MOLLER Project Update

IPP AGM Meeting, June 23, 2023

Michael Gericke

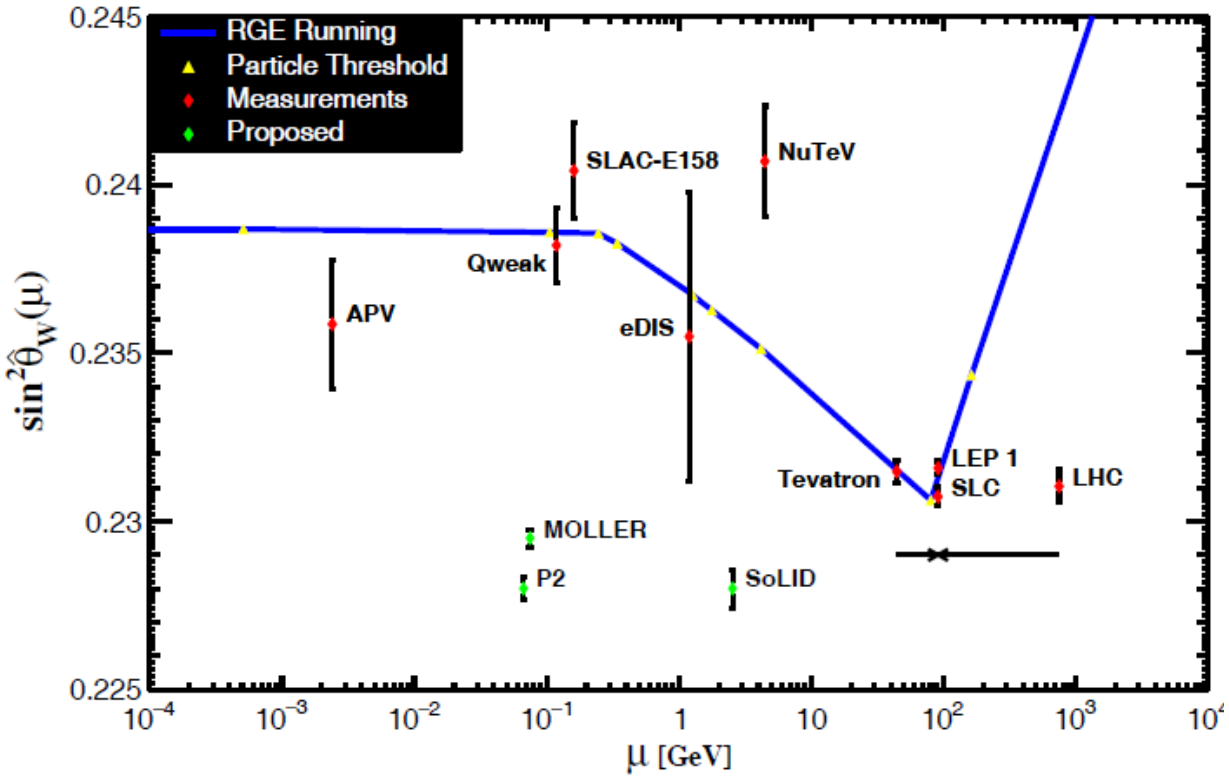
For the Canadian MOLLER Team

A. Aleksejevs, S. Barkanova, B. Blaikie, W. Deconinck, M. Gaffar, M. Gericke, F. Gorgannejad, A. Gunawardhana, K. Isaak, T. Kainth, E. Korkmaz, S. Longo, J. Mammei, R. Mammei, J. Martin, L. Mohammad, N. Niloy, J. Pan, S. Prabhakar, S. Rahman, W. Rathnakela, W.T.H. van Oers, N. A. Cruz Venegas

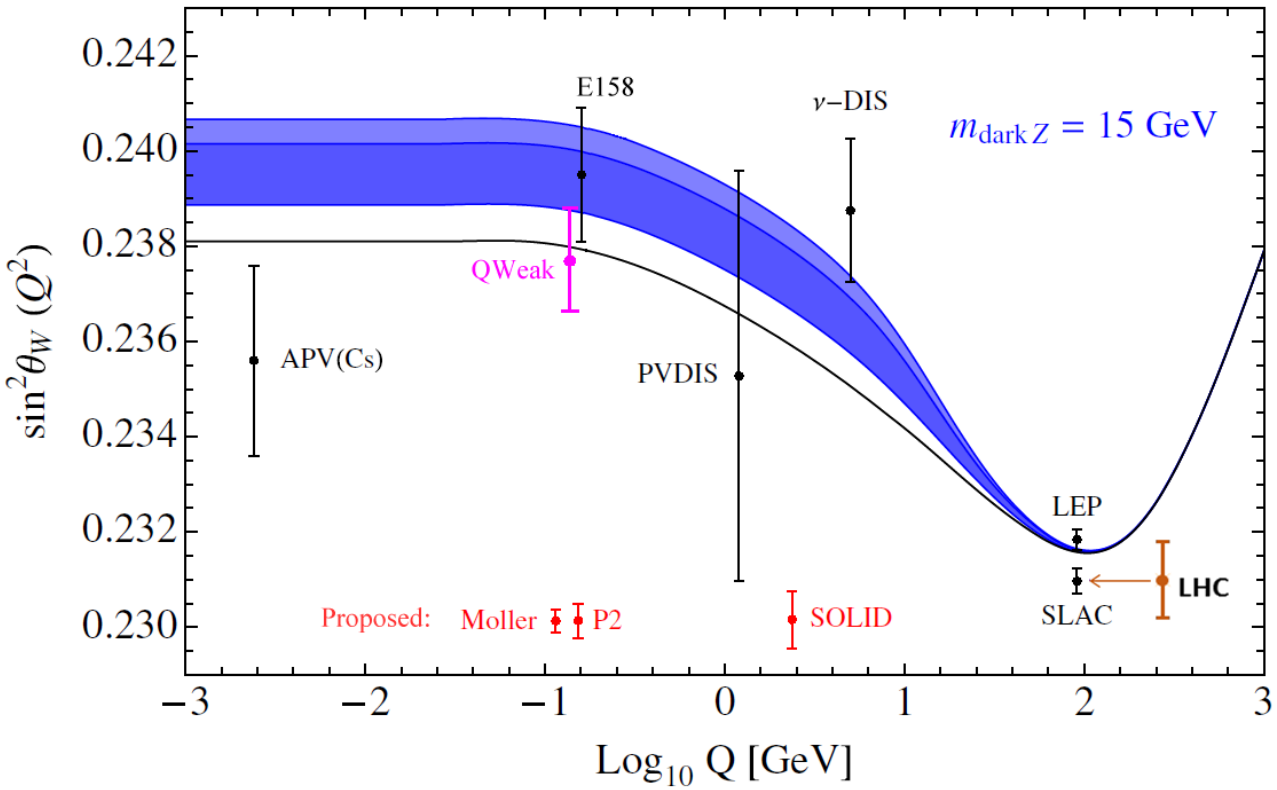
About 10% of the overall collaboration, ~200 people from the US, Canada, Germany, Italy, France, and Mexico

Motivation:

J. Erler (JGU), reproduced with permission



Adapted from Davoudiasl et al. PRD 92, 055005 (2015)

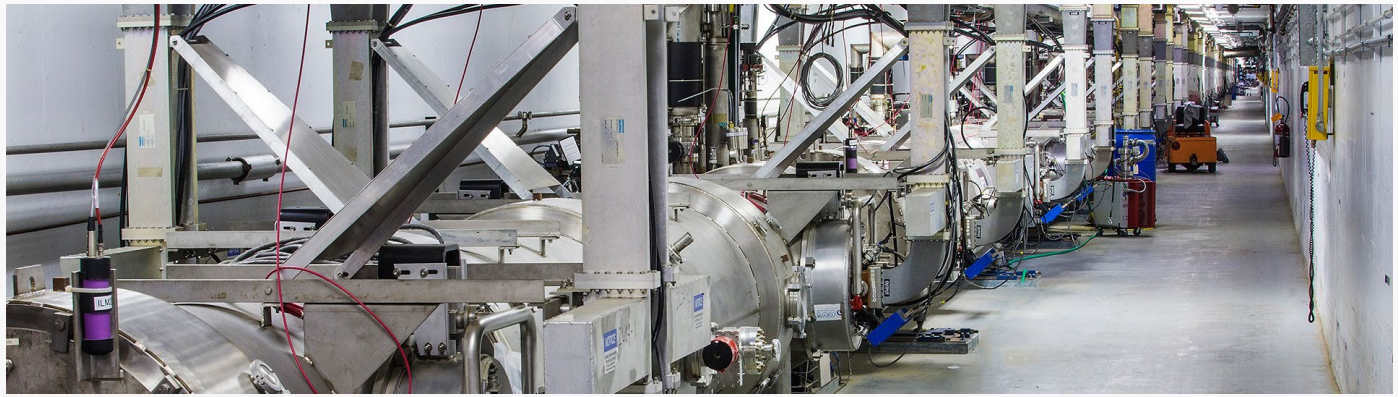


MOLLER will run at the Thomas Jefferson National Accelerator Facility, Virgina, USA making use of the high intensity high energy electron beam with the highest possible electron beam polarization.

The experiment will be located in hall A, the largest of the 4 halls.

Particular beam properties that are important include:

- High luminosity
- Parity quality beam: High polarization with high beam stability and systematic control
- High precision beam polarimetry measurements must be possible
- High power LH2 target (which the facility has experience with)



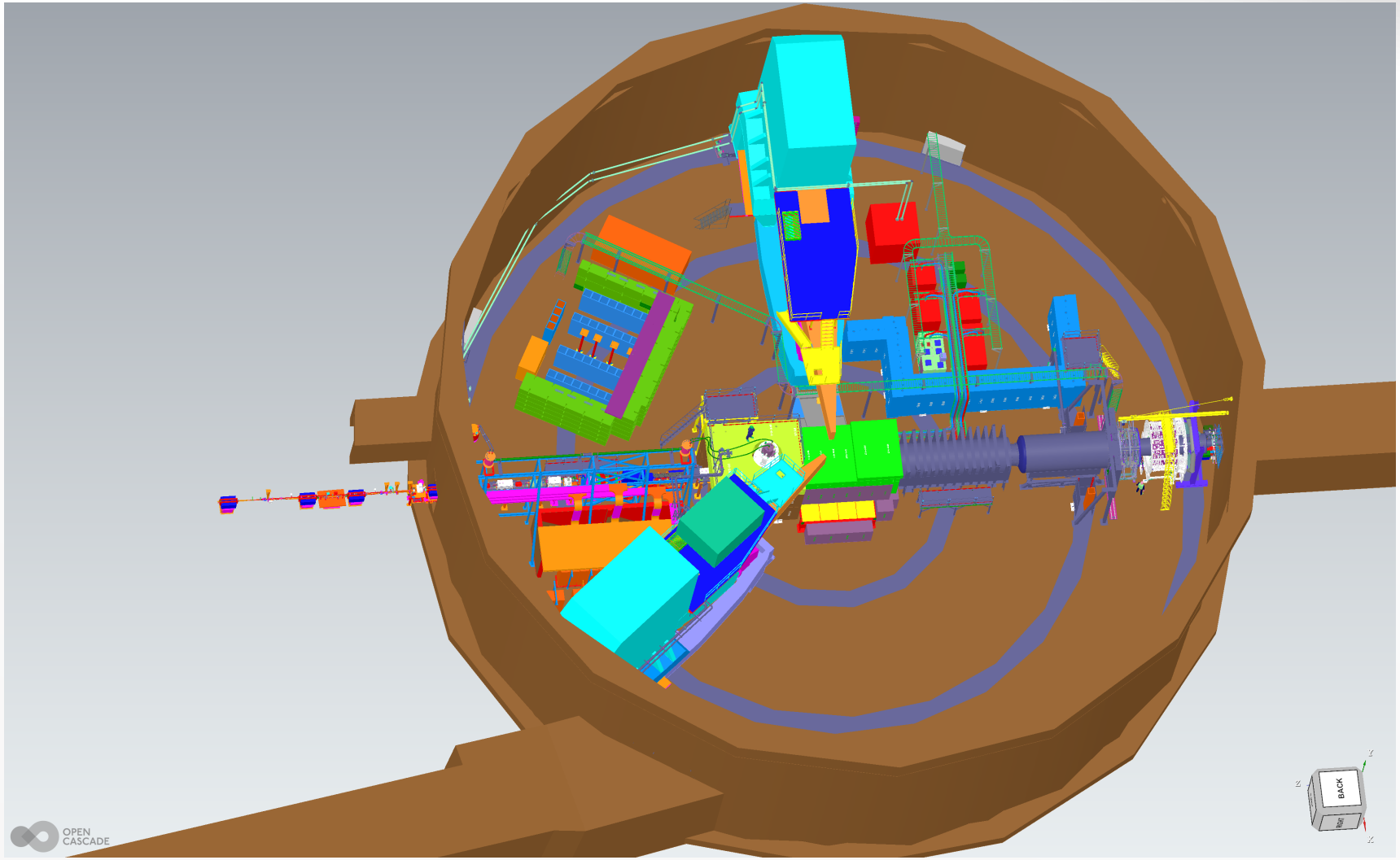
MOLLER in Hall A:

The beam enters from the lower left.

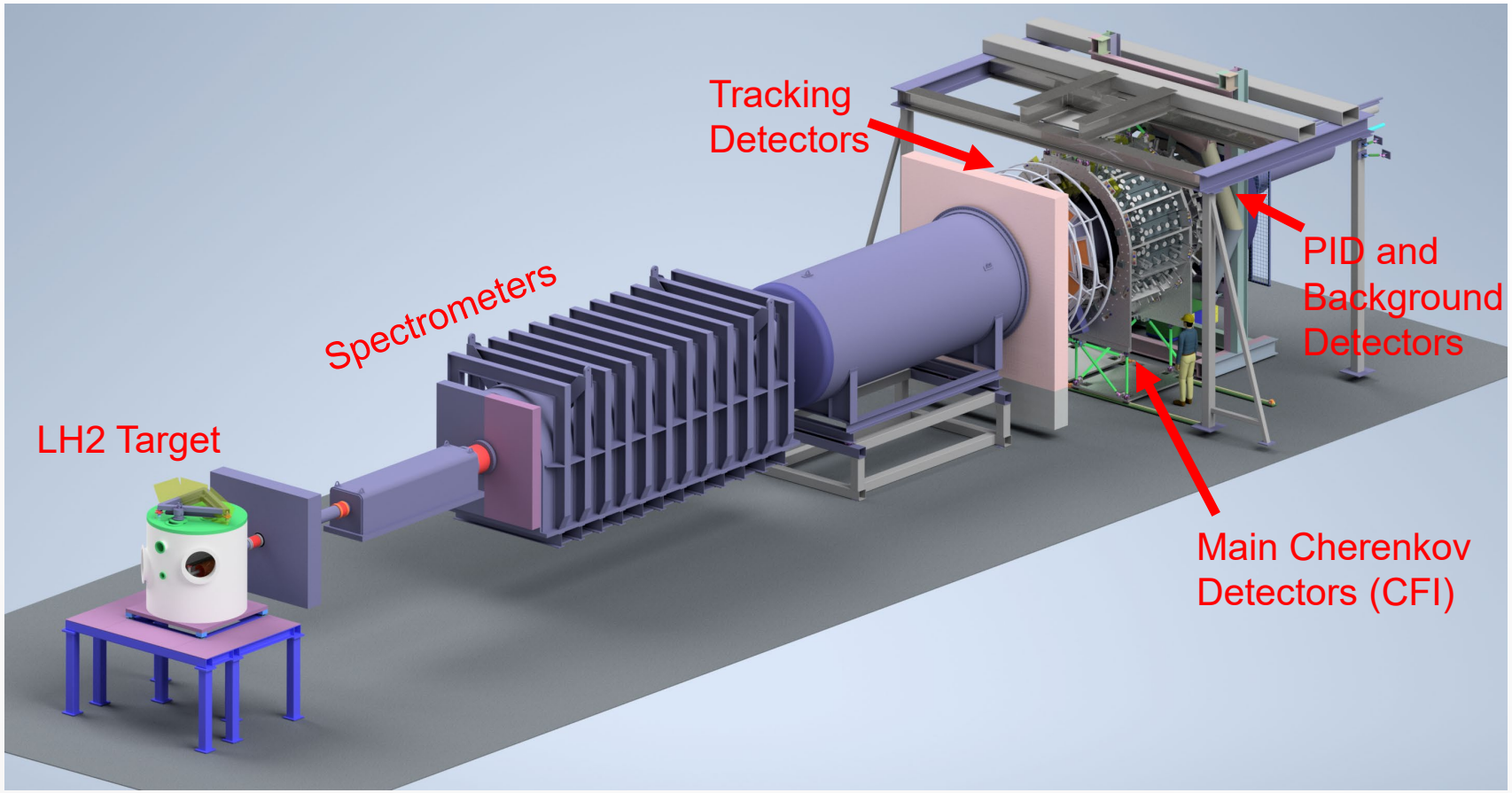
Electrons are scattered by target electrons and steered into a large set of high precision detectors.

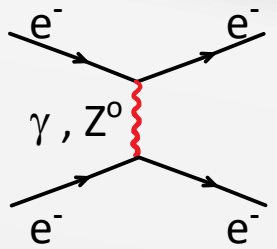
Main Detectors (CFI funded Canadian contribution) located at the far left in the figure.

A large part of the detector system is funded by the CFI.



Partial Hall A CAD Illustration





$E_{beam} = 11\ GeV$

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

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

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

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

$A_{PV} = 32\ ppb$

$\delta A_{PV} = 0.8\ ppb$

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

$\Delta Q_W^e = 2.4\%$

$\Delta sin^2\theta_W = 0.1\%$

Main Observable:
PV asymmetry with detectors
Weak Charge of the electron

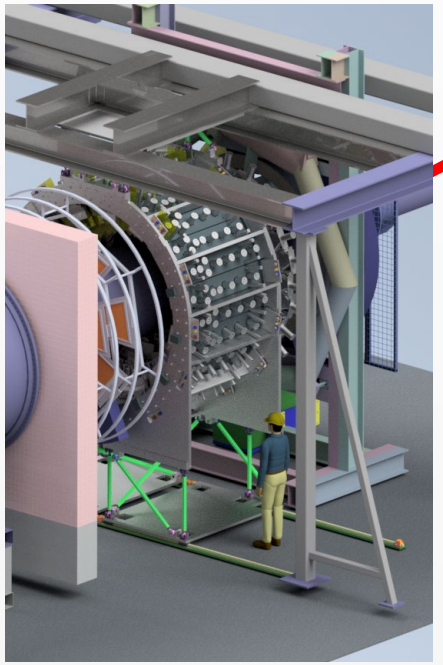
$$A_{PV} = m_e E \frac{G_F}{\pi\alpha\sqrt{2}} \frac{4sin^2\theta}{(3 + cos^2\theta)^2} Q_W^e$$

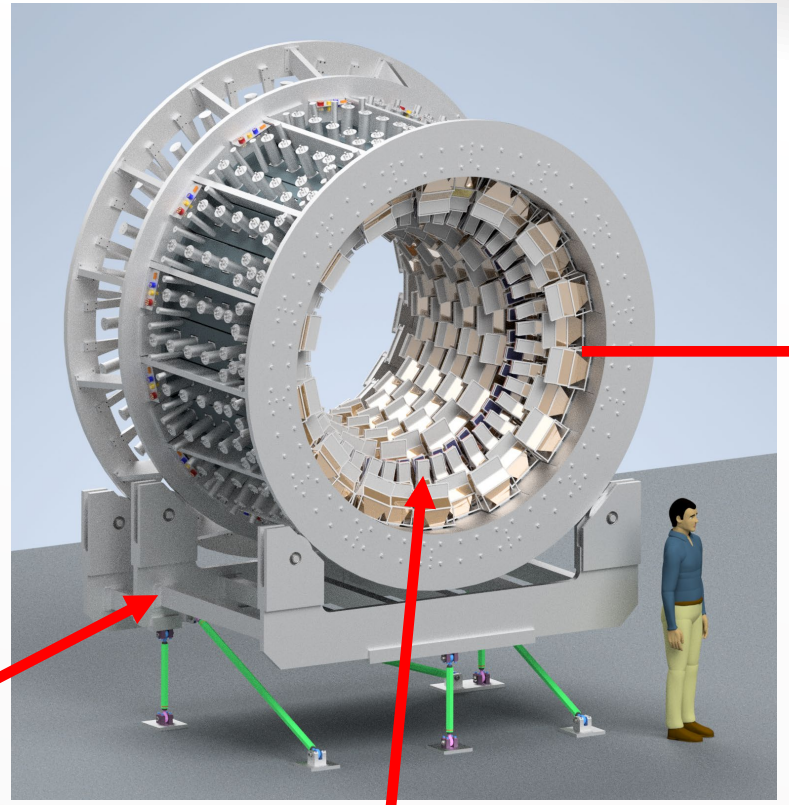
The CFI funded Detectors

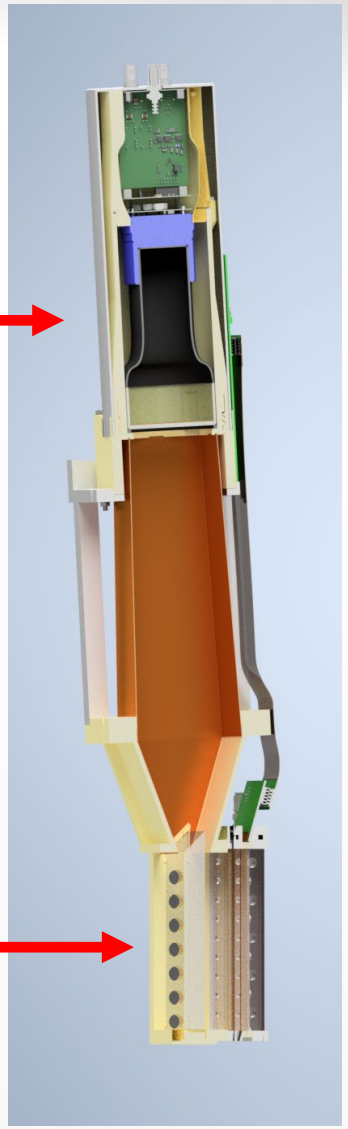
The integrating detector package consists of 252 separate detector modules. The 224 “thin” detectors are CFI funded, including:

1. Mounting structure
2. Quartz active material
3. Light guide
4. Photo-multiplier tube and base
5. HVMAPS Pixel Sensors
6. Front-end electronics
7. ADC boards
8. Cabling, Power Supplies, etc.
9. Cooling/dry air flushing

The detectors are used to measure the asymmetry for all event types.





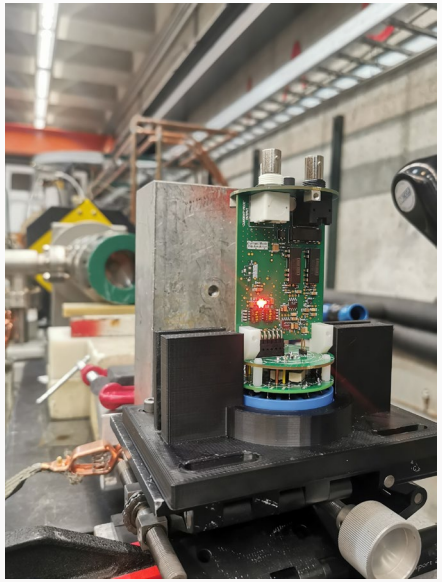


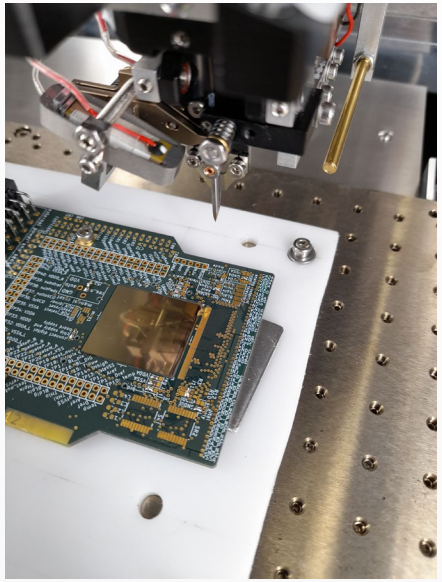
Ring 5: 84 detectors - quartz /HVMAPS combination

Other rings: 140 detectors - quartz only

Detector and electronics prototyping and testing

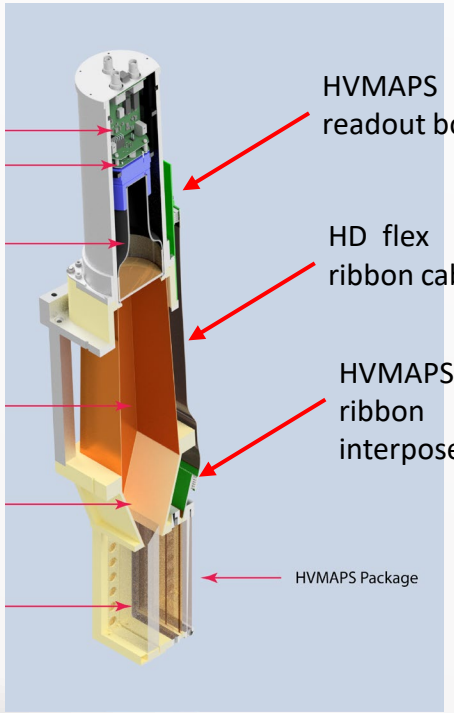
- 2021-2022 prototyping and beam testing campaign for main detector modules and electronics
- Technical design and prototyping complete at the 90% level (down to minor final modifications based on most recent test results)
- Entire electronics chain has been tested and verified to work.

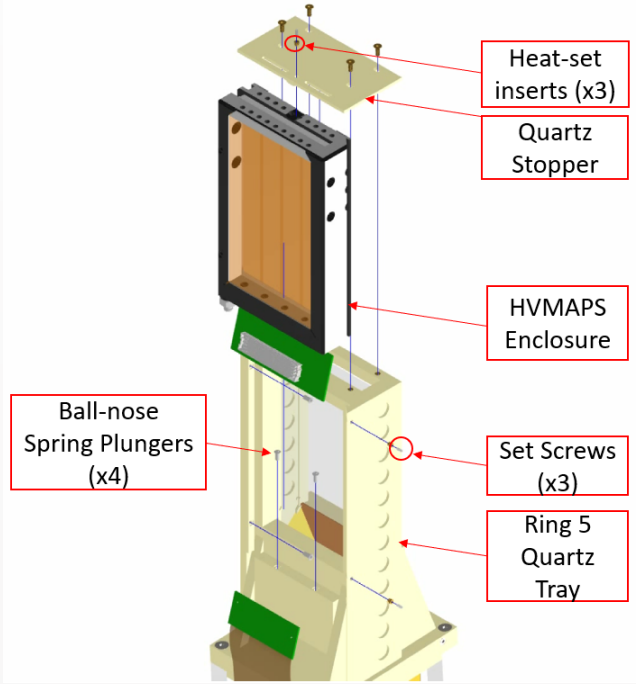


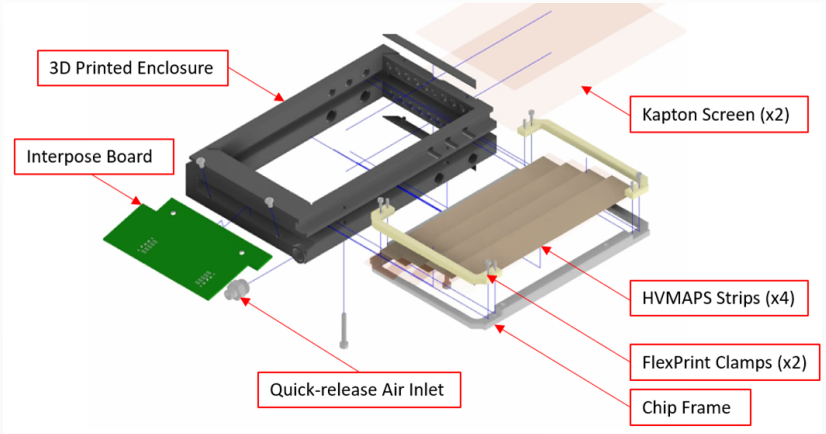


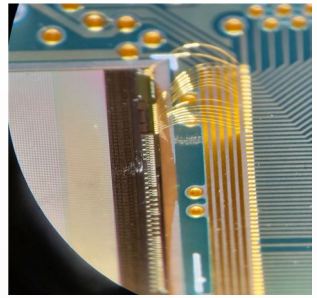
HVMAPS module design

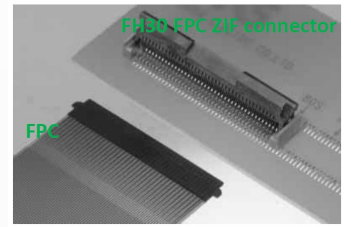
- Located behind each ring 5 quartz tile is an array of 28 pixel sensor chips called High Voltage Monolithic Active Pixel Sensors.
- Design of the modules is nearing the end.
- The final sensor chip has been tested and can go to production.



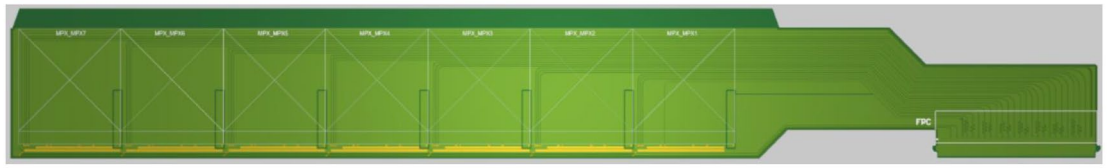






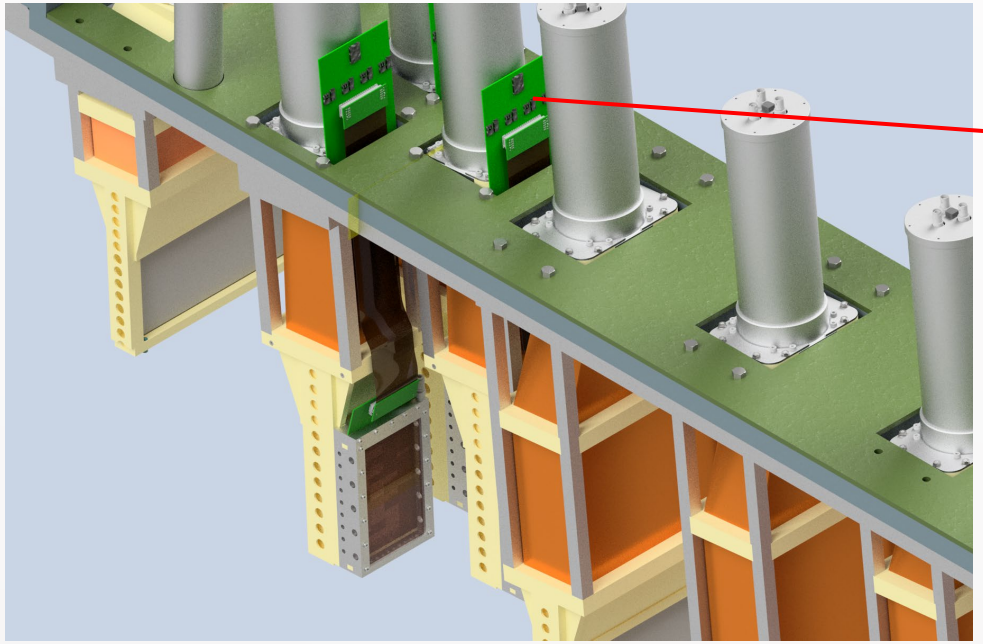


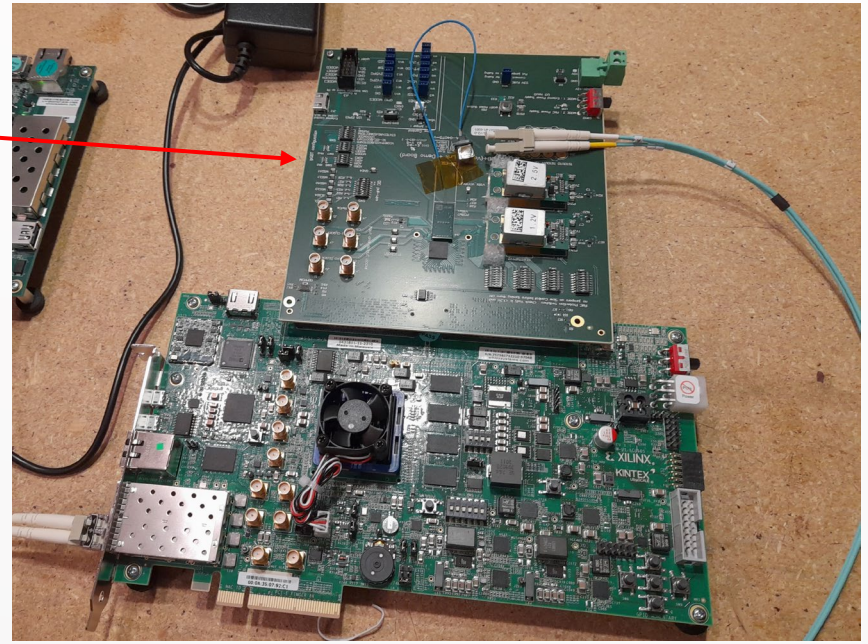
For each Ring 5 Quartz tile: TAB-bond 7 chips to a flex-print, have 4 such strips per detector



HVMAPS module design

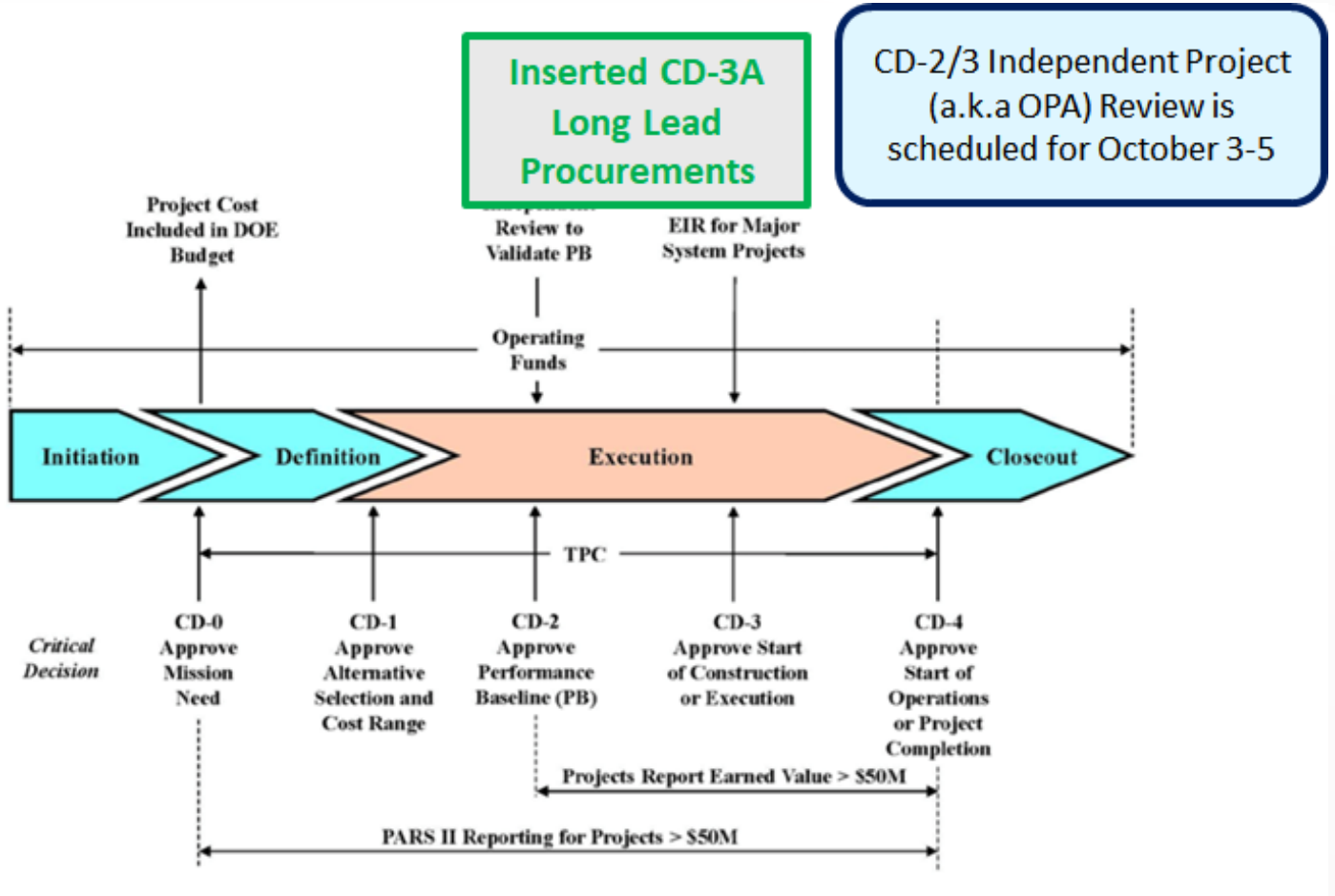
- HVMAPS chips are controlled (including low voltage supply) and read out via a readout board that will be located behind the PMT housing.
- Incorporating the CERN lpGBT and VTRX+ chips.
- **This is MRS supported (Carleton/Winnipeg).**





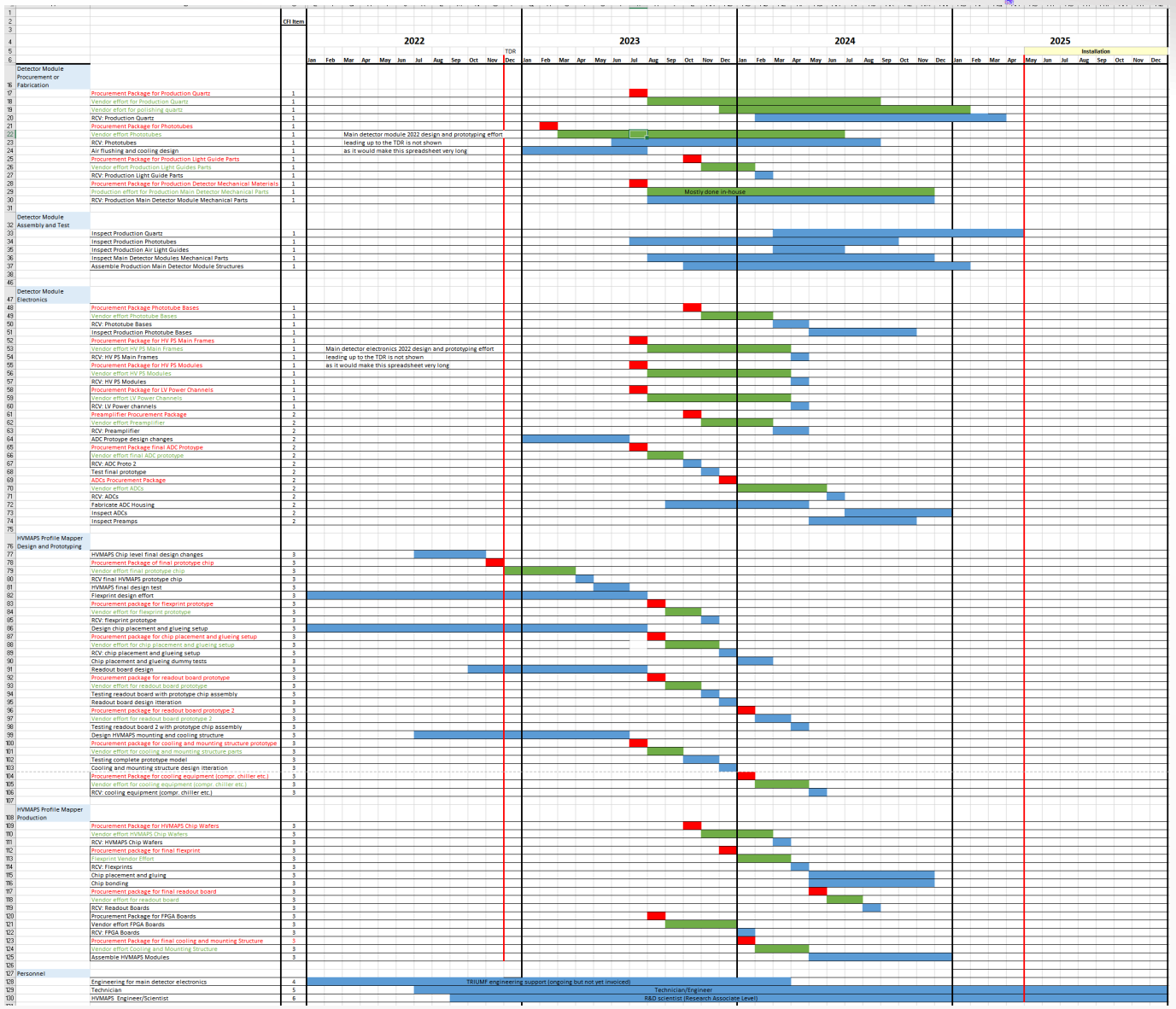
MOLLER Schedule

- Final design review passed in December 2022
- DOE CD 2/3a passed in January 2023
  - Long lead time items procurement started
  - Magnet and other large installation items
- CD 3 review in the Fall of 2023
- Facility schedule requires demonstration of installation readiness by Spring 2024
  - Have half the detector modules constructed by May 2024
  - Complete the remainder by end of 2024
- Start main detector installation in May 2025
- Commissioning by end of 2025

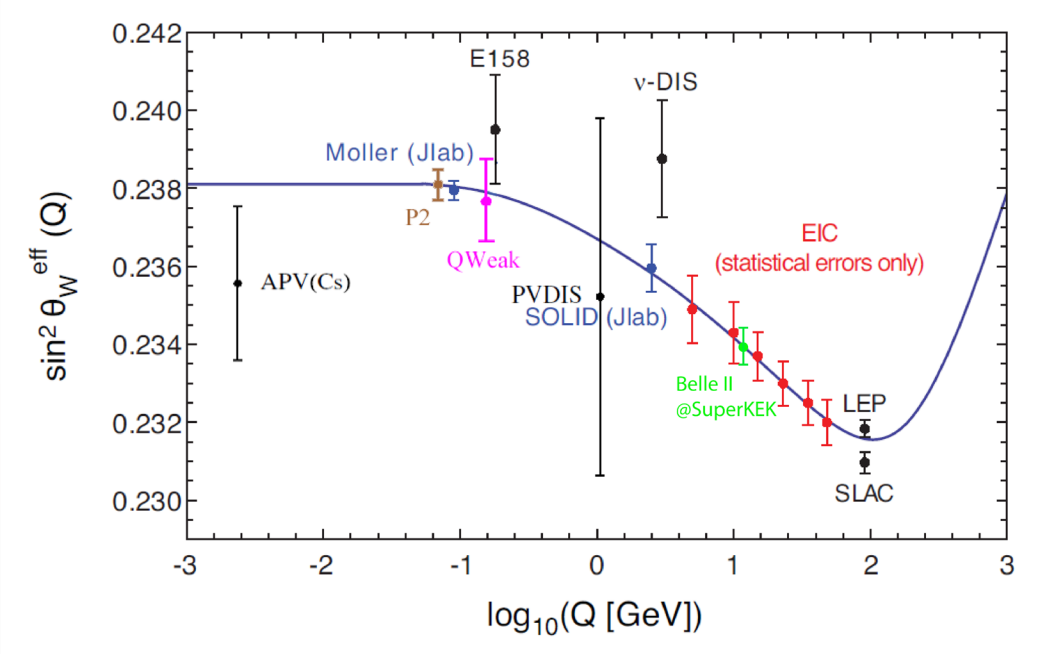


CFI Schedule

- Majority of the major cost item procurement will happen in 2023
- Some items have long lead times (> year) and finalization of designs was delayed
  - Post-pandemic supply chain issues
  - Hiring delays for technical staff and HQP
- Final delivery for some of the items will extend into early 2025
- Some large quantity items will be delivered in bunches at various times (e.g. PMTs 20/month for > year, fused silica tiles in 4 stages for > 1 year)
- Assembly of detector modules will proceed in parallel with part delivery
- Module structure hardware will be made in-house, starting later this summer
- Submission of HVMAPS chips production to foundry planned for this Fall. Assembly (placement, bonding) to start early in 2024.



Thank you


0.242
0.240
0.238
0.236
0.234
0.232
0.230
-3
-2
-1
0
1
2
3
$\sin^2\theta_W^{eff}(Q)$
$\log_{10}(Q\ [GeV])$
E158
ν-DIS
Moller (Jlab)
P2
QWeak
APV(Cs)
PVDIS
SOLID (Jlab)
EIC
(statistical errors only)
Belle II
@SuperKEK
LEP
SLAC