Final setting of the winter2023 Monte-Carlo campaign

E. Perez, M. Selvaggi

Summary of the changes that went in - converged upon during the Xmas break.

- Key4hep stack version: 2022-12-23
- Delphes version : 3.5.1.pre05

New machine parameters

Updated set of parameters (Dec 6, 2022), see talk F. Zimmerman at the IS workshop.

Relevant for our samples:
- Beam energy spread: e.g. at 240 GeV, increased to 0.185% (was 0.165% earlier)
- Size of the luminous region

	Z peak	WW	ZH	top
σ vtx, x	5.96 µm	14.69 µm	9.8 µm	27.3 µm
σ vtx, y	23.8 nm	46.5 nm	25.4 nm	48.8 nm
σ vtx, z	0.397 mm	0.966 mm	0.646 mm	1.33 mm
σ vtx, t	36.3 ps	18.9 ps	14.1 ps	6.46 ps

Enters in the generator cards.

NB: Whizard samples now have a beam-spot (bug in spring2021, all events were at the nominal IP)

Updated Delphes card (IDEA) : geometry

- Smaller beam-pipe, R = 1 cm, and subsequent re-optimisations of the vertex detector, following engineer design (F. Bedeschi, F. Palla, F. Bossi) :
  - Beam pipe is now at 1 cm radius and the %X0 has gone from 0.34 to 0.67% (MDI)
  - The inner and outer layers of the vertex detector have been optimized (same %X0 for the time being)
    - Esp. 1st barrel layer now at R = 1.2 cm (instead of 1.7 cm)
  - The inner disks have gone from 2 double layers to three single layers and their position has been optimized (same %X0)

- ECAL resolution: now assumes a crystal calorimeter as in 2008.00338

$$\frac{\sigma_E}{E} = \frac{3\%}{\sqrt{E}} \oplus \frac{0.2\%}{E} \oplus 0.5\%$$

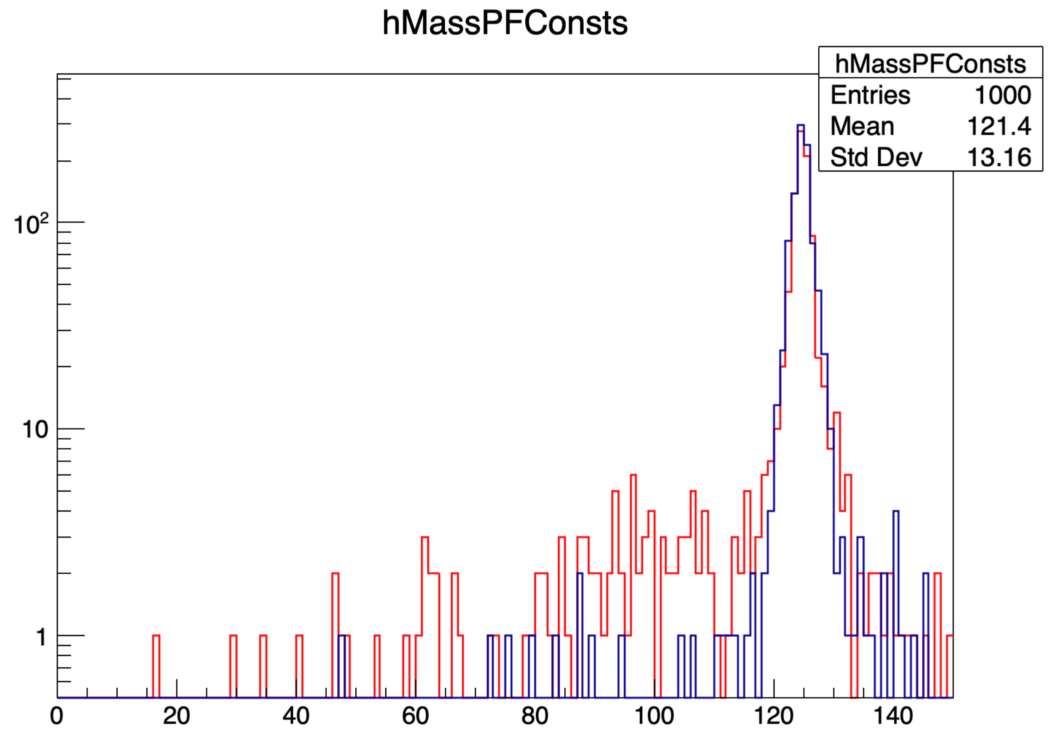
Updated generator cards: particles that decay outside the tracker

Particles are decayed only if the decay vertex is within a cylindrical volume, corresponding to the volume of the tracker.
In case the decay vertex would be outside the tracker volume, the particle is not decayed and treated as stable.

Reason: e.g. Ks -> pi+ pi- . If the Ks decays outside the tracker volume, Delphes removes the daughter pions since they can't be propagated and the Ks is "lost". With the new settings, the Ks is reco'ed as a neutral hadron in the calorimeter.

Visible mass in H → ss events:

Blue = updated settings,
Red = old ones.



Electrons smearing: recap from last meeting

Tracks in Delphes: account for MS but not for secondary interactions, brems.

Spring2021 samples: same resolution for electron tracks and muon tracks

- resolution of reco'ed electrons appeared worse, but that was due to non optimal configuration of the Pflow module

Would be overdoing to implement brems in Delphes… Still, some accounting of the effect is desirable, via some simple ad-hoc smearing of electrons w.r.t. muons

- Studied in Full Simulation with a hacked version of the CLD tracker: reduce the material of the CLD Si tracker such that the total material budget is similar to that of IDEA.
- Gaussian fit to the core of the resolution distribution: electrons are O(20%) worse than muons
  - Also confirmed by recent Full Simulations of IDEA (Lia Lavezzi)
- But for "effective resolution" : electrons (from track) are worse than muons by a factor of O(2), low energy tail due to brems.

Electrons smearing

Improvements (w.r.t. the electron track momentum, measured by a Kalman filter) can come from:

- GSF tracking (but gain is probably limited)
- Recovery of bremstrahlung photons in the calorimeter

Closer look at the brems in single electron files.
Example: E = 50 GeV, theta = 70 deg. At this angle: total material = O(5% X0).
Muons at this angle / energy are measured to 70 MeV.

- < Total E > carried by the brem. photons : 2.3 GeV per event
  - Consistent with expected 5% x 50 GeV
- 63% of the events make no brem
  - For these electrons: resolution is very similar to that of μ's, only a few % diff
- For the 37% of electrons that make >= 1 brem : < Total E brem > = 6 GeV
  - Ideal brem recovery in the ECAL: this energy is measured with a resolution of 3% x $\sqrt{6}$ = 70 MeV (with crystals)
  - Post-brem track expected to be measured to about 70 MeV too (brems arrive early)
  - With E = track + Ebrem, expect a resolution $\sqrt{2}$ worse than μ's
- Overall: expect O(15%) worse

Recovery of brem photons

No crystal ECAL in the "light CLD" detector used for these full simulations → need some modeling of the brem recovery.

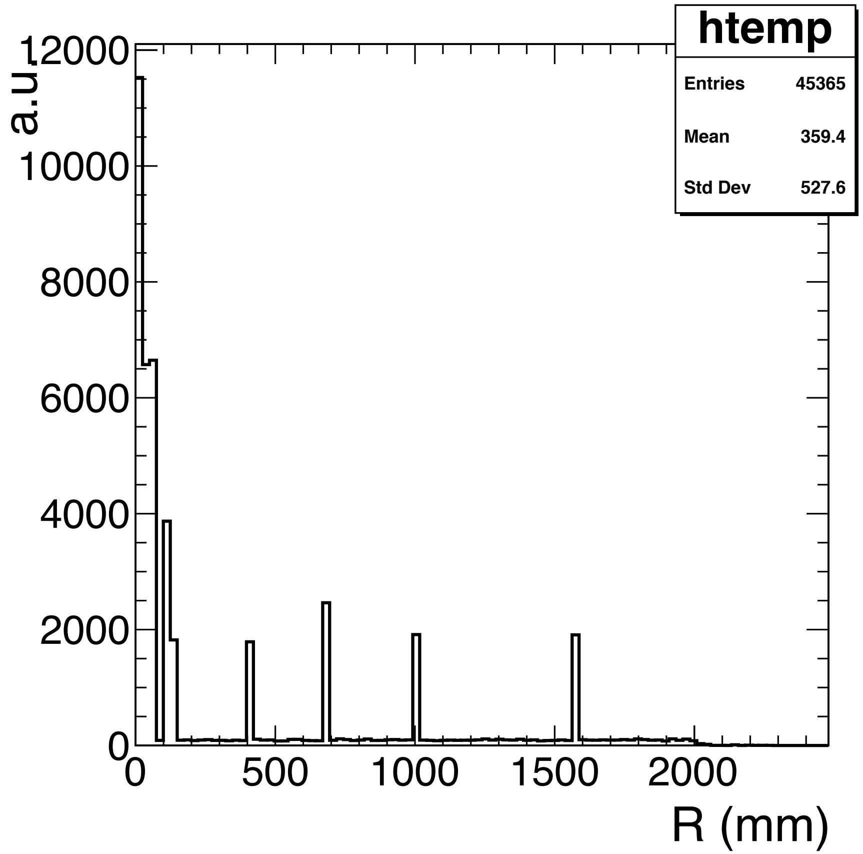
For each sim-level brem photon from GEANT:

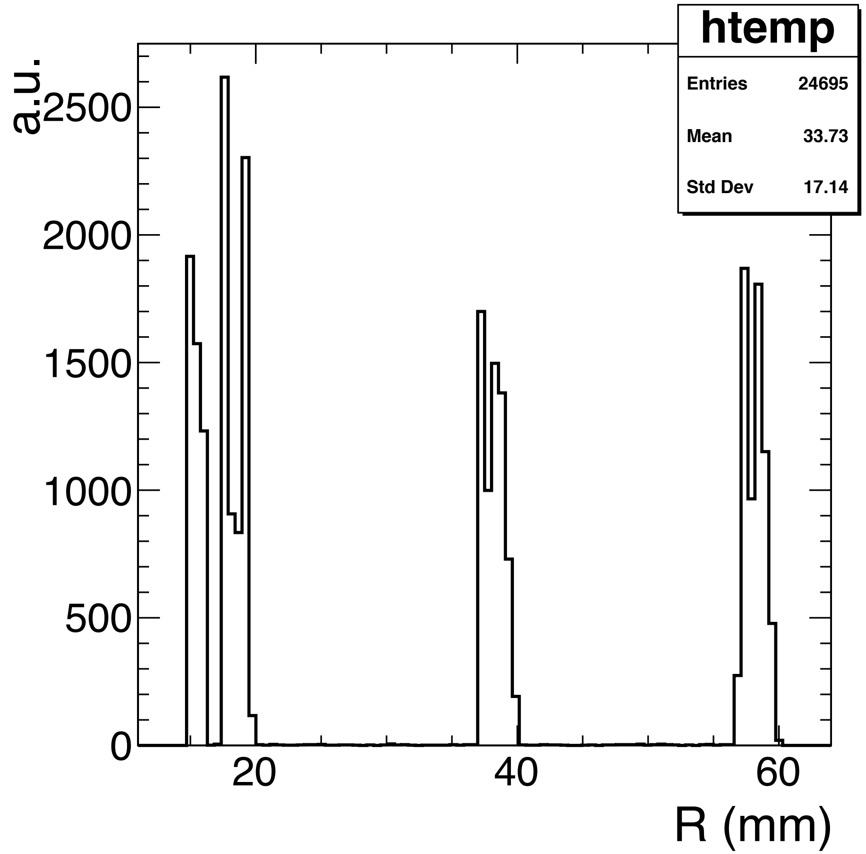
- Find the point where it enters the ECAL
- From the electron track states at the IP and at the ECAL entrance, define an angular window
- If the photon falls within this angular window:
  - And if the photon entry point is not too close to the track entry point (ECAL granularity, for example with an assumed granularity of 5x5 mm2, demand $R\Delta\varphi > Dmax = 10$ mm, corresponds to one empty cell between the photon and the track) :
    - Smear the true energy of the photon (3% x $\sqrt{E}$)
    - If the energy is above some threshold, sum it up

Emission of the brems

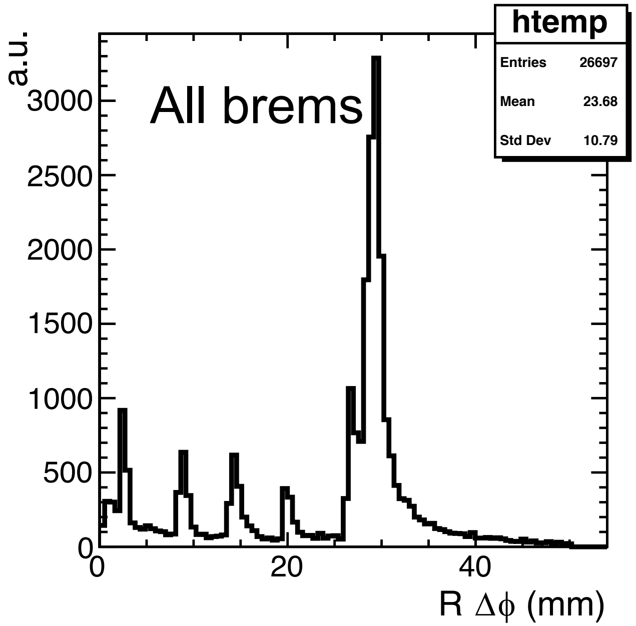
E = 50 GeV, theta = 70 deg

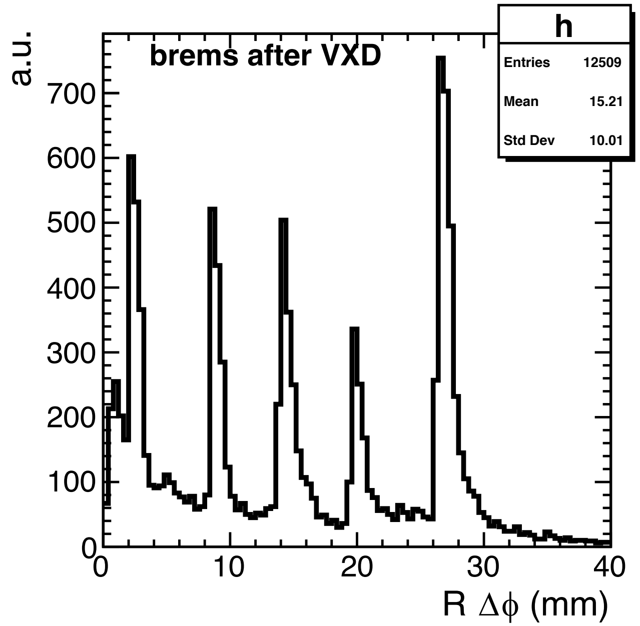
CLD: last layer of VXD is at R = 5.8 cm



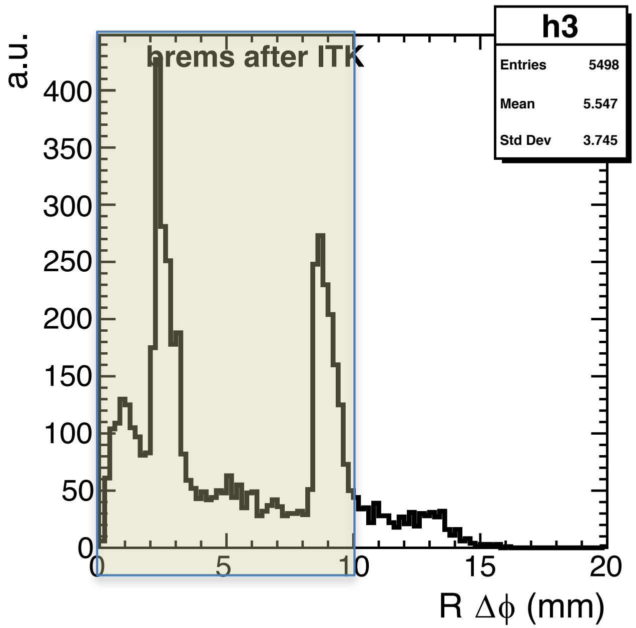


Distance between the brem & the electron track at the ECAL entrance





The later the brem occurs, the closest it is to the track entry point.



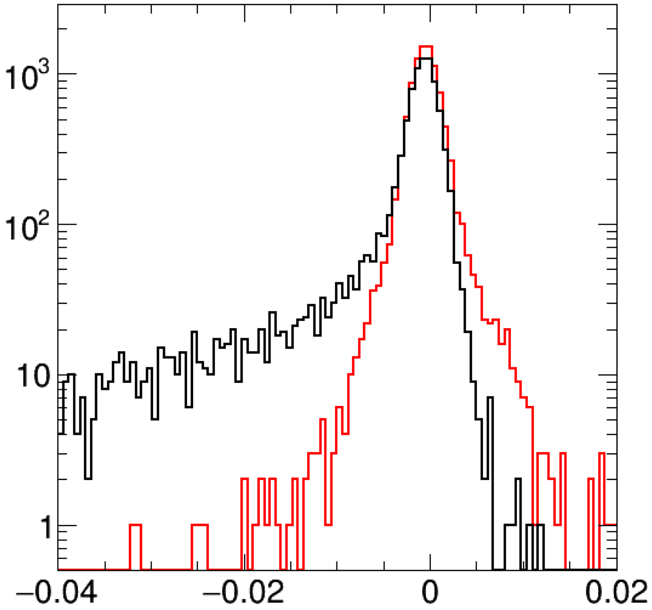
With a granularity of 5x5 mm: the photon may not be clustered with the electron if RΔφ > 10 mm. The only brems that one does not recover are the ones that are emitted after the ITK, i.e. at R > 67 cm.
With crystals of 3x3 cm: many more brems would not be recovered.

NB: in IDEA, brems occuring in the Si wrapper will probably be unrecoverable.

E.Perez

Effective resolutions with brem recovery

Add the recovered brems energy to the track momentum to define the electron energy.



(pT_reco – pT_gen) / pT_gen

Black = track only
Red = with brem recovery, 5x5 mm2

(little asymmetry (tail right-hand side) may come from some double counting at the GEANT level in the MCParticle collection used here, to be further investigated..)

Determine the effective resolutions from these histograms.

Result for Dmax = 10 mm: about 20% worse than muons, little dependence on the angle.
Entered a scale factor of 25% in the Delphes card – after the ParticleFlow module, this results in a degradation of 20% w.r.t. muons.

Conclusions on electron resolutions

- With the excellent muon track resolution that we have in IDEA: a highly performant recovery of the brems is needed, to achieve electron resolutions that are similar to muon resolutions
  - A difference with older studies made with CMS, or with LEP, where the muon track resolution was much worse

- The brem recovery depends on the ECAL granularity (transverse but also longitudinal), which will drive the performance of the clustering and the ability to separate the photons from the electron cluster.
  - To be studied in IDEA's full sim

- Scale factor of 1.2 in winter2023 : over-smearing may be applied at the analysis level, depending on the result of these full sim studies.

Current set of winter2023 samples

- Many samples at 240 GeV already produced
  - Higgs processes and various backgrounds
  - Compared to spring2021: many more exclusive samples

- Special thanks to Louis Portales (LLR, MC contact for the Higgs group) for updating or preparing the cards and submitting the jobs !

- Samples in EOS:
  - /eos/experiment/fcc/ee/generation/DelphesEvents/winter2023/IDEA
  - 110 samples so far, 500 M events
  - http://fcc-physics-events.web.cern.ch/fcc-physics-events/FCCee/winter2023/Delphesevents_IDEA.php