

New results from beam simulation with CAIN

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Outline

- Motivation
- Simulation
- Results for
 - beam alignment
 - magnetic field
 - crossing angle
 - beam pipe shape
- Conclusions

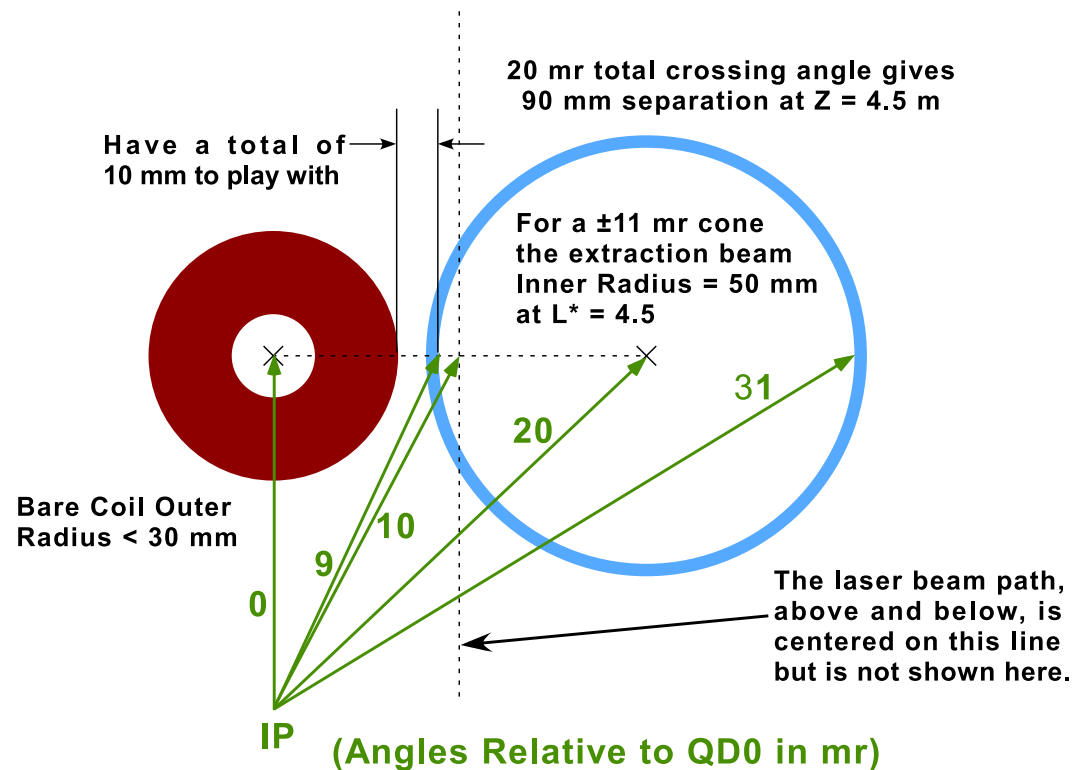
Motivation

20 mrad crossing angle is considered for the baseline ILC design.

Is it compatible with Photon Collider option?

The final dipole with outer radius below 40 mm has recently been designed (e^+e^- ?)

⇒ possible layout of 20 mrad Photon Collider (Brett Parker):



Simulation

Simulation performed using CAIN ver. 2.35.

Compiled and run under linux (Fedora Core 4)

Few problems found when running the code:

- compiler dependent end-less loops (uninitialized variable in routine SMESH1)
- particle losses when tracking in magnetic field (routine DRFEXT)

Beam configuration as in TESLA TDR + optimized laser parameters.

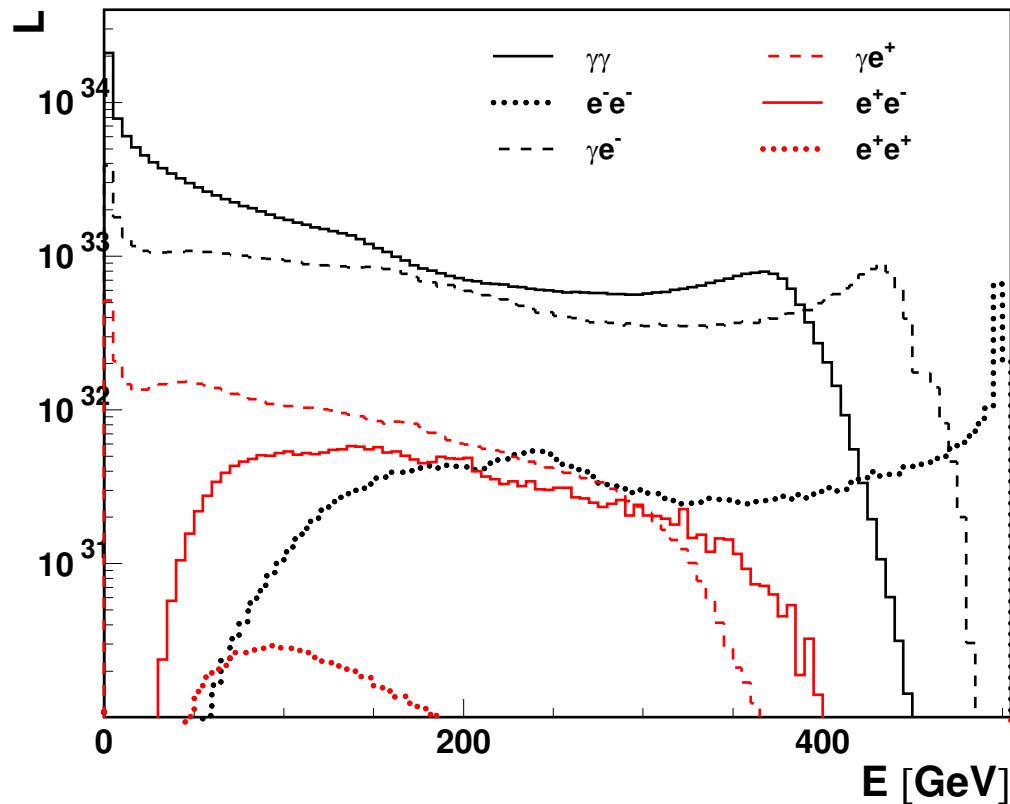
Configuration file prepared by Klaus Moenig.

Number of macro particles (limited by CPU time):

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

Simulation

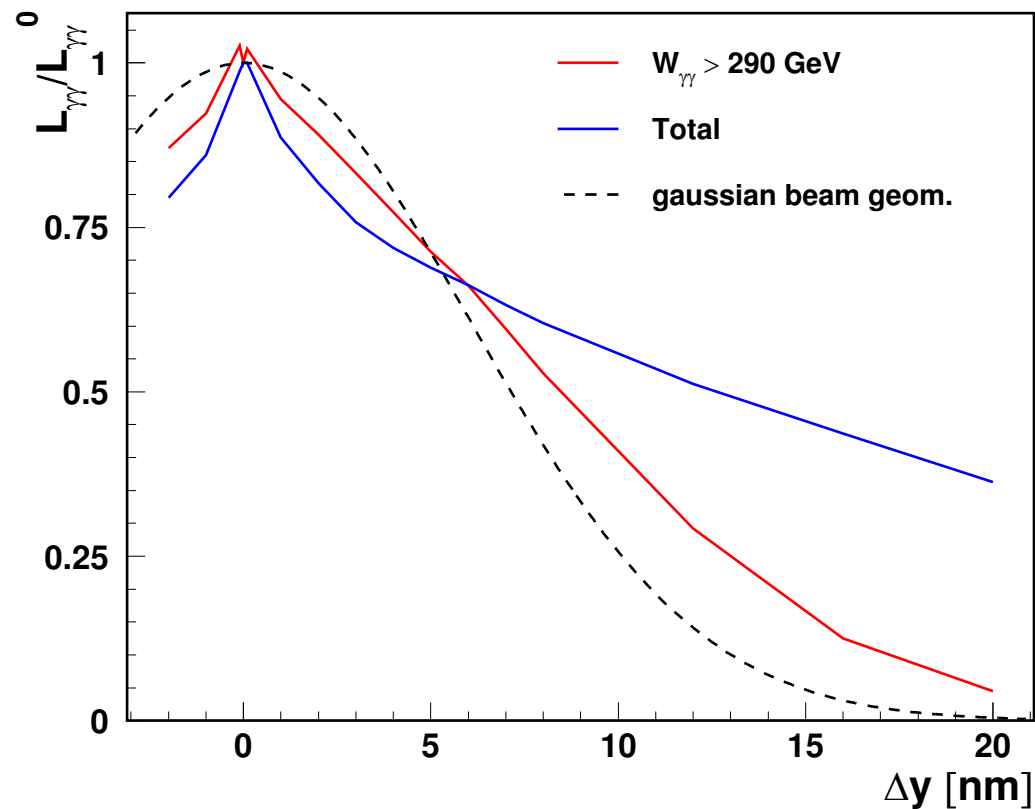
Luminosity spectra for nominal beam parameters, for $\theta_c=34$ mrad



Total $\gamma\gamma$ luminosity $1.33 \cdot 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$, $1.3 \cdot 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ for $W_{\gamma\gamma} > 300$ GeV.

Vertical alignment

How well should the beams be aligned in vertical direction?



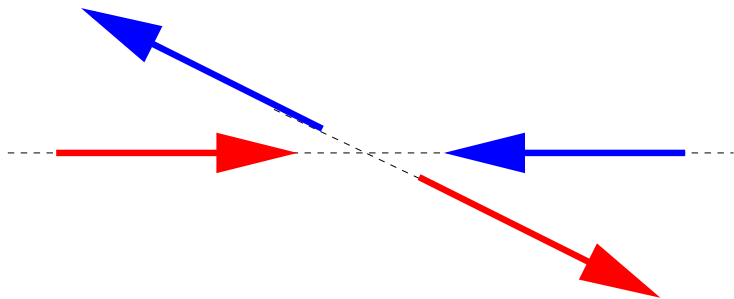
Precision of 1-2 nm required !

Vertical alignment

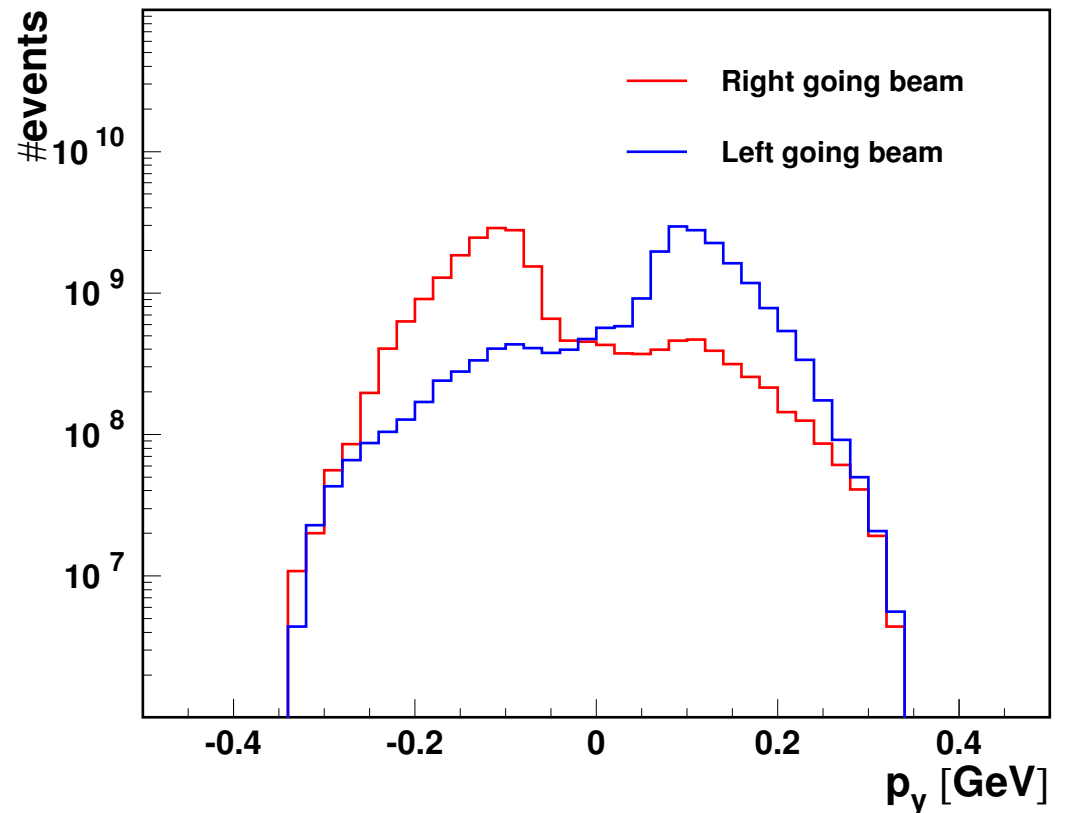
Other results also very sensitive to vertical beam alignment.

Due to beam-beam interactions the electron beam can be deflected up or down.

For $\Delta y = 0$ (head-on collision)



spontaneous symmetry breaking !...

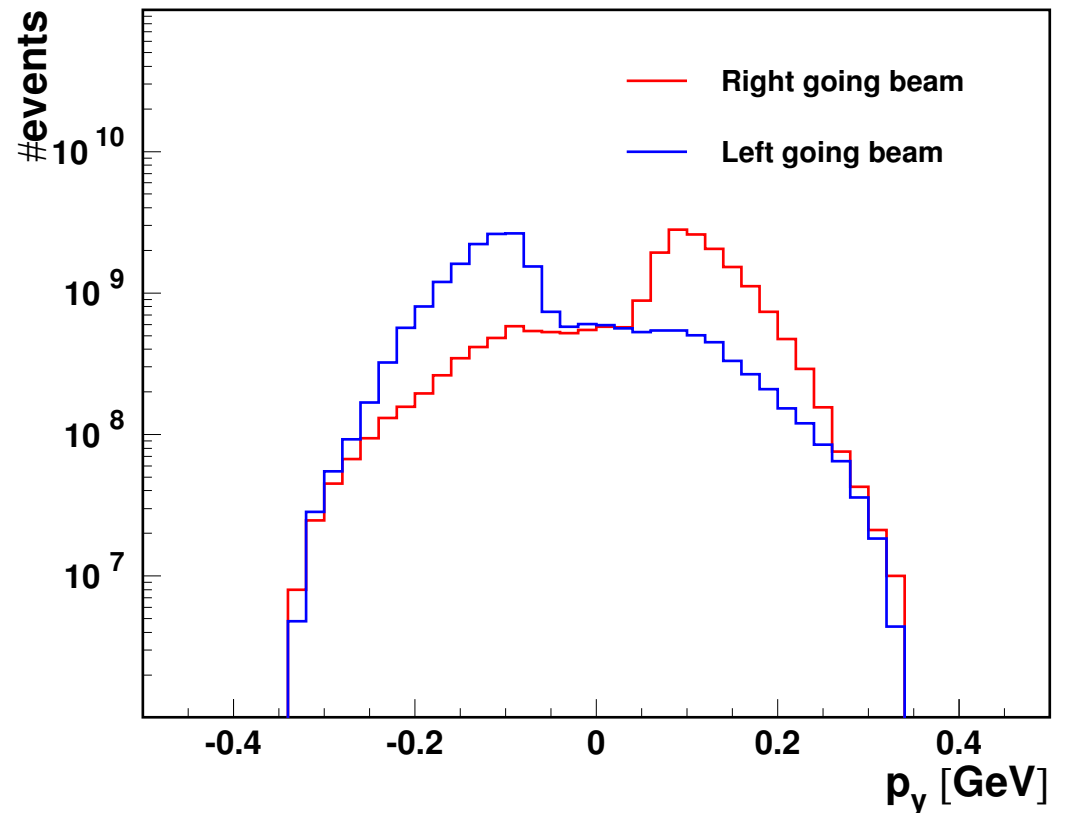
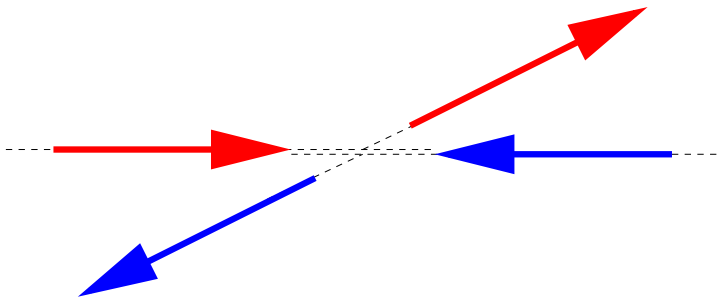


Vertical alignment

Simulation results very sensitive to vertical beam alignment.

Due to beam-beam interactions the electron beam can be deflected up or down.

For $\Delta y = 0.1 \text{ nm} \ll \sigma_y \approx 4 \text{ nm}$

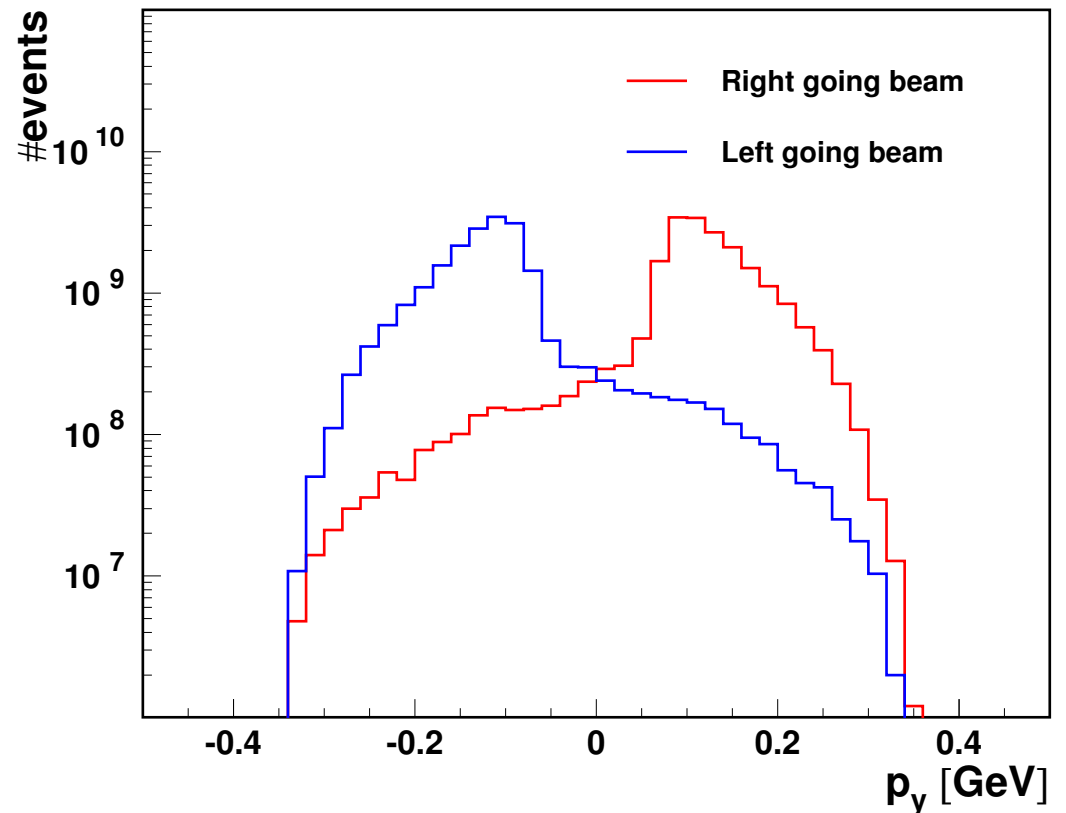
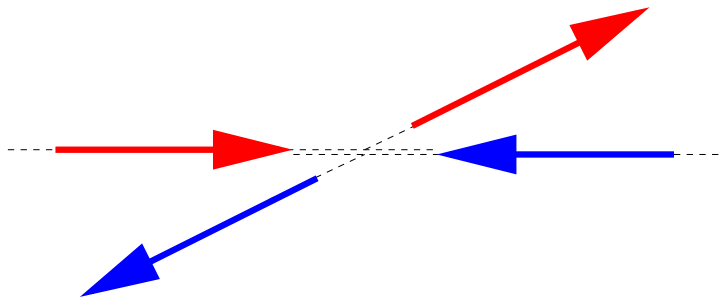


Vertical alignment

Simulation results very sensitive to vertical beam alignment.

Due to beam-beam interactions the electron beam can be deflected up or down.

For $\Delta y = 1$ nm

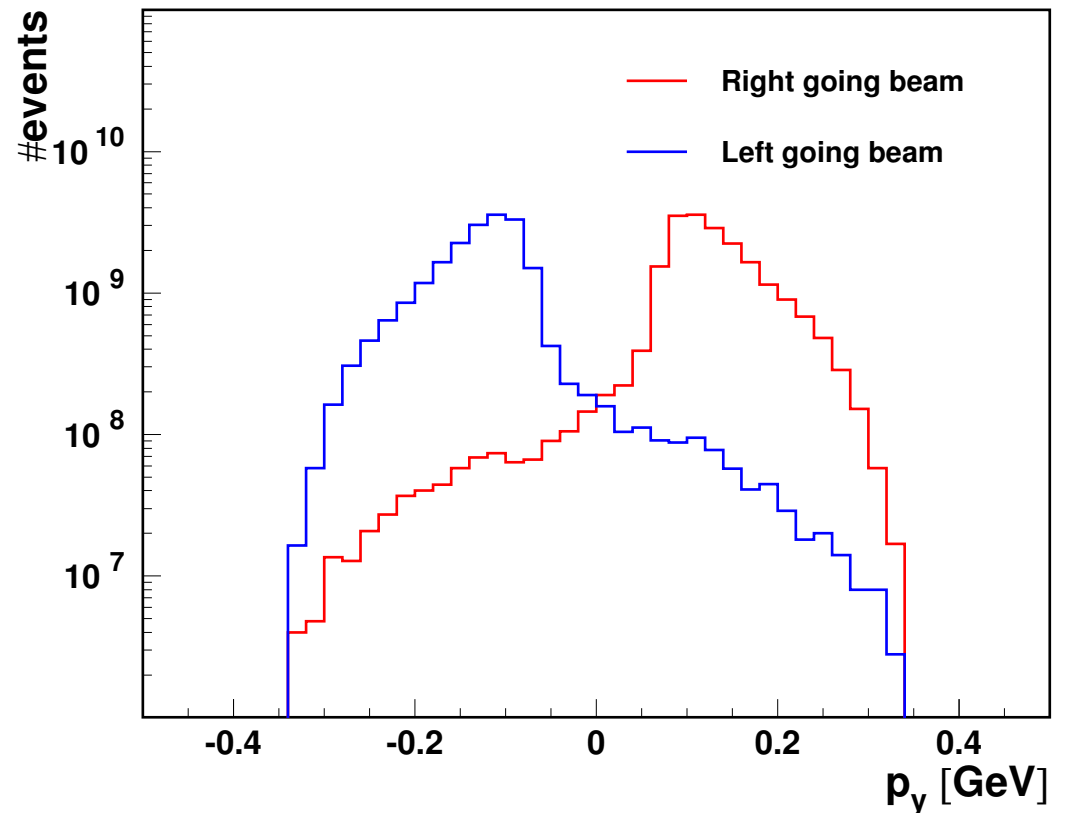
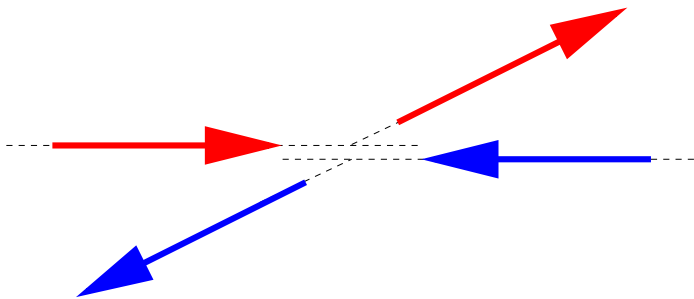


Vertical alignment

Simulation results very sensitive to vertical beam alignment.

Due to beam-beam interactions the electron beam can be deflected up or down.

For $\Delta y = 2$ nm

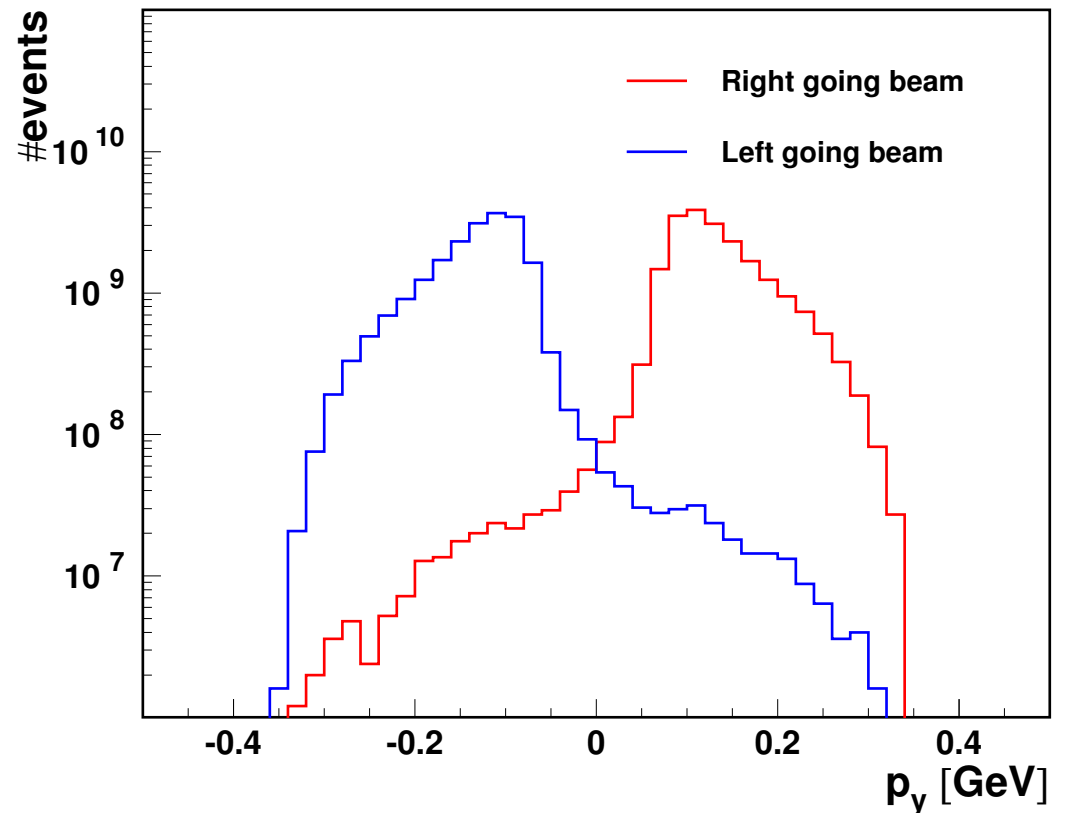
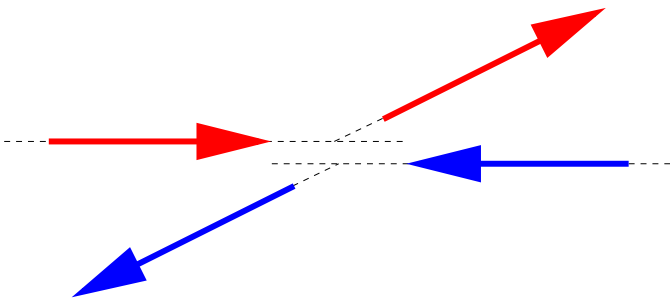


Vertical alignment

Simulation results very sensitive to vertical beam alignment.

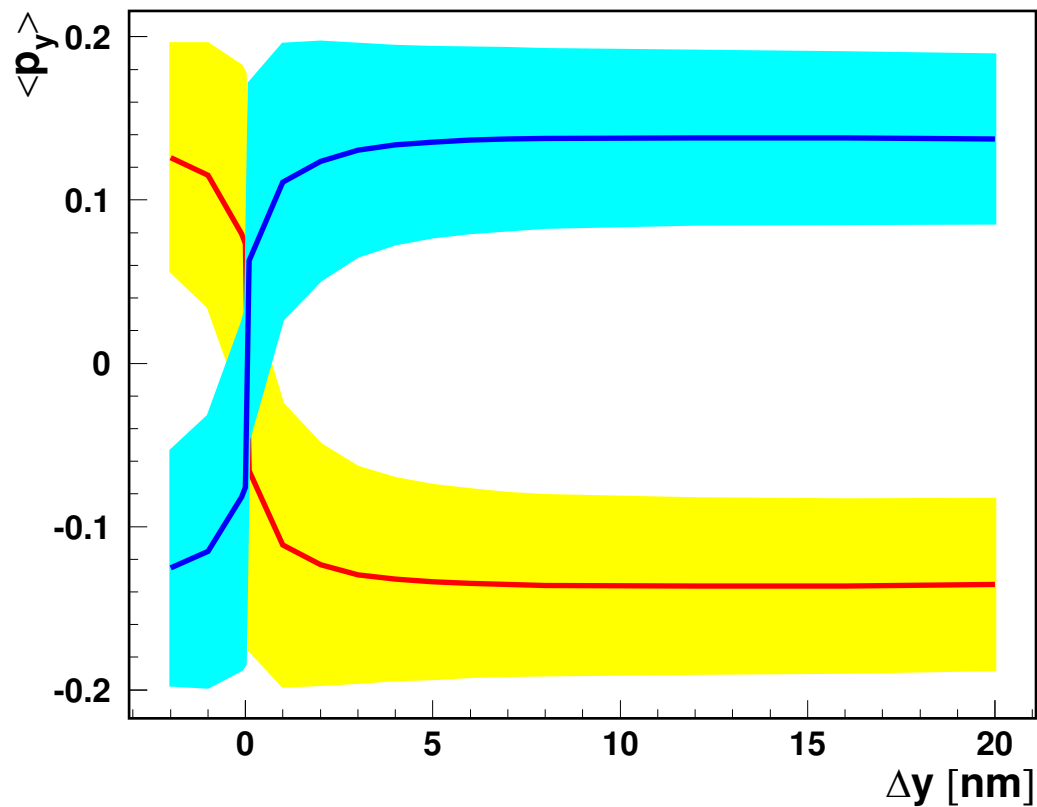
Due to beam-beam interactions the electron beam can be deflected up or down.

For $\Delta y = 4$ nm



Vertical alignment

Mean vertical momentum of electrons after beam-beam interaction

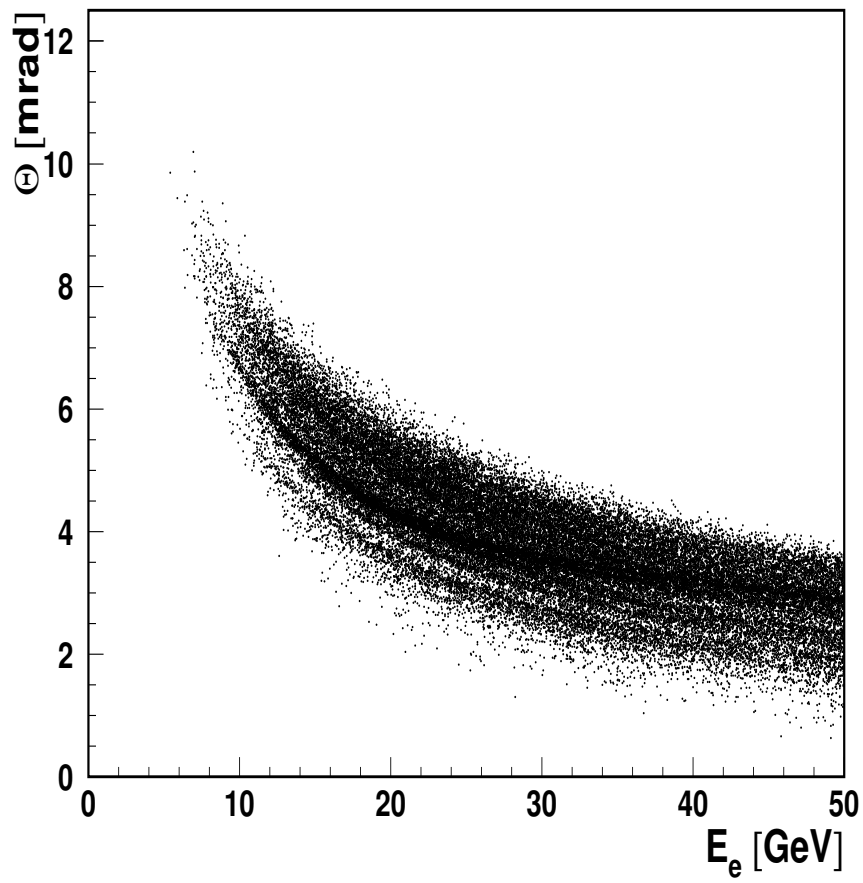


Step-like behavior \Rightarrow small vertical misalignment imposed to get stable results

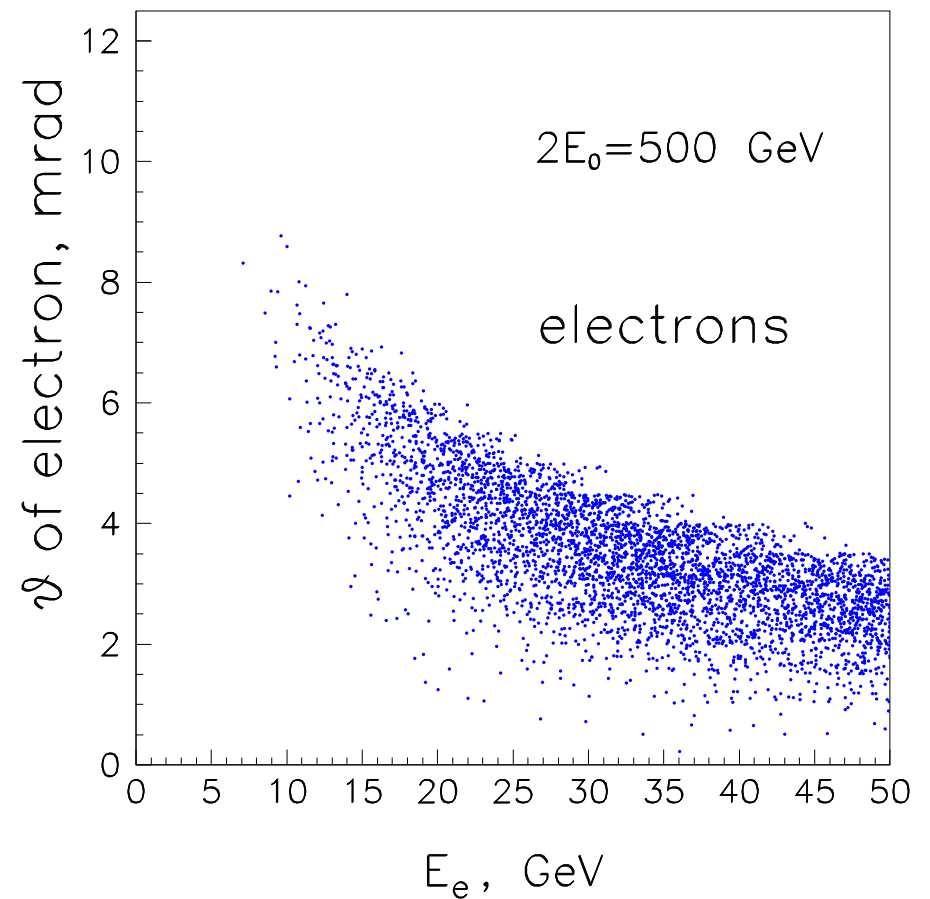
Beam deflection

Comparison of CAIN results with simulation by V.Telnov

CAIN $\Delta y = 1$ nm

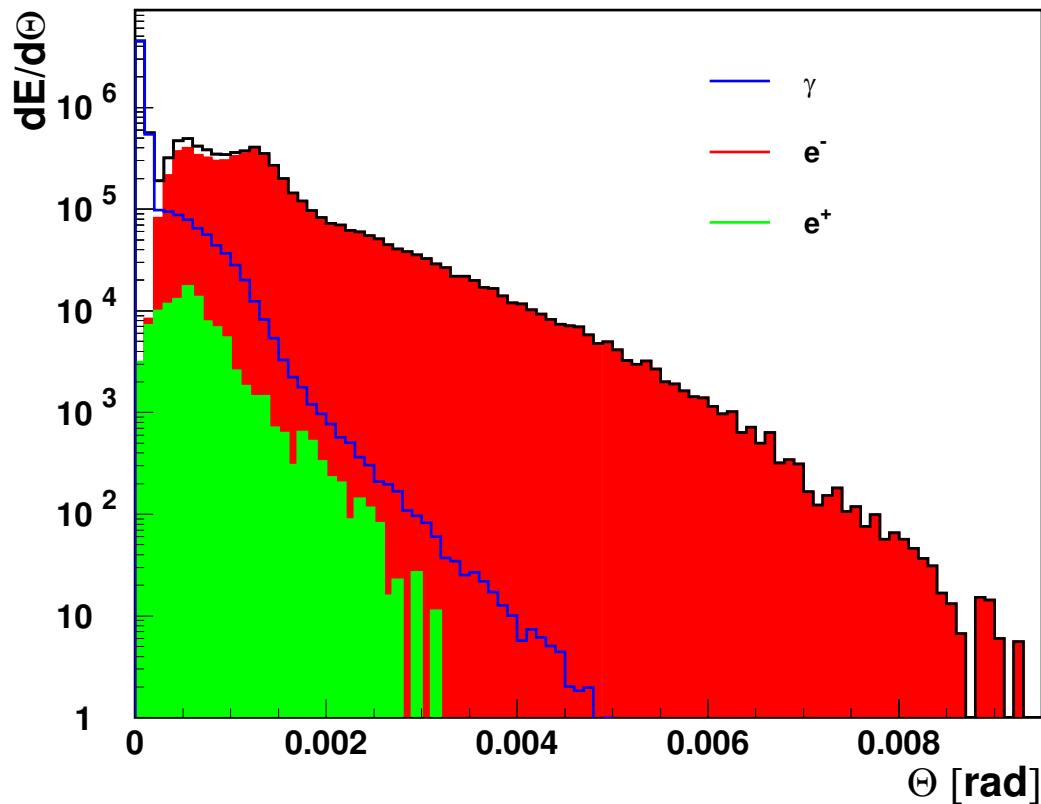


V.Telnov $\Delta y = 0$



Energy flow

Angular energy flow after beam-beam interaction (one beam).

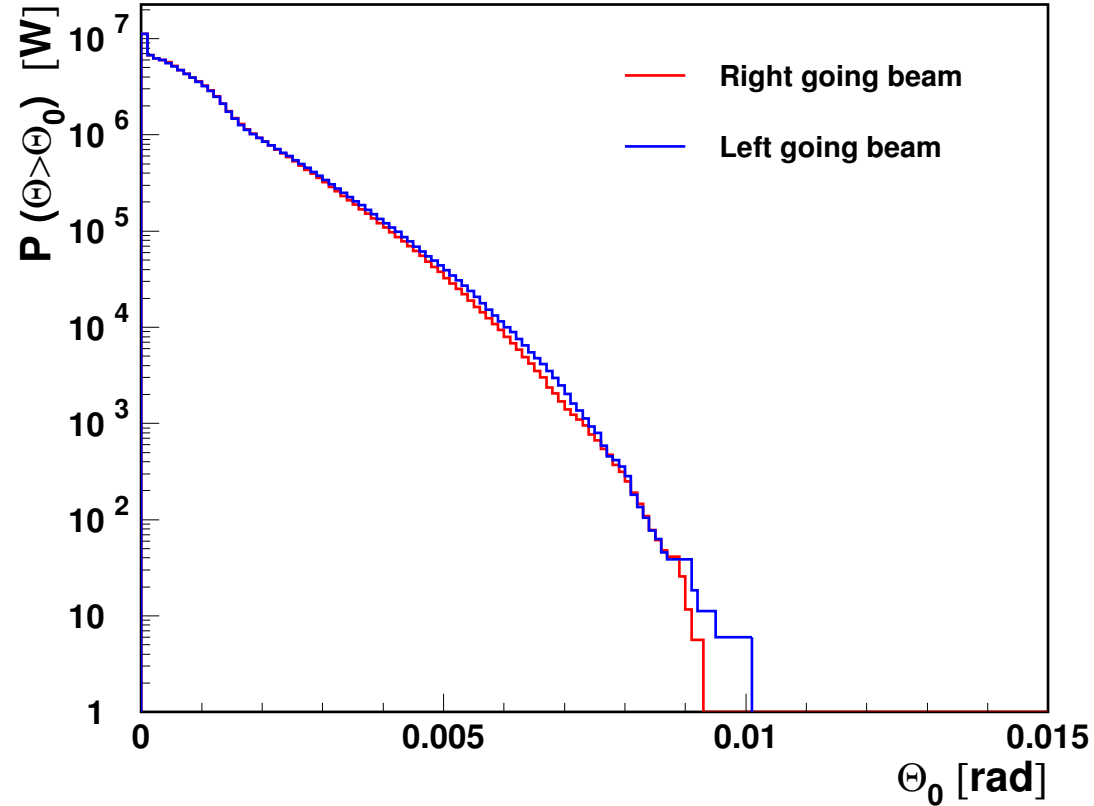


Beam halo dominated by electrons.

Energy flow

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

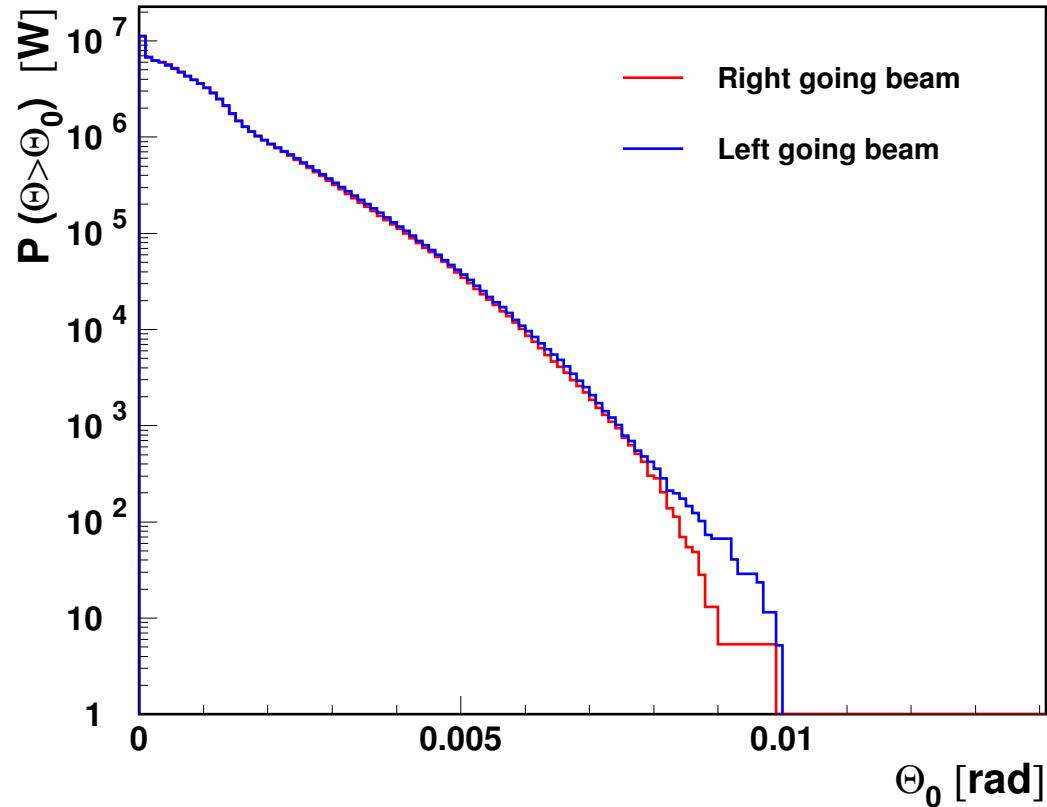
Calculated at the interaction point! (just after the beam-beam collision)



Magnetic field

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

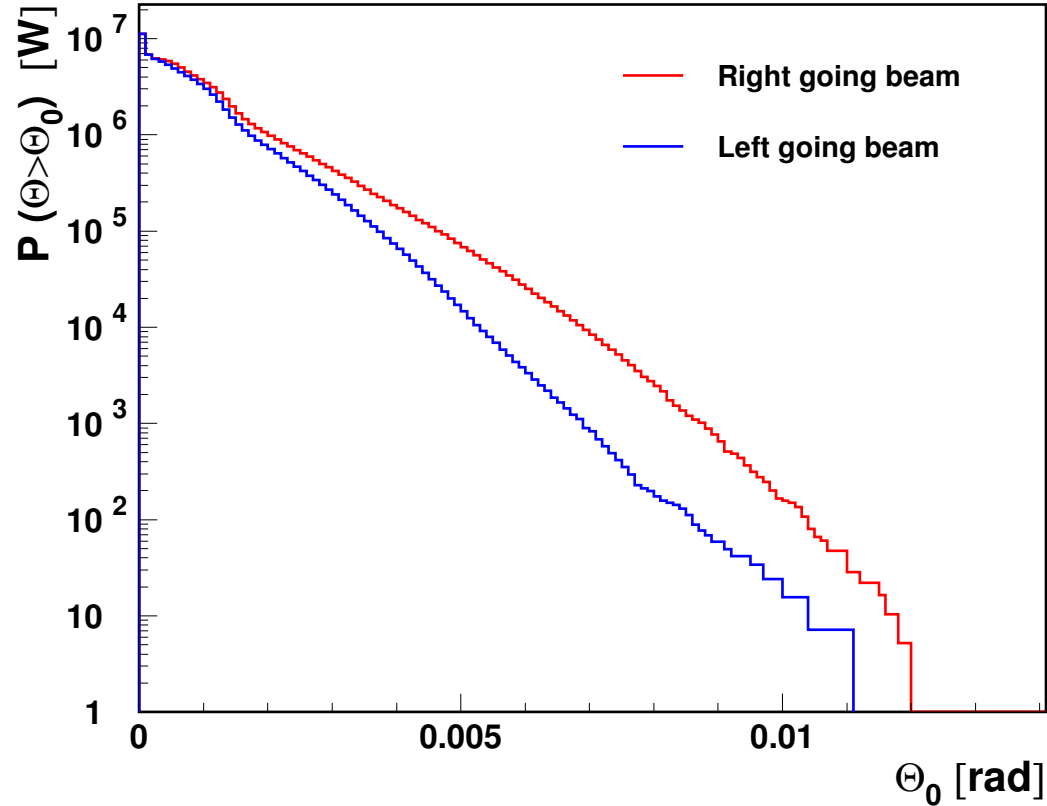
Calculated 3 m from interaction point: **No magnetic field**



Magnetic field

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

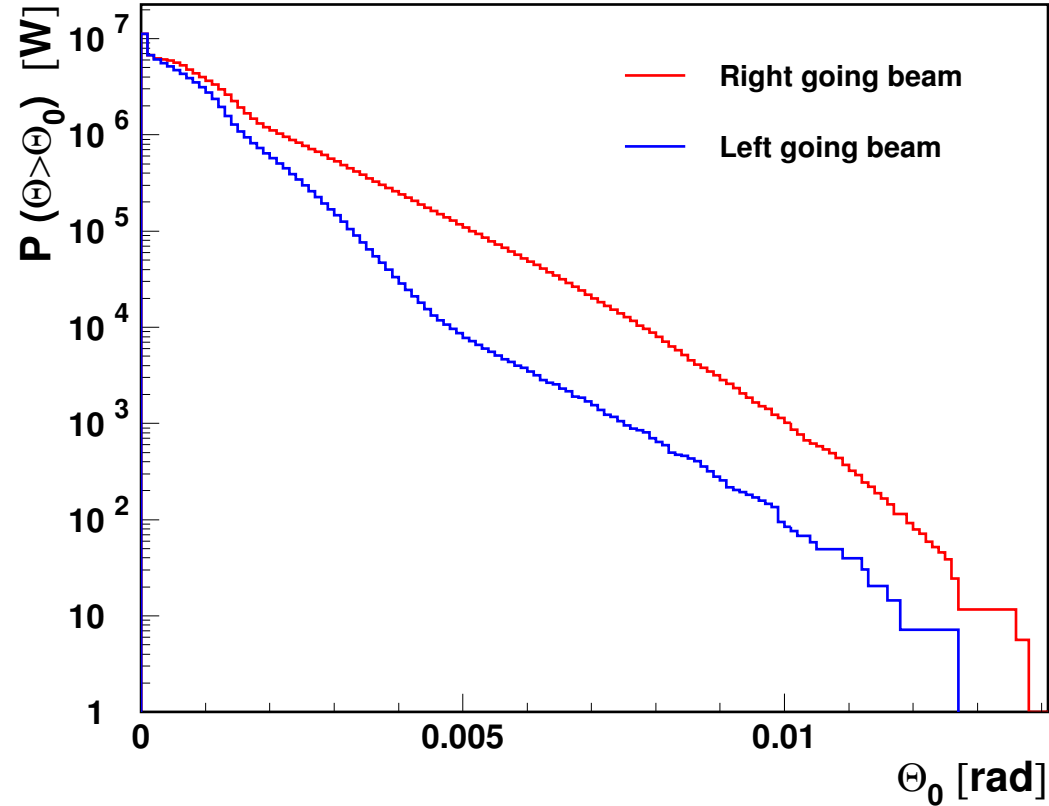
Calculated 3 m from interaction point: $B=2\text{ T}$



Magnetic field

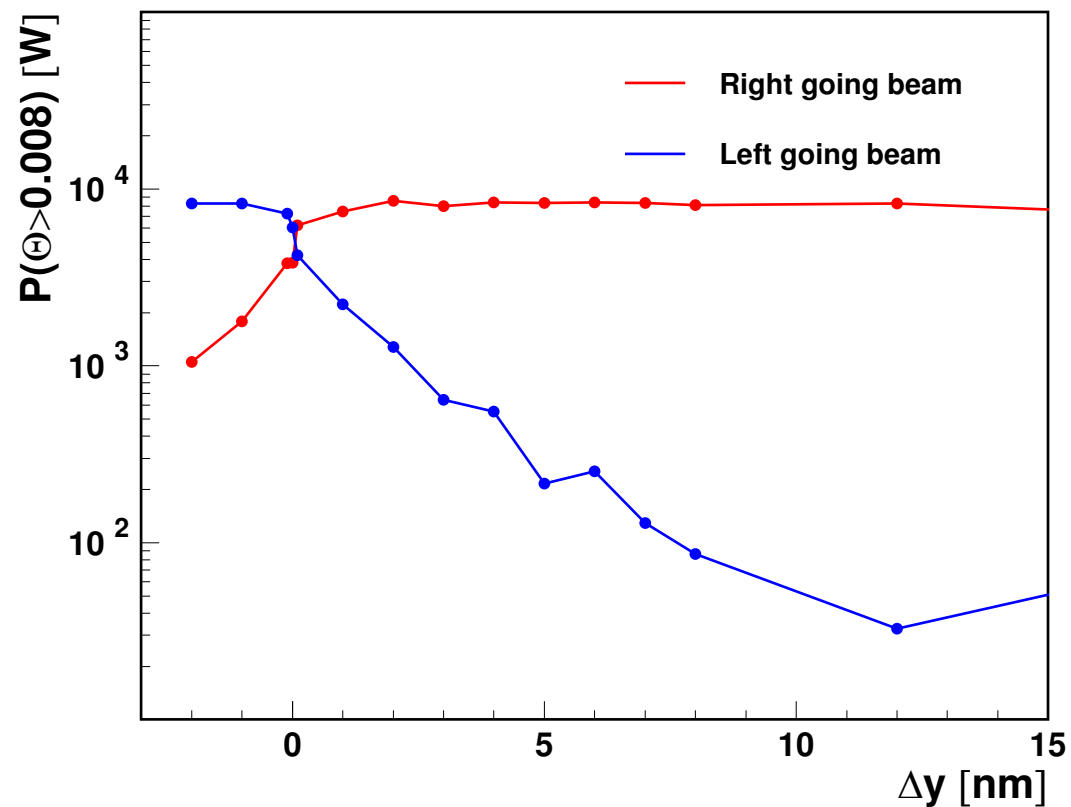
Integrated energy flow: power emitted above given angle (beam pipe cone)

Calculated 3 m from interaction point: $B=4$ T



Magnetic field

Energy flow outside 8 mrad cone, observed 3 m from interaction point, as a function of vertical beam alignment:

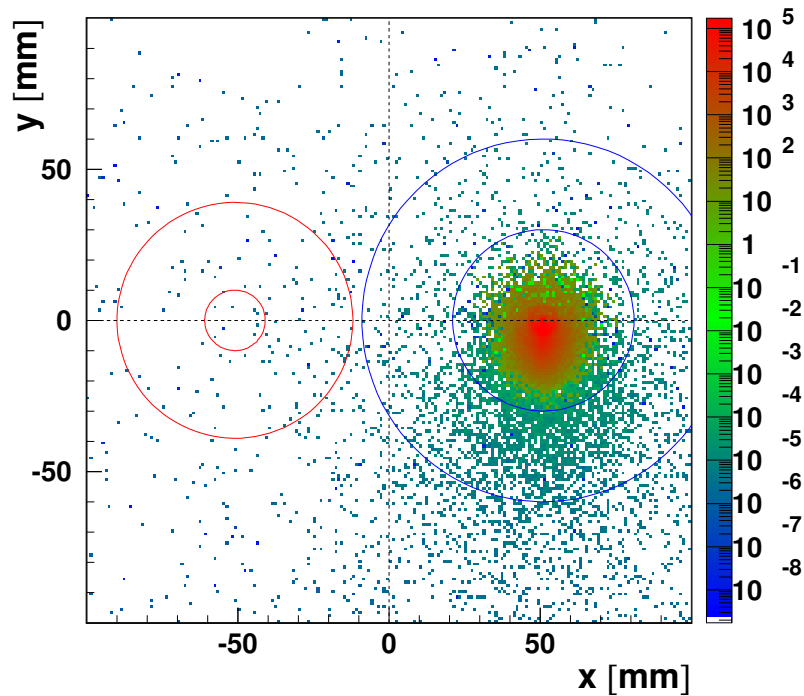


Magnetic field

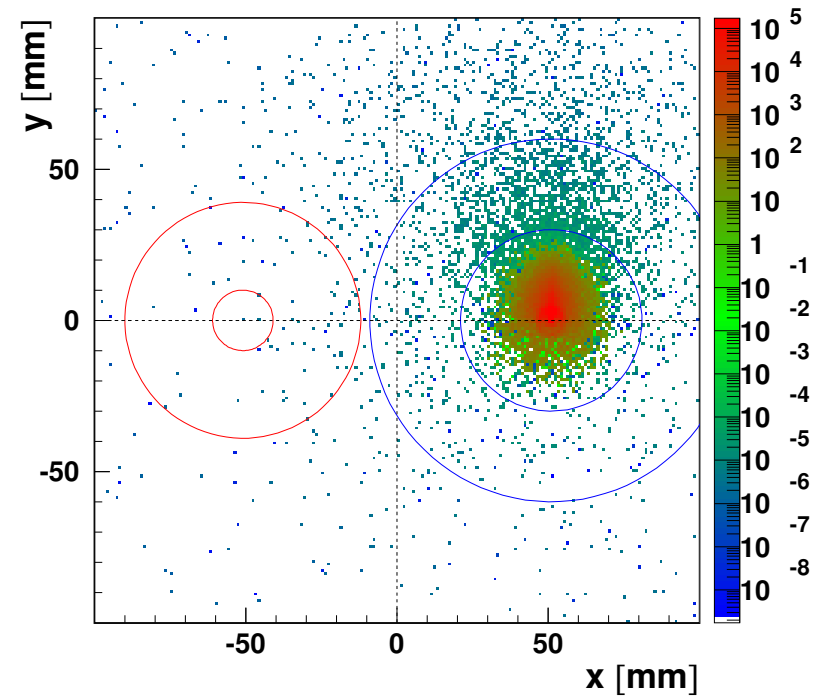
Influence of the detector field on the beam propagation.

Transverse profile of the beam 3 m from interaction point:

$B=0$



Left going beam



Right going beam

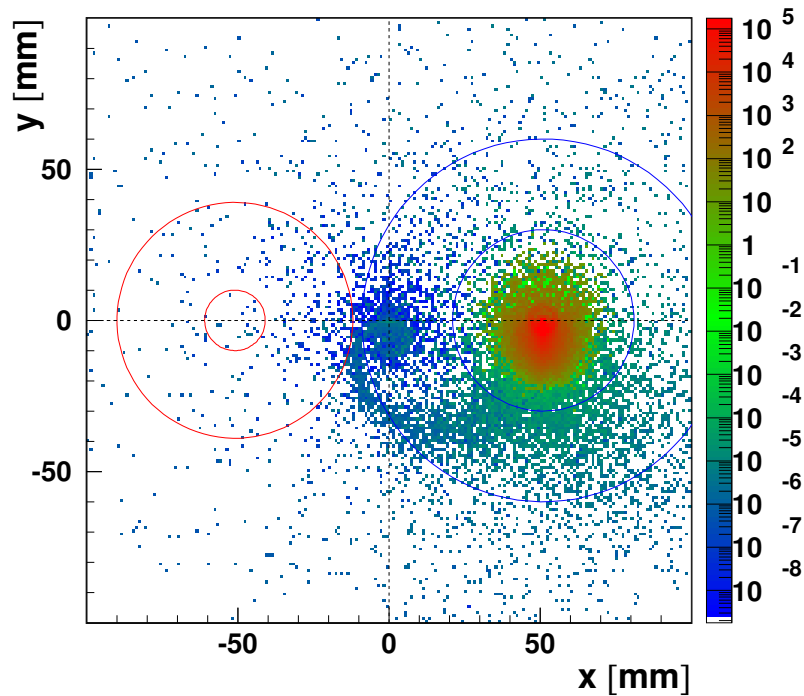
energy weighted, note logarithmic scale

Magnetic field

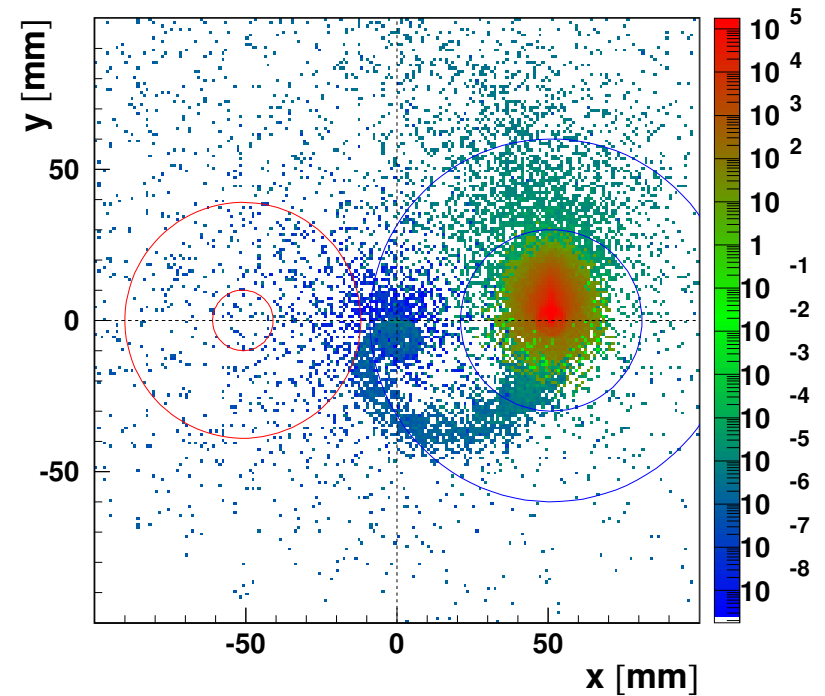
Influence of the detector field on the beam propagation.

Transverse profile of the beam 3 m from interaction point:

$B=1\text{ T}$



Left going beam



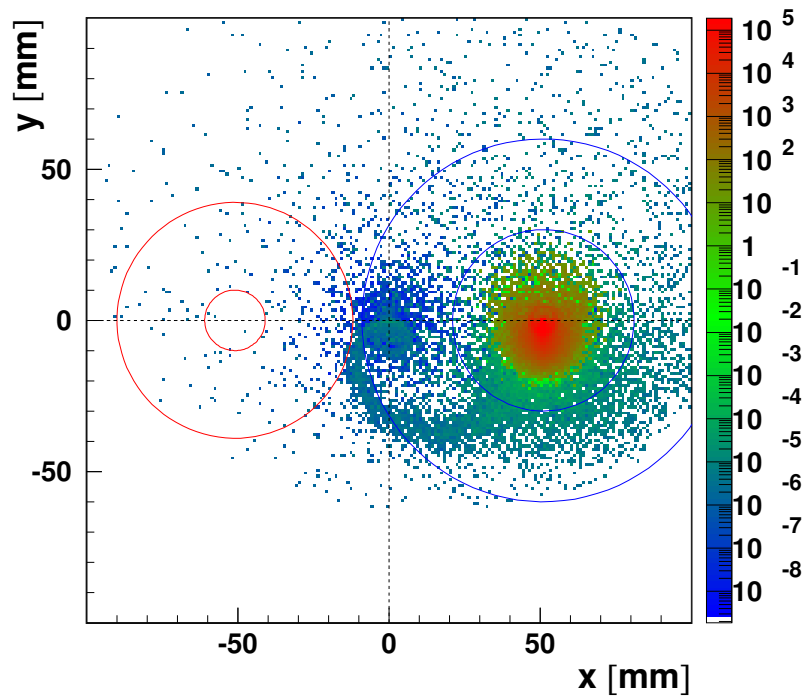
Right going beam

Magnetic field

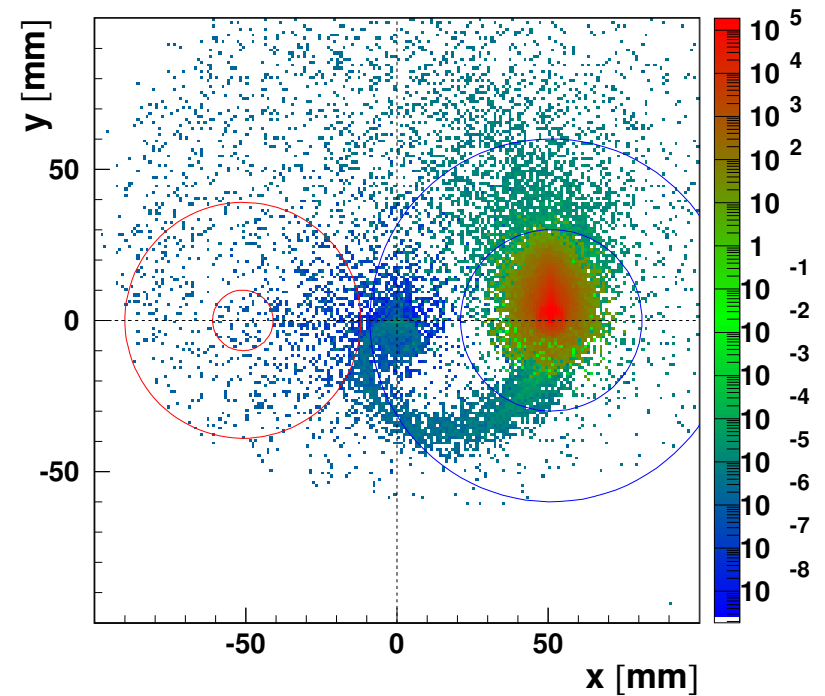
Influence of the detector field on the beam propagation.

Transverse profile of the beam 3 m from interaction point:

$B=2\text{ T}$



Left going beam



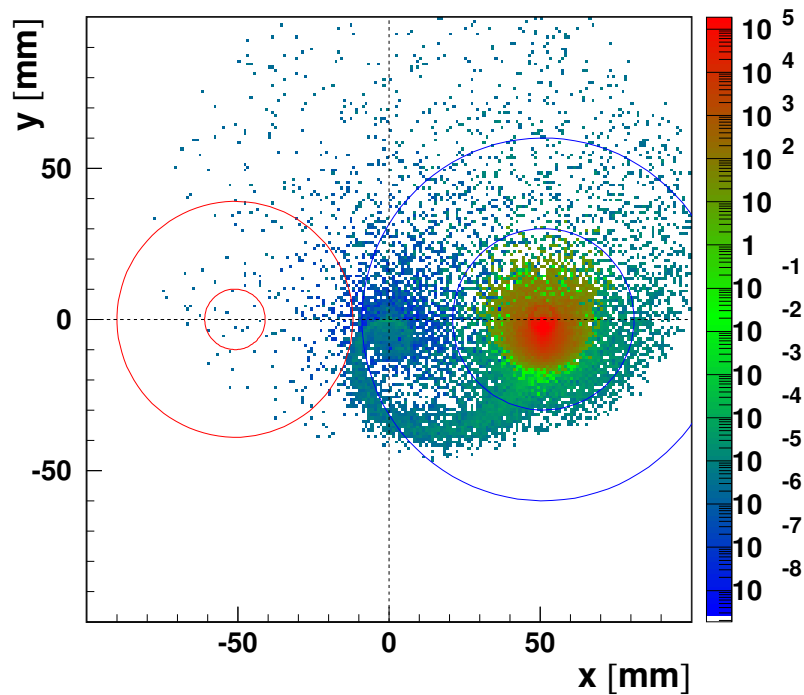
Right going beam

Magnetic field

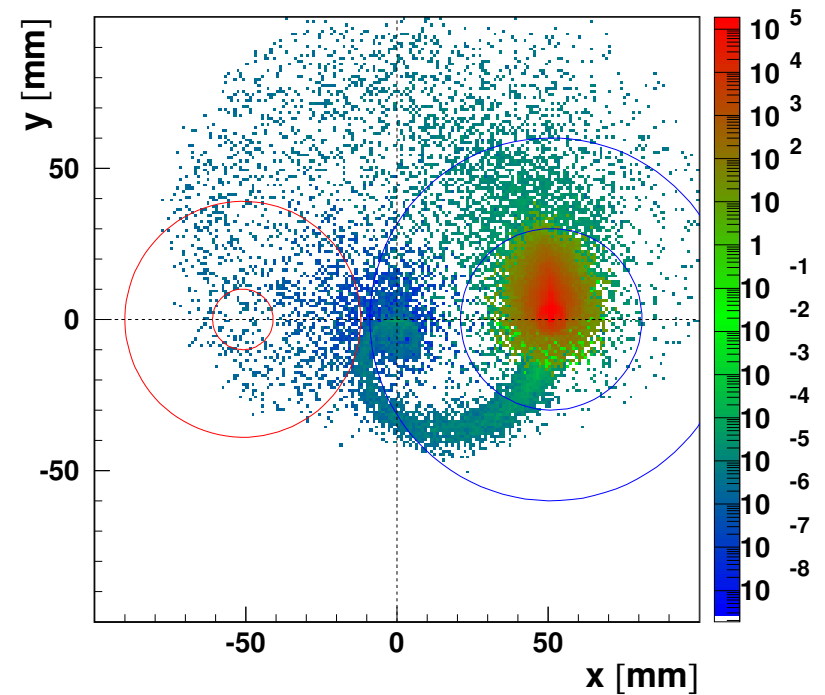
Influence of the detector field on the beam propagation.

Transverse profile of the beam 3 m from interaction point:

$B=3\text{ T}$



Left going beam



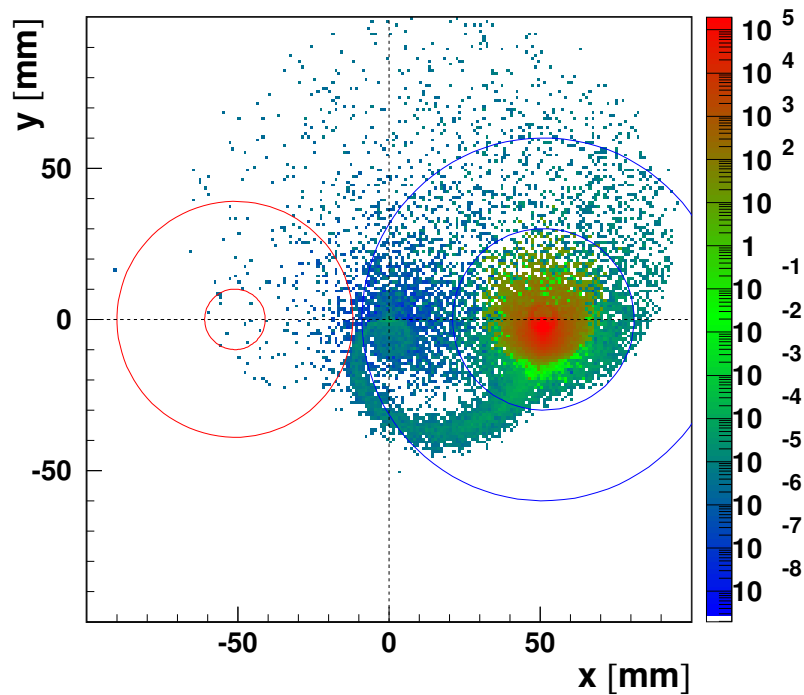
Right going beam

Magnetic field

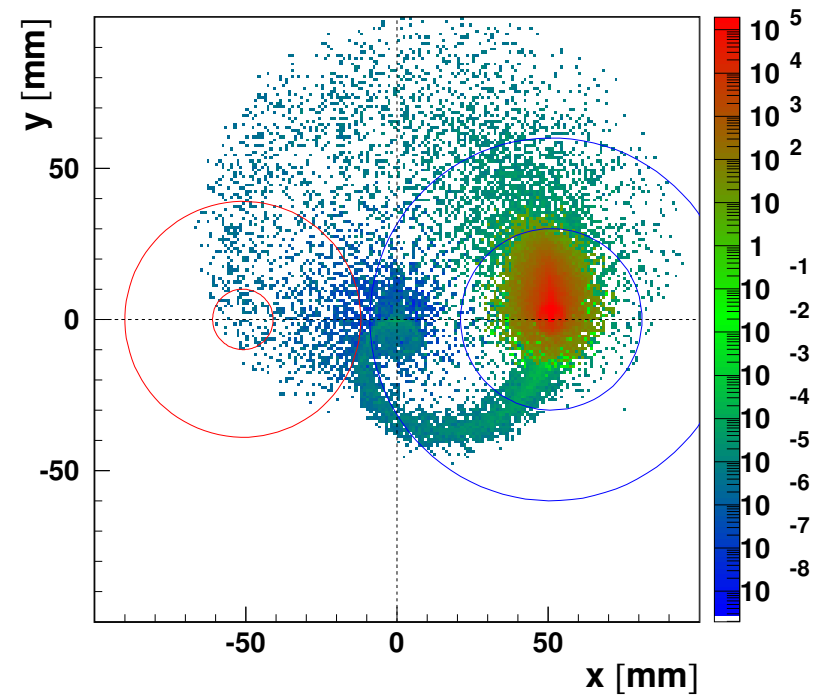
Influence of the detector field on the beam propagation.

Transverse profile of the beam 3 m from interaction point:

$B=4\text{ T}$



Left going beam



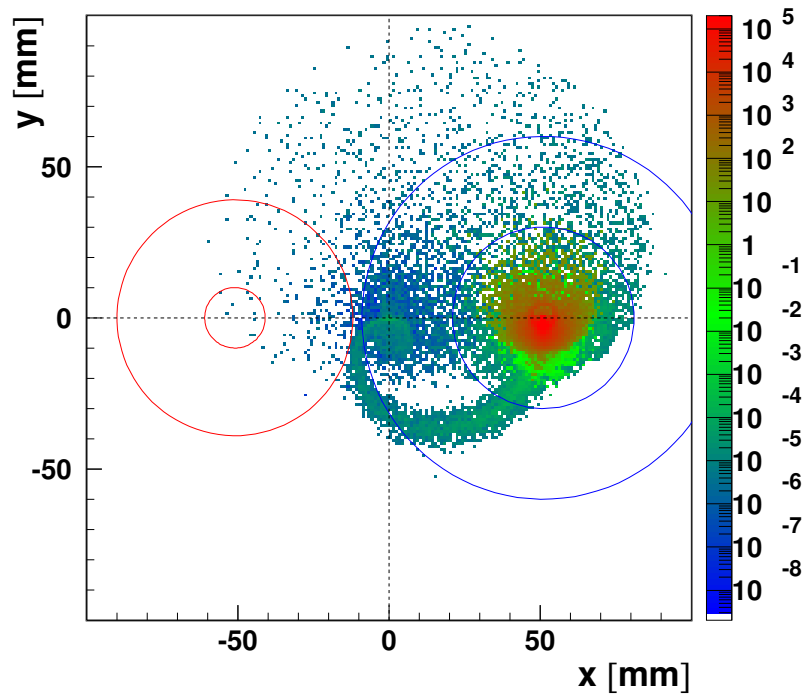
Right going beam

Magnetic field

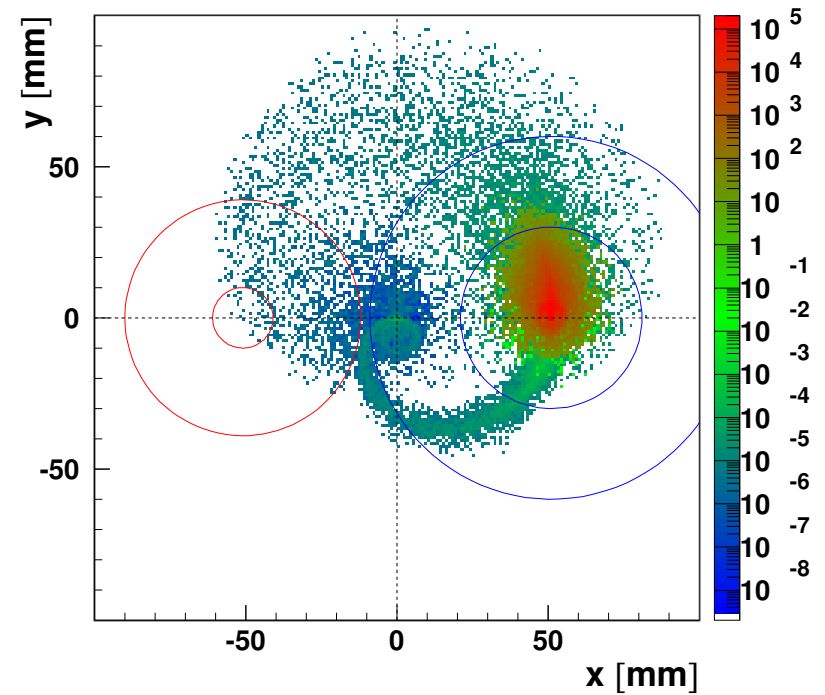
Influence of the detector field on the beam propagation.

Transverse profile of the beam 3 m from interaction point:

$B=5\text{ T}$



Left going beam



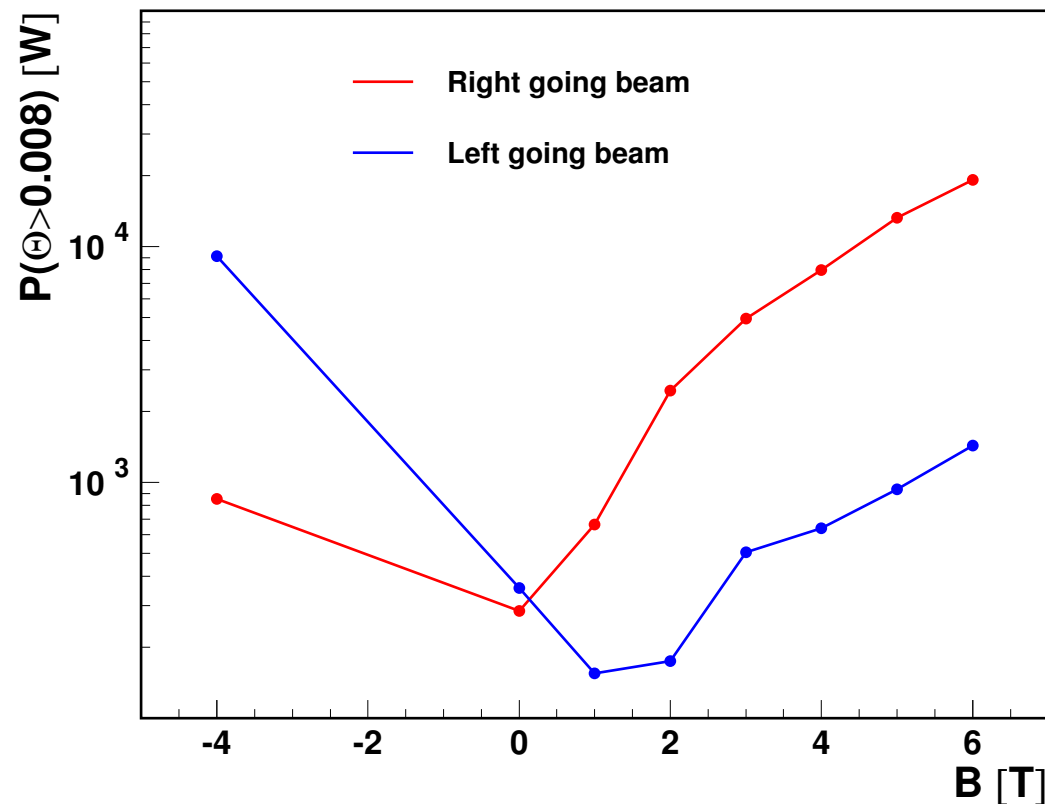
Right going beam

Magnetic field deflects both beams in the same direction!

One beam is moved towards and the other from the nominal beam axis.

Magnetic field

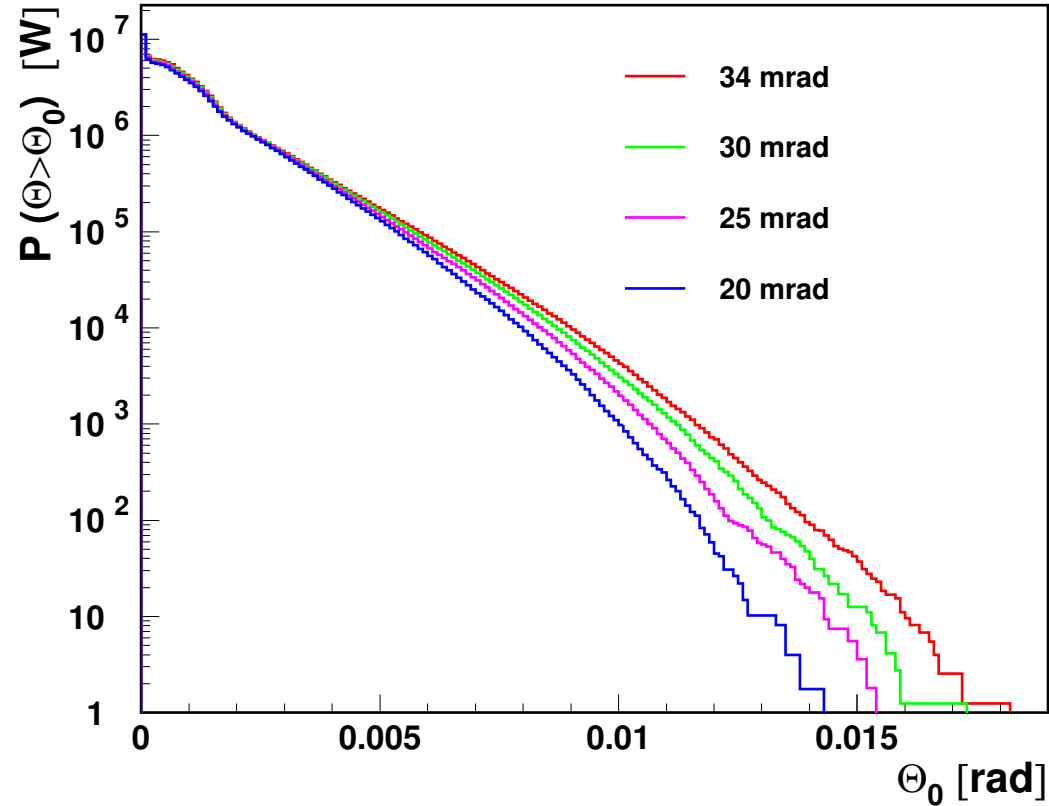
Energy flow outside 8 mrad cone, observed 3 m from interaction point, as a function of the detector field:



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

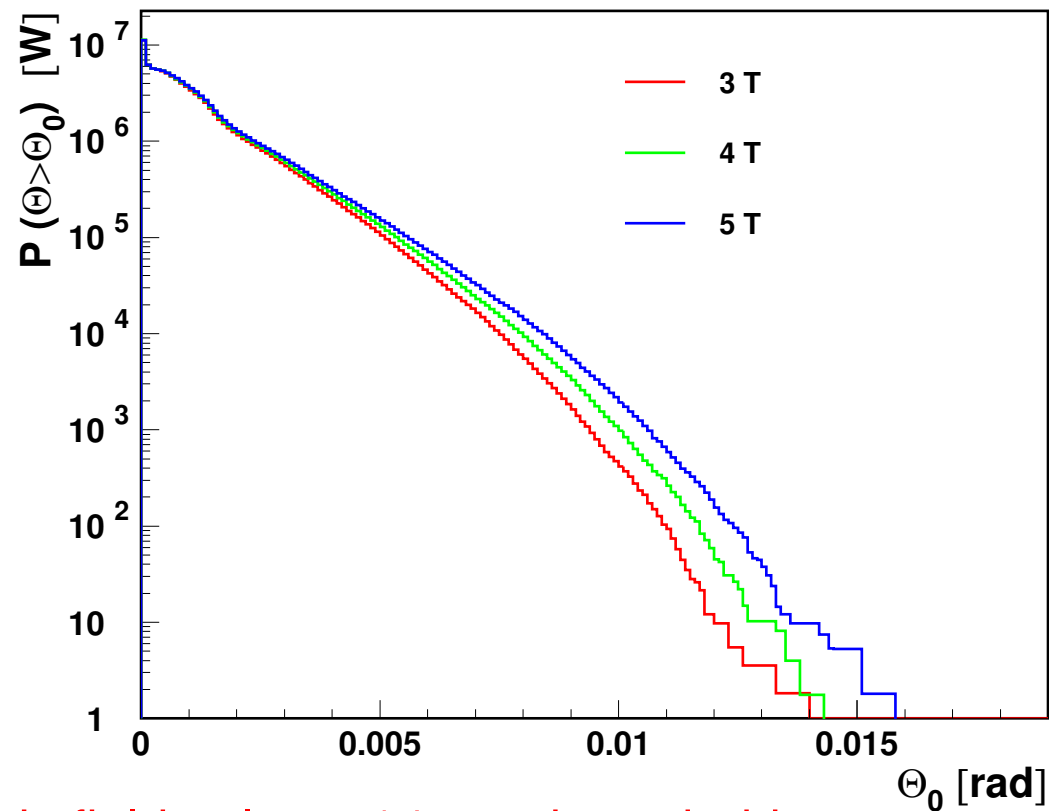
Crossing angle

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



Crossing angle

Integrated energy flow (power emitted above given angle),
calculated 4.5 m from interaction point, for crossing angle of 20 mrad.

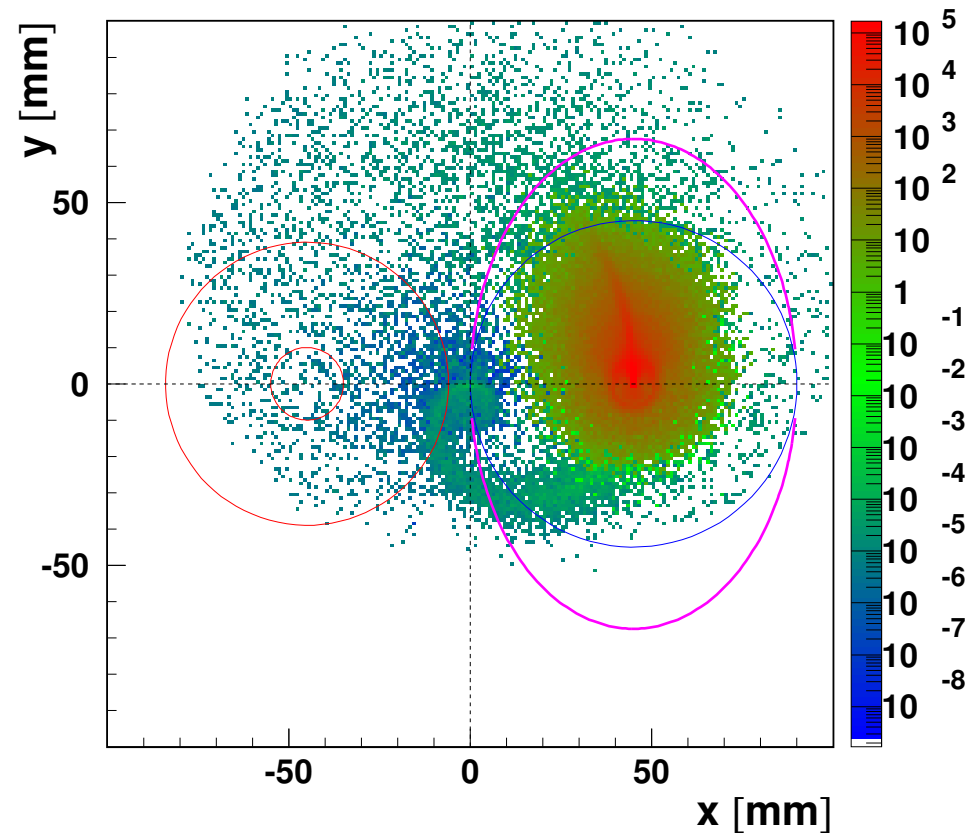


Even with low magnetic field at least 14 mrad needed !...

Beam pipe shape

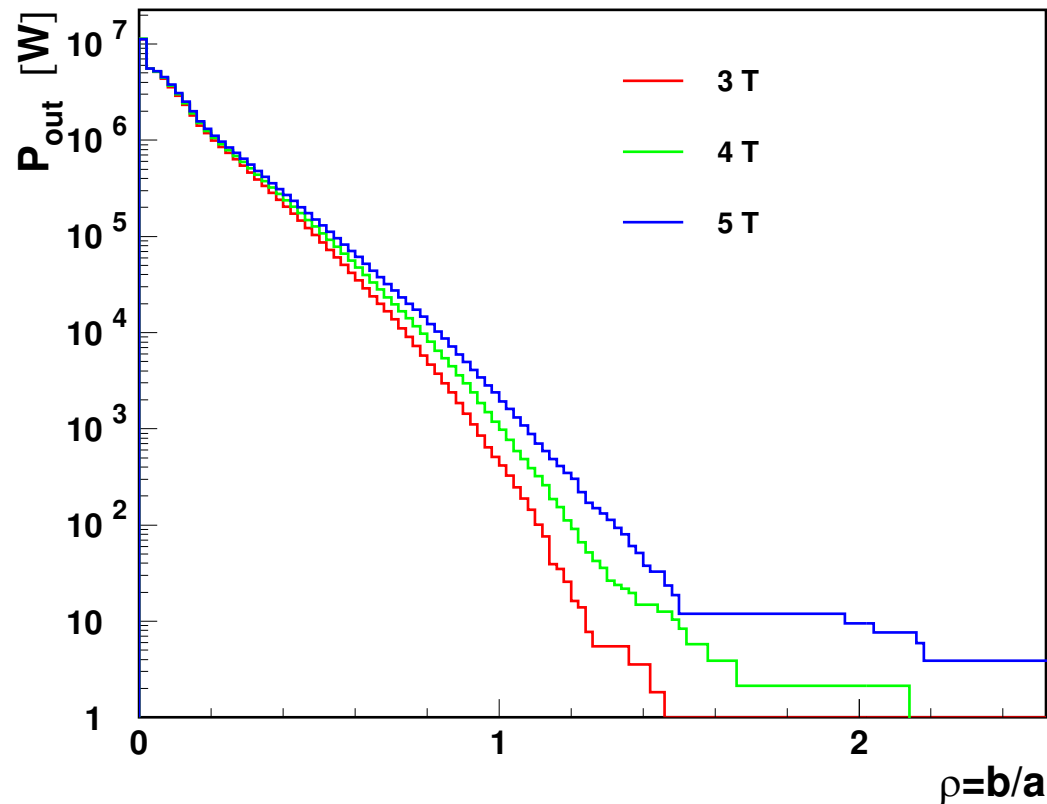
20 mrad crossing angle with $L^*=4.5$ m is **excluded** only for circular beam pipe shape.

We could try to make the beampipe larger in the vertical direction:



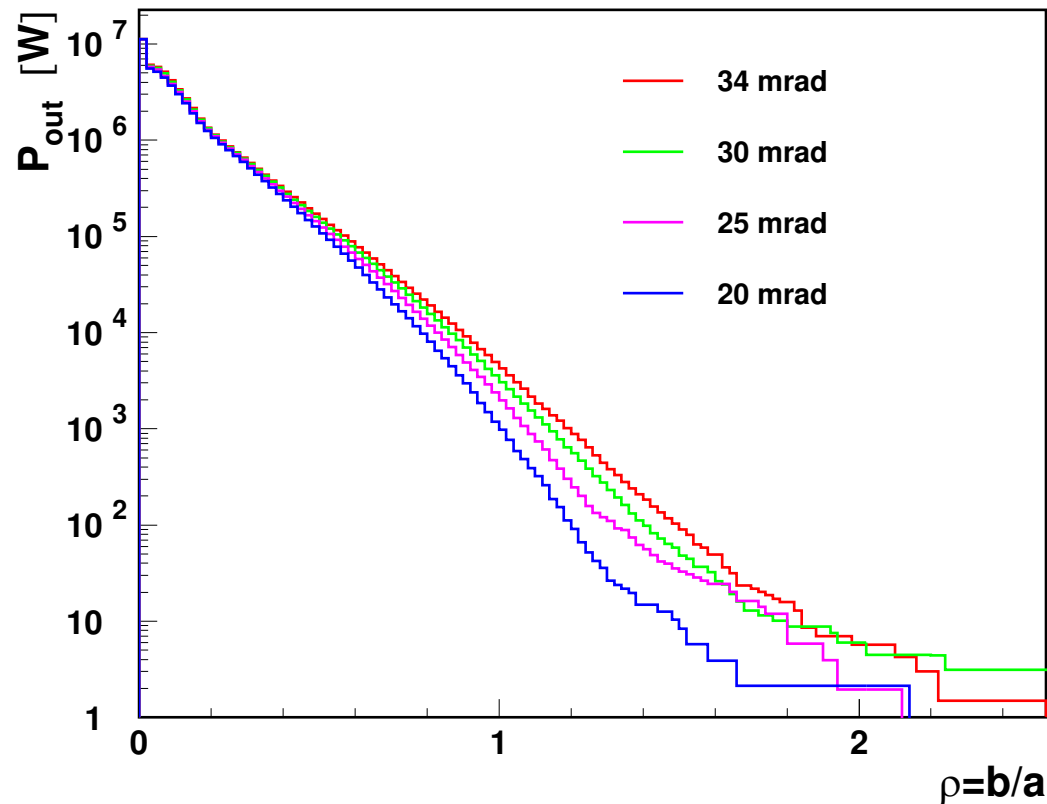
Beam pipe shape

Integrated energy flow outside the beam pipe
as a function of the vertical b to horizontal a beam pipe opening, for $a = 10$ mrad.
Flow calculated 4.5 m from interaction point, for crossing angle of 20 mrad.



Beam pipe shape

Integrated energy flow outside the beam pipe
as a function of the vertical b to horizontal a beam pipe opening, for $a = 10$ mrad.
Flow calculated 4.5 m from interaction point, for magnetic field of 4T.

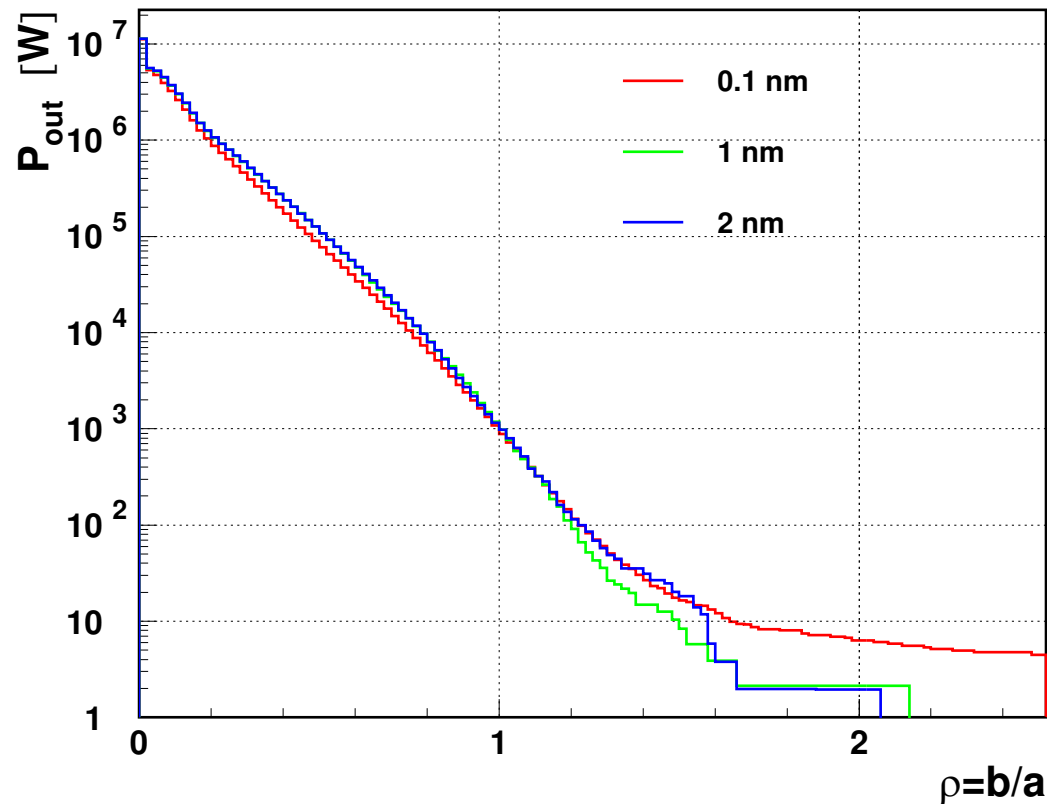


Beam pipe shape

Integrated energy flow outside the beam pipe

as a function of the vertical b to horizontal a beam pipe opening, for $a = 10$ mrad.

4.5 m from interaction point, for crossing angle of 20 mrad and magnetic field of 4T.

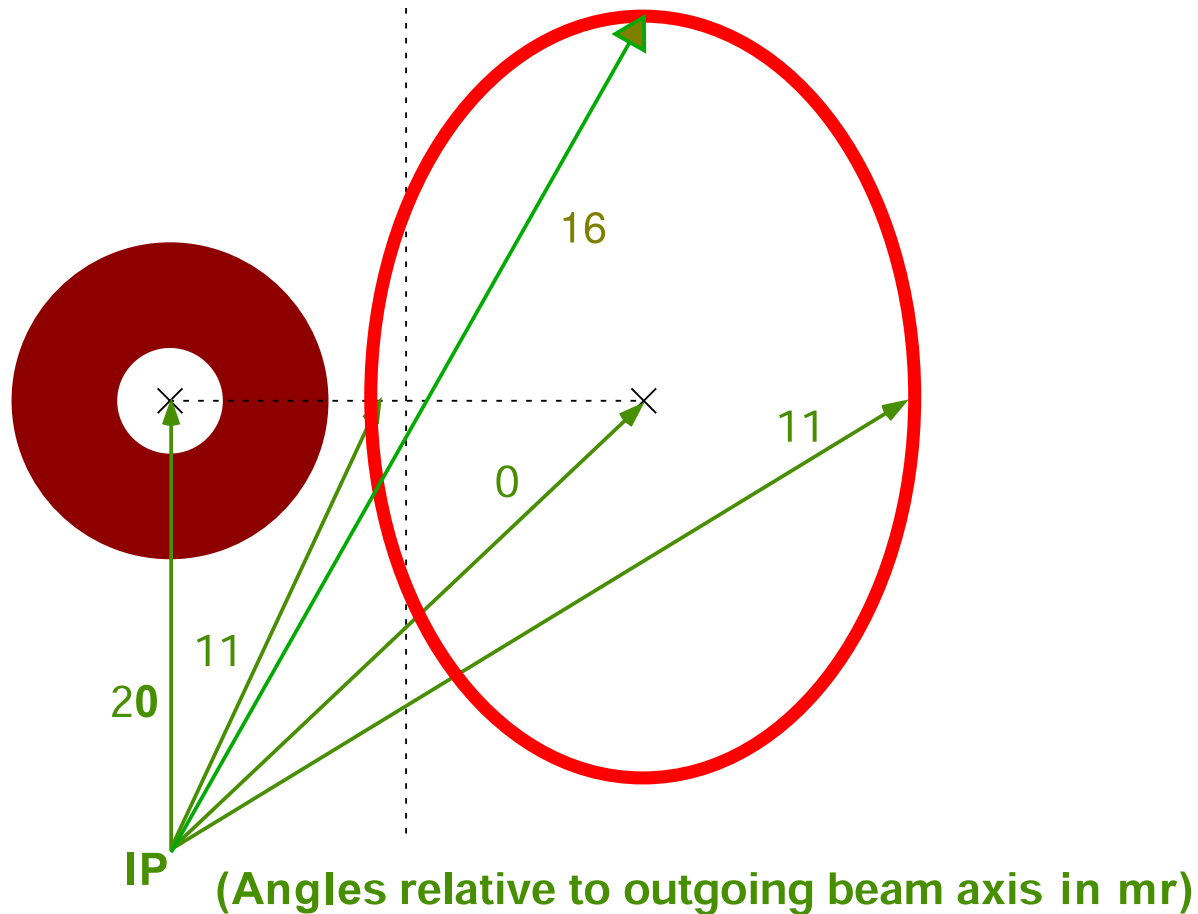


Conclusions

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

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

Remaining power dissipation $O(10)$ W



Final Dipole background

Added as a result of the discussion after the talk.

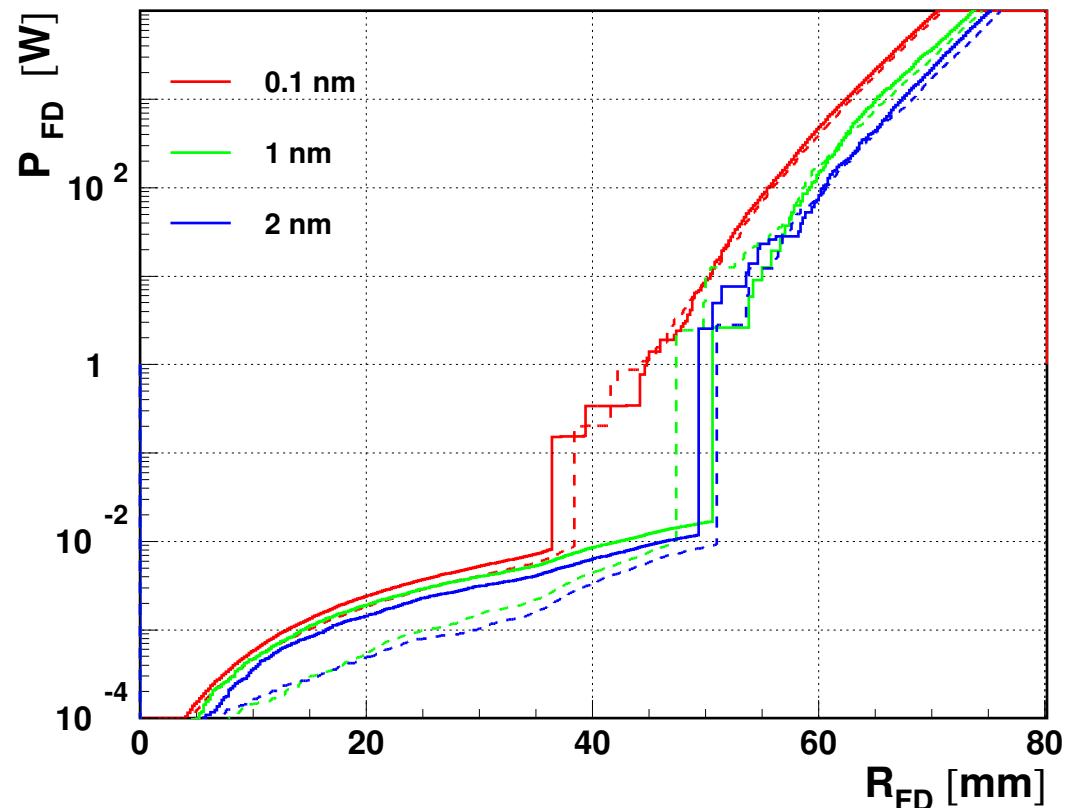
The beam pipe shape can be adjusted to the expected background.

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 interaction point, for magnetic field of 4T, for different values of vertical beam alignment.



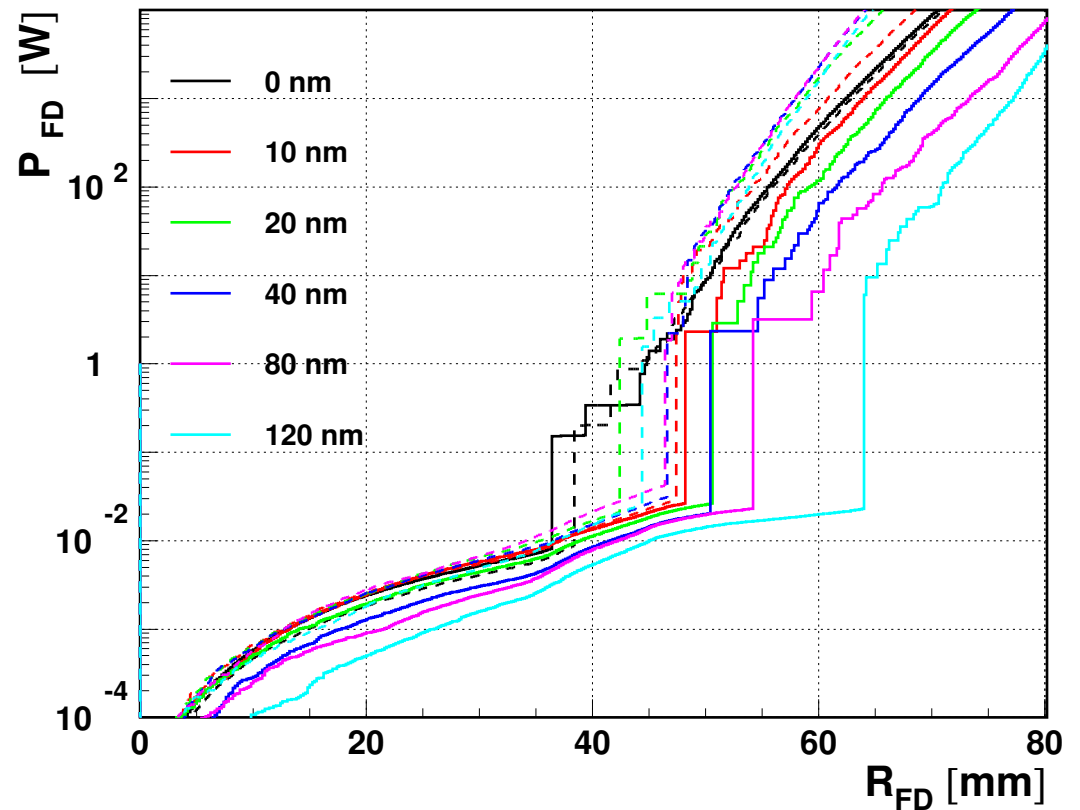
Final Dipole background

Added as a result of the discussion after the talk.

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

Deposit calculated 4.5 m from interaction point, for magnetic field of 4T, for different values of horizontal beam alignment:

For 40 mm outer radius of the Final Dipole the total deposit is in all cases below 1 W ...

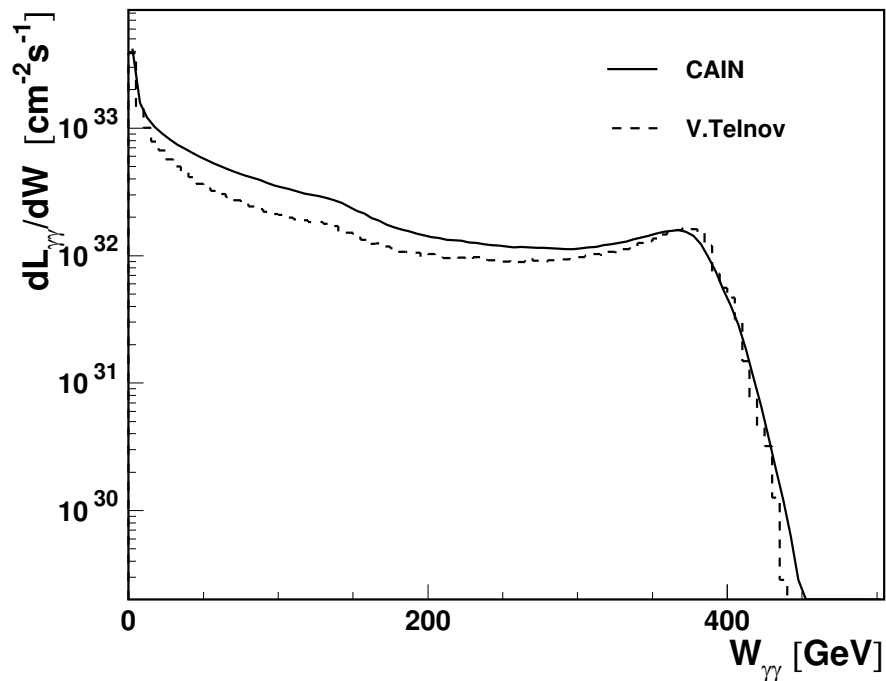


Extra slides

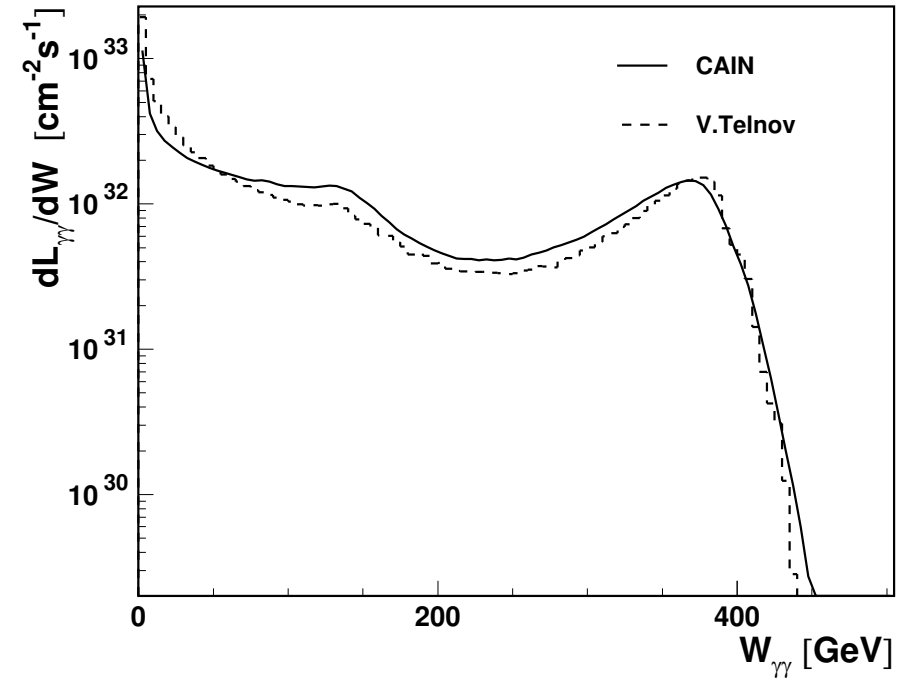
Luminosity spectra

Comparison of **CAIN** simulation results with luminosity spectra from **V.Telnov**

All $\gamma\gamma$

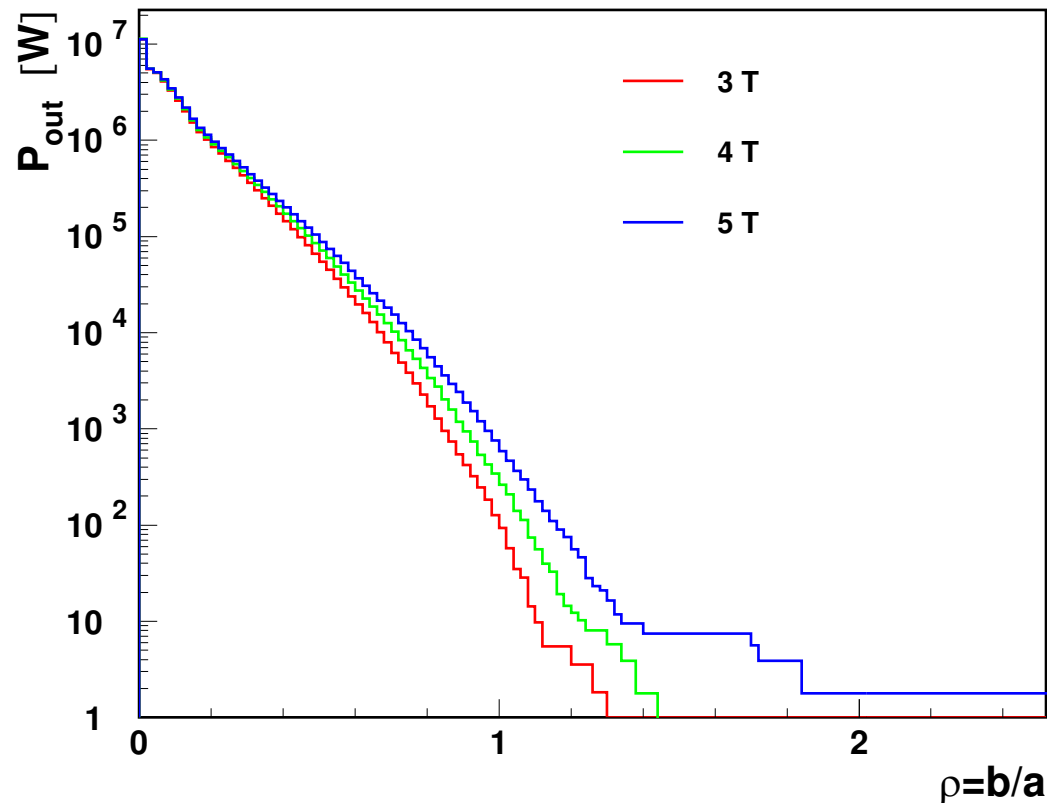


$J_z = 0$



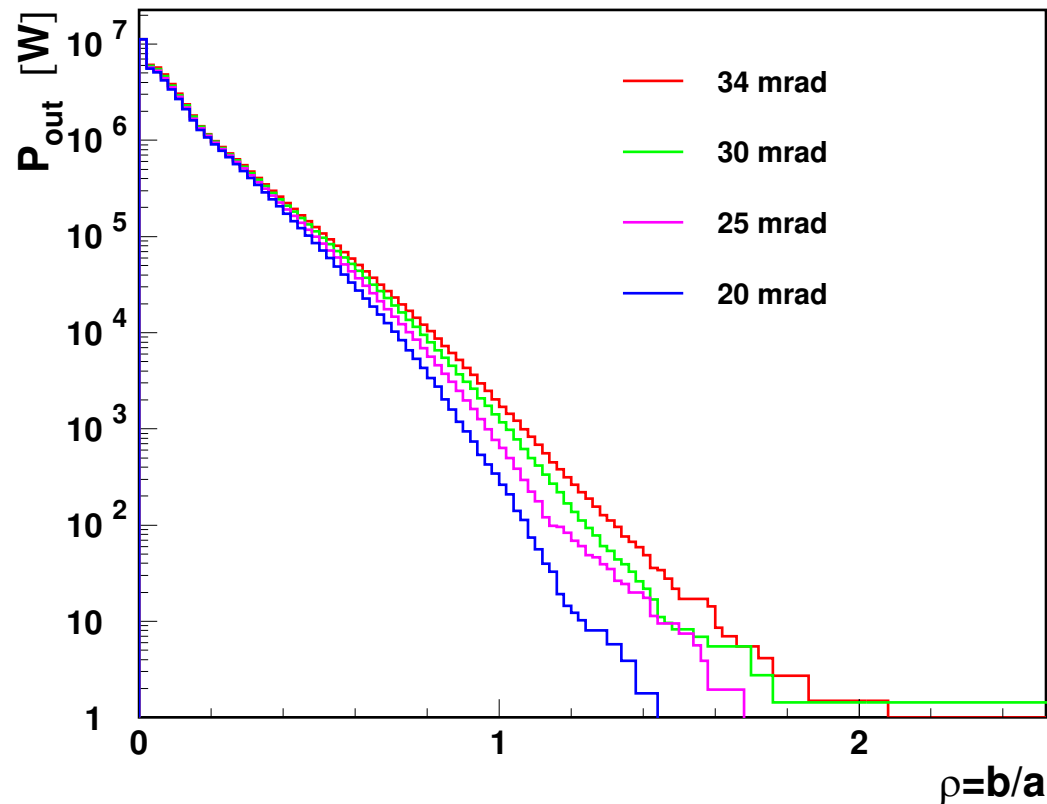
Extra slides

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.



Extra slides

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 magnetic field of 4T.



Extra slides

Integrated energy flow outside the beam pipe

as a function of the vertical b to horizontal a beam pipe opening, for $a = 11$ mrad.

4.5 m from interaction point, for crossing angle of 20 mrad and magnetic field of 4T.

