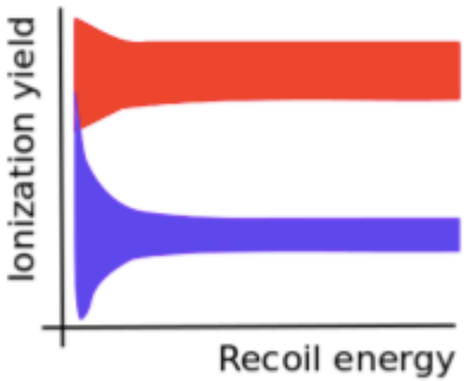
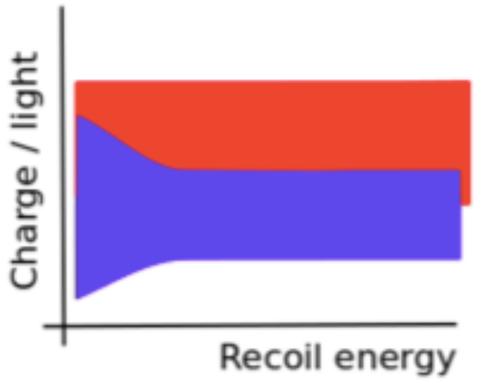
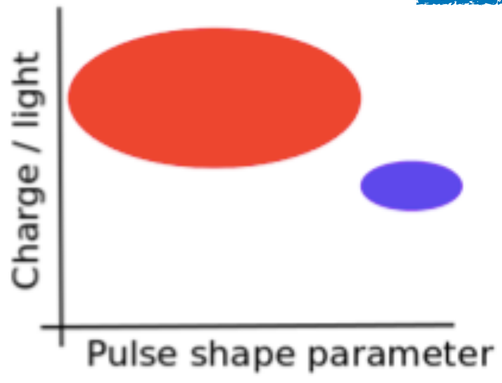
discrimination

liquid, cryogenic
medium (O 1000 eV) threshold
high sensibility and
scalability





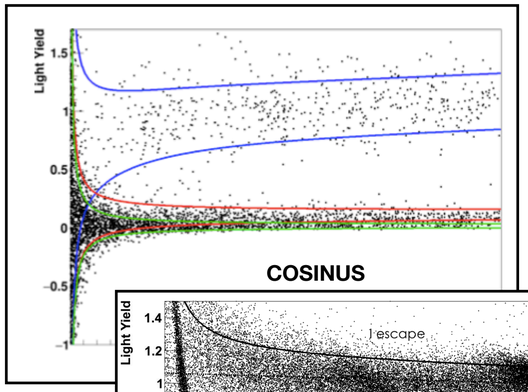


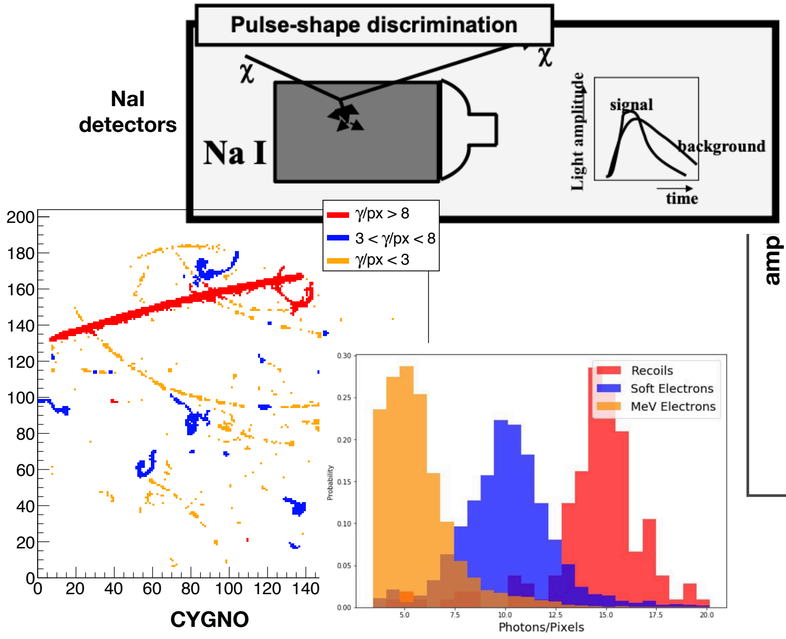
solid/cryogenics

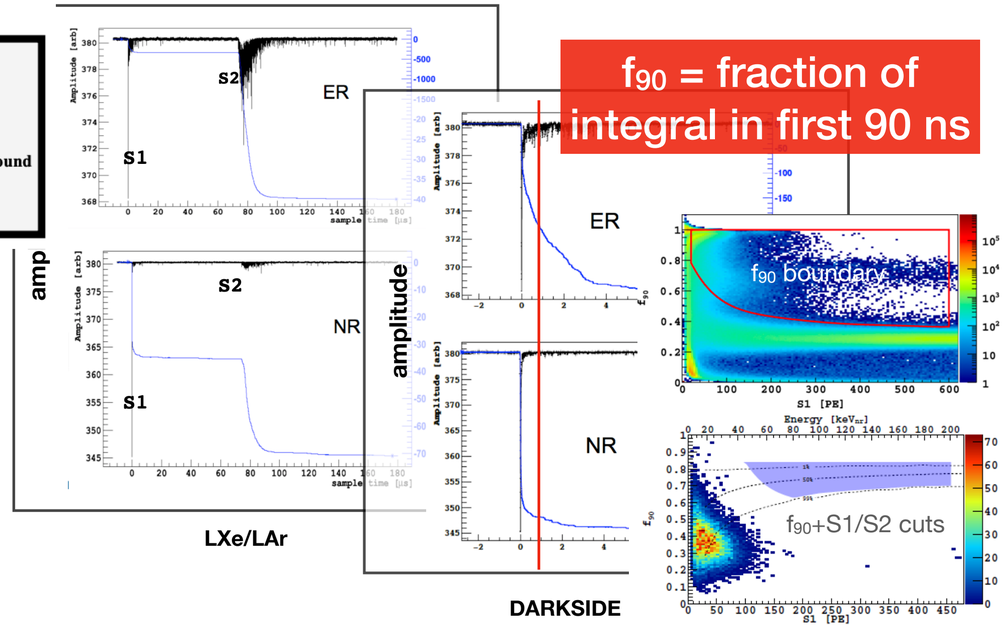
gass/liquid (Xe/Ar)

scintillator/liquid (Ar)

CREEST





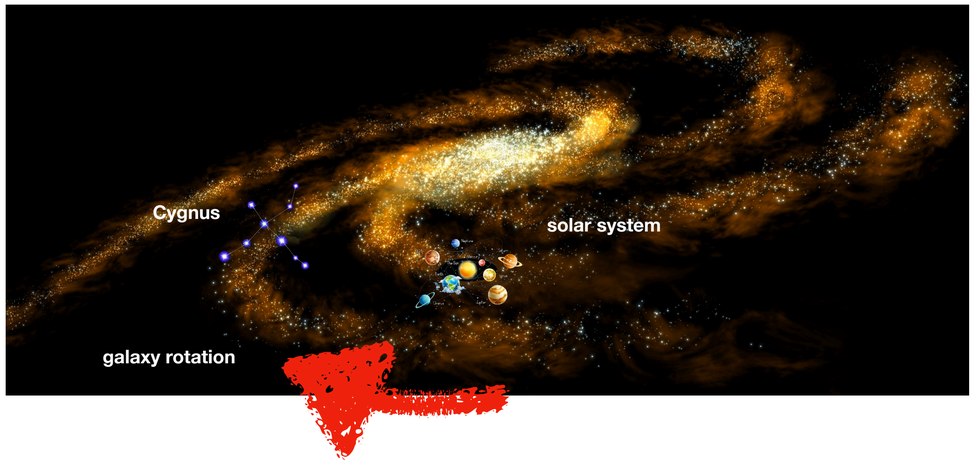


f_{90} = fraction of integral in first 90 ns

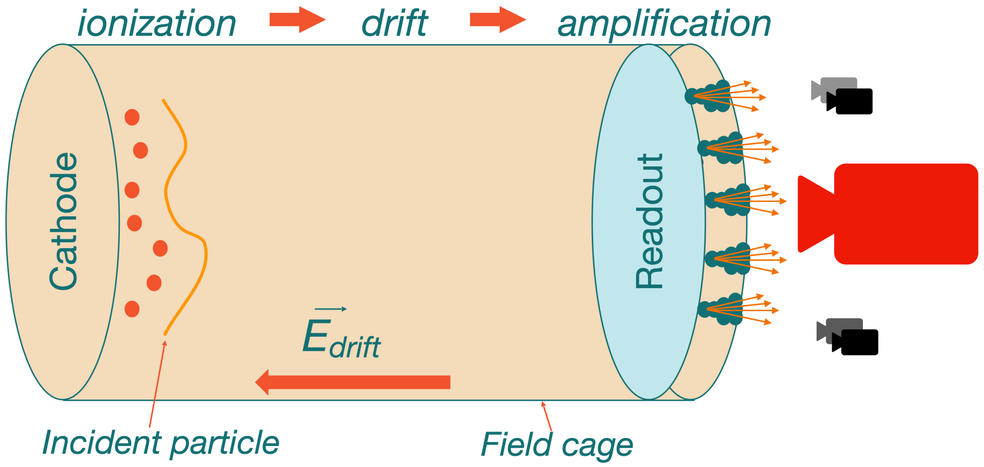
DarkSide Collaboration, Phys. Rev. D 98 102006 (2018)

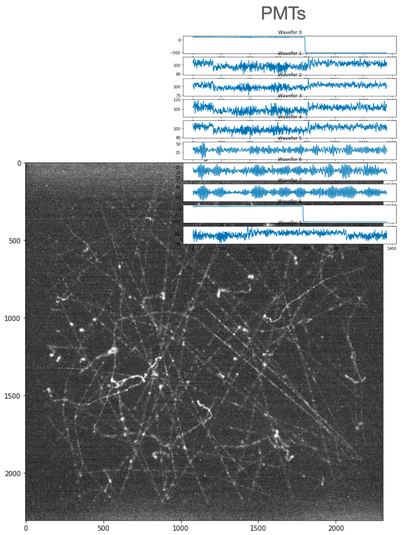
gaseous TPC

exploiting the progress in commercial scientific Active Pixel Sensors (APS) based on CMOS technology to realise a large gaseous Time Projection Chamber (TPC) for Dark Matter and Solar Neutrino search.



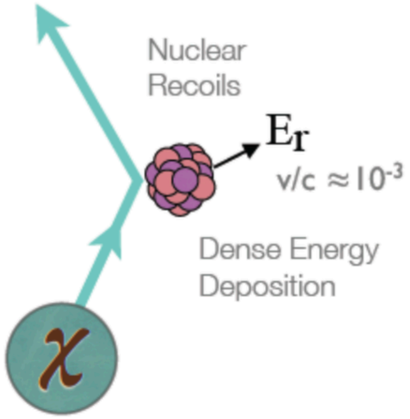
optical readout in a nutshell

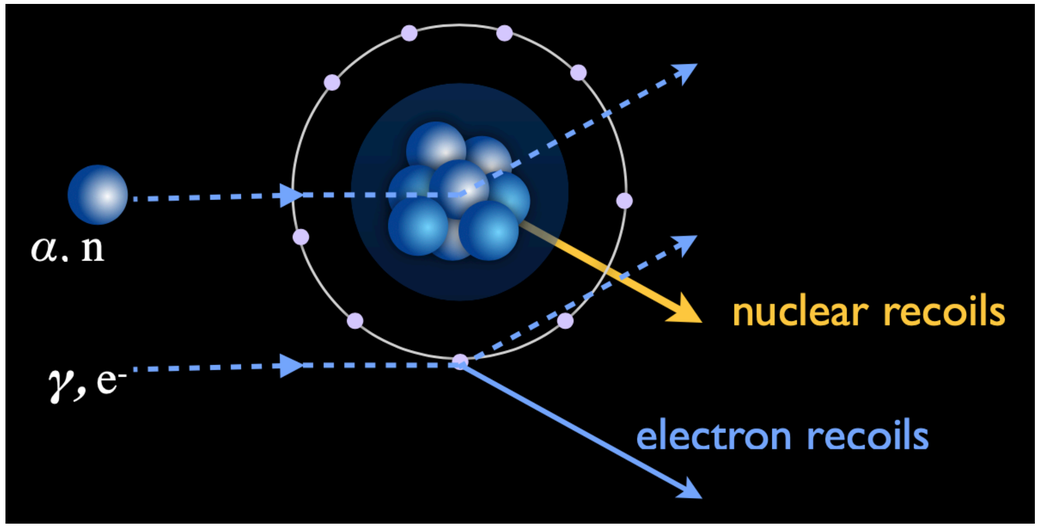


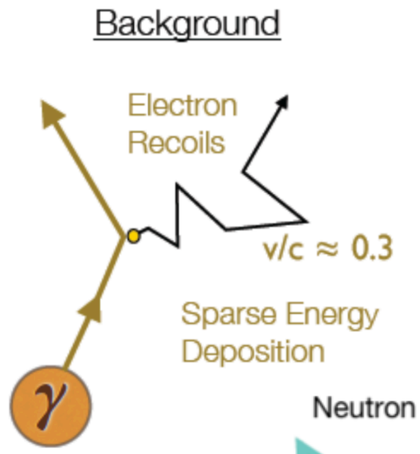


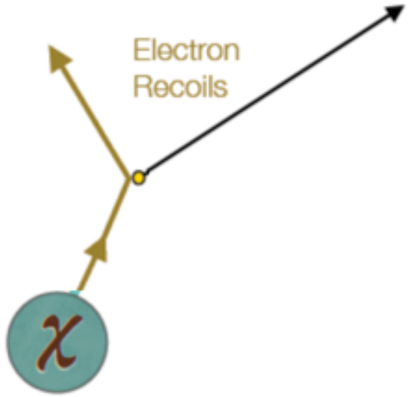
cosmic and radioactivity at see level,
in 500 ms image over 30*30 cm area

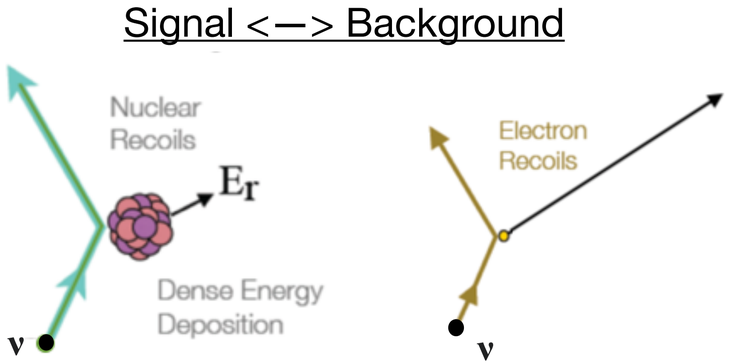
underground signal and background

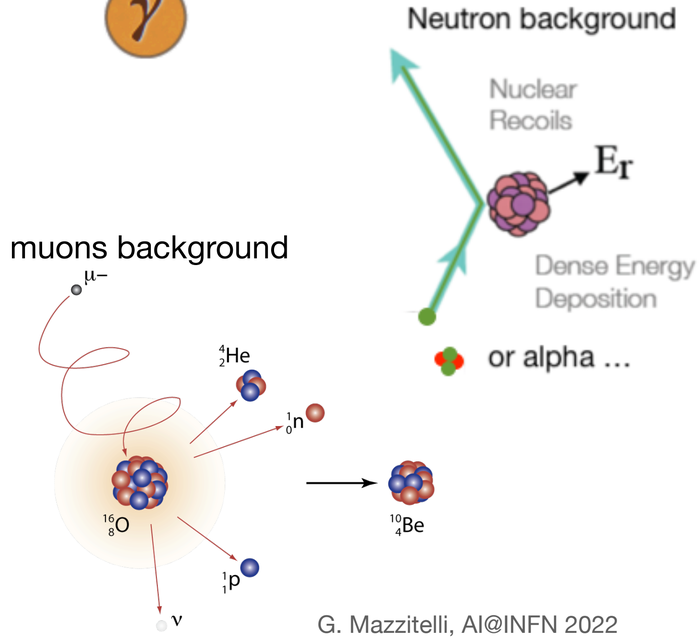






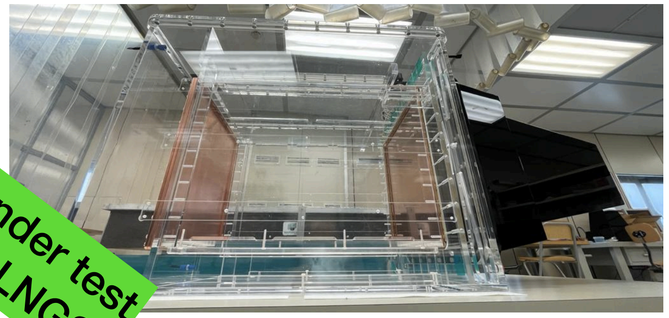






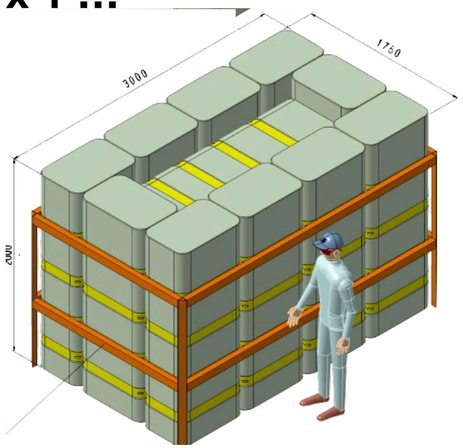
CYGNO (tech goal) to CYGNO 30 (physic goal)

the bet



under test at LNGS

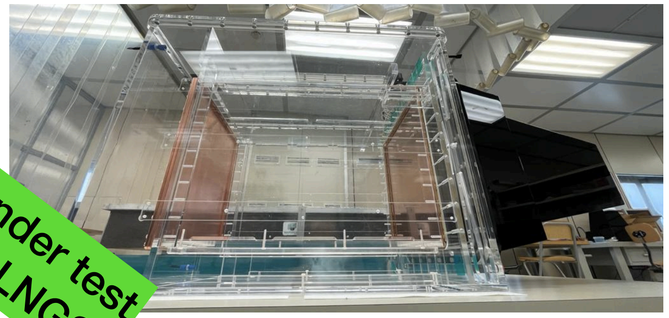
x 1 ...



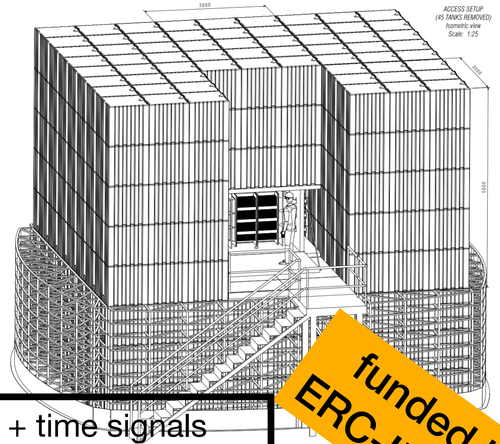
5*10 litres, 1 camera
2.5 MB/event 0.2—>0.01 Hz

CYGNO (tech goal) to CYGNO 30 (physic goal)

the bet



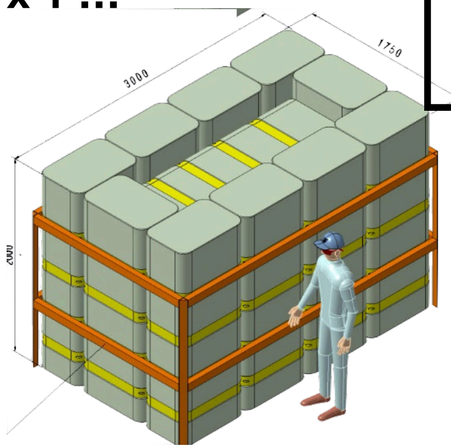
under test at LNGS



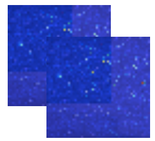
funded by ERC-INITIUM

10^7 readout channels + time signals
18 cameras monitoring 330*330 mm
each with **150 µm resolution** and a
sensitivity of ~ **1 ph / 2 eV** released in gas

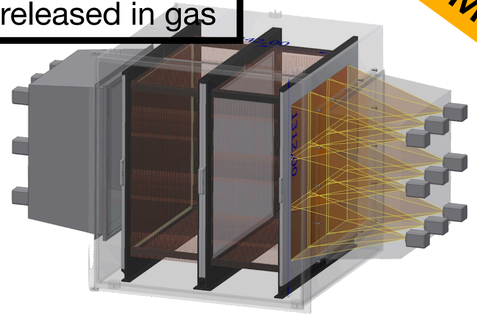
x 1 …



5*10 litres, 1 camera
2.5 MB/event 0.2—>0.01 Hz



x 9 …

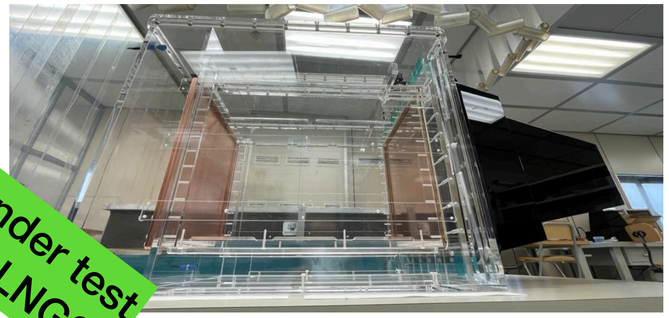


x 9 …

1*10^3 litres, 18 cameras
45 MB/event (Hz ?)

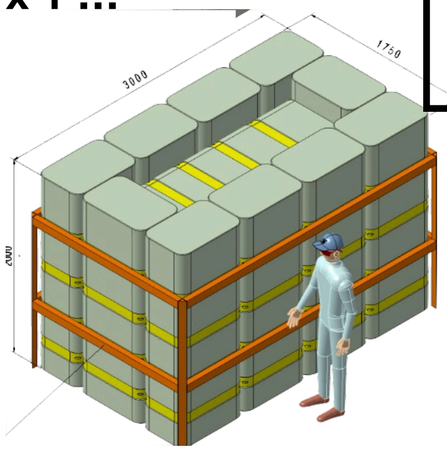
CYGNO (tech goal) to CYGNO 30 (physic goal)

the bet

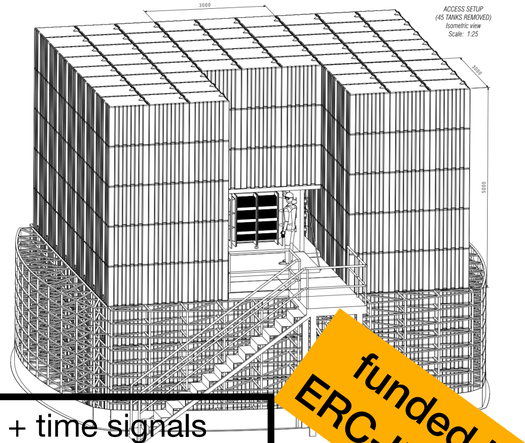


under test at LNGS

x 1 ...



5*10 litres, 1 camera
2.5 MB/event 0.2—>0.01 Hz



10^7 readout channels + time signals
18 cameras monitoring 330*330 mm
each with **150 µm resolution** and a
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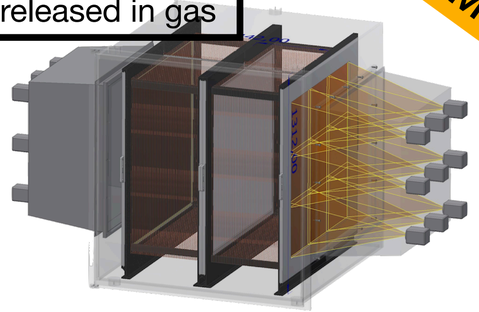
funded by ERC-INITIUM

x 9 ...

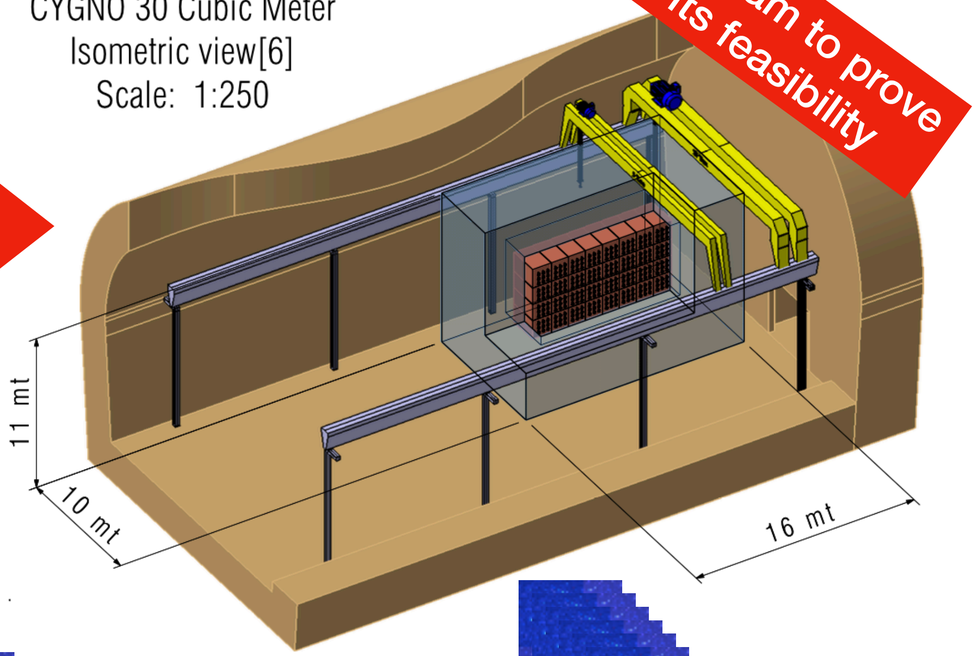


1*10^3 litres, 18 cameras
45 MB/event (Hz ?)

x 9 ...

LNGS - HALL "C" WITH
CYGNO 30 Cubic Meter
Isometric view[6]
Scale: 1:250

a dream to prove its feasibility



x N ...

3*10^4 litres, 540 cameras
1.3 GB/event (Hz ?)

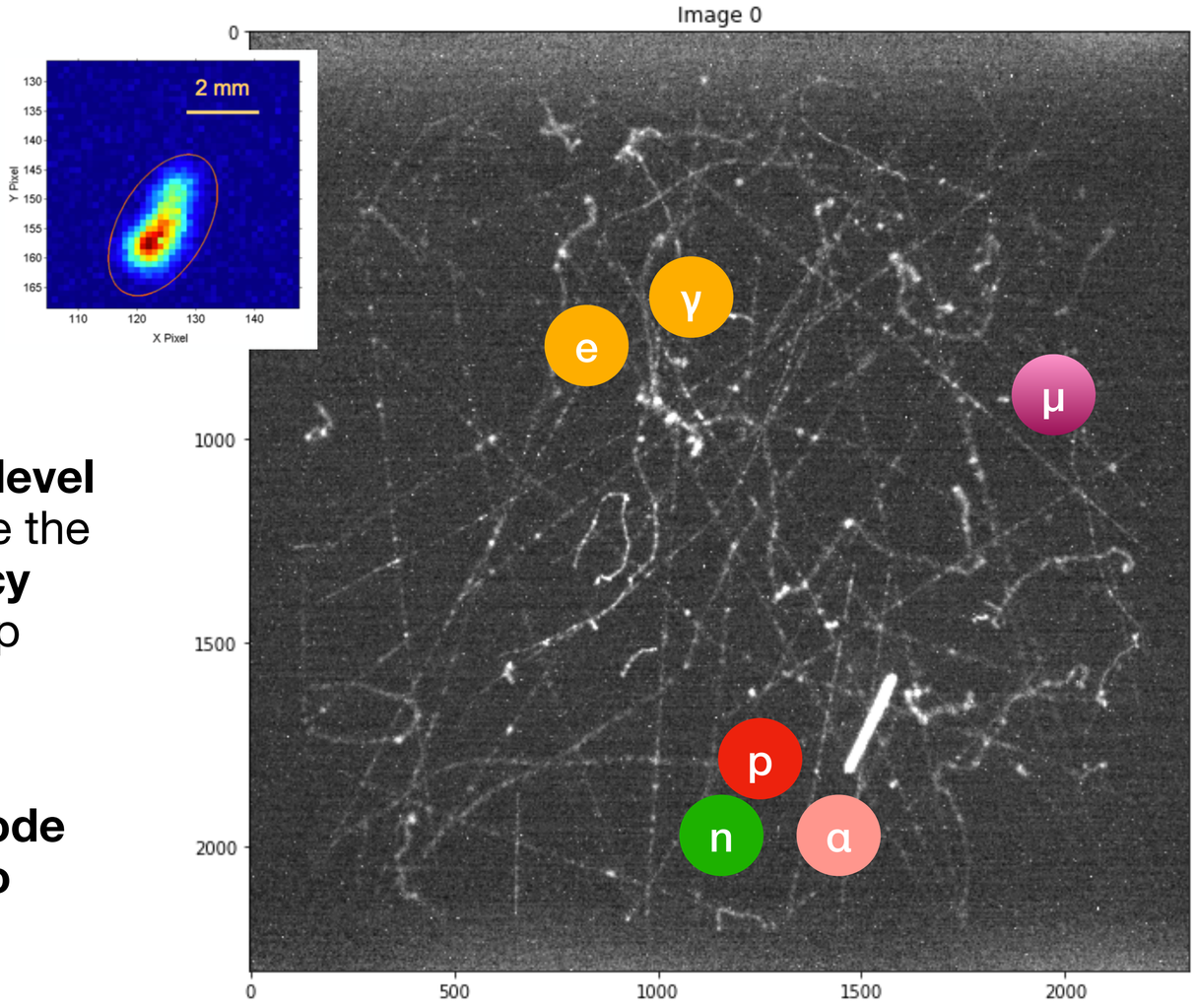
particle identification “gym”

nuclear recoil, neutrino vs beta/gamma discrimination

- exploiting dE/dx ionisation power (density)
- exploiting dE/dx ionisation profile vs path (shape, head-tail, snaking, etc)
- exploiting directionality
- exploiting time shape profile

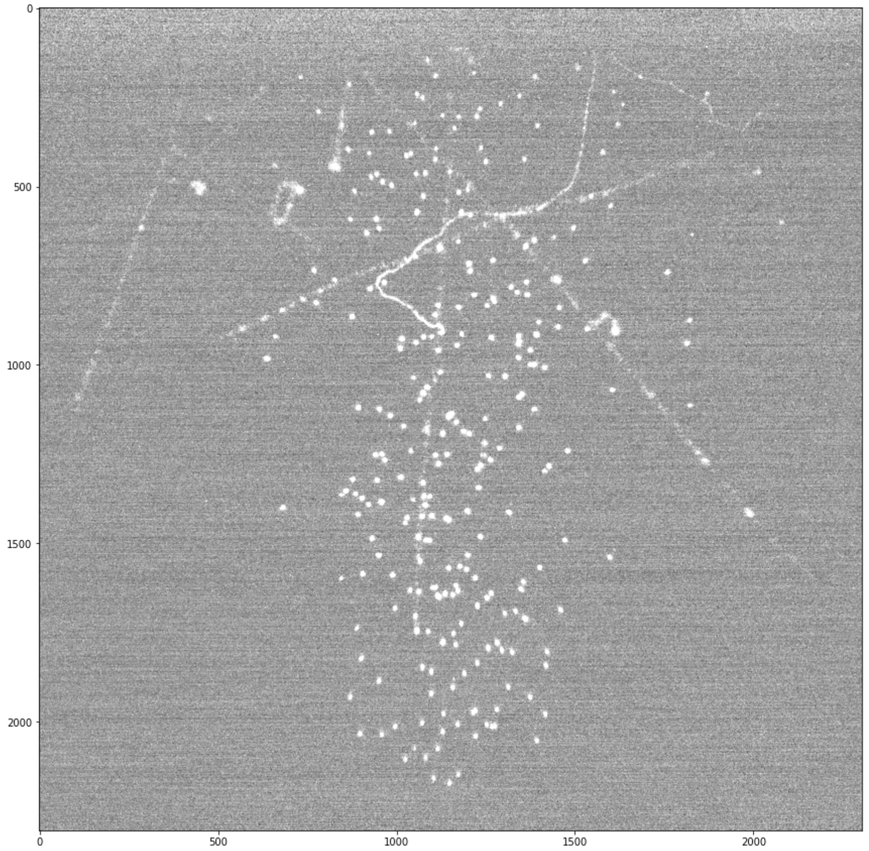
up to now we are **training our software** in the “**sea level gym**” where natural radioactivity and cosmic rays are the main issue to deal with, generating strong **occupancy and pileup** in the data. This has forcing us to develop code aimed mainly at removing **background** (not expected underground) than to identify the signal

LIME, just installed underground, will allow to **test code** in the real environment **and validate the Montecarlo** simulation



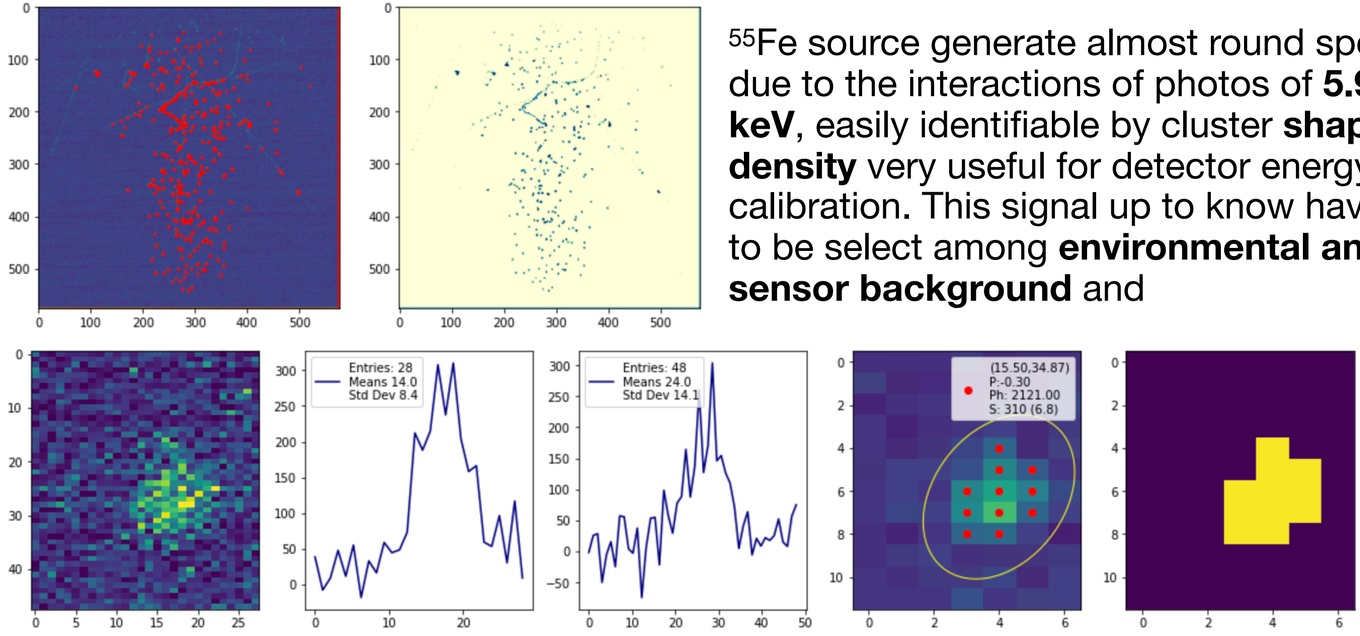
clustering

unsupervised learning NCC, KNN, HC to DBSCAN



^{55}Fe source, in 50 ms image over 30*30 cm area

```
DEBUG: number of points, clusters: 4865 255
Elapsed time 10 events: 49.4
['iTr: 0.00', 'cluster_lable: 255.00', 'pixels: 310.00', 'photons: 2121.00', 'ph_pixels: 6.84', 'x0start: 1148.00', 'y0start: 2160.00', 'x0end: 1148.
00', 'y0end: 2176.00', 'width: 15.50', 'height: 34.87', 'pearson: -0.30']
```

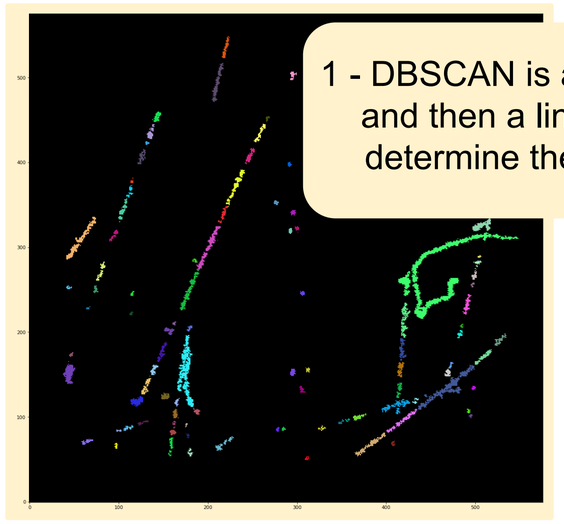


^{55}Fe source generate almost round spot due to the interactions of photos of **5.9 keV**, easily identifiable by cluster **shape/ density** very useful for detector energy calibration. This signal up to know have to be select among **environmental and sensor background** and

we start using NCC (Nearest Neighbors Clustering), K-Nearest Neighbors (KNN), Hierarchical clustering to arrive to Density Based Spatial Clustering able to detect closer in noise environments (DBSCAN)

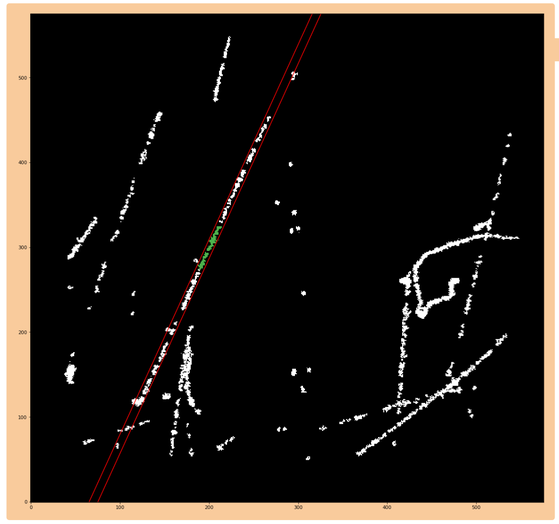
iDDBSCAN

i-ntensity Directional DBSCAN to identify cosmic rays

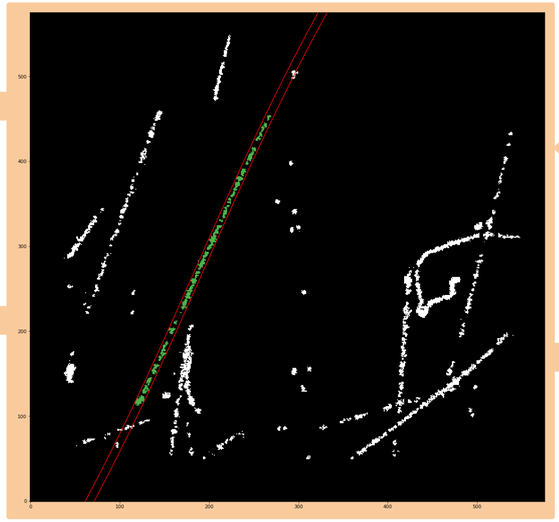


1 - DBSCAN is applied to detect the seeds and then a linear-RANSAC is used to determine the unidirectional clusters.

2 - The clustering restarts from the unidirectional clusters and a polynomial-RANSAC is used to fit them.



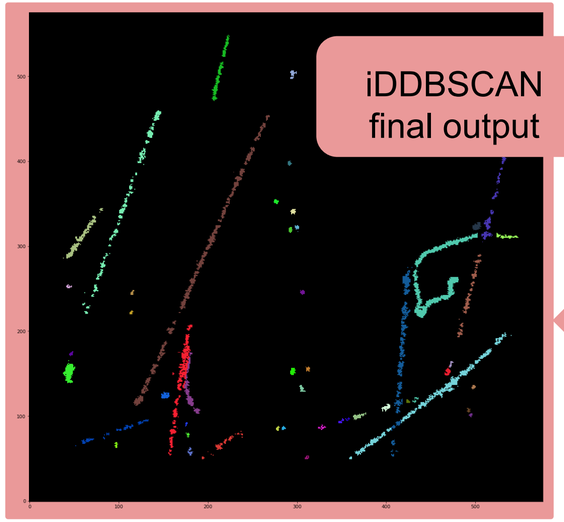
3 - Nearby points are added to the cluster based on the fit.



4 - The fit is updated whenever new points are added to the cluster.

5 - The procedure (2, 3, 4) is repeated on all unidirectional seeds.

6 - The remaining data is clustered using the DBSCAN logic.



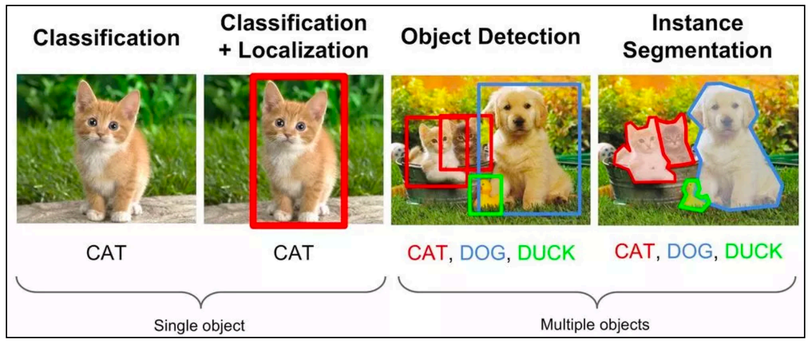
iDDBSCAN final output

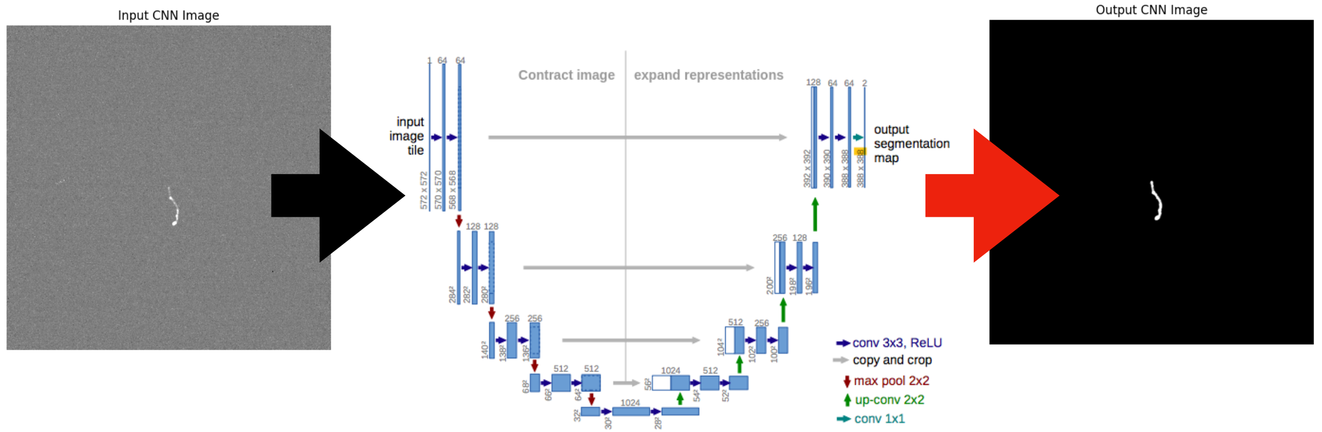
I. Pains et all. @ ufjf.br

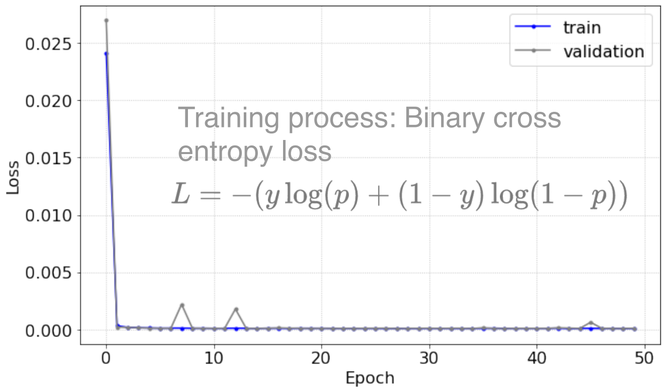
Fully Convolutional Network for pixel-wise selection

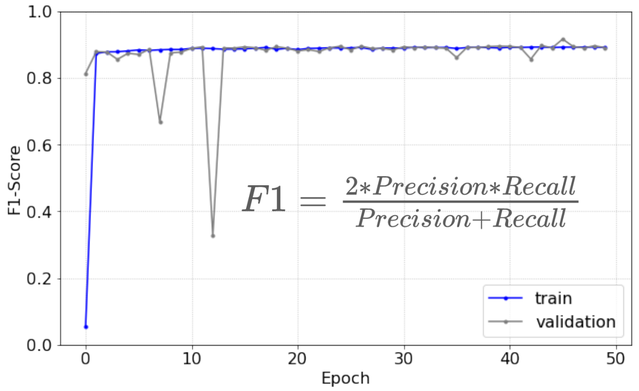
U-Net Fully Convolutional Network

- objective: increase signal pixels sent to reconstruction code, decreasing the number of background pixels, reducing the number of processed elements
- noise simulated by considering the density probability function of each pixel on camera.
- signal simulated with GEANT4 (for ER) or SRIM (for NR) 1-60keV
- each pixel is classified as signal or background
- 70% of samples were using for training







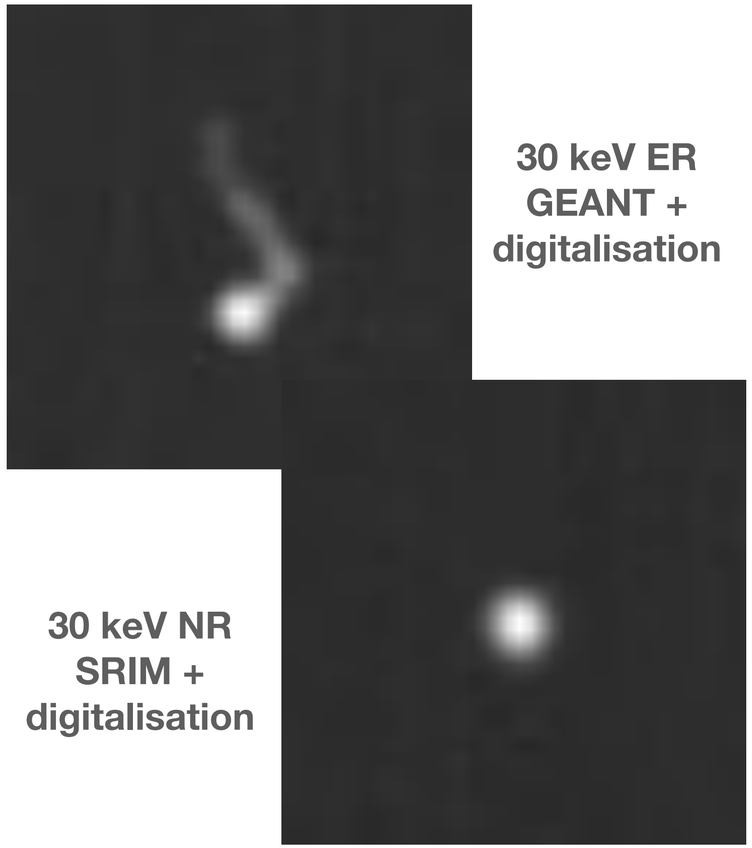


G .Lopes et al. @ .ufjf.br

deep learning models comparison

Deep Neural Network, Random Forest Classifier, Gradient Boosted Classifier

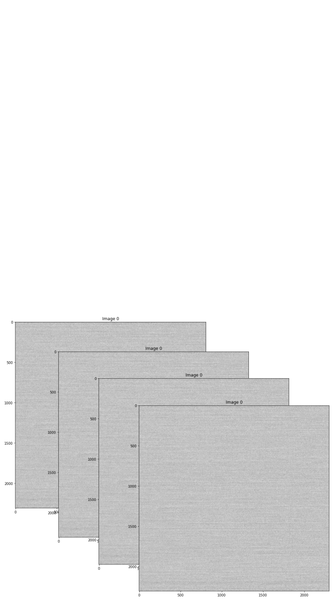
- **interaction** of the particles with gas is simulated using either GEANT4 (for ER) or SRIM (for NR)
- **detector/readout** effects are added to these track i.e. diffusion, camera noise, effective ionisation, gain fluctuations and geometrical acceptance etc.
- **digitised** images are reconstructed with a density based algorithm to find the cluster around the track.
- **topological** informations of reconstructed track can be used as discriminating variables (features)
- **features**: Length Along Principle Axis (LAPA), Maximum Density (MaxDen), Cylindrical Thickness (CylThick), Standard Deviation of Charge Distribution (SDCD), etc.
- the features were used for **training the networks**.



A. Prajapati and Gustavo V. Lopez. et al. @ GSSI.it

deep learning models comparison

Deep Neural Network, Random Forest Classifier, Gradient Boosted Classifier



measured
sensor noise 10ms

beta/gamma (ER) interaction
and propagation
simulated by GEANT (1-40keV)

e

ionisation, diffusion
and propagation in
$HeCF_4$

n

Nuclear Recoil (NR) interaction
and propagation
simulated by SRIM (1-40keV)

CYGNO
digitisation
code

CYGNO
reconstruction
code

sample of images

feature
length
density
thickness
charge distribution
…

comparison to identify NR and ER
Deep Neural Network,
Random Forest Classifier,
Gradient Boosted Classifier

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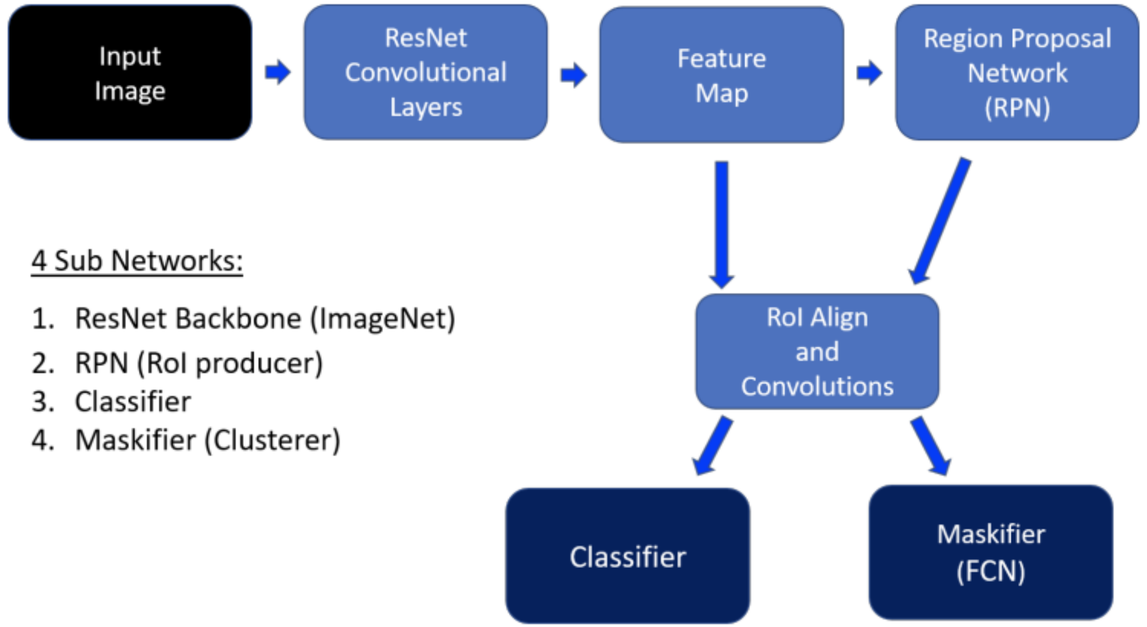
next steps 1/2

Convolutional Neural Network

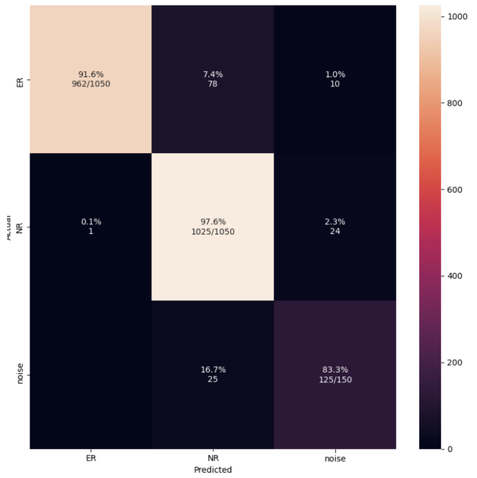
- operate on real data with CNN for the **reconstruction, classification** and computing physical quantities associated to the track.
- A ResNet model and a CNN classifier is already been made and tested on simulated data.



4 Sub Networks:

1. ResNet Backbone (ImageNet)
2. RPN (RoI producer)
3. Classifier
4. Maskifier (Clusterer)

results of CNN are very similar to the one of DNN



ER classification
92.3% DNN ->91.6% CNN
NR classification
95.9% DNN -> 97.6% CNN

ResNet CNN model (60 keV ER)

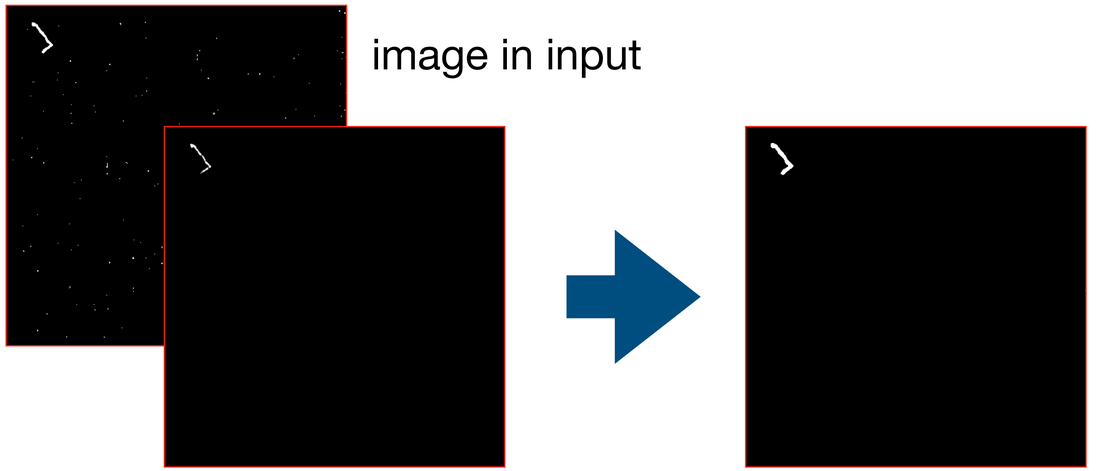


image in input

mask

prediction of the network

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next steps 2/2

combining CMOS and PMTs data