Dead material impact on MIP energy measurement

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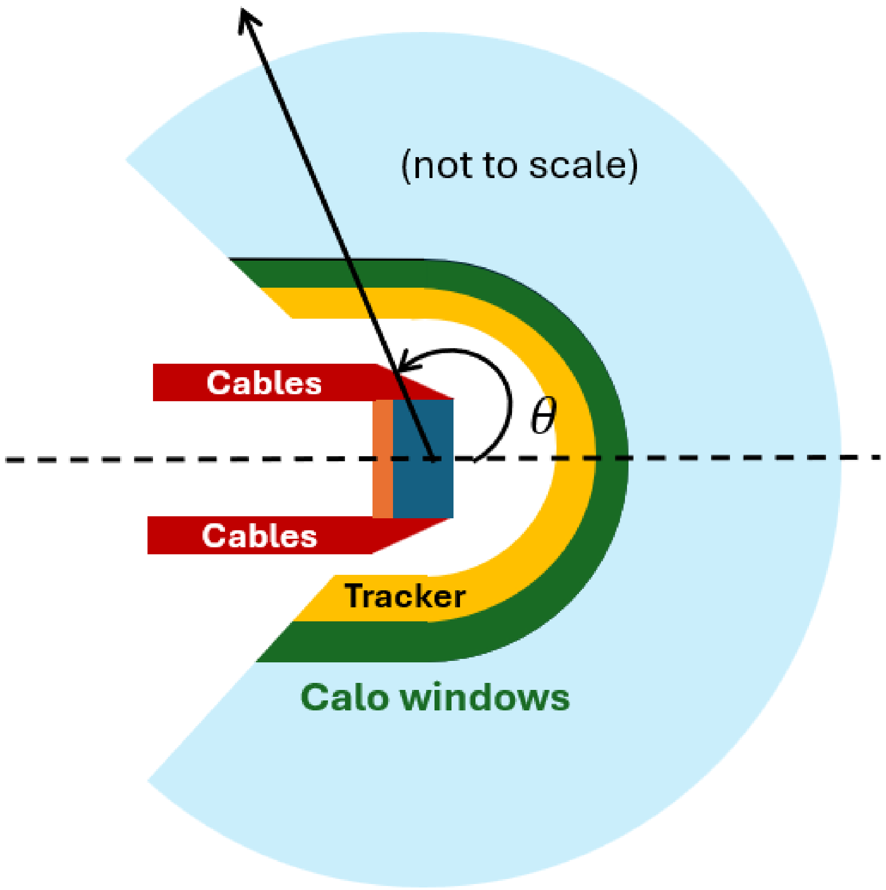
Goals

1. Obtain an estimate of the energy lost due to dead material as a function of θ_{MIP}

2. Using this method to estimate energy loss in dead material:
   → What is the resultant spread in measured energy for a signal at a specified energy?
   → How does this spread change with different geometries?
   → What is a useful fiducial volume?

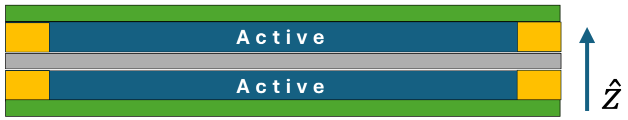
Ultimately, how much dead material can PIONEER tolerate?

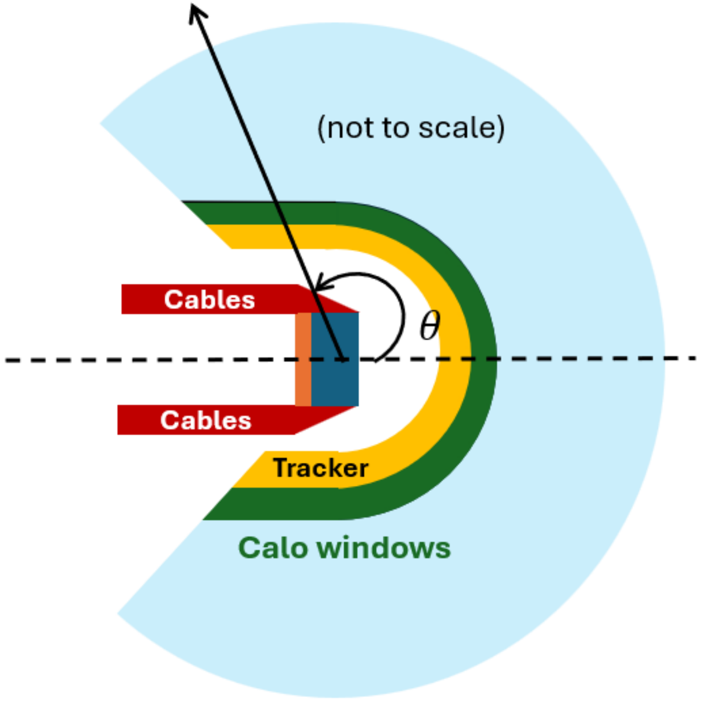


Geometry

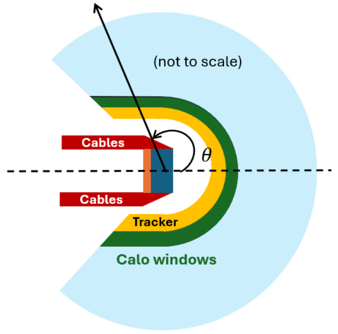
- LXe calorimeter with $\theta = [0, 145]$ degrees
- Atar
  - 24 sandwich layers which contains 48 layers of 100 strips each
  - One sandwich layer has:
    - Two layers of strips (active), surrounded by aluminum guard rings: **0.4 mm thick**
    - Aluminum backing separating active strips: **1 μm thick**
    - Electrodes for each strip: **1 μm thick**
  - Sandwich layers are separated by an HV layer: **15 μm** of Kapton
- Windows
  - Inner material: Aluminim
  - **Inner Thickness: 0.5 mm**
  - Outer material: 90% titanium, 6% aluminum, 4% vanadium
  - Density: 4.5 g/cm^3
  - **Outer Thickness: 0.2 mm**
- Tracker (micro urwell, circa 2022)
  - Layers of glue, copper, Kapton, and gas
  - **Total thickness of 4 mm**
- Cables
  - Density: 0.45 g/cm^3, 45% aluminum, 55% Kapton

Sketch of one sandwich layer in atar

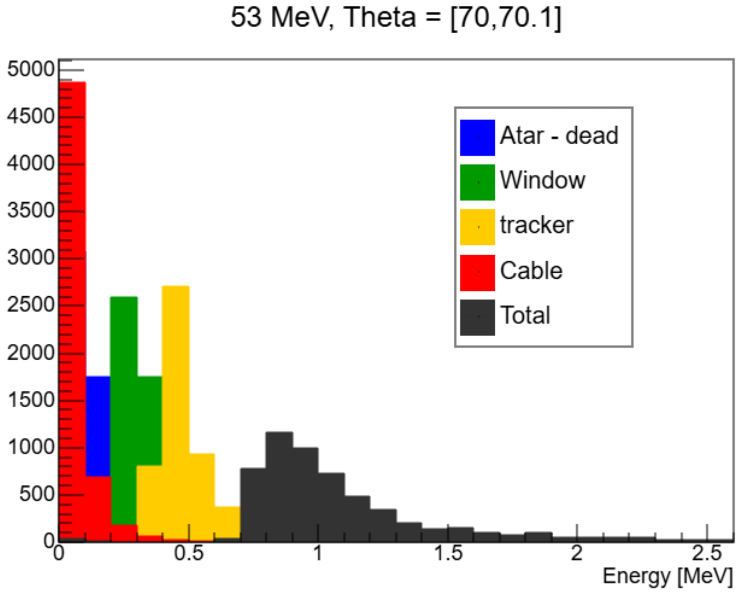


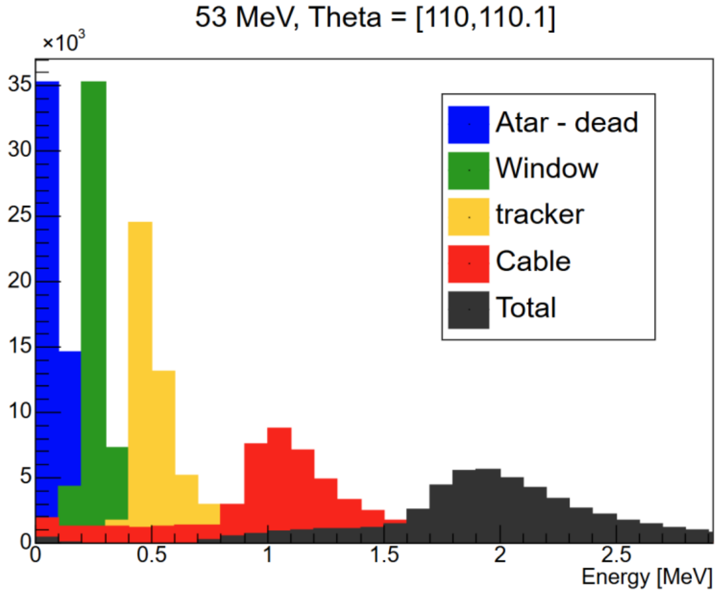


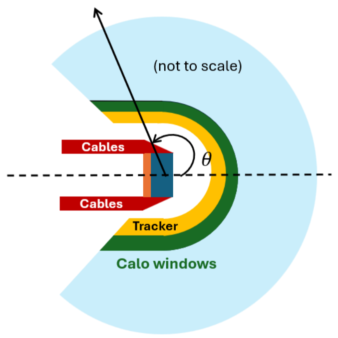
Strategy



- The energy lost in a given amount of dead material follows a Landau distribution
- The amount of dead material a MIP travels through is strongly correlated to θ_{MIP}
- Thus, **we can use the mean of the Landau distribution as an estimate of the energy lost in dead material** for a given θ_{MIP}
- We expect this to increase the spread of the energy distribution without changing its mean

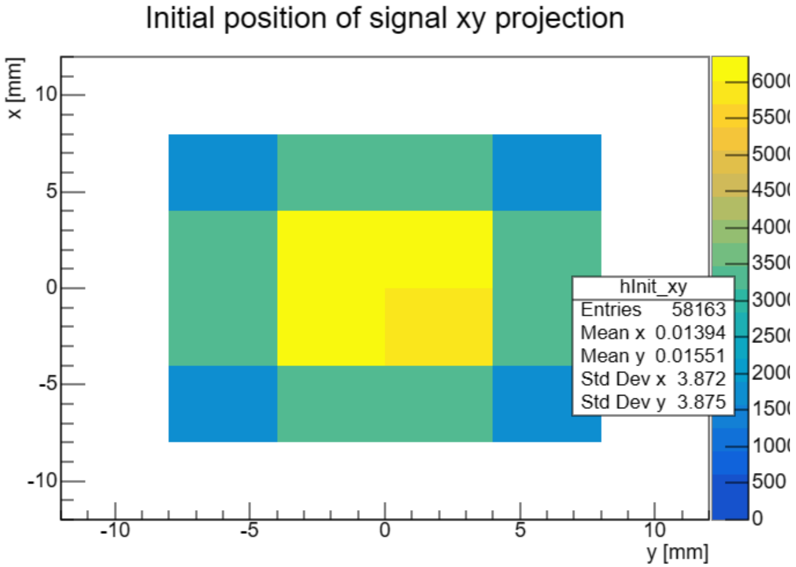






Set up

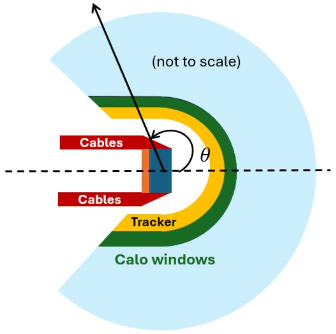
- 53 MeV positron signal generated with a Gaussian distribution centered in ATAR $(\sigma_{x,y} = 5\ mm, \sigma_z = 2\ mm)$ with $\theta_{MIP} \in \{[0,0.1], [10,10.1], \dots, [170,170.1]\}$ deg



Cuts:

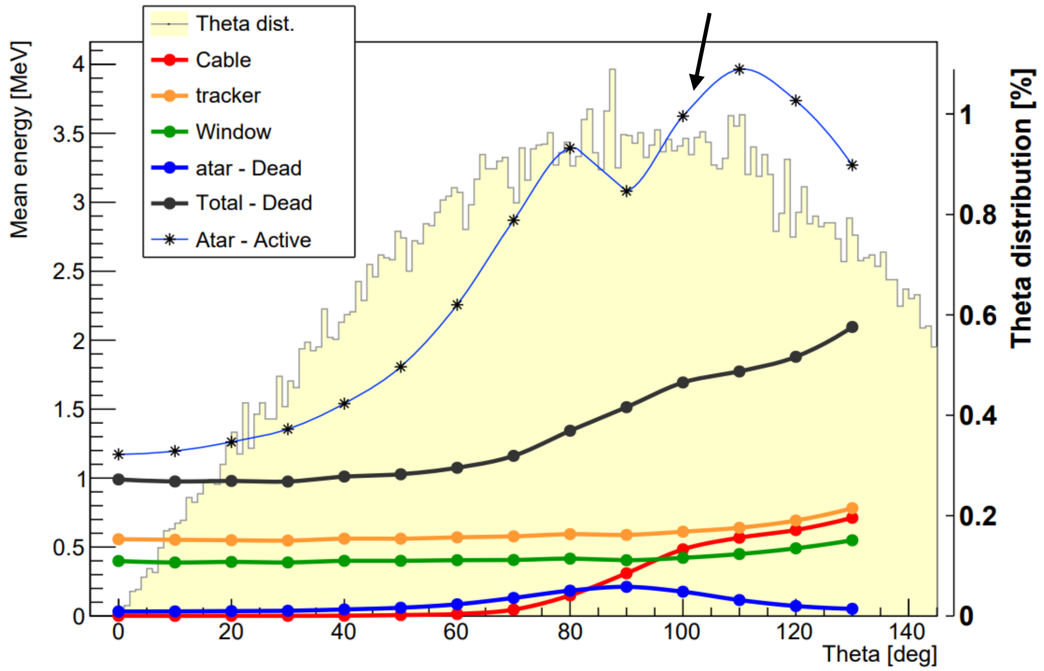
- Positrons generated outside of abs(x) < 8, abs(y) < 8, or 1.2 < z < 4.8

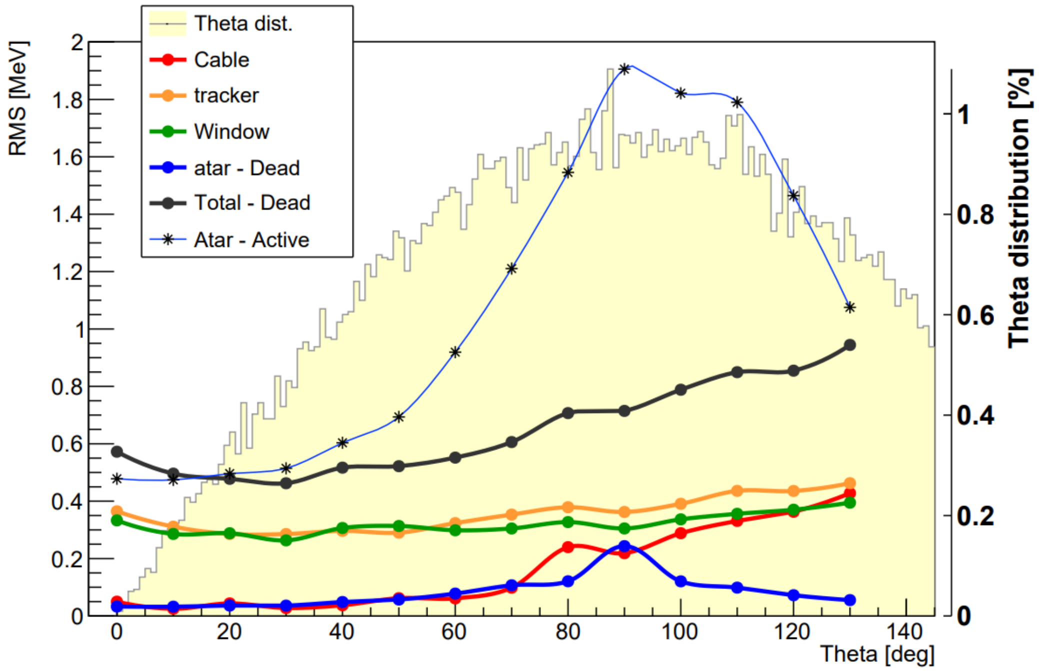
Quantifying Energy Loss in Dead Material



- Default geometry:

DTAR edep included with ATAR

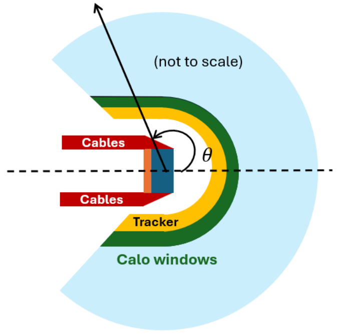


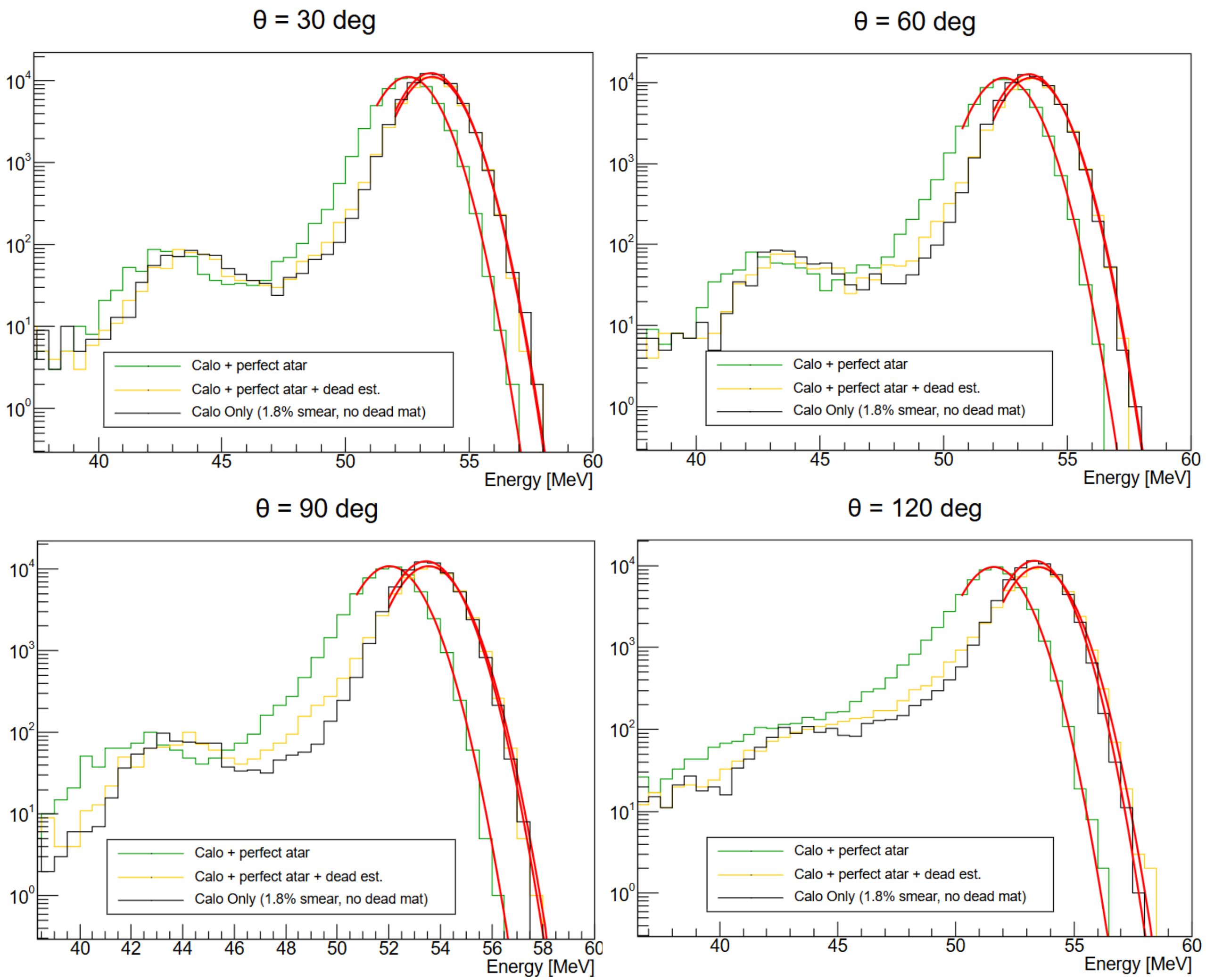


→ The mean total energy loss (black) will be added back to each event as a function of theta. Values are determined by interpolating between the computed results

→ Resolution in dead material is dominated by cables in the regions with the most events

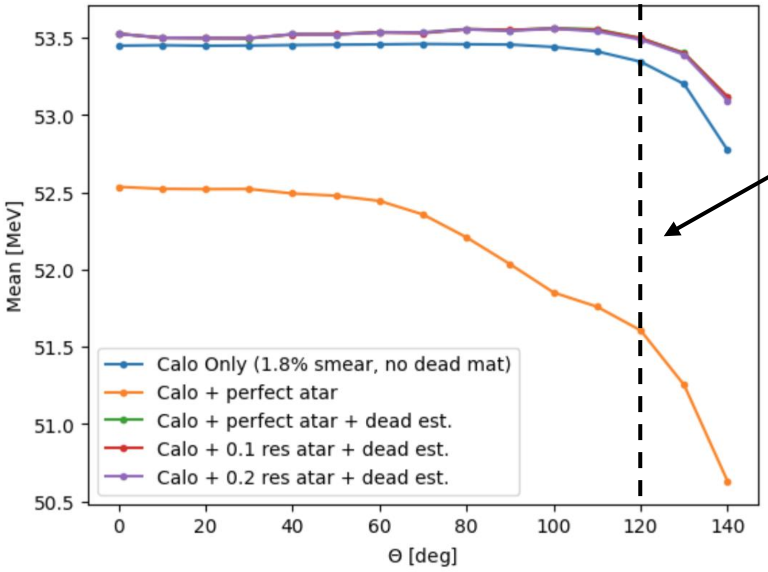
Effect of dead material on resolution



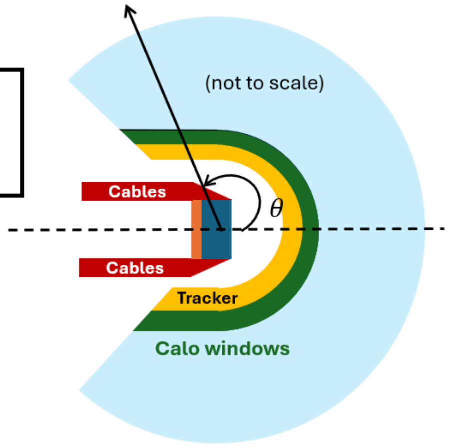


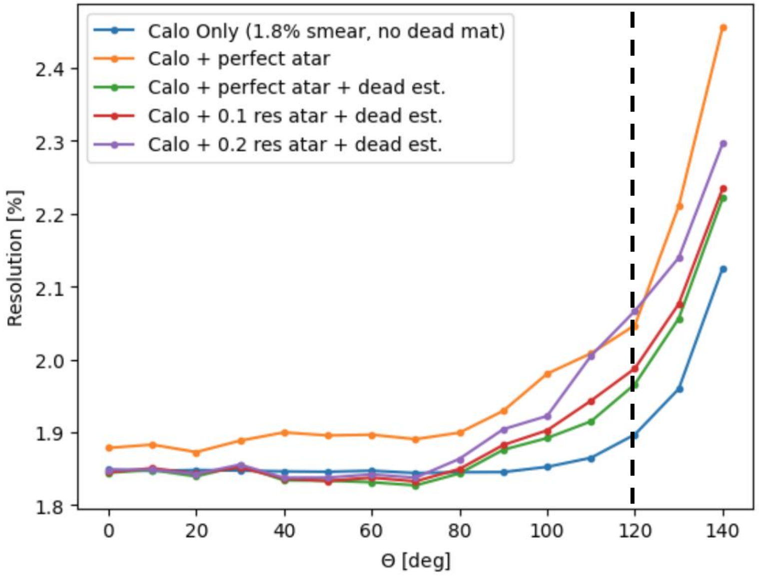
- The dead energy added back is determined via interpolation and fitted with a Gaussian
- "Calo Only" has <u>no atar or dead material</u> (acts as our "best detector")
- The addition of the dead estimate gives a mean close to that of the "best detector," but is a bit broader
- Note that the Gaussian fit is worse at larger angles due to leakage in the calo

Effect of dead material on resolution



End of fiducial volume





→ Atar resolution has a larger affect at larger angles

→ Dead estimate is better when $\theta < 80°$ (before cables start to have a substantial affect)

Notice:

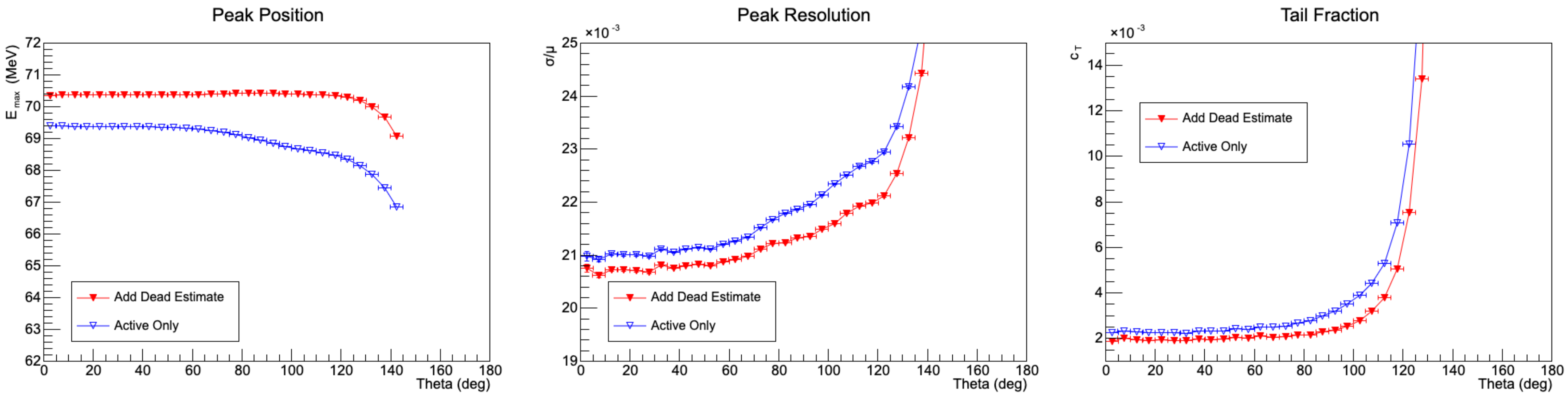
→ Resolution at larger angles is skewed by larger tails from leakage

Inclusive ($\theta \in [0,120]$ deg):

- Calo only
  - Mean: 53.439
  - Resolution: 1.840%
- Calo + perfect atar (w/ dead material):
  - Mean: 52.204
  - Resolution: 1.983%
- Calo + perfect atar + dead estimate:
  - Mean: 53.529
  - Resolution: 1.865%
- Calo + 10% atar resolution + dead estimate:
  - Mean: 53.532
  - Resolution: 1.867%
- Calo + 20% atar resolution + dead estimate:
  - Mean: 53.529
  - Resolution: 1.891%

Adding it to the framework

- Dead material correction implemented in the central simulation/reconstruction
- Impact of the correction for pienu sample



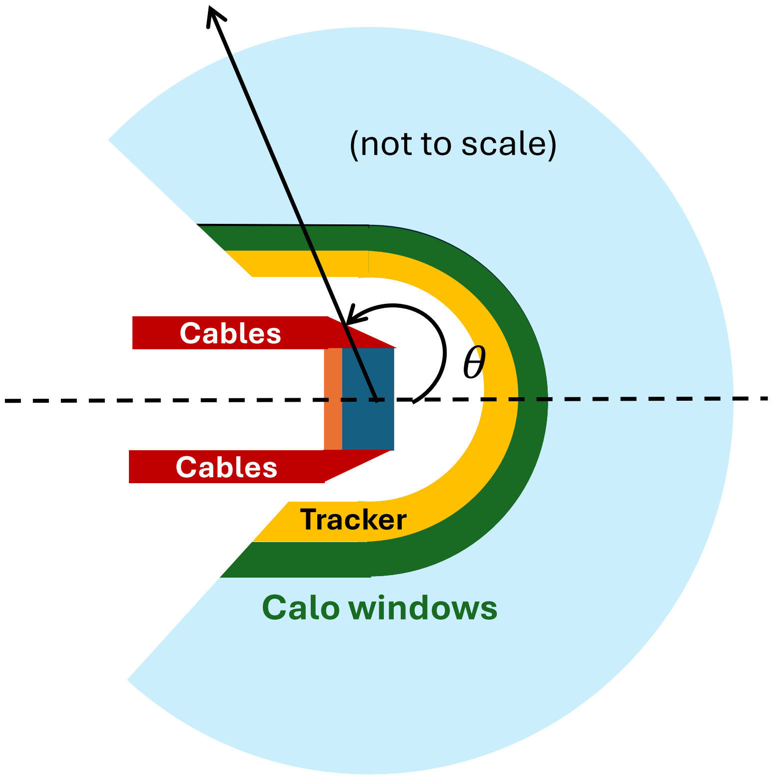
Summary

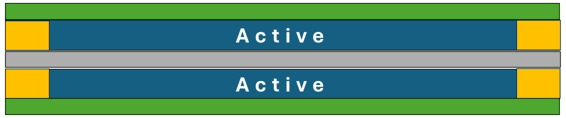
- Impact of dead material on energy resolution is strongly dependant on θ_{MIP}
- Key numbers:
  - Around 1-2 MeV of energy lost in dead material per event (vs. 3-4 MeV measured by the ATAR)
  - Resolution decreases from $\sim$2% to $\sim$1.85-1.9% with dead energy estimate
- Study can be repeated for different geometries to determine:
  - How much energy is lost in a given dead volume
  - Effects on resolution
- Estimates (and therefore resolutions) can be improved by:
  - Computing the average energy lost fore more theta values
  - Parameterizing with respect to phi, position, and energy

Backup

Tracker Layers

Material	Thickness (cm)
Glue	0.01
Copper	0.0005
uRWELLGas	0.2
Copper	0.0005
Kapton	0.005
Carbon	0.00001
Glue	0.0028
Copper	0.0017
Glue	0.0028
Copper	0.0017
Kapton	0.16
Copper	0.0017





uRWELLGas = 45% argon + 15% CO_2 + 40% CF_4