Measurements of the electron beam size at the absorber prototype test bench

ANNA MITSKOVETS

BELARUSIAN STATE UNIVERSITY

SUPERVISOR:
ALEXANDER SHEMYAKIN

ACCELERATOR DIVISION

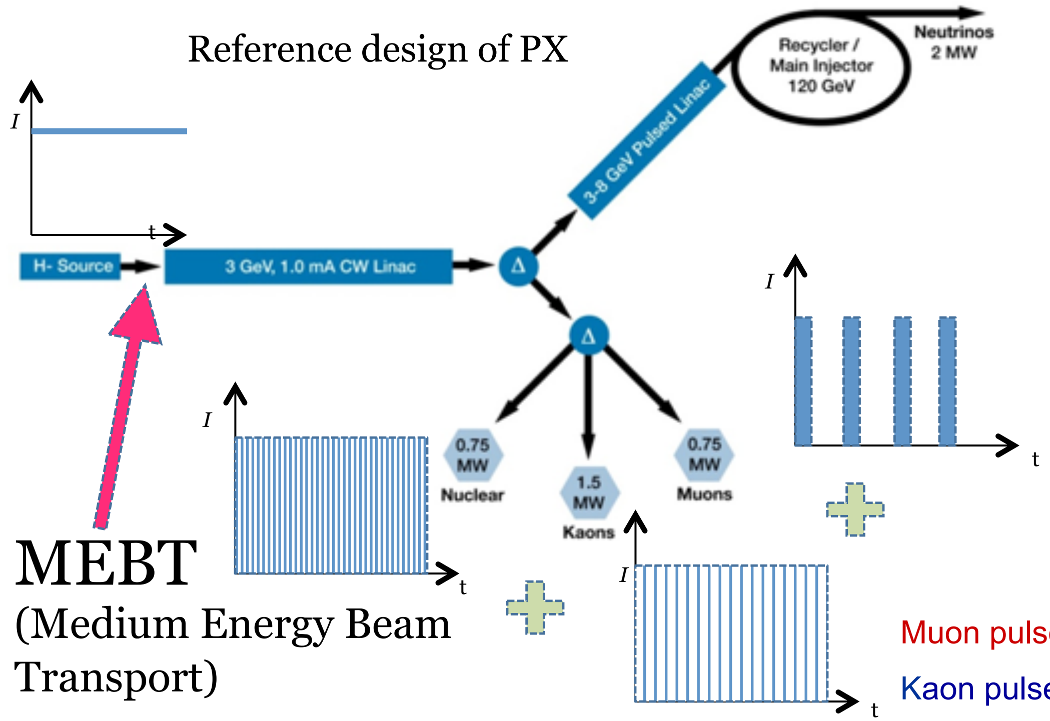
Project X
a new unique accelerator

- Multiple users with different needs
- An arbitrary bunched intense beam of protons

PXIE
(Project X Injector Experiment)

Integrated systems test for PX front end components

Reference design of PX

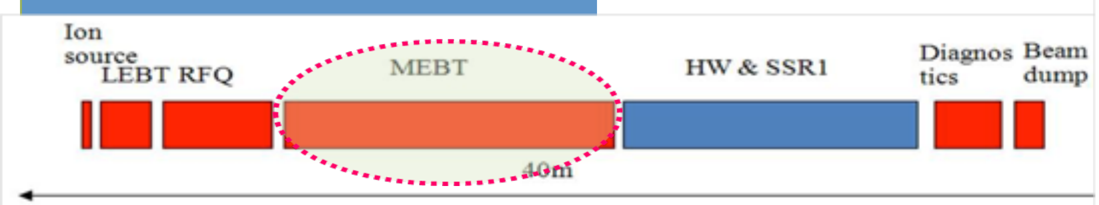


MEBT
(Medium Energy Beam Transport)

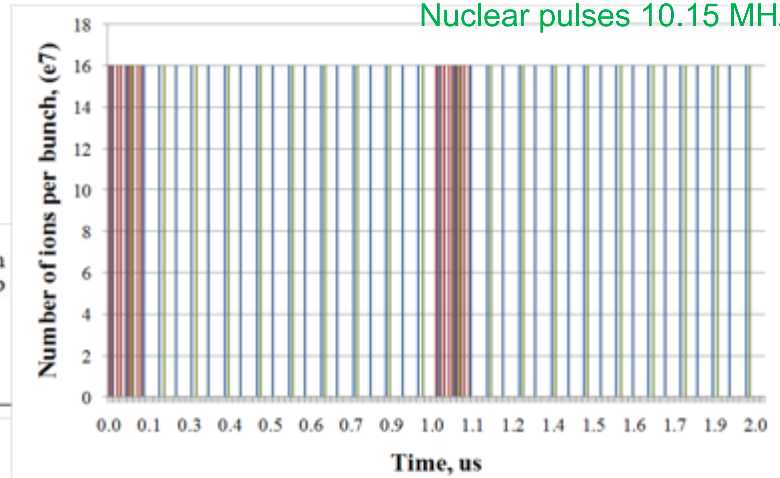
Muon pulses 81.25 MHz

Kaon pulses 20.3 MHz

Nuclear pulses 10.15 MHz



PXIE schematic layout

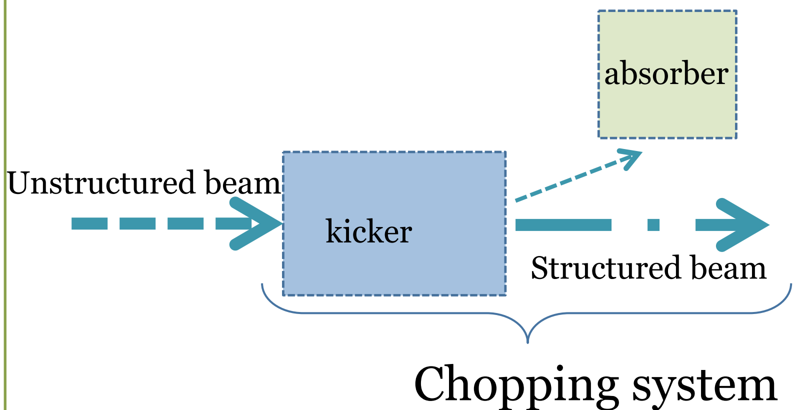


Absorber

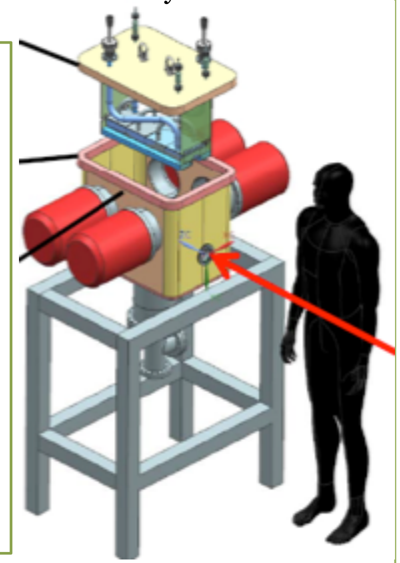
Forms the bunch structure required for the linac

Nominal parameters of the H^- beam:

- energy 2.1 MeV
- current 10 mA
- rms radius 2 mm



Conceptual design of the absorber by C. Baffes



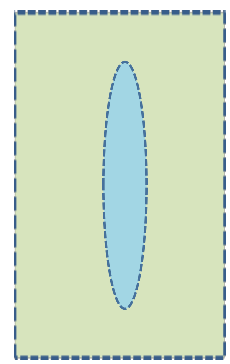
Difficulties:

– Thermal load
– Outgassing
– Blistering
– Sputtering

Thermal load of the absorber can be tested with an electron beam

Shallow angle of incidence ≈ 30mrad

Power density 25 W/mm²



Footprint of absorber surface

Absorber prototype test bench

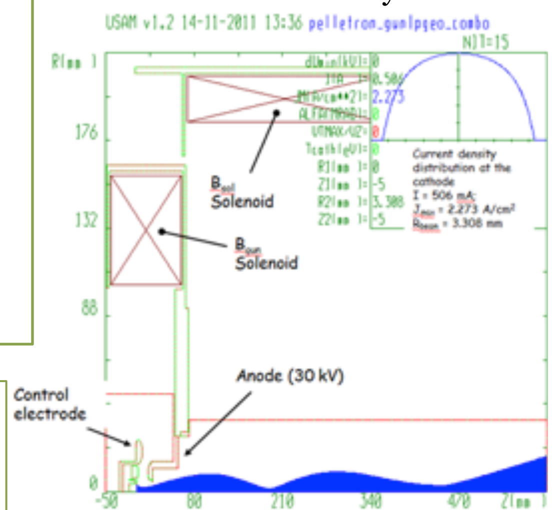
Nominal parameters of the beam at the absorber prototype test bench:

- operational voltage 29 kV
- current 180 mA
- rms radius 2 mm

Angle of incidence =0.12 rad

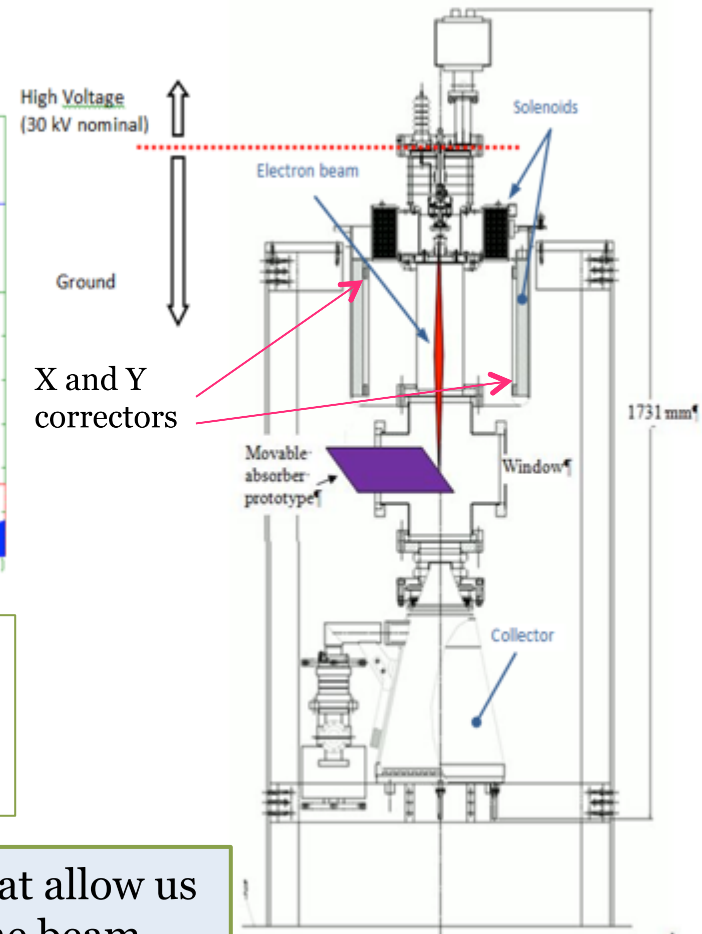
Power density 25 W/mm²

Beam simulation by L. Prost

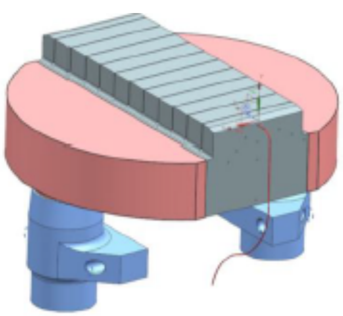


Simulation parameters:

- Voltage 30 kV
- Lens current 1.9 A
- Solenoid current 5.3 A

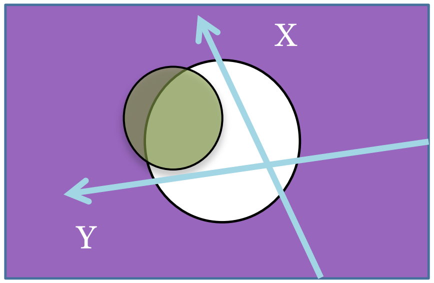


We need a procedure that allow us to measure the size of the beam with 10 % accuracy

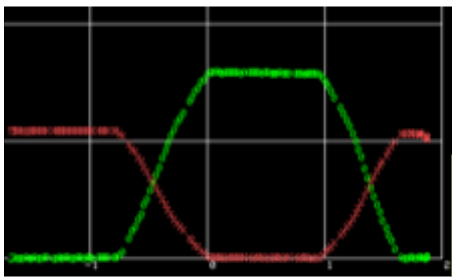


Absorber prototype design by C. Baffes

Method of the beam size measurement



Scanning of the hole with the beam



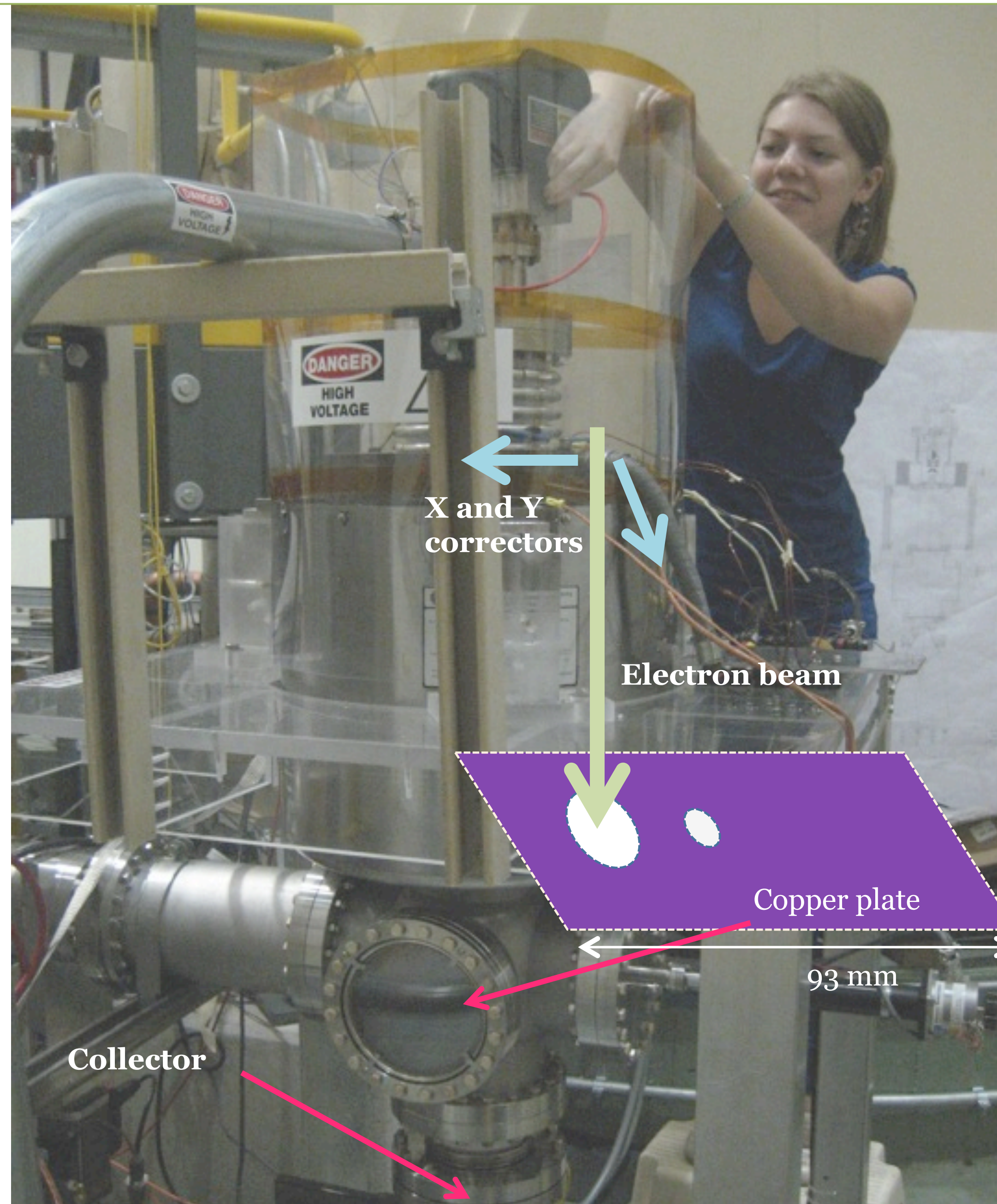
Scan of the hole in X corrector direction

Green – collector current
Red – plate current

My goals:

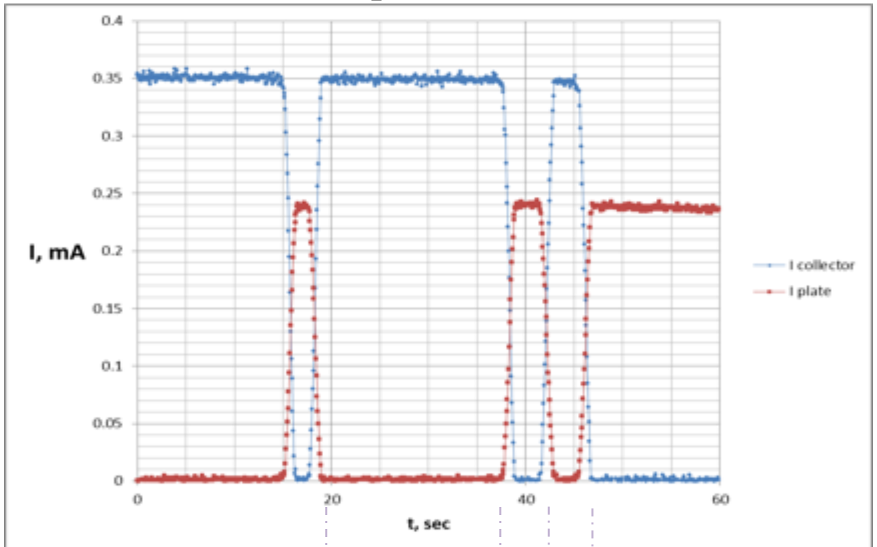
-To participate in commissioning of the test bench

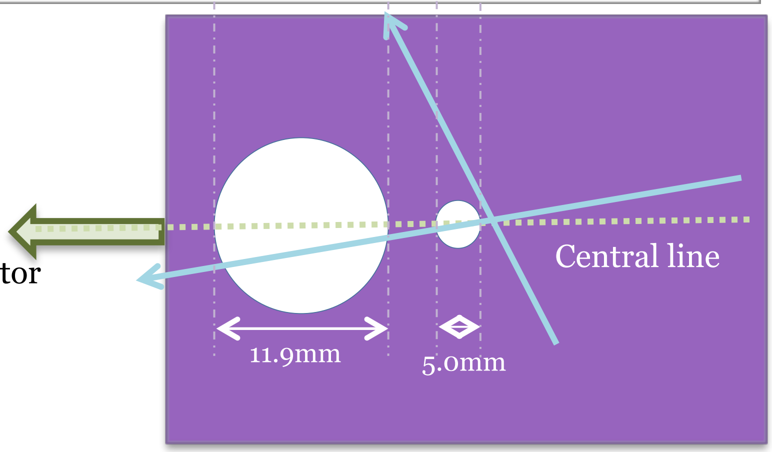
-To develop a procedure of the electron beam size measurement



Measurements with low current

Mechanical scan of the plate with DC current





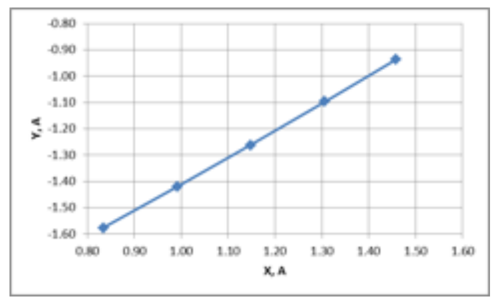
Calibration of the correctors:

The small hole was scanned through its center in X and Y directions. Assuming that the diameter of the hole is 4.98 mm:

- *X calibration 4.69 mm/A*
- *Y calibration 4.57 mm/A*

The small hole was scanned in X and Y corrector directions and the position of center of the hole in terms of X and Y corrector currents was determined. Then the was shifted and the procedure was repeated. Taking in account the determined calibration values of the X and Y correctors, we obtained the directions of the X and Y correctors.

- *Angle between correctors 91.1°*
- *Angle between X corrector and the central line 45.5°*



Pass of the hole center in X-Y corrector coordinates

Additional independent measurement for self consistency:

Find a ratio between X and Y correctors currents, that allow to move the beam along the edge of the plate.

Limitations

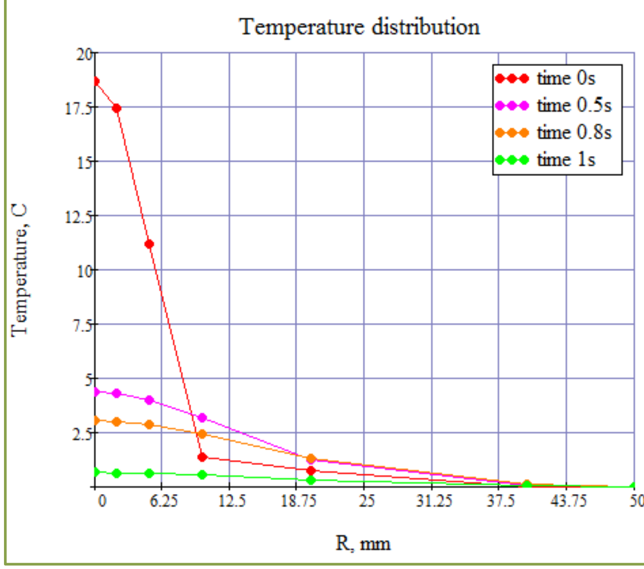
Power of the beam 5kW (no water cooling of the plate)

The safe temperature 200 ° C

Power of radiation cooling (at 200° C) 25 W

Heat removal due to thermal conductivity (at 200° C) 2W

Consider 0.3 sec 200 mA beam pulse:



The plot shows the rate of the temperature distribution in the simplest model:

- the plate is infinite with no holes
- the heat is produced at the spot with the radius equal to the radius of the beam
- the heat is produced homogeneously throughout the whole thickness of the plate
- for 1 sec time we neglect heat losses

We can take for the time of temperature relaxation 1 sec

The shortest pulse duration 0.3 sec – limited by the power supply

The period in the beam pulses is going 1.3 sec

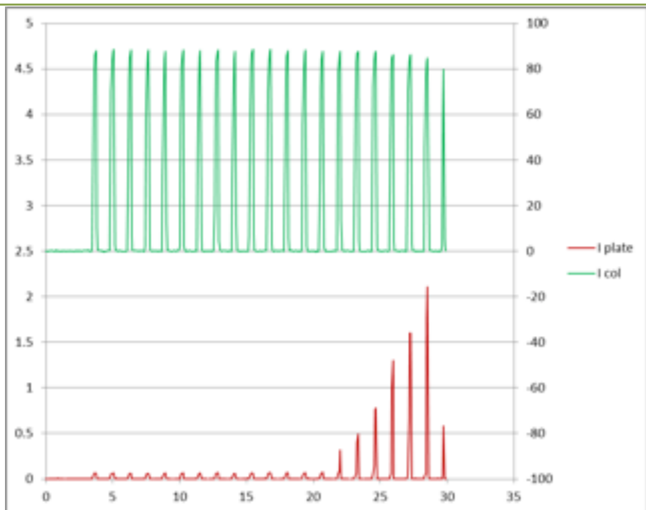
To keep constant 200° C

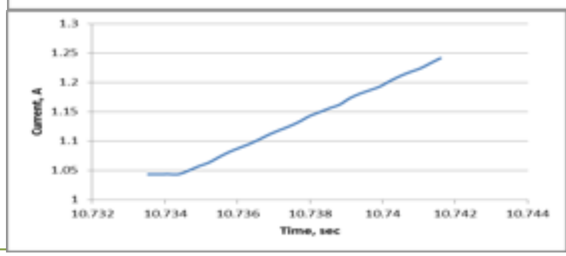
Conclusions:

- **0.3 sec pulsed beam**
- **we can hit the plate only partially with 3mA current**

Measurements with 88 mA CW beam

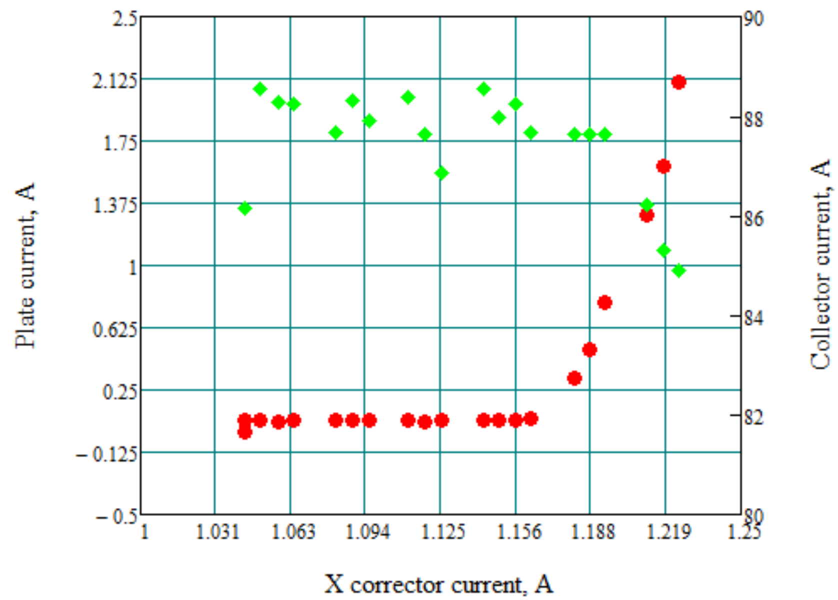
The plot shows the plate's and the collector's currents vs time.





The X corrector current vs time

Data analyses with Mathcad

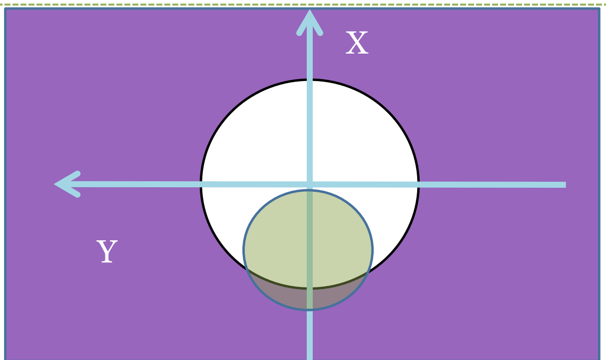


Scanning of the edges of the hole with CW beam is made by a Java program "Wave generator" (Z.Yuan).

It opens the gun for 0.3 sec, closes it, moves the beam with correctors and repeats the pulse in 1 sec.

Mathcad program
- takes maximum plate's and collector's currents during 1 pulse
- coordinates frequencies of read backs
- prepares the plots of the scans – currents at the plate and at the collector vs corrector's currents

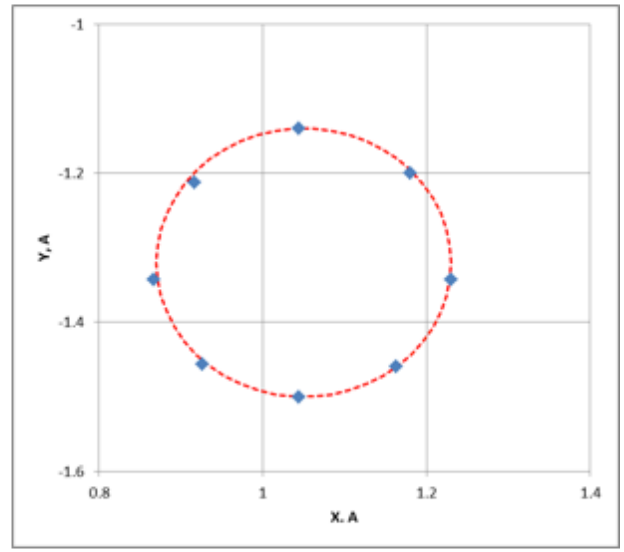
Size of the beam

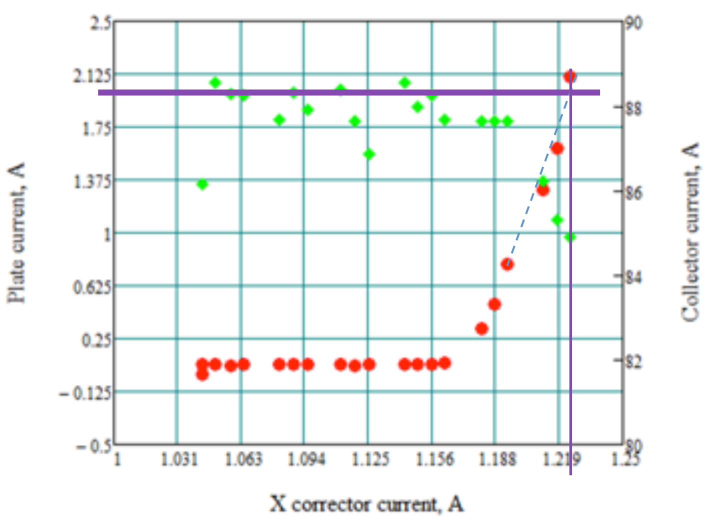


Definition of the beam touching the plate is the plate's current 2mA (3% of the beam).

88 mA beam with 2.1 A solenoid current

4 scans of the small hole in different directions:
0°, 45°, 90°, and 135°.





The coordinates of the center of the beam when it touches the hole. Dashed red line is a circle fitting.

Given the calibration values of the corrector currents and the diameter of the hole we calculated the diameter of the beam 3.3 mm.

Summary

- The cathode was activated and the 200 mA current was reached
- The procedure of correctors calibration in three independent measurements was developed
- Correctors calibration for 2.1 A solenoid current with DC low current beam was performed
- Characteristic times of thermal processes in the plate were estimated, and the parameters of the time mod for safe operation were chosen.
- The procedure of the beam size measurement was developed, and the size of the 88 mA beam was measured

Acknowledgments to the people who designed the test bench, assembled it or took part in the measurements: Jim Walton, Kermit Carlson, Bruce Hanna, Lionel Prost, Sasha Shemyakin.

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Scheme of the Test Bench