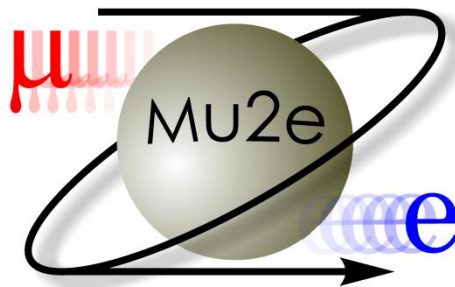


Mu2e-II

Cosmic Ray Veto

Triangular Quadcounter Module Update

Craig Dukes
July 21, 2021



Mu2e-II: Mu2e in the PIP-II Era

We wish to seize the opportunity provided by upgrades of the Fermilab accelerator complex being built for DUNE to increase the Mu2e sensitivity:

- Proton Improvement Plan II (PIP-II): Present Booster proton beam replaced by Superconducting Linac
- Allows an order of magnitude increase in sensitivity over Mu2e
 - ~3X in muon beam stops
 - ~3X in running time (through a better duty factor): Note cosmic-ray background scales with time!

Need to improve the CRV efficiency: cosmic-ray induced background 3X larger

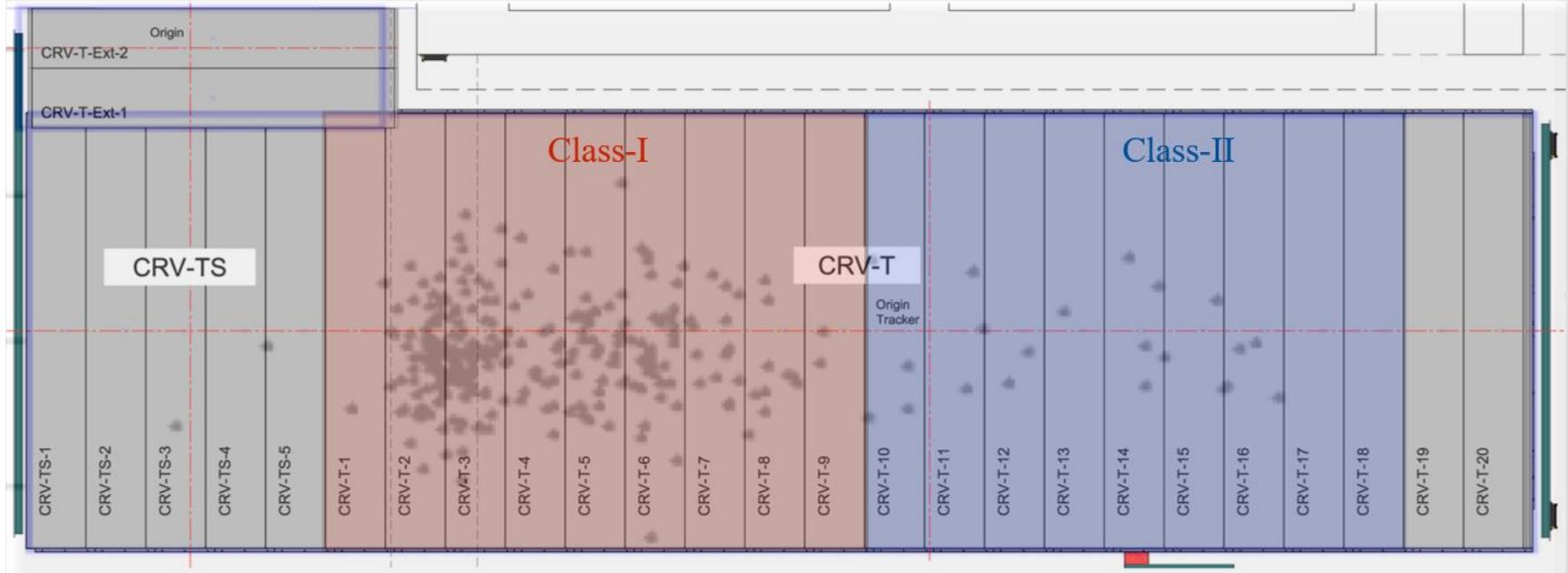
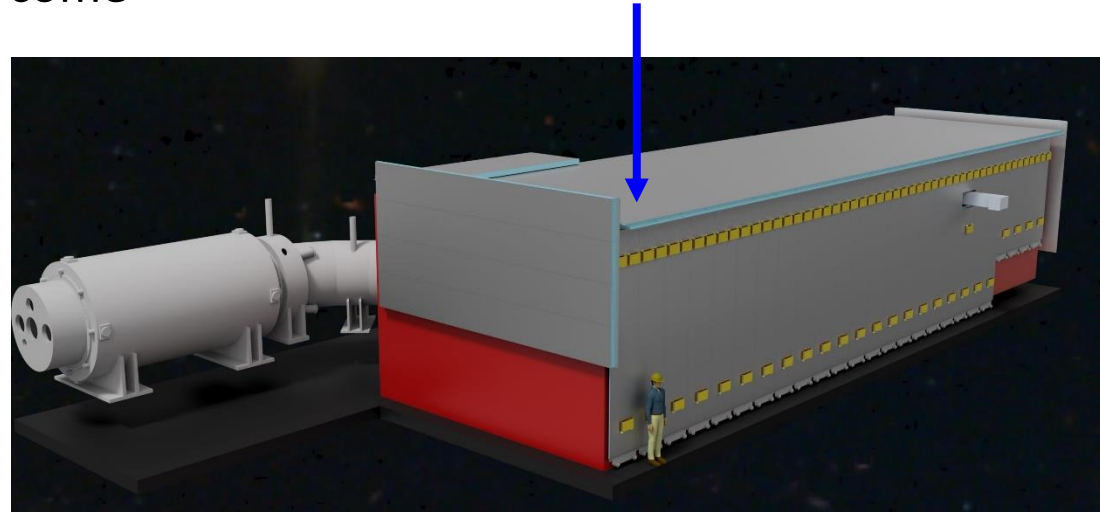
CRV needs to handle 3X higher instantaneous rates



Sources of non-Vetoed Cosmic Ray Muons

Most background producing muons come through top of CRV

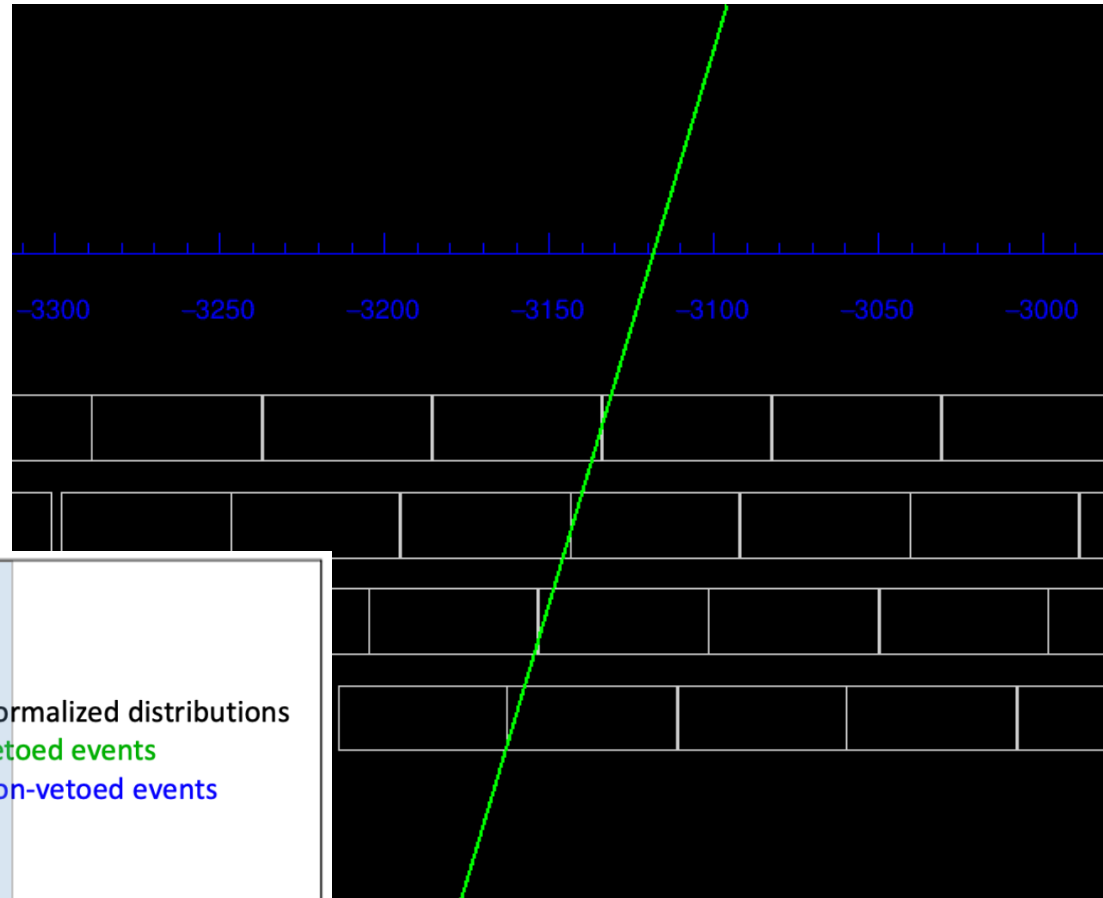
Oksuzian



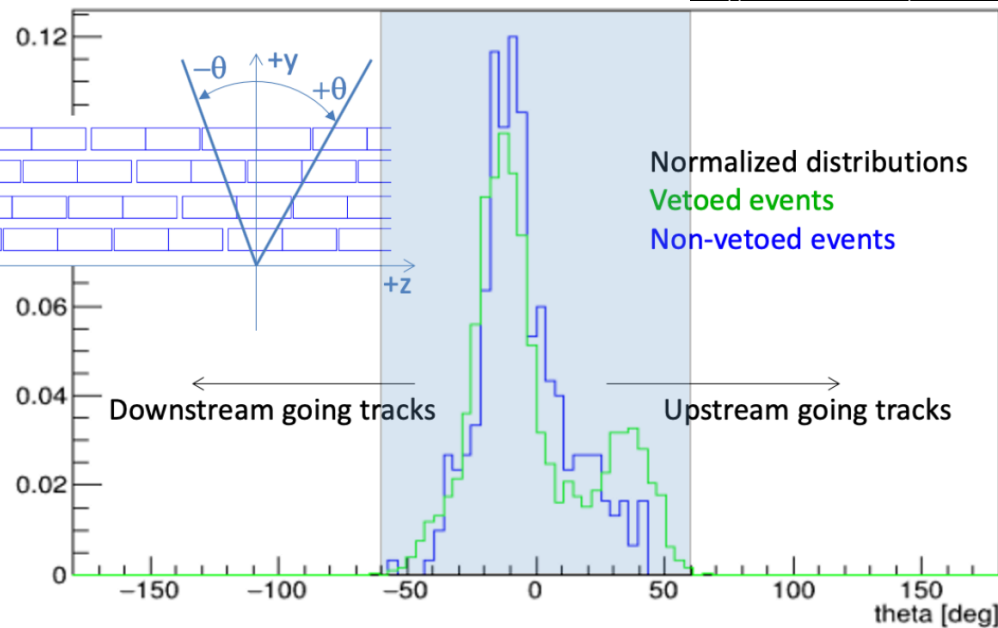
Sources of non-Vetoed Cosmic Ray Muons

Oksuzian

Most come at nearly vertical angles, and can traverse gaps between counters and not be vetoed

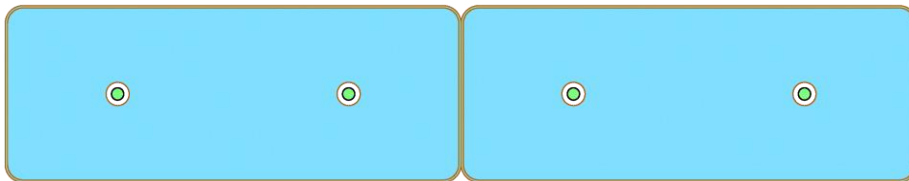


Continues on hitting material in the spectrometer, producing a 105 MeV electron

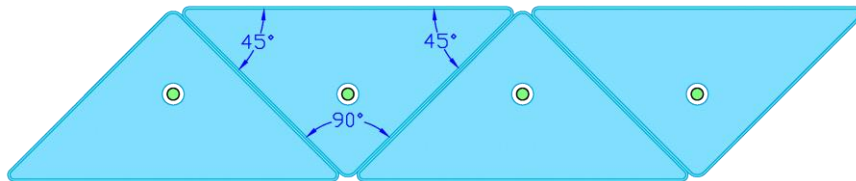


Improving the Cosmic Ray Veto Design

Replace the critical top modules with modules using triangular-based extrusions



Mu2e “di-counter”

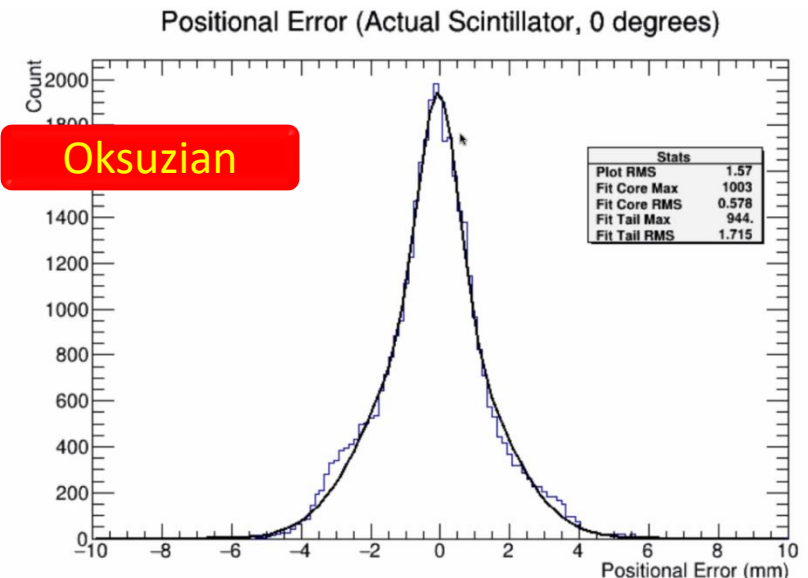


Mu2e-II “quad-counter”

Minimize gap problem by using triangular extrusions

Smaller size reduces singles rates, which are extremely high

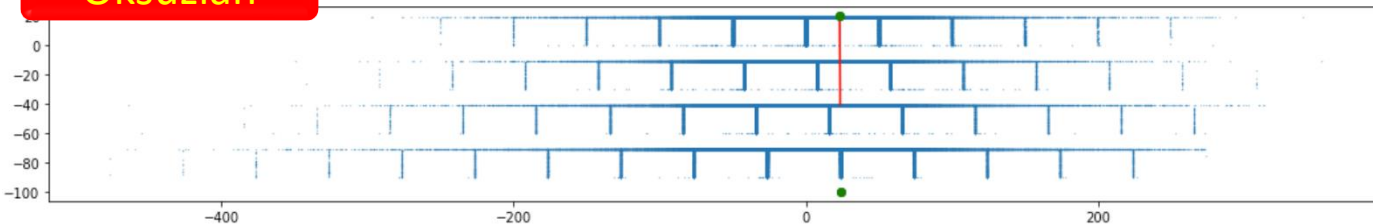
Better resolution ($\sigma \sim 1.5$ mm) reduces fake track-stub coincidences, and hence deadtime



Simulated position resolution

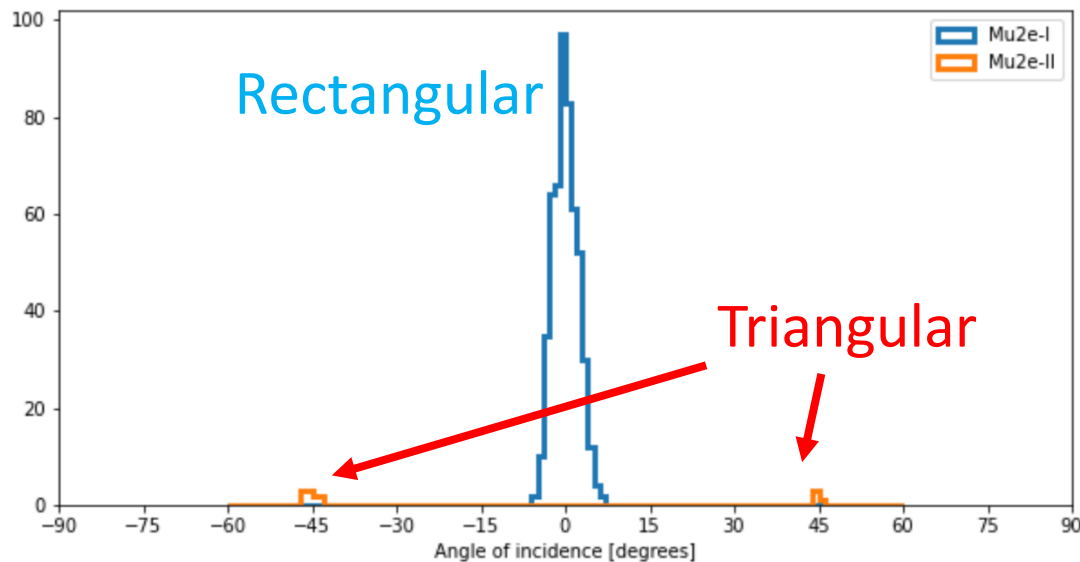
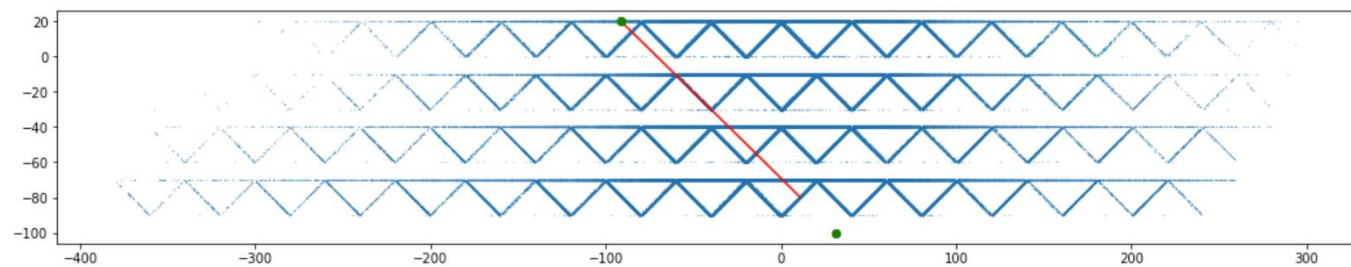
Simulated Response to Cosmic Ray Muons

Oksuzian



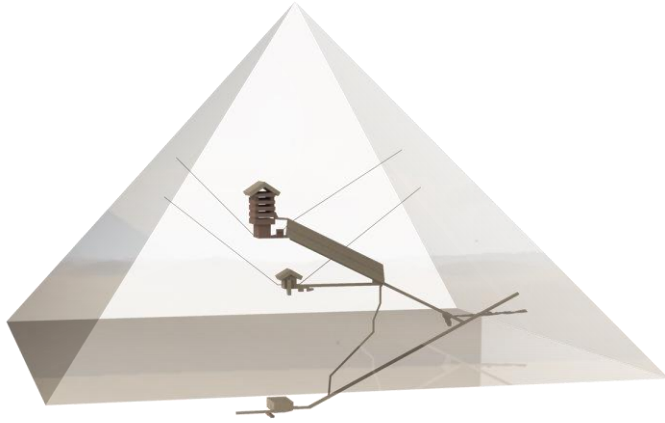
Mu2e
rectangular

Mu2e-II
triangular



Rectangular counters have
highest inefficiency at 0°
Triangular counters at $\pm 45^\circ$

Mu2e-II Not the Only Interested Party



Exploring the Great Pyramid (EGP) Project

- Same design as Mu2e-II
- \$200K in seed funding exhausted mostly in simulation work

Exploring the Temple of Kukulcan at Chichen Itza

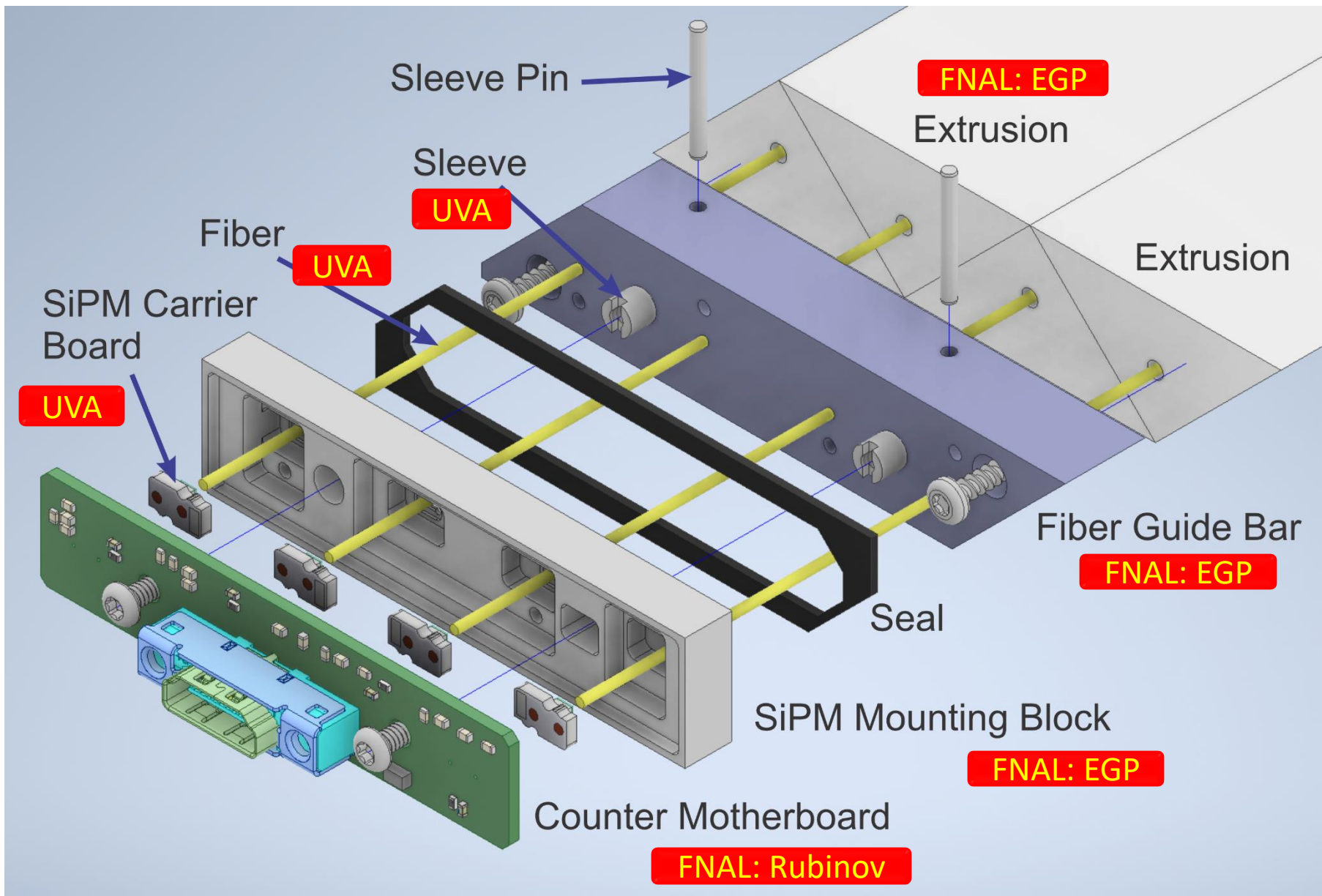
- Same design as EGP, but smaller arrays
- Funded by NSF



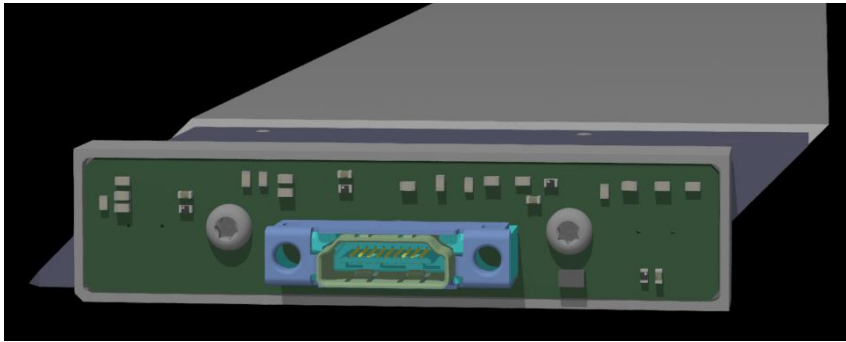
DUNE

- Exploring similar design for Near Detector

Prototype Quadcounter Parts being Fabricated



Prototype Detector Fabrication Underway



Quad-counter manifold end showing counter motherboard

Quad-counter design completed

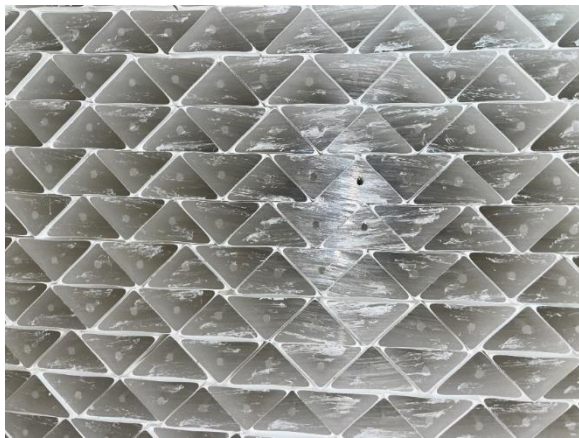
Extrusions fabricated

Manifold parts ordered

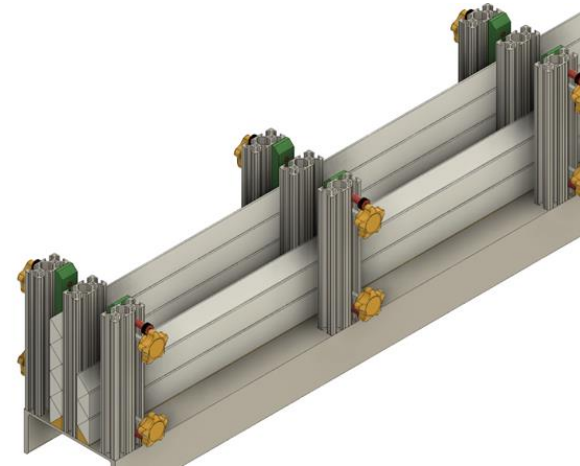
Counter motherboard design completed;
prototypes in hand

Fabrication jig design completed

Plan is to fabricate several planes of 1 x 1 m²
quadcounters



Triangular extrusions fabricated
at Fermilab NICADD facility



Vertical assembly jig design

Moving Forward

- UVA personnel have developed a design and procedures for fabricating quadcounters and single layer $1 \times 1 \text{ m}^2$ planes for a prototype detector
- We estimate about \$20K is needed to fabricate a prototype with 6 planes: cost roughly half labor and half module (not quadcounter) parts
- EGP is out of funds
- Other sources?

Action Items from ANL Workshop:

- 1) Develop plan for beam delivery
- 2) Develop plan for and pursue R&D for 100 kW production target
- 3) Engage labs & funding agencies to identify resources for detector R&D
- 4) Formulate list of high priority simulations tasks