UPDATE OF POSITRON PRODUCTION CODE KONN

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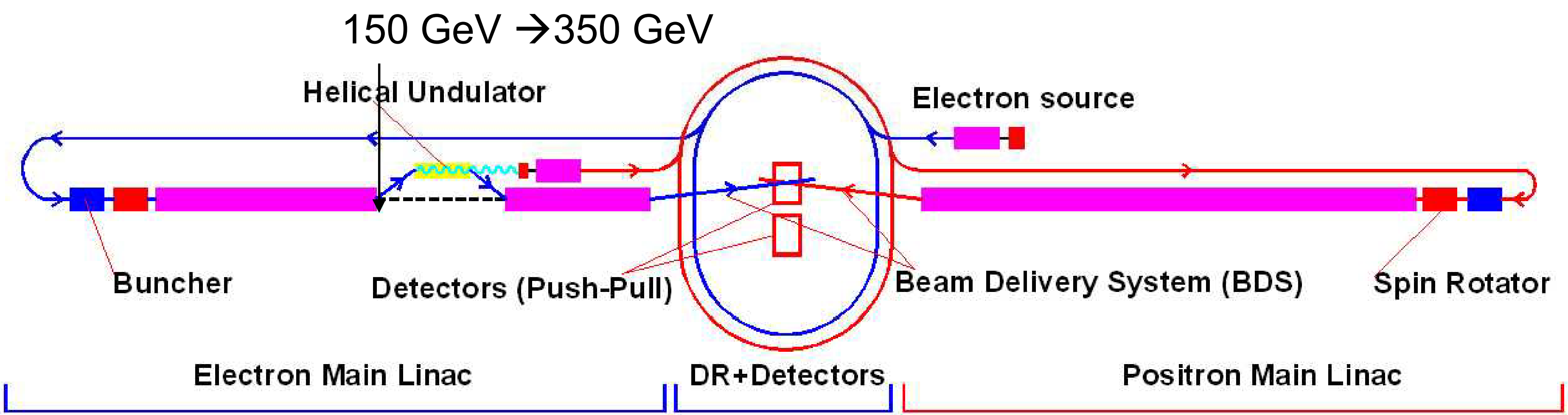
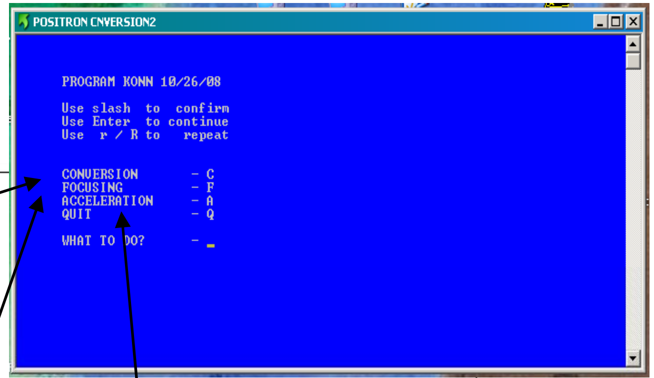
ILC Baseline

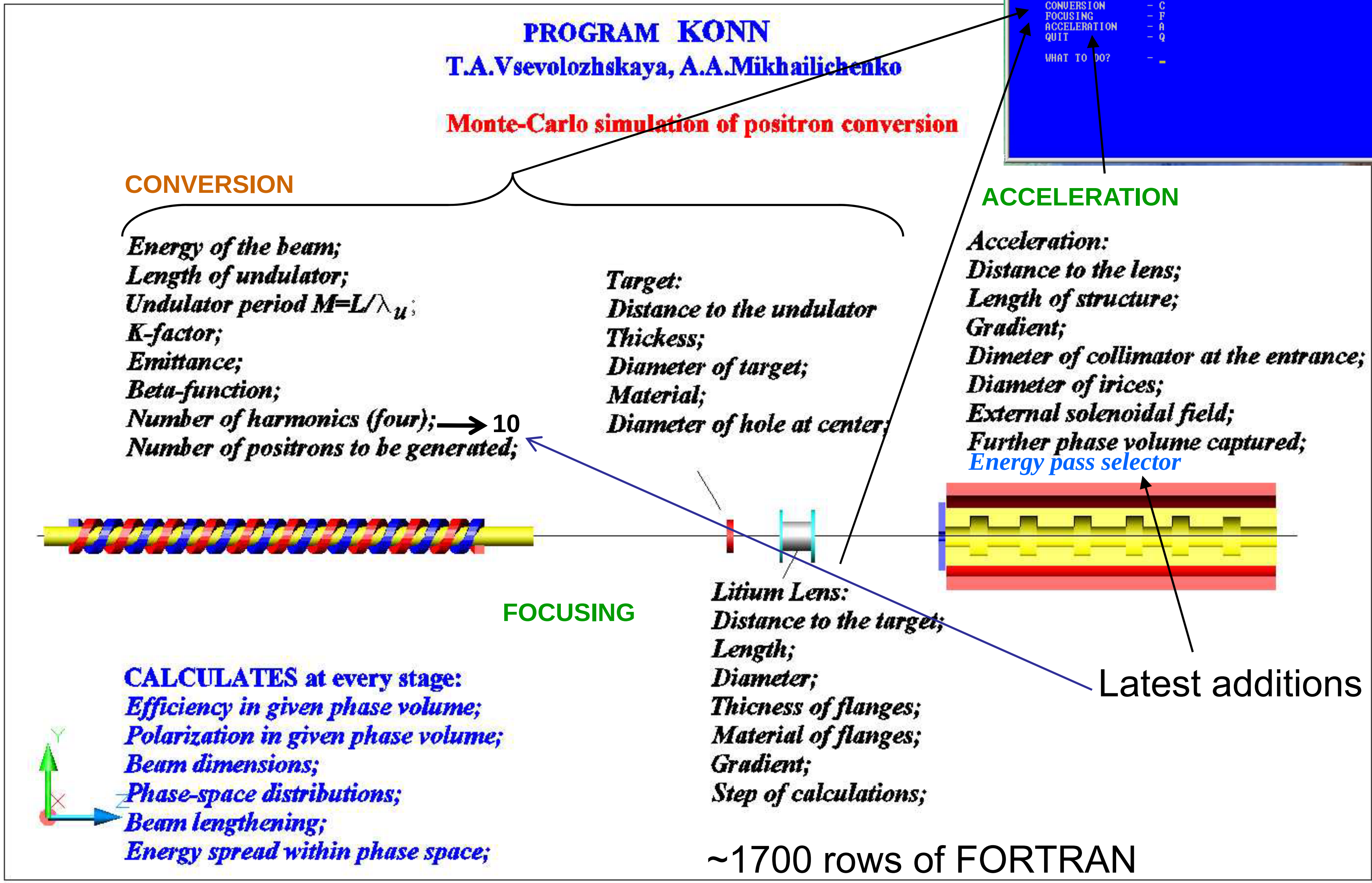


150 GeV could be raised to higher value, 350GeV, while adding accelerator sections for energy upgrade if undulator remains at the same place

Analytical calculations accompanied by Numerical ones

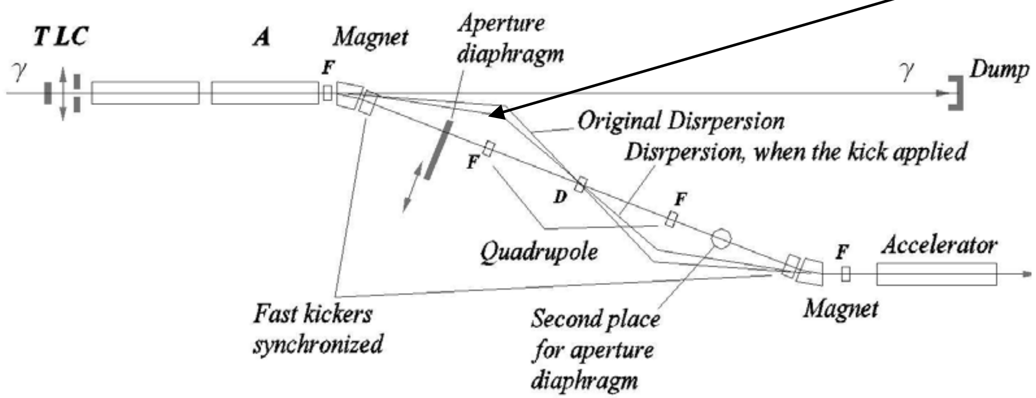
Used CONVER (≈EGS4, A.D. Bukin, BINP) for comparison

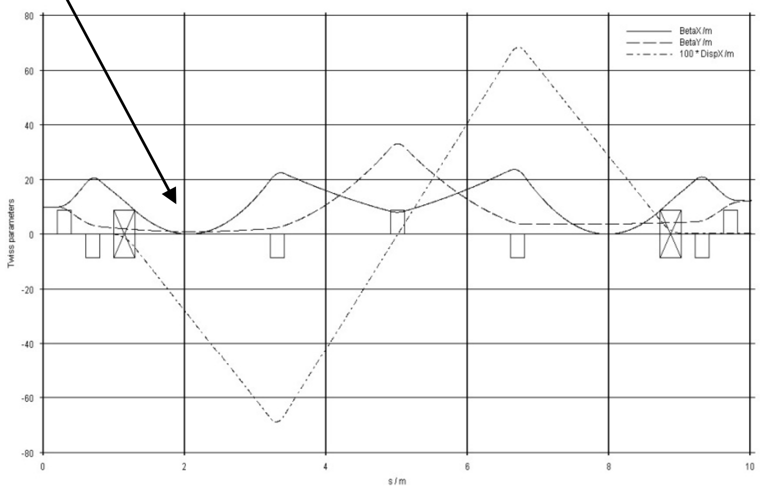




Possible optics for energy selection was considered in 2006 (AM)

Region with minimal envelope function





Fast kickers could be used for fast bunch by bunch operation

ONE EXAMPLE OF CALCULATIONS

PV0	AL0	ALMB	K	EPS	BT	RTG	GG
150000.0	17000.0	1.000	.440	1.0E-09	40000.0	.05	.065

```
RMS  =    .673   AMS =    .024  DEM =   5.185    EM  =   59.824   D7  =15000.00
PTM  =   1.528   PZM =  59.804  DPZ =   5.529   PRM  =   -.009   PVG =  17.901
 TM  = 101.329   DTM =    .246   WW =   1.518    WP  =    .736    NO = 5000
 RF  = 2.00 GHz AL/Xo=  .57      HO =  .045    EPSF  =  9.00 MeVxcm
EPAS=   54.00 MeV    EMAX = 110.00 MeV
```

EFF(EX,CT)

.0000	.0000	.0000	.0000	.0000	.0000
.1093	.1919	.1310	.0770	.0410	.0221
.2976	.2372	.0268	.0006	.0000	.0000
.1161	.1122	.0144	.0008	.0000	.0000
.0394	.0401	.0152	.0004	.0000	.0000

EFP(EX,CT)

.0000	.0000	.0000	.0000	.0000	.0000
.5939	.5899	.5964	.5868	.5450	.5905
.7660	.7509	.7587	.7492	.0000	.0000
.7982	.7823	.7781	.7394	.0000	.0000
.7463	.7245	.7665	.7063	.0000	.0000

POSITRONS ACCEPTED= 8779

ENERGY,MeV	EFF/e	POL,%
29.0	.000000	.00
34.0	.000000	.00
39.0	.000000	.00
44.0	.000000	.00
49.0	.092462	44.23
55.0	.911216	68.35
60.0	.382414	78.65
65.0	.093972	74.92
70.0	.044852	82.61
75.0	.014809	84.57
81.0	.004773	80.70
86.0	.002210	83.03

<EFF>= 1.546708   <EFP>= 70.480 %

K-factor K=0.44

Length of the target →$0.57X_0$

Energy selection arranged in place with dispersion

PV0	AL0	ALMB	K	EPS	BT	RTG	GG
50000.0	1.0	.254	.170	1.0E-09	4000.0	.20	.030

```
RMS =     .475   AMS =     .157   DEM =     .412   EM =    5.615   D7 =   35.00
PTM =     .864   PZM =    5.525   DPZ =********   PRM =    -.443   PVG =   9.084
 TM =    2.260   DTM =     .057    WW =     .000   WP =     .903   N0 =  240
 RF = 2.00 GHz AL/Xo=  .20        H0 =  .045    EPSF =  9.00 MeVxcm
EPAS=    5.00 MeV    EMAX =    6.50 MeV
```

EFF(EX,CT)

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

EFP(EX,CT)

.0000	.0000	.0000	.0000	.0000	.0000
.0000	.0000	.0000	.0000	.0000	.0000
.9394	.9285	.9015	-.7598	.0000	.0000
.7291	.8355	.9072	-.0155	.0000	.0000
.0000	.0000	.0000	.0000	.0000	.0000

POSITRONS ACCEPTED= 42

ENERGY,MeV	EFF/e	POL,%
3.0	.000000	.00
4.0	.000000	.00
4.0	.000000	.00
4.0	.000000	.00
5.0	.000000	91.21
5.0	.000001	88.76
6.0	.000000	67.30
6.0	.000000	80.40
6.0	.000000	95.73
7.0	.000000	.00
7.0	.000000	.00
8.0	.000000	.00

<EFF>= .000002 <EFP>= 85.610 %

Another example of conversion

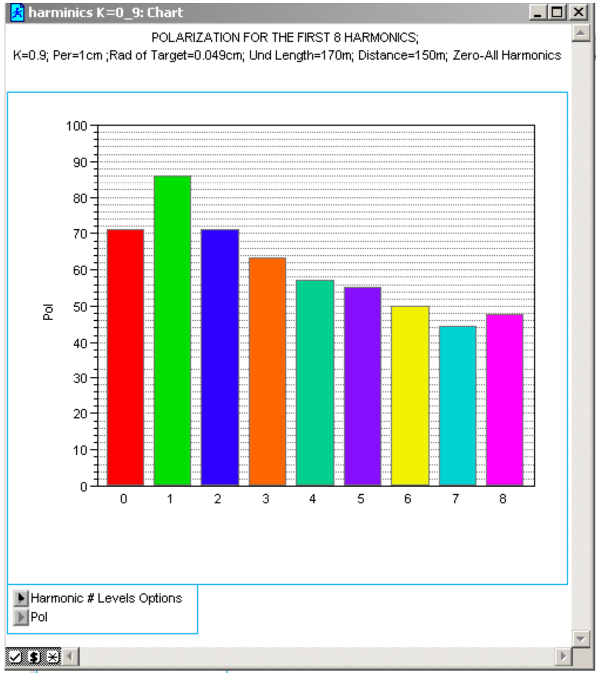
50GeV beam;
1m-long undulator;
Per=0.254cm;
No acceleration;
Lens~ the same focal length as at E-166;
Energy 5-6.5MeV

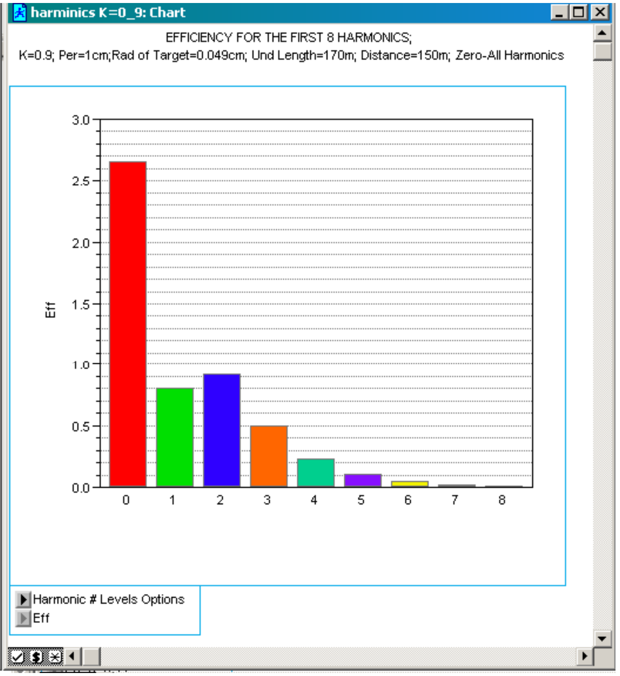
Reference:
Polarization measured in E-166
<P>~85%

Harmonic content; 8 harmonics

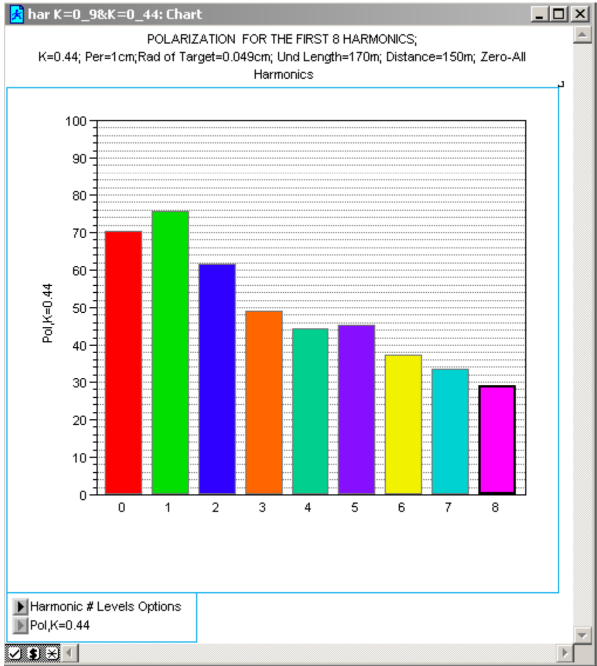
0-all harmonics together

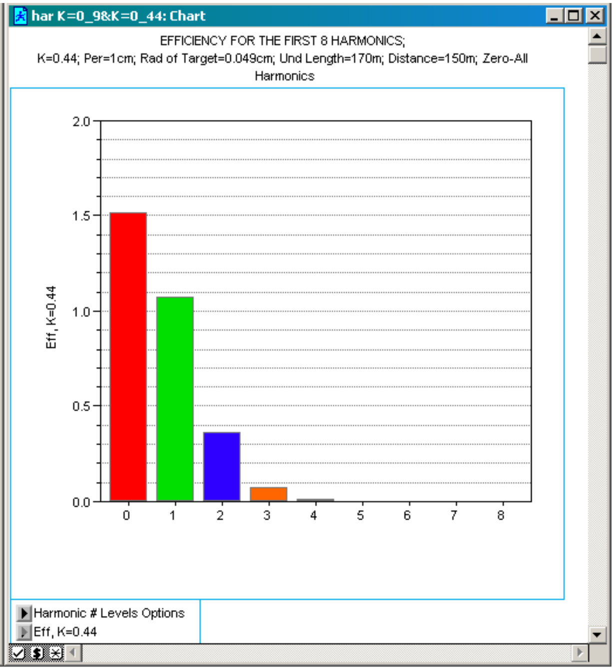
K=0.9





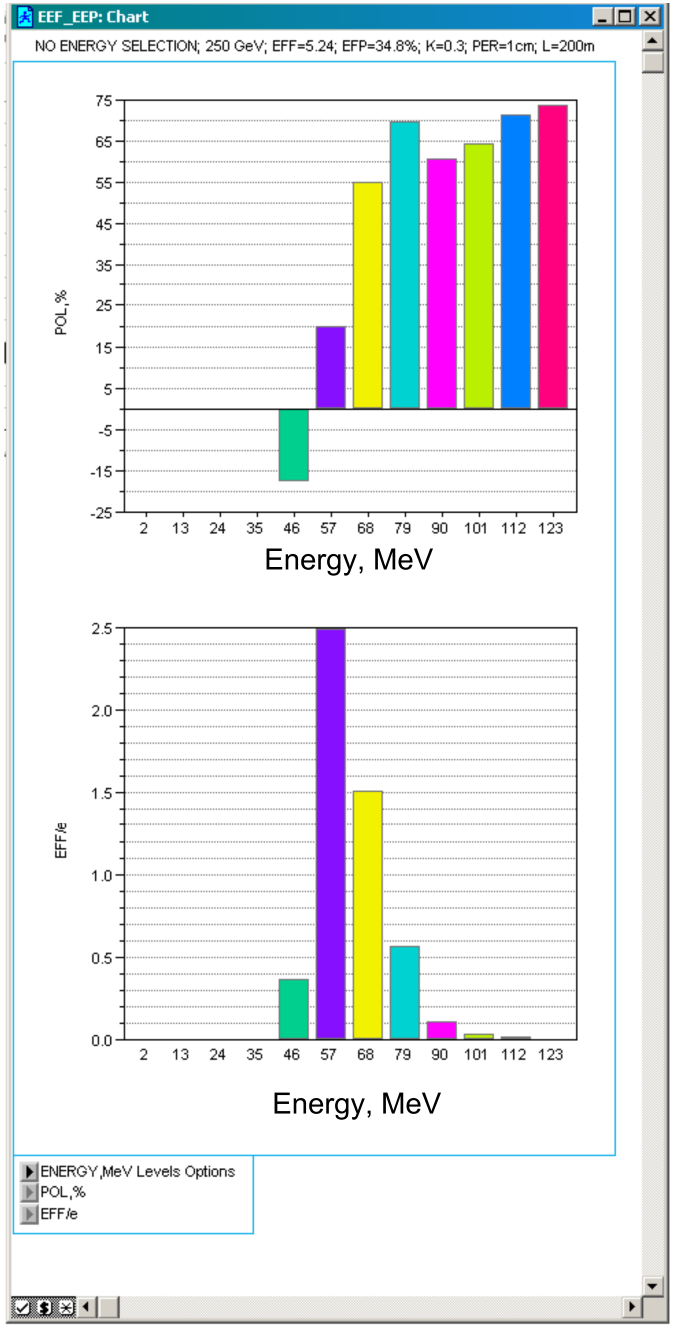
K=0.44



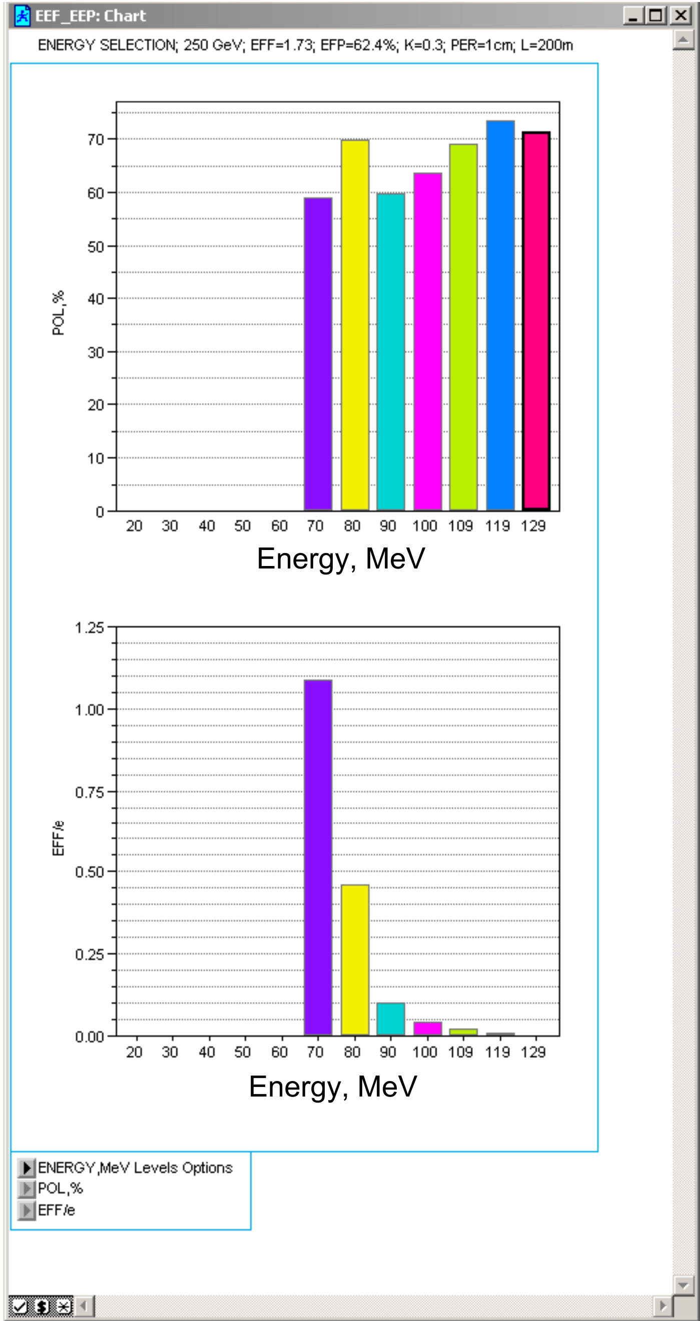


Energy selection after acceleration; 250 GeV; K=0.3

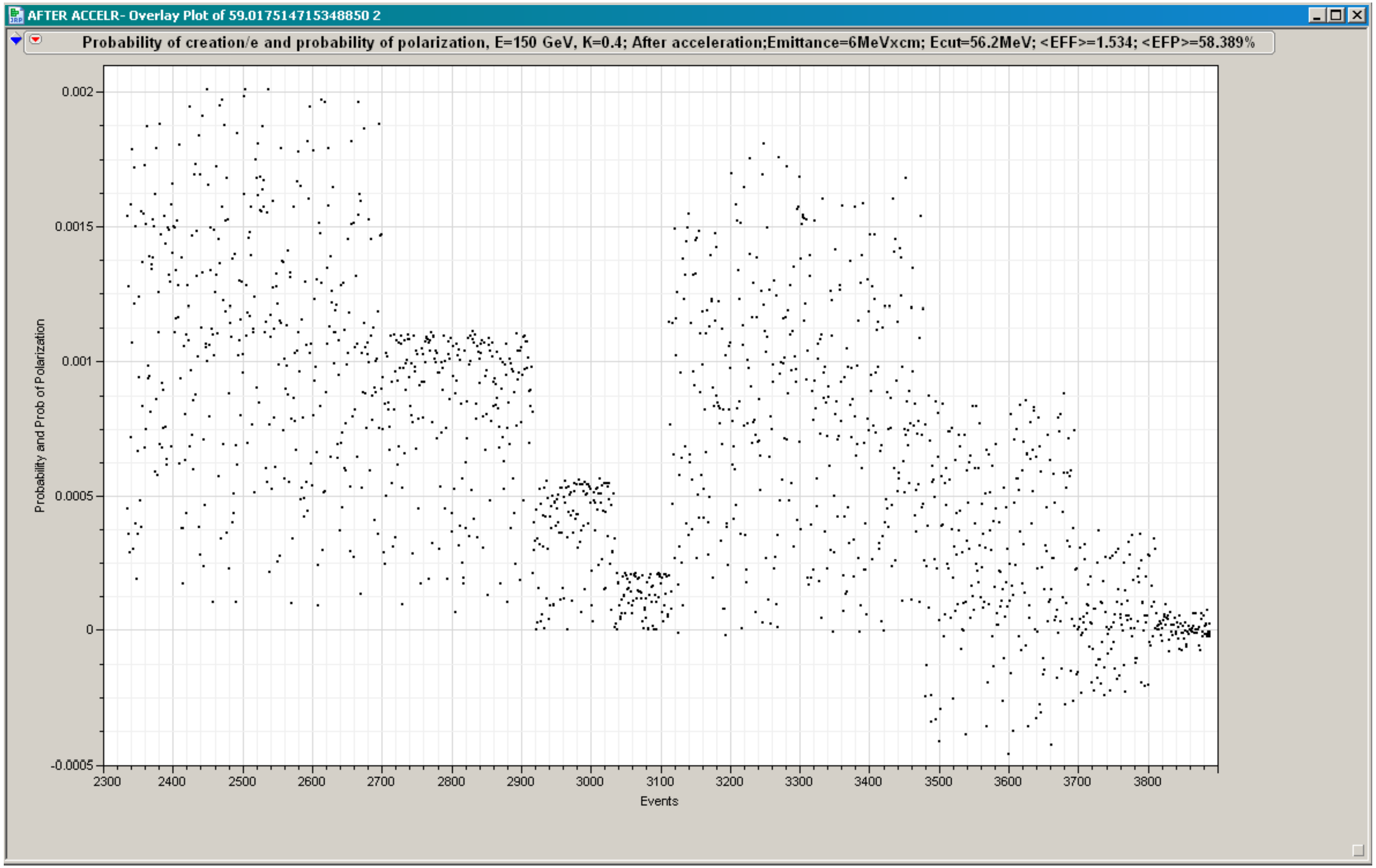
No energy selection



Energy selection after acceleration



Fragment of output file



Efficiency/e; first 4 harmonics Polarization; first 4 harmonics

SUMMARY

Latest additions to KONN improved accuracy and functionality (10 undulator harmonics, energy selection)

RESULTS OBTAINED WITH KONN

Undulator could be kept at the same place up to~1TeV CM (if located at 150 GeV originally);

K factor could be <0.5

Focusing with Li lens is possible at 350 GeV ; current is ~ the same as for 150-GeV conversion;

Efficiency per each initial electron/positron could be 1.5 with polarization 70%

80% polarization could be reached;(~220m undulator+more sophisticated energy selection, PAC2009)

Backup slides

```
    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

Lithium lens powering looks guarantied with new switching devices

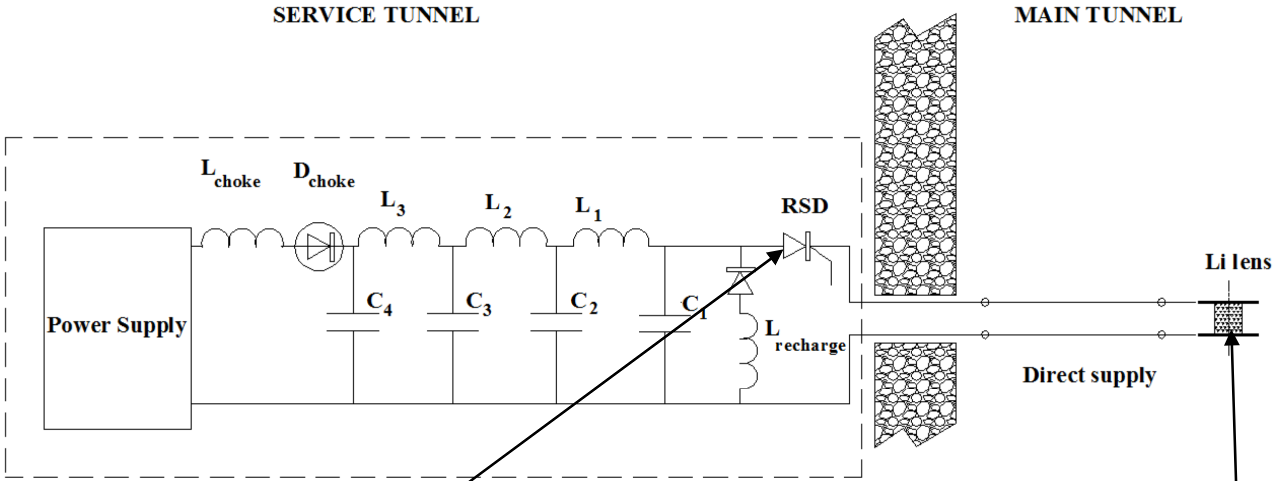
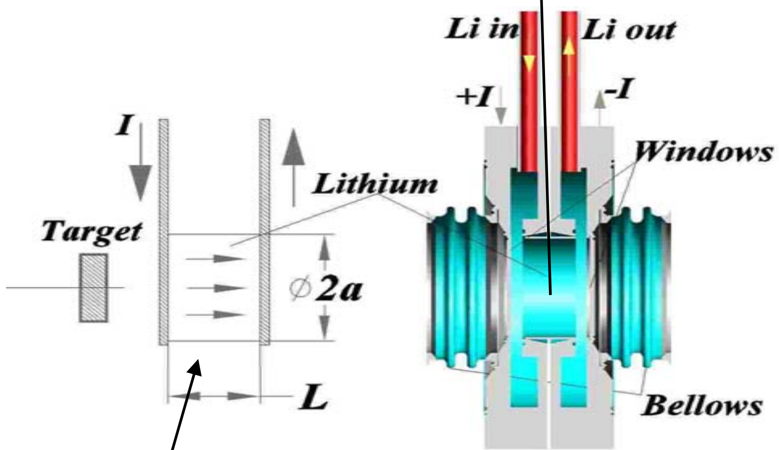


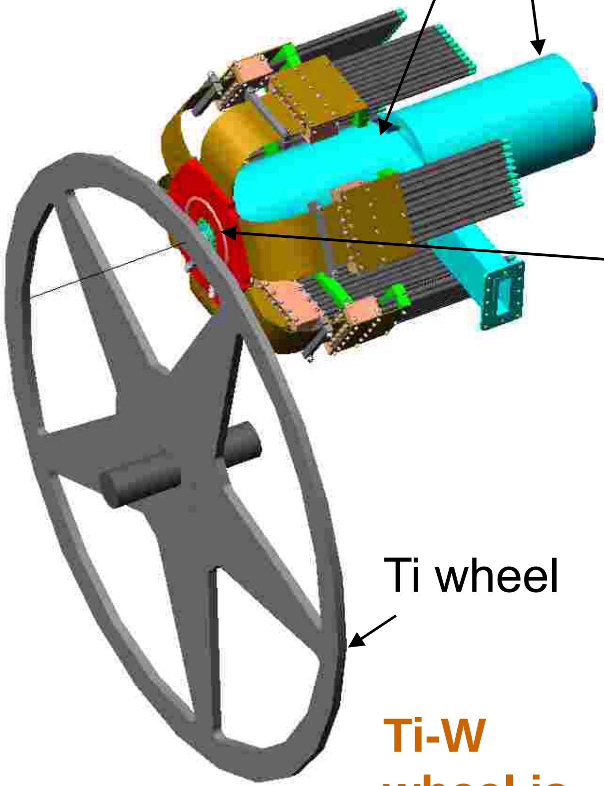
Fig.2. Reverse – switched dinistors for peak current from 200 kA to 500 kA and blocking voltage of 2400 V, encapsullated in hermetic metal – ceramic housing and without housing (RSD sizes of 64, 76, and 100 mm)

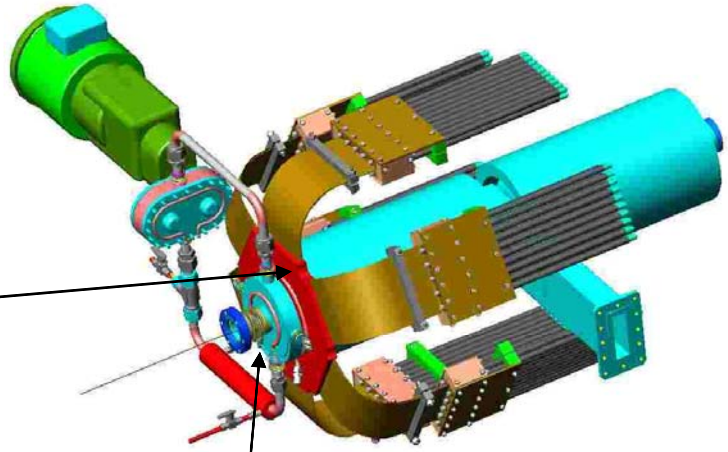


Current required for 250 GeV operation -120-150kA

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

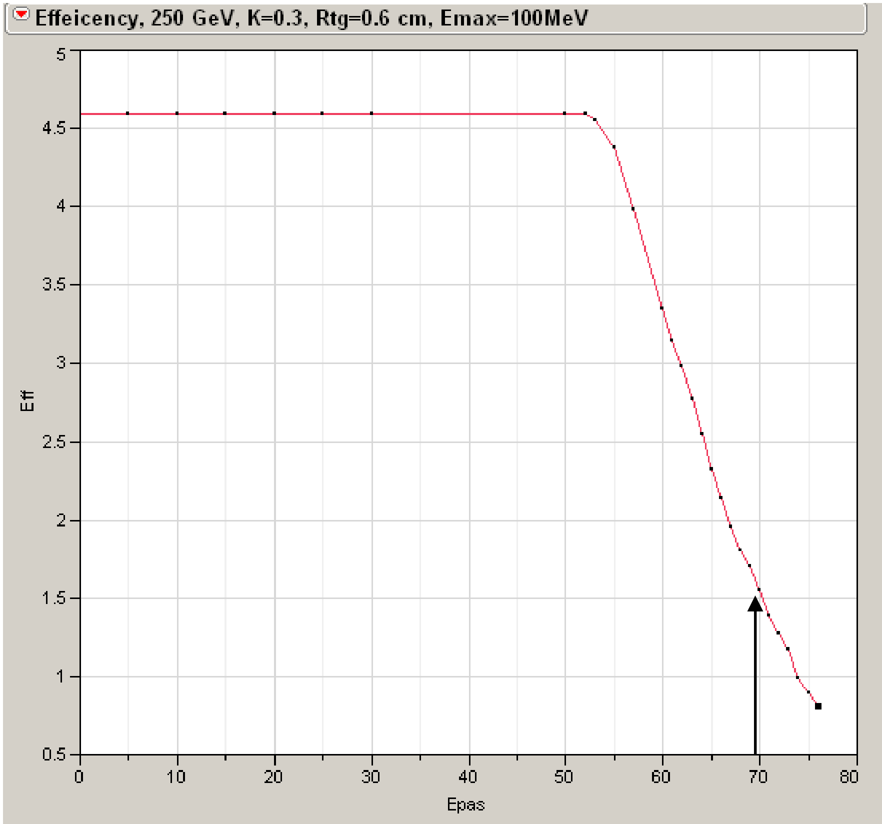
Ti-W wheel is possible

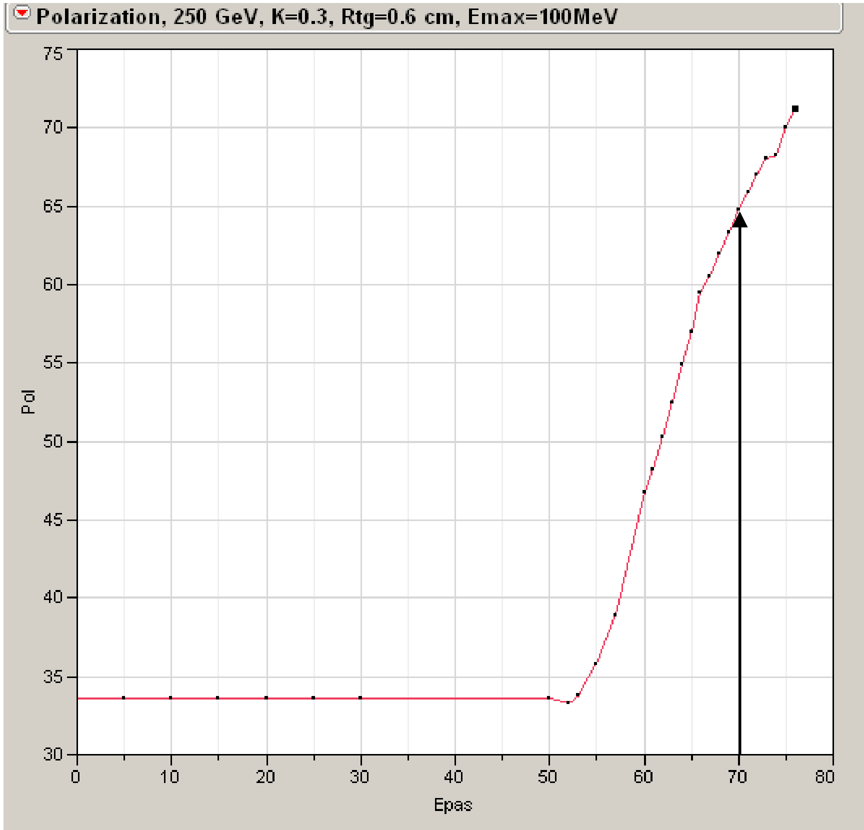
Accelerator structure could operate at third harmonics (~4GHz)

Transition optics between solenoid and FODO is well known

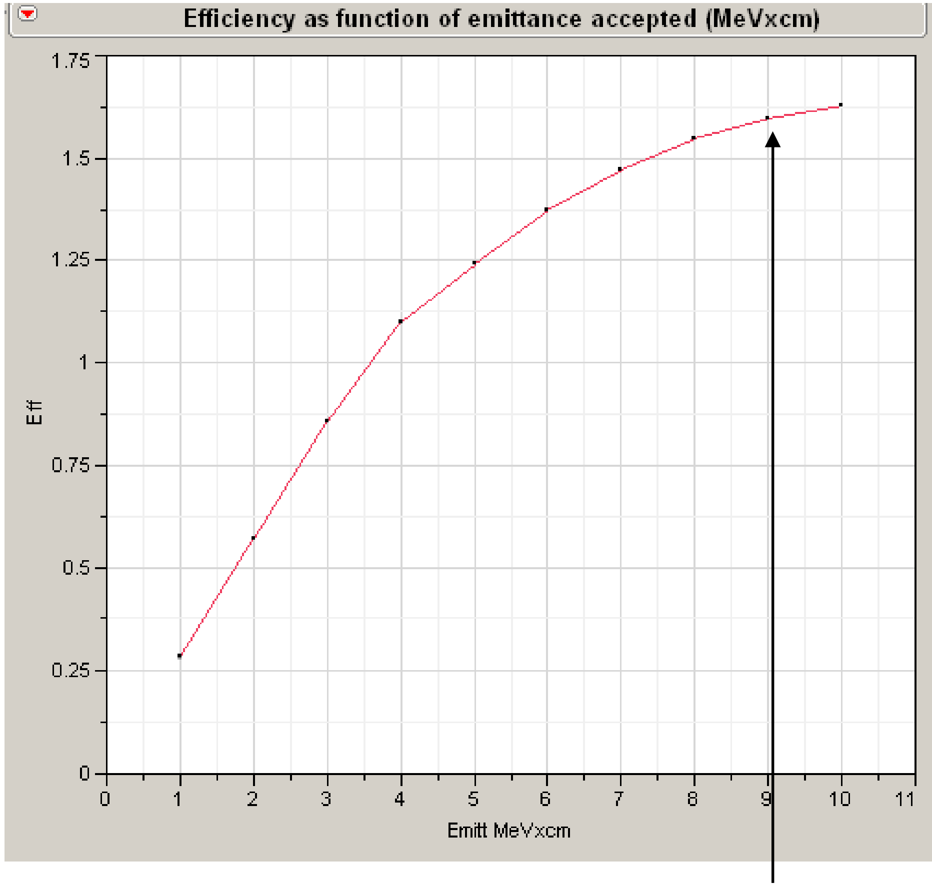
Efficiency and polarization as functions of lower boundary energy cut

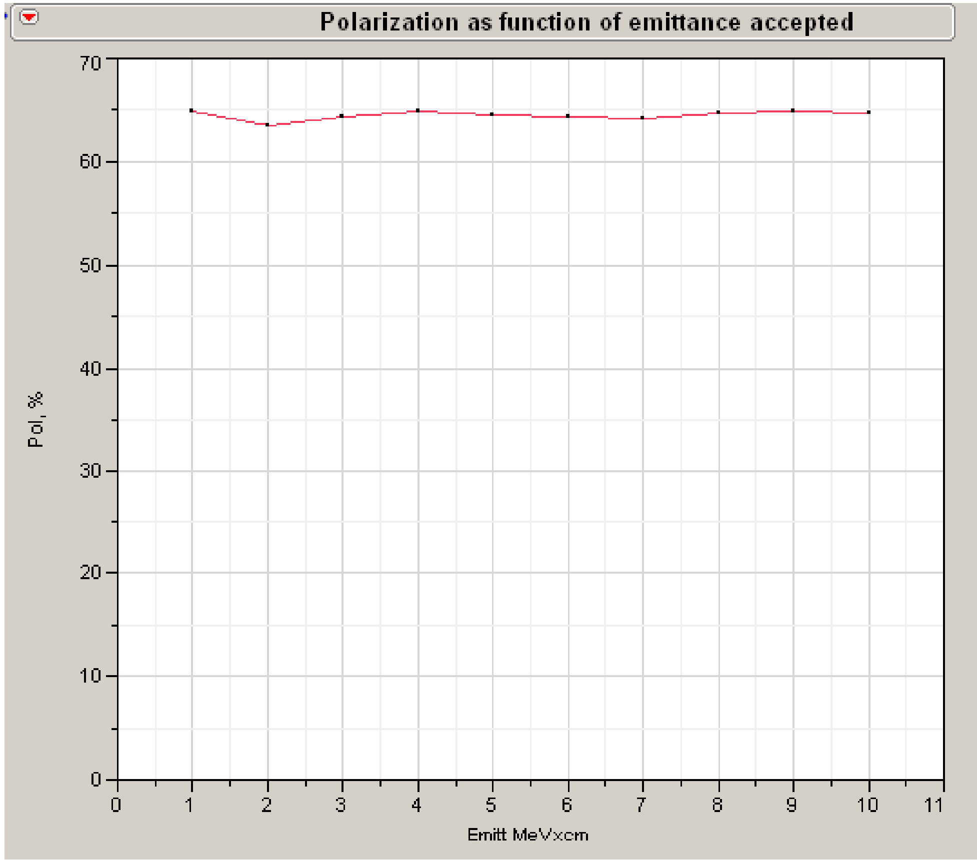
This cut could be arranged in place with dispersion by scrapping low energy particles





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

What is the energy acceptance and max admittance of DR?

Source: ILC reference Design Report

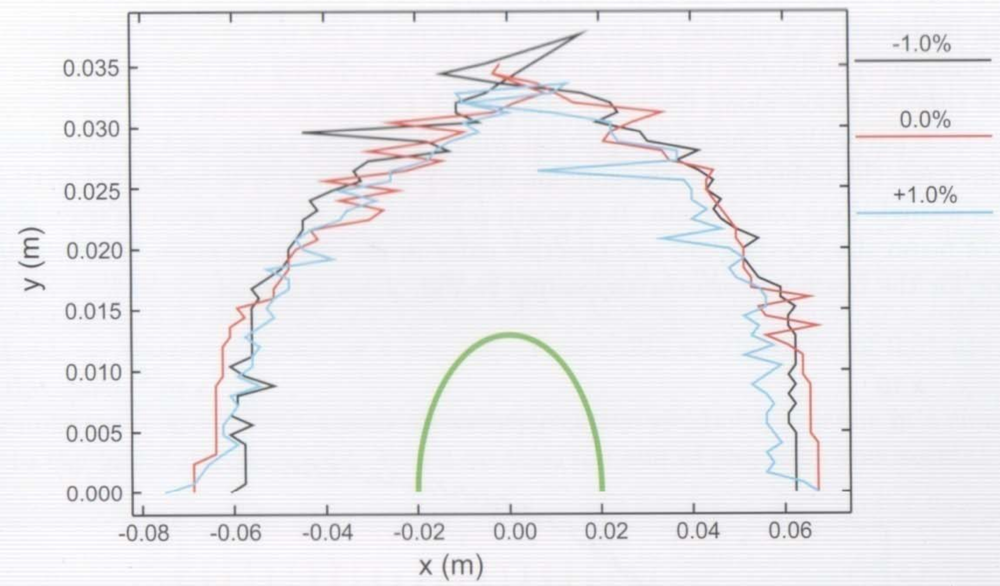


FIGURE 2.4-3. Dynamic aperture of the ILC Damping Ring (without field and alignment errors) for relati momentum errors of -1%, 0% and 1% at x = 44 m and y = 18 m. The thick green line represents the si of the injected positron beam.

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

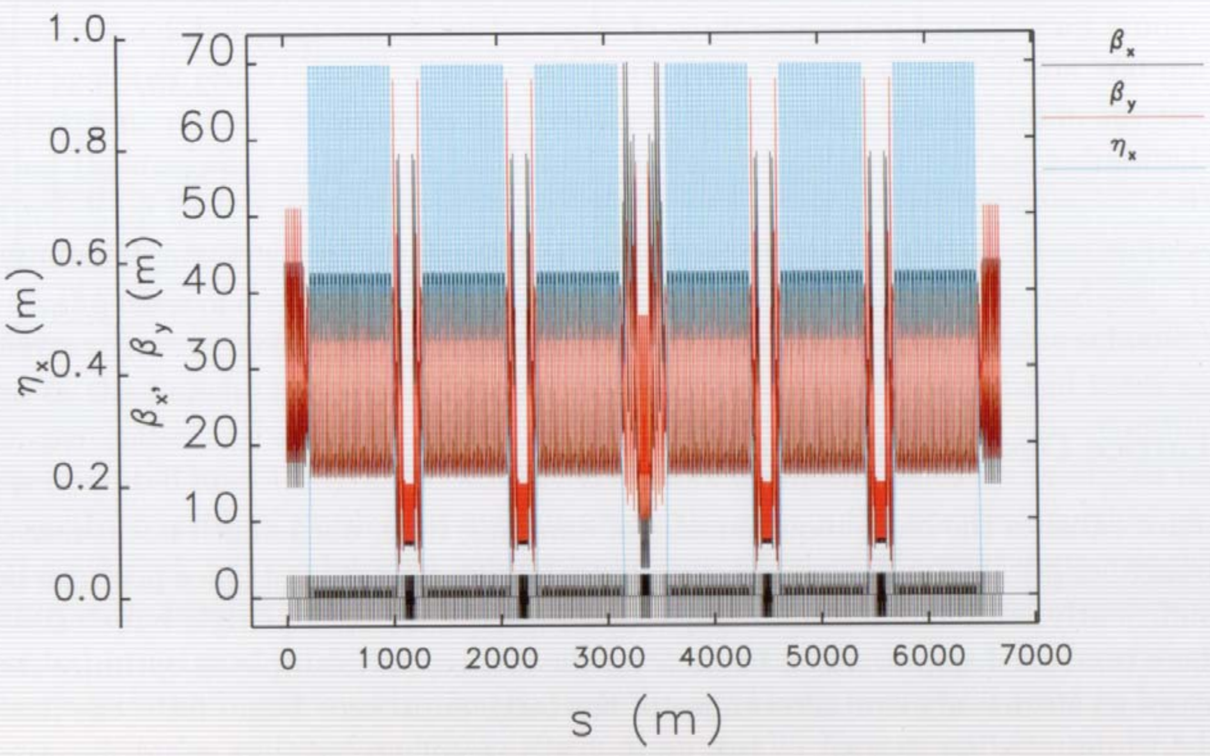


FIGURE 2.4-2. Optical functions of the ILC Damping Ring.

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).

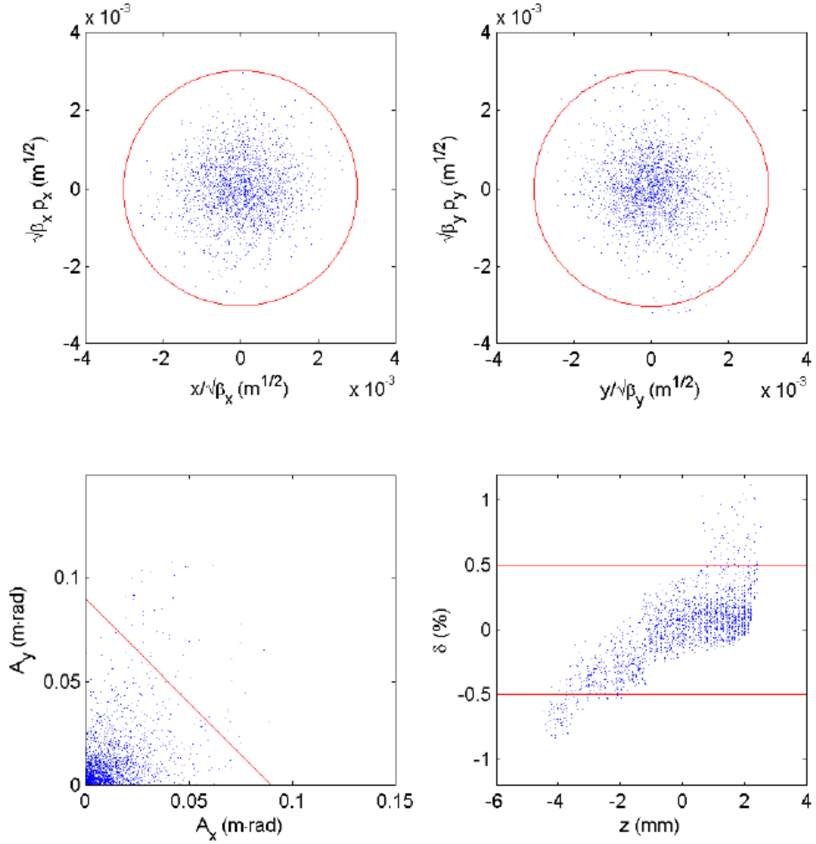


Figure 3.29: Distribution of injected positrons from Batygin (the YB distribution). Top: horizontal (left) and vertical (right) phase space in normalized coordinates; the red circles show the limits given by $A_{x,y} < 0.09$ m·rad. Bottom left: transverse distribution of betatron amplitudes; the red 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 $s = \omega_n / \omega_n^{max}$

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

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

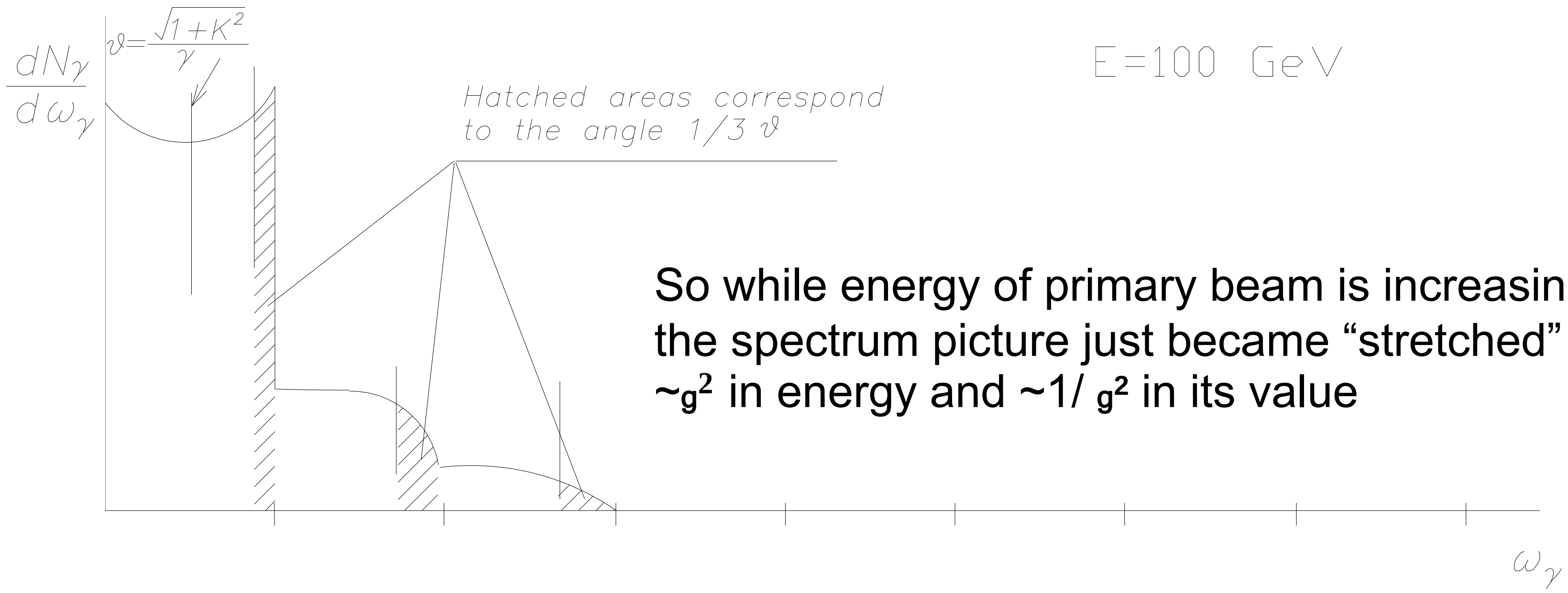
But the phonon flux expressed as a function of (not normalized) energy is

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

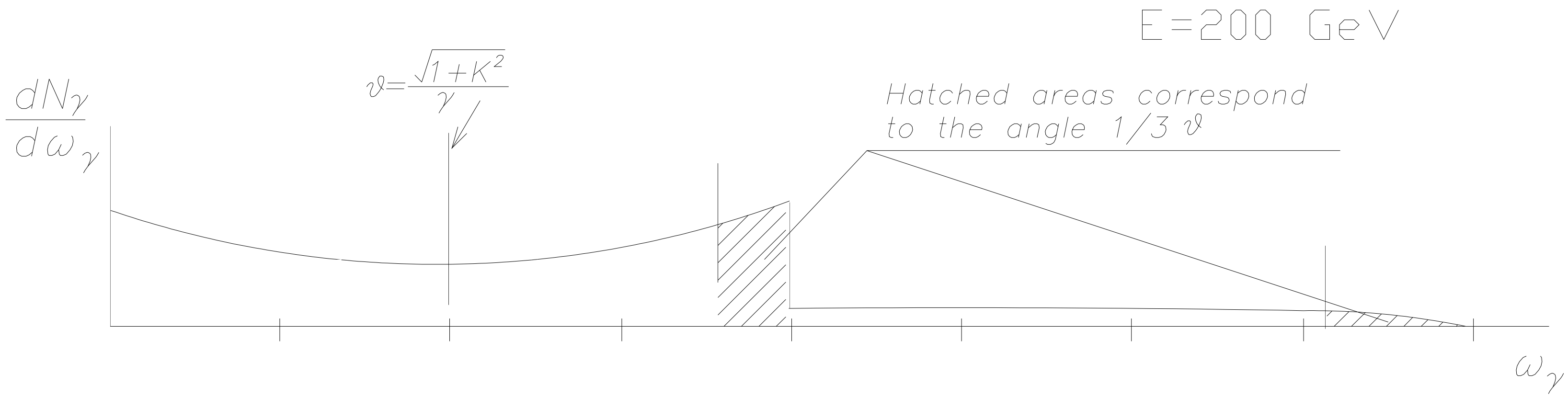
So one can see, that the photon density drops ~$1/\gamma^2$

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

PHOTON SPECTRUM

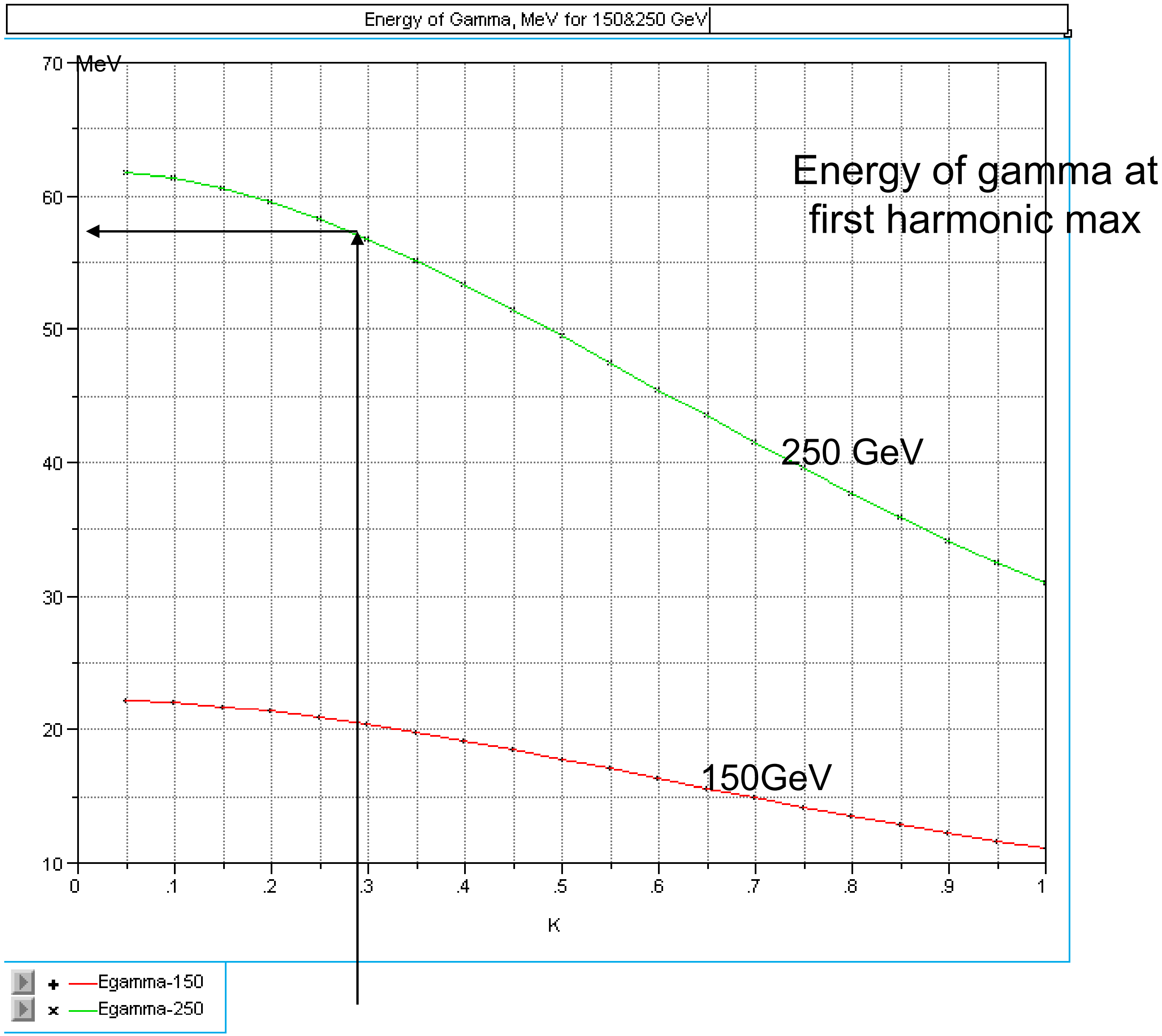


So while energy of primary beam is increasing, the spectrum picture just became “stretched” $\sim g^2$ in energy and $\sim 1/\ g^2$ in its value

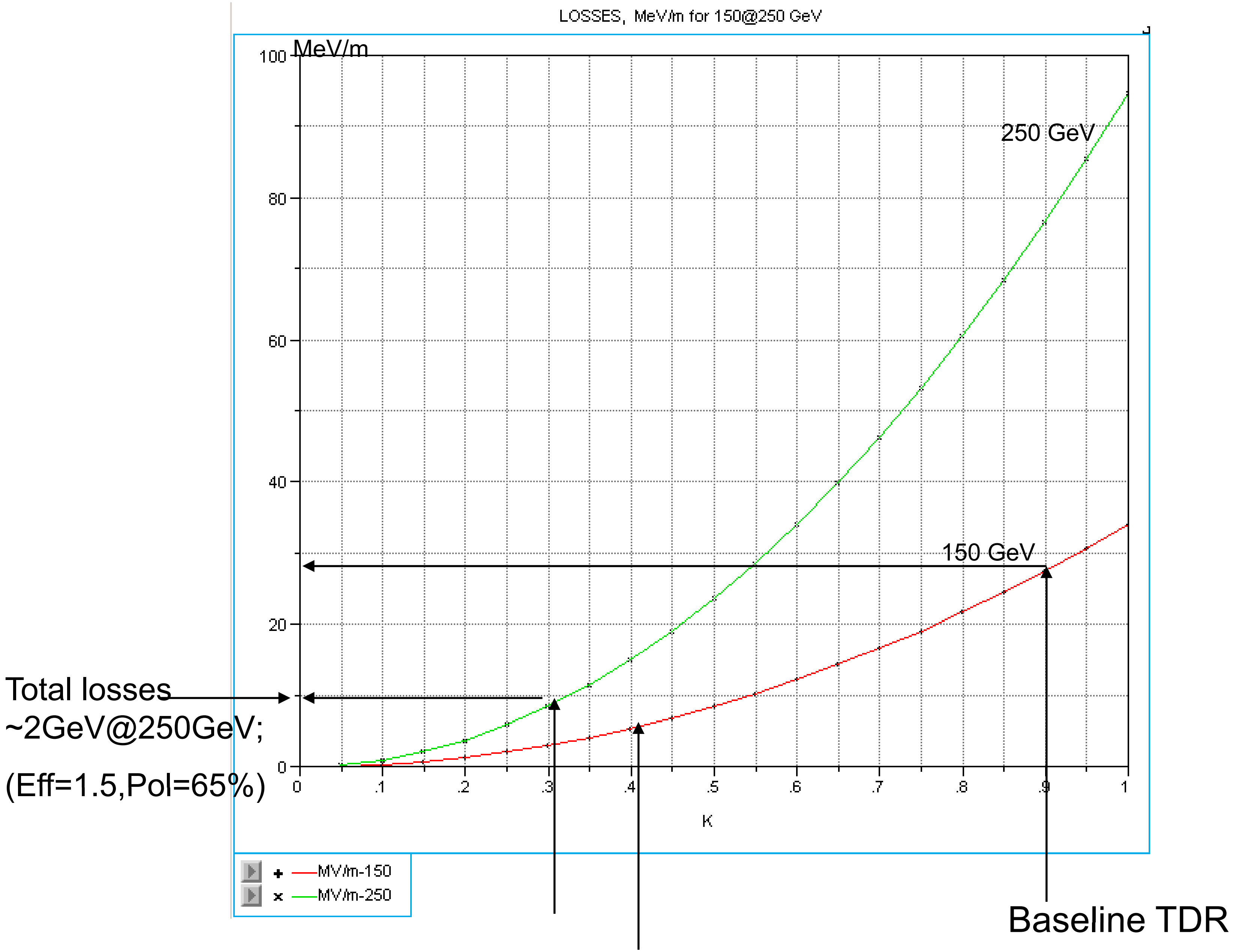


So the hatched area remains the same

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

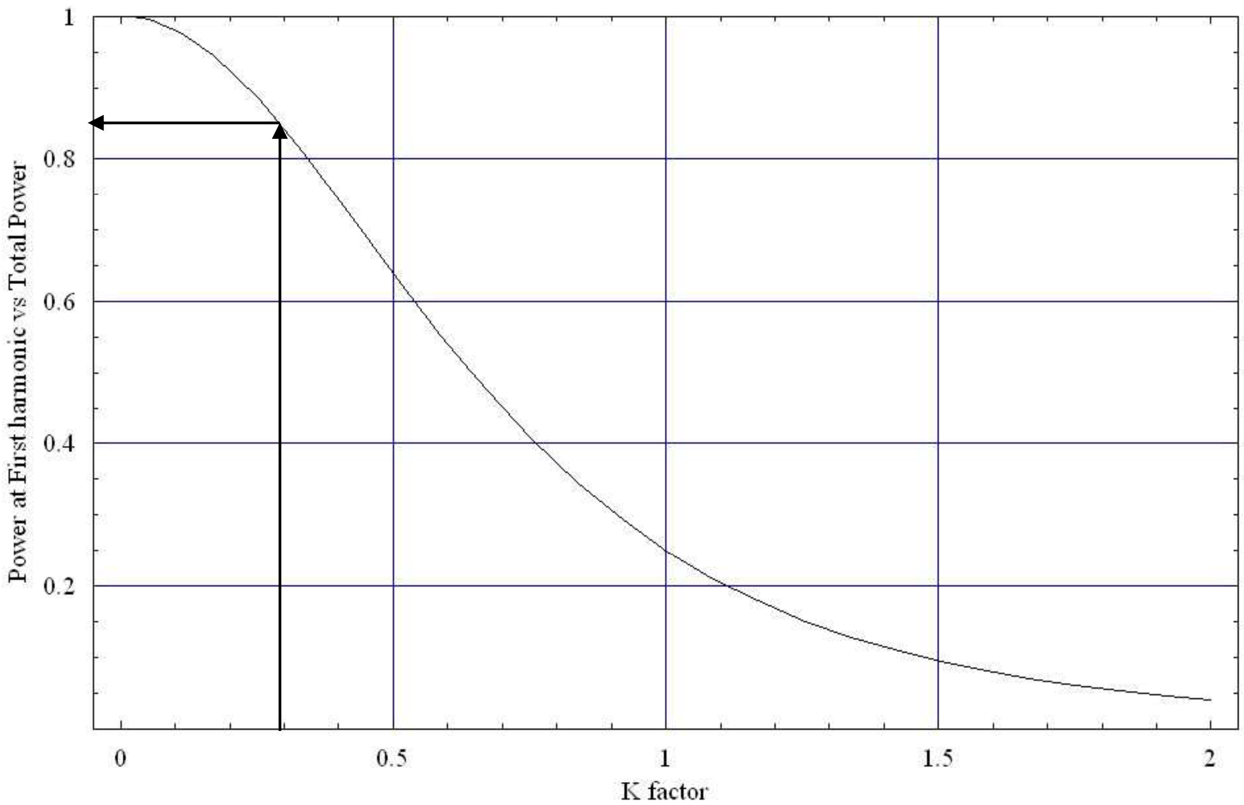


(We will see, that optimal value is K≤0.3)



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