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University of Wisconsin, USA

Prepare for the D-T Burning in IECF – relocation, remote operation, and tritium handling –

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What we did since last meeting

at Kansai University

- Improve high voltage holding

  baking / outgasing of chamber / high voltage feedthrough

  → 45kV, 50mA discharge (Hydrogen / Deuterium)

  add a stabilizing resistor / corona ring

  → 60kV, 20mA, 0.63Pa (Hydrogen) discharge

- Preliminary D_2 discharge and neutron measurement

  maximum 8.76×10^5 n/s at 45kV-50mA, 1.0Pa

- Make and test prototype of getter pump
- Make and test tritium recovery system

at Osaka University

- Relocation of IECF device to the OKTAVIAN main hall
- Remote operation
- Moving into the heavy irradiation room

Contents

- Intense 14MeV Neutron Source Facility (OKTAVIAN)
- Restrictions
- Relocation of IECF device to the OKTAVIAN main hall
- Remote operation
- Moving into the heavy irradiation room

    Weekly experiment schedule
- Getter pump system, water bubbler (Tritium handling)

Facility ?

The IEC facility at IAE dose not have a license to use isotope. Isotope laboratory in main building has a license to use tritium but does not have neutron shield.

? what we can do

(1) As tritium less than 1GBq is not considered isotope, it is possible to make experiment with keeping total inventory in the facility less than 1GBq for proof-of-principle D-T IEC experiment. → university code does not allow

(2) find out some place which has both license.

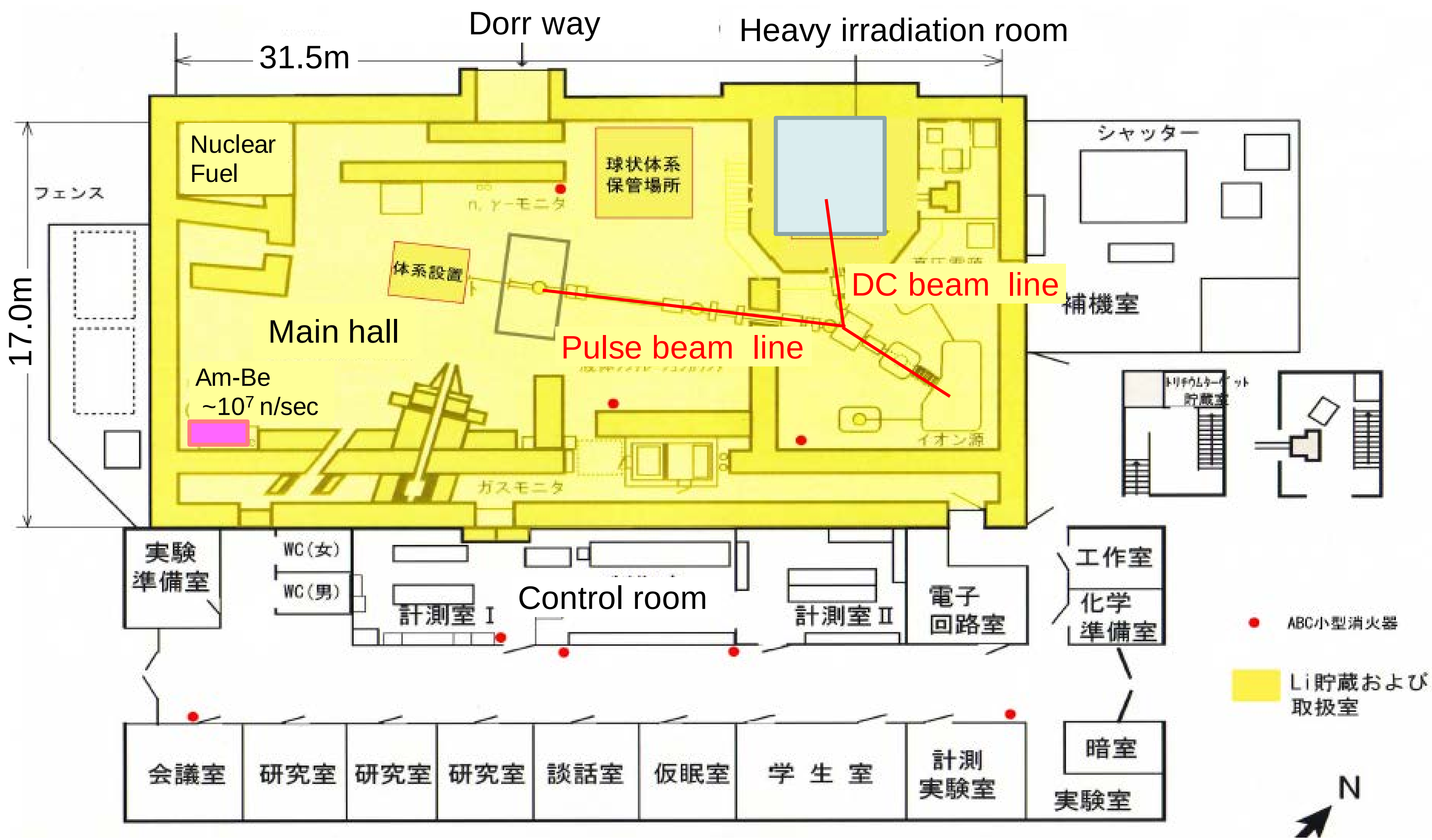
→ OKTAVIAN facility at Osaka University.

restriction no license for gaseous tritium

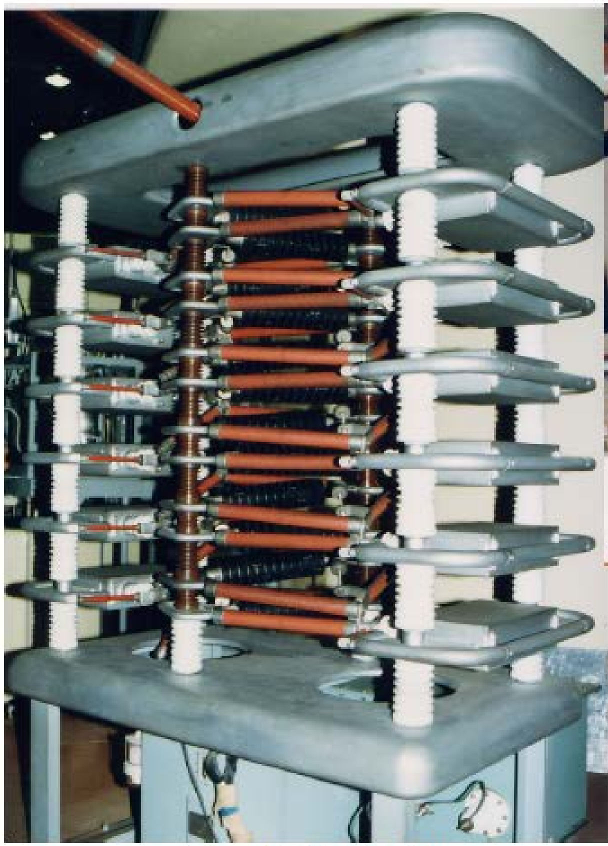
tritium gas must not be detected

entrance size 1m x 1.8m

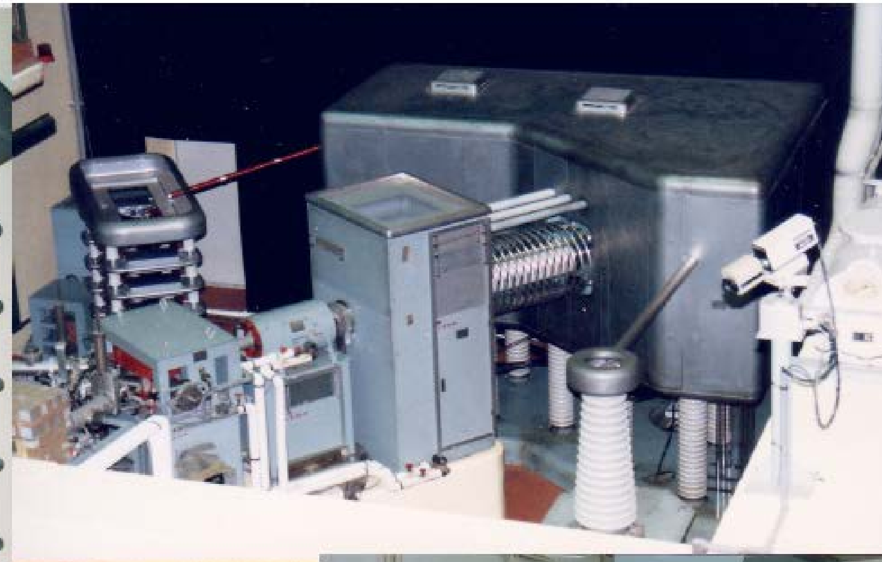
Subcritical assembly Building (OKTAVIAN Facility)



OKTAVIAN Facility Photographs (1)



Cockroft-Walton's apparatus

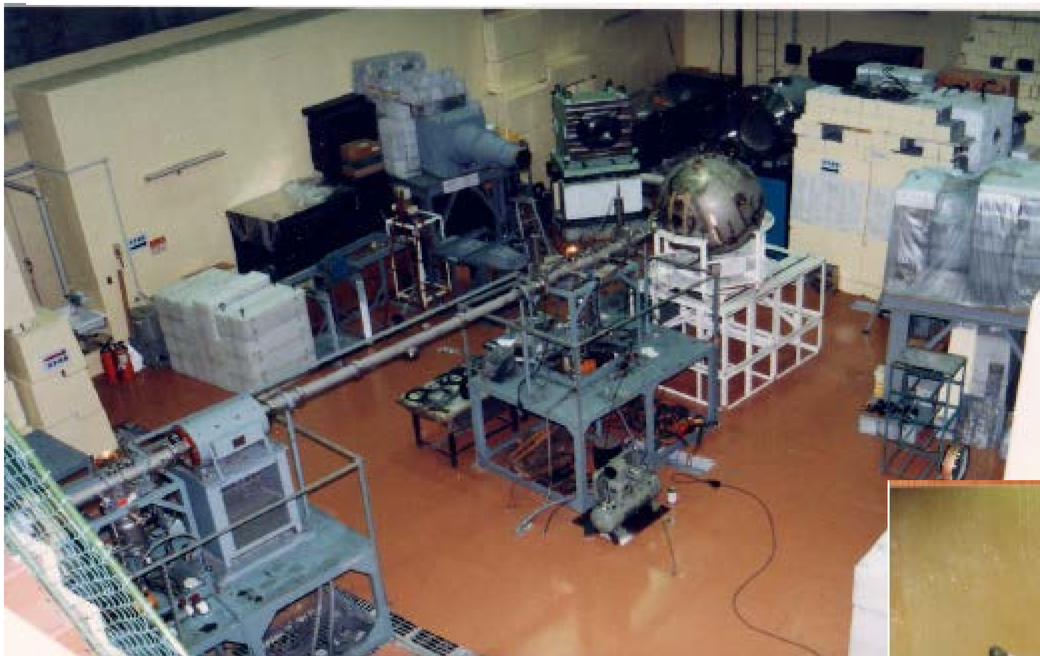


Accelerator system

Control room

OKTAVIAN Facility Photographs (2)

Pulse beam line



Design : 1×10^9 n/sec (20μA)
pulse width 2nsec
max repetition 2MHz
Current : 5×10^8 n/sec (5μA)
pulse width 3nsec

Rotating target with water cooling
Replaced by fixed target now.

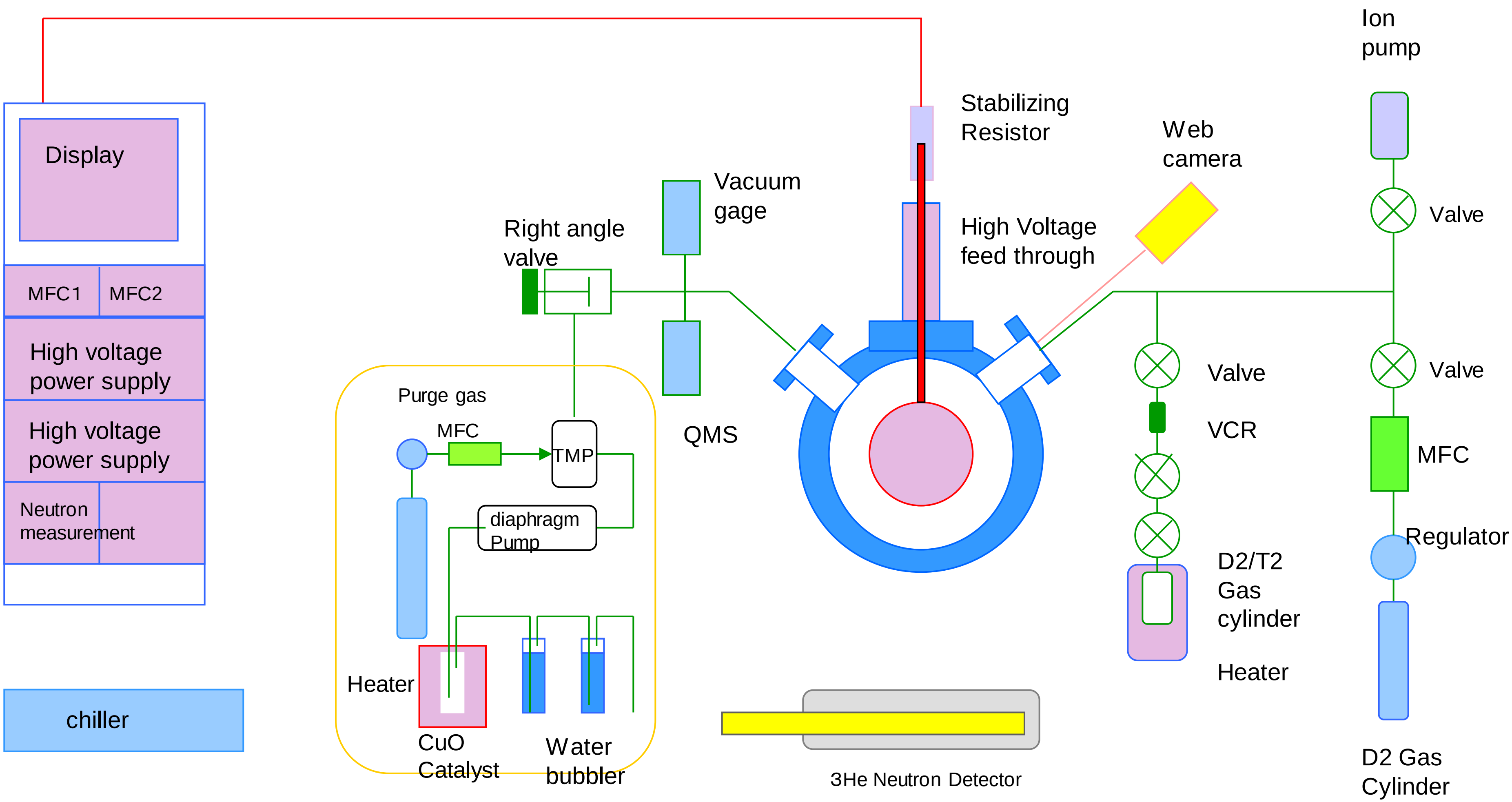
DC beam line

Design : 3×10^{12} n/sec (20mA)
Current : 1×10^{11} n/sec (1mA)
due to target problems

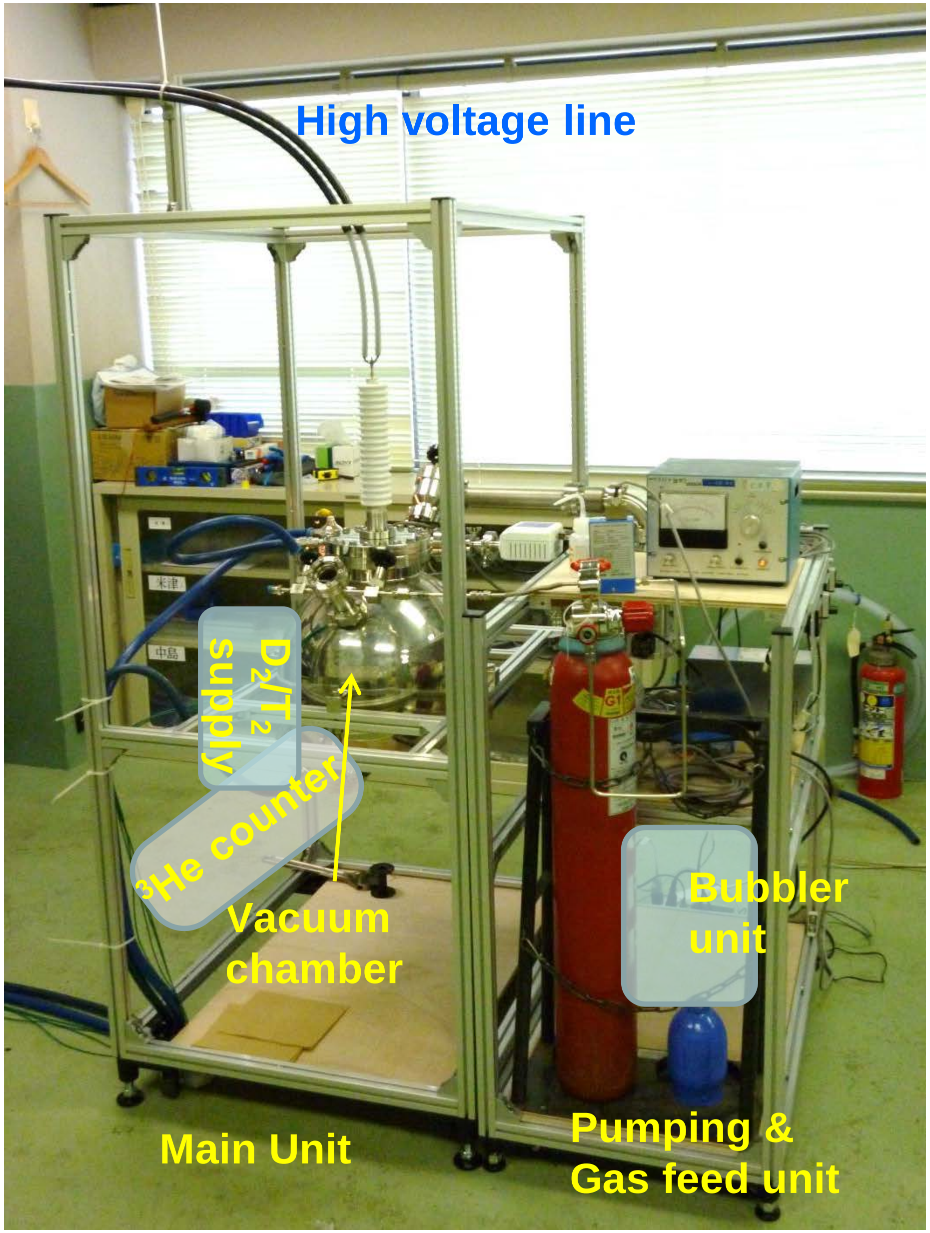
Restrictions for the IECF experiments

- The facility does not have license for gaseous tritium
  - ✓ Tritium must be absorbed in metal for bring in/out of the facility.
    - → non-evaporate getter pump with temperature control for hydrogen pressure
  - ✓ Tritium density in the facility must be kept normal level as a facility with sealed radiation sources (< 70 Bq/cc)
    - → IEC discharge with getter pump
      Tritium recovery device
      purge gas line, oxidation catalyst and water bubbler
- Entry to the experimental area is limited during neutron production
  - ✓ A few minutes entry to Main hall
  - ✓ No entry into the heavy irradiation room
    - → remote operation using KVM extender
- Machine time

Schematics of experimental device



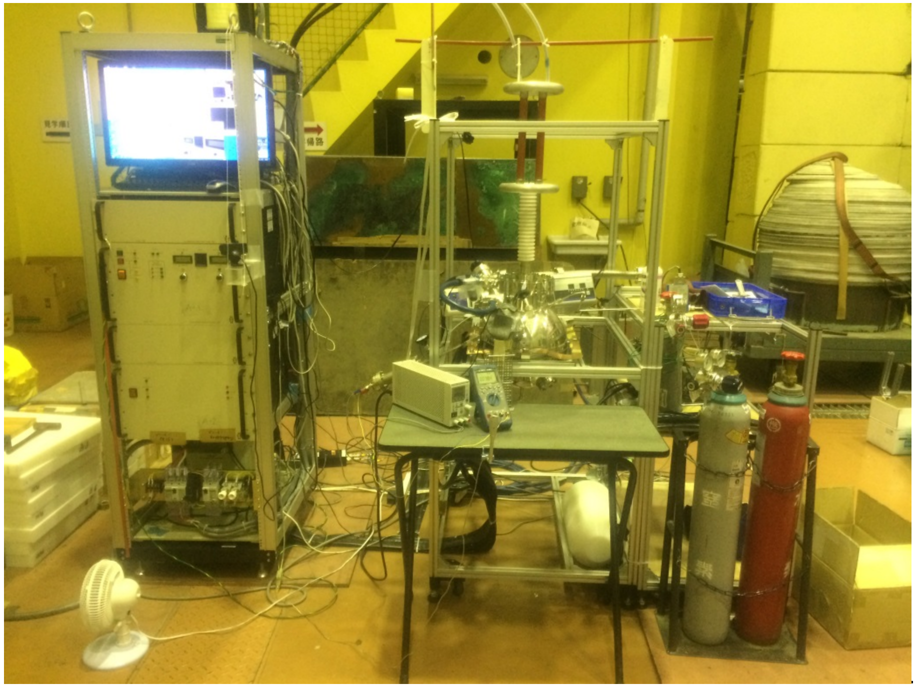
Experimental setup at Kansai Univ.



Relocation of the IECF device to Mail Hall

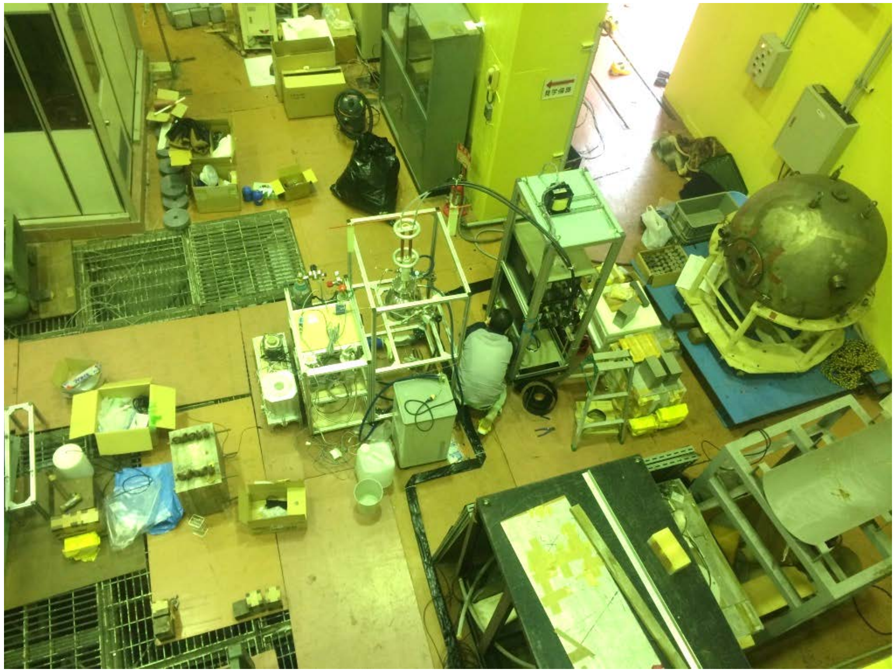
February 27, 2014 ~

- Relocation
- Chiller replacement for high power experiments
- Install and test remote operation
  base on KVM extender + USB cameras
- ^{3}He neutron counter calibration using Am-Be source
- D-D experiments
- Install getter pump

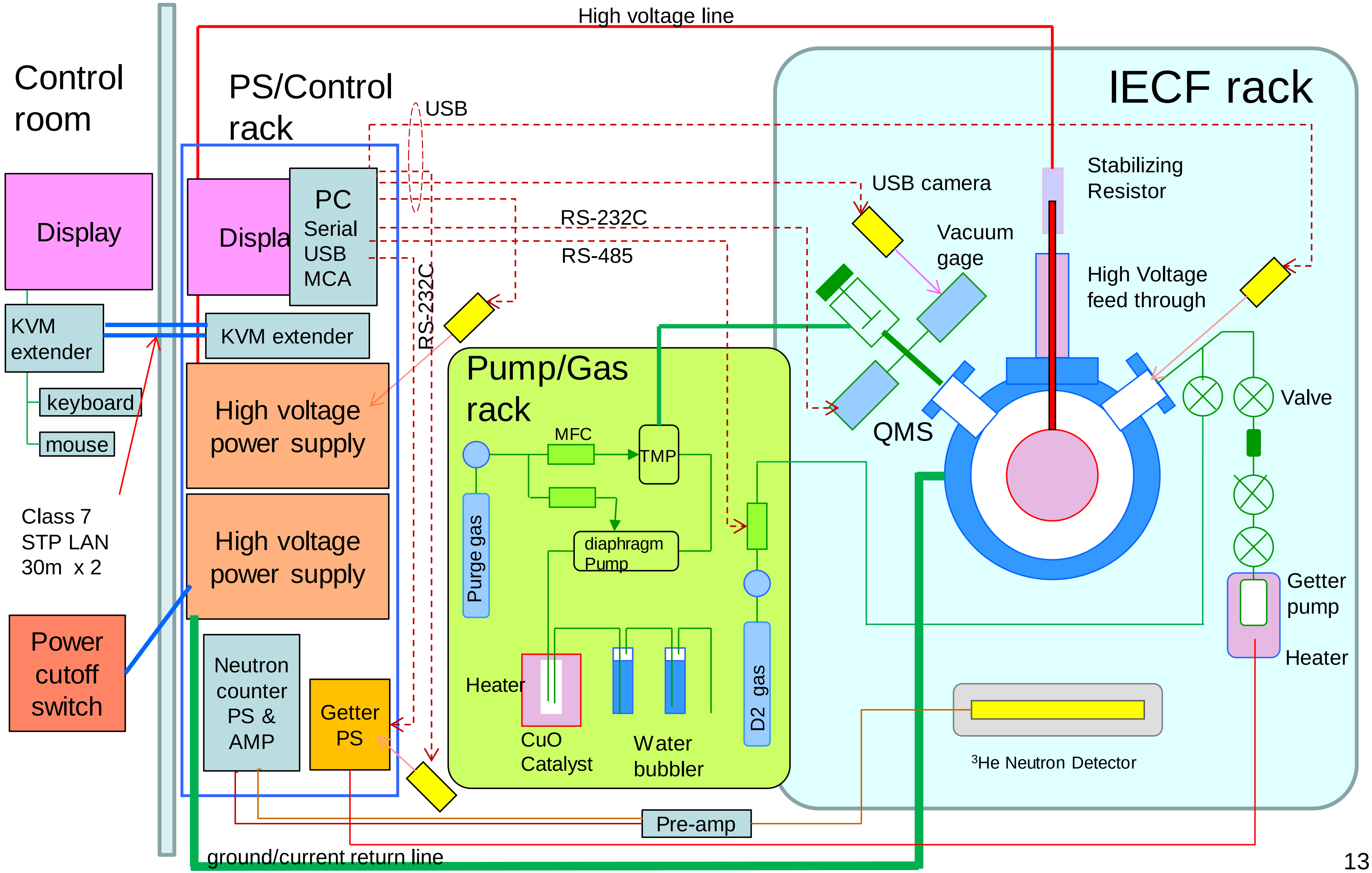


Relocation of the IECF device to Mail Hall

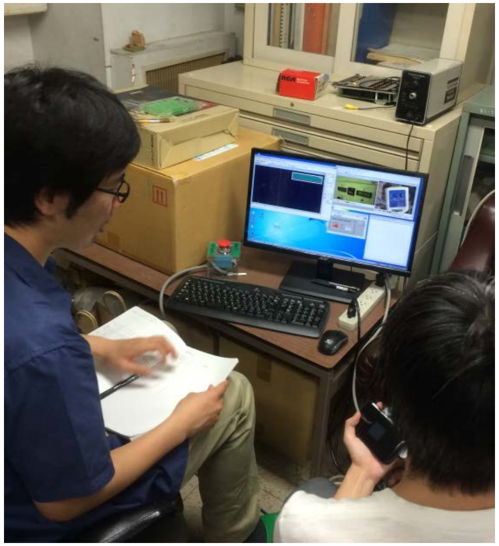
February 27, 2014 ~



Schematics of remote control system



Remote Operation



Remote PC operation

Emergency power cutoff switch

Camera views

Plasma

getter PS

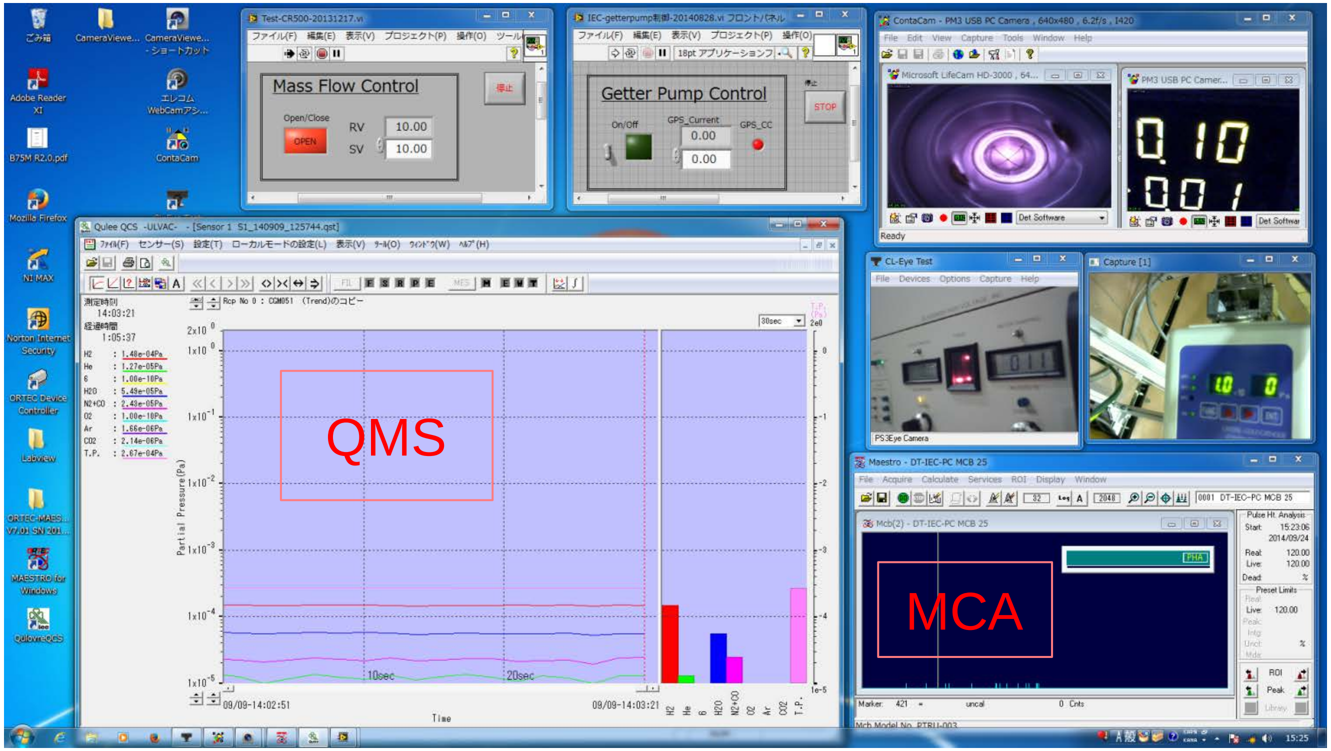
Power supply

Vacuum gage

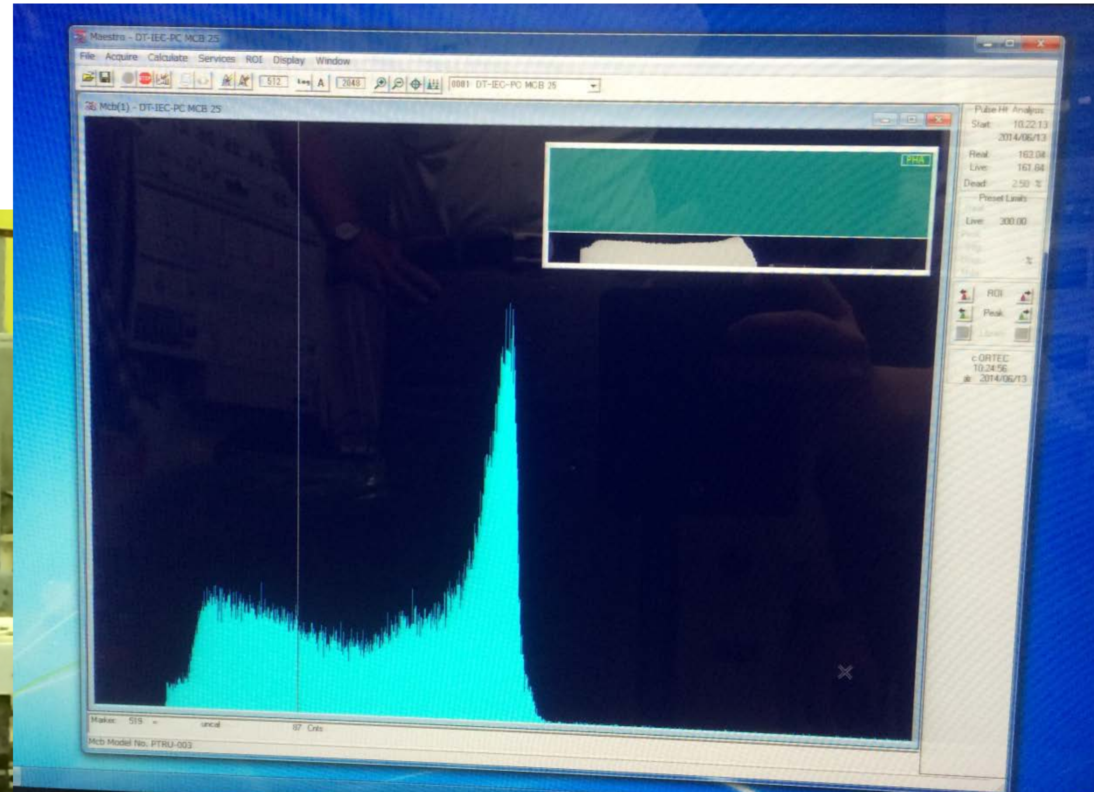
Labview panels

Mass flow

Getter PS



Calibration using Am-Be source



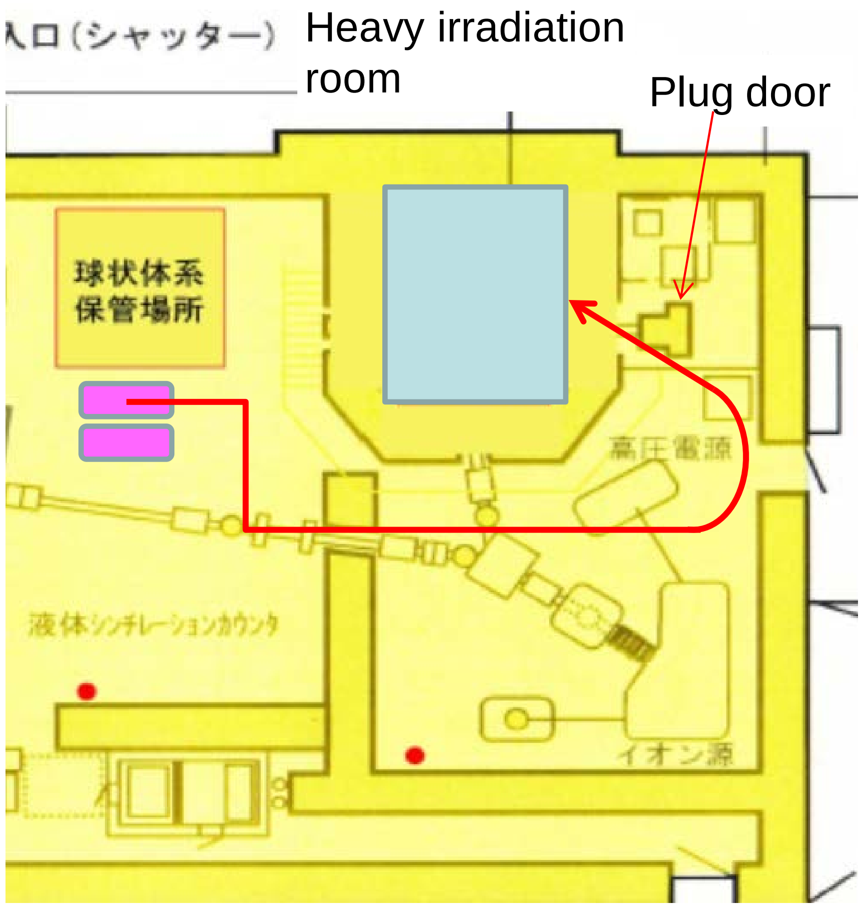
D-D operations

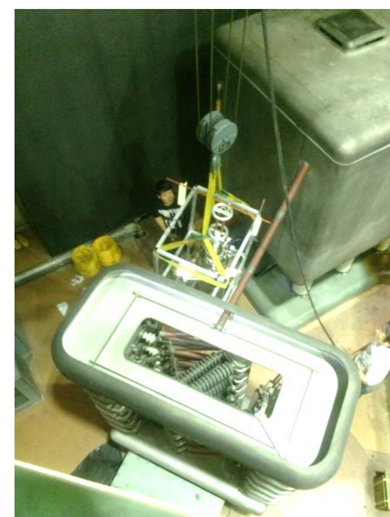
- Preliminary experiments at Kansai Univ., we got 7.0×10^5 n/sec neutron production at 45-kV, 50 mA discharge.
- D-D discharge experiments at OKTAVIAN facility, 8.8×10^5 n/sec was obtained at 60-kV, 10mA discharge.

→ detail of the results will be presented by Mr. Miyamoto at Poster session.

Installation to the heavy irradiation room

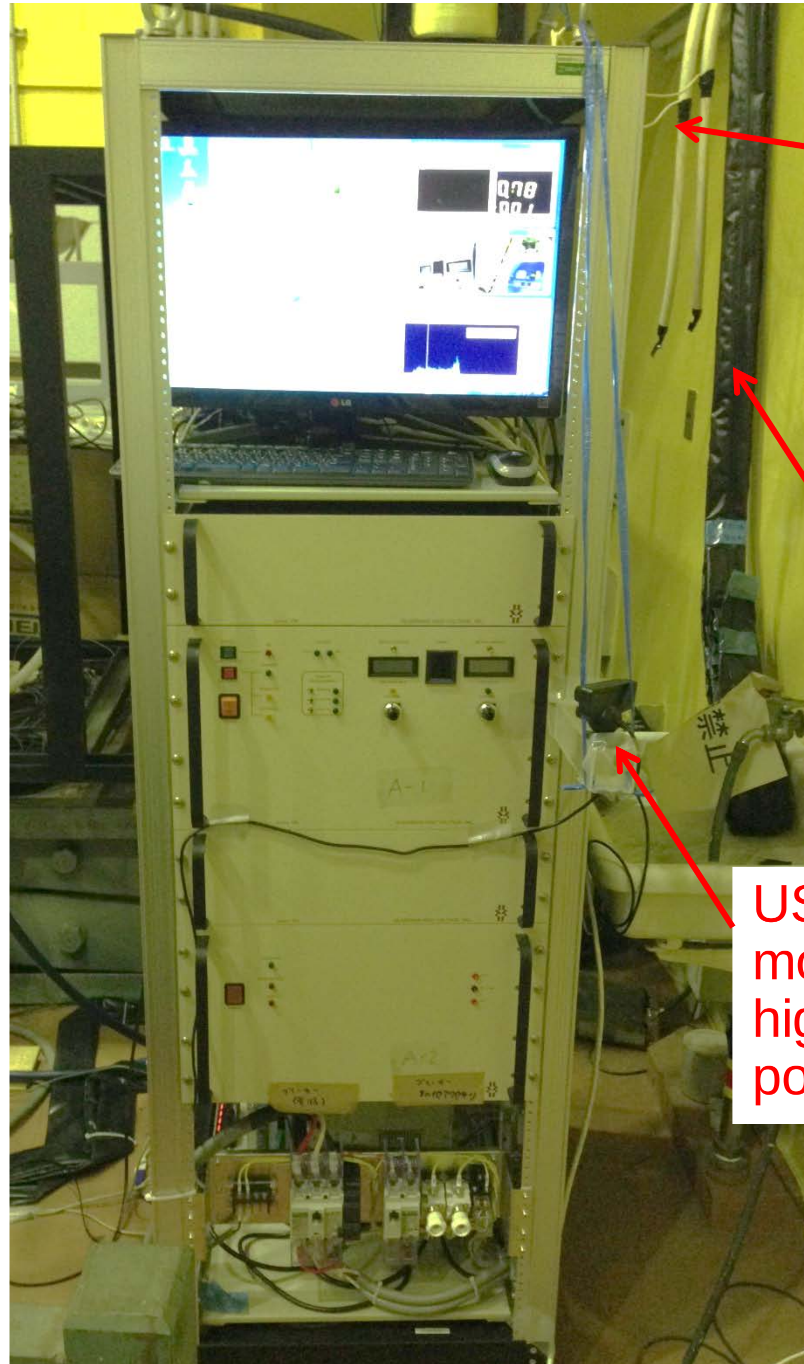
First trial installation and removal of IECF system to the heavy irradiation room was carried out September 22, 2014.





Installation to the heavy irradiation room

Power supply/control PC rack was also moved to just beside the wall

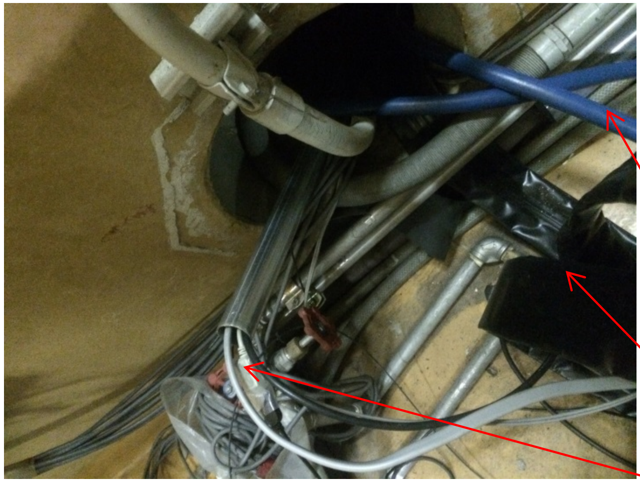


IECF system in the heavy irradiation room

Upper through hole

High voltage Line

Current return Line



Cooling water

Ground plate

Control/measurement lines

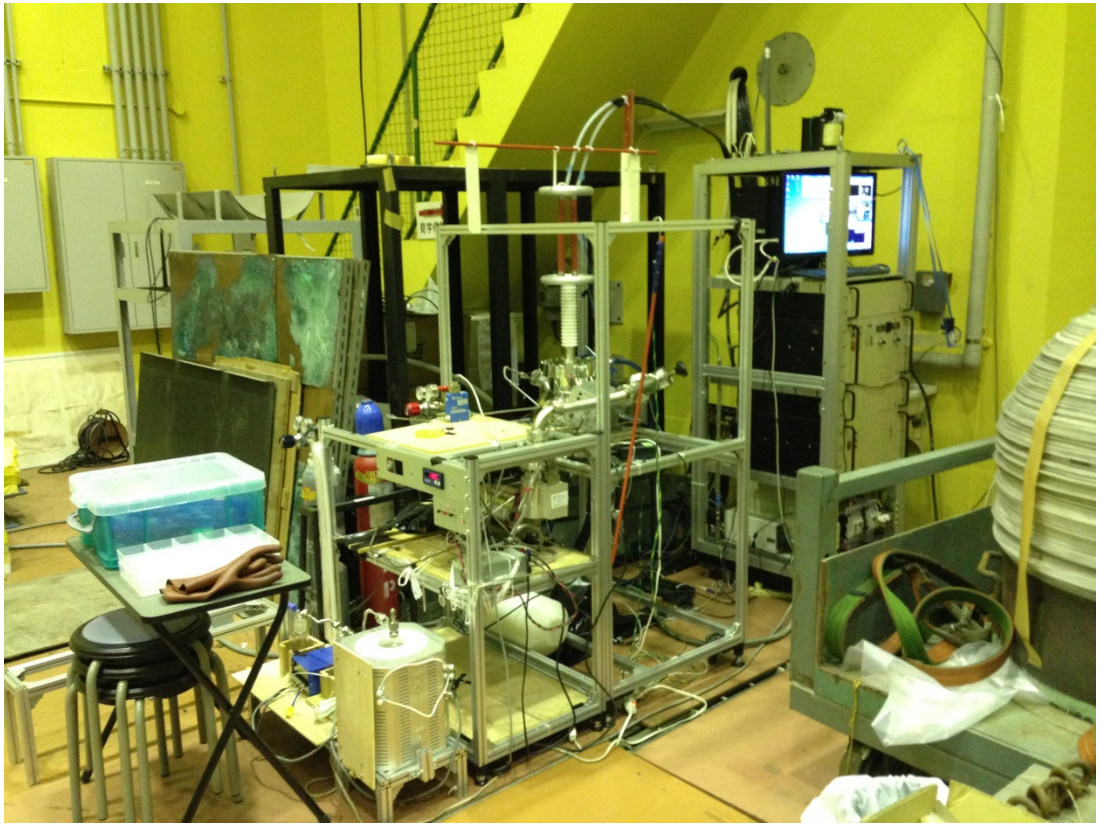
Floor tunnel

IECF system in the heavy irradiation room

First Discharge with D_2 gas
at 1Pa, 10kV, 10mA
2014/9/22 ~ PM 7:00

Removal from the room

Since strong neutron radiation from OKTAVIAN operation might damage electronic circuits in QMS, IG, TMP etc., and make detectable activation of materials which will be problem for relocation from the facility to Kansai University, we are requested to remove all device after each machine time.



Weekly schedule of the experiment

Monday :

- Moving : the IECF/Vacuum system rack into the heavy irradiation room
- Connections : water, electrical, vacuum system
- Test 1 : vacuum, high voltage holding
- Test 2 : neutron measurements, reference operation with D_2 gas

Tuesday, Wednesday :

- Move pump/gas rack to adjoining room, close plug door
- D-T Experiments

Thursday :

- Install pump/gas rack, tritium collection system
- Discharge clearing of the chamber and tritium collection

Friday :

- Removal from the heavy irradiation room

How much tritium do we need to use ?

- Gas quantity needed for experiments

  maximum pressure 4 Pa

  chamber volume ~10 l

  $\Rightarrow$ 40 Pa･l = 1.76x10^{-5} mol = 0.395 SCCM

- If tritium ratio is 10% (first trial),

  quantity of the tritium is

  1.76×10^{-6} [mol] = 1.056×10^{-5} [g] = 3.8×10^{9} [Bq]

- If tritium ratio is 50% (goal),

  quantity of the tritium is

  8.8×10^{-6} [mol] = 5.28×10^{-5} [g] = 19.0×10^{9} [Bq]

Consideration about a gas supply system

- In order to use tritium, IECF operation with sealed vessel is indispensable.
- In the IECF system developed for the landmine detection,
  - SASE Getter SORB-AC GP-50 cartridge pump was adopted for both evacuation of impurity gas and deuterium supply. Deuterium pressure was controlled by temperature of the getter material.
  - The inventor of deuterium gas in the GP-50 pump is
    about 20Torr･l/g x 32 g = 640Torr･l = 8.5×10^4 Pa･l = 0.04 mol,
  - which is more than 2,000 times larger than maximum required D_2 quantity for discharge.
- To keep tritium use as low as possible, we need to reduce inventor in the getter material.
  - We try to make small pump using SASE Getter St 707strips St707/CTS/NI/8D (amount of getter material is 3.6g/m) with current heating

Hydrogen supply/recover system using St.707 strip

- Strip length calculation

Pressure 4 Pa

Volume 10 *l*

Hydrogen density in St.707

7 Torr･*l*/g = 931 Pa･*l*/g

↓

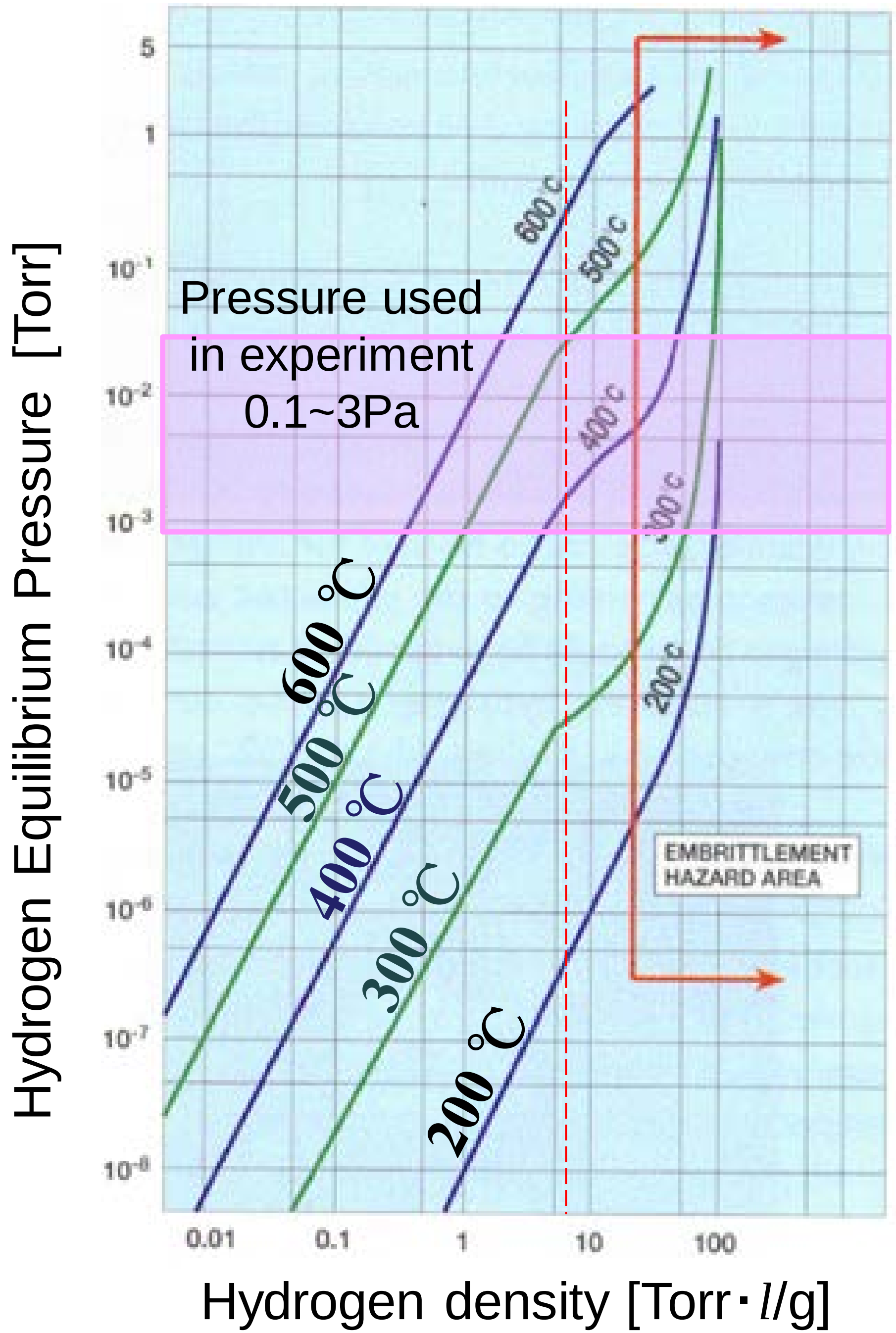
required amount of the alloy

$^{4\times10}/_{931} = 0.0429$ [g]

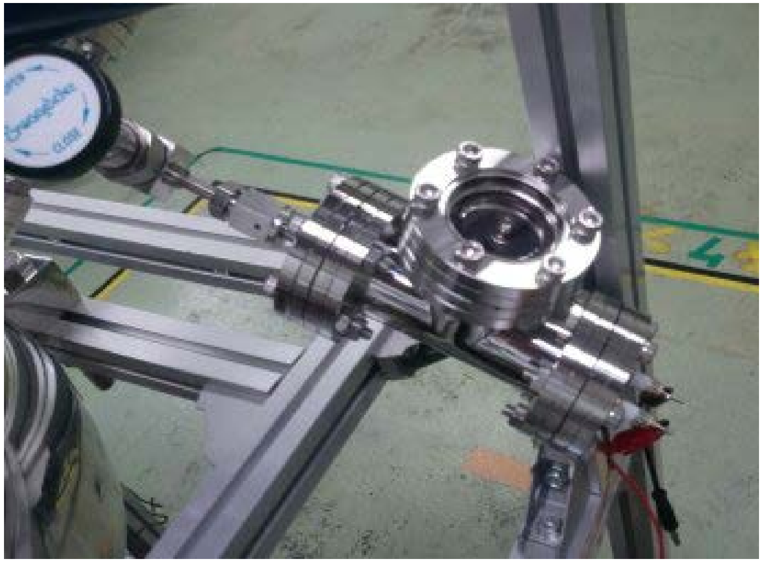
As strip includes 3.6 g alloy/m

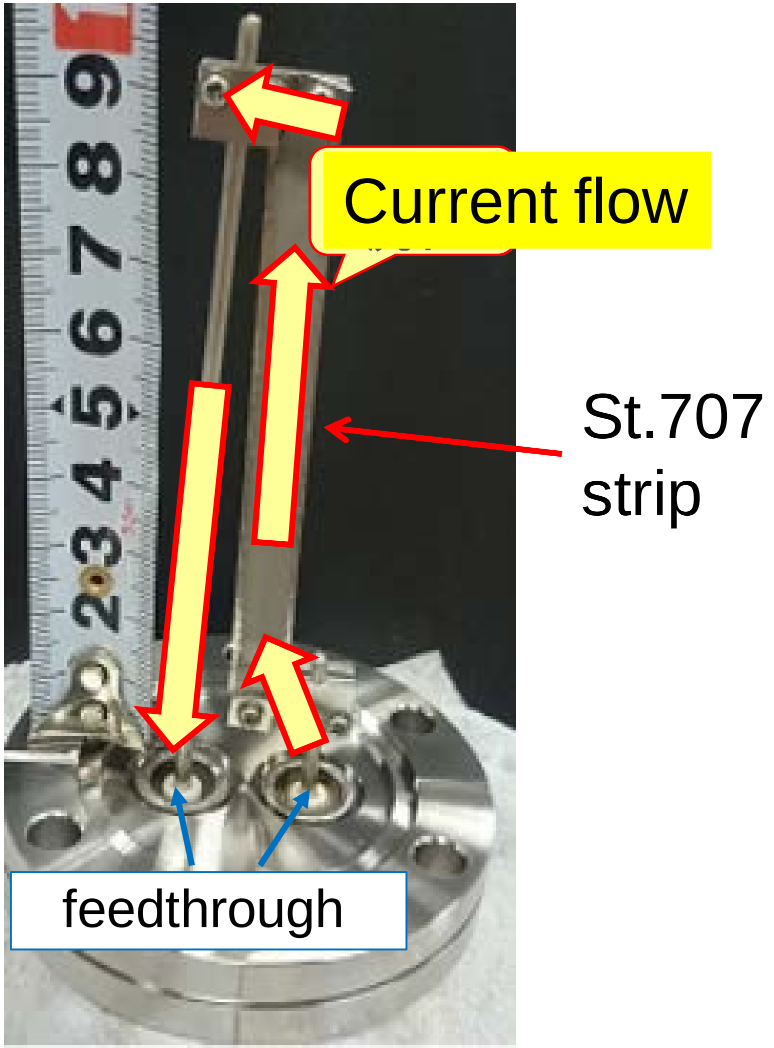
$^{0.0429}/_{3.6} = 0.0119$ [m]

~12 cm of the strip is required

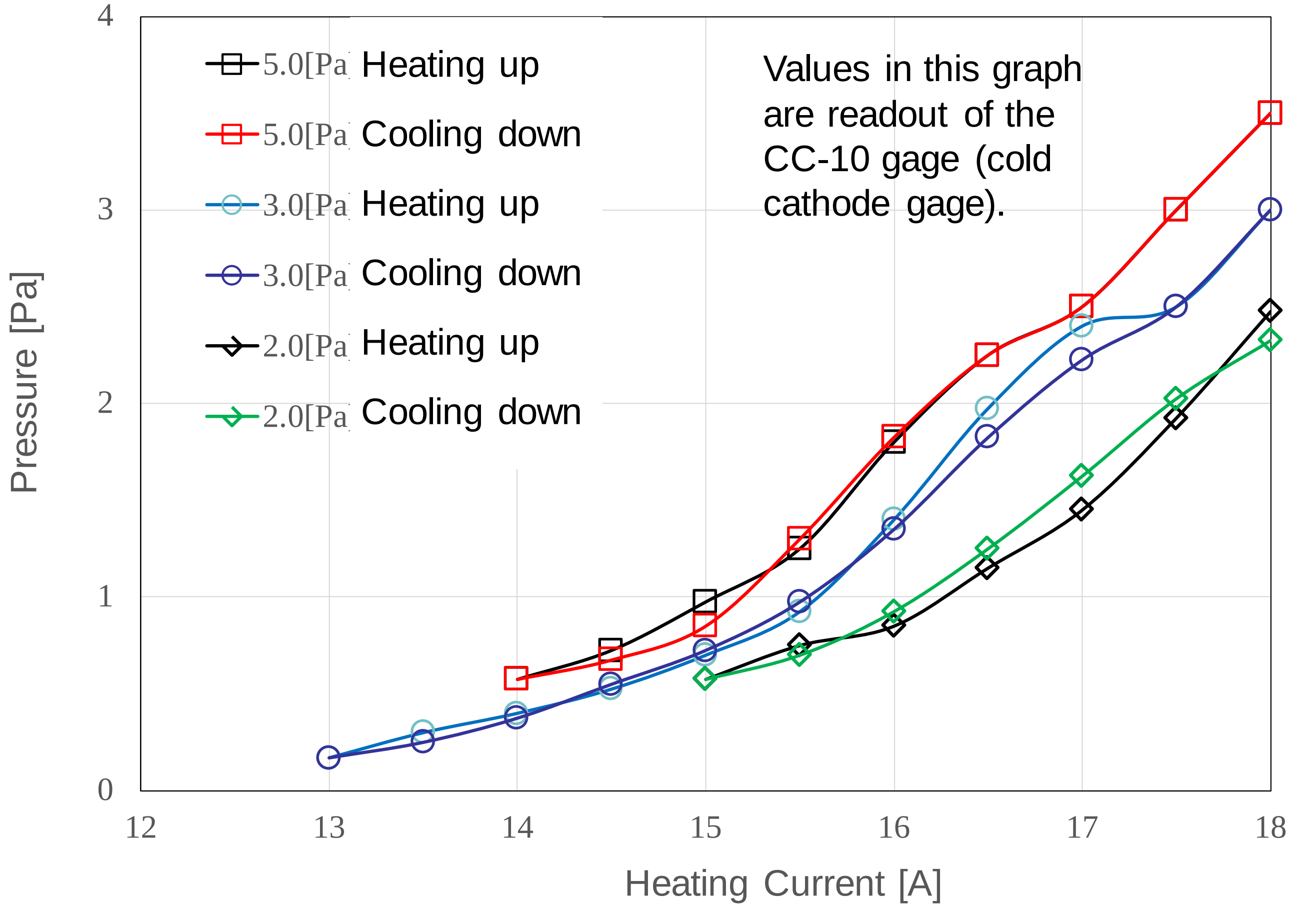


First trial production





Pressure vs. heating current



Since deuterium density in the getter material changes with initial packing pressure, the equilibrium pressure over temperature (heating current) differs.

Result is within what is expected, and has reproducible.

Characteristics ultimate pressure

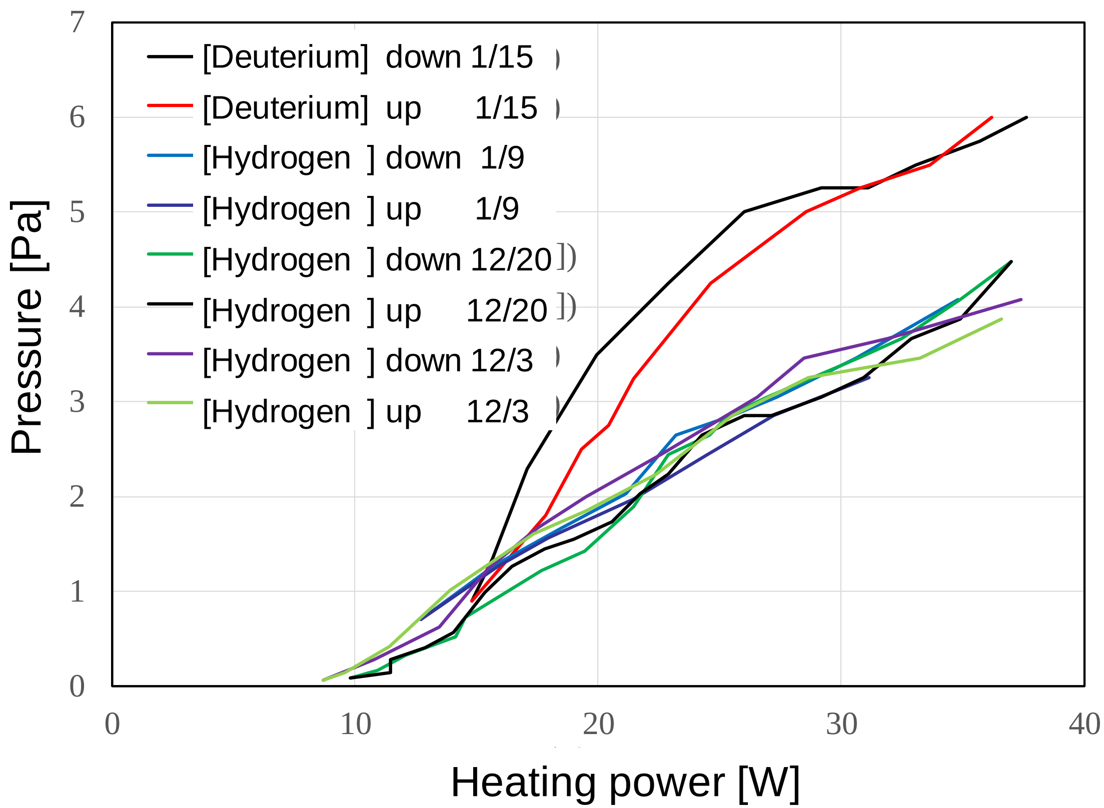
Ultimate pressure after deuterium/tritium is absorbed into the getter is important to determine how much gas is remained in the chamber. We measured it for different loading amount of deuterium gas at room temperature.

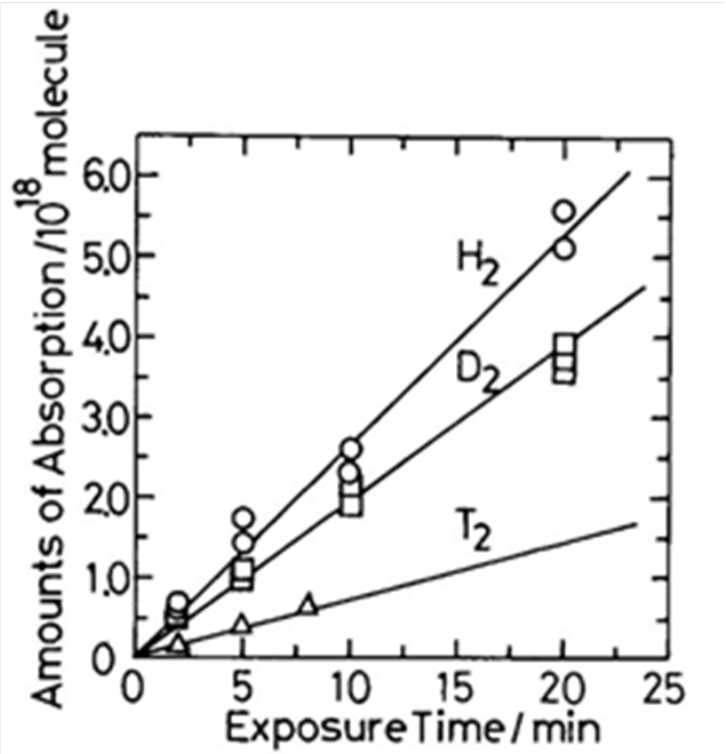
Loading pressure	Ultimate pressure
Average (all)	3.25×10^{-3}[Pa]
5.0 [Pa]	2.25×10^{-3}[Pa]
3.0 [Pa]	2.15×10^{-3}[Pa]

Values are readout of cold cathode gage

It is about 1/1000 of the loading gas pressure.

Isotope effect ?

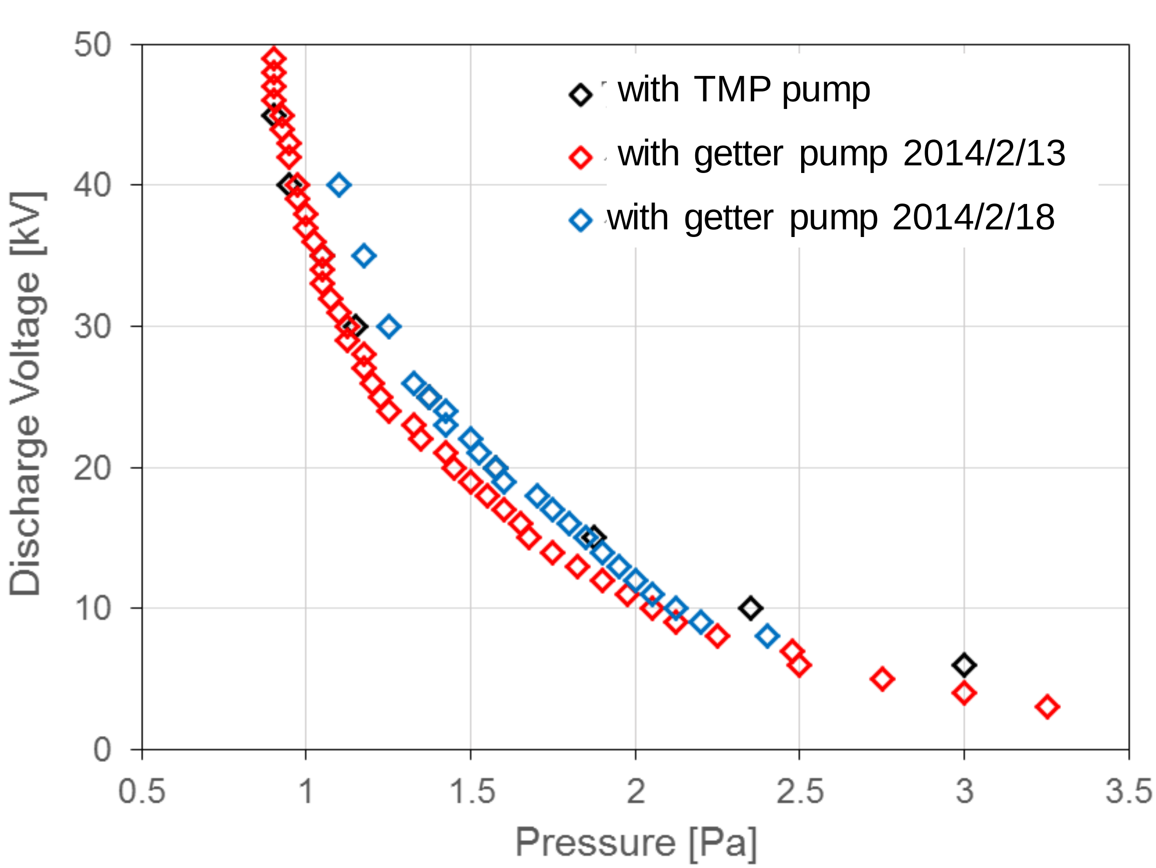




H_2, D_2, T_2の常温での変化吸収量
井上直哉他, Zr-V-Feゲッターの活性化過程及び水素同位体の吸蔵—脱離と同位体効果、富山大水トリチウム科学センター研究報告 3, 1983.

Deuterium case shows higher equilibrium pressure than that of hydrogen case for same heating power.

Comparison of discharge characteristics



Discharge voltage dependence on gas pressure with getter pump is same as that with TMP exhaust. Impurities are not problem with a small getter pump.

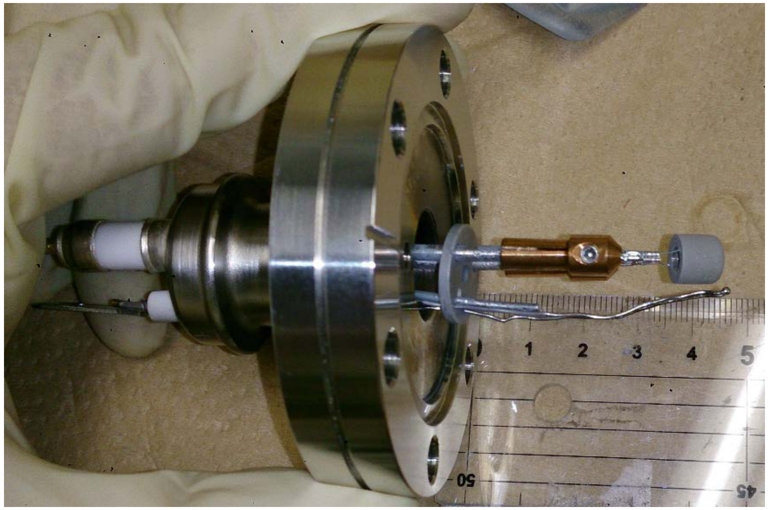
Second trial with St.172 sintered porous getter

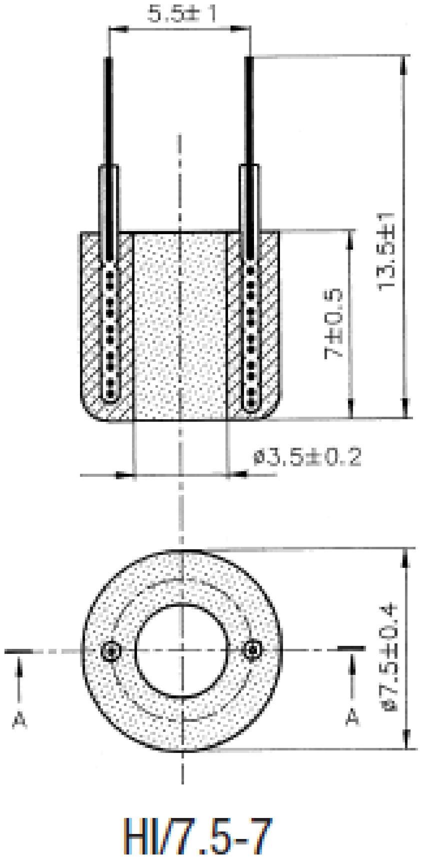
Since resistivity of St.707 strip (St.707/CTS/NI/8D) is small, it requires large current at low voltage (0.8V-44A) to heat.

This high current requires large feedthrough, thus we try to use St.172 Sintered porous Getter (St.172/HI/7.5-7).

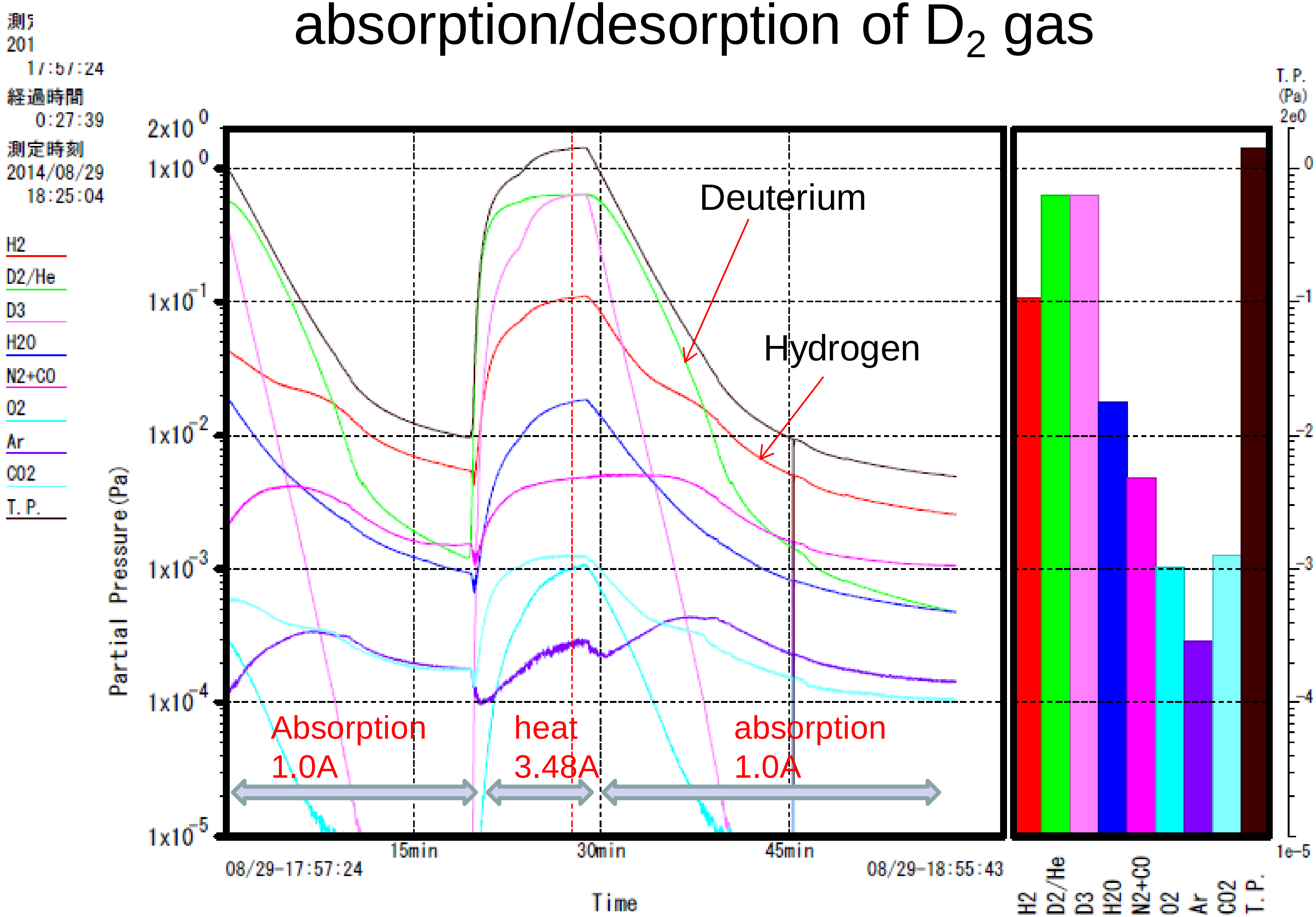
It is made of St. 707 alloy and includes heater.

Dimension is 7.5mm diameter x 7mm high, amount of getter material 775 mg.





Partial pressure measurement during absorption/desorption of D_2 gas



Mixed gas operation & problem

- Why

D-T burning experiment will start from low tritium ratio and increase ratio to deuterium : tritium = 50% : 50%.

When we asked prof. Hatano about mixed gas supply, he told us it takes a few month to prepare new mixture, and currently available mixture is H_2:D_2:T_2 = 82%: 13.3%: 4.7%.

- Experiments with H_2:D_2=4:1 mixture gas

We made experiments with hydrogen / deuterium gas mixture gas, to investigate characteristics of discharge, neutron production et. al.

9.5×10^3 n/sec at 45kV, 10mA, 0.43 Pa (readout)

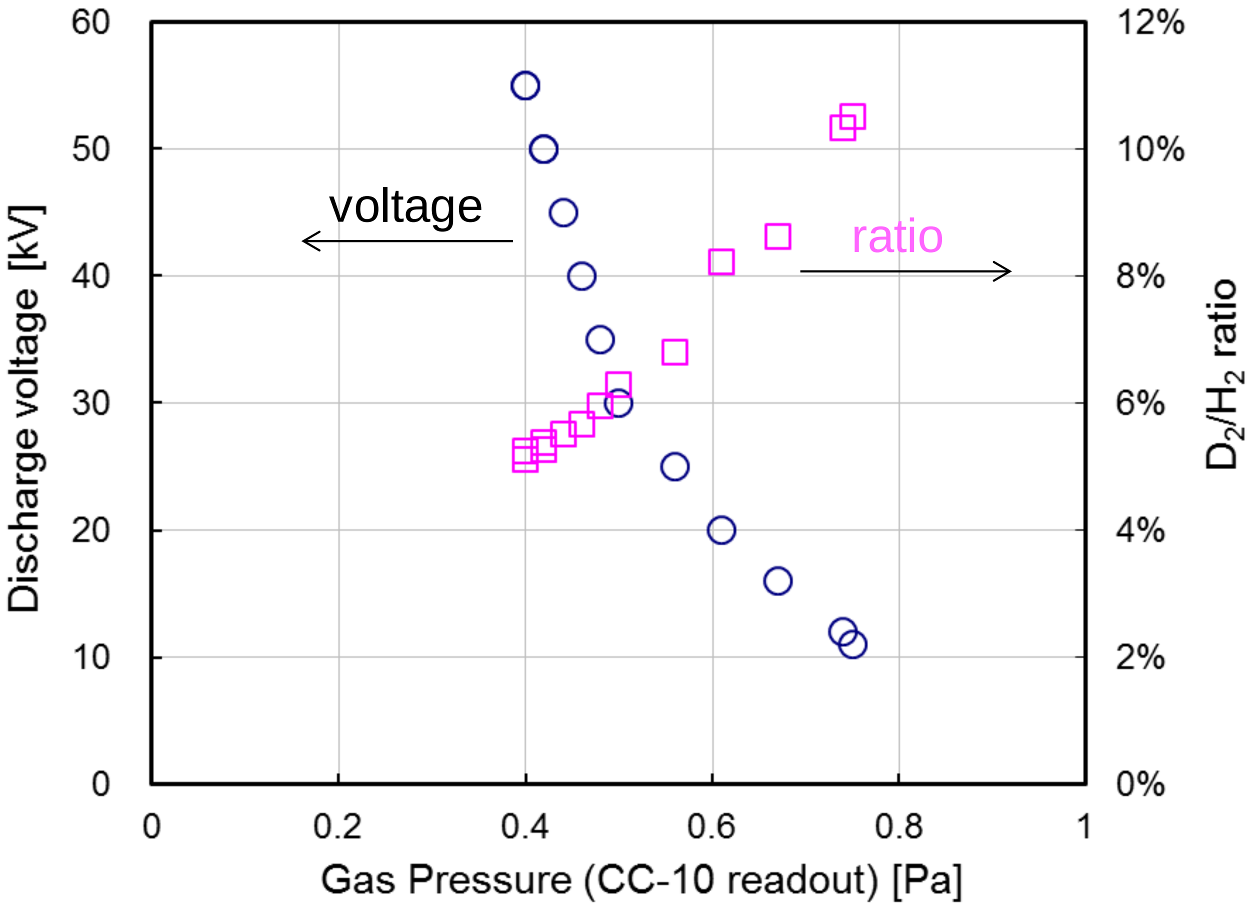
QMS measurement shows mixture ratio changes when total pressure is changed (getter temperature is changed).

add more D_2

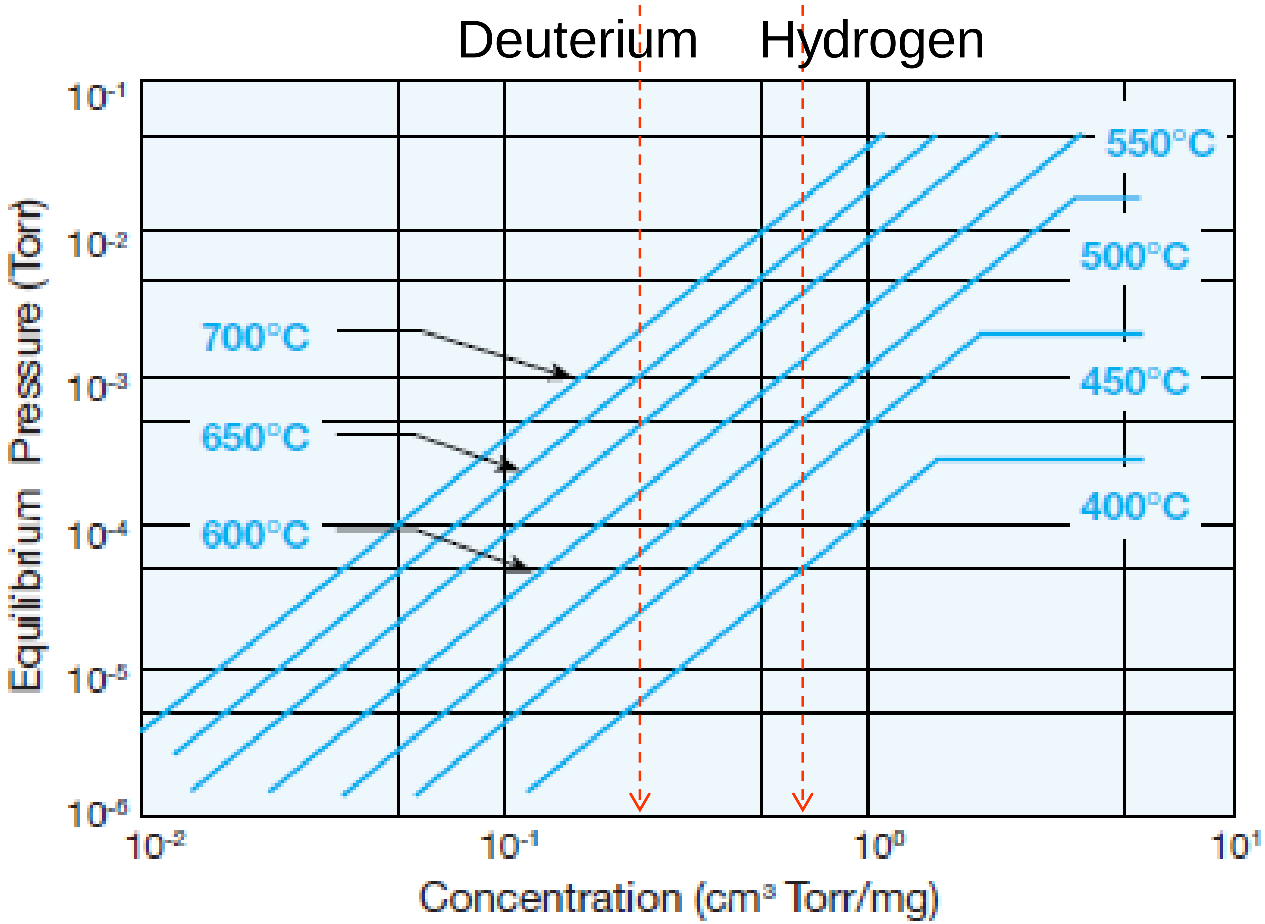
2.5×10^4 n/sec at 55kV, 10mA, D_2 ratio is about 10%

Discharge voltage, Mixture ratio vs. Gas pressure

2014/9/9 H_2 3.8Pa + D_2 0.83Pa

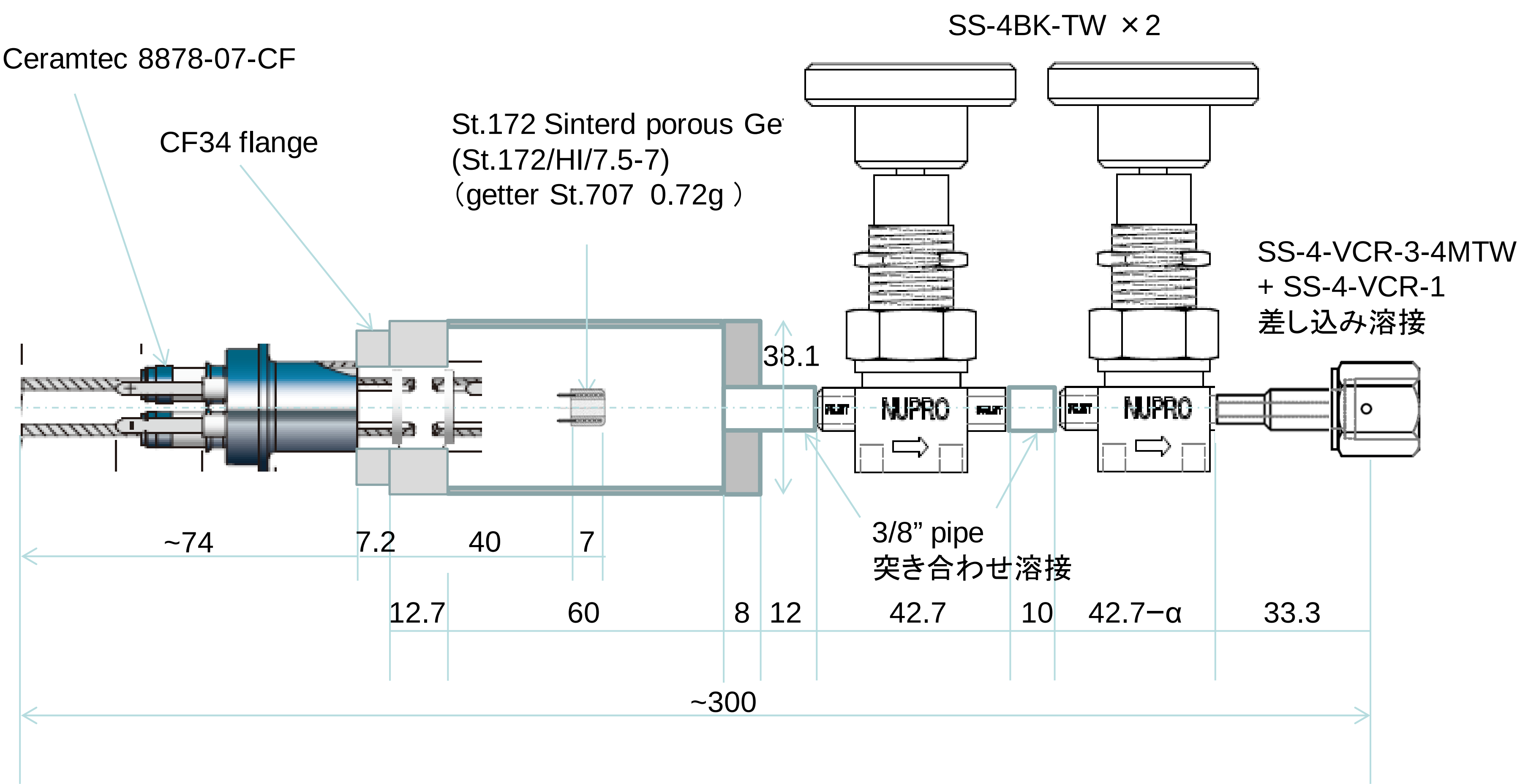


Equilibrium pressure of H_2 is a function of the H_2 concentration in the getter material

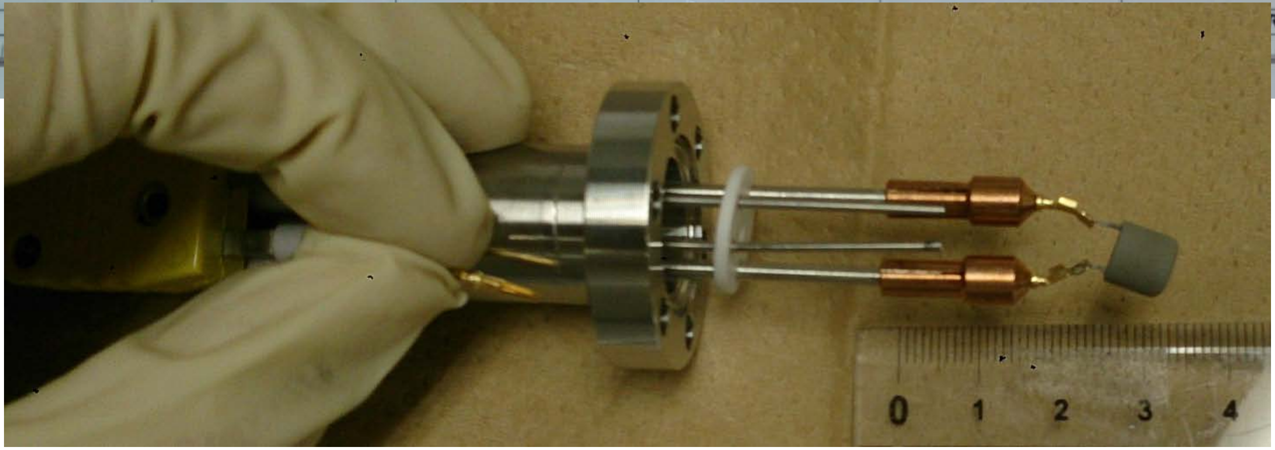


Equilibrium pressure of H_2, D_2, T_2 is depended on the concentration of each gas in getter material, thus ratio of H_2, D_2, T_2 is not constant and changes with temperature of the getter material.

Final design of getter pump



Getter pump unit



Summary

Preparations for proof-of-principle D-T burning experiments have been made in following area.

- Improve high voltage holding problem, the IECF device is able to operate up to 60kV.
- 8.76×10^5 n/s is obtained at 45kV-50mA, D_2(1.0Pa) discharge at Kansai Univ.
- Test of a prototype getter pump was done, and there is no difference in discharge / neutron production characteristics between TMP pumping and getter pumping.
- Relocation of the device to OKTAVIAN, installation of remote operation system have been done.
- Trial of moving into the heavy radiation room and first discharge in the room was successfully made.

We are almost ready to start, remaining issues we need to do are

- trial runs to proof we can do it within machine time (1 week) without any failure, especially tritium handing,
- $T_2/D_2/H_2$ ratio control / measurement in the experiment.