The Cosmic Ray Veto in Mu2e-II

Mu2e-II Workshop

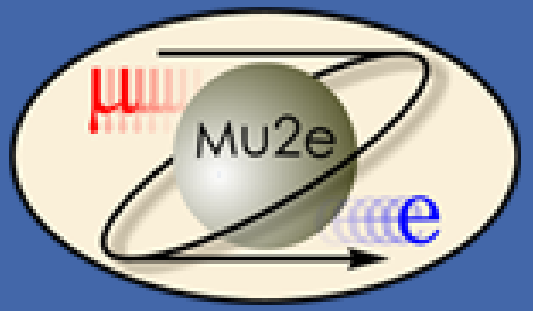
Northwestern University

August 30, 2018

R. Kreswell Neely,

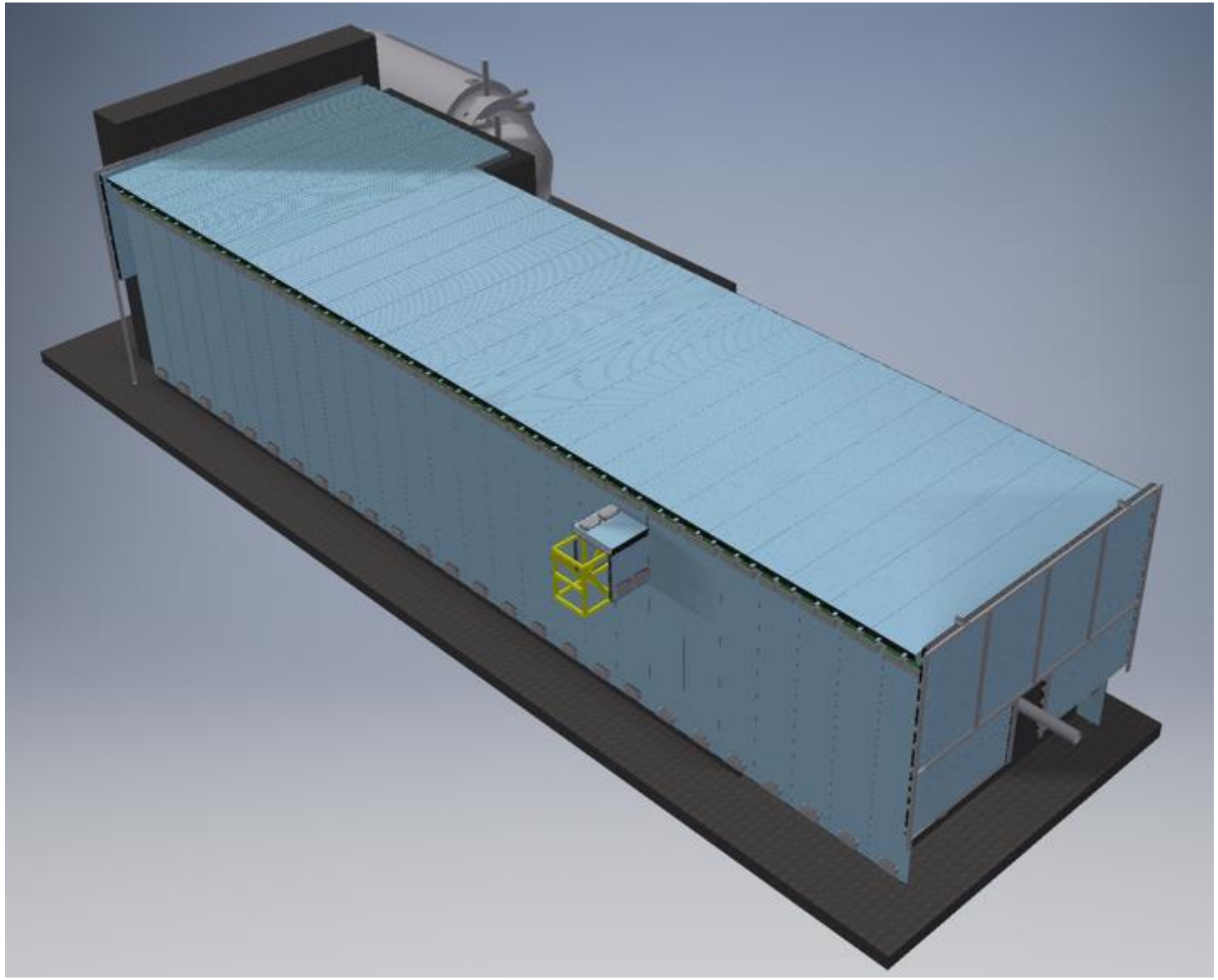
Kansas State University

On Behalf of the Mu2e-II CRV Working Group



CRV Brief Summary

- Plastic scintillator extrusions with wavelength shifting fibers instrumented with SiPMs.
- Four parallel, staggered layers covering top and sides.
- 99.99% efficiency required.



Yesterday's Discussion

Attendance:

Jerry Blazey, Craig Dukes, Craig Group, Kres Neely, Yuri Oksuzian, Lei Xia, Ron Ray, Andrei Gaponenko

Presentations:

- Rates at the CRV for Mu2e-II: Yuri Oksuzian
- CRV Aging: Yuri Oksuzian
- RPCs in high-rate areas for the CRV: Lei Xia
- SiPMs: Jerry Blazey

Additional Topics Discussed:

- Electronics
- Pixel tracker

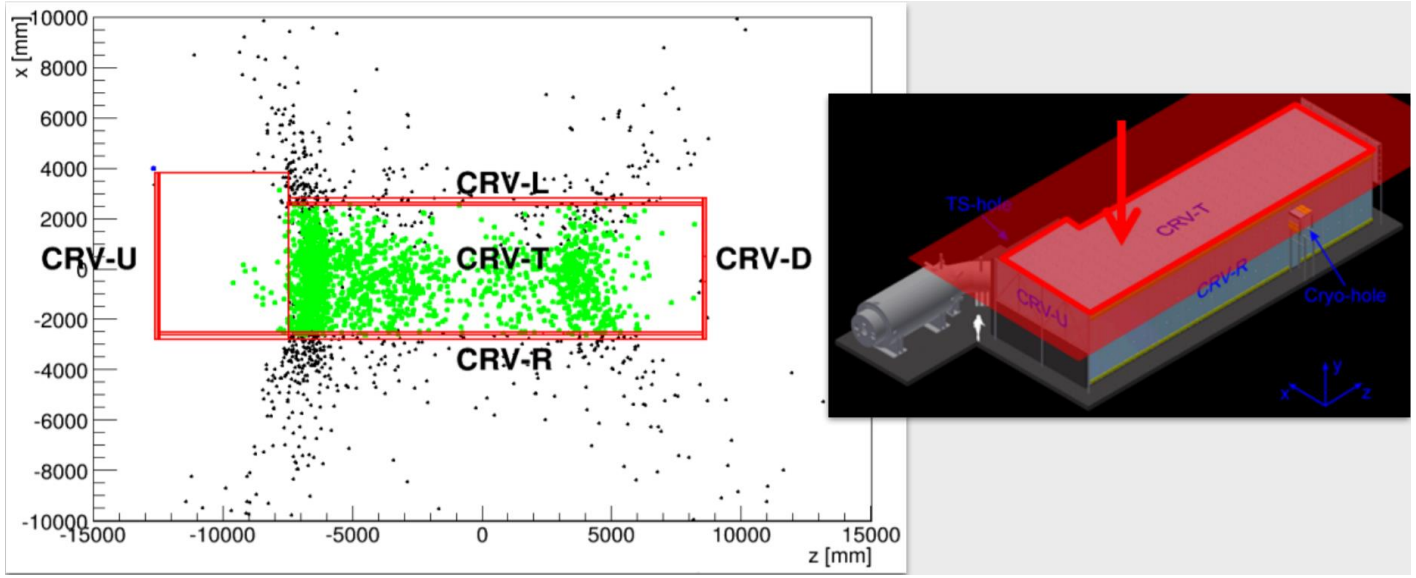
Major Concerns for Mu2e-II

1. Cosmic ray events scale with duty factor
   - Factor of 3.
   - Improve total efficiency.
2. Neutrons from production target scale with intensity
   - Factor of 3.
   - High data rates in hot regions.
3. Aging/Degradation of components
   - Scintillator.
   - SiPM.
   - Electronics.

Incremental upgrades, but more radical changes could be considered.

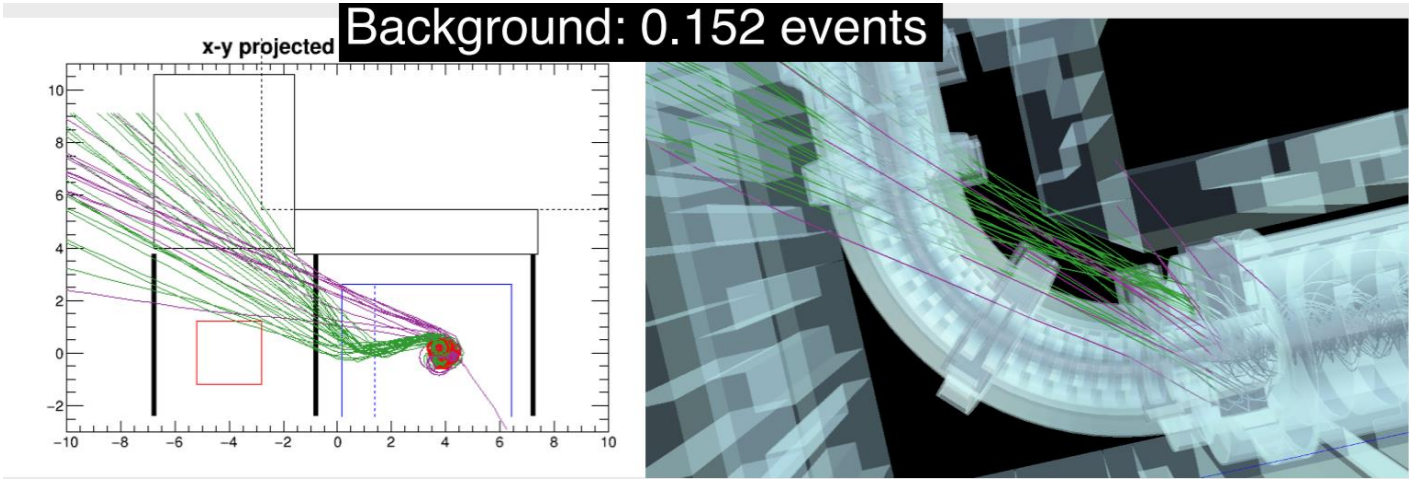
Efficiency Improvements

- Most conversion-like cosmic events pass through top modules (CRV-T).
  - Especially near stopping target and tracker.
- Possible solutions:
  - Extra detector layers.
  - Improve light yield.
  - Probably only needed in highest demand regions.



TS Hole

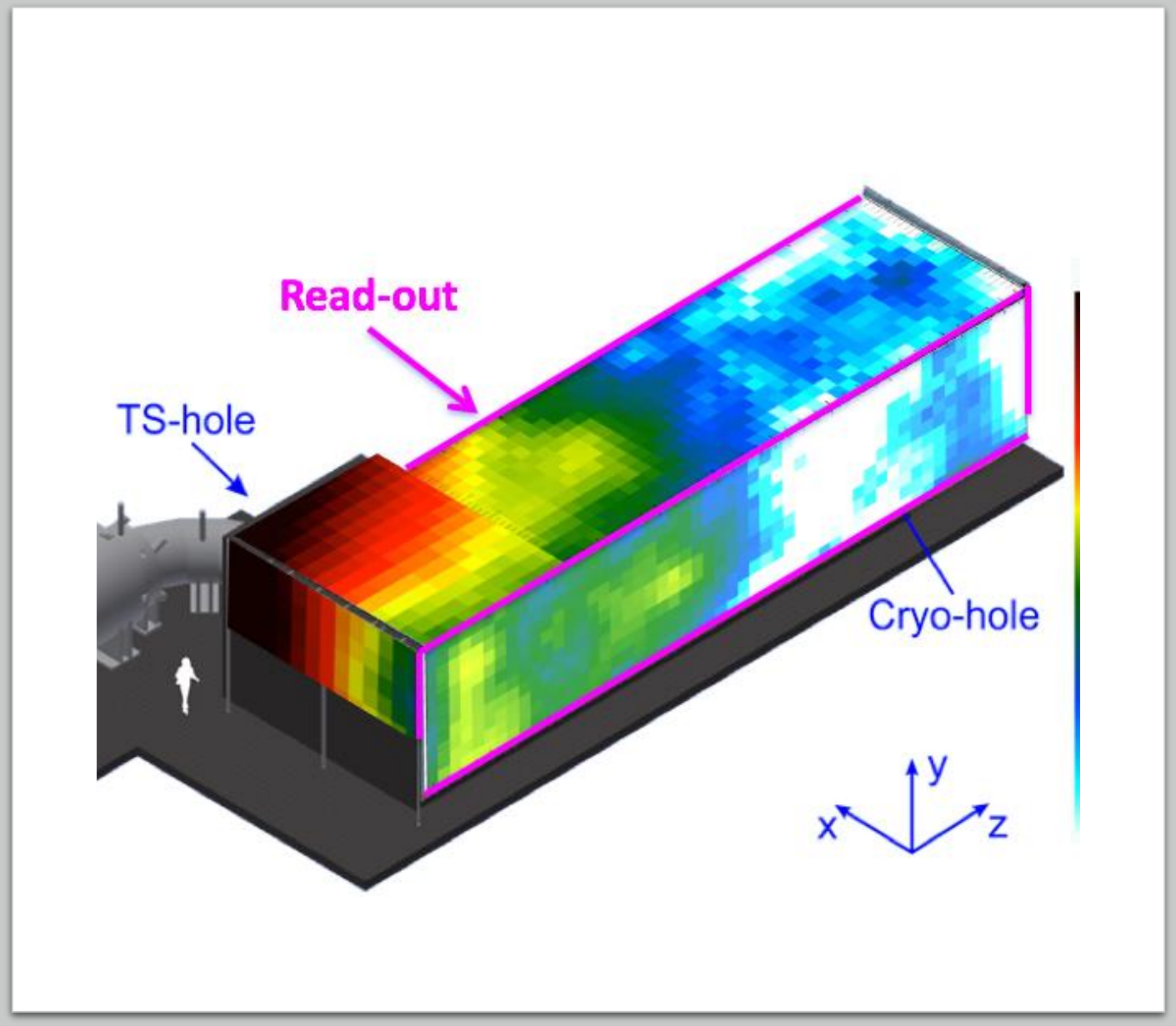
- Biggest chink in our armor.
- 0.15 events over run of Mu2e.
  - Improved to 0.05 with passive absorbers, extended CRV.
- 0.15 events in Mu2e-II.
- Possible fixes:
  - Passive absorbers
  - Active vetoes (scintillator tiles, pixels, RPCs) in corner.



Production Target Radiation

Radiation from the production target presents several challenges in specific regions:

- High dose to SiPMs and electronics.
- High hit rate.
  - ~2 kHz/cm^2 in Mu2e.
  - ~20 kHz/cm^2 in Mu2e-II.
- Increase in dead time.
- Good HRS would help a lot.
- More uniform spills will help too.



SiPM Degradation

- Radiation on SiPMs causes increase in dark noise.
  - Loss of single PE separation.
  - Increase in data rates in FEBs.
    - Requires increase in thresholds.
    - Loss of detector efficiency.
- Several avenues for improvement.
  - More rad-hard.
    - Different semiconductors.
    - Custom active area.
    - Faster recovery.
    - Junction electric field engineering.
  - Better alignment between WSF transmission spectrum and SiPM peak efficiency.
  - In-situ Annealing.

Data Rates/Dead Time

- 6m scintillators in the hottest region leads to very high data rates, increasing dead time and potentially overloading FEBs/ROCs.
- Potential solutions:
  - Improved timing.
  - Implement coincidence.
  - Additional detectors (segmented scintillator, RPC) in the hottest regions.

Resistive Plate Chambers

Many attractive features:

- More channels – lower data rate per channel.
- Much thinner than plastic scintillators.
- High enough efficiency (>90%) for TS region.

Could be used in the hot corner, as extra layer on critical CRV-T regions, or in TS hole.

Worth prototyping in Mu2e.

Other Considerations

Radiation damage to electronics

- Initial tests suggest it's fine, but could be understood better.

Electronics upgrade?

- Better tech available by Mu2e-II. Worth upgrading?

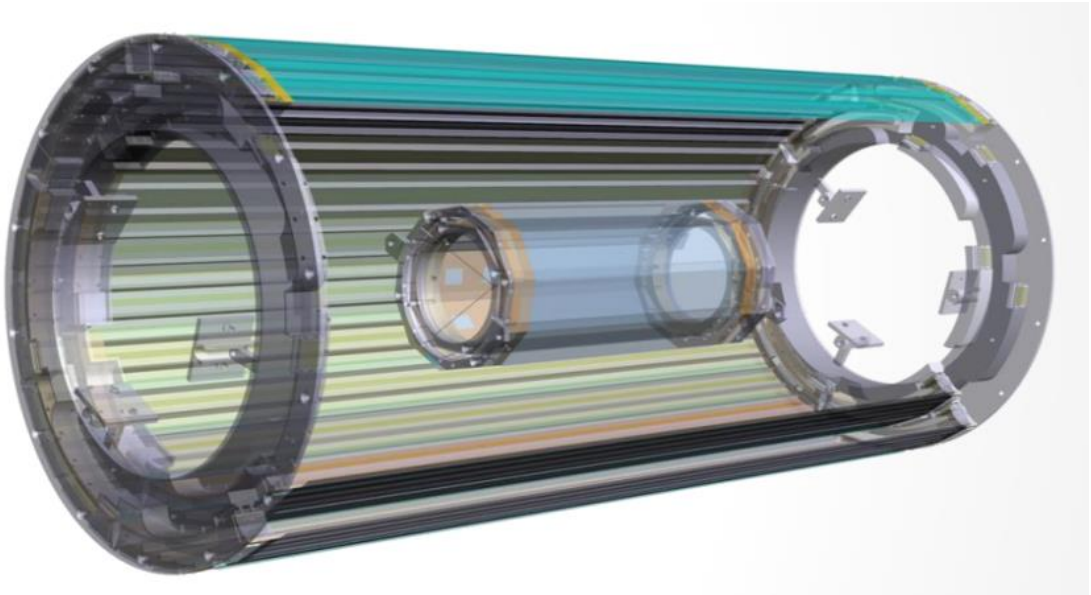
Electronics/Firmware modifications for variable beam structure.

Scintillator Aging

- Source and beam tests suggest ~10% in year 1, less in subsequent years.
- Exact causes not understood.
- More study necessary.

Radical Design Change: Pixel Tracker

- A la Mu3e
- Potentially replace CRV and tracker.
- Major redesign, but potentially more compact, better coverage, more efficient.



Source: https://indico.cern.ch/event/709379/

Summary

- Increased beam intensity and duty factor will increase the backgrounds due to cosmics and stopping target radiation.
- Most of these issues occur around the hottest corner of the TS region and the TS hole.
- High quality HRS would help us out a lot!
- There are many avenues by which we can incrementally address these issues.

Sources

- Blazey, Gerald, *SiPMs for Mu2eII*. Mu2e-II Workshop, August 29, 2018.
- Oksuzian, Yuri, *R&D ideas for CRV at Mu2e-II.* Mu2e-II Workshop, August 29, 2018.
- Wiedner, Dirk, The Mu3e Collaboration. *Mu3e*. July 17, 2018. https://indico.cern.ch/event/709379/
- Xia, Lei, *High Rate RPC for Mu2e II CRV*. Mu2e-II Workshop, August 29, 2018.