MATHUSLA Efficiency Studies

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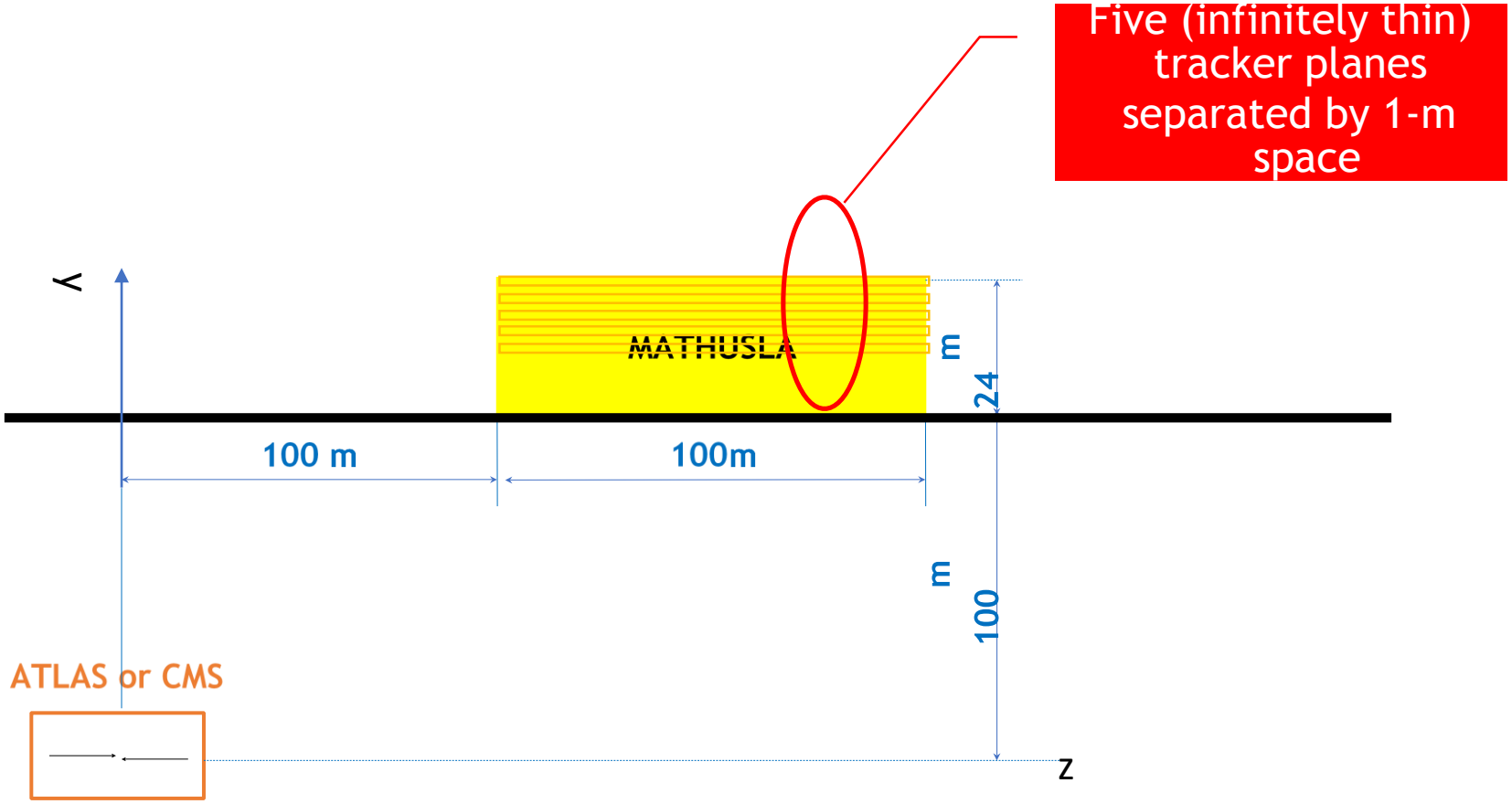
Short outline

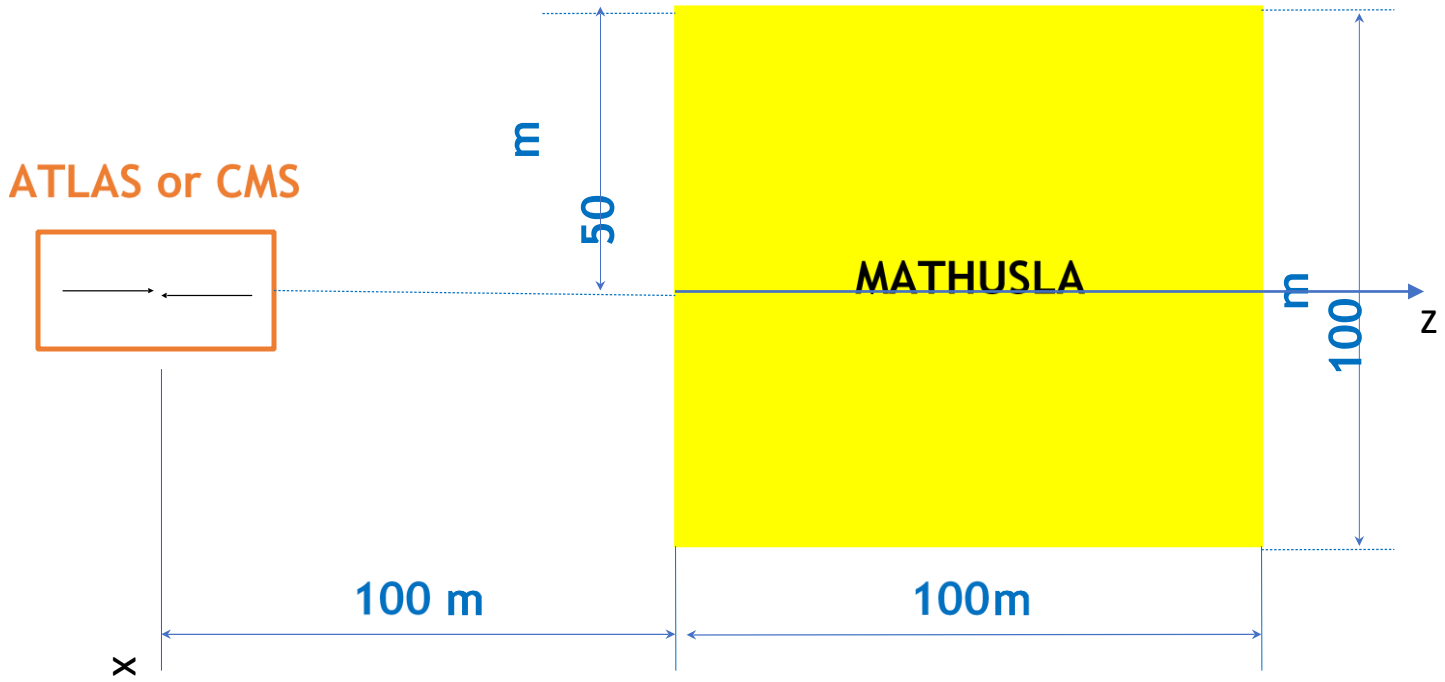
- Detector Geometry
- Datasets
- Efficiency
- Summary

Detector Geometry



Side View of layout

- The detector tracker plane ranges from 20m to 24m on top of the ground



Top View of layout

- $100m \times 100m$ without gap
- 100m away from the collision point

Datasets

- user.calpigia.MC15.100810.MadGraphPythia8EvtGen_A14NNPDF23LO_HSS_LLP_mH125_mS15_bb.evgen.e5102_v03_SKIMMED
- user.calpigia.MC15.100811.MadGraphPythia8EvtGen_A14NNPDF23LO_HSS_LLP_mH125_mS15_mumu.evgen.e5102_v03_SKIMMED
- user.calpigia.MC15.100814.MadGraphPythia8EvtGen_A14NNPDF23LO_HSS_LLP_mH125_mS15_bbcc.evgen.e5102_v04_SKIMMED
- user.calpigia.MC15.100812.MadGraphPythia8EvtGen_A14NNPDF23LO_HSS_LLP_mH125_mS50_bb.evgen.e5102_v03_SKIMMED
- user.calpigia.MC15.100813.MadGraphPythia8EvtGen_A14NNPDF23LO_HSS_LLP_mH125_mS50_mumu.evgen.e5102_v03_SKIMMED
- user.calpigia.MC15.100815.MadGraphPythia8EvtGen_A14NNPDF23LO_HSS_LLP_mH125_mS50_bbcc.evgen.e5102_v04_SKIMMED

Efficiency

What has been done?

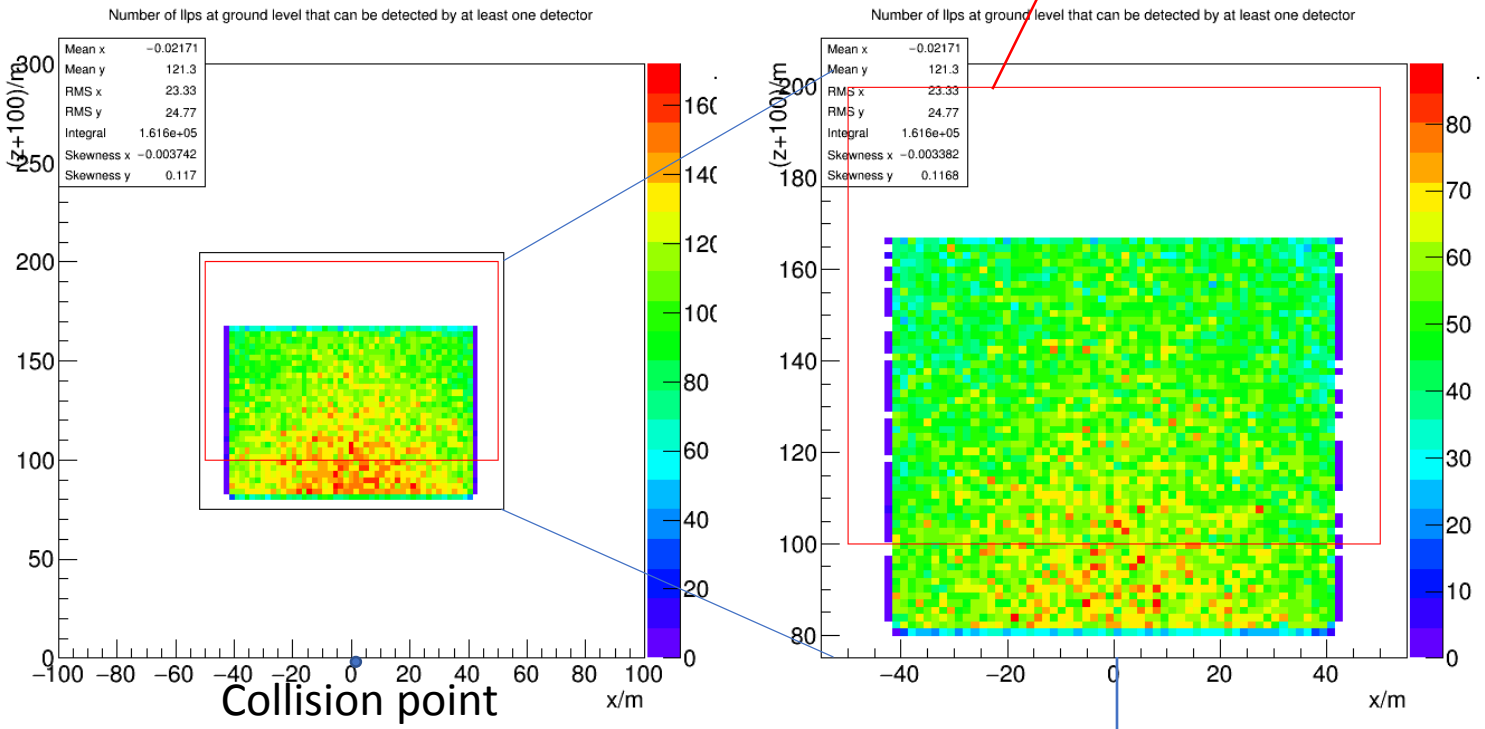
What has been done?

- ‘Efficiency’ is defined here by the LLP (rather than the charged decay products) intersecting a detector plane.
- It is not the real efficiency but the limit where decay products travel along the direction of the parent LLP.
- Real efficiencies expected to show broadly similar trends.

LLPs at Ground Level Detected by at least One Plane

- LLPs can be detected are confined in a rectangular region close to the detector

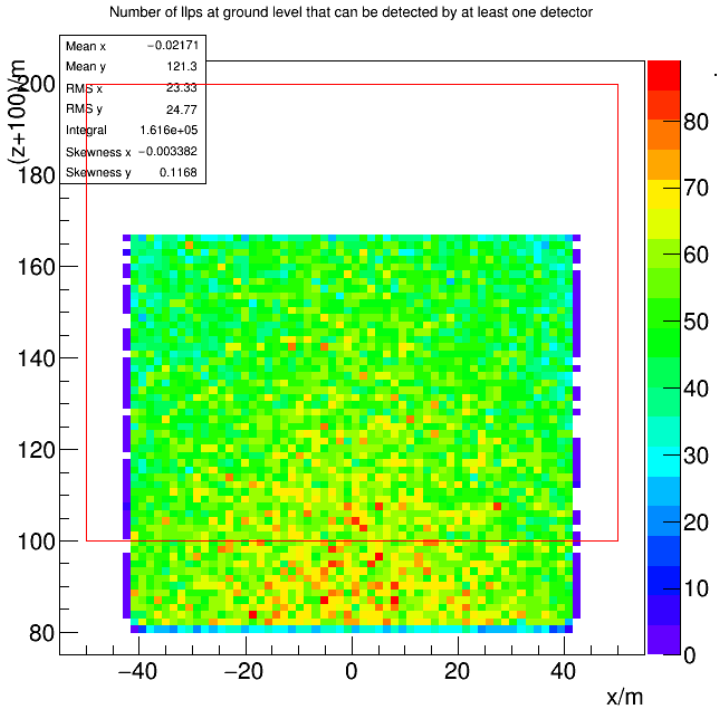
Red outline is footprint of MATHUSAL



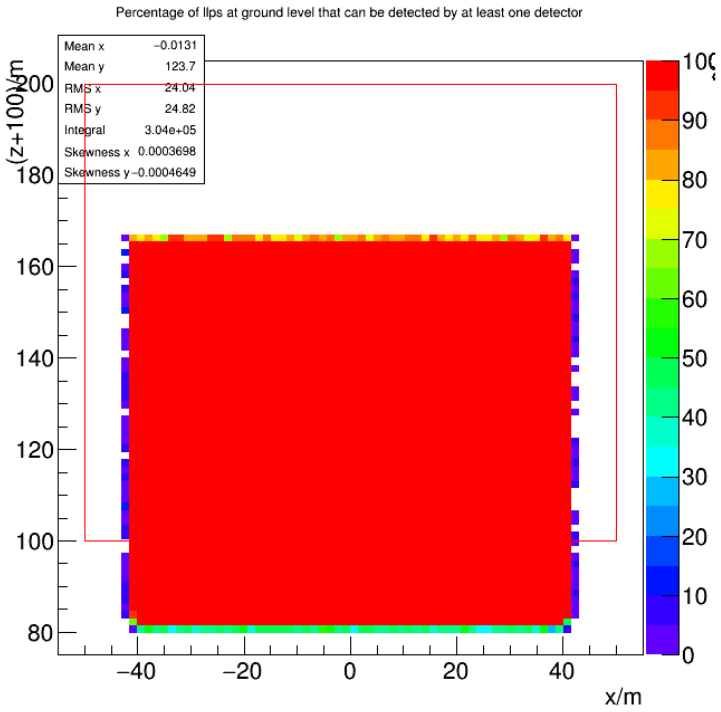
Number of LLPs at ground level can be detected by at least one detector

Collision point

LLPs at Ground Level Detected by at least One Plane

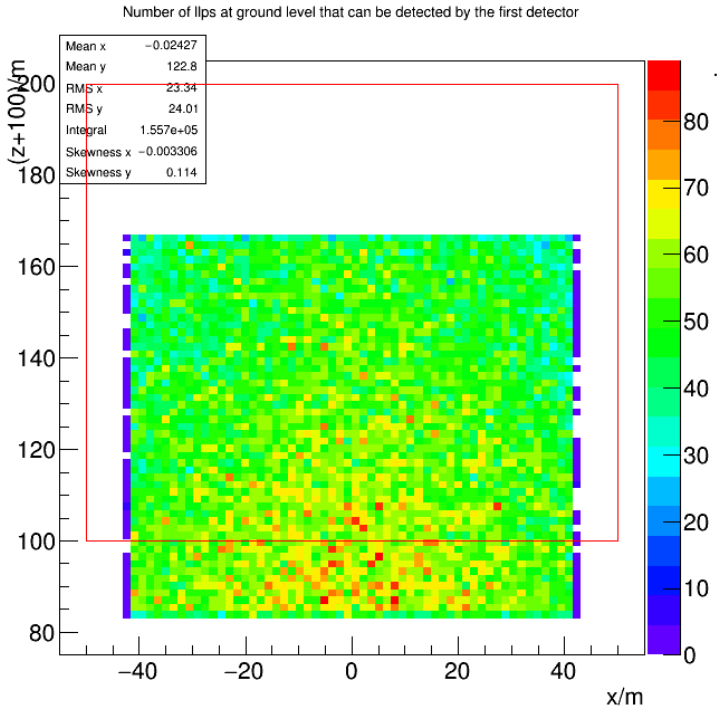


Number of LLPs at ground level can be detected by at least one detector

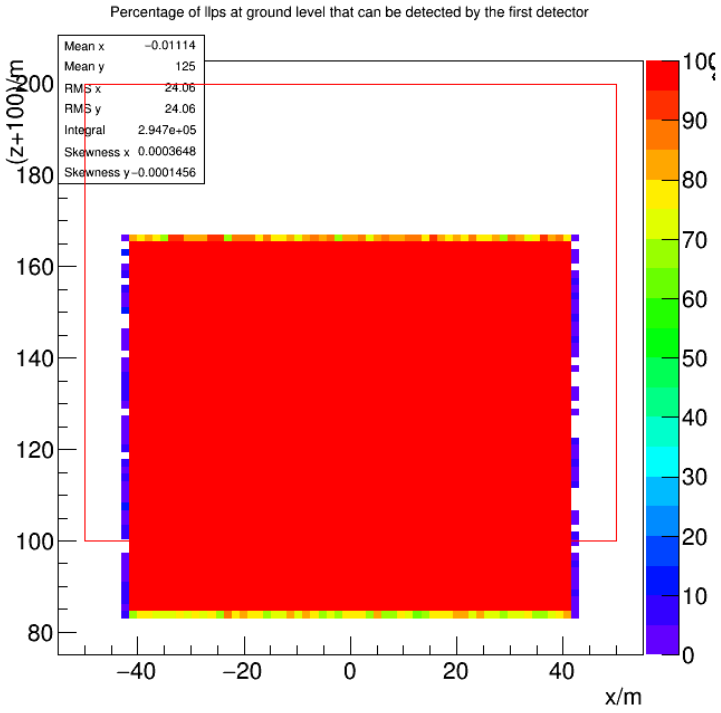


Percentage of LLPs at ground level can be detected by at least one detector

- Symmetric about x=0
- 100% efficiency in the middle as expected
- Close efficiency at the boundary



Number of LLPs at ground level can be detected by the first detector

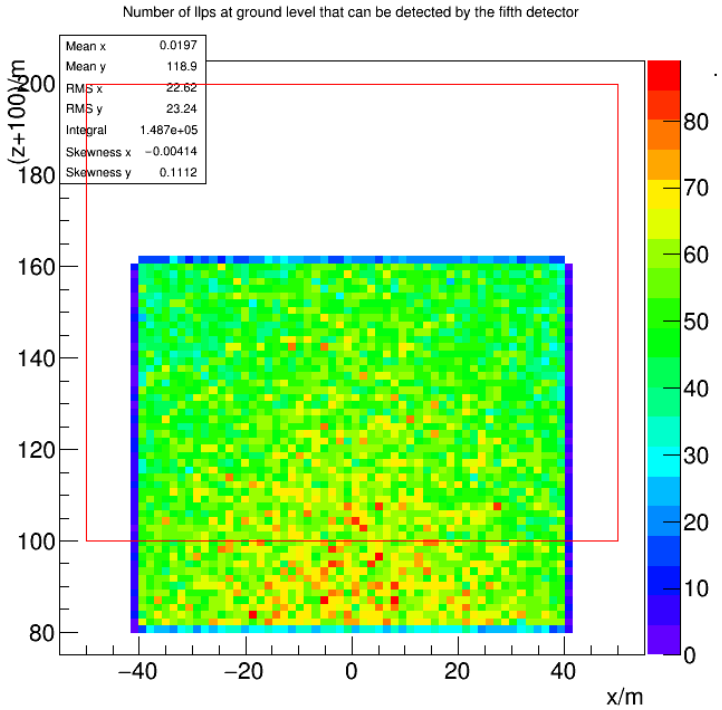


Percentage of LLPs at ground level can be detected by the first detector

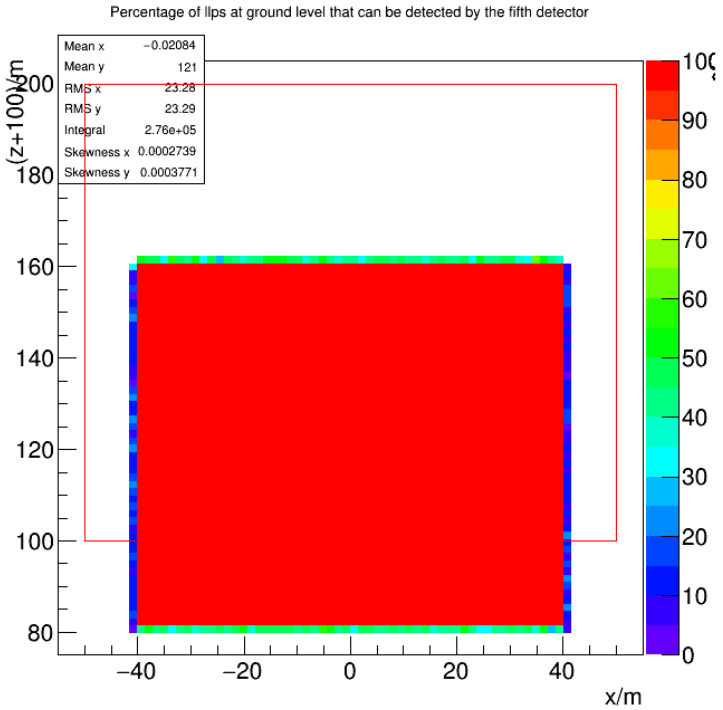
LLPs at Ground Level Detected by the First Plane

- Same upper and side boundaries as the previous plot
- A higher z value for lower boundary
- Exactly the same for other three boundaries

LLPs at Ground Level Detected by the Fifth Plane



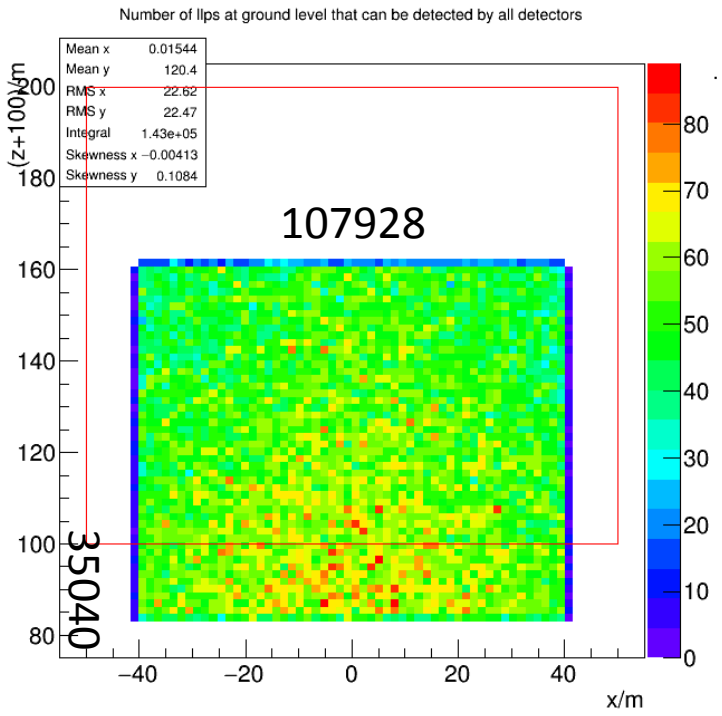
Number of LLPs at ground level can be detected by the fifth detector



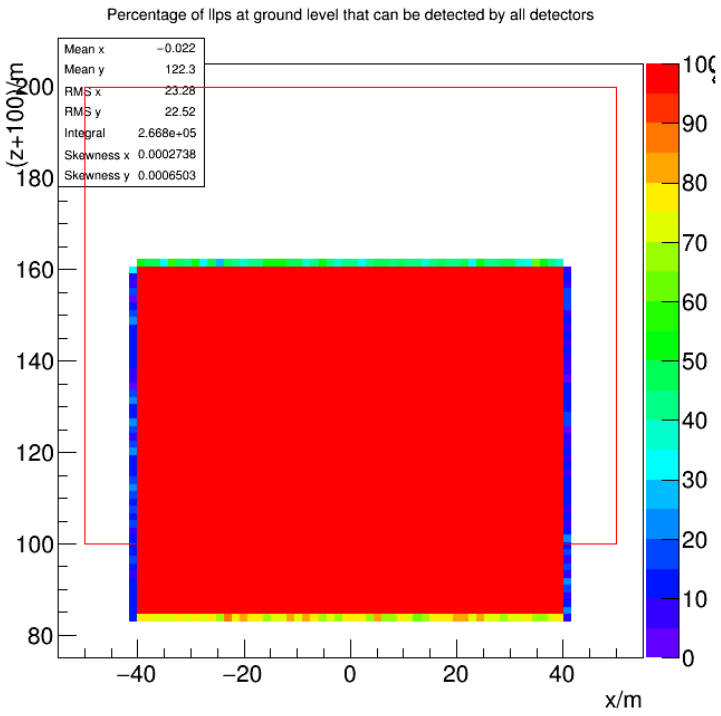
Percentage of LLPs at ground level can be detected by the fifth detector

- Upper boundary moving to lower z value when compared with “any one plane”.
- Other three boundaries unchanged.

LLPs at Ground Level Detected by All Planes



Number of LLPs at ground level can be detected by all detectors



Percentage of LLPs at ground level can be detected by all detector

- Same upper and side boundaries as the previous plot
- A higher lower boundary
- 35K out of 143K LLPs emerge from the ground before the footprint area. A hermetic veto will cause 25% loss of decays at ground level.
- Inefficiencies for large z recoverable with a detector wall at end of MATHUSLA

Summary

- LLPs emitted uniformly in the azimuthal angle
- Most LLPs concentrate close to the collision point
- Only a small fraction of LLPs pass through the detector plane
- Physics works!
- If we only restrict ourselves to the LLPs decayed in MATHUSLA, a lot of data would be ignored, rough $1/4$ in this simple model

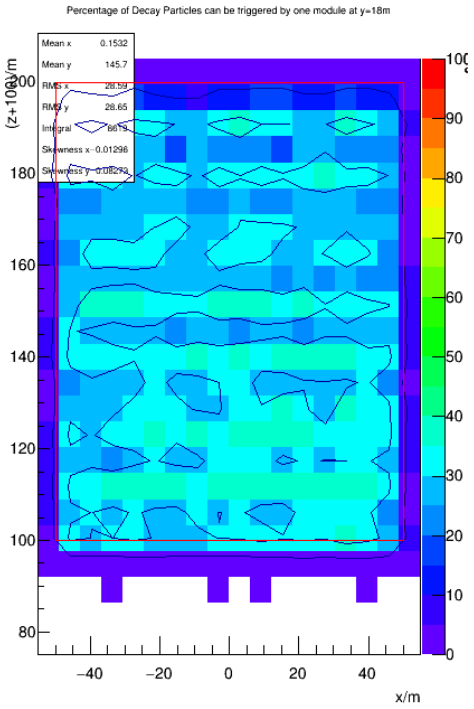
What else has been done?

- Efficiency is defined here by percentage of LLPs whose charged decayed products of can cross all five layers of detection planes
- Trigger means at least one of the charged decayed products can cross all five layers of detection planes
- Reconstruct means two or more charged decayed products can cross all five layers of detection planes
- Relative Reconstruct Efficiency means $\frac{Number\ of\ Reconstructed\ Events}{Number\ of\ Triggered\ Events}$
- One Module means a $10m \times 10m$ module

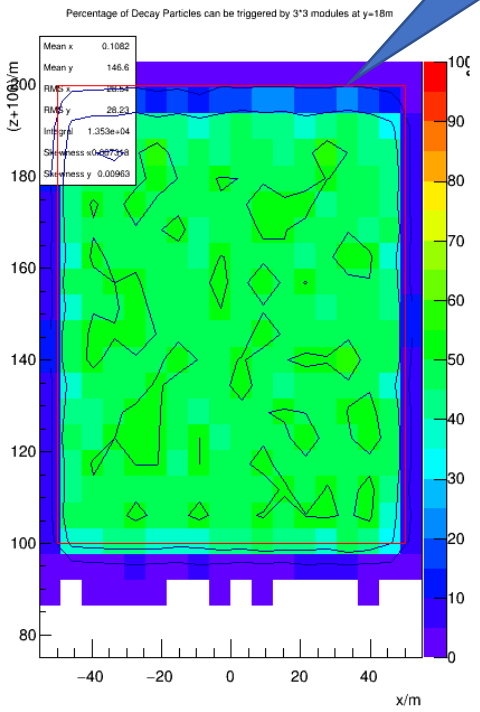
Dataset
A 125 GeV Higgs-like boson decays into two long-lived scalars with a mass of 50 GeV that decays into a pair of muons

user.calpigia.MC15.100813.MadGraphPythia8EvtGen_A14NNPDF23LO_HSS_LLP_mH125_mS50_mumu.evgen.e5102_v03_SKIMMED

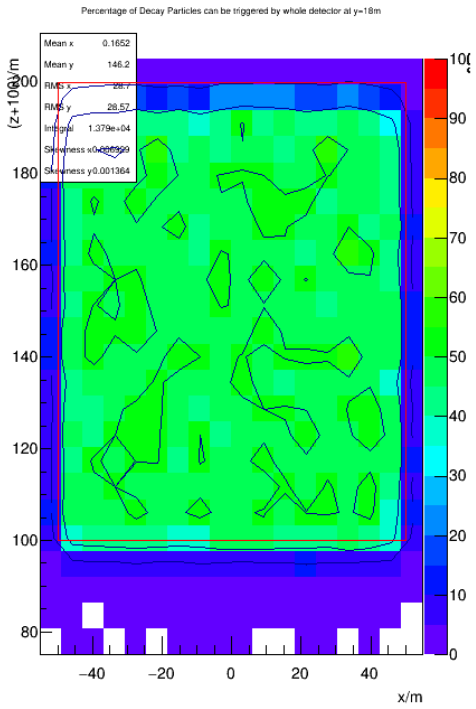
Triggering Efficiency Plot of Decaying Events at $y = 18m$



Efficiency of One Module Triggering



Efficiency of 3*3 Modules Triggering



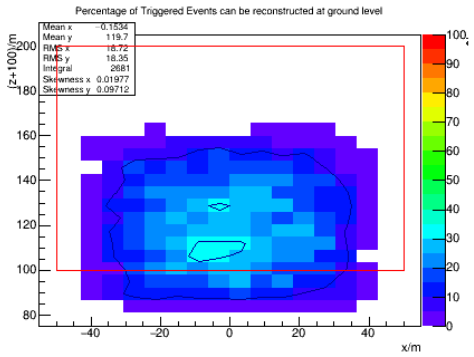
Efficiency of Whole Detector Triggering

MATHUSLA Footprint

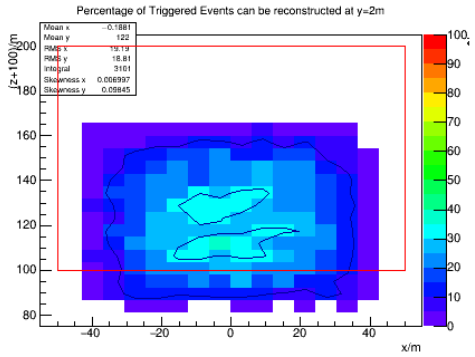
- Triggering by 3*3 modules has almost the same efficiency with triggering by whole detector inside MATHUSLA, with a sharper cut off at the edge of MATHUSLA
- Triggering by one module has significantly lower efficiency

Relative Reconstruct Efficiency Plot of Decaying Events

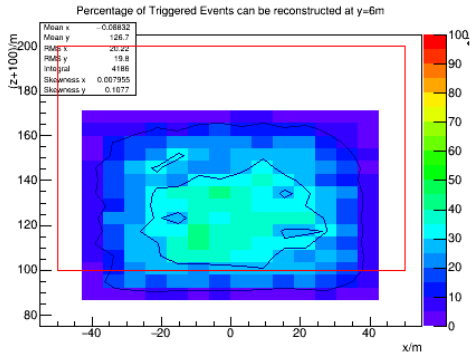
0 m

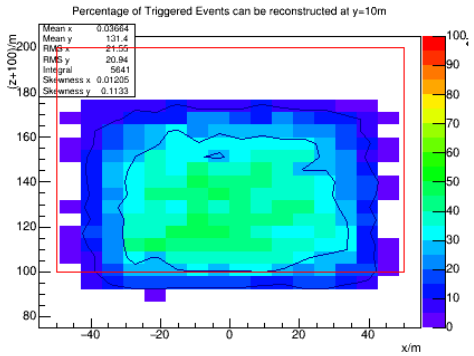


2 m

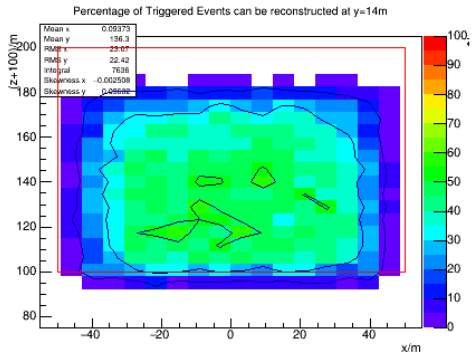


6 m

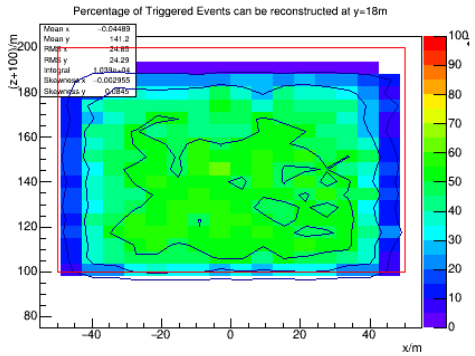




10 m



14 m



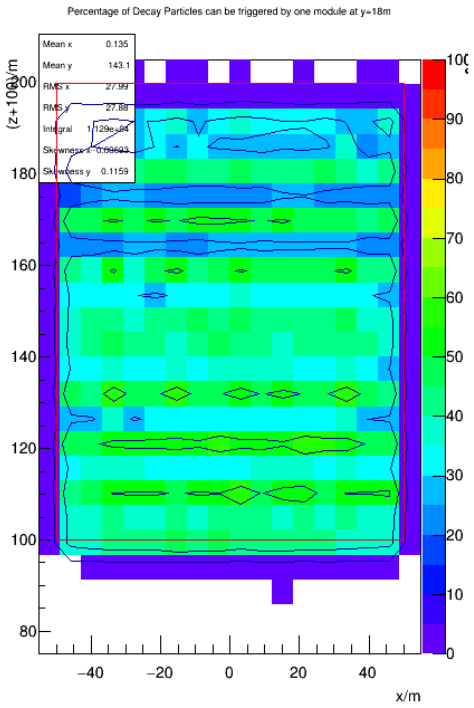
18 m

- Relative Reconstruction Efficiency increase with decaying height above ground level
  - 0 m
  - 2 m
  - 6 m
  - 10 m
  - 14 m
  - 18 m

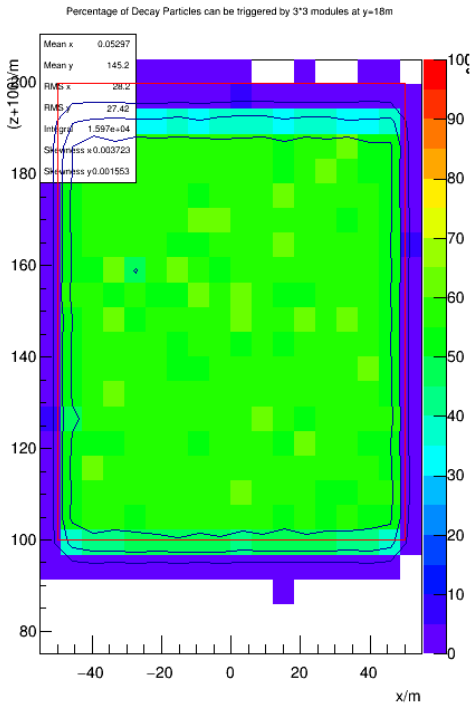
Dataset
A 125 GeV Higgs-like boson decays into two long-lived scalars with a mass of 15 GeV that decays into a pair of muons

user.calpigia.MC15.100811.MadGraphPythia8EvtGen_A14NNPDF23LO_HSS_LLP_mH125_mS15_mumu.evgen.e5102_v03_SKIMMED

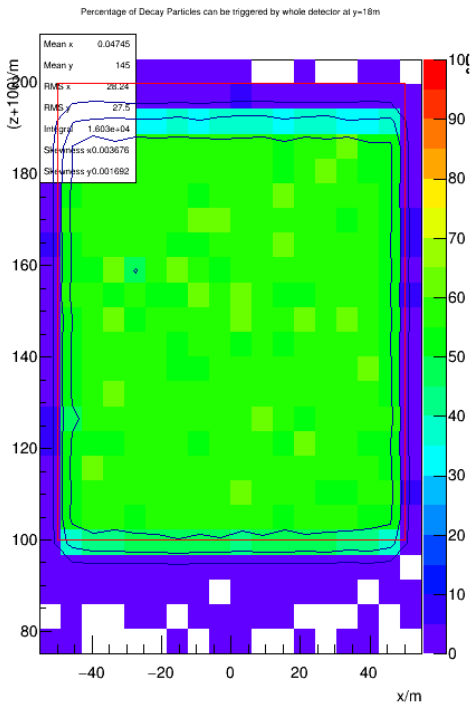
Triggering Efficiency Plot of Decaying Events at $y = 18m$



Efficiency of One Module Triggering



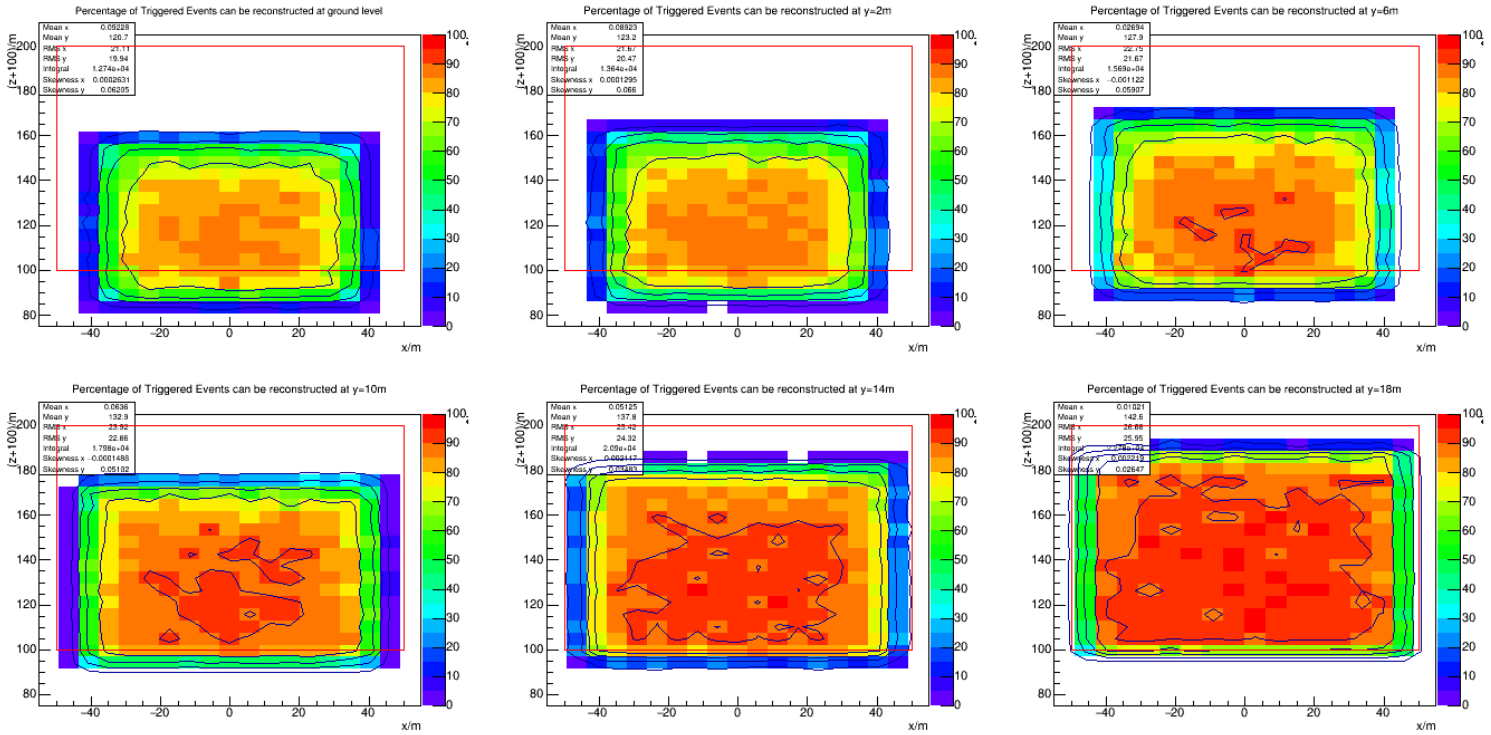
Efficiency of 3*3 Modules Triggering



Efficiency of Whole Detector Triggering

- Triggering efficiency slightly higher than the case of 50 GeV LLP
- Triggering by 3*3 modules has almost the same efficiency with triggering by whole detector inside MATHUSLA, with a sharper cut off at the edge of MATHUSLA
- Triggering by one module has significantly lower efficiency

Relative Reconstruct Efficiency Plot of Decaying Events



- Much better relative reconstruction efficiency than the case of 50 GeV LLP
- Relative reconstruction efficiency increase with decaying height

Summary

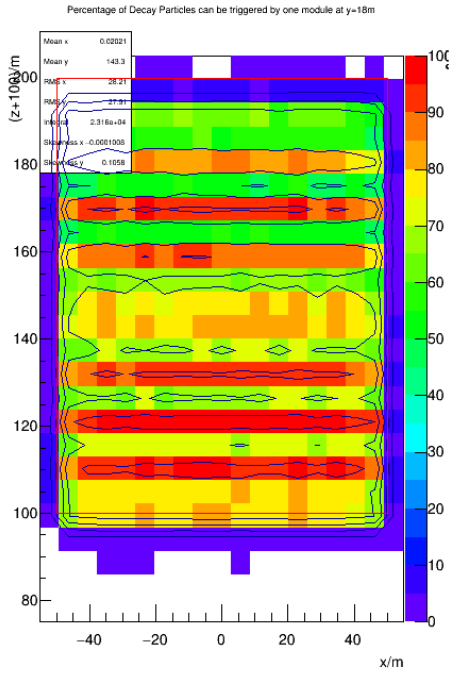
- For LLPs decaying into two muons, relative reconstruct efficiency is much larger for less massive LLPs
- 3*3 Modules Triggering performs almost as well as Whole Detector Triggering while one module triggering performs much worse

Dataset
A 125 GeV Higgs-like boson decays into two long-lived scalars with a mass of 15 GeV that decays into multiple hadrons

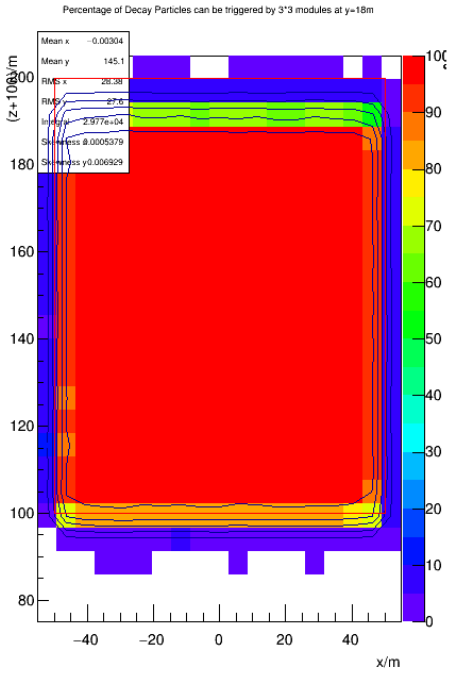
user.calpigia.MC15.100810.MadGraphPythia8EvtGen_A14NNPDF23LO_HSS_LLP_mH125_mS15_bb.evgen.e5102_v03_SKIMMED

Triggering Efficiency Plot of Decaying Events at $y = 18m$

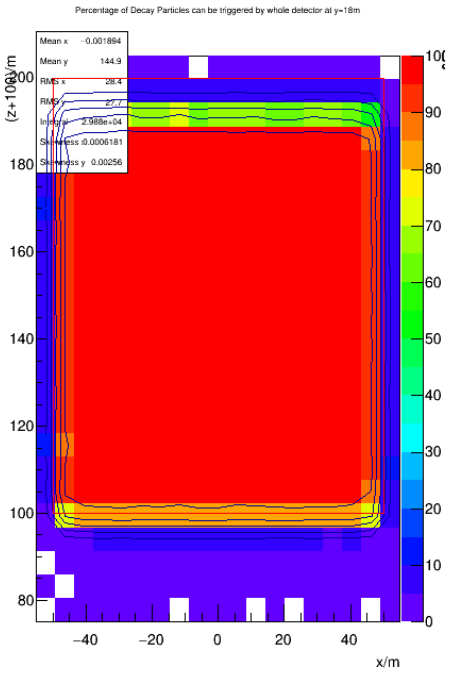
- Perfect triggering efficiency for decays happen inside MATHUSLA if triggered by 3*3 modules or whole detector
- Triggering efficiency drops sharply for decays happen out of MATHUSLA
- Triggering by one module performs much worse



Efficiency of One Module Triggering



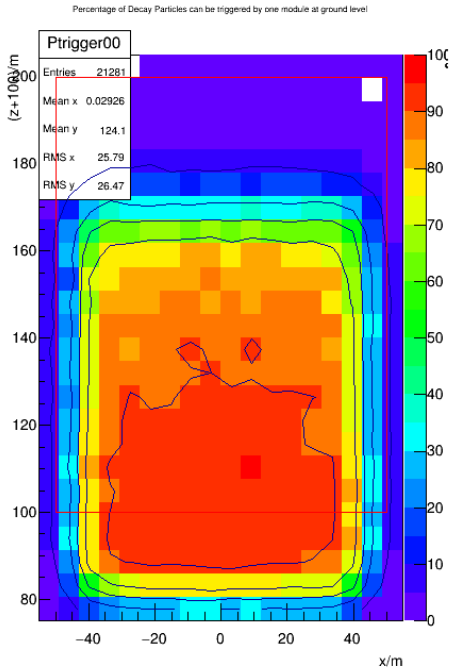
Efficiency of 3*3 Modules Triggering



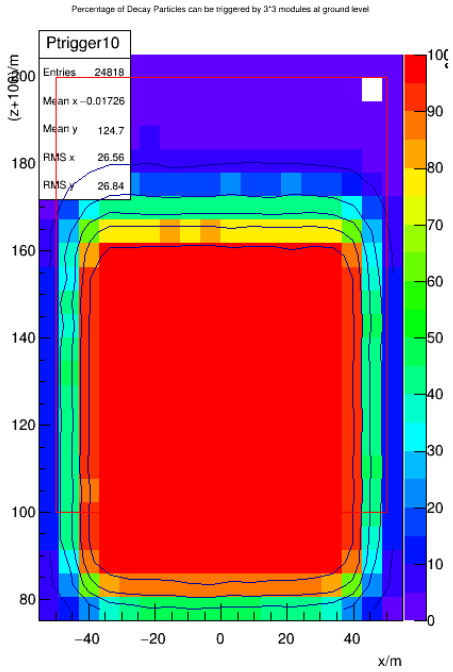
Efficiency of Whole Detector Triggering

Triggering Efficiency Plot of Decaying Events at Ground Level

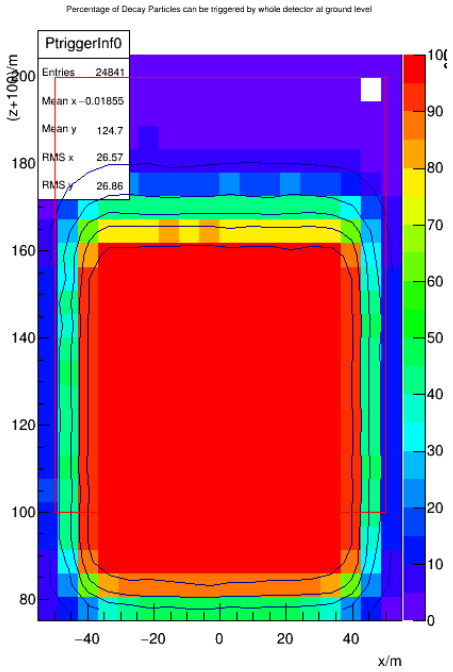
- The whole spectrum shrinks and moves downwards
- No bands for one module triggering



Efficiency of One Module Triggering



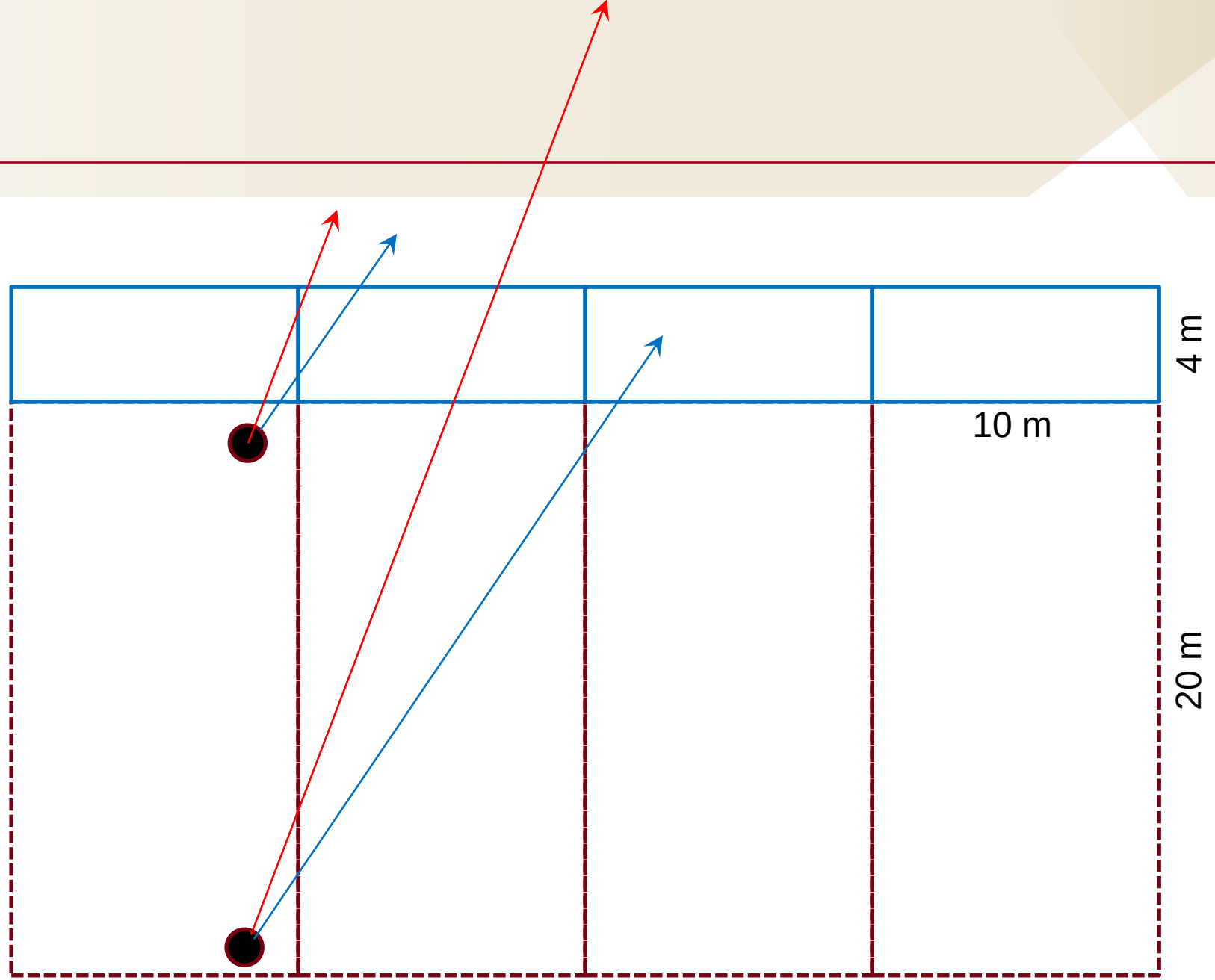
Efficiency of 3*3 Modules Triggering



Efficiency of Whole Detector Triggering

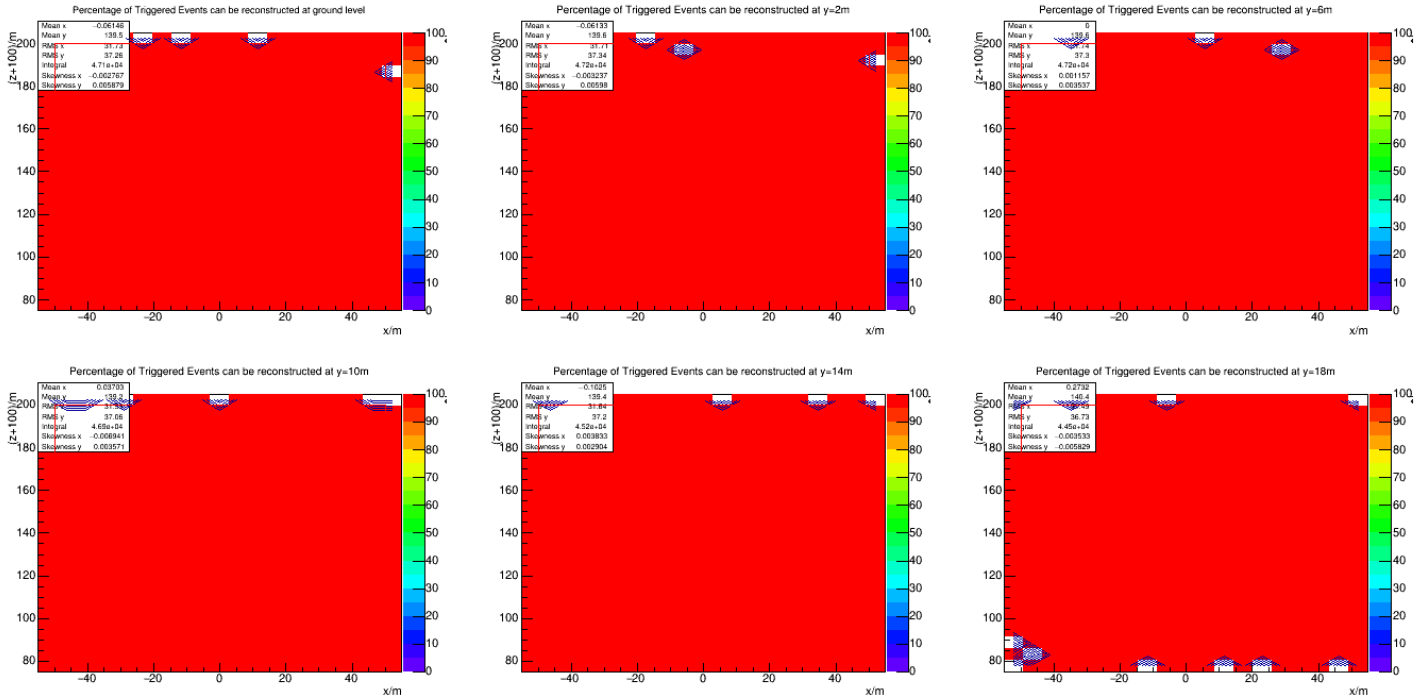
- LLP decay near the detector
  - Decay products are still close together in detector.
  - If one track crosses module boundary, it is likely that all other tracks will also cross module boundary.

- LLP decay near the floor
  - Decay products are more spread out in detector.
  - It is more likely that at least one track will not cross module boundary.


4 m
10 m
20 m

Relative Reconstruct Efficiency Plot of Decaying Events

- Perfect relative reconstruction efficiency almost everywhere



Dataset
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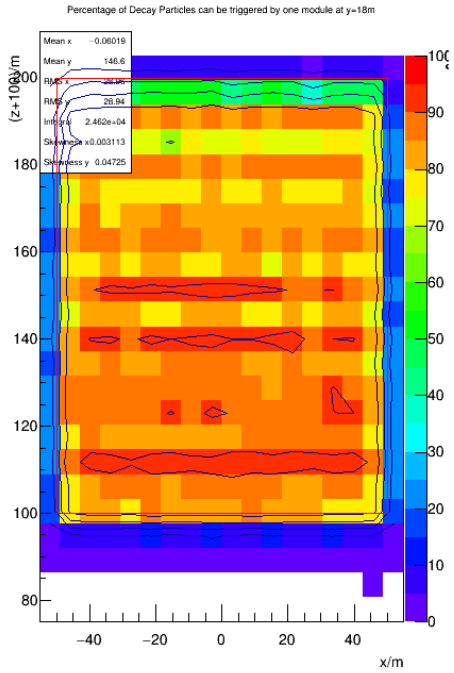
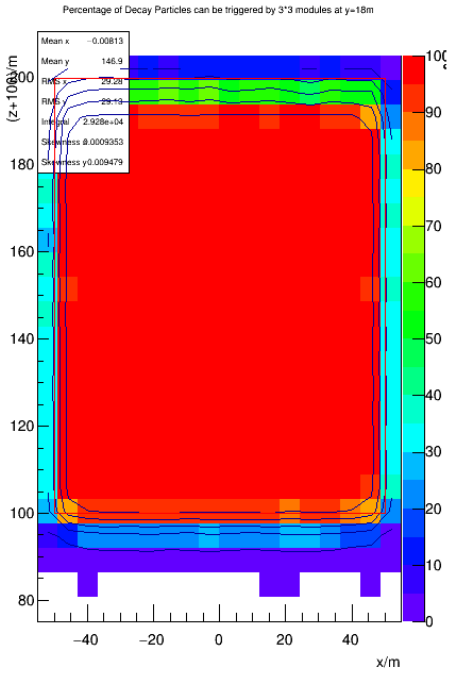
Triggering Efficiency Plot of Decaying Events at $y = 18m$

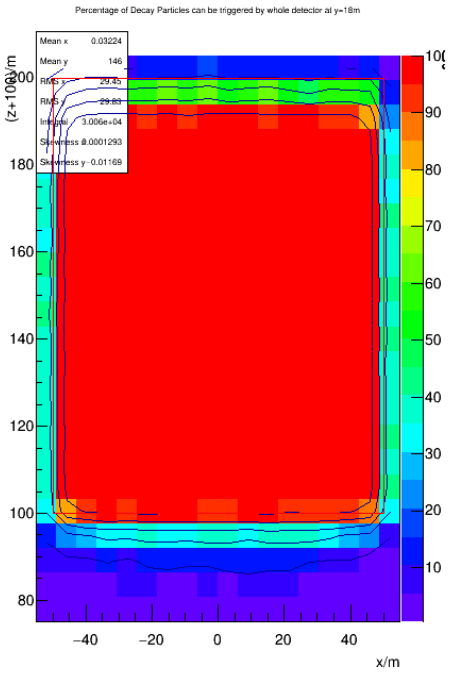
- Almost perfect triggering efficiency for decays happen inside MATHUSLA if triggered by 3*3 modules or whole detector
- Triggering efficiency drops more gently at the edges
- Triggering by one module performs much worse



Efficiency of One Module Triggering



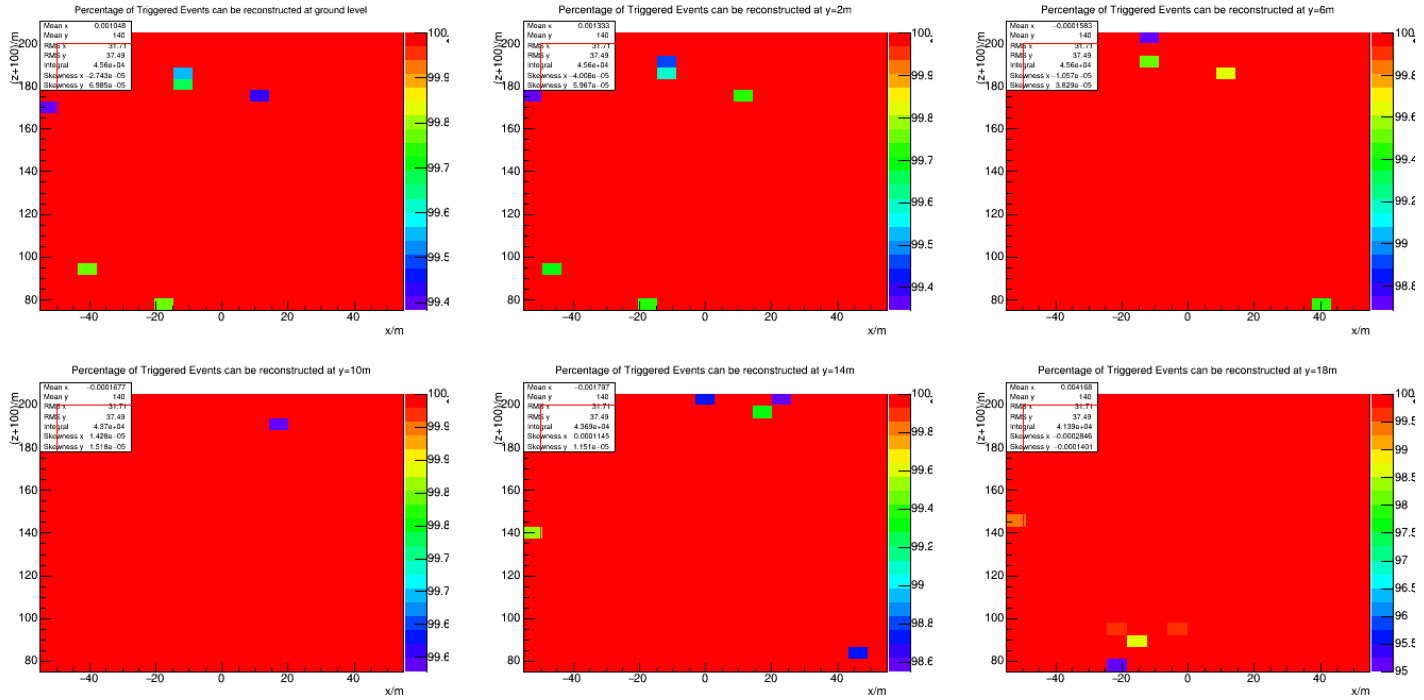
Efficiency of 3*3 Modules Triggering



Efficiency of Whole Detector Triggering

Relative Reconstruct Efficiency Plot of Decaying Events

- Perfect relative reconstruction efficiency everywhere



Summary

- For LLPs decaying into multiple hadrons, relative reconstruct efficiency is almost perfect
- 3*3 Modules Triggering performs almost as well as Whole Detector Triggering while one module triggering performs much worse for all the trail events
- For LLPs decaying into multiple hadrons , 3*3 Modules Triggering has almost perfect efficiency if we only study the decays that happen inside MATHUSLA
- All the outputs have been uploaded to https://gitlab.cern.ch/mathusla/TriggerAnalysis and arranged in folders named after the datasets used
- In each folder, there's a root file naming 'output' contains all the plots otherwise also available in the folder as png files

Efficiency – suggested further study

What next?

What next?

- Introduce gap between detectors
- Change the size of MATHUSLA
- Put MATHUSLA at different places