Status and Prospects of MEG II experiment

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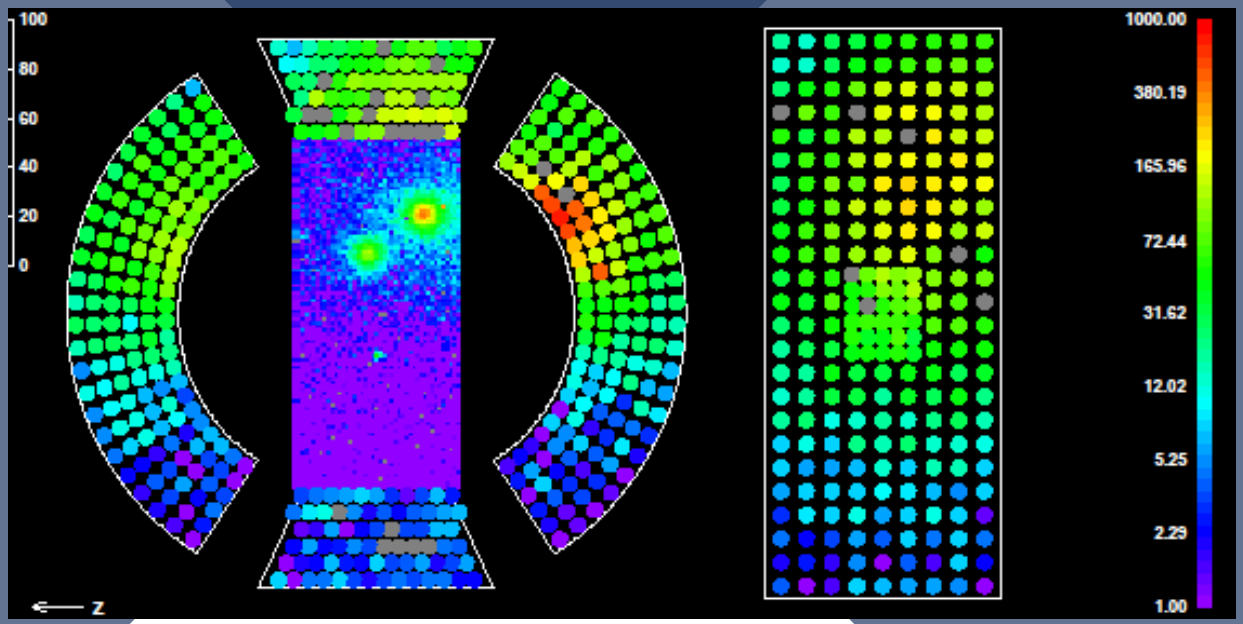


Core-to-Core Program

Flavor Physics Workshop

Outline

- Introduction
  - Charged Lepton Flavor Violation
  - $\mu \to e\gamma$ search
  - MEG II experiment
- Engineering run 2021
  - Status
  - Schedule
- Summary

MEG II - Search for $\mu^+ \to e^+ \gamma$ -

MEG result (2016)

$Br(\mu \to e\gamma) < 4.2 \times 10^{-13}$ (90% C.L.)

UTokyo
KEK
Kobe Uni.

PSI
ETHZ

INFN Genoa
INFN Lecce
INFN Pavia
INFN Pisa
INFN Roma

BINP
JINR

UC Irvine

~60 physicists

×2 intensity muon beam
×2 resolution
×2 efficiency

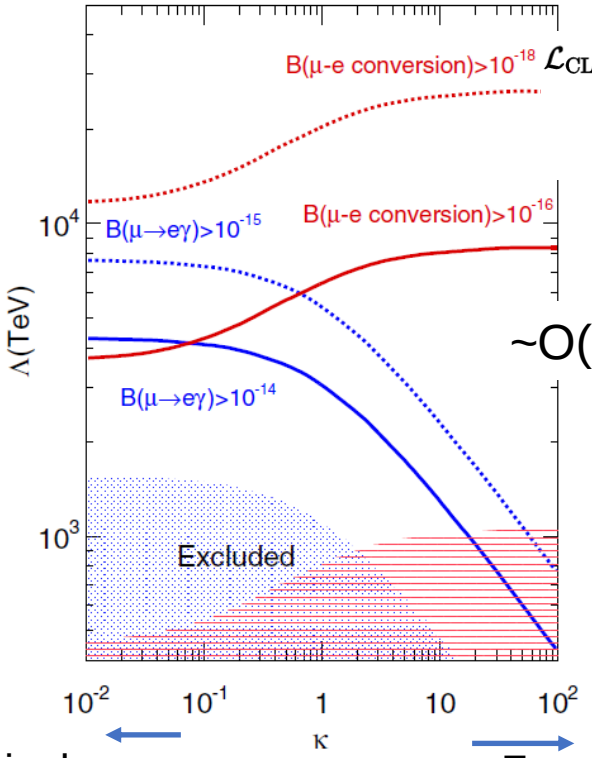
MEG II plan

$Br(\mu \to e\gamma) \sim 6 \times 10^{-14}$
(90% C.L. sensitivity)

- Upgrade from MEG experiment
- Intensity frontier experiment
  - High intensity muon beam at Paul Scherrer Institute (PSI), Switzerland

Charged Lepton Flavor Violation

1	2	3	
Quarks			Discovered
u d	⟷	c s	⟷ t b
Charged Leptons			**Undiscovered**
e	⟷ (MEG)	μ	⟷ (B-factory) τ
Neutrinos			Discovered
ν_e	⟷	ν_μ	⟷ ν_τ



$$\mathcal{L}_{\mathrm{CLFV}} = \frac{m_\mu}{(\kappa+1)\Lambda^2}\bar{\mu}_{\mathrm{R}}\sigma_{\mu\nu}e_{\mathrm{L}}F^{\mu\nu} + \frac{\kappa}{(\kappa+1)\Lambda^2}\bar{\mu}_{\mathrm{L}}\gamma_\mu e_{\mathrm{L}}(\bar{e}\gamma^\mu e)$$

~O(10^3)TeV

Dipole interaction

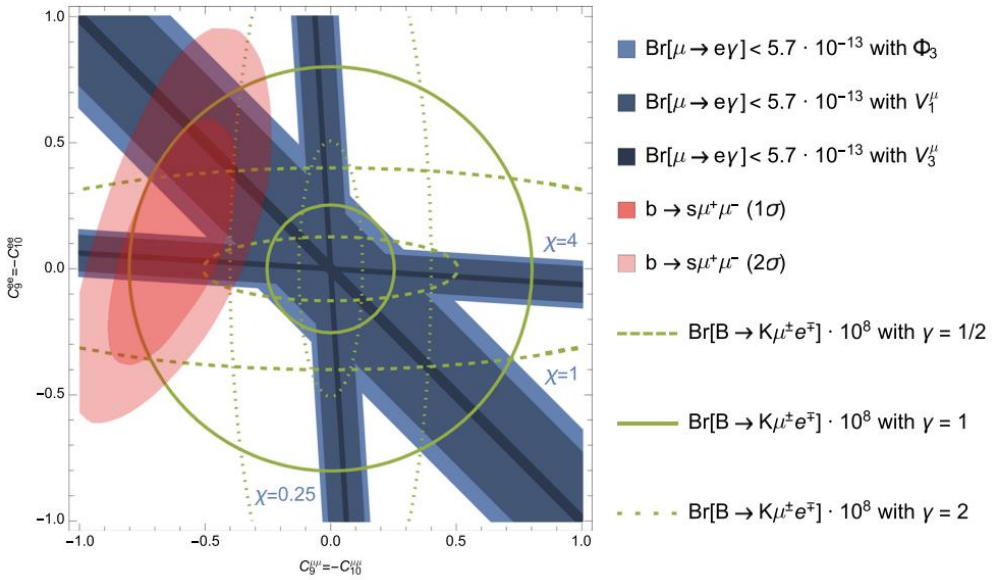
Four-fermion interaction

Journal of the Physical Society of Japan 85, 091002 (2016)

- Rates are too small ($Br(\mu \to e\gamma) \sim 10^{-54}$) in the SM.
- Large enhancement is predicted by new physics.
- High energy scale beyond LHC is indirectly accessible.

Charged Lepton Flavor Violation

Synergy with B-anomalies



Phys. Rev. D 97 (2018) 015019

Muon cLFV

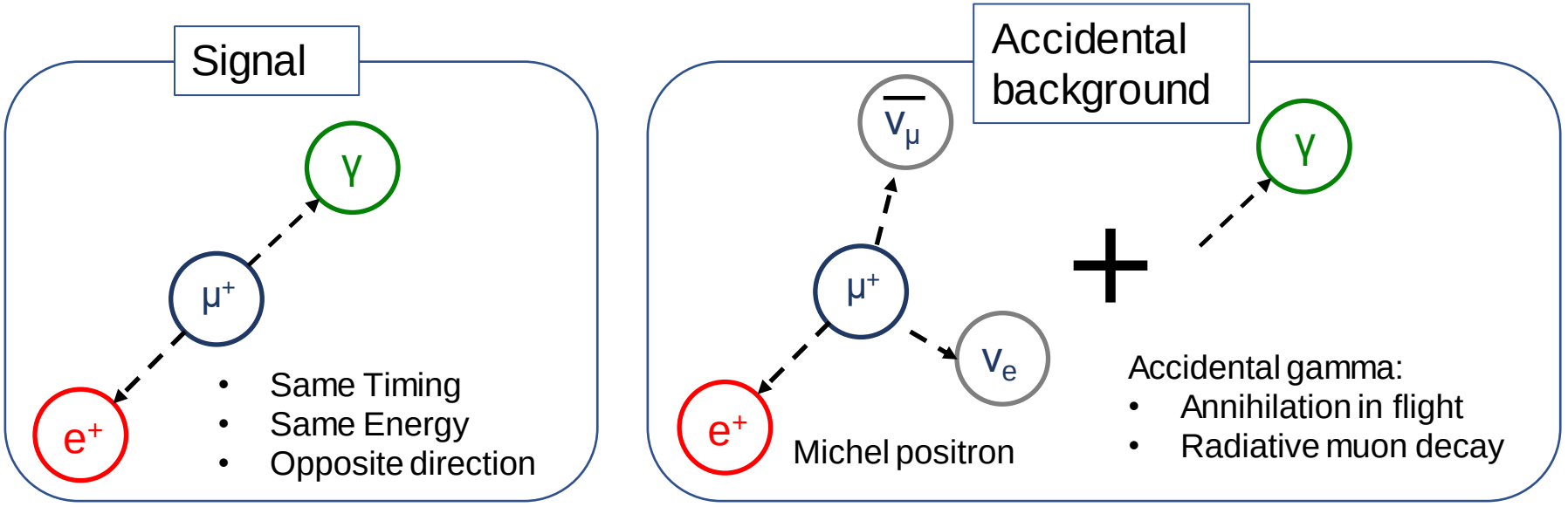
MEG II (PSI)
COMET (J-PARC)
DeeMe(J-PARC)
Mu2e (FermiLab)
Mu3e (PSI)

Tau cLFV

Belle II (KEK)
LHCb (LHC)
ATLAS (LHC)
CMS (LHC)

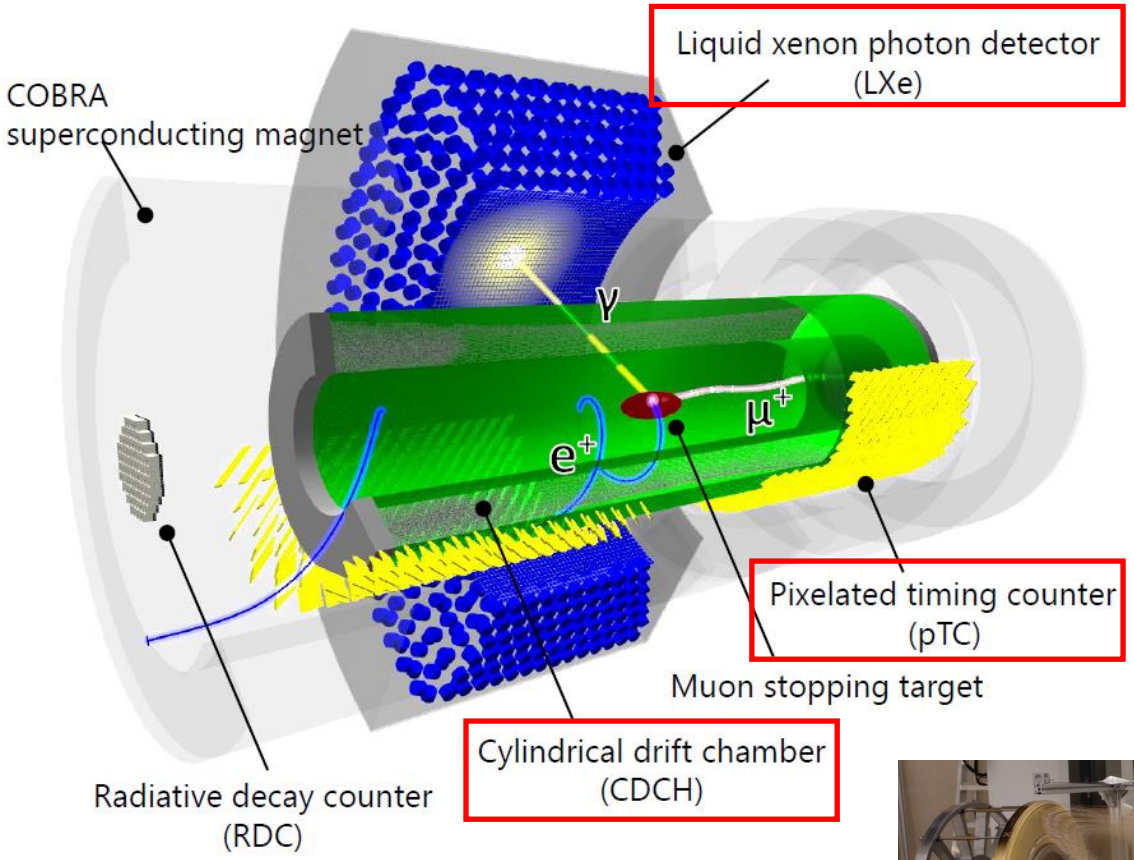
- $\mu \to e\gamma$ search has a sizable synergy with recent anomalies / results such as muon g-2 and R(K*), R($D^{(*)}$) from B-factory.
  - Through Leptoquark(LQ) models for example.

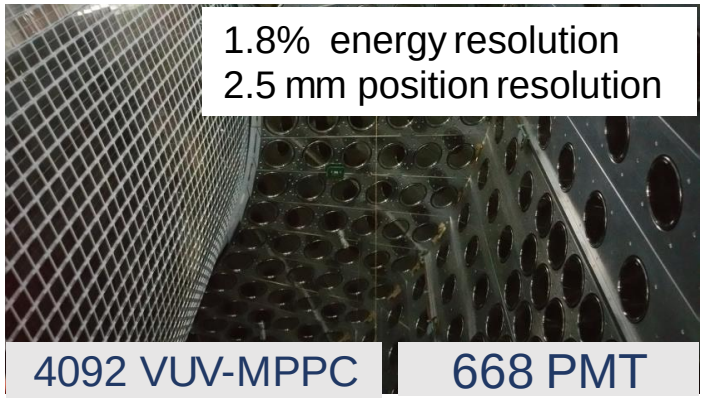
μ→eγ Search

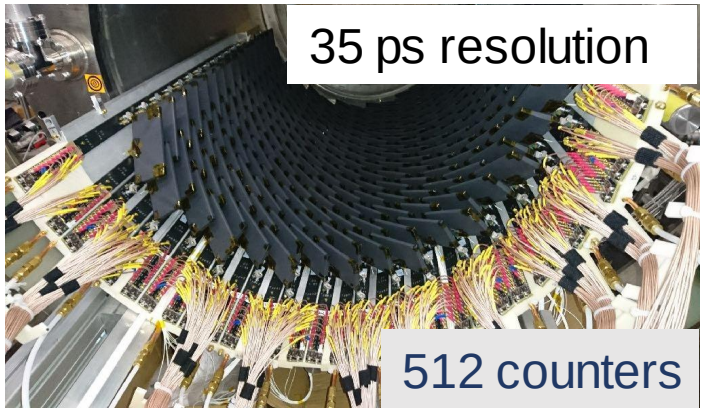


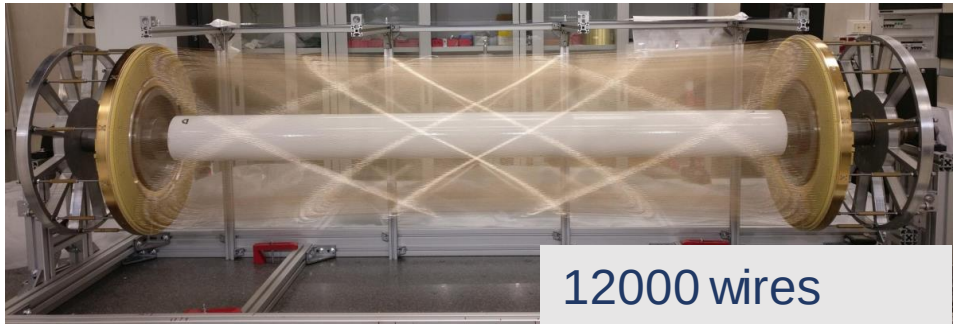
- $\mu \to e\gamma$ decay: two-body decay
  - Main background: accidental
    - Positron from Michel decay + accidental gamma-ray.
  - Key: Precise measurement of positron + gamma-ray to discriminate signal and BG.

MEG II Detectors









Goal of Engineering run 2021

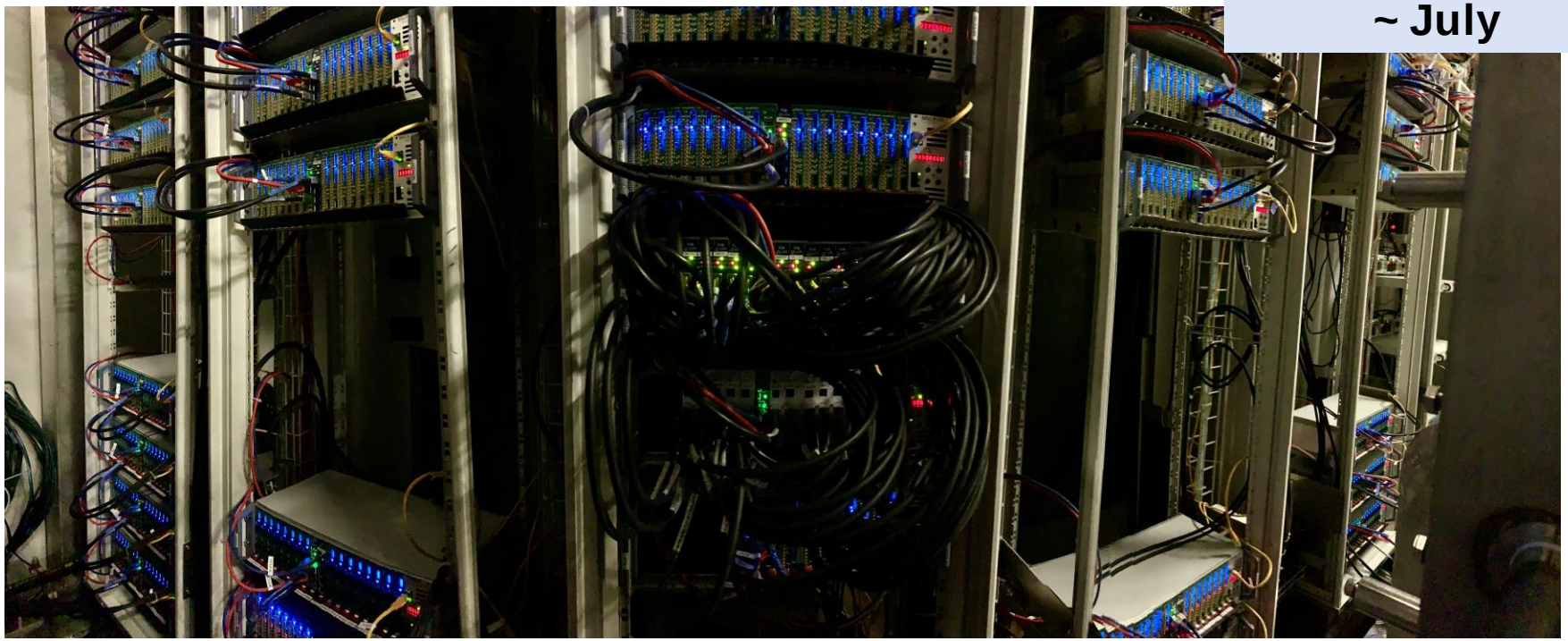
Primary Goal:
Start a short but first physics data acquisition

Requirements:

- Stable operation of all detectors in beam.
- Test of full electronics + DAQ system
- Monitor of LXe MPPC PDE radiation damage
- Positron tracking analysis.
- Trigger commissioning

Engineering run 2021 - Electronics -

~ July

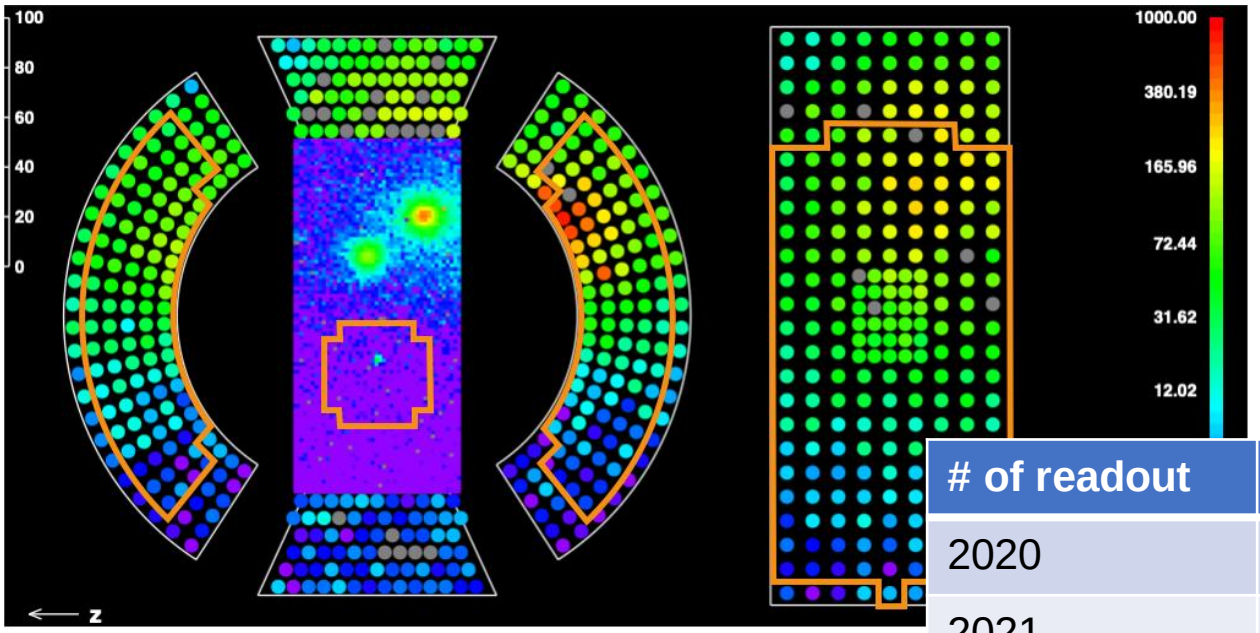


- The full readout electronics was installed in the first half of 2021.
- DAQ: stable with a reasonable DAQ rate 5-10 Hz.
  - 1.4 GSPS, 100 MB/s

Engineering run 2021 - LXe -

Gamma-ray event display with pileups

July ~ August



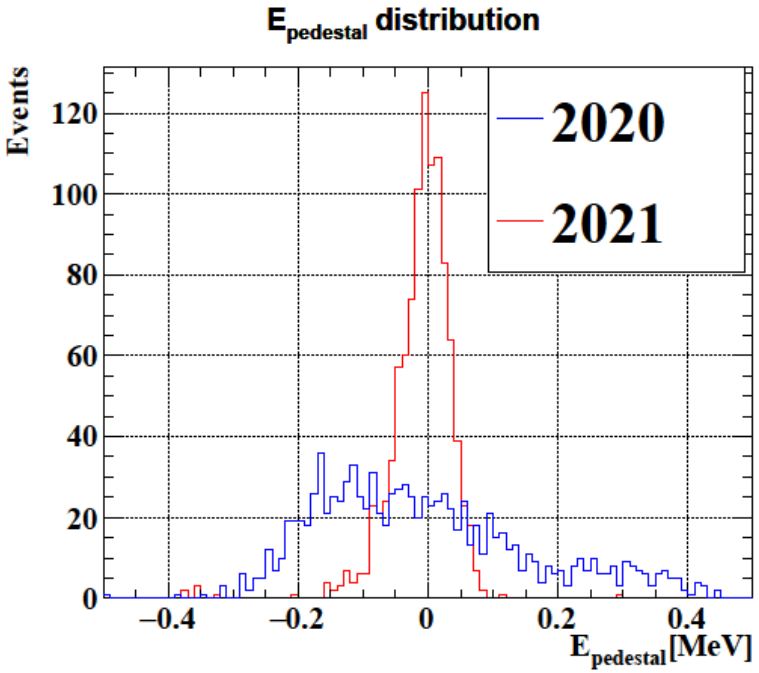
Orange: 2020 readout

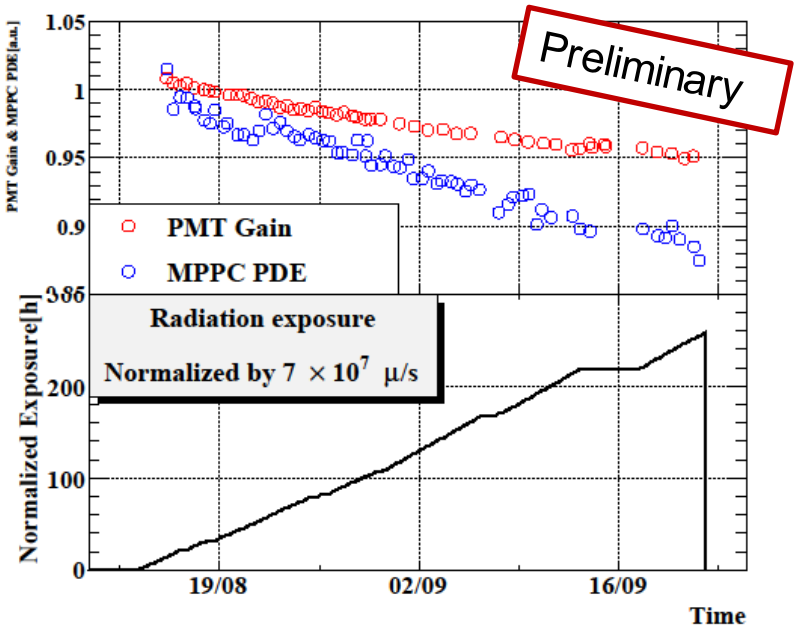
# of readout	MPPC	PMT	Total
2020	640	364	1004
2021	4092	668	4760

- **99%** of photosensors are working well.
  - 28 MPPC & 27 PMT are not working due to short circuit / HV supply

Engineering run 2021 - LXe -

August ~ September

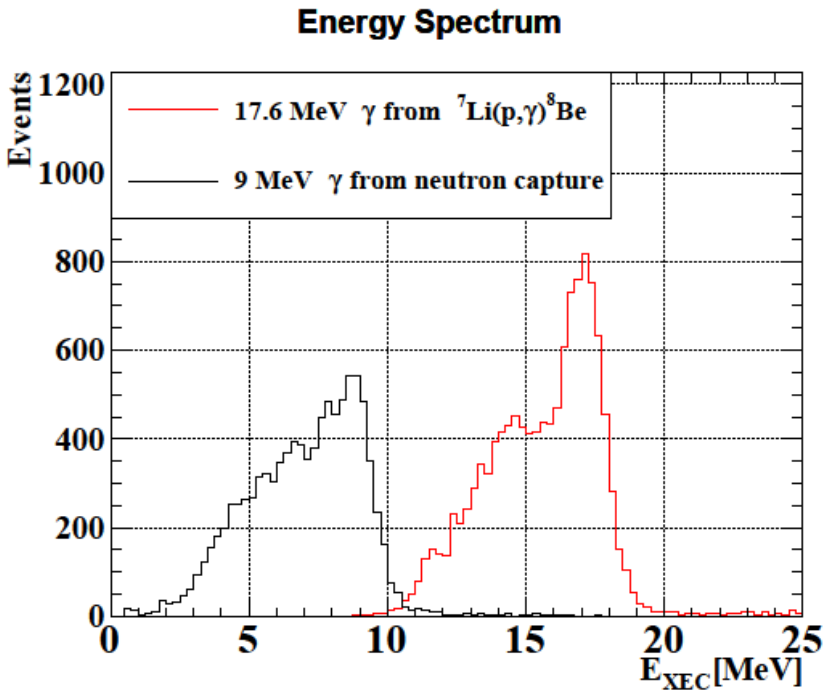


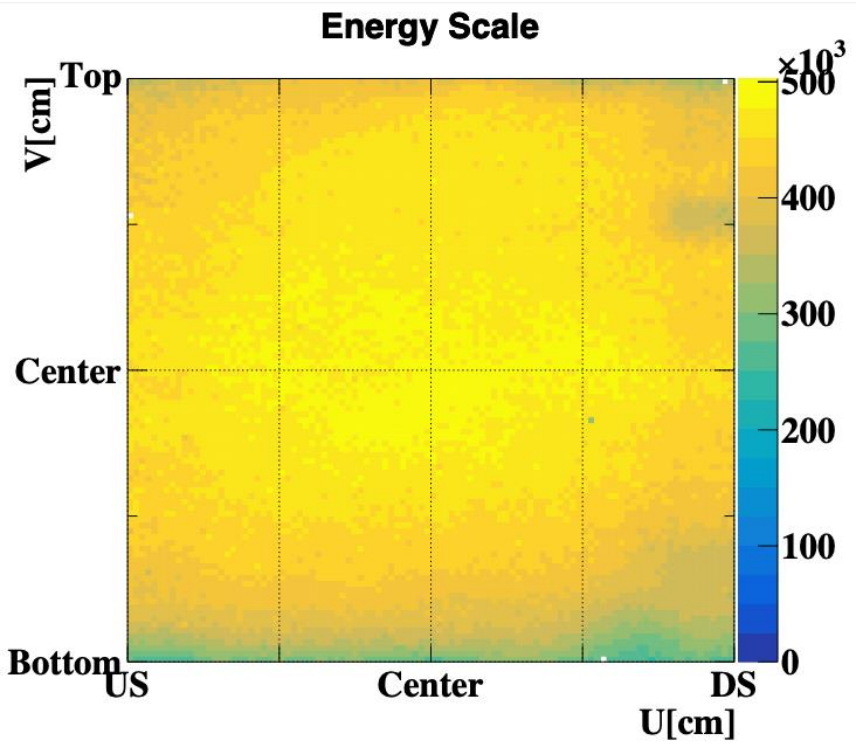


- Noise contribution to energy resolution: totally negligible.
  - 37 keV : 0.08% of 52.8 MeV (Signal energy)
- Radiation damage of MPPC PDE is monitored through the beam time.
  - Deterioration rate: roughly consistent with previous measurements.

Engineering run 2021 - LXe -

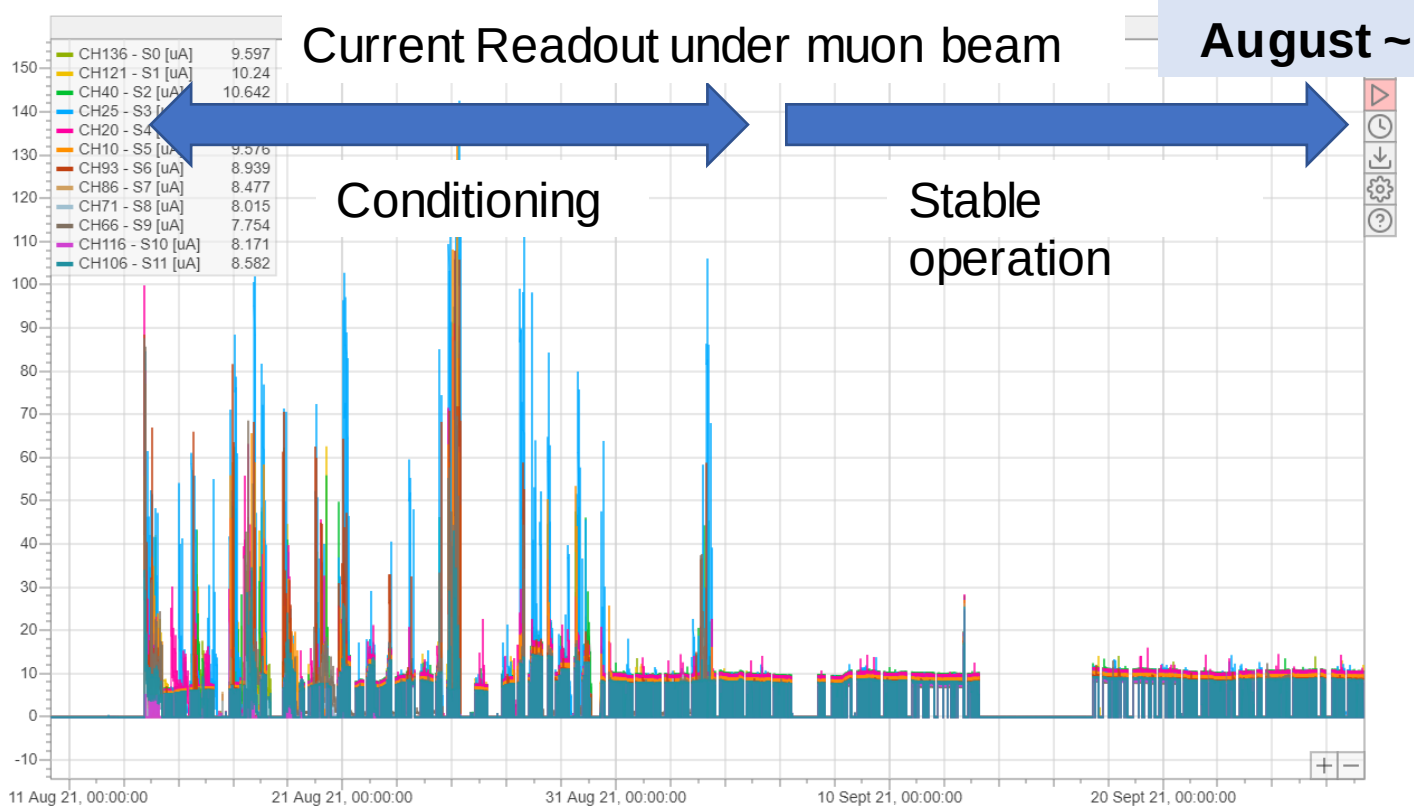
August ~ September





- Calibration measurement with external gamma-ray source is set up.
  - 17.6 MeV gamma-ray from Li target + proton beam.
  - 9 MeV gamma-ray from capture of thermalized neutrons.
- Uniformity over the entrance face is being studied for the first time.

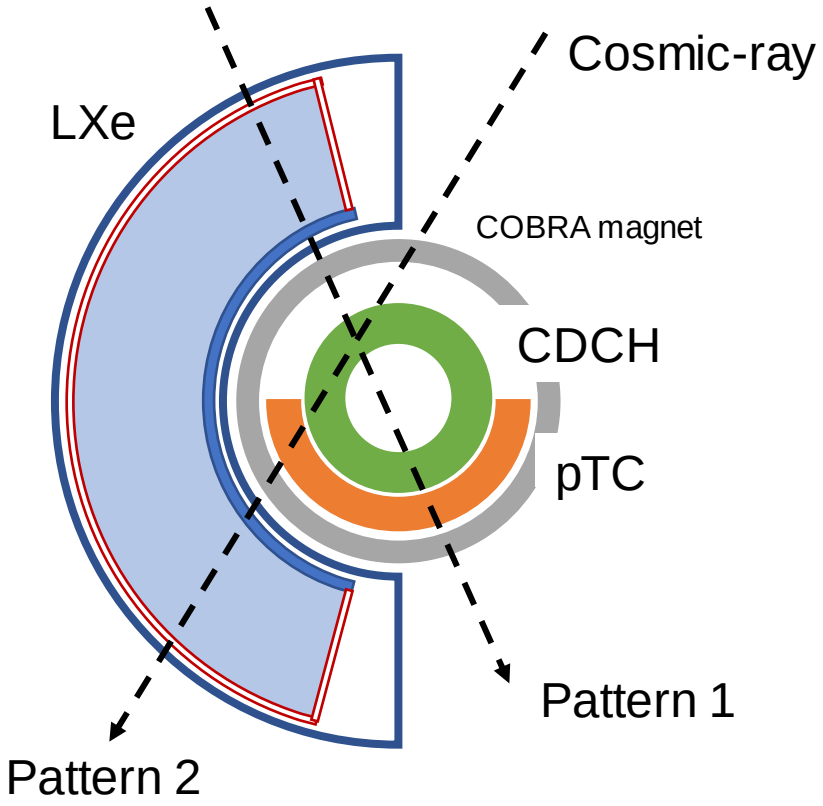
Engineering run 2021 – CDCH conditioning-



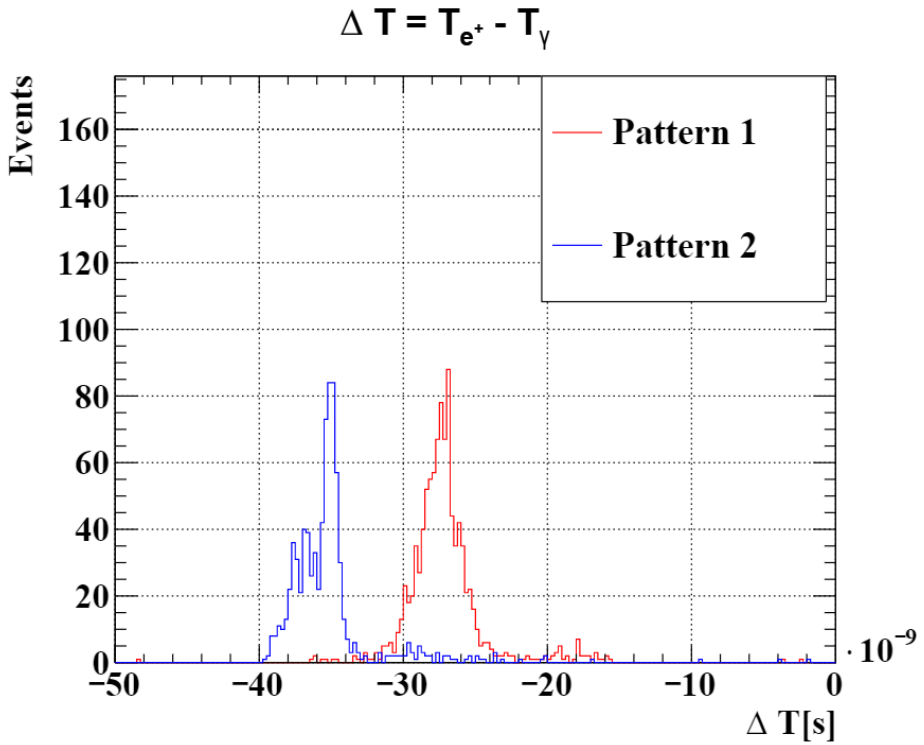
- Drift chamber is stabilized by conditioning under beam.
  - O_2 cleaning with high HV (Working point + 50V)

Now both positron and gamma detectors are ready!

Working proof 1: Cosmic-ray

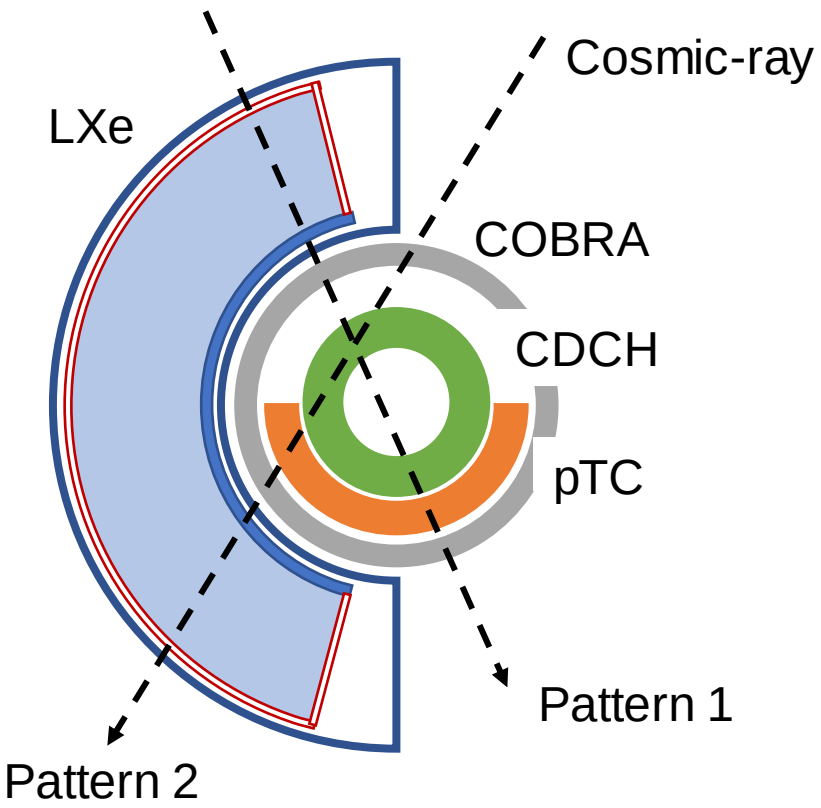


September

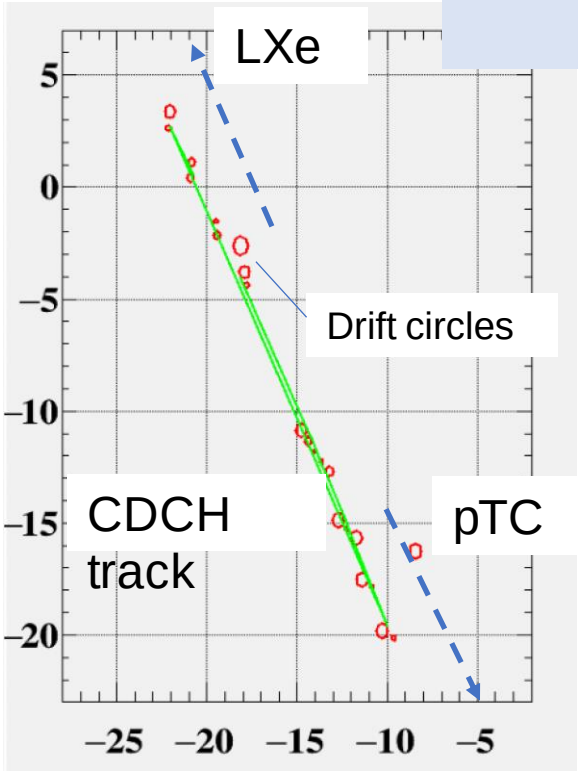


- Cosmic-ray data are useful for **time & position alignment.**
- Time coincidence between LXe and pTC is observed with cosmic-ray.

Working proof 1: Cosmic-ray



September



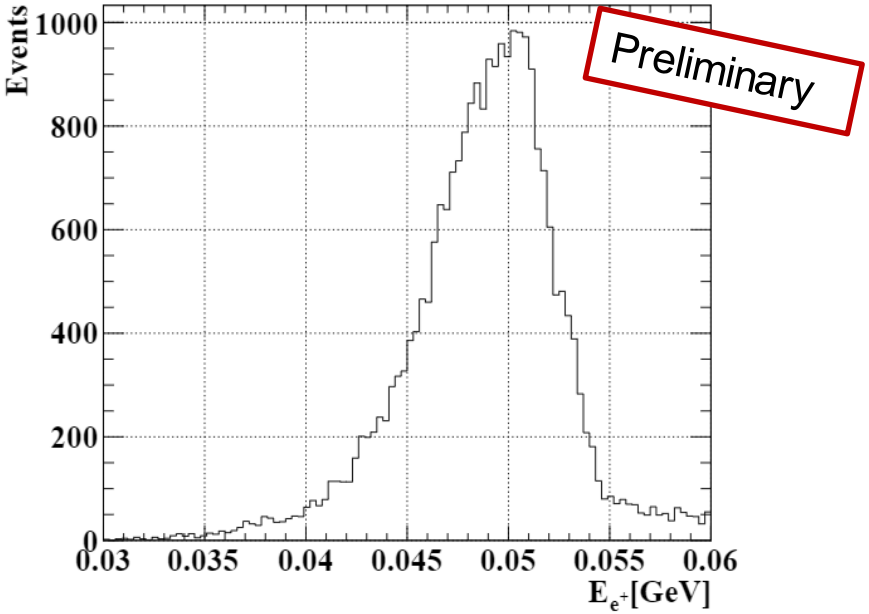
- We have a cosmic-ray track with many drift circles in CDCH.

➡ Position & Time alignment between detectors is getting ready.

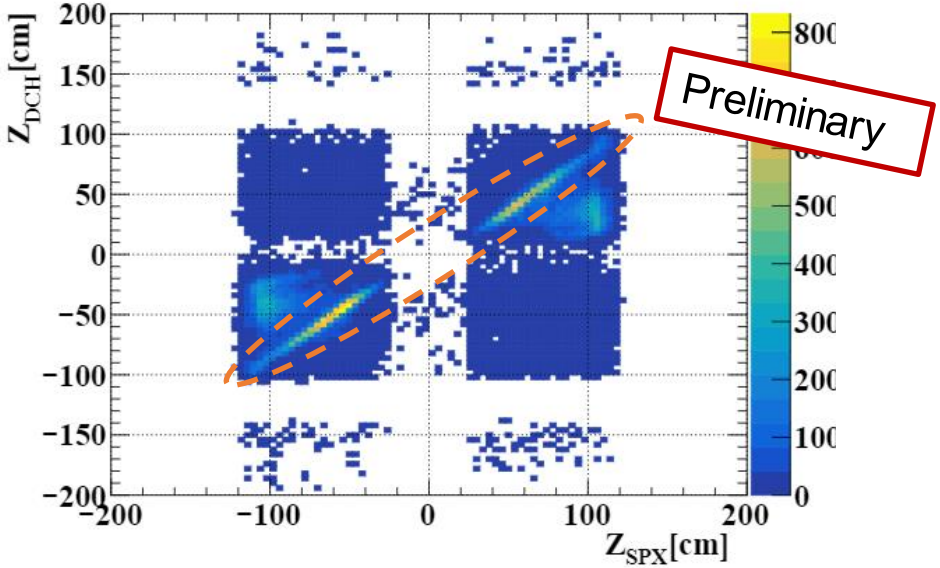
Working proof 2: Positron Tracking

Just in progress

Positron energy spectrum



TC and CDCH z position correlation



- Positron energy spectrum mainly from Michel decay
- pTC cluster and CDCH track are geometrically correlated

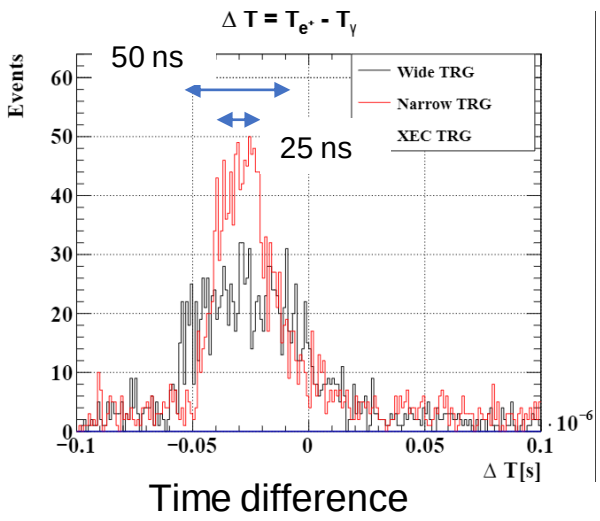
Positron tracking study with the real dataset is under development.

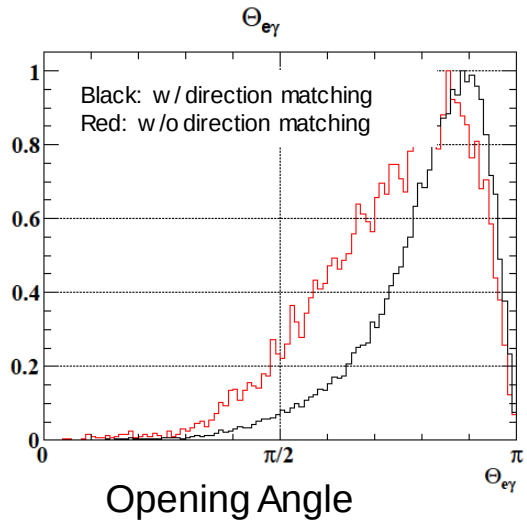
Working proof 3: Trigger Development

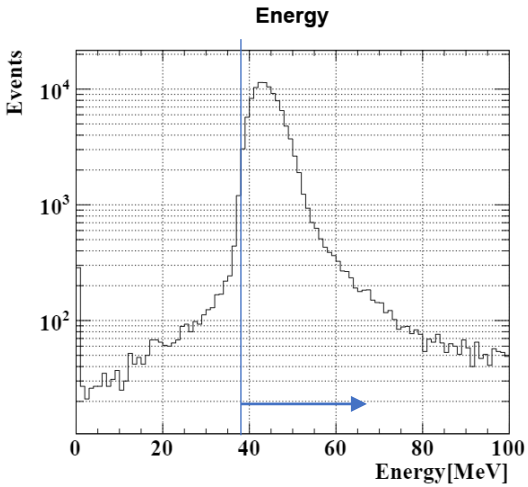
Preliminary

Just in progress

Coincidence Trigger + Opening Angle Trigger + Gamma-ray energy



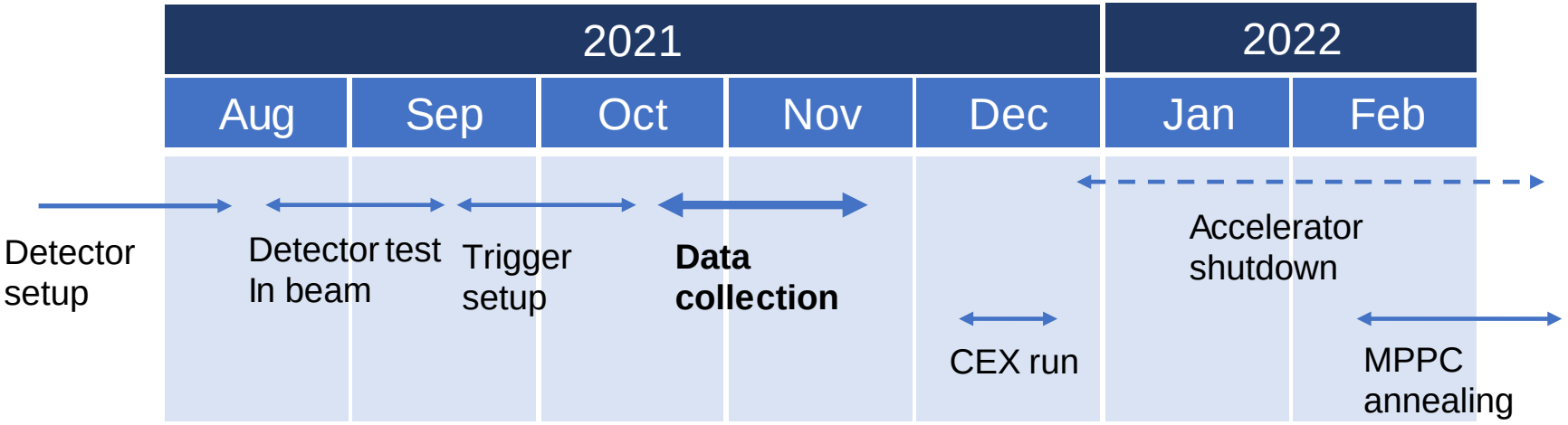




- Trigger commissioning is in progress.
  - Coincident + back-to-back + high-energy positron & gamma-ray

→ Data collection with MEG trigger is coming soon!!

Schedule

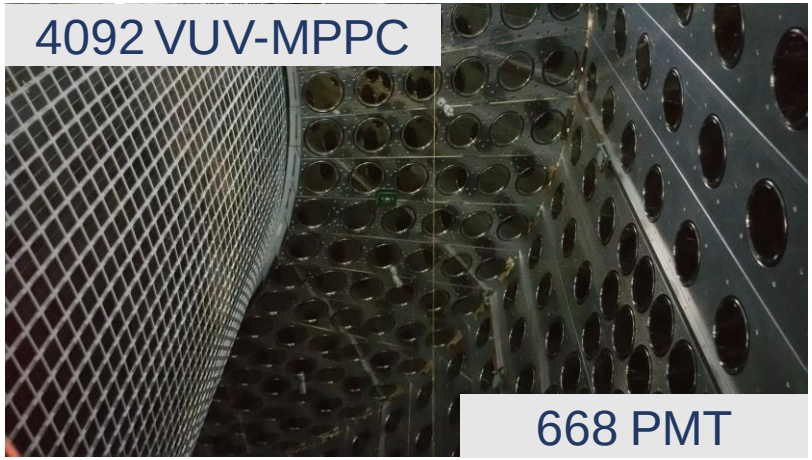


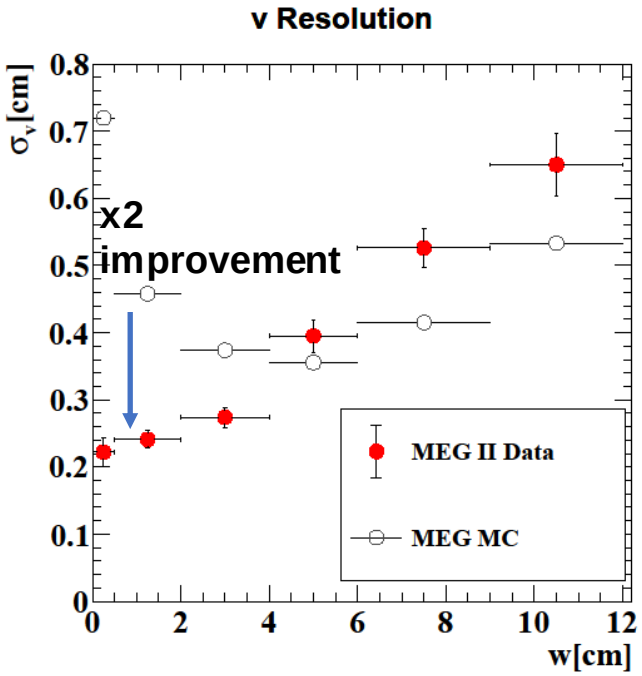
- We will start data collection for a month.
  - **The first physics data acquisition with MEG II setup**.
- After the muon beam time, we will measure the timing & energy resolution of LXe.
- Toward a long physics run in 2022, we will recover MPPC PDE radiation damage by thermal annealing.

Summary

- MEG II experiment is an intensity frontier experiment that searches for $\boldsymbol{\mu \to e\gamma}$ **decay**.
  - Projected sensitivity: Br($\mu \to e\gamma$)$\sim 6 \times 10^{-14}$.
- The commissioning of all detectors with the full readout electronics is in progress.
- We will start the first physics data acquisition very soon.
  - For one month with beam intensity $3 \times 10^{7} \mu/s$.

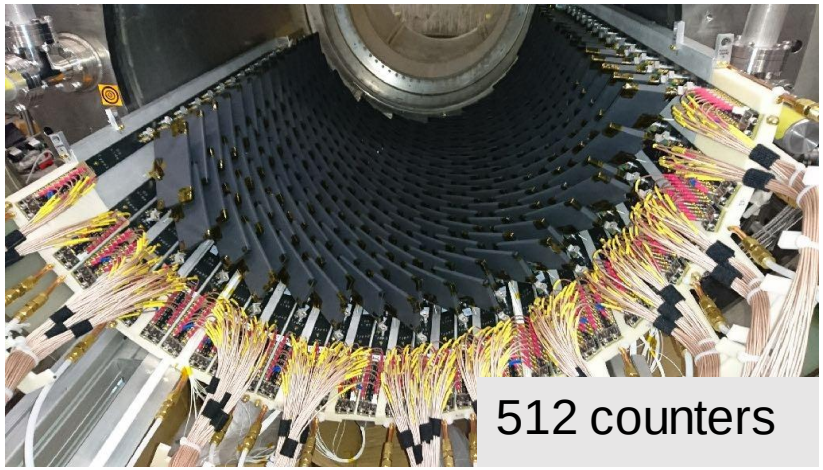
Liquid Xenon gamma-ray detector (LXe)



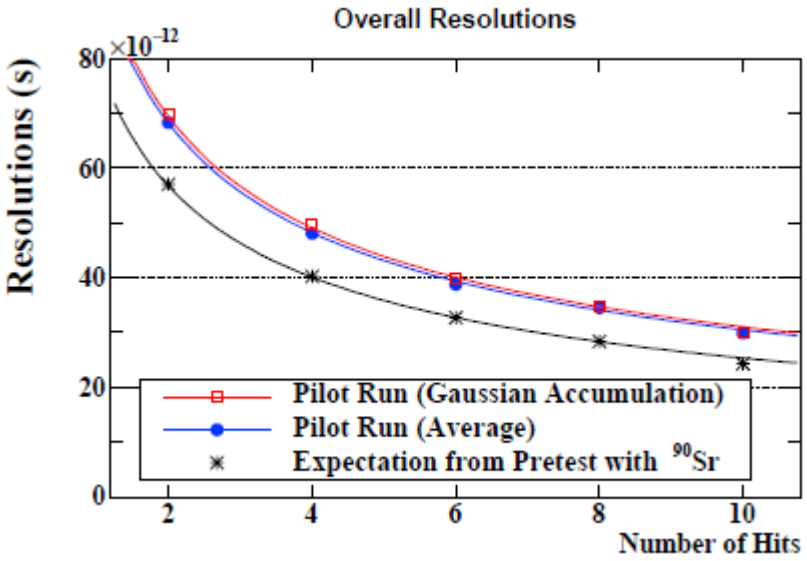


Concept	900 L liquid xenon volume + VUV-sensitive photosensors
Upgrade	Replaced 216 PMTs with **4,092 VUV-MPPCs** on the entrance face
Achievement	**Acceptable energy & good position resolution**(1.8% / 2.5 mm).
Issue	Radical decrease of MPPC PDE under high intensity muon beam.

pixelated Timing Counter (pTC)



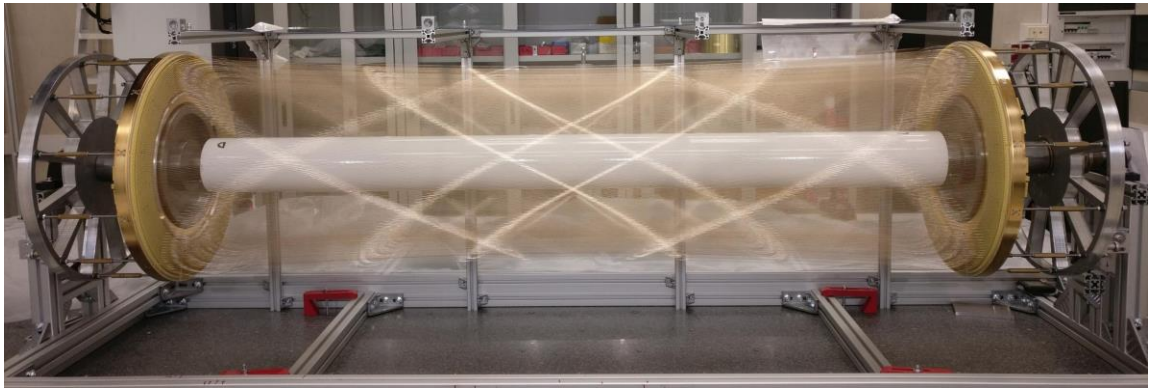
512 counters

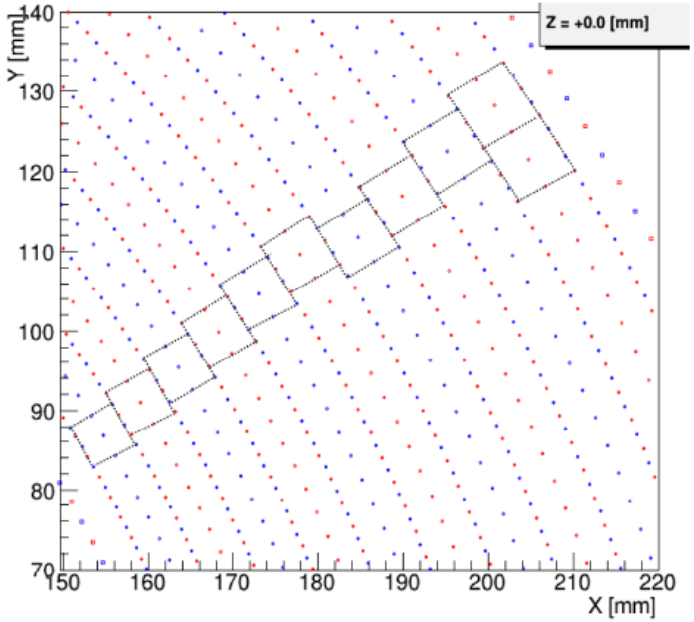


M. Nishimura PhD thesis

Concept	Fast plastic scintillator + SiPM series readout
Achievement	**Good timing resolution** (35 ps).
Issue	Radiation damage of SiPM • Solution: cooling & replacement

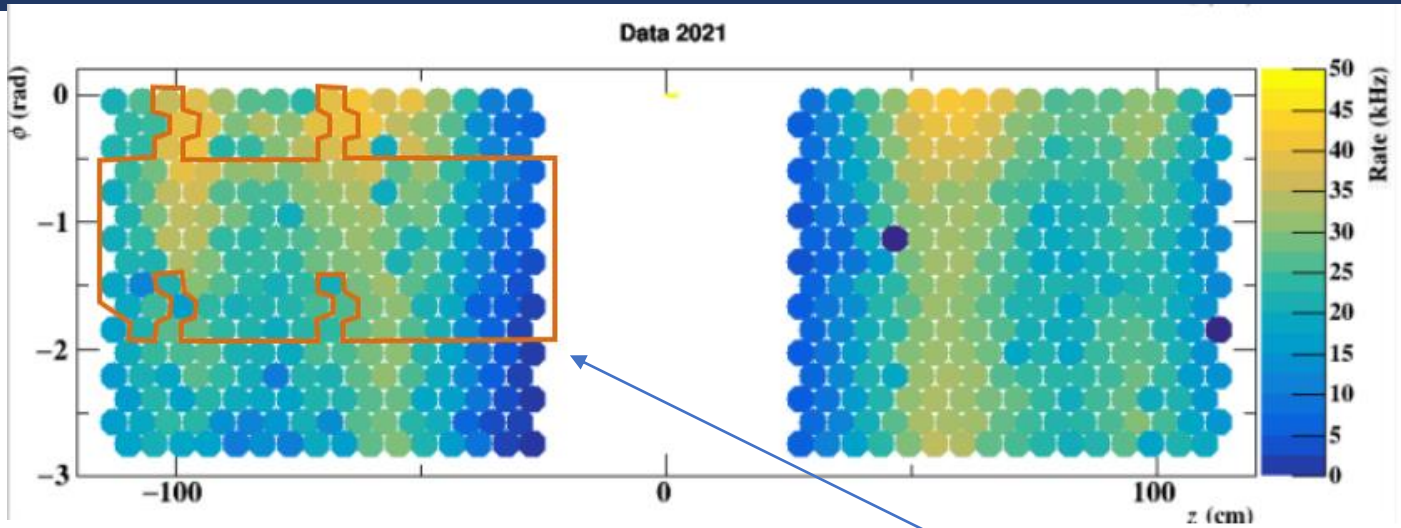
Cylindrical Drift Chamber (CDCH)

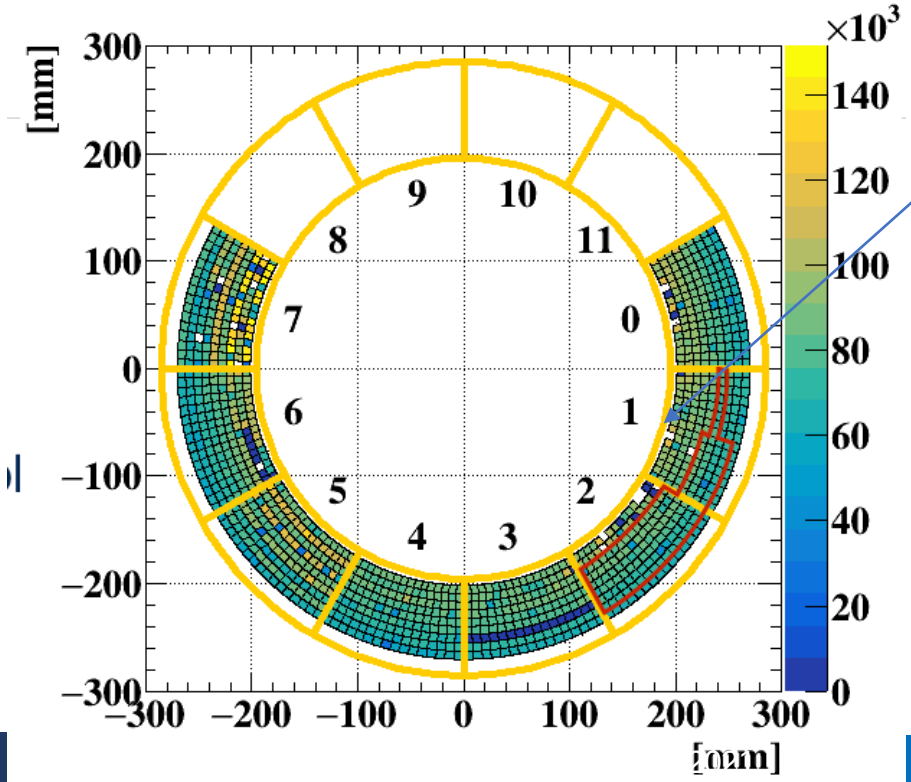




Concept	Ultra-low mass cylindrical stereo wire chamber
Achievement	Optimization of gas mixture + conditioning • He:iC4H10 (90:10) + 1.2% 2-propanol + 0.5% O2
Issue	Wire-breaking & aging • Dry wire volume + extraction of broken wires

Engineering run 2021 – pTC & CDCH -





2020 readout

	2020	2021
pTC	128	512
CDCH	128	1152

- Tracking study with full coverage is in progress.

$\mu \to e\gamma$ search History