Recent results from MicroBooNE

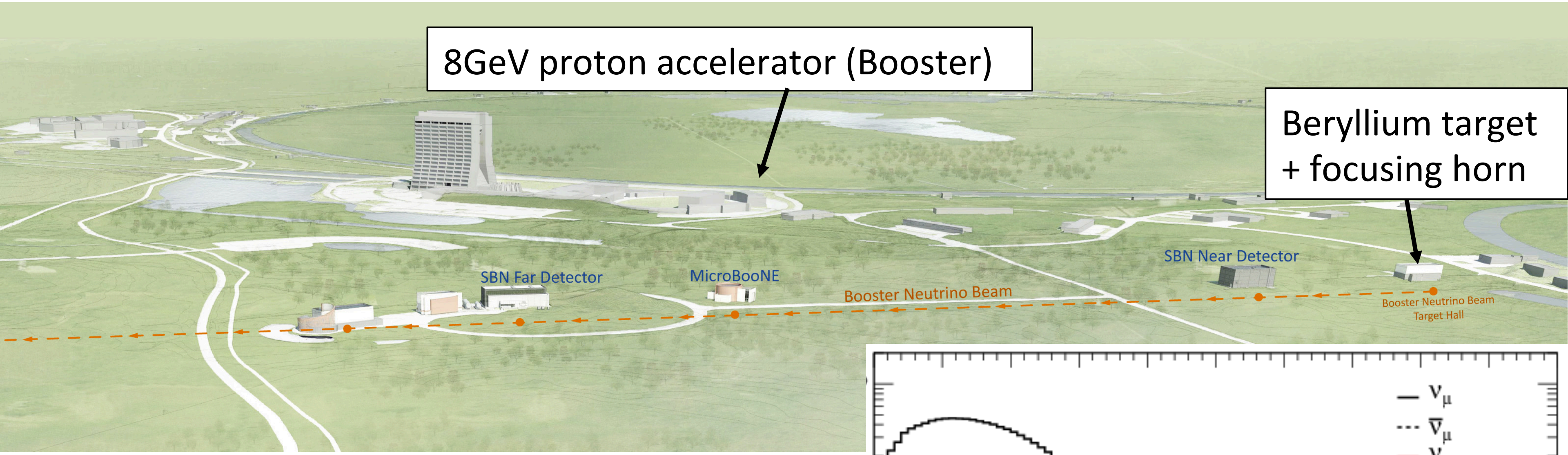
Andy Furmanski for the MicroBooNE collaboration

June 26th 2017

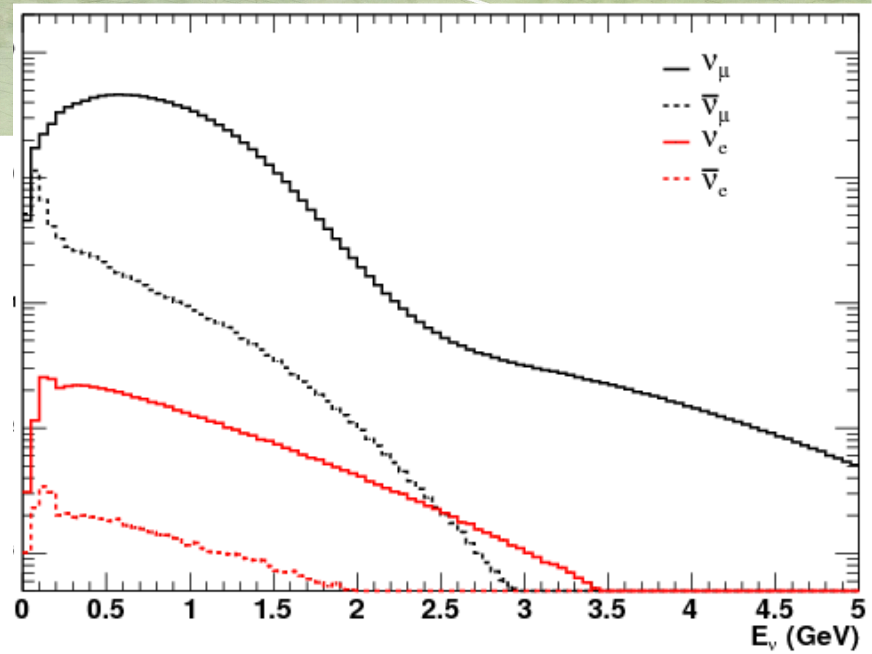
NuInt 2017, Toronto, Canada

MANCHESTER 1824
The University of Manchester

SBN (an aside)



- Fermilab Short Baseline Neutrino program
- Three LArTPCs along the Booster Neutrino Beam
- World leading sensitivity to eV-scale sterile neutrinos
- Crucial low energy ν-Ar interaction measurements



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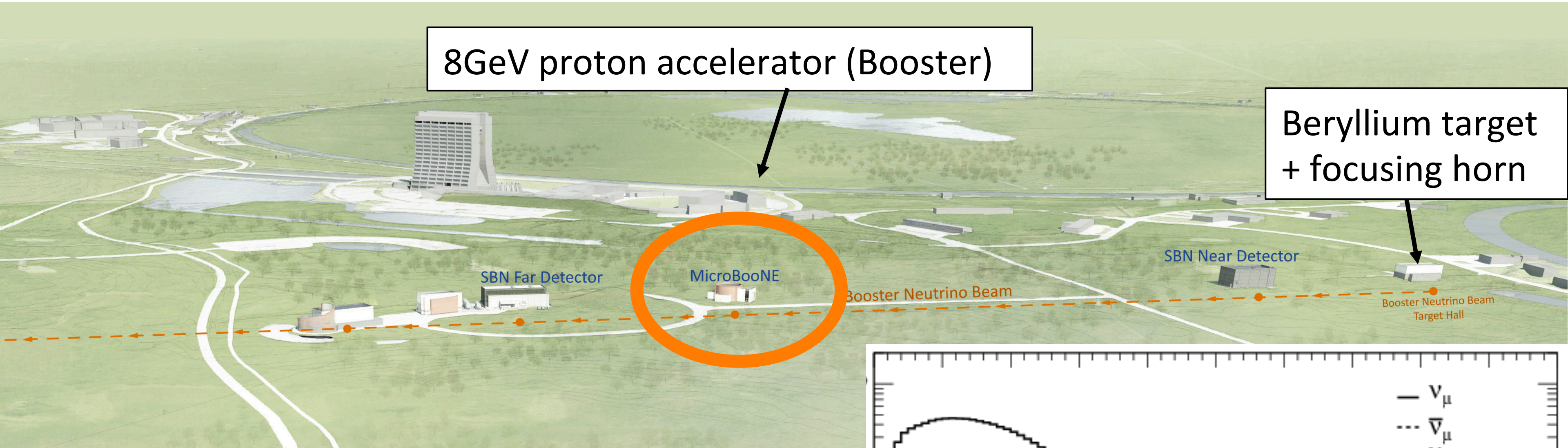

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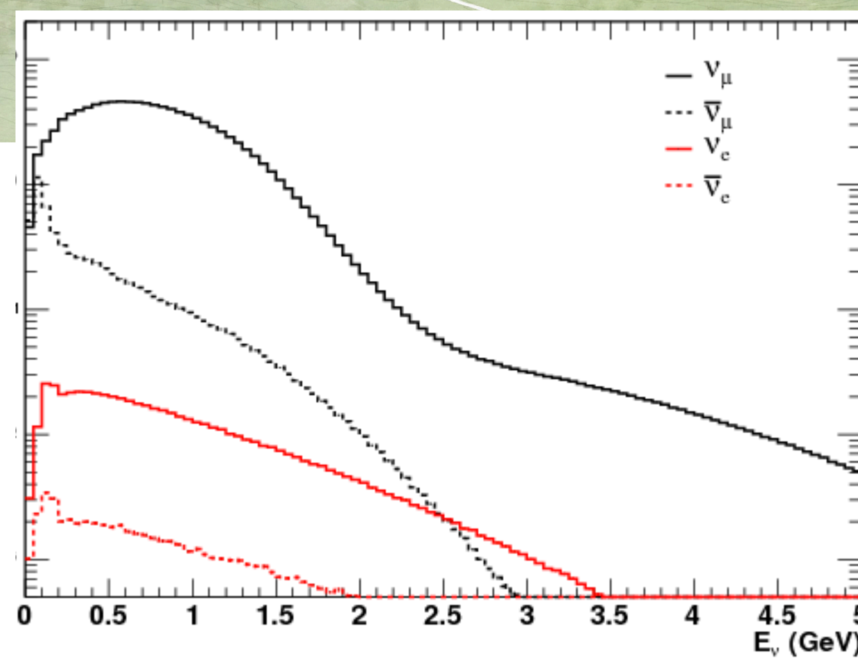
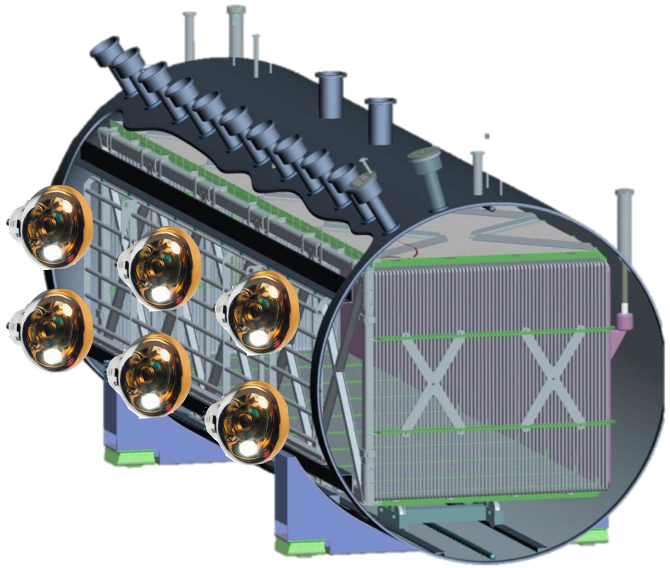


MicroBooNE in one slide

R. Acciarri et al 2017 *JINST* **12** P02017



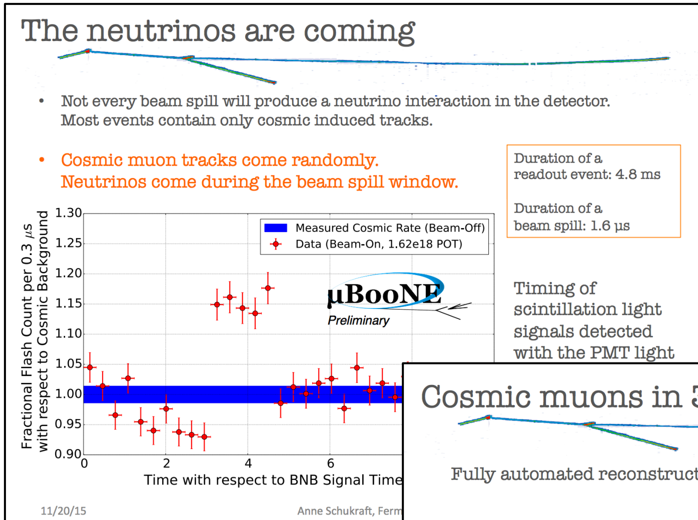
- 170 tons of liquid argon
  - 50% inside the TPC
- 32 eight-inch PMTs for scintillation light (fast)
- 10.4 m x 2.6 m x 2.3 m TPC (70 kV: 273 V/cm)

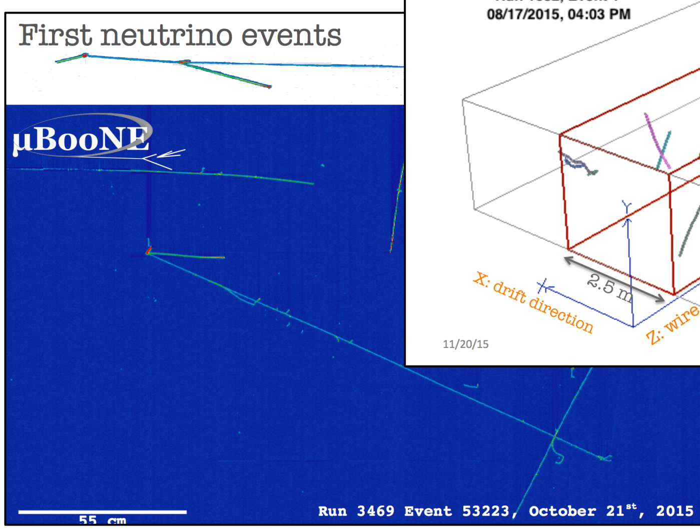
- PMTs used for online triggering (don't save every event)
- TPC drift time ~2ms

cosmic rate ~200 $m^{-2}s^{-1}$: ~8 muons per drift time

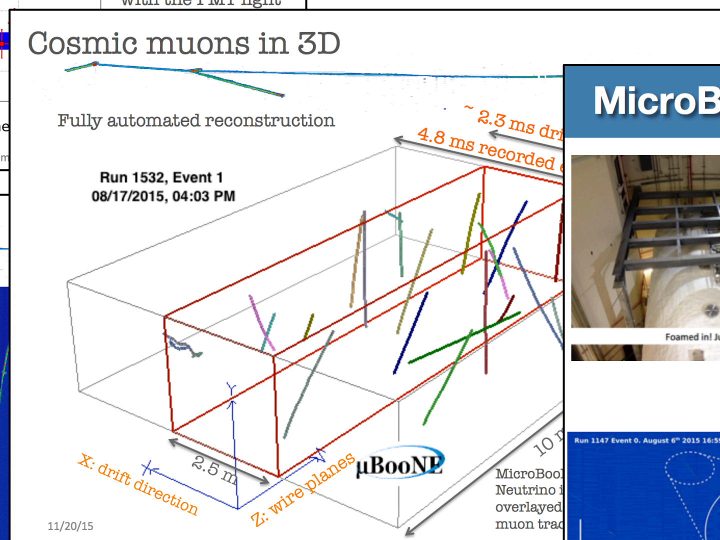
Last time at NuInt

<u>NuInt 2015 – Japan</u>
- Fully installed and commissioned
- First data, **first neutrinos**
- MicroBooNE “graduates” from the future experiments session!

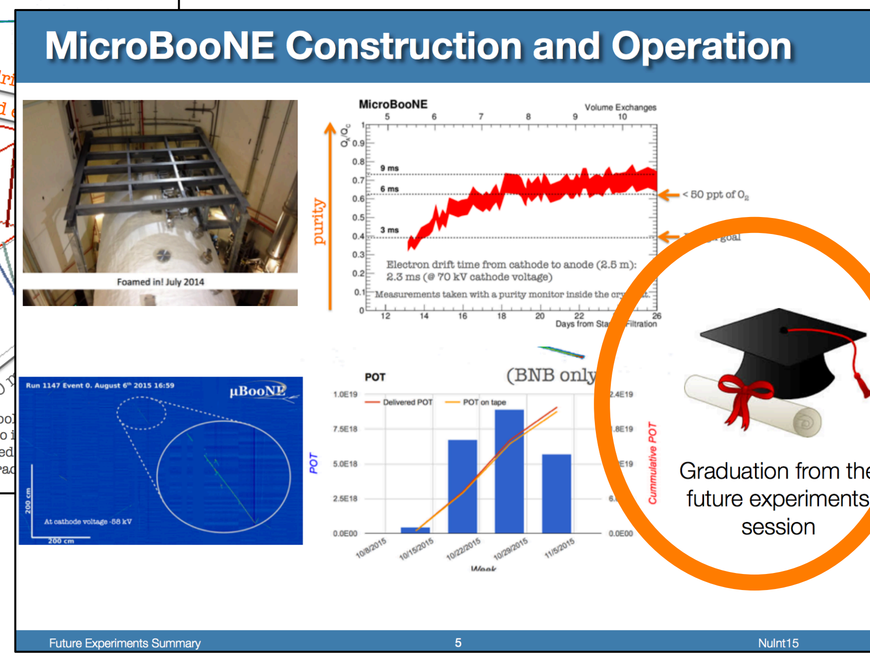




A. Schukraft

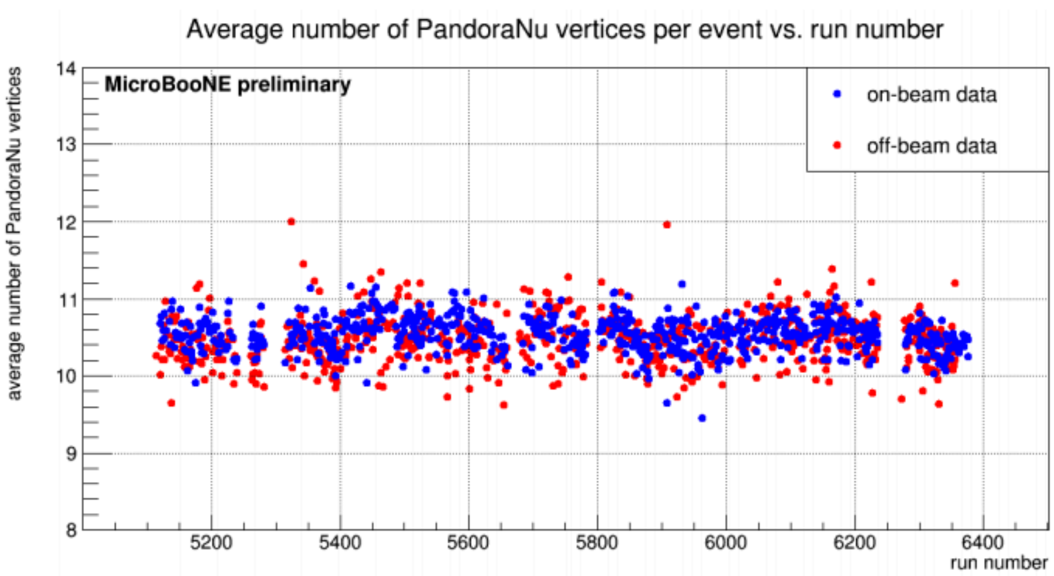


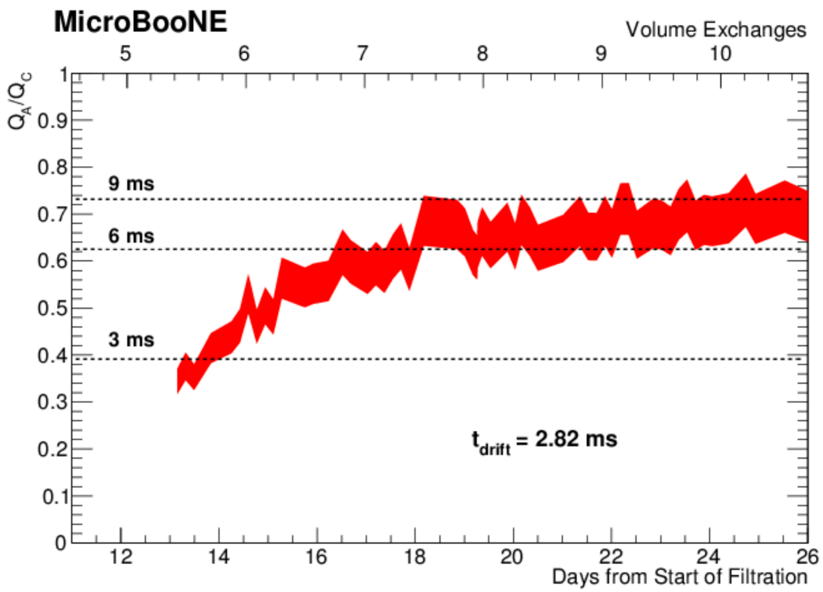
M. Hartz



Detector performance

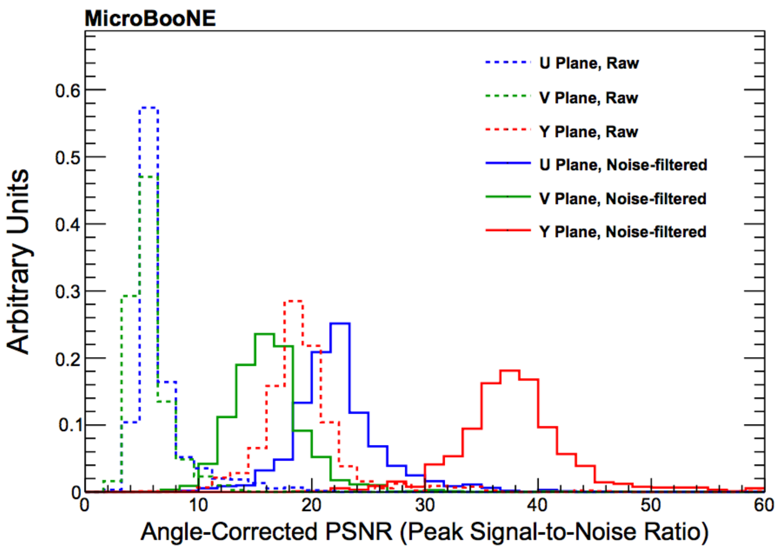
- Stable performance of TPC, readout electronics, and PMT system
- Purity stable and well above design
  - Consistently above 10 ms free electron lifetime

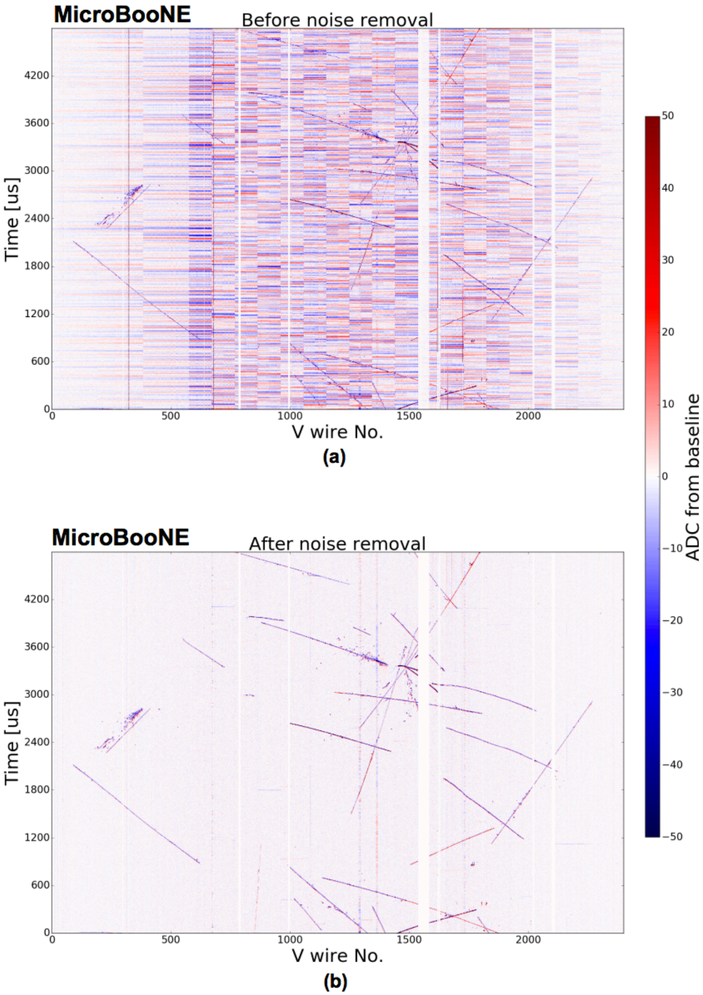




Detector noise

- Noise fully characterised
  - Filtered out in software
  - Peak S/N ratio >30!
- Added hardware filtering in summer 2016

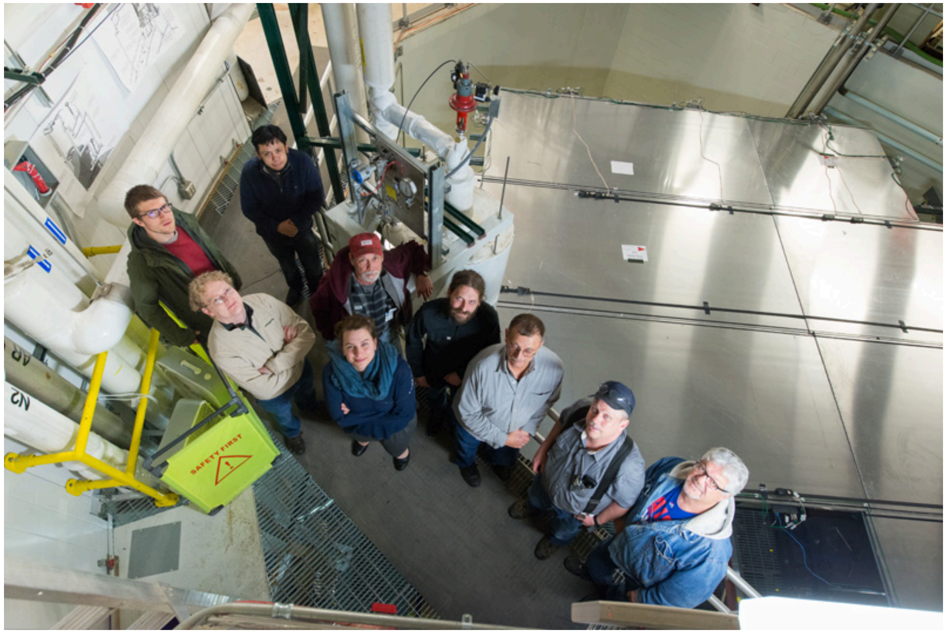


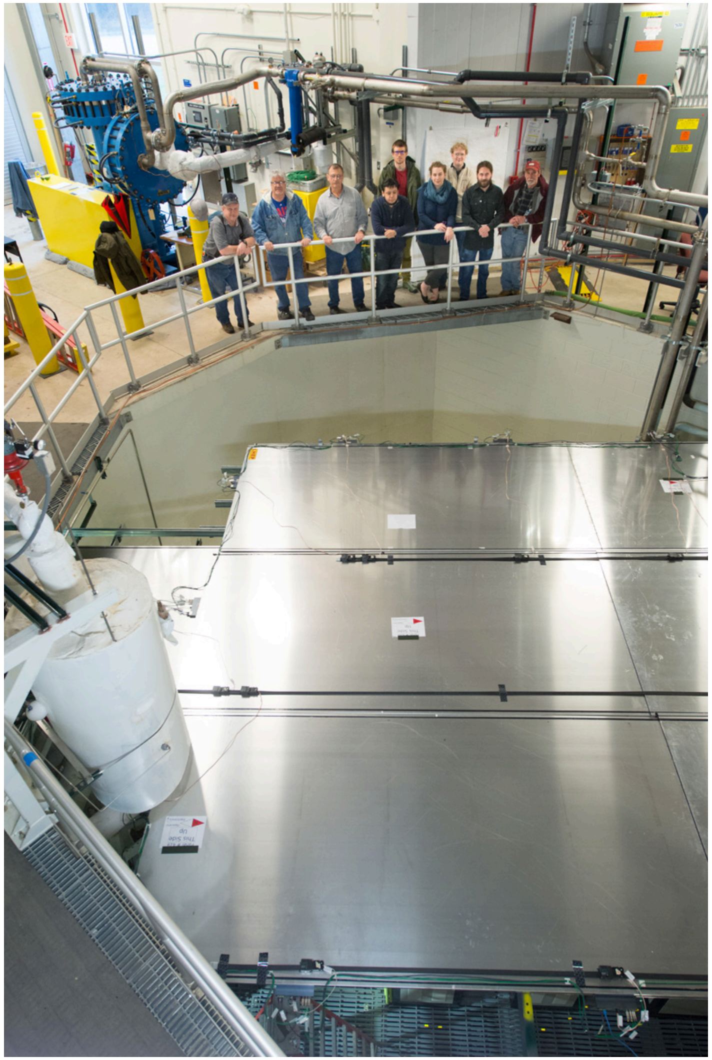


arXiv:1705.07341

Cosmic Ray Tagger

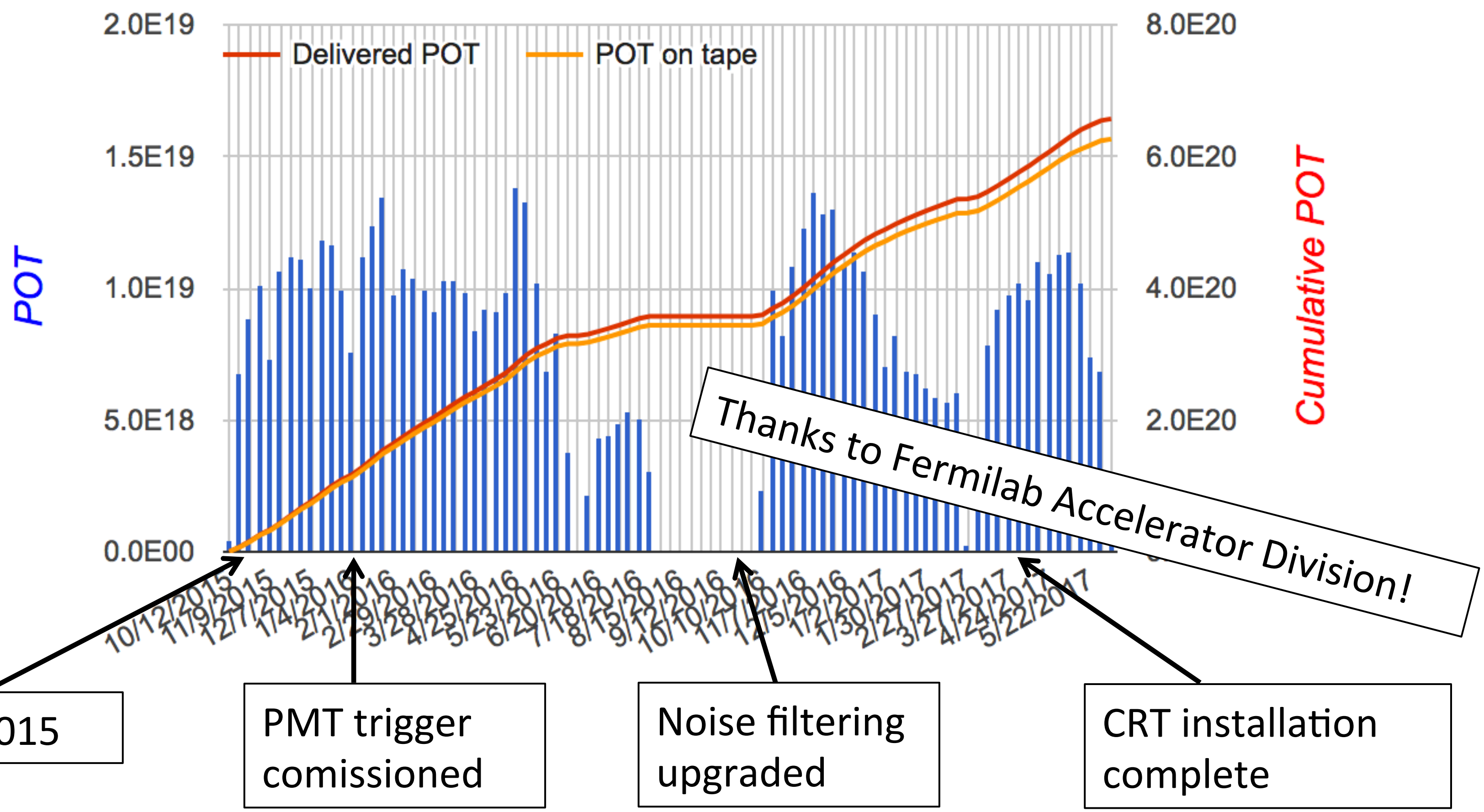
- Cosmic Ray Tagger (CRT) installed
- Phased installation over the past year
- 85% coverage





Beam Performance

- Nominal 3-year POT delivered in 2 years!
- Only 5e19 POT analysed so far

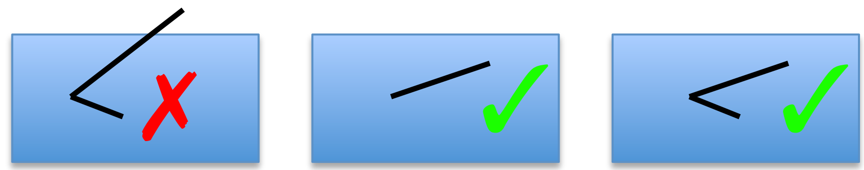


Ok, now for some physics!

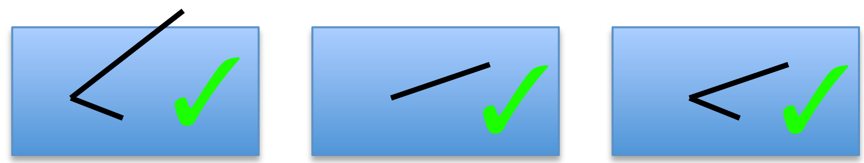
CC inclusive event selection

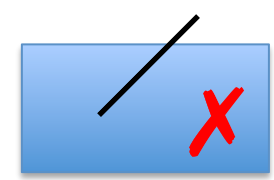
- Require **PMT activity** (>50PE) in time with the beam spill
- Then **2 selections** developed

- **Selection I:**
  - Fully contained
  - Intended to be simple

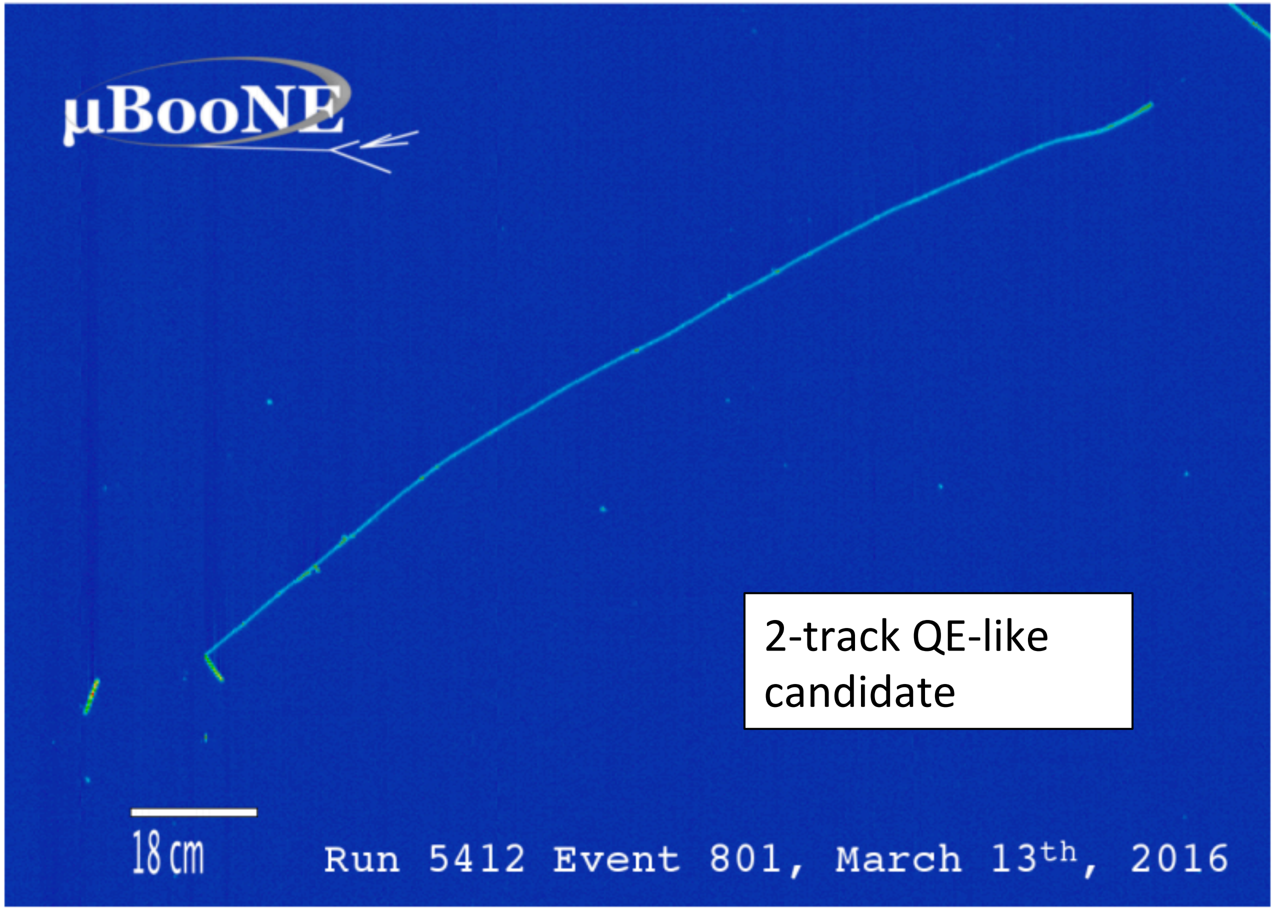


- **Selection II:**
  - Single-track contained
  - Multi-track contained
  - Multi-track uncontained
  - Intended to increase efficiency



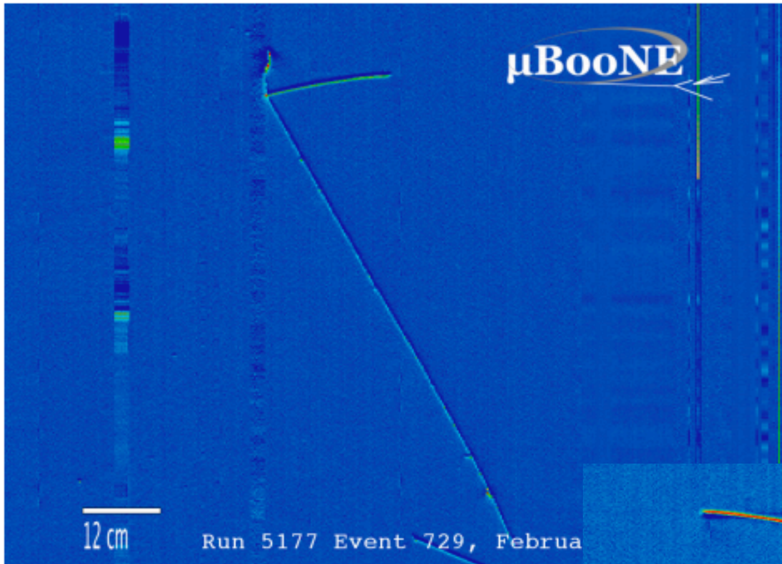


Event candidates

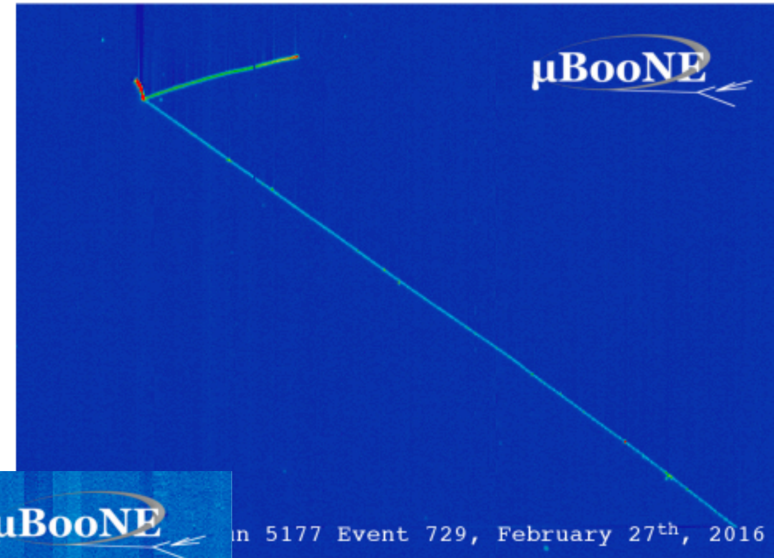


(a) Collection plane (Y)

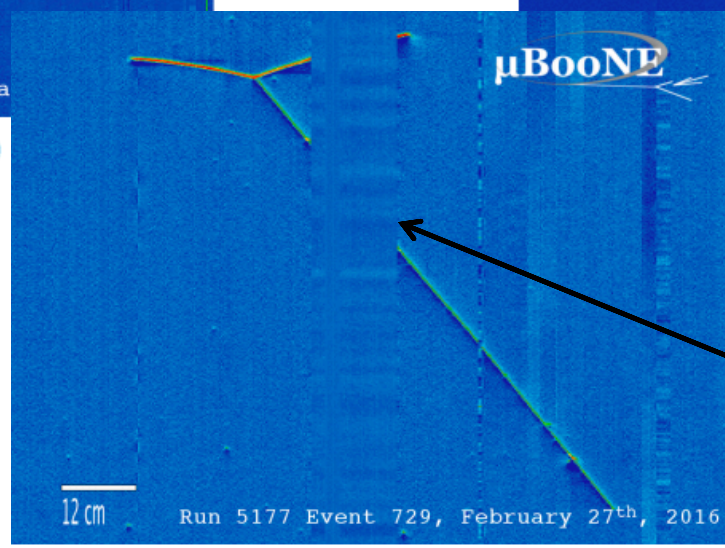
Event candidates



(e) Induction plane (V)



(a) Collection plane (Y)

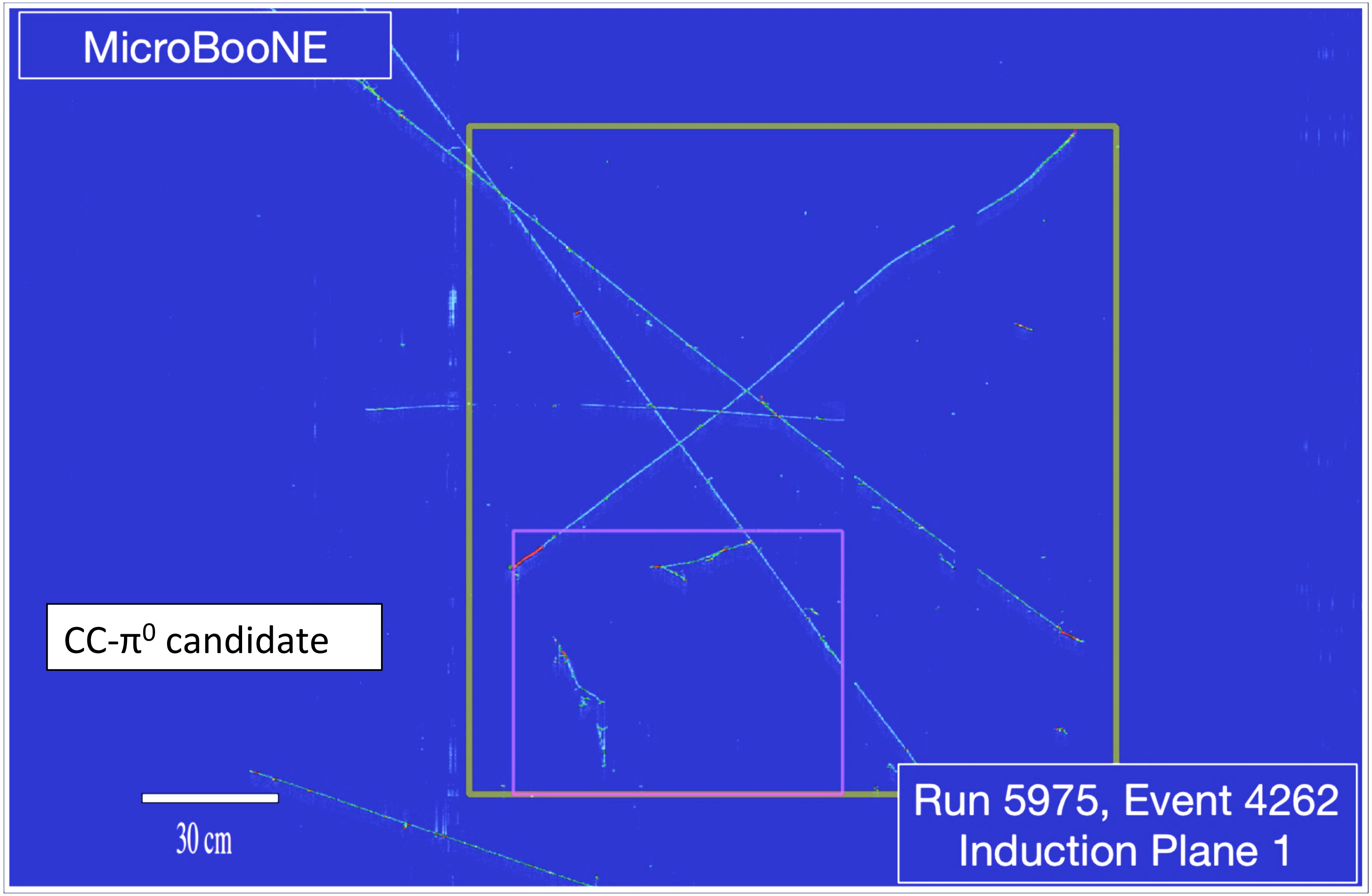


(c) Induction plane (U)

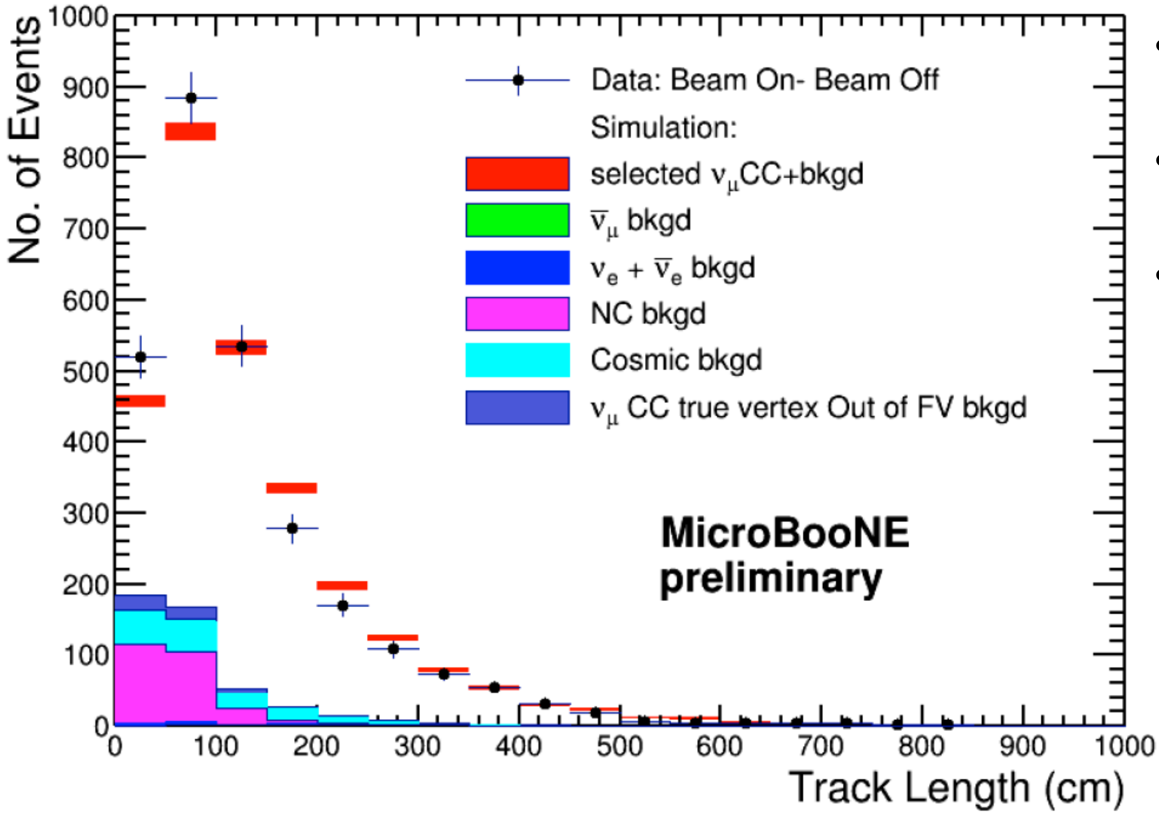
3-track RES-like candidate

Wire gaps in one plane don't matter if we can track in the other 2 planes!

Event candidates

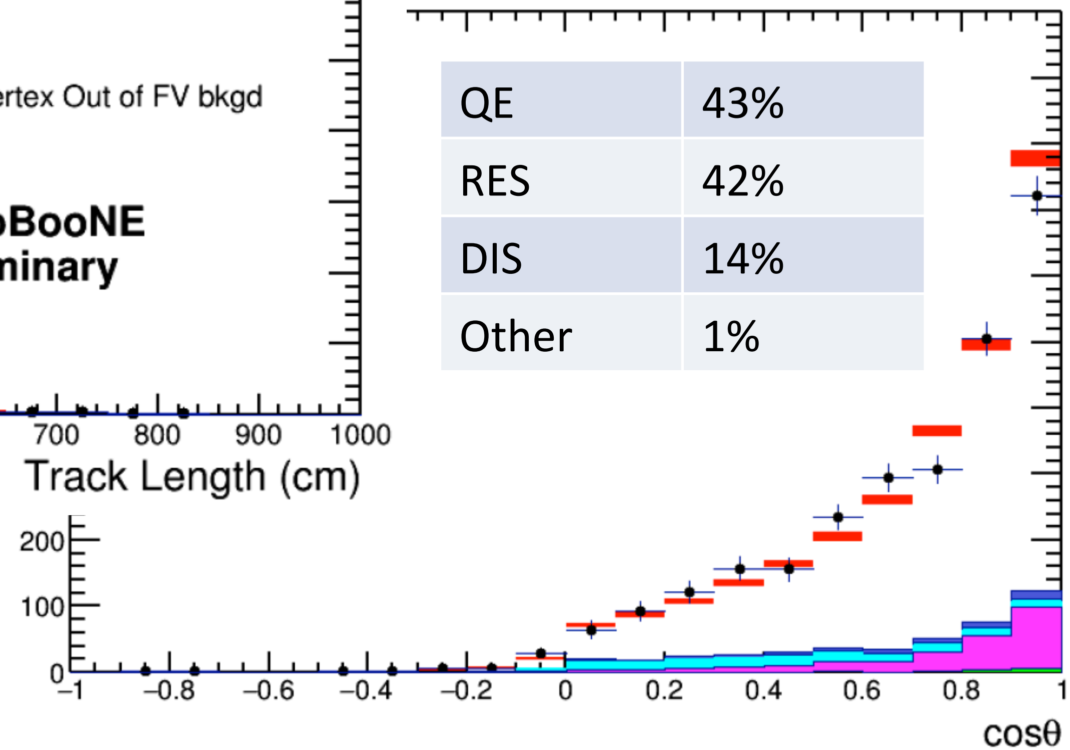


Muon Candidate Kinematics



- **Selection II shown – Selection I in backups**
- **Statistical errors only (both data and MC)**
- **MC is GENIE 2.10.0 Default**

QE	43%
RES	42%
DIS	14%
Other	1%



- **Shape-normalised event rate**
- **Track length includes contained and uncontained**

Particle Multiplicity Measurement

- Start with selection I (contained interactions)
  - No multiplicity-dependent cuts
- Additional (conservative) track/vertex quality requirements
  - Focusing on the collection plane (best S/N)
- Fit neutrino and cosmic component in 4 samples of varying purity
- Count tracks associated with vertex

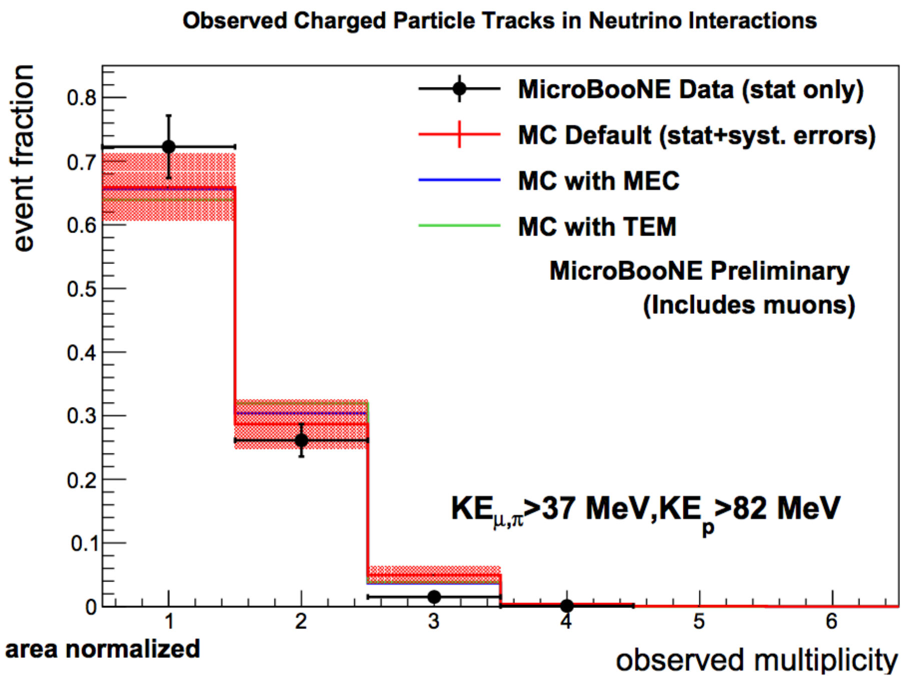
What we do

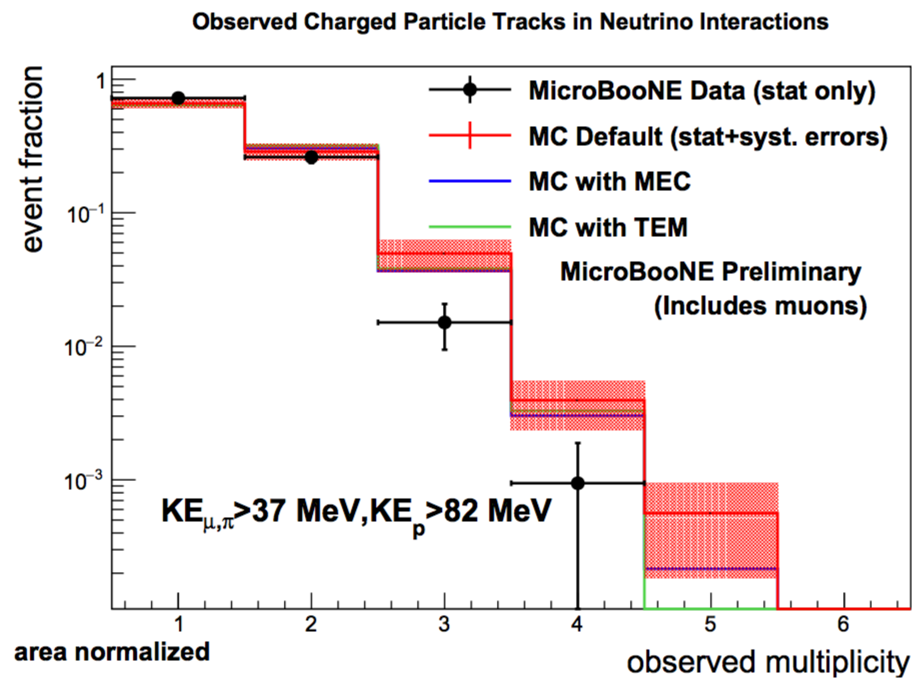
- **Do not** correct for efficiency, acceptance, missing tracks, split tracks
- **Do not** separate particle types
- **Do not** subtract background (NC, anti-nu)
- **Systematics not final**
  - Conservative estimates made for detector and beam uncertainties

What we don't do

Particle Multiplicity Results

- **Good agreement** seen with GENIE default and 2 alternate QE-like models
- **Relatively high proton threshold**
  - Interesting to see how this distribution changes as this is reduced
  - Next iteration already has a reduced proton threshold
- Statistics-limited at higher multiplicities, but can track 4 or 5 particles!





Future Inclusive Results

- Current event selections limit the phase space
  - To remove large cosmic backgrounds
  - Updated event selection uses improved **PMT-TPC matching**
  - Utilise new **Cosmic Ray Tagger**!
- Muon threshold high
  - 75cm threshold reduces $NC\pi^{+}$ backgrounds
  - **μ/π separation** in development
- Improved statistics
  - 12 times what is shown here

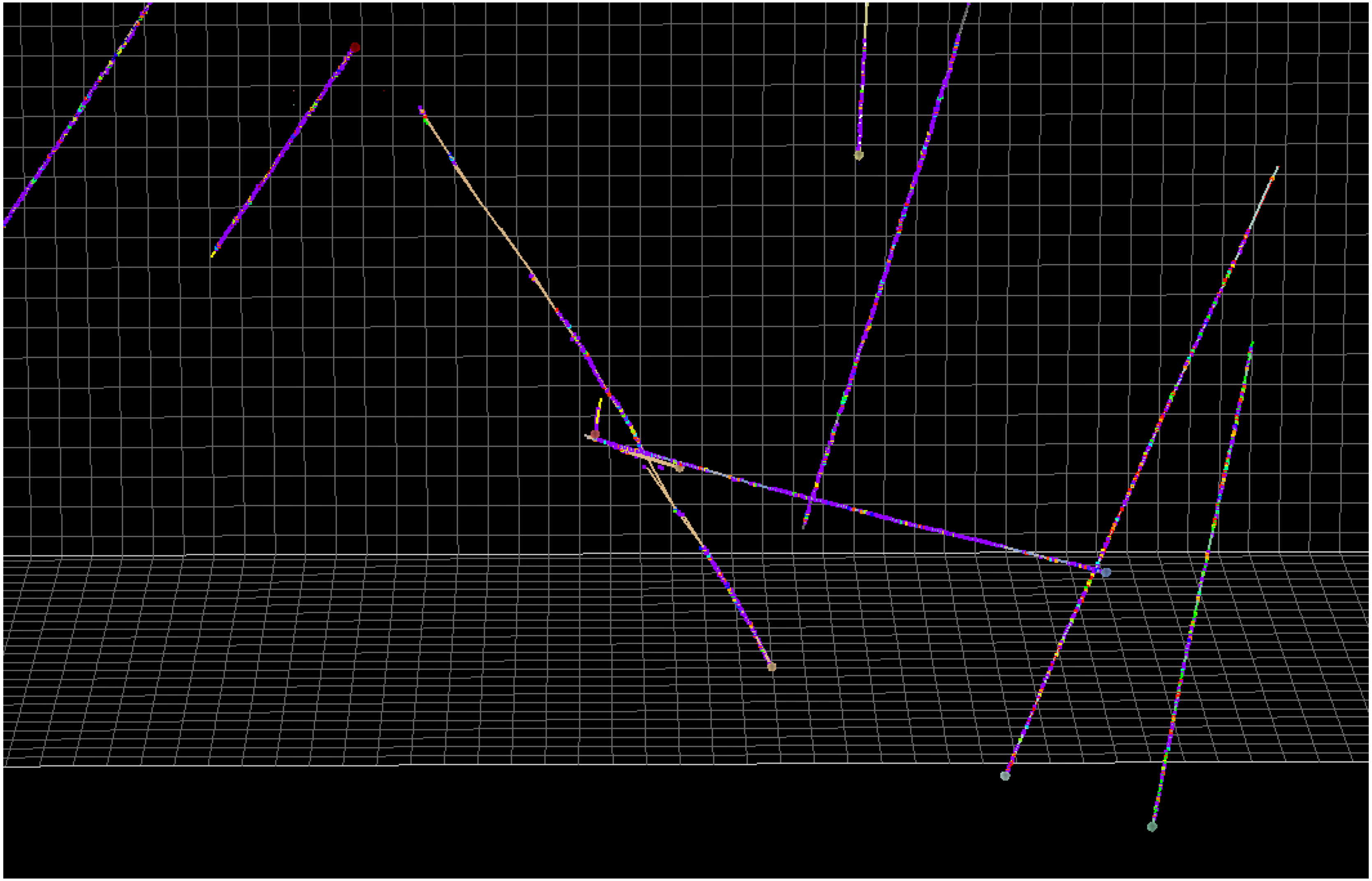
Other analyses in development

- **NC elastic (~20k events on tape)**
  - Lower threshold for proton detection than fine-grained scintillators
- **CCπ^0 (~10k events on tape)**
  - Very important for oscillation analysis
- **CC0π (~100k events on tape)**
  - 1μ1p, 1μ2p, proton multiplicity

- Watch this space!

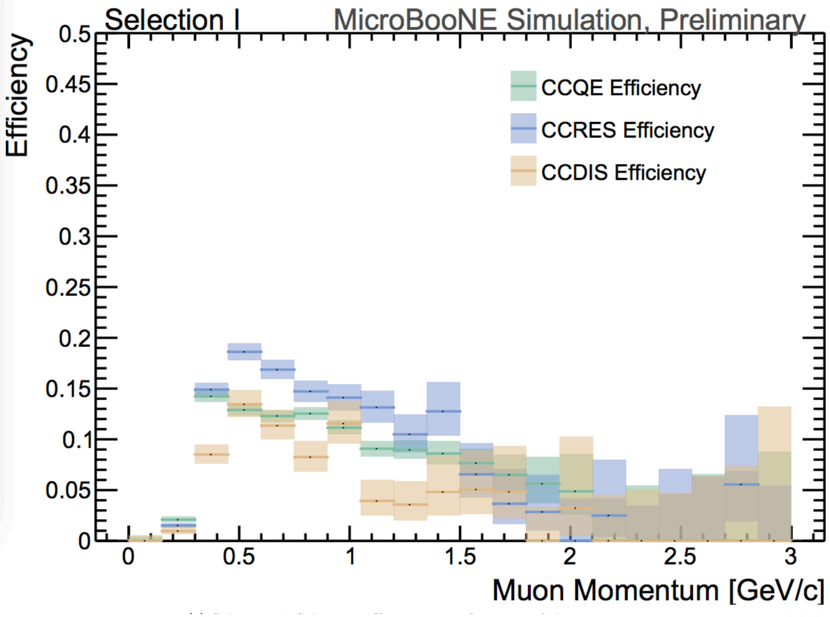
http://www-microboone.fnal.gov/publications/publicnotes/index.html

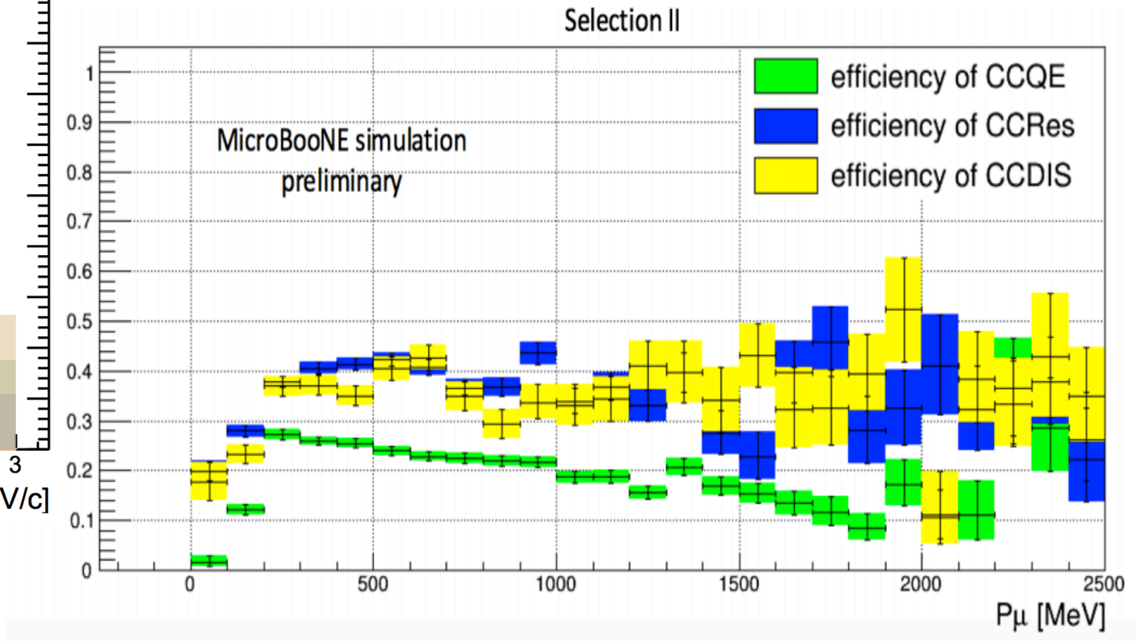
Thank you



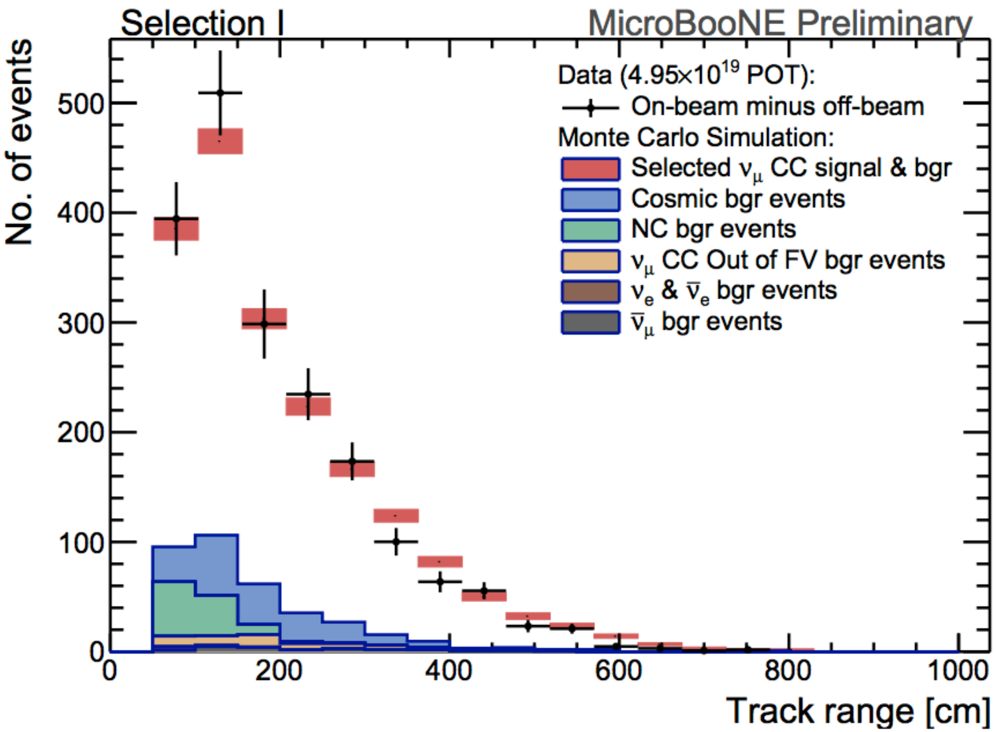
Backup slides

Efficiencies

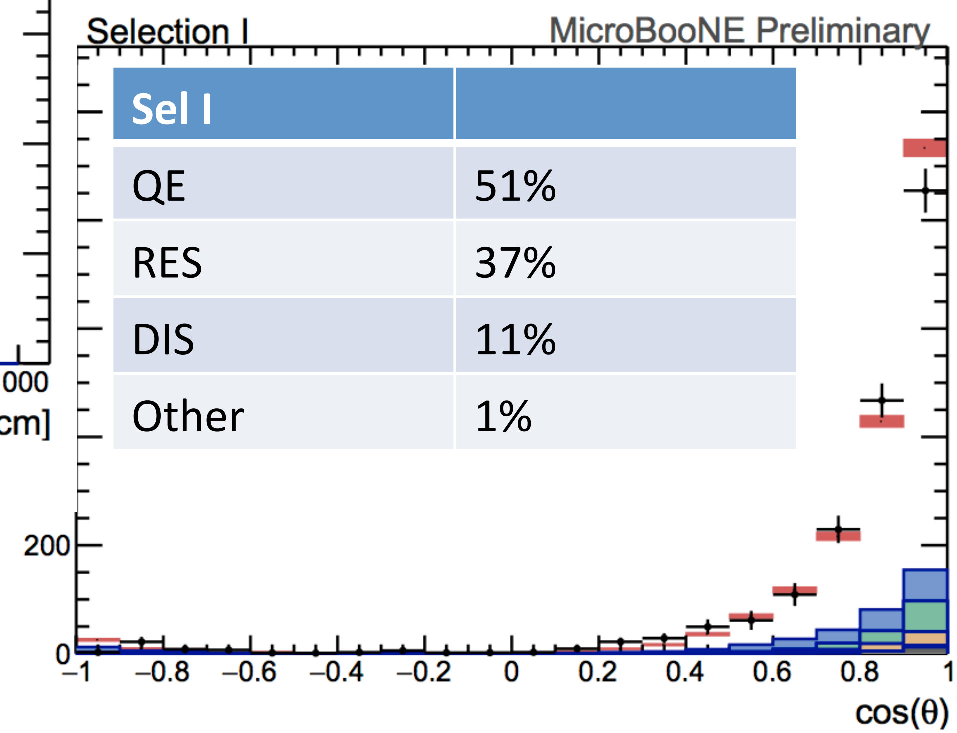




Selection I distributions



(a) Selection I



Sel I	
QE	51%
RES	37%
DIS	11%
Other	1%

(a) Selection I

CPM tests

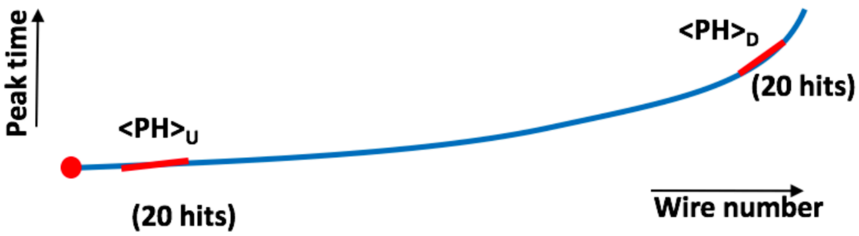


Figure 4: Diagram showing PH test for a candidate muon track.

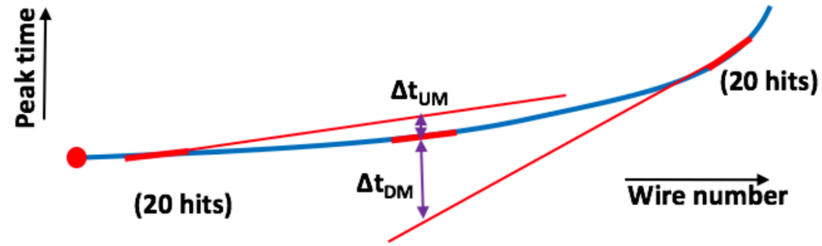
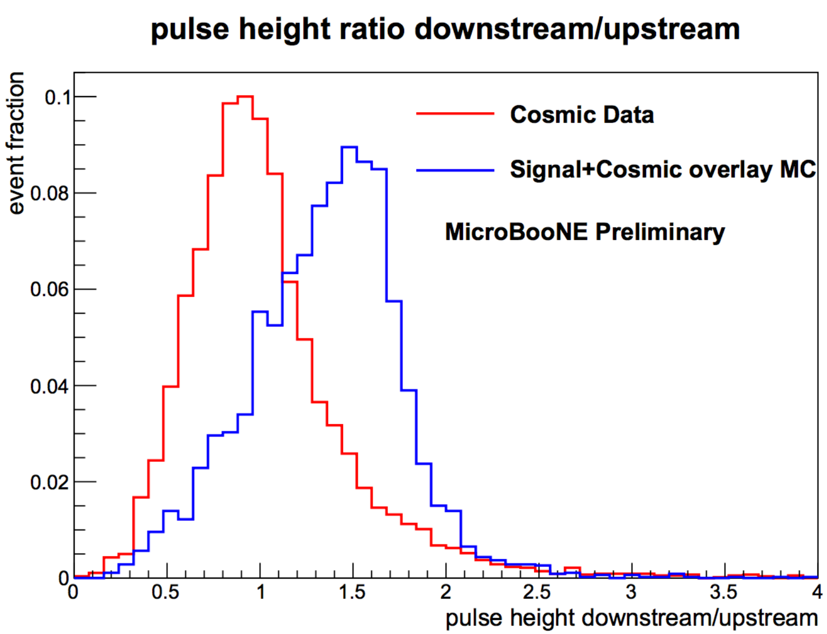
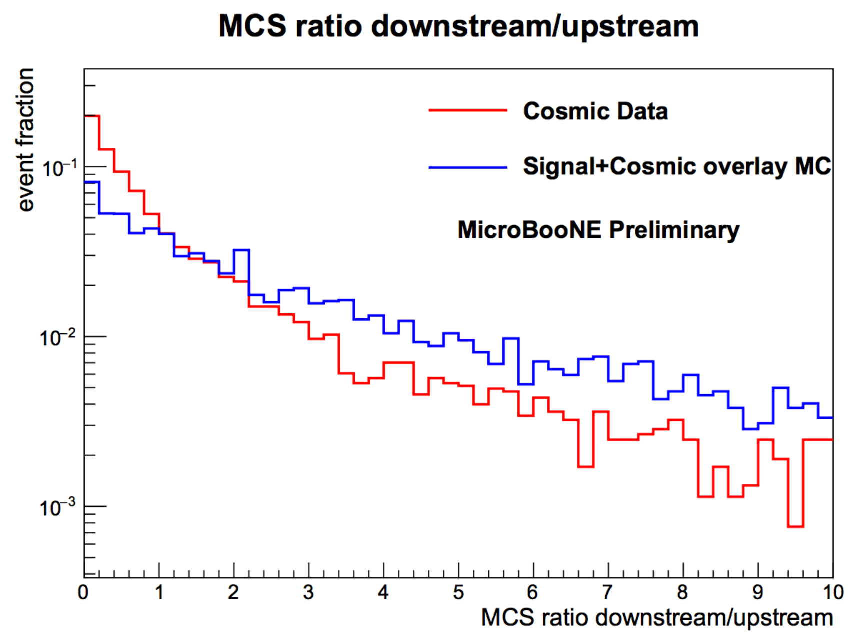


Figure 6: Diagram of MCS directionality test for a candidate muon track.





CPM fit

- Float number of neutrino and CR events in each bin
- Float probabilities of passing/failing each test
- Fit to data results in 4 categories – (P,P) (P,F) (F,P) (F,F)

	Fit Results	
Parameters	**BNB+Cosmic MC**	**MicroBooNE Data**
$\hat{N}_\nu$	3602±154	1056±169
$\hat{N}_{CR}$	607±144	865±169
$\hat{N}'_{CR}$	5267±73	5267±73
$P(PH)$	0.859±0.017	0.784±0.052
$P(MCS)$	0.775±0.012	0.732± 0.038
$Q(PH)$	0.554±0.007	0.554±0.007
$Q(MCS)$	0.544±0.007	0.544± 0.007