# The $H^-/D^-$ RF source at the edge towards large area beam extraction and long pulses

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# Developement of RF sources for ITER

**At IPP under an EFDA contract since 2002 on two testbeds**

**Goals**

## Batman:

- High current density in $H^-$ and $D^-$
- low electron current,
- low pressure operation

With small extraction area (67 - 74 $cm^2$) and short pulses < 6 s

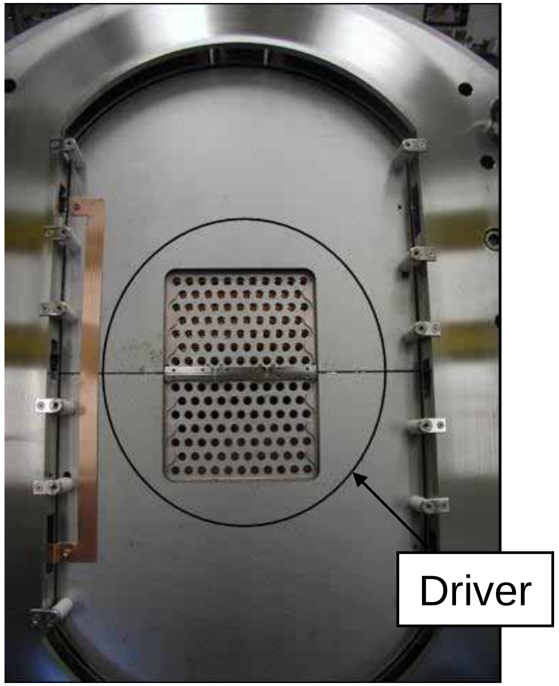
## MANITU (multi ampere negative ion test unit)

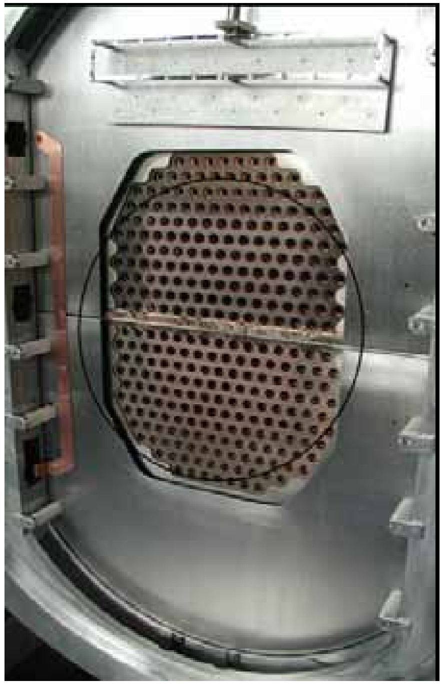
- Large area beam extraction
- long pulse operation up to 3600 s in $D^-$

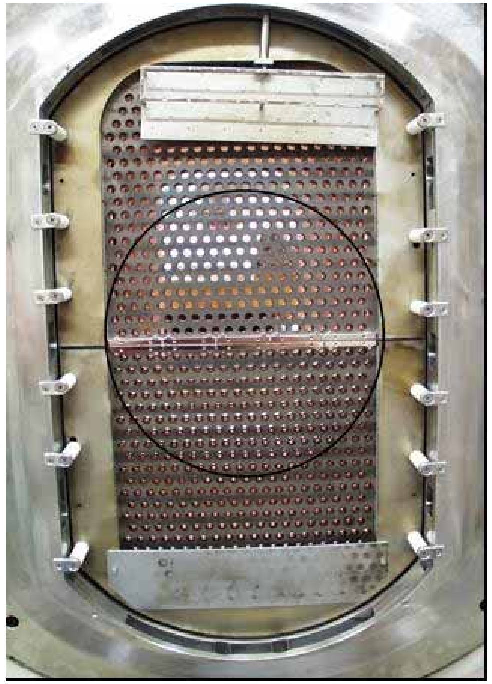
# Outline

- **Extension of the extraction area**
- **Upgrade of MANITU for long pulses**
  - Source
  - Power supply
  - Vacuum system
  - Calorimeter
  - Neutron shielding
- **First long pulses with partely upgraded set-up**

# Extension of the extraction area





**74 cm²**
Initial size

**152 cm²**

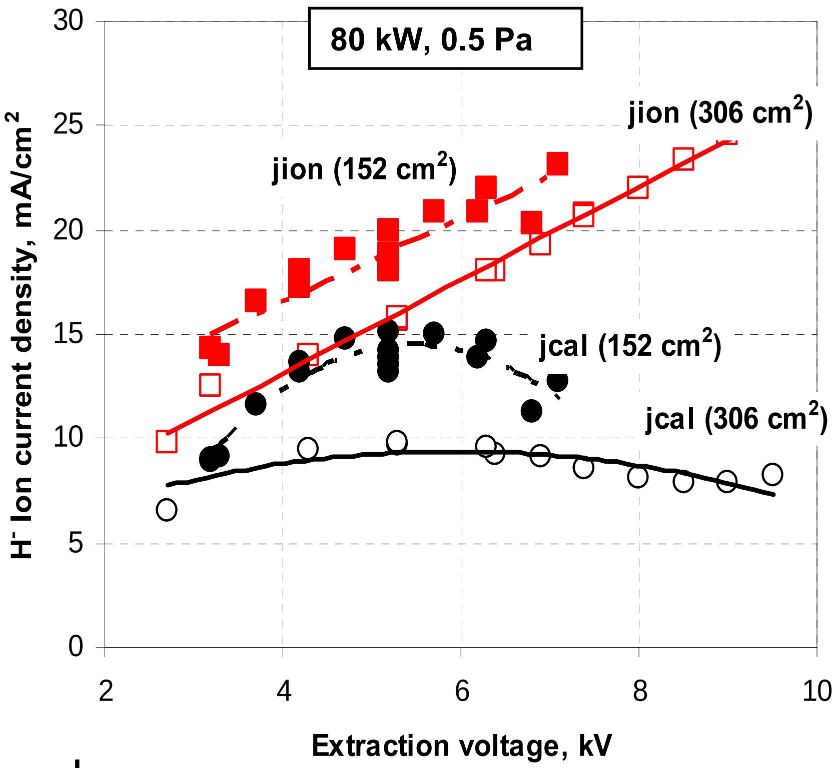
**306 cm²**

# Beam extraction with large extraction area

**74 => 152 cm²:**

No substantial change of the ion current density jion.

Max. 19.3 mA/cm² at 0.45 Pa on the calorimeter (90 kW).




**152 => 306 cm²:**

Ion current density only slightly reduced

Max. jion of 32 mA/cm² corresponding to a total $H^-$ current of 9.7 A (0.5 Pa, 100 kW, 10.5 kV)).

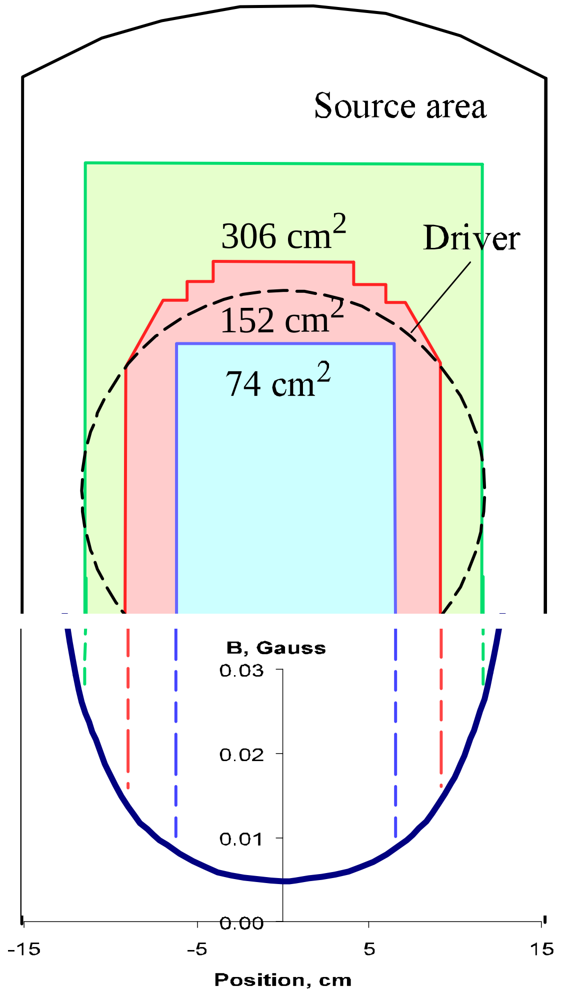
# Calorimetric current with large extraction area

**152 => 306 cm²:**

Smaller fraction of the ion current reaches the calorimeter

**Possible reason:**

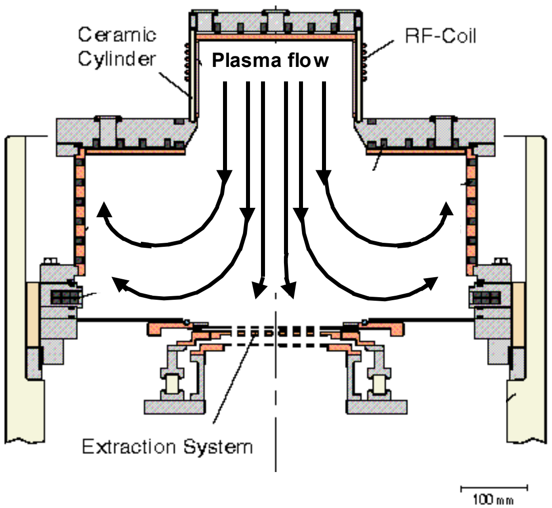
deflection of extracted ions due to the strong increase in the magnetic filter field at the edge of the large extraction area

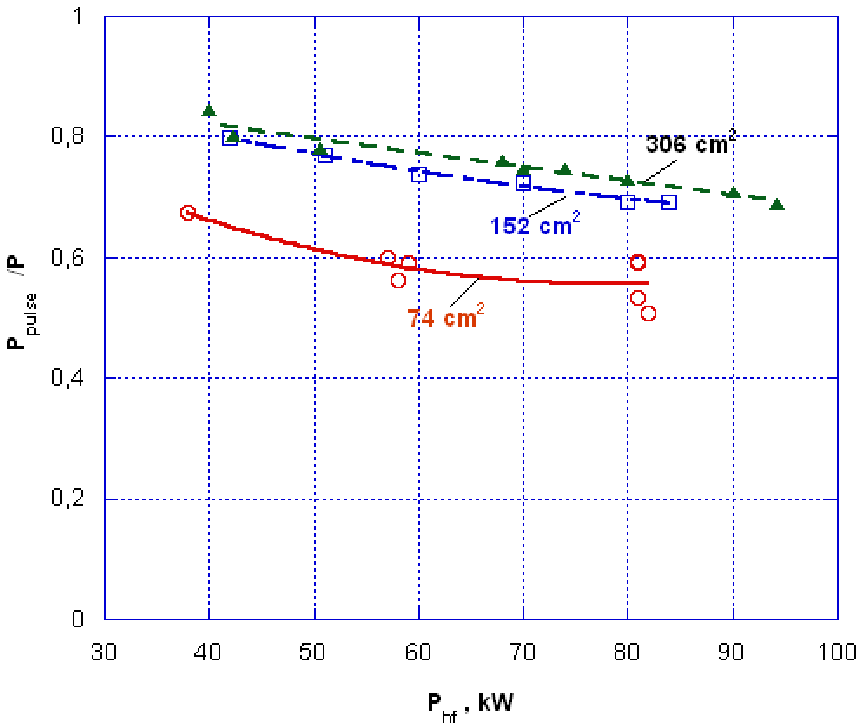


# Pressure in the driver

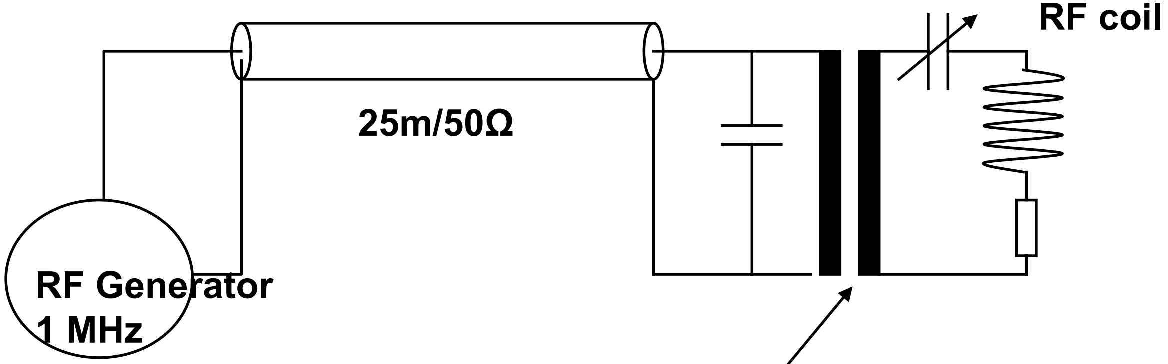
The pressure drop during the RF discharge is much smaller with the larger extraction areas

(gas flow is higher in relation to the plasma flow)



# Upgrade of the RF Power Supply for cw operation




120kW/10s RF generator replaced by a

**new 180 kW / cw**

**RF generator**

(2 tetrodes in push-pull-arrangement)

Including new cooling system

**Improved RF transformer**

Reduced temperature rise of the ferrites :

1°C/s => 0.05°C/s

(100 kW)

**Transformer not needed for ITER!**

# HV Power Supply

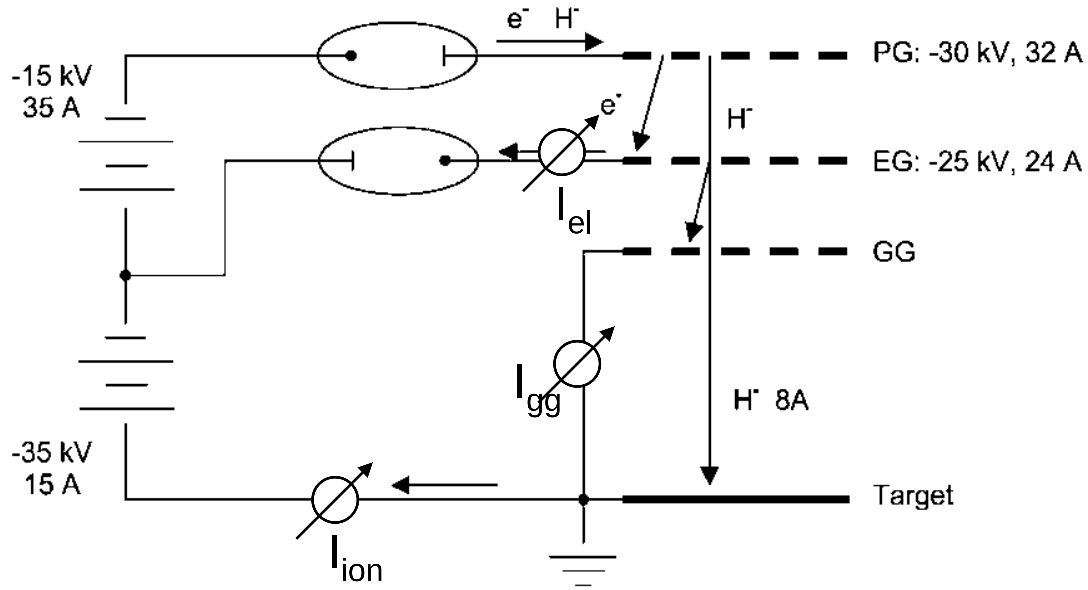
## New cw HV power supplies:

extraction voltage

(15 kV, 35 A)

acceleration voltage

(35 kV, 15 A)



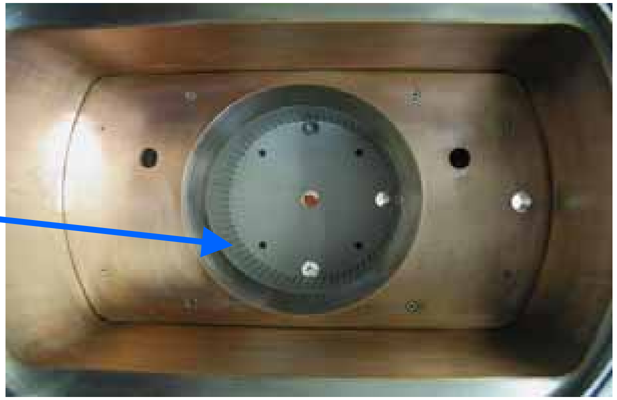

## New HV circuit and voltage regulation system using two triodes

⇒ No longer dependent on the central IPP HV power supply

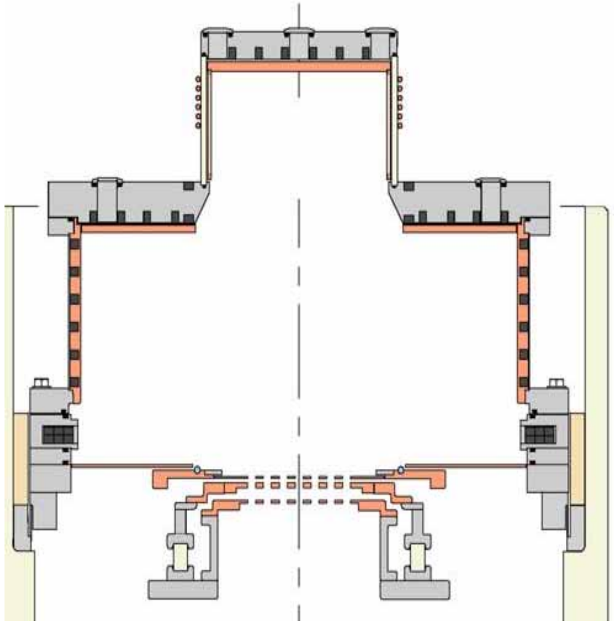
⇒ More time for experiments

# Upgrade of the source

- New actively cooled **Faraday Shield**



- Gas cooling of the plasma grid



- **Temperature control** of source body and plasma grid

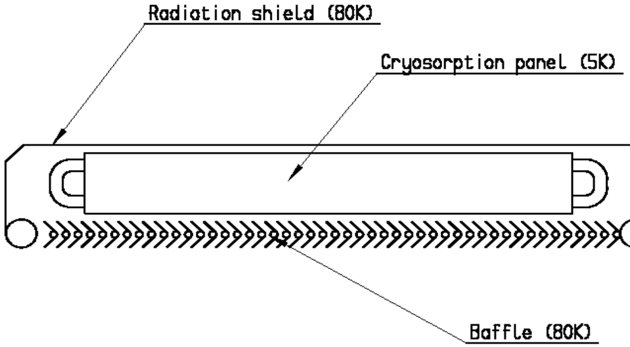
# Vacuum system

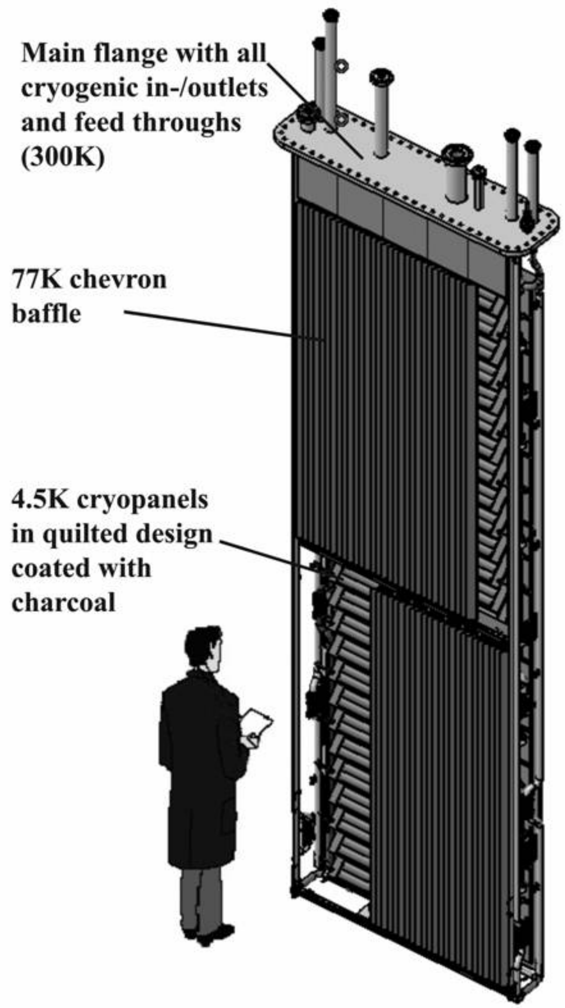
Titanium evaporation pumps (10–15 s) replaced

by a

**cryo pump system** (collab. with FZK)

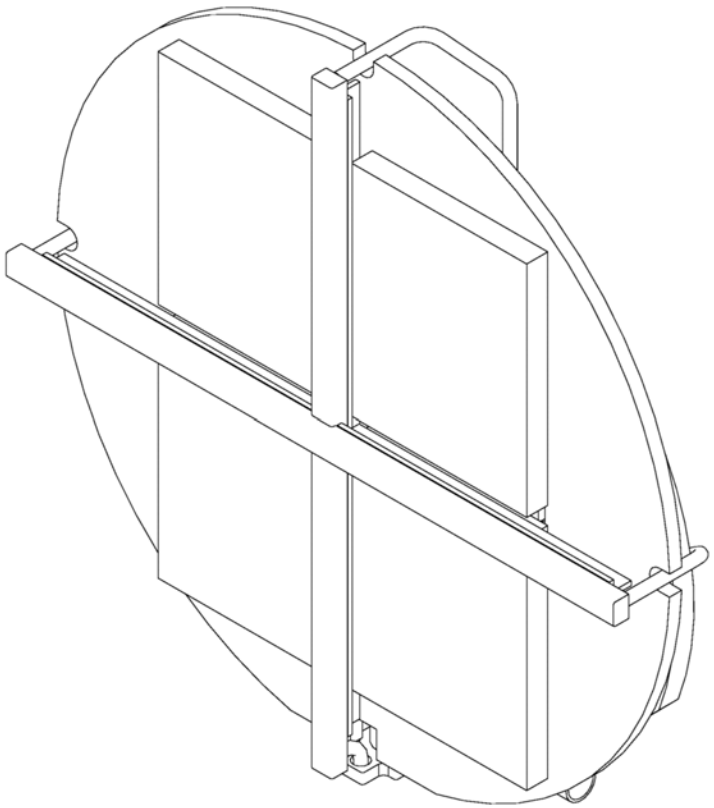
- pumping speed of $7 \times 10^5$ l/s
- pumping capacity of $1 \times 10^6$ mbarl
- two cryosorption pumps
- uses the He liquefier of ASDEX-Ug



# Calorimeter for cw operation

- Actively cooled
- Diameter of 600 mm
- 350 kW total power capability
- Maximum power density of 6 $MW/m^2$.
- 4 ASDEX-Upgrade calorimeter panels
- Beam profile measurement



# Data and testbed control system

- **New control system**

  including HF and HV power supply, gas and vacuum system

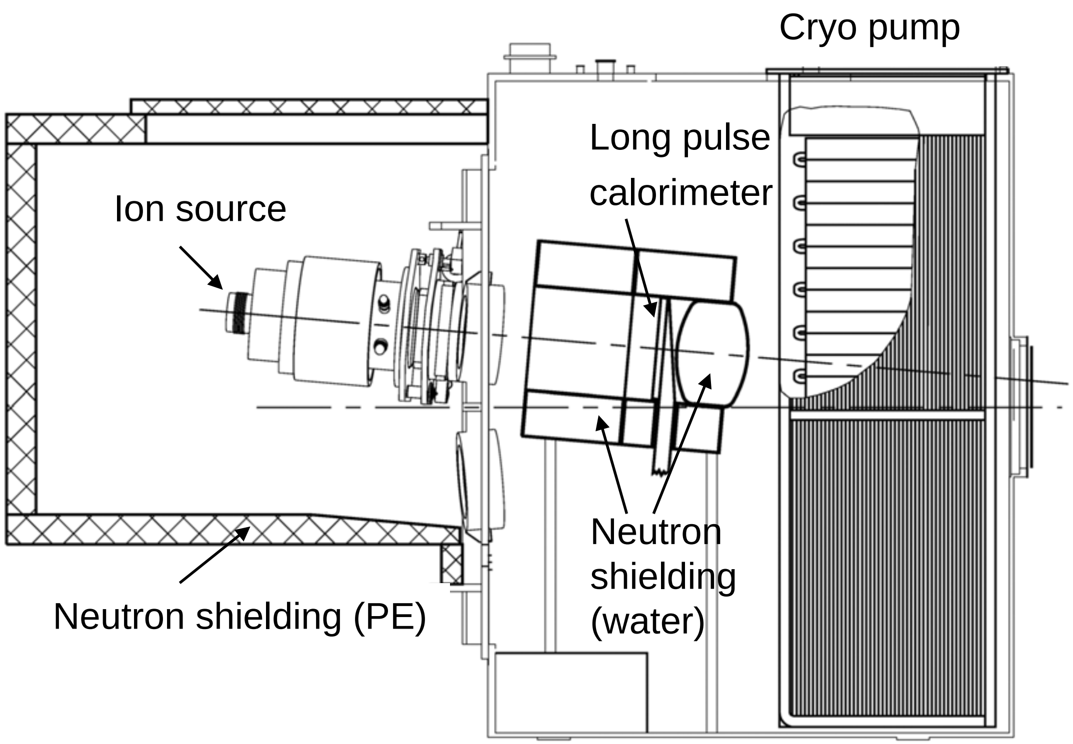
- **Improved data acquisition system**

  compatible with long pulses

  (Carmac => µ-MUSYCS)

# Neutron shielding I

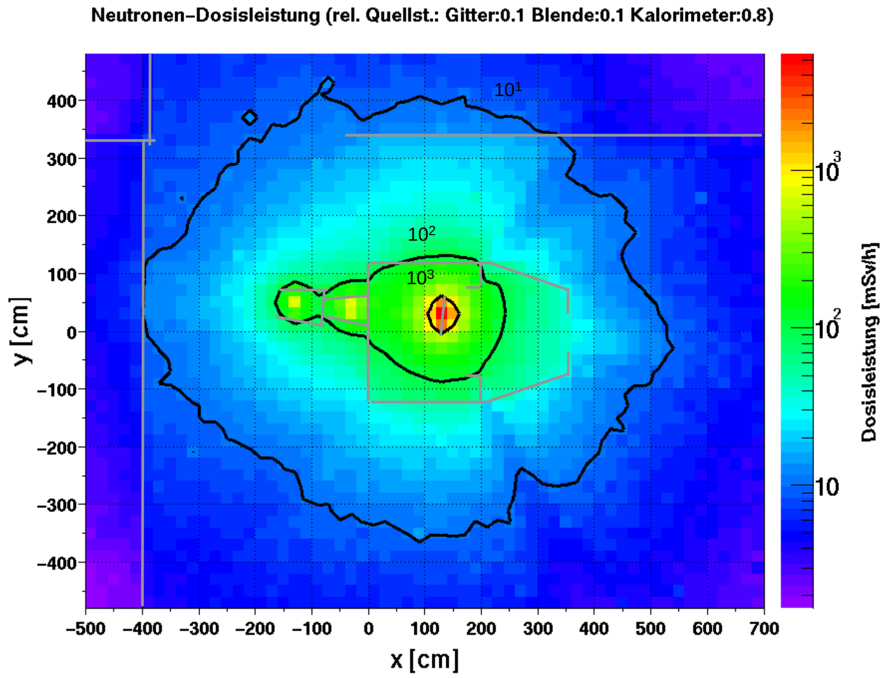
**Source** and the **extraction system** are enclosed in a cabine with 20 cm **polyethylene walls, calorimeter** by 30 cm thick double walled **water tanks** inside the vacuum chamber.



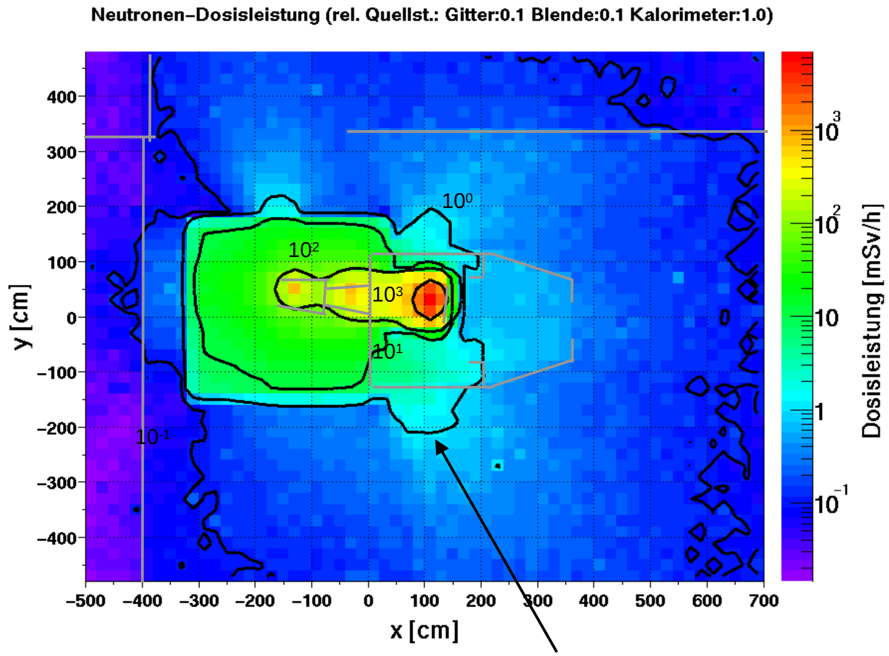
# Neutron shielding II

# Calculated neutron radiation dosis

Without




With shielding




1 mSv/h

Total pulse duration of > 6 hours per year (6 mSv/h) for Deuterium operation.

# Status

Operational are the **new RF and HV power supplies**, the **control** and the **data acquisition system**.

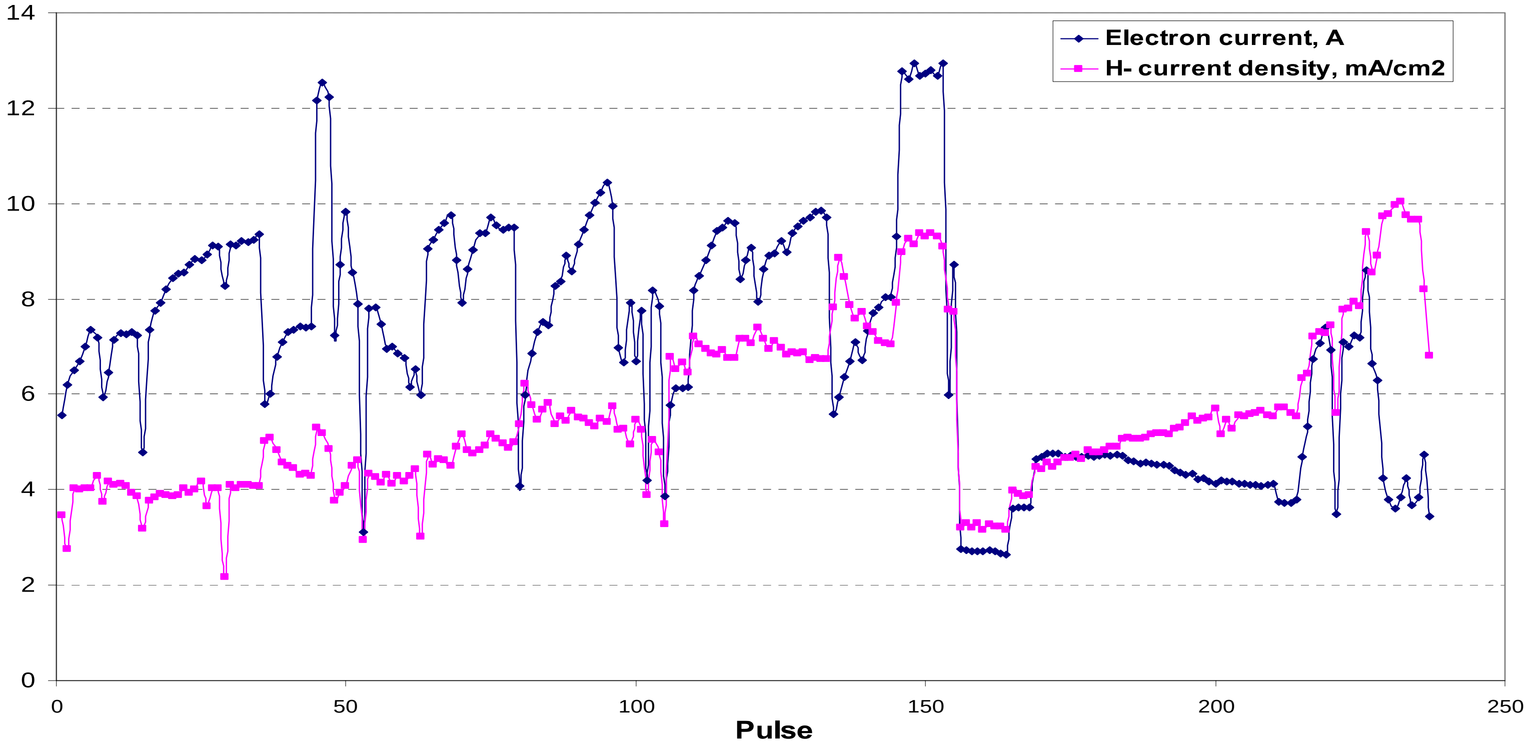
As an intermediate solution an **inertially cooled calorimeter** is used, which allows pulses of several 10 seconds length

Extraction area: **152 $cm^2$**

The maximum pulse length is presently limited by the heat up of the old Faraday shield and the pressure rise in the vacuum tank.

# First beam extraction with extended pulse length

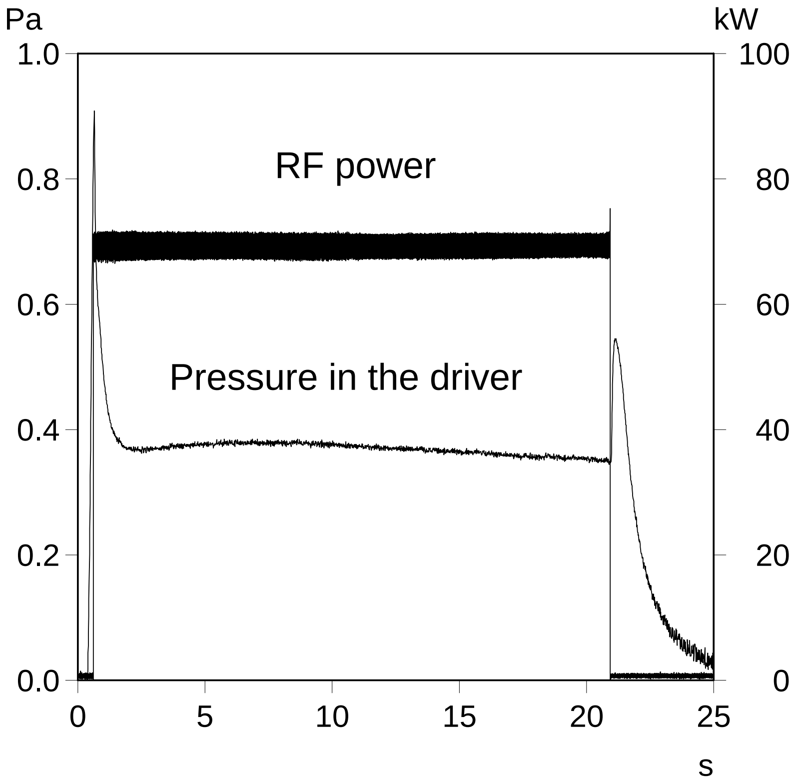
Pulse length 10 – 20 s

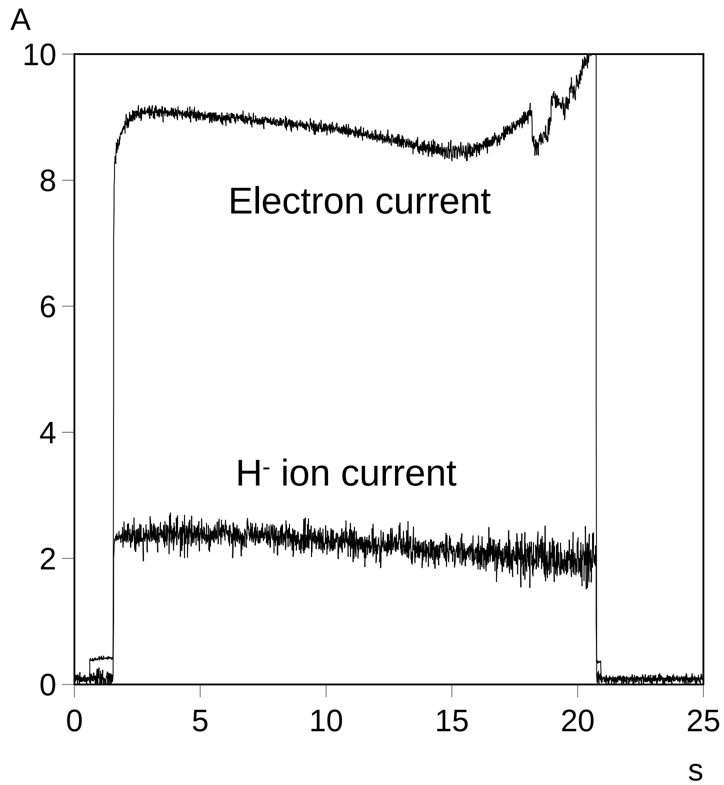



Iel ↓ and j(H-) ↑
some but not yet sufficient surface production

# First 20 s pulse

70 kW, 0.5 Pa




**Current density on the calorimeter 8.7 mA/cm$^2$**

# Next steps

- **2 mm Mo plate with chamfered holes mounted onto the plasma grid.**

  Batman results => higher $H^-$ current and lower electron current

- In June the actively cooled **Faraday shield** and the **long pulse calorimeter** will be available and the **cyro pumps** will be operational.

- Extraction area 152 => **250 cm$^2$**

# Summary

- The electrically measured $H^-$ current density showed no significant dependence on the extraction area.

- The rf source has the potential to deliver a $H^-$ current of nearly 10 A over an area corresponding to that supplied by one driver in the ITER source.

- The extension of the pulse length required substantial modifications of the source and the MANITU testbed. Using a partly upgraded system, first beam extraction experiments with pulse lengths up to 20 s have been successfully carried out.