Ultimate abilities of conventional positron sources

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Development of positron production system.

- High power positron production target
- Effective matching device
- Effective accelerating and focusing system for positron beam
- Joint optimization of all these three items.

Basic problems

- A huge increase of the target temperature during powerful pulse.
- Long macro pulse leads to stronger kick-effect and decreasing of useful magnetic field maximum in FC magnet.
- Longer pulse also means lower accelerating gradient in the first structure for positrons.
- High positron production rate leads to high activation level and radiation damages of positron production system elements.

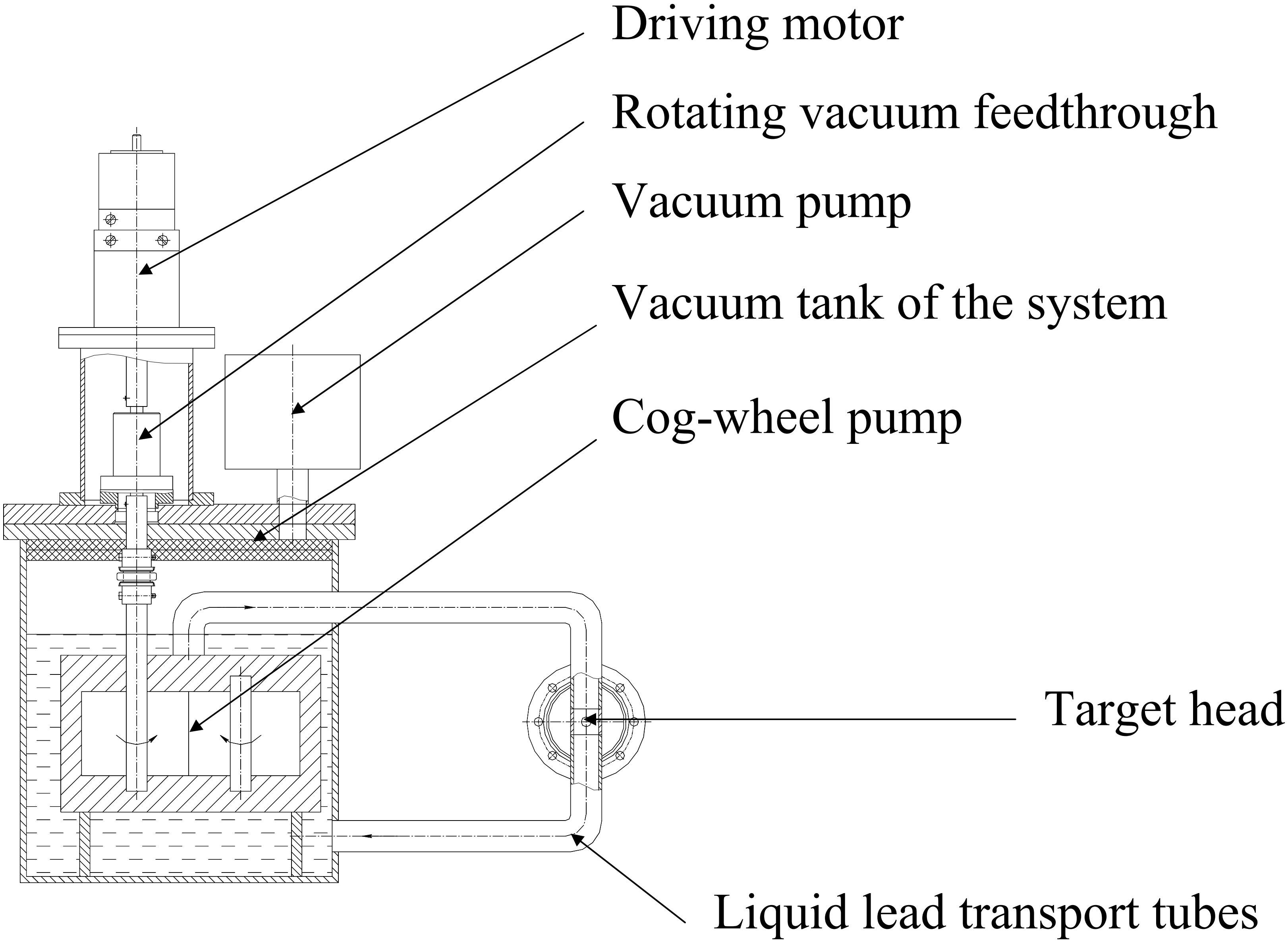
The basic directions of R&D

- High power liquid lead target in comparison with rotating solid-state WRe target.
- Effective matching device (Flux Concentrator or Lithium Lens).
- High gradient accelerating structure immersed in the max. possible DC magnetic field
- High radiation resistance of all elements.

The main aims of this R&D.

- To determine the technical limit of driving beam intensity and duration for each component of positron production system.
- To optimize each component for the best integrated system performance.

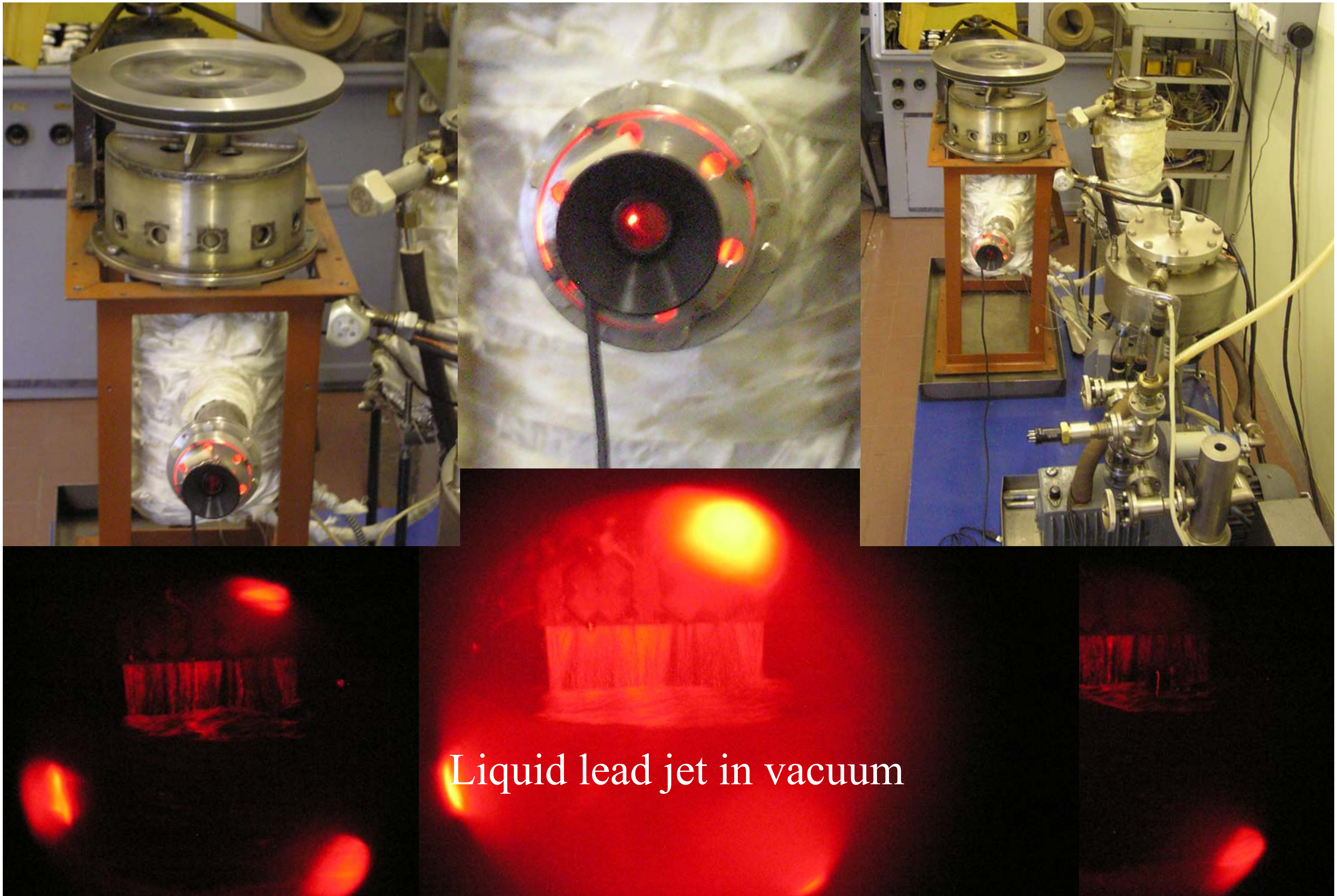
Scheme of the prototype of liquid lead positron production target.



The present stage of BINP activity in liquid lead target development.

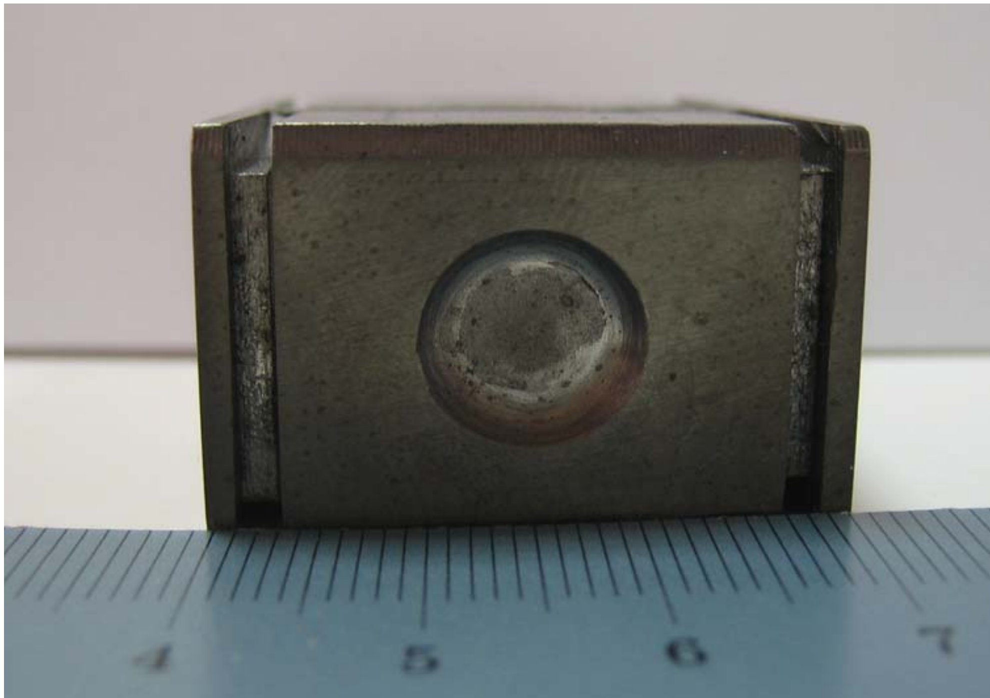
- 15000 h of liquid lead contour successful run with cog-wheel pump has been reached. The system is in operation now, the test is in progress (90% Pb, 10% (mass)Sn alloy, 300ºC).
- The shock-wave test of BN windows showed the dynamical stretch limit at the level of 39 GPa. For previous NLC design the value of 3-4 GPa was estimated. For present ILC variant this value will be even less (about 0.01 GPa) due to longer macro pulse.
- The test of window braising technology is in progress.
- The prototype of liquid lead positron production target is in production now. This prototype is specially designed for output window destruction test on KEKB.

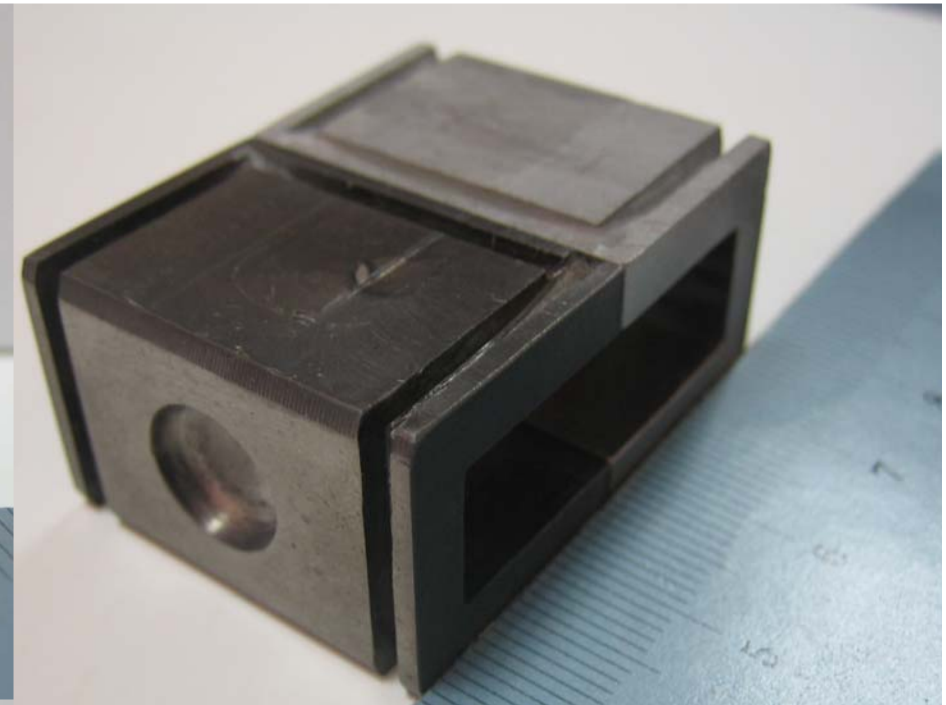
The parts of liquid lead cog-wheel pump

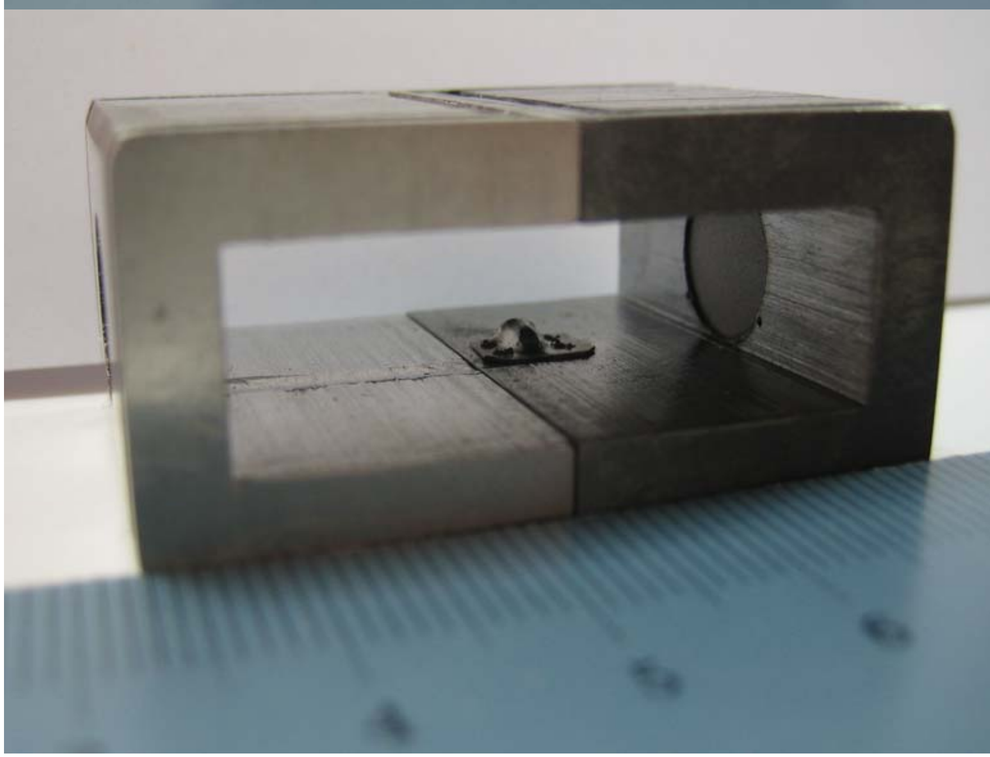


Liquid lead jet in vacuum

Cog-wheel pump test bench is in continues run
(15000 h up to now) with liquid lead jet. 90% Pb, 10% Sn alloy at 300ºC.



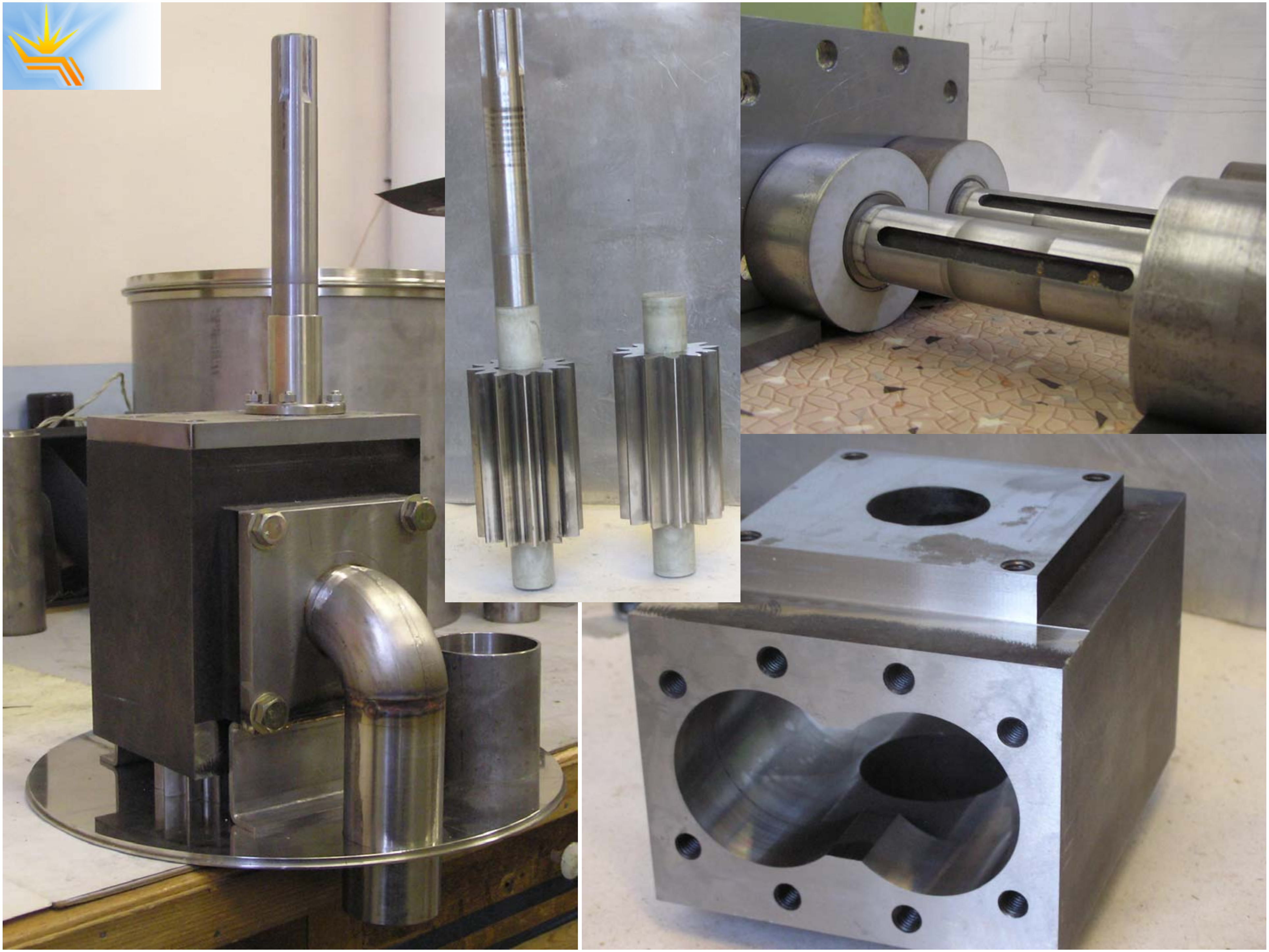


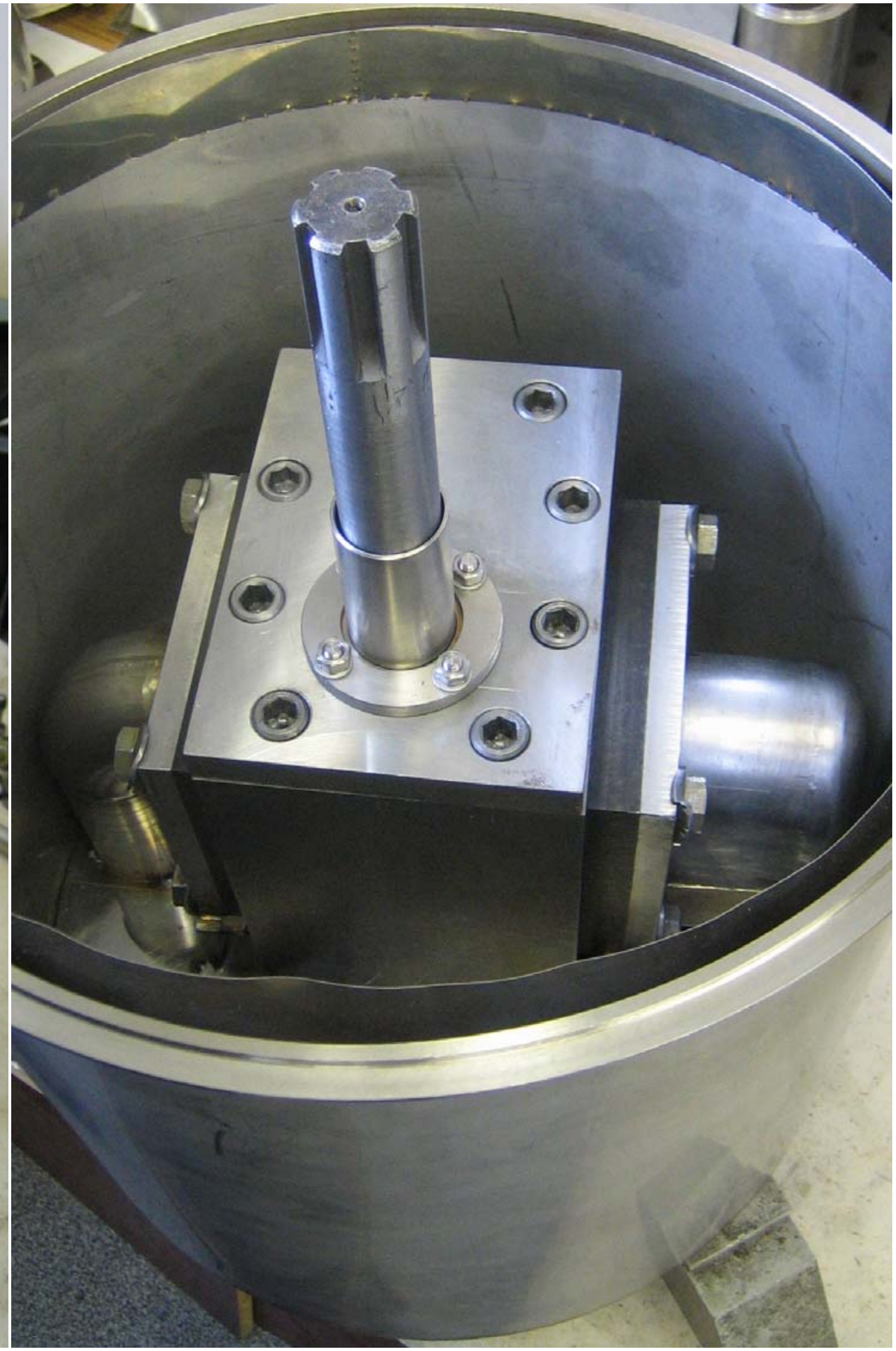


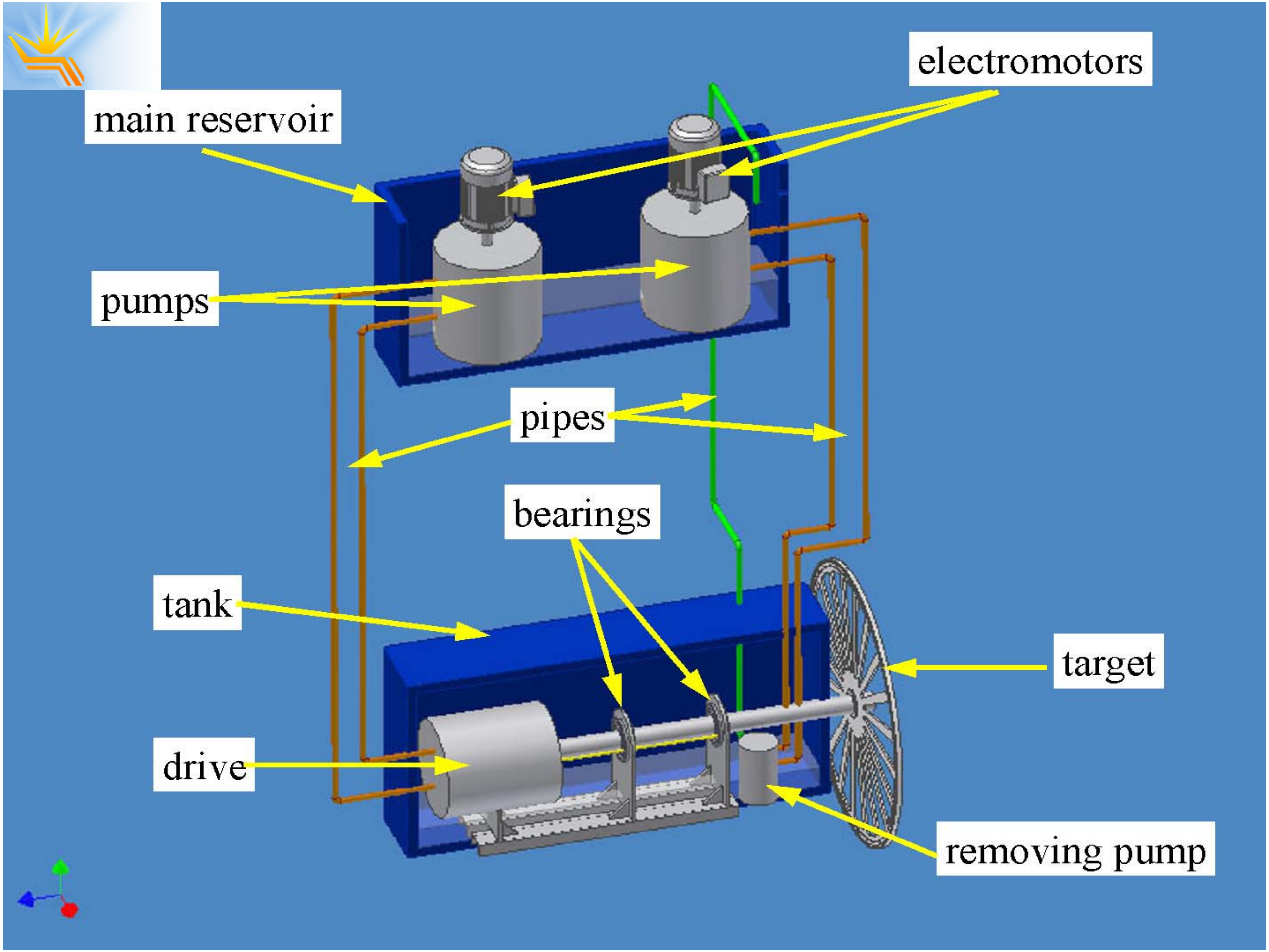
Prototype of target head with BN windows.

Test samples after 1000 h exposition
in liquid lead alloy at 300ºC
(no any damage of brazing joint).

BN disks for windows



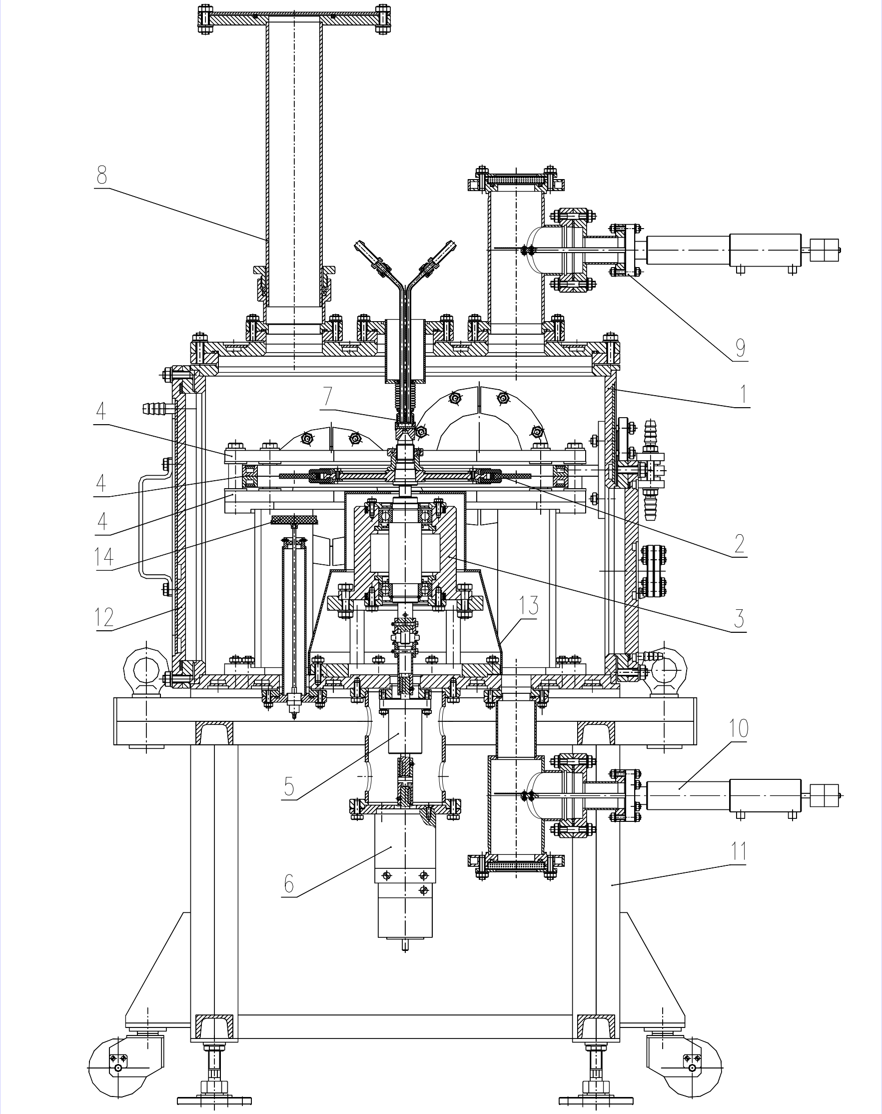




electromotors
main reservoir
pumps
pipes
bearings
tank
target
drive
removing pump

BINP experience in solid state rotating targets.

- The target is cooled by thermal radiation
- Max reached power in 1 cm diameter spot – 70 kW DC.
- 1200 – 3000 RPM.
- Target operating temperature is 2200 K.
- Target material is high density graphite
- 80 h non-stop run at 50 kW.

The scheme of prototype.



1 - vacuum chamber,

2 – converters wheel,

3 - bearing unit,

4 - cooling panels,

5 - rotary motion feedthrough,

6 - electric motor,

7 - shaft cooling unit,

8 – connective vacuum chamber,

9,10 – optic windows units,

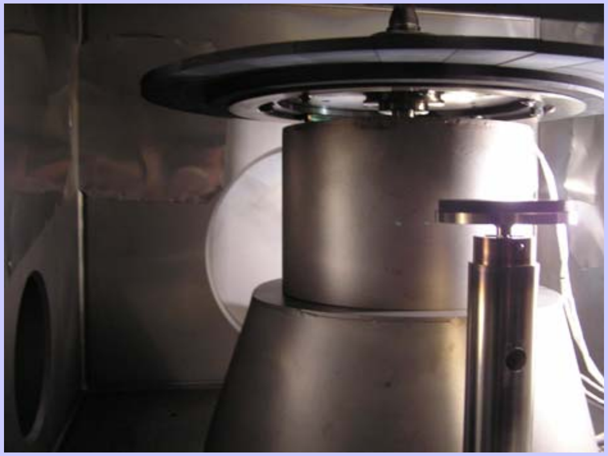
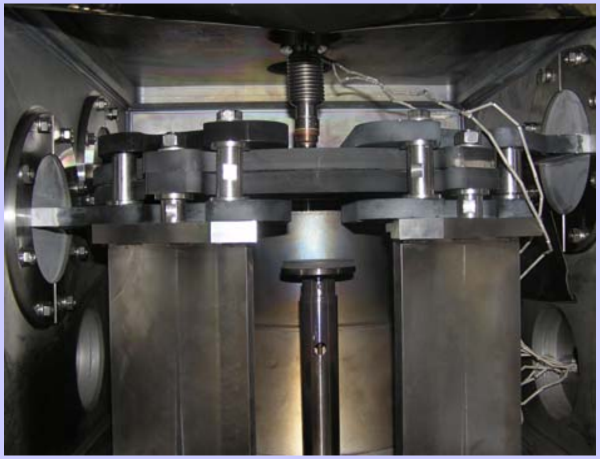
11 - stand,

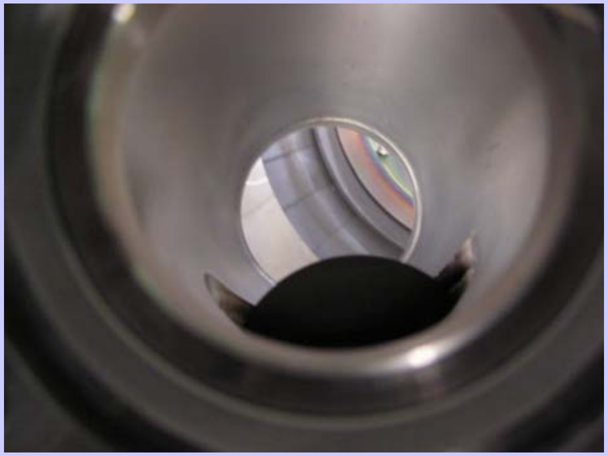
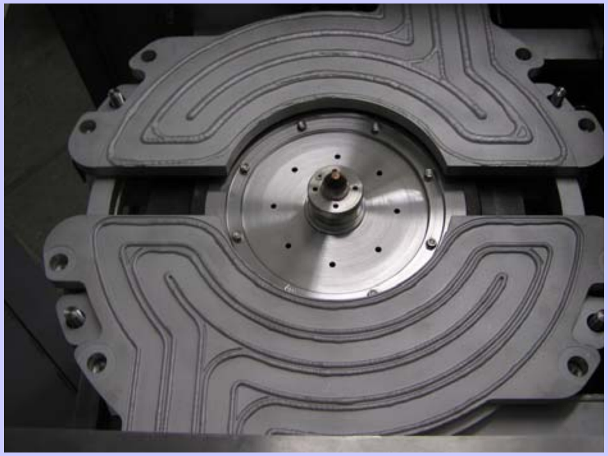
12 – removable flange,

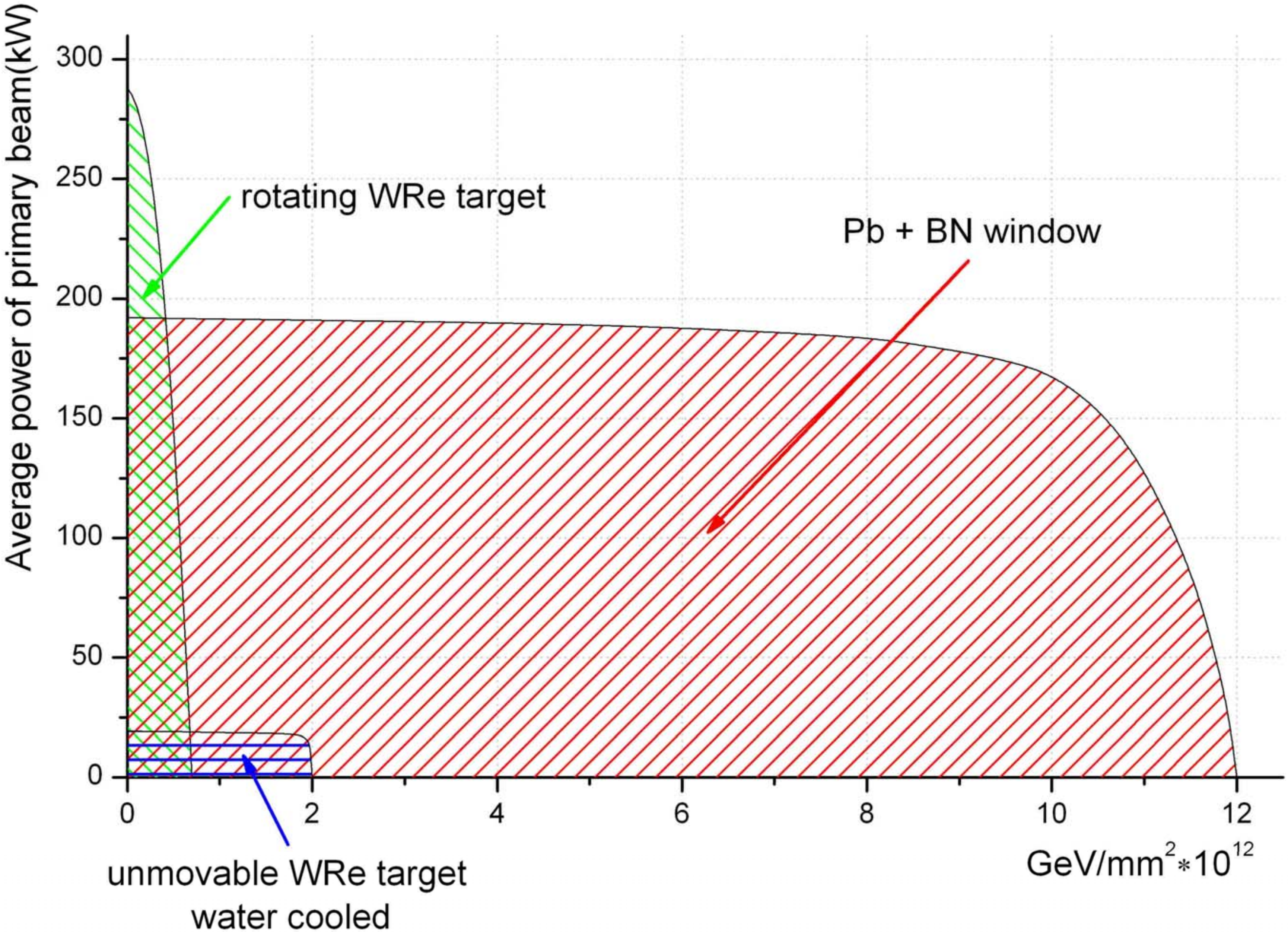
13 - heat shield,

14 – measuring sensor

Views of prototype.



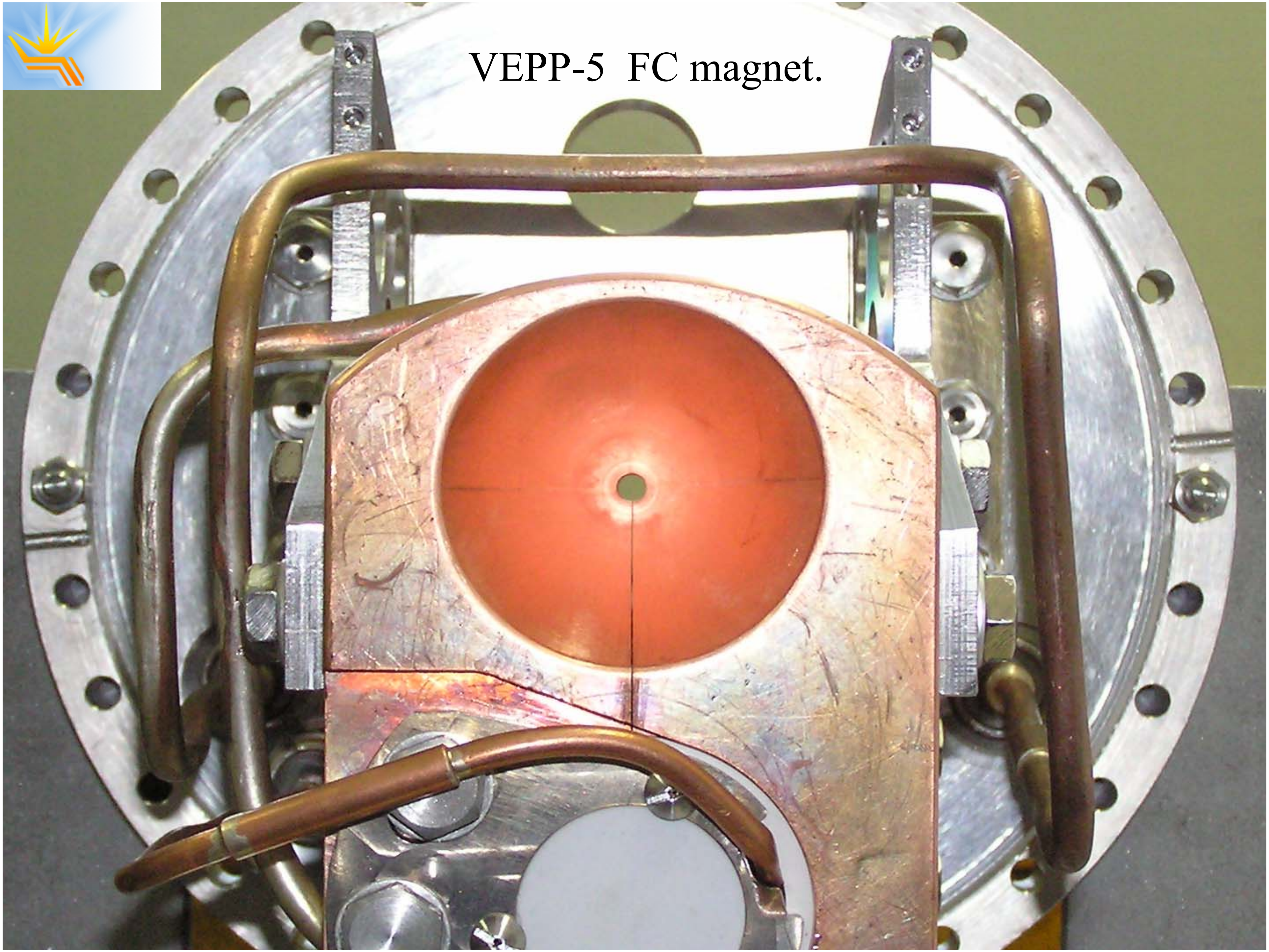
Average power of primary beam(kW)
300
250
200
150
100
50
0
0
2
4
6
8
10
12
GeV/mm^2*10^{12}
rotating WRe target
Pb + BN window
unmovable WRe target
water cooled

The present stage of BINP activity in Matching Device development.

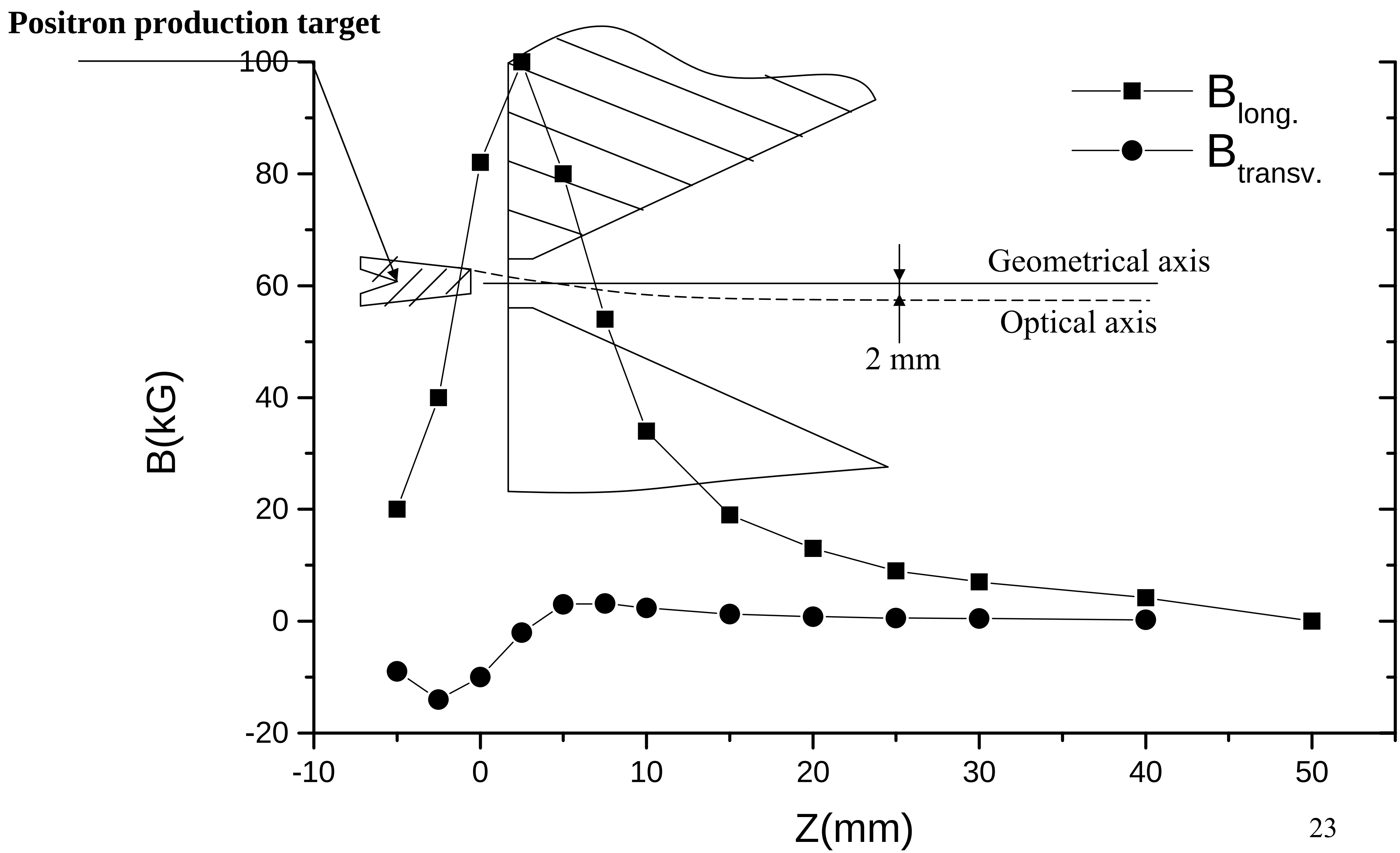
- The successful test of VEPP-5 positron production system was performed. Flux Concentrator magnet (FC) was tested up to 70 kG (30 μs pulse duration) without saturation in positron yield.
- The investigation of the technical limit for maximum FC pulse duration is in progress.
- Flat face FC for 30 μs pulse duration, 10 T maximum field and good field quality for KEKB is in production now at BINP.

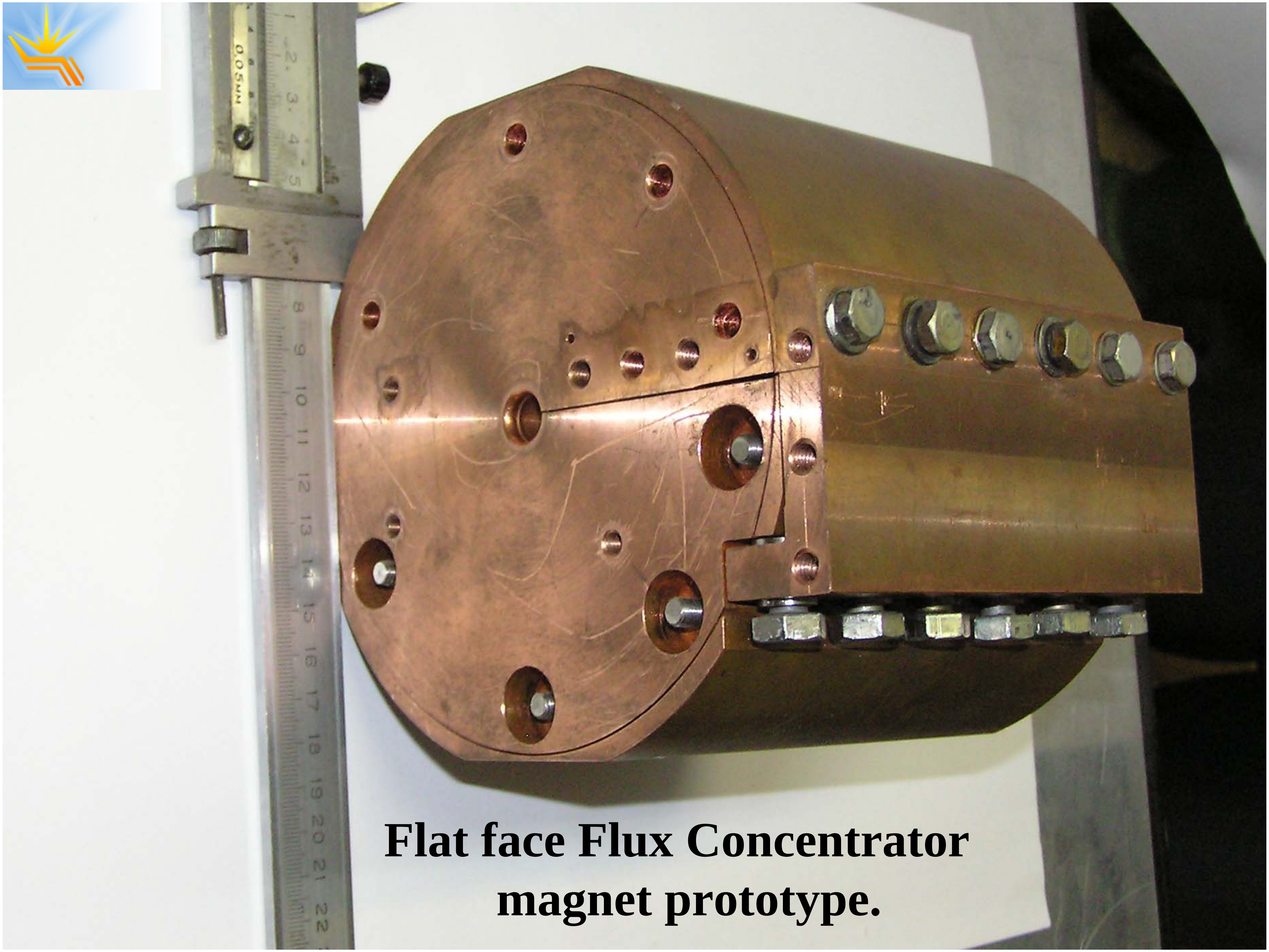

Positron system of VEPP-5 Injection complex
in BINP.
СТОЙ
НАПРЯЖЕНИЕ

VEPP-5 FC magnet.



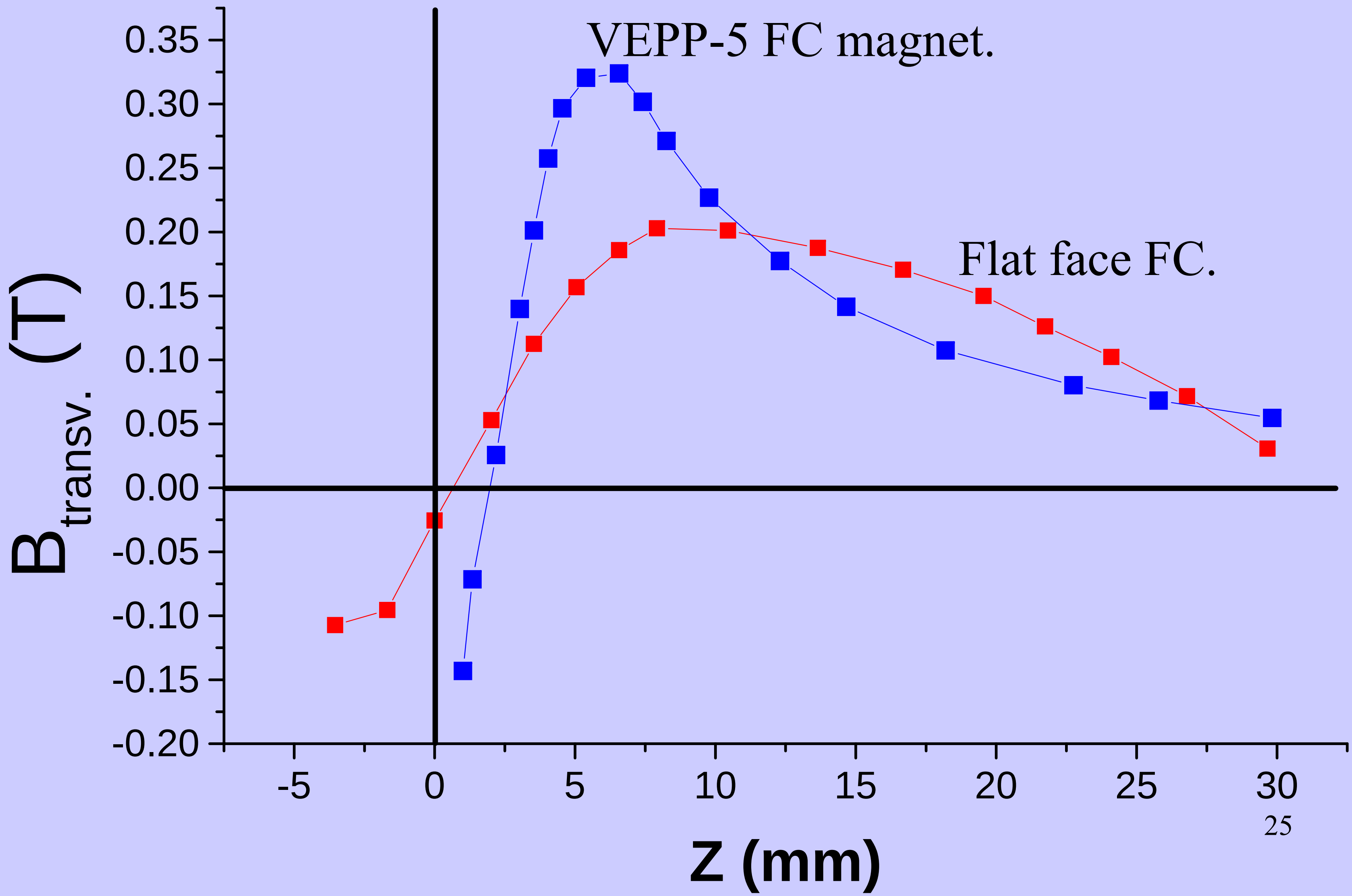
The dependencies of longitudinal and transverse magnetic fields on the geometrical axis of VEPP-5 FC magnet (measurements).





Flat face Flux Concentrator magnet prototype.

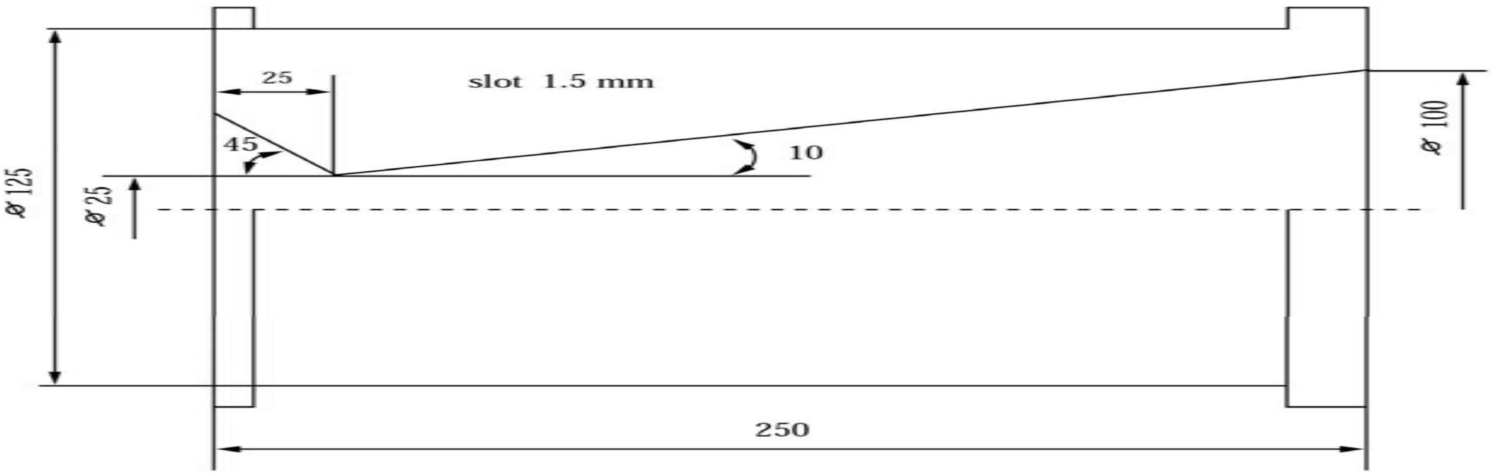
The dependencies of transverse magnetic field in matching devices upon the coordinate along the axis (magnetic measurements).

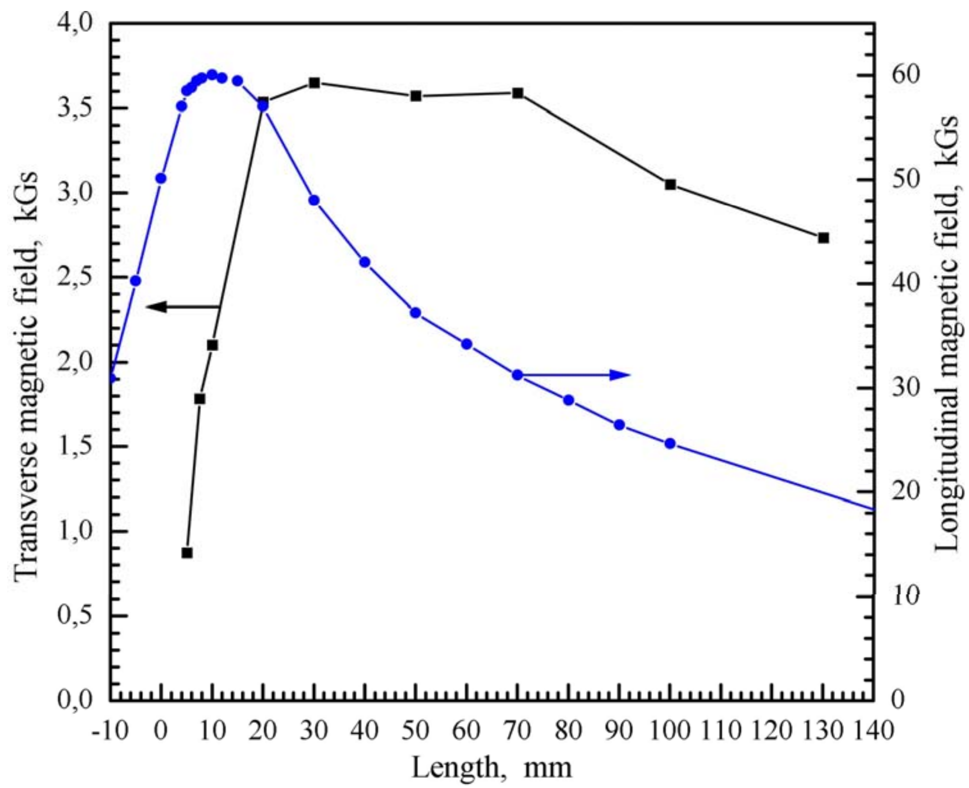


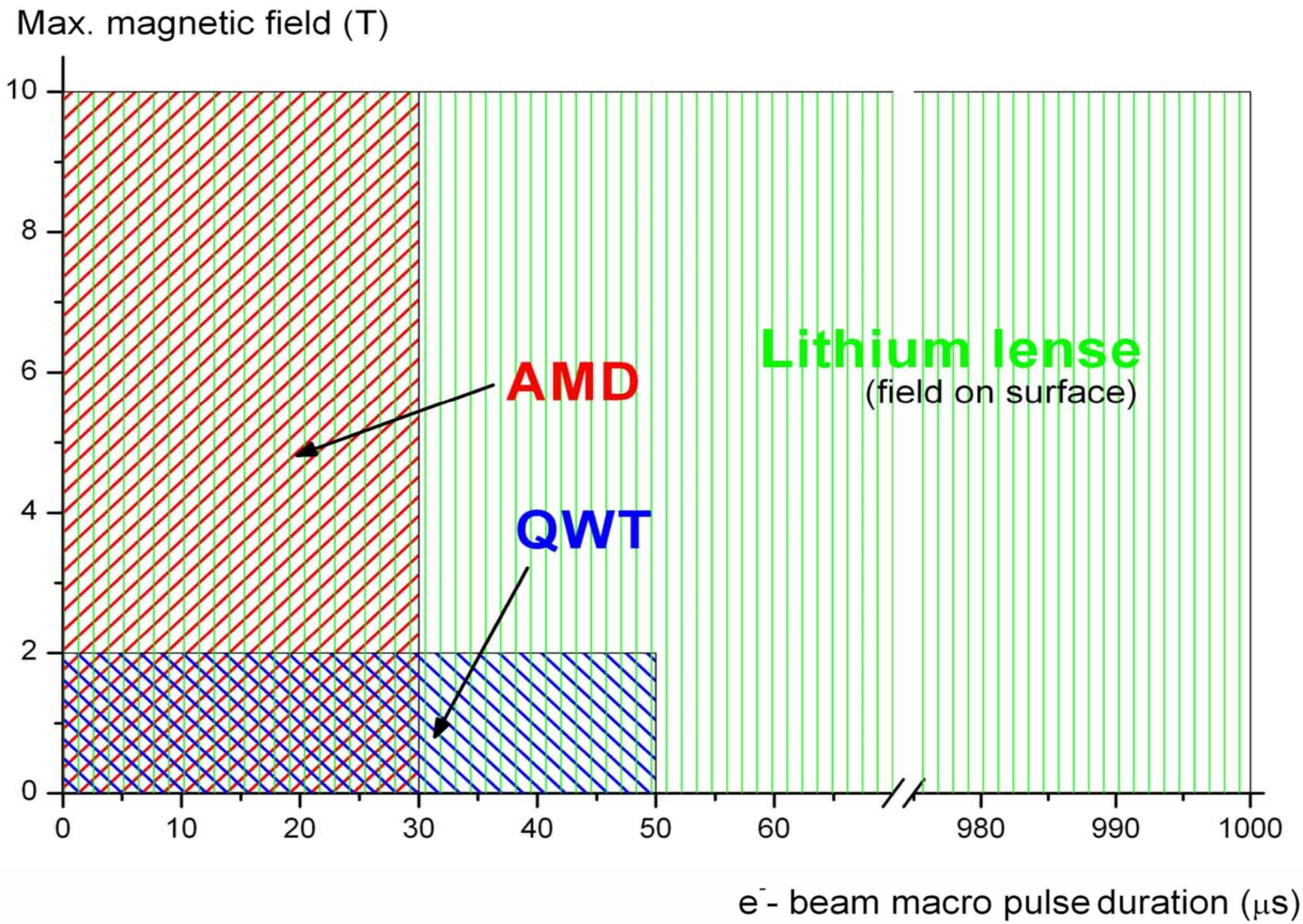
Problems with long macro pulse in ILC

- The skin-depth increasing leads to effective increasing of the device aperture and a region size with asymmetric transverse magnetic field. The longitudinal integral of this field determines the kick effect.
- For longer pulse – more problems with the field quality.
- For longer pulse – the energetic efficiency of all the system is less.
- Also the mechanical problems arise with the increasing of the pulse length.
- The technical limit for pulse duration should be determined.

1 ms FC prototype and its field quality.





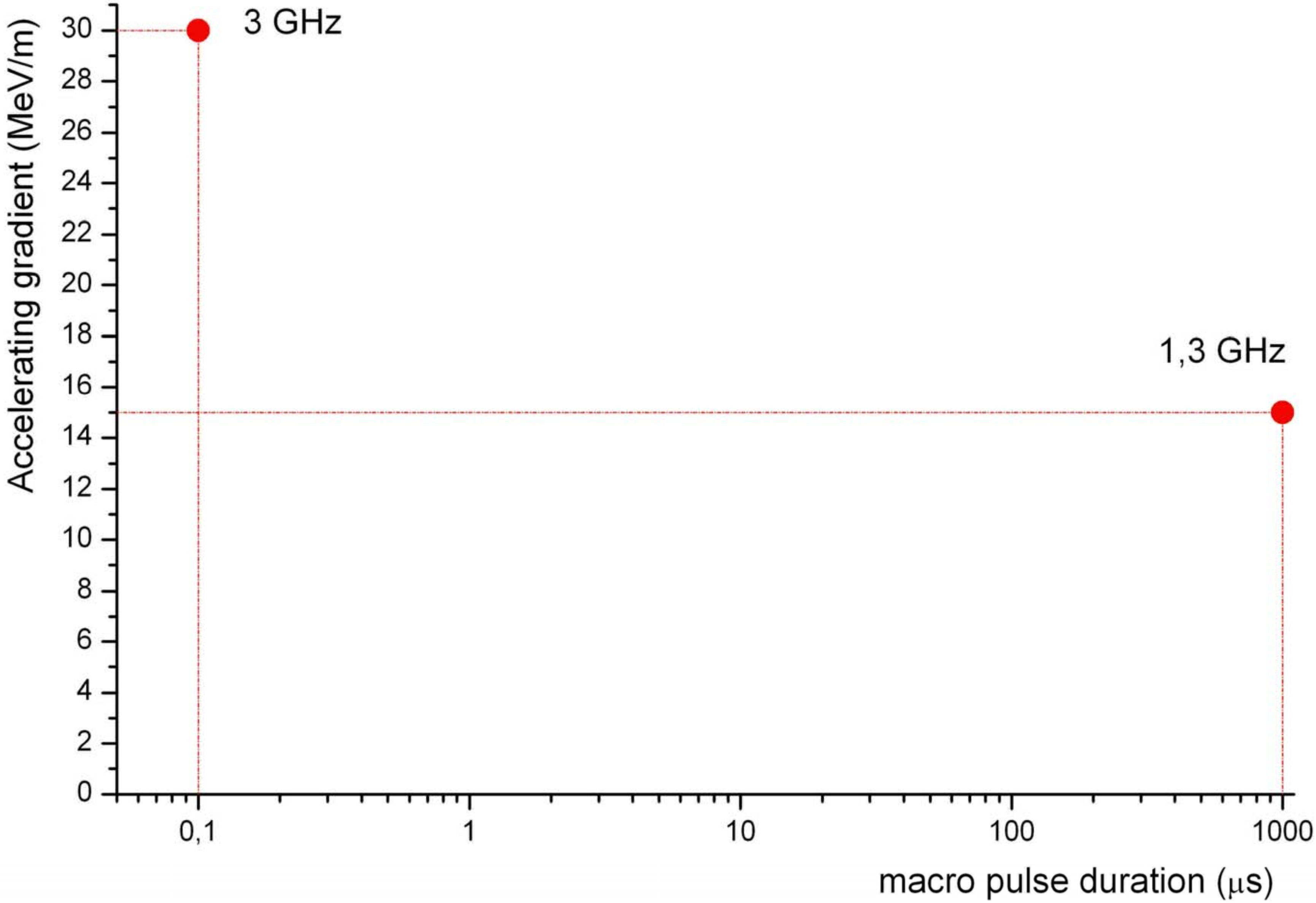


Max. magnetic field (T)
10
8
6
4
2
0
0
10
20
30
40
50
60
980
990
1000
AMD
QWT
Lithium lense
(field on surface)
e⁻- beam macro pulse duration (μs)

Summary

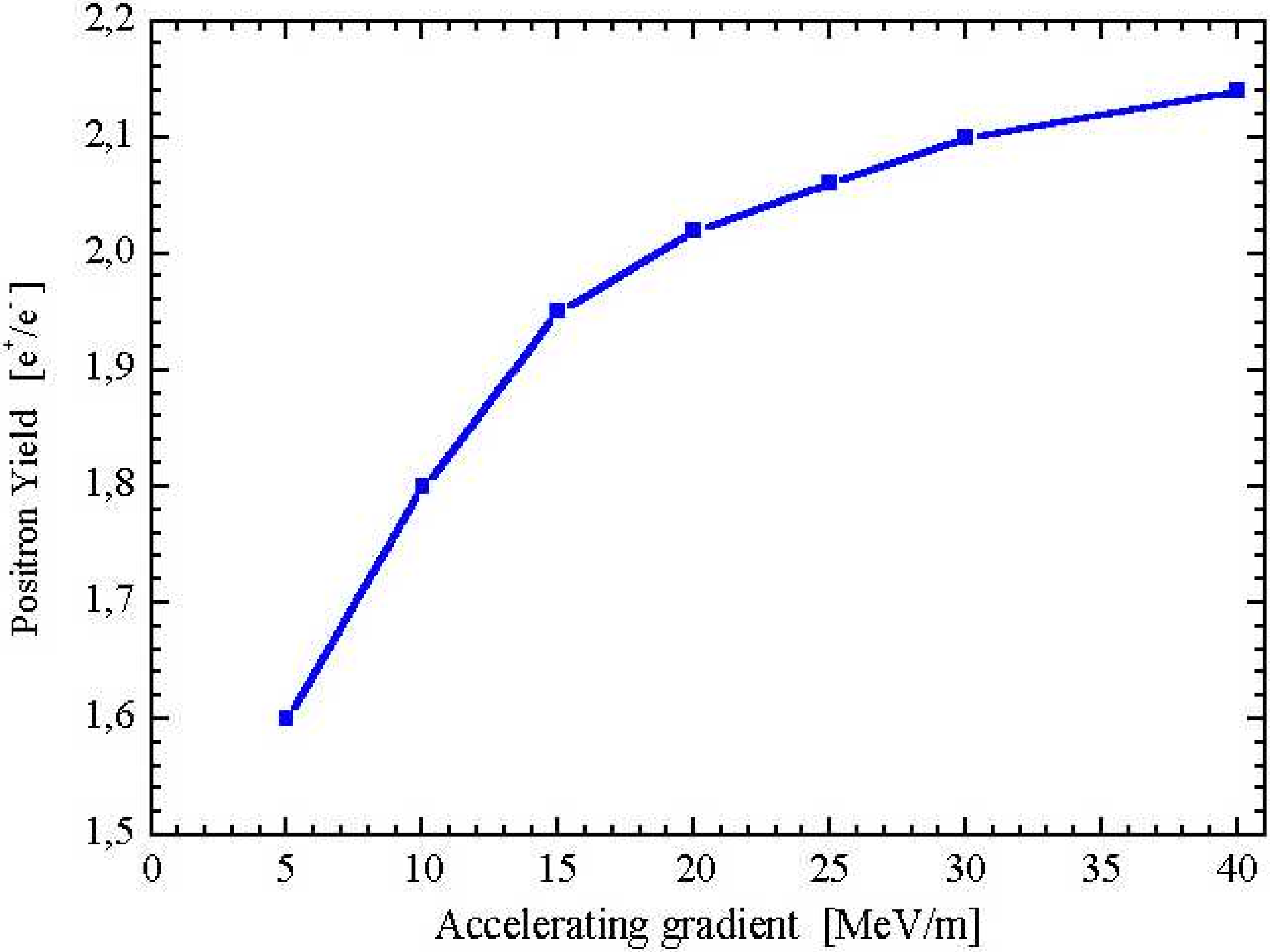
- Existing positron sources, which are in operation, haven't reached yet the limits of their application areas.
- Significant improvements in some directions may lead to about one order of magnitude increase in positron production rate for best existing installations.
- Conventional positron production technology still has some reserves for such up-to-date projects as International Linear Collider (ILC) or Super B-factory.

STOP



3 GHz
1,3 GHz
Accelerating gradient (MeV/m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
0,1
1
10
100
1000
macro pulse duration (μs)

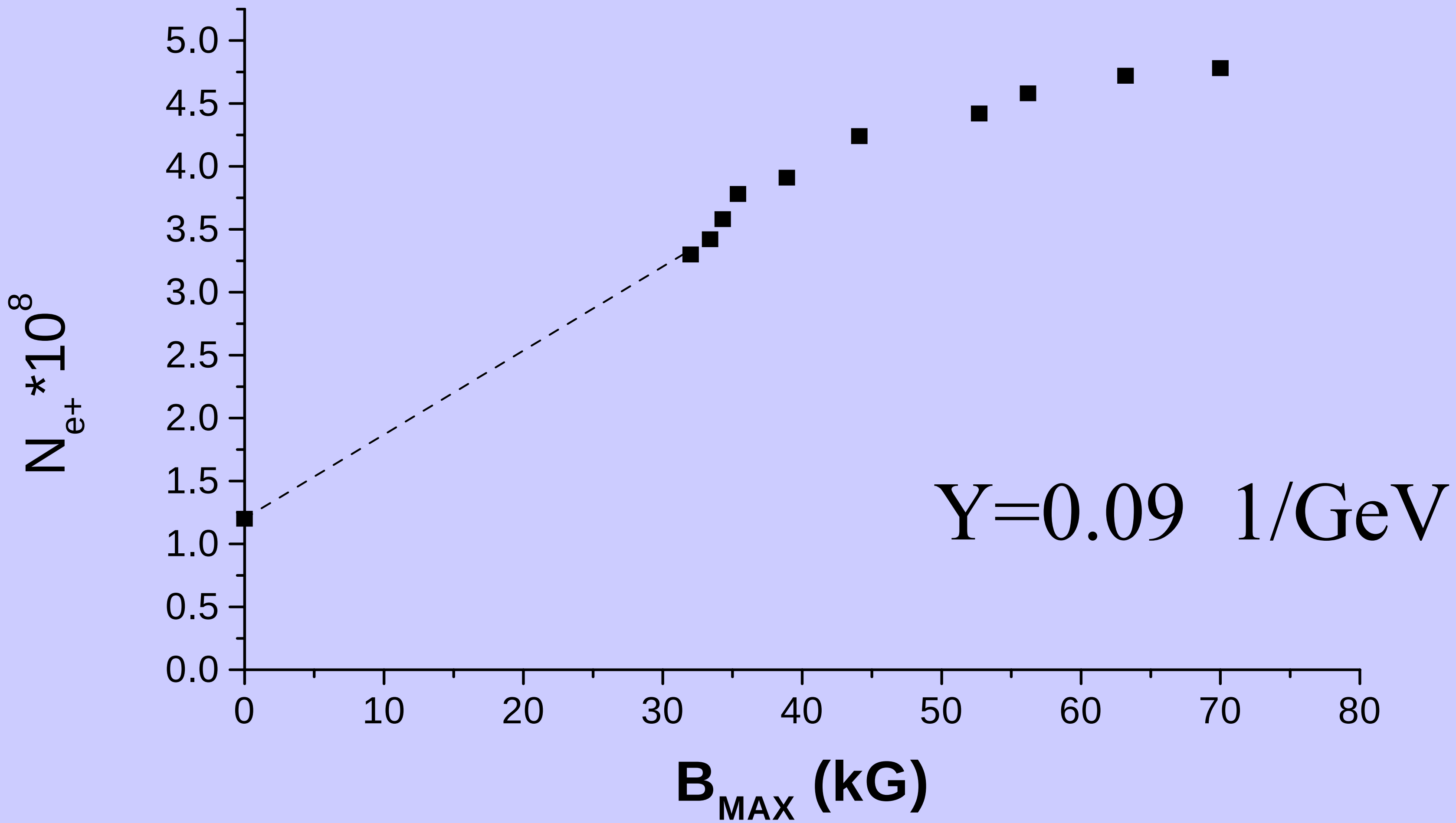
FC – ideal field, 10 T, 10 mm – input diameter, L-band, driving e- bunch Length – 0.3 mm. Acceleration up to 9 GeV. Different acc. gradient only at first 100 MeV.



The dependence of positrons number upon the maximum field in VEPP-5 FC.

Driving electron beam energy - 265 MeV.

Number of electrons in primary electron beam - $1.8 \cdot 10^{10}$



Requirements for ILC positron production target (conventional variant).

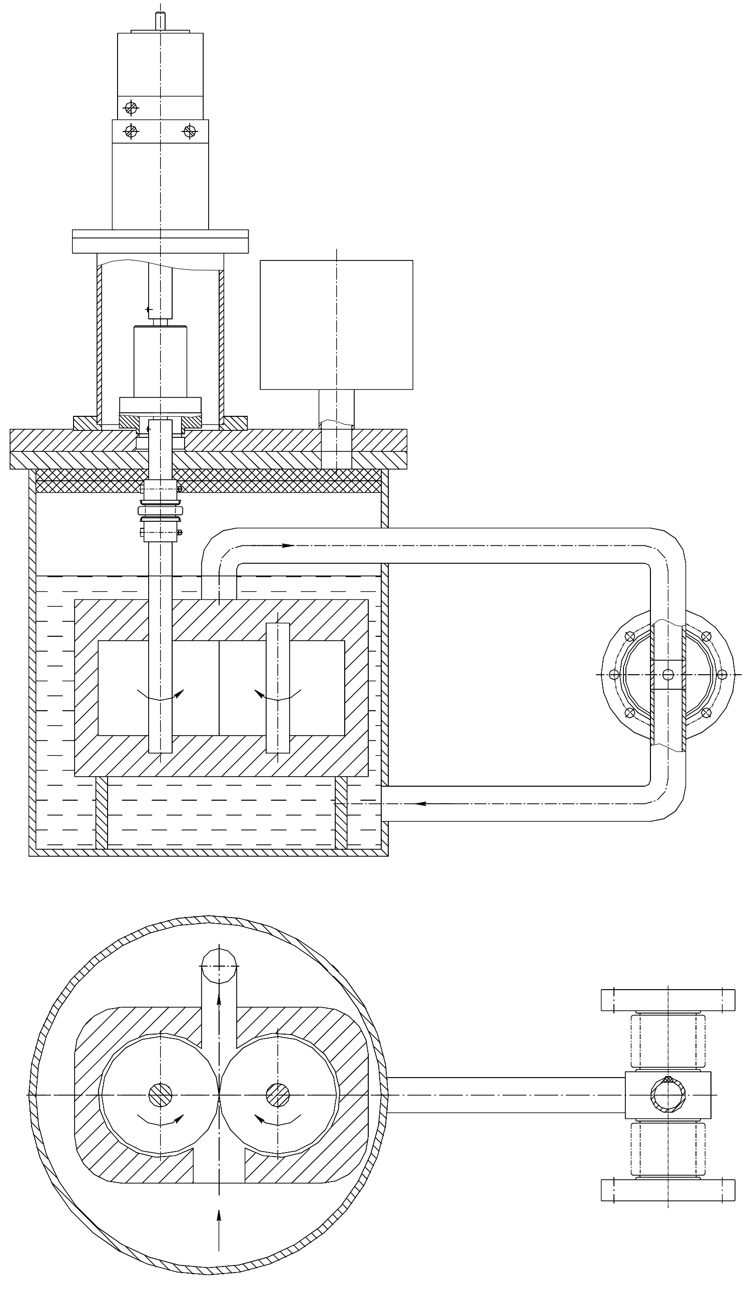
- $2 \cdot 10^{10}$ e/bunch, 2820 bunches in the train, 5 trains per second, 308 ns between bunches, 870 μs - duration of the train, driving beam energy – 6 GeV.
- Driving beam average power 270 kW, 19.2 J/bunch, heat power dissipation in Pb target – 56.8 kW(21% of driving beam), target length 5X0 (28 mm).
- Heating energy in the target - 4 J/bunch, specific energy density – 0.02 J/mm^3*bunch, temperature rising up in the hottest place of the target – 17 º C/bunch, 85 bunches (300ºC – 1750ºC), boiling point is reached in 26 μs. For jet velocity 20 m/s *0.026 ms = 0.5 mm – half of beam diameter. The maximum specific energy deposition has the same order of magnitude as a specific energy of sublimation at normal pressure. So the output window is a matter of great concern. It can be damaged by overheated lead. Necessary to test on the beam in order to find the practical limit.

The aims of liquid lead target prototype test at KEKB.

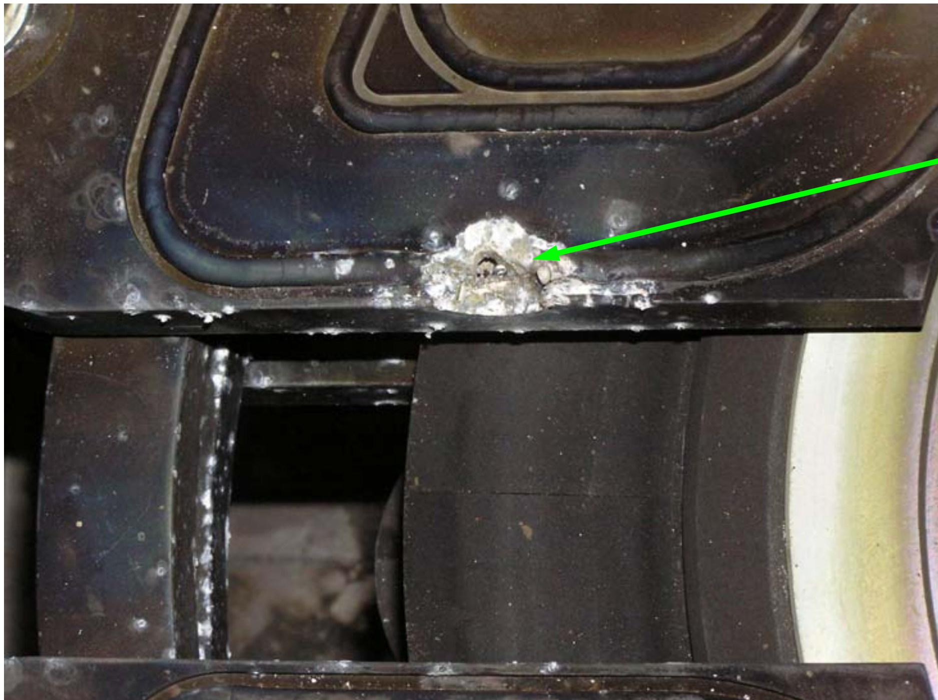
- To perform the single train test at nominal energy (8 GeV) with optimum target length.
- To establish the practical single train energy dissipation limit for liquid lead target head.
- To demonstrate the proper operation of beam line vacuum shielding and target itself in the case of complete destruction of the target head.

Parameters of the test at KEKB.

- Length of the scanning trajectory – 50 mm.
- Alloy volume interacting with the beam – 1.46 cm^3.
- Mass interacting with the beam – 15 g (0.54 K/J)
- 35000 J per pulse for 4.5 X0 of the target length – 19600K.



Finish of experiment. Second water accident.



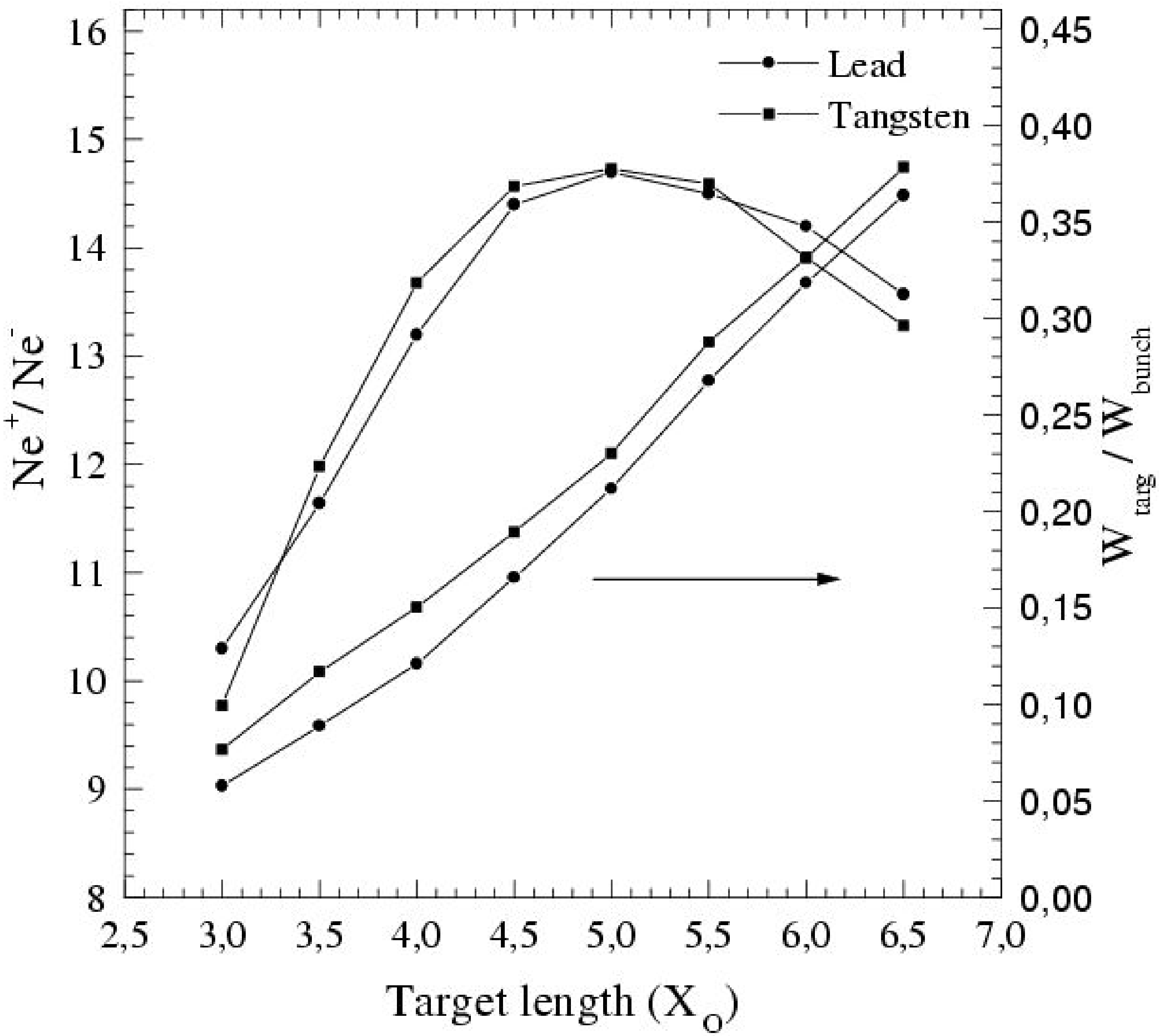
Reason – the beam of full power got to aluminum cooling cannel.

The whole of prototype volume was Filled by water.

Results:

- all another prototype system does not have any damages.

Comparison of Tungsten and Lead Targets for 6 GeV driving electron beam




VEPP-5 FC magnet