Reconstruction of Neutral Final-State Particles in Neutrino-Argon Interactions

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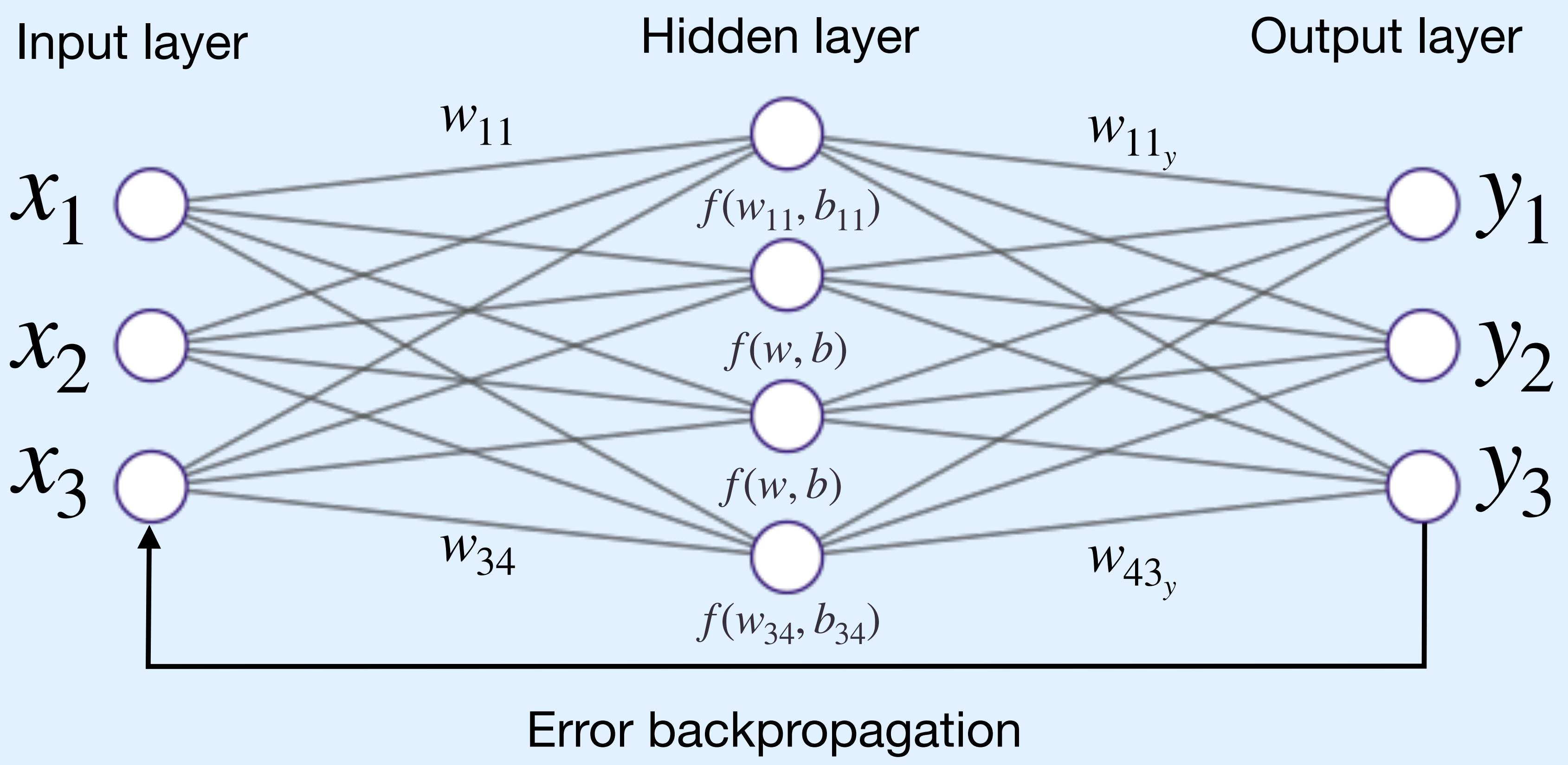
Introduction

The next generation of neutrino experiments will be able to:

- Resolve neutrino oscillation parameters δ_{CP}, θ_{23} and the neutrino mass ordering
- Detect ν_e flux from near supernovae explosions
- Search for proton decay

Neural networks are widely used across particle physics experiments to improve event reconstruction.

Easily applied to regression problems, such as predicting the energy of an incoming particle.



B. Abi et al, DUNE collaboration, 2002.03005 (2020)

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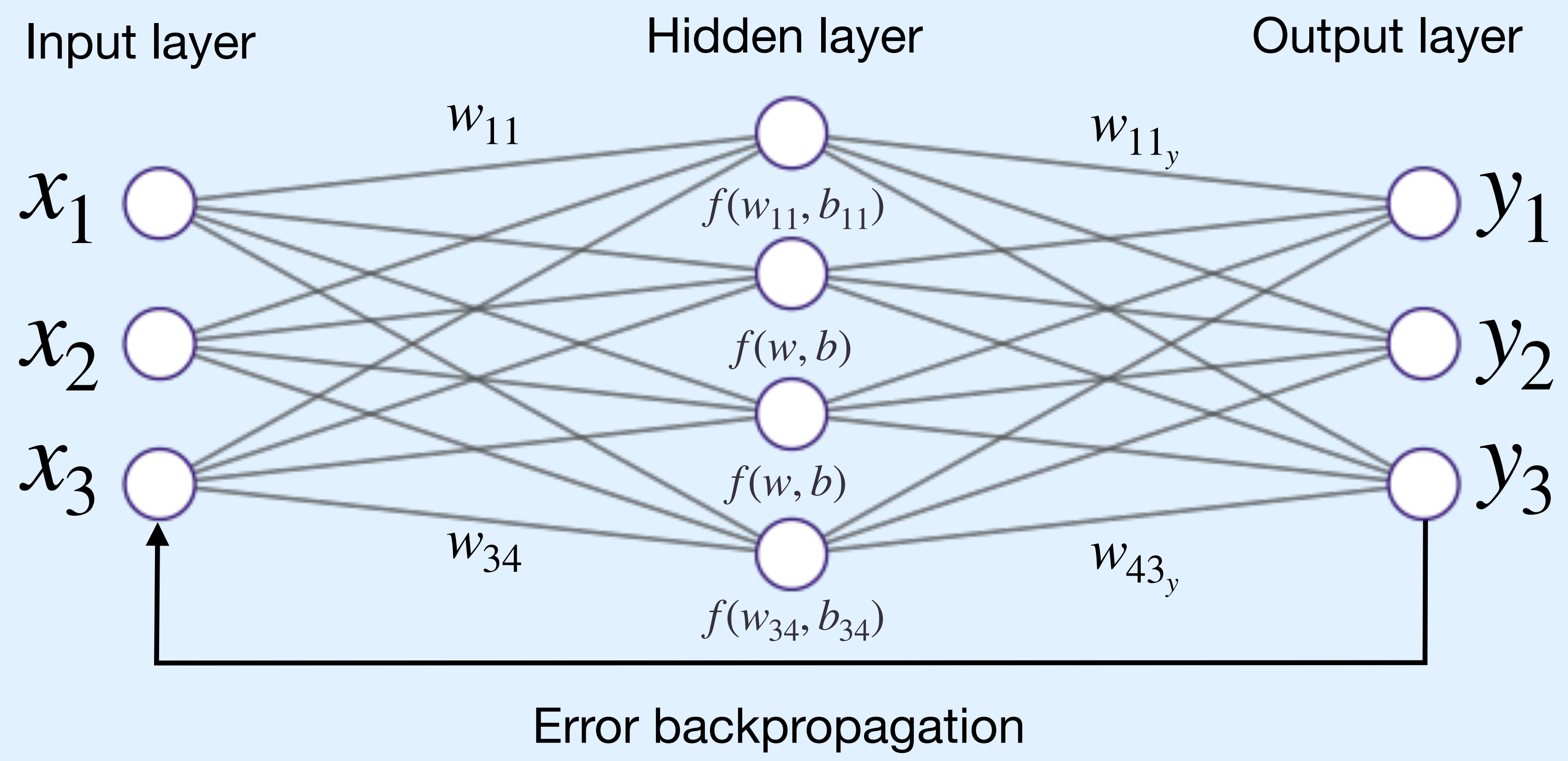

Invisible particles in final state of neutrino nucleon interaction still pose a challenge to accurate energy reconstruction.

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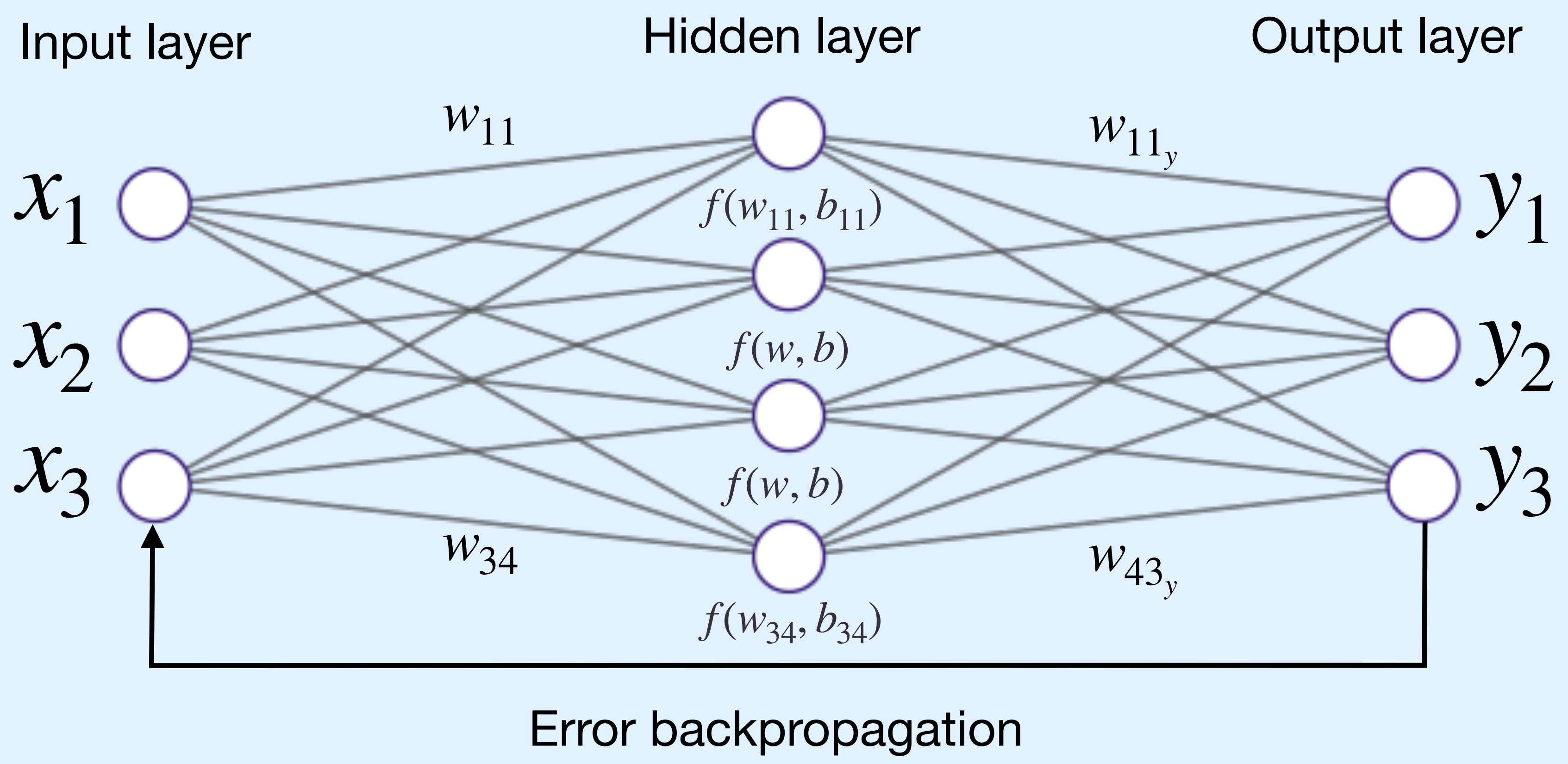

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UCL

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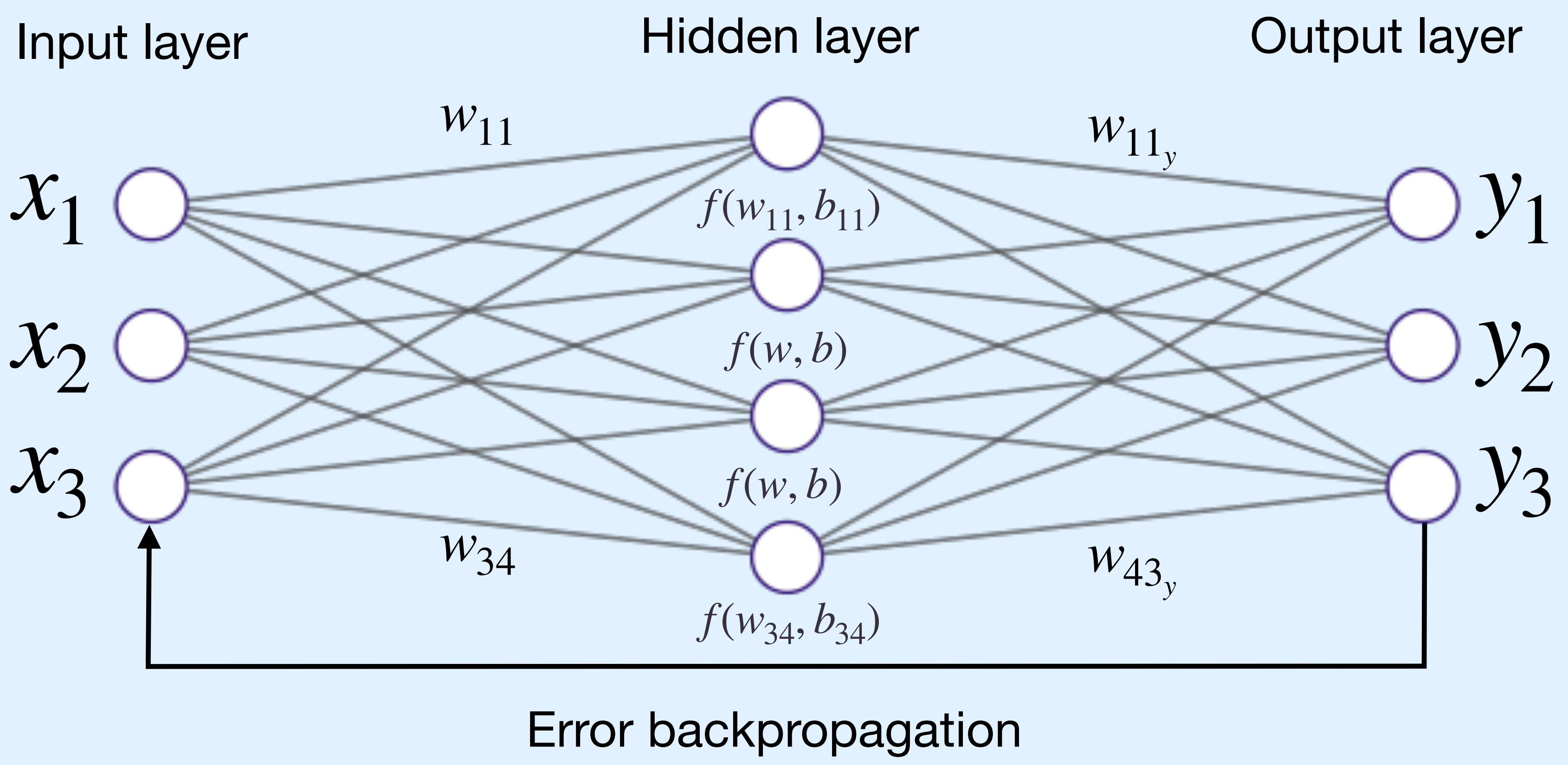

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→

Train a neural network to reconstruct neutrino energy.

Use dataset with detector constraints applied.

Test performance for beam and atmospheric neutrinos.

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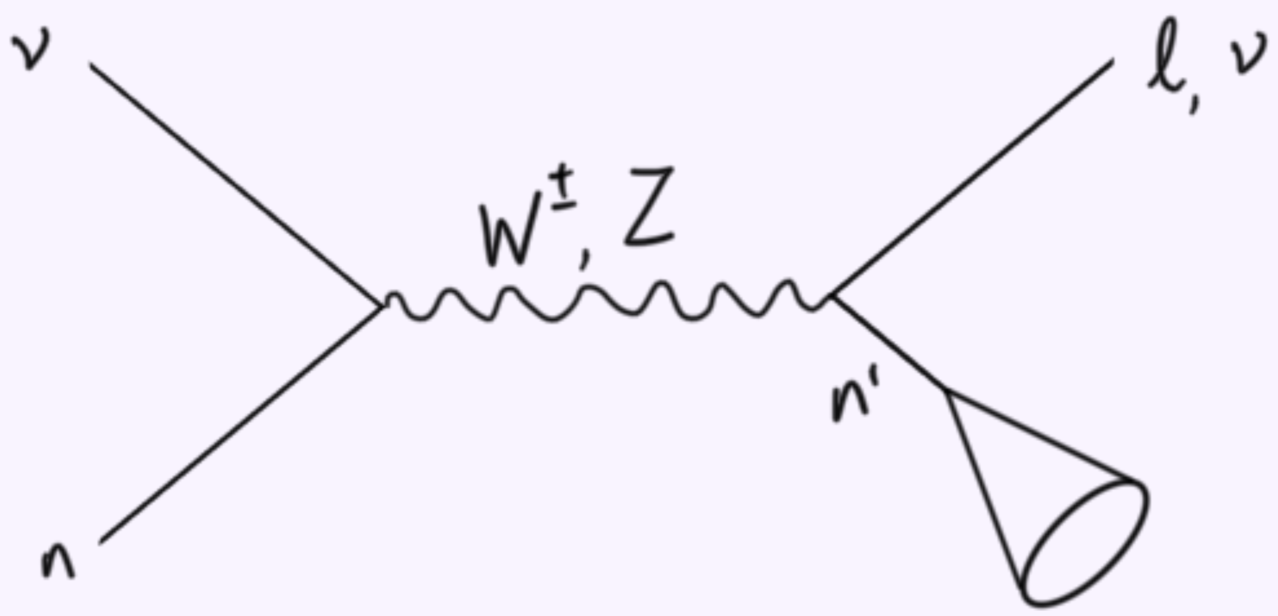
Dataset and Network



Generate 5×10^5 $\nu_\alpha(\overline{\nu_\alpha})$ events with energies from 0.2 - 6 GeV using NuWro.

Use DUNE flux for beam neutrinos, flat flux for atmospherics.

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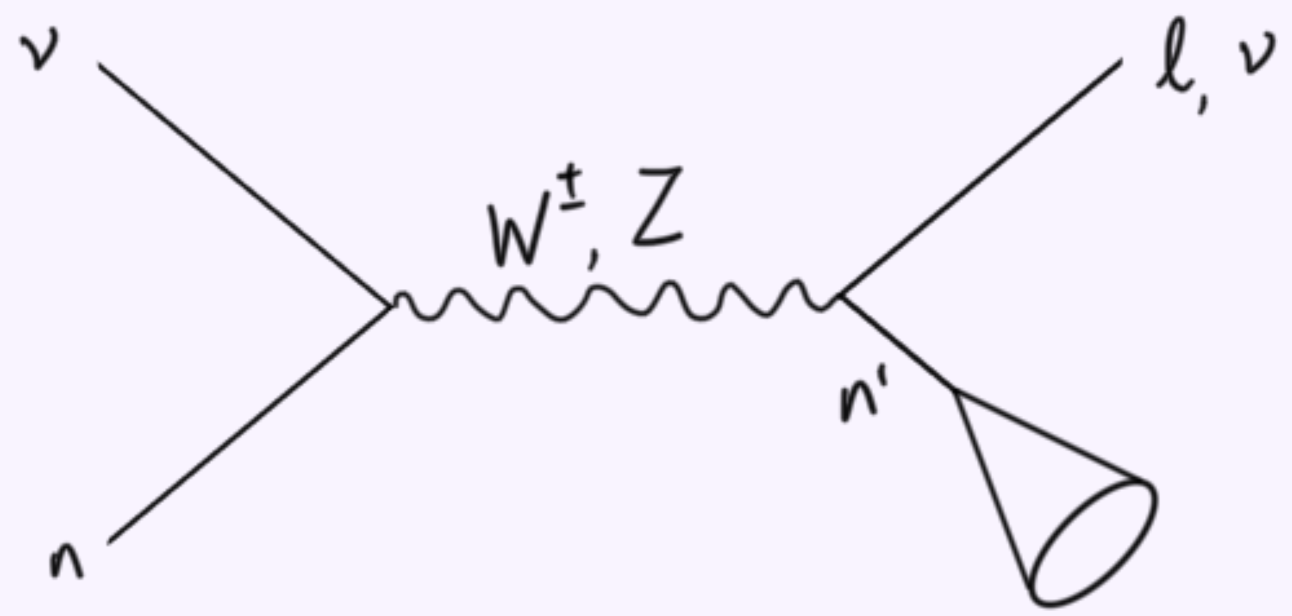

Particle	Minimum K.E.	Angular Uncertainty	Energy Uncertainty
Proton	30 MeV	10°	10%
Pion \ Kaon	30 MeV	10°	10%
Neutron	30 MeV	10°	40%
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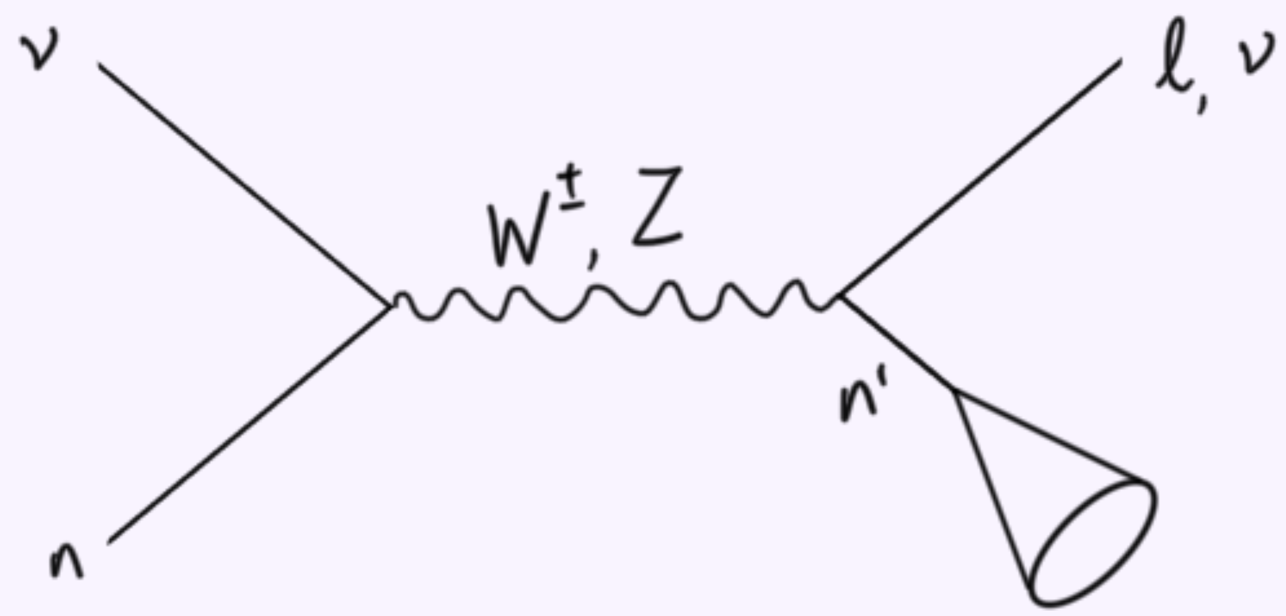
Smear energy and $\underline{p}$.

Randomly rotate events if training for atmospherics.

Remove invisible particles.

Dataset and Network



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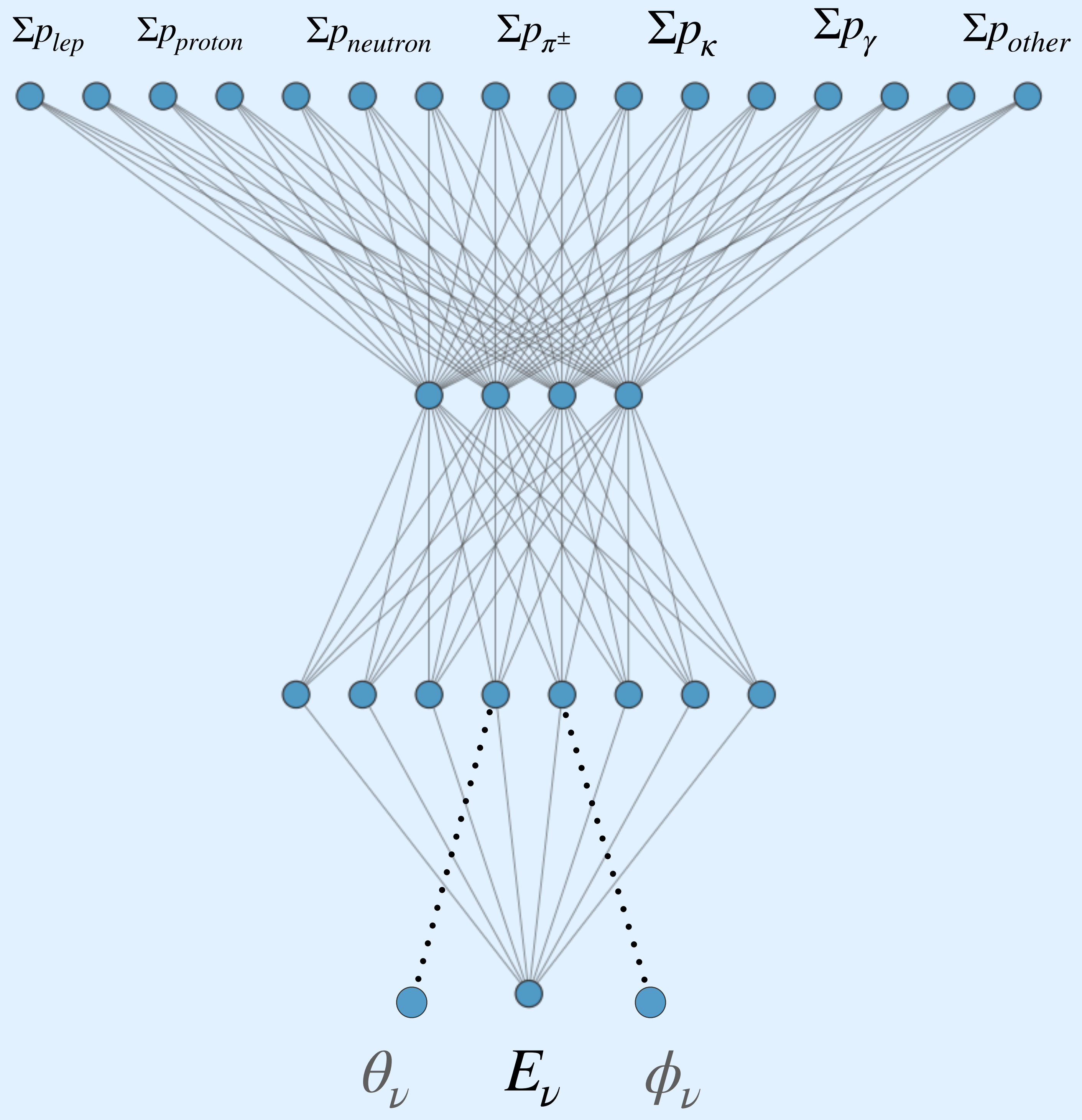

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Remove invisible particles.

Feed to fully connected layer regression network

Results

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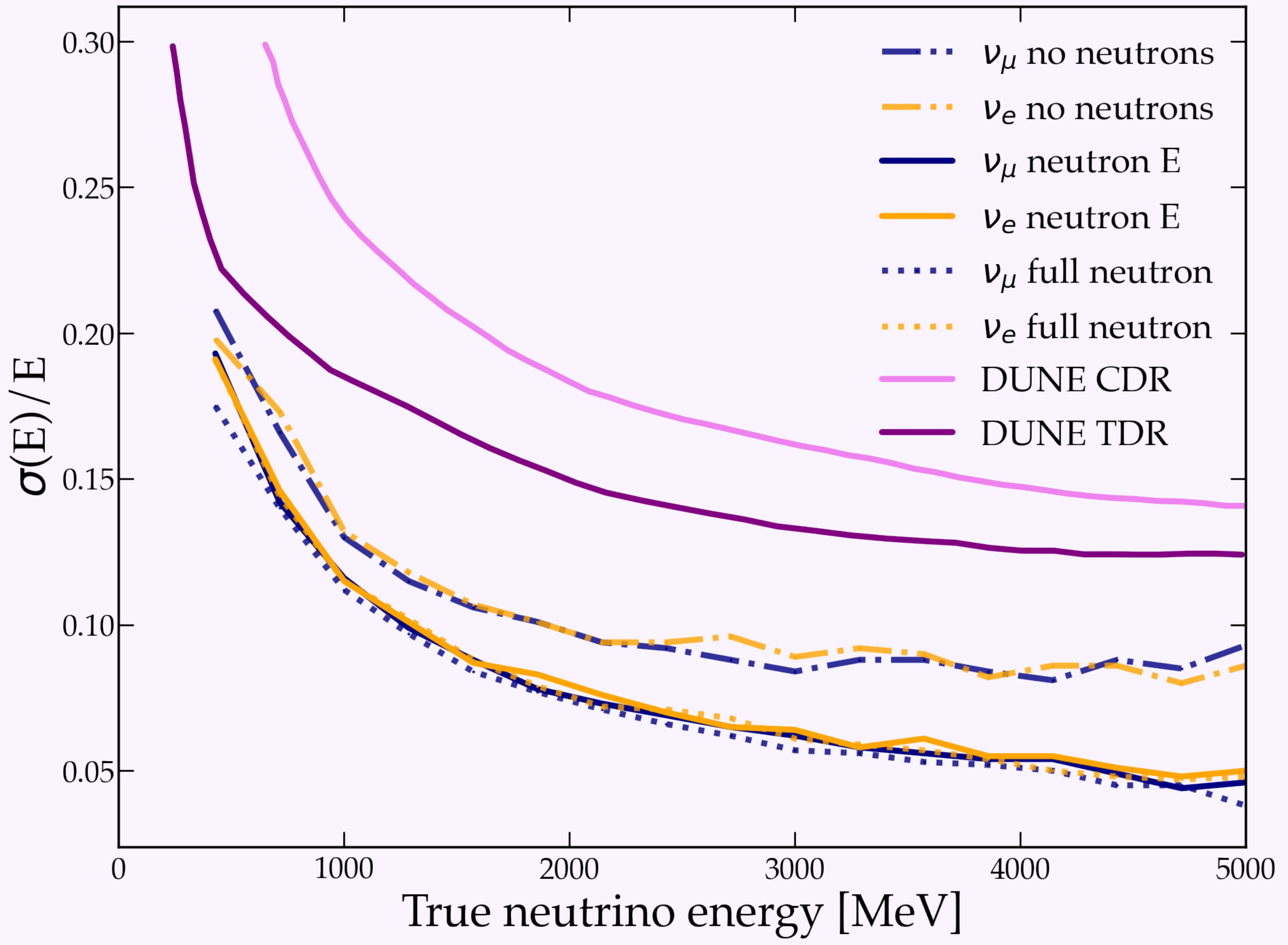
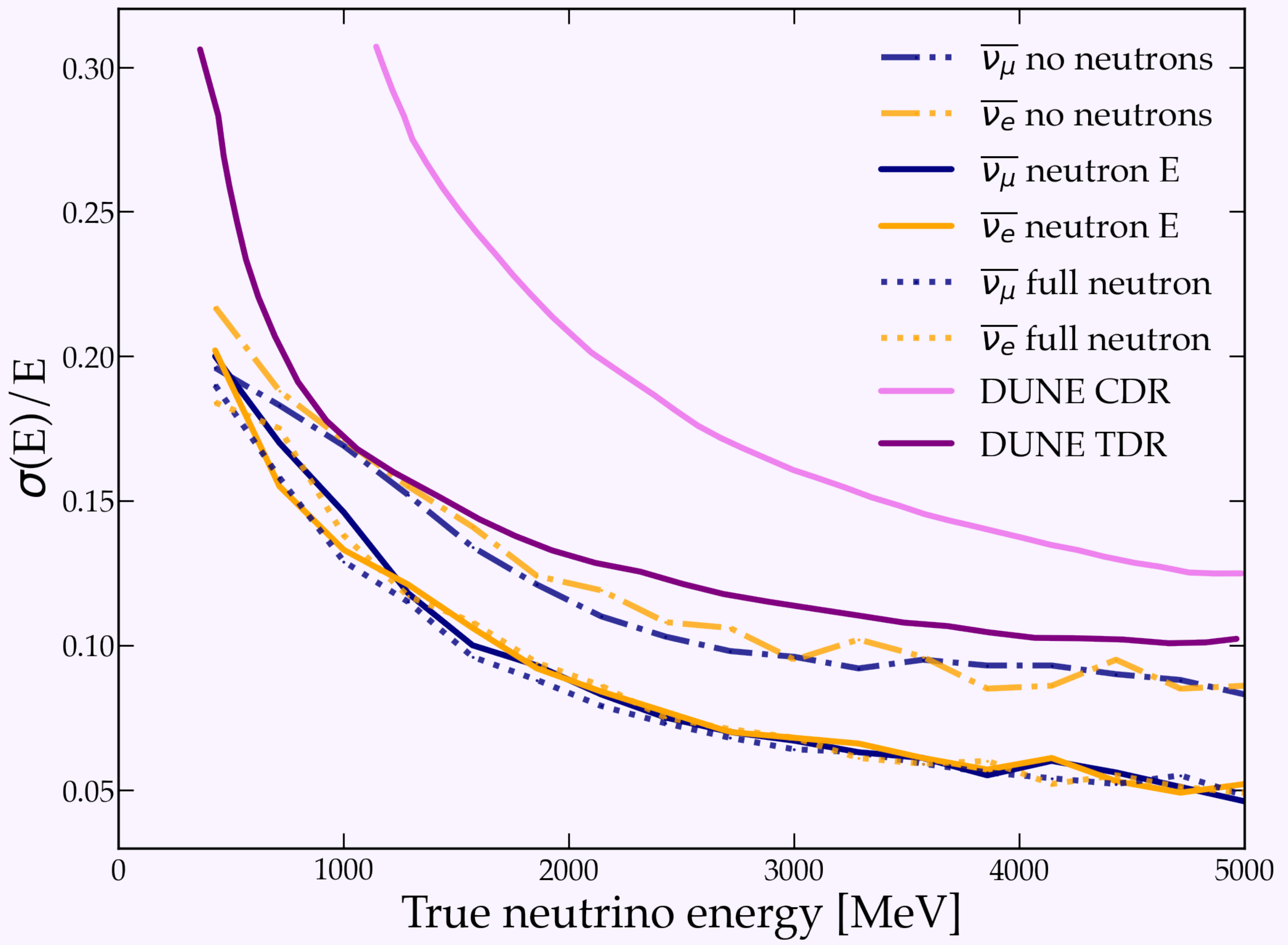


Beam neutrinos

Best resolution goes from $13\,\%$ (TDR) $\rightarrow 6\,\%$ (network with neutron E)

Having access to neutron energy information improves network resolution by a factor of 1.5

Adding neutron 3-momentum yields minimum improvement



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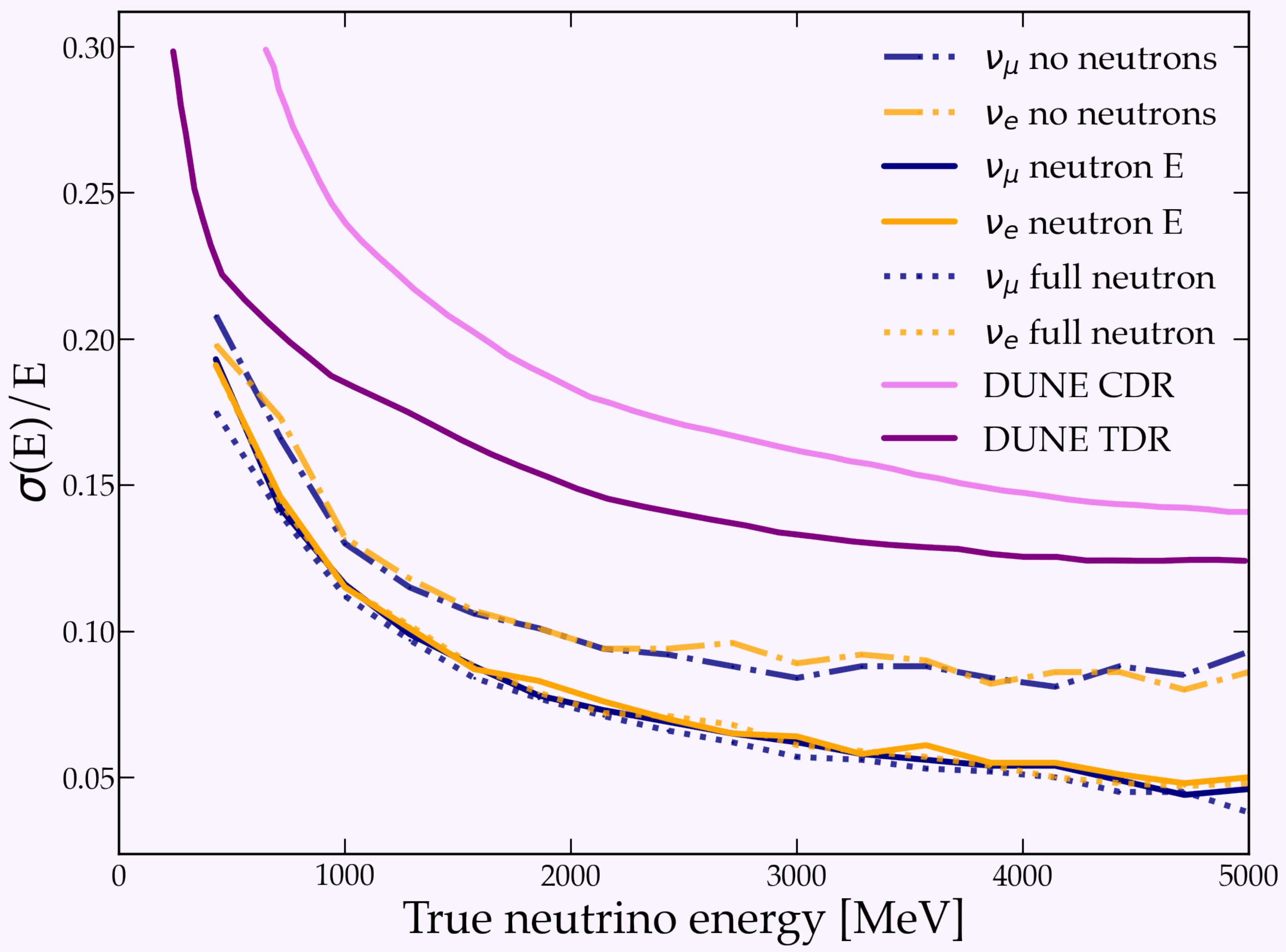

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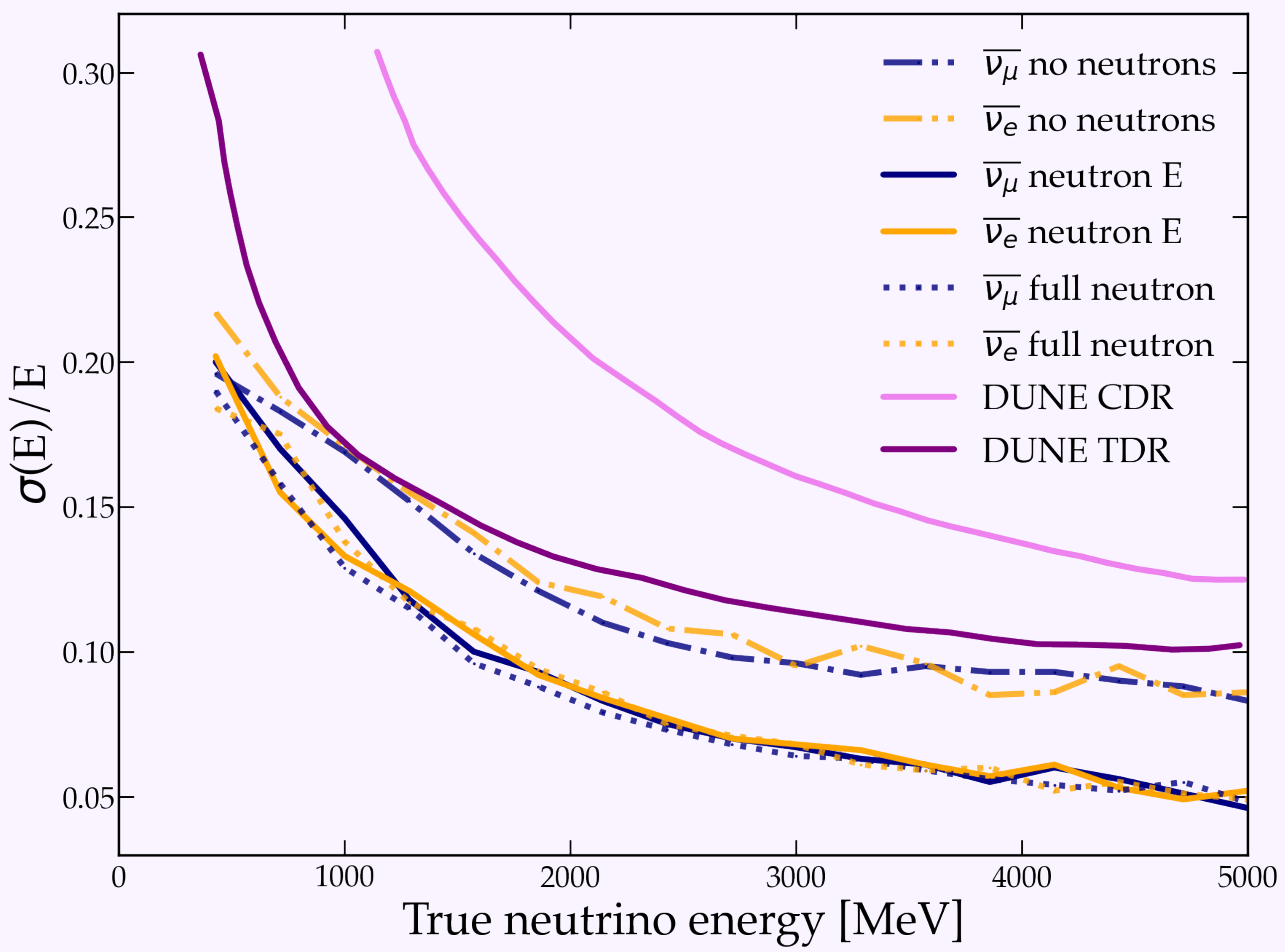

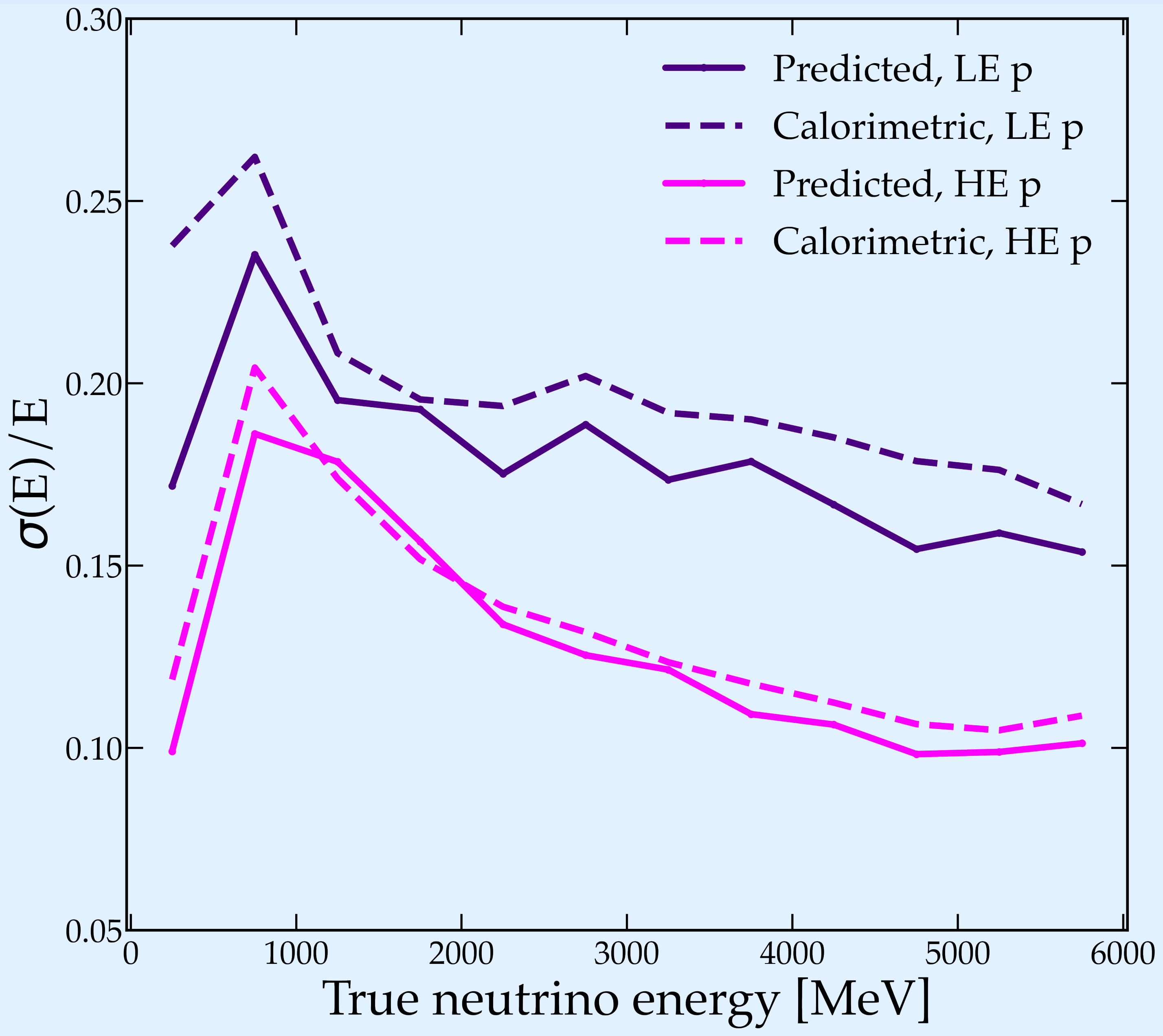

Atmospheric neutrinos

Network energy resolution outperforms calorimetric for events without a high energy proton in the final state

Improvement in angular reconstruction is minimal except for high energy neutrinos with low final state hadronic energy

Haven't tested the effect of adding neutron information for atmospherics… yet!