Background Rejection and Reconstruction in front ECAL

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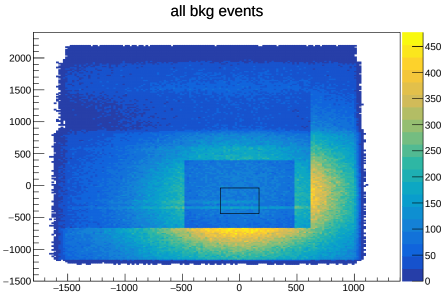
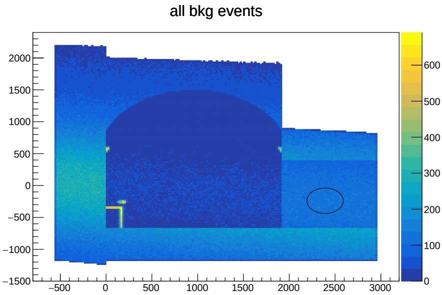
Analysis Framework

- This background study is focused on beam monitoring using Ecal
- ECAL+STT detector configuration as in docdb #13262
- Signal: Ecal events in "Front Ecal FV"
  - Front Ecal FV: 11 barrel modules, with $|X - x0| < 1.69m$ (22.75 t mass)
- Background: muons from CC interactions in surrounding rocks of ND hall
- Analysis chain: GENIE $\Rightarrow$ Edep-sim(Geant4) $\Rightarrow$ reconstruction smearing from hits

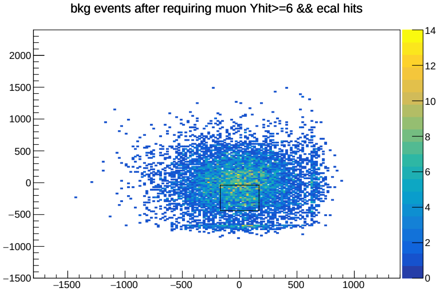
Rock Events

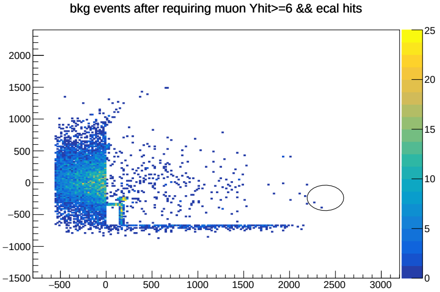




- Initial vertex distribution of simulated events

Rock events reconstructed in SAND





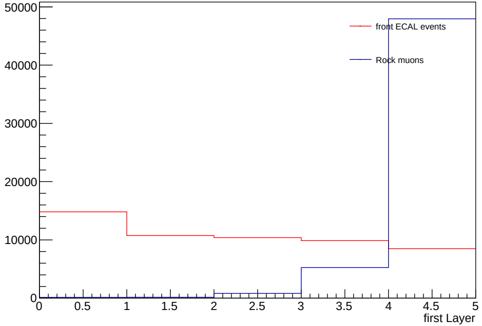
- Reconstructed muon in STT with N(Y) hit $>=$ 6 (YZ: bending plane)
- Reconstructed hits in FV of front ECAL with deposited energy in (active) cell $>= 100keV$

Reconstruction and selection efficiency

- Events from the side and downstream rocks result in negligible background in front ECAL FV
- Background from rock muons almost entirely from rocks & materials in front of SAND
- Background reconstructed in STT and ECAL: 0.4%
- Signal reconstructed in STT and ECAL : 73%

ECAL timing

Earliest Hit	Layer 0	Layer 1	Layer 2	Layer 3	Layer 4
Ecal events	27.28%	19.78%	19.12%	18.18%	15.63%
Rock muons	0.03%	0.10%	1.53%	9.70%	88.64%

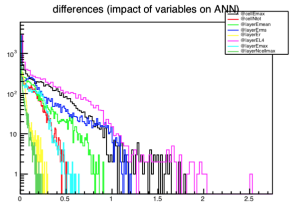


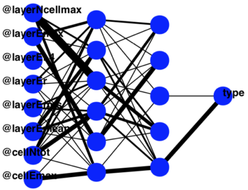
- Apply smearing according to average ECAL timing resolution $\sigma = 260ps$ (to be improved with $54ps/sqrt(E) \bigoplus 50ps$)
- select the ECAL layer (out of 5) with the earliest detected signal

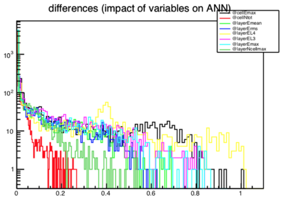
Strategy for event selection

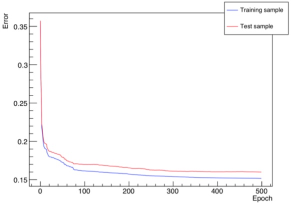
- Select events with the earliest hit in layer $==4$ (outermost plane)
- Study the energy depositions and cell topology in ECAL
- Choose various discriminating variables to be used as input of neural network
- Optimize the NN architecture, train and select cut
- Repeat all of the above steps for each of the remaining layers $== 3, 2, 1, 0$

Neural network analysis



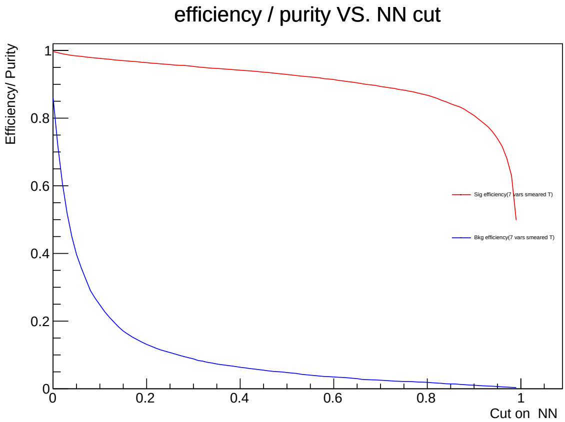




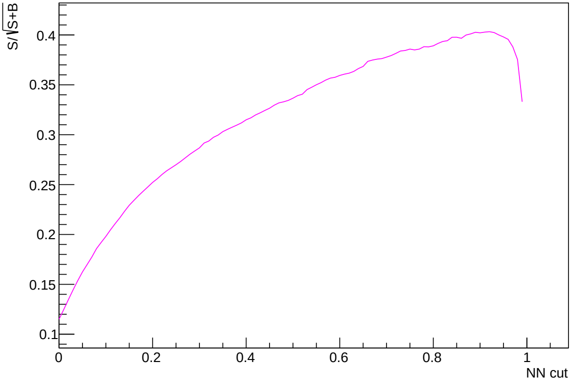


- 8284 train and 8285 test entries, 8063 signal and 8506 background events
- Events normalized to expected POT per spill : $7.5E13$

Events with earliest hit in layer 4

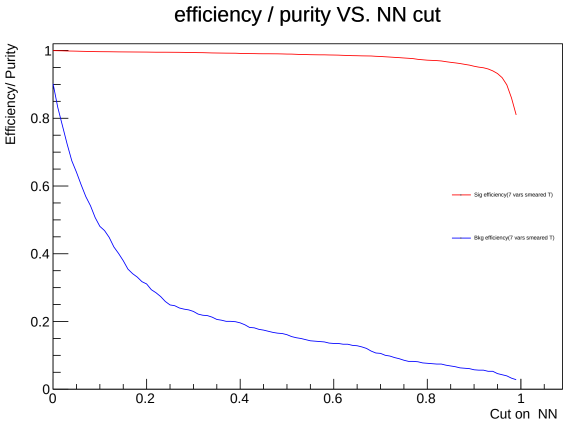


- Example Cut = 0.92 Signal eff: 0.785798, Bkg eff: 0.00862
- The final cut will be optimized



- Samples normalized to expected POT per spill

Events with earliest hit in layer 3



- Example Cut = 0.9 Signal eff: 0.95362, bkg eff: 0.0574
- The final cut will be optimized

Rejection of Background from magnet

- Simulate CC events in the entire SAND magnet with GENIE + EdepSim(Geant4) + reconstruction smeared from hits
- Require a reconstructed muon in STT with $N(Y) >= 6$ and hits in the front ECAL FV
- Apply exactly the same NN selection (same cuts without retraining) used to reject rock muons: no additional loss of signal efficiency
- Evaluate residual background from events in the SAND magnet and compare with rock muon background

Event selection

Cuts	ECAL	Ecal efficiency	Rock	Rock efficiency	Magnet	Magnet Efficiency
No Cut	2.234	100%	1447.26	100%	50.82	100%
Muon in ECAL FV	2.234	100%	12.73	0.88%	18.92	37.22%
$STTN(Y) > 6\&\&ECALhits$	1.630	72.93%	6.048	47.51%	3.443	18.20%
NN cut	1.556	95.51%	0.100	1.65%	0.069	2.02%

- Further improvements possible with optimization and increased simulated statistics
- Same cuts rejecting rock muons also reject magnet events
- NN selection results in only 5% signal loss. A tighter cut on NN would result in further bkg reduction

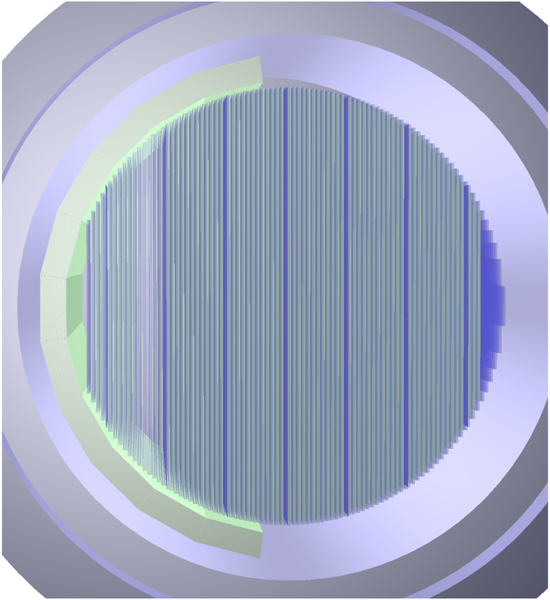
Summary of background study

- Studied background from rock and magnet CC events with GENIE+EDEPSIM(GEANT4)+ reconstruction smearing from hits
- Method to separate rock and magnet events from genuine ECAL events developed using a combination of timing and topological information (NN) in ECAL
- Results indicate an efficient rejection of both rock muon and magnet backgrounds with minimal signal loss
- Implementation of active veto systems less critical

EnergyreconstructionforECAL events

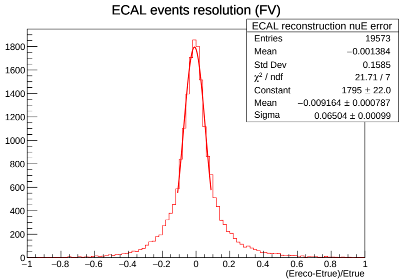
- Front ECAL Fiducial volume:
  - 11 Front ECAL barrel modules, with $|X - x0| < 1.69m$ (22.75 t mass)
- Require a reconstructed muon track in STT (N (Y) hit $>= 6$)
- Energy = calibrated summed energy in cells + deposited energy in liquid argon meniscus + kinetic energy for particles entering STT
- STT smearing used equation Gluckstern formula + multiscattering term, consistent with reconstruction of circular fit+reconstruction of neutral particles from STT hits +ECAL clusters

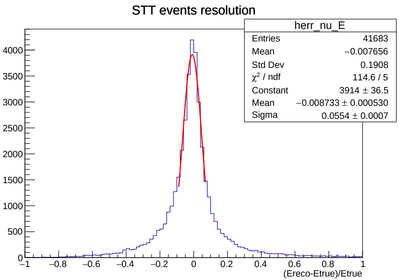
SAND with STT



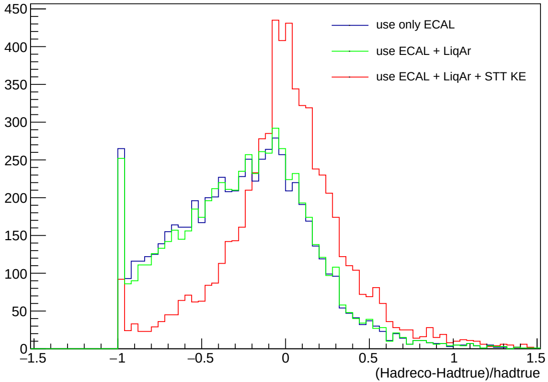
- Simulate one week statistics with the complete dk2nu+GENIE+edep-sim(GEANT4) +reconstruction smearing
- Uniform acceptance of STT for particles exiting from front ECAL
- Average STT (maximal) density about 0.18 gcm3
- Optimize energy reconstruction for the combined ECAL+LAr+STT sub-detectors

Review: ECAL Events Resolution (comparing with STT resolution



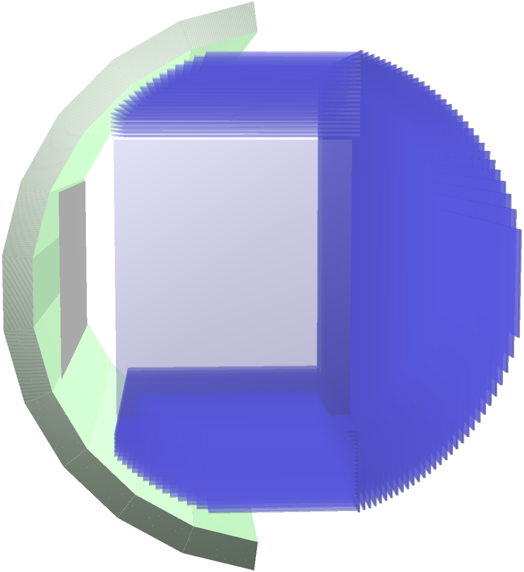


Hadronic energy resolution



Substantial leakage from ECAL recovered by STT

SAND with 3DST

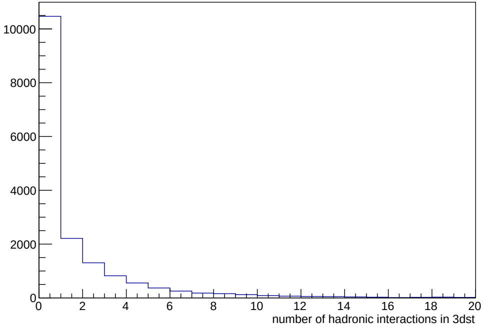


- Consider an ECAL+3DST+STT configuration similar to the 3DST+TPC in CDR
- Simulate one week statistics with the complete dk2nu+GENIE+edep-sim(GEANT4)+reconstruction smearing
- Study detector and reconstruction effects

ACCEPTANCE: presence of side tracker affects number of reconstructed events, as well as the energy resolution (escaping particles)

Secondary interactions in 3DST

Average hadronic interactions per event in 3DST: 1.5



- 3DST thickness about 5 X0 and 2.5 interaction lengths
- Amount of material crossed by particles about 3.6 times larger than entire STT with maximal density
- Nonuniform acceptance for particles exiting from front ECAL

RECONSTRUCTION: secondary interactions in 3DST need dedicated studies