

Electron-Muon Ranger (EMR) Data Quality

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Data quality tests

- The EMR data acquisition is regularly monitored by the shifters and through the onrec plots.
- Contacted once for a single arming issue, solved over the phone.
Continuous DAQ through cycle 2017/03
- A selection of runs (summarized below) were taken from the 2017/03 ISIS user cycle to test the performance of the EMR in multiple ways:
 - Raw efficiency of the hardware at in the MA and SAPMTs;
 - Efficiency of the reconstruction at different levels;
 - Beam profiles at different momenta;
 - PID variable reconstruction.

Setting	Run ID	TOF1 triggers	EMR events	EMR tracks
300 MeV/c	10305	370146	63532	61654
400 MeV/c	10307	363289	71973	69747

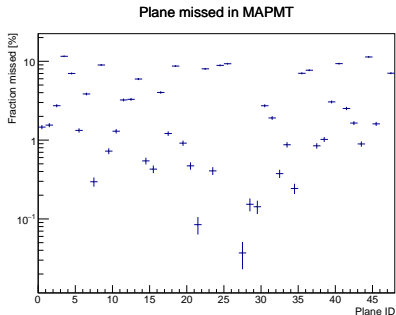
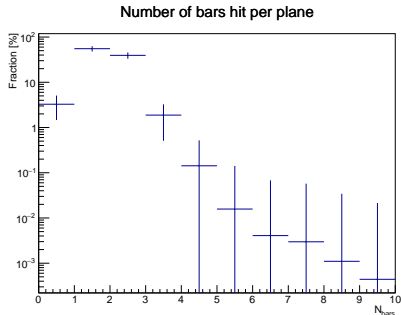
Hardware efficiency: raw MAPMT hits

Highest momentum setting (run 10307) is used to investigate the amount of bars hit per plane on average (the muons punch through)

- **$96.73 \pm 1.81\%$ global digit efficiency** (consistent with CM48)
- One bar hit $\sim 51\%$ of the time, 2 bars $\sim 45\%$ of the time

On a plane to plane basis

- Levels of inefficiencies consistent with CM48, still reliable to reconstruct full tracks as probability of missing track is extremely low



Hardware efficiency: raw SAPMT charge

Highest momentum setting (run 10307) is used to investigate the amount of charge deposited in each plane (the muons punch through)

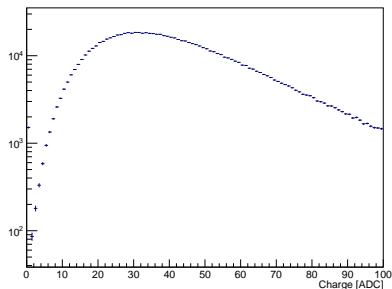
→ **99.834% global SAPMT efficiency**

On a plane to plane basis

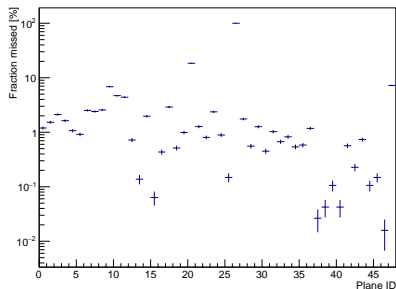
→ Two planes inefficient at the level of $\sim 10\%$

→ Plane 26 off at the time of data taking (often trips)

Plane charge



Plane missed in SAPMT



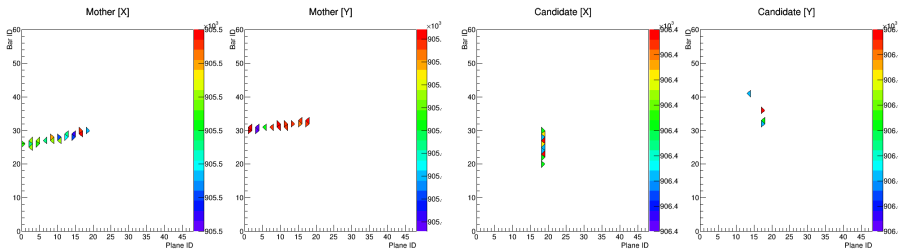
First level of reconstruction: plane hits

EMR readout

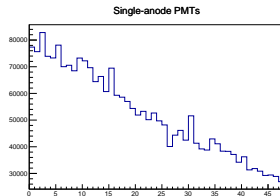
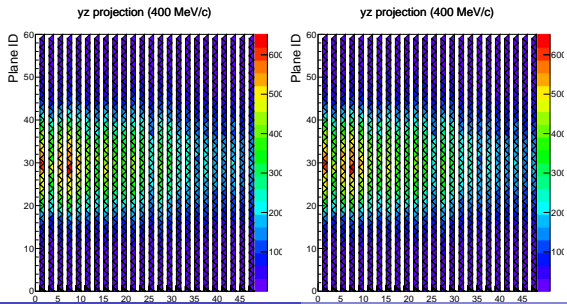
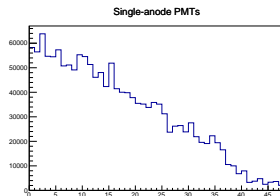
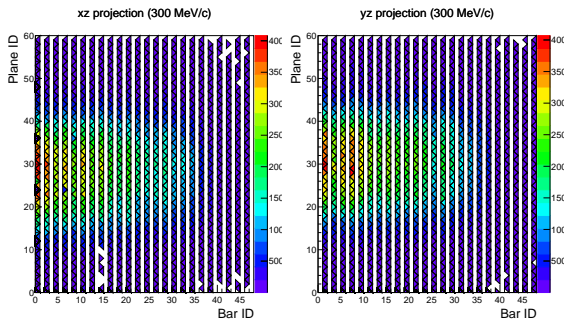
- Bar time-over-threshold and TDC recorded for each hit above threshold, stored **for the entire spill** in 48 DBBs
- Charge in each plane (ADC) integrated when **fADC triggered**

Plane hit reconstruction

- DBB hits and corresponding fADC charge are matched by their temporal proximity ($\Delta t \sim 500$ ns) and create a plane hit
- Leftover bar hits are bunched in time and form decay candidates

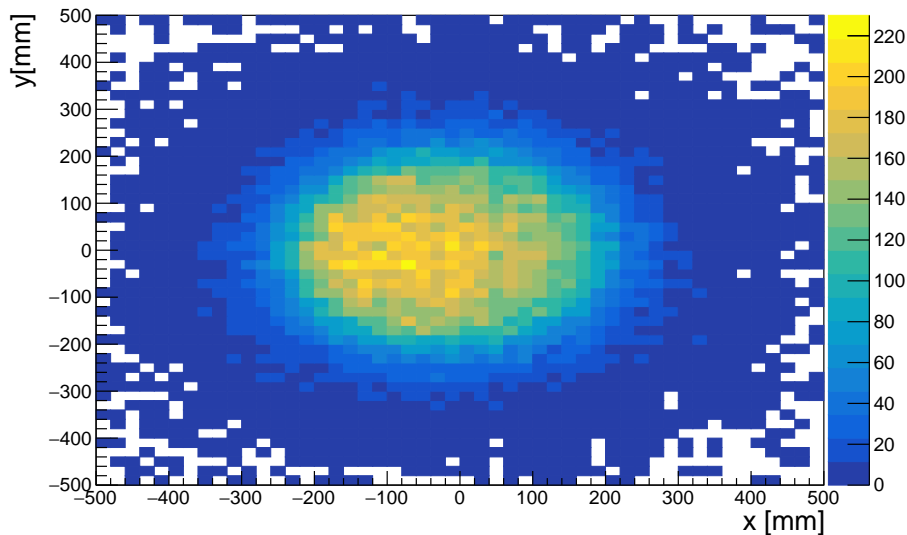


Occupancy (bar hits)



Beam profile at the entrance of the EMR

Origin track point (400 MeV/c)



Detector efficiency and acceptance

Efficiency*Acceptance for a 400 MeV/c muon beam (run 010307)

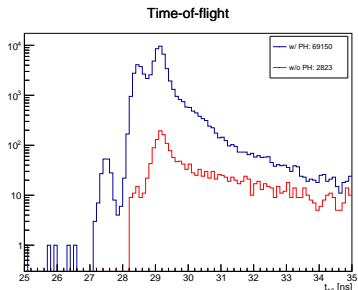
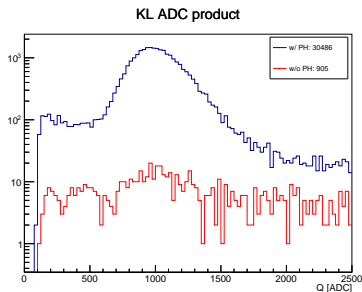
- Select events with SP in TOF2
- $\alpha E_{PH} = 97.6\%$ (**stable**)

Sources of "inefficiency"

- Particles that scatter out of the EMR fiducial volume
- Particles that stop in the KL ($2.5X_0$ in KL + magnet bore)
- Real detector inefficiency?

Select fast particles (muons):

- $\alpha E_{PH} = 99.9\%$
- **No real inefficiency**



Higher level of the reconstruction

Space point reconstruction

- XT rejection (keep highest ToT bunch)
- One SP per bar with $\sigma_i = \sigma_q \sqrt{Q_P/Q_i}$
- Corrects the hit charge for attenuation

Track reconstruction

- A line is fitted to the set of space point (least squares)
- χ^2/N , parameters, track points, etc.
- Reconstructs the total charge

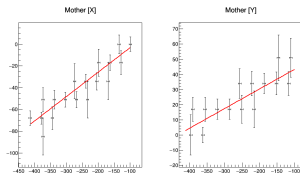
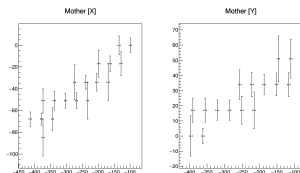
Range, Momentum

- Range recon:

$$\int_0^{z_{\max}} \sqrt{1 + (\partial P_x / \partial z)^2 + (\partial P_y / \partial z)^2} dz$$

- Momentum unfolding (CSDA):

$$R = \int_{p_0}^0 \frac{dp}{\langle dE/dx \rangle} \beta m_i c^2$$



Reconstruction efficiencies

Efficiency of the space point reconstruction provided PHs

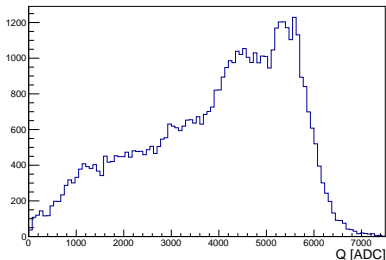
- Events that do not record at least one hit in each projection don't allow for SP recon
 - Electron/Positron showers
 - Very shallow tracks
- Noisy SAPMT without MAPMT hits (common)
- $E_{SP} = 95.80\%$
 - With the same criterion as for PH, we get $E_{SP} = \mathbf{99.7\%}$

Efficiency of the track fitting provided SPs

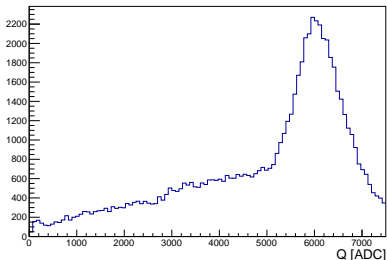
- Can never fail because there is no selection on the goodness of fit (electrons are likely to badly fit a line, which is a PID criterion)
- $E_T = 100\%$

Charge and range

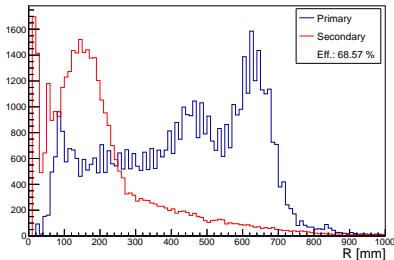
Total integrated charge (300 MeV/c)



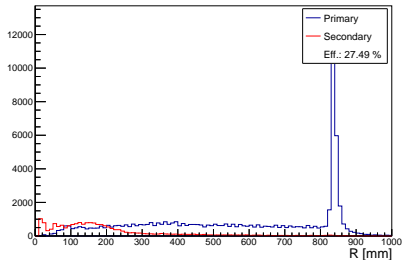
Total integrated charge (400 MeV/c)



Range in PS (300 MeV/c)



Range in PS (400 MeV/c)



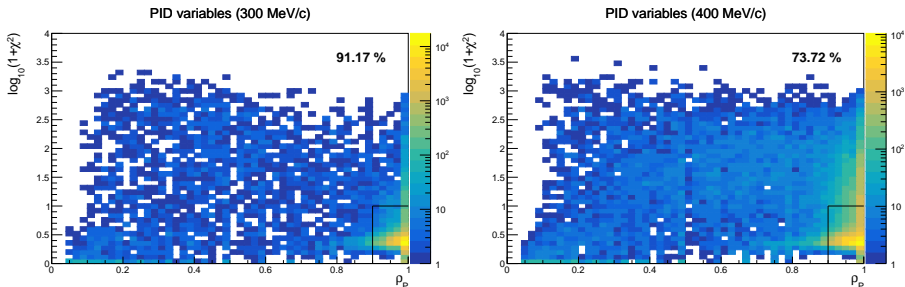
PID variables for positron rejection

Two main PID variables present in the online reconstruction

- **Density**, ρ_P , i.e. the fraction of the planes hit on the particle path
- Spread, quantified by χ^2/N , i.e. the **dispersion** of hits in the xy plane

Three main populations in the ρ_P - $\log \hat{\chi}^2$ plot

- Muons and pions, dense and straight (bottom right)
- EM showers, loose and wide (top left cloud)
- Photon deep hits, loose and straight (bottom left line)



Conclusions

Raw efficiencies

- Stable since CM48 analysis
- One problematic SAPMT

Reconstruction efficiencies

- Have not been altered since last analysis
- For fast muons, the presence of digits in the EMR is virtually guaranteed if they hit TOF2 first
- If a track is present, space points are associated with the hits
- Higher level of reconstruction are guaranteed given SPs

Particle identification

- The EMR is still able to separate muons from positrons