Deep learning in LArTPCs with SBND

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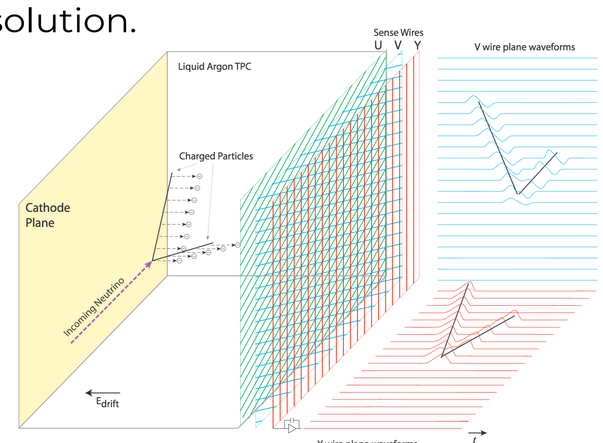
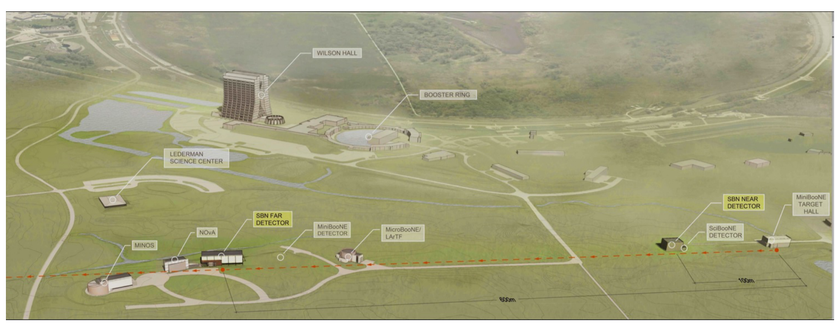
SBN Program

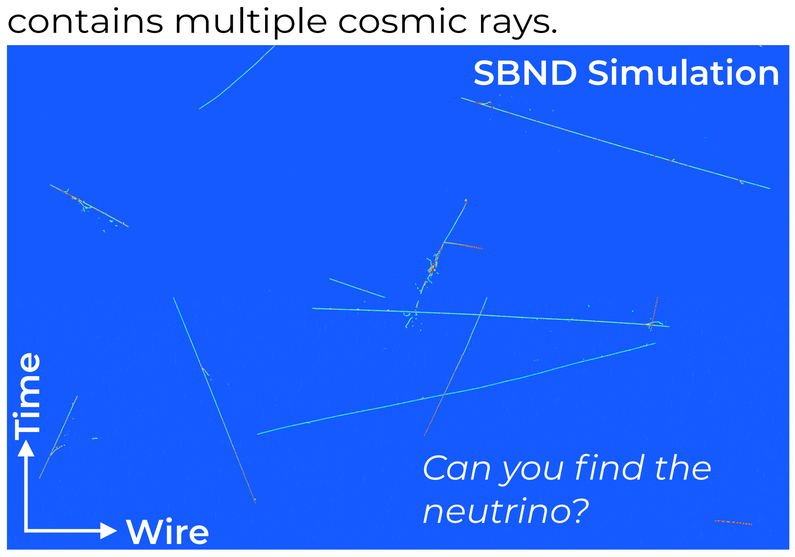
The liquid argon time projection chamber (LArTPC)[1] projects 3D particle interactions onto several planes of sense wires. This creates complentary images of particle interactions with very high (3mm) resolution.





The Short-Baseline Program at Fermilab will probe oscillation anomalies and measure precision neutrino-argon cross sections (GeV range), using three liquid argon time projection chambers along the Booster Neutrino Beam.[2]

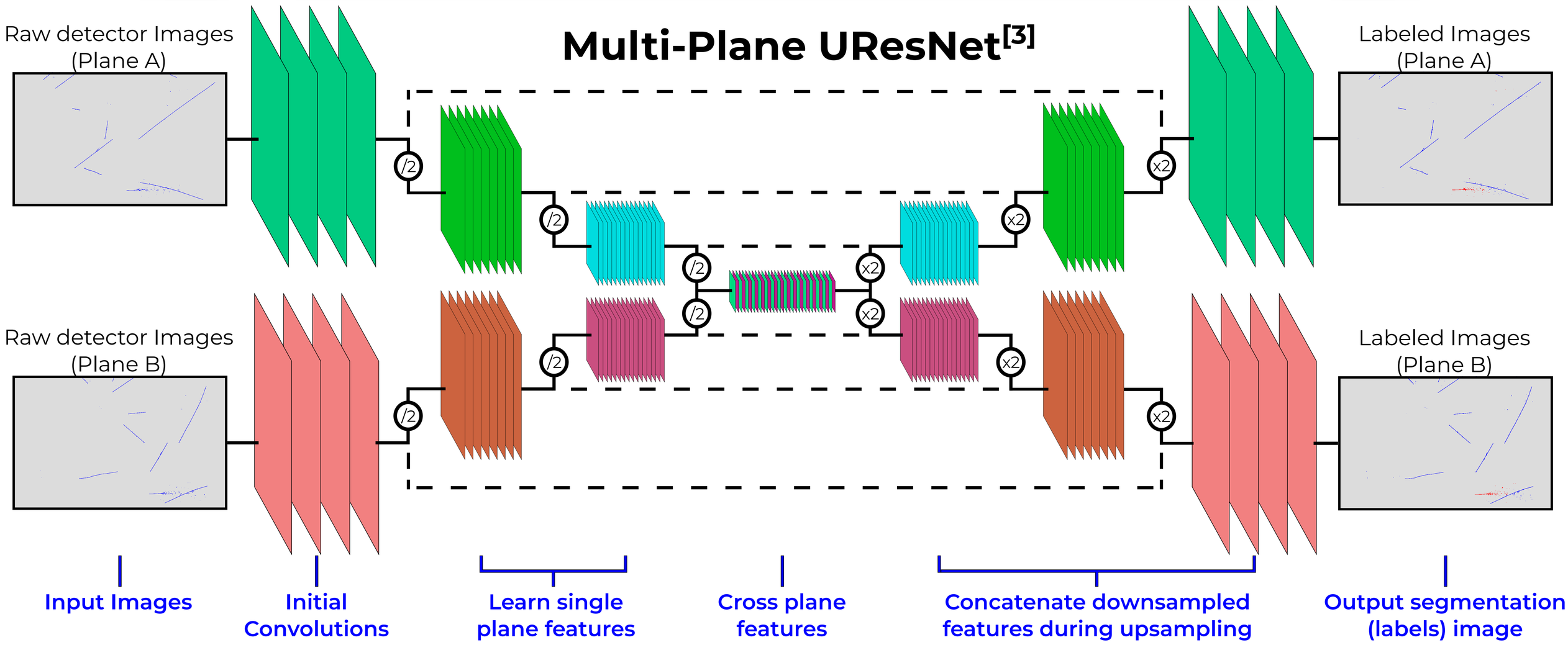
Slow drift times plus surface operations means that every trigger of SBN detectors contains multiple cosmic rays.



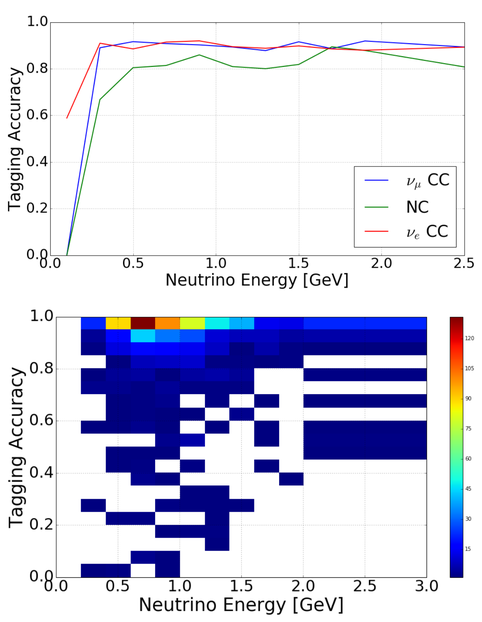
Mitigating cosmic backgrounds is critical to the SBN Program.

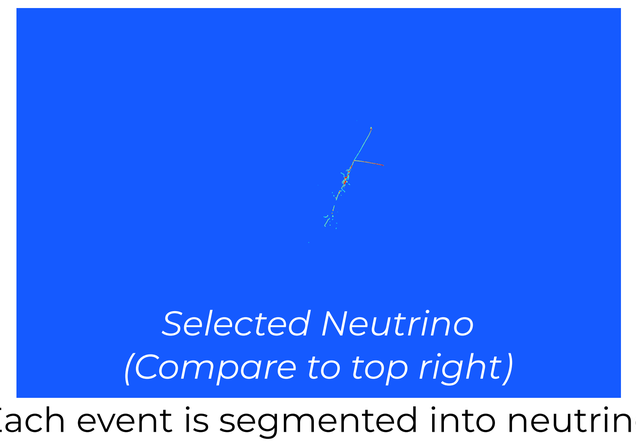
We showcase a novel deep learning approach to removing cosmic activity from events in the Short Baseline Near Detector (SBND)

Multi-Plane UResNet[3]



Neutrino Pixel Tagging





Each event is segmented into neutrino and cosmic images, with **an accuracy greater than 90%** on average for charged current interactions above a few hundred MeV.

Cosmic Event Rejection

Pixel Count Threshold:

$N_{neutrino} > 5$

Cross-Plane Overlap:

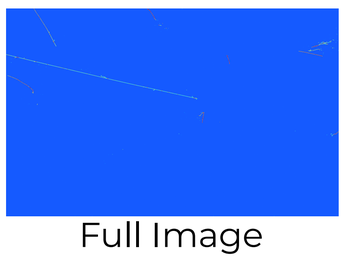
$$\frac{|\bar{y}_i - \bar{y}_j|}{max(\sigma_{y_i}, \sigma_{y_j})} < 1$$

	Events/ Year	Eff.	Filtered Events	% of Filtered
ν_μ CC	1.7e6	81%	1.4e6	71%
ν_e CC	1.2e4	89%	1.1e4	0.5%
NC	6.7e5	50%	3.3e5	17%
Pure Cosmic	4.0e6	5.7%	2.3e5	11.5%

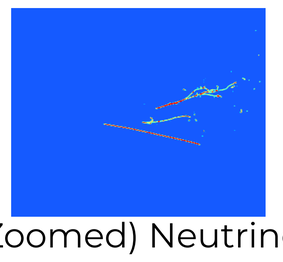
By requiring at least 5 neutrino labeled pixels in each plane, and requiring the cross-plane overlap of neutrino labeled pixels in the drift direction (y direction), we enhance the SBND dataset from 37% neutrino purity to **89% neutrino purity**, with a flux weighted **efficiency of 72%**.

Conclusions

We have developed a novel deep learning technique to tag neutrino pixels with high accuracy and low false positive rates.



Full Image



(Zoomed) Neutrino Selection

Future Improvements

- **Decrease mask pixel (currently 1.2cm x 1.2cm)**
- **Predict Neutrino vertex location in all three planes**
- **Improve cosmic rejection cuts**
- **Extend to other SBN detectors, MicroBooNE and ICARUS**

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References

[1] C. Rubbia, "The Liquid Argon Time Projection Chamber: A New Concept for Neutrino Detectors", 1977, CERN-EP-INT-77-08

[2] M. Antonello and others, "A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam", 2015, arxiv:1503.01520

[3] O. Ronneberger, P. Fischer, T. Brox, "U-net: Convolutional networks for biomedical image segmentation," 2015, International Conference on Medical Image computing and computer-assisted intervention