Beam Induced Background @ CEPC

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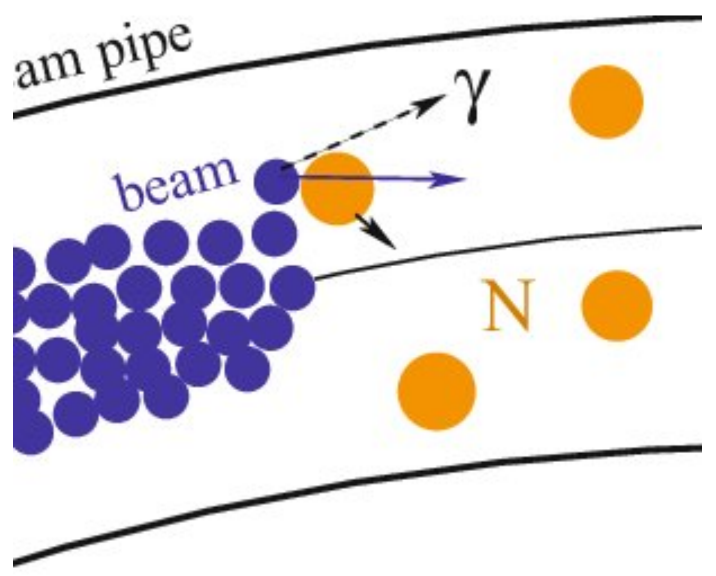
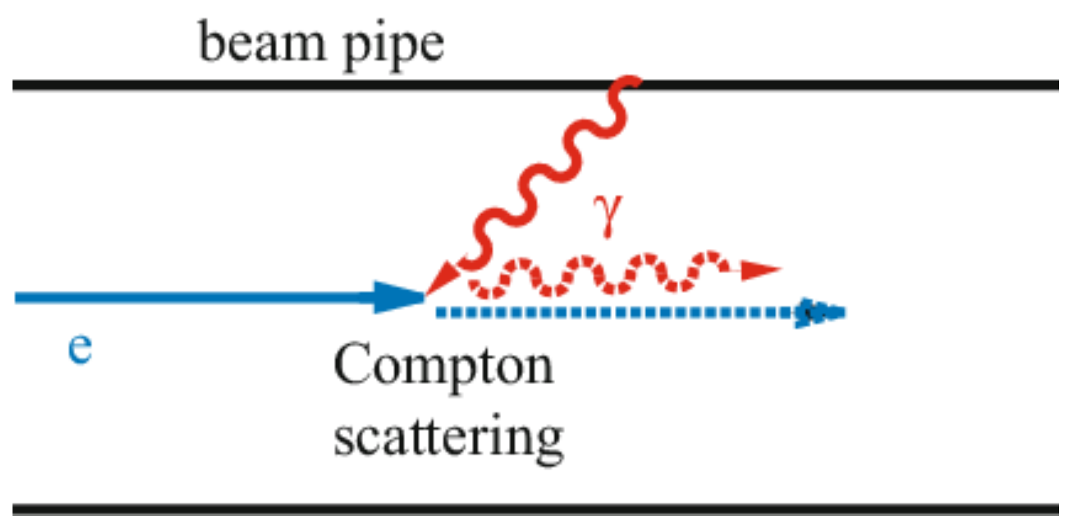
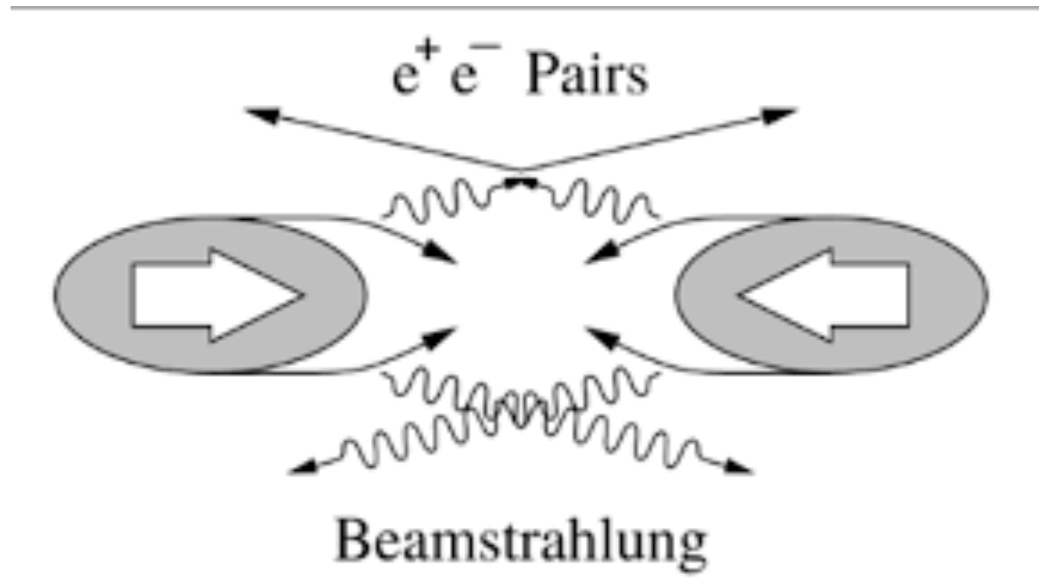
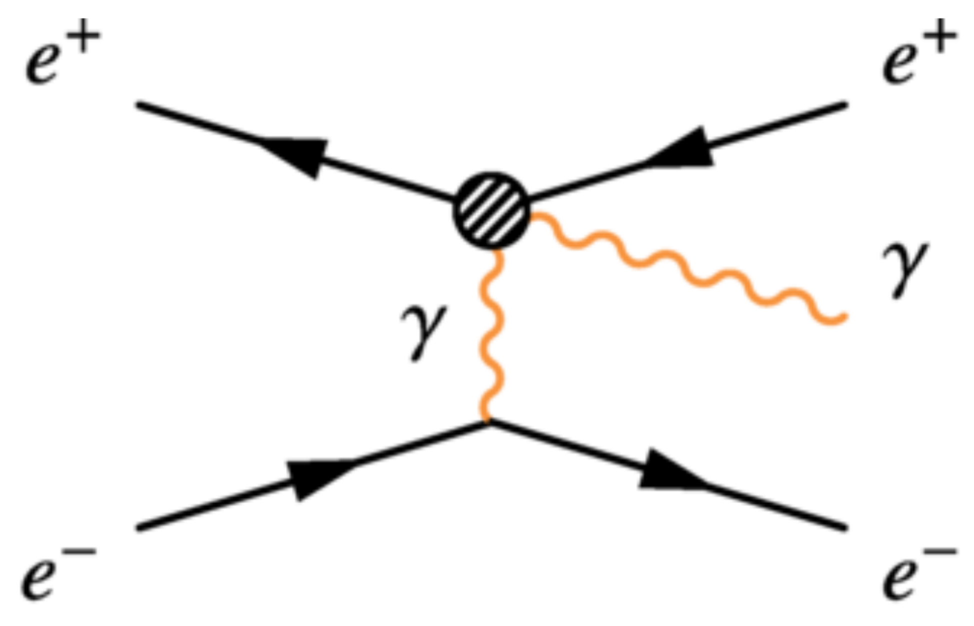
Introduction

- In addition to the normal ee scattering, some physical processes may cause particles to strike the detector
  - Touschek Scattering [TSK]
  - Beam Gas Scattering [BGS]
  - Beam Thermal Photon Scattering [BTH]
  - Radiative Bhabha [RBB]
  - Beamstrahlung / Pair-production [BS/Pairs]
  - Synchrotron Radiation [SR]
- Injection background is not documented in TDR
- All studies are conducted with ideal beam conditions









Current Results	**Pair-producton**	**SR**
Hit Rate at the **1st** silicon layer	2.7 MHz/cm^2 [safety factor 2]	5.6 KHz/cm^2 [safety factor 10]

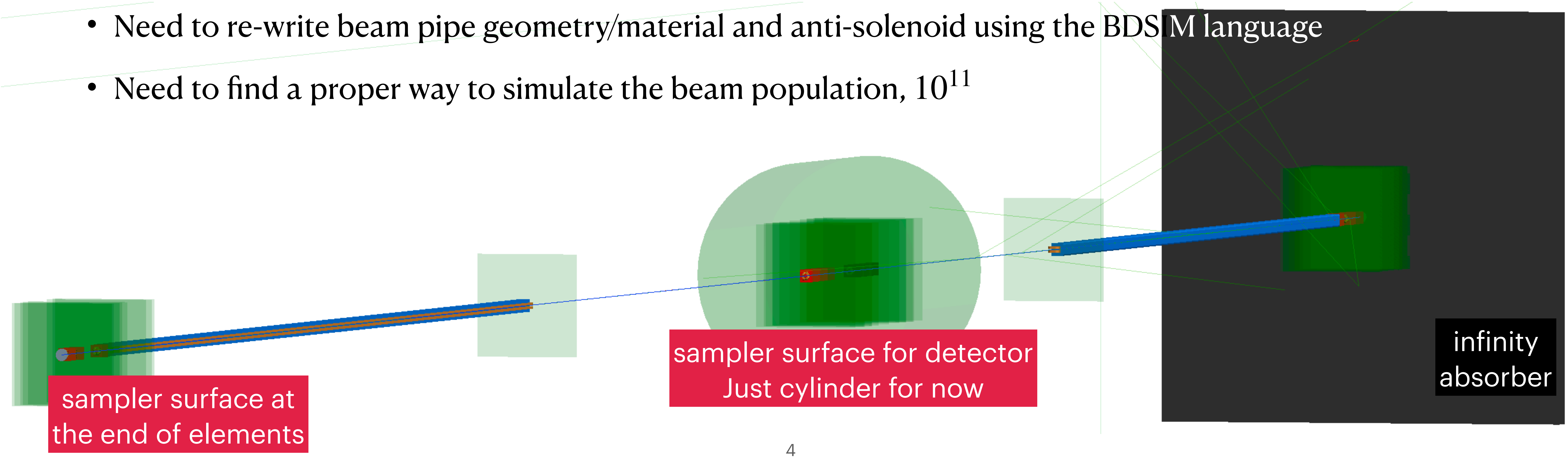
Introduction

1. For the TSK and BGS, based on the BESIII study where the data/MC < 1, the TDR result is considered conservative
   - Together with BTH, from the perspectives of beam loss and radiation power, they are much less than Pairs and SR. No explicit results regarding the background hit rates
   - Simulations are somewhat far from reality, for example, uniform vacuum pressure for beam-gas
2. RBB and BS photons dump through an exit window, but no studies address the dump tunnel design [size, distance to IP...]
   - Beam-beam effect can smear the direction of RBB photons
3. For pairs, the theoretical uncertainty on the cross-sections needs to be checked using different QED generator
4. A new framework based on BDSIM is being developed for SR to account for potential systematic effects, such as the real beam orbit, misalignment between beam elements and backgrounds from distant beam elements

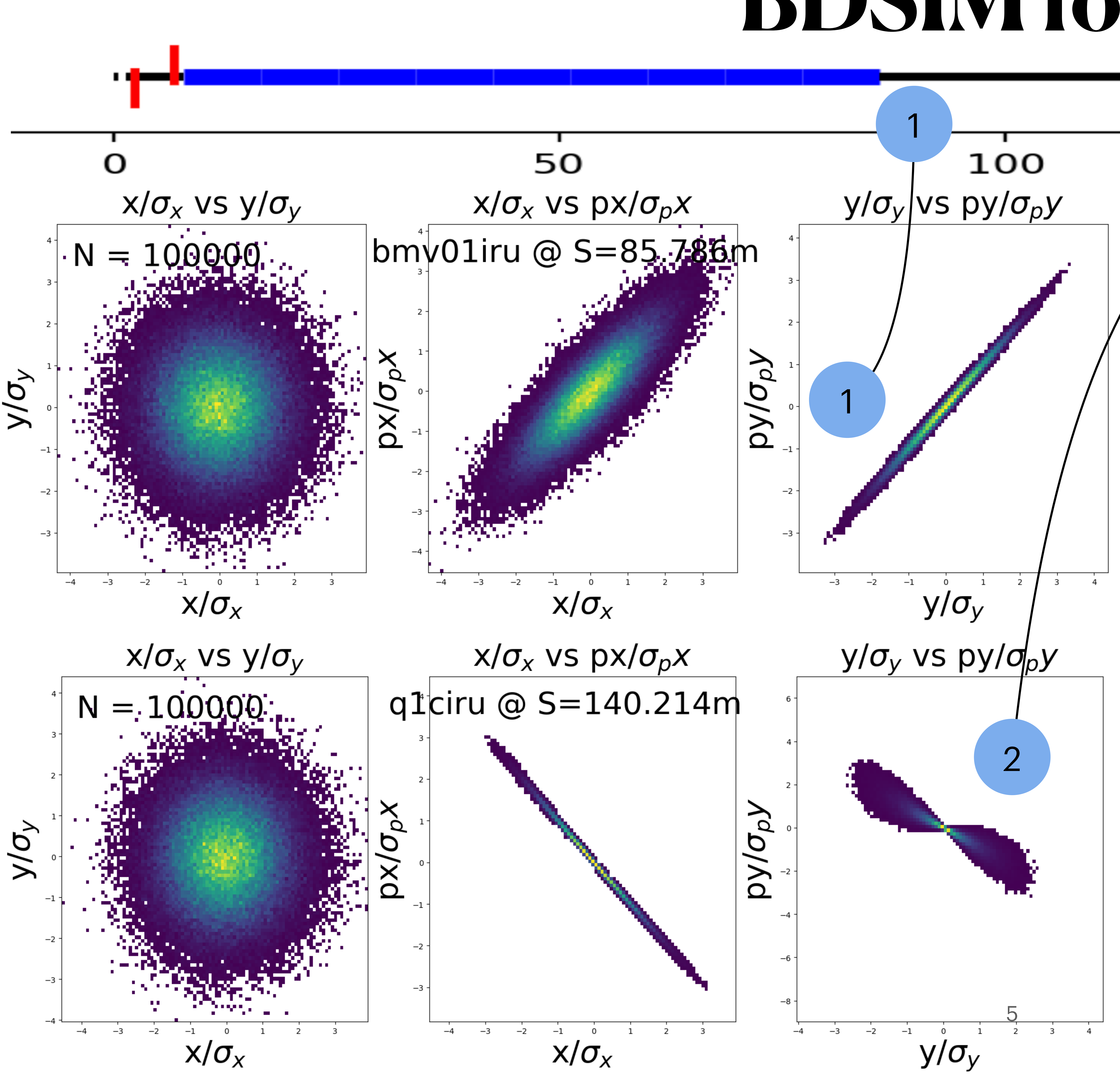
This talk focuses on the last two items and shows some recent progress and a work plan

BDSIM for SR

- The BIB from SR is under control but its extremely large source term may lead to significant uncertainties. [safety factor of 10]
- BDSIM [beam delivery simulation] is developed for accelerator design and is chosen to perform a cross check with the current one
- First working version is ready. But there are some tasks to do
  - Currently, the beam lifetime is short and cannot complete one turn. Simulate only 300m arc around the IP
  - Need to re-write beam pipe geometry/material and anti-solenoid using the BDSIM language
  - Need to find a proper way to simulate the beam population, 10^{11}



BDSIM for SR

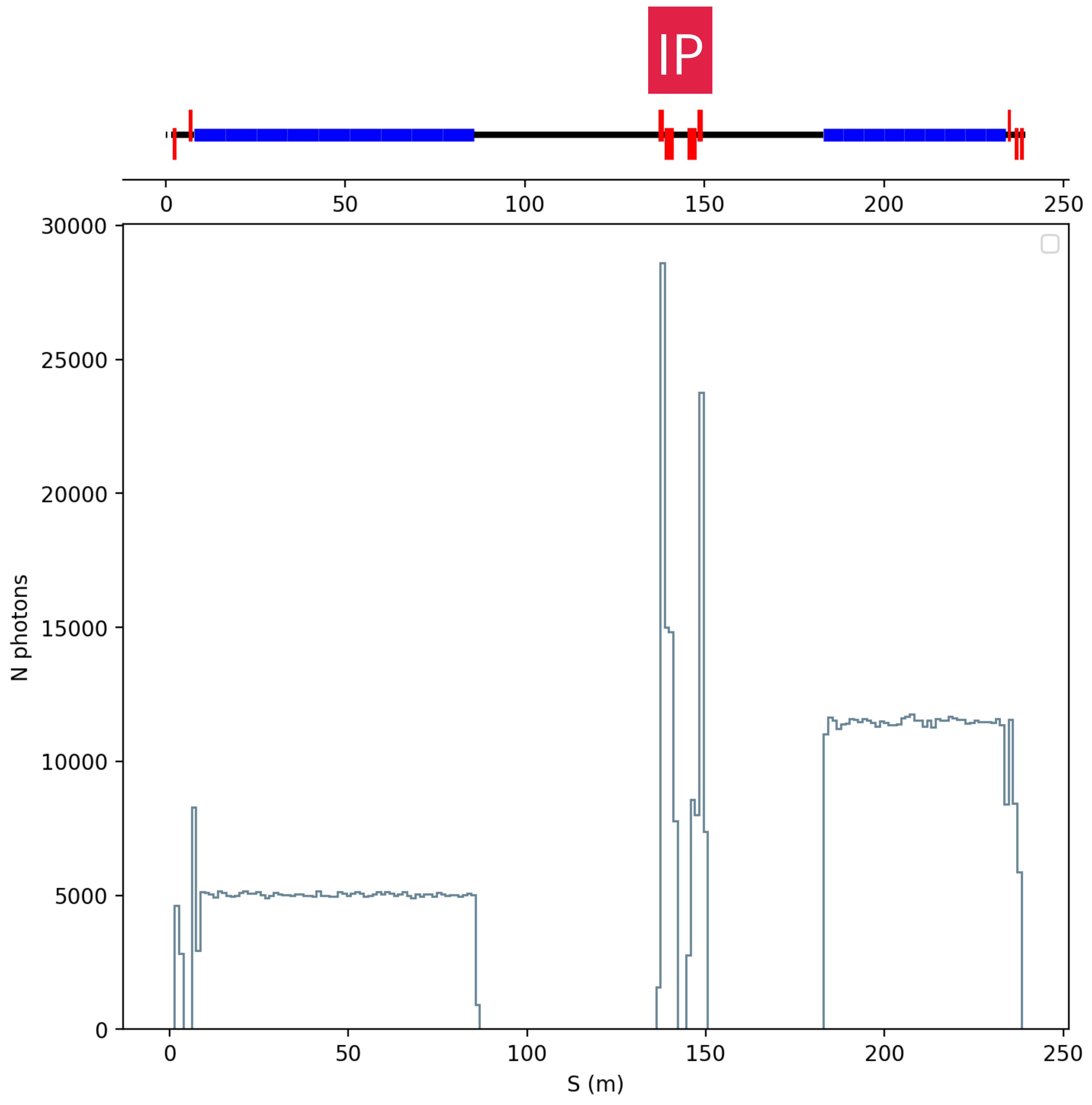


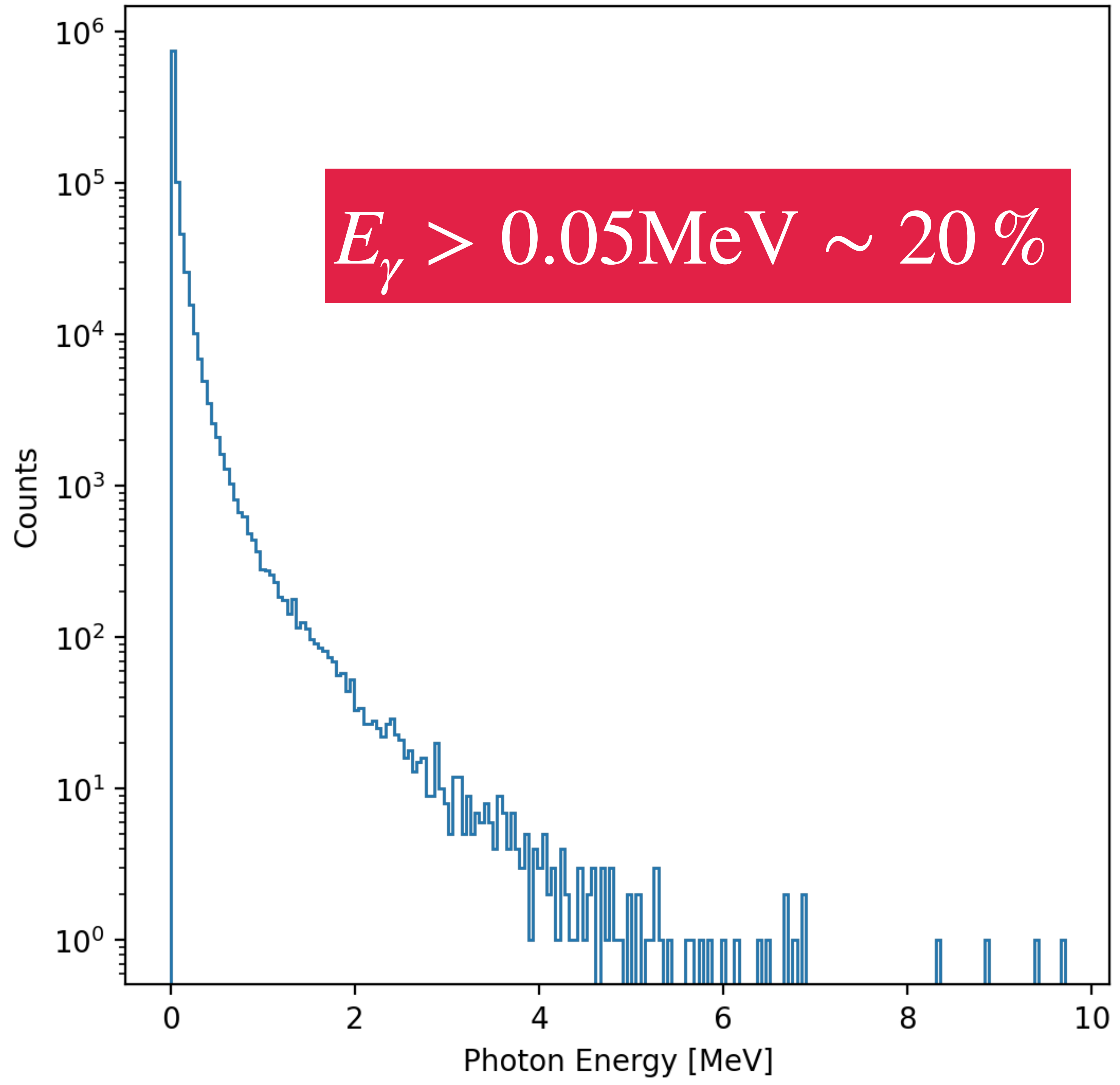
- Beam transverse distributions for x/σ_x $vs.$ y/σ_y [left], p_x/σ_{p_x} $vs.$ x/σ_x [middle] and p_y/σ_{p_y} $vs.$ y/σ_y [right]
- At the last dipole [top]
- At the last quadrupole [bottom]
- Beam population is fine

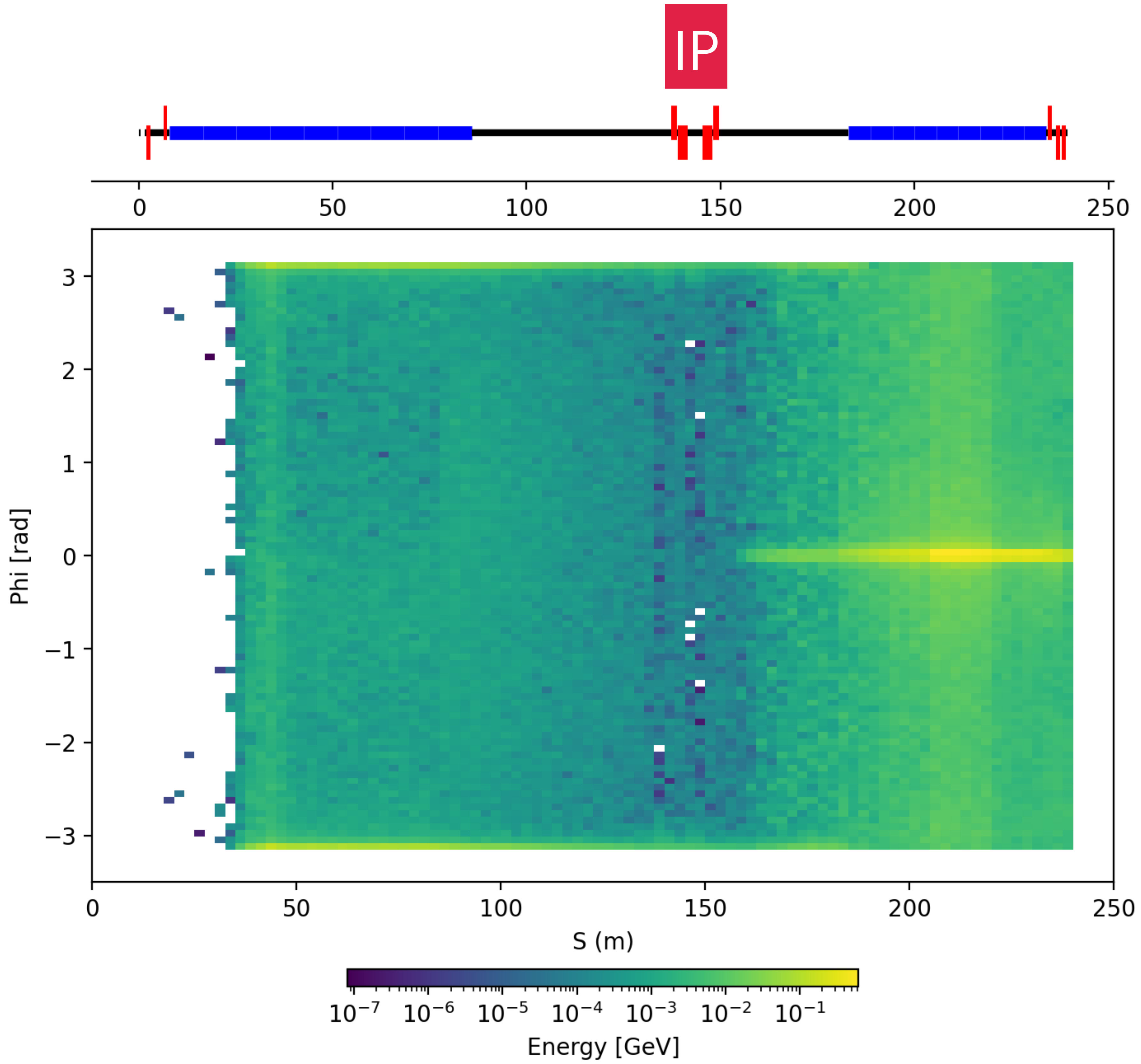
- This work, 1e4 particles per job ~ 10 min
- If 1e11 particles ~ 10000 jobs x 100 days
  - TDR simulates 1e9 particles
- Detector simulation is not included

BDSIM for SR

Beam population=1e5







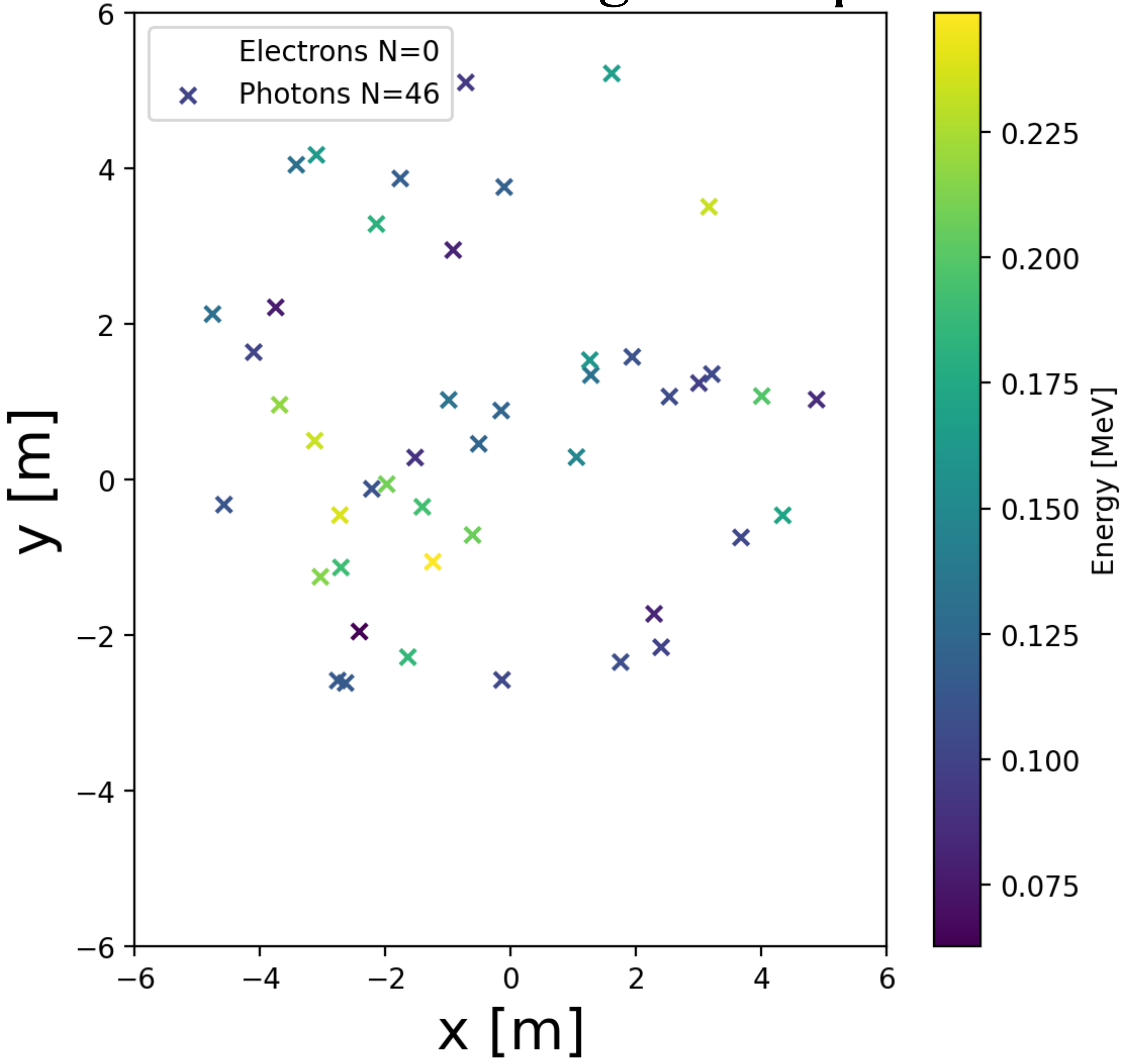
- Origin of photons

- Photon energy spectrum

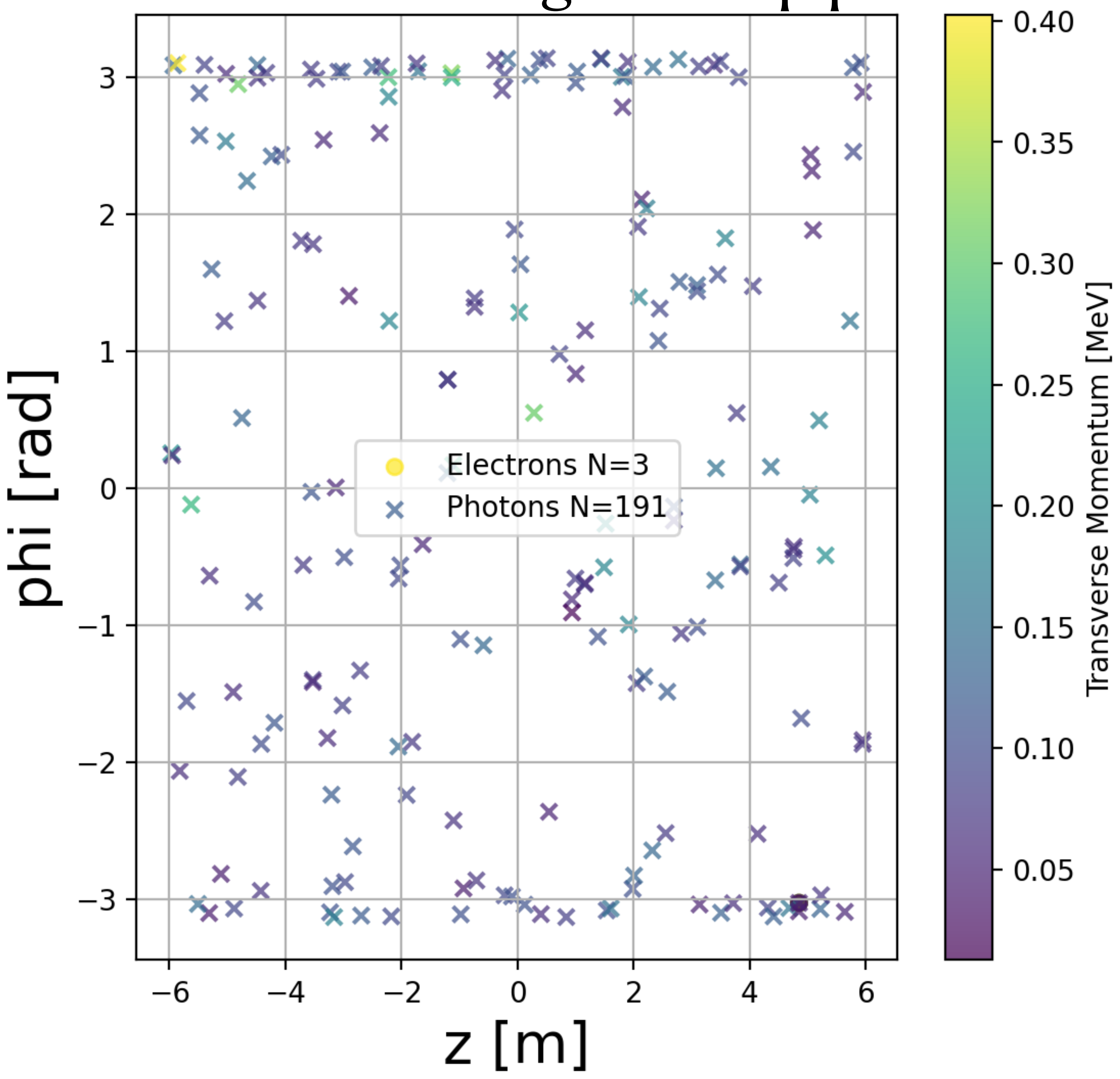
- Energy deposition in the accelerator elements [1e5 electrons, no shield added]
- Input for thermal analysis

BDSIM for SR

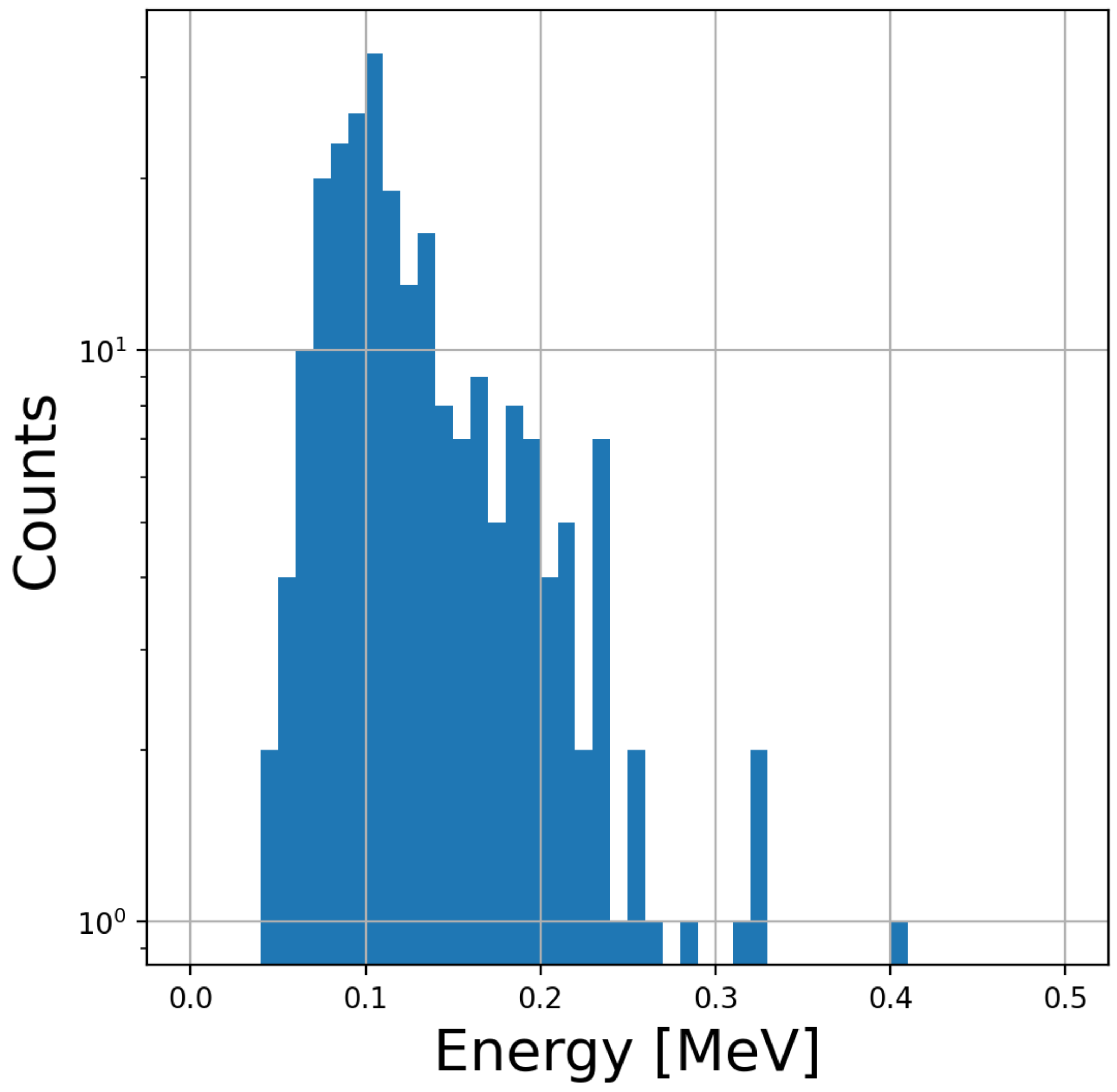
Particles entry into the detector through endcap



Particles entry into the detector through beam pipe



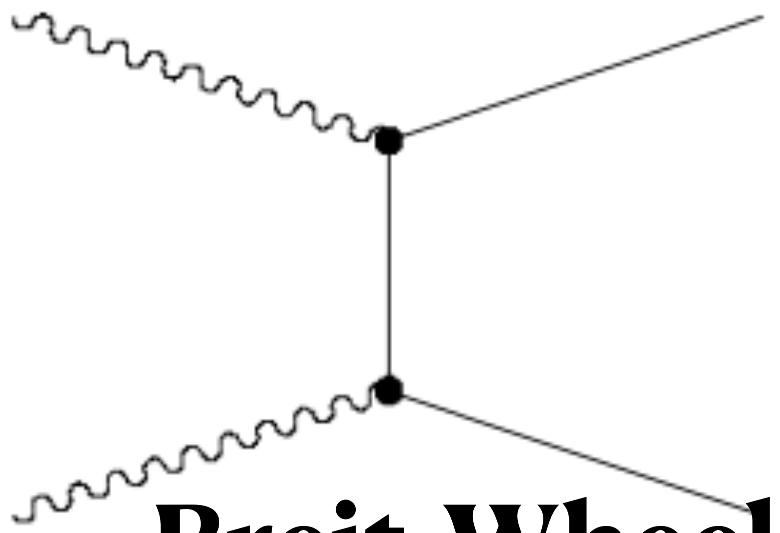
Spectra of incident particles



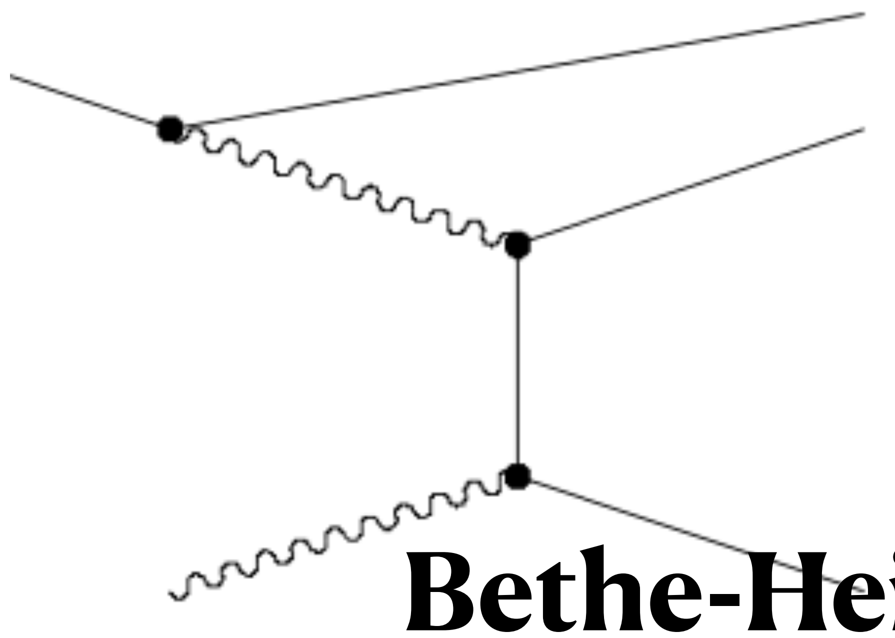
- Beam with 1e5 electrons leads to ~200 indecent particles with energy less than 1MeV [NO SHIELD ADDED]
- Input for the performance simulation

Pair-production & GuineaPig

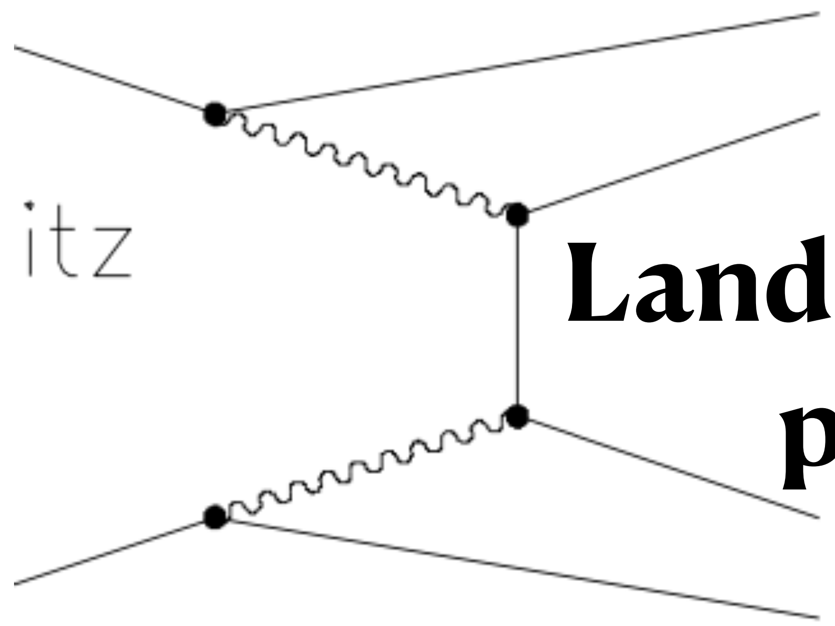
- Beamstrahlung is the synchrotron radiation in the opposing beam's field
- Photon-photon collisions generate fermion pairs



Breit-Wheeler process



Bethe-Heitler process

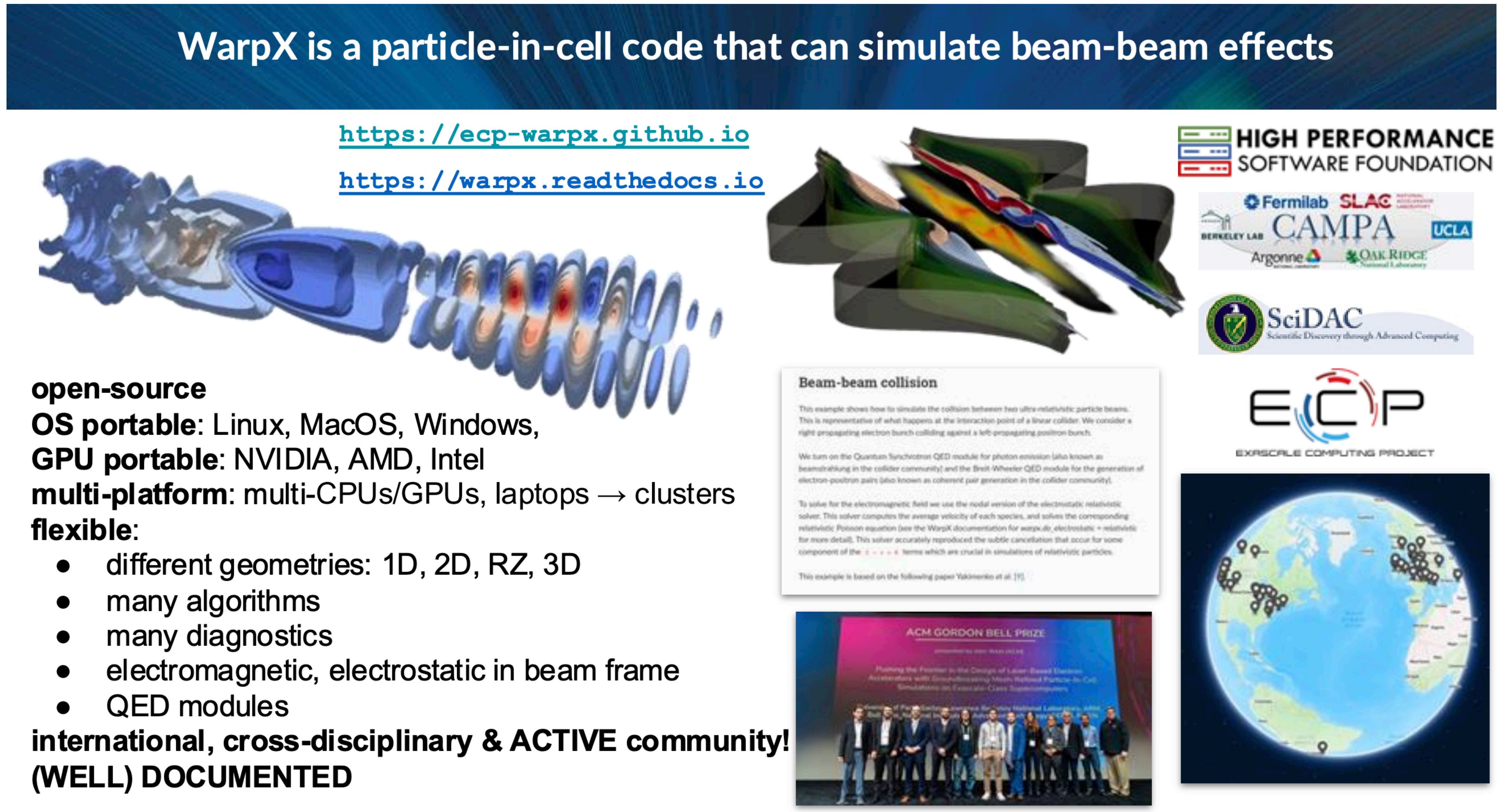


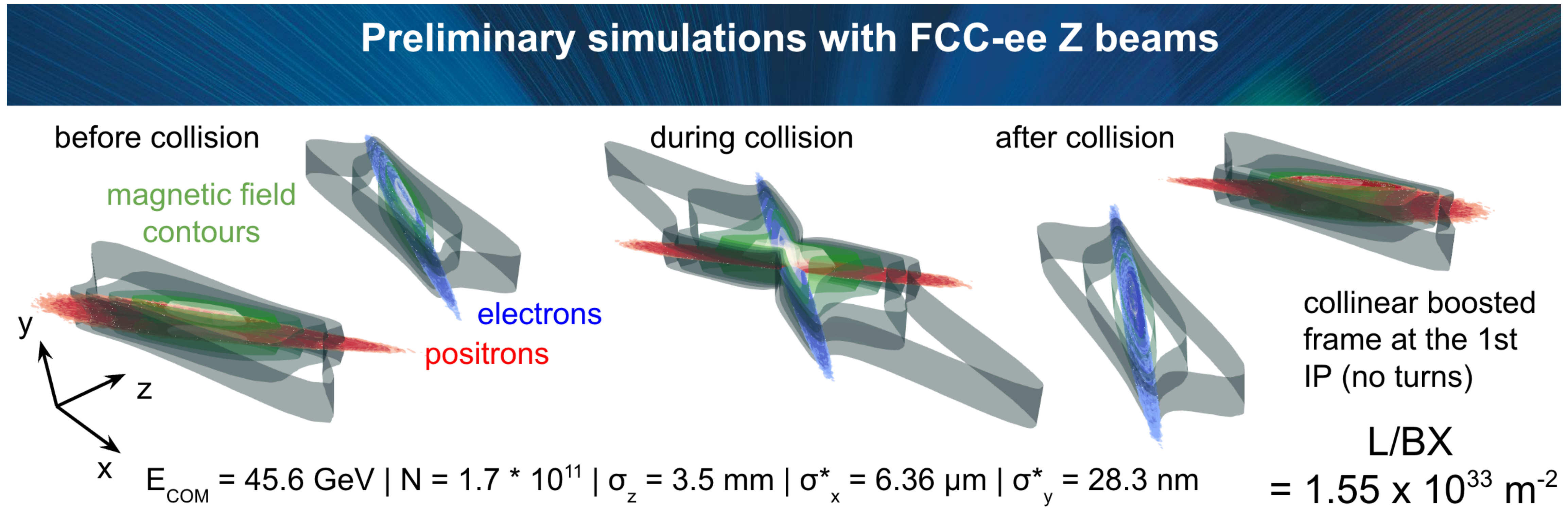
Landau-Lifshitz process

- GuineaPig is the software used for the pair-production study
- Event generator
  - **A QED trick, the Equivalent Photon Approximation, is used for the BH and LL**
  - **How precise is the Equivalent Photon Approximation with CEPC beam parameters?**
  - **<u>Some studies show discrepancies w.r.t. real QED</u> [safety factor = 2]**
- Beams' field simulation
  - Particle in Cell algorithm solves the electromagnetic field [machine expensive]
  - Track the pairs trough the field, **pairs can be de/accelerated**

Pair-production [Todo]

- To validate the Equivalent Photon Approximation method using CEPC beam parameters
- Modern beam-beam simulation code can be used
  - Beam-beam simulation is machine expensive
  - Some new softwares work with GPU, already tested by FCC





US Higgs Factory FCC workshop 2025

Summary

- A summary about the BIB, particularly focusing on SR and Pairs, was presented
  - Beam-Gas, Touschek, following BESIII progress
  - Dump line for BS and RBB photons

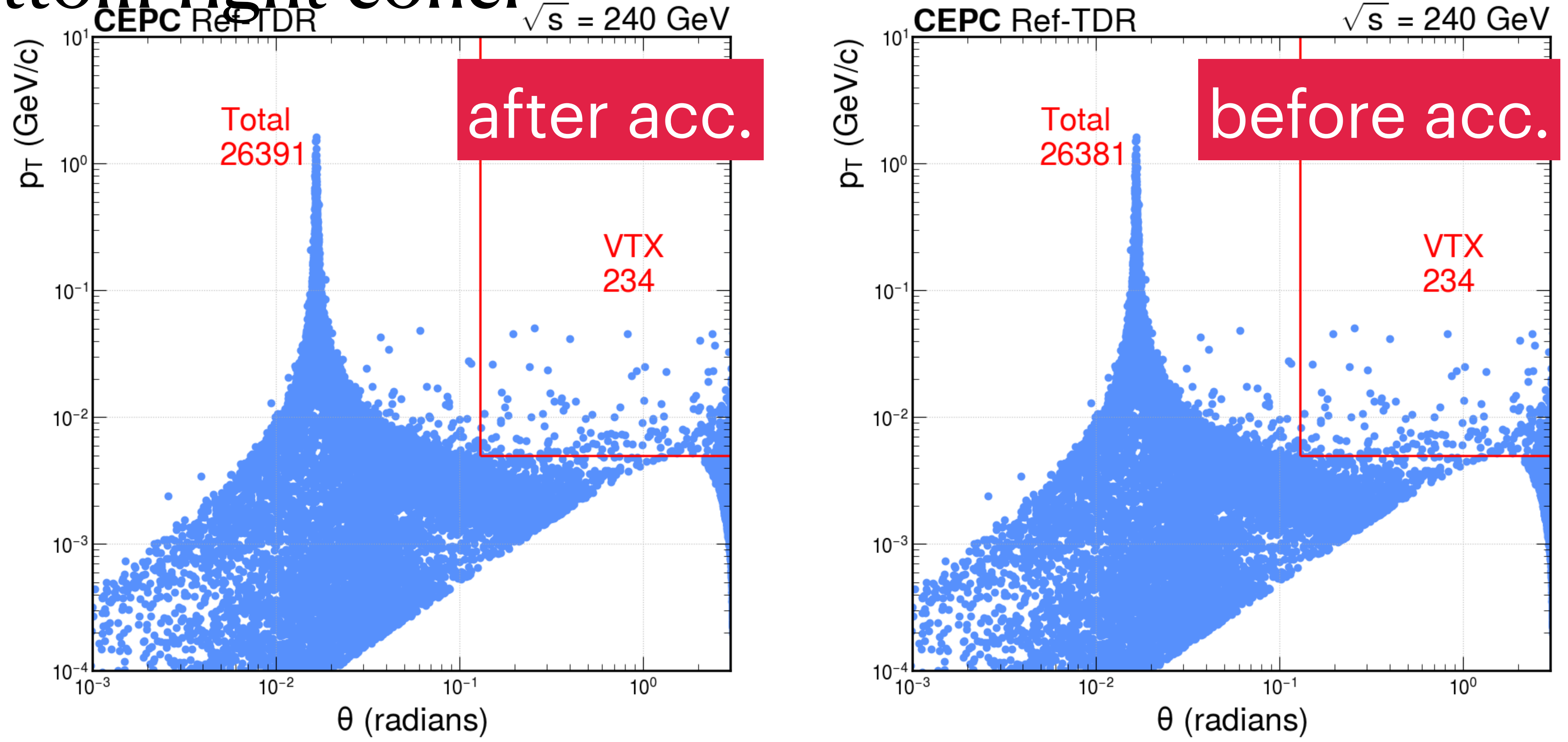
  - BDSIM framework is being developed and tested
    - Mainly for cross-checking SR and including possible systematics
    - Beam-gas, thermal photon can also be modelled by BDSIM as well
  - For pair-production and beam-beam simulation
    - To study the systematic uncertainties, particularly the theoretical one
    - Trying to find a more efficient simulation tool

- Finally, all the studies conducted assume ideal beam conditions. Need to collaborate with accelerator colleagues to define possible beam biases

BACKUP

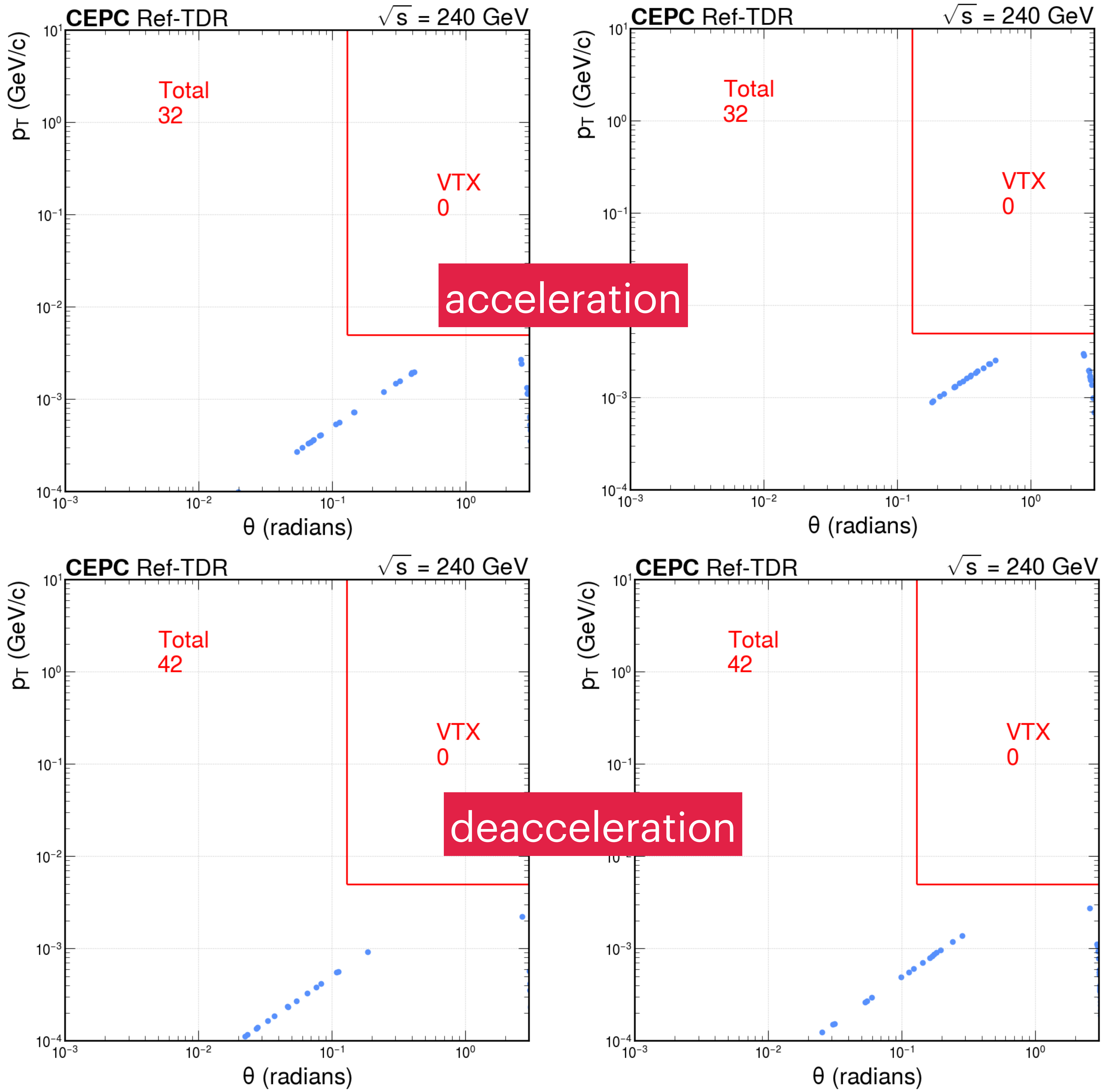
Pair-production [beam-field acceleration]

- The problem focuses on the empty triangle in the bottom-right coner



- It is related a default electron energy cut of 5 MeV
- It is said that due to kinematic constraints, electrons with energies below 5 MeV cannot reach the detector
- It is also stated that due to dynamic, the EPA does not apply for electrons with energies below 5 MeV
- The first one was checked
- Even though electrons with energies below 5 MeV can not reach the detector, the beam field can accelerate them. How large is this effect?

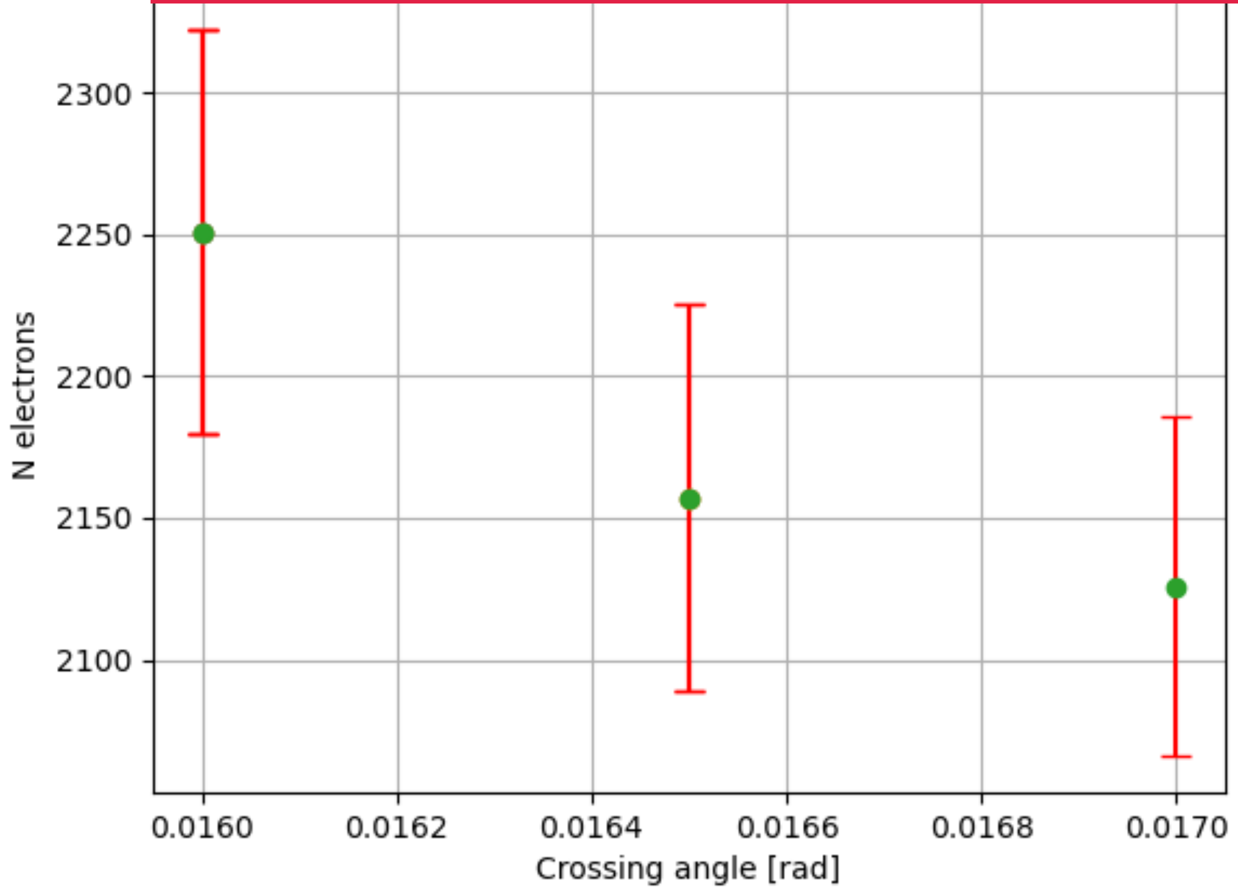
- Particles climb over the threshold by beam field; No impacts on the detector acceptance



Pair-production [experimental variations]

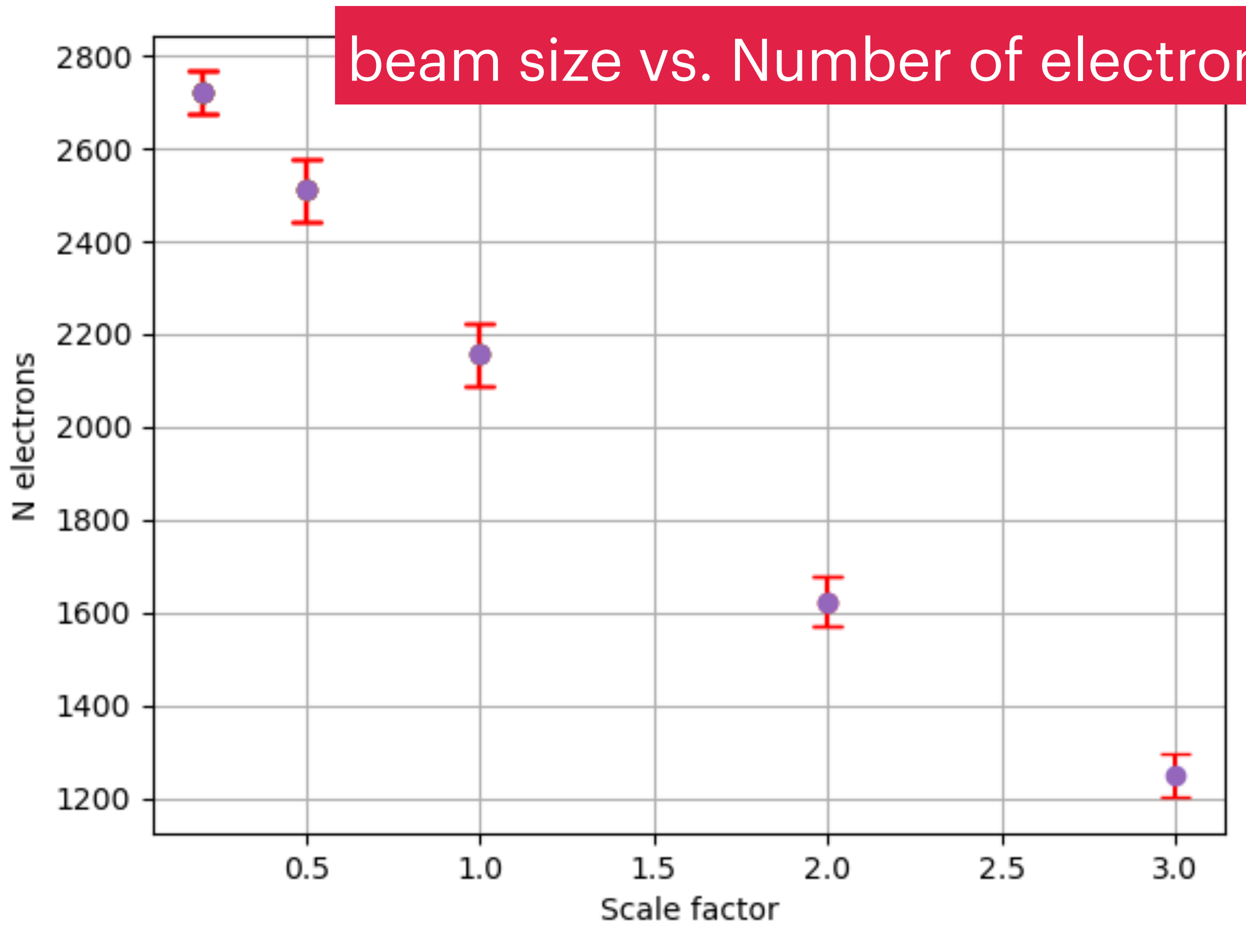
- Beam variations can change pair-production
  - Beam size: charge density
  - Crossing-angle: centre mass energy
  - Offset to orbit: distance to the sensors

Crossing-angle vs. Number of electrons

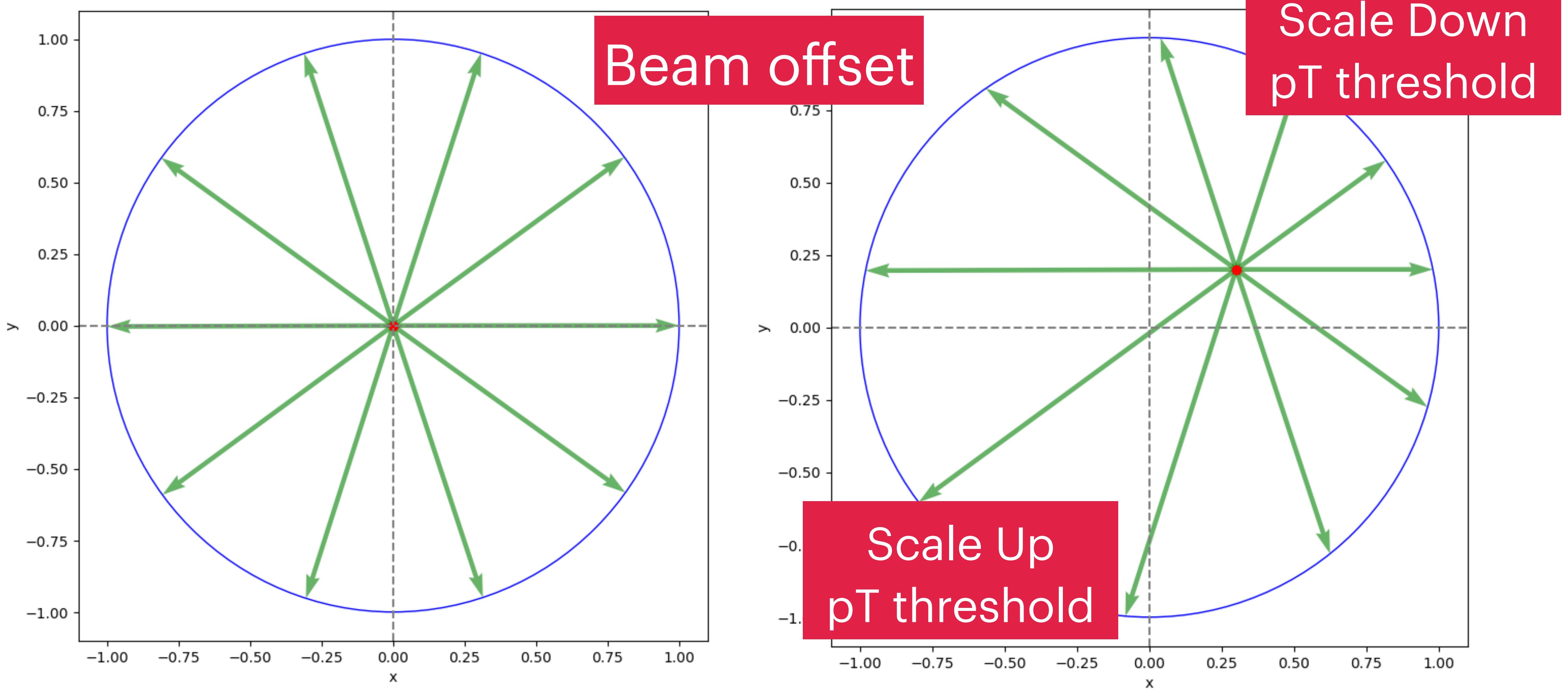


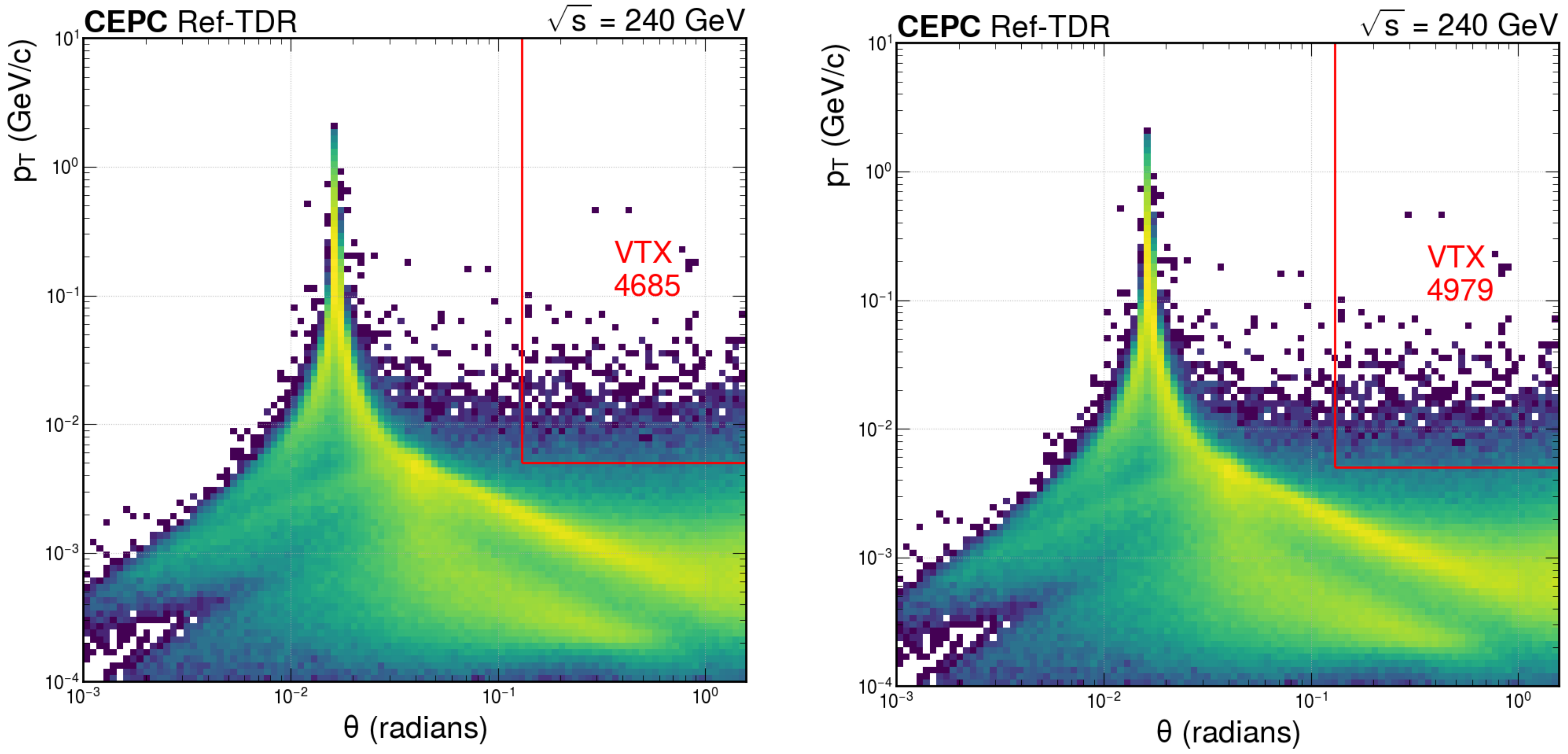
- Input error, from accelerator group, +/- 1 mrad
- Number of electron ~ +/-0.5%

beam size vs. Number of electrons



- sigma_x +/- 1% —>
- N electrons +/- 6 —> 6/2200 < 0.5%





- 1mm offset -> 10% increase
- 0.1 mm offset -> .2% increase