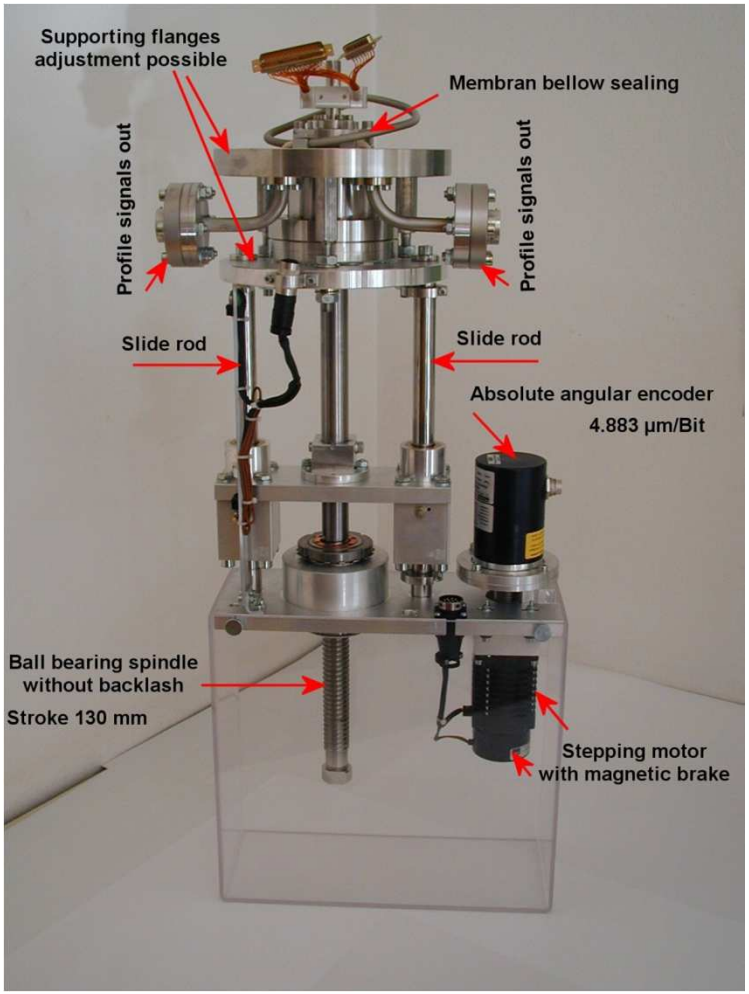
Beam Diagnostics

NTG Neue Technologien GmbH is a worldwide operating mechanical engineering company located in the heart of the European Union.
From January first 2011 NTG has taken over well known company PET-Darmstadt owned by Dr. P. Strehl and H. Kraus. The implementation of PET´s products and components into the NTG product range results in a considerable extension of the product range, especially in the field of accelerator physics and beam diagnostic.
This presentation gives an overview about NTG's competence and product range in this fields.

UHV-Feedthroughs, Single Version LM 23



- Stroke: 150 mm
- Ball bearing spindle, no backlash
- Two slide bars, sliding bearing, adjustable
- Membrane bellow sealing, CF-system
- Drive: Stepping motors, tooth shaped belt
- Position measurement: Absolute angular encoder
- Serial, SSI, resolution < 0.0025 mm
- Magnetic brake (24V DC/0.5 A)
- Limit switches
- Cooling: Through the hollow spindle

Beam Diagnostics

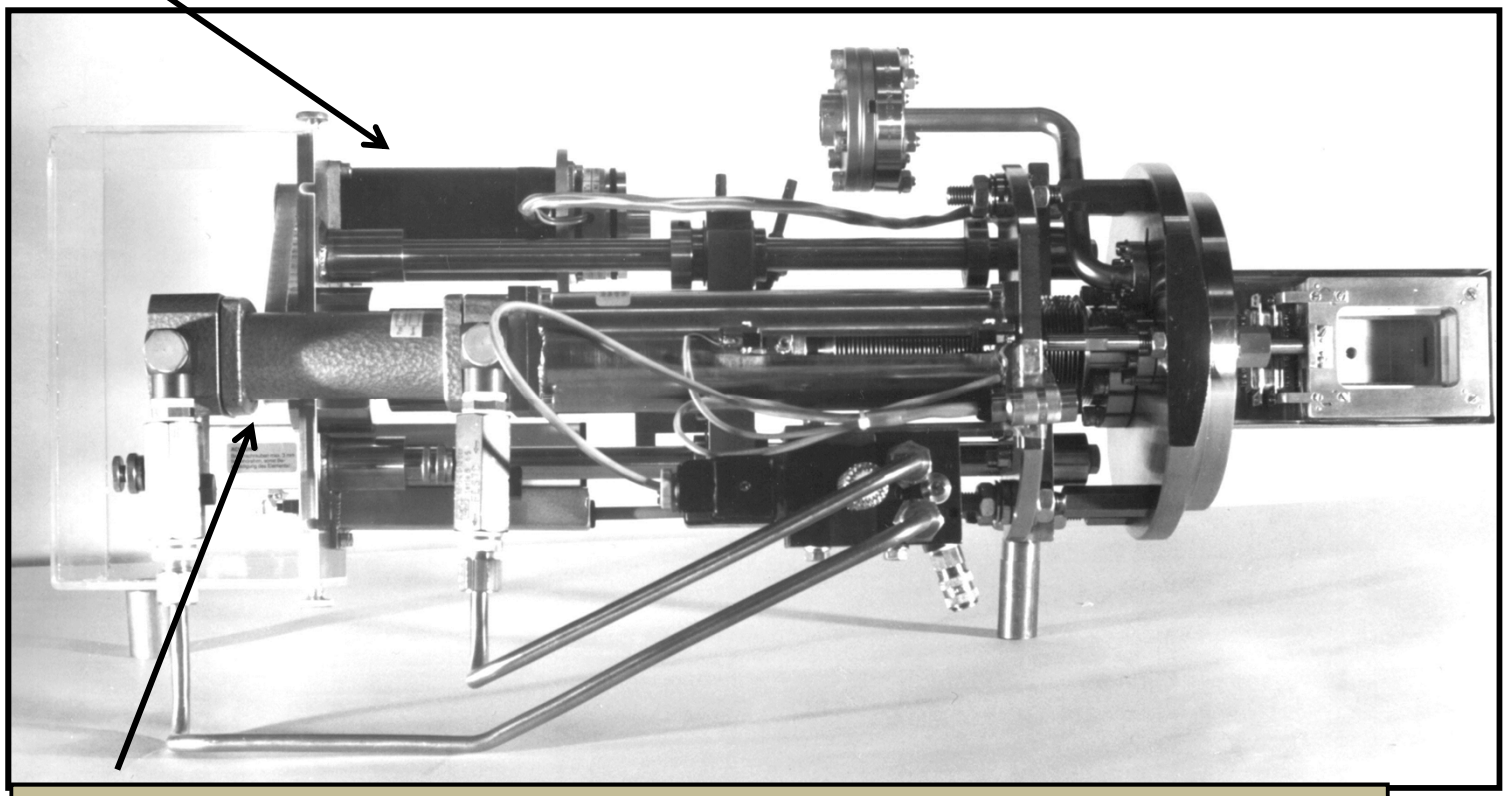
- Stroke (mm):

50 (LM 50), 100 (LM 100, 150 (LM 150)

- Ball bearing spindle, no backlash
- Two slide bars, sliding bearing, adjustable
- Membran bellow sealing, CF-system
- Drive: Two stepping motors, tooth shaped belt
- Position measurement: Linear potentiometer (1/10mm), optional absolute angular encoder (serial, SSI, < 0.0025 mm)
- Magnetic brake (24V DC/0.5 A)
- Limit switches
- Cooling: Through the hollow spindle

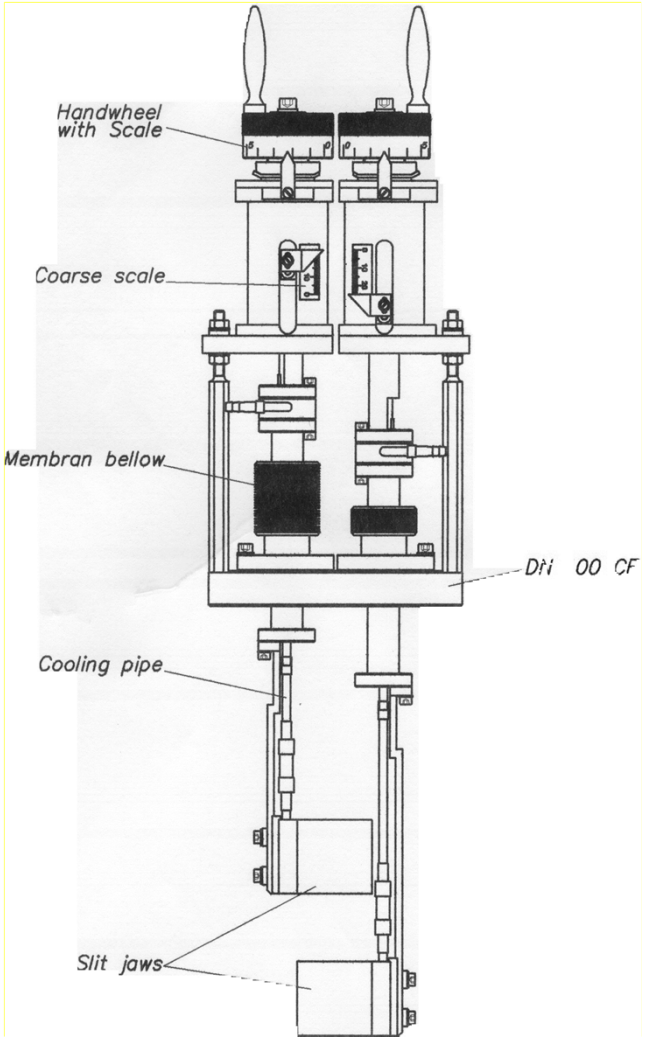
Combined UHV-Feedthrough

Stepping motor for precise linear motion



Pneumatic jack for IN – OUT motion with compressed air actuator

Manual Actuator, Twin Version, LH03



LH03 - Specification

Stroke: 25 mm each

Drive: Micrometer screw, motor drive available

Accuracy of positioning: 1/10 mm

Sealing: Membrane bellows

Supporting flange: DN 100 CF

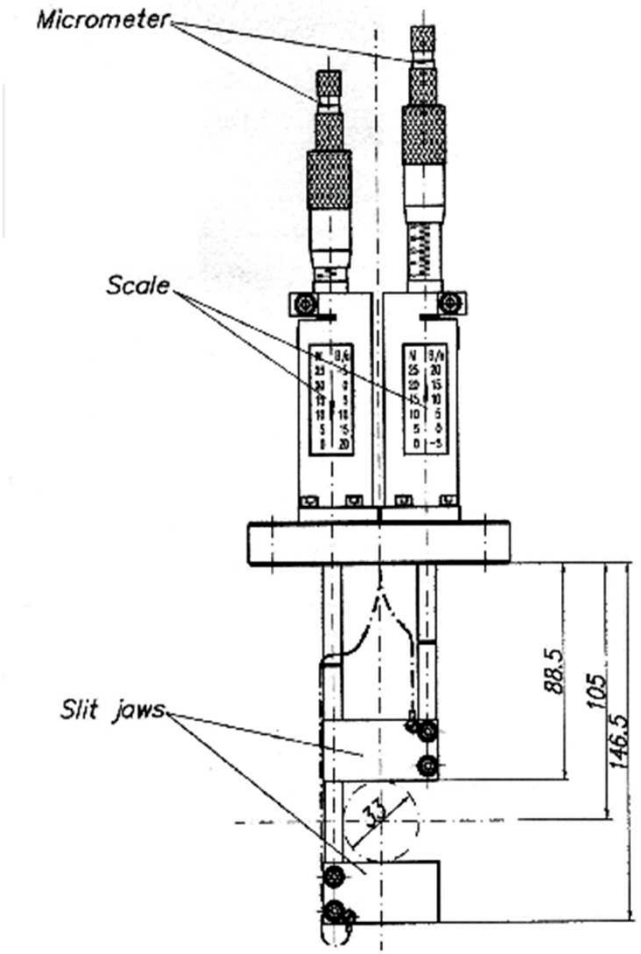
Adjustment: Possible via 3-point support

Mounting of elements: DN 16 CF

Cooling of mounted elements: Possible

Current measurement: Possible

Manual Actuator, Twin Version



Mini-compressed Air Actuator

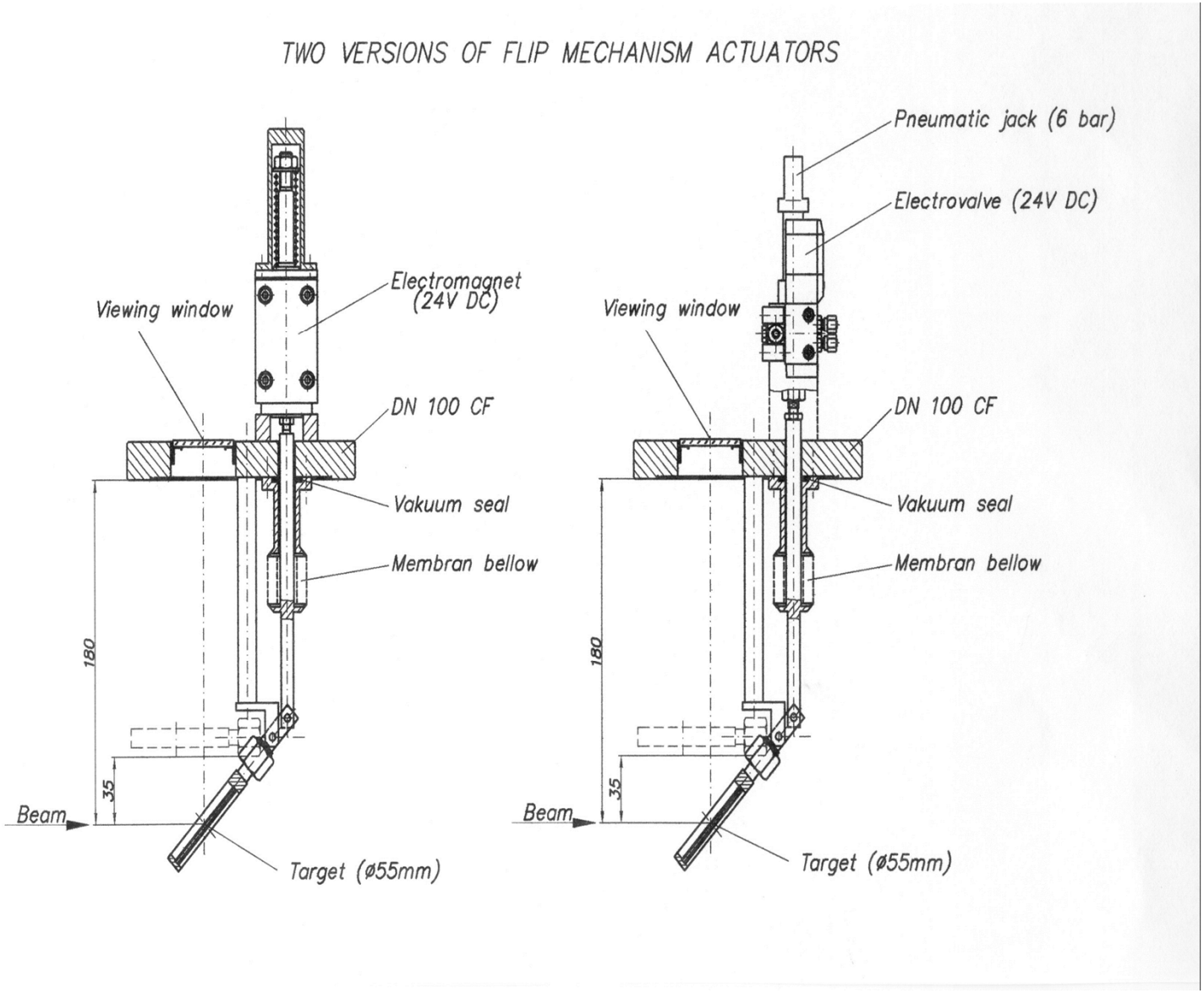
Type: LP 35

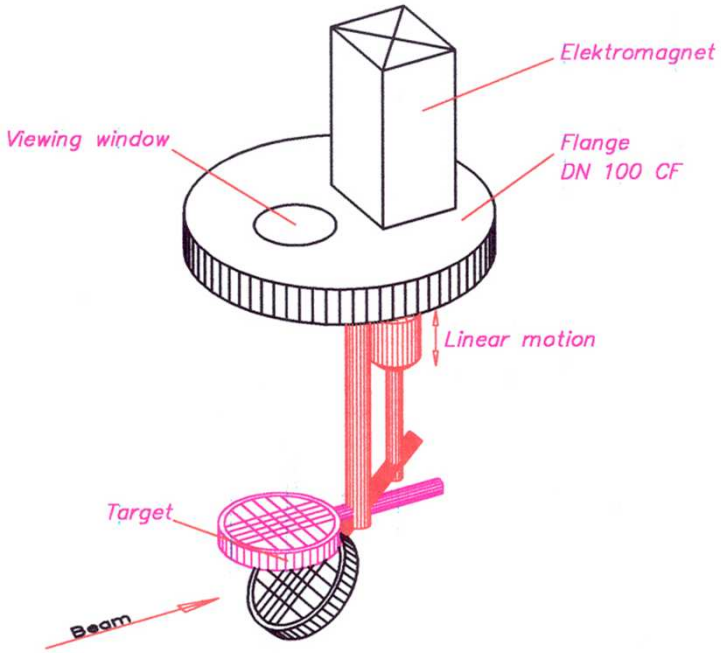
Stroke: 40 mm

Membrane bellow Sealing,

CF – System,

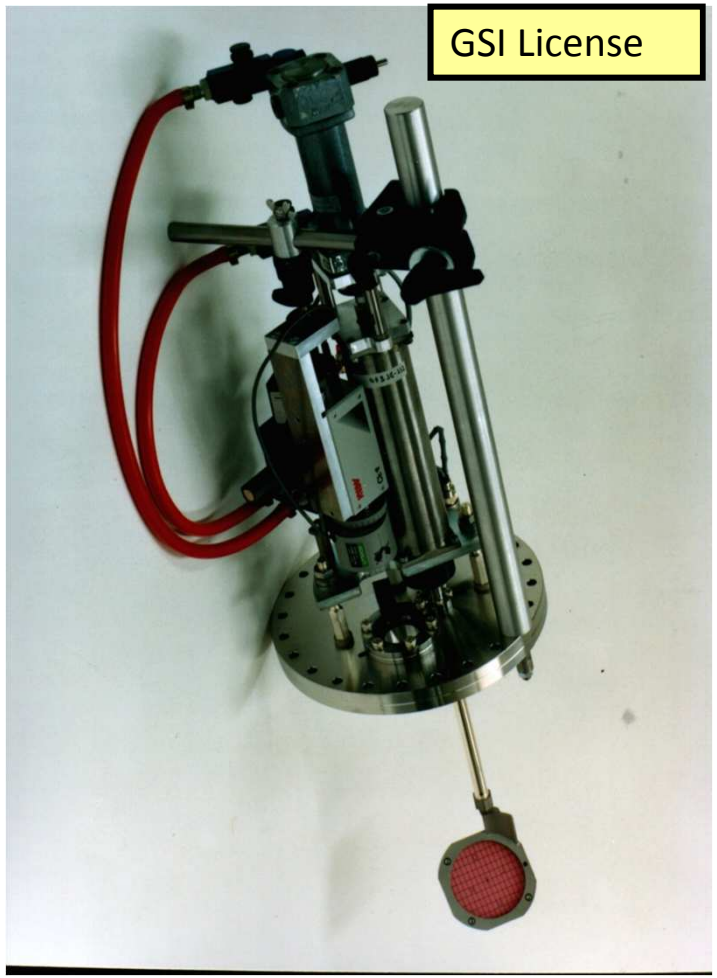
Adjustable, ...


TWO VERSIONS OF FLIP MECHANISM ACTUATORS
Viewing window
Electromagnet (24V DC)
DN 100 CF
Vakuum seal
Membran bellow
180
35
Beam
Target (ø55mm)
Pneumatic jack (6 bar)
Electrovalve (24V DC)
Viewing window
DN 100 CF
Vakuum seal
Membran bellow
180
35
Beam
Target (ø55mm)



Also with compressed air actuator available

Viewing Screen,attached to a compressed Air Actuator



Screen material:

Chrolox 6,

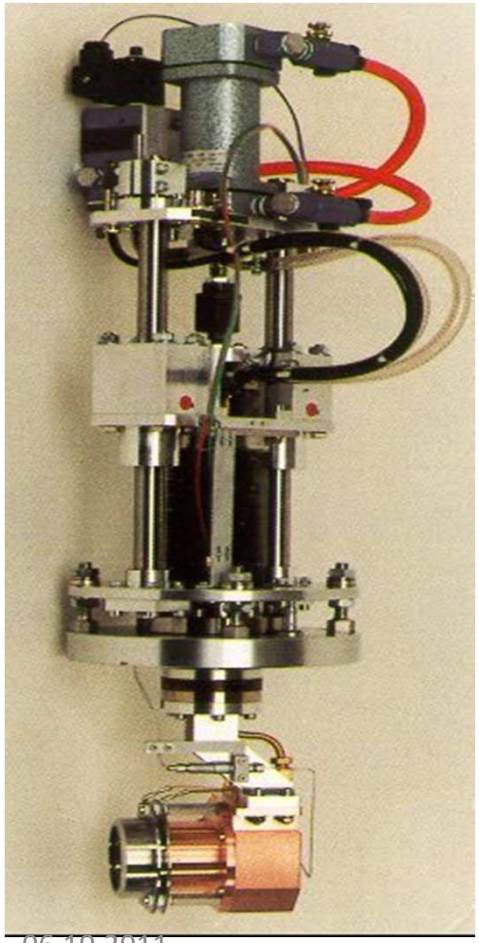
Sensitivity:

10E6 Protons/mm²

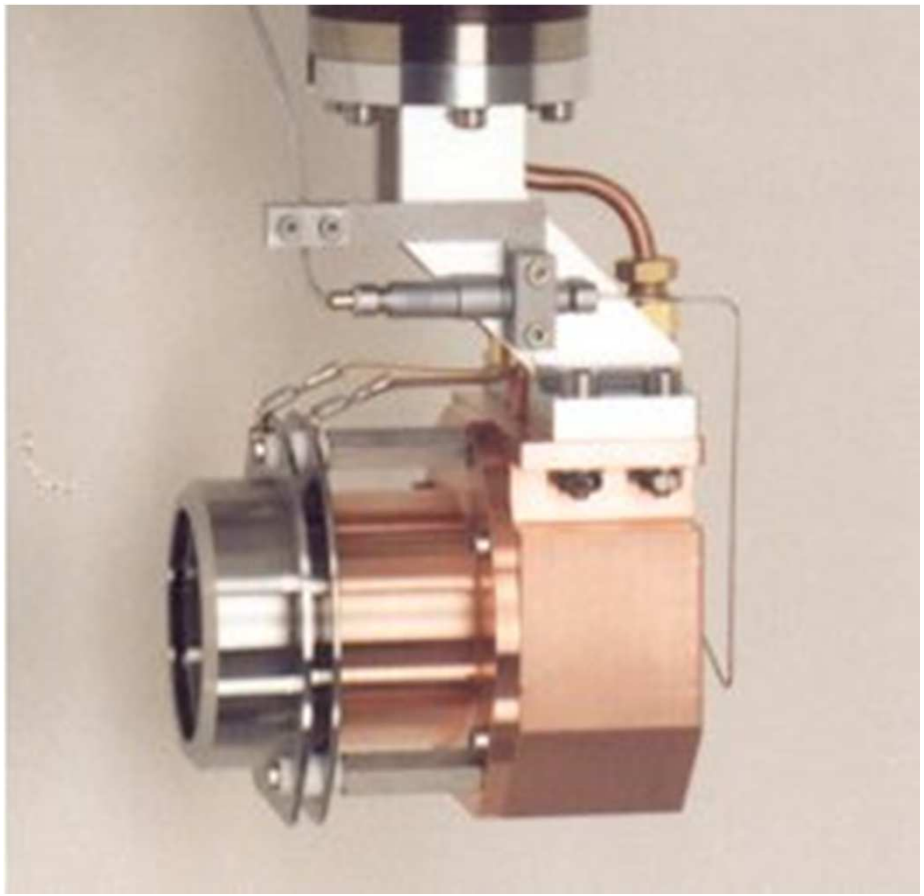
Decay time ~ms

λ = 700 nm

Compressed Air Actuator with cooled high Power Faraday Cup



- Type: FC 31
- Stroke: 100 mm
- Sealing: Membranbellow
- Supporting flange: DN CF 100
- Two slide bars, sliding bearing,
- Limit switches
- Adjustable, ...



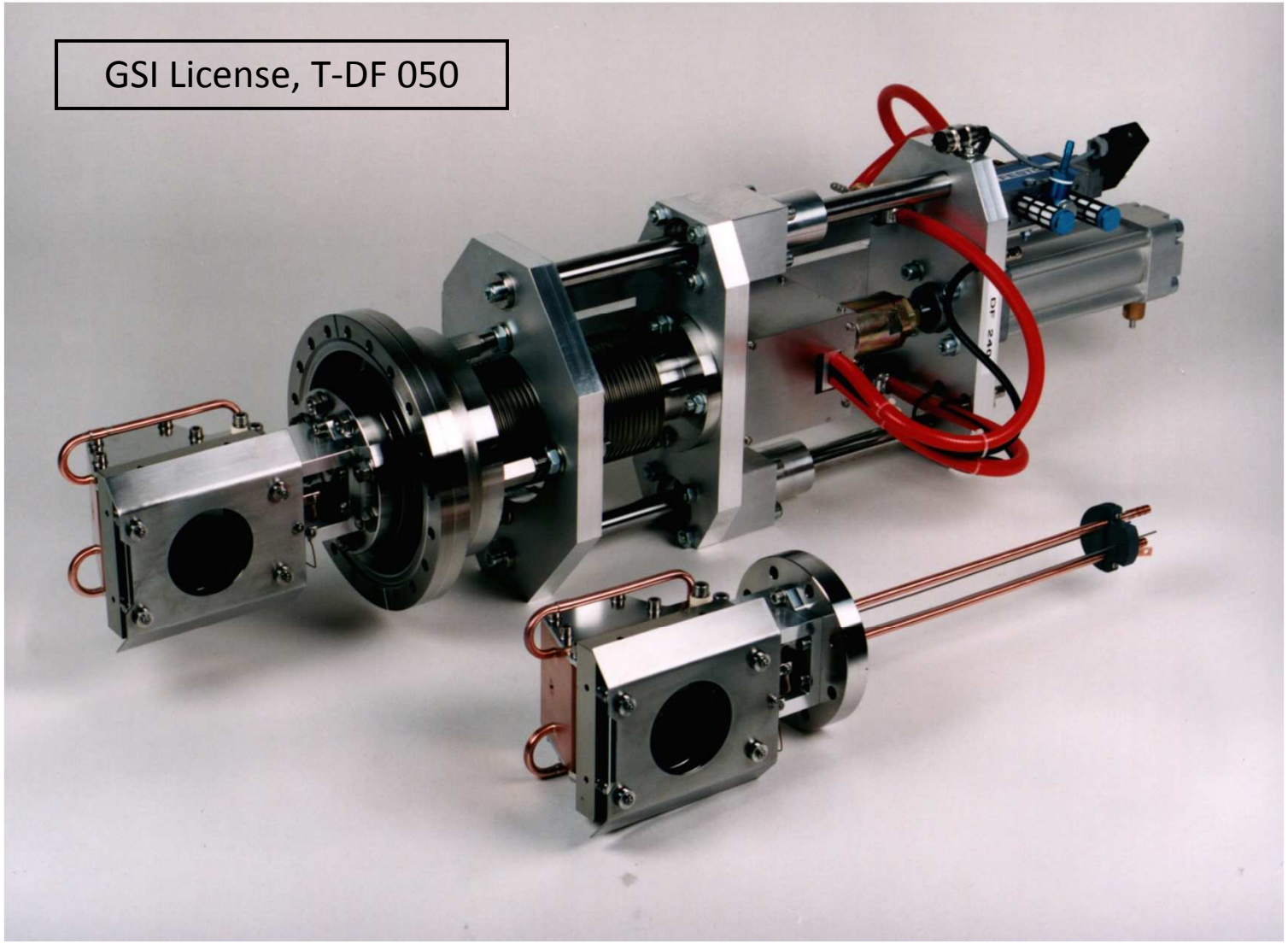
Maximum beam power:

6 kW (DC),

Stopper material:

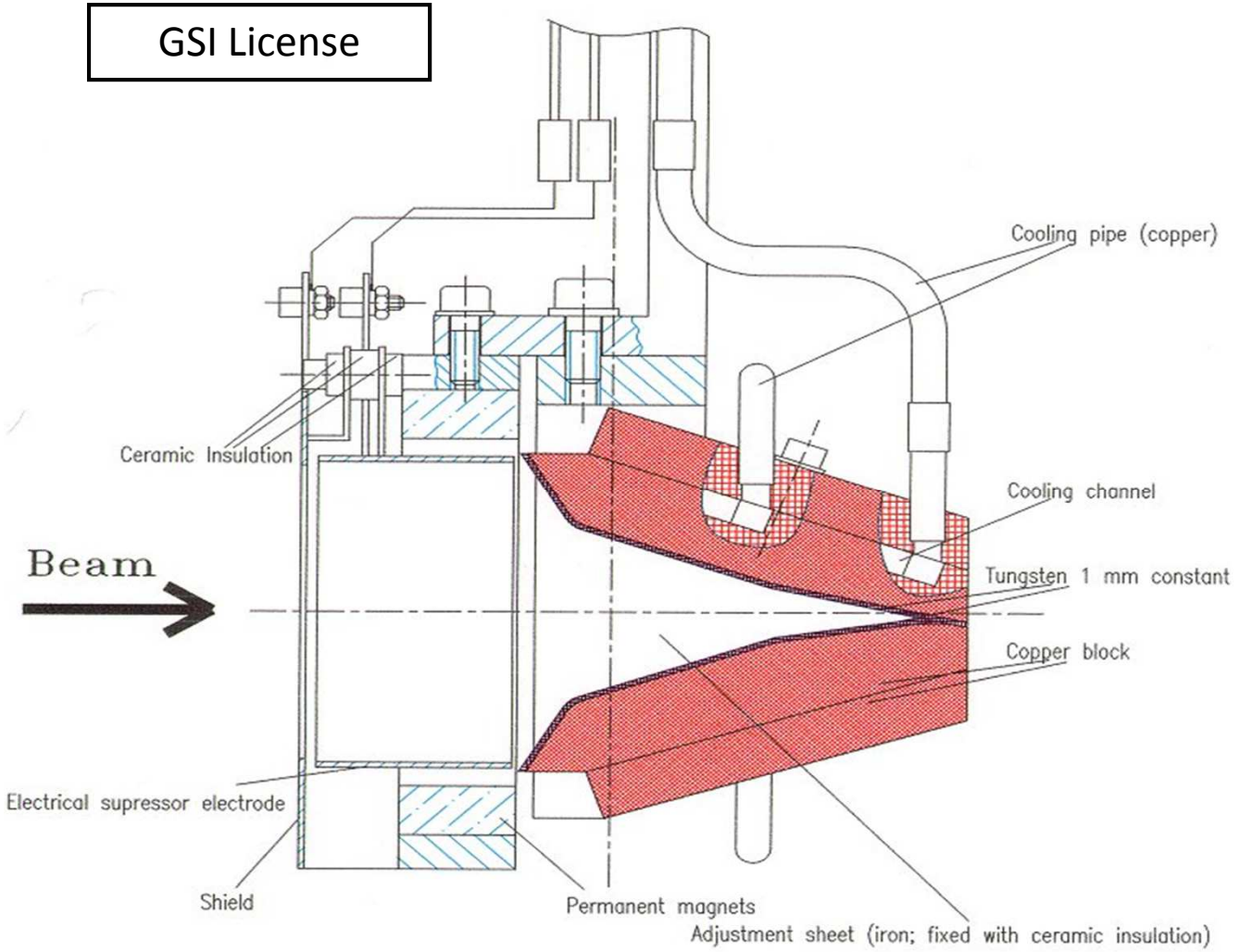
Copper (45 MeV p),

Electrical Secondary electron suppression can be supplemented by a magnetic one.


GSI License, T-DF 050

1.4 MW pulse, 200 µs, 10 kW DC

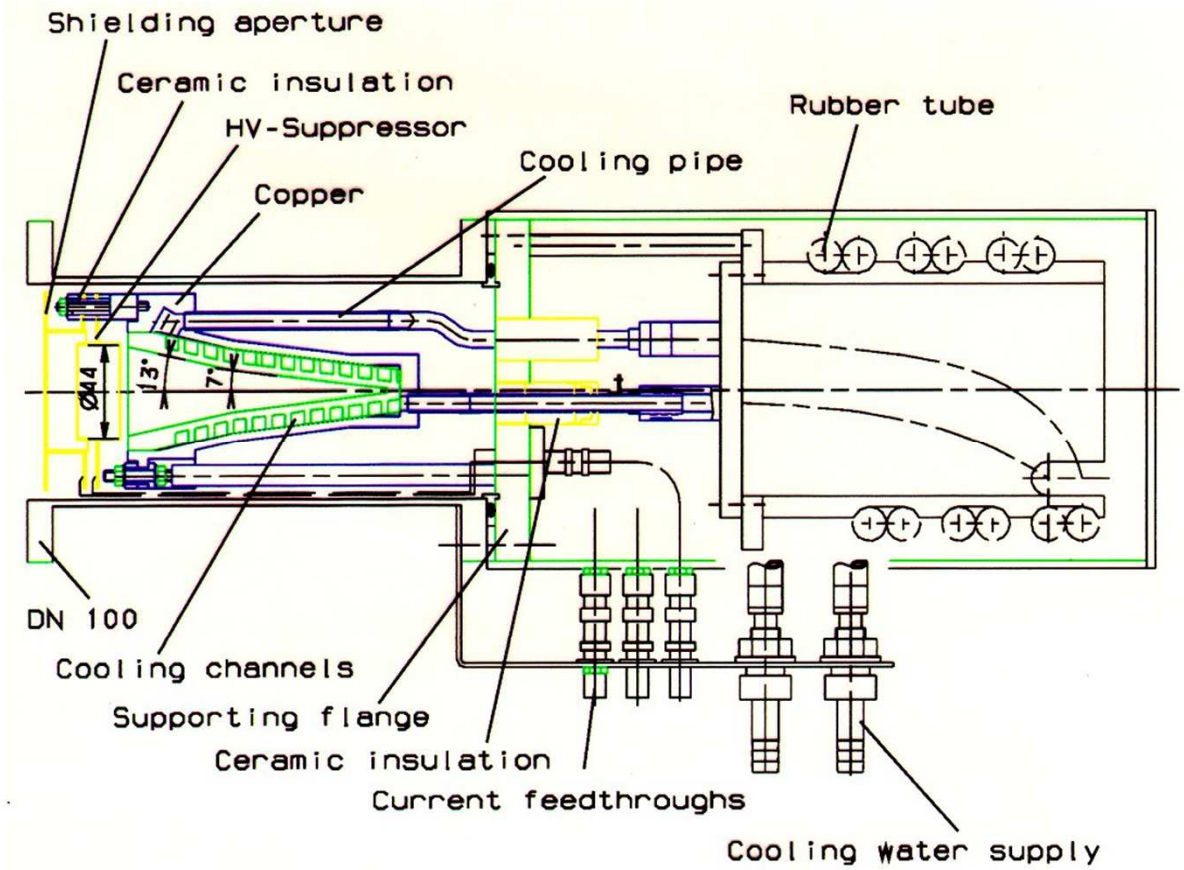
GSI License



Stopper material: Copper (45 MeV Protons)

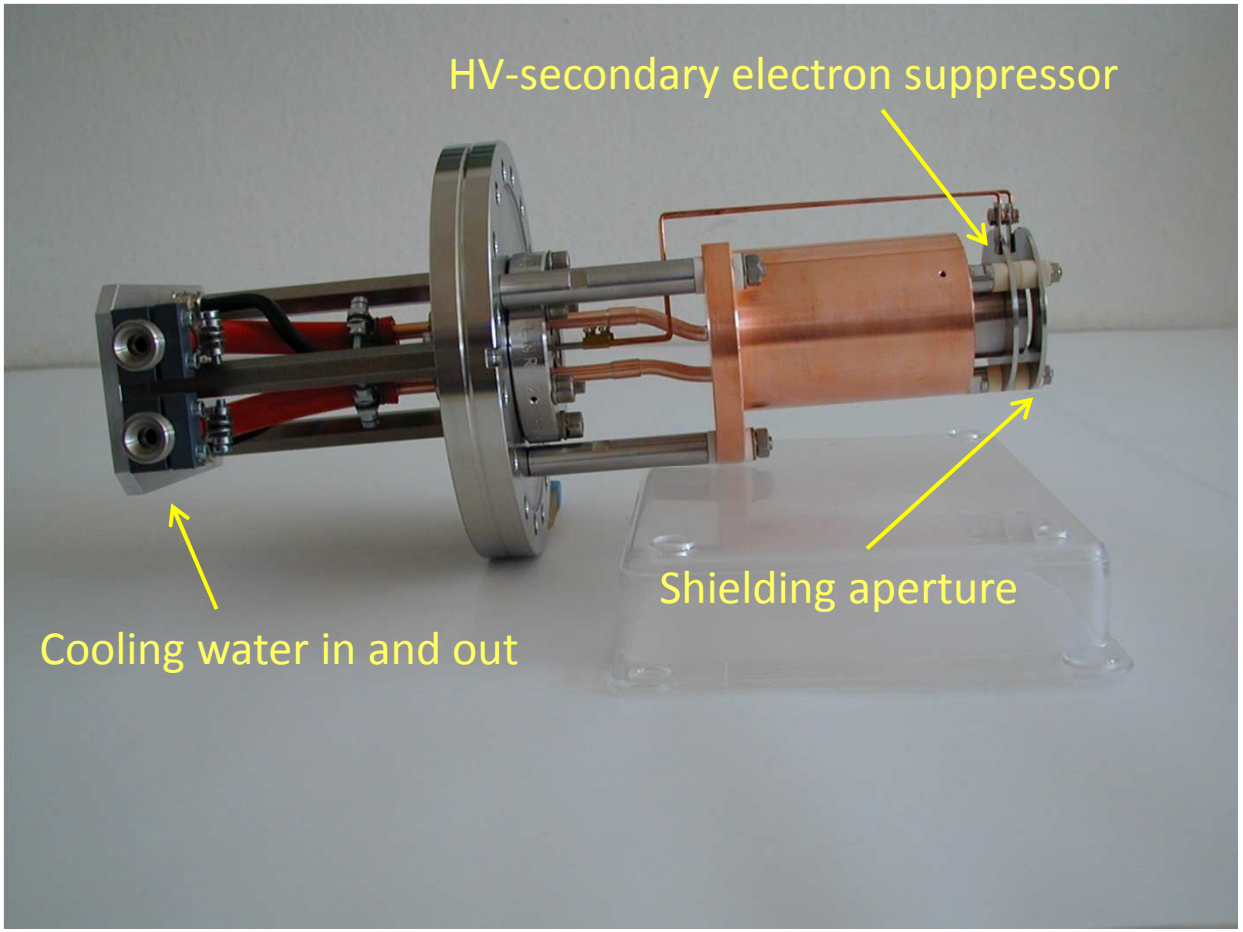
Maximum beam power: 25 kW (DC)

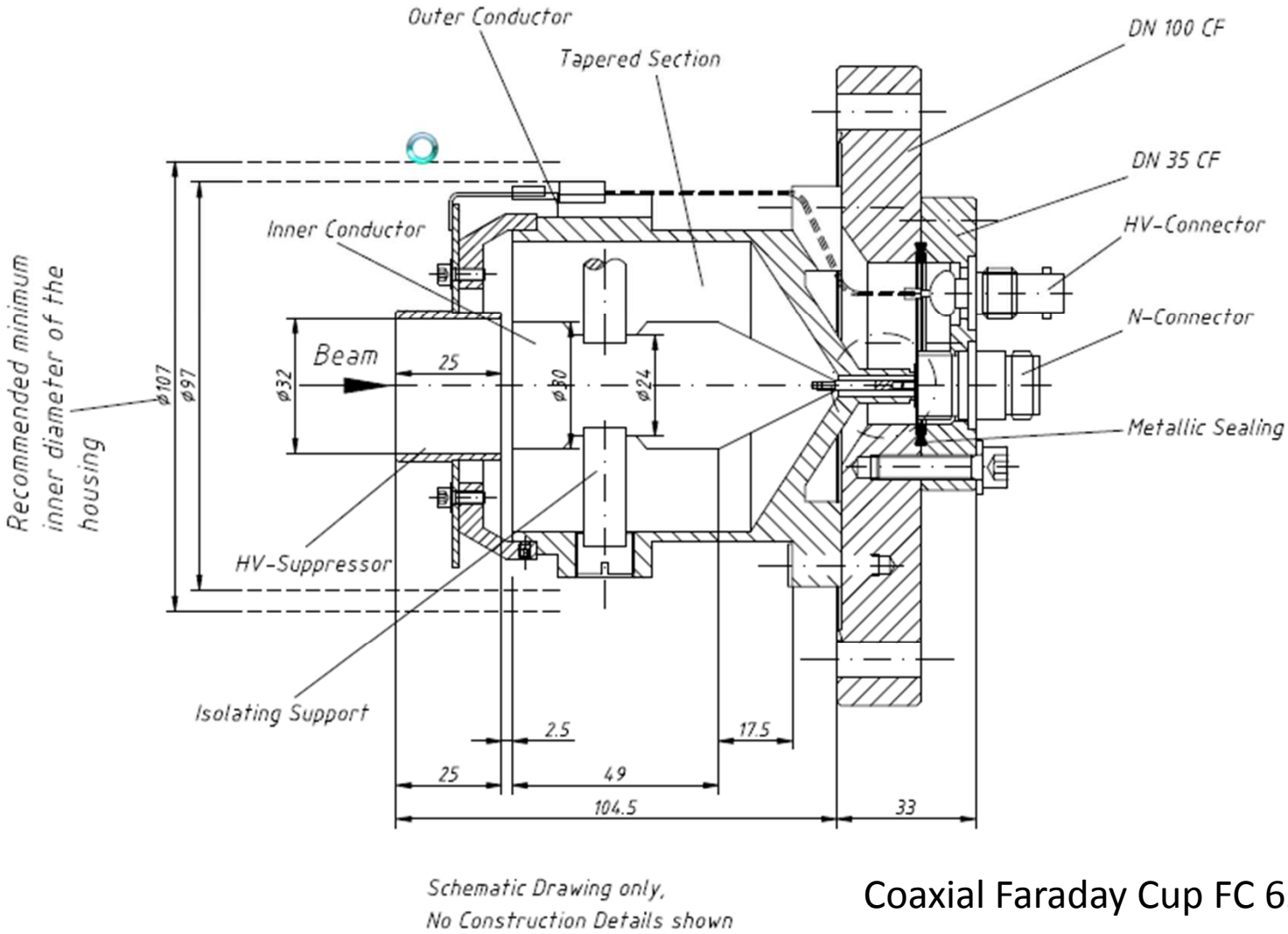
Maximum beam power density 10 kW/cm^2



Cooled End Faraday Cup, Stopper Material: Copper

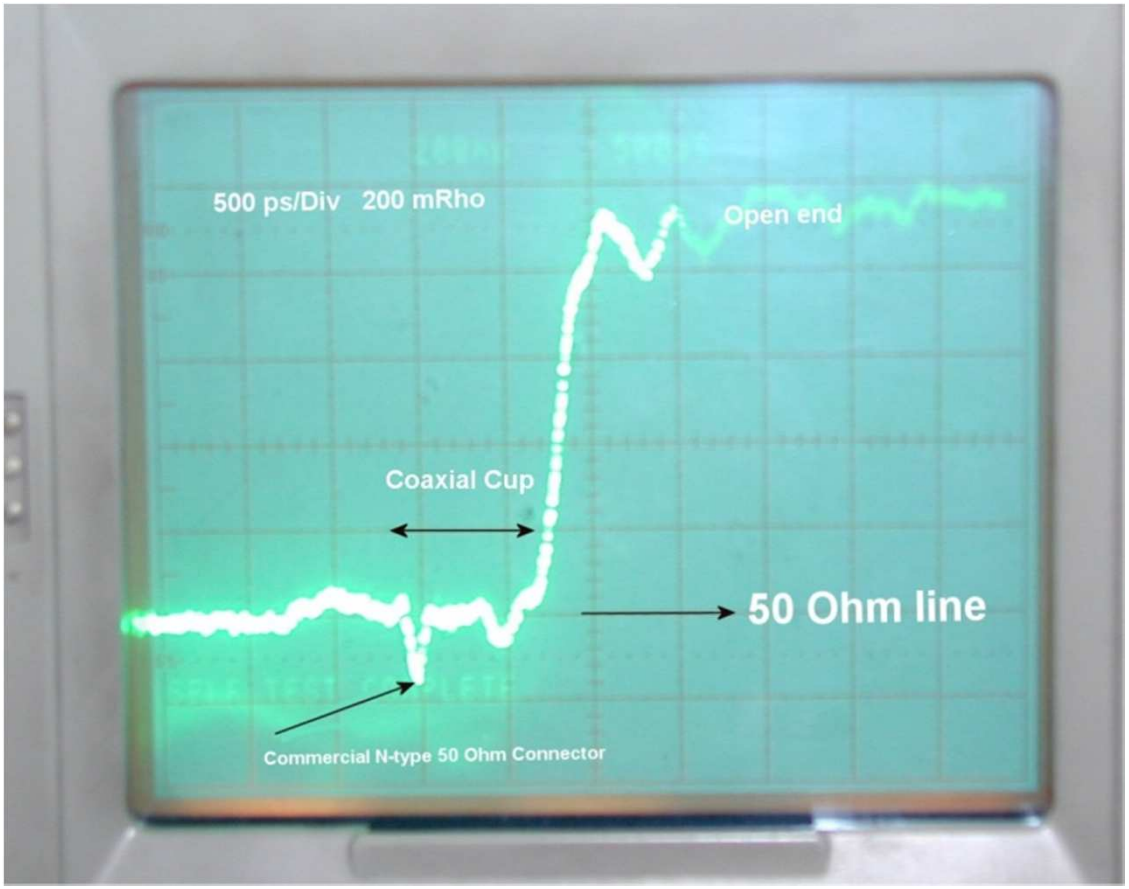
Maximum Beam Power: 10 kW (DC)



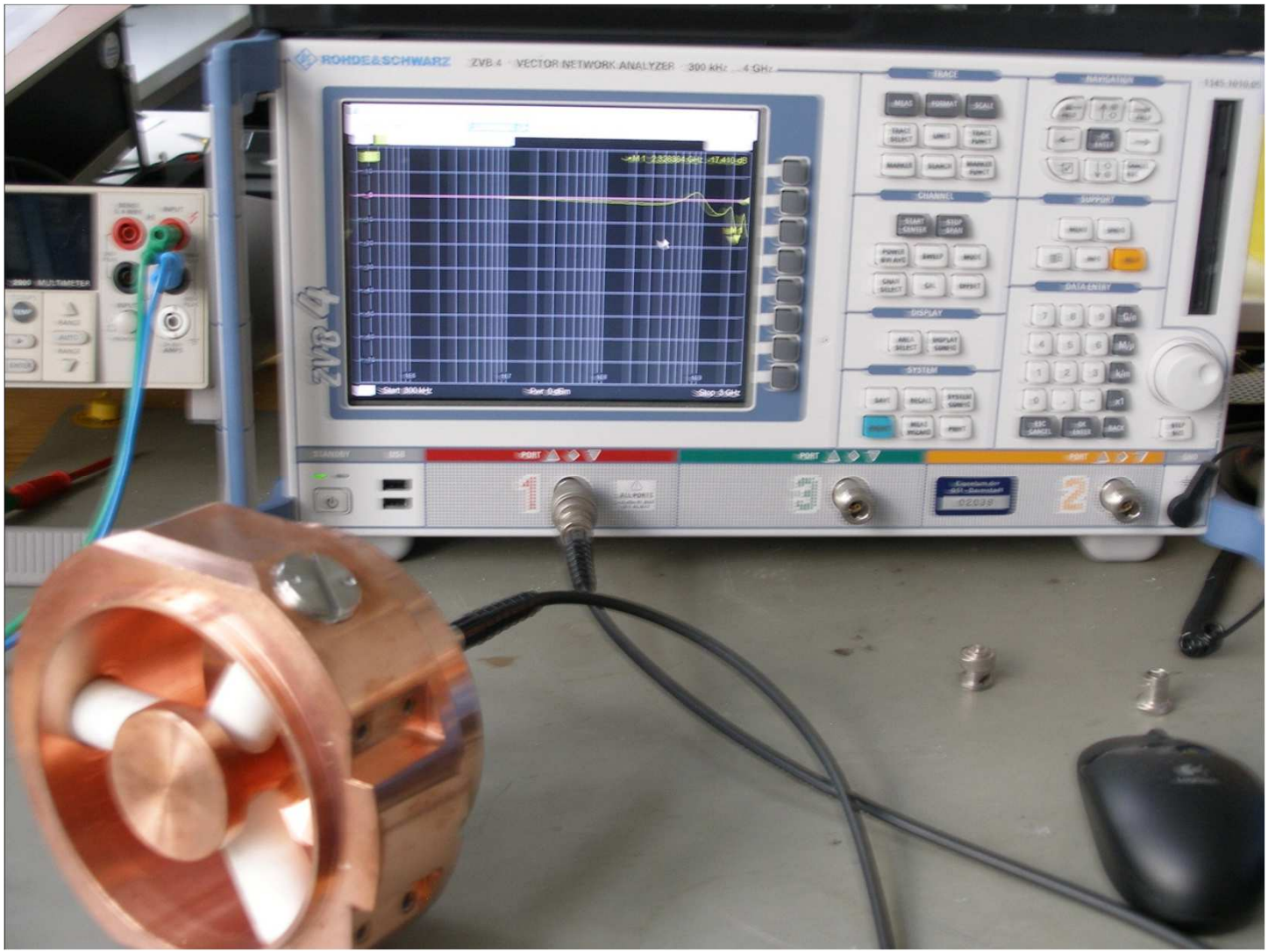


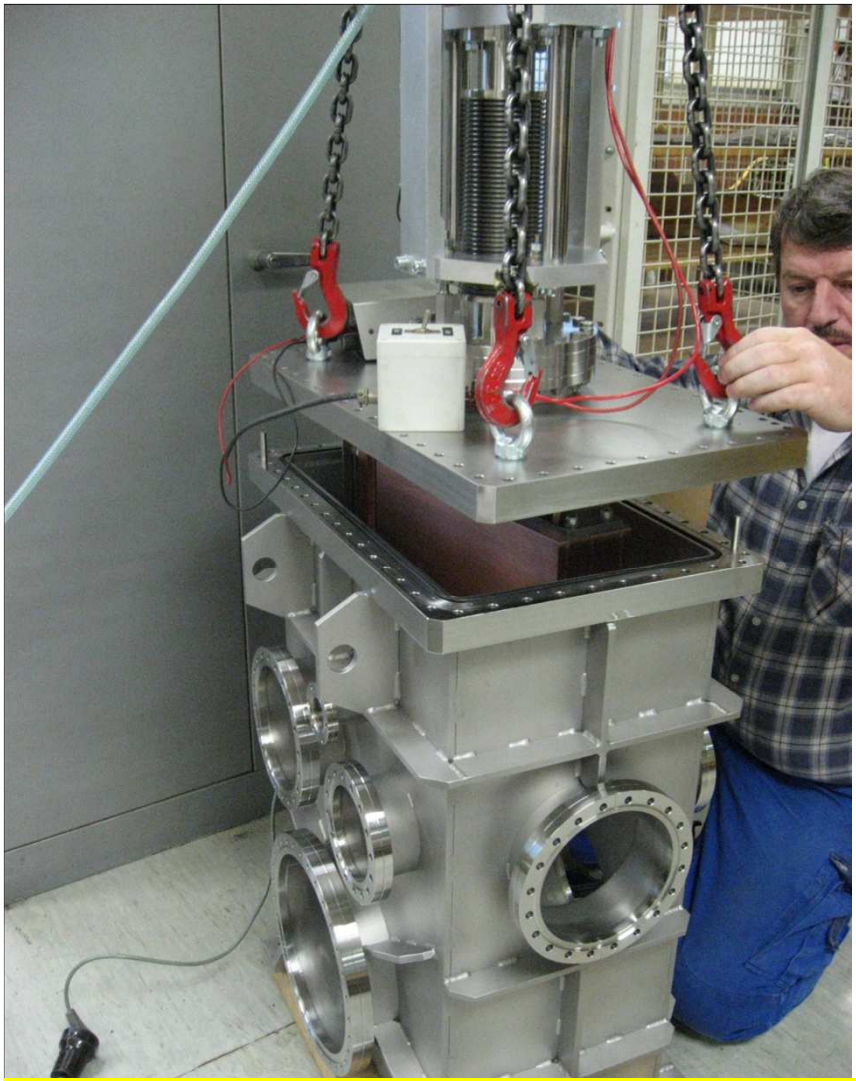
Coaxial Faraday Cup FC 62

TDR – Impedance measurement on the coaxial Faraday cup with 25 ps pulse rise time. Corresponds to a bandwidth of 14 GHz



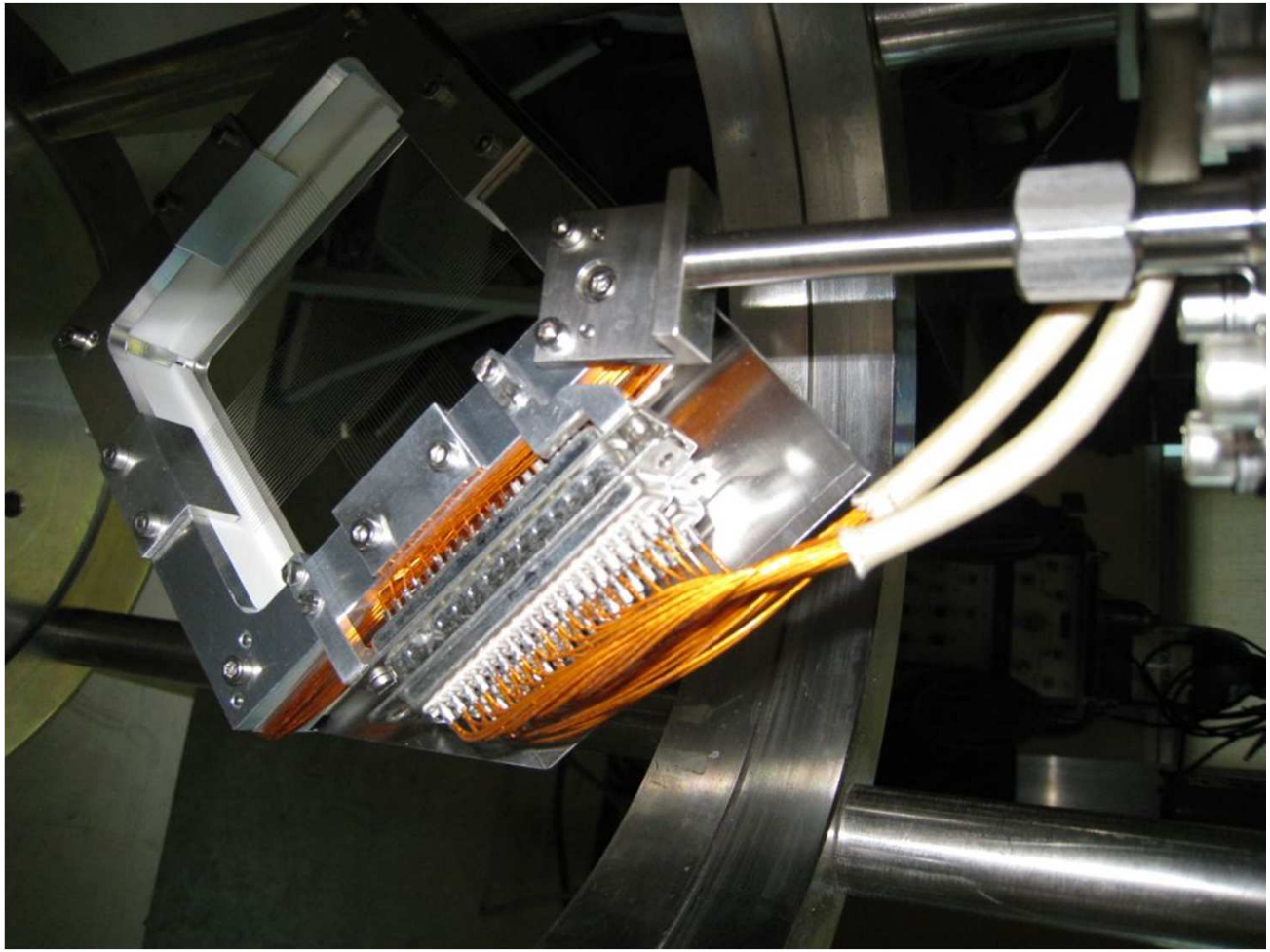
Testing a large coaxial Faraday cup with a spectrum analyzer





FC for high intense beams: 120 keV Protons, 25 kW DC

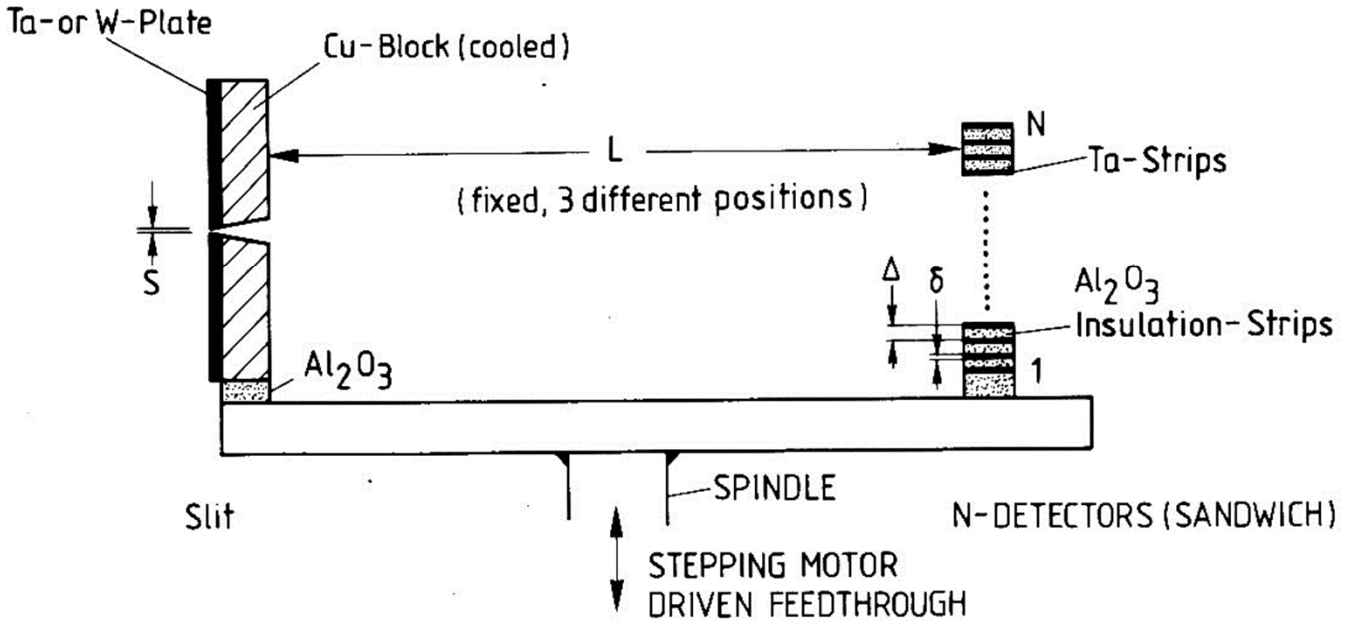
Emittance measuring system based on a stepping motor driven crossed slit and a profile grid (see next foil). Both units mounted onto a 45 degree Port.



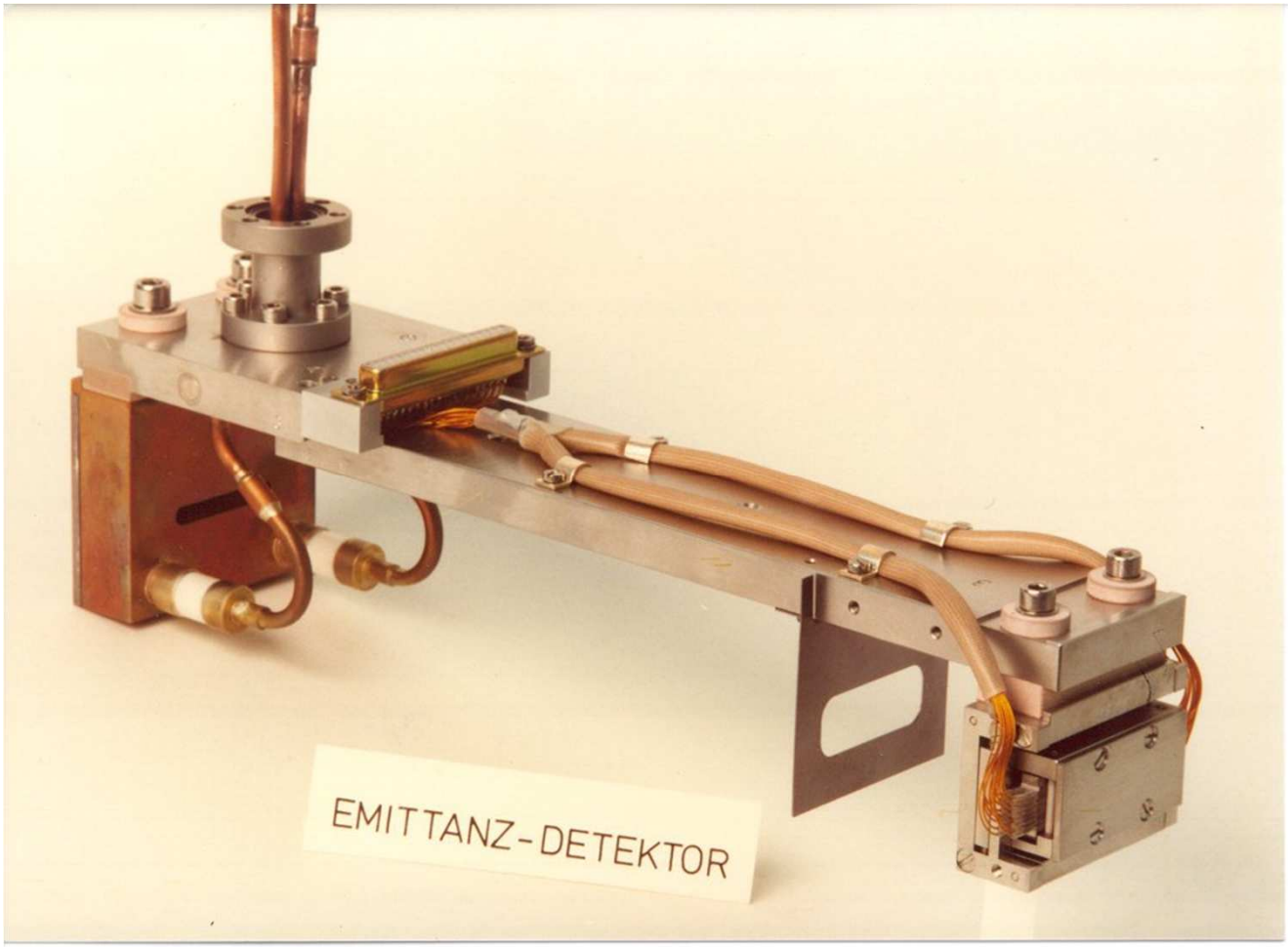
Profile grid mounted onto a 45 degree port, provided for emittance Measuring. The grid is driven through the beam by a stepping motor

Another Scheme of an Emittance Measuring Device

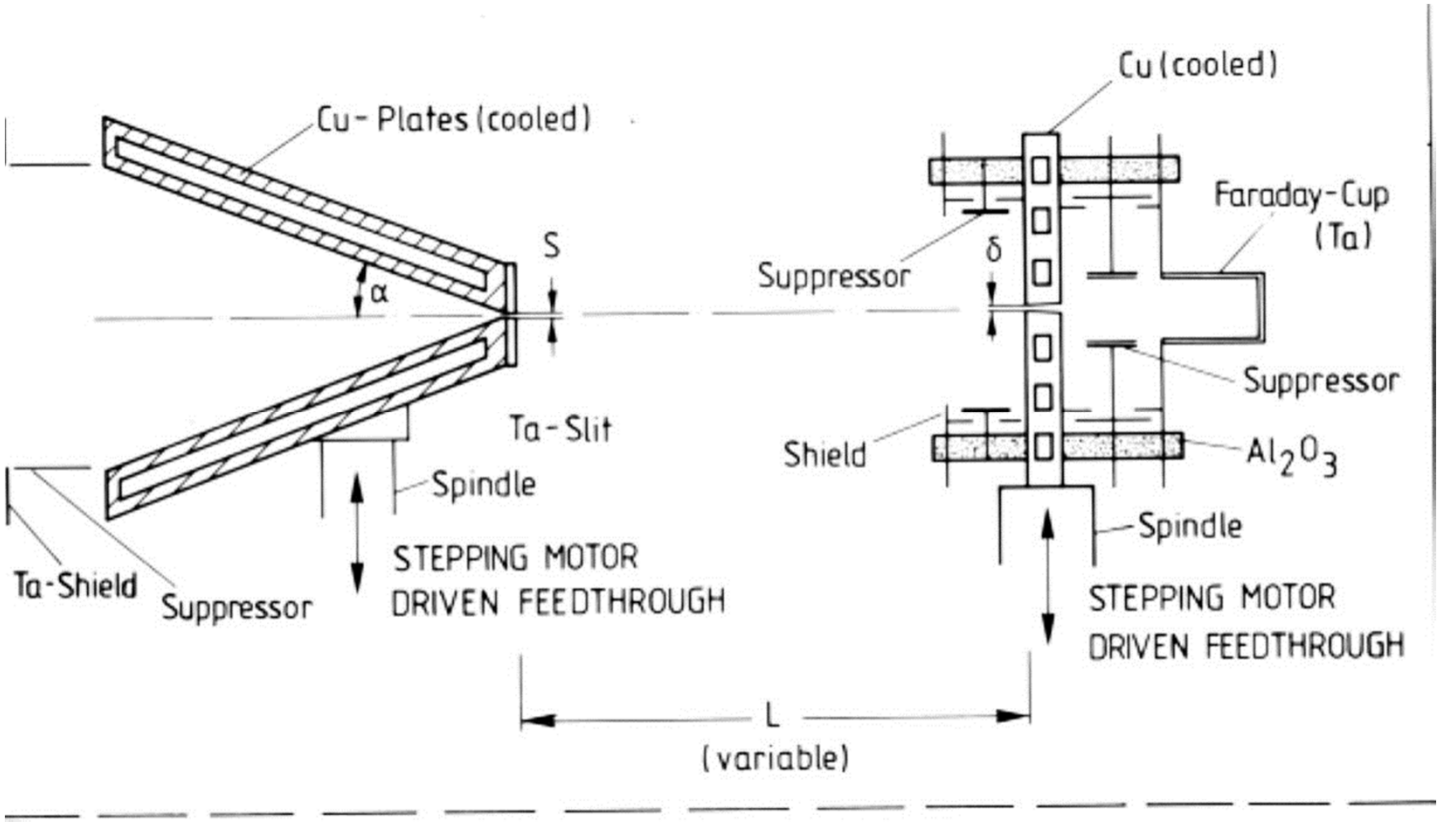
Slit with detector sandwich mounted on one stepping motor driven bar



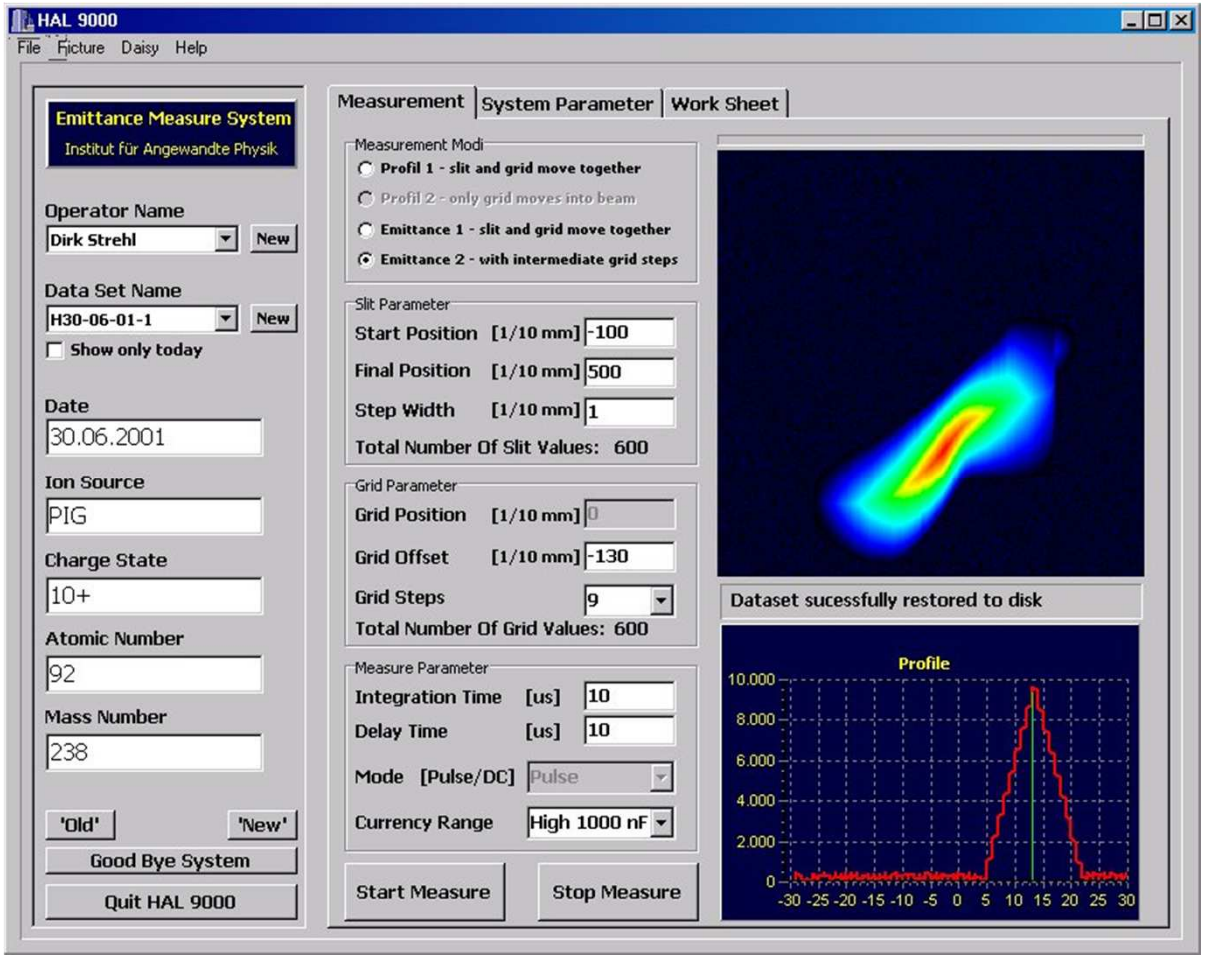
Slit-Sandwich Detector



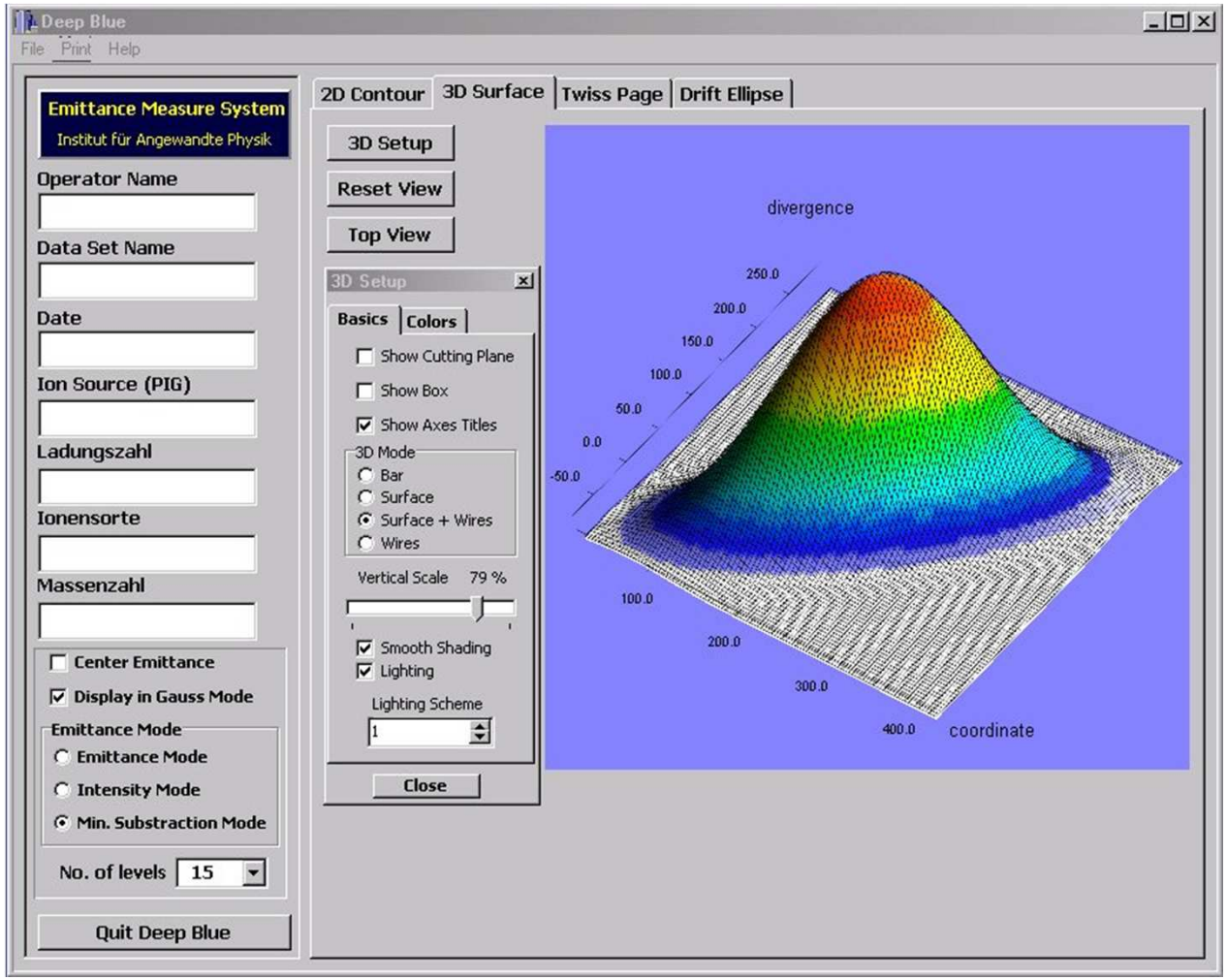
Scheme of Emittance measuring system, provided for intense beams



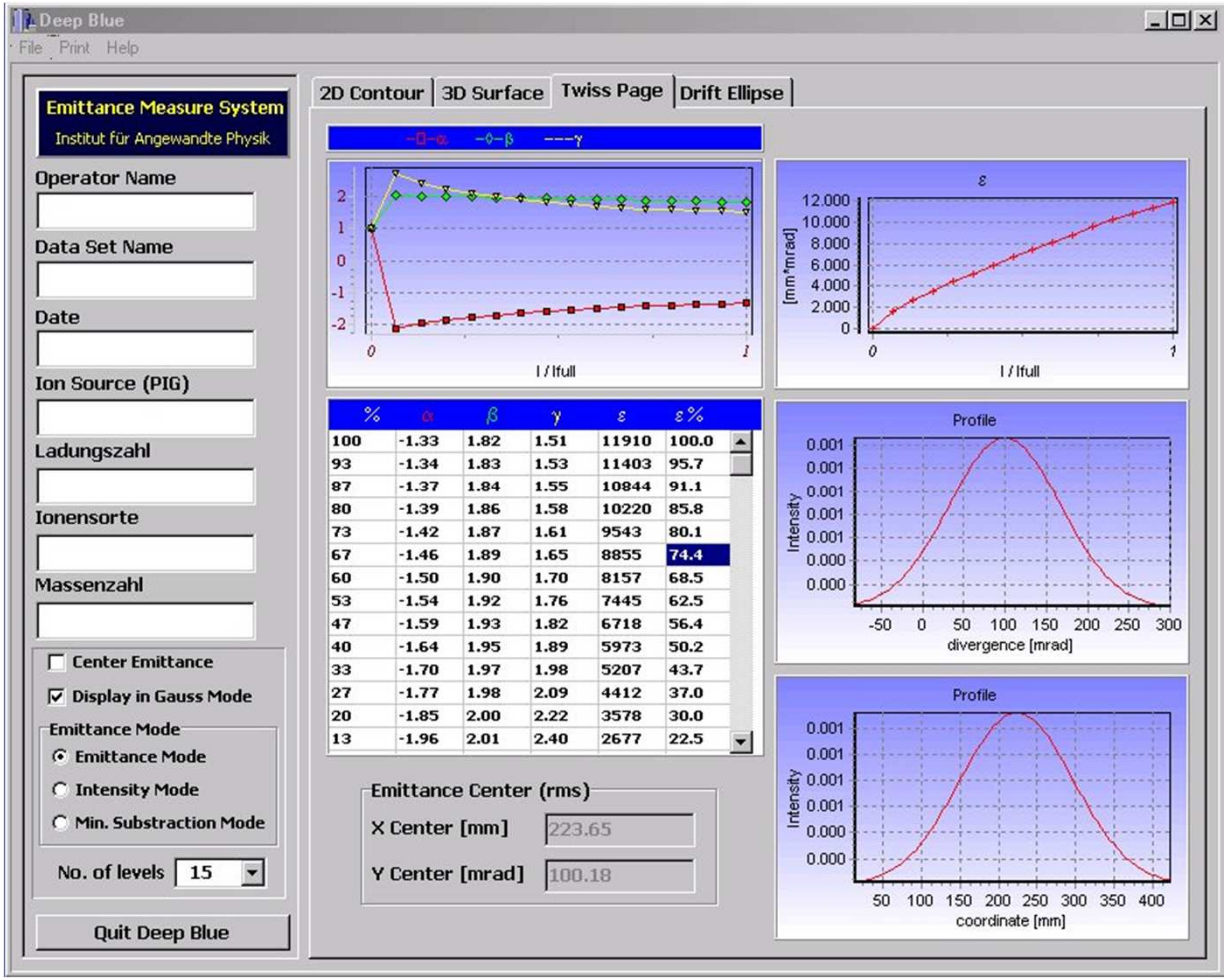
PC-Menu for Setup of an Emittance measuring System



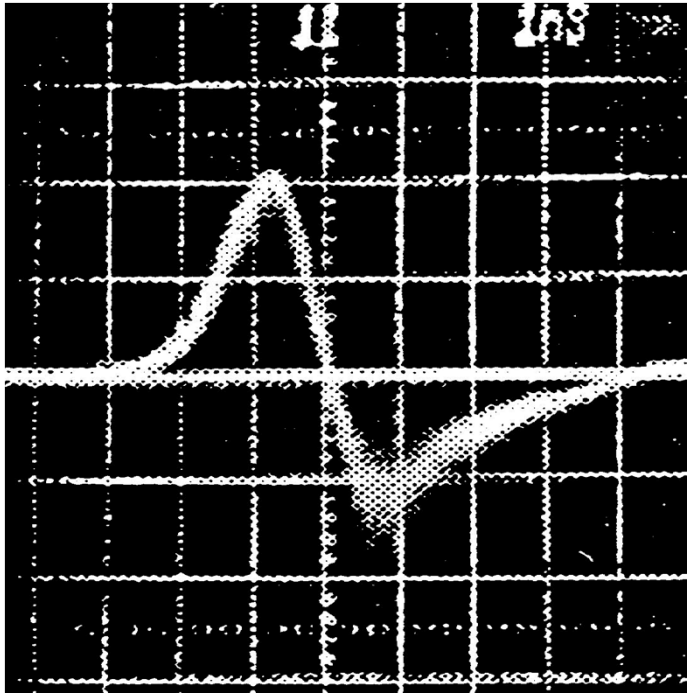
3D Presentation of Emittance Data



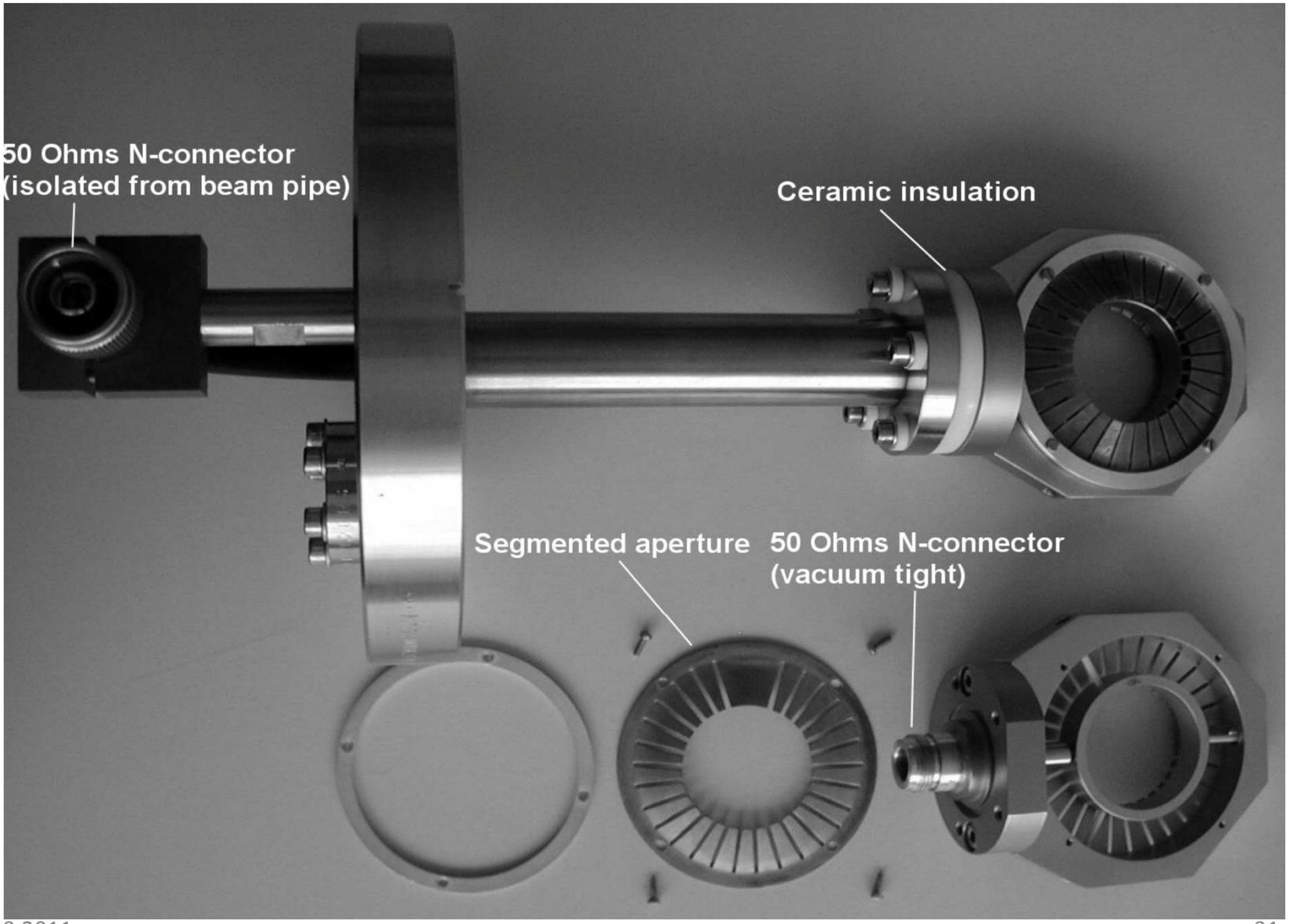
Evaluation of Twiss Parameters



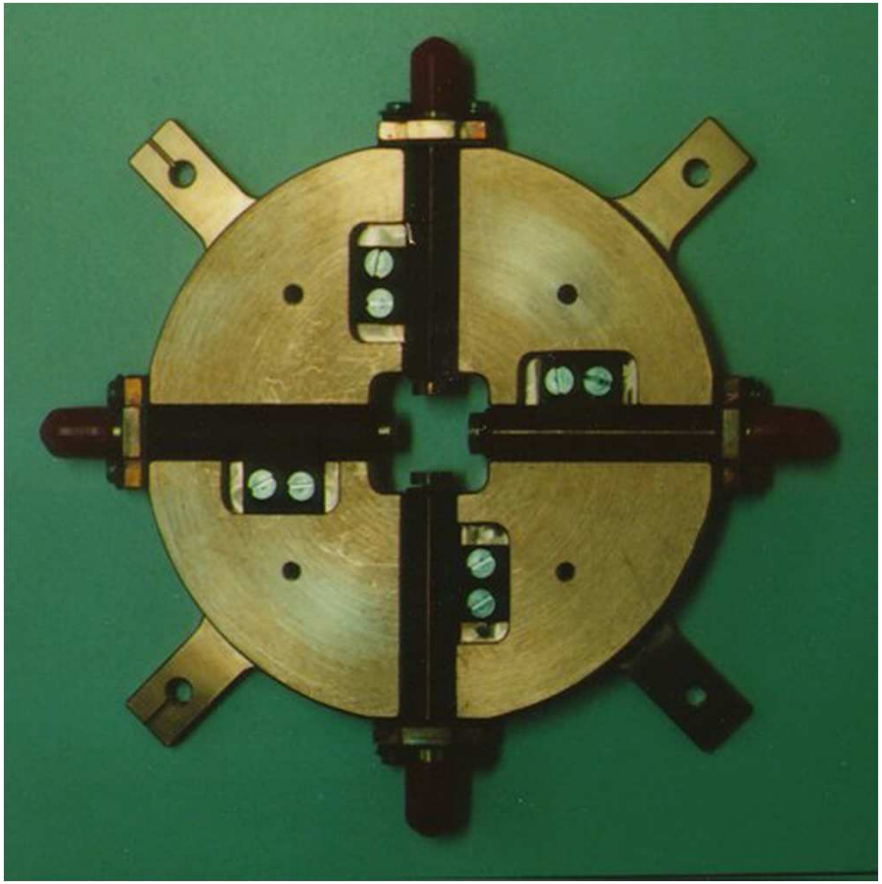
Capacitive Pick-up DB 040 Provided for Measurements in the Longitudinal Phase Space

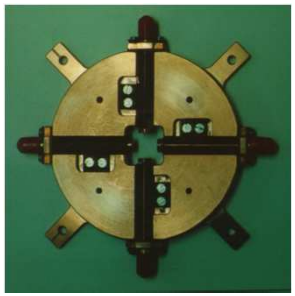


Impedance →50 Ohms, Bandwidth →2 GHz Aperture 35 mm (Standard, other possible)


50 Ohms N-connector
(isolated from beam pipe)
Ceramic insulation
Segmented aperture
50 Ohms N-connector
(vacuum tight)

PET - Broadband Pick-up PS 04 provided for Measurement of Bunch Shape, Time of Flight (TOF), Beam Position.





- Principle:	capacitive
- Impedance:	50 Ohms
- Bandwidth:	ca. 2 GHz
- Electrodes:	4 (disk-shape)
- Diameter:	7 mm
- Aperture:	12 mm
- Sum signal:	ca. 20-40 pA/e
- Difference signal:	ca. 3-5 pA/e
- Connector:	SMA-coax
- Material (housing)	Copper
- Insulation:	Vespel

Capacitive pick up

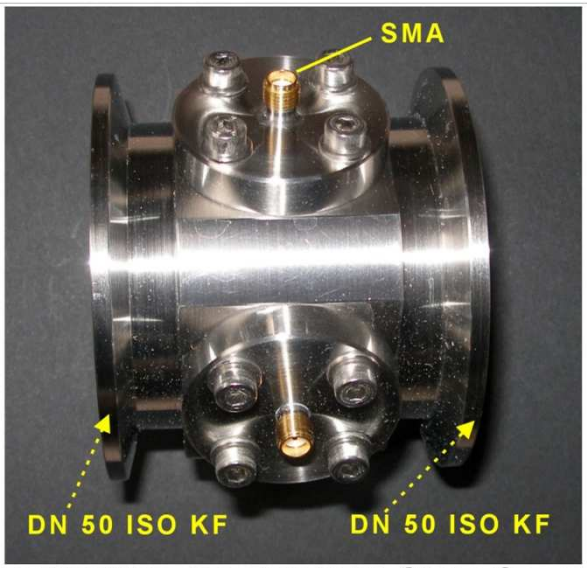
DB 520/550/590

Insertion length [mm]	100
Electrode length [mm]	20
Aperture [mm]	50 /60
Flange system	CF 100
Impedance	50 Ω
Bandwidth	1 GHz
Signal processing *	$2x\Sigma, 2x\Delta$
Σ(216 MHz)*	L+R, U+D
Δ (216 MHz)*	L-R, U-D

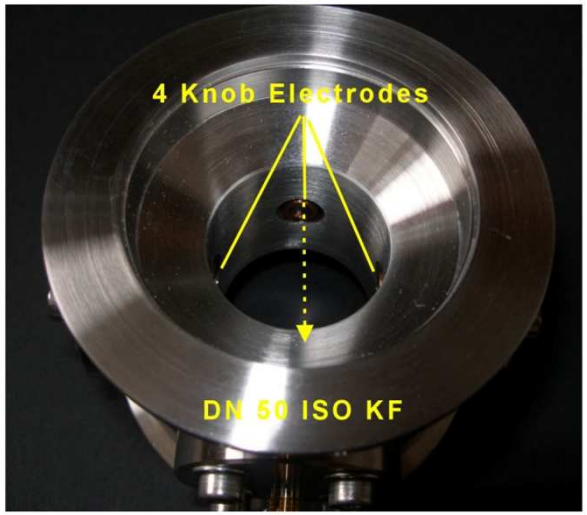
Example:
Required charges per Bunch
S:N = 1:1, 1 mm Displacement

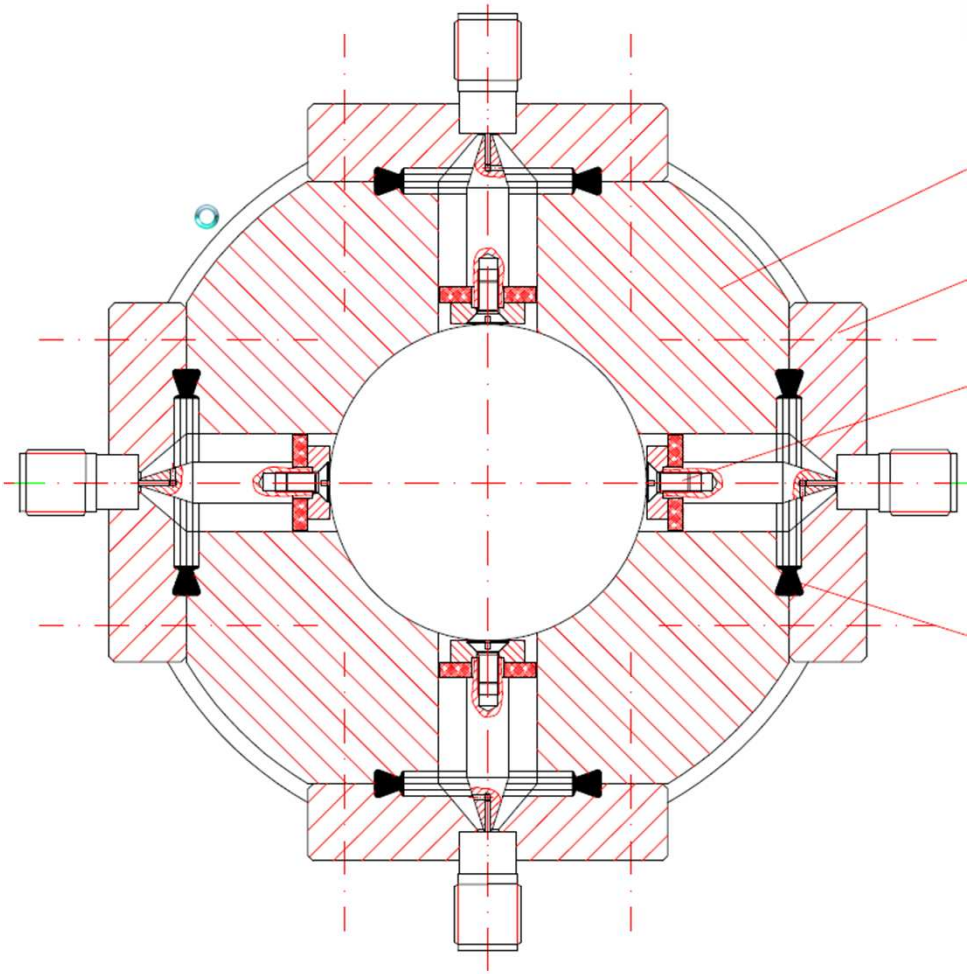
Δt (ns)	$\beta = v/c$ [%]	required charges
1	1.6 (RFQ)	$2 \cdot 10^7$
1	4 (IH1)	$4 \cdot 10^6$
1	5.5 (IH2)	$2.5 \cdot 10^6$
0.5	5.5 (IH2)	$2 \cdot 10^6$
1.5	5.5 (IH2)	$3 \cdot 10^6$

Beam Diagnostics

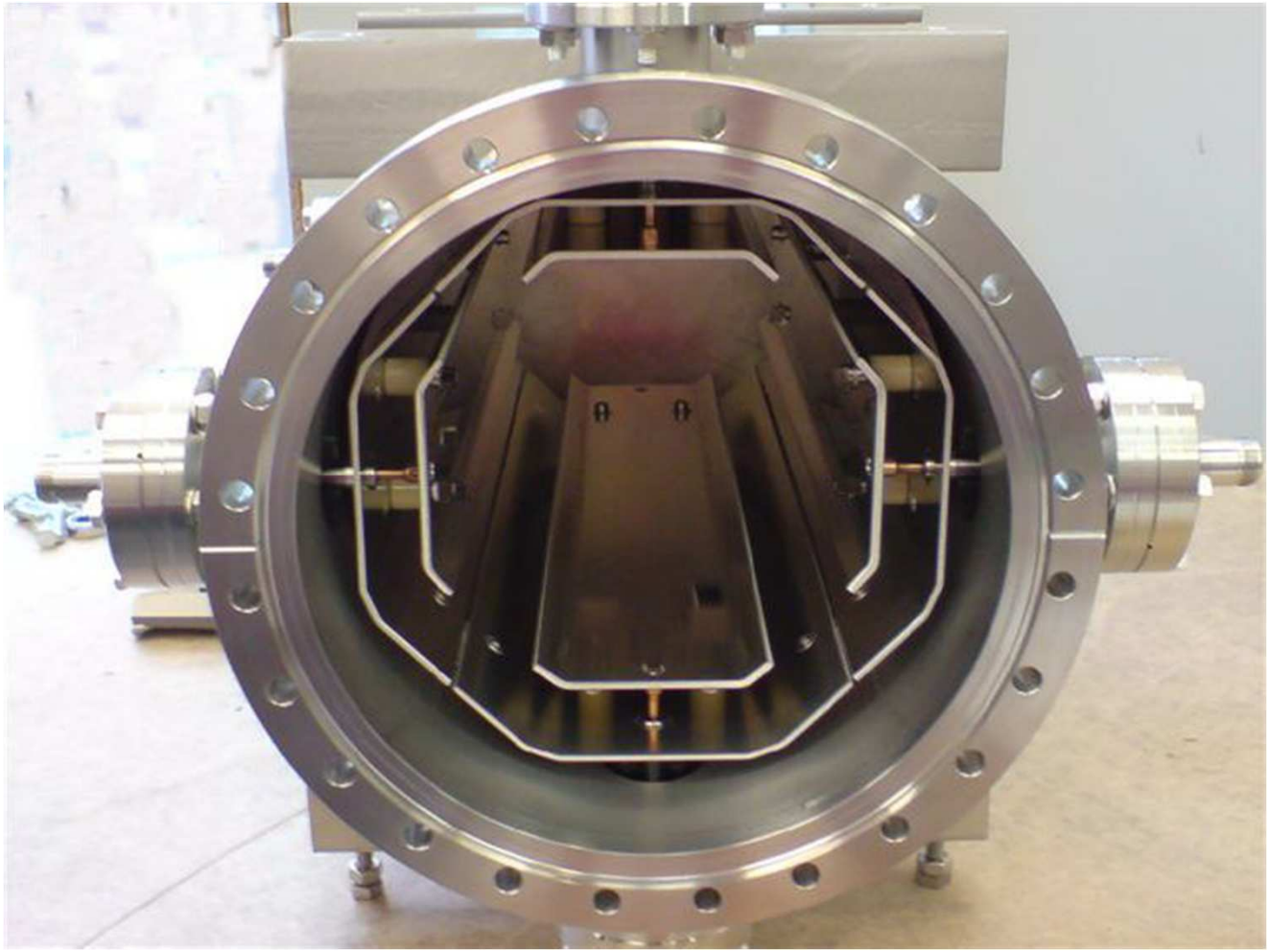


Beam Position Monitor in 50 Ohms Geometry

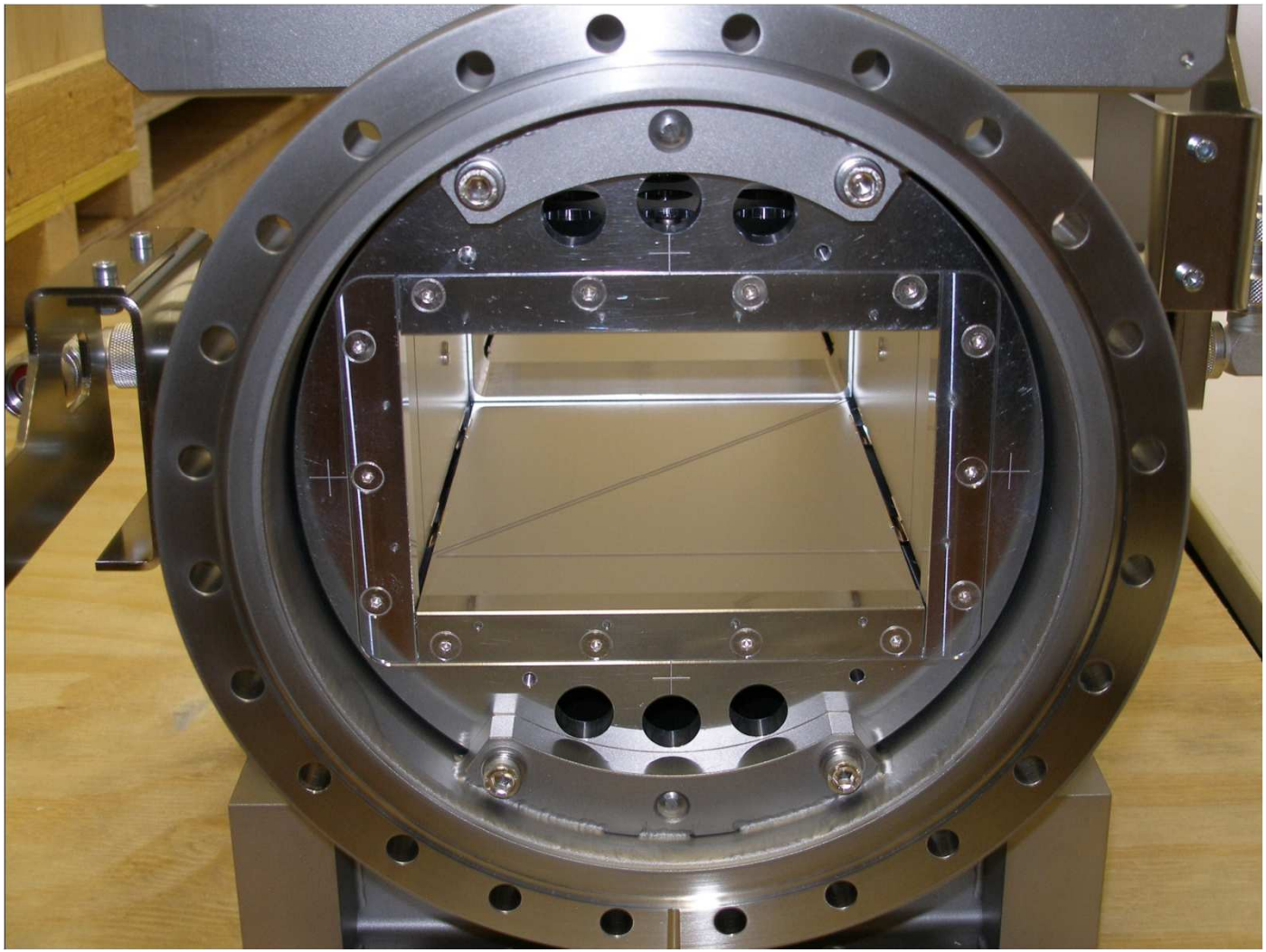




50 Ohms Pick up System Provided for Schottky, BTF and K-Modulation in Synchrotrons



Beam Positions Monitor (BPM) for Synchrotrons



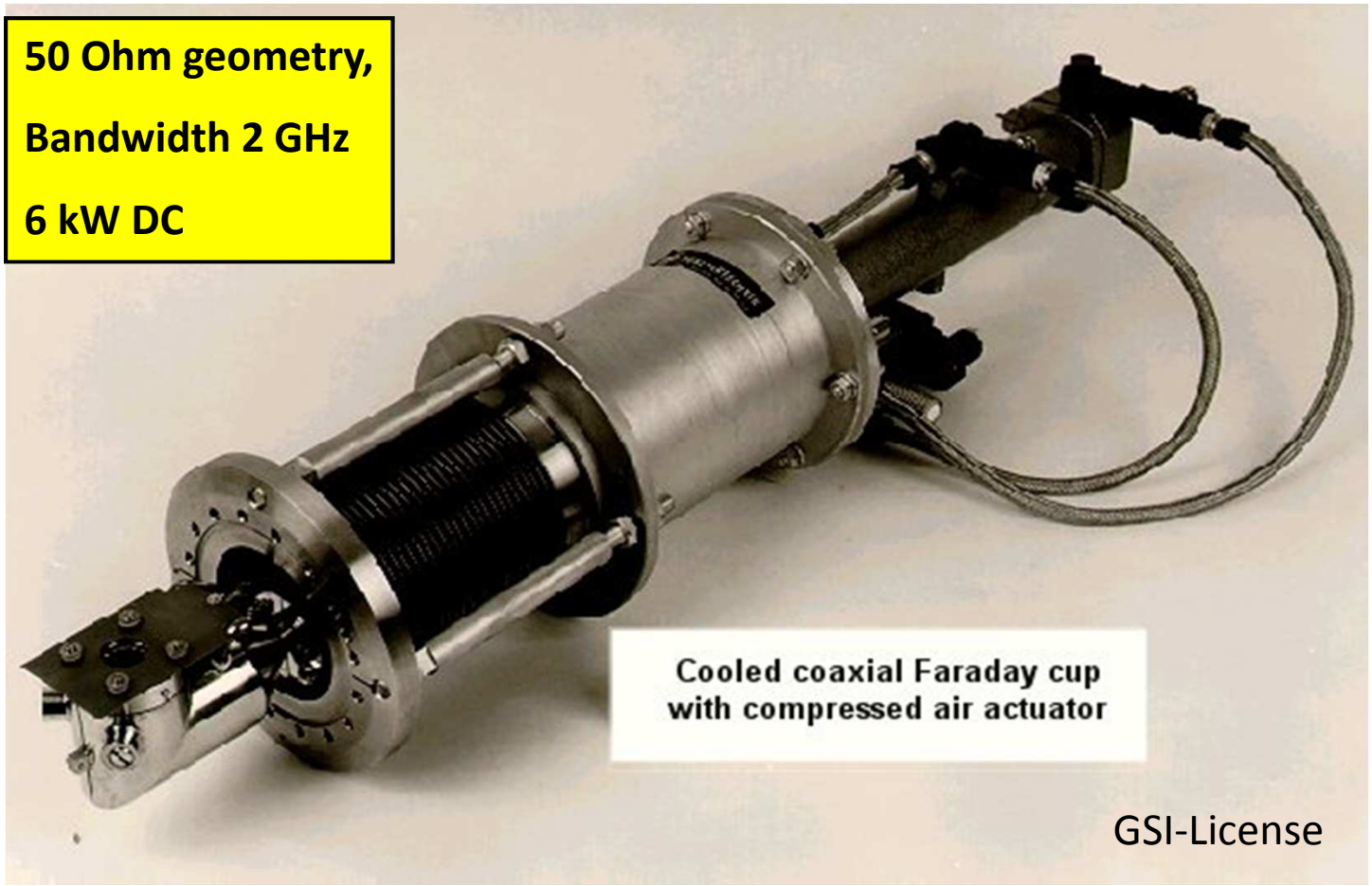
Set of Beam Positions Monitors (BPM) for Synchrotrons

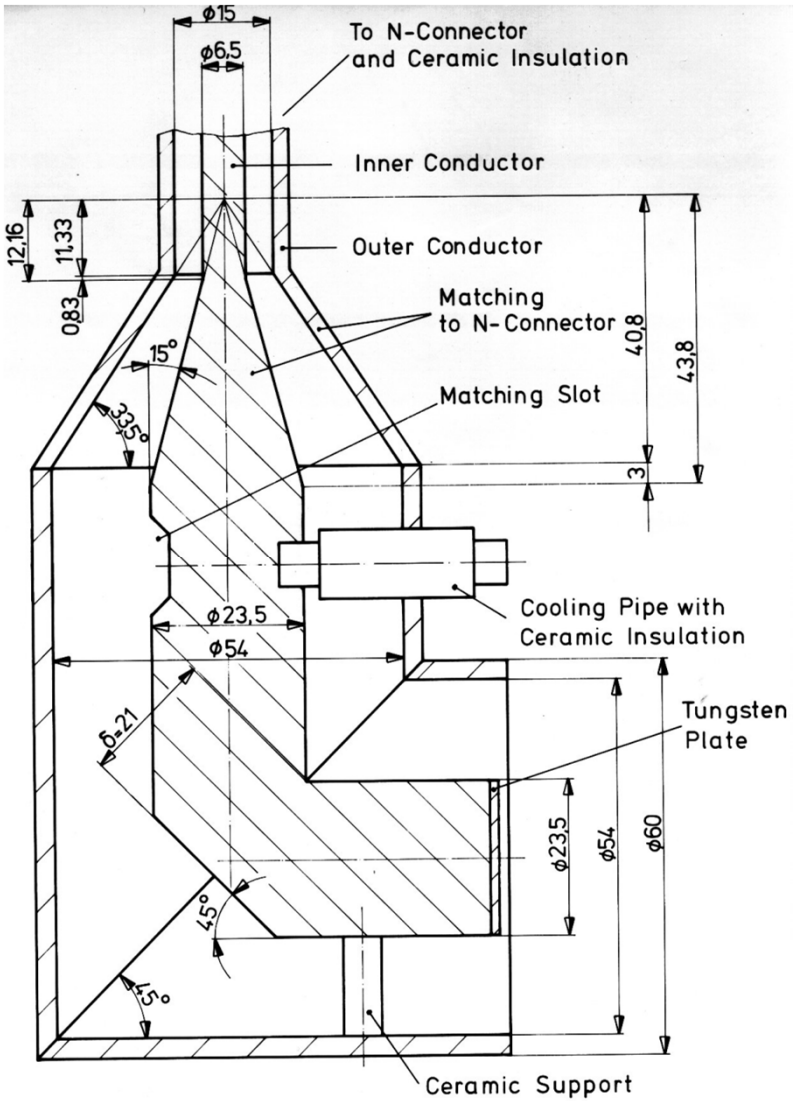
Cooled Faraday Cup DF 040 with Compressed Air Actuator

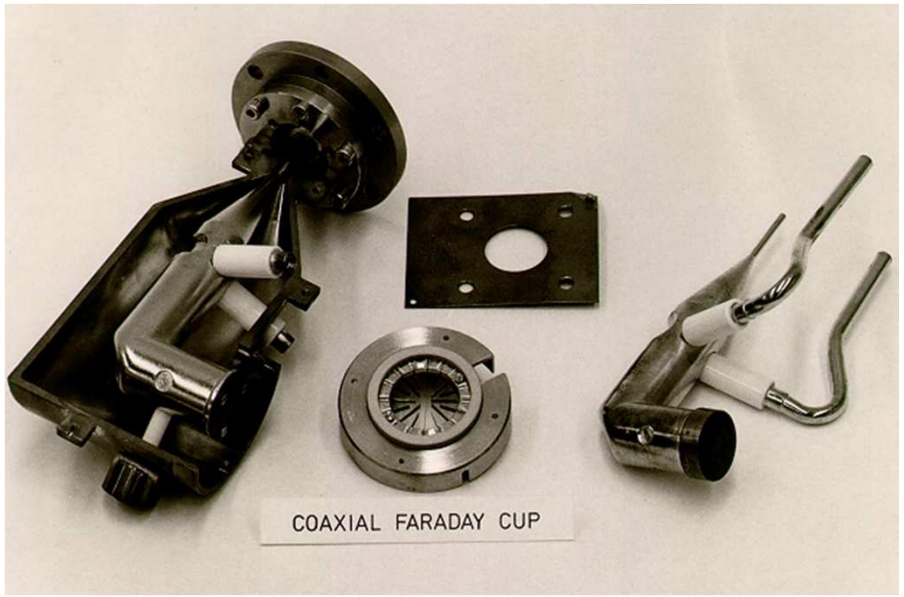
50 Ohm geometry,

Bandwidth 2 GHz

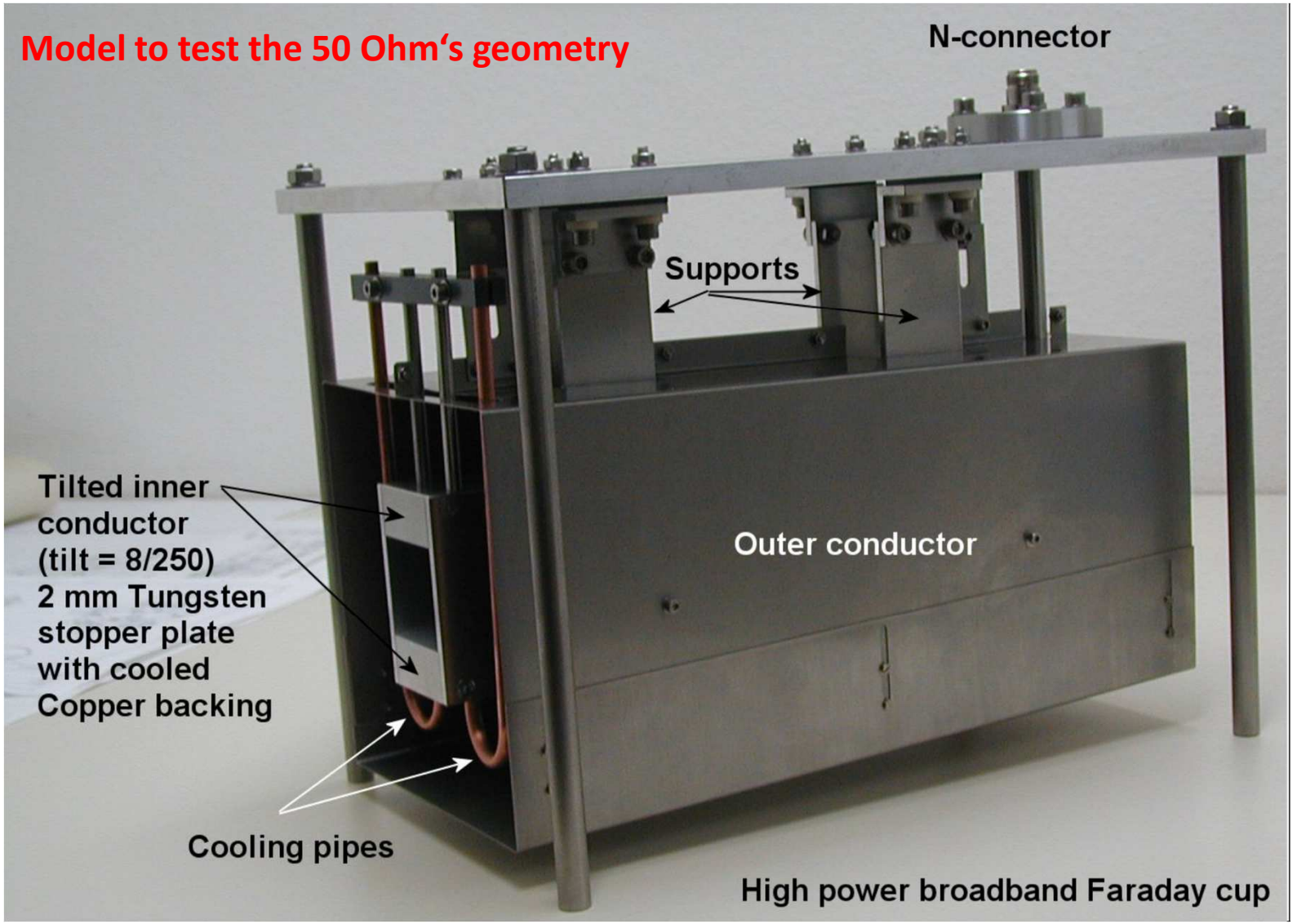
6 kW DC







The grid is provided to suppress secondary electrons as well as the advanced longitudinal field of the bunches


Model to test the 50 Ohm‘s geometry
N-connector
Supports
Tilted inner conductor (tilt = 8/250) 2 mm Tungsten stopper plate with cooled Copper backing
Outer conductor
Cooling pipes
High power broadband Faraday cup

Large Profile Grid
with compressed Air Actuator

Actuator:

Stroke: 200 mm

Membrane bellow

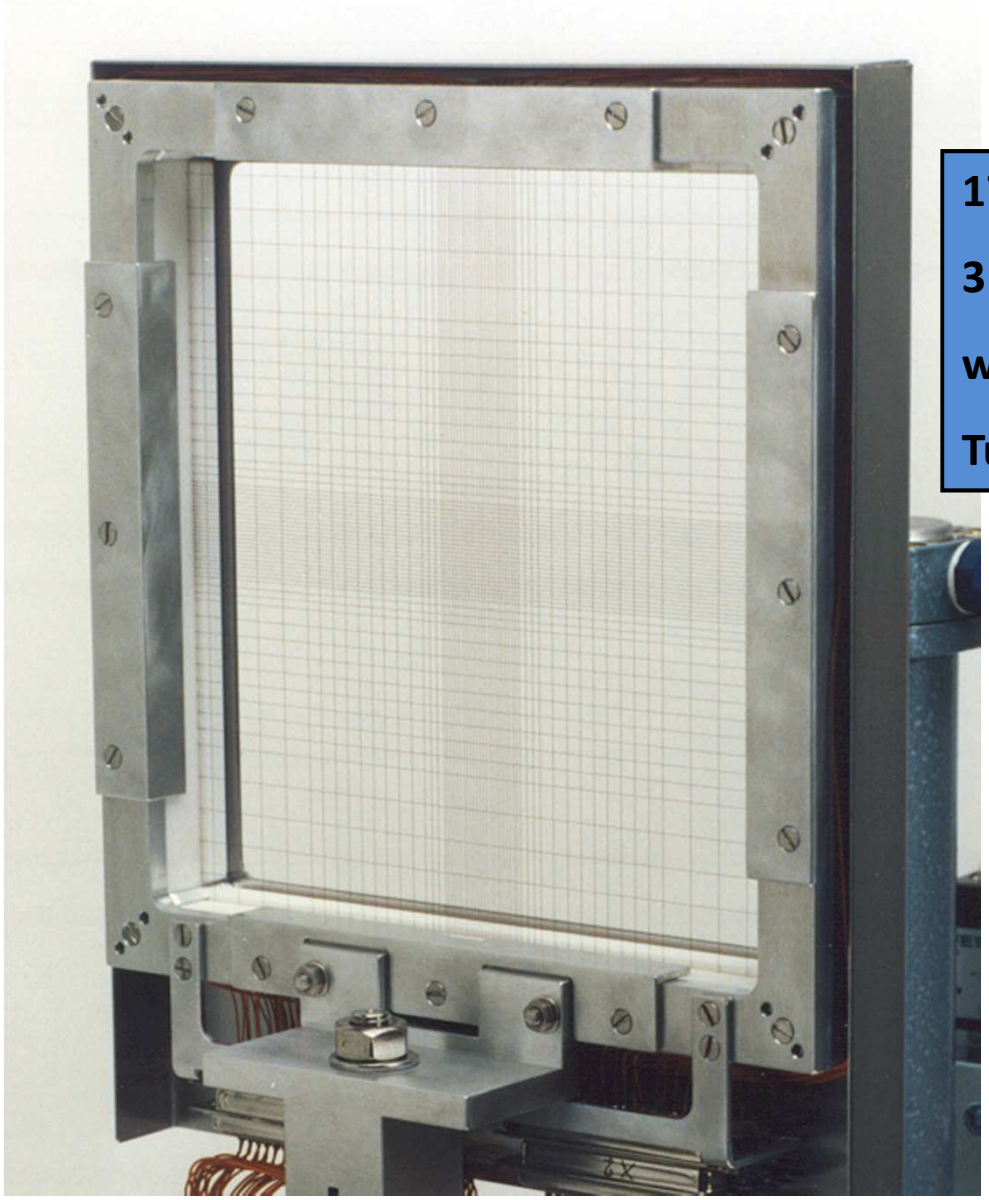
DN CF 250

Three slide bars,

sliding bearing,

Limit switches

Adjustable, ...



170 x 170 mm, spacing: 1.5 mm (center),

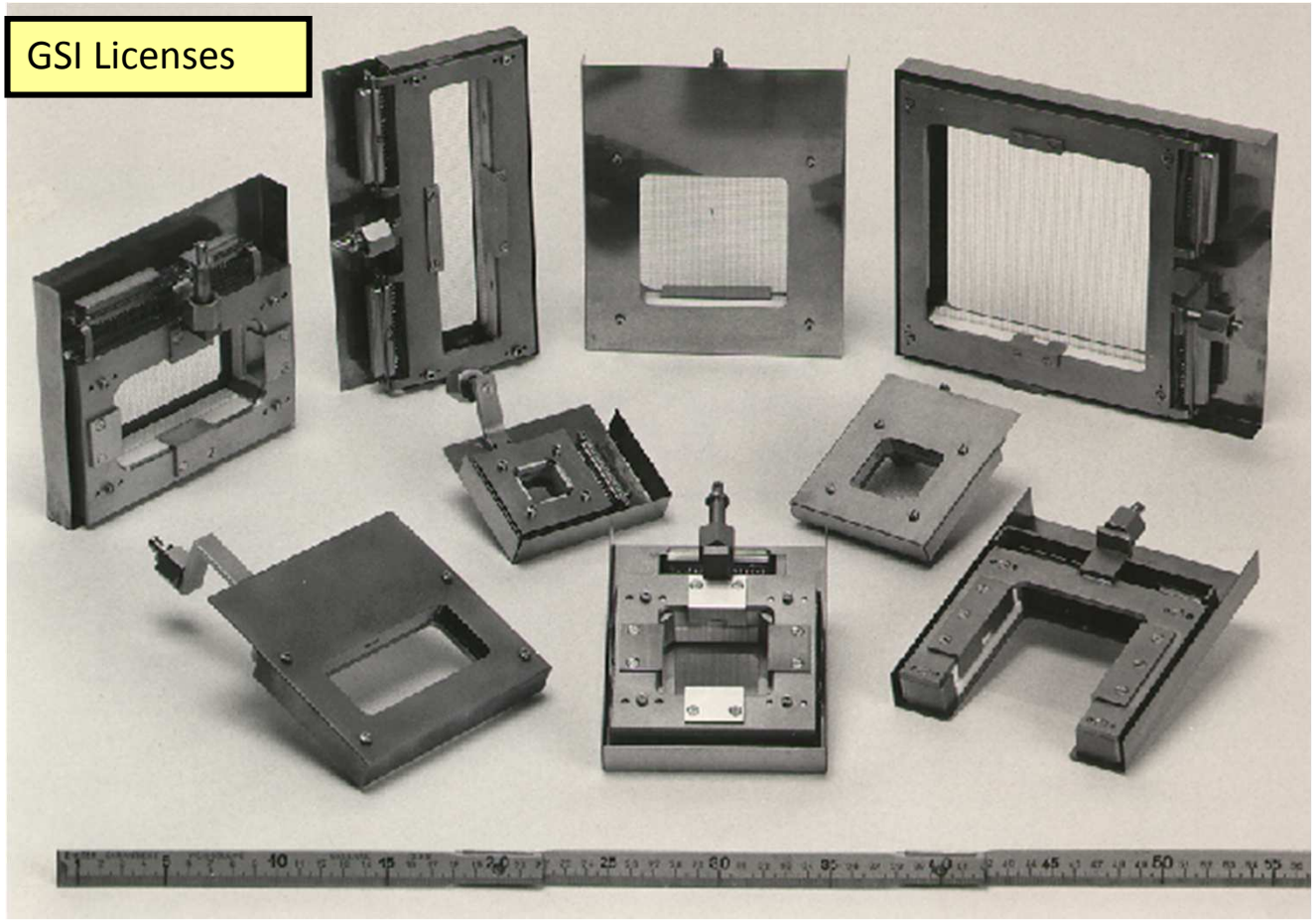
3 mm, 4.5 mm (most outside),

wire diameter 0.1 mm,

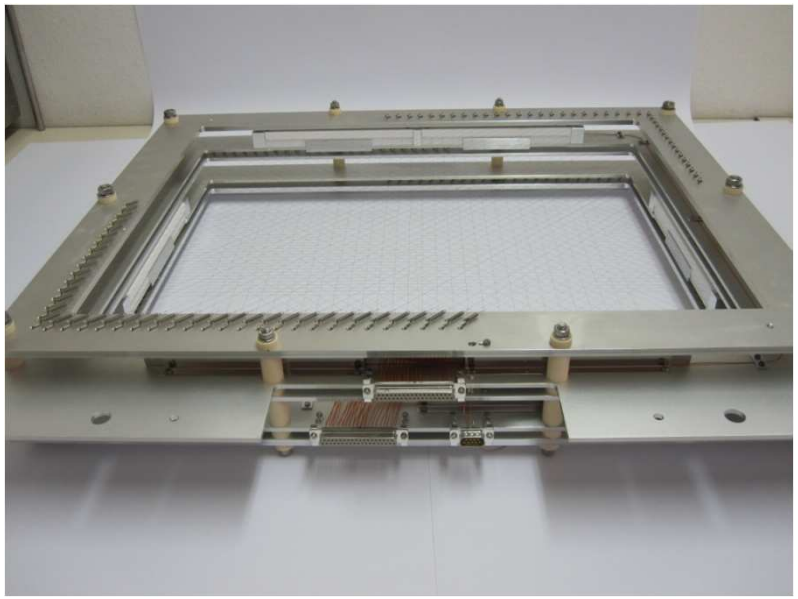
Tungsten-Rhenium wires

Harp provided for Emittance Measurements. The Harp measures the Beam Profile behind a Slit moved through the Beam

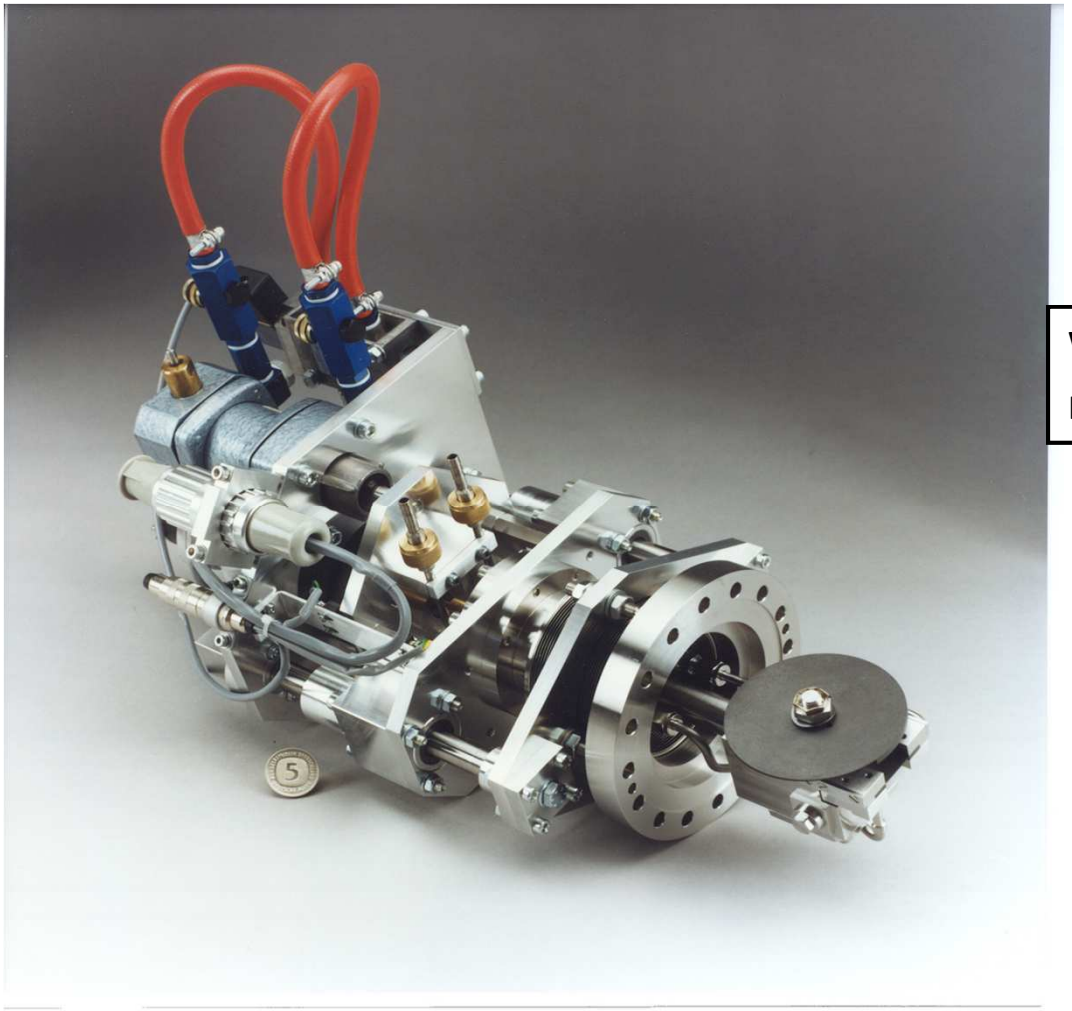
Collection of Profile Grids



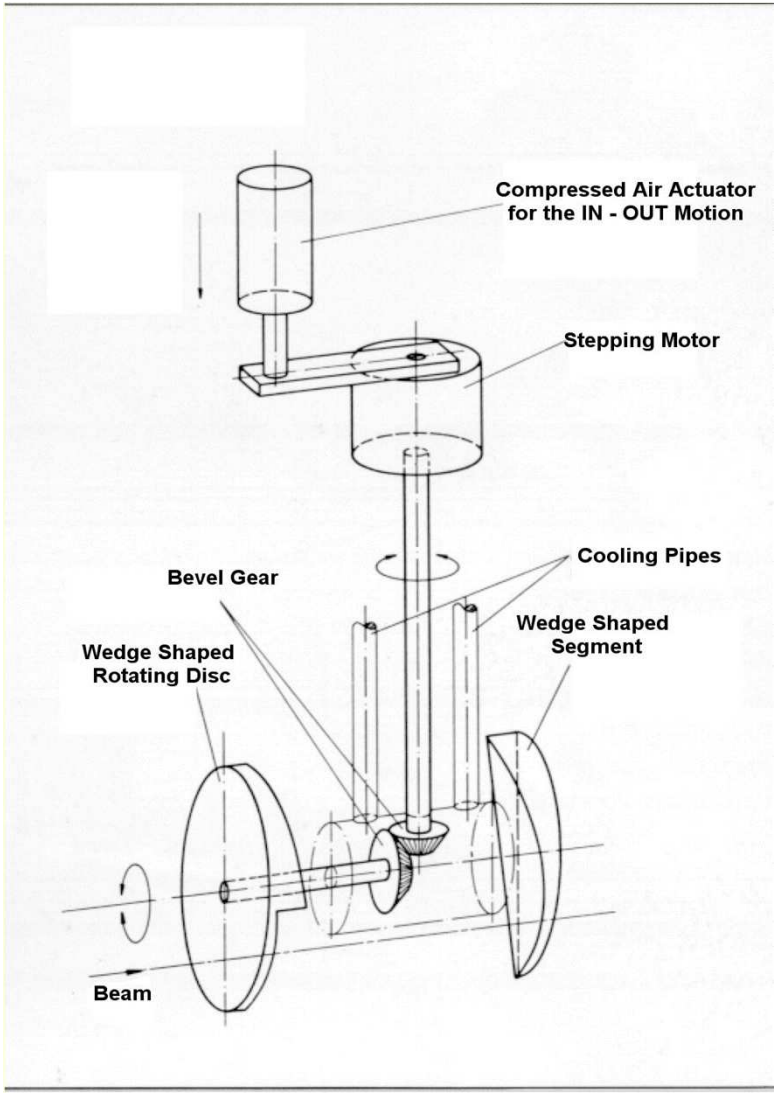
Frames of a 5 Plane Large Profil Grid. Dimension about 480 x 640 mm



NTG – Energy Moderator MD 05



Working principle see next foil



Diameter of the discs: 86 mm

Thickness variation : .24 mm 3.94mm

Material: Graphite

Stroke of the actuator: 50 mm

Minimum step width: 0.72 degrees

Maximum frequency: ca. 5 Hz, wobble mode

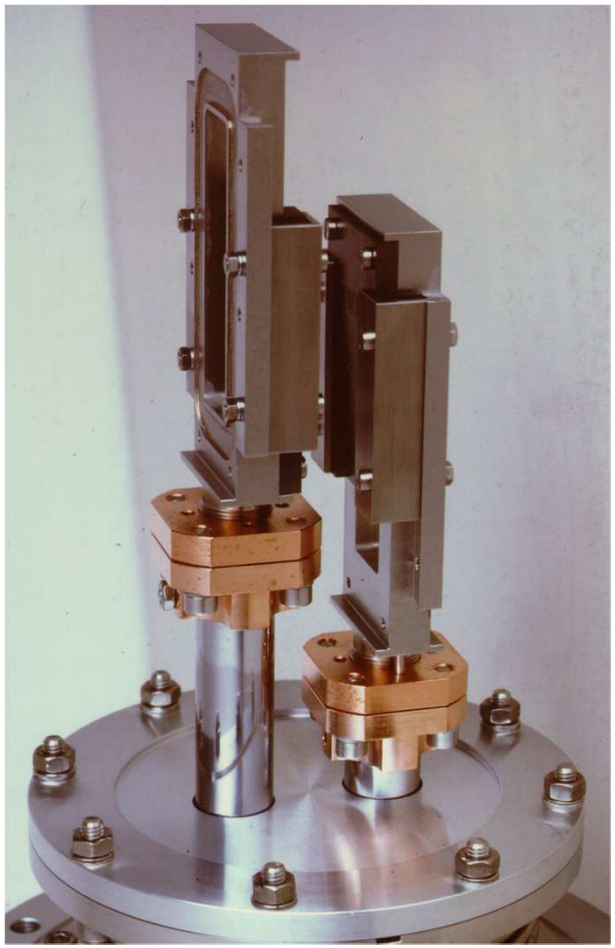
Max. beam power loss: 500 Watts/wedge

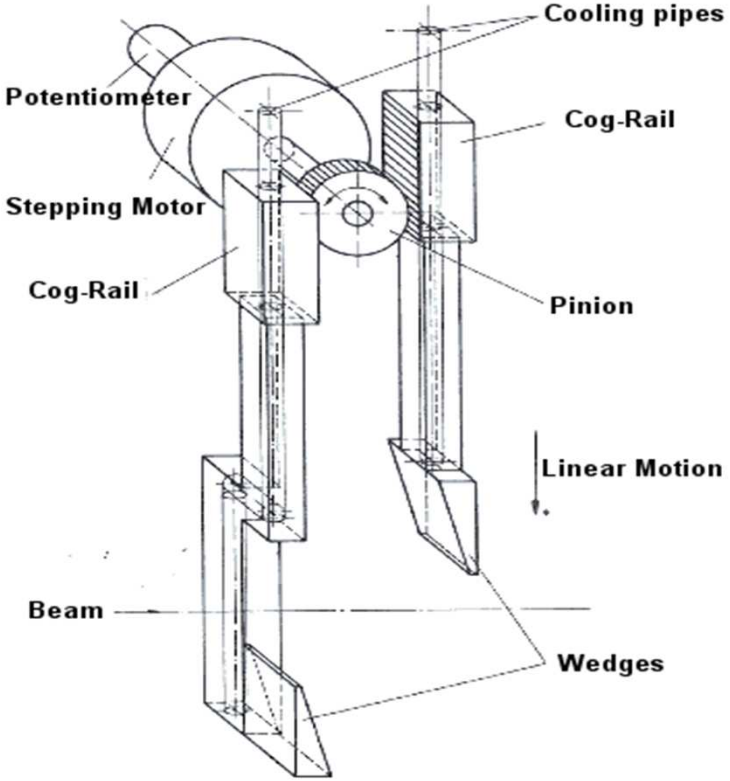
Max. energy range: 39-45 MeV protons

Control PC or microprocessor

Applications → in Material Research

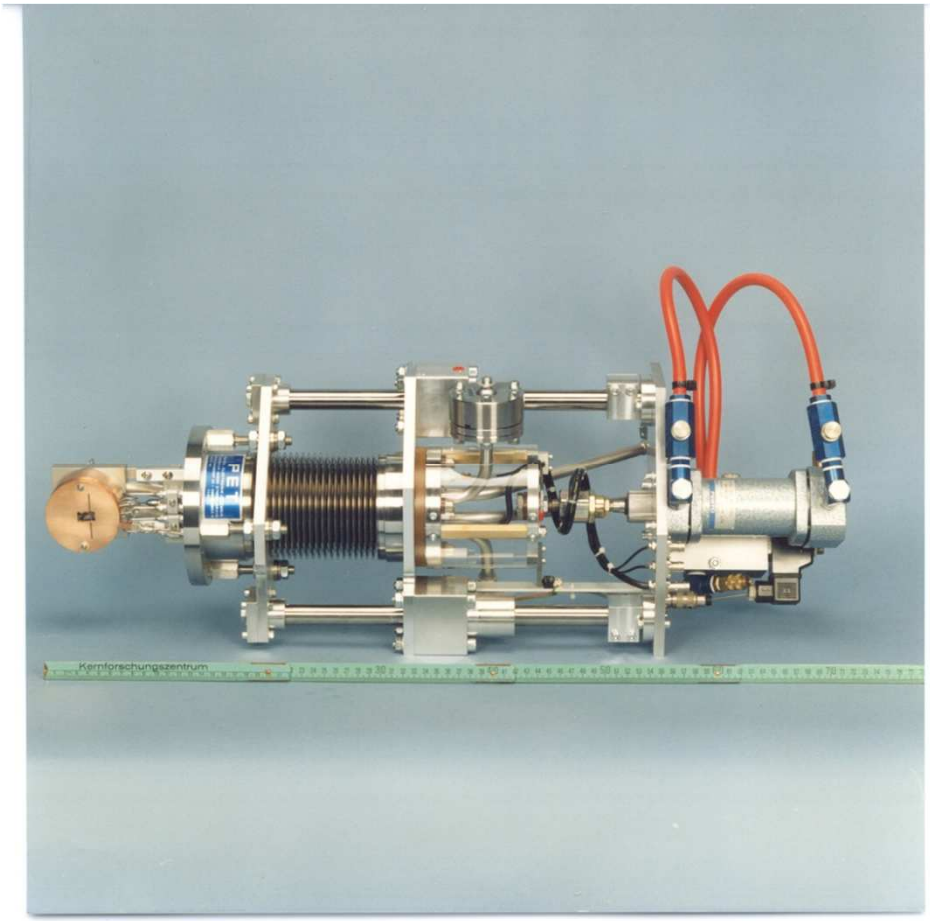
NTG-Energy Moderator MD04





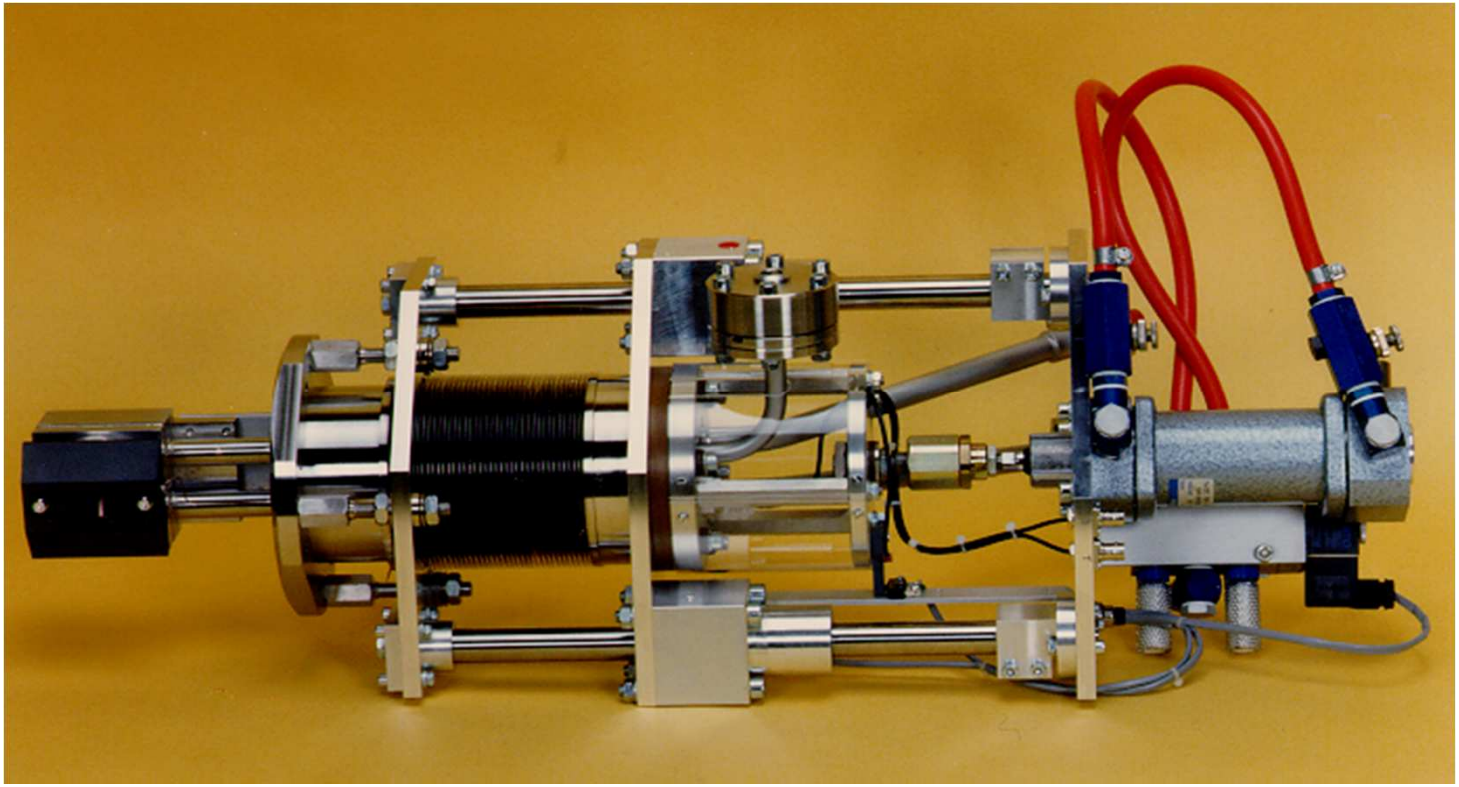
Applications → in Material Research

Irradiation Probe BE 01 with compressed Air Actuator and Probe Heating

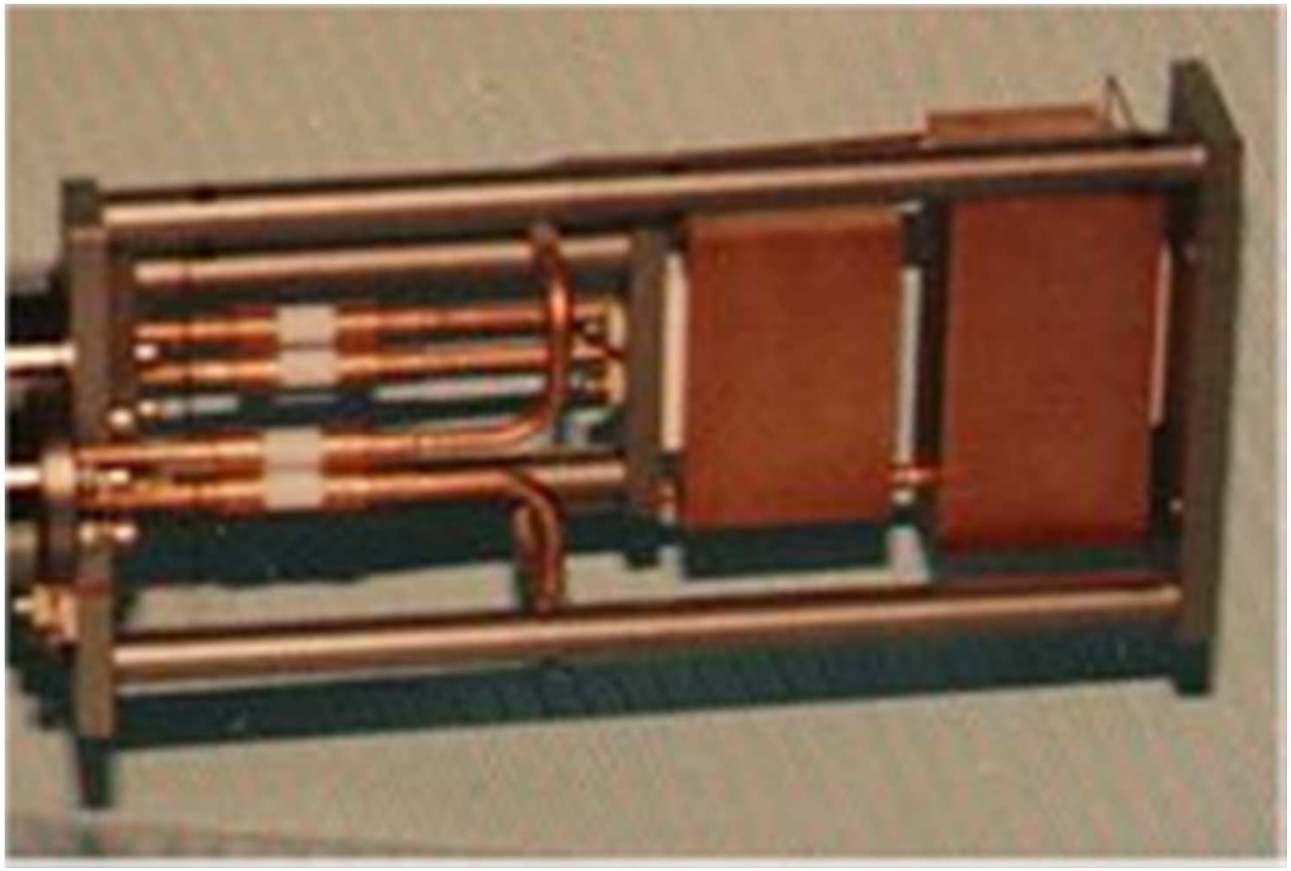


Applications → in Material Research

High Power Aperture (Graphite), mounted onto a compressed Air Actuator

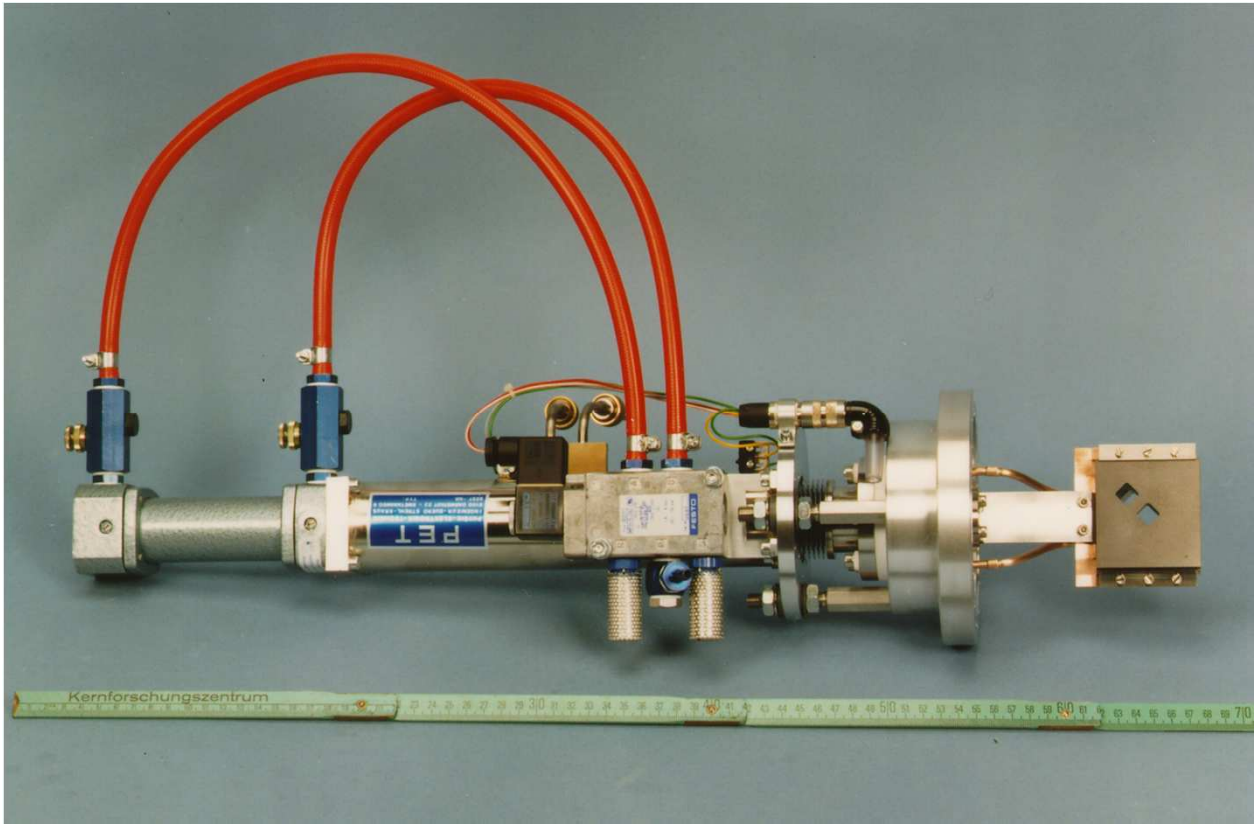


High Current Water Cooled Slit System



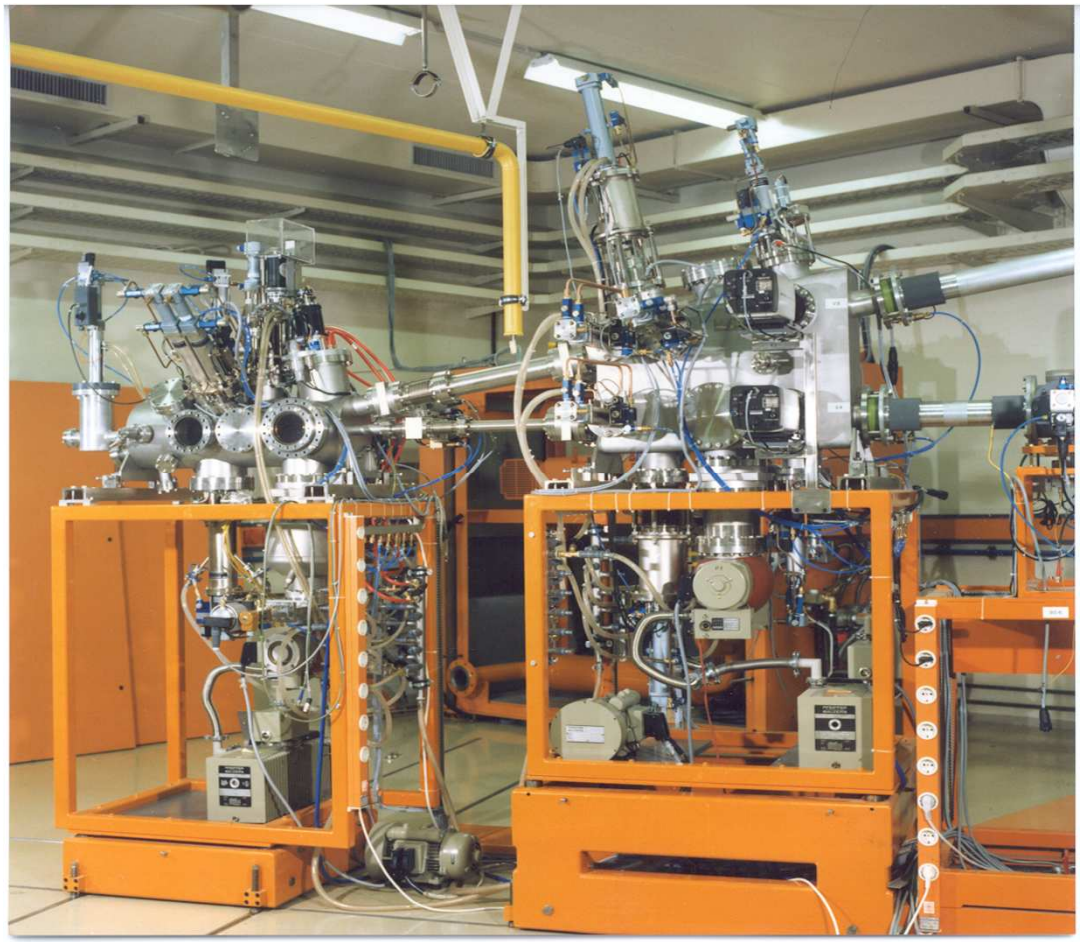
To be mounted onto a stepping motor driven UHV feedthrough

Two Apertures (cooled), mounted onto a compressed Air Actuator



The Aperture has been designed for a two beam experimental setup →see next Foil

Two Beam Experimental Setup
Equipped with Diverse Diagnostic Elements

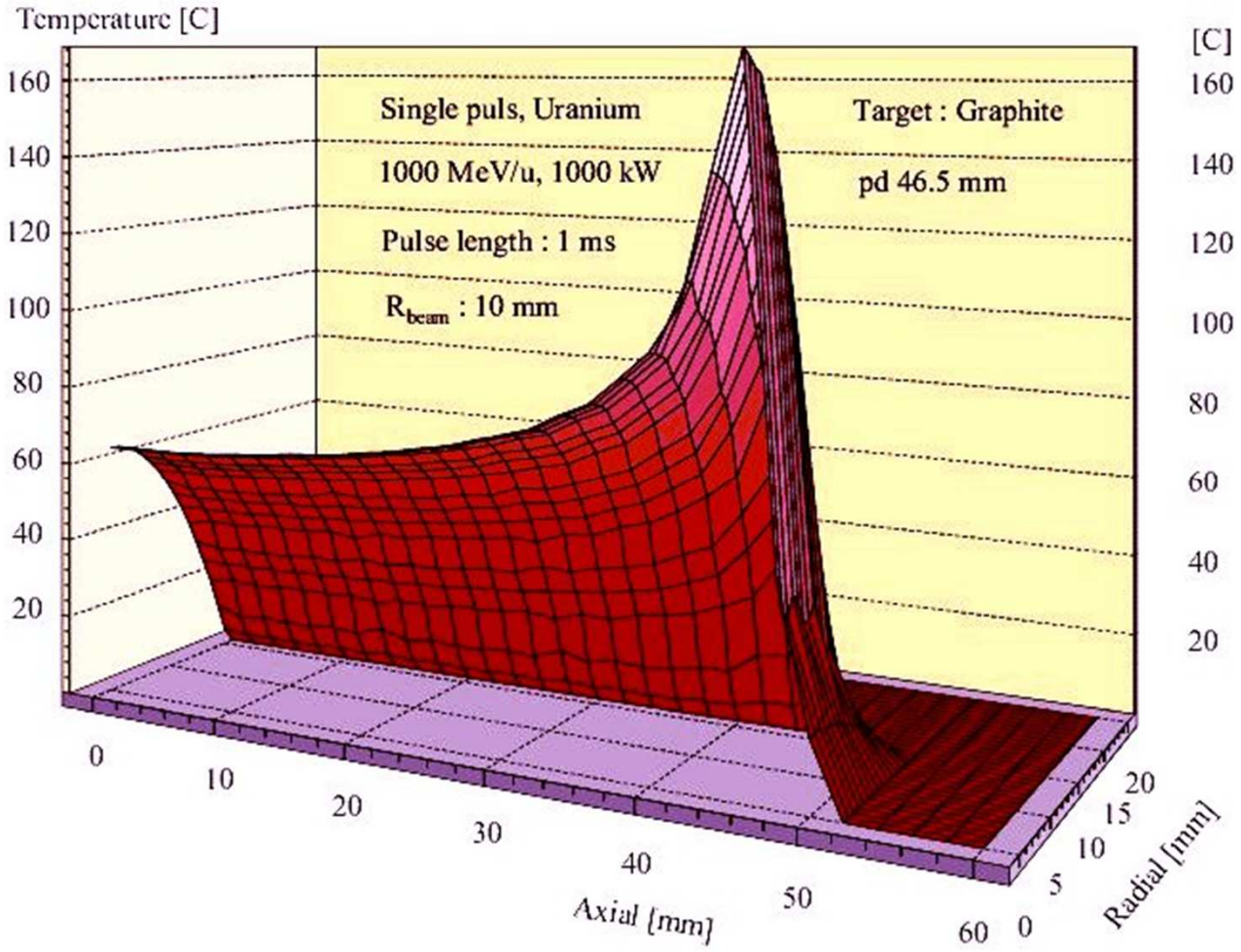


Physics

- **Design of beam diagnostic systems**
- **System analysis**
- **Signal calculation for all kinds of monitors**
- **Thermal calculations**
- **High intensity beam diagnostics**
- **Emittance measuring systems**
- **Development of application software**
- **Particle dynamics**
- **Estimation of space charge effects**

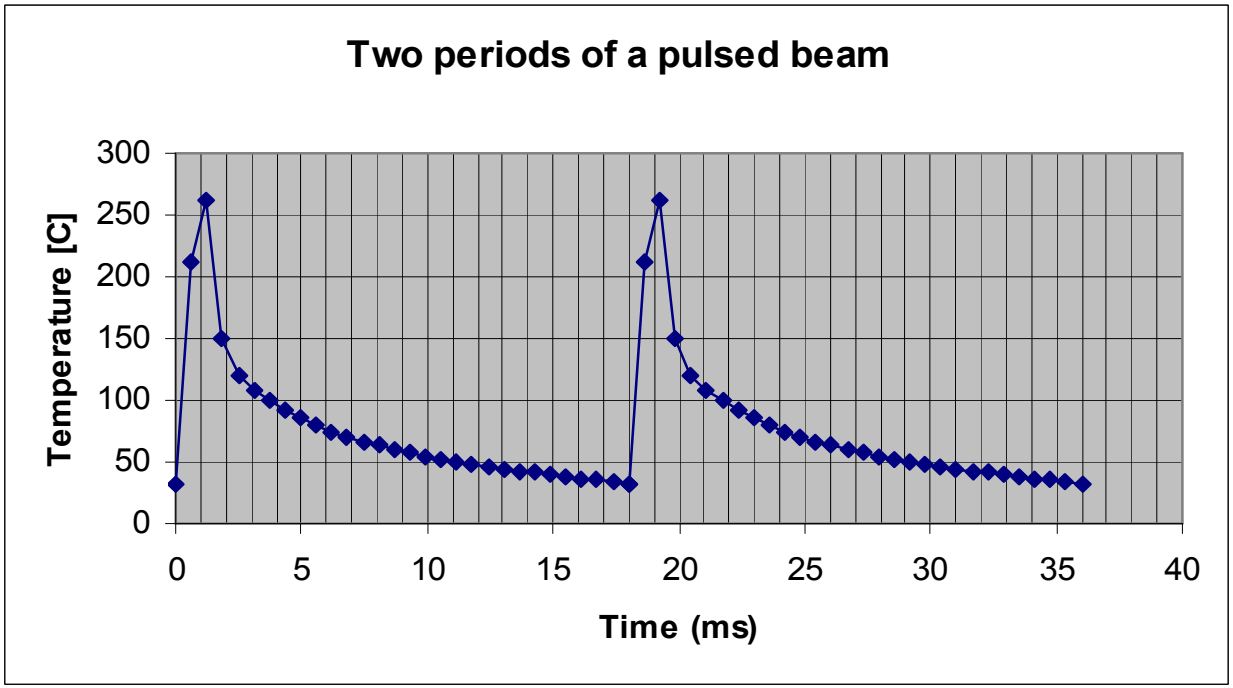
Consulting

Calculations, some Examples

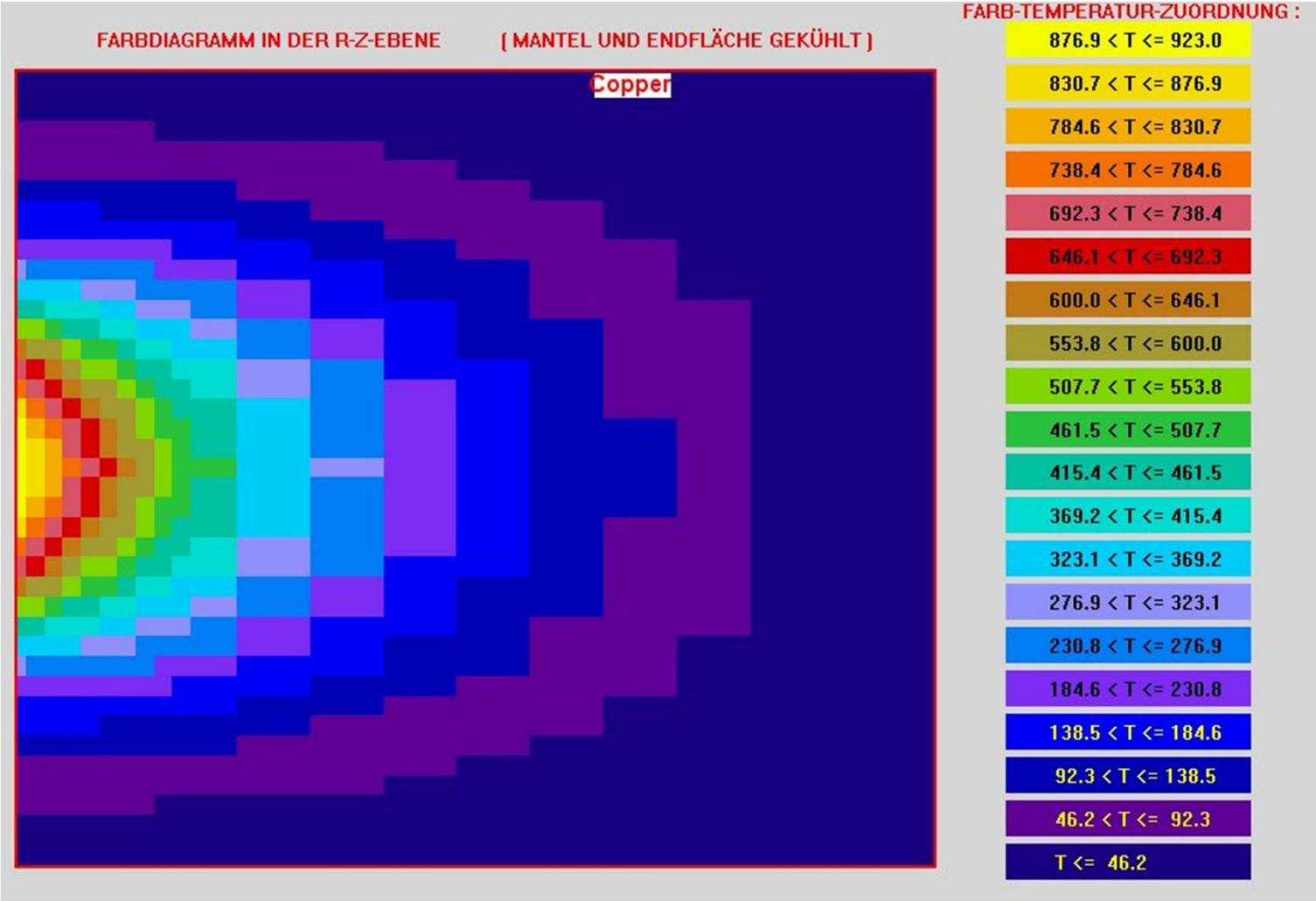


Solution of the Partial Differential Equation of Heat Transfer

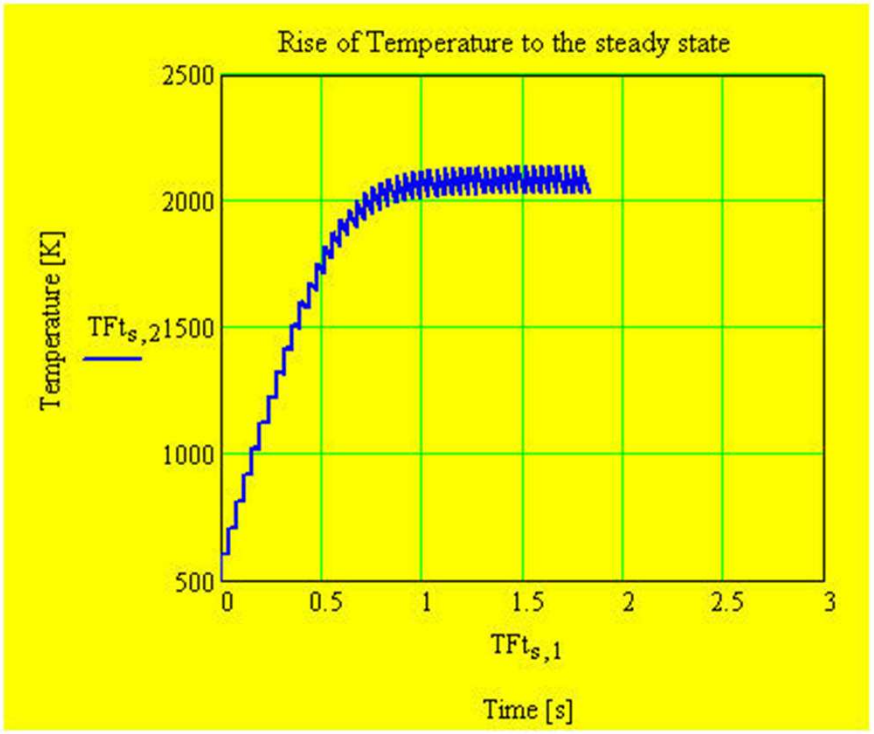
$$\frac{\partial T}{\partial t} = a^2 \cdot \Delta T + \frac{\dot{Q}(x,y,z)}{V}$$



The example shows the heating of a target by a pulsed beam



The example shows the distribution of heat in a circular beam stopper hit by a DC beam



Calculation of the Maximum Thermal Load on a Profile Grid for a Pulsed Beam.
The Steady State is determined by Radiation according to the Stefan-Boltzman law.

$\rho = 19.3$ Tungsten/Re wires, [g/cm²]

$Ppmm2 \cdot 100 = 1.2 \times 10^{4}$ [W/cm²]

$\Delta t = 2 \times 10^{-4}$ pulse length, [s]

$f_r = 25$ repetition frequency, [Hz]

Technics

Construction and manufacturing of:

- Beam diagnostic elements
- Experimental set-ups
- Moderators provided for energy degrading
- Elements for material research
- UHV-high temperature ovens
- Vacuum technics
- High precision mechanical devices

Project management

Technics

Construction and manufacturing of:

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Project management

Parameters Characterizing a Particle Beam

- Type of particle (may be: Electrons, Protons, Ions, Neutral Particles)
  - In case of ions mass number A, atomic number Z as well as the charge state of the ion is of interest
- Beam current:
  - DC (Remark: Also a DC beam may have a microstructure, respectively contain bunches)
  - Pulsed: One needs the pulse macrostructure as well as the microstructure (Bunch shape),
  - → FWHM, Repetition frequency

Continued → next Foil

- Beam energy:
  - In case of ions MeV/u is usual
- Beam spot size:
  - Diameter, if not a round beam it has to be specified.
  - Also the intensity distribution within the spot is of interest
- Beam emittance:
  - If there is an interest in the design of an emittance measuring system an estimate of the relevant emittance parameters should be given

Continued → next Foil

- Pressure in the beam pipe
- Required sealing (O-ring, metallic)
- Required type of flanges (CF, KF,...)
- Allowed maximum insertion length in beam direction
- Distance: Supporting flange – beam axis
- Pressure of cooling water, if needed
- Required free aperture in case a movable device has to be retracted out of the beam
- In case of slit-systems: Required dimensions of the jaws, required stroke, required free aperture in case of open slits, required accuracy of position measurement

Continued → next Foil

- In case of Faraday cups: End cup or movable cup required (compressed air actuator, ...), Broadband coaxial Faraday cup required, required secondary electron suppression (electric or electric and magnetic)
- In case of beam transformers: Isolating gap performed with O-ring or ceramics with metallic sealing, required bandwidth.
- In case of profile grids (harps): Diameter of the wires, length of the wires, spacing, required number of wires, ceramic or PVC – connector required (PVC=standard)