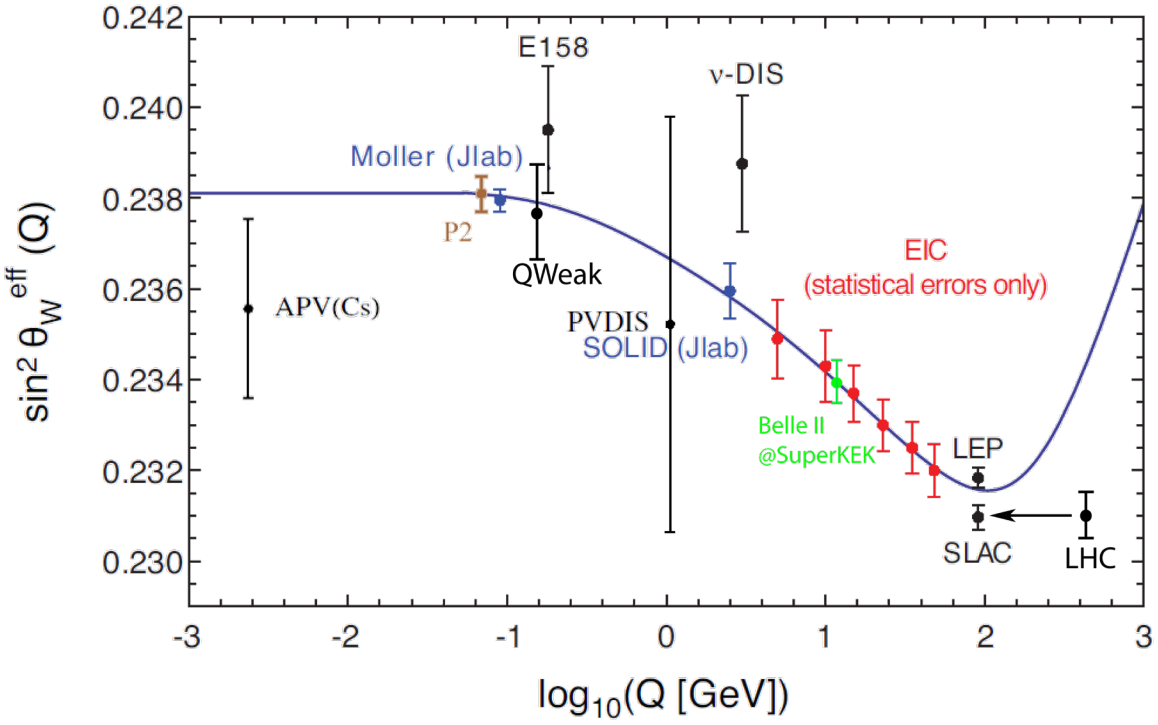
Measurement Of a Lepton Lepton Electroweak Reaction using Parity Violating Electron-Electron Scattering

Michael Gericke (Manitoba), for the Canadian MOLLER group

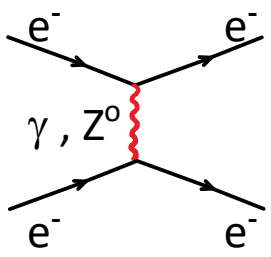
A proposed 2.4% measurement of the electron weak charge:

$$Q_W^e = -(1 - 4sin^2\theta_W)$$

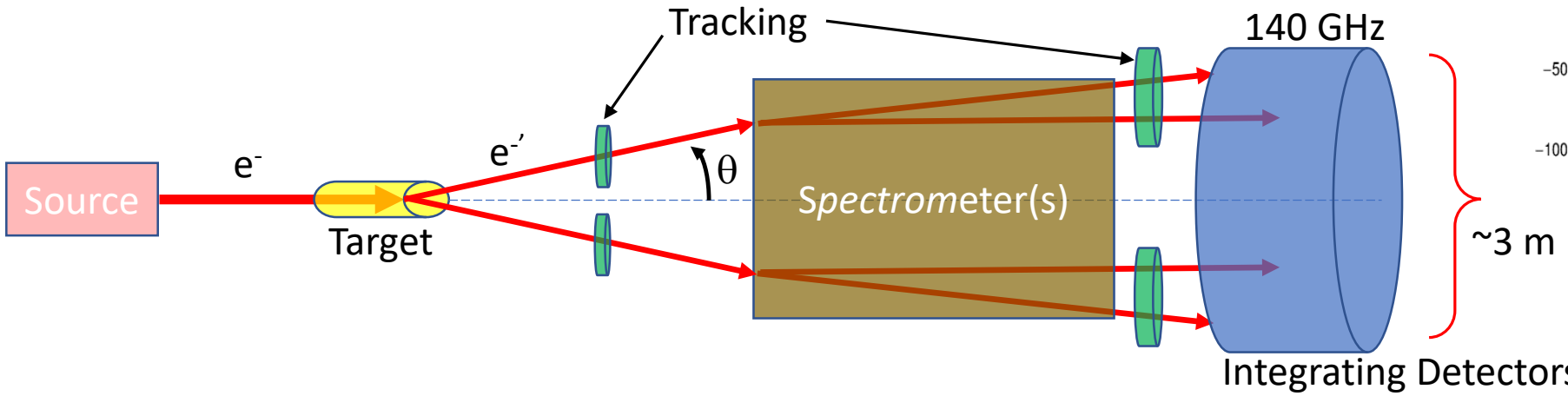
A test for physics beyond the Standard Model

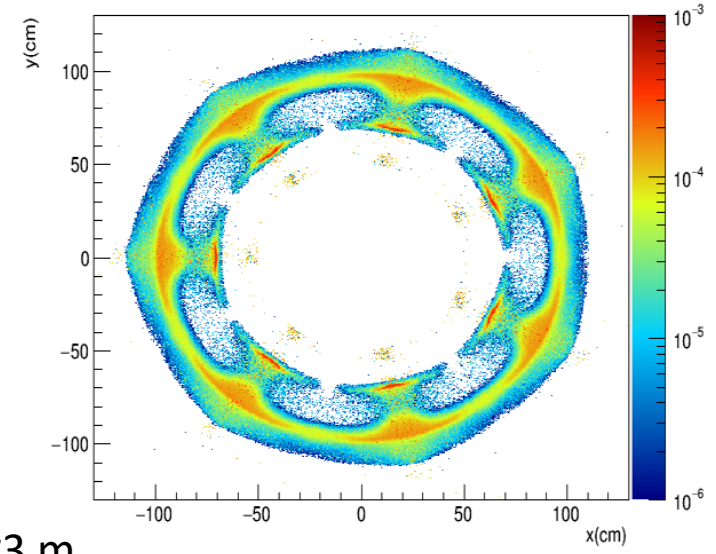


Methodology:



$$Q_W^e = -(1 - 4sin^2\theta_W)$$





- Highly polarized electron beam with fast helicity flip rate
- Separate into e-e , e-p , and inelastic bins using two toroidal spectrometers
- Measure PV asymmetry with integrating detectors:

$$A_{PV} = m_e E \frac{G_F}{\pi\alpha\sqrt{2}} \frac{4sin^2\theta}{(3 + cos^2\theta)^2} Q_W^e$$

- Measure scattering angle with tracking detectors

$$E_{beam} = 11\ GeV$$

$$I_{beam} = 65\ \mu A$$

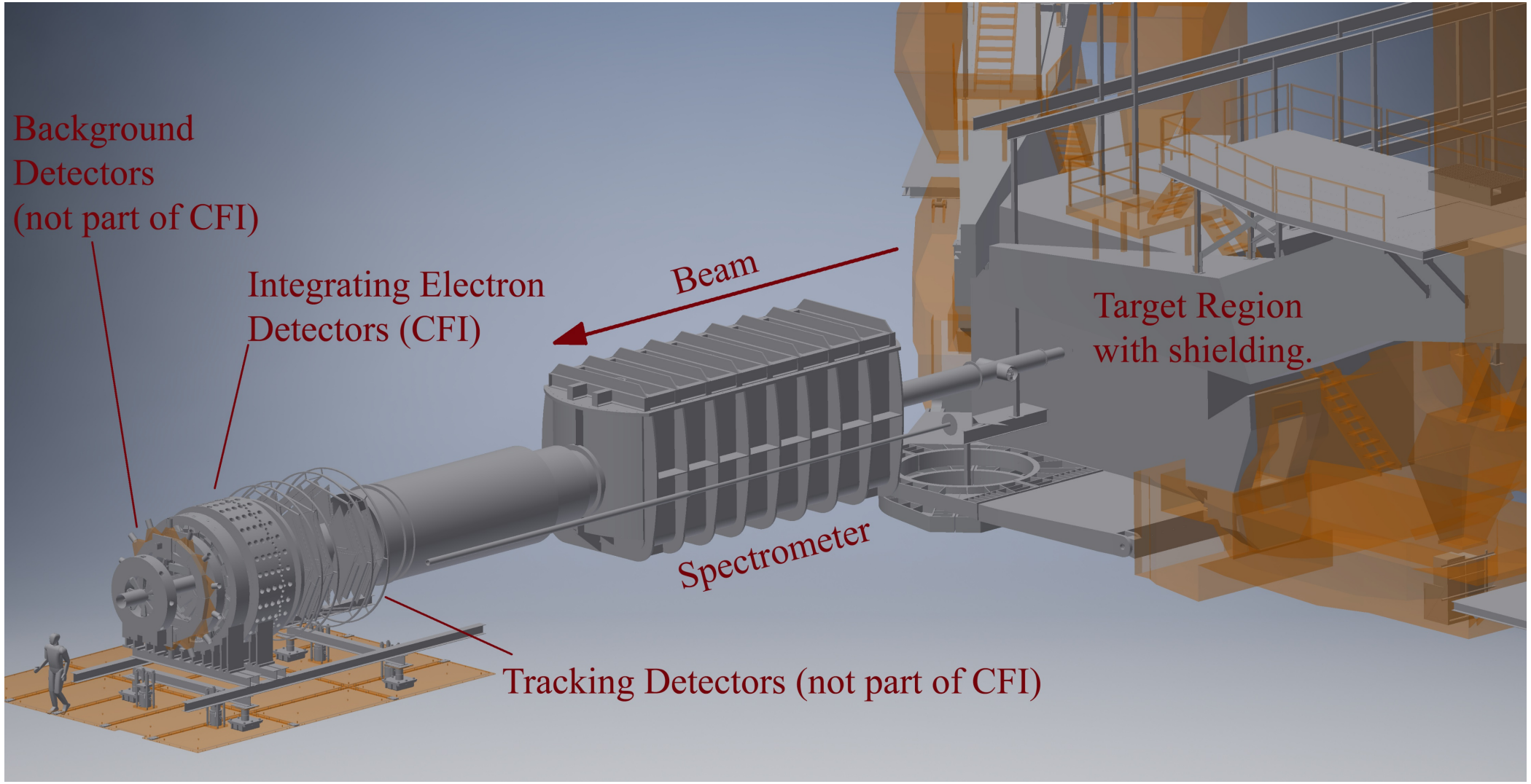
$$\mathcal{L} = 3 \times 10^{39}\ cm^{-2} \cdot s^{-1}$$

$$2.75 \leq E_{scat} \leq 8.25\ GeV$$

$$P_{beam} \geq 90 \pm 0.5\ \%$$

Partial CAD Illustration of the MOLLER Experiment in Hall A at Jefferson Lab. in the US

Not shown: Upstream collimation, polarimetry, and beam monitoring.

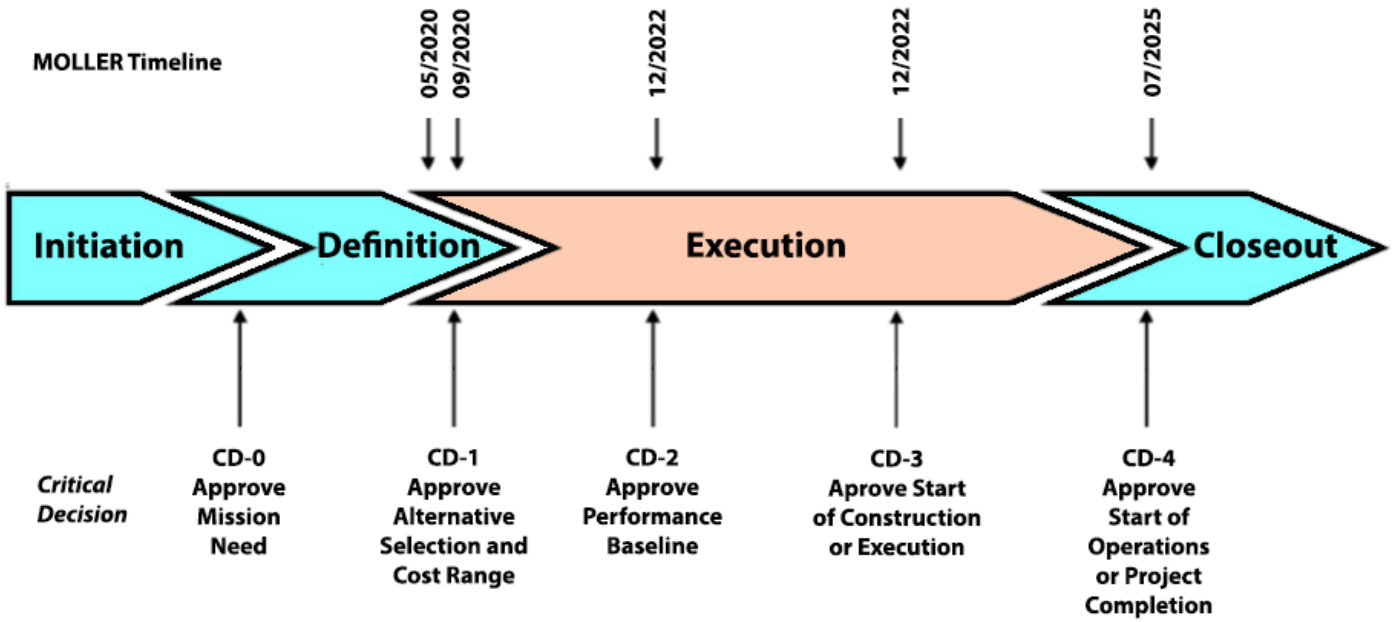


Status:

- MOLLER has about 120 collaborators from the US, Canada (the founding + lead countries), Germany, France, Italy, and Mexico – Canadian group is the second largest contiguous group in the experiment
- MOLLER Received DOE CD-0 designation ("mission need") in 2017
- Undergone multiple science, technical, and cost and schedule reviews since then
- MOLLER cost is ~40M US
- First DOE funding installment for MOLLER was approved for the 2020 budget for engineering and R&D
- CD-1 review (freeze the conceptual design) scheduled for September 2020
- MOLLER has received 4 years of NSERC funding so far (about CAD 1M – started small, but ramping up)
- A CAD ~6M CFI IF submission under evaluation in the current round, for the integrating detectors – Juliette Mammei and M. Gericke are co-leads.
- There are currently 9 faculty level PIs and 12 HQP in the Canadian group (2 RAs, 8 Grad, 2 UGrad)
- The 2 RAs identify as women and are from an ethnic minority; 4 grad stud. Identify as women, 6 are from an ethnic minority; one of the ugrad students identifies as female and is indigenous.

Schedule:

- 2022: CD-2 and 3 (construction start)
- 2025: CD-4 (end of project – production start with a 2 year float to 2027)
- 2025(27) to 2028(30): Data production
- 2028 → : Analysis and publication



Given the present situation, there is a distinct possibility for this go beyond the built-in schedule float.

We expect a latest finish (all done) date of roughly 2035, including publication of all physics measurements.

Canadian Group and Contributions:

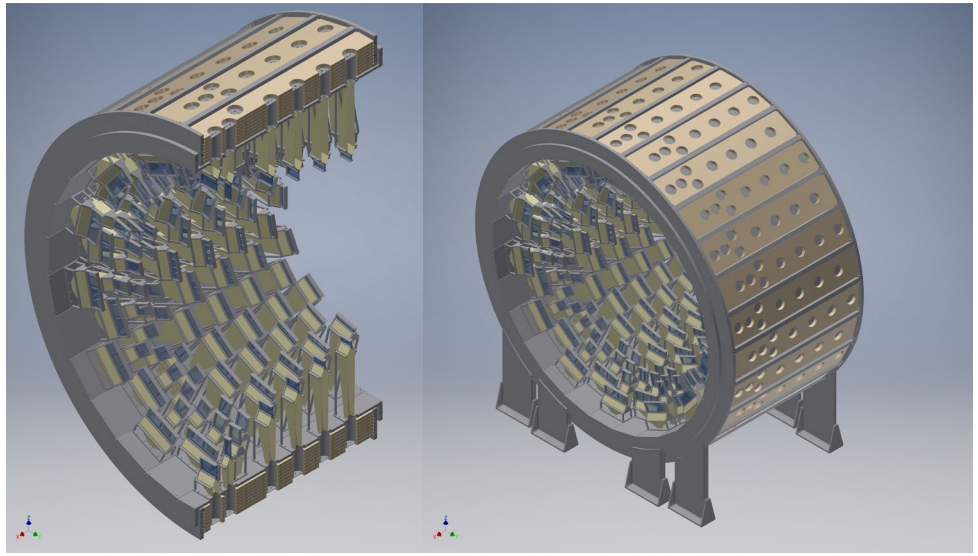
- 9 Faculty, from U. Manitoba, U. Winnipeg, Memorial U. of Newfoundland, U. of Northern British Columbia
- Radiative corrections and simulations (Memorial)
- Simulations and data analysis software (U. Manitoba)
- Detector design and prototyping (U. Manitoba, U. Winnipeg, UNBC)
- Detector electronics (U. Manitoba & TRIUMF)
- Spectrometer design and beam optics (U. Manitoba)
- Electron beam polarimetry (U. Manitoba, U. Winnipeg)
- J. Mammei and M. Gericke are the MOLLER experimental leads on the spectrometers and integrating detectors

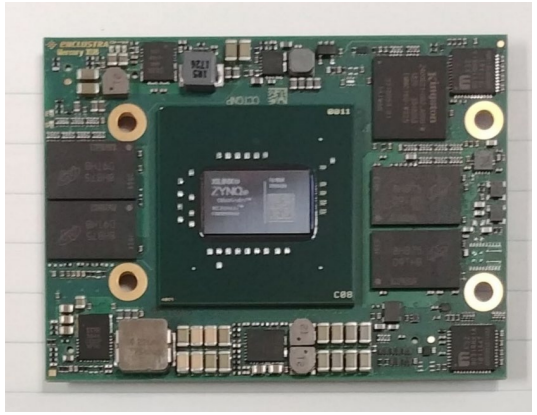
The Canadian group is asking for CFI funding to build the main electron detectors for the experiment. The proposal asks for CAD 6M in total (40% CFI, 40% Manitoba, 20% DOE).

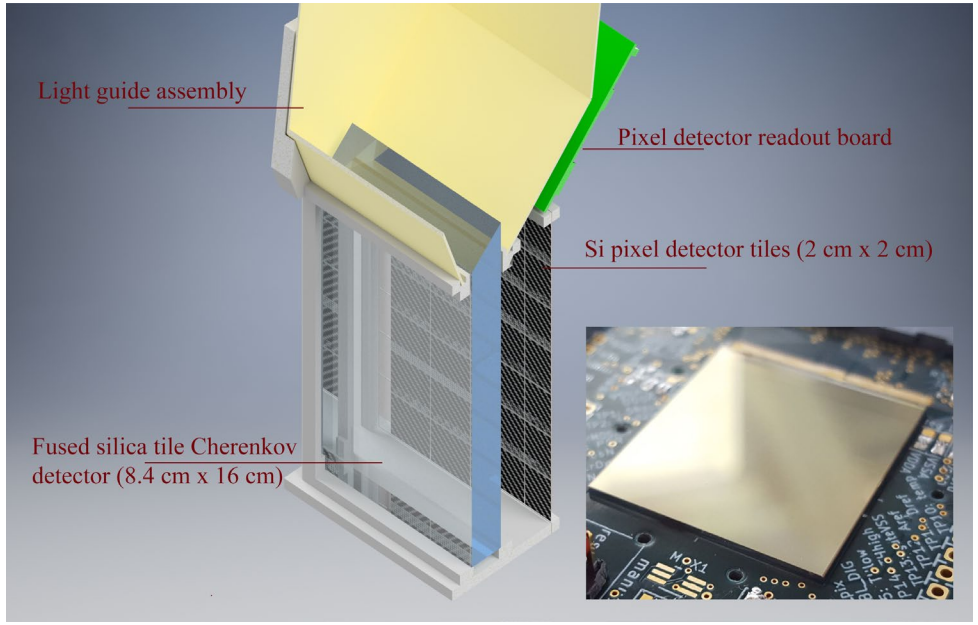
Canadian Contributions:

CFI:

- 252 detector modules each consisting of a fused silica (e.g. quartz) tile, light guide, PMTs, and profile pixel detectors
- Readout/front-end electronics
- Engineering cost (TRIUMF)
- Technical personnel







Funding outlook:

	2015	2016	2017	2018	2019	2020	2021	Optimal Funding 2022-25 /year	Optimal Funding 2026-29 /year	Optimal Funding 2030-33 /year
Investigator FTEs	2.5	2.5	2.6	2.6	2.6	2.7	2.9	3.1	3.4	2.5
NSERC (k$)	65.0	130.0	162.0	162.0	185.0	205.0	215.0	400.0	500.0	250.0
CFI (k$)						6000.0				
NSERC RTI (k$)			40.0				250.0			

- Current funding cycle ends March 2022
- Funding request is projected to ramp up starting in 2022, especially if the CFI is successful
- After 2021 the numbers correspond to average amount per year and assume a significant increase in HQP
- If CFI is not successful, will request RTI funding to pick up a strongly scaled back portion of the hardware (electronics)
- Largest operational financial support will be needed during data collection (2025 - 2030)
- Additional PI to join the effort are always welcome

Thank You

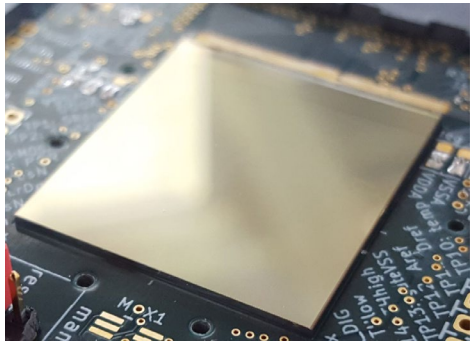
Collaboration Effort Split:

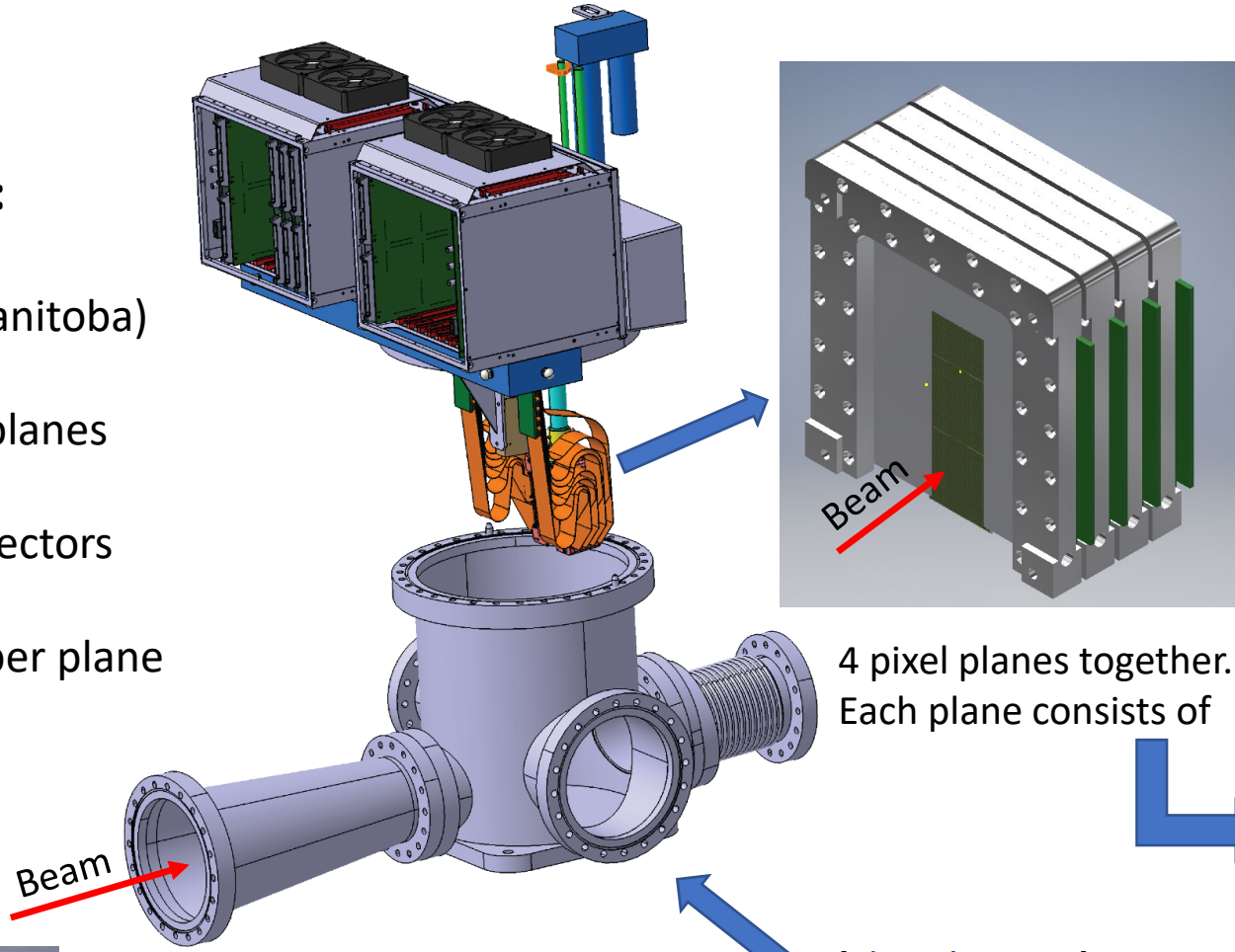
• Polarized source:	UVa, JLab, Miss. St.
• Hydrogen Target:	JLab, CalState LA, Miss. St.
• Spectrometer Magnets:	Canada and MIT, ANL, SBU, UVa, UMass
• Main Detectors (CFI):	Canada, U. of Mainz (Germany), Idaho State, UMass, Syracuse
• Luminosity Monitors:	VaTech, Ohio
• Pion Detectors:	William & Mary, SBU, LATech, UNC A&T, Canada
• Tracking Detectors:	William & Mary, Canada, SBU, UVa, INFN Roma, MIT
• Electronics:	Canada and U. of Mainz, JLab, TRIUMF
• Beamline Instrumentation:	VaTech, UVA, JLab, Stanford
• Polarimetry:	UVa, and Canada, JLab, CMU, ANL, Miss.St., William & Mary, Temple
• Data Acquisition:	Ohio, Rutgers, JLab
• Simulations:	Canada and SBU, UMAss, Berkeley, Idaho State, UVa, LaTech
• Software:	Ohio, USA, JLab, Canada

Compton Polarimetry:

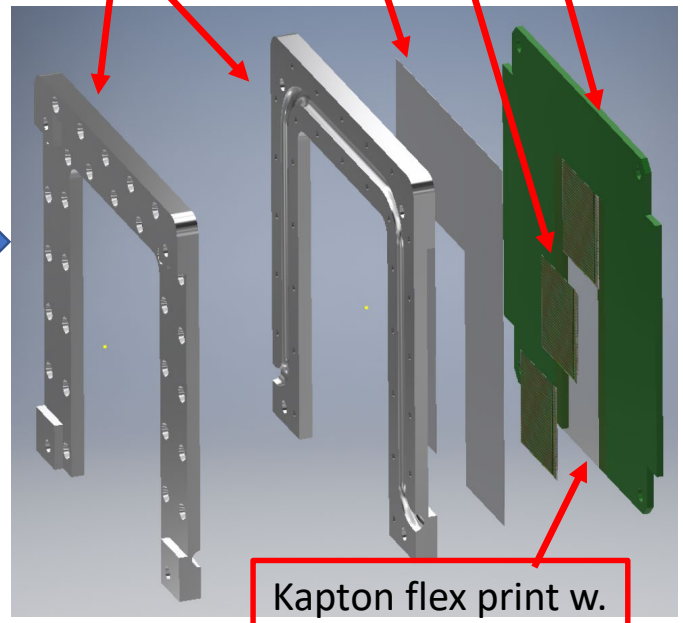
Electron detectors (U. Manitoba)

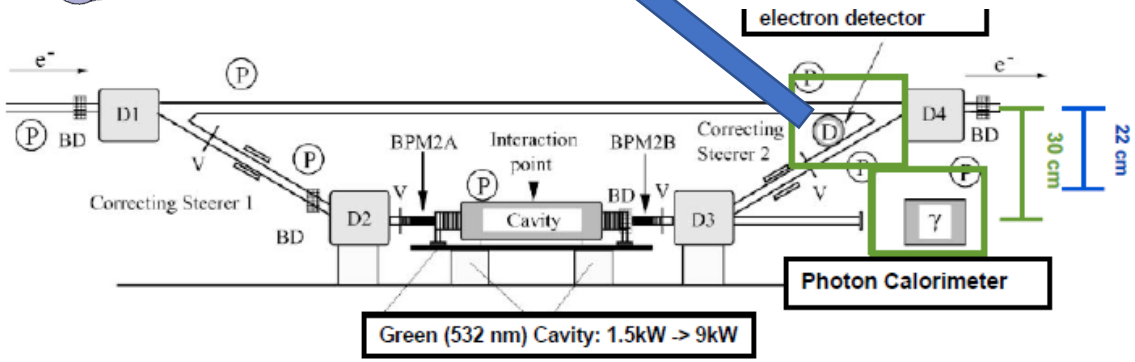
- 4 pixel detector planes
- HVMAP pixel detectors
- 3 2x2 cm^2 chips per plane
- 80x80 µm pixels





4 pixel planes together.
Each plane consists of

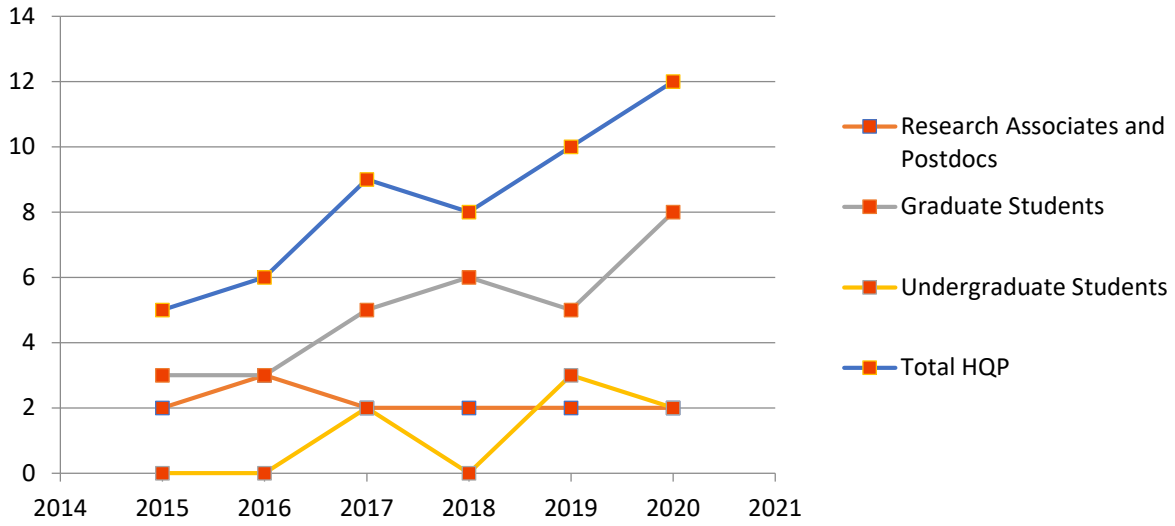




Recommendations and Needs:

HQP:

- Number of HQP is largely limited by finances
- Opportunities for RA's and GS to present and participate internationally also limited by finances
- NSERC EvSec consistently "suggests" taking on fewer GS when cutting requested budget amounts – yet HQP numbers are highly important in the evaluation of the proposals (disconnect)



Computing:

- We currently have 173 core years for this cycle, through Compute Canada
- Increase to 400 core years during highest analysis periods
- ~4 Pbytes of data storage needs (mirror the data set)

Technical:

- TRIUMF engineering to develop electronics
- MRS engineering and technical support (if not TRIUMF)

BSM Physics:

- Hidden Weak scale scenarios: Compressed Supersymmetry
- Lepton number violation (doubly charged scalars)
- MeV scale dark matter mediators (dark Z)
- MSSM (R-parity)
- TeV scale Z'
- Lepton compositeness

Model independent reach:

$$\frac{\Lambda}{\sqrt{|g_{RR}^2 - g_{LL}^2|}} = \frac{1}{\sqrt{\sqrt{2}G_F|\Delta Q_W^e|}} \backsimeq 7.5\ TeV$$

Lepton compositeness:

$$\sqrt{|g_{RR}^2 - g_{LL}^2|} = 2\pi \qquad \Rightarrow \qquad \Lambda \backsimeq 47\ TeV$$