XENONnT Event Reconstruction with Machine Learning Techniques

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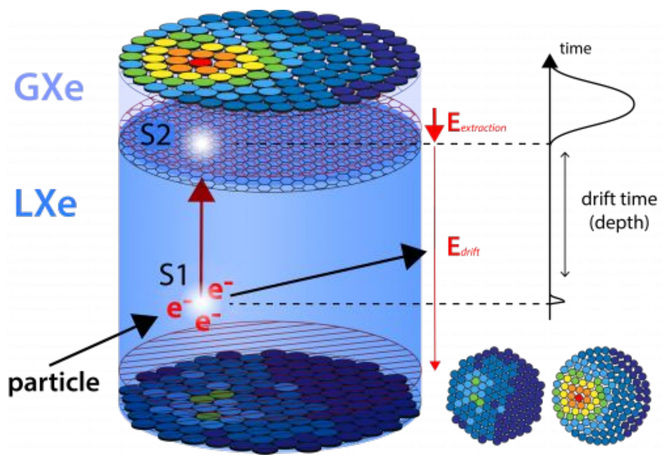
XENONnT Time Projection Chamber

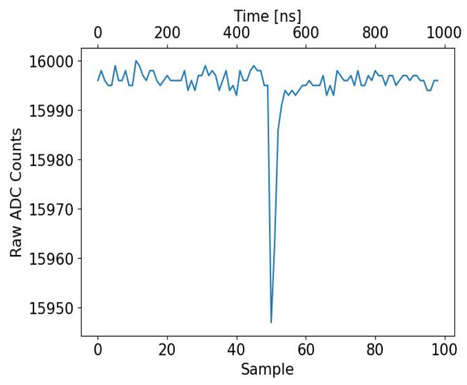
- Detector for direct dark matter (DM) search
- 5.9 t active target mass of liquid xenon
- Placed at the LNGS underground laboratories to reduce cosmic radiation background
- Active muon-veto and neutron-veto water Cherenkov detectors with Gd-loading to suppress neutron backgrounds



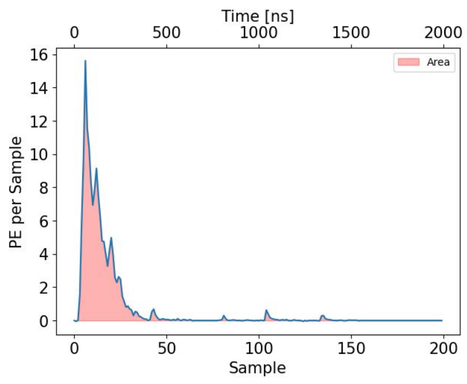
Schematic of the working principle of a dual-phase time projection chamber (TPC).

TPC Signals

- PMT Waveforms in 10ns samples from 14 bit FADCs, grouped together in hits
- ADC counts are converted to photoelectrons (PE)
- Hits merged, depending on if they stem from S1, S2 signals

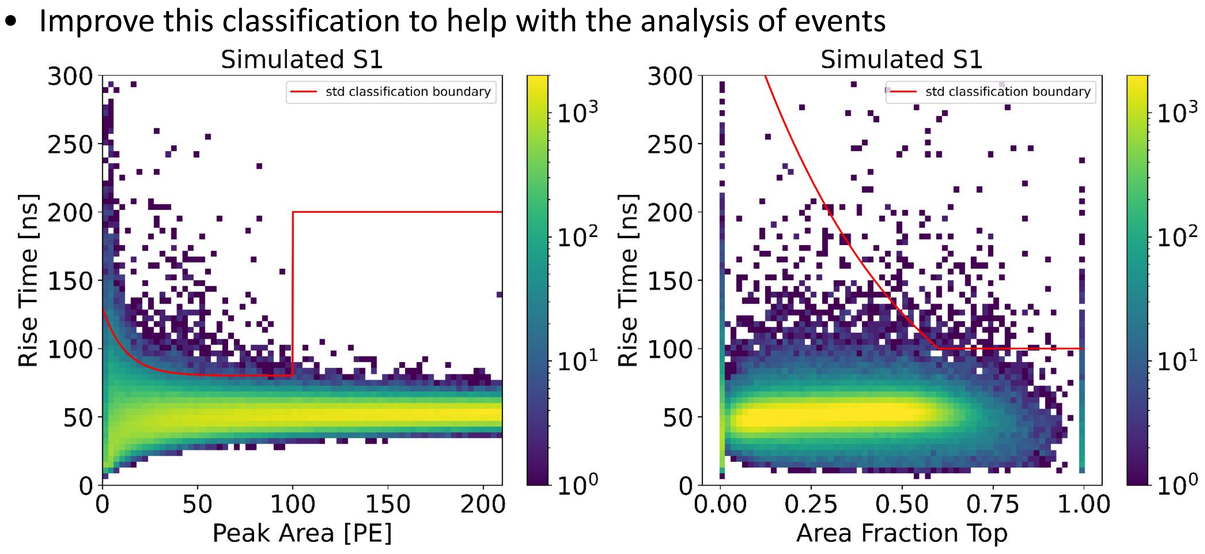


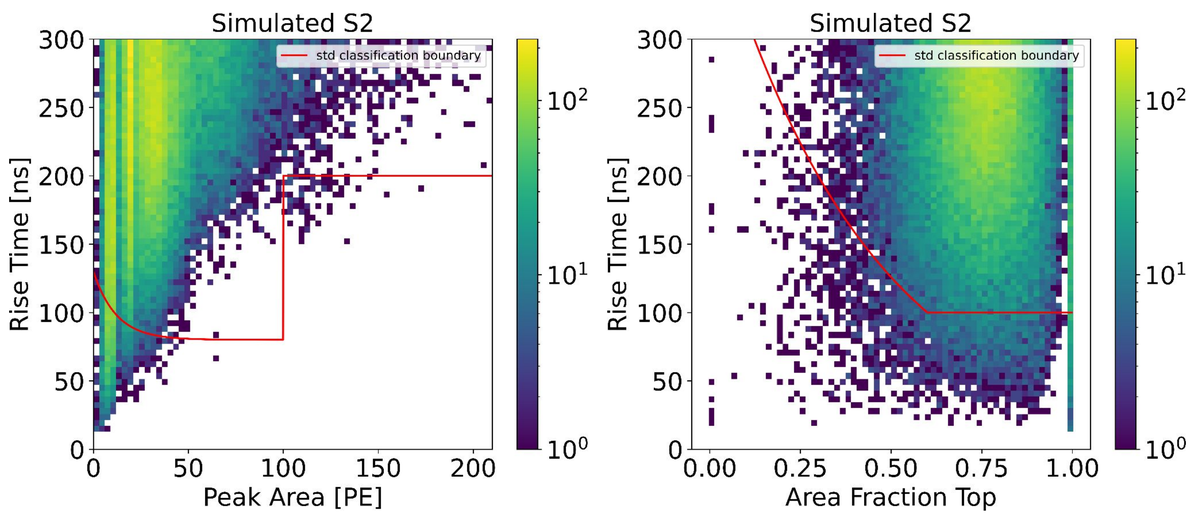
- Peak Area is the sum of PEs over all samples
- Area Fraction Top (AFT) is the part of the area that was seen by the top array
- Rise Time is the time between 10% of the peak area and 50% of the peak area
- Peaks are then used for event building



Single Electron Pollution

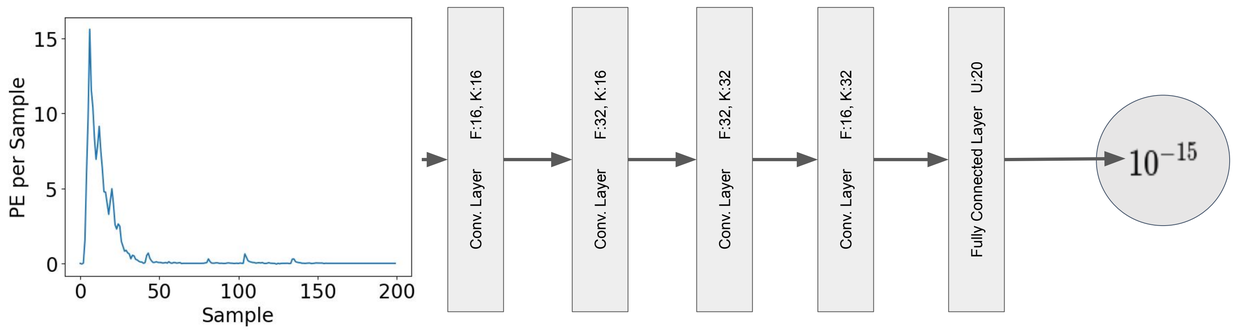
- Classification boundaries in Area - Rise Time and AFT - Rise Time space
- Peaks below this boundary are classified as S1
- Photoionization of neutral impurities gives a substantial single electron background
- Some part of the single electron population is below this boundary -> confusion with small S1 signals
- Improve this classification to help with the analysis of events





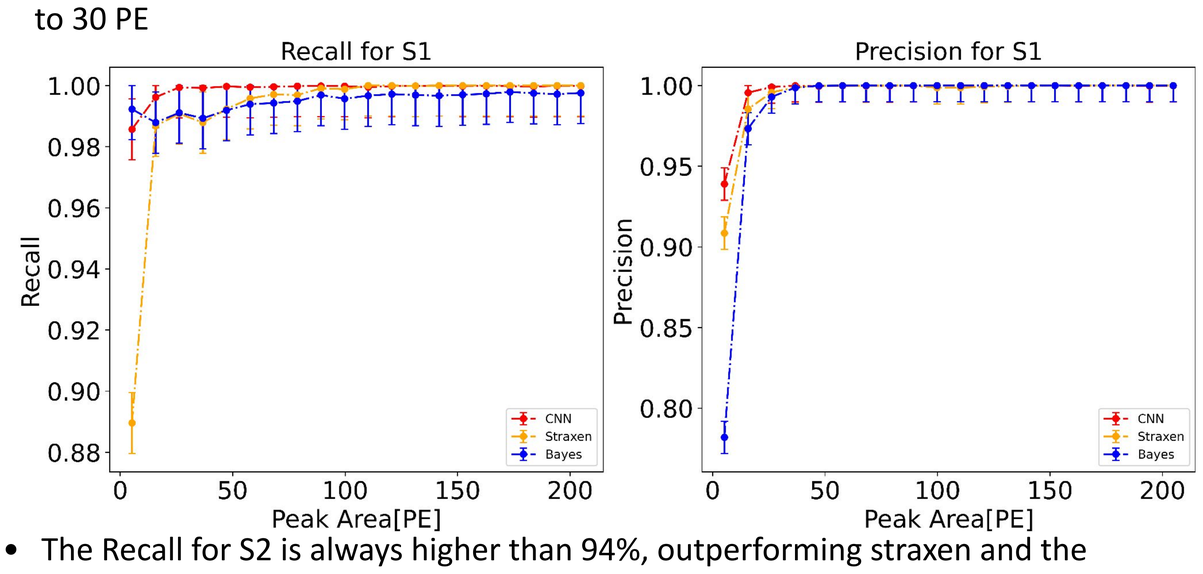
Model Architecture

- Classify peaks by looking at the waveform -> 1D Convolutional Network
- Waveform is processed through different number of Filters (F), Kernelsizes (K) and Units (U)
- Output is the probability of the peak being S2

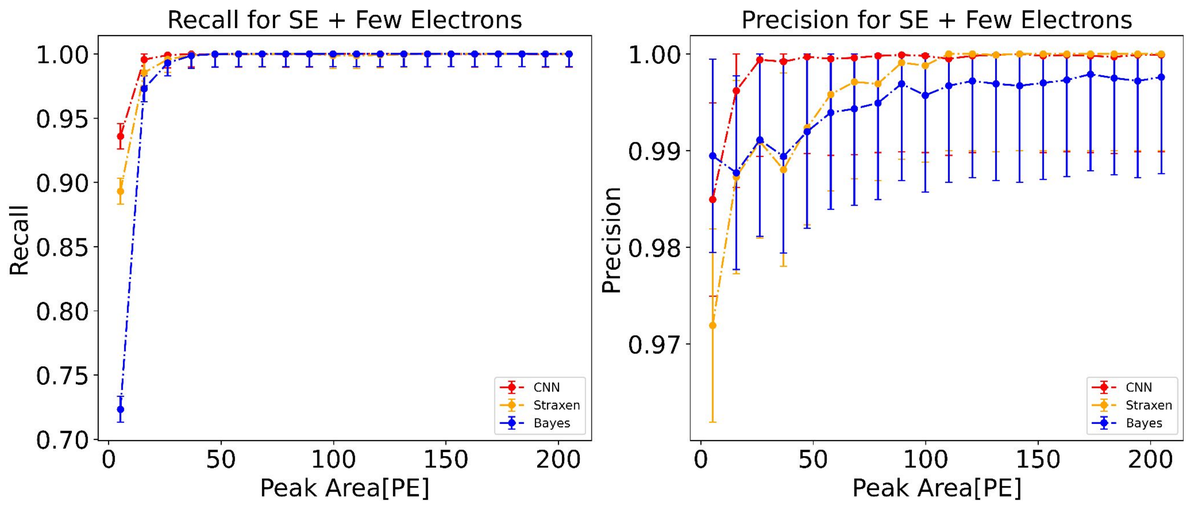


Comparison with other Classification Methods

- Model was tested in an S2 area range up to 200 PE
- Evaluation by using Recall (= Acceptance) and Precision (= Purity)
- Comparison with the default classification method of our analysis software straxen[2] and classification by a Bayesian network[3]
- For S1 the Recall is above 98% over the whole area range, outperforming straxen and the Bayesian network in the range up to 50 PE
- Precision for S1 is higher than for straxen or the Bayesian network in the range up to 30 PE



- The Recall for S2 is always higher than 94%, outperforming straxen and the Bayesian network over the area range up to around 30 PE
- S2 Precision is above 97% for all methods with no larger differences between them



2. https://github.com/XENONnT/straxen

3. E. Aprile *et al.* (XENON Collaboration), *Detector signal characterization with a Bayesian network in XENONnT*, Physical Review Letters 10.1103/PhysRevD.108.012016

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