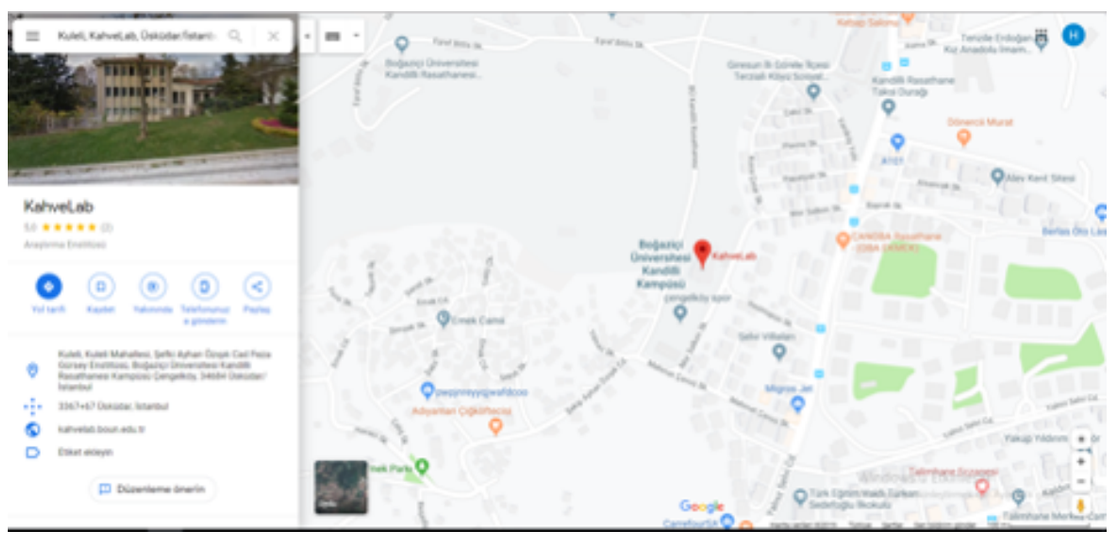
KAHVE Laboratory Status and Plans

Aytul ADIGUZEL, On behalf of KAHVELab

05 September, 2022; Turkish Physical Society 38th International Physics Congress (TPS-38)

KAHVE LABORATORY



- **KAHVELab** (Kandilli Detector, Accelerator and Instrumentation Laboratory) is a **particle detector, accelerator and instrumentation research laboratory** located in the Feza Gürsey Institute building at Boğaziçi University, Kandilli Observatory Campus.
- In addition to the host Boğaziçi University, our team consists of and closely collaborates with researchers from a number of institutes from all around Turkey.
- Build a number of particle detectors and electron and proton machines aiming keV and MeV energies, all with local resources.
- Also experimental particle physics research at CERN.

OUTLINE

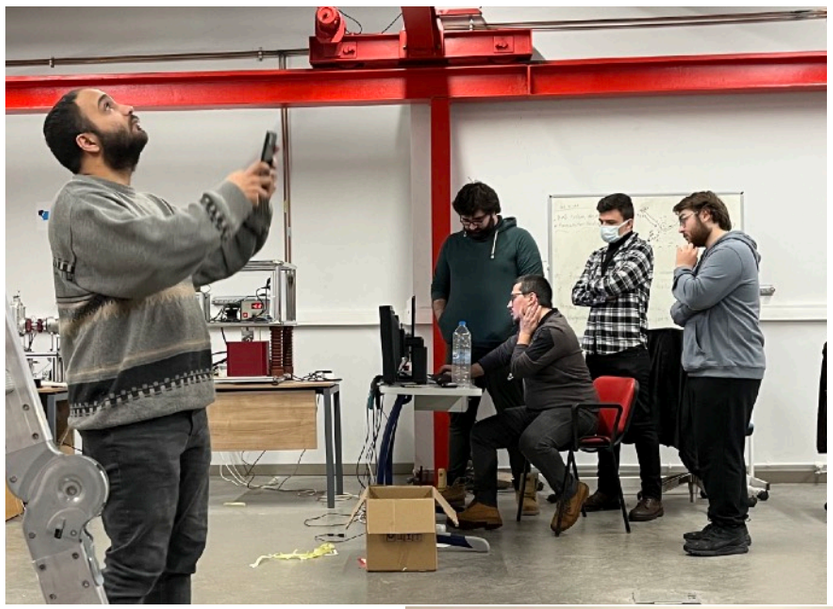
Kandilli
Algıç
Hızlandırıcı
Ve
Enstrümantasyon

✳Algıç - Detector
- ☑ GETO - DWC
- ☑ Scintillator counters
  - ☑ Local & 3D printed
- ☑ Beam Measurements
- ☑ Scanning E. Microscope

✳Enstrümantasyon - Instrumentation
- ☑ Automation & Control
  - ☑ Electron Beam Lithography
- ☑ Readout & Digitization
- ☑ Software

✳Hızlandırıcı - Accelerator
- ☑ PROTON
  - ☑ 2 MeV Linac
    - ☑ 20 keV MD Ion Source
    - ☑ LEBT Line
      - ☑ Measurement BOX
  - ☑ Radio Frequency Quadrupole
- ☑ ELECTRON
  - ☑ 50 keV : Electron Gun
    - ☑ Electron Beam Welding
    - ☑ Electron Beam Hardening
  - ☑ 1 MeV : Rhodotoron
- ☑ RF
  - ☑ FM band
    - ☑ PSU
    - ☑ RF Transmission Line
  - ☑ UHF band
    - ☑ PSU
    - ☑ RF Transmission Line

The Team



and others

ACCELERATOR : Electrons

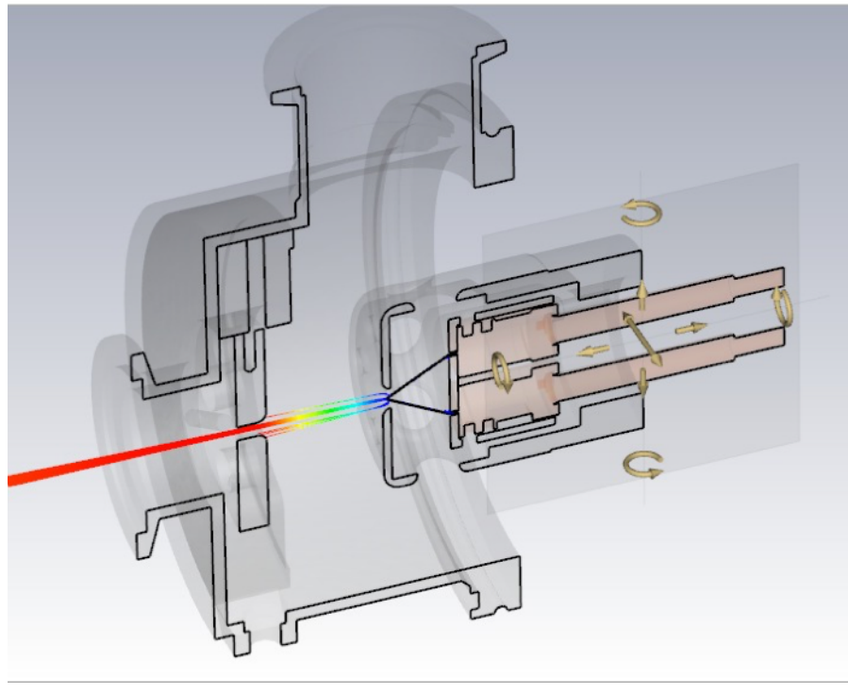
- ☑ ELECTRON
  - ☑ 50 keV : Electron Gun
    - ☑ Electron Beam Welding
    - ☑ Electron Beam Hardening
  - ☑ 1 MeV : Rhodotoron

50 keV eGun

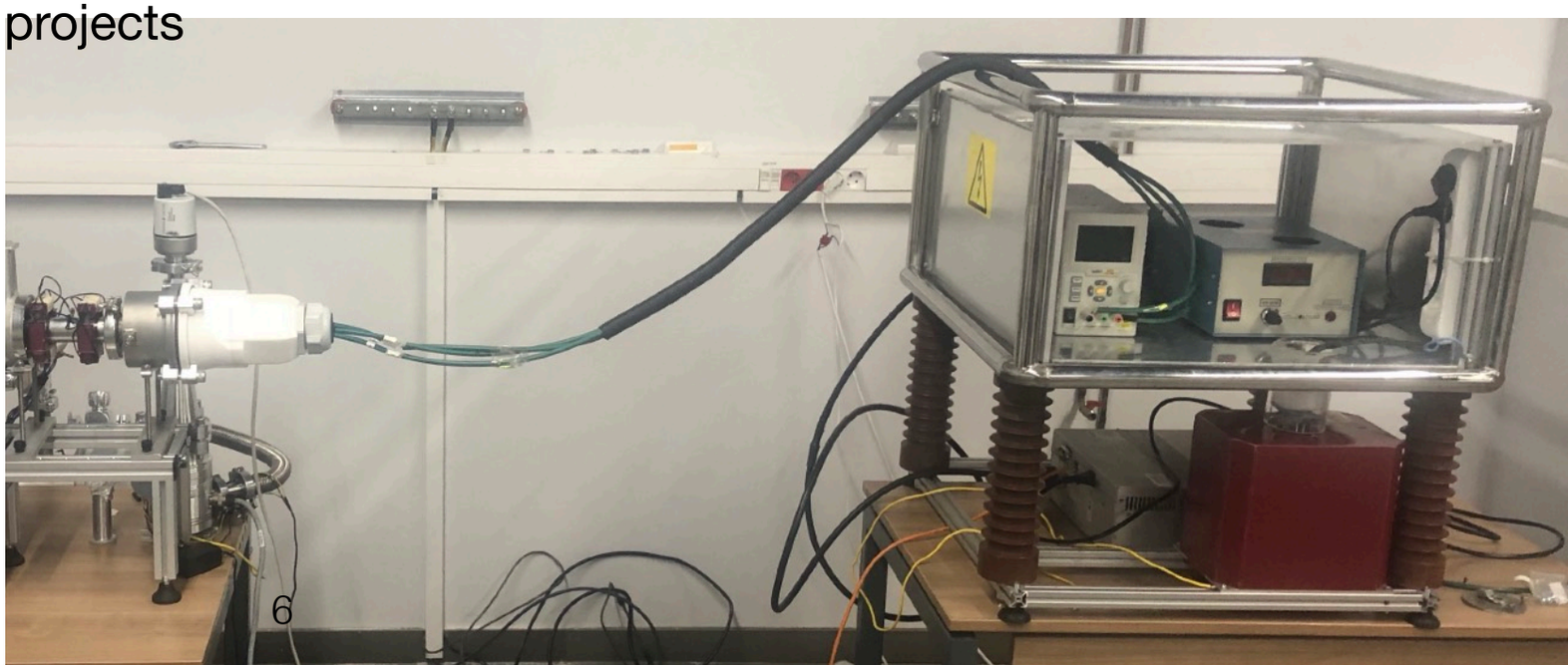
PSU & Vac. Rack

- Local design & manufacture
  - springboard project
- Tested a number of ideas
  - W, W(Th), LaB6, Disp cathodes
  - Al_2O_3, PEEK, Teflon insulators
  - HV platform insulation, safety
  - Remote control & monitoring via BT & WiFi
  - Magnet production: steerer & focusing coils
  - Automatic beam control: PID controller
  - PLC vs Labview
  - ...

✓ Stable operation
- after lots of grounding work
- ready for other projects

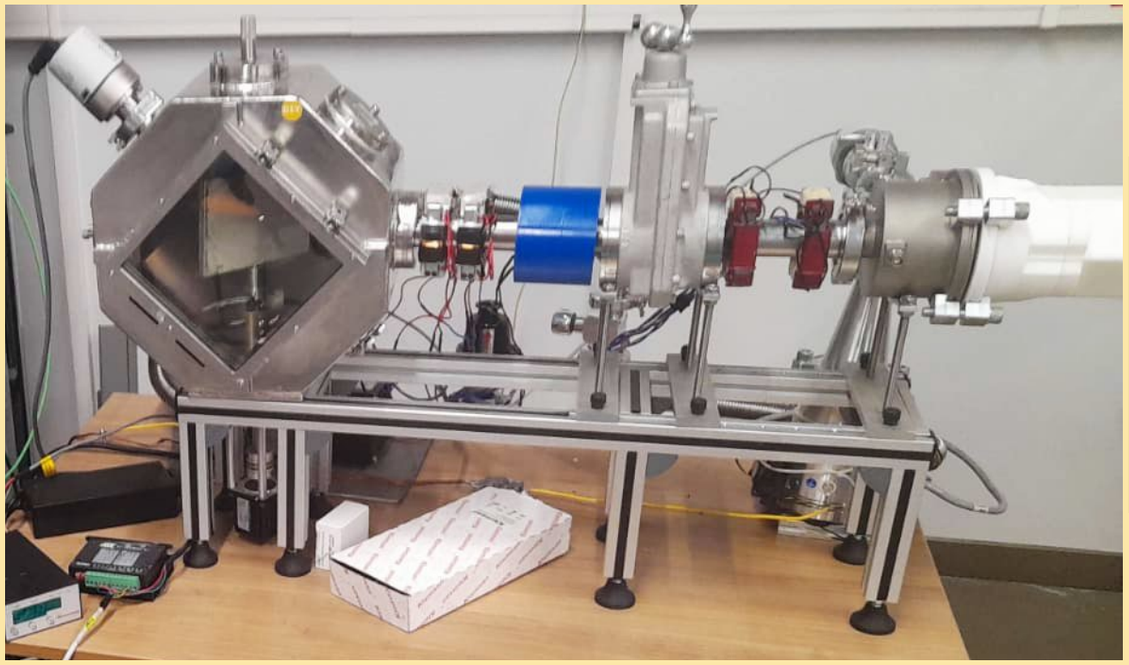


CST simulation

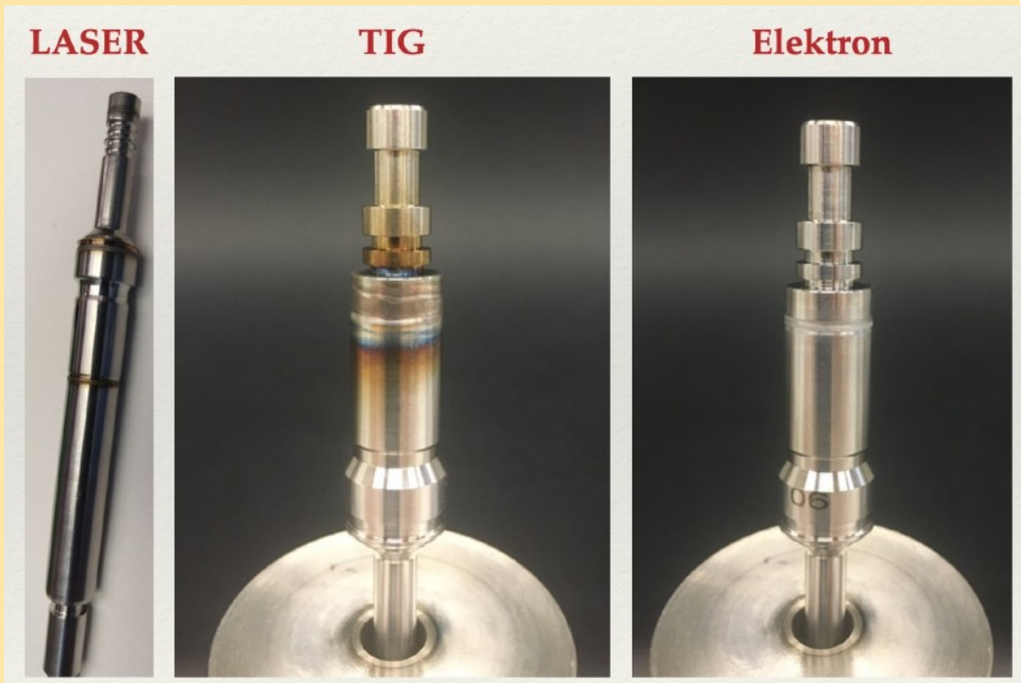


eGun applications

EBWelding

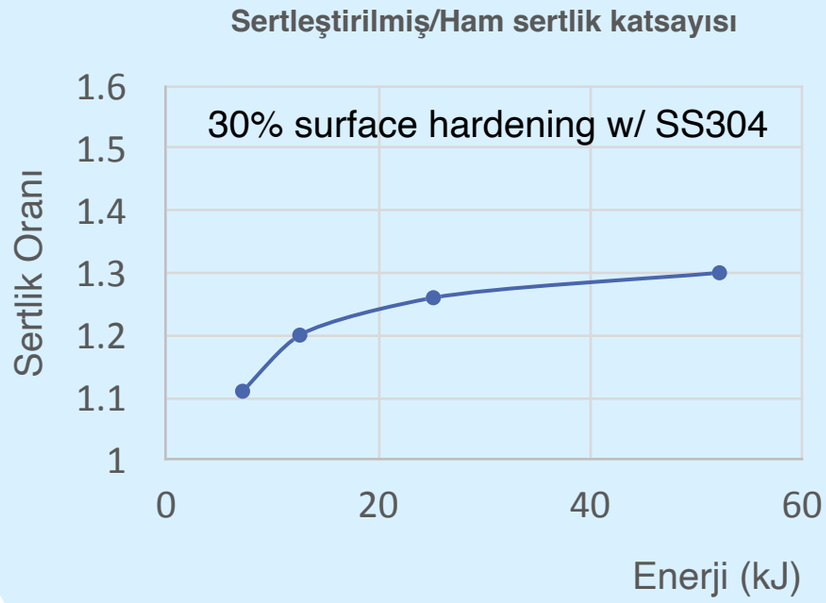


50 kV 40 mA
ϕ 100 x 200 mm
10^{-7} mbar
2 dof
~mm spot size

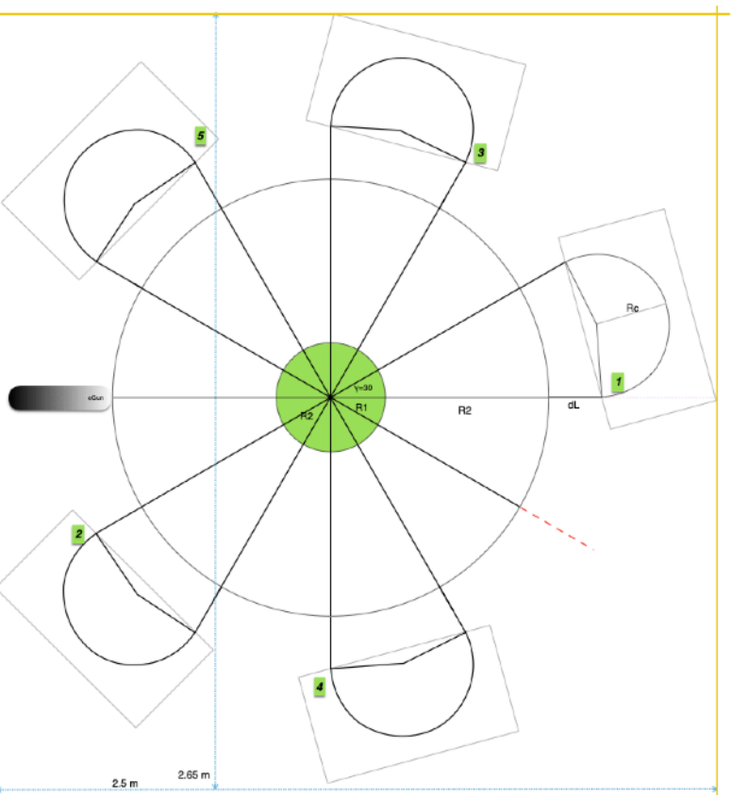


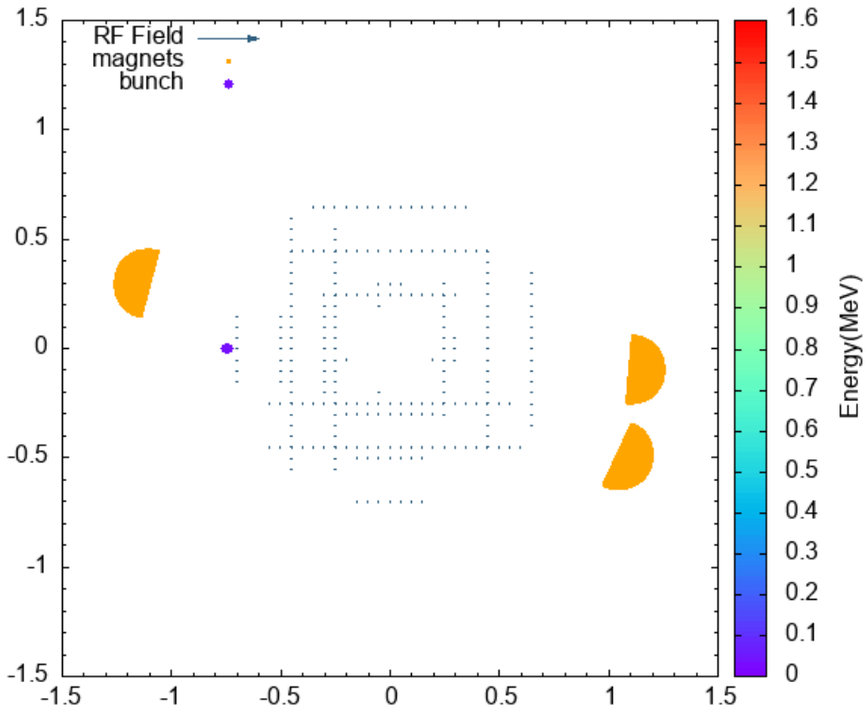
Radiographic Inspection

EBHardening



1MeV Rhodotron

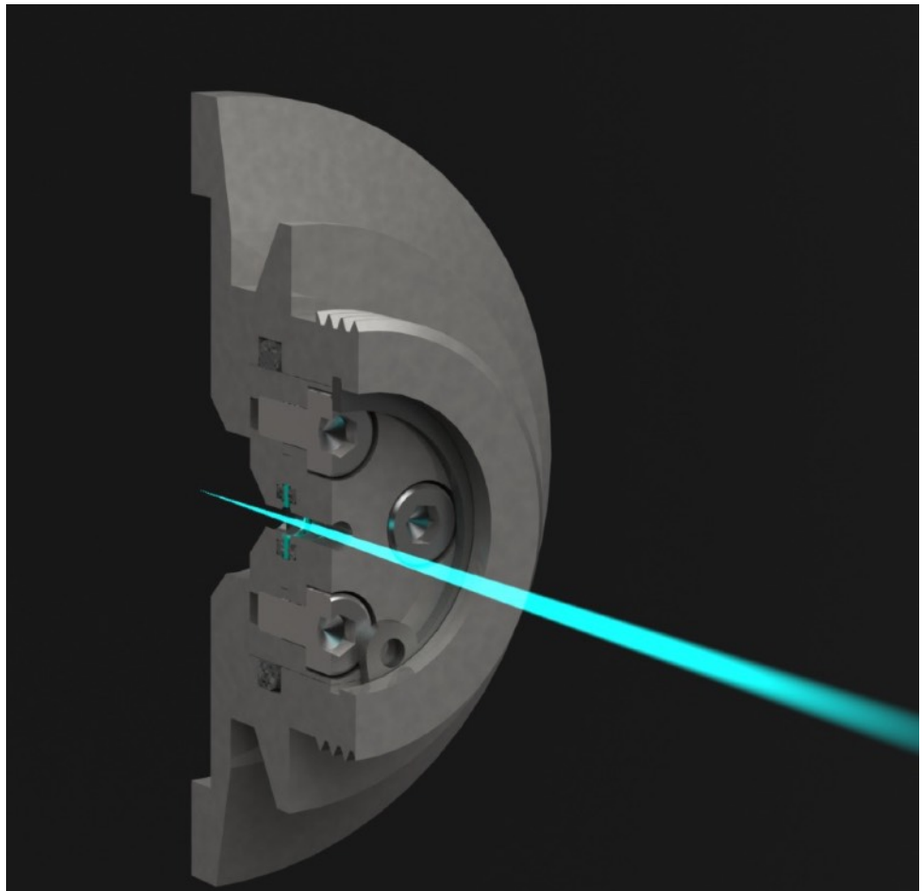




- Rhodotron starts with an eGun
  - sync e- with RF phase
  - multipass machine
- 1MeV machine design completed
  - dedicated sw being developed
- Construction ongoing
  - had some initial setbacks
  - vacuum tests to be completed by summer
- First beam in 2023

next...

- Finish Rhodotron
- EB microscope
- ebeam to air
- xray production



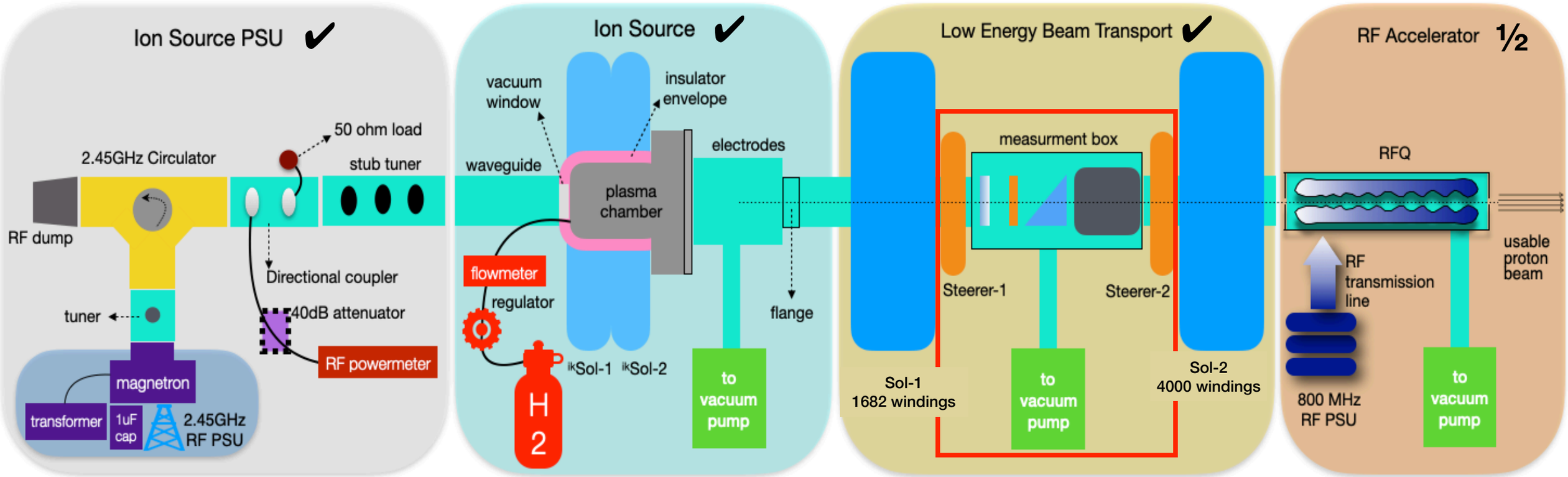
ACCELERATOR : Protons

- ☑ PROTON
  - ☑ 2 MeV Linac
    - ☑ 20 keV MD Ion Source
    - ☑ LEBT Line
      - ☑ Measurement BOX
  - ☑ Radio Frequency Quadrupole

PROTON TESTBEAM at KANDİLLİ (PTAK)

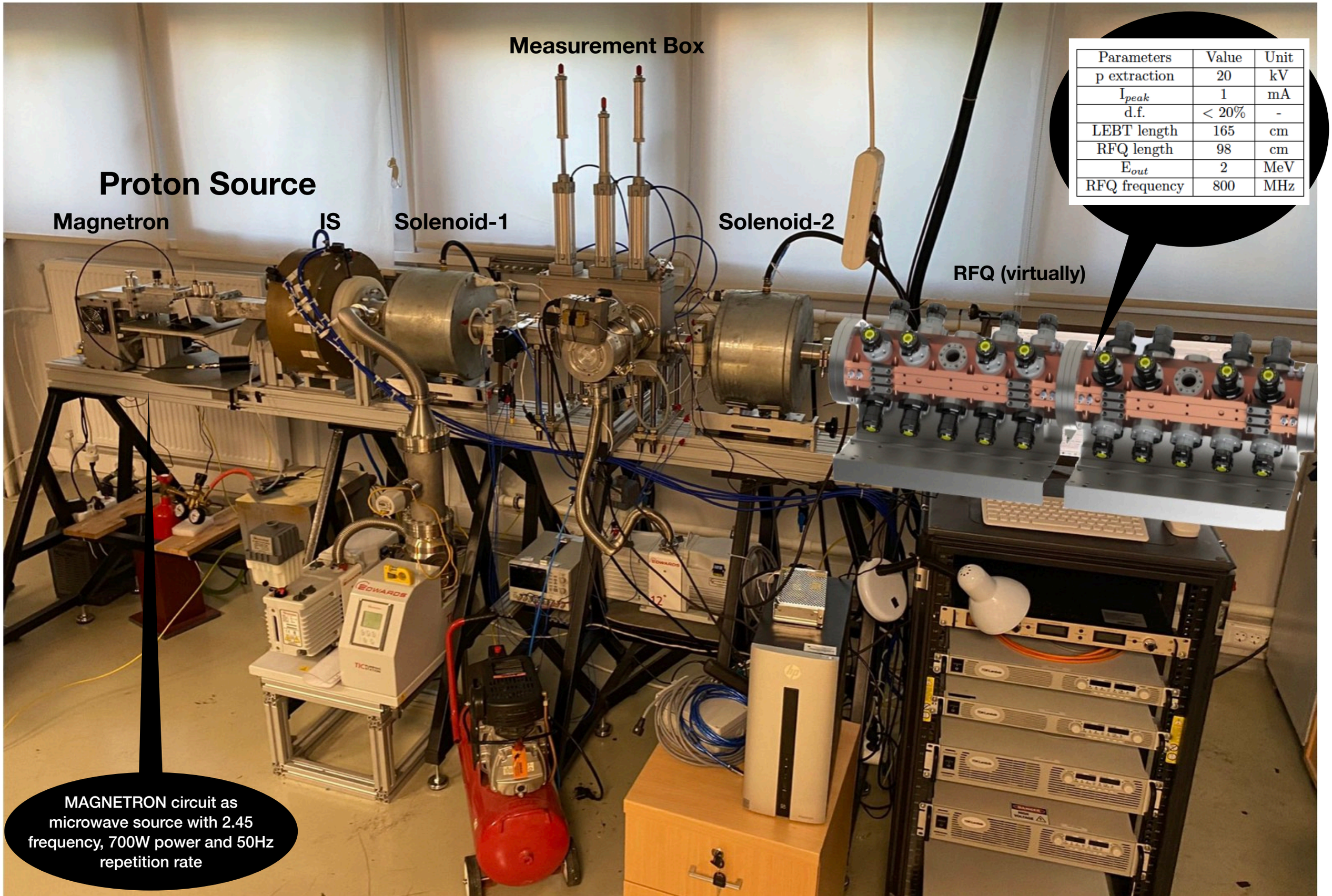
- Proton beamline using an RFQ @ 800 MHz to accelerate 1 mA, 20 keV energy proton beam to **2 MeV.**

2MeV Linac



- Project Goals:
  - educating the next generation of accelerator physicists and engineers on the job
  - accumulating operational know-how
- Components are locally designed and manufactured in tandem with local companies.
- Secondary purpose of the project is to be a particle accelerator technologies test set up such as PIXE

Proton Testbeam At Kandilli (PTAK)

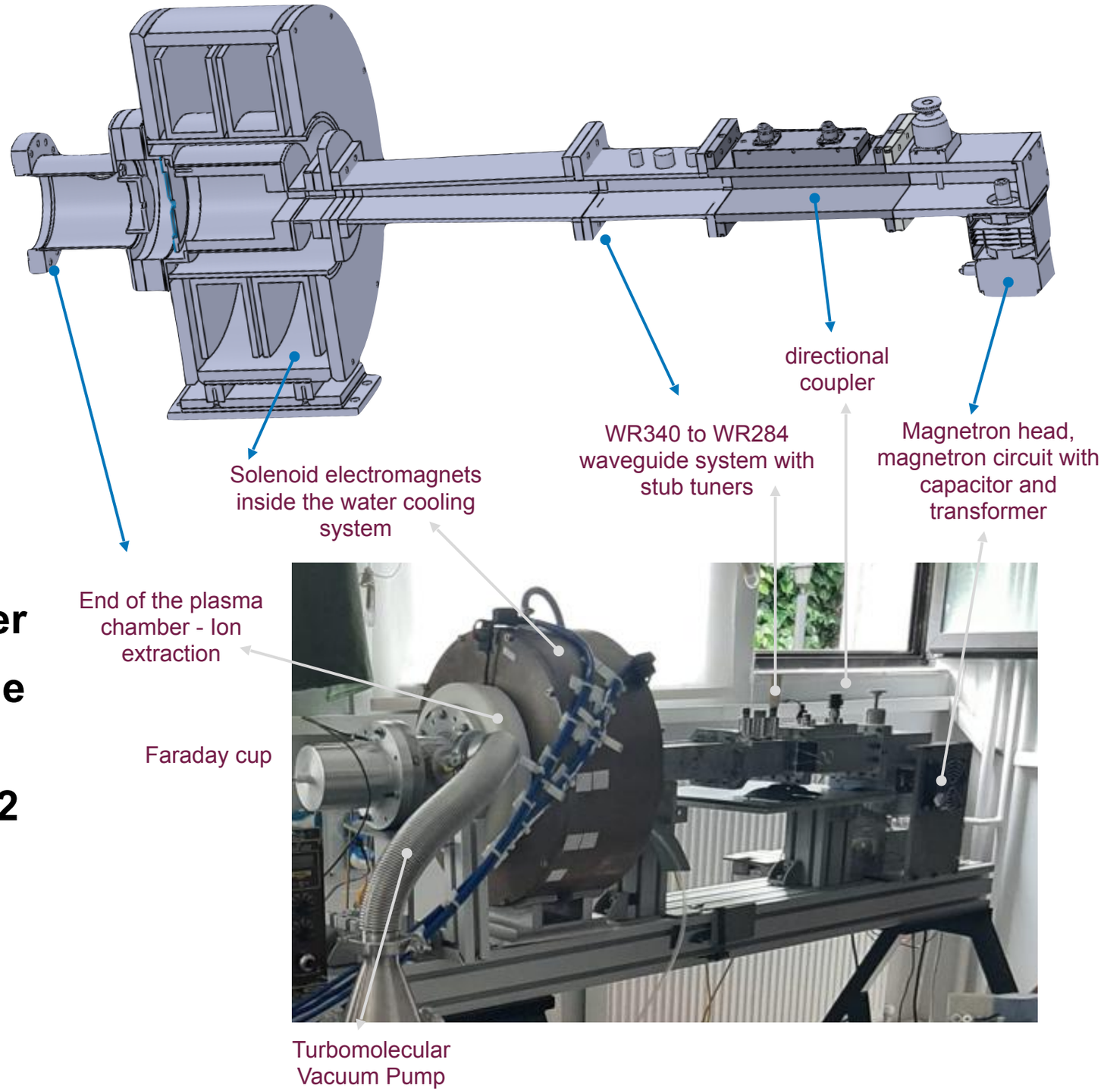


Parameters	Value	Unit
p extraction	20	kV
I_{peak}	1	mA
d.f.	$< 20\%$	-
LEBT length	165	cm
RFQ length	98	cm
E_{out}	2	MeV
RFQ frequency	800	MHz

PTAK IonSource 1 - EM MDIS

- **Design with IBsimu**
- **Local construction**
- **20 kV extraction voltage**
- **HV insulation via Teflon & Delrin**
- **Vacuum ~ 10^{-7} without beam**
- **possible to control uWave power via magnetron power control**
- **possible to monitor transmitted and reflected power (not simultaneously)**
- **IS sols: current source + cooling water**
- **simulations show @1.3 mA current the RMS emittance is 0.0254 π.mm.mrad**
- **stable operation in Q4 2021 ... Q1 2022**

- **IS upgraded to PM MDIS...**

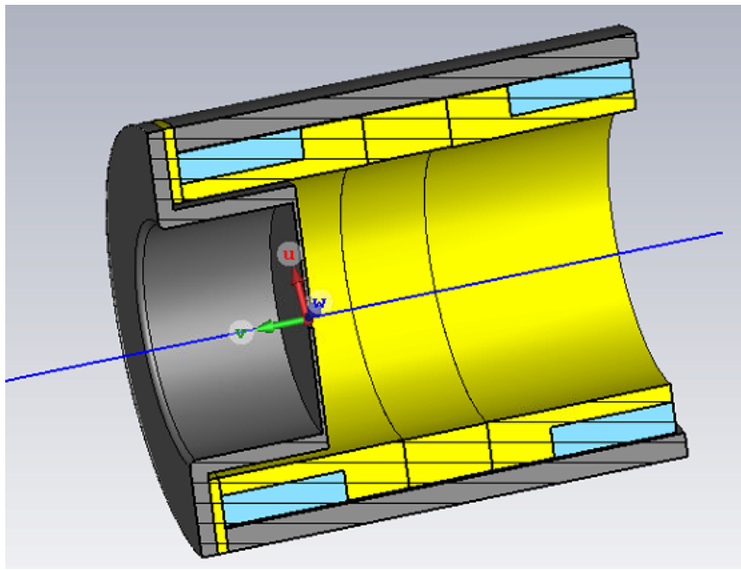


MDIS setup with electromagnets

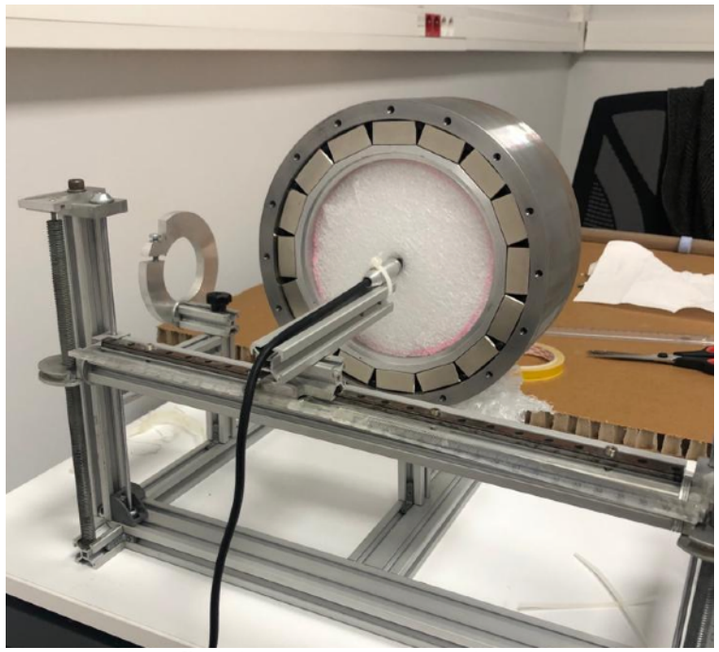
PTAK IonSource 2 - PM MDIS

- Electromagnets are good but...
  - occasional sparks between solenoids & plasma chamber
  - need coolling (ohmic losses & the plasma chamber's heat)
- The permanent magnets are better:
  - can be kept under HV
  - do not require additional PSU
- 32 N40 type neodymium magnets

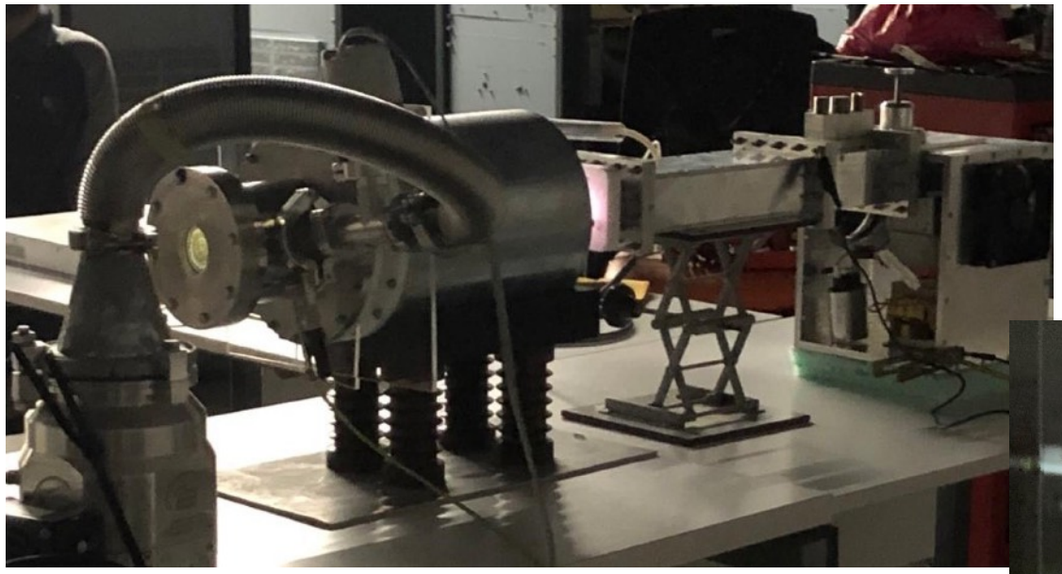
H_2 : 0.01 sccm
V_E : 20 kV
P : 4×10^{-5} mbar
I_{ave} : 0.4 ... 1.5 mA



The PM-MDIS design with plasma chamber and electrode extraction part

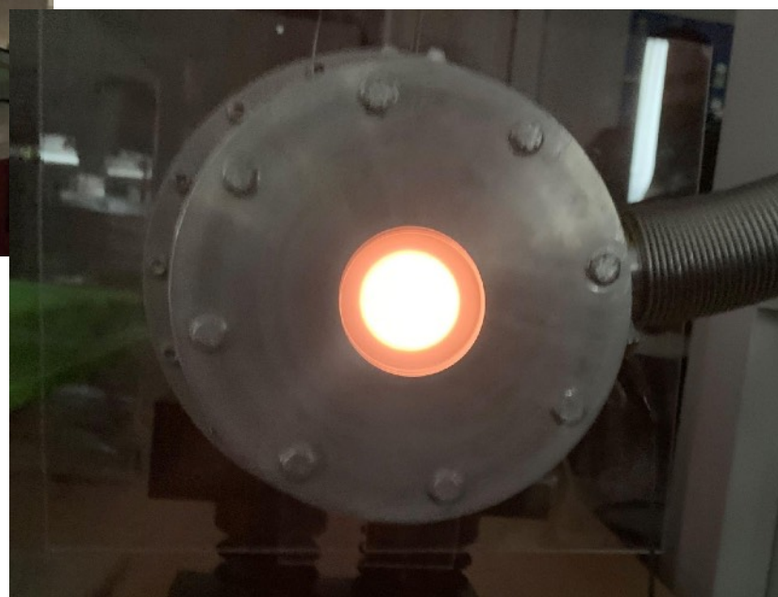


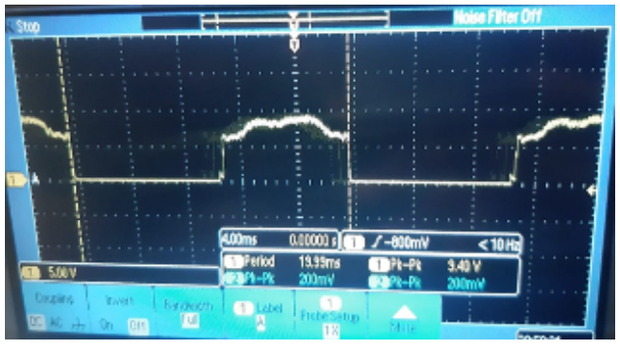
The field measurement setup for the trial production



Magnetron circuit and microwave transmission waveguide system, hydrogen plasma visible in pink at the end of the waveguide line, and PM-MDIS operating under 20kV voltage.

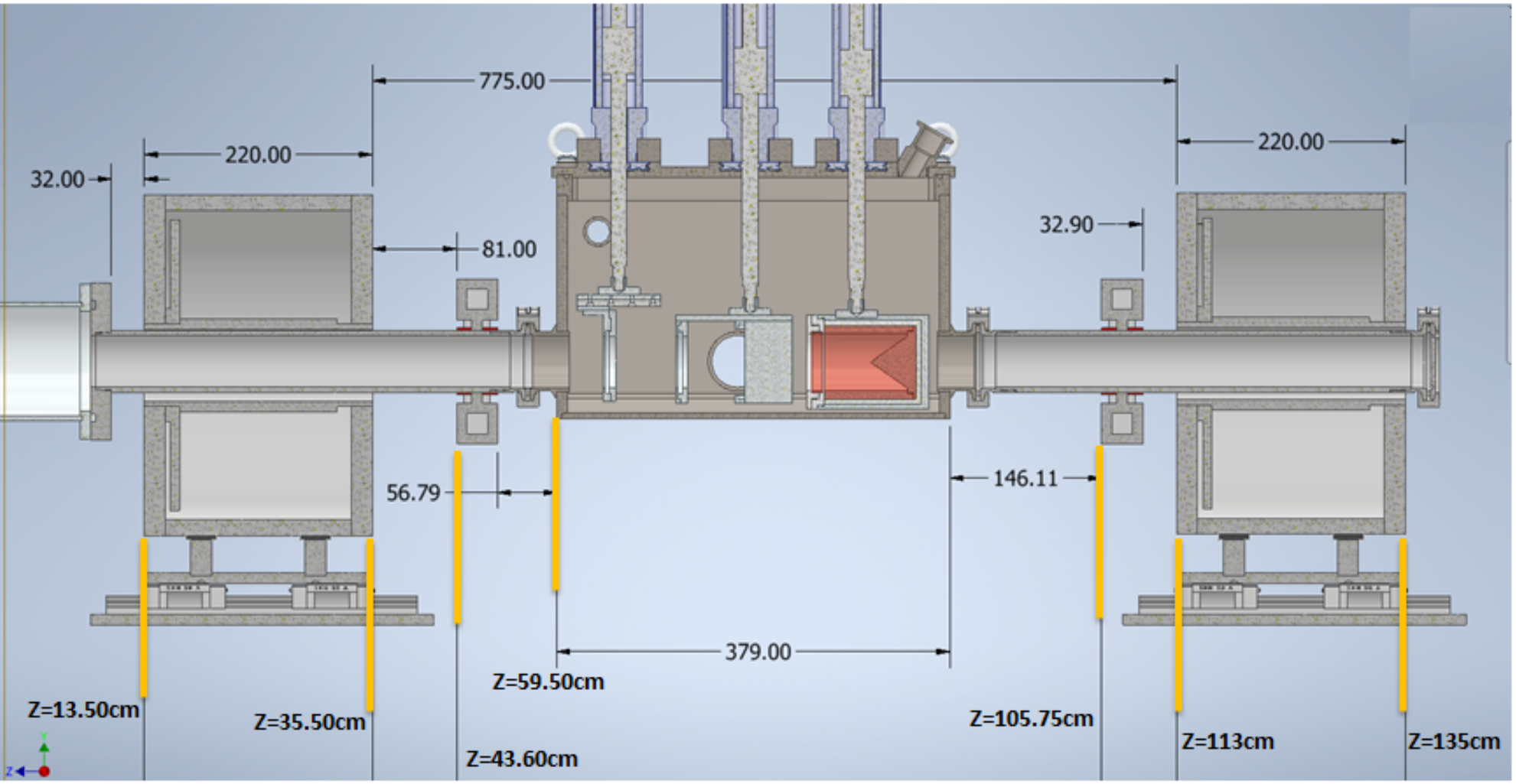
The obtained beam image from the fluorescent screen placed at the end of the PM-MDIS system.

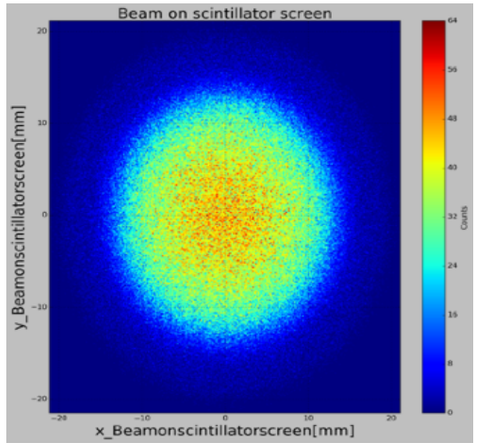




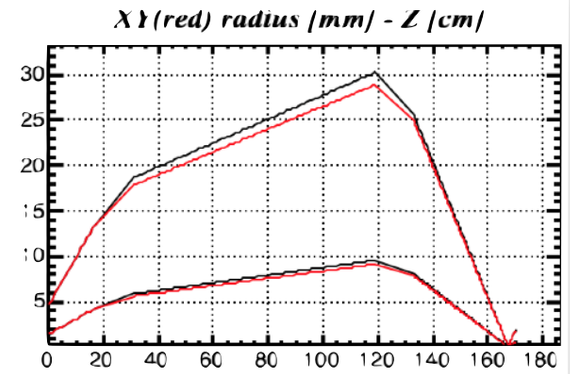
Faraday cup through the oscilloscope is found as 0.38mA. The difference is about 8% wrt HV PSU.

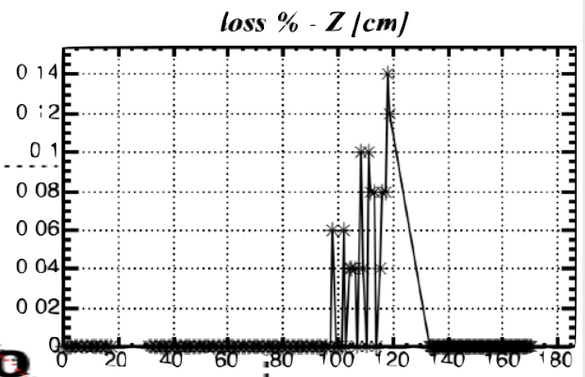
PTAK - Low Energy Beam Transport

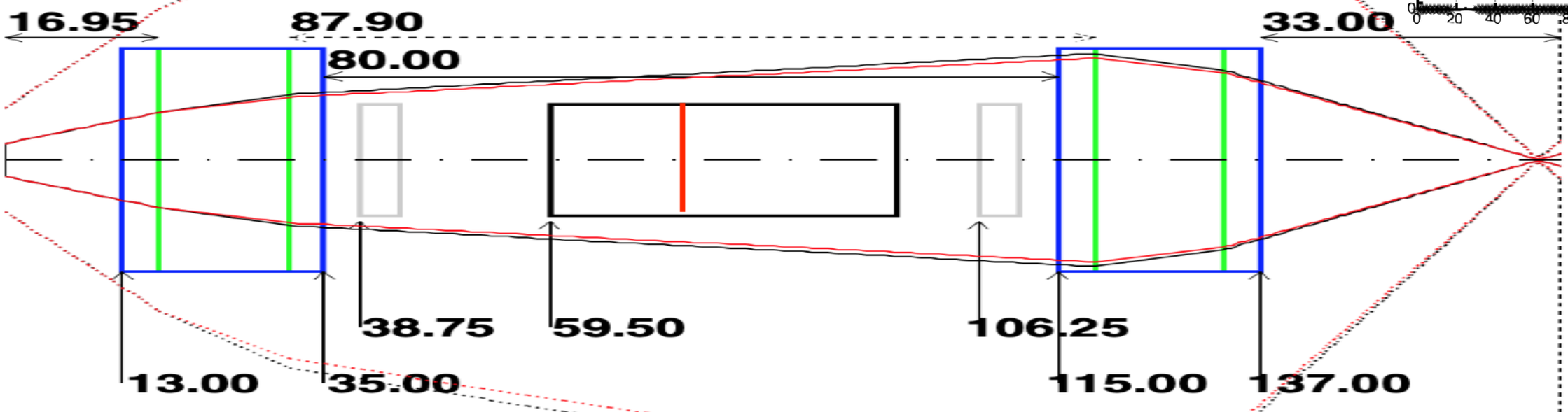




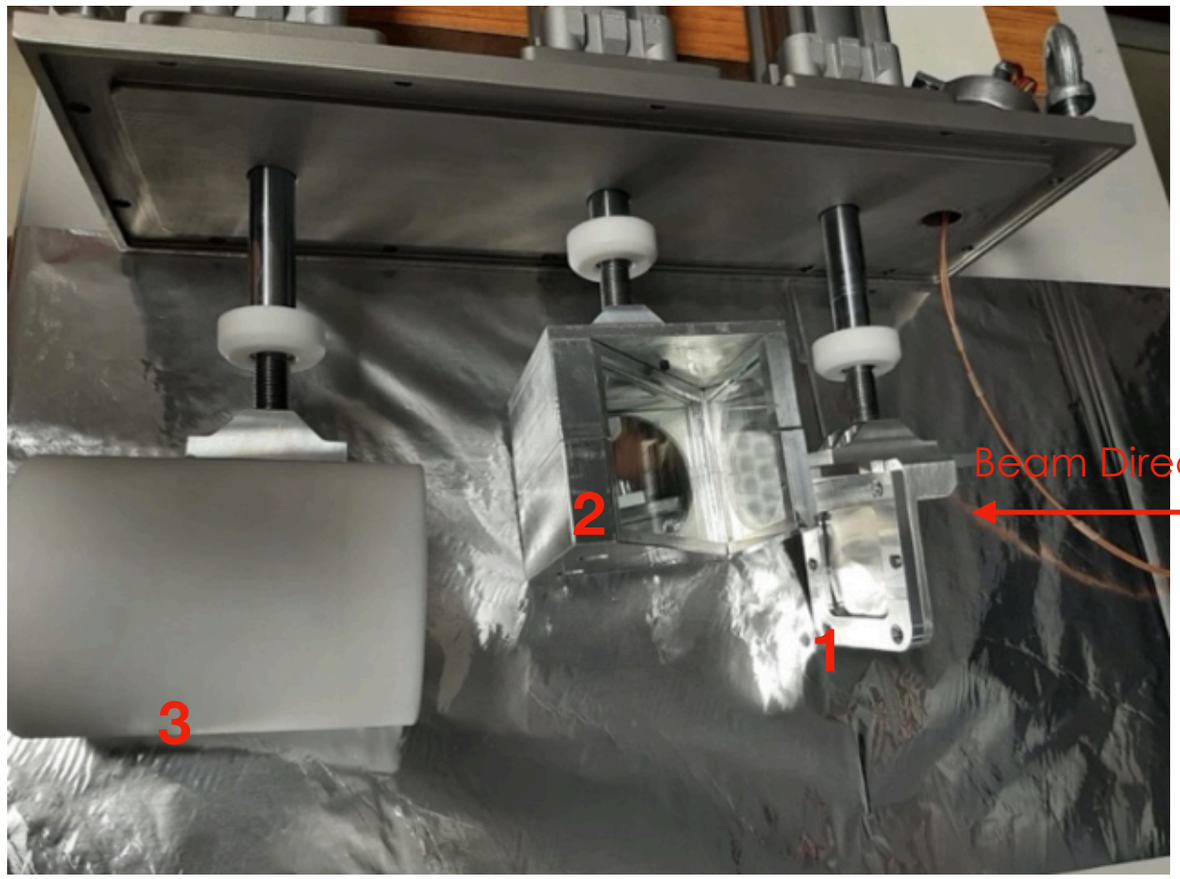
DemirciPRO simulations:
1σ ~16mm @z=70 cm (noSC)





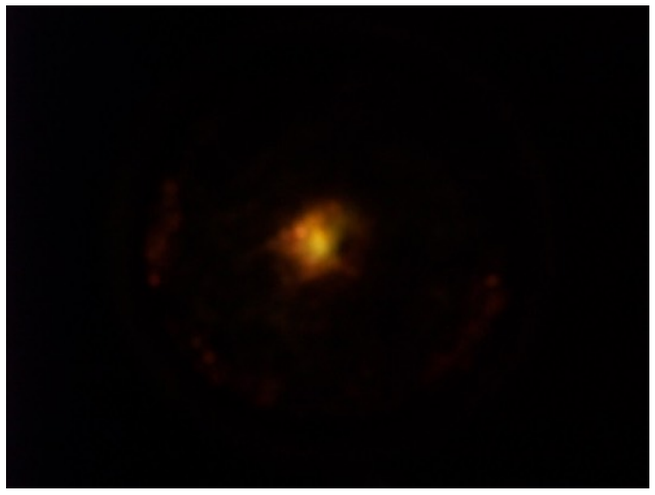


PTAK - LEBT - MBOX

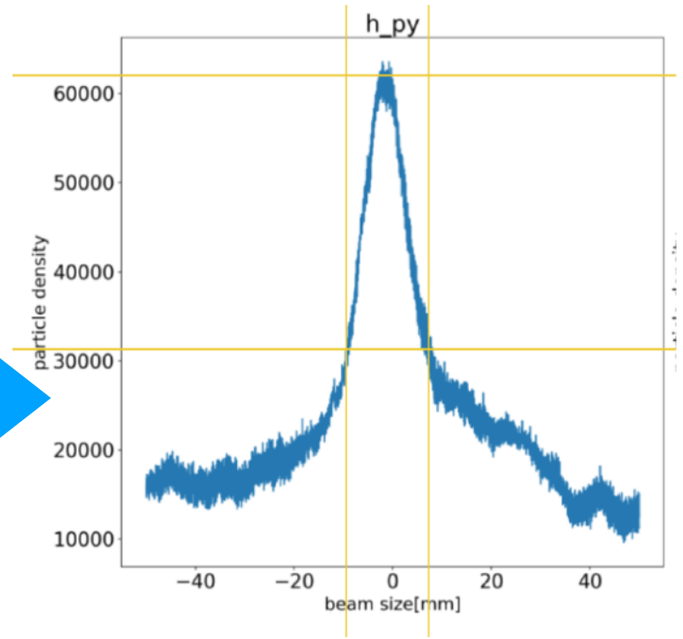


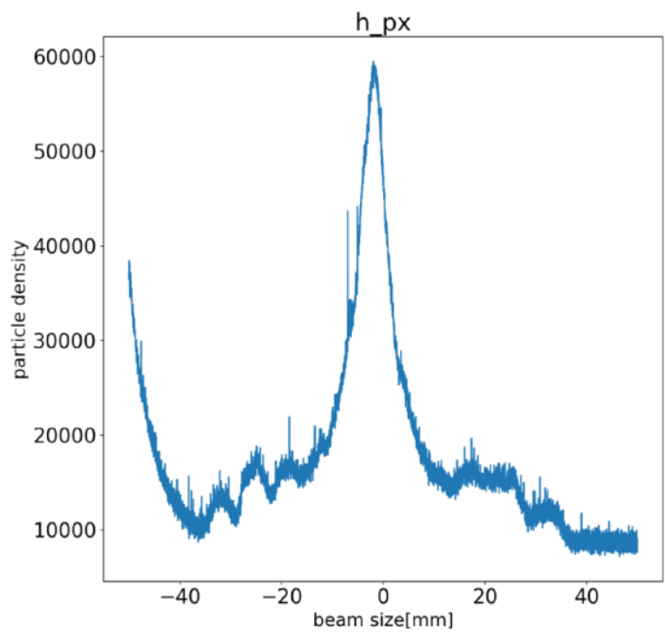
Beam Diagnostics:
1 & 2 : emittance
2 : profile
3 : current

- Placed between LEBT line magnets
- Used for beam measurements:
  - ✓ beam emittance (Pepper Pot Mask)
  - ✓ beam profile (Scintillator Screen)
  - ✓ beam current (Faraday Cup)



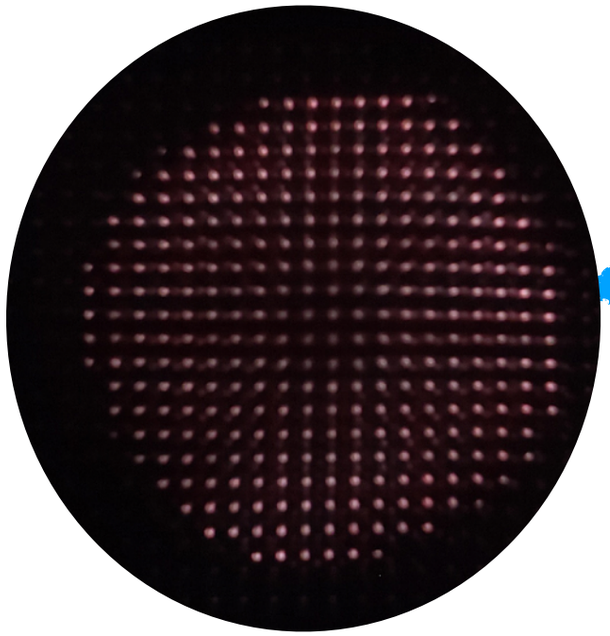
beam diameter (FWHM) : ~16 mm in x & y

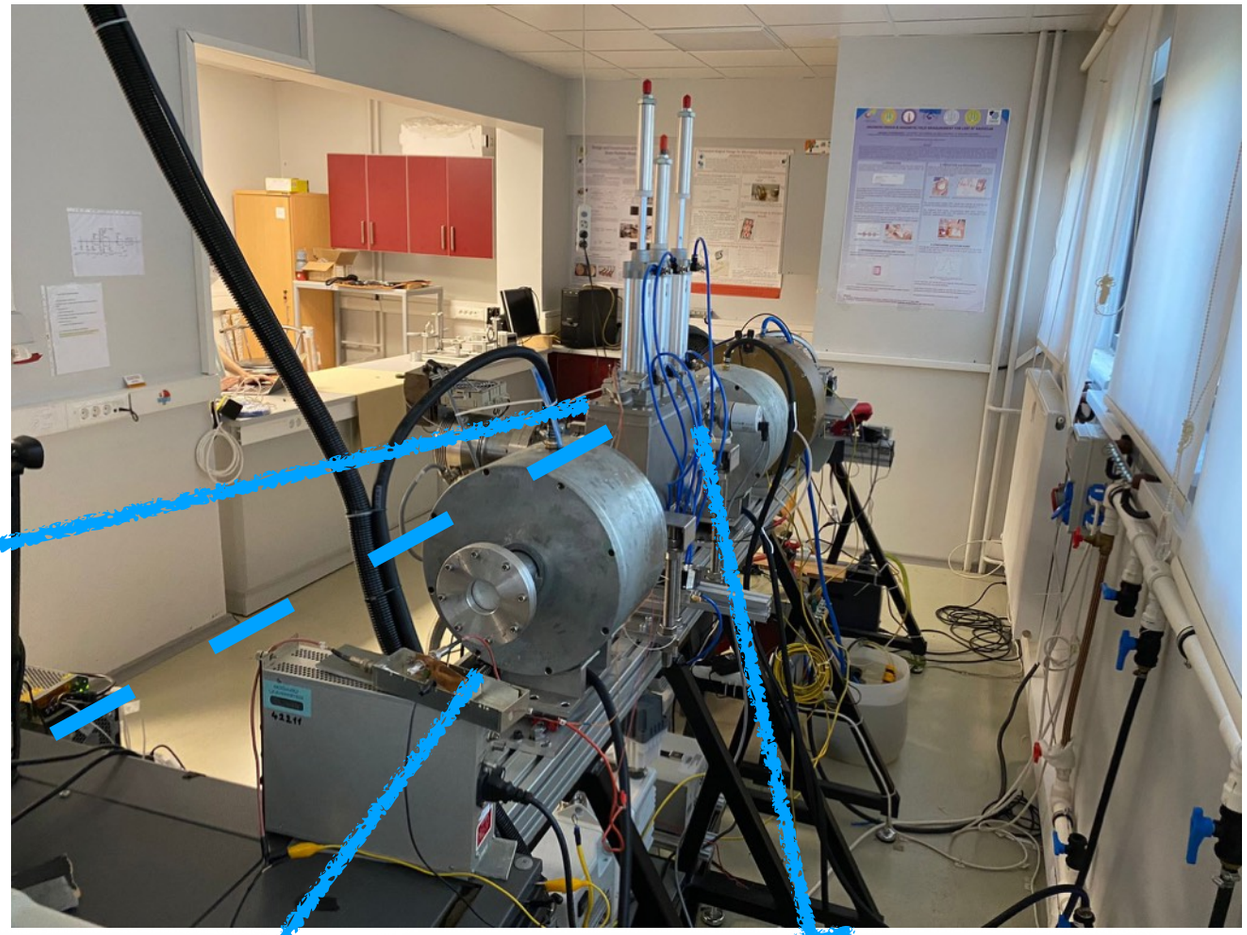


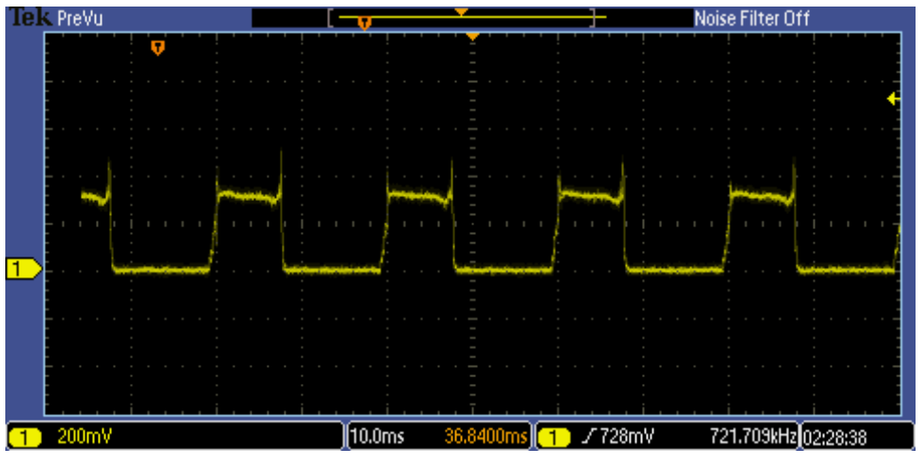


PTAK - LEBT - Results

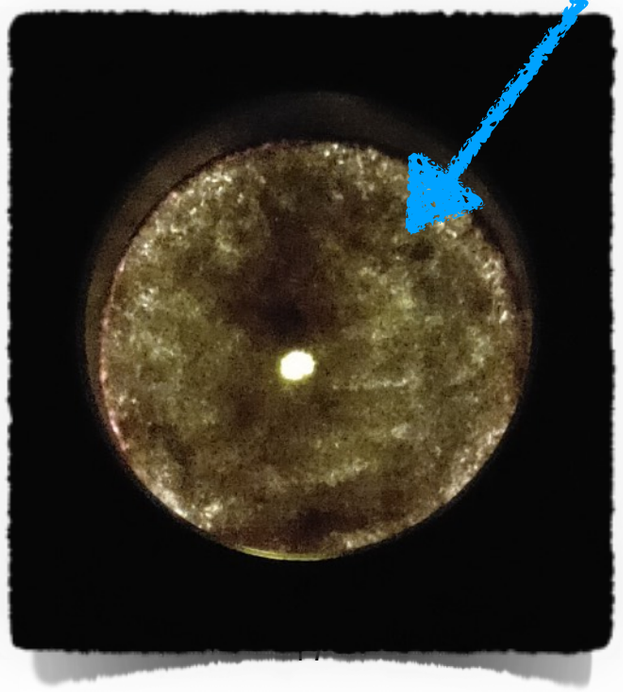
	Sim.	Measure
ε-norm [πmm.mrad]	0.031	0.029
α	-4.5	-18.9
β [mm/π.mrad]	1.33	2.13
beam size(mbox) [mm]	14.8	15
beam size after s2 [mm]	1.9	2

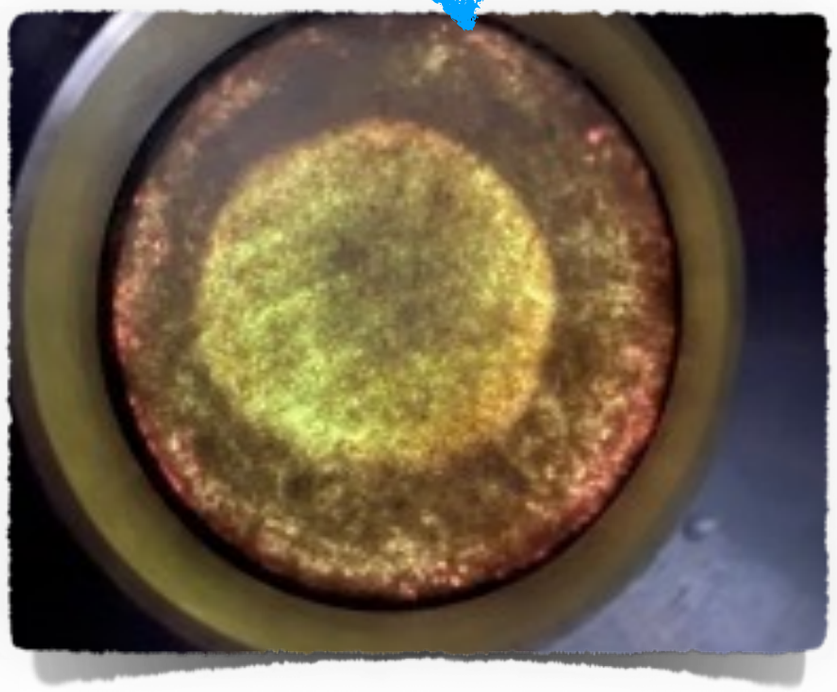






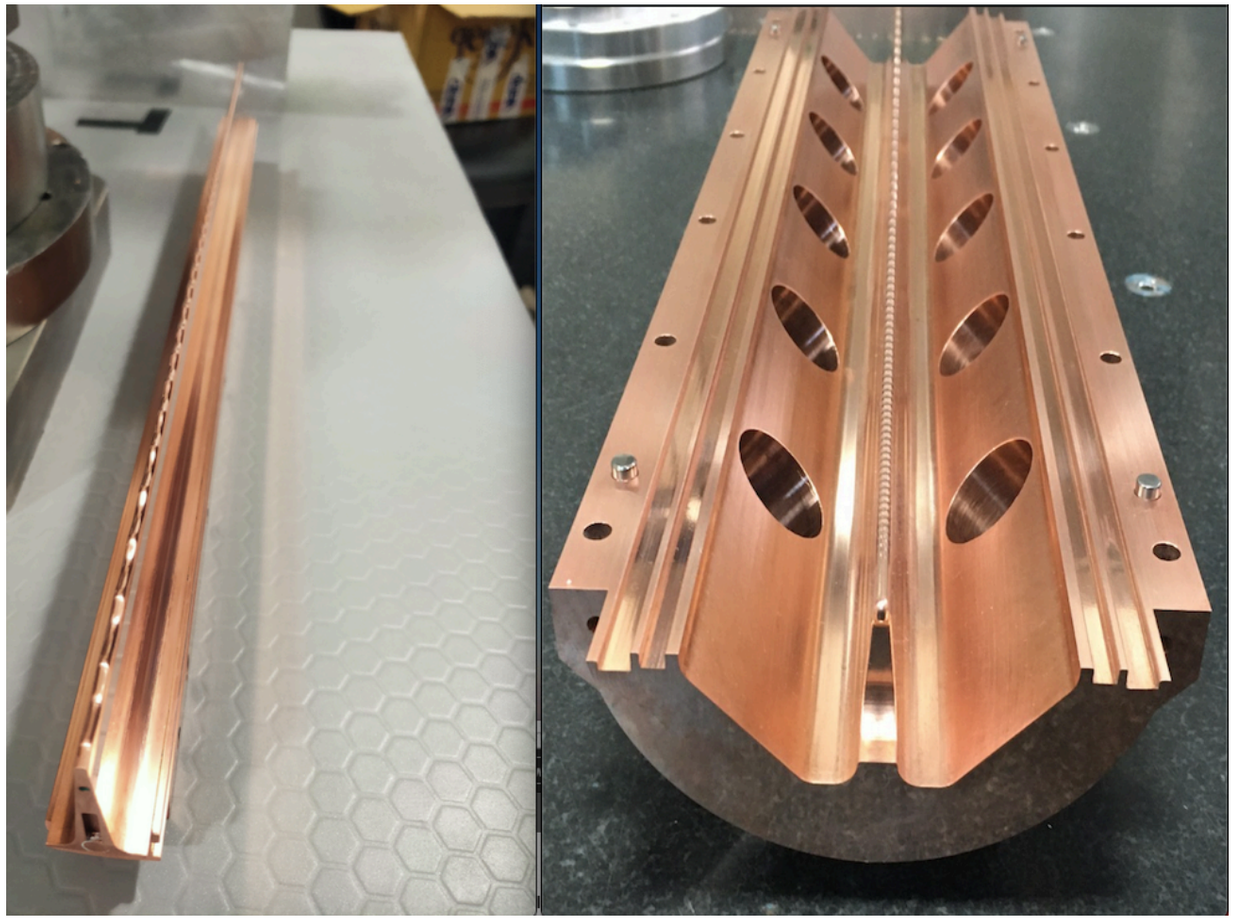
df = 0.4
rep. rate: 50 Hz
I = 0.03mA



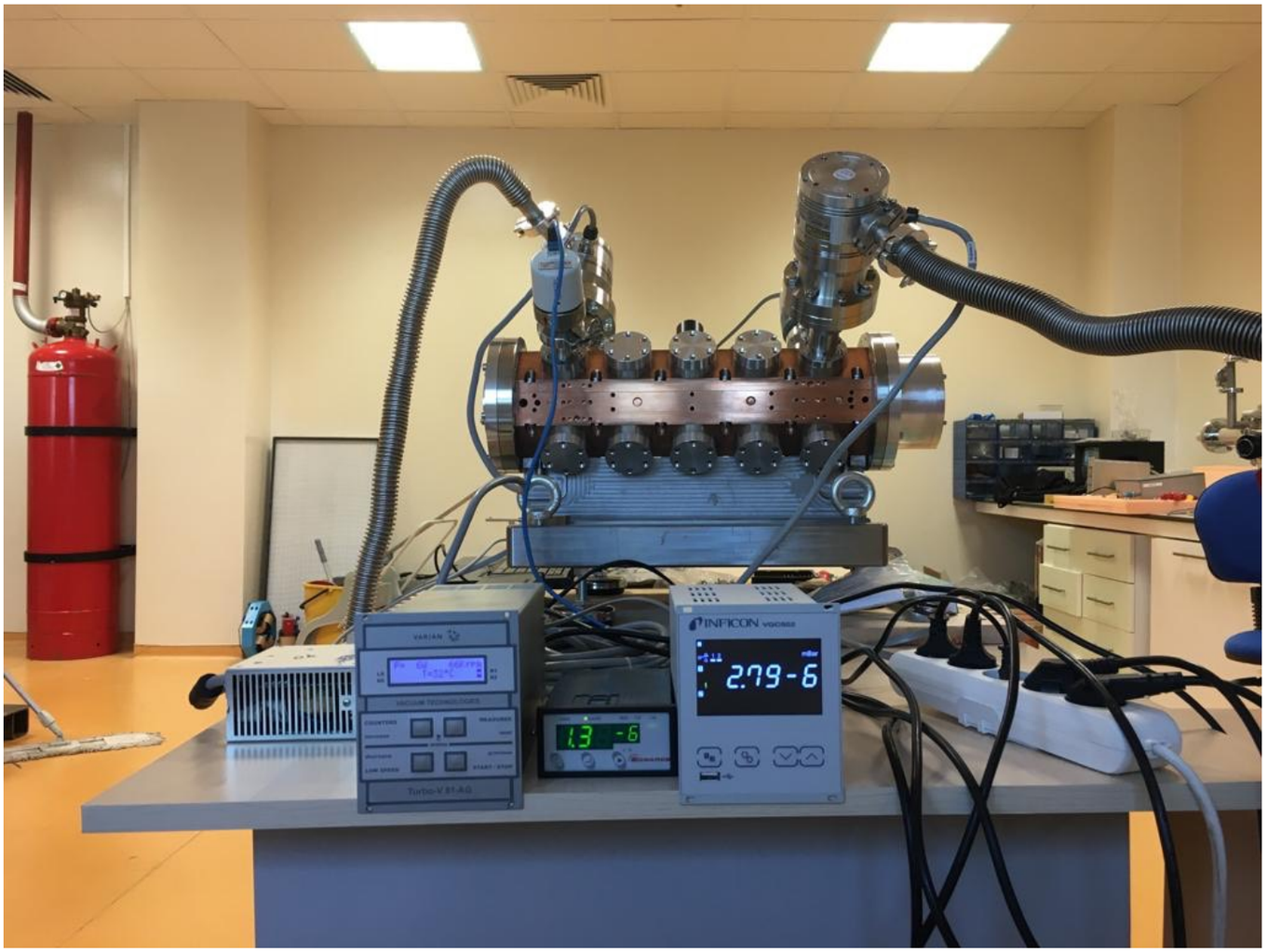


PTAK RFQ

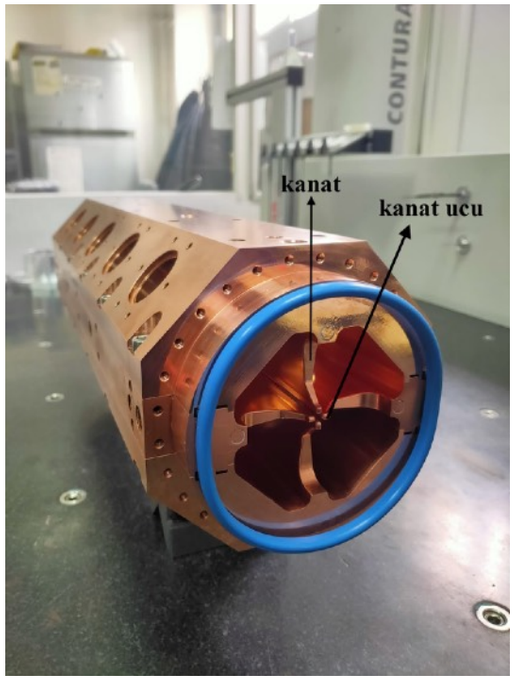
	f_{res} (MHz)	E_{in} (MeV)	Eout (MeV)	L_V (cm)	$T_{total/acc}$ (%)	P_{RF} (kW)	V_v (kV)	S_f (Kp)	max d.f.	Q	vanetip r(mm)	bore radius r0(mm)
PTAK	800	0.02	2.0	98	90/30	48.6	33	1.39	2%	7036	1.392	1.392

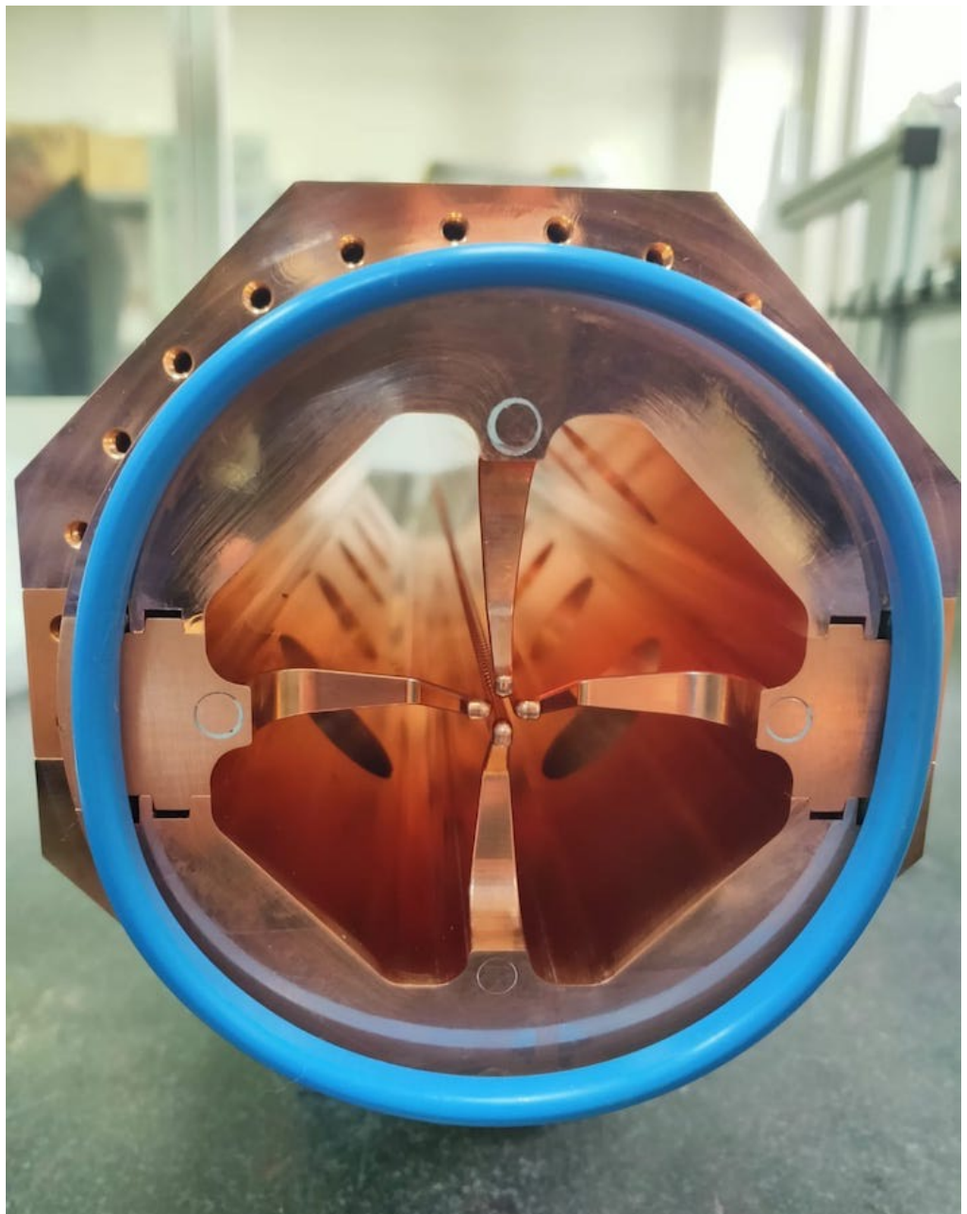


- Module-0 from Copper produced to finalize the manufacture procedure
- Vacuum and EM tests completed
- mounting sensitivity: 18 +- 1 um

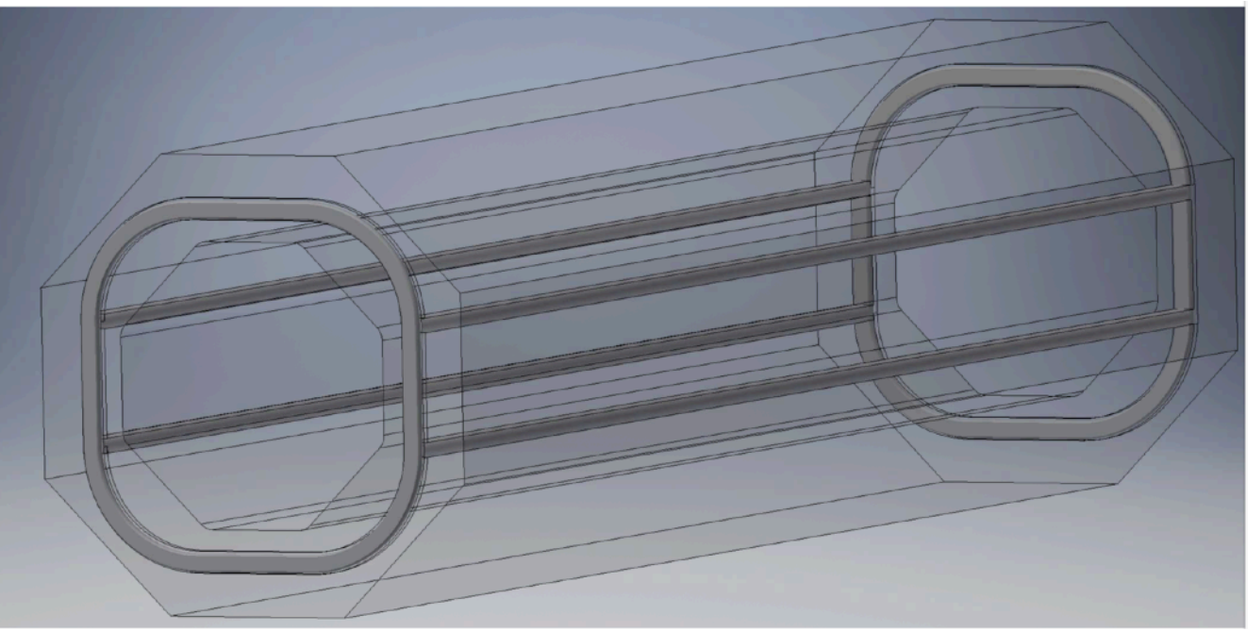


PTAK RFQ Vacuum



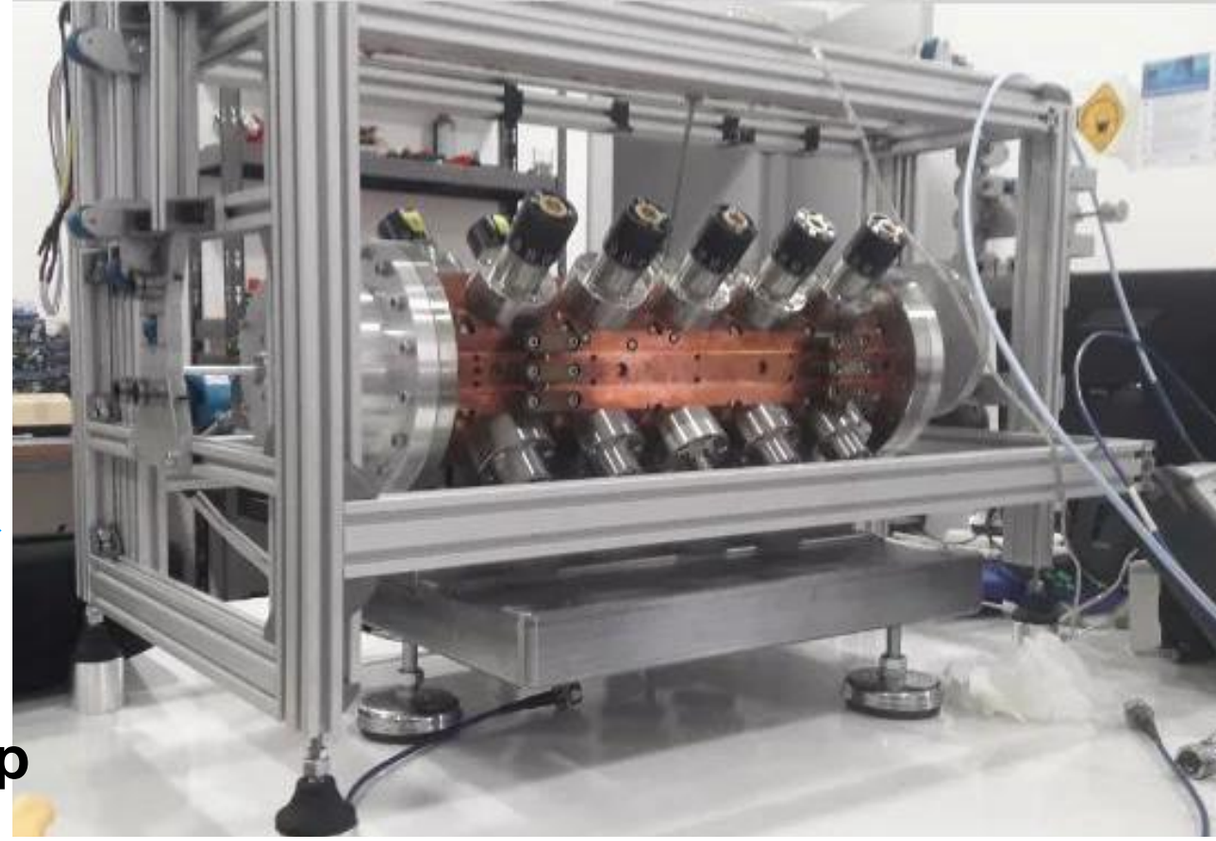


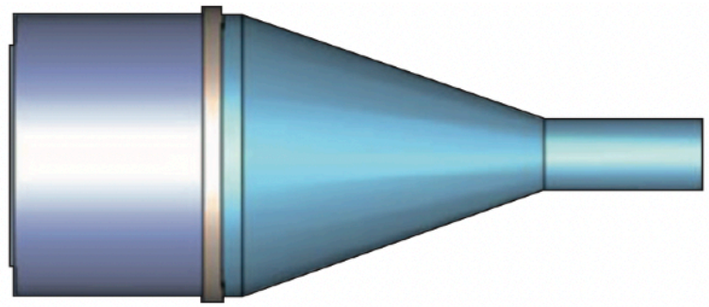
sealing with 3D o-ring
$1x10^{-6}$ mb achieved



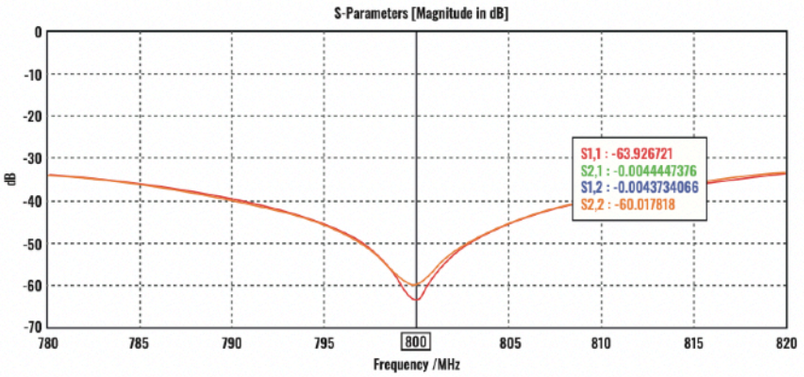
PTAK RFQ EM

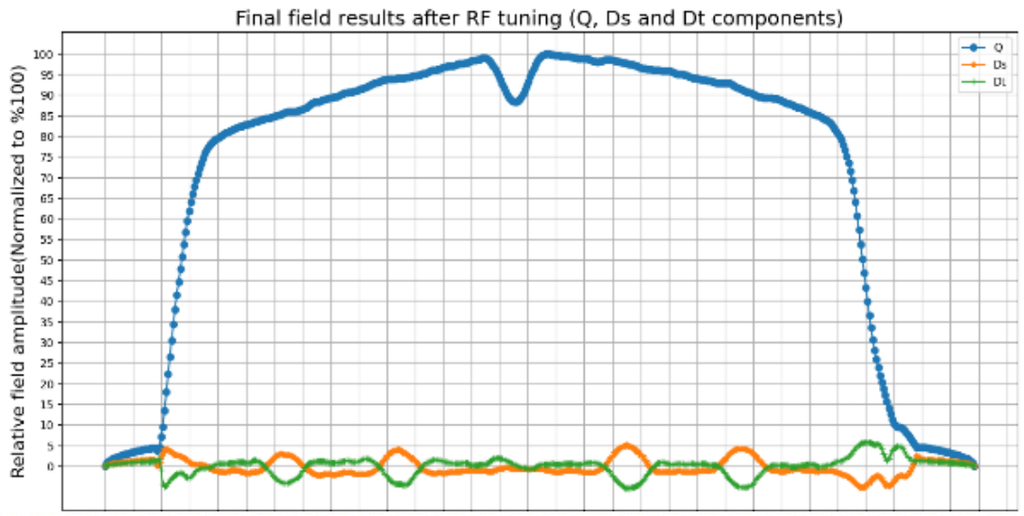
beadpull setup

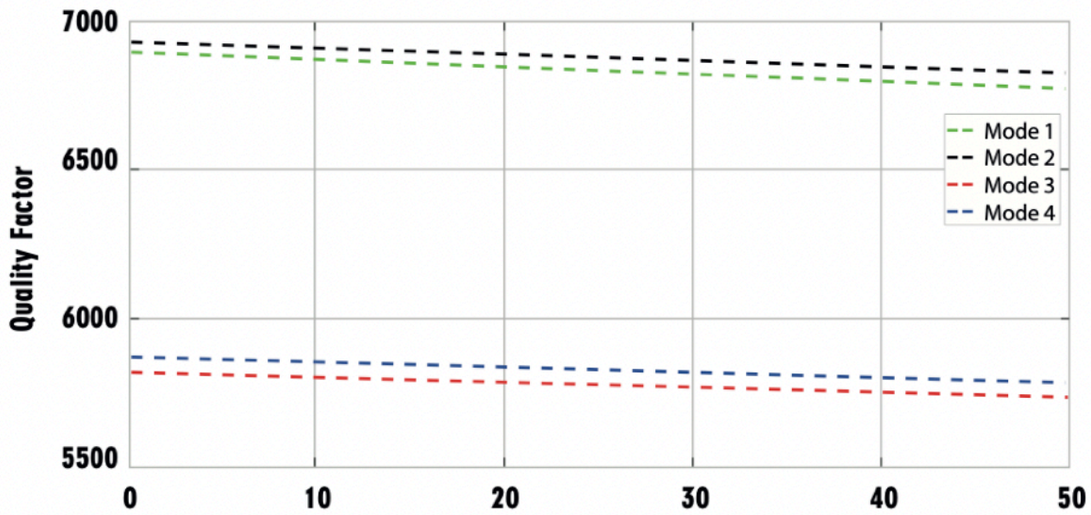




Alumina window coupler design and size image







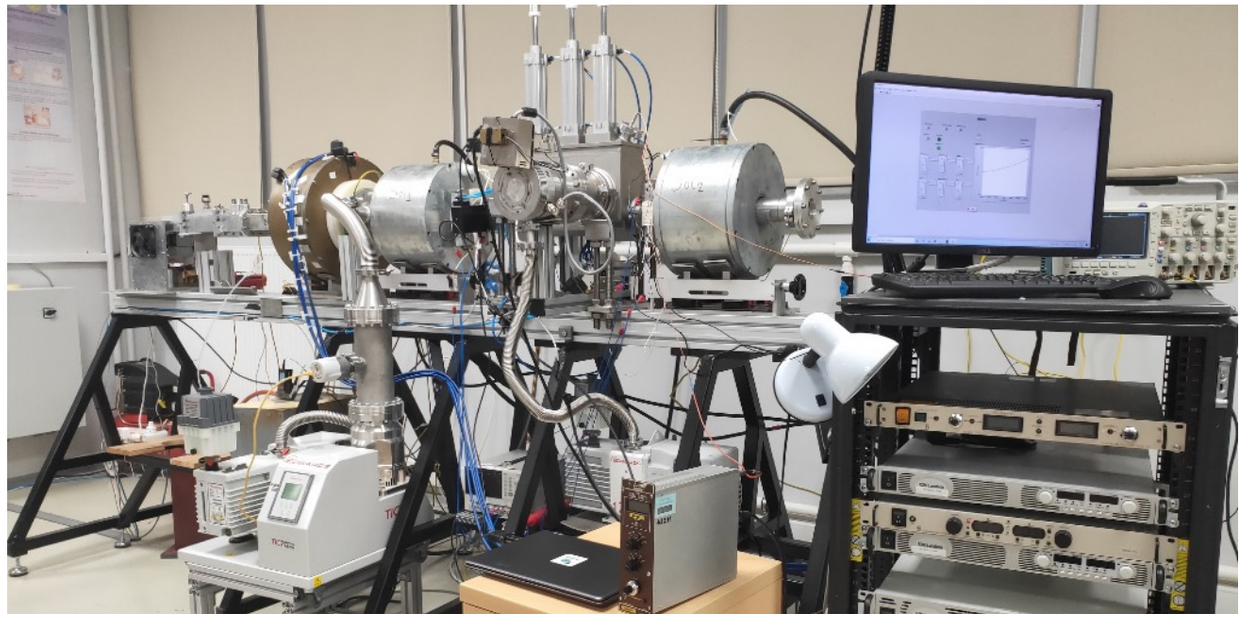
all tuners are flush;

Fquadrupole : 796.05 MHz,

Q_0 : 6973 sim. & 5850 mea.

RF studies on:
surface roughness,
multipacting

PTAK Status & Plans



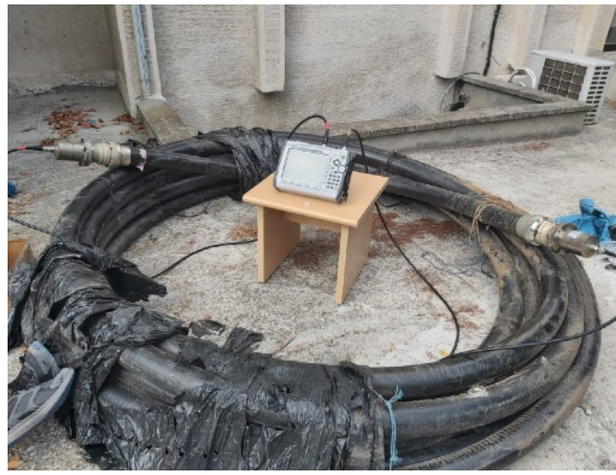
- ★ IS + LEBT installed, system being commissioned
  - ★ 2.45 GHz circulator being added, PMIS to be used now on
  - ★ Beam measurement station now fully automated
- ★ RFQ being manufactured
  - ★ Cu module-0 produced, tested.
  - ★ OFE-CU modules 1 & 2 production to start in coming weeks
  - ★ installation in 2022
  - ★ Vacuum, RF training in Q1 2023
  - ★ First beam in Q3 of 2023 depending on RF PSU status

ACCELERATOR : RF

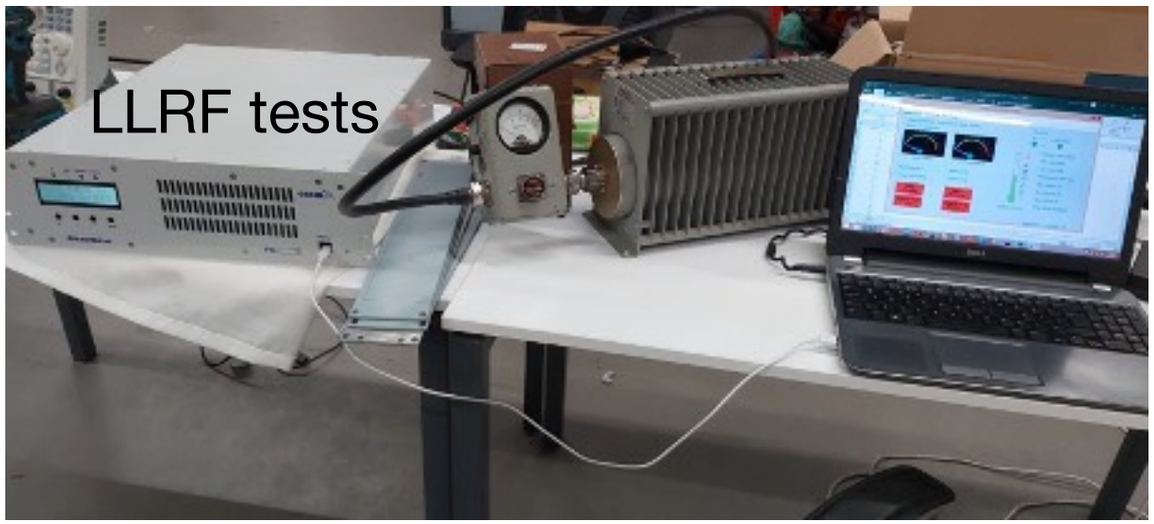
- ☑ RF
  - ☑ FM band
    - ☑ PSU
    - ☑ RF Transmission Line
  - ☑ UHF band
    - ☑ PSU
    - ☑ RF Transmission Line

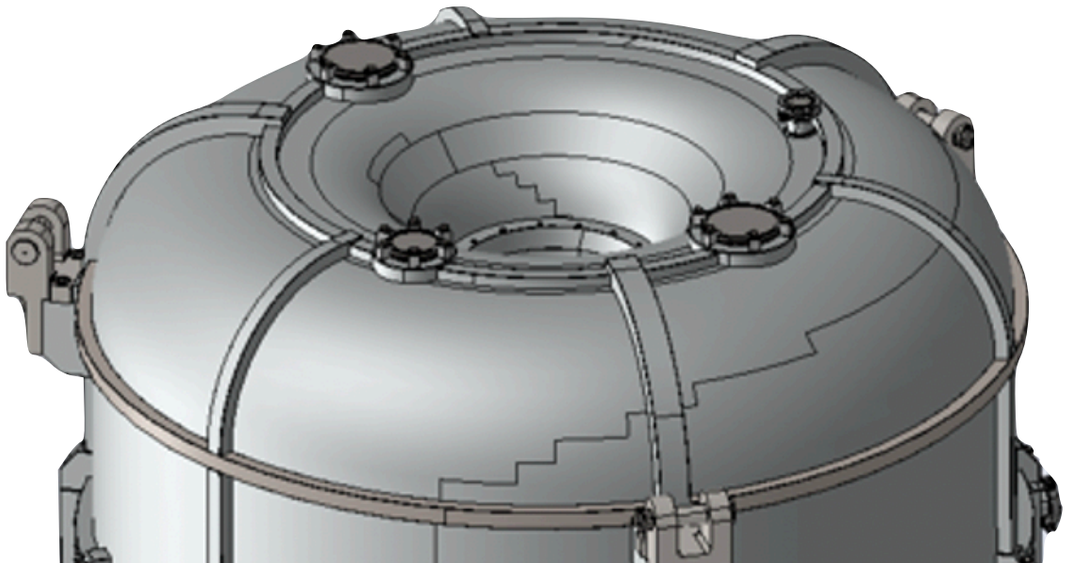
RF - FM band

- 2D (SFISH) & 3D simulations (CST) to calculate Q and Pwall
  - f=107.5 MHz, Q ~ (60k) 45k, Tfill ~ 0.120ms
  - Simulations for 50kW total power
- Common RF source
  - merge two RF PSUs
- Status
  - all PSUs indivudually tested
  - will use coaxial transmission line
  - RF signal generator and preamplifier tested
  - remote control tested
  - need a good RF load
- Design being finalized
  - 3dB adder or feed cavity in two places
  - coupler(s) design beeing checked
  - multipactings verifications ongoing



30kW FM PSUs





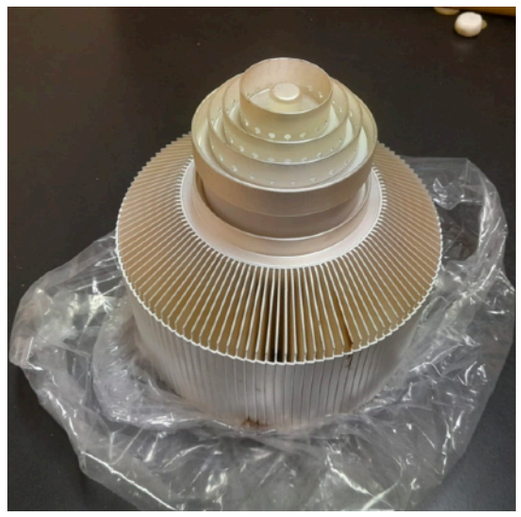
RF - UHF Band

800MHz RFQ	parmteq	Demirci
Q	7036	7190
capacitance (pF/m)	91	122
stored energy (mJ)	67.8	71.7
rf power loss (kW)	48.5	50.6
max surface field (MV/m)	36	=1.38KP

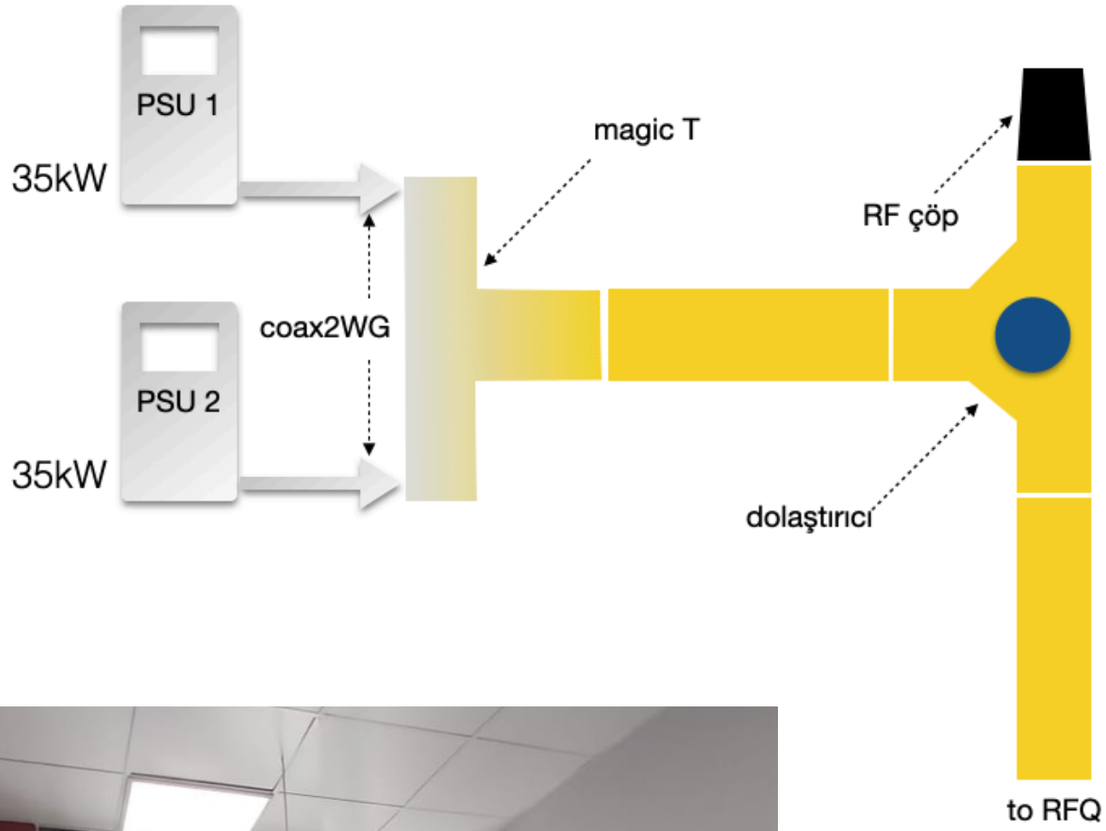
- Assuming 40% safety factor, max RF power needed ~ 70kW
- Assuming 30% RF PSU efficiency, 2% d.f. wall power needed = 4.7kVA
- Received 1+1 RF PSUs as donations
  - ➡ TH582 & TH382 Tetrodes + spares
  - ➡ max power delivered by TH582 in pulsed mode = 35kW.
  - ➡ RF power combination via a magic Tee
- PSUs are being rejuvenated

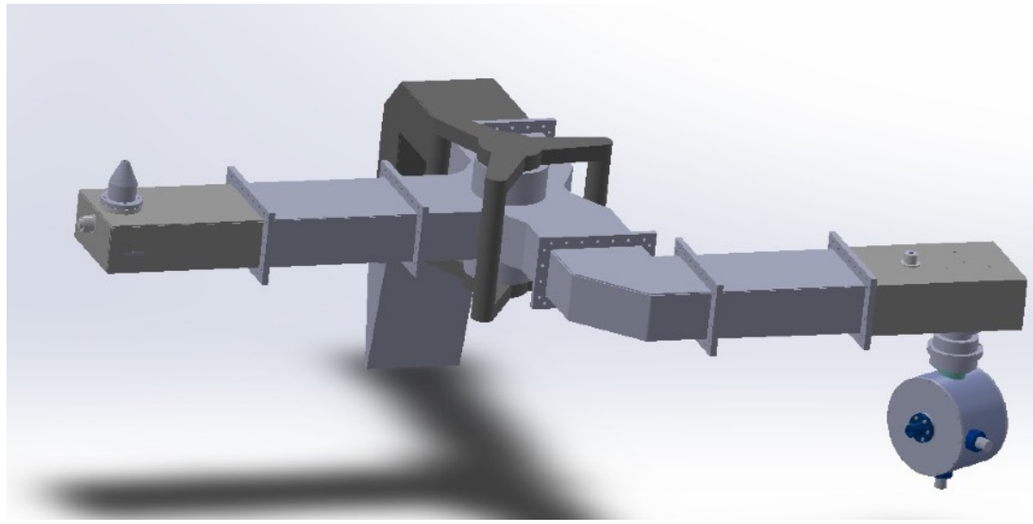
RF container

TH382



RF - UHF - Transmission Line

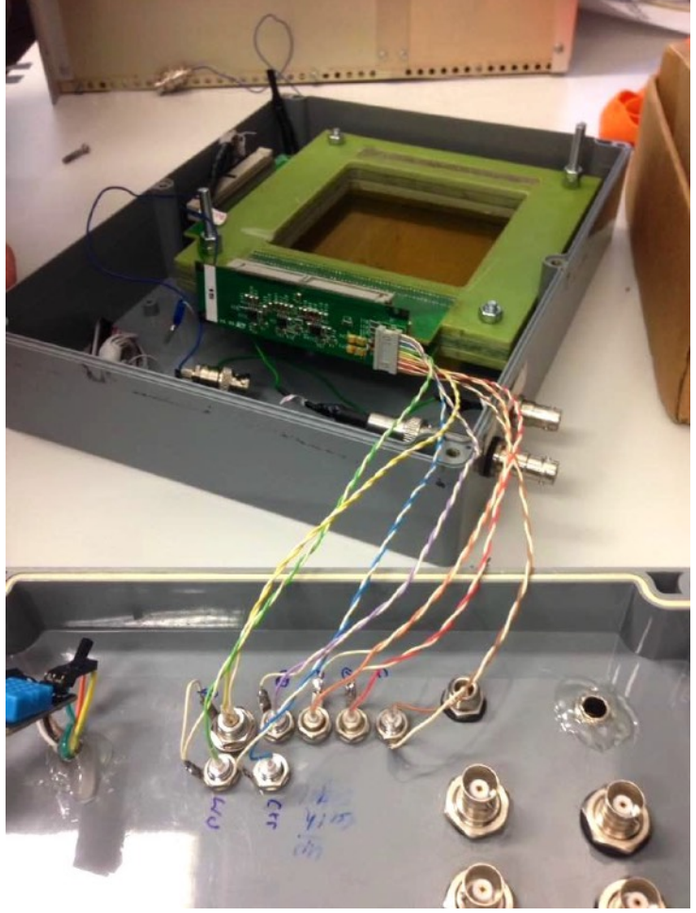




combined power to cavity via WG circulator

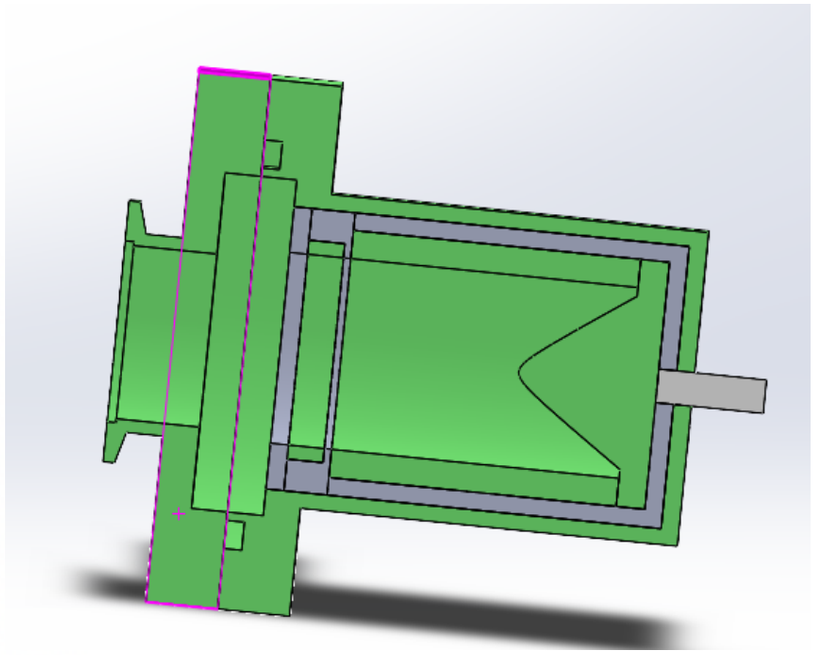
waveguide (T) combiner

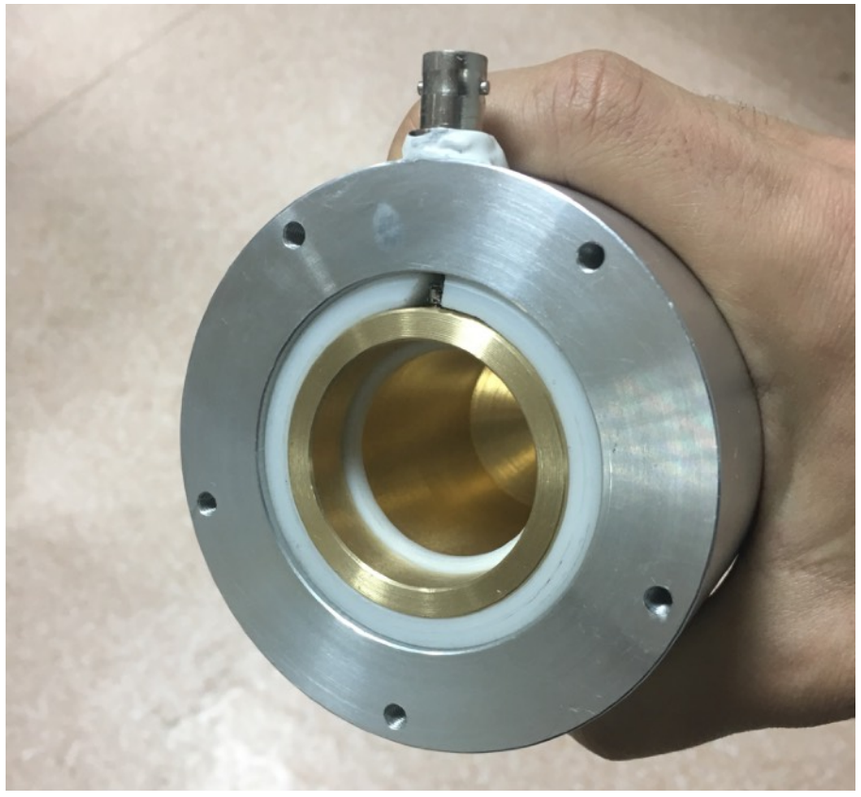
- ✓ Signal generator
- ✓ SS preamplifiers (1.5 kW each)
- ✓ circulator, WGs & RF loads
- ✓ Magic Tee



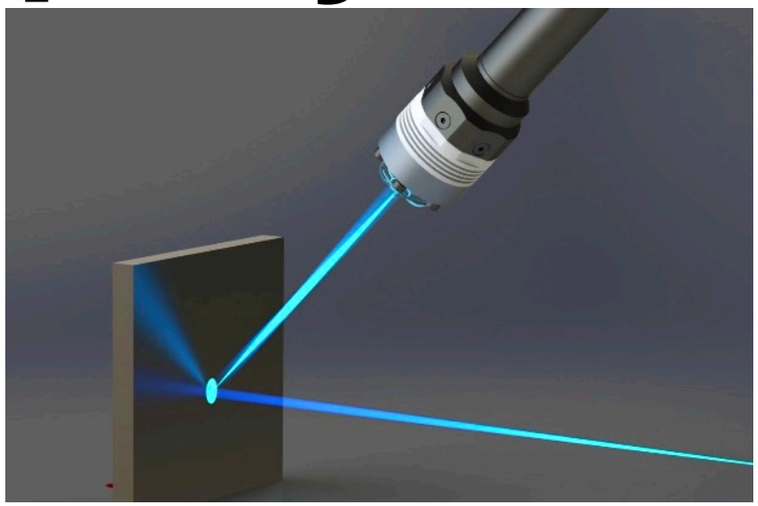
Detector

- Algıç - Detector
  - ☑ GETO - DWC
  - ☑ Scintillator counters
    - ☑ Local & 3D printed
  - ☑ Beam Measurements
  - ☑ Scanning E. Microscope

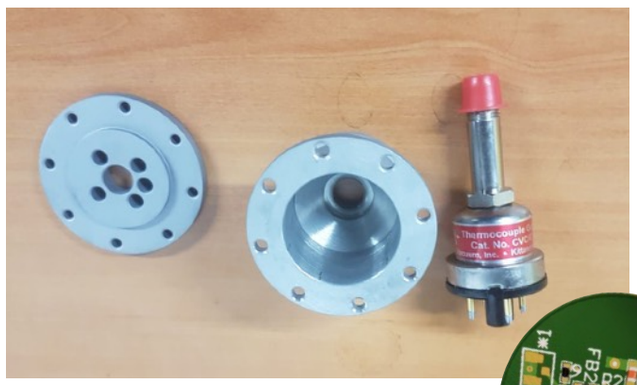


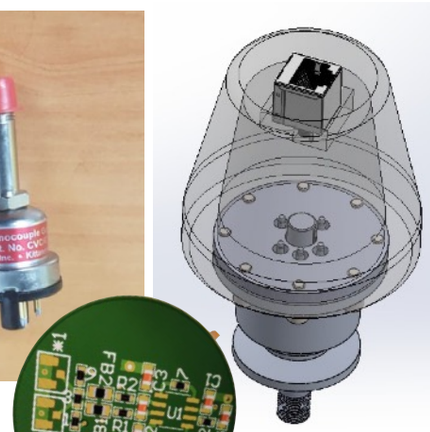


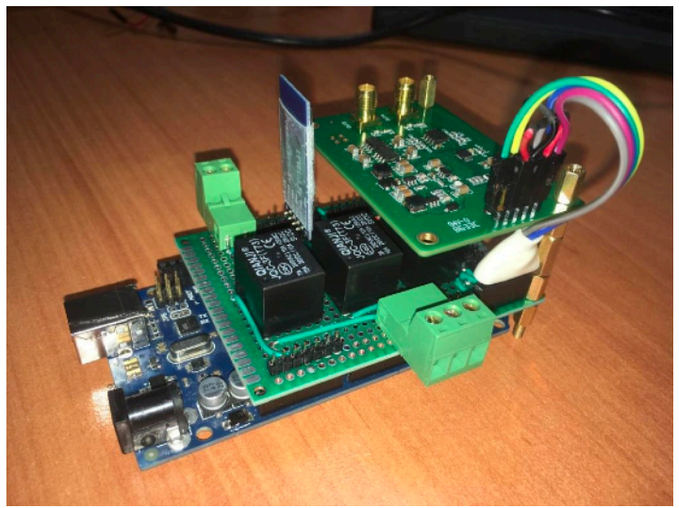
ongoing projects



- EB microscopy
- TC vacuum gauge
- Beam monitor screen
- wifi/bt voltage/current controller
- wifi/bt anode & target current sensors

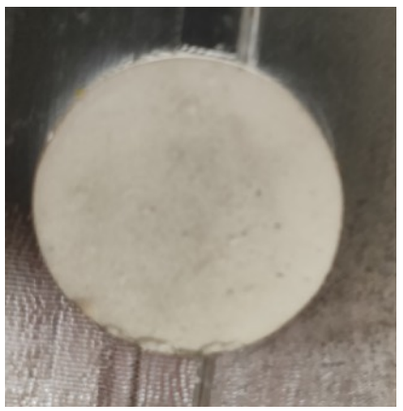


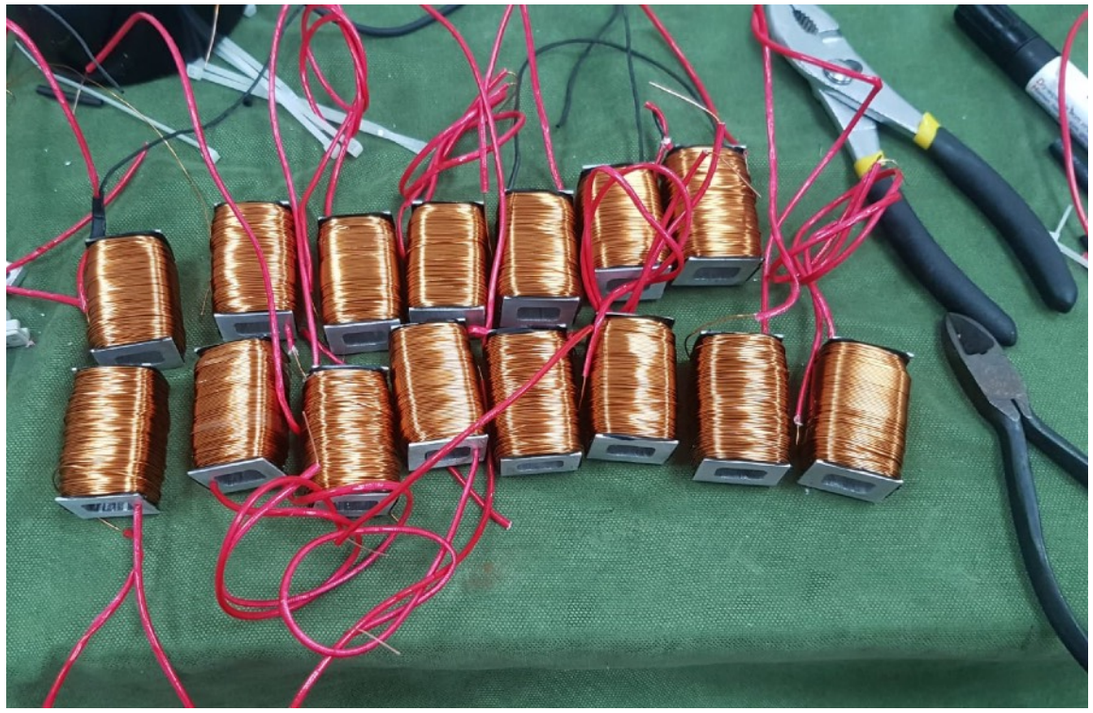




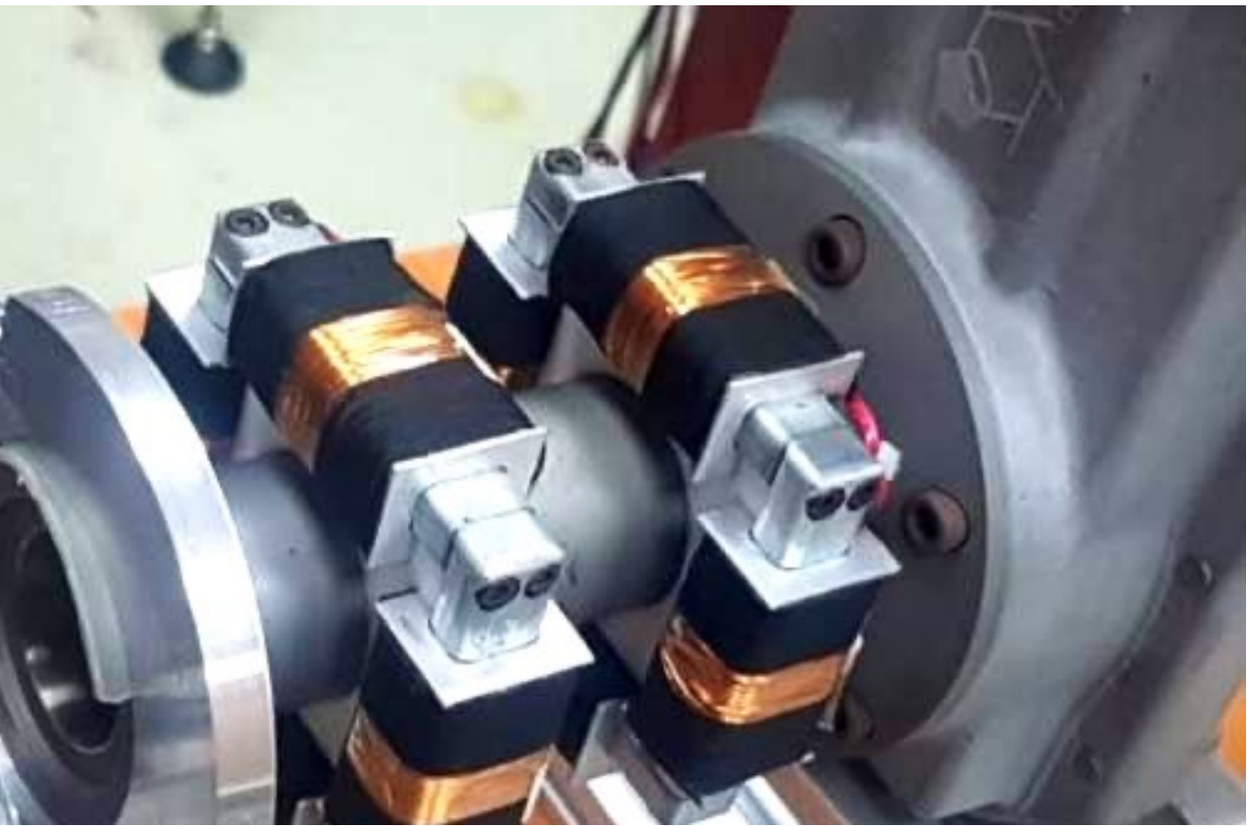
F

Al2O3

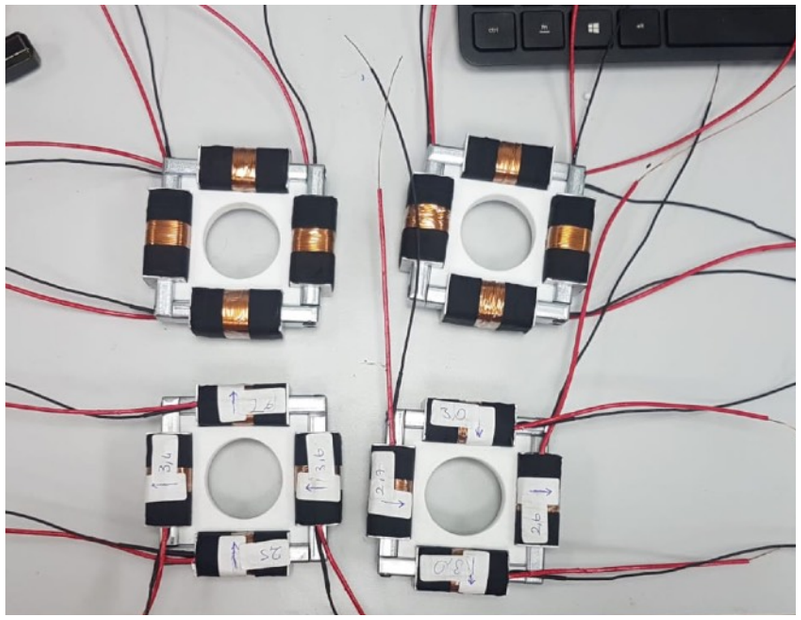




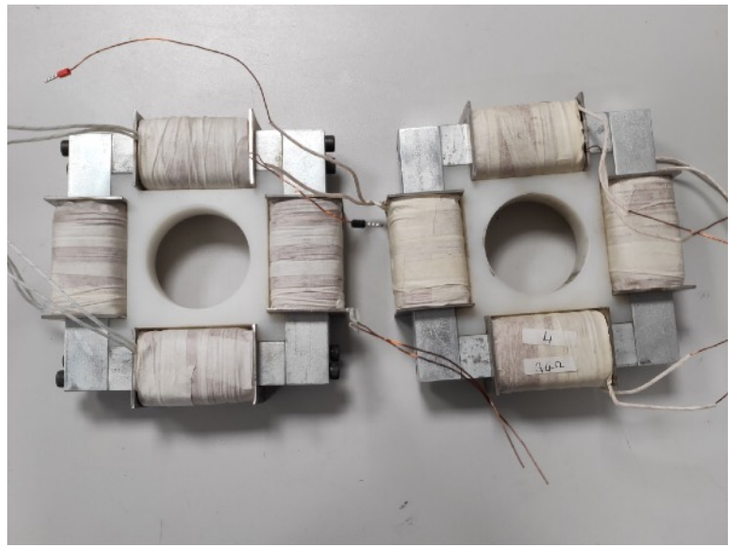
Instrumentation



28

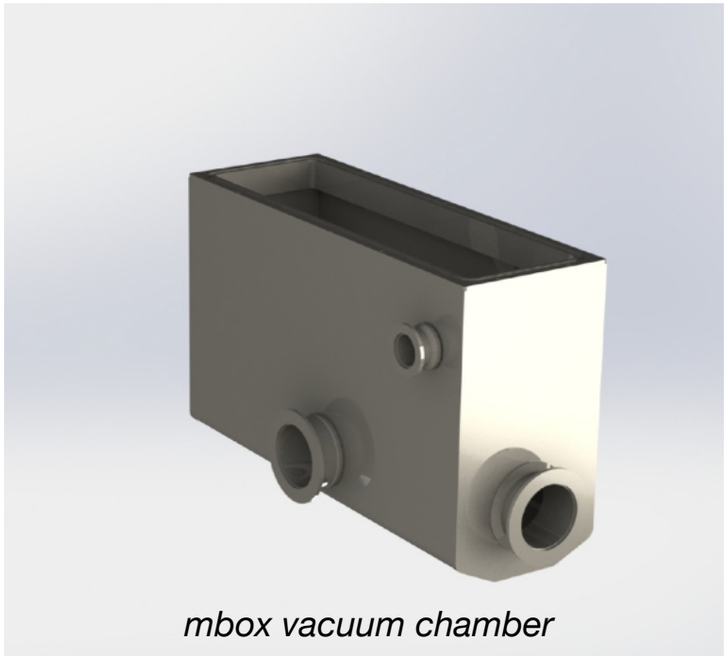


for electron beamline



for proton beamline

MBOX from design to installation



mbox vacuum chamber

diagnostic station and pneumatic cylinders

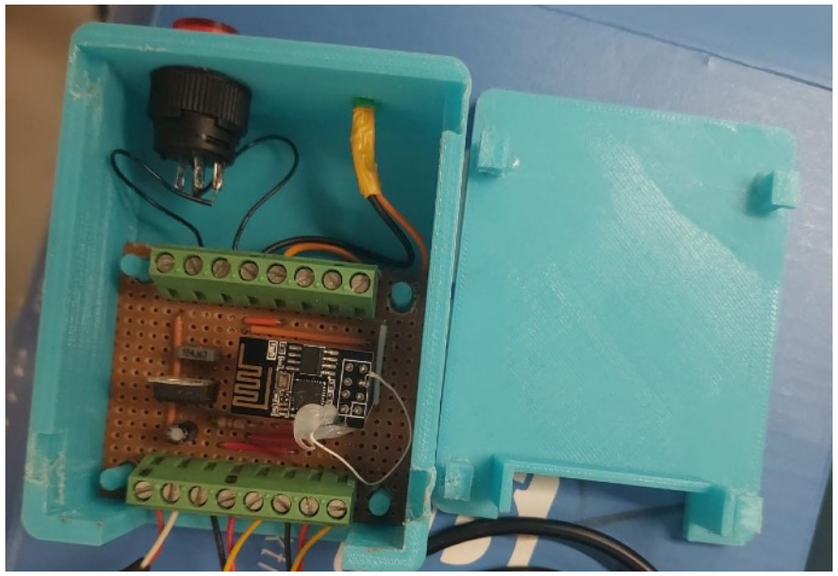
mbox assembled

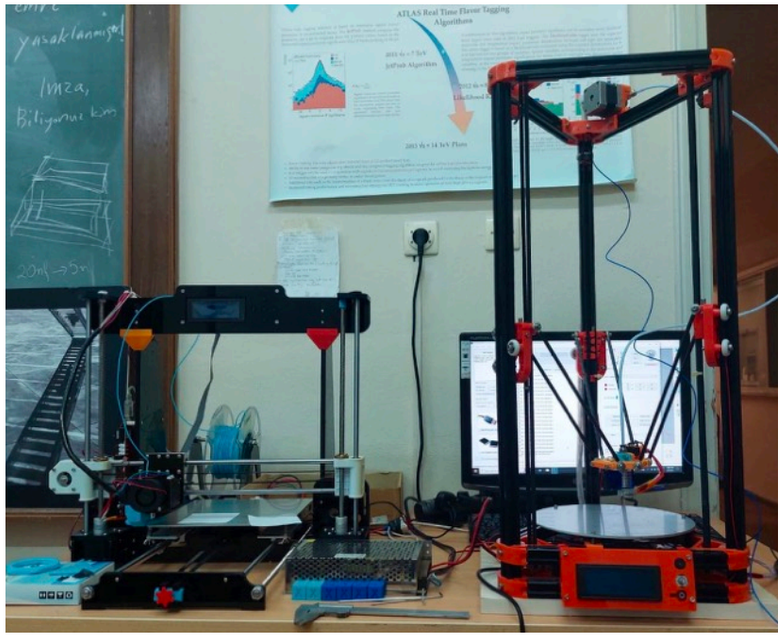
Vacuum Tests

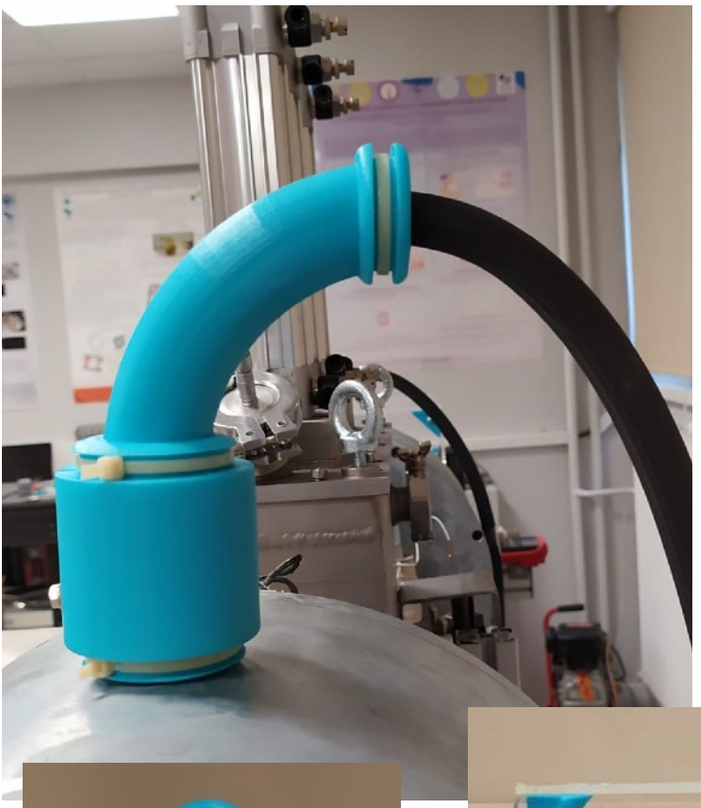
MBOX had good vacuum:
no beam: 1.3e-6mbar
with beam: 1.9e-5mbar

Installation

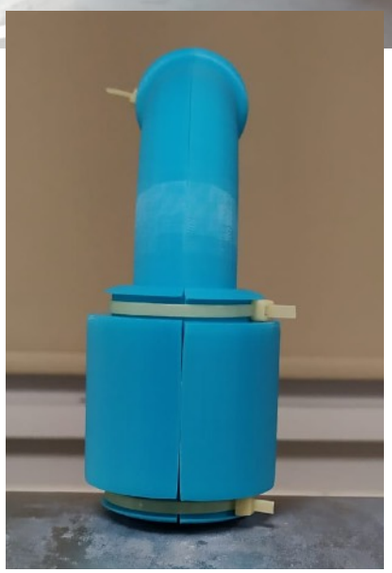
by Dr. O. Ilday, UFOLab, Bilkent



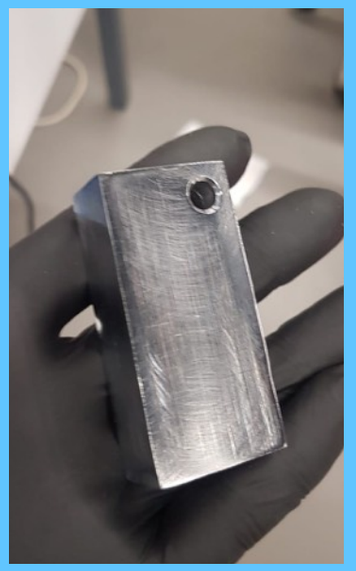




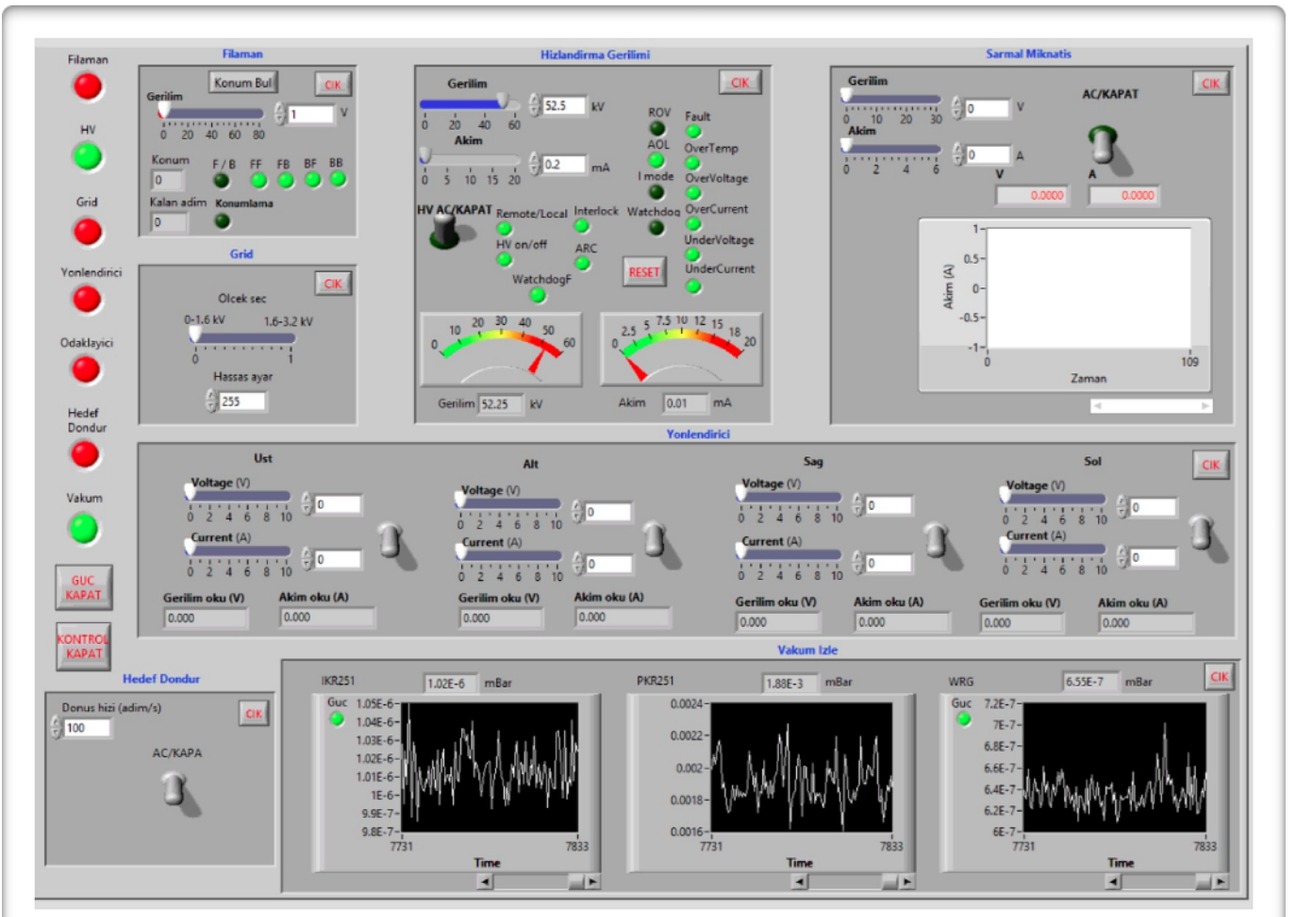
a 3D printer is a very useful tool to have

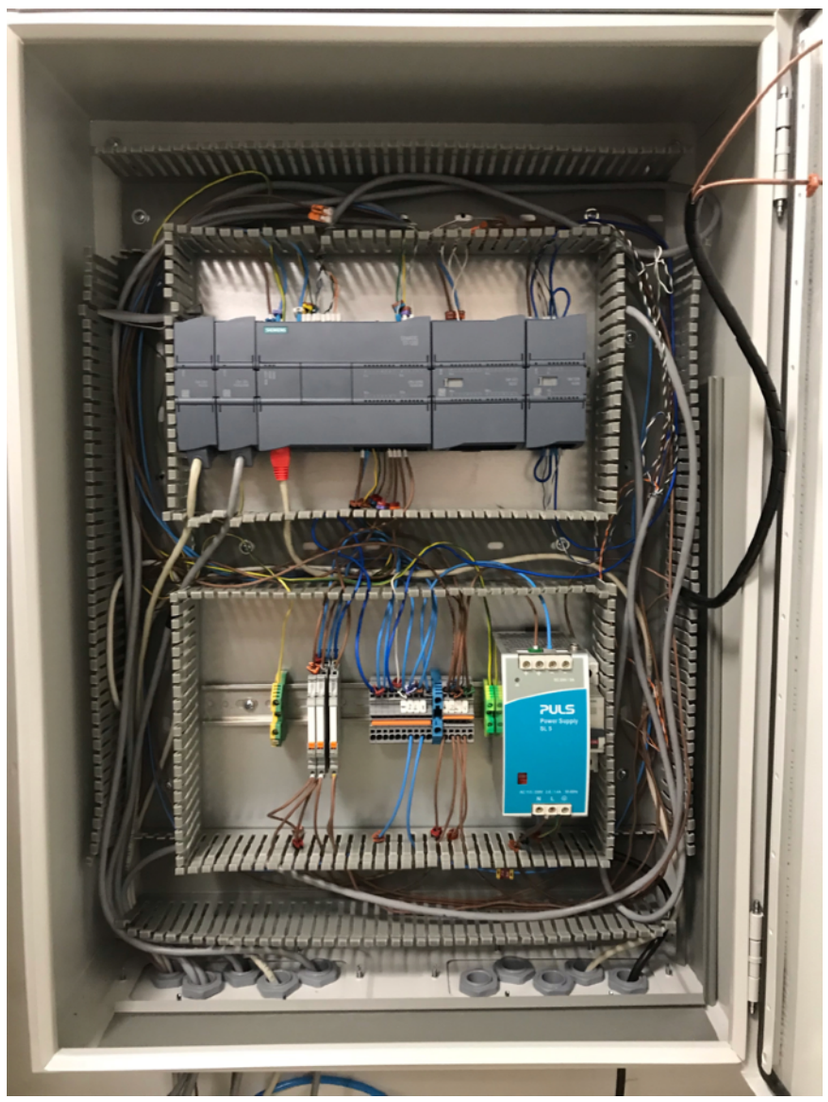


copper coating



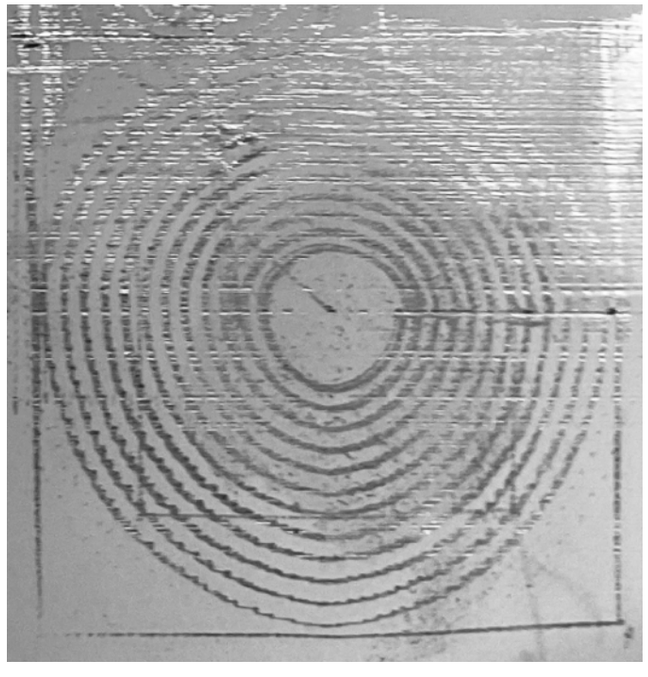
controlling the beam

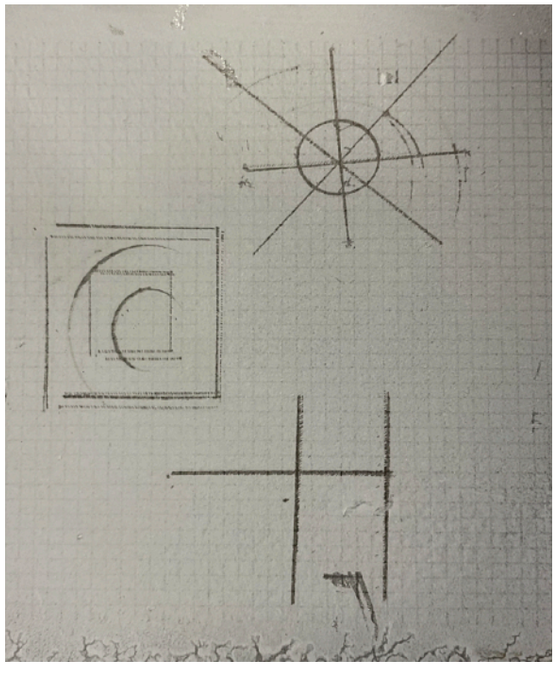




- PLC
- LabView
- uController (arduino)

Hardware and software being developed to fine control the ebeam





possible applications:
ebeam lithography

summary & outlook

- by 2023 KAHVELab aims to have MeV level e- and p beams
  - mA current, in house designed
  - Maximal local construction,
  - Educational and application value
- Beams to test detectors, instrumentation & readout systems
  - gasseous detectors, scintillator detectors
  - locally develop, internationally deploy
- Looking for collaborations
  - qualified personpower always needed
  - know-how for building stuff, e.g. Al_2O_3, Ferrites,...

backup slides

RFQ types
RFQ history
Vacuum sealing
Comparison with CERN HF RFQs