Current Status of the ULQ2 Experiment

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Ultra Low Q^2 (ULQ2) experiment

ULQ2 experiment

- Proton radius measurement with electron scattering
- Removing model dependencies as much as possible

characteristics

① Extreme low Q^2 : $\mathbf{0.0003 \leq Q^2 \leq 0.008}$ $(\mathrm{GeV}/c)^2$.

② Rosenbluth separated $G_E(Q^2)$ and $G_M(Q^2)$.

$\Rightarrow E_e = \mathbf{10 - 60\ MeV},\ \theta = 30 - 150°$

Lowest-ever beam energy !!

③ Absolute cross section with $\sim 10^{-3}$ accuracy.

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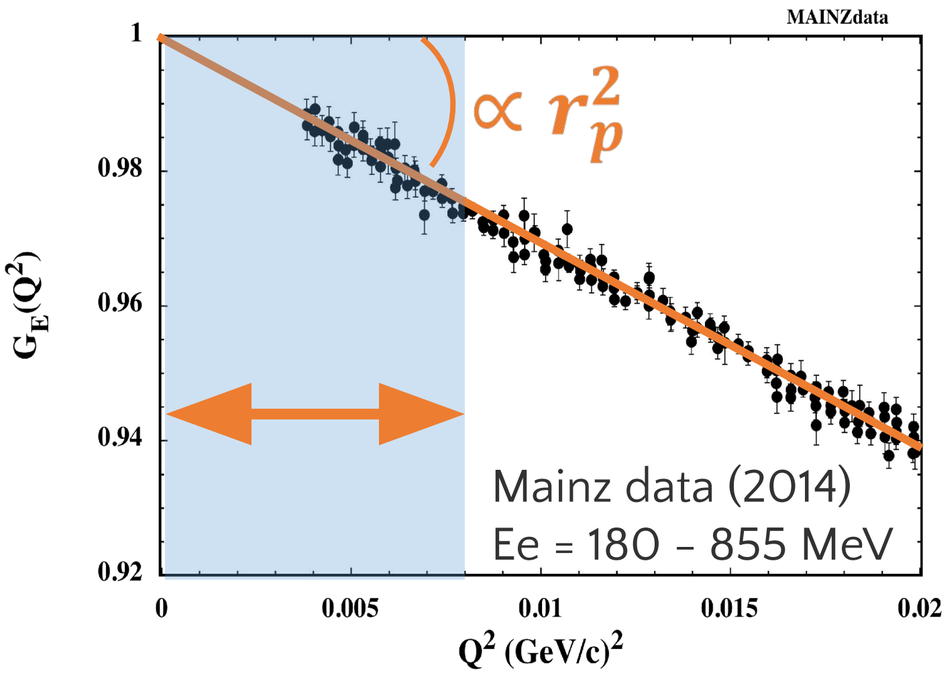
$$r_p^2 \equiv -6 \frac{dG_E(Q^2)}{dQ^2}\Big|_{Q^2 \to 0}$$



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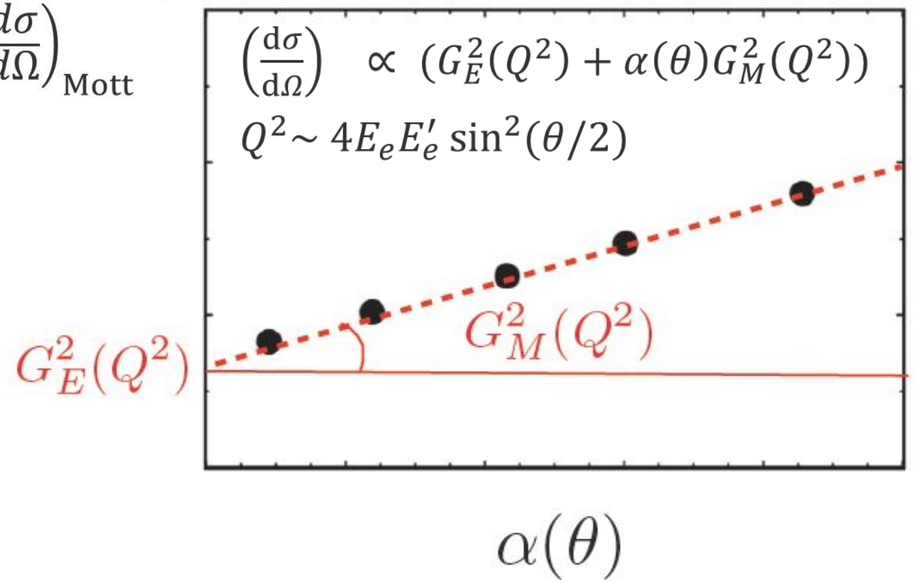
$$\frac{(1+\tau)\left(\frac{d\sigma}{d\Omega}\right)}{\left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{Mott}}}$$

Rosenbluth separation



- Rosenbluth separation requires frequently change of E_e and θ

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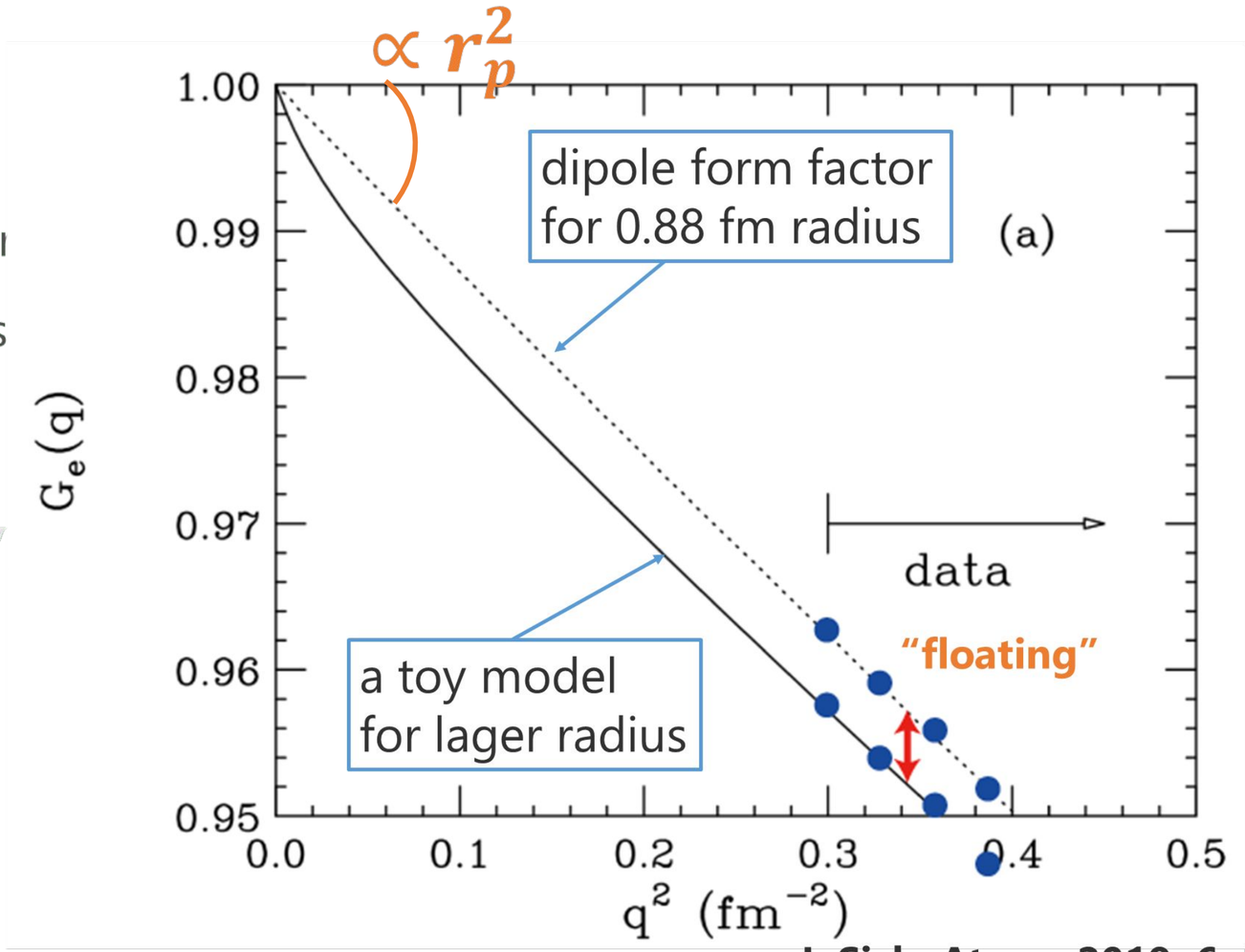

I. Sick, Atoms 2018, 6, 2

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Lowest-ever beam energy !!

③ **Absolute** cross section with ~10^{-3} accuracy.

- Relative measurement to well-known cross section.
  e+p / e+C scattering → **CH_2 target**

$$\left(\frac{d\sigma}{d\Omega}\right)_{e+p} = \frac{N_{e+p}(\Delta\Omega)}{N_p \quad N_e \quad \Delta\Omega}$$

N_p: p target number; N_e: Beam dose; $\Delta\Omega$: Solid angle

$$\left(\frac{d\sigma}{d\Omega}\right)_{e+p} = \frac{N_{e+p}(\Delta\Omega)/N_{e+C}(\Delta\Omega)}{N_p/N_C} \left(\frac{d\sigma}{d\Omega}\right)_{e+C}$$

N_p/N_C: Ratio of p and C, measure with LC/MS; $\left(\frac{d\sigma}{d\Omega}\right)_{e+C}$: Well known

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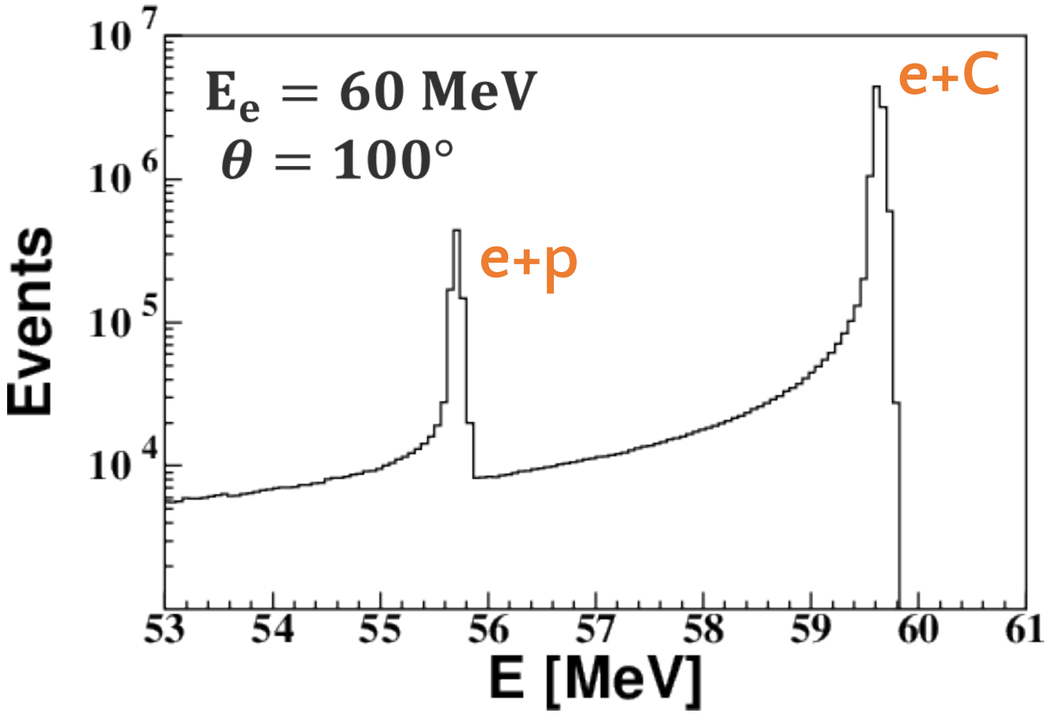


Ultra Low Q^2 (ULQ2) experiment

To achieve $\Delta r_p / r_p = 1\%$

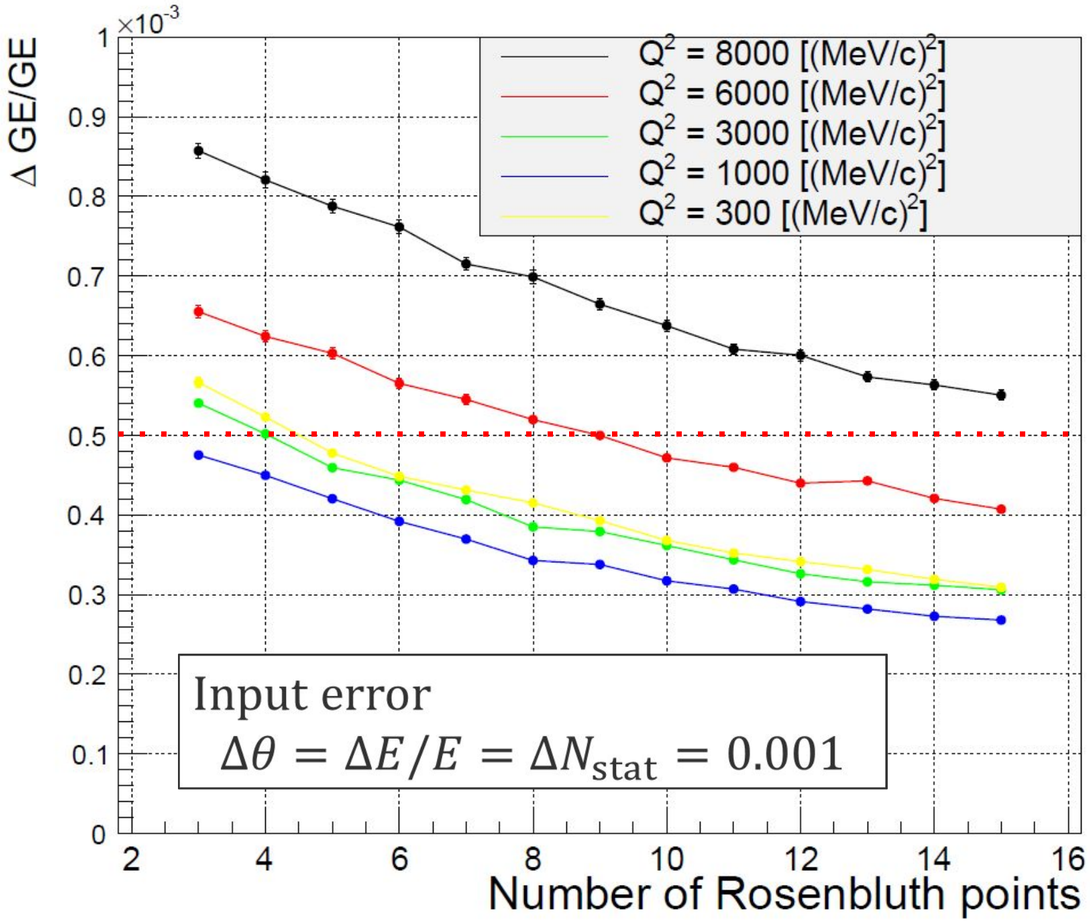
- We need more than 9 of Q^2 data points with $\Delta G_E / G_E = 5 \times 10^{-4}$

To achieve $\Delta G_E / G_E = 5 \times 10^{-4}$

- 3 – 16 data points are required for Rosenbluth separation with $\Delta\theta = \Delta E/E = \Delta N_{\mathrm{stat}} = 0.001$
  - $\Delta\theta = 0.001$: 1 mm misalignment.
  - $\Delta E/E = 0.001$: 0.8 mm shift at detector

Total 48 data points

- 12 h / data point
  -> total beam time ~ 1 month



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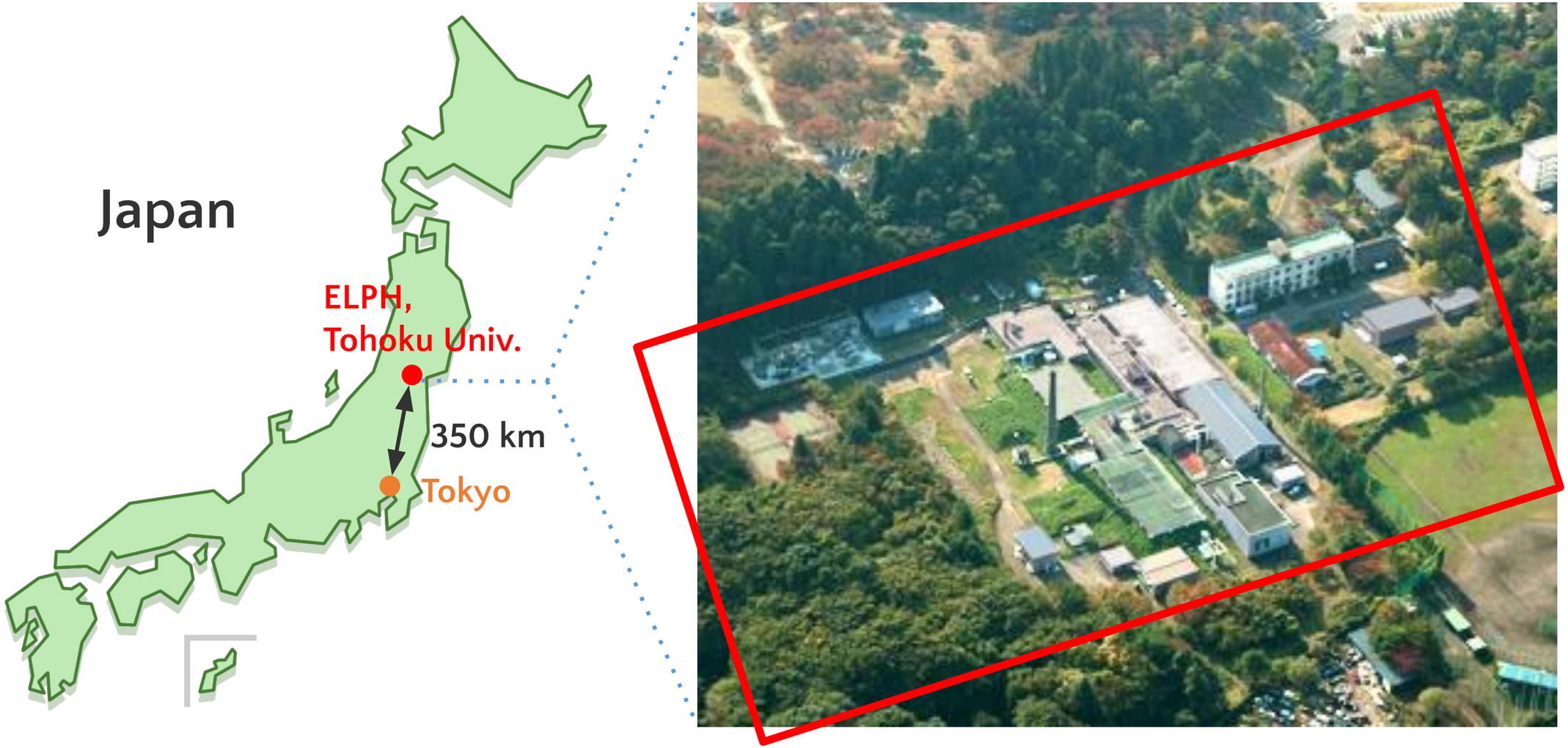

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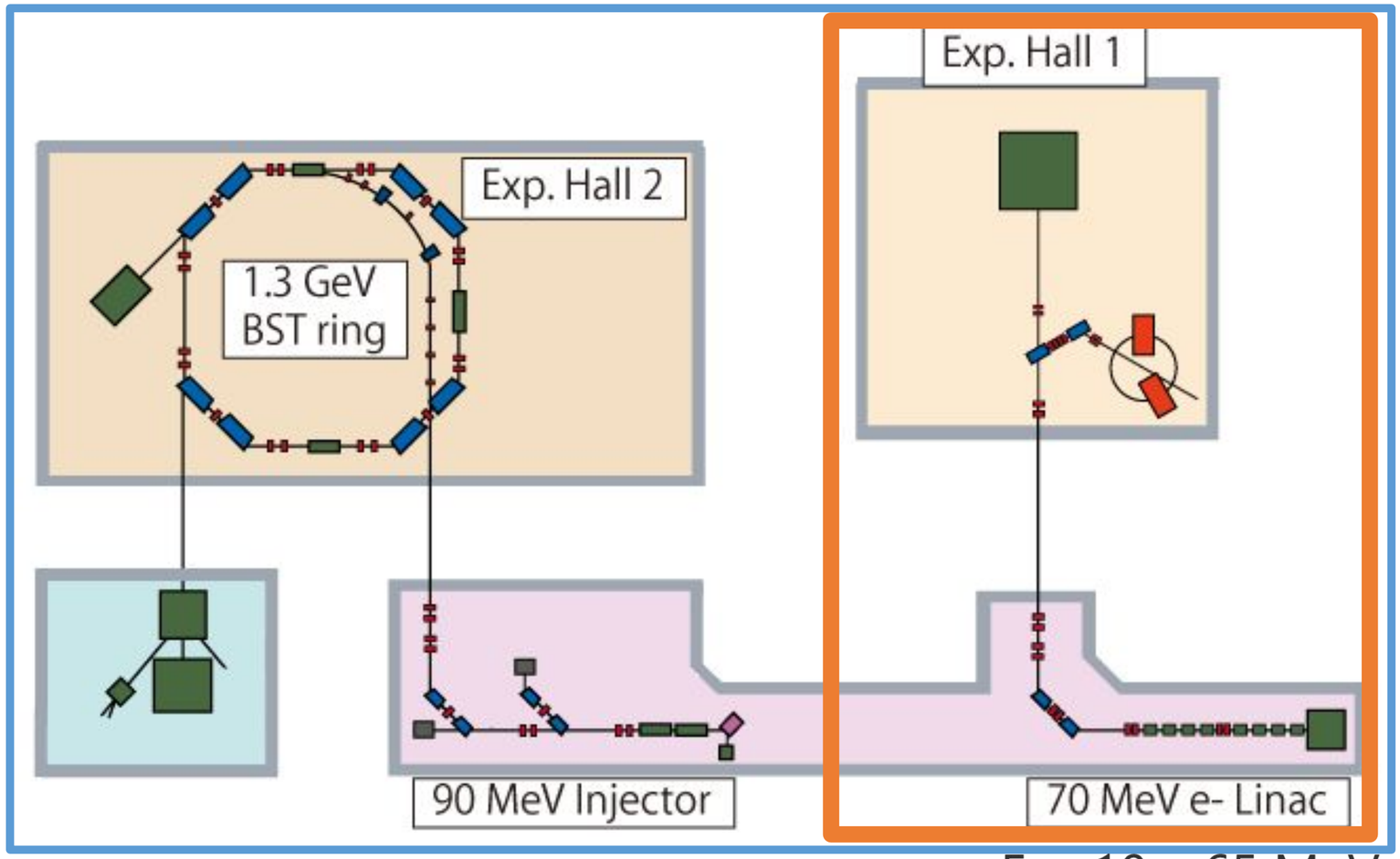
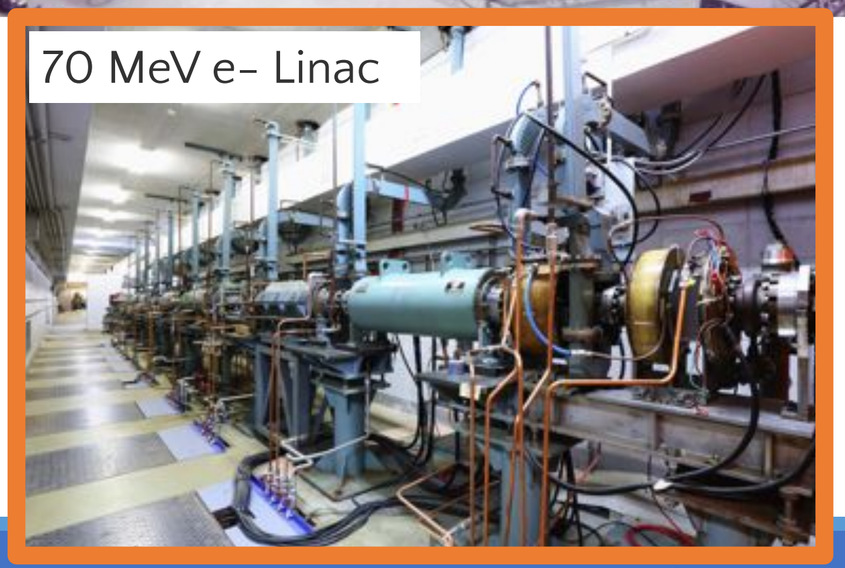
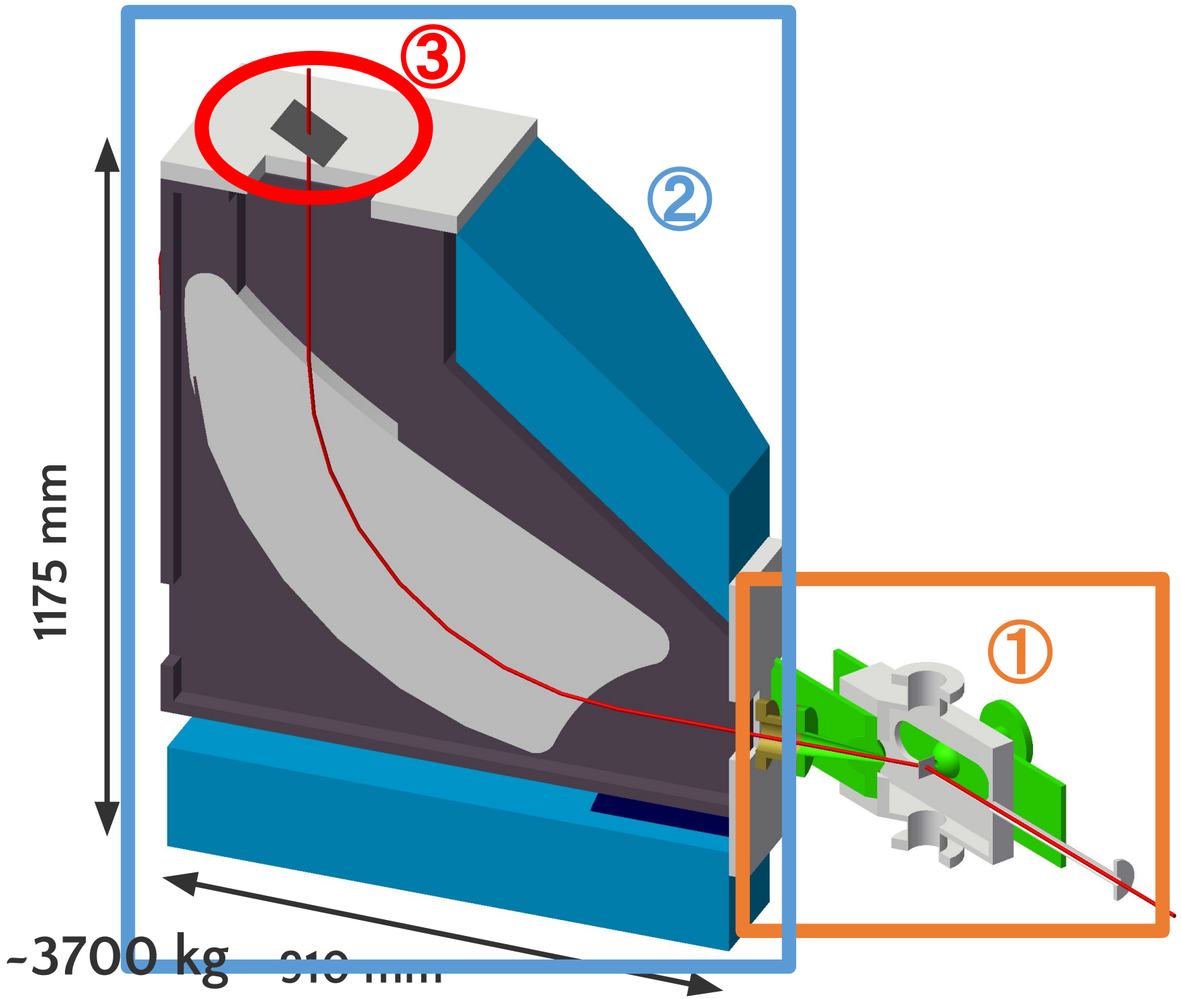


E = 10 – 65 MeV

$I_e = 180\ \mu A$

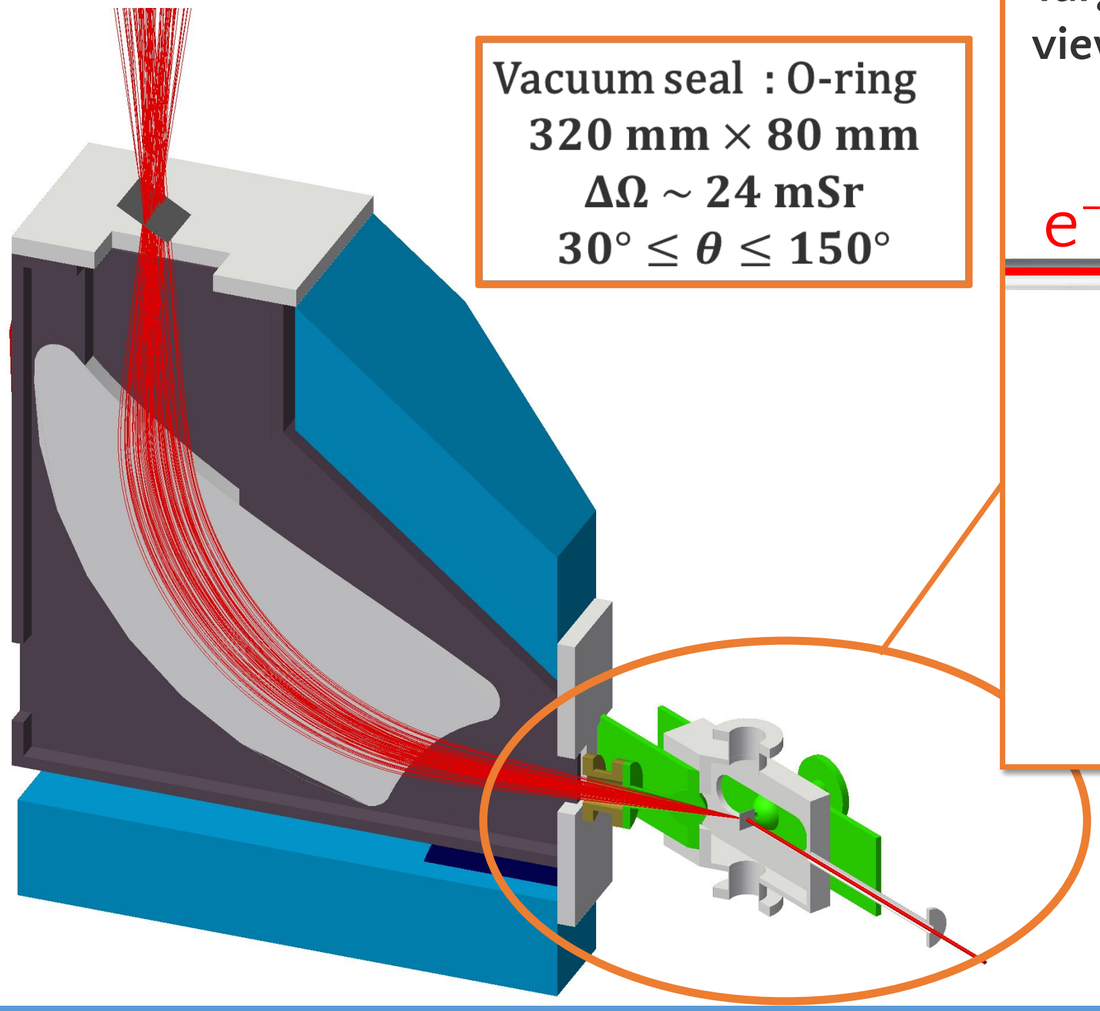


Spectrometer for low-energy electron



- Simple structure
  1. Target chamber
  2. Dipole magnet
  3. Focal plane detector
- Specialized for low-energy electron
  - Windowless
  - Tracking less

Angle changeable target chamber

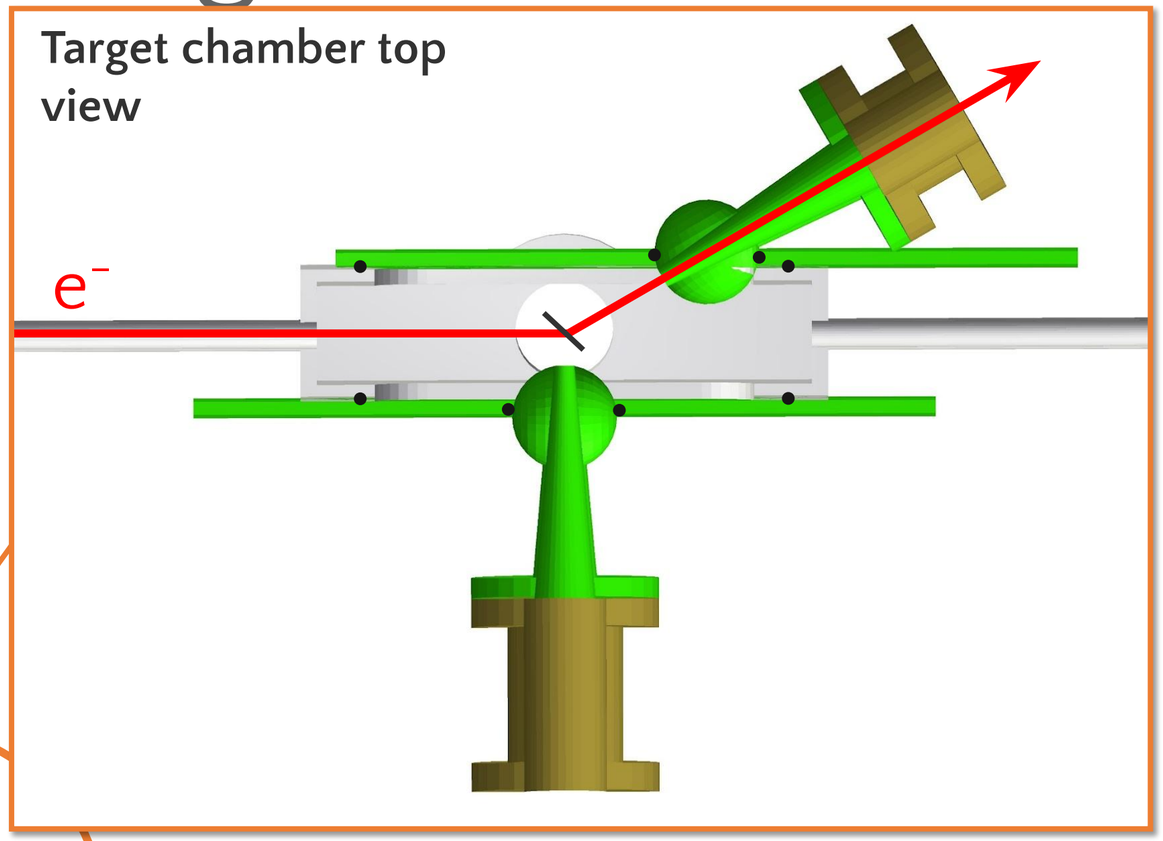


Vacuum seal : O-ring

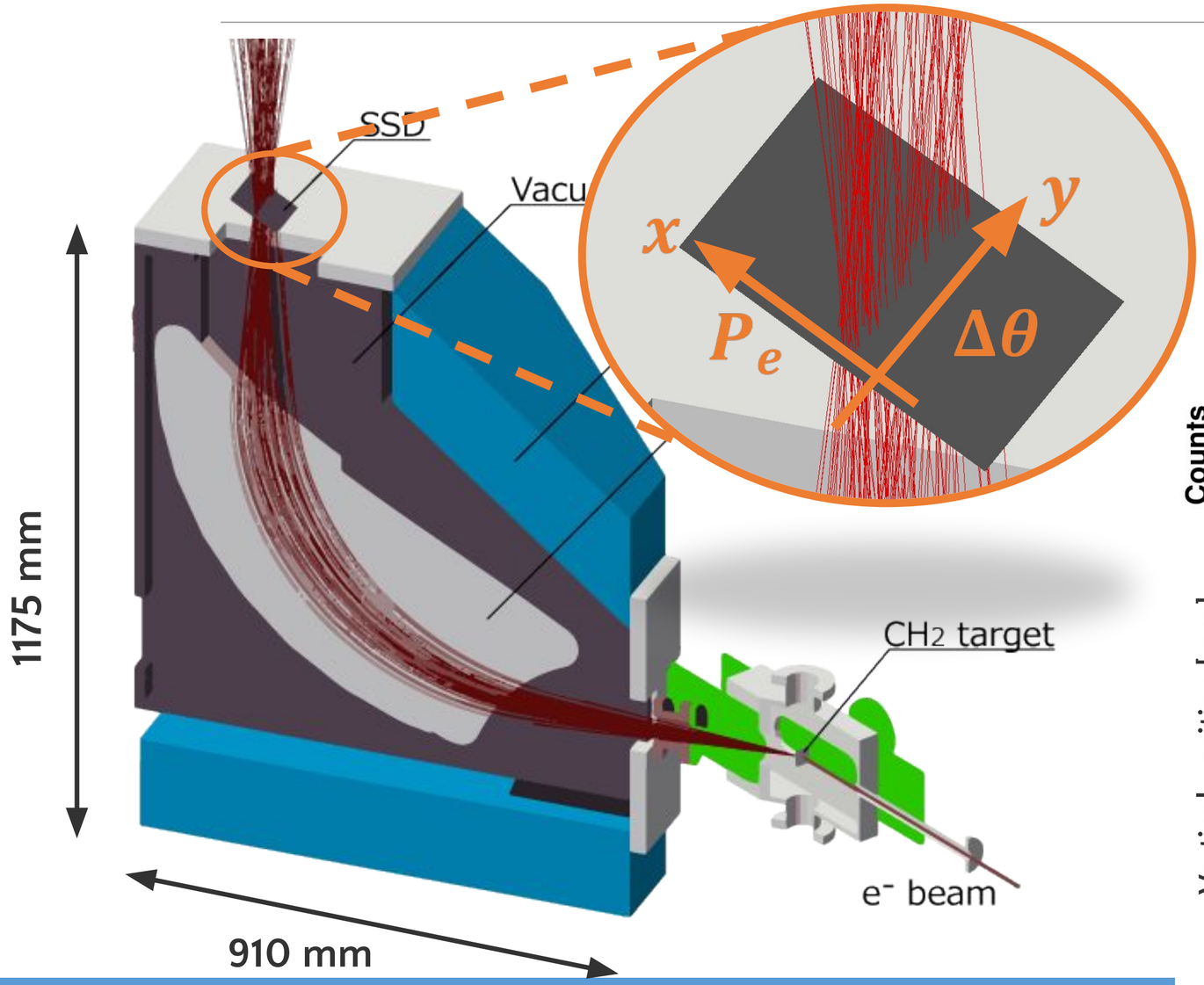
$320\ \text{mm} \times 80\ \text{mm}$

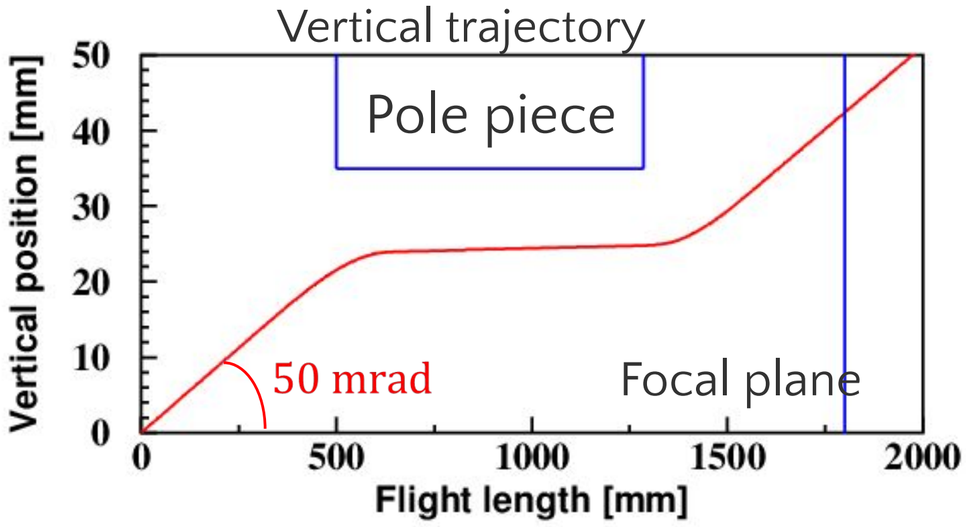
$\Delta\Omega \sim 24\ \text{mSr}$

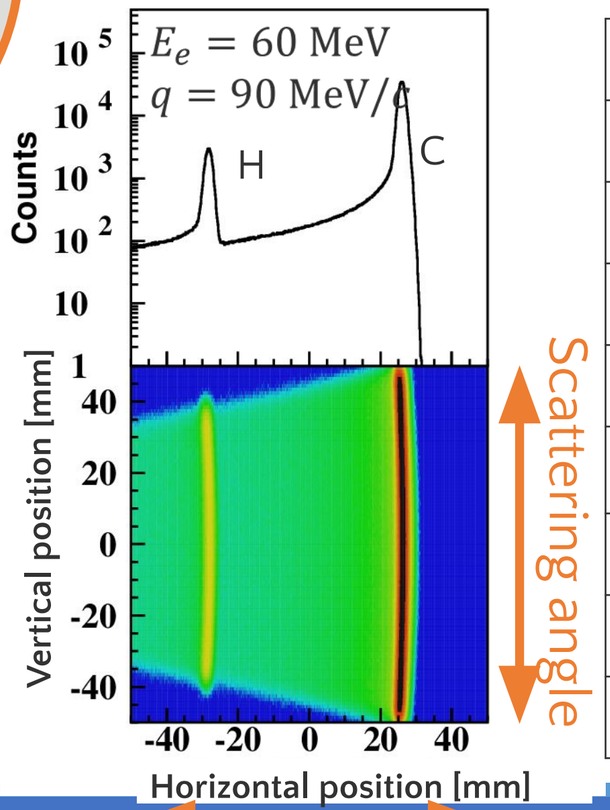
$30° \leq \theta \leq 150°$



Spectrometer

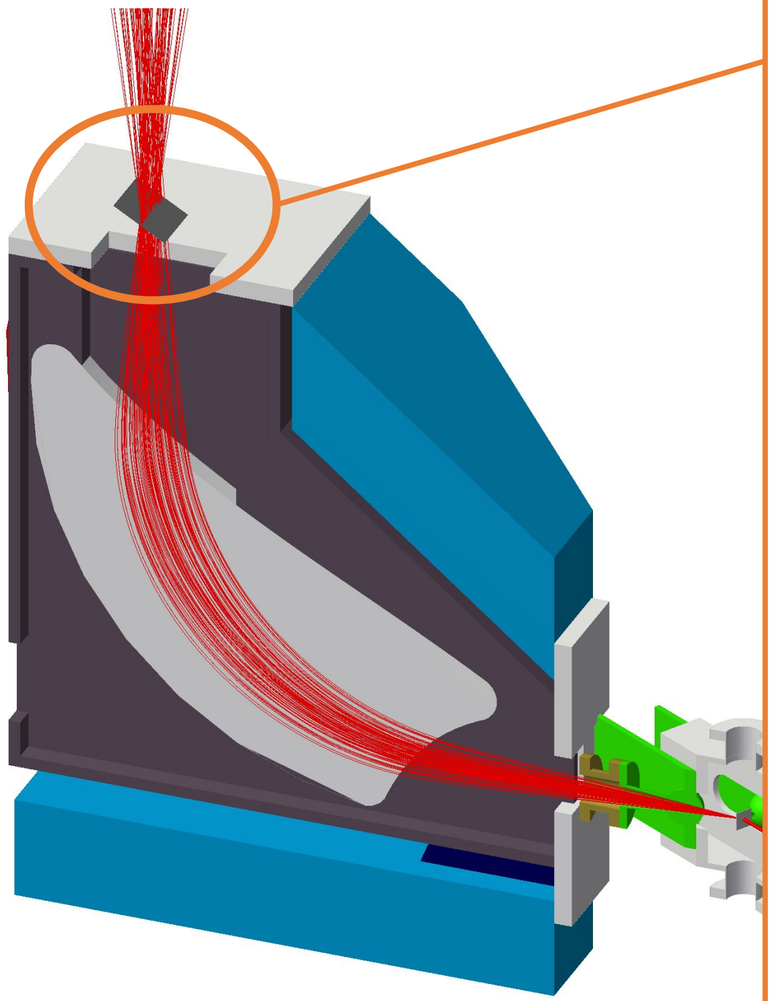




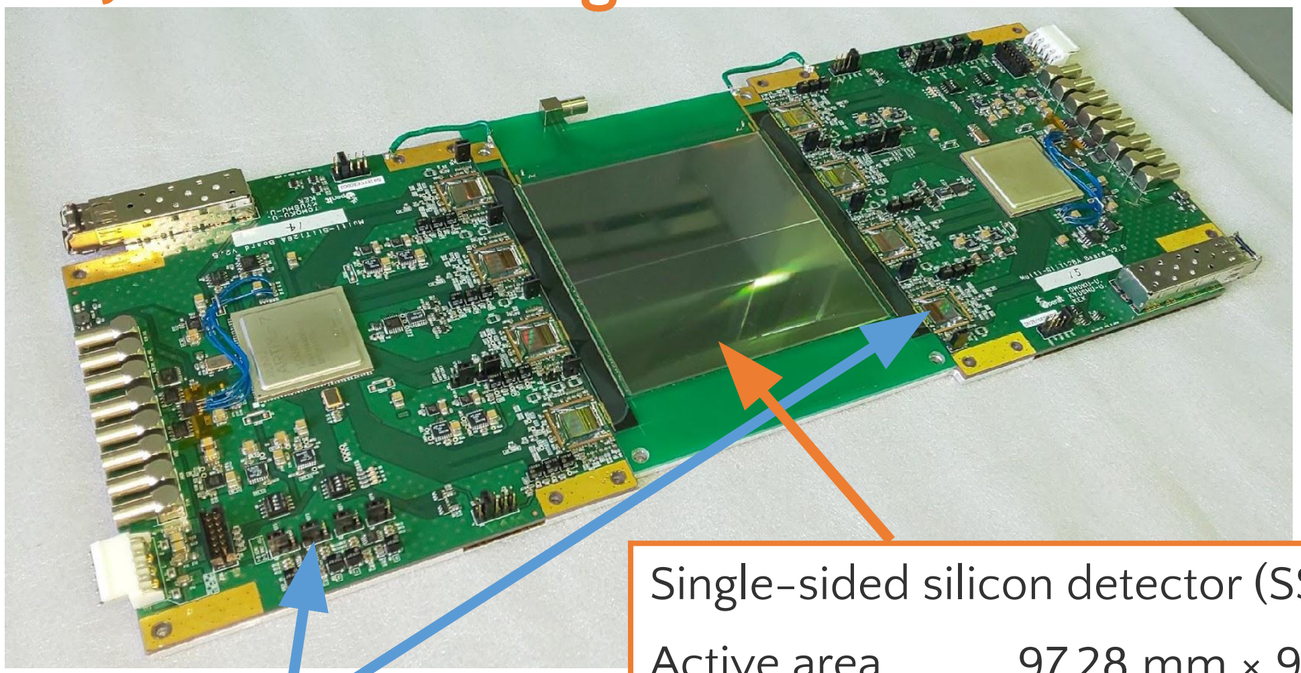


radius	50 cm
bending angle	90°
	0.4 T @ 60 MeV
gap	70 mm
dispersion	855 mm
momentum bite	11 %
	5 mrad
solid angle	10 mSr

Focal plane detector



J-PARC muon g-2/EDM Test module2



Readout boards
"Multi-Slit128A board"
Four ASICs "Slit128A"
(128 ch/chip)

Single-sided silicon detector (SSSD)

Active area	97.28 mm × 97.28 mm
Thickness	0.32 mm
Strip length	48.575 mm
Strip pitch	0.19 mm
No. of strips	512 ch × 2

ULQ2 exp. up to now

Mar. 2019 1st spectrometer construction

Sep. 2020First beam @ ULQ2 beamline

Sep. 2020 ~ 1st spectrometer commissioning

Aug. 2021 2nd spectrometer construction

Nov. 2021 ~ 2nd spectrometer commissioning

Dec. 2021 ~ New rotational vacuum chamber installation and test.

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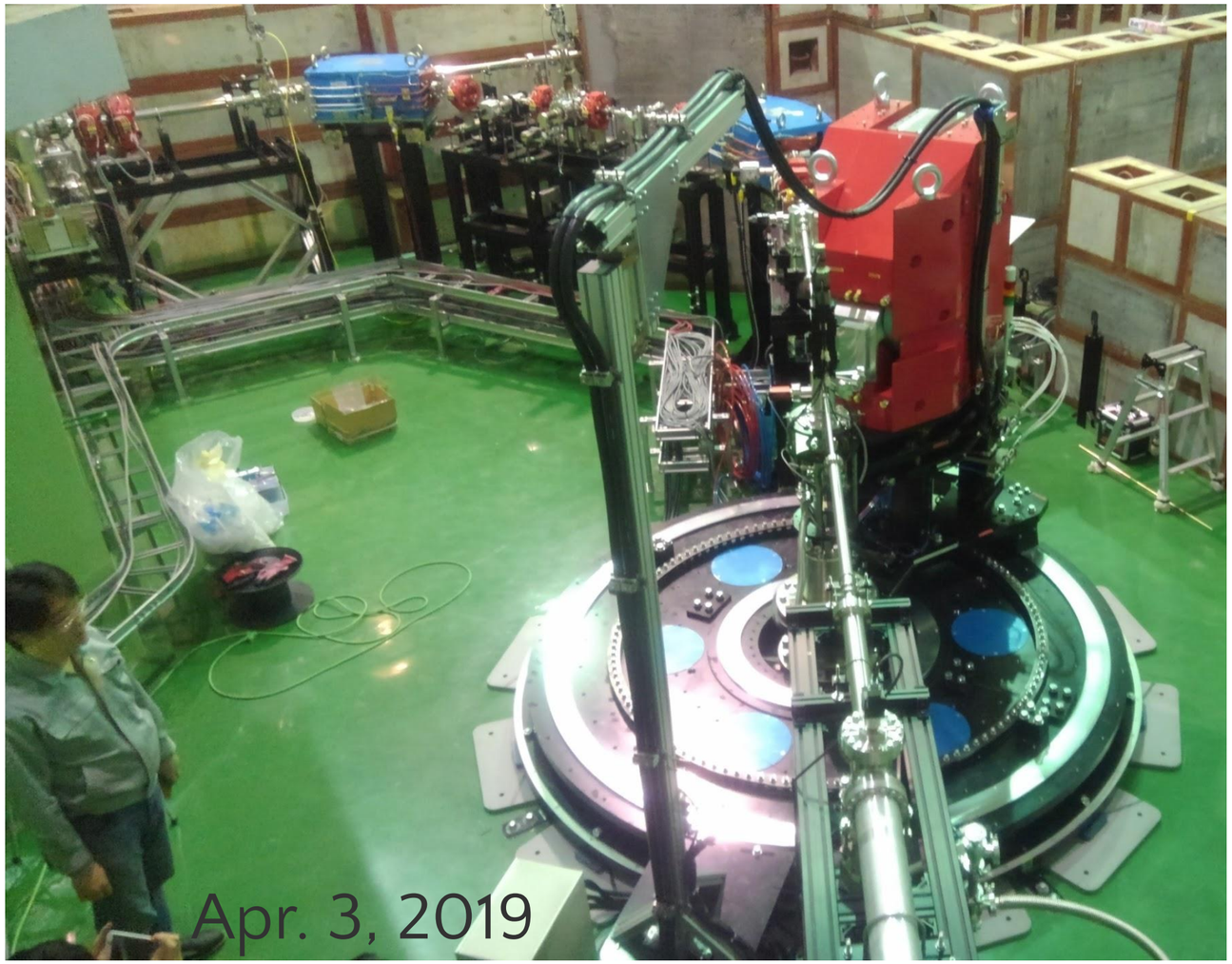

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■ Previous status

- $E_e = 20 - 60$ MeV
- $\sigma_E/E_e \sim 0.5$ %
- $\sigma_{x,y} \sim 3$ mm
- $I_{\max} \sim 180$ μA

■ Requirement : ULQ2 exp.

- $E_e = 10 - 60$ MeV
- $\sigma_E/E_e \leq 0.1$ %
- $\sigma_{x,y} \leq 1$ mm
- $I_{\max} \sim 1$ μA

First beam@ULQ2
Sep. 11th, 2020

■ Commissioning

- $E_e = 50$ MeV
- $\sigma_E/E_e = 0.06$ %
- $\sigma_{x,y} \sim 0.6$ mm
- $I \sim 50$ nA (not max)

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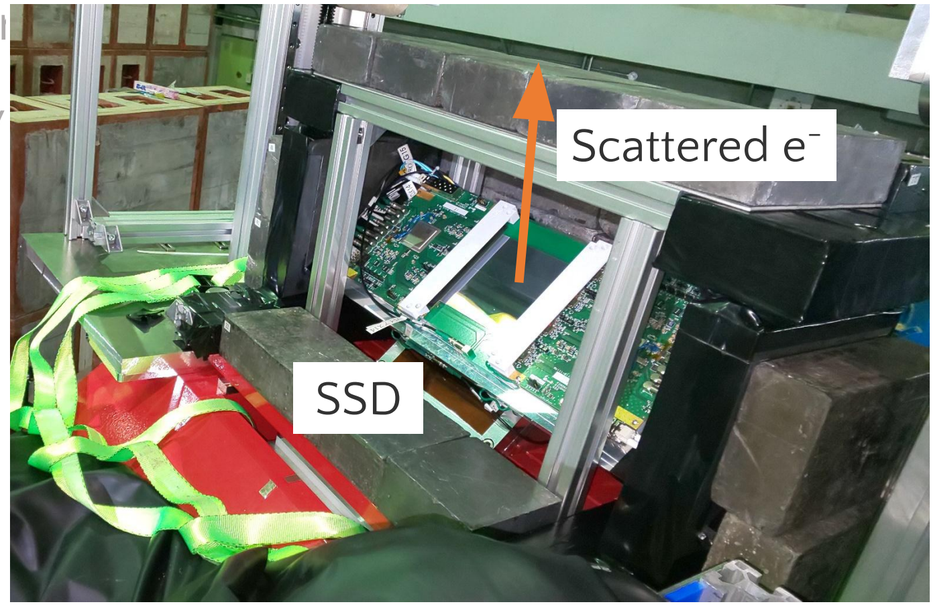
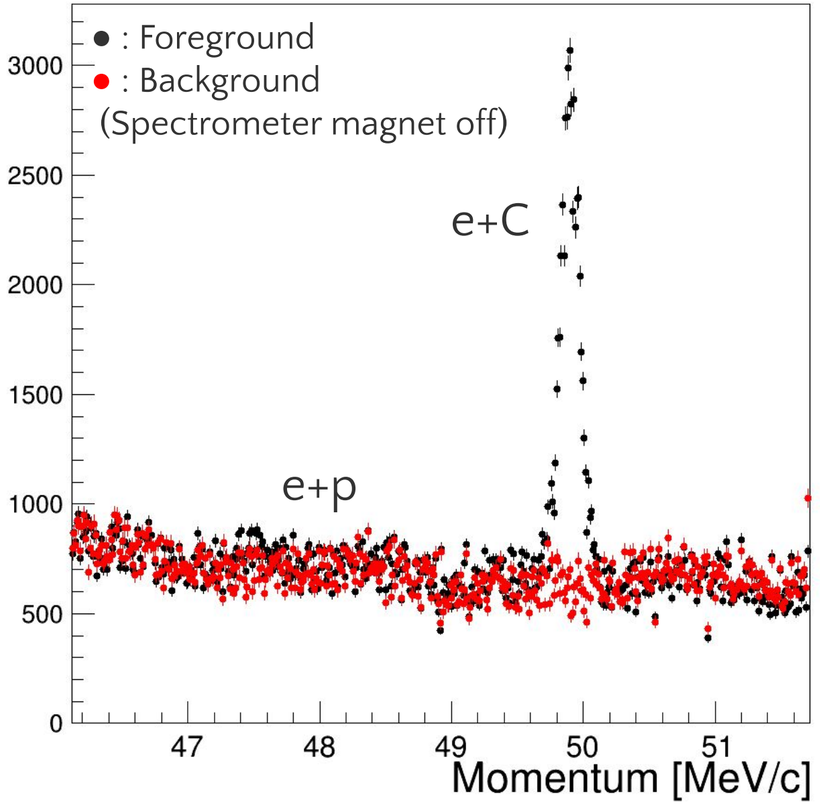
Focal plane detector





e+C, e+p peaks were observed
Measured momentum resolution, optical properties $(x|\delta)$, $(x|x)$

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2nd spectrometer for luminosity monitor.
Monitor C H ratio during experiment.

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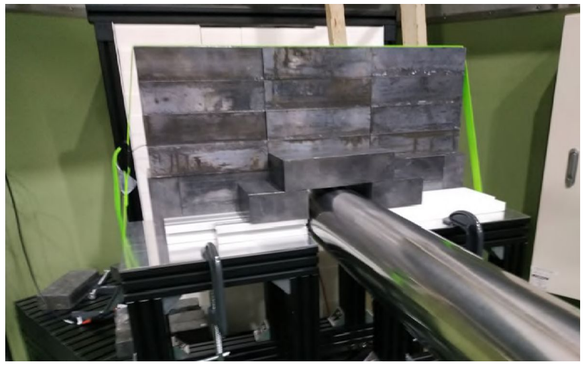
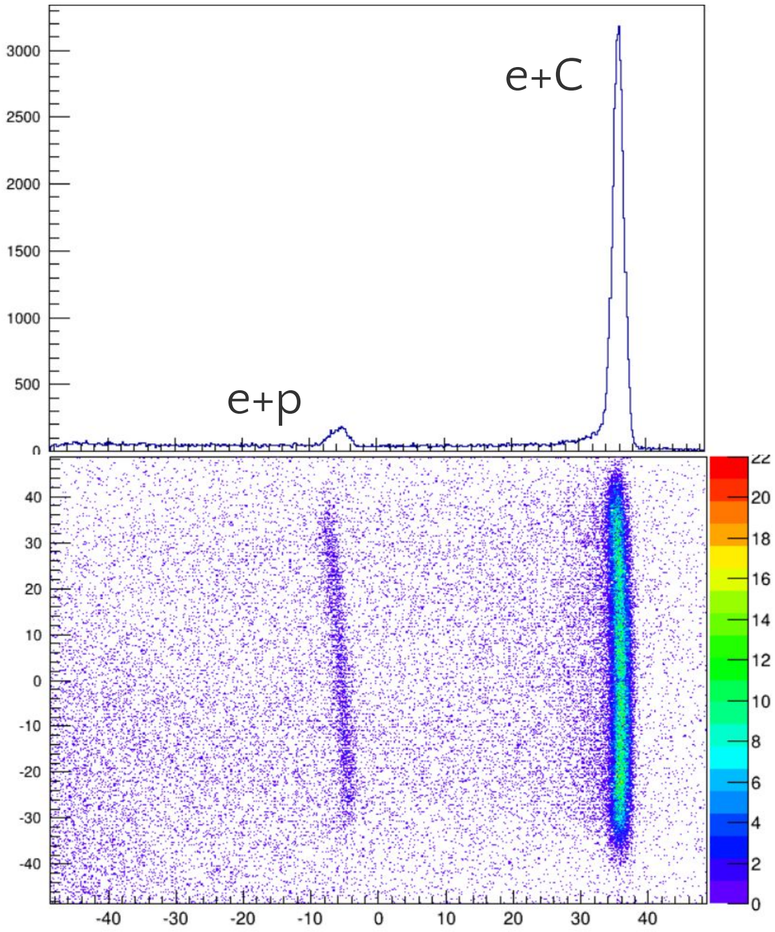
Add and improve shield





Reduced background greatly, and measured optical properties $(x|\delta), (x|\delta\theta), (y|\theta), (y|\theta\delta), \ldots\ldots$ Confirmed our spectrometer fulfill experimental requirements.

$$(x|\delta) = 866.1 \pm 0.7$$
$$\sigma_p/p = (5.28 \pm 0.07) \times 10^{-3}$$
$$E^{\mathrm{exp}} = 50.0 \pm 0.2\ \mathrm{MeV}$$

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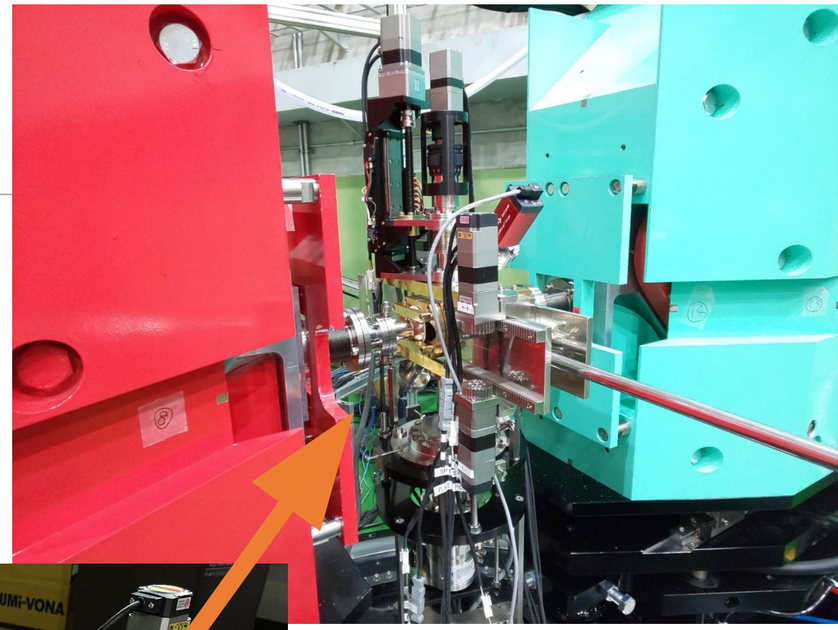

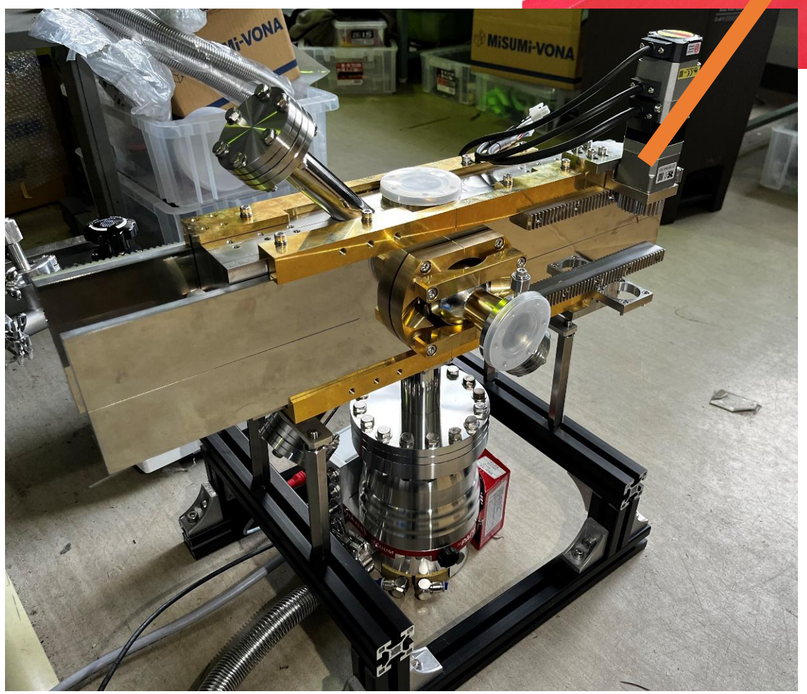

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The essential experimental equipment have been constructed, and their performances fulfill the experimental requirements.

Future tasks

- Detector efficiency study
  - We have to know position dependence of the detector efficiency with 10^{-3} accuracy.
  - Scattering events with a continuous momentum distribution more than 10 % are required.
  - Study with thick (2mm^{t}) carbon target is ongoing. $\Delta E@\mathrm{target} = 0 \sim 2.2\ \mathrm{MeV}$
- Beam energy determination
  - Improve the accuracy of the momentum dispersion.

- Radiative correction
- Electron mass 2 % effect
- Coulomb distortion 0.4 % effect

→ For these study, we will try to measure the charge form factor at 2 points in July.

We will start physics run in FY2022.

Magnetic form factor