A compact 35 keV ECR proton ion source with advanced chopping for neutron source applications

G. Anda[1], D. Czémán[1], M. Lampert[2], M. Merse[3], A. Zsákai[1]

[1]HUN-REN Centre for Energy Research, Budapest, Hungary, [2]Princeton Plasma Physics Laboratory, Princeton, NJ, USA

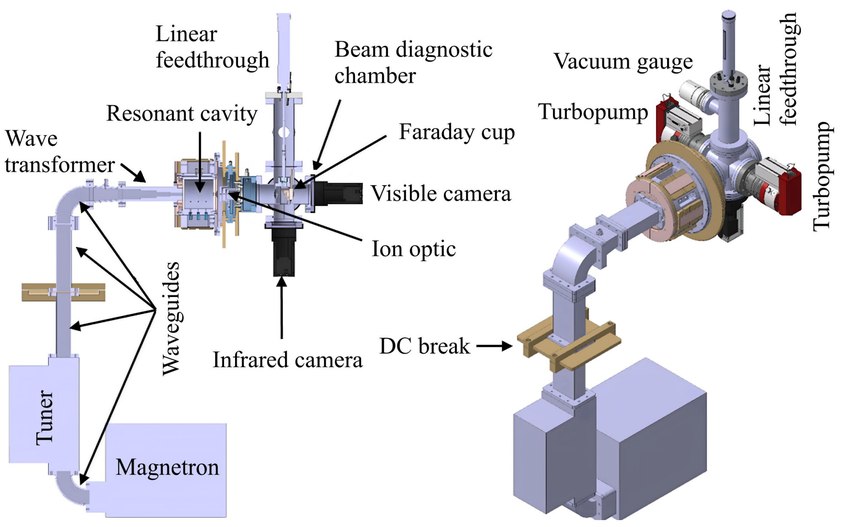
[3]KTH Royal Institute of Technology, Stockholm, Sweden, [4]Budapest University of Technology and Economics, Budapest, Hungary

Parameters of the CER p-source

Development has started for a compact neutron source application (being built at Martonvásár, Hungary).

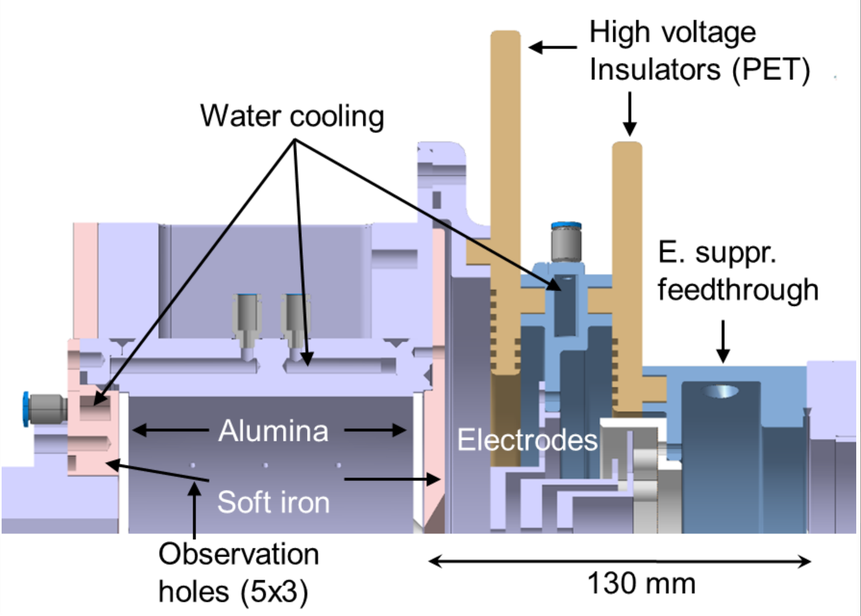
- 35kV, 20mA
- Continuous or pulsed (0.01-40Hz, duration is 0.1-10ms) mode
- Energy ripple below 1%
- Beam emittance below 1 π mm mrad
- ECR (87.5mT @ 2.45GHz)
- Compact design (source aperture – RFQ distance is ~ 500mm
- Double solenoid for beam focusing (2.5kW each)
- Water cooled Faraday cup with (infrared) observation camera (current and current distribution measurement)
- Novel HV insulation design
- Standard and novel beam chopping (using deflection plates at ~ 3kV)

Design



- Standard design
- Cavity: 90/100mm (diameter/length)
- Permanent magnets: 6 blocks (10 times 10x25x50 pieces, grade N52)
- Ion optics: 4 electrodes (HV, ground, e. suppr., ground)
- DC break: 3mm DOCALENE HD500
- H inlet: VAT 21124-KE0X dosing valve, stepper motor.

HV and cooling



- HV insulators made of PET (or PEEK, if necessary). Internal cooling channels in the cavity, its closing flange and at the extractor electrode [2].
- Alumina is used as electron multiplier.

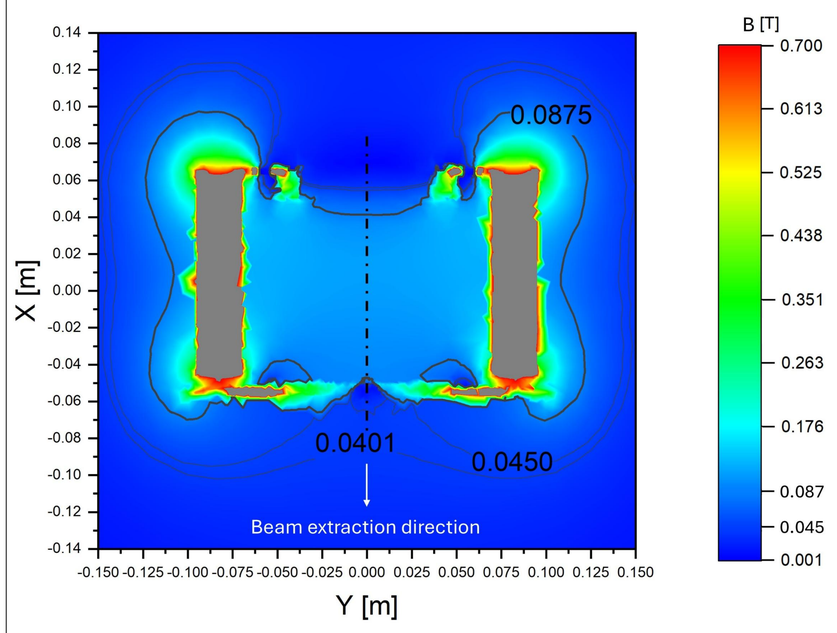
References

[1] G. Anda et al, Rev. Sci. Instrum, Design and preliminary results of the microwave-driven proton ion source developed at the Centre for Energy Research,

[2[G. Anda et al; Rev. Sci. Instrum. 89, 013503 (2018)

Magnetic field

- ANSYS Discovery AIM Electromagnetics software was used to optimize the magnetic field.

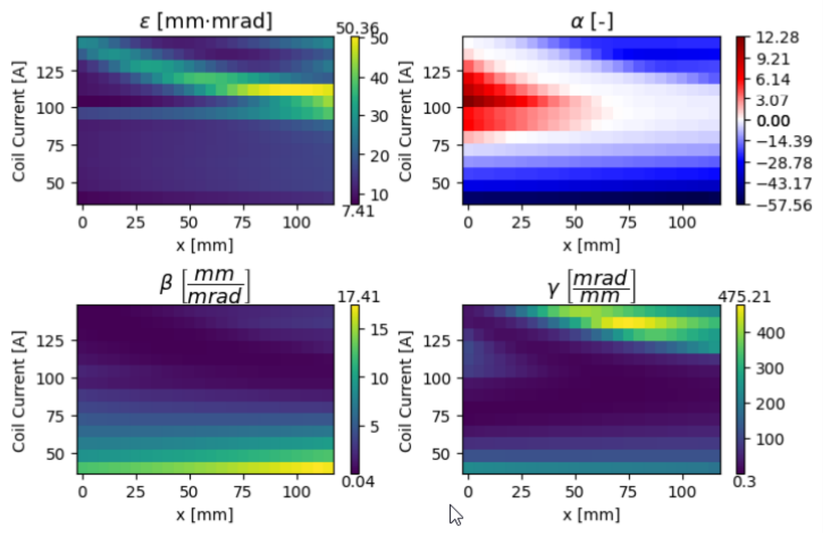


- All magnet poles are oriented in the same direction (solenoid like magnetic field), with soft iron end plates. ECR flux surfaces are situated both at the microwave entrance and at the beam extraction aperture.
- The magnetic field can be fine-tuned using soft iron plates (shunts) placed on the magnet blocks.

Beam focusing

The main goal of the (Charged Particle Optics, CPO) simulation is to define how the requested beam emittance and Twiss parameters (α, β, γ) – defined by the manufacturer of the RFQ, can be reached.

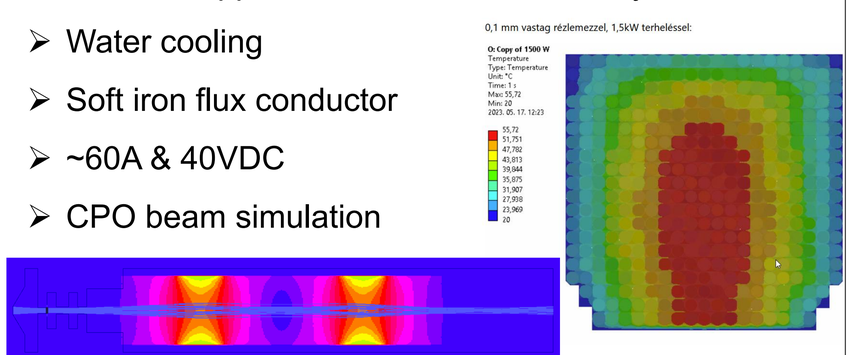
α	β	γ	emittance
6.41	0.05679 mm/mrad	742.59 mrad/mm	32.4062 mm·mrad



Achieving the needed beam emittance and Twiss parameter values is possible, but the solenoids must be positioned **directly** before the RFQ.

Water cooled solenoid design

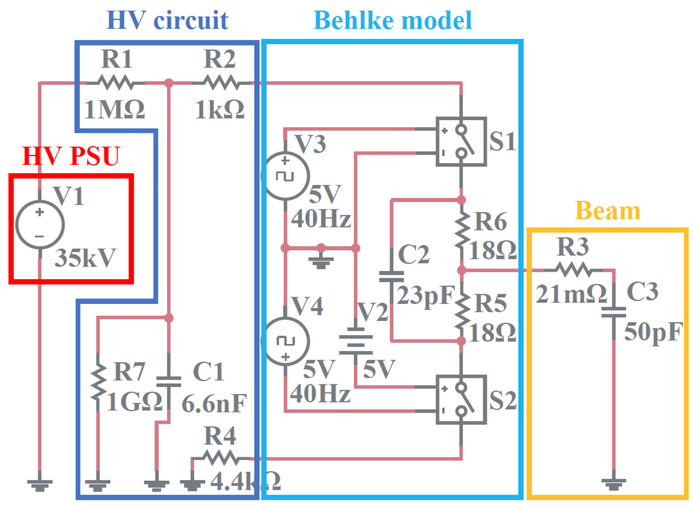
- Winding number: 400 (20 x 20)
- Coil diameter: 3 mm
- 0.1 mm copper sheets between each layer
- Water cooling
- Soft iron flux conductor
- ~60A & 40VDC
- CPO beam simulation



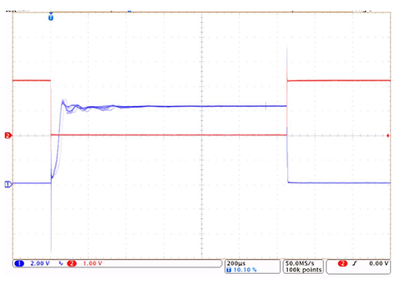
Chopping – standard

Switch the potential at the extraction electrode between 0 and 35kV.

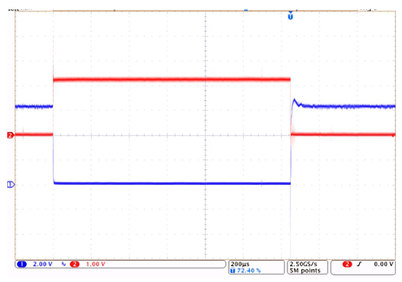
Purpose-built MOSFET: Behlke HTS 401-10-GSM



Measurement. Blue: beam current in FC, red: signal generator.



5 % duty factor

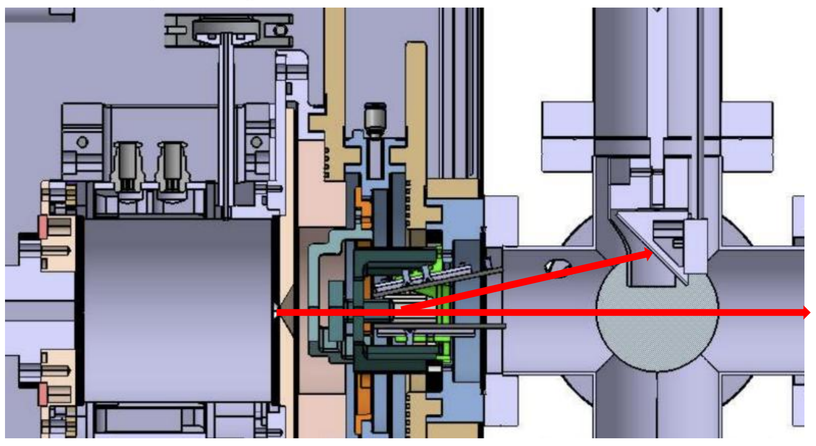


95% duty factor

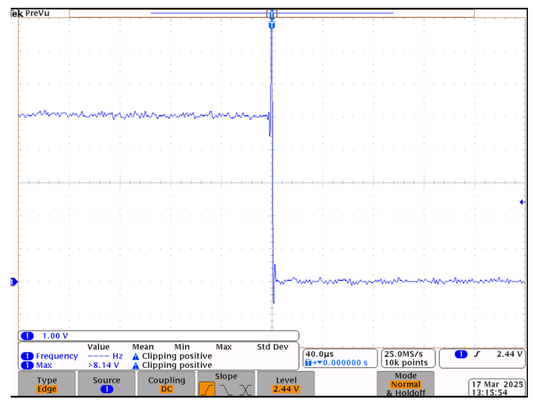
Chopping – with deflection

Use of deflection plate and move the beam onto the upper positioned Faraday cup.

Necessary voltages: ± 3 kV



Measurement (FC current)



Summary

- ✓ Beam current measurement: ~5 mA at 250 W with 4 mm aperture diameter (~40 mA/cm^2)
- ✓ Water-cooled Faraday cup for beam current and distribution measurement
- ✓ Proper high-voltage insulation
- ✓ Beam chopping via deflection plates
- ❖ Emittance measurement
- ❖ Measurement of proton / H_2^+ / H_3^+ ratio

Next step: Increase aperture size to allow higher beam current.