Reconstruction and Particle Identification with CYGNO Experiment

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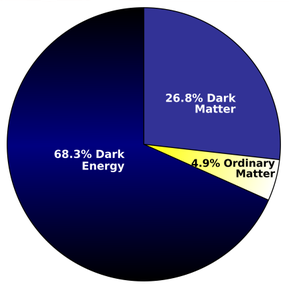
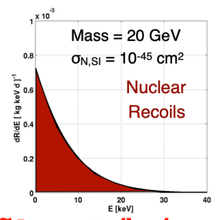
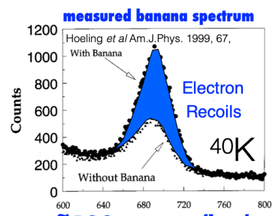
Dark Matter and Background

- 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

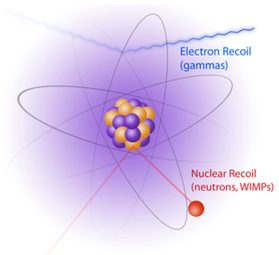




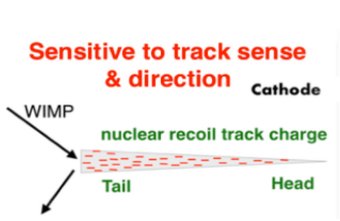
~1 events/kg/year

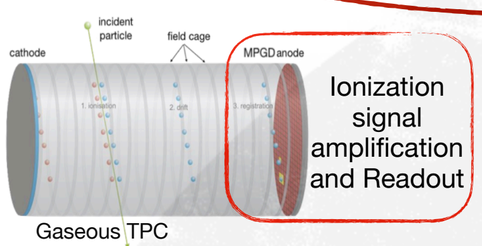


~100 events/kg/s



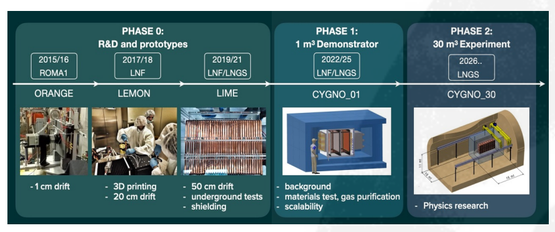
CYGNO/INITIUM Approach





Gaseous TPC

Ionization signal amplification and Readout



Project is already funded till phase 1.

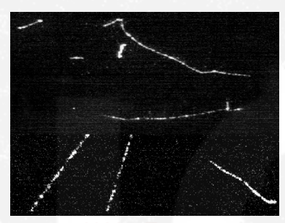
READOUT

CYGNO/INITIUM

- CYGNO works with gas mixture of He:CF_4 (60:40) at atmospheric pressure and room temperature
- 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].

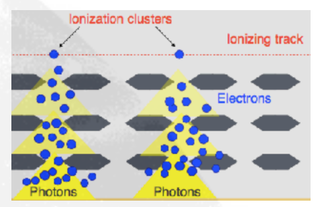
sCOMS Camera

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



X-Y + Energy

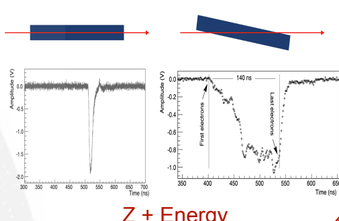
Triple GEM



Camera PMT

PMT

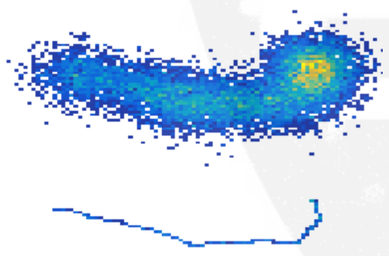
- Fast
- Integrated energy measurement



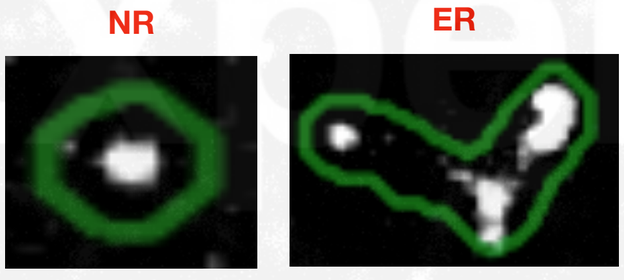
Z + Energy

Track Simulation and Reconstruction

- 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 an iterative density based scanning algorithm (IDBSCAN) used in [2][3]

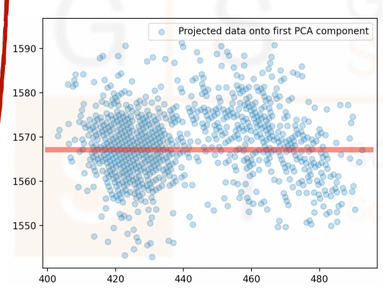


A. Diffused & Un-diffused track

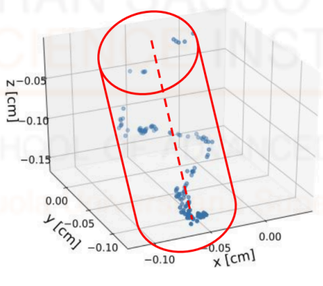


B. Reconstructed Clusters

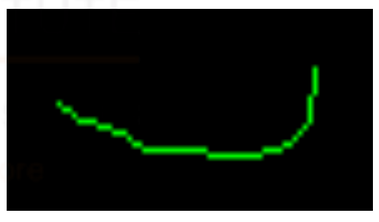
- Topological information of reconstructed track can be used as discriminating variables
- Some Discriminating Variables: Length Along Principle Axis (LAPA), Maximum Density (MaxDen), Cylindrical Thickness (CylThick), Standard Deviation of Charge Distribution (SDCD).[7]
- Skeleton track length is the one pixel width representation of the track found using the thinning method



C. LAPA.



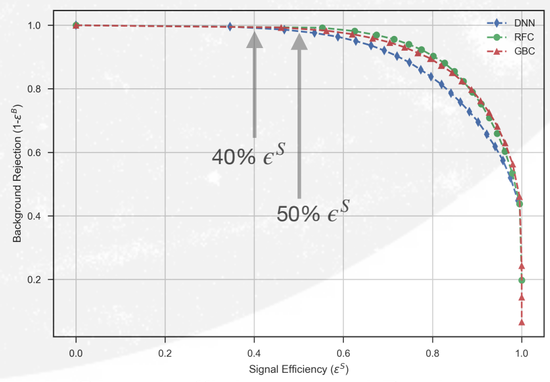
D. CylThick



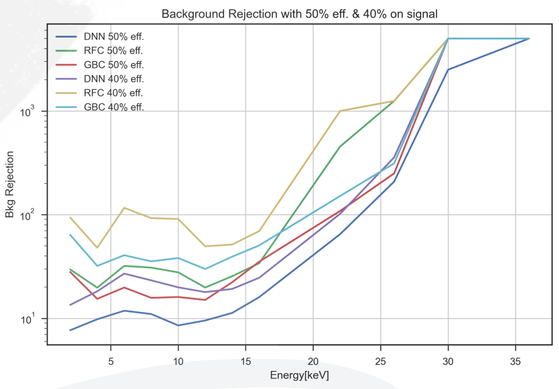
E. Skeletonization

Particle Identification Studies

- It is very difficult to discriminate signal and background at very low energy [0-20 keV] with traditional approach
- Deep learning models can improve the discrimination at low energies
- Topological 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. Signal efficiency and Background Rejection



B. Background Rejection with 40% and 50% efficiency on signal in each energy bin

Models	ϵ_S^{total} [%]	$1-\epsilon_B^{total}$ [%] Background Rejection
RFC	50	***97.5***
	40	***99.1***
GBC	50	***96.5***
	40	***98.3***
DNN	50	***93.5***
	40	***96.6***

C. Background Rejection of all the models with 40 and 50 % signal efficiency overall

Ongoing work:

- Development of Convolutional Neural Network for track reconstruction and classification

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Bibliography

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