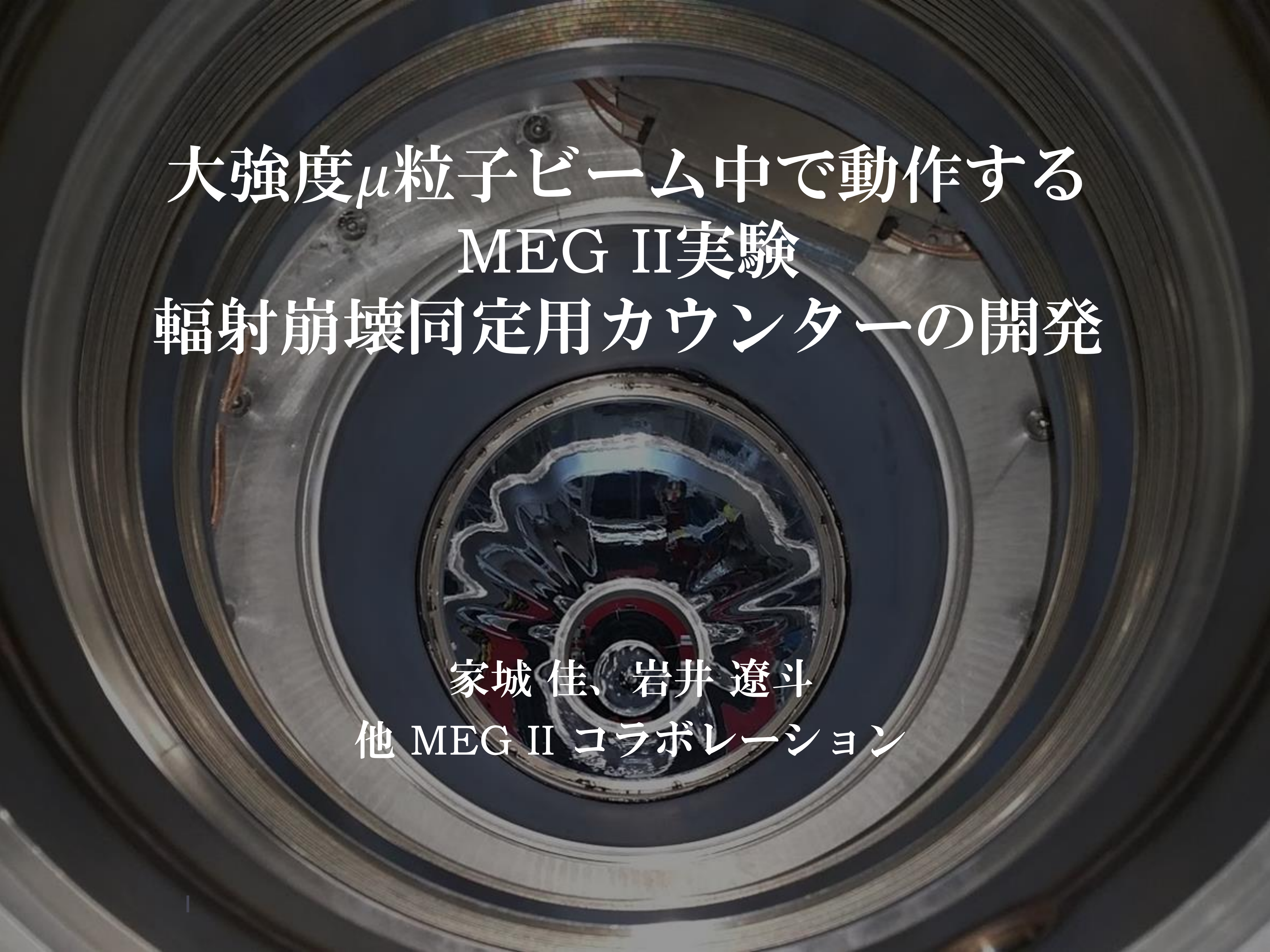
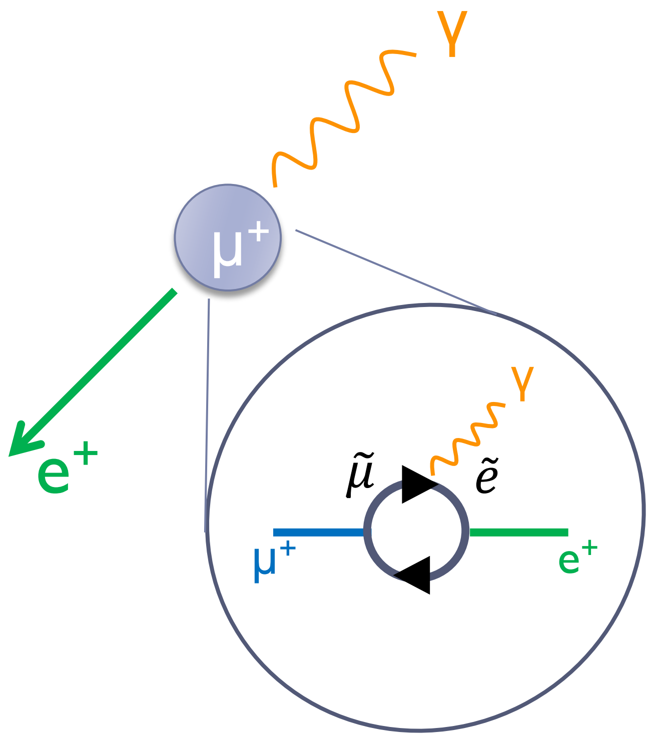


大強度μ粒子ビーム中で動作する MEG II実験 輻射崩壊同定用カウンターの開発

家城 佳、岩井 遼斗
他 MEG II コラボレーション

$\mu \to e\gamma$ search



BSM physics
(e.g. SUSY)

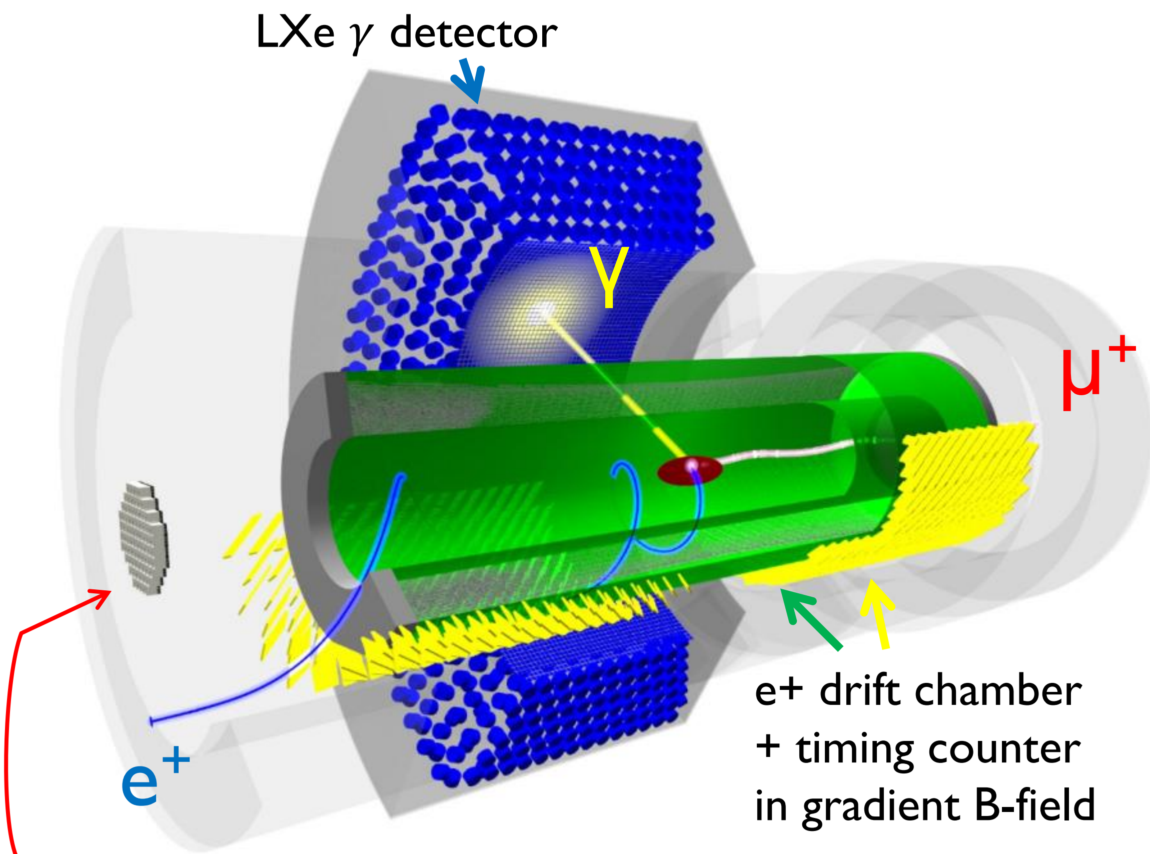
$\mu \to e\gamma$ is lepton flavor violating decay
Observation = Evidence of BSM physics

Current limit:
4.2×10^{-13} (90%C.L.,) by MEG (2016)

BSM prediction:
$\sim O(10^{-14})$ (e.g. SUSY-seesaw)

MEG II goal:
4×10^{-14}

MEG II @ PSI



Radiative Decay Counter (new in MEG II)

MEG

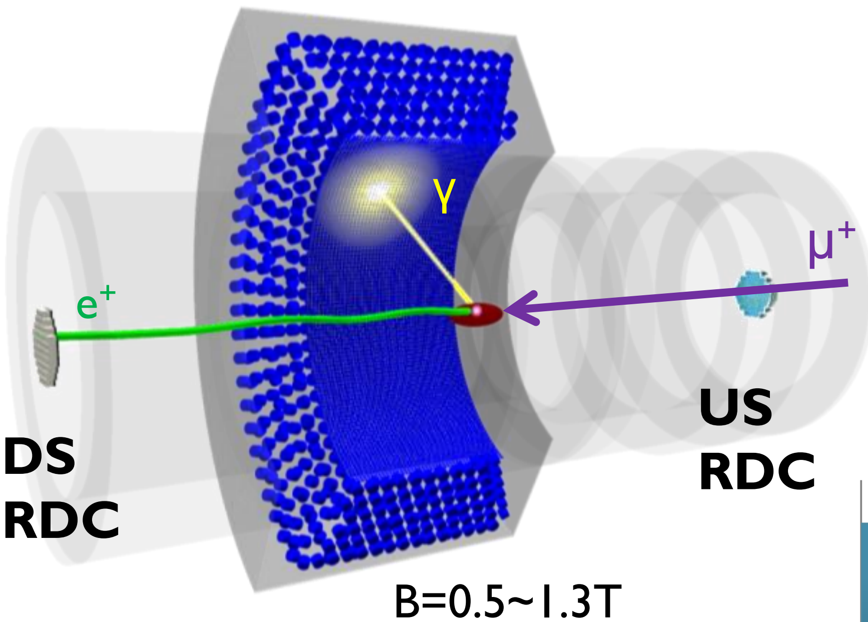
Upgrade
- **x2** beam rate
- **x2** resolution
- **x2** efficiency

MEG II

x10 better sensitivity

Upgraded detectors are already constructed except for e^+ drift chamber!

Radiative Decay Counter (RDC)



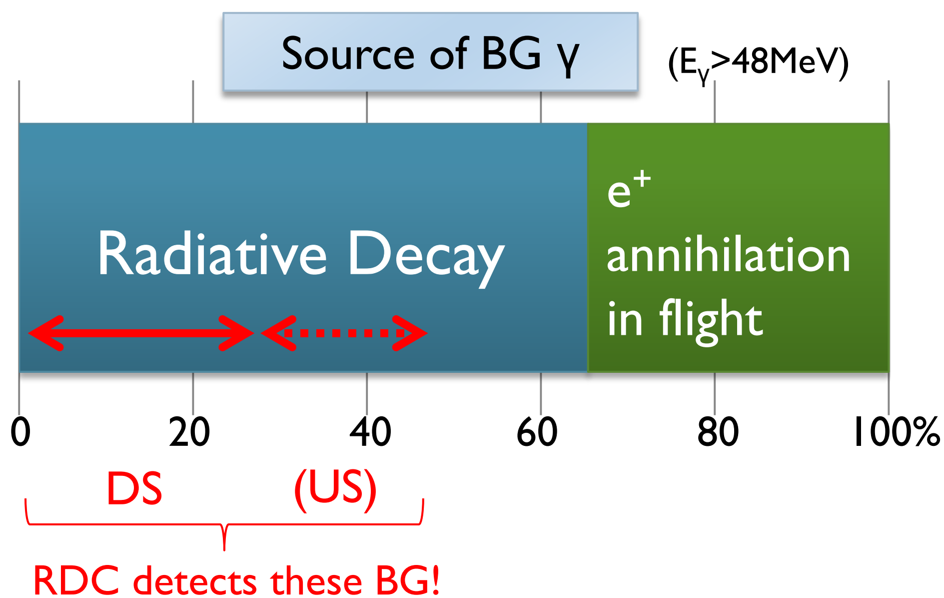
RDC identifies **Radiative Decay**

$$\mu^+ \to e^+ \nu\nu\boldsymbol{\gamma}$$

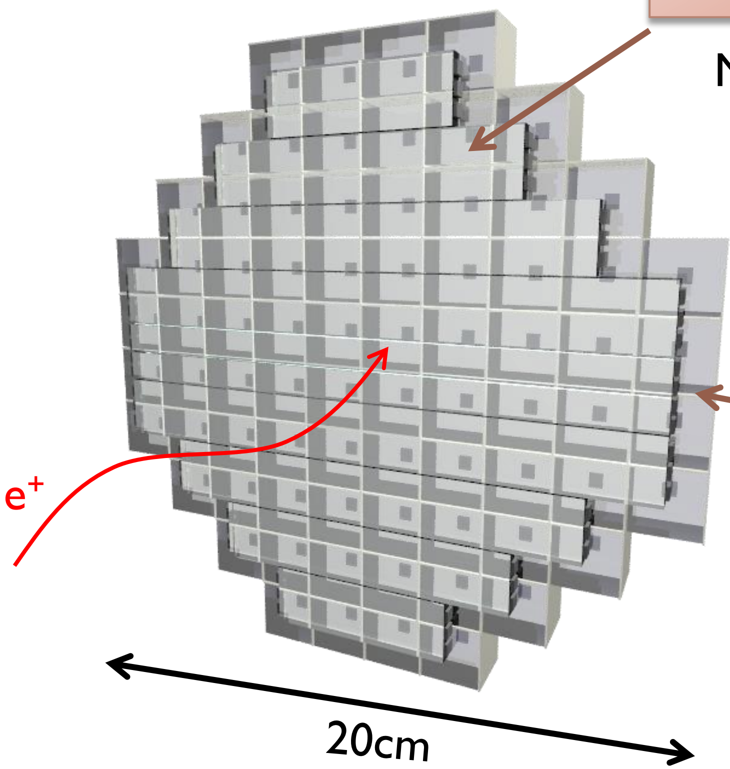
main source of BG when >~48 MeV

c.f. signal γ: 52.8 MeV

This BG γ can be identified by detecting low momentum e^+ with RDC



RDC downstream detector



Plastic Scintillators (PS)

Measure e^+ timing

→ $\mu \rightarrow e\nu\nu\gamma$ will have e^+ & γ time coincidence

12 fast plastic scintillators (BC418)

+ 2~3 MPPCs connected in series at both ends

LYSO crystals

Measure e^+ energy

→ Distinguish radiative decay (E_e =1~2MeV)

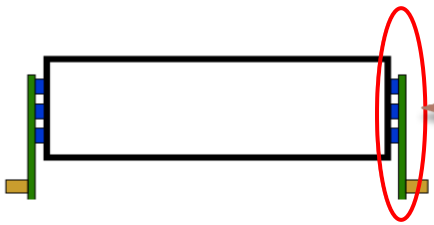
from normal decay ($\mu \rightarrow e\nu\nu$, $E_e < 53$MeV)

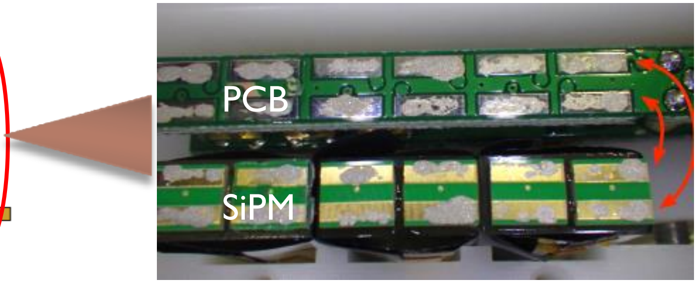
76 LYSO crystals (2x2x2 cm^3) + MPPC

Construction and test

(JPS2016Autumn 21aSE06)

Construction was finished.
Performance was successfully demonstrated in μ beam, but there were several bad channels due to bad electrical connection on plastic scintillators.



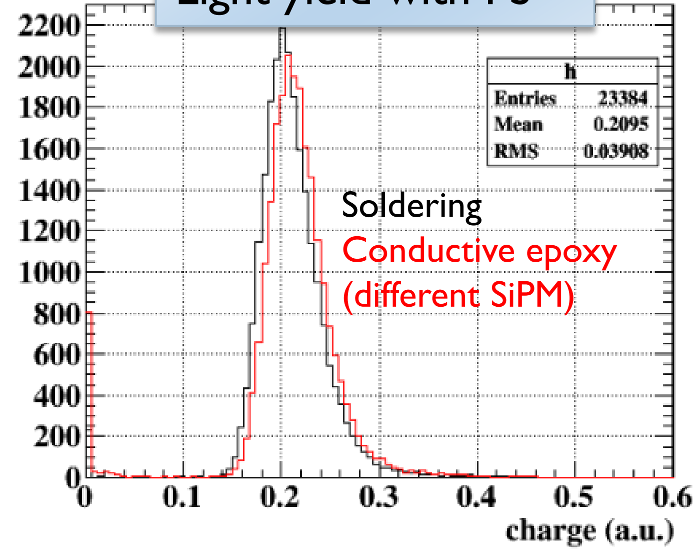


We used conductive epoxy instead of soldering to avoid heat damage
→ However it was fragile

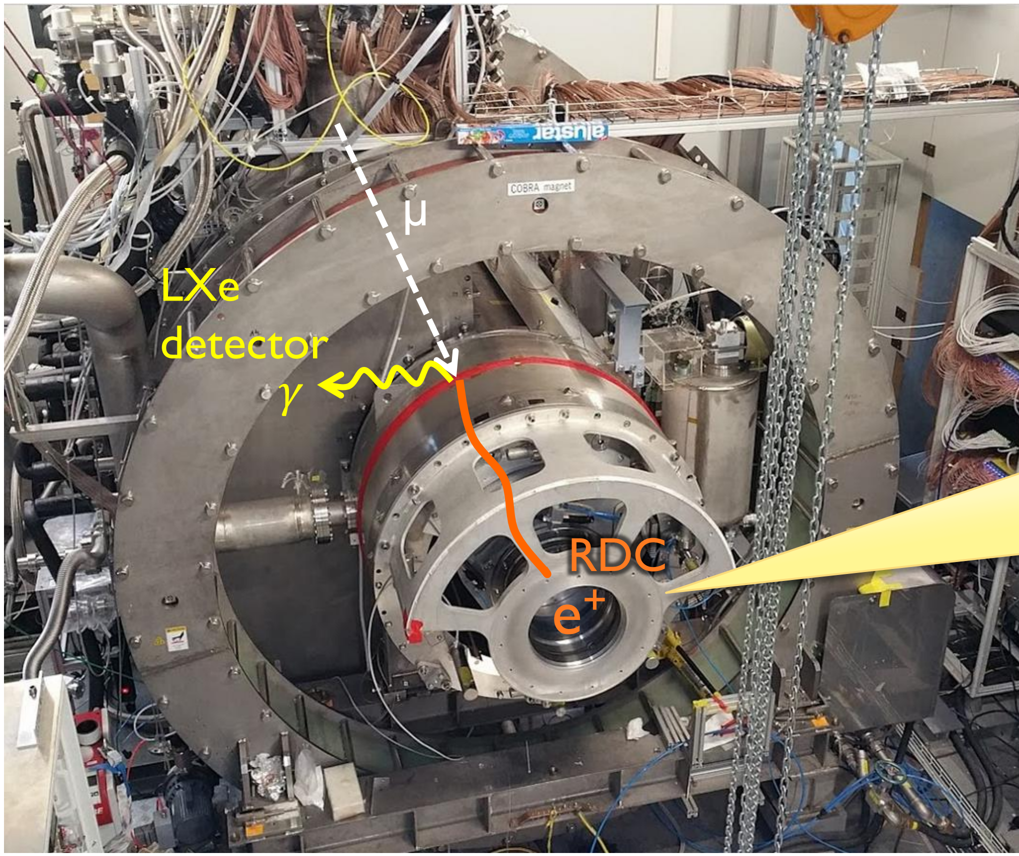
We reproduced all counters by soldering.

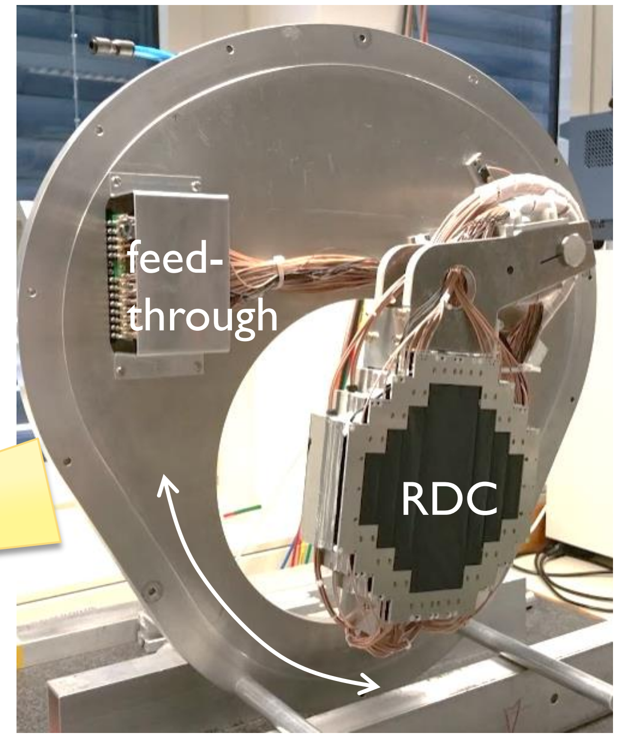
Light yield did not change.
Resolution was measured to be good for all ch (90~100ps, with ^{90}Sr source)

Light yield with PS



Installation



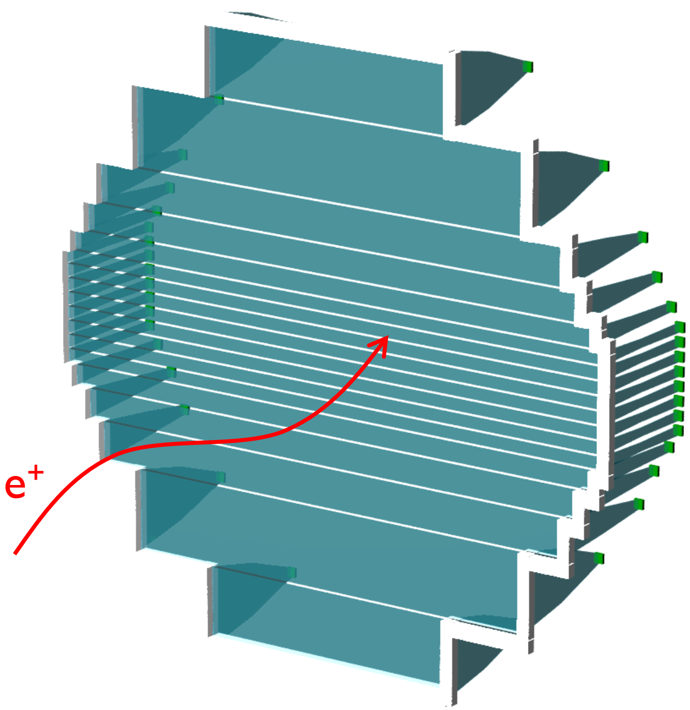


pneumatic pump mover moves the detector to insert calibration target from DS

DS RDC is installed!

To be tested in μ beam with LXe detector in the end of this year.

RDC upstream detector



Upstream detector is must be placed in the μ beam before stopping target.

- Requirements
  - Thin (not to affect the μ beam optics)
  - Operational in high rate ($\sim 10^8 \mu$/s)

- Possible candidate
  250 μm scintillation fiber + SiPM readout
  ↓
  Thin, fast response → operational in high rate μ beam

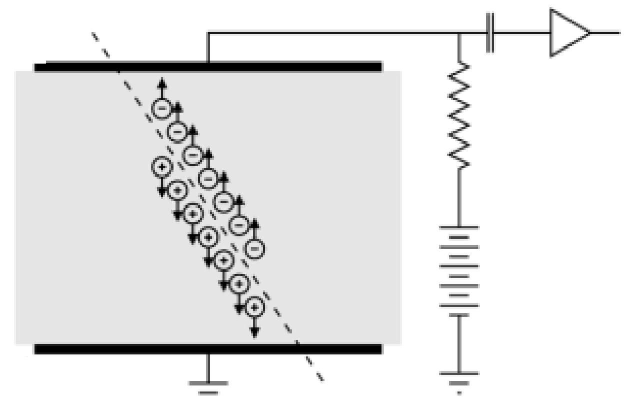
However, **radiation damage** might be serious.
<1/2 light yield decrease expected in 2 weeks.

JPS2017Spring, 18aK33-6

Diamond sensor

Diamond is an other candidate for upstream RDC.

It works similar to Si detector→



Properties:

- ☺ Radiation hard (~MGy)
- ☺ Can be very thin (~100μm)
- ☺ Fast (<1ns)
- 😐 Small signal

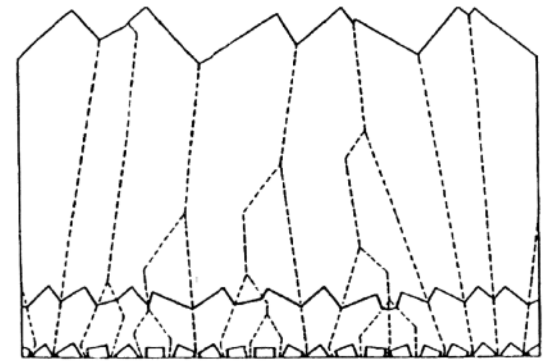
↳ e^+ energy deposit is only ~50 keV for 100 μm diamond.
Energy to create an e/h pair is large (13eV)
(c.f. It is only 3.6eV for silicon.)

→ Let's see whether we can see e signal with 100μm diamond

Synthetic diamonds

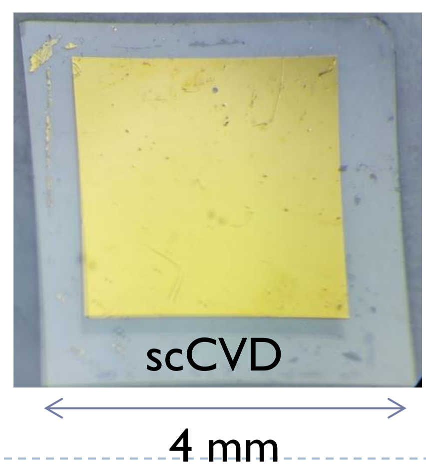
CVD (Chemical Vapor Deposition) diamonds are commonly used for sensors.
Two types of crystals are available:

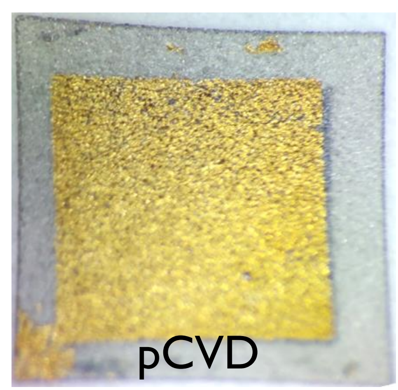
- Polycrystalline (**pCVD**): small signal due to trapping on boundaries→ but cheap
- Single crystal (**scCVD**): large signal, expensive



polycrystalline diamond

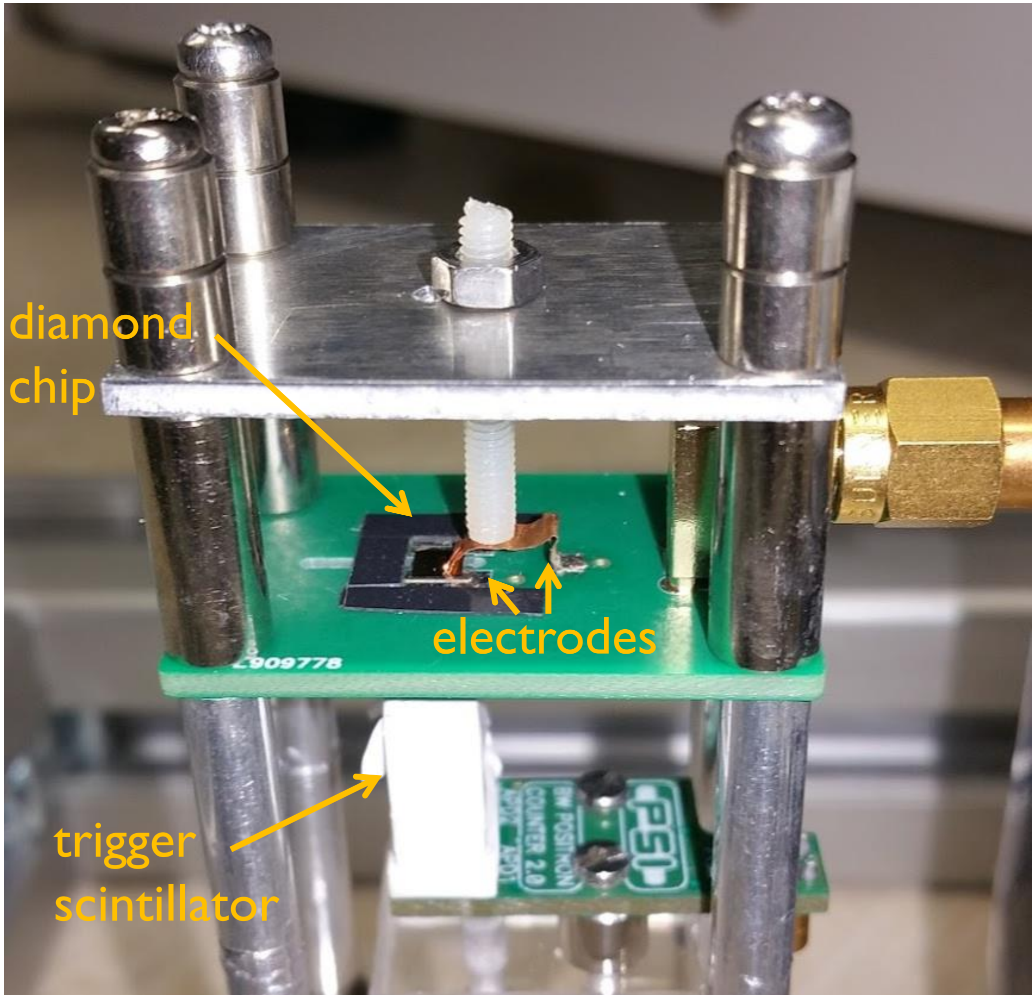
Test of diamond samples: 4mm x 4mm x **100μm** (*Applied Diamond, Inc.)*





Au (200nm) on both sides as electrodes

Test of diamond sensor samples



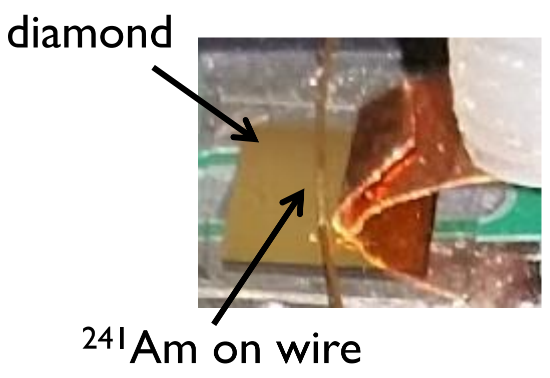
We tested diamond samples with radioactive sources placed on diamond.

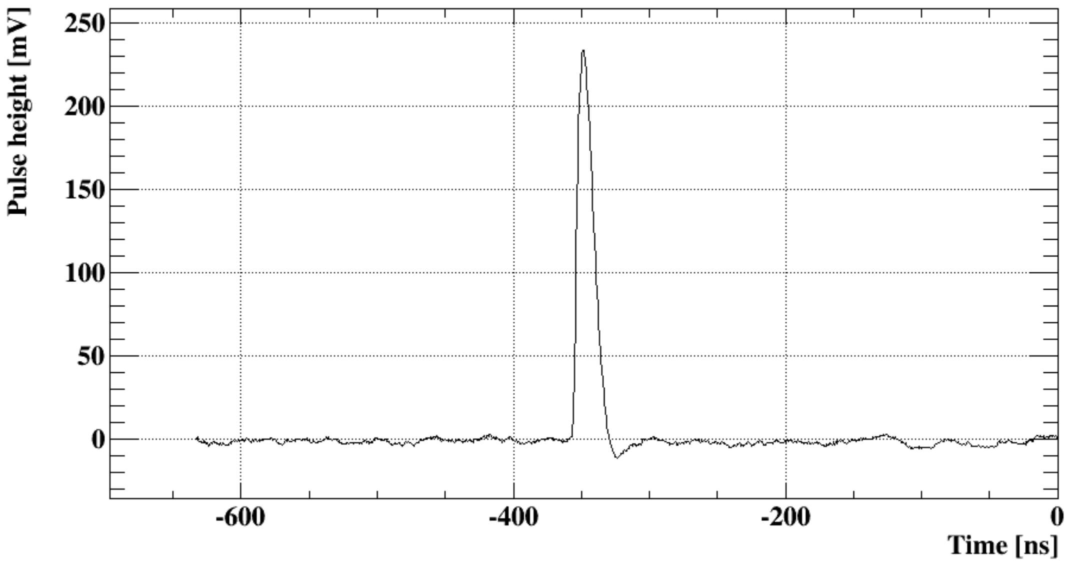
High gain, low noise charge amplifier (CIVIDEC C6HV0177), 5.7 mV/fC,

Readout:
- Charge amp.
  - + Waveform digitizer

α source signal

First, we checked the signal with ^{241}Am alpha source on wire.
α does not reach the trigger scintillator and stops inside diamond.
(Energy deposit ~ 5 MeV)

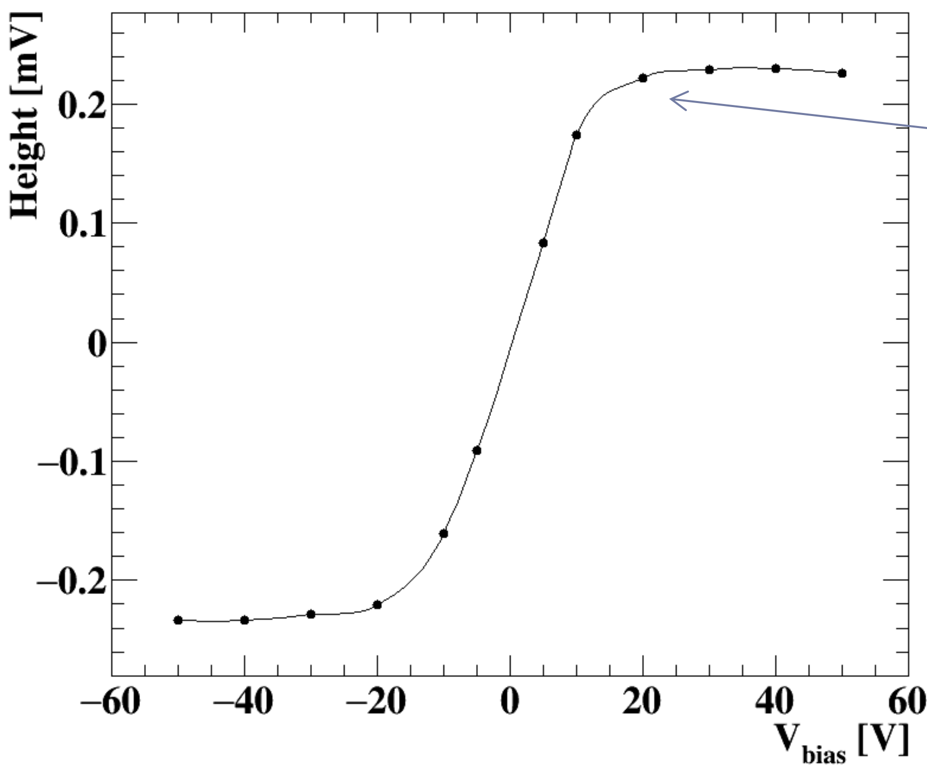




Successfully observed the signal with scCVD!
However, the signal was not observed for the pCVD sample (too small?).

Pulse height vs. V_{bias}

Pulse height of α signal is measured by changing V_{bias} from -50V to +50V



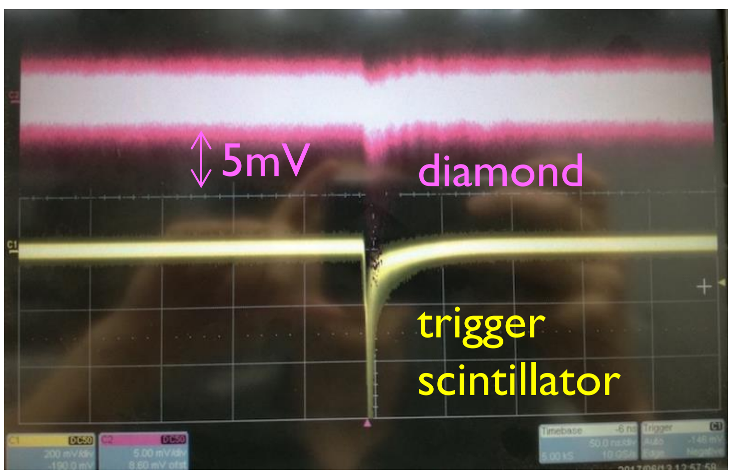
Pulse height became maximum around ±20V.

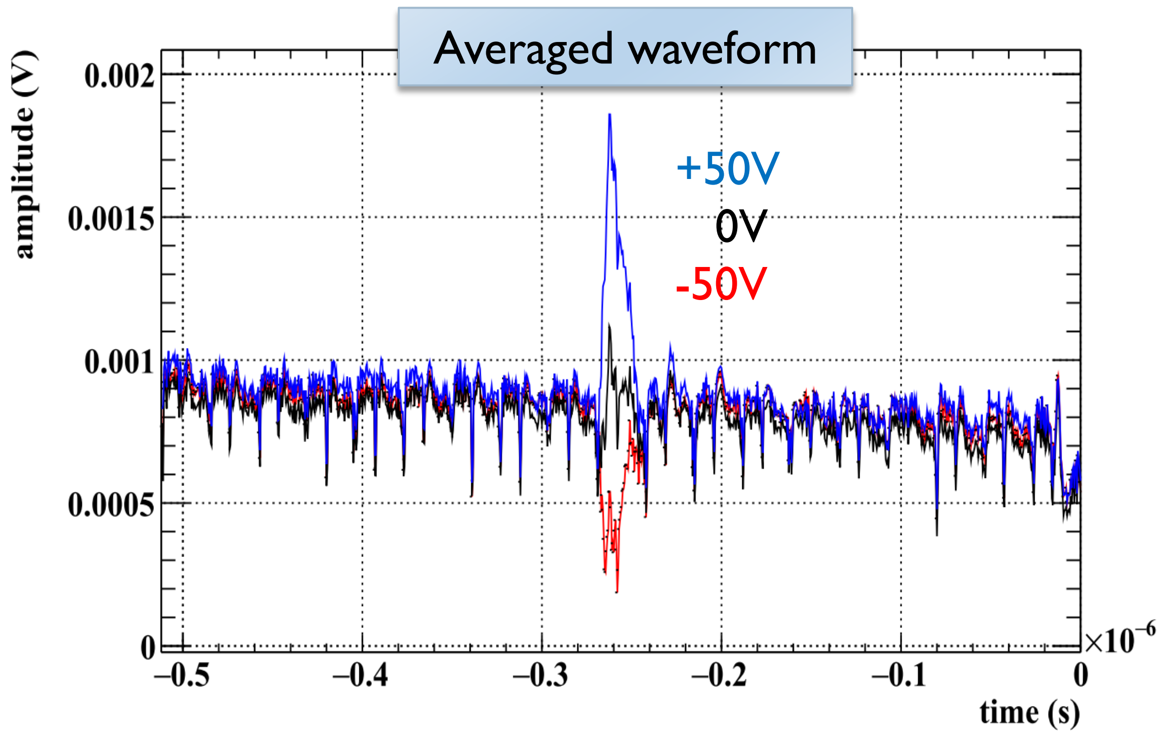
This is because the
Charge Collection Distance (CCD)
(= Average distance of e-h movement)
reached the size of the diamond thickness.

CCD increases are V_{bias} increase.

β source (^{90}Sr) signal

β source signal is small. Energy deposit is only ~ 50keV (1/100 of α).
The signal size (~2mV) was compatible with noise.
Therefore, it was not possible to distinguish the signal from noise.
The signal can be seen in the averaged waveform.

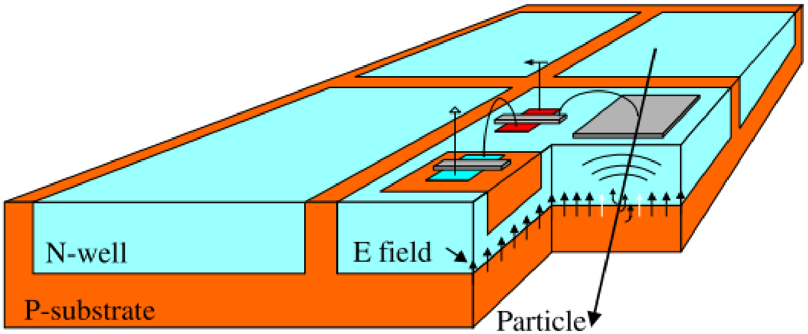




Next step

Possible approaches
- Amplifier modification (noise reduction?)
- Use silicon detector

Example:
50μm thick silicon detector
in Mu3e experiment @ PSI



Thin, fast, works in high rate
Availability? Radiation hardness?

If upstream RDC can detect radiative decay BG with 100% efficiency,
$\mu \to e\gamma$ sensitivity will be improved from 4.3×10^{-14} to 3.9×10^{-14}.

Summary

- MEG II RDC detector identifies the main γ BG, $\mu \rightarrow e\nu\nu\gamma$
- Downstream RDC is already constructed and installed. It will be tested with LXe detector in μ beam in the end of this year.
- Diamond sensor was tested as a candidate for upstream RDC detector. Signal size was measured to be small for the electrons. Other possible solution: silicon detector?