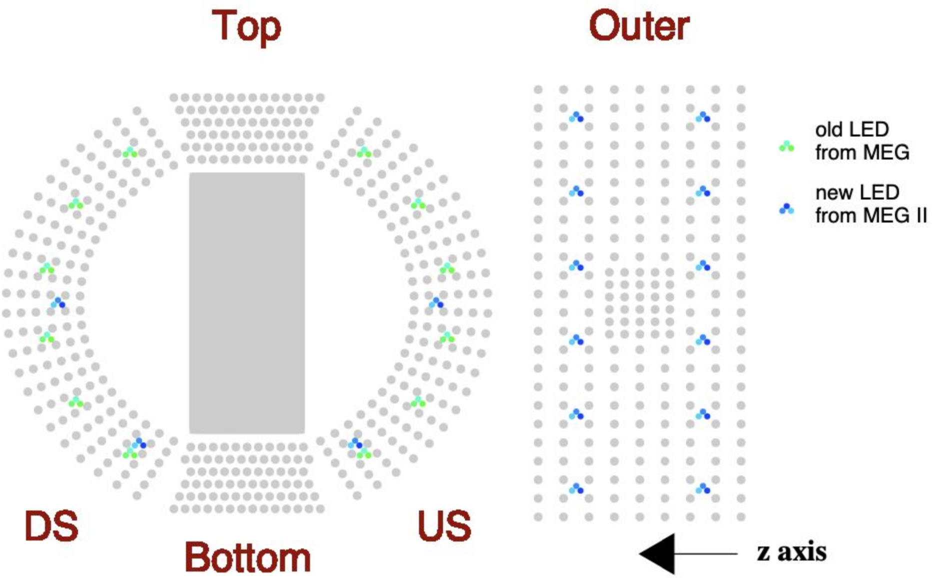
PIONEER Calo Review

Part II: LXe

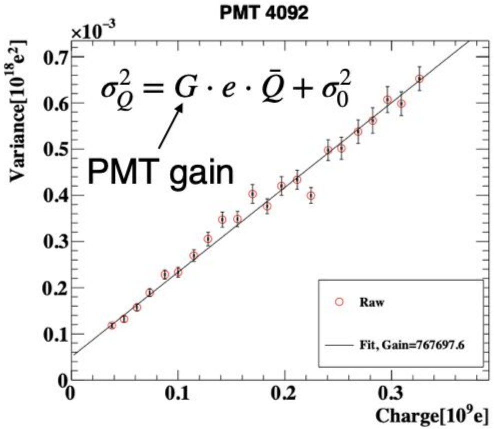
Calibration Concept/maturity Toshiyuki

	Reaction	Energy	Purpose	Frequency
LED		UV light	PMT/MPPC gain	Continuously
^{241}Am radioactive source		5.5 MeV α	PMT/MPPC QE, LXe purity	Weekly
Charge exchange	$\pi^- p \rightarrow \pi^0 n$, $\pi^0 \rightarrow \gamma\gamma$	55, 83, 129 MeV	Energy scale, resolution	Annually
Michel positron	$\mu \rightarrow e\nu\nu$	52.8 MeV end point	uniformity	Continuously
Cosmic ray		~GeV	LXe purity	Weekly

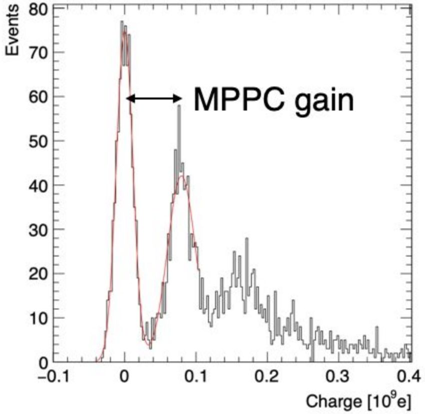
LED

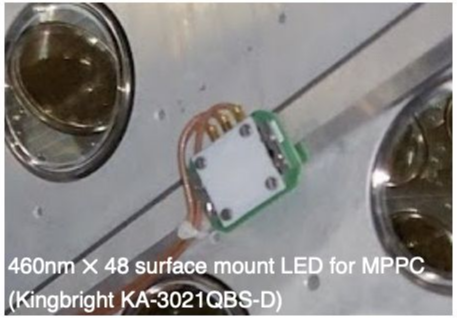


Variance vs Charge mean
w/ different LED intensities



Charge spectrum
w/ low intensity LED





- PMT/MPPC gain, MPPC cross talk/after pulse measurements
- PMT gain decreases under muon beam
- LEDs can be installed to PIONEER easily

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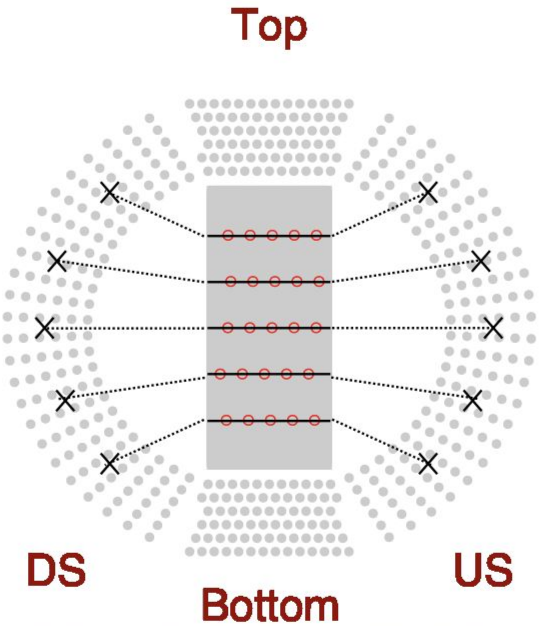
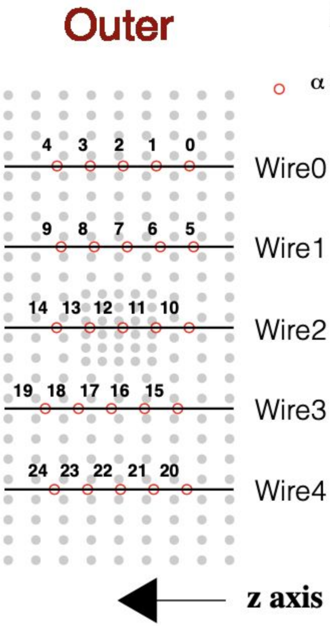
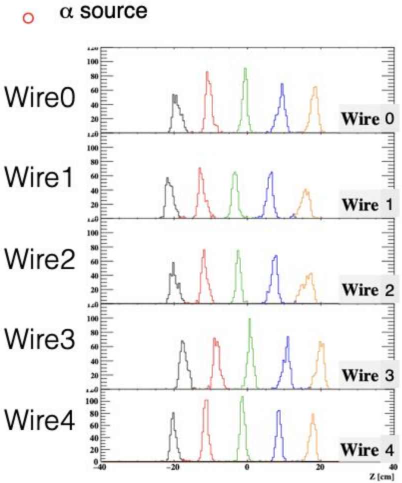
α sources

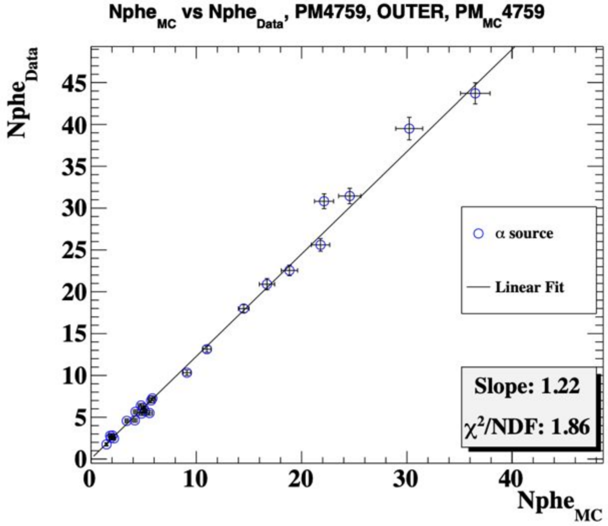


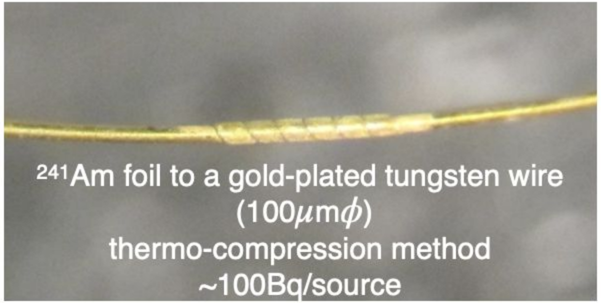


Reconstructed z position of α sources



Ratio of data/MC for a PMT





- PMT QE/MPPC PDE including LXe light yield extracted from ^{241}Am α sources
- MPPC PDE decreases under muon beam
- There might be a problem to produce new sources (Sorad Ltd. which produced the MEG α sources does not exist anymore). Five wires in the MEG II are available

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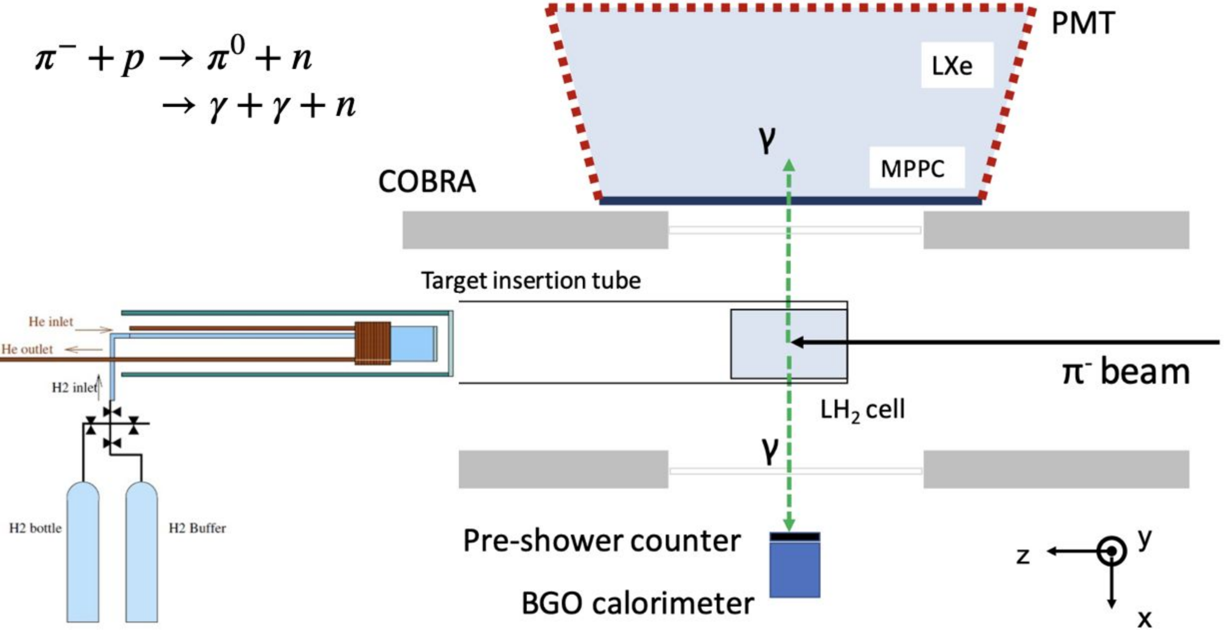
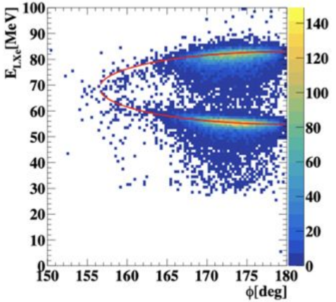
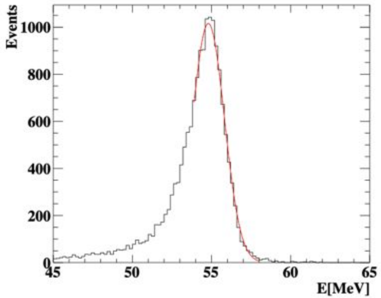
Back-to-back photons from π^0 decay

$$\pi^- + p \rightarrow \pi^0 + n$$
$$\rightarrow \gamma + \gamma + n$$



- γ energy scale, uniformity and resolution measurements at 55, 83, and 129 MeV once per year
- No need to prepare γ tagging detector
- LH2 target must be installed from the upstream side. Dedicated design is needed





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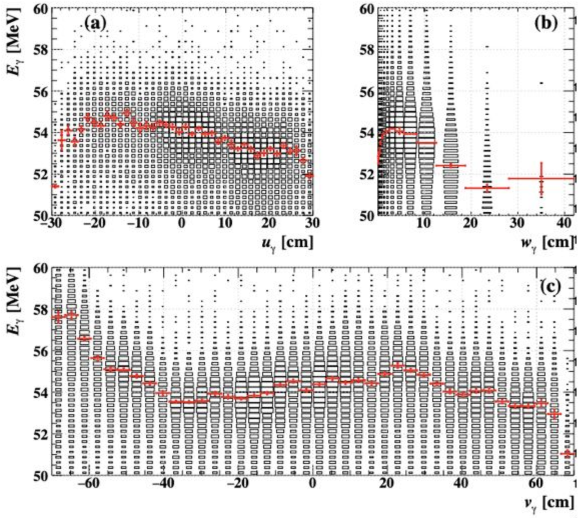
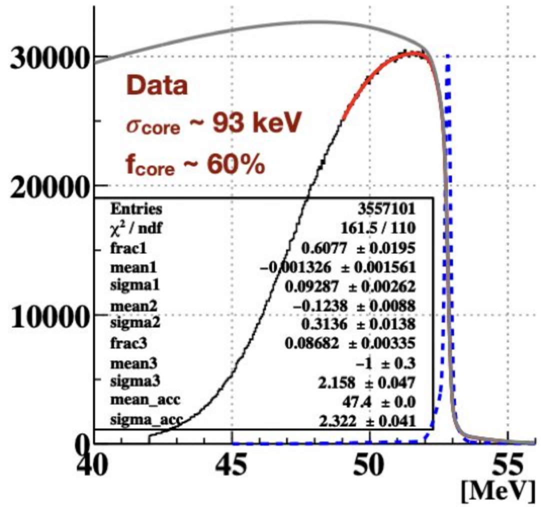
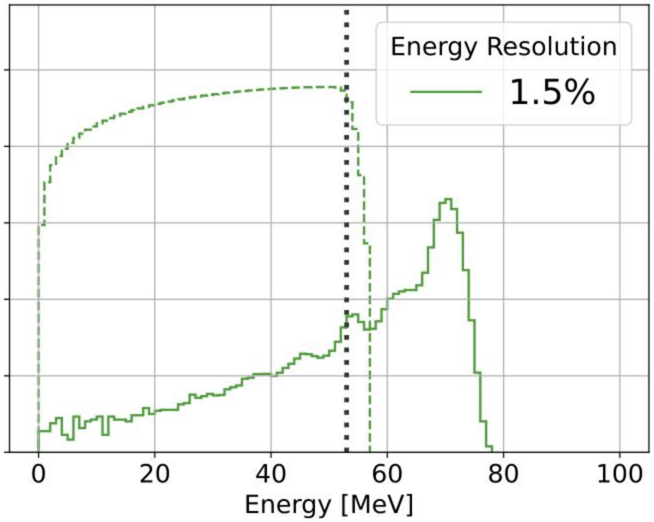


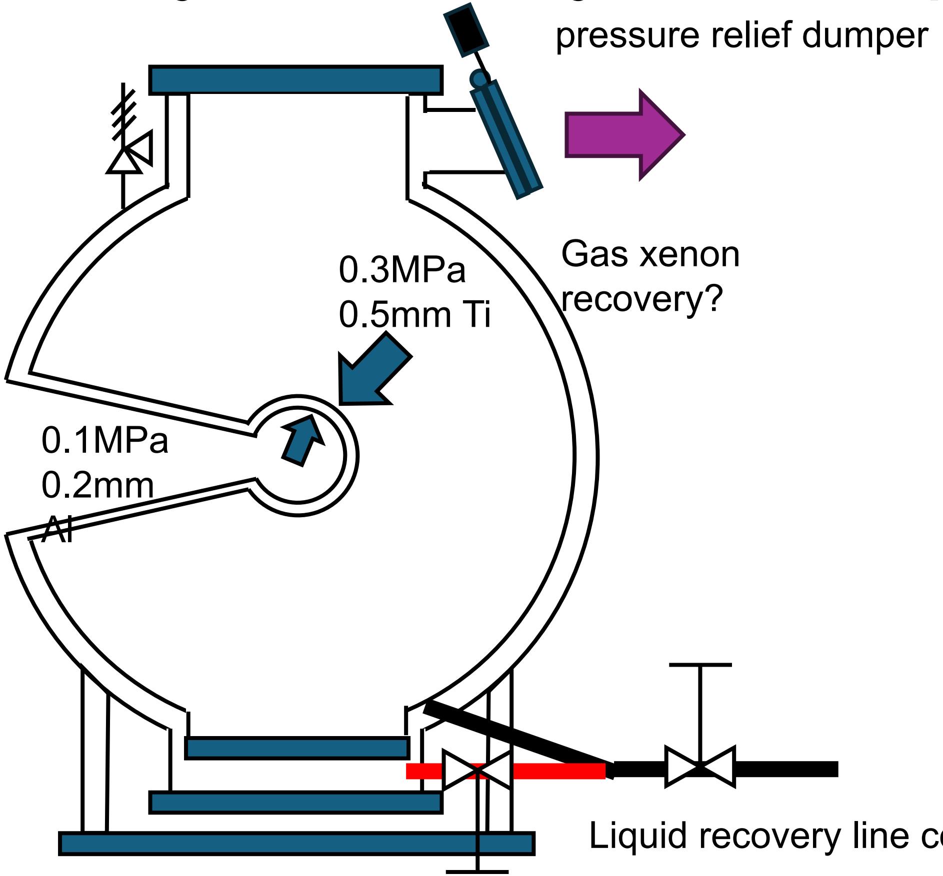
Michel positron





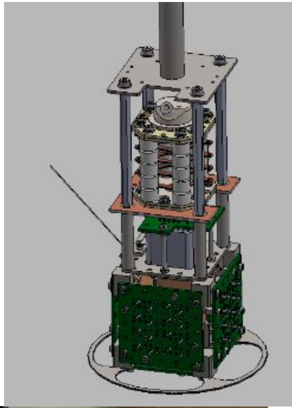
- Position dependent energy scale, resolution can be extracted from 53 MeV Michel edge fitting in the same way that the MEG II experiment is doing
- Optional
  - Direct positron beam at 70 MeV can be used to know the energy scale at the downstream side, and energy scale at different position can be calibrated with Michel edge data

Safety/Recovery Philosophy - Satoshi



- Vacuum window breakage
  - Insulation vacuum lost
  - Heat inflow increases
  - Recovery in gaseous and liquid phase
- Xenon window breakage
  - Xenon spills out to the insulation vacuum & evaporates
  - Quick pressure relief
    - Safety
    - Protect the target and beam line
  - Minimize xenon loss

Prototype -Chloé



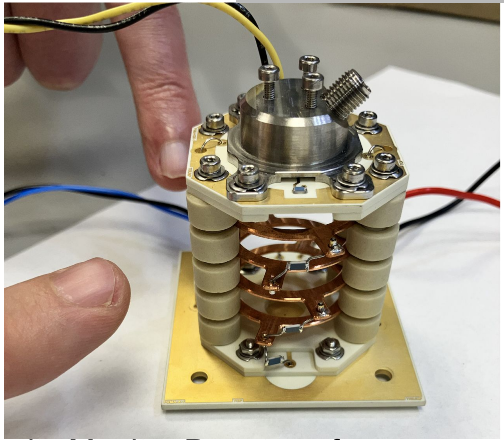
Goals of the prototype

1/ Benchmark our simulations with a e+ beam
Important to verify the performance of the scaling on DATA to properly extrapolate to the full PIONEER calo

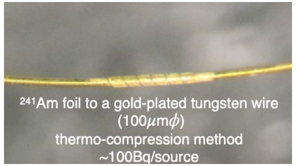
2/ Measure response function to a 70 MeV e+ beam (tail measurement/photonuclear effect in LXe, shower leakage versus angle albedo)

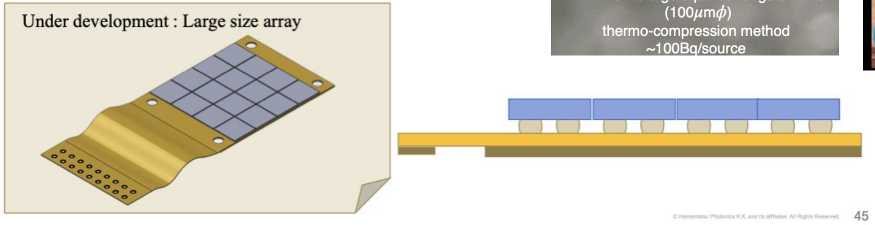
500um Ti -6Al-4V window

3/ Prototyping of key components for the main calo
- **thin windows** (developments by Satoshi)
- **purity monitor** (developments at TRIUMF
 prototype ready to insert in LoLX - run scheduled end of October)
- **SiPM on flex** (if time allows for 2025 - Wataru in communication with Hamamatsu)
72 channels of 12x12mm on the window would lead to 30% coverage
- **Calibration**
Inner alpha wires, LEDs, CEX reaction



Purity Monitor Prototype for Calo prototype





Prototype

<u>Status</u>

o PMTs and PMT Support structure: almost finalized

~140 PMTs tested (QE measurements at 215nm in vacuum and RT ongoing)
Mechanical design almost finalized (rail system, aluminium frame, spring-loaded PMT holders to account for thermal compression, mechanism to hold alpha wire)
Remaining: LED holders, concept for installation of SiPM on film, outside fillers

o Power supply, feedthrough, DAQ: ongoing

Power supply tested
Testing 1 crate (50 channels). 2 additional crates would need to be supplied and tested
Feedthrough and flange selection: ongoing

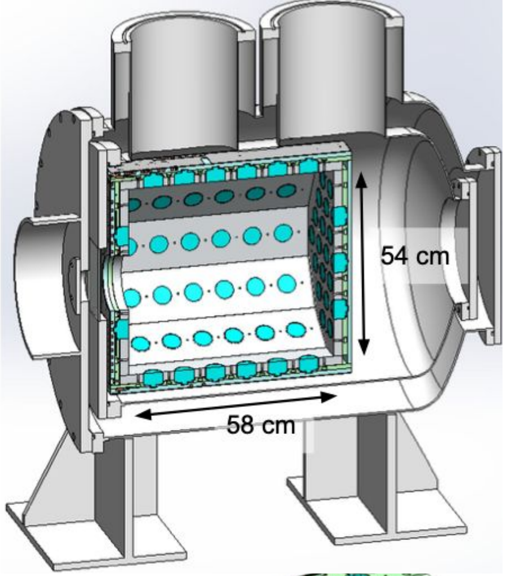
o LXe system: ongoing

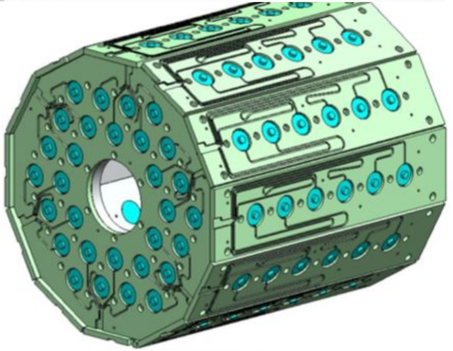
- Xenon
  - BNL: 13 L (TBC after transfer happening in October)
  - ICEPP + KEK purchasing 60 L (first 20L purchase from WISCO through PSI ongoing)
  - TRIUMF 40 L

~113 L should be available - continue effort to collect more xenon

- Purity monitor: prototype ready
- Purification: new getter and new pump to be purchased to improve purification speed
- Xenon storage tank: to be identified
- safety: Toshiyuki in communication with PSI

o Preparation outside PiM1 and transport to PiM1 : space identified, transport stage being designed at PSI



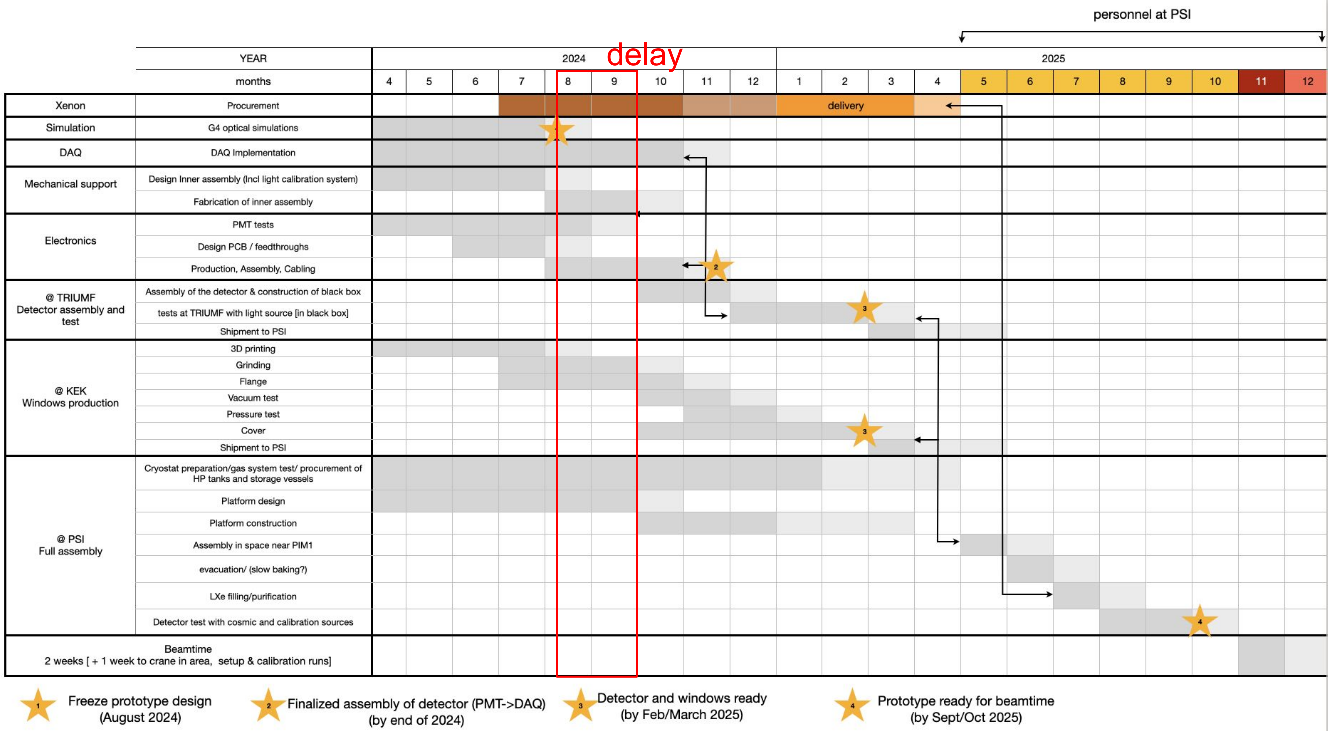


15 % coverage with PMT
Larger coverage of the window with SiPM (30%)

Prototype

<u>Timeline</u>

Keeping the initial target: **request beamtime in PIM1 at the end of 2025**
Delay was induced by prioritizing main calo studies for this review + enabled the understanding of features in the prototype simulations
Within the next two weeks : finalise mechanical assembly - construction can happen in the fall. Built-in contingency might allow catching up on delay by the end of the year



2025 :

- Lots of work on DAQ [incl. getting additional crates], testing of PMT assembly at TRIUMF, installation and preparation at PSI

- purchase of remaining xenon should happen within the next 6 months

- Readiness of prototype in 2025: Important for mid-funding review and renewal of funding

Readout of the MEG II detector

Toshiyuki

- WaveDREAM board
  - DRS4 waveform digitizer in 0.8 – 5 GSPS, 1024-cell analog memory with a resolution of 12 bit
  - Raw data ~ 1.5 kB/ch ~ 16 MB/event
- Trigger rate
  - ~10 Hz depending on trigger threshold and beam rate
  - Original data size ~ 160 MB/s
- Sampling frequency
  - 1.2 GSPS for CDCH
  - 1.4 GSPS for others including LXe: 731 ns time window for an event

Detector	Channel type	# channels	MEG
LXe det. inner face	MPPC	4092	216(PMT)
LXe det.	PMT	668	630
pTC	SiPM	1024	60
CDCH	Differential	2432	1728
	Frontend		
Others	Various	57	≈ 50
Total		8591	2639

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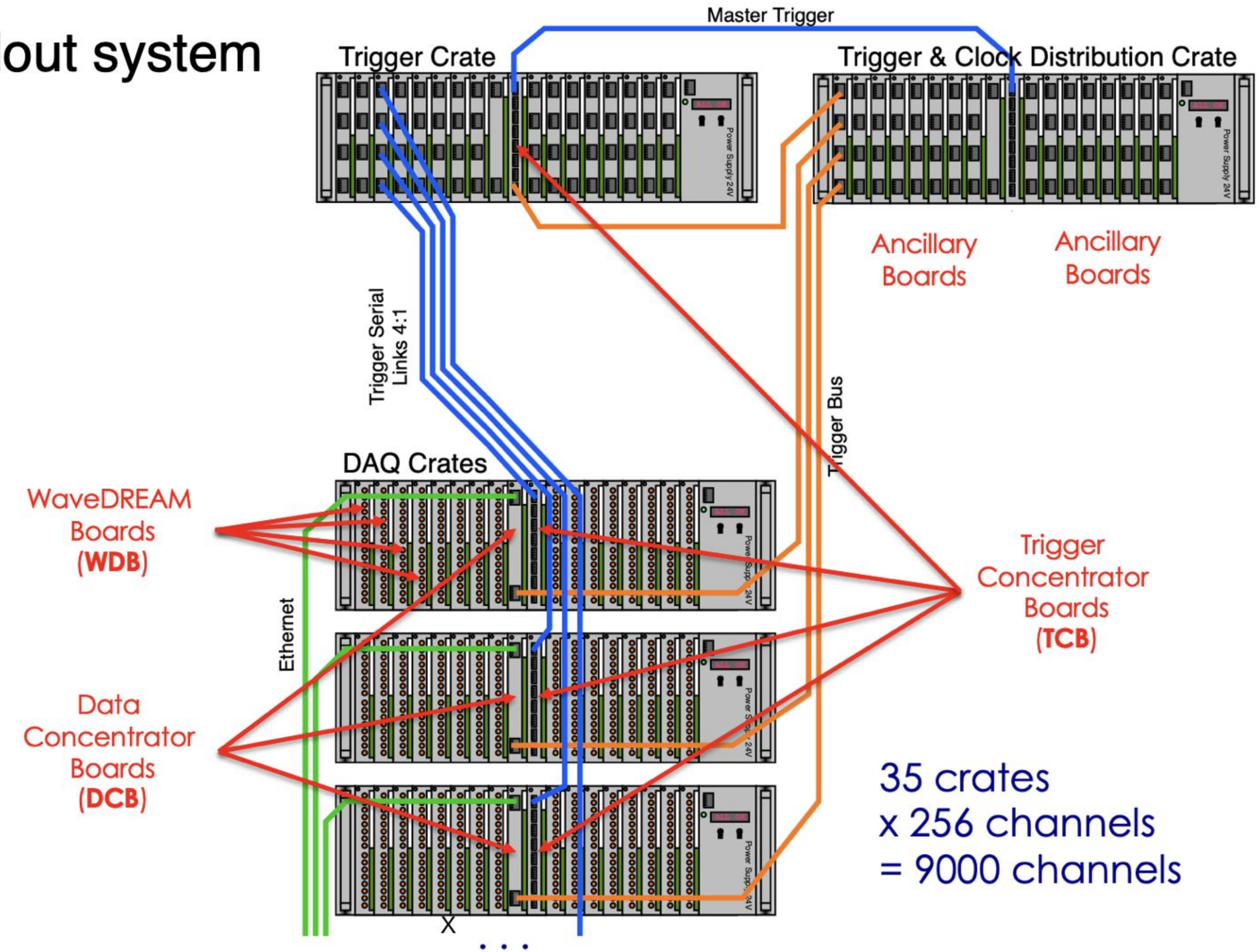
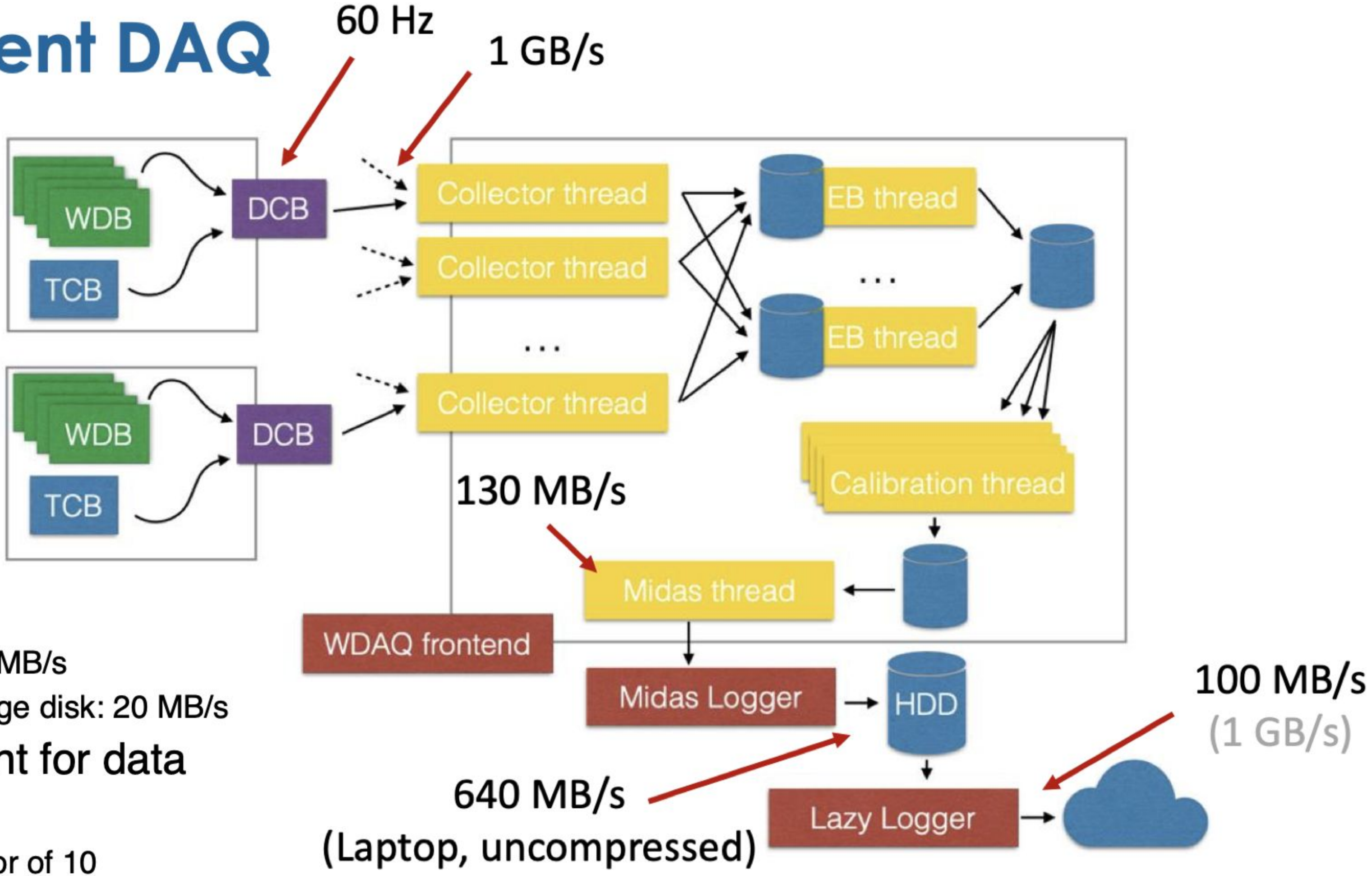
MEG II readout system



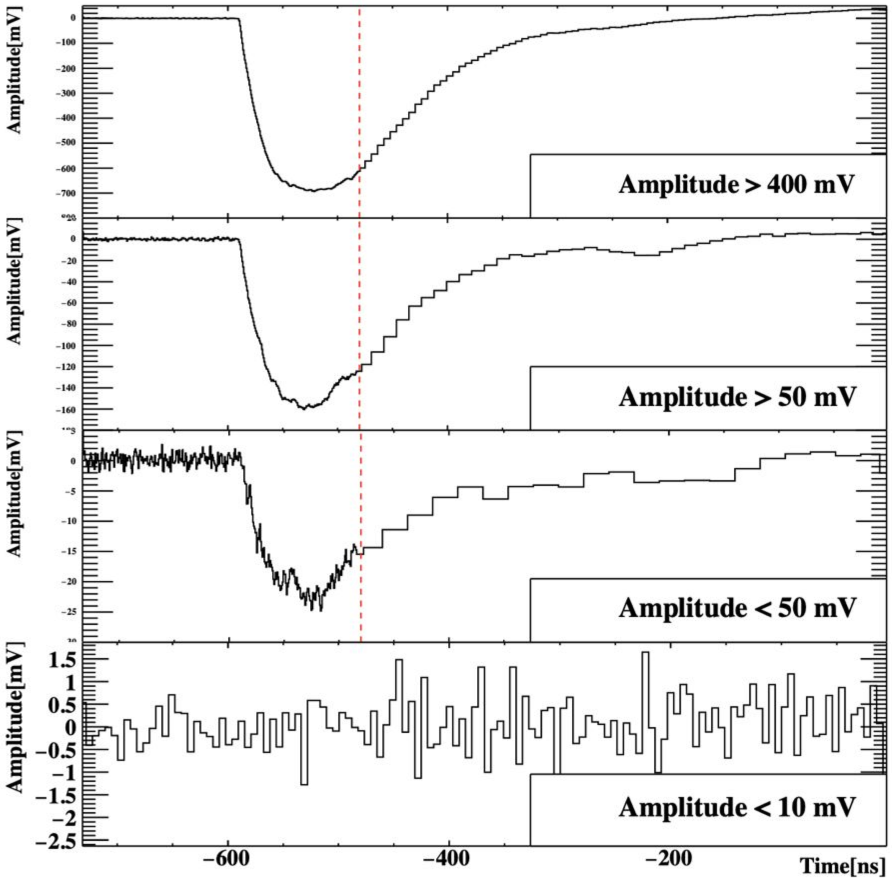
Current DAQ



- Limitation
  - Online: 130 MB/s
  - Offline storage disk: 20 MB/s
- Requirement for data reduction
  - about a factor of 10

LXe rebin

- The data reduction of LXe is important
  - LXe data size is 40% of all data
  - rising part is important for time reconstruction, charge doesn't require fine sampling, small pulses are not used for time reconstruction
- Rebinning
  - Apk < 10 mV: fully rebinned by eight
  - 10 mV< Apk < 50 mV: tail part of the waveform is rebinned by 32
  - 50 mV< Apk < 400 mV: tail part of the waveform is rebinned by 16
  - 400 mV< Apk: tail part of the waveform is rebinned by 8
- The LXe data size after the rebinding becomes 40% of that before



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Data reduction

- Method
  - Waveform re-binning: merge the waveform bins in groups of 2^n (n=1,2,3,4,5)
  - Region of interest (ROI): slice the waveform in a predefined window around the trigger time
  - Zero suppression: discard waveform without pulses
- Detector specific methods are applied
  - LXe
    - re-binning
  - Timing counter
    - zero suppression and ROI are applied (S/N ratio is good)
  - Cylindrical drift chamber
    - re-binning and ROI (no impact from the re-binning for reconstructed tracks)
- Offline storage
  - PBzip2 compression will reduce the data size to 40%
- In total, event size reduction is a factor of 10 achieved
  - Storage disk of 2 PB is assumed for the MEG II
  - 160MB/s * 0.1 (reduction) * 120 days * 5 years ~ 1 PB