MICROBOONE UPDATE

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Presentation at Fall 2017 PAC Pre-Meeting
November 10, 2017

This Talk

2. MicroBooNE:

The committee is asked to comment on progress towards understanding the ultimate sensitivity of the experiment including (i) the plans for staging physics results, (ii) progress on calibrations, (iii) the impact of the realized detector performance on the ability of the experiment to measure the low-energy excess seen by MiniBooNE.

- Where are we (update from the July PAC) and our plans for getting out our next round of results …
  - Understanding the MicroBooNE detector
  - Evaluating the performance of our reconstruction
  - Understanding argon as a nucleus
  - Establishing a track record as a collaboration
  - Getting to low energy excess results in MicroBooNE*

charge question (ii) — first two items

charge question (i) — third and fourth items

charge question (iii) — fifth item

- Will submit a written document addressing questions from last time

Understanding the MicroBooNE Detector

- Noise (JINST 12, P08003 (2017))
- * TPC signals (public note #1017)
  - *two papers in preparation, >100 pages*
  - *more on this when discuss low energy excess analysis*

- * Space charge effects (public note #1018)
  - *UV laser + cosmics*
  - *moving from edge effects to understanding the bulk*
- * Electron lifetime (public notes #1003, 1026)
- Recombination
- Diffusion

the main ingredients

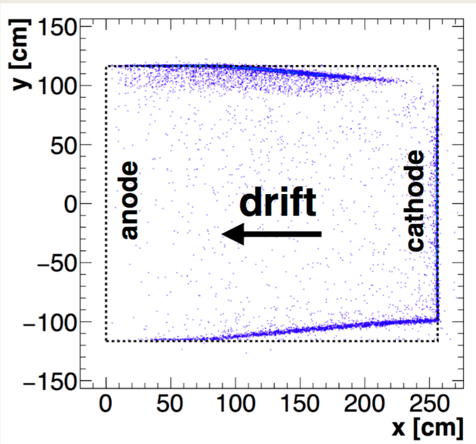
- Relative calibration
  - *Make sure detector response is uniform over space and time* (public note #1013)
- Absolute calibration
  - *Convert dQ/dx (ADC/cm) to dE/dx (MeV/cm)*

- Detector systematics
  - *evaluation of uncertainties from above measurements + analysis of special runs*

* next slides

Space Charge Effects

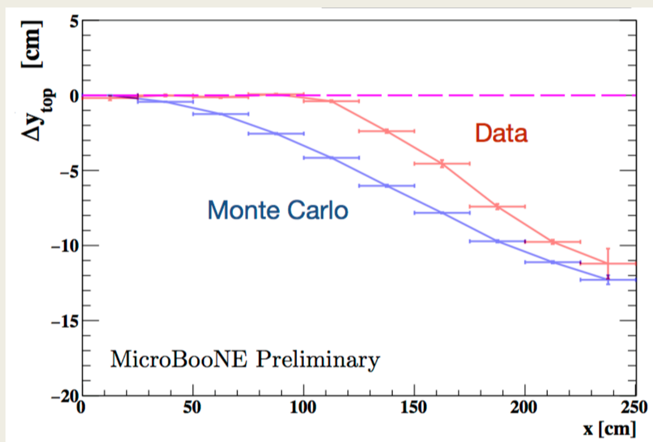
- Accumulated positive ions create a space charge effect that distort tracks in the TPC



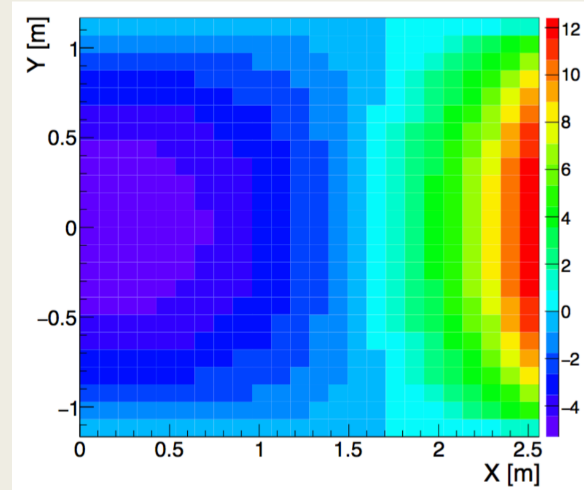
(from small muon counter)

- moving from MC estimates to data-based metrics

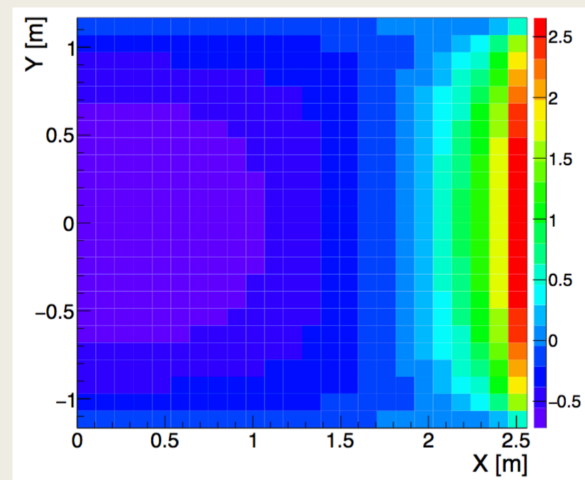
- Edge effects: anode or cathode piercing cosmics
- Bulk: UV laser and TPC crossing cosmics
- Focused effort to finalize these measurements since has impact on the broader calibration program



end of the TPC:

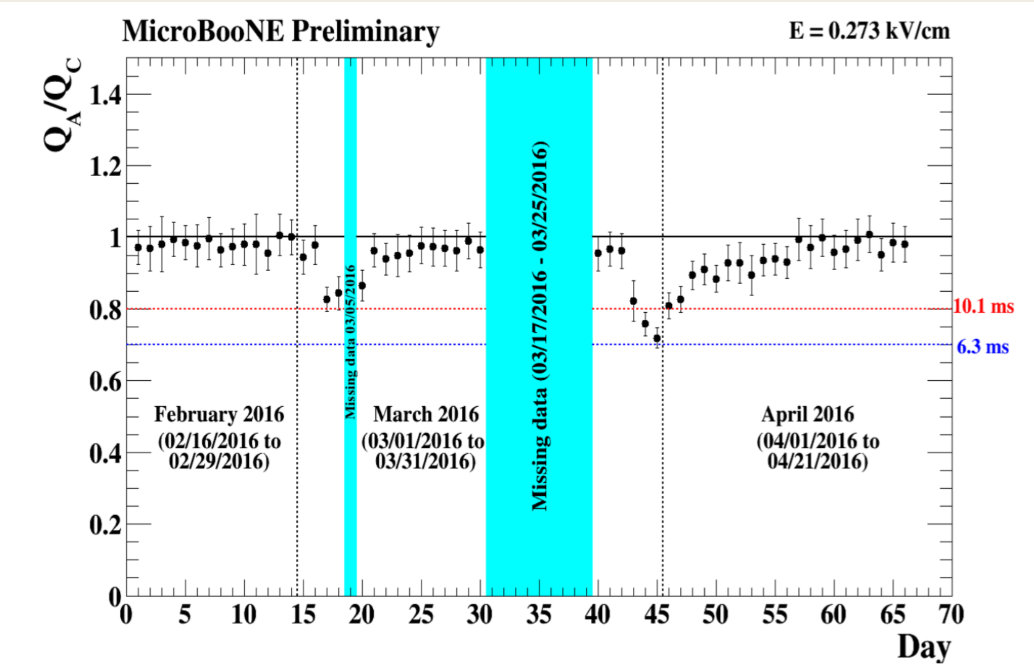


central slice in z:



MicroBooNE public note #1018

Argon Purity (new since the last PAC meeting)



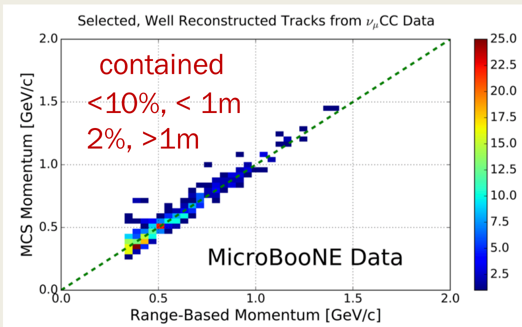
MicroBooNE public note #1026
(DPF 2017)

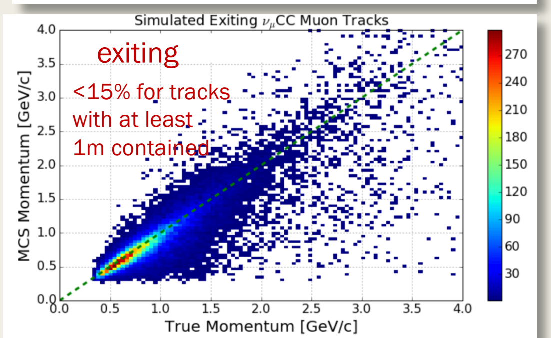
- Measure the argon purity using TPC-crossing cosmic ray μ tracks that have a known start time (t_0)
  - *(public note #1028)*
  - *protoDUNE*
- Measured electron lifetime is > 18 ms, < 17 ppt O_2 at 70 kV
  - *Design: > 3 ms, < 100 ppt O_2 at 128 kV*
  - *Dominant systematics on QA/QC: 5% space charge effects, 2% diffusion, 1% recombination (public note #1026)*
- Analysis is also run in real-time and purity trends logged in e-log
- Argon purity is not an issue in MicroBooNE

Understanding our Reconstruction

(new since the last PAC meeting)

- Improved tuning of MCS parameters for argon
- Important for exiting muons



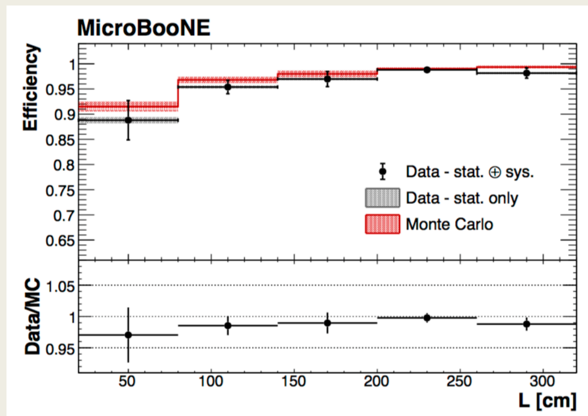


JINST 12, P10010 (2017)

- Muon track identification using small μ counter system

ε_{data} = (97.1 +/- 0.1 (stat) +/- 1.4 (syst))%
ε_{MC} = (97.4 +/- 0.1)%

- Plan to repeat with full CRT

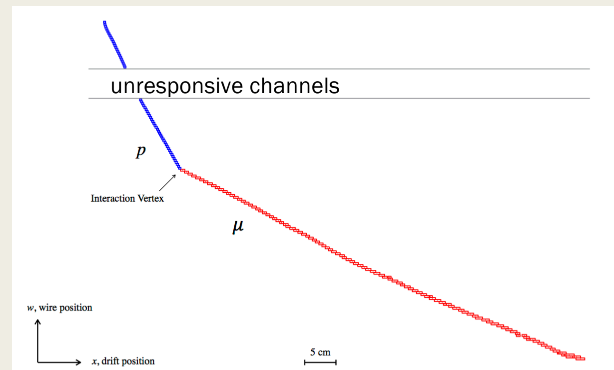


arXiv:1707.09903, submitted to JINST

- Pandora reconstruction performance (gaps, CRs)

  1p, Np, π^+, π^0, 1γ final states

- Used by many of our σ_ν analyses



#Matched Particles	0	1	2	3+
μ	1.3%	95.8%	2.9%	0.1%
p	8.9%	87.3%	3.6%	0.2%

arXiv:1708.03135 submitted to Eur. Phys. J. C.

Understanding Argon as a Nucleus

- This is critical given that we are studying ν_e interactions in a E_ν range (~few 100 MeV) and on a nucleus (argon) that together have not been previously scrutinized
  - *GENIE tuned to external data (lots of new measurements, mostly carbon-based)*
  - *MicroBooNE ν_μ analyses in argon*
  - *Provide crucial constraints for our low energy excess search*

CC inclusive	CC 0π	CC π	CC kaons	NC	ν_e's

CC inclusive

- ν_μ CC inclusive
  Marco Del Tutto (Oxford)
  Anne Schukraft (FNAL)
  public notes #1004, 1010
- charged track multiplicities
  Aleena Rafique (KSU)
  public note #1024
- μ/π^+ separation
  Jessica Esquivel (Syracuse)

CC 0π

- ν_μ 1μ+1p
  Erez Cohen (Tel Aviv)
- ν_μ 1μ+2p
  Raquel Castillo Fernandez (FNAL)
- ν_μ 1μ+Np
  Libo Jiang (UPitt)
- improved proton reconstruction & calorimetry
  Adam Lister (Lancaster)
  Simone Marcocci (FNAL)
  Joris Jan de Vries (Cambridge)

CC π

- ν_μ 1μ+1π^0
  David Caratelli (Columbia)
  Ariana Hackenburg (Yale)
  Joseph Zennamo (UChicago)
  public note #1012
- ν_μ 1μ+1π^+
  Danny Devitt (Lancaster)
  Kirsty Duffy (FNAL)
  Ilker Parmaksiz (UT Arlington)

CC kaons

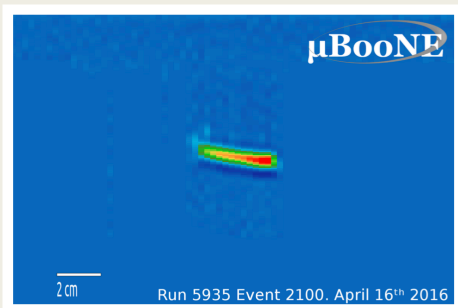
- ν_μ K^+
  Elena Gramellini (Yale)
  Varuna Meddage (KSU)

NC

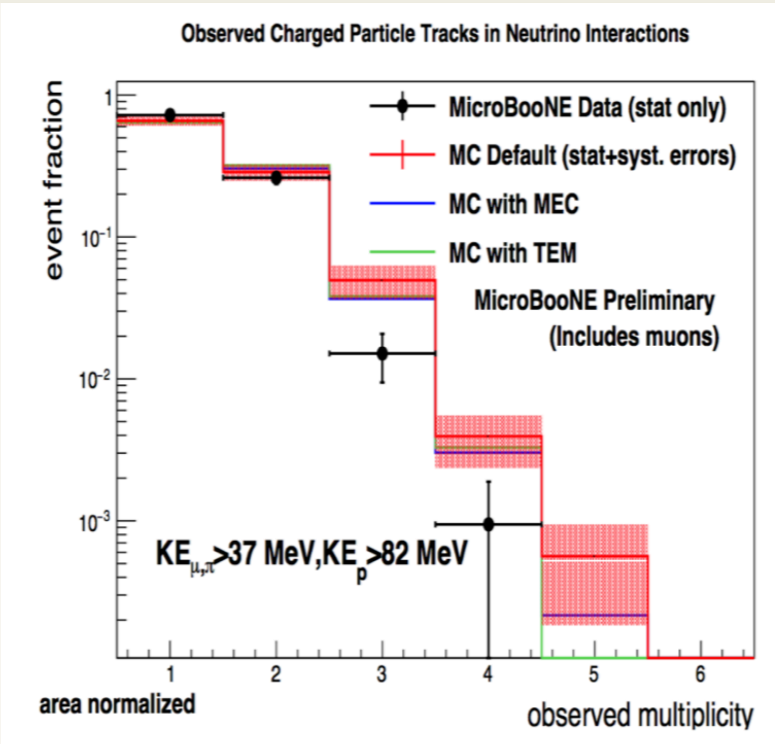
- NC elastic
  Katherine Woodruff (NMSU)
  public note #1025

ν_e's

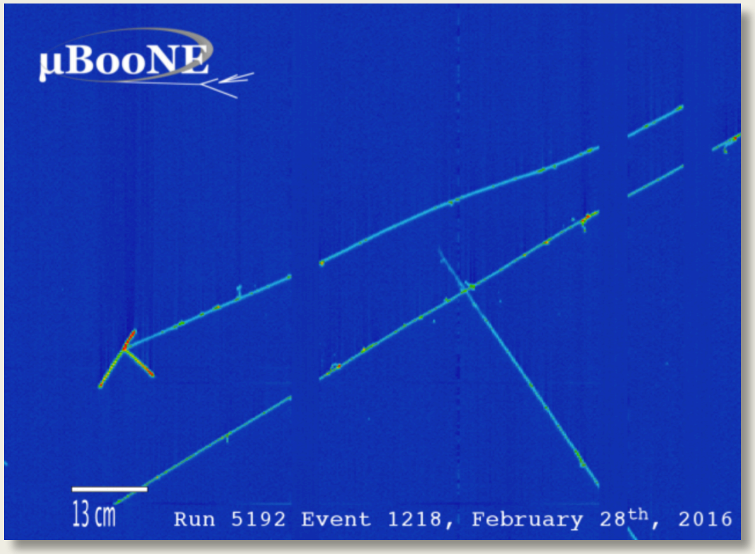
- ν_e CC inclusive in NuMI
  Colton Hill (Manchester)



Charged Track Multiplicities



MicroBooNE public note #1024



- First measurement of charged track multiplicities in ν_μ CC interactions in argon
  - Showcases the technology
  - Provides a stringent test of models
- Paper currently under collaboration review provides a first detailed look at how well GENIE predicts ν scattering in argon for a variety of kinematic distributions

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    } charge question (ii)
  - ✓ Understanding argon as a nucleus
  - Establishing a track record as a collaboration
    } charge question (i)
  - Getting to low energy excess results in MicroBooNE* } charge question (iii)
- Will submit a written document addressing questions from last time

Establishing a Track Record

- In our first year of operations, MicroBooNE produced 15 public notes
- In 2017, MicroBooNE has produced 7 papers so far:
  - *(1) Detector paper, JINST 12, P02017 (2017)*
  - *(2) CNN for neutrino/cosmic separation, JINST 12, P03011 (2017)*
  - *(3) Muon multiple Coulomb scattering in argon, JINST 12, P10010 (2017) → now published*
  - *(4) Michel electrons, JINST 12, P09014 (2017) → now published*
  - *(5) Noise sources and mitigation, JINST 12, P08003 (2017) → now published*
  - *(6) Muon track identification, submitted to JINST → new since last PAC*
  - *(7) Pandora reconstruction and PID, submitted to Eur. Phys. J. C. → new since last PAC*
- Have 9 more papers in the pipeline …
  - *(1) Charged track multiplicities in ν_μ CC interactions → first draft in collaboration review*
  - *(2) Signal processing (2 papers) → first draft in collaboration review*
  - *(3) MicroBooNE flux prediction*
  - *(4) SSNet for shower/track separation*
  - *(5) CNN optimization for PID*
  - *(6) Analysis of ν_μ CC π^0 interactions in argon*
  - *(7) Study of ν_μ CC 0π interactions and improved E_ν determination*
  - *(8) Supernova readout stream*

Pipeline

- We are a well-oiled machine at this point …
- Multiple analyses have been reviewed and are presently under review
  - We have an incredible amount of documentation, much of which we are releasing as public notes
- Results must go through multiple layers of approval
  - Work starts in a working group
  - 46 senior members (3/4) of the collaboration have been members of Editorial Boards

webpage of MicroBooNE analyses:

#	Analysis	Group	Analysis Contact	EB	Date created	Internal note	Public Note	Bi-weekly	Paper draft	Publication
1036	CNN optimization for PID	AT	Ariana, Eric, Kazu, Kevin	Kirby, Glenn	Oct 2017	1036-INT	1036-PUB	DocDB-11933		
1035	SSNet for track shower separation	AT	Kazu, Taritree, Vic	Eric, Giuseppe	Oct 2017	1035-INT		DocDB-11933	DocDB-10745	
1033	Signal processing and performance in simulaiton	Det. Phys.	Brooke, Hanyo	Igor, Leon	Oct 2017	see 1017		DocDB-12242	DocDB-11861	
1032	CCpi0 cross section	Det. Phys.	Joseph, Ariana	Jonathan, Donna, TBD	Oct 2017	1032-INT	1032-PUB	DocDB-11690		
1028	t0 from anode/cathode piercing tracks	Calib	Chris B., David C.	Tracy, Bryce	Dec 2016	DocDB-6829	DocDB-6825			
1027	Pi0 peak	Osc	Ariana H., David C.	Leslie, Jonathan, Randy	Dec 2016	DocDB-6866	Note-1027-PUB			
1026	Lifetime	Det. Phys.	Varuna, Sowjanya	Xin, Donna, Leon	Dec 2016	DocDB-[illegible]23	DocDB-58[illegible]			
1025	NC elastic / proton	Xsec	Katherine	Sowjanya, Josh, Tim	Nov 2016	DocDB-588[illegible]	DocDB-6[illegible]1			
1024	Charged Particle Track Multiplicity	Xsec	Aleena	Tingjun, Steve D, Georgia	Nov 2016	DocDB-6821	DocDB-7108	DocDB-9731	PRD(tbc) / DocDB-11153	
1023	Multiple Coulomb Scattering	Xsec	David K., Polina A.	Igor, Bruce, Camillo	Nov 2016	DocDB-6741	no PUB		JINST / DocDB-6741	arxiv:1708.03135 JINST 12, P10010 (2017)
1021	Use of MuCS tagged tracks for tracking efficiency studies	Det. Phys.	Roberto S.	Andy B., Vassili	Sep 2016	DocDB-5975	no PUB		JINST / DocDB-7626	arxiv:1707.09903 Submitted to JINST
1019	Particle ID and neutrino identification with Deep Learning (CNN)	Osc	Kazu, Taritree	Brett, Panagiotis	May 2016	DocDB-5855	DocDB-5905		JINST / DocDB-6376	arxiv:1611.05531 JINST 12, P03011 (2017)
1018	Space charge measurement from cosmic muons	Det. Phys.	Mike M	Kirk, Craig, Nathaniel	May 2016	DocDB-5860	DocDB-5860		Expected 2018	

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1017	TPC signal processing	Det. Phys.	Xin	Igor, Richard	May 2016	DocDB-5808	DocDB-5808		1033/1034	
1016	TPC noise filtering	Det. Phys.	Jyoti	Mark C, Byron	May 2016	DocDB-5854	DocDB-5854		JINST / DocDB-7318	arxiv:1705.07341 JINST 12, P08003 (2017)
1015	Pandora reconstruction in uB	Reco	John M	Bruce, Leon	May 2016	DocDB-5828	DocDB-5987		EPJC / DocDB-7561	arxiv:1708.03135 Submitted to EPJC
1014	Reconstructed cosmic data/MC comparison	Reco	Adam L, Danny D	Eric, Cat	May 2016	DocDB-5849	DocDB-5989			
1013	Detector stability for 5E19 POT	Analysis To[illegible]	Aleena	Steve W, Stephen P	May 2016	DocDB-5850	DocDB-5986			
1012	Reco[illegible]structing golde[illegible] Pi0	[illegible]sc	[illegible]oseph Z	Leslie, Jonathan, Randy	May 2016	DocDB-5864	DocDB-5864			
[illegible]11	[illegible]m ti[illegible]g	[illegible]eam	T[illegible]arko et al.	Alberto M, Mary B.	Mar 2016	DocDB-4984	Note #1011			
101[illegible]	First Nu[illegible]C distributions [illegible]n data	Xsec	Anne S.	Xin Q., Mike S.	Feb 2016	DocDB-5851	DocDB-5982			
1009	Drift speed measurement with UV laser data (for APS)	Det. Phys.	Joseph Z.	Bruce B., Mike M.	Mar 2016	DocDB-5509	DocDB-5509			
1008	Michel electron spectrum	Det. Phys.	David C.	Gerry G., Roxanne G.	Feb 2016	DocDB-5486	DocDB-5579		JINST / DocDB-6813	arxiv:1704.02927 JINST 12, P09014 (2017)
1006	NC Pi0 event selection study (for APS 2016)	Xsec	Ryan G.	Leslie C., Jonathan A.	Feb 2016	DocDB-5510	DocDB-5580			
1005	Cosmic ray studies in MicroBooNE	"Overburden" task force	Sowjanya G.	Georgia K., Donna N.	Dec 2015	DocDB-4231	DocDB-5211			
1004	Numu CC inclusive cross section study based on simulation	Xsec	Anne S.	Xin Q., Mike S.	Oct 2015		1004 / DocDB-4994			
1003	Electronegative concentration and electron lifetime		Ben C., M. Zuckerbrot	Josh S, Brian R.	Sept 2015	DocDB-4823	DocDB-4928			
1002	First neutrino events	Reco	Anne S., Andy F.	Dave S., Andrzej	Sept 2015	DocDB-4874	DocDB-4903			
	Nucleon Decay	APE	Elena G.	Jen R., Eric C.	Aug 2015		DocDB-4765			
1001	Noise vs. Fill Level	Commissioning	David C.	Bryce L., Vittorio P.	July 2015		DocDB-4717			

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Getting to a Low Energy Excess Result

Common tools

- Data Quality
- Calibration
- MC simulation
- Data/MC production
- Systematic Errors
- Final fits

Pandora

Deep Learning

Wire Cell

TrajCluster

Different paradigms are complimentary

- Different approaches with respect to
  - Neutrino channel
  - Energy range
  - Reconstruction techniques
  - General approach to analysis

→ Efficiencies and Purities

- Comparison of “targets”: consistency check and motivational

Cross section measurements using these paradigms underscore credibility of LEE results

Cross-check with MiniBooNE data collected concurrently with MicroBooNE running

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Common tools

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Targets: consistency check and motivational
Evaluated with open data sets (ie: 5E19 now)

- Vertex reconstruction precision
- Track and shower reconstruction precision
- e/γ separation (dE/dx plot)
- π^0 mass peak for shower energy calibration
- ν_μ CC inclusive and 1μNp event rates
    - data/MC comparisons
    - Constraint of ν_e intrinsics
    - Uncertainties of nuclear effects on Argon
- ν_e selection (efficiency)
- Background rejection (purity)

- Error budget on signal and background

Getting to a Low Energy Excess Result

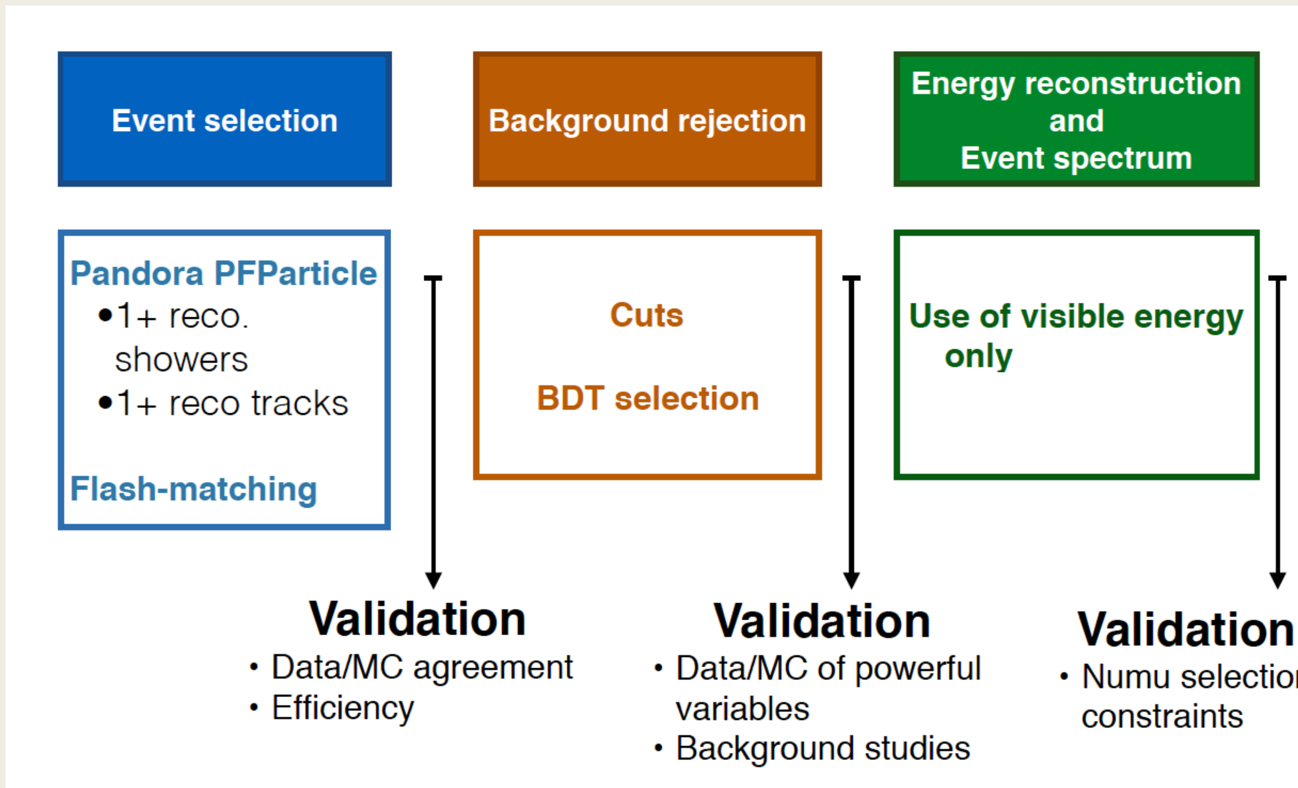
Pandora

Evaluating $1\ell Np$ across broad energy range

N determined by maximizing sensitivity

Push analysis through to end then refine where needed

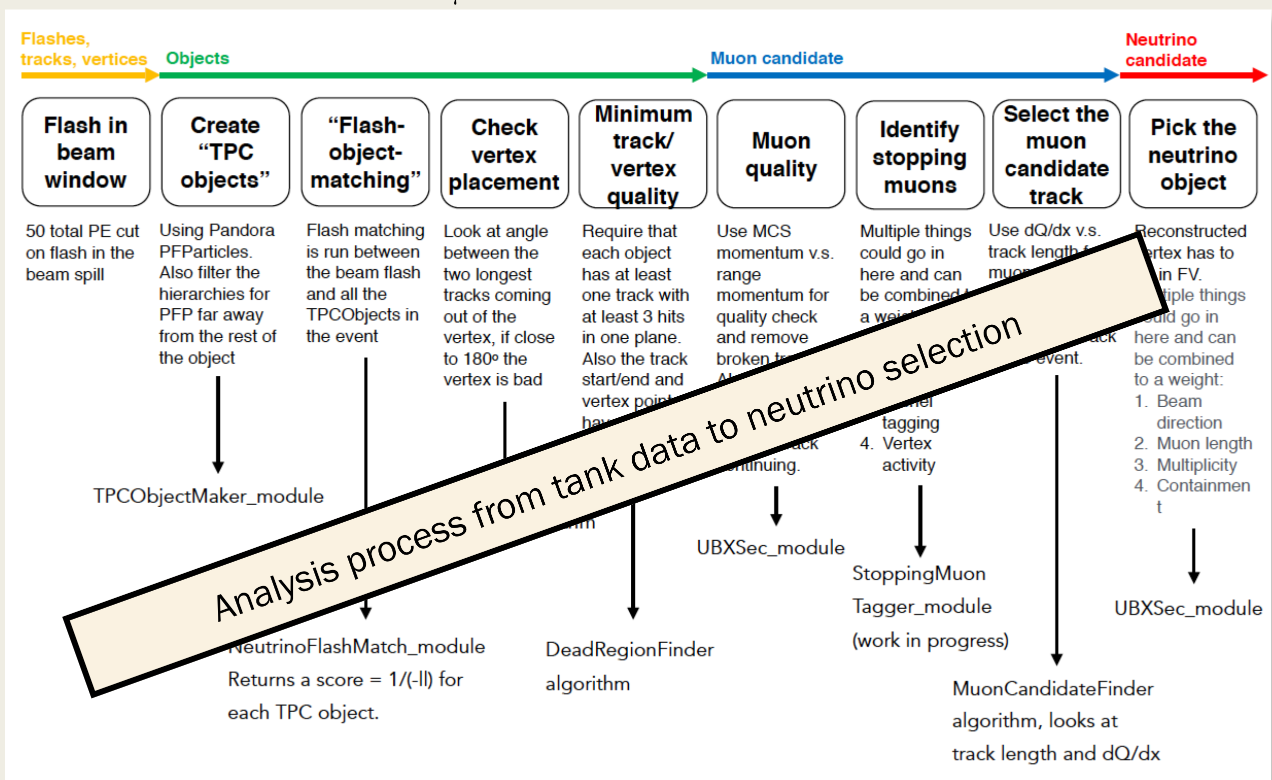
Use Pandora toolset for reconstruction



Getting to a Low Energy Excess Result

Pandora

ν_μ CC inclusive



Pandora PID and reconstruction, submitted to Eur. Phys. J. C.

Getting to a Low Energy Excess Result

Deep Learning

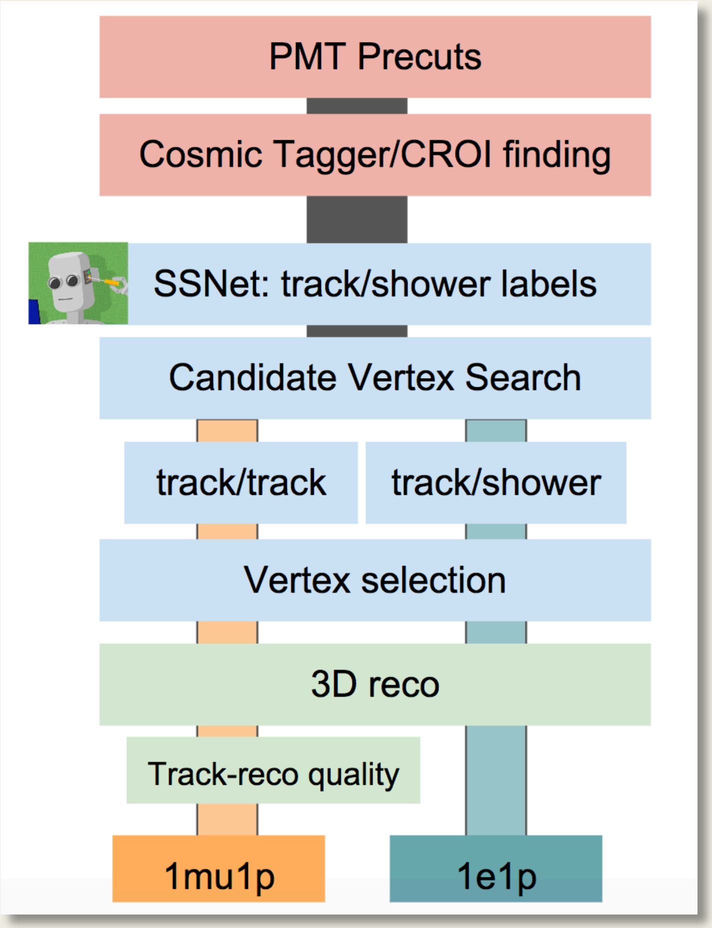
Focus on $1\ell1p$ maximizing efficiency below 600 MeV but retaining efficiency above this

Mostly "traditional" reconstruction

CNN's used for pixel ID as tracks or showers and for particle ID once constituent particles have been identified

Push analysis through to end then refine where needed

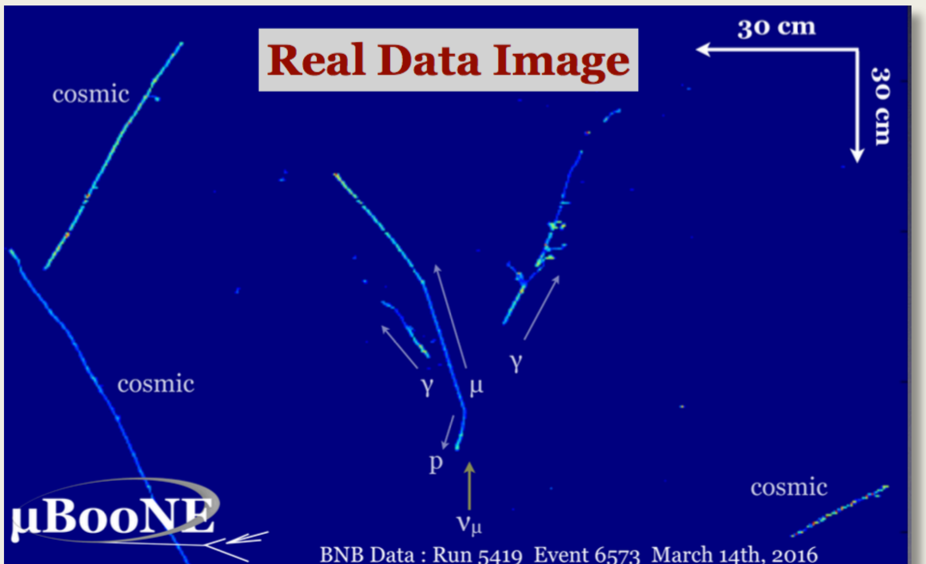
- *CNN neutrino/cosmic separation: JINST 12, P03011 (2017)*
- *SSNet for shower/track separation: in preparation*
- *CNN optimization for PID: in preparation*

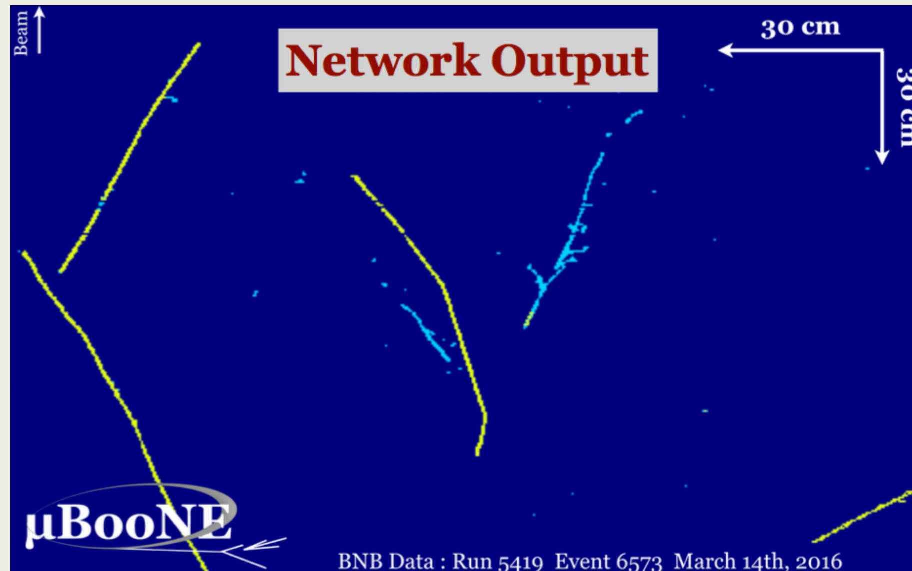


Getting to a Low Energy Excess Result

Deep Learning

CNN classifies pixels as track-like or shower-like
→ within cluster can separately ID track like segments vs shower like segments



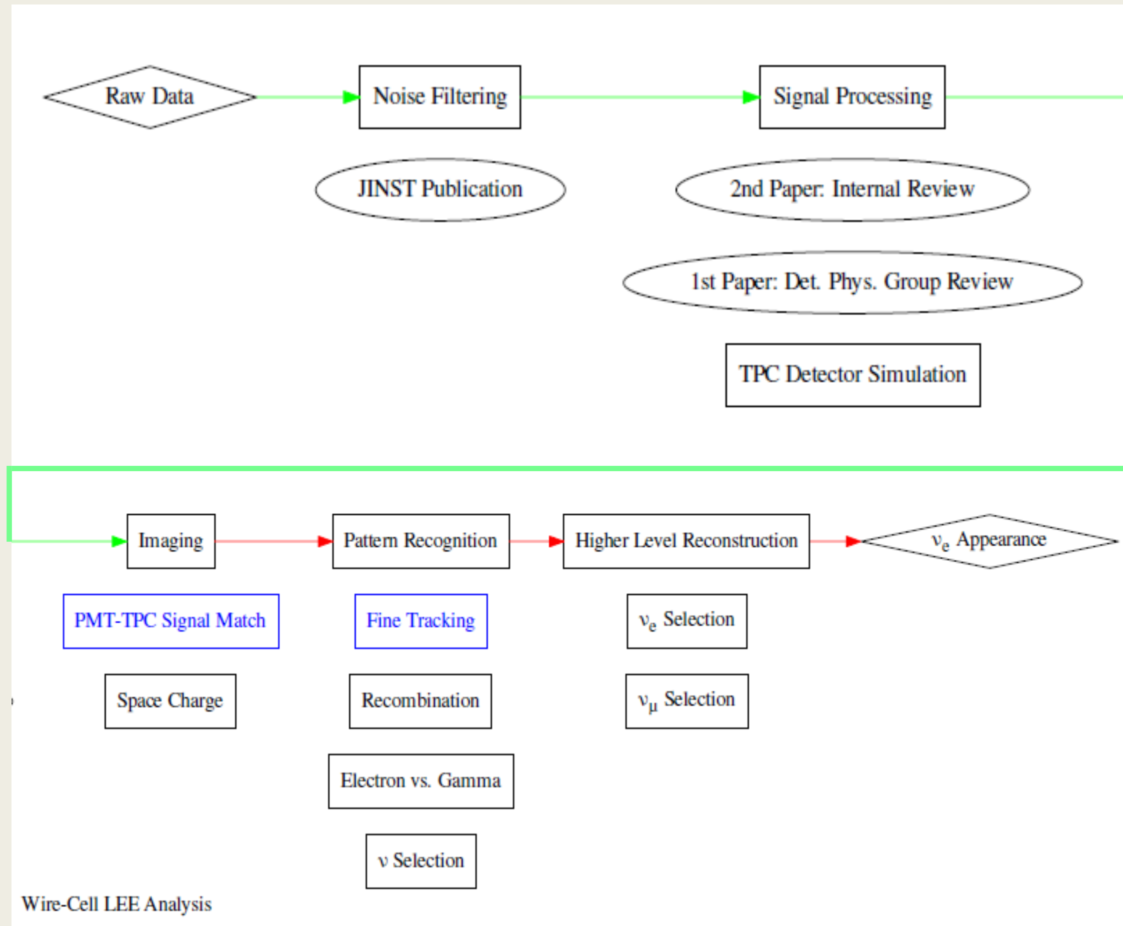


Getting to a Low Energy Excess Result

Wire Cell

- Analysis of raw data through signal processing with 2D deconvolution to recover ionization charge
- Use charge matching to reconstruct 3D images independent of event topology (from "wire" to "cell")
- Downstream reconstruction and PID benefit

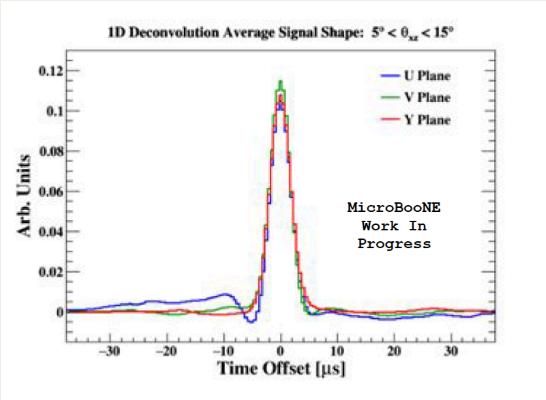
- *Noise sources and mitigation, JINST 12, P08003 (2017) → published*
- *Signal processing (2 papers) → first draft in collaboration review*

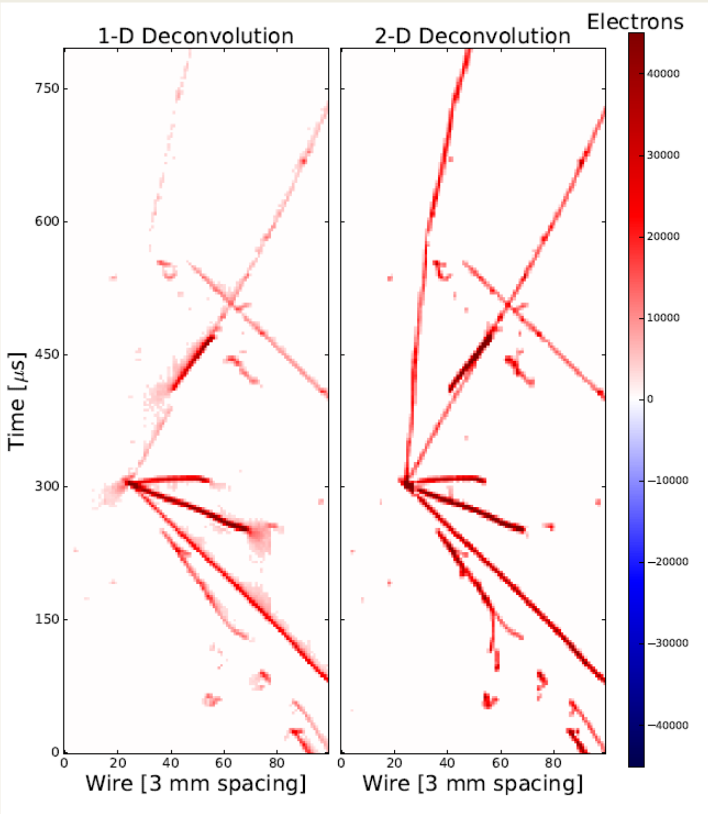


Getting to a Low Energy Excess Result

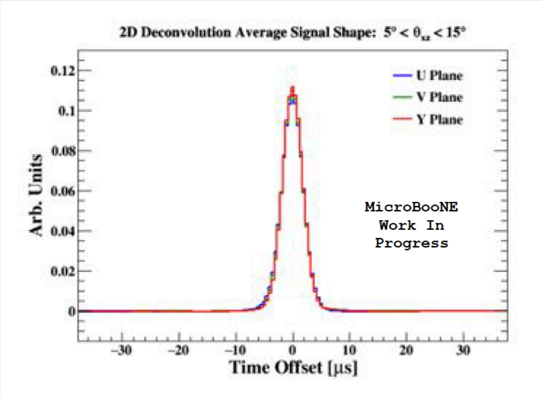
Wire Cell

De-convolve in 2D instead of 1D to better determine (resurrect) highly inclined tracks



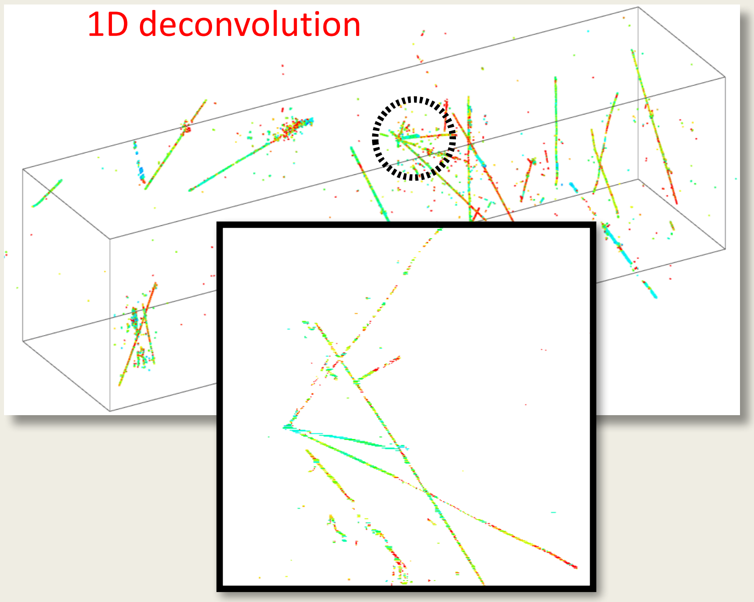


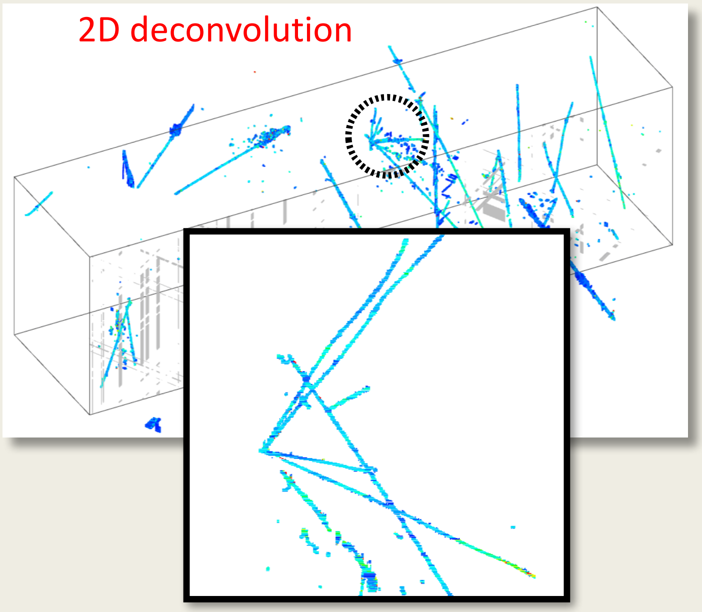
hit level impact
1D (above)
2D (right)



Getting to a Low Energy Excess Result

Wire Cell → From "wire" to "cell": Utilize charge matching and advanced compressed sensing technique to reconstruct 3D cells (space points) → first time this has even been done!



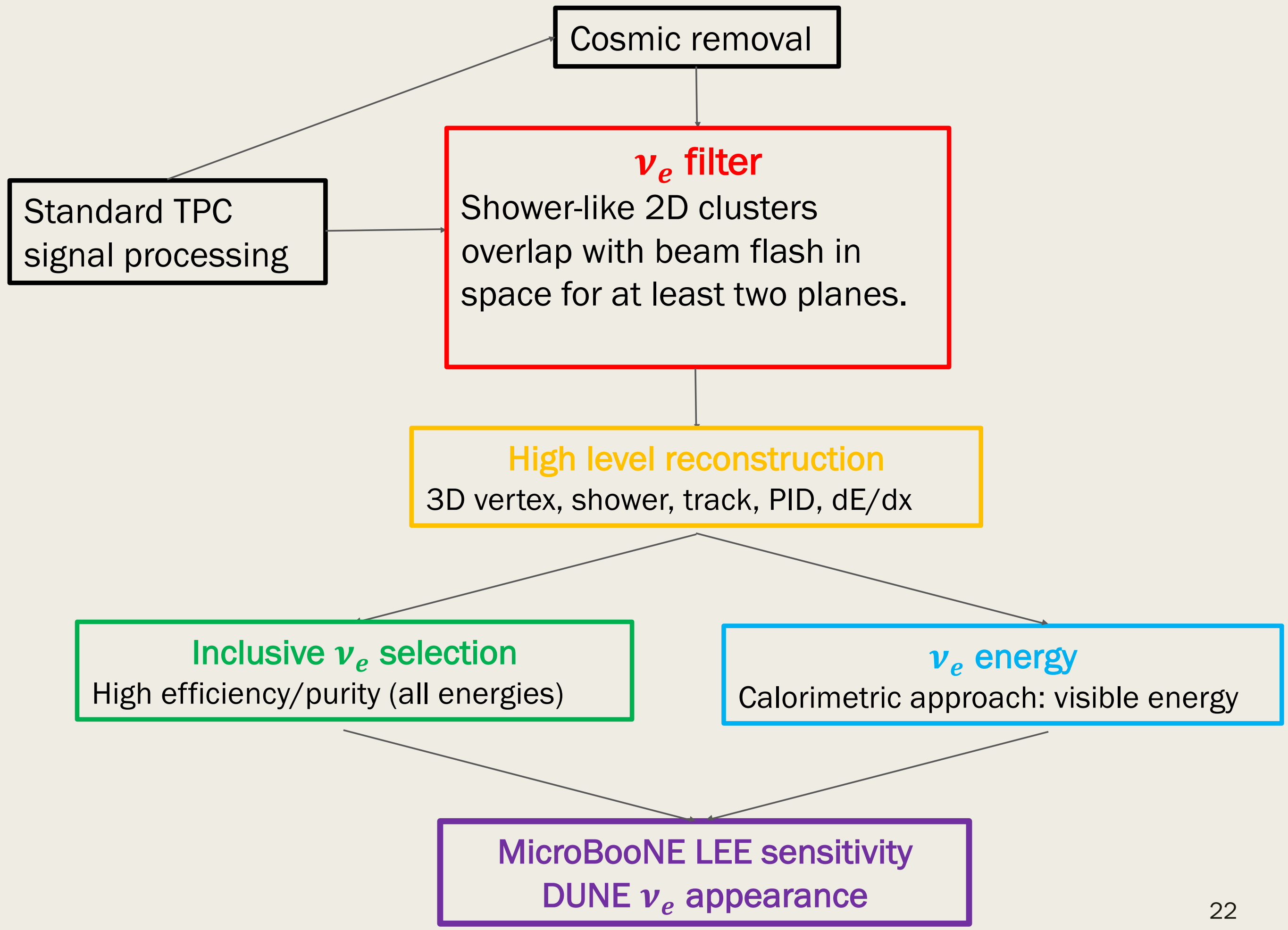


Better determining charge at hit level on all wires enables for the first time a direct 3D imaging, which reduce challenges in downstream reconstruction and PID

Getting to a Low Energy Excess Result

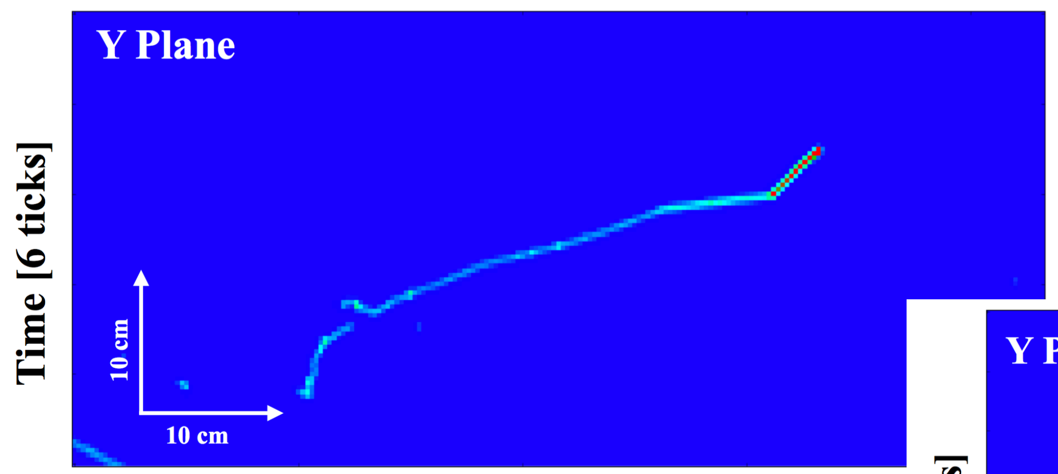
Traj Cluster

- Fully inclusive ν_e CC selection
- Goal is to maintain high efficiency across a broad energy range (from below 200 MeV to above 1 GeV)
- Needs full hadronic reconstruction & calorimetry



Low vs. High Energy ν_e in MicroBooNE

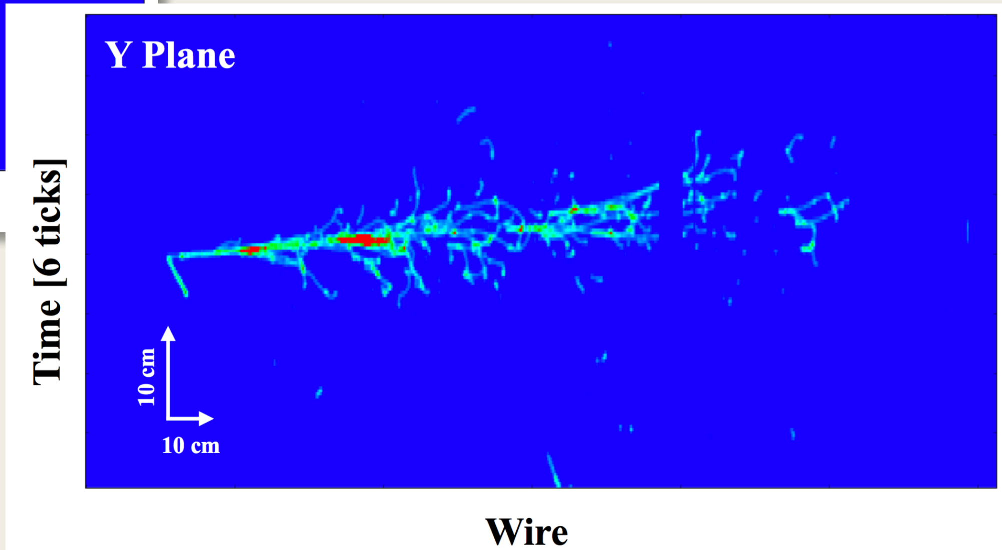
- We have a more challenging job than DUNE …



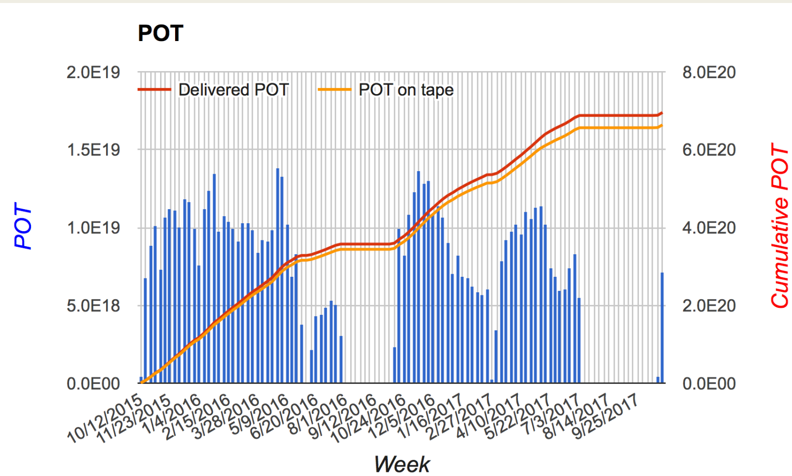
Simulated events passing DL selection

← 134 MeV electron
181 MeV proton

2.96 GeV electron →
87 MeV proton



Data Collected to Date



- Total BNB delivered to MicroBooNE since start of operations (detector on):

totals (to date)
- **6.6×10^{20} POT collected**
- **6.3×10^{20} POT on-tape** (95% uptime)

- Run 1 (pre service boards, pre CRT): 3.6×10^{20} POT*
- Total with new service boards: 3.0×10^{20} POT*
- Total with CRT: 1.0×10^{20} POT*
  (is a subset of previous line item)

- MicroBooNE is approved to run through FY18 → thank you!
- expect to collect an additional ~(2-3)x10^{20} POT this year with NuMI & g-2
  (M. Convery, July 2017 PAC presentation)

* collected (not recorded) POT, no data quality cuts

Biggest Challenges (Right Now)

- Data and Monte Carlo processing
  - *Currently takes 6 months to complete a full scale production (limiting factors: dCache disk, I/O)*
  - *Added 3 more people to Production team + 24/7 monitoring of production jobs by shifters*
  - *Launched a task force to study how we can reduce our processing timeline by reducing file sizes*
- Cosmic backgrounds
  - *Advancing light/charge matching to further reduce cosmic backgrounds*
  - *Developing strategies for collecting/harvesting more data for data-driven subtraction*
  - *Take more data with the Cosmic Ray Tagger (CRT). So far: ~$1x10^{20}$ POT*
- Identifying and reconstructing <u>low energy</u> electron neutrinos in a <u>surface</u> detector
  - *We currently have 4 approaches*
  - *We are learning their strengths and weaknesses to maximize our sensitivity*
- Resources
  - *We are not a very large collaboration and many people are split between multiple LAr efforts*

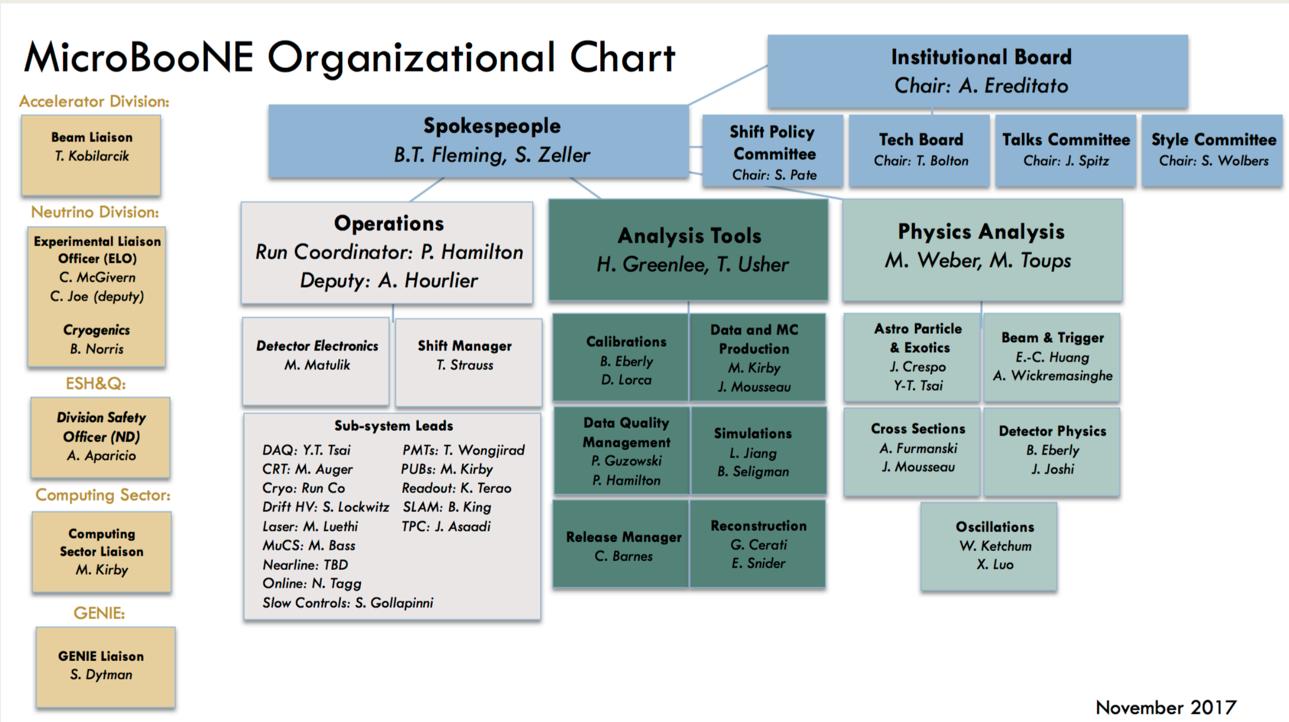
Conclusions

- To date, we have collected a total of 6.6×10^{20} POT (6.3×10^{20} POT on-tape), 1×10^{20} POT of which includes the cosmic ray tagger. Expect to get to a total of $(8\text{-}9) \times 10^{20}$ POT by summer 2018.
- We remain on an ambitious path for producing new results at summer 2018 conferences. These plans are unchanged from the July PAC, but we are concerned about how long it will take to produce the data and MC samples needed to advance these analyses.
- MicroBooNE has established a strong track record of maintaining stable operations (95% uptime over past 2 years of running) and being able to get results out of this detector (19 public notes + 7 papers, 9 more in the pipeline).
- We have a clear plan for producing low energy excess results and we are leading the path for SBN and DUNE.

Backup

Collaboration Structure

- We are organized in a way that supports this body of work



- on-boarded 7 new conveners since the last PAC meeting
  (part of our natural life cycle)
- new Run Coordinator
  (turn-over every 3 months)
- new IB chair (elected)
- new Talks Committee members + chair

- 180 scientists from 31 institutions in 5 countries (U.S., U.K., Switzerland, Israel, Turkey)
  - 10 new collaborators since the last PAC meeting

Getting to a Low Energy Excess Result

Common tools

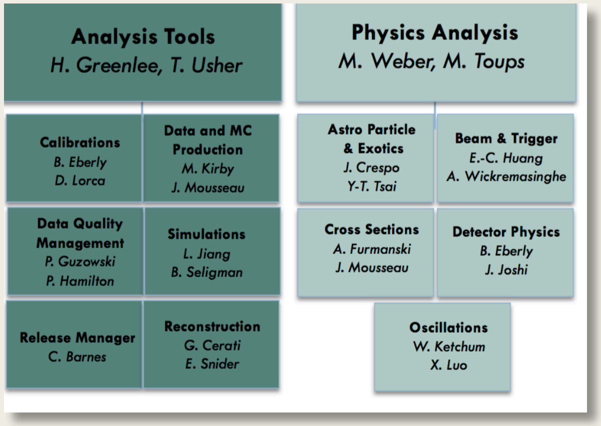
- Data Quality
- Calibration
- MC simulation
- Data/MC production
- Systematic Errors
- Final fits

Pandora

Deep Learning

Wire Cell

TrajCluster



- Each is an ***"Analysis Group"*** within the oscillations group. Each has a Point of Contact.
- Have dedicated Analysis Group meetings
- Report in Oscillations Working group, Analysis Tools Working group, Reconstruction working group
- Participate in other relevant Working group meetings: Cross Sections, Calibrations, DQM, etc.

MicroBooNE Collaboration (November 2017)

University of Bern, Switzerland: M. Auger, Y. Chen, A. Ereditato, D. Goeldi, I. Kreslo, D. Lorca, M. Lüethi, T. Mettler, C. Rudolf von Rohr, J. Sinclair, M. Weber
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University of Cambridge: J. Anthony, L. Escudero Sanchez, J. Jan de Vries, J. Marshall, A. Smith, M. Thomson
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University of Cincinnati: R. Grosso, R.A. Johnson
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Fermilab: B. Baller, F. Cavanna, R. Castillo Fernandez, G. Cerati, K. Duffy, H. Greenlee, C. James, H. Jostlein, W. Ketchum, M. Kirby, T. Kobilarcik, S. Lockwitz, B. Lundberg, A. Marchionni, S. Marcocci, C. Moore, O. Palamara, Z. Pavlovic, S. Pordes, J.L. Raaf, A. Schukraft, A. E. Snider, P. Spentzouris, J. St. John, T. Strauss, M. Toups, S. Wolbers, T. Yang, G.P. Zeller*
Harvard University: C. Adams, R. Guenette, J. Martin-Albo
Illinois Institute of Technology: R. An, B. Littlejohn, D. Martinez
Kansas State University: M. Alrashed, T. Bolton, G. Horton-Smith, V. Meddage, A. Rafique
Lancaster University: A. Blake, D. Devitt, A. Lister, J. Nowak
Los Alamos: G. Garvey, E-C. Huang, W.C. Louis, T. Thornton, R. Van de Water
University of Manchester: J. Evans, A. Furmanski, D. Gamez, O. Goodwin, P. Guzowski, J. Hewes, C. Hill, K. Mistry, R. Murrells, D. Porzio, S. Söldner-Rembold, A.M. Szelc
MIT: A. Ashkenazi, R. Carr, J.M. Conrad, G. Collin, A. Diaz, O. Hen, A. Hourlier, J. Moon, A. Papadopoulou, L. Yates
University of Michigan, Ann Arbor: C. Barnes, R. Fitzpatrick, J. Mousseau, J. Spitz
New Mexico State University: V. Papavassiliou, S.F. Pate, S. Sword-Fehlberg, K. Woodruff
Otterbein University: N. Tagg
University of Oxford: G. Barr, M. Del Tutto, A. Laube, R. Soleti, W. Van De Pontseele
University of Pittsburgh: S. Dytman, L. Jiang, D. Naples, V. Paolone, A. Wickremasinghe
Pacific Northwest National Laboratory: E. Church, K. Bhattacharya, K. Wierman
Saint Mary's University of Minnesota: P. Nienaber
SLAC: M. Convery, B. Eberly, L. Rochester, K. Terao, Y-T. Tsai, T. Usher
Syracuse University: A. Bhat, J. Esquivel, P. Hamilton, G. Pulliam, M. Soderberg
Tel Aviv University: E. Cohen, E. Piasetzky
University of Tennessee, Knoxville: S. Gollapinni, A. Mogan, W. Tang, G. Yarbrough
University of Texas at Arlington: J. Asaadi, E. Davenport, Z. Williams
Tubitak Space Technologies Research Institute, Turkey: F. Bay, B. Kocaman, M. Kopru
Tufts University: *R. Sharankova*, T. Wongjirad
Virginia Tech: C. Mariani, M. Murphy, V. Pandey
Yale University: S. Balasubramanian, B.T. Fleming*, E. Gramellini, A. Hackenburg, X. Luo, B. Russell, L. Cooper-Troendle, S. Tufanli

*spokespeople

180 collaborators
31 institutions (7 non-U.S.)
40 postdocs
58 graduate students

- 10 new collaborators since last PAC meeting

Summer Shutdown Activities

- We had a very busy summer. Since our briefing at the July 2017 PAC:
  - Cryogenics system maintenance
  - New PMT high voltage power source
  - Studies of late light
  - Investigations of remaining unknown source of noise ("zig-zag")
  - UV Laser maintenance
  - DAQ and computing kernel upgrades
  - Completed Supernova readout stream commissioning
  - Additional dedicated cosmic data taking (Oct 6-27)

  - Work to understand networking router failures in LArTF
  - Investigations of the loss of a PMT on our trigger efficiency

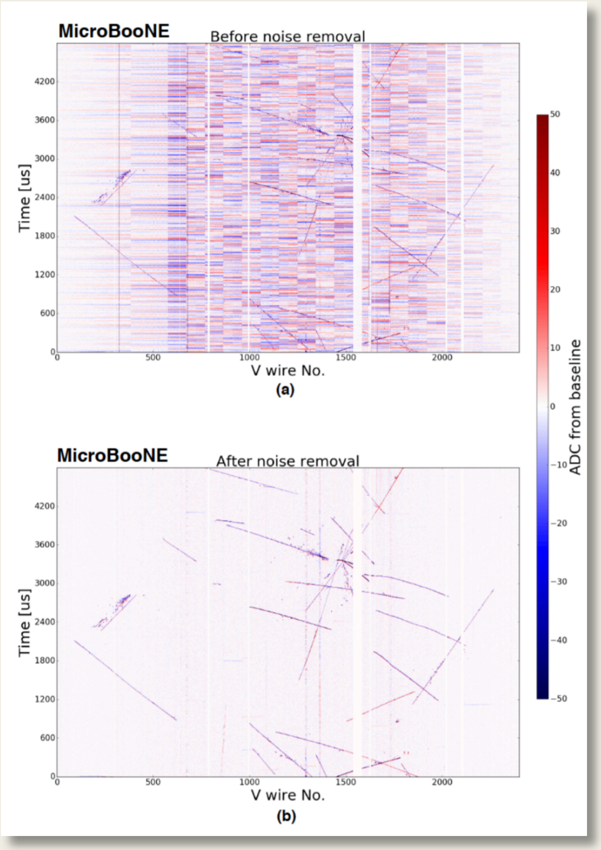
Improvements in MicroBooNE Monte Carlo

(MCC8.4)

- Multiple GENIE configurations (with alternate nuclear models, e.g., MEC)
- Data-driven noise model
- Data-driven field response
- Signal processing that includes misconfigured ASIC channels
- Updated geometry including CRT
- Optical + trigger simulation improvements including improved optical reconstruction
- Common optical filter for physics analyses
- Space charge simulation
- Support for cosmic overlays
- Addition of time dependency in simulated quantities
- New Kalman filter track fitting
- MCS track momentum code
- Improved pattern recognition algorithms (Pandora, Traj Cluster, shower reconstruction)
- Updated beam quality monitoring due to failed device in BNB
- Data quality monitoring updates extending through Run 1 data
- Analysis tree updates for analyzers
- NuMI software trigger simulation bug fix

Impact of MicroBooNE Noise Studies

- **ASIC saturation:** new generation ASICs now have additional input bias current settings
- **Wire vibrations:** spacers have been added to support the anode wires in the design of new LAr TPCs to reduce vibrations and wire motion from fluid flow
- **Misconfigured channels:** additional electrostatic discharge protection has been added on the configuration pins in next generation ASICs
- **ASIC startup:** design margin of the bandgap reference circuit has been increased in the new ASIC design to remove start-up problems
- **Electronics environment:** additional attention is being paid to grounding during building construction (e.g., SBND, ICARUS) and current monitoring
- **Offline noise filtering:** MicroBooNE approach and code had immediate impact on DUNE 35 ton data analysis → see picture to the left



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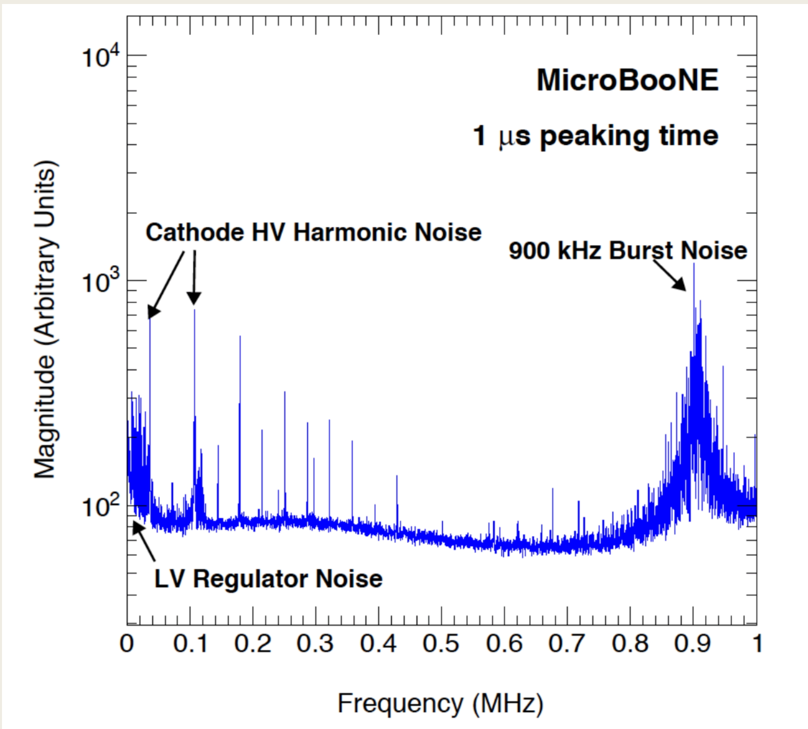
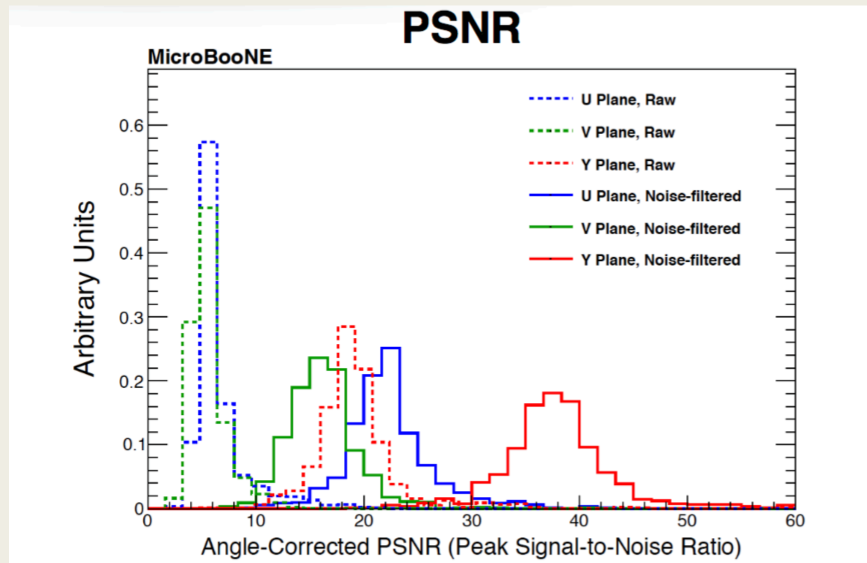
Signal/Noise in MicroBooNE



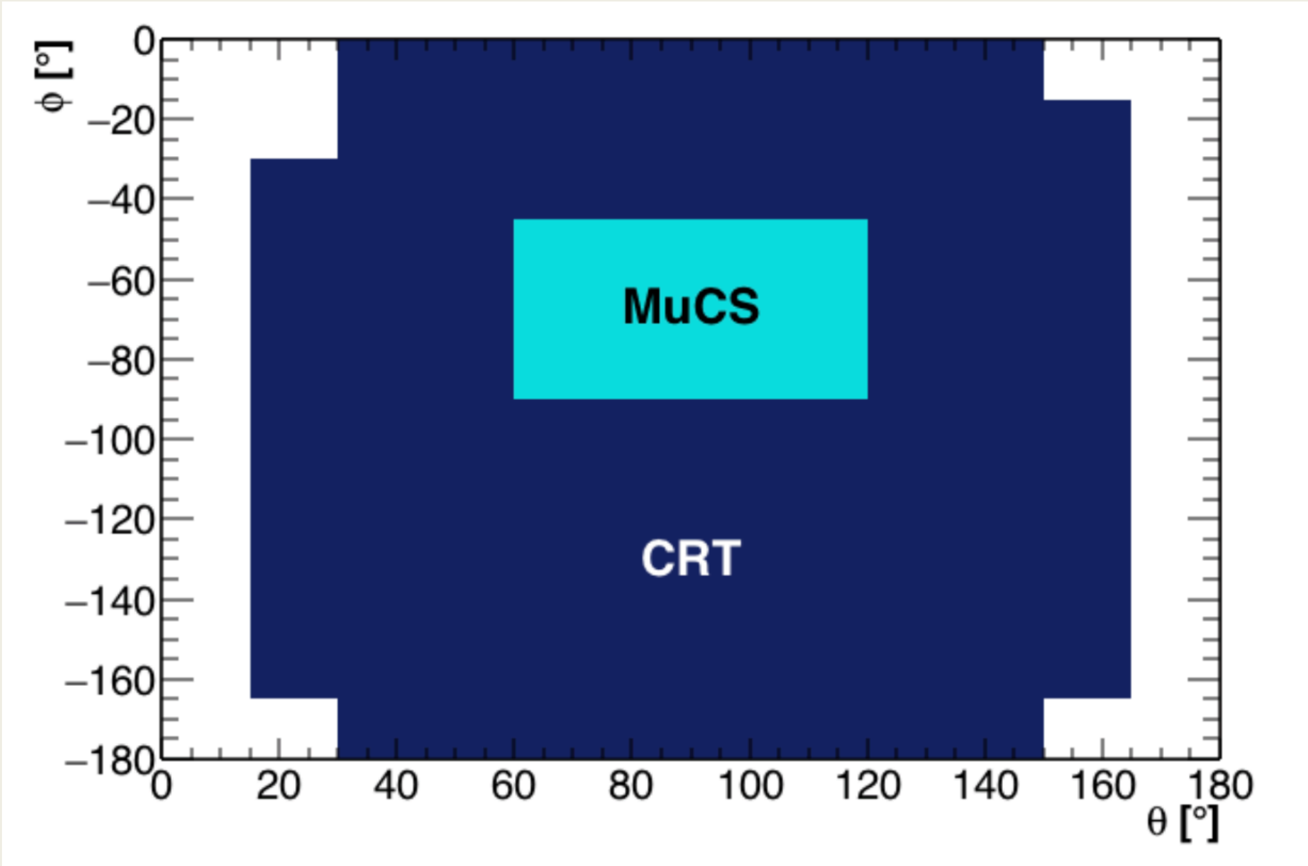
- Low frequency noise from voltage regulator
- Drift high voltage power supply noise
- 900 KHz burst noise



Waveform Type	U Plane PSNR	V Plane PSNR	Y Plane PSNR
Raw Data	6.6	5.7	19.5
After Noise Filtering	22.3	16.2	37.9

JINST 12, P08003 (2017)

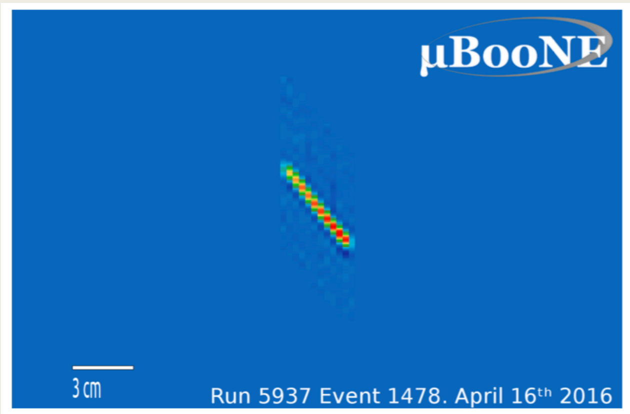
CRT Coverage



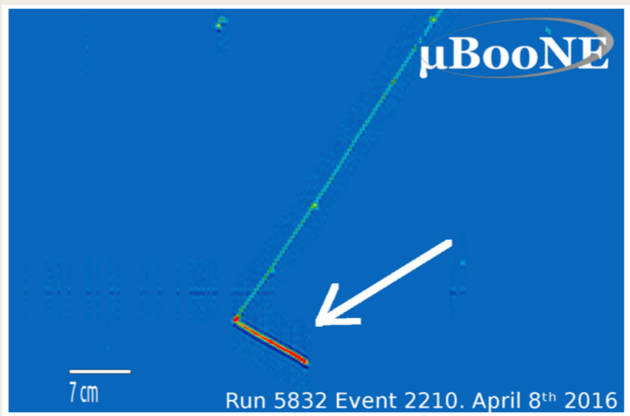
arXiv:1707.09903, submitted to JINST

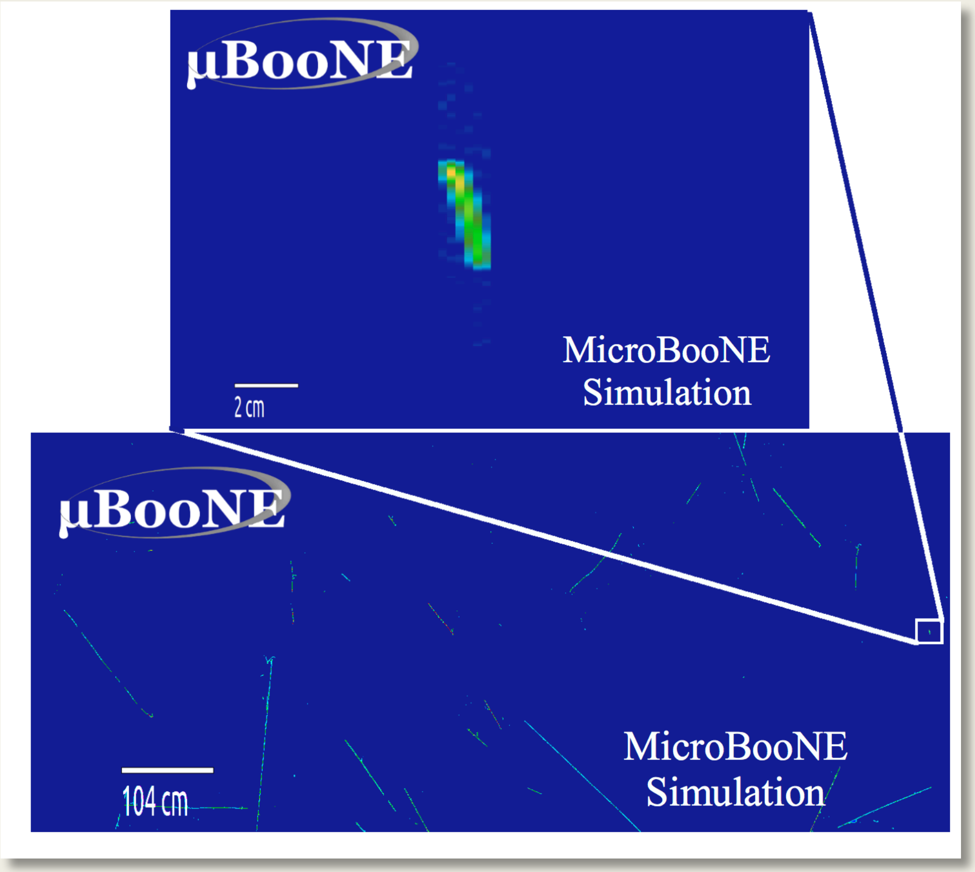
NC Elastic Events (ν_μ + Ar → ν_μ + nucleons)

NC candidate:



CC candidate:





MicroBooNE public note #1025