Status of CRT Simulation and Reconstruction

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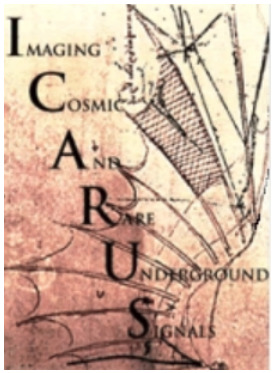
Fermilab



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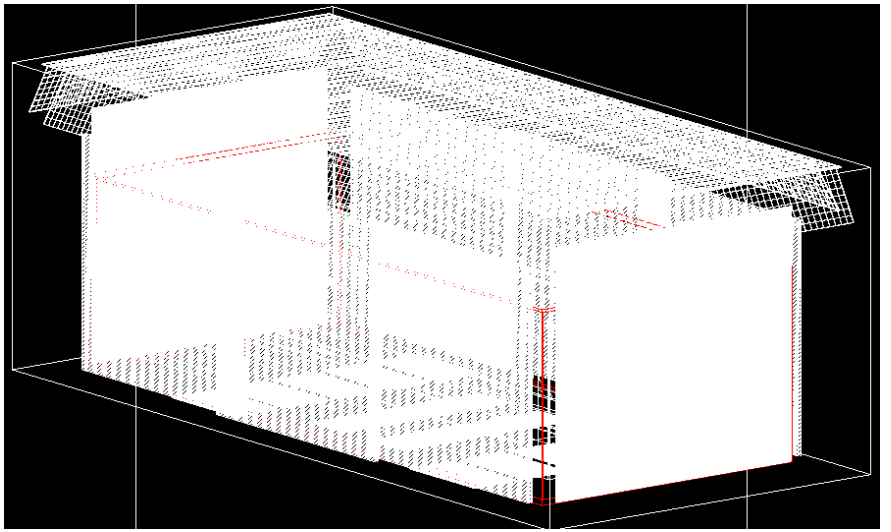
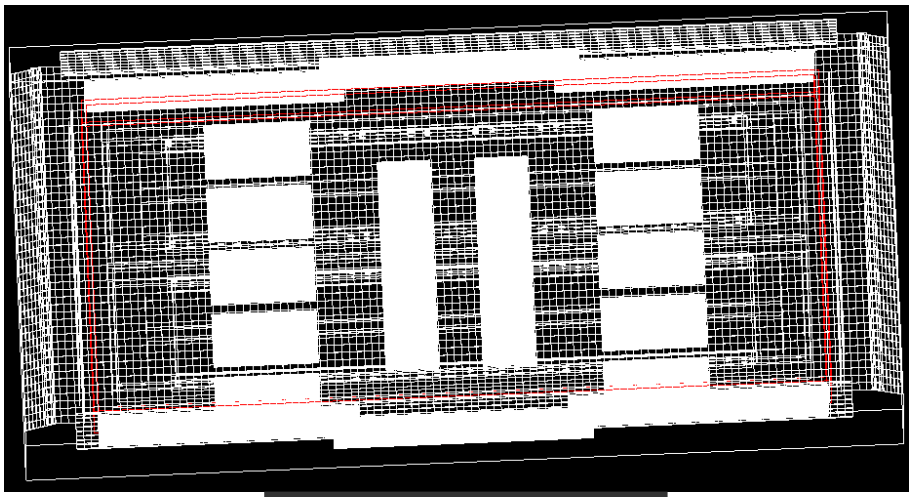
Geometry

- Note actual system does not provide 4π coverage!
  - Sparse coverage on bottom due to installation constraints
  - Mechanical mounting/layout of top/sides is work in progress – latest updates not included in MCC1
  - Geometric efficiency expected to improve
- Each CRT module approximated as polystyrene strips contained in an Al box
- Mounting structure not yet included – significant amount of material will impact rate of beam induced CRT signals





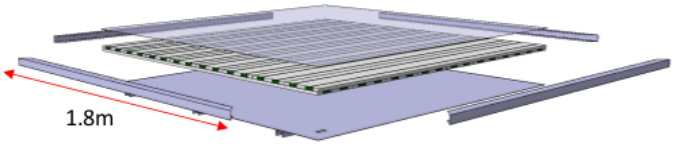
Outer cryostat
CRT strips

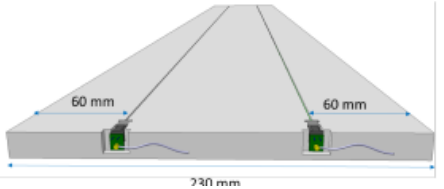
Geant4 Validation

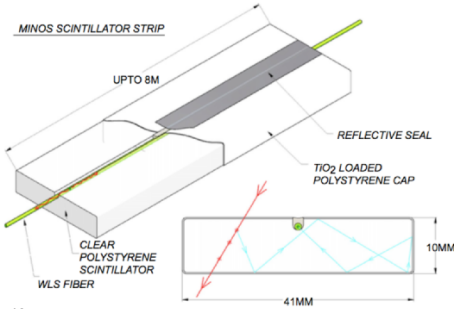
- Cosmic mu sample from CRY
- Consistent with previous results (internal note *Cosmic Ray Tagger*. M. Nessi, U. Kose, P.R. Sala, et al. 20 May 2015)
- Geometric efficiency entering the LAr active volume
  - Hitting 2 or more CRT strips: 98.6%
  - Hitting one or more CRT modules (“vector”) per CRT region (e.g. top → bottom): 34.5%
- Rates
  - In CRT (strips hit not trigger rate): 35 kHz
  - In fiducial volume (same as SBN proposal): 11 kHz

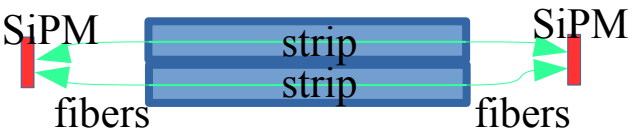
CRT Subsystems

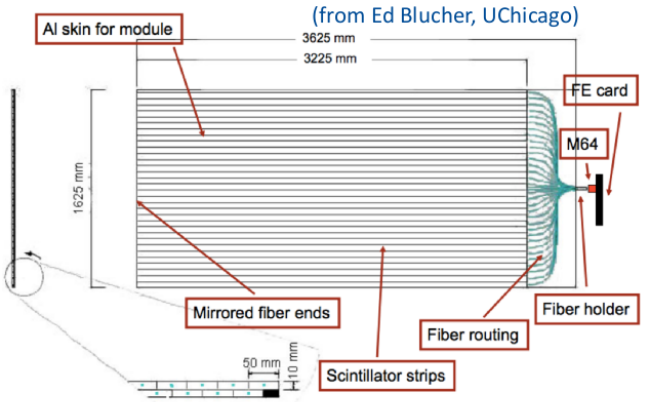
- See Bob's talk from Wednesday morning for more technical overview and status
- Top
  - Self-contained coincidence units in X-Y configurat
  - 2 layers / module, 8 scintillator strips / layer, 2 WLS fibers / strip
  - Single ended readout
- Sides
  - 1 layer / module, 20 1 WLS fiber / strip
  - Dual ended readout
  - Upstream (South) face in X-Y configuration
  - Downstream (North) face same as upstream for now, but won't be the case (layout not yet known)
  - Lateral sides in X-X configuration
- Bottom
  - 2 layers / module, 32 strips / layer, 1 WLS fiber / strip
  - Single ended readout











Test Sample: μ's as Cosmics

- Single particle gun
- Initial position just below overburden and above top CRT modules
- Initial distribution footprint centered over and confined to single cryostat (useful for other studies)
- Angular distribution cosmic like
- Momentum 5 GeV
- 200 primary μ's

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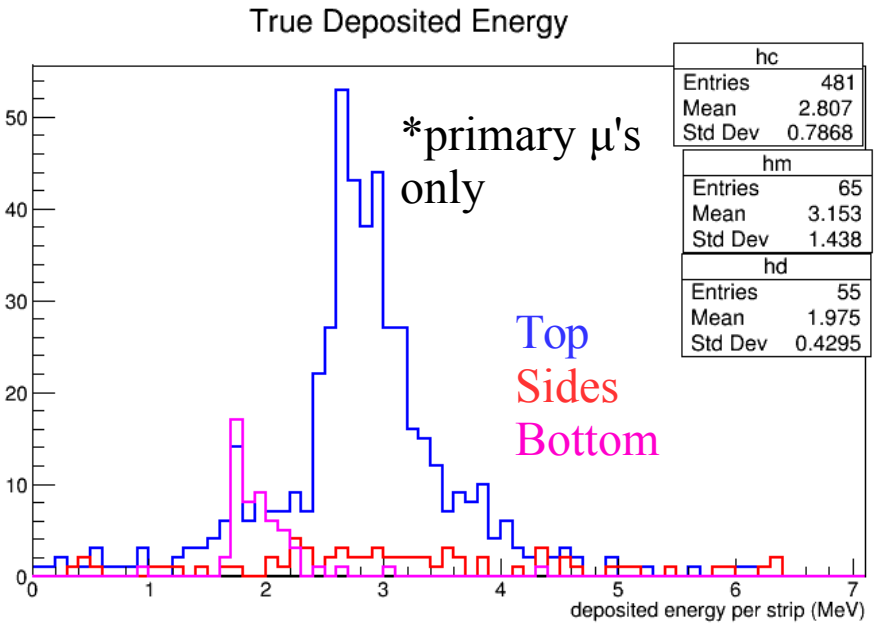
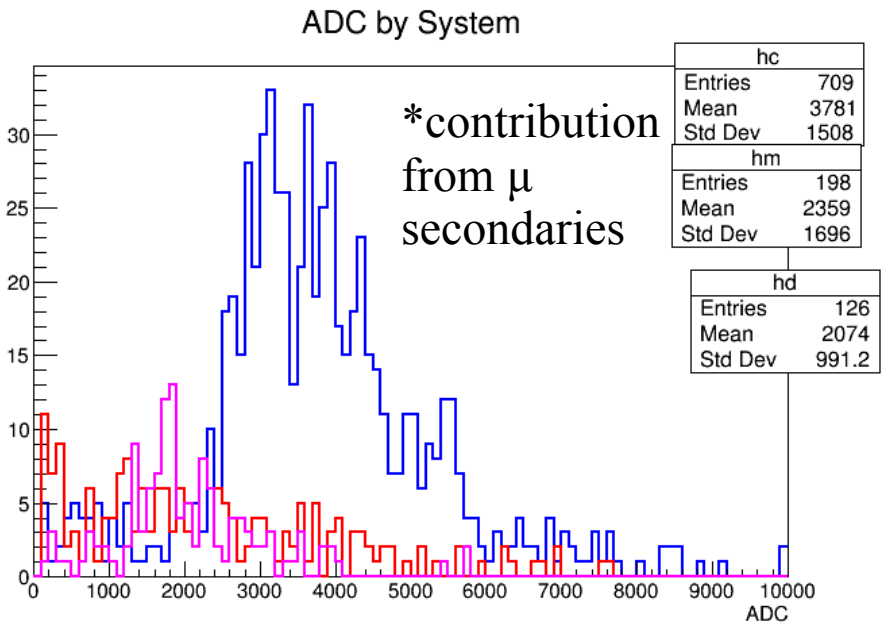
CRT Detector Simulation

- Geometrical
  - Attenuation in bulk (transverse) and in WLS fiber (longitudinal)
  - Propagation delay with amplitude dependent smearing
- Light Yield (LY)
  - Expect $LY_{Top} >\sim LY_{Sides} > LY_{Bottom}$
  - For now, use parameterization obtained from side CRT test data
- Poisson fluctuated LY at photosensor
- Front-end electronics
  - Nominal pedestal, gain measurement taken from side CRT test data
  - Amplitude dependent smearing of time from descriminator, interpolator
  - 22μs dead time, track-n-hold effect, rapid hit biasing
  - Trigger logic different for each subsystem
    - Top: SiPM-SiPM coincidence in strip, coincidence between X-Y layers in a module
    - Sides: one or more strips per module, coincidence between adjacent layers
    - Bottom: one or more strips in a module, coincidence between X-X layers in a module

MIP Energy Deposited





- Light yield and, pedestal, and gain modeled from side CRT test data taken over summer 2017
- Dark noise is not included here – significant for SiPMs
- Coincidence requirements eliminate most of dark noise effect so secondary concern at this point

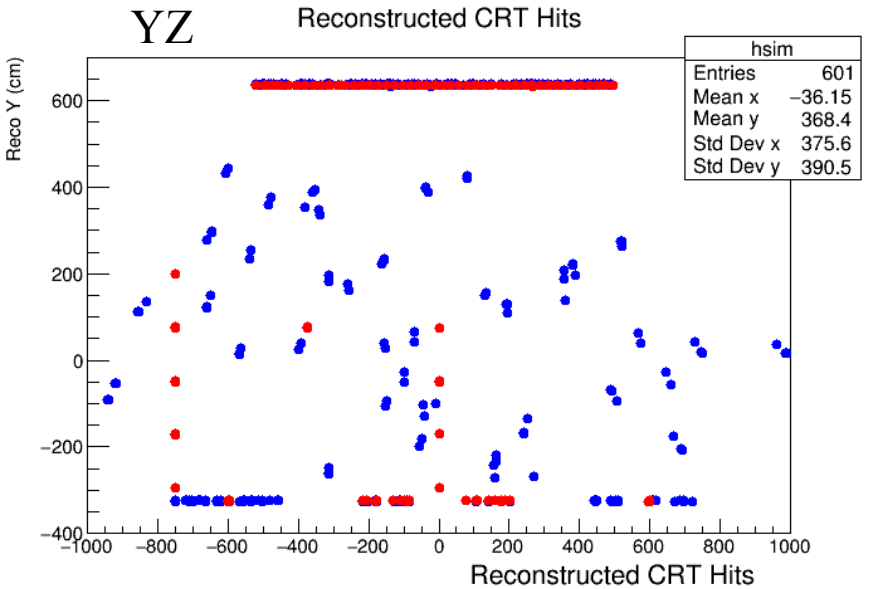
CRT Tagging Efficiency

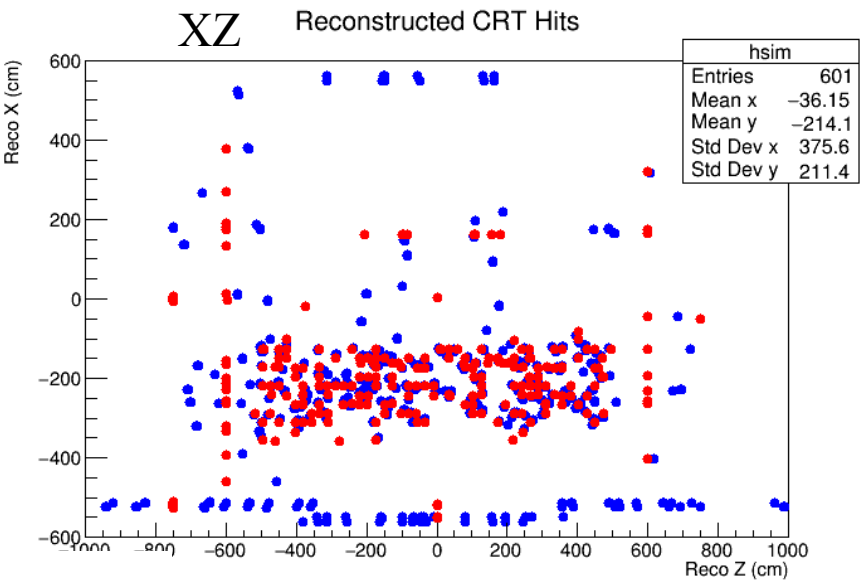
- At least 1 CRT trigger corresponding the offending track
  - Can only provide CRT “hits” (position and time)
  - With this clean sample (kindly avoiding gaps), 99.9% tracks tagged
- At least 2 different CRT modules trigger
  - Can reconstruct a “vector” to project the track into the TPC
  - Useful for calibration, efficiency studies
  - With this sample, ~40% tracks tagged as vectors
- Expect tagging efficiencies to worsen using cosmic samples (work in progress)

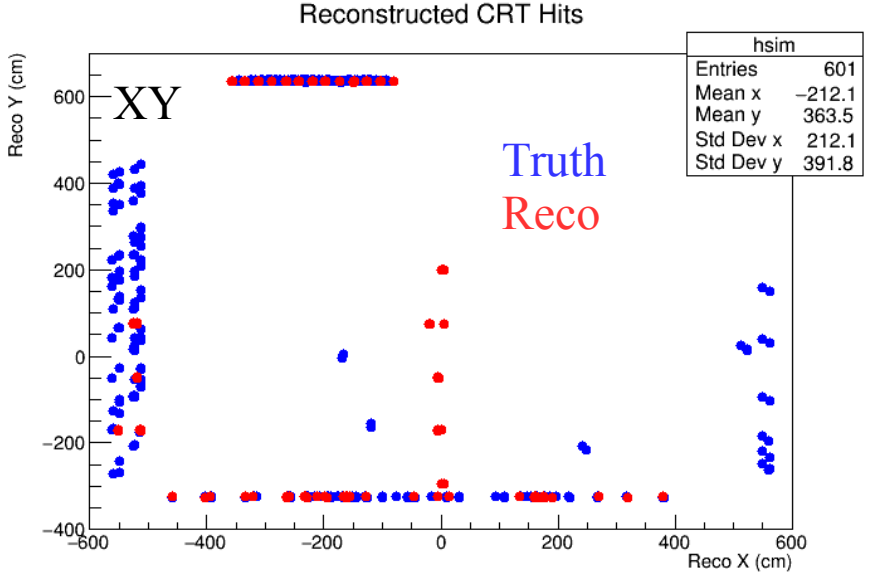
CRT Reconstruction

- Development just getting underway, borrowing from work done in SBND
- First step is to construct CRT hits from DetSim products, different for each subsystem
- Top
  - X-Y configuration (in principle) has position resolution (σ_x) ~ 7cm
  - Accidental coincidences, threshold effects can cause problems
- Upstream side: X-Y, σ_x ~ 3cm
- Other sides:
  - X-X, strips parallel to X-Z plane
  - $\sigma_{vertical}$ ~ 2.4cm
  - If readout triggered at only 1 end, $\sigma_{horizontal}$ ~ 2.3m
  - If readout triggered at both ends, both FEBs in coincidence, time difference gives position
  - Dual ended $\sigma_{horizontal}$ ~ CRT time resolution (σ_t), e.g. σ_t = 2ns gives possible $\sigma_{horizontal}$ ~ 30cm (not yet implemented)

First Look at CRT Hits







- By eye, hits are reconstructed well for top and bottom, sides need work
- Truth matching study underway to understand position, time resolution

Summary

- The CRT simulation has been validated with cosmic and single muon samples
- A front-end centric simulation with data products similar to what expected for DAQ
- The LY spectra and electronics effects have been tuned from side CRT test data
- The first step has been made in CRT reconstruction
- Truth matching study underway to understand reconstruction resolution

Next

- Tune CRT timing simulation for trigger studies
- Continue development of CRT reconstruction tools for cosmic muon removal
- Reproduce and extend previous studies on cosmogenic γ's, update impact on ν_e analysis
- Study possible trigger configurations of interest for acquiring background and calibration samples, useful for DAQ group