K^0 kinematics and their rough reconstruction

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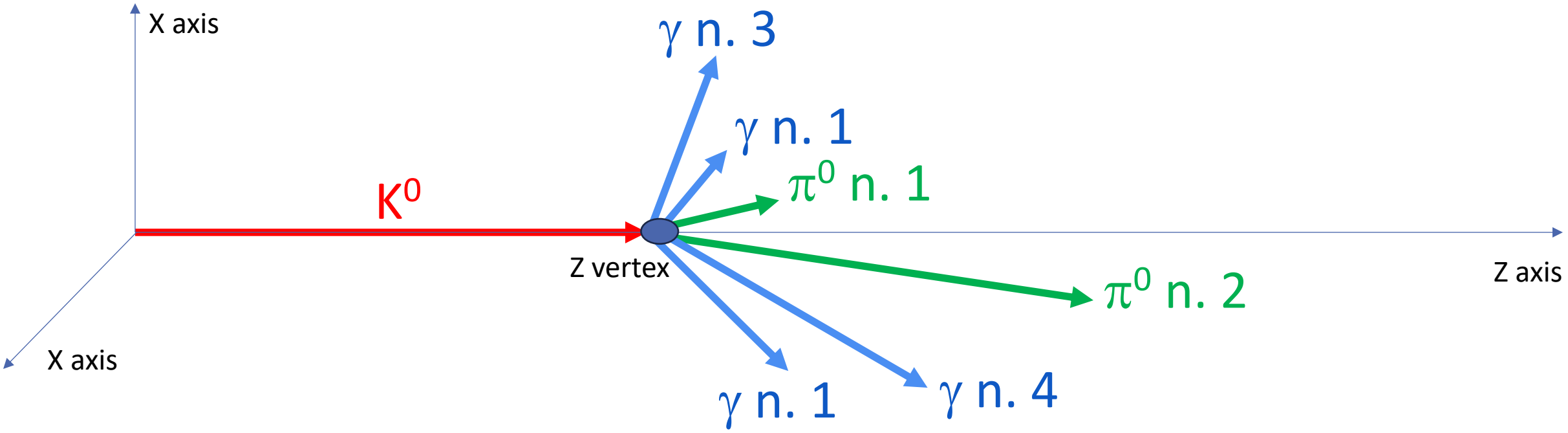
The simple idea in few steps (I)

- I decided to do this simple study essentially to learn Python!!!!!
  - Please, it is useful to cross-check my results….

- Generate single monoenergetic K^0_s, in the forward direction (θ=0) with Pythia (under Python)
  - $\tau=0.8954.10^{-10}$ s
  - $c\tau$=2.7 cm
  - $\gamma\beta ct$=54 m for 1 TeV K^0
- Allow them to decay at a certain z_{vertex}
- Select π^0 π^0 decays (Br=30.7%) (final state with $\gamma\gamma\gamma\gamma$, produced at the same point, since π^0 lifetime is very short!)
- Pre-select events with:
  - Decay vertex < 140 m
  - 4 γ reaching the TAN region in a 20 cm radius circle
- Save data in a file

The kinematics



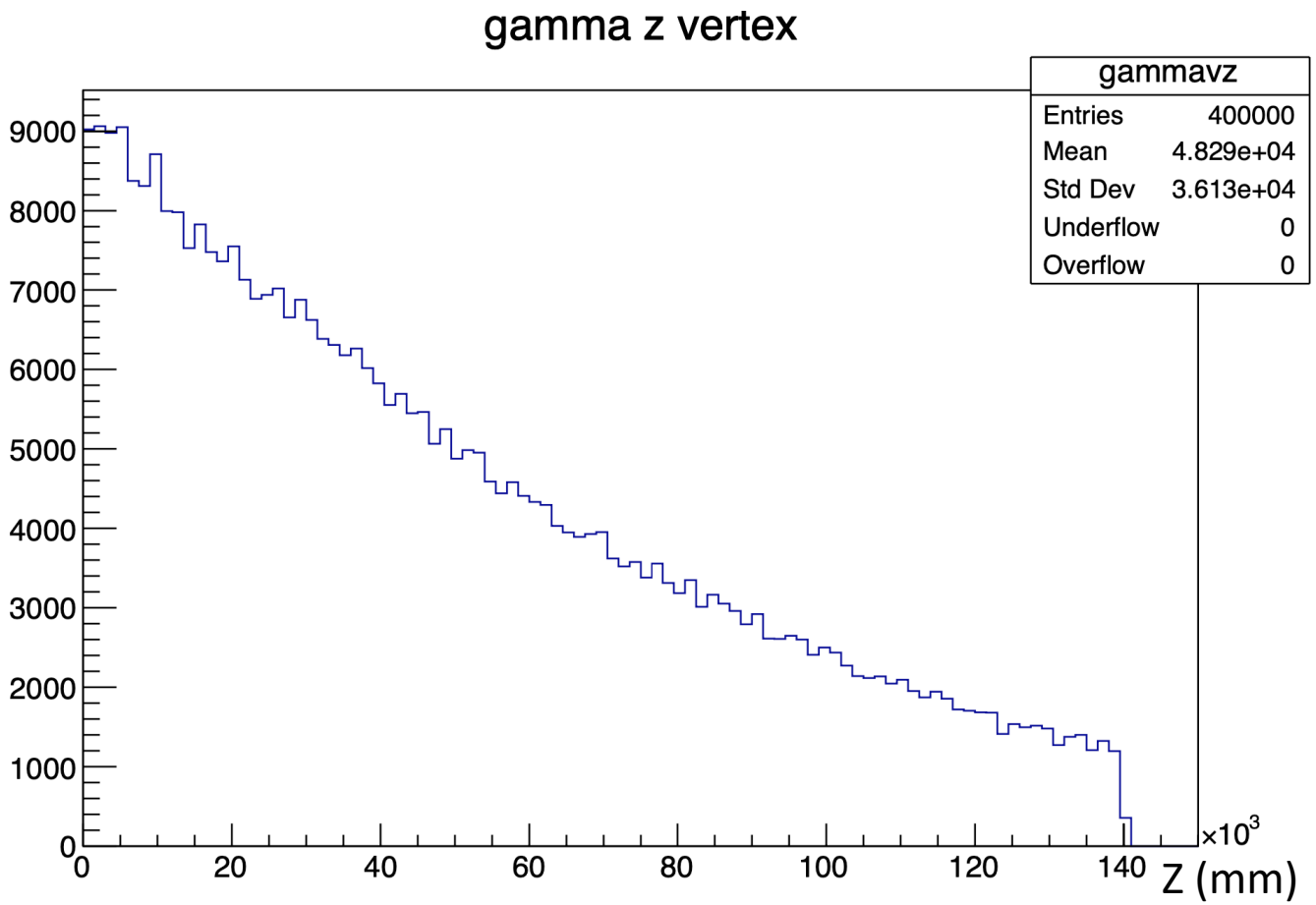
The simple idea in few steps(II)

- Extrapolate the 4 γ to the LHCf z coordinate (140 m)
- Find their intersection with the small and large towers
- Select events with 4 γ hitting the towers, with some minimum distance between them
  - Interesting kinematics is selected, see later!
- Smear their energies and x-y impact points
- Try to reconstruct the 2 π^0 (and then the K^0) with some simple fitting procedure, only from the hits on the towers

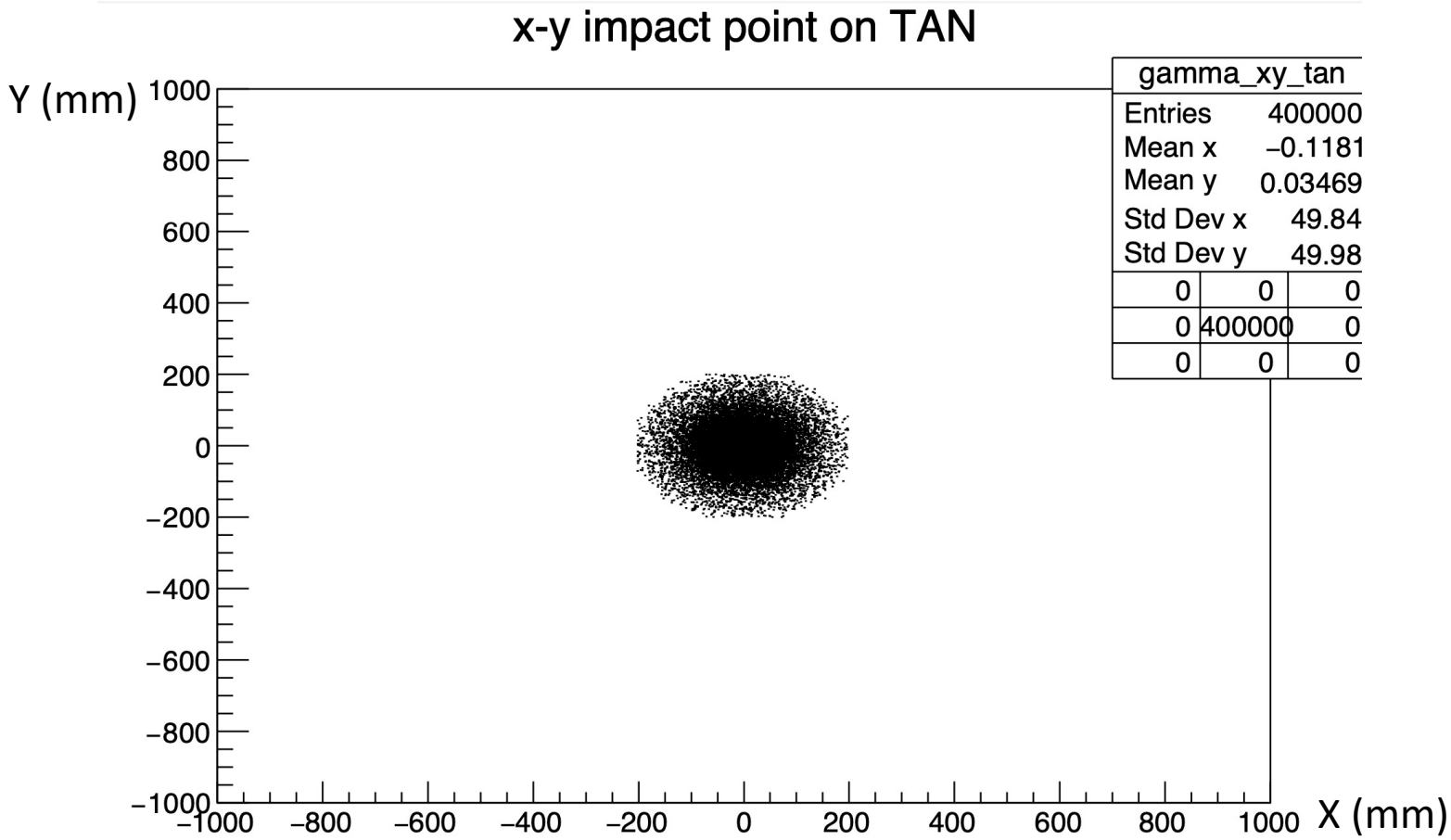
And now some more details….

- 500 GeV, 1 TeV, 2.5 TeV, 5 TeV, 7.5 TeV K^0 energies
  - 1 TeV is the ‘reference energy’
  - All the plots are for this energy

Z coordinate of the decay vertex

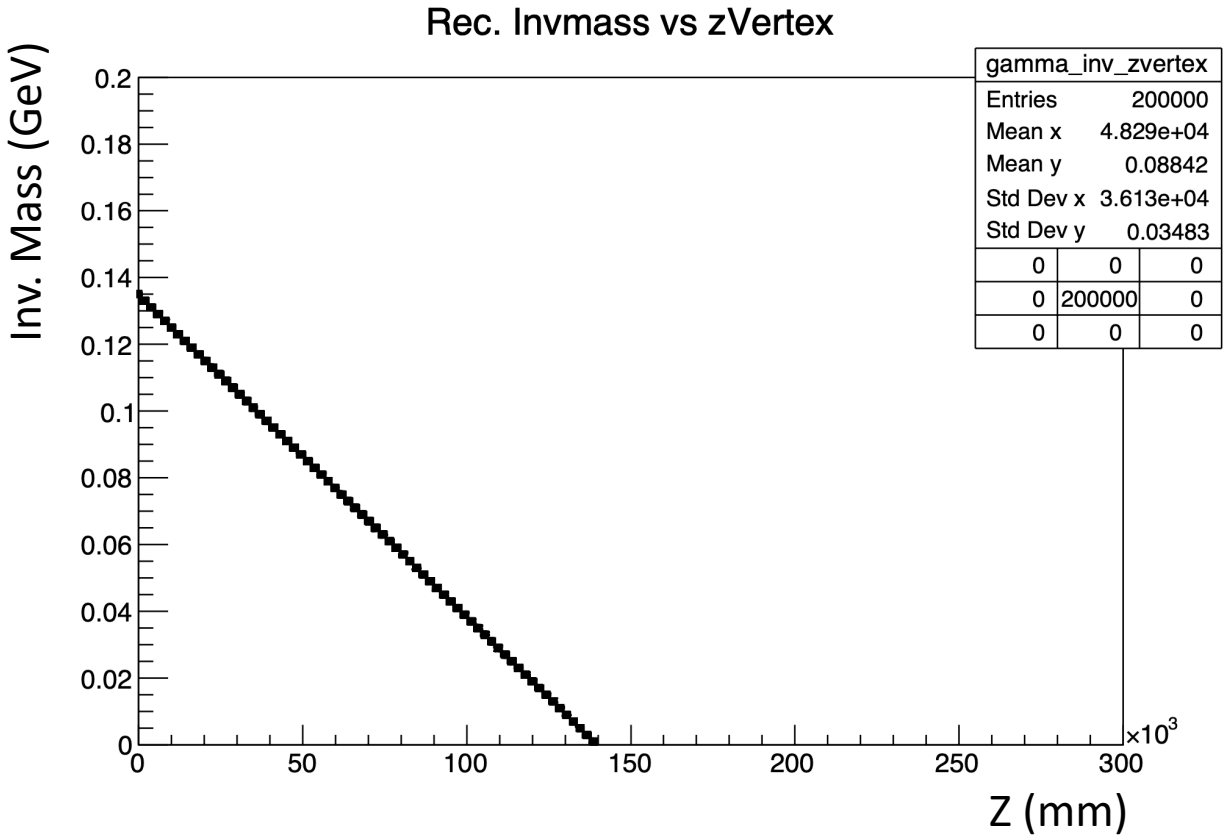


x-y on LHCf of pre-selected events (20 cm radius)



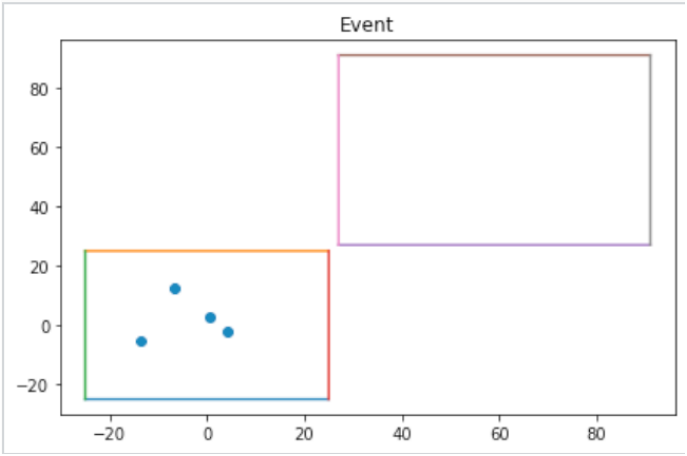
What happens if we simply assume that the γs are produced at the IP (z=0)?

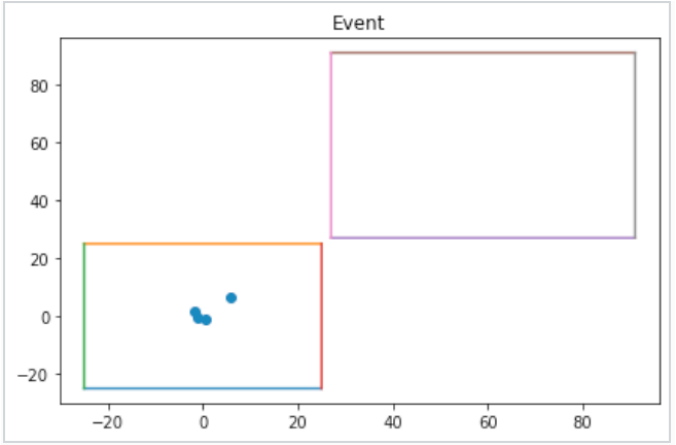
- A nightmare!!!!!! The γγ invariant mass is completely wrong, and correlated to the vertex position (on preselected only events)

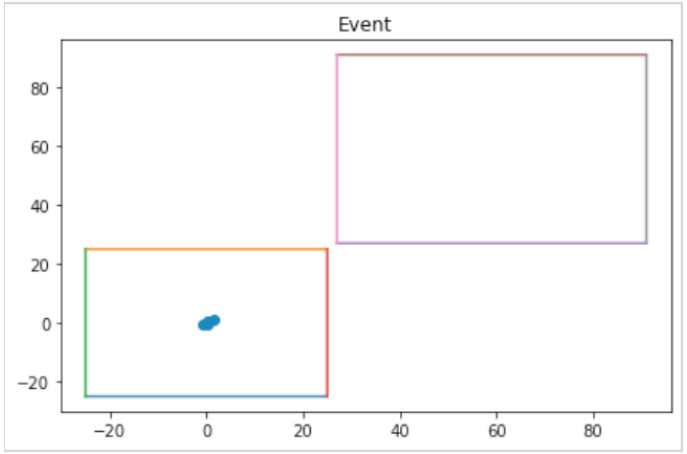


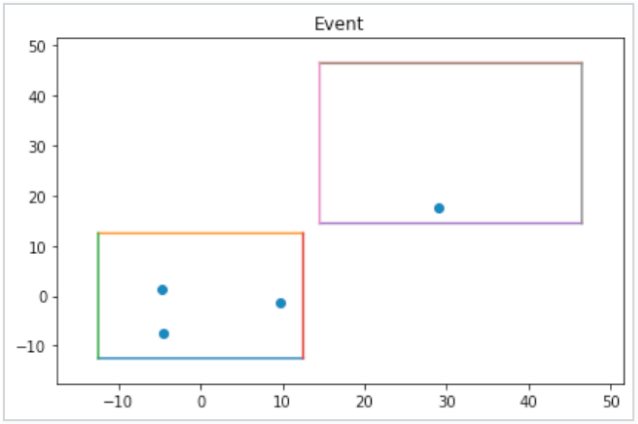
The knowledge of the decay vertex is essential!!!!!

Let’s find the ‘golden’ events (4 γ on the LHCf towers)









- Few events @1 TeV
- Most of the events are concentrated on the small tower
- 4 γ in ST, 0 g in LT
- Very few events have:
- 3 γ in ST, 1 g in LT

Smearing

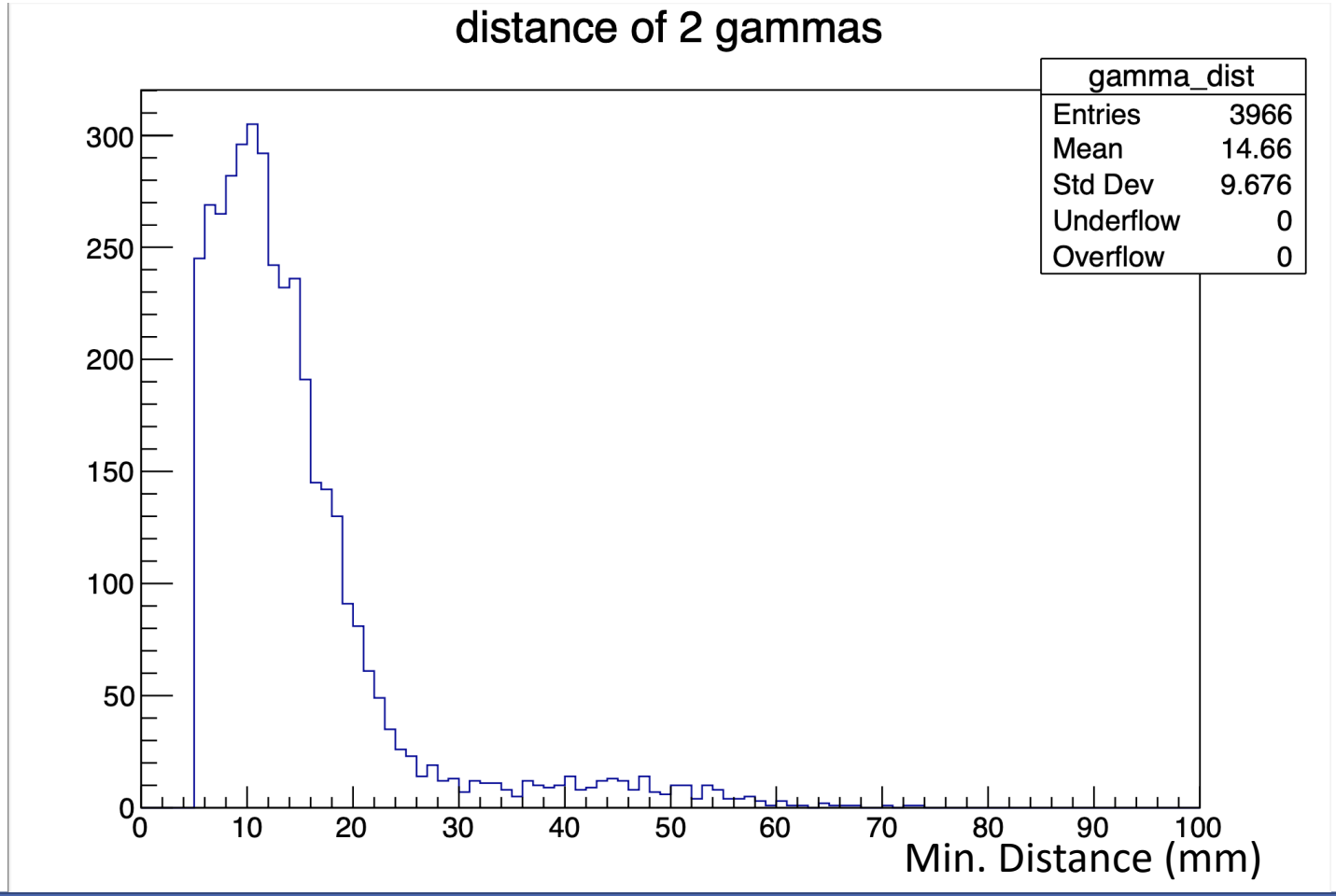
- A gaussian smearing on x, y, energy for each γ is applied
  - 10% energy smearing
  - 0.5 mm impact point smearing
  - Other values are used later for cross checks

Here some statistics (with 5 mm minimum distance btw γs)

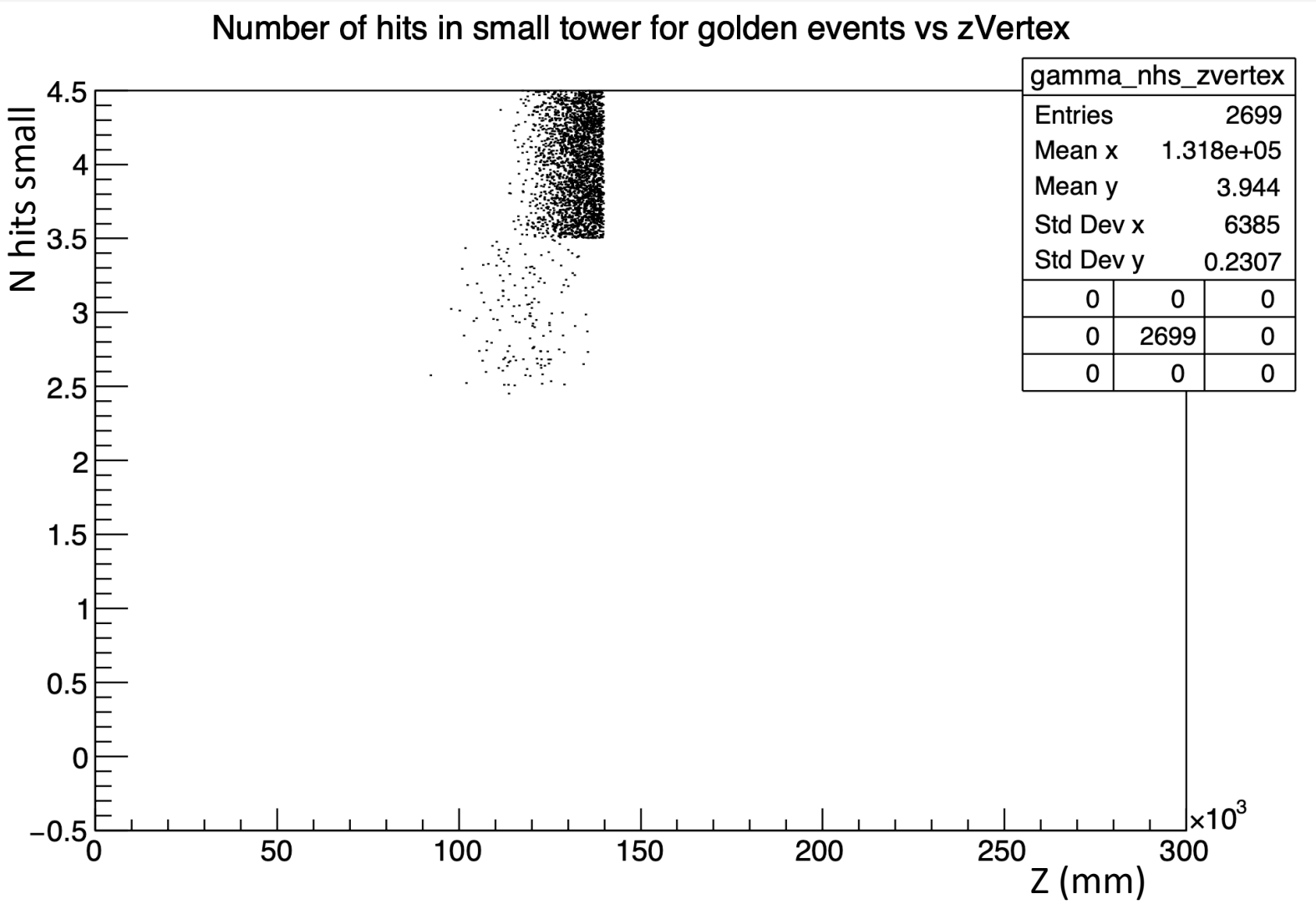
Energy (GeV)	Generated K0	4S, 0L	3S, 1L	2S, 2L	1S,3L	0S, 4L	Golden events	Golden/generated
500	1361000	555	32	0	0	0	157	0.012%
1000	471000	2550	148	1	0	0	661	0.140%
2500	532000	13620	692	3	0	0	3646	0.685%
5000	830000	35866	1568	5	0	0	9440	1.137%
7500	1143000	57114	1242	2	0	0	12663	1.108%

Golden=4 gammas in the 2 towers acceptance, with >5mm minimum distance btw 2 gammas

Distance btw 2 γ on the towers (5 mm cut is applied)



Event topology vs Z_{vertex} in LHCf



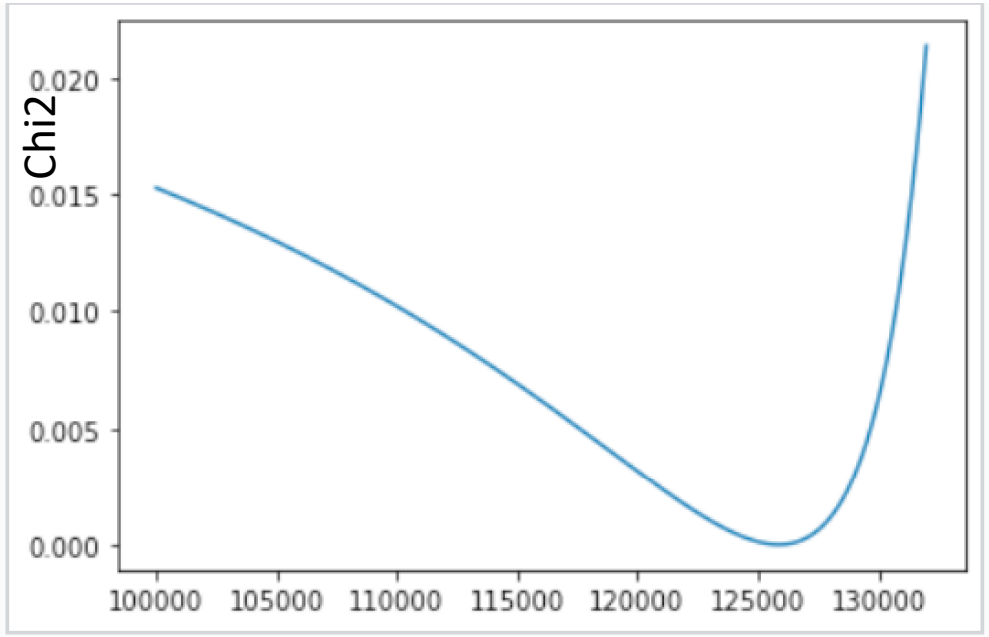
- Essentially all the 'golden events' correspond to decays in the last 20—30 meters
- Remember that a proper z_{vertex} reconstruction is necessary to reconstruct π^0 and K^0!!!

The z_{vertex} fit procedure (I)

- Starting point: 4 γs on LHCf
- The reconstructed invariant masses depend on the z_{vertex}
- Construct a 'sort of χ^2' and minimize it to find the best z_{vertex}
- Since we have 4 γ we should pair them in the proper way to identify the pairs coming from the same π^0
- Since the 4 γ are produced in the same vertex, the 2 correct reconstructed invariant masses should be identical (identically wrong…)
- Pair identification: the 2 pairs that produce the 2 more similar invariant masses

The z_{vertex} fit procedure (II)

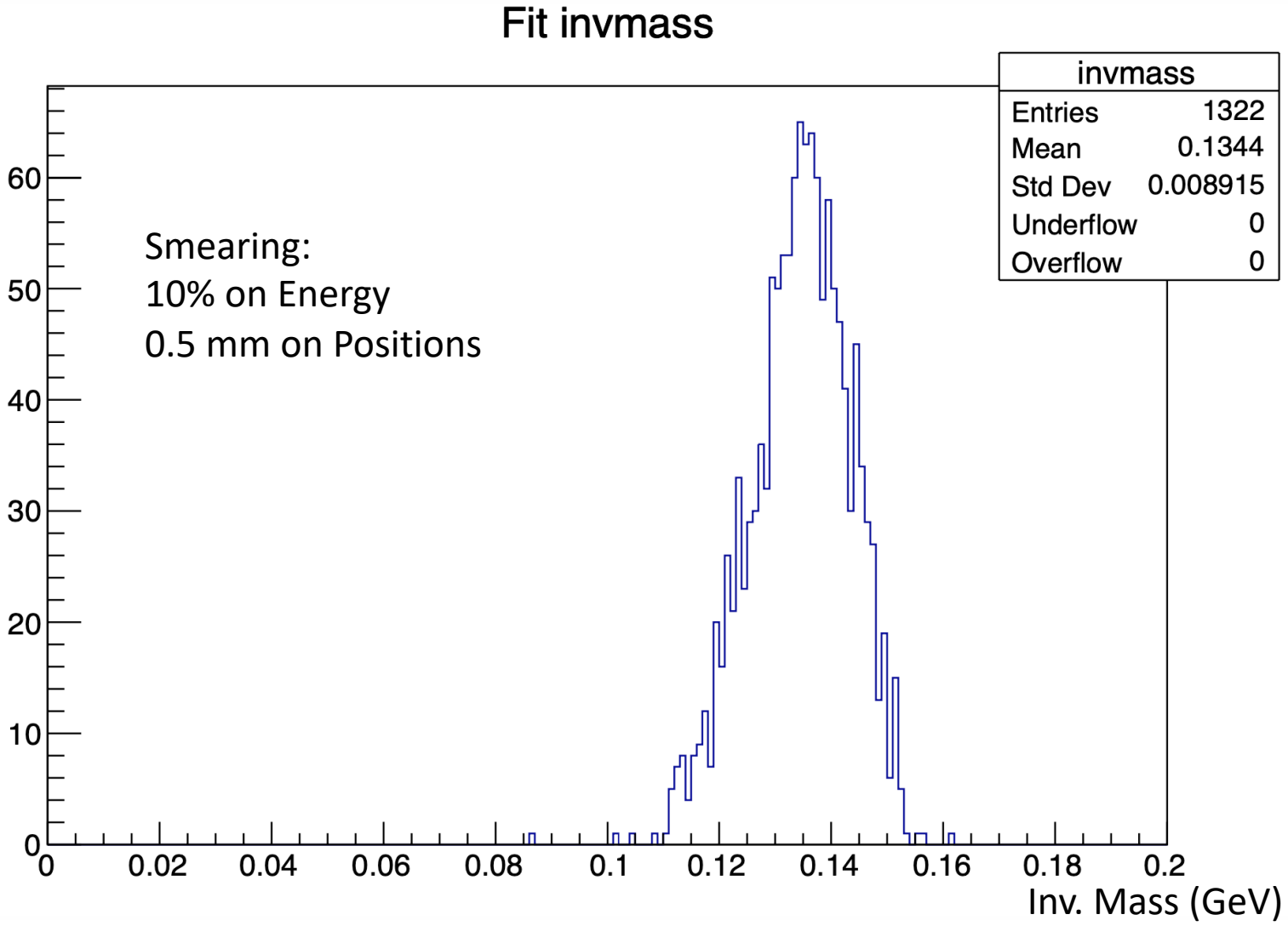
- Once we have the best 2 pairs → minimize χ^2
- χ^2= (Invmass1-m(π^0))^2+ (Invmass2-m(π^0))^2
- It is not a real χ^2, it can be largely improved!!!!!
- χ^2 is function of the z_{vertex} → minimization procedure to find the best z_{vertex}



The π^0 and K^0 invariant mass after the z_{vertex} fit

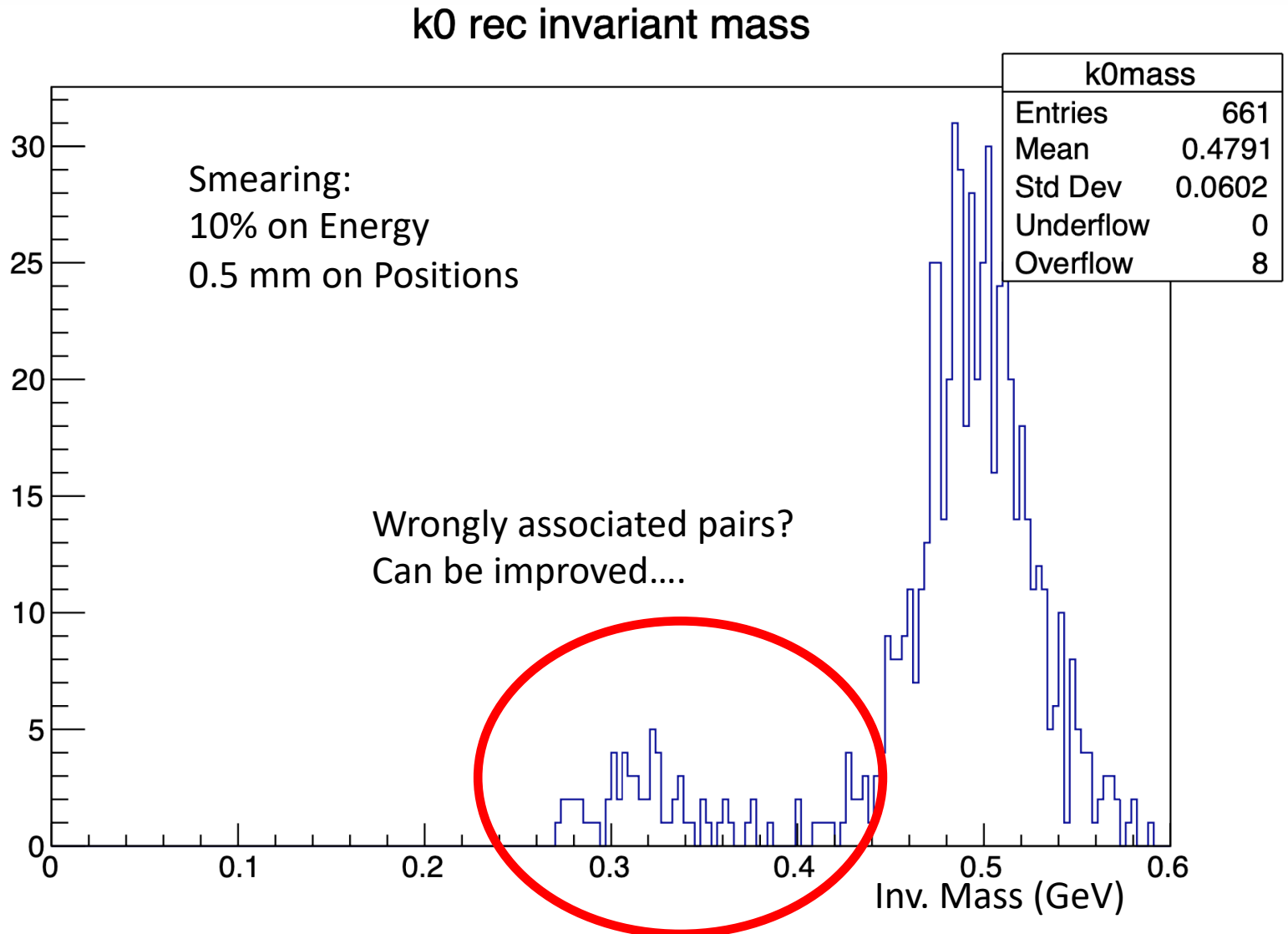
- If we know the z_{vertex}, we can compute the correct invariant masses, since we know the γ correct 4-vectors (we know their energies)!
- We can do this first for $\gamma\gamma$, then for $\pi^0\pi^0$

π^0 invariant mass

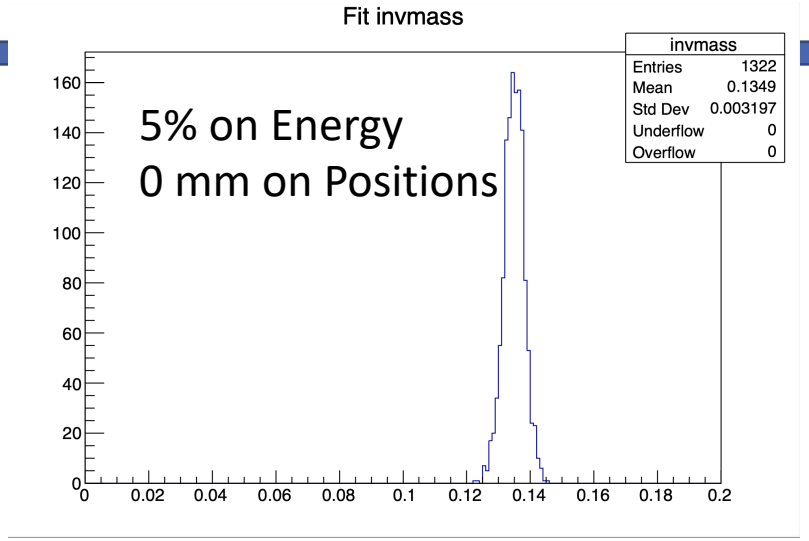


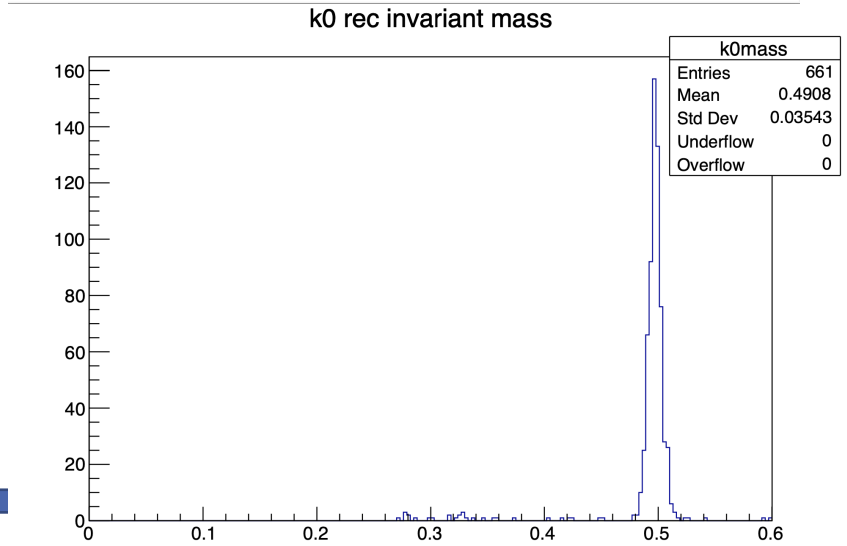
- Please note: I am using info coming only from LHCf hits!
- 10% energy smearing
- 0.5 mm position smearing

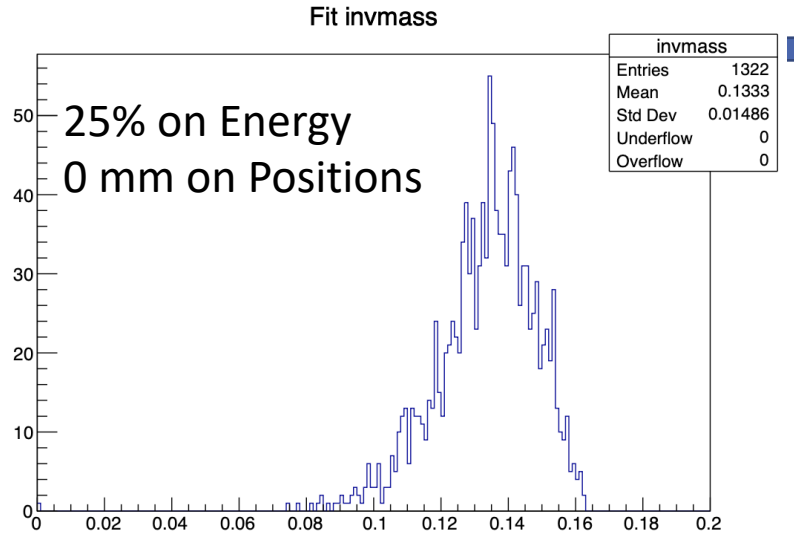
K^0 invariant mass

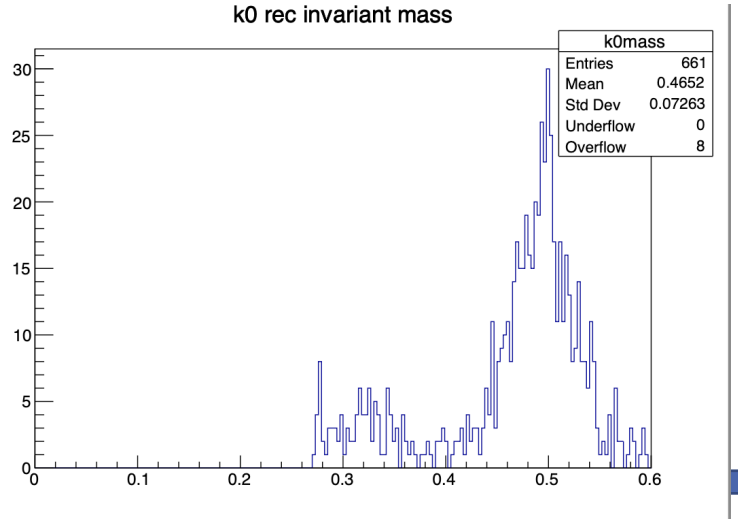


Effect of the smearing









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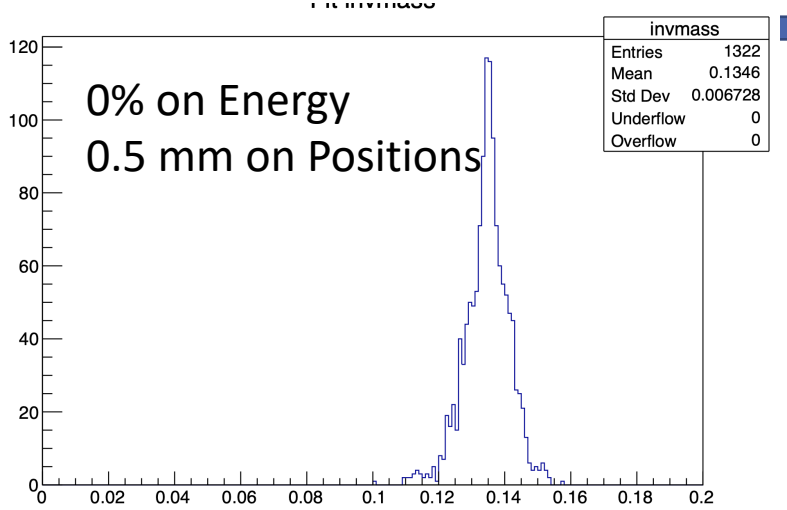

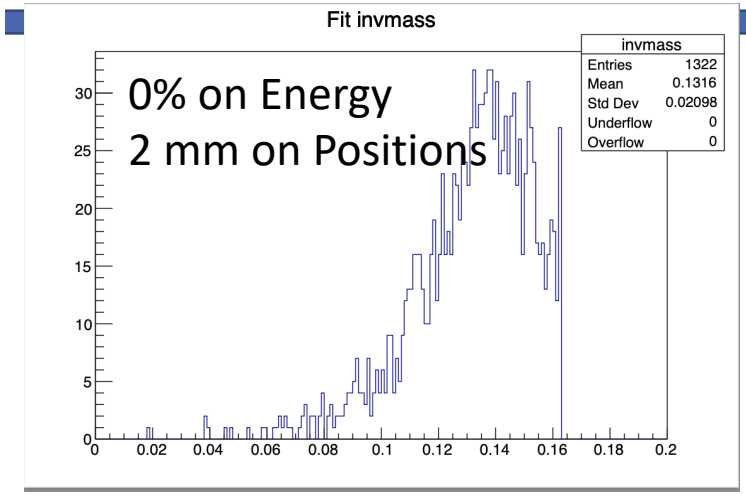

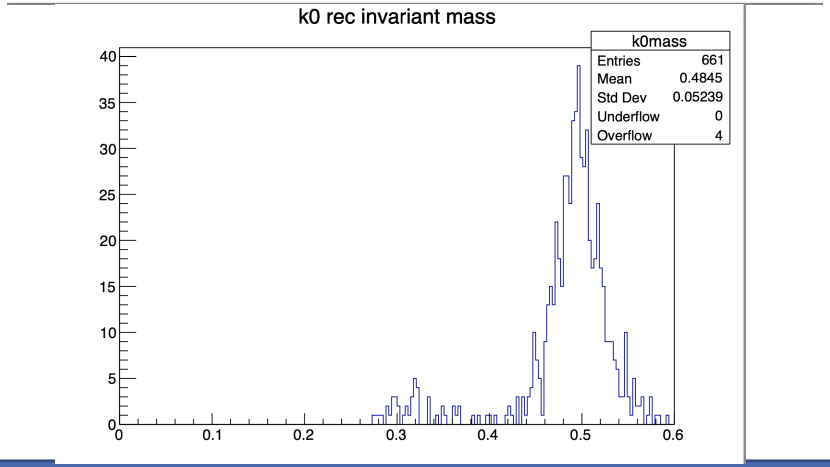

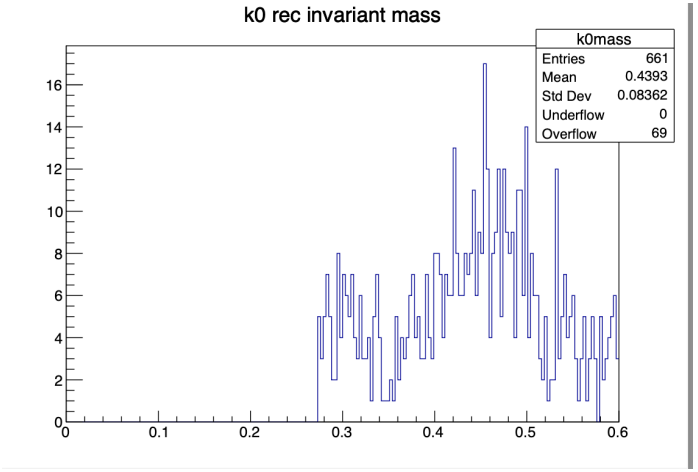

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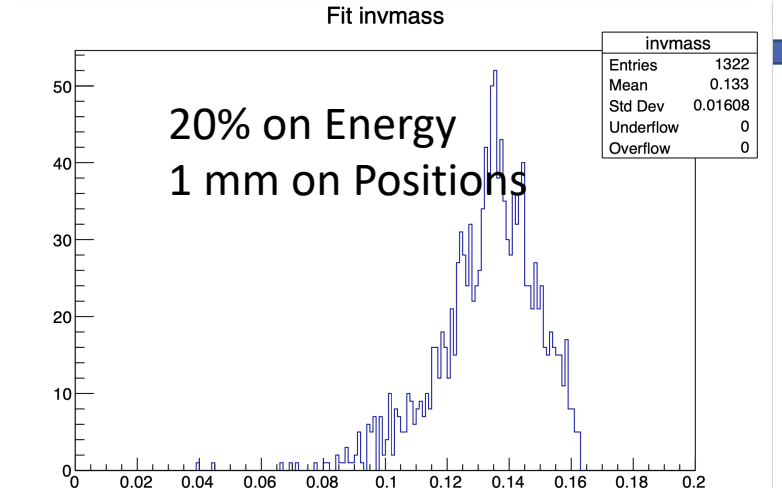

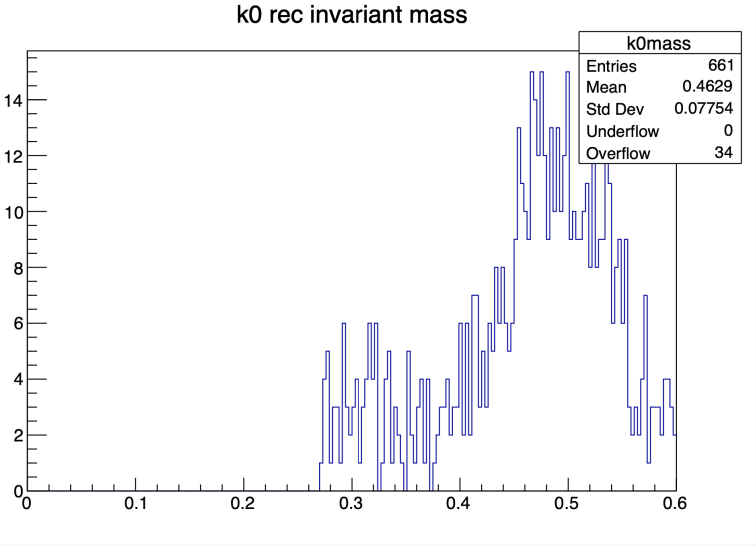

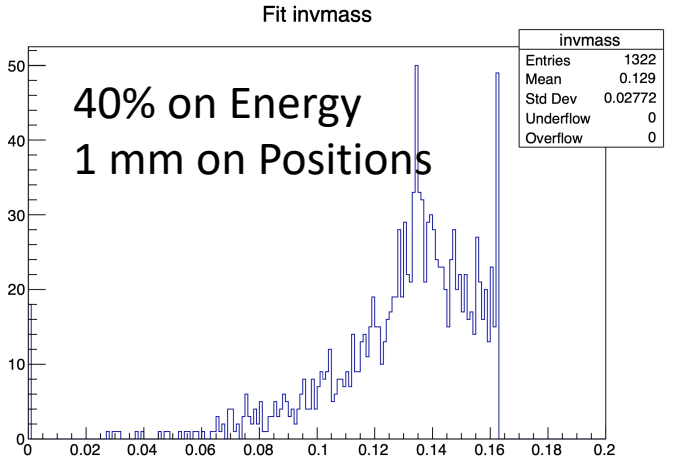

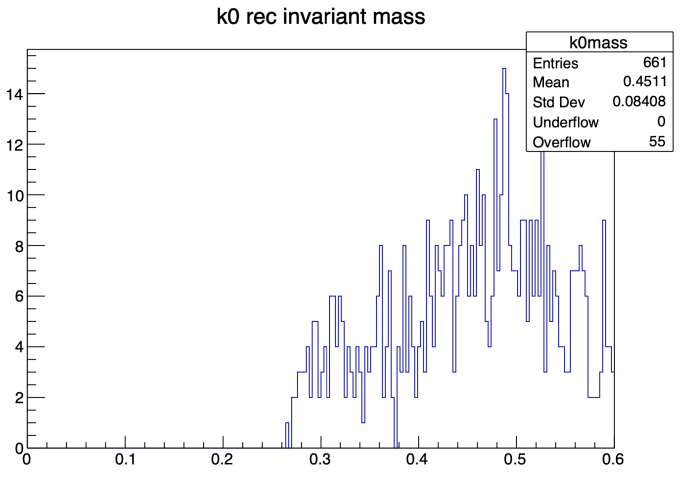

At least:

- 20% Energy resolution
- 1 mm position resolution

are necessary

Open points and possible improvements

- Only ”on axis” K^0 have been generated → should we expect some effects from small angles generation?
- The function to be minimized can be largely improved (using of a Likelihood is certainly better than this wrong χ^2!)
- Possible improvements in the γ pair selection mechanism → Iterative mechanism?
- Since in the golden events γ are generated quite close to LHCf, we can try to reconstruct the angle wrt the beam line directly from the LHCf information (from the first two x-y layers) → a simple check could be done from this simple simulation

Conclusions

- I started this simple study essentially to learn Pyhton….
  - Since it was interesting, I went a little bit more inside
- Essential points:
  - Only K^0 decaying in the last 20-30 meters can be identified
  - Most of the events produce 4 hits in the small tower → impossible to really reconstruct?
  - Some events produce 3 hits in the ST and 1 hit in the LT → Possible????
  - The z_{vertex} position should be determined by an optimal fitting procedure to properly reconstruct the invariant masses
- Clearly a real LHCf simulation should be done!!!!
  - How many golden K^0 can we expect from the data, given an integrated luminosity? I have no idea!!!!
  - It is feasible to reconstruct at least 3 γ in the small tower? With which energy and position resolution?
  - If this would not be possible, and we should rely on the 2ST/2LT topology, the statistics will be largely decreased (But I have no idea of the luminosity!!!!)