Status and Plan of MDI WP towards CEPC Detector Ref-TDR

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On Behalf of the CEPC MDI&Lumi WP of Detector Ref-TDR

CEPC Day

2024.2.28

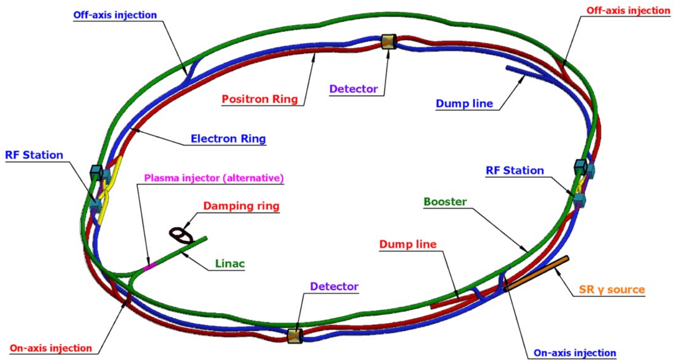
MDI+LumiCal

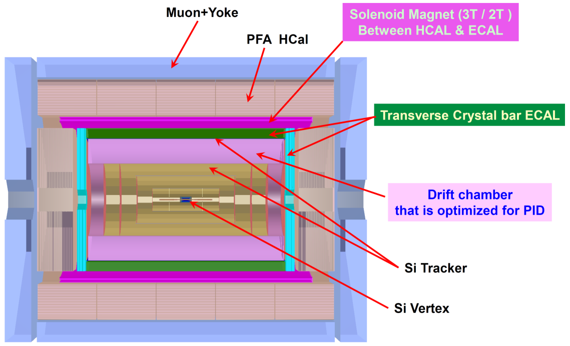
- Interface region with Acc.(Discussion when needed)
- Beam Induced Backgrounds(1 staff+0.2 postdoc+1 undergraduated+2 graduates from det.)
  - Estimation(Simulation) of Impacts and Radiation Environment
  - Software Upgrade/Migration
  - Validation and optimization of the Codes/Results
- LumiCal(Led by Suen/Lei, several students from Nanjing University)
  - Detector Design of the LumiCal
    - Detector Technology/Electronics/Readout…
    - Software/Simulation
  - Interference with other detectors/acc components
- Optimization of Interaction Region/MDI(several staff, including acc.)
  - Shielding for the detectors/detector hall
  - Working together with accelerator colleagues
- Key Technology Issues(2 staffs):
  - Gold Coating
  - The manufacture of Beryllium pipe, including the welding with Al.

Inputs – CEPC MDI

- MDI stands for ”Machine Detector Interface”
  - Interaction Region and other components
  - 2 IPs
  - 33mrad Crossing angle
- Flexible optics design
  - Common Layout in IR for all energies – TDR 50MW
  - High Luminosity, low background impact, low error
  - Stable and easy to install, replace/repair

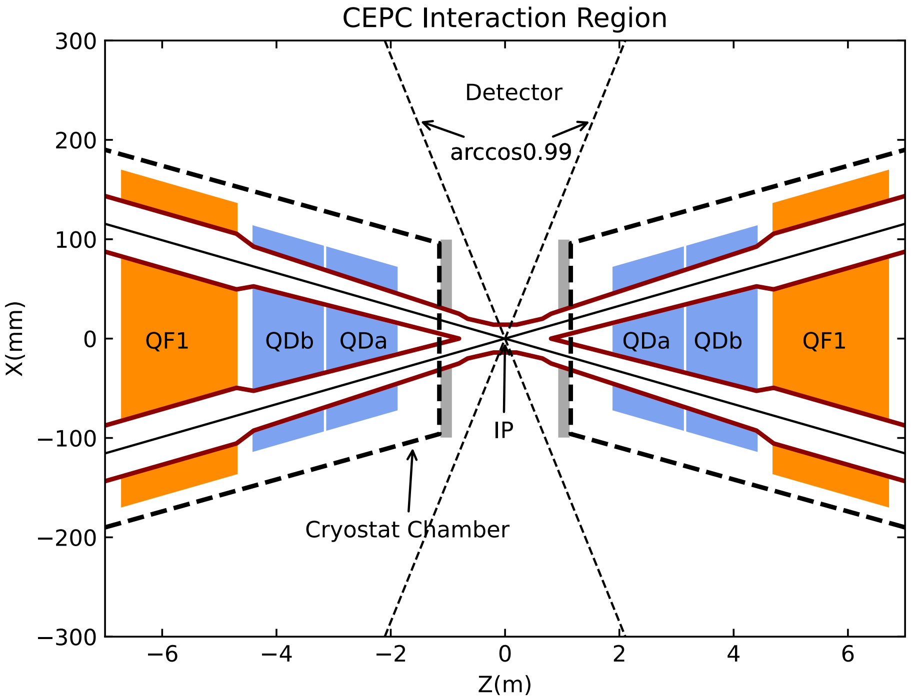
	Higgs	Z	W	$t\bar{t}$
Number of IPs	2			
Circumference (km)	100.0			
SR power per beam (MW)	50			
Half crossing angle at IP (mrad)	16.5			
Bending radius (km)	10.7			
Energy (GeV)	120	45.5	80	180
Energy loss per turn (GeV)	1.8	0.037	0.357	9.1
Damping time $\tau_x/\tau_y/\tau_z$ (ms)	44.6/44.6/22.3	816/816/408	150/150/75	13.2/13.2/6.6
Piwinski angle	4.88	29.52	5.98	1.23
Bunch number	446	13104	2162	58
Bunch spacing (ns)	355 (53% gap)	23 (10% gap)	154	2714 (53% gap)
Bunch population (10^{11})	1.3	2.14	1.35	2.0
Beam current (mA)	27.8	1340.9	140.2	5.5
Phase advance of arc FODO (°)	90	60	60	90
Momentum compaction (10^{-5})	0.71	1.43	1.43	0.71
Beta functions at IP β_x^*/β_y^* (m/mm)	0.3/1	0.13/0.9	0.21/1	1.04/2.7
Emittance $\varepsilon_x/\varepsilon_y$ (nm/pm)	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Betatron tune ν_x/ν_y	445/445	317/317	317/317	445/445
Beam size at IP σ_x/σ_y (um/nm)	14/36	6/35	13/42	39/113
Bunch length (natural/total) (mm)	2.3/4.1	2.7/10.6	2.5/4.9	2.2/2.9
Energy spread (natural/total) (%)	0.10/0.17	0.04/0.15	0.07/0.14	0.15/0.20
Energy acceptance (DA/RF) (%)	1.6/2.2	1.0/1.5	1.05/2.5	2.0/2.6
Beam-beam parameters ξ_x/ξ_y	0.015/0.11	0.0045/0.13	0.012/0.113	0.071/0.1
RF voltage (GV)	2.2	0.1	0.7	10
RF frequency (MHz)	650			
Longitudinal tune ν_s	0.049	0.032	0.062	0.078
Beam lifetime (Bhabha/beamstrahlung) (min)	40/40	90/930	60/195	81/23
Beam lifetime requirement (min)	20	81	25	18
Hourglass Factor	0.9	0.97	0.9	0.89
Luminosity per IP (10^{34} cm^{-2} s^{-1})	8.3	192	26.7	0.8

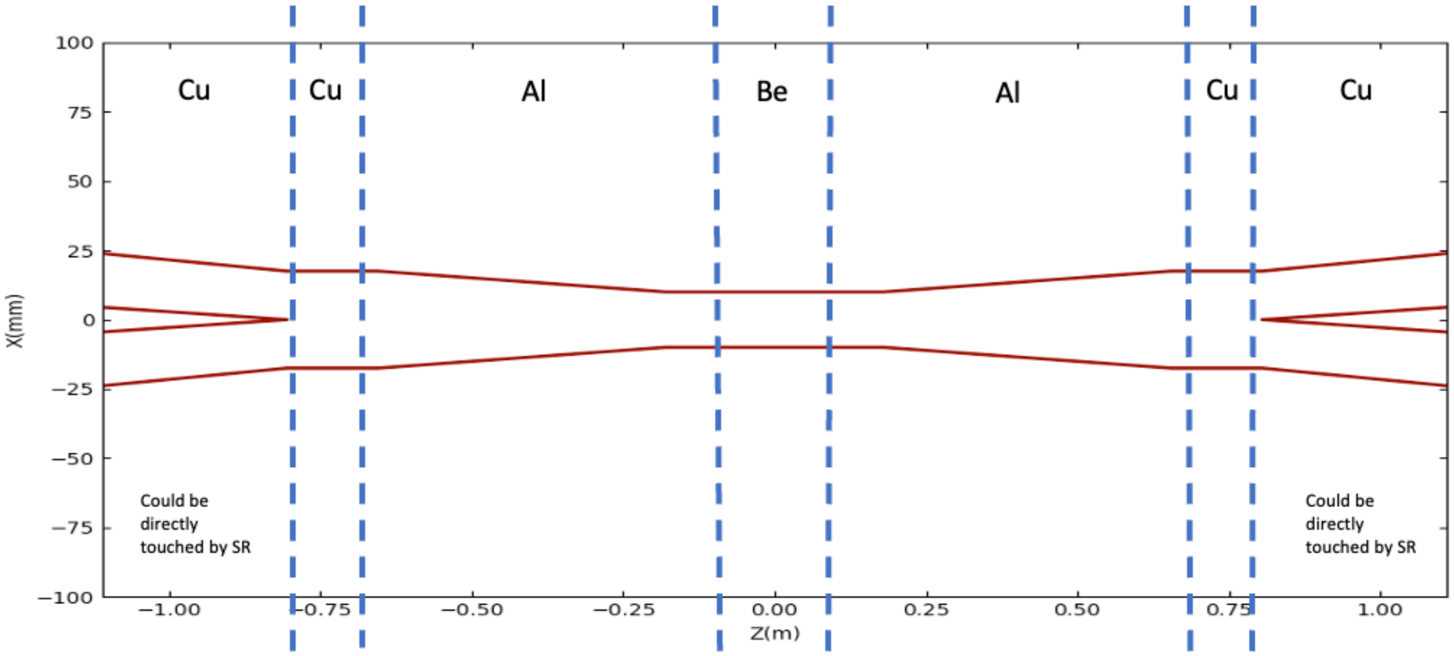




Current Design of the IR

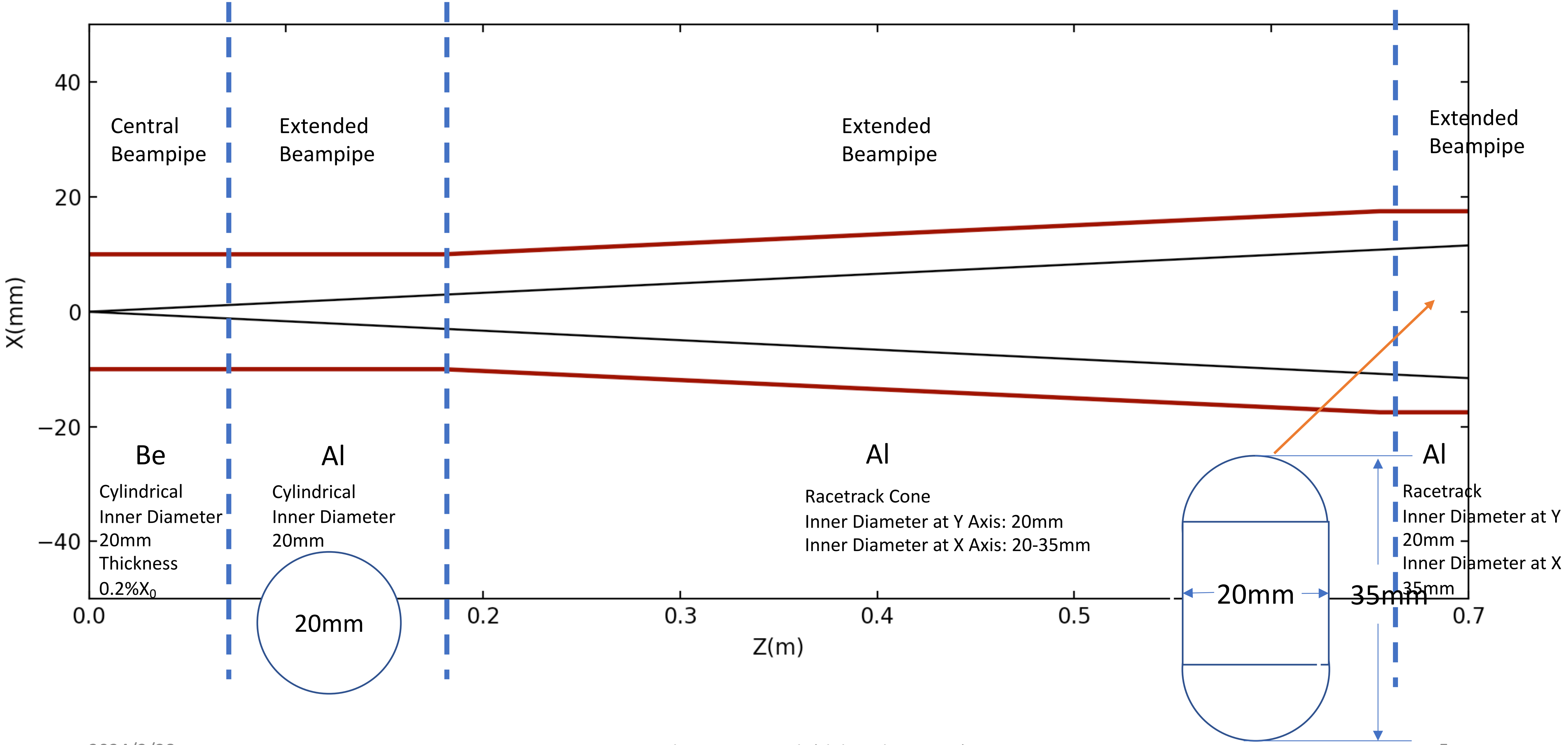
- Interaction Region Layout/Parameters
  - L* = 1.9m / Detector Acceptance = 0.99





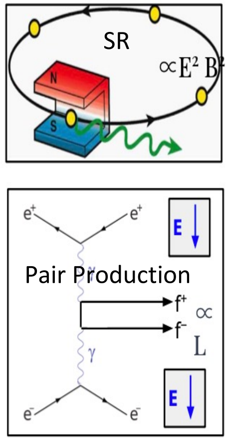
The length of Interaction Region is -7m~7m at TDR Phase

New Beampipe Design – Half Detector pipe



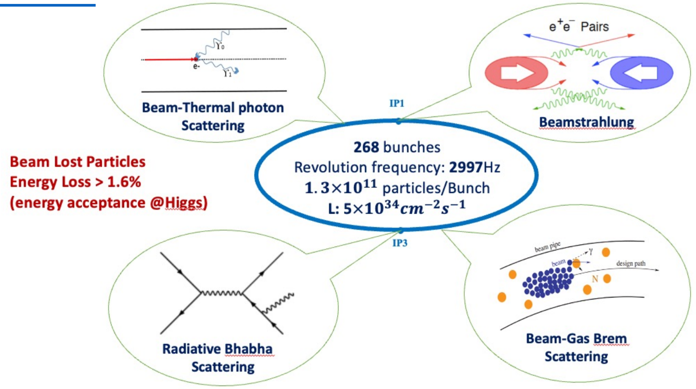
Background Estimation

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



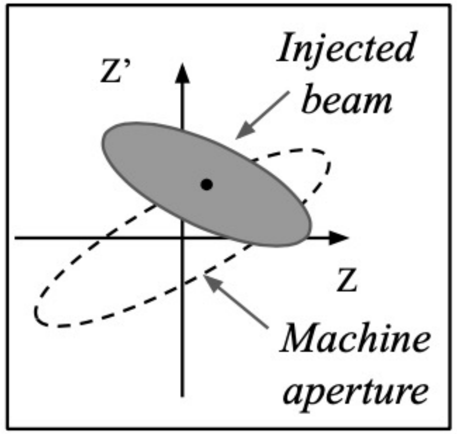
A. Natochii

Photon BG



Beam Loss BG

A. Natochii



Injection BG

Background	Generation	Tracking	Detector Simu.
Synchrotron Radiation	BDSim	BDSim/Geant4	Mokka/CEPCSW/FLUKA
Beamstrahlung/Pair Production	Guinea-Pig++	SAD	
Beam-Thermal Photon	PyBTH[Ref]		
Beam-Gas Bremsstrahlung	PyBGB[Ref]		
Beam-Gas Coulomb	BGC in SAD		
Radiative Bhabha	BBBREM		
Touschek	TSC in SAD		

- One Beam Simulated
- Simulate each background separately
- Whole-Ring generation for single beam BGs
- Multi-turn tracking(50 turns)
  - Using built-in LOSSMAP
  - SR emitting/RF on
  - Radtaper on
  - No detector solenoid yet(Z updating)

Beam Induced Backgrounds

- Estimation of Impacts and Radiation Environment(50MW)
  - First Preliminary version: Using existing geometry in CEPCSoft with beam pipe and inner vertex updated; Focusing on Higgs/Z of vertex; without any safety factor – Early March
  - Implementing BG Simulation in CEPCSW(Generator-like): Before the end of June(Thanks for help from Zhan/Tianyuan)
  - Second Preliminary version: Using new tool/geometry; all 4 modes; without any safety factor – Late July/Early August
  - Optimization of the IR layout/configuration…(need help from all sub-D)
  - Final Ref-TDR version: Based on CEPCSW; all 4 modes; with optimized safety factor if possible-- Late October/Early November
- Offering BG samples for mixing/detector optimization: when needed, data saved as database, mixing in hit level
- Validation of the tool/simulation: Using BII/BIIU this year.
- Manpower: Haoyu Shi, Zhan Li(CEPCSW), Tianyuan Zhang(CEPCSW), Wei Xu(CEPCSoft), Qiying Huang(CEPCSoft)

Beam Induced Backgrounds

- Current Status towards First Pre. Version(Based on CEPCSoft):

Background	Mode	Generation	Tracking	Noise Estimation	Rad. Da. Esti.	Rad. Env. Esti.
Synchrotron Radiation	Higgs	To do	To do	To do	-	-
	Z	To do	To do	To do	-	-
Beamstrahlung/Pair Production	Higgs	Done	-	Doing with VTX	Doing with VTX	-
	Z	Doing	-	Doing with VTX	Doing with VTX	-
Beam-Thermal Photon	Higgs	Done	Done	Doing with VTX	Doing with VTX	-
	Z	Done	Done	Doing with VTX	Doing with VTX	-
Beam-Gas Bremsstrahlung	Higgs	Done	Done	Doing with VTX	Doing with VTX	-
	Z	Done	Done	Doing with VTX	Doing with VTX	-
Beam-Gas Coulomb	Higgs	Done	Done	Doing with VTX	Doing with VTX	-
	Z	Done	Done	Doing with VTX	Doing with VTX	-
Radiative Bhabha	Higgs	-	-	-	-	-
	Z	-	-	-	-	-
Touschek	Higgs	-	-	-	-	-
	Z	Doing	Doing	To do	To do	-

LumiCal

- After lots of iteration(>10 times) in last three years, currently we have baseline detector ready.

Suen Hou

LumiCal in GEANT

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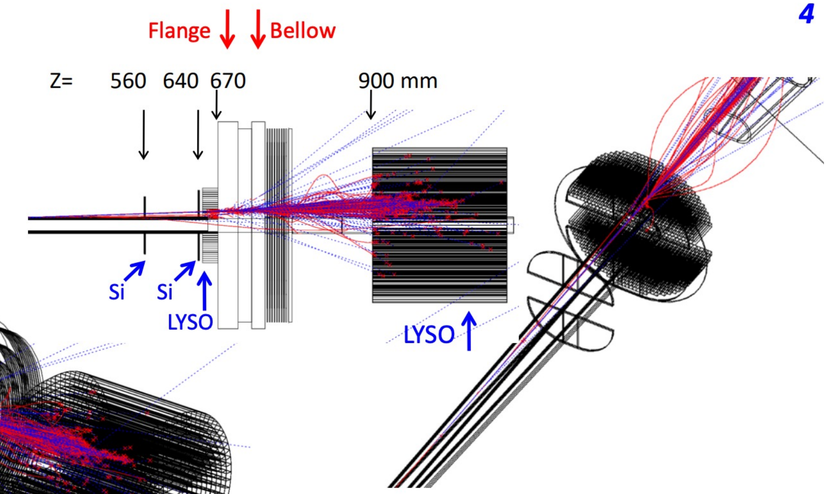

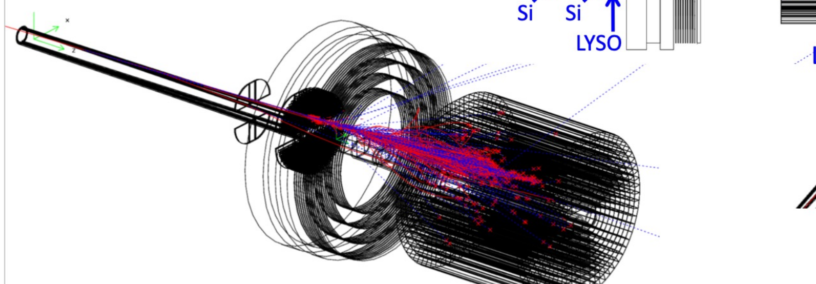

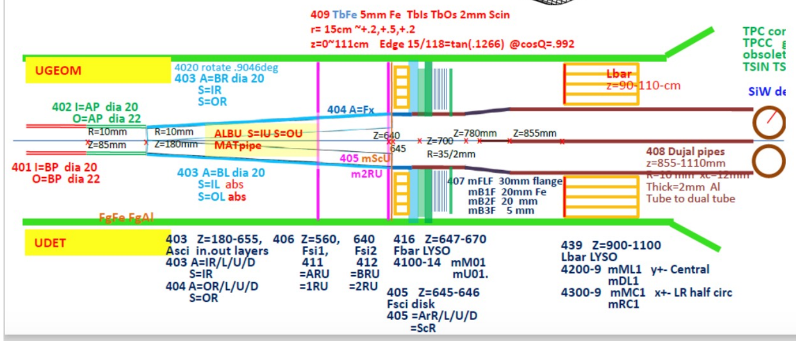

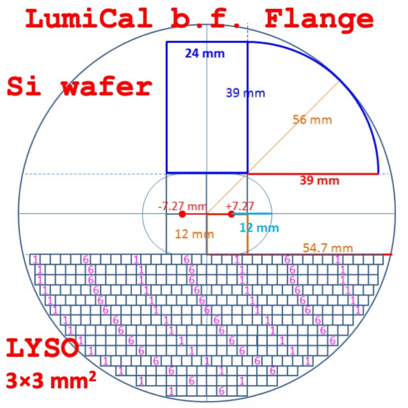

LumiCal geometry

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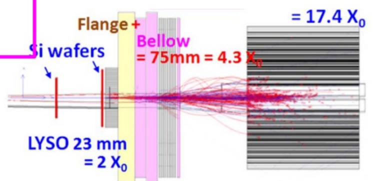
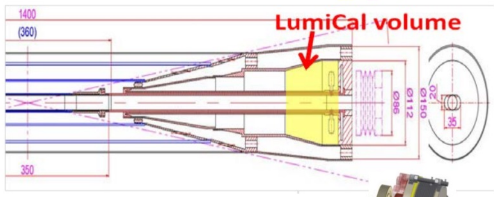
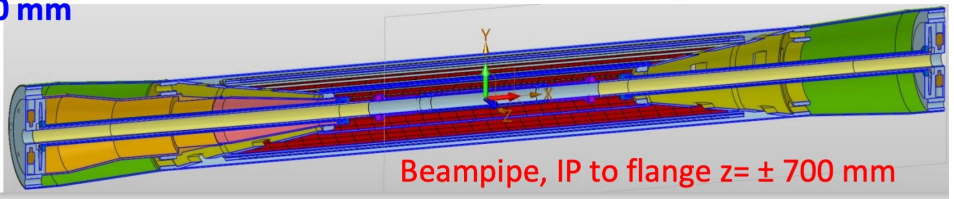
- ➢ ***L=2x10^36/cm²s¹* @Z-pole**, goal is ***10^-4*** systematics
  - ***ø 20 mm*** racetrack, beam-crossing: ***33 mRad***
  - IP bunch : ***σ_x σ_y σ_z = 6 μm, 35 nm, 9 mm***
  - Bunch crossing: ***23 ns***
- ➢ ***LumiCal before Flange***
  - z = 560~700 mm
  - **Low-mass window**: **Be 1mm thick**
    - 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**







LumiCal

- Remaining tasks
  - Requirement/Goal: 1e-4 precision measurement of integrated lumi; fast meet the requirement from acc/lumical.
  - CAD Drawing of latest design, then implement to CEPCSW together with MDI Geometry
  - Simulate the updated beampipe with the electron and photon from Bhabha
  - Finalize the design of the tracker and the EM calorimeter, logically consistent
    - The silicon/diamond tracker and crystal detector of the LumiCal will closely following the central detector
  - Finalize the readout electronics/TDAQ
  - Simulation studies to be finished by September to October 2024
  - Test beam or cosmic ray studies using particle telescope to validate the simulation of the beam pipe interacting with electron/photon
  - Manpower: Suen Hou, Lei Zhang, Weiming Song and Several students from Nanjing/Jilin University: Yilun Wang, Chuanye Wang, Junhui Yang, Jiading Gong, Xingyang Sun, Gaodeng Fan, Jialiang Chang and Guangyan Xiao

TOC of Ref-TDR

- One whole Chapter(same with CDR): Machine Detector Interface and Luminosity Detectors (Haoyu/Suen/Sha)
  - Introduction & Requirements
  - IR Layout(Haoyu/Sha/Quan/Haijing)
  - Key design/parameters(beampipe, final focusing, etc..)(Haoyu/Sha/….)
  - Detector/IR Backgrounds(Haoyu)
    - Introduction
    - Shielding Design/mitigation methods
    - Estimation
  - Luminosity Measurement System(Suen/Lei/Weiming)
  - Summary & Outlook
  - Ref. List

Thank You

Backup

Table updated on 1st Vertex Layer

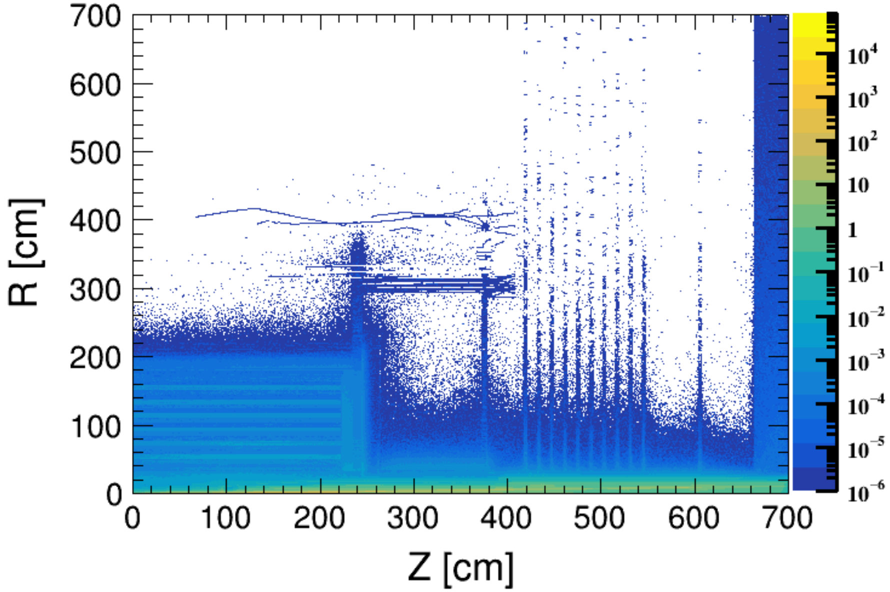
- Still Preliminary, without safety factor. Currently assuming 10000000s running time per year. Calculating based on the TDR value of Luminosity.

	Higgs	Z
BXRate(Hz)	**1.34e6**	**3.93e7**

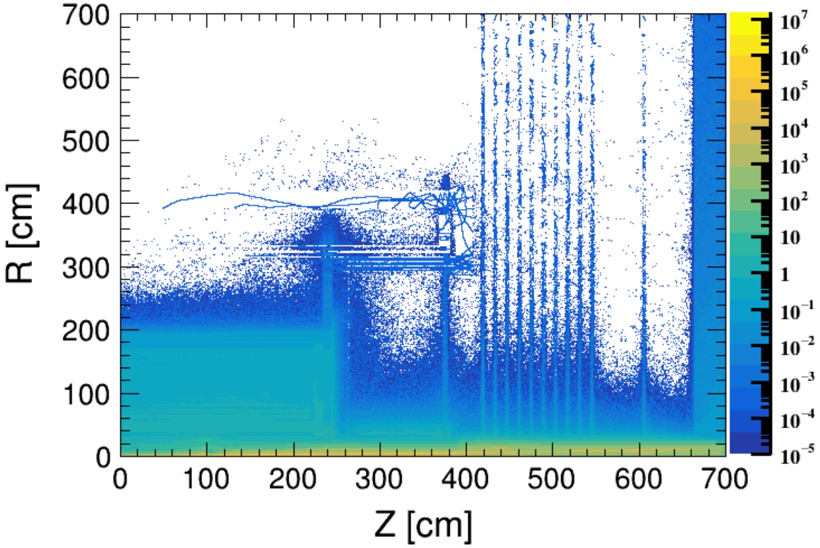
Background	Hit Density($cm^{-2} \cdot s^{-1}$)		TID($Mrad \cdot yr^{-1}$)		1 MeV equivalent neutron fluence ($n_{eq} \times 10^{12} \cdot cm^{-2} \cdot yr^{-1}$)	
	Higgs	Z	Higgs	Z	Higgs	Z
Pair production	2.95e5	9.83e6	3.2	3.5	44.23	0.11
Beam Loss						
Total						

Figure of Pair Production

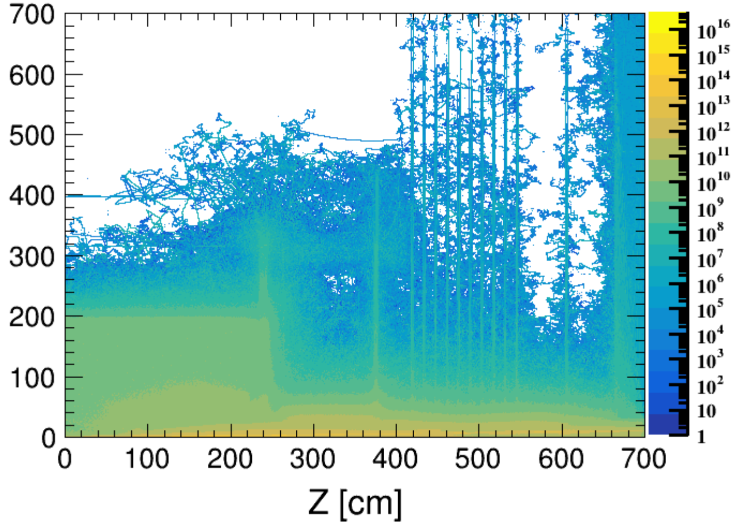
Charged Particle fluence/BX



TID krad/yr



1 MeV eq. Si. Neutron Fluence /yr



Next Step

- Action items:
  - Discussion on mechanical drawings with accelerator people, this Thursday afternoon
  - Updating the BG Table using CEPCSoft, with help from detector designers
  - Migrate to CEPCSW:
    - Training on geometry implementation of CEPCSW
    - Algorithms in CEPCSW to get hit rate/occupancy