

# Development of an Electron LINAC for calibration of the Super-Kamiokande Detector

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# Super Kamiokande (SK)



## 1 | タンク上部

天井はドーム状になっており、エレクトロニクスハットの他、様々な検出器校正装置が設置されています。

### Dome area

In the dome area electronics huts and several calibration systems are located.

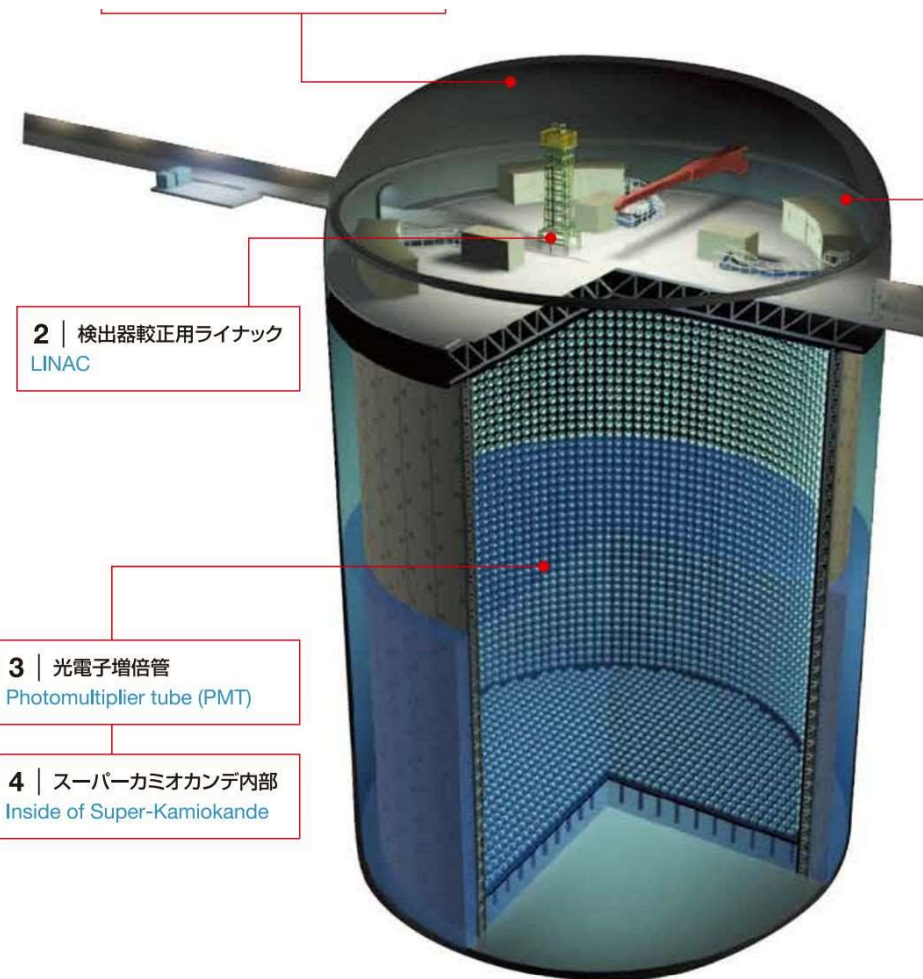


## 2 | 検出器校正用ライナック

この装置によりニュートリノのエネルギーを精度よく測定することが出来ます。

### LINAC

The detector is precisely calibrated by the LINAC system.



Max :15 MeV

For SK-Gd project, calibration of 20 MeV-30 MeV is required

# Electron accelerator for SK



Electron Accelerator Room

## **New electron accelerator for SK-Gd project**

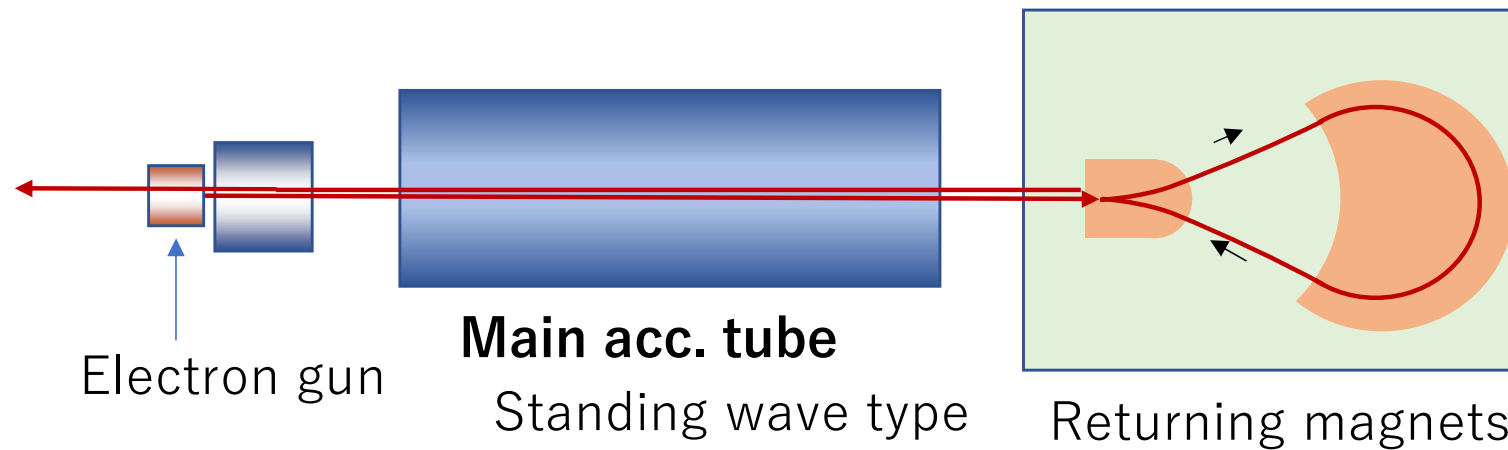
Compact

Max energy : 20 MeV (1<sup>st</sup> step) 30 MeV(2<sup>nd</sup> step)

Energy variable

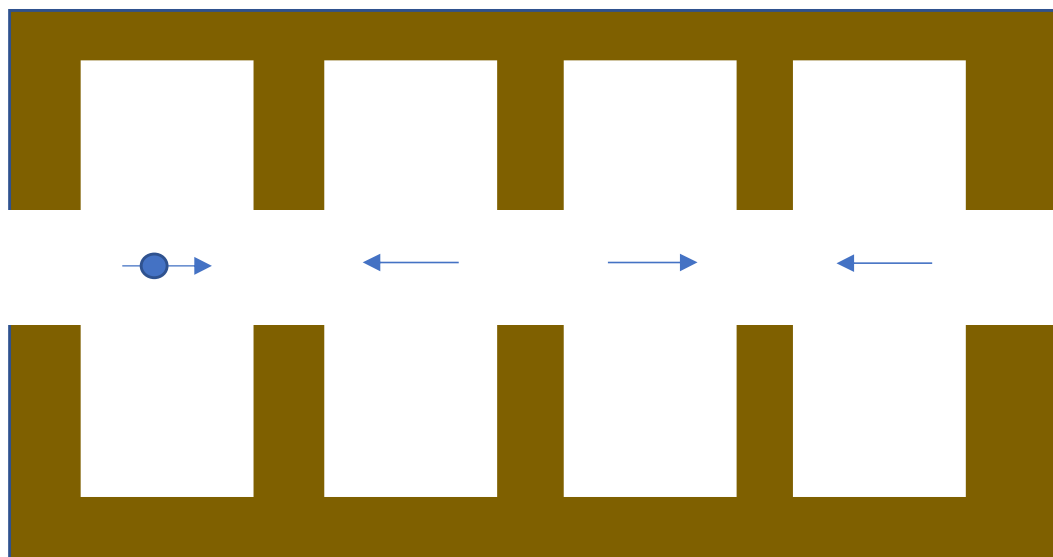
# New electron accelerator

## Both-way acceleration using a standing wave accelerating tube

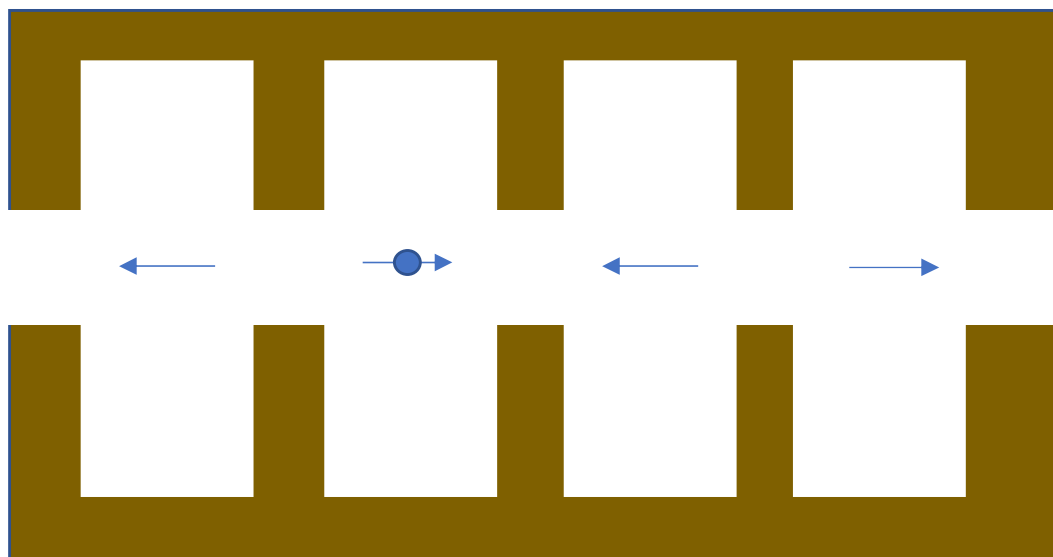


# Electron Acceleration (Standing wave accelerating tube)

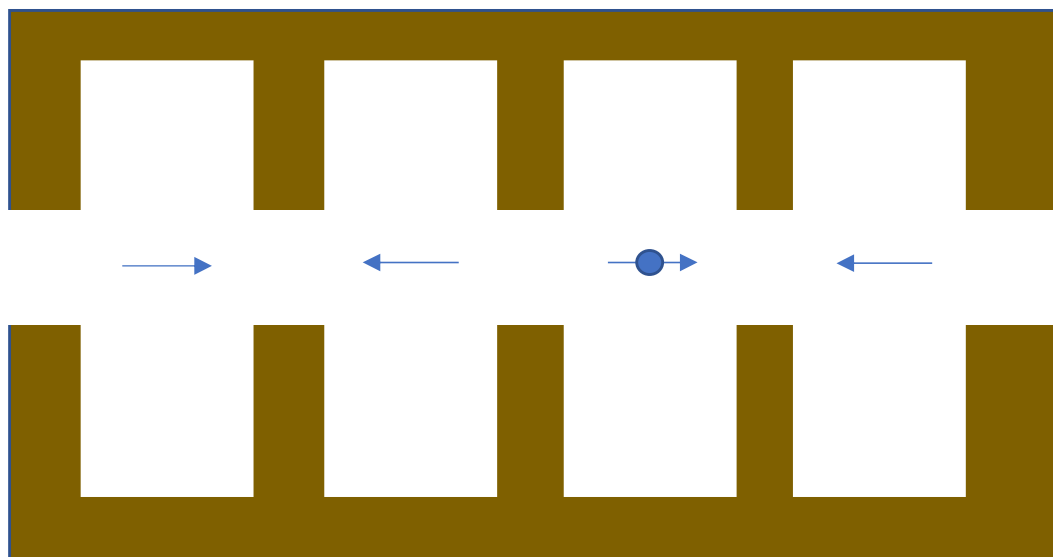
0°



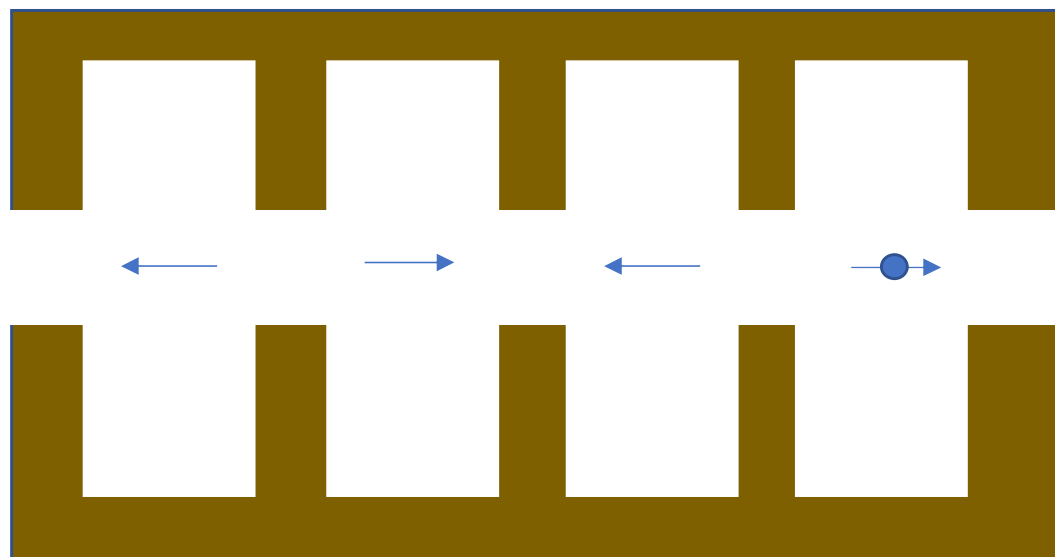
180°



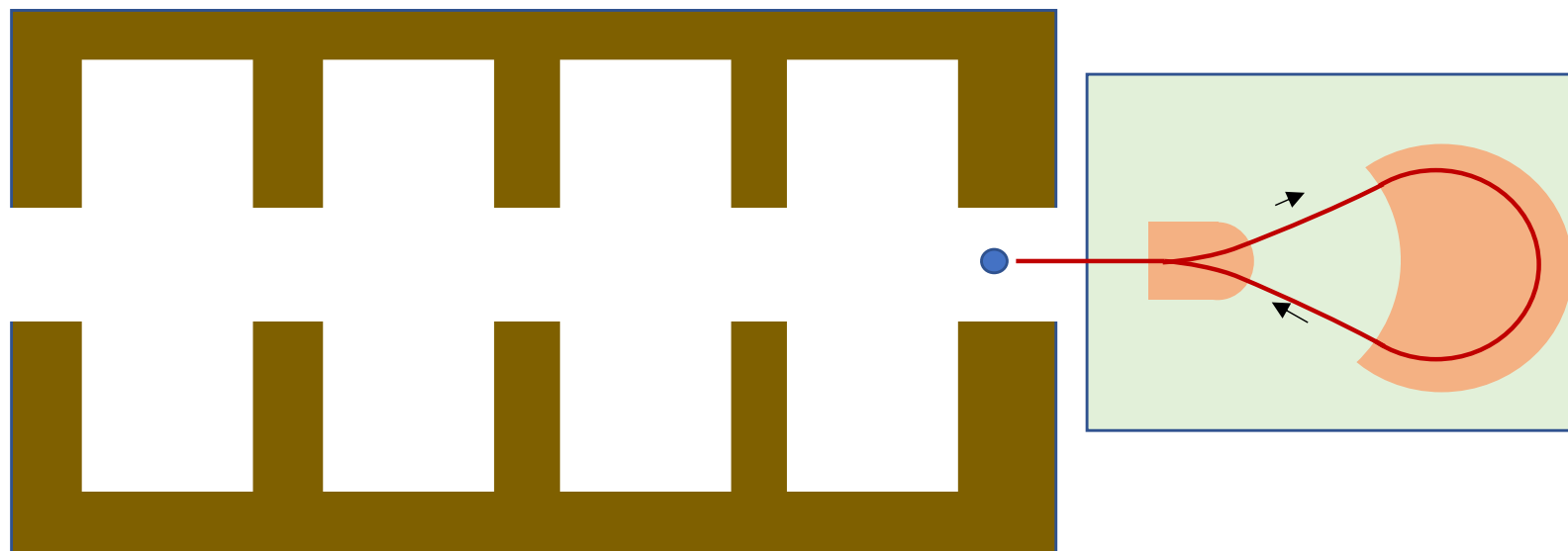
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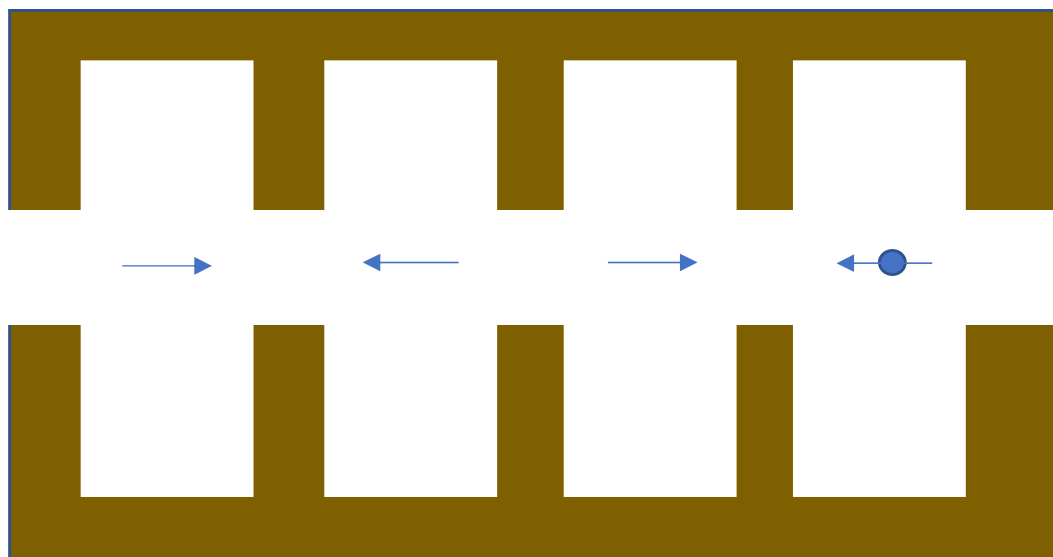
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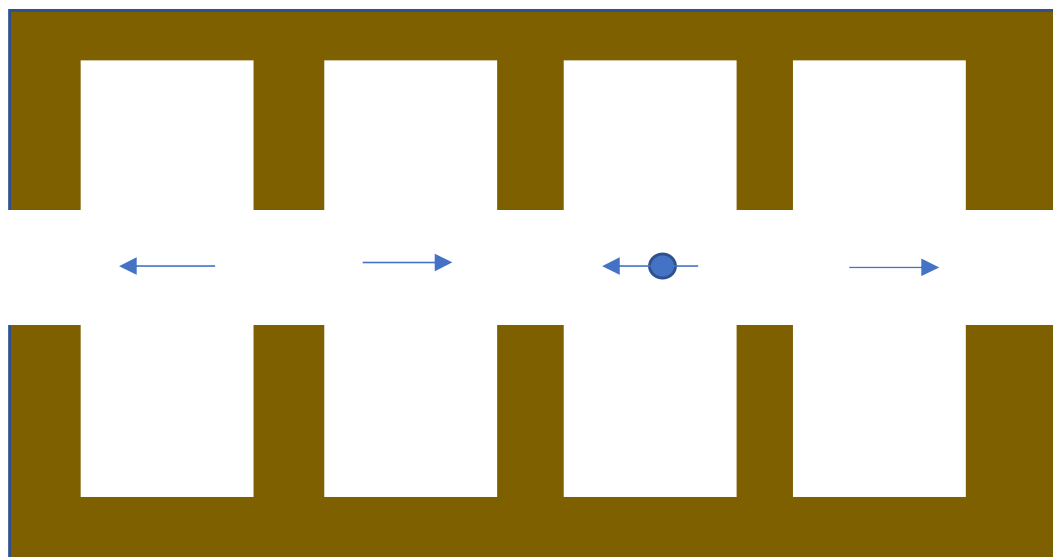




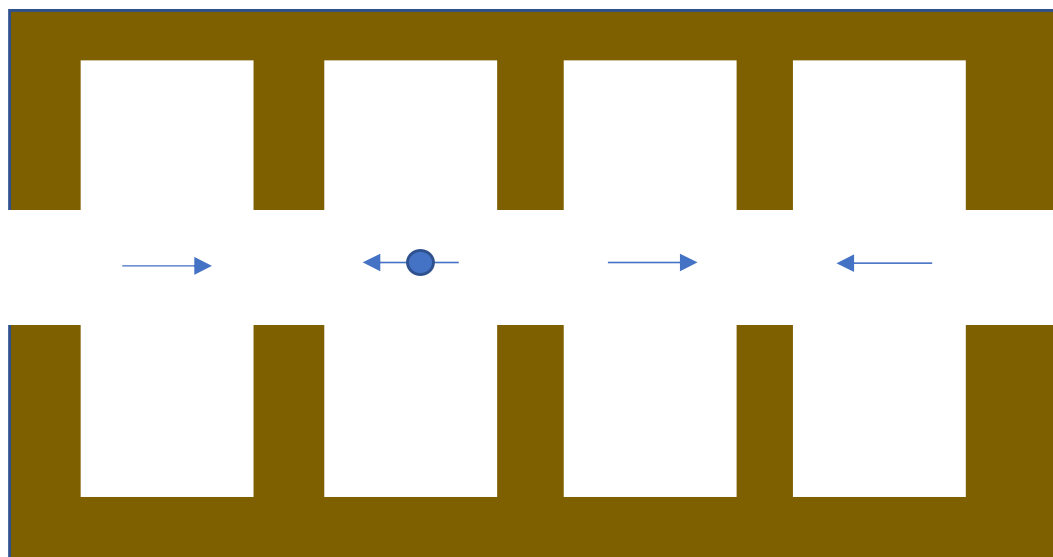
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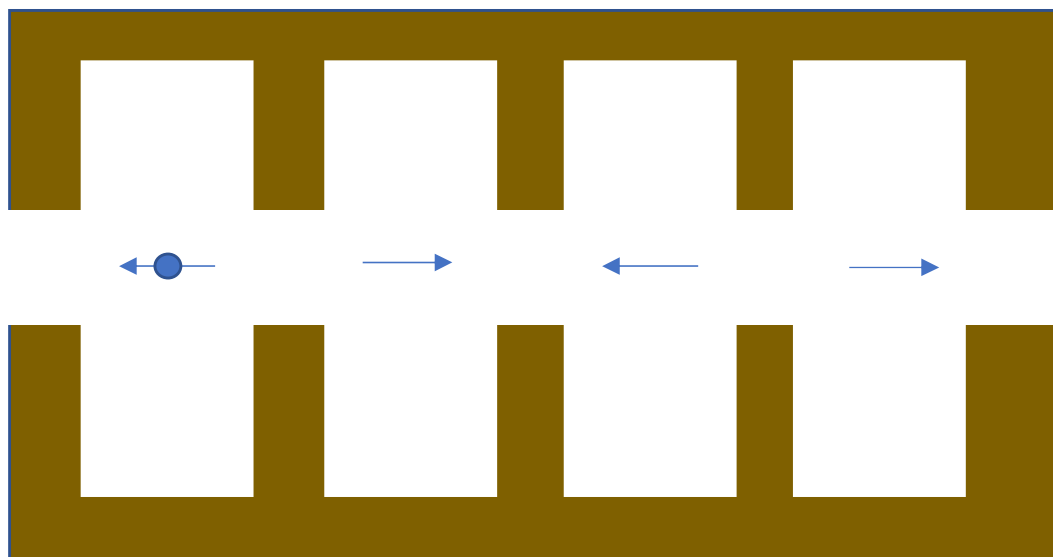
180°



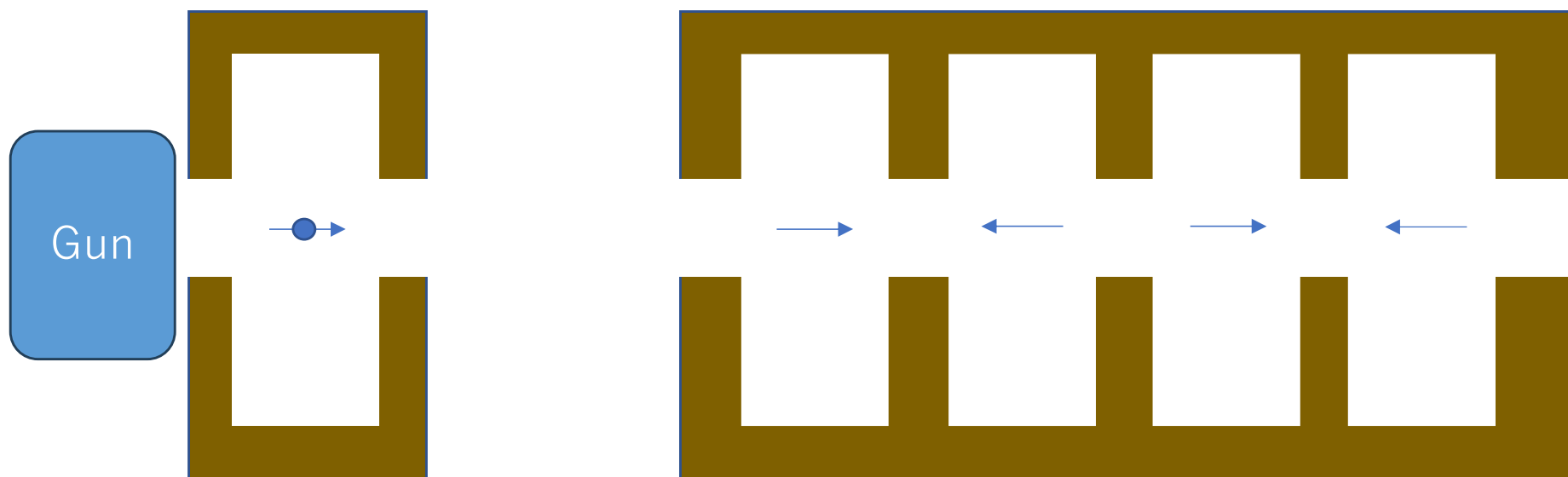
0°



180°



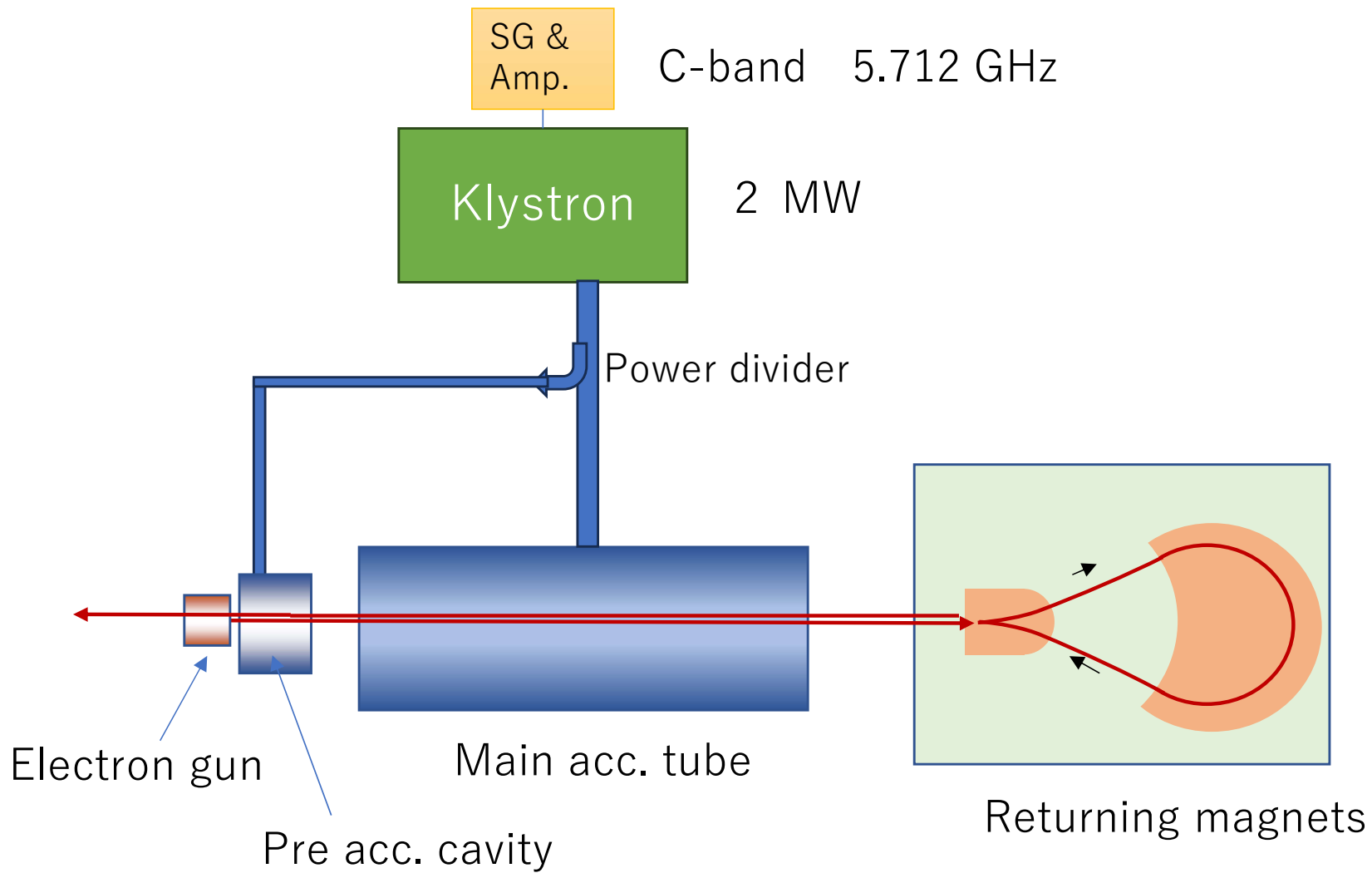
# Electron Acceleration with pre-accelerating cavity



Pre-accelerating cavity

Main accelerating tube

# Developed electron accelerator

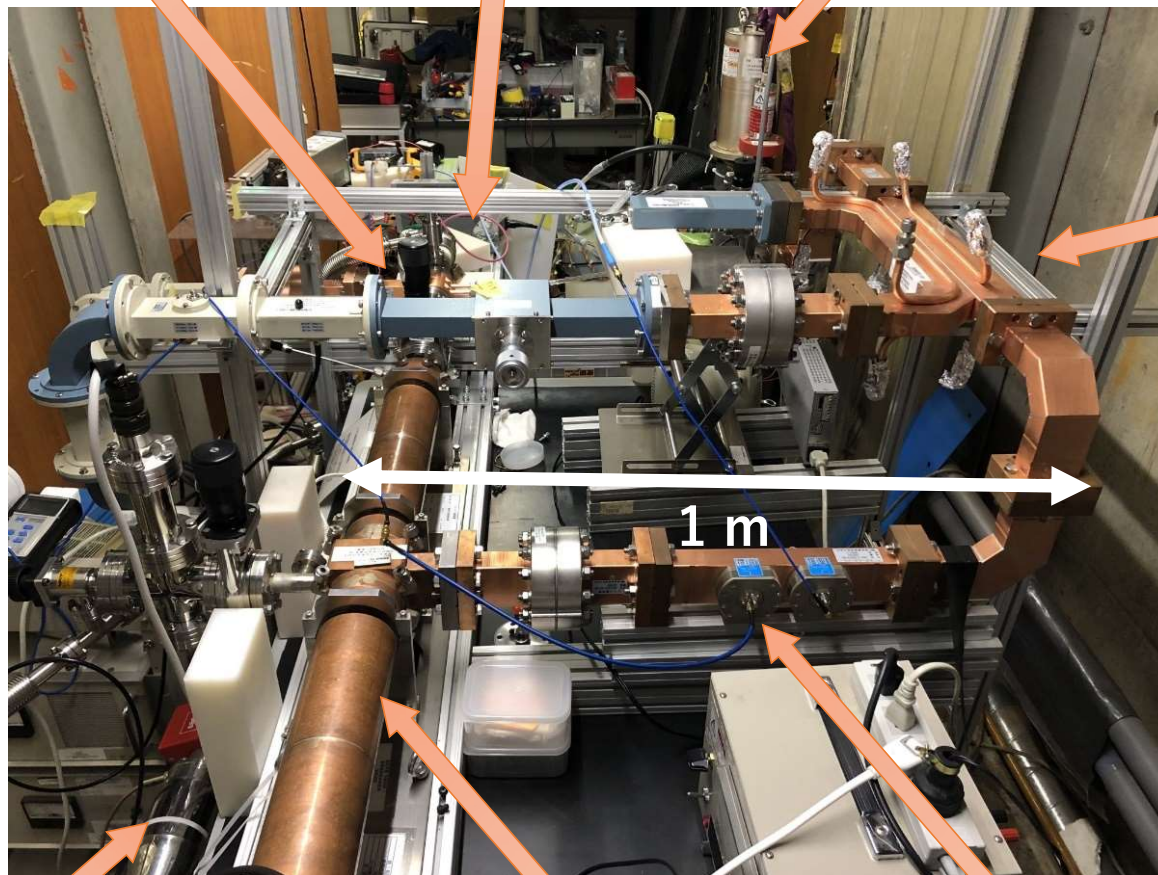


# Developed electron accelerator

Pre acc. cavity

Electron gun

Klystron



Power divider

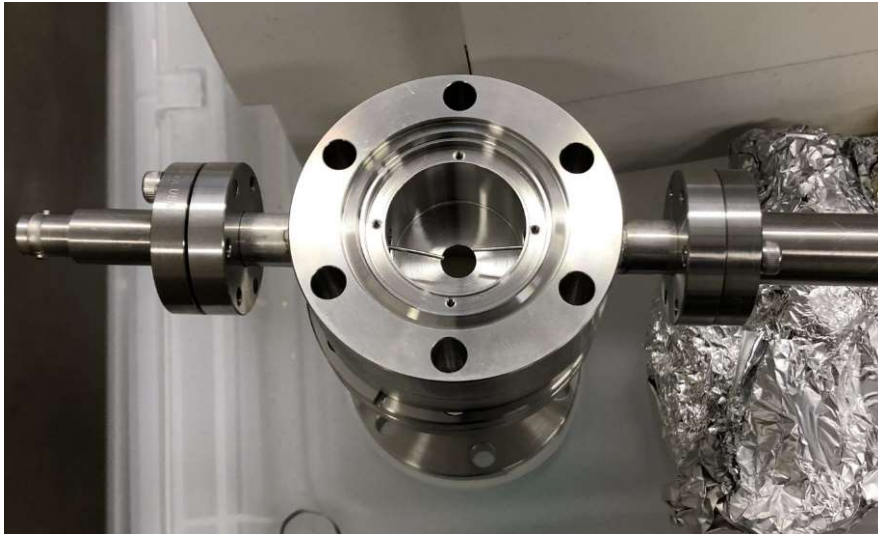
Vacuum Pump

Main acc. tube

Power monitor



# Electron Accelerator Components



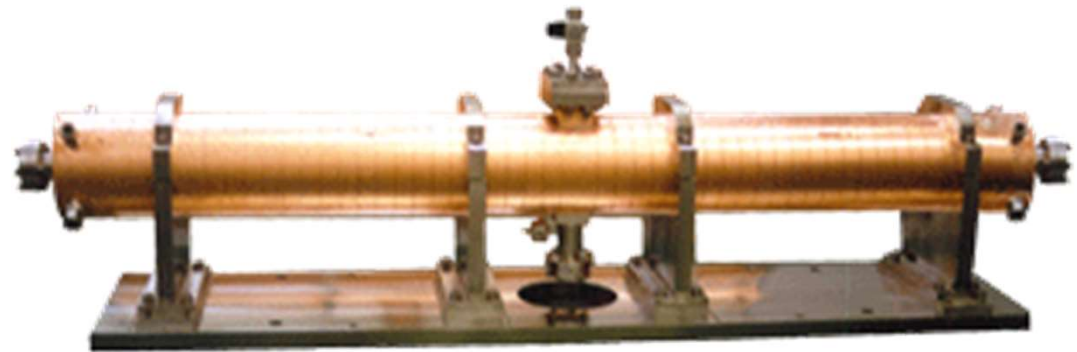
Electron gun  
Cathode: W filament



Pre accelerating cavity  
5.712 GHz single cavity  
Max. 100 kW

# Main accelerating tube

C band: 5.712GHz

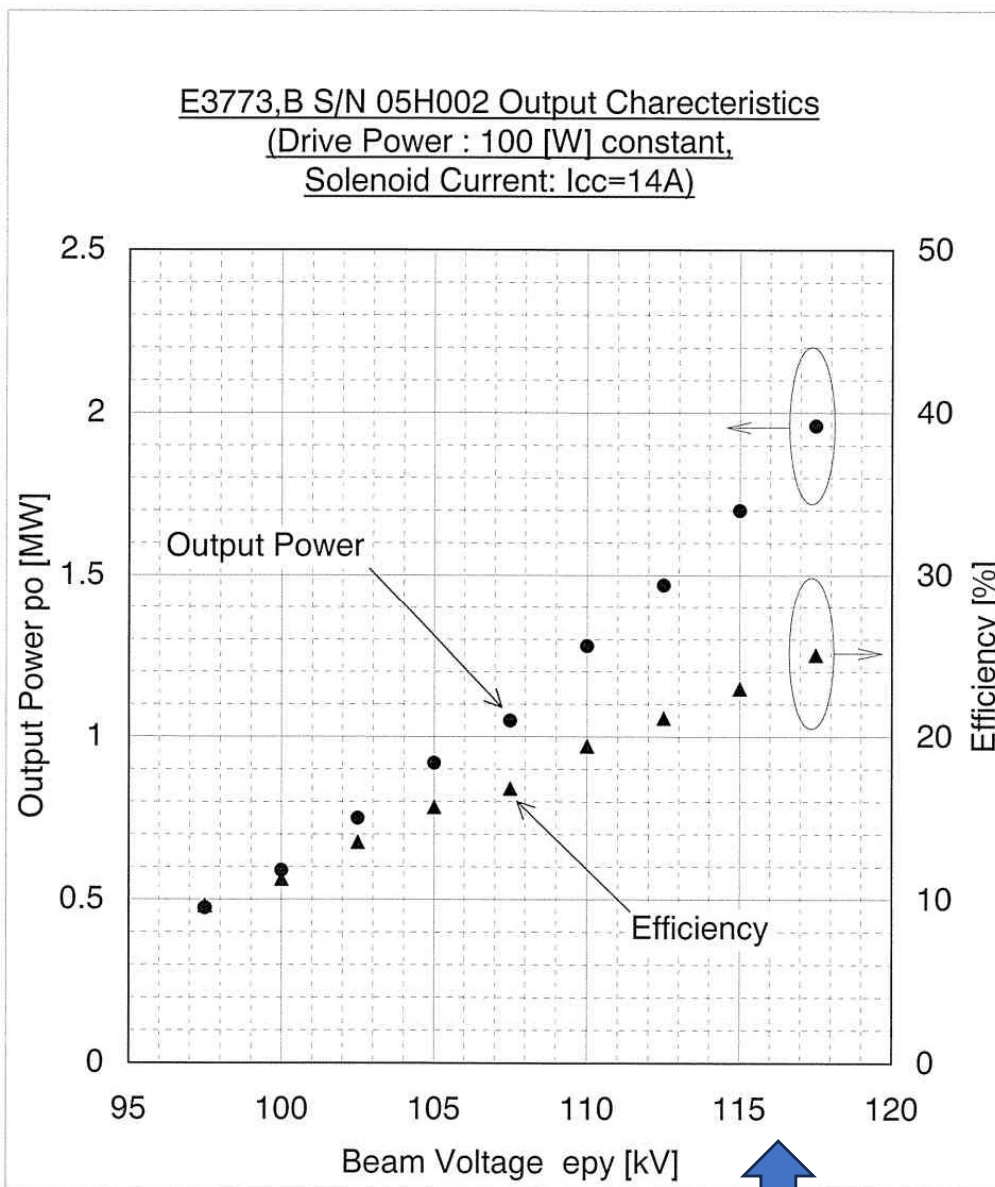


Structure	On-axis standing wave type
Material	OFHC
Accelerating tube length	80 cm 30 cells
Frequency	5712±0.1 MHz
Q <sub>o</sub>	11,000
Shunt impedance	75 MΩ/m
Energy gain (1 pass)	10 MeV @1.9 MW, 15 MeV @4 MW

# Klystron: High-power microwave amplifier



Klystron  
E3773,B Toshiba(Canon)



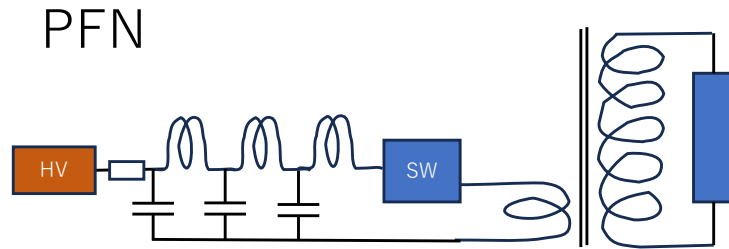
Energy gain: 10 MeV

# High voltage pulse generator

2 MW Klystron

– 120 kV 65 A

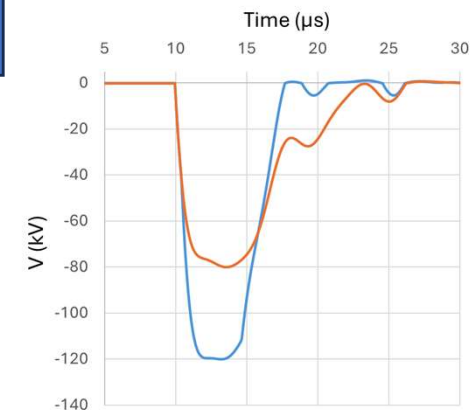
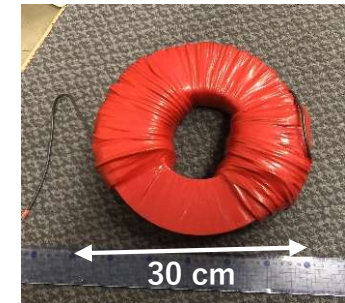
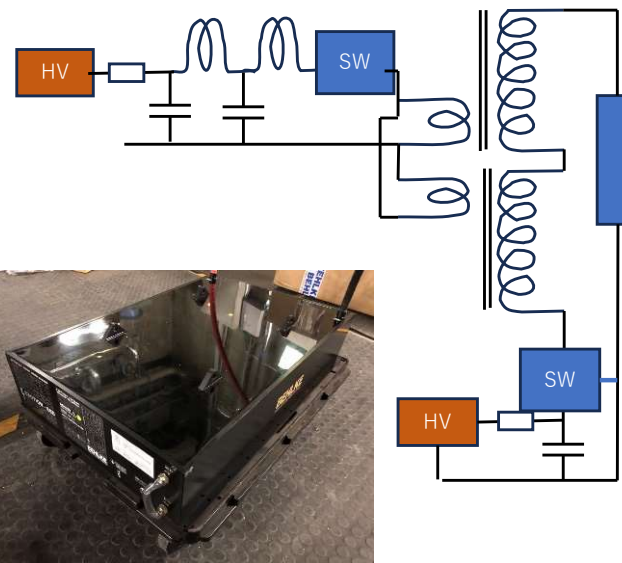
## Conventional method



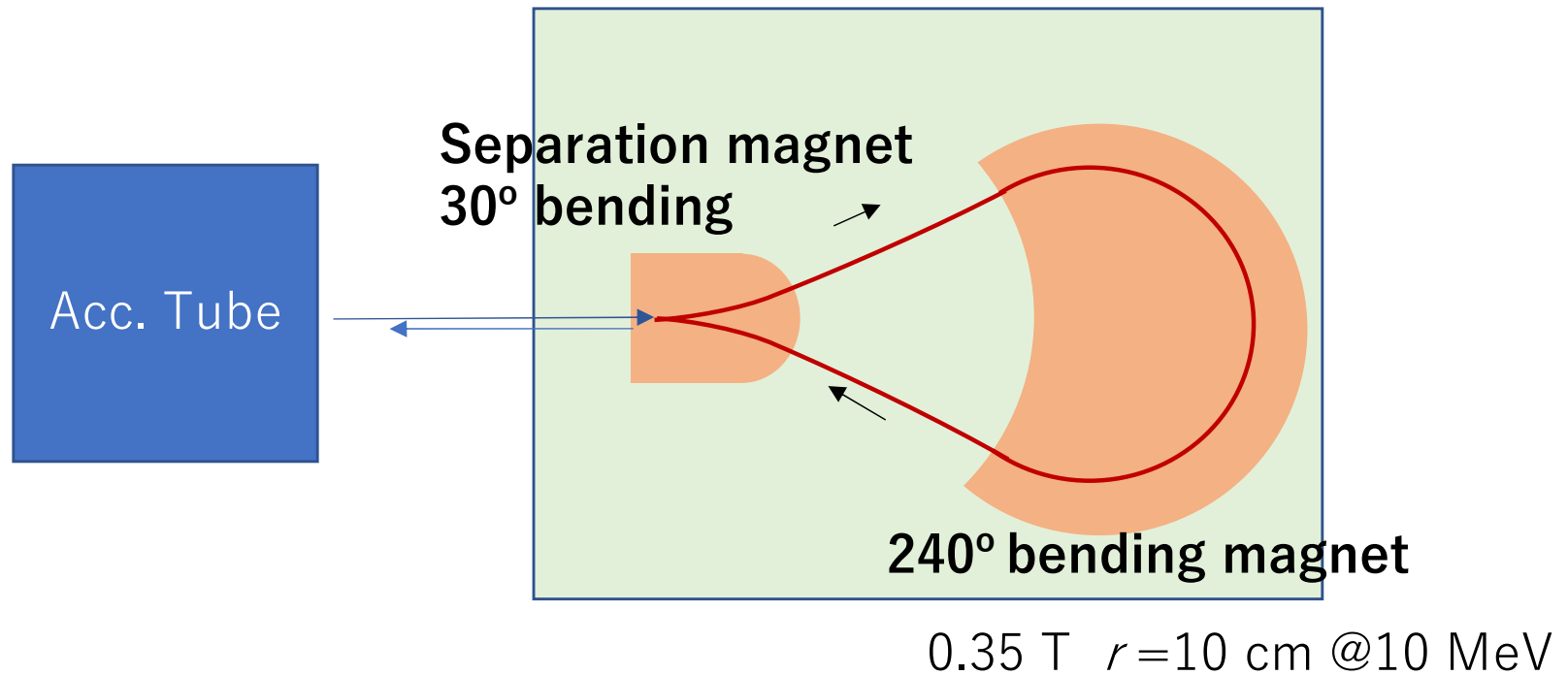
Large HV transformer is required

## Developed method

PFN with 2 transformers  
+  
Switched capacitor booster



# Returning magnets (energy selector)

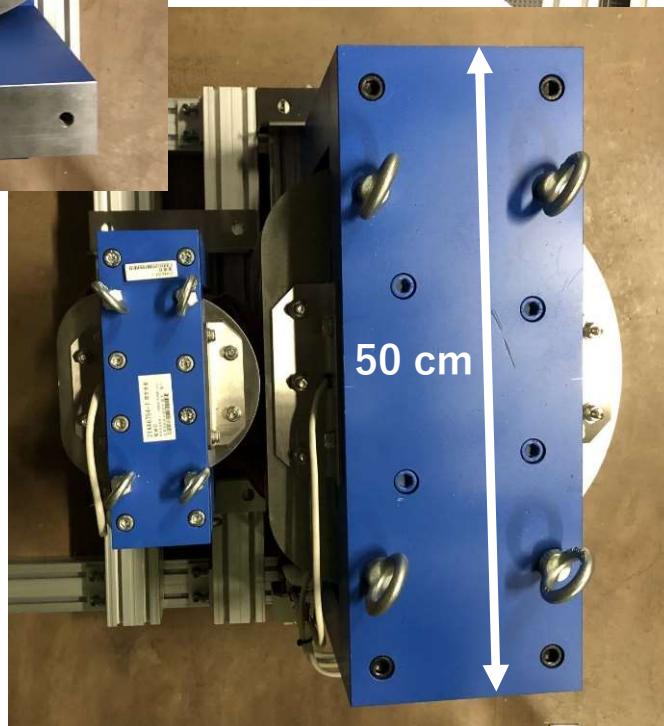
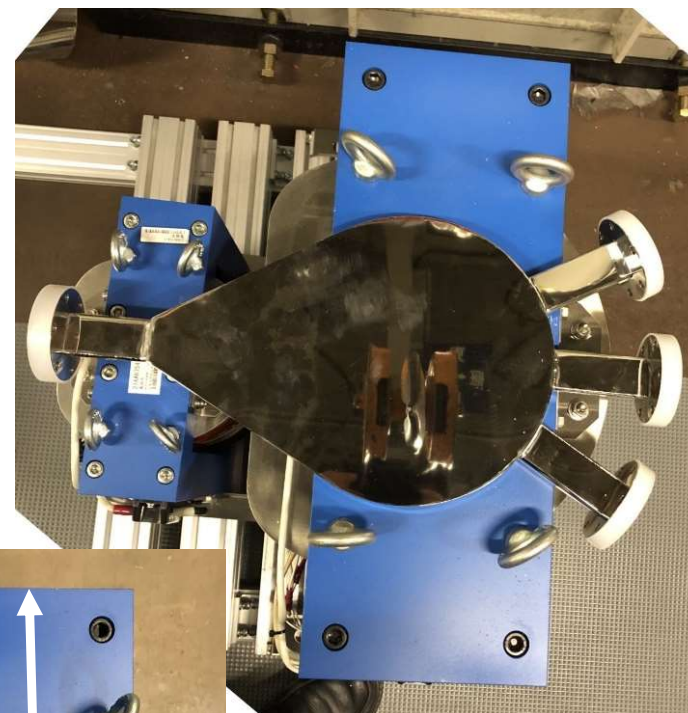
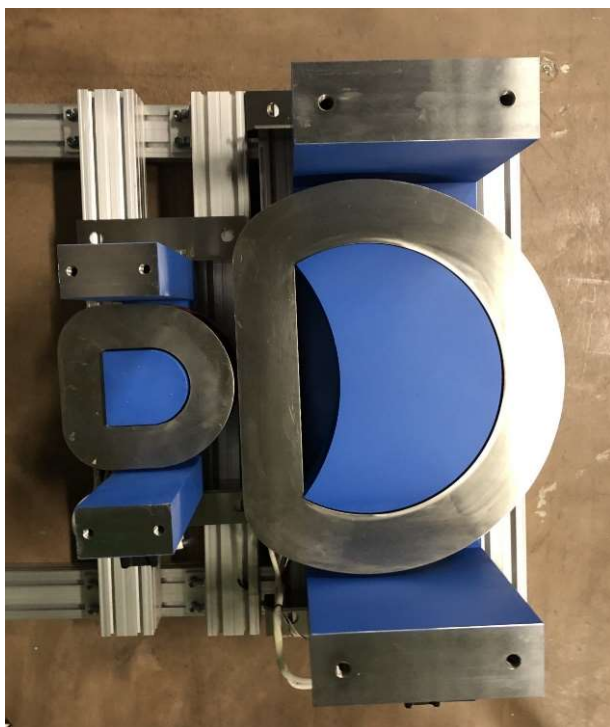


The flight distance can be changed by adjusting the magnetic field.

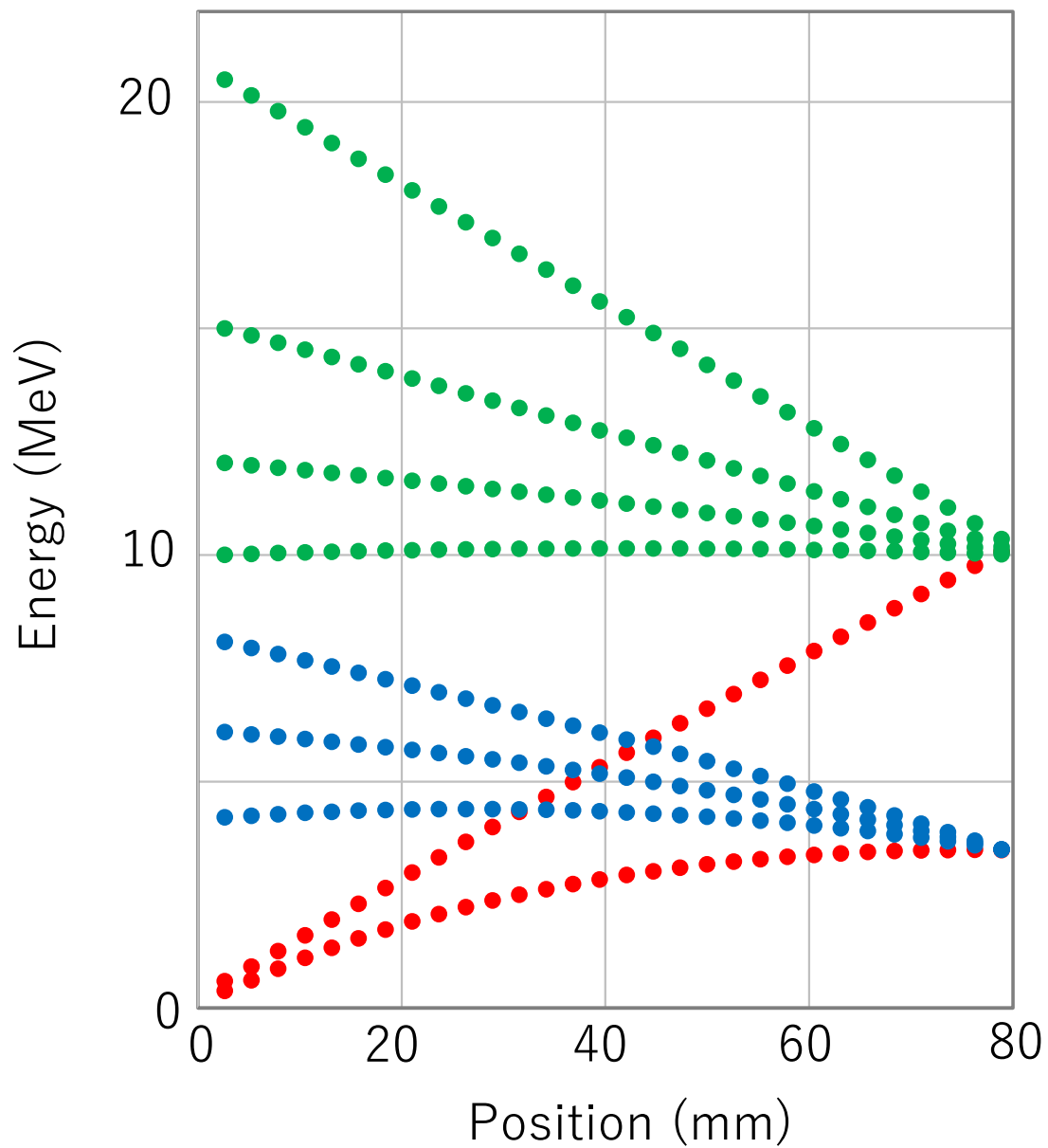


Accelerating phase of returned electrons is adjustable.

# Returning Magnets

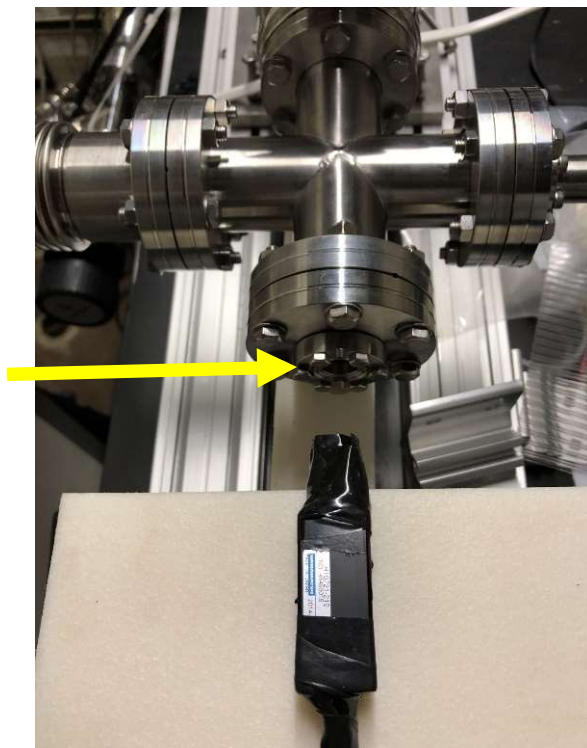


# Electron Energy in the Accelerating Tube

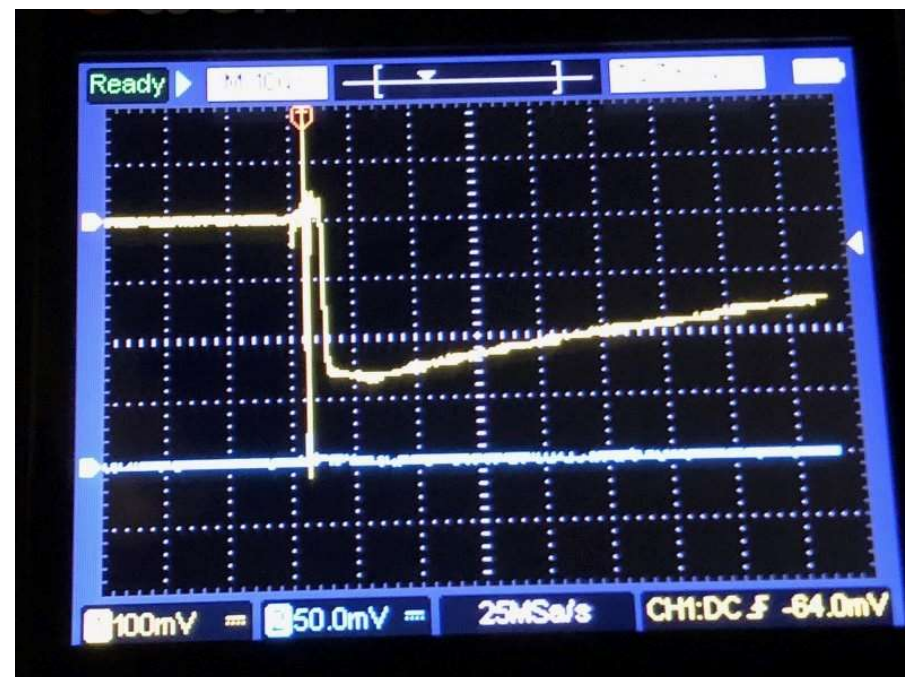


# Acceleration experiment (one way)

Exit port  
Ti window



Plastic scintillator  
and PMT

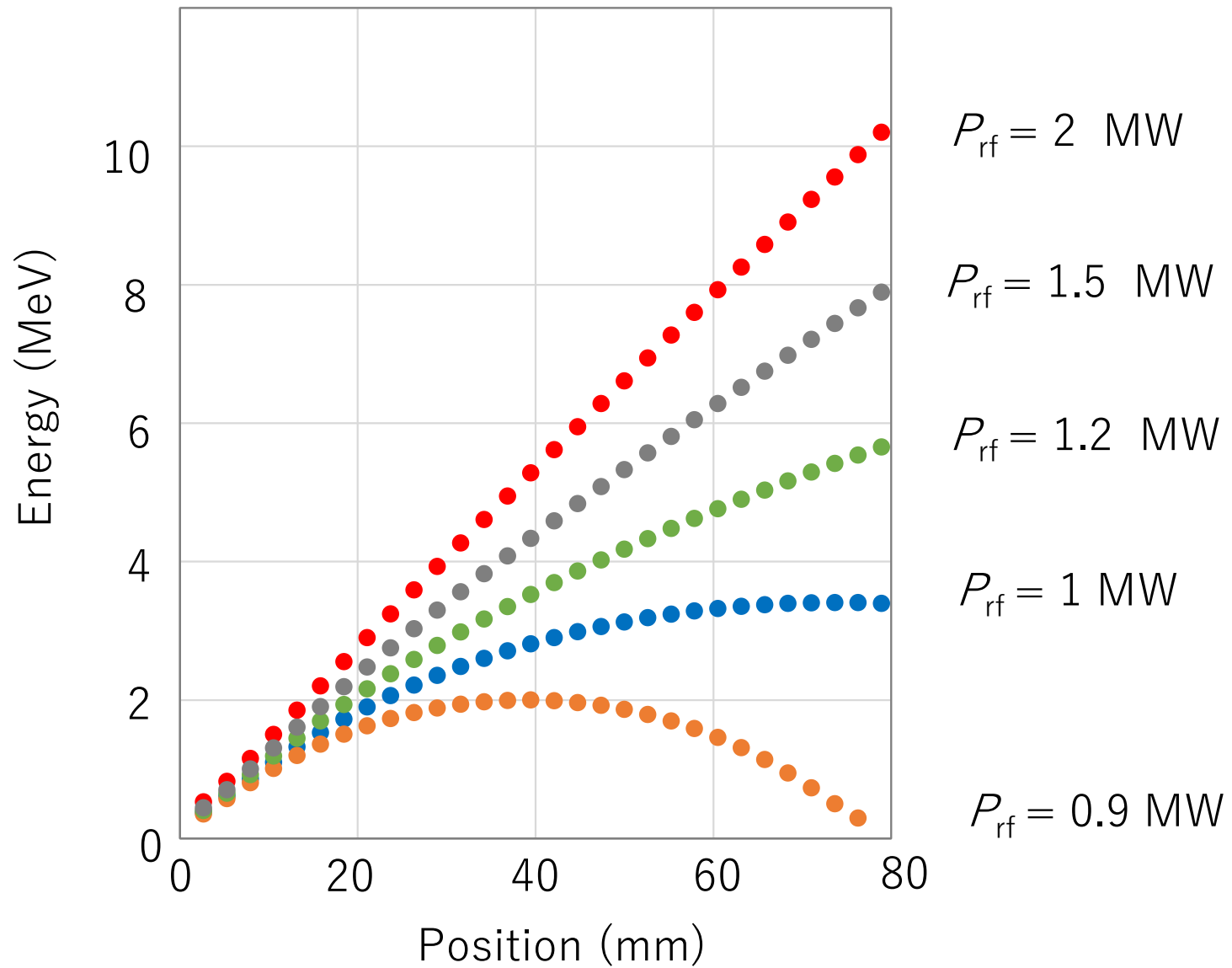


With 1 mm PE plate

We observed accelerated electron signal  
when  $P_{rf} > 1$  MW.

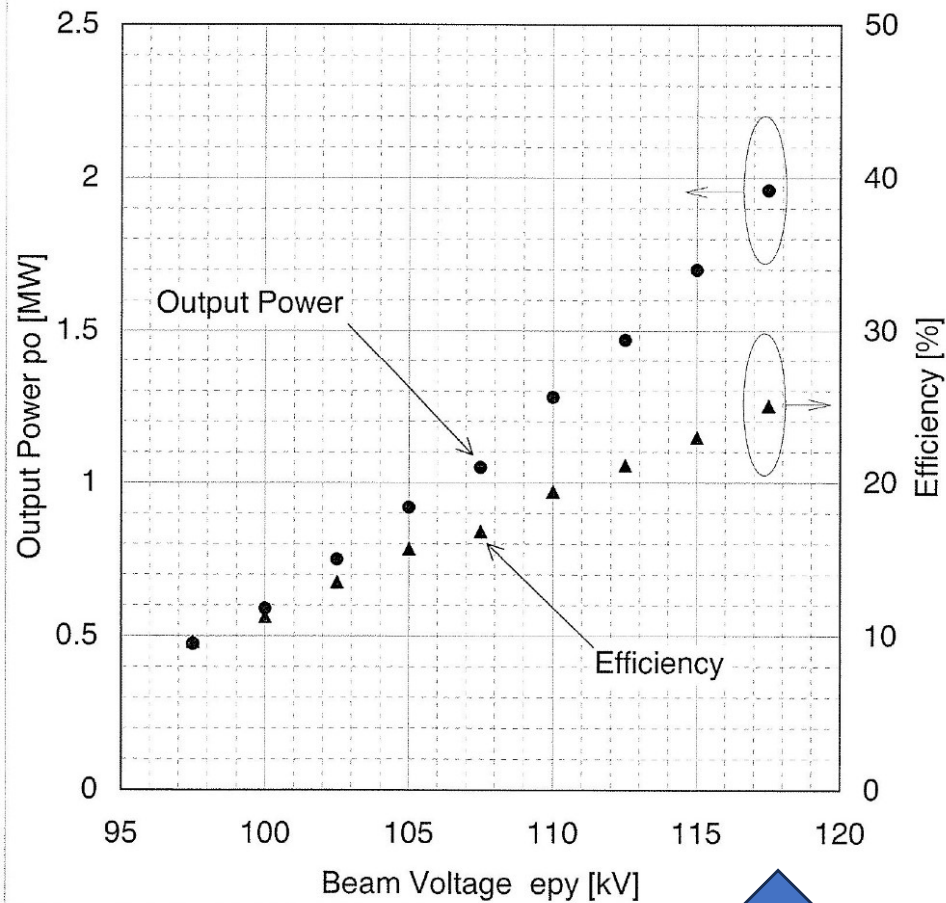


# Electron Energy in the Accelerating Tube



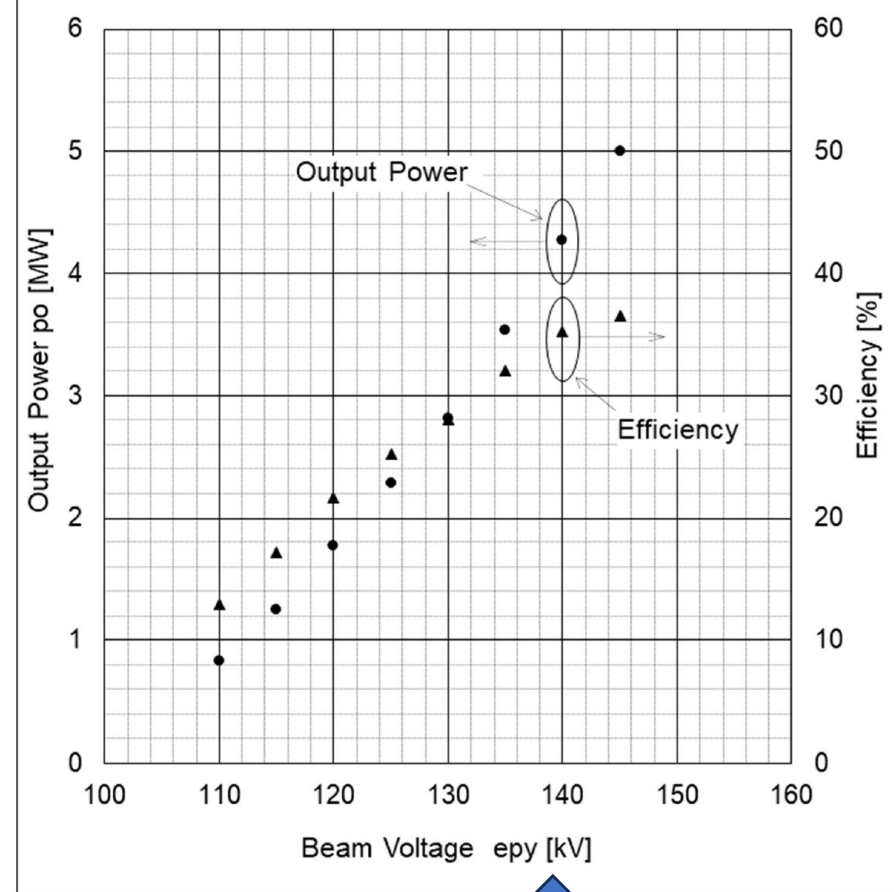
# C-band Klystron E3773

**E3773,B** 120 kV 65 A



$\delta E$ : 10 MeV

**E3773,D** 140 kV 90 A

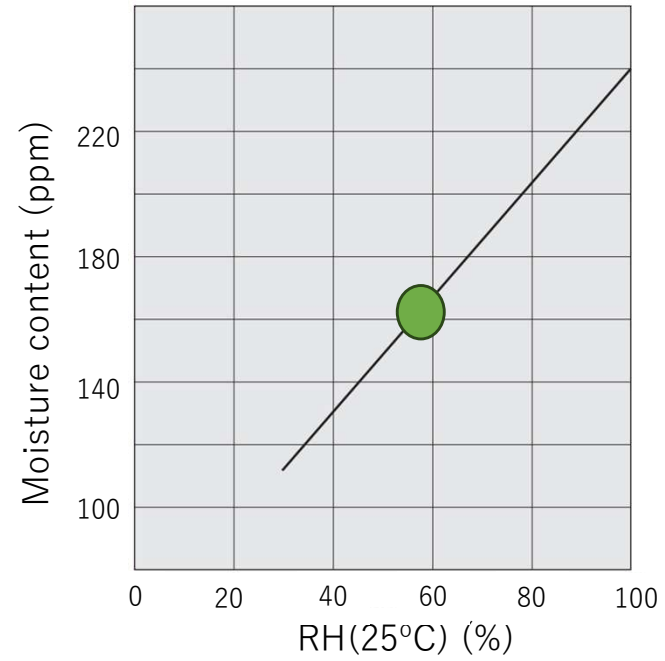


$\delta E$ : 15 MeV

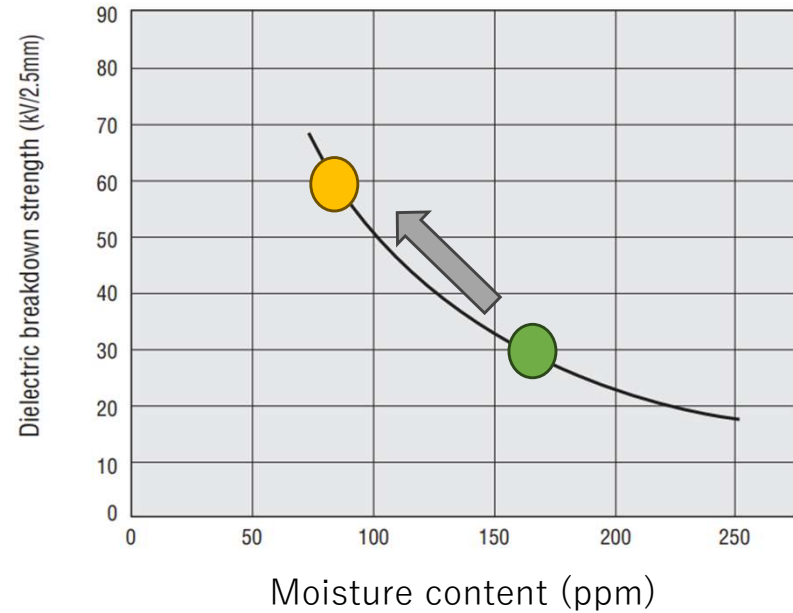
# Klystron tank



## Silicone oil (KF96)



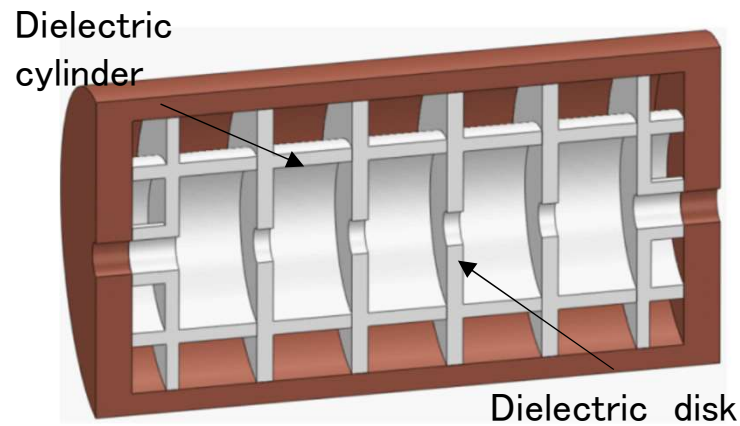
Moisture content and relative humidity



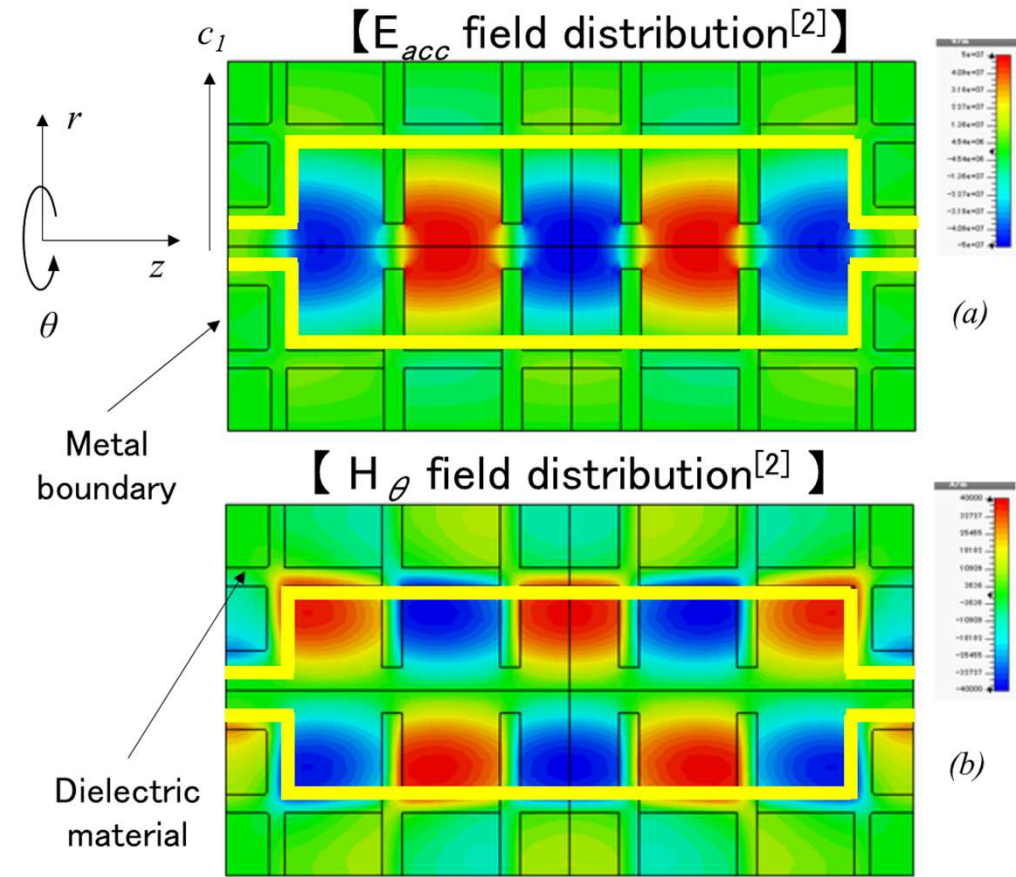
Moisture content and dielectric breakdown strength

# Dielectric Assist Acceleration (DAA)

## 【Conceptual diagram of DAA structure】



- DAA consists of **dielectric cylinders and disks with irises** which are periodically arranged in a metallic enclosure.
  - Higher order  **$TM_{02n}$  mode** is used for beam acceleration.
- Wall loss on conducting surface is drastically reduced in DAA structure**



$TM_{01} - \pi$  mode like

**Q-value x10**

[1] D. Satoh, et al., PRAB 19, 011302 (2016)  
 [2] D. Satoh, et. al., PRAB 20, 091302 (2017)

Patent :  
 PCT/JP2016/087683

# Summary

**A compact electron accelerator (one way:10 MeV, both way:20 MeV) has been developed for calibration of the SK detector.**

**One way electron acceleration is confirmed and both way acceleration experiment will be carried out shortly.**

**We are investigating higher energy acceleration up to 30 MeV.**