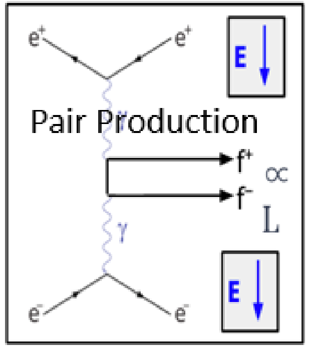
# Beamstrahlung/Pair Production

Wei Xu, Yanbang Tang

- Incoherent Pair Creation/Two photon…
- Charged Particles attract by the opposite beam emit photons(beamstrahlung), followed by some processes including the electron-positron pair production.
- Using Guinea-pig++(v1.2.1) as the generator
  - Same as FCC-ee, ILC and CLIC.
  - Implementing the external magnetic field by code updating by Wei Xu. FCC-ee doesn't considered this yet, therefore they need to trace the particles back.
- The generator using center-of-mass frame, performing the interaction slice by slice using macro particles.
- 1 BX at Higgs runs 8 hours.
- The average number of primary beam particles lost per second is ~9e9(according to the beam life time of 40min).
- The average number of electrons/positrons generated per BX is ~1300(with the threshold of 5MeV).
- Currently, we are working on understanding the code, and the integration to APES together with acc. colleagues.

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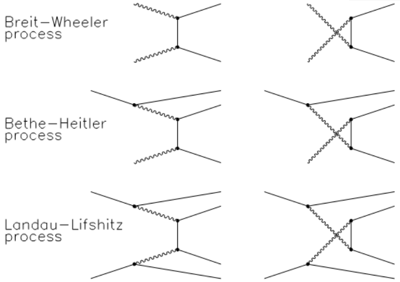
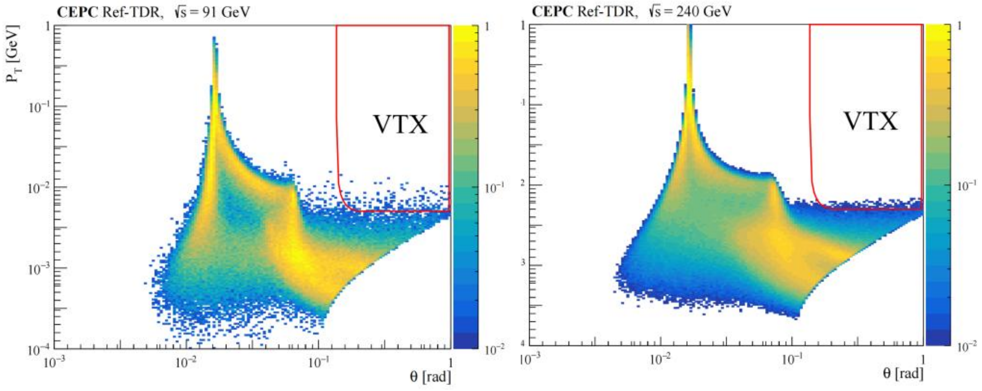
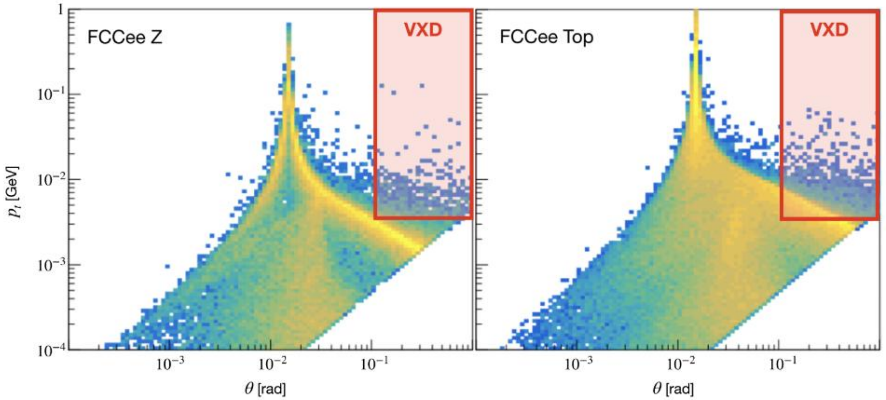



**Figure 4.1:** The incoherent pair production processes.



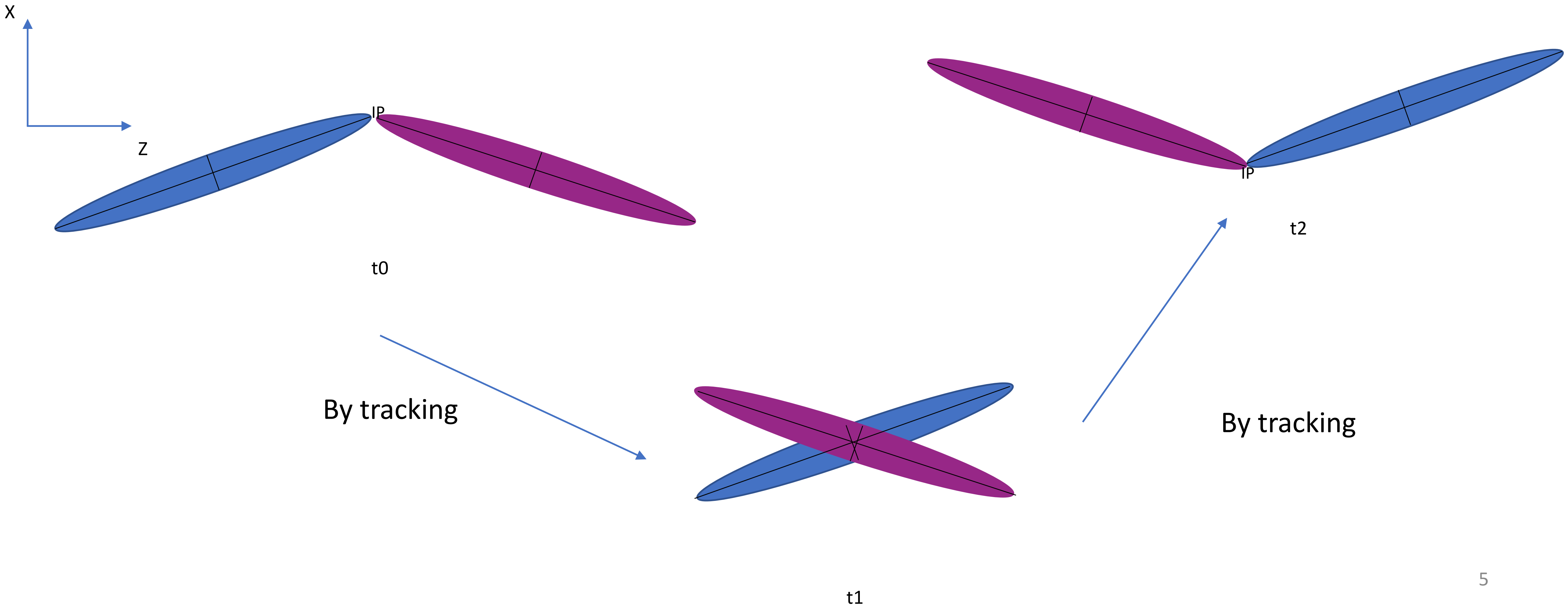




FCCee Results

# How GP++ works - I

Wei Xu, Yanbang Tang

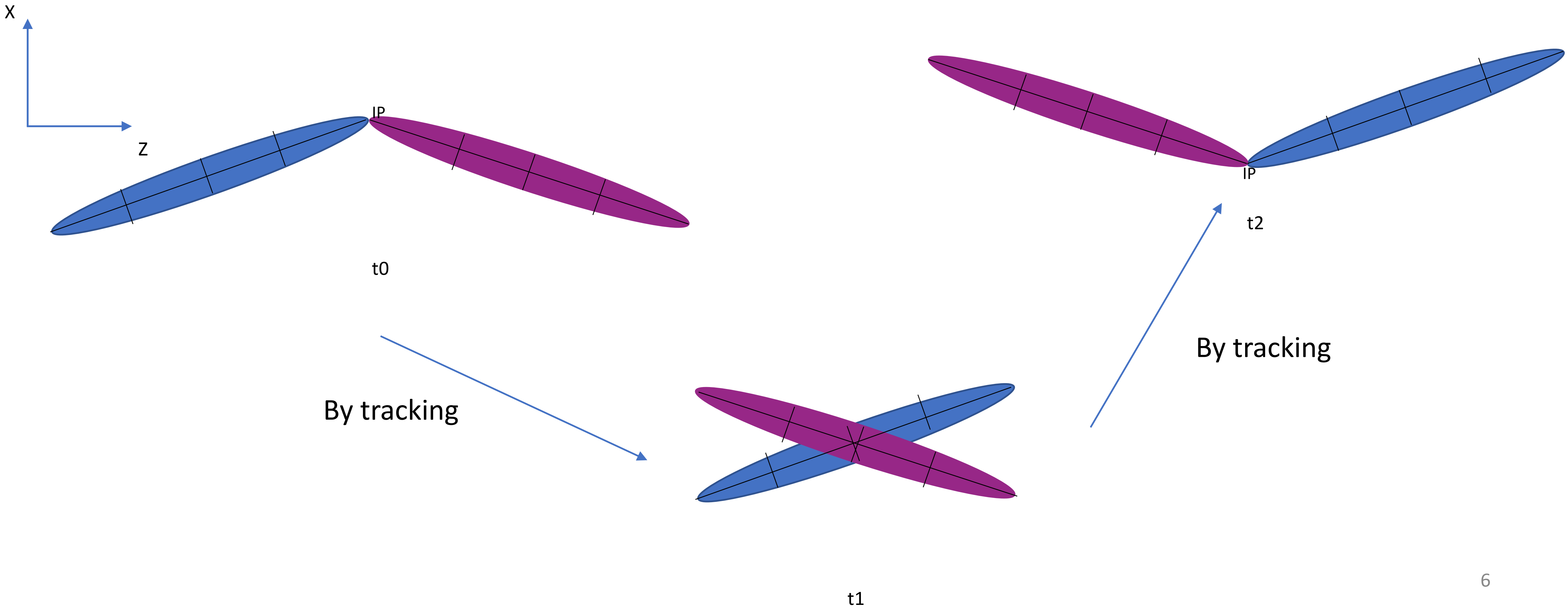
- How the calculation been performed?
  - By time slicing, and gird by gird simulation using macro particles(macro particle = 50000)
  - There are two kinds of parameters, the range of computing, and the number of bins in 4D (X,Y,Z,t).
  - Let’s assume X=Z=2, Y=1, t=3. Pink is a positron bunch, blue is electron.
  - The grid interacts 2*2*2*2*3=48 times.



# How GP++ works - II

Wei Xu, Yanbang Tang

- How the calculation been performed?
  - By time slicing, and gird by gird simulation using macro particles(macro particle = 50000)
  - There are two kinds of parameters, the range of computing, and the number of bins in 4D (X,Y,Z,t).
  - Let's assume X=Z=4, Y=1, t=3. Pink is a positron bunch, blue is electron
  - The grid interacts 4*4*4*4*3=768 times



# How GP++ works - III

Wei Xu, Yanbang Tang

- How the calculation been performed?
  - By time slicing, and gird by gird simulation using macro particles(macro particle = 50000).
  - There are two kinds of parameters, the range of computing, and the number of bins in 4D (X,Y,Z,t).
  - In real case, the range of X is 150*Sigma_X, the range of Y is 60*Sigma_Y, and the range of Z is 3*Sigma_Z
  - The bin number in X is 64*4(256), the bin number in Y is 64*4(256), the bin number in Z is 61, and the time slicing number is 10.
  - Huge times of computing.
  - The FCC has the same range with us. They have even more bin size, the same size as our CDR phase(X=64*25, Y=64*10).
    - The reason for reducing the size is to speed up the simulation.
  - All the information are calculated and stored, like the beam particles, primary photons generated, secondary electron/positrons/mini-jets/hadrons generated…

```
acc.dat    hadron.dat                   JobBeamstrahlung1.err  pairsB.dat
beam1.dat  htcjob_JobBeamstrahlung1.sh  JobBeamstrahlung1.log  pairs.dat
beam2.dat  JobBeamstrahlung1.dat        minijet.dat            photon.dat
```

- Questions to be discussed:
  - How accurate we need? How to determine it?
  - How the detector solenoid affect the particles? How to implement this effects?

# Synchrotron Radiation - I

Yanbang Tang

- The SR photons are produced by beam particles in Geant4 since Dec. 2024.
  - It's the same tool with SuperKEKB. The BDSIM is used at CDR and at FCCee. The SynRad is used for accelerator people to calculate the vacuum level, not for background.
  - The beam generated at -150m, tracked to 150m. The roughness of the pipe is 1600nm.
  - The magnetic field is added into the geometry using the parameters given by accelerator group. Currently, the last upstream bending magnet, the final focusing quadruples and the detector solenoid(uniform) is integrated.
  - We verified our generator by tracking the electron(positron) beams. It can go through the IP in our generator with the fields.
  - Using a dedicated physics list(including the X-ray reflection, the photelectric, Compton scattering, Rayleigh scattering and pair production), recording the SR photons generated and tracking them.
  - If the photons can leave the beam pipe(after interacting with beam pipe) in certain region, it will be recorded.
  - There comes the first judgement on the effectiveness of the mitigation methods.
  - The beam has a transverse Gaussian distribution on position. However, in the first stage, we started our work with no transverse distribution(pointwise). Then we tried to add the transverse distribution, starting from 3-sigma, now we extended it to 10 sigma.
- There are two kinds of works in parallel by same person, one is the optimization of the mitigation methods of the SR, the other is the improvement of the generator(like the adding of the quadruple field, the ability to have transverse distribution of the beam).

# Synchrotron Radiation - II

Yanbang Tang

- The output file will be used to run detector simulation in CEPCSW.
  - The BX rate is 1.4 MHz@ Higgs.
  - The bunch population is 1.3e11 @ Higgs.
  - One electron generates 3 photons on average.
  - The photons are ~1e18 per second per beam.
  - Currently, we simulated 1~100 Billion electrons. (FCC-ee did 10~25M.)

| Shielding Methods | Hit Density at VXD ($MHz/cm^2$) | Note |
|---|---|---|
| Original(No Paraffin and Wall) | 234,384 | No X-Y distribution, Step scale, no quads |
| Paraffin/Wall(PW) | 25,080 | No X-Y distribution, Step scale, no quads |
| -1.9m 4mm Cu mask+5um Au+PW | 123.4 | No X-Y distribution, Step scale, no quads |
| -1.9m +-4.3 4mm Cu mask+5um Au+PW | 20 | No X-Y distribution, Step scale, no quads |
| -1.9m +-7.2m 4mm Cu mask+5um Au+PW | <1(0) | No X-Y distribution, hit scale, no quads |
| -1.9m 4mm+-7.2m 3mm Cu mask+5um Au+PW | 34.6 | 3 sigma, hit scale, no quads |
| -1.9m W 4mm mask+5um Au+PW | 2.9e-3 | 10 sigma, hit scale |
| -1.9m + -7.2m W 4mm mask+5um Au+PW | 5.7e-5 | 10 sigma, hit scale |

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