

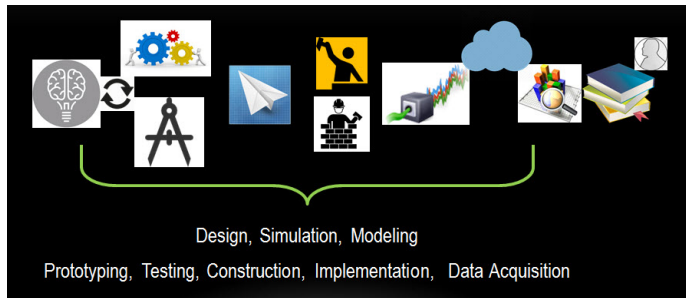


TRIUMF Science Technology Department: towards a long range plan

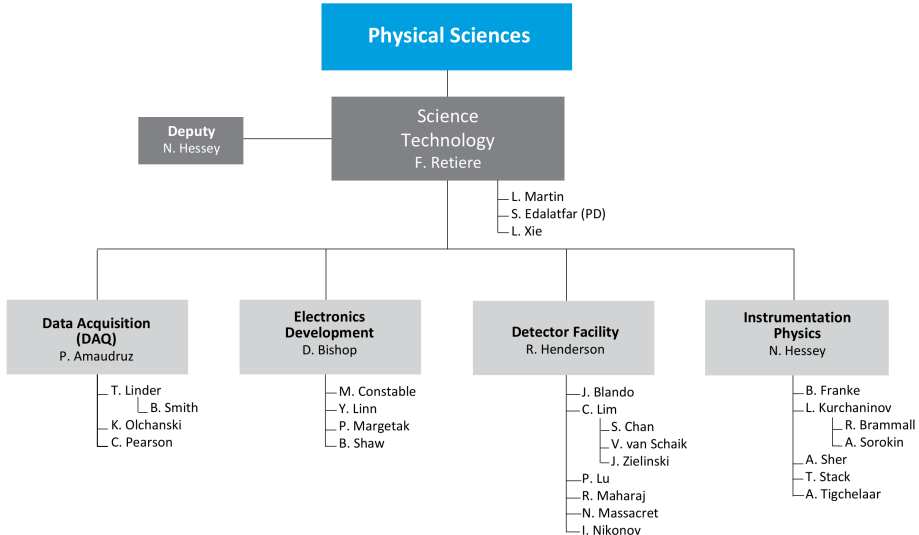
Nigel Hessey
TRIUMF

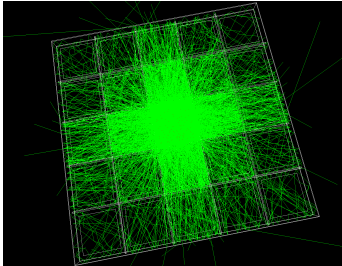
TRIUMF 5-YP, European Strategy Group, and SnowMass process all call for increased effort to develop particle detector technology for future experiments

- Overview of the Department and its Groups
- Future Developments

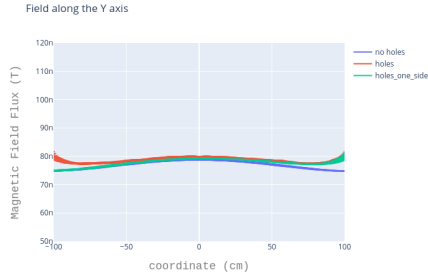


- ▶ Keep Canada at the forefront of Particle and Nuclear Physics:
 - ▶ Support Canadian experimentalists to make excellent detectors for projects falling under TRIUMF's mission
 - ▶ Advance detector technologies to enable future science
- ▶ How?
 - ▶ Develop and maintain a versatile and flexible team with broad experience in detector systems and associated instrumentation
 - ▶ Maintain and up-date the necessary tools and infrastructure
 - ▶ Design and develop the best mechanics, electronics, instrumentation, and DAQ for detectors
 - ▶ R&D in particle detectors, electronics, DAQ for future experiments: to make better measurements and searches possible.
 - ▶ Support important non-detector TRIUMF projects, such as ARIEL-targets gas-cooling

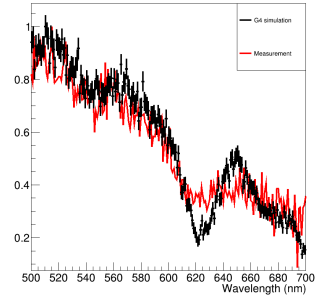




(a) Avalanche photon transport to neighbouring SiPM cell



(b) nano-Tesla field variations in magnetically shielded room for nEDM



(c) Comparison of GEANT4 photon transport in fibres with measurement

- ▶ Early-stage detector development:
 - ▶ GEANT4 simulation
 - ▶ Electromagnetic FEA
 - ▶ Garfield simulation of gaseous detectors
 - ▶ Analysis optimisation (e.g. application of neural networks)
 - ▶ Experimental verification of simulations
- ▶ Front-end analogue development: in particular ATLAS LAr Electronics Upgrade



(a) ALPHA-g wires

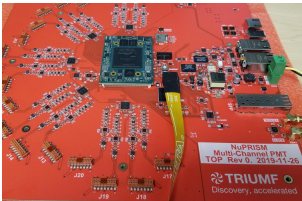


(b) ALPHA-g upright + team

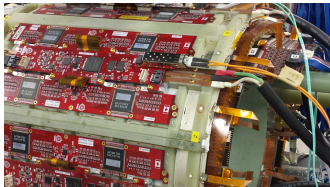


(c) SciTech 5-axis CNC Mill

- ▶ Design, Engineering, Fabrication, Assembly, Testing and Commissioning of detectors
 - ▶ Design, optimise and find solution
 - ▶ Assemble, test and commission
 - ▶ Machine Shop to manufacture parts
- ▶ Equipment available:
 - ▶ 5-axis CNC machine (Oil free to preserve scintillators)
 - ▶ Lathe and other machine tools; 3D Printers, ...
 - ▶ Solidworks expertise for 3D CAD
 - ▶ Mechanical FEA expertise
 - ▶ Cleanrooms, granite tables, wire chamber assembly tooling
 - ▶ Large detector lab, with benches and equipment for assembling and testing detectors
 - ▶ Dark rooms, laser room



(a) NuPrism 20-channel mPMT acquisition board



(b) ALPHA-g TPC front-end electronics



(c) GRIFFIN VME64x 16-channel data acquisition module

- ▶ Provide high-quality custom electronic devices and firmware
 - ▶ Schematic Capture and PCB Layout
 - ▶ SPICE simulation
 - ▶ Firmware for FPGAs and embedded processors (VERILOG/VHDL)
 - ▶ Firmware for data filtering/algorithm/data reduction/read-out
 - ▶ Chip design (currently in Instrumentation Physics group)
 - ▶ Over-seeing manufacture in industry
- ▶ Equipment available:
 - ▶ Oscilloscopes, signal generators, power supplies, microscopes, clock distribution modules, I/O Boards
 - ▶ Climate chamber

DarkSide DAQ Proposal (Design)

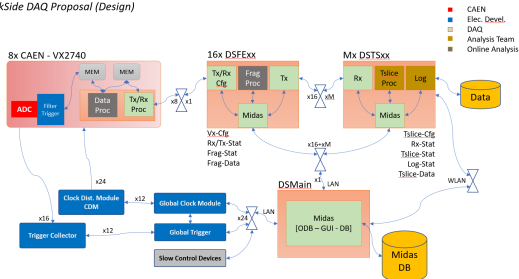


Figure: Darkside DAQ Proposal

- ▶ Dedicated hardware, firmware, and software development for DAQ
- ▶ 100 computers dedicated to DAQ
- ▶ Expertise to set up DAQ for entire experiments
- ▶ DAQ system MIDAS (25 years development), with full web integration
 - ▶ Used in CMMS and almost all nuclear physics on site; ALPHA-g and DEAP-3600 off-site

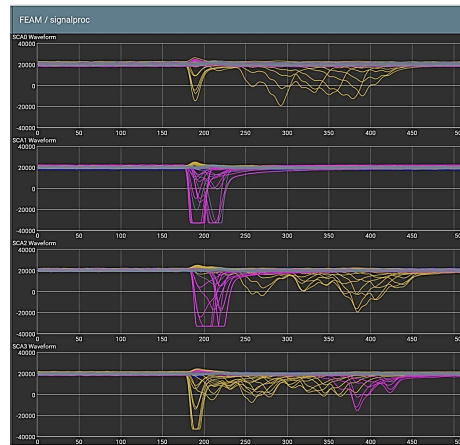
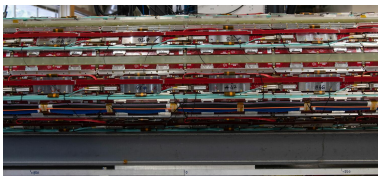
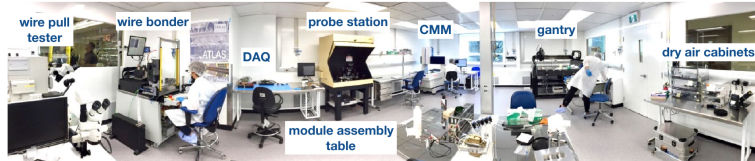


Figure: Triumf Acquisition module with integrated waveform web display server



(a) ALPHA-g Electronics



(b) ITk Equipment and MHESA Cleanroom

▶ Learn from the past:

▶ ALPHA-g

- ▶ Whole system development - **our preferred project style**
- ▶ SciTech offers complete integration of design, mechanics, front end electronics, DAQ, ...from concept to data taking
- ▶ Get involved with physicists early

▶ ATLAS ITk

- ▶ Benefit from this and similar big experiments with acquisition of specialist equipment
- ▶ MHESA Cleanroom, wire-bonder, 3D gantry, optical coordinate measuring machine, ...
- ▶ Well positioned for further R&D in silicon detectors

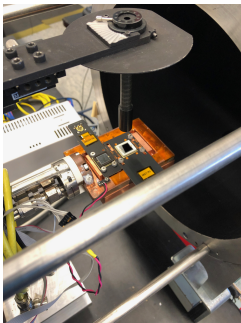
▶ Nuclear Physics: Mainly electronics and DAQ support

- ▶ Open to support more: Cryogenics, lasers, detectors, ...

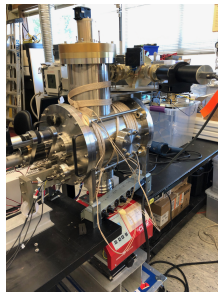
▶ We continue to support current projects, and need to prepare for future projects:

- ▶ Near future: mPMT for HyperK, Darkside-20k, nEXO, Moller, Data Science, Quantum Computing ...
- ▶ Further future: ILC/CLIC/FCC/...

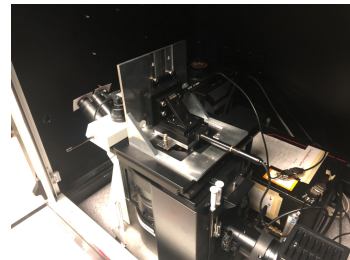
- ▶ Keeping SciTech fit for future projects:
 - ▶ Next slides: ideas for near future needs; your input wanted. All require:
 - ▶ Perpetual evolution of skills and equipment
 - ▶ Talent critical: Foster high class, versatile, flexible talent
 - ▶ Talent retention critical: CFI funded positions tend to lose the talent at the end of the grant



(a) VERA



(b) VERA



(c) LEIM

- ▶ Support next generation photon-detector development, especially silicon photomultipliers (SiPM) and Low Gain Avalanche Detectors (LGAD)
- ▶ See Fabrice Retiere talk tomorrow
- ▶ TRIUMF main input in photonics
 - ▶ VERA (Vacuum Efficiency, Reflectivity, and Absorption)
 - ▶ Measure materials/coatings for 120 - 1000 nm photons
 - ▶ LEIM (Light Emission and Injection Microscope)
 - ▶ 1 μm spot size LN₂-cooled camera/spectrometer
 - ▶ Funded 2017 CFI-IF
- ▶ Photon lab/Darkroom built with McDonald Institute funding

- ▶ Inner layers of new ATLAS Pixel Detector for 2027 will die after about 5 years operation
- ▶ ILC, FCC, ... will give even higher radiation while needing to be even closer to the beam pipe
- ▶ What will follow current ATLAS ITk project at TRIUMF?
- ▶ Proposal for Canadian institutes to join World-wide effort via CERN RD50 to develop next generation of rad-hard pixel detectors
- ▶ Benefit from investments in ATLAS ITk silicon tracker
 - ▶ Cleanrooms, equipment such as probe stations, wire-bonder, gantry, Coordinate Measuring Machine (CMM)
 - ▶ SFU 4D labs Si wafer processing ability
 - ▶ Carleton University Microfabrication Facility (CUMFF)
- ▶ Start basic R&D now; see talk tomorrow by Thomas Koffas

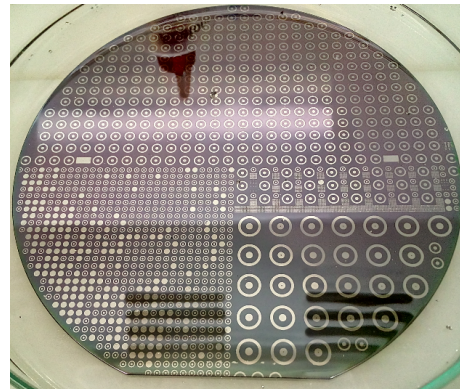
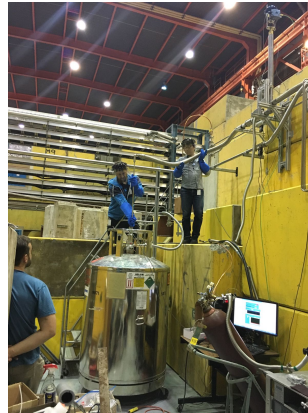


Figure: Silicon wafer with structures for irradiation testing

- ▶ SuperCDMS, UCN, nEDM, quantum sensing, traps ... all need cryogenics
 - ▶ Beyond the additional ^4He liquification capacity which is also needed, UCN needs advanced techniques including ^3He closed loop, superfluid 1 K isotopically pure ^4He closed loop, ...
 - ▶ Consolidated TRIUMF effort needed
- ▶ Inner Trackers need specialised materials and ultra low mass cooling ($\approx -40\text{ }^\circ\text{C}$, $\approx 100\text{ kW}$)
- ▶ Need to build up and retain expertise
 - ▶ All need specialised cryogenic engineering expertise
 - ▶ Sci Tech alone needs access to a full time expert for at least a decade
 - ▶ Need to ensure continuity of skills at TRIUMF
 - ▶ Investigate how best to organise this


 (a) UCN ^4He Cooling for test run

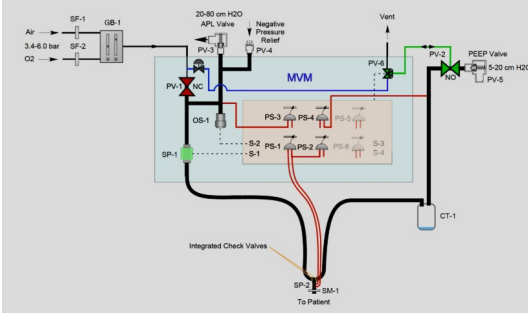
 (b) UCN: *Brrrr!*

- ▶ NSERC MRS resources within Sub-atomic Physics are becoming more national.
- ▶ Aims:
 - ▶ Facilitate large project development by using available resources in Canada efficiently
 - ▶ More specialisation in centres, and pool resources
 - ▶ Ensure available expertise matches community needs
- ▶ Process
 - ▶ Case made within Long Range Plan context in June/July 2020, at CINP, IPP, ...
 - ▶ Arrange joint meeting TRIUMF SciTech and MRS institutes Sept 2020
 - ▶ Setup Sub-atomic Physics technical advisory board (1 member per MRS institute + 1 TRIUMF + 1 IPP + 1 CINP + 2 members at large)
 - ▶ Centralize large project requests for technical resources into single portal (Sci Tech request form will continue to be used for small projects)
 - ▶ Board advises projects to seek resources from specific institutes (TRIUMF + MRS)
 - ▶ Board advises institutes (TRIUMF + MRS) regarding evolution of expertise and capabilities

- ▶ Instrumentation Physics:
 - ▶ TCAD simulation of silicon detectors
 - ▶ Comsol FEA for thermal behaviour etc.
 - ▶ Wave optics software for photonics
- ▶ Detector Facility Machine Shop
 - ▶ Better high precision measurement for QC
 - ▶ Higher precision machining
 - ▶ Composites for Inner Tracker cooling and supports
 - ▶ Advanced equipment, for example metal 3D printer
- ▶ Electronics
 - ▶ Quantum computing support
 - ▶ Chip design: evolution of expertise and capabilities after ATLAS calorimeter work, Canada team with Sherbrook and others
 - ▶ Extend FPGA capability
- ▶ DAQ
 - ▶ Large fraction of DAQ group working on operational support: how to find effort to keep up-to-date?
 - ▶ Further development of MIDAS
 - ▶ R&D on in-line data-processing using latest technology, e.g. GPUs and AI
- ▶ Cryogenics, as mentioned

Mechanical Ventilator Milano

<http://mvm.care>

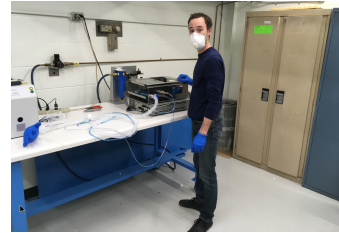


Started by Cristiano Galbiati of *The Global Argon Dark Matter Collaboration* Triumf contacted in late March 2020 for support

11 countries involved, including Canada:

Canadian Nuclear Laboratories, Chalk River
Queen's University, Kingston
Sudbury Neutrino Observatory Laboratory, Creighton Mine
TRIUMF: Canada's particle accelerator centre, Vancouver
The Mosaic Company, Regina
University of Toronto, Toronto

Played an important role in prototyping, software, equipment certification testing over the five-month project. Awaiting Health Canada approval for distribution (10K units)



Prototype testing April 26/2020



Final Unit Jul 28/2020

- ▶ SciTech is here to support detector development and associated instrumentation
- ▶ Input welcome from experimentalists about what is needed
- ▶ Early-stage detector development to keep Canada at the forefront
- ▶ So we can evolve and continue to support and enable the new physics you want to do
- ▶ Thank you for your attention