW strip trigger commissioning in preparation for HL-LHC**

- Critical upgrade for trigger muons at high luminosity
- Major TRIUMF contributions to construction (half-gaps for 54 quadruplets)
- Significant TRIUMF contributions to installation and operation
- Leadership: R. McPherson (sTGC project leader), E. Perez (NSW deputy project leader), I. Trigger (sTGC coordinator), S. Tsigaridas (sTGC operations manager)

ITK: the Inner Tracker Upgrade

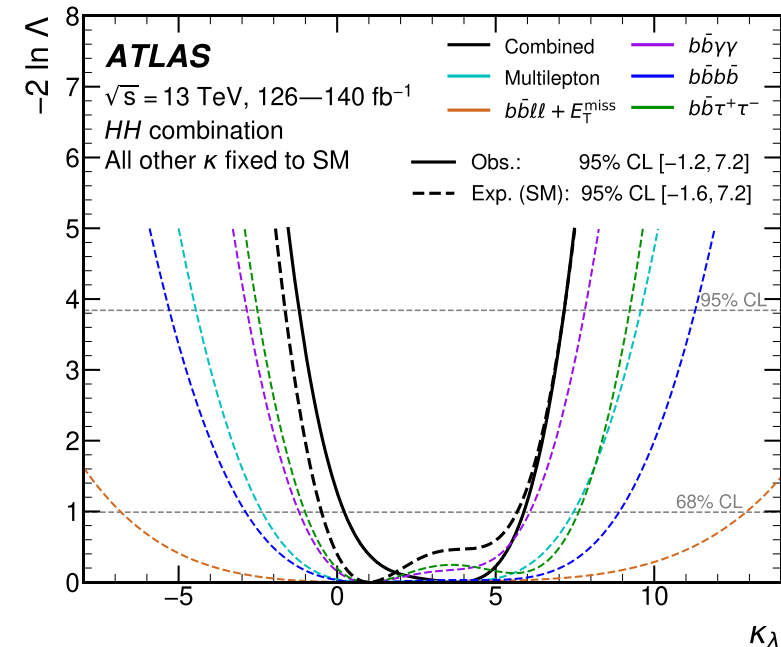
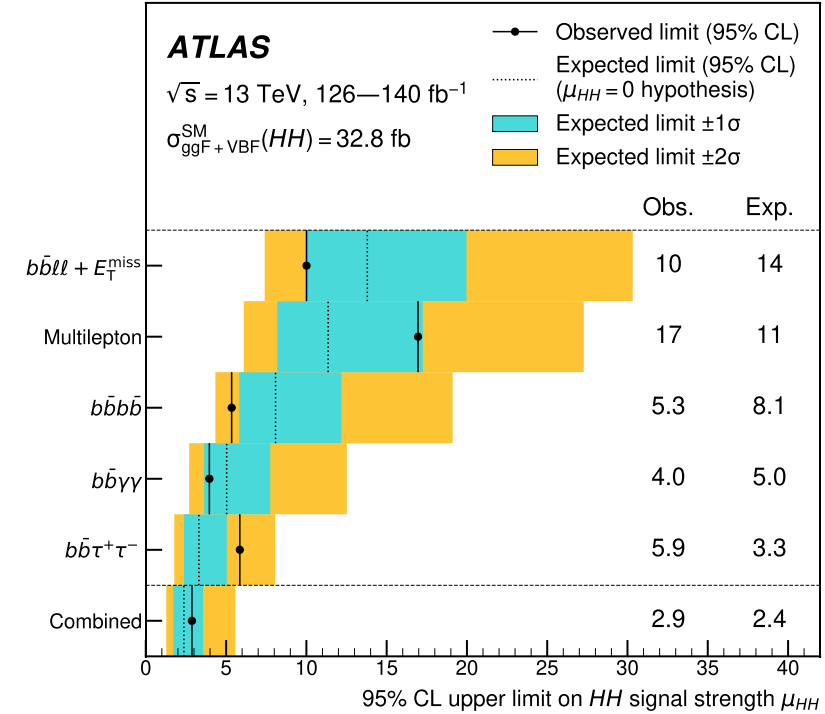
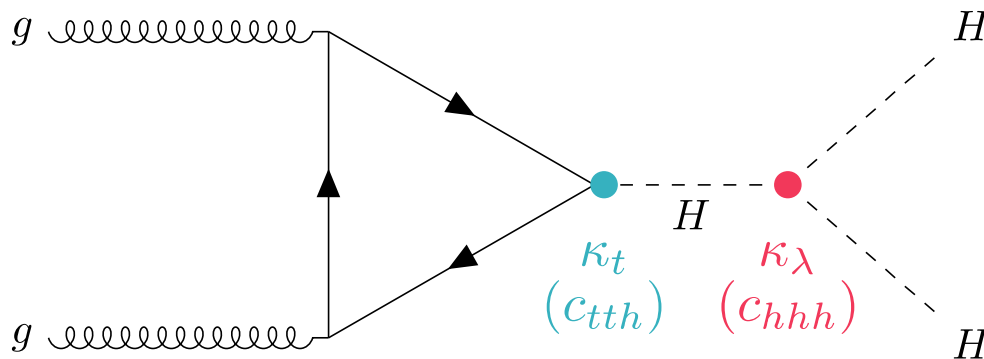
- Major upgrade to ATLAS inner tracker: $\frac{1}{4}$ of endcap petals and $\frac{1}{6}$ of module production, $\frac{1}{4}$ of sensor testing, at SFU/TRIUMF
- Significant TRIUMF leadership: L. Poley (strip module coordinator), B. Stelzer (module mounting coordinator)
- Recent progress:
 - Vancouver team leading investigations & solutions to 'module cracking' in endcap
 - Reliability problem at low temperatures
 - Produced only two petals with both potential solutions fully deployed: key for next ATLAS FDR
 - Leading central reporting framework development
- **5YP Goals: production and commissioning ITk**



Physics Highlight: DiHiggs

Measuring Higgs pair production allows for measurement of the Higgs potential via $\kappa\lambda$ coupling

- Latest combination of searches using Run 2 data published: [Phys. Rev. Lett. 133 \(2024\) 101801](#)
- ATLAS sub-group led by M. Valente, several papers led by M. Valente and M. Swiatlowski (including forthcoming ATLAS+CMS combination)
- **5YP Goals: Full Run3 combination (focus on 4b+comb), pushing towards 3σ with CMS**



Trigger and Performance:

- Muon trigger scale factors, Global Performance and Particle Flow development (group convener), Trigger Upgrade Physics coordinator

LAr Phase 1 and Phase 2 Upgrades:

- LAr phase 1 upgrade commissioned and operational: significant trigger bandwidth improvements
- Phase 2 frontend ASIC being developed at TRIUMF: fully digital readout, all 2σ cells read out at 40 MHz

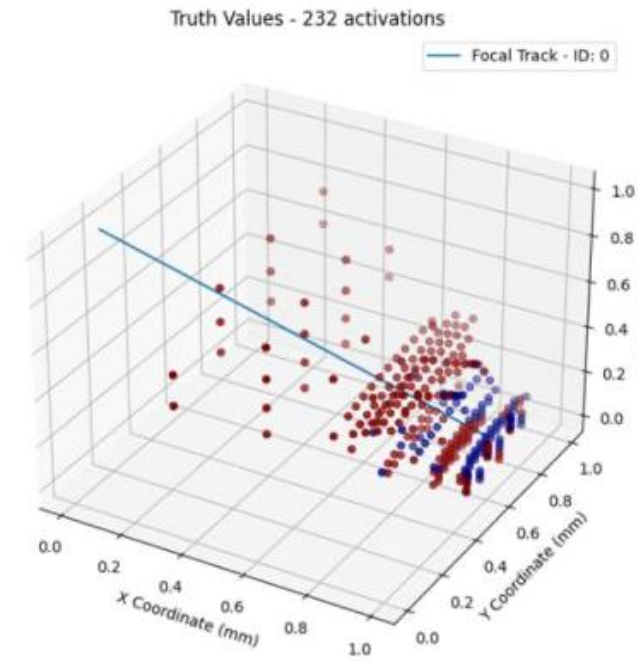
Tier 1 computing center operations and upgrade

- Running at high efficiency
- CFI application for HL-LHC operations submitting soon

Physics analysis: measurements and searches

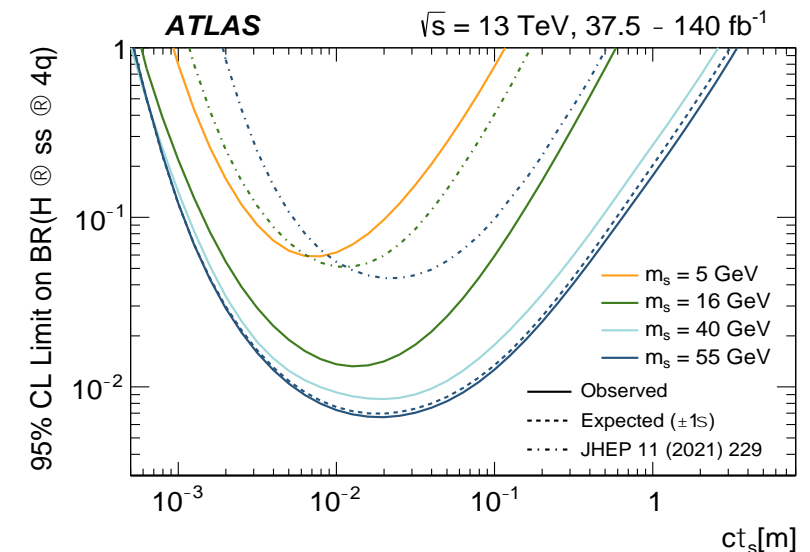
- Higgs properties (WW* channel group convener)
- BSM searches (especially long-lived)
- Diboson production measurements, including EFT

5YP Goals: Deliver upgrade, push BSM searches, develop Higgs and EWK measurements



ML models for PFlow and Trigger

Limits on Higgs decays to LLPs



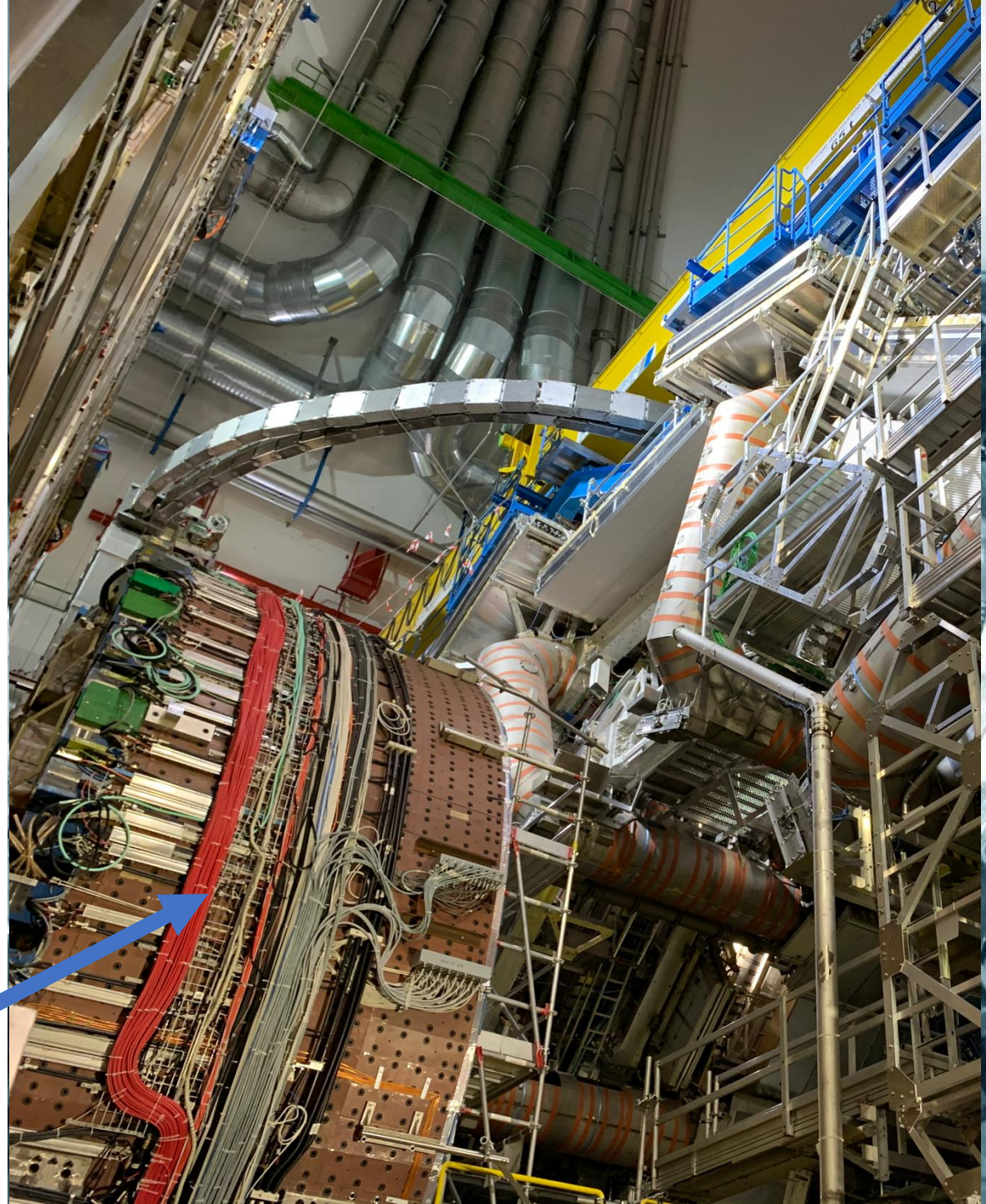
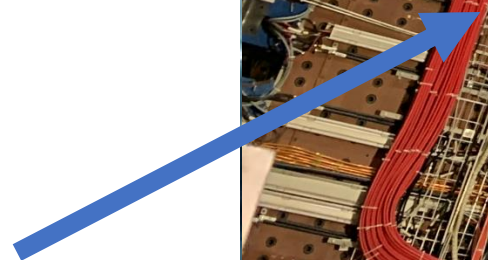
Thank you
Merci

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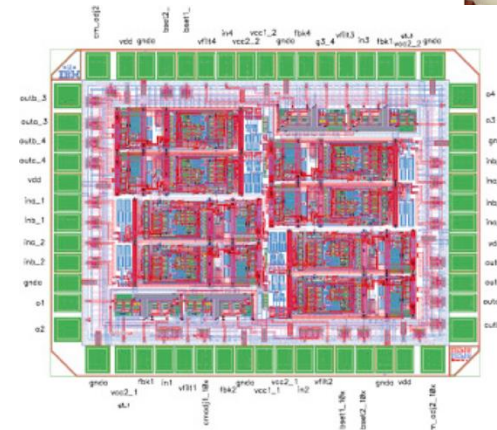
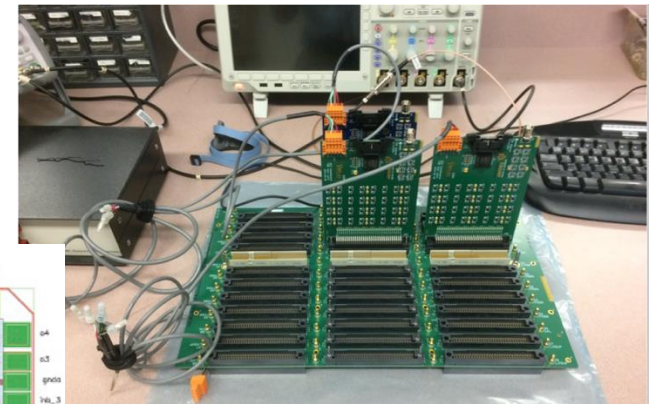
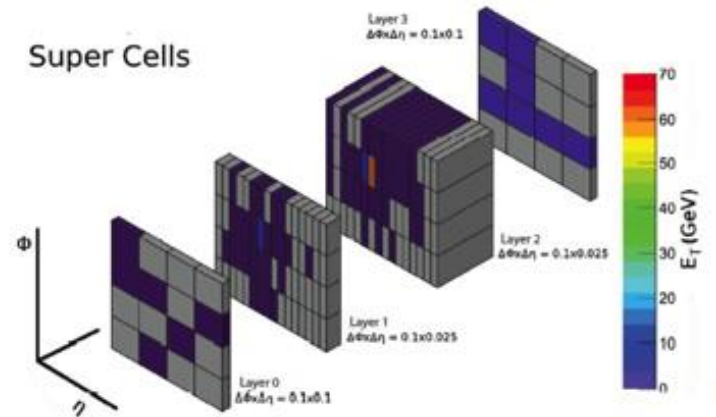


Hadronic Endcap Calorimeter:
Produced at TRIUMF!

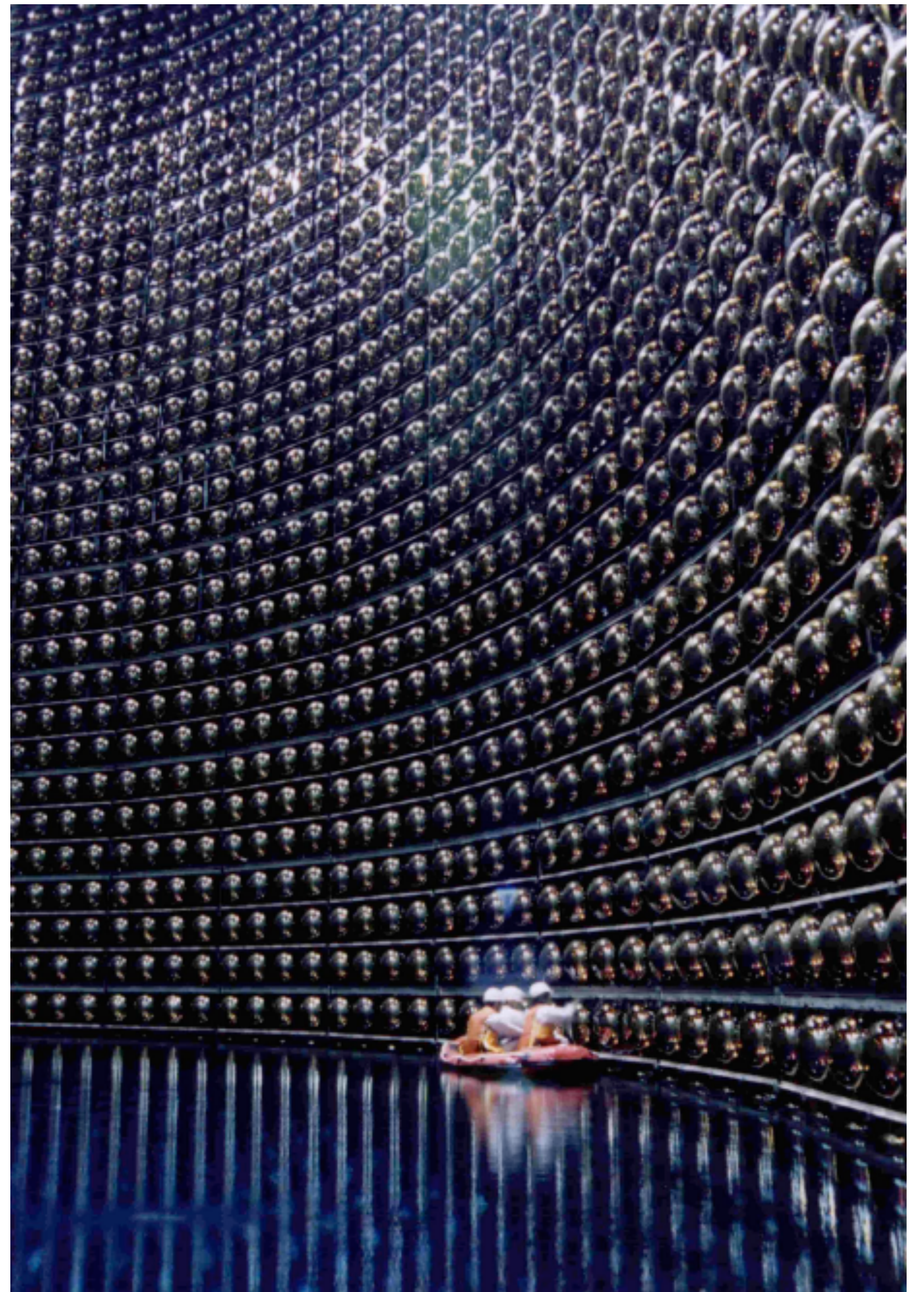


Liquid Argon Calorimeter Electronics Upgrades

- Key component of ATLAS trigger strategy for Run-3
- Canadian expertise in Hadronic Endcap from original ATLAS detector design and construction
- Improve granularity of information supplied to the Level-1 trigger to improve background suppression
- Phase 1: Implementation requires new Front-End Crate “baseplanes”
 - Design, prototyping and assembly at TRIUMF
 - Fully installed and commissioned for 2022
- Phase 2: Complete replacement of Front End (FE)
 - TRIUMF focus on new FE ASIC design
 - Preproduction yield 92%
 - Full production and packaging in progress
 - Radiation testing and QC tests soon



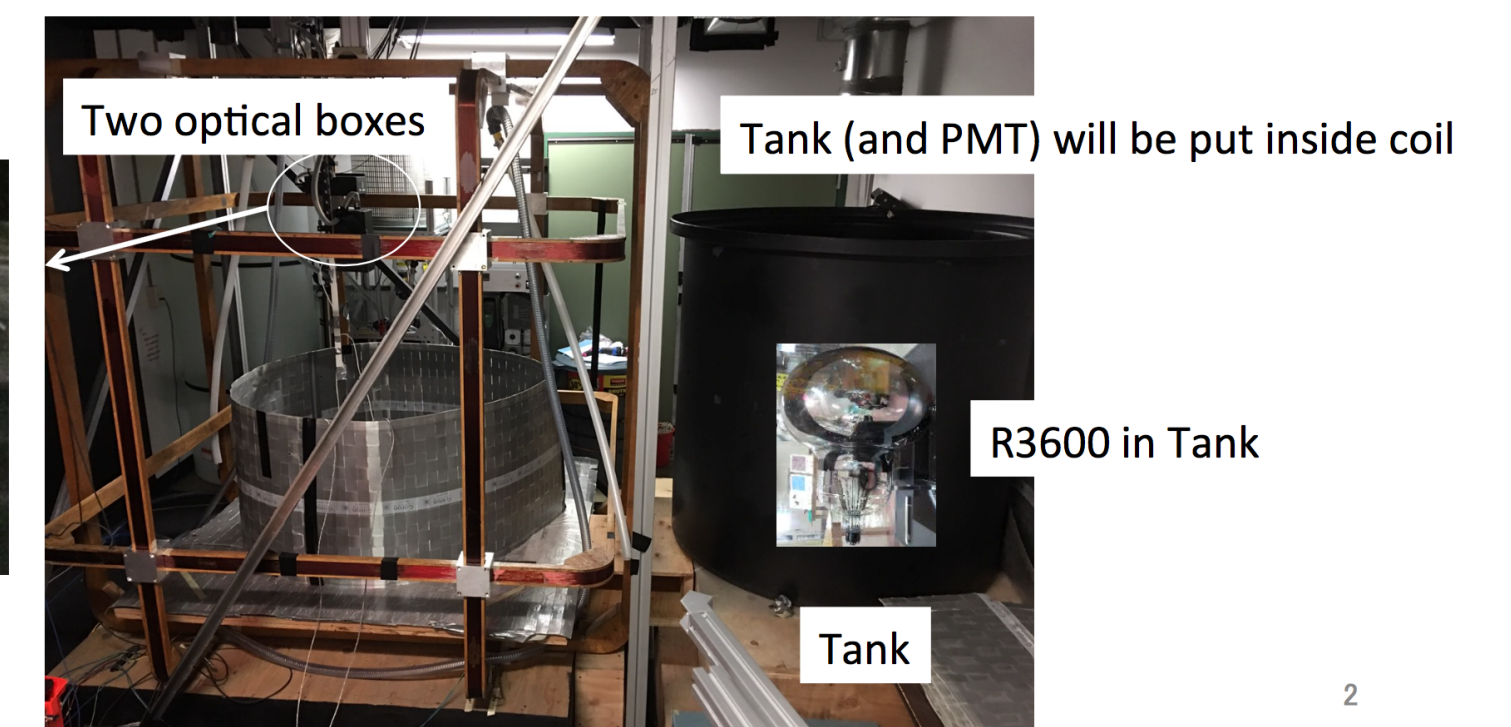
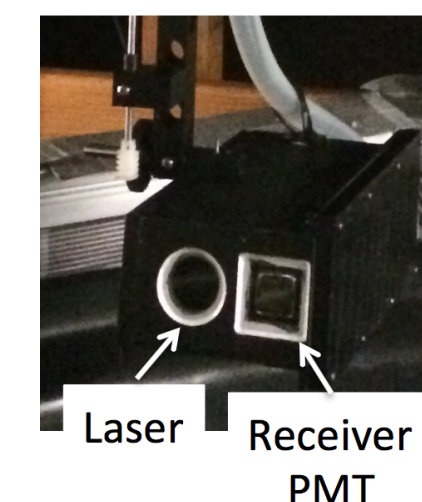
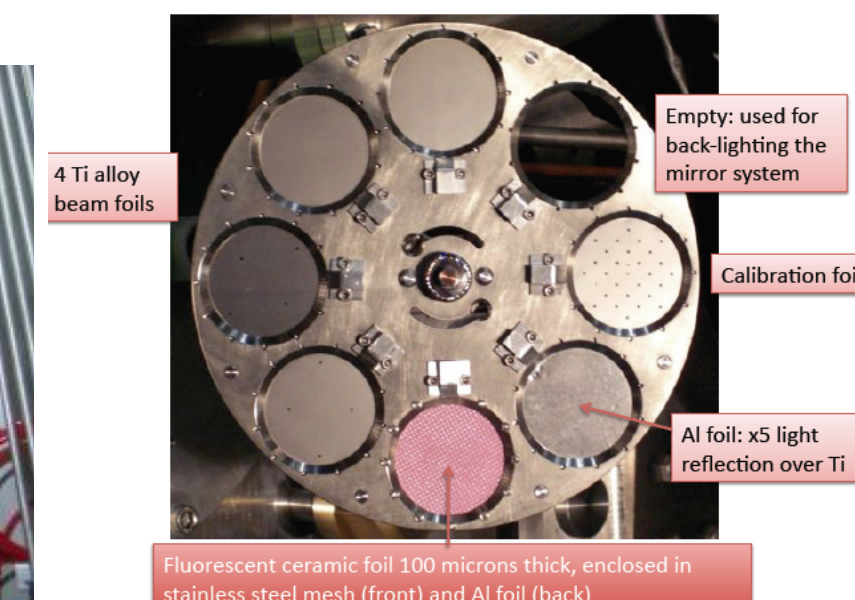
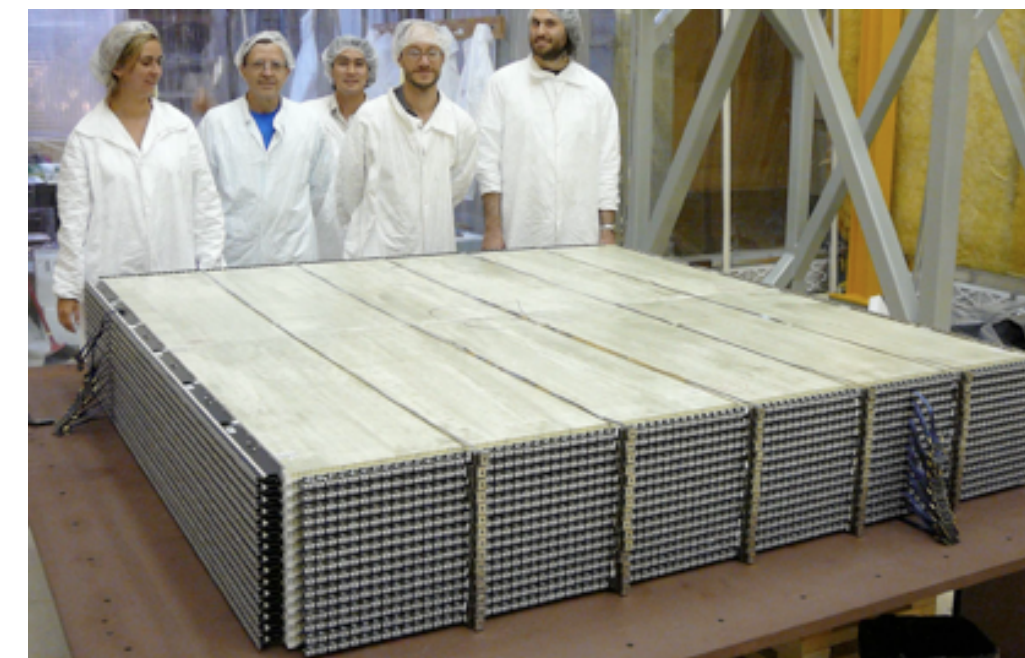
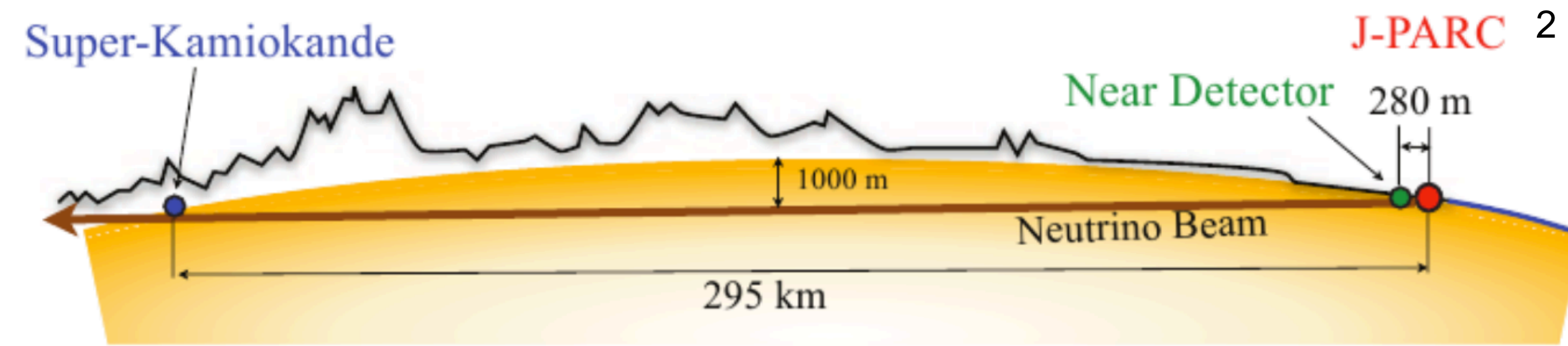
T2K/HyperK Updates



Discovery,
accelerated

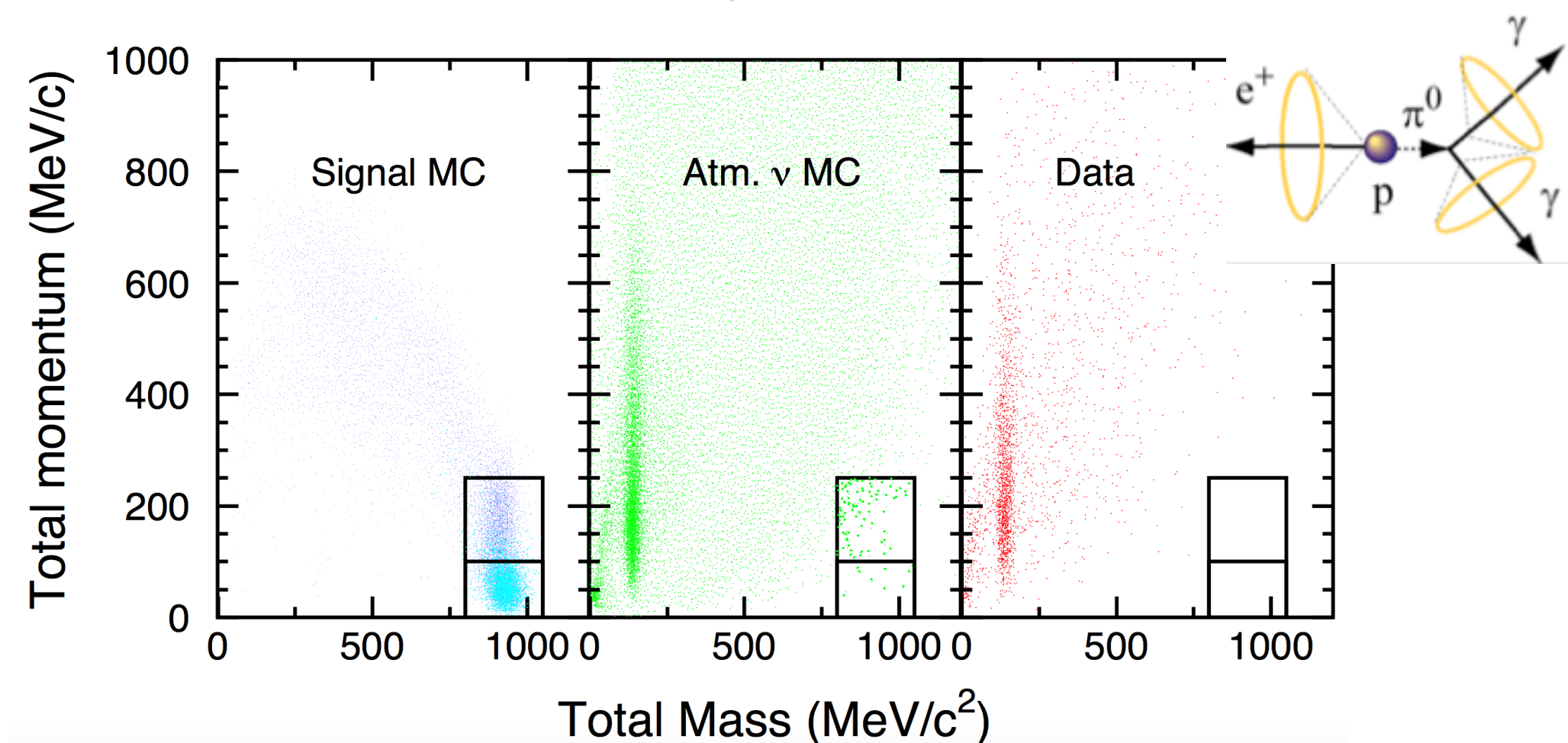
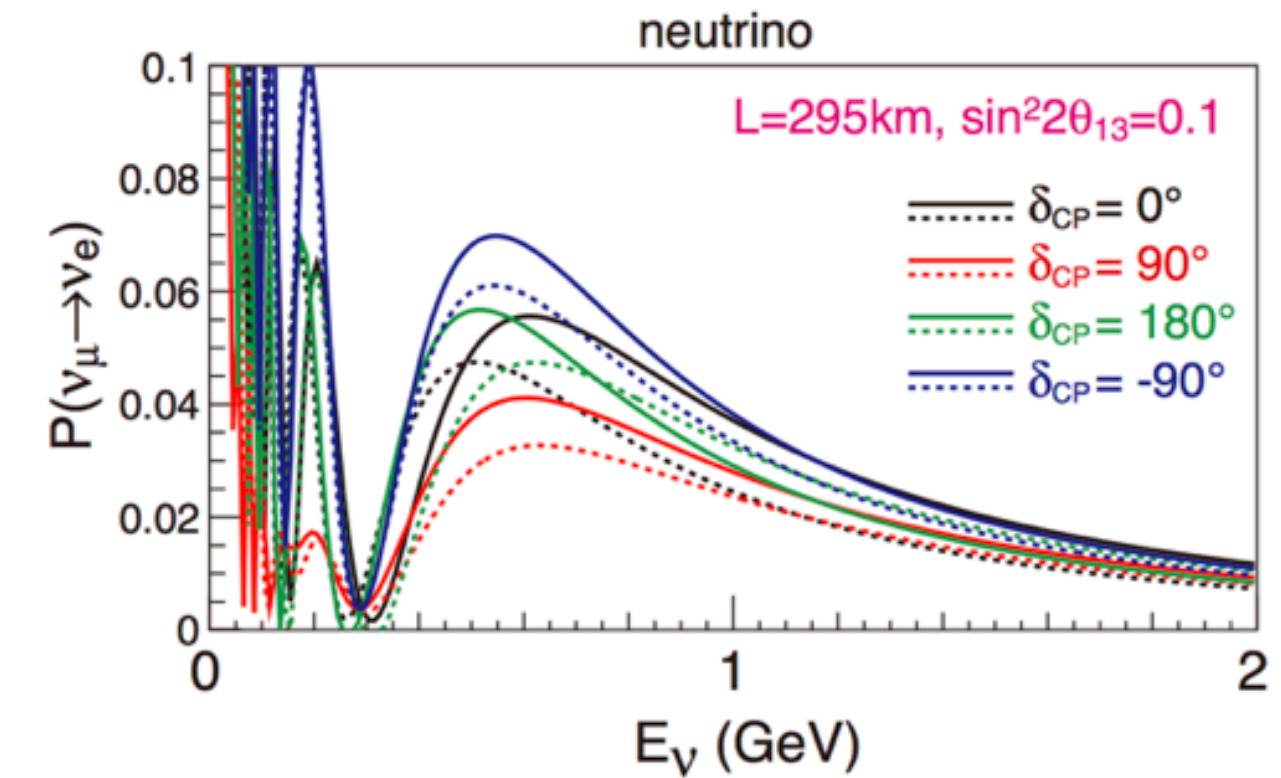
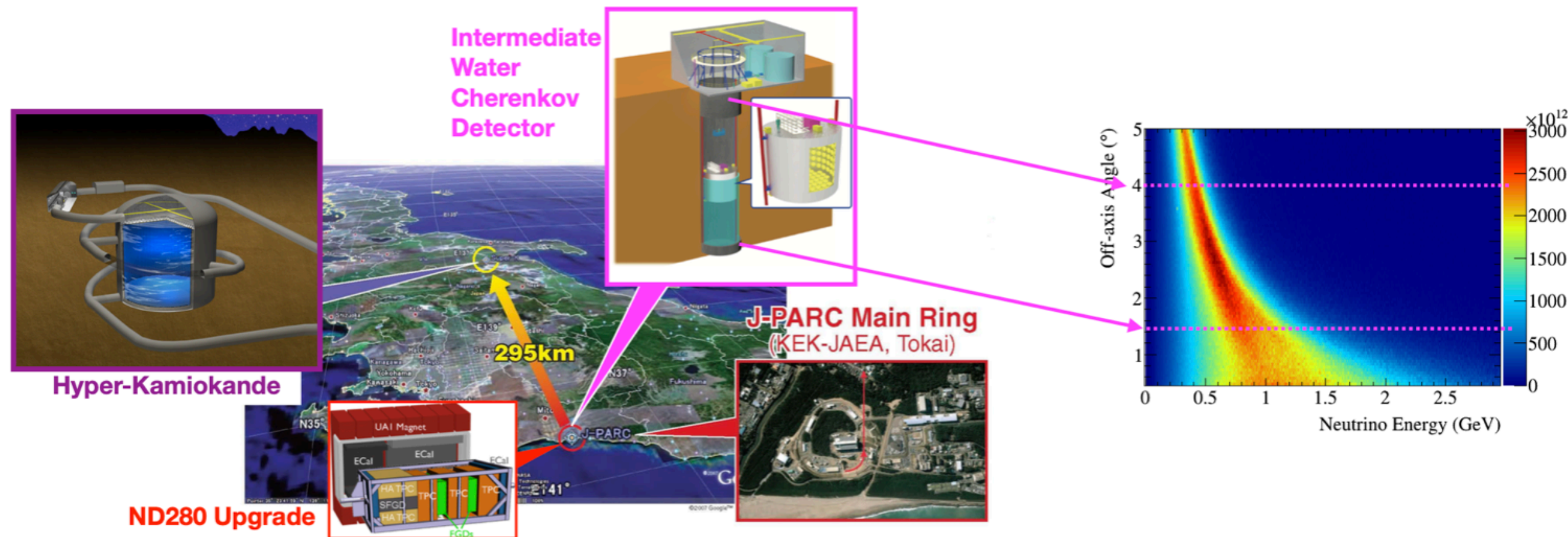
T2K and SuperK

- Canadian contributions to T2K and SuperK
 - Design: Off-axis beam concept, $\nu_\mu \rightarrow \nu_e$ with ν superbeam
 - Remote handling cell, FODO combined function lattice
 - KEK-TRIUMF collaboration from KAON factory
 - TPC (MPGD), FGD (SiPM), OTR in front of the target
 - Analysis: beam, near detector (Banff fit), SK fit (FitQun)
 - Analysis coordinator (leader): Hiro Tanaka, Mark Hartz
discovery of $\nu_\mu \rightarrow \nu_e$ appearance and hint(?) of CP viol.
- On-going and future contributions
 - Operation and upgrade of the OTR monitor (RTI)
 - Remote handling upgrade at the final focusing section (RTI)
 - PMT characterization at the photosensor test facility (PTF)
 - Urgent magnetic field effect study on-going
 - SuperK event reconstruction using machine learning
 - WatChMal (Water Cherenkov Machine Learning)
 - improved angular resolution and particle identification



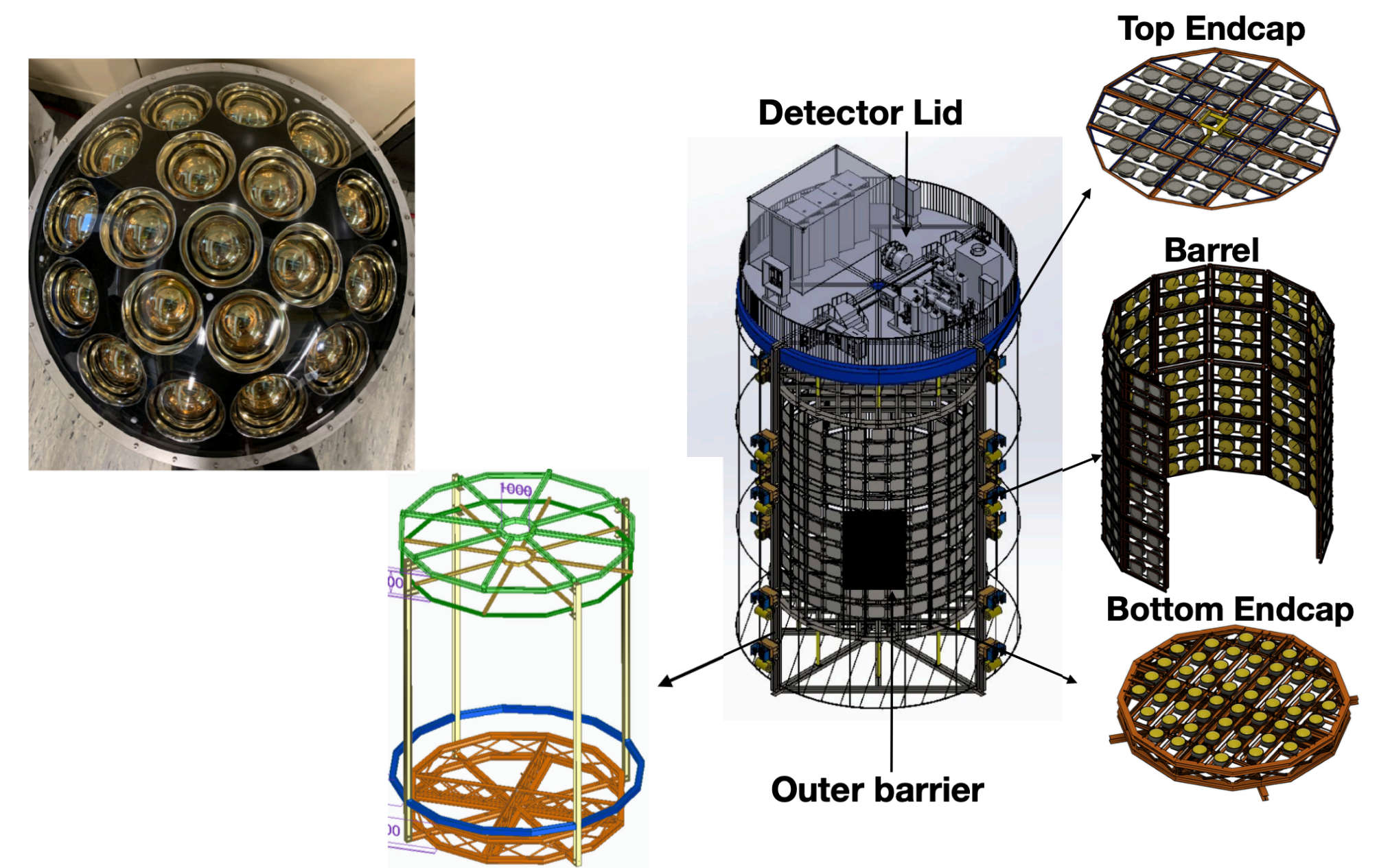
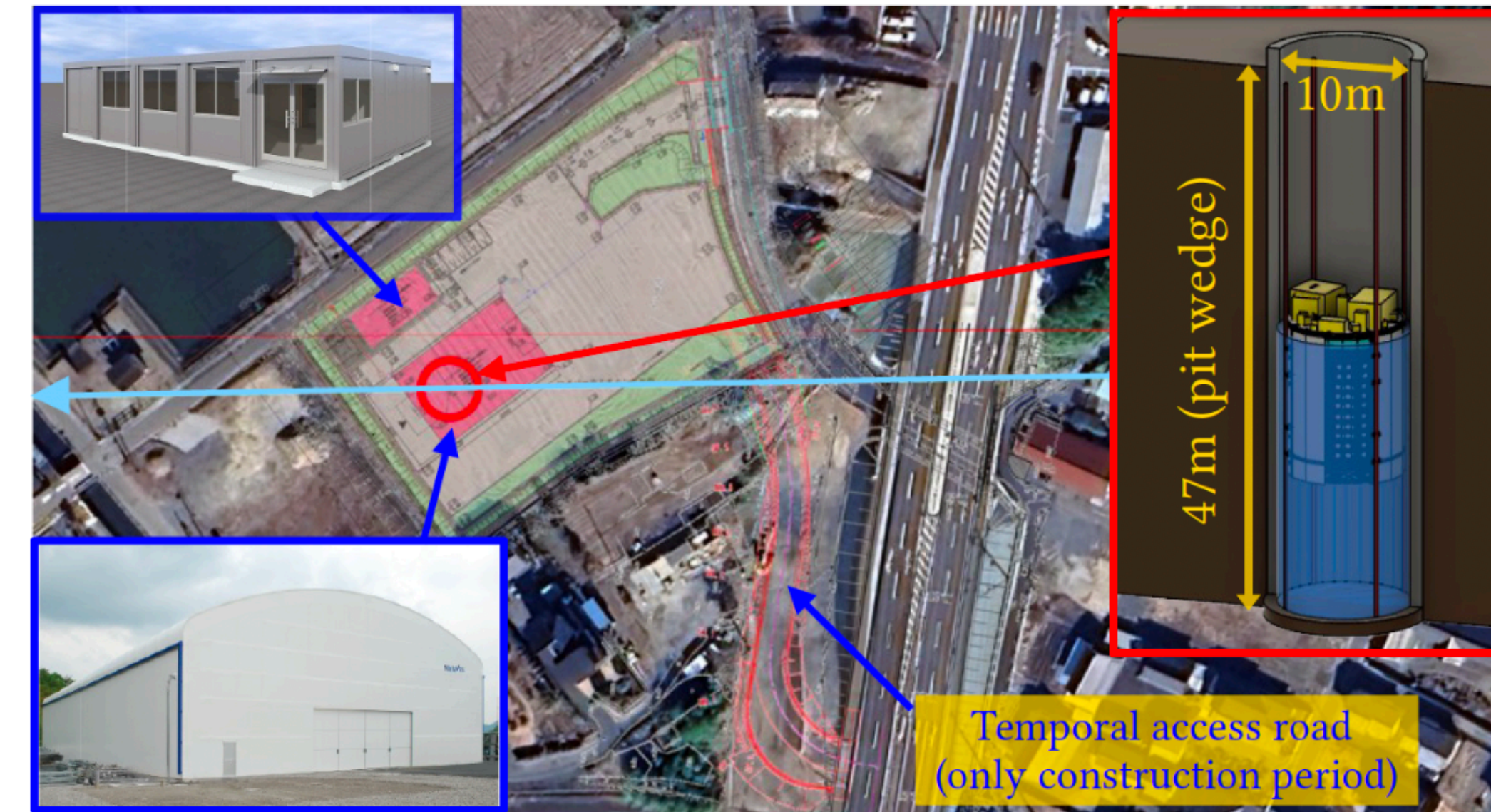
HyperK

- The next generation HyperK construction under way
 - x8 larger fiducial volume, x2.5 higher intensity (1.3MW)
 - Near water Cherenkov (IWCD) proposed/lead by Canada
 - “Prism” approach, also adopted by DUNE
 - Project leader: Mark Hartz
 - Start data taking in the end of 2027
- Wide range of physics topics
 - Precision measurement of neutrino oscillation and CP violation
 - long baseline from J-PARC, atmospheric neutrinos
 - BSM physics: nucleon decays, dark matter search, $n-\bar{n}$ oscillation
 - Neutrino astronomy: supernova burst, diffused (relic) supernova
- Canadian contributions
 - IWCD to address systematic uncertainty in flux and cross section
 - Calibration in the far detector: funded by CFI2023
 - LED multi-PMT (mPMT): 7000 pulsed sub-nsec LED
 - photogrammetry for geometry measurement and water monitoring



Intermediate Water Cherenkov detector (IWCD)

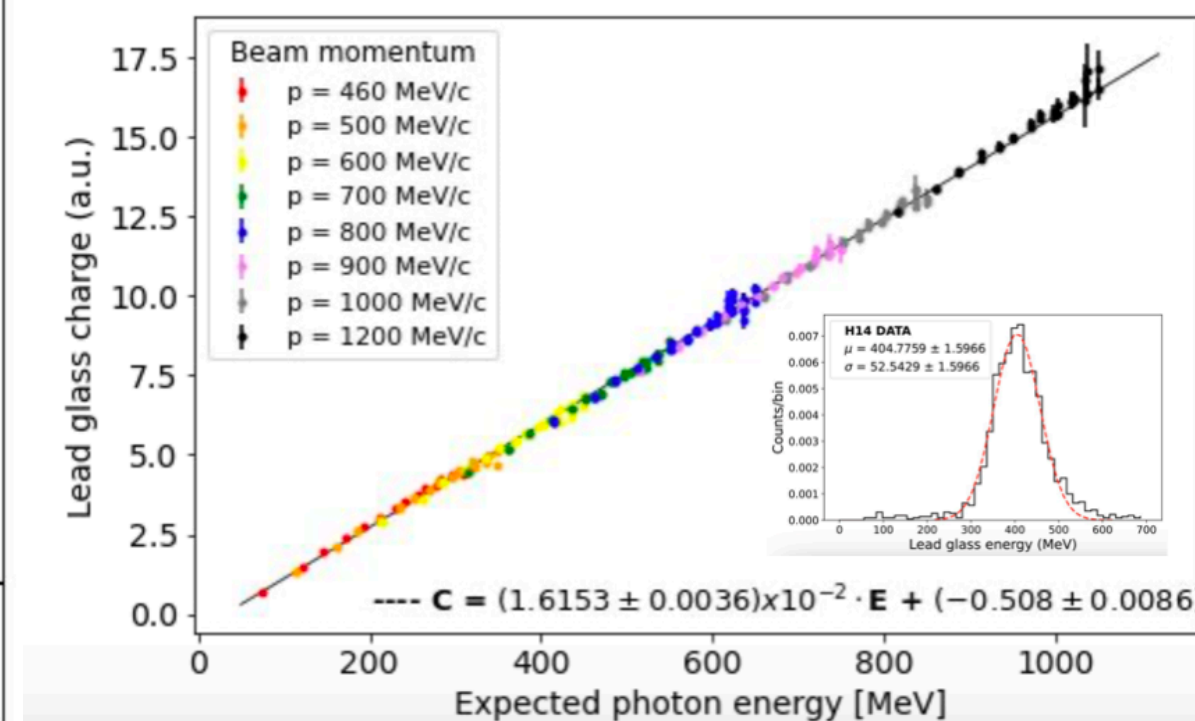
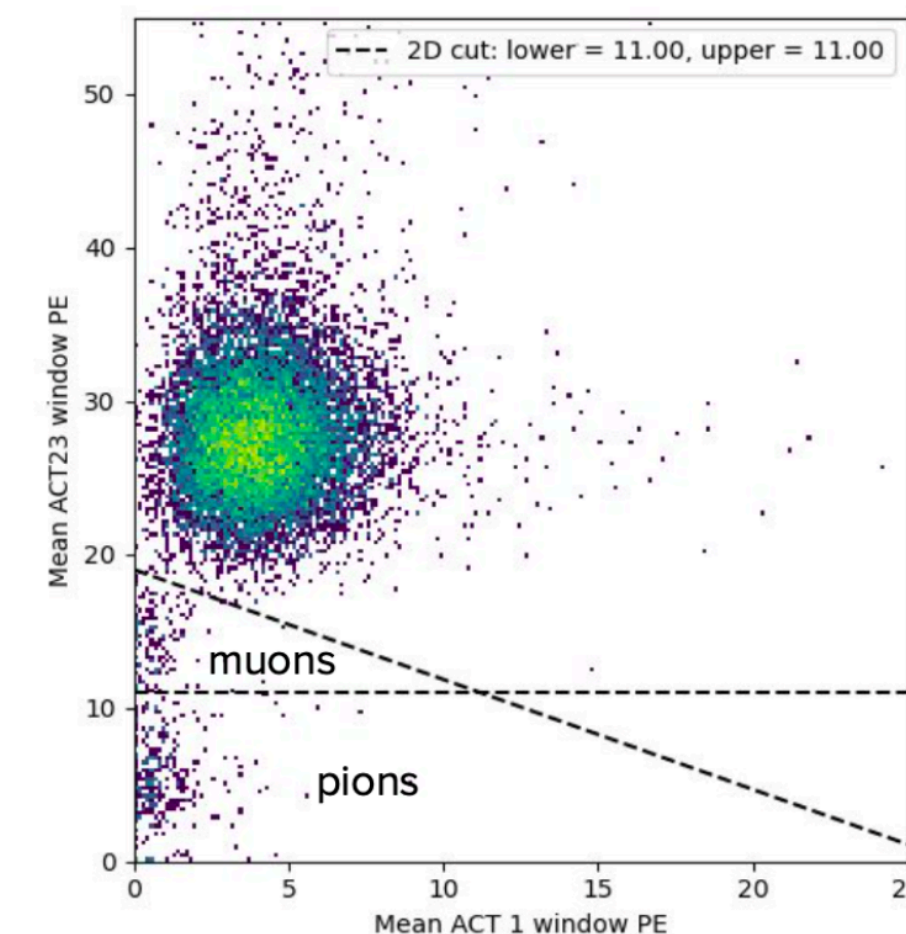
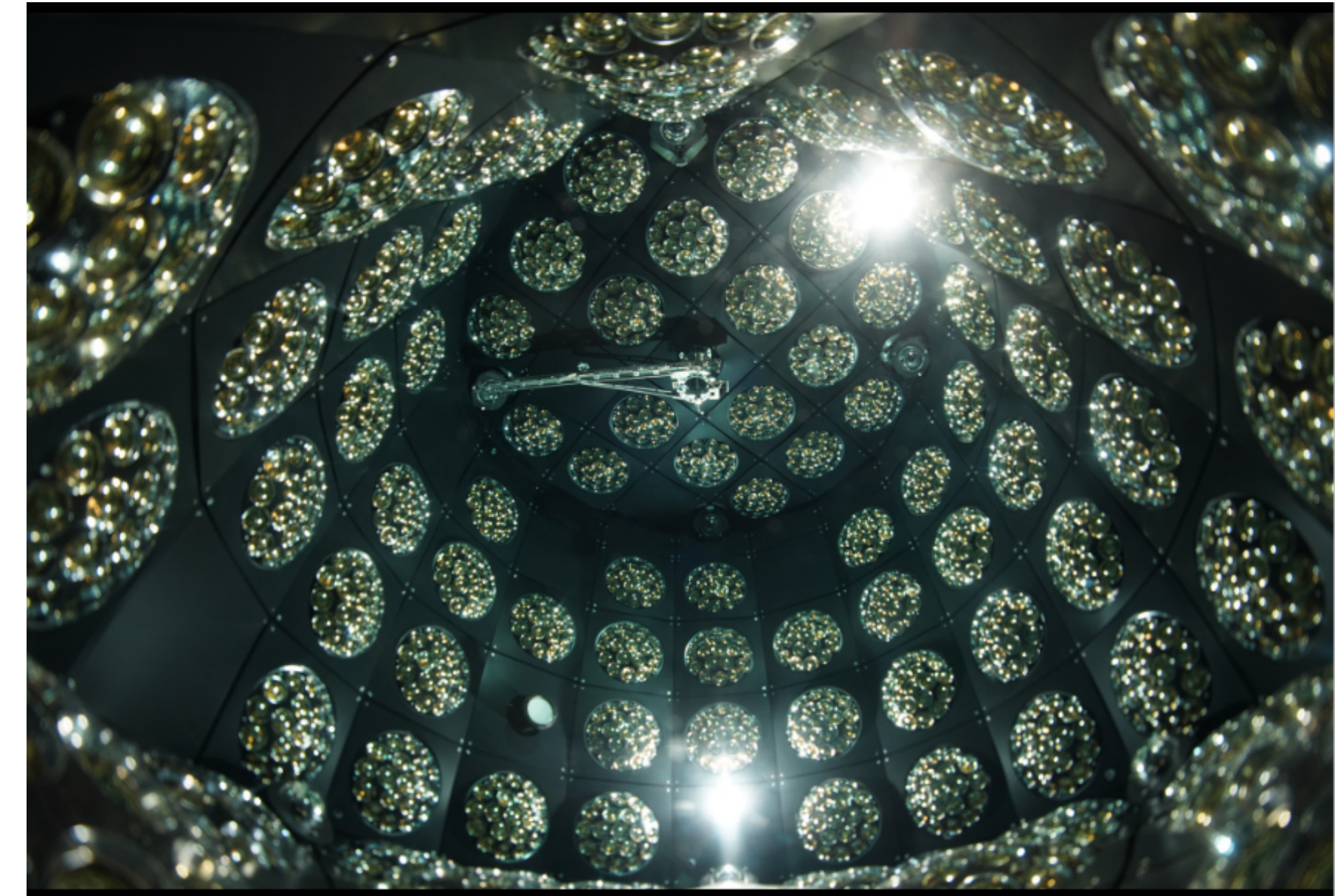
- NuPRISM concept developed at TRIUMF
 - Correlated neutrino flux at different off-axis angles
 - Cancel (flux x cross-section) systematics
 - linear combination for monochromatic ν energy response
 - electron neutrino cross-section measurement
- Detailed engineering design is underway
 - Low-cost elevator by changing the pit water height
 - Facility funded in Japan, and the land is secured by KEK
- Canadian contributions
 - Main mPMT (250) and photogrammetry: CFI2020
 - Project leadership: Mark Hartz (TRIUMF)
 - WCTE as a prototype test at CERN



Water Cherenkov Test Experiment (WCTE)

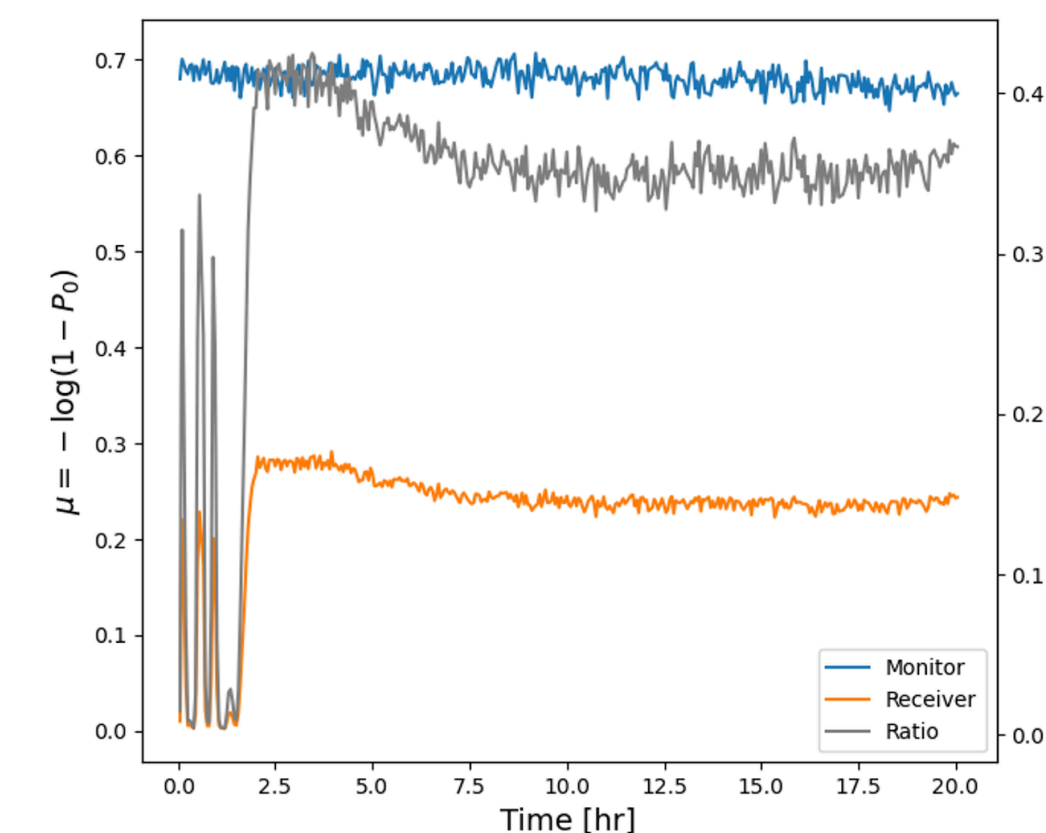
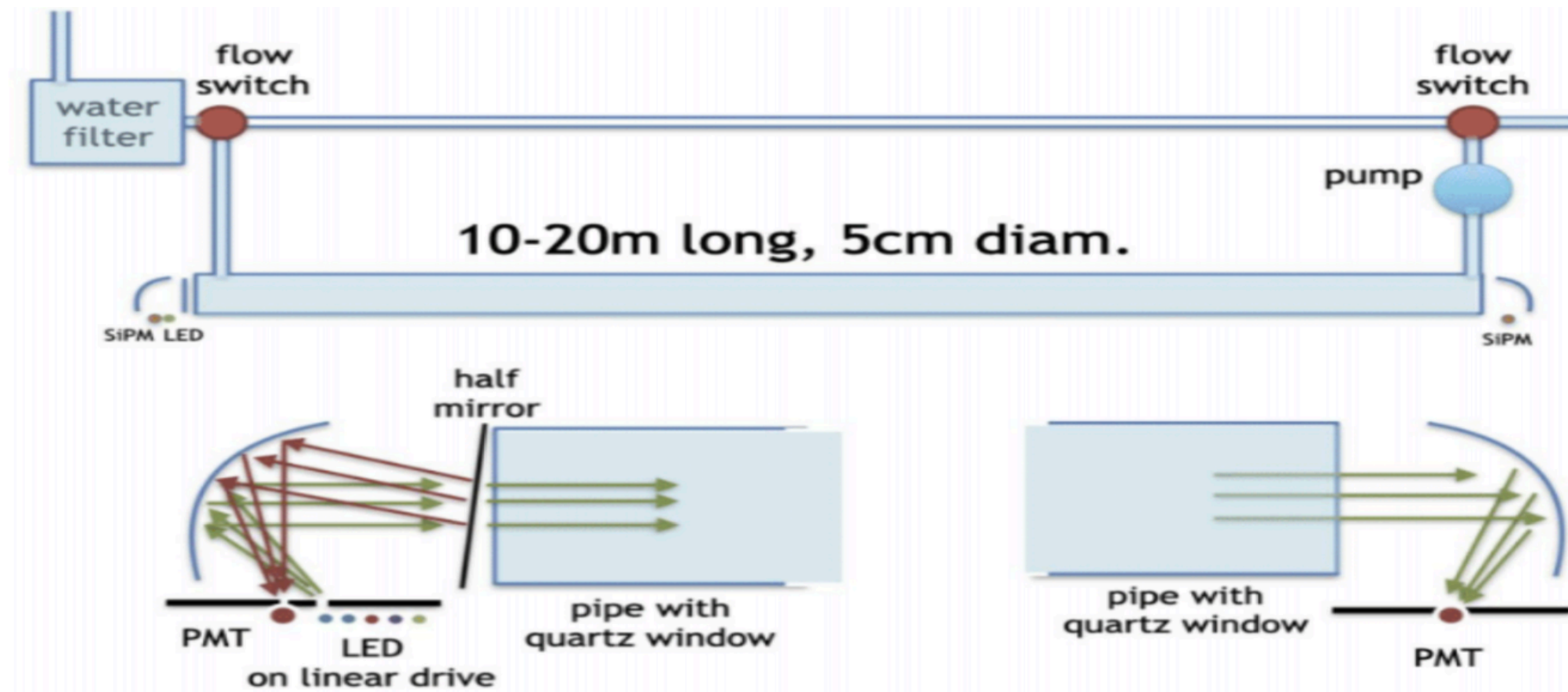
- Prototype IWCD (1/2 in scale in each dimension)
 - Test of mPMT and its calibration
 - Photogrammetry and water monitoring test
 - Water Cherenkov response for sub-GeV e, μ, π, p and γ
 - Aerogel Cherenkov with index of 1.006-1.15
 - Compact tagged γ facility using Neodymium magnet (1.7T)
- Rich physics program for training next generation scientists
 - pion response in water Cherenkov \rightarrow CC1 π /NC π
 - e/μ energy scale calibration \rightarrow Δm^2 for ν mass ordering
 - demonstrate e/γ separation using machine learning
 - μ quasi-elastic scattering to constrain ν interaction model
 - hadronic ^9Li production for the diffused (relic) supernova search
- Status: currently taking beam data at CERN (2024 and 2025)

Inside WCTE Filled with Water



Water quality monitoring

- Water transmission needs to be monitored precisely
 - Rayleigh scattering, Absorption, Mie scattering
 - Raman scattering is not negligible and study newly
- High sensitivity water monitoring system
 - improved version from SuperK water monitoring system
 - 8m-long sample volume
 - Photon counting: $\text{Prob}(0 \text{ hit}) = \exp(-\mu)$ [Poisson distrib.]
 - sub- nsec LED (200-600nm) focused by parabolic mirror
- Application to drinking water monitoring
 - reaching drinking water sensitivity by online measurement: current approach requires 1-2 weeks of laboratory tests
 - new paradigm in water monitoring
 - UVC LED down to 200nm is sensitive to organics and metals
 - Microcystin (cyanotoxin in lakes), Mercury from melting permafrost
 - Collaboration with First Nations community and municipal water facility
 - MOU with the First Nations University of Canada



TUCAN update

See PowerPoint

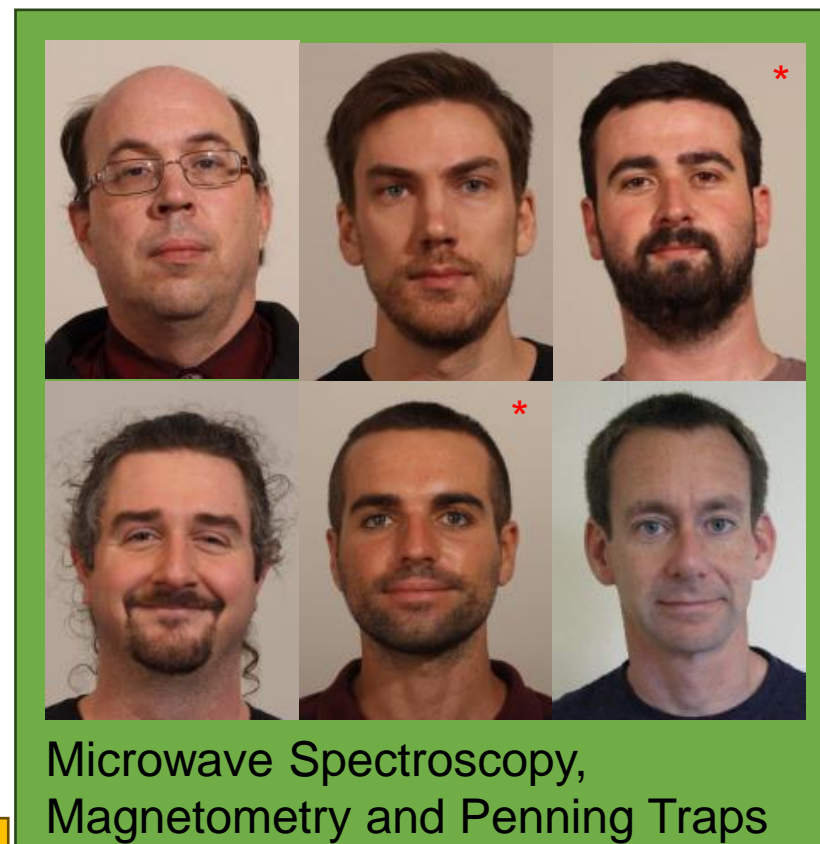
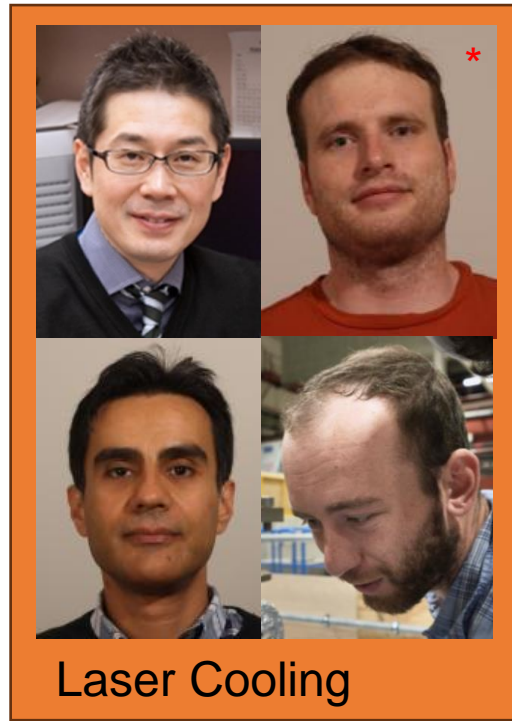
The Scientific Goal



- Perform antimatter/matter comparison at highest attainable precision
 - E.g., Determine 1S-2S transition frequency in antihydrogen with the same precision of hydrogen
- Test the fundamental symmetries that underlie Standard Model and General Relativity

The Team (ALPHA-Canada)

* Denotes HPQ



PI

me



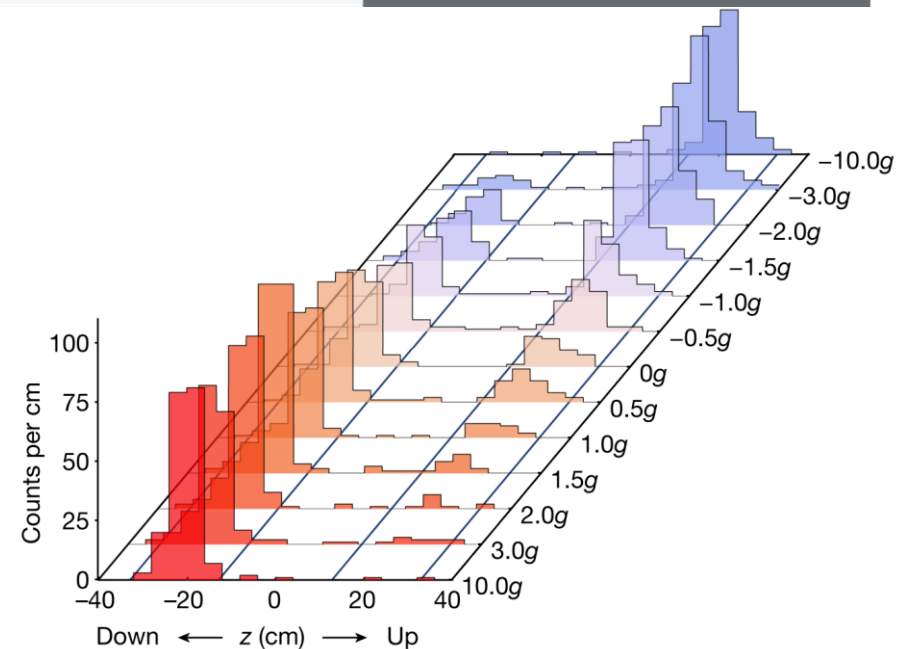
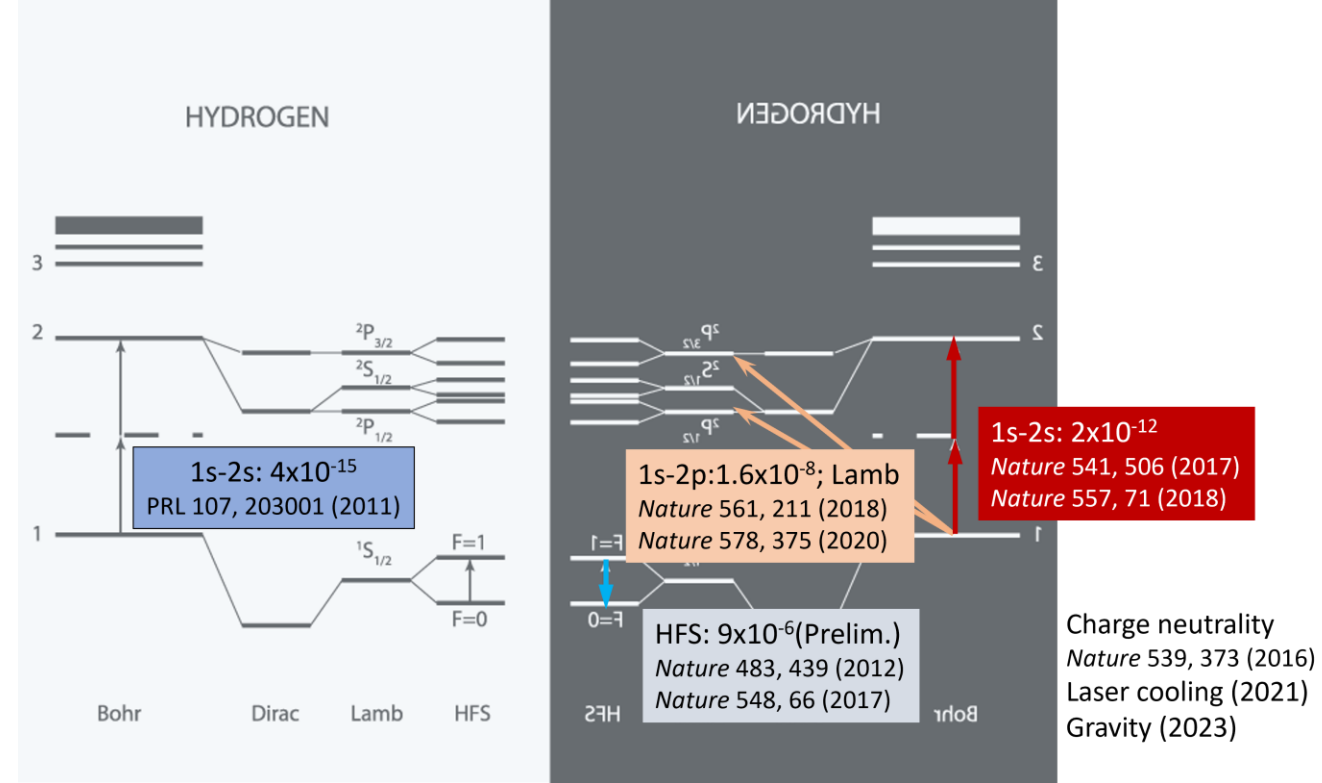
Apologies to newest grad students, co-op students and past members.

Discovery, accelerated

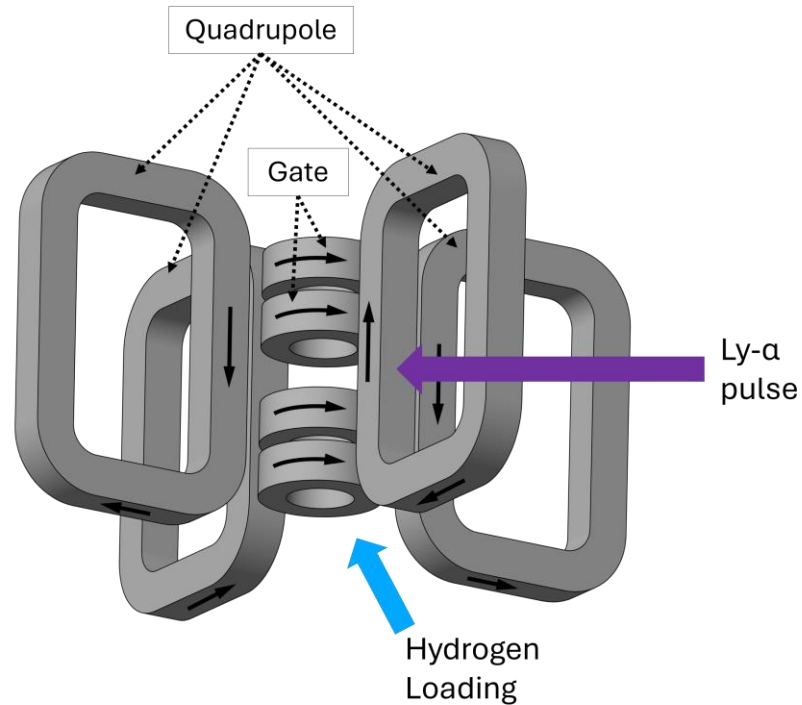
The Current Status

- **ALPHA-2:** trapping antihydrogen for 12 years and counting
 - 1S-2S, microwave spectroscopy
 - Laser cooling
 - Indirect determination of Lamb shift
 - New transition being probed, e.g., 2S-4P
 - Record breaking number of antiatoms stores: $>10^4$

- **ALPHA-g:** dropping trapped antihydrogen
 - First experiment in 2022 (~20% error on first measurement)
 - Currently trapping and dropping unprecedented number of antiatoms



HAICU (now – 2031?)

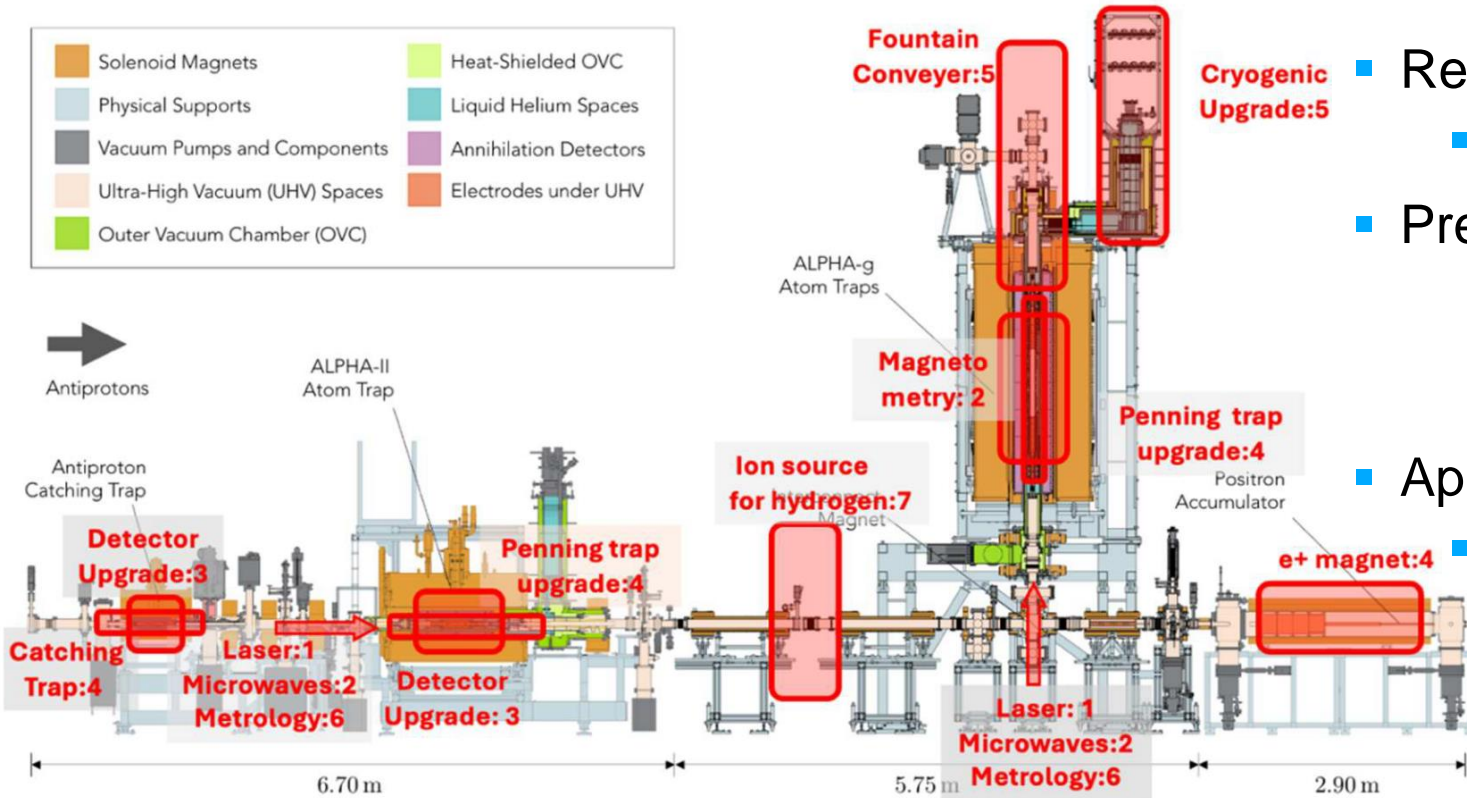


Gate coils assembly at TRIUMF (Oct. 2024)



- Hydrogen-Antihydrogen Infrastructure of Canadian Universities
- Platform to develop quantum sensing techniques on H & pathfinder for next generation of \bar{H} experiments
- Long-term goal: Make the first hydrogen fountain
- Phase 1: Construction is ongoing at TRIUMF and UBC – first trapped atoms expected early next year
- HAICU does not depend on the cyclotron
- If infrastructure is ready, no additional resources required

ALPHA Next Generation (2027-?)



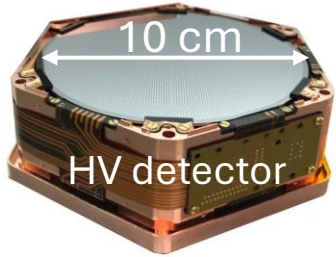
- Reach *hydrogen-level* precision
 - Microwave and laser (1S-2S) spectroscopy
- Precision gravitational studies

- Application to be submitted to CFI IF2025
 - Timely with CERN LS3 (injectors)

- Modernization of decades-old facilities and tools
 - To name a few: DAQ, trap CS
 - Increase automation and sustainability (e.g., liquid helium consumption)

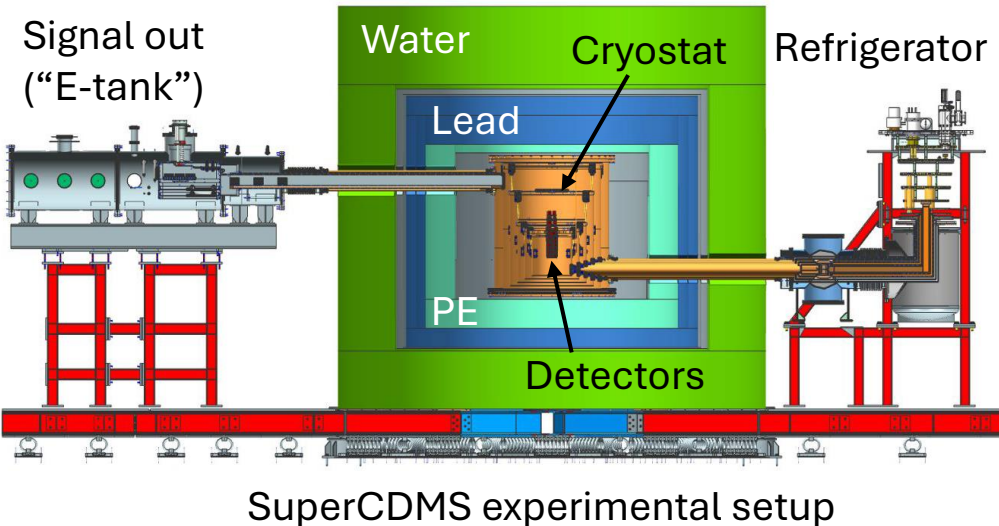
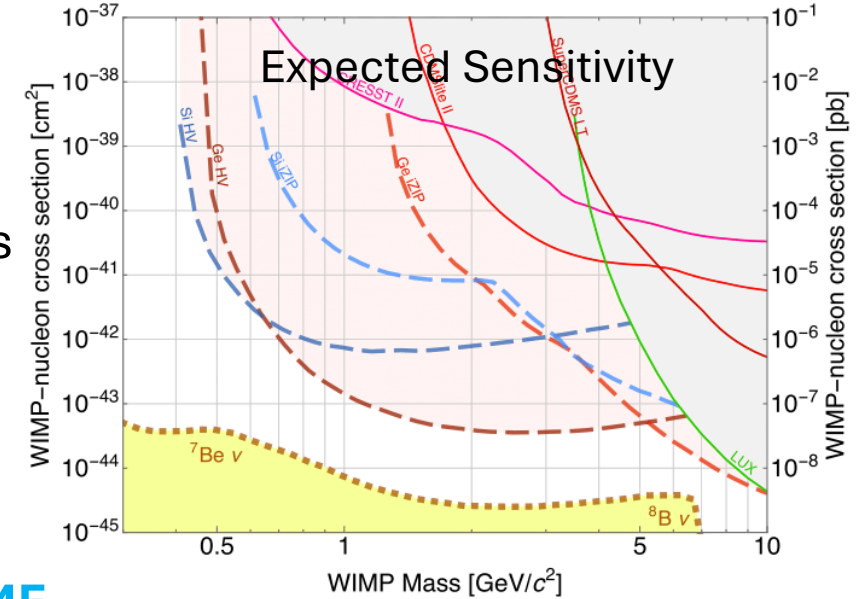
- Direct antihydrogen-hydrogen comparison
 - Hydrogen loading and detection

Dark Matter Search with Cryogenic Detectors



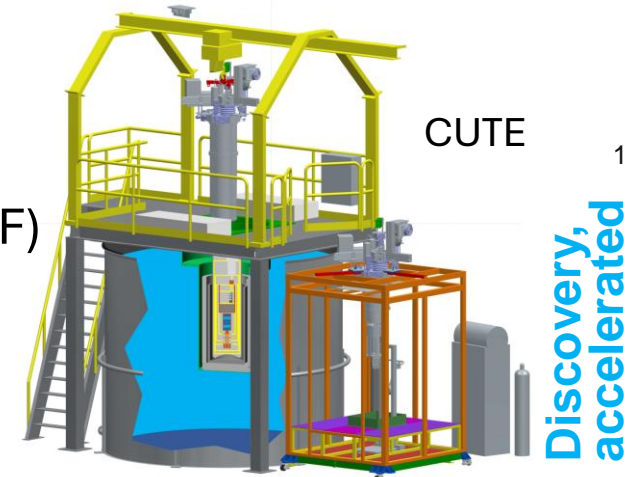
SuperCDMS Overview

- Under construction at SNOLAB
- 18 Ge and 6 Si detectors (~30 kg) operated at ~30 mK
- Measure energy depositions through charges/phonons
- “iZIP”: ph./ch. signals for background identification
- “HV”: measure ch. through amplified ph. signal
- Low threshold (O(100 eV phonons); single charges)
- Shielding: 6000 mwe, lead, PE, water



SuperCDMS and TRIUMF

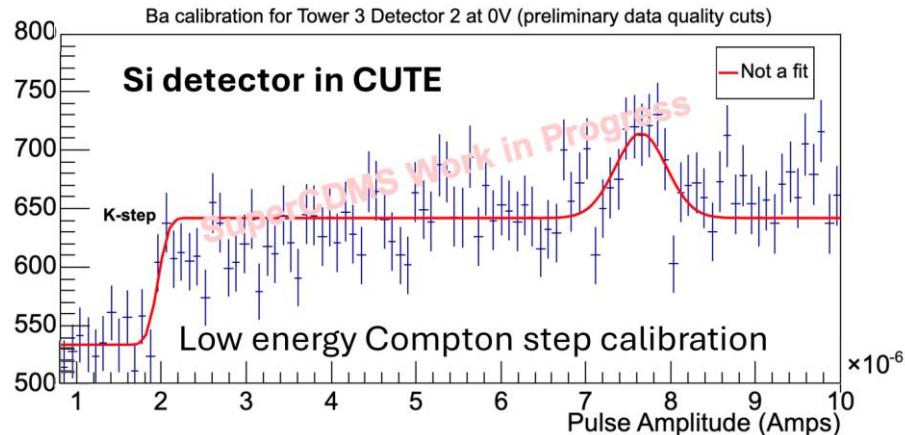
- TRIUMF/UBC: W. Rau, S. Oser, 2 PDFs, 3 grad students
- MIDAS DAQ developed at TRIUMF (Oser)
- Detector testing at CUTE (Rau)
- Analysis coordinator (Y. Liu, PDF)
- Various leadership roles in SuperCDMS



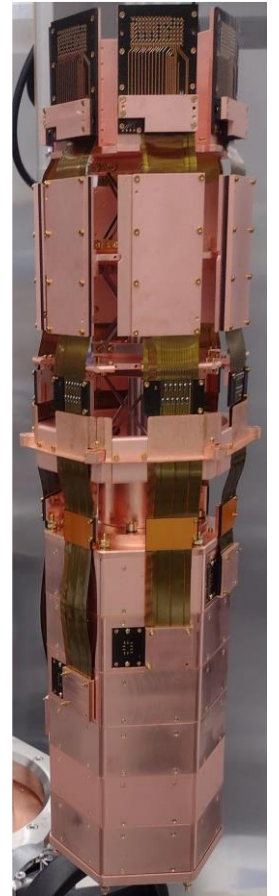
Dark Matter Search with Cryogenic Detectors

Status and near-term future

- Construction progressing at SNOLAB
- Almost all major components on site
- DAQ installation complete
- Developing analysis methods and tools using data from SuperCDMS detectors @ CUTE
- Commissioning preparation in full swing (Lessons-learned from CUTE operations)
- First cooldown expected for summer 2025
- Commissioning phase ~0.5 years
- Start of science data taking: early 2026



Outer cryostat can, placed on the bottom of the shielding



“Tower” of 6 stacked detectors

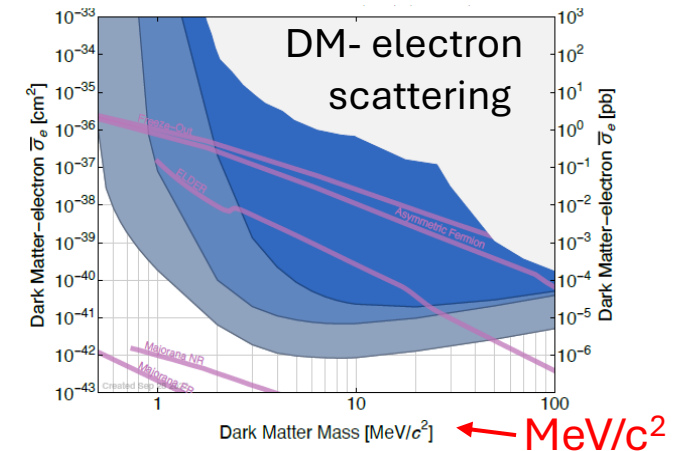
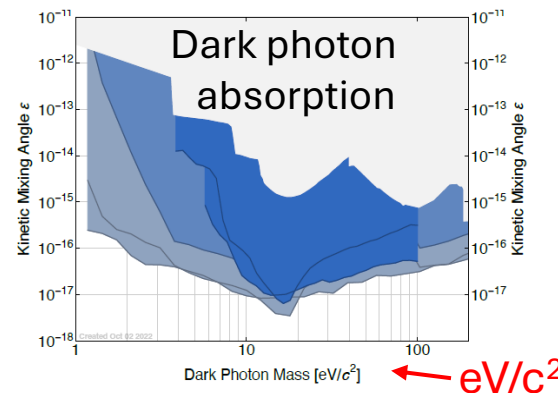
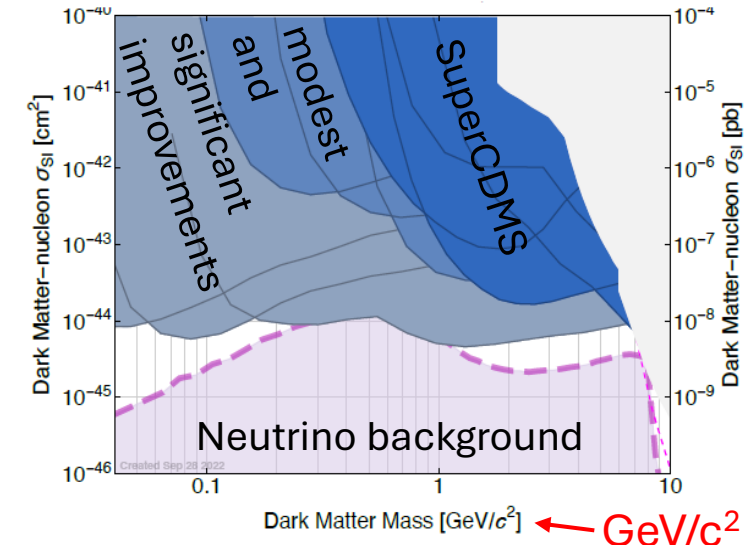
Dark Matter Search with Cryogenic Detectors

Longer-term outlook

- SuperCDMS SNOLAB science run (funded): 2026 – 2028
- Ongoing data analysis effort until at least 2030
- Variety of upgrade options are considered (arXiv:2203.08463v2):
 - Smaller detectors / sensor area provide better energy resolution
 - Better crystal quality can improve charge transport
 - Improved readout electronics can improve charge resolution
 - Lower superconducting transition temperature improves phonon energy resolution
 - Background reductions improve sensitivity
- Start of modest R&D efforts once SuperCDMS SNOLAB is operational
- Detector test facility at TRIUMF and CUTE contribute to testing of improved detectors
- Operation of improved detectors at SNOLAB potentially from 2029 onwards

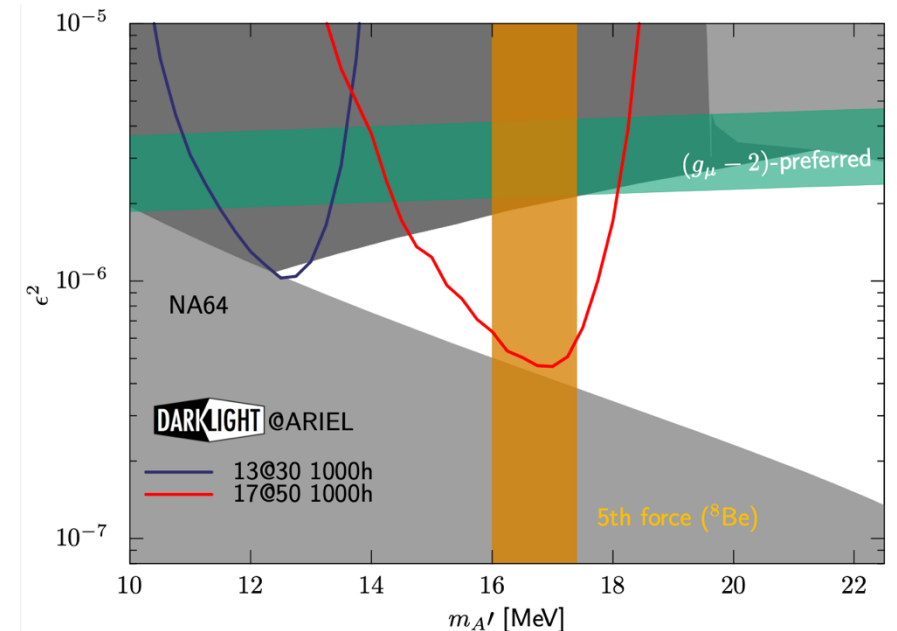
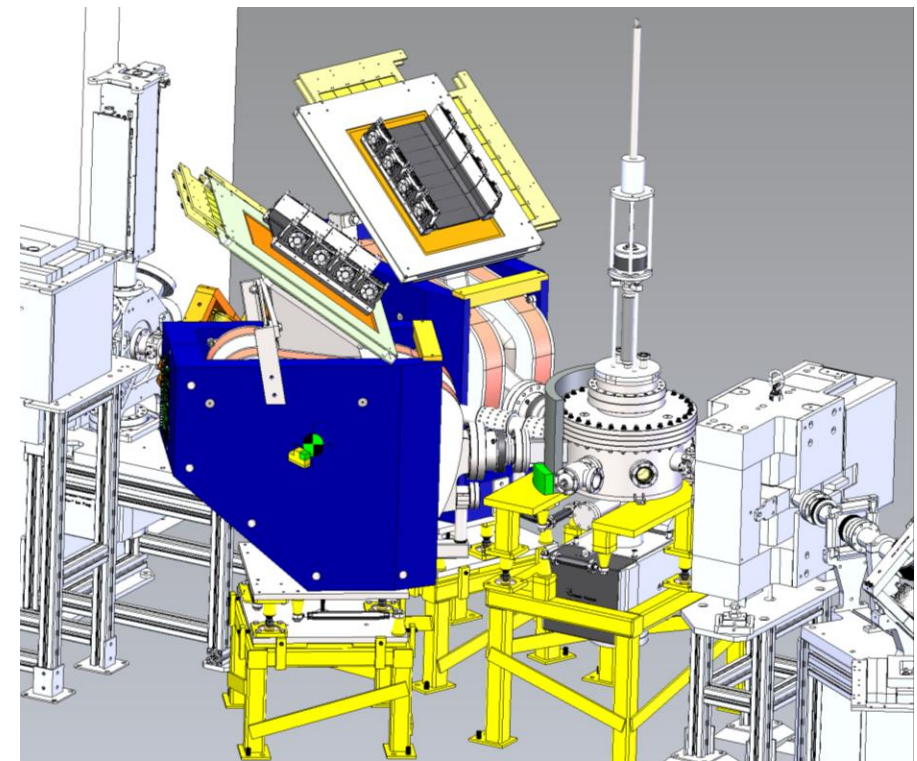
Example sensitivity projections

Dark matter – nucleon scattering



DarkLight @ ARIEL overview & timeline

- For new committee members: DarkLight is an approved experiment currently under construction at the ARIEL e-linac. It will search for new bosons with mass $\sim 10\text{-}20$ MeV decaying to e^+e^-
- Two running stages: 30 MeV and (following anticipated e-linac upgrade) 50 MeV
- Installation planned for early in new year, working around other shutdown job commitments
 - Depends on getting last few components on site, getting CNSC approval to proceed, and on e-linac being ready to host new experiment. Currently linac still requires beam development time before this is possible.
- 30 MeV run must happen before 2026 shutdown. 50 MeV run must happen immediately afterwards: upgrade must be handled during shutdown year.
 - Consequences of delay are being passed by rival experiments and a high likelihood of international collaborators losing funding.



Darklight @ ARIEL experiment status

- Design complete.
- Spectrometer magnets (MIT) arrived at TRIUMF and field mapping is in progress
- Target chamber required modifications; ongoing work by MIT/contractors. Will be vacuum tested before shipment to TRIUMF. Other vacuum chambers ready and tested.
- Trigger detector construction almost done (Gabby, Mike + SciTech); DAQ needs integration with tracking detectors
- Tracking detectors mechanically ready but readout needs development; ongoing (Hampton U., TRIUMF)
- Integration at TRIUMF (cabling, controls, power supplies, etc) ongoing
- Beamline components mostly available; still need collimator.



Spectrometer prepared for mapping

Further status and concerns

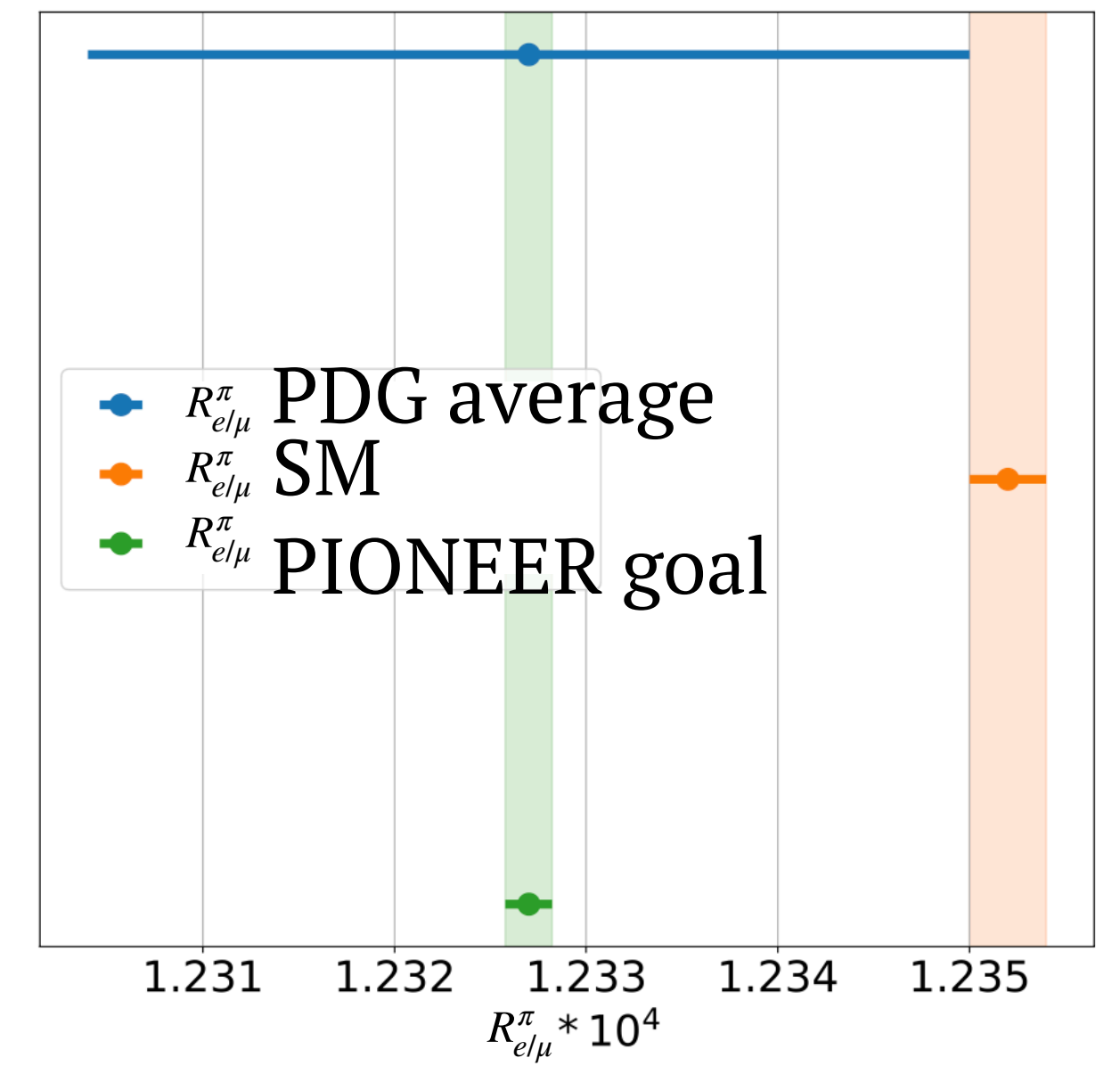
- TRIUMF reviews: ongoing
 - Technical reviews complete
 - Safety review completed; now making requested modifications to SAR before final document sign-off
 - Gate 2&3 scheduled before Christmas.
- CNSC approval status: understanding is that SAR will be discussed with them at upcoming site visit.
- Funding status: DarkLight received NSERC RTI grant to fund construction of recirculating ring for energy upgrade (April 2024).
 - Not possible to proceed with ring due to long shutdown plans. Instead, TRIUMF proposes to pivot to more expensive but less personnel-intensive plan for new cryomodule
 - DarkLight involved in discussions with JLab to try to help obtain cryomodule components. Visit/discussion scheduled early December
 - Pivoting to cryomodule plan will require NSERC approval for reallocation of RTI funds. This approval not yet requested since plan still in the air.

PIONEER

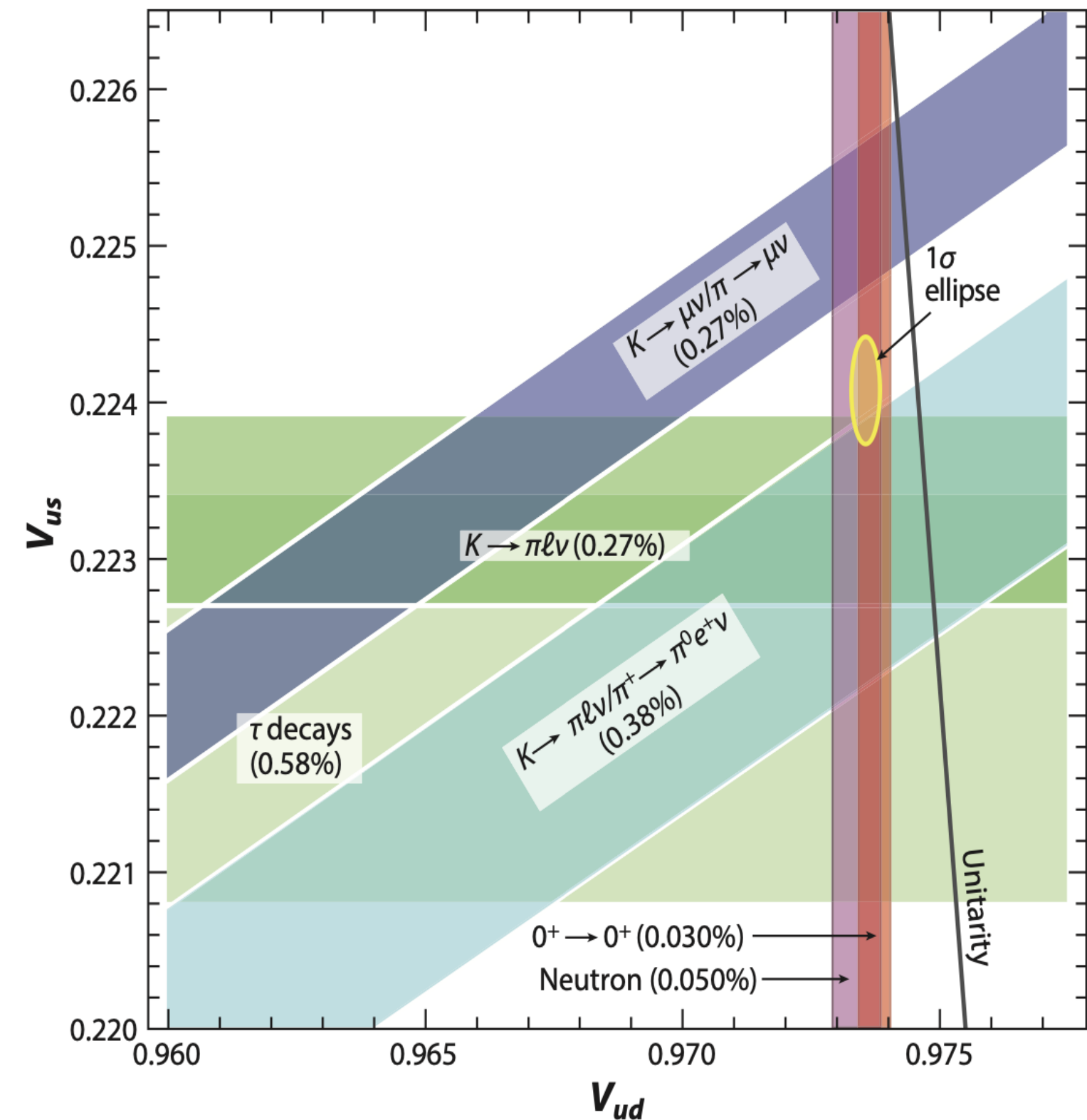
- New experiment addressing tensions in the flavor sector (LFUV, V_{ud}) using low energy pions (~ 70 MeV/c) at the Paul Scherrer Institute (Switzerland).
Phased experiment - Phase I **approved with high priority** at PSI
- Timescale : 10-15 years. Commissioning of the experiment planned for ~ 2031
- PIONEER builds on the techniques refined in previous pion decay experiments: PIENU@ TRIUMF
- PIONEER will employ **emerging technologies** which are **synergistic** with other developments at TRIUMF (Noble Liquid calorimetry, VUV photosensors, LGADs, in nEXO, NA62, ATLAS)
- TRIUMF process: Gate 0 and Gate 1 passed (in 2023 and 2024)
Awaiting support for CFI IF 2025
- Canadian group (McGill, TRIUMF, UBC) involved in all aspects of the experiments with focus on the **LXe calorimeter**

Phase 1:

$$R^\pi = \frac{\pi \rightarrow e\nu(\gamma)}{\pi \rightarrow \mu\nu(\gamma)}$$



Phase 2 and 3 :
 $B(\pi^+ \rightarrow \pi^0 e^+ \nu)$

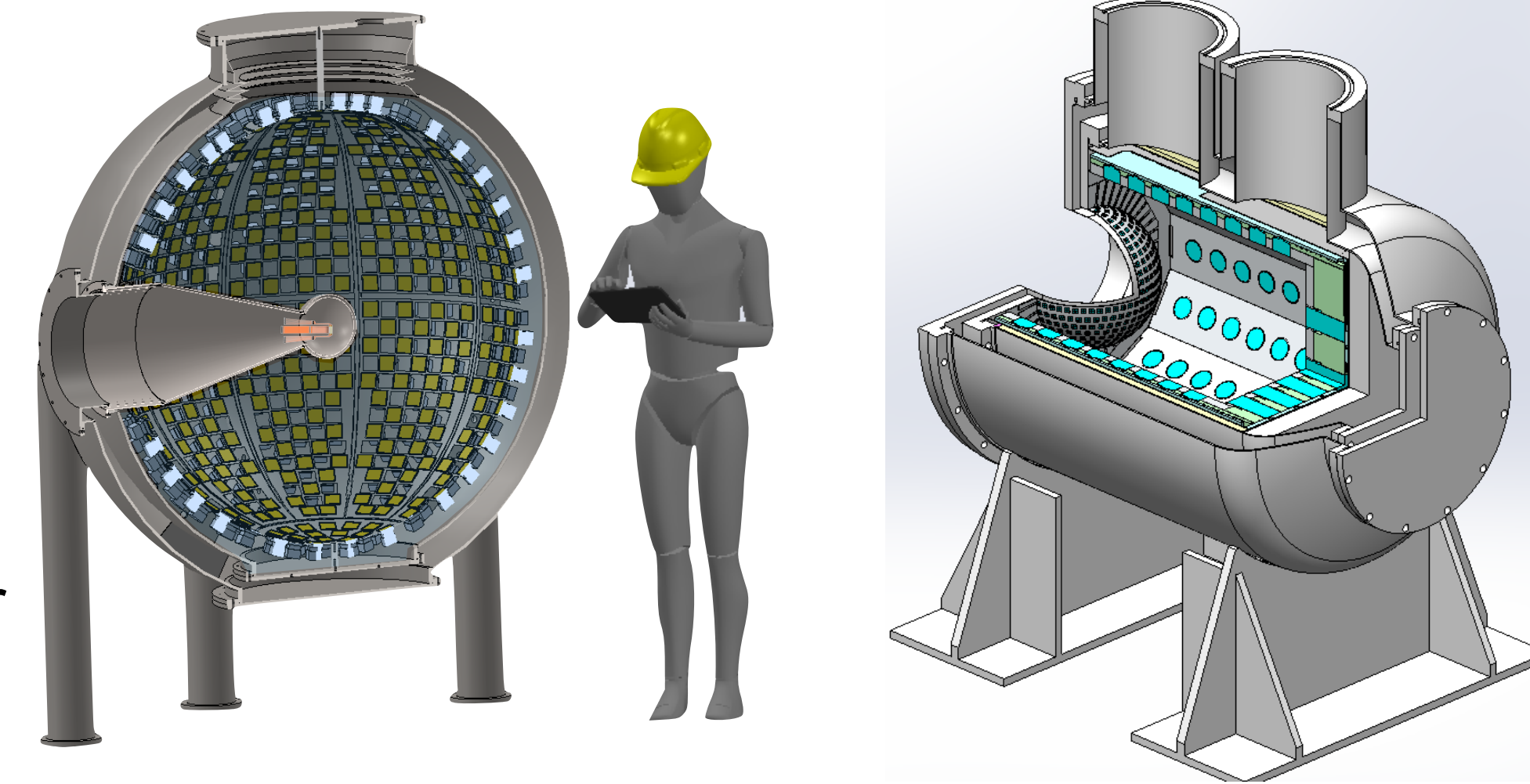


Existing tensions in the 1st-row CKM unitarity test.

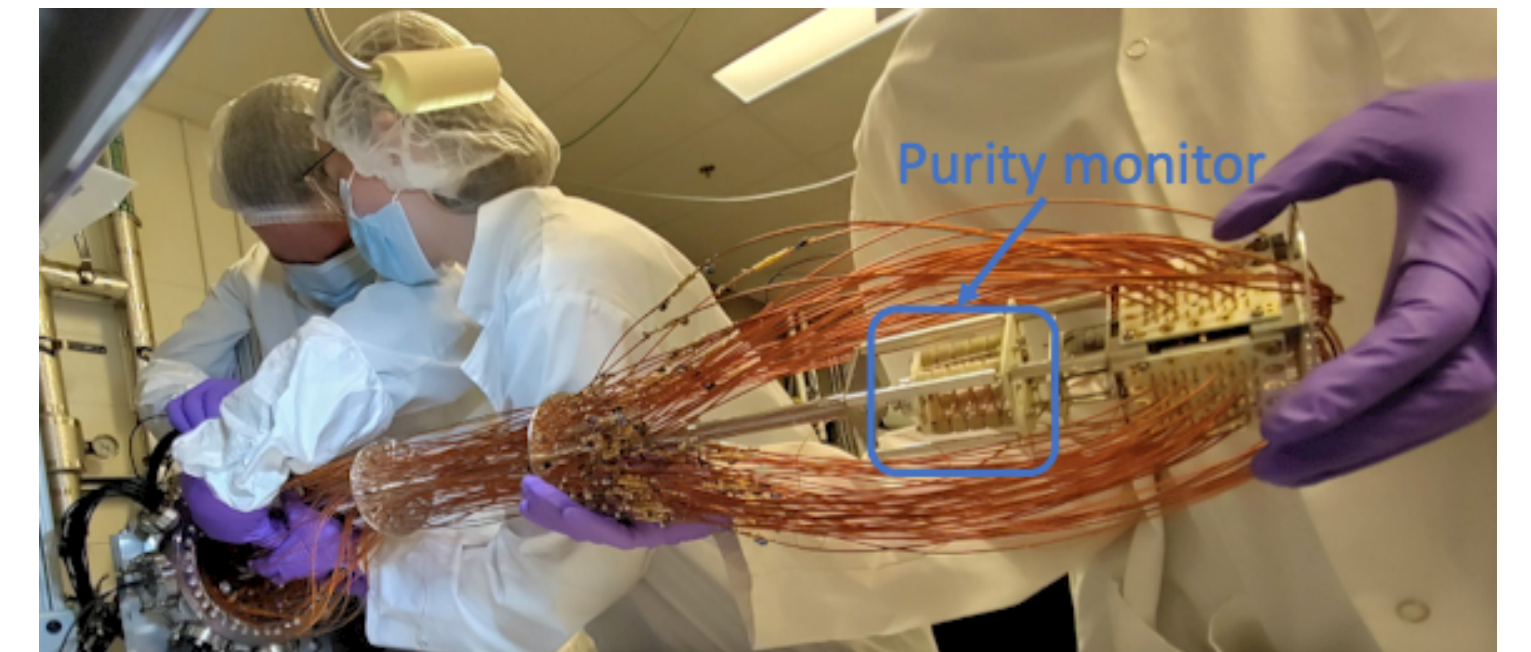
PIONEER

Conceptual design (cut-out view) of PIONEER's LXe calorimeter

PIONEER's LXe facility (CFI 2025)



Installation of PIONEER's purity monitor prototype in LoLX (McGill)



- **FUNDING:**

The group is NSERC funded through 2026
Preparing CFI IF 2025 proposal (University envelopes of \$3.8M) to fund the LXe facility for PIONEER

- 1st and 2nd collaboration meetings at CENPA, University of Washington in October 2023 and June 2024

Next Collaboration meeting at TRIUMF (January 2025)

- **TEAM:** PIs: T. Brunner [McGill], C. Malbrunot [TRIUMF, McGill, UBC] (Deputy spokesperson, NSERC PI), D. Bryman [UBC] (Founding spokesperson)

New PIONEER HQPs at TRIUMF

- Postdoc:

- Ben Davis-Purcell started Nov 1st 2023 - Recipient of an NSERC fellowship (starting April 1st 2024)
- joint PIONEER/NA62 postdoc starting Dec 1st 2024

- PhD student

- Emma Klemets (UBC) started her PhD Sept 1st 2023
Recipient of an NSERC CGS-D scholarship (starting Sept 2024)

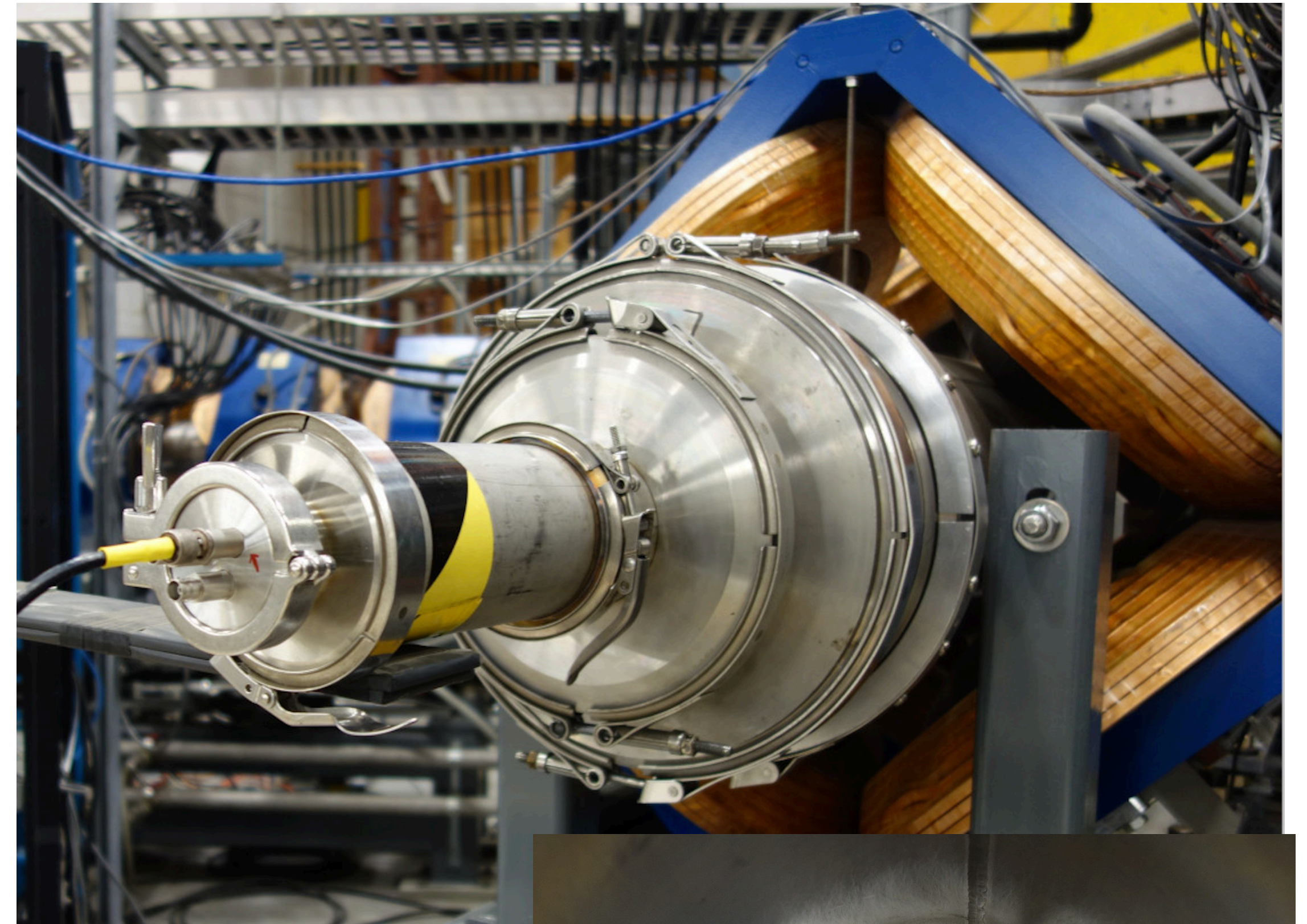
- Many undergraduate students (co-op students, MITACS)

PIONEER

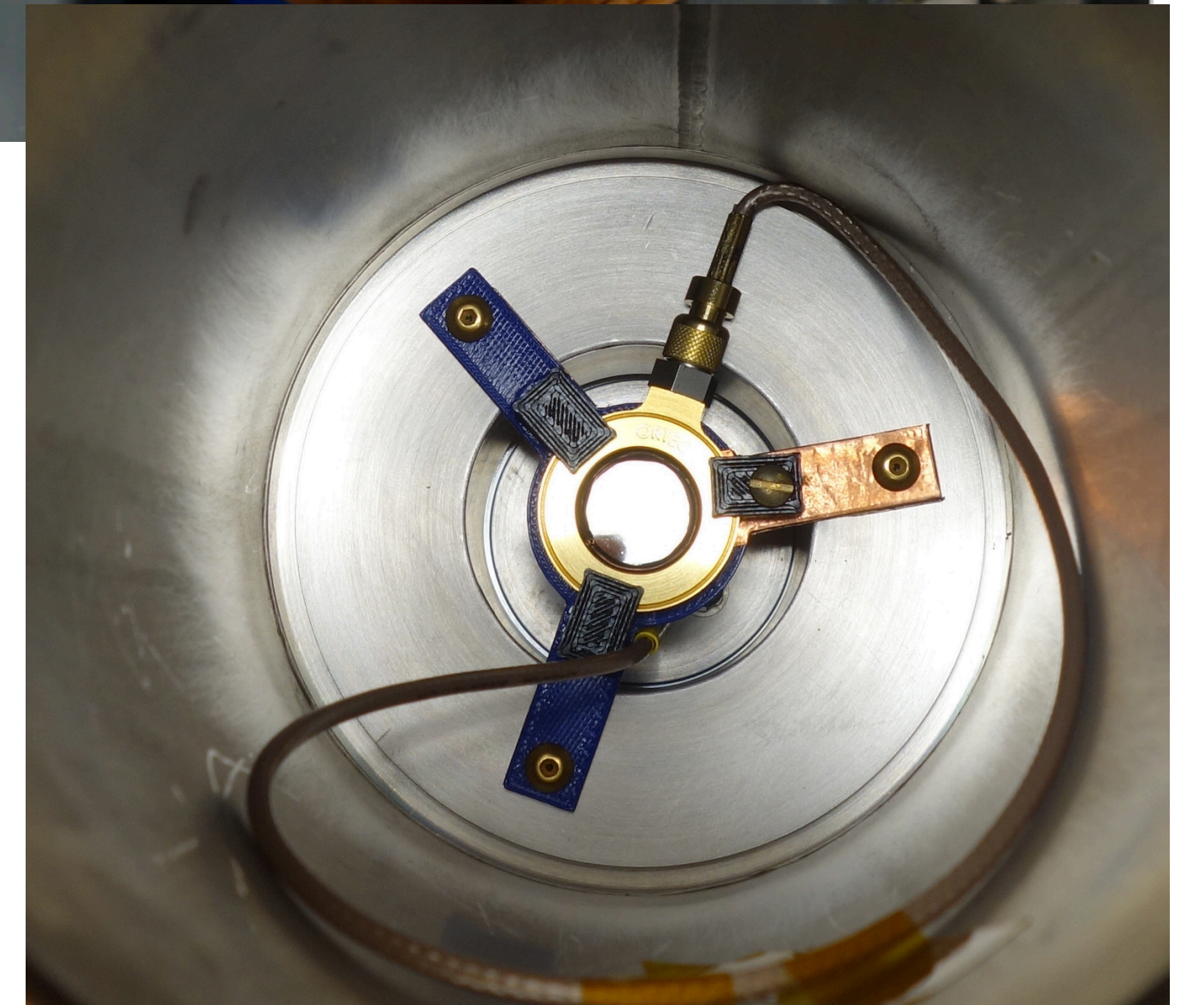
- Potential experiment at TRIUMF in connection with PIONEER : improved measurement of the **pion lifetime**. Effort led by B. Velghe. May 2024 PP-EEC endorsed the updated LOI including request for further validation measurements.

Thanks to PIF/NIF coordinator C.Belanger-Champagne and Gerald Morris (CMMS) and to the accelerator team for their strong support and availability.

Nice support/synergy across the lab!



test in M20 beamline



nEXO At TRIUMF

Board Appointed Employees

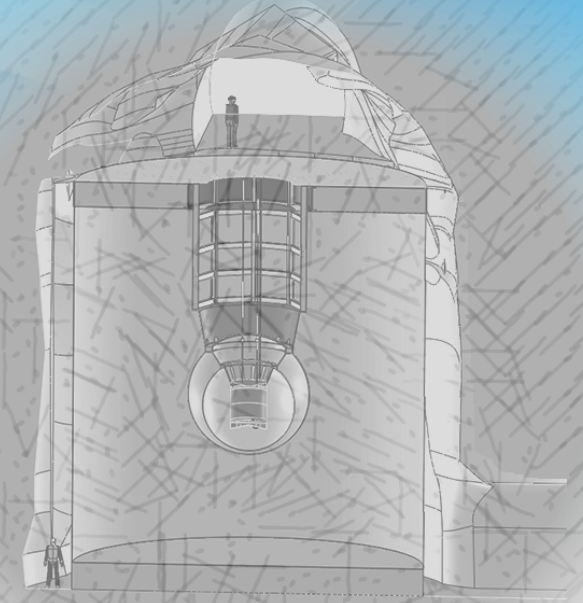
- Jason Holt – theory
- Annia Kwiatkowski – Barium tagging
- Annika Lennarz – Calibration
- **Chloe Malbrunot** - liquid Xenon
- Fabrice Retiere – SiPM

Highly Qualified Personnel

- Stephanie Bron – Postdoc (2023-2024) – Light only Liquid Xenon experiment
- Sara Craft-Hamilton - Undergraduate (2024) – SiPM characterization
- Harry Lewis – Postdoc (2023-2024) – SiPM characterization
- Xiang (Alex) Li – PhD (2023-) – Light production, transport and detection in LXe
- Fandresena Ramonjisson – Msc (2024-2026) – Light only event reconstruction in LXe
- Lei Wang – Postdoc (2025-) – SiPM characterization

Support personnel for SiPM testing work (CFI IF 2020)

- Maia Henriksson-Ward – Automation specialist (2023-2024) – SiPM mass testing
- Kurtis Raymond – System engineer in training (2023-) – SiPM characterization
- Feng Shi – Project Scientist (2023-2025) – SiPM mass testing



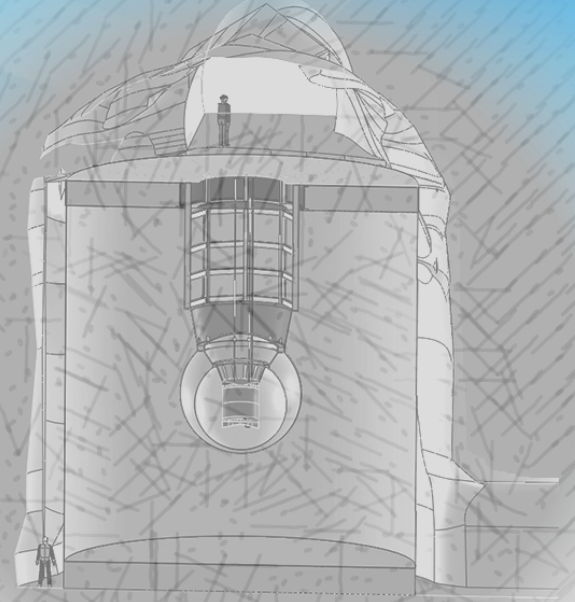


Politics

US in holding pattern

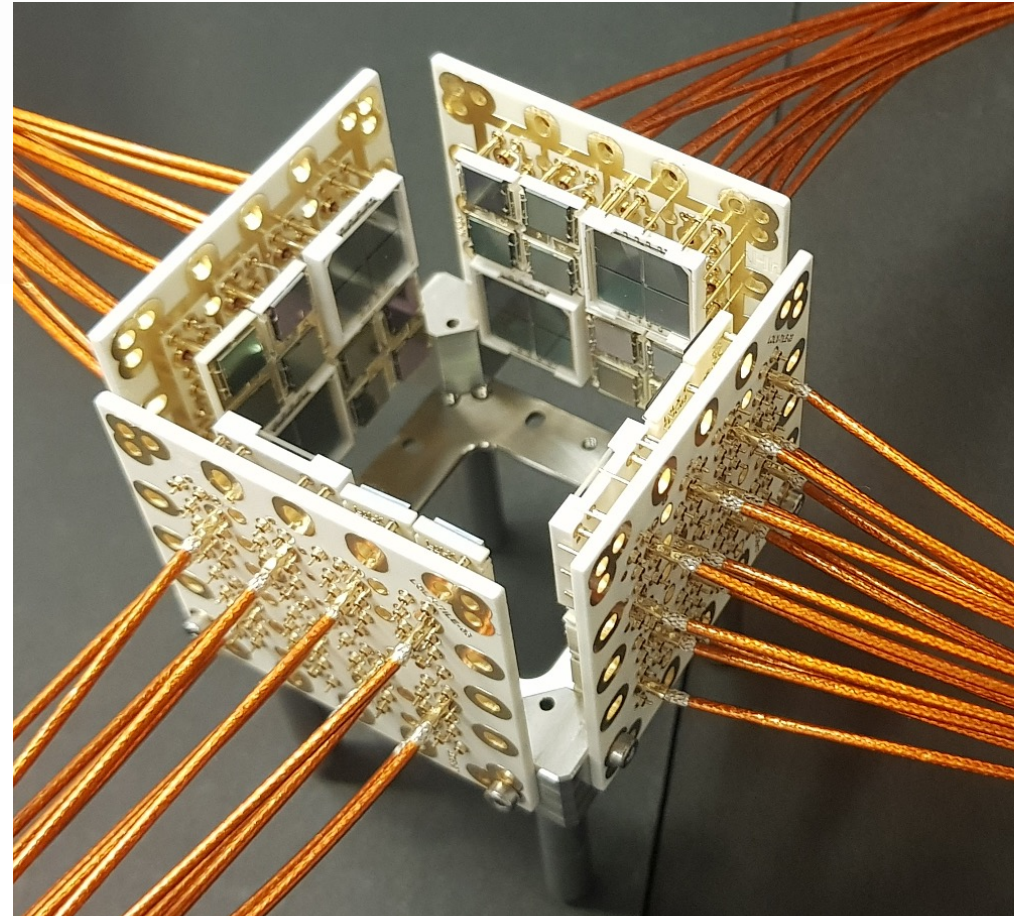
No CD1 review scheduled

Focus on building infrastructure and doing R&D

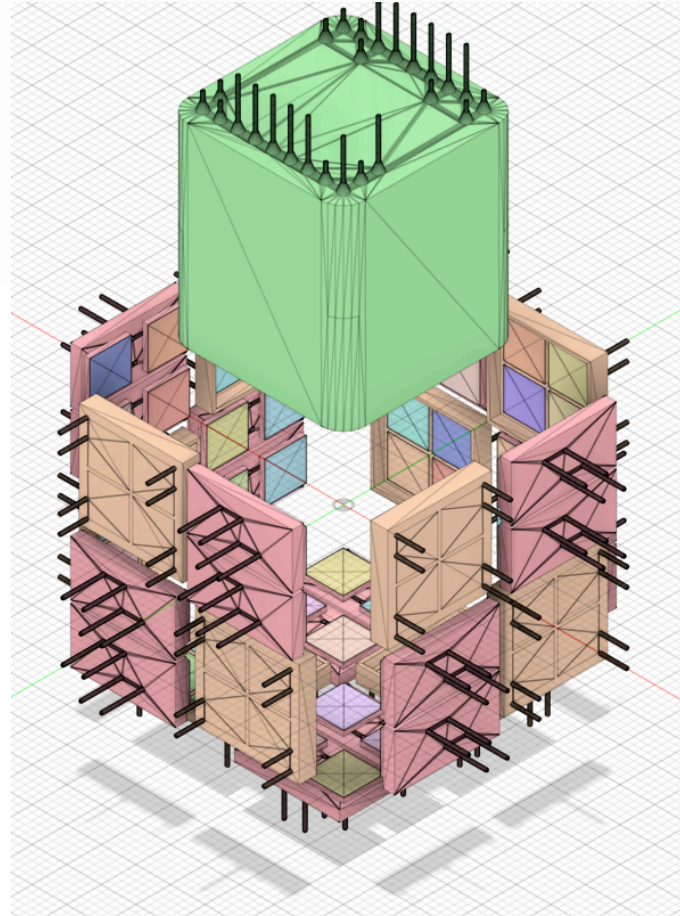


Light only Liquid Xenon (LOLX)

LoLX2 Inner chamber built at TRIUMF



LoLX2 in simulations



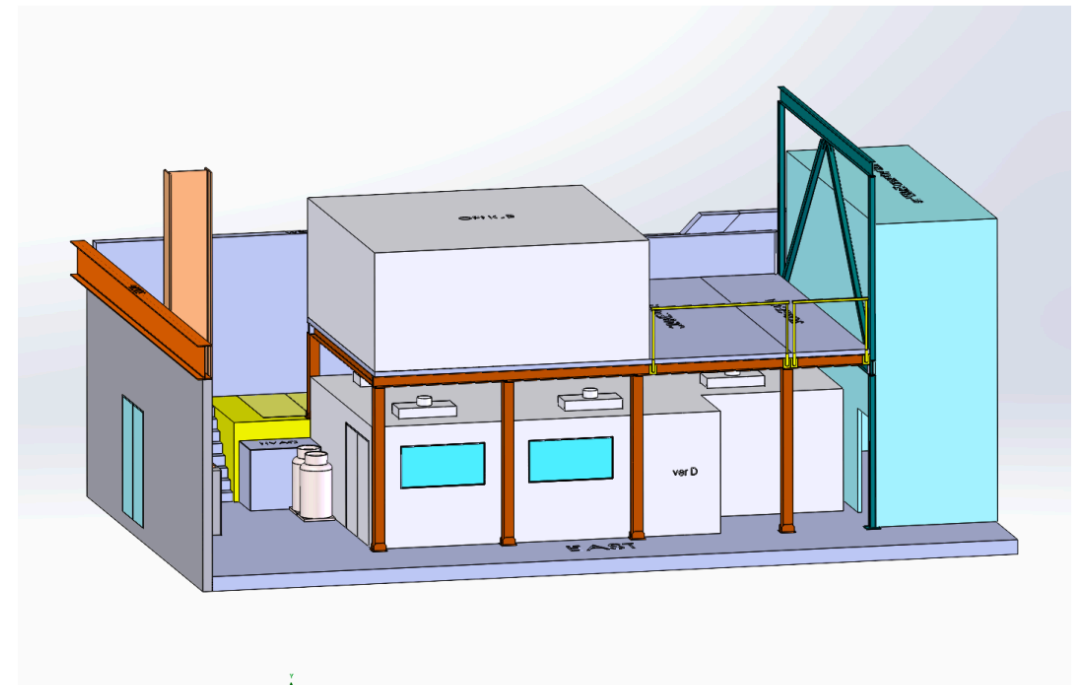
- LoLX1 in 2021
 - Paper in preparation
- LoLX2 Run 1 in 2023
 - SiPM comparison
 - Energy and position resolution in LXe
- LoLX2 Run 2 in 2024

SiPM mass testing infrastructure

- CFI IF 2020 funded for testing 5 m² of SiPMs
- Aim to complete the clean room by mid 2025
- Aim to finalize testing methodology by February 2025
- First tile prototype in 1-2 months

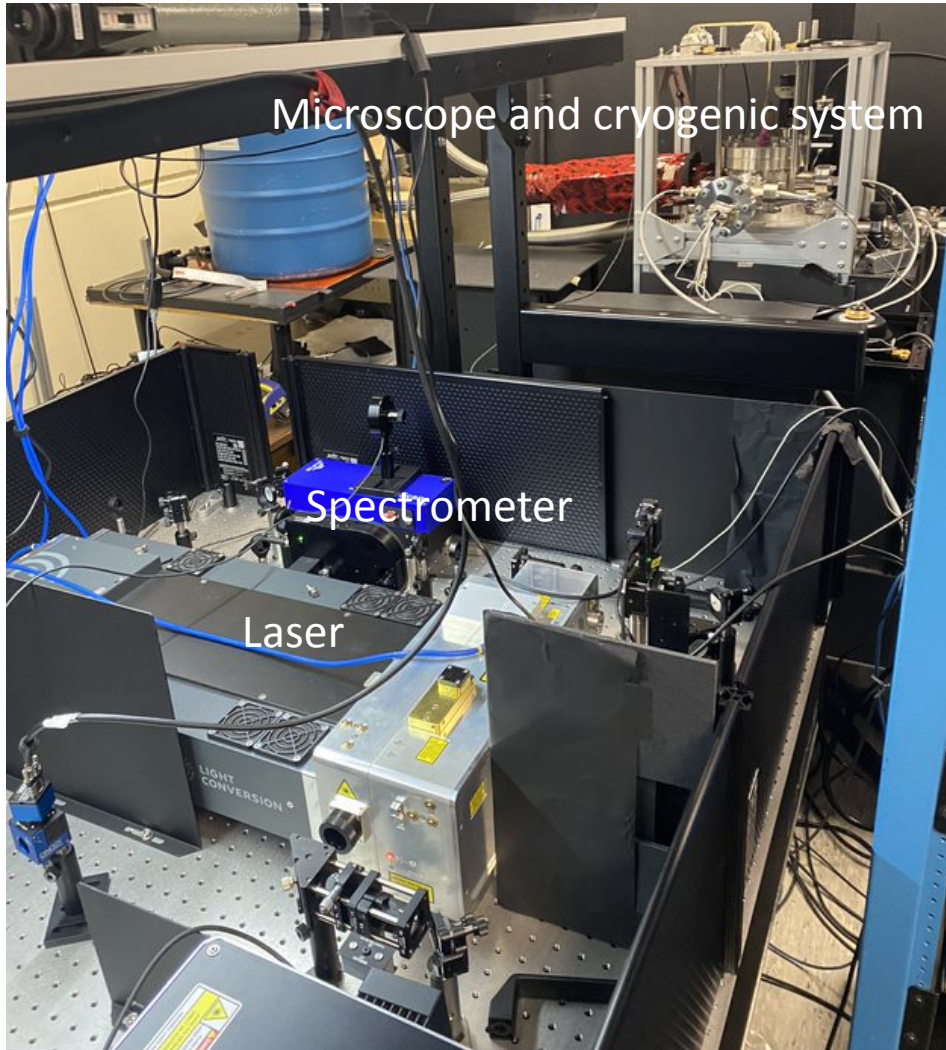


Proposed site of the nEXO clean room and above office facility in the Meson Hall Extension



Conceptual illustration of the proposed nEXO facility and above office on the mezzanine

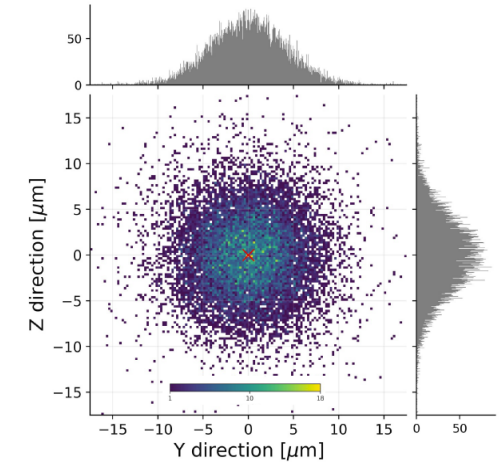
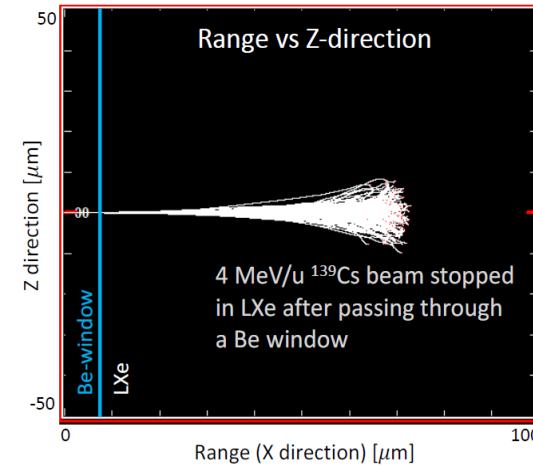
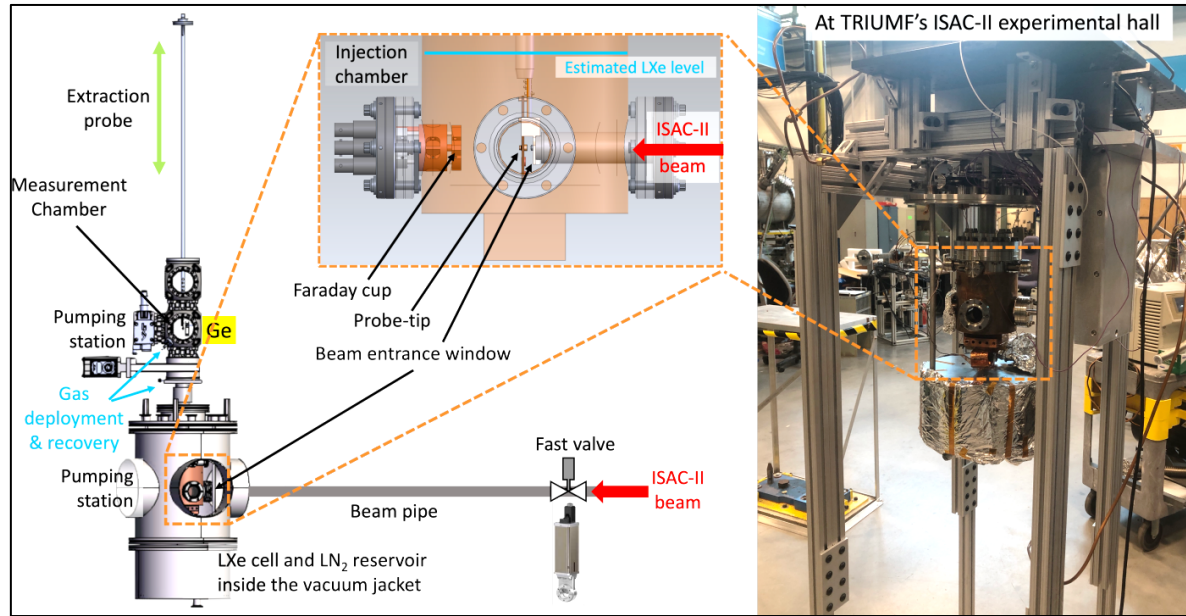
SiPM characterization



- Upgrade of MIEL (Microscope for the Injection and Emission of Light) completed
 - New laser (300-2000nm tunable, 200fs pulse width)
- Papers
 - H. Lewis et al., “Measurements of the Quantum Yield of Silicon using Geiger-mode Avalanche Photodiodes”, submitted to IEEE Trans El. Dev., in Nov 2024
 - K. Raymond et al., “Stimulated Secondary Emission of Single-Photon Avalanche Diodes”, published in IEEE Trans El. Dev. in Oct 2024
 - “Dark noise source characterization”, in preparation (2024)
 - A. de Ste Croix, “Modeling SiPM efficiency from ultra-violet to infra-red”, in preparation (2024)

Ba-tagging at TRIUMF for a future neutrinoless double beta decay search in nEXO

Novel radioactive beam approach for ion implantation into LXe volume and subsequent extraction



Status updates on simulations and hardware progress

- COMSOL simulations of Ba ion motion in LXe and GAr were performed.
- Vertical motion of electrostatic probe into LXe chamber is configured with a servo motor.
- Set up of probe biasing with HV is underway.
- HPGe detector calibration and testing is in progress.
- HPGe detector simulations to characterize γ -signature of $^{139}\text{Ba} \rightarrow ^{139}\text{Cs}$ decay were completed.
- Machining components and acquisition of Be beam entrance window in progress.

