Performance of machine learning algorithm for predicting muon multiplicity in the INO-ICAL prototype

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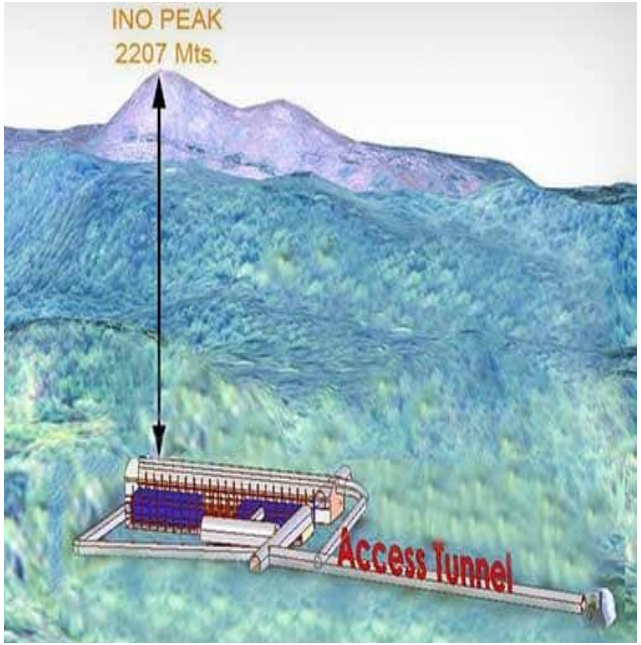
India based Neutrino Observatory (INO)

- Proposed underground laboratory (≈1.5 km rock overburden),
- Primary goals:
  - Measurement of atm. neutrino oscillation parameters using Iron CALorimeter (ICAL)
  - Addressing the mass hierarchy problem
- As a first phase study, atmospheric neutrinos with energy from 1-15 GeV are to be studied



INO-ICAL

ICAL	
No. of modules	3
Module dimension	16 m × 16 m × 14.5 m
Detector dimension	48 m × 16 m × 14.5 m
No. of layers	151
Iron plate thickness	5.6 cm
Gap for RPC trays	4.0 cm
Magnetic field	1.5 Tesla
RPC	
RPC unit dimension	2 m × 2 m
Readout strip width	3 cm
No. of RPC units/Layer/Module	64
Total no. of RPC units	∼ 30,000
No. of electronic readout channels	3.9×10^6

Table 1: Specifications of the ICAL detector.

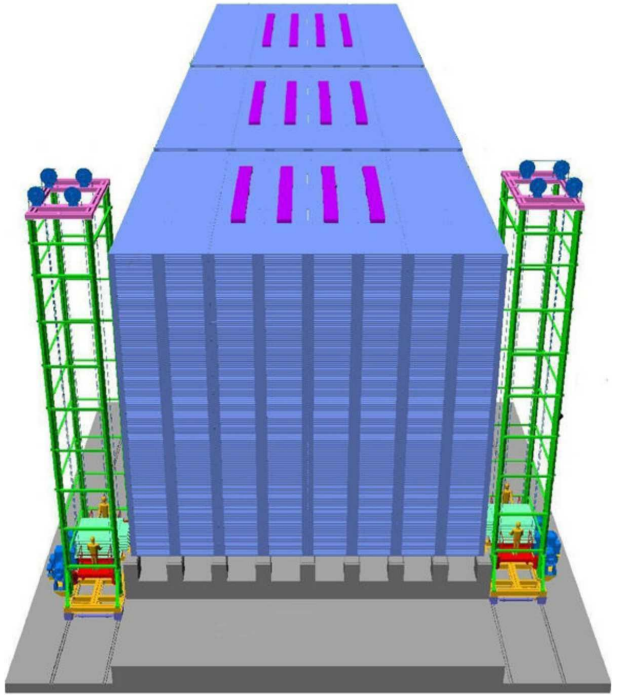


Fig. 1: Schematic view of INO-ICAL detector with magnet coils shown on top.

Background

- -Prototype stacks continuously track cosmic muons
- -Analysis routines
  - focus on single muon tracks
  - Reject noisy tracks
  - → Multi-muon track also rejected as noise
  - → Reduces the physics potential
- This work: Development of a ML-based algorithm for:
  - Identifying multi-muon events
  - Predicting the multiplicity

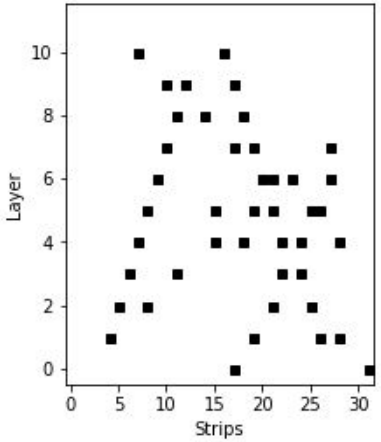
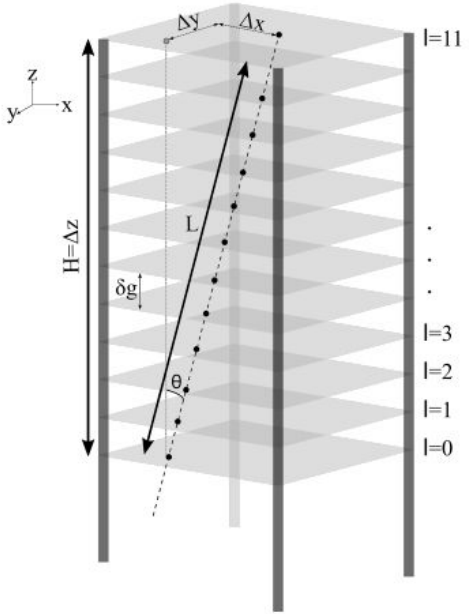


Fig 2: Event with multiplicity 6

Prototype Stack

Fig 3. 1m x 1m RPC stack at TIFR



Number of detector layers	12
Distance between each layer	16.8 cm
Number of strips	32

Machine Learning (ML)

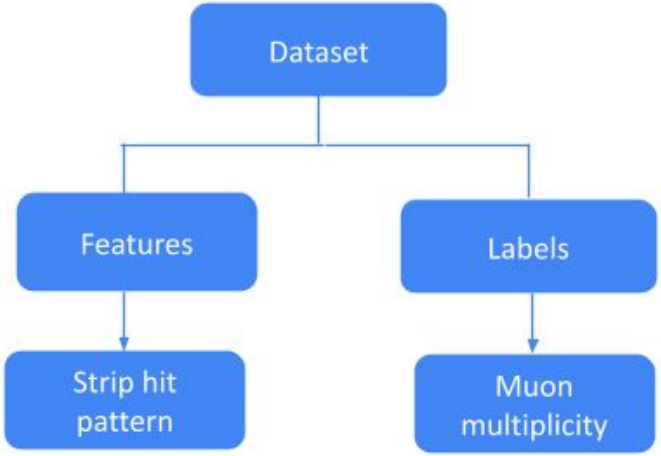


Fig 4: Data set pattern

XGBClassifier model

Data generation

Dataset	No. of events for each multiplicity	Max. multiplicity	Tot. No. of events
I: Clean tracks	1000	11	11000
II: Tracks including (η=80%)	1000	7	7000
III: Tracks including η & (Sm)	1000	5	5000
IV: Tracks including η, Sm & (Nm)	1000	3	3000

Table 1. The four datasets used for machine learning model training and testing.

- Detector efficiency (η) : 80%
- Strip hit multiplicity (Sm) : 1.5
- Noise multiplicity (Nm): 3 hits per layer

Results

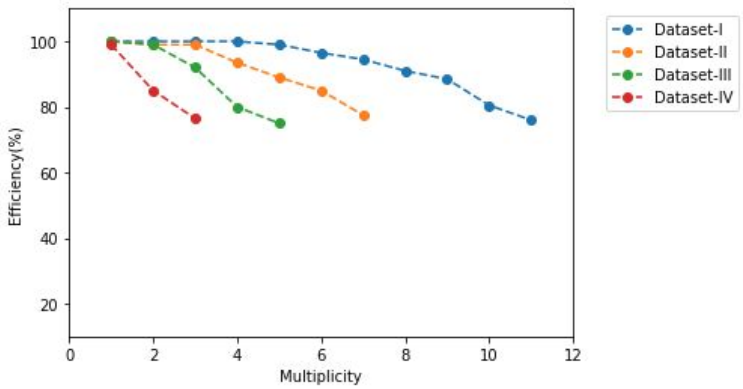


Fig.5: Efficiency plot as a function of multiplicity for all four datasets

Dataset	Time taken for training (min)	Time taken for testing (sec)
I	4.2	0.4
II	3	0.3
III	1.5	0.2
IV	0.3	0.03

Table 2. Time taken for training and testing each model

- All the datasets were trained and tested on a system with Windows 10 Pro, a 64-bit operating system, and an Intel Core i7-7500U CPU with 16 GB physical memory.

References

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