

Improving MicroBooNE's Inclusive Single-Photon Search with Low-Energy Hadronic Identification

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Introduction & Motivation

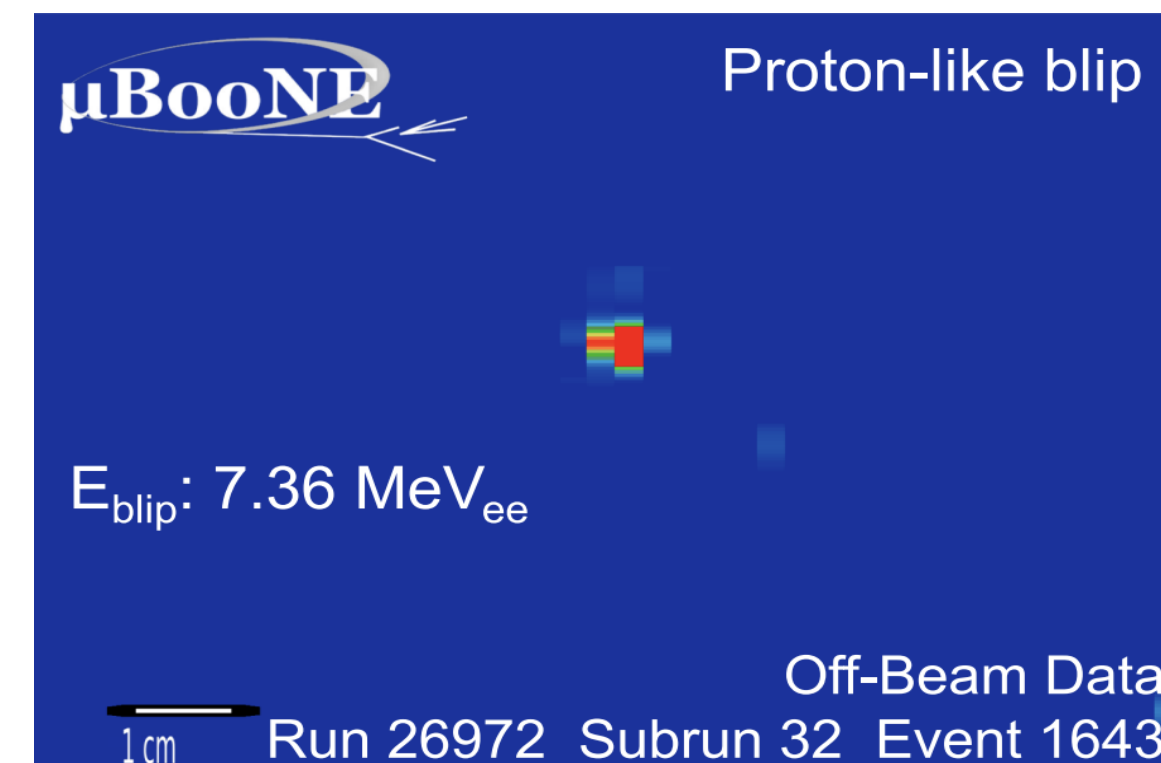


Fig. 1: Proton-like blip.

► **Blips:** MeV-scale energy deposits visible in LArTPCs as small, isolated clusters of ionization of few mm- to cm

► Use LArTPC MeV-scale sensitivity via blips to identify **low-energy protons** and **neutrons** missed by standard reconstruction tools

► Apply these new techniques in our **inclusive single-photon ($1\gamma X$)** analysis, which reported a 2.2σ sigma excess in shower energy < 600 MeV, for events with **no reconstructed protons** [1]
See Poster ID 117

► Expanded single-photon channel search can provide further insight into a possible explanation for the MiniBooNE anomaly [2]

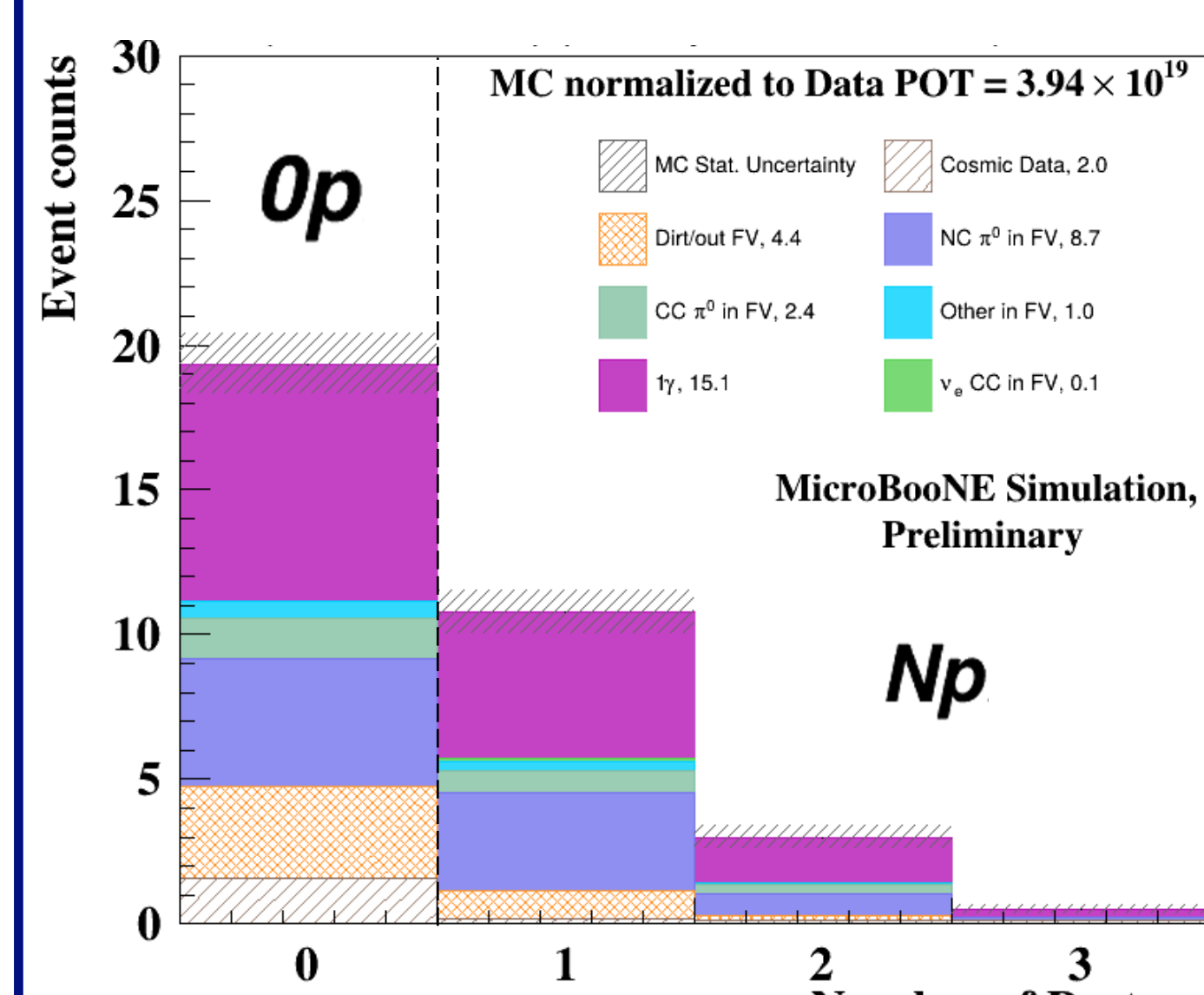
Blip-based neutron characterization

Neutron characterization blip-metrics: $SumE_{Blip}$ and N_{blip} [5]

• If $SumE_{Blip} \leq 11 MeV_{ee}$ AND $N_{Blip} \leq 2 blips \rightarrow Reco On$

• Otherwise $\rightarrow Reco Nn$

Reco-On
Low blip activity events
(consistent with ambient radiogenic & cosmic levels)



Reco-Nn
High blip activity events

Absence of de-excitation γ 's in the MicroBooNE simulation may bias the MC prediction of **low-energy blip activity** !!!
 \rightarrow Systematic & Simulation studies

Fig. 4: Events are split by blip activity as a proxy for neutron characterization, defining four exclusive topologies: $Op0n$ -, $Np0n$ -, $OpNn$ -, and $NpNn$ -like.

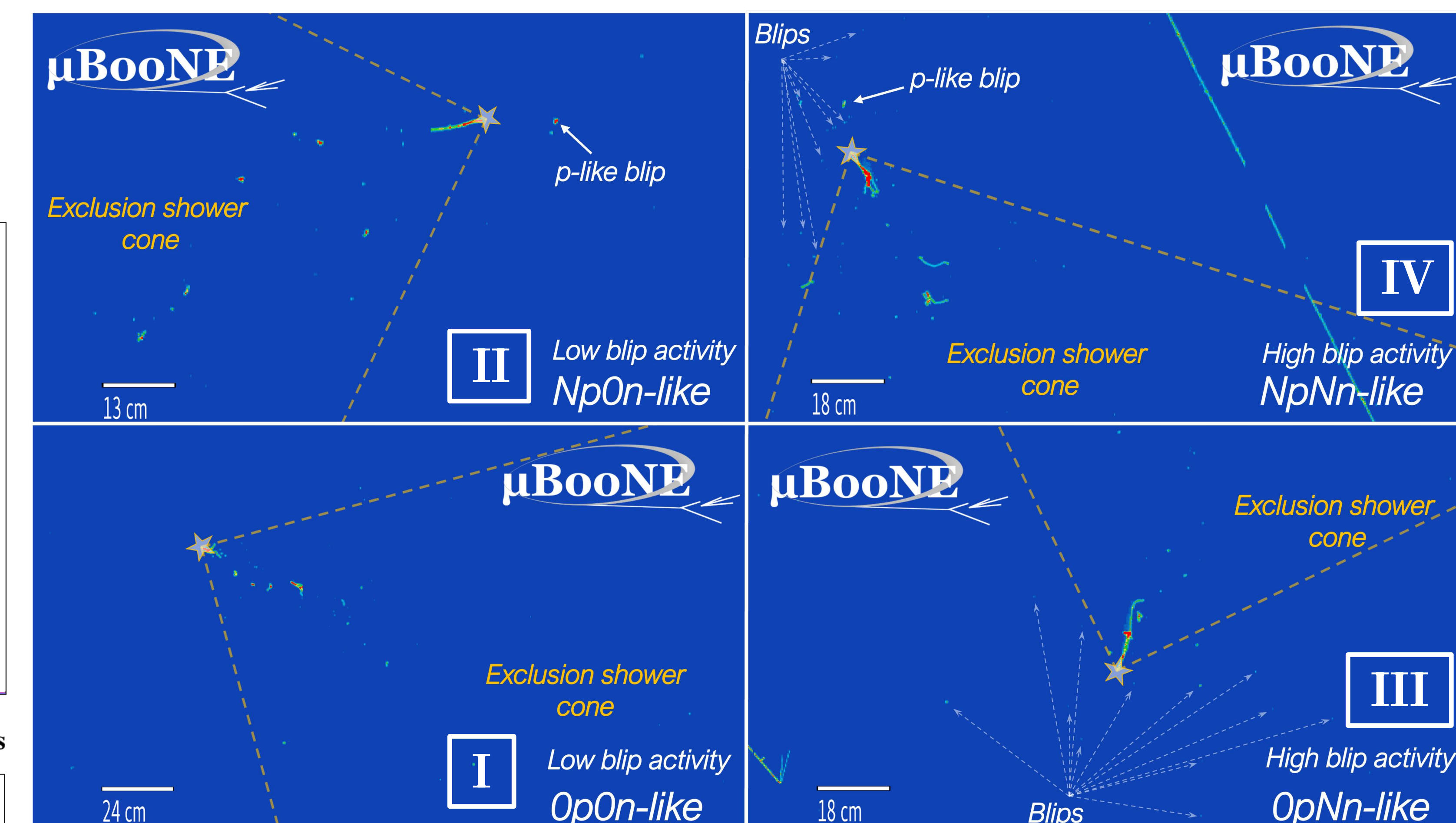


Fig. 5: The four exclusive topologies: $Op0n$ -, $Np0n$ -, $OpNn$ -, and $NpNn$ -like, defined via blip-based neutron characterization. The exclusion cone encloses blip activity from the shower.

MeV-scale reconstruction provides more information about MicroBooNE's inclusive $1\gamma 0p$ (2.2σ) excess

► Reconstruction of MeV-scale LArTPC features (blips) can reveal formerly unidentified final-state particles near 'isolated' single showers:

- Diffuse low-energy (0-3 MeV) blips: inelastic scattering of **final state neutrons**
- Higher-energy blips upstream of the isolated shower: **final-state protons**

Low-energy hadronic ID

► Identify low-energy missed content via MeV-reconstruction [3,4]:

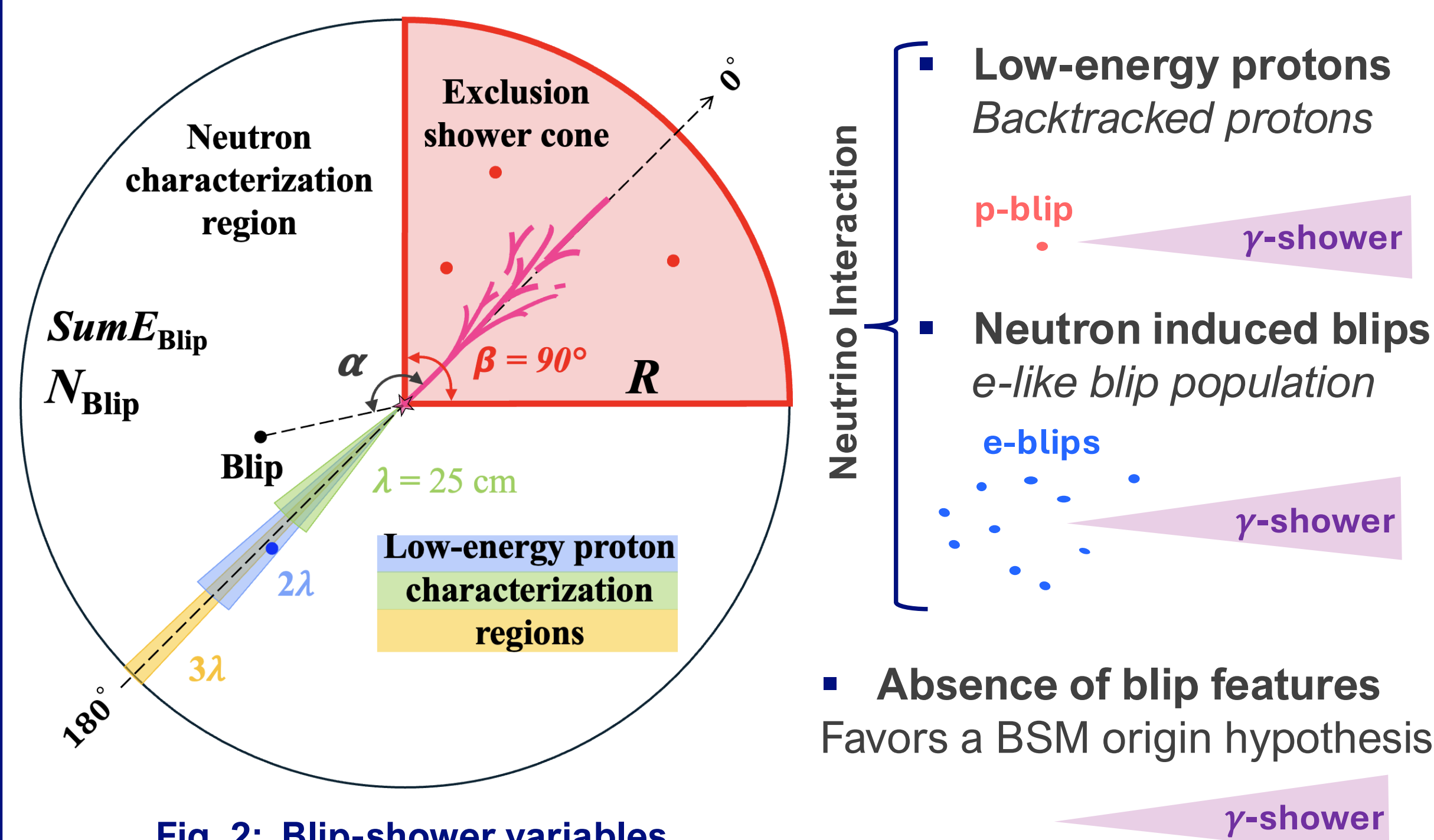


Fig. 2: Blip-shower variables

Low-energy protons
Backtracked protons

Neutrino Interaction

- p-blip $\rightarrow \gamma$ -shower
- Neutron induced blips $\rightarrow e$ -like blip population
- e-blips $\rightarrow \gamma$ -shower

Absence of blip features
Favors a BSM origin hypothesis

N_{Blip} and $SumE_{Blip}$ suggest:
- Neutron presence
- Nucleus de-excitation γ 's

First ever observation of MeV-scale activity from NC Neutrino interactions

Fig. 3: Blip multiplicity for $1\gamma X$ events in Runs 1-3 for Op and Np events compared to EXT data (ambient blips).

Improvements to the next generation $1\gamma X$

- Full dataset (Runs 1-5)
- Cosmic Ray Tagger (CRT) veto
 - No events in time with CRT hits
- Wire-Cell proton proximity cut
 - Protons within 75 cm from vertex
- Enhanced Op/Np split using blips

Blips found in backtracking regions are counted as proton candidates

Under the **enhanced Op/Np**
Events could migrate from **Reco- Op \rightarrow Reco- Np**

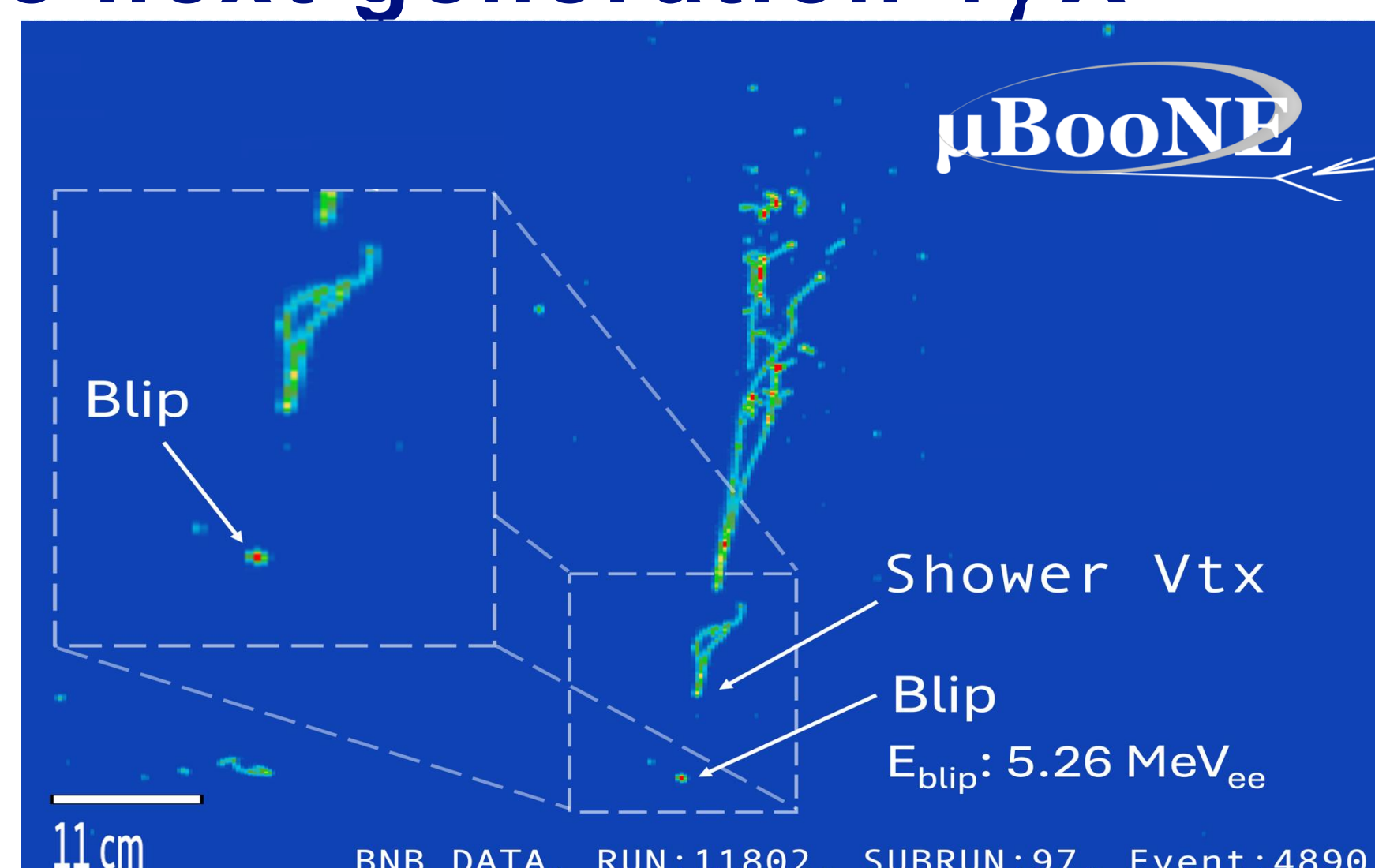


Fig. 6: Wire-Cell $1\gamma 0p$ event with a backtracked p-like blip of 5.26 MeV_{ee} reconstructed energy corresponding to a true proton with $\sim 22 MeV KE$ [4], reclassified into the $1\gamma Np$.

Summary

1. New features incorporated into the inclusive single-photon analysis include a CRT veto, Wire-Cell proton proximity requirement, and blip-based low-energy proton identification to improve the Op/Np classification.
2. First time using blip-based techniques that provide access to hadronic activity in neutrino interaction final states: **$Op0n$ -like, $OpNn$ -like, $Np0n$ -like, and $NpNn$ -like**.
3. The signal sample can be split into subsets of high and low adjacent blip activity, interpreted as neutron-inclusive and neutron-exclusive final states respectively, making possible the first blip-based separation of neutrino interaction final states in a neutrino LArTPC dataset.

References

- [1] Phys. Rev. Lett. 136, 181806 (2026)
[2] Phys. Rev. D. 103, 052022 (2021)

- [3] Phys. Rev. D 109, 052007 (2024)
[4] Phys. Rev. D 111, 032005 (2025)
[5] MICROBOONE-NOTE-1134 -PUB