μBooNE

Detector performances and cosmic-ray reconstruction efficiency in MicroBooNE

Stefano Roberto Soleti

WIN 2017, University of California - Irvine, 23rd June 2017

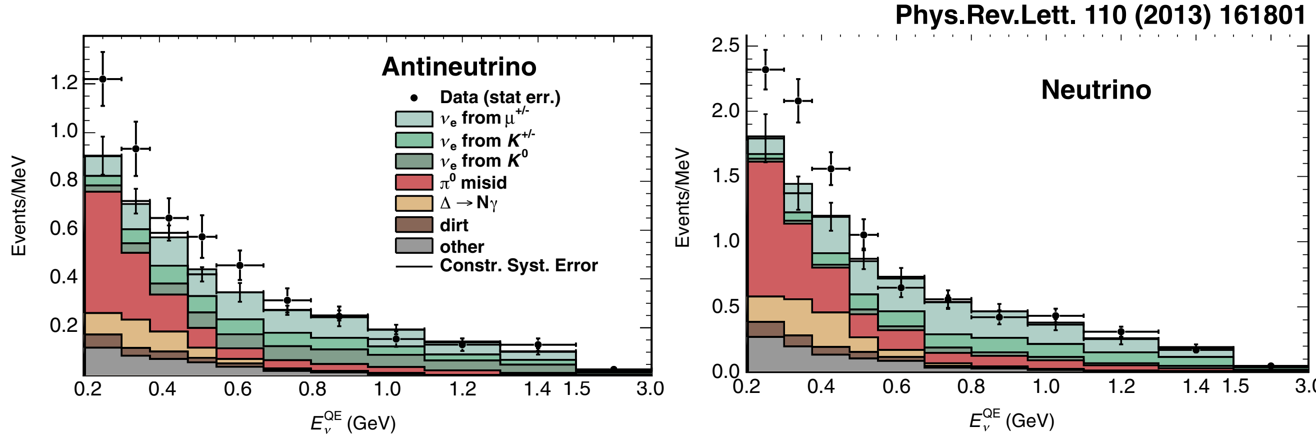
UNIVERSITY OF OXFORD

MicroBooNE physics goals

Investigate short-baseline neutrino anomalies

- LSND excess.
- MiniBooNE low energy excess.
- Reactor neutrino anomalies.

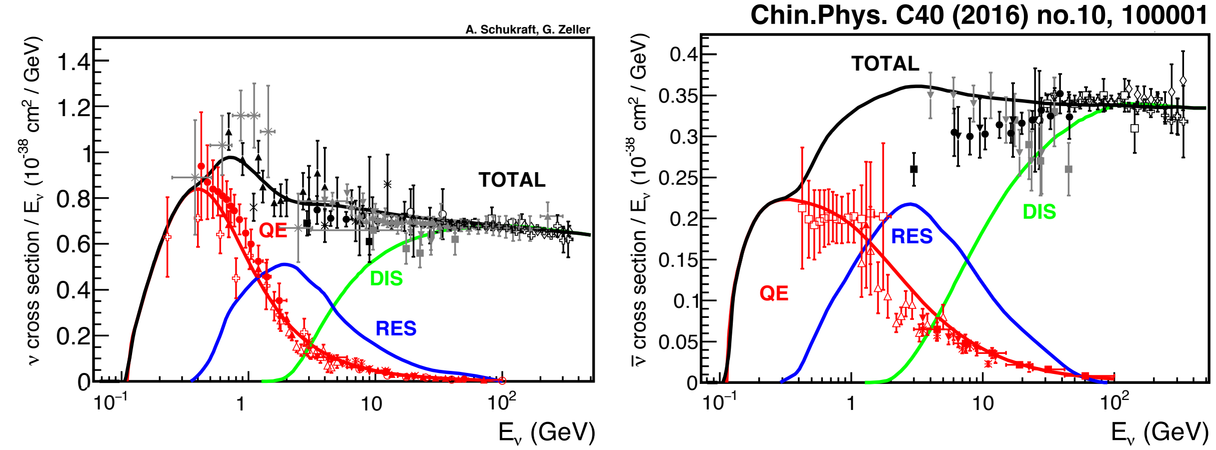
Phys.Rev.Lett. 110 (2013) 161801



Cross-section measurements

- Precise measurements of ν-Ar cross section for future LAr experiments (DUNE).
- Probe different theories of nuclear effects in ν-Ar scattering.

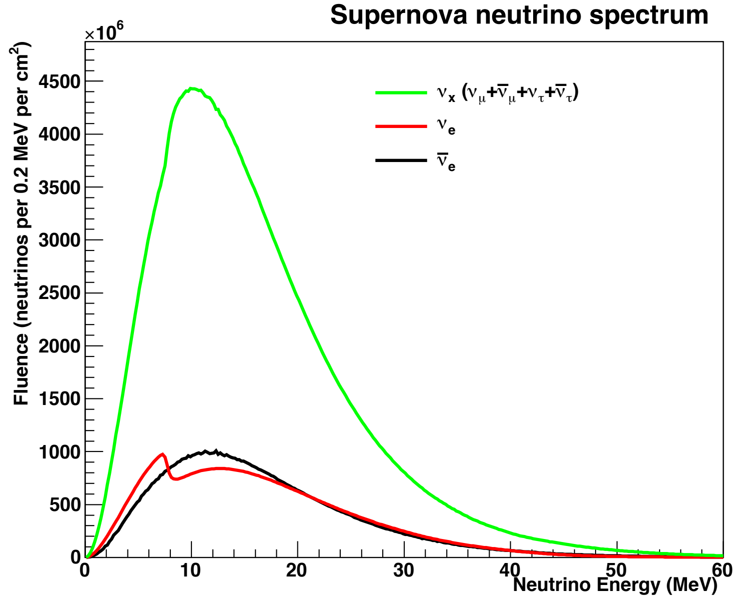
Chin.Phys. C40 (2016) no.10, 100001



Supernova neutrino and exotic physics

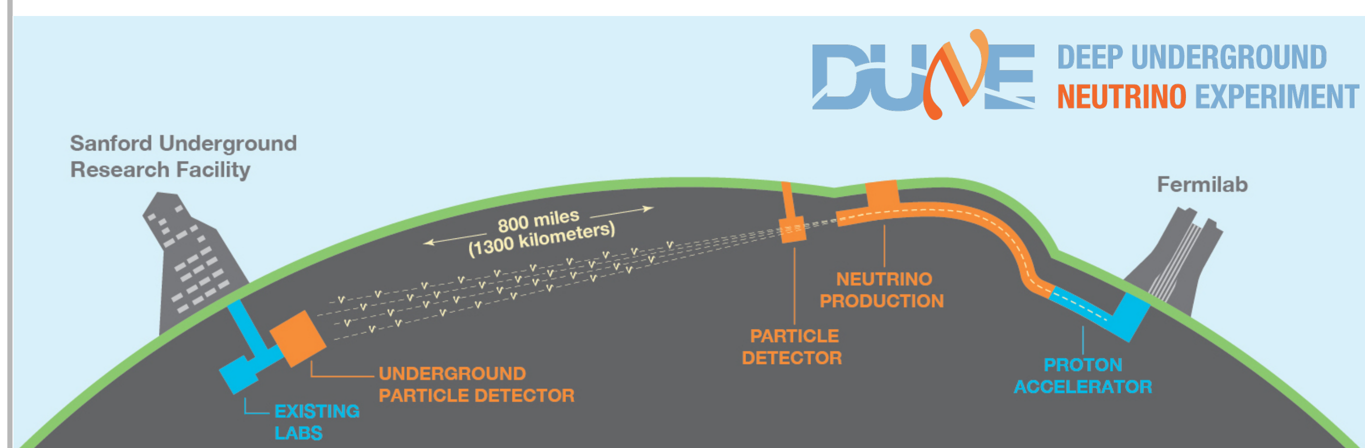
- Supernova neutrinos (~10 MeV) using the SNEWS alert system
- Proton decay backgrounds study: $K_L^0 + p \rightarrow K^+ + n$

Supernova neutrino spectrum



LArTPC detector R&D

- Detector effects to further develop LArTPC technology
  - Space charge effect, wire response, noise studies, electron lifetime…
- Essential for future experiments.

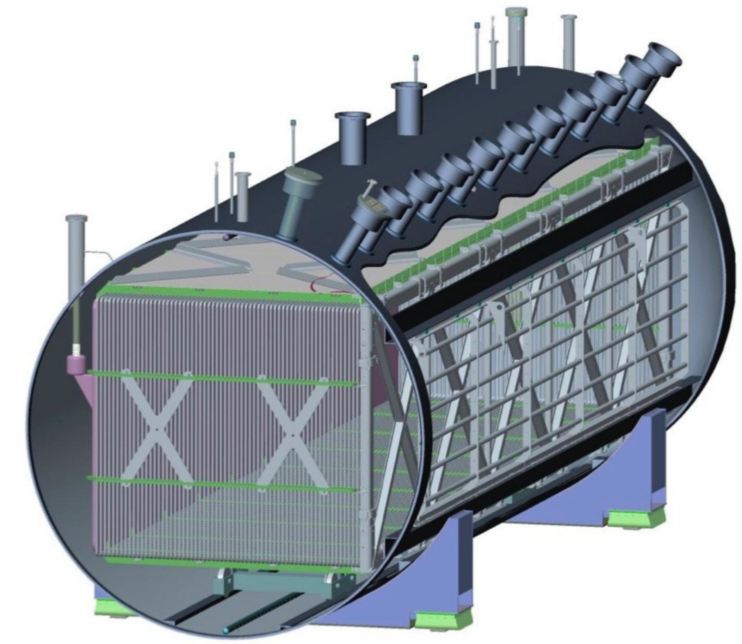


MicroBooNE in a nutshell

What is it?

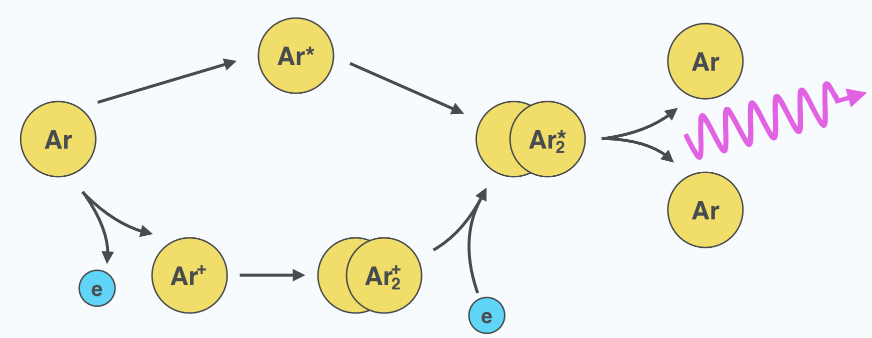
MicroBooNE is a 85 active mass ton **Liquid Argon Time Projection Chamber** at Fermilab, located:

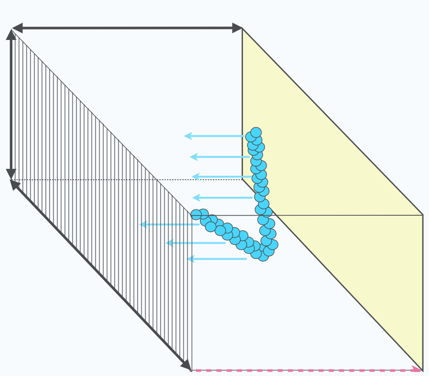
- on the axis of the Booster Neutrino Beam (BNB);
- off the axis of the Neutrinos at the Main Injector (NuMI) beam.



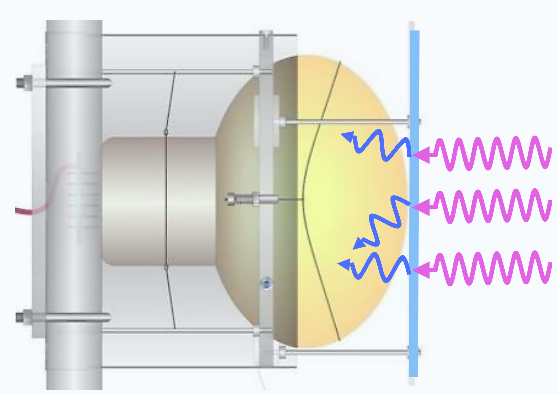
How does it work?

As a charged particle passes through the liquid argon, the argon atom experiences one of two processes, it becomes ionized, or excited. Both paths end by de-excitation via **scintillation**.



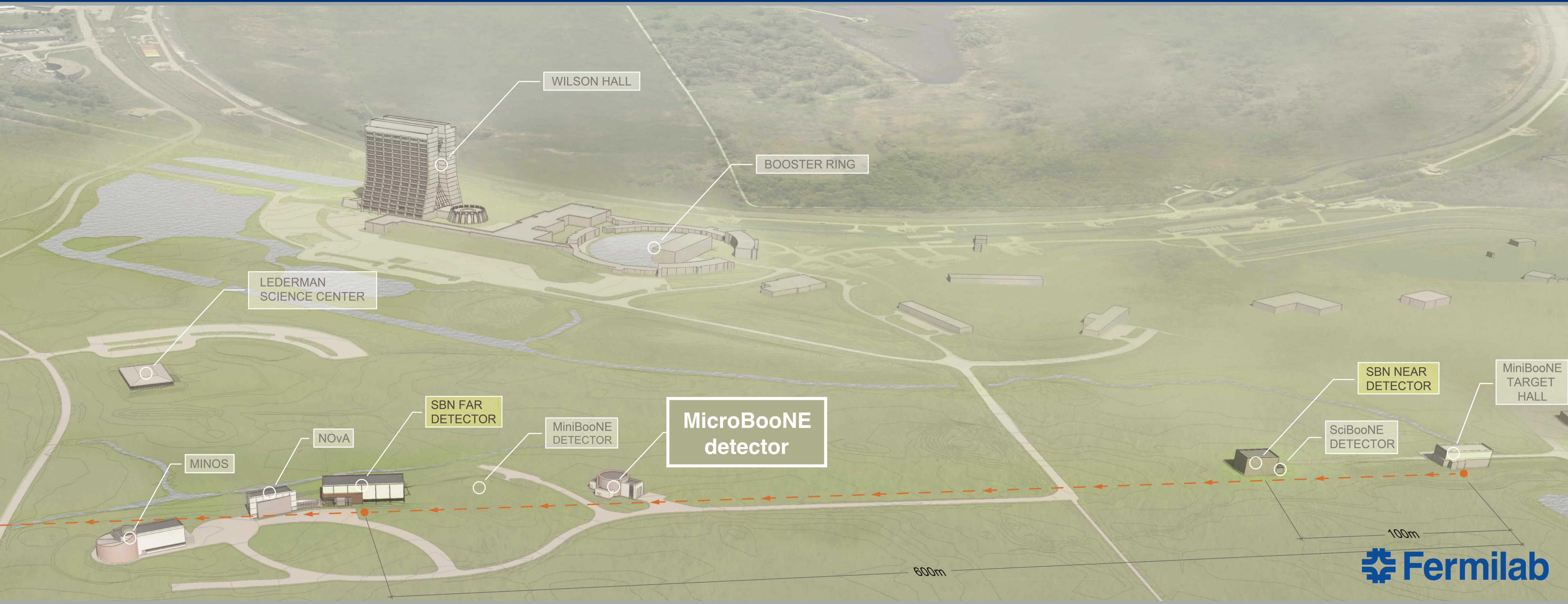


Ionized **electrons** travel through the liquid argon in a constant electric field and are **collected by the TPC**.

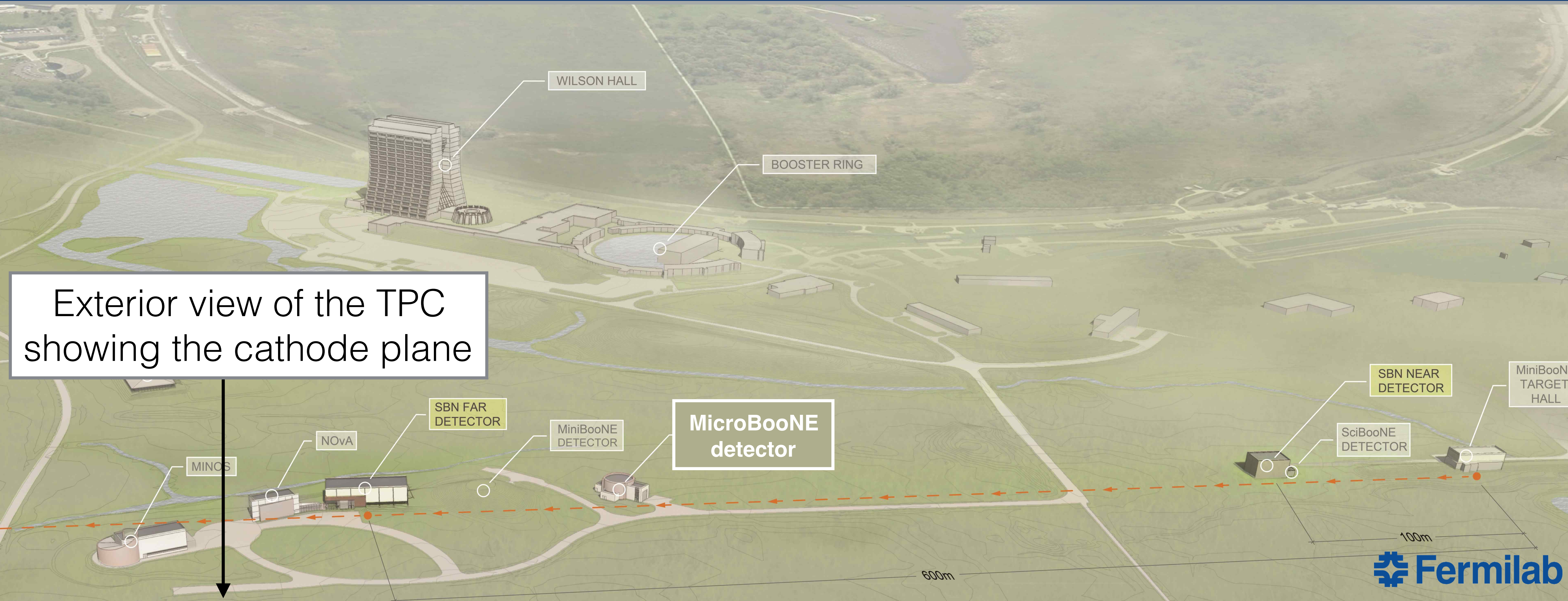


The **photons** are collected by one of the 32 8-inch **photomultipliers (PMTs)**,

The MicroBooNE experiment

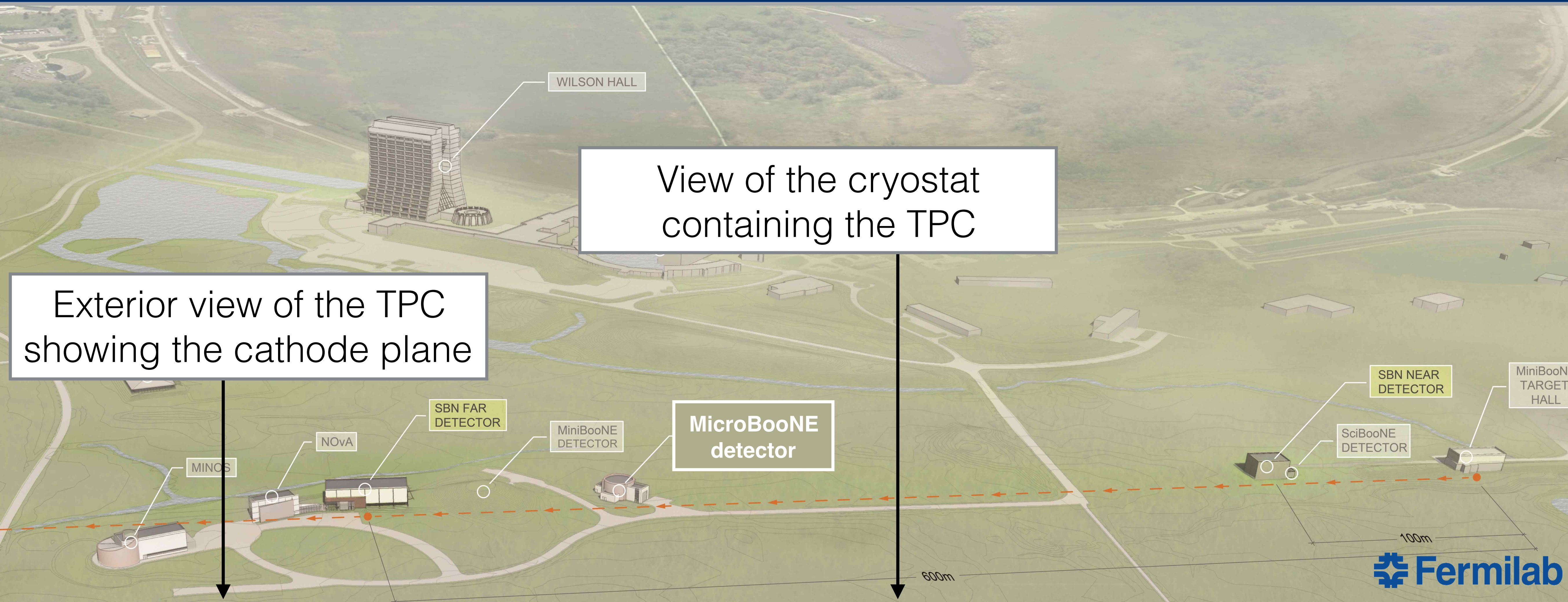


The MicroBooNE experiment



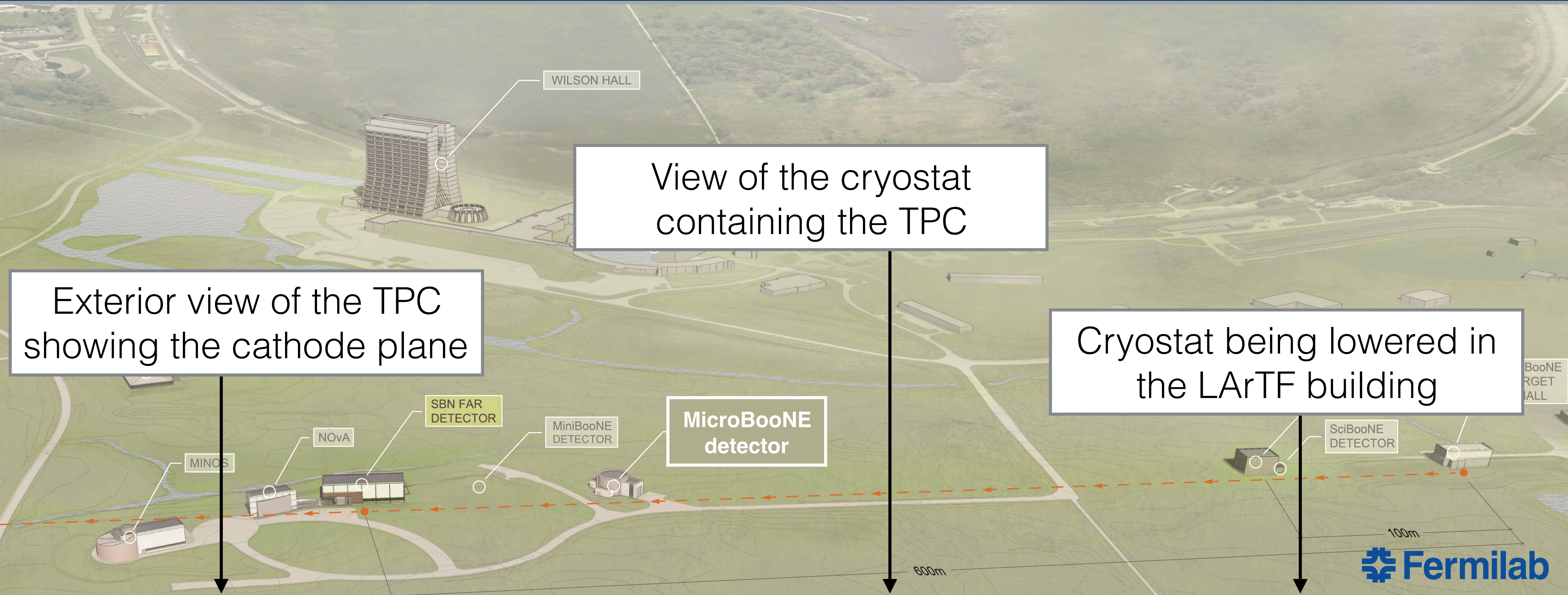
Exterior view of the TPC showing the cathode plane

The MicroBooNE experiment



arXiv:1612.05824

The MicroBooNE experiment



Exterior view of the TPC showing the cathode plane

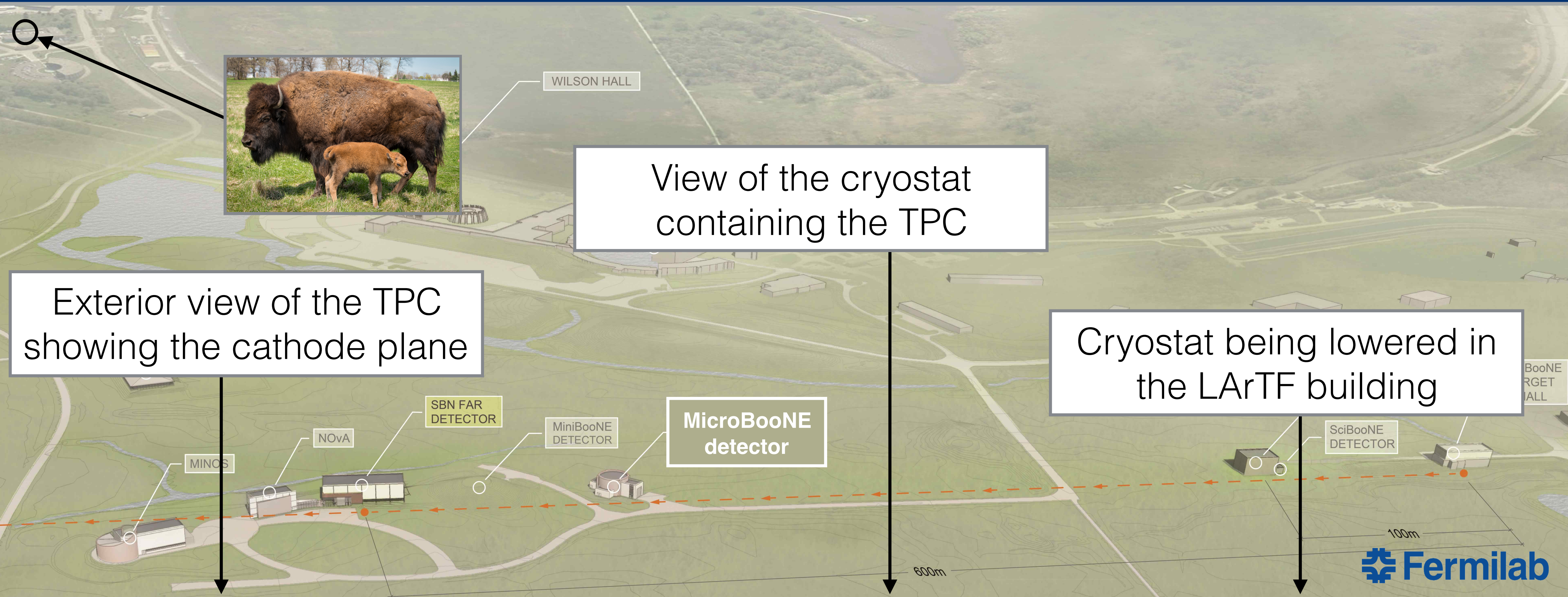
View of the cryostat containing the TPC

Cryostat being lowered in the LArTF building

arXiv:1612.05824

The MicroBooNE experiment

µBooNE

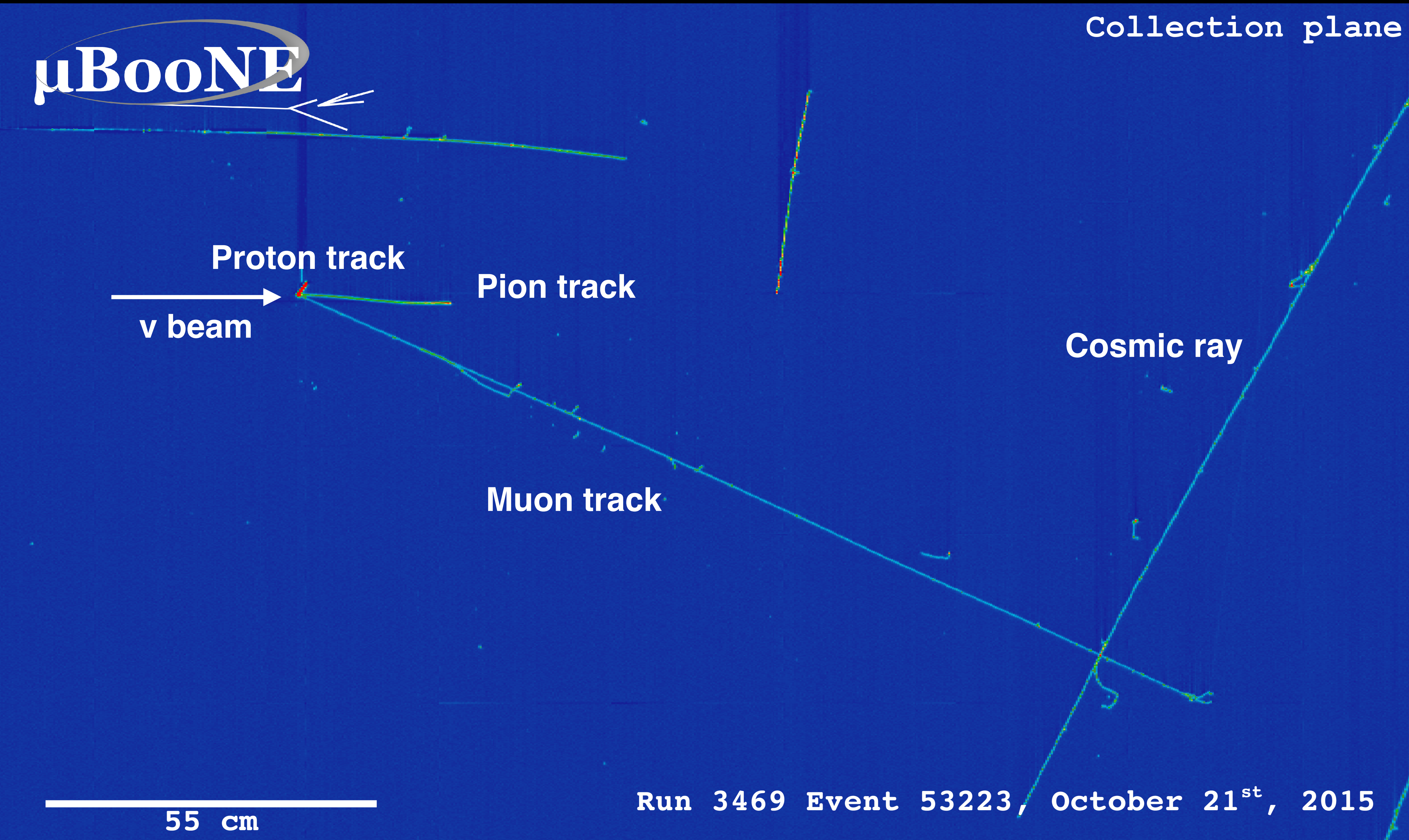


Exterior view of the TPC showing the cathode plane

View of the cryostat containing the TPC

Cryostat being lowered in the LArTF building

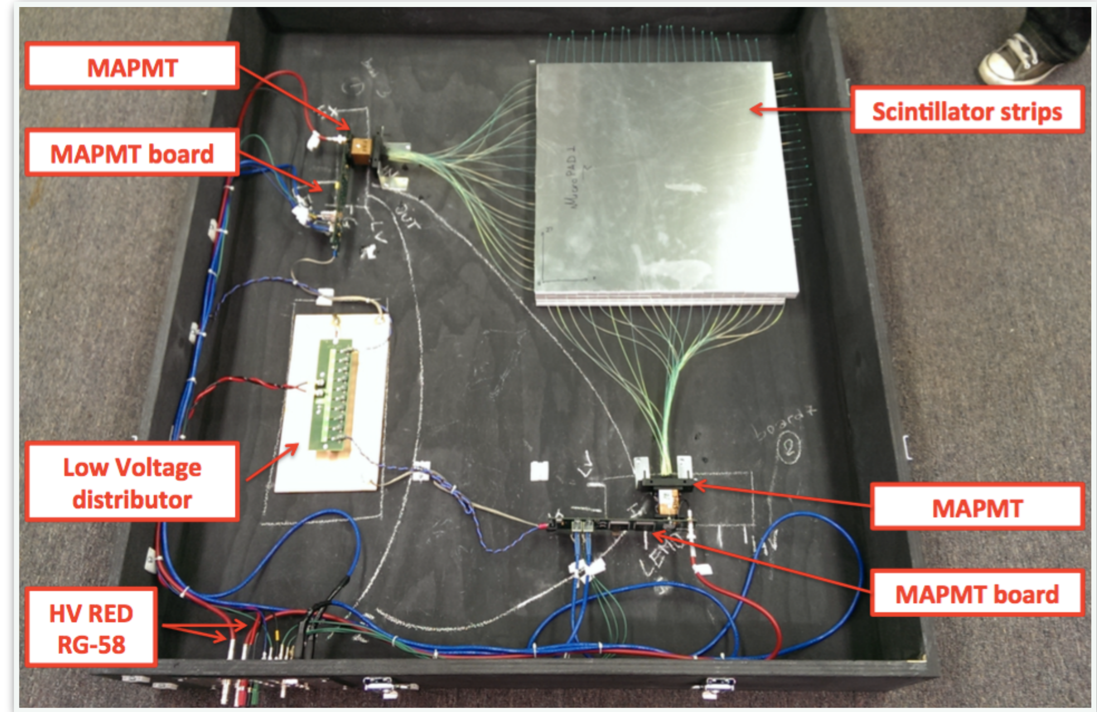
arXiv:1612.05824

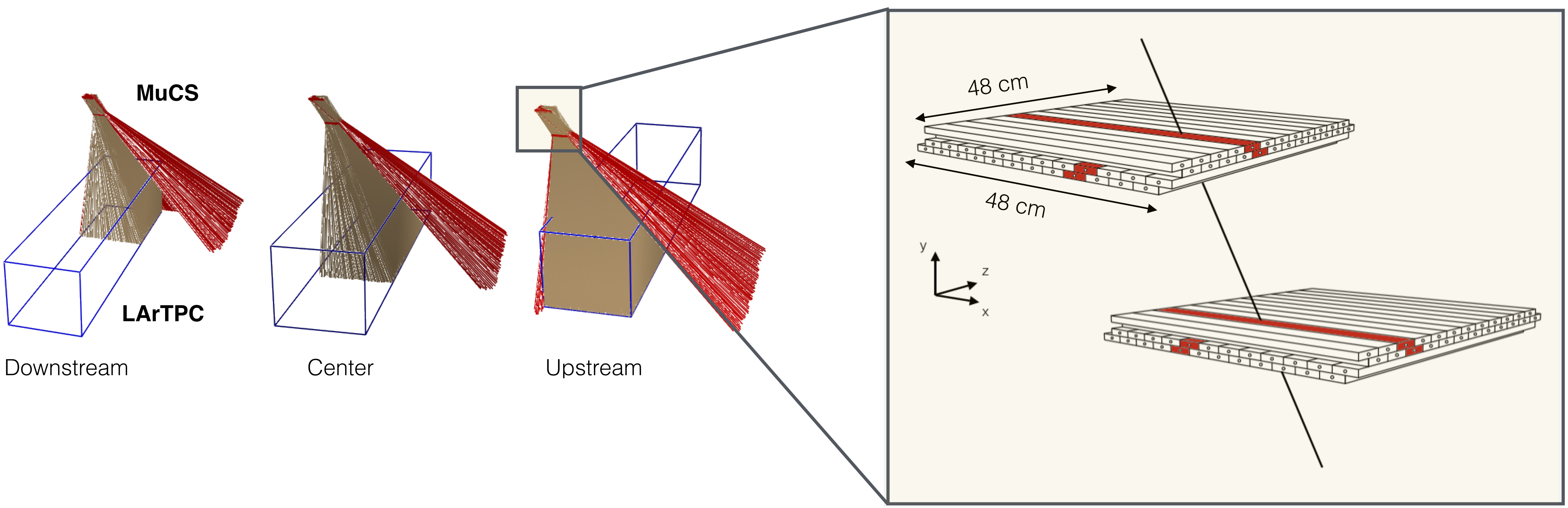


μBooNE
Collection plane
Proton track
Pion track
ν beam
Cosmic ray
Muon track
55 cm
Run 3469 Event 53223, October 21st, 2015

The Muon Counter Stack

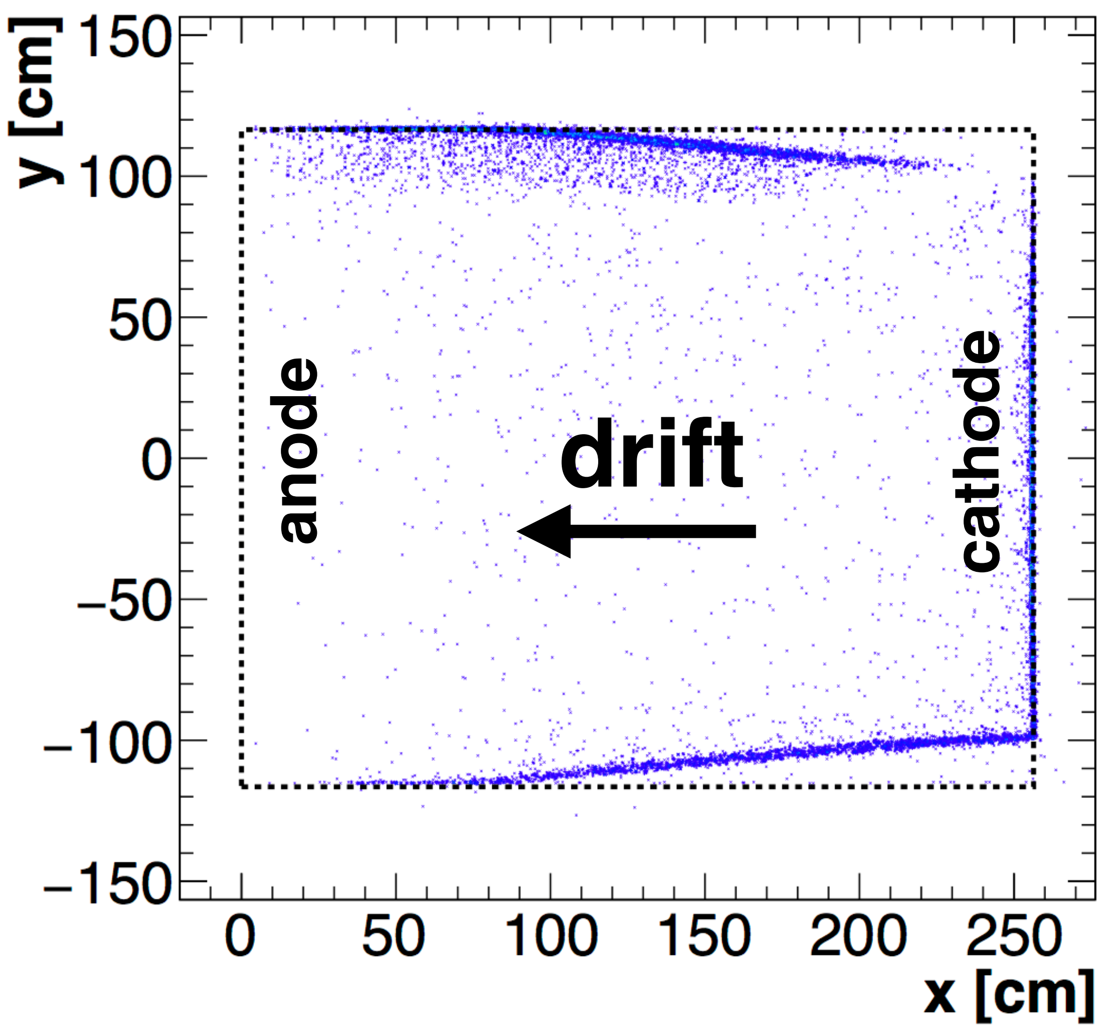
- Being MicroBooNE located near the surface, **cosmic muons can be a source of backgrounds to many analyses** (~10 cosmic muons per 2.2 ms drift time).
- A small muon counter stack (MuCS) has been installed on top of the TPC to help with several studies:
  - **Data reconstruction efficiency**
  - Optical system - TPC matching efficiency
  - Trigger efficiency
  - **Detector performances** (space-charge effect, collected charge, collected light…)



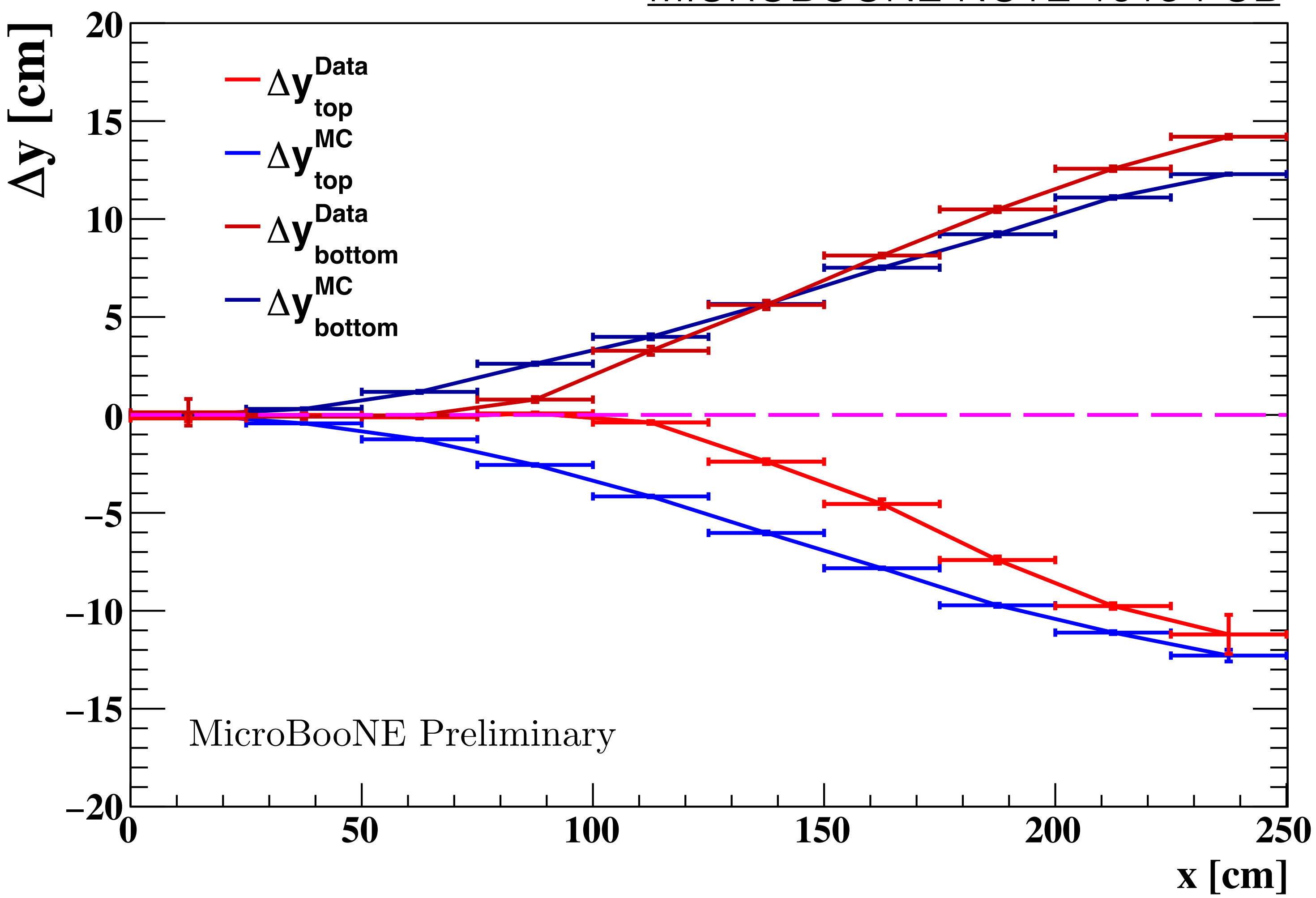


MuCS and space-charge effect

- The positive argon ions can cause a **distortion in the electrical field** of the TPC.
- We can use the MuCS dataset to quantify this **space-charge effect** (SCE).
- SCE simulation qualitatively reproduces effect.
  - Agrees in normalization and base shape features.
  - Offset near anode probably caused by liquid argon flow.
- Can impact track/shower reconstruction and calorimetry.

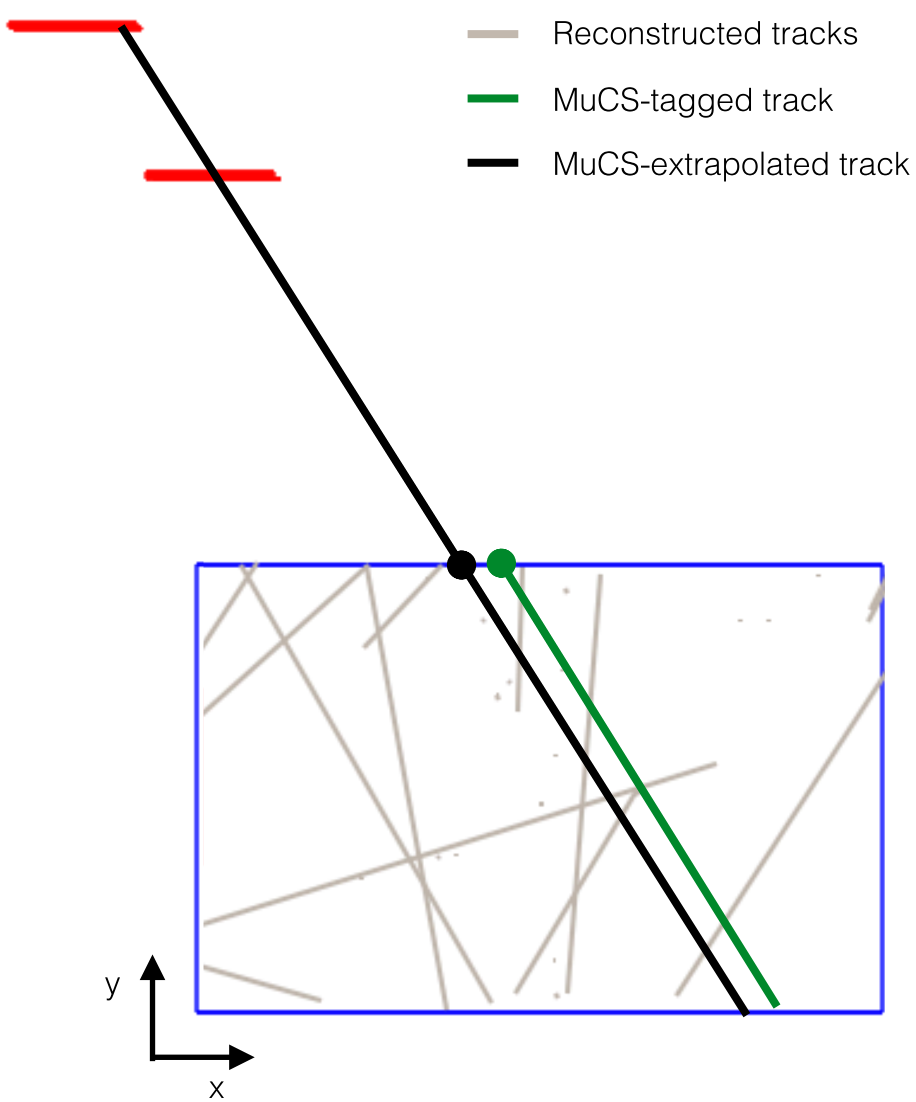


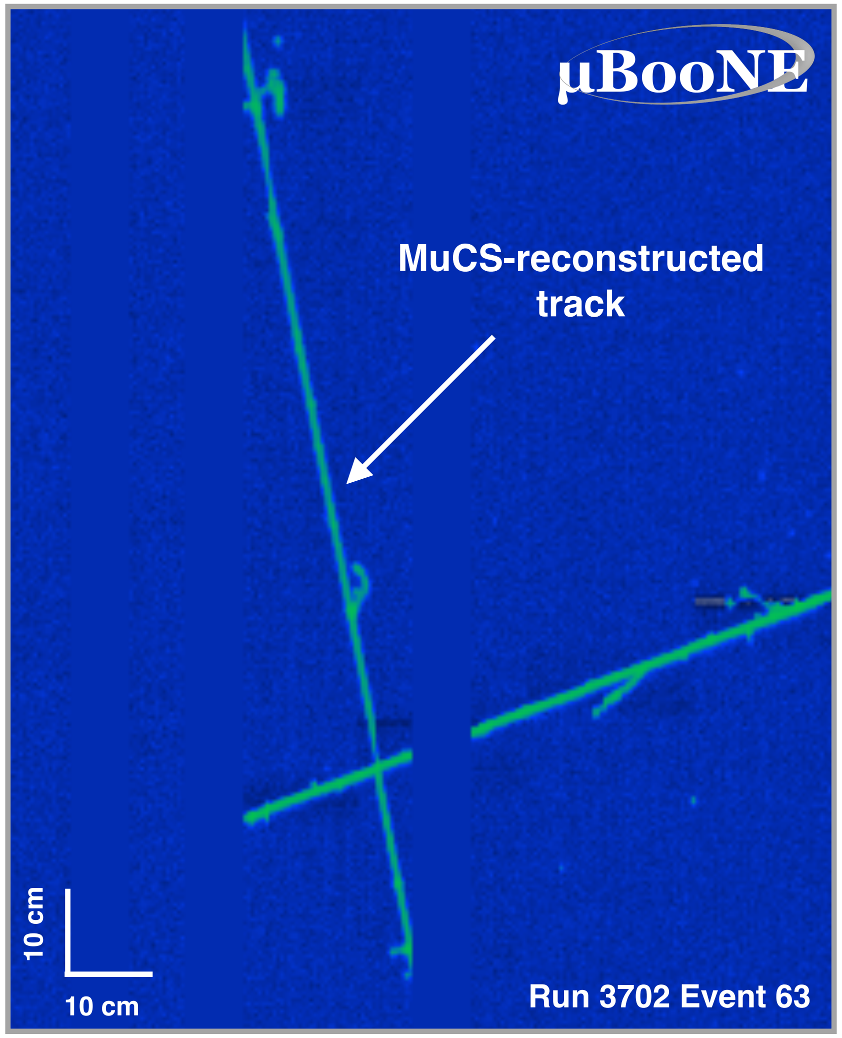
MICROBOONE-NOTE-1018-PUB



Reconstructing MuCS data

- Each MuCS event is **triggered by a cosmic ray going through the MuCS panels**.
- Each MuCS event will contain more than one reconstructed cosmic-ray track (we have ~10 cosmic rays per 2.2 ms drift window).
- We find the **reconstructed track with the starting points closest to the intersection** between the extrapolated MuCS trajectory (**MuCS-extrapolated track**) and the TPC, within a maximum distance (**MuCS-tagged track**).
- Number of MuCS-tagged tracks is corrected by the purity and the acceptance of the cut on the maximum distance.

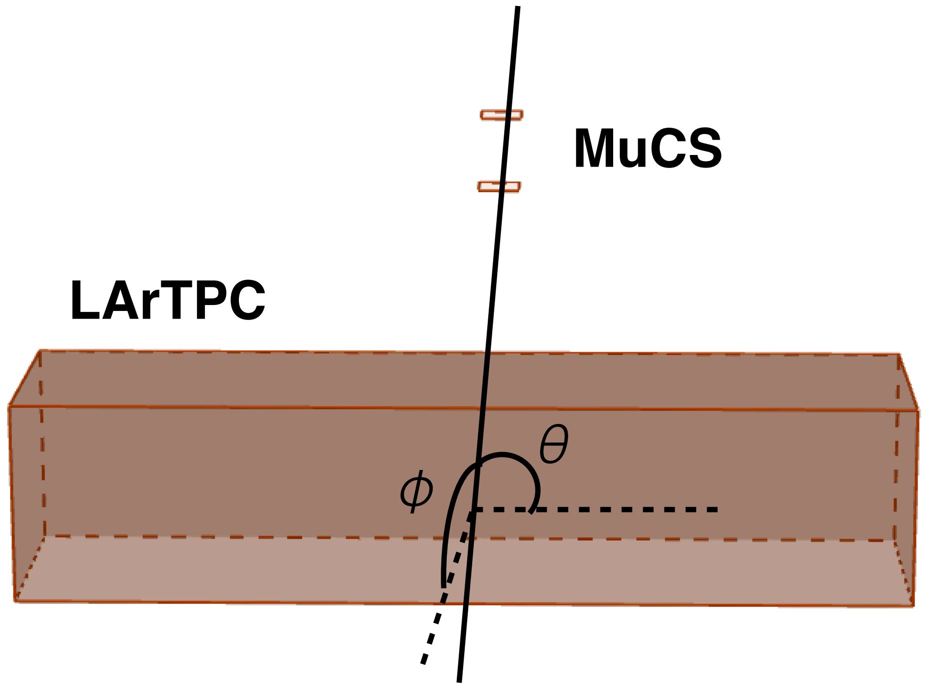




Efficiency measurement

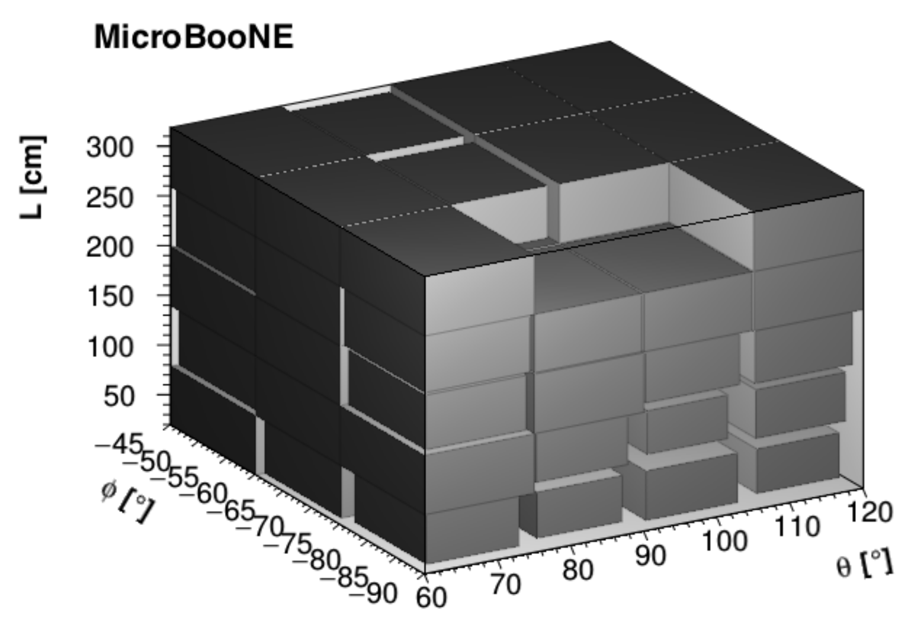
Using the **(x_{top}, y_{top}, z_{top})** and **(x_{bottom}, y_{bottom}, z_{bottom})** points given by the MuCS panels, it is possible to measure the reconstruction efficiency as a function of θ, **ϕ** and extrapolated length in the TPC L.

$$\phi = \operatorname{atan}\left(\frac{y_{\mathrm{top}} - y_{\mathrm{bottom}}}{x_{\mathrm{top}} - x_{\mathrm{bottom}}}\right), \quad \theta = \operatorname{acos}\left(\frac{z_{\mathrm{top}} - z_{\mathrm{bottom}}}{r}\right)$$



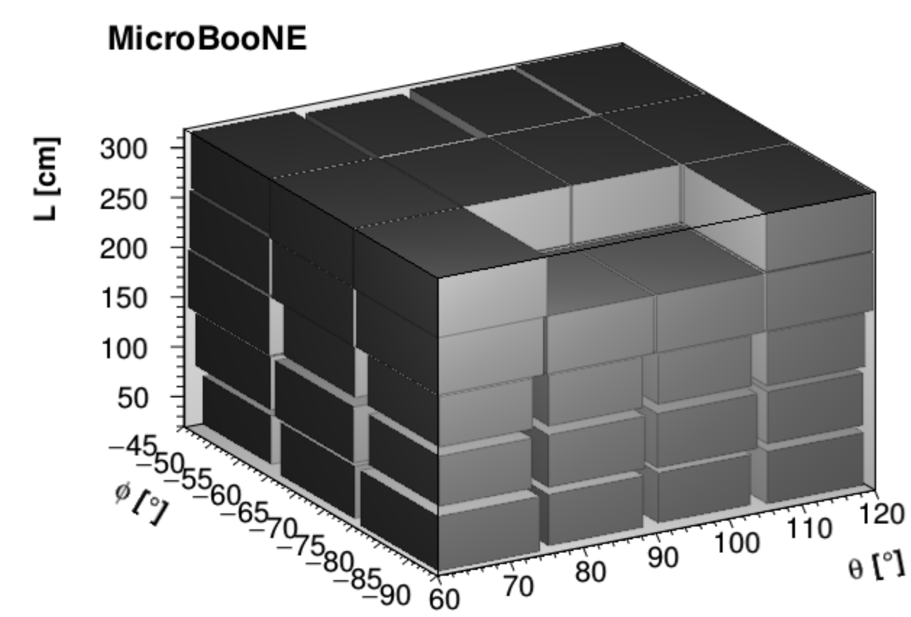
Monte Carlo

$$\epsilon_{\mathrm{MC}} = \frac{\text{N. of reconstructed cosmic rays}}{\text{N. of generated cosmic rays}} = 97.3 \pm 0.1\ \%$$



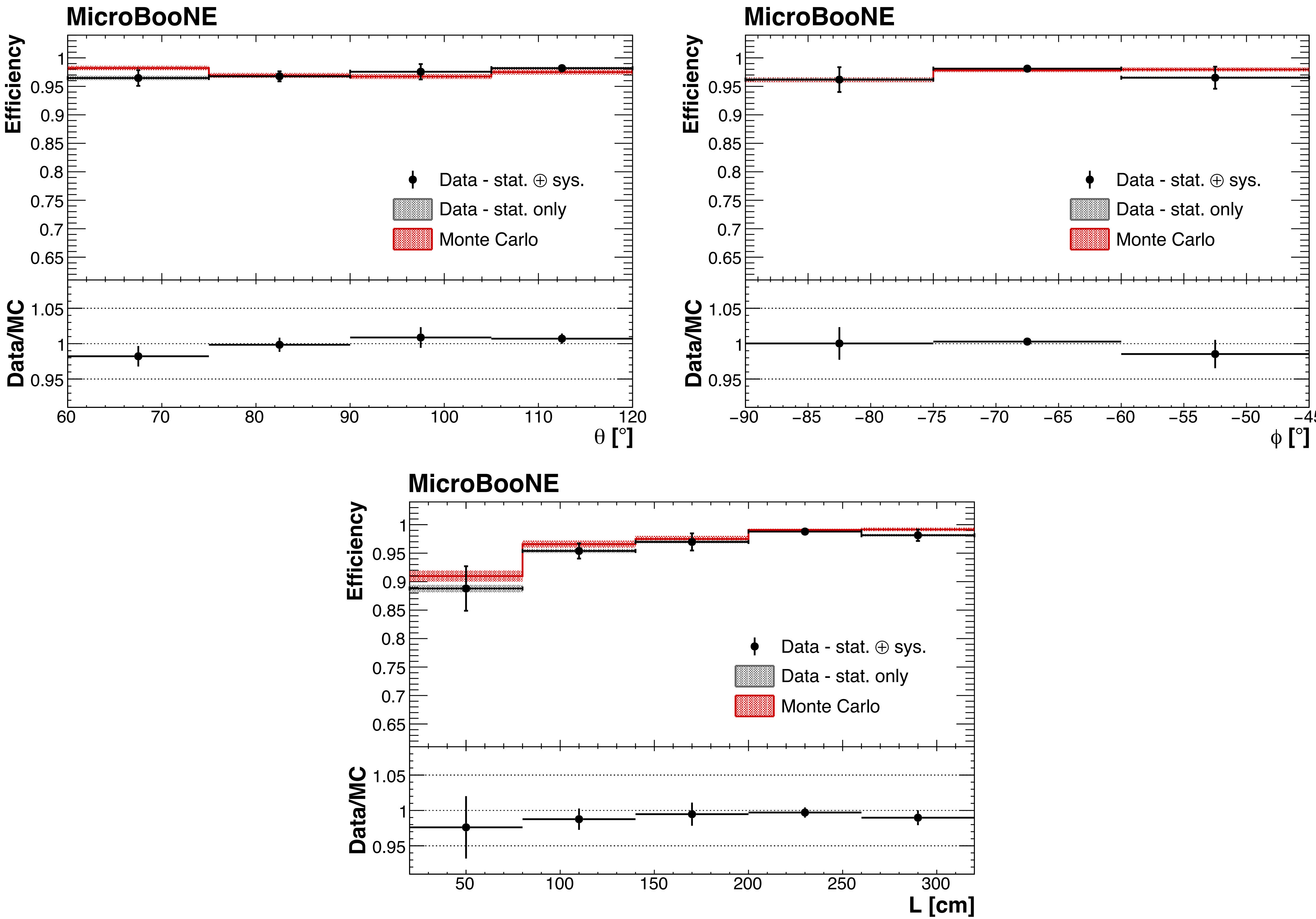
Data

$$\epsilon_{\mathrm{data}} = \frac{\text{N. of reco. MuCS cosmic-ray events}}{\text{N. of MuCS triggered events}} = 97.1 \pm 0.1\ (\text{stat}) \pm 1.4\ (\text{sys})\ \%$$



Results

One-dimensional projections

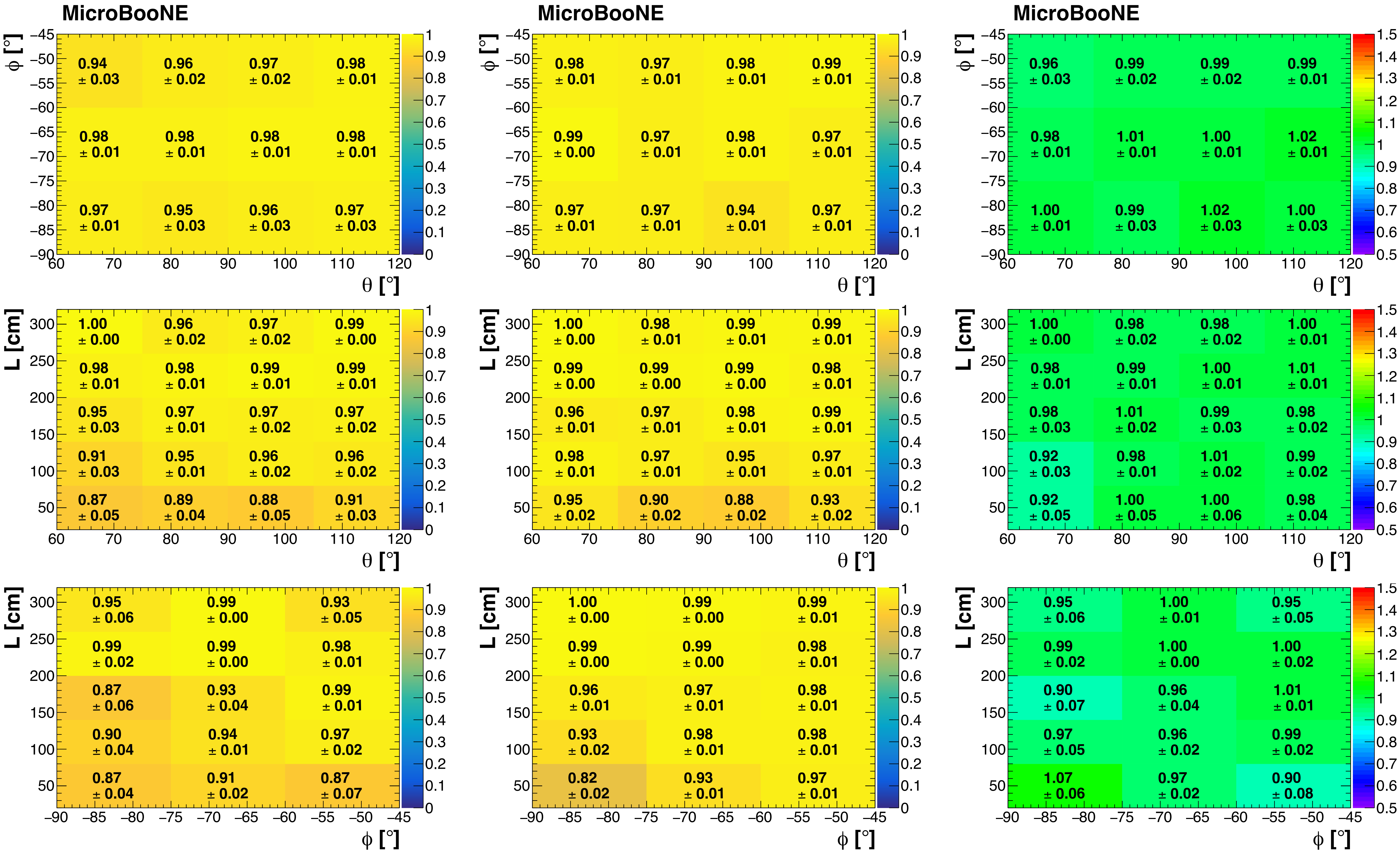


UNIVERSITY OF OXFORD

Results

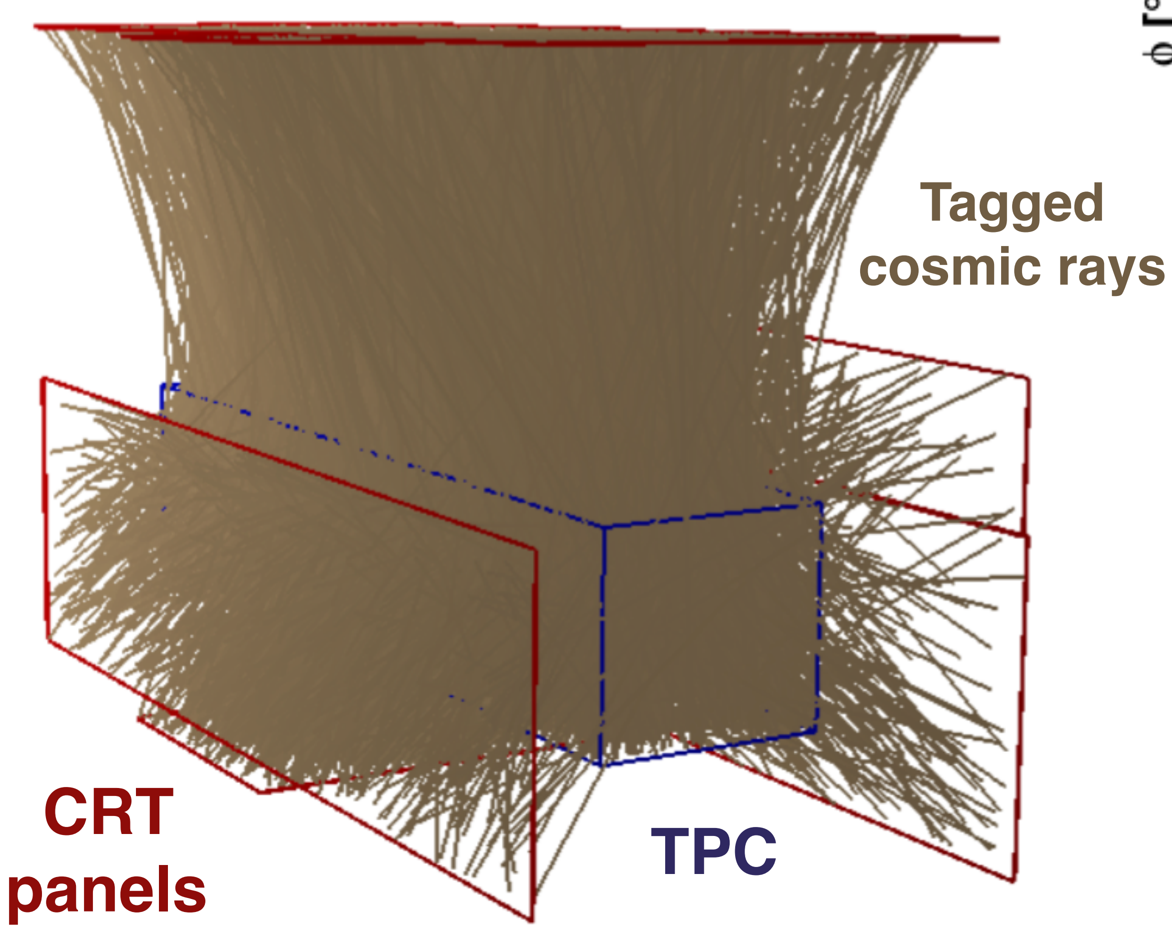
Two-dimensional projections

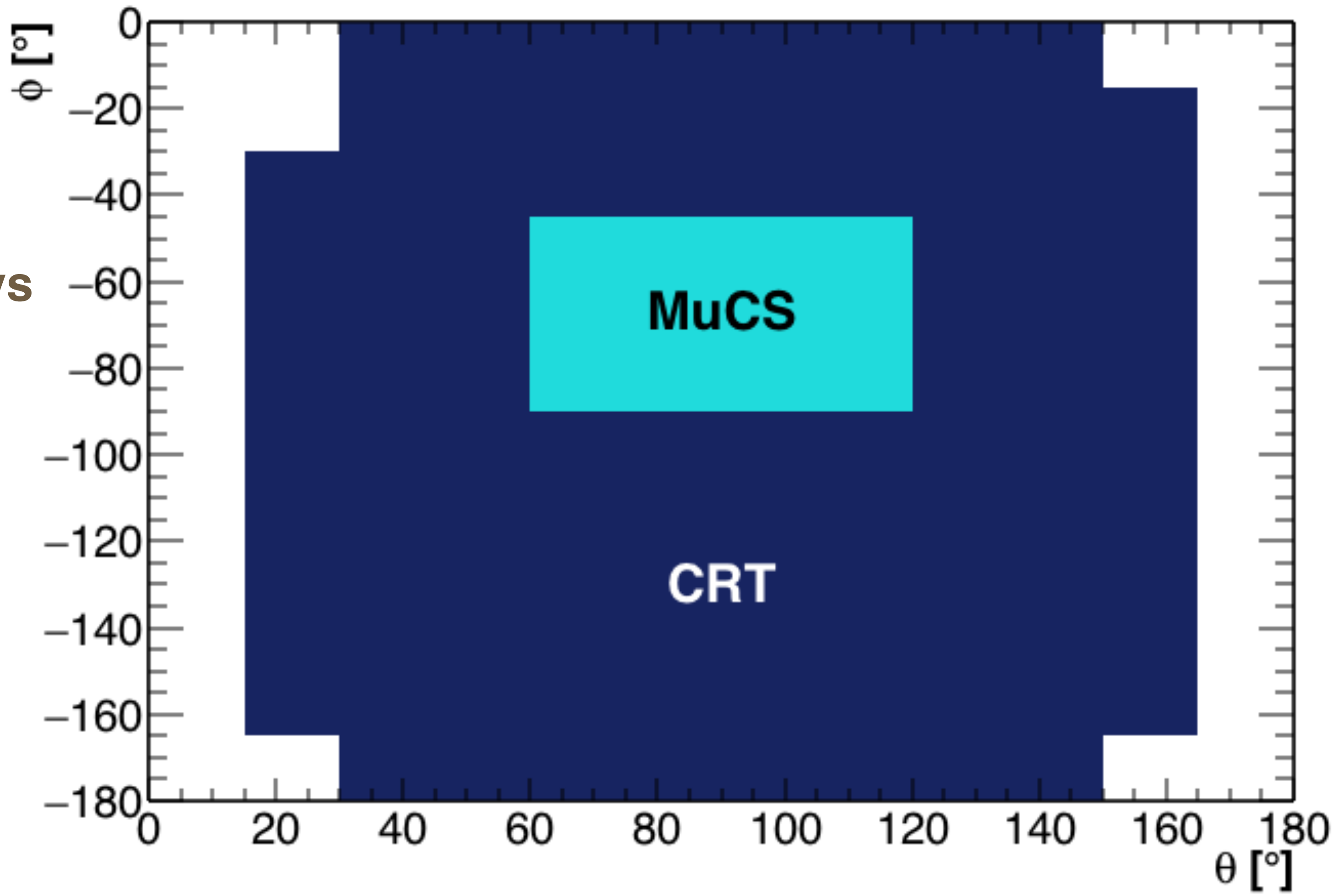
Data | **Monte Carlo** | **Data/Monte Carlo**



Cosmic Ray Tagger

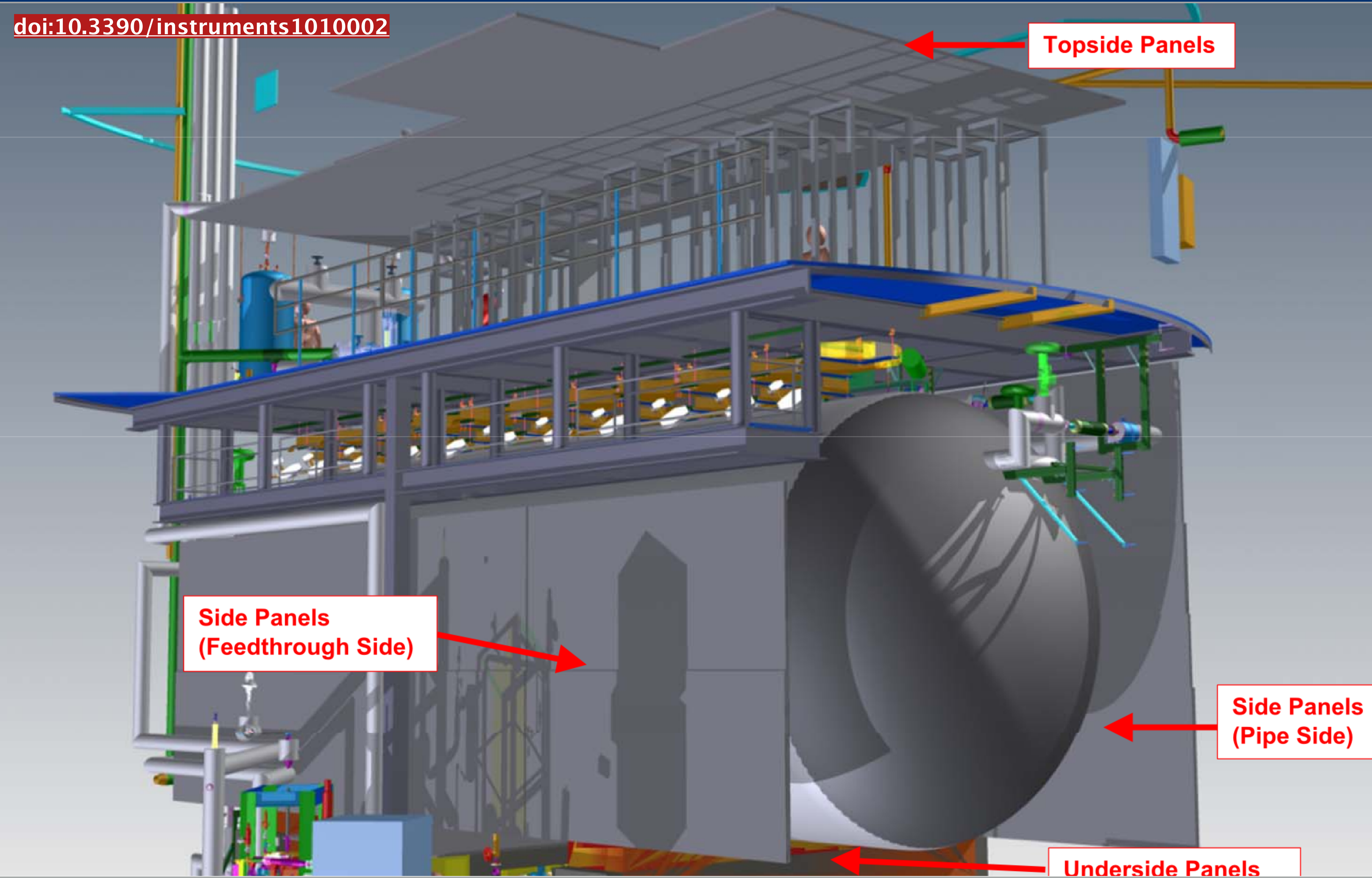
- This analysis represents a small-scale demonstration of the method that can be used with the data coming from the **Cosmic Ray Tagger**, a system of scintillation panels able to tag 85% of the cosmic-ray flux.
- The Cosmic Ray Tagger installation has been completed in January, 2017.
- The angular coverage provided by the CRT is much larger than the one of the MuCS and close to 100%. It will be possible to **measure efficiency-corrected quantities**, such as the cosmic-ray flux in MicroBooNE, and mitigate the cosmic-ray background.





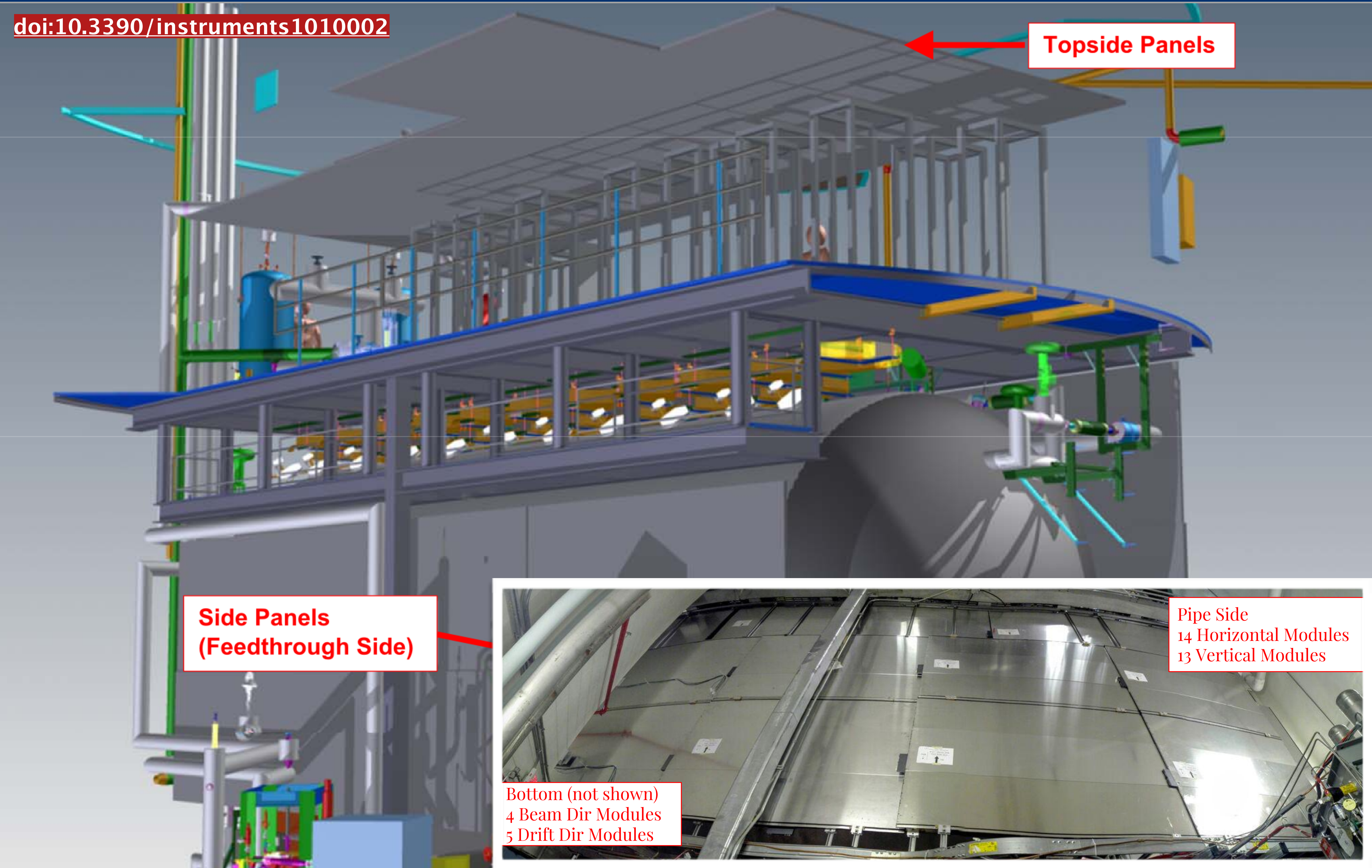
Cosmic Ray Tagger

doi:10.3390/instruments1010002



Cosmic Ray Tagger

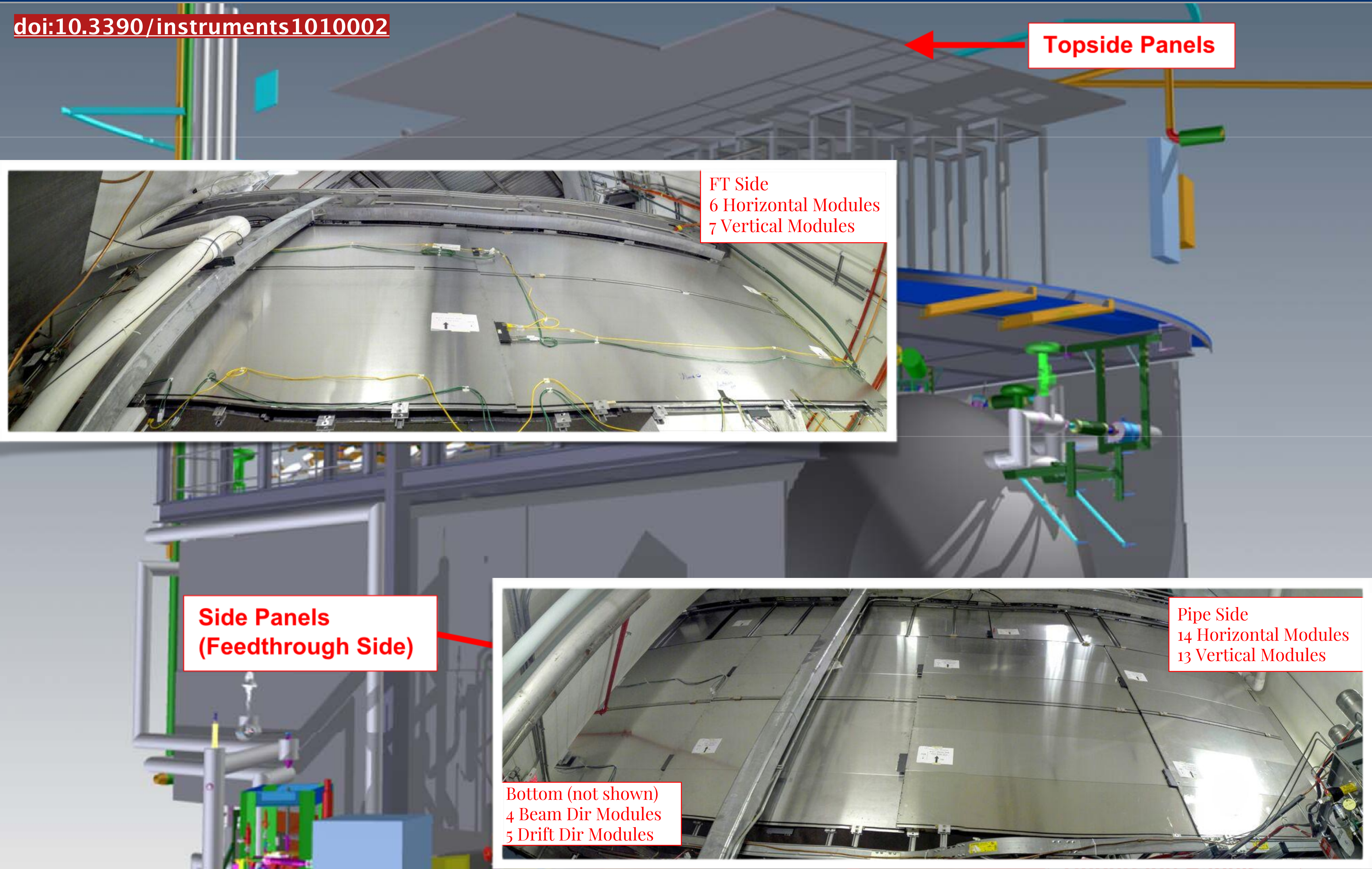
doi:10.3390/instruments1010002



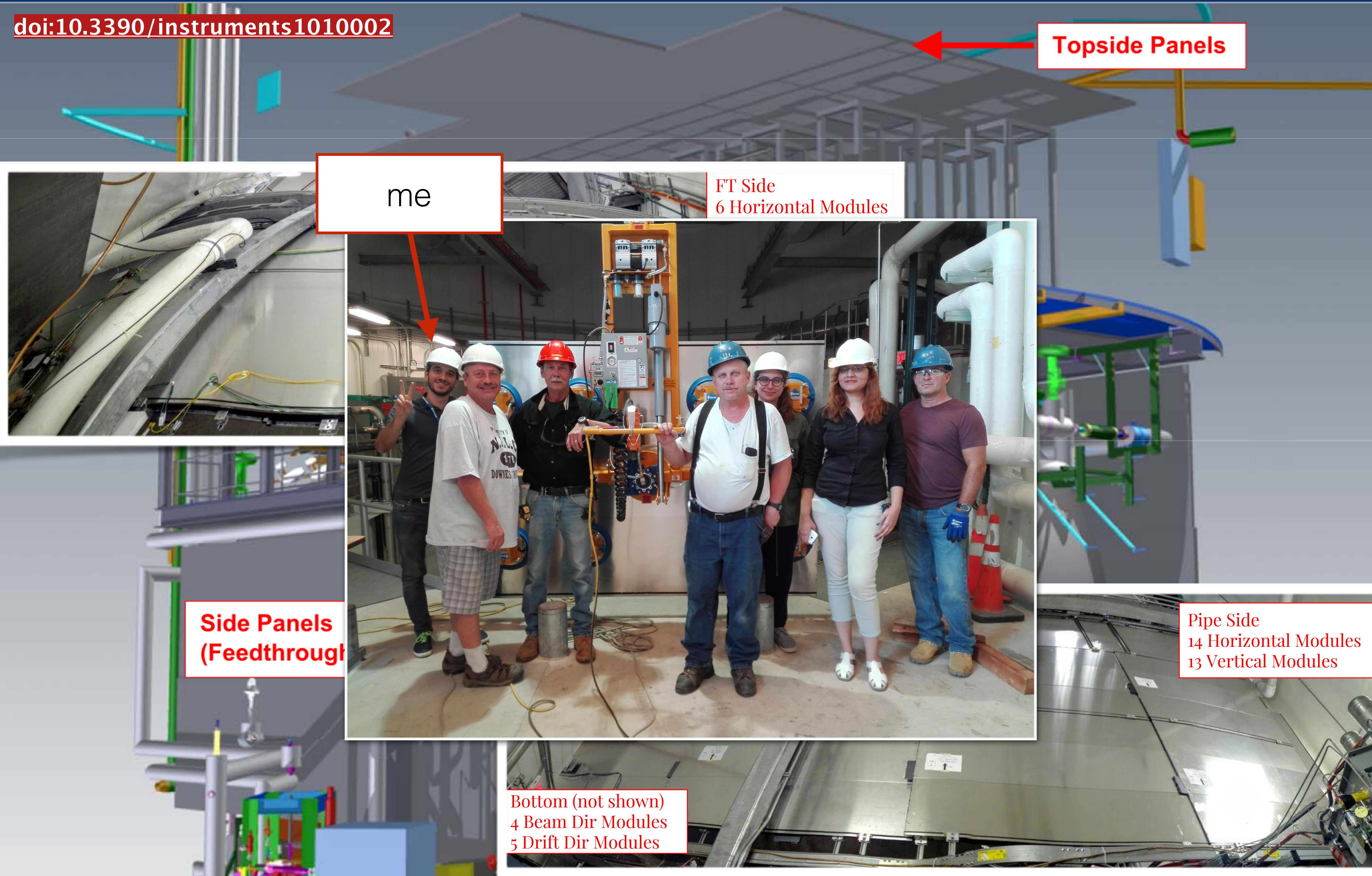
UNIVERSITY OF OXFORD

Cosmic Ray Tagger

μBooNE



Cosmic Ray Tagger



Conclusions

- The MicroBooNE experiment has a **broad physics program** and LArTPC R&D. The detector is up and running: 15 public notes and 5 papers already published.
- A small muon counter stack has the capabilities to assess **several performances of the LArTPC**.
- **Space-charge effect** must be taken into account when reconstructing LArTPC information, but it can be correctly simulated.
- The finding and **reconstruction efficiency of tracks in MicroBooNE is very high** (97.1%) and in good agreement with the simulation.
- The analysis has been included in a paper to be submitted to JINST.
- The **Cosmic Ray Tagger** provides increased coverage for efficiency studies and cosmic-ray background mitigation. Extremely important for future SBN program (ICARUS, SBND) and DUNE.


THANK YOU!
KOVAL
About
Fermilab