CONVERSION EFFICIENCY AT 250 GeV

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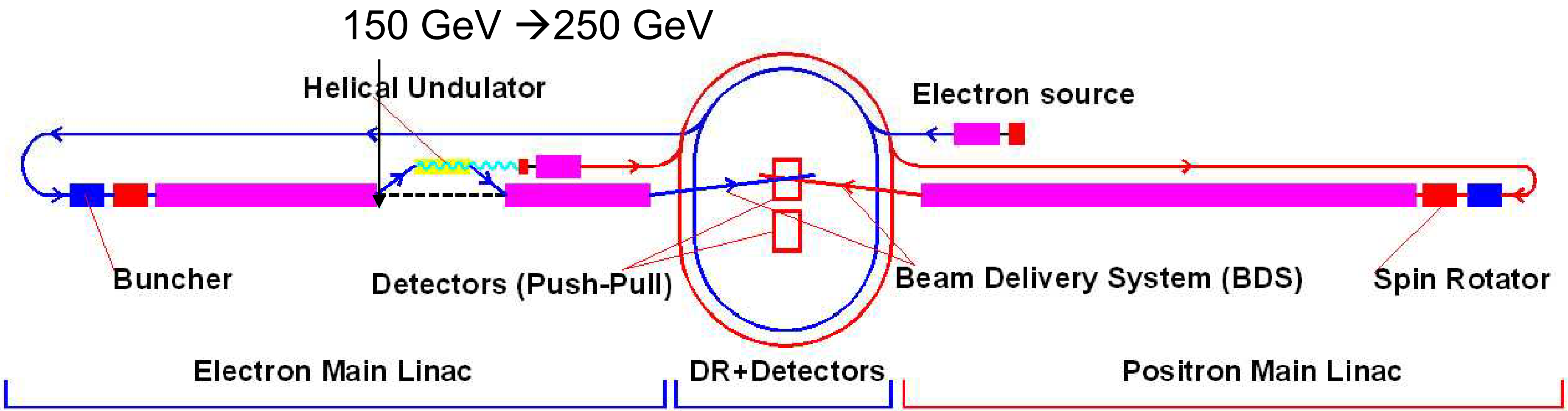
ILC Baseline



REASONS FOR HIGHER BEAM ENERGY AT CONVERSION POINT

150 GeV could be changed to higher value, 250GeV, while adding accelerator sections for energy upgrade if undulator remains at the same place

In some scenario, one can suggest to move undulator to the end of linac at all

So consideration of undulator-based conversion at higher energy has an interest

What is the energy acceptance and max admittance of DR?

Source: ILC reference Design Report

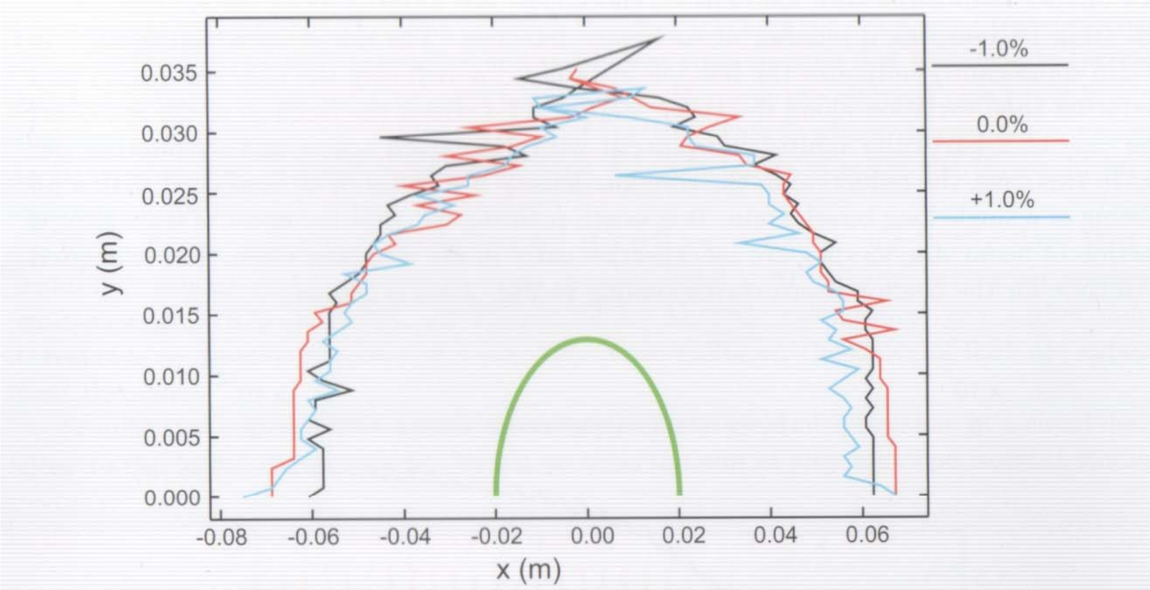


FIGURE 2.4-3. Dynamic aperture of the ILC Damping Ring (without field and alignment errors) for relati momentum errors of -1%, 0% and 1% at x = 44 m and y = 18 m. The thick green line represents the si of the injected positron beam.

β_x =44m? β_y =18m?

The energy acceptance ±1% → ±50MeV looks guarantied

Admittance concluded from this figure →2x10-3cmxrad=10MeVxcm

From the figure above, even ±5 cm radial aperture is possible

From ILC reference Design Report

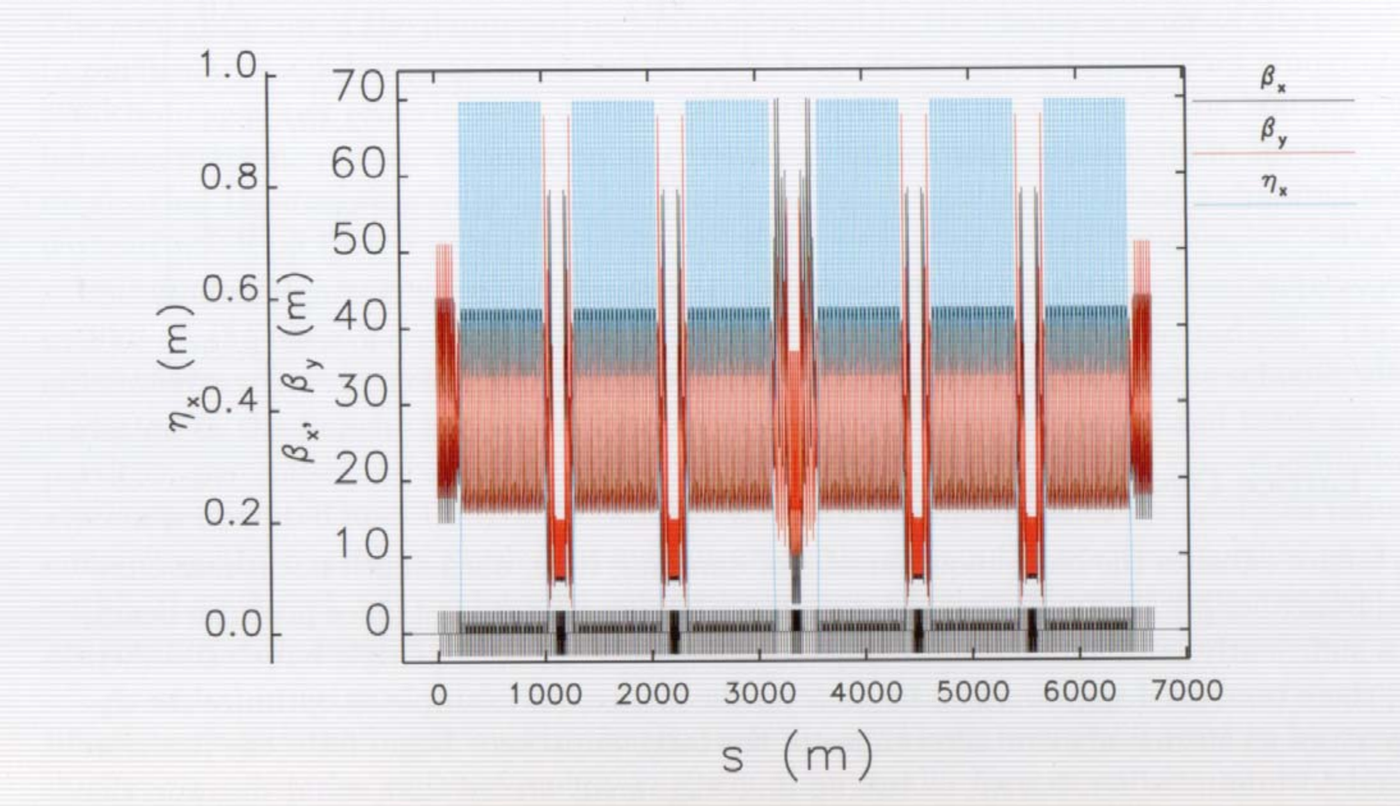


FIGURE 2.4-2. Optical functions of the ILC Damping Ring.

β- functions are within 15-40 m; max~ 57m

A. Wolski, J. Gao, S. Guiducci (eds.) “Configuration Studies and Recommendations for the ILC Damping Rings," LBNL-59449 (2006).

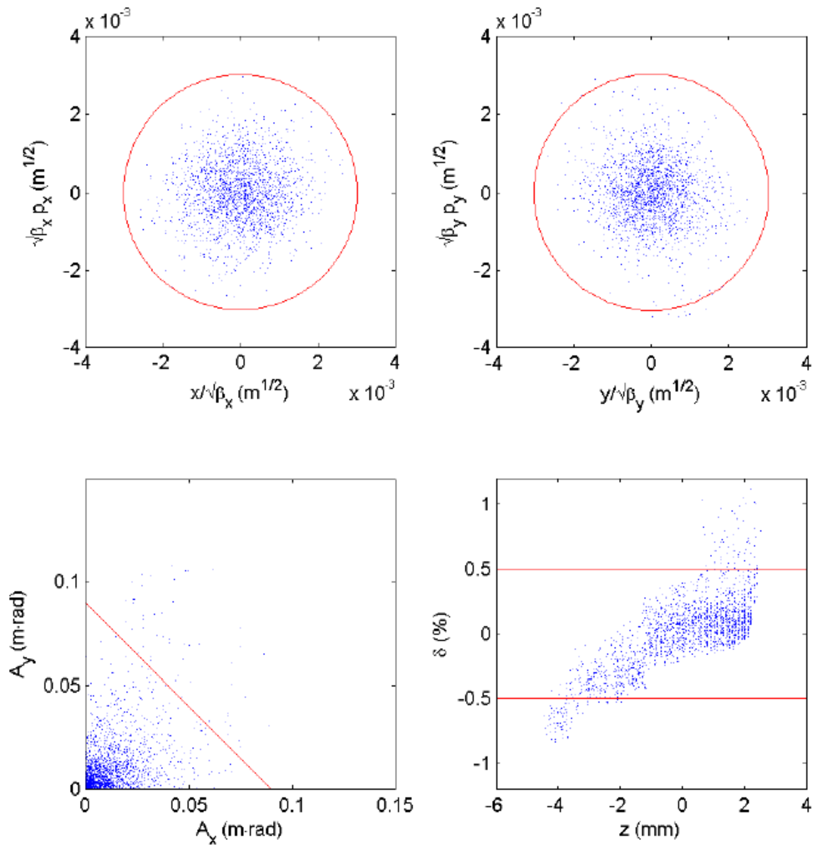


Figure 3.29: Distribution of injected positrons from Batygin (the YB distribution). Top: horizontal (left) and vertical (right) phase space in normalized coordinates; the red circles show the limits given by $A_{x,y} < 0.09$ m·rad. Bottom left: transverse distribution of betatron amplitudes; the red line shows the limit given by $A_x + A_y < 0.09$ m·rad. Bottom right: longitudinal phase space distribution; the red lines show the limits given by $|\delta| < 0.5\%$. 90% of the particles meet both the transverse and longitudinal specifications.

Dynamic aperture picture in final report (shown above) looks better, than the ones in this report

$$\frac{A_x}{\gamma} = \gamma_x x^2 + 2\alpha_x x p_x + \beta_x p_x^2$$

where $\gamma_x, \alpha_x, \beta_x$ stands for Twiss parameters

RMS emittance defined as

$$\varepsilon_x = \frac{\langle A_x \rangle}{2\gamma}$$

$$\langle A_x \rangle = 2\gamma\varepsilon_x$$

So A_x is an invariant emittancex2

About energy for conversion: A.Mikhailichenko in “Proceedings of the Workshop on New Kinds of Positron Sources for Linear Colliders”, 1997,SLAC-R-502, p.283

Photon spectrum normalized to the maximal photon energy $s = \omega_n / \omega_n^{max}$

$$\frac{dN_{n\gamma}}{ds} \cong 4\pi\alpha n M \frac{K^2}{1+K^2} \times \begin{cases} \frac{1}{2}(1-2s+2s^2), & n=1 \\ 2s(1-s)(1-s+2s^2), & n=2 \\ \dots \\ F_n(K,s) \end{cases}$$

It is ***not a function of energy*** of primary electron beam

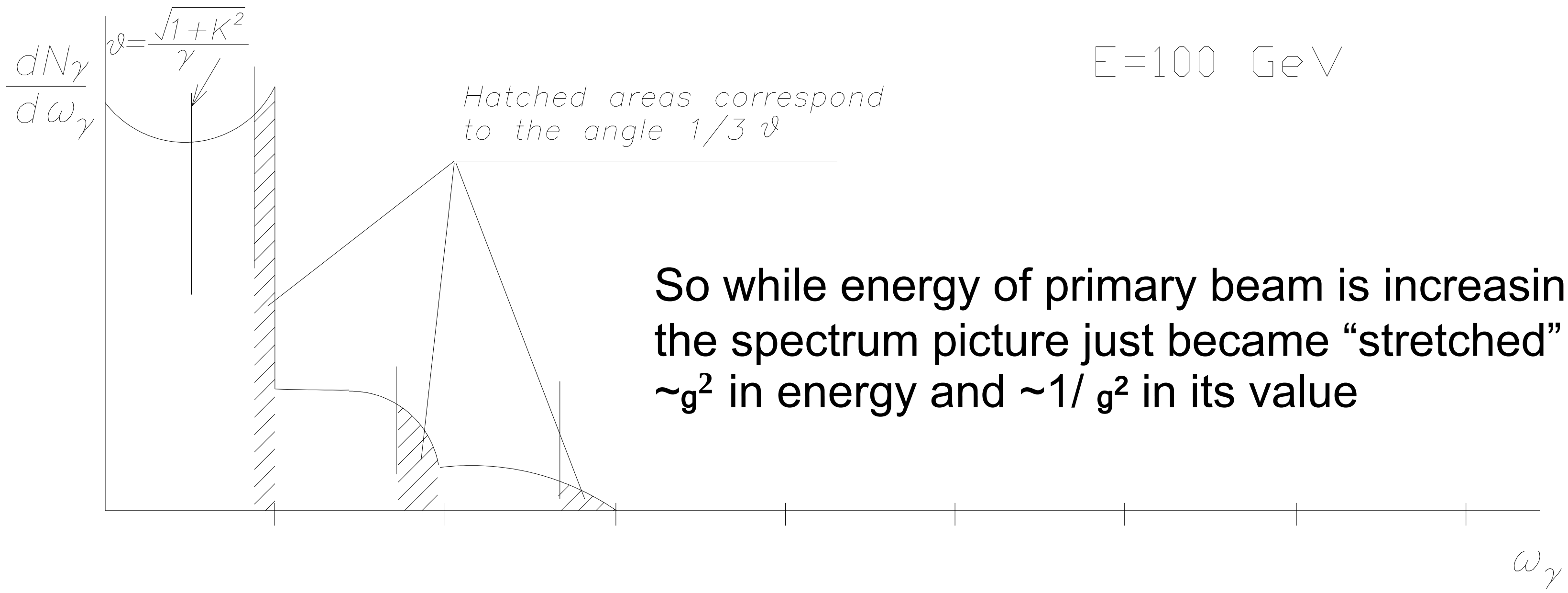
But the phonon flux expressed as a function of (not normalized) energy is

$$\frac{dN_{\gamma n}}{d(\omega_n / \omega_n^{max})} \to \frac{dN_{\gamma n}}{d\omega_n} \cong \frac{4\pi\alpha n M}{\omega_n^{max}} \frac{K^2}{1+K^2} F_n(K,s) = \frac{4\pi\alpha n M}{2\gamma^2 \Omega} K^2 F_n(K,s)$$

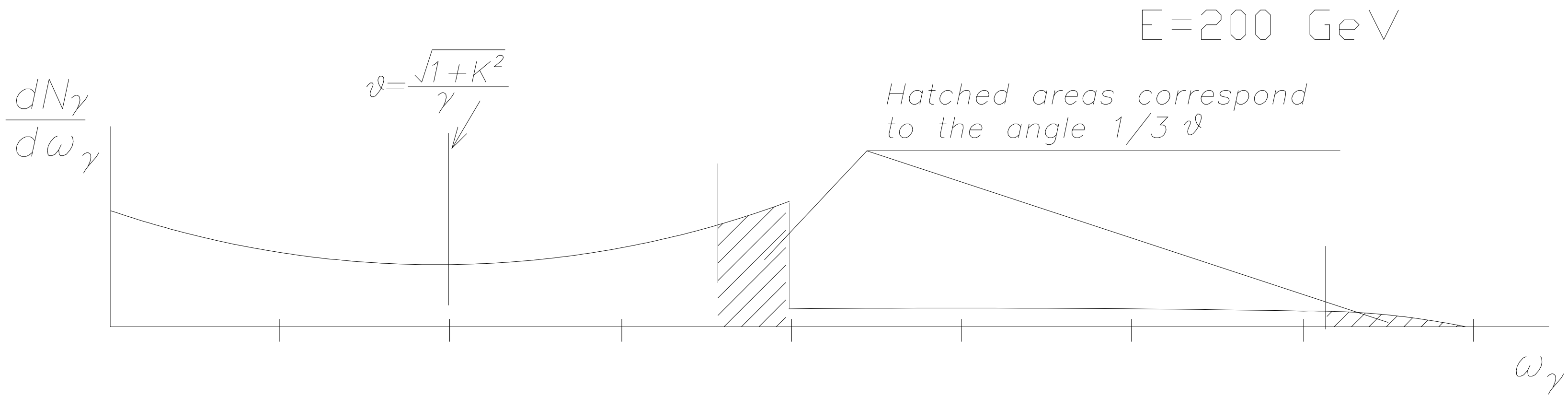
So one can see, that the photon density drops ~1/γ^2

So the energy acceptance of collection optics and DR is now a limiting factor

PHOTON SPECTRUM

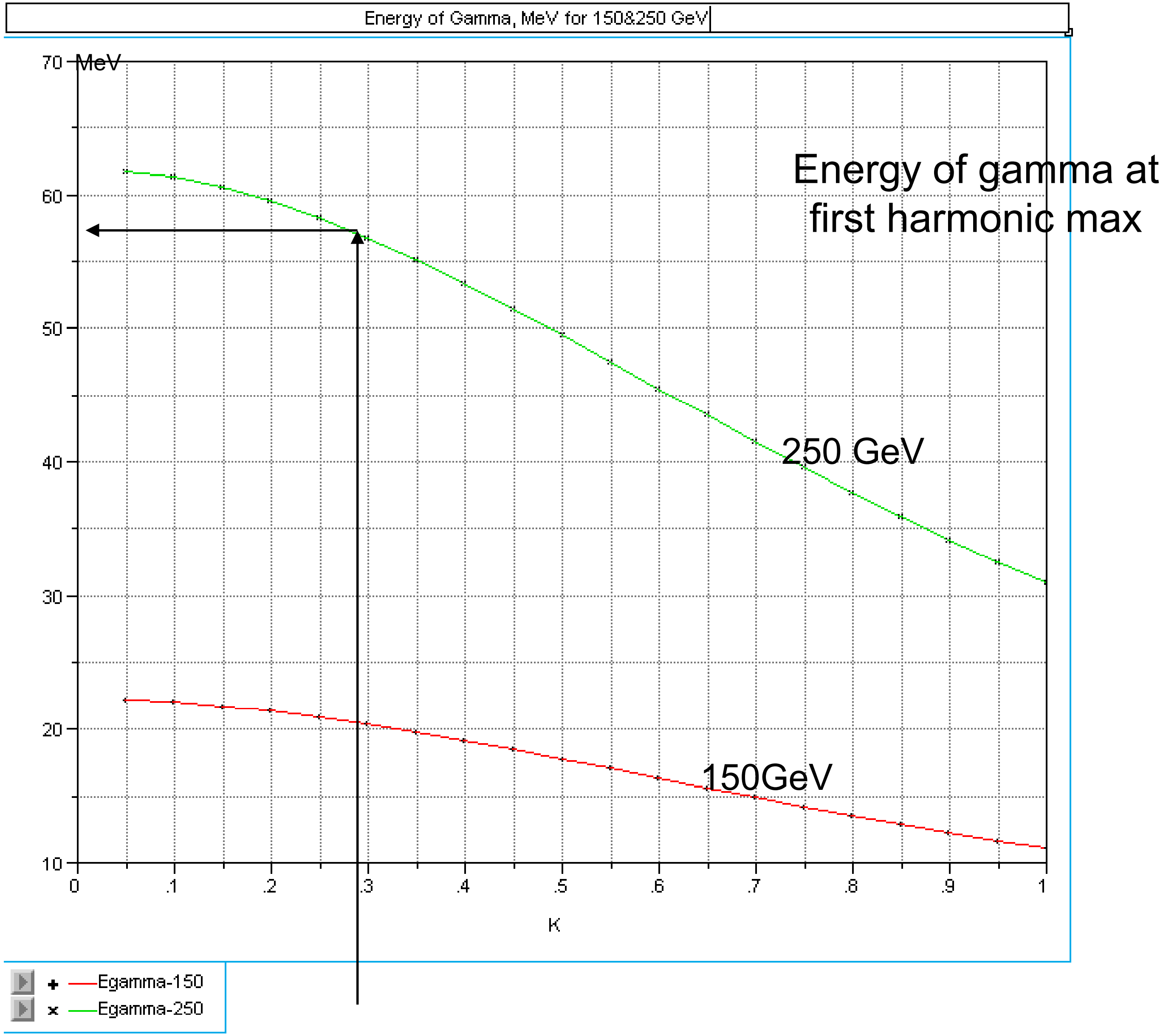


So while energy of primary beam is increasing, the spectrum picture just became “stretched” ~g^2 in energy and ~1/ g^2 in its value

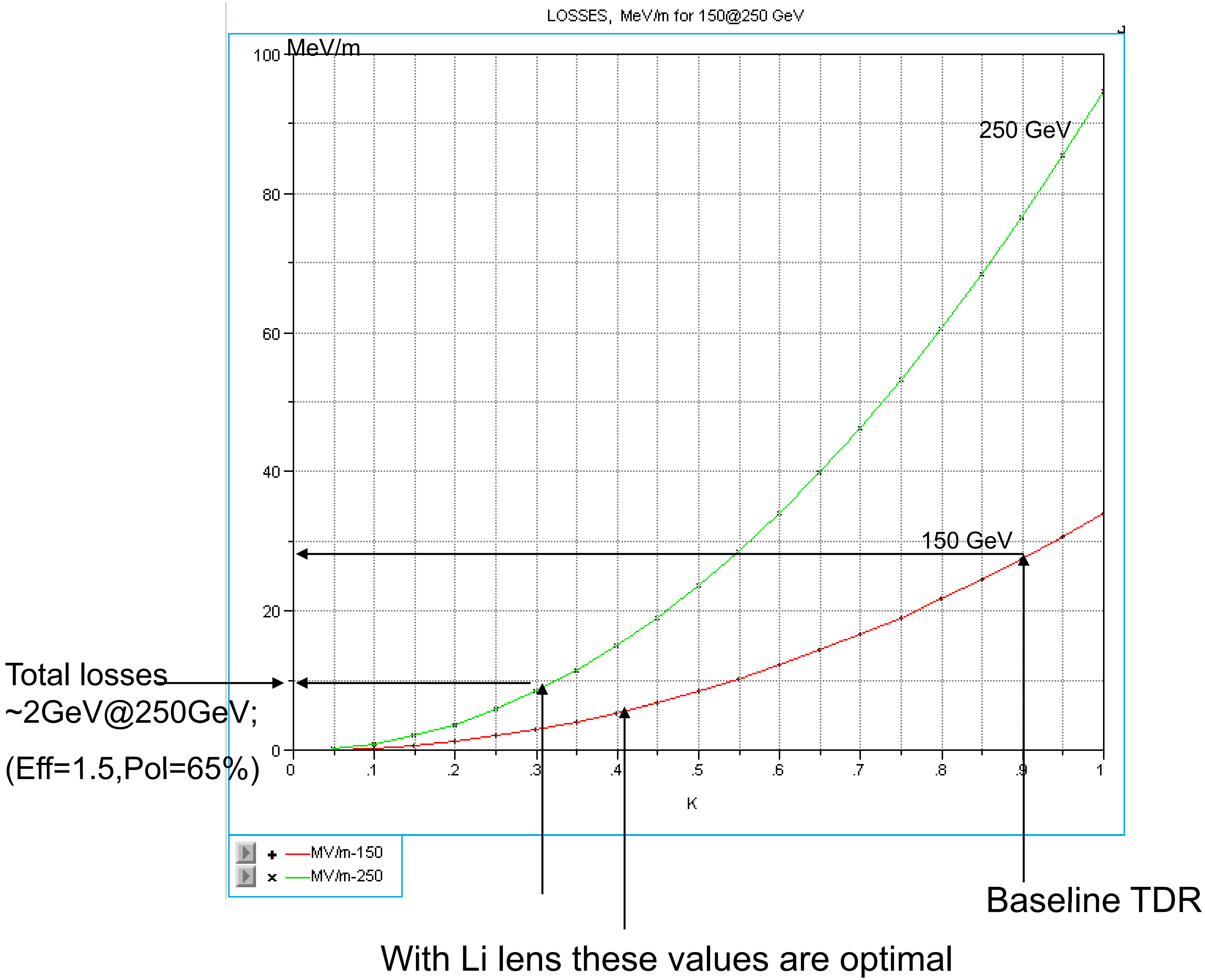


So the hatched area remains the same

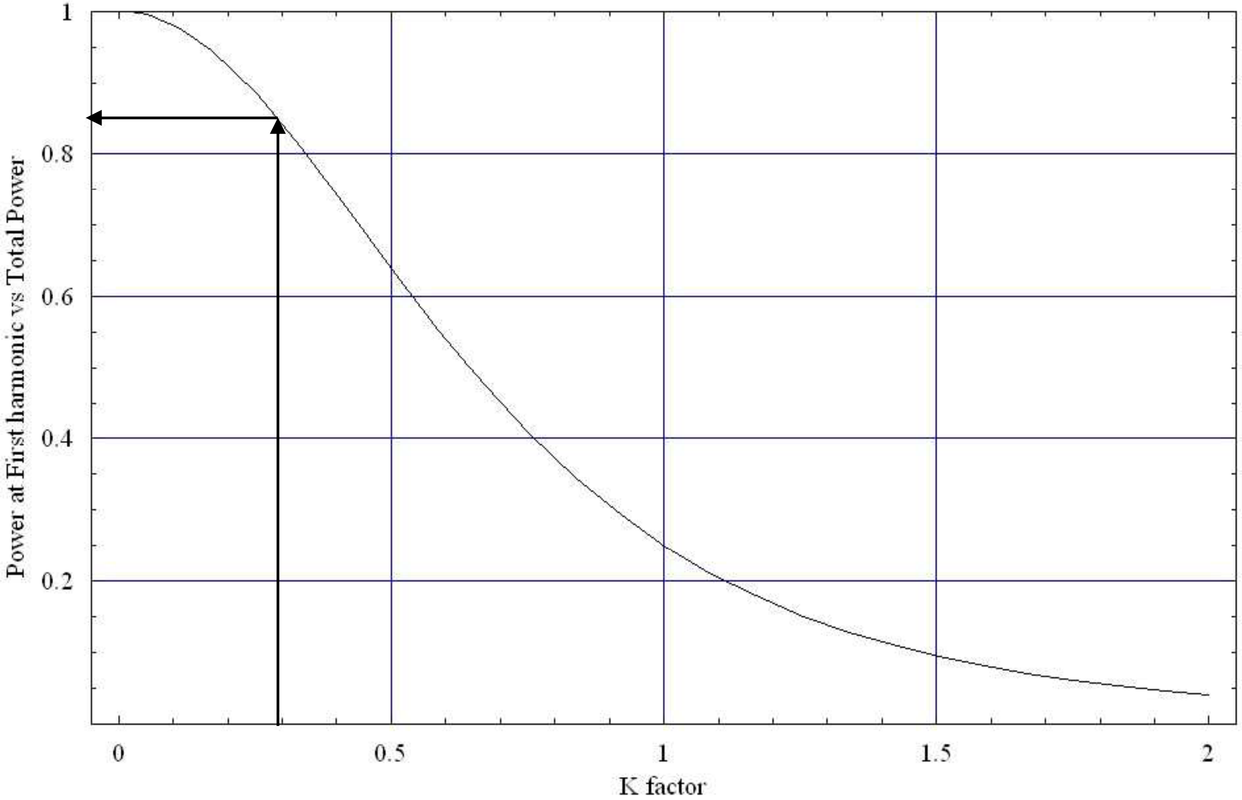
Energy of gamma comes to ~55 MeV- good for conversion



(We will see, that optimal value is K≤0.3)


LOSSES, MeV/m for 150@250 GeV
MeV/m
100
80
60
40
20
0
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
K
250 GeV
150 GeV
MV/m-150
MV/m-250
Total losses
~2GeV@250GeV;
(Eff=1.5,Pol=65%)
Baseline TDR
With Li lens these values are optimal

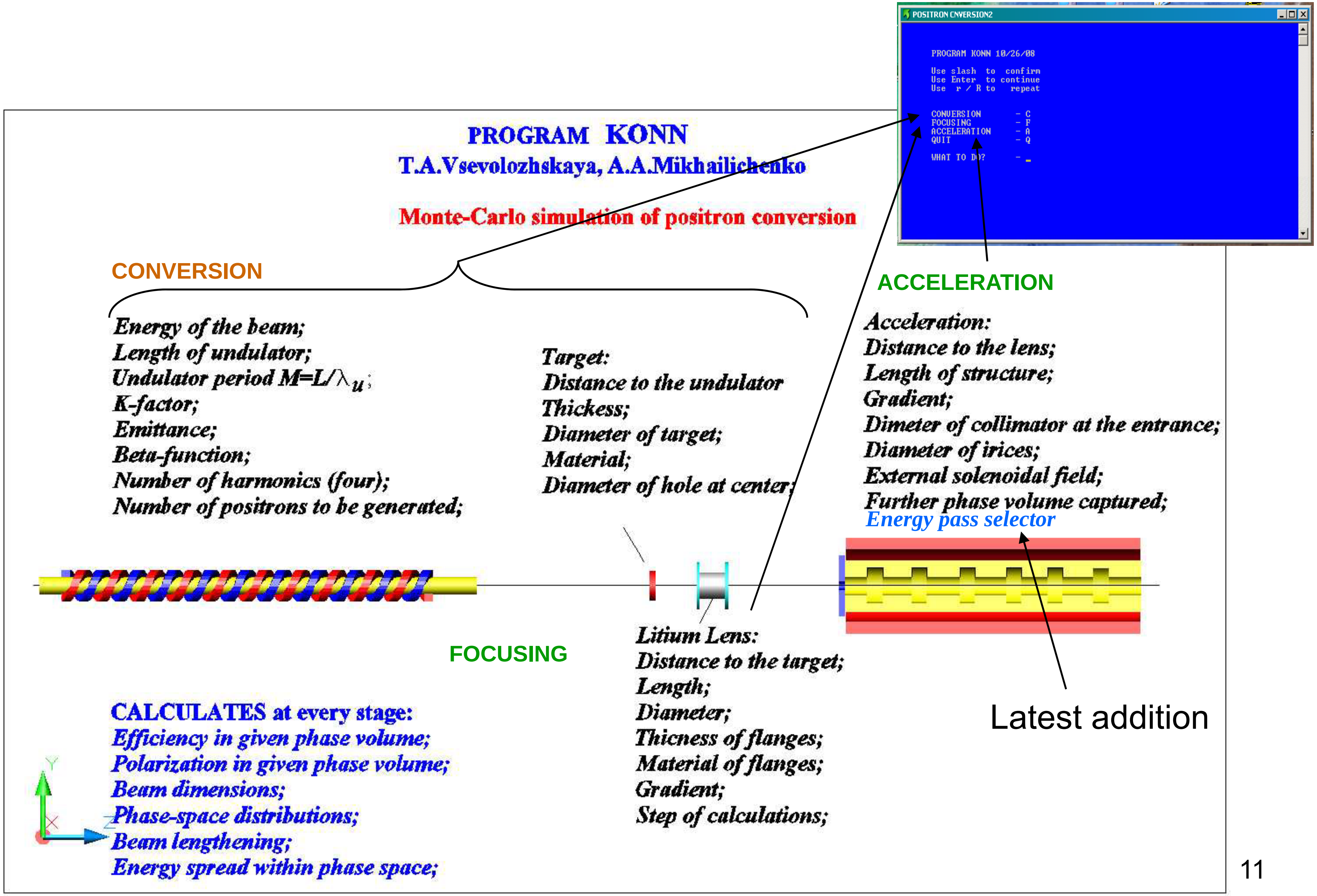
Power radiated at first harmonic versus total power as function of K-factor.



So ~85% of power radiated at first harmonic for K~0.3

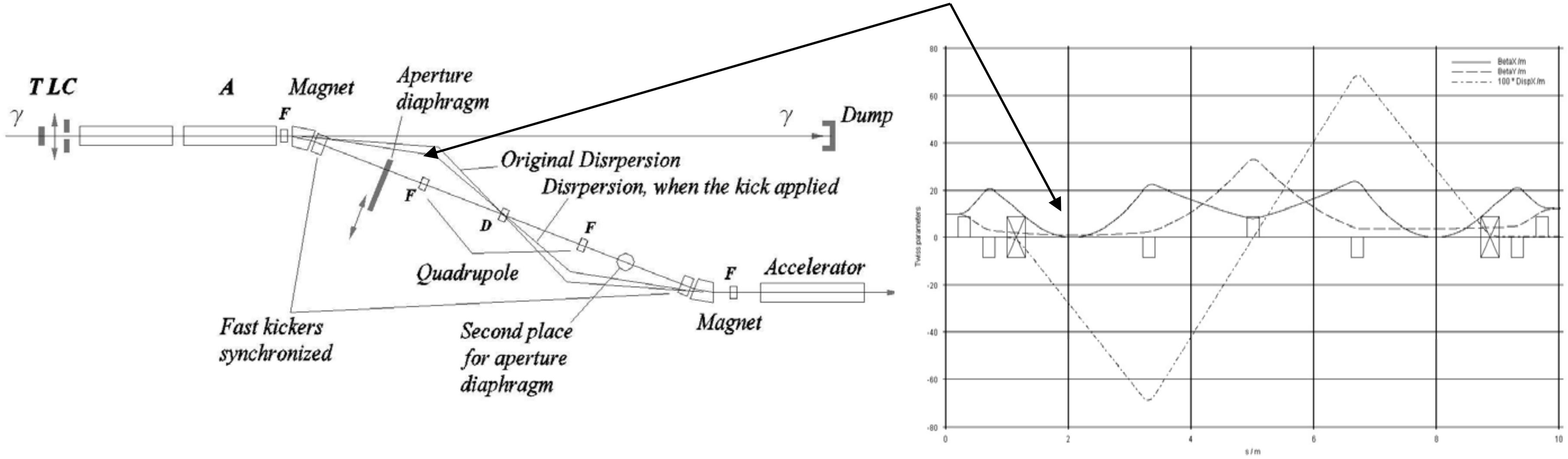
One positive thing is that in this case gamma-collimator does not required

Analytical calculations accompanied by Numerical ones



Such energy selection system was considered in 2006 (AM)

Region with minimal
envelope function



Fast kickers could be used for fast bunch by bunch operation

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     WHAT TO DO?       -


   *** PARAMETERS OF ACCELERATION ***

 WAVELENGTH OF STRUCTURE, cm =  23.060:=
 PHASE SHIFT OF CREST    ,rad =   -.313:=
 DISTANCE TO RF STRUCTURE cm =   2.000:=
 RADIUS OF DIAPHRAGM       cm =   3.000:=
 LENGTH OF RF STRUCTURE  cm  = 100.000:=
 GRADIENT      MeV/cm        =    .500:=
 LONGITUDINAL FIELD MGs      =    .045:=
 INNER RADIUS OF DIPHRAGM cm =   3.000:=
 FURTHER ACEPTANCE  MeVxcm   =   8.000:=
 ENERGY FILTER, E>- MeV      =  71.000:=70

 ENERGY FILTER, E<- MeV      = 100.000:=

                 ***


POSITRONS PASSED= 4402 POSITRONS ACCEPTED = 1555
WW =    2.076  WWP =    1.332
F0 =   -1.041  BETA =   .159 DE/DT = -1.256   EFF =    2.076


    PV0         AL0       ALMB      K        EPS        BT         RTG      GG

 250000.0    20000.0   1.000    .300    .000001    40000.0     .60     .069


RMS =    .638   AMS =    .051  DEM = 627.700   EM =  78.298   D7 =20000.00
PTM =   4.004   PZM =  78.194  DPZ =   7.150  PRM =    .284  PVG =  54.555
 TM =  101.445  DTM =    .550   WW =   2.076   WP =    .642   N0 = 2400
 RF = 3.00 GHz AL/Xo=  .65      H0 =  .045   EPSF =  8.00 MeVxcm
EPAS=  70.00 MeV   EMAX = 100.00 MeV


                   EFF(EX,CT)

 .0000   .0000   .0000   .0000   .0000   .0000

 .1030   .1446   .0831   .0163   .0000   .0000

 .4295   .5917   .1638   .0370   .0007   .0000

 .2136   .1809   .0313   .0011   .0000   .0000

 .0505   .0251   .0043   .0000   .0000   .0000

                   EFP(EX,CT)

 .0000   .0000   .0000   .0000   .0000   .0000

 .5163   .5720   .5294   .5695   .0000   .0000

 .6564   .6381   .6205   .5824   .3162   .0000

 .7372   .7265   .7173   .6771   .0000   .0000

 .6135   .5830   .5960   .0000   .0000   .0000


         EFF = 1.550    EFP=  64.786 %
```

ONE EXAMPLE OF CALCULATIONS

K-factor going down to K=0.3

Length of the target → 0.65X_0

Gradient in lens increased to 69kG/cm ←→current 120kA

Radius=0.6cm, Length=0.7cm

Some trade between gradient and length is possible

Energy selection arranged in place with dispersion

```
    WHAT TO DO?       -


  *** PARAMETERS OF ACCELERATION ***

 WAVELENGTH OF STRUCTURE, cm =  23.060:=
 PHASE SHIFT OF CREST    ,rad =   -.313:=
 DISTANCE TO RF STRUCTURE cm =   2.000:=
 RADIUS OF DIAPHRAGM      cm =   3.000:=
 LENGTH OF RF STRUCTURE  cm  = 100.000:=
 GRADIENT       MeV/cm       =    .500:=
 LONGITUDINAL FIELD MGs      =    .045:=
 INNER RADIUS OF DIPHRAGM cm =   3.000:=
 FURTHER ACEPTANCE  MeVxcm   =   8.000:=
 ENERGY FILTER, E>- MeV      =  70.000:=20

 ENERGY FILTER, E<- MeV      = 100.000:=

                   ***

POSITRONS PASSED= 4402 POSITRONS ACCEPTED = 3876
WW =     6.034  WWP =     1.925
F0 =     -.036  BETA =    .224 DE/DT = -3.908    EFF =     6.034


   PV0          AL0       ALMB      K        EPS         BT         RTG     GG

 250000.0    20000.0   1.000     .300     .000001    40000.0      .60    .069


RMS =     .726   AMS =     .047  DEM = 371.192   EM =  67.424   D7 =20000.00
PTM =    3.245   PZM =  67.346  DPZ =   9.688  PRM =    .012  PVG =  54.555
 TM =  101.648   DTM =    .698   WW =   6.034   WP =    .319   N0 = 2400
 RF = 3.00 GHz AL/Xo=  .65      H0 =  .045   EPSF =  8.00 MeVxcm
EPAS=  20.00 MeV    EMAX = 100.00 MeV


                   EFF(EX,CT)

 .1631   .3200   .3371   .3093   .2275   .3950

 .6260  1.0462   .7034   .1549   .0183   .0018

 .4295   .5917   .1638   .0370   .0007   .0000

 .2136   .1809   .0313   .0011   .0000   .0000

 .0504   .0271   .0043   .0000   .0000   .0000
                   EFP(EX,CT)

 .0278   .0155  -.0274  -.1075  -.1204  -.1488

 .3444   .3742   .3560   .3030  -.2798   .0258

 .6564   .6381   .6205   .5824   .3162   .0000

 .7372   .7265   .7173   .6771   .0000   .0000

 .6147   .6070   .5960   .0000   .0000   .0000

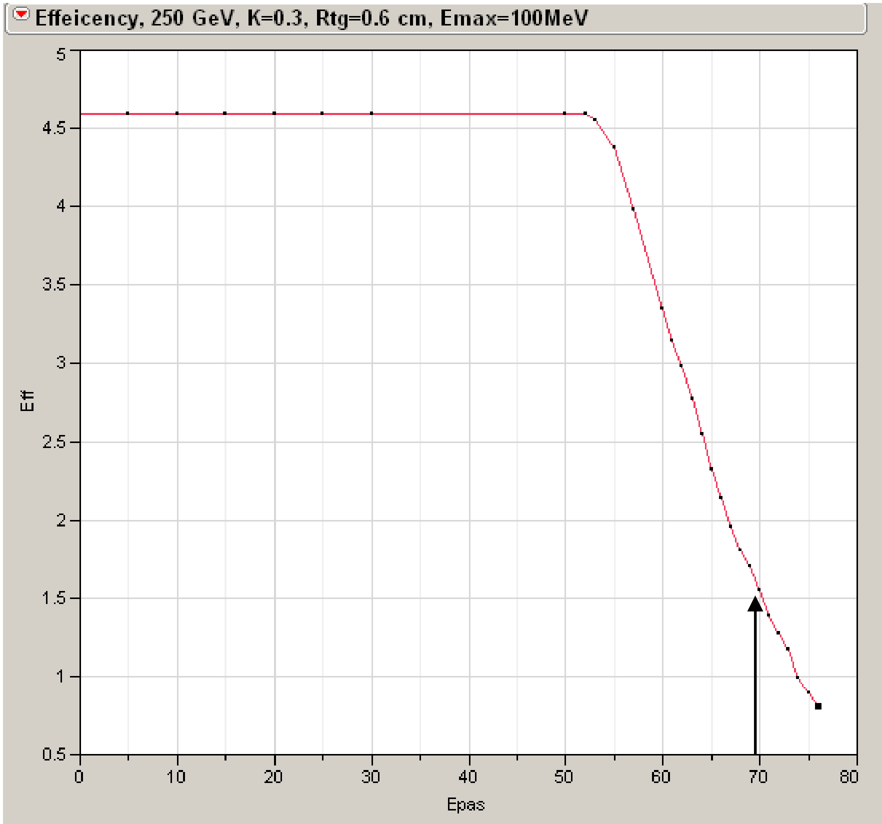
         EFF = 4.588    EFP=  33.610 %
```

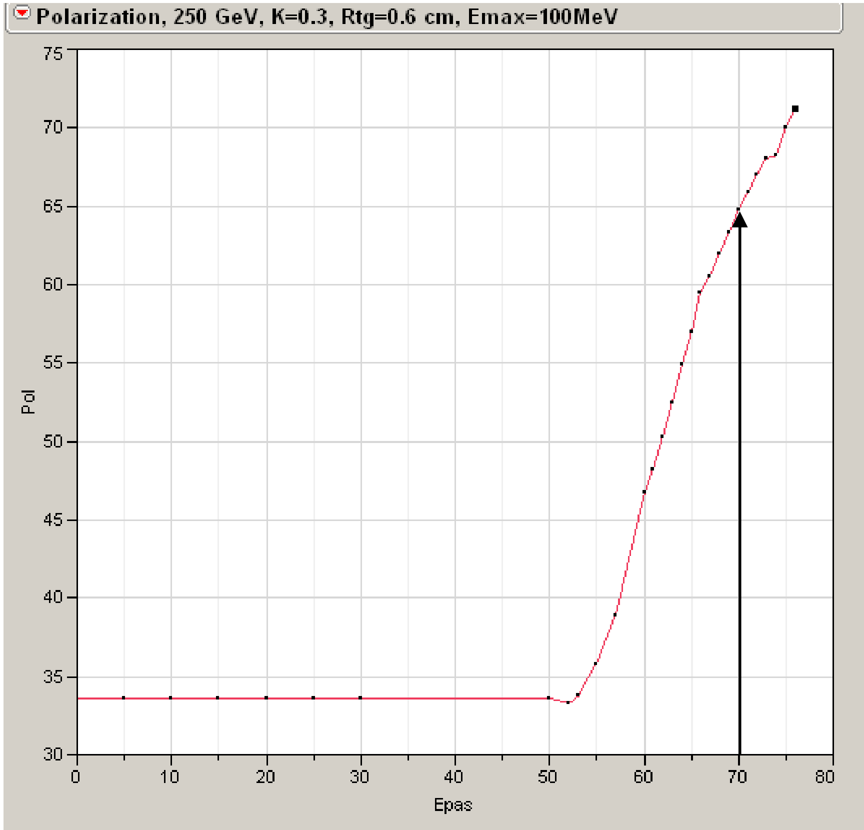
For extended energy acceptance the Efficiency is ~3 times higher, than for high Polarization mode

This is close to the limits of DR energy acceptance

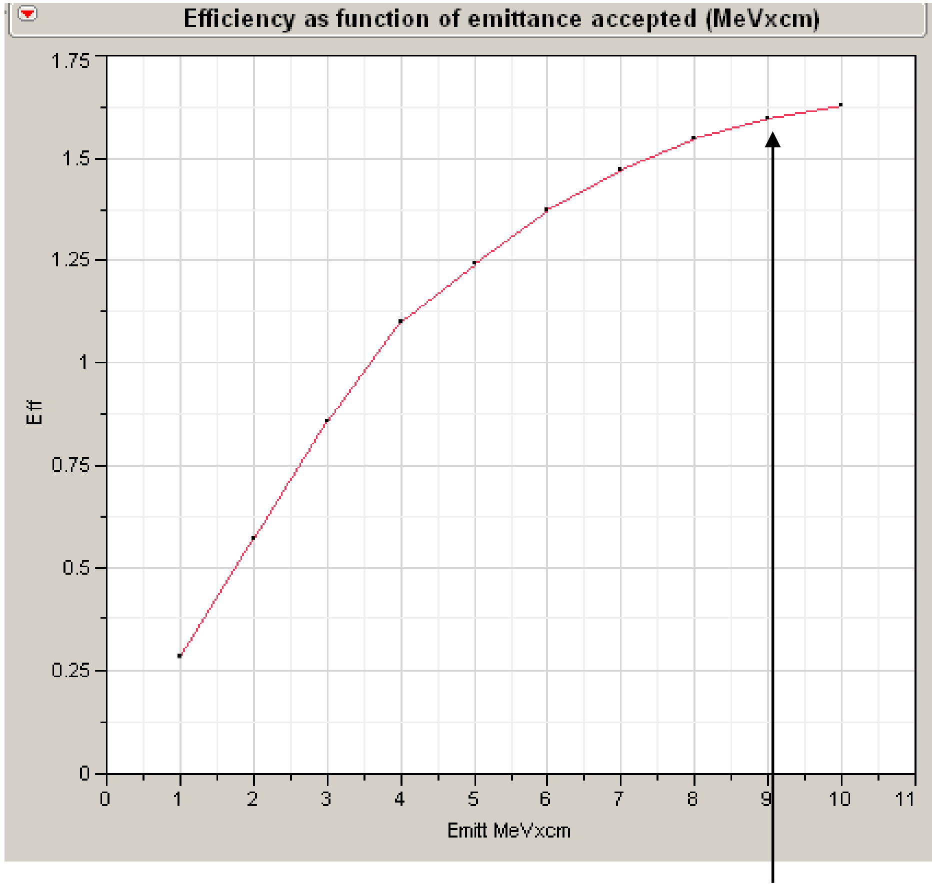
Efficiency and polarization as functions of lower boundary energy cut

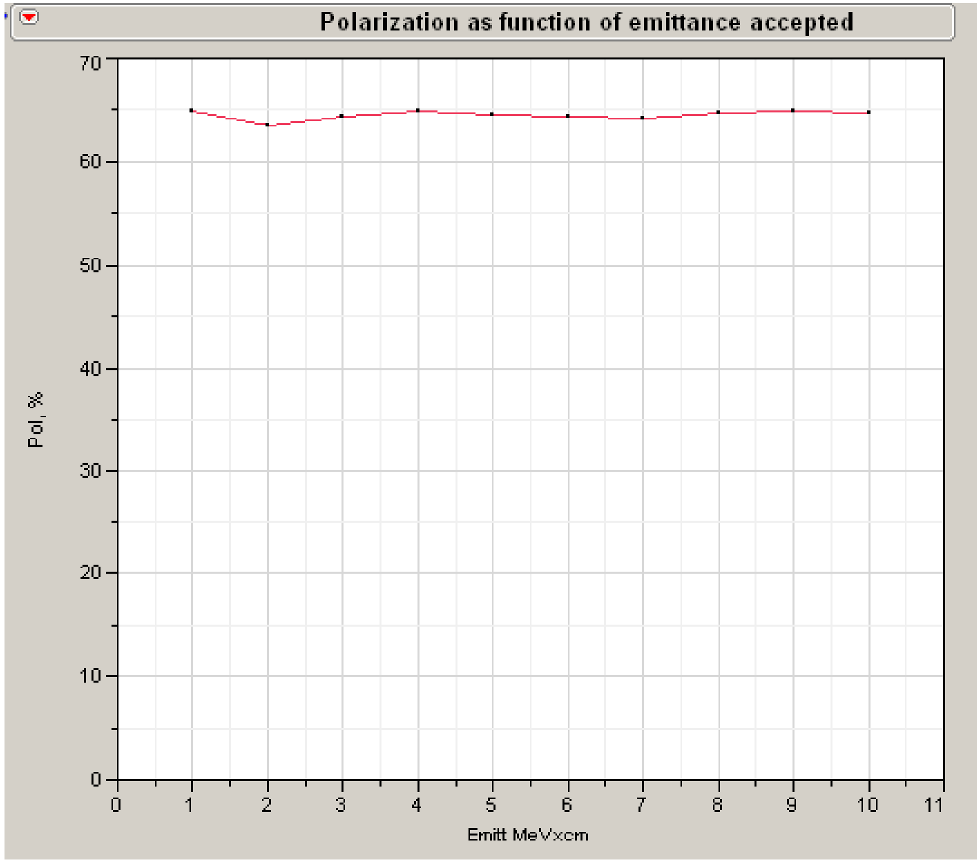
This cut could be arranged in place with dispersion by scrapping low energy particles





For K=0.3, game with collimator diameter does not improve polarization





Acceptance of DR according TDR

$$\varepsilon_x = 2cp_x \cdot \Delta x = 2\frac{cp_x}{cp_\parallel} \cdot mc^2\gamma \cdot \Delta x = 2mc^2\gamma \cdot \Delta x' \Delta x; \;\; MeV \times cm$$

$$\gamma \cdot \Delta x' \Delta x = \varepsilon_x / 2mc^2$$

So our 10 MeVxcm←→A=10cmxrad

Lithium lens powering looks guarantied with new switching devices

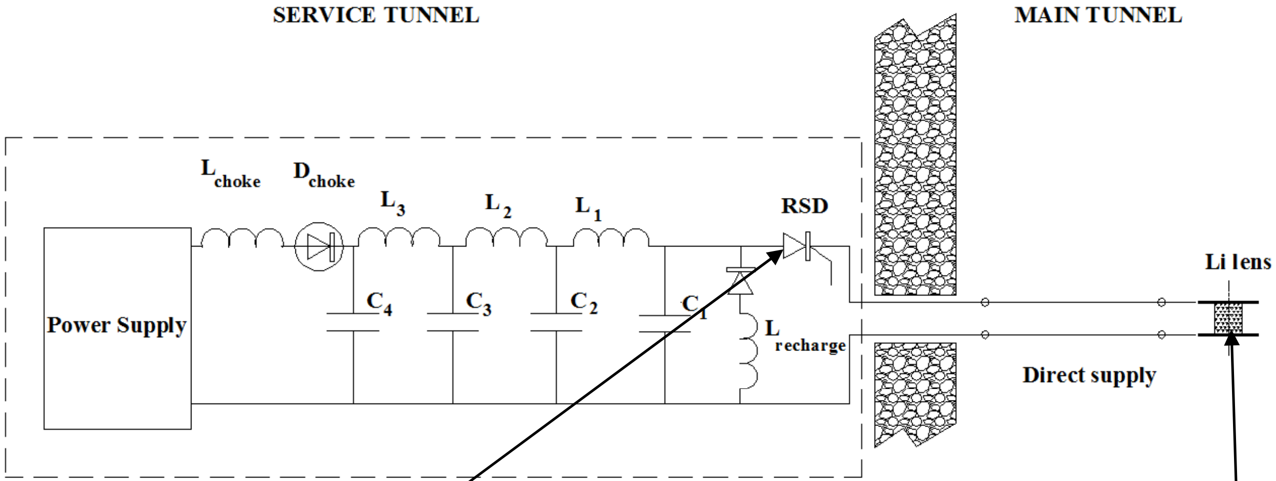
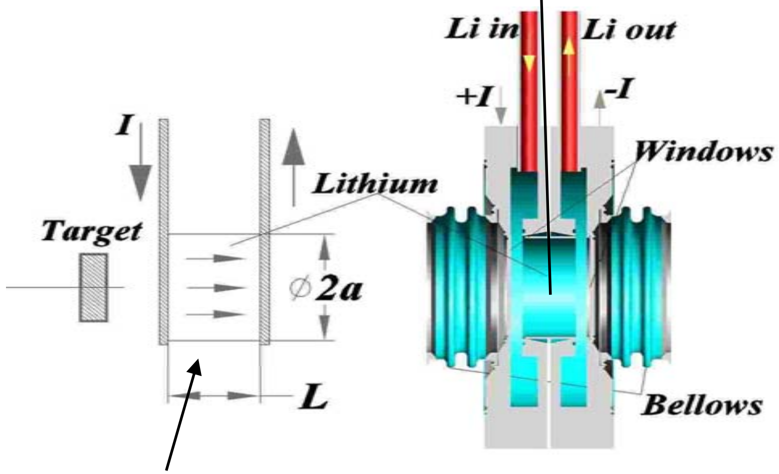


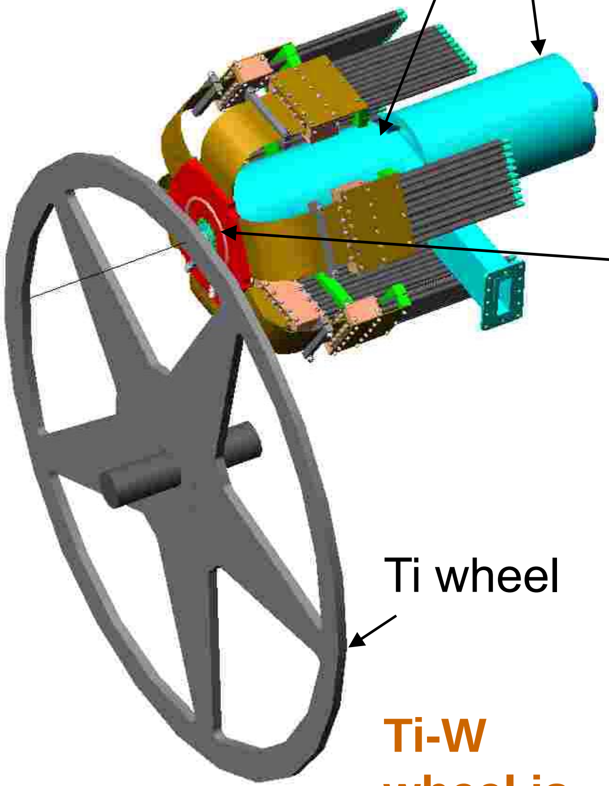
Fig.2. Reverse – switched dinistors for peak current from 200 kA to 500 kA and blocking voltage of 2400 V, encapsullated in hermetic metal – ceramic housing and without housing (RSD sizes of 64, 76, and 100 mm)

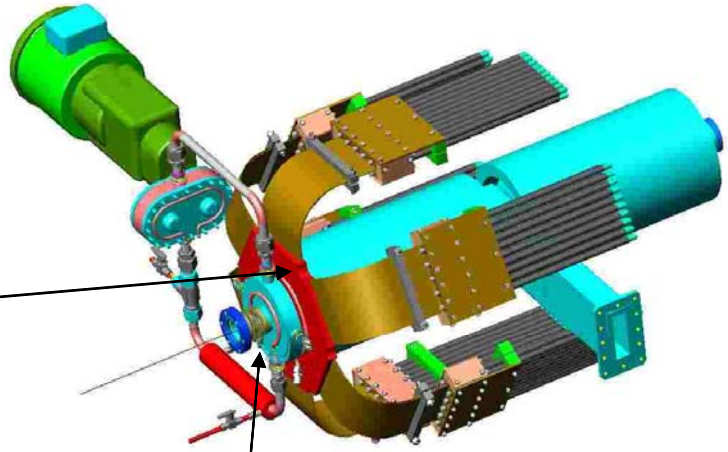


Current required for 250 GeV operation -120-150kA

Variants of installation Li lens with rotating target (left) and liquid metal target (right) are the same as for 150 GeV conversion

Aluminum-conductor solenoid required on first section only; further focusing arranged with quads; Al made accelerator section could have longitudinal cut, so quasi-pulsed feeding is possible; vacuum could be kept by thin-wall StSteel wrap.





Li lens

Liquid Bi-Pb alloy or Hg target

Ti wheel

Ti-W wheel is possible

Accelerator structure could operate at third harmonics (~4GHz)

Transition optics between solenoid and FODO is well known

SUMMARY

Conversion at 250 GeV requires wider energy acceptance ~30-50MeV, which is within the energy acceptance of DR (±50 MeV), however;

For K=0.3, λ_u=1cm, L=200m efficiency Eff=1.5 with Pol=65% is possible by energy selection;

Focusing with Li lens is possible with increased gradient and length, current is ~same as for 150-GeV conversion;

In full energy spectrum it is possible to have Eff=4.5, Pol=33.6% with the same undulator (K=0.3). For efficiency Eff=1.5, the length of undulator could be made~70m only ;

For higher K the undulator could be even shorter;

So, the undulator could be kept at the same place up to~700 GeV CM at least (if located at 150 GeV originally);

Cornell has tested SC undulator with Copper chamber having aperture a= Ø8mm with λ_u=1cm, K=0.467