

Beam backgrounds at the FCC-ee: Guinea-Pig Dev for IPC

Jan Eysermans, Katie Kudela, Mariarosaria D'Alfonso, Christoph Paus

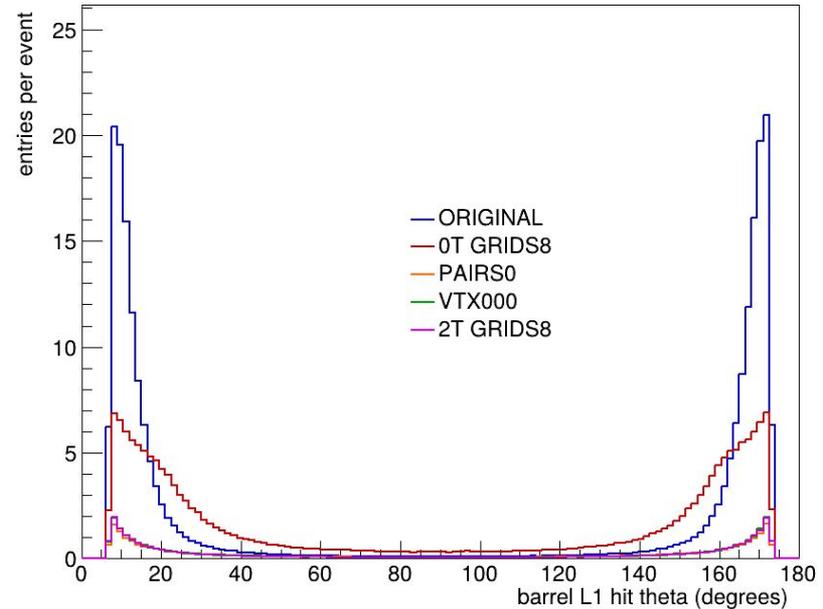
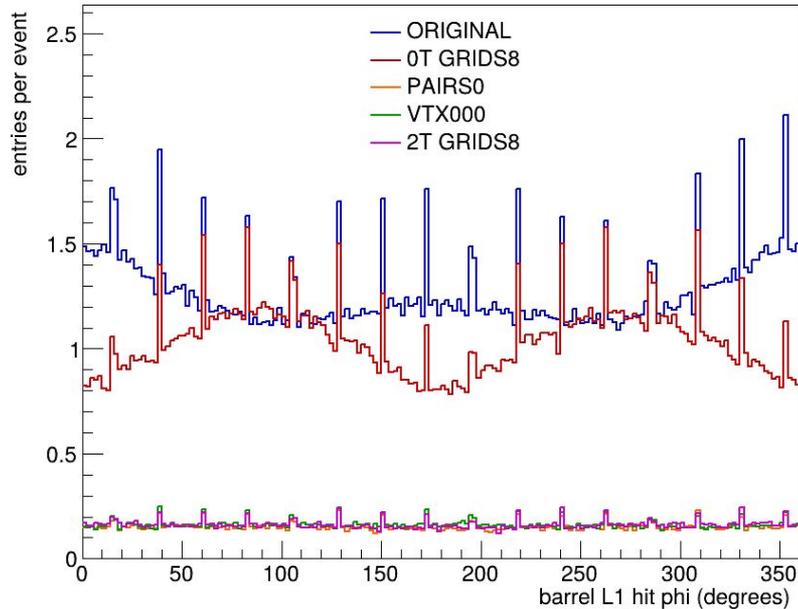
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New FSR Lattice detector results

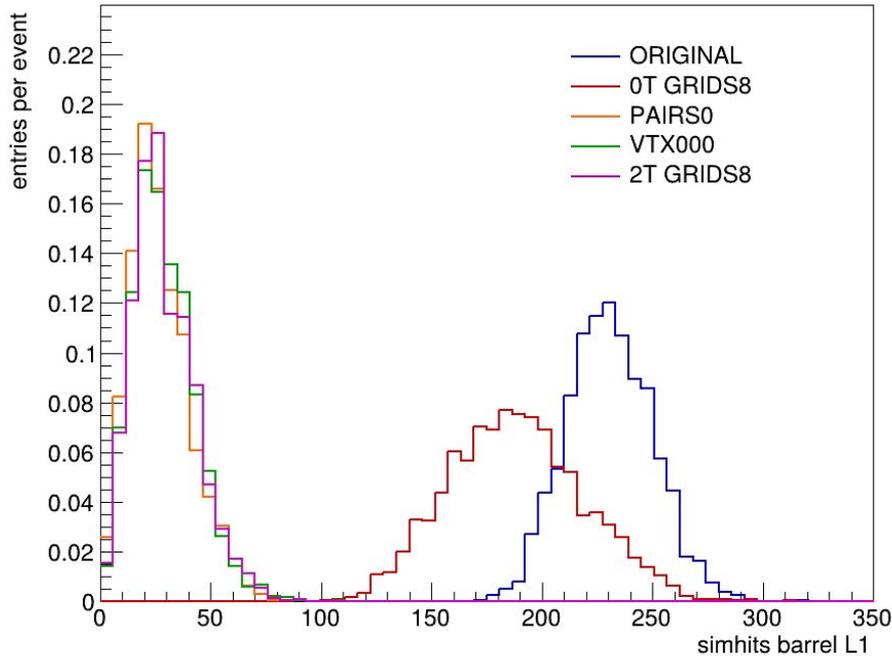
- We redid all these detector studies with the latest lattice candidate for FCC-ee; same story as before
- The spread of the simhits per bunch crossing is also the same for the three identical configurations (vtx000, pairs0, 2T grids8)





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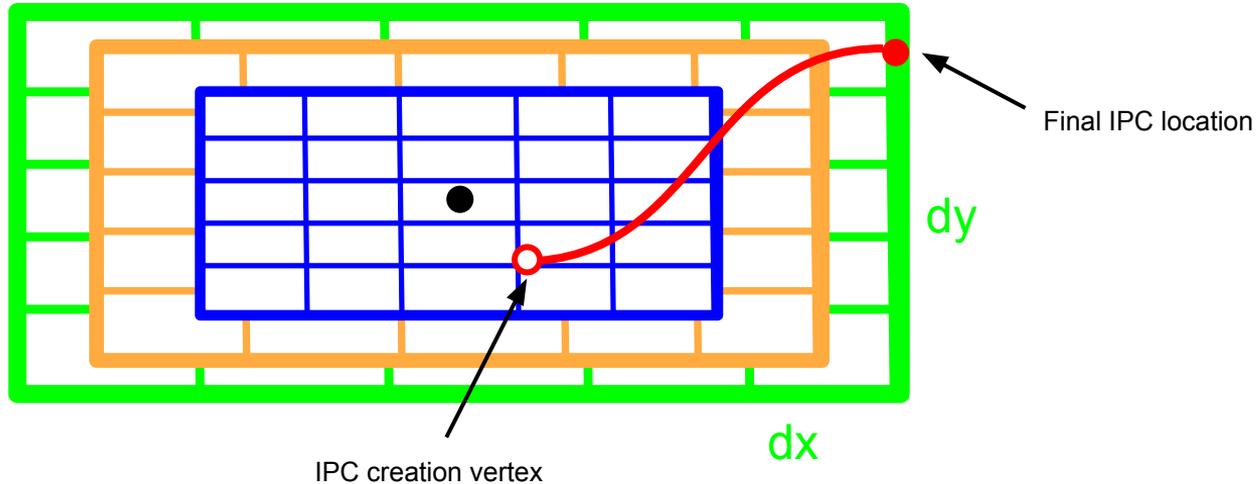
FSR Lattice	Avg # hits
Original	230.64
Moved to IP (VTX000)	29.22
Production kinematics (GRIDS0)	27.62
Stopped at beampipe GRIDS8 + 0T in GP	188.08
Stopped at beampipe GRIDS8 + 2T in GP	29.14



Guinea-Pig timing study

We want to see if tracking particles through the grids is computationally expensive.

- Cartesian 3D grid propagates the beams and calculate the EM fields in each cell
- Multiple grids are layered over each other to reduce computing time
 - Each grid has same number of divisions in each axis (granularity)
 - Particles are propagated through the fields
- We can toggle the tracking / no tracking between runs that share the same seed and compare the computing time

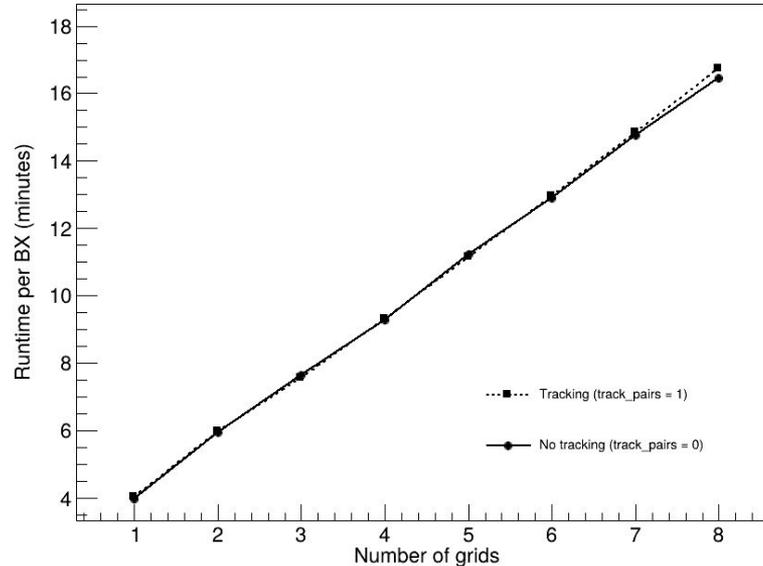




Guinea-Pig timing study

We want to see if tracking particles through the grids is computationally expensive.

- Side note: all grids are built and field calculations are done for both tracking and no tracking
- Tracking does not significantly affect runtime
- But why is this plot perfectly linear?

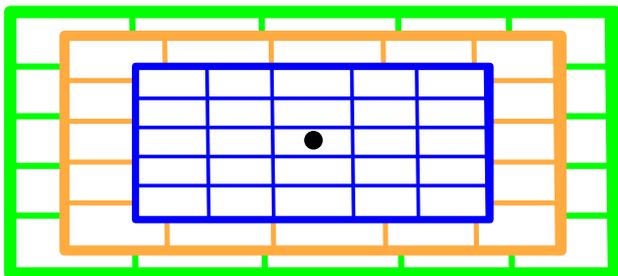




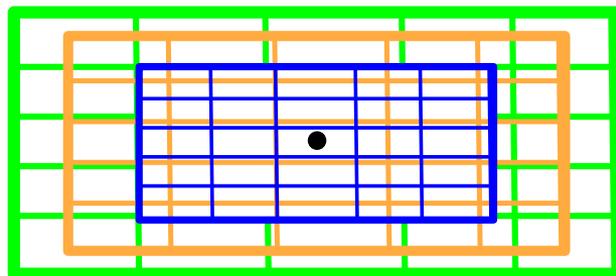
Guinea-Pig timing study

Why is the runtime linear with number of grids?

- In principle, the number of times the beam fields must be calculated (i.e. number of cells to be calculated in a GP run) determines runtime
- Previous plot is linear → equal number of cells are being calculated per grid
 - Cells in regions where grids overlap are being calculated
- Physically this is useless
- After investigation, it turns out there is a FFT package that forces this structure in Guinea-Pig
- Meeting with WarpX developers to discuss further



more computationally attractive



reality of Guinea-Pig



Conclusions and next steps

CONCLUSIONS

- Redid all detector studies with FSR lattice
- Determined there are redundant field calculations in Guinea-Pig
- Comment from last time: checked effect of beam fields on particle incidence angle through the detector: no change

TODO

- Finalize Guinea-Pig dev validations by analyzing new output ROOT files instead of text files
- Introduce magnetic field of the detector to the beams themselves
- Look into how different IPC processes scale with lumi
- Meet with WarpX developers to discuss grids
- Continue to write note

Characterization of Incoherent Pair Creation at FCC-ee using Guinea-Pig

Jan Eyermann, Katie Kulela

February 8, 2026

Abstract

Incoherent pair creation (IPC) is a key beam-induced background at FCC-ee with direct impact on detector occupancy and interaction-region design. We present a characterization of IPC using Guinea-Pig, which models beam-beam interactions through self-consistent electromagnetic fields on a 3D grid and deterministic tracking of the resulting particles. We discuss recent improvements and implementations in our Guinea-Pig setup aimed at more precise IPC sampling and stable large-scale production for IPCTec conditions. The resulting samples are used to study the production kinematics and distance of IPC pairs including energy spectra and time distributions and their correlation with the cooling beam fields. We finally conduct the impact on detector occupancy distribution, identifying the dominant systematic problems that drive beam backgrounds and providing input for detector optimization and background mitigation strategies.

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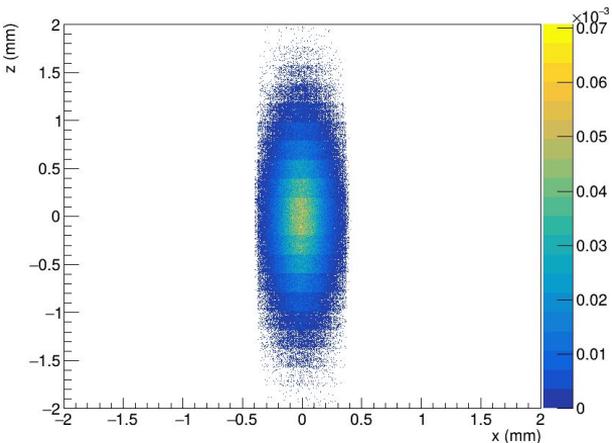
Backup



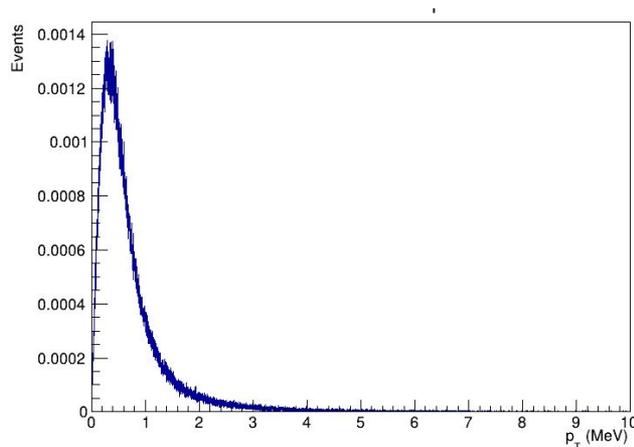
IPC production kinematics

- IPCs are created on the primary grid according to the 3 production processes
- Mostly created near the IP where the beam fields are the strongest \sim local lumi
- Very soft momentum spectrum, with a most probable value of 1–2 MeV

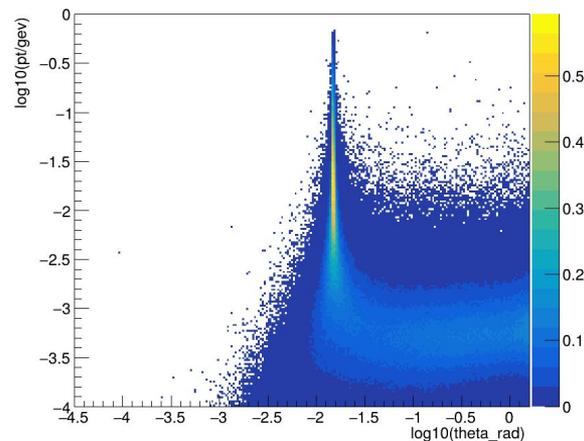
Production phase space xy



Transverse momentum (MeV)



θ - p_T distribution



Production volume

$dx = \pm 0.5$ mm

$dy = \pm 0.2$ μ m

$dz = \pm 2$ mm



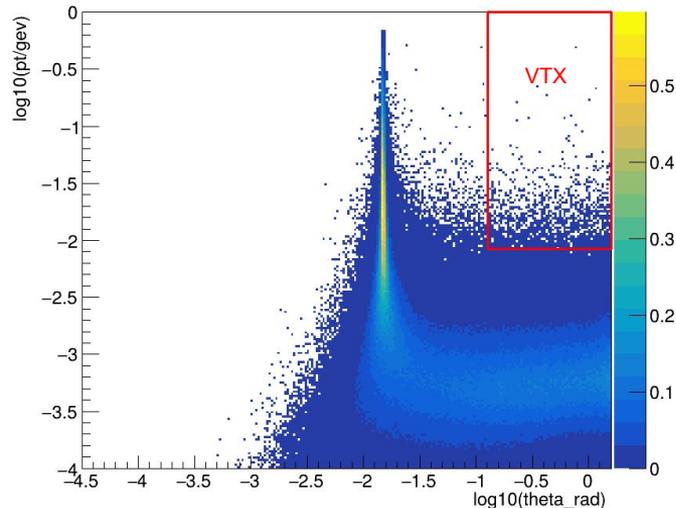
Influence of the beam fields on IPCs

IPC particles feel the EM fields of the beams strongly → change of IPC dynamics

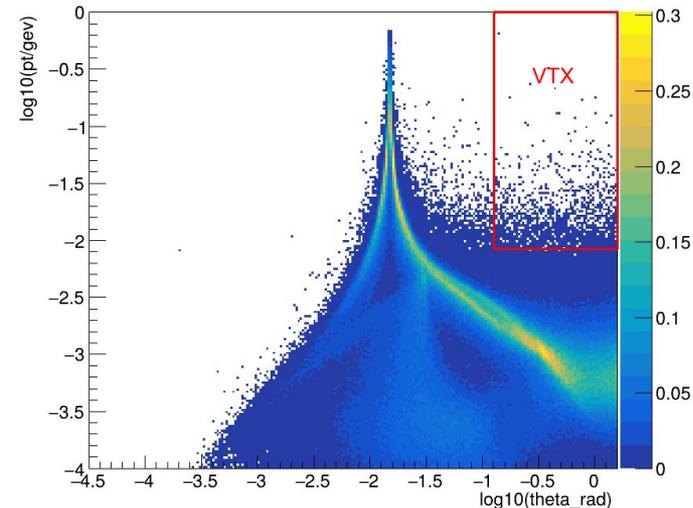
- Electrons are focused by positron beams and vice versa
- IPCs gain energy from the beam fields (on average 0.8 MeV)

Kinematic reach of the IPCs to vertex layer at 13 mm shown in the red box

- The tails are more important than the core of the distributions
- Typically <1% reaches first vertex layer → implies to generate lot of statistics for detector studies



Production kinematics w/o beam fields



Production kinematics w/ beam fields