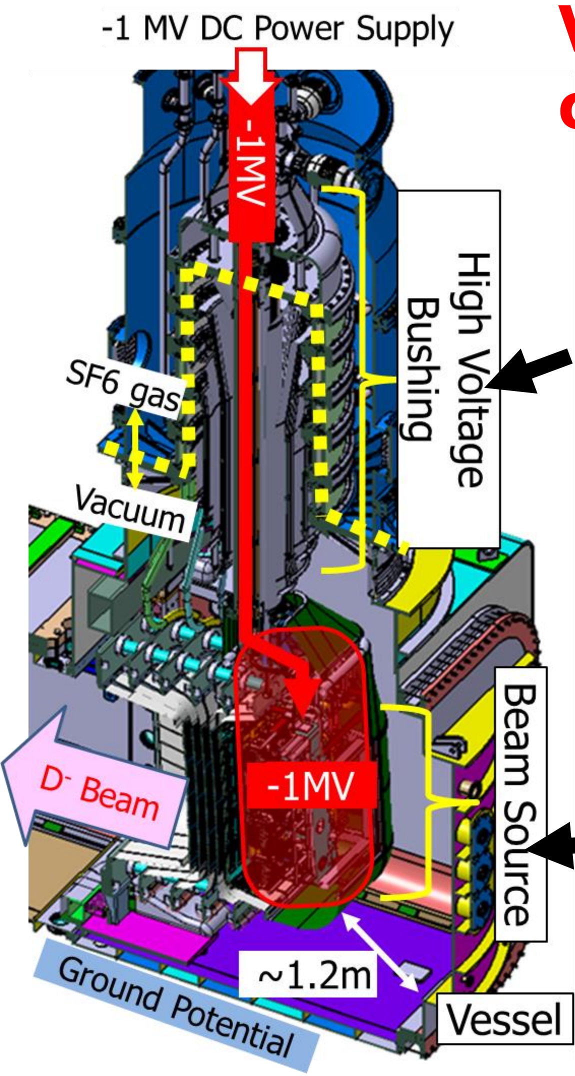
Development of the design technique with empirical scaling of vacuum insulation for electrostatic accelerators with large surface area and locally concentrated electric field for fusion application

A. Kojima, *e-mail: kojima.atsushi@qst.go.jp*
H. Tobari, N. Umeda, M. Kashiwagi, M. Ichikawa, J. Hiratsuka, and Y. Yamano[1]
National Institutes for Quantum and Radiological Science and Technology, Naka, Ibaraki 311-0193, Japan
[1]Saitama University, Saitama, Saitama-ken 338-8570, Japan

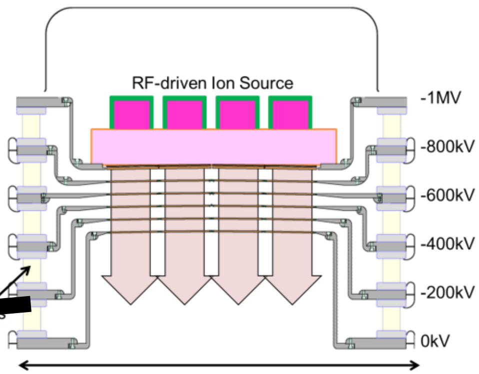
ITER requires 1 MeV, 40 A D- ion beams.



Vacuum insulation of 1 MV is one of critical issues.

High Voltage Bushing

・5-stage coaxial electrodes (~6m^2)



Accelerator for Beam Source

・5-stage plane/coaxial electrodes (~5m^2) having corner region

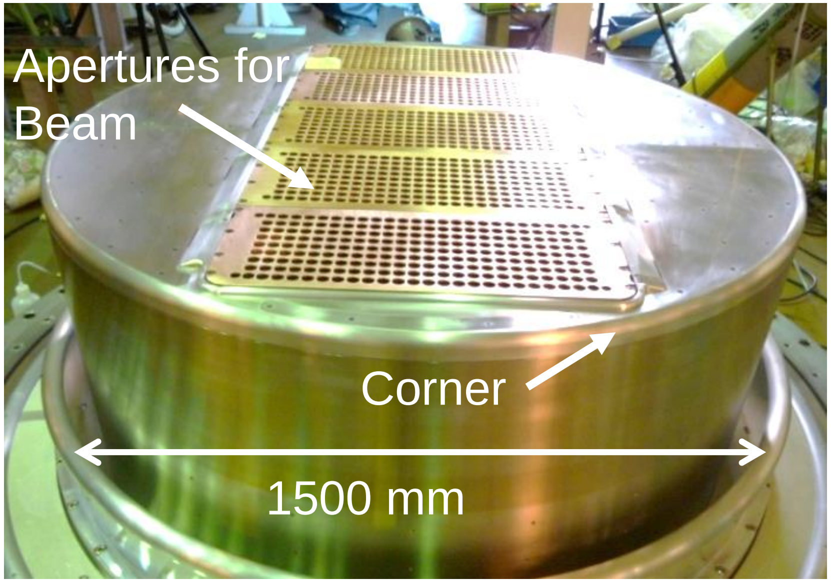
・nested structure

Vacuum Insulated Beam Source

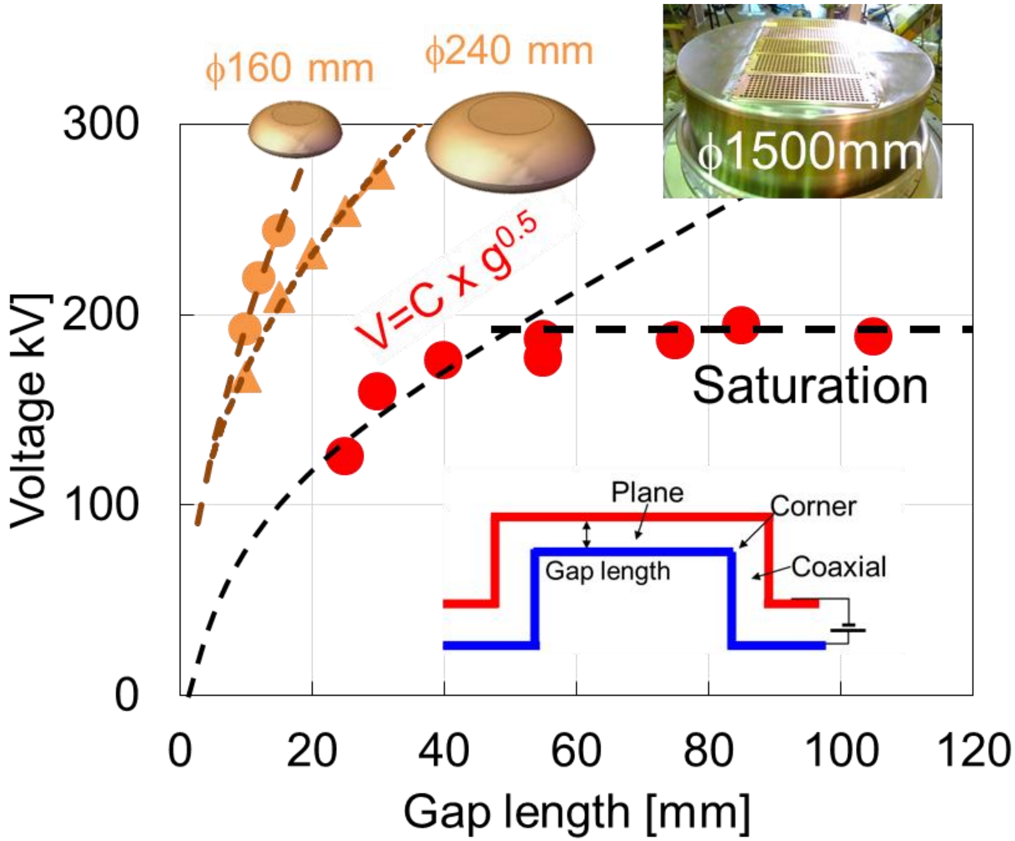
・1 MV Vacuum insulation with long gap length (1.2 m).

Long gap insulation of large size plane/coaxial electrodes with locally strong electric field. →Needs for Empirical scaling, design technique

Starting point of our HV study



An acceleration grid of an accelerator for fusion



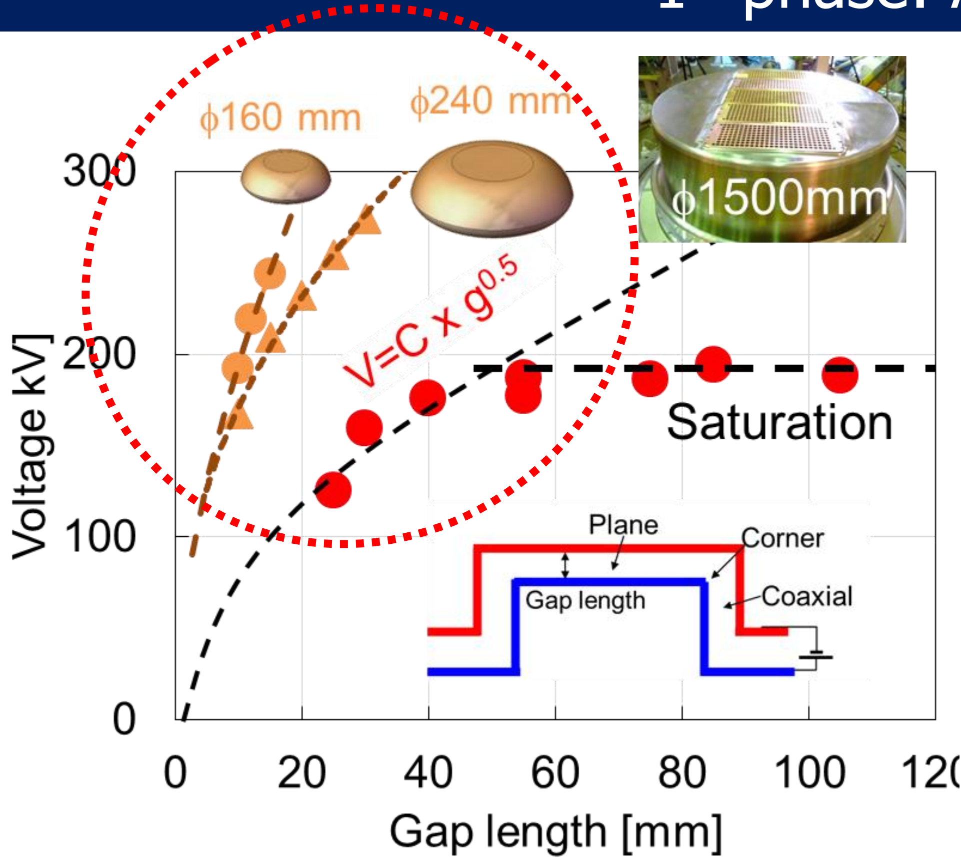
<Starting point>

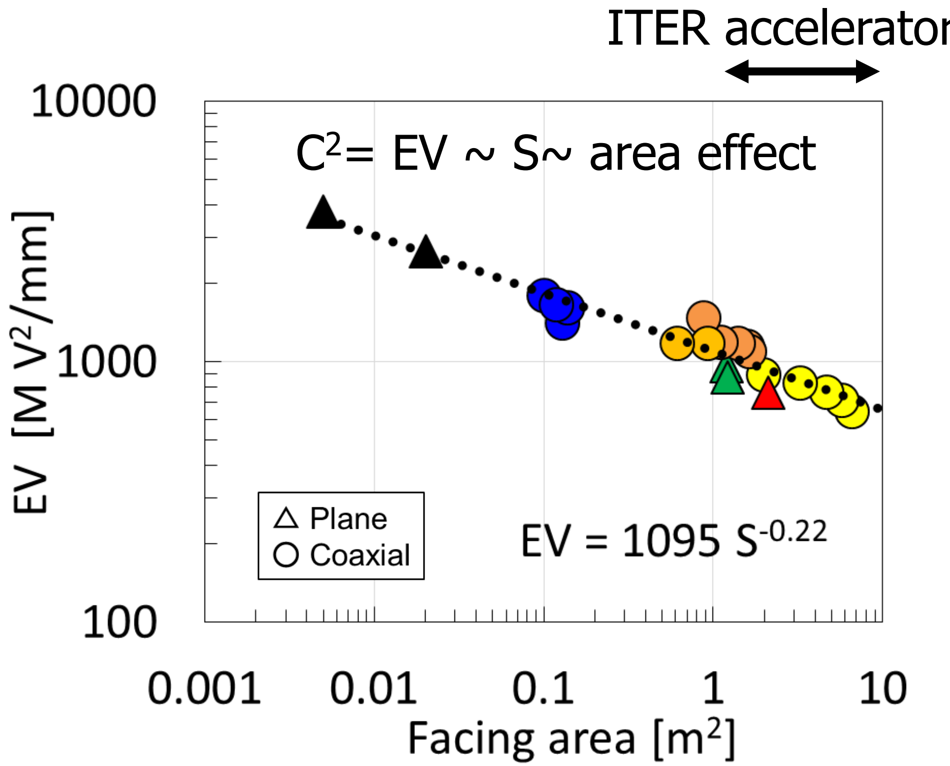
An electrostatic 3-tage accelerator used for Japan's fusion machine (JT-60) could not achieve the rated voltage due to BD at the acceleration grid.

We started the HV test by using small and large electrodes in order to understand the voltage holding capability of electrodes.

- Gap dependence of the acceleration grid has 2-phase,

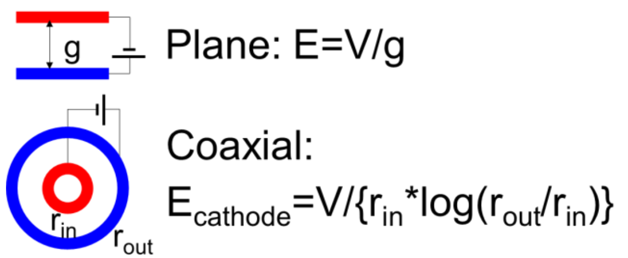
1st phase: Area effect





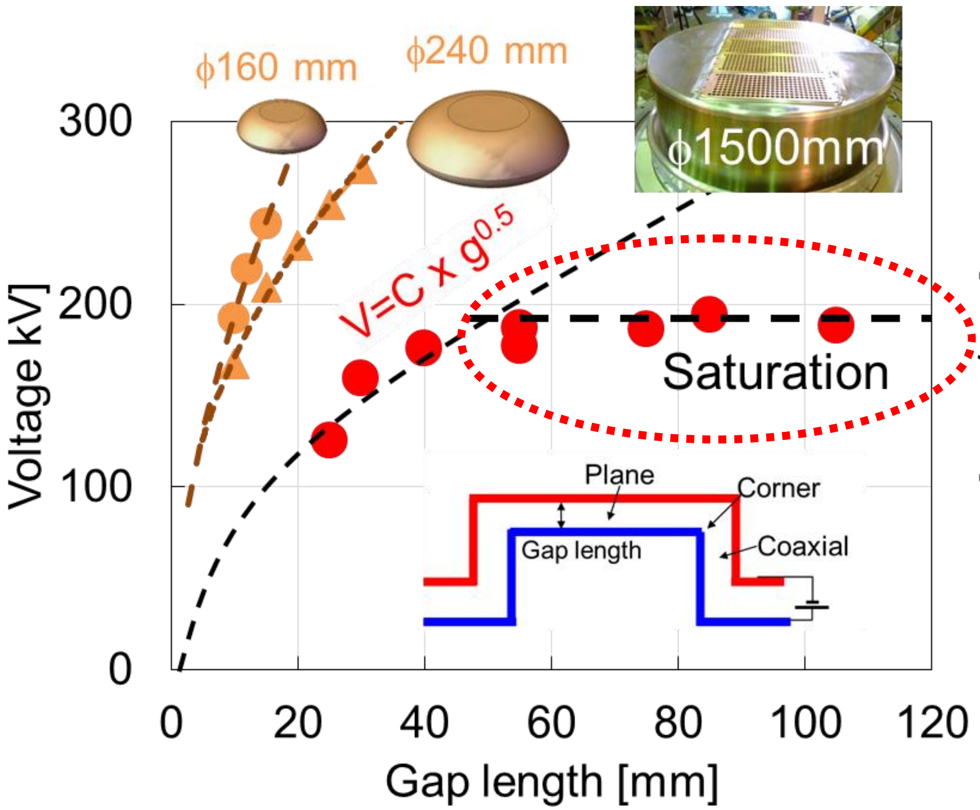
<1st phase : relatively short gap>

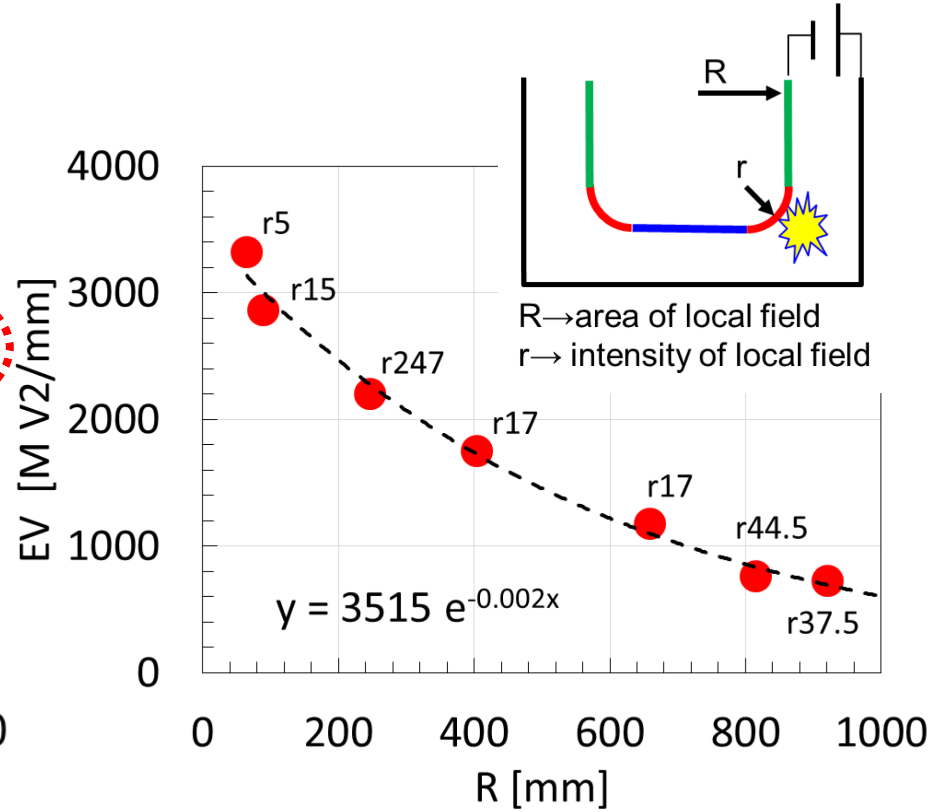
- V increases with gap$^{0.5}$($V=C \times g^{0.5}$)
- C is decreased with surface area. → Area effect
  $C=V/g^{0.5}$, $g=V/E$, $C^2=EV$



Area effect of sustainable EV has been investigated by using Plane(<ϕ1500) and Coaxial electrodes(R<400) in a wide rage of 0.005 - 6.7m^2.

2nd phase: Corner effect





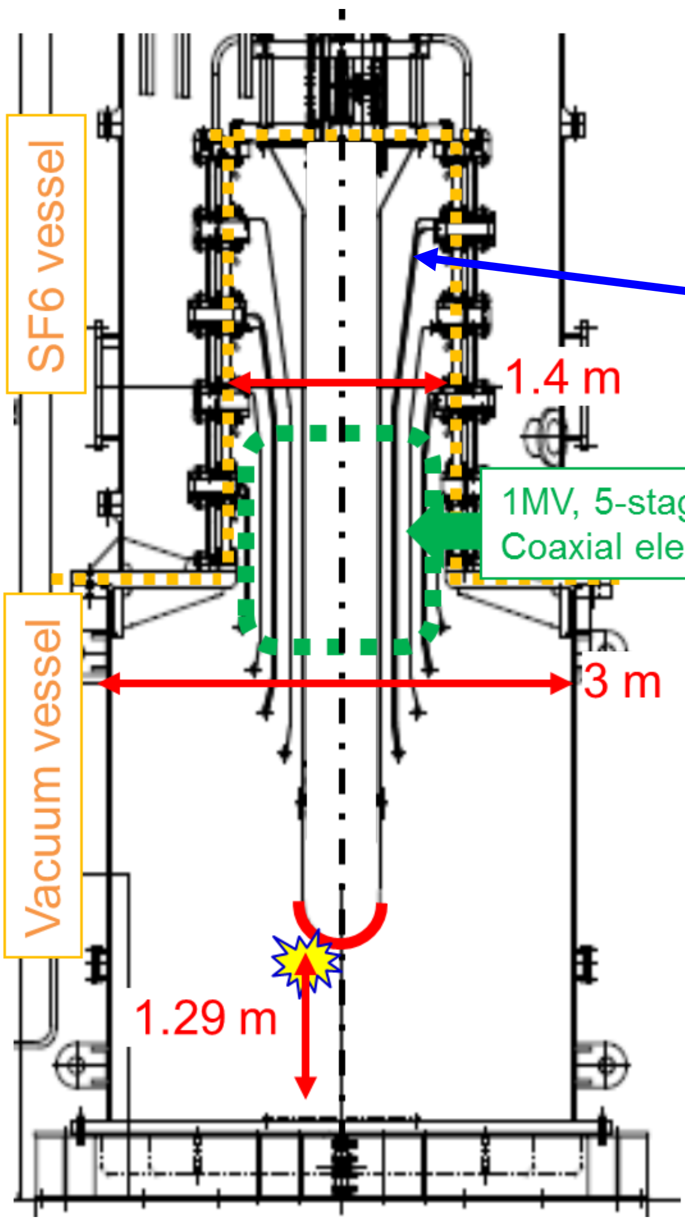
<2nd phase: longer gap>

- V is almost saturated by BD at the corner

→ Saturation due to electric field determined by the configuration

Empirical scaling of the saturation value (EV) at the corner region has been obtained by changing R/r of electrodes.
(Area effect is also seen for local electric field.)
By using these empirical scaling, plane/coaxial electrodes can be designed.

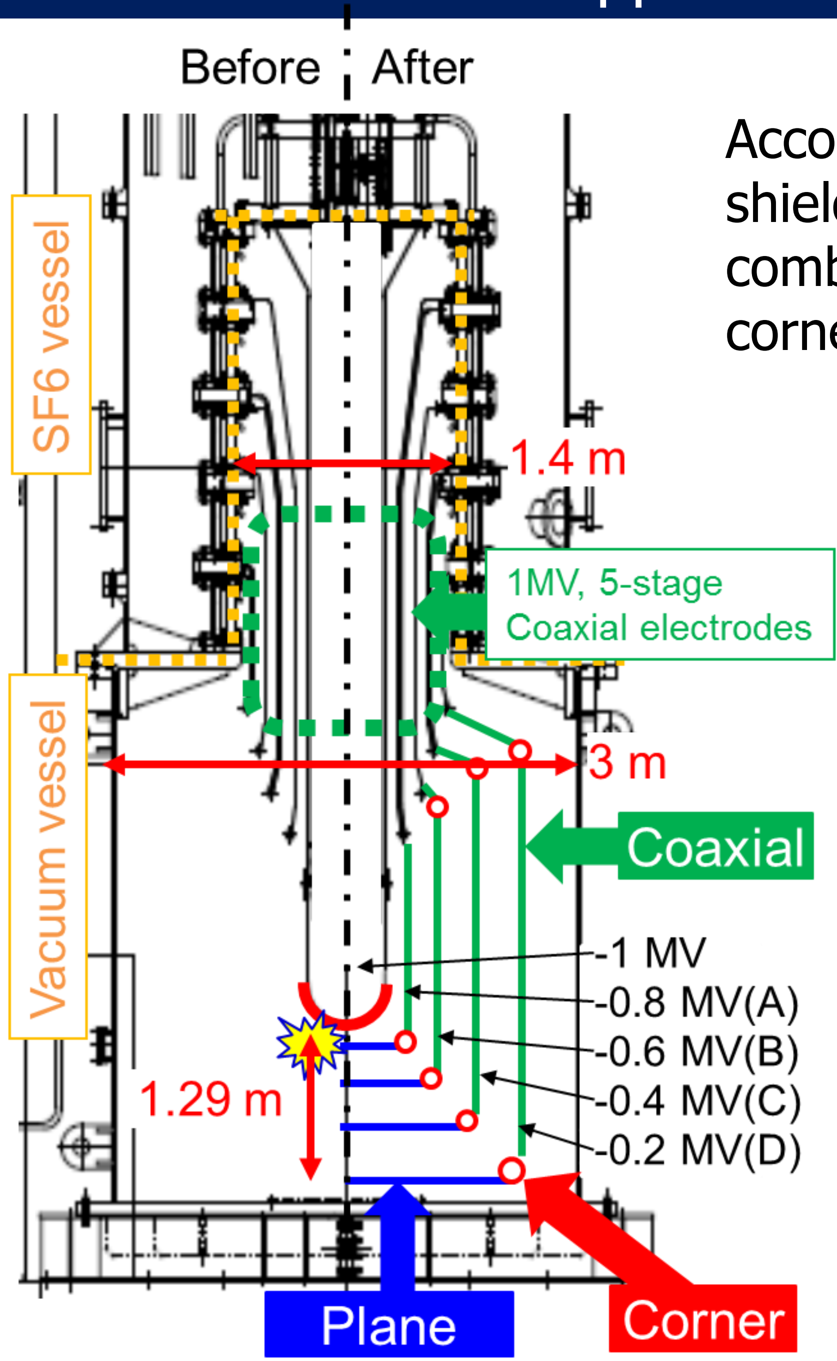
An application of empirical scaling



In the vacuum HV test for only the high voltage bushing aiming for 1 MV, BD occurred at 700 kV at the long gap insulation of 1.3 m between center electrode and the vessel.

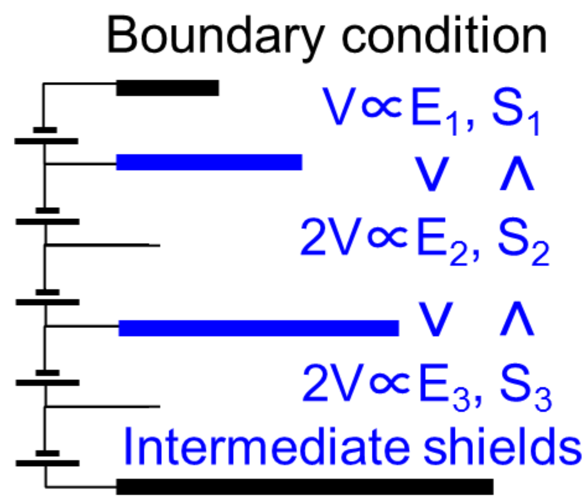
The intermediated shields has been designed by applying the empirical scaling.

An application of empirical scaling

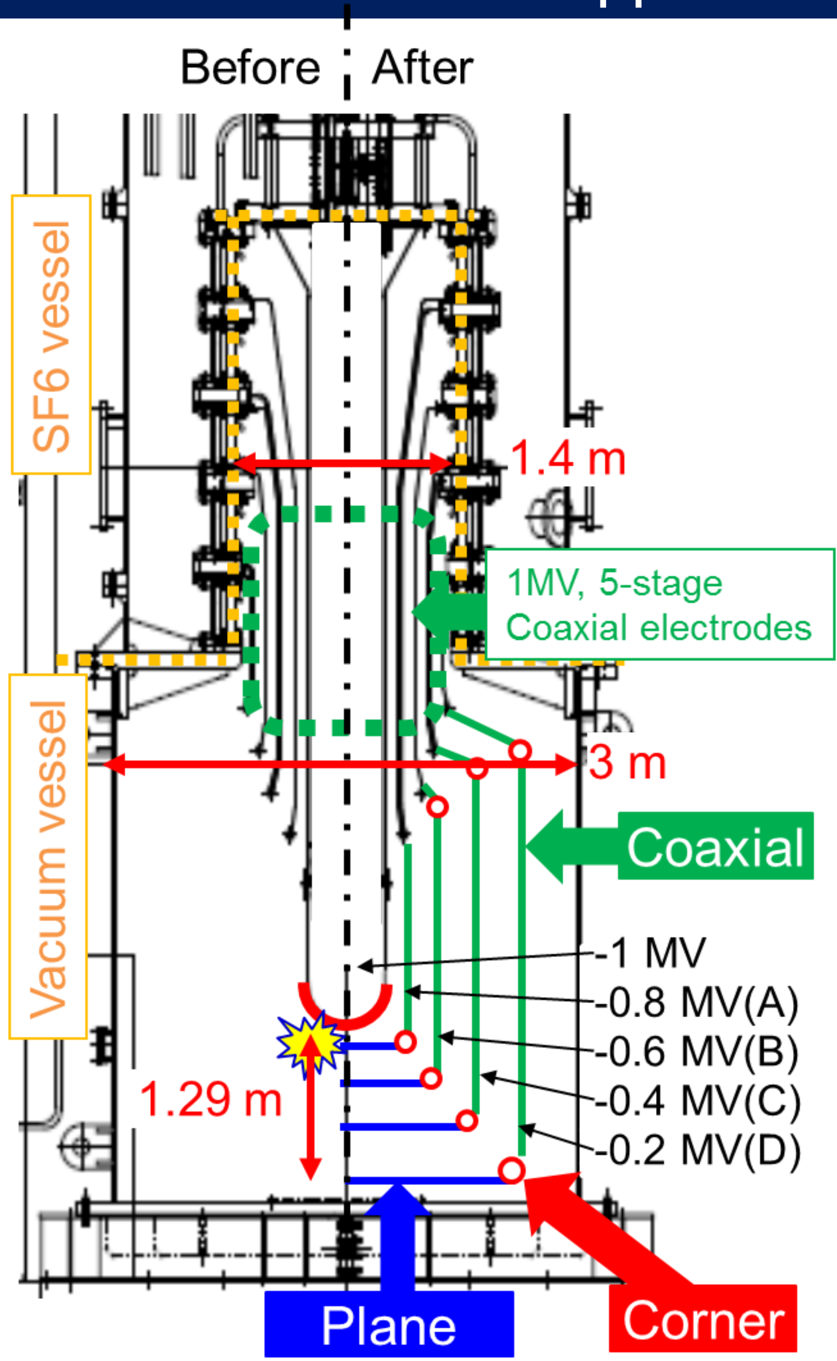


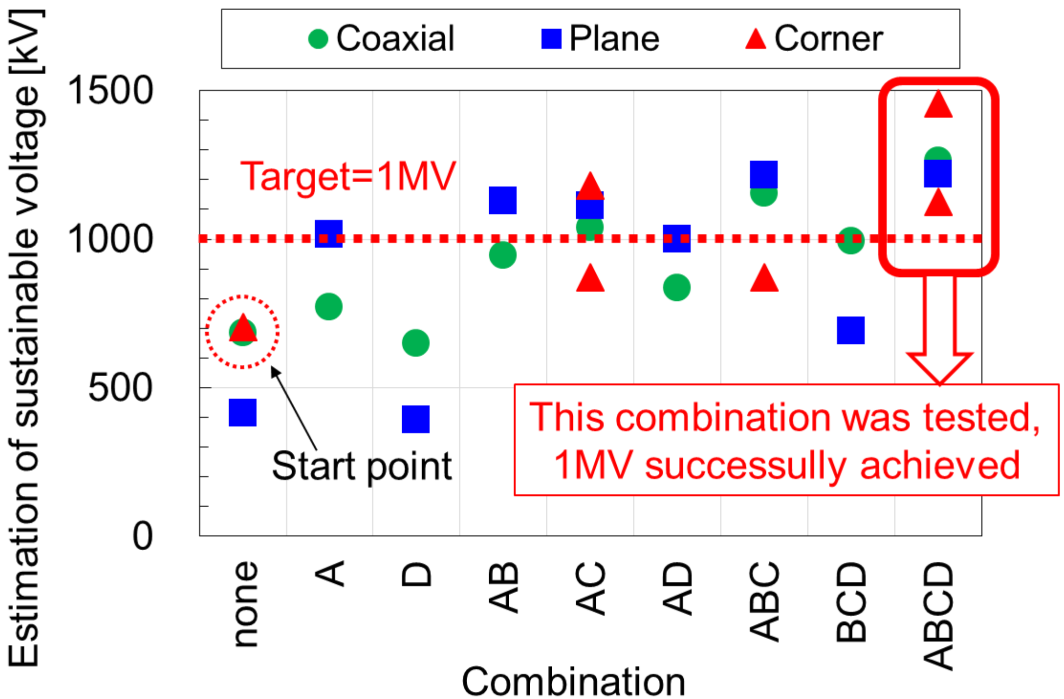
According to the empirical scaling, intermediate shields has been designed, which was combination of plane/coaxial electrodes with corner.

In addition,
Voltage holding capability is maximized by adjusting E depending on the surface area on each stage, within the boundary condition, by using the empirical scaling.



An application of empirical scaling





The empirical scaling can give us the quick-analysis of the voltage holding capability.

Finally, the combination of 5-stage shields has been tested experimentally, and 1 MV has been successfully achieved.

Summary

● Empirical scaling has been developed by testing plane and coaxial electrodes with locally-concentrated electric field.

● Reliability of the design technique has been demonstrated by achieving 1 MV with developed intermediate shields for HVB.

I would like to discuss in detail in the poster session.

Thank you for your attention.