

放射線耐性テストの計画

EIC日本グループ会合

2021年5月11日(火)

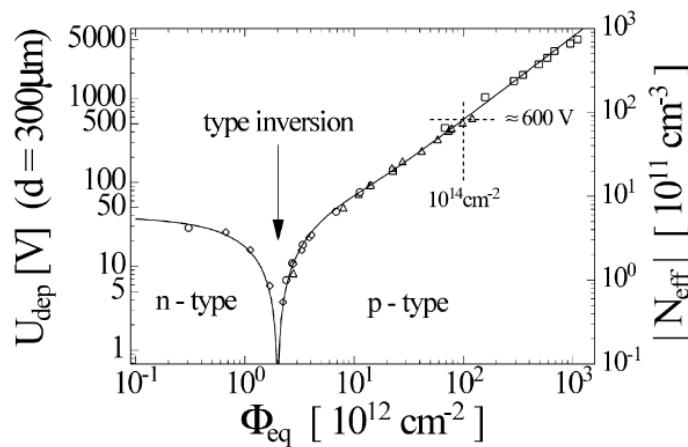
後藤雄二 (理研)

Radiation issues

- Measure FoCal-E Pad radiation hardness
- Estimate Radiation dose or fluence at zero-degree
 - RHIC (for RHICf-II)
 - EIC
 - Neutron vs photon?
- CMS HGCAL
 - p+p 3000 fb⁻¹ integrated luminosity (Run4)
 - 10¹⁴ n_{eq}/cm² @ outer radius
 - 10¹⁶ n_{eq}/cm² @ inner radius
 - > 1.5 MGy
- ALICE FoCal
 - Pb+Pb 10 nb⁻¹ + p+Pb 50 nb⁻¹ + p+p 6 pb⁻¹
 - Much smaller (10⁴ level) than CMS
 - 1 MeV neutron equivalent fluence: 0.5-1 × 10¹² n_{eq}/cm²
 - Total ionization dose (TID): 1-2 kGy

Pad sensor: p-type or n-type

- n to p type inversion at $> 10^{12}$ neutron/cm 2 ?
 - p-type sensor is operational after high irradiation with high bias voltage
- Change in the bulk material as measured immediately after irradiation
 - CMS-TDR shows even n-type sensor is operational after type inversion (high irradiation $> 10^{14}$ neutron/cm 2) with high bias voltage



Radiation dose @ RHIC zero degree

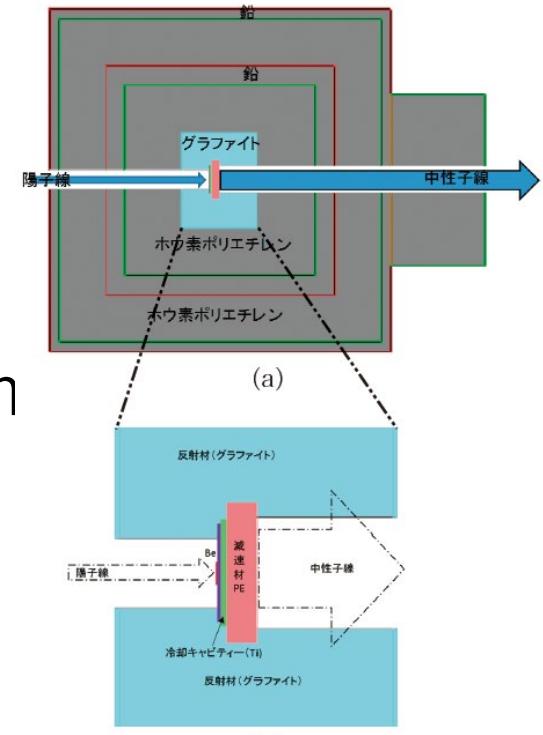
- For 100GeV photon, assuming 1.4GeV absorption (2.24×10^{-10} J) for 2cm x 2cm x 0.1cm GSO (7g/cm³ → 2.8g), radiation dose = 0.8×10^{-7} Gy/event
 - Sako-san's rough calculation
 - 10^{31} luminosity, 50mb, 3% interaction -> 15kHz
 - 1day = 10^5 s: 120Gy/day
 - 1year = 10^7 s: 12kGy/year
 - 1.75×10^{32} average store luminosity in 2024 run @ RHIC → 260kHz (50mb, 3% interaction)
 - 1day = 10^5 s: 26×10^9 event: 2.1 kGy/day
 - 1year = 10^7 s: 26×10^{11} event: 210 kGy/year
 - 50mb, 3% interaction is too high estimation for ZDC 100GeV photon
 - No 100GeV photon/event
 - 100GeV neutron: >100 smaller Gy (see next page)
- RHIC ZDC paper
 - NIM A 470, 488 (2001)
 - 1 kGy / several years
 - for 8×10^{31} luminosity for 100GeV?
 - Too low?
- 1k – 100k Gy/year?

Radiation dose @ EIC zero degree

- For 100GeV neutron, assuming 2.2GeV absorption (3.52×10^{-10} J, Yuya's calc.) for 5cm x 5cm x 5 Tungsten ($19.3\text{g/cm}^3 \rightarrow 2.4\text{kg}$), radiation dose = 1.5×10^{-10} Gy/event
 - Beam gas 10MHz @ EIC
 - 1day = 10^5 s: 15Gy/day
 - 1year = 10^7 s: 1.5kGy/year

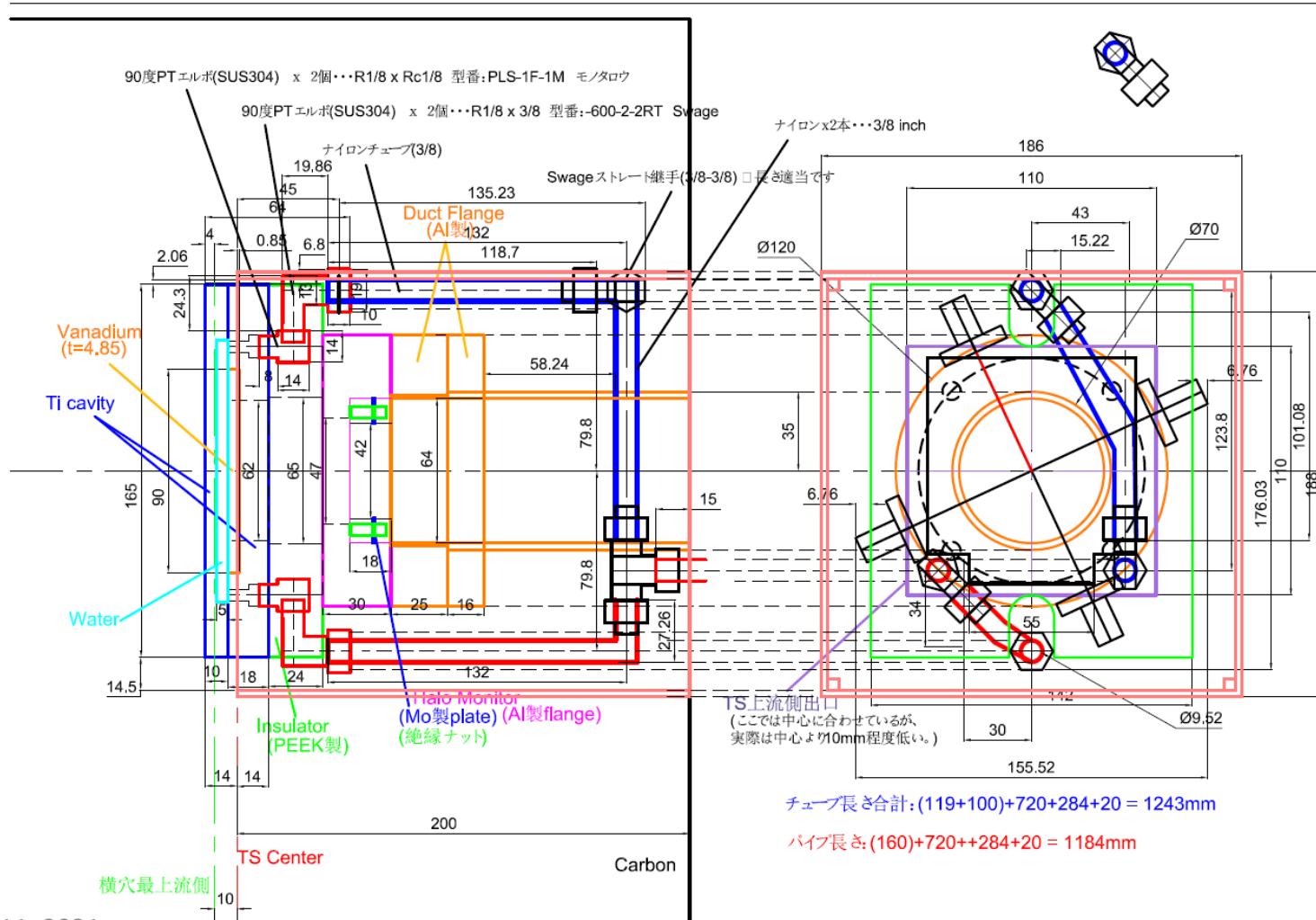
RANS performance

- RANS
 - Proton 7MeV, 100 μ A
 - 6×10^{13} proton/s
 - Be target
 - Neutron 5MeV max.
 - 10^{12} neutron/s from the target
- RANS-II
 - Proton 2.49MeV, 100 μ A
 - Li target
 - Neutron 0.7MeV max.
- Radiation dose calculation or sim
 - FLUKA/MARS/PHITS



標的周りの図

- ・(関係者内での閲覧)
 - ・RANS担当：若林さん



Test scheme

- We will place Pad sensors & monitor SiPDs in several locations at different distances from the neutron production target.
 - The closest location should be as close to the target as possible, e.g. 5cm from the target; $10^{12} / (4\pi \cdot 25) = 3 \times 10^9 / \text{cm}^2/\text{s} \rightarrow 10^{14}/\text{cm}^2$ by 30,000s = 8 hours
 - e.g. upstream space of the target
- Step-1
 - Pad sensor test without bias voltage
 - We may skip this step, if not required.
- Step-2
 - With bias voltage & current monitoring
- I-V monitoring
- Bias voltage supply
- SiPD monitor (& CR39)
 - K. Ueno et al.: Development of Real-Time 1-MeV Equivalent Neutron Fluence Monitor Based on SiPD for COMET Experiment

SiPD monitor

- K. Ueno et al.: Development of Real-Time 1-MeV Equivalent Neutron Fluence Monitor Based on SiPD for COMET Experiment

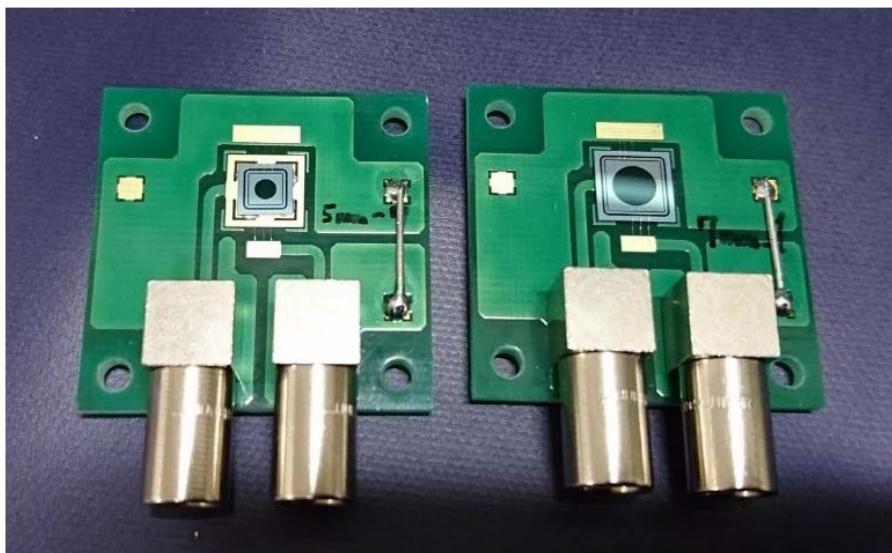


Fig. 2 Photograph of prototype neutron fluence monitors based on . the SiPDs with the thickness of $320\ \mu\text{m}$ and the size of $5 \times 5\ \text{mm}^2$ and $7 \times 7\ \text{mm}^2$.

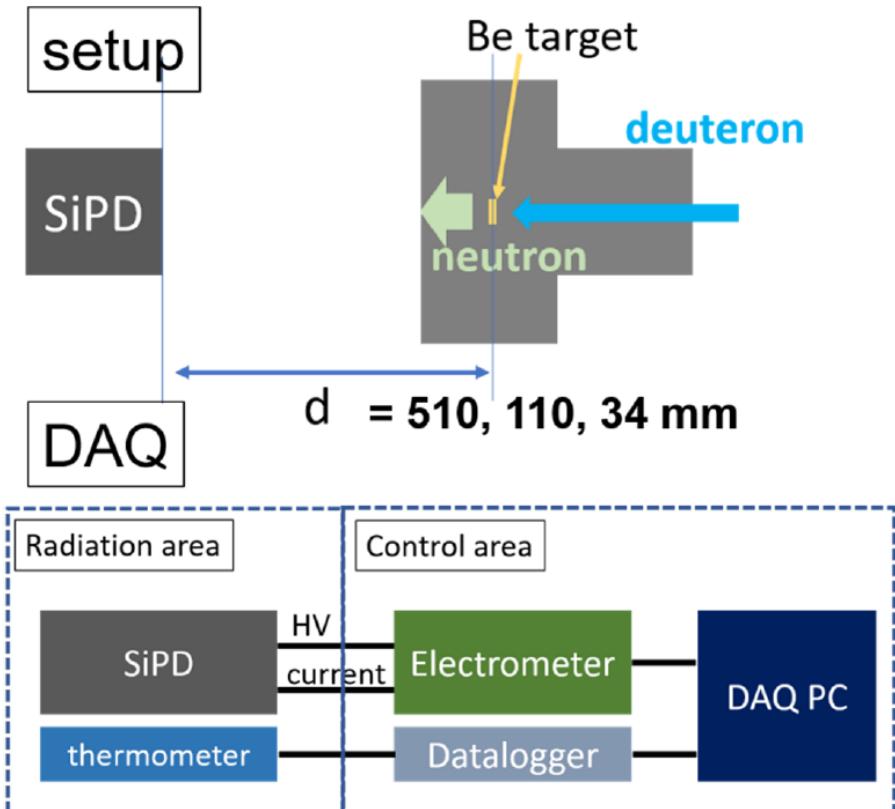


Fig. 4 Experimental setup. Leakage current of SiPD was measured changing distance (d) between SiPD and Be target. Electrometer was used for applying bias voltage and measuring leakage current. Thermometer was also mounted near SiPD and the temperature was recorded with datalogger.

SiPD monitor

- CR-39 dosimeter
 - 固体飛跡検出器
 - measured and the results was used for the reference.
- the monitor can be utilized with the accuracy of ~20% even if the annealing effect and detailed temperature correction were not considered.

放射線耐性テスト@RANSへ向けて

- RANSでの放射線耐性テスト用に九州大保有のSiPDを使用
 - g-2所有：三部さん、吉岡さんの了承済
 - 5mm角、7mm角、それぞれ5個程度
- RANS標的周りの詳しい情報を得る
 - FLUKA/MARS/PHITSによる放射線量（中性子、光子）の見積を行う
- FoCal-E Padと共に固定方法、読み出し方法を稻葉さんらと議論して進める
- RANSへの提案書を作成する
 - 今月中を目指とする！

Backup Slides

Design optimization

- p-type or n-type
- Silicon thickness
 - 350micron or > 500micron
 - Dynamic range: up to ? GeV
- W thickness
 - FoCal-E design
 - Tungsten: 3.5 mm x 20 layers
 - $20 X_0$, $0.7 \lambda_l$
 - Make it as thick as RHICf calorimeter
 - RHICf = LHCf Arm-1
 - Tunsten: 7mm x 10 layers + 14mm x 6 layers
 - $44 X_0$, $1.6 \lambda_l$
- Readout scheme
 - Streaming or triggering
 - Streaming readout of HGCROC up to 1MHz?
 - No self-triggering in the baseline design
 - External triggering assumed