RADIATIVE BHABHA AND OTHER INCONSISTENCIES

Andrea Ciarma

Thanks for helpful discussions to
A. Frasca, G. Lerner, M. Dam, V. Gawas, J. Salvesen

Updates on:

Radiative Bhabhas:

- irregularities in particles distribution spotted by M. Dam, triggered by high values of dose on the LumiCal from FLUKA tracking (MDI#62)

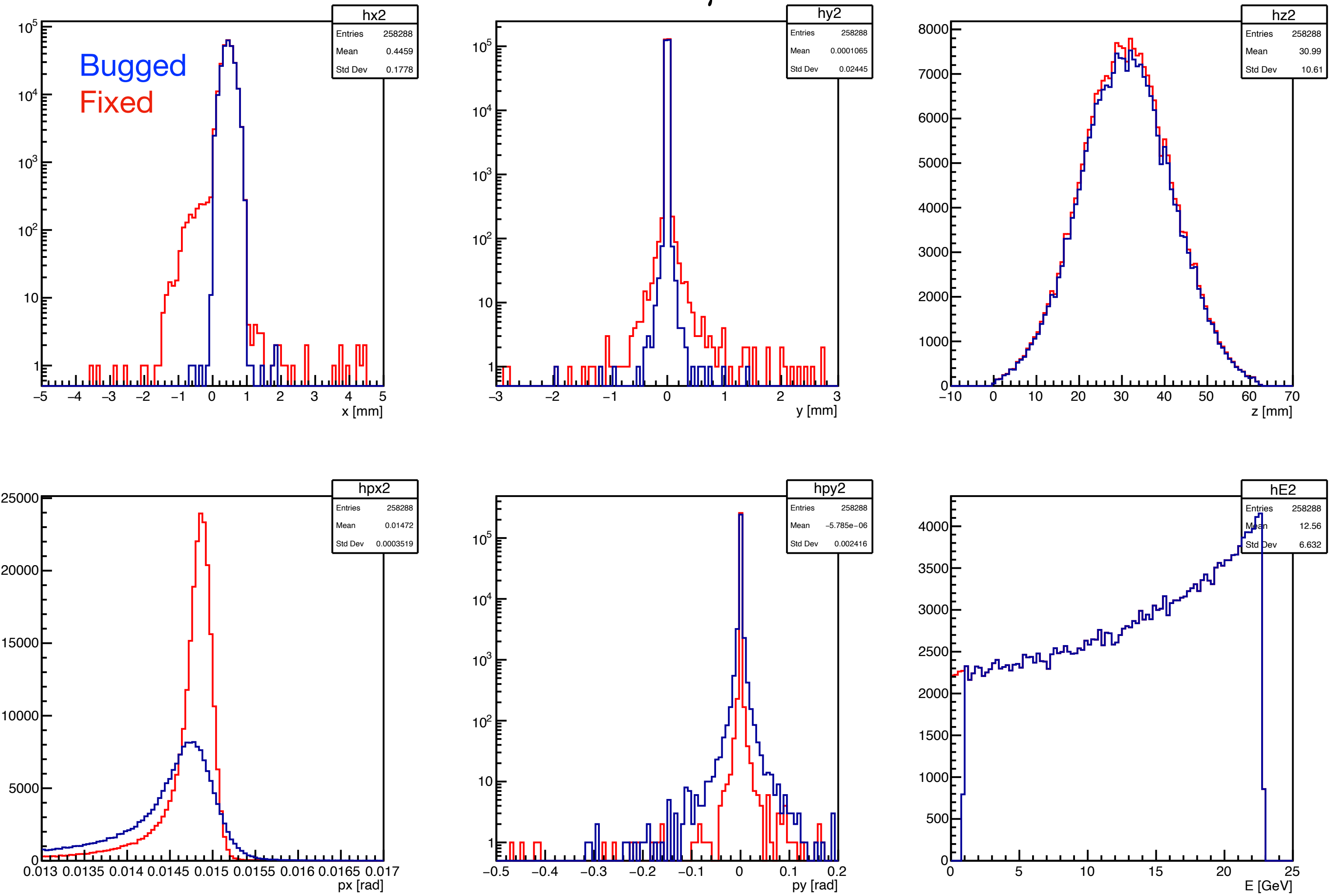
Incoherent Pairs Creation:

- inconsistency on pairs number observed by V. Gawas (MDI #61)

Crossing angle and GuineaPig:

- private discussions on beamstrahlung photons with A. Frasca and J. Salvesen, question on the reference frame and crossing angle definition in GP

V24.3 - Z - $E_\gamma > 50\,\%$

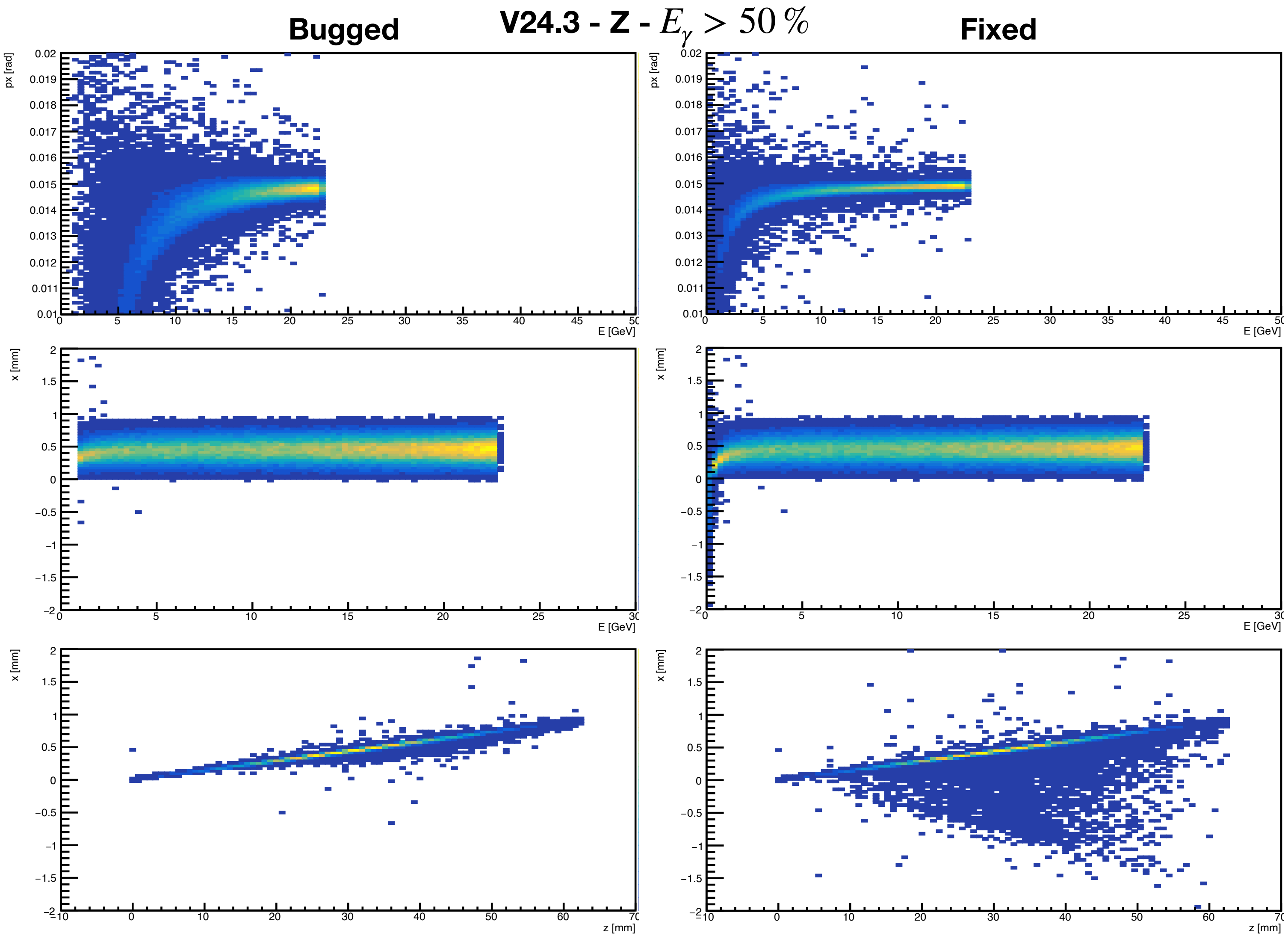


Radiative Bhabha … what's wrong?

Found minor bug in the radiative bhabha sample script, at the level of output writing (generator and parameters are fine)

- overestimate of px/p
- cut of low energy particles <2%

Samples have been corrected and the FLUKA studies have been rerun (see A. Frasca next).



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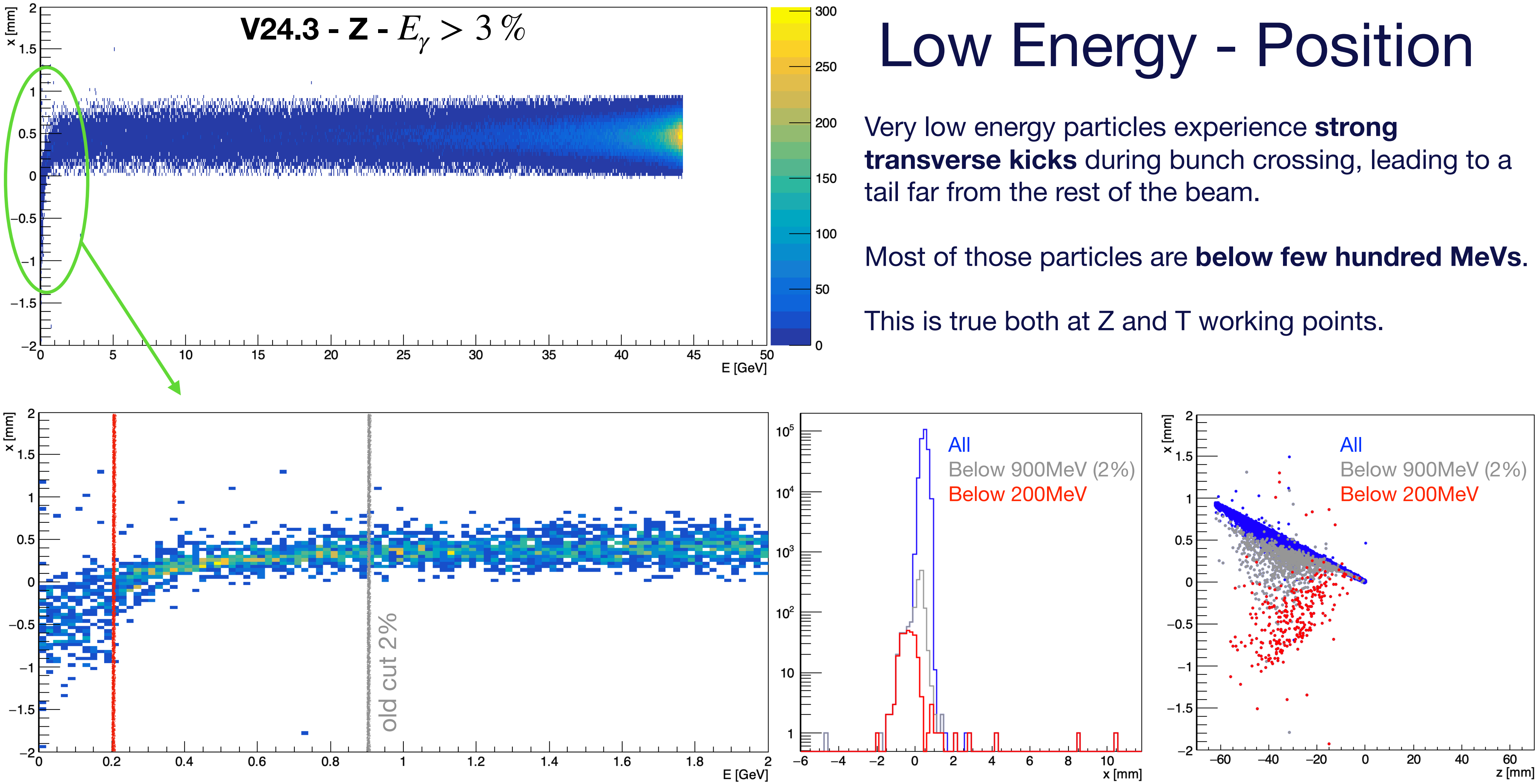
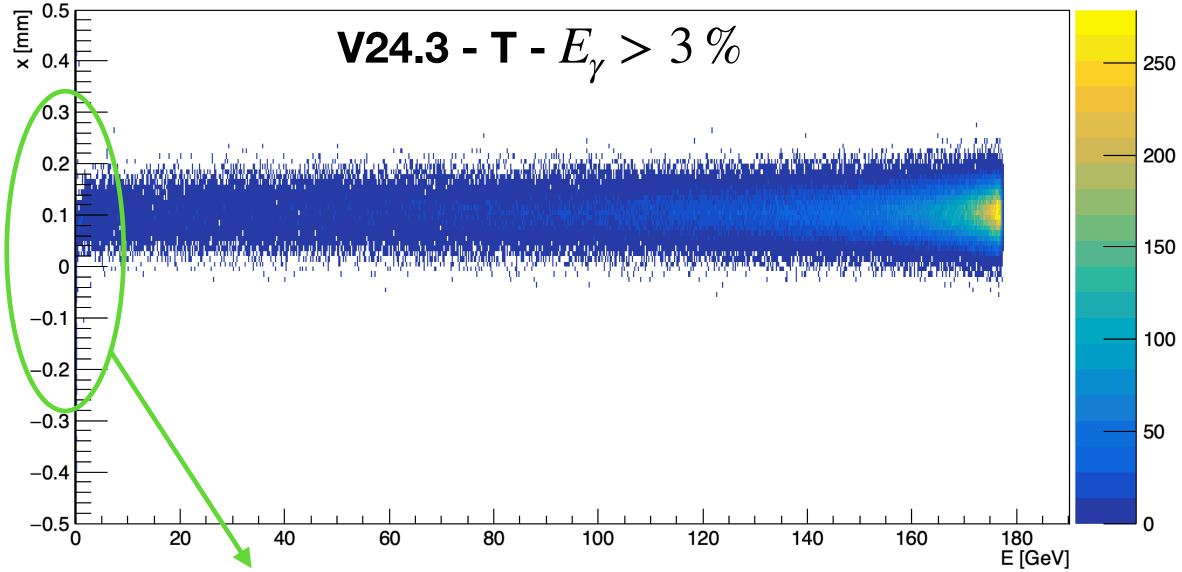
Low Energy - Position

Very low energy particles experience **strong transverse kicks** during bunch crossing, leading to a tail far from the rest of the beam.

Most of those particles are **below few hundred MeVs.**

This is true both at Z and T working points.





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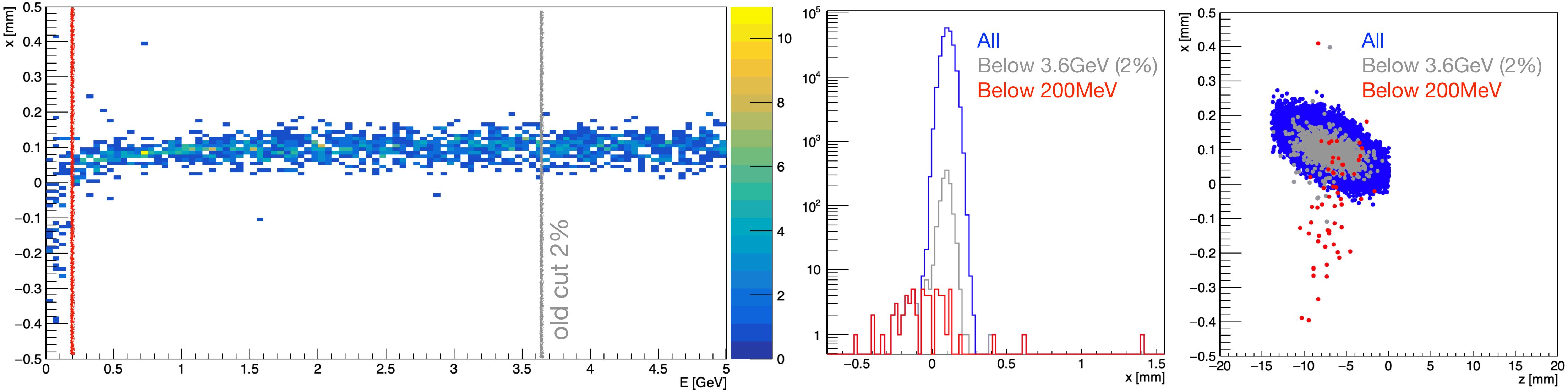
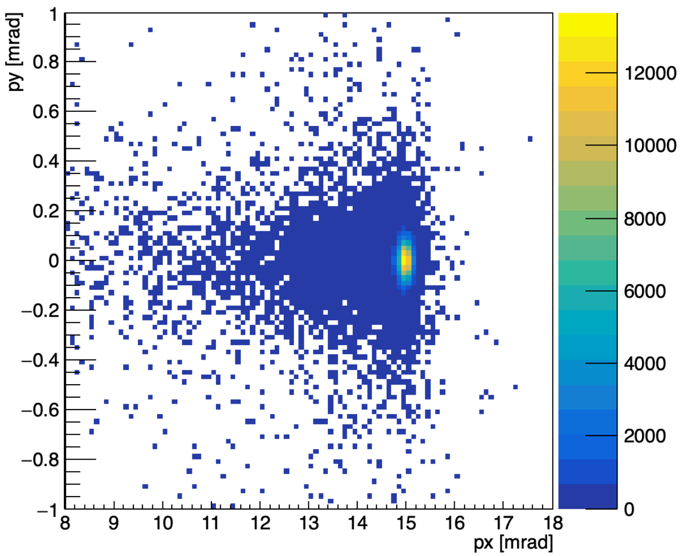


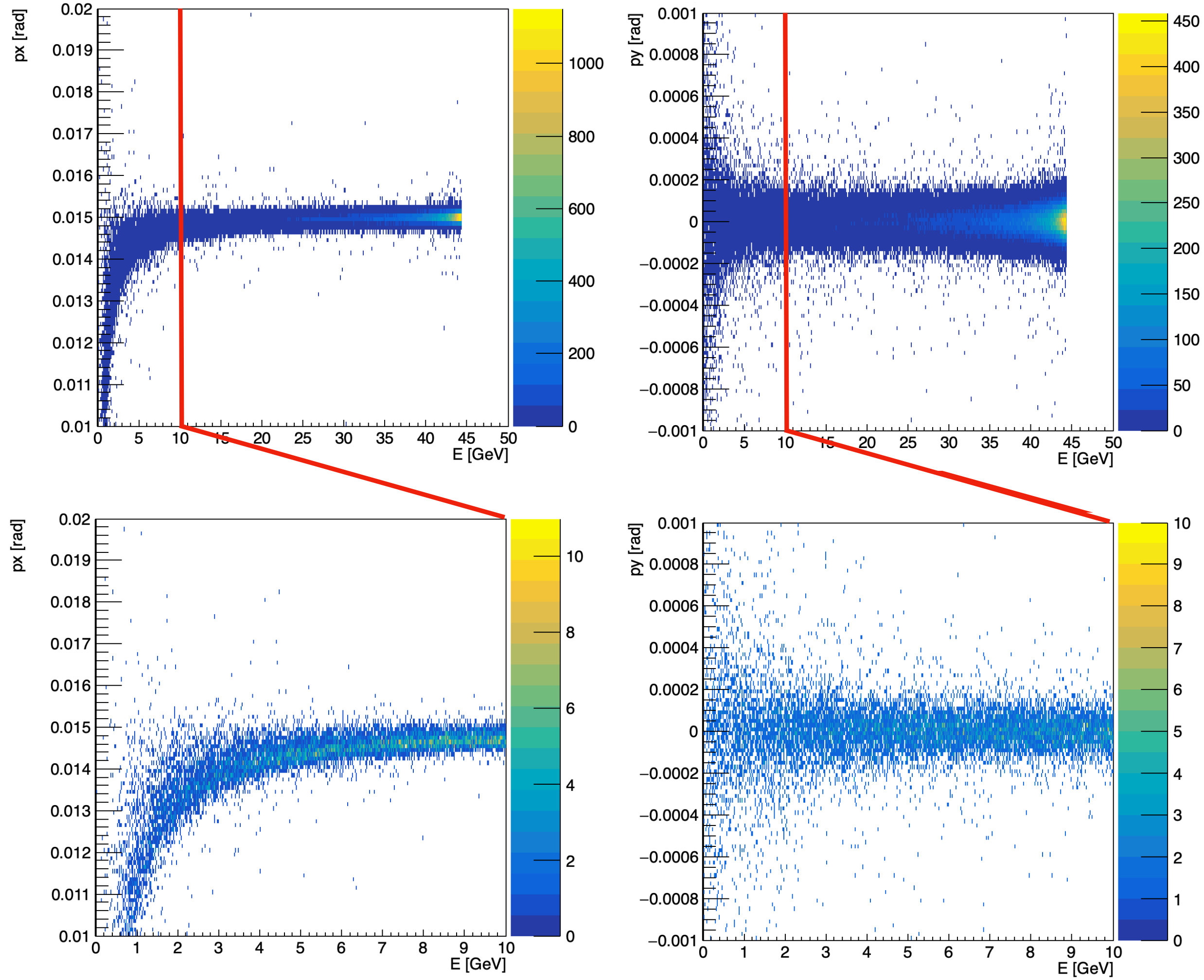
Low Energy - Momentum

For the same reason, low energy particles at the end of the PIC tracking have larger transverse momentum.

On the horizontal plane the effect is asymmetric due to the crossing angle, on the vertical it's symmetric instead.



V24.3 - Z - $E_\gamma > 3\ \%$



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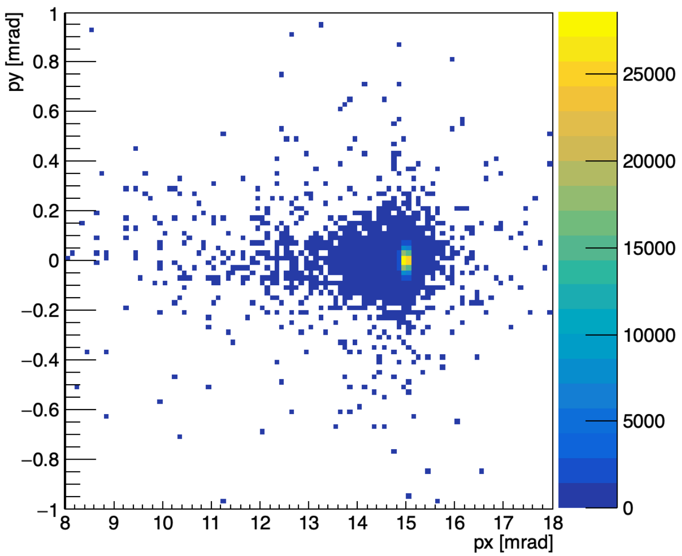
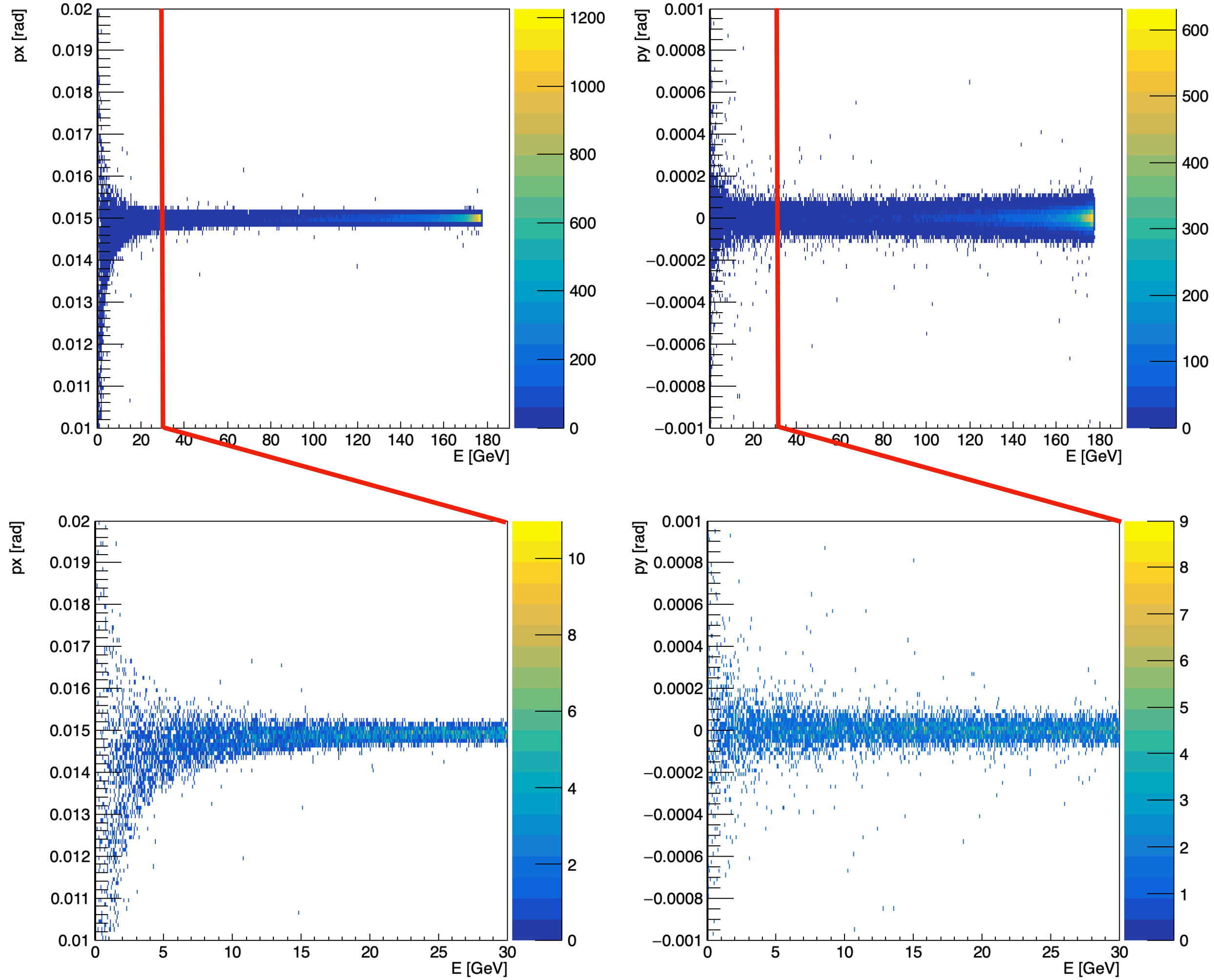


V24.3 - T - $E_\gamma > 3\,\%$



Radiative Bhabha EOS Repository

A repository for the radiative bhabha particles can be found at:

/eos/experiment/fcc/users/a/aciarma/radbhabha

This will be updated with samples for new stable lattice parameters or on request.

For each sample are available:

- BBBREM log to get the total cross section to be used for normalization
- ASCII file for bhabha particles in the detector frame
- ASCII file for bhabha particles in the downstream beam frame
- ASCII file for bhabha photons in the downstream beam frame
- ROOT file with bhabha particles and photons
- plots for the particles and photons distributions

Notice that in the simulation only beam1 radiates, so the file will contain only these particles.
For beam2 the effect is expected to be symmetric.

Incoherent Pairs Creation

FCC-ee Meeting #61 (02/12/2024) V. Gawas observed incongruence in number of particles/BX produced with GuineaPig++

Guinea Pig Pair Production

V. Gawas

Statistics

FCCee: Z working point: 300-350 pairs per BX **-> ~600 particles**
Energy spectra peak: 0.01 GeV, Average energy: 1.328 GeV

FCCee: tt working point: 900-1000 pairs per BX **-> ~1900 particles**
Energy spectra peak: 0.01 GeV, Average energy: 3.511 GeV

…while I get

(V24.3)	**avg. particles / BX**
Z	~1300
Top	~3300

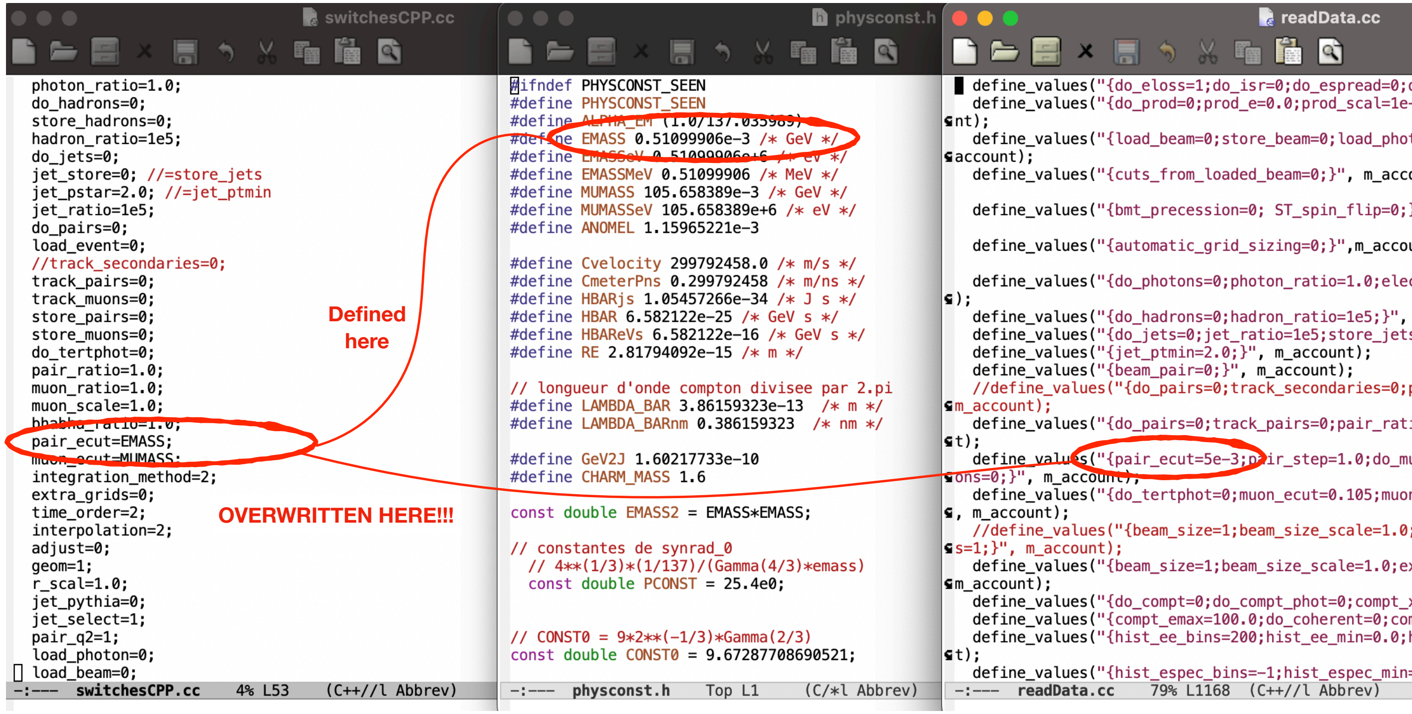
Incoherent Pairs Creation

GuineaPig has several parameters that may be set via a steering file.

If a parameter is not set, a default value is taken.

> pair_ecut (DOUBLE) Minimal energy in GeV the particles from pair creation need to have to be stored. Default is electron rest mass.

For some reason, in the GP source code this variable is correctly initialized but then redefined as 5 MeV.



To remove this cut this variable should be defined in the steering file

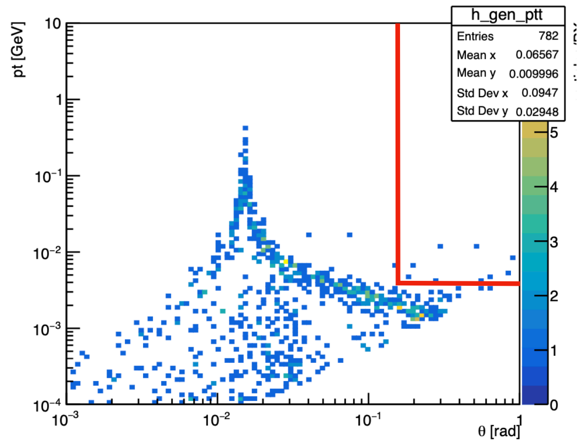
```
store_pairs=1;
pair_ecut = 0.000511;
hadron_ratio=100000;
```

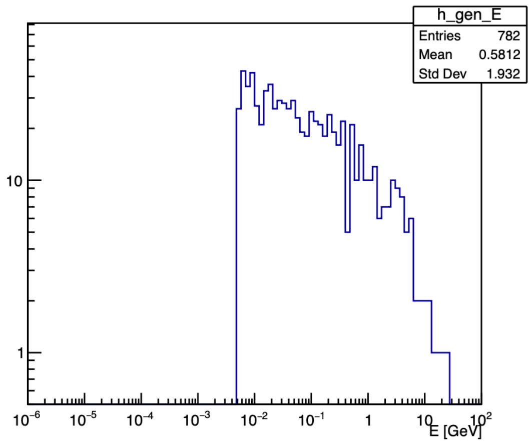
Samples used up to now <u>already had this fix</u>

/eos/experiment/fcc/users/a/aciarma/pairs

Incoherent Pairs Creation

pairs_ecut = 0.005 (hardcoded)

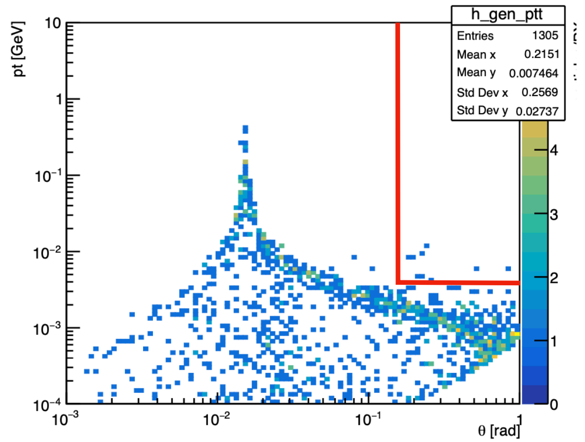


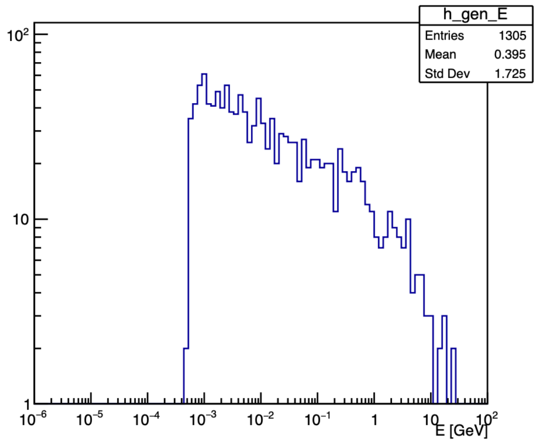


If `pair_ecut` is not manually set in the steering file, the cut is set to 5MeV and therefore fewer particles are stored.

The results with and without this parameter in the steering file have been crosschecked also with V. Gawas for gaussian beams.

pairs_ecut = 0.000511





email from V.Gawas

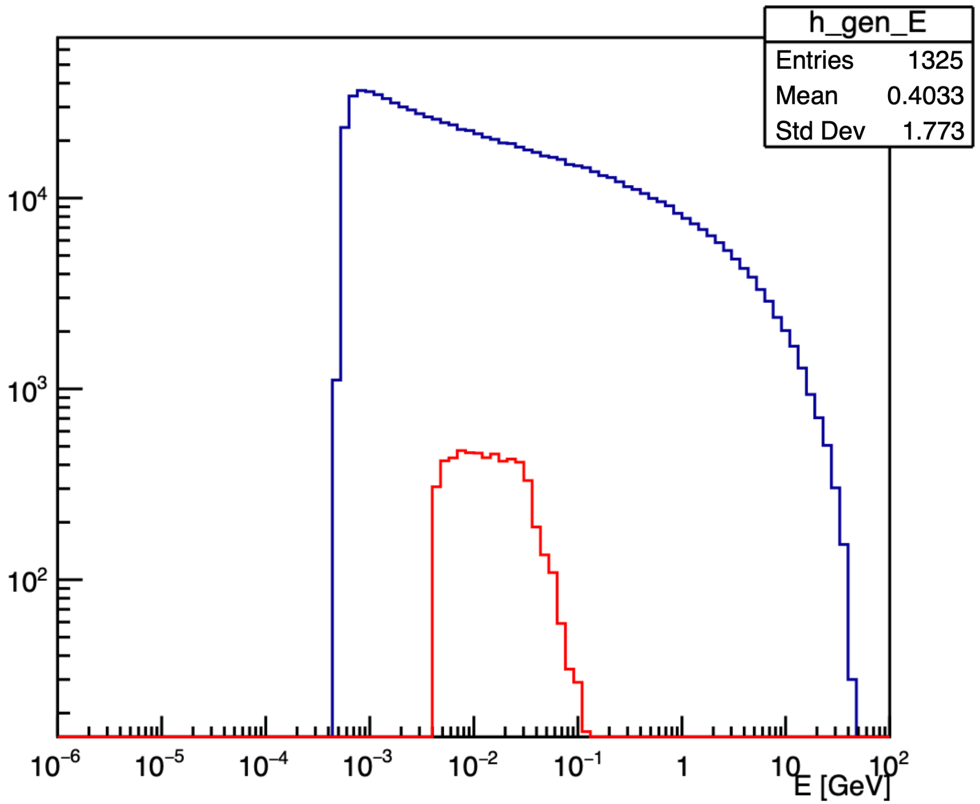
At Z working point:

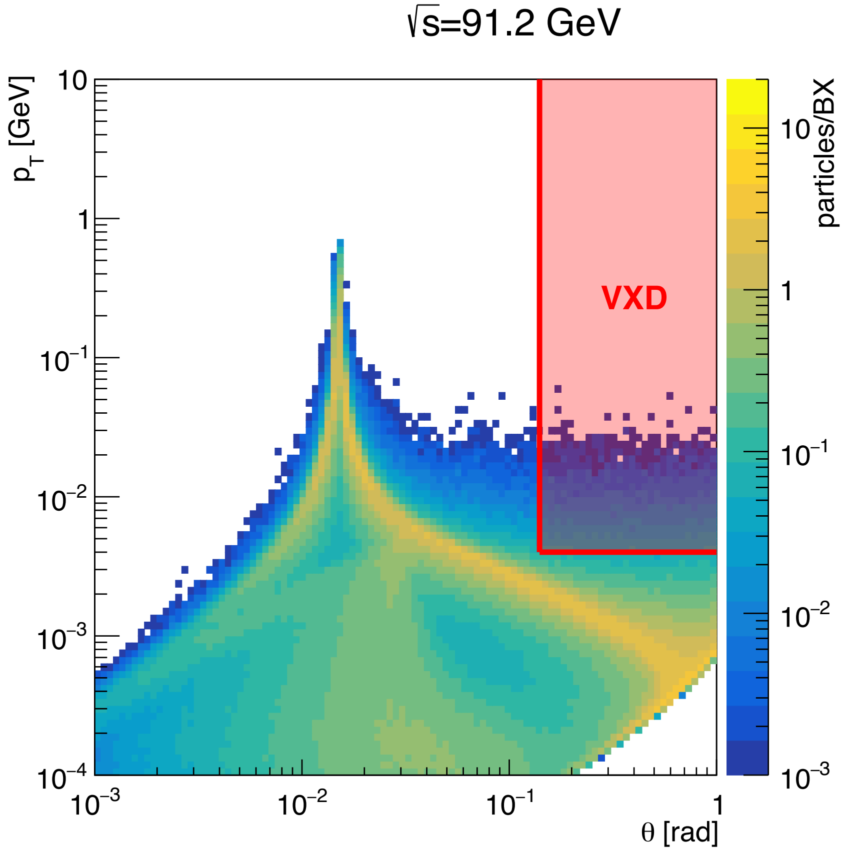
with pair ecut ~~1200-1250 (no. of lines)
without pair ecut ~~600-700

At tt working point:

with pair ecut ~~3200-3400
without pair ecut ~~1900-2100

Considering the innermost detector acceptance of 140mrad and radius 13mm, with a 2T solenoid field we see that only particles with E>4MeV can hit the detector.



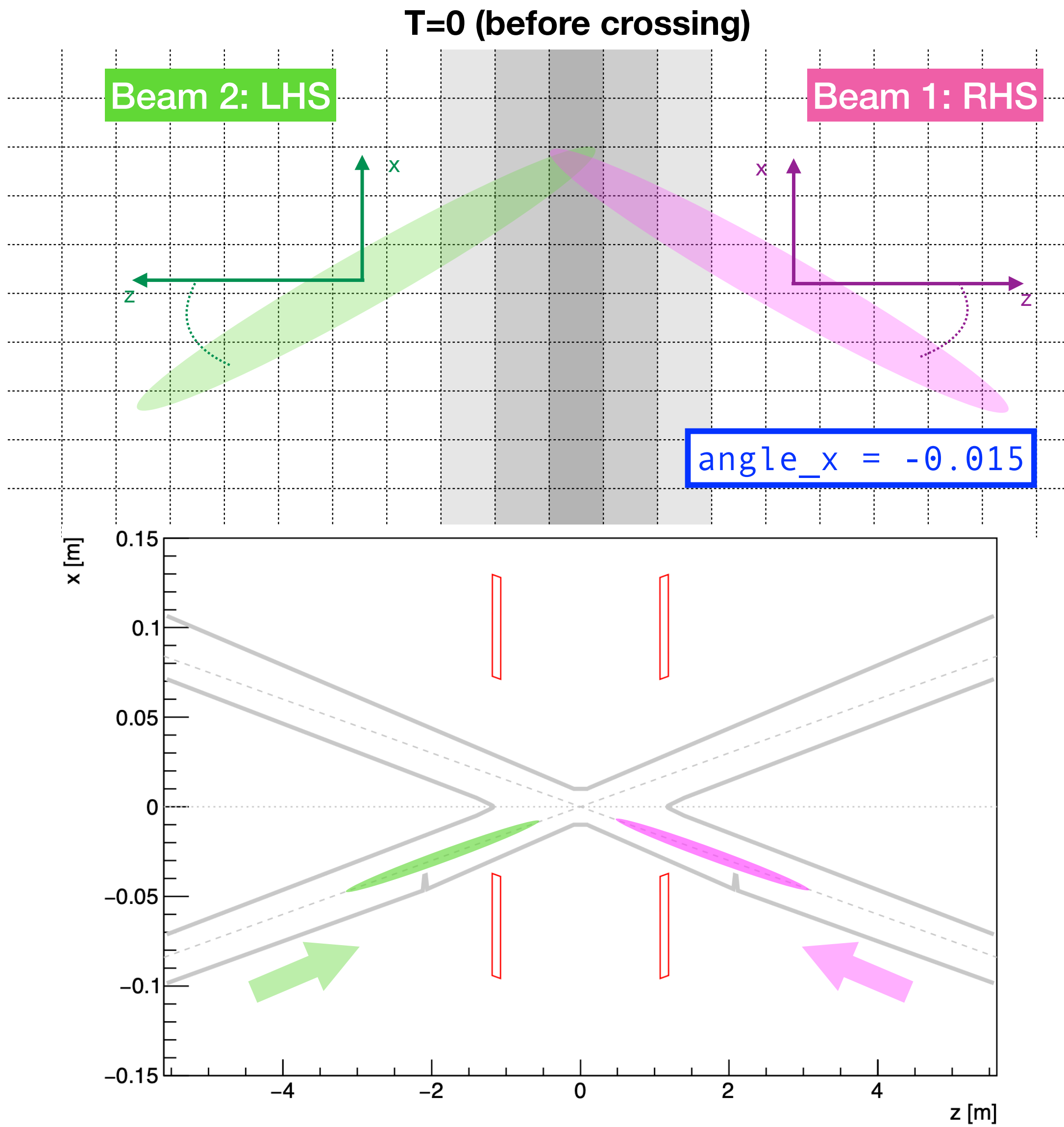


Crossing Angle in GuineaPig

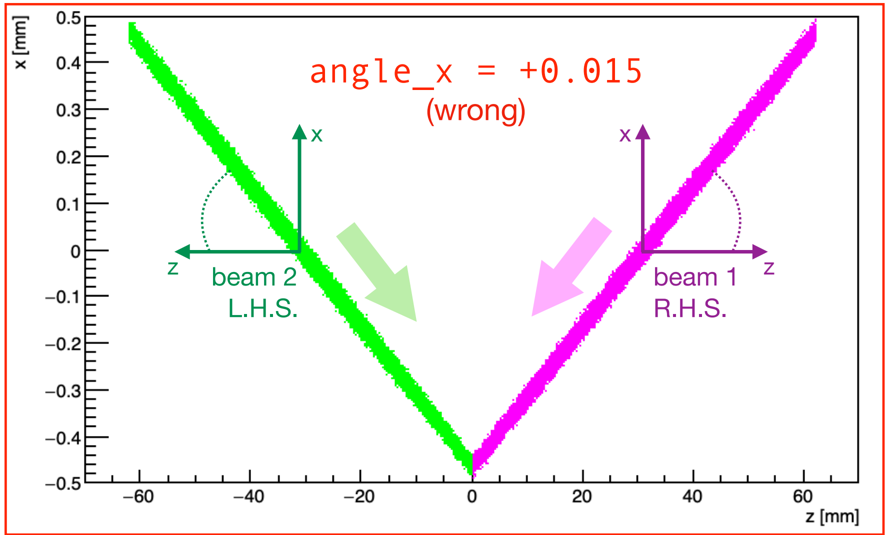
In GuineaPig++ the rotation of the beams is defined via the variable `angle_x`.

beam1 moves from +z to -z (right to left) and is defined in a Right Handed System
beam2 moves from -z to +z (left to right) and is defined in a Left Handed System

To be in the detector reference frame (except for the Lorentz boost) `angle_x` should be set **negative**.



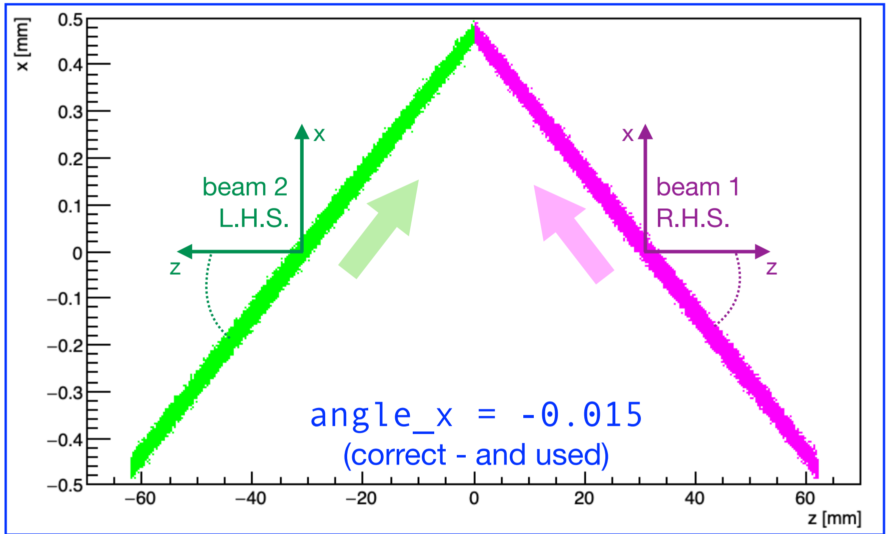
*GP simulations at Z, changing only the angle. T=0 (before crossing)

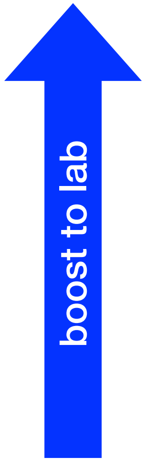


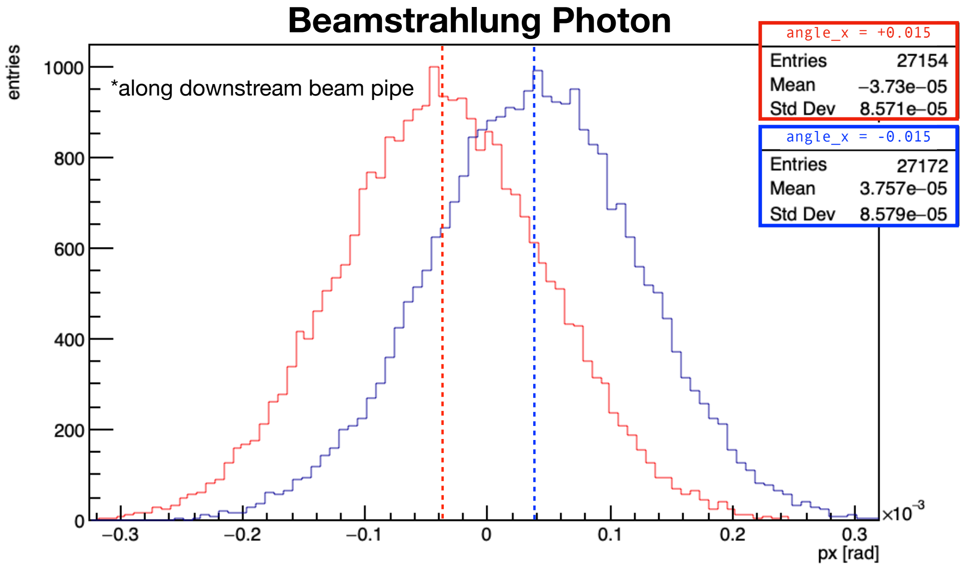
Crossing Angle in GuineaPig (2)

The position of the two beams at the start of the GP simulation can be checked by dumping the particles in the grid during the first step, before the crossing starts.

Improperly setting this angle may lead to a misdefinition of the angles of final state particles for further studies - e.g. beamstrahlung radiation







Summary

Radiative Bhabhas:

- irregularities in particles distribution spotted by M. Dam, triggered by high values of dose on the LumiCal from FLUKA tracking (MDI #62)

➡ minor bug spotted on output writing

✓ fixed samples, FLUKA simulations re-done

Incoherent Pairs Creation:

- inconsistency on pairs number spotted by V. Gawas (MDI #61)

➡ hardcoded value in GP for pairs energy cut if not explicited

✓ samples used up to now for background studies are correct

Crossing angle and GuineaPig:

- private discussions on beamstrahlung photons with A. Frasca and J. Salvesen

➡ mis-definition of crossing angle in GP can flip x-axis

✓ samples produced and used for BS characterisation studies are correct

Cross-checking is important! These generators should not be seen as plug&play for occupancy studies, as small mistakes can bring to not easy-to-spot differences.

BACKUPS

Cutoff on the momentum transfer

Radiative Bhabha Cross Section [mbarn]				MINIMUM PHOTON ENERGY			LUMINOSITY/IP	
ENERGY	LATTICE	CUTOFF		0.01%	3%	50%	$cm^{-2}s^{-1}$	$ab^{-1}yr^{-1}$
Z	v530 (V22)	1 sigmaY	33.7 nm	–	**112.1**	**18.2**	1.82E+36	20.9
T	v530 (V22)	1 sigmaY	69.0 nm	–	**118.5**	**19.2**	1.24E+34	0.14
Z	v572 (V23)	1 sigmaY	36.5 nm	–	**112.7**	**18.3**	1.41E+36	16.2
T	v572 (V23)	1 sigmaY	49.0 nm	–	**115.4**	**18.7**	1.38E+34	0.16
Z	v605 (V24.3)	1 sigmaY	36.5 nm	**332.6**	**112.7**	**18.3**	1.43E+36	16.4
T	v605 (V24.3)	1 sigmaY	43.6 nm	**337.1**	**114.3**	**18.6**	1.38E+34	0.16

$$L_{int} = L_{true}T_{physics}E_{factor} = (0.90\, L_{nominal}[cm^{-2}s^{-1}]) \cdot (185 \cdot 86400[s]) \cdot 0.80 = 1.15 \cdot 10^7[s]\ L_{nominal}[cm^{-2}s^{-1}]$$

Momentum transfer t is related to the distance between the interacting particles

$$t = \left(\frac{\hbar c}{d}\right)^2$$

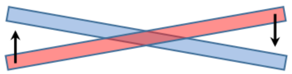
Due to bunch dimensions and density effects, the interaction range is not infinite.

We apply a cut on t assuming as a critical distance:

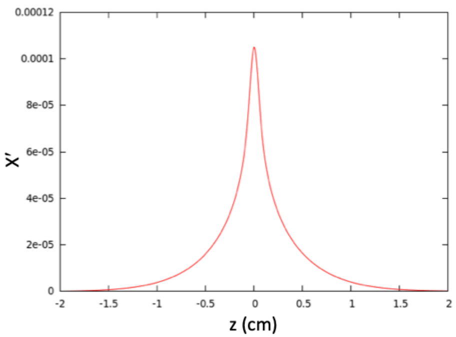
$$d_0 = \sigma_y$$

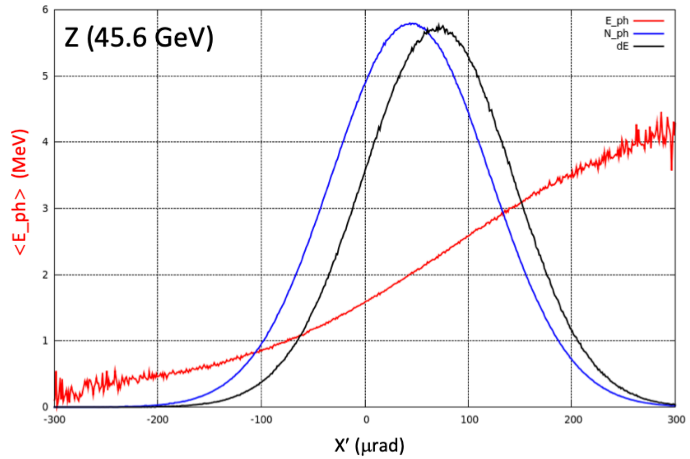
$$t > t_0 = d < d_0$$

X′ – Energy Correlation

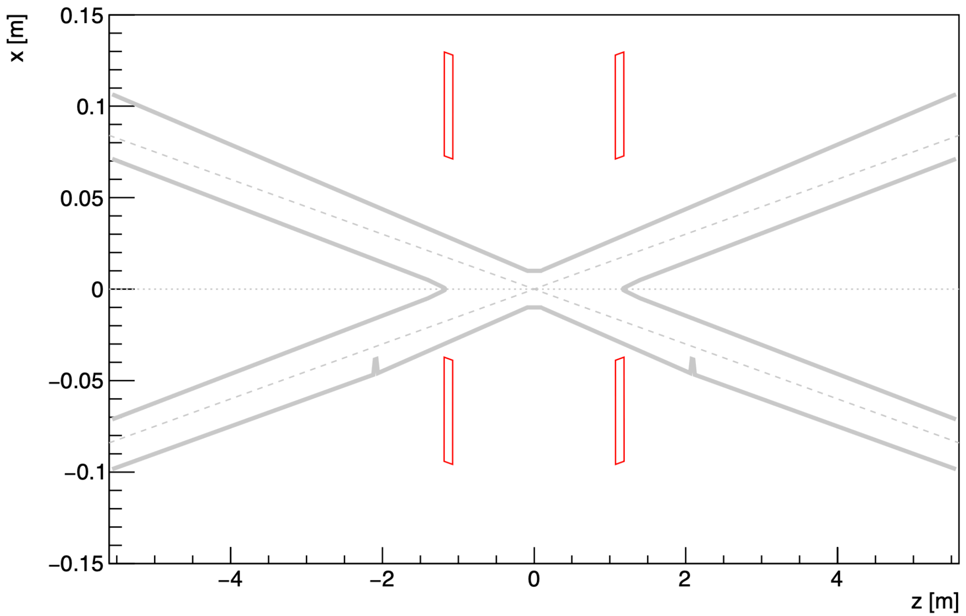


Photons with maximum energy are emitted at the IP, where the angle X′ is also maximal.

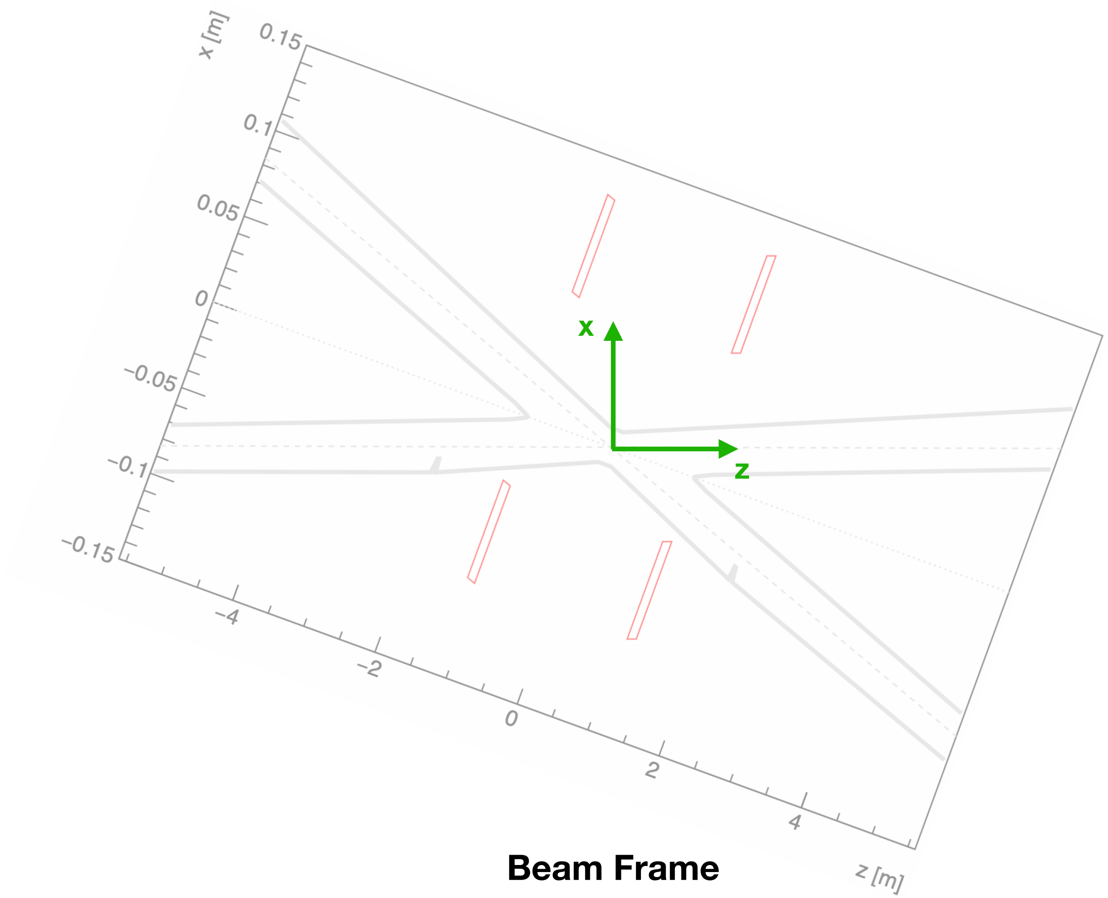




This correlation depends on the Piwinski angle. Therefore, at high energies, it will be weaker.



Lab Frame / Detector Frame



Beam Frame

Luminosity Enhancement

- Both Crab Waist and Strong-Strong beam effects cause luminosity enhancement
- N.B. results here are all comparisons for ideal case, no machine errors yet simulated