LINEAR COLLIDER COLLABORATION

World-Wide Studies of ILC Physics and Detectors

FCAL Collaboration High precision design

Study of the Beamstrahlung pairs energy deposition in BeamCal and backscattering to the IP in view of the ILD L* changes

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on behalf of the FCAL collaboration

HELMHOLTZ | ASSOCIATION

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DESY

1. Motivation

Request of L*, *the distance between the edge of the final quadrupole field and the interaction point (IP),* **equalization for ILD and SiD:**

Different L would demand additional tuning of the machine after ILD and SiD swap*

*** for ILD L* diminish from 4.4 to 4.0 m**

Analyze the consequences of this for:

*** background in BeamCal**

Important for shower reconstrucitons (from single high energy electrons on top of this background)

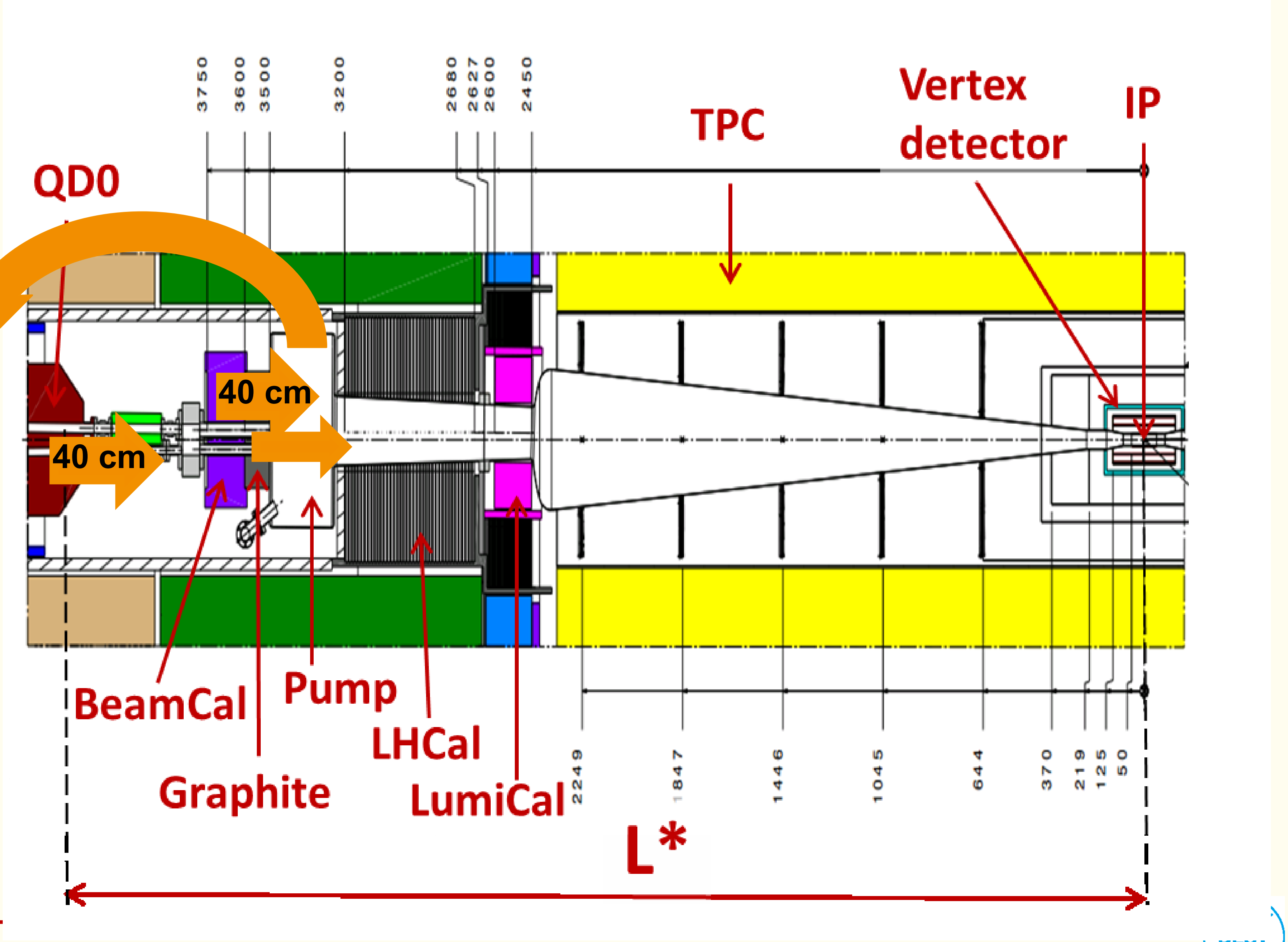
*** flux of backscatterd particles in the central region**

In the central area Vertex is especially sensitive

Outline

1. Motivation
2. Forward region of the ILD
3. The simulation model
4. Geometries analyzed
5. Beamstrahlung pairs
6. Energy deposition in the BeamCal
7. Backscattered particles
8. Conclusion

2. The forward region of the ILD



3. Simulation model

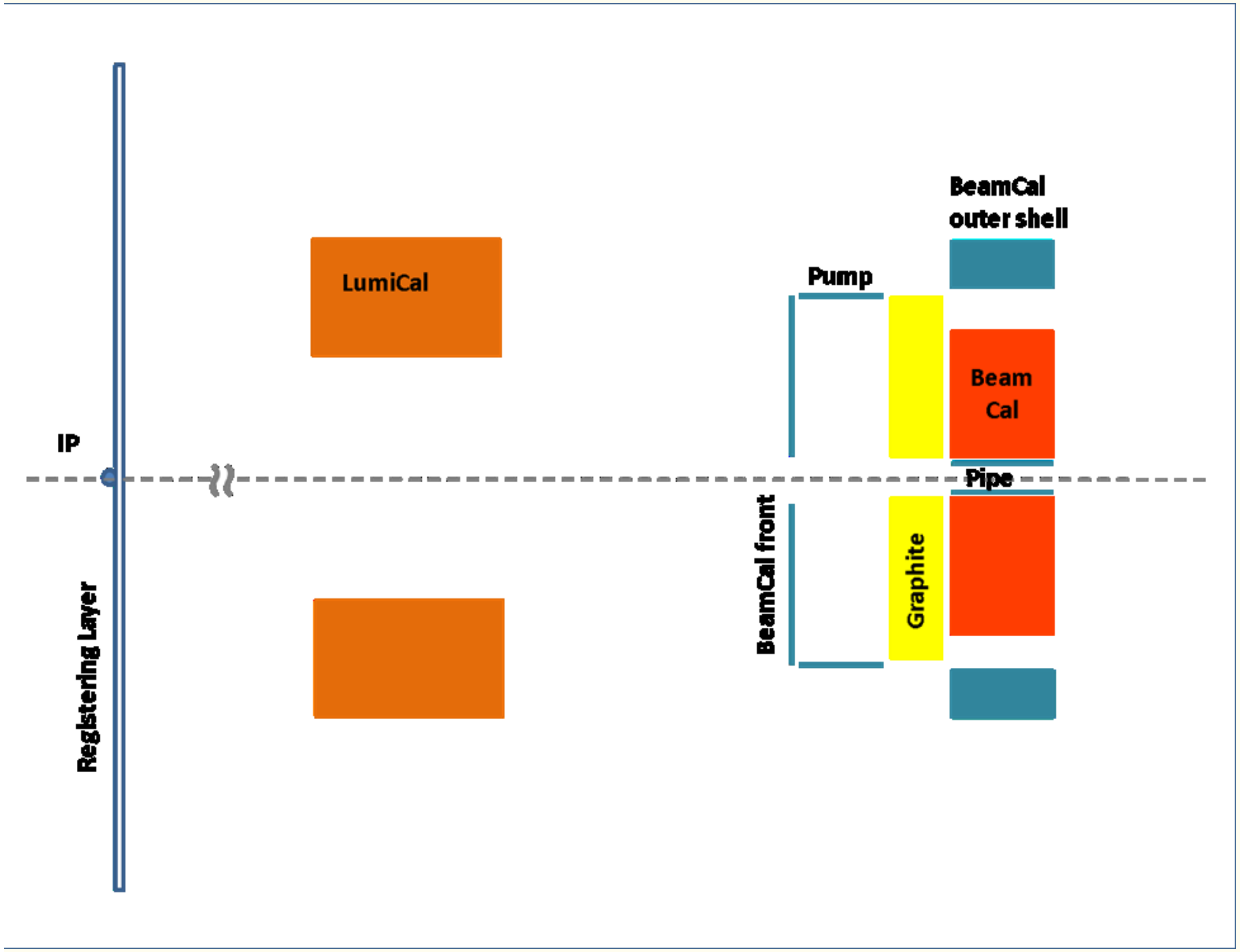
GEANT-4 based simulation package **BeCaS**

Includes:

- **Anti-DID** map of the **magnetic field**
- **Pipes**, **support**, **graphite** and rough **LumiCal** model
- **Registering layer** for backscattered particles registration

Performs:

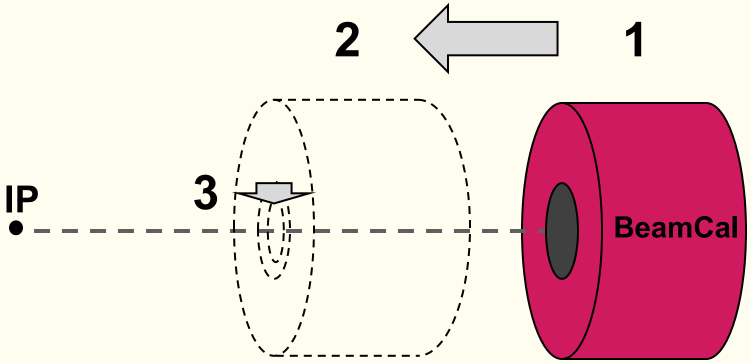
- **shower development** in BeamCal
- **creats backscattered particles**



4. Geometries

In order to study the influence of the L* change on the flux of the backscattered particles, three geometries were considered:

- **Geometry 1:** IP – BeamCal distance is 360 cm, Rin of the BeamCal is 2 cm
  Baseline design
- **Geometry 2:** IP – BeamCal distance is 320 cm, Rin of the BeamCal is 2 cm
  40 cm closer to IP according to request
- **Geometry 3:** IP – BeamCal distance is 320 cm, Rin of the BeamCal is **1.78** cm
  additionally inner radius decreased to cover same polar angle as for baseline design

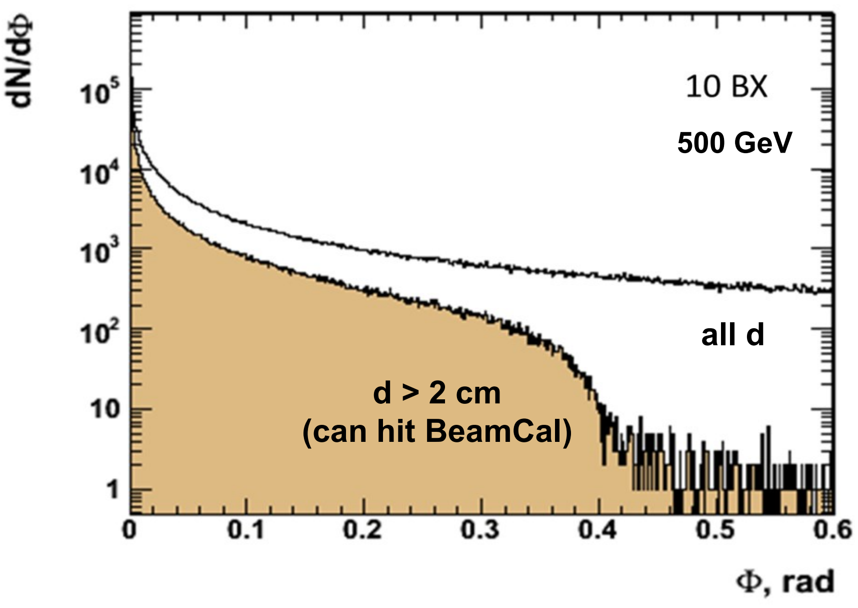


5. Beamstrahlung pairs

- BS e-e+ pairs are generated with the MC program Guinea Pig
- Beam parameter sets:
  - * "baseline 500"
  - * "upgrades 1000 (B1b)"
- Pairs are traced through solenoidal 4 T magnetic field with anti-DID correction
- Charged particles begin their helical trajectory at the IP and have the maximal deviation from the beam axis on the half circle of the helix

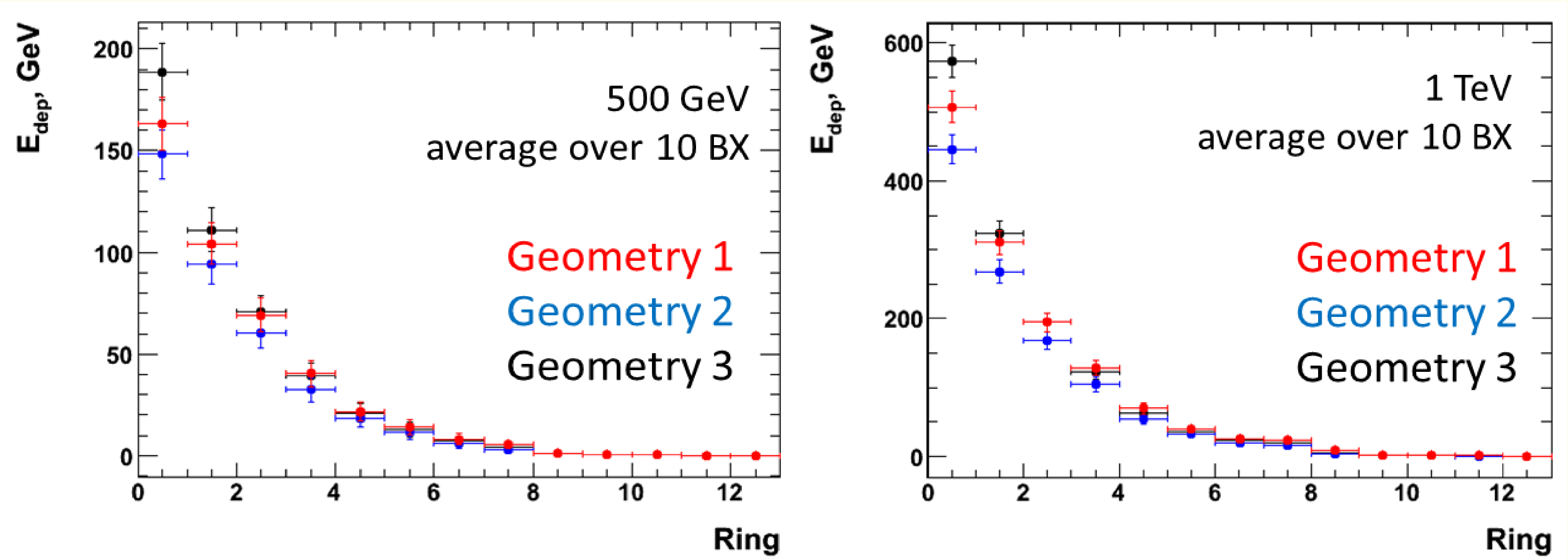
  => Only the particles with diameter of the curvature above 2 cm can potentially hit the BeamCal

Angle on which pairs will rotate, when they reach BeamCal.



- **Most of the particles, that can possibly hit the Beamcal, have angle below 20° => BS particles, hitting BeamCal, are moving almost along the initial velocity vector**

6. Energy deposition in the BeamCal



- **Geometry 2:** when BeamCal moves closer to IP, it covers bigger polar angles *(inner & outer)*, => it results in less energy deposition

- **Geometry 3:** when Rin additionally decreases, BeamCal covers bigger range of polar angles: *(from inner polar angle of geometry 1 to outer polar angle of geometry 2)* => it results in bigger energy deposition per ring compare to baseline geometry

- The energy deposition per ring for 1 TeV option is ~3 times larger, then for 500 GeV option

7. Backscattered particles

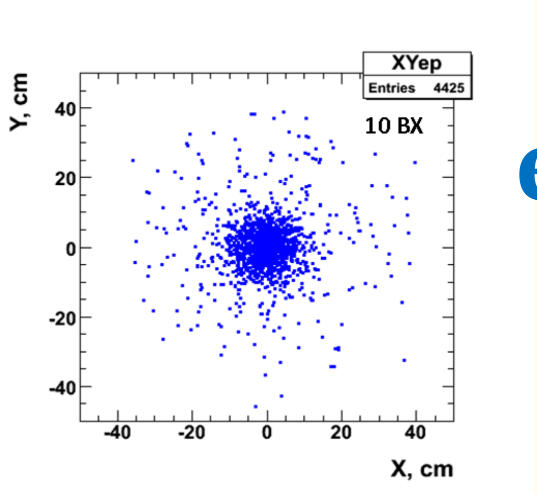
500 GeV in CM

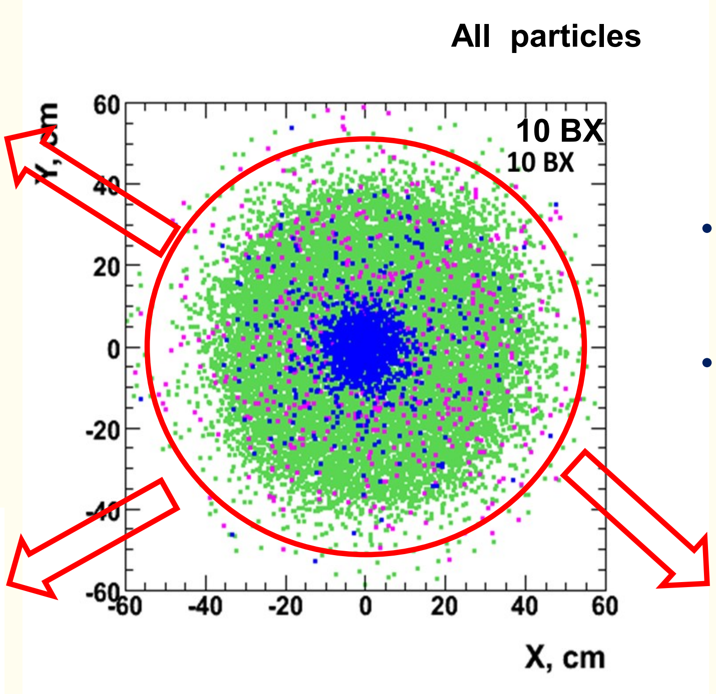
- **For R > 50 cm the amount of particles drops almost to zero, due to absorption in the LumiCal**

  => region with R < 50 cm will be further considered

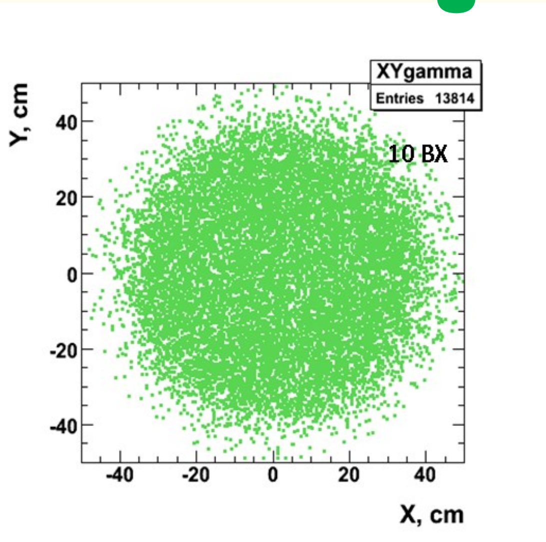
- **e-e+ mostly concentrated at the center within this area**
- **photons & neutrons distrubuted uniformly**

e^+e^-

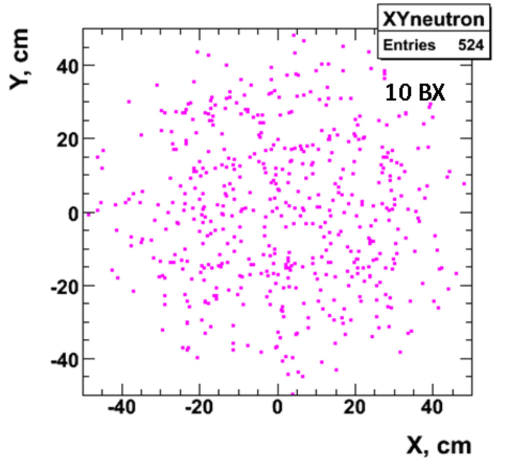




γ



n



7.1. Composition of backscattered particles

500 GeV

	Number of particles	Percentage
ɣ	1381.4	73.4 %
e- / e+	373.7 / 68.8	19.8 % / 3.7 %
n	52.4	2.8 %
rest*	4.9	0.3 %
rest* = $\mu^{\pm}, \pi^{\pm}$, p		

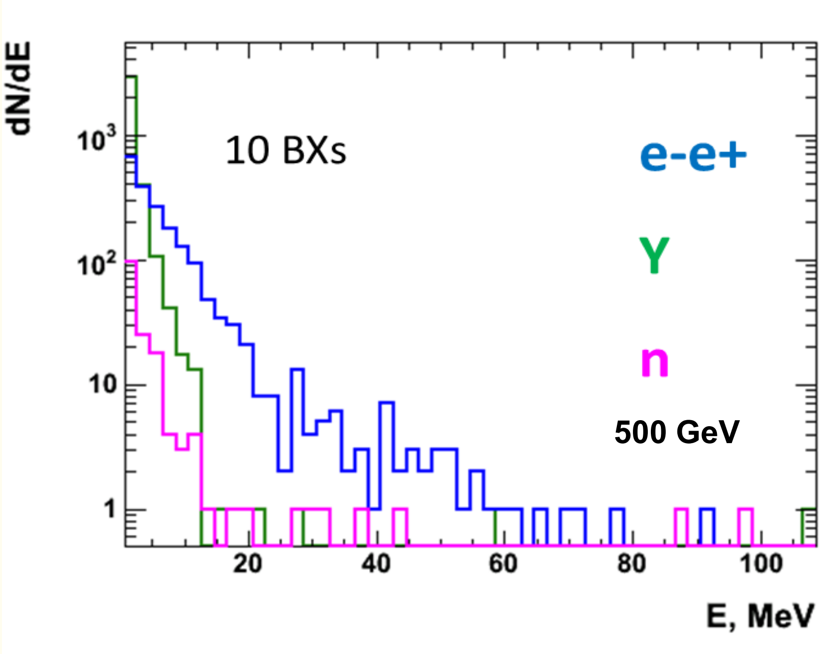
1 TeV

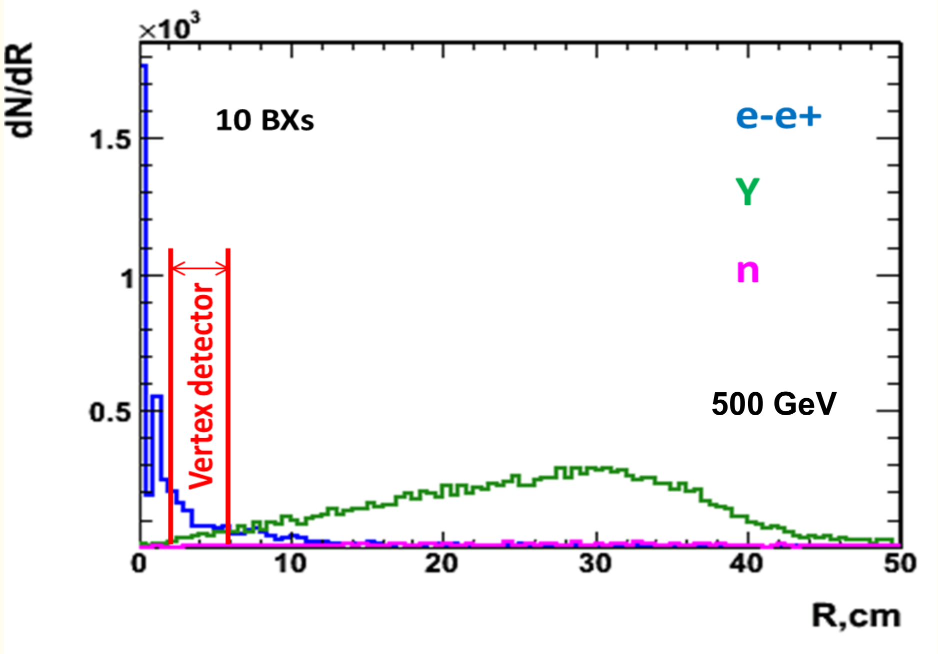
	Number of particles	Percentage
ɣ	3713.3	80.6%
e-/e+	651.0 / 96.7	14.1% / 2.1%
n	137.1	3.0%
rest*	9.3	0.2%
rest* = $\mu^{\pm}, \pi^{\pm}$, p		

- Averaged over 10 BX
- In a circular area of registering layer with R<50 cm
- Geometry 1

=> total number backscattered particles for 1 TeV is ~2.5 times larger

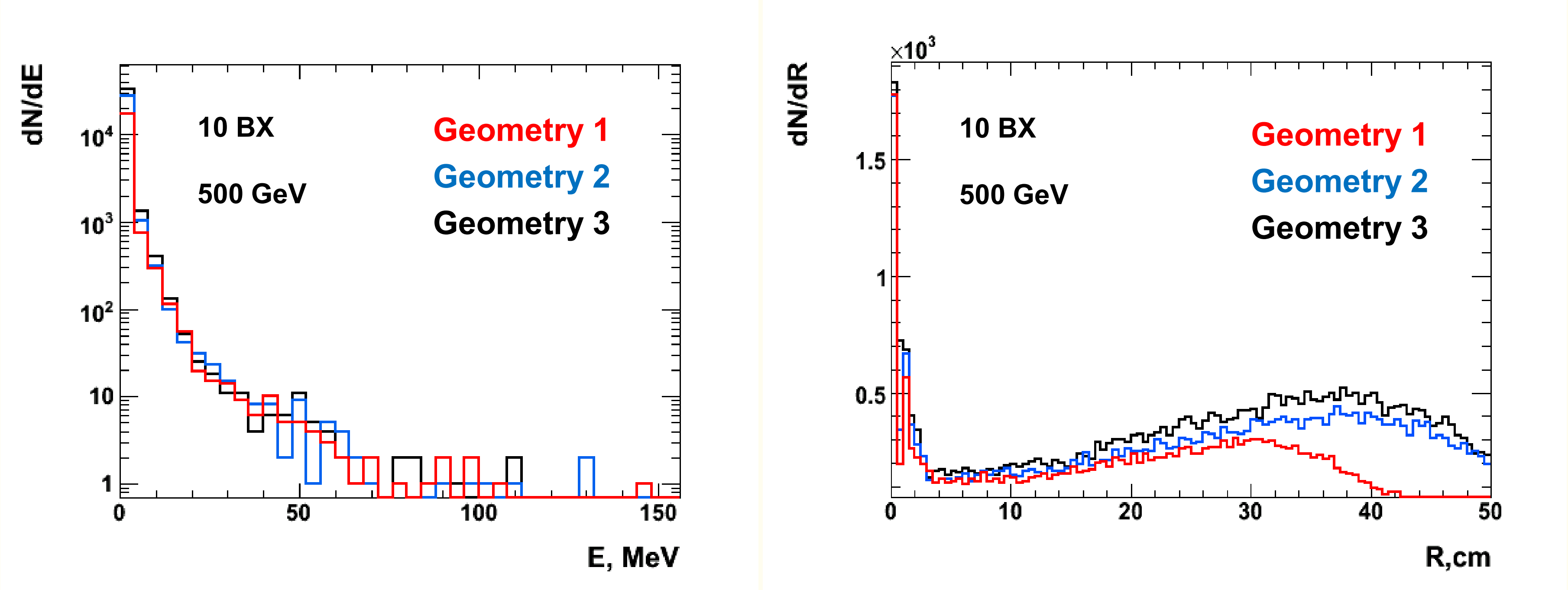
7.2. Energy and radial distributions for geometry 1





- All particle species are distributed over a similar range of energy
- It extends up to several tens of MeV
- Significant part of e-e+ fly to the beam pipe
- But there is a large part of them, which will hit the vertex detector, especially the inner layer

7.3. From geometry 1 to geometry 3



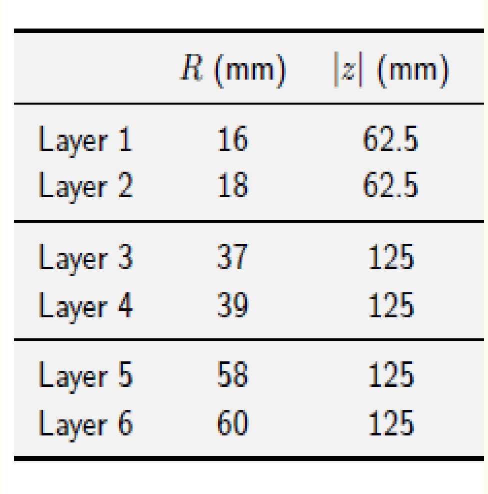
- Energy distributions for all 3 geometries don't differ significantly
- Number of particles at larger radii is increasing mostly due to a large number of photons at the large radii
- Number of particles is increasing from geometry 1 to geometry 3

7.4. ILD vertex detector

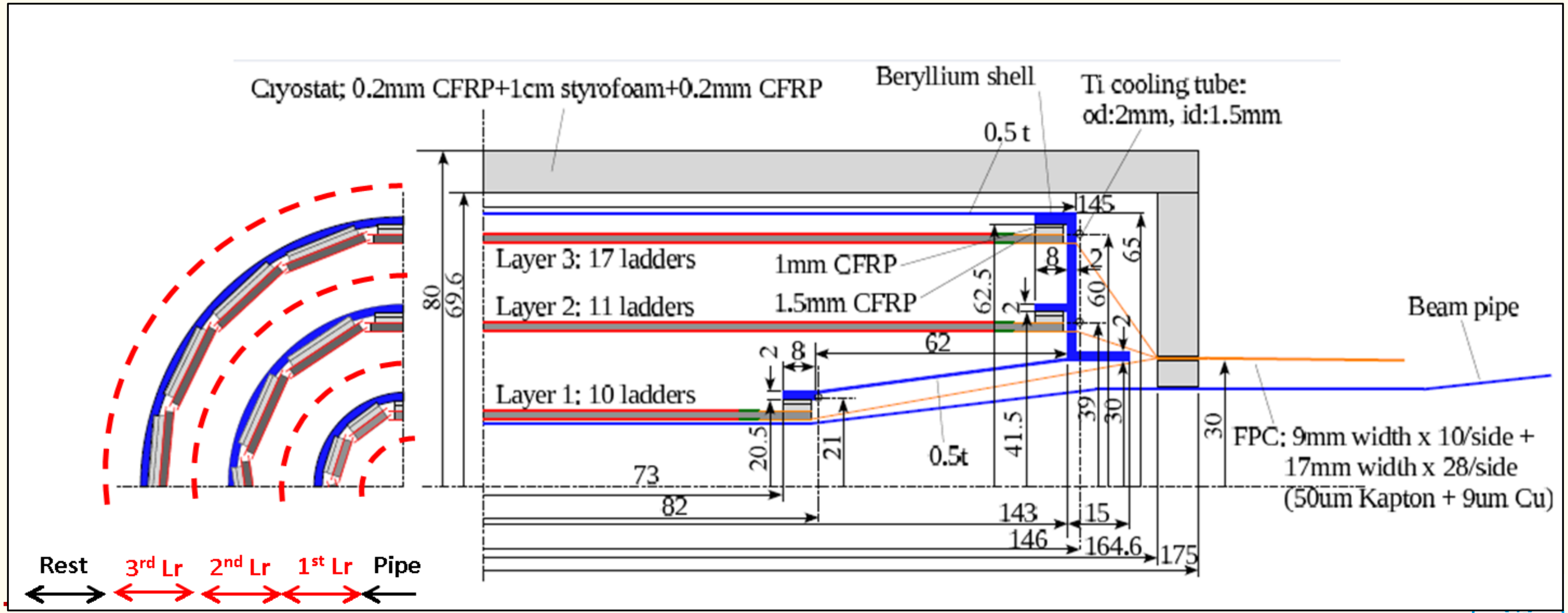
- **Baseline design:** multi-layer pixel detector, 3 cylindrical concentric double layers at radii from 16 to 60 mm

- **Vertex detector**
  ** already hit by original beamstrahlung particles
  ** may also suffer by additional depositions from backscattered particles

- To study occupancy of backscattered particles at the cross section area at the IP, it is divided into rings, such that the boundary radii are in the middle between vertex detector double layers

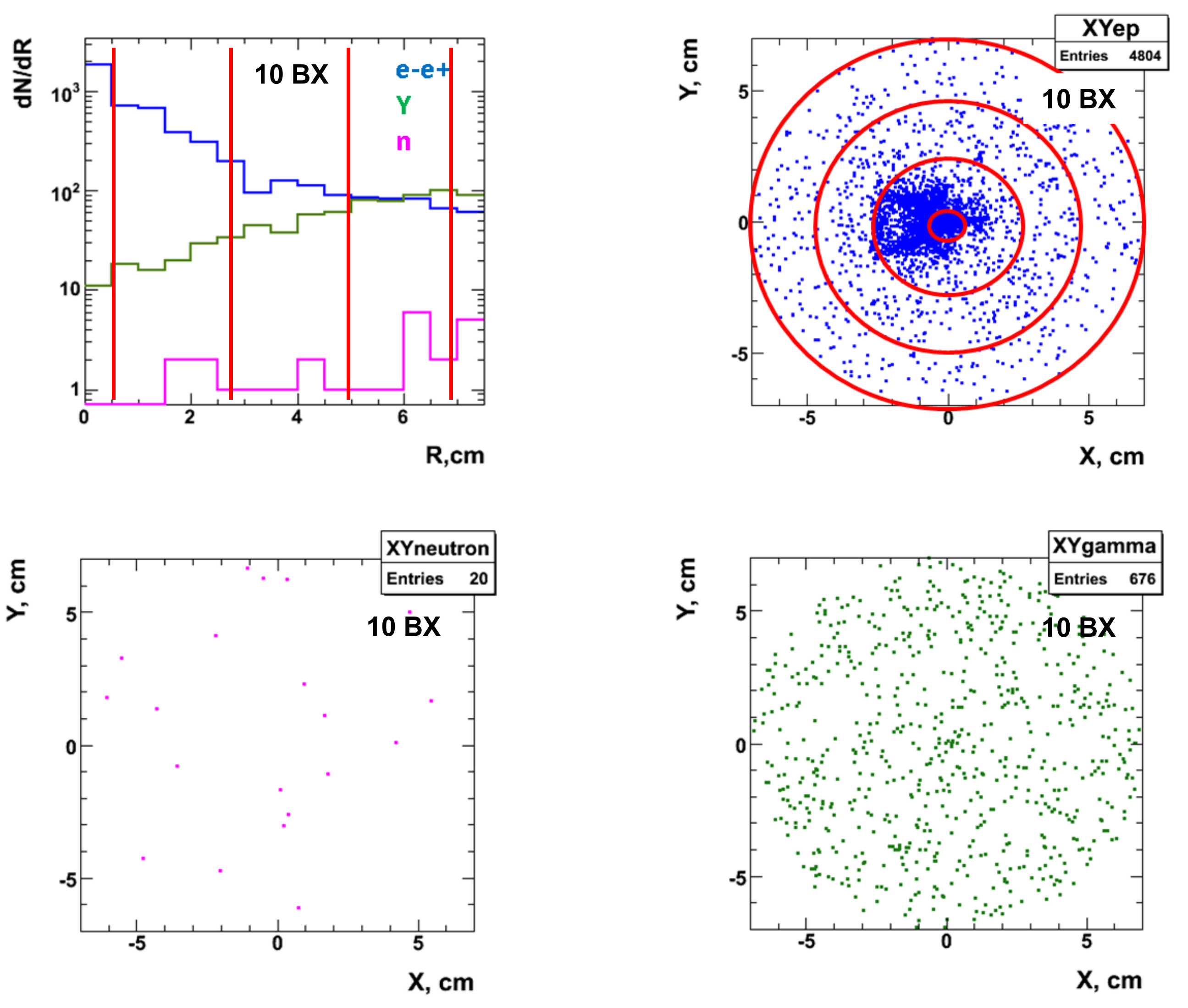


	R (mm)	$\|z\|$ (mm)
Layer 1	16	62.5
Layer 2	18	62.5
Layer 3	37	125
Layer 4	39	125
Layer 5	58	125
Layer 6	60	125



7.4. Occupancy in the ILD vertex detector

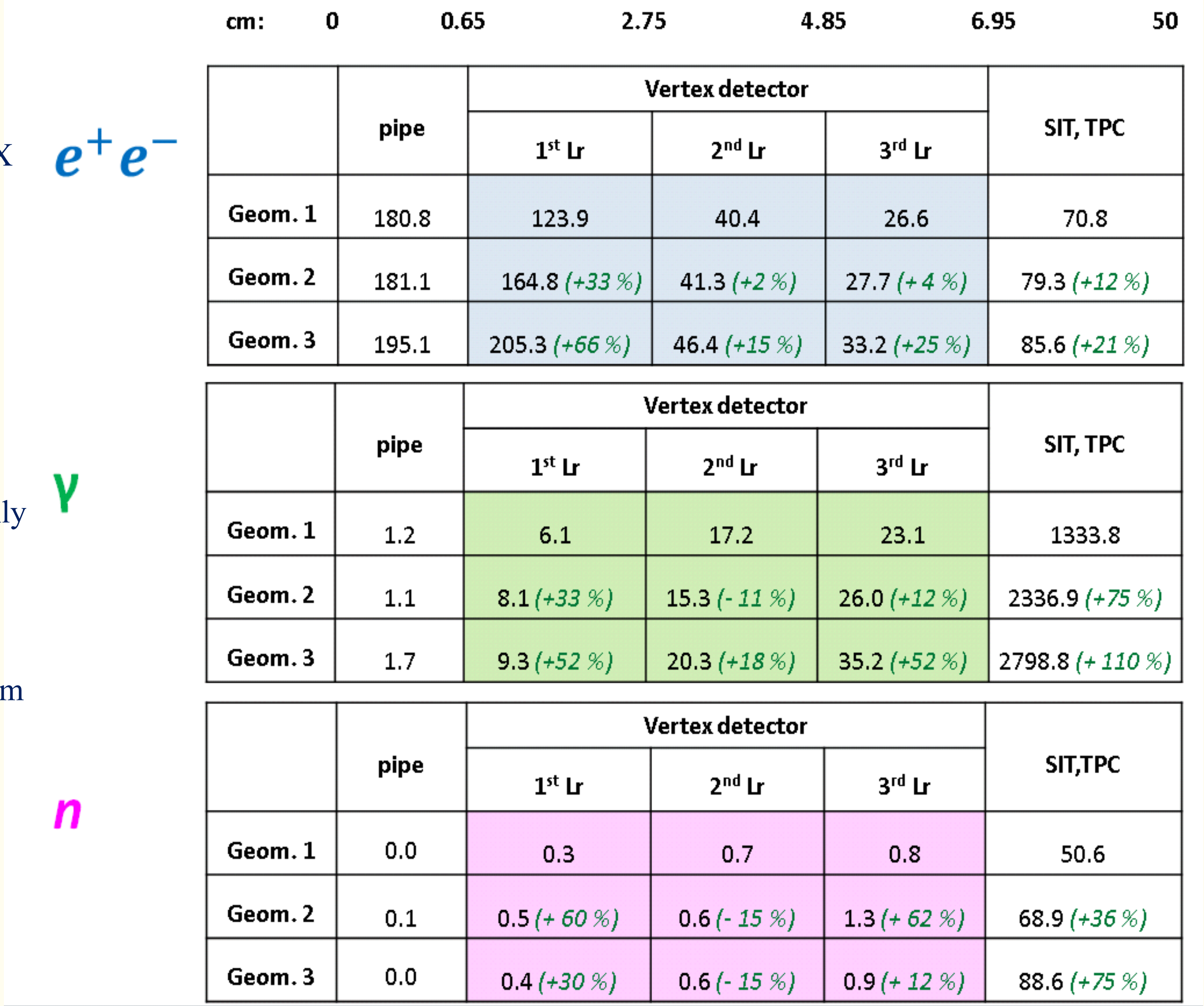
- Geometry 3
- e-e+ mostly concentrated near the beam axis and have asymmetrical shape
  => biggest occupancy in 1st layer of the vertex detector
- Photons and neutrons are distributed uniformly



7.4. Occupancy in the ILD vertex detector

Table: average number of backscattered particles for 1 BX for each ring area for the each geometry

- For geometries 2 and 3 the increase of the number of particles is also given relative to geometry 1
- The vertex detector is mainly sensitive to charged particles, i.e. electrons and positrons. Their amount is increasing with moving from geometry 1 to geometry 3, and the 1st Lr shows the largest increase of 66 %



cm: 0 0.65 2.75 4.85 6.95 50

e^+e^-

	pipe	Vertex detector			SIT, TPC
		1st Lr	2nd Lr	3rd Lr	
Geom. 1	180.8	123.9	40.4	26.6	70.8
Geom. 2	181.1	164.8 *(+33 %)*	41.3 *(+2 %)*	27.7 *(+ 4 %)*	79.3 *(+12 %)*
Geom. 3	195.1	205.3 *(+66 %)*	46.4 *(+15 %)*	33.2 *(+25 %)*	85.6 *(+21 %)*

γ

	pipe	Vertex detector			SIT, TPC
		1st Lr	2nd Lr	3rd Lr	
Geom. 1	1.2	6.1	17.2	23.1	1333.8
Geom. 2	1.1	8.1 *(+33 %)*	15.3 *(- 11 %)*	26.0 *(+12 %)*	2336.9 *(+75 %)*
Geom. 3	1.7	9.3 *(+52 %)*	20.3 *(+18 %)*	35.2 *(+52 %)*	2798.8 *(+ 110 %)*

n

	pipe	Vertex detector			SIT,TPC
		1st Lr	2nd Lr	3rd Lr	
Geom. 1	0.0	0.3	0.7	0.8	50.6
Geom. 2	0.1	0.5 *(+ 60 %)*	0.6 *(- 15 %)*	1.3 *(+ 62 %)*	68.9 *(+36 %)*
Geom. 3	0.0	0.4 *(+30 %)*	0.6 *(- 15 %)*	0.9 *(+ 12 %)*	88.6 *(+75 %)*

8. Conclusion

The influence of the change of L* were studied concerning deposited energy in BeamCal and backscatterd particles in the central region of the ILD detector

- **Beamstrahlung particles**, that potentially can hit BeamCal, move in a cone volume from IP
- **Energy deposition in BeamCal:** for Geometry 2 *(just move by 40 cm)* is less and for Geometry 3 *(move + Rin decreased)* is larger compare to the Geometry 1 (baseline design). For the upgrade 1 TeV option energy deposition is ~3 times larger
- **Backscattered particles** near the IP consist mostly of gammas, around 70 % and the charged particles (e-e+) constitute around 20 %. For the 1 TeV option the total amount of backscattered particles is ~2.5 times larger

  The energy range of backscattered particles extends up to ~100 MeV. e-e+ mostly concentrate around beam axis area and biggest part fly to the beam pipe, gammas distributed widely.

  With changing geometries from 1 to 3, the number of backscattered particles is increasing, and the energy range doesn't change. The biggest challenge backscattered particles will create in the first layer of the vertex detector

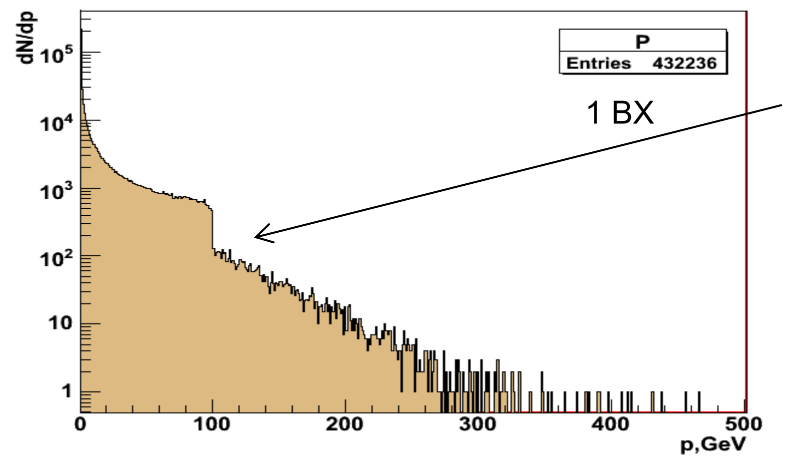
In this way, changing L* from 4.4 m to 4 m will result in larger energy deposition from Beamstrahlung pairs in the inner part of the BeamCal (+ ~15%) and in increasing of the flux of the backscatterd particles in the central region of the ILD detector (e-e+ up to 66 % for 1st layer of the Vertex detector)

Thank you for your attention!

Backup slides

I. BS studies: Energy distributions of BS particles

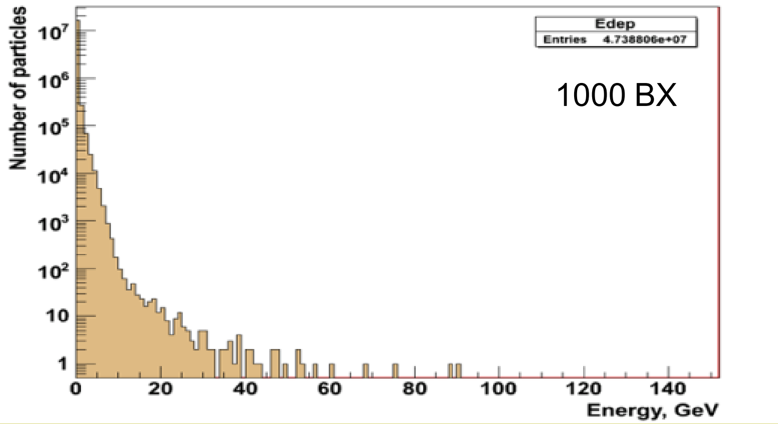
Momentum distribution of all e-e+ pairs



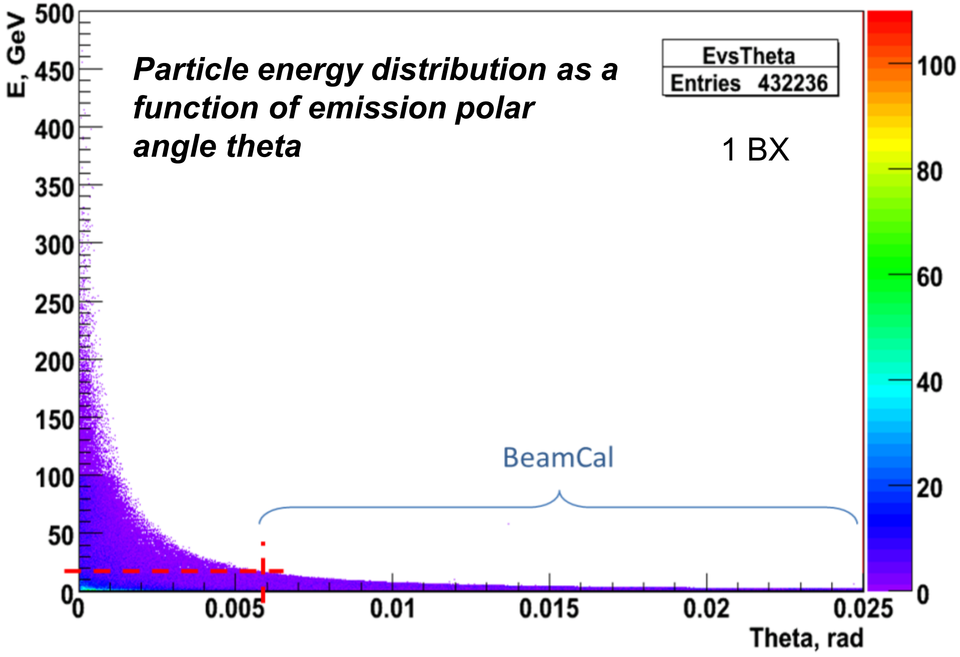
1 BX

Cut on 100 GeV for Compton electrons made on a production level of GP, but particles with energies bigger then 100 GeV fly to the beam pipe anyway and not relevant for this study

Energy distribution of beamstrahlung pairs from 1000 bunch crossings that hit BeamCal.



1000 BX

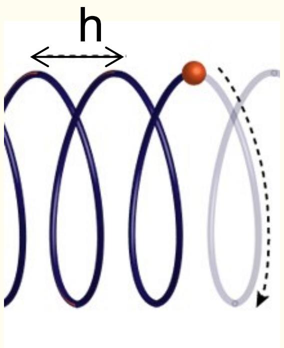


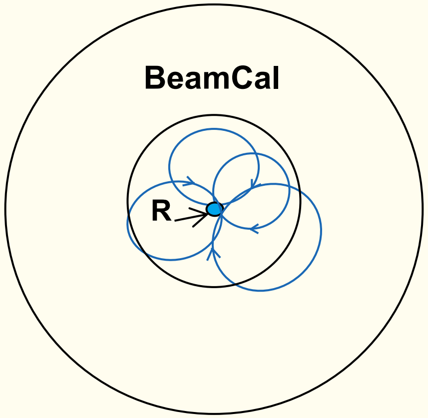
Particle energy distribution as a function of emission polar angle theta

1 BX

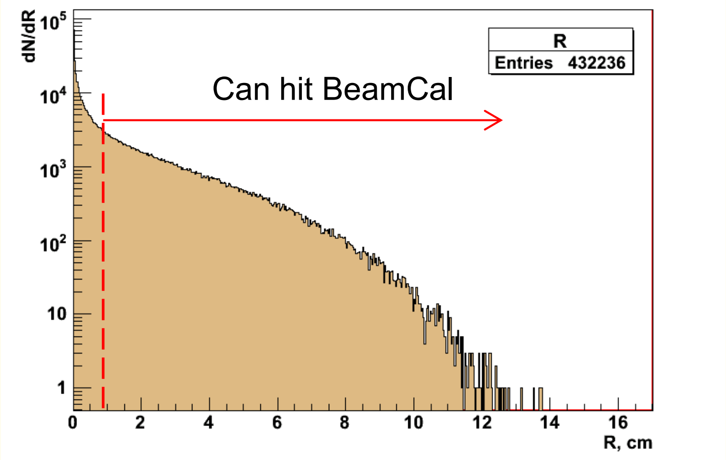
I. BS studies: Radius and Step of curling

Produced e-e+ curling in magnetic field B = 4T (field map antiDID)



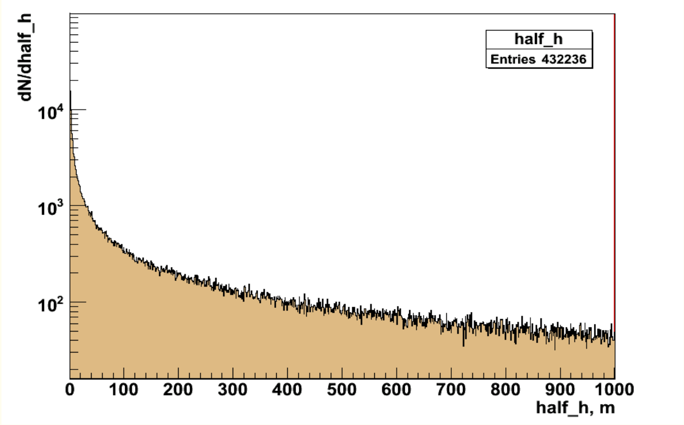


Distribution of radii of all curling particles

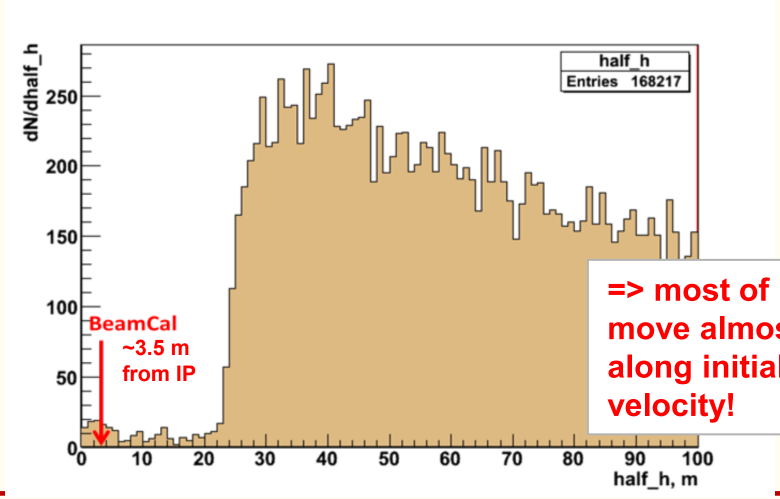


Whether particle hit BeamCal or not also depend on step of curling h
*** On a half-step particle has maximal deviation from beam axis.**

halfstep h/2 distribution for all pairs



halfstep h/2 distribution for pairs with R>1cm



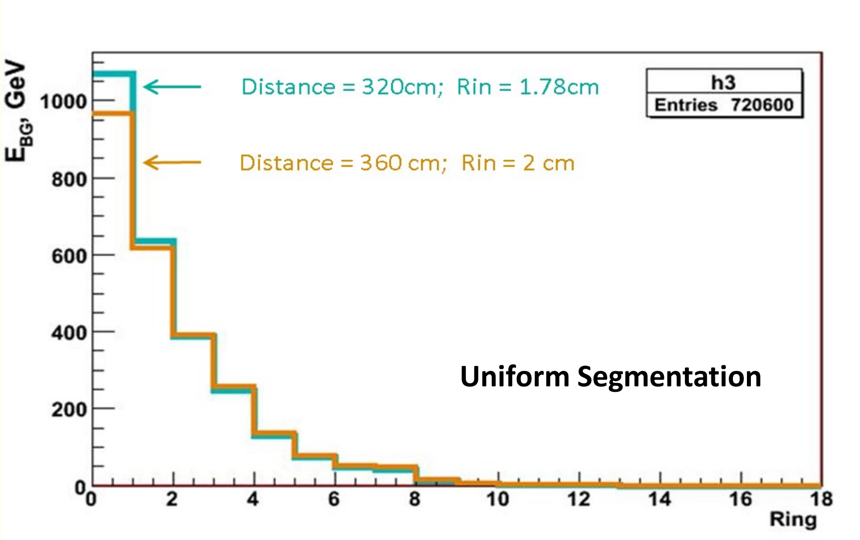
=> most of particles will move almost straight along initial vector of velocity!

I. BS studies: Remarks

- Note! when Rin of BeamCal stays unchanged on 320 cm, it allows easier to reconstruct showers having less BG, but from other side BeamCal aimed on masking QD0, which is situated directly after BeamCal around the beam pipe. => it is needed to decrease Rin of BeamCal to 1,78 cm to cover the same polar angle θ_{in} as on 360 cm

- Then pad of the same area on 320 cm distance will cover bigger solid angle, then on 360 cm distance, therefore energy deposition per pad will be bigger (see fig.)

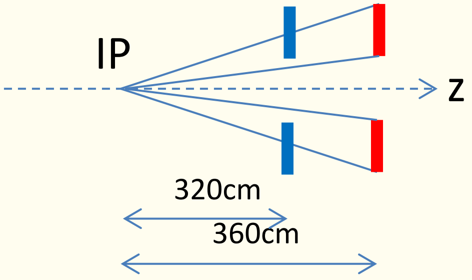
- Thus, when changing L* to 4 m and moving BeamCal closer to IP, while keeping inner polar angle θ_{in} the same, the density of BG according to the area will be slightly increased and it motivates us even more to move to another segmentation (f.e. PS) where SNR is better



- Also, moving BeamCal closer to IP the picture of backscattered particles from first layers of BeamCal will be changed as well. I expect to see bigger occupancy of backscattered particles around beam axis, when move BeamCal closer to IP and keeping polar angle . To see this distributions it is needed to make full simulations, but to estimate relative changes to use BeCaS is sufficient

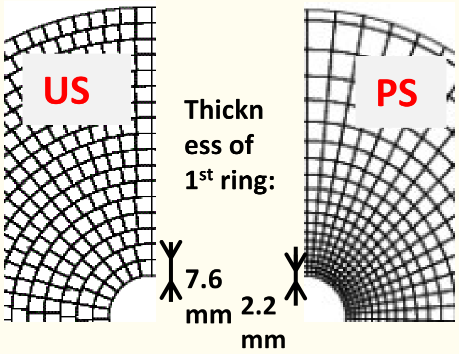
I. BS studies: deposited in BeamCal energy from BS

Moving BeamCal closer to IP it covers bigger polar angles (both: inner and outer angle), hence deposited energy from beamstrahlung pairs will be smaller

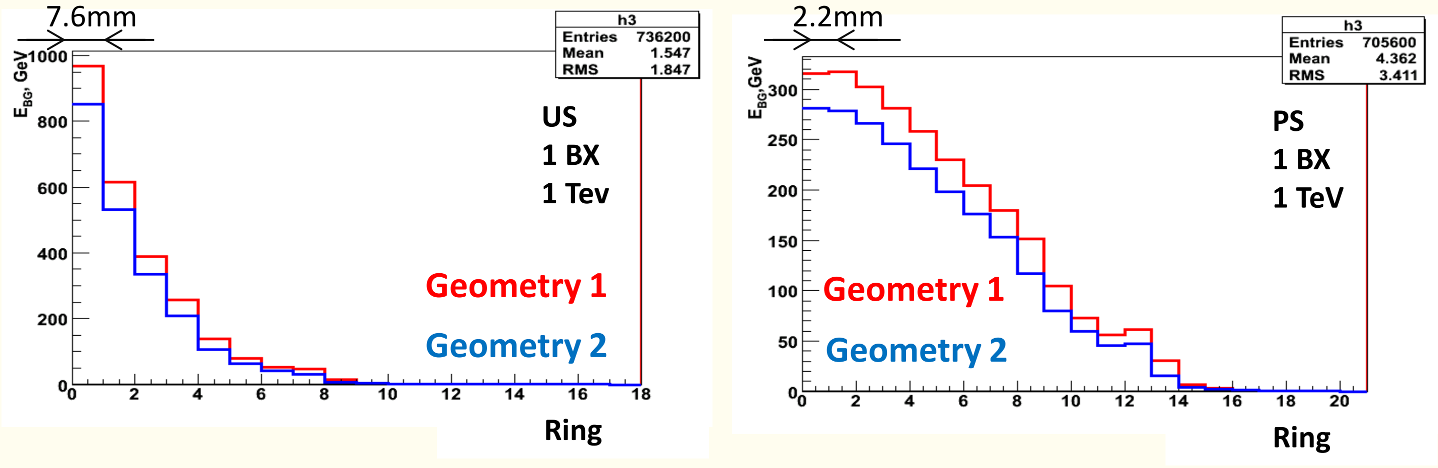


-> Deposited energy per ring for 320cm distance is ~14% smaller then for 360cm.

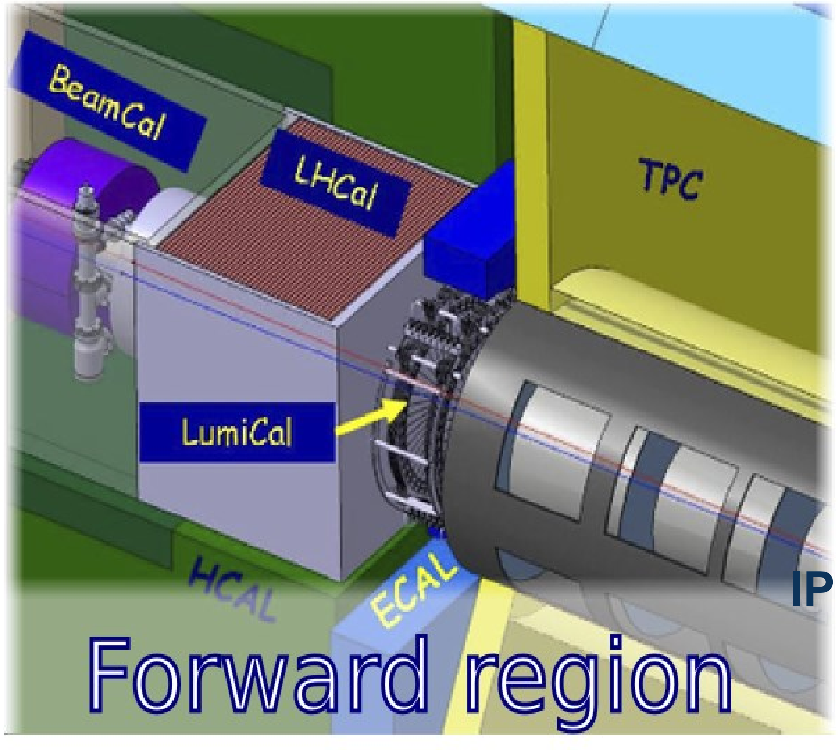
-> In the same time polar angle is getting ~13% bigger



Average E_{dep} versus rings over all azimuthal angles and over all layers



Beam Calorimeter at ILC

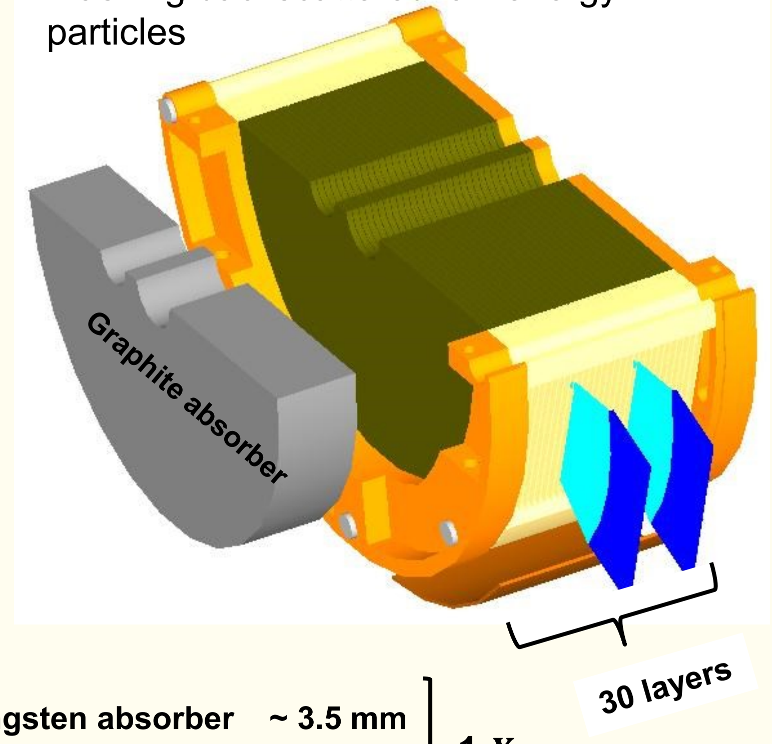


Beam parameters from the ILC Technical Design Report (November 2012)

- Nominal parameter set
- Center-of-mass energy 1 TeV

Purposes of BeamCal:

- Detect showers(SH) from single high energy electrons on the top of the background (BG)
- Determine Beam Parameters
- Masking backscattered low energy particles



Tungsten absorber	**~ 3.5 mm**	**1 X_0**
Sensor	**~ 0.3 mm**	
Readout plane	**~ 0.2 mm**	