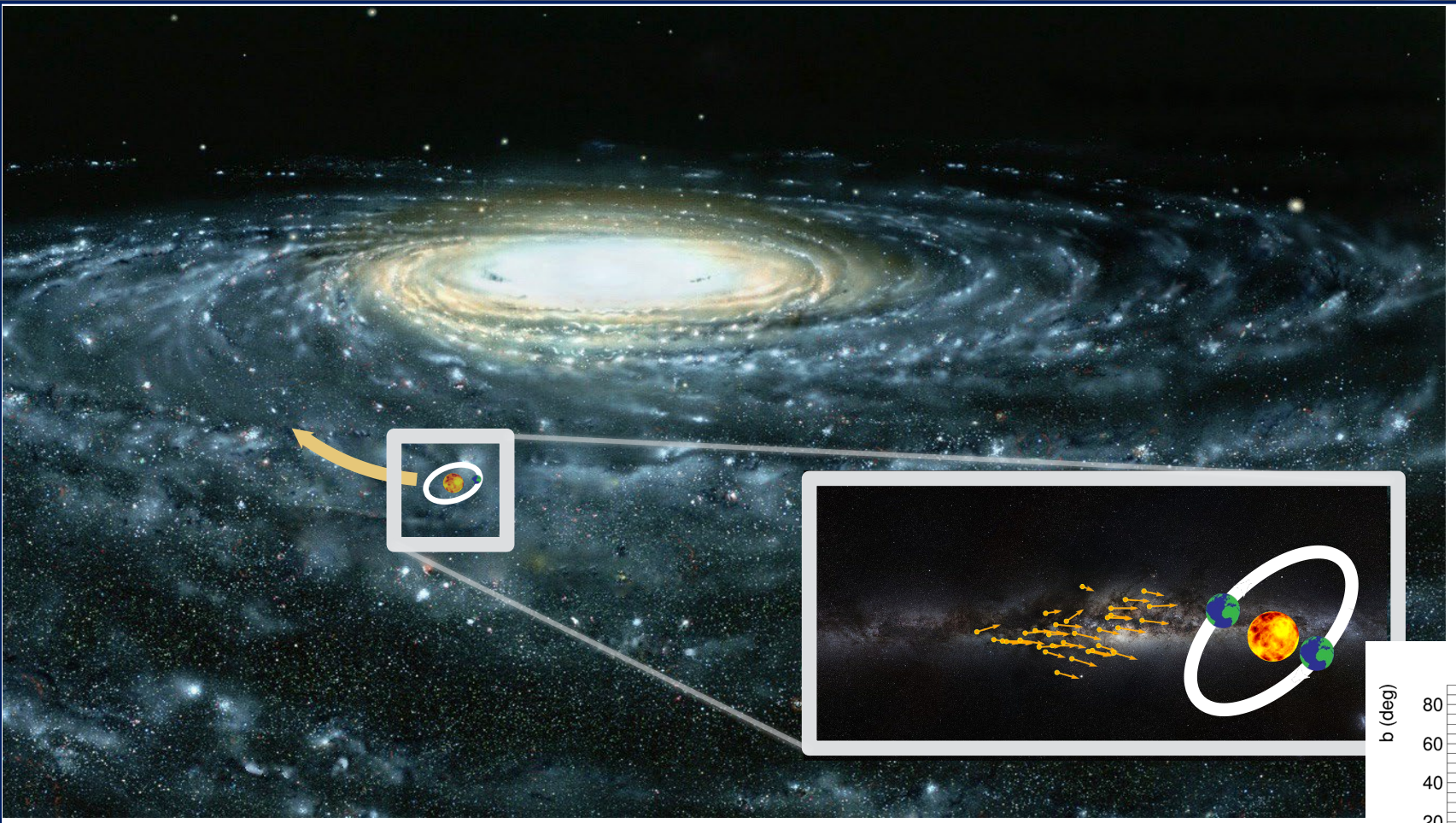
# THE CYGNO EXPERIMENT


Davide Fiorina

*Gran Sasso Science Institute & INFN LNGS*

On behalf of the CYGNO collaboration

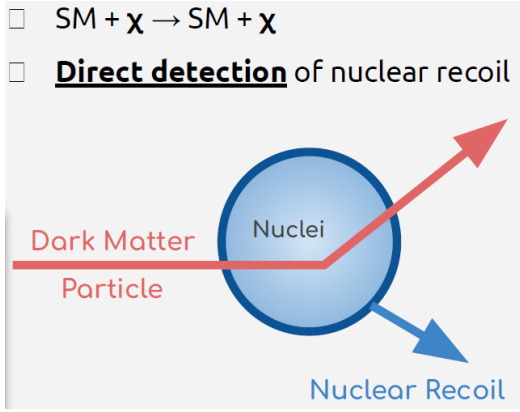
# It's a Dark Universe

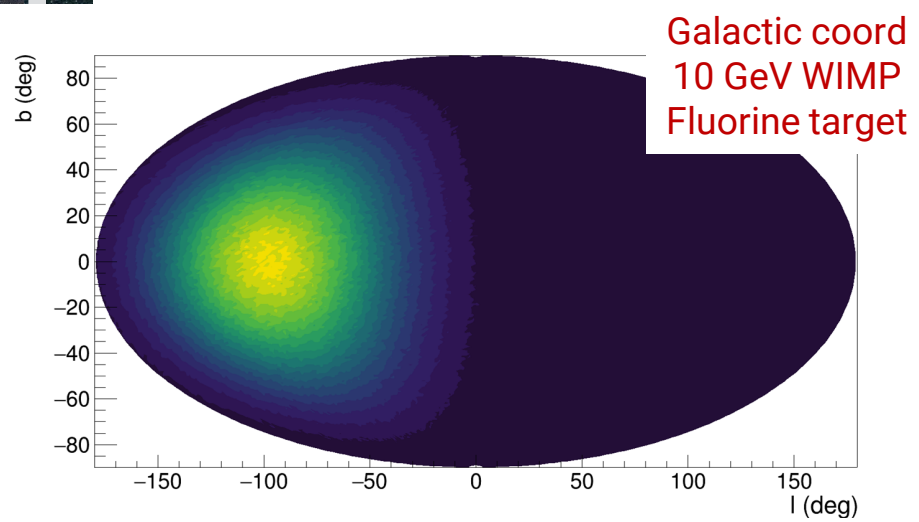


## Assumption

→ Dark Matter is made of
**W**eakly **I**nteracting **M**assive **P**articles.

- $SM + \chi \rightarrow SM + \chi$
- **Direct detection** of nuclear recoil




**ENERGY** → Excess would result in **falling exponentials**.

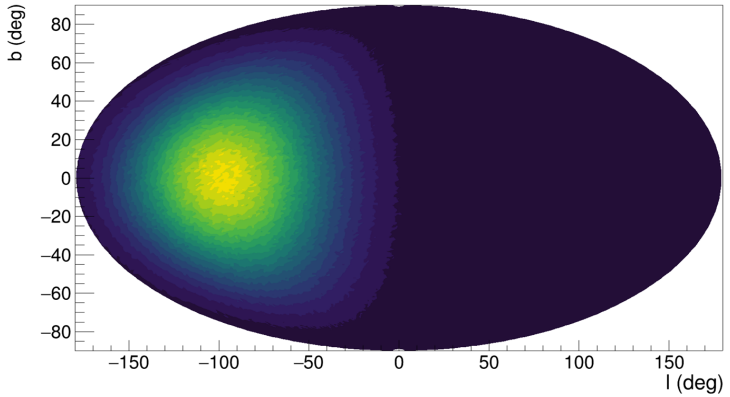
**TIME** → Results in a **few % annual modulation.**

# Directionality of the DM flux

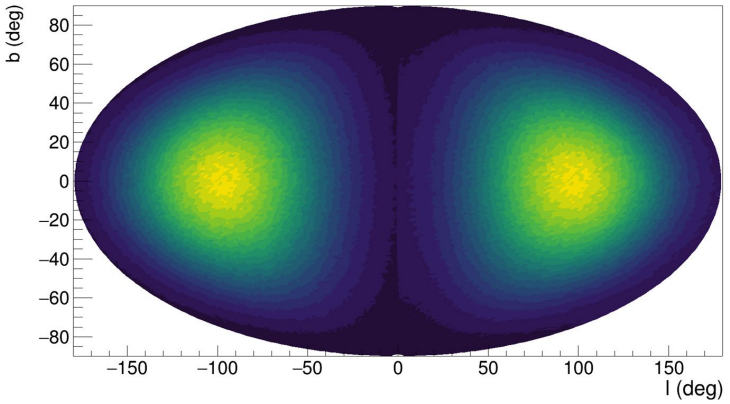
**This is the only generic and unambiguous terrestrial signature of DM that results solely from the assumption that we live inside a DM halo.**

[The future of directional searches, Ciaran O'Hare]

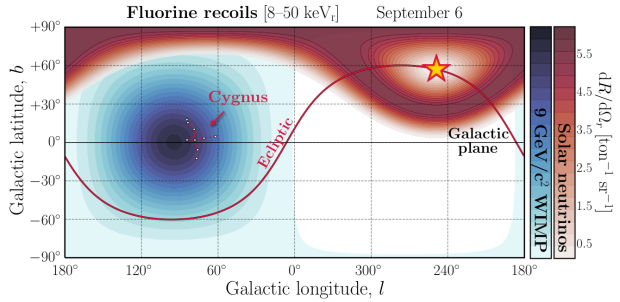
- **Only signature of DM halo presence**
- **Rejection of background isotropy**
- **Identification of solar neutrinos**
- **Only way to do DM astronomy**

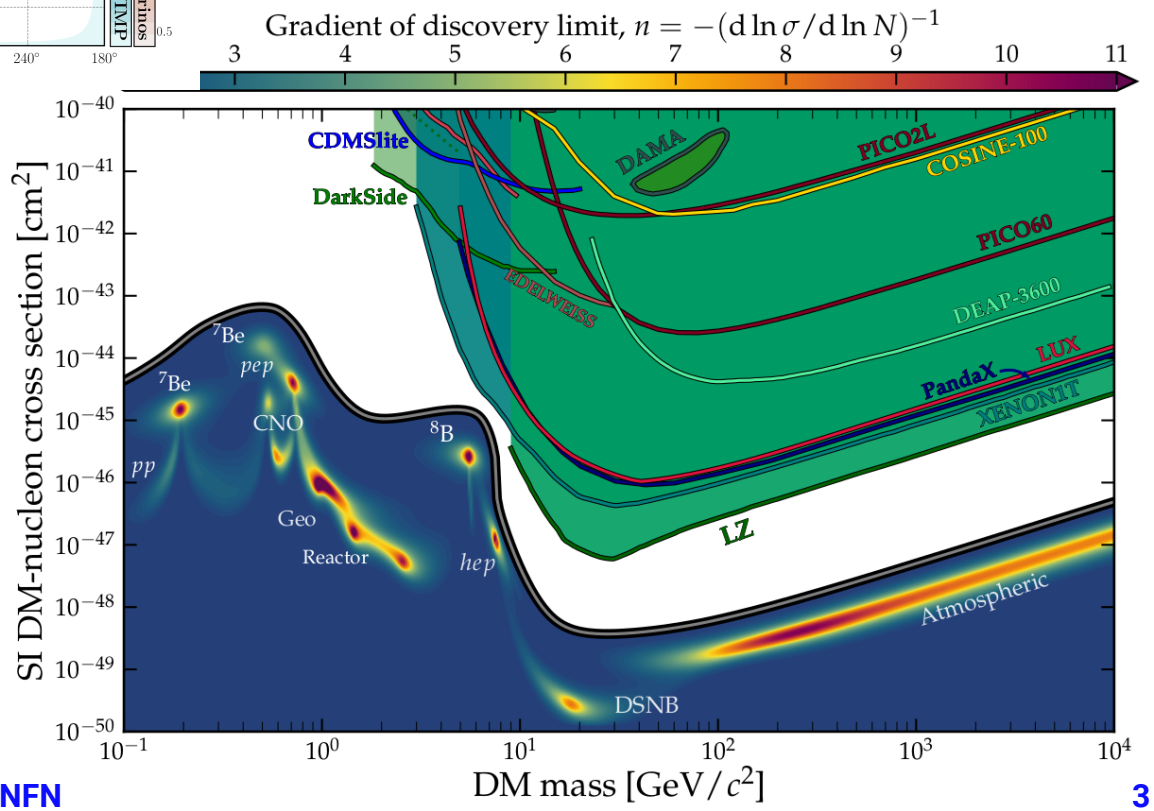



Full Head-Tail



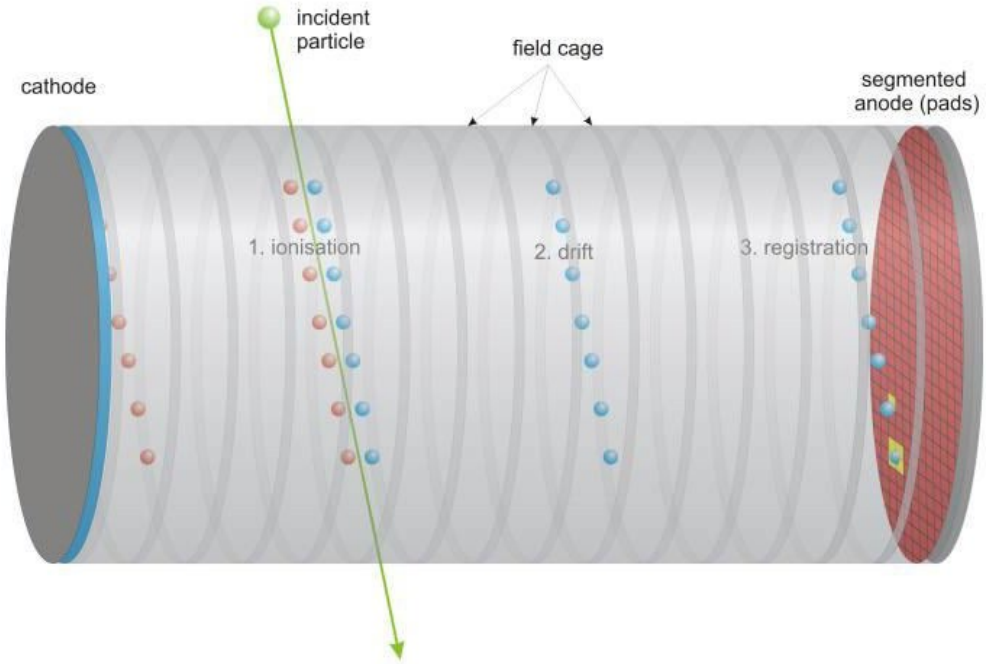

No Head-Tail

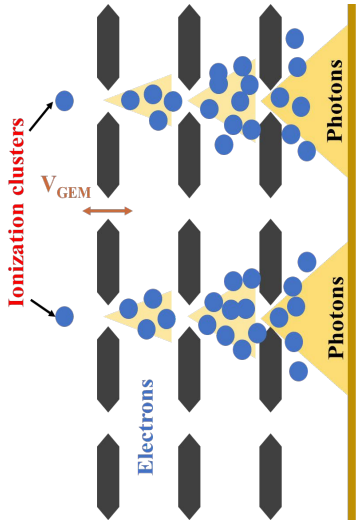


# CYGNO paradigm

## Gas at 293K and 900mbar (ambient at LNGS) He/$CF_4$ 60/40



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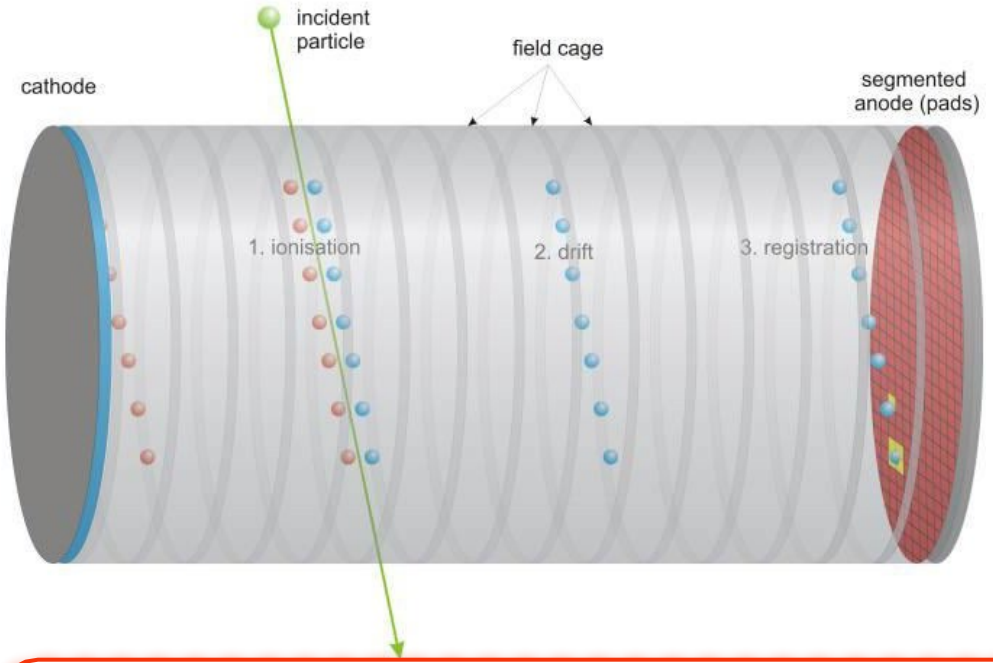
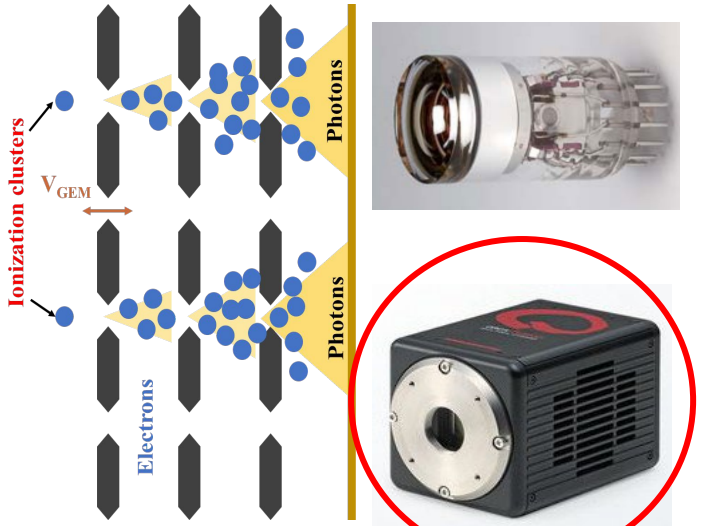
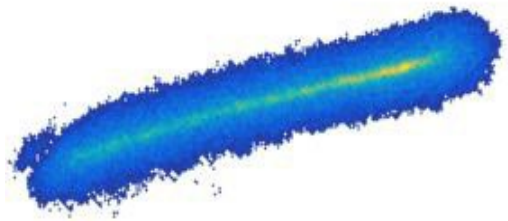







With the high granularity of the camera, we measure **energy** + **X & Y coordinates**



## Absolute Z measurement $\sigma_T \propto \sqrt{z}$

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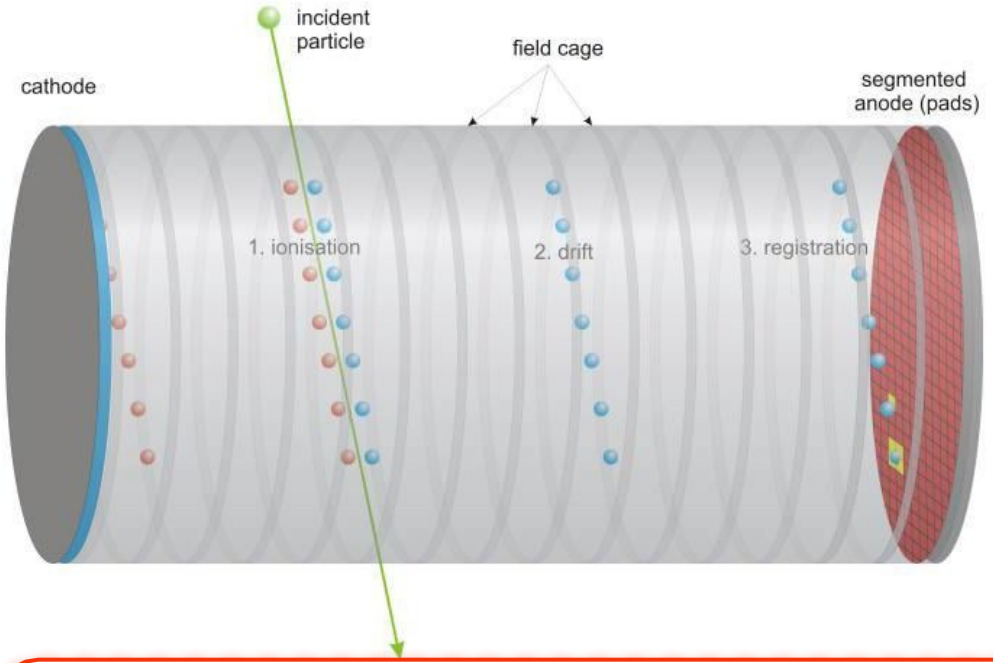


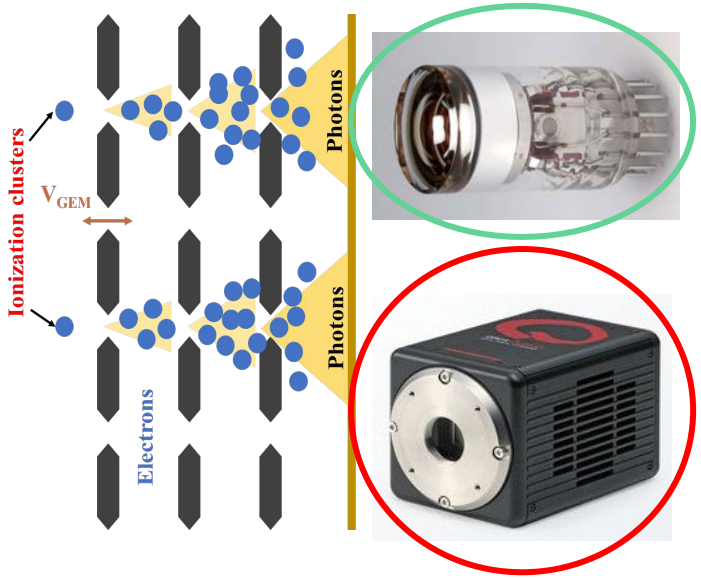






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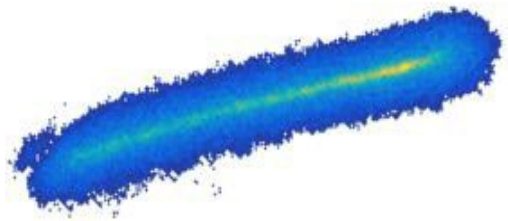
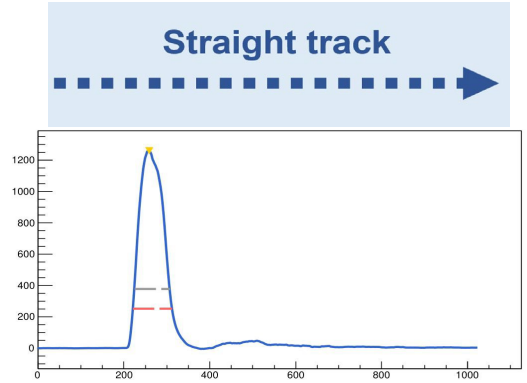


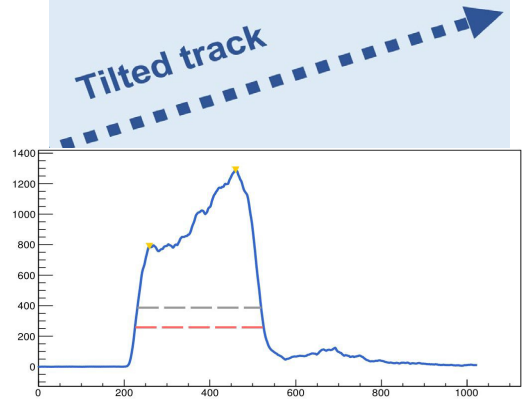
## Absolute Z measurement $\sigma_T \propto \sqrt{z}$

## ΔZ of the track

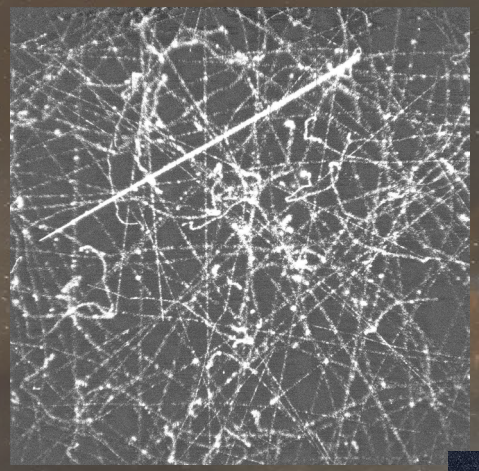
1.Independent **energy** measurement.

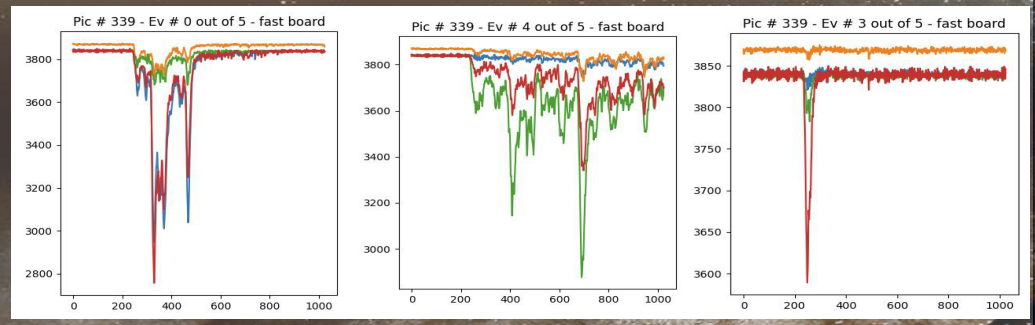
2.Electrons **times of arrival** ⇒ **dZ coordinate** (track's tilt)

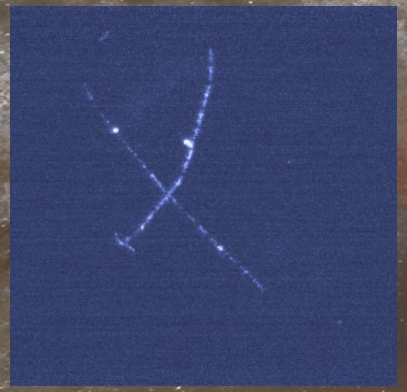


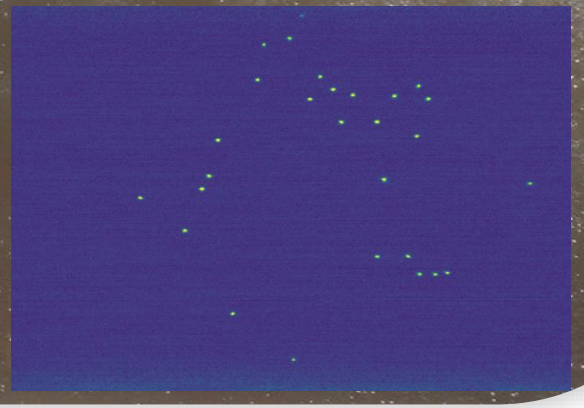



# Detector PoV









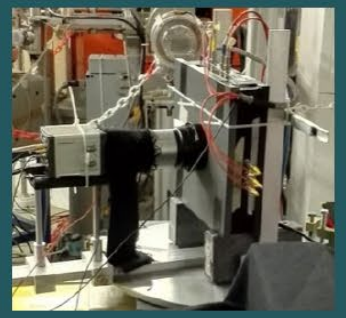
# CYGNO roadmap

The CYGNO Experiment

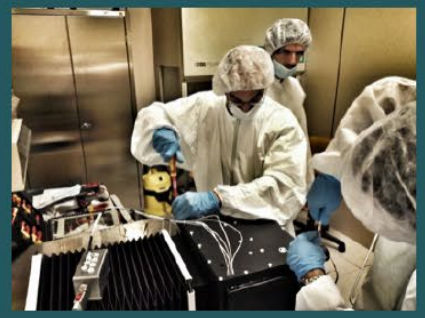
## PHASE 0: R&D and prototypes

2015/16 ROMA1 → 2017/18 LNF → 2019/25 LNF/LNGS

ORANGE → LEMON → LIME



- 1 cm drift



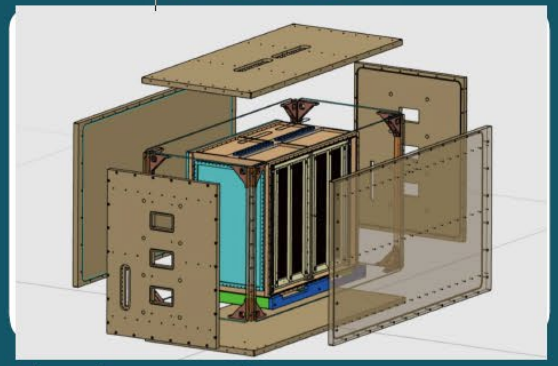
- 3D printing
- 20 cm drift

- 50 cm drift
- underground tests
- shielding

## PHASE 1: 1 m³ Demonstrator

2026/28 LNF/LNGS

CYGNO_04

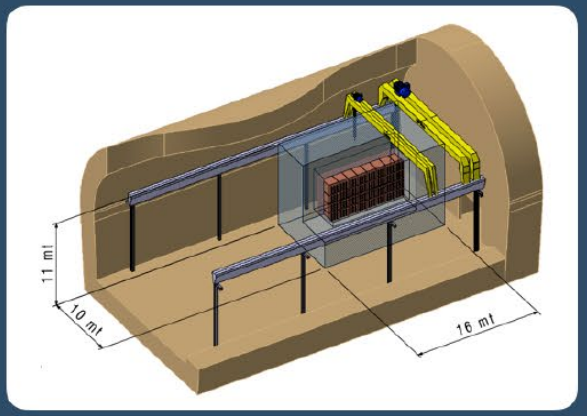


- background
- materials test, gas purification
- scalability

## PHASE 2: 30 m³ Experiment

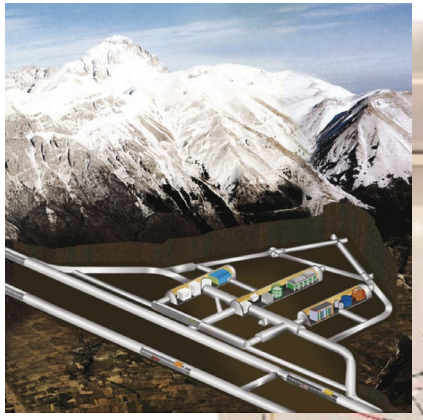
2029… LNGS

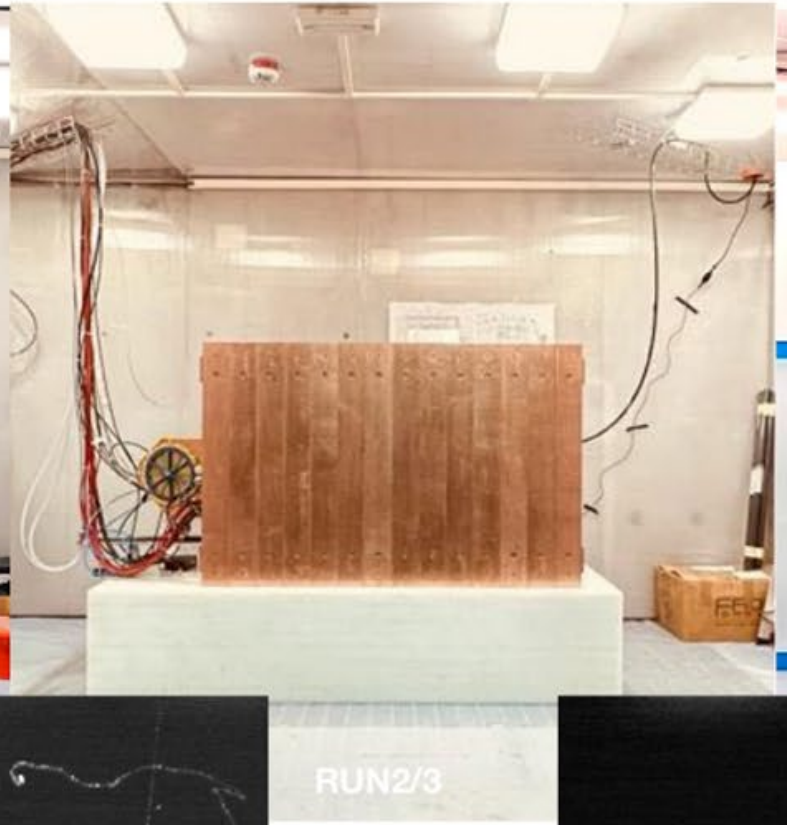
CYGNO_30

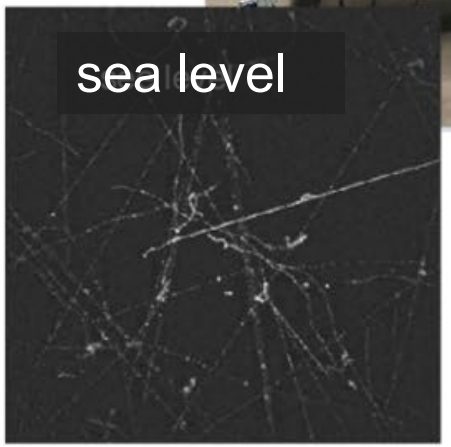


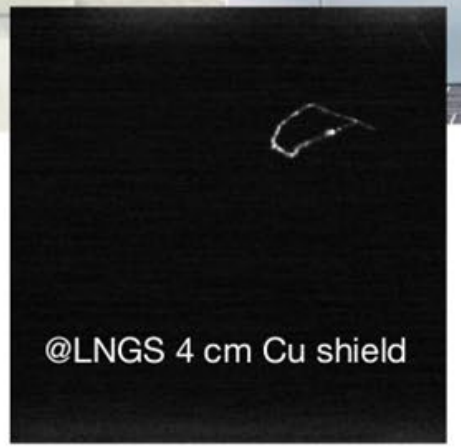

- Physics research

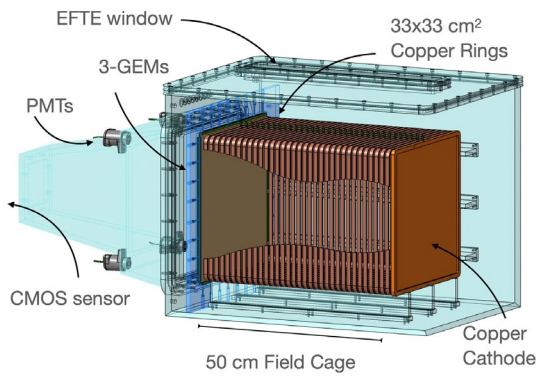
# LIME Underground Runs









# LIME Underground Runs

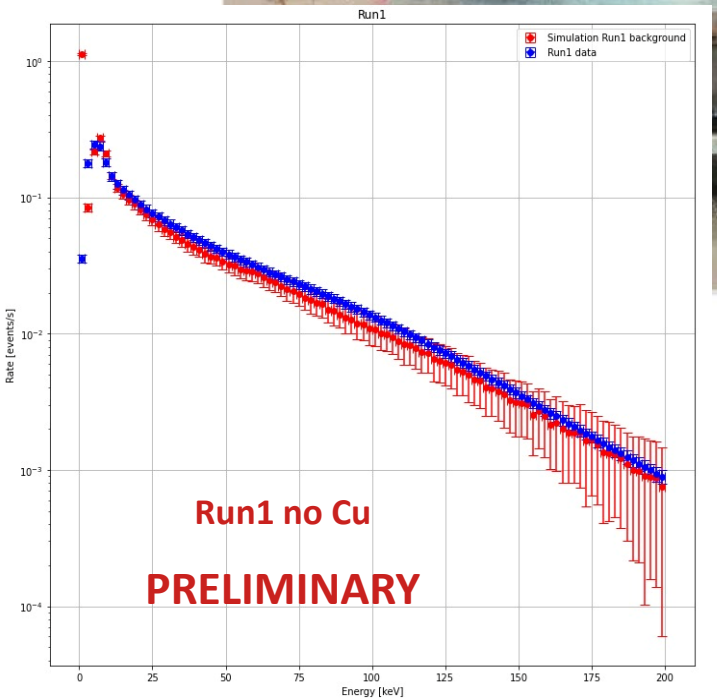
| | Time slot | Number of pictures | Event rate | Number of events |
|---|---|---|---|---|
| **RUN 1: No-shielding** | 3 Nov 2022 - 15 Dec 2022 | $4\ 10^5$ | 35 Hz | $4\ 10^6$ |
| **RUN 2: 4 cm Cu shielding** | 15 Feb 2023 - 15 March 2023 | $4.5\ 10^5$ | 3.5 Hz | $5\ 10^5$ |
| **RUN 3: 10 cm Cu shielding** | 5 May 2023 - 16 Nov 2023 | $1.6\ 10^6$ | 1.5 Hz | $7.3\ 10^5$ |
| **RUN 4: 10 cm Cu + 40 cm water shielding** | 30 Nov 2023 - 31 March 2024 | $2\ 10^6$ | 1.0 Hz | $6\ 10^5$ |
| **RUN 5: 10 cm Cu shielding (neutron flux measurements)** | 17 May 2024 - 1 Dec 2024 | $12\ 10^6$ | 1.5 Hz | $5.4\ 10^6$ |

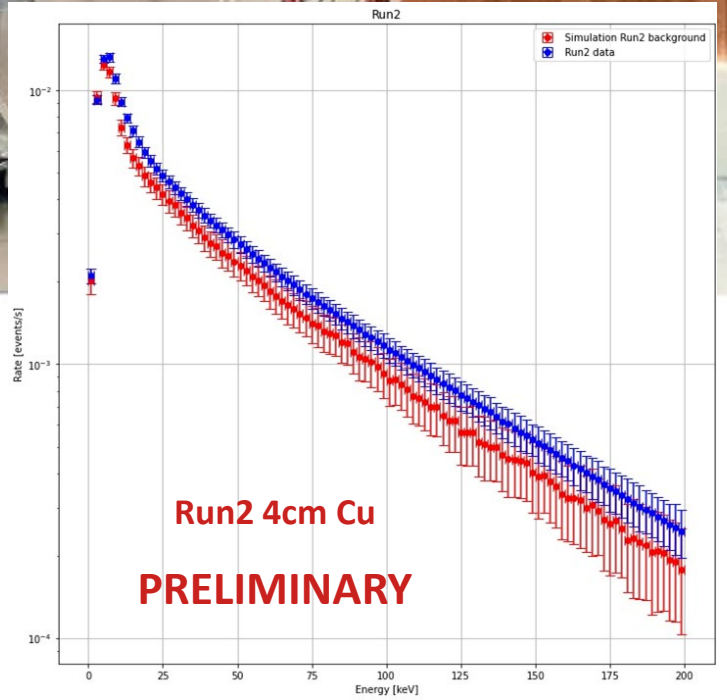
**Modeling the light response of an optically readout GEM based TPC for the CYGNO experiment**

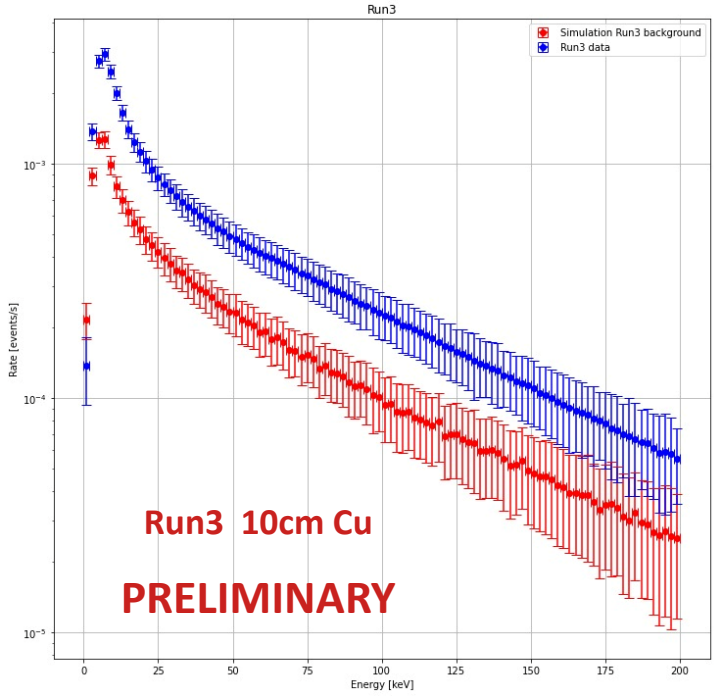
Fernando Dominques Amaro[1], Rita Antonietti[2,3], Elisabetta Baracchini[4,5], Luigi Benussi[6], Stefano Bianco[6], Roberto Campagnola[6], Cesidio Capoccia[6], Michele Caponero[6,9], Gianluca Cavoto[7,8], Igor Abritta Costa[6], Antonio Croce[6], Emiliano Dané[6], Melba D'Astolfo[4,5], Giorgio Dho[6], Flaminia Di Giambattista[4,5], Emanuele Di Marco[7], Giulia D'Imperio[7], Joaquim Marques Ferreira dos Santos[1], Davide Fiorina[4,5], Francesco Iacoangeli[7], Zahoor Ul Islam[4,5], Herman Pessoa Lima Júnior[4,5], Ernesto Kemp[10], Francesca Lewis[8], Giovanni Maccarrone[6], Rui Daniel Passos Mano[1], Robert Renz Marcelo Gregorio[11], David José Gaspar Marques[4,5], Luan Gomes Mattosinhos de Carvalho[12], Giovanni Mazzitelli[6], Alasdair Gregor McLean[11], Pietro Meloni[2,3], Andrea Messina[7,8], Cristina Maria Bernardes Monteiro[1], Rafael Antunes Nobrega[12], Igor Fonseca Pains[12], Matteo Pantalena[8], Emiliano Paoletti[6], Luciano Passamonti[6], Fabrizio Petrucci[2,3], Stefano Piacentini[4,5], Davide Piccolo[6], Daniele Pierluigi[6], Davide Pinci[7a], Atul Prajapati[4,5], Francesco Renga[7], Rita Joana Cruz Roque[1], Filippo Rosatelli[6], Alessandro Russo[6], Sabrina Salamino[8], Giovanna Saviano[6,13], Federico Francesco Scamporlino[8], Angelo Serrecchia[8], Pedro Alberto Oliveira Costa Silva[1], Neil John Curwen Spooner[11], Roberto Tesauro[6], Sandro Tomassini[6], Samuele Torelli[4,5], and Donatella Tozzi[7,8]

[Modeling the light response of an optically readout GEM based TPC for the CYGNO experiment]

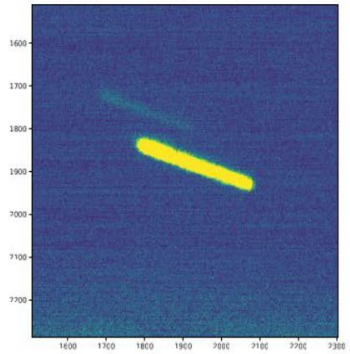
**Internal contamination detected**

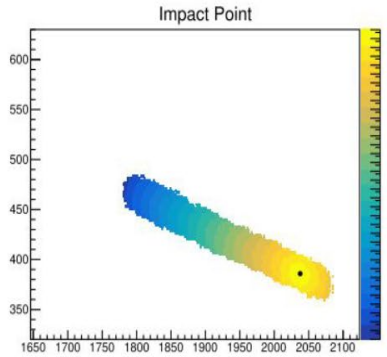


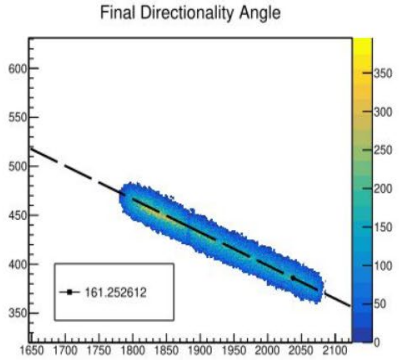



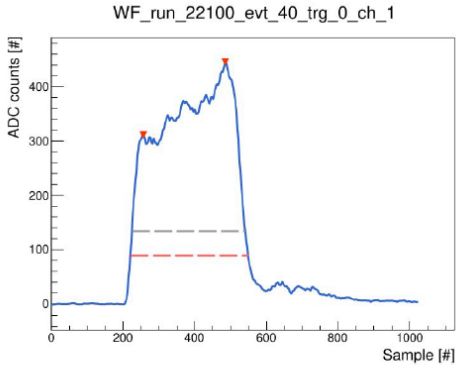



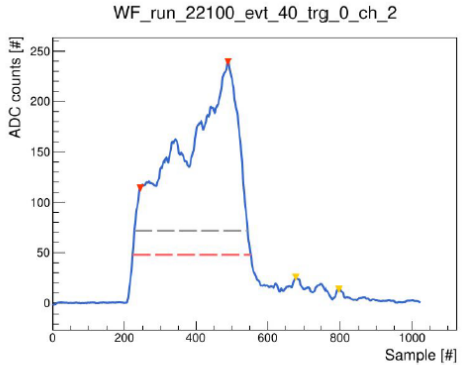
# 3D reconstruction

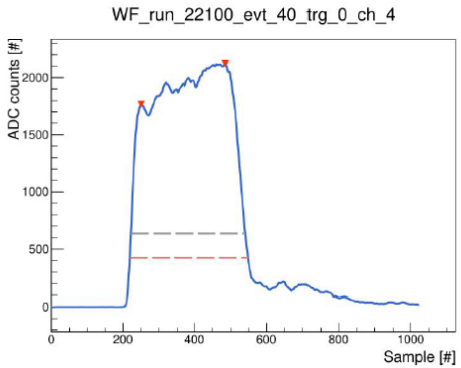


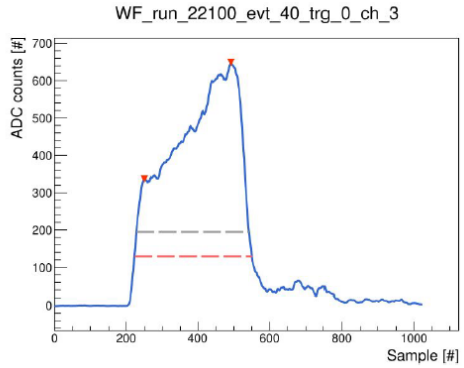


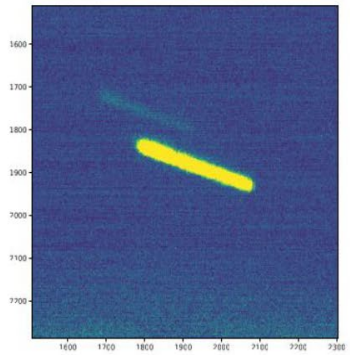

- Different responses of the 4 PMTs in LIME
- Multivariate Bayesian fit procedure
- Calibrated on $^{55}$Fe source
- **Precision of ~1 cm**

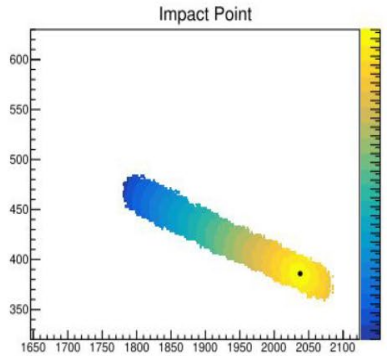
**Bayesian network 3D event reconstruction in the Cygno optical TPC for dark matter direct detection**

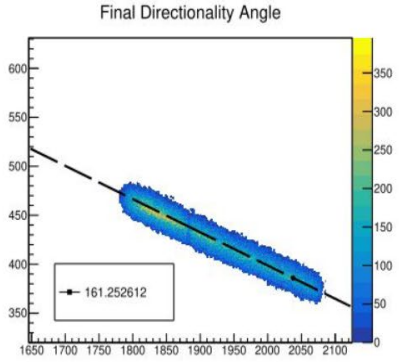
Fernando Domingues Amaro[1], Rita Antonietti[2,3], Elisabetta Baracchini[4,5], Luigi Benussi[6], Stefano Bianco[6], Francesco Borra[2,3a], Cesidio Capoccia[6], Michele Caponero[6,9], Gianluca Cavoto[7,8], Igor Abritta Costa[6], Antonio Croce[6], Emiliano Dané[6], Melba D'Astolfo[4,5], Giorgio Dho[6], Flaminia Di Giambattista[4,5], Emanuele Di Marco[7], Giulia D'Imperio[7], Matteo Folcarelli[7,8b], Joaquim Marques Ferreira dos Santos[1], Davide Fiorina[4,5], Francesco Iacoangeli[7], Zahoor Ul Islam[4,5], Herman Pessoa Lima Júnior[4,5], Ernesto Kemp[10], Giovanni Maccarrone[6], Rui Daniel Passos Mano[1], David José Gaspar Marques[4,5c], Luan Gomes Mattosinhos de Carvalho[12], Giovanni Mazzitelli[6], Alasdair Gregor McLean[11], Pietro Meloni[2,3], Andrea Messina[7,8], Cristina Maria Bernardes Monteiro[1], Rafael Antunes Nobrega[12], Igor Fonseca Pains[12], Emiliano Paoletti[6], Luciano Passamonti[6], Fabrizio Petrucci[2,3], Stefano Piacentini[4,5], Davide Piccolo[6], Daniele Pierluigi[6], Davide Pinci[7], Atul Prajapati[4,5d], Francesco Renga[7], Rita Joana Cruz Roque[1], Filippo Rosatelli[6], Alessandro Russo[6], Giovanna Saviano[6,13], Pedro Alberto Oliveira Costa Silva[1], Neil John Curwen Spooner[11], Roberto Tesauro[6], Sandro Tomassini[6], Samuele Torelli[4,5e], and Donatella Tozzi[7,8]

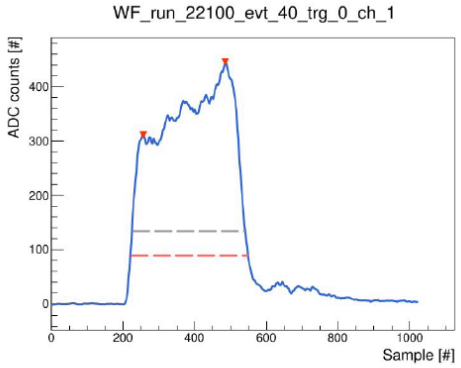
Bayesian network 3D event reconstruction in the Cygno optical TPC for dark matter direct detection

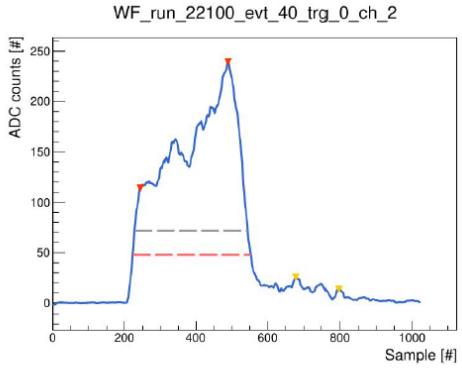
# 3D reconstruction

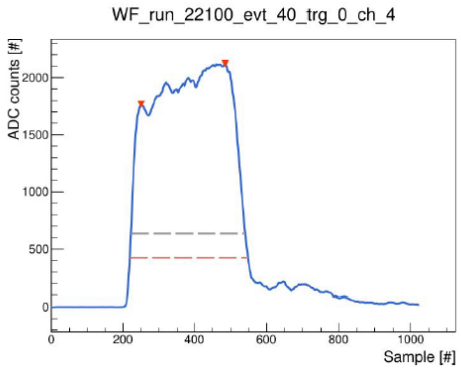


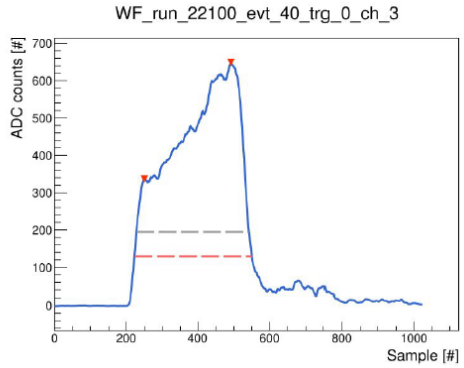


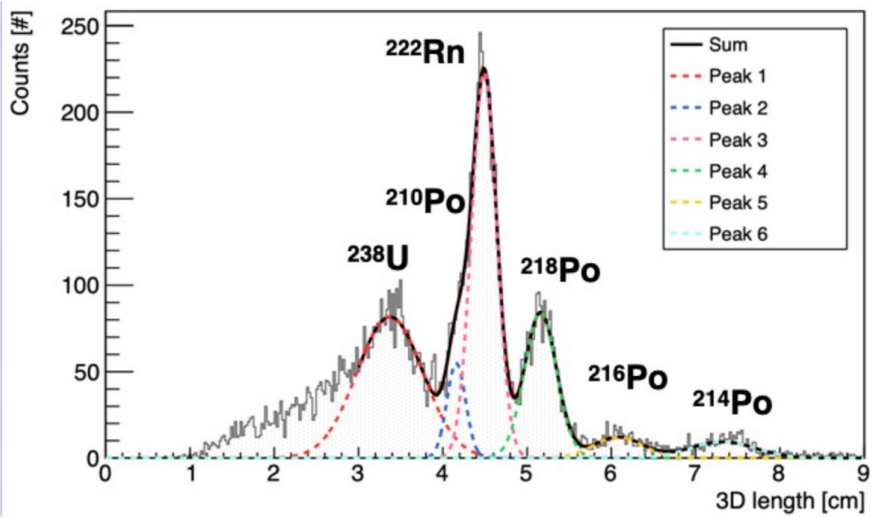




- Different responses of the 4 PMTs in LIME
- Multivariate Bayesian fit procedure
- Calibrated on $^{55}$Fe source
- **Precision of ~1 cm**




**Full 3D reconstruction of alpha enables radon progeny spettroscopy**

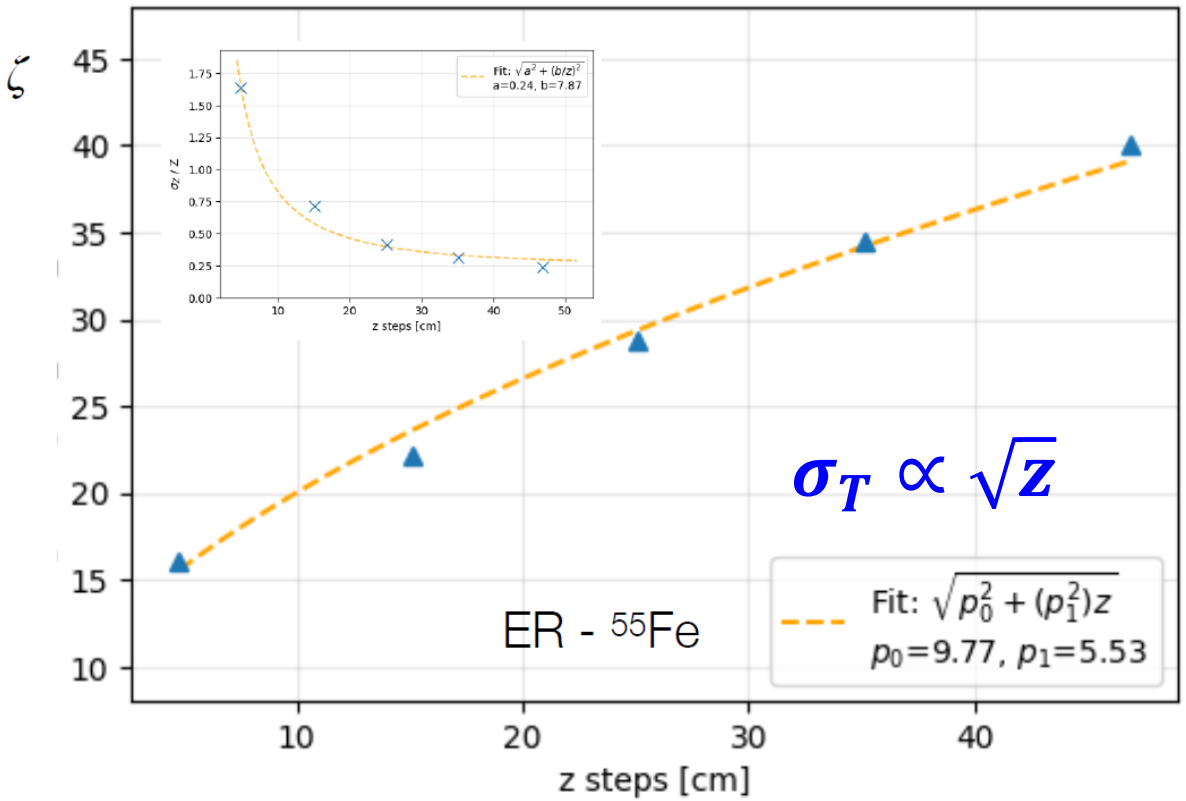
**Bayesian network 3D event reconstruction in the Cygno optical TPC for dark matter direct detection**

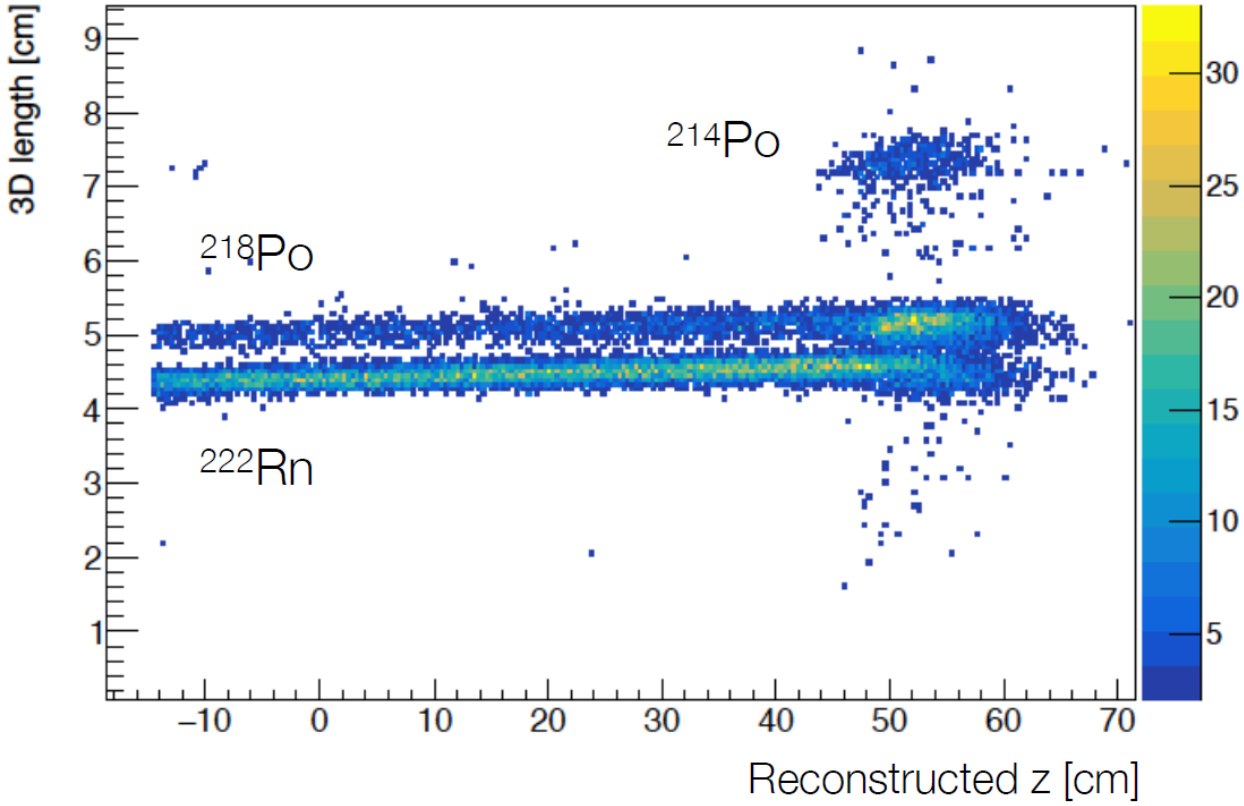
Fernando Domingues Amaro[1], Rita Antonietti[2,3], Elisabetta Baracchini[4,5], Luigi Benussi[6], Stefano Bianco[6], Francesco Borra[2,3a], Cesidio Capoccia[6], Michele Caponero[6,9], Gianluca Cavoto[7,8], Igor Abritta Costa[6], Antonio Croce[6], Emiliano Dané[6], Melba D'Astolfo[4,5], Giorgio Dho[6], Flaminia Di Giambattista[4,5], Emanuele Di Marco[7], Giulia D'Imperio[7], Matteo Folcarelli[7,8b], Joaquim Marques Ferreira dos Santos[1], Davide Fiorina[4,5], Francesco Iacoangeli[7], Zahoor Ul Islam[4,5], Herman Pessoa Lima Júnior[4,5], Ernesto Kemp[10], Giovanni Maccarrone[6], Rui Daniel Passos Mano[1], David José Gaspar Marques[4,5c], Luan Gomes Mattosinhos de Carvalho[12], Giovanni Mazzitelli[6], Alasdair Gregor McLean[11], Pietro Meloni[2,3], Andrea Messina[7,8], Cristina Maria Bernardes Monteiro[1], Rafael Antunes Nobrega[12], Igor Fonseca Pains[12], Emiliano Paoletti[6], Luciano Passamonti[6], Fabrizio Petrucci[2,3], Stefano Piacentini[4,5], Davide Piccolo[6], Daniele Pierluigi[6], Davide Pinci[7], Atul Prajapati[4,5d], Francesco Renga[7], Rita Joana Cruz Roque[1], Filippo Rosatelli[6], Alessandro Russo[6], Giovanna Saviano[6,13], Pedro Alberto Oliveira Costa Silva[1], Neil John Curwen Spooner[11], Roberto Tesauro[6], Sandro Tomassini[6], Samuele Torelli[4,5e], and Donatella Tozzi[7,8]

Bayesian network 3D event reconstruction in the Cygno optical TPC for dark matter direct detection

# Z reconstruction

- To develop tools to evaluate the absolute z of low-energy ER, we use $^{55}$Fe events;
- Several variables spot-shape were studied, and the most effective resulted that takes into account the distribution of the hits within the spot.



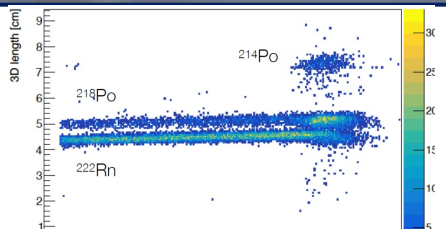




David Marques (GSSI) - PhD thesis

# 3D fiducialization

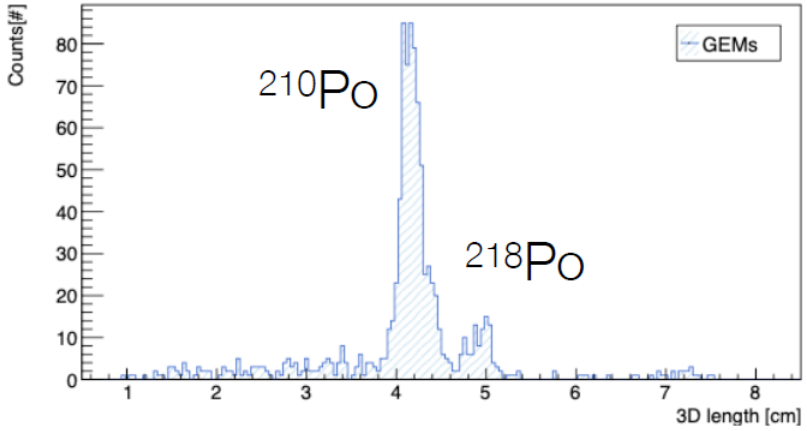
By reconstructing the 3D positions of the alphas, we can separate the contributions of

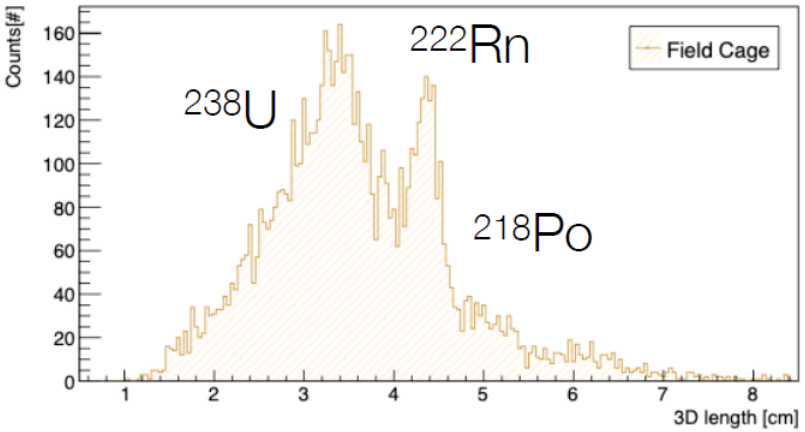
- $^{222}$Rn chain (gas and cathode)
- $^{238}$U and $^{232}$Th chains as found in the GEM and Field Cage copper by HPGe

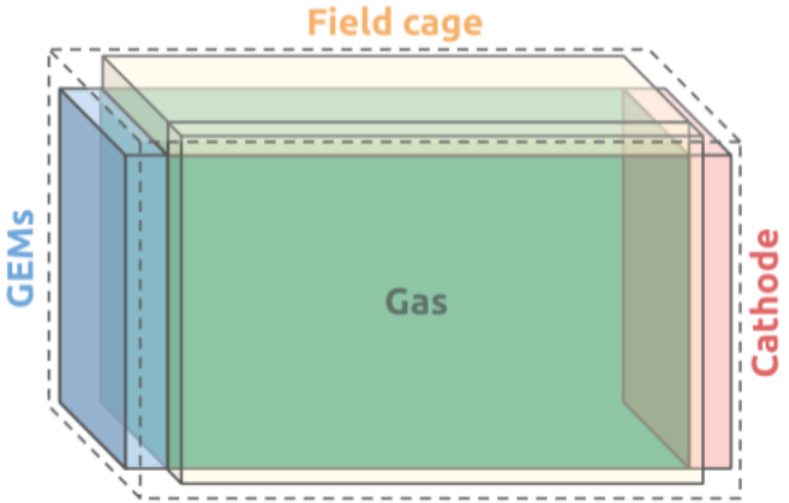


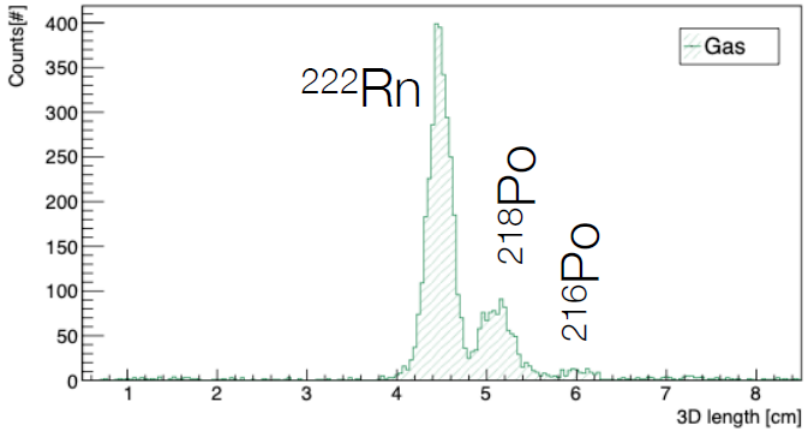

$^{232}$Rn chain

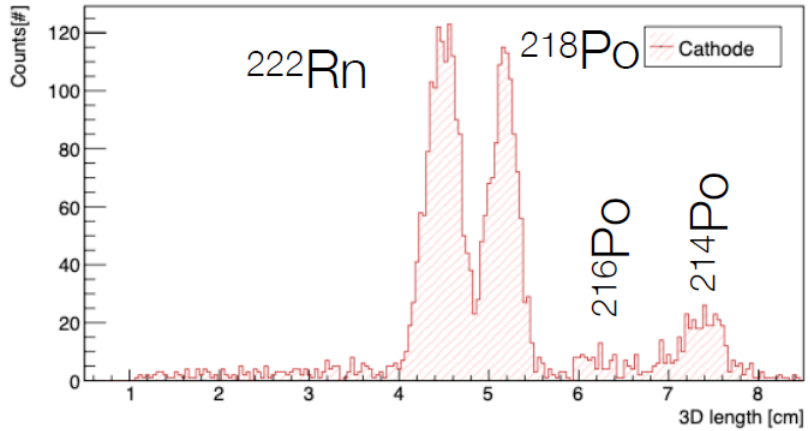
$^{238}$U and $^{232}$Th chains




David Marques (GSSI) - PhD thesis

# Radon progeny Nuclear Recoil

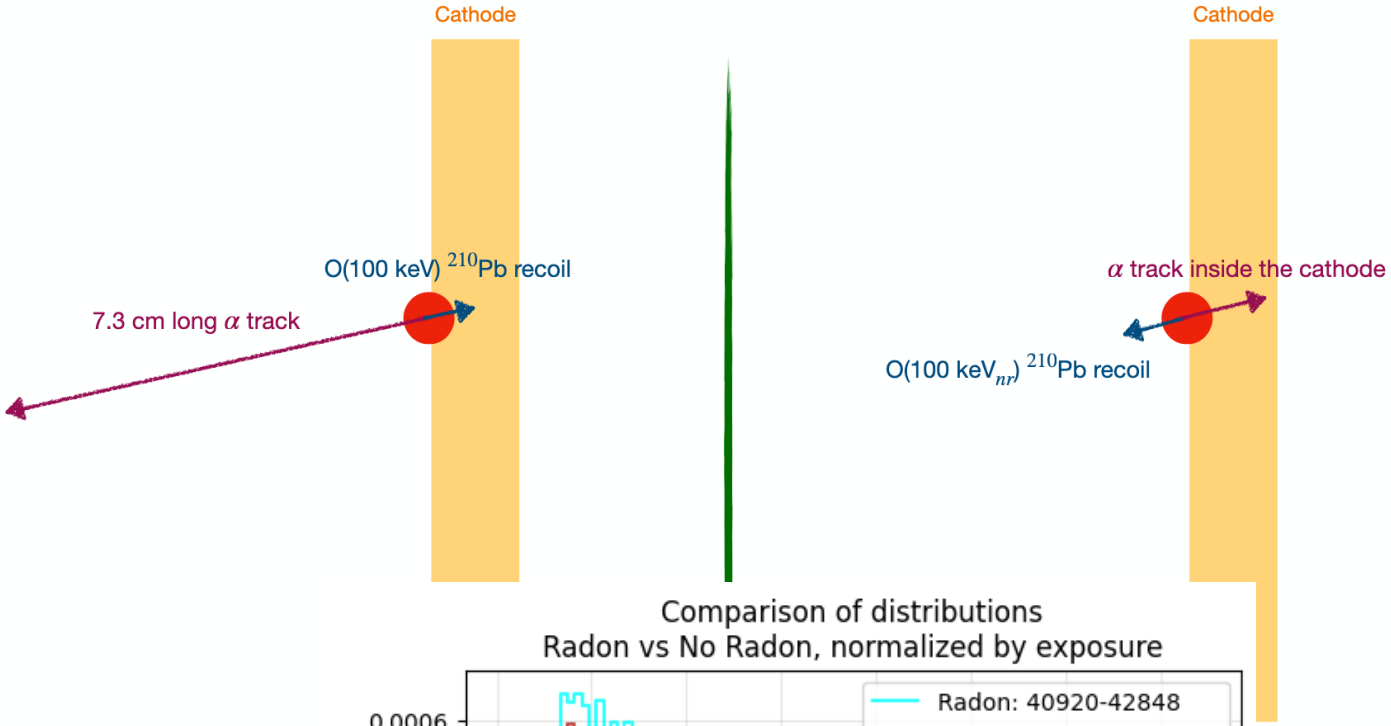
First detection of radon progeny recoil tracks by MIMAC

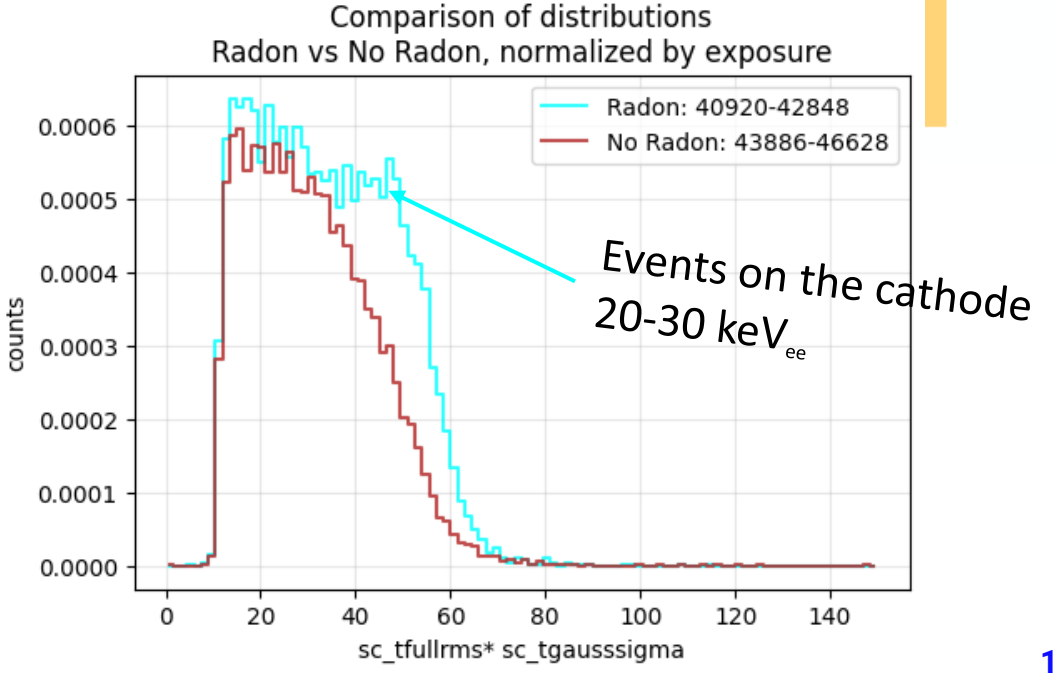
Q. Riffard, D. Santos, O. Guillaudin, G. Bosson, O. Bourrion, J. Bouvier, T. Descombes, C. Fourel, J.-F. Muraz, L. Lebreton · Show full author list

Published 30 June 2017 · © 2017 IOP Publishing Ltd and Sissa Medialab
Journal of Instrumentation, Volume 12, June 2017
Citation Q. Riffard *et al* 2017 *JINST* **12** P06021
DOI 10.1088/1748-0221/12/06/P06021

MIMAC paper: 10.1088/1748-0221/12/06/P06021

| Parent | $T_{1/2}$ | Mode | $E^{kin}_{\alpha/\beta\,max}$ [MeV] | Daughter | $E^{kin}_{recoil}$ [keV] | $E^{ioni}_{recoil}$ [keVee] |
|---|---|---|---|---|---|---|
| From $^{222}$Rn | | | | | | |
| $^{222}$Rn | 3.8 days | $\alpha$ | 5.489 | $^{218}$Po | 100.8 | 38.23 |
| $^{218}$Po | 3.1 min | $\alpha$ | 6.002 | $^{214}$Pb | 112.3 | 43.90 |
| $^{214}$Pb | 27 min | $\beta^-$ | 1.024 | $^{214}$Bi | - | - |
| $^{214}$Bi | 20 min | $\beta^-$ | 3.272 | $^{214}$Po | - | - |
| $^{214}$Po | 164 µs | $\alpha$ | 7.687 | $^{210}$Pb | 146.5 | 58.78 |
| $^{210}$Pb | 22 years | $\beta^-$ | 0.064 | $^{210}$Bi | - | - |
| $^{210}$Bi | 5 days | $\beta^-$ | 1.163 | $^{210}$Po | - | - |
| $^{210}$Po | 138 days | $\alpha$ | 5.304 | $^{206}$Pb (stable) | 103.7 | 40.28 |

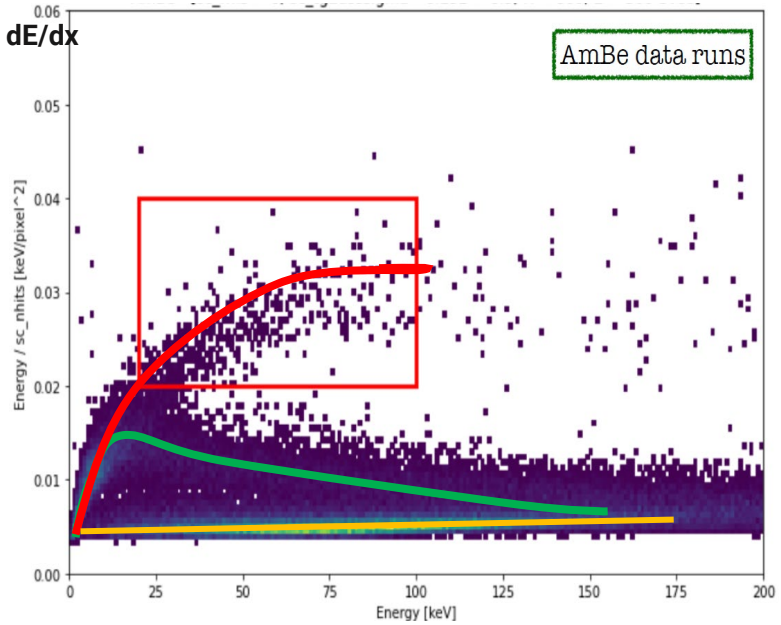



- 10%-20% Quenching Factor for Pb at the 150 keV energy, we should expect 15-30 keV$_{ee}$
- The identification of this dangerous background component will allow us to reject it
- **Analysis currently Ongoing!**

# NR-ER discrimination

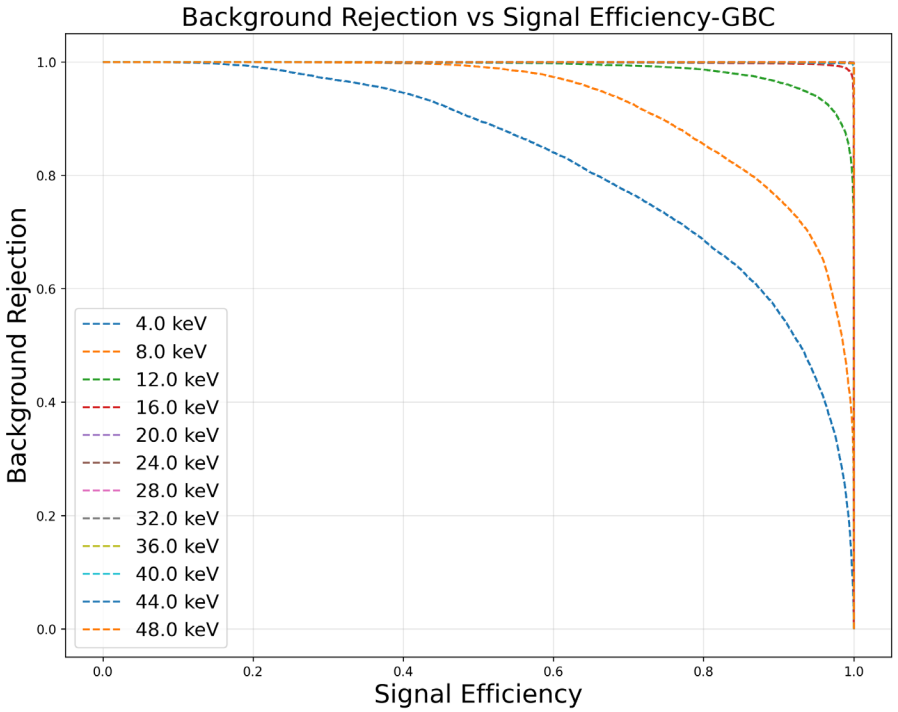
**We have access to many variables related to the signal shape!**




## Convolution Neural Network

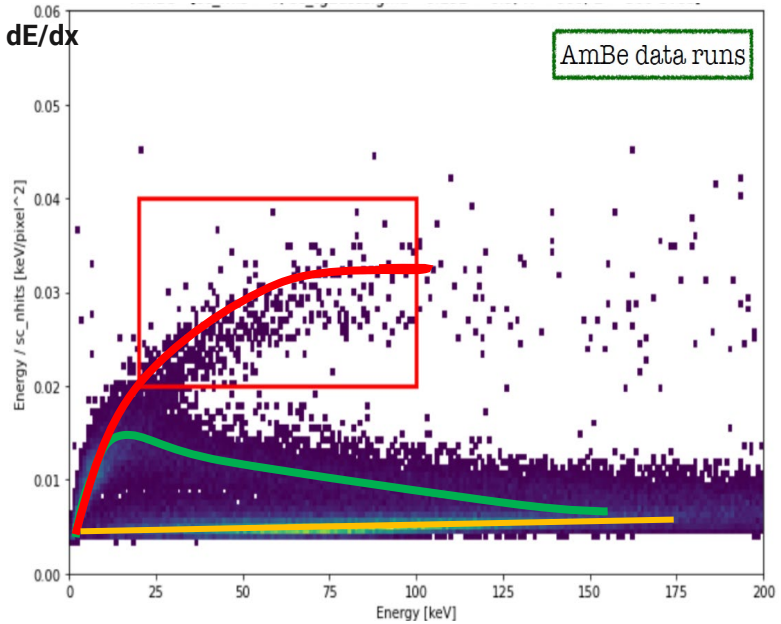
**Atul Prajapati Thesis**

- Training on **MC** using multiple shape variables
- Promising results beyond traditional analysis



# NR-ER discrimination

## We have access to many variables related to the signal shape!




## Convolution Neural Network

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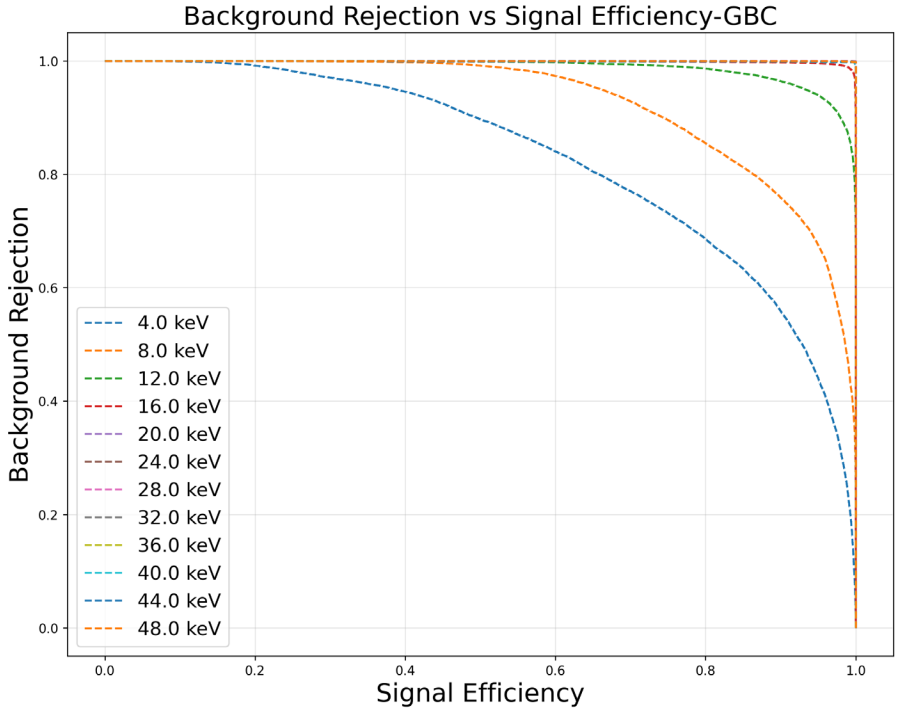
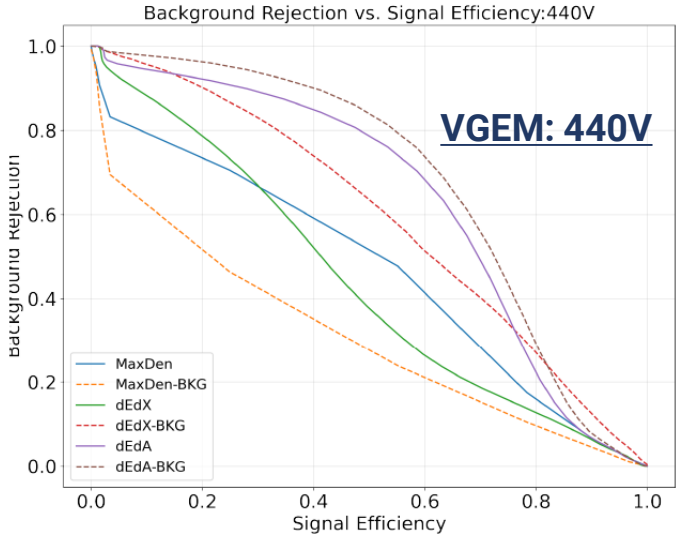
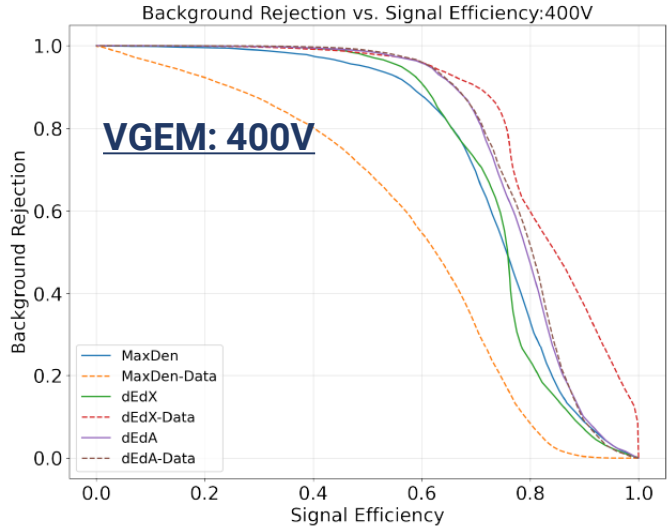



## Saturation is clearly present in LIME!

## And it affects the ER/NR discrimination

2406.05713

**Modeling the light response of an optically readout GEM based TPC for the CYGNO experiment**

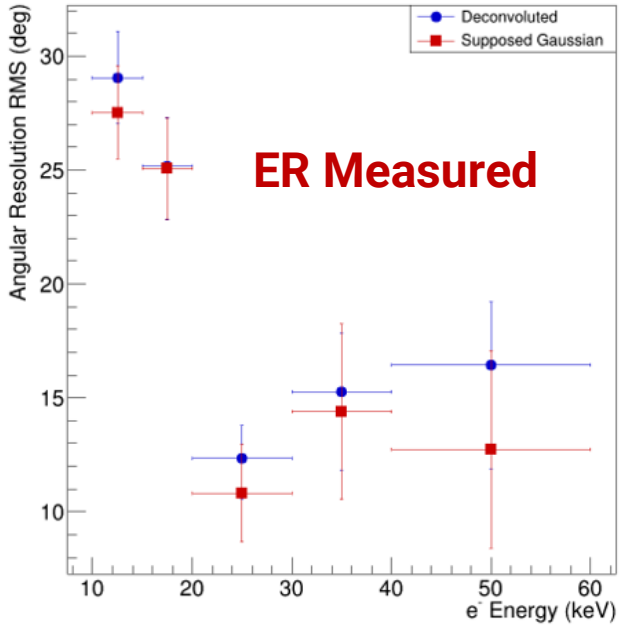
Fernando Dominques Amaro[1], Rita Antonietti[2,3], Elisabetta Baracchini[4,5], Luigi Benussi[6], Stefano Bianco[6], Campagnola[6], Cesidio Capoccia[6], Michele Caponero[6,9], Gianluca Cavoto[7,8], Igor Abritta Costa[6], Antonio Emiliano Dané[6], Melba D'Astolfo[4,5], Giorgio Dho[6], Flaminia Di Giambattista[4,5], Emanuele Di Marco[7], D'Imperio[7], Joaquim Marques Ferreira dos Santos[1], Davide Fiorina[4,5], Francesco Iacoangeli[7], Zahoor Ul Herman Pessoa Lima Júnior[4,5], Ernesto Kemp[10], Francesca Lewis[8], Giovanni Maccarrone[6], Rui Daniel Pas Robert Renz Marcelo Gregorio[11], David José Gaspar Marques[4,5], Luan Gomes Mattosinhos de Carvalho[1] Mazzitelli[6], Alasdair Gregor McLean[11], Pietro Meloni[2,3], Andrea Messina[7,8], Cristina Maria Bernardes M Rafael Antunes Nobrega[12], Igor Fonseca Pains[12], Matteo Pantalena[8], Emiliano Paoletti[6], Luciano Passa Fabrizio Petrucci[2,3], Stefano Piacentini[4,5], Davide Piccolo[6], Daniele Pierluigi[6], Davide Pinci[7a], Atul Praj Francesco Renga[7], Rita Joana Cruz Roque[1], Filippo Rosatelli[6], Alessandro Russo[6], Sabrina Salamino[8], Saviano[6,13], Federico Francesco Scamporlino[8], Angelo Serrecchia[8], Pedro Alberto Oliveira Costa Silva[1], Curwen Spooner[11], Roberto Tesauro[6], Sandro Tomassini[6], Samuele Torelli[4,5], and Donatella Tozzi[7,8]

Modeling the light response of an optically readout GEM based TPC for the CYGNO experiment

**Enhancing the light yield of He:$CF_4$ based gaseous detector**

Fernando Domingues Amaro[1], Rita Antonietti[2,3], Elisabetta Baracchini[4,5], Luigi Benussi[6], Stefano Bianco[6], Roberto Campagnola[6], Cesidio Capoccia[6], Michele Caponero[6,7], Danilo Santos Cardoso[8], Luan Gomes Mattosinhos de Carvalho[9], Gianluca Cavoto[10,11], Igor Abritta Costa[6], Antonio Croce[6], Emiliano Dané[6], Giorgio Dho[4,6,a], Flaminia Di Giambattista[4,5], Emanuele Di Marco[11], Melba D'Astolfo[4,5], Giulia D'Imperio[11], Davide Fiorina[4,5], Francesco Iacoangeli[11], Zahoor ul Islam[4,5], Herman Pessoa Lima Júnior[4,8], Ernesto Kemp[12], Giovanni Maccarrone[6], Rui Daniel Passos Mano[1], Robert Renz Marcelo Gregorio[13], David José Gaspar Marques[4,5], Giovanni Mazzitelli[6], Alasdair Gregor McLean[13], Andrea Messina[10,11], Pietro Meloni[2,3], Cristina Maria Bernardes Monteiro[1], Rafael Antunes Nobrega[9], Igor Fonseca Pains[9], Emiliano Paoletti[6], Luciano Passamonti[6], Fabrizio Petrucci[2,3], Stefano Piacentini[4,5], Davide Piccolo[6], Daniele Pierluigi[6], Davide Pinci[11], Atul Prajapati[4,5], Francesco Renga[11], Rita Joana da Cruz Roque[1], Filippo Rosatelli[6], Alessandro Russo[6], Joaquim Marques Ferreira dos Santos[1], Giovanna Saviano[6,14], Pedro Alberto Oliveira Costa Silva[1], Neil John Curwen Spooner[13], Roberto Tesauro[6], Sandro Tomassini[6], Samuele Torelli[4,5]

# Angular Resolution




## ER angular resolution

- Measured by 90Sr electrons irradiation
- Good match with Simulated data

Detecting Solar neutrinos with the CYGNO gas TPC · CDEX Indico

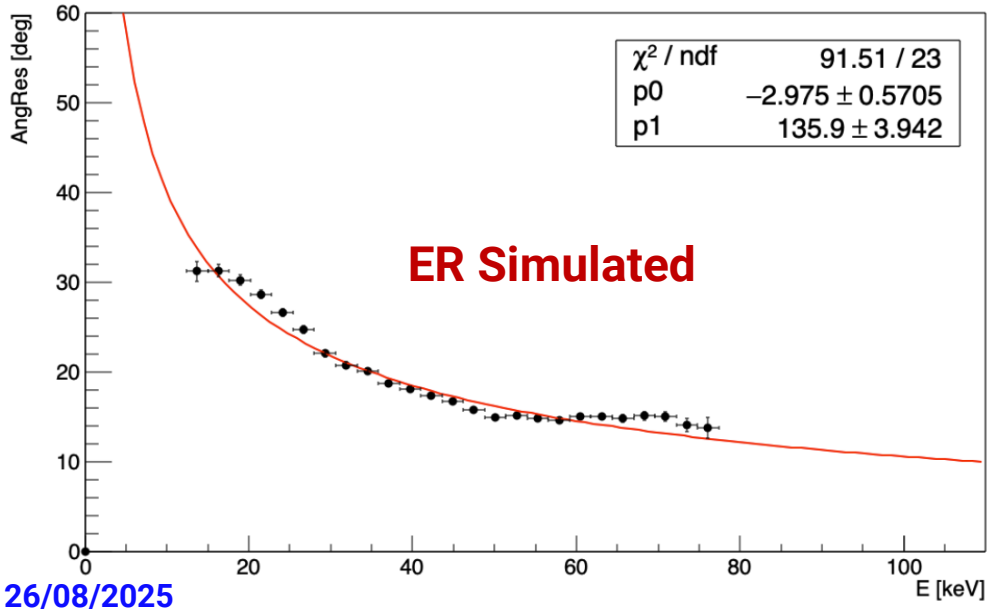
Detecting Solar neutrinos with the CYGNO gas TPC

26 Aug 2025, 17:00
20m
North Hall #2

Oral | Neutrino Physics an... | Neutrino Physics and A...

Speaker

Samuele Torelli (Donostia International Physics Center)



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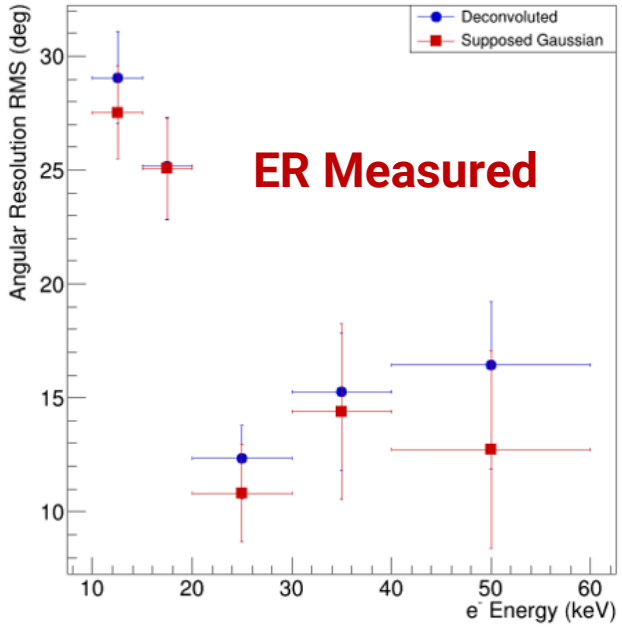


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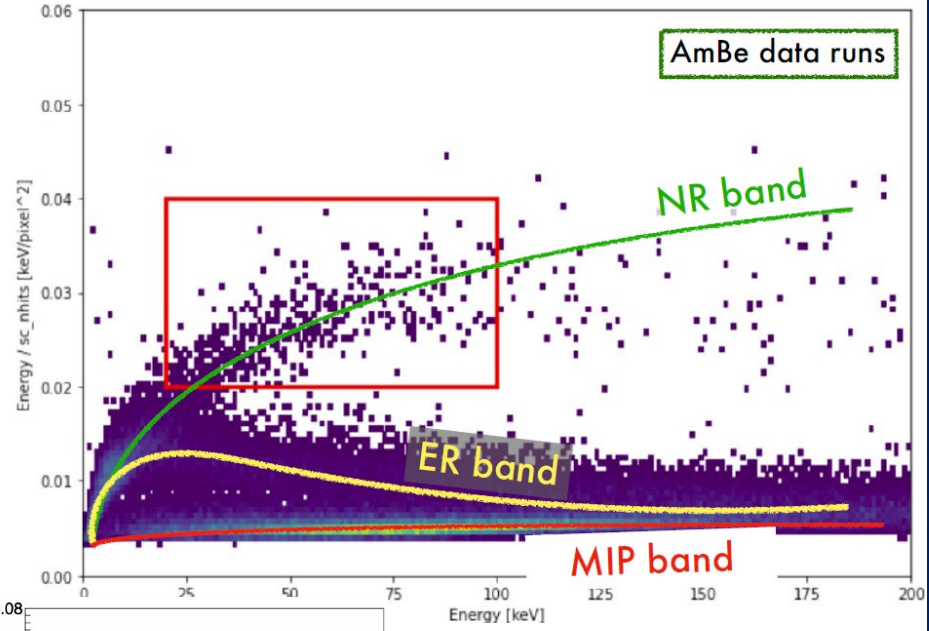
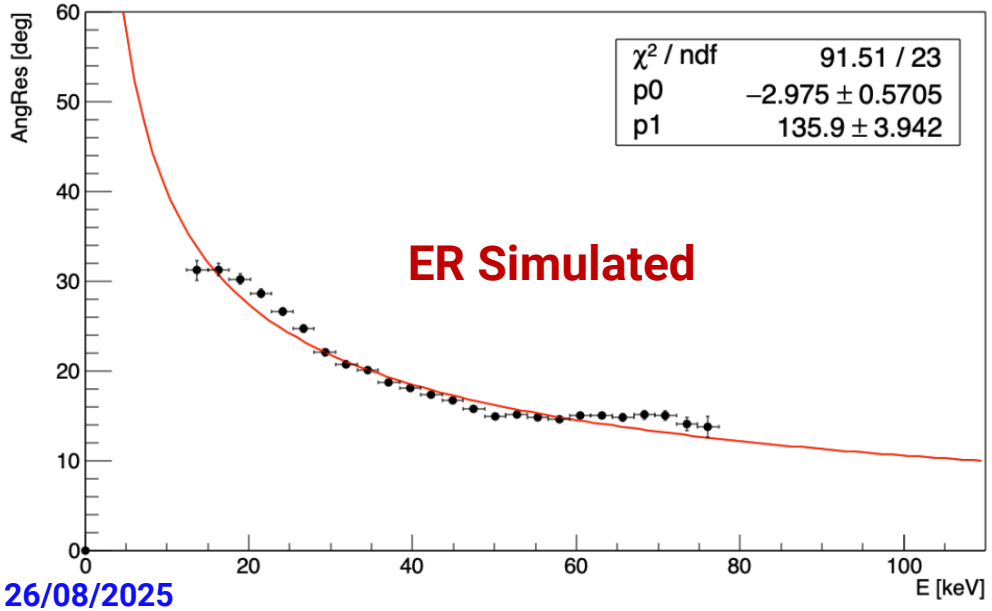
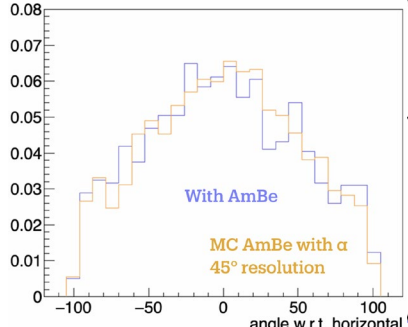
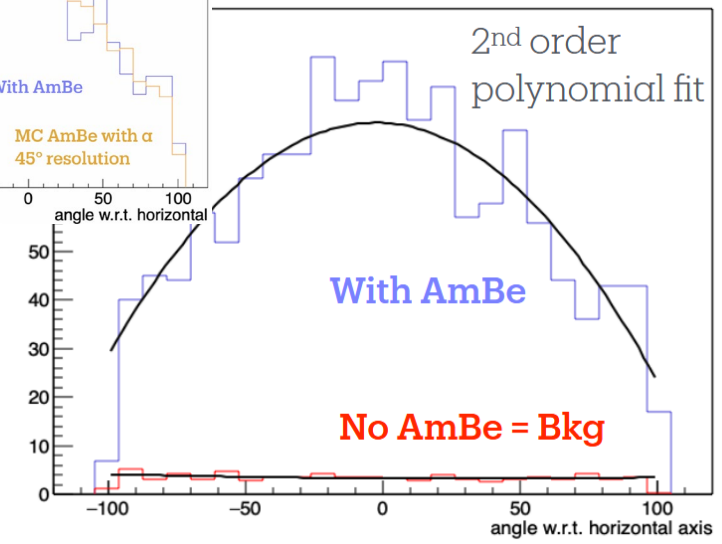



## NR angular resolution

- Estimated via naive assumption on AmBe neutron source data taking
- Estiamted 45° RMS (>20 $keV_{ee}$)
  - Upper Limit!



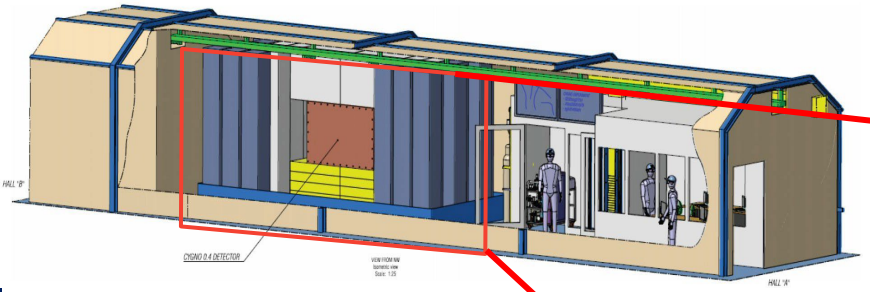



# CYGNO_04

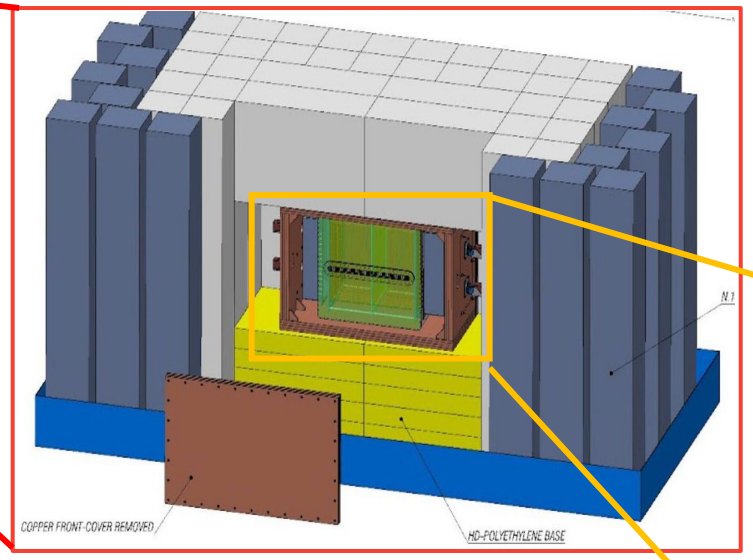
## Scalability of the Technology

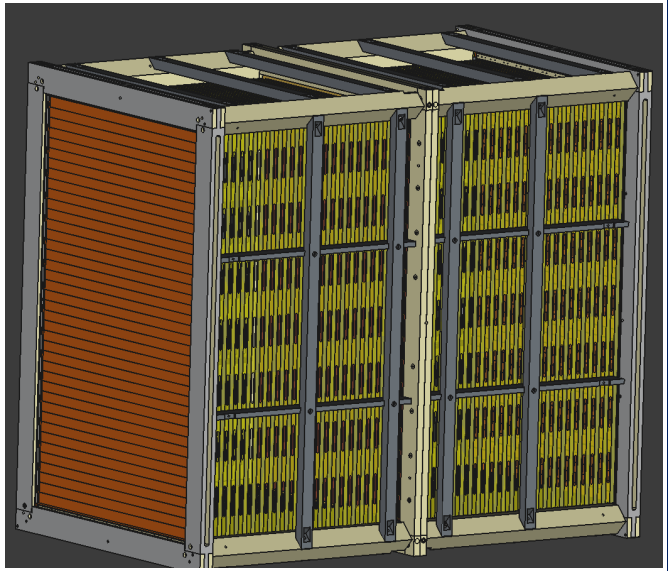
### Radiopure materials

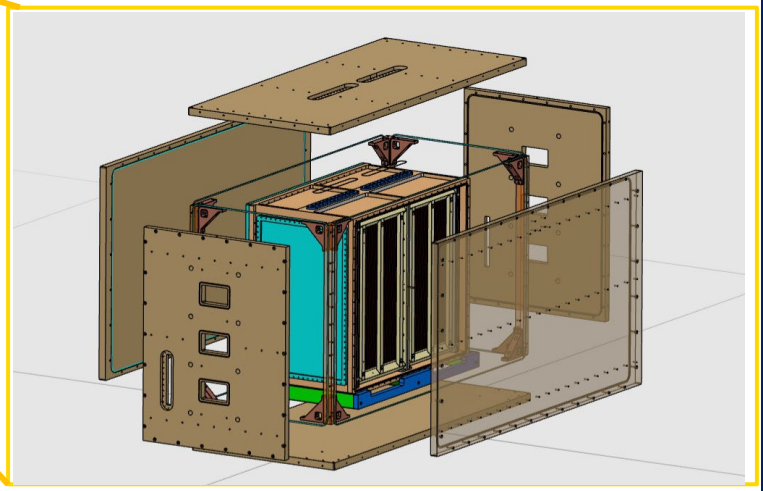
### Feasibility for a larger scale detector based on multiple CYGNO_04 modules



LNGS Hall F

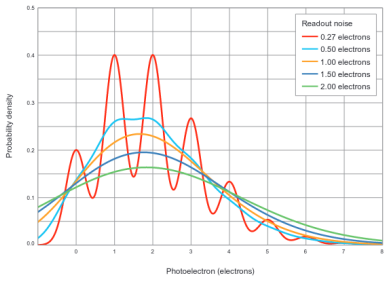




**0.4m3 common cathode TPC**

- 3 ORCA QUEST2 (next-gen) per side
- 8 PMTs per side
- 4+6cm copper shielding (radiopure+traditional)
- 100cm of water




**Throughput expected ≈20Mb/s**
**Computational resources very demanding**

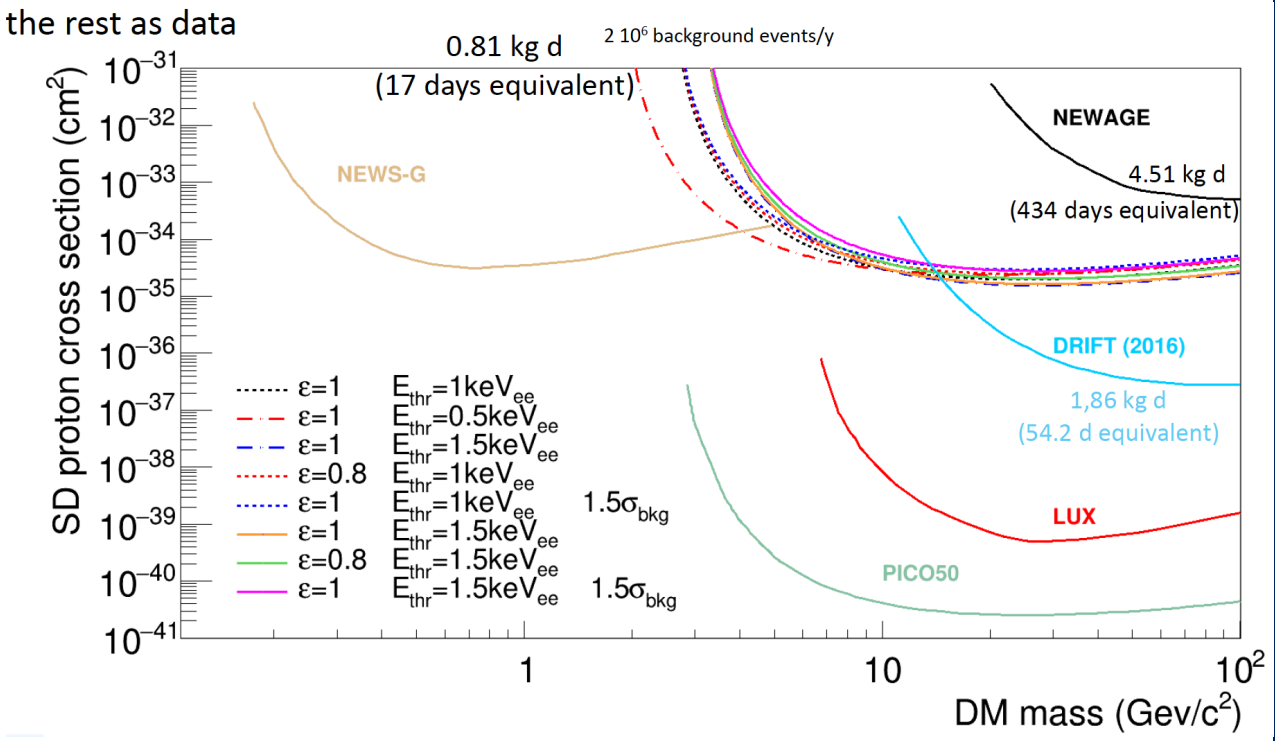
**→ Triggerless data selection with ML on GPU**

# Expected Limits

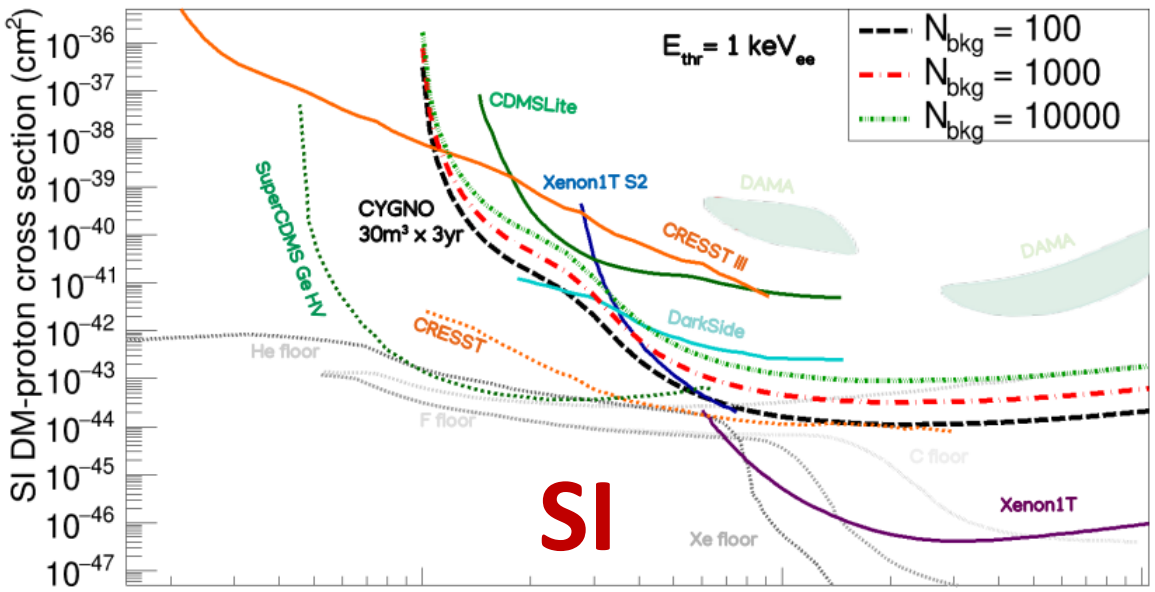
LIME naive limits with a subsample of 17 days

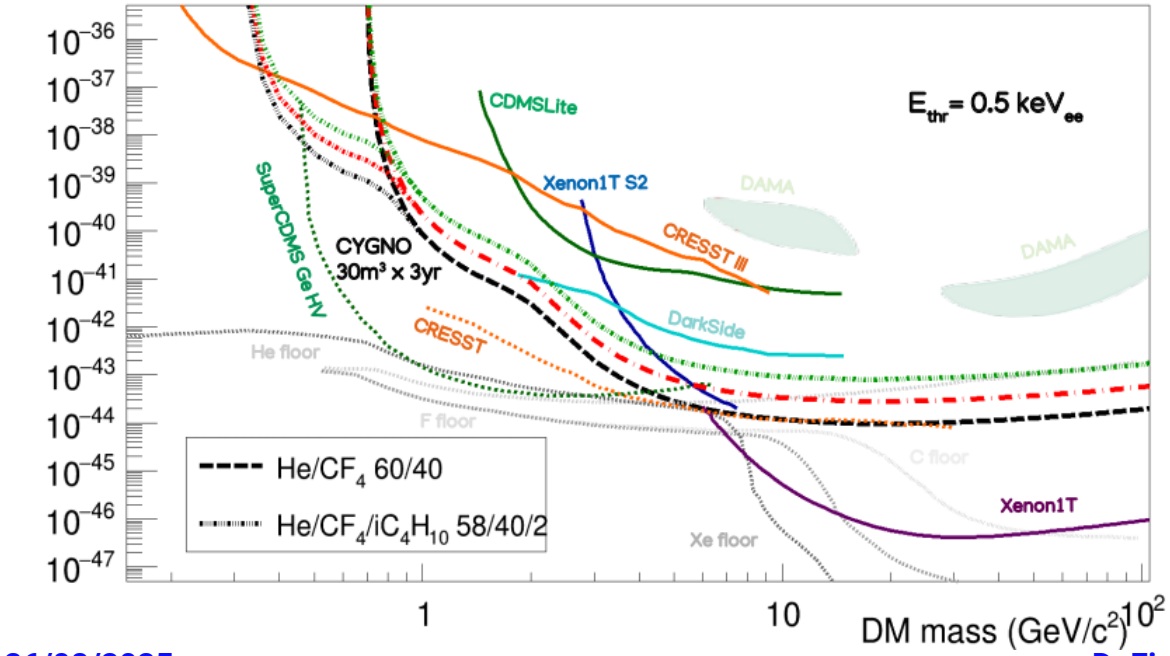
- Not a radiopure detector
- No solid background model
- No Directionality

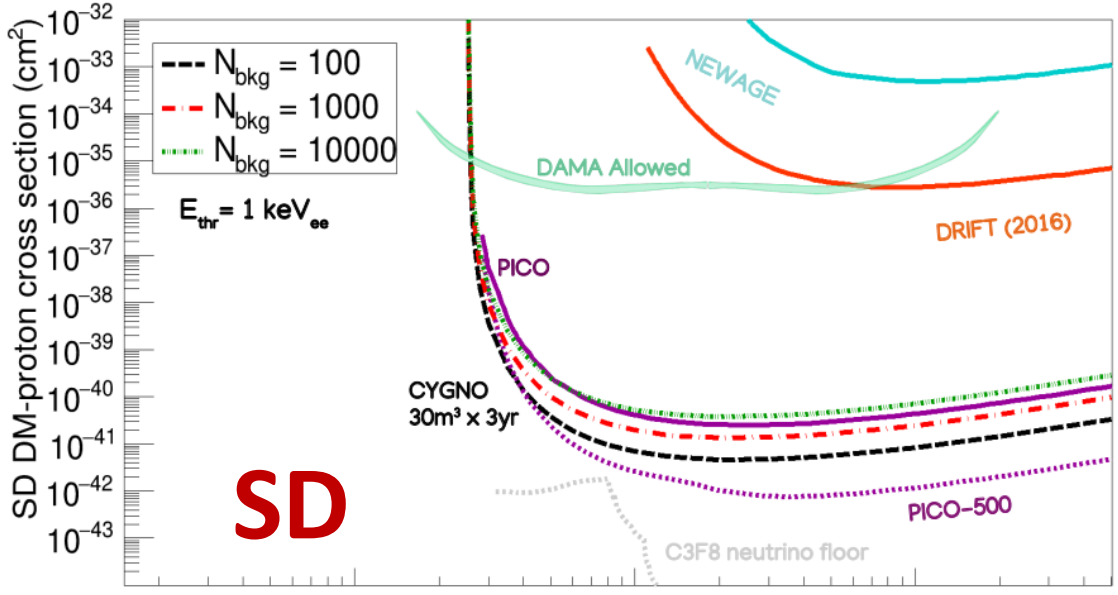
→ **A detector not designed for physics is competitive with the only other directional detector.**

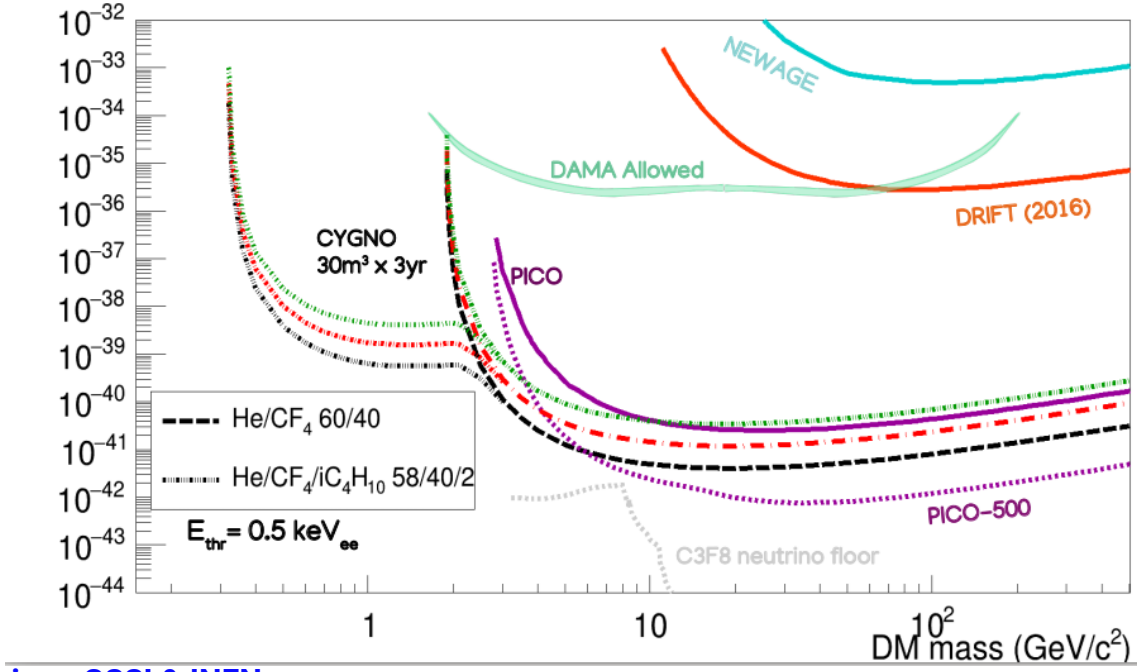


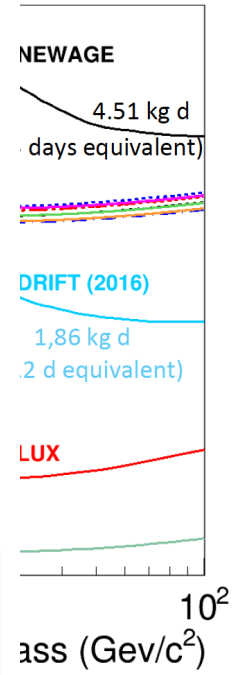
# Expected Limits



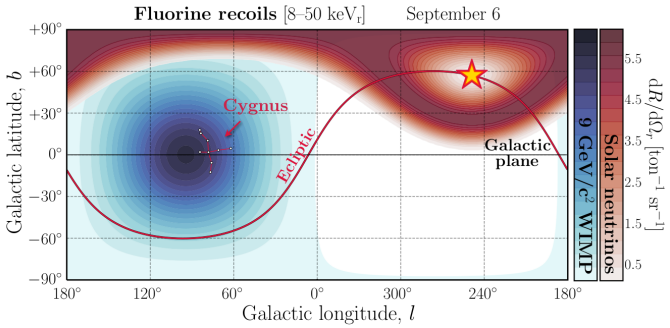



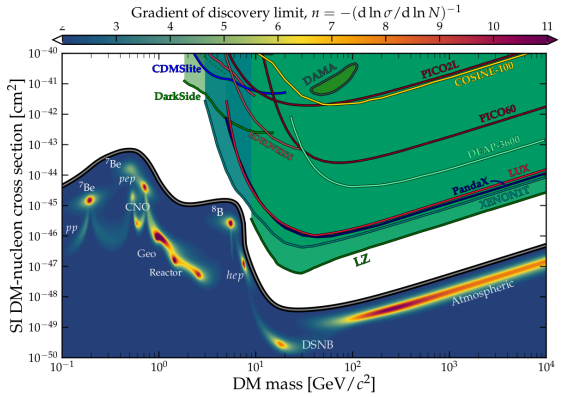



# Conclusion

**The CYGNO collaboration is developing a high-precision triple-GEM TPC at atmospheric pressure with optical readout.**

- The main focus is the **directional direct search** of DM WIMP-like particles in the low mass range (0.5-10 GeV) with a threshold of 0.5 $keV_{ee}$.
  - Directionality provides a unique handle to confirm the presence of the Galactic dark matter halo.
  - Isotropic Background rejection
  - Operations beyond Neutrino Fog



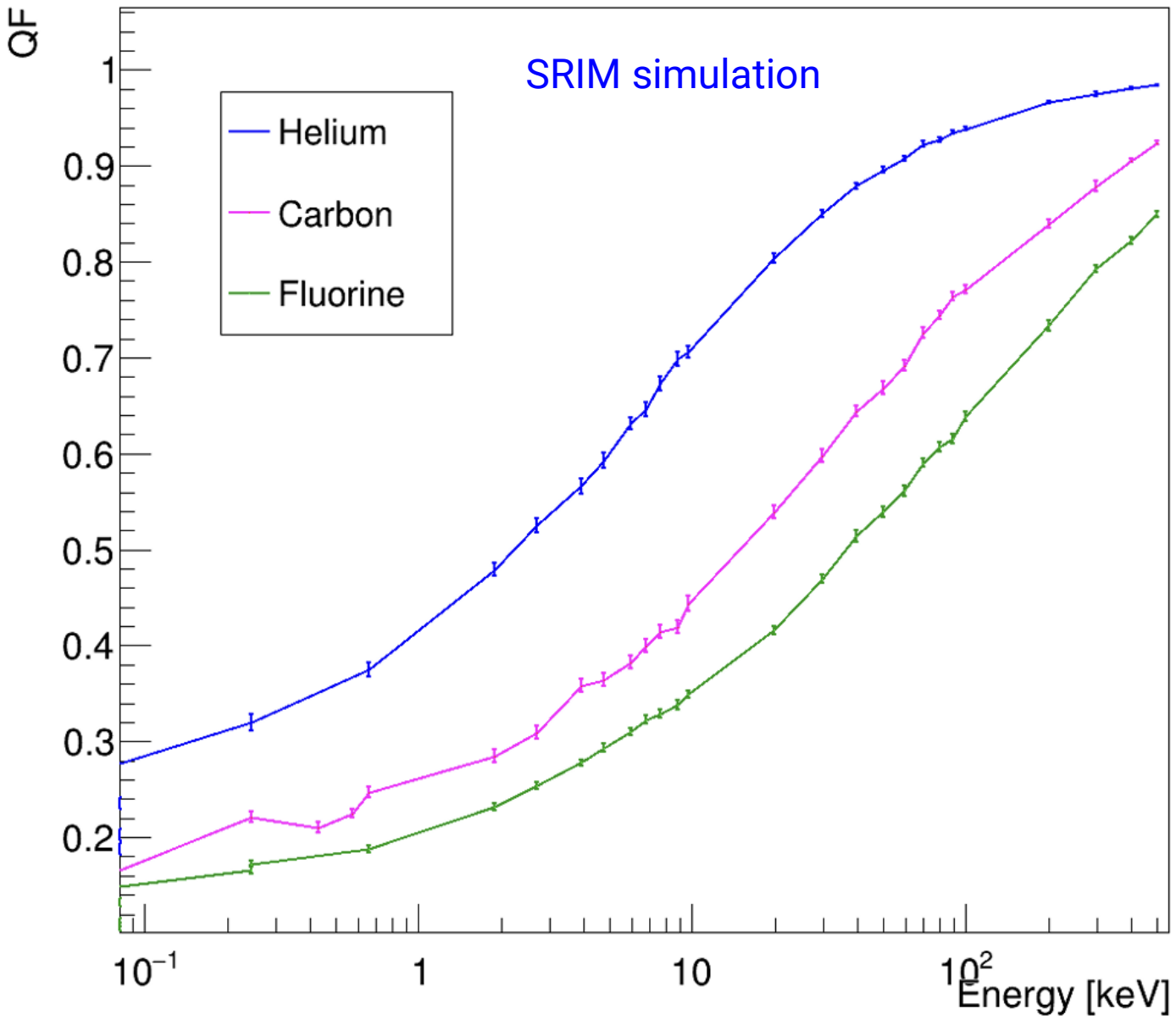




- LIME demonstrated the feasibility of such a detector for **rare event search,** validating our **MC chain**
- CYGNO04 will prove the scalability of our detector model for a larger project starting in the **first trimester of 2026**

| Experiment | Where | Amplification + Readout | Gas Pressure [mbar] | Volume [L] | Energy Thr [$keV_{ee}$] | Active Mass [gr] |
|---|---|---|---|---|---|---|
| DRIFT | UK | MWPC | 55 | 800 | 20 | 33 |
| NEWAGE | Japan | 1 GEM +muPIC | 100 | 37 | 20 | 11.5 |
| MIMAC | France | Micromegas | 50 | 5.8 | 2 | 1.2 |
| D3 | Australia | 2 GEM + pixelated RO | 1000 | 40 | 5 | 60 |
| CYGNO | Italy | 3 GEMs + sCMOS + PMT | 900 | 400 | 1 | 600 |

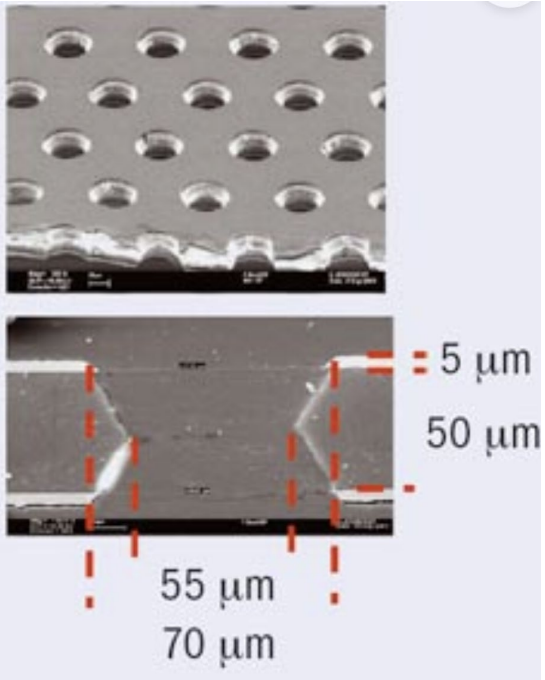
# BACKUP

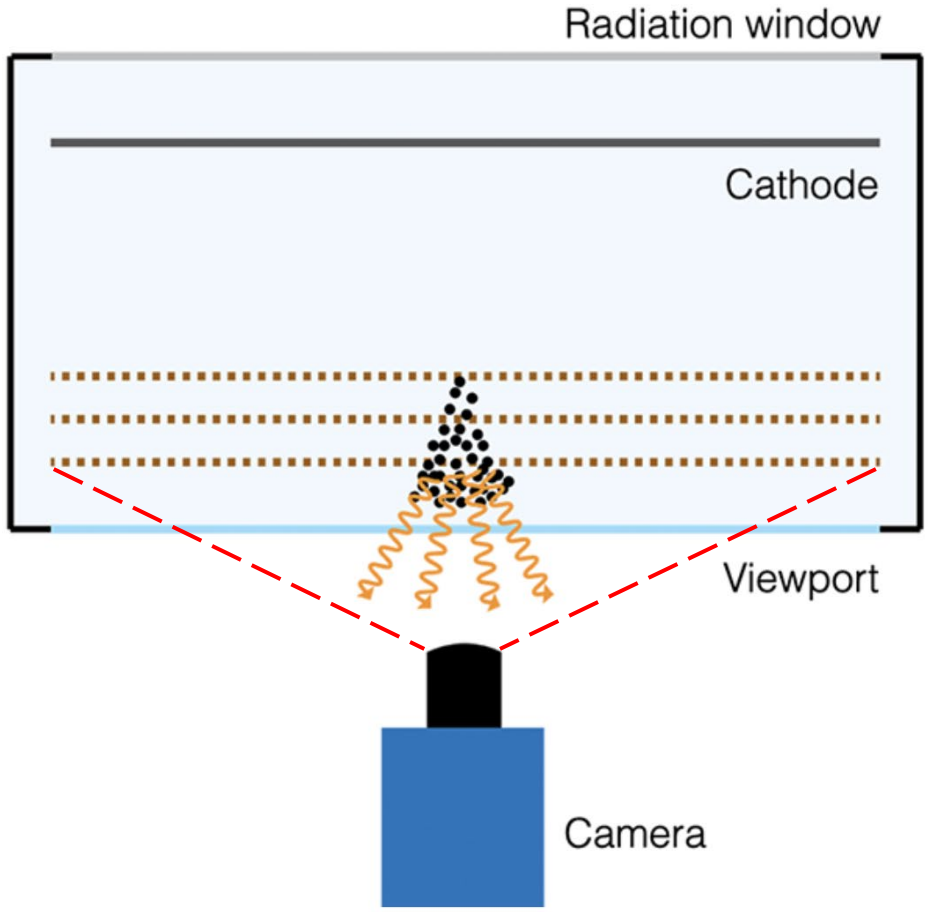
# Quenching factor

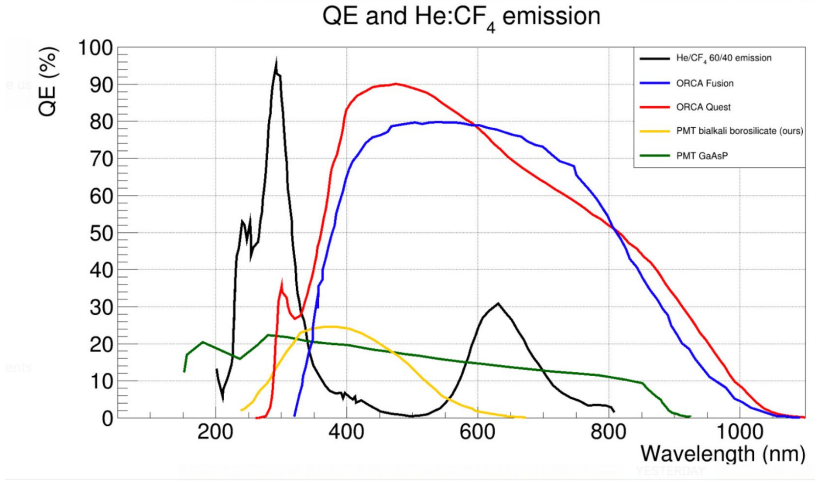


# Detector overview

**Gas volume filled with**
**$He/CF_4$ 60/40**
**1atm**

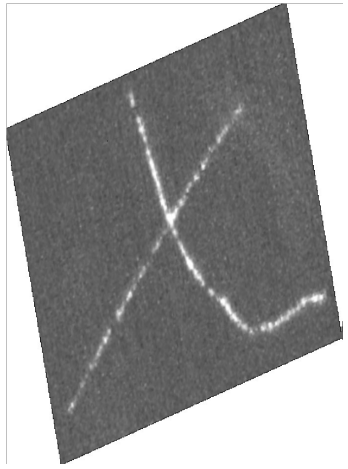



**CMOS**
**Hamamatsu**
**ORCA Quest (2)**

**High-granularity**
**X+Y+Energy**
**measurement**



# It's a Dark Universe

**Energy, Time, and other widely used methods are <u>not enough</u> to prove that an eventual signal is a Dark Matter signal**

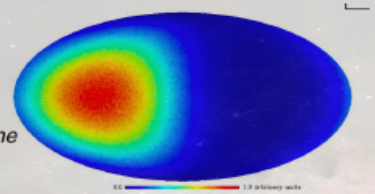
## Capability to reject isotropy

### Dive into the Neutrino Fog

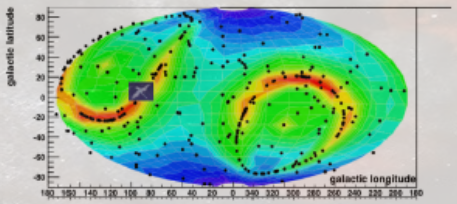
A. M. Green et. al, Astropart. Phys. 27 (2007) 142

***WIMP signal (recoil map)***

*Angular distribution of Fluorine recoils [5;50] keV*

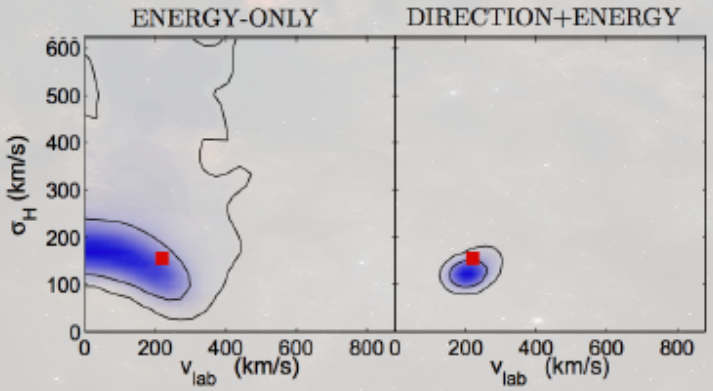


***Background***



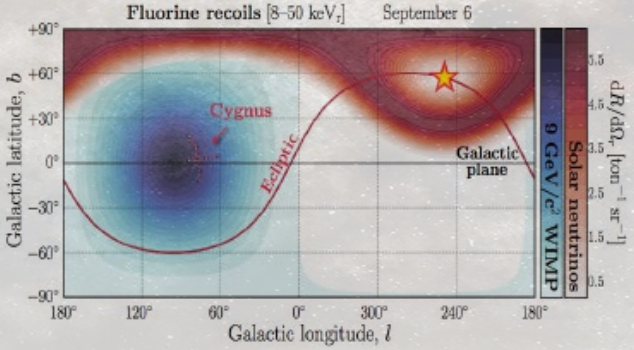
## <u>Directionality of the DM flux</u>

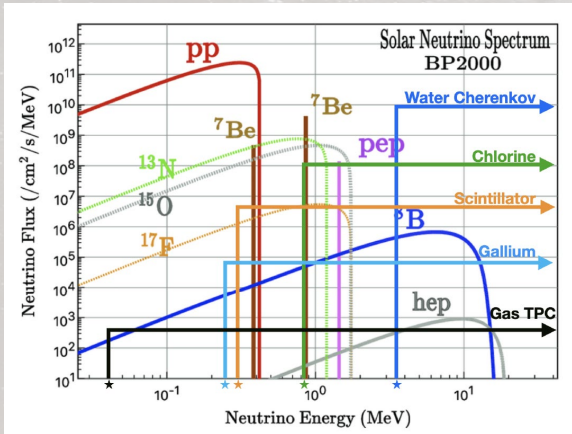
*Phys.Rept.* 627 (2016) 1-49




## Capability to identify Solar neutrinos

e-Print: 2102.04596



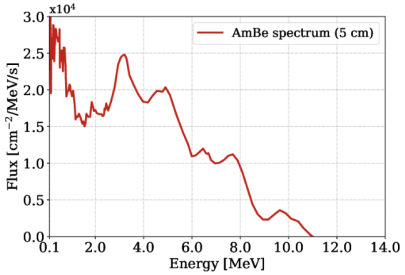

**This is the only generic and unambiguous terrestrial signature of DM that results solely from the assumption that we live inside a DM halo.**

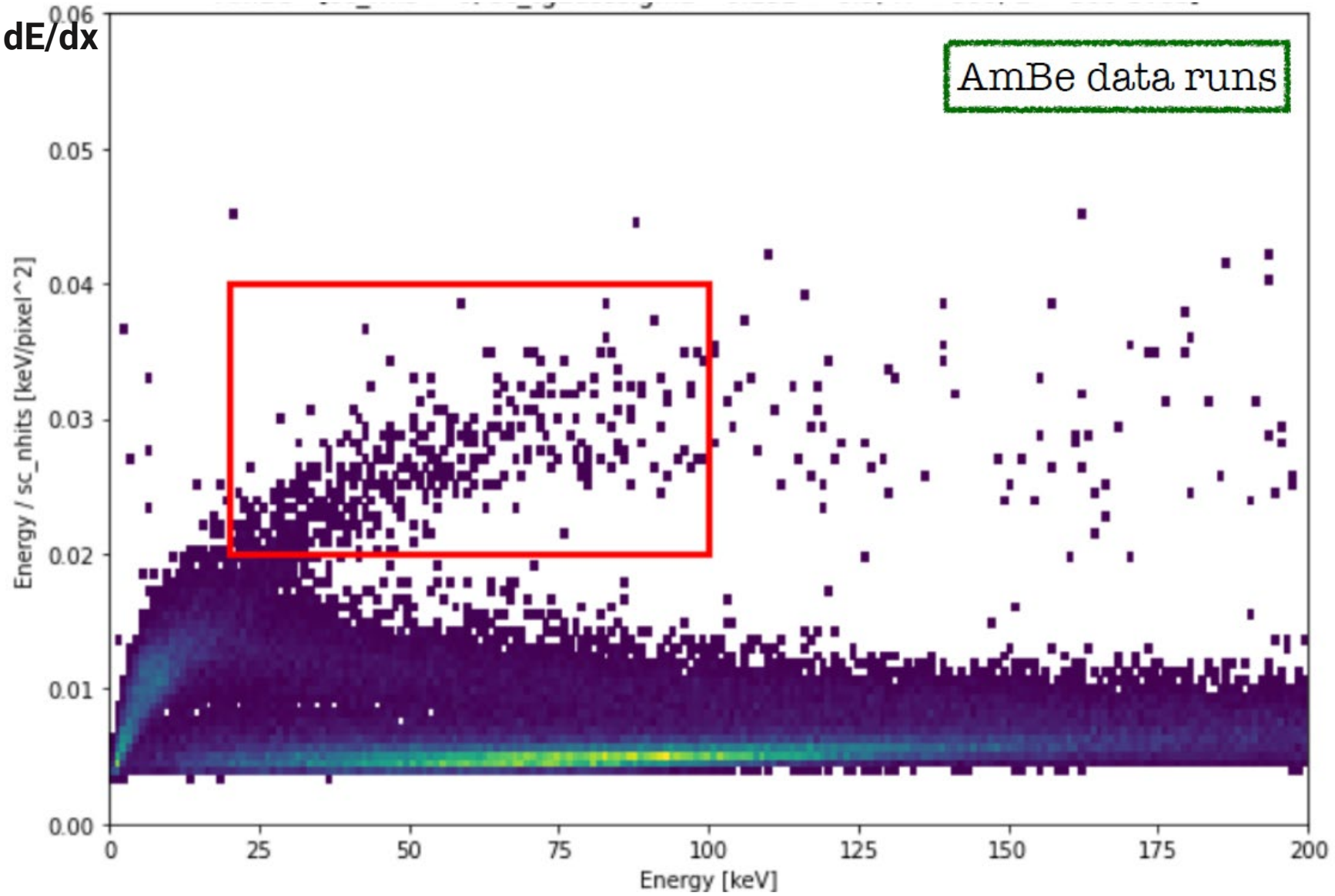
<u>The future of directional searches, Ciaran O'Hare</u>

<u>[2408.03760] Feasibility of a directional solar neutrino measurement with the CYGNO/INITIUM experiment (arxiv.org)</u>

# Background Rejection

Data taking with Americium-beryllium source → Neutrons to induce Nuclear Recoil signals



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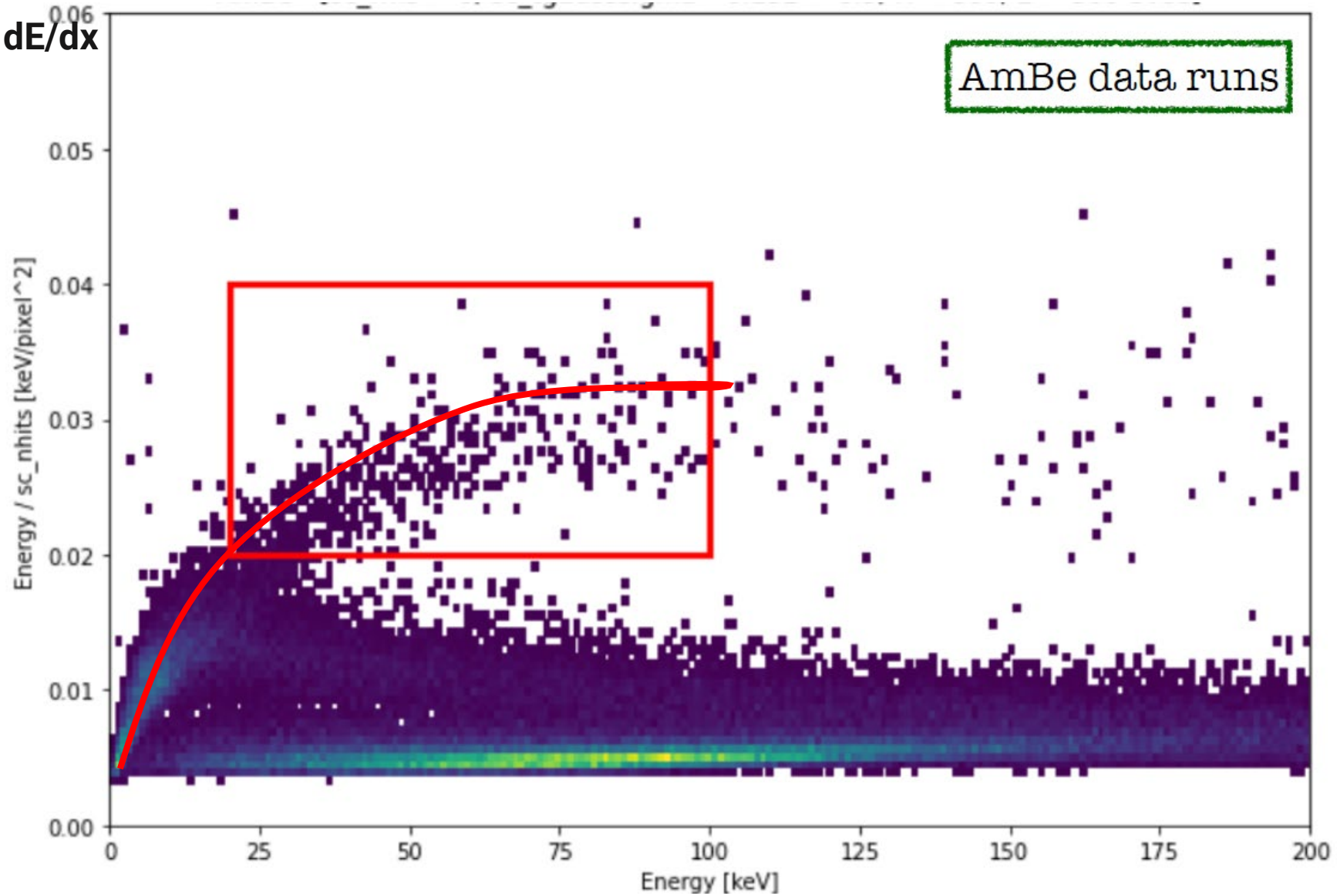
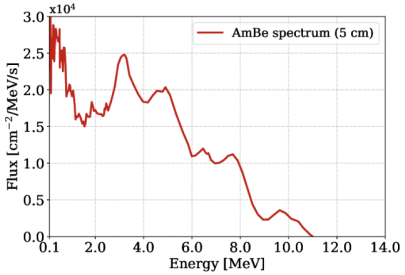
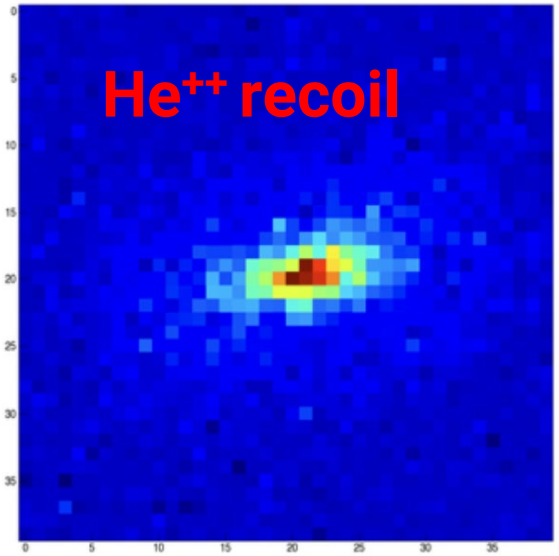


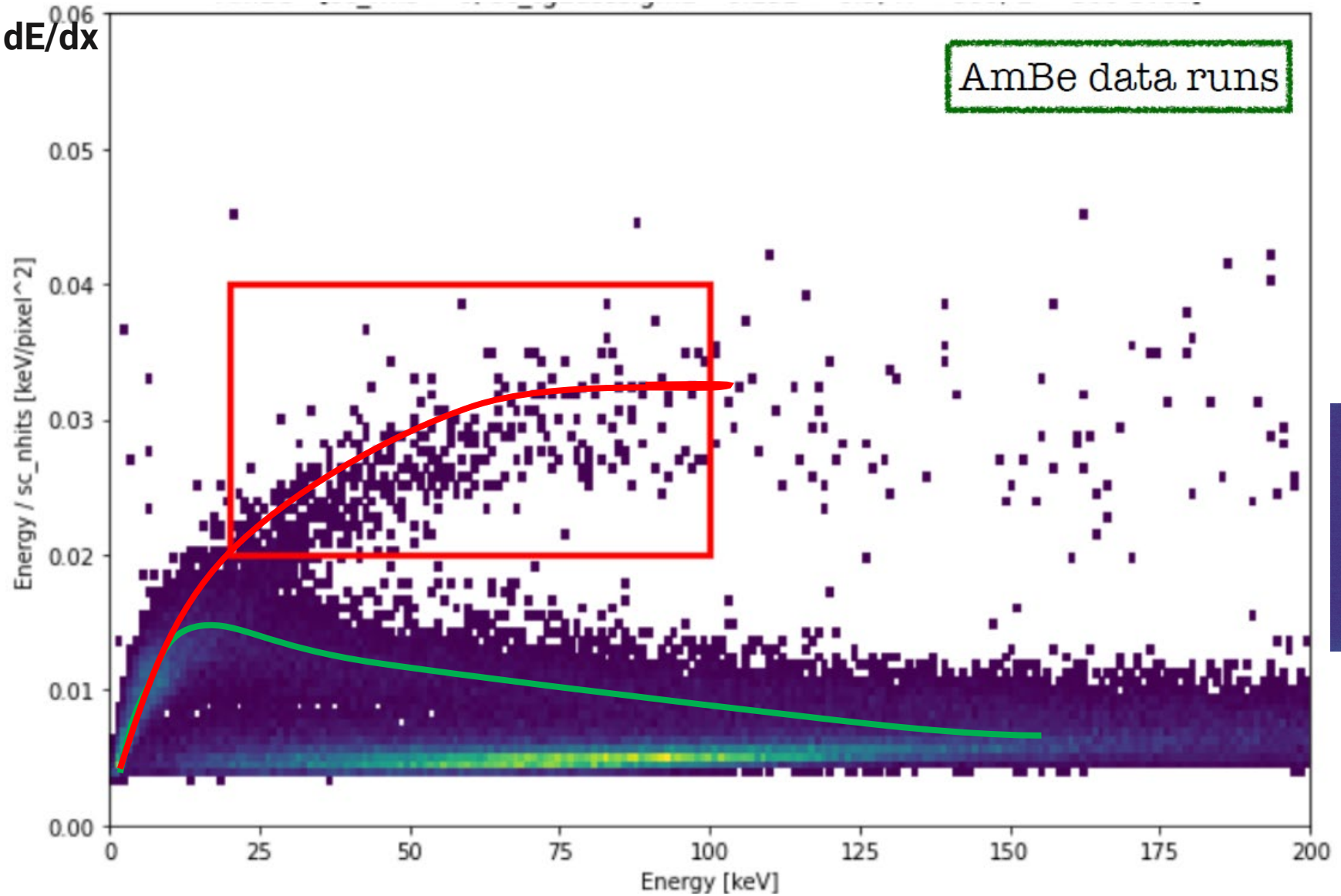



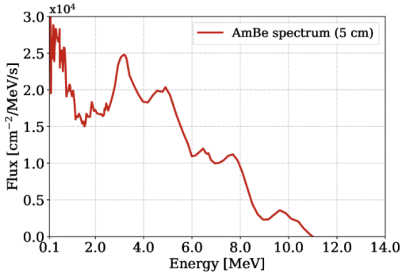

**Nuclear Recoils**



# Background Rejection

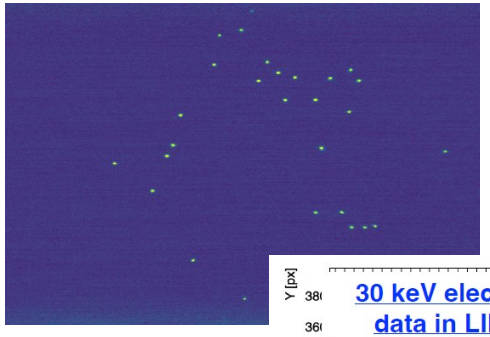
Data taking with Americium-beryllium source → Neutrons to induce Nuclear Recoil signals

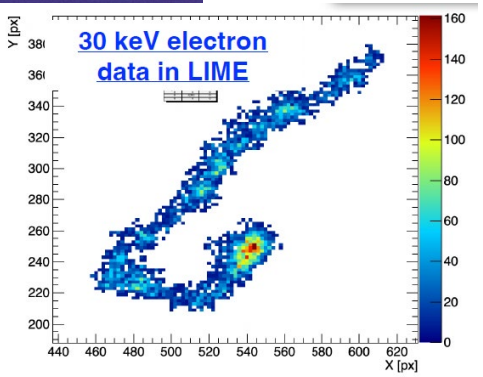



**Electron Recoils**

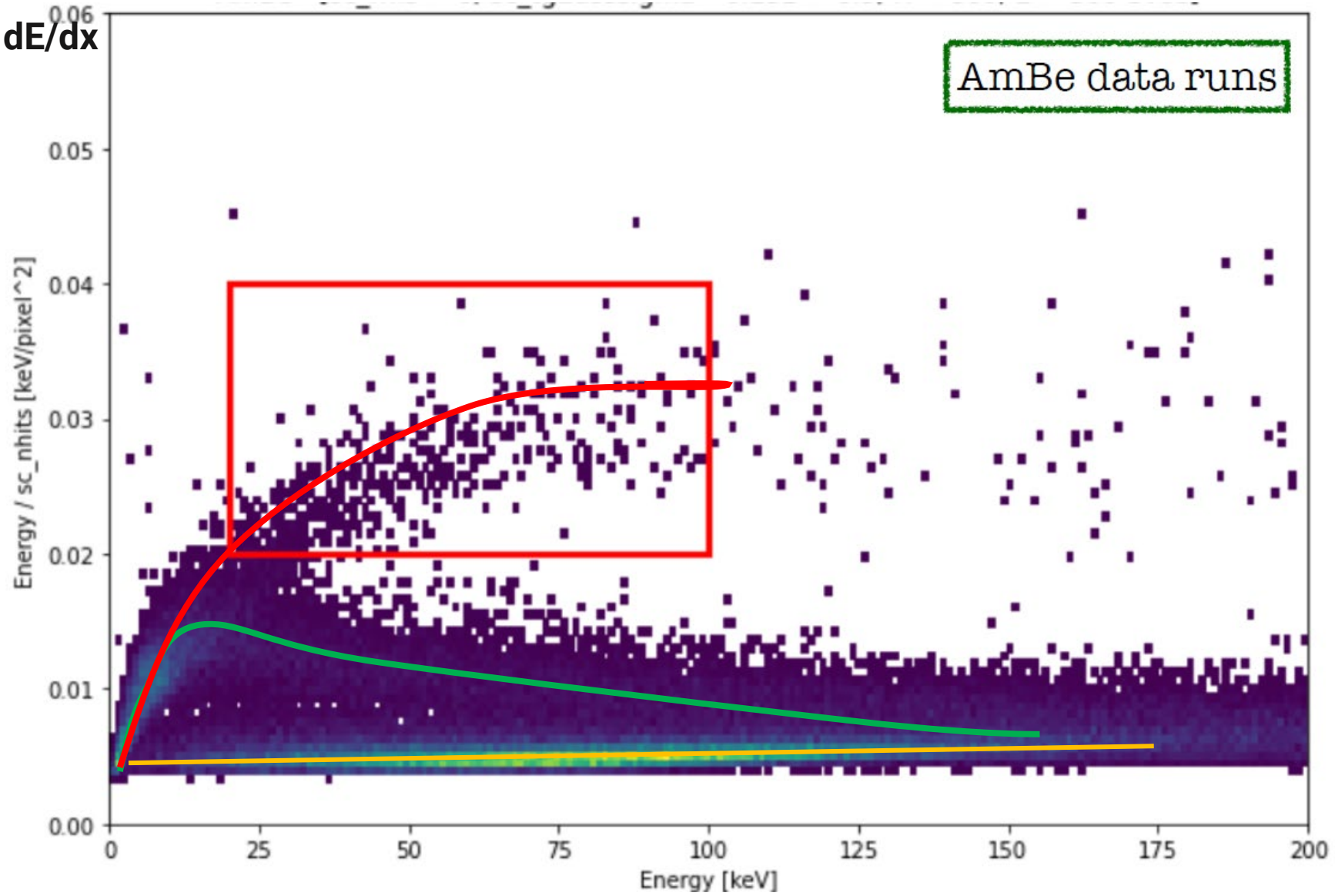
**Nuclear Recoils**

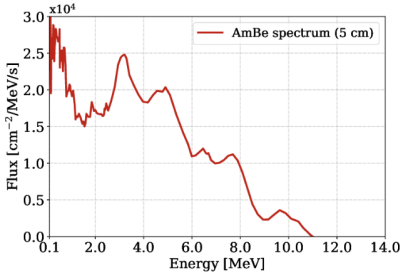




# Background Rejection

Data taking with Americium-beryllium source → Neutrons to induce Nuclear Recoil signals



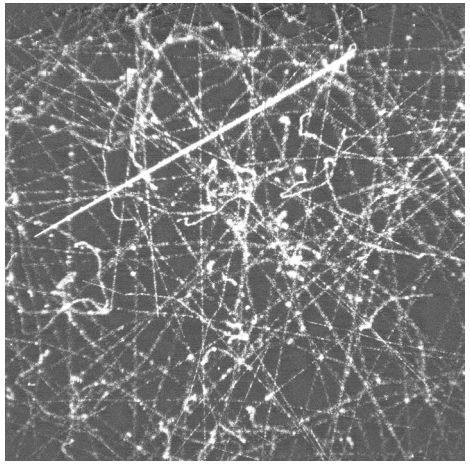




**MIP**

(muons and high energy electrons)

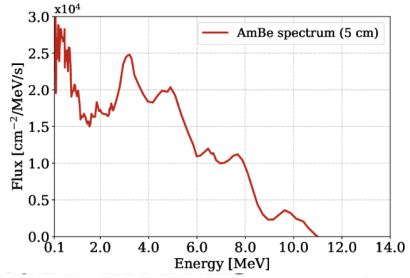
**Electron Recoils**

**Nuclear Recoils**

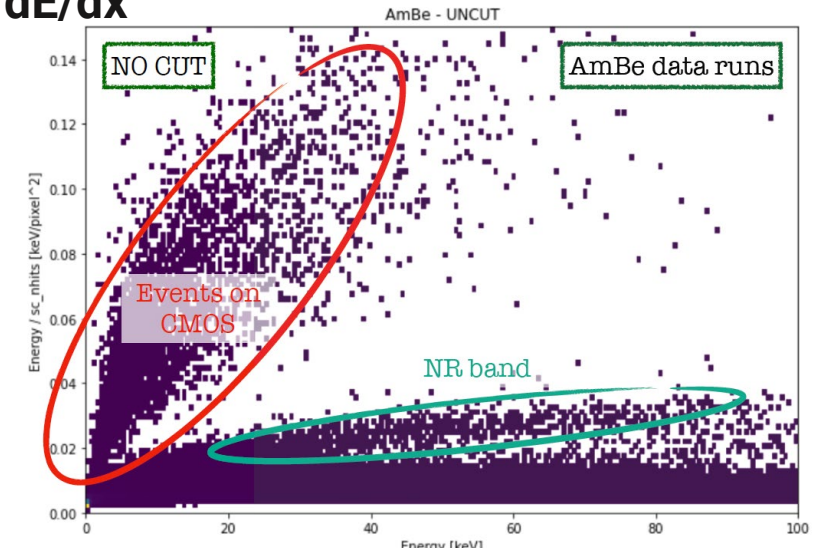


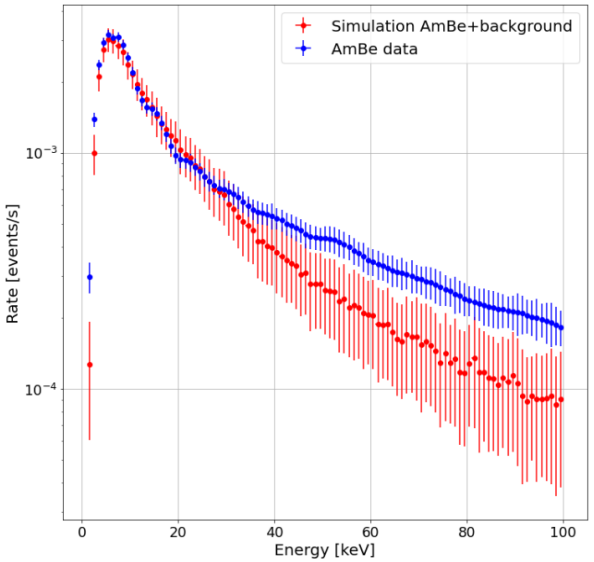
# Background Rejection

Data taking with Americium-beryllium source → Neutrons to induce Nuclear Recoil signals

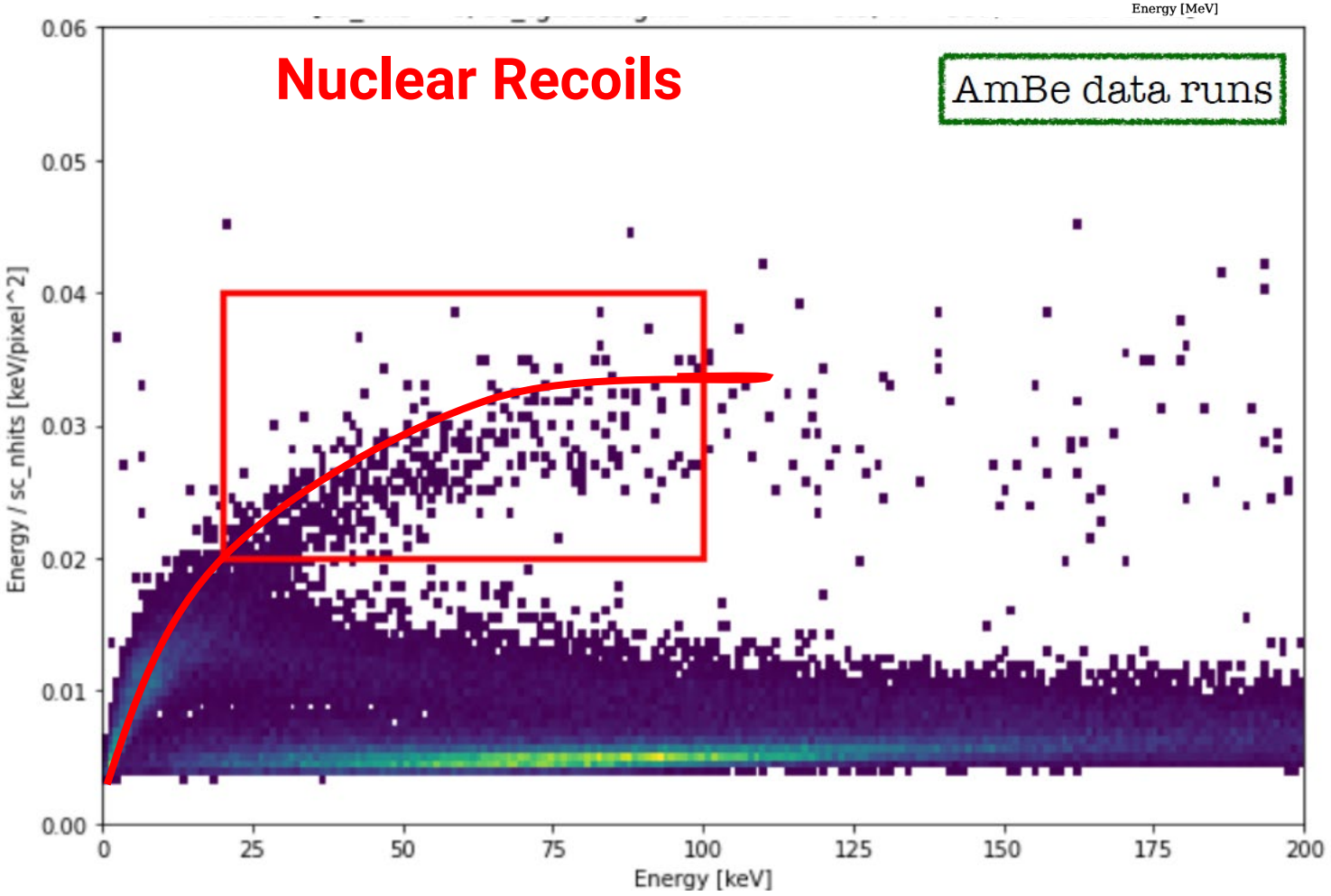



**dE/dx**



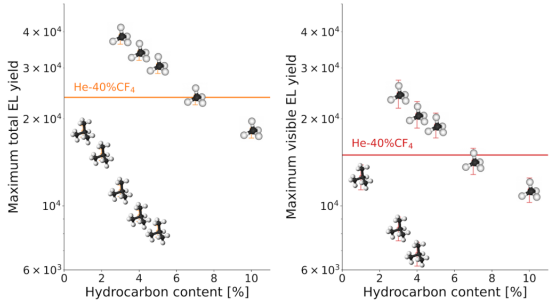

Simulation of AmBe gamma spectrum is correctly reproduced when background does not dominate

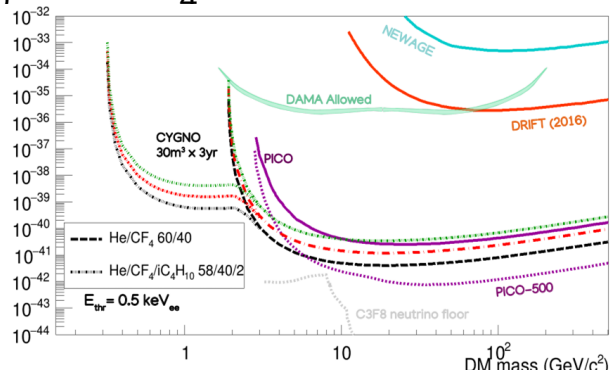


# R&D activities

## Hydrogen Rich Gas

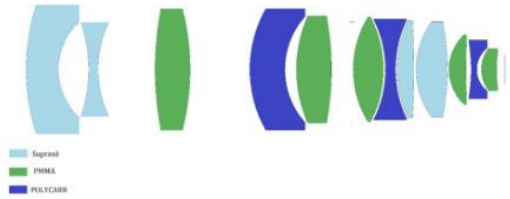
- Add hydrogen-rich gas is under study to gain sensitivity to lower DM masses $iC_4H_{10}$ and $CH_4$ with <10% concentration




## Low radioactivity Lens

- Building low radioactivity camera sensor and lens together with Hamamatsu/BMI experts



*Feasibility study for low radioactivity lens*

## Enhanced Light Yield

[2406.05713] Enhancing the light yield of He:CF$_4$ based gaseous detector (arxiv.org)

**G. Dho**

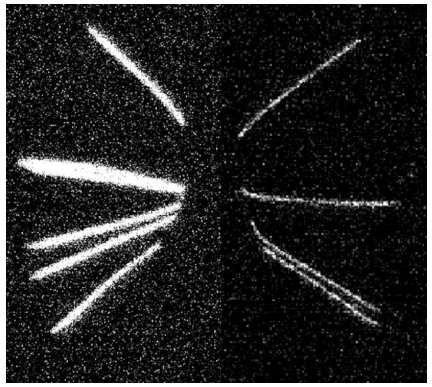
**Impact of a strong electric field below the GEM on light yield and saturation in a He:CF4 based Time Projection Chamber**

## Negative Ions $SF_6$

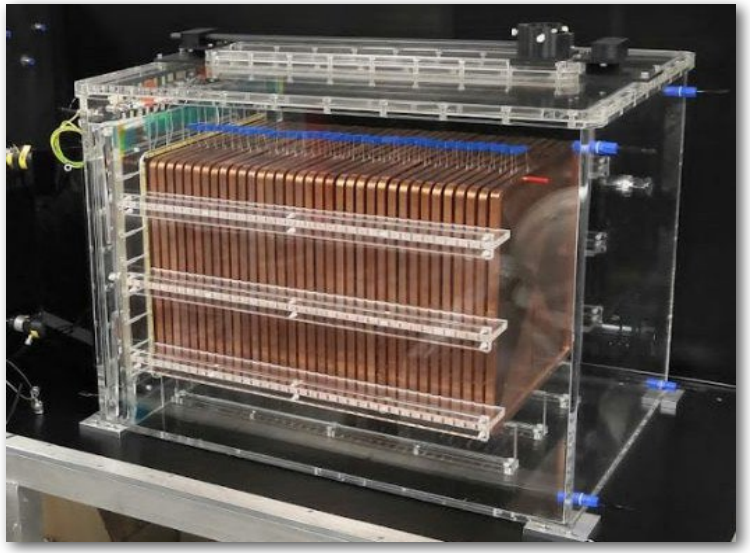
He:CF4:SF6 (59,39.4:1.6)

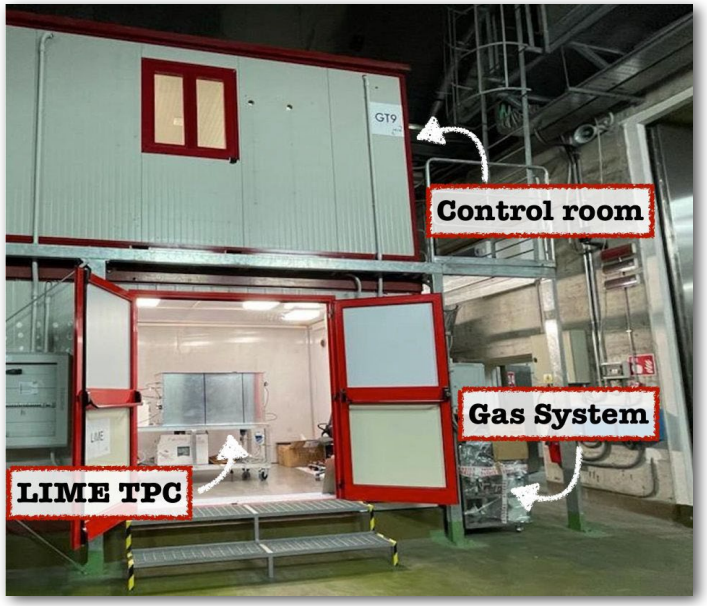
Reduce diffusion during drift by adding $SF_6$ (thus negative ions) to the gas mixture.

→ **Operation at 900mbar!**



# LIME – Long Imaging ModulE






**50L single-side TPC**
**Commissioning done in LNF in 2021/22**

33x33 $cm^2$ standard triple GEM
- D/T1/T2: 500/2/2 mm – 1/2.5/2.5 kV/cm
- VGEM: 440V

**Imaging:**
- ORCA FUSION camera 2304x2304 pixel granularity 155 x 155 $um^2$
- 4 PMTs on the four edges
- Schneider Xenon lens (F=0.95, f=25.6mm)

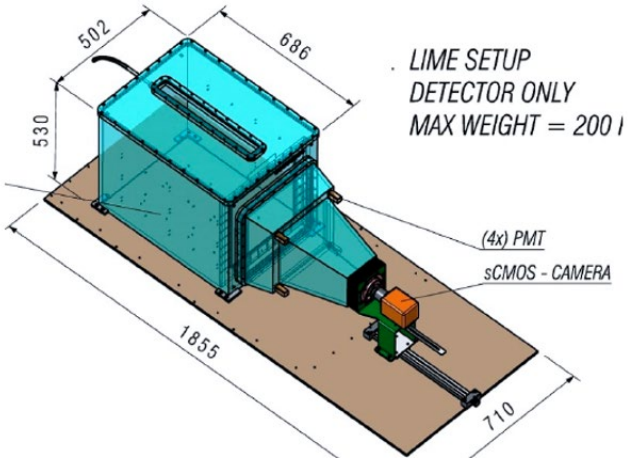
**Work at 910 mbar (atmospheric)**
- He/CF4 60/40 in recirculation mode (5+20 L/h fresh+recirculated)
- Oxygen+Nitrogen+radon filters

**DAQ based on MIDAS**
- Single USB 3.1 readout from camera
- Fast+slow VME ADCs for PMTs waveforms

**Trigger**
- >2 PMT over the threshold (FPGA-based)
- Save 300ms exposed camera picture

**55Fe source stability/calibration**
- At different drift distances
- Standard candle for intrinsic working parameters

$$\sigma_T \propto \sqrt{Z}$$

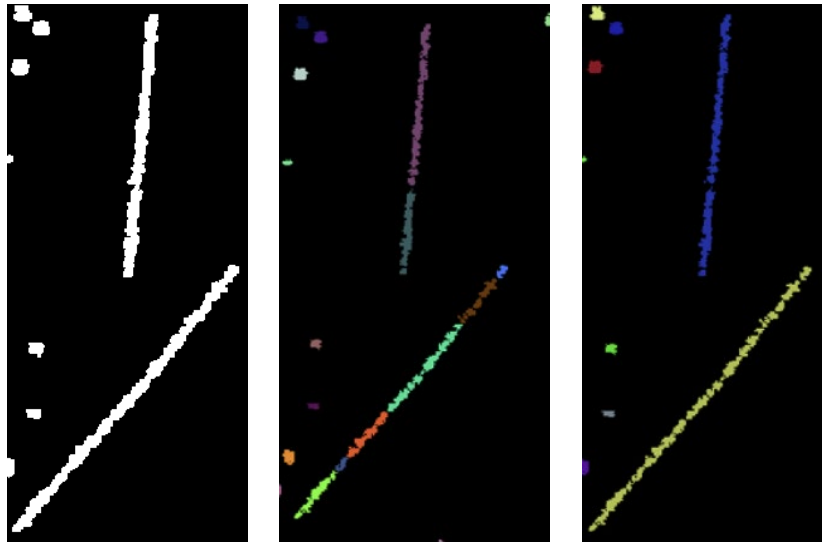


# LIME – Long Imaging ModulE

## Reconstruction:

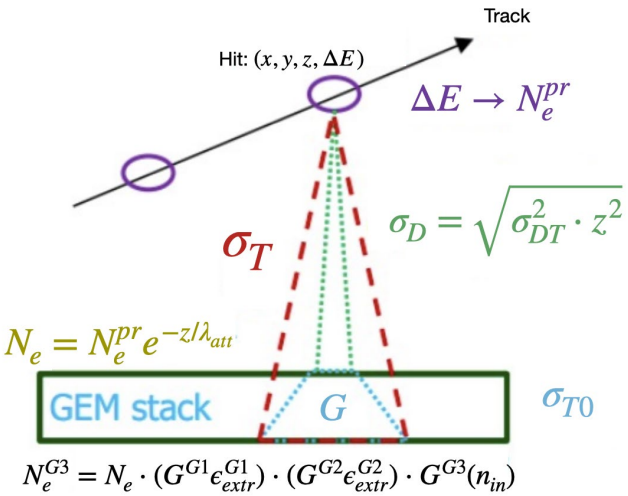
Directional iDBSCAN to detect cosmic-ray tracks for the CYGNO experiment – IOPscience
A density-based clustering algorithm for the CYGNO data analysis - IOPscience

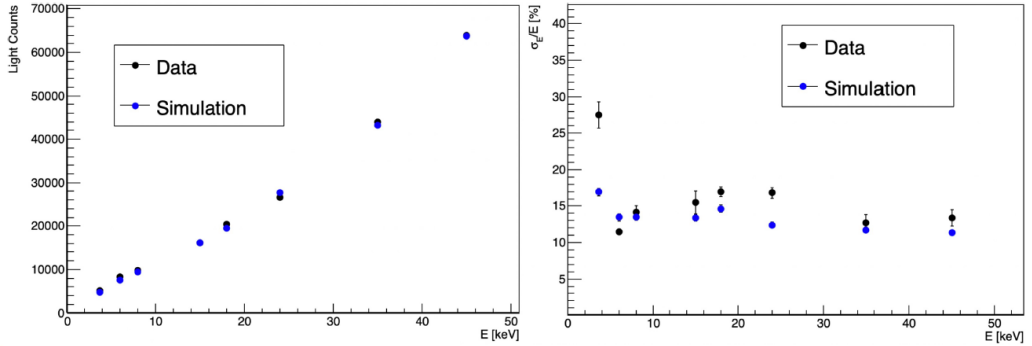
- Based on the iDBscan algorithm + Directional cluster search

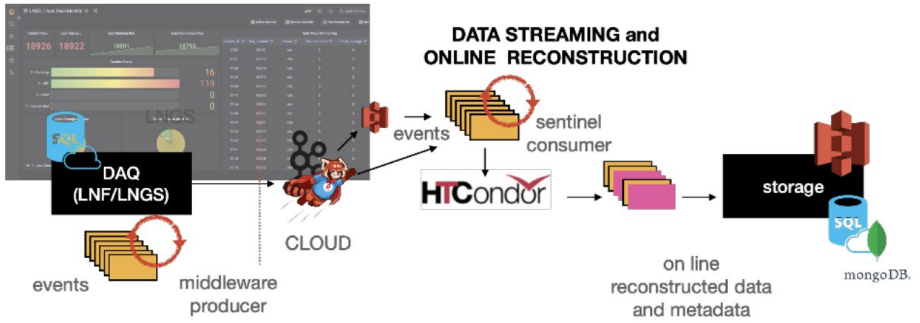


## Digitization:

- Fast simulation to mimic the response function without a full simulation




## CYGNO data managing

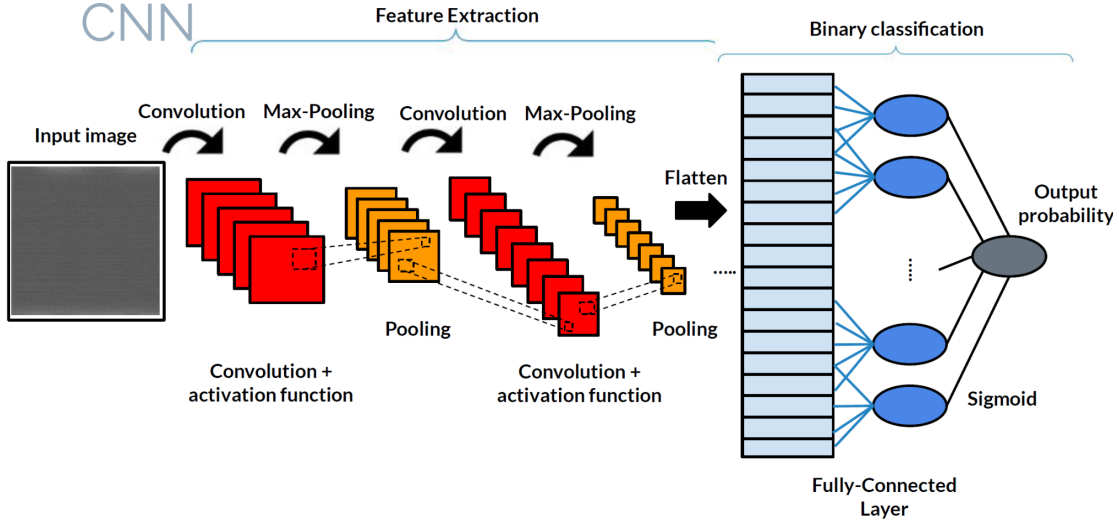
Data handling of CYGNO experiment using INFN-Cloud solution (epj-conferences.org)

- Beta tester of the INFN-Cloud project
- Data streamlined on cloud, where it is reconstructed and stored
- **Thoughput ≈ 3 Mb/s**
- **Reconstruction queue 40CPUs**

# CYGNO_04 TDAQ

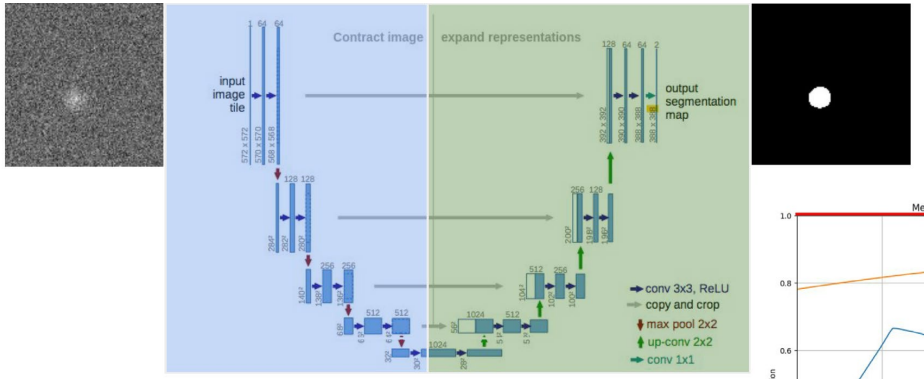
## 1° Level Trigger -Trained CNN classificator

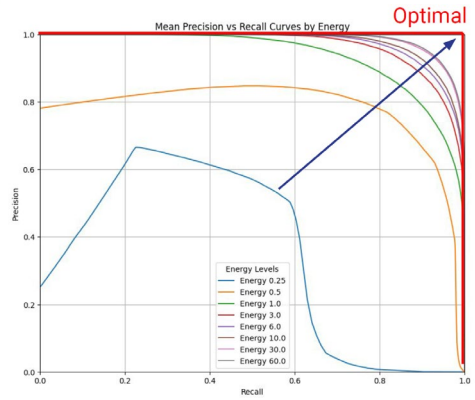
Individuate for every image if it contains signals or not




## 2° Level Trigger+Reco – U-Net CNN

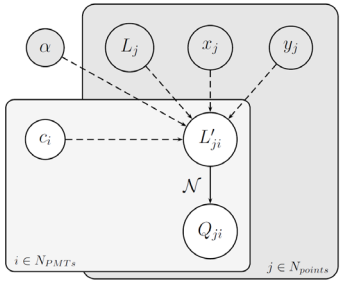
→ Signal/Noise classification on the pixels basis




## 3° Level PMT association – Bayesian FIT

Associate each PMT waveform to the correct camera cluster



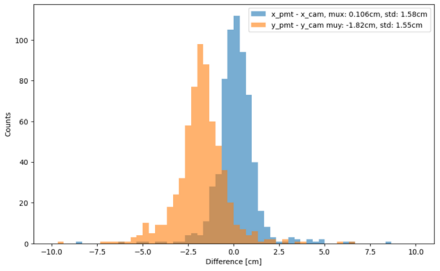

**LIME tested**

Fixed $x_j$, $y_j$, $L_j$ !

$$p(\{x_{ij}\}\,|\,\theta) = \prod_{j=1}^{N_{points}} \prod_{i=1}^{4} \mathcal{N}(\{x_{ij}\}\,|\,L'_{ij}(\theta))$$

With:

- $L'_{ji} = c_i \frac{L_j}{R_{ij}^{\alpha}}$
- $R_{ji} = \sqrt{x_{ji}^2 + y_{ji}^2 + z^2}$
- $\alpha = 4$




1to1 association

$\sigma_{X/Y} \approx 1.5$cm

## Expected Pipeline for commissioned CYGNO_04

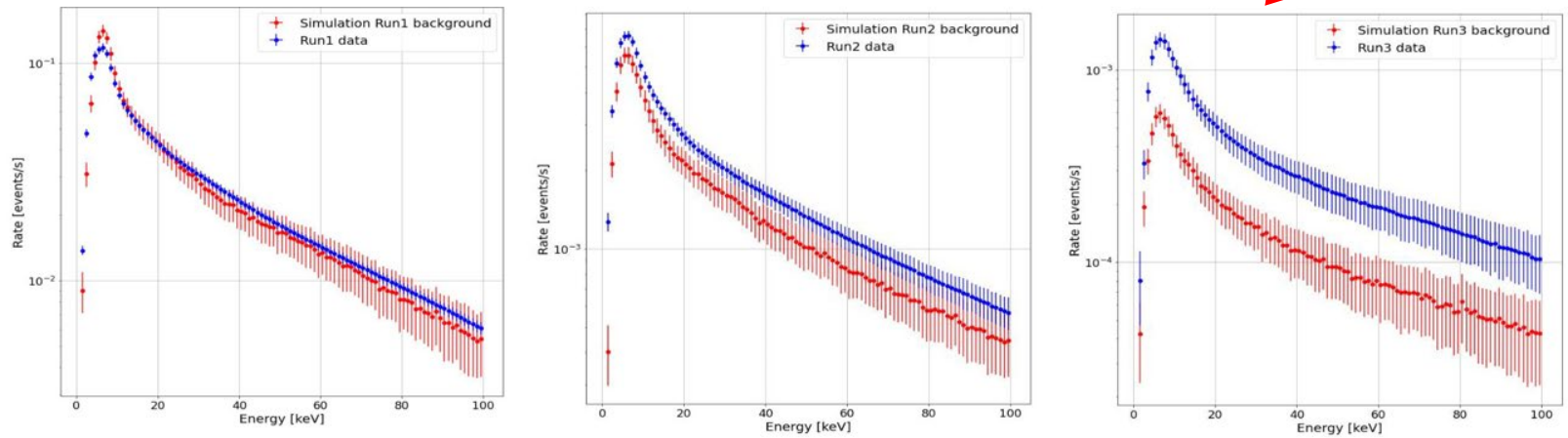
- Reduce throughput
- Imporved reconstruction performance
- Possible automatic 3D reco

# LIME performance

- **Prove we can operate such a detector underground**
- **Study and improve out MC chain**

| Phase | Shielding | GEM V [V] | # pictures | Live time [s] | Rate PMTs [Hz] |
|---|---|---|---|---|---|
| Run 1 | None | 420 | 285665 | 175627 | 30 |
| Run 2 | 4 cm Cu | 440 | 297992 | 191382 | 3.5 |
| Run 3 | 10 cm Cu | 440 | 171579 | 191471 | 1.6 |
| Run 4 | +40 cm H2O | Great external neutron suppression ⇒ *Under analysis…* | | | |

***Run1*** ***Run2 - Run3*** ***Run4***




**Main Suspect:**
**Alpha Contamination by r adon**

External background consistent with MC
With increasing shield, we highlight a non-expected background.