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SHEET ELECTRON PROBE FOR ION BEAM TOMOGRAPHY

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Muons, Inc. (Muons) is a private-sector, high-energy accelerator physics firm. Muons has a staff of experienced and accomplished accelerator scientists and engineers, and elementary-particle physicists. We collaborate closely with 9 National Laboratories and 7 Universities. Muons was formed in 2002 to design the next atom smasher, the Muon Collider, in order to help the U.S. regain the lead in the energy frontier by studying the most fundamental forces and constituents of matter. We have expanded from SBIR-STTR funded R&D into other topics of national and global interest, including development, design, and implementation of systems and components for discovery science, national security, medicine, energy, and environment.

Status: Phase II, no-cost extension

SHEET ELECTRON PROBE INNOVATION

An electron beam probe has been successfully used for the determination of accelerated particle density distributions.

Large size and complex design, which limit the broad use of this diagnostic for tomography of accelerated bunches.

New approach: generate a **pulsed sheet** of electrons.

1. Ion beam bunches pass through the sheet
2. Distortions in the distribution of sheet electrons measured on luminescent screen with a CCD – continuous measurement of beam profile
3. Strip cathode rather than scanning electron beam probe:
    1. Smaller, simpler design (cheaper manufacturing process)
    2. Better magnetic shielding
    3. Higher sensitivity and higher space and time resolution

With this device it is possible to develop almost ideal tomography diagnostics of bunches in linear accelerators and in circular accelerators and storage rings.

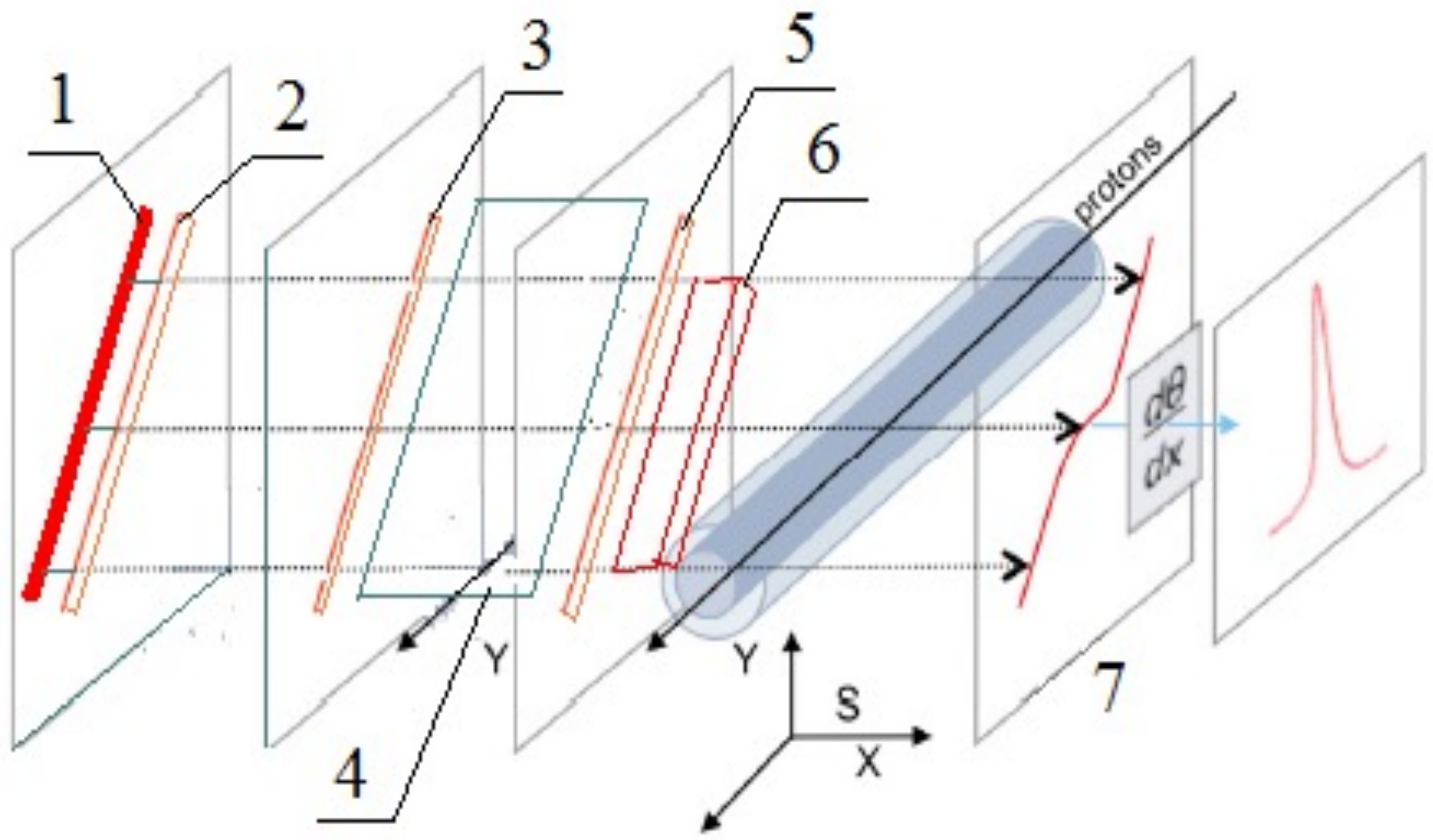


Fig. 1. Sheet electron probe beam profile monitor with a strip cathode.

1-strip cathode;
2-extractor;
3-first slit of collimator;
4-deflecting plate;
5-secondslit of collimator;
6-sheet slice of electron beam probe;
7-luminiscent screen.

ADVANCED SHEET ELECTRON PROBE BEAM PROFILE MONITOR

The advanced sheet electron probe beam profile monitor (SEPBPM) with the strip cathode is proposed as shown in Fig. 1. For the slice of sheet electron probe (6) formation is used the strip cathode (1) with extractor (2). The sheet electron probe is formed by a collimator with two slits (3) and (5). The short slide of sheet electron probe (6) formed after deflection by electric field of proton bunch is visualized on the luminescent screen (7) and fixed by a fast CCD camera for further processing by the corresponding software. This version of the SEPBPM is smaller, and easy for fabrication, operation, and magnetic shielding. Several similar systems can be integrated for the production of the tomographic 3-D image of proton bunches. The proposed tomographic system is more compact, easier to operate, and less expensive than the residual gas ionization profile monitor (IPM).

An isometric view of the diagnostic system is shown in Fig. 2 (next slide).

SIMULATION OF PROBE BEAM DEFLECTION BY PROTON BUNCH

A computer program for simulation probe beam deflection by proton bunch has been developed Adaption of the SCAPRO Program by Galina Dudnikova.

Examples of simulations are presented in Fig. 3 that shows deformations of the sheet electron probe beam with energy 30 keV by a proton bunch with $\gamma=10$ and different proton numbers.

Distance between max and min of blue curves $\Delta y=0.24$ cm is related to horizontal dimension of proton bunch. Amplitude of deflection $\Delta x=0.36$ cm is proportional to number of protons, γ-factor of proton bunch, and inverse proportional of electron beam energy.

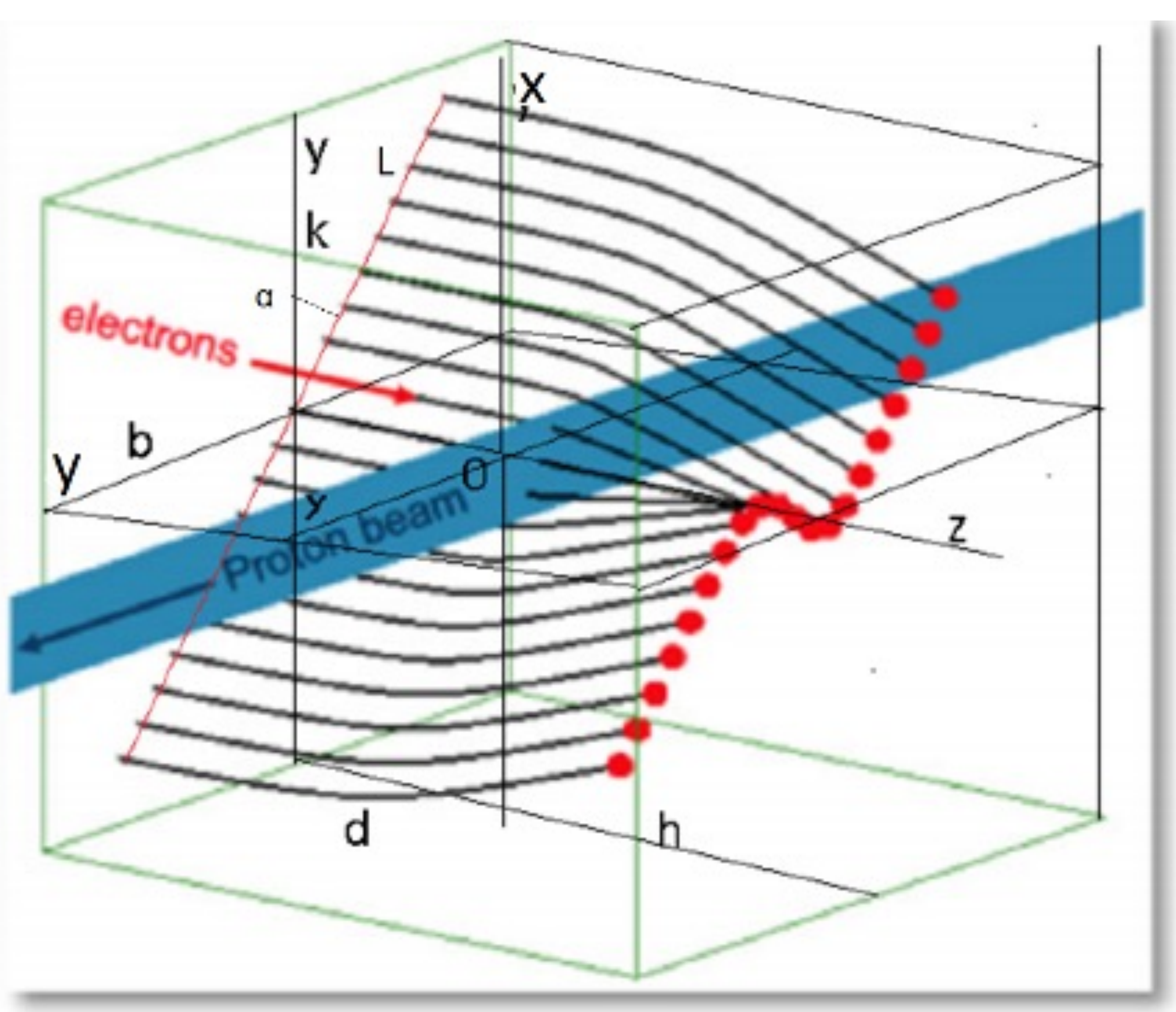


Fig. 2. Isometric view of modification of strip e-beam profile monitor with a slice of the sheet electron probe.

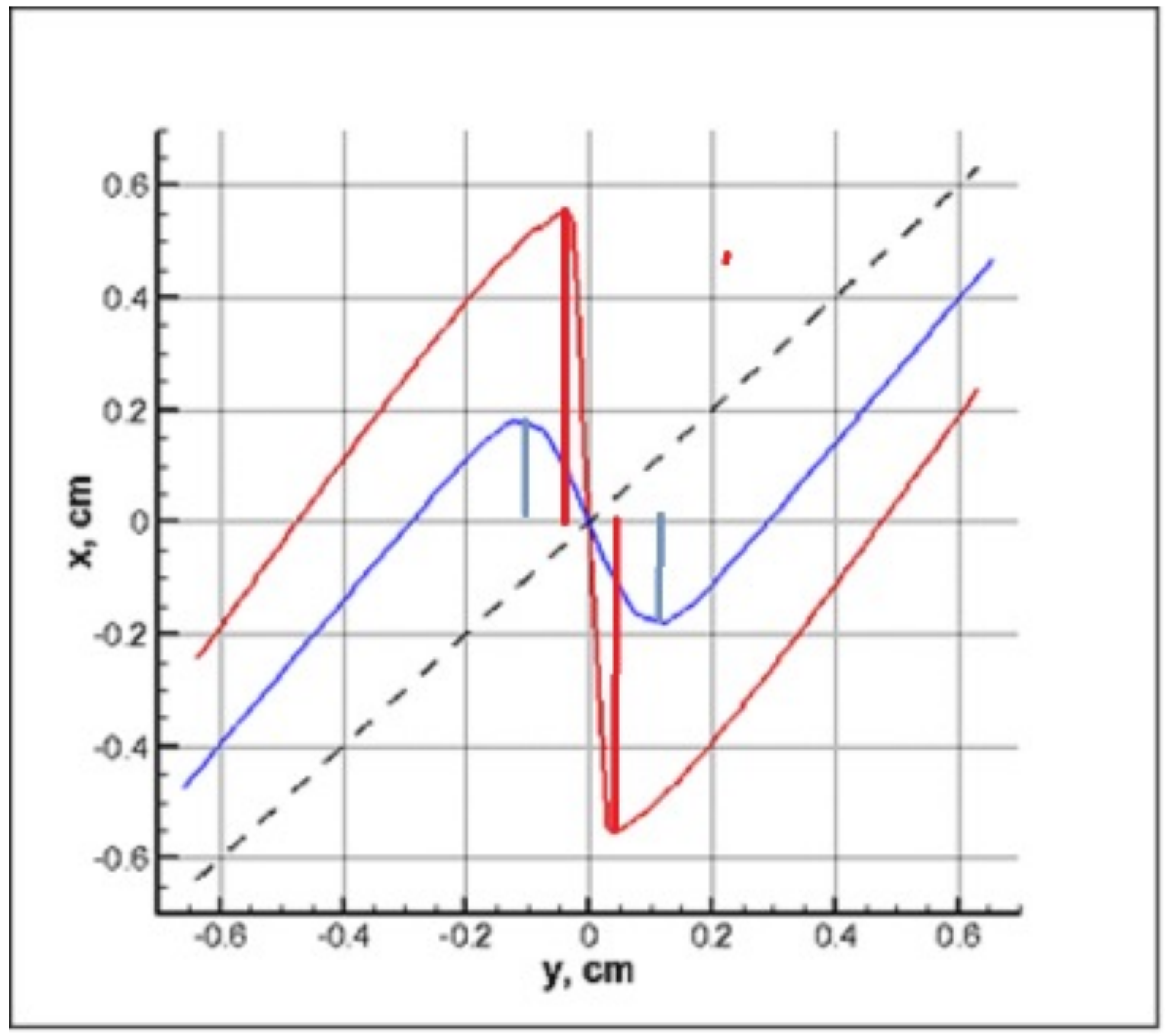


Fig. 3. Tracks of deflected electron beam on the luminescent screen for RUN1-red, RUN2-blue. Dashed line is trace of non-deflected electron beam.

BEAM CHARACTERIZATIONS FROM PROBE BEAM DEFLECTION

Depending on energy, ion species and i.p. (interaction point) optics the rms width of the beam in RHIC and in Fermilab can vary from 0.7mm to 6.5mm. The channel spacing has to be small enough that a reasonable measurement can be made on the most narrow beam but the collector has to be wide enough to see the largest beam with some allowance for mis-steering and betatron oscillations.

The charge distribution (beam profile) δ (x,y) can be restored from the electron beam deflection angle $\theta\ (x)$with respect to the impact parameter:

$$\frac{d\theta_0(x)}{dx} = \int_L \frac{e}{mv^2}\frac{\delta(x,y)}{\varepsilon_0}dy.$$

We see that derivative of the electron beam deflection angle $\theta\ (x)$with respect to the impact parameter gives the projection of the charge distribution δ (x,y) on the x axis or, in other words, the beam profile, as it would be measured by an usual wire scanner.

ELECTRON GUN

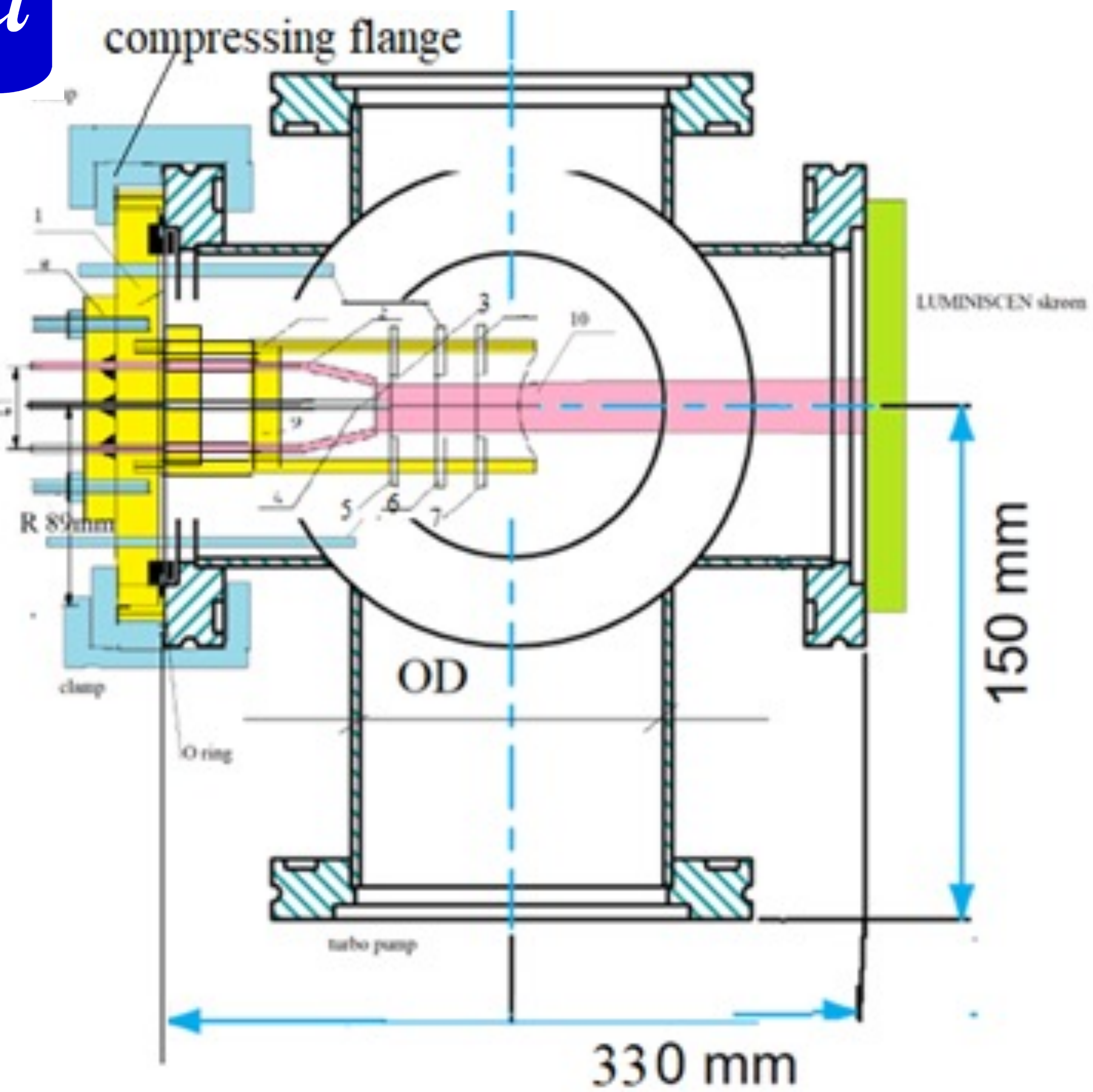


Fig. 4. Schematic of electron gun for production of Sheet electron Probe Beam.
1-ceramic disc,
2-current leads,
3- WCe emitter of electron,
4- feedthrough,
5- extraction electrode,
6-accelerating electrode,
9-compression ceramic,
10-sheet electron Probe Beam.

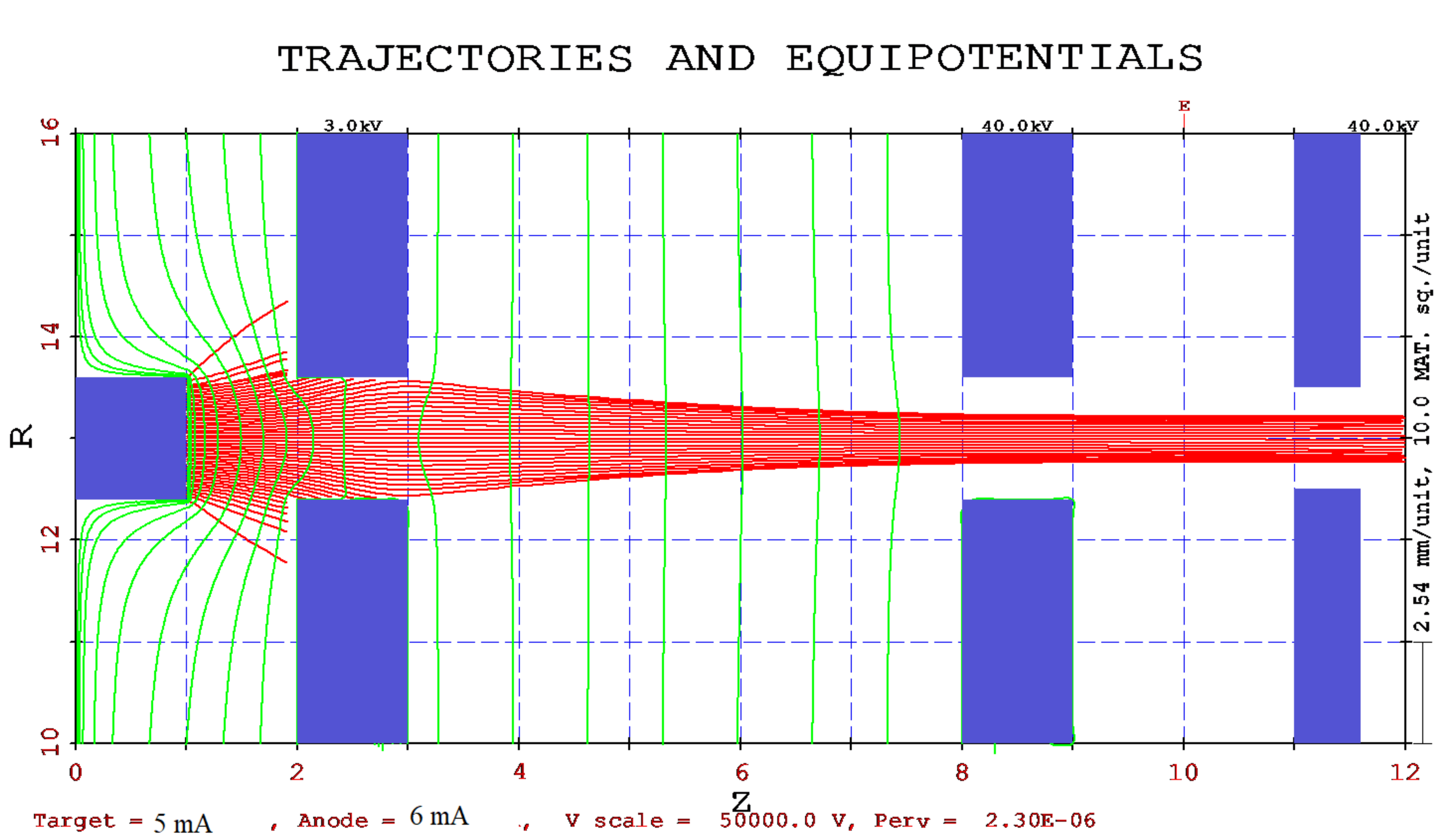


Fig. 5. Optimal focusing with low aberrations Vext=3 kV, energy 40 keV.

An electron gun is the source of the sheet beam – the schematic is shown in Fig. 4. The electron gun consists of

1. A ceramic disc with a diameter of 20 cm and thickness of 15 mm,

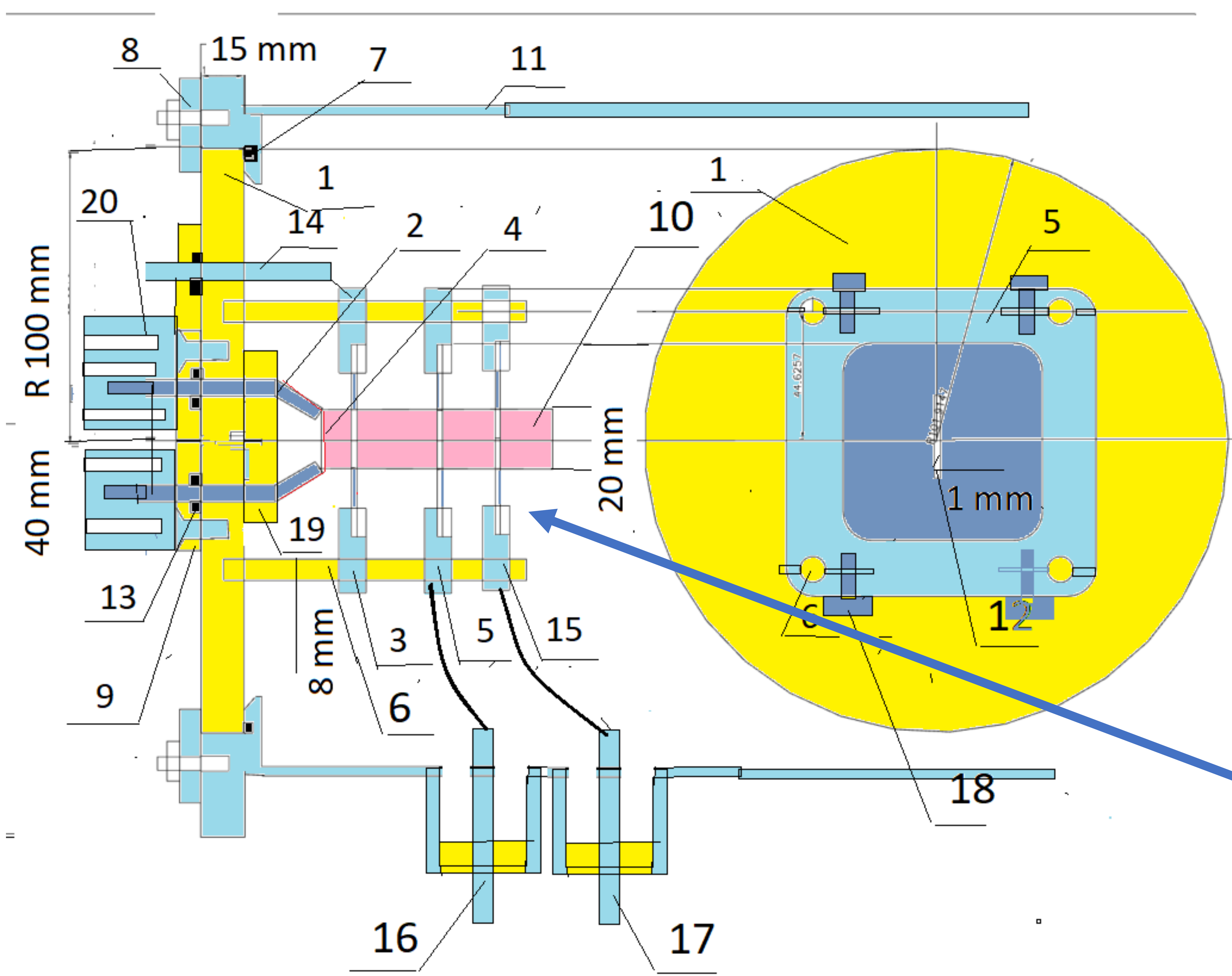
2. Two current leads for heating a WCe electron emitter 2x20x0.2 mm, welded to current leads

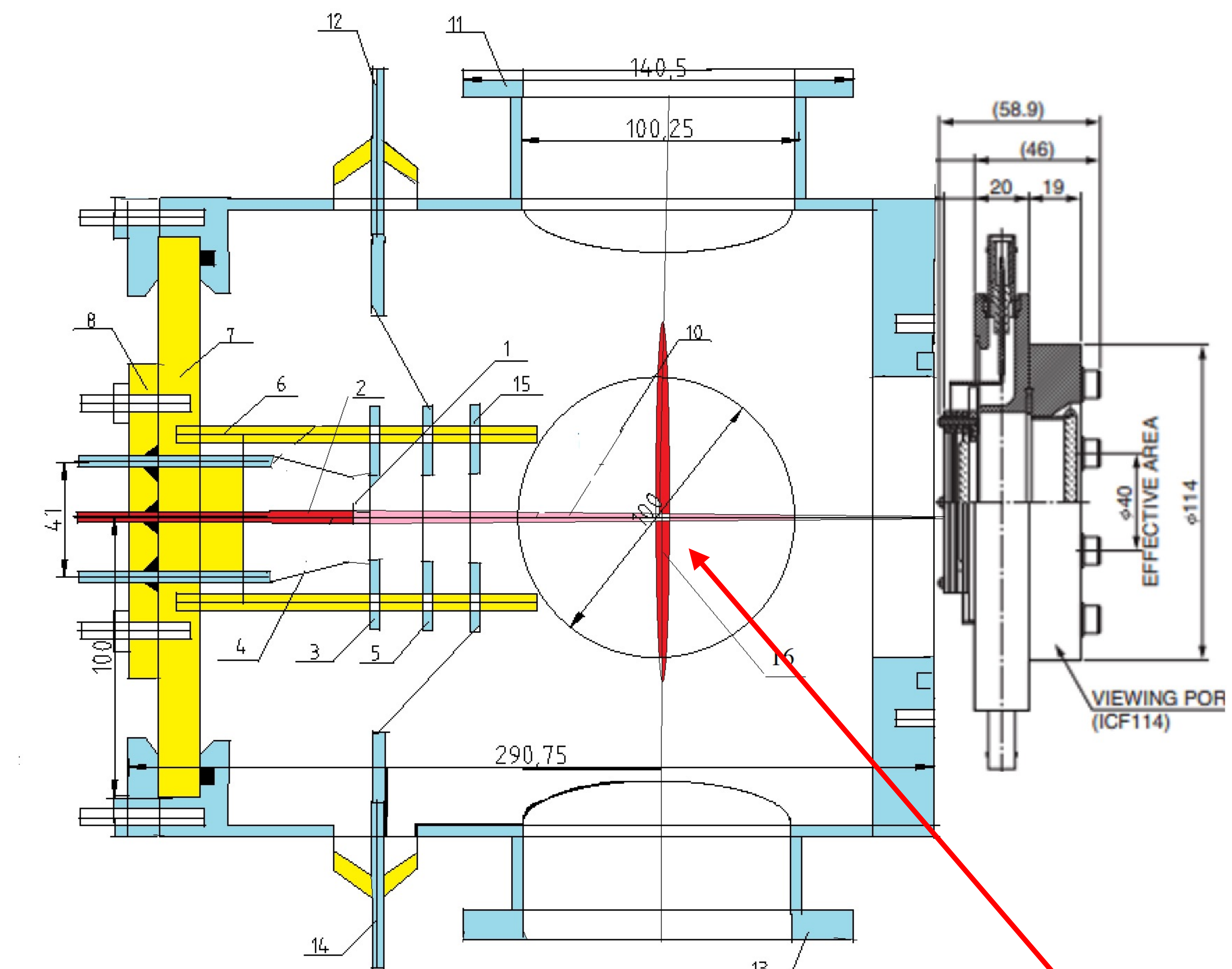
3. An extractor electrode aperture 1x20 mm

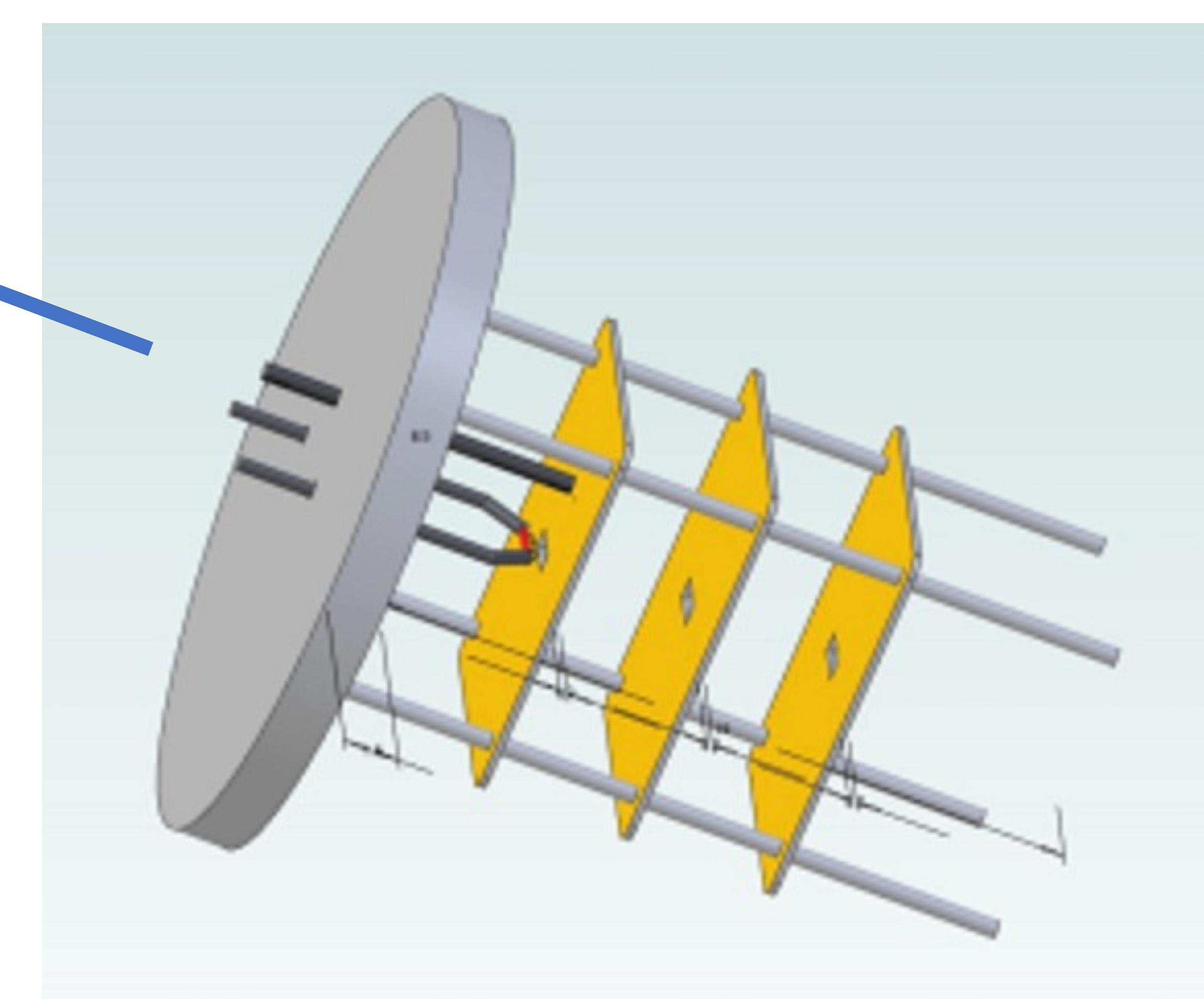
4. An accelerating electrode, aperture 1x20 mm

A sheet electron beam is emitted by WCe emitter and accelerated by extraction electrode and accelerating electrode 5. High voltage up to 100 kV is applied to emitter. Pulsed extraction voltage ~ 3 kV is applied to the extraction electrode and extract sheet electron beam. The electron beam is passed through a proton bunch and is deflected by electric and magnetic field of bunches and registered by the luminescent screen.

ELECTRON GUN AND ASSEMBLY







Ion beam

Area of emitter = 0.01*2*2+0.2*2*2=0.88 cm^2

Cross section of emitter 0.01 x0.2 cm^2, Radiation Area of emitter 0.88 sm2

power 21.8x0.8=17.5 W

Radiated 17.5x0.4=7 W.

ENGINEERING DESIGN OF ELECTRON GUN ASSEMBLY

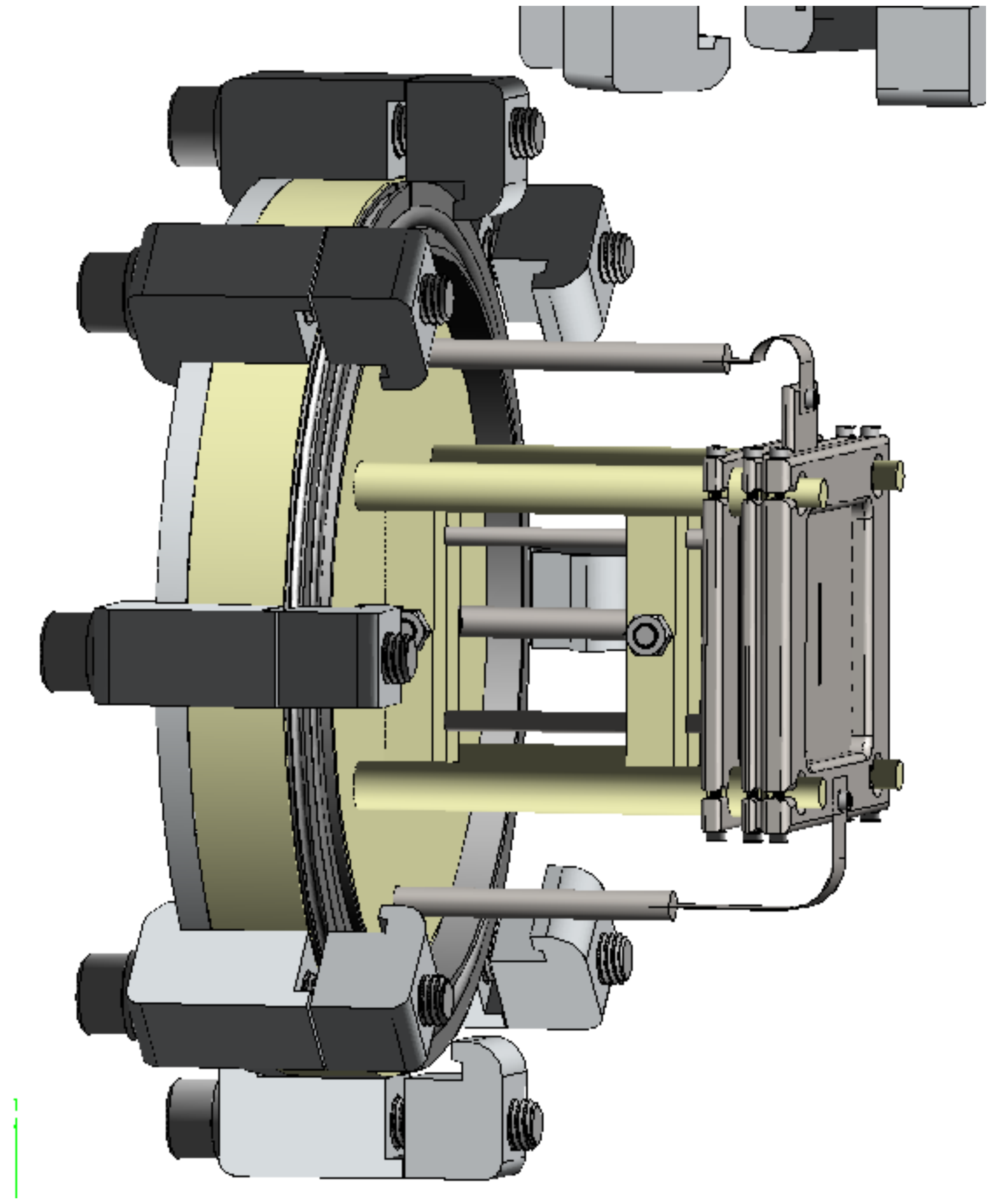


Fig.6. Solid work 3 D model of an electron gun for the production of the sheet electron beam.

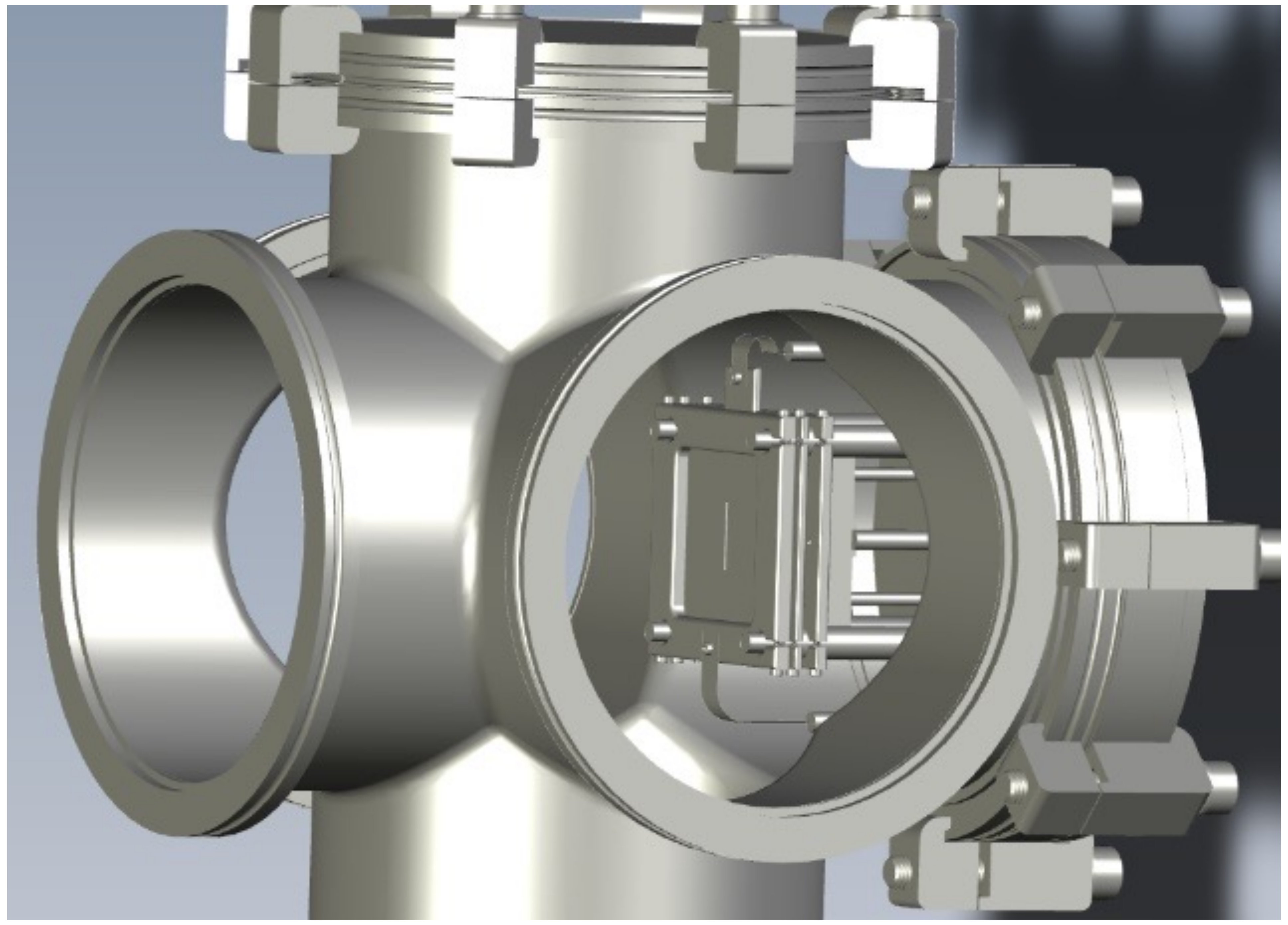


Fig.7. Solid work 3 D model of an electron gun for the production of the sheet electron beam in 6- way cross.

Fig.8. 6 - way cross with turbo pump.

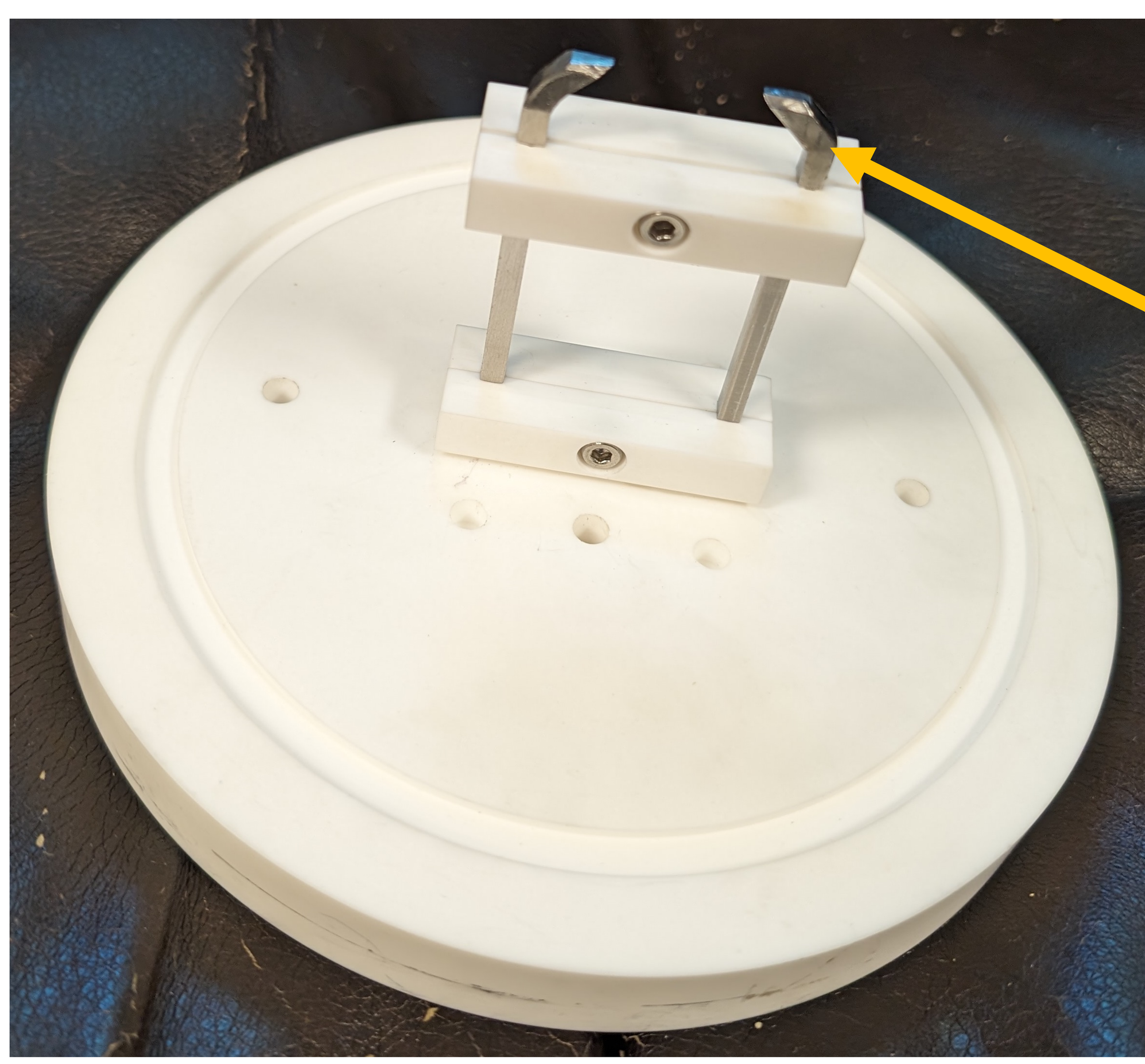


Fig.9. Current leads for emitter.

Strip cathode to be welded here

Tungsten ceriated alloy (2%)
Machining is a challenge

Currently in contact with new company with promising solution

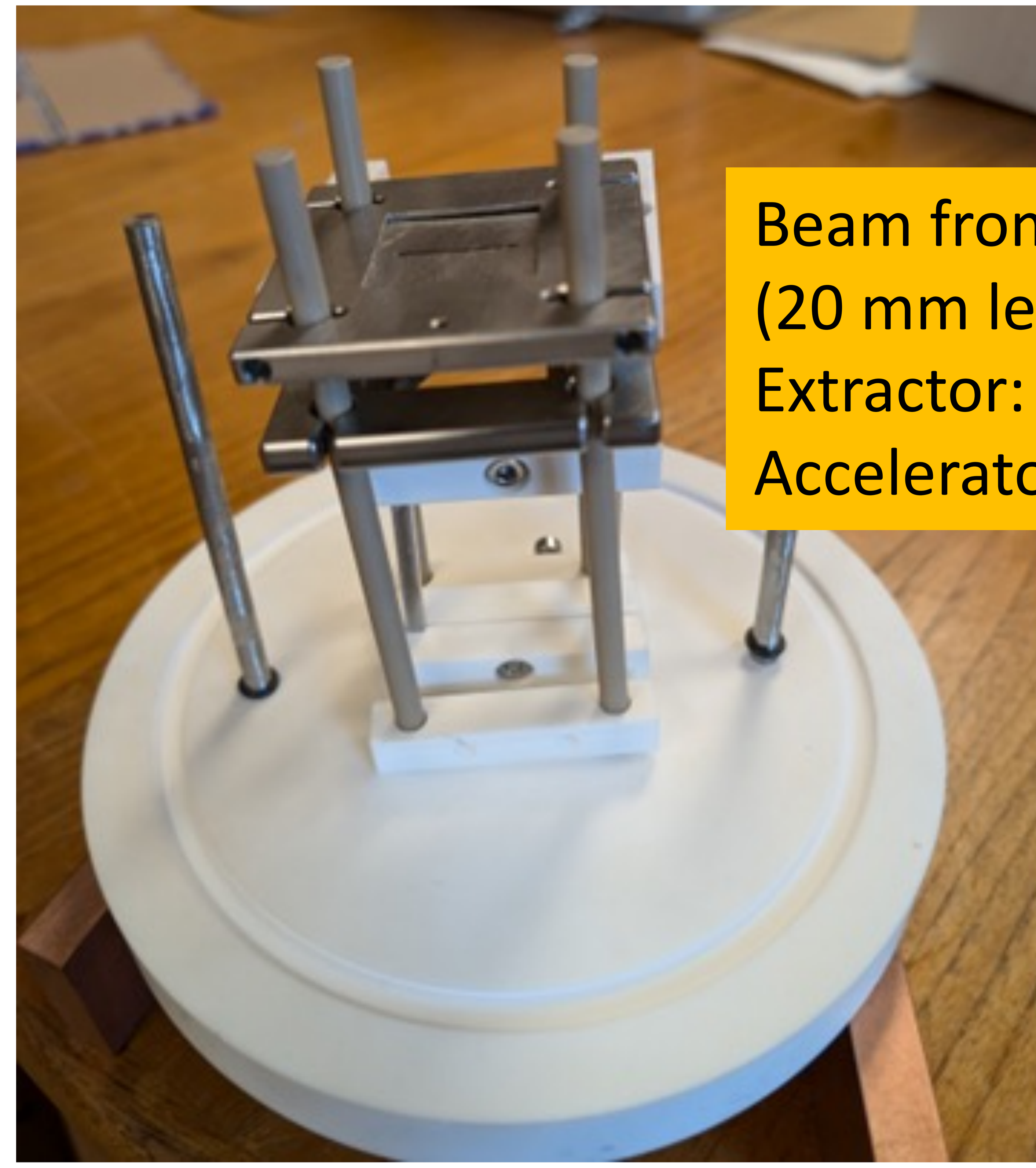
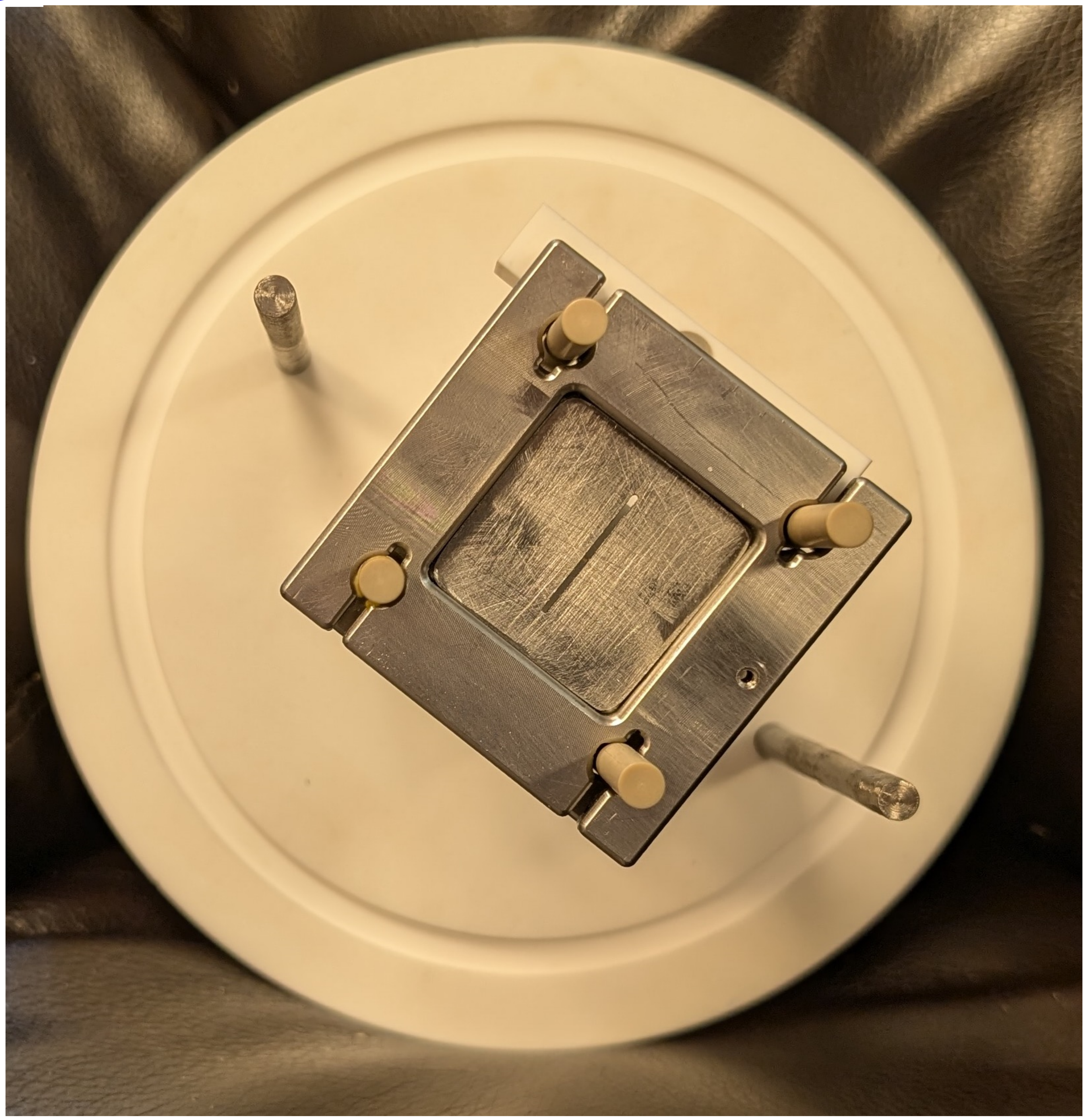


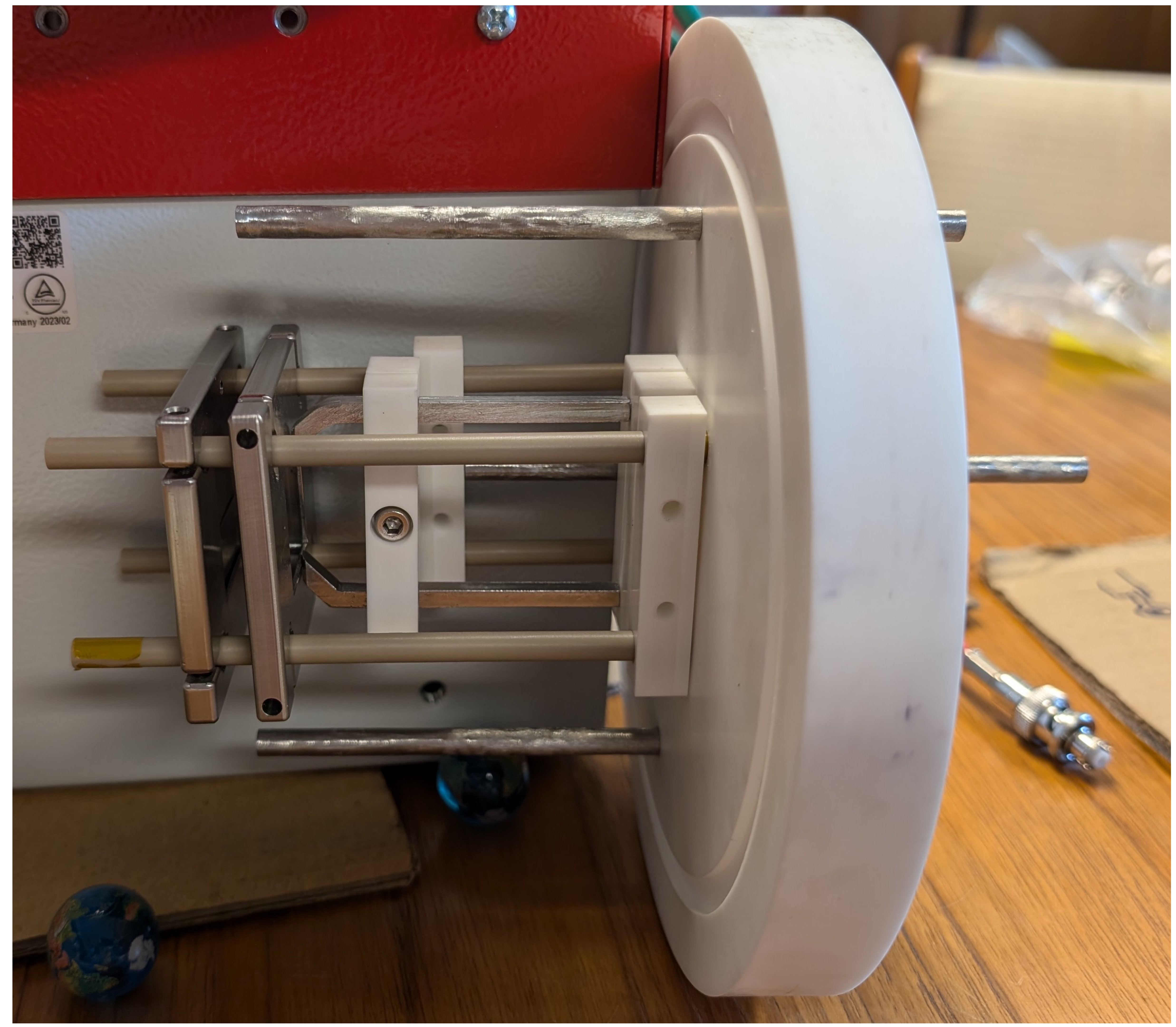
Fig.10. Emitter with extraction and accelerating electrodes.

Beam from strip cathode (20 mm length)
Extractor: 3kV
Accelerator: 43kV

Fig.12. Base plate on 6-way cross.



Front view of the sheet electron gun - from Fig. 9



Side view of sheet electron gun – Fig. 9

Back view of sheet electron gun

6-way cross with vacuum gauge and feedthroughs.

MANUFACTURING FACILITY AND PARTNERSHIP WITH RICHARDSON, ELECTRONICS, LLC. (RELL)

We have recently entered into a partnership with Richardson (RELL) which has proved very productive!

LaFox, IL - Local to many of the Muons, Inc. personnel

Several magnetron projects ongoing - (1.497GHz, 3GHz, 10GHz)

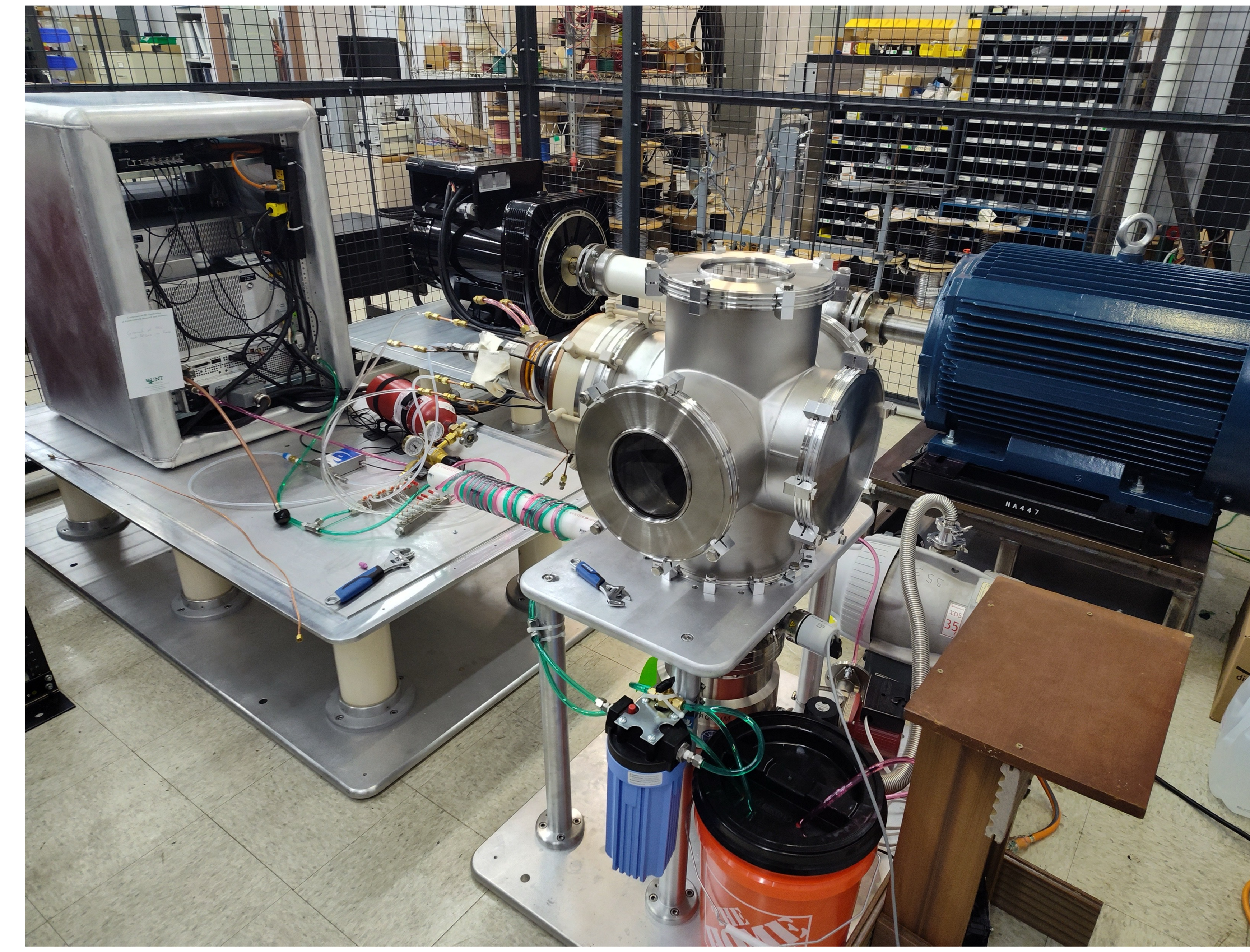
Current priority project is a deuterium and tritium source for an Italian project (ENEA). Vadim Dudnikov, designer.

Broad manufacturing capabilities – machining, welding, glass-blowing, deposition, etc. with a network of specialty partners

HV, cooling water, gas (including hydrogen) and highly professional staff

Desire to partner with future projects!!

MANY THANKS TO MICHELLE SHINN FOR HER PATIENCE!



ENEA source assembly and test

Space for sheet e beam assembly and test