Photon Conversions in Delphes

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Photon in matter

- number of photons surviving by traveling a distance "x" in material is given by:

$$N_\gamma(x) = N_0 \exp(-x/\lambda)$$

where "λ" is the mean free path.

- probability of **NOT** converting after distance "x"

$$P(\text{not conv. after } x) = N_\gamma(x) / N_0$$

$$= \exp(-x/\lambda)$$

Poisson Law
$p(n=0, x/\lambda)$

Algo ingredients

- probability of converting after distance "Δx"

$$P(\text{conv. after } \Delta x) = 1 - \exp(-\Delta x / \lambda)$$

1) the material budget map can be provided via

$\lambda^{-1}(r, z, phi)$ = average conversion rate per unit length (m^{-1})

$= 7 / 9 * \rho / X_0$

2) the step length "Δx"

Algo (I)

1) propagate intial photon (at $\mathbf{x_0}$) for a length Δx, and find coordinates of the position x_1

2) read value of λ^{-1} (x_1) , and compute p_{conv}

3) throw random number p in [0, 1]

4) if $p > p_{conv}$ keep propagating by starting again from 1)
   if not, convert photon is converted in e^+e^- pair.

At $E >> m_e$, electron and positron are emitted colinear to initial photon

Algo (II)

5) At $E >> m_e$, electron and positron are emitted colinear to initial photon.

Only need to generate the energy fraction "x" that goes into each:

$$d\sigma / dx \sim 1 - 4/3 \; x(1-x)$$

→ generate $x = x_1$, $x_2 = 1 - x_1$

6) add new $e^+ e^-$ to event record... That's it! Let Delphes do the propagation in magnetic field from now...

In practice

```
#########################################
# Order of execution of various modules
#########################################

set ExecutionPath {

  PhotonConversions
  ParticlePropagator

  ...
```

```
##################################
# Propagate particles in cylinder
##################################

module PhotonConversions PhotonConversions {
  set InputArray Delphes/stableParticles

  set OutputArray stableParticles

  # radius of the magnetic field coverage, in m

  set Radius 1.29

  set HalfLength 3.0

  set EtaMin -2.5
  set EtaMax  2.5

  # material budget map: (uniform for now)
  # distribution of the detector mass ( density / X0), can be thought as
  # conversion rate per meter function of r,phi,z

  # unit: m-1

  set Step 0.001

  set ConversionMap {
```

Δx ← `set Step 0.001`

$\lambda^{-1}(r, z, \varphi)$ ← `set ConversionMap {`

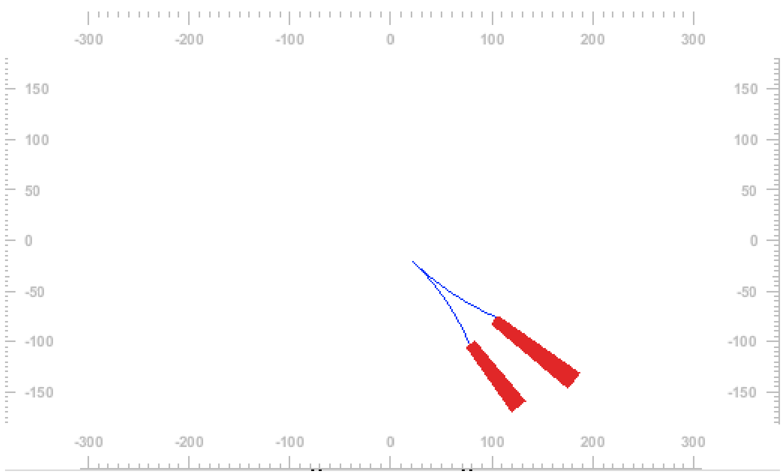
```
(abs(z) < 0.3 && r < 0.035 && r > 0.030)  * (1.00) +
(abs(z) < 0.3 && r < 0.065 && r > 0.060)  * (1.00) +
(abs(z) < 0.3 && r < 0.100 && r > 0.095)  * (1.00) +


(abs(z) < 0.355 && abs(z) > 0.345 && r < 0.150 && r > 0.050)  * (1.00) +
(abs(z) < 0.455 && abs(z) > 0.445 && r < 0.150 && r > 0.050)  * (1.00) +


(abs(z) < 0.7 && r < 0.205 && r > 0.195)  * (1.00) +
(abs(z) < 0.7 && r < 0.305 && r > 0.295)  * (1.00) +
(abs(z) < 0.7 && r < 0.405 && r > 0.395)  * (1.00) +
(abs(z) < 0.7 && r < 0.505 && r > 0.495)  * (1.00) +


(abs(z) < 0.805 && abs(z) > 0.795 && r < 0.500 && r > 0.200)  * (1.00) +
(abs(z) < 0.905 && abs(z) > 0.895 && r < 0.500 && r > 0.200)  * (1.00) +
(abs(z) < 1.005 && abs(z) > 0.995 && r < 0.500 && r > 0.200)  * (1.00) +
```

Display (I)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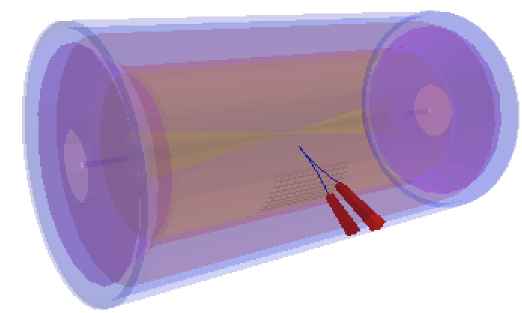
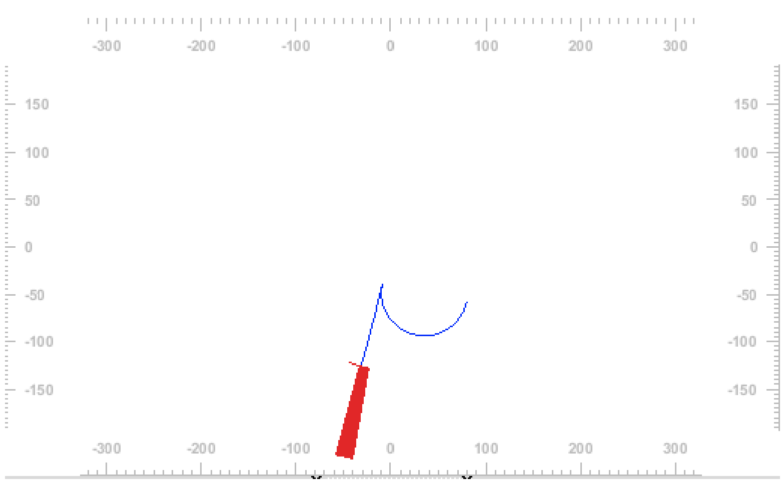
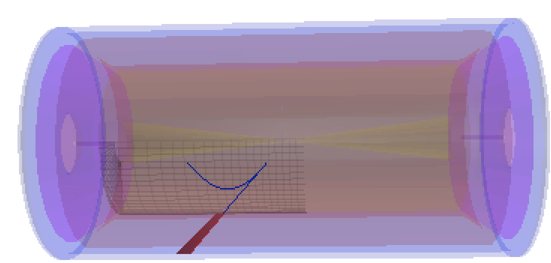
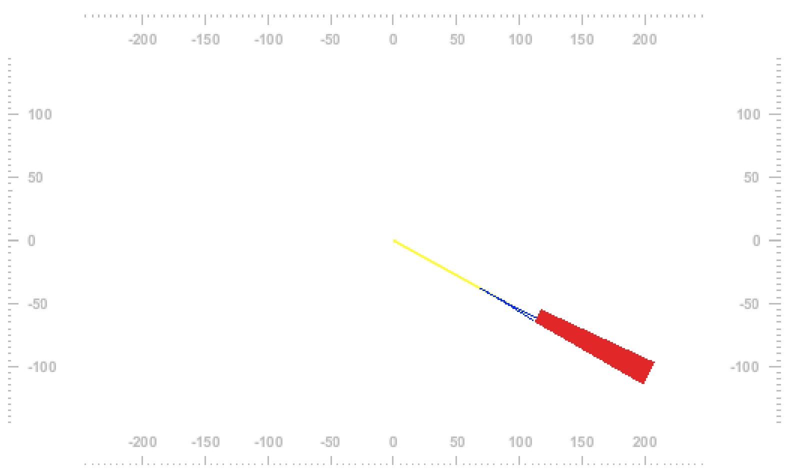
150 100 50 0 -50 -100 -150

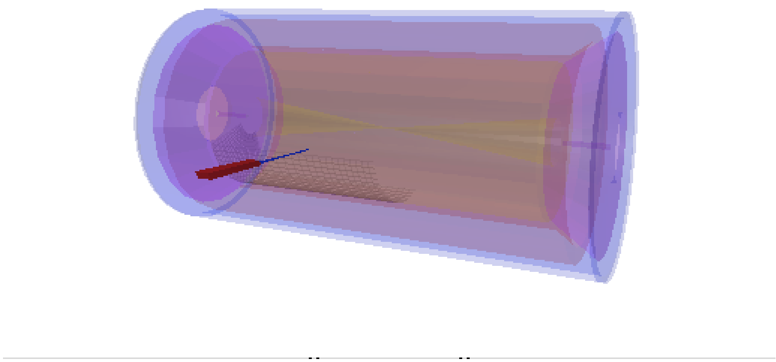


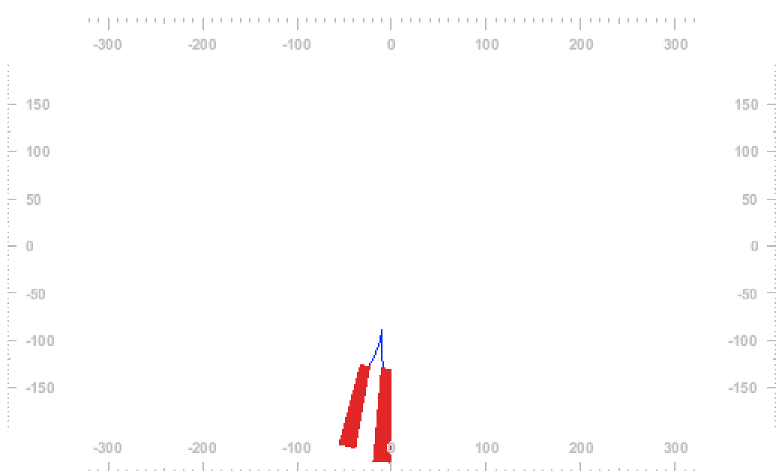

-300 -200 -100 0 100 200 300
150 100 50 0 -50 -100 -150

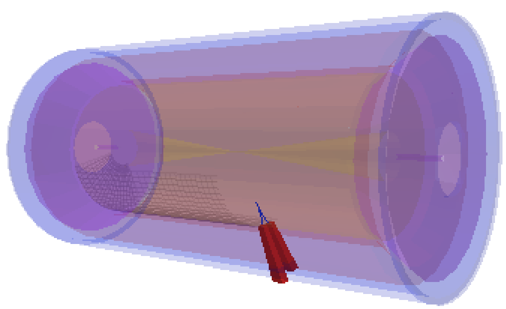


Display (II)

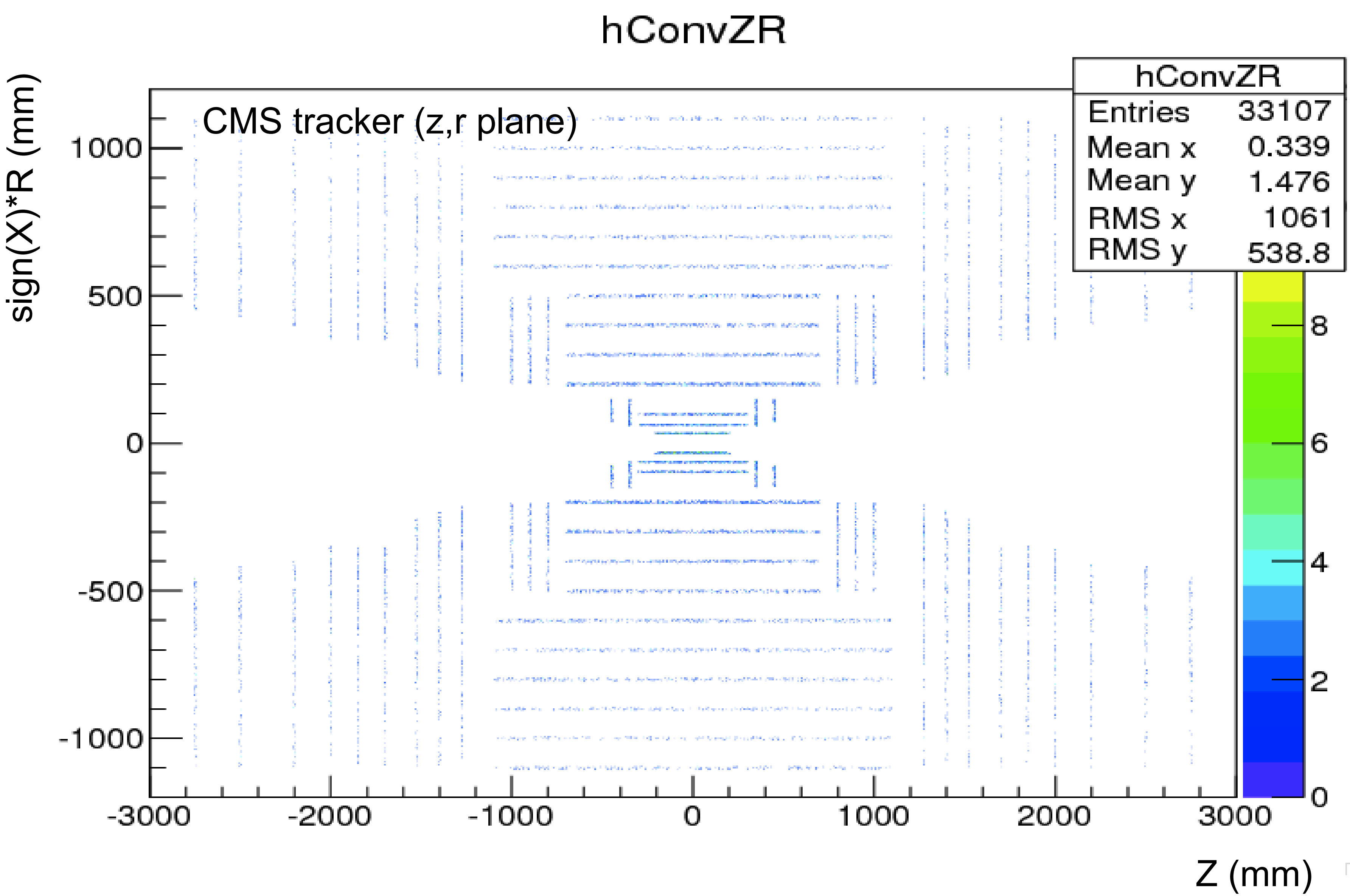

-200 -150 -100 -50 0 50 100 150 200
100
50
0
-50
-100




-300 -200 -100 0 100 200 300
150
100
50
0
-50
-100
-150



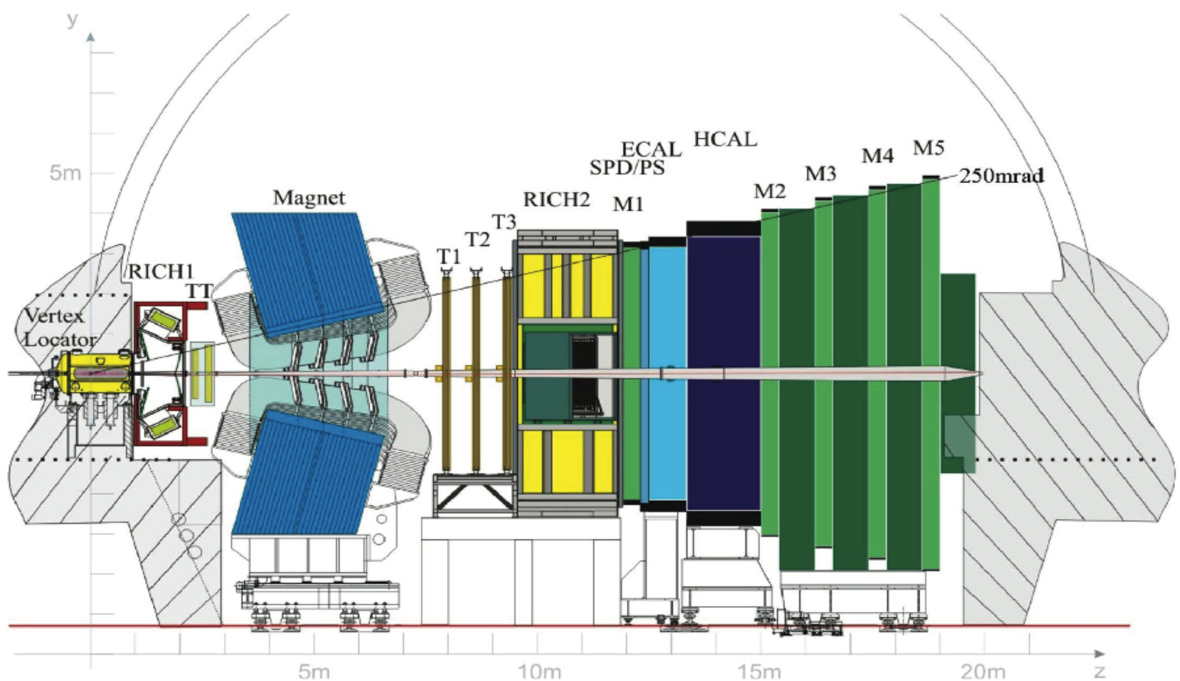
Conversion Map



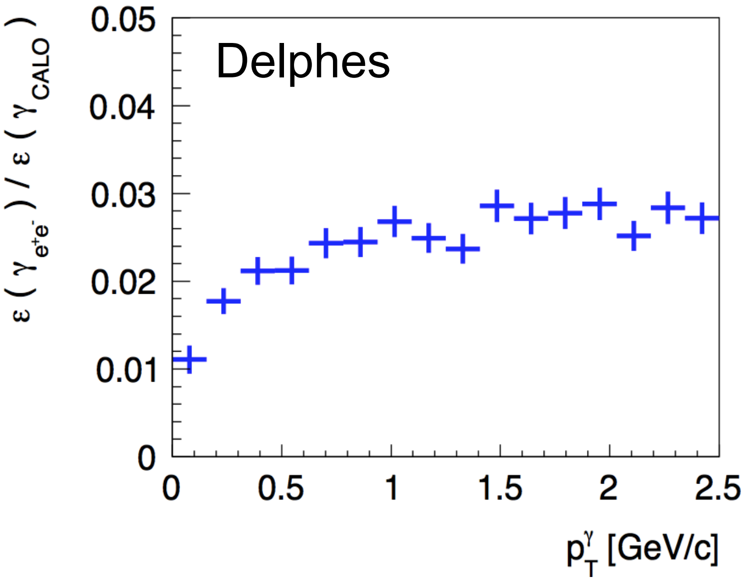
Validation (LHCb)

- LHCb is good playground for conversions, because of non ermetic acceptance:

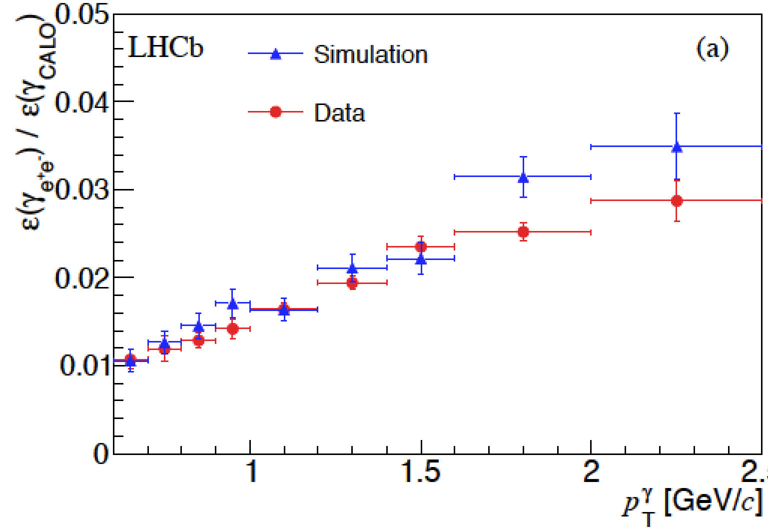
→ expect low momentum e^+e^- pairs from conversions in early stages of the tracker, to not make it to the calorimeters.



Validation (LHCb)



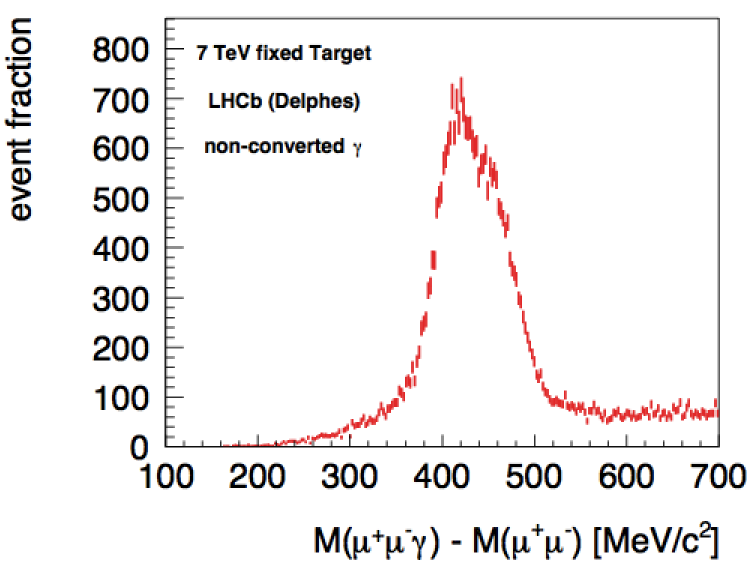
1307.4285

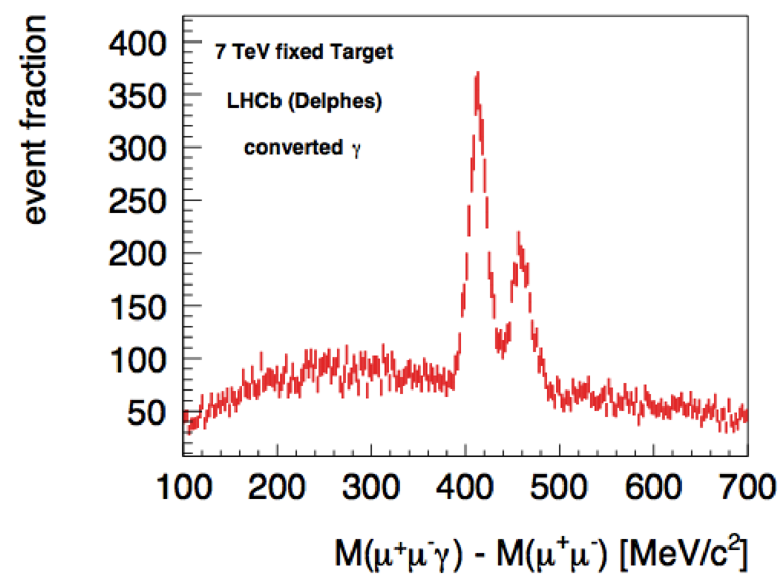


- if assume flat calo photon efficiency, this is basically eff(e^+e^-)
- reproduce efficiency loss at low p_T
  - → magnetic field drives ele. out of acceptance
  - → less material, so less conversions overall (very small)
- convexity is wrongly reporduced ...

Validation (LHCb)

- converted photons can be used to improve photon momentum resolution
- useful for resolving overlapping resonance (χ_{c1}, χ_{c2})





Conclusion

- basic ingredients are there ...
- to have a more complete description we still need to account for a decrease in performance in the ele pairs reconstruction as a function of where the conversion occured:

$\longrightarrow$ a possible approach would be to paramterize electron efficiency and resolution as a function of the track impact parameter (cf. Christophe).

We have all ingredients for that, but there are no public plots from collaboration for such parametrization.