

# An Updated Comparison of Simulation to Data of Muons in AHCAL.

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- > Motivation and Goals
- > Overview
- >  $\langle N_{Hit} \rangle$  Per Layer Distributions
- >  $\langle E_{Hit} \rangle$  Per Layer Distributions
- >  $N_{Hits}$  Distributions
- >  $E_{Hit}$  Distributions
- > Rejected and 'Hadron' Events

- > **Previous analyses of muons** in AHCAL measured **unexpected differences** between simulation and data.
- > **Independent validation measurement** was performed using
  - > **additional analysis tools** developed by the group.
  - > **updated simulation** including **airgap effects**;
- > **Disclaimer: research is still ongoing!**

- > Analysis overview:
  - > SPS June 2018
  - >  $1.0 \times 10^6$  MC Events;
  - >  $5.172 \times 10^6$  Data Events;
  - > Physics List: QGSP\_BERT;
  - > Rectangular beam profile to cover whole calorimeter face.

Several goals:

- > Compare the track reconstruction methods;
- > Study PID separated components of data vs MC;



Figure: Analysis Megazord

# Analysis Flow

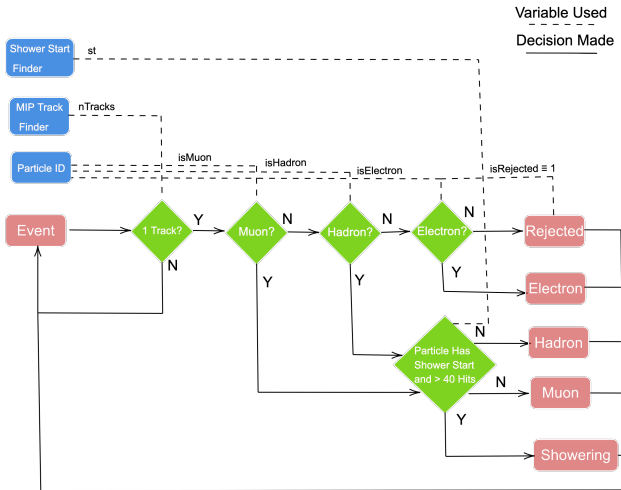


Figure: Analysis flowchart

# # Track Proportions

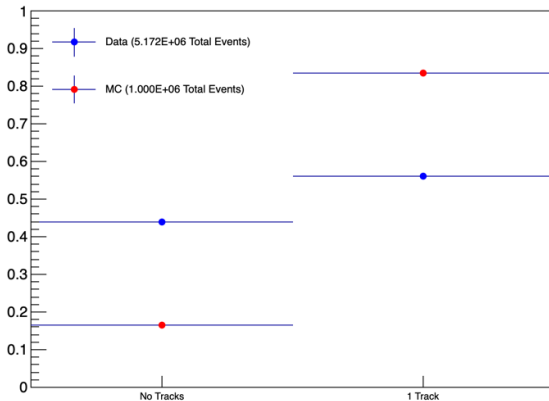


Figure: Proportions of # Tracks in Data and MC

# PID Proportions

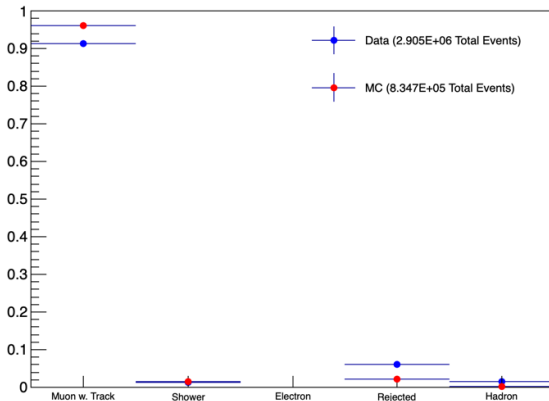
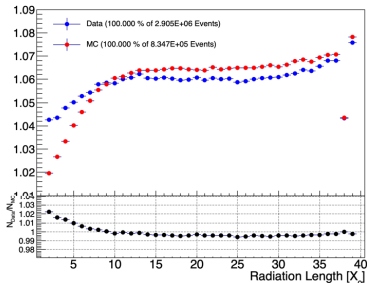


Figure: Proportions of event classes in Data and MC

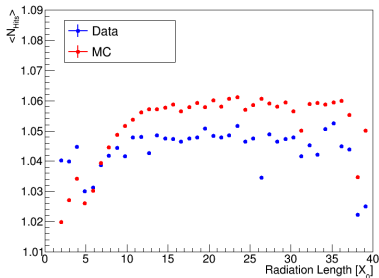
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# $\langle N_{Hit} \rangle$ Per Layer



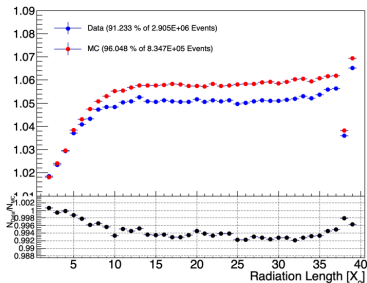
((a)) Eldwan's Method



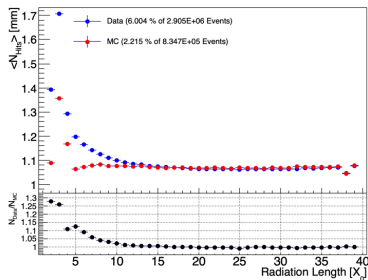
((b)) Saiva's Method

- > **Strange effect significantly reduced disparity by using Eldwan's track finder;**

# $\langle N_{Hits} \rangle$ Per Layer



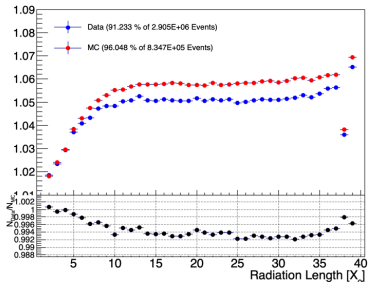
((c)) Eldwan's Method (Track Muons Only)



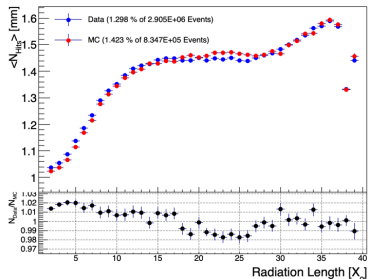
((d)) Eldwan's Method (Rejected Events Only)

- > Disparity at low layers reduced by PID;
- > Rejection of events with isolated hits far from the track in first few layers;

# $\langle N_{Hit} \rangle$ Per Layer



((e)) Eldwan's Method (Track Muons)

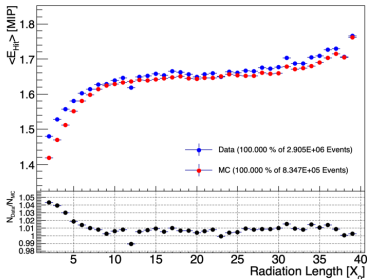


((f)) Eldwan's Method (Showering)

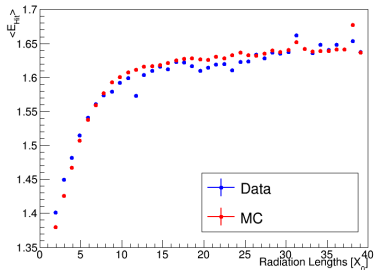
➤ Showering particles show good agreement between Data and MC.

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# $\langle E_{Hit} \rangle$ Per Layer



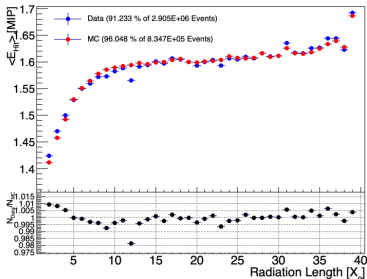
((g)) Eldwan's Method



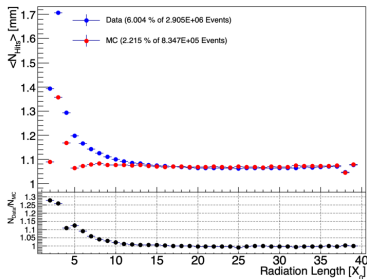
((h)) Saiva's Method

- Good agreement in both cases though disparity observed in first layers;

# $\langle E_{Hit} \rangle$ Per Layer



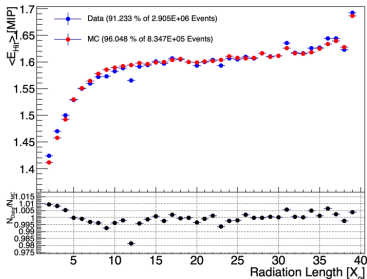
((i)) Eldwan's Method (Track Muons Only)



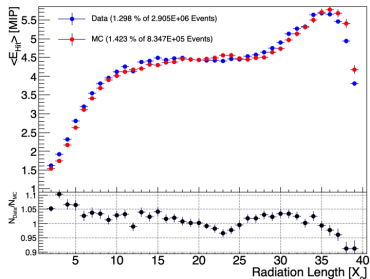
((j)) Eldwan's Method (Rejected Events Only)

- Disparity at low layers reduced by PID.
- Original sample contains events with isolated hits far from the track in first few layers;

# < $E_{Hits}$ > Per Layer



((k)) Eldwan's Method



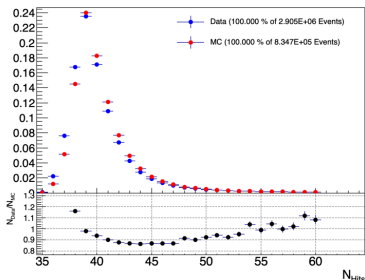
((l)) Eldwan's Method (Showering)

> Showering particles again show good agreement.

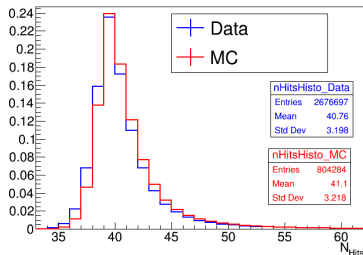
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# $N_{Hit}$ Distribution



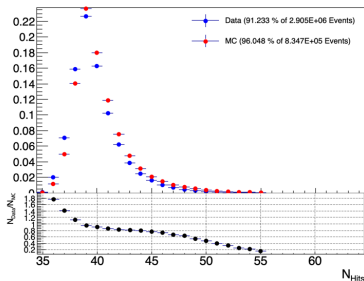
((m)) Eldwan's Method (Track Muons)



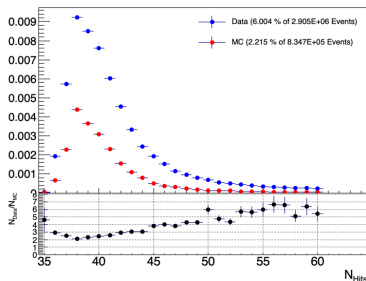
((n)) Saivas's Method

- > Lower numbers of hits in event observed below average in Data than MC;
- > Greater numbers of hits in event observed above average in Data than MC.

# $N_{Hit}$ Distribution



((o)) Eldwan's Method (Track Muons Only)

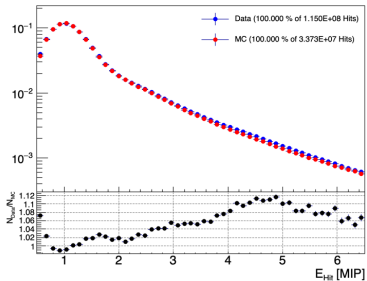


((p)) Eldwan's Method (Rejected Events Only)

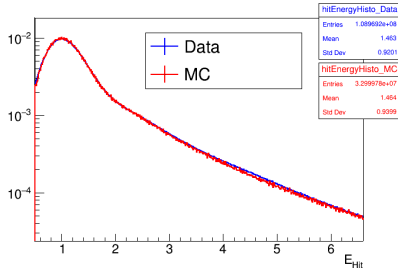
- > Use of PID results in more events with greater numbers of hits in MC than data;
- > Does not resolve disparity at low numbers of hits.

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# $E_{Hit}$ Distribution



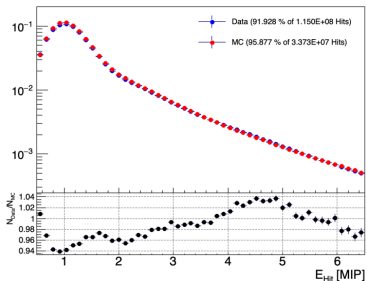
((q)) Eldwan's Method



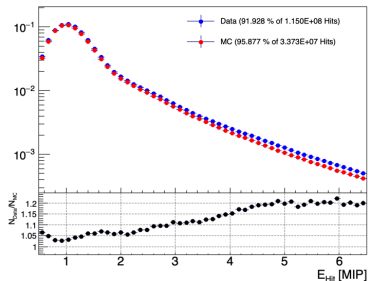
((r)) Saivas's Method

- > There are increasingly fewer events at high energies in MC than data;

# $E_{Hit}$ Distribution



((s)) Eldwan's Method (Track Muons Only)

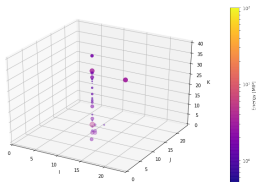


((t)) Eldwan's Method (Track Muons Only, Hits on Track)

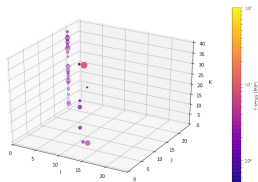
- Even on the track itself, there are increasingly fewer events at high energies in MC than data;

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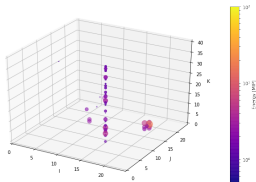
# Rejected Events in Data



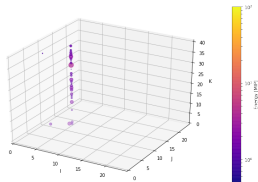
((u)) Example 1



((v)) Example 2



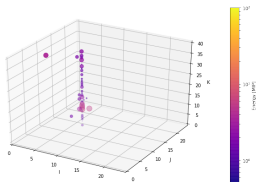
((w)) Example 3



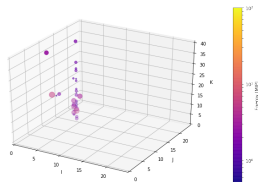
((x)) Example 4

- > Partial tracks;
- > Partial multiple tracks;
- > 'Displaced hits'

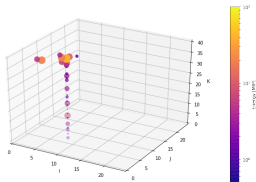
# Misclassified 'Hadrons' in Data



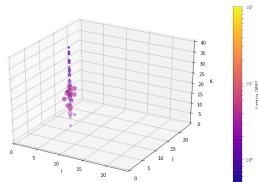
((y)) Example 1



((z)) Example 2



(()) Example 3



(()) Example 4

- > Interacting muons that do not shower;
  - > Late showering muons;
  - > 'Displaced hits'



- > The **magnitude** of the **strange effect** is **affected by** choice of **muon track finding algorithm**;
- > **PID** oftentimes **appears to improve agreement of Data and MC**;
- > **Contribution of more unexpected untracked/poor quality in data** events may **have further effects on disparities**;
- > **Showering particles**, under the definition given in the analysis, show **good agreement between data and MC**.
- > **Perhaps more sophisticated approach** to partial tracks/'displaced hits' in data **required?**