MEG II実験：2021年エンジニアリングランの現状と計画

The MEG II experiment: status and plan of the 2021 engineering run

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on behalf of MEG II collaboration

日本物理学会2021年年次大会
令和3年9月17日

17pT1-4

MEG II in search of $\mu^+ \rightarrow e^+\gamma$

- An intensity frontier experiment
- Upgraded from MEG experiment
- To get definitive evidence for BSM

UTokyo
KEK
Kobe Uni.

PSI
ETHZ

INFN Genoa
INFN Lecce
INFN Pavia
INFN Pisa
INFN Roma

BINP
JINR

UC Irvine

~60 physicists

MEG result (2016)

$B(\mu^+ \rightarrow e^+\gamma) < 4.2\times10^{-13}$
@90% C.L.
(while 5.3×10^{-13} expected)

×2 intensity muon beam
×2 resolution everywhere
×2 efficiency

Search for $\mu^+ \rightarrow e^+\gamma$ down to

6×10^{-14}

(90% C.L. sensitivity)

Ultra-high scale

GUT

Force unification
Matter unification
Charge quantization

Seesaw

Neutrino mass
Leptogenesis

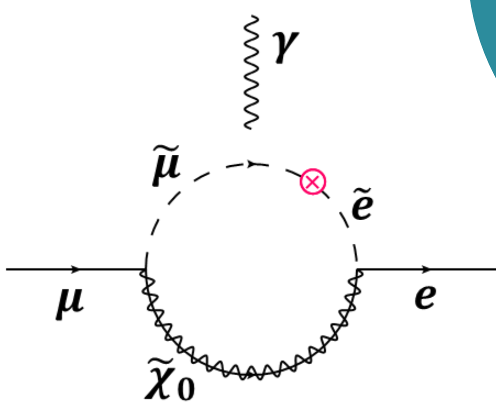
Flavor violation from quark Yukawa

Flavor violation from neutrino Yukawa

TeV scale

SUSY

Spacetime–internal sym. unification
Dark matter?
Solution for hierarchy problem?



Low scale

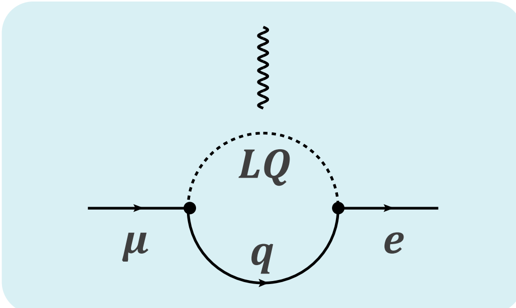
LFV

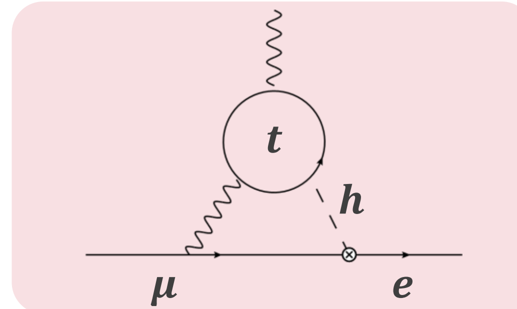
Lepton flavor violation

$B(\mu \to e\gamma) \sim 10^{-11} - 10^{-14}$

top-down

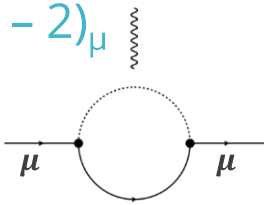
Other reasons



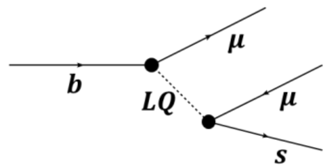


two-loop

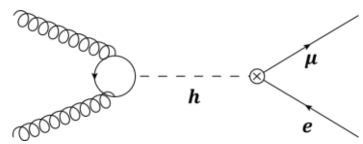
$(g-2)_\mu$



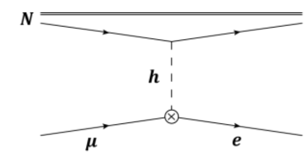
LHCb



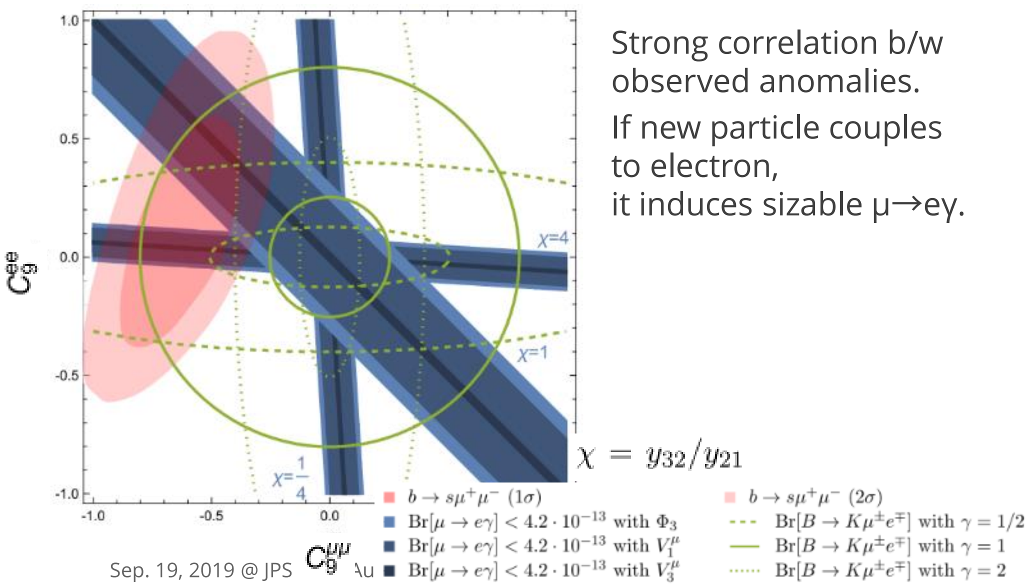
CMS



mu2e/COMET



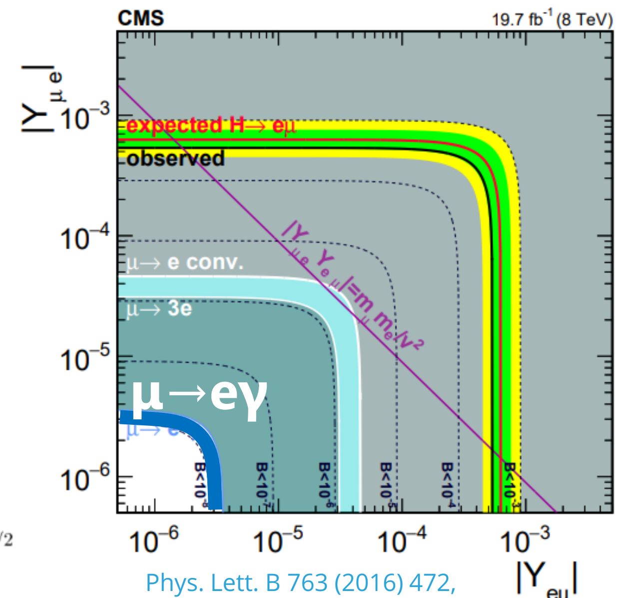
tree



Phys. Rev. D 97 (2018) 015019

Strong correlation b/w observed anomalies.

If new particle couples to electron, it induces sizable μ→eγ.



Phys. Lett. B 763 (2016) 472, JHEP 03 (2013) 026

Limit on μ→eγ provides the most stringent limit on the LFV Higgs decay

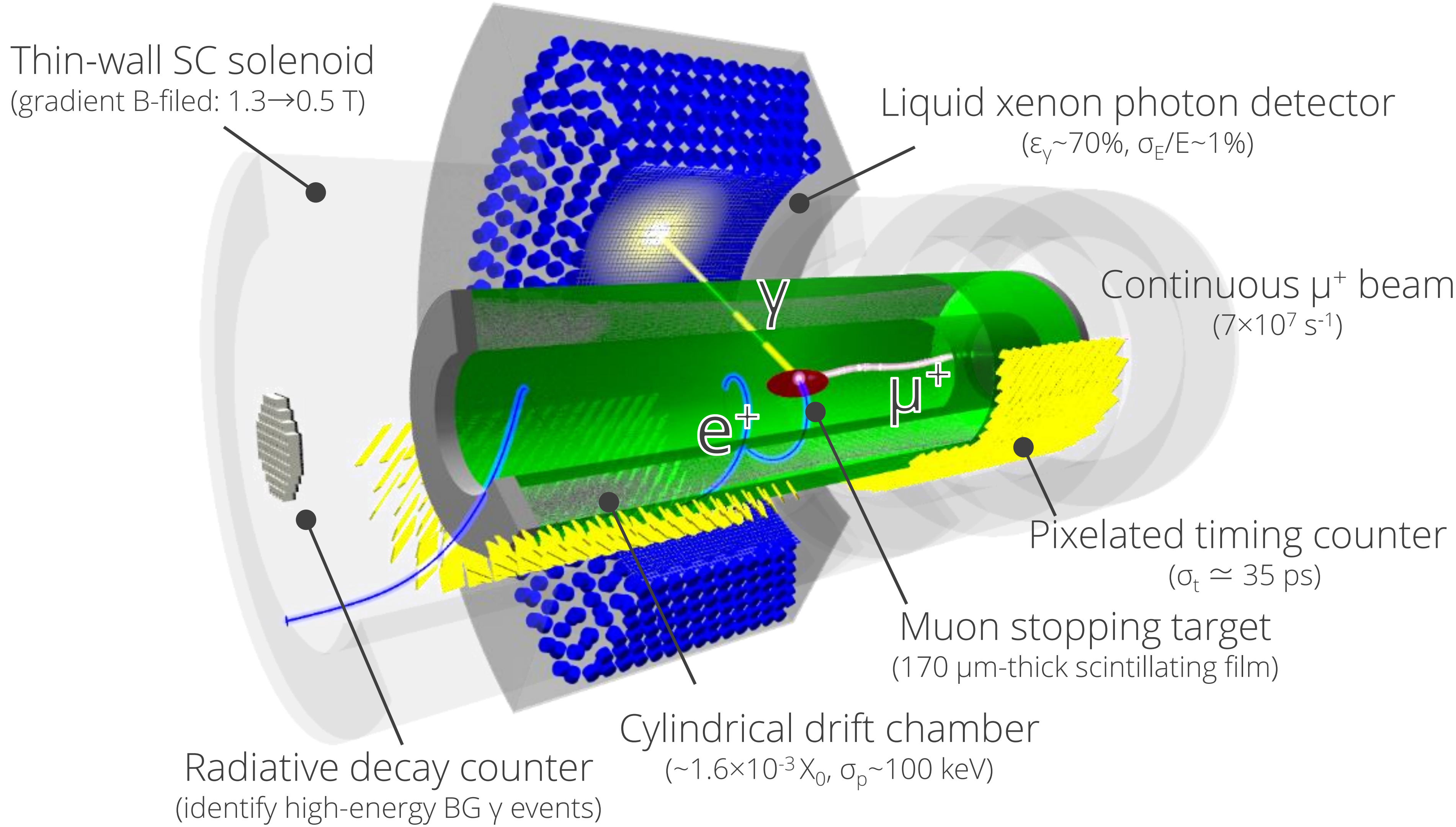
BR(h→μe) < 10^{-8}

(CMS limit:

BR(h→μe) < 3.5×10^{-4})

MEG II

EPJ-C **78** (2018) 380



Current status & outstanding issues

All the apparatus has been constructed.
Each detector has been tested in beam so far.

To be studied

1 Electronics

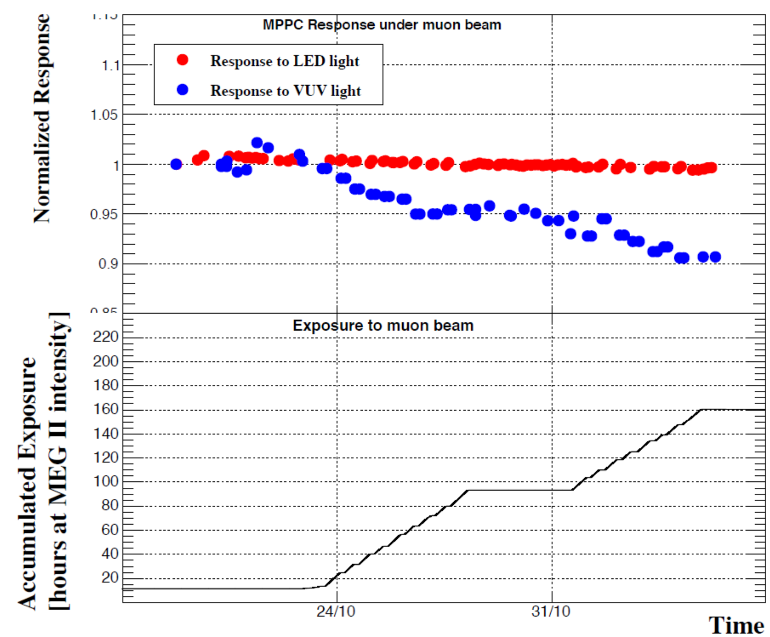
Full electronics has not yet been tested.

2 LXe detector

Lack of study with full channel readout.
Degradation of MPPC PDE.
Evaluation of timing resolution.

3 Drift chamber

Stable operation of the detector in beam.
Bad S/N.
Lack of tracking study due to limited electronics.



2020年年次大会、小林

Goal of 2021

To address all the issues.

To setup μ→eγ trigger and collect the initial data of MEG II.

To be studied

1. **Electronics**
   Full electronics has not yet been tested. ⇨ Complete production & deploy

2. **LXe detector**
   Lack of study with full channel readout. ⇨ Long-term study in beam.
   Degradation of MPPC PDE.
   Evaluation of timing resolution. ⇨ New measurement with improved setup.

3. **Drift chamber**
   Stable operation of the detector in beam. ⇨ Long-term study in beam.
   Bad S/N. ⇨ Noise investigation under final condition.
   Lack of tracking study due to limited electronics.

1 Electronics

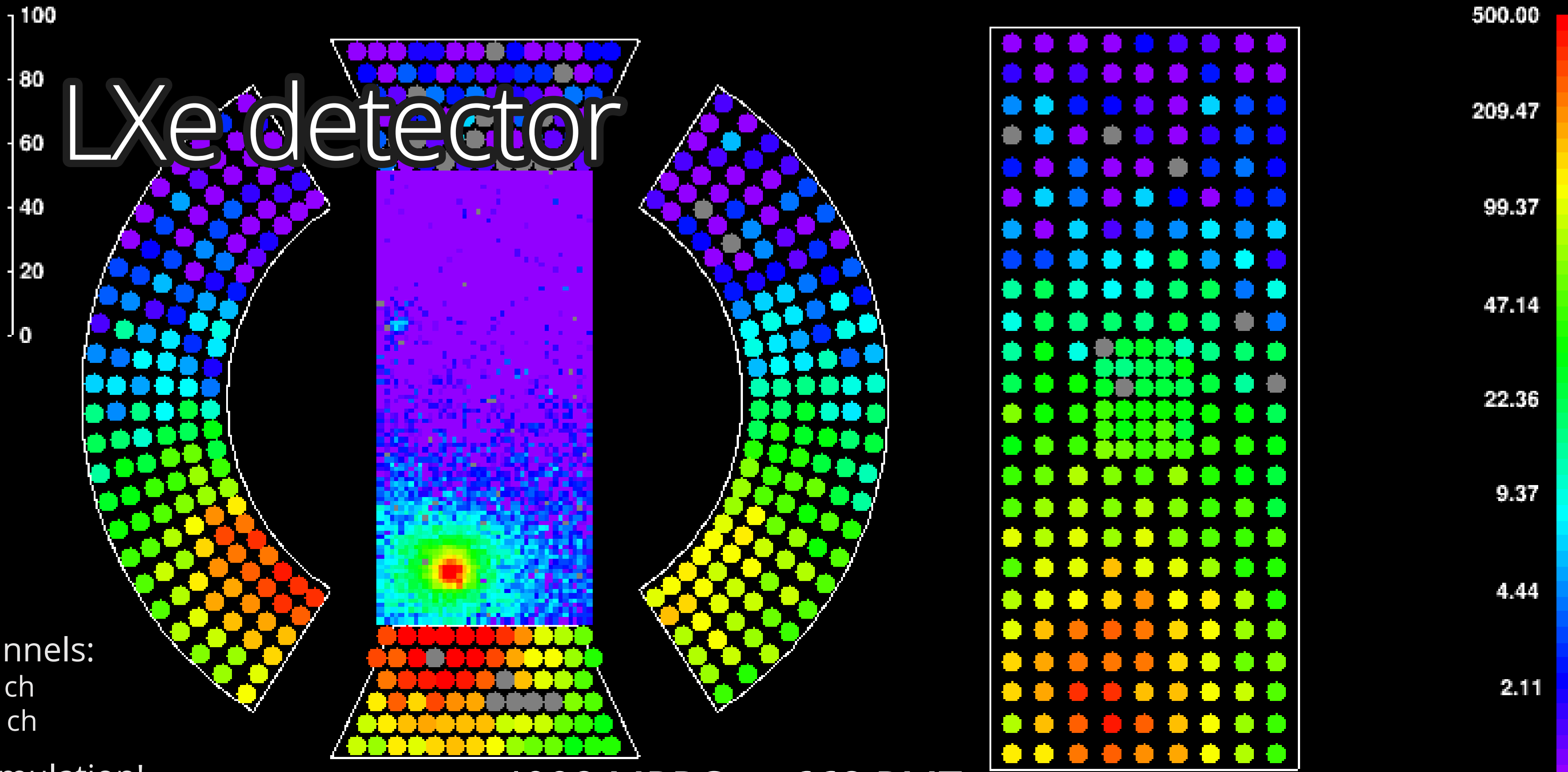
Mass-production finished & installed in Mar.

DAQ with the full channels in operation

Basically, the system works (debugging ongoing).
Stable DAQ at data rate of 1.5 Gbps. ~2 TB/day in storage.

Better noise situation for LXe, but worse for pTC.

2 LXe detector



Bad channels:
MPPC 28 ch
PMT 27 ch

Not a simulation!

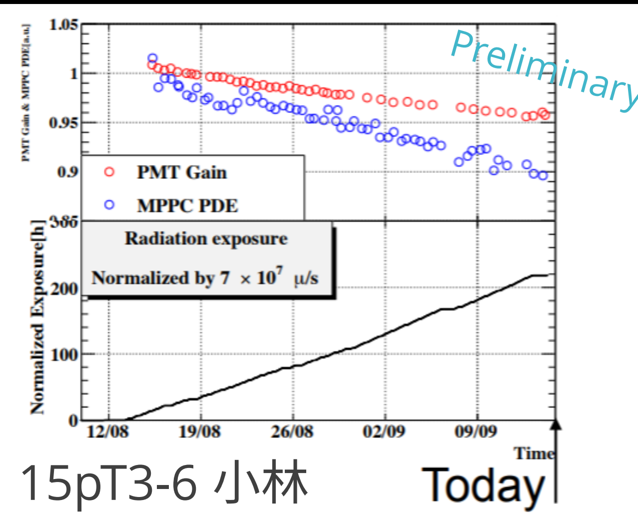
4092 MPPCs + 668 PMTs

Commissioning with the full electronics done.

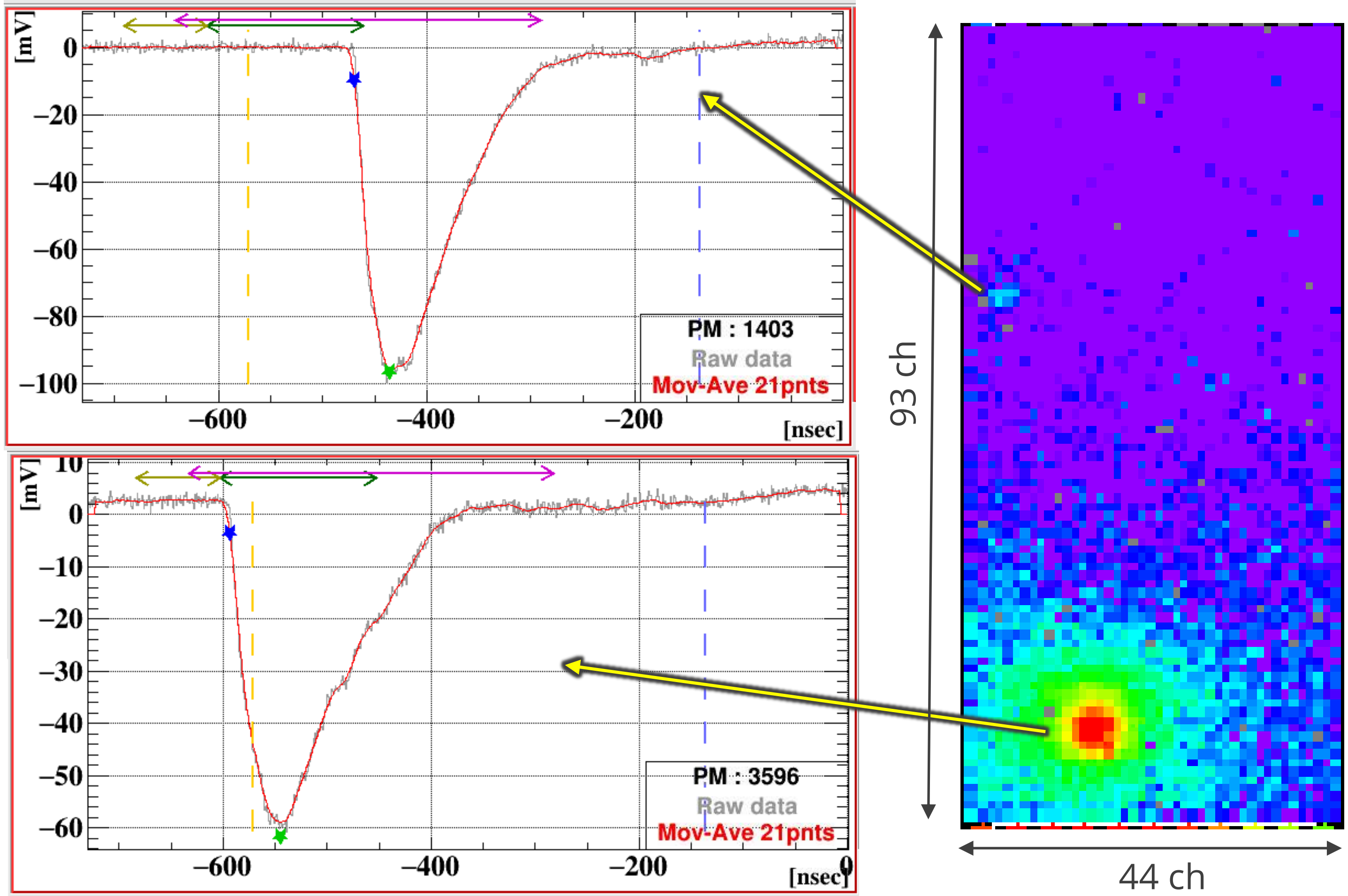
Calibration & monitoring continued.

Using beam from mid. Aug (~1 month)

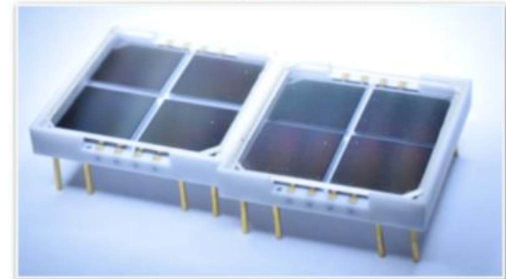
- To study the MPPC PDE decrease.
- Basically, confirmed previous observations (preliminary).
  → No sign of saturation of the degradation.

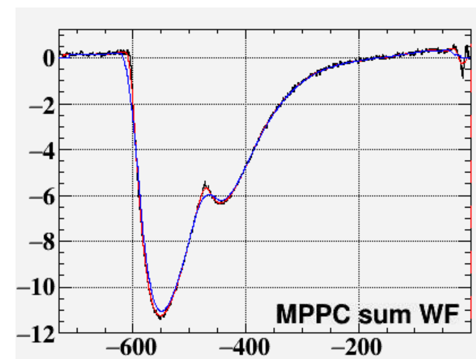


15pT3-6 小林



S10943-4372





High granularity readout

4092 MPPCs + 668 PMTs

Waveform data for the 4760 channels

1024 points @ 1.4 GSPS

⇒ **Pileup identification & unfolding**

See 15pT3-7 恩田

3 Drift chamber

Conditioning done

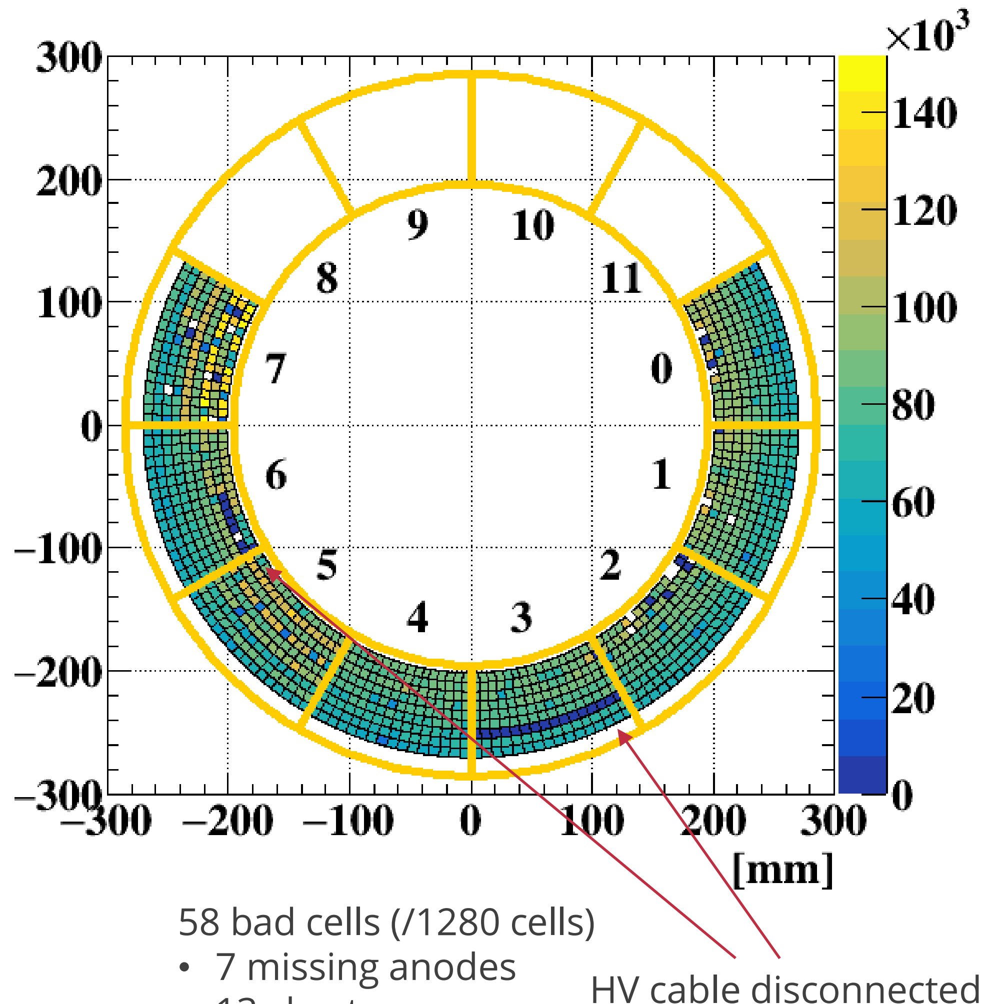
- In beam with high concentration of O_2 (2%).
- High current (corona discharge) is reducing.
- Gas mixture: He:iC_4H_{10}(90:10)
  + 1.2% 2-propanol + 0.5% O_2

Noise study

- Identified several sources of noise.
- Some were fixed, others require hardware modification.

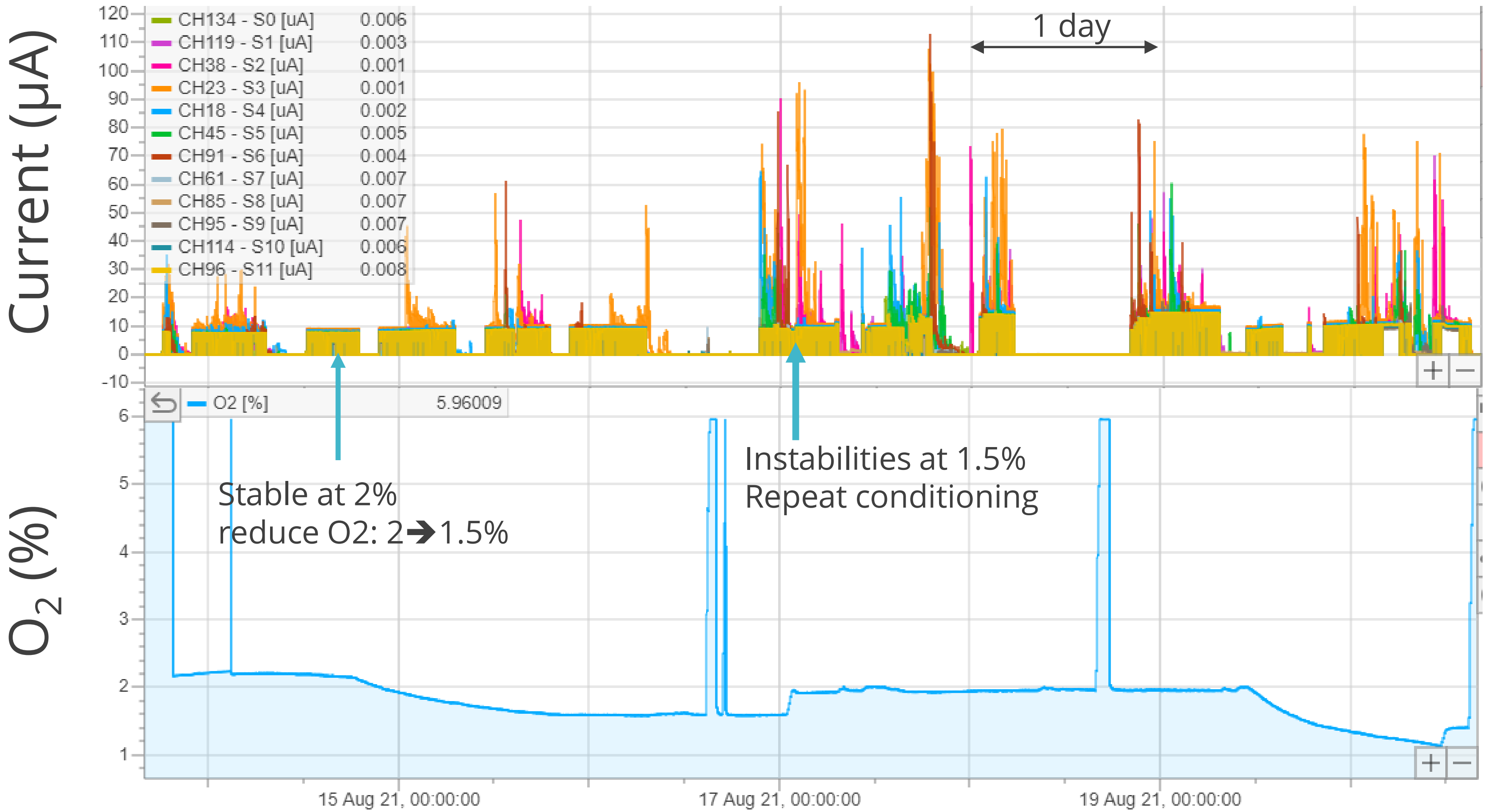
Tracking study started

- Cosmic ray and e^+ from muon decay.
- Calibration and alignment are underway.



58 bad cells (/1280 cells)
- 7 missing anodes
- 13 short

Conditioning in beam



Building new drift chamber

Risk of wire breaking

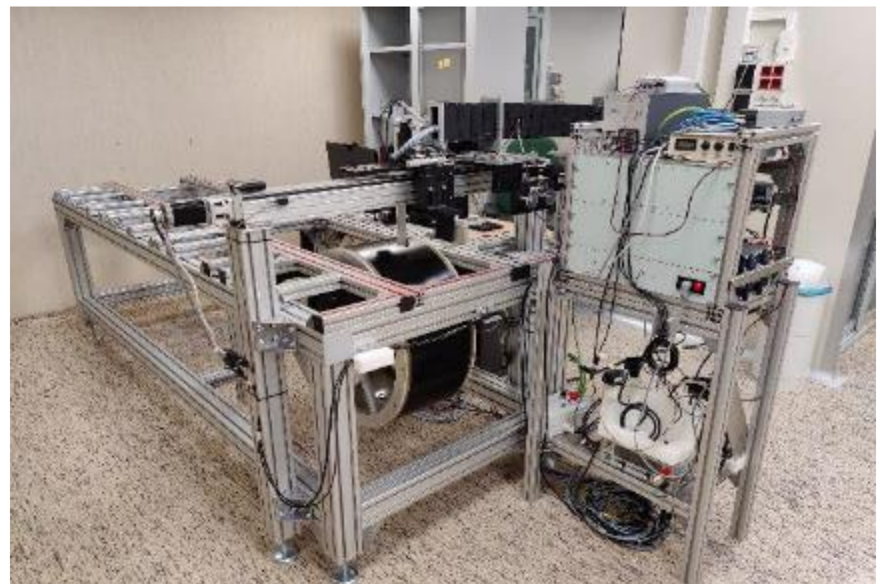
- Exposure to humidity during the construction
- Bad coating (Ag) due to an ultra-finishing process to make 40-μm wire

We decided to construct another drift chamber

- Use 50-μm Ag-coated Al wires without the finishing process (California Fine Wire)
- Recover the original 10-layer configuration.
  (Existing chamber has 9 layers due to construction schedule.)
- Modify/improve some parts based on
  the experience of the 1st chamber.

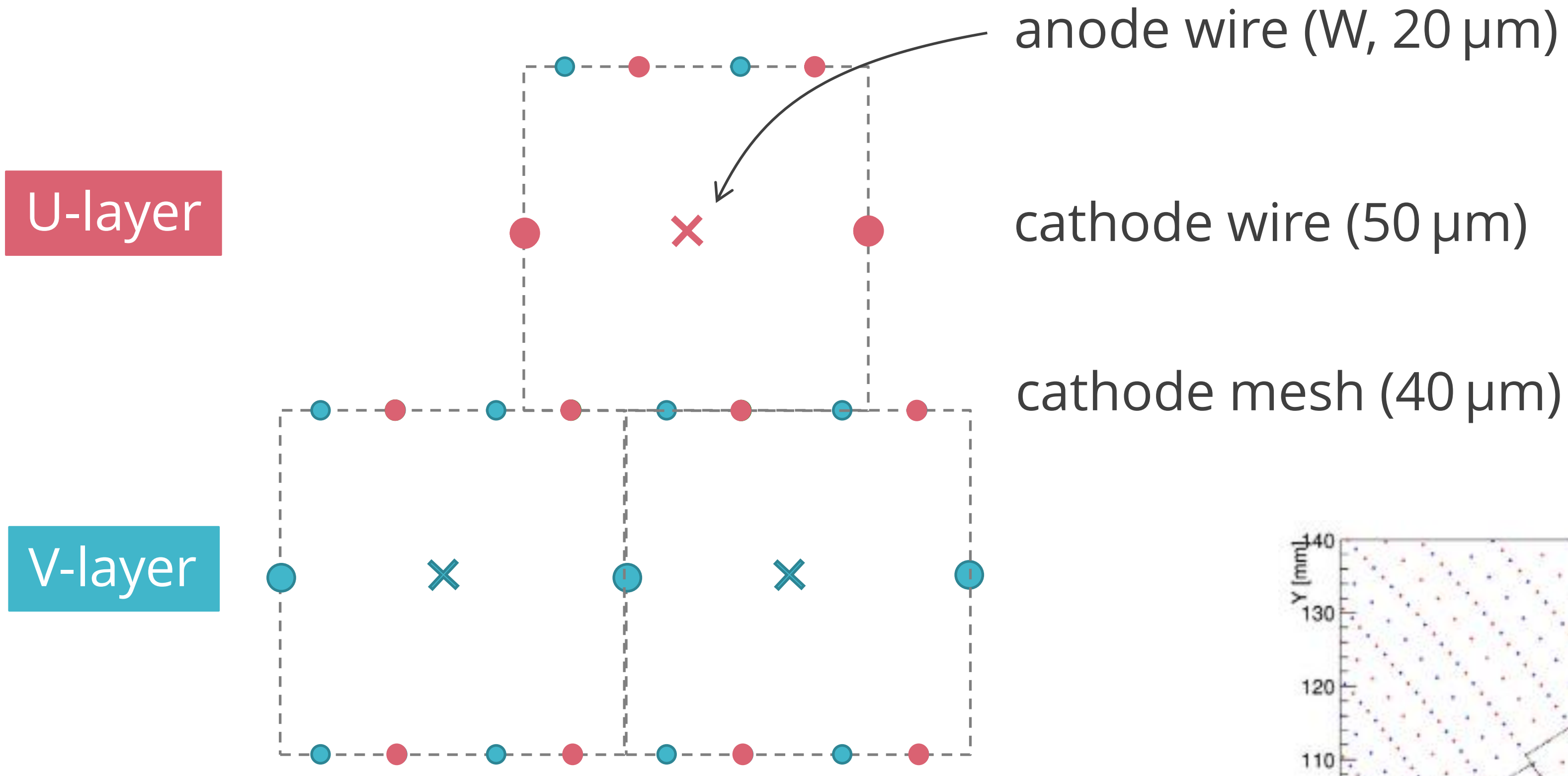
Schedule

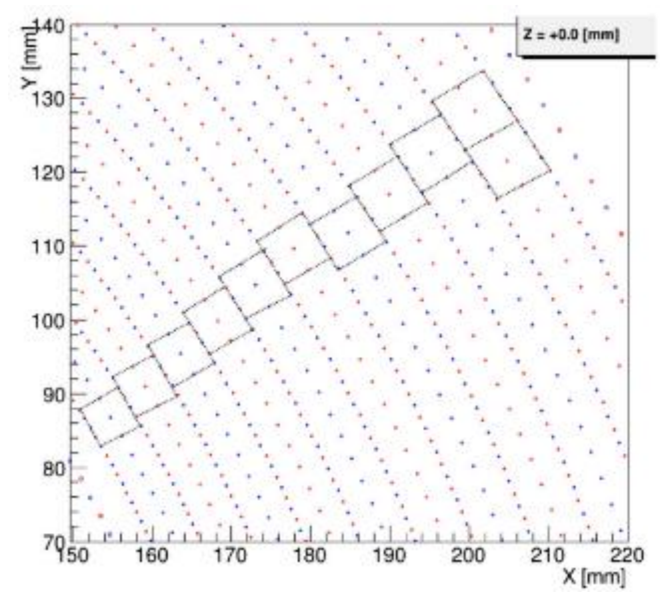
- Budget secured (Italy).
- Material procurement started.
- Wiring takes 62 weeks.
- Complete by Mar. 2023.
  → Use it from 2023 run.



Wiring machine re-assembled in INFN-Pisa

Drift cell configuration

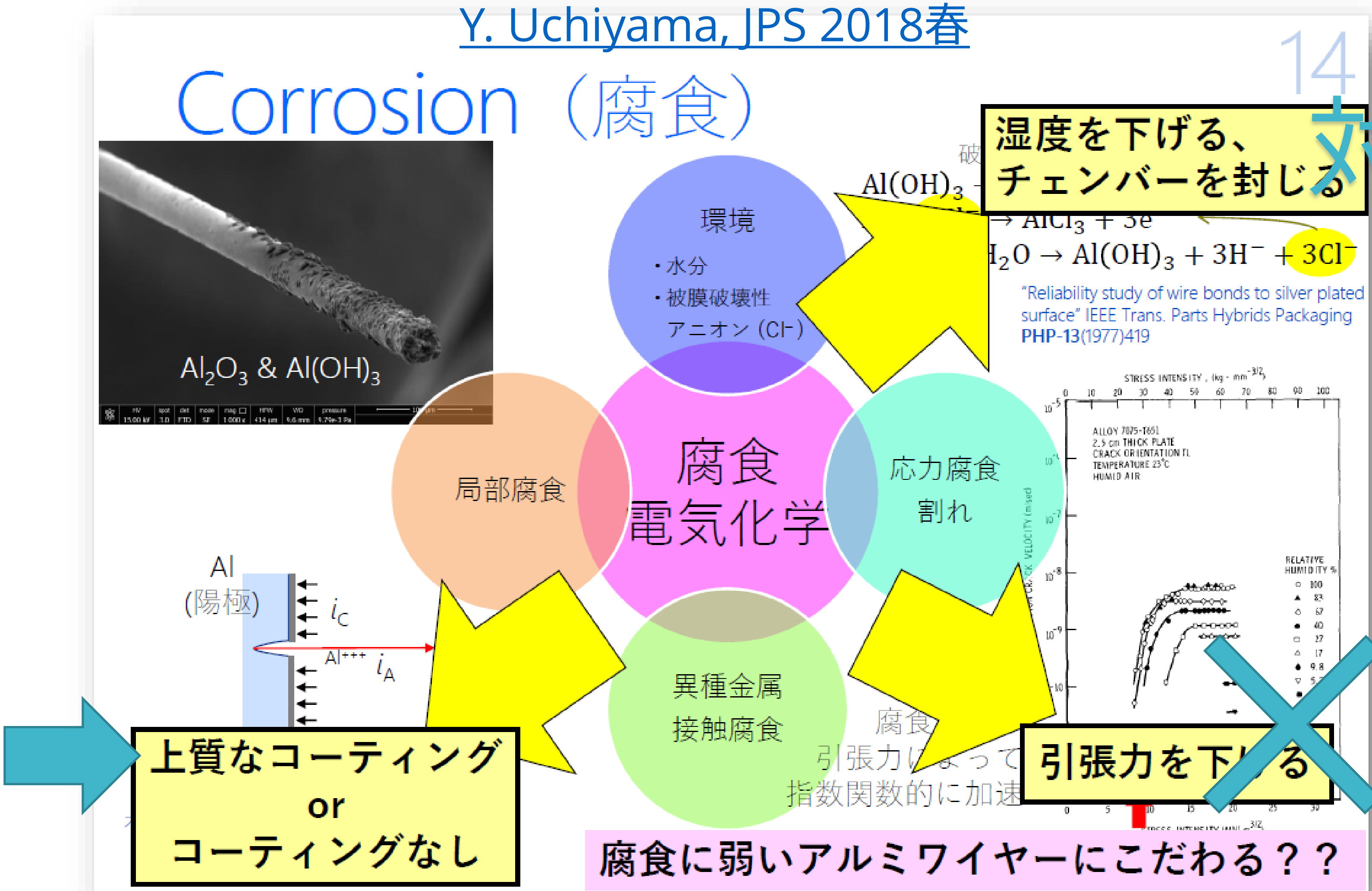




In the new CDCH, 50 μm wire will be used also for the cathode mesh.

[Y. Uchiyama, JPS 2018春]

対応済

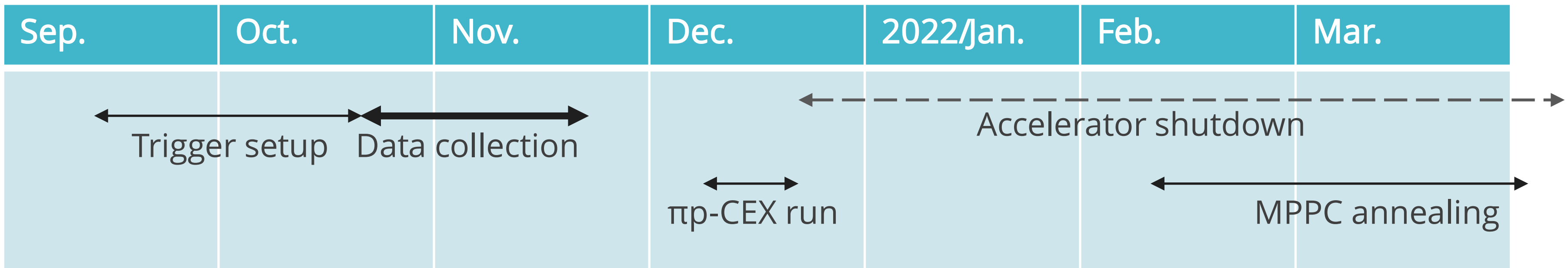


静電力に耐えるために下げられない。

アルミと銀の境界 ＋ 水分 ＋ 張力 ＝ 腐食による断線

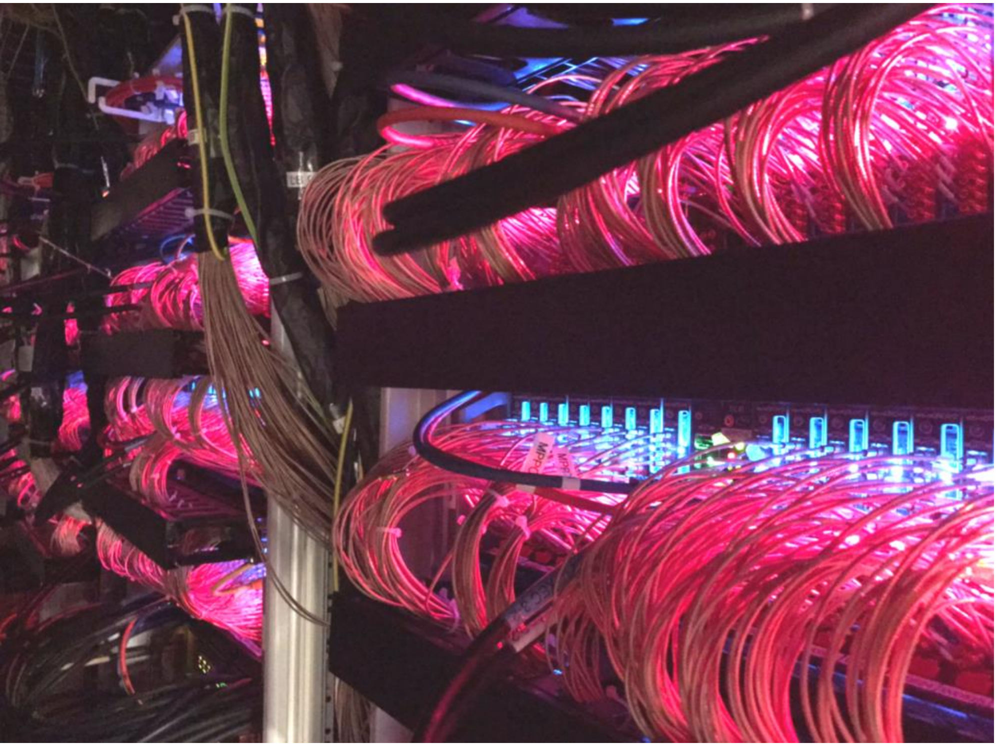
陰極ワイヤ：40 or 50 μm 銀コーティングアルミニウムワイヤ

Schedule



- μ→eγ trigger setup is starting now.
- Collect μ→eγ trigger data until Nov.
  This will be the first MEG II physics data
- Performance evaluation with πp charge-exchange reaction in Dec.
  Measure energy resolution with full elec.
  Improve method for the measurement of timing resolution.
- Perform MPPC annealing in the next spring.
  Annealing was not performed in the last shutdown period.
  Study of the procedure is underway

Summary



The MEG II engineering run is underway,

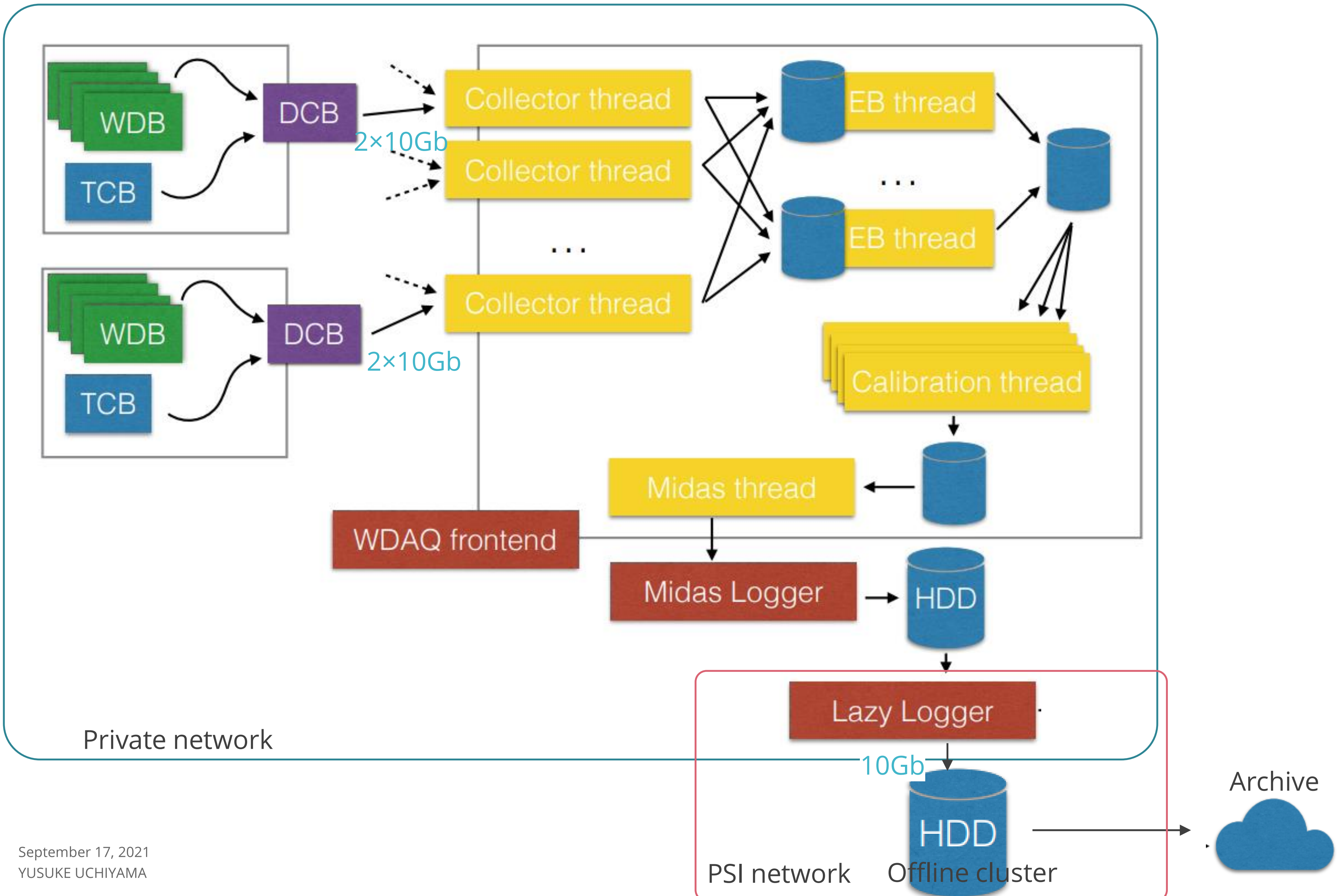
- Finally with the full readout electronics.
- All the detectors were installed and under commissioning in beam.
- Beamtime continues until Dec.

The main goals are

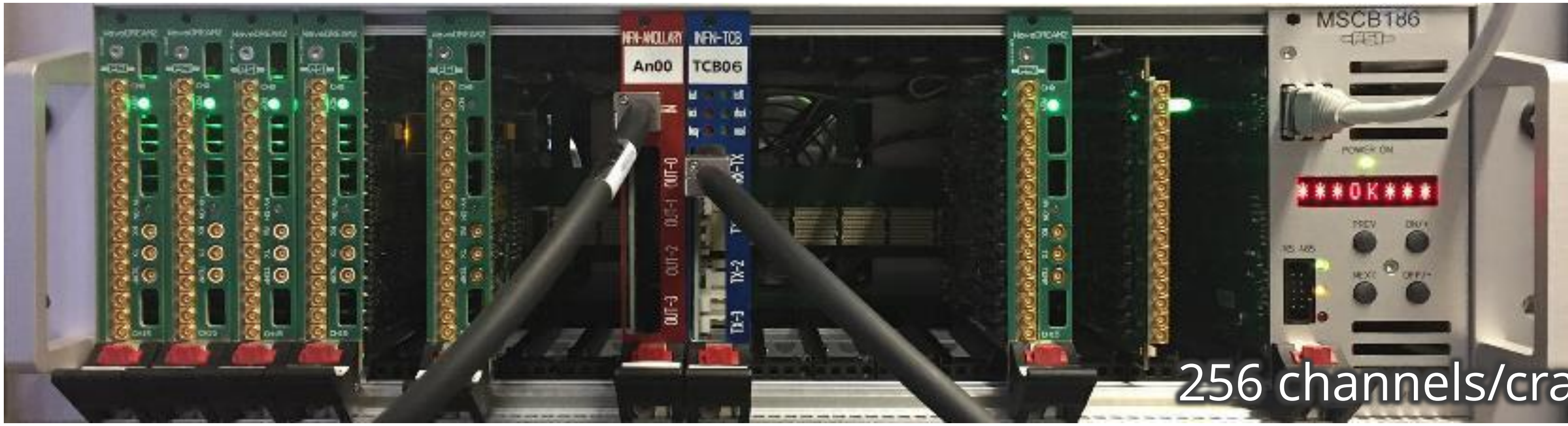
- To study & understand the LXe MPPC PDE decrease phenomenon
  and decide the operation scenario.
- To achieve stable operation of CDCH.
- To establish the μ→eγ trigger and begin the physics data collection.

Recently, Kobe University group has officially joined the MEG II collaboration., contributing to the development of upstream RDC with unique RPC technique.

Dataflow


WDB
TCB
DCB
2×10Gb
WDB
TCB
DCB
2×10Gb
Collector thread
Collector thread
...
Collector thread
EB thread
...
EB thread
Calibration thread
Midas thread
WDAQ frontend
Midas Logger
HDD
Lazy Logger
Private network
10Gb
HDD
PSI network
Offline cluster
Archive

Readout electronics

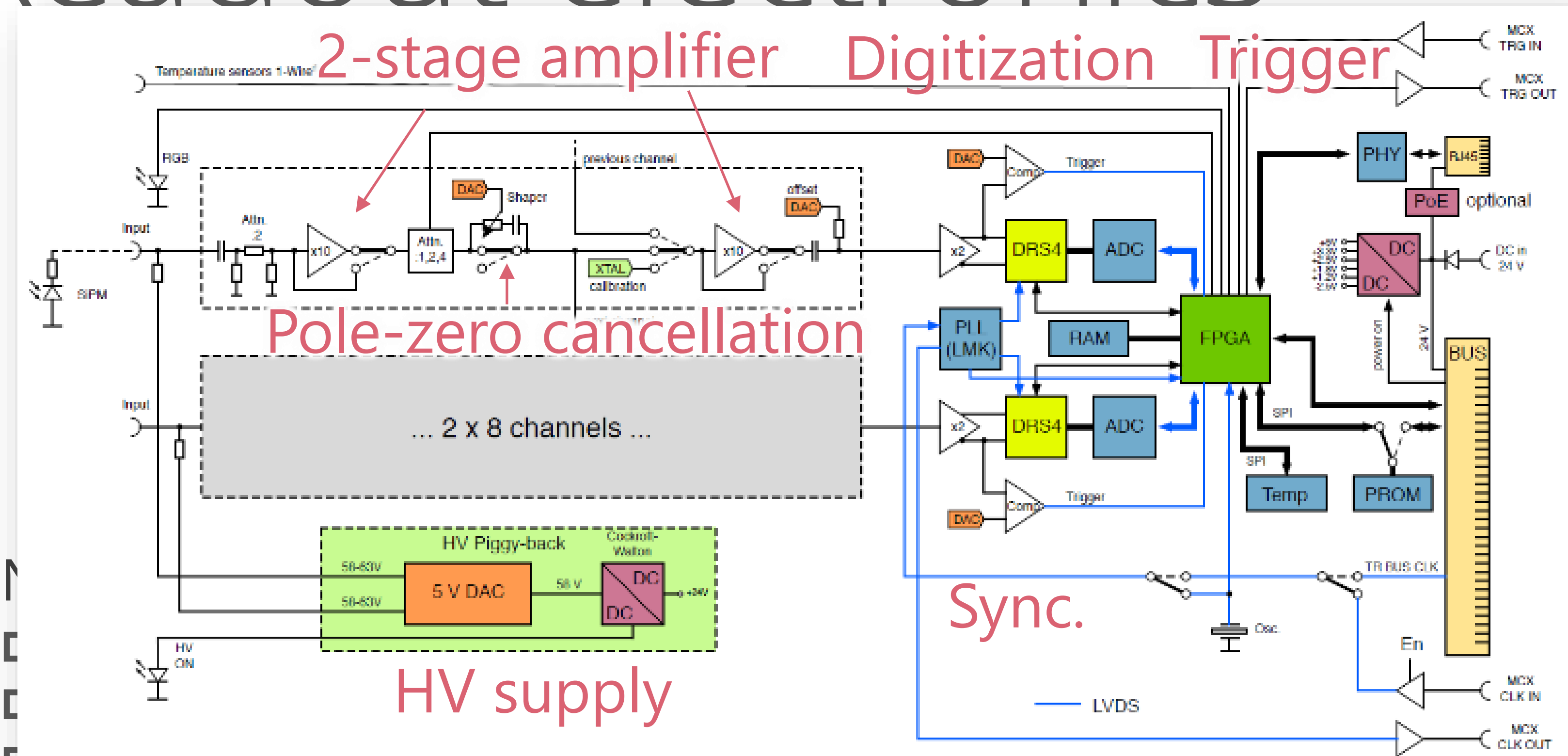


- New DAQ/Trigger system
  - ☐ Use it for all MEG-II detectors in common
  - ☐ Dense & compact system to cope with increased # of channels.
  - ☐ Custom multi-functional readout board: **WaveDREAM**

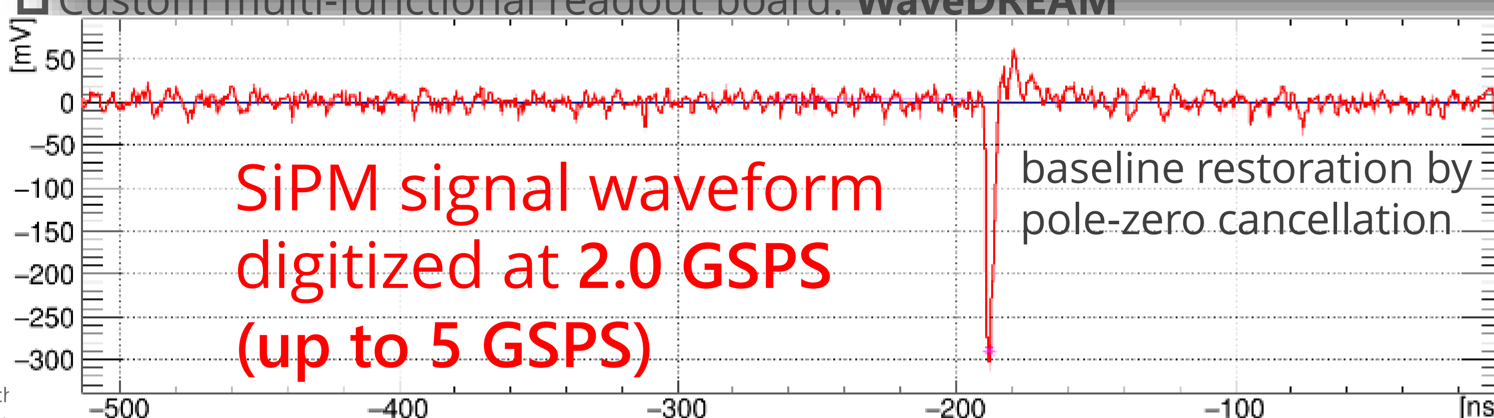
    Analog FE (programmable shaper & amplifier),
    SiPM bias-voltage supply, waveform sampling (DRS4),
    digitization, discriminator, FPGA-based trigger in one module

    No pre-amplifier at detector side
  - ☐ Synchronization accuracy < **20 ps** (over different crate module

Readout electronics

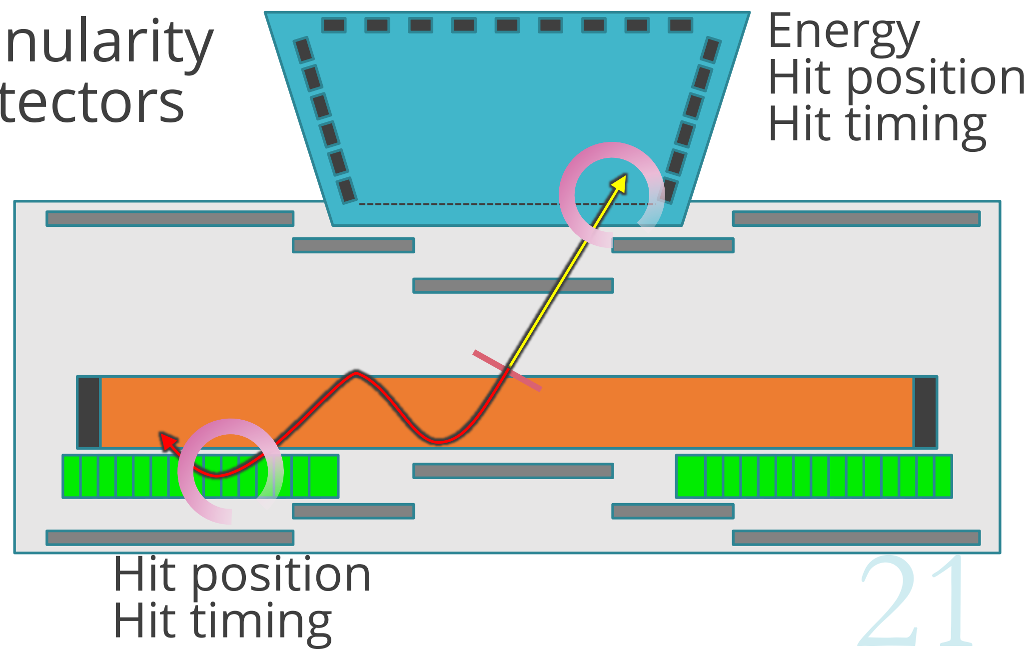


Custom multi-functional readout board: WaveDREAM



Trigger

- More efficient trigger is indispensable.
- Trigger logics (basically same as MEG)
  1. Gamma-ray energy threshold
  2. Time coincidence
  3. e–γ direction matching (close to 180°)
- Improve by use of higher granularity & better resolution of the detectors



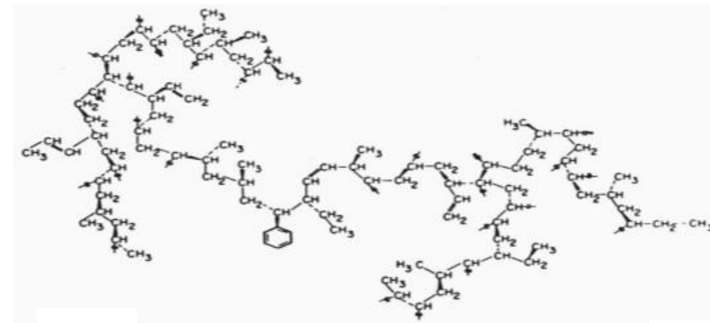
Wire conditioning, aging, & additives

Conditioning (HV training)

Eliminate dust, contamination, deposit.
Necessary to apply HV after opening chamber or after aging.

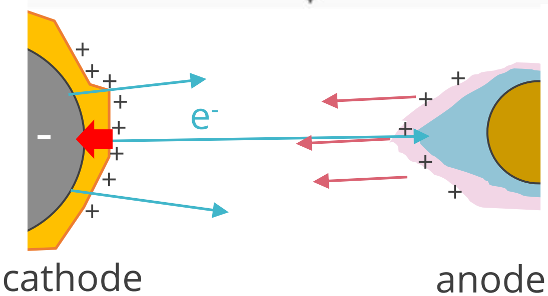
Wire aging (in He:iC_4H_{10})

Polymer formations by radicals (of HC) created in avalanche.



Anode aging:
Gain decrease (thicker wire), gain non-uniformity along wire.

Cathode aging:
Self-sustain high current and discharge by Malter effect.



Additives to mitigate/recover from aging

Alcohols (in our case 2-propanol)
Reduction of polymerization rate
Absorption of UV photons ⇔ Reduction in gas gain

O_2
Etching (cleaning) of HC-deposit
React with HC, becoming stable and volatile
Capture e^- emitted from Malter effect. ⇔ Reduction of primary e^-

Low-mass drift chambers

	Gas	Cell size	Sense wire	Field wire	
CLEO II	Ar:C_2H_6 50:50	14 mm	20-µm Au-W	110-µm Au-**Al**, 110-µm Cu/Be	Crimp
BESIII	He:C_3H_8 60:40	12–16.2 mm	25-µm Au-W	110-µm Au-**Al**	Crimp
Belle II	He:C_2H_6 50:50	6–18 mm	30-µm Au-W	126-µm **Al**	Crimp
COMET-Phase I	He:iC_4H_{10} 90:10	16–16.8 mm	25-µm Au-W	126-µm **Al**	Crimp
KLOE	He:iC_4H_{10} 90:10	20–30 mm	25-µm Au-W	81-µm Ag-**Al**	Crimp
MEG II	He:iC_4H_{10} 90:10	6.6–9 mm	20-µm Au-W	40-µm Ag-**Al**	Solder

- **KLOE** used same type of wire without any problem for **>10 years**
  Constructed under 50% R.H., never observed salt formation

Type	X_0 (mm)	$\langle X\rangle^{wires}$ (10^{-3} X_0)	$\langle X\rangle^{tot}$ (10^{-3} X_0)	θ^{wires}_{MCS} (mrad)	θ^{tot}_{MCS} (mrad)
Al (5056)	89	0.72	1.5	5	7.6
Ti	36	1.26	2.1	6.8	9
CuBe	14.7	2.58	3.4	10.1	11.7
Stainless Steel (302)	17.8	2.2	3	9.3	11

Other material than Al is **not acceptable** from the resolution point of view.

- **Bare Al wire** could be a better alternative, but difficulty in soldering.
  (Naturally coated by Al_2O_3)