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Deep learning reconstruction of the neutrino energy with a shallow Askaryan detector

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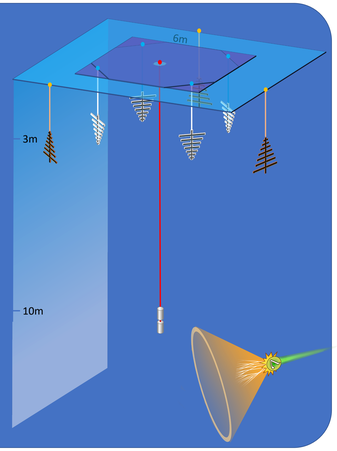
Shallow radio detector station

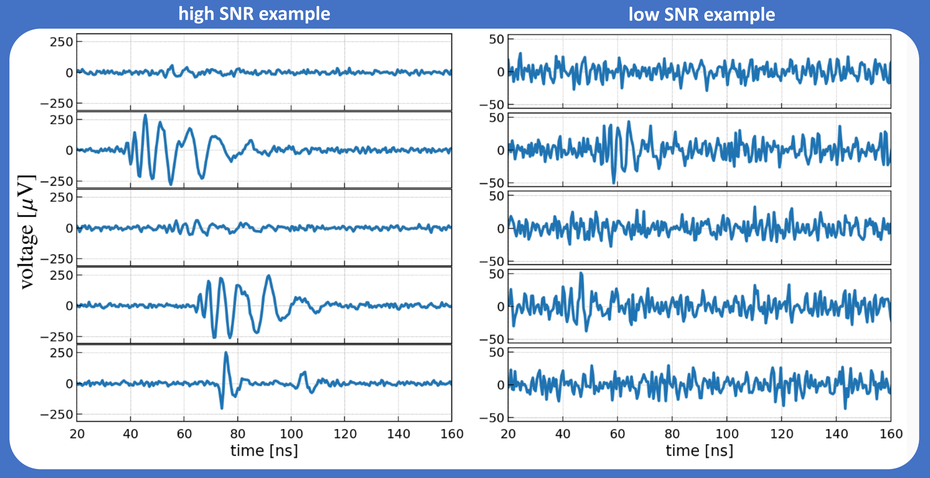
two pairs of orthogonal downward high-gain broadband LPDAs
-> signal direction, polarization and frequency spectrum sensitivity
dipole at O(10m) for D'n'R measurement (direct and reflected signal)
-> vertex distance and viewing angle sensitivity
three upward LPDAs
-> cosmic-ray veto

shallow station design
- based on ARIANNA legacy (thorough in-situ tests #1151)
- foreseen for ARIANNA-200 array *(see #1190)*
- part of RNO-G (currently being constructed in Greenland, #1058)
- foreseen as part of IceCube-Gen2 radio array (#1183)



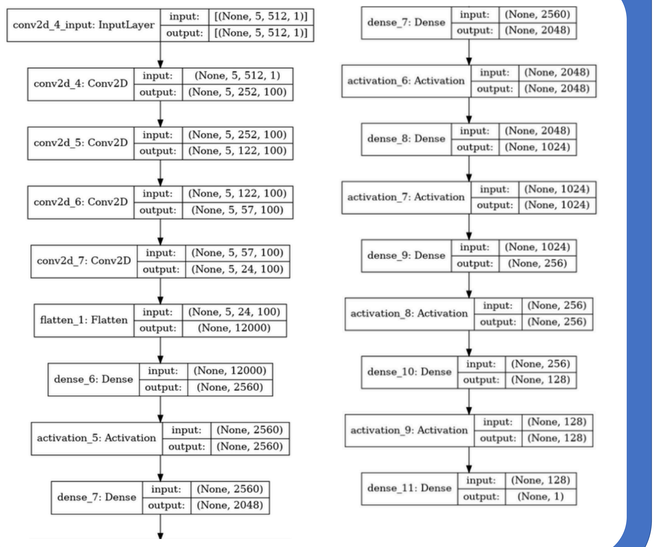
Data set generation

NuRadioMC used to generate large and accurate data set
- 393 million triggered events (772 GB)
- uniform energy distribution between 10^{17} eV – 10^{20} eV
- ice properties of Moore's Bay on Ross Ice Shelf
- so far only non-ν_e-CC interactions
- bandwidth optimized (#1050) trigger with real-time noise rejection (#1074)



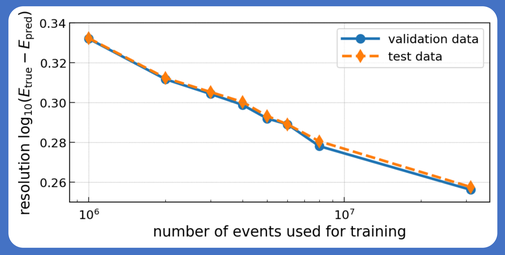
Neural network structure

- Convolution layers followed by dense layers
- 39 million free parameters
- antennas are kept separately in convolutions



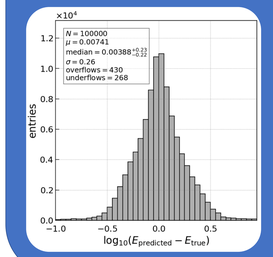
Performance increases with data size

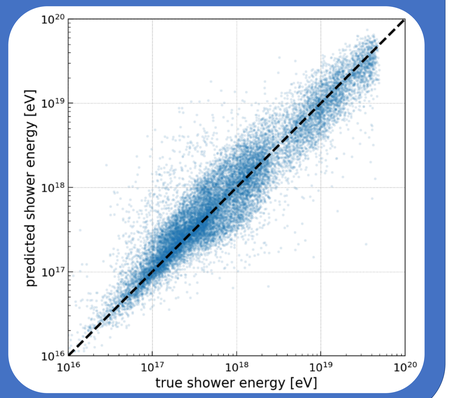
dependence suggests that energy resolution can be improved with more training data



Results

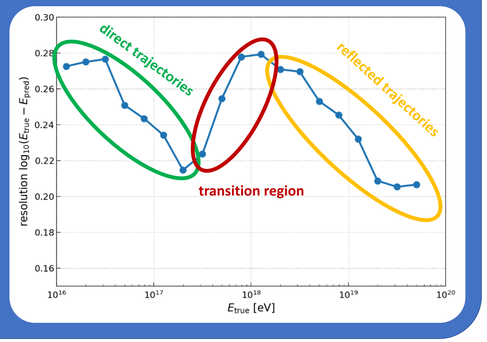
- target resolution: better than the intrinsic uncertainty from unknown inelasticity of a factor of two
  - i.e., how much neutrino energy is transferred into the shower
- Neural network predicts true shower energy well
- Average resolution: 80% (=0.26 on a log scale)





Energy Dependence of Resolution

- Complex energy dependence due to properties of Ross Ice Shelf
- Bottom of ice shelf reflects radio signals back up -> additional signal trajectories if amplitudes are large enough
- Transition region "direct to reflected trajectories" around 10^{18} eV



Deep neural network can reconstruct neutrino energy from raw radio detector data