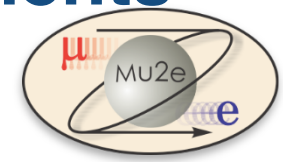
Fermilab

U.S. DEPARTMENT OF ENERGY Office of Science

Mu2e CD-2 Director Review: Calorimeter Requirements

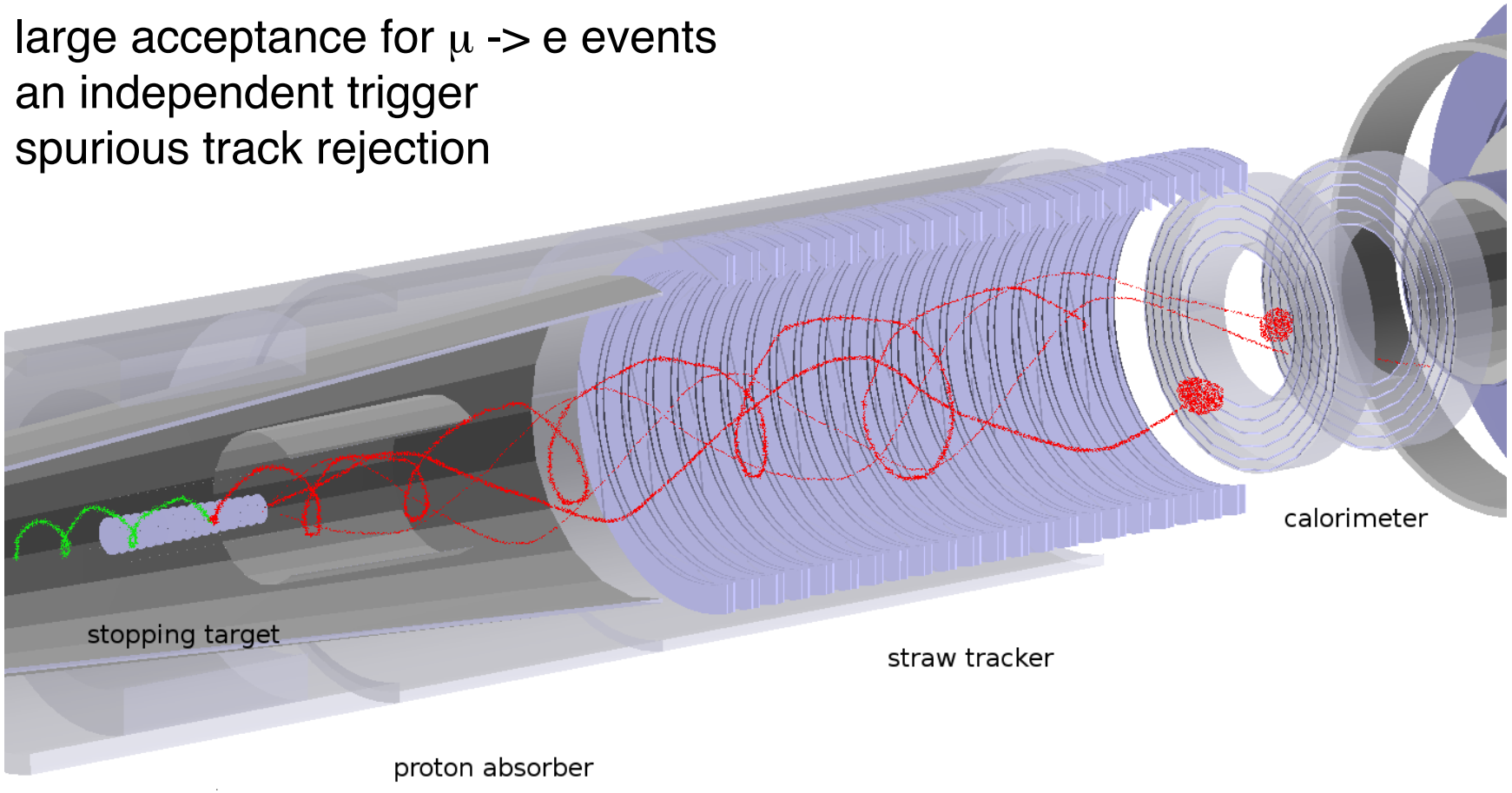


Pavel Murat, Fermilab

07/09/2014

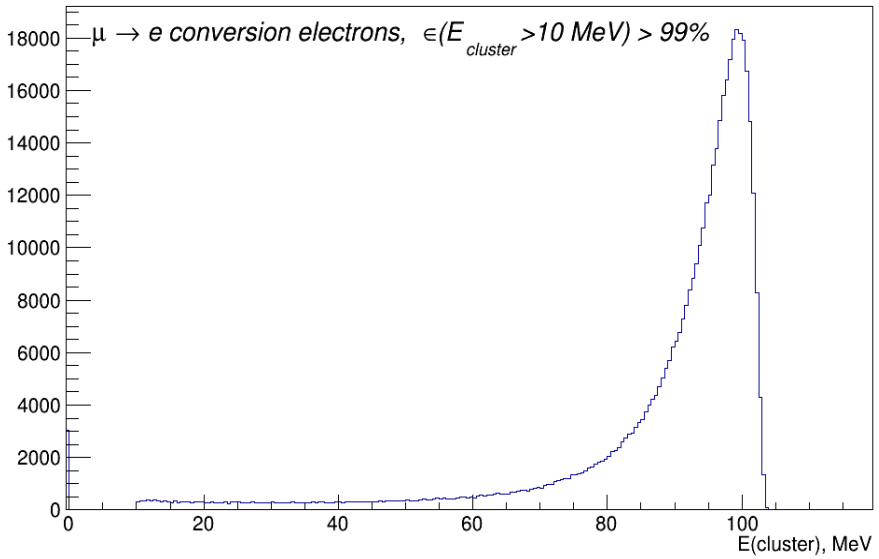
Requirements: Mu2e-docdb 864

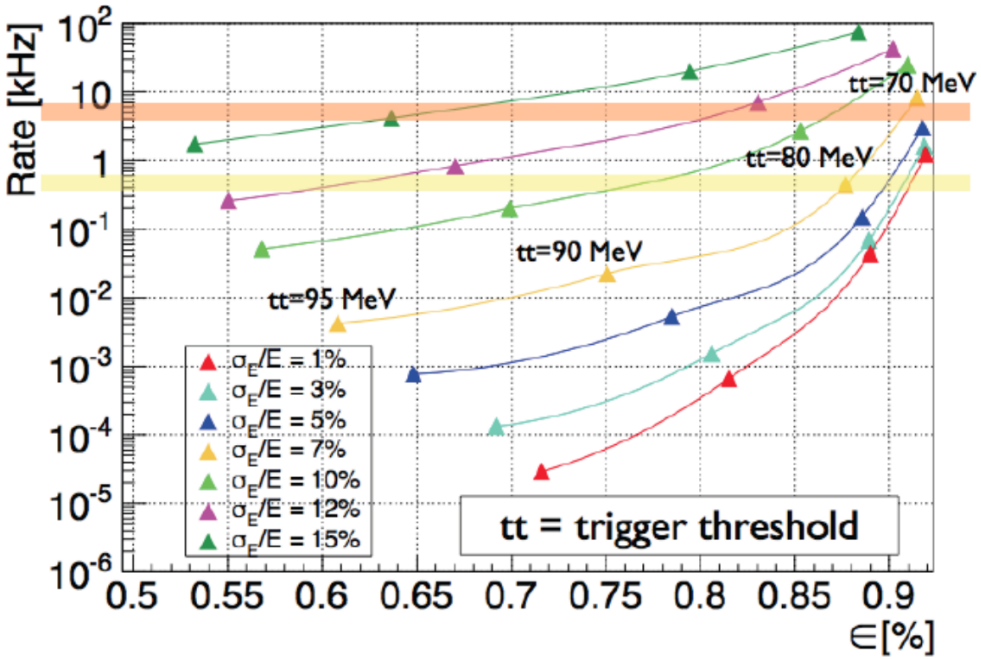
- large acceptance for μ -> e events
- an independent trigger
- spurious track rejection



- “seeds” to improve track finding efficiency at high occupancy
- particle identification capabilities

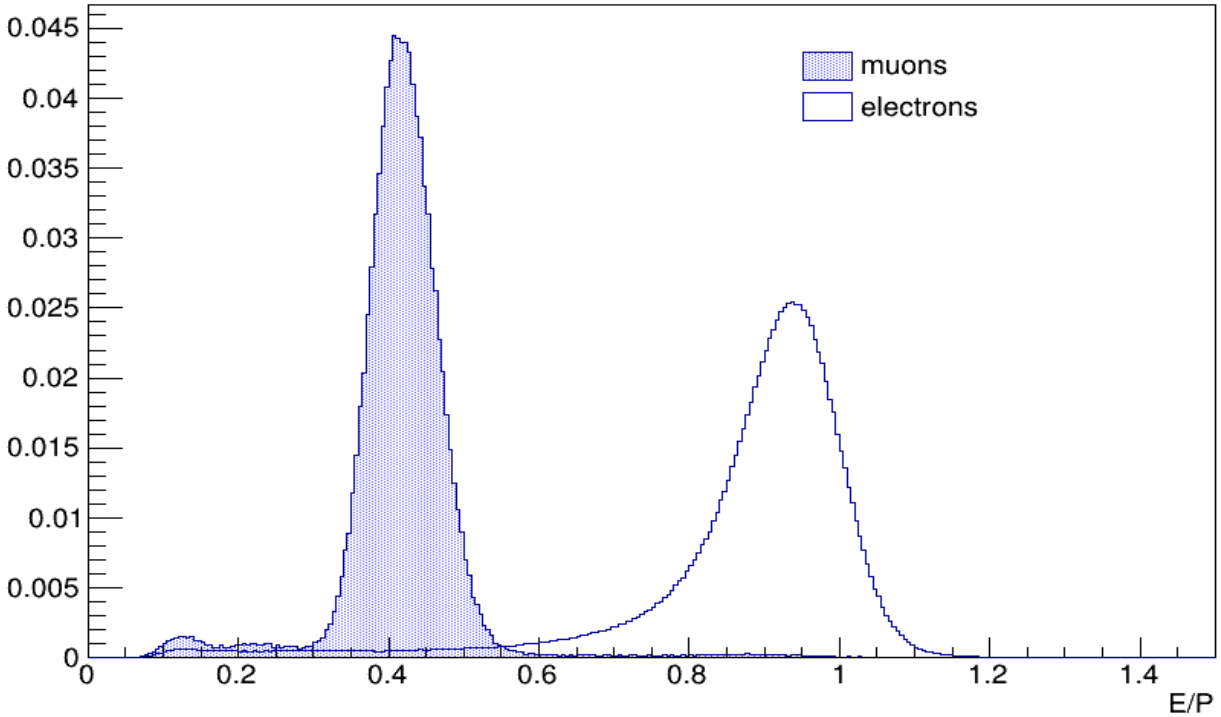
Calorimeter-based Trigger





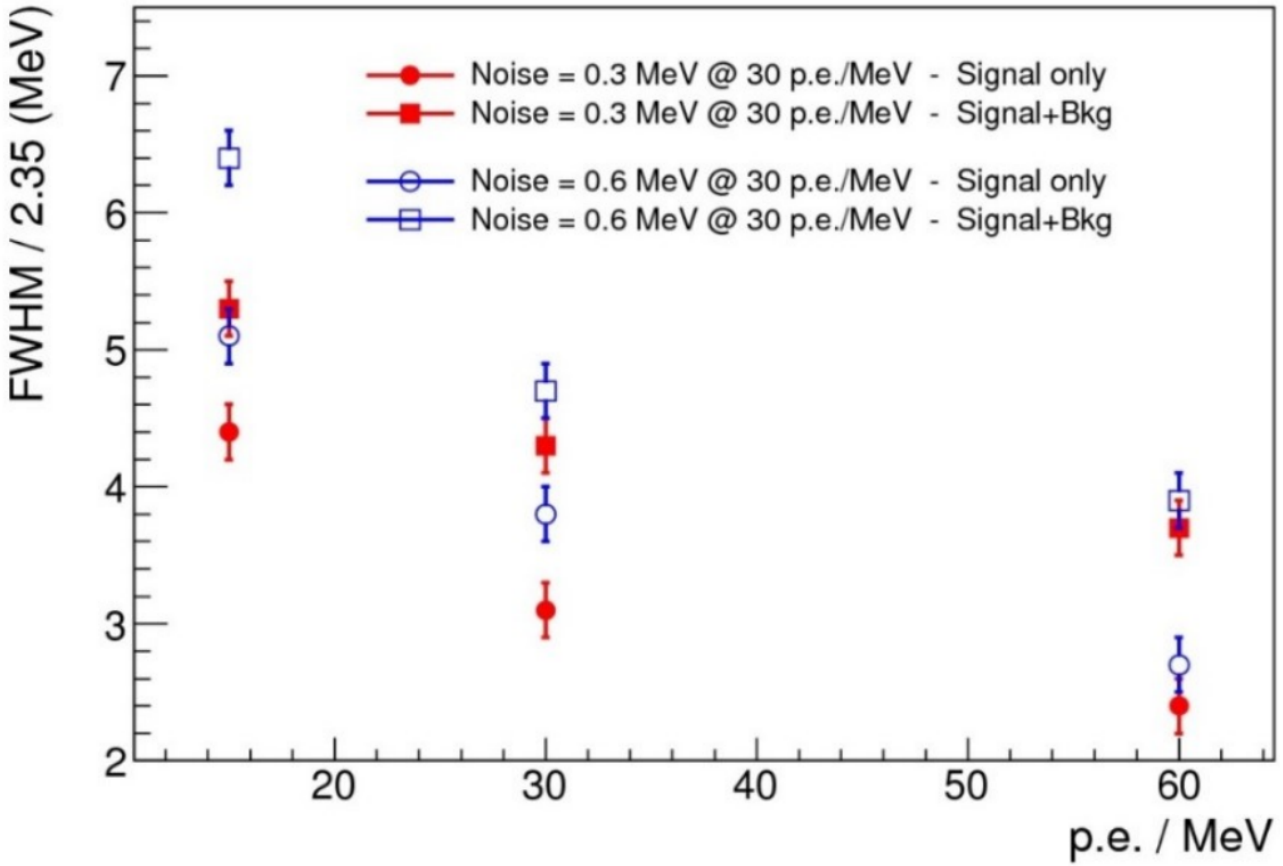
- acceptance: >99% of events with good tracks have a cluster E > 10 MeV
- standalone calorimeter-based online trigger may be required
  - tracker momentum calibration (i.e., π^0 –> eν) needs a non-tracker trigger
  - DAQ bandwidth limitations
- trigger logic: a cluster with E > E(min)
- ε(CE) = 90% at 2 KHz requires σ(E)/E < 7%

Energy Resolution



- need to separate 100 MeV/c electrons from muons
- on average, muons deposit about 43 MeV, electrons – about 95 MeV
- Energy resolution $\sigma(E)/E < 5\%$ sufficient
- timing requirement: need to separate muon decays and captures
- calorimeter and its readout have to be fast enough (**talk by I.Sarra**)

Energy Resolution



- MC : for the expected light yield (30 p.e./MeV) and noise level (< 0.3 MeV), resolution $\sigma(E)/E < 5\%$ can be achieved
- more details – talk by B. Echenard

Energy Calibration

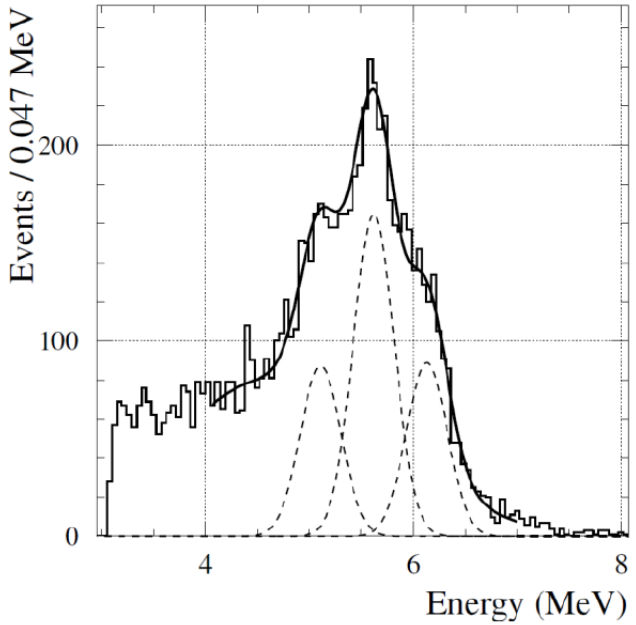
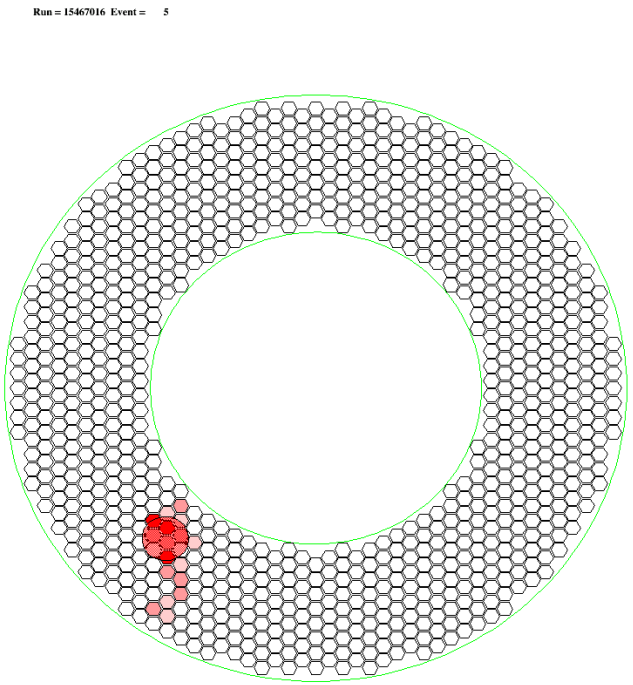


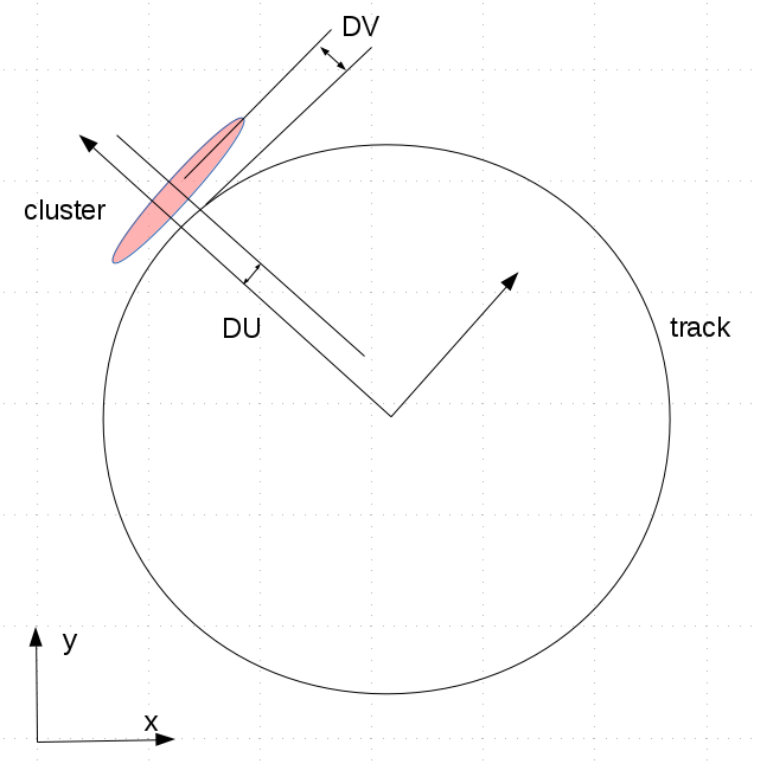
Figure 3. Typical source calibration spectrum from a *BABAR* CsI(Tl) crystal showing the 6.13 MeV peak, along with two escape peaks, which provide a gain calibration.

plan to use multiple calibrations:

- laser calibration
- neutron-activated ^{19}F source - calibration at 6 MeV
- higher energies: cosmic rays, DIO electrons
- energy response to be calibrated to the accuracy $\sigma(E)/E \sim 0.5\%$
- more details: talk by K. Flood

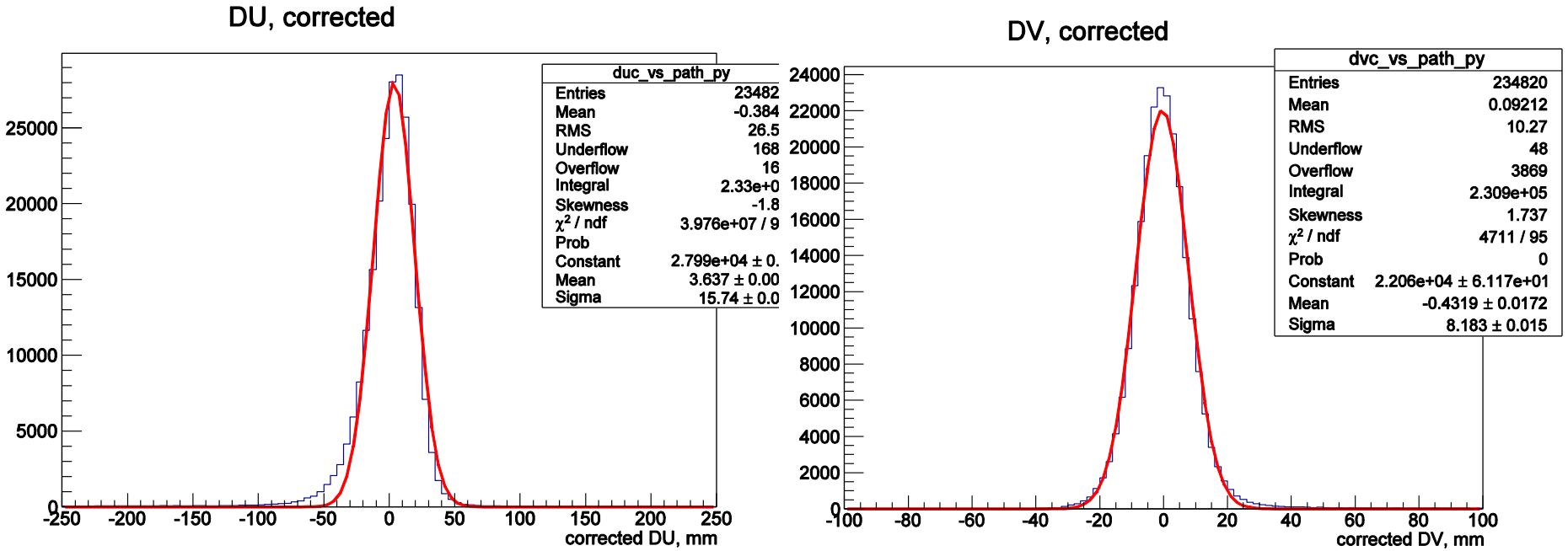
Coordinate Resolution





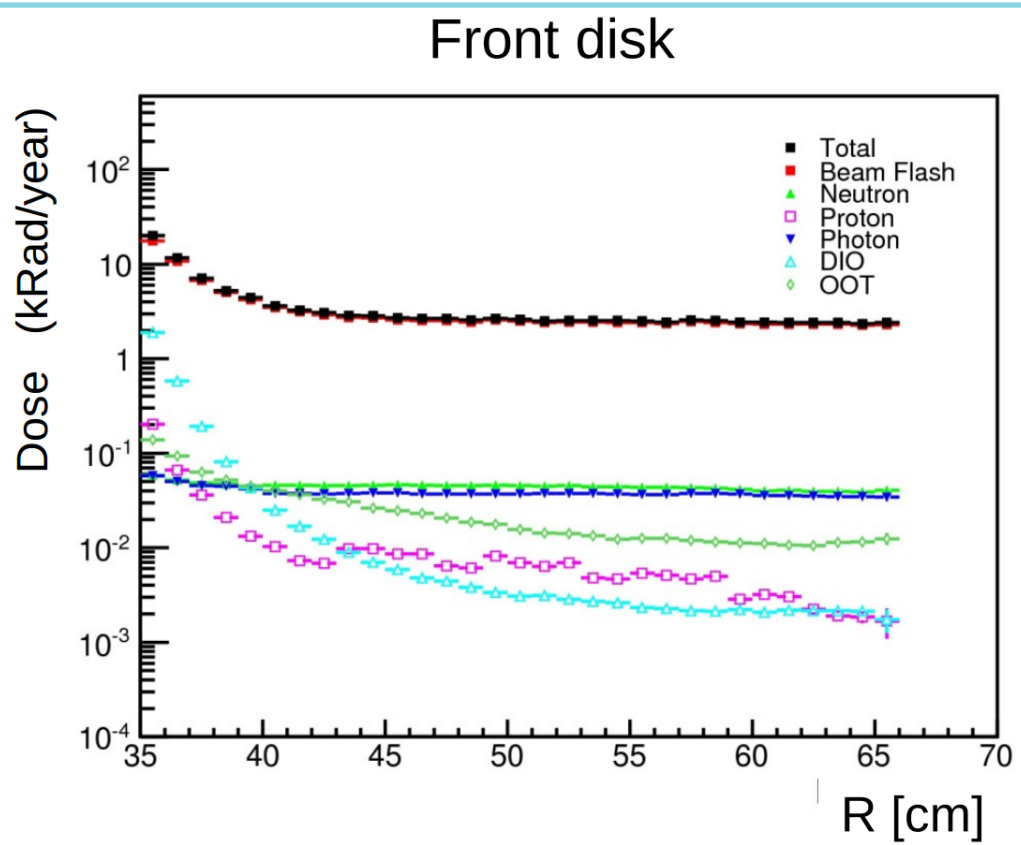
- track extrapolation accuracy - several mm
- typical cluster “size” ~ several cm
- cluster position resolution requirement: ~1cm or better

Coordinate Resolution



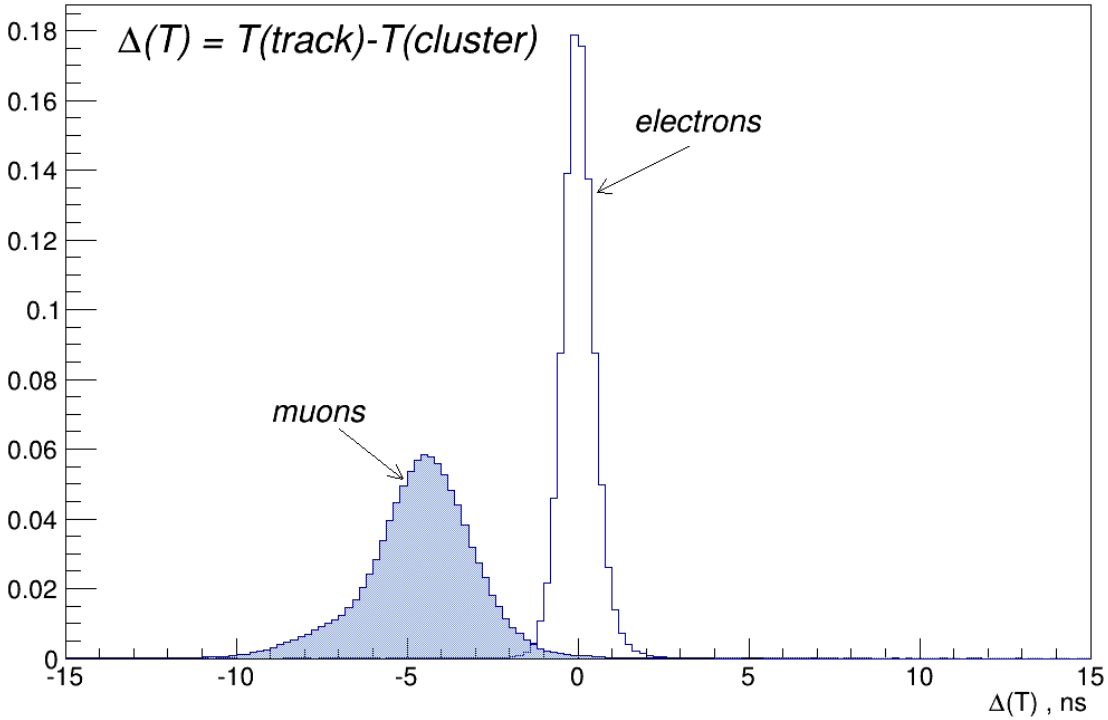
- MC studies: resolution better than 1cm can be achieved
- coordinate resolution important for rejecting random coincidences in high occupancy environment

Radiation Hardness, Stability, and Monitoring



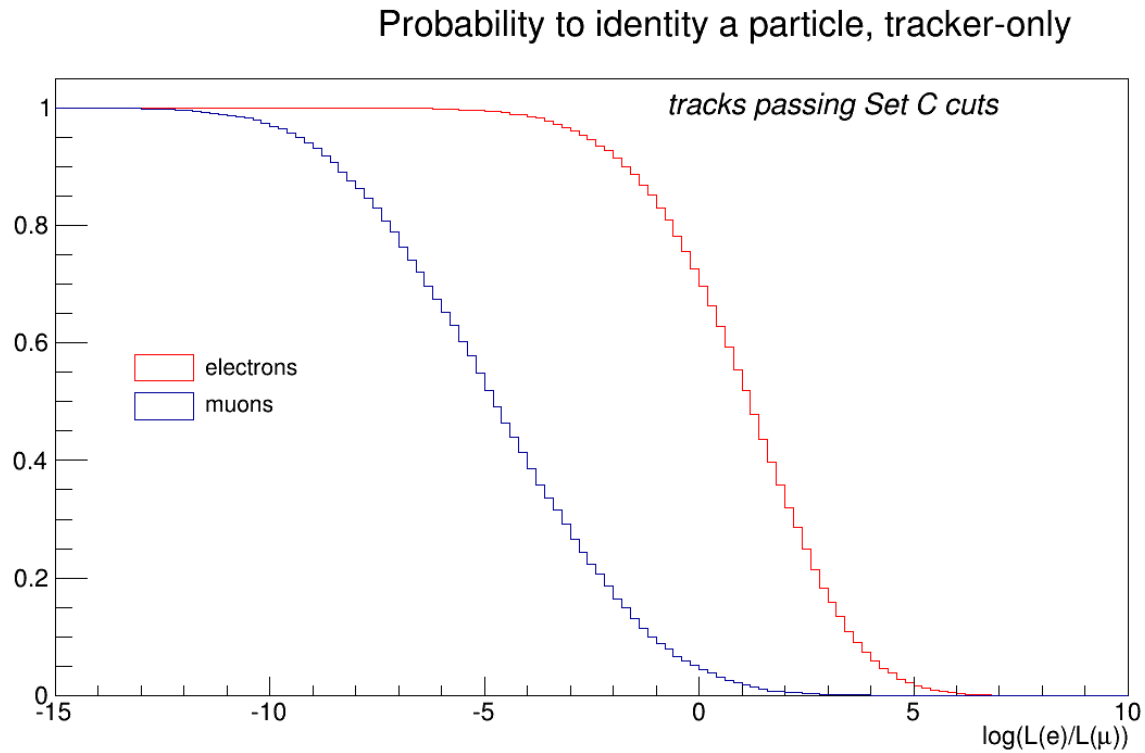
- calorimeter must operated at B = 1T in high radiation environment
- innermost crystals of the 1st disk will acquire doses up to 200 Gy/year
- require crystal response be stable for < 50 Gy/year
- more discussion of radiation damage in the upcoming talks

Timing Resolution



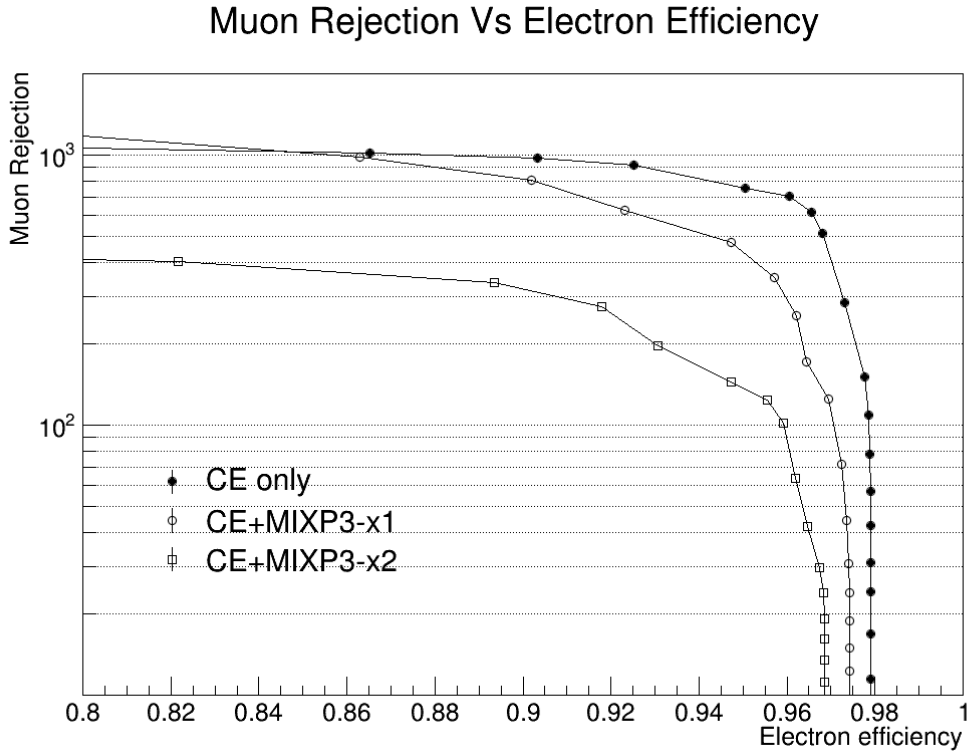
- Mu2e detector doesn´ t have an ¨event time´´
- track T0 is determined from the track fit, σ_{T0} ~ 0.5 ns
- muons are reconstructed under electron hypothesis
- to improve tracking, calorimeter timing resolution has to be < 0.5 ns

Particle Identification



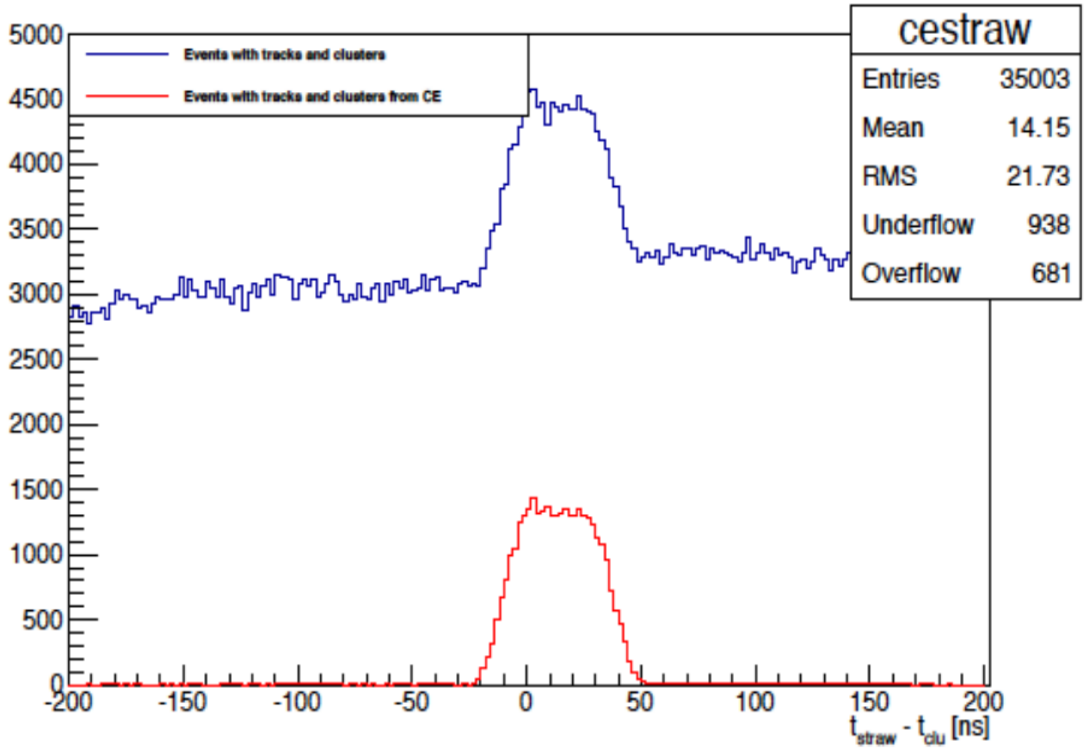
- reducing the cosmic background to the level < 0.1 events over 3 years of running requires muon rejection factor of ~200
- Mu2e tracker has PID capabilities (timing and dE/dX)
- for muon rejection factor of 200, the tracker-only PID has efficiency < 50%

Particle Identification



- combine tracking and calorimeter information
  - use position and timing matching to reject random background
  - build PID likelihood using E/P and combined timing information
- for expected background and rejection of 200, ε(electrons) > 96%
- more details in the talk by G. Pezzullo

Calorimeter-seeded Track Finding



- S/N = number of background hits / number of CE hits
- reconstructed calorimeter cluster time predicts times of the track straw hits
- allows to reduce the pattern recognition S/N from 1:100 down to ~ 1:1
- more details - in the talk by G. Pezzullo

Summary

Mu2e calorimeter has to

- provide energy resolution $\sigma(E)/E <= 5\%$ monitored at a level of $< 0.5\%$
- provide timing resolution $\sigma(T) < 0.5$ ns
- provide position resolution < 1 cm
- provide cluster-based track seeds for track finding
- provide high electron reconstruction efficiency for muon rejection of 200
- provide online trigger capabilities
- operate in high radiation environment, 50 Gy/year
- have monitoring of temperature, pressure, radiation dose rate

Studies by the Mu2e collaboration show that these requirements can be met