

# Particle Physics / Quantum Center

Chloe Malbrunot / Oliver Stelzer-Chilton (for Particle Physics)

PSD retreat

May 24<sup>th</sup>, 2024

# Particle Physics Department

**Particle Physics – O. Stelzer-Chilton**

**Deputy – M. Hartz**

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*

## Particle Physics within the Physical Sciences Division

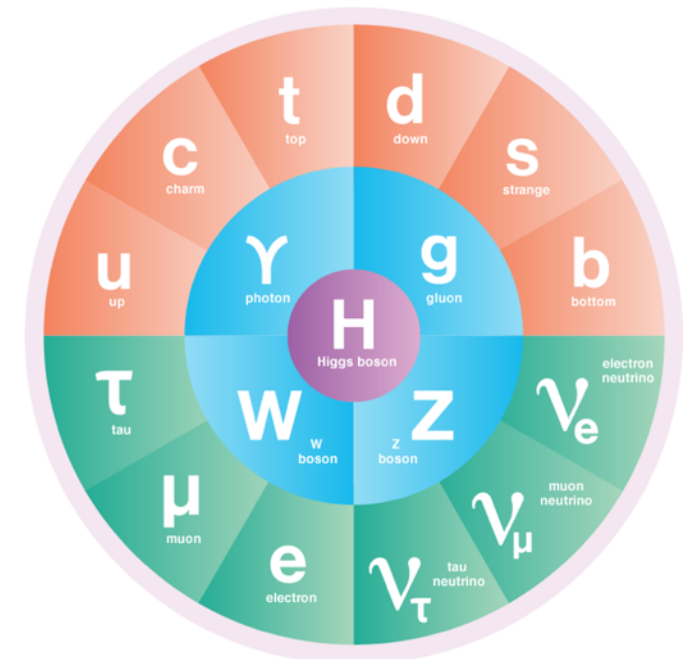
The departments of **Particle Physics, Science & Technology** and **Scientific Computing** address the areas:

- 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



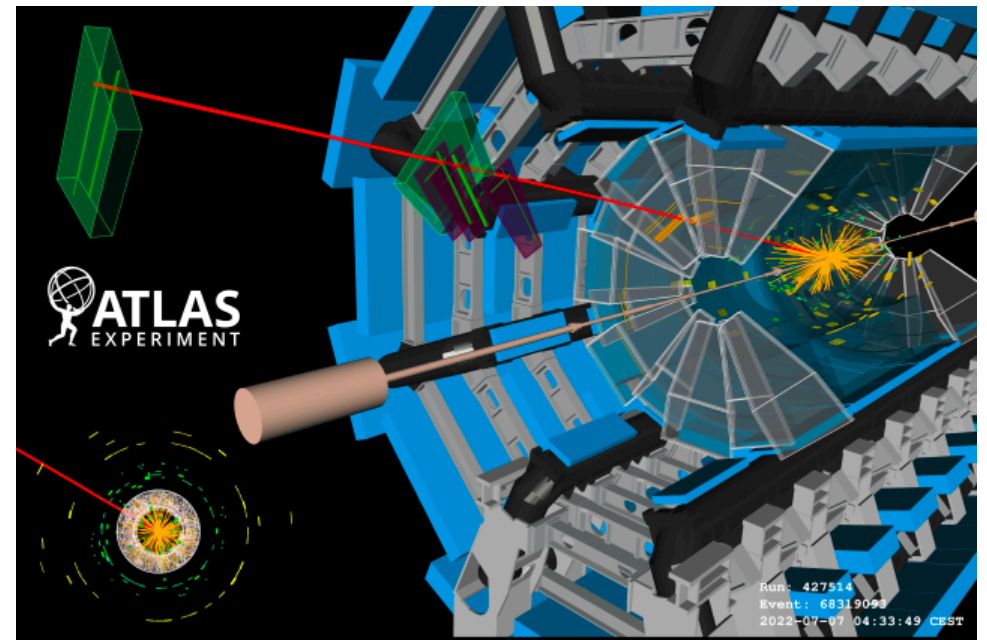
## Enable Particle Physics in Canada and Abroad

- 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

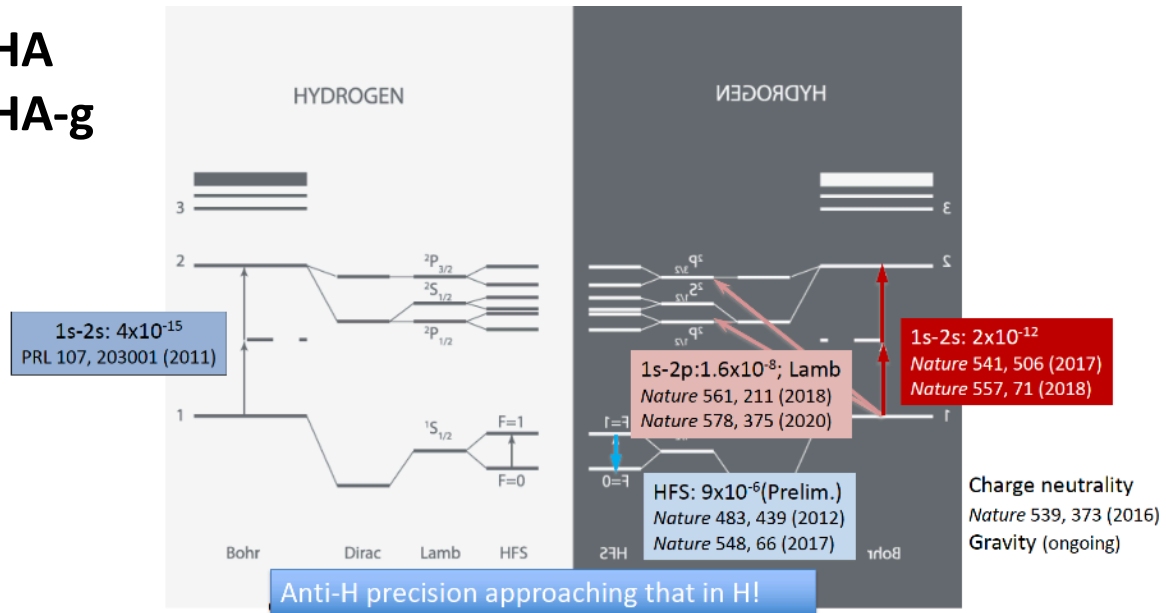


# CERN

- ATLAS
- Legacy measurements on
  - Higgs potential, couplings, self-coupling
  - Searches for New Physics and Measurements
- Deliver on upgrades for HL-LHC



- ALPHA
- ALPHA-g

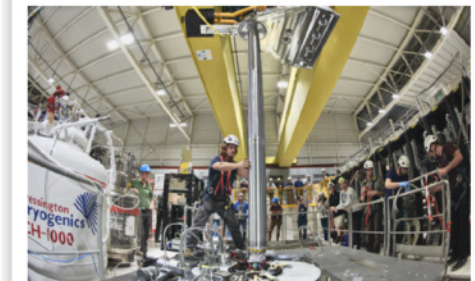


A communication resource from the world's particle physics laboratories.

## ALPHA experiment at CERN observes the influence of gravity on antimatter

27 September 2023 - CERN

The result is a milestone in the study of the properties and behaviour of antimatter



**DATE ISSUED:**  
September 27th, 2023

**SOURCE:**  
CERN

**CONTENT:**  
Press Release

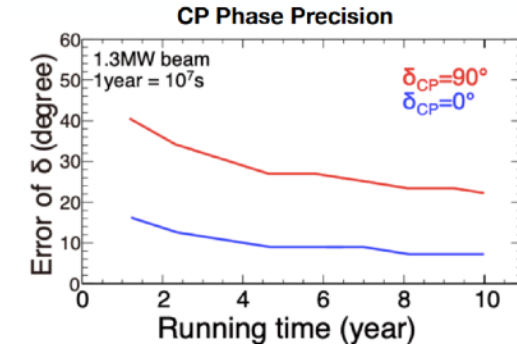
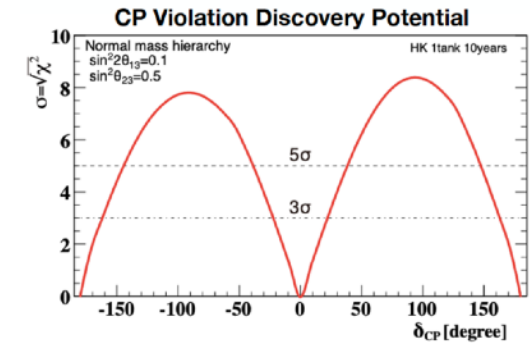
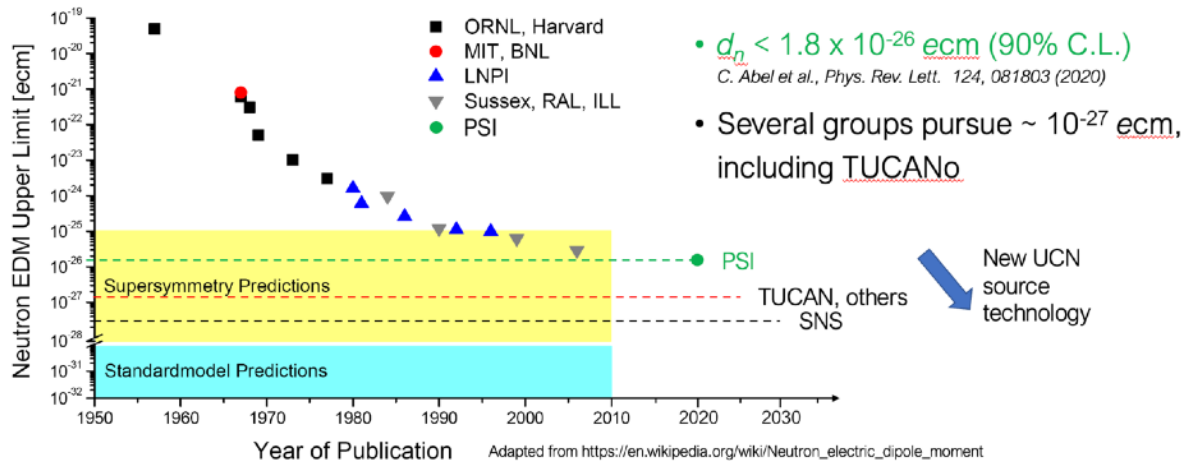
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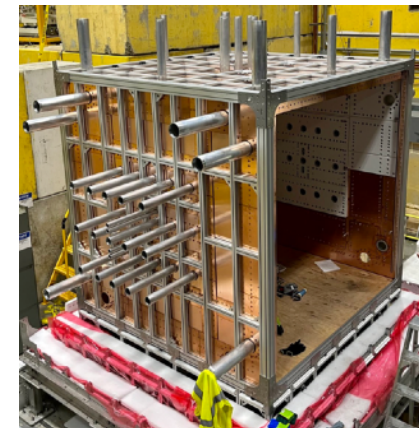
# JAPAN

- T2K/Hyper-K
- Major goal is the search for CP violation in neutrino oscillations!
- Deliver on upgrades

- TUCAN
- EDM experiment for search for strong CP violation
- Deliver on source and EDM experiment



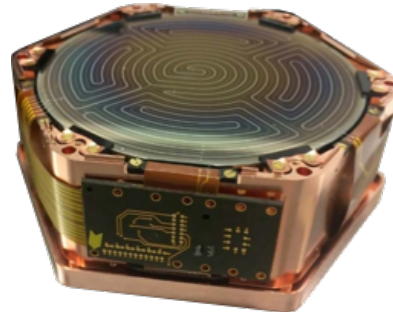
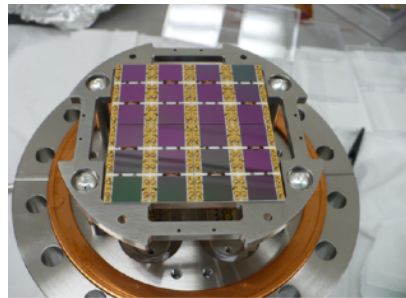
- PENELOPE (2<sup>nd</sup> port)
- World's best neutron lifetime measurement



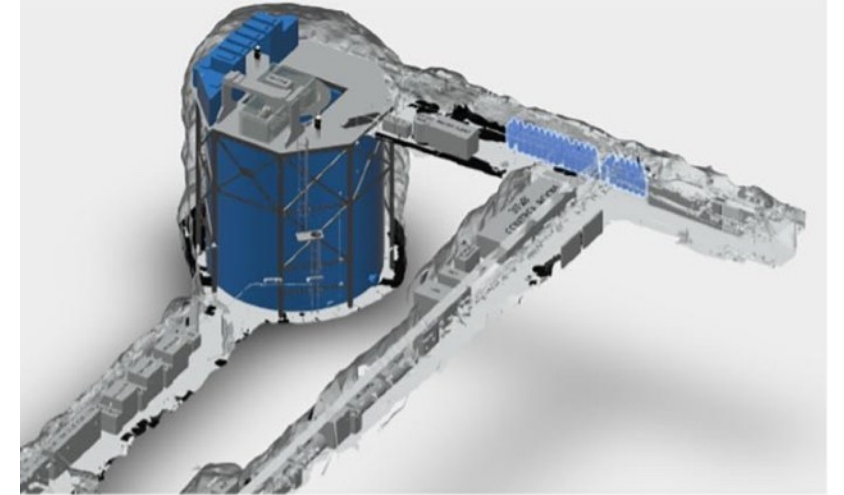
Discovery, accelerated

# SNOLAB

- **nEXO**
- next generation neutrinoless double beta decay experiment under consideration for SNOLAB
- Silicon photo-multiplier SiPM performances enable reaching nEXO target energy resolution



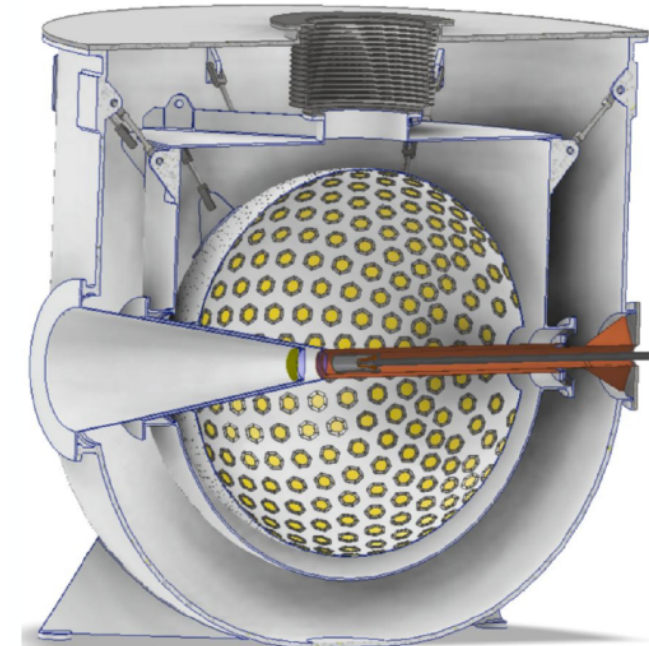
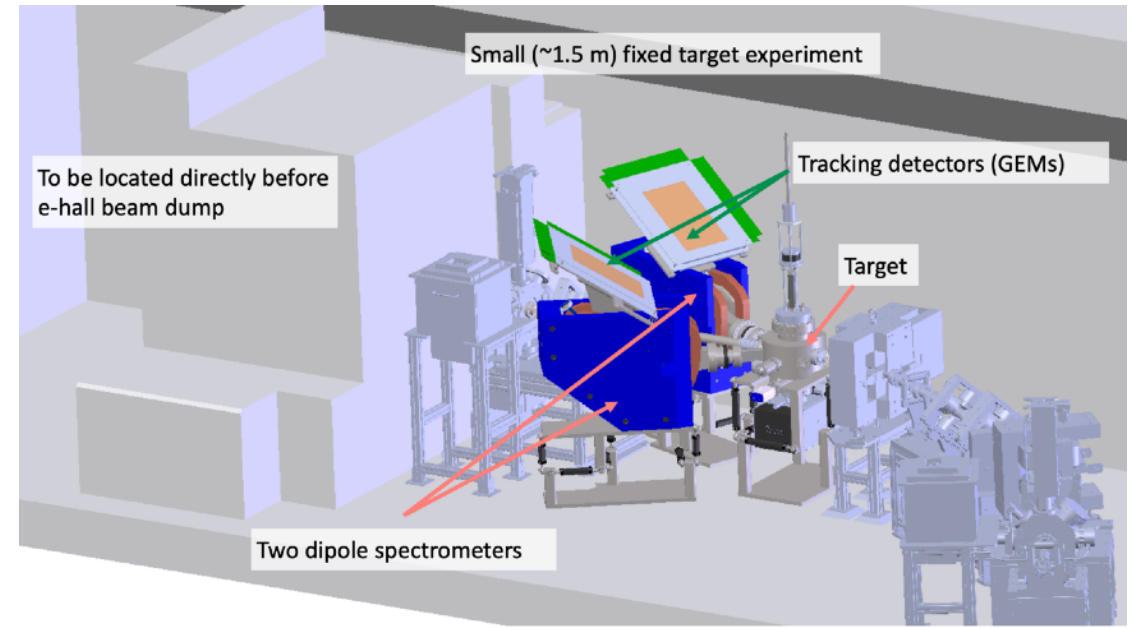
- **SuperCDMS**
- Direct dark matter search with cryogenic Ge and Si detectors
- Focus on low-mass Dark Matter
- CUTE (cryogenic underground test facility)



# TRIUMF

- **DarkLight**
- Early science case for ARIEL
- New experiment at e-linac to search for new low mass dark boson

- **PIONEER**
- Successor of PIENU
- $R_{SM}^{\pi} = (\pi \rightarrow e\nu(\gamma))/(\pi \rightarrow \mu\nu(\gamma))$ :
- Worlds most precise e- $\mu$  universality test
- Includes improved world class pion lifetime measurement





## 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- $\mu$  universality test**

## 5YP Scenarios

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

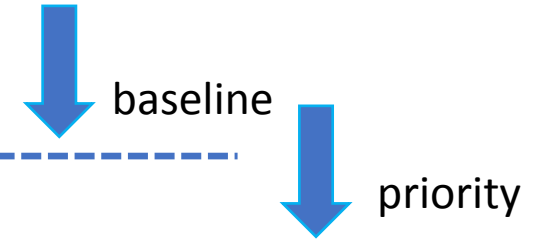
Scenario	Shutdown for a year to finish ARIEL construction	Business as usual 6 months shutdown – 6 months beam
<b>Pros</b>	<ul style="list-style-type: none"> <li>Get ARIEL done quickly to free resources</li> <li>Hopefully able to install the re-circulation ring which would allow DarkLight to perform a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

# Hiring Priorities

- Baseline highest priority for 2025-2030

- TUCAN
- Hyper-K (succession)

- Strengthening Science & Technology capabilities



- Growth area (possibly also with university partners / joint-hires - not ranked)

- Astro-particle / nEXO / DarkSide-20k (*SNOLAB connection*)
- PIONEER (*secure critical mass*)
- P-ONE (*potentially big local experiment*)
- Future Collider
- TUCAN
- Quantum/Precision

## 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 (EOI ~December)

- ATLAS-Tier-1
- Integrated Detector Development (ID<sup>2</sup>)
- ALPHA
- PIONEER
- TUCAN
- nEXO
- Liquid Ar



## Centers at TRIUMF

- First Five-Year Plan in decades without new major accelerator component
- Centers for
  - **Detector Development**
  - **Quantum Technologies**
  - **Data Science / AI**
- Strengthen/re-gaining TRIUMF's core competencies (especially for R&D) while **aligning with government priorities** around Quantum Technologies, AI and Sustainability
- Alignment with 20-year vision
- Consider focusing on one “Quantum & Instrumentation Center” for this Five-Year Plan
  - Includes enhanced capabilities in ML



## Criticality

- Unique R&D staff and expertise that enables innovation, mission critical work and training
  - Difficult to hire and retain on a temporary basis (e.g. CFI hires) and needs long term perspective
  - Complementary to Science & Technology core mission
- Funding multipliers for hardware and technical personnel through dedicated grants



## Training

- TRIUMF has an excellent track record on graduate student training and has a first-class undergraduate & coop program
- Building on GRIDS, opportunity for e.g. a CREATE program
  - On-the-job training in cutting-edge research environment
  - Work integrated learning, in collaboration with e.g. BCIT

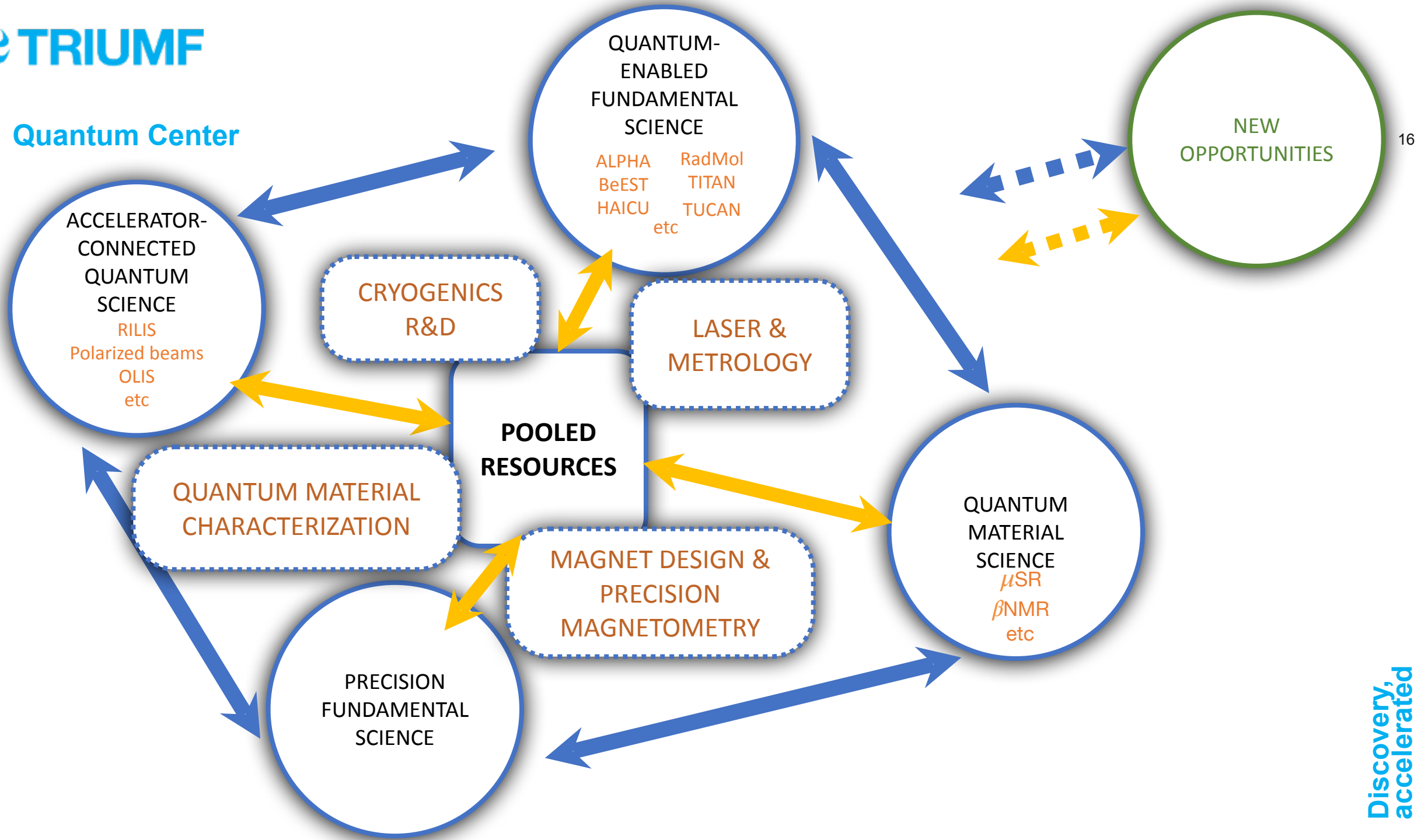


## Quantum Center

- Existing quantum experiments spans across the laboratory and departments
  - Spin polarized beams  $\mu$ SR and  $\beta$ NMR, TUCAN, ALPHA/HAICU, RadMol, Francium trapping, etc
- Require common expertise and infrastructure when pooled will allow for cross-fertilization and new R&D for novel use of quantum technologies
- Take advantage of National Quantum Strategy and new programs from NSERC, MITACS and NRC

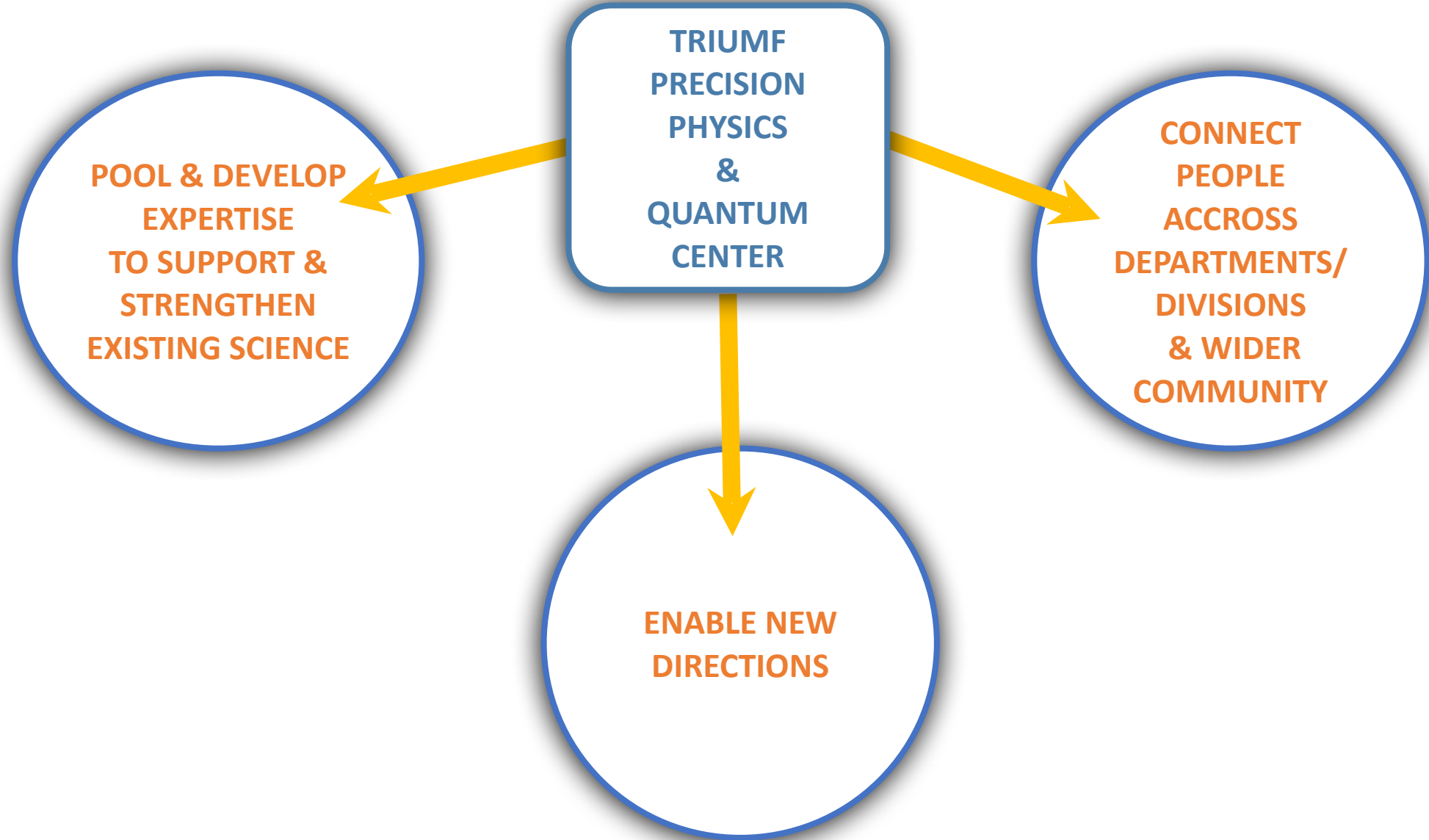


# Quantum Center





## Quantum Center



## Goals

- Pool the R&D resources and sustain the expertise in the long term and allow better cross-fertilization across departments and divisions
- Span across TRIUMF's existing divisional structure & connect to new fields (e.g. quantum chemistry)
- Establish & support new flagship experiments at TRIUMF
- Connect Canadian and international community in novel use of quantum and precision experiments in fundamental and applied science. The center will develop the existing Quantum forum initiative to the next level, leverage resources and be a structure that organizes workshops, conferences, and schools on precision, AMO and quantum physics and their connections to other fields.
- Act as a wedge for longer-term growth in quantum & precision physics - strategically important areas for TRIUMF

## Advantages

- The fundamental aspect of TRIUMF quantum-related science program is relatively distinct in the Canadian quantum network ecosystem
- Accelerator-based quantum-related science is certainly unique in Canada
- The already existing wide scope (user-inspired/fundamental) of quantum-related research and precision experiments at TRIUMF is a strength for future cross-fertilization
- TRIUMF existing quantum-related program extends beyond what was presented here (e.g. quantum computing for fundamental science → connects to AI center proposal )

## Summary

- Particle Physics addresses many of the most compelling questions
  - **Many breakthrough results expected over the next Five-Year Plan (need resources)**
  - Higgs, Probing CP violation in neutrinos, neutron EDM and lifetime, precision with antimatter...
- Three 5YP scenarios have direct impact on Particle Physics program in particular for DarkLight (preference for 2026 shutdown) and UCN (preference for 6 months shutdown – 6 months beam, see dedicated talks)
  - **Questions:**
    - **In case of a 2026 shutdown, how likely is it that ARIEL is completed by summer 2027?**
    - **Is the availability of Science & Technology personnel impacted by the shutdown?**
- **Case for new centers:**
  - **Unique R&D staff and expertise that enables innovation for breakthrough science**
  - Difficult to hire and retain on a temporary basis (e.g. CFI hires) and needs long term perspective
  - Funding multipliers for hardware and technical personnel through dedicated grants + training HQP
- Discussion on single “Quantum & Instrumentation Center” (name TBD)
  - Start with most pressing needs for key personnel & seed funds ~\$1M/year
  - Opportunity with “Weft and Warp” to identify how to gain organizational efficiencies

Thank you  
Merci

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