Calorimeter energy and time calibration in extracted position using CRY dataset

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Calorimeter Energy/Time Calibration

Cosmic Ray events will be used during the commissioning phase in extracted position for calibration and monitoring purposes:

- Relative **energy response** equalization
- Relative **time offset** equalization (2-step calibration: raw T0 offset + iterative procedure to align cell times at O(10 ps) level)
- **Stability** of energy and time response
- Calibration of **Waveform templates** (once for all)
- Development of **reconstruction algorithms** (ex: determination of z-coordinate)

Energy and time calibration algorithms extensively studied with MDC2018 MC campaign and successfully applied to Module-0 calorimeter prototype (Mu2e-doc-24588, Mu2e-doc-37325, Mu2e-doc-43984)

New MDC2020 CR production

- 10 hour data taking with cosmics in extracted position using CRY generator
- No B field, calo triggered events

Recent Work

- **Important Tasks Completed Since Last update:**
  - *CRY 10hr Extracted:*
    - *For calibration and alignment routine development.*
    - *See talk: mu2e-doc-db-**46026-v3***

Name	Files	Events
dts.mu2e.CosmicCRYExtracted.MDC2020y_perfect_v1_1.art	9998	242809548
dig.mu2e.CosmicCRYExtractedCatDigiTrk.MDC2020y_perfect_v1_1.art	849	24957784
dig.mu2e.CosmicCRYExtractedCatDigiTrk.MDC2020y_best_v1_1.art	881	25836556
dig.mu2e.CosmicCRYExtractedCatDigiTrk.MDC2020y_startup_v1_1.art	947	27735028
dig.mu2e.CosmicCRYExtractedCatDigiCalo.MDC2020y_perfect_v1_1.art	844	1512236
dig.mu2e.CosmicCRYExtractedCatDigiCalo.MDC2020y_best_v1_1.art	904	1618964
dig.mu2e.CosmicCRYExtractedCatDigiCalo.MDC2020y_startup_v1_1.art	943	1689327

Caltech

Production Manager Update – Sophie Middleton – smidd@caltech.edu

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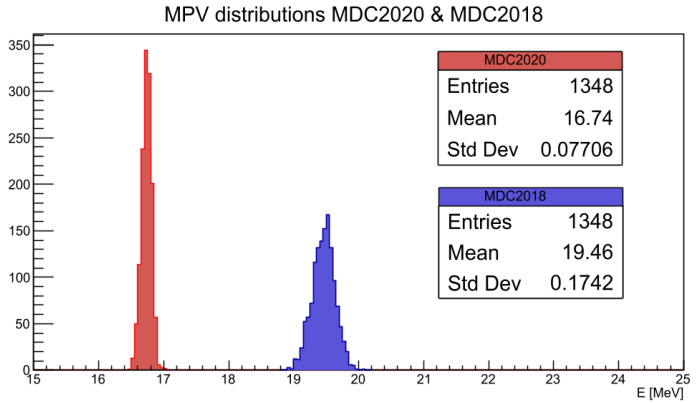
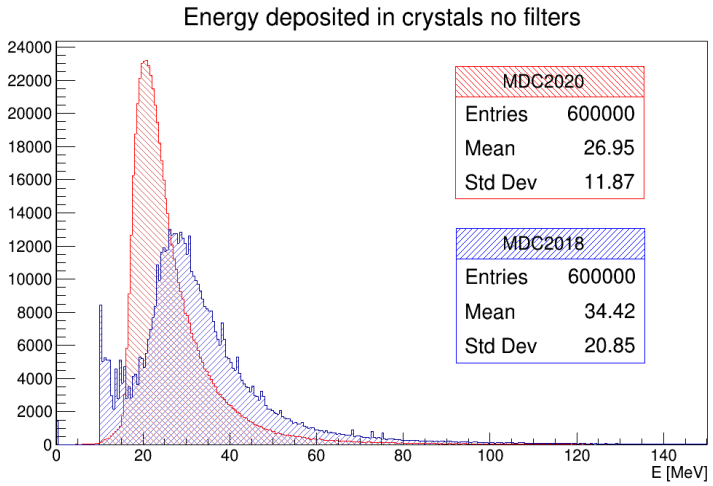
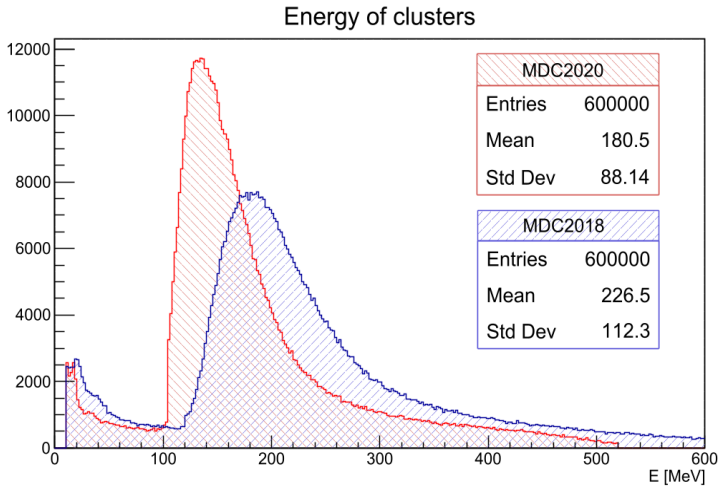
MDC2020 & MDC2018 comparison: energy distributions

We found an unexpected shift (~15%) in the energy response of the calorimeter from MDC2018 to MDC2020

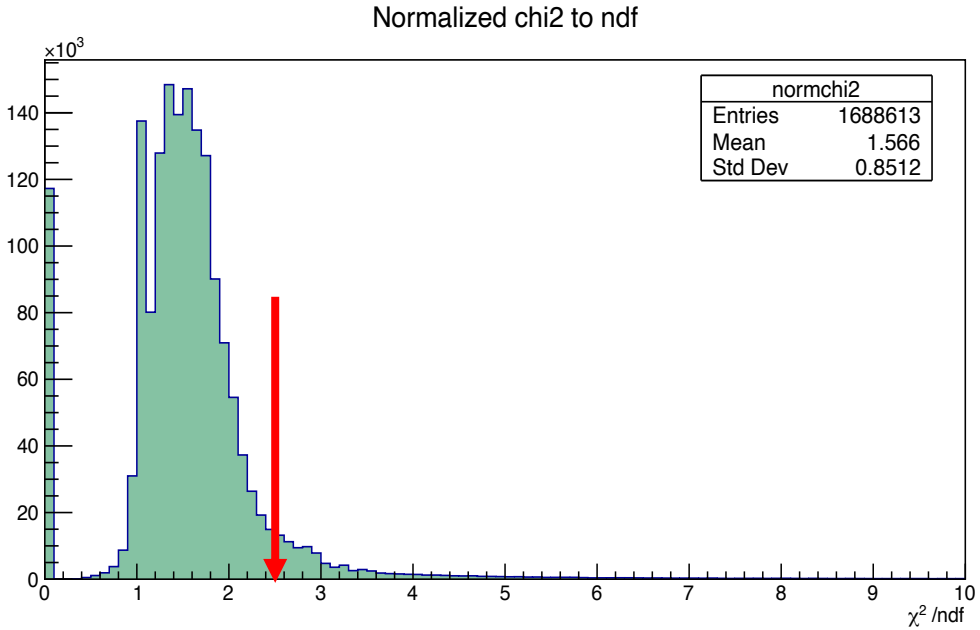




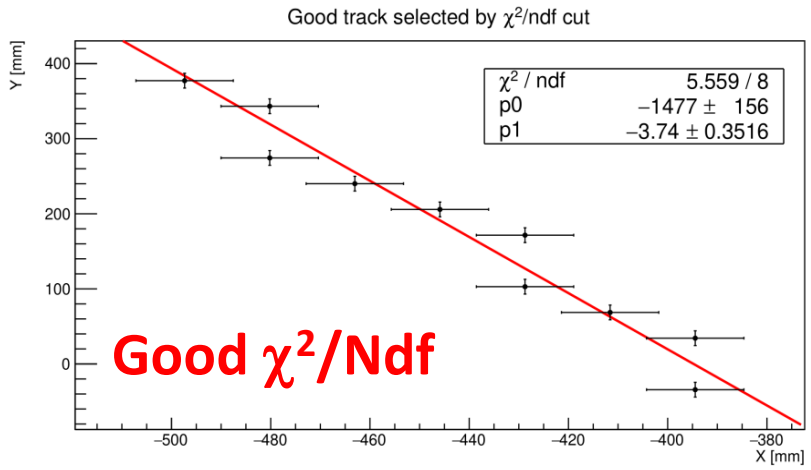


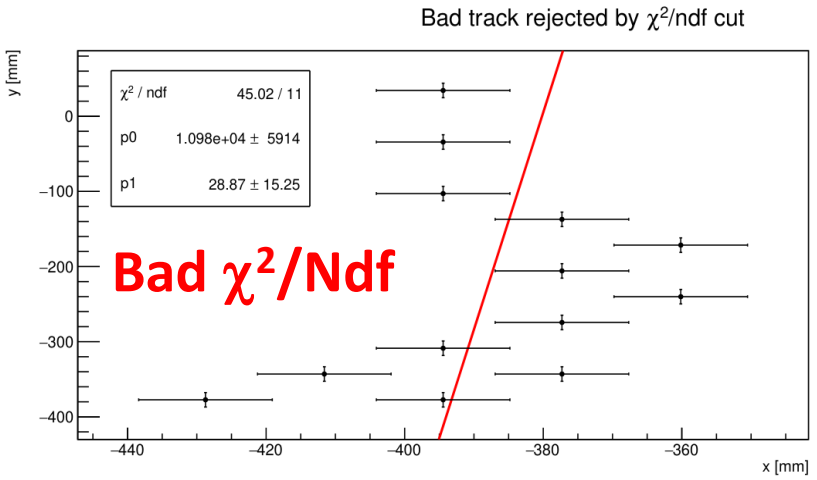
Event selection

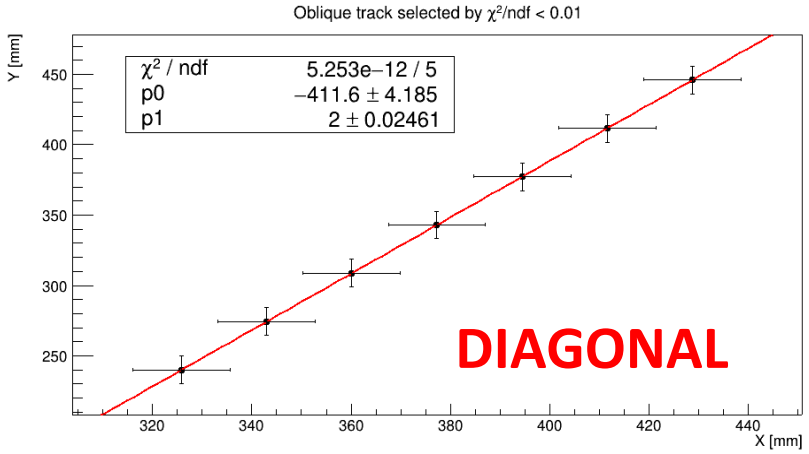
- At least 3 crystals with $E_{cry} > 15$ MeV connected to a calorimeter cluster
- Selection of three types of straight tracks:
  - Vertical tracks, requiring $\Delta X < 35$ mm
  - Diagonal tracks i.e. CRs hitting 1 crystal per layer
  - General tracks $\chi^2/Ndf < 2.5$ from the linear fit applied to cell center positions

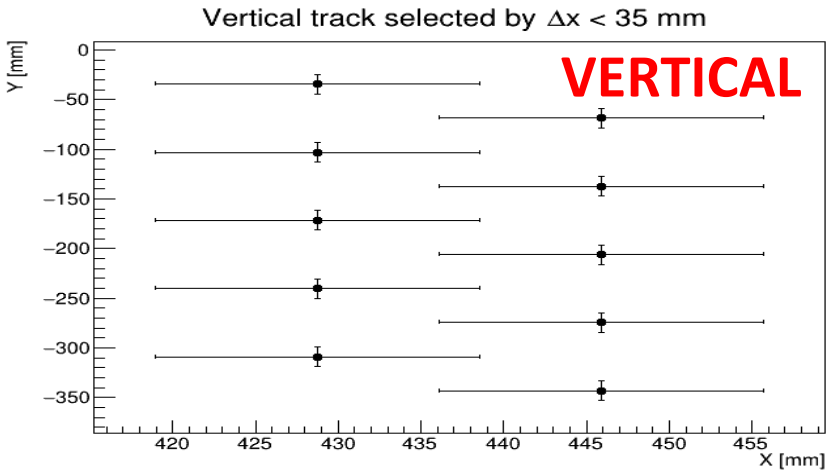


Example of tracks selected and rejected









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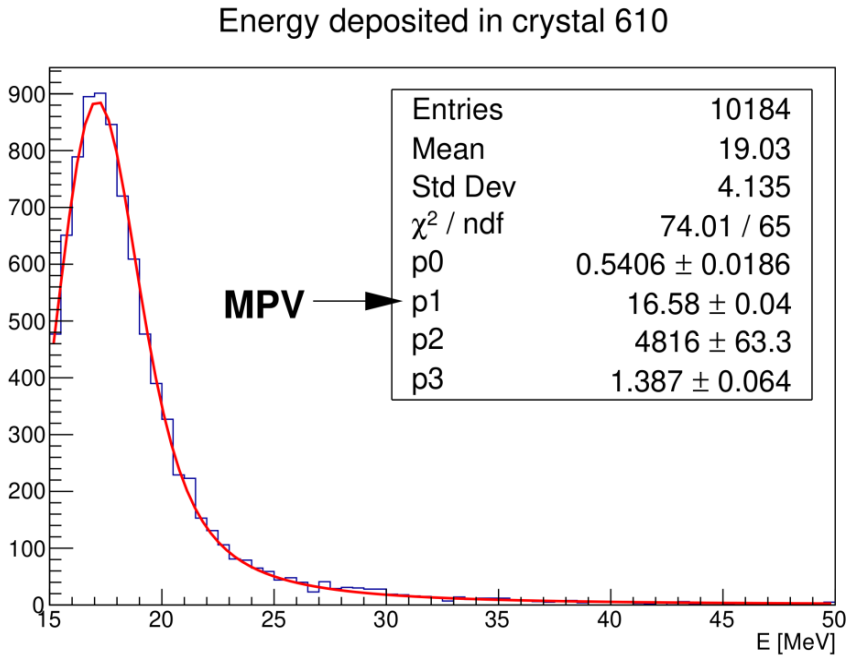
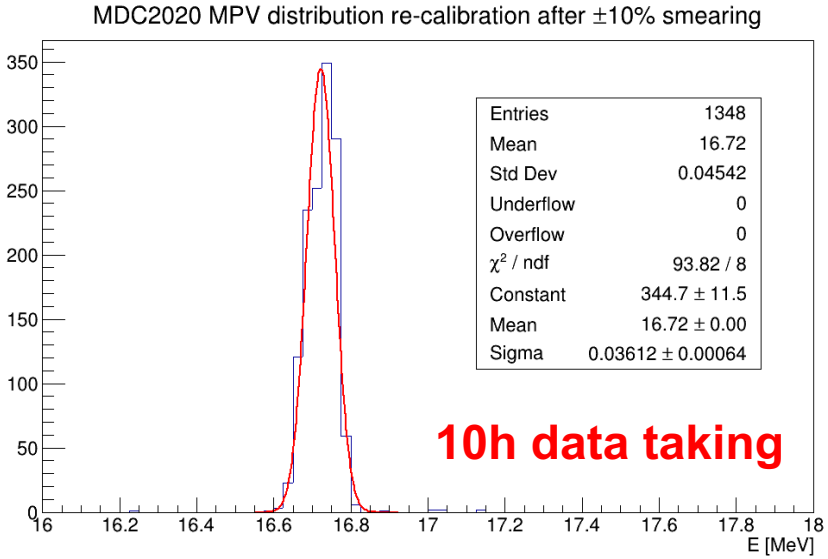
Calibration method – Energy Deposited Langaus function

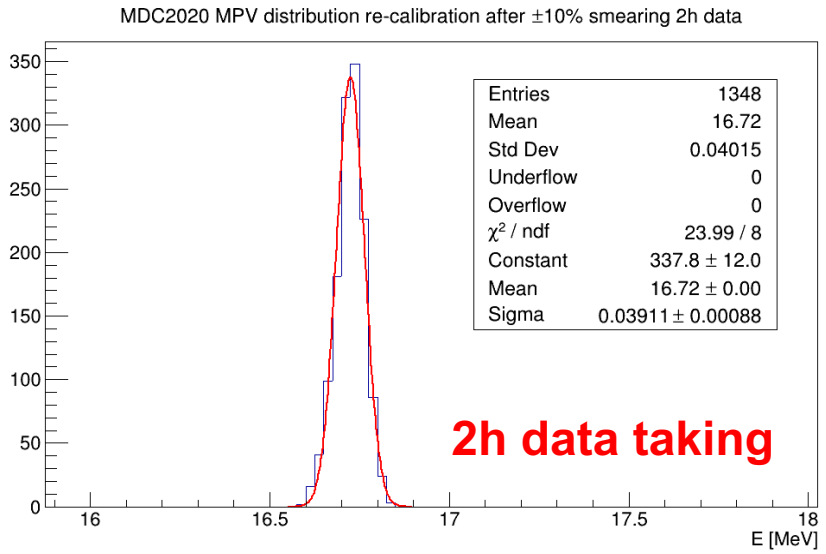
- For all the events that pass the selection we build the energy deposited distribution for each crystal, and we fit it with a Langaus function
- From the fit we extract the MPV value for each crystal and we build the distribution of all the MPV's



MDC2020 calibration exercise - smearing

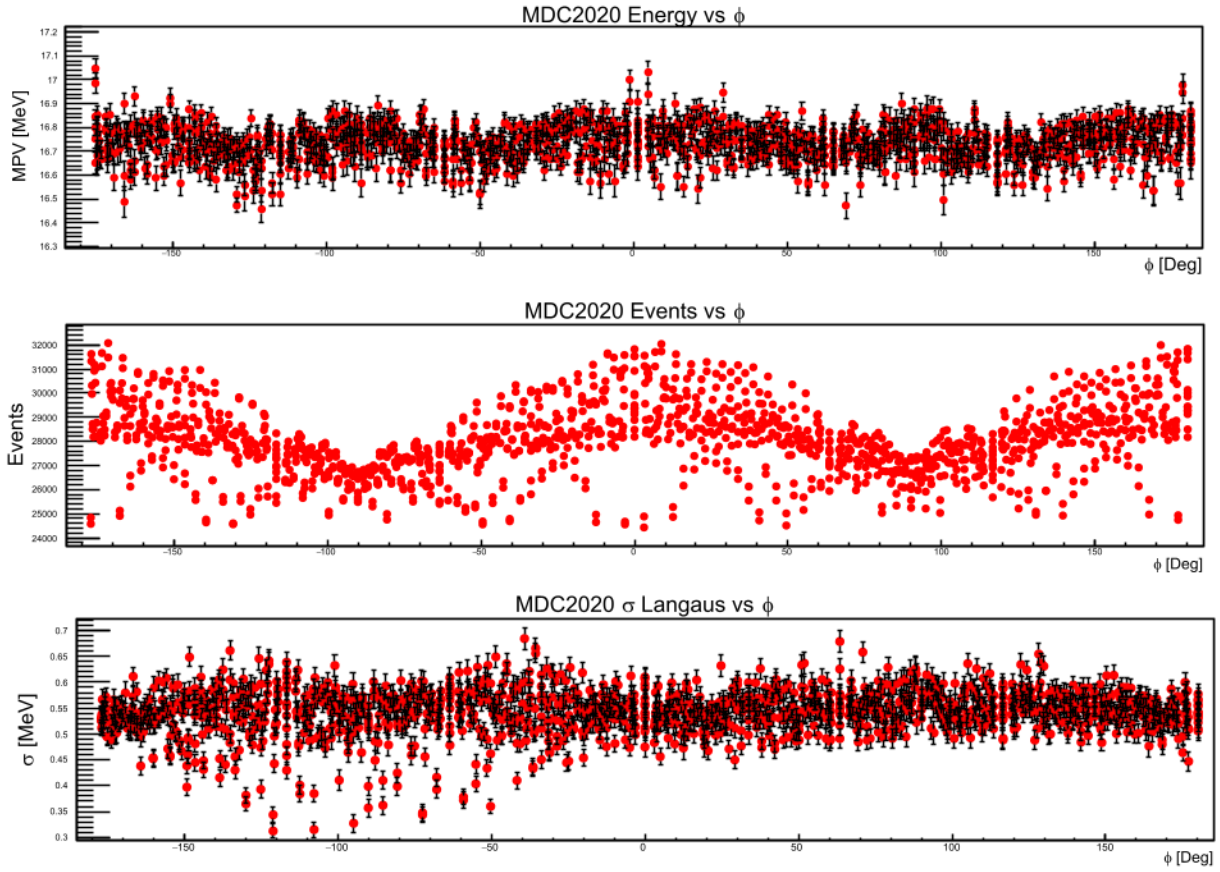
10% random uniform smearing applied to Ecry to simulate a possible experimental offset





We calibrate using MPV/ MPV_smeared obtaining σ/MPV= 2‰

MDC2020 final results - trends vs phi



Flatter behavior along the azimuthal angle of the calorimeter

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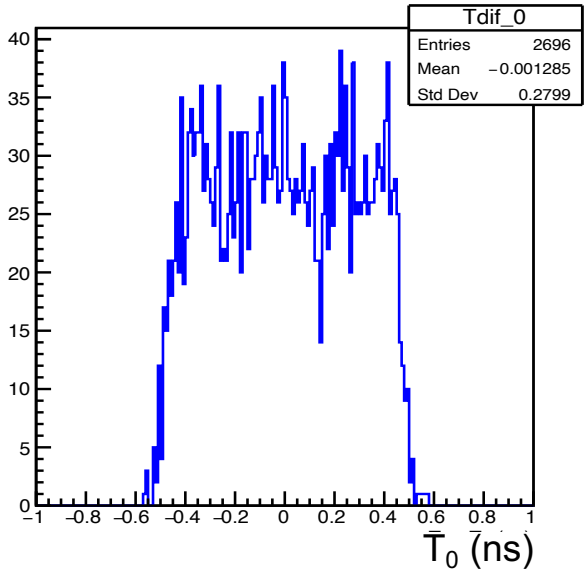
T_0 alignment procedure

Reminder:

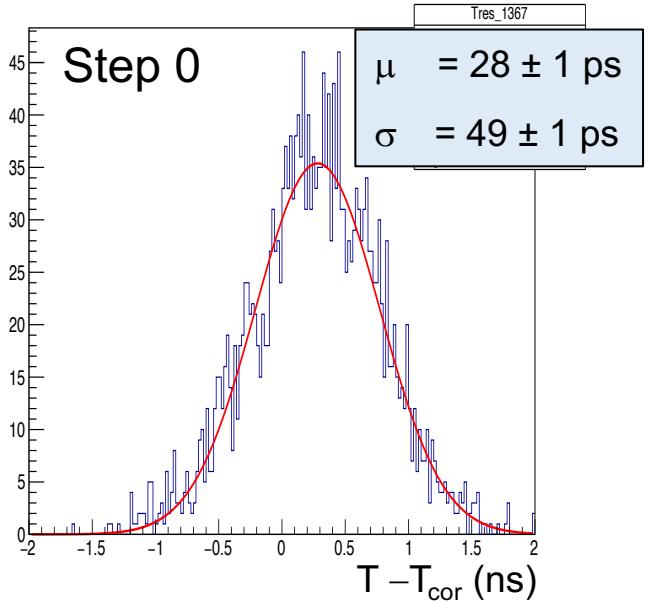
- Only clusters with at least three fired cells are included in the procedure
- All cells with $10 < E_{cry} < 30$ MeV of the selected clusters used
- For each event, least square linear fit to time vs relative distance of the cells, imposing light velocity. Common T_0 subtracted to all cells
- Good linear fit ($\chi^2/N_{dof} < 2$)
- Fit residuals of each calorimeter channel with a Gaussian
- Extract first calibration set from the fit (T_{corr})
- Apply an iterative procedure, subtracting residuals and repeating the fit until the procedure converges

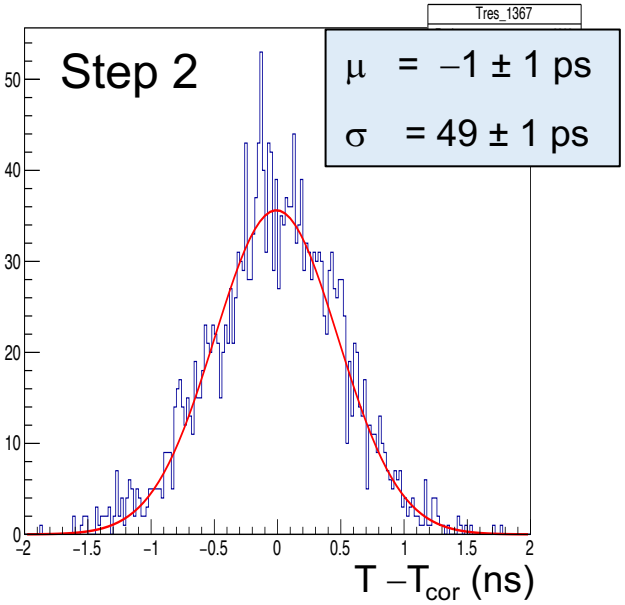
T0 alignment on MDC2020

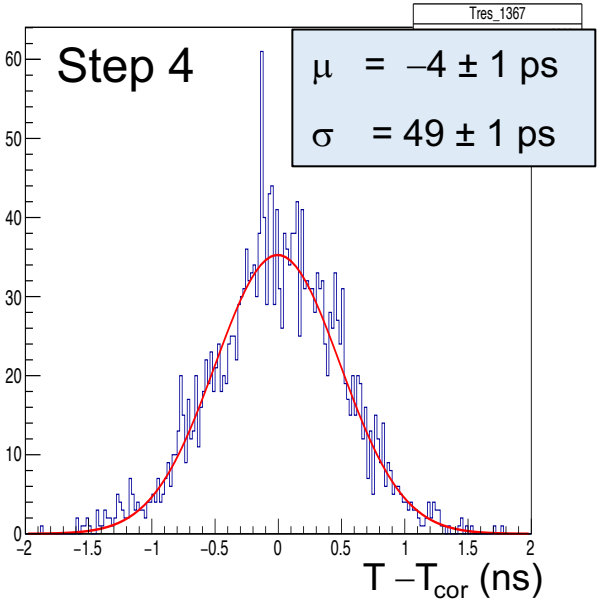


T_0 offset for each readout channel applied:
± 0.5 ns uniform distribution

Time distribution for a specific channel (ROid =1367)
at different steps of the procedure

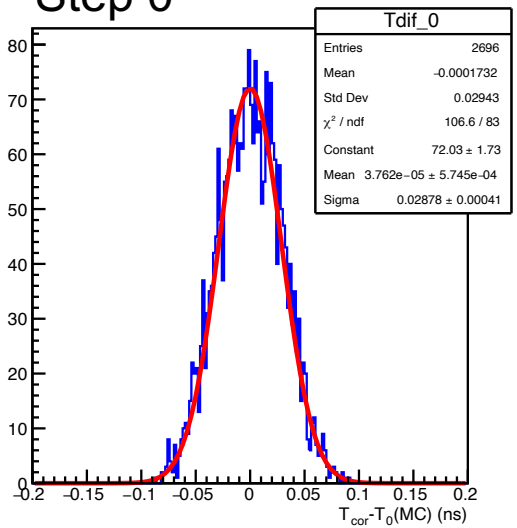




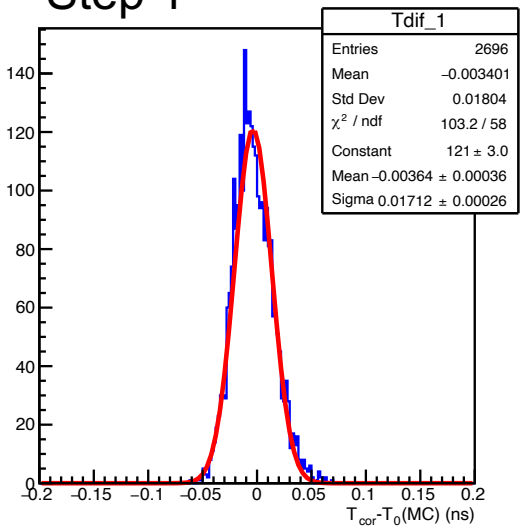


T0 alignment: results

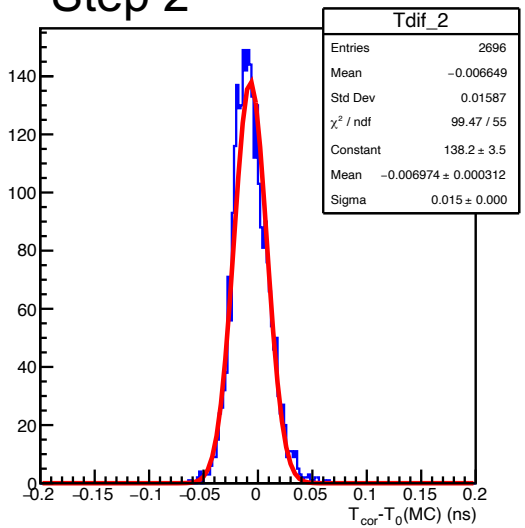
Step 0



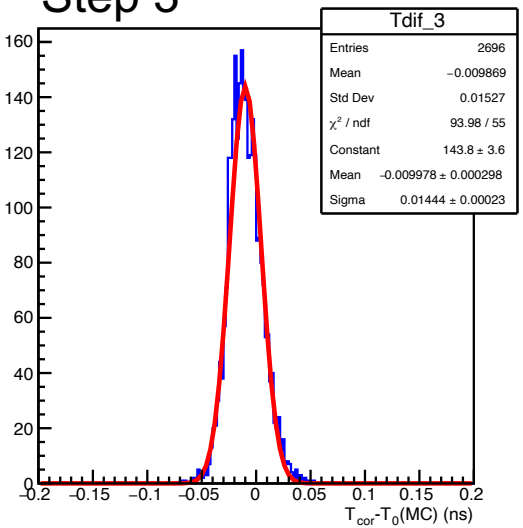
Step 1



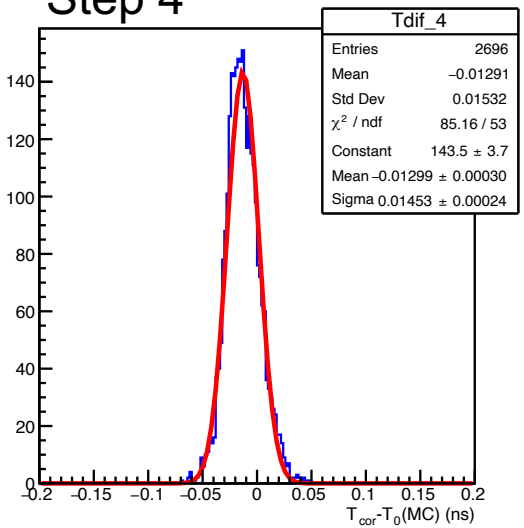
Step 2



Step 3

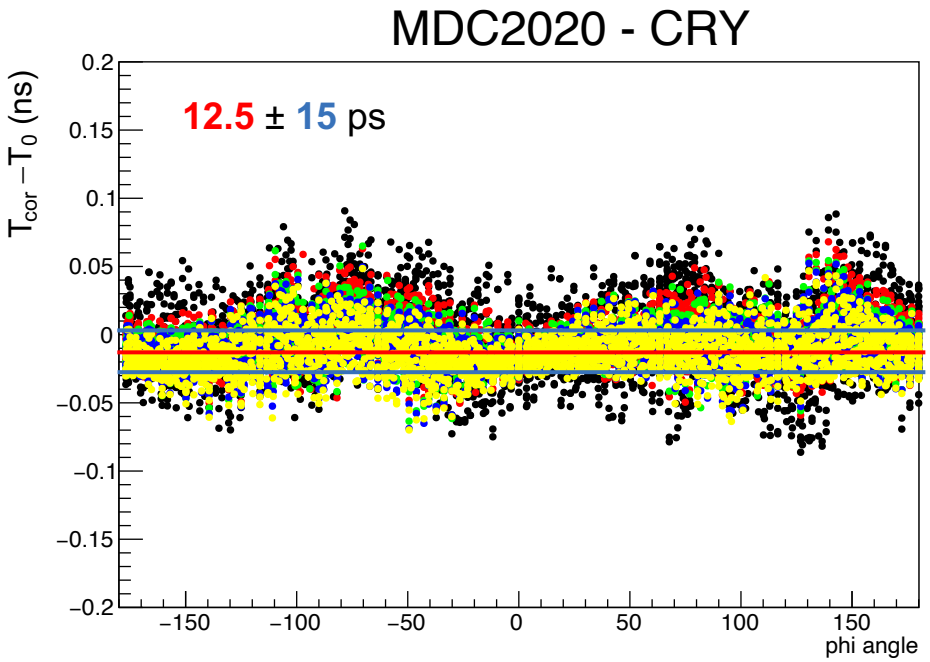


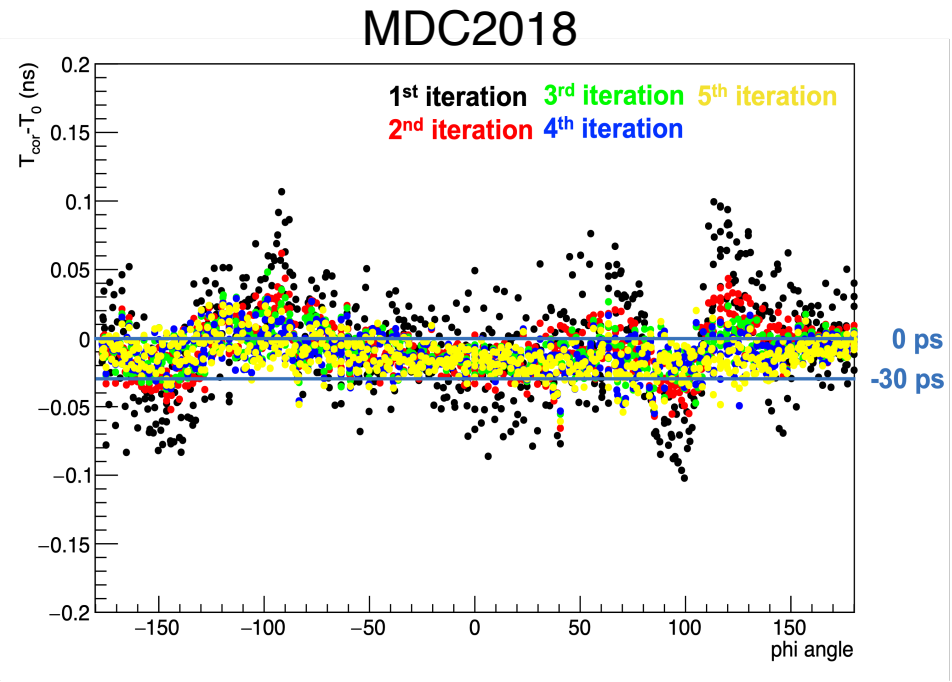
Step 4



Step	μ (ps)	σ (ps)
0	0.0 ± 0.4	28.8 ± 0.4
1	–0.4 ± 0.4	17.7 ± 0.3
2	–0.7 ± 0.4	15.0 ± 0.2
3	–10.0 ± 0.4	14.4 ± 0.2
4	–13.0 ± 0.4	14.5 ± 0.2

T0 alignment: correction



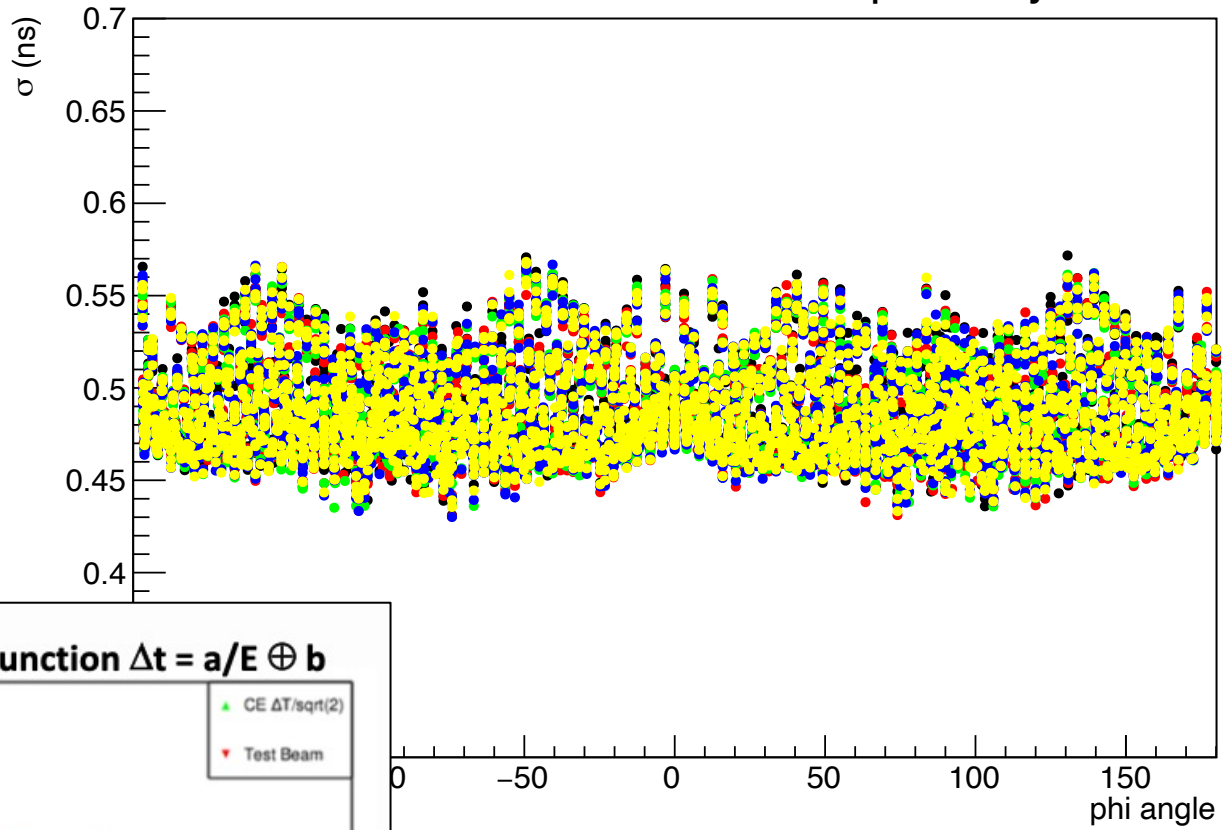


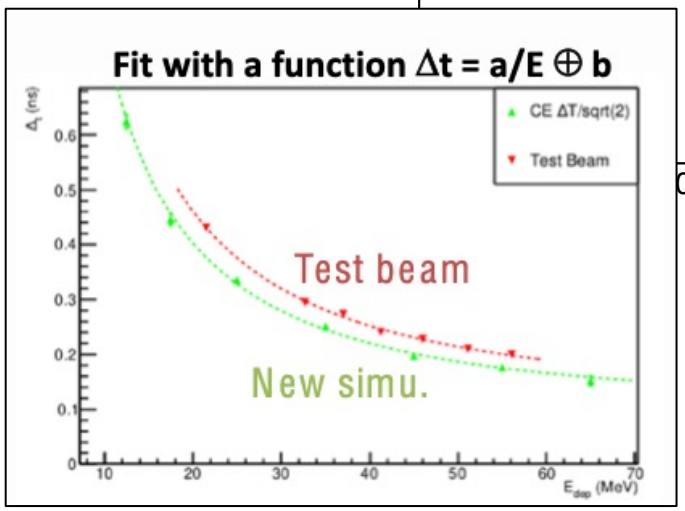
MDC2020:

- larger spread (improved noise simulation)
- better uniformity (no B field)

T0 alignment: resolution

Flat ~ 500 ps resolution for readout channels → 350 ps at crystal level





- In agreement with expectations for a 20 MeV equivalent deposit from old test beam data (current MC production)
- Slightly larger than current evaluation with Module-0 and template fit

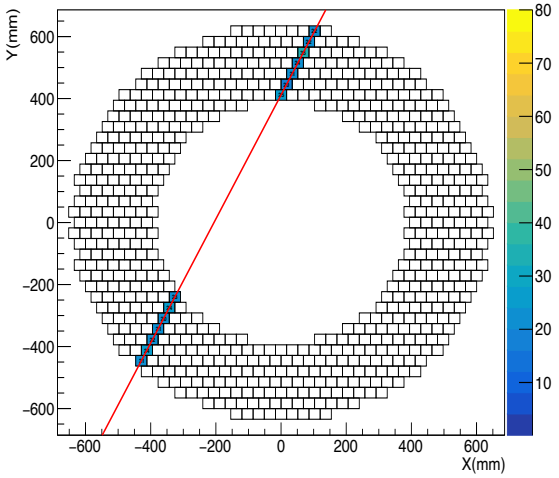
Summary

- Energy and time calibration studies for calorimeter performed with the MDC2020 CRY sample, corresponding to 10h running in extracted position
  - T_0 calibration at 15 ps level produced by a stable procedure
  - Energy calibration at 0.2% level
- A Mu2e/CaloCalibration repository exists to accommodate code for calo conditions DB handling and calorimeter calibration software
  - caloT0alig module already in GitHub
  - caloEneCcsmicsCalib ready, to be tested

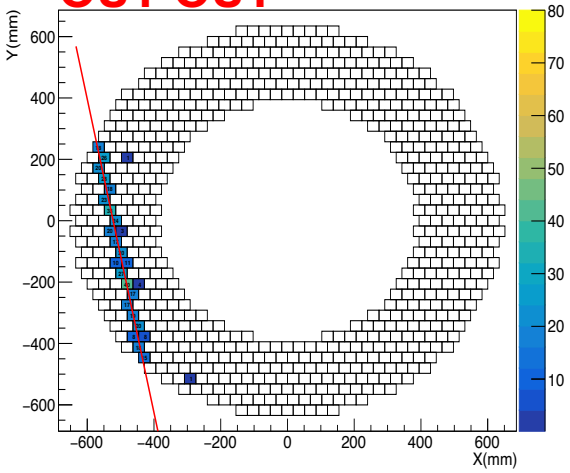
Trigger filter for Cosmic Ray evts

- Calo-cosmic.MDC2018f sample (~2Mevts) used to develop a new trigger filter algorithm for CR events
- Four different topologies of events with clusters with 120 < E < 600 MeV
- Information both at cluster and crystal level used
- CaloCalibCosmics already in CaloFilters trg library

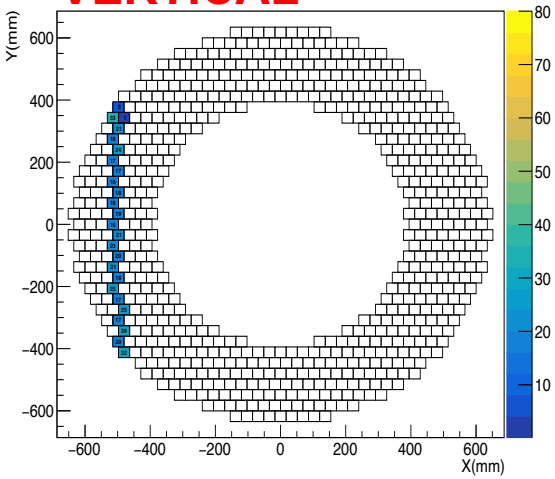
IN-OUT or OUT-IN



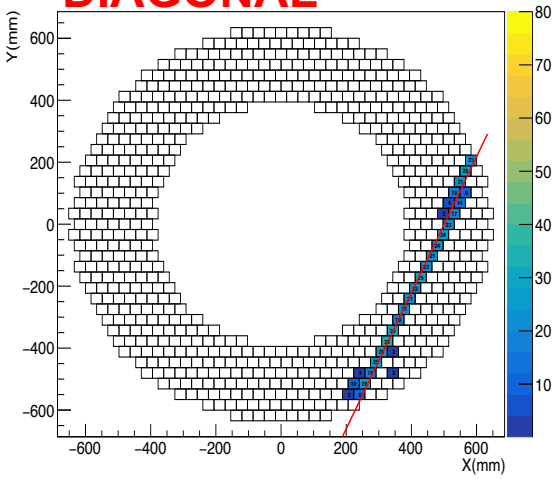
OUT-OUT



VERTICAL



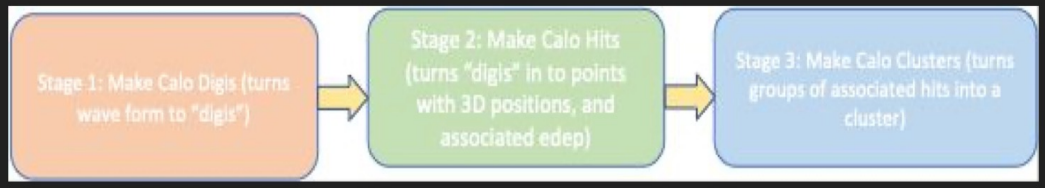
DIAGONAL



Calorimeter calibration DB

Mu2e-doc-41541

Progress since last CM



- Focus so far on energy calibration - currently have just simple .txt file used in HitMaker to convert ADC → MeV
- Define two types of table:
  - Archive Table: contain information which might be useful, but not needed on every reconstruction event.
  - Reco. Table: contain information which are required for reconstruction.
- Individual calibration methods to have their own archive table
- Fed into a CalCombineAlg class which will contain the algorithm which will output the combined calibration constants.
- CalCombineAlg outputs a table which is our RecoTable: CalEnergyCalibTable.
- ProditionsService can talk to this table and use the contents in reconstruction.
- Produtitions Entitiy (Object) = CalEnergyCalib built from final reco table.
- Not in Offline yet but branch exists: https://github.com/sophiemiddleton/Offline/tree/CaloDB