INTEGRATED Li LENS-TARGET SYSTEM

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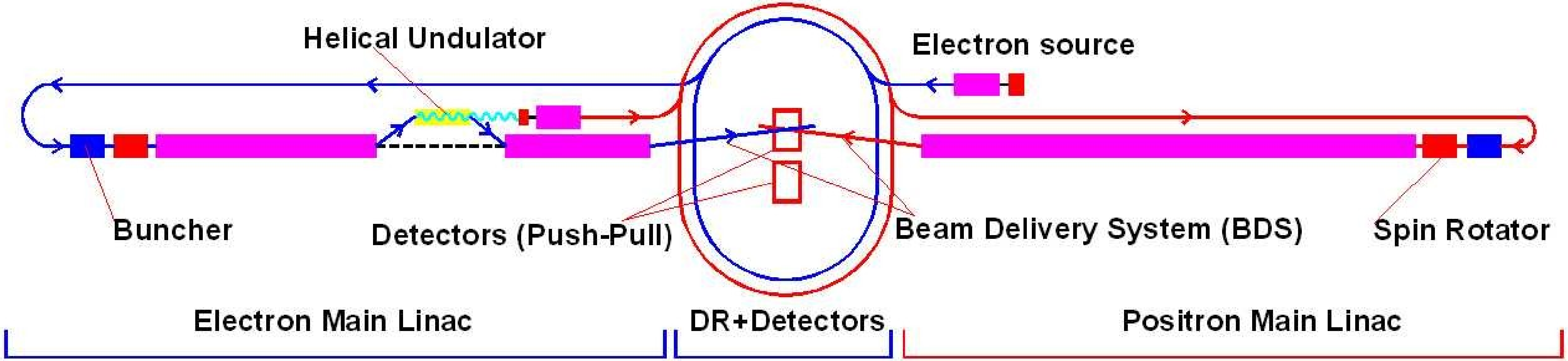
POSITRON SOURCE FOR ILC



>60% positron polarization

Polarized electrons can be obtained in the same way

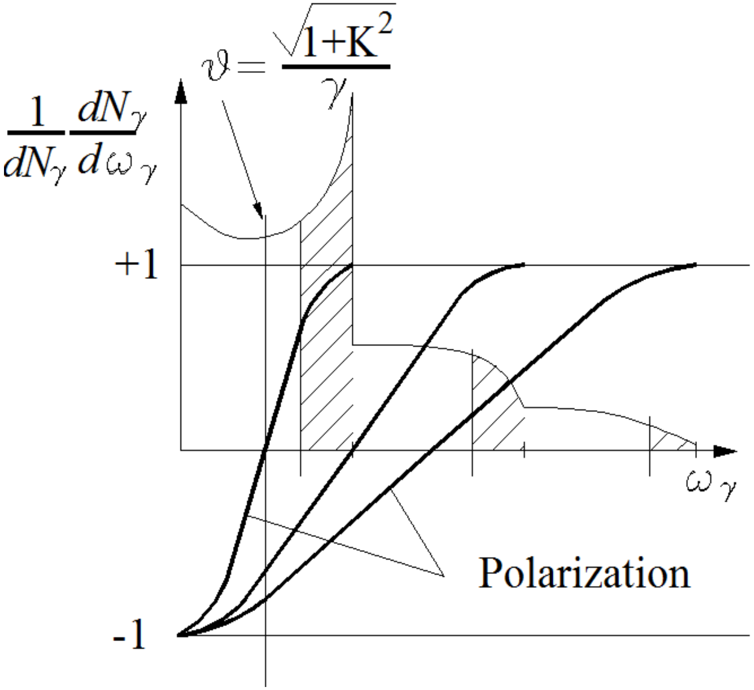
In principle, positrons could be generated by positrons, so the linacs become independent

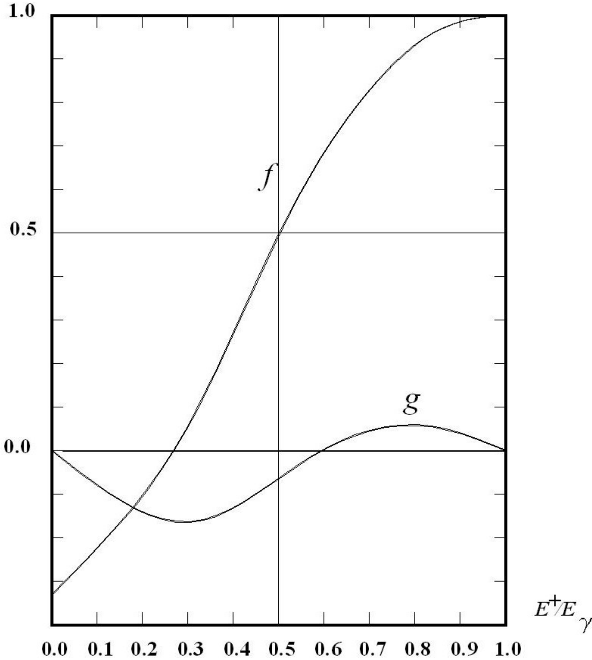
Spectral distribution and polarization schematics for Undulator Radiation

All higher harmonics have zero intensity in straight forward direction

Angle of radiation and the energy of the photon are not independent

Polarization curve needs to be convolved with the photon density





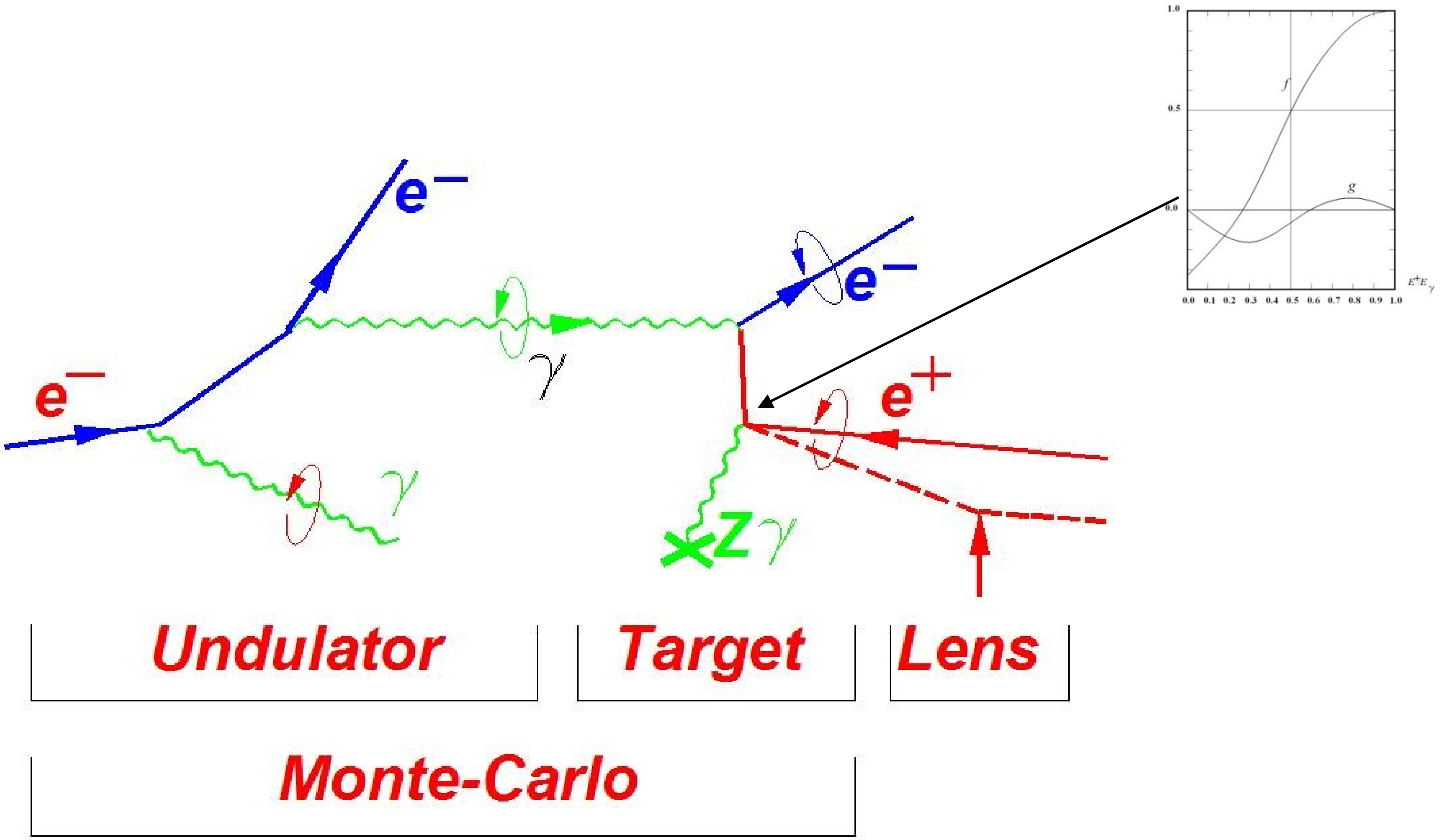
Olsen, Maximon

Hatched areas correspond to the passage of radiation through the collimator

Collimator helps to enhance integrated photon polarization

Code KONN

Initiated in 1986; continued in 2007-
3000 FORTRAN lines



Undulator **Target** **Lens**

Monte-Carlo

PROGRAM KONN

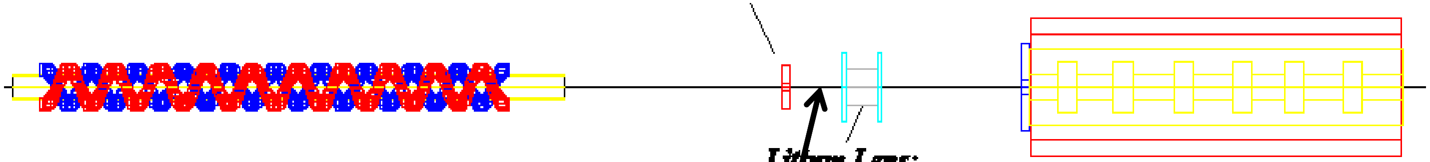
T.A.Vsevolozhskaya, A.A.Mikhailichenko

Monte-Carlo simulation of positron conversion

Energy of the beam;
Length of undulator;
Undulator period $M=L/\lambda_u$;
K-factor;
Emittance;
Beta-function;
Number of harmonics (four);
Number of positrons to be generated;

Target:
Distance to the undulator
Thickess;
Diameter of target;
Material;
Diameter of hole at center;
Step of calculation

Acceleration:
Distance to the lens;
Length of structure;
Gradient;
Diameter of collimator at the entrance;
Diameter of irices;
External solenoidal field;
Further phase volume captured;



Lithium Lens:
Distance to the target;
Length;
Diameter;
Thicness of flanges;
Material of flanges;
Gradient;
Step of calculations;

CALCULATES at every stage:
Efficiency in given phase volume;
Polarization in given phase volume;
Beam dimensions;
Phase-space distributions;
Beam lengthening;
Energy spread within phase space;

Interactive code, now has ~3000 lines

Optimized efficiency and polarization for rotating target calculated with KONN

Beam energy, *GeV*	150	250	350	500
Length of undulator, *m*	170	200	200	200
K factor	0.44	0.44	0.35	0.28
Period of undulator, *cm*	1.0	1.0	1.0	1.0
Distance to the target, *m*	150	150	150	150
Radius of gamma collimator, *cm*	0.049	0.03	0.02	0.02
Emittance, *cm·rad*	1e-9	1e-9	1e-9	1e-9
Bunch length, *cm*	0.05	0.05	0.05	0.05
Beta-function, *m*	400	400	400	400
Length of target/X_0	0.57	0.6	0.65	0.65
Distance to the length, *cm*	0.5	0.5	0.5	0.5
Radius of the lens, *cm*	0.7	0.7	0.7	0.7
Length of the lens, *cm*	0.5	0.5	0.5	0.5
Gradient, *MG/cm*	0.065	0.065	0.08	0.1
Wavelength of RF, *cm*	23.06	23.06	23.06	23.06
Phase shift of crest, *rad*	-0.29	-0.29	-0.29	-0.29
Distance to RF str., *cm*	2.0	2.0	2.0	2.0
Radius of RF collimator, *cm*	2.0	2.0	2.0	2.0
Length of RF str., *cm*	500	500	500	500
Gradient, *MeV/cm*	0.1	0.1	0.1	0.1
Longitudinal field, *MG*	0.015	0.015	0.015	0.015
Inner rad. of irises, *cm*	3.0	3.0	3.0	3.0
Acceptance, *MeV·cm*	5.0	5.0	5.0	5.0
Energy filter, E > -*MeV*	54	74	92	114
Energy filter, E< -*MeV*	110	222	222	222
Efficiency, e^+/e^-	**1.5**	**1.8**	**1.5**	**1.5**
Polarization, %	**70**	**76**	**75**	**70**

LOSSES FOR DIFFERENT MATERIAL OF TARGET

If energy Q deposited in mass m, then the temperature rise is

$$\Delta T = \frac{Q}{mc_V},$$

where c_V stands for the heat capacity. In its turn, for the $1cm^2$ cross section

$$Q \cong l[cm] \times 1[cm^2] \times 2[MeV/g/cm^2] \times \rho[g/cm^3].$$

For the gamma target, the length l is a fraction of radiation length, $l \cong \frac{1}{2} X_0 / \rho$,

$$Q \cong X_0 \times 1[MeV]$$

From the other hand $m = \rho \times 1[cm^2] \times \frac{X_0}{2\rho} = \frac{1}{2} X_0 \times 1[g],$

so the temperature gain goes to be

$$\Delta T \cong \frac{2}{c_V[J/g/^oK]}[^oK] \quad \left(\cong \frac{2A}{25[Mol/g/^oK] \cong const : (D - P\ law)} \right)$$

For Ti c_V=$0.5\ J/g/^oK$; for W c_V=$0.134\ J/g/^oK$; for Pb c_V=$0.13\ J/g/^oK$,
So ratio of temperatures comes to

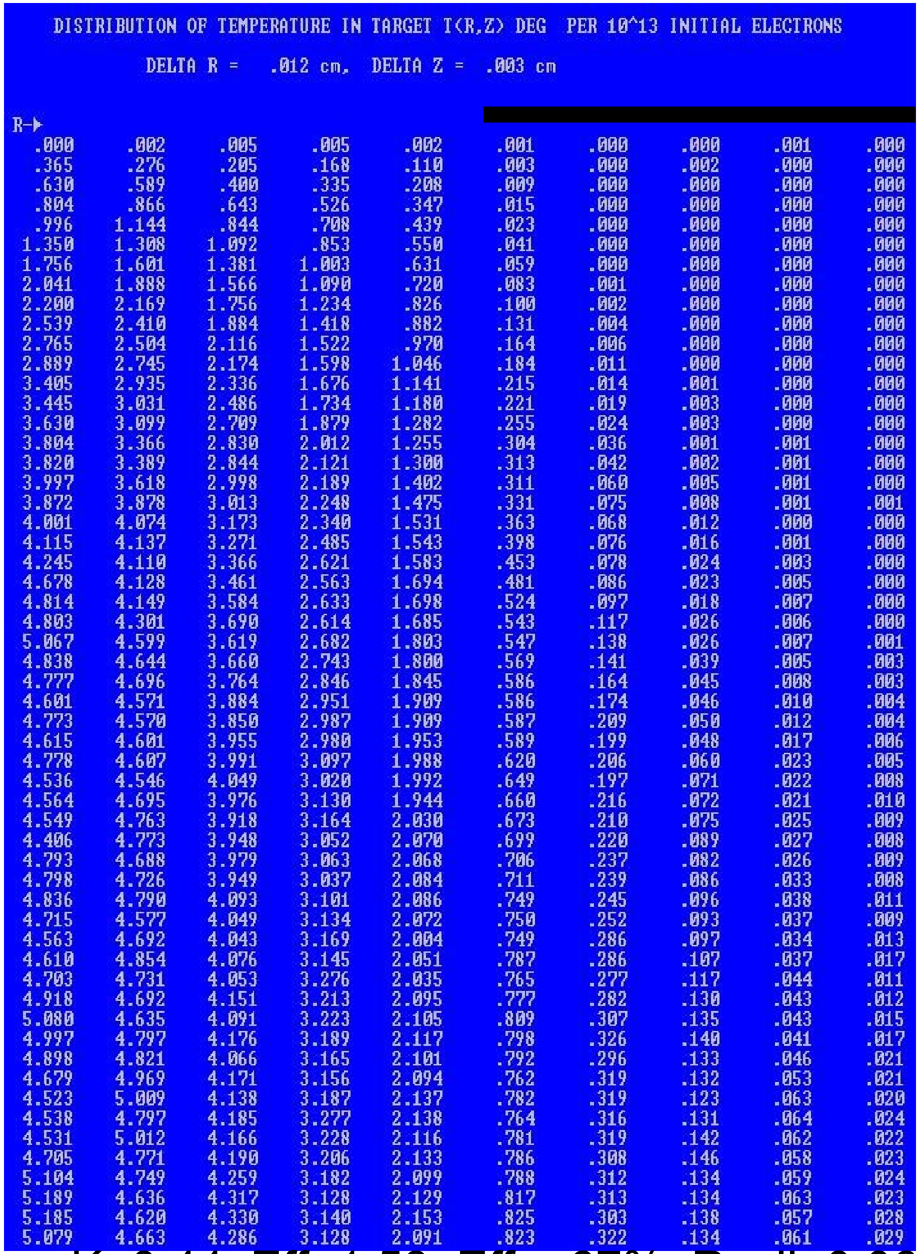
$$\Delta T_{Ti} : \Delta T_W : \Delta T_{Pb} \cong 1 : 3.7 : 3.8 ; \qquad (A_{Ti} : A_W : A_{Pb} \cong 47 : 183 : 207)$$

The ratio difference in temperature gain is not so drastic; however it is important if the temperature approaching the melting threshold.

Usage of heavier targets desirable from the point of lowering of focal depth (~10 times) needed to be serviced by capturing optics, however. Also, the positron production efficiency is higher for heavier materials. All together this gives ~50% higher yield for W compared with Ti.

E-166 PREFERRED W TARGET

↓ Moving target --- **TEMPERATURE IN A TARGERT**---Stationary target ↓



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   DISTRIBUTION OF TEMPERATURE IN TARGET T(R,Z) DEG  PER 10^13 INITIAL ELECTRONS

            DELTA R =   .012 cm,  DELTA Z =  .003 cm


R->
   .000     .002     .005     .005     .002     .001     .000     .000     .001     .000
   .365     .276     .205     .168     .110     .003     .000     .002     .000     .000
   .630     .589     .400     .335     .208     .009     .000     .000     .000     .000
   .804     .866     .643     .526     .347     .015     .000     .000     .000     .000
   .996    1.144     .844     .708     .439     .023     .000     .000     .000     .000
  1.350    1.308    1.092     .853     .550     .041     .000     .000     .000     .000
  1.756    1.601    1.381    1.003     .631     .059     .000     .000     .000     .000
  2.041    1.888    1.566    1.090     .720     .083     .001     .000     .000     .000
  2.200    2.169    1.756    1.234     .826     .100     .002     .000     .000     .000
  2.539    2.410    1.884    1.418     .882     .131     .004     .000     .000     .000
  2.765    2.504    2.116    1.522     .970     .164     .006     .000     .000     .000
  2.889    2.745    2.174    1.598    1.046     .184     .011     .000     .000     .000
  3.405    2.935    2.336    1.676    1.141     .215     .014     .001     .000     .000
  3.445    3.031    2.486    1.734    1.180     .221     .019     .003     .000     .000
  3.630    3.099    2.709    1.879    1.282     .255     .024     .003     .000     .000
  3.804    3.366    2.830    2.012    1.255     .304     .036     .001     .001     .000
  3.820    3.389    2.844    2.121    1.300     .313     .042     .002     .001     .000
  3.997    3.618    2.998    2.189    1.402     .311     .060     .005     .001     .000
  3.872    3.878    3.013    2.248    1.475     .331     .075     .008     .001     .001
  4.001    4.074    3.173    2.340    1.531     .363     .068     .012     .000     .000
  4.115    4.137    3.271    2.485    1.543     .398     .076     .016     .001     .000
  4.245    4.110    3.366    2.621    1.583     .453     .078     .024     .003     .000
  4.678    4.128    3.461    2.563    1.694     .481     .086     .023     .005     .000
  4.814    4.149    3.584    2.633    1.698     .524     .097     .018     .007     .000
  4.803    4.301    3.690    2.614    1.685     .543     .117     .026     .006     .000
  5.067    4.599    3.619    2.682    1.803     .547     .138     .026     .007     .001
  4.838    4.644    3.660    2.743    1.800     .569     .141     .039     .005     .003
  4.777    4.696    3.764    2.846    1.845     .586     .164     .045     .008     .003
  4.601    4.571    3.884    2.951    1.909     .586     .174     .046     .010     .004
  4.773    4.570    3.850    2.987    1.909     .587     .209     .050     .012     .004
  4.615    4.601    3.955    2.980    1.953     .589     .199     .048     .017     .006
  4.778    4.607    3.991    3.097    1.988     .620     .206     .060     .023     .005
  4.536    4.546    4.049    3.020    1.992     .649     .197     .071     .022     .008
  4.564    4.695    3.976    3.130    1.944     .660     .216     .072     .021     .010
  4.549    4.763    3.918    3.164    2.030     .673     .210     .075     .025     .009
  4.406    4.773    3.948    3.052    2.070     .699     .220     .089     .027     .008
  4.793    4.688    3.979    3.063    2.068     .706     .237     .082     .026     .009
  4.798    4.726    3.949    3.037    2.084     .711     .239     .086     .033     .008
  4.836    4.790    4.093    3.101    2.086     .749     .245     .096     .038     .011
  4.715    4.577    4.049    3.134    2.072     .750     .252     .093     .037     .009
  4.563    4.692    4.043    3.169    2.004     .749     .286     .097     .034     .013
  4.610    4.854    4.076    3.145    2.051     .787     .286     .107     .037     .017
  4.703    4.731    4.053    3.276    2.035     .765     .277     .117     .044     .011
  4.918    4.692    4.151    3.213    2.095     .777     .282     .130     .043     .012
  5.080    4.635    4.091    3.223    2.105     .809     .307     .135     .043     .015
  4.997    4.797    4.176    3.189    2.117     .798     .326     .140     .041     .017
  4.898    4.821    4.066    3.165    2.101     .792     .296     .133     .046     .021
  4.679    4.969    4.171    3.156    2.094     .762     .319     .132     .053     .021
  4.523    5.009    4.138    3.187    2.137     .782     .319     .123     .063     .020
  4.538    4.797    4.185    3.277    2.138     .764     .316     .131     .064     .024
  4.531    5.012    4.166    3.228    2.116     .781     .319     .142     .062     .022
  4.705    4.771    4.190    3.206    2.133     .786     .308     .146     .058     .023
  5.104    4.749    4.259    3.182    2.099     .788     .312     .134     .059     .024
  5.189    4.636    4.317    3.128    2.129     .817     .313     .134     .063     .023
  5.185    4.620    4.330    3.140    2.153     .825     .303     .138     .057     .028
  5.079    4.663    4.286    3.128    2.091     .823     .322     .134     .061     .029
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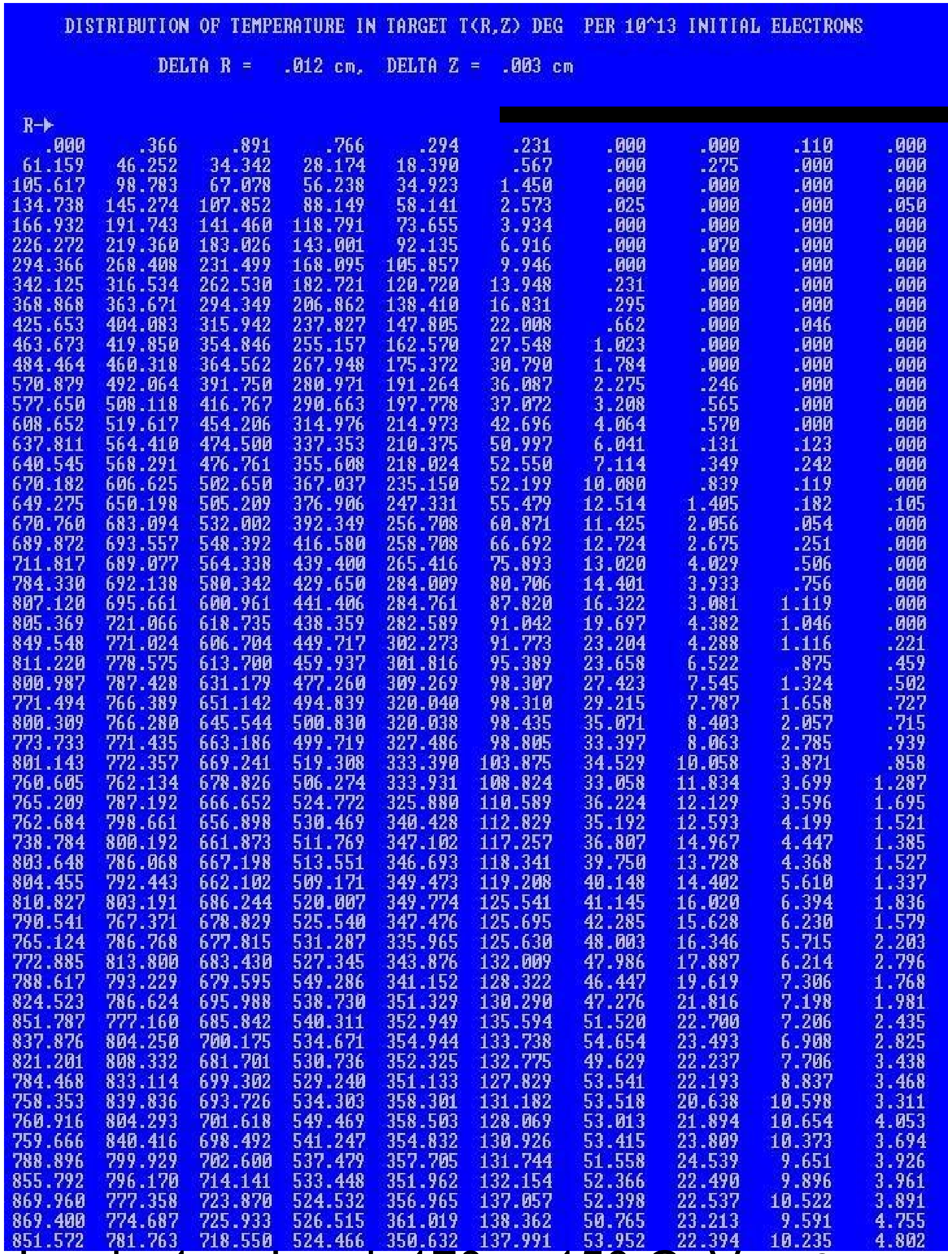

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   DISTRIBUTION OF TEMPERATURE IN TARGET T(R,Z) DEG  PER 10^13 INITIAL ELECTRONS

            DELTA R =   .012 cm,  DELTA Z =  .003 cm

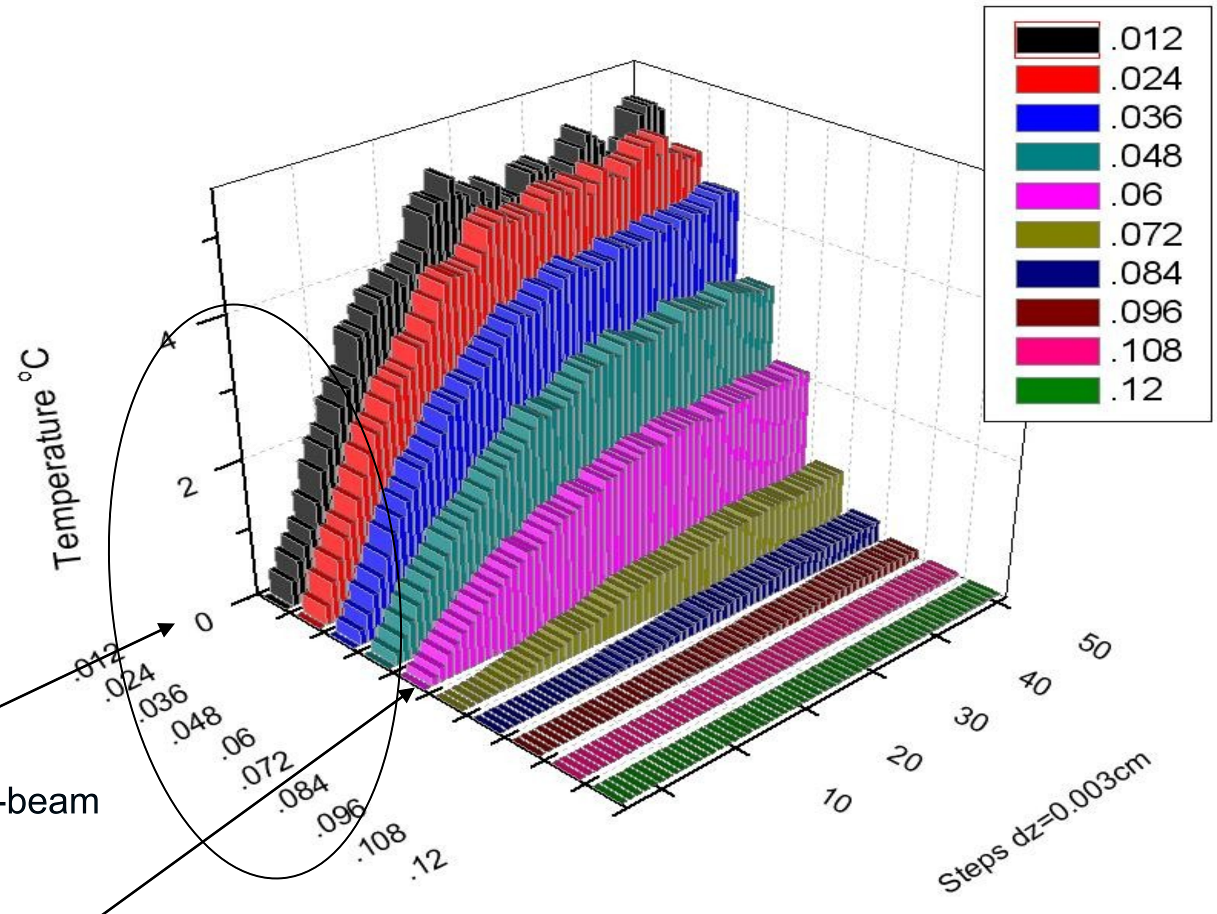

R->
   .000     .366     .891     .766     .294     .231     .000     .000     .110     .000
 61.159   46.252   34.342   28.174   18.390     .567     .000     .275     .000     .000
105.617   98.783   67.078   56.238   34.923    1.450     .000     .000     .000     .000
134.738  145.274  107.852   88.149   58.141    2.573     .025     .000     .000     .050
166.932  191.743  141.460  118.791   73.655    3.934     .000     .000     .000     .000
226.272  219.360  183.026  143.001   92.135    6.916     .000     .070     .000     .000
294.366  268.408  231.499  168.095  105.857    9.946     .000     .000     .000     .000
342.125  316.534  262.530  182.721  120.720   13.948     .231     .000     .000     .000
368.868  363.671  294.349  206.862  138.410   16.831     .295     .000     .000     .000
425.653  404.083  315.942  237.827  147.805   22.008     .662     .000     .046     .000
463.673  419.850  354.846  255.157  162.570   27.548    1.023     .000     .000     .000
484.464  460.318  364.562  267.948  175.372   30.790    1.784     .000     .000     .000
570.879  492.064  391.750  280.971  191.264   36.087    2.275     .246     .000     .000
577.650  508.118  416.767  290.663  197.778   37.072    3.208     .565     .000     .000
608.652  519.617  454.206  314.976  214.973   42.696    4.064     .570     .000     .000
637.811  564.410  474.500  337.353  210.375   50.997    6.041     .131     .123     .000
640.545  568.291  476.761  355.608  218.024   52.550    7.114     .349     .242     .000
670.182  606.625  502.650  367.037  235.150   52.199   10.080     .839     .119     .000
649.275  650.198  505.209  376.906  247.331   55.479   12.514    1.405     .182     .105
670.760  683.094  532.002  392.349  256.708   60.871   11.425    2.056     .054     .000
689.872  693.557  548.392  416.580  258.708   66.692   12.724    2.675     .251     .000
711.817  689.077  564.338  439.400  265.416   75.893   13.020    4.029     .506     .000
784.330  692.138  580.342  429.650  284.009   80.706   14.401    3.933     .756     .000
807.120  695.661  600.961  441.406  284.761   87.820   16.322    3.081    1.119     .000
805.369  721.066  618.735  438.359  282.589   91.042   19.697    4.382    1.046     .000
849.548  771.024  606.704  449.717  302.273   91.773   23.204    4.288    1.116     .221
811.220  778.575  613.700  459.937  301.816   95.389   23.658    6.522     .875     .459
800.987  787.428  631.179  477.260  309.269   98.307   27.423    7.545    1.324     .502
771.494  766.389  651.142  494.839  320.040   98.310   29.215    7.787    1.658     .727
800.309  766.280  645.544  500.830  320.038   98.435   35.071    8.403    2.057     .715
773.733  771.435  663.186  499.719  327.486   98.805   33.397    8.063    2.785     .939
801.143  772.357  669.241  519.308  333.390  103.875   34.529   10.058    3.871     .858
760.605  762.134  678.826  506.274  333.931  108.824   33.058   11.834    3.699    1.287
765.209  787.192  666.652  524.772  325.880  110.589   36.224   12.129    3.596    1.695
762.684  798.661  656.898  530.469  340.428  112.829   35.192   12.593    4.199    1.521
738.784  800.192  661.873  511.769  347.102  117.257   36.807   14.967    4.447    1.385
803.648  786.068  667.198  513.551  346.693  118.341   39.750   13.728    4.368    1.527
804.455  792.443  662.102  509.171  349.473  119.208   40.148   14.402    5.610    1.337
810.827  803.191  686.244  520.007  349.774  125.541   41.145   16.020    6.394    1.836
790.541  767.371  678.829  525.540  347.476  125.695   42.285   15.628    6.230    1.579
765.124  786.768  677.815  531.287  335.965  125.630   48.003   16.346    5.715    2.203
772.885  813.800  683.430  527.345  343.876  132.009   47.986   17.887    6.214    2.796
788.617  793.229  679.595  549.286  341.152  128.322   46.447   19.619    7.306    1.768
824.523  786.624  695.988  538.730  351.329  130.290   47.276   21.816    7.198    1.981
851.787  777.160  685.842  540.311  352.949  135.594   51.520   22.700    7.206    2.435
837.876  804.250  700.175  534.671  354.944  133.738   54.654   23.493    6.908    2.825
821.201  808.332  681.701  530.736  352.325  132.775   49.629   22.237    7.706    3.438
784.468  833.114  699.302  529.240  351.133  127.829   53.541   22.193    8.837    3.468
758.353  839.836  693.726  534.303  358.301  131.182   53.518   20.638   10.598    3.311
760.916  804.293  701.618  549.469  358.503  128.069   53.013   21.894   10.654    4.053
759.666  840.416  698.492  541.247  354.832  130.926   53.415   23.809   10.373    3.694
788.896  799.929  702.600  537.479  357.705  131.744   51.558   24.539    9.651    3.926
855.792  796.170  714.141  533.448  351.962  132.154   52.366   22.490    9.896    3.961
869.960  777.358  723.870  524.532  356.965  137.057   52.398   22.537   10.522    3.891
869.400  774.687  725.933  526.515  361.019  138.362   50.765   23.213    9.591    4.755
851.572  781.763  718.550  524.466  350.632  137.991   53.952   22.394   10.235    4.802
```

K=0.44; Eff=1.58; Effp=67%; Rcoll=0.06; Lamb=1cm;Lund=170m; 150 GeV

Each particle radiates 1.07 GeV in undulator

TEMPERATURE ALONG THE **W** TARGET FOR DIFFERENT RADIUSES

per 10^{13} initial electrons; spinning target



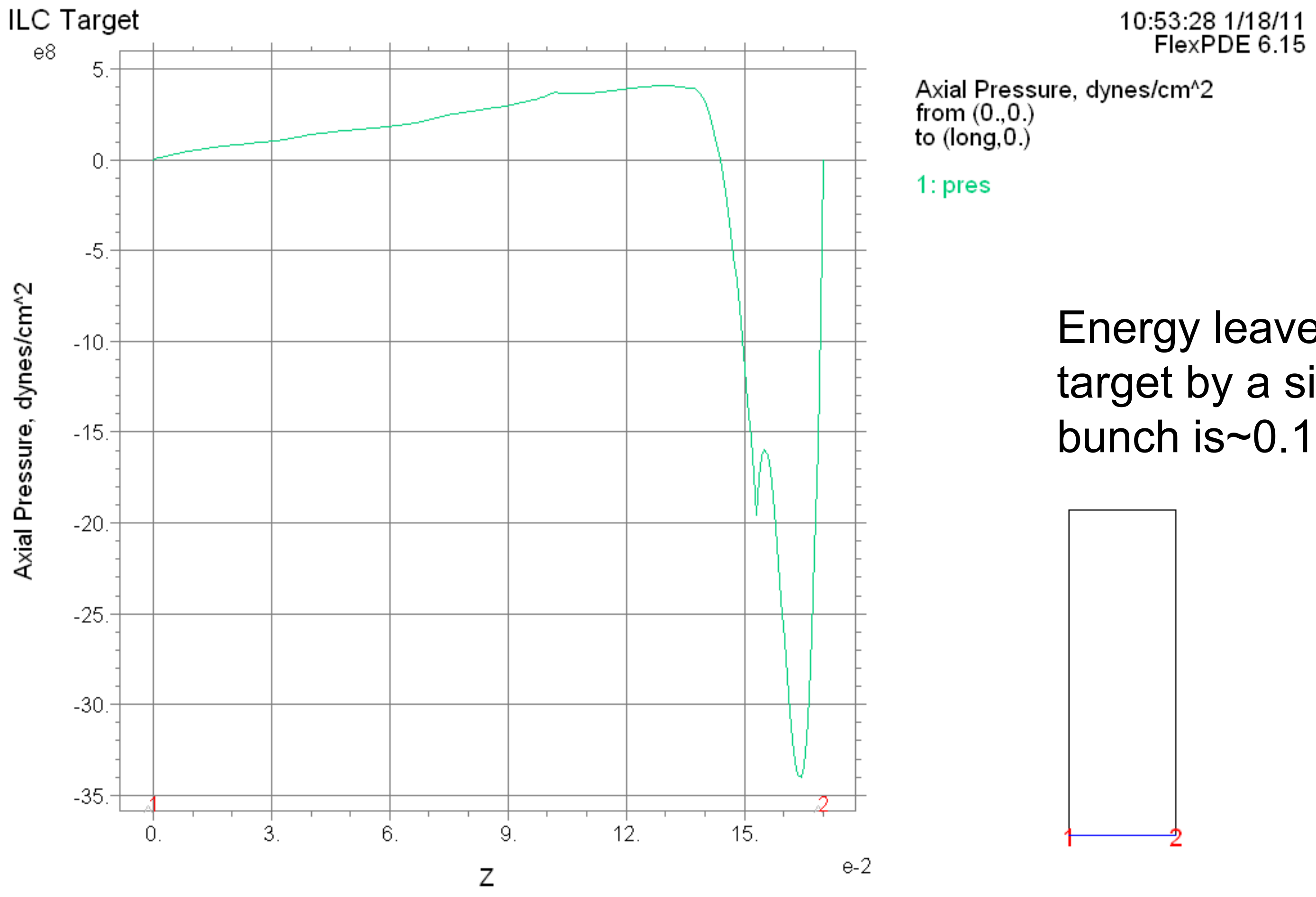
Center of Gamma-beam

Edge of collimator.

Each particle radiates 2.76 GeV in undulator

The negative pressure phenomenon confirmed here

Dyne/cm^2=10^{-6} bar



ILC_Target_with _pressure: Cycle=10264 Time= 1.0000e-10 dt= 8.6496e-15 P3 Nodes=1500 Cells=394 RMS Err= !
sigmar= 0.250000 sigmaz= 0.050000 Surf_Integral= -9.271943

Energy leaved in the target by a single bunch is~0.1 Joule

Pressure along the target; beam passed from the left to the right 0.1 *ns* ago

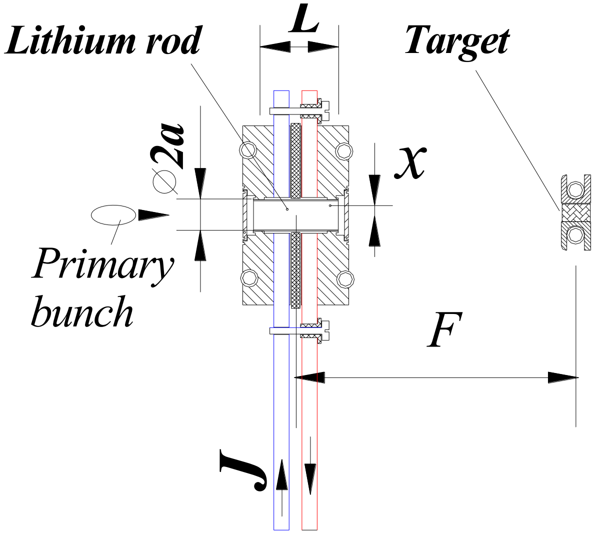
LITHIUM LENS BASICS

If steady current *I* runs through the round conductor having radius *a*, its azimuthal magnetic field inside the rod could be described as

$$H_\vartheta(r) = \frac{0.4\pi I r}{2\pi a^2}$$

where magnetic field is measured in *Gs*, *a* –in *cm*, *I* –in Amperes. Current density comes to $j_s = I/\pi a^2$ The particle, passed through the rod, will get the transverse kick

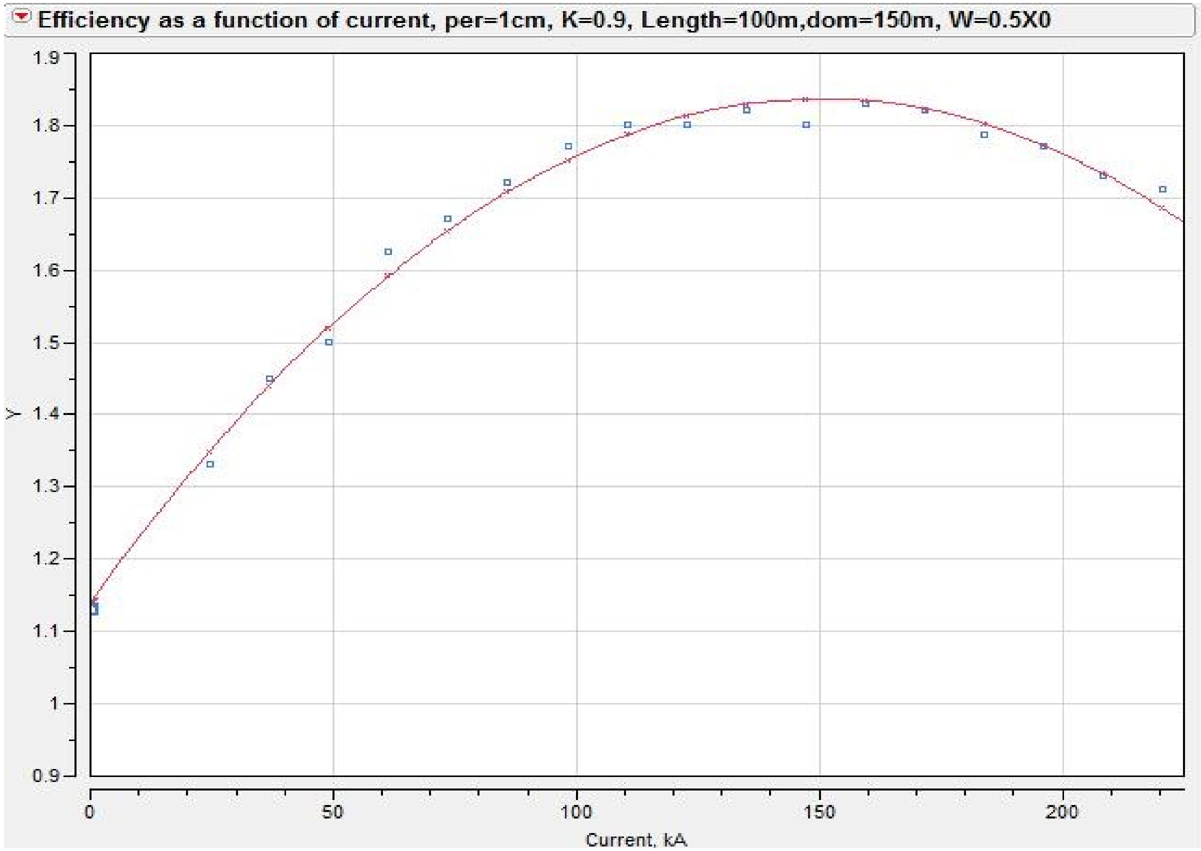
$$\alpha \cong \frac{H(x)\cdot L}{(HR)} \cong \frac{0.2 I L x}{a^2\cdot(HR)}$$



This picture drawn for the focusing of electron beam to the target

So the focal distance could be defined as the following $F \cong \dfrac{a^2\cdot(HR)}{0.2IL}$

First of all, how important is the lens for the collection business?

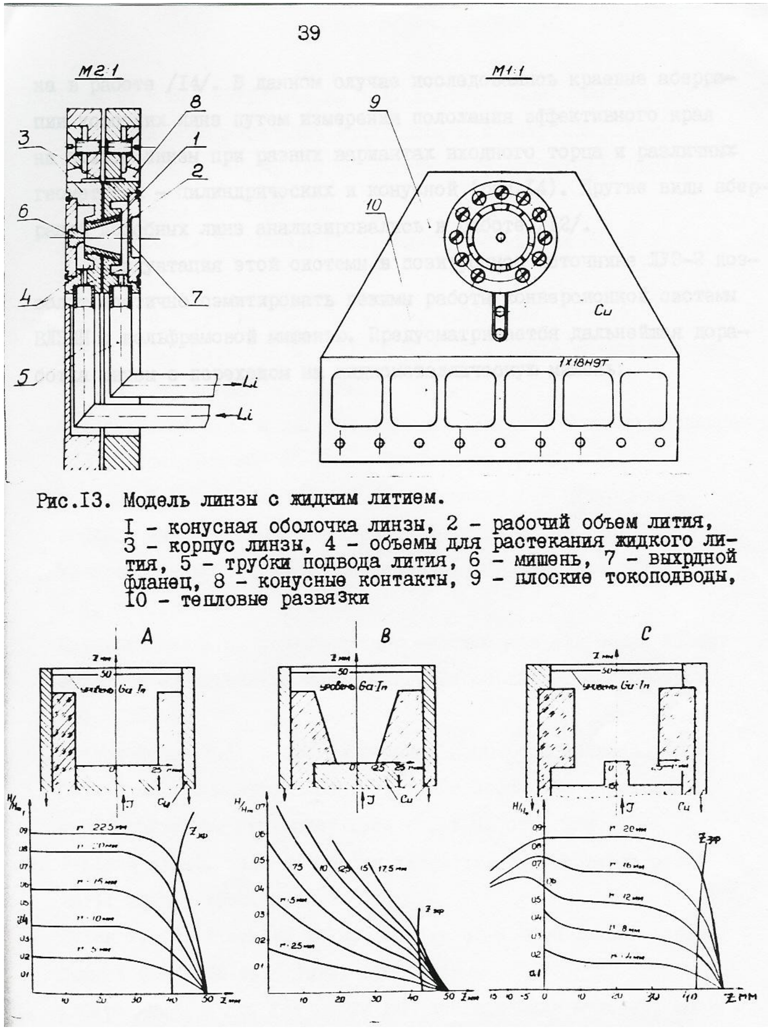


Efficiency of positron production normalized to the primary electron as function of feeding current in a lens. *K*=0.9, 100m long undulator, lens is 0.5 cm-long, ε`6MeV-cm.

One can see that LL potentially adds ~70% of positrons. But even without lens efficiency is more than one already.

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

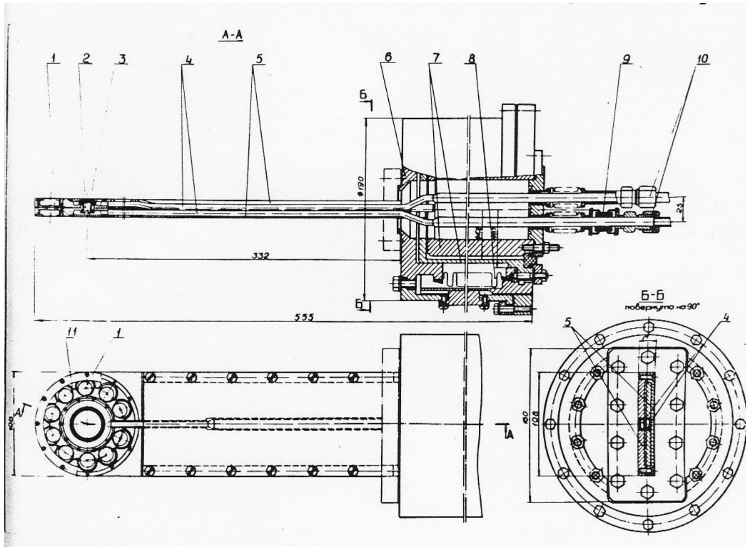


39

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

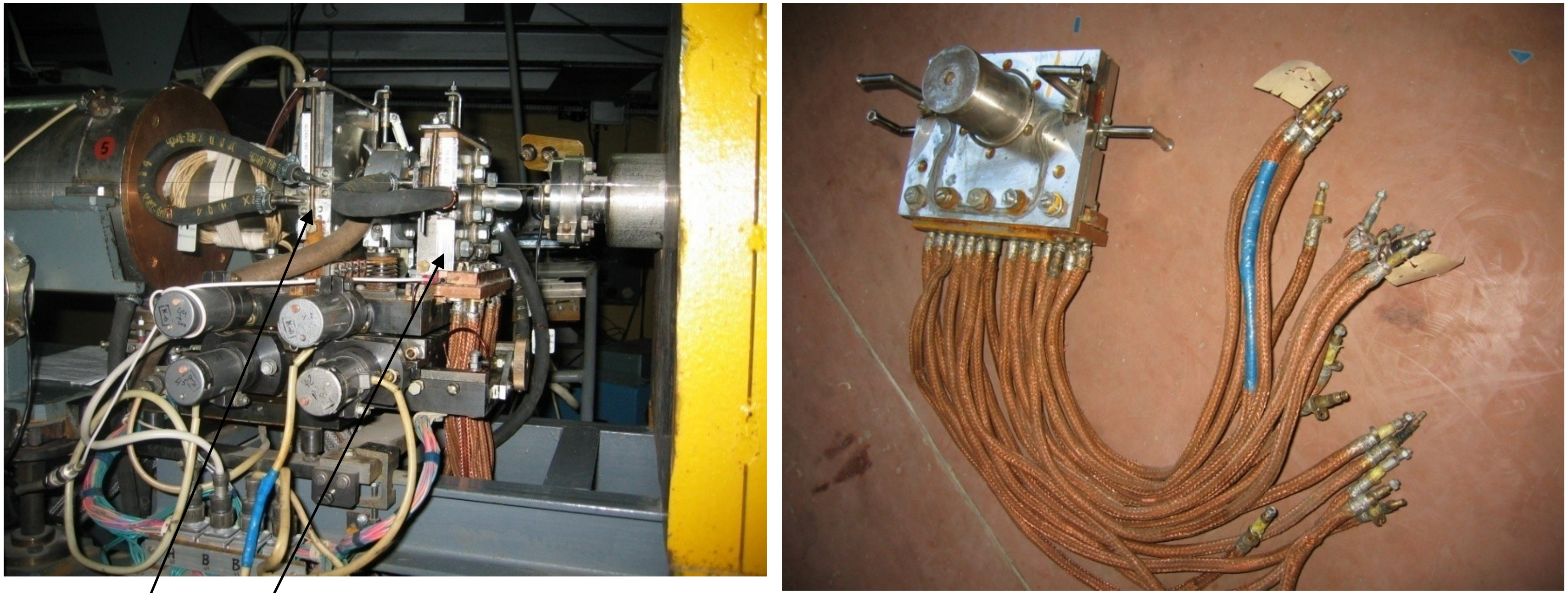
Field measured in liquid Gallium model.
A-cylindrical lens with homogenous current leads supply at the end
B- conical lens with the same current feed
C –lens with cylindrical target at the entrance flange



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.

Doublet of Solid Lithium lenses in Novosibirsk BINP

Photo- courtesy of Yu Shatunov



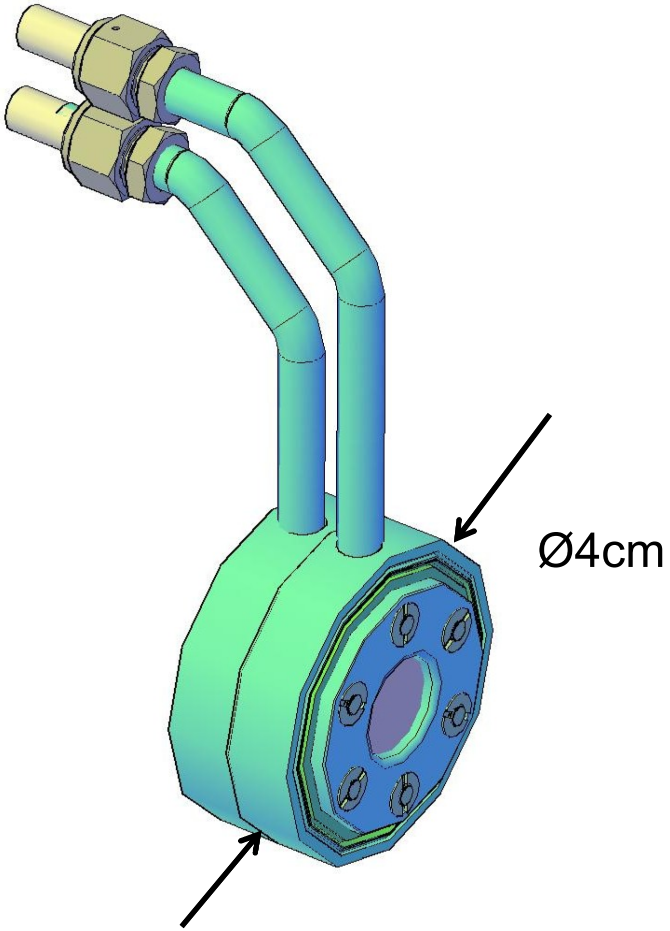
First lens is used for focusing of primary 250 MeV electron beam onto the W target,

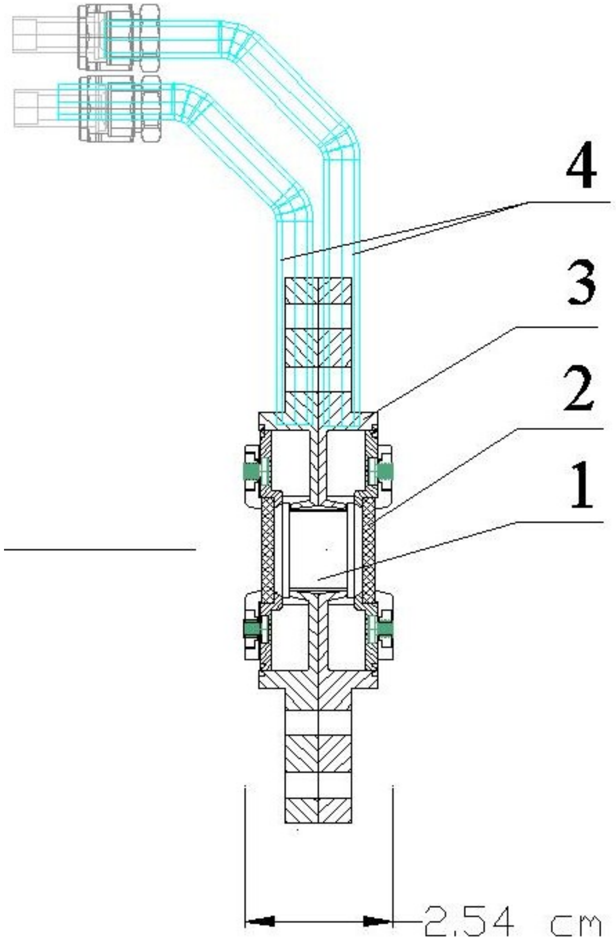
Second lens installed after the target and collects positrons at ~150MeV

Number of primary electrons per pulse ~$2\cdot10^{+11}$; ~0.7Hz operation (defined by the beam cooling rate in a Damping Ring)

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

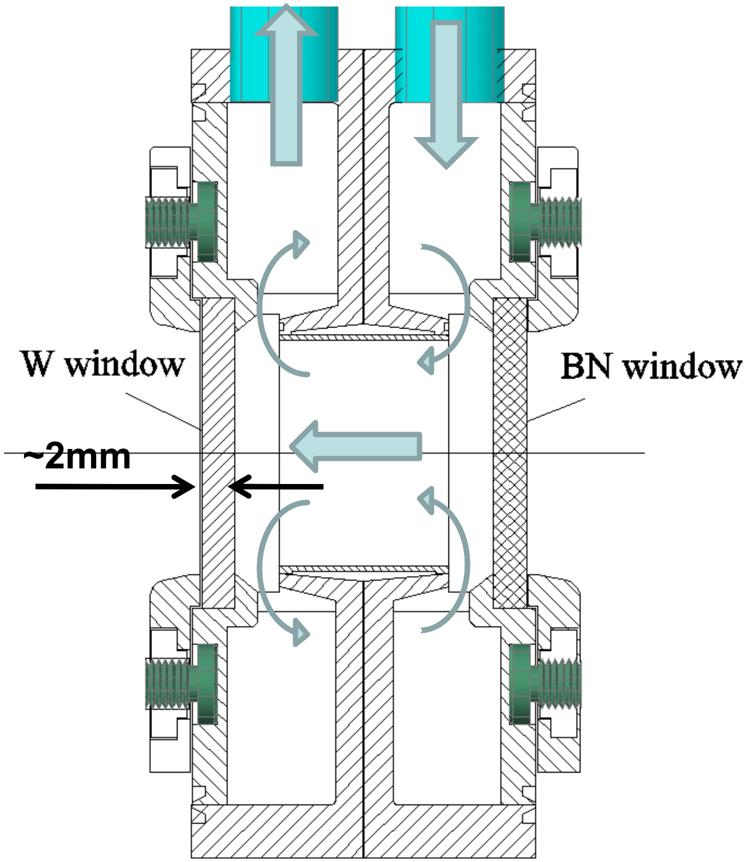
Lens with liquid Lithium for ILC
last generation with classic collet clamp





Lithium Lens for ILC positron source; extended flanges serve for electrical contact. 1–volume with Lithium, 2–window (Be/BC/BN), 3–electrical contacts with caverns for Li, 4–tubing for Lithium in/out. At the left-the latest variant with collet contacts.

THE CONCEPT



The gamma beam is coming from the left. By arrows it is shown the liquid Lithium flow.

To the choice of material for windows

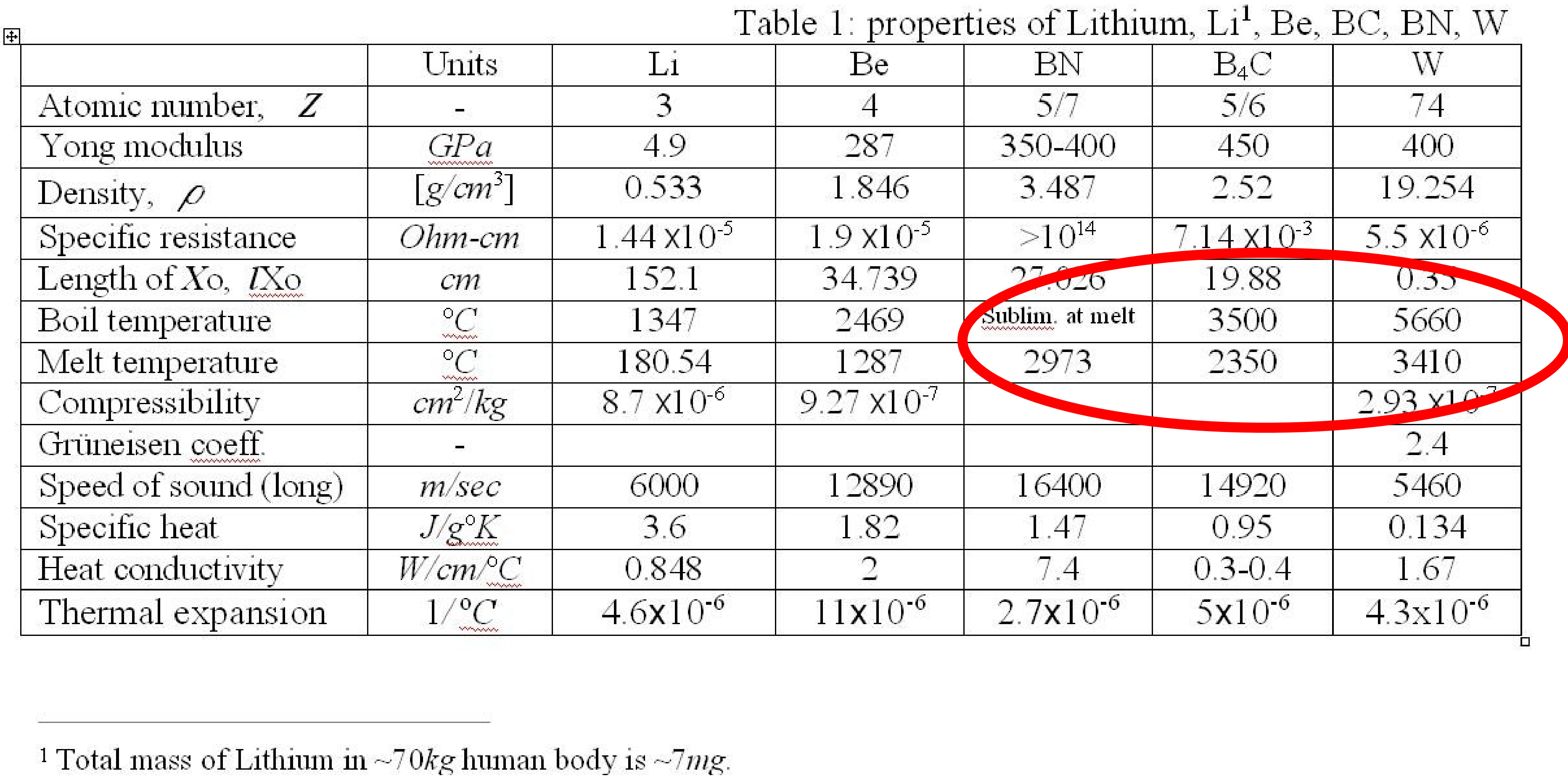


Table 1: properties of Lithium, Li[1], Be, BC, BN, W

	Units	Li	Be	BN	B_4C	W
Atomic number, Z	-	3	4	5/7	5/6	74
Yong modulus	*GPa*	4.9	287	350-400	450	400
Density, ρ	$[g/cm^3]$	0.533	1.846	3.487	2.52	19.254
Specific resistance	*Ohm-cm*	$1.44 x10^{-5}$	$1.9 x10^{-5}$	$>10^{14}$	$7.14 x10^{-3}$	$5.5 x10^{-6}$
Length of X_o, lX_o	*cm*	152.1	34.739	27.026	19.88	0.35
Boil temperature	°C	1347	2469	Sublim. at melt	3500	5660
Melt temperature	°C	180.54	1287	2973	2350	3410
Compressibility	cm^2/kg	$8.7 x10^{-6}$	$9.27 x10^{-7}$			$2.93 x10^{-7}$
Grüneisen coeff.	-					2.4
Speed of sound (long)	*m/sec*	6000	12890	16400	14920	5460
Specific heat	*J/g°K*	3.6	1.82	1.47	0.95	0.134
Heat conductivity	*W/cm/°C*	0.848	2	7.4	0.3-0.4	1.67
Thermal expansion	1/°C	$4.6x10^{-6}$	$11x10^{-6}$	$2.7x10^{-6}$	$5x10^{-6}$	$4.3x10^{-6}$

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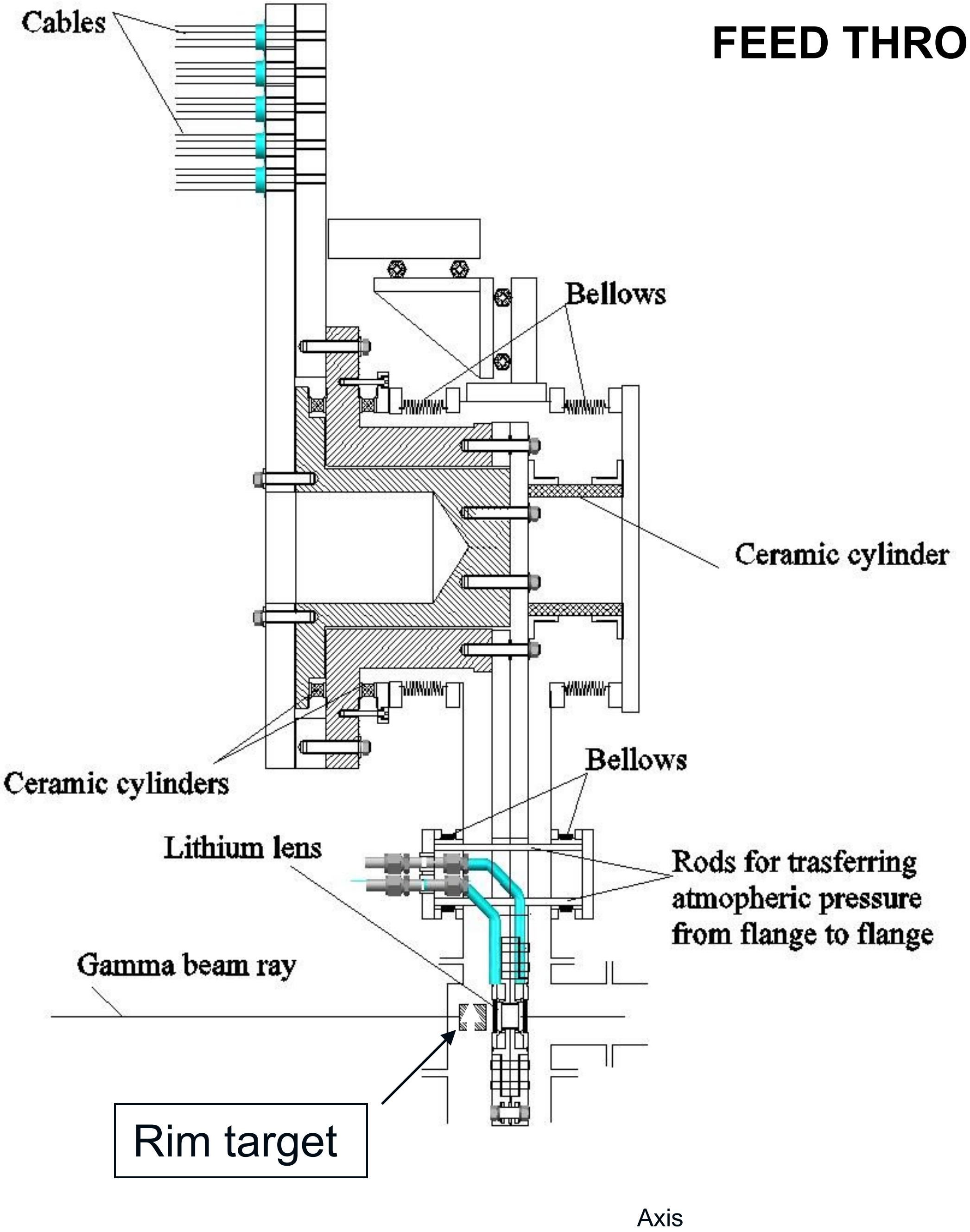
[1] Total mass of Lithium in ~70*kg* human body is ~7*mg*.

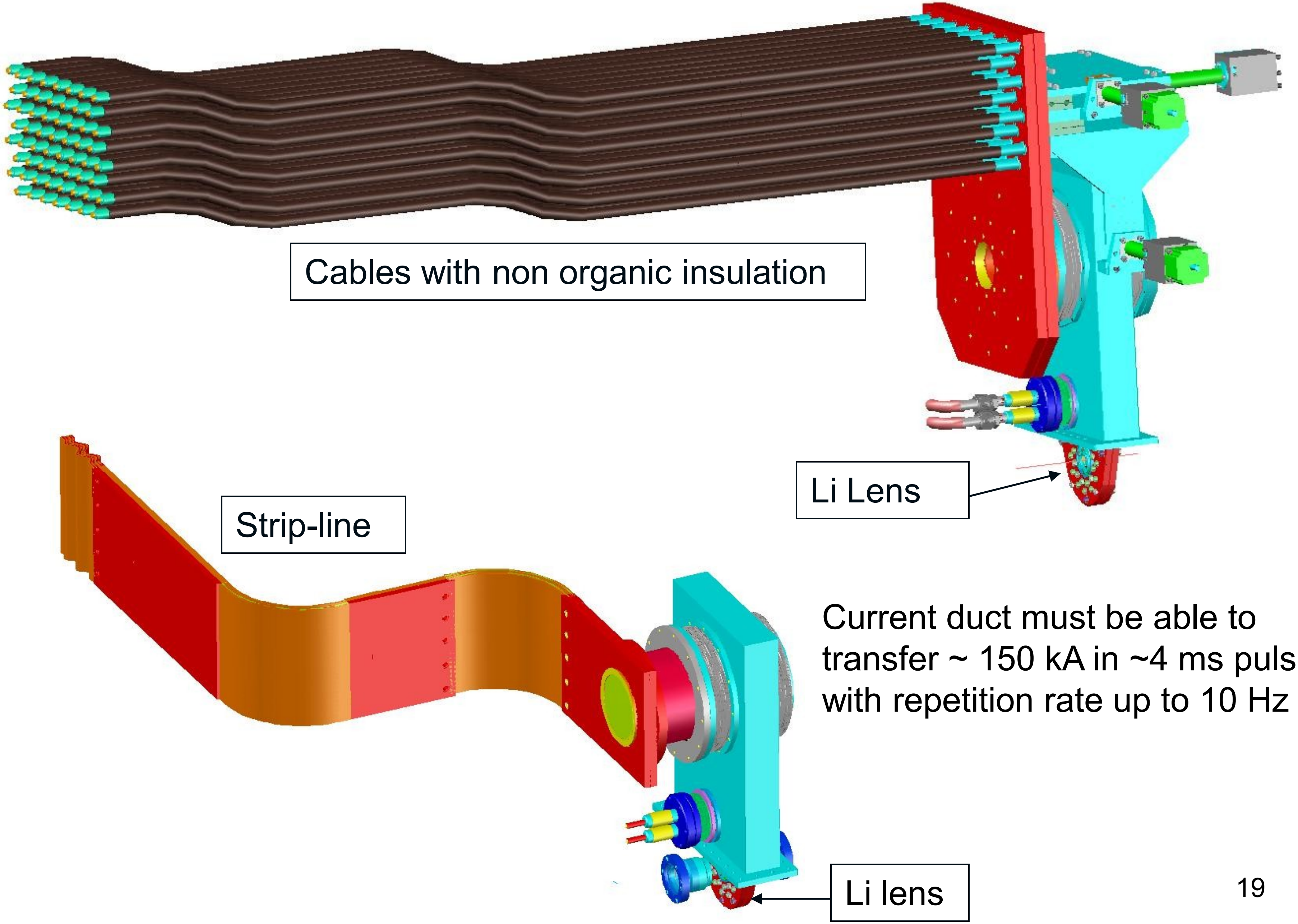
FEED THROUGH IN DETAIL



System with two bellows excludes net force from atmospheric pressure;

Positioning system serves for ajustment the distance between target and lens –what is required by optimization of yield/heating for the entrance window

Variants of current duct



Cables with non organic insulation

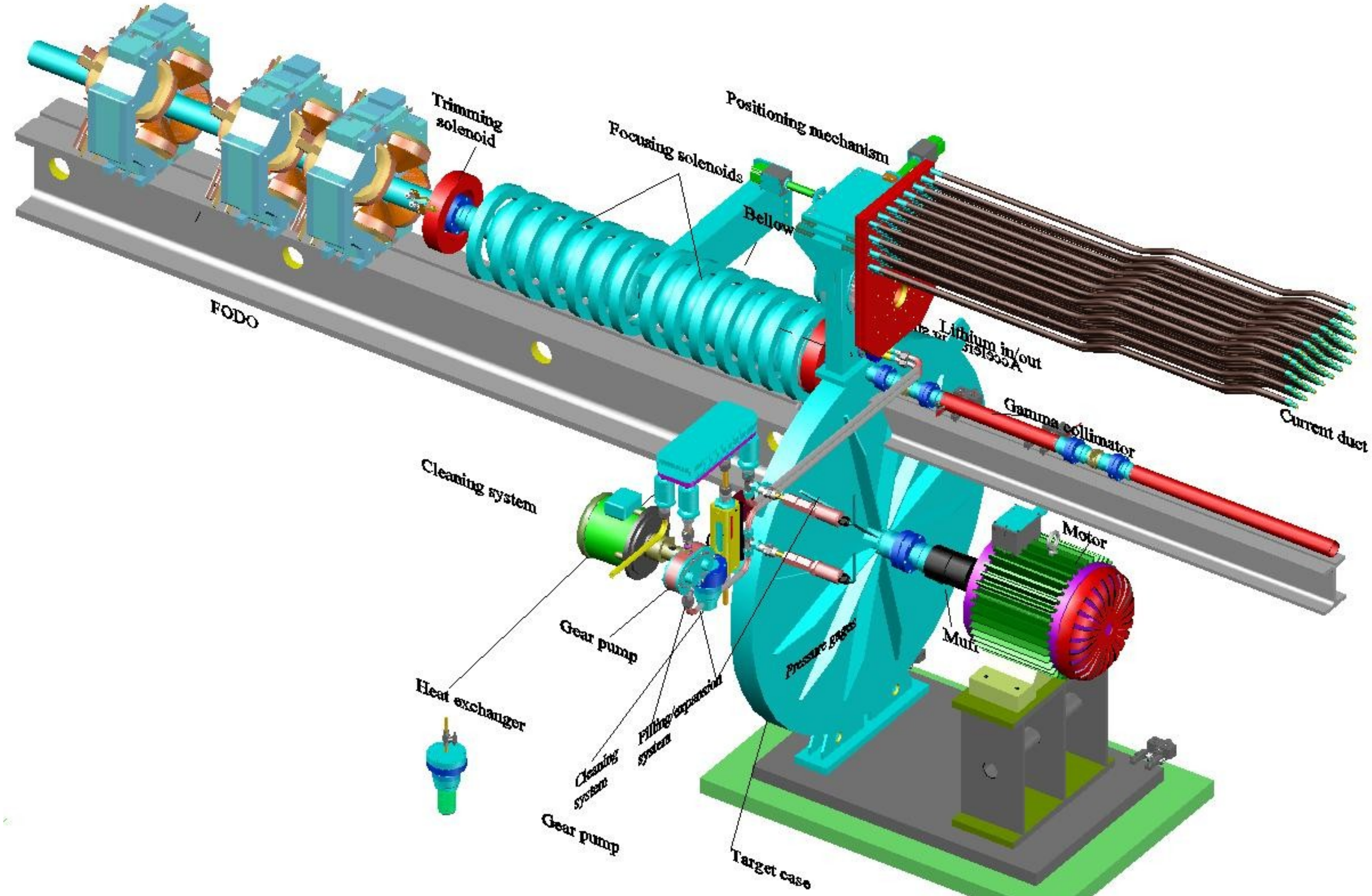
Li Lens

Strip-line

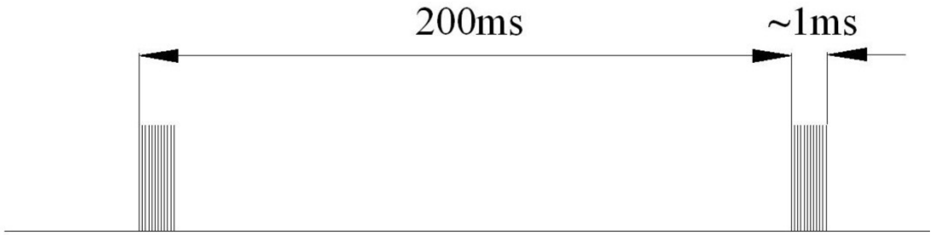
Li lens

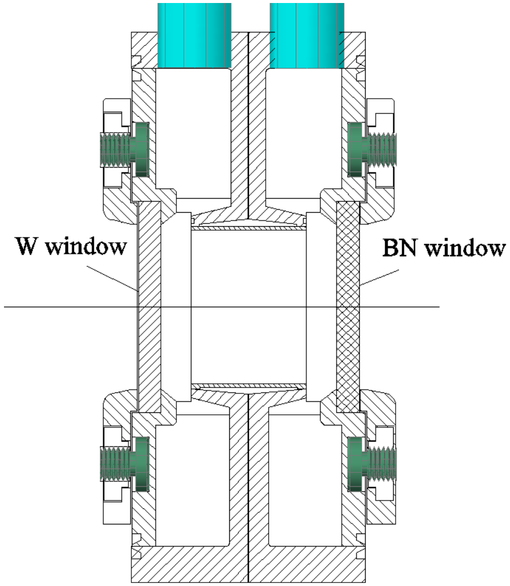
Current duct must be able to transfer ~ 150 kA in ~4 ms pulse with repetition rate up to 10 Hz

A.Mikhailichenko,” Lithium Lens (I)”, CBN -09-4, Aug 2009, 17pp.
http://www.lepp.cornell.edu/public/CBN/2009/CBN09-4/CBN%2009-04.pdf
A.Mikhailichenko,” Lithium Lens (II)”, CBN -10-3, Aug 2010, 37pp
http://www.lepp.cornell.edu/public/CBN/2010/CBN10-3/CBN%2010-03.pdf



Beam pattern in ILC





Equation for thermal diffusion in window

$$\nabla(k\nabla T)+\dot{Q}=\rho c_V \dot{T}$$

defines time of relaxation from its characteristic

$$\frac{dx^2}{k}=\frac{dt}{\rho c_V}\rightarrow \quad \delta^2=\frac{k}{\rho c_V}\tau \rightarrow \tau=\frac{\rho c_V}{k}\delta^2$$

For W: k=1.67 $W/cm/^oK$, ρ=19g/cm^3 , c_V=0.13 $J/g/^oK$

If $\delta\sim 1/2X_0/2\sim 0.09cm$

$$\tau=\frac{19\cdot 0.13}{1.67}8\cdot 10^{-3}\cong 12ms$$

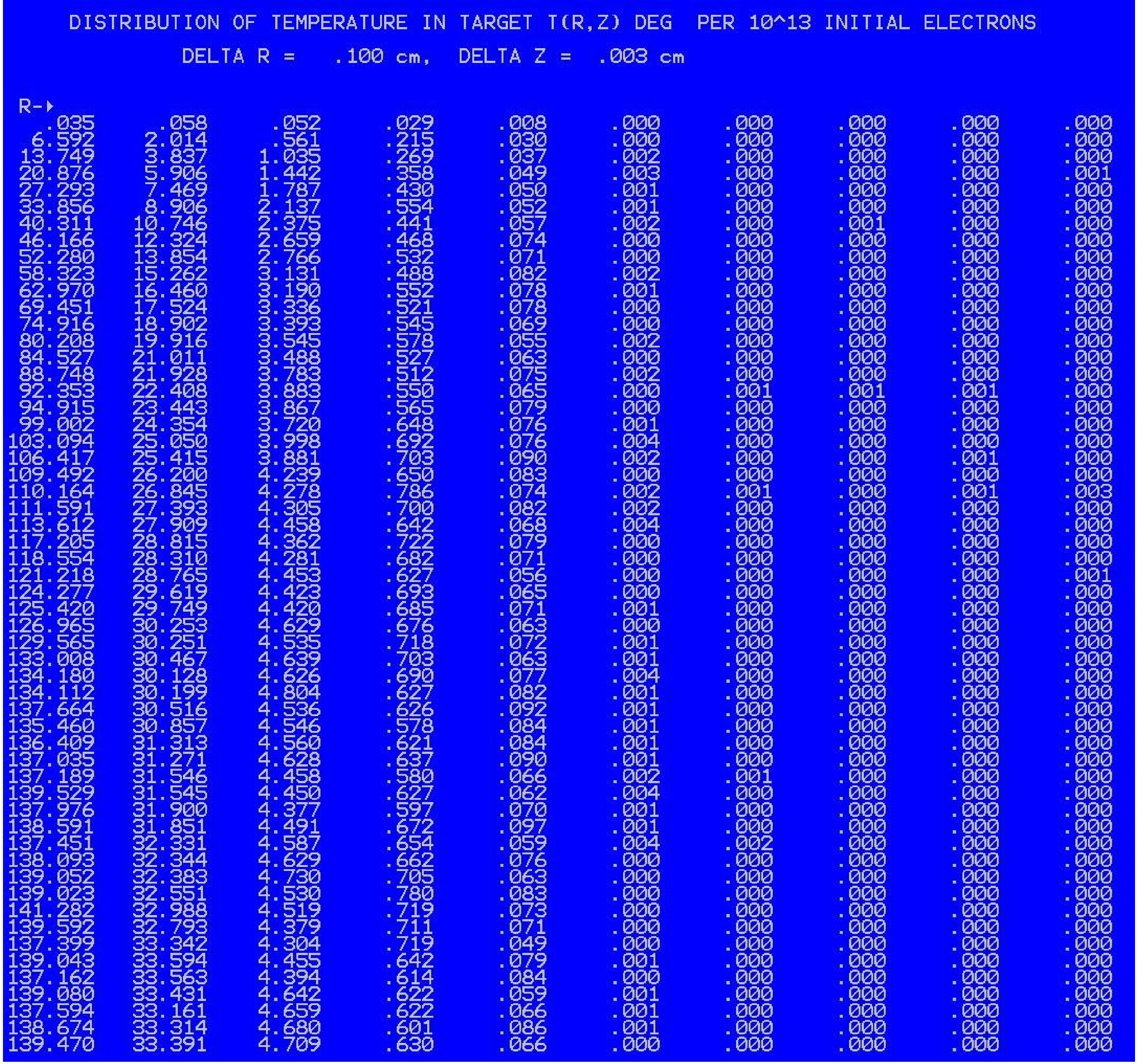
This gives ~20% temperature drop even within a train for W;
To the next train the target will be cool

Can W survive as a flange?

The gamma spot size should be increased.
This reduces performance of system slightly

Calculations with KONN for combined target-lens system

Beam energy, GeV	100	150	250
Length of undulator, m	220	170	170
K factor	0.66	0.36	0.28
Period of undulator, cm	1	1	1
Distance to the target, m	200	350	600
Thick. of target/X_o	0.55	0.57	0.6
Radius of lens, cm	0.6	0.6	0.6
Gradient, kG/cm	60	60	65
Length of the lens, cm	0.7	0.7	0.7
Current, kA	108	108	117
Radius of collimator, cm	0.2	0.5	0.15
Rad, of irises in RF, cm	3	3	3
Rad of coll. before RF, cm	2	2	2
Acceptance, MeVxcm	9	9	9
Energy filter E> , MeV	51	54	63
Energy filter E< , MeV	110	110	180
ΔT per train 10^13 e-, ^{o}C	172	139	270
ΔT in lens from beam, ^{o}C	18	35	80
ΔT in lens from current, ^{o}C	90	90	100
Efficiency, e+/e-	1.52	1.57	1.52
Polarization, %	54	57	64



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    DISTRIBUTION OF TEMPERATURE IN TARGET T(R,Z) DEG  PER 10^13 INITIAL ELECTRONS
               DELTA R =   .100 cm,  DELTA Z =  .003 cm

 R-▸
   .035          .058          .052          .029          .008          .000          .000          .000          .000          .000
  6.592         2.014          .561          .215          .030          .000          .000          .000          .000          .000
 13.749         3.837         1.035          .269          .037          .002          .000          .000          .000          .000
 20.876         5.906         1.442          .358          .049          .003          .000          .000          .000          .001
 27.293         7.469         1.787          .430          .050          .001          .000          .000          .000          .000
 33.856         8.906         2.137          .554          .052          .001          .000          .000          .000          .000
 40.311        10.746         2.375          .441          .057          .002          .000          .001          .000          .000
 46.166        12.324         2.659          .468          .074          .000          .000          .000          .000          .000
 52.280        13.854         2.766          .532          .071          .000          .000          .000          .000          .000
 58.323        15.262         3.131          .488          .082          .002          .000          .000          .000          .000
 62.970        16.460         3.190          .552          .078          .001          .000          .000          .000          .000
 69.451        17.524         3.336          .521          .078          .000          .000          .000          .000          .000
 74.916        18.902         3.393          .545          .069          .000          .000          .000          .000          .000
 80.208        19.916         3.545          .578          .055          .002          .000          .000          .000          .000
 84.527        21.011         3.488          .527          .063          .000          .000          .000          .000          .000
 88.748        21.928         3.783          .512          .075          .002          .000          .000          .000          .000
 92.353        22.408         3.883          .550          .065          .000          .001          .001          .001          .000
 94.915        23.443         3.867          .565          .079          .000          .000          .000          .000          .000
 99.002        24.354         3.720          .648          .076          .001          .000          .000          .000          .000
103.094        25.050         3.998          .692          .076          .004          .000          .000          .000          .000
106.417        25.415         3.881          .703          .090          .002          .000          .000          .001          .000
109.492        26.200         4.239          .650          .083          .000          .000          .000          .000          .000
110.164        26.845         4.278          .786          .074          .002          .001          .000          .001          .003
111.591        27.393         4.305          .700          .082          .002          .000          .000          .000          .000
113.612        27.909         4.458          .642          .068          .004          .000          .000          .000          .000
117.205        28.815         4.362          .722          .079          .000          .000          .000          .000          .000
118.554        28.310         4.281          .682          .071          .000          .000          .000          .000          .000
121.218        28.765         4.453          .627          .056          .000          .000          .000          .000          .001
124.277        29.619         4.423          .693          .065          .000          .000          .000          .000          .000
125.420        29.749         4.420          .685          .071          .001          .000          .000          .000          .000
126.965        30.253         4.629          .676          .063          .000          .000          .000          .000          .000
129.565        30.251         4.535          .718          .072          .001          .000          .000          .000          .000
133.008        30.467         4.639          .703          .063          .001          .000          .000          .000          .000
134.180        30.128         4.626          .690          .077          .004          .000          .000          .000          .000
134.112        30.199         4.804          .627          .082          .001          .000          .000          .000          .000
137.664        30.516         4.536          .626          .092          .001          .000          .000          .000          .000
135.460        30.857         4.546          .578          .084          .001          .000          .000          .000          .000
136.409        31.313         4.560          .621          .084          .001          .000          .000          .000          .000
137.035        31.271         4.628          .637          .090          .001          .000          .000          .000          .000
137.189        31.546         4.458          .580          .066          .002          .001          .000          .000          .000
139.529        31.545         4.450          .627          .062          .004          .000          .000          .000          .000
137.976        31.900         4.377          .597          .070          .001          .000          .000          .000          .000
138.591        31.851         4.491          .672          .097          .001          .000          .000          .000          .000
137.451        32.331         4.587          .654          .059          .004          .002          .000          .000          .000
138.093        32.344         4.629          .662          .076          .000          .000          .000          .000          .000
139.052        32.383         4.730          .705          .063          .000          .000          .000          .000          .000
139.023        32.551         4.530          .780          .083          .000          .000          .000          .000          .000
141.282        32.988         4.519          .719          .073          .000          .000          .000          .000          .000
139.592        32.793         4.379          .711          .071          .000          .000          .000          .000          .000
137.399        33.342         4.304          .719          .049          .000          .000          .000          .000          .000
139.043        33.594         4.455          .642          .079          .001          .000          .000          .000          .000
137.162        33.563         4.394          .614          .084          .000          .000          .000          .000          .000
139.080        33.431         4.642          .622          .059          .001          .000          .000          .000          .000
137.594        33.161         4.659          .622          .066          .001          .000          .000          .000          .000
138.674        33.314         4.680          .601          .086          .001          .000          .000          .000          .000
139.470        33.391         4.709          .630          .066          .000          .000          .000          .000          .000
```

CONCLUSIONS

- As the target is not in motion, the optimization carried for reduction of the temperature jump in a target.

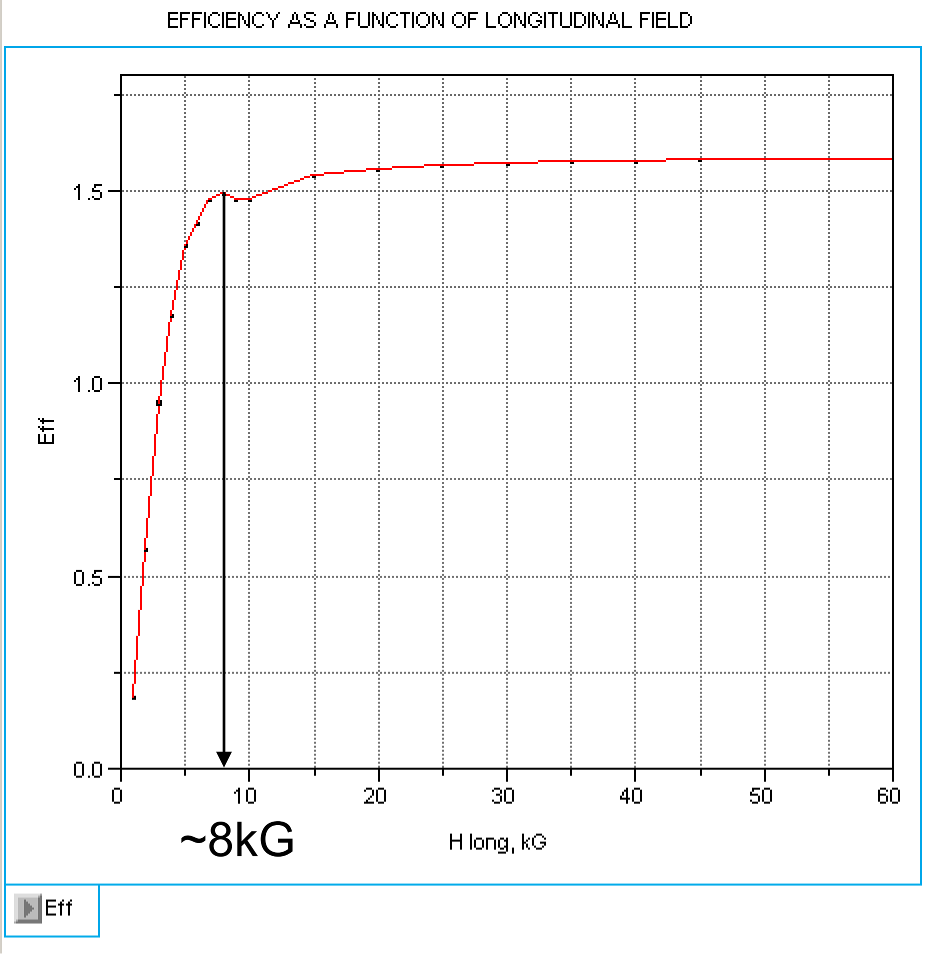
- This reduces overall parameters of the system slightly, compared with moving target; Still efficiency 1.5 can be reached, polarization slightly lower~60%

- Dependence of positron yield as function of Be window thickness is pretty monotonic. Be windows of up to 5 mm thick is possible. Usage of BC, BN windows allow have them thinner.

- This type of lens/Target combined device might be recommended for the CLIC-type collider as in this case the power consumption in the target is minimal and polarization can be restored for ~70% again.

- BACKUP SLIDES

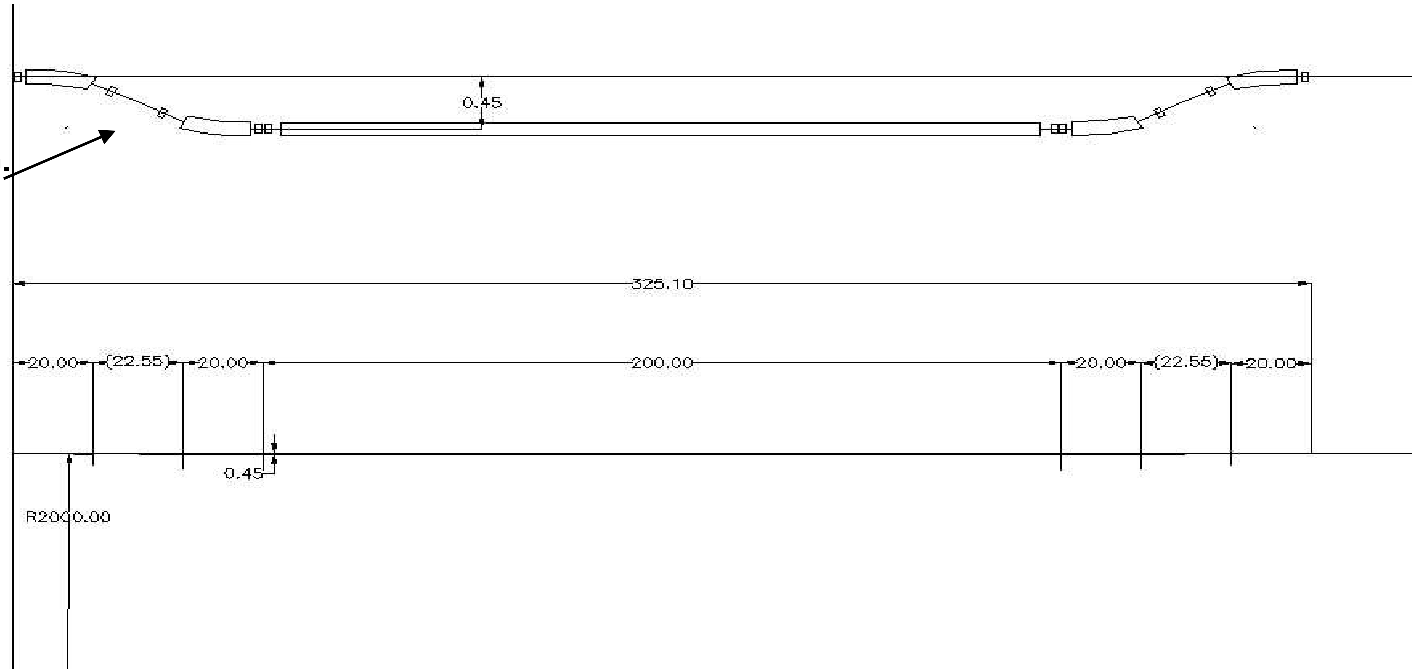
If all other parameters are kept fixed, then efficiency of conversion as a function of longitudinal magnetic field around accelerating structure looks like:



~8kG

Pretty moderate field indeed

Undulator bypass line

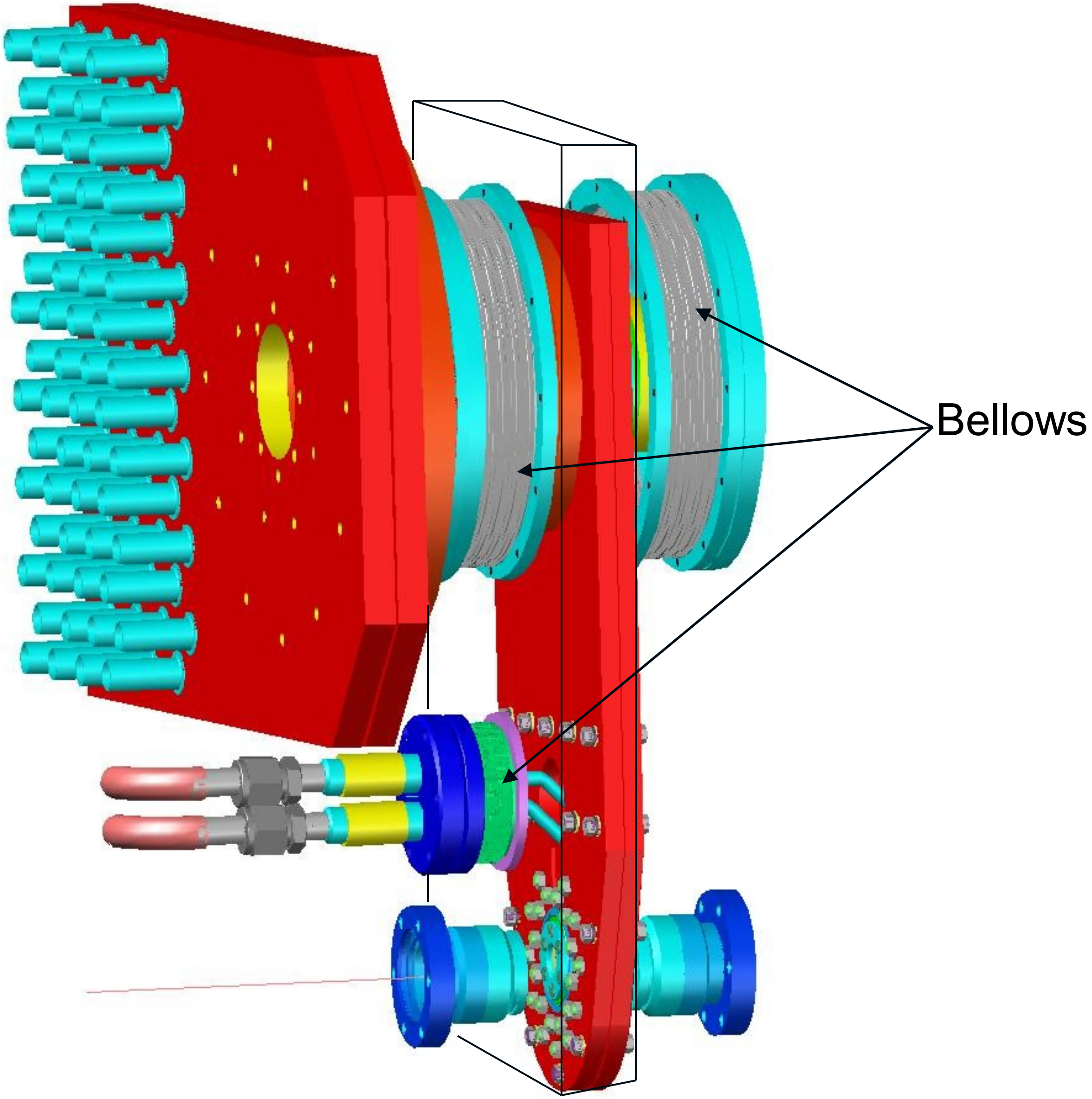


V.V. Vladimirsky, D.G. Koshkarev,1958

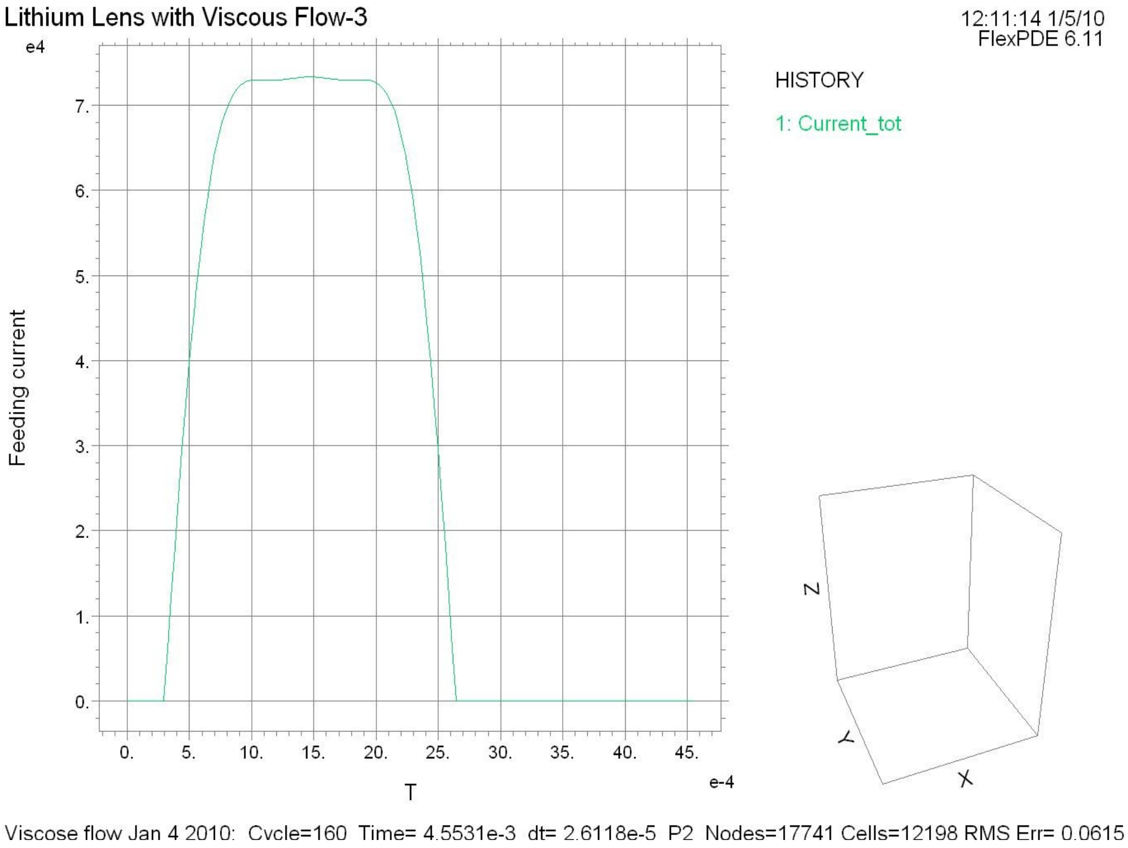
Very high density of SR in any bending magnet, as emittance is extremely small

T.A.Vsevolojskaya, A.A.Mikhailichenko, G.I Silvestrov, A.N. Cherniakin, "*To the Project of Conversion System for Obtaining Polarized Beams at VLEPP Complex*", internal report BINP, Novosibirsk, 1986.

Scaled view on vacuumed feed through and lens; vacuum case not shown



Feeding voltage composed with three odd harmonics 1,3,5

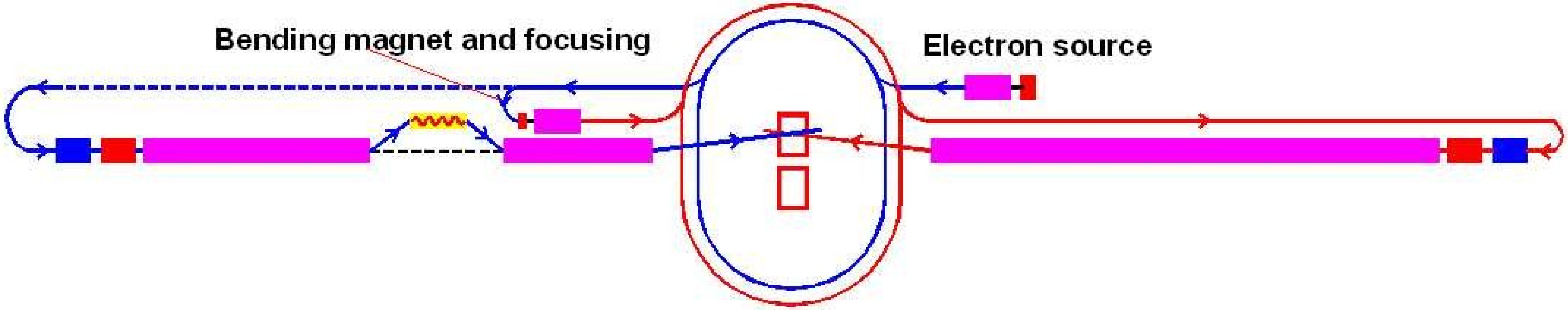


Viscose flow Jan 4 2010: Cycle=160 Time= 4.5531e-3 dt= 2.6118e-5 P2 Nodes=17741 Cells=12198 RMS Err= 0.0615

Voltage applied

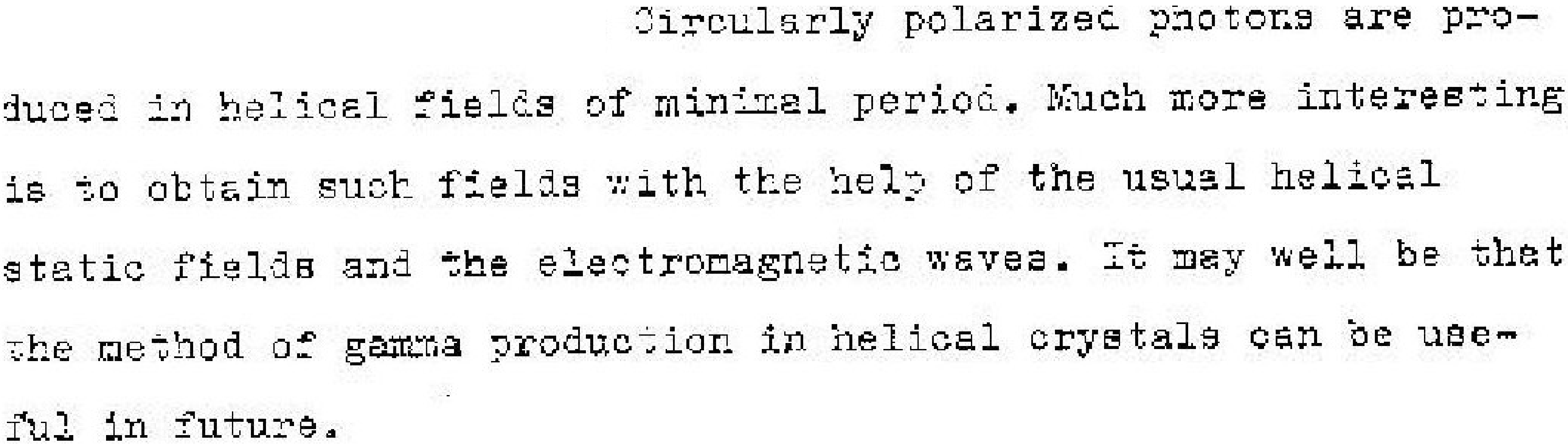
$$U(t) = U_0 \cdot [-4.5 \cdot Sin(\frac{\pi \cdot (t - \tau/10)}{\tau}) - 0.9 \cdot Sin(\frac{3\pi \cdot (t - \tau/10)}{\tau}) - 0.17 \cdot Sin(\frac{5\pi \cdot (t - \tau/10)}{\tau})]$$

Filling positron ring from electron source



Additional “keep alive” source not required

Fragment from the publication of Balakin-Mikhailichenko, Budker INP 79-85, Sept. 13, 1979.

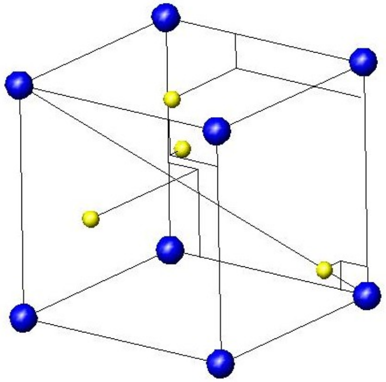


Circularly polarized photons are produced in helical fields of minimal period. Much more interesting is to obtain such fields with the help of the usual helical static fields and the electromagnetic waves. It may well be that the method of gamma production in helical crystals can be useful in future.

Scattering on the Laser radiation is the same process as the scattering on the electromagnetic wave.

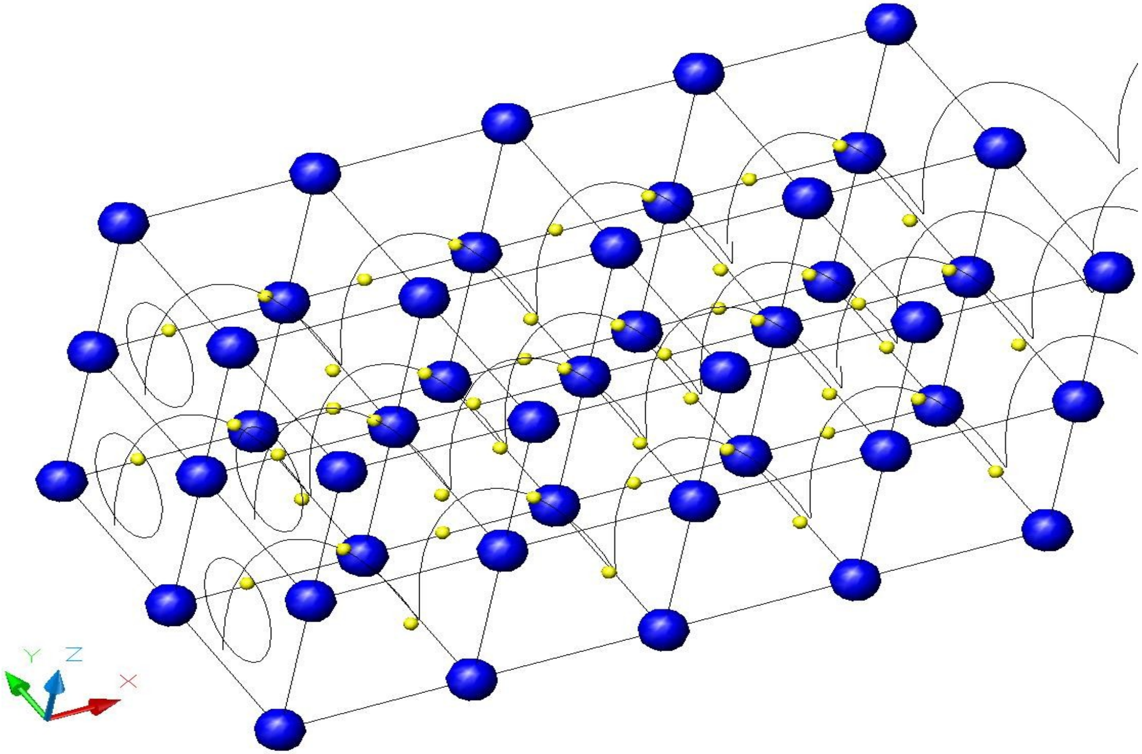
One comment about helical crystals first .

Helical (chiral) crystals



Crystal structure MnSi and FeGe

P.Bak, M.H.Jensen, J.Phys.C: Solid St.Physics, 13,(1980) L881-5



Helical structure demonstrates also $CsCuCl_3$, $Ba_2CuGe_2O_7$, MnS_2

Laser bunch as an undulator

The number of the quantas radiated by an electron by scattering on photons - real from the laser or virtual from the undulator:

$$N_\gamma \cong 4\pi\alpha \frac{L}{\lambda_u}\frac{K^2}{1+K^2} = 4\pi\frac{e^2}{\hbar c}\frac{L}{\lambda_u}\left(\frac{eH\lambda_u}{2\pi mc^2}\right)^2 \approx \left(\frac{e^2}{mc^2}\right)^2 \frac{L\lambda_u}{2\pi\hbar c}H^2 \cong r_0^2 L\frac{H^2}{\hbar\Omega} \cong \sigma_\gamma n_\gamma L$$

$$K = eH\lambda_u / 2\pi mc^2 \cong 0.934\cdot H[T]\cdot\lambda_u[cm] \quad K = \beta_\perp\gamma \quad \sigma_\gamma \cong \pi r_0^2 \quad n_\gamma \cong \frac{H^2}{\hbar\Omega} \quad \Omega = \frac{2\pi c}{\lambda_u}$$

Formation length in undulator $l_f \cong \lambda_u$ L- length of undulator

$$N_\gamma \cong L/\sigma_\gamma n_\gamma = L/l_\gamma$$

$l_\gamma \cong 1/\sigma_\gamma n_\gamma$ – Length of interaction

Written in this form it is clear that the photon back scattering (especially with 90^o crossing angle) is an equivalent of radiation in an undulator (as soon as the photon energy is much less, than the energy of particle).