Vertex Detector Status

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- **CCD R&D status**

- **Beam background**

Pair background;
  - **Uniform v.s. Realistic B field**
  - **Strength of B field and R_{min}**

Neutron ;
  - **FLUKA**
  - **GEANT3+Maruyama code**

CCD R&D Status

R&D goal :

Normal temperature (> 0 deg.) operation of CCD vertex detector in the environment of JLC experiment to;

- avoid thermal distortion of wafers
- keep free space (no cryostat) for forward-tracker and beam monitors

Collaboration:

KEK
Saga Univ.
Tohoku Univ.
Niigata Univ.
Toyama Nat. Col. of Maritime Tech.

R&D issues

- Study of spatial resolution:

$\sigma < 3\ \mu m$ has been achieved for normal incident MIPs.
However resolution for inclined incident particles is not clear yet.

- Thin wafer:

Study of support structure (KEK)

Measurement of (thermal) distortion of Si wafer (Niigata U. and Toyama C.M.T.)

- Radiation hardness

β(^{90}Sr) and neutron(^{252}Cf) irradiation test
(Saga U. and KEK -> Stefanov's talk)

γ(^{60}Co) irradiation test (Tohoku U.)

-

Radiation damage on CCD sensors

- Increase of dark current (surface, bulk)
- Shift of operation voltage (surface)
- Increase of charge transfer inefficiency(CTI) (bulk)

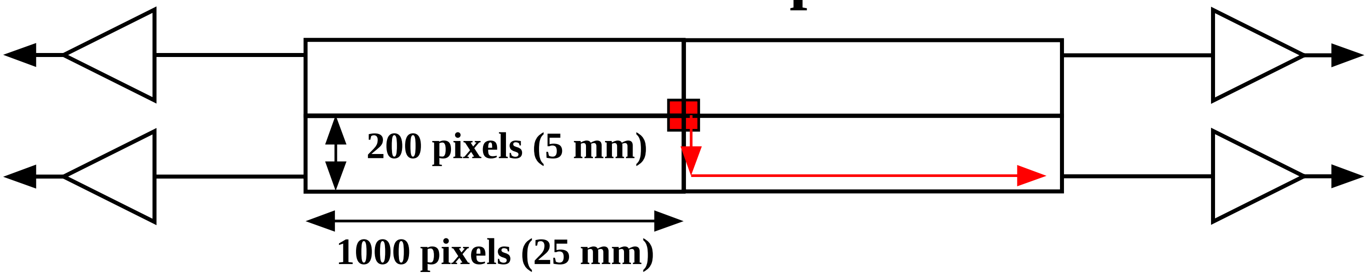
Requirement for CTI:

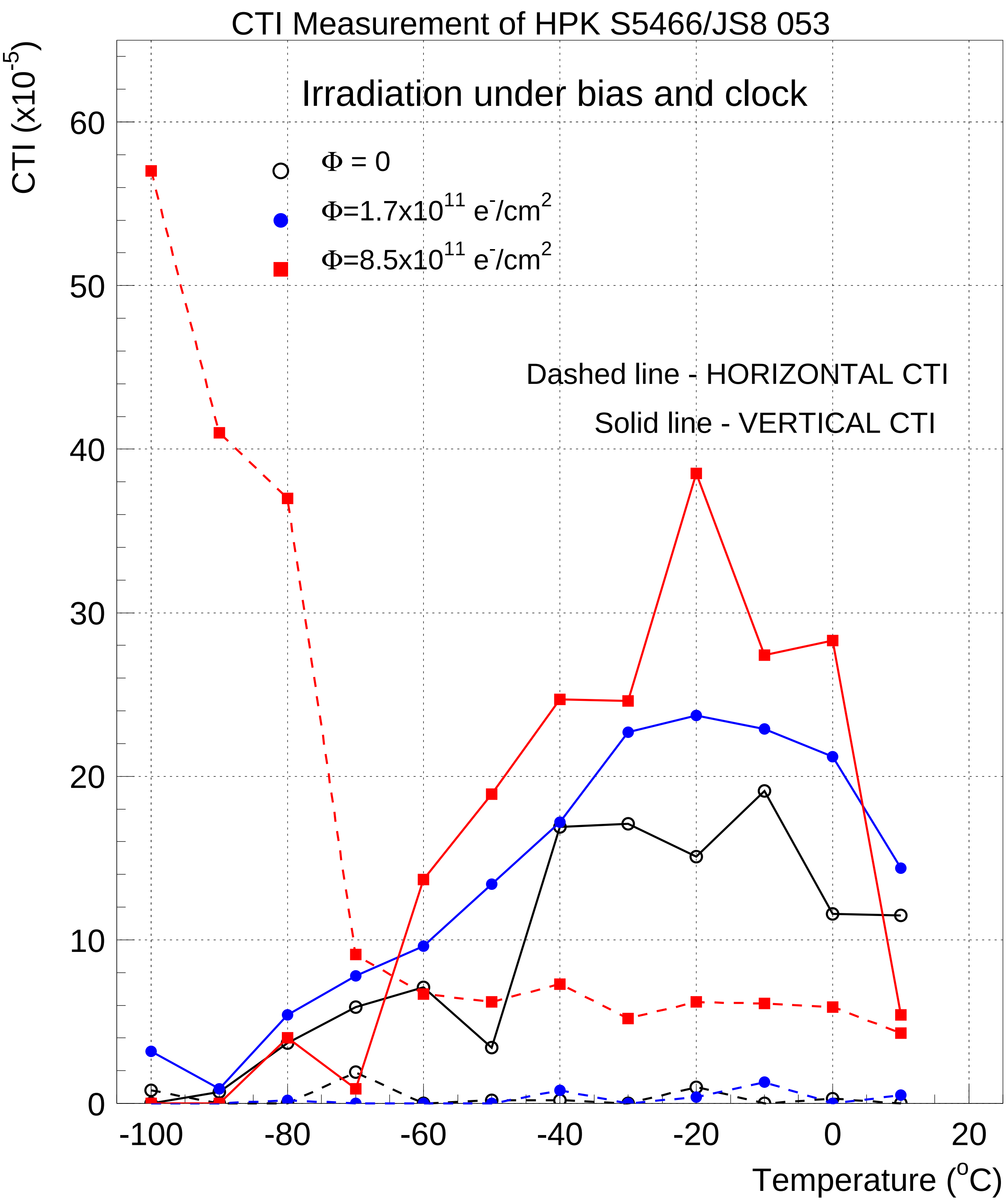
Vertical CTI < $1*10^{-3}$: $(1-0.001)^{200} = 0.82$

Horizontal CTI < $0.2*10^{-3}$: $(1-0.0002)^{1000} = 0.82$

-> Worst case: $0.82*0.82 = 0.67$

Model chip



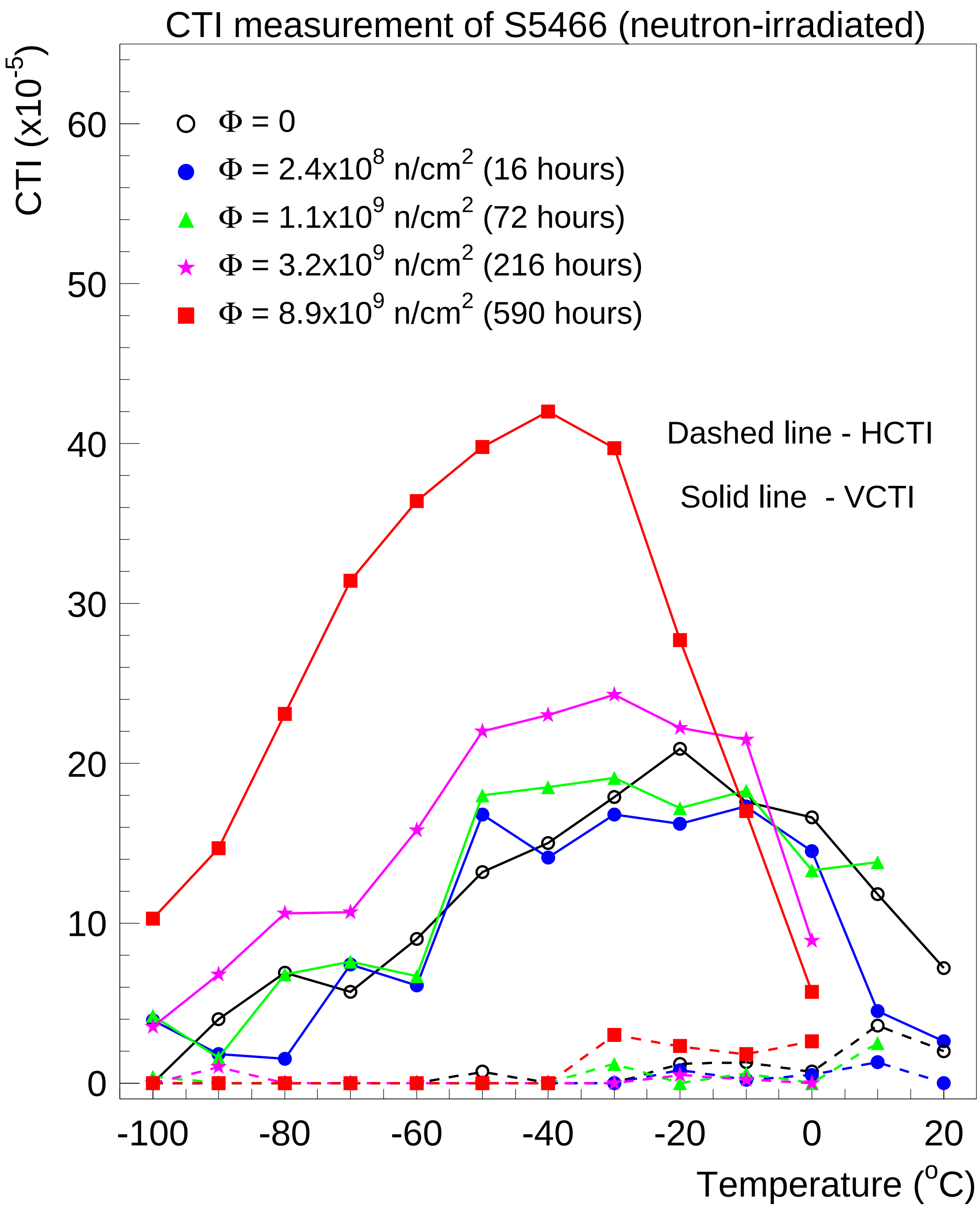


-> Limit ~ $1.5*10^{12}$ e/cm^2

Note that bulk damage by MIP electrons is stronger (few times but less than x10) than low energy (~1 MeV) electrons.

-> Limit > $1.5*10^{11}$ e(MIP)/cm^2

Neutron damage - ^{252}Cf



-> Limit ~ 1.5*10^{10} n/cm^{2}

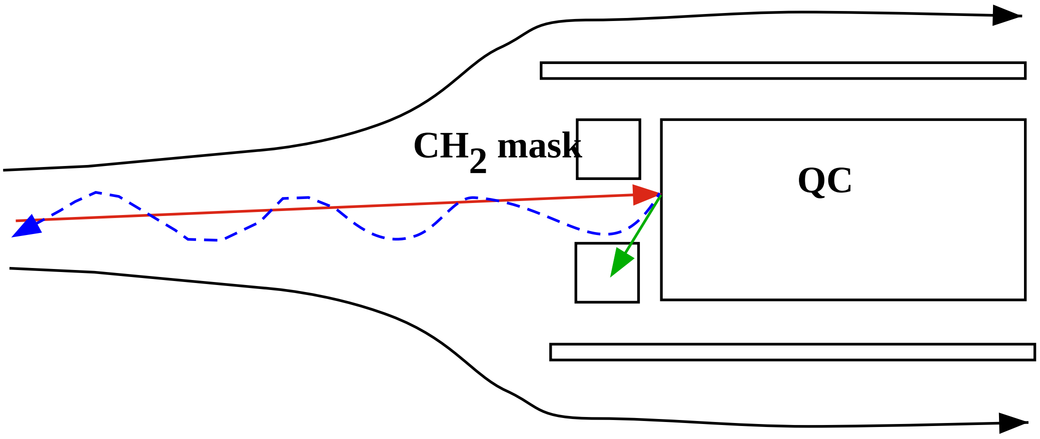
Pair background with different B fields

Previous simulation:

-Uniform B field of 2T
(compensation and Q magnets OFF)

Realistic B field

-> Suppression of backscatted
electrons is anticipated



Stronger solenoid B field (3,4, and 6 T)

Generation of e^+e^- pair ; CAIN

Input parameters;

- Bunch population	$0.75*10^{10}$/bunch
- Ebeam	250 GeV (4.3MW/beam)
- Bunch length	90 μm
- Emittance $\gamma\varepsilon_{x\,/\,y}$	4 /0.06 $*10^{-6}$m
- β_x / β_y	10 /0.1 mm

Luminosity;

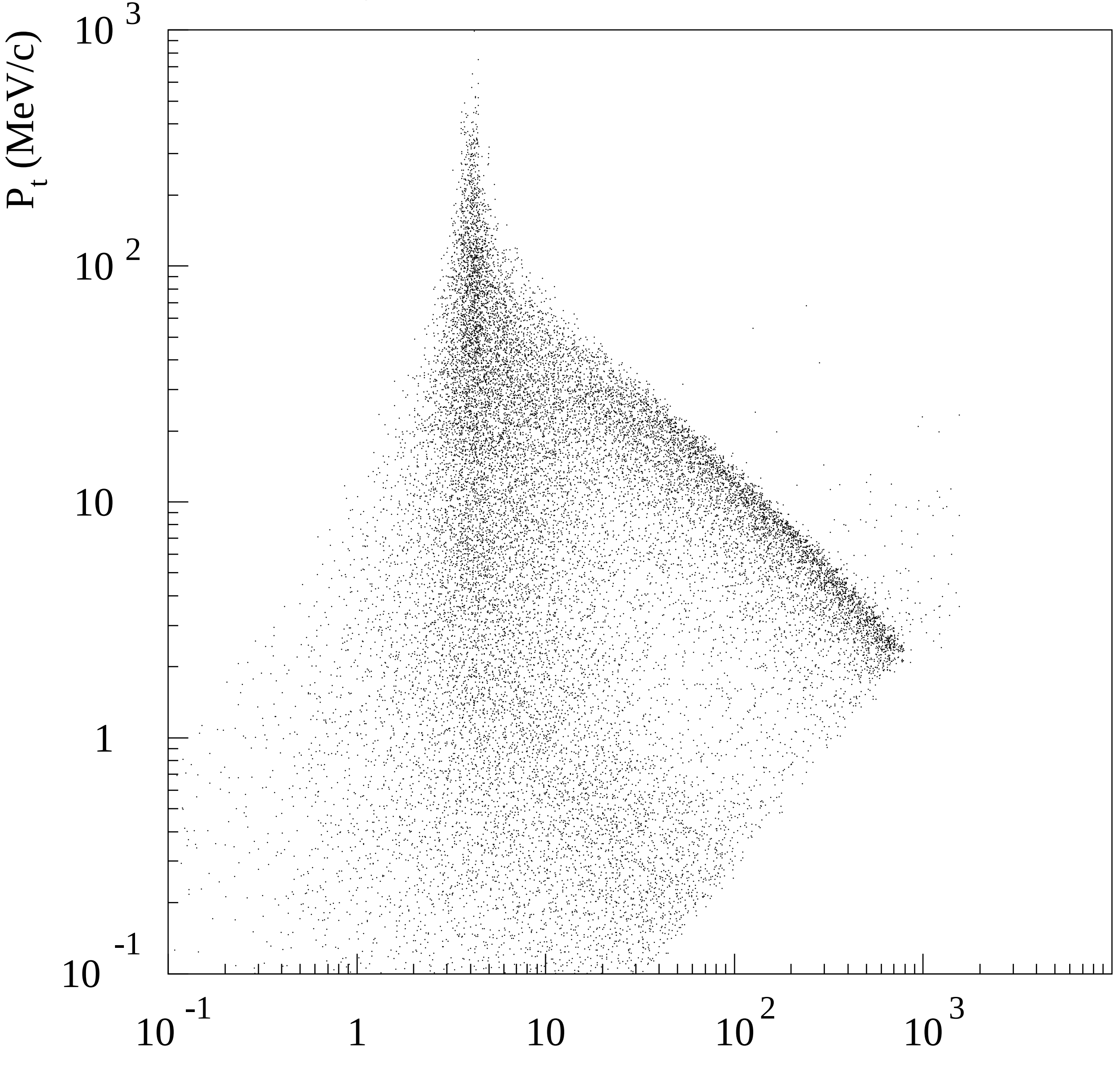
- L	$0.64*10^{34}$ /cm^{2}s
- H_DL	$0.88*10^{34}$ /cm^{2}s

Pair background;

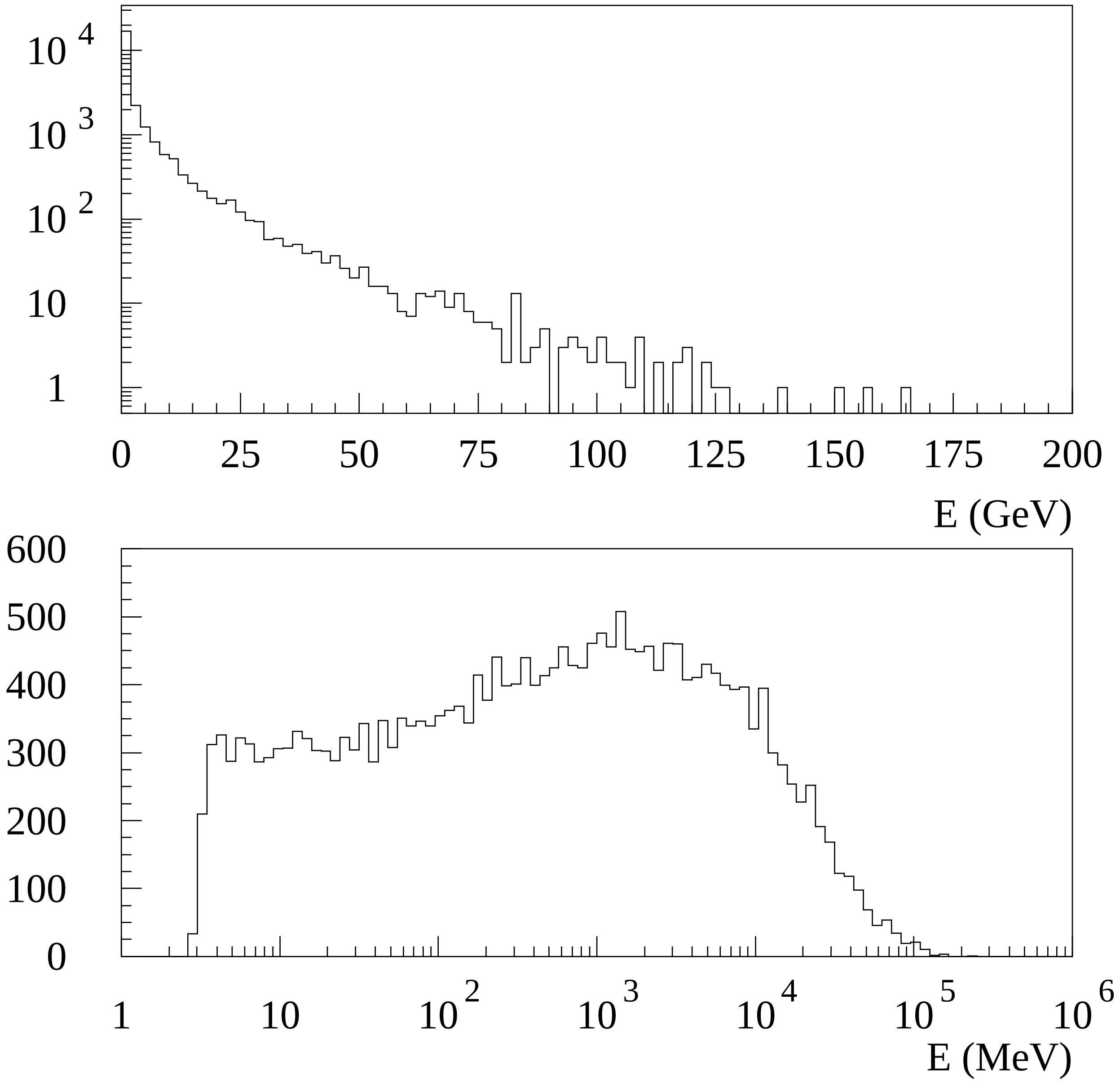
- # of e^+e^-	25 k / BX
- $\langle E_e \rangle$	4 GeV
- Total energy	100 TeV / BX

Beamstrahlung γ;

- # of γ	$1.5*10^{10}$ / BX
- $\langle E_\gamma \rangle$	10 GeV
- Total energy	340 kW
- δ_{BS}	4.0 %

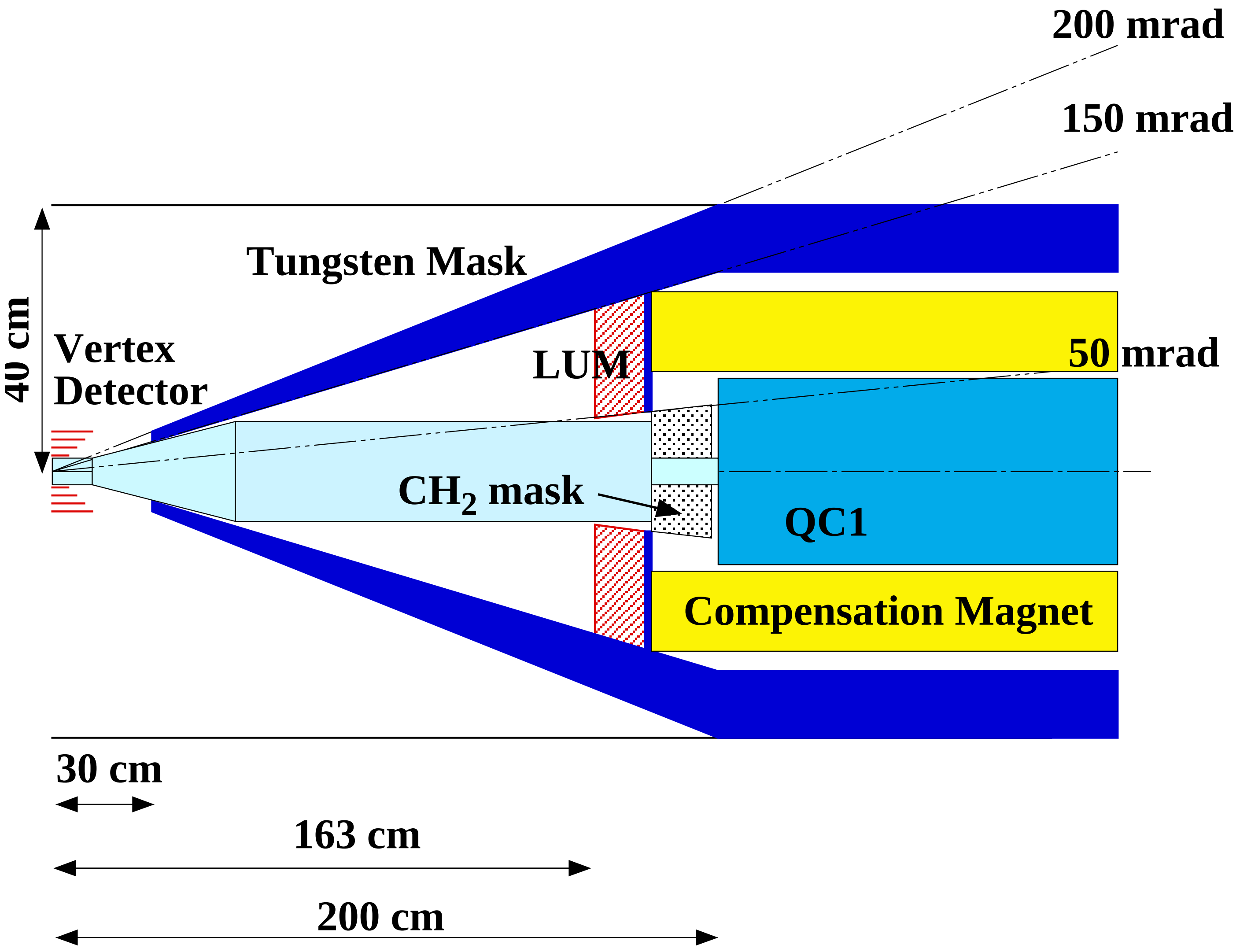


Energy of e^+e^- pair background



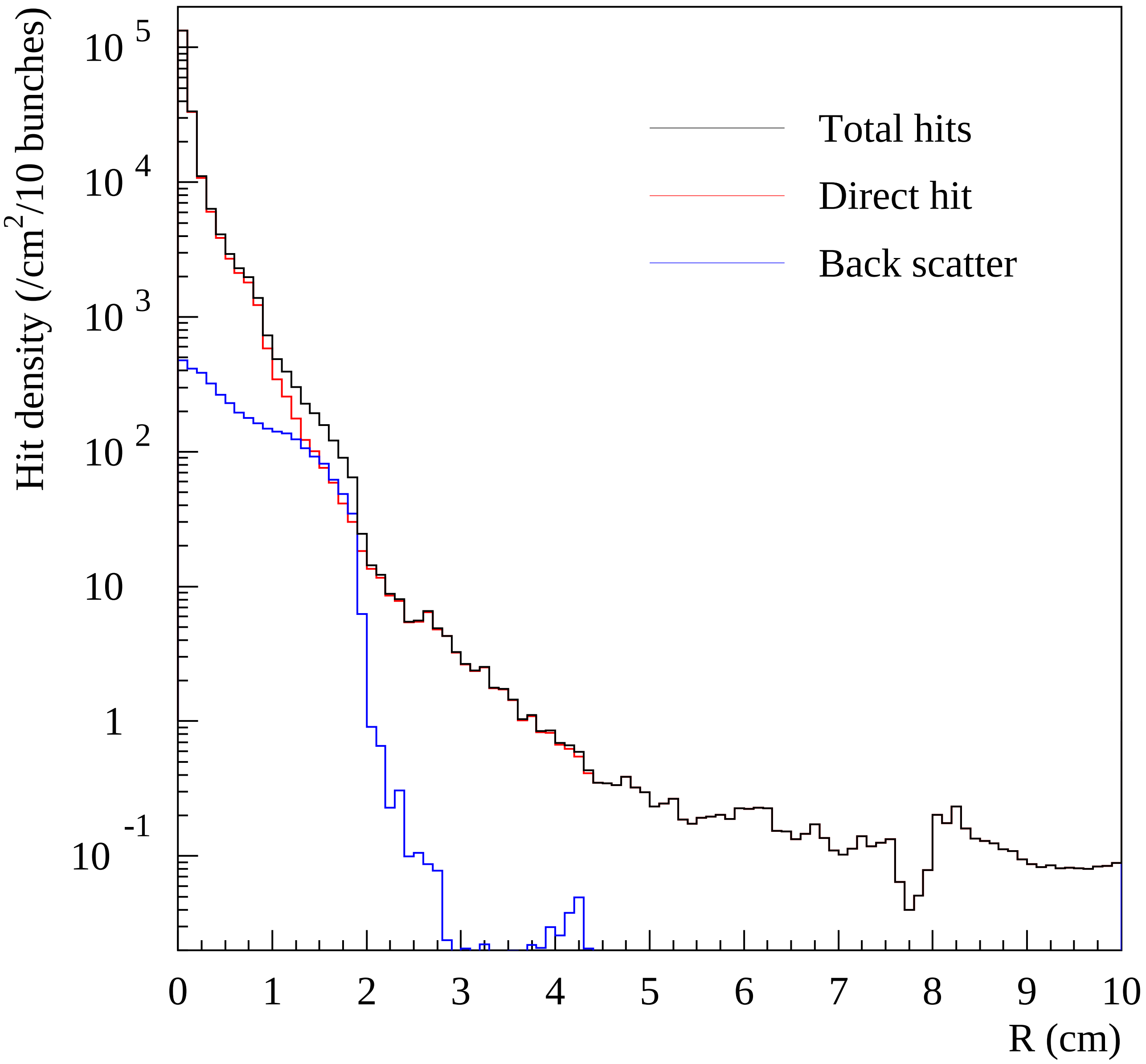
Detector simulation

- Beam pipe   r = 2.0 (Be) / 7.5 (Al) cm
- Polyethylene (CH_2) mask, r_{in} = 2 cm
- Vertex detector;
  r = 2.4, 3.6, 4.8, 6.0 cm
  $\cos\theta < 0.9$
- Luminosity Monitor;
  z = 163 cm
  r = 8 cm (50 mrad)

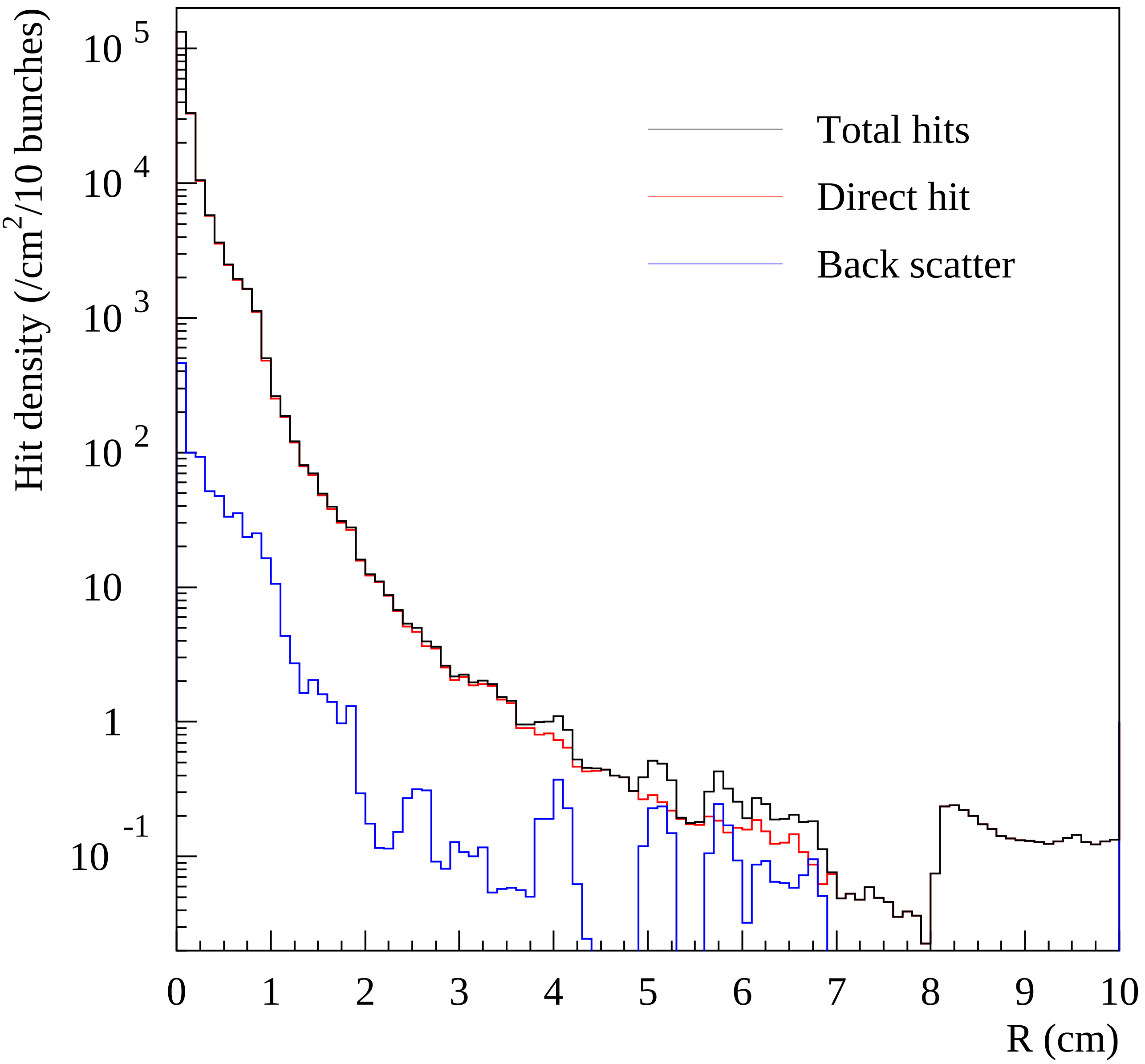


Comparison between uniform and realistic fields

Vertex detector hit density in uniform B (2T)
cos θ < 0.9



Vertex detector hit density in realistic B (2T)
cos θ < 0.9



Energy deposit on the QC magnet;

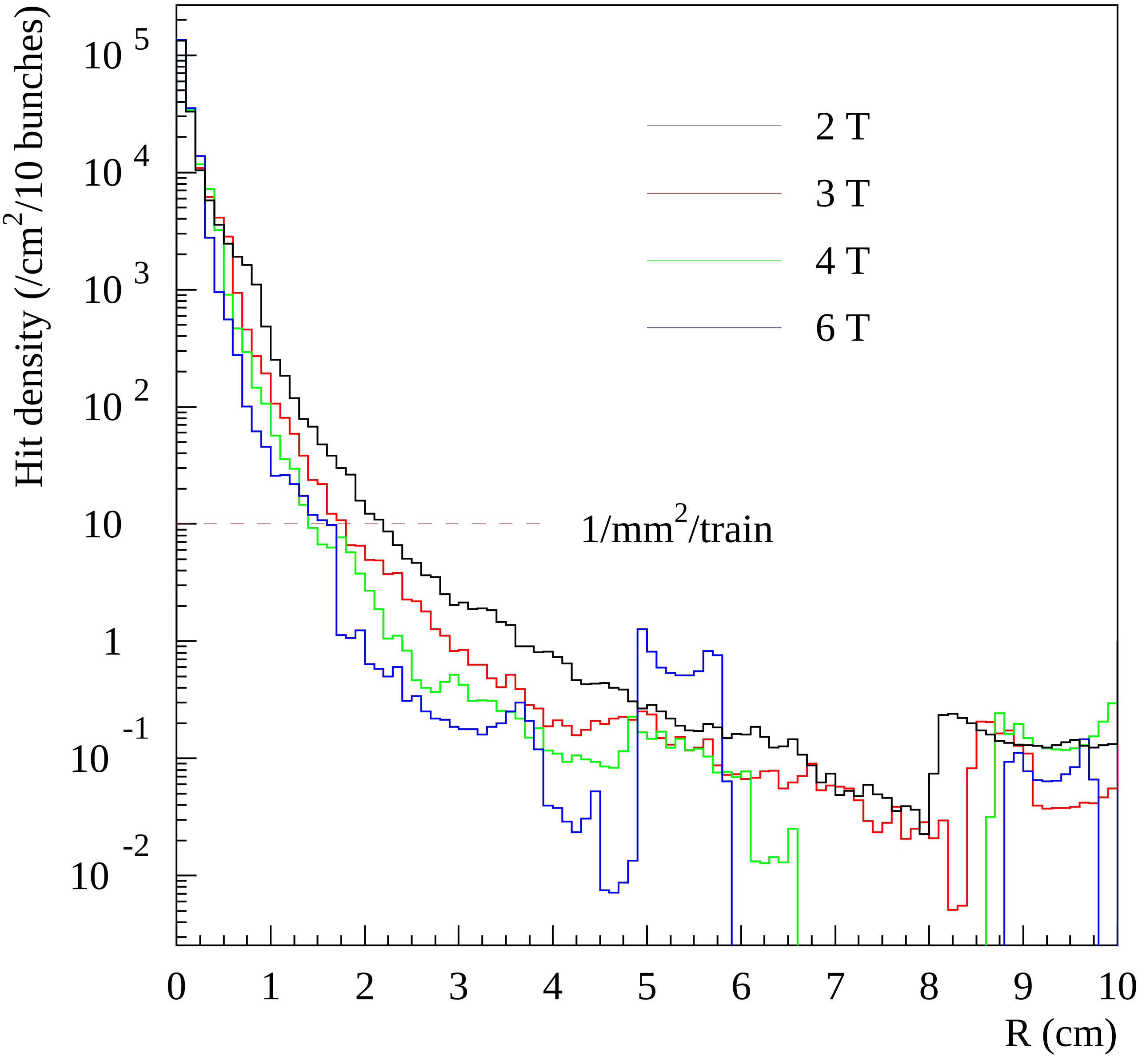
w/o -> ~13 TeV/bunch

with -> ~25 TeV/bunch

Neutron background may increase.

Vertex detector hit density in various B fields

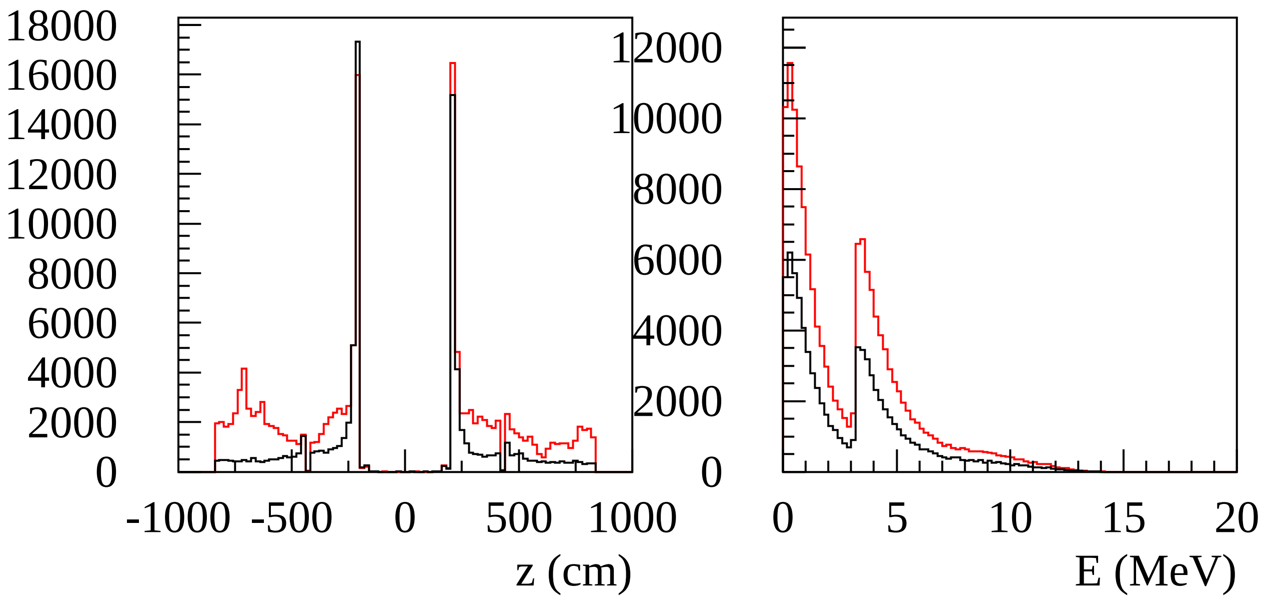
$\cos\theta < 0.9$



Neutron Background

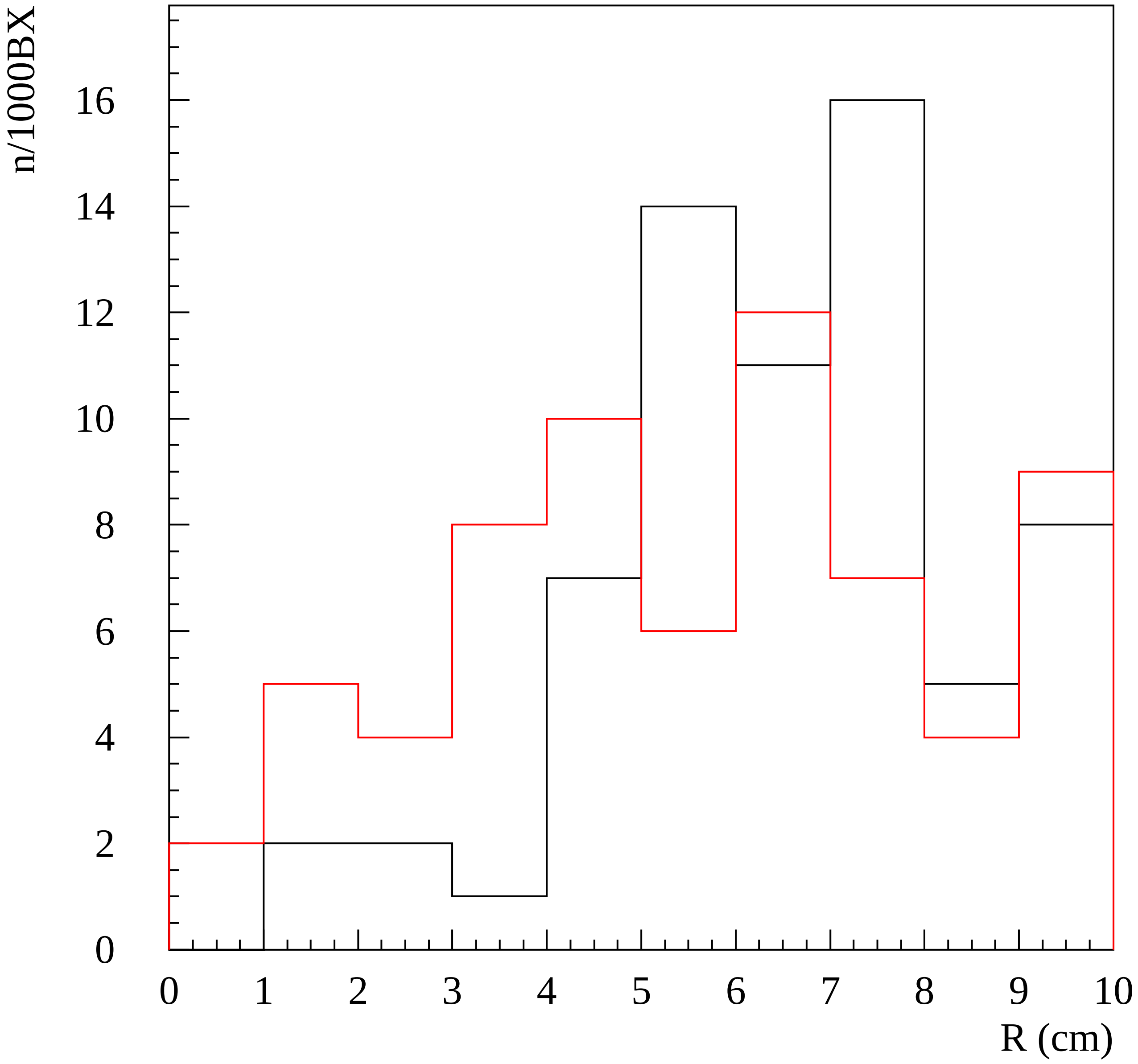
GEANT3 + Maruyama code;

- **e^+e^- pair -> EM shower in QC**
  -> Photonuclear reaction
- **Neutron generation code;**
  written by T.Maruyama
  implemented into GEANT3
- **Production cross section was artificially multiplied by 100 in the simulation**
- **FLUKA(E>20 MeV) or MICAP(E<20 MeV) used for neutron transportation in G3 (neutral hadron cut off energy = 1 keV)**



Neutron production point   Neutron kinetic energy

Neutron flux at IP



R distribution at z=0

Entries:

Uniform field; 66

Realistic field; 67

66 / $\pi r(=10\ \mathrm{cm})^2 / (10*100)\mathrm{BX}$

$= 3*10^7\ /\mathrm{cm}^2\mathrm{y}$

Neutron Background

Requirement by CCD Vertex Detector:

Vertical CTI < 1×10^{-3} => Neutron flux < 1.5×10^{10} n/cm^2

Previous estimate:

Done by Y.Sugimoto, using
Geant3
neutron generation code by T.Maruyama(SLAC)

Result: 3.0×10^{7}/cm^{2}y by e+e- pair hitting QC

1.0×10^{7}/cm^{2}y by Beamstrahlung photon dumped water dump at 300 m from IP.

This study:

Similar analysis by Fluka-98
More realistic magnetic field map for QC and Detector Solenoid

Fluka-98 parameters

Cutoff

neutron transport: > 1 keV
e+/e- transport: > 10.511MeV
Photon transport: > 4 MeV

Biases:

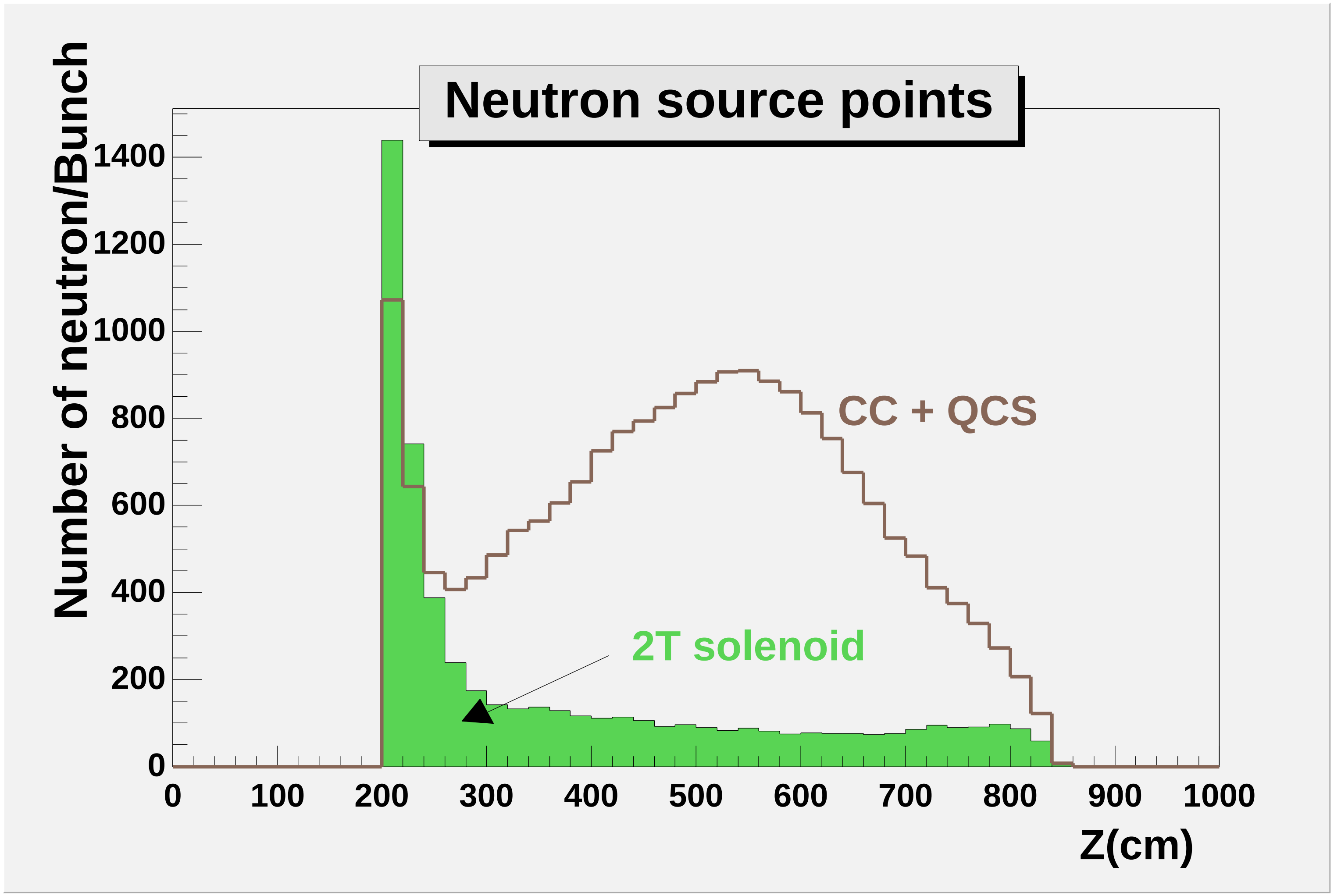
Interaction length of photon for neutron production: x 0.01

Leading particle bias for electron and photon.

Magnetic Field:

2 Tesla solenoid in whole region.

2 Tesla solenoid + Conpensation Magnet + QC field


Neutron source points
Number of neutron/Bunch
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
1000
Z(cm)
CC + QCS
2T solenoid

Summary

		Neutron yield at IP(/cm^{2}y)
e^+e^-:	Old	3x10^7
	New w 2T solenoid	5 x10^7
	New w. CC and QC	7 x10^7
beamstrahllung:	Old	1x10^7
	New	2.5x10^7

Statistical error of new estimate is roughly a few x 10^7 (guess)

New estimate is well below the requirement,

< 1.5x10^{10} n/cm^2

for the CCD vertex detector

Neutron background from other sources are under study.

Conclusion

Beam background simulations with realistic and stronger B fields have been done.

When the B fields of compensation magnet and the quadrapole magnet are taken into account, back scattering of the pair background from the QC to the IR region decreases.

From the study of radiation damage of CCDs and the background simulations, it seems that the innermost layer of the CCD vertex detector put at r=24mm in 2T B field at normal temp. can survive the pair background for one year without any rad. hard technologies.

With stronger solenoid magnet, the vertex detector hit density decreases.
With 3 T, the innermost layer of the vertex detector can be put at r=18mm.

Both simulations based on FLUKA and Maruyama's code on neutron background show that the neutron b.g. is not a serious problem for the vertex detector.
(But may be serious for the CDC.)

To make Rmin smaller, higher B and/or rad. hard technologies of CCDs or low temperature operation is necessary.