LumiCal数据率的估计

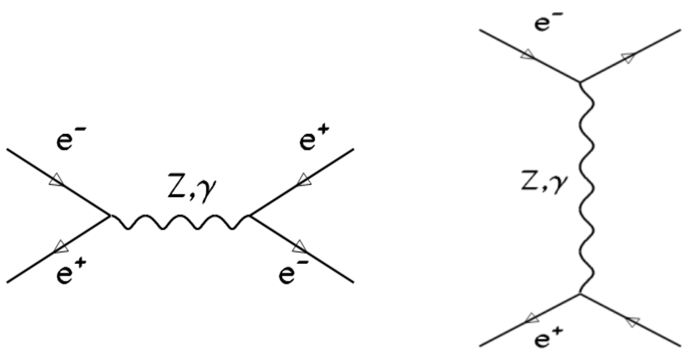
Lei Zhang (张雷)

Based on the work from Suen Hou, Haoyu Shi, Yilun Wang Renjie Ma,

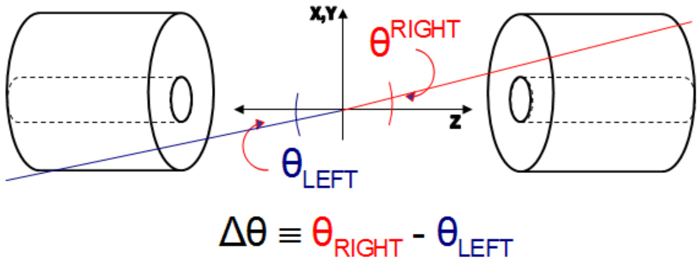
CEPC RefTDR electronics meeting, 28 Mar. 2024

Luminosity measurement

- ***Observable cross section*** $N = \sigma \cdot \int L$ *L: Luminosity of* e^+e^- *collisions*
- ***Luminosity*** measured by counting ***Bhabha*** *events,* QED precision < 0.1%
  - ***a pair of back-back electrons,***
  - ***precision*** ϑ ***on e,e(γ) in fiducial region***



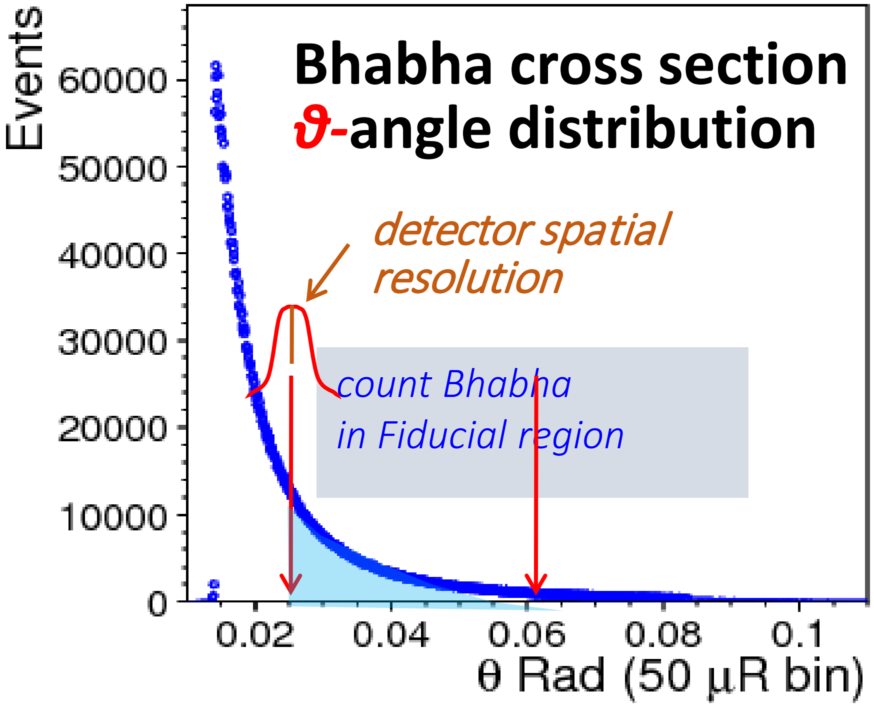
$$e^+e^- \rightarrow e^+e^-(\gamma)$$



Physics request: *Luminosity to* 10^{-4} *precision*

Precision

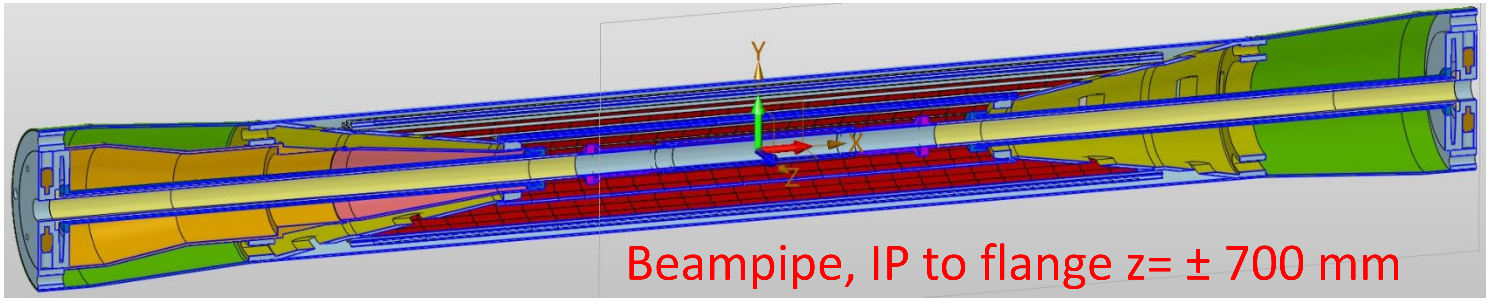
- ***Bhabha systematic error : $\delta L/L \sim 2\, \delta\vartheta/\vartheta_{min}$***
  - **requiring** ***$\delta L/L = 10^{-4}$***
- at **$z = \pm 1$ m, θ_{min} = 20 mRad** → *$\delta\vartheta$ = **1 μRad*** or ***dr = 1 μm***
- error due to offset on Z → ***50 μm*** *on Z eq. $dr = \delta z \times \vartheta$* ***= 1 μm***



Luminosity systematics
due to events in/out fiducial edge
→ offset on the mean of θ_{min}

Geometry

- *L=2x10^36/cm²s¹* **@Z-pole**, goal is *10^-4* systematics
  - ***ø 20 mm*** racetrack, beam-crossing: ***33 mRad***
  - IP bunch : ***σ_x σ_y σ_z = 6 μm, 35 nm, 9 mm***
  - Bunch crossing: ***23 ns***



- ***LumiCal before Flange***

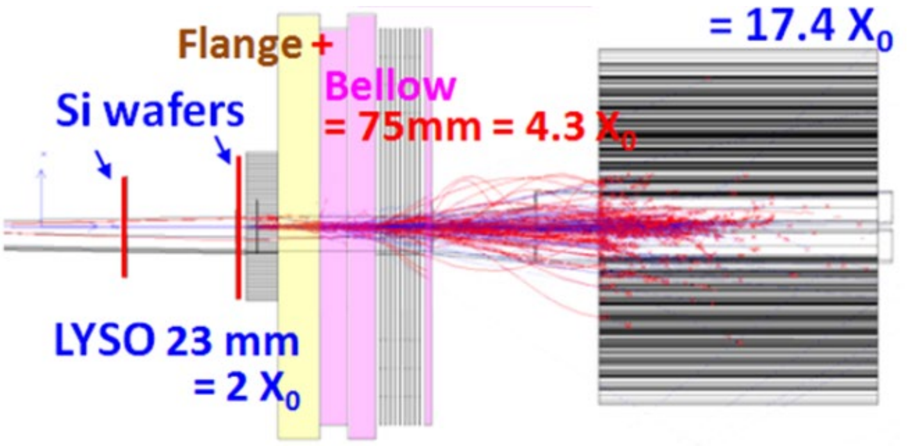
  z = 560~700 mm
  - **Two Si-wafers** for $e^{\pm}$ impact θ
  - **$2X_0$ LYSO** = 23 mm

- ***LumiCal* behind *Flange*:**

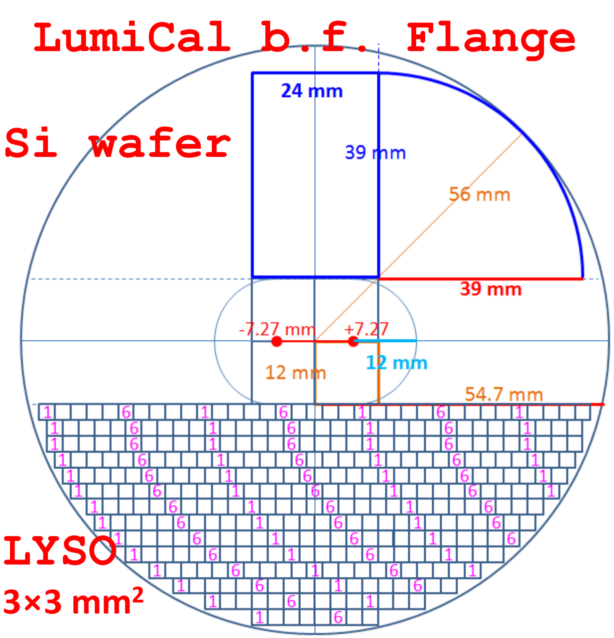
  z= 900~1100 mm
  - **17 X_0 LYSO 200 mm**

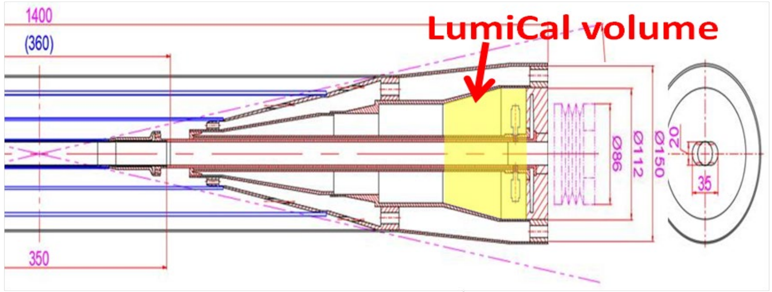
Geometry

- ***LumiCal before Flange***
  z = 560~700 mm
  - **Low-mass window**: **Be 1mm thick**
    traversing @22 mRad traversing L= 45 mm,
    = 0.13 X_0 (Be), 0.50 X_0 (Al)
  - **Two Si-wafers** for $e^{\pm}$ impact θ
  - **$2X_0$ LYSO** = 23 mm

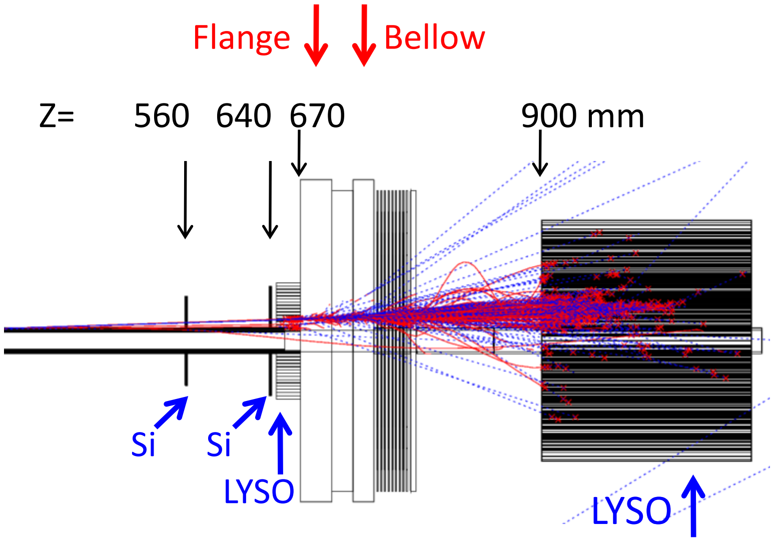


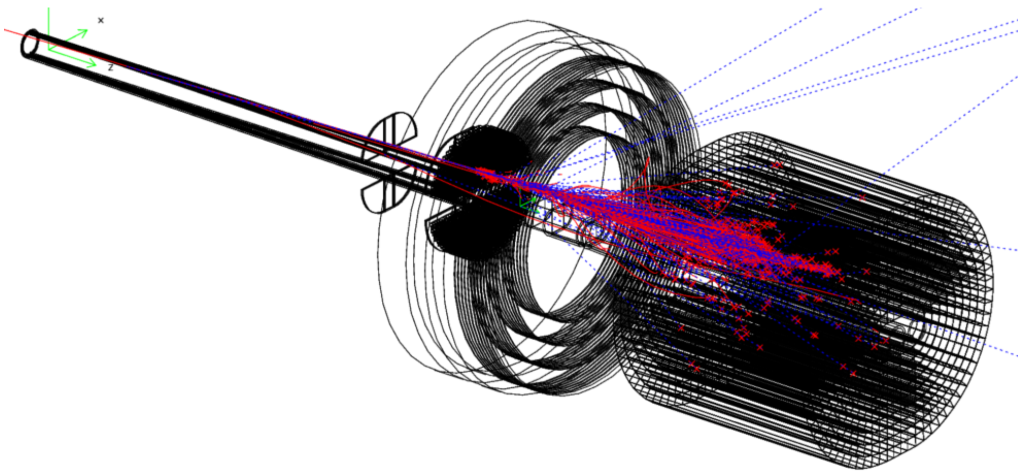
- ***LumiCal* behind Bellow:**
  z= 900~1100 mm
  - **Flange+Bellow : ~60 mm, 6 X_0**
  - **17 X_0 LYSO 200 mm**

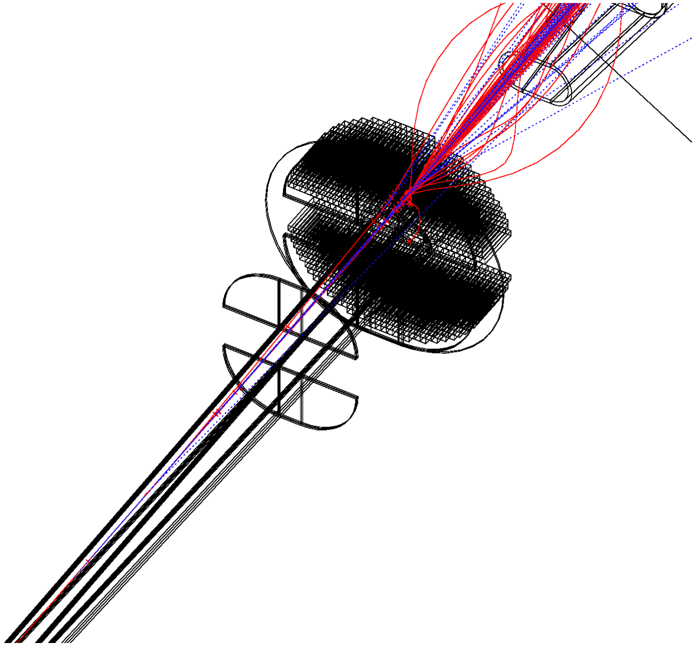




Geometry

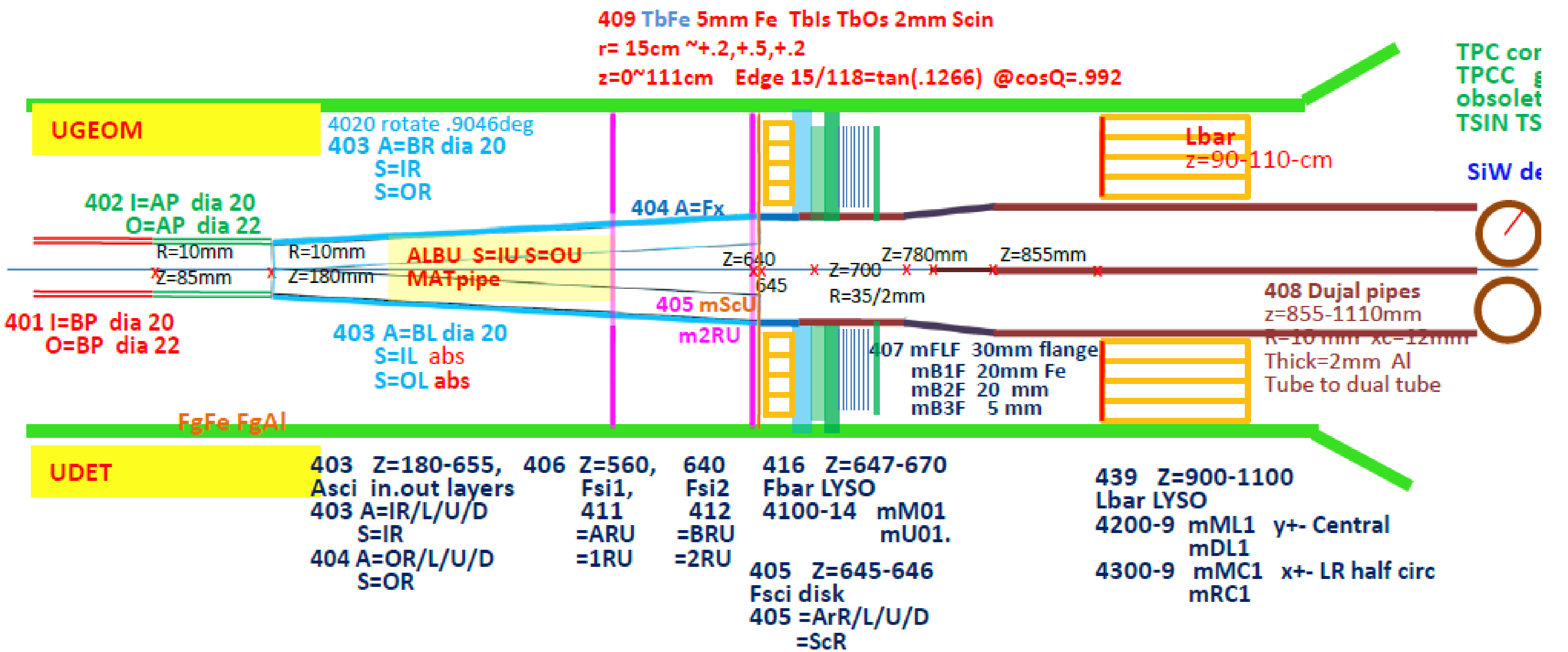






Geometry

- LYSO readout based on SiPM
- Since silicon confront the beam more directly, we focus on the Si Wafer's event rate today.



CEPC Luminosity at TDR

CEPC
Technical Design Report
Accelerator

Table 1.3: Primary CEPC design objectives (@ 30 MW)

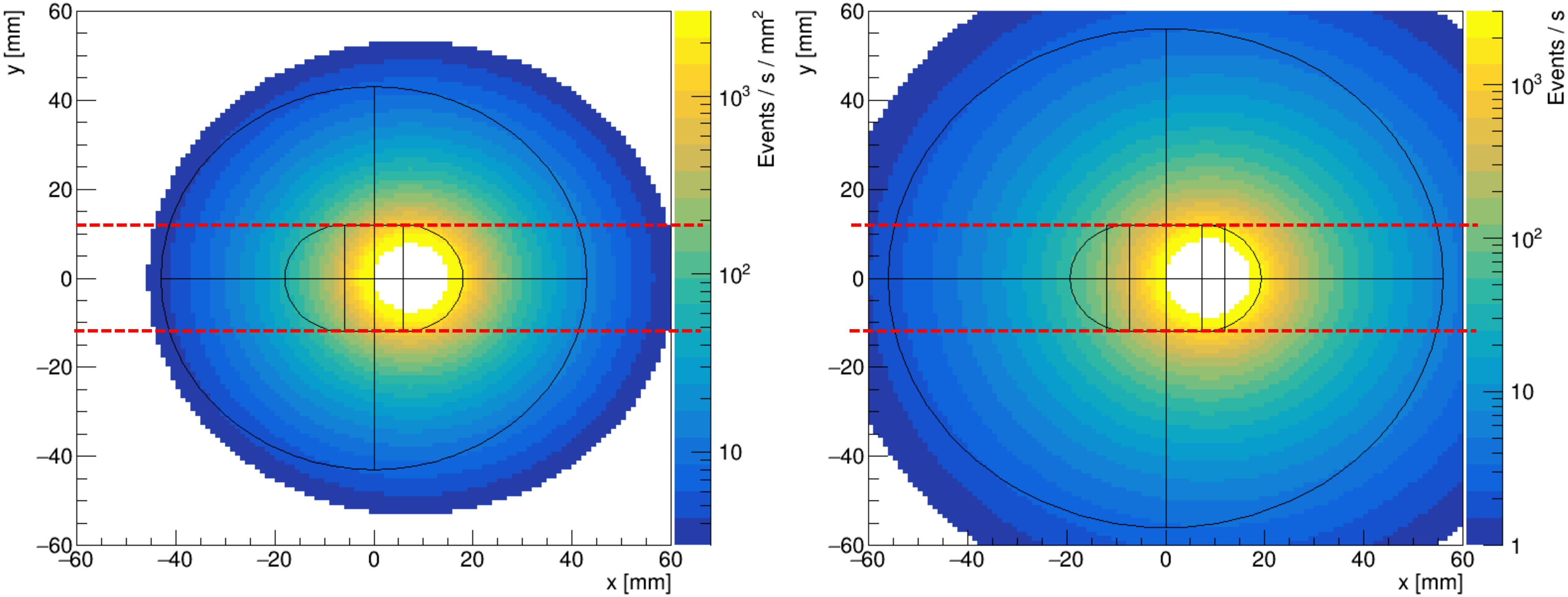
Parameter	Operation mode			
	H	Z	W	$t\bar{t}$
Colliding particles	e^+, e^-			
Center-of-mass energy (GeV)	240	91	160	360
Luminosity (10^{34} cm^{-2}s^{-1})	5	115	16	0.5
No. of interaction points	2			

Table 1.4: Primary CEPC design objectives (@ 50 MW)

Parameter	Operation mode			
	H	Z	W	$t\bar{t}$
Colliding particles	e^+, e^-			
Center-of-mass energy (GeV)	240	91	160	360
Luminosity (10^{34} cm^{-2}s^{-1})	8.3	192	27	0.8
No. of interaction points	2			

Bhabha event rates Z (@50MW)

- Signal rate O(kHz), data rate should around O(Mbps)



硅片1 ($z = 560mm$)

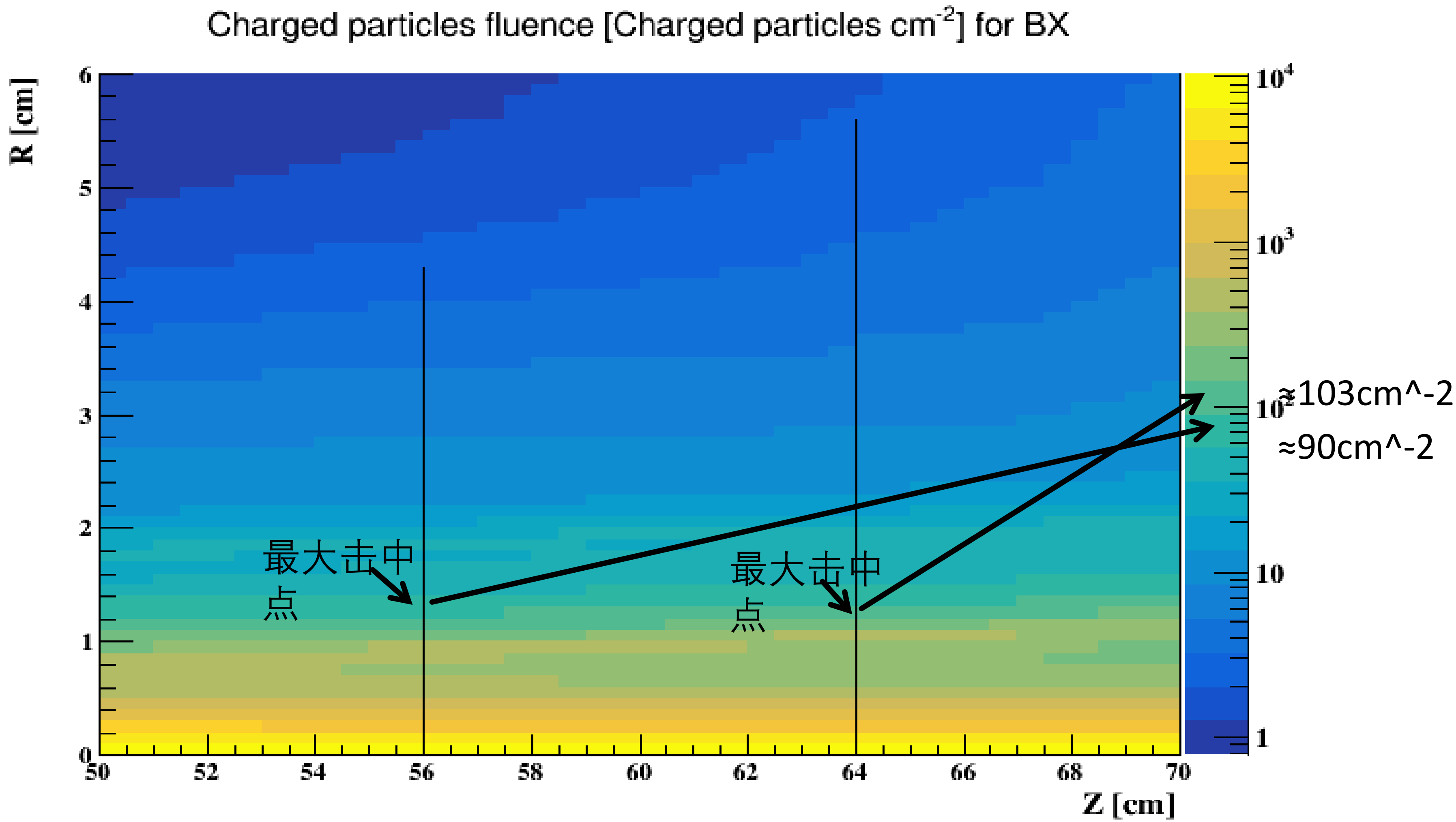
硅片2 ($z = 640mm$)

Background Estimation

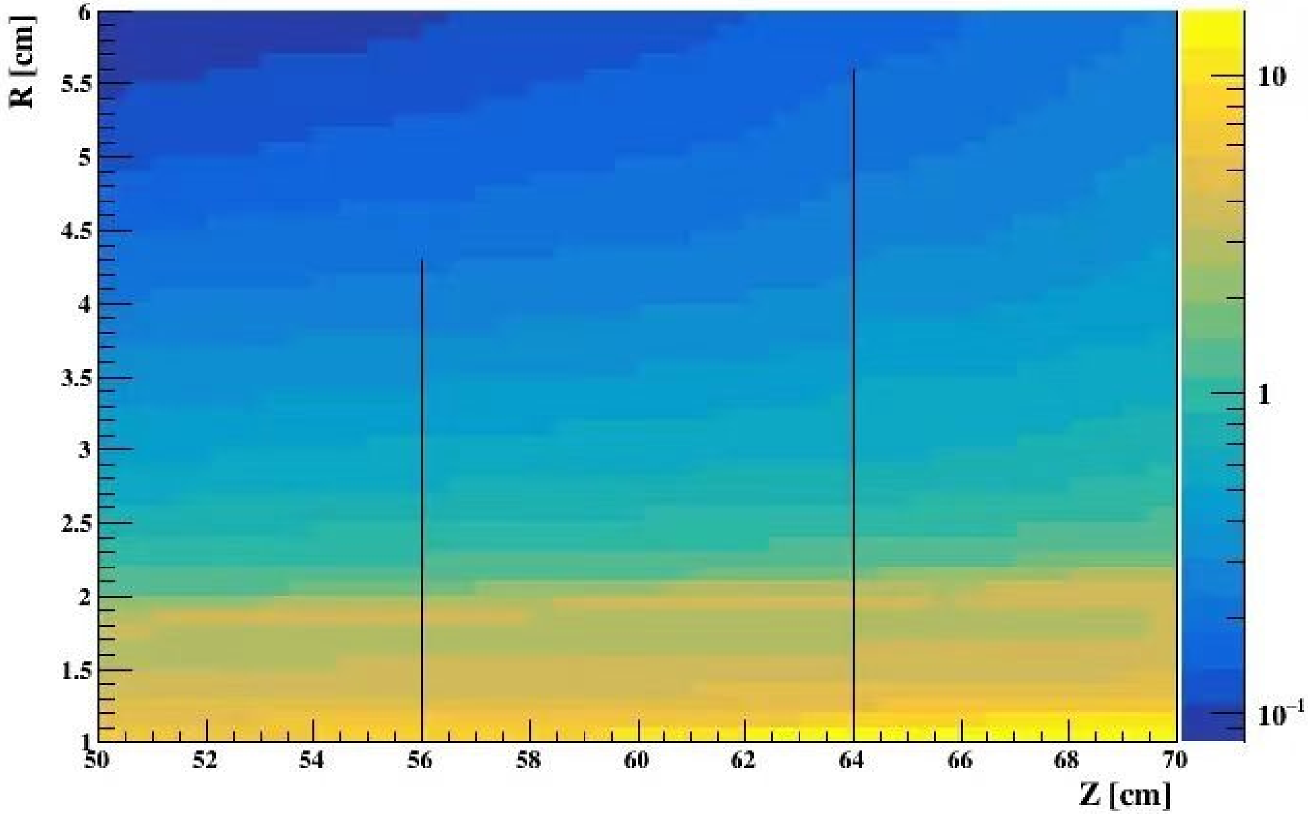
- Single Beam
  - Touschek Scattering
  - Beam Gas Scattering(Elastic/inelastic)
  - Beam Thermal Photon Scattering
  - Synchrotron Radiation
- Luminosity Related
  - Beamstrahlung
  - Radiative Bhabha Scattering
- Injection

Beamstrahlung @ Higgs

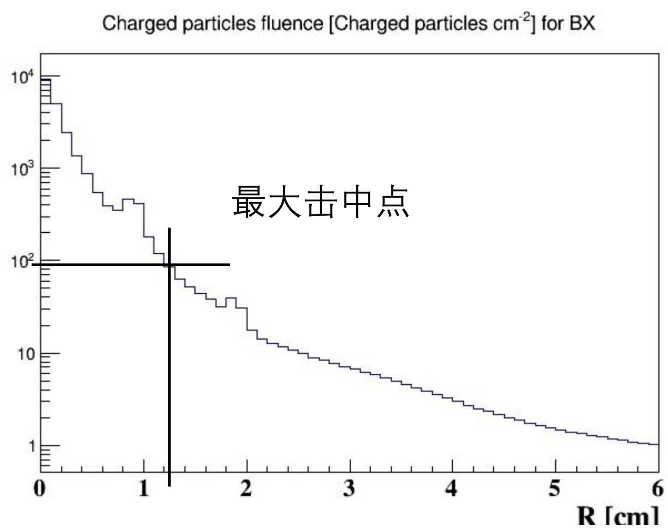
- Dominant background



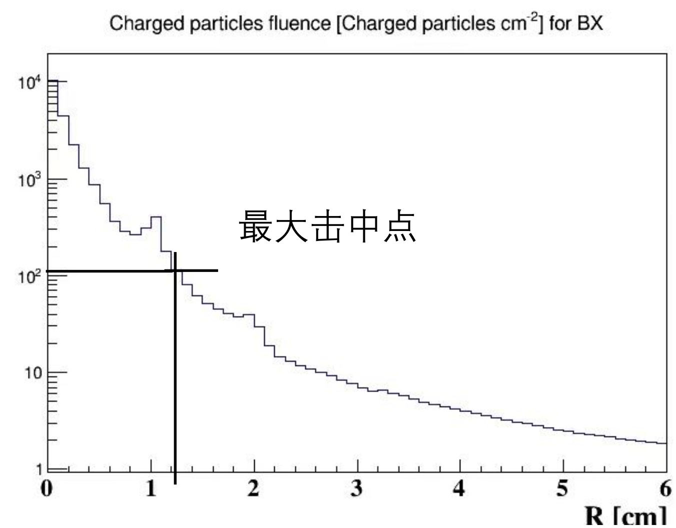
Charged particles fluence [Charged particles cm^{-2}] for BX



Lumical最小半径r=12mm

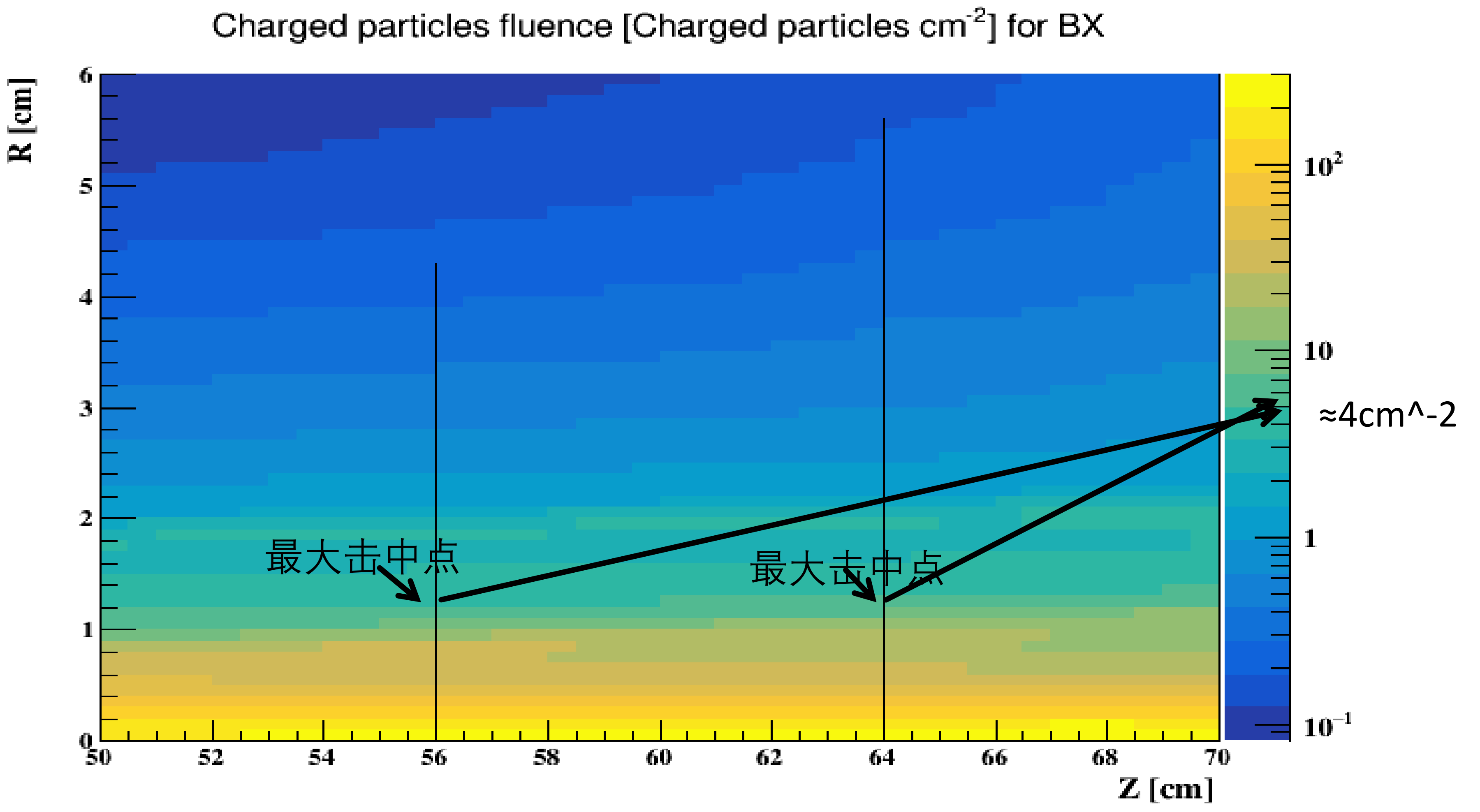


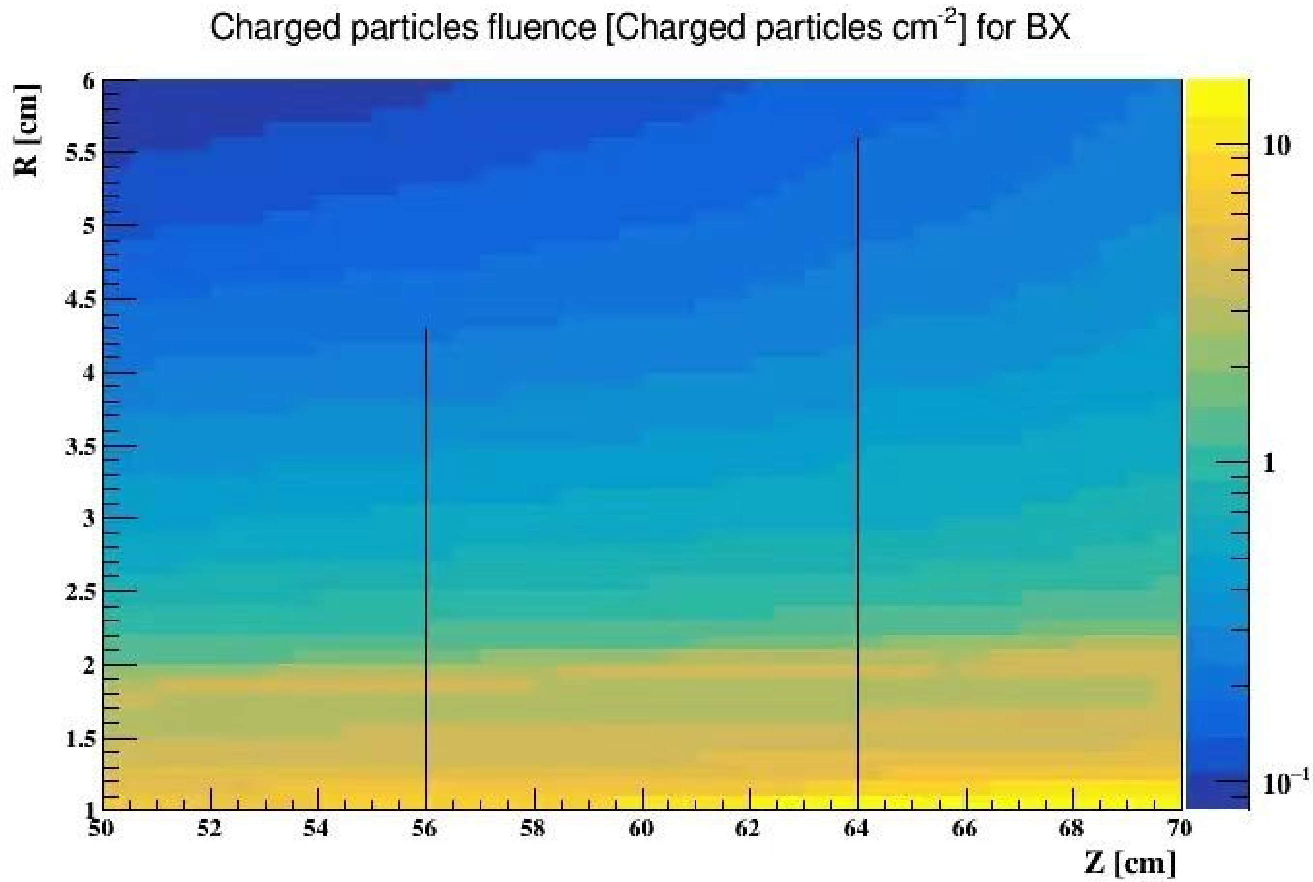
z=560mm



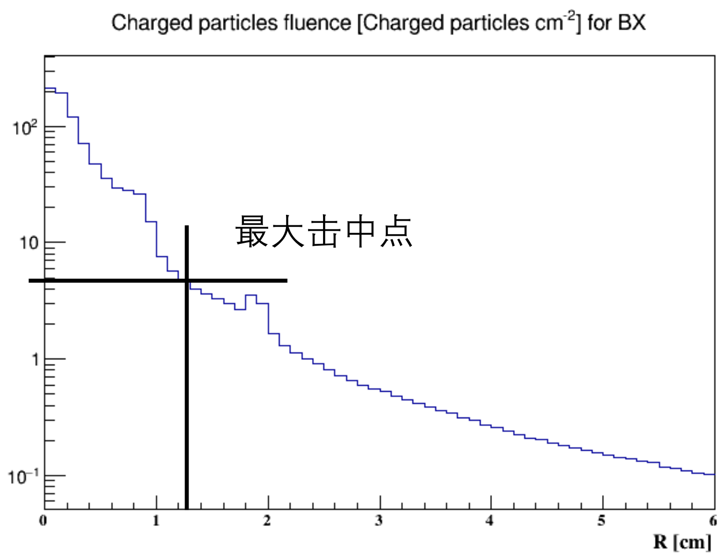
z=640mm

Beamstrahlung @ Z

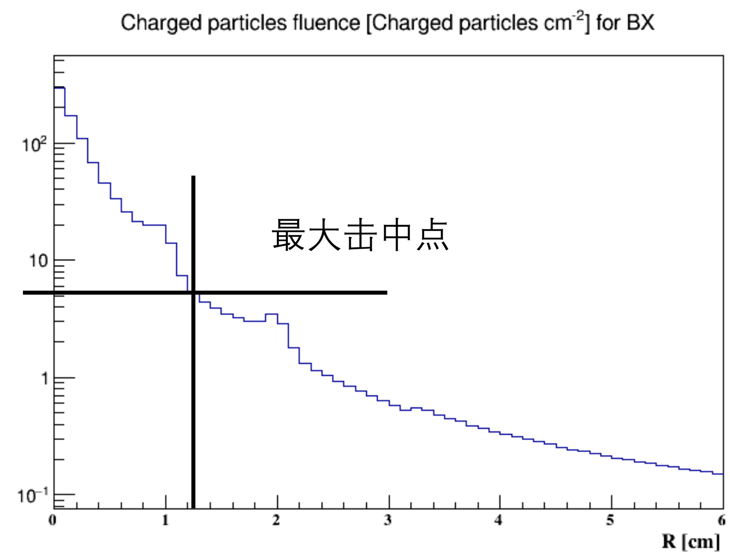




Charged particles fluence [Charged particles cm^{-2}] for BX
R [cm]
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
50
52
54
56
58
60
62
64
66
68
70
Z [cm]
10
1
10^{-1}



z=560mm



z=640mm

Summary

	Higgs	Z
BXRate(Hz)	1.34e6	3.93e7

maxevents	Higgs	Z
z=560mm(Hz/cm^2)	83. 2*1. 34e6=1. 11e8	3. 63*3. 93e7=1. 43e8
z=640mm(Hz/cm^2)	102*1. 34e6=1. 37e8	4. 25*3. 93e7=1. 67e8

- At Z pole, the rate is about 0.17 GHz.
- Assuming 32/48 per hit, the data rate is 5.4/8.2 GBps/cm^2
  - This should be a maximum
- CEPCSW simulation implementation undergoing

Outlook

- Detector precision requirement , i.e. theta, to further studied
- Some physics, e.g. ISR, di-photon, BSM, etc, needs alignment with the whole detector.
  - L1 trigger signal
- Wireless readout for the far side LYSO?