# Reconstruction and Particle Identification with CYGNO Experiment

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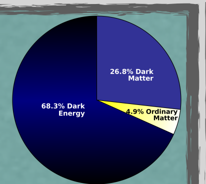
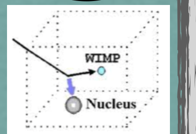
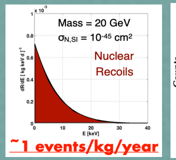
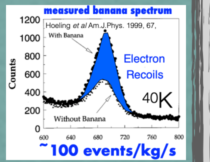
## Dark Matter and Background

- Our Galaxy is believed to reside in a halo of Dark Matter (DM)
- Direct Dark Matter detection measuring the recoiling nuclei in the elastic scattering of Dark Matter Particles
- Recoiling nuclei (Signal) and electrons (Background) produce different patterns in the detector medium
- WIMP interactions, at a rate as low as 0.1 events/kg/year, must be discriminated against the much higher background rate
- Important background sources are:
  - Neutrinos from sun and atmosphere
  - Cosmic rays and cosmogenic activation of detector material, Natural radioactivity

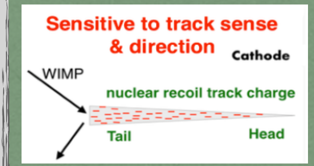


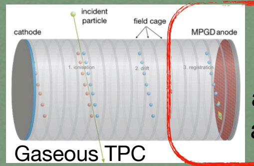




## CYGNO/INITIUM Approch




Ionization signal amplification and Readout

CYGNO/INITIUM

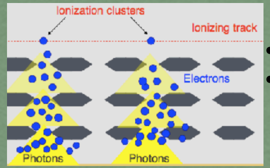
- CYGNO works with gas mixture of He:$CF_4$ (60:40) at STP
- INITIUM is a part of CYGNO project which focuses on the development of gaseous TPC with negative ion drift using $SF_6$ gas (Funded by ERC) [5][6].

sCOMS Camera

- Single photon sensitivity
- High granularity
- Large area for detection

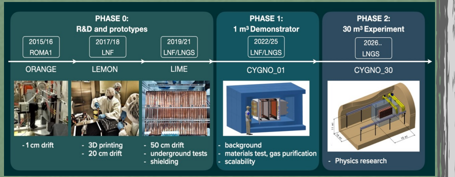
X-Y + Energy

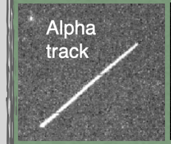
Triple GEM

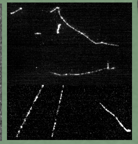



PMT

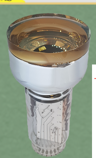
- Fast
- Integrated energy measurement



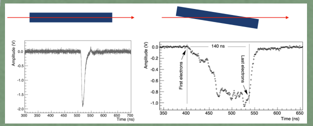



Camera



PMT

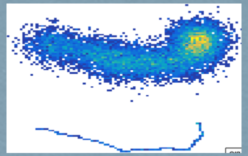
Z + Energy



Project is already funded till phase 1.

## Monte-Carlo Simulations

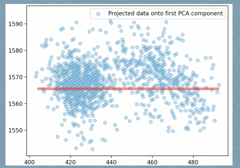
- Interaction of the particles with gas is simulated using either GEANT4 (for ER) or SRIM (for NR)
- Detector/readout effects are added to these track i.e. diffusion, camera noise, effective ionisation, gain fluctuations and geometrical acceptance etc.
- Tracks are reconstructed with algorithm used in [2][3]



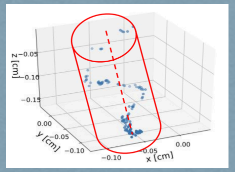


A. Undiffused & Diffused track. B. Reconstructed Clusters

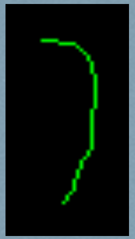
- Topological information of reconstructed track can be used as discriminating variables
- Variables: Length Along Principle Axis (LAPA), Maximum Density (MaxDen), Cylindrical Thickness (CylThick), Standard Deviation of Charge Distribution (SDCD).[7]




C. LAPA.



D. CylThick

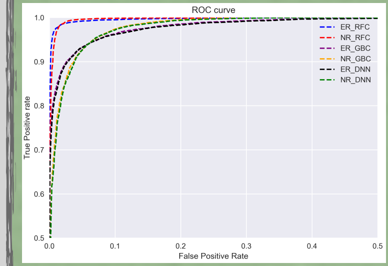


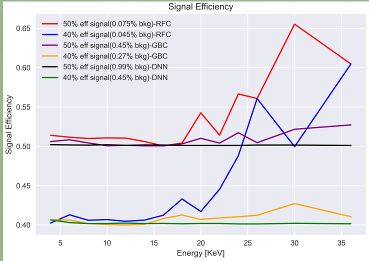
Skeletonized track is used to find the track length.

E. Skeletonization

## Particle Identification Studies

- It is very difficult to discriminate signal and background at very low energy [0-20 keV] with traditional approach
- Track's topology variables were used to train three different deep learning models
- Three models are:
  - Random Forest Classifier (RFC)
  - Gradient Boosted Classifier (GBC)
  - Deep Neural Network (DNN)
- RFC performance is an order better in rejecting background than DNN in all the energy range between 1-40 keV for ER (background) & NR (signal)




A. ROC curve B. Signal efficiency at different energies

C. Background with an efficiency of 50% and 40% on NR

| Models | $\varepsilon_s^{total}$ | $\varepsilon_B^{total}$ |
|---|---|---|
| RFC | 50% | 0.075% |
| | 40% | 0.045% |
| GBC | 50% | 0.45% |
| | 40% | 0.27% |
| DNN | 50% | 0.99% |
| | 40% | 0.45% |

Ongoing work: Development of convolutional neural network.

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INFN

erc

INITIUM

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