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Status of the long-lived particles reconstruction study at the ILD

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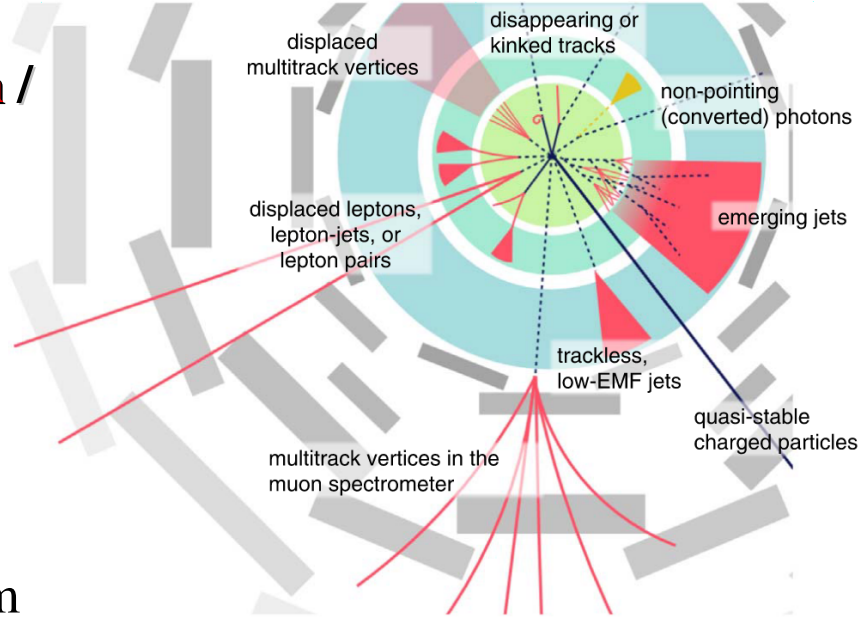
Long-lived particle signatures

What do we need for tracks that do not **originate from** / **point to** the IP:

- Efficient hit/segment finding
- Good track reconstruction
- Secondary vertex finding
- Particle ID

All can be challenging for tracks with small momentum



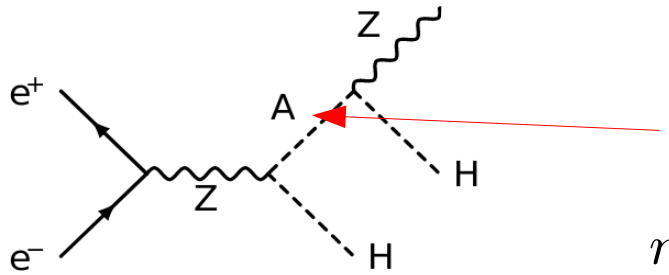
Framework and signature

This talk:

- **Track reconstruction** and **vertex finding**
- Events with **displaced vertices**

As a challenging case (small boost) we considered:

→ (tuned) Inert Doublet Model sample with small mass splitting, $Z^* \to \mu\mu$



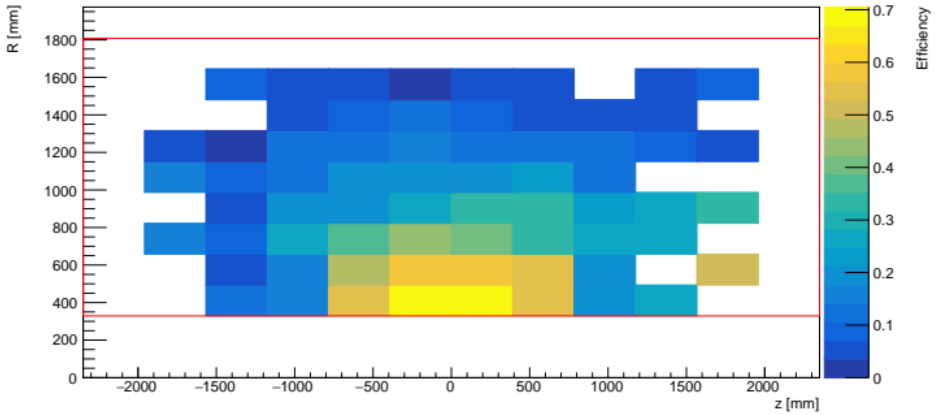
Long-lived, with $c\tau = 1\,\mathrm{m}$

$m_A - m_H = 1\,\mathrm{GeV}, 5\,\mathrm{GeV}$

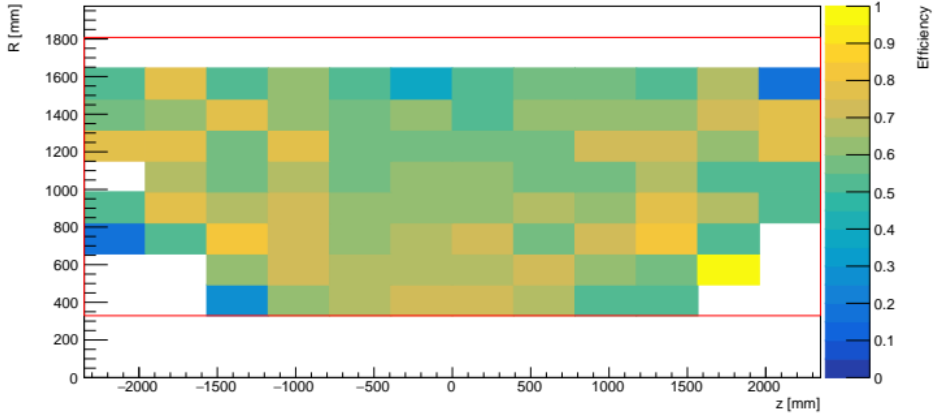
First limitations

Tracking efficiency strongly suppressed by default cuts d0, z0 < 500 mm in the *FullLDCTracking_MarlinTrk* processor → simply remove (or loosen) the cut

Position of a LLP decay vertex



Position of a LLP decay vertex

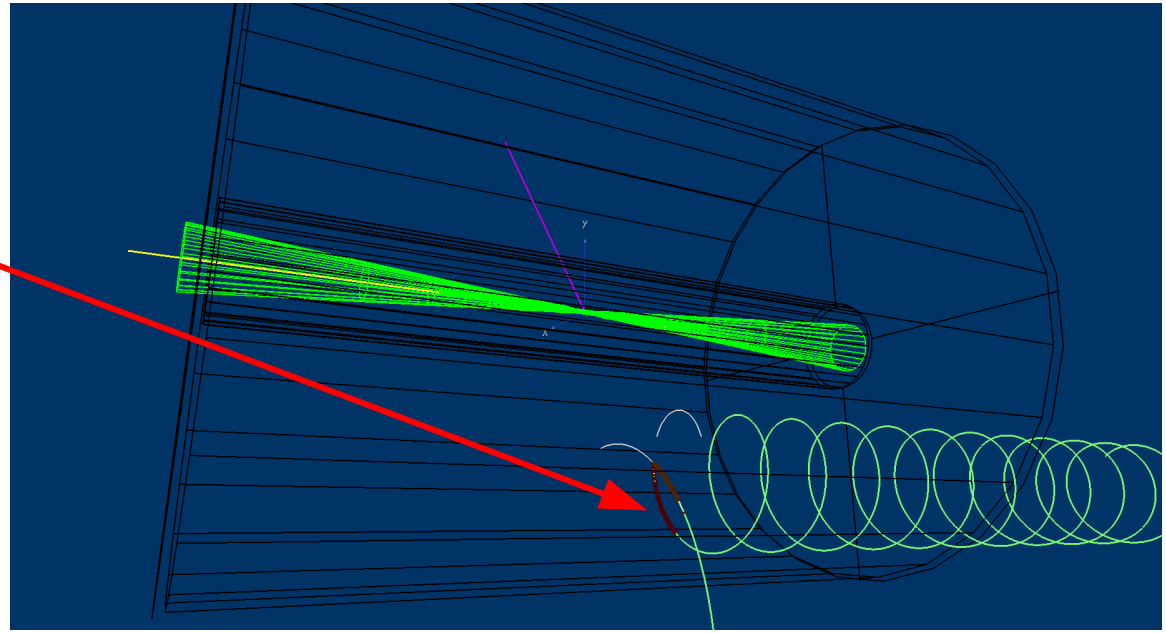


$\Delta m_{AH} = 1\,\mathrm{GeV}$

Further problems

Tracks often reconstructed in the wrong direction (resulting in the opposite charge!)

	Px	Py	Pz
MC:	0.113	-0.339	0.061
Reco:	-0.103	0.344	-0.062



- Switch direction in first (last) hit if Pz does not point into Z coordinate of the last (first) hit
- Efficiency improvement by ~10%

Further problems – missing hits

Virtual volumes in the TPC

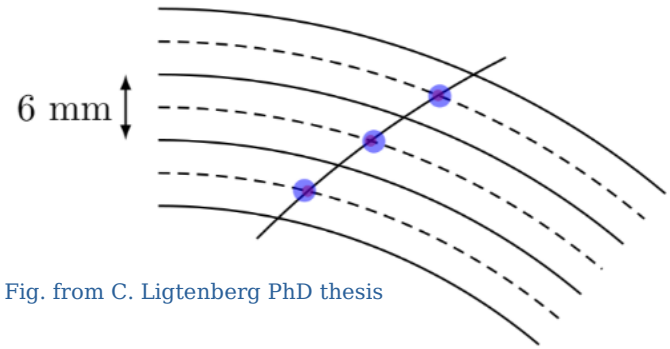
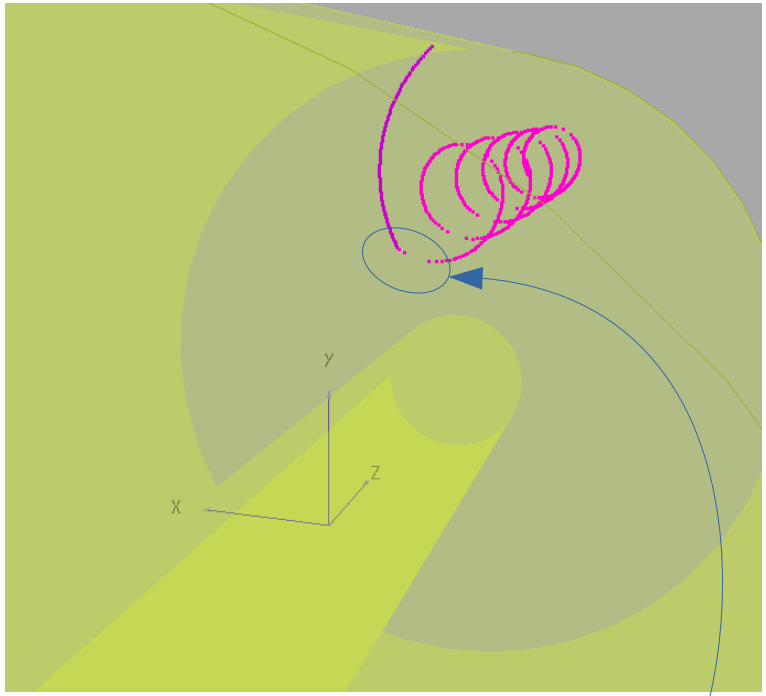


Fig. from C. Ligtenberg PhD thesis

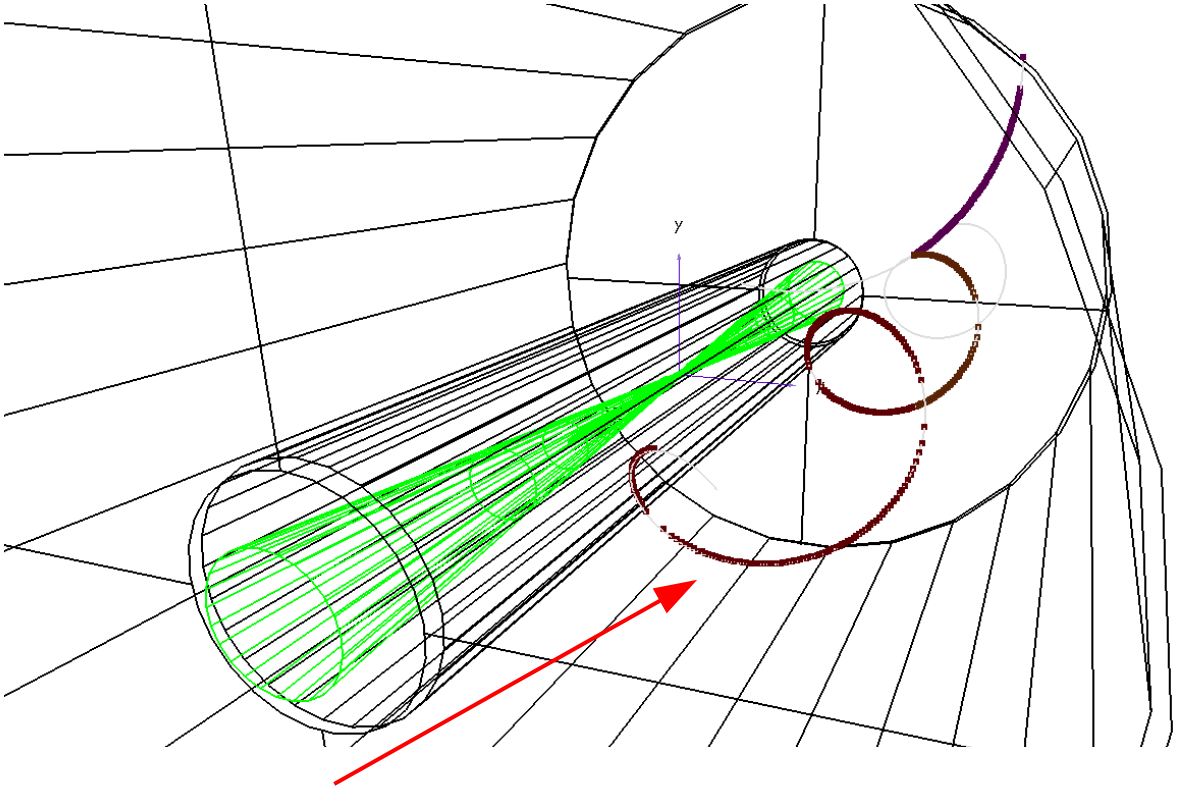
Particle travelling alongside the boundaries generates no hits

TPC SimTrackerHits



Long distance between first hit and true vertex leads to wrong track parameters!

Further problems – split tracks



Missing hits problem

Single track can often be reconstructed as several ones

Becomes more important if we **look for vertices far from the IP** or **want to use track parameters in first/last hit**

This track was reconstructed as two separate ones, with very distant reference points

Tracking efficiency

Take only LLP decays inside the TPC

Track state in the first or the last hit (for now take one closer to the true vertex)

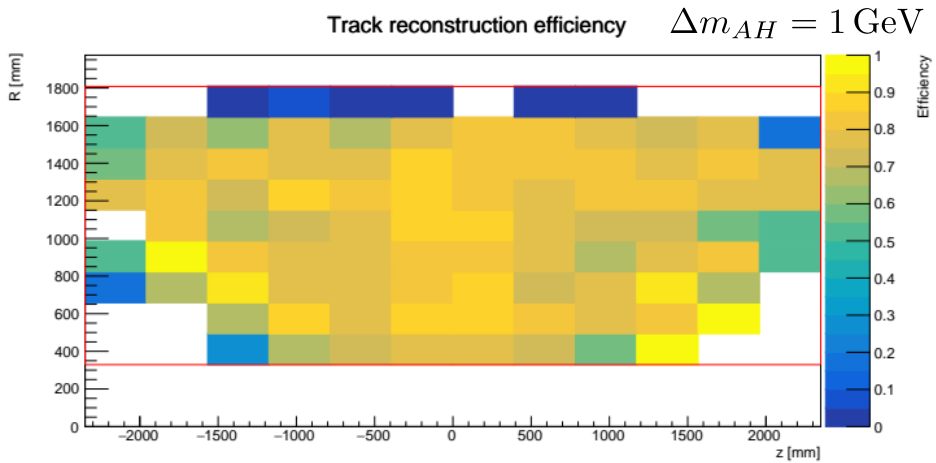
In matching to MC require:

- Angular separation < 0.2 between true and reco. direction
- Good charge sign

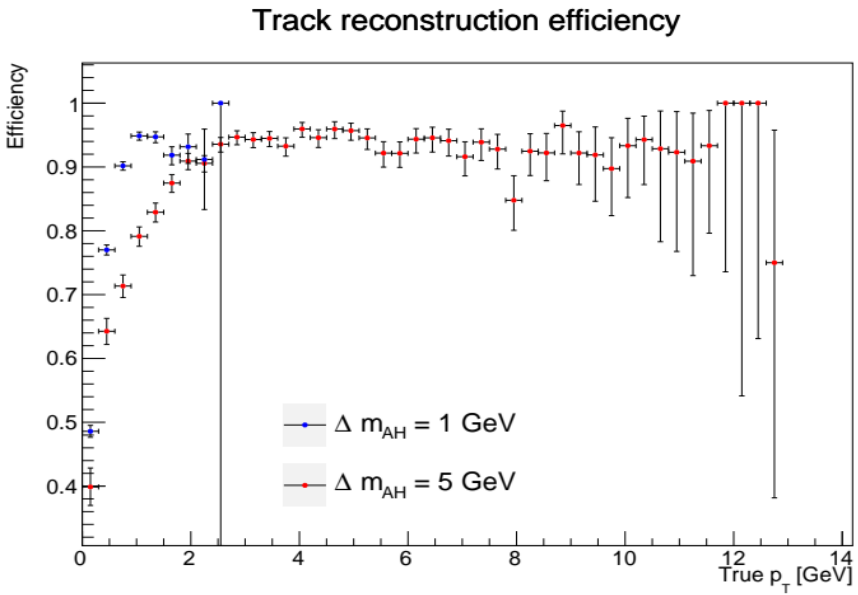
With fixes from slides 4-5 efficiency:

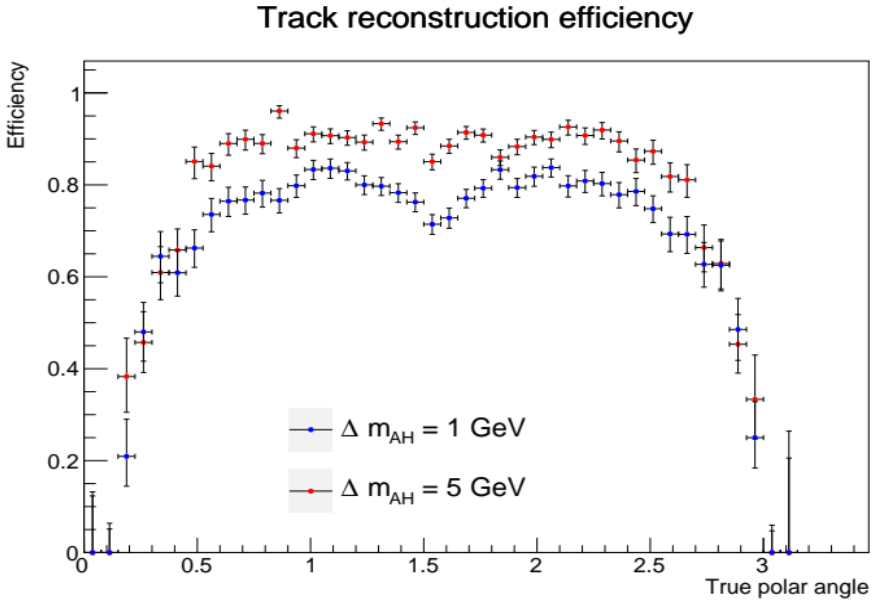
$$\sim 75\% \; (\Delta m_{AH} = 1\,\mathrm{GeV})$$

$$\sim 85\% \; (\Delta m_{AH} = 5\,\mathrm{GeV})$$



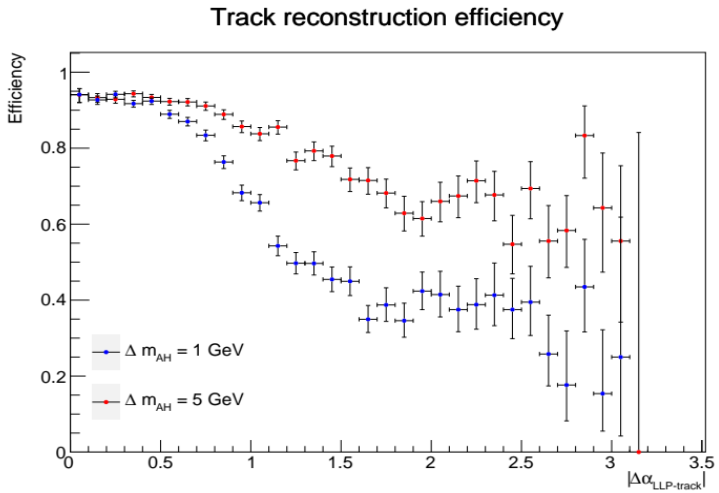
Efficiency distributions



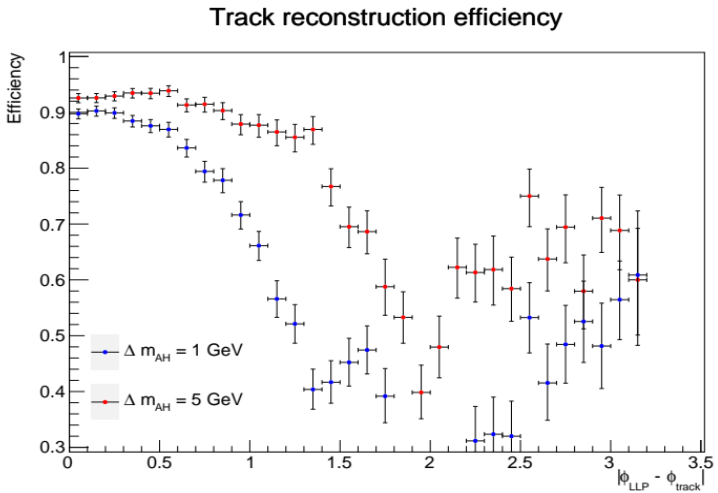


- **Good performance for the high pT**, but no consistent dependence for different mass splittings
- Low efficiency for the forward tracks; small dip in the central region
  → curlers at very high angles (perpendicular) and LLP decays next to the outer TPC wall

Efficiency distributions



True 3D angle between LLP and track vectors



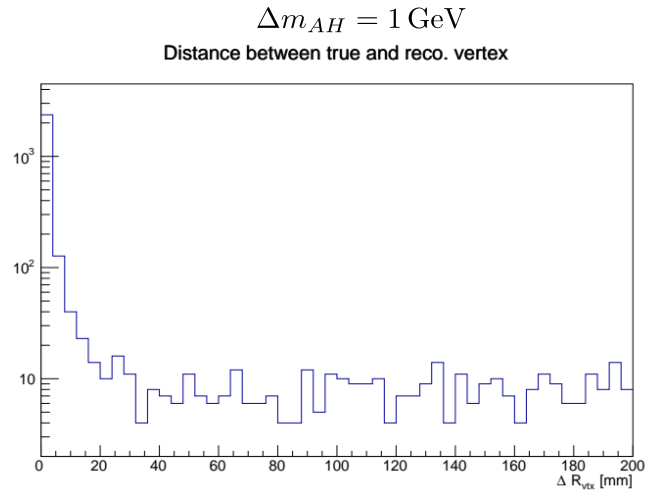
True azimuthal angle difference between LLP and track

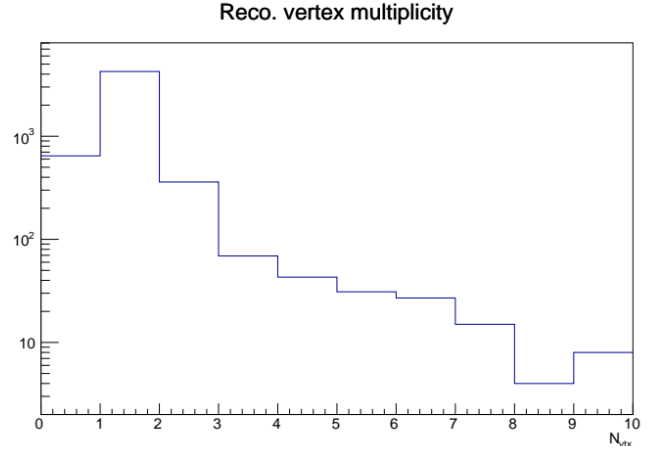
- **High efficiency** for the small angles between track and LLP **when tracks point into the IP**
- For higher boost, more tracks at small angles and better overall efficiency
- At large decay angles missing hits problem more frequent

Vertex finding

Approach as in the V0Finder:

- Consider tracks in pairs
- Calculate distance between helices (*getDistanceToHelix* method from MarlinUtil)
- For now no additional cuts $\Longrightarrow$ significant background





In the matching consider decays inside TPC and require:

- Distance between true and reco. vtx < 30 mm

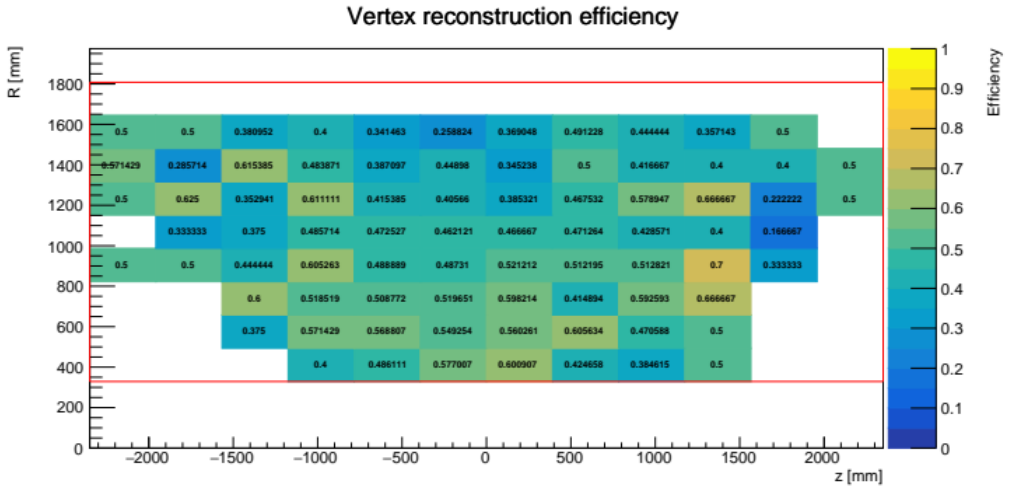
Total efficiency:

$\sim 48\%\ (\Delta m_{AH} = 1\,\mathrm{GeV})$

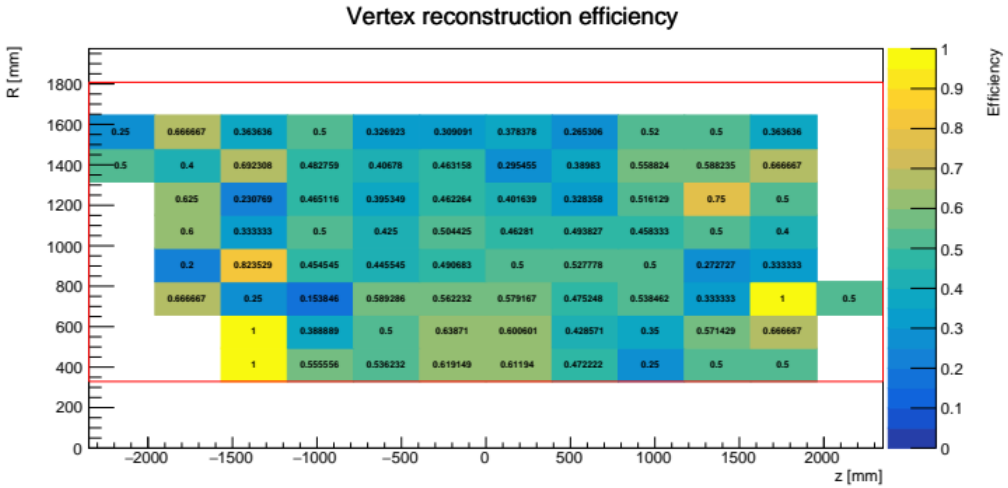
$\sim 49\%\ (\Delta m_{AH} = 5\,\mathrm{GeV})$

Vertex finding efficiency

$\Delta m_{AH} = 1\,\mathrm{GeV}$

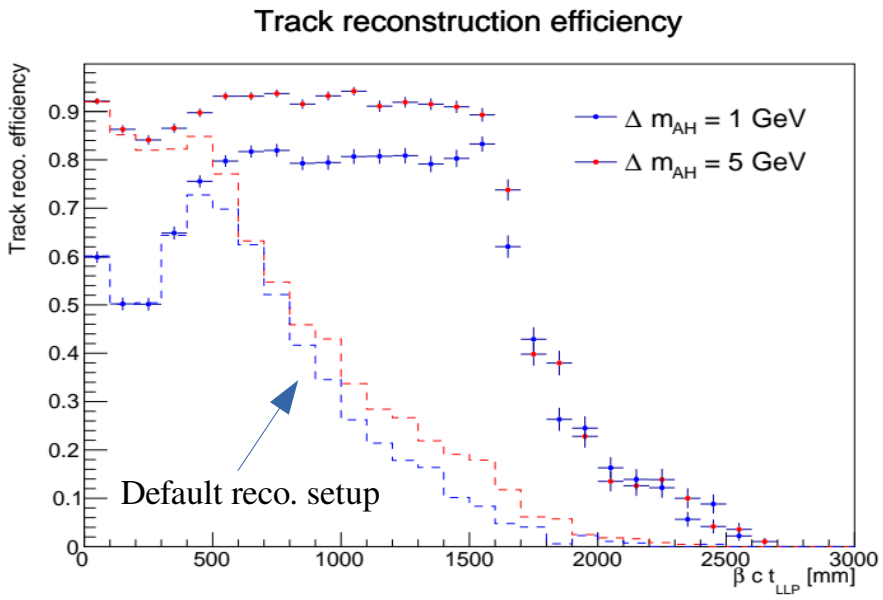


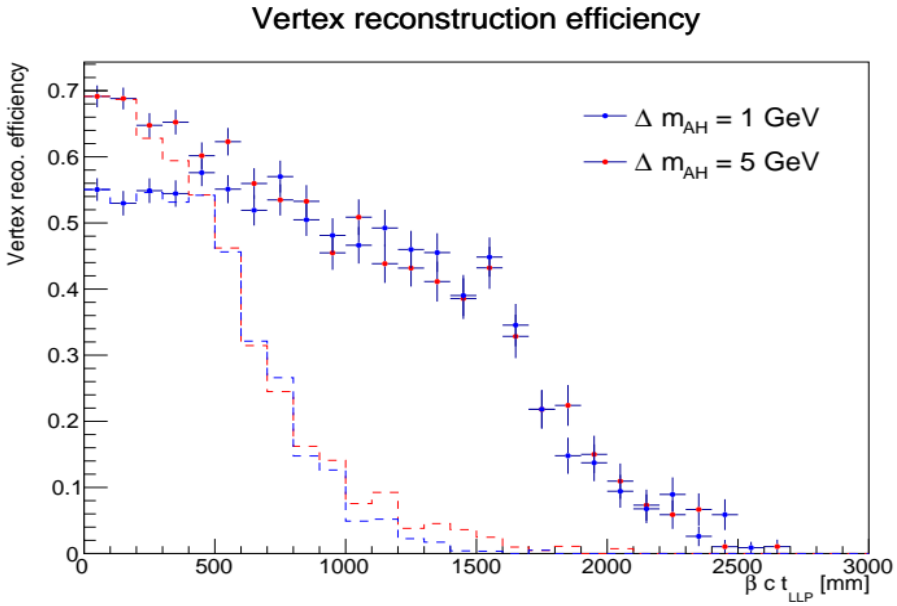
$\Delta m_{AH} = 5\,\mathrm{GeV}$



- Small dependence on the vertex position in TPC
- Small dependence on the mass splitting

Efficiency vs. LLP decay length





- Efficiency limited for default reconstruction settings
- Large improvement can still be achieved

Conclusions

- Events with **displaced vertices**, **small mass splitting** and **low-momenta products** studied
- The main limitations in the track reconstruction identified

  → missing hits due to TPC geometry problematic
- First look into vertex finding

  → partly limited by track reconstruction, but must be further understood

  → work in progress

Open questions:

- Do we accept this and proceed?
- Should the tracking issues be fixed first?