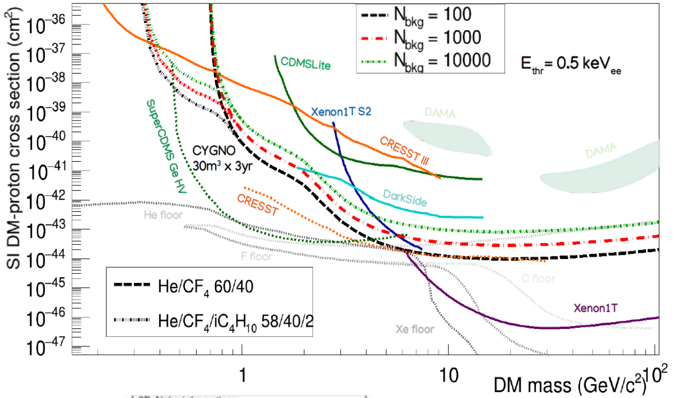
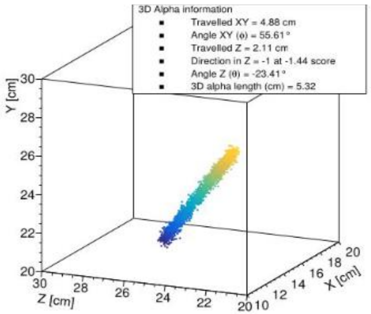


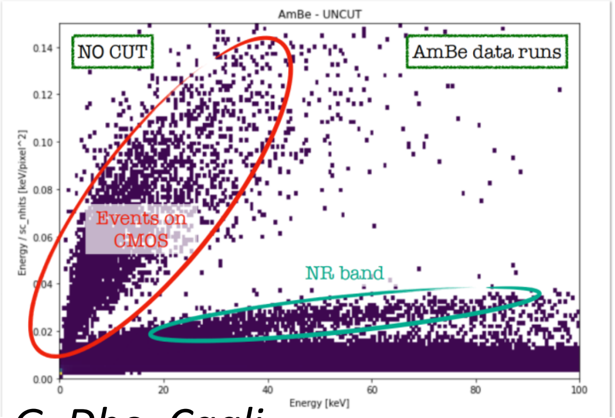


Status of Analysis

Giorgio Dho

Istituto Nazionale di Fisica Nucleare (INFN-LNF), Frascati (RM), Italy

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati



CYGNO Collaboration meeting

G. Dho, Cagli

Nov 28 2024

Who Are We

- People from different institutions joined the effort of analysis

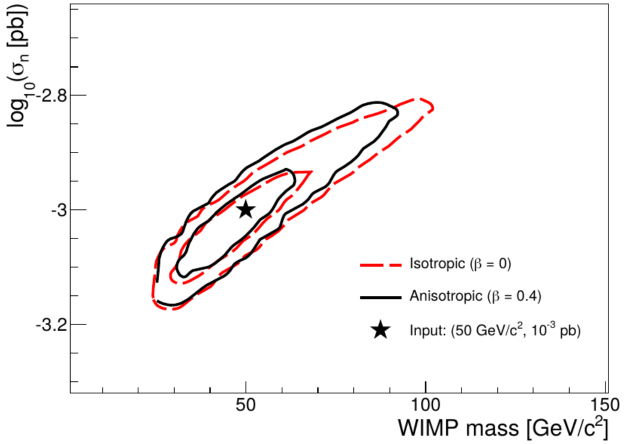
G. Dho
R. Antonietti (Leaving?)
P. Meloni
D. Pinci
S. Piacentini
D. Fiorina
D. Marques (Leaving?)
M. D’Astolfo

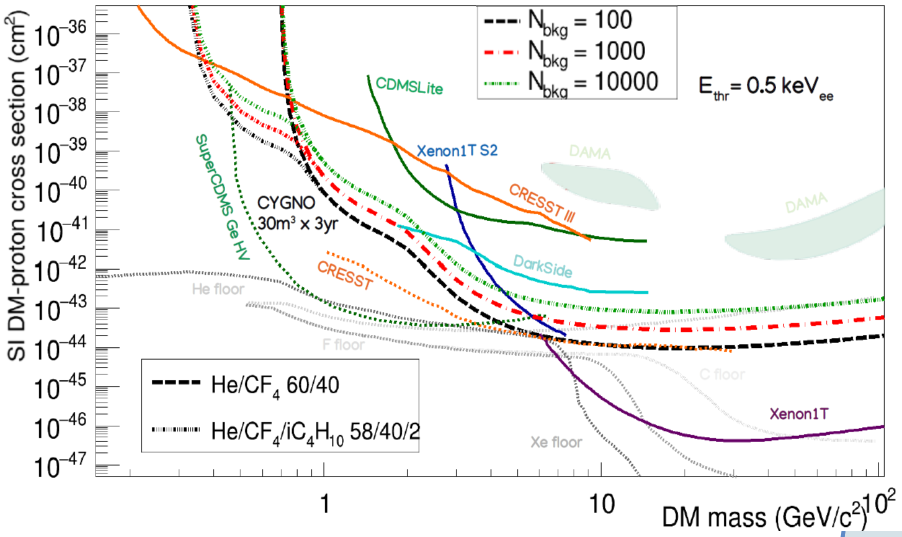
E. Baracchini
D. Mano
P. Silva
L. Gomes
G. Lopes
I. Pains
J. Venacio

- We look a lot but almost no-one is full time on analysis
- We should focus on key elements for CYGNO science (spoilers ahead)

DM Analysis

- We aim to make measurements (.. Ok limits) of DM
- CYGNO-04 will not be a physics search experiment, but has to prove what CYGNO could achieve
- These limits and especially the **directional** ones (we are not Geiger counters) should be what drive physics feedback on detector development
- Other DM models and physics cases (found by WP1 like X-ray polarimetry, neutrinos) which induce recoils could be tested by CYGNO
- Stefano, I started this work, Samuele improved it and Rita* recently picked up putting basis for a statistical framework
- **A person is needed on this topic** to expand and make this statistical study as realistic as possible

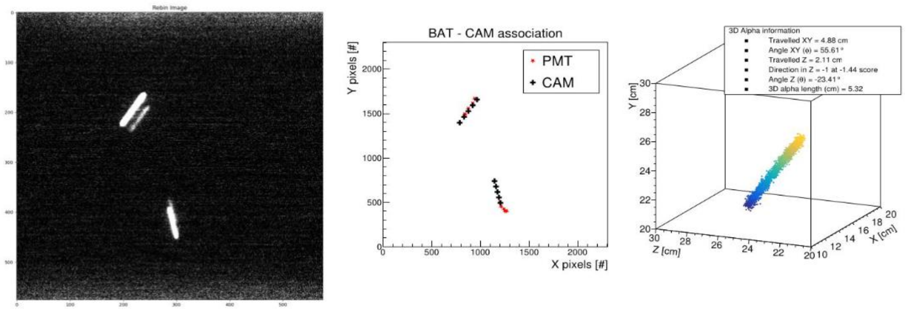




*See Antonietti's presentation of yesterday

3D Reconstruction

- We are 3D detector with PMT and camera.
- Most of the analysis is performed only with the camera data
- 3D encloses huge amount of information and can improve all the topics that will follow
- David did a great job and now a early version for straight tracks intense works*
- Expansion to electron recoil (ER) track and large scale implementation is needed **(more people-effort needed here)**



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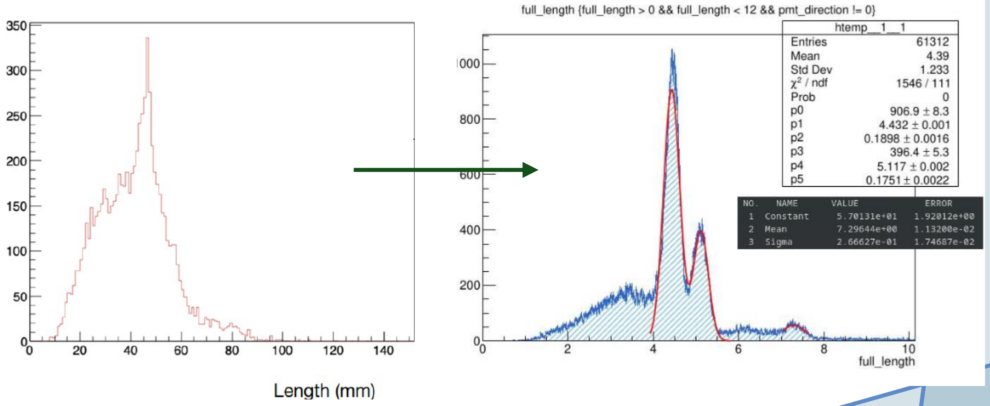
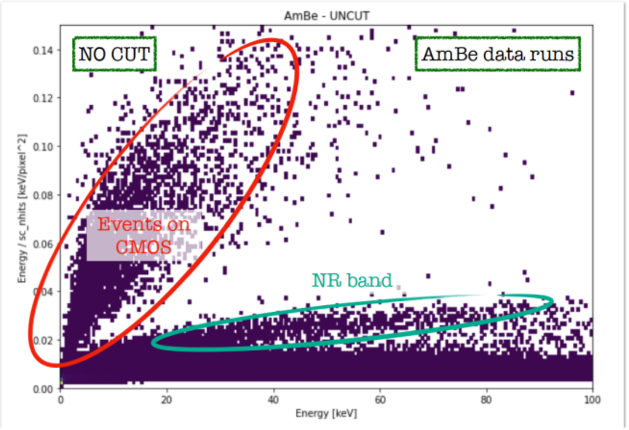
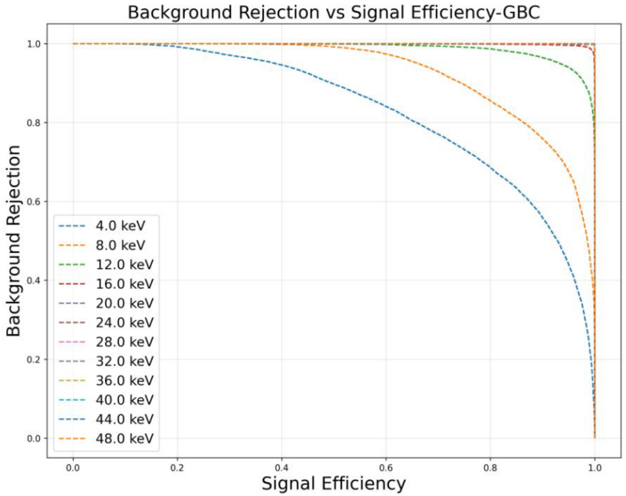


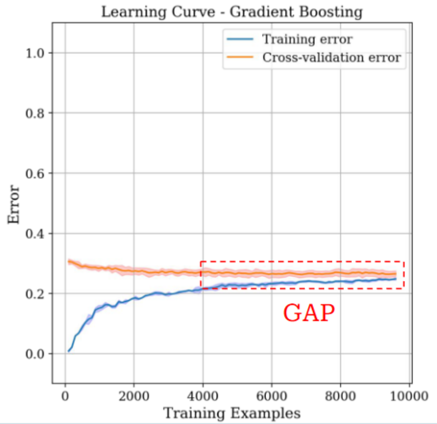
*See Marques' presentation later

ER vs NR

- Key tool is to be able to determine signal from background
- **We need a spectrum of rejection power as a function of energy**
- Studies with machine learning started by Atul
- New variables can help (Atul, Stefano)
- Luan, Jordan and Trieste ML group are starting to tackle this







$$\rho \equiv \frac{\text{sc\_rms}}{\text{sc\_nhits}}$$

- energy
- size
- nhits
- length
- width
- slimness
- Gaussian Width
- LAPA
- thin track
- SDCD
- ChargeUnif
- MaxDen
- CylThick
- eta
- dE/dX
- dE/dA

Background Understanding

- Understanding the behaviour of the background from LIME data is important to:

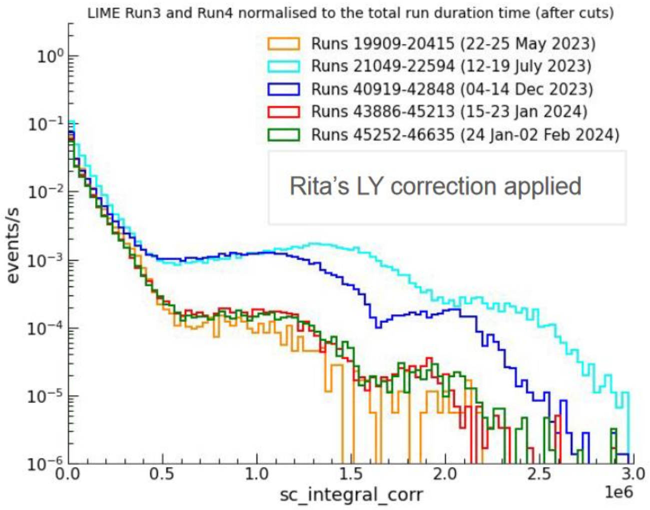
  Validate the MC chain

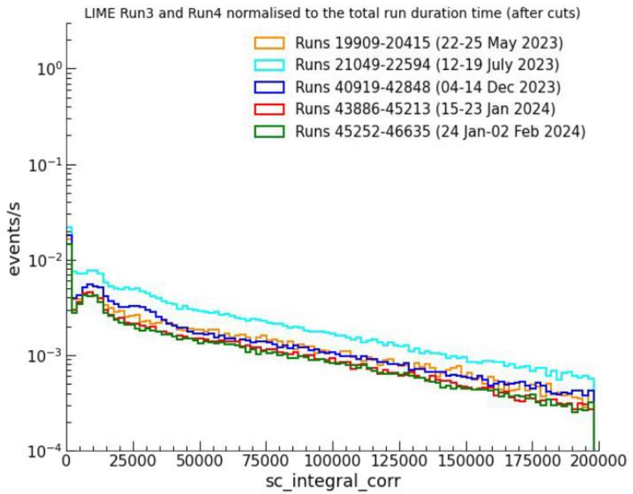
  Understand how data looks like

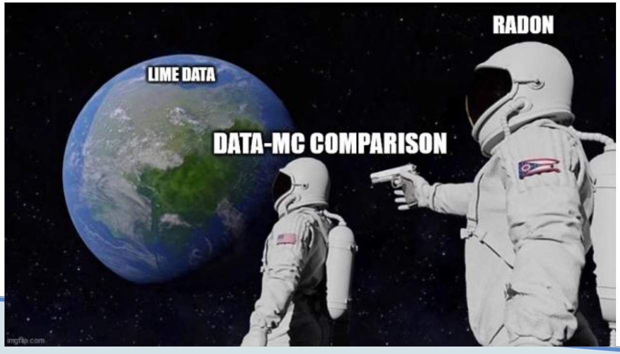
- Run4 data-MC comparison still missing (Mano on the task)

- Alpha-Rn contamination was found (Pinci, Marques and others) and proved

- Effect on low energy to be tackled then we should move on



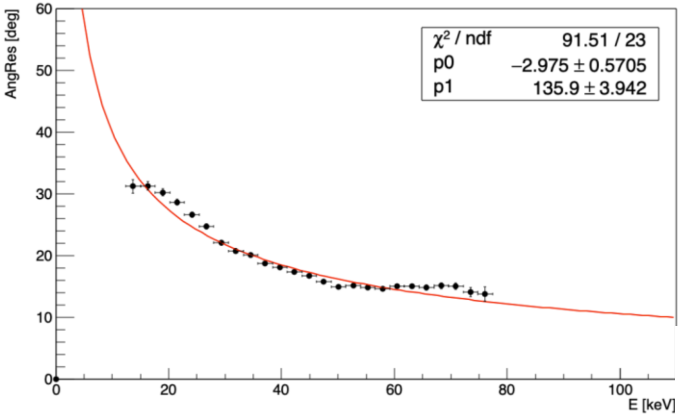


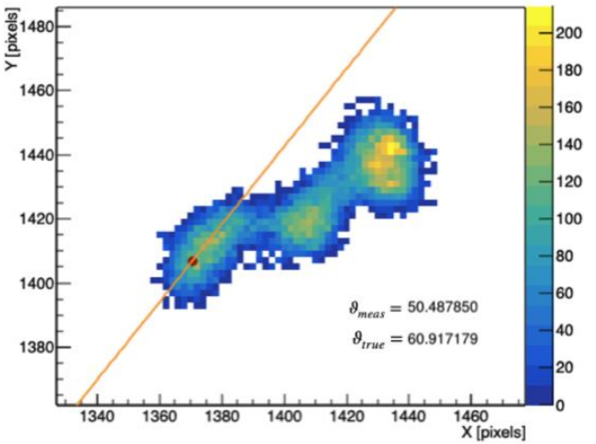


*See Mano's presentation later

Head-Tail and Angular Resolution

- Head-tail recognition and angular resolution affect the limits calculation and quality of physics reach





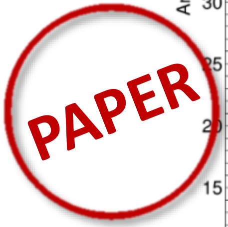
- Samuele did a lot of work especially for ER

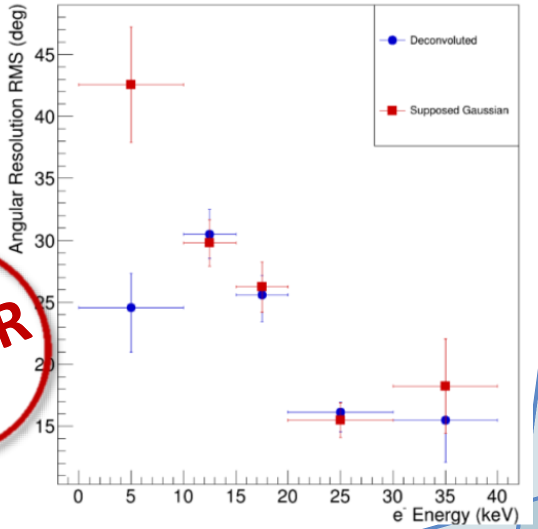
- Fiorina expanded using polarimetry data

- **We need a similar plot for NR**, possibly on data

- **We need a plot for HT**

- No one on the task for NR (maybe Trieste ML group)





*See Torelli's presentation of yesterday

Z-fiducialization

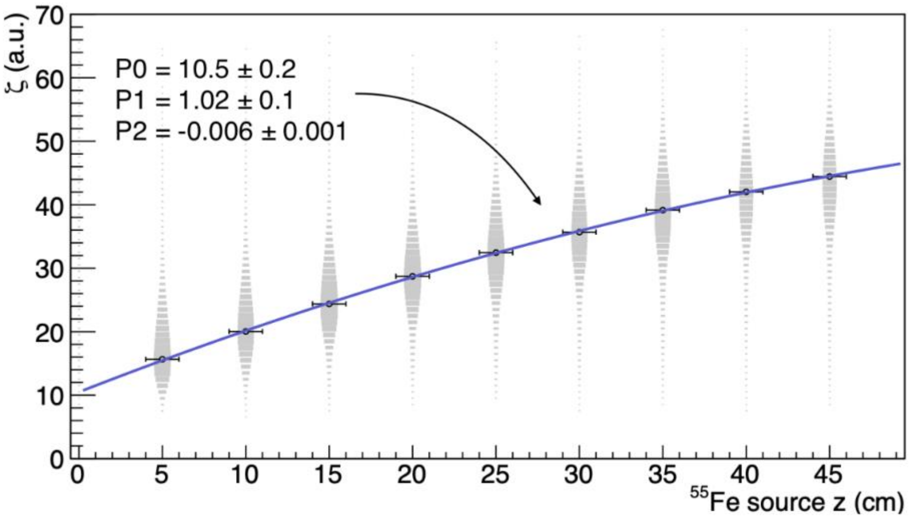
- Determination of absolute z is the only way to fiducialize the detector for events close to cathode or GEM

- Studies by Emanuele and Rita Roque suggested 4 cm resolution close to GEM and 8 cm close to cathode. **Should be improved**

- These variables turned out better than tgausssigma, we should at least use them

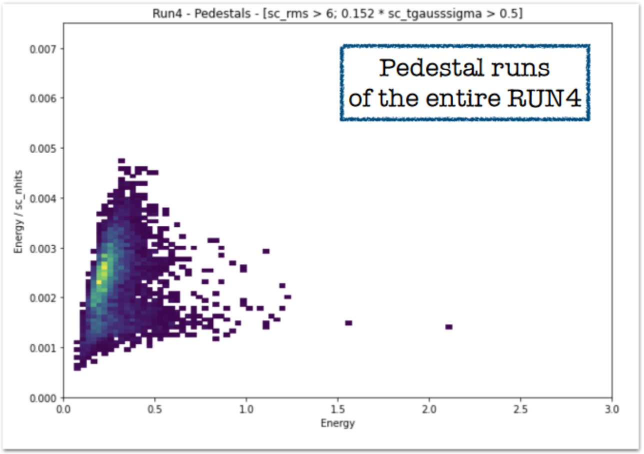
- How is this changing with low gain configuration?

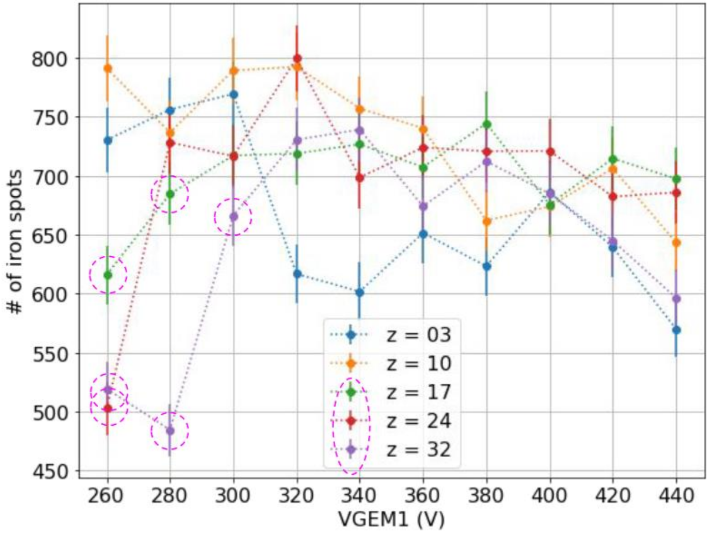
- **No one working on this.** (maybe Trieste ML group)



Energy Threshold and Efficiency

- Energy threshold is and detection efficiency are required to determine where to look for signal
- Data used for saturation studies could help (Rafael last year)
- Those data suggest that with 440 VGEM, 0.4 keV_{ee} could be detectable with 60% efficiency at far z. (0.6 keV_{ee} with 400V GEM but unknown efficiency)
- But clusters from camera may change the energy threshold. And PMT?
- While Guilherme is working on this from a simulation point of view, **we need someone to summarize and put pieces together**



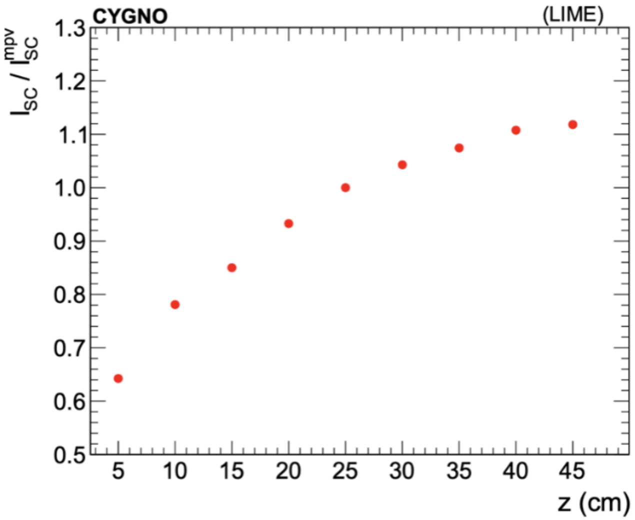


Saturation

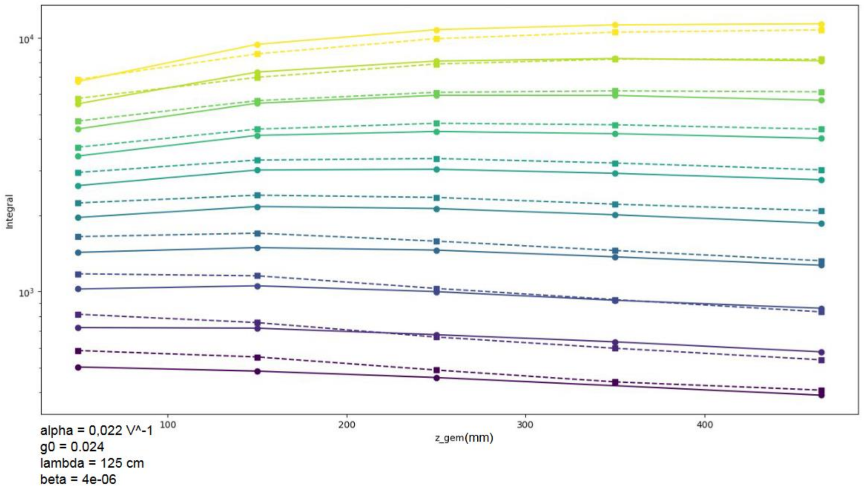
- We are saturating, the charge density is too large in GEM holes and space-charge effects limit the amplification

- This is terrible:

    - Energy threshold and response strongly depends on z
    - Detector non-linear at low energies
    - Z determination becomes fundamental with cm resolution
    - HT and angular resolution worsen at low energy
    - ER and NR are more similar



Saturation: Model



- Large effort by DavideP and Pietro to model and use the digitization to determine saturation characteristics
- One thing is modelling, another is correcting event by event basis
- Being a saturation effect this is by definition extremely hard if not prohibitive at very large saturation

$$G_{tot} = \frac{p_0^3}{1 + p_1 p_0^2 / \sigma_3 (p_0 - 1)} = \frac{p_0^3 \sigma^3}{\sigma^3 + p_1 p_0^2 (p_0 - 1)}$$

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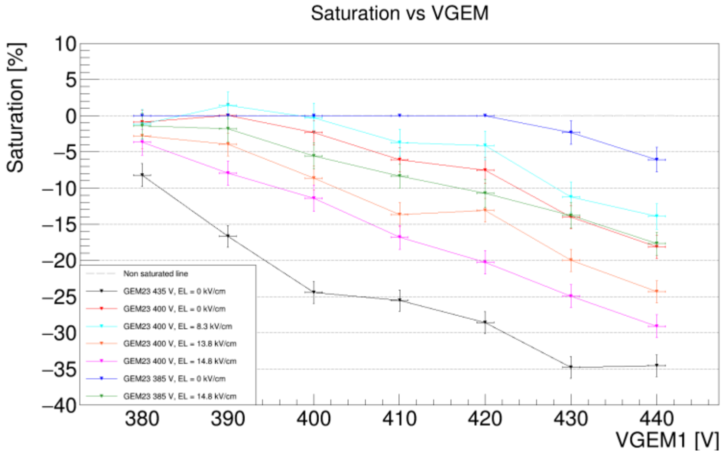
G.Dho

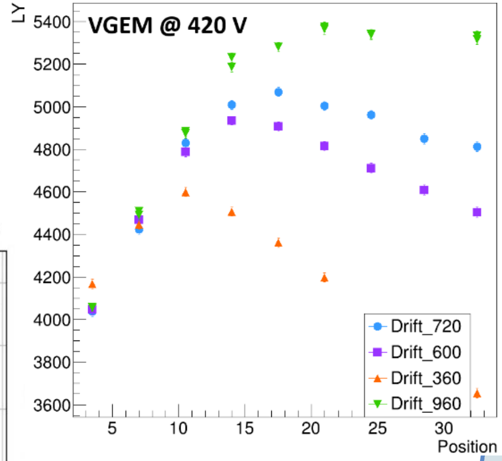
*See Pinci's presentation later and Meloni's yesterday

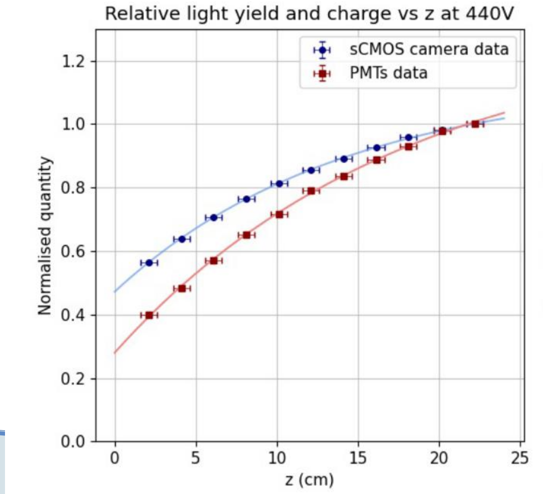
Saturation: Solve

- Analysis and hardware (WP6?) solutions can be employed
- Use of ITO seems the most promising. But it is not ready for CYGNO-04:

  tests on larger distances, stability tests (myself)
- Lowering VGEM and drift field does not fully solve but strongly mitigates (DavideF)
- Measurements with GIN lead to the possibility of PMT saturating differently from CMOS. (to be confirmed and in case further studied)

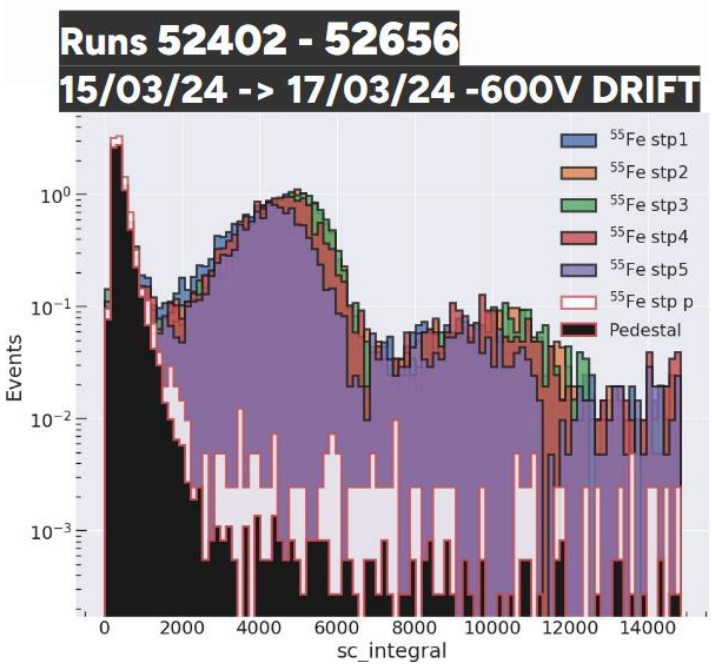




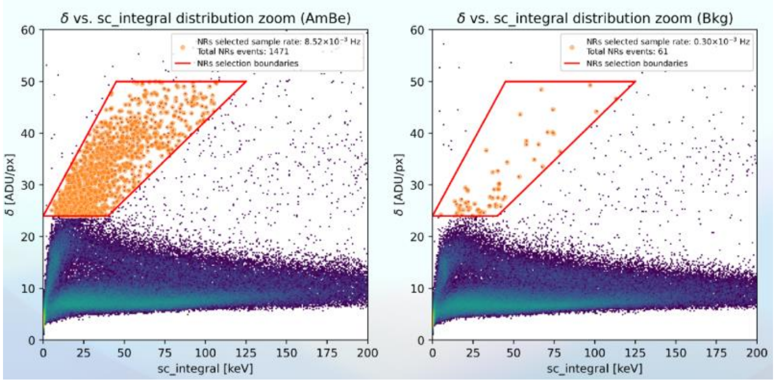


Saturation: Choose

- Data in low gain configuration (0.5 kV/cm drift and 400 VGEM) was collected during Run4 and all Run5
- Analysis and performance studies on this data is crucial (Pedro on it)
- Do we already know in which configuration we want to run CYGNO-04?



AmBe Analysis



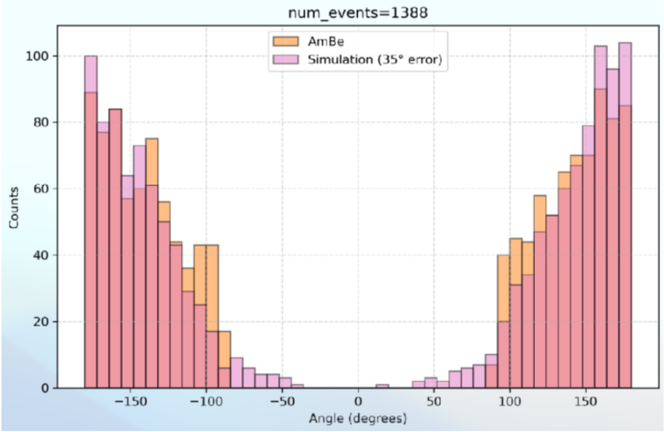
- To tackle the still unknown parameters of the experiment specific data collections are very important

- AmBe run provided known X-rays and especially NR

- High gain data is not as much as we desired but usable. Studies by Luca Zappaterra must be deepened

- Low gain AmBe soon to come will provide more data to study

- **Someone is needed to take on this**



*See Pinci's presentation later

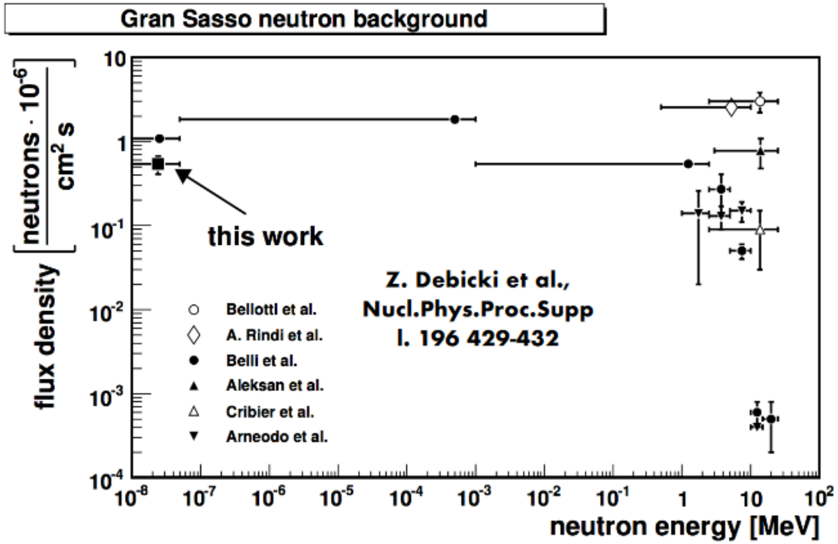
Run5: Neutrons

- Run5 will provide a long stable data set to study NR induced by neutrons

- Again, the capabilities of the experiment can be tested on this data where we are literally searching for NRs

- Not to forget the measurement of the neutron flux itself, with 250 pure events expected to be detected

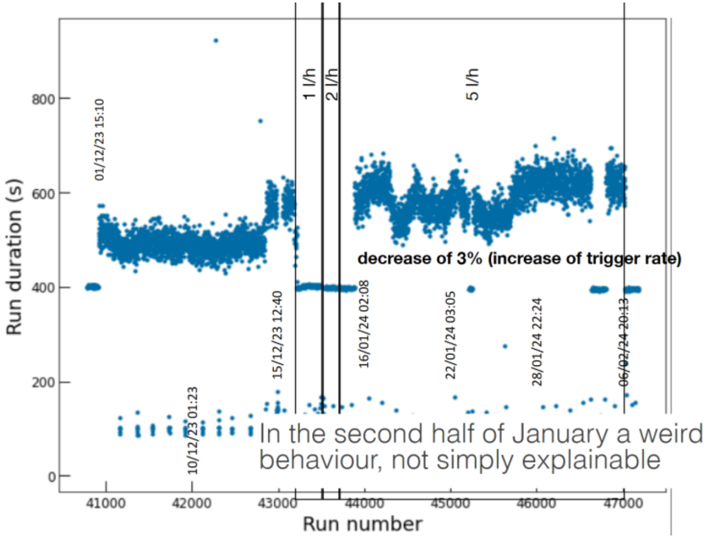
- Melba will work on this*

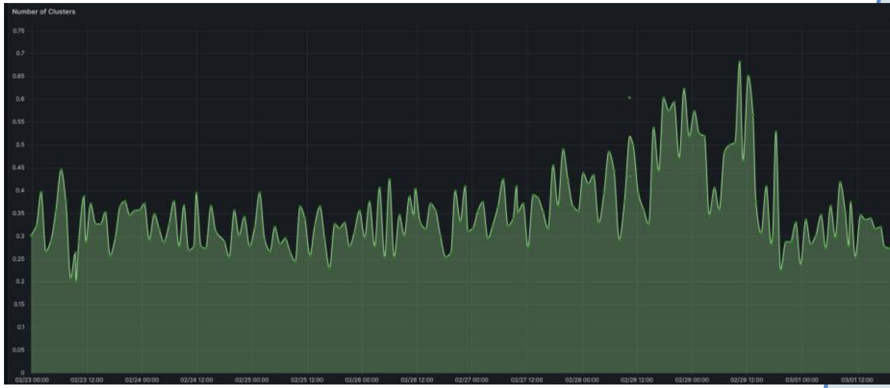


*See Melba's presentation later

Gas Quality Monitor

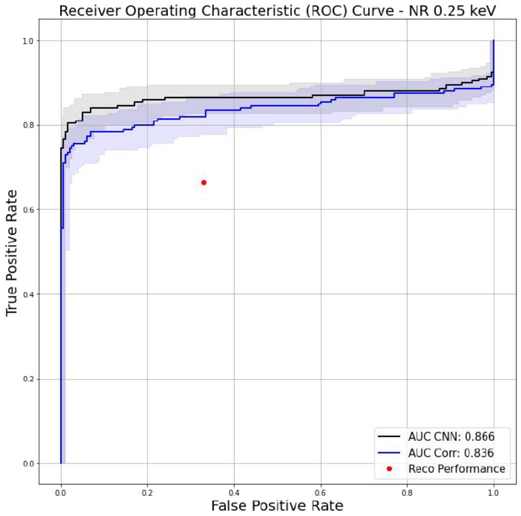
- The data monitor, especially of the gas properties provided insights on the behaviour of the detector with respect to time
- Rita A worked on understanding their effect, but now no one is working on this topic
- Understanding the LY dependence on oxygen, humidity, pressure, filters can help providing stable data sets
- Once understood, could this avoid the need of a moving source? Could this allow to introduce a live correction to VGEM to stabilize the gain?

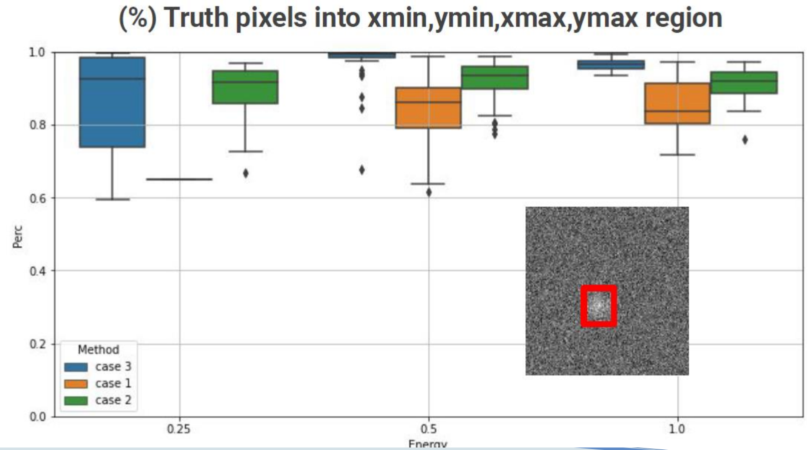




Data Reduction and pixel selection

- Data reduction topic in intertwined with DAQ (WP5) and will be discussed in detail tomorrow.
- The code could improve the signal detection efficiency of current reconstruction code
- Similarly ML techniques to select the signal pixels improving the reconstruction code





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*See Pain and Gomes presentations later

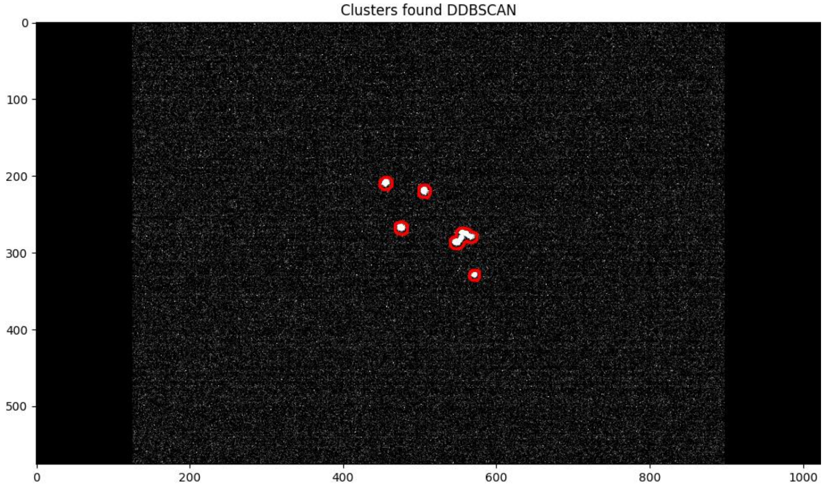
Reconstruction and Cloud

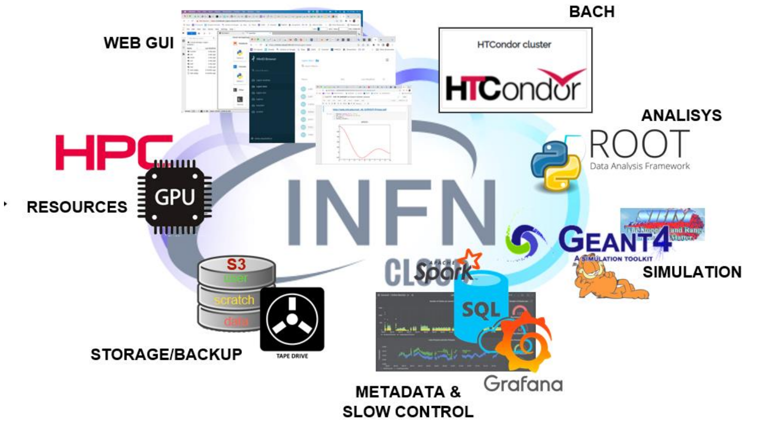
- The reconstruction code needs constant maintenance and improvements to avoid crashes and provide users with more information

- A lot of wok was done, but still a lot ahead to cope with CYGNO-04 (myself)

- Similarly, the cloud storage and resources are now the skeleton of data analysis

- Improvements on stability and performance are ongoing





Conclusion

- WP2 goal is to provide the framework to analyse data and transform it from images to physics and experimental results

- The number of FTE is quite limited for the amount of tasks to cover

- A lot of relevant and excellent work has been carried out

- Some important detector performances are still to be addressed or finalised and we should focus on these

  ER/NR, 3D reconstruction, directional parameters, z-fiducialization

- Crucial for CYGNO-04 is the understanding of the saturation conditions we want to work on

- Secondary, works on R&D like NID and ITO are also very important for future developments