Photon Collider beam simulation with CAIN

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Outline

- Introduction: motivation and tools
- Background contributions
- Possible 20 mrad layout
- Background levels
- Conclusions

Introduction

Motivation

- Understanding of the beam related background
- Feasibility of the Photon Collider running with 20 mrad electron beam crossing angle (as proposed in the baseline configuration)

Tools

Simulation performed using CAIN ver. 2.35.
Compiled and run under linux (Fedora Core 4)

Beam configuration for e^-e^- at $\sqrt{s_{ee}}$ =500 GeV as in TESLA TDR
+ optimized laser parameters.
Reference configuration file prepared by Klaus Moenig.

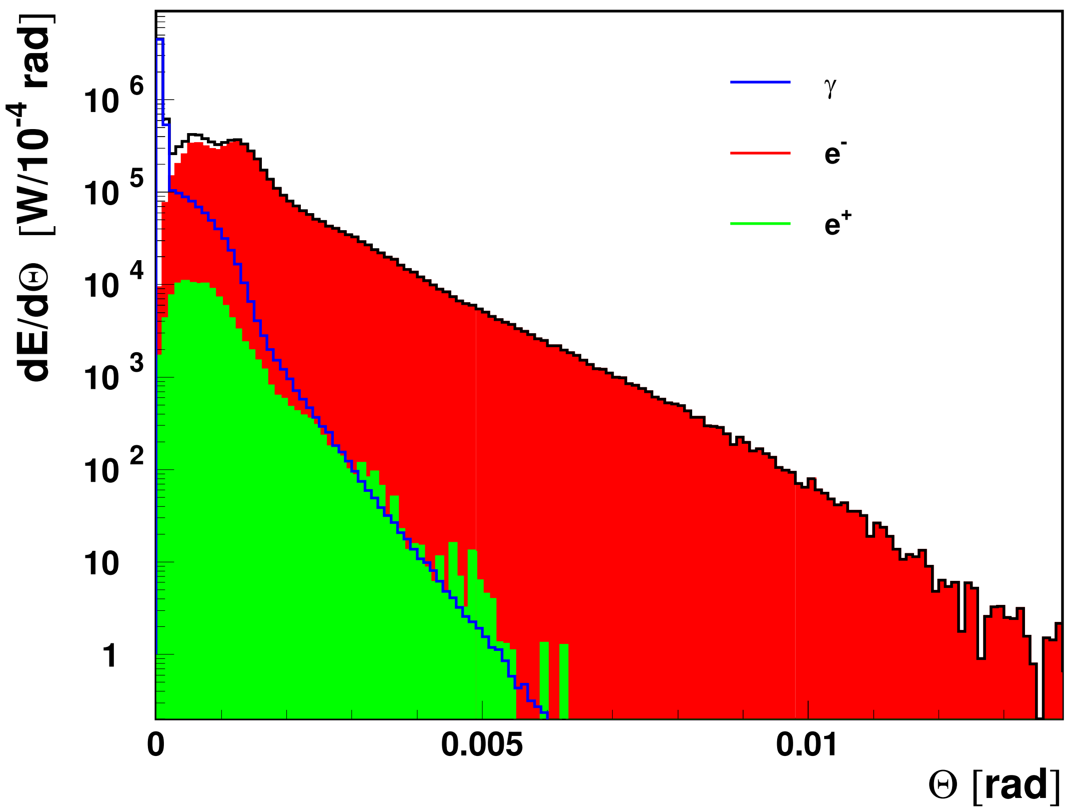
Number of macro particles (limited by CPU time):

- 50'000 for tests
- 200'000 or more for final results (real particles $2 \cdot 10^{10}$)

Motivation

Beam simulation results for 34 mrad beam crossing angle.

Angular energy flow observed 3m from IP (one beam).



Background (beam halo) mainly due to electrons.

About 15 mrad opening angle needed to contain the outgoing beam.

⇒ What effects contribute to the beam background?

⇒ Why is the beam background much higher than for e^+e^-?

⇒ How it changes with crossing angle?

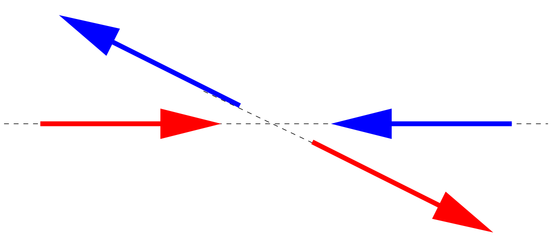
Beam-beam interactions

The angular spread of the beam after Compton scattering is below 1 mrad (negligible).

Due to beam-beam interactions at the IP the electron beams are deflected up and down.

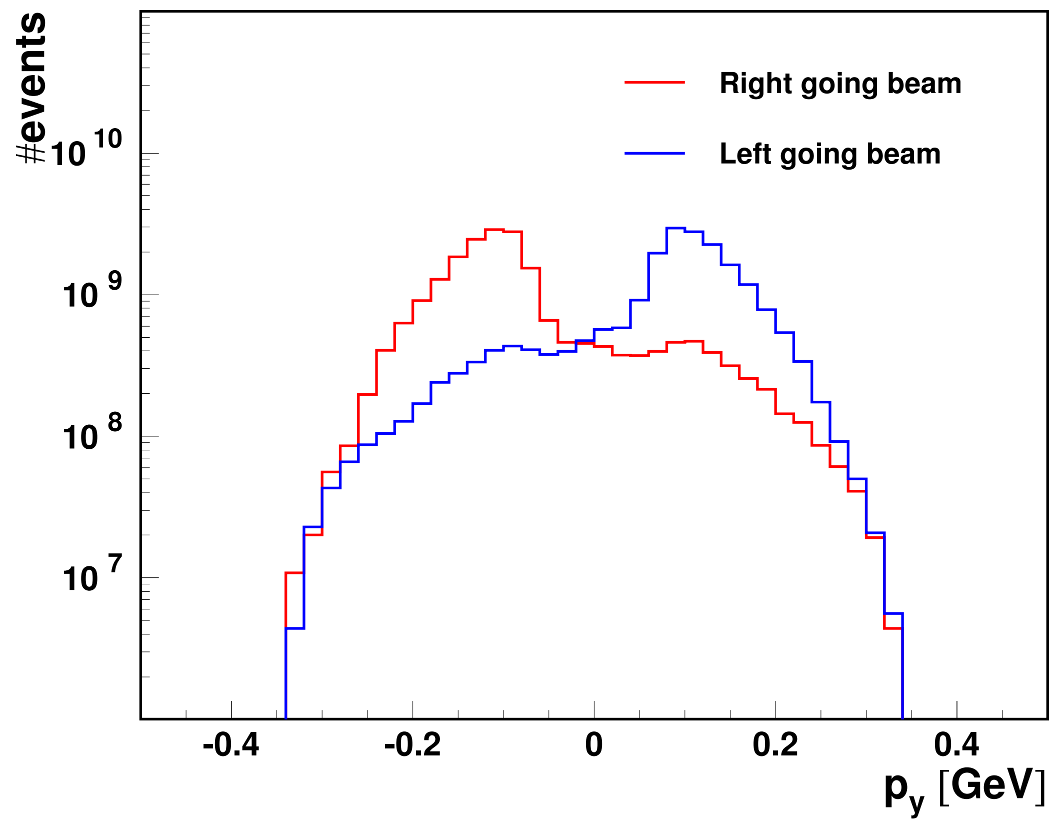
Even for $\Delta y = 0$

(head-on collision)



“spontaneous symmetry breaking”

(due to particle fluctuations inside bunches)

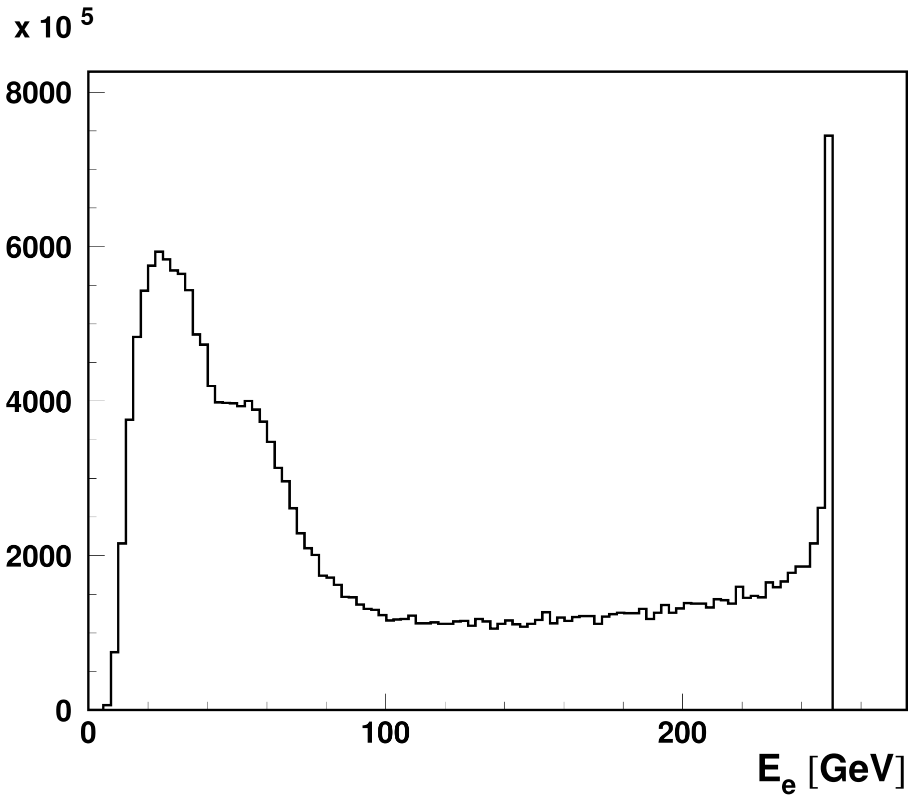


Beam-beam interactions

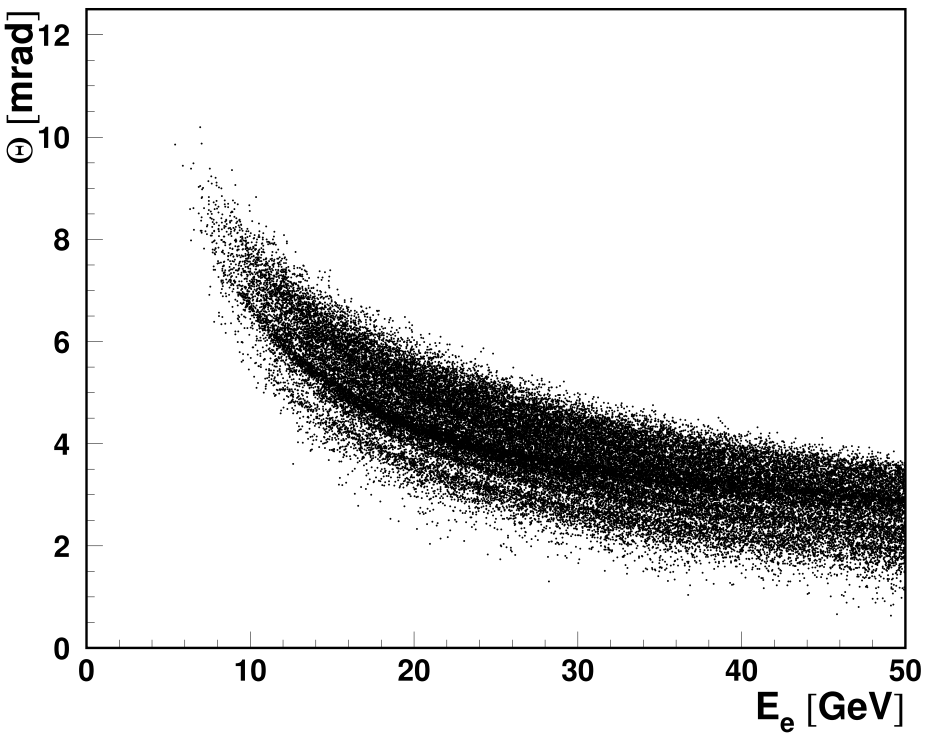
Large background is due to low energy electrons resulting from Compton scattering.

Lower energy $\Rightarrow$ larger deflection

Electron energy distribution at IP
after Compton scattering



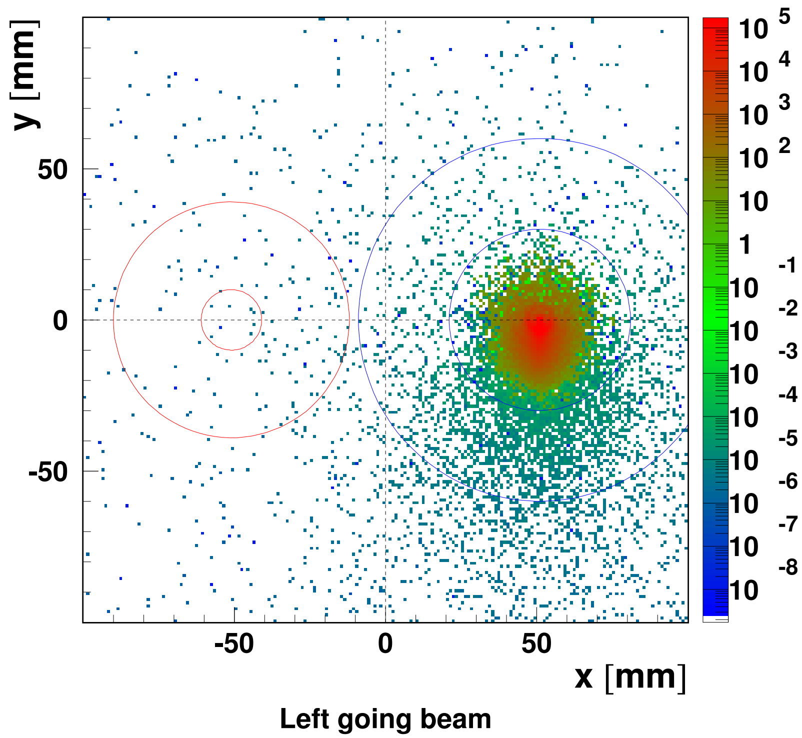
Electron deflection at IP
as a function of energy

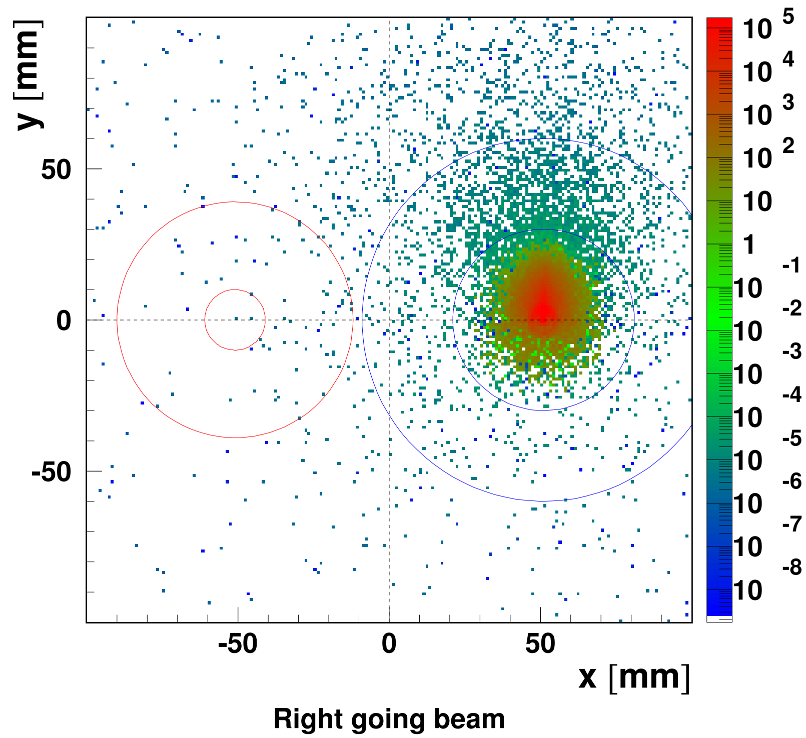


Magnetic field

Transverse profile of the beam 3 m from interaction point, 34 mrad crossing angle.

No magnetic field: B=0





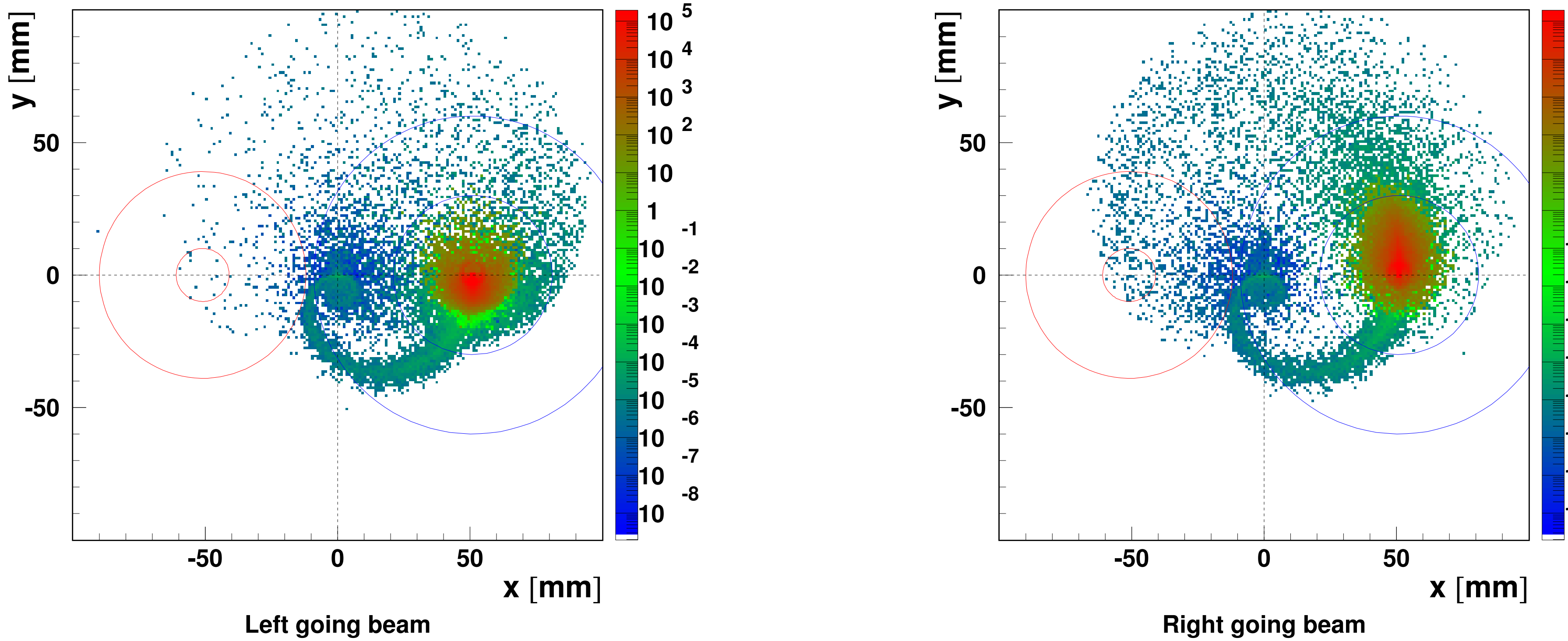
energy weighted, note logarithmic scale

blue circles: 10 and 20 mrad

Magnetic field

Transverse profile of the beam 3 m from interaction point, 34 mrad crossing angle.

Uniform magnetic field in the detector assumed: B=4 T



Magnetic field deflects both beams in the same direction! (plots above: up)

One beam (left) is moved towards and the other (right) from the nominal beam axis.

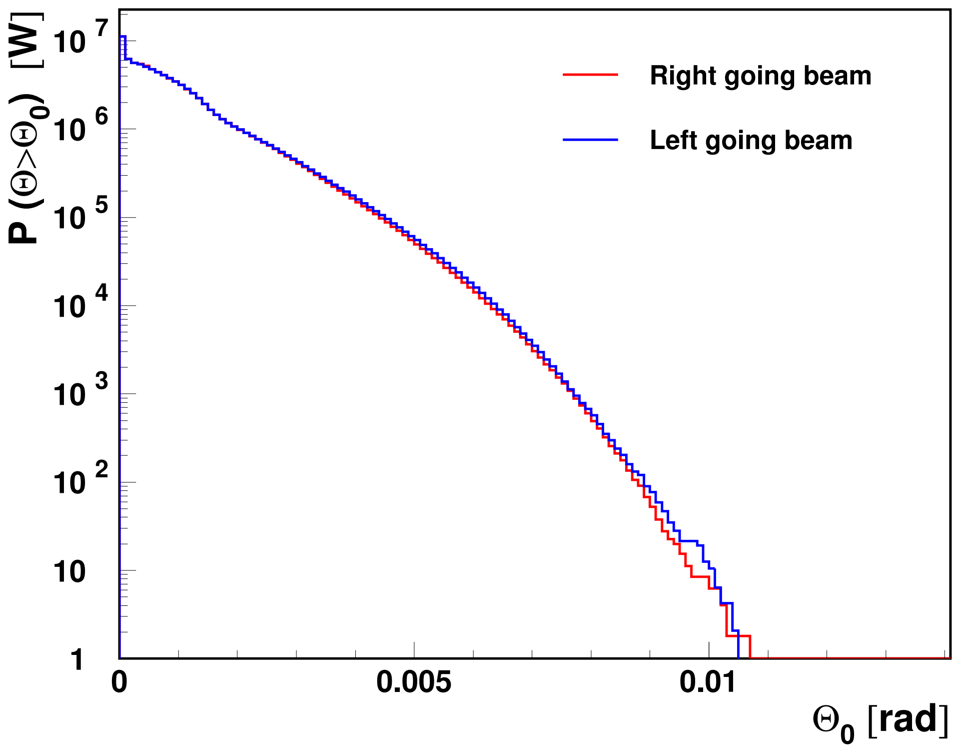
Magnetic field

Integrated energy flow: power emitted above given angle (cone around beam axis)

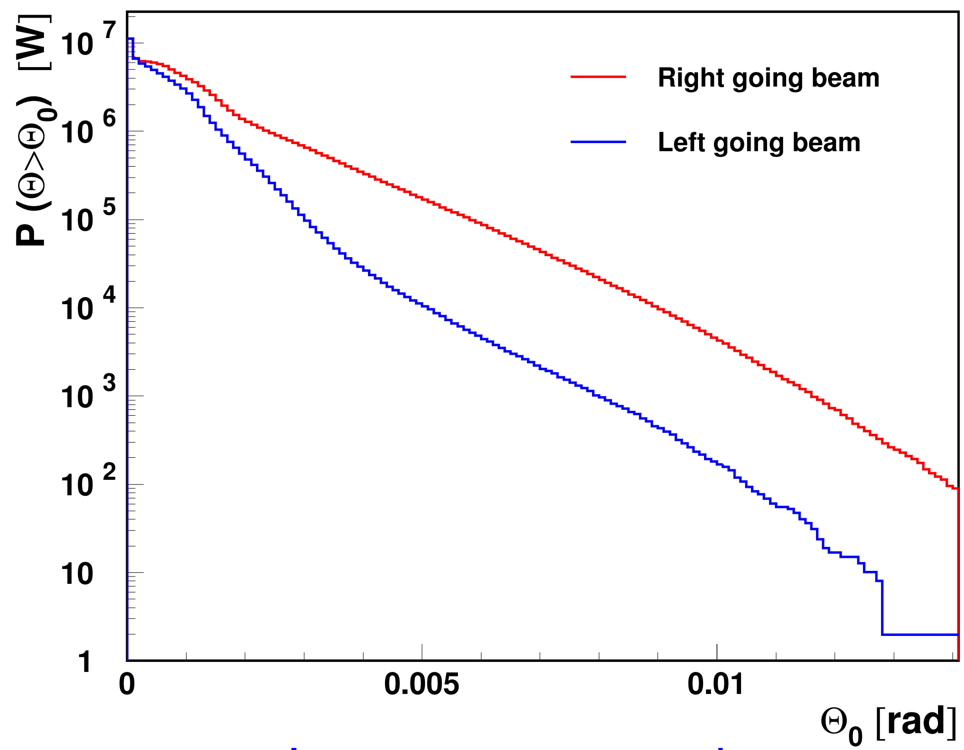
Calculated 4.5 m from interaction point.

crossing angle of 34 mrad

No magnetic field:



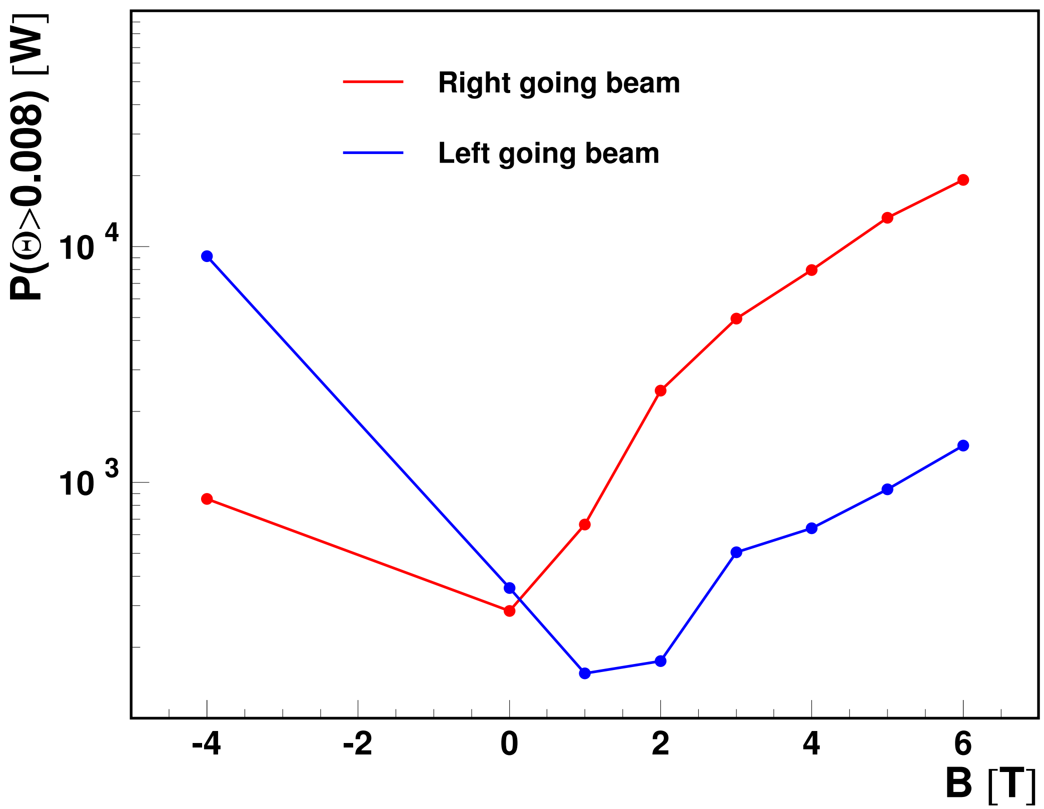
B = 4 T



⇒ Large asymmetry !

Magnetic field

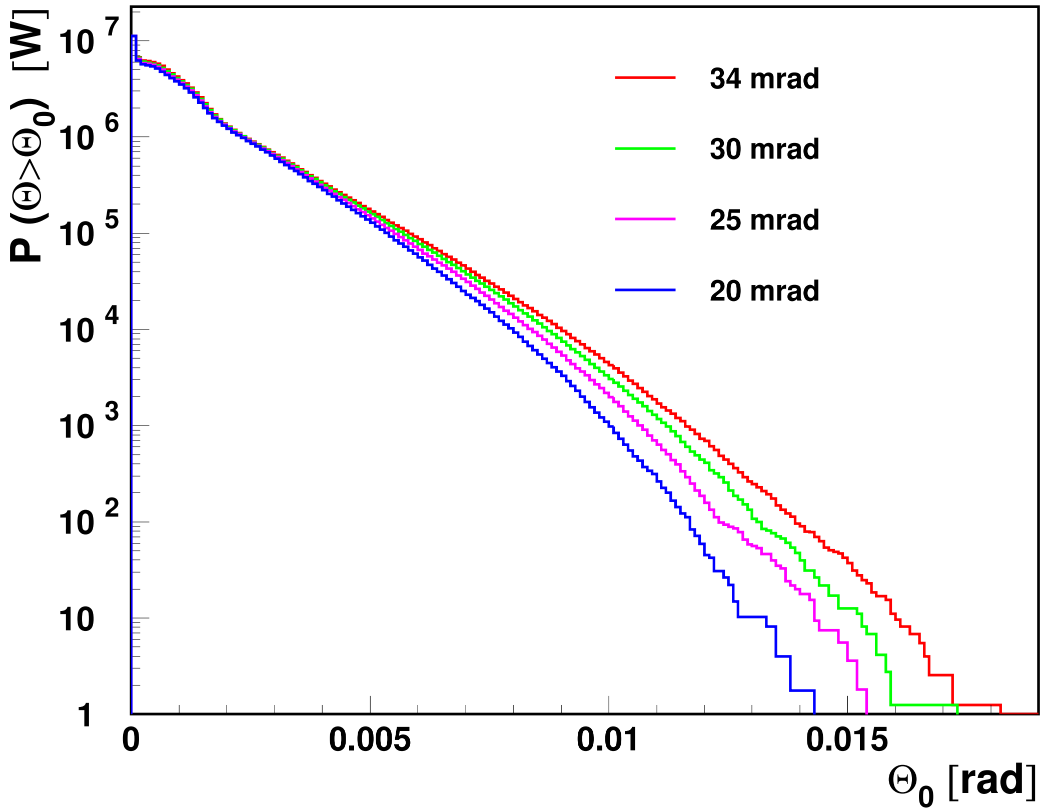
Energy flow outside 8 mrad cone, observed 3 m from interaction point, as a function of the detector field:



Strength of magnetic field has very strong influence on the expected background level!

Crossing angle

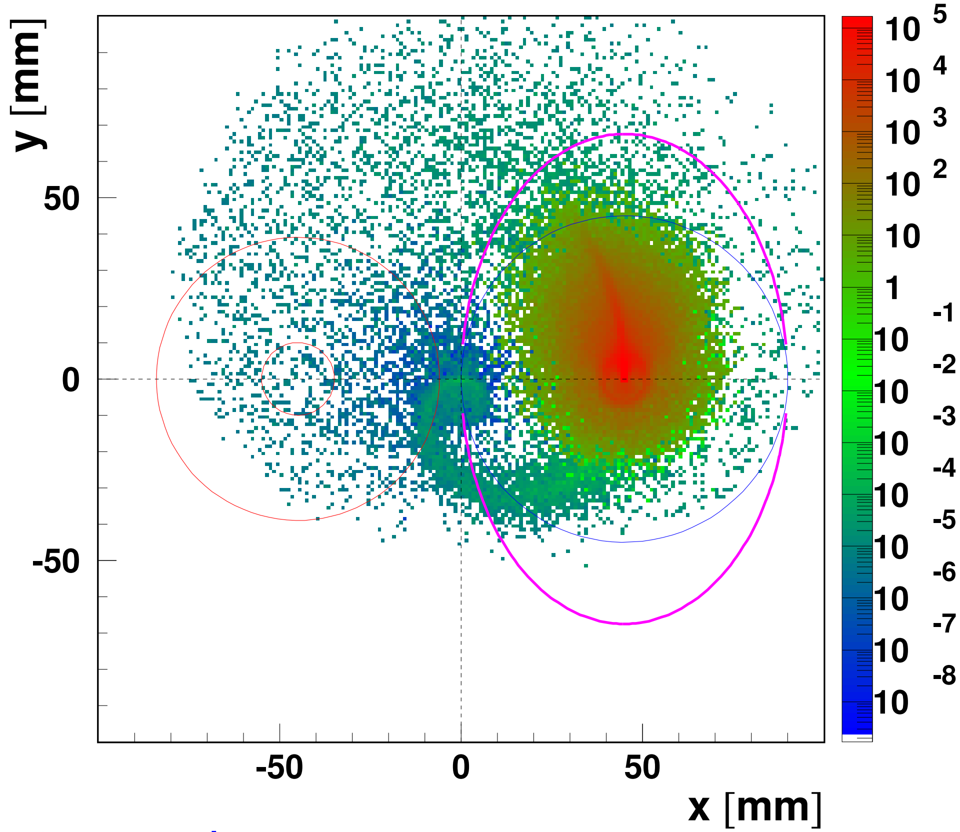
Integrated energy flow (power emitted above given angle), calculated 4.5 m from interaction point, for magnetic field B=4T.



With decreasing crossing angle the influence of magnetic field decreases.

Crossing angle

Transverse profile of the beam 4.5 m from IP,
20 mrad crossing angle, B=4 T.



About 1 kW emitted outside 10 mrad cone.

However, we can adjust the shape of the beam pipe for best extraction of the outgoing beam.

We should make the beampipe wider in the vertical direction.

blue: 10 mrad cone

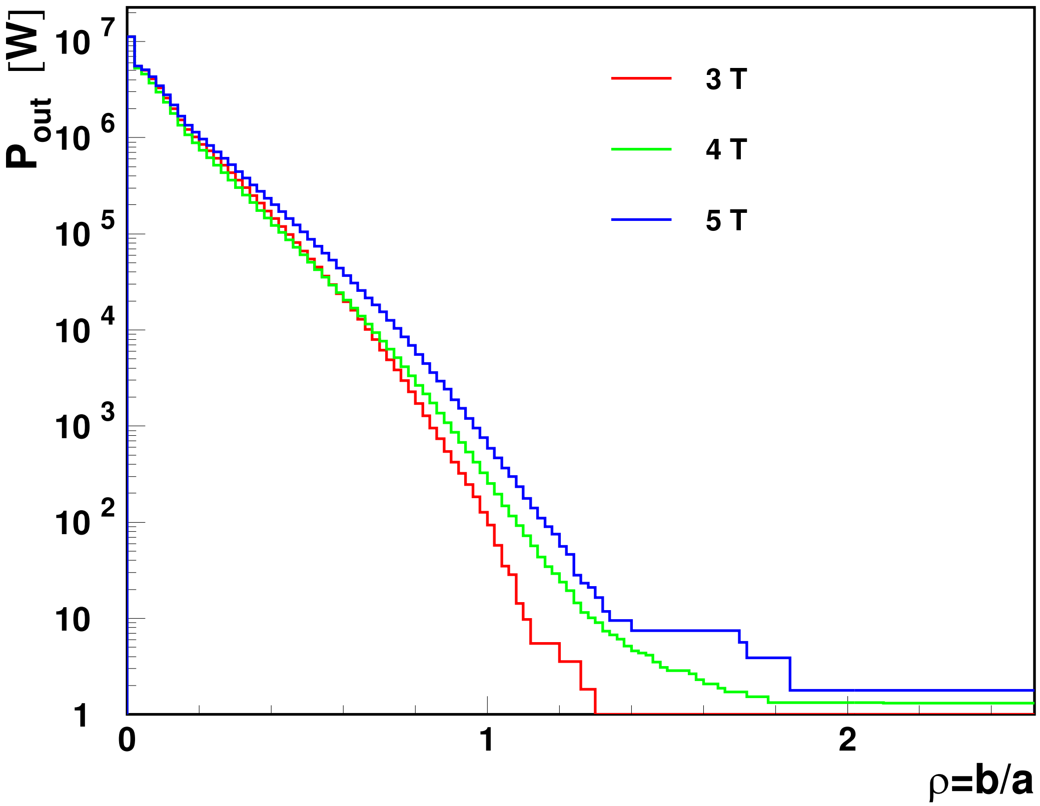
red: 40 mm radius of final dipole, $L^{\star}$=4.5

magenta:
possible choice of elliptical pipe

Beam pipe shape

Integrated energy flow outside the beam pipe
as a function of the vertical b to horizontal a beam pipe opening, for a =11 mrad.

Flow calculated 4.5 m from interaction point, for crossing angle of 20 mrad.



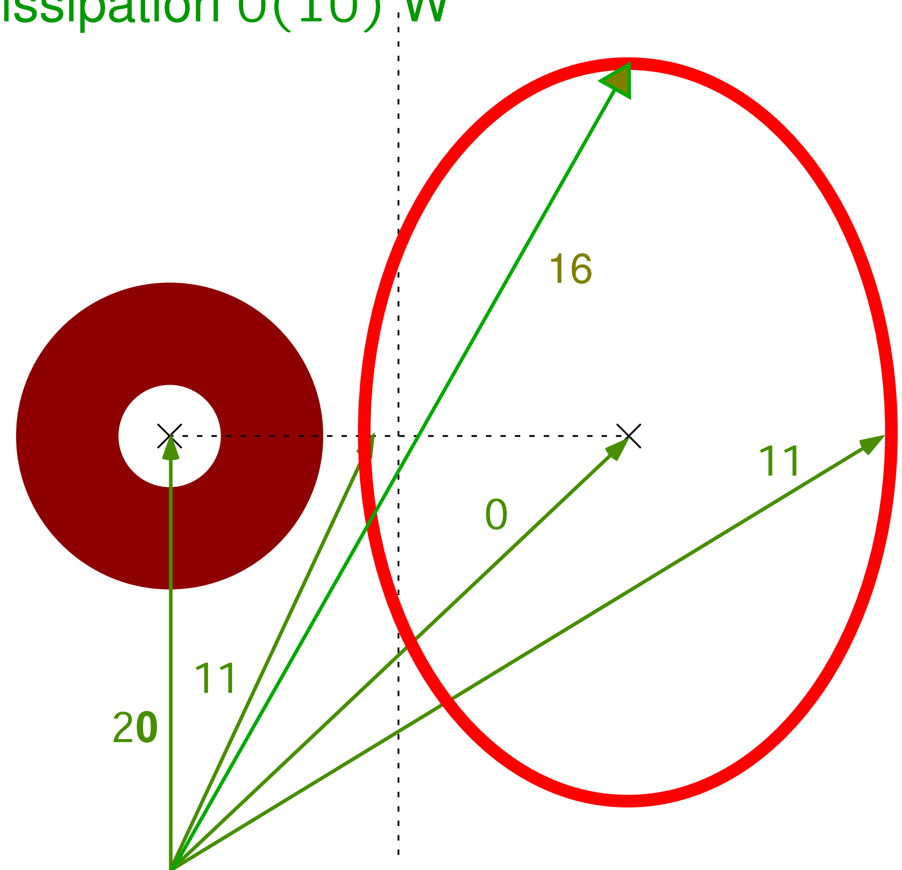
Increasing the vertical opening by 50% we decrease the power dissipation by $\sim$ 2 orders of magnitude

Beam pipe shape

If it is feasible to build the final dipole with $<$40 mm outer radius:

$\Rightarrow$ Photon Collider might fit in 20 mrad crossing angle option with $L^{\star}$=4.5m

Remaining power dissipation O(10) W



(Angles relative to outgoing beam axis in mr)

Background levels

The beam pipe shape can be adjusted to the expected background.

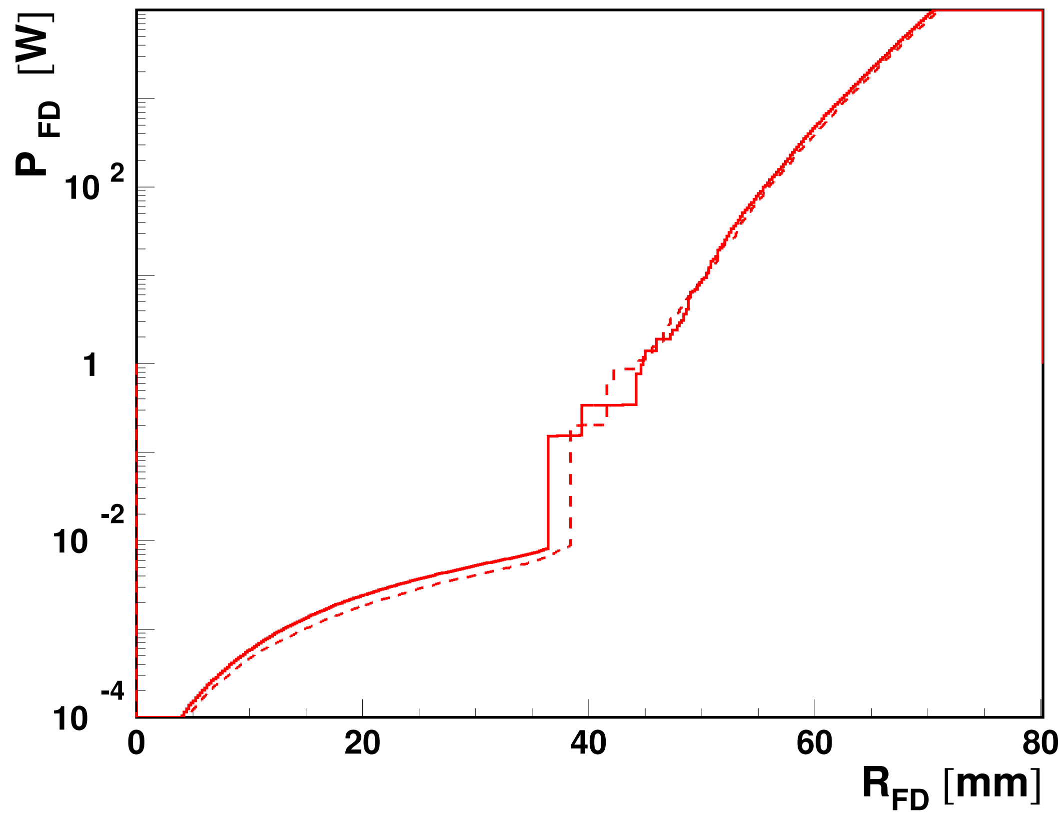
We can also consider surrounding all beams (incoming and outgoing electron beams, as well as laser beams) by one large vacuum pipe within the detector volume (idea of V.Telnov)

The crucial point is the background from direct hits at the face of the Final Dipole.

Power hitting the Final Dipole, as a function of the FD outer radius.

Deposit calculated 4.5 m from IP, for magnetic field of 4T.

⇒ Direct deposit below 1 W (for 40 mm radius)

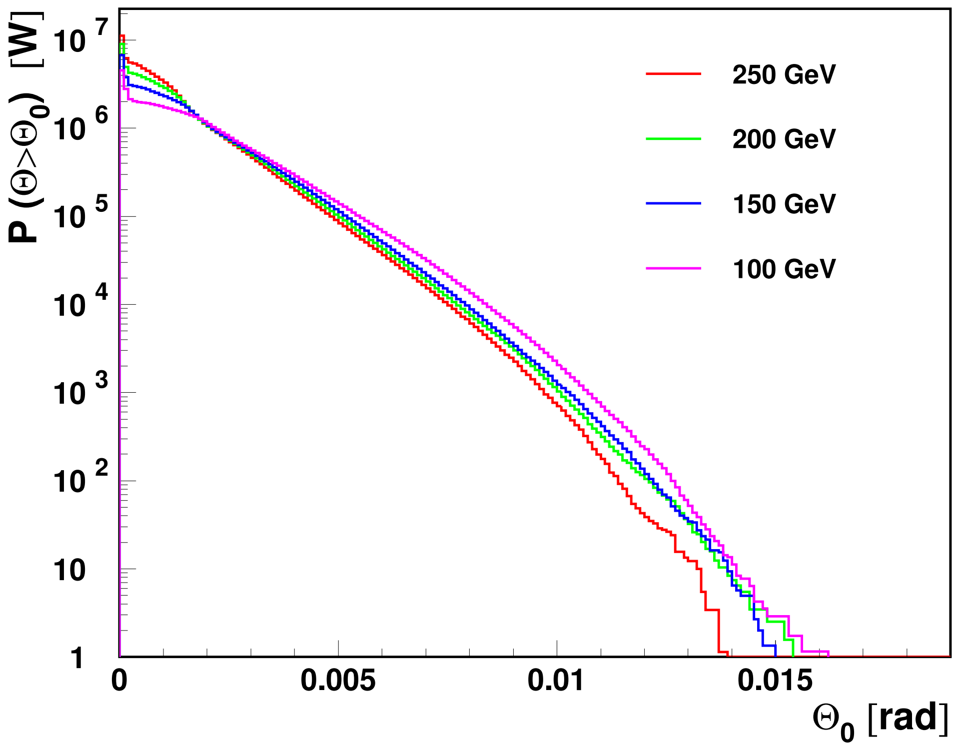


Background levels

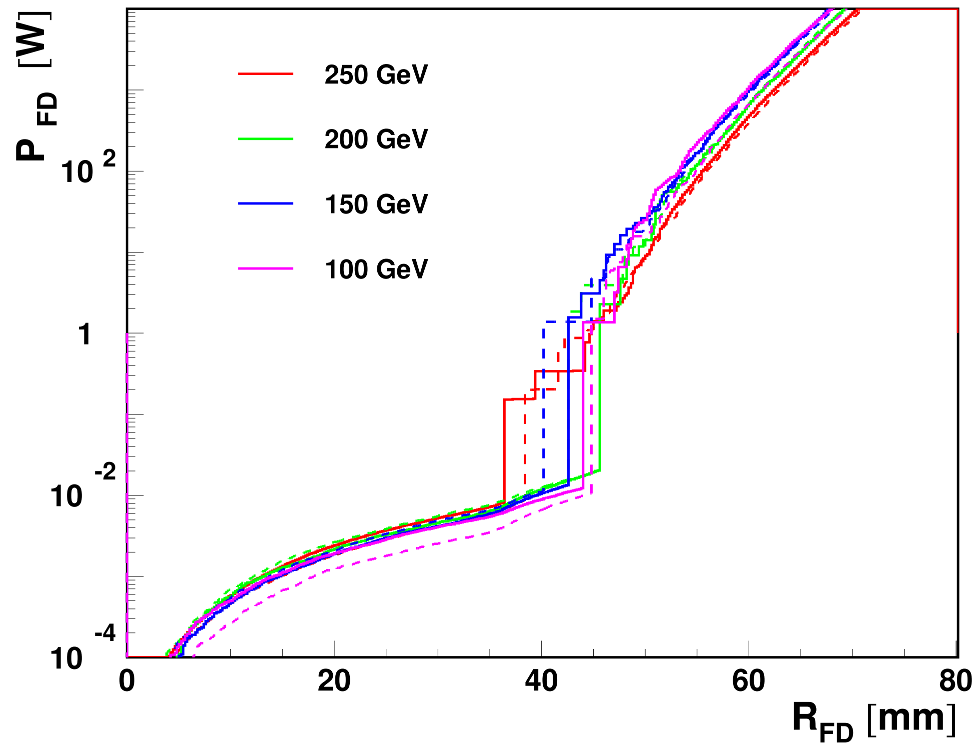
All results presented so far were obtained for electron beam of 250 GeV.

For lower beam energies the expected background increases only slightly.

Integrated energy flow



Power hitting the Final Dipole

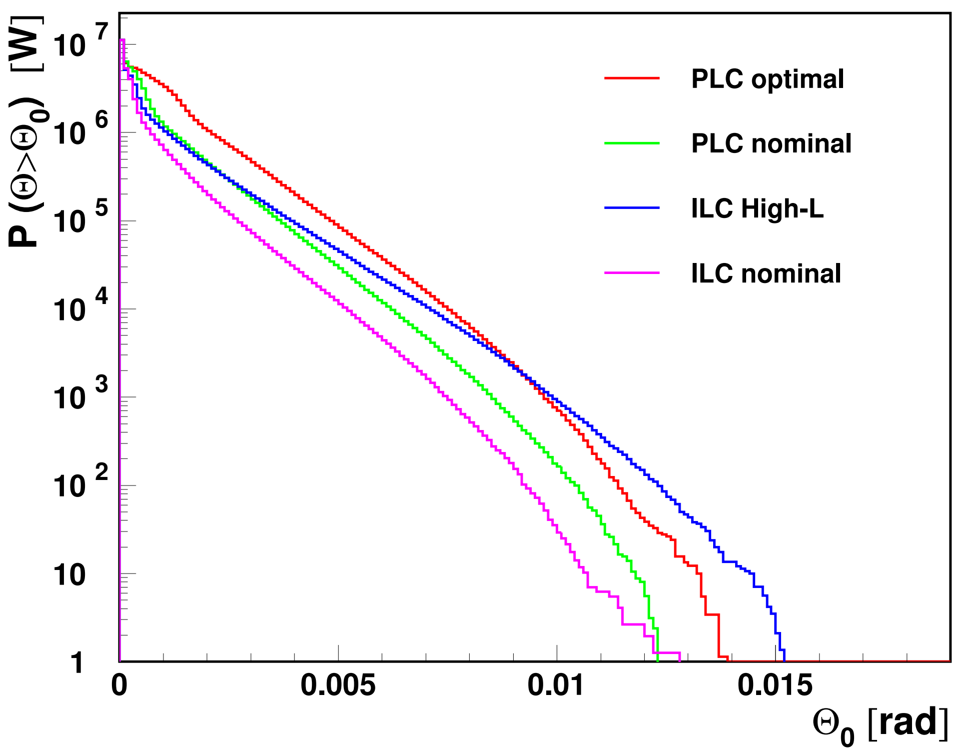


Background levels

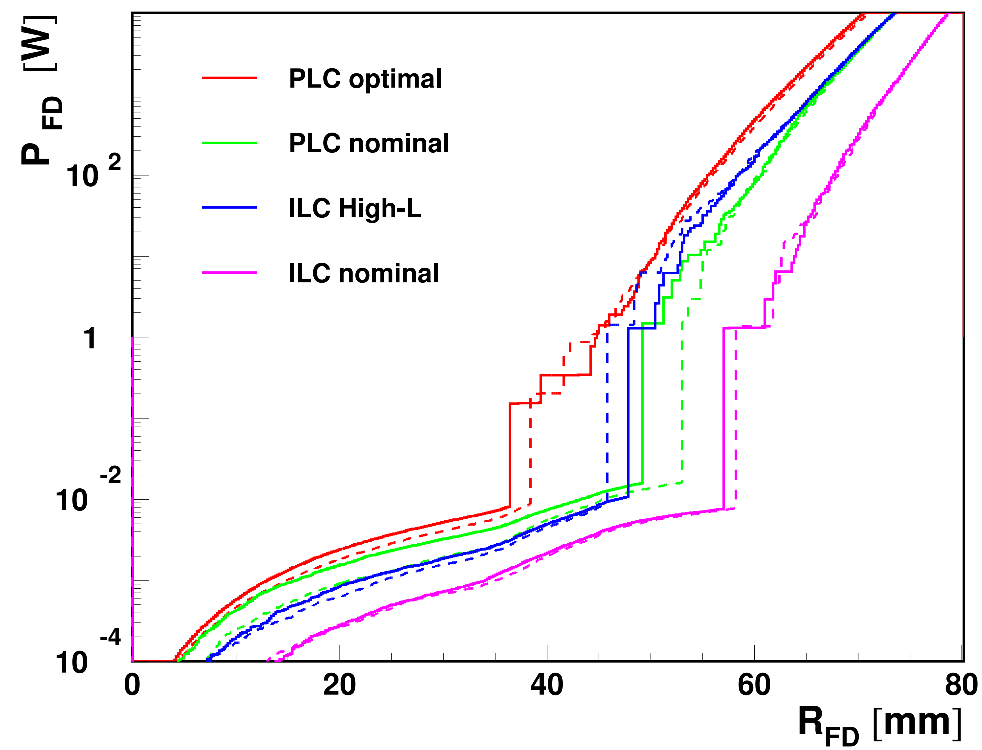
Assumed beam parameters, optimal for PLC running, result in the highest $\gamma\gamma$ luminosity, but require damping ring upgrade.

For nominal PLC parameters (ILC damping rings) background levels significantly smaller

Integrated energy flow



Power hitting the Final Dipole



Conclusions

Background coming from beam halo at the Photon Collider is significantly higher than in e^+e^- due to low energy electrons remaining after Compton scattering.

The Photon Collider running at 20 mrad crossing angle require about 11 mrad of horizontal opening for the outgoing beam.

This is consistent with $L^\star$=4.5m and the final dipole with 40 mm outer radius
$\Rightarrow$ expected power dissipation at the magnet face is below 1 W.

Slight increase in the background levels is expected for running at lower beam energy.

Beam parameters

	Photon Collider		ILC	
	Optimal (TDR)	Nominal	High L	Nominal
$\gamma\epsilon_x^\star$ [mm· rad]	2.5	10	10	10
$\gamma\epsilon_y^\star$ [mm· rad]	0.03	0.04	0.03	0.04
$\beta_x^\star$ [mm]	1.5	5	10	21
$\beta_y^\star$ [mm]	0.3	0.3	0.2	0.4
$\sigma_x^\star$ [nm]	88	320	452	655
$\sigma_y^\star$ [nm]	4.3	5.0	3.5	5.7
σ_z [μm]	300	300	150	300
$\mathcal{L}_{geom}$ [10^{34}]	12	2.8	2.8	1.2