2025.9.30

Discussion on Safety Factor

Safety Factor

- There is a discussion on safety factor after the IDRC Review Meeting last Wednesday.
- The initial statement is we keep no extra safety factor(sf=1) based on the BESIII study shown in TDR Sec 3.3(also published in NIMA)
- But BESIII study only considered the single beam loss(TSC+BGS), SR should be also included in experiment but not in simulation.
- At CEPC, the pair production is the dominate BG process.
  - For 1st layer VTX,

	Total	Pair	Single Beam Loss	SR
Higgs 50MW Ave	2.7 MHz/cm2	2.67 MHz/cm2	~0.01 MHz/cm2	~ 0.02 MHz/cm2
LZ 12.1MW Ave	7.3 MHz/cm2	~7.2 MHz/cm2	~0.08 MHz/cm2	< 0.01 MHz/cm2

- We plan to analysis through cross-section, beam condition and material effects.

Pair Production – Cross Section

- Three processes:
  - Breit-Wheeler (BW): Two real photons
  - Bethe-Heitler (BH): One real, one virtual
  - and Landau-Lifshitz (LL): Two virtual
- We are using Guinea-Pig++ as the generator
  - In the paper written by the author of Gienea-Pig++(GP), CAIN and BDK used for comparison
- BDK is a generator could be used to calculated LL process
  - Prof. Haibo Li told us BDK could be treated as “right” for LL
  - We are using the paper results

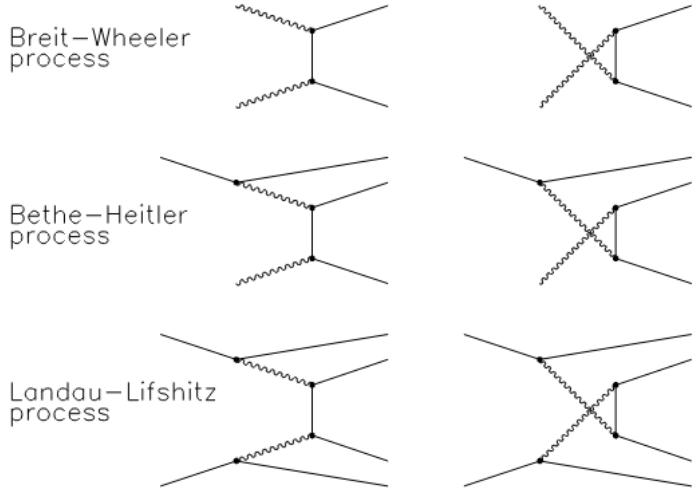
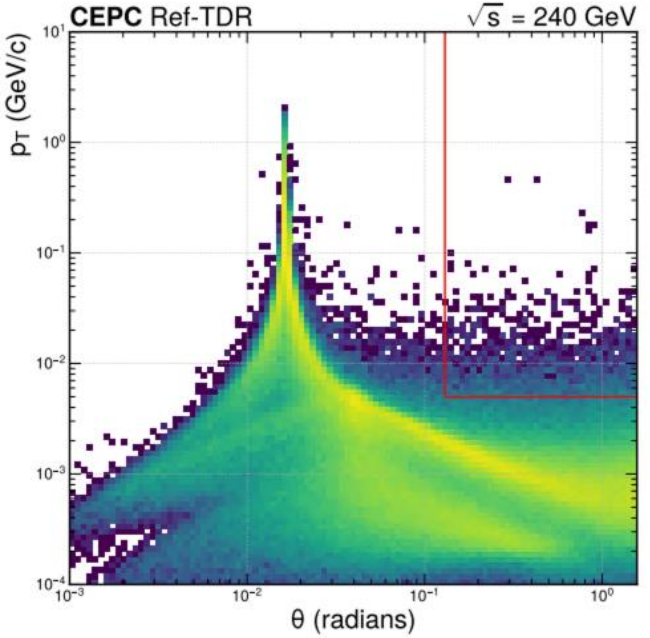


Figure 4.1: The incoherent pair production processes.



Pair Production – Cross Section

- In paper, they have two different comparisons:
  - Total cross section between GP and BDK
  - The cross section of VTX region(Pt > 5 MeV and θ > 10°)
- If we consider the total cross-section, GP results is higher than BDK(~7%). That's means the cross-section calculation is conservation.

TABLE III. Cross sections for incoherent pair production without finite beam-size suppression effects in GUINEA-PIG, CAIN, and BDK

σ (mb)	GUINEA-PIG	CAIN	BDK
All processes	101	89.5	
Breit-Wheeler	1.01	1.11	
Bethe-Heitler	66.3	61.7	
Landau-Lifshitz	33.9	26.7	31.8

Pair Production - Cross Section

- However, if we consider the cross-section within the VTX region((Pt > 5 MeV and θ > 10°), the GP result is lower than BDK
  - The uncertainty is ~ 43% if we also consider the stats error listed in this table.
  - It is an underestimation.
  - At CEPC, the VTX region is θ > 8.1°

TABLE IV. Cross sections for the pair background reaching the VD predicted by GUINEA-PIG, CAIN, and BDK, with (upper lines) and without (lower lines) the "beam-size effect."

σ (μb)	GUINEA-PIG	CAIN	BDK
All processes	64.1 ± 5.9	37.4 ± 4.5	
	60.5 ± 6.0	36.5 ± 4.5	
Breit-Wheeler	8.2 ± 2.1	6.4 ± 1.9	
	10.3 ± 2.4	7.0 ± 2.0	
Bethe-Heitler	26.6 ± 3.8	20.9 ± 3.3	
	20.5 ± 3.3	16.6 ± 3.0	
Landau-Lifshitz	29.3 ± 4.0	10.2 ± 2.3	
	29.7 ± 4.0	13.4 ± 2.7	37.5 ± 5.3

Pair Production – Cross Section and Beam

- Cross Section:
  - Currently, we are doing the generation in GP with P $\geq$ 0.511 MeV and no angle cut in setting
  - Therefore, the uncertainty for LL might be less than 43%
  - But we have no further information, than we keep 43%, and use this number for the other two processes.
- Beam Parameter Change:
  - The increase is at the level of 1%

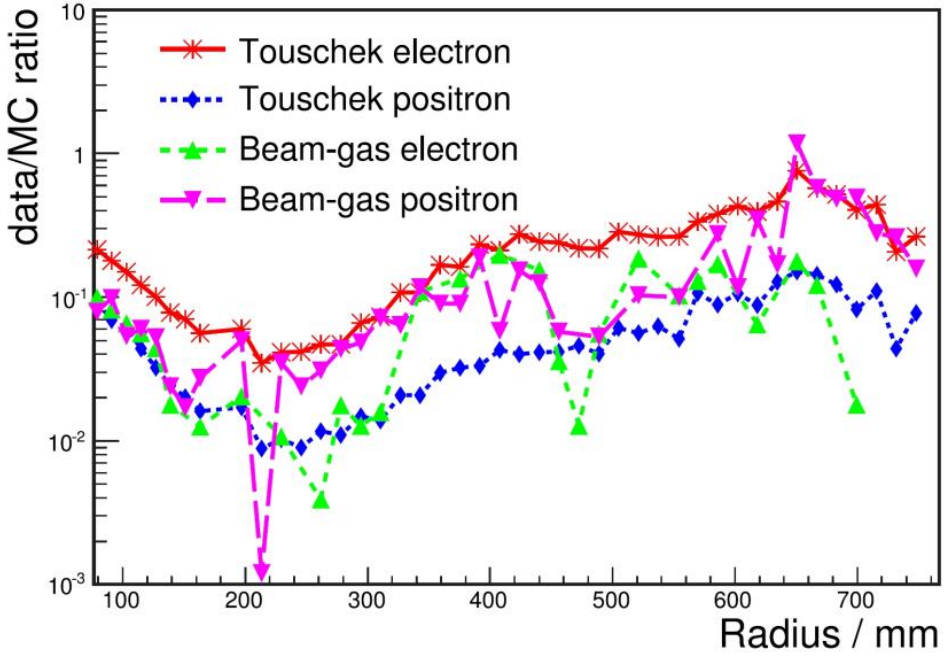
Change of the Beam Condition	Results
0.1 mm offset at the IP	< 0.2%
0.5 mrad offset at the IP at X axis	~ 1%
1 mrad offset at the IP at Y axis	- 90%
Sigma_X 2x	- 20%

Pair Production – Material and Total

- The material safety factor is for the lacking of the material in simulation, or the geometry is missing some of the detail information.
- For FCC, they have a SF of 3 due to the material effects.
- For CEPC, comparing with the design, the geometry in CEPCSW is already with lots of detail, so we can expect a lower SF due to material effects.
- Therefore, for pair production, we could have
  - SF of 1.5, only consider cross-section, claim material is considered in Geant4
  - SF of 2, consider cross-section for 45%, and material for another 40%

Single Beam Loss

- Consider BGS/BTH/TSC together
- We are using the same formula-based generator and the same accelerator tracking tool(SAD) with BESIII
  - Therefore, based on BESIII results published in NIMA, the simulation is generally speaking > 5x higher than data, we could argue that current simulation is conservative.



SR

- Currently, we got a total hit rate in VTX region is 5.5kHz/cm2, while the 1st layer is 0.02MHz/cm2. We don't see SR in other detectors.
- We already simulated 10 sigma in transverse distribution.
  - We also changed the position offset for 0.1mm at the entrance of Dipole and quads. We do not see increase in simulation.
- We know that we still needs to improve the stats, and the are lacking of the study on the real anti-solenoid distribution
  - We are now having a 0~3T change at the edge of coil region, which we do see photon emitted in simulation, but the number / energy is different from the real case
- Therefore, we propose a SF of 10 for SR
  - Even with a SF of 10 taken into account, the VTX 1st layer is 0.2MHz/cm2, still small comparing with Pair.

New Number with SF

- Therefore, the SF choice could still be dominated by Pair Production.
  - The SF of 10 for SR is considered.
- We can still take the 1st layer of VTX as example.[MHz/cm2]

	Current Number	SF 1.5	SF 2.0
Higgs – 50MW - Ave	2.8	4.3	5.6
Higgs – 50MW -Max	5.1	7.6	10.2
Higgs -30 MW - Ave	1.7	2.6	3.4
Higgs -30 MW - Max	3.1	4.7	6.2
LZ – Ave	7.3	11	14.6
LZ - Max	19	29	38