Experimental activities on hybrid positron source with granular converter

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Outline

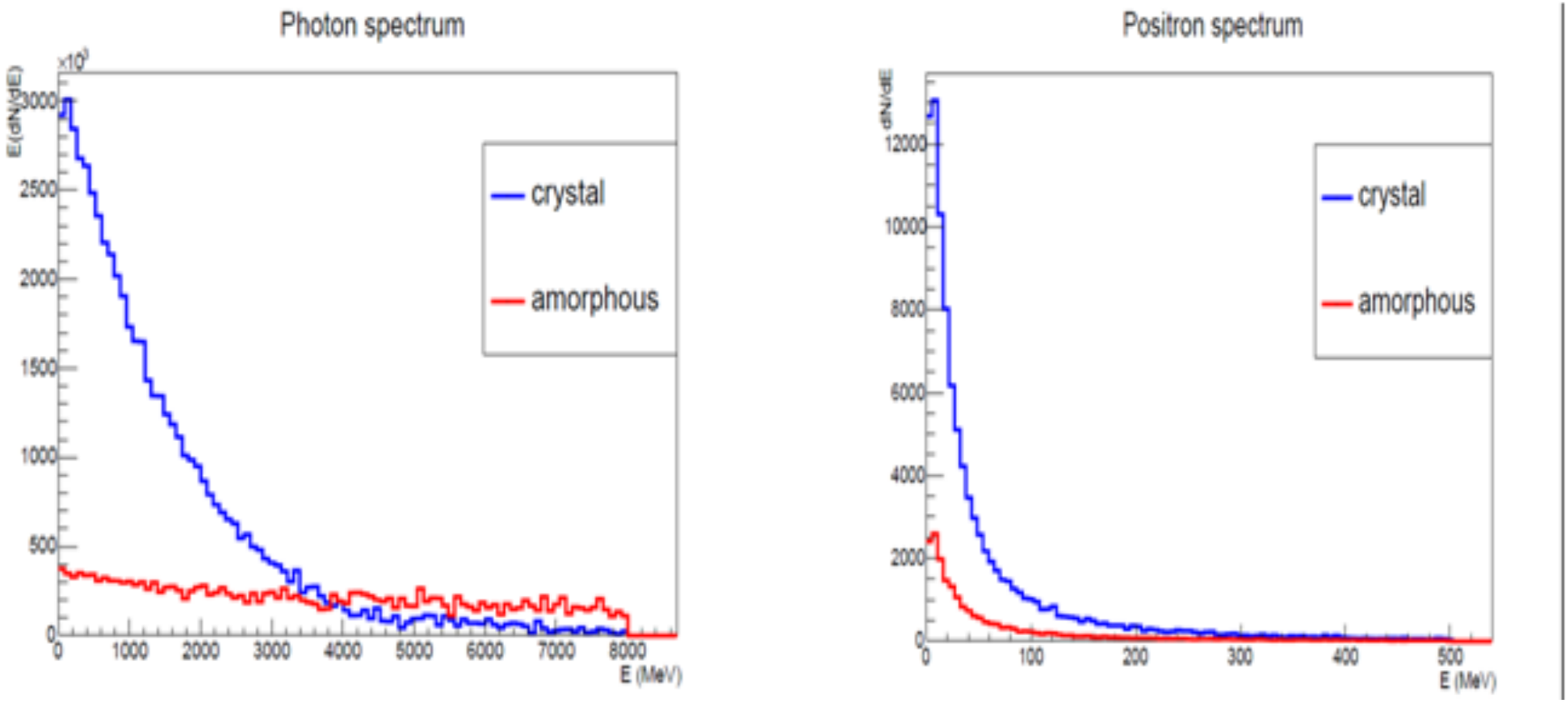
- introduction
  - General situation
  - Channeling vs Bremsstrahlung
- Situation of ongoing simulations
- Experiments at KEK
- Some first results and analysis
- summary and outlook

POSITRON SOURCES FOR FUTURE COLLIDERS BASED ON CHANNELING: A REVIEW

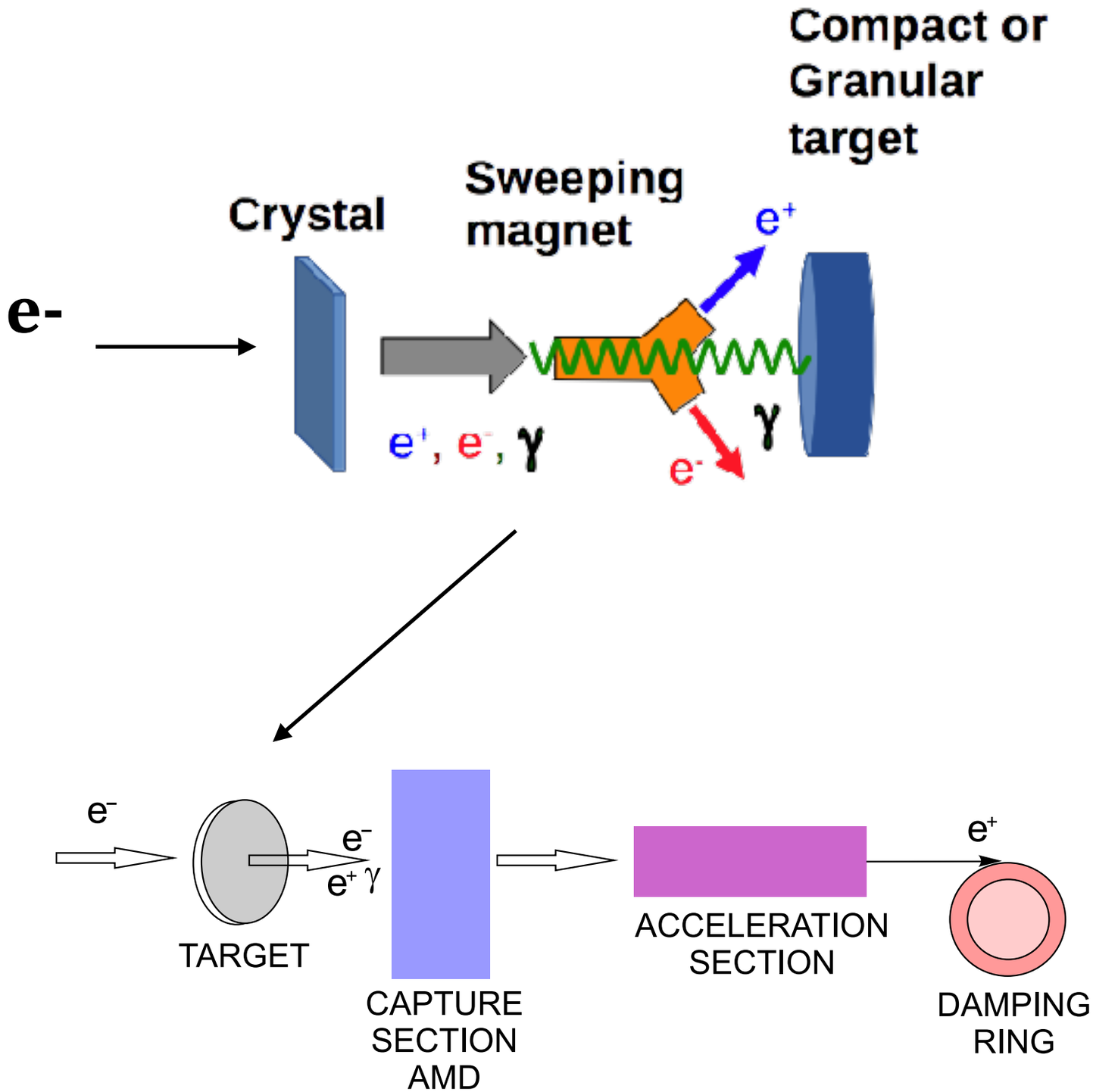
- **OPTIMIZATION OF THE RADIATION CHARACTERISTICS**
- **# Choice of crystals with good mosaicity: test with γ sources**
- **# Choice of axis vs plan → stronger potentials**
- **# Choice of high Z materials (for W, Potential well depth Uo ~ 1kV at room temperature)**
- **# Incident electron beam with weak divergence $\theta < \psi_{cr}$**
- **# Moderate crystal thickness: there is an optimum thickness (Lo) for which the radiation is maximum at a given collimation angle (V.N.Baier et al.). For GeV e- energies:**
- **$\max(\gamma^{-1}, \psi_{cr}) < \theta_{coH} << \theta_s$**
- **Calculations (BKS) give an optimum length of 0.65 mm for W <111> at normal temperature and at 1 GeV . For this value, the optimum collimation is ~ some mrad ($\theta_s \sim 6.5$ mrad)**
- **In our simulations for ILC and CLIC projects we have chosen Lo=1 mm for E-=10 GeV and Lo = 1.4 mm for E-= 5 Gev.**

COMPARED PHOTON AND POSITRON SPECTRA FOR HYBRID-GRANULAR SOURCE WITH ORIENTED AND RANDOM ORIENTATION OF THE CRYSTAL

The γ and e+ spectra for the 2 cases :oriented (blue) and random (red) Enhancements in photon and positron yields for the oriented crystal (crystal) w.r.t. the random (amorphous) are clearly seen. For the photon spectrum the vertical scale is E.dN/dE in order to take into evidence the 1/E behaviour of bremsstrahlung. This kind of source provides a large number of soft photons and hence, soft positrons too. In the energy domain 5 to 15 MeV, the enhancement ➔ 3 between crystal and amorphous.



Hybrid e+ source



Experimental setup

KEK Experimental setup with hybrid source at key

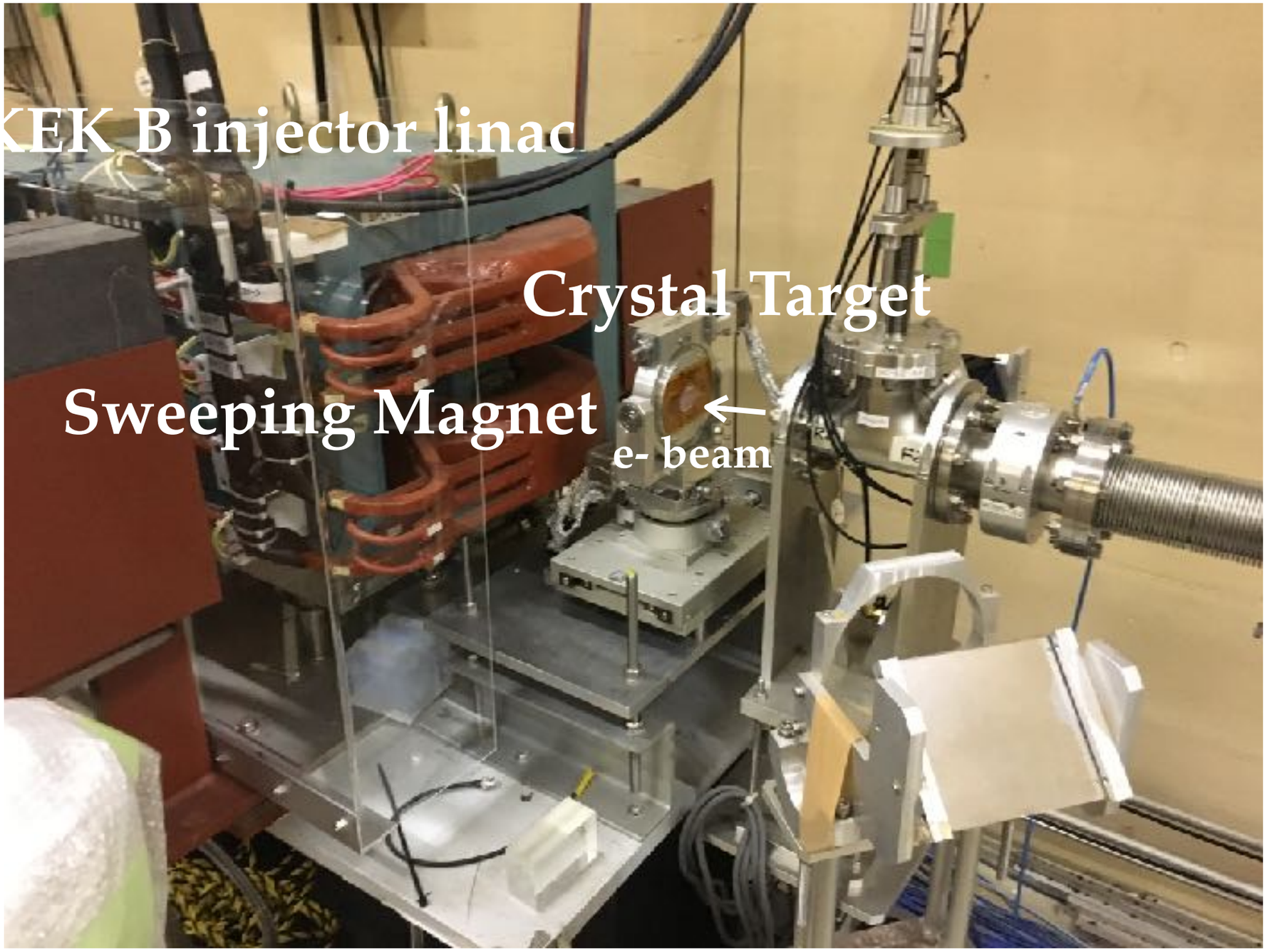
- **Y.Uesugi et al. NIMB 319 (2014)17A** series of measurements were operated with a W crystal 1 mm thick oriented on its <111> axis associated to a compact amorphous converter. The charged particles exiting from the W crystal were swept off and only the photons were impinging on the amorphous converter.

New measurements : 2015 and 2016

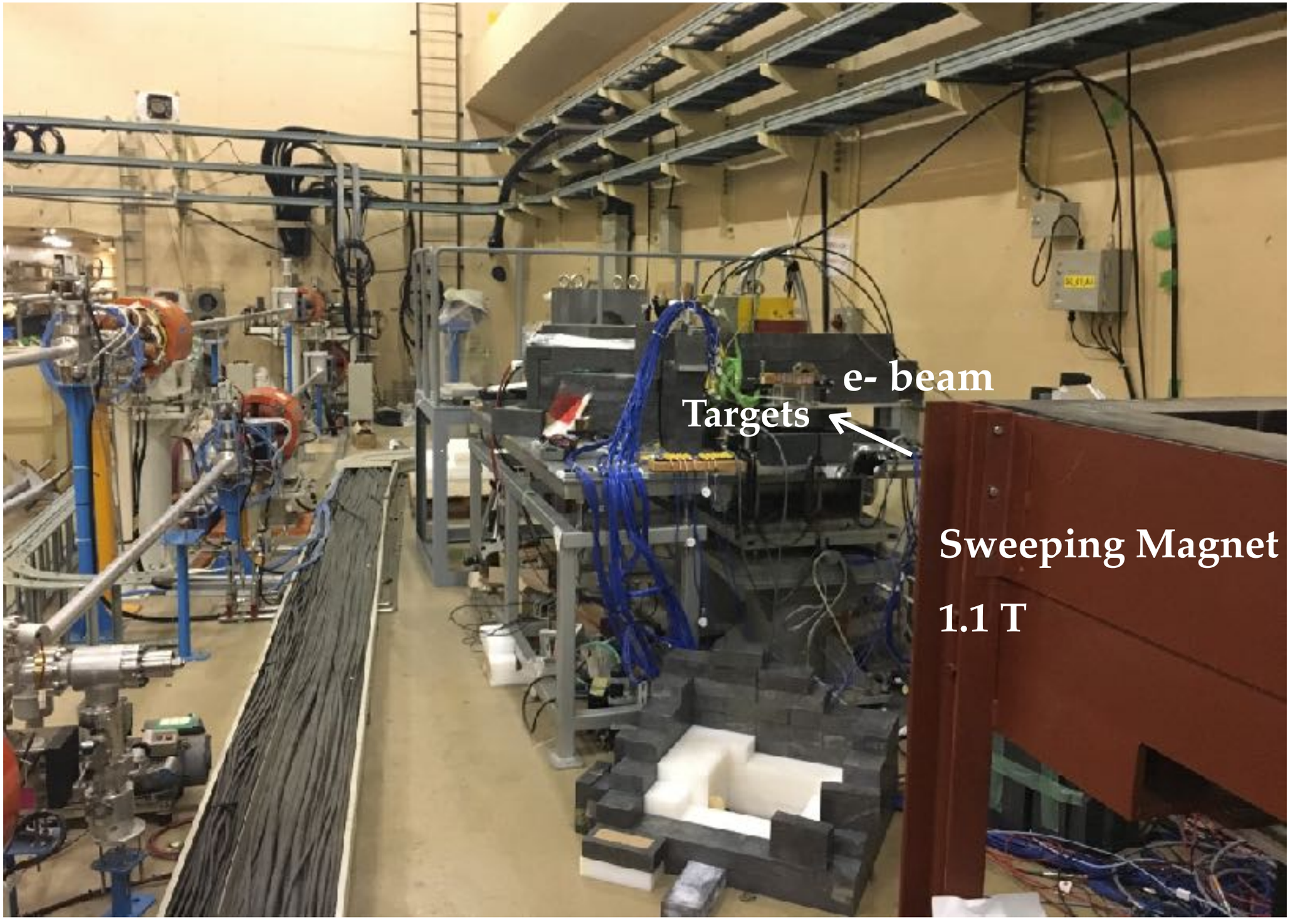
With **granular amorphous converter(s)**

2,4,6 and 8 layers

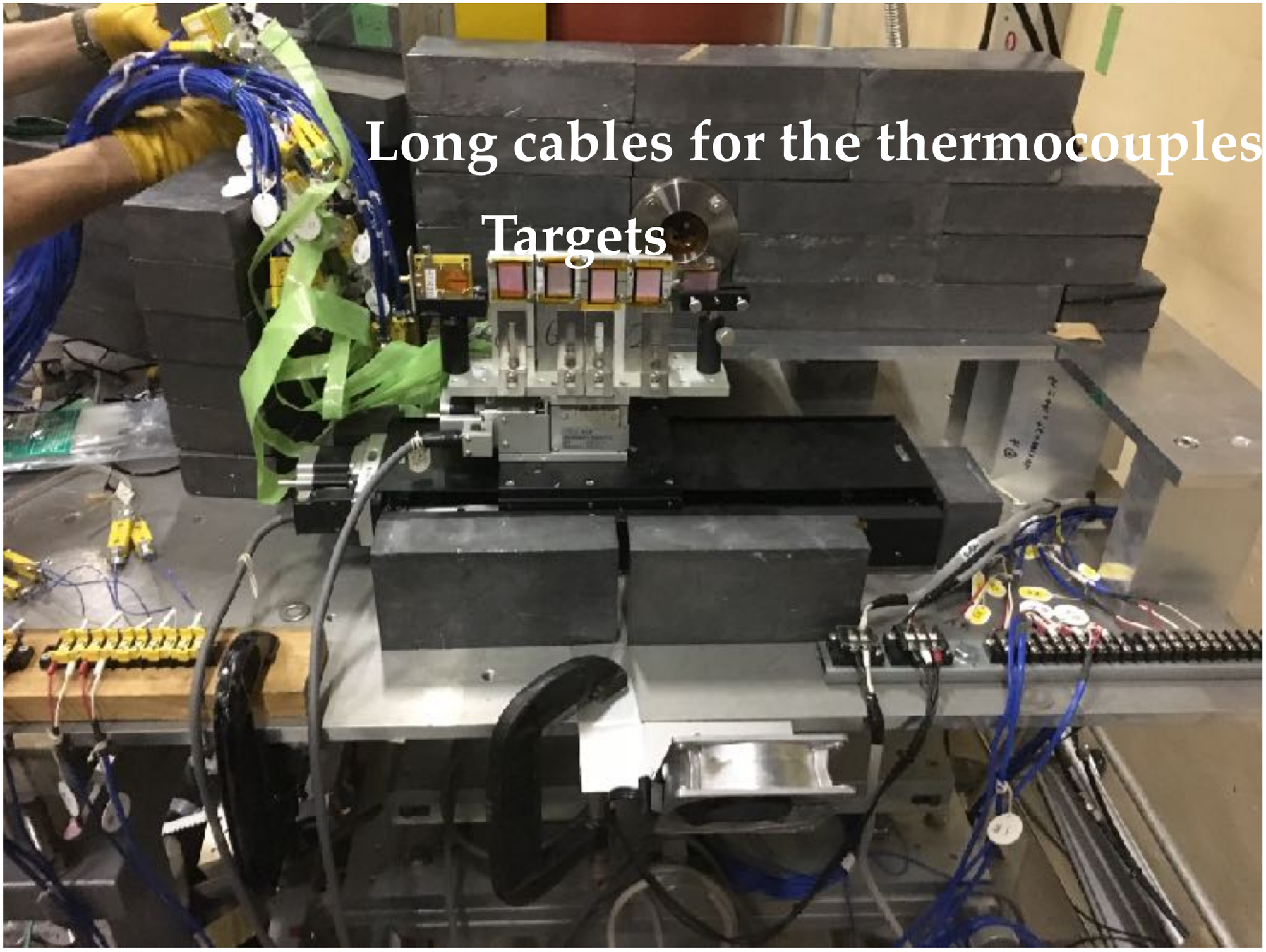
Experiment layout



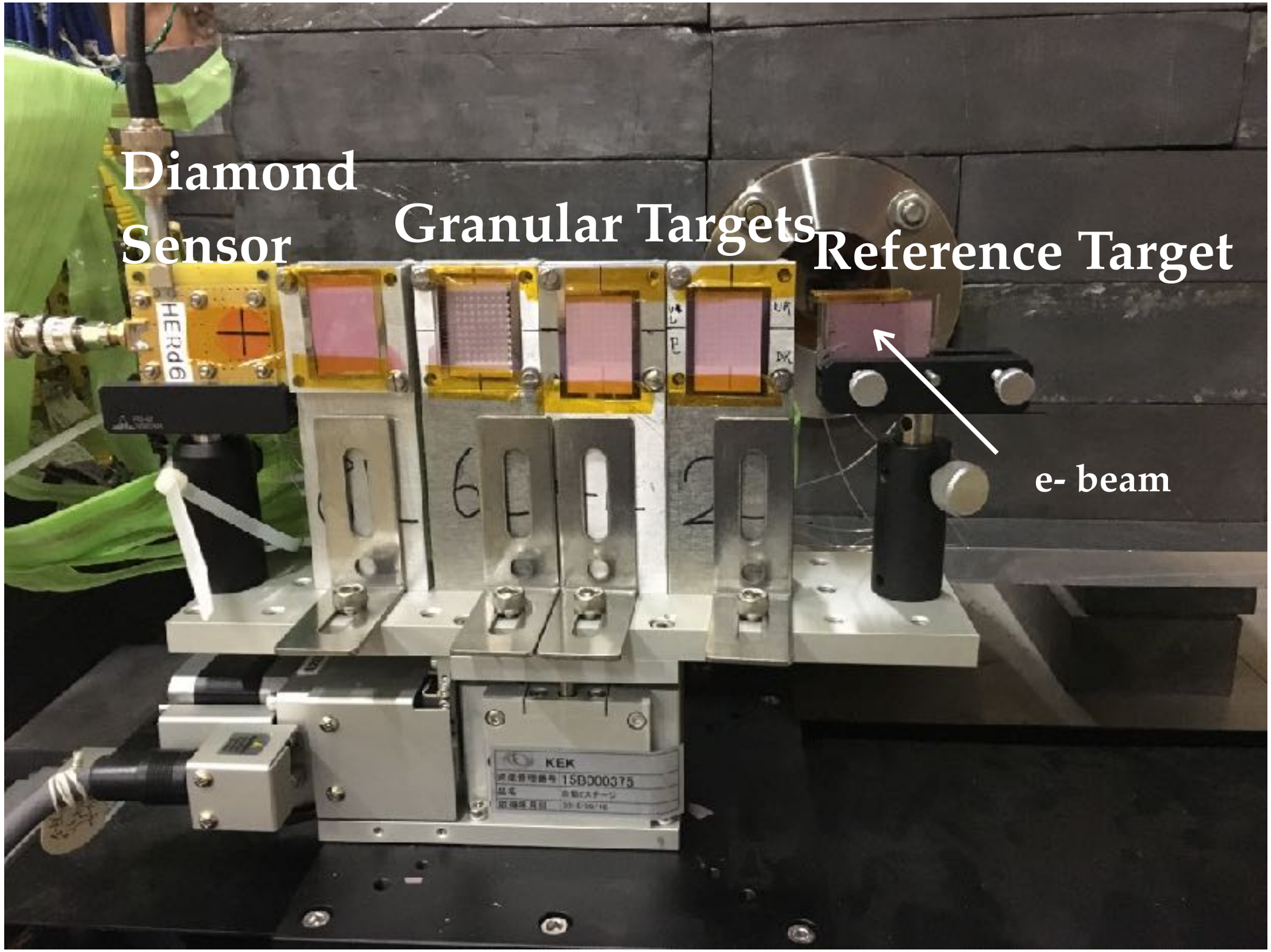
Experiment layout



Experiment layout

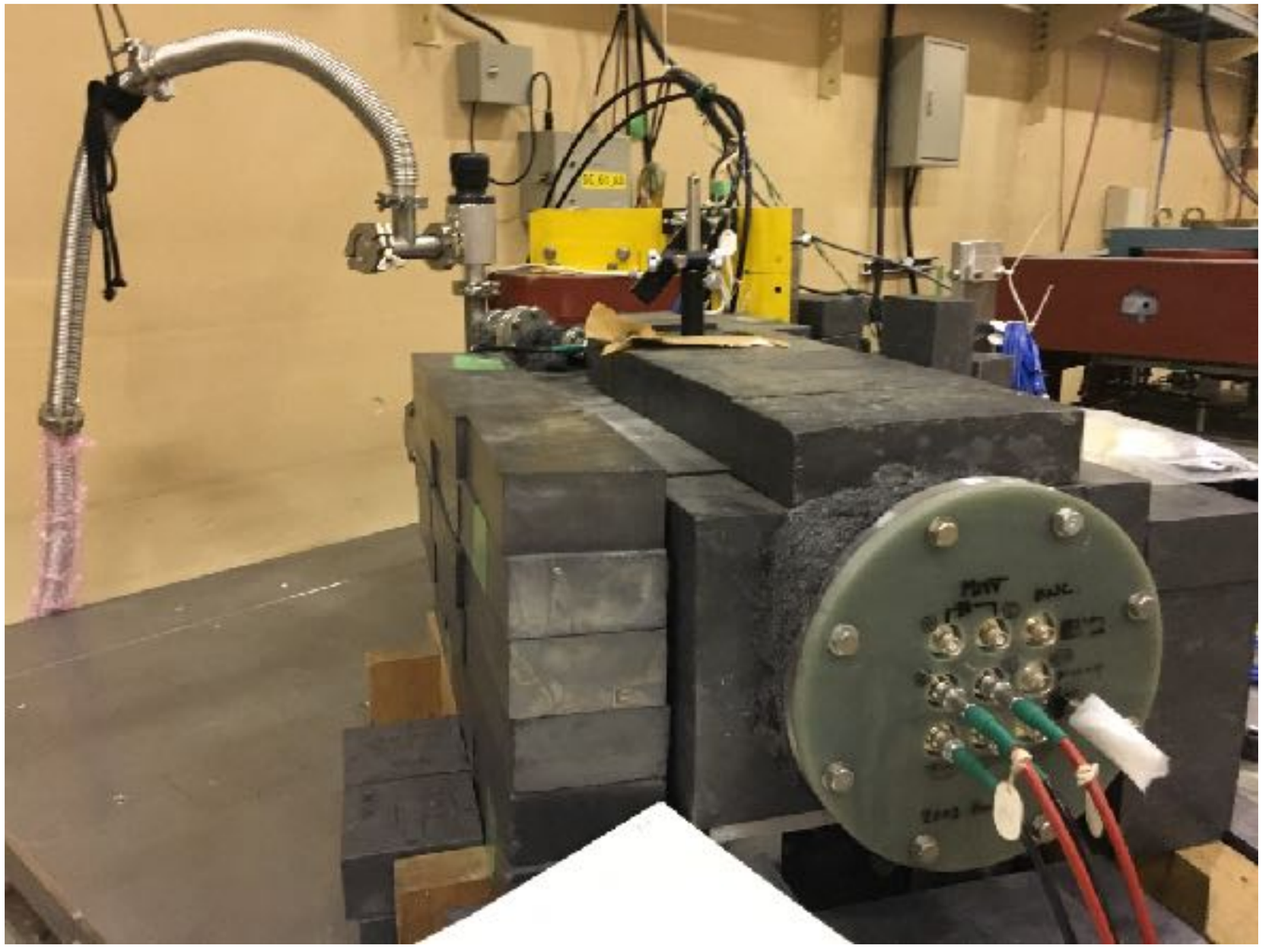


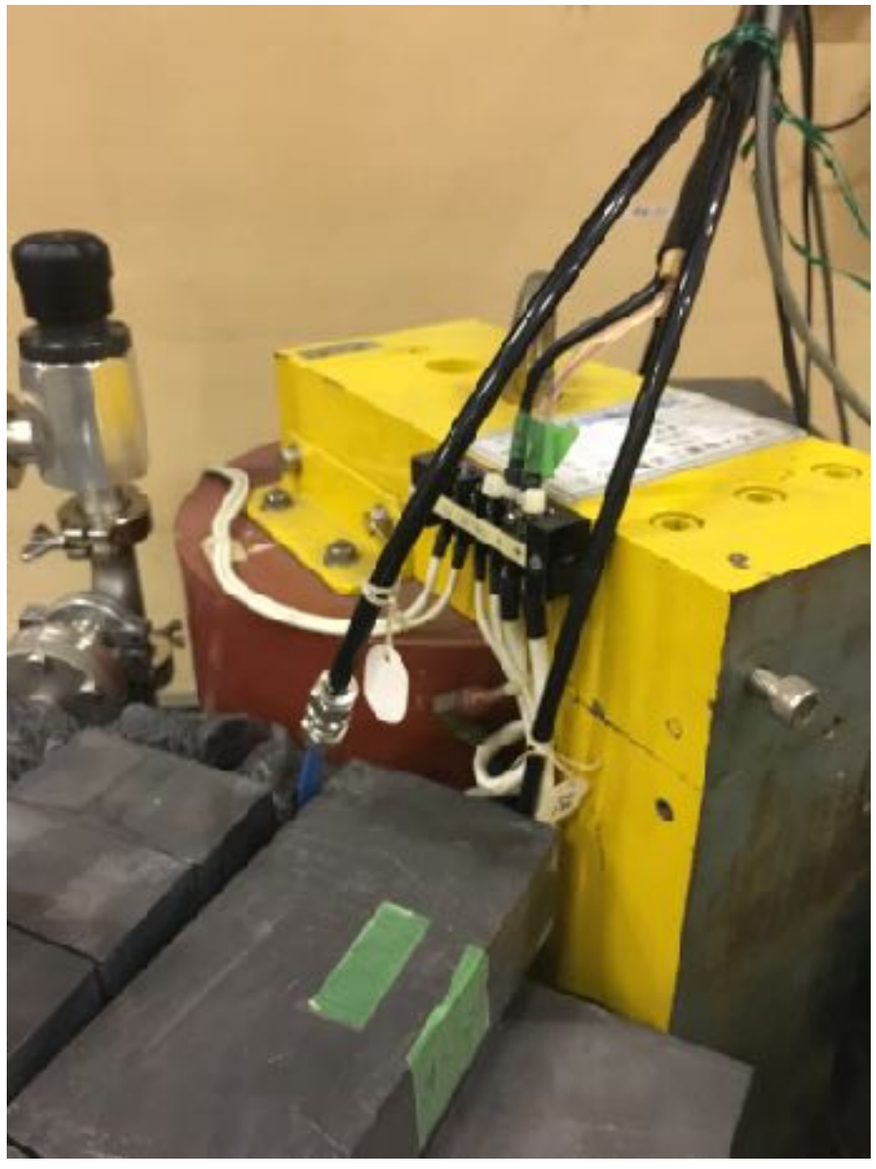
Target installation



Experiment layout

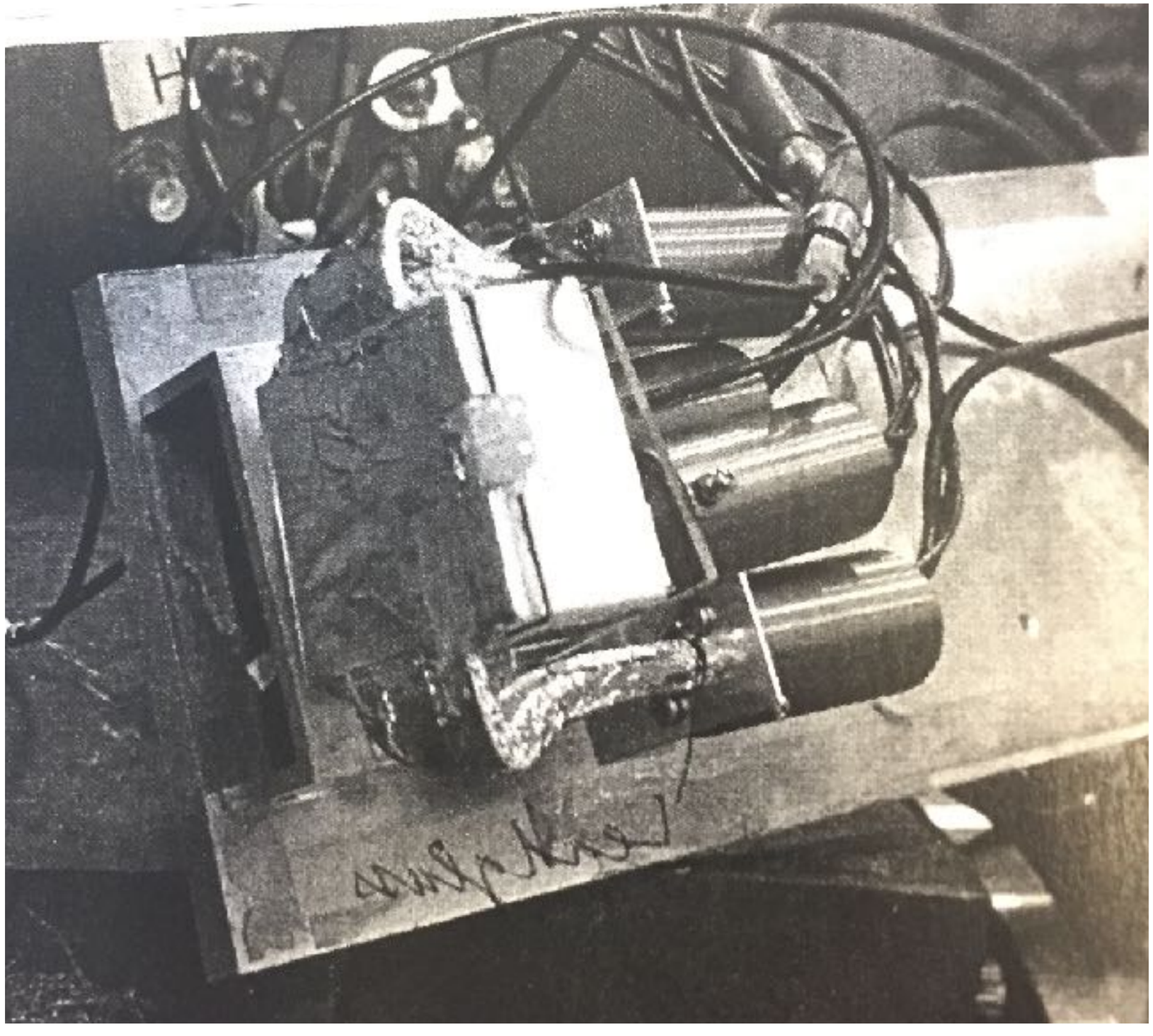
Analysing Magnet settings: 5, 10, 15 and 20 MeV





Experiment layout

Lucite counter (2 PMT) + Lead glass (2 PMT)

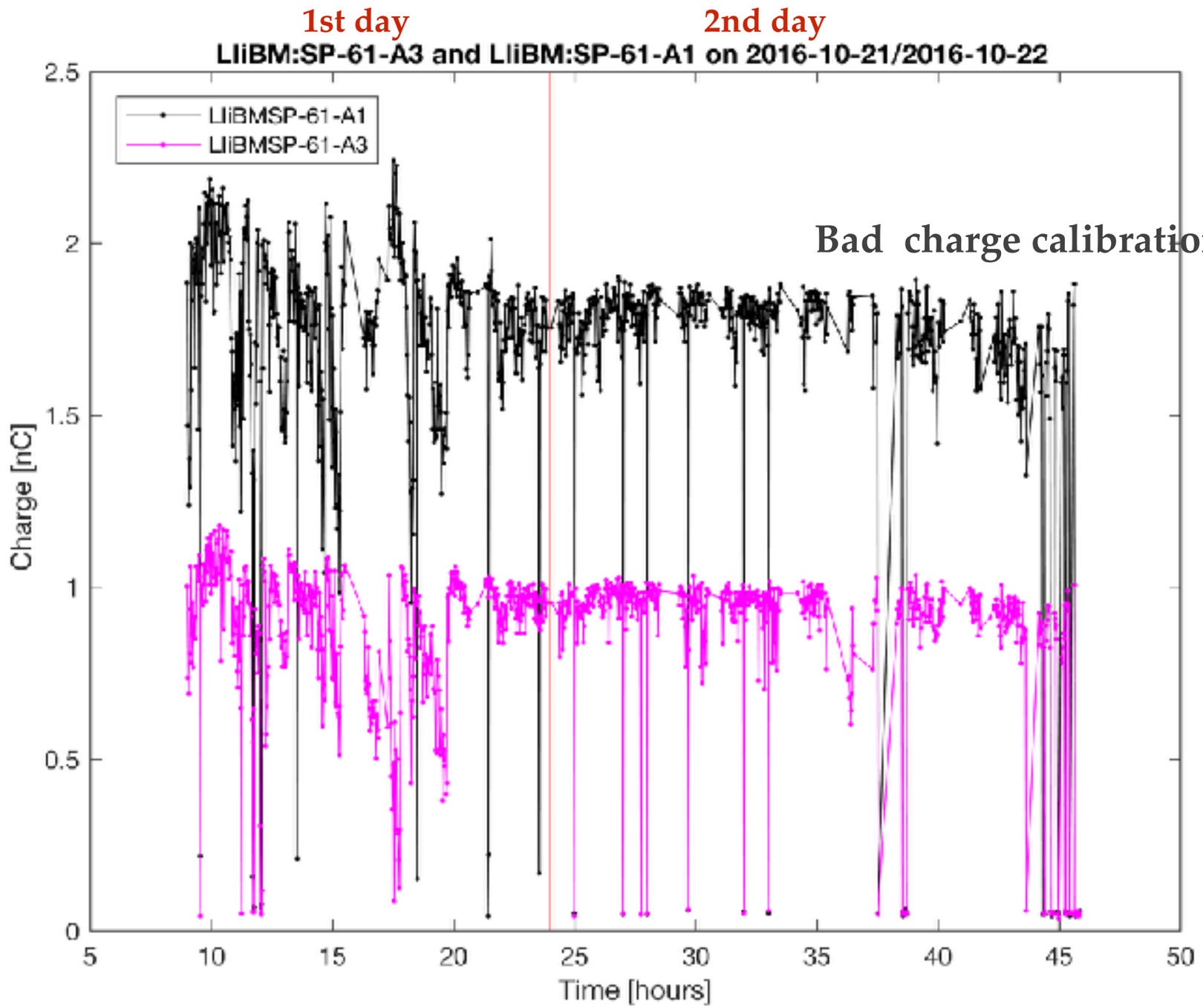


Measurement program

- Positron yield
  - ON/OFF axis crystal (Bremsstrahlung vs Channelling)
  - Due to **channeling photons only** (Sweeping magnet **ON**)
  - Due to full particles spectrum from W crystal (Sweeping magnet **OFF**)
    - With different **amorphous converter thickness**
- positron spectrum
- Compare hybrid scheme to conventional
  - Channeling vs Bremsstrahlung
- Temperature measurement :
  - Granular vs Compact target

Measurements

Electron beam parameters



Bad charge calibration for SP-61-A3

Beam charge distribution measured by the BPMs for two days of the experiment.

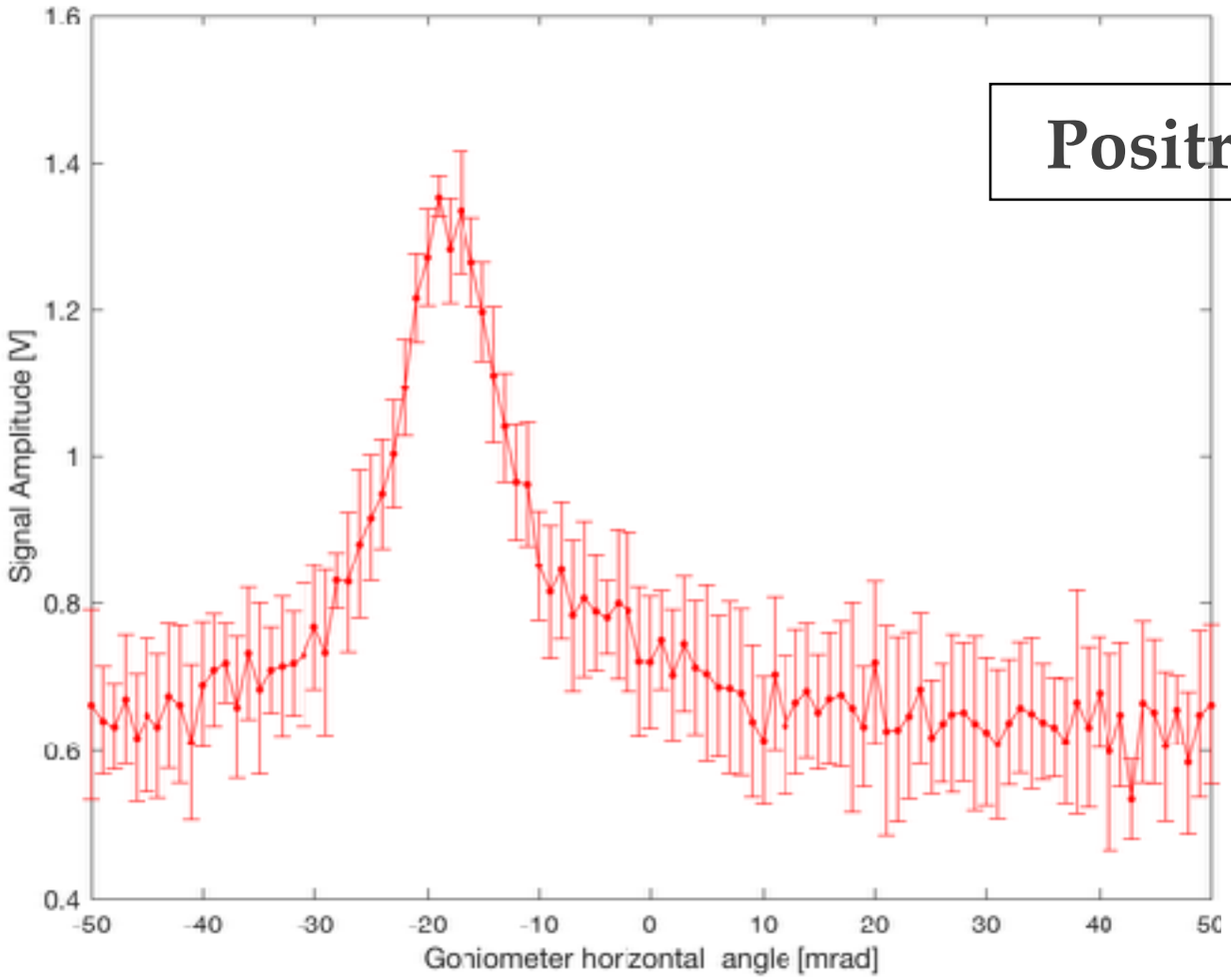
Find the channeling axis

- Could take long time with manual scan on 2 angles
- Method improved last run :
  - Mainly due to the measurement of channeling photons with dedicated **diamond detector**
  - previous methods used e+ flux measurement (produced at granular or compact converter)

Angular scan: channeling regime

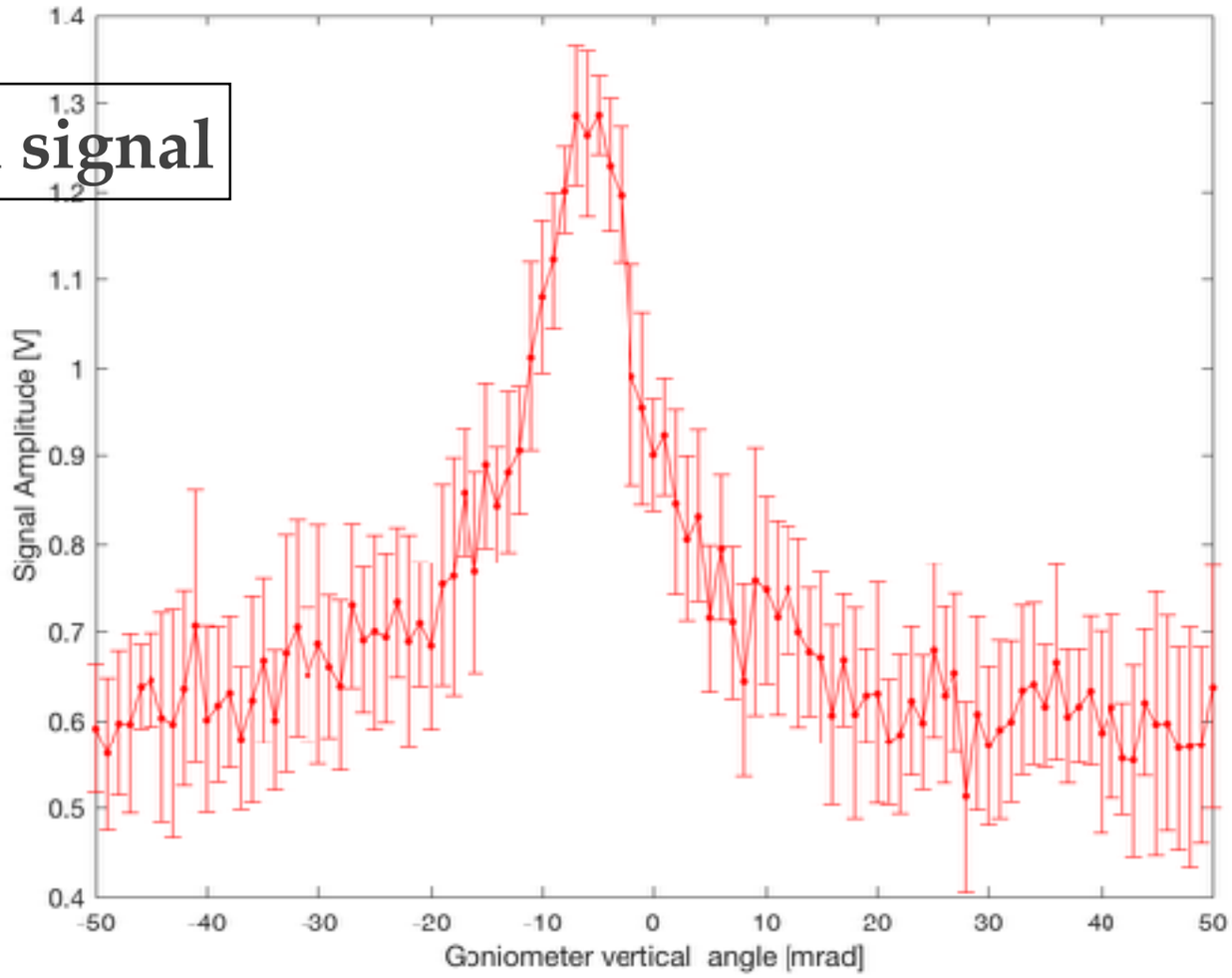
Angular scan made by using the positron detector (**AM set to 20 MeV**) and 6-Layers granular target for the positron production.

Horizontal position: -18.3 mad



Positron signal

Vertical position: -5.4 mad

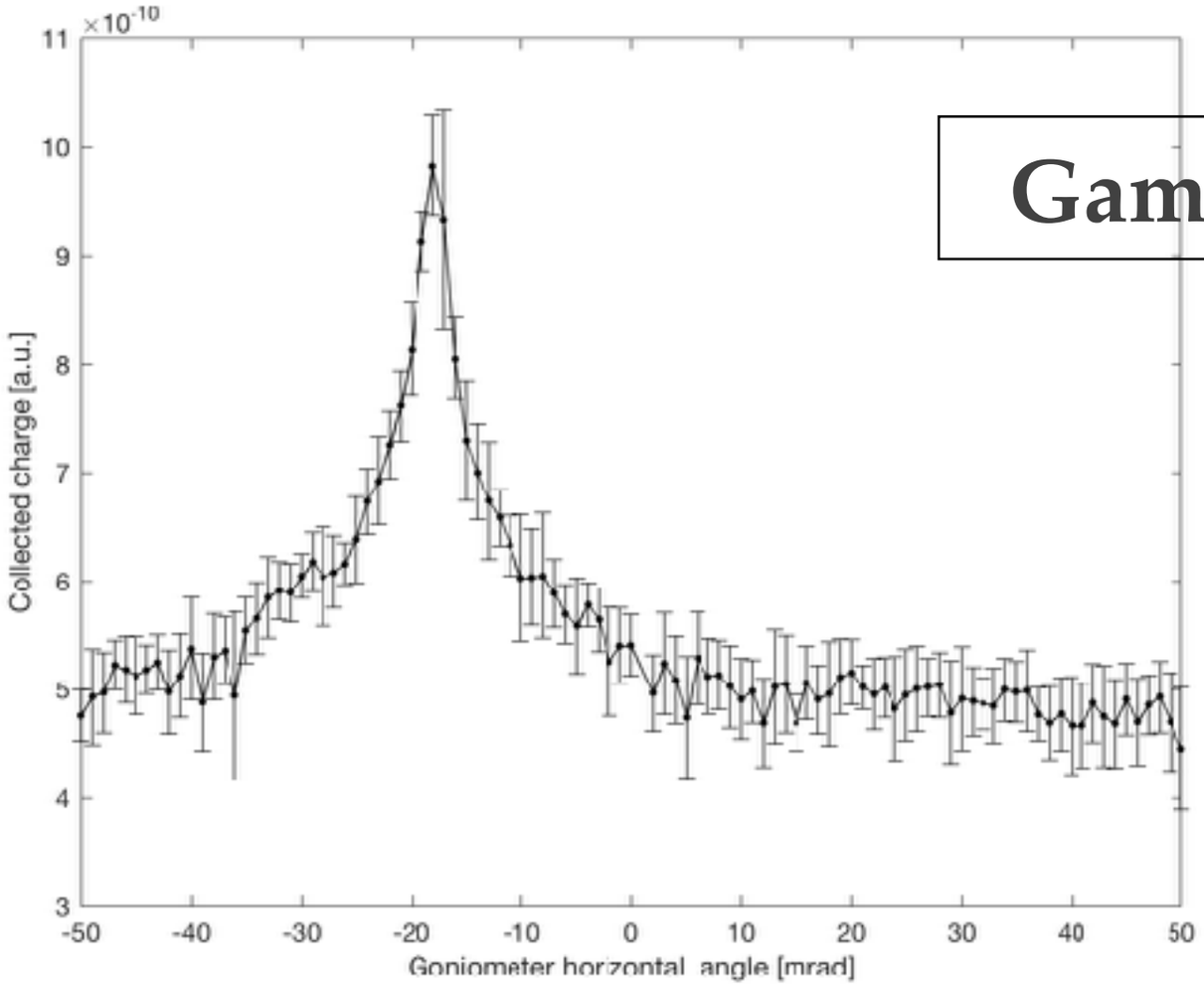


Rocking curve shows the **e+ yield measured** while changing relative angle between the crystal axis and the electron beam direction.

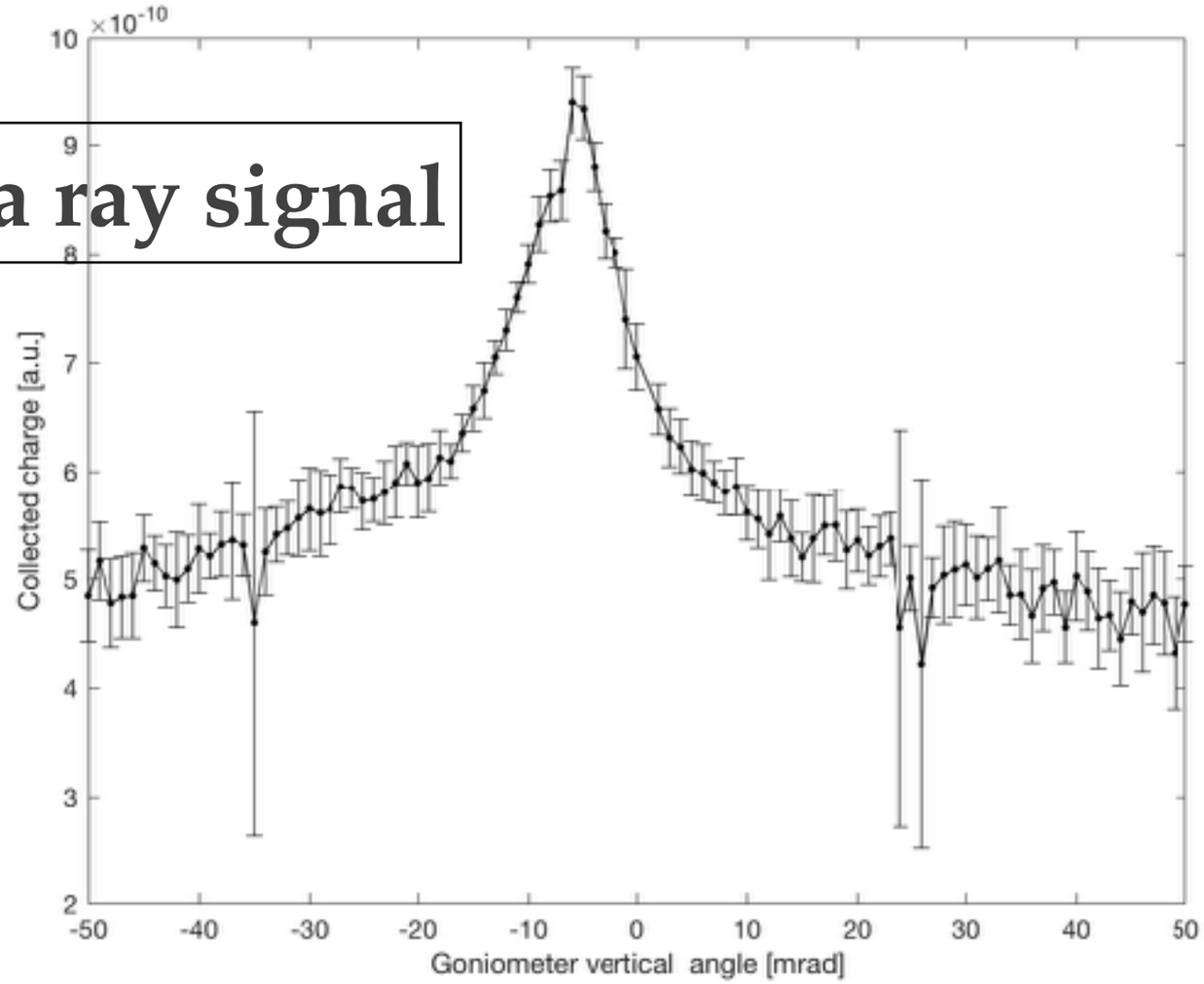
Angular scan: channeling regime

During this experimental campaign, we have used the **Diamond Detector** to perform the angular scan and measure the **flux of the gamma rays**.

Horizontal position: -18.3 mad



Vertical position: -5.4 mad



Gamma ray signal

Rocking curve shows the flux of the **gamma rays measured** while changing relative angle between the crystal axis and the electron beam direction.

Positron yield measurement

We took the data under the following conditions:

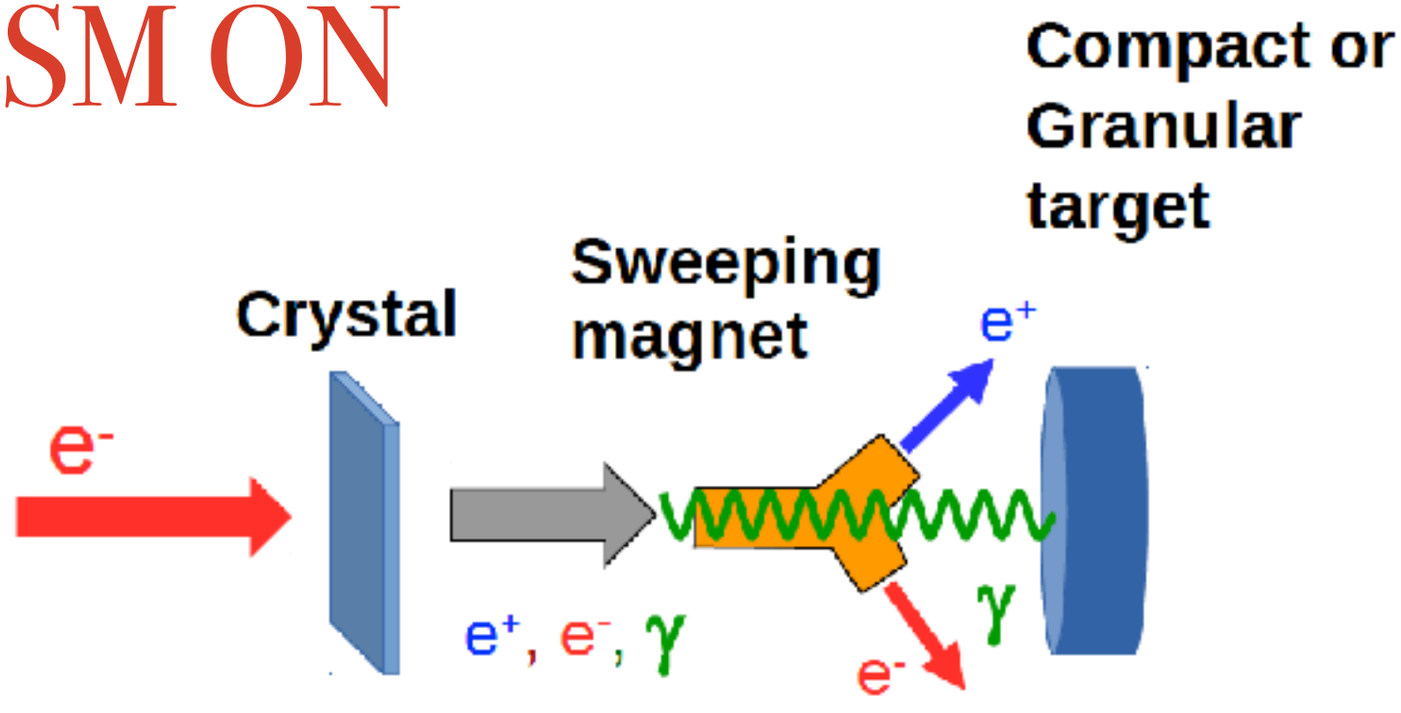
- Momentum scan under crystal the **Axis :**
  - **ON** —> crystal is aligned to satisfy the channeling conditions
  - **OFF** —> crystal axis is offset by ~50 mrad.

- Momentum scan under the **Sweeping Magnet (SM) :**
  - **ON** —> only the gamma rays impinge on the amorphous target
  - **OFF** —> all particles exiting the crystal target impinge on the amorphous target)

Hybrid scheme: Ref. target

Axis ON/OFF

SM ON

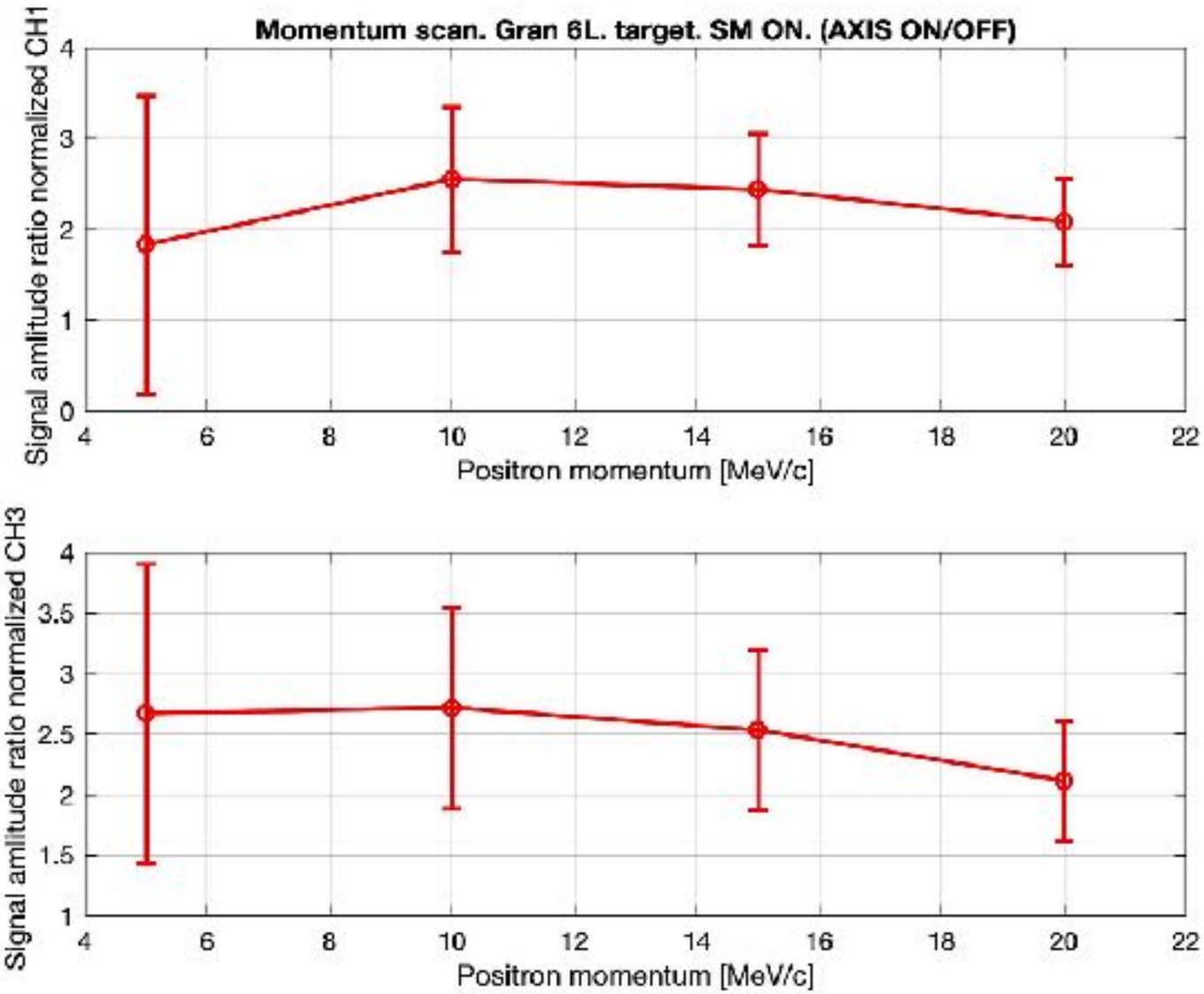


6L Granular target: hybrid scheme

HYBRID SOURCE TEST AT KEK: **6-LAYERS GRANULAR CONVERTER**

Enhancement in e+ production ➔ **ON** AXIS/ **OFF** AXIS or **channeling/random**

The measured enhancement > 2; that corresponds to 6 layers of W spheres



Temperature measurements

Temperature measurement

- Thermocouples have been glued on some W sphere at the exit of the converter. They are referenced with numbers.
- The temperature is measured by the type K thermocouples attached to the backside of the targets.
- Dynamic range : 0 - 100 °C.
- Ambient temperature in the tunnel measured with a dedicated thermocouple
- The data are taken continuously without any beam trigger (synchronisation by time later on if needed).

Thermocouples configuration

Reference target

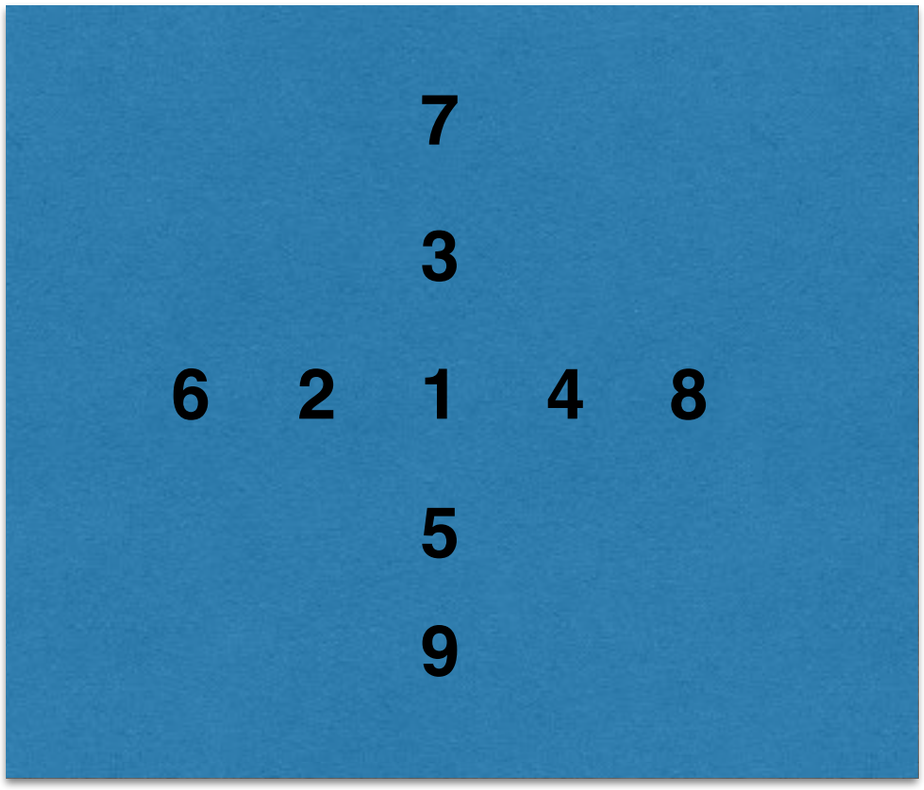
Target size: 23 x 23 x 8 mm

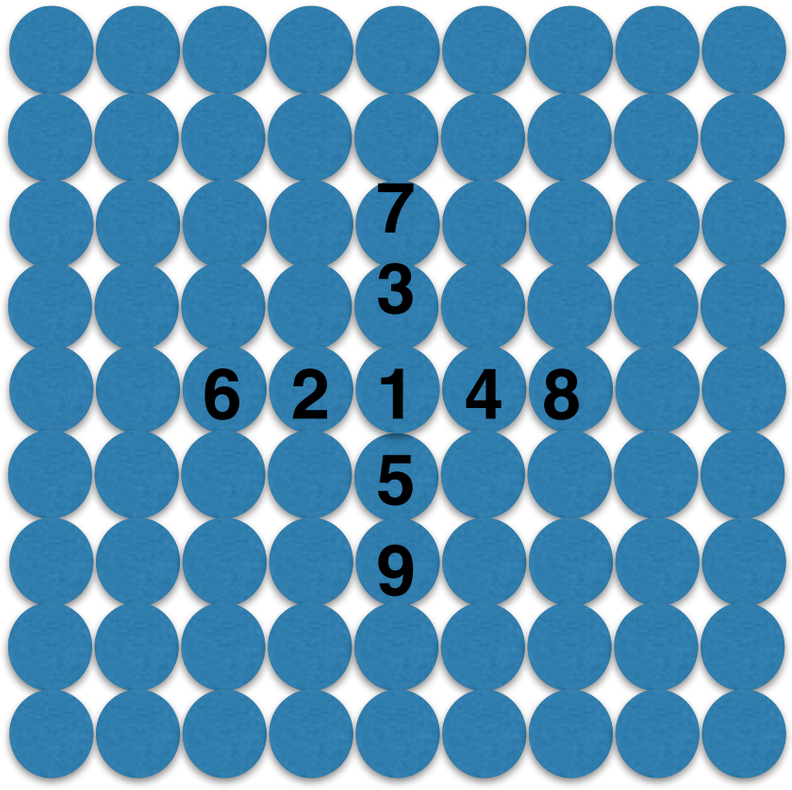
Distance between the thermocouples: 2 mm

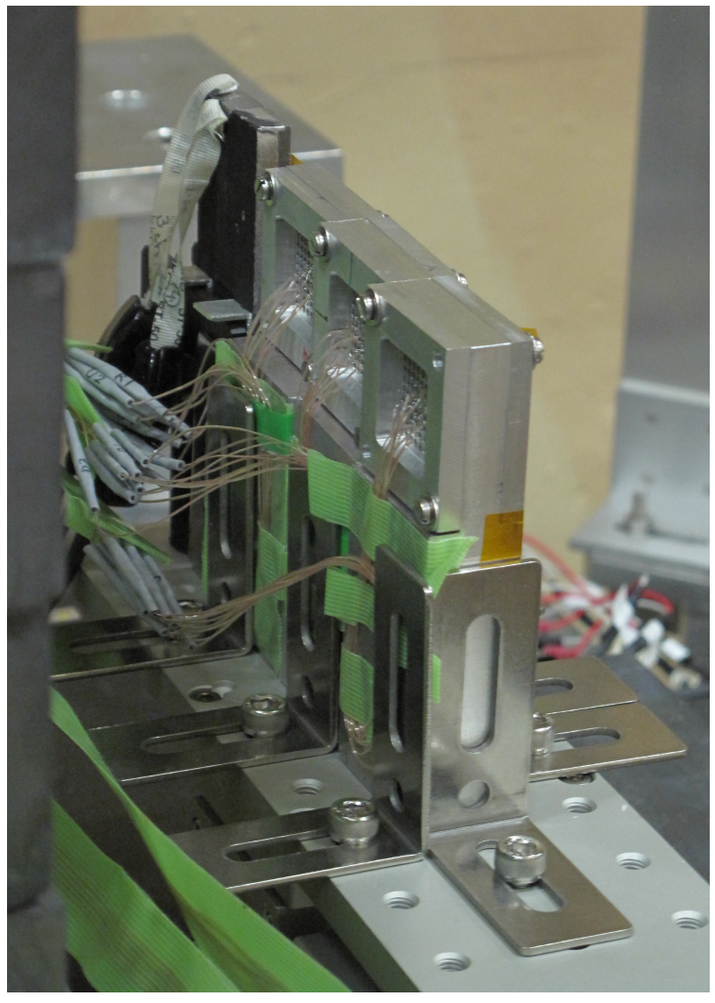
Granular target (4L and 6L)

Target size: 23 x 23 x 8 mm + Al frame

Distance between the thermocouples: 2.2 mm







Temperature measurement

We took the data under the following conditions:

- Crystal Axis ON/OFF (crystal is aligned to satisfy the channeling conditions/ crystal axis is offset by ~50 mrad).

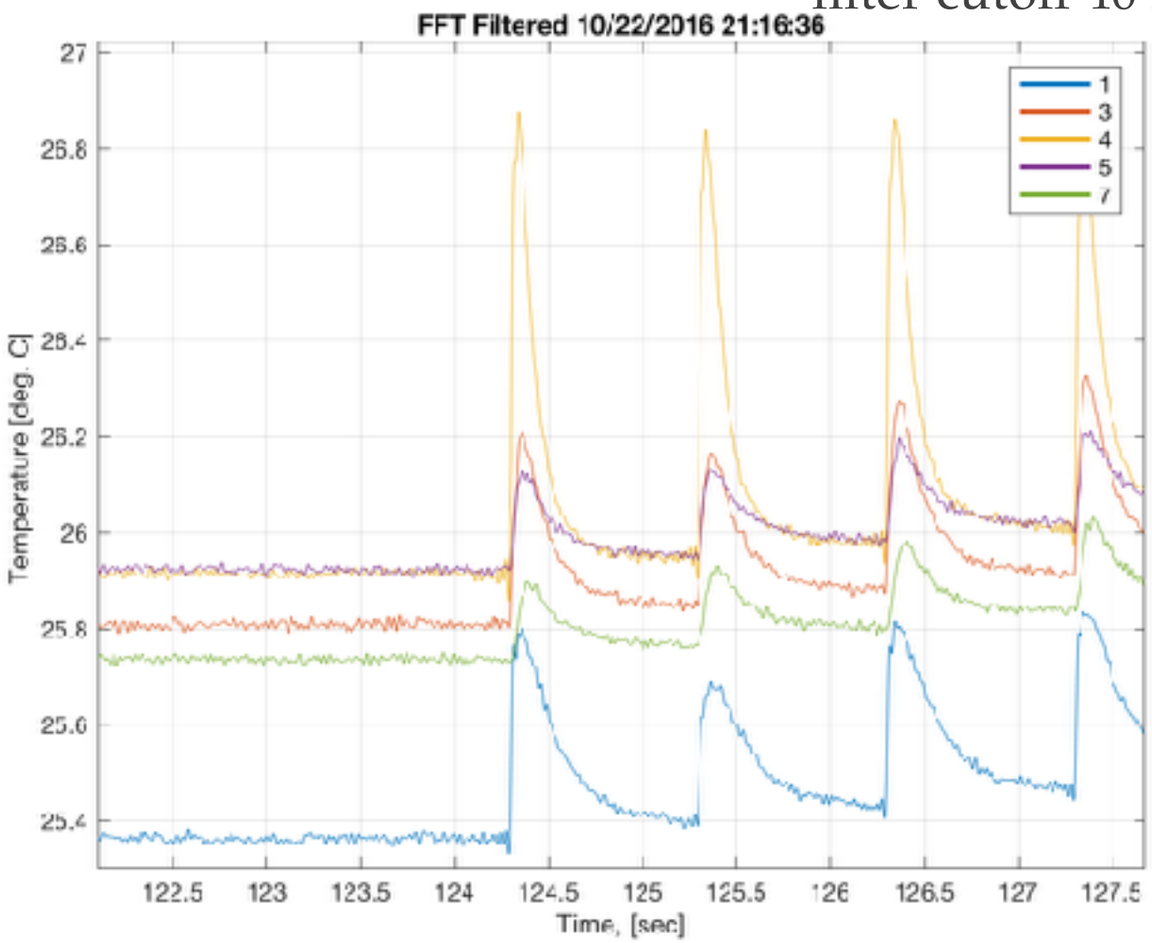
- Different Frep: 1 Hz, 5 Hz, 25 Hz.

- Sweeping Magnet (SM) ON/OFF (only the gamma rays impinge on the amorphous target/all particles exiting the crystal target impinge on the amorphous target). /@ Axis ON/

Bunch-by-Bunch operation (1 Hz)

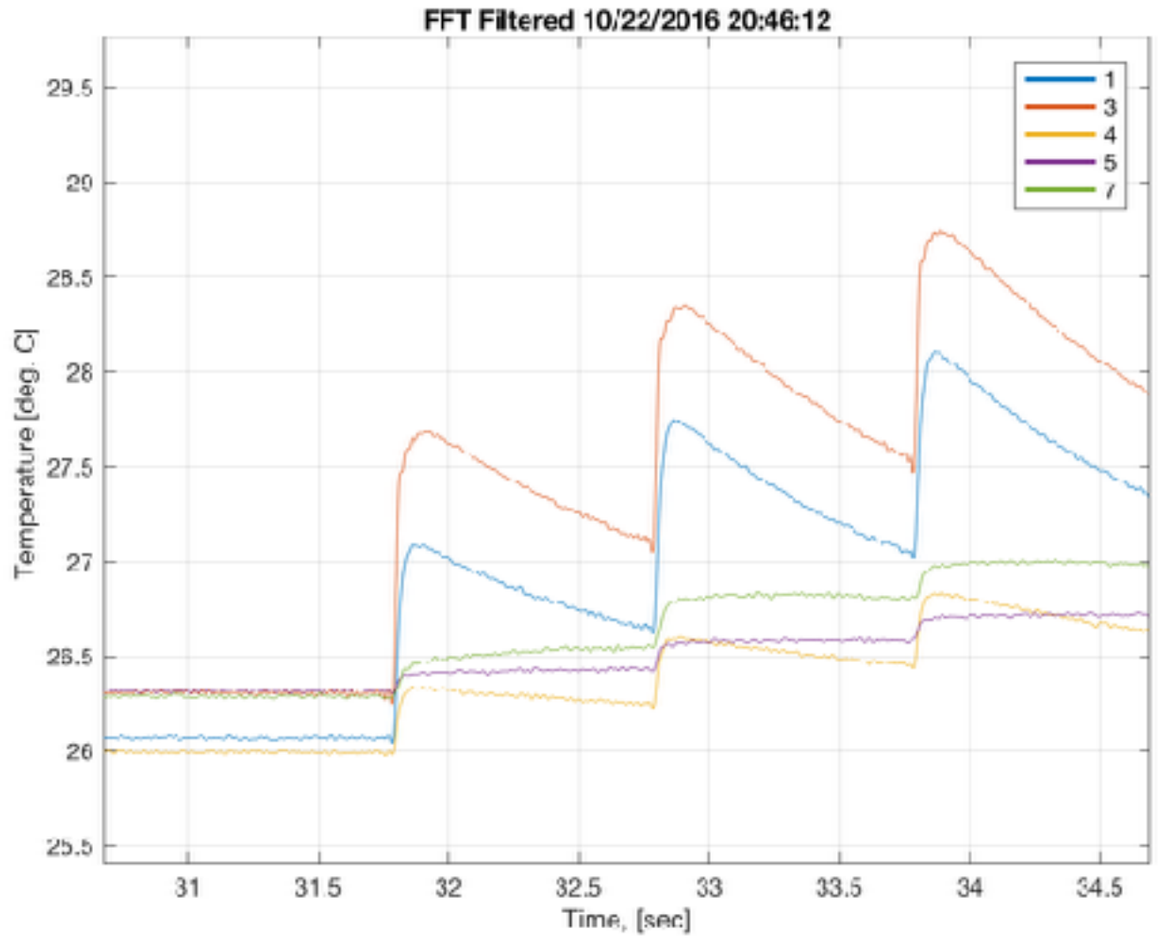
Reference target

filter cutoff 40 Hz



Granular 6L target

filter cutoff 40 Hz

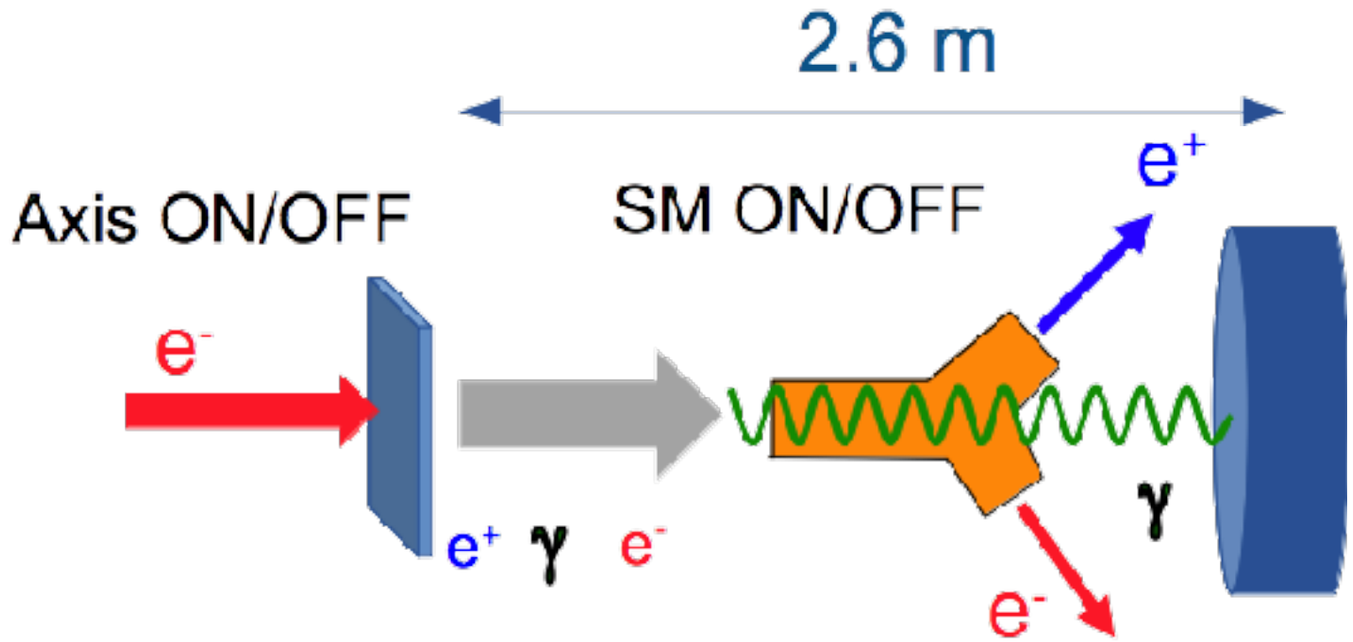


Simulations

Simulations

- 2 main axis :
  - **G4 simulation :**
    - Simulate future possible schemes (ILC, CLIC, ..)
    - Simulate the experimental setup at KEK
    - Simulate the generation of channeling photons (G4Fot)
  - **Thermal simulations**
    - Mainly centralized by P. Sievers (CERN)
      - understand thermal load seen at KEK
      - simulate and evaluate shocks inside the converter

Geant4 model description

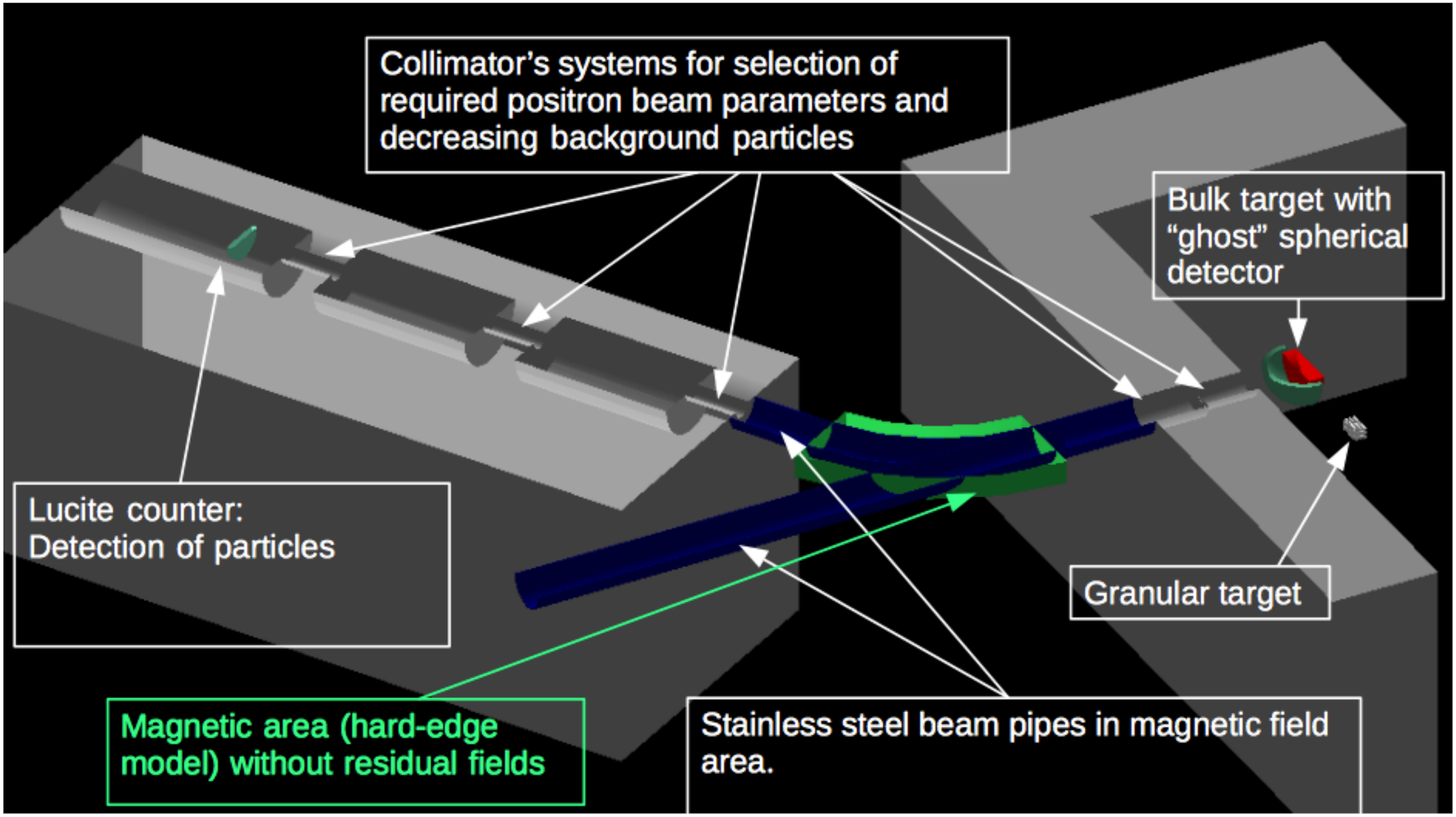


Target-radiator => 1 mm thick W crystal, Target-convertor => 8 mm compact (bulk) or granular W targets (4, 6 and 8-Layers).

Possible configurations:

- Hybrid scheme: alignment of the crystal: Axis ON/OFF
  - Axis OFF state is the ordinary bremsstrahlung radiation (no photon enhancement given by the channeling).
- Hybrid scheme: status of the Sweeping Magnet (SM) ON/OFF
  - SM OFF state allows the charged particles reach the target-converter.
- Conventional scheme (without crystal)

Experimental set-up simulated in Geant4



Summary and Perspectives

- Choosing a hybrid e+ source using channeling **already meets the requirements of the ILC and CLIC.**
- Replacing the compact converter with a granular one made of small spheres **improves the heat dissipation, decreases the PEDD** and **provides better resistance to the shocks**.
- New option of the hybrid source with a granular converter => Experimental tests are mandatory => Recent beam tests at KEK.
- The experimental data have been acquired. **The analysis is ongoing.**
- **G4 simulation** is still ongoing with detailed description of KEK experimental setup.
- The **simulations of the thermal load** in the target-converter and evaluations of the shocks are of great importance.

Thanks