NIBS award lecture

Development of long-pulse high-intensity negative ion beam accelerations for Fusion reactors

Mieko Kashiwagi

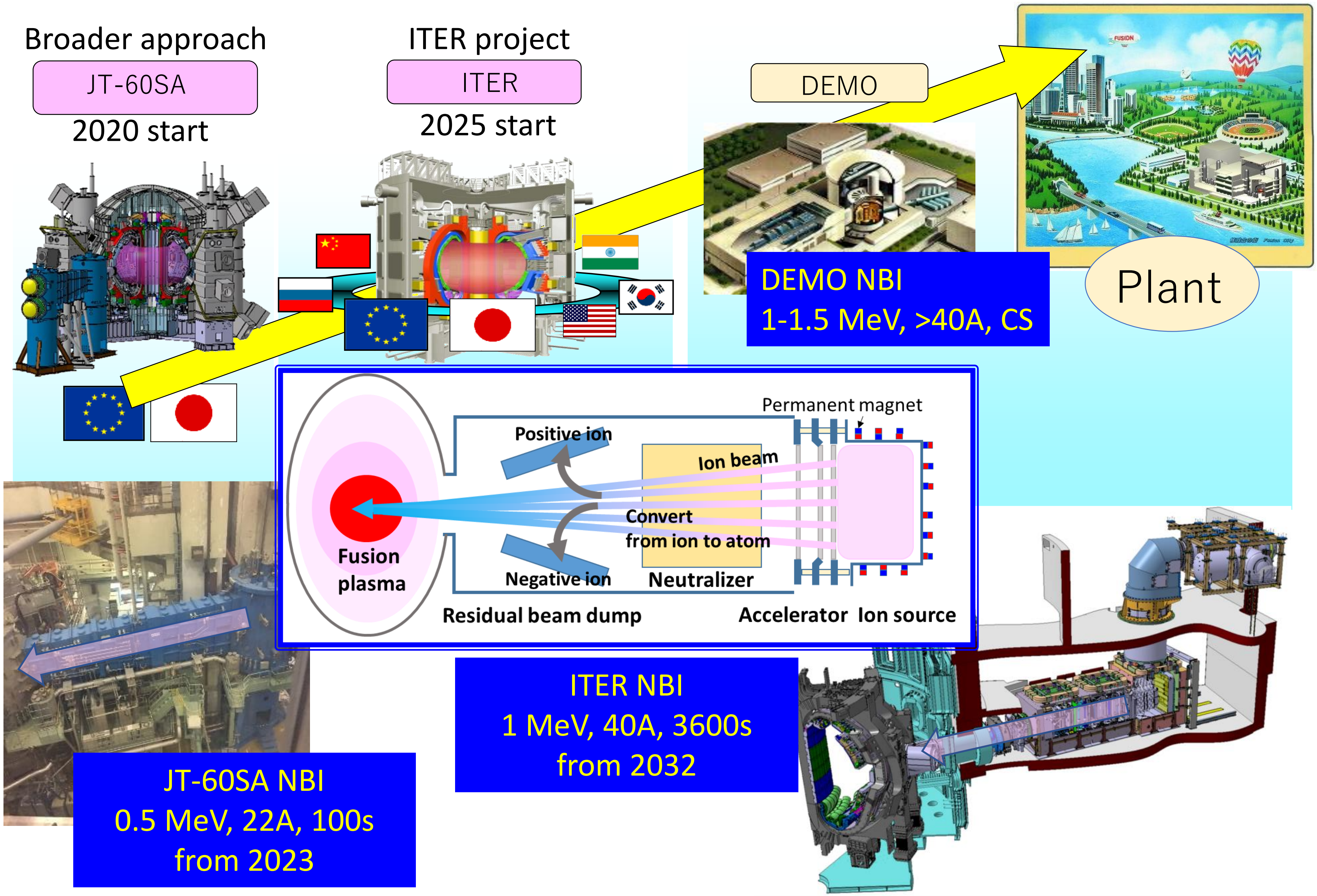
Atsushi Kojima, Junichi Hiratsuka, Masahiro Ichikawa

and NB heating technology group

NAKA fusion institute

QST, Japan

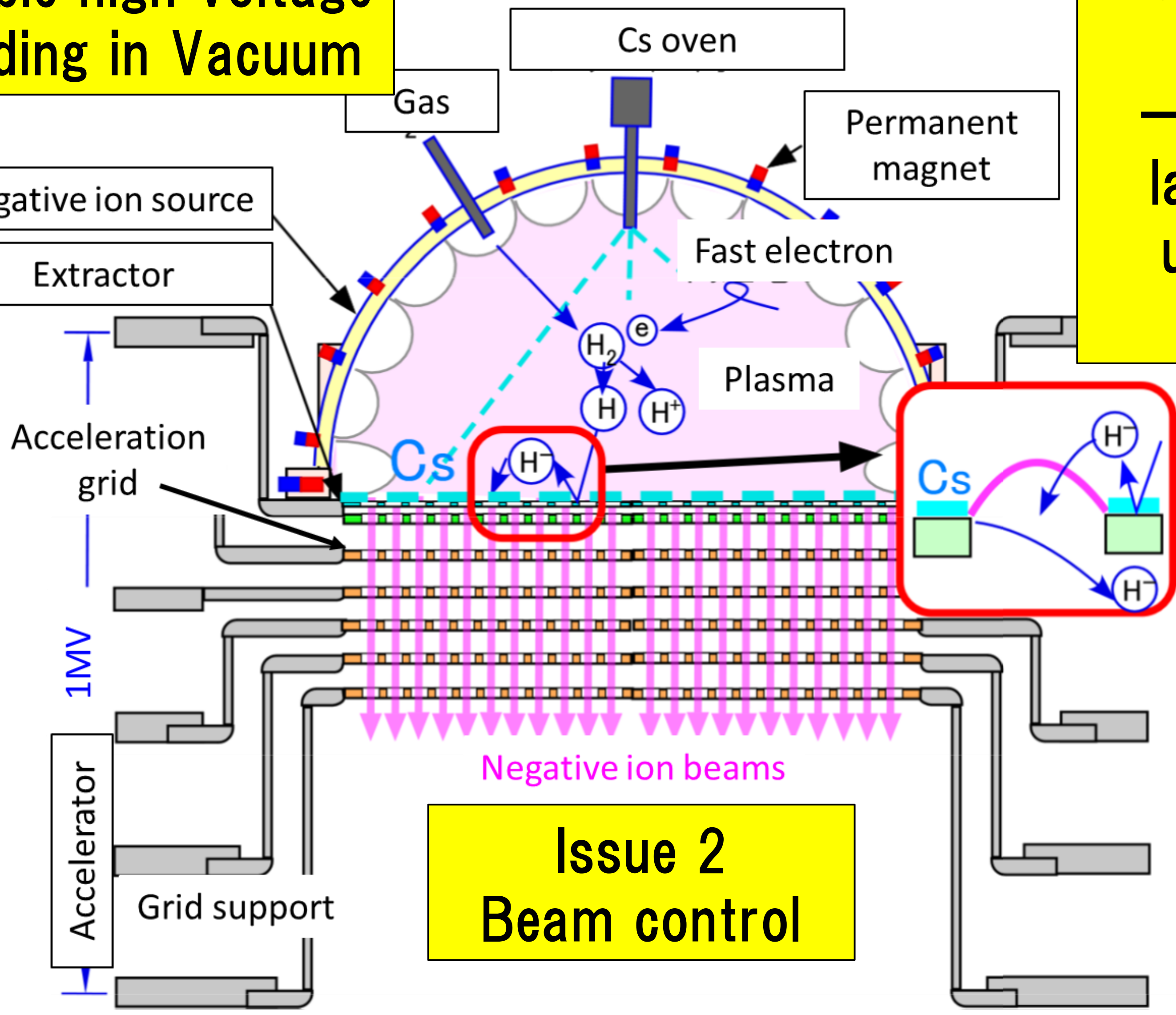
Activity of NBI for fusion reactors



Toward long pulse beam acceleration

Issue 1
Stable high voltage holding in Vacuum

Issue 3
Stable negative ion production
→Control of Cs layer on PG by understanding Cs behavior



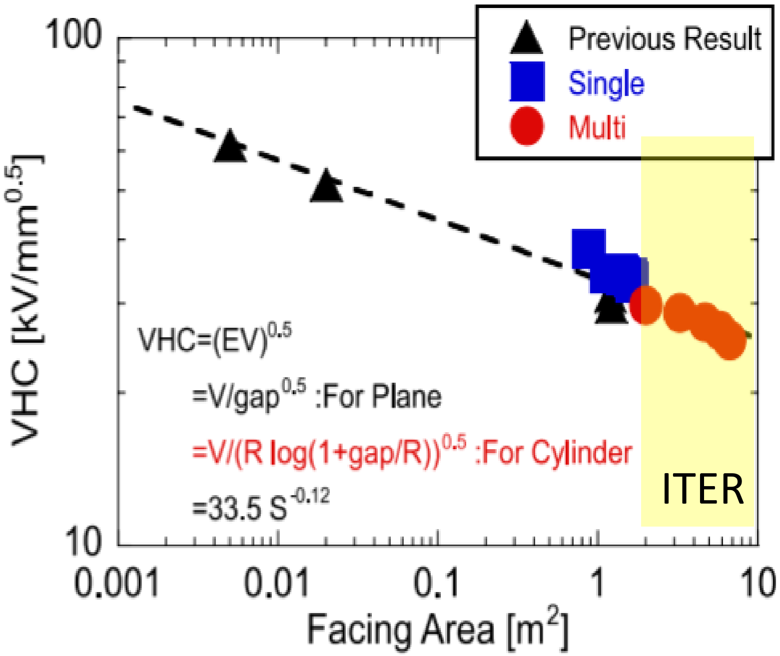
Issue 2
Beam control

Stable high voltage holding in vacuum

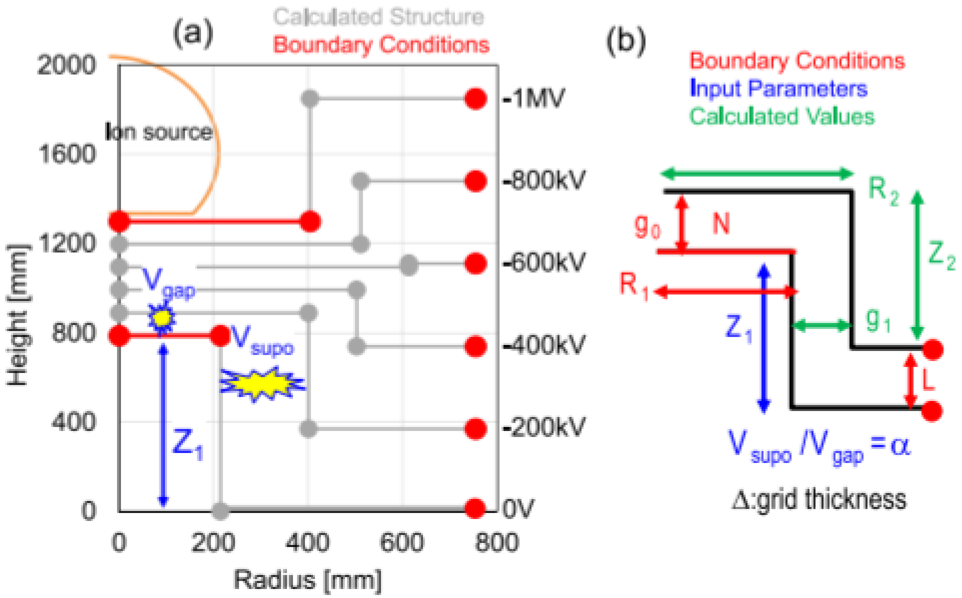
A. Kojima et al; FED. 123, p236(2017)

Originally, sustainable voltage in vacuum was 80% of the requirement.
This fact had limited to the performance of high energy beam operation.

Establishment of empirical scaling of voltage holding

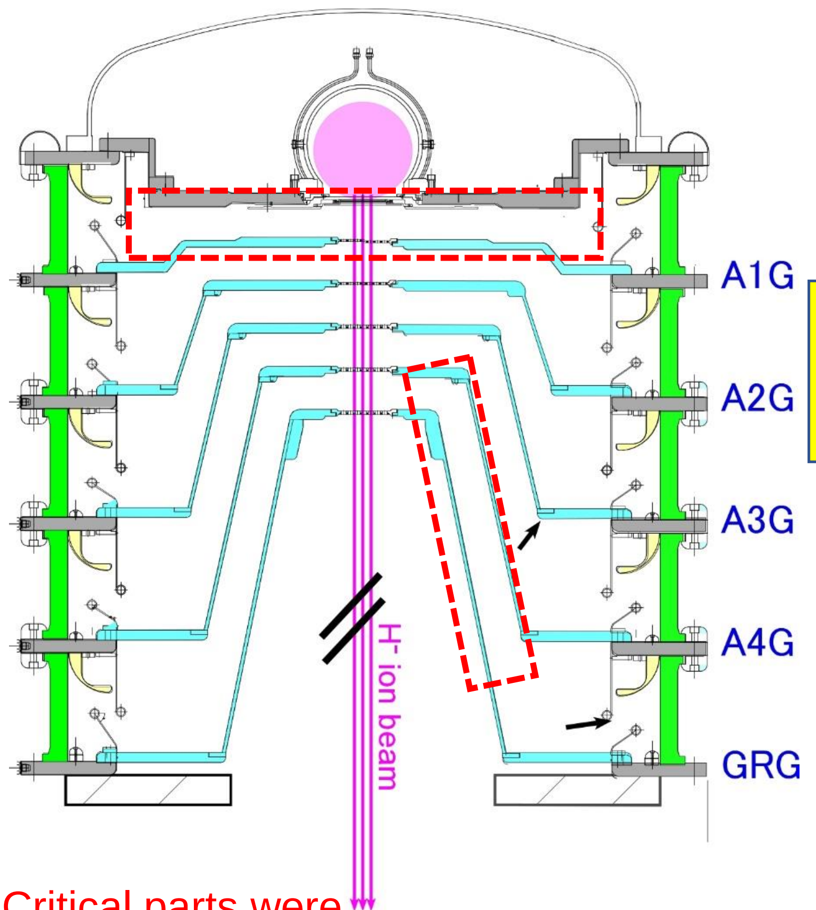


Establishment of calculation model for optimization of accelerator configuration

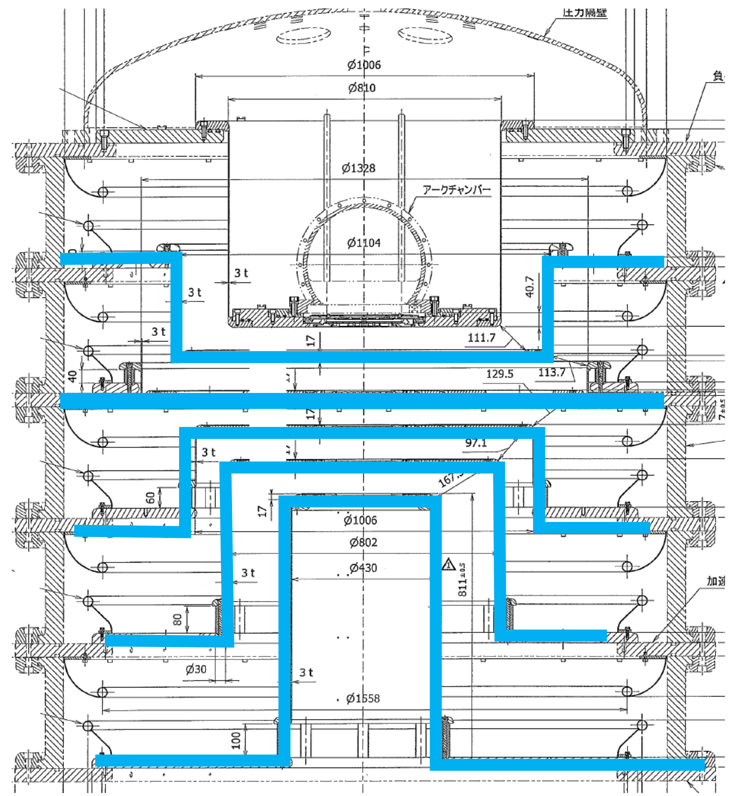


Based on various kinds of mock-up test, empirical scaling of voltage holding have been established for planer, cylinder flanges and aperture area.

Application to real five stage accelerator



Modify by empirical scaling



Critical parts were
Large planer grid (A1G) and large cylindrical (A4G)

Marginal voltage holding : 1 MV

Gap between metal → Expanded
Facing area → Decreased

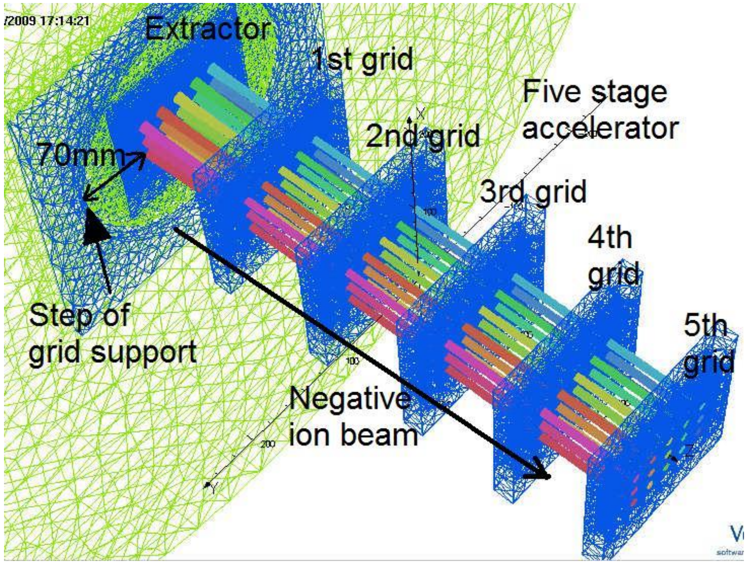
Stable voltage of 1.2 MV
including the margin of 20 %.
Stable voltage of 1MeV beam

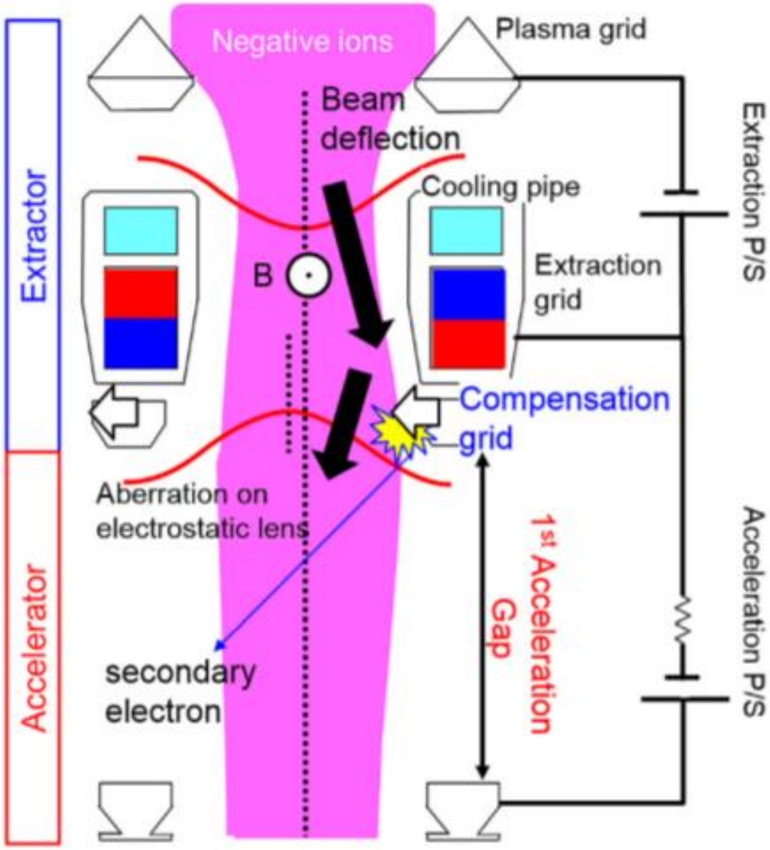
Beam control

A. Kojima et al; Rev. Sci. Instrum. 87, 02B304(2016)
J. Hiratsuka et al, Rev. Sci. Instrum. 91, 023506 (2020)

Expansion of the gap length for the voltage holding caused beam divergence.
Grid configuration has been optimized again by using the 3D beam analysis.

3D beam analysis including space charge, magnetic field, and stripping loss can be included (OPERA-3d).



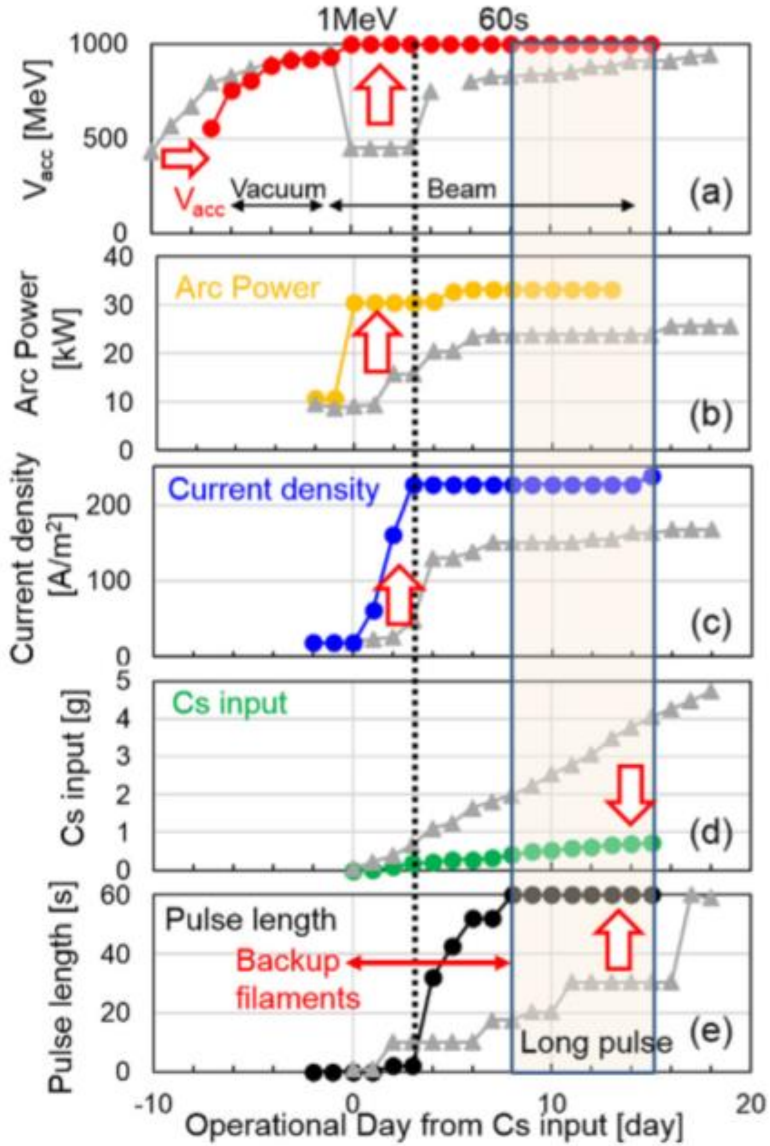


Details of grid, such as shape, aperture size etc have been changed to suppress beam deflection, secondary electron according to gap length.

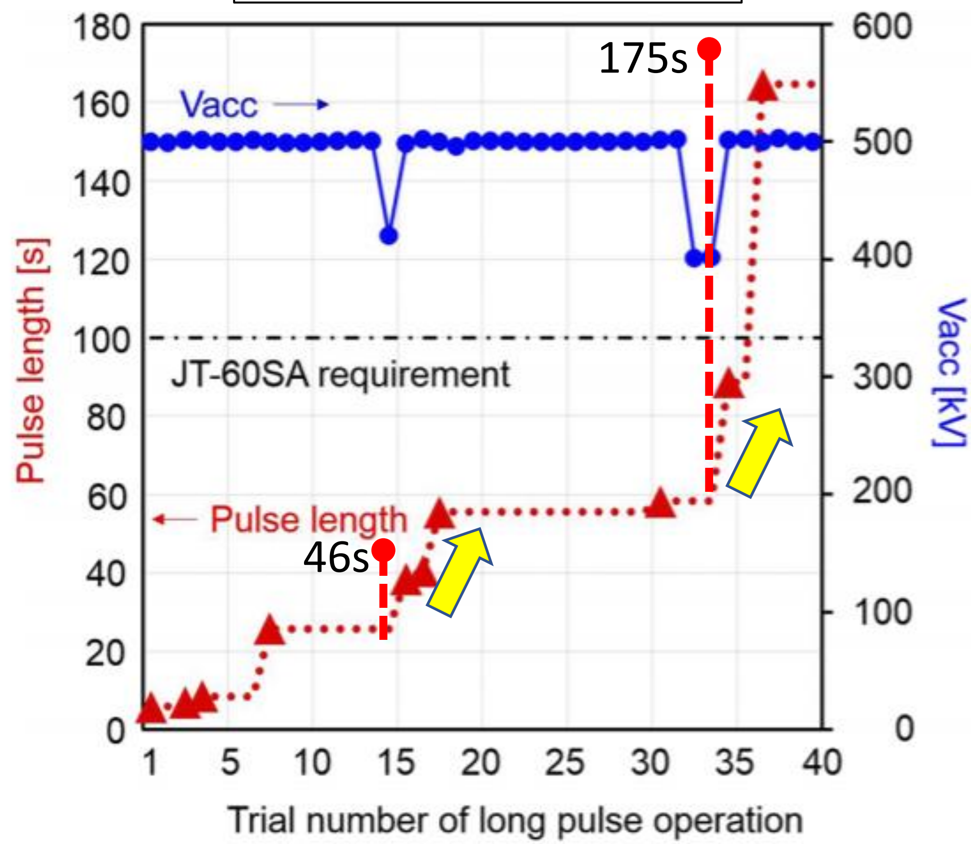
Conditioning technique

Conditioning method have been established based on the experiments.

Smooth start up



Beam conditioning with longer pulse & lower energy was effective to extend the beam pulse



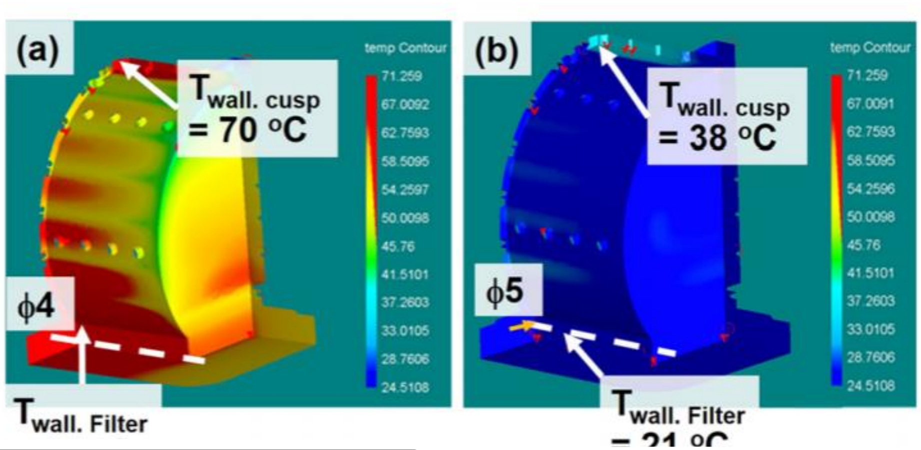
A. Kojima et al; Rev. Sci. Instrum. 87, 02B304(2016)
J. Hiratsuka et al, Rev. Sci. Instrum. 91, 023506 (2020)

Cs management for stable ion production

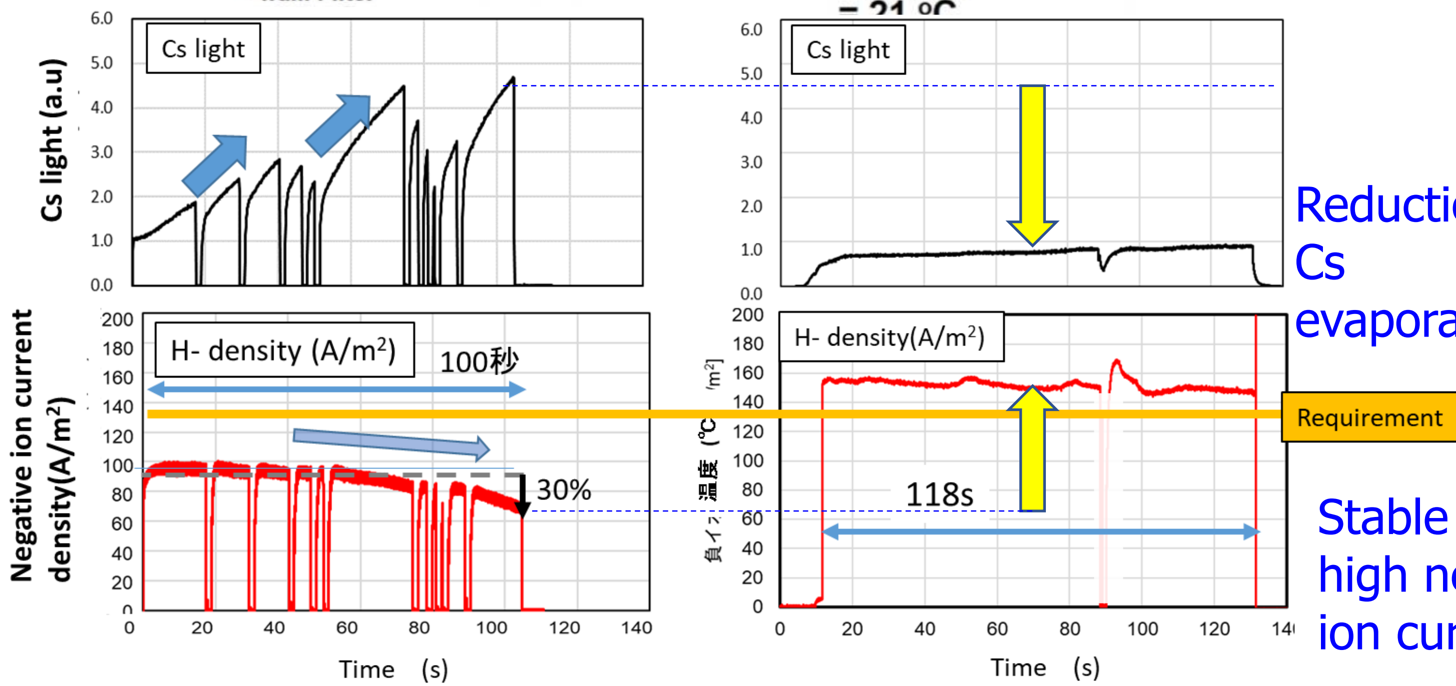
M. Ichikawa et al; Rev. Sci. Instrum. 91, 02B502(2020)

Excess Cs evaporation from the wall increases the Cs layer on the PG, concludingly, negative ion production decreased.

Wall temperature at 100s.



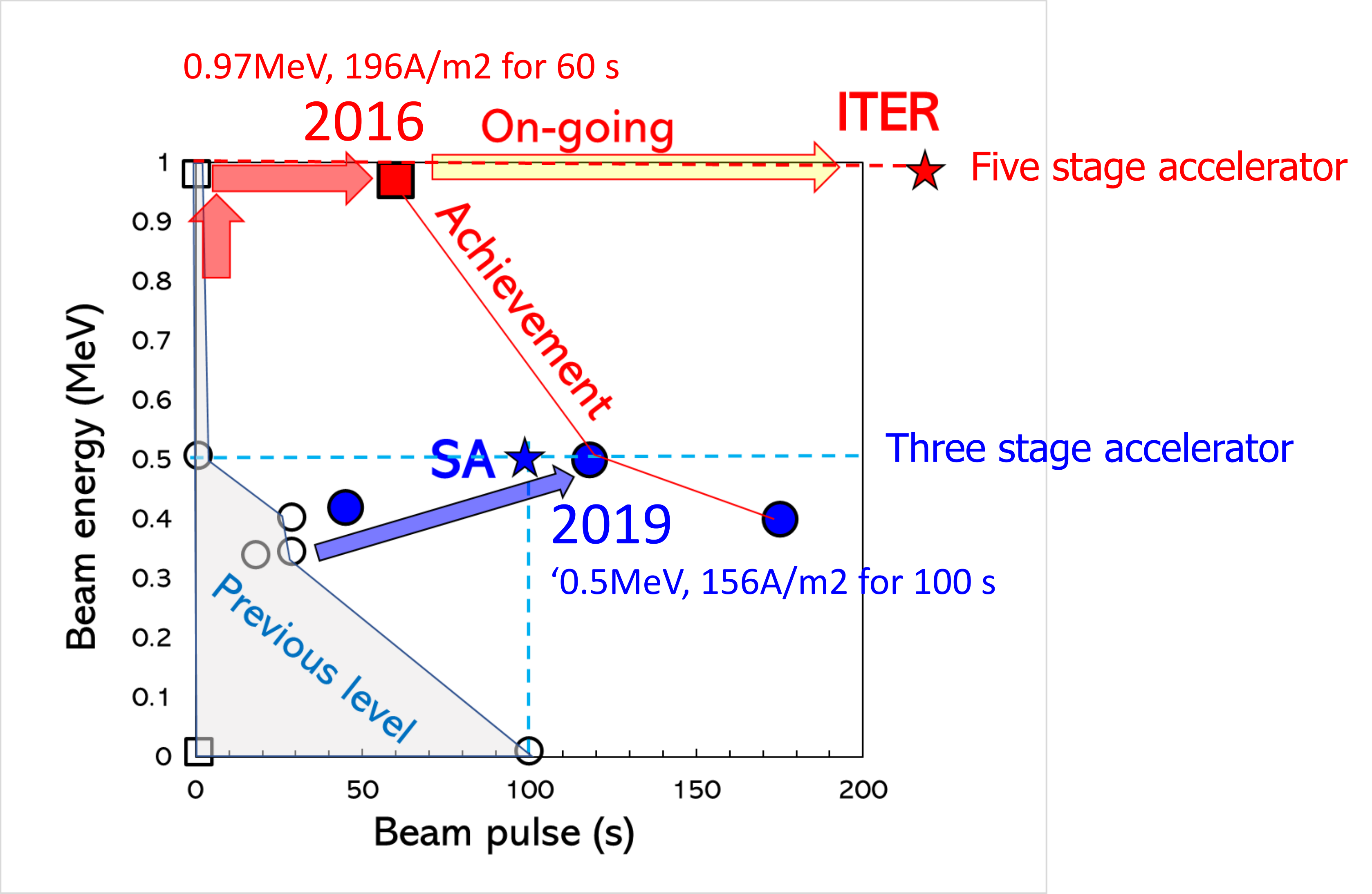
Water channel was modified to keep wall temperature < 60°C.



Reduction of Cs evaporation

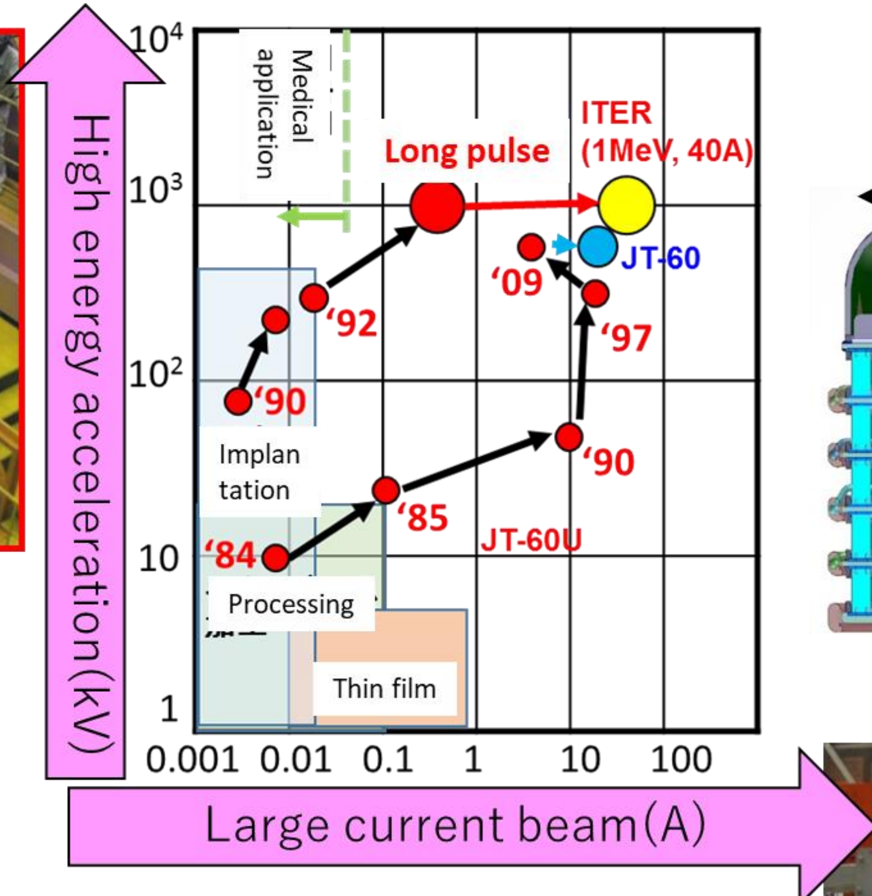
Stable and high negative ion current.

Overview of NBTF award 2020

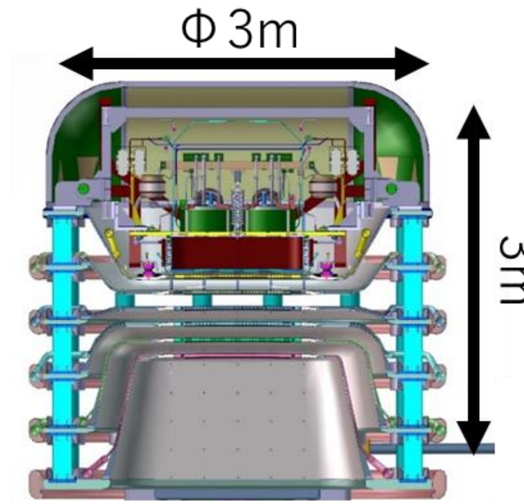


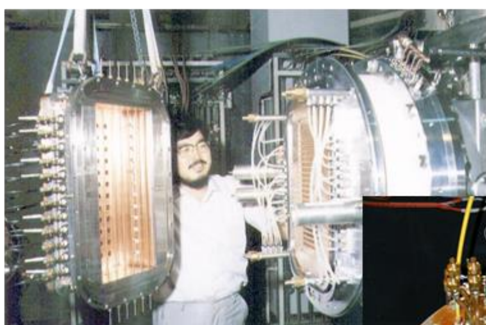
High power negative ion source development in NAKA/QST

MeV accelerator

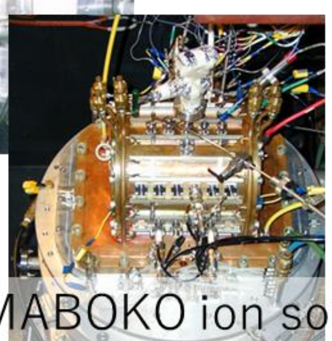


ITER用
Beam source

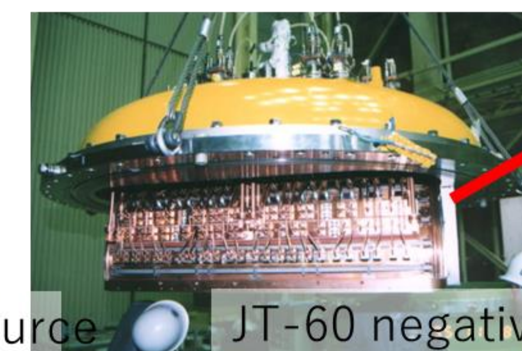




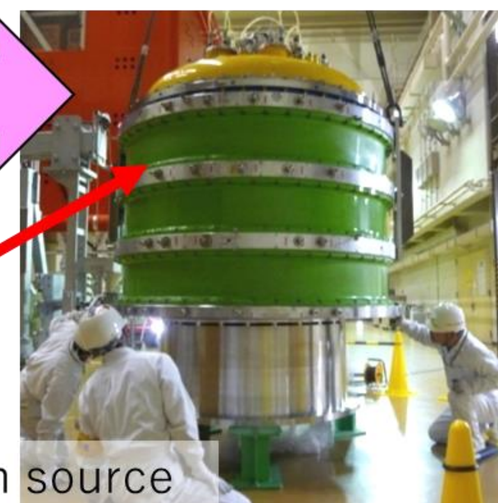
10A ion source



High dense KAMABOKO ion source



JT-60 negative ion source



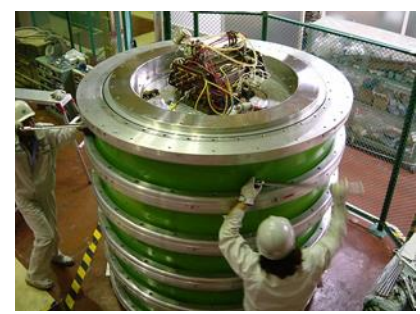
Our history with NBI development

JT-60U | ITER project | ITER NBTF PA | JT-60SA NBI

1980	1990	2000	2010	2020

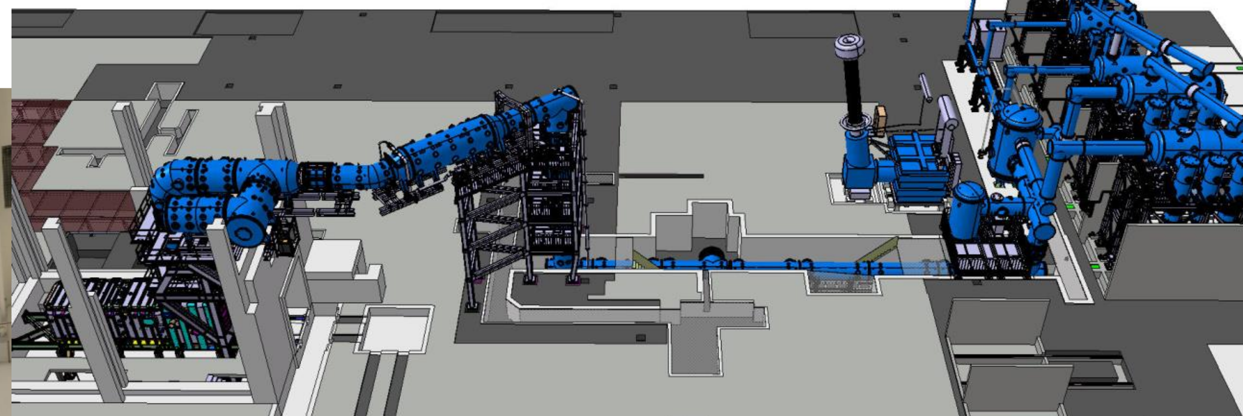
High density R&D | High energy & high power R&D | Long pulse R&D

- ‘86 Design of 500keV, 22.5A Negative ion source
- ‘91 Design of Negative ion source for JT-60
- ‘95 Start of MeV test facility for ITER
- ‘98 Start of Negative ion beam for JT-60
- ‘02 PoP test of Plasma neutralizer
- Selection of multi-stage accelerator for ITER
- Close of JT-60U for JT-60SA
- ‘11 0.98MeV, 180A/m2 for 0.3 s
- ‘16 0.97MeV, 196A/m2 for 60 s
- ‘19 0.5MeV, 156A/m2 for 100 s
- ～ 1000s



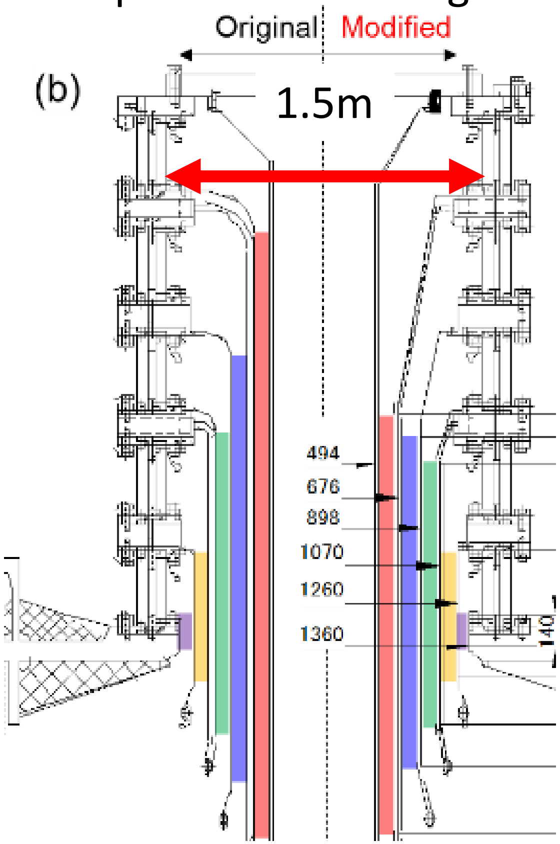
NBI: Integrated system from various fields

1MV power supply for ITER has been developed based on JT-60U experience in Japan.
Final test is under performing in NBTF, Italy.



Application to ITER procurement activity

Surface area (5 m^2) was modified according to the experimental scaling.



1MV was sustained stably and repeatedly during three days test period.

Delivered to the NBTF site (RFX).

Realization of this special component contributes to the realize the vacuum insulation technology for the ITER NBI.

Thanks to Larry

Prof. Larry Grisham (Princeton Plasma Physics Laboratory)
have supported and encouraged our project and members.

60 years old celebration in the control room of JT-60