Advanced e+ source

High possibility to make reliable target system using liquid lead target and S-band linac as one of advanced e+ source for ILC.

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ILC positron sources

1) undulator-based e^+ source

base line choice

1st stage: non-polarized source

later: upgrade to polarized source

2) Compton-based e^+ source

advanced alternative

polarized source

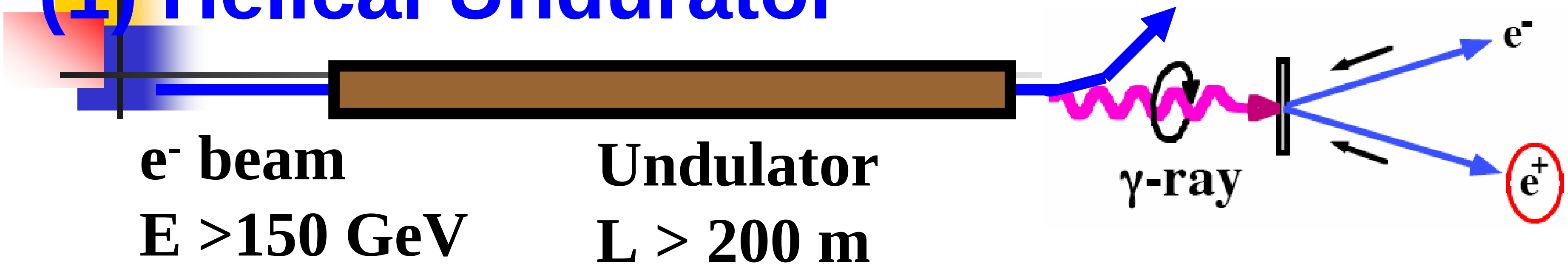
3) Conventional e^+ source

back up

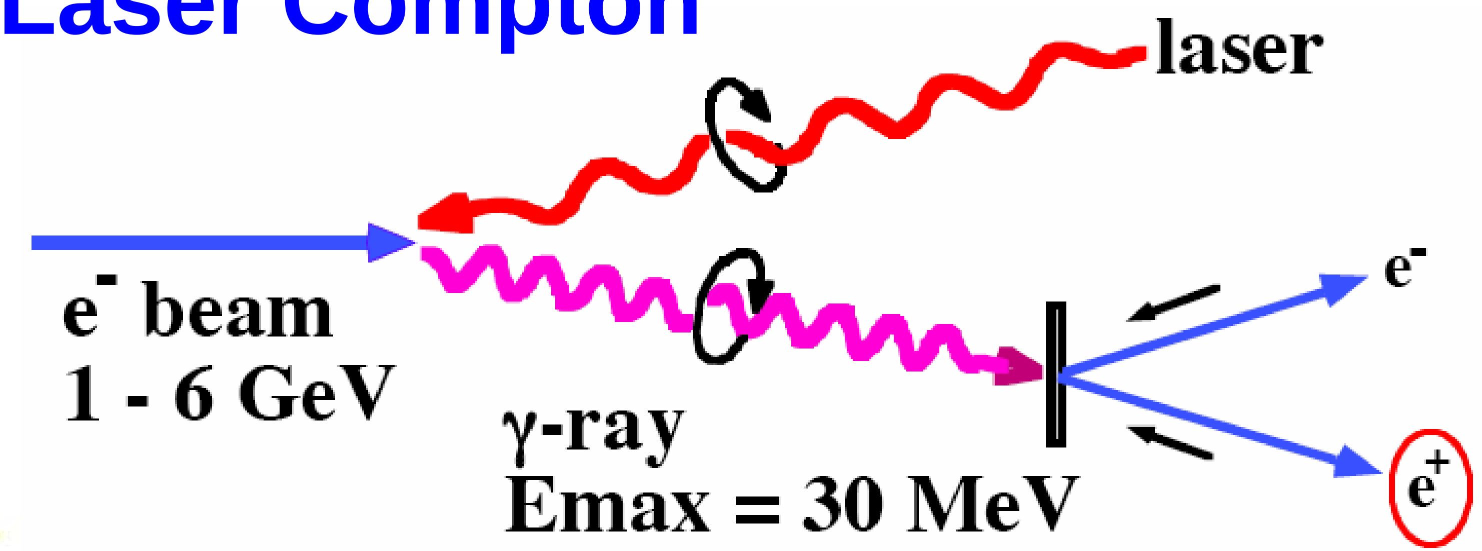
non-polarized source

Two ways to get pol. e^+

(1) Helical Undurator

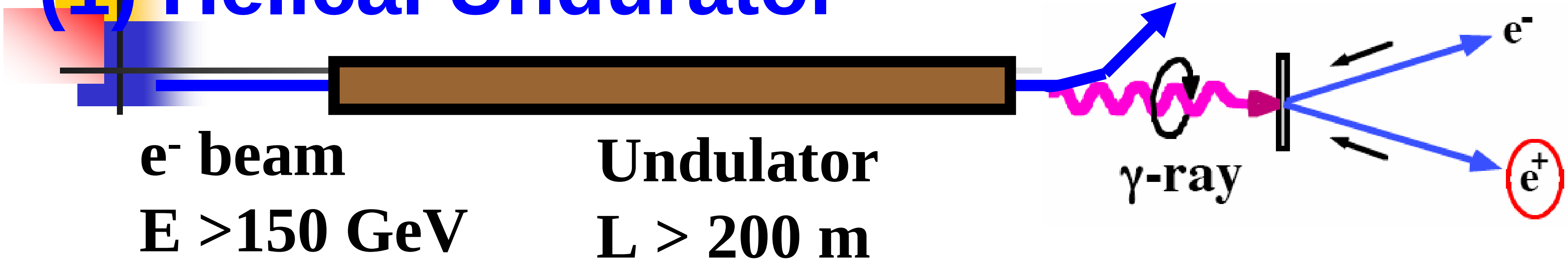


(2) Laser Compton



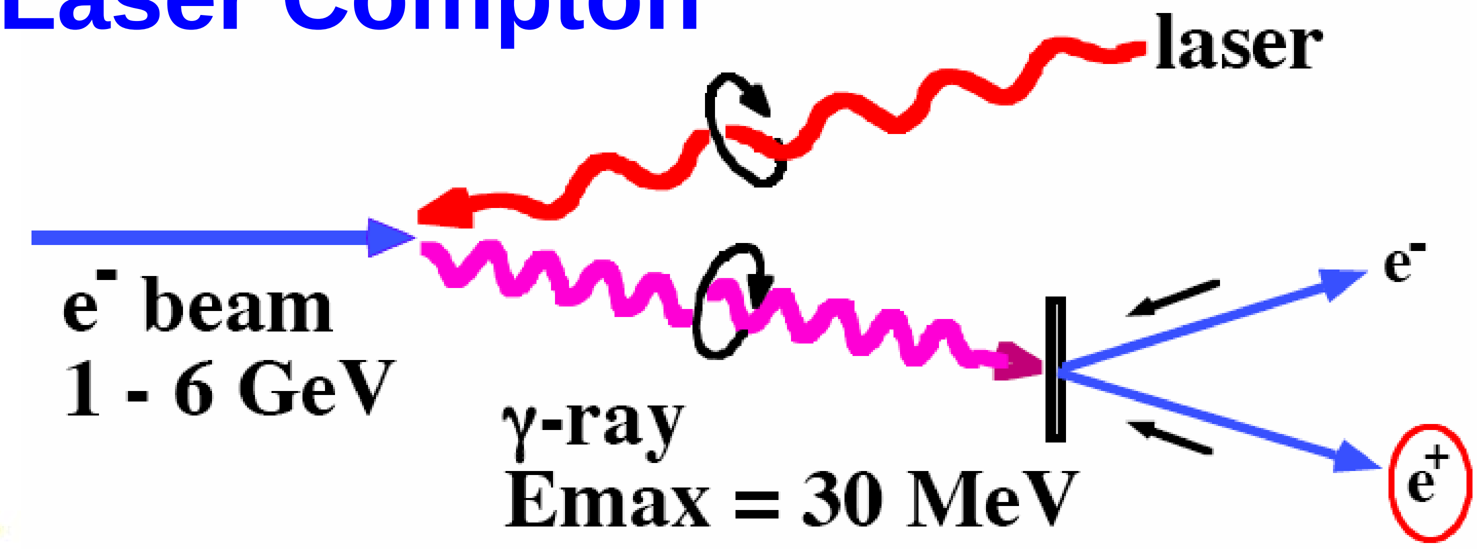
Two ways to get pol. e^+

(1) Helical Undurator



Our Proposal

(2) Laser Compton



Why Laser Compton ?

also liquid target and conventinal target.

i) Independence

Undulator-base e^+ : use e^- main linac

Problem on design, construction, commissioning, maintenance

Laser-base e^+ : independent

Easier construction, operation, commissioning, maintenance

ii) Low energy operation

Undulator-base e^+ : need deccelation

Laser-base e^+ : no problem

Advanced e+ source
New Target : Liquid Lead

Liquid Lead Target
Question: Can Liquid Lead Target (& BN window) survive the 3000-bunch-creation in 1 m sec?
Answer: No
BN window is OK against shock wave. BN window is broken by heat. Lead evaporates.

Solution: e+ Creation in 100 m sec --> 100 bunches/train x 300 Hz S-band Linac operation
BN window is OK for 100 bunches.
Lead dose not evaporate with 100 bunches.
Lead move 32 mm in 3.3 msec, then heat is removed.
(speed of lead = 10 m/sec)

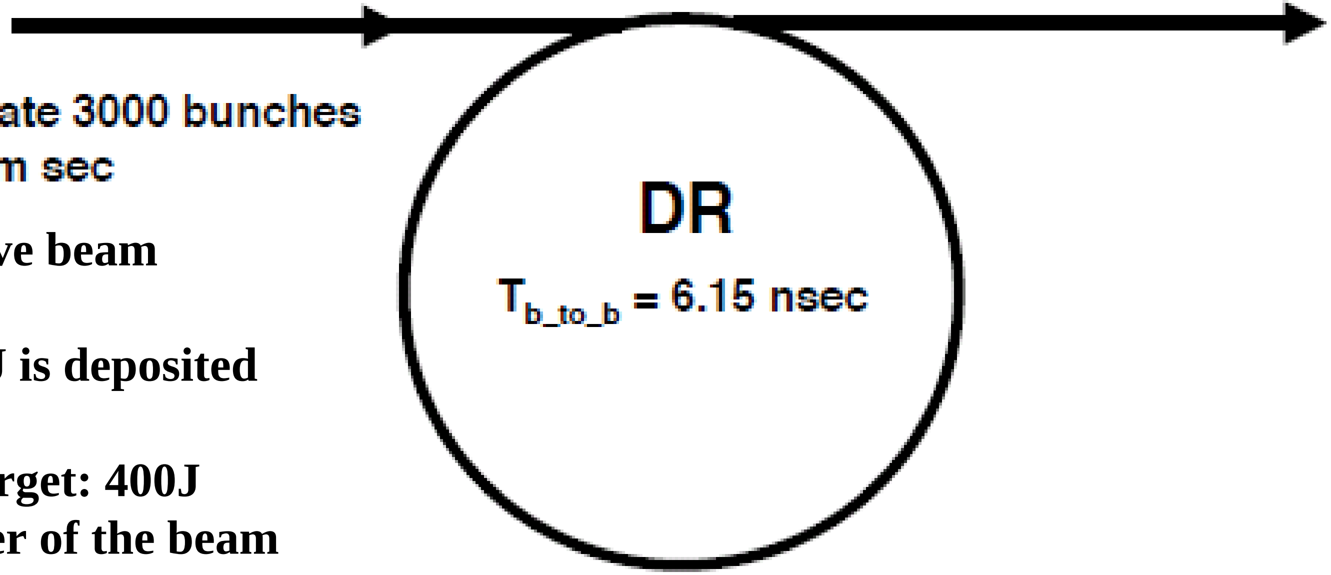
e+ creation

100 bunches/train x 300 Hz
$T_{b\_to\_b}$ = 6.15 nsec

go to main linac

3000 bunches/train x 5 Hz
$T_{b\_to\_b}$ = 300 nsec

We create 3000 bunches
in 100 m sec



Time for damping = 100 m sec which requests about 14msec damping time.

total energy of the drive beam bunch: 2000J
Assume 20 % of 2000J is deposited in the target.
every deposit in the target: 400J
Assume 5 mm diameter of the beam on the target. Weight of the target :
5.6 g =0.0056 kg for 4.5 r.l.
(2.5x2.5x3.14x28x11gx10x{-3} = 5.6g)
28mm correspond to 4.5 r.l.
ΔT = 400J / (140J/K*Kg) / 0.0056Kg= 510K

14msec damping time is requested to DR Area Group.
Table : The 300 Hz Conventional e+ Source Option with Liquid Lead Target
bunches/train : 100, repetition rate: 300 Hz (We can create 3000 bunches in 100 m sec.)
drive beam energy: 6 GeV, bunch-to-bunch separation: 6.15 n sec
pulse length 615 n sec (6.15x100)

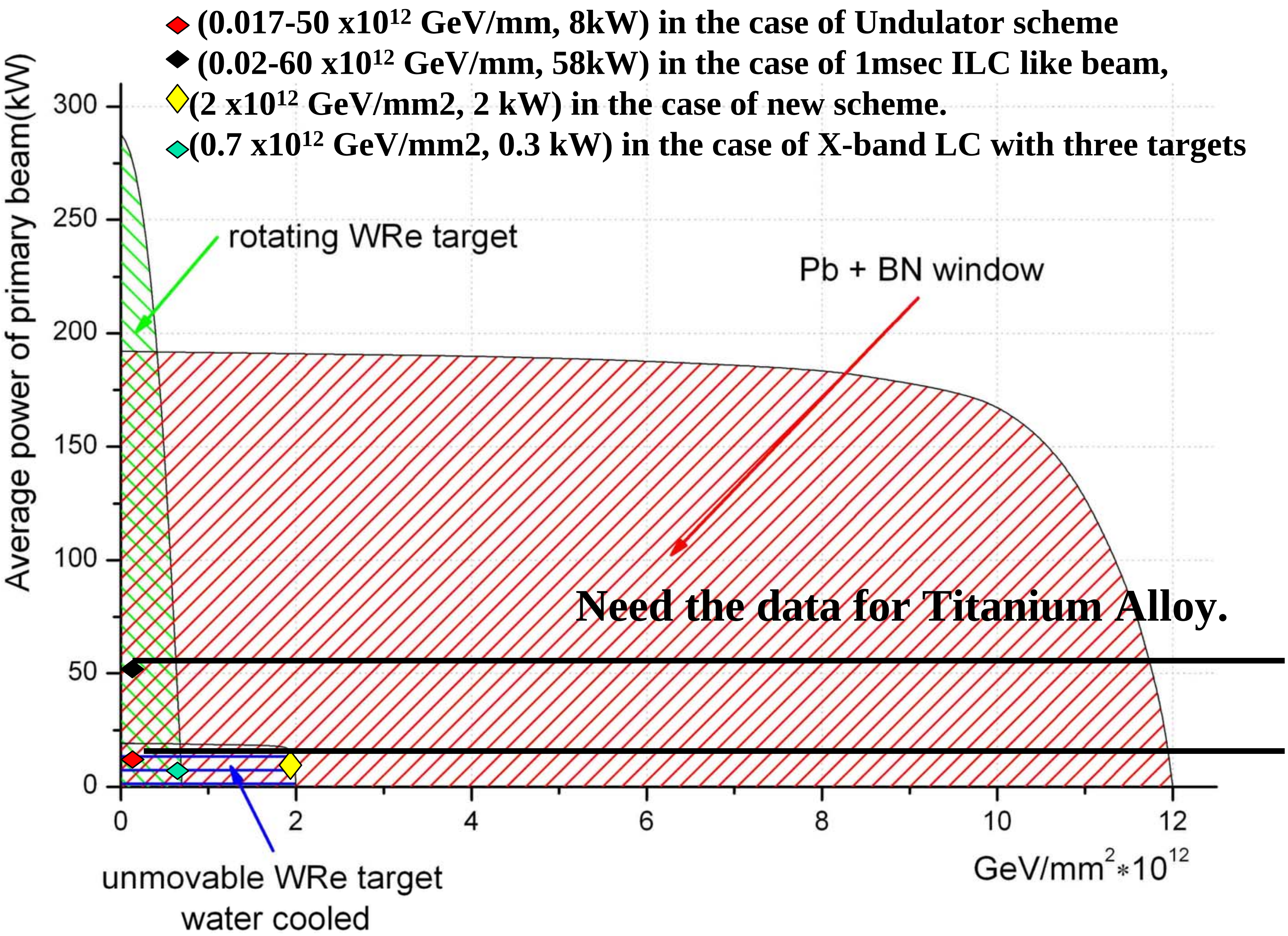
Rough Estimation of beam power and density on target

1. Undulator Scheme, γ-beam requirement for ILC positron source :
5 x 10^{15} at 10 MeV γ is enough to generate necessary positron beam.
5 x 10^{15} x 10 MeV=8 kJ / 1msec, 8 kJ/1.6x10^{-19} =50 GeV/mm^2 x10^{12}
(0.017-50 x10^{12} GeV/mm^2, 8 kW)

2. Conventinal Scheme, 1m electron beam generates positron :
6 GeV, 2x10^{10}, 1msec electron beam can generate necessary positron beam.
6 x 10^9 x2x10^{10} x 3000 =58 kJ , (0.02-60 x10^{12} GeV/mm^2, 58 kW)

3. New scheme using liquid lead target and S-band linac
100 bunches/train x 2 x 10^{10} x 6GeV =2000J, (2 GeV/mm^2 x 10^{12},2kW)
300Hz Operation

4. X-band Linear Collider positron source target
Assuming 150Hz operation, 192 bunches/train, 1.4nsec, 0.79 x 10^{10}
We need three targets for keeping target safe.
6GeV, 0.79x10^{10}, 300nsec pulse width, 6 x 10^9 x0.79x10^{10} x 192 = 0.91kJ
Need three rotating target (4.5 r.l. WRe), 0.91kJ/3 = 0.3kJ
1.92x10^{12} GeV/mm^2 , 1.92/3=0.7 x 10^{12} GeV/mm^2
This is reason for three targets. (0.7 x10^{12} GeV/mm^2, 0.3 kW)


(0.017-50 x10^12 GeV/mm, 8kW) in the case of Undulator scheme
(0.02-60 x10^12 GeV/mm, 58kW) in the case of 1msec ILC like beam,
(2 x10^12 GeV/mm2, 2 kW) in the case of new scheme.
(0.7 x10^12 GeV/mm2, 0.3 kW) in the case of X-band LC with three targets
Average power of primary beam(kW)
300
250
200
150
100
50
0
rotating WRe target
Pb + BN window
Need the data for Titanium Alloy.
0
2
4
6
8
10
12
GeV/mm^2*10^12
unmovable WRe target
water cooled

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.

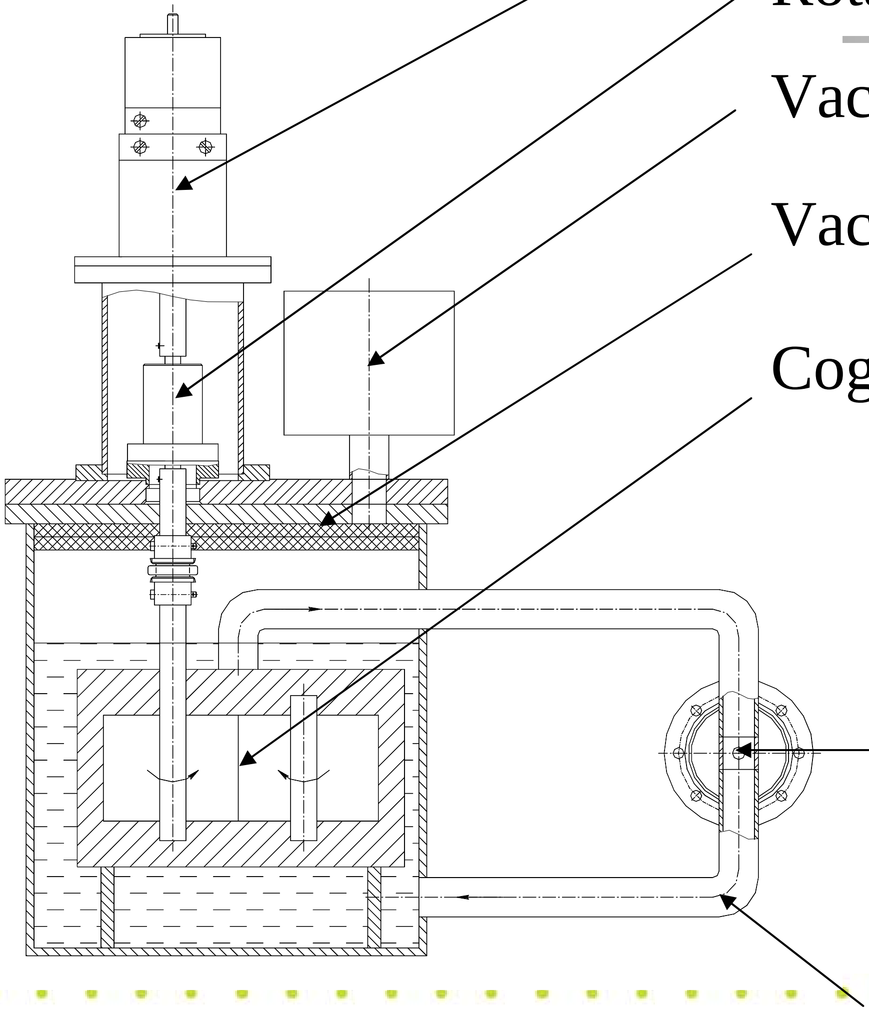
The basic directions of R&D

- High power liquid lead target in comparison with rotating solid-state WRe target.
- Effective matching device (Flux Concentrator, 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.

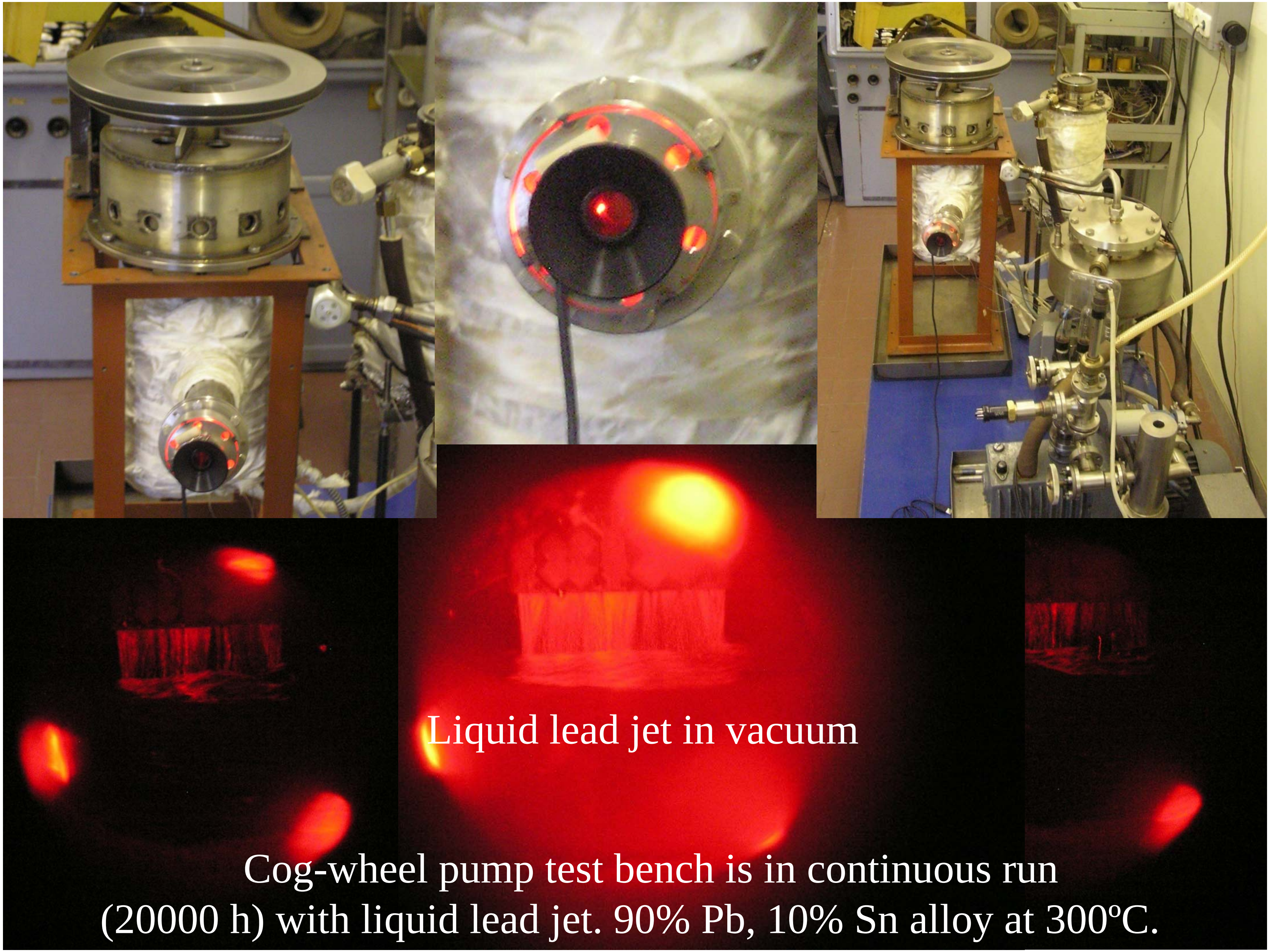


The present stage of BINP activity in liquid lead target development.

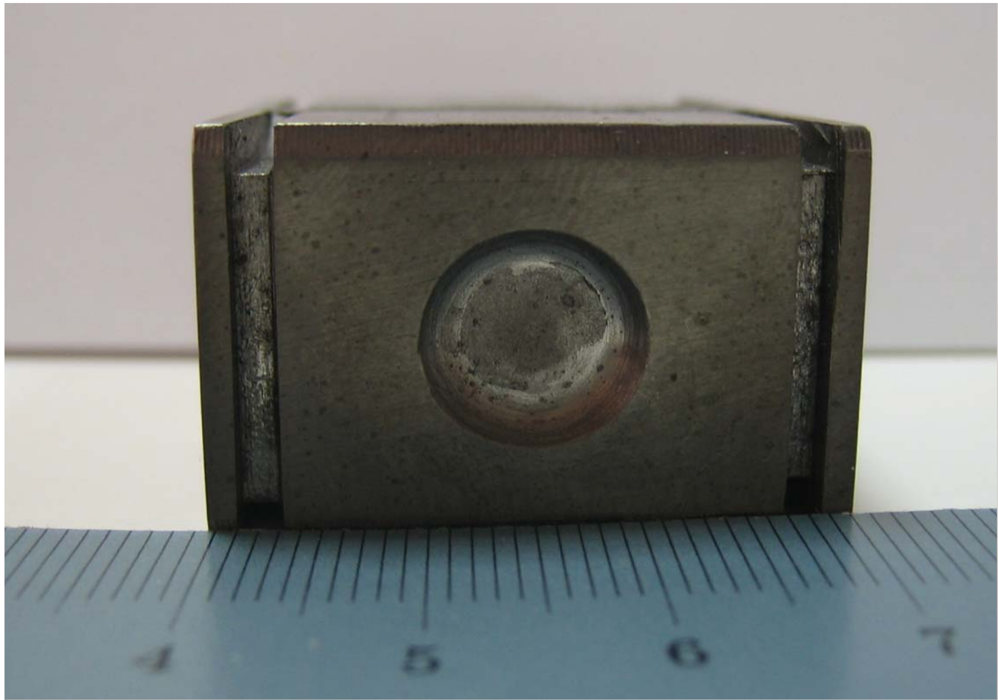
- 20000 h of liquid lead contour successful run with cog-wheel pump has been reached (90% Pb, 10% (mass)Sn alloy, 300ºC).
- The shock-wave test of BN windows showed the dynamical stretch limit at the level of 39 GPa. For previous NLC design the value of 3-4 GPa was estimated. For present ILC variant this value will be even less (about 0.01 GPa) due to longer macro pulse.

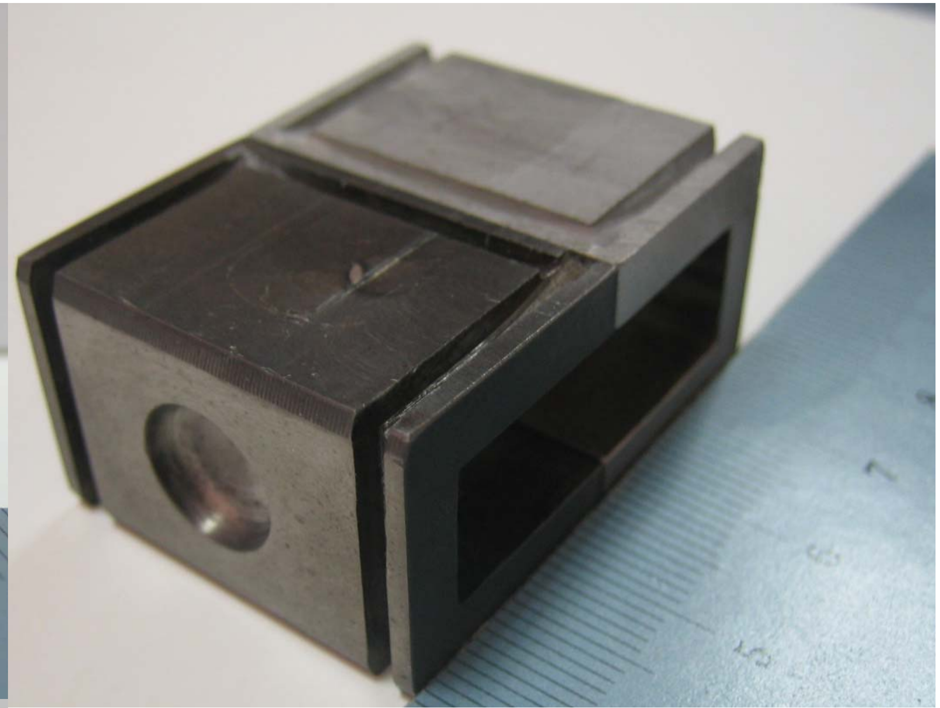
  （Above description is wrong, I think. Ask Pavel soon.）
- The test of window braising technology successfully finished.
- The prototype of liquid lead positron production target is under commissioning now. This prototype is specially designed for output window destruction test on KEKB.

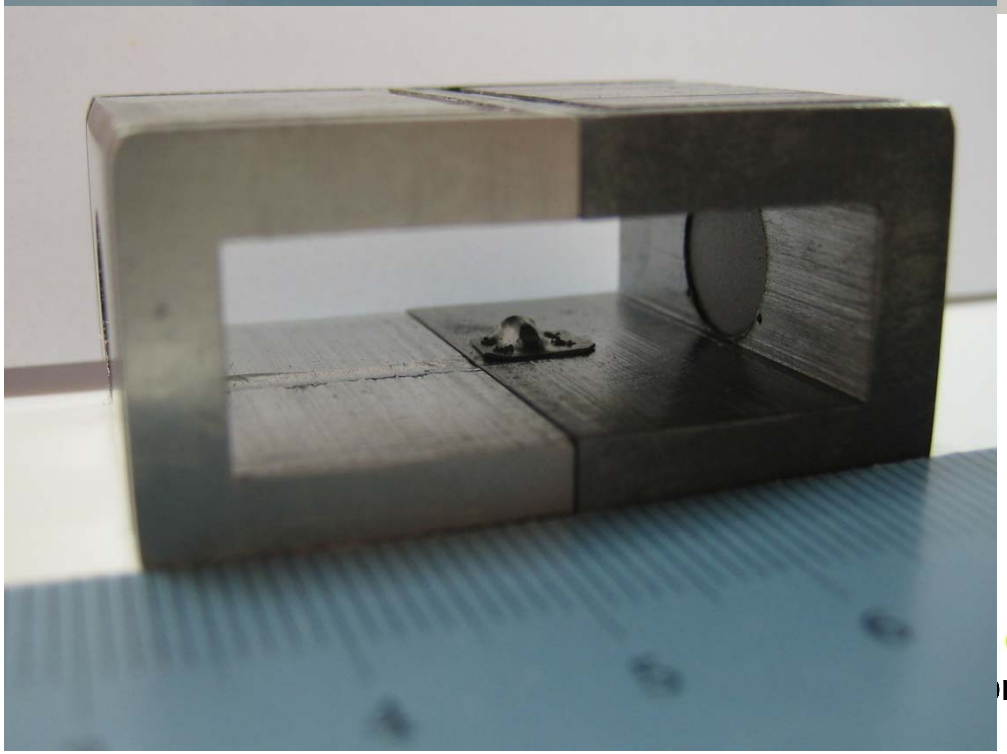
The parts of liquid lead cog-wheel pump



Cog-wheel pump test bench is in continuous run (20000 h) with liquid lead jet. 90% Pb, 10% Sn alloy at 300ºC.

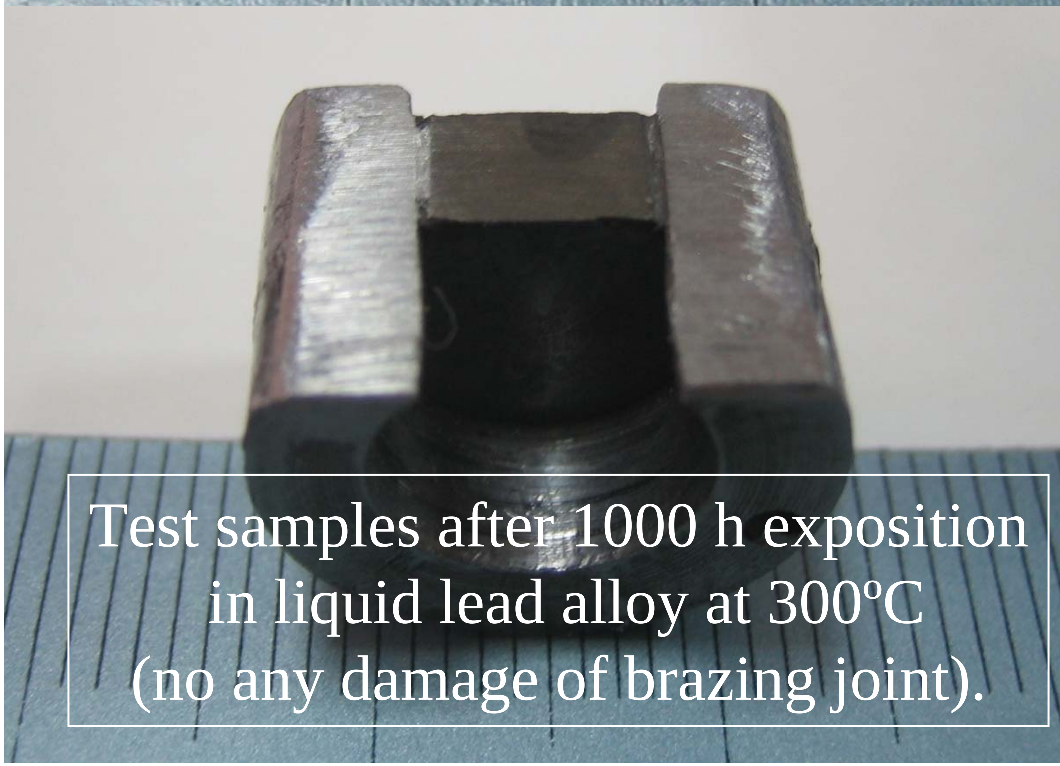




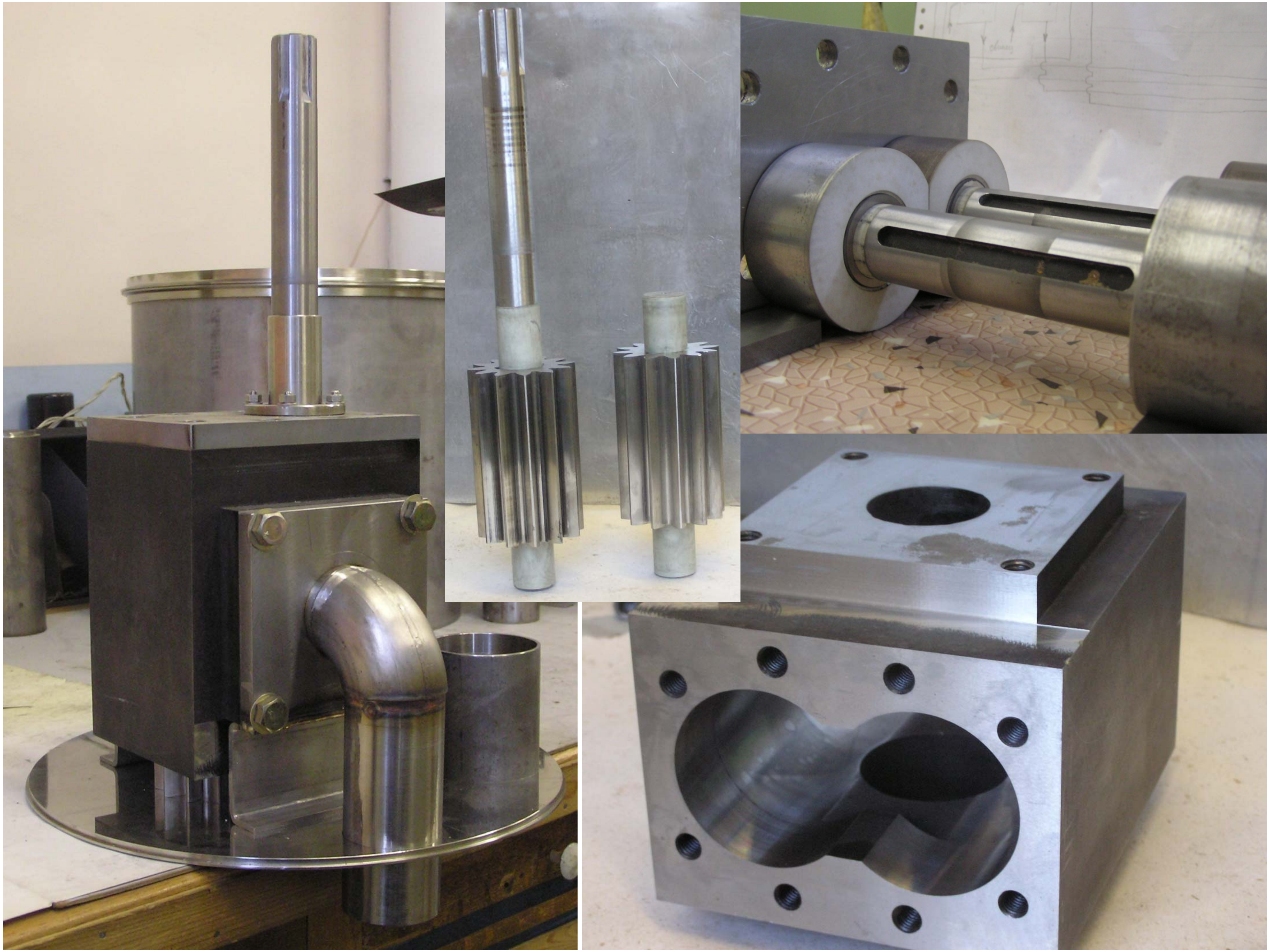


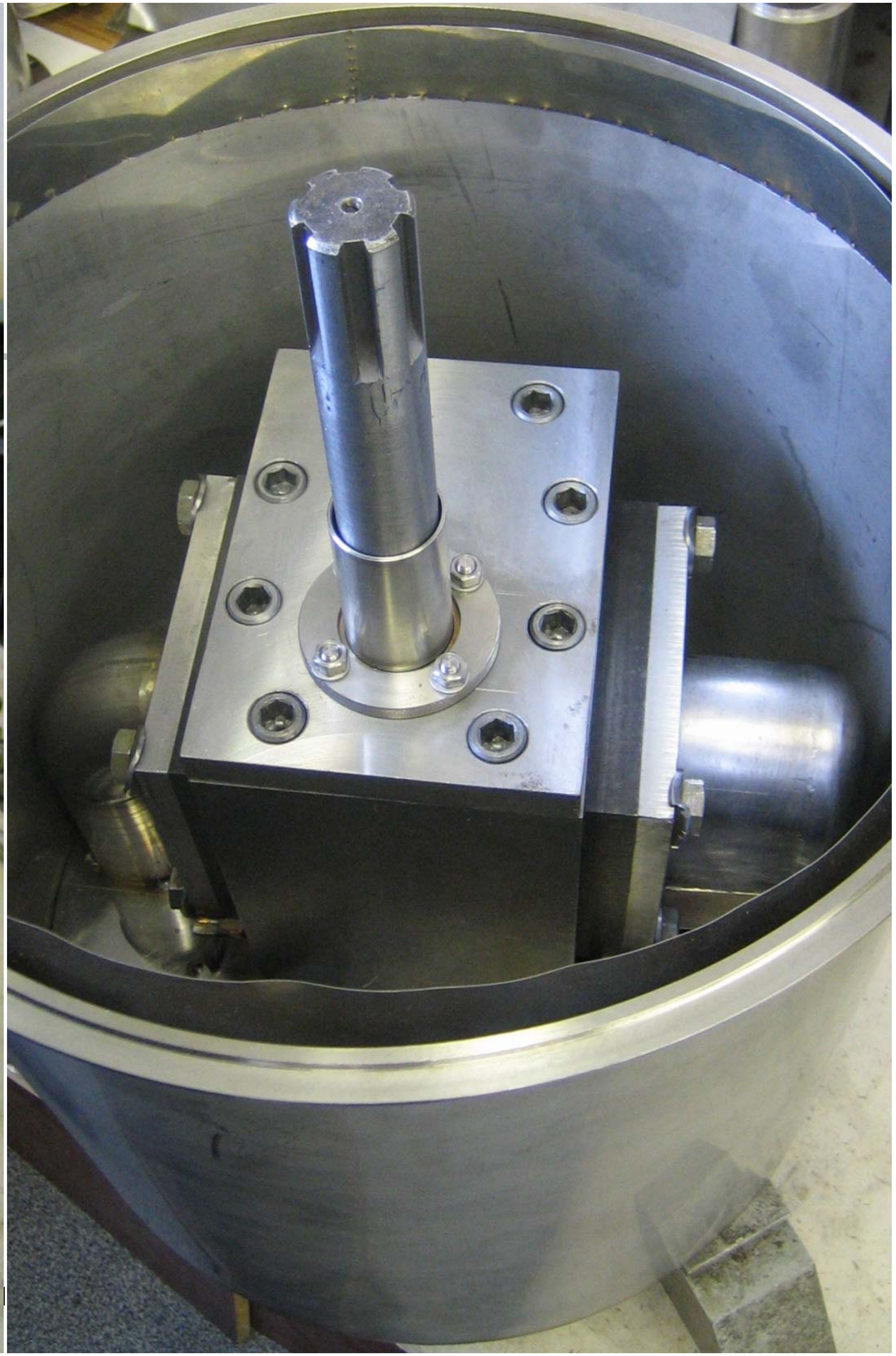
Prototype of target head with BN windows.

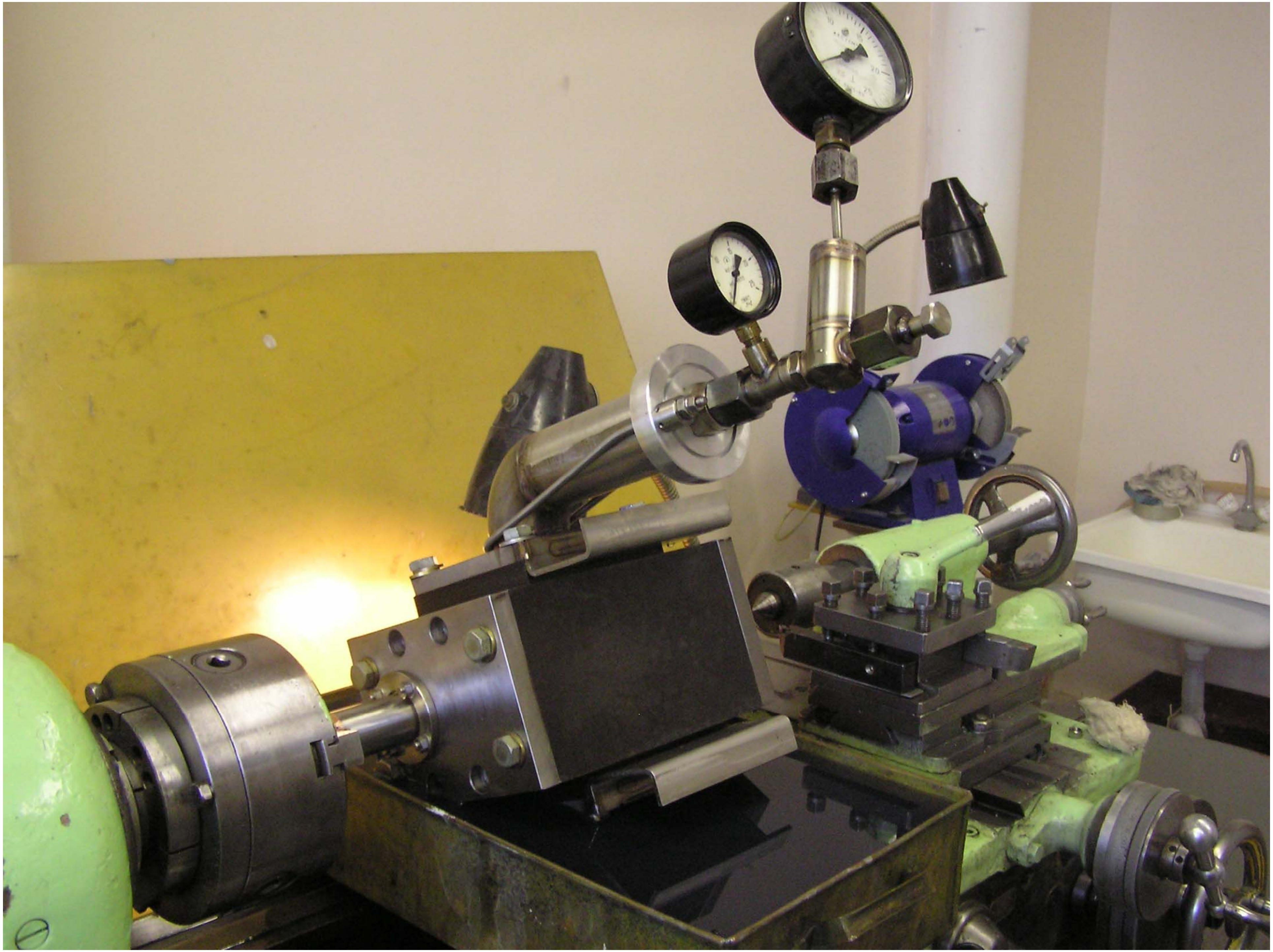
BN disks for windows



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





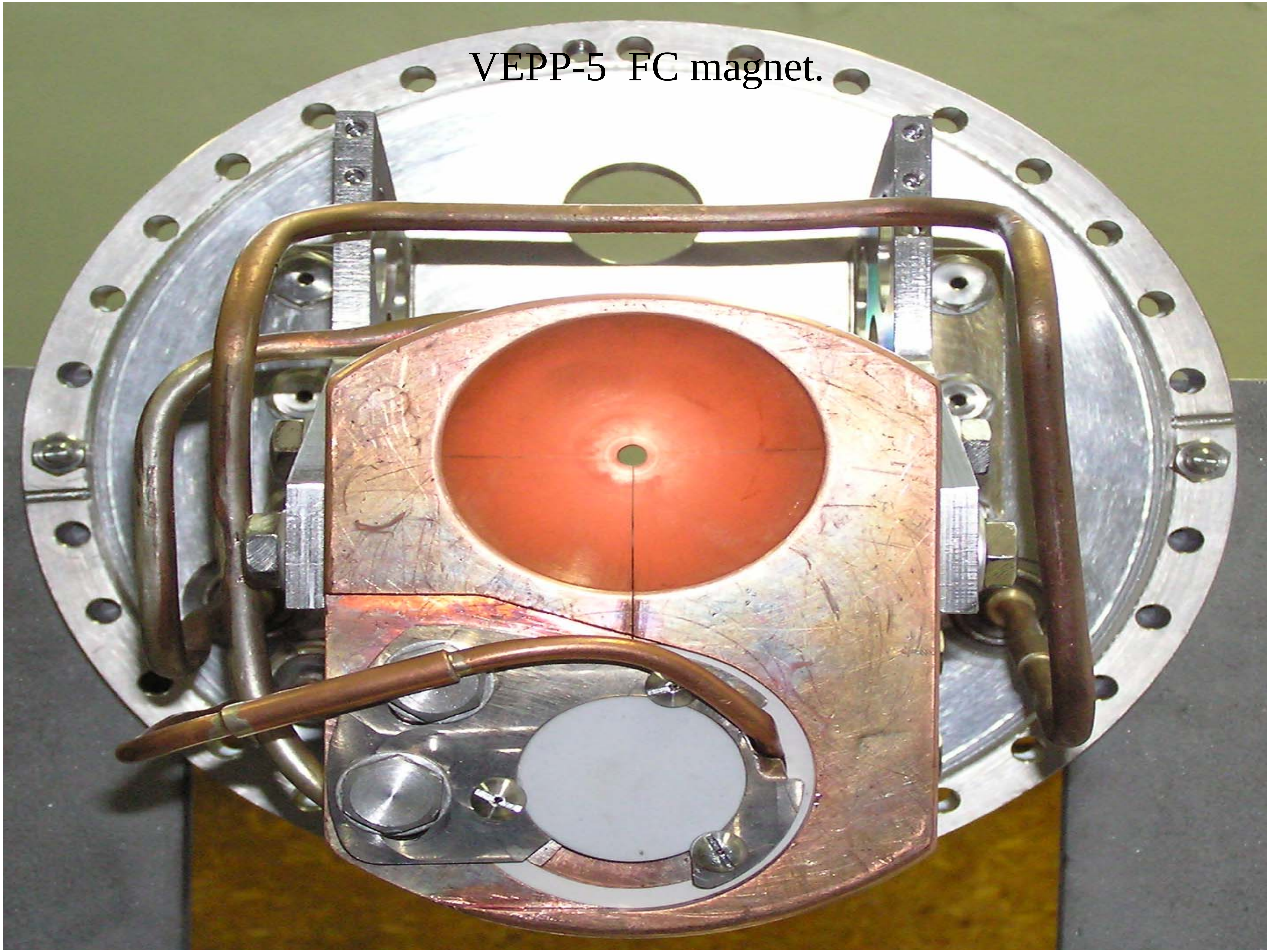


The present stage of BINP activity in Matching Device development.

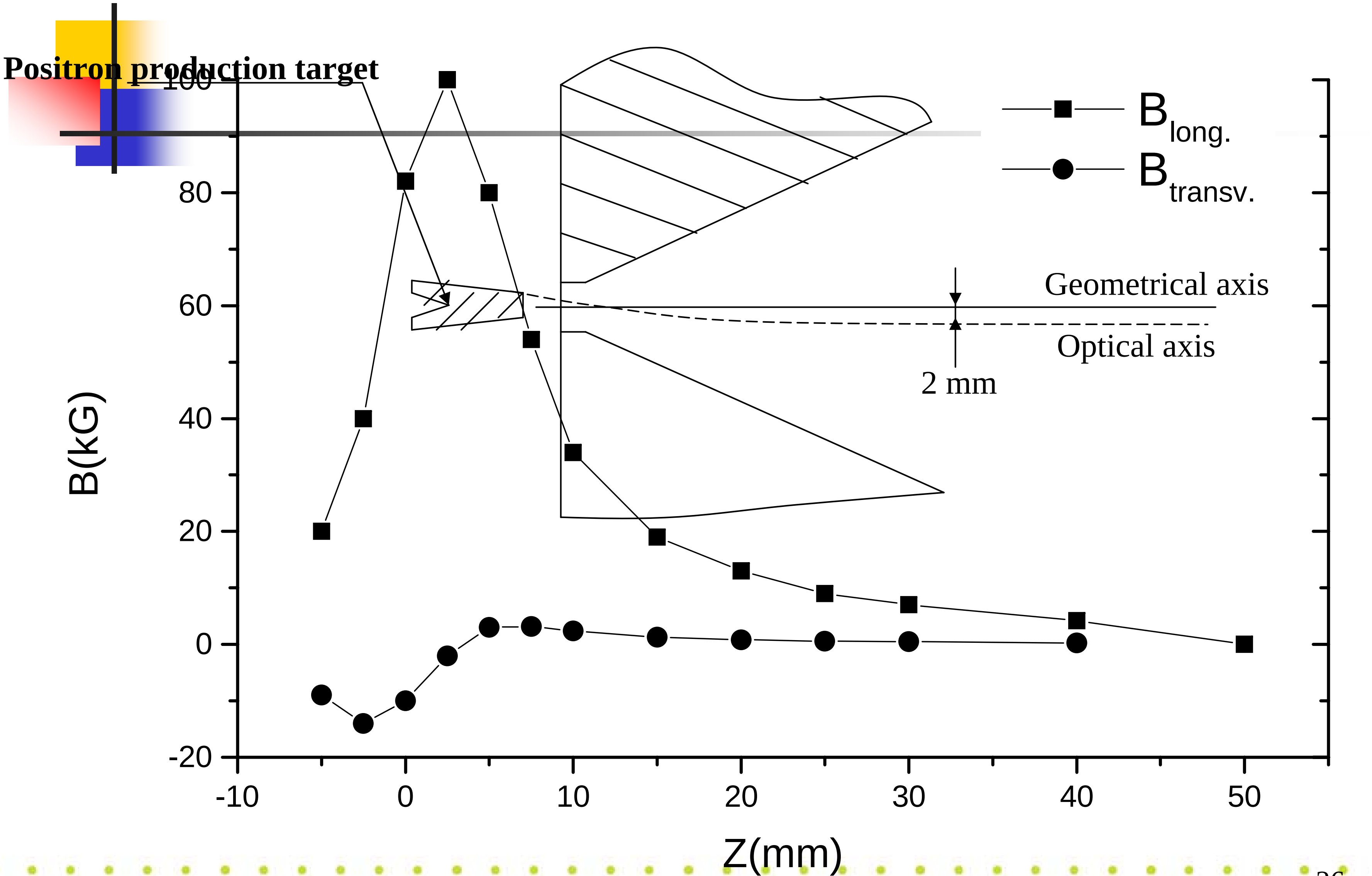
- The successful test of VEPP-5 positron production system was performed. Flux Concentrator magnet (FC) was tested up to 70 kG (30 μs pulse duration) without saturation in positron yield.
- The investigation of the technical limit for maximum FC pulse duration is in progress.
- Flat face FC for 30 μs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

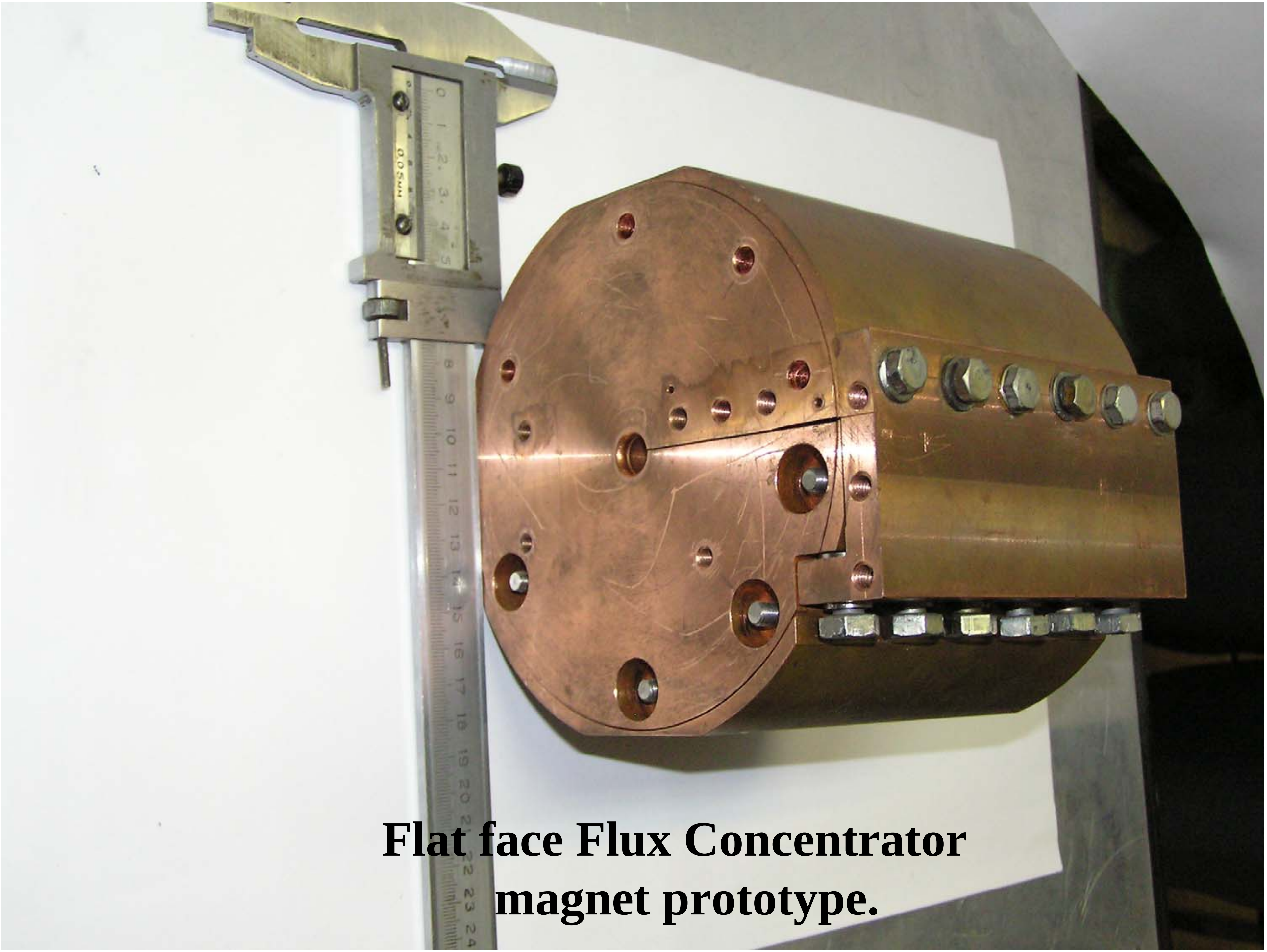

Positron system of VEPP-5 Injection complex
in BINP.
СТОЙ
НАПРЯЖЕНИЕ

VEPP-5 FC magnet.



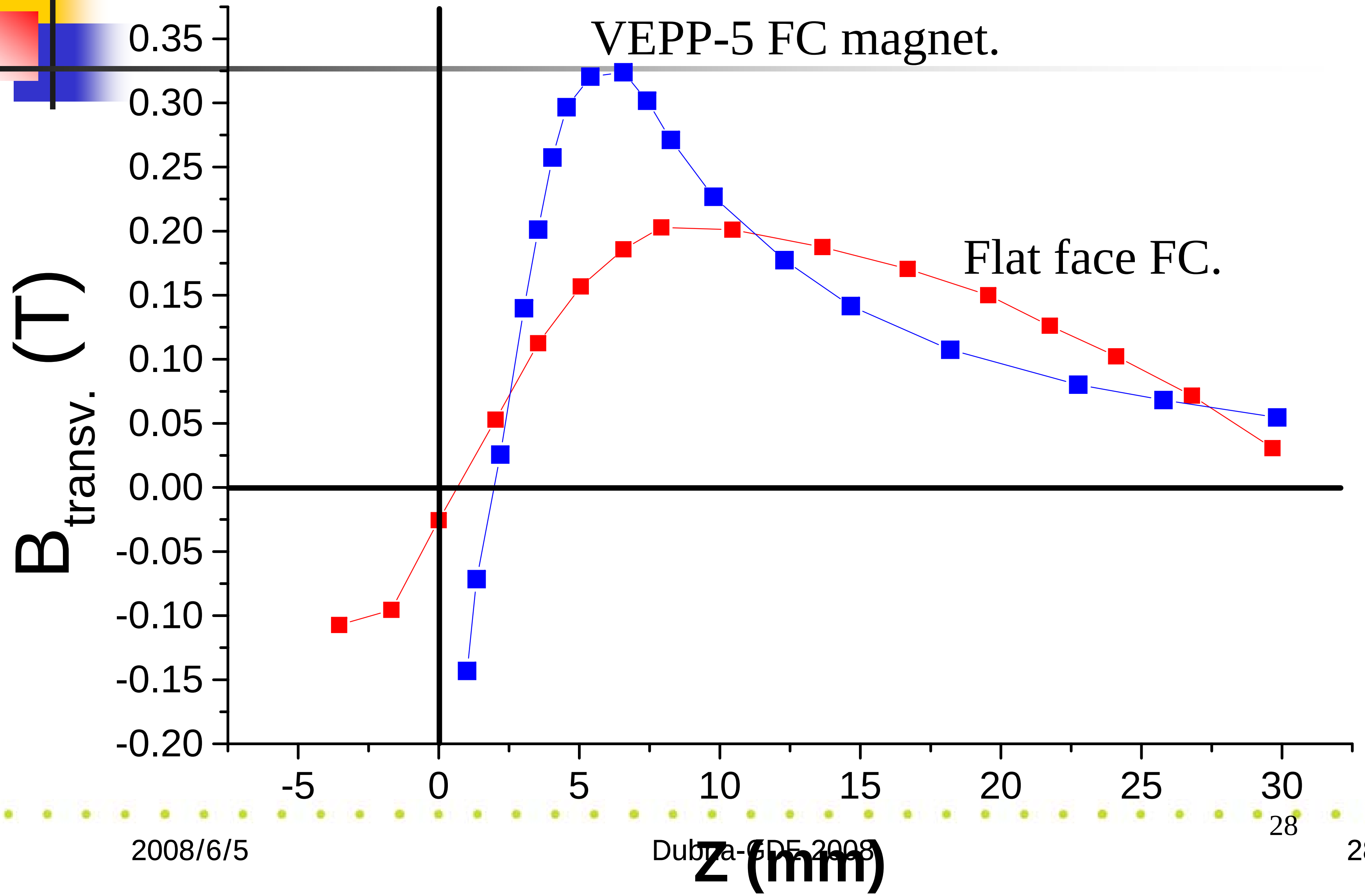
The dependencies of longitudinal and transverse magnetic fields on the geometrical axis of VEPP-5 FC magnet (measurements).





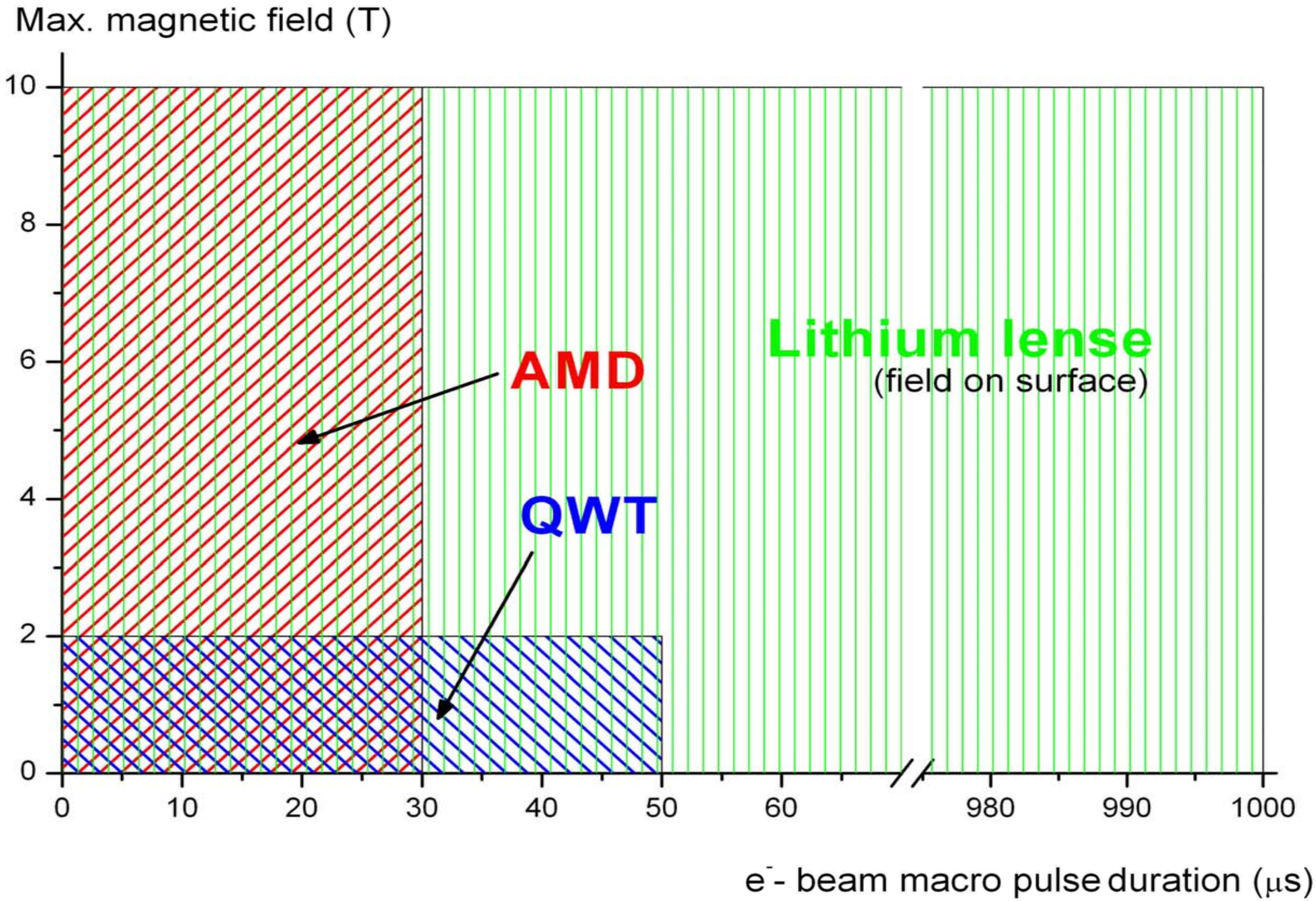
Flat face Flux Concentrator magnet prototype.

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.


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.

My summary on new target

- Enough margin as reliable positron source system.
- Use usual injection kicker system.
- Use mature technology on AMD---
- Mini-bunch train : 50 to 200 bunches/pulse.
- Require about 14msec damping time, we consider 3km double ring or increase damping wigglers.
- Need the test of BN window and liquid lead target with KEKB Ampere beam. Small hall is necessary.