THE STATUS OF POSITRON SOURCE DEVELOPMENT AT CORNELL

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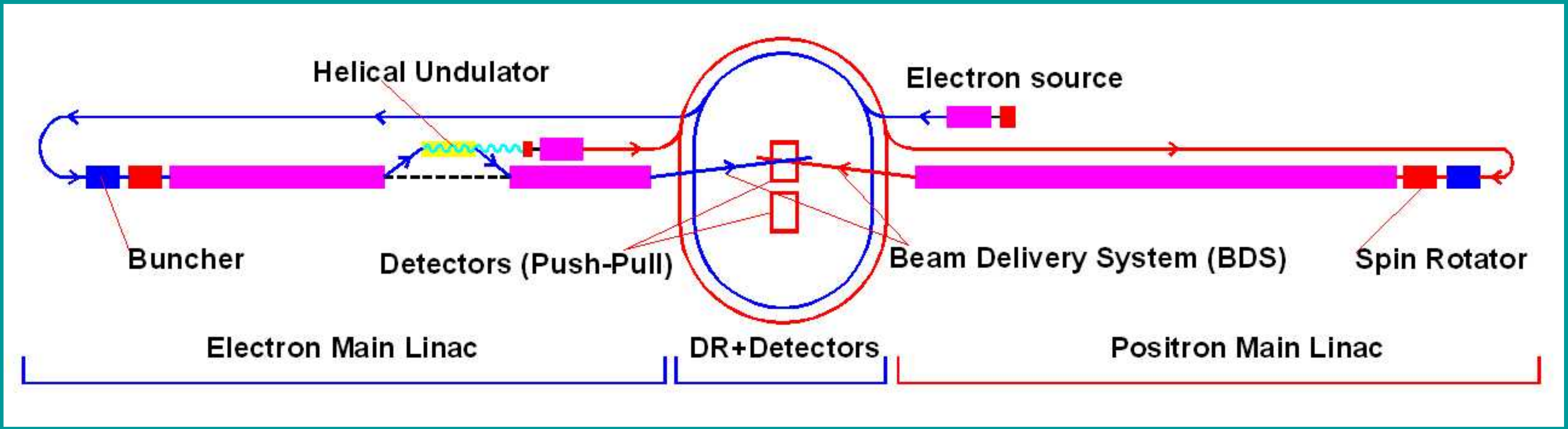
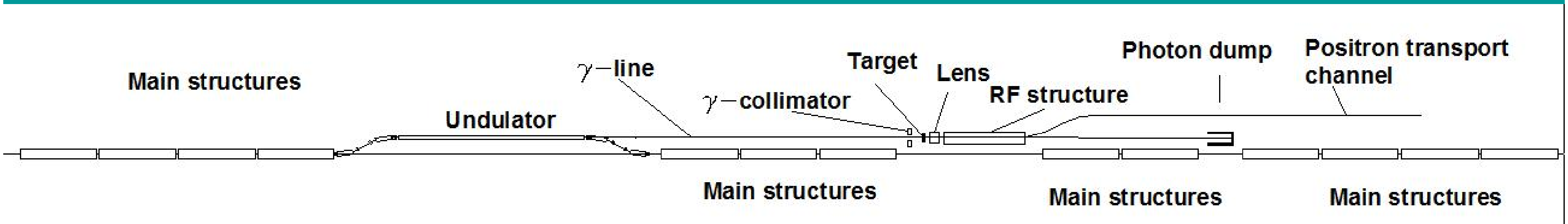
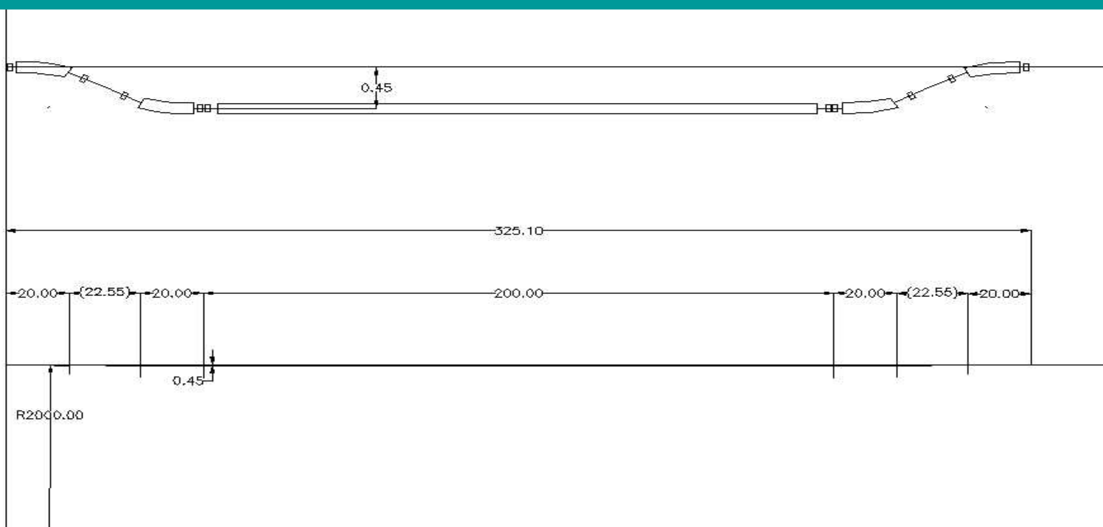
Positron Source Meeting, Sep 17-19, 2007 Argonne National Laboratory

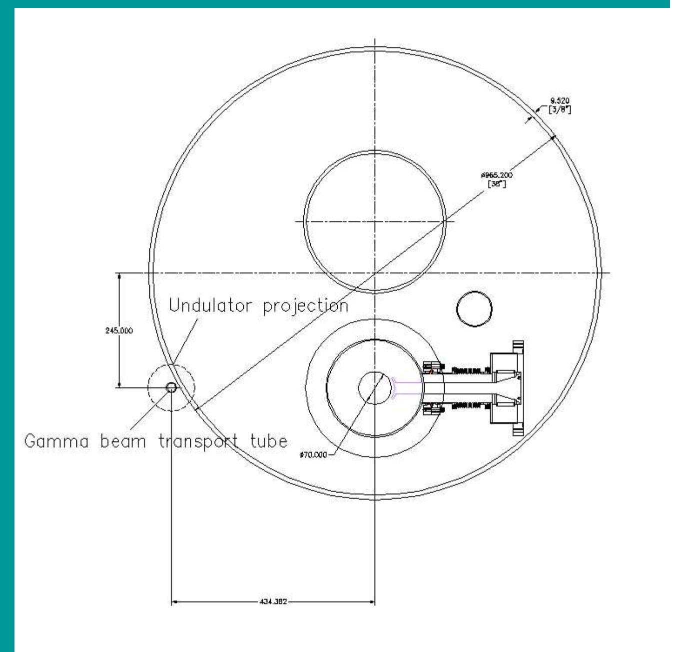
GENERAL WIEV



Preliminary remark

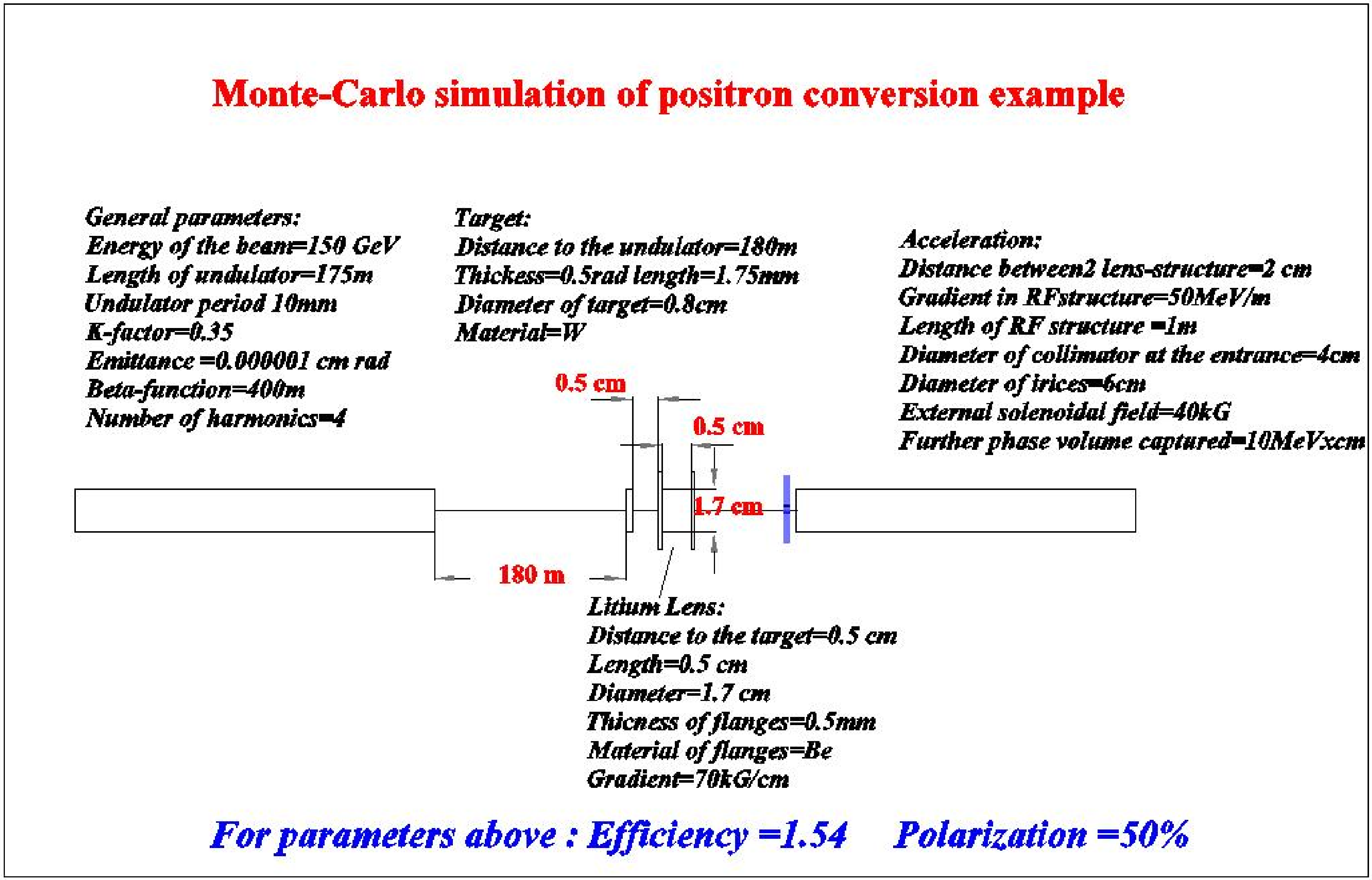






Tasks	Description	Time frame	Cost (pre-preliminary)
Monte-Carlo code for simulation of conversion	•Choice of undulator parameters (period, K, aperture) •Choice of target dimensions (thickness, Ø) •Choice of collection optics parameters (type, efficiency—Li lens dual layer solenoid)	2007-2008	30k$
Undulator design	•Design and fabrication of modular cryostat •System for magnetic measurements (4 m) •Alignment, pumping, pickups •String setup of 4 m long undulator	2008-2009	200k$+150k$
Target design	•Rotating W-Ti (sandwich) •Liquid metal target design (Pb-Bi and Hg, model) •Shock waves in target (enhancement of	2007-2009 2007-2008 2007-2008	– 70k$+100k$ 30k$
Collection optics design	•Lithium lens (dynamics, windows: Be, BN, model) •Dual layer solenoid with compensated input	2007-2008 2007-2008	70k$+70k$ 50k$
Collimators	•Collimators for gammas •Collimators for full power beam •Structure of power deposition in undulator	2009 2009 2008	– – 20k$
Undulator chicane	•Minimal possible parallel shift ~450mm (optics, no hall option) •power density deposition	2008 2008	– 20k$
Perturbation of emittance	•Dynamical perturbations of emittance (regular part, fringe fields and tapering, chicane) •Radiative perturbations	2008 2007-2008	30k$ –
Handling of polarization	•Compensation of spin tilt in undulator (scheme) •Fast spin flip schemes with helical field	2008 2008-2009	20k$ 40k$
Combining scheme	•Two targets combining scheme calculations	2009	30k$

Parameters optimized with Monte-Carlo code KONN



K-factor can be small, K<0.4, what brings a lot of relief to all elements of system

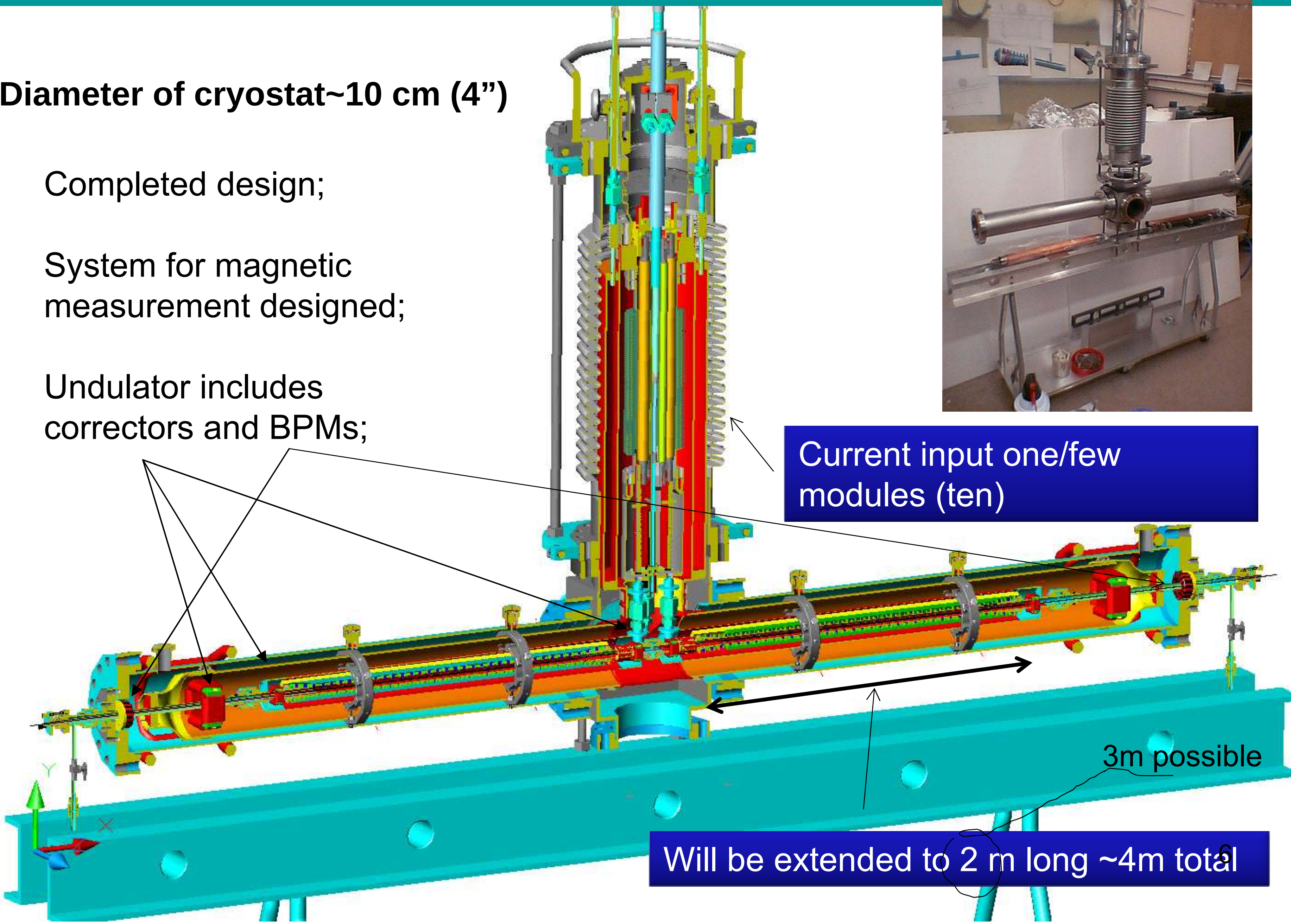
UNDULATOR DESIGN

Diameter of cryostat~10 cm (4”)

Completed design;

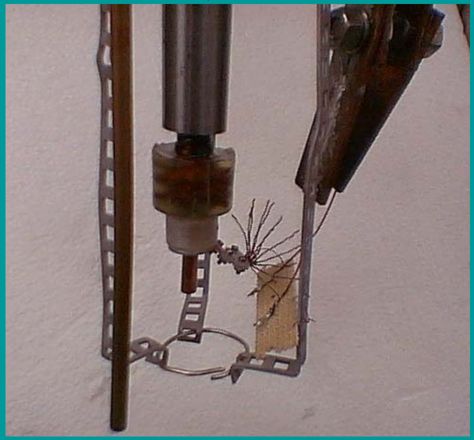
System for magnetic measurement designed;

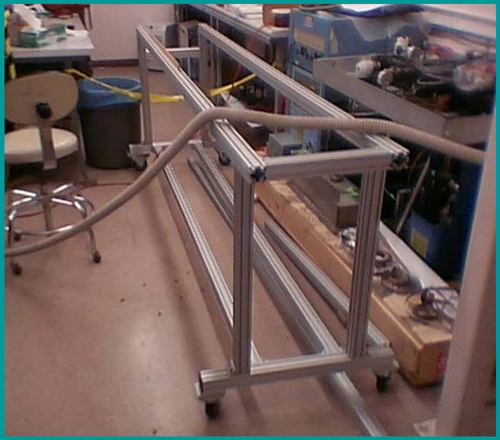
Undulator includes correctors and BPMs;



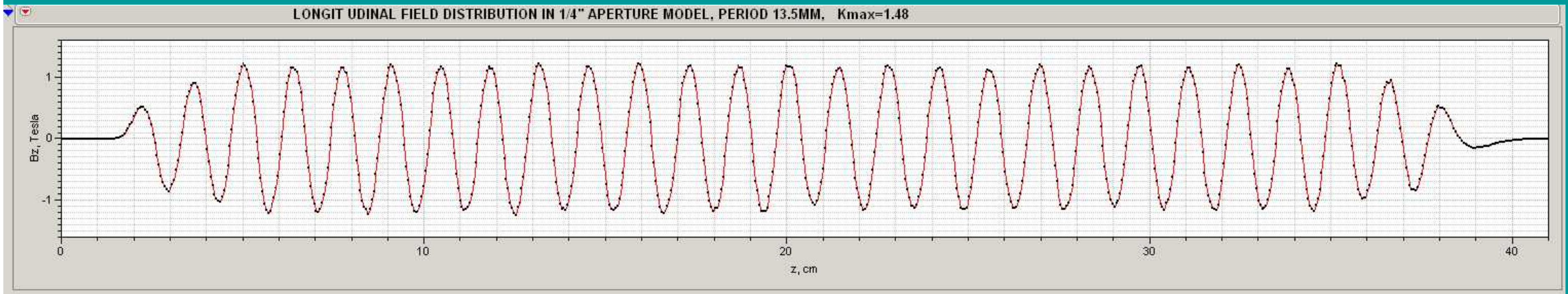
New tapering tested: conical transition from Iron to brass helix yoke
New original technology of wire return tested
New iron spacing technology
New winding machine

1 in





Fabricated undulator with 6.35 mm Inner diameter (1/4”) available for the beam; 13.5 mm period → K=1.48 measured



Right now the cold mass has diameter 1.5 inch. Designed cold mass with1 inch diameter

TESTED UNDULATORS

For aperture available for the beam 8 mm in Ø clear

OFC vacuum chamber, RF smoothness

SC wire	54 filaments	56 filaments	56 filaments	56 filaments
# layers	5	6	11	9 (12) +sectioning
λ=10 mm @*300 ºK*	K=0.36 tested	K=0.42 tested	K=0.467 tested	K≈0.5 (calculated)
λ=12 mm@*300 ºK*	K=0.72 tested	K=0.83 tested		K≈1 (calculated)

For aperture available for the beam 6.35 mm (1/4”) in Ø clear

OFC vacuum chamber, RF smoothness

# layers	11			12+sectioning
λ=13.5 mm@*300 ºK*	K=1.48 tested			K≈1.6 calculated
λ=10.0 mm@*300 ºK*	K≈0.7calculated			K≈0.72 calculated

Two sections of 45 cm long (8mm) each will be measured in cryostat to the end of this year; The plan is to test it with the beam at Cornell ERL test module setup.

4m long prototype will be assembled in general to the end of 2007, Field distribution will be measured earlier in 2008

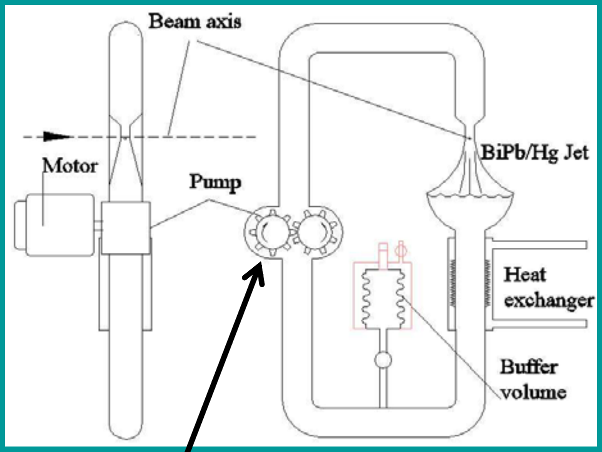
NEWS ABOUT TARGET DESIGN

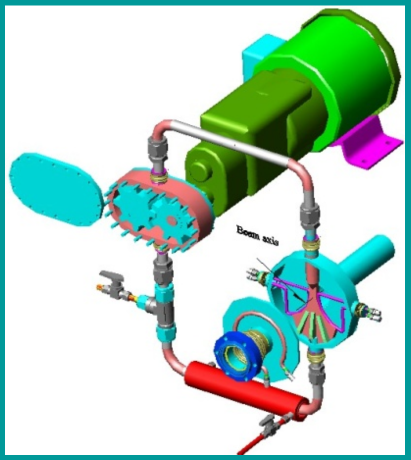
Ti rotating wheel target is under development at Livermore, SLAC, Daresbury.

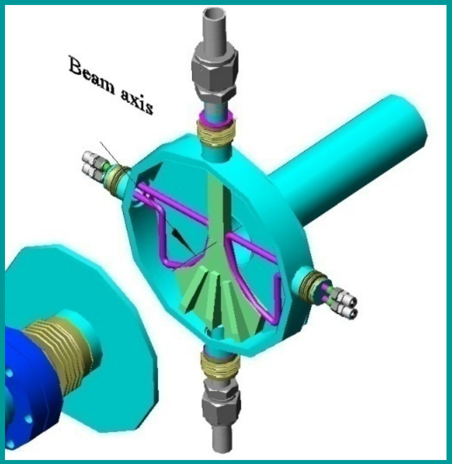
We are looking for other solutions

Liquid metal target with Pb-Bi or Hg; Out window : Be or BN

Bi-Pb has melting temperature 154 deg C.   Hg has boiling temperature 354 deg C







Gear pump. Jet velocity~10m/s

Pressure waves in a target

FlePDE model calculates temperature and pressure according equations

$$\nabla(k\nabla T) + \dot{Q} = \rho c_V \dot{T} \qquad \ddot{P} - \nabla(c_0^2 \nabla P) = \frac{\Gamma}{V_0}\ddot{Q}$$

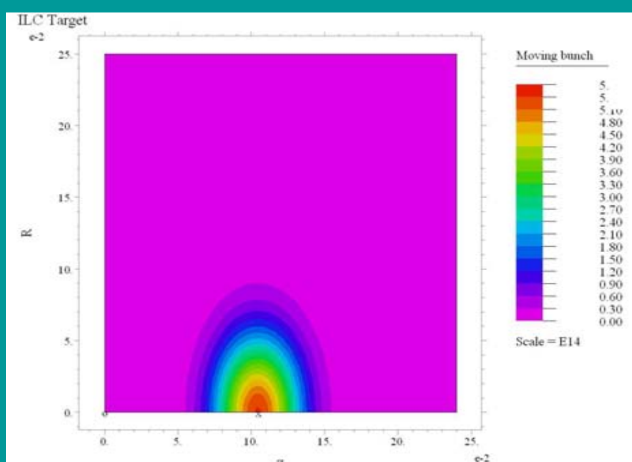
$$\dot{Q} = \sum_i \frac{2cQ_{bunch}}{\pi\sqrt{\pi}\sigma_z \sigma_{\perp\gamma}^2 l_T} \frac{z}{l_T} \exp\left(-\frac{(z+z_0-c(t-i\cdot t_0))^2}{\sigma_z^2}\right)\cdot \exp\left(-\frac{r^2}{\sigma_{\perp\gamma}^2}\right) \qquad \varepsilon_c(V) = \frac{c_0^2}{2}\left(1+\frac{V_0}{V}\right)^2$$

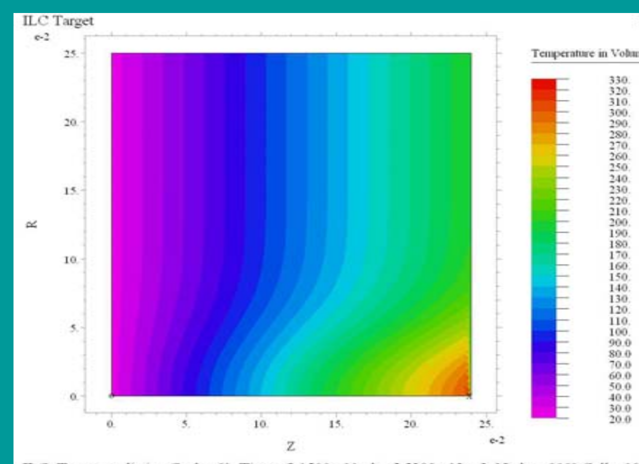
$$P = p_T + p_c = \Gamma\frac{\varepsilon_T}{V} - \frac{d\varepsilon_c}{dt}$$

c_0 -speed of sound

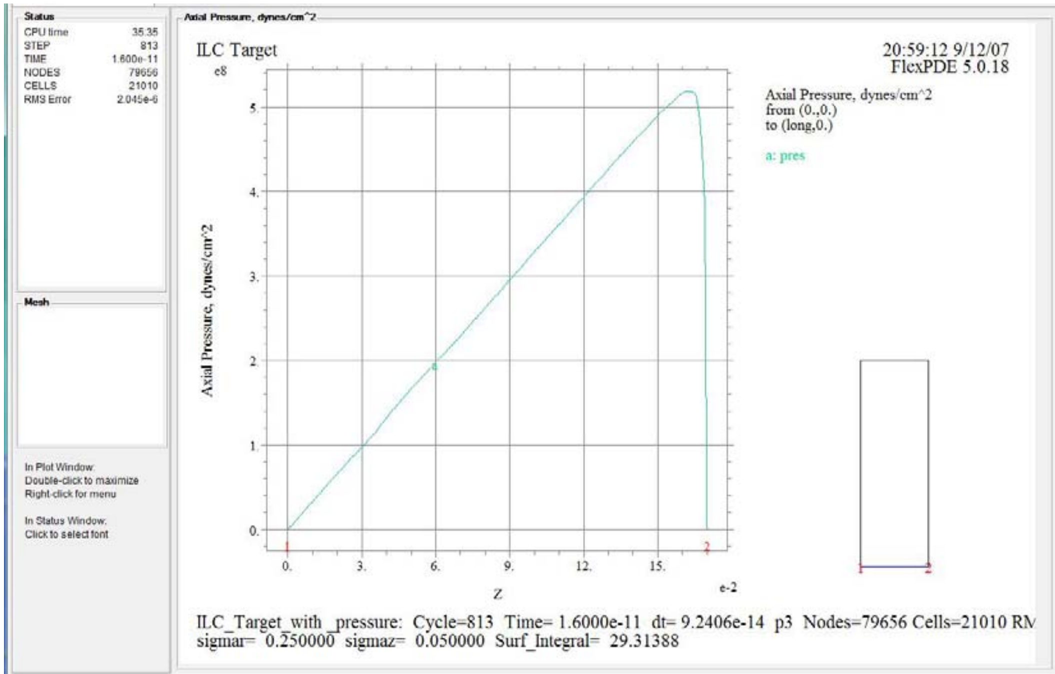
where $\Gamma(V) = V / c_V (\partial P / \partial T_V)$ characterizing the ratio of the thermal pressure to the

specific thermal energy ε_T / V called Grüneisen coefficient.





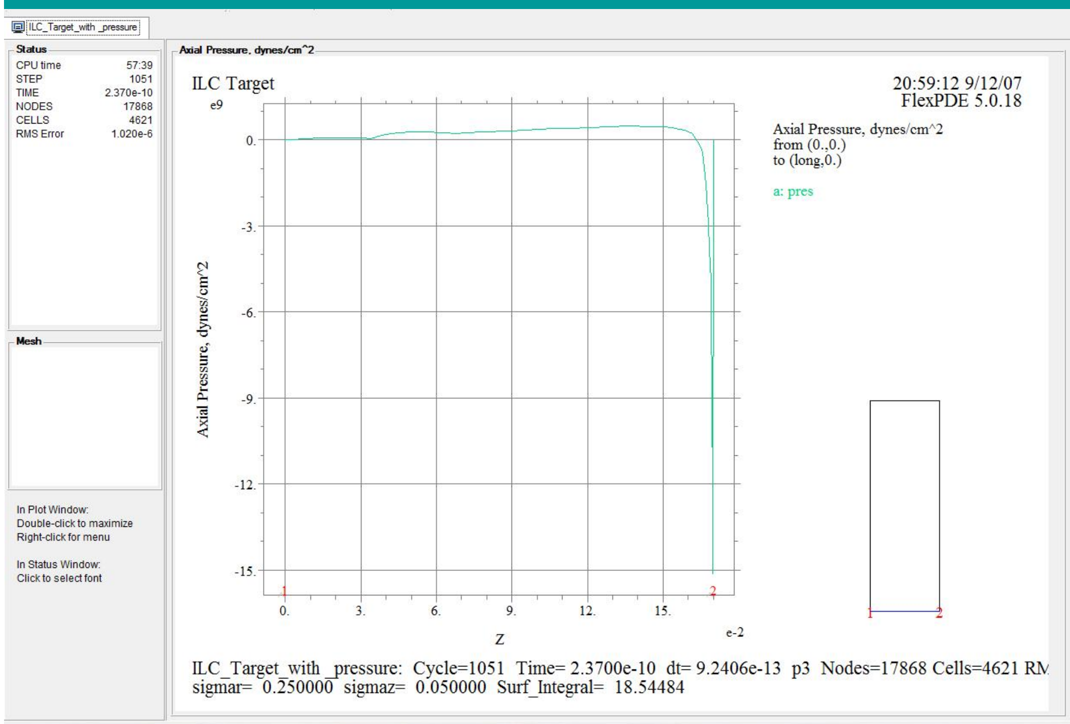
Instant position of the bunch moving in the target, at the left. Isotherms right after the bunch passage, at the right.



Example of Pb Target

Pressure along axis right after the beam passed

(Have a movie)



Pressure soon after. Negative pressure is few tens times higher, than compressive one

For liquid target it is not dangerous

The same “enhancement” is valid for Ti, so it cracks more likely right after the first shot

CONCLUSIONS

Start to end code for Monte-Carlo simulation of conversion under development;

According to our calculations low K factor possible; K<0.4 with period 10 mm (Li lens)

For 500 GeV, a conversion system requires more efforts; one solution is to move the system as a whole to a new 150 GeV point, other solution -longer period of undulator

Helical iron yokes of ~3 m long obtained from industry;

Reached K=0.467 for 10 mm period; aperture 8 mm;

Reached K=0.83 for 12 mm period; aperture 8 mm (old wire);

Reached K=1.48 for 13.5 mm period; aperture 6.35mm (¼")

Pumping of Helium was tested, gain >10%;

Calculations of pressure waves indicate ~30 times higher negative pressure, than compression one due to energy deposition (Ti target not surviving with present margins, sorry)

4-m long Undulator module fabrication and its test is a priority job→ 2007-2008;

Back up slides

Technology developed for fabrication of continuous yoke of necessary length (2-3m)

Wire having diameter 0.33mm chosen as a baseline one for now

For 10mm period the coil has 8(z)x11(r) wires; bonded in 4strands

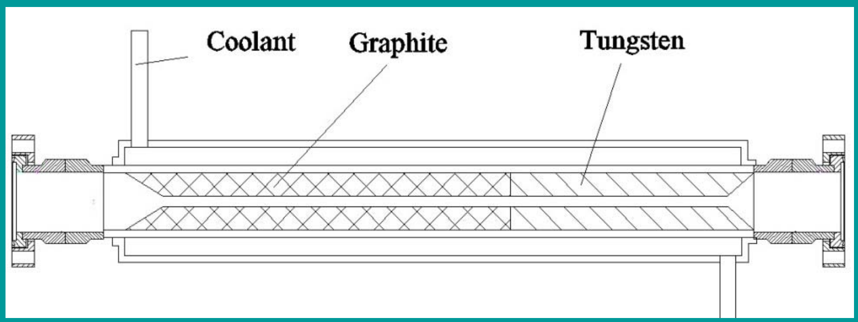
For 12mm period the coil has 12(z)x12(r) wires bonded in 6 strands

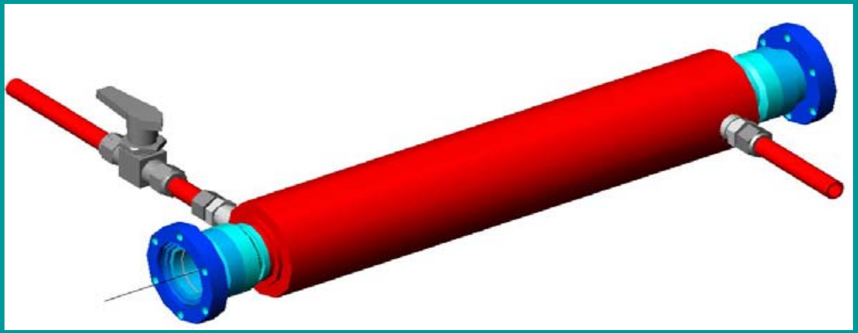
Fabricated undulator with 6.35 mm Inner diameter (1/4”) available for the beam; K=1.48 measured (13.5 mm period)

Two meter long yoke under visual inspection by William Trusk

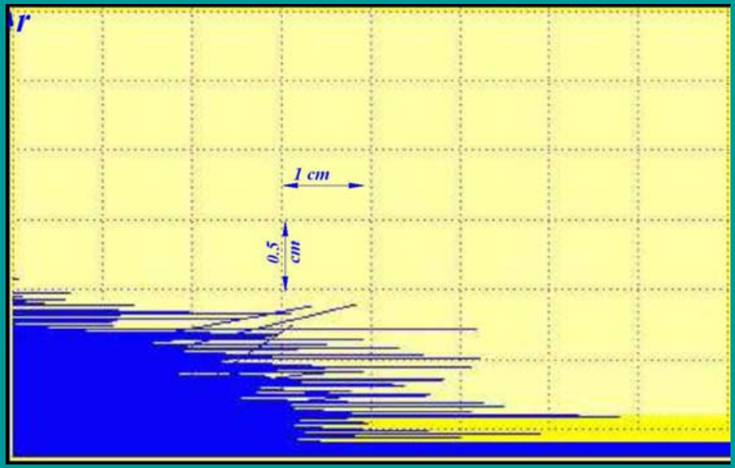
Collimator for gammas

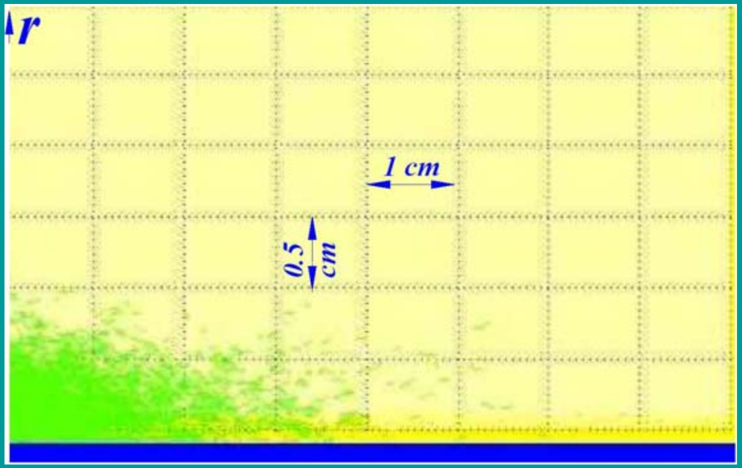
Pyrolytic Graphite (PG) is used here. The purpose of it is to increase the beam diameter, before entering to the W part. Vacuum outgassing is negligible for this material. Heat conductivity ~300 W/m-oK is comparable with meals.





Transverse dimensions defined by Moliere radius



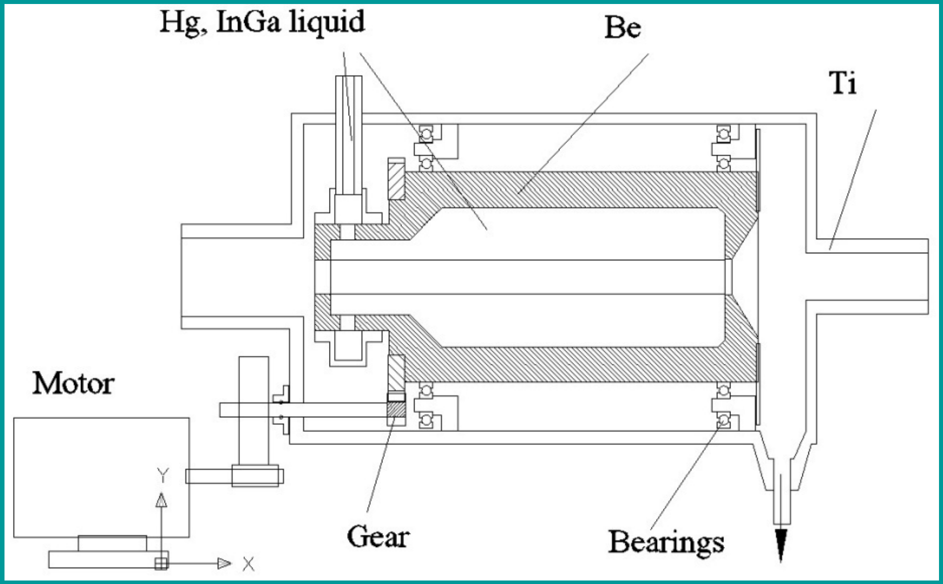


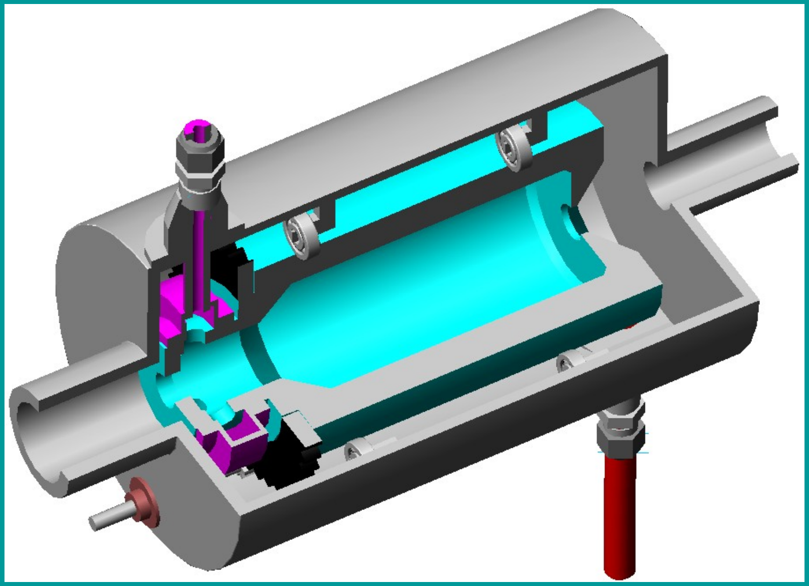
Gamma-beam. s_g= 0.5cm, diameter of the hole (blue strip at the bottom) *d*=2 mm. Energy of gamma-beam coming from the left is 20 *MeV*.

Positron component of cascade

High power collimator

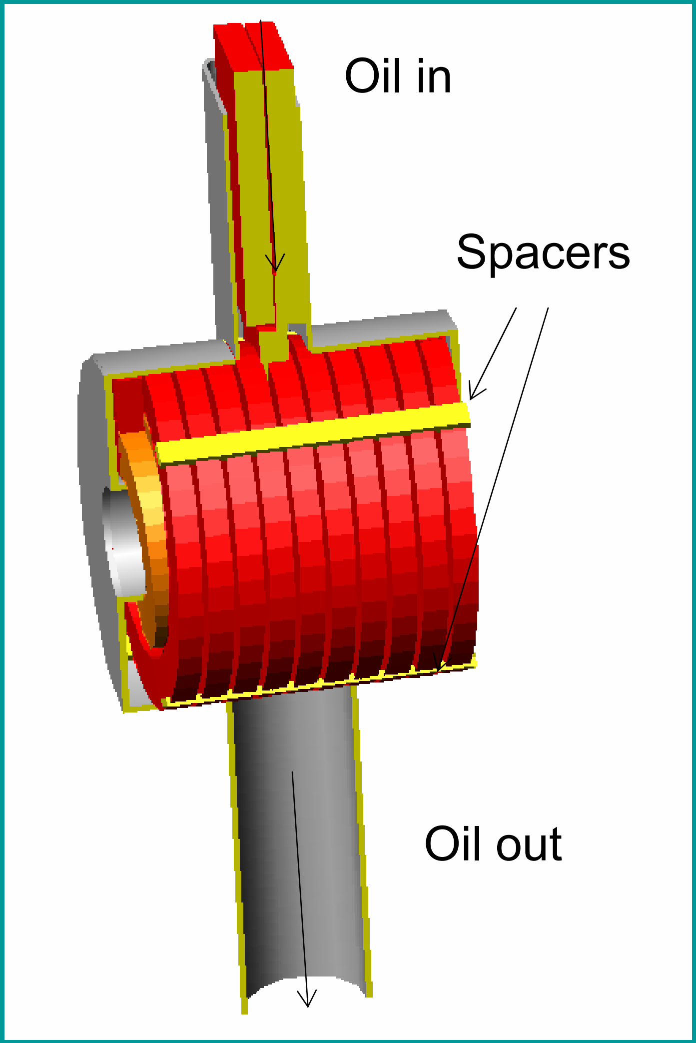
This a liquid metal one. Liquid formed a cylinder as result of rotation and centrifugal force



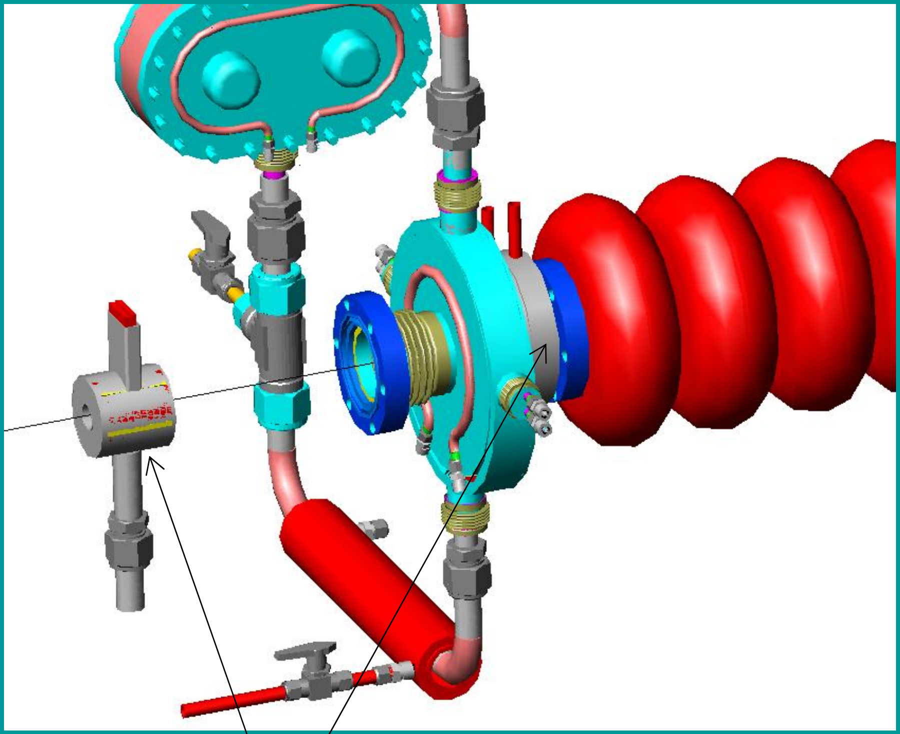


High average power collimator. Beam is coming from the right.

Solenoidal lens could be designed with dimensions ~ a bit larger than the Lithium lens



For the number of turns =20, current in one turn goes to I_1~15 kA during~10msec duty time; Two harmonics for feeding current.
Conductor cross-section~ 5x10mm^2;
Coolant-oil



Lenses in comparison; for Li lens current leads are not shown

T.A.Vsevolojskaja,A.A.Mikhailichenko, G.I.Silvestrov, A.D.Cherniakin

“To the Conversion System for Generation of Polarized Beams in VLEPP”, BINP, 1986

39

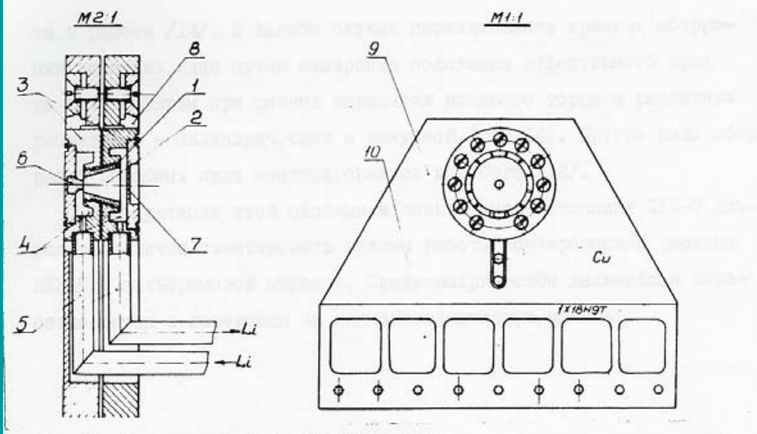
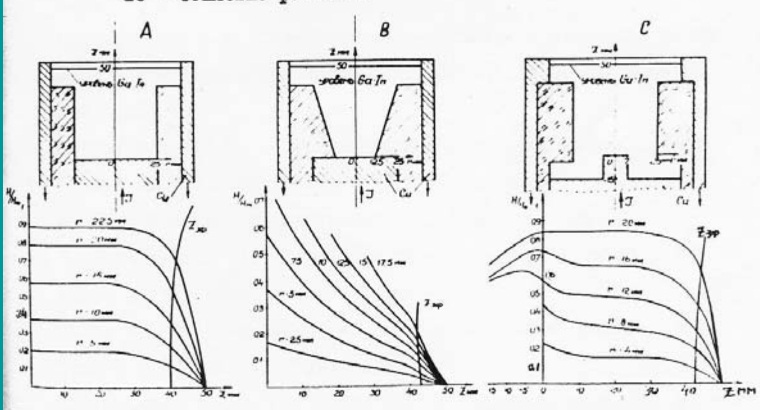
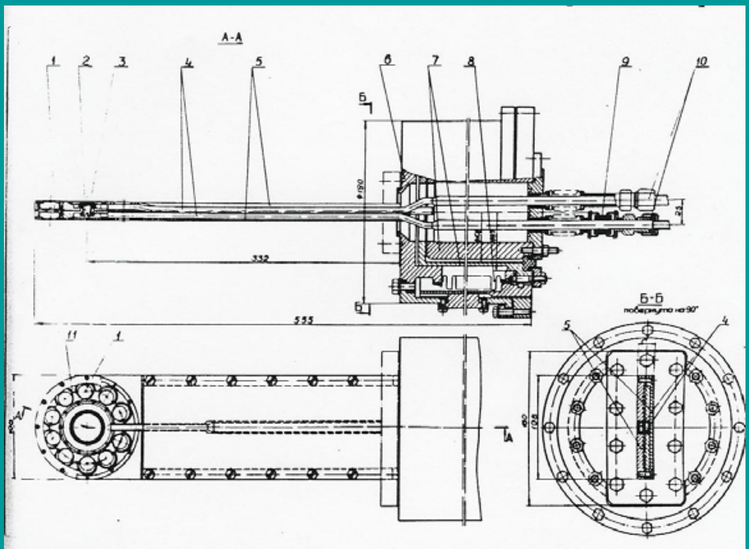


Рис.I3. Модель линзы с жидким литием.
I – конусная оболочка линзы, 2 – рабочий объем лития, 3 – корпус линзы, 4 – объемы для растекания жидкого лития, 5 – трубки подвода лития, 6 – мишень, 7 – выхрдной фланец, 8 – конусные контакты, 9 – плоские токоподводы, I0 – тепловые развязки

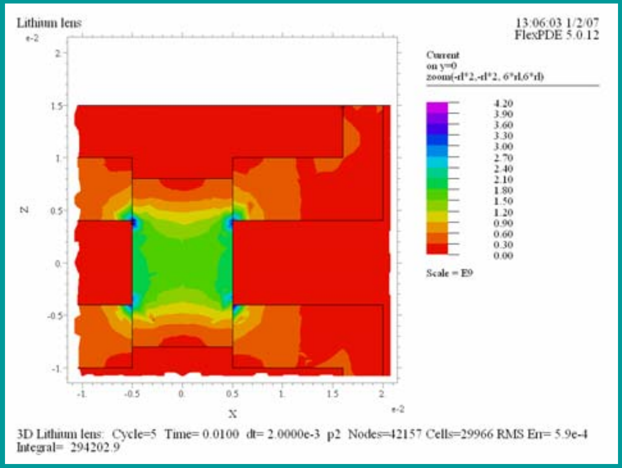


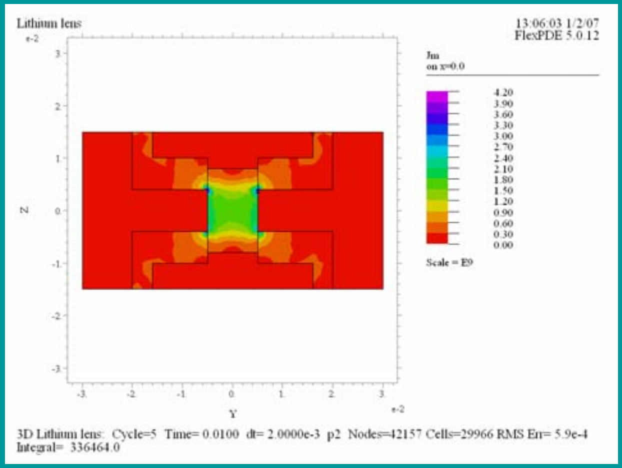
Field measured in liquid Gallium model.
A-cylindrical lens with homogenous current leads supply at the end
B- conical lens with the same current feed
C –lens with cylindrical target at the entrance flange

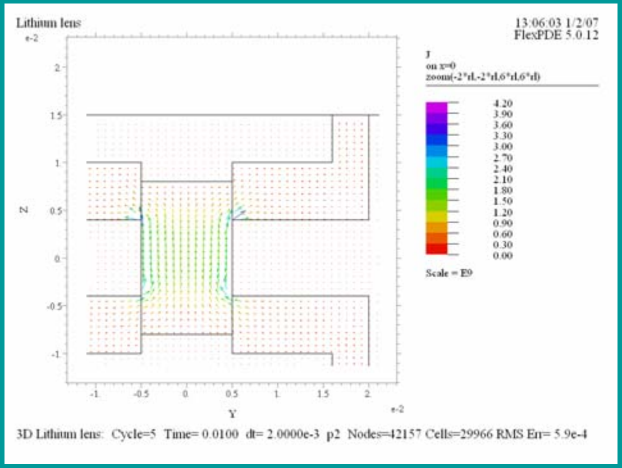


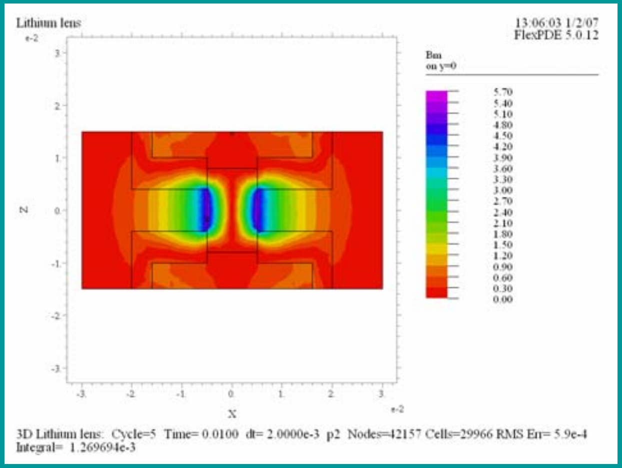
1-ex-centric contact pushers;2-conic lens body; 3-W target; 4-Ti tubing for LI supply; 5-flat current leads; 6-vacuum chamber; 7-coaxial fraction of current leads; 8-bellows; 9-ceramic insulators; 10-conical gasket; 11-set of ex-centric pushers.

Recent calculation of Lithium lens done with FlexPDE© code



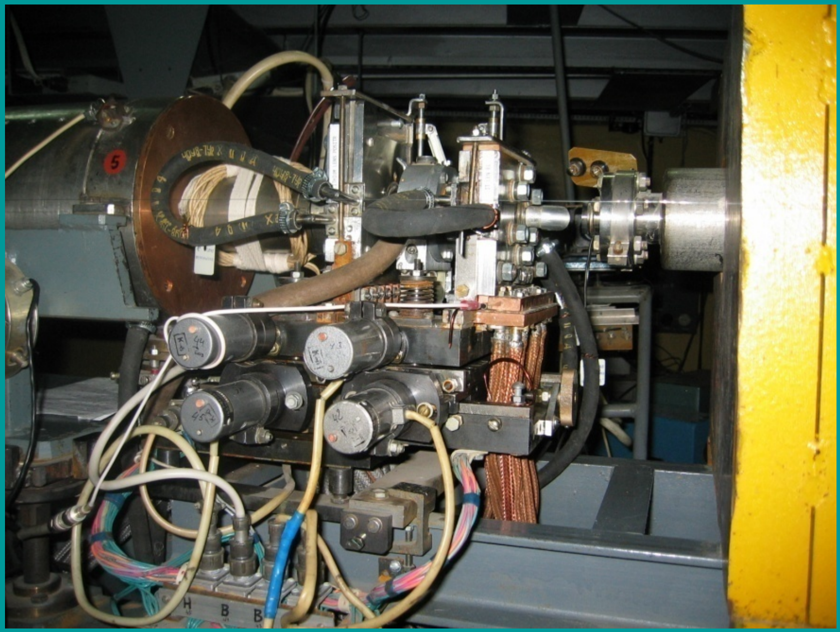


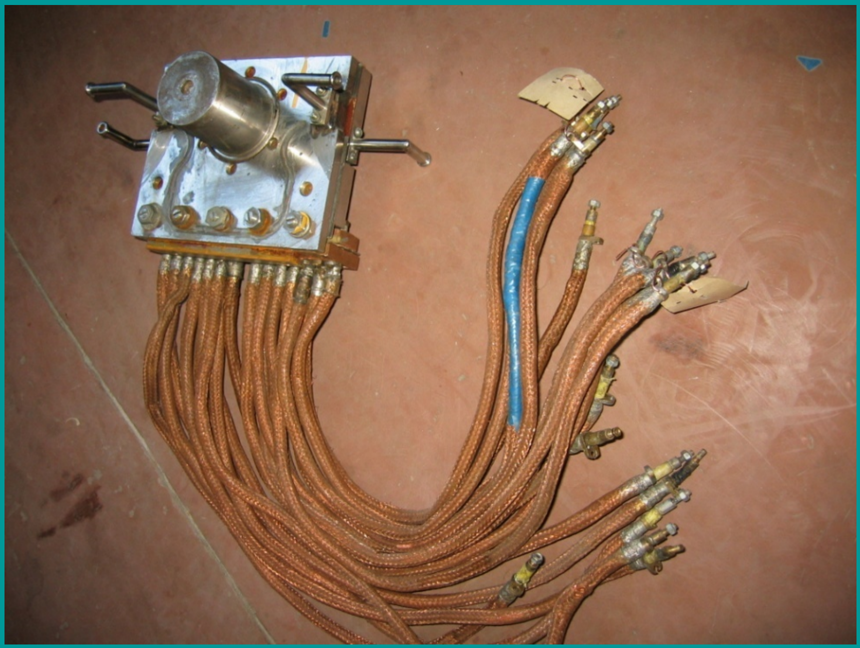




Doublet of Lithium lenses in Novosibirsk BINP

Photo- courtesy of Yu Shatunov (May 2007)





First lens is used for focusing of primary 250 MeV electron beam onto the W target,

Second lens installed after the target and collects positrons at ~150MeV

Number of particles in pulse ~2E+11; ~0.7Hz operation (defined by the beam cooling in Damping Ring)

Lenses shown served ~30 Years without serious problem (!)