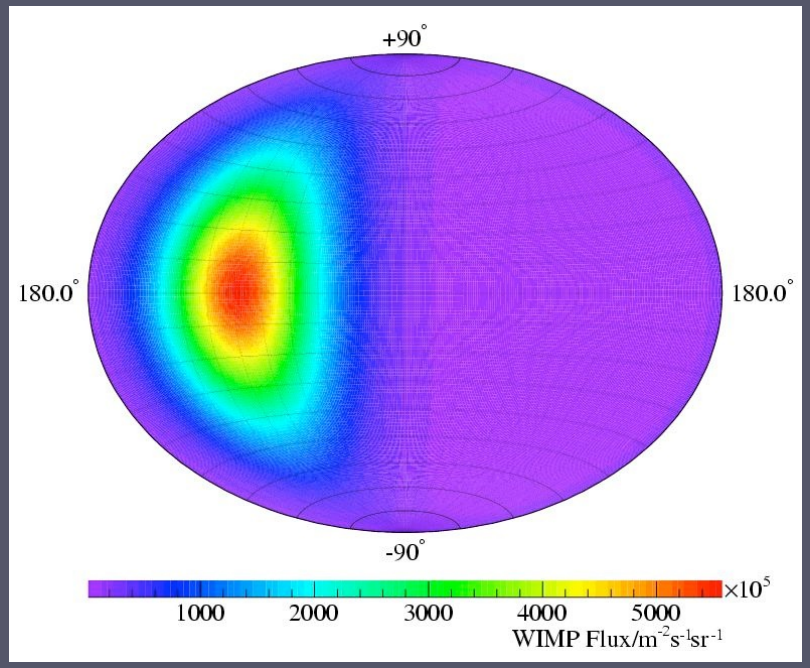
CYGNO - Sheffield update



- CYGNUS
- R&D relevant to CYGNO

Neil Spooner, University of Sheffield

Group: Callum Eldridge, Anthony Ezeribe, Trevor Gamble, Rob Gregorio, Warren Lynch (now York), Ali McClean (from Oct.), Robbie Neal, Andrew Scarff,

Special thanks to the group and many others for contributions to the slides

R&D Work at Sheffield

CYGNUS - A multi-site Galactic Nuclear Recoil Observatory

Facilities

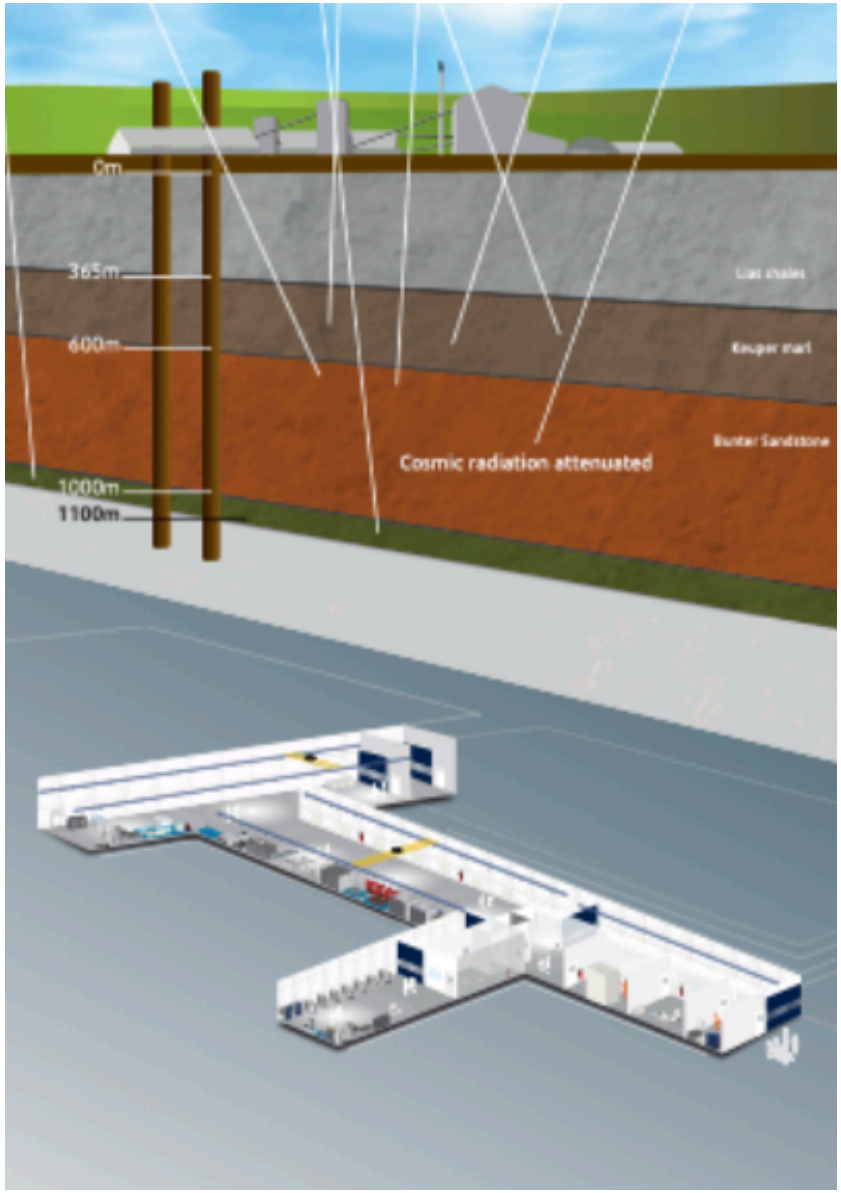
- Boulby Laboratory
- DT Neutron source and building
- Three labs at Sheffield, gas TPC facilities
- Computing cluster

R&D and expertise

- DRIFT operation and analysis
- Shielding design
- Gas purification and radon scrubbing systems (SF_6 etc)
- ThGEM and Micromegas development
- Optical readout and cameras
- Simple wire readout with high gain and -ve ion
- Background simulations
- Electron/nuclear recoil simulations
- Engineering and construction (vessel, readout etc)

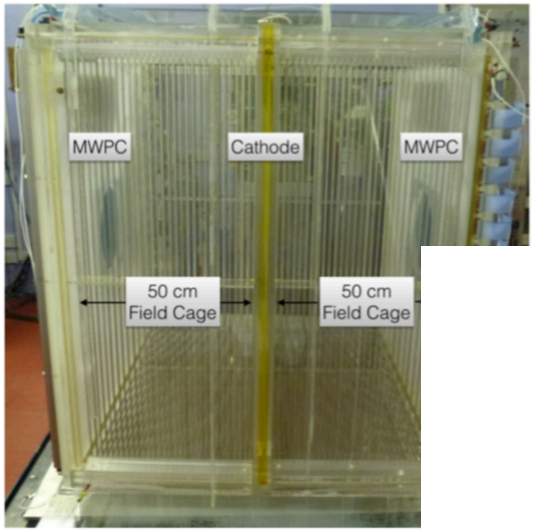
CYGNUS-10 concept development

Boulby - available site



DRIFT Sheffield

Still operational at Boulby, facilities can be used, new data analysis using BDT



Run	Usage	Days	Events
WIMP Run 1	Background	99.99	358164
Co60	Background	2.98	34112
Neutron	Signal	0.90	51550
WIMP Run 2	WIMP search	55.24	239008

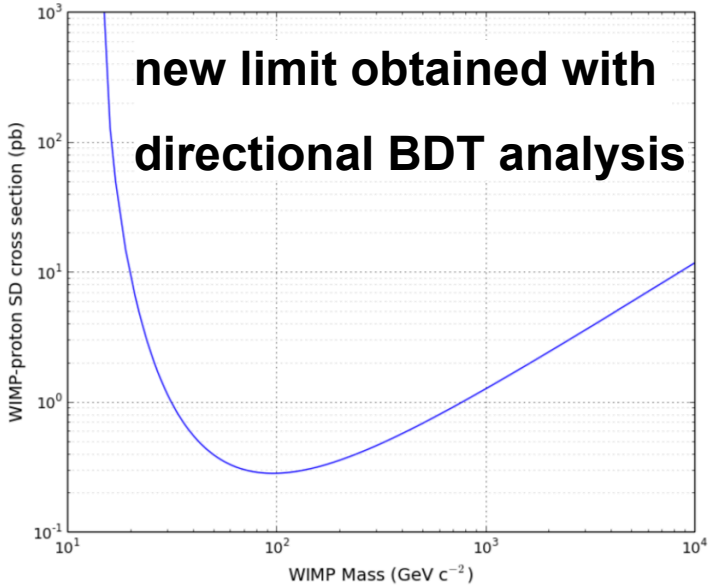


Figure 8: DRIFT-IId SD WIMP exclusion limits for the RFC analysis.

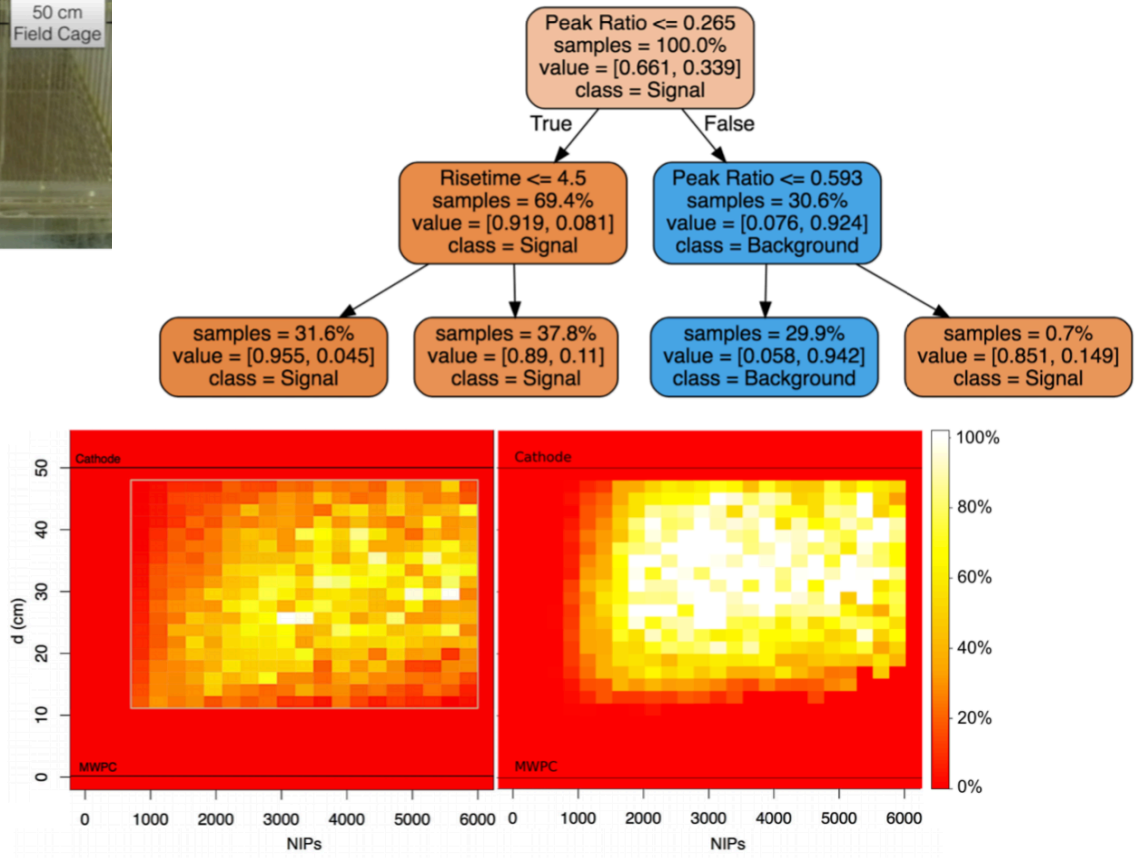
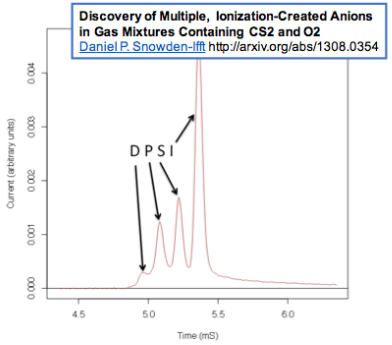


Figure 6: Efficiency maps for the previous (left) and RFC analysis (right). White = 100%, red = 0%. The image on the left was taken from [4].

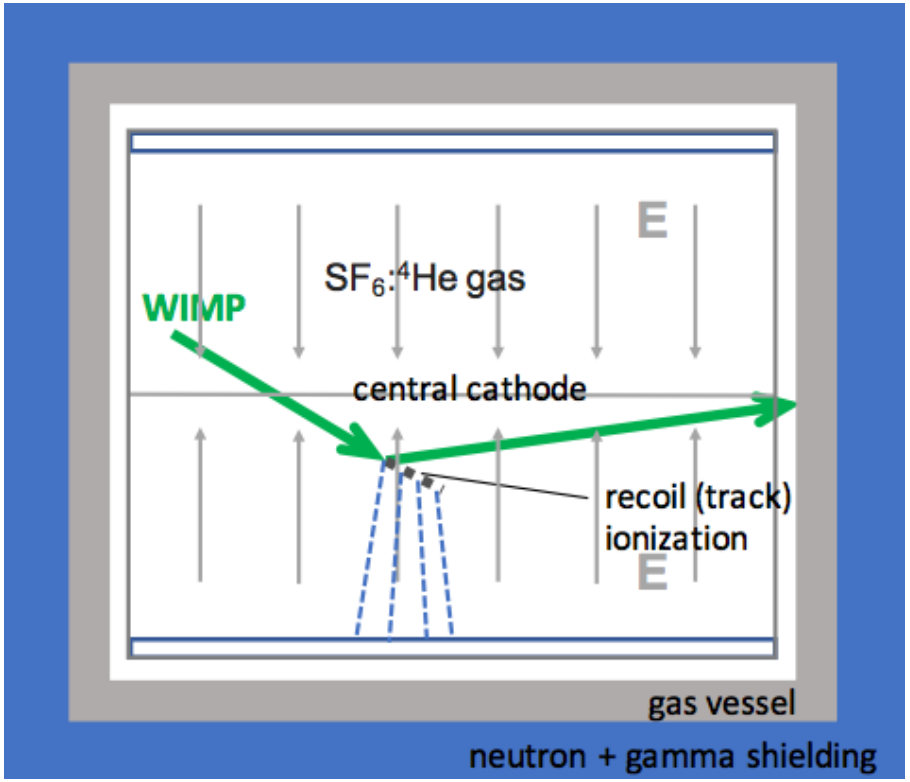
CYGNUS-10 Development

- Paper in preparation

- **Gas Mixtures: SF_6:He, p ~1atm, CF_4:SF_6:He etc**
  - Can switch between higher density (search mode) and lower density gas for (improved) directional confirmation of WIMP signal
- **Threshold at <1 keV_e**
  - Use of high gain stages
  - Ultimate is W~30 eV
- **Active electron rejection at ~GeV**
- **Reduced diffusion via -ve ion drift**
- **3D Fiducialisation**
  - SF_6 minority carriers
  - charge cloud profile



- **He target**
  - Improved sensitivity to low mass WIMP
  - Longer recoil tracks, extending directionality to lower energies
- **Reasonable detector volumes (10 m^3)**



Gas Recirculation and Radon Scrub

- Paper in preparation, See Rob's talk

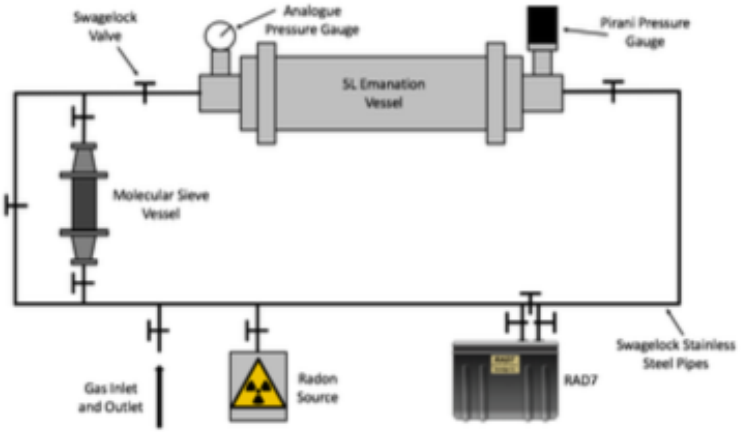


FIG. 3. Schematic of radon filtration test equipment.

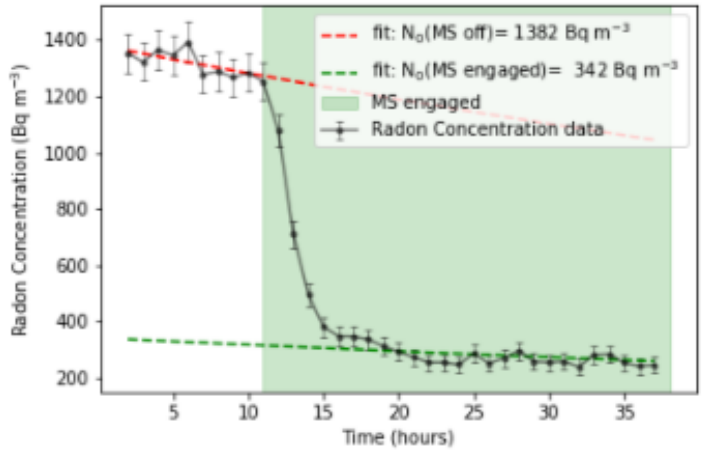
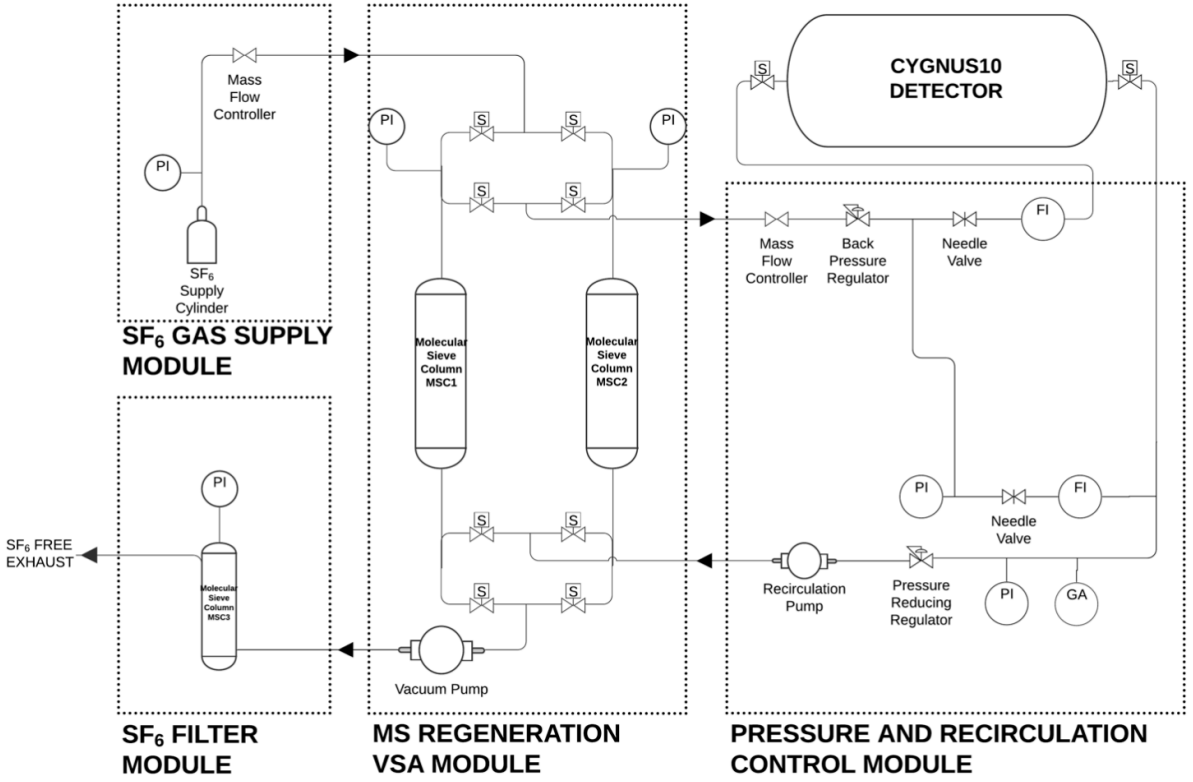


FIG. 7. Plot of the change in radon concentration observed due to application of molecular sieve sample 3.

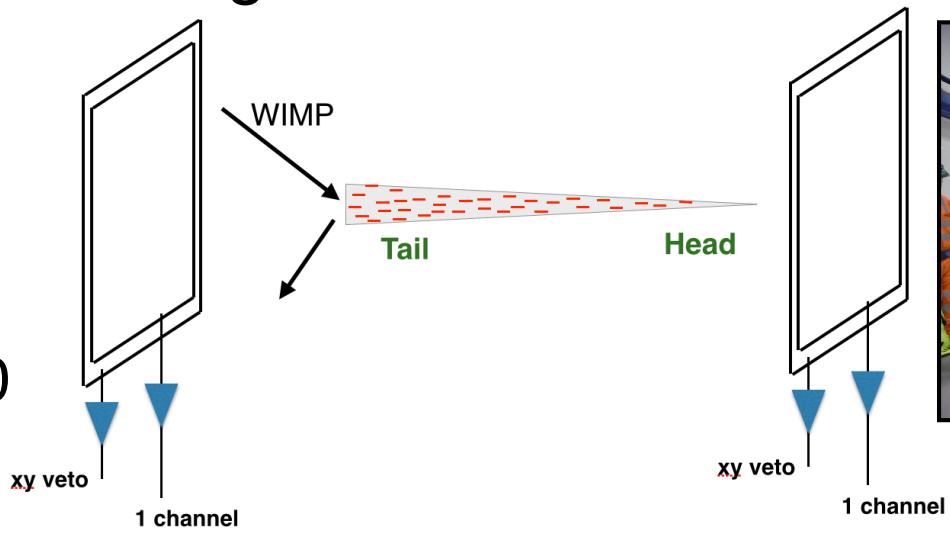
- New Design

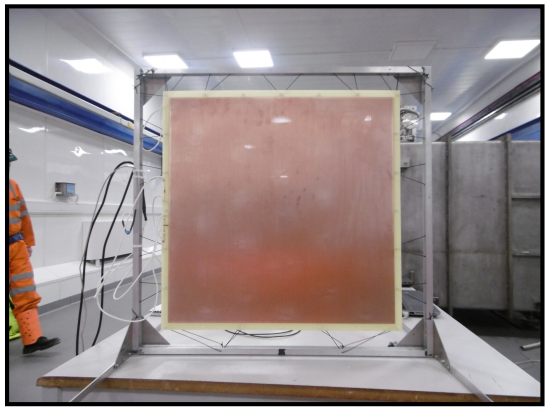


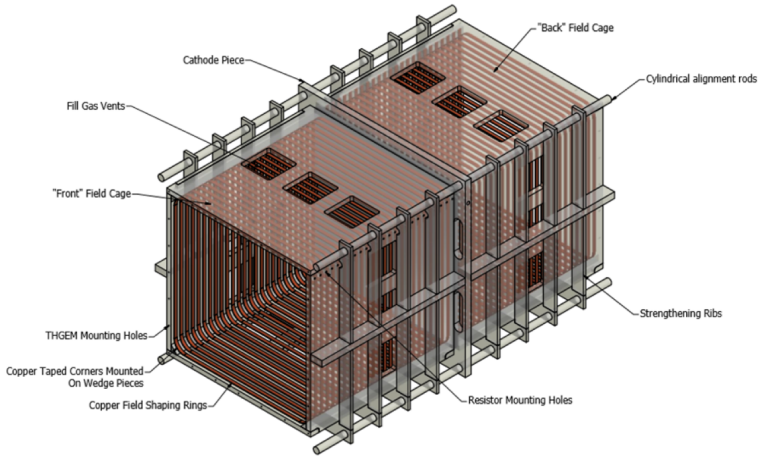
1D-HT Concept R&D

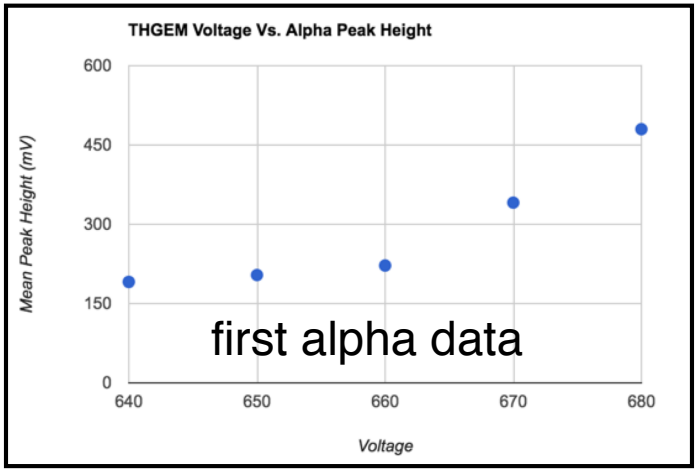
- What is the simplest possible readout that might just work?
- May be needed for large detector later

- test of large ThGEM 0.4mm hole dia.
- pitch 1mm, 2cm drift 300 V/cm, 100 Torr CF_4

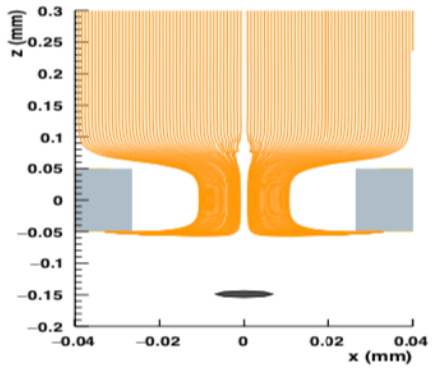




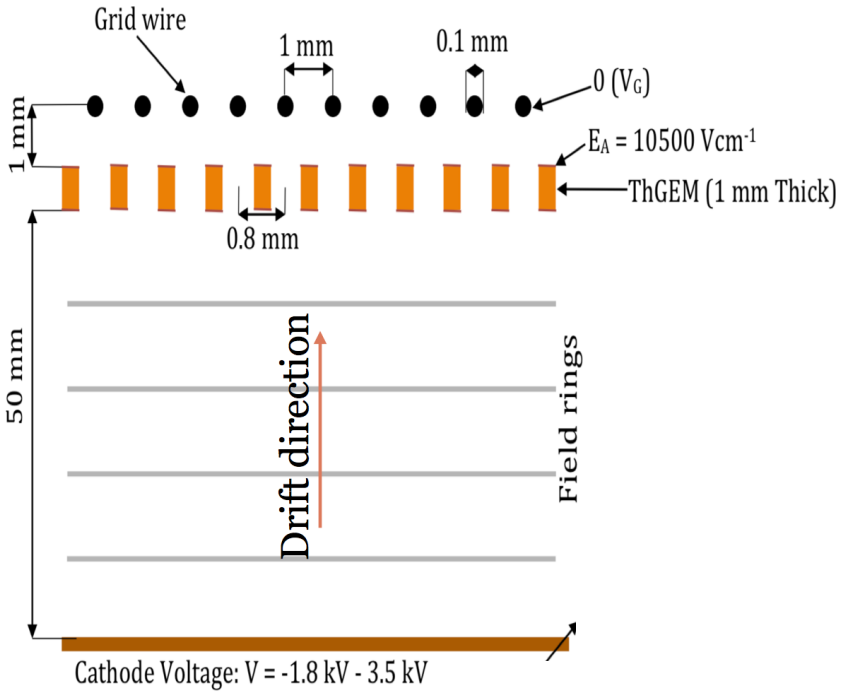




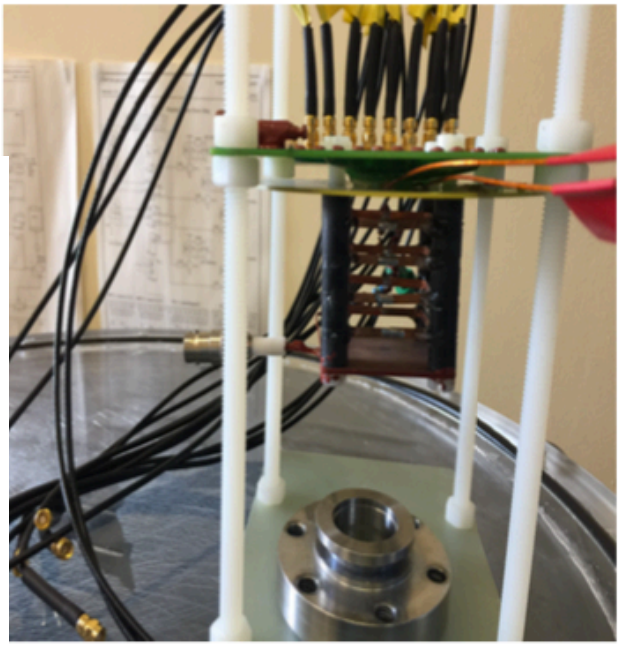
GEM-Wire 2D-HT hybrid Readout



(b) Electric field lines.

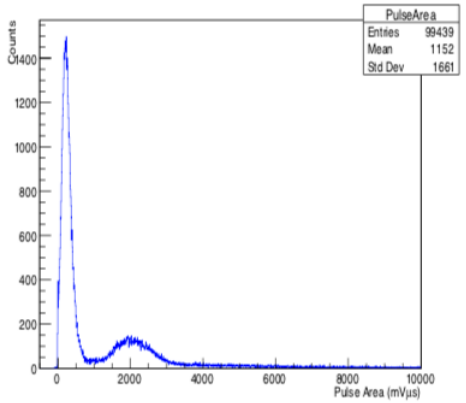


- Paper in preparation



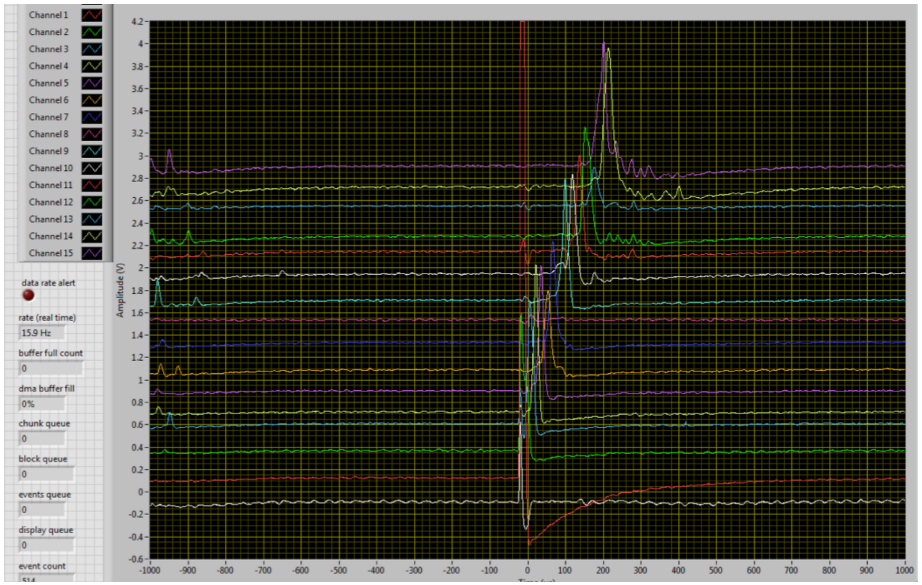
(b) Pictorial view of the detector.

- Alpha tracks in 50 Torr SF_6 -ve ion drift, readout by wires (no gain) with ThGEM providing gain stage (paper in prep.)



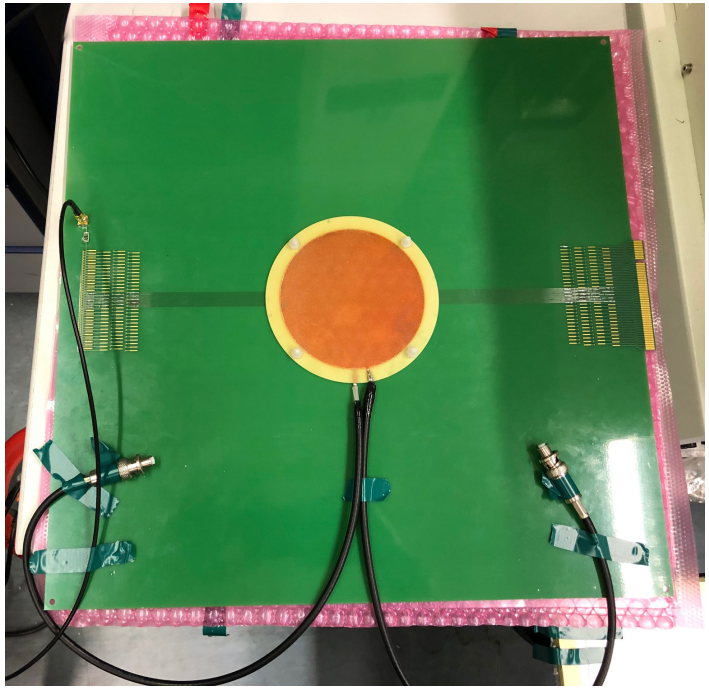
(a) Data spectrum from the Fe55 run.

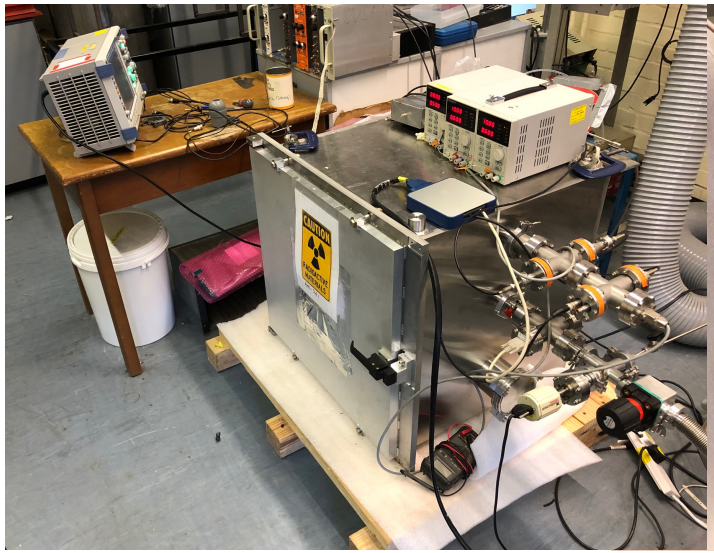
- ^{55}Fe

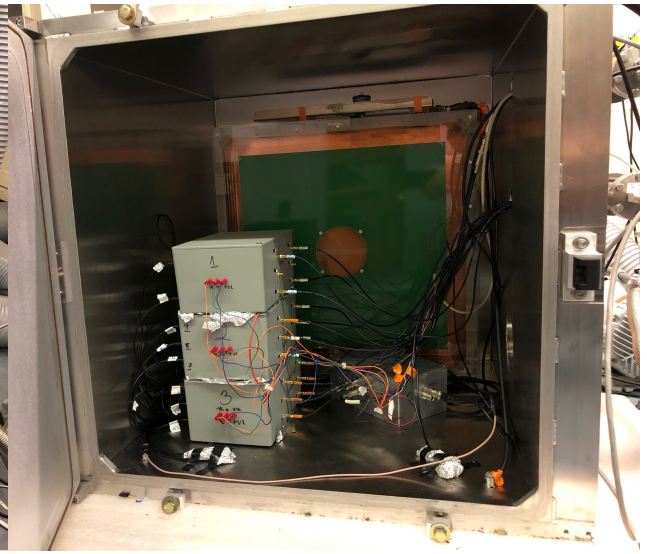


GEM-Wire 2D-HT hybrid Scale-up

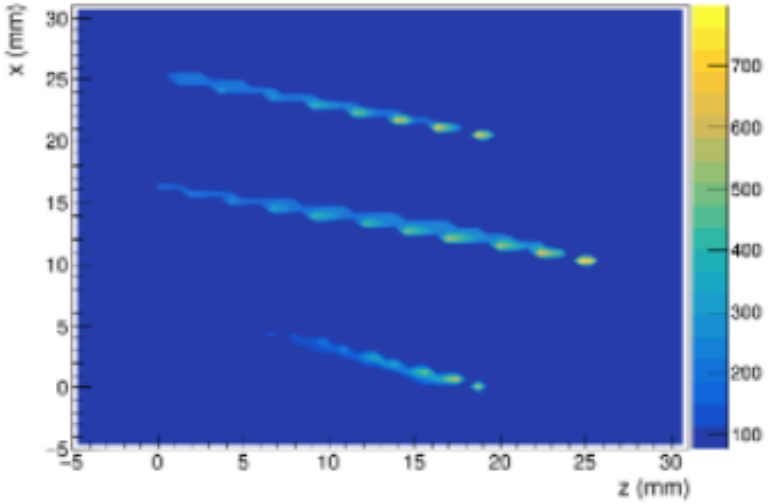
- 30 cm wires and ThGEM tests



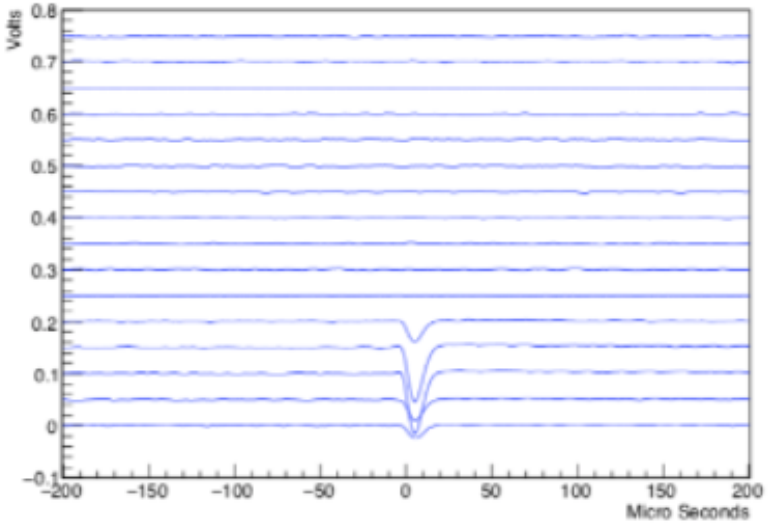




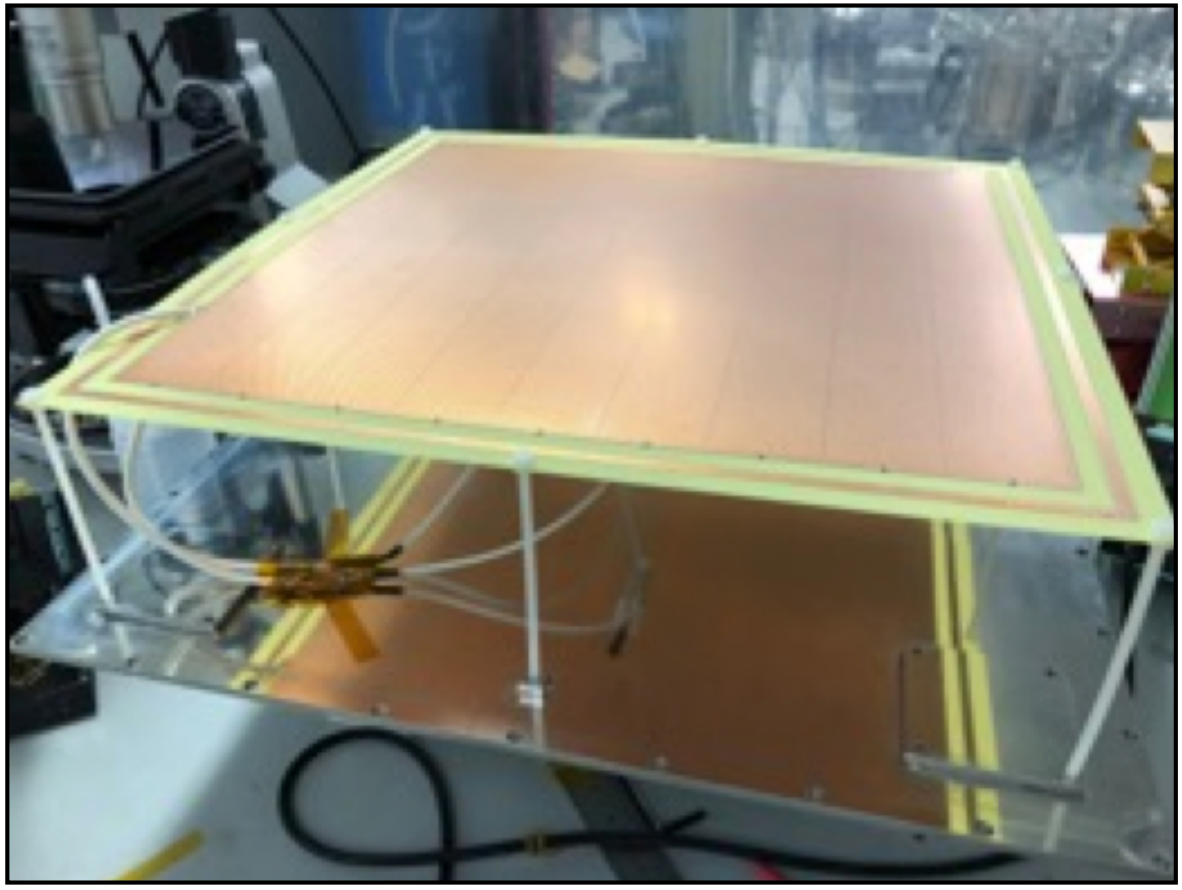
- Reconstructed alphas



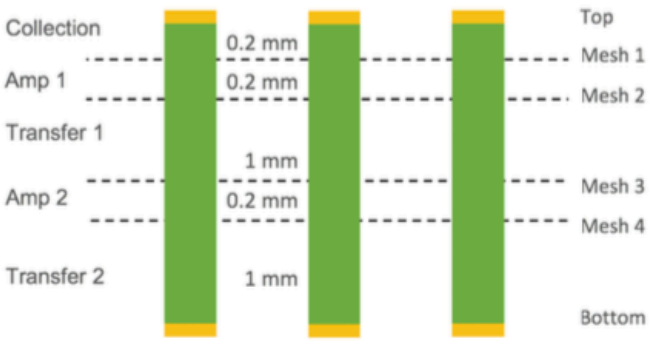
- ^{55}Fe tracks



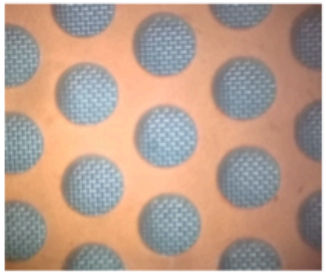
Large Area ThGEM tests (from CERN/AWE)



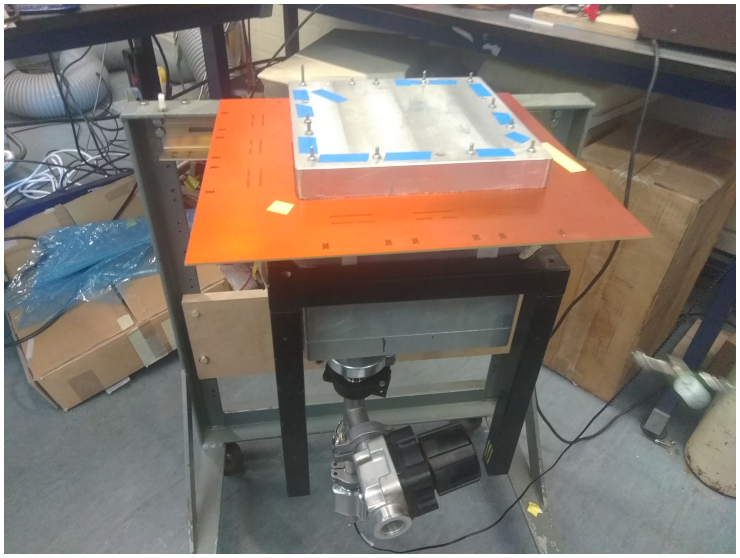
Micromegas with MM-ThGEM Gain

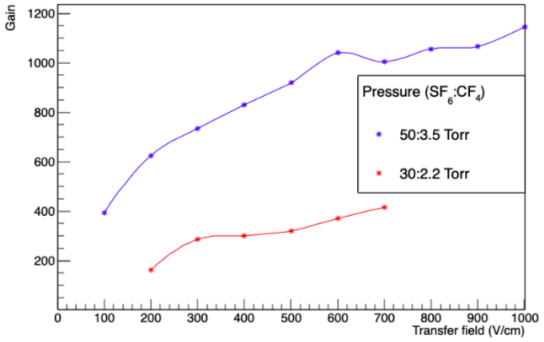


(a) Cross-section of the MMThGEM detector with the field names (left), plane names (right) and the gap widths (centre-left) above

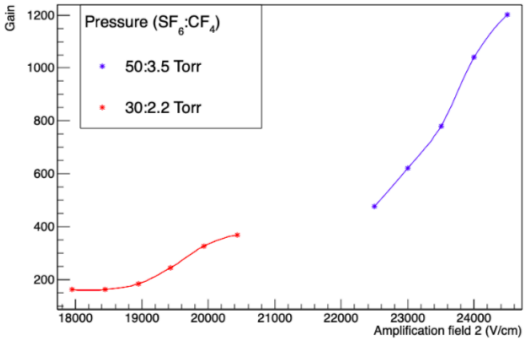


(b) Picture of the MM-ThGEM holes from





(a) Transfer field against gain in CF_4:SF_6



(b) Second amplification field against gain in CF_4:SF_6

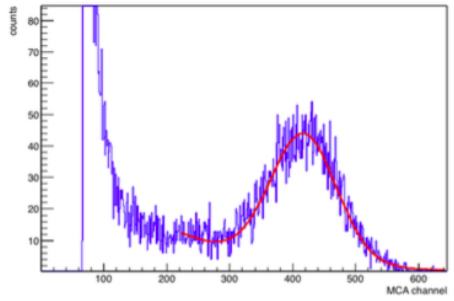
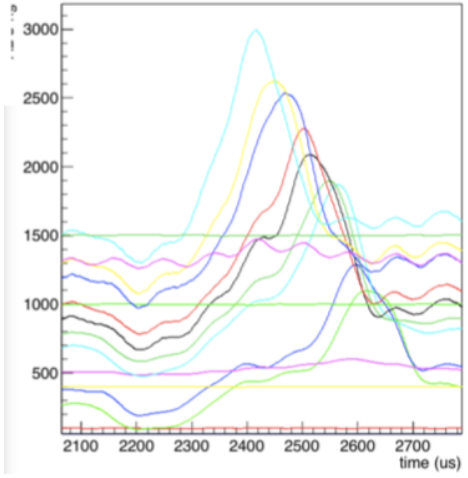
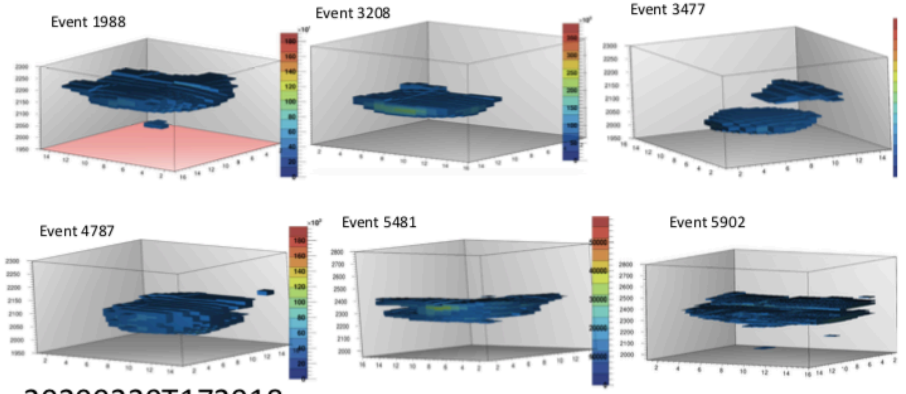


Figure 2: MCA spectrum of ^{55}Fe in CF_4 along with the fitted gaussian

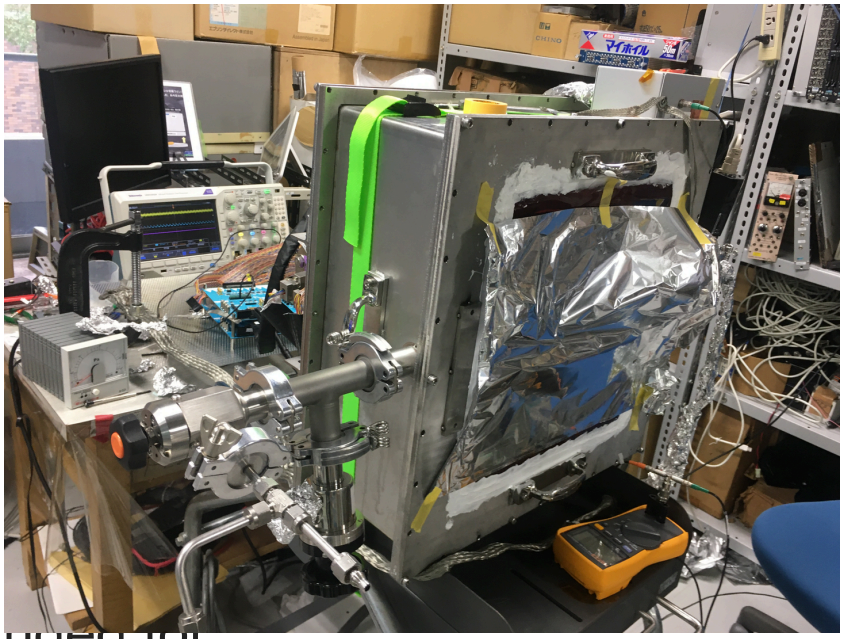


Fe^{55}

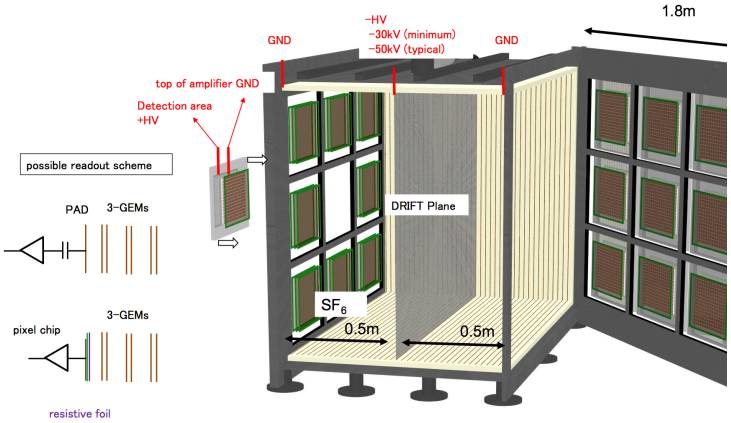


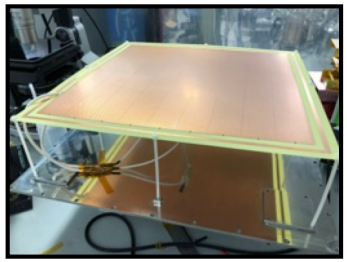
CF4 : SF6
39.0 : 1.8 Torr 20200229T172918

CYGNUS-KM and Kobe-Sheffield

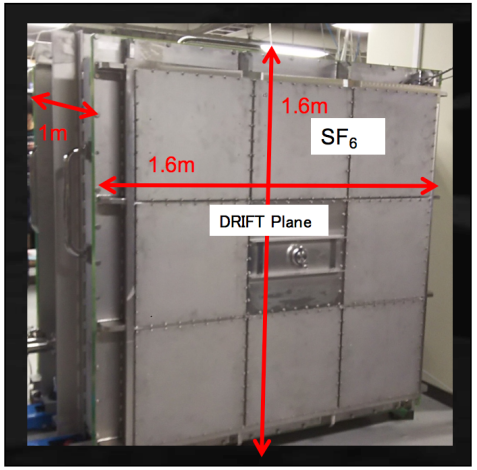


- Collaboration between Kobe and Sheffield funded for travel by JSPS and the UK Royal Society
- Aims to apply Kobe electronics to new charge readout techniques for directional dark matter detection





ThGEM prototype (Sheffield group)

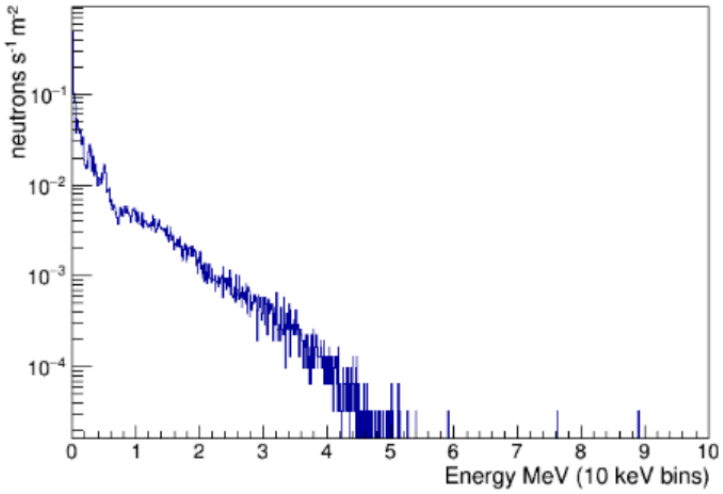


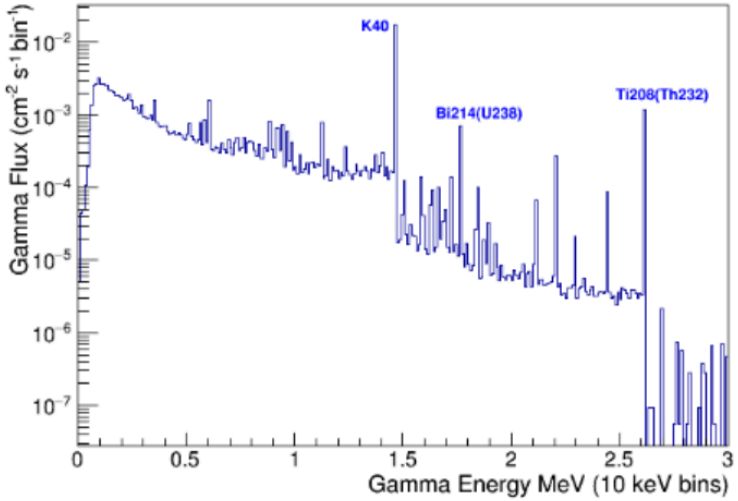
PhD Students: Warren Lynch, Callum Eldridge, Rob Gregorio

Background Simulations

- Geant4, MUSUN etc for neutron, gamma, background predictions
- CYGNUS-1000, CYGNO and CYGNUS-10

- e.g. rock neutrons and gammas





- e.g. total electron recoil background from internal TPC components

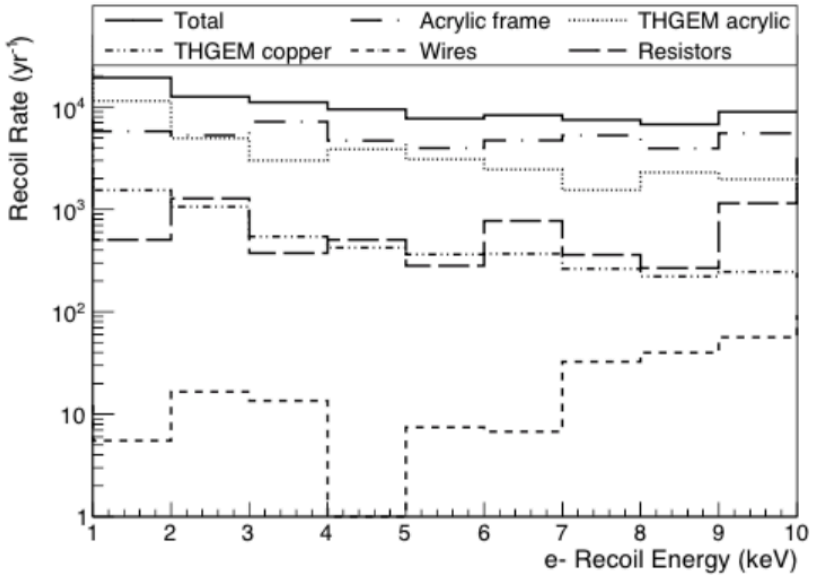
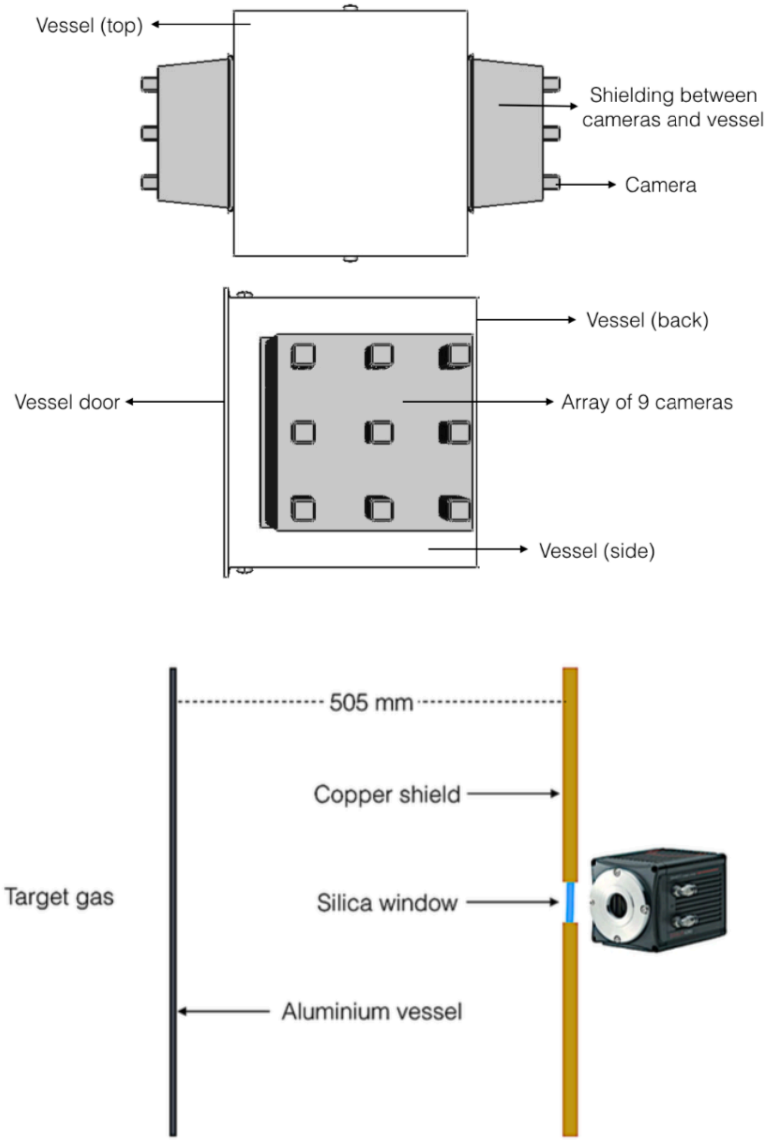


Figure 24. The internal TPC electron recoil background, between 1 and 10 keV, originating from gammas produced within the structural materials listed in Table 8. The total rate is shown by the solid black line.

CYGNO Background Simulations

- Geant4, MUSUN etc for neutron, gamma, background predictions



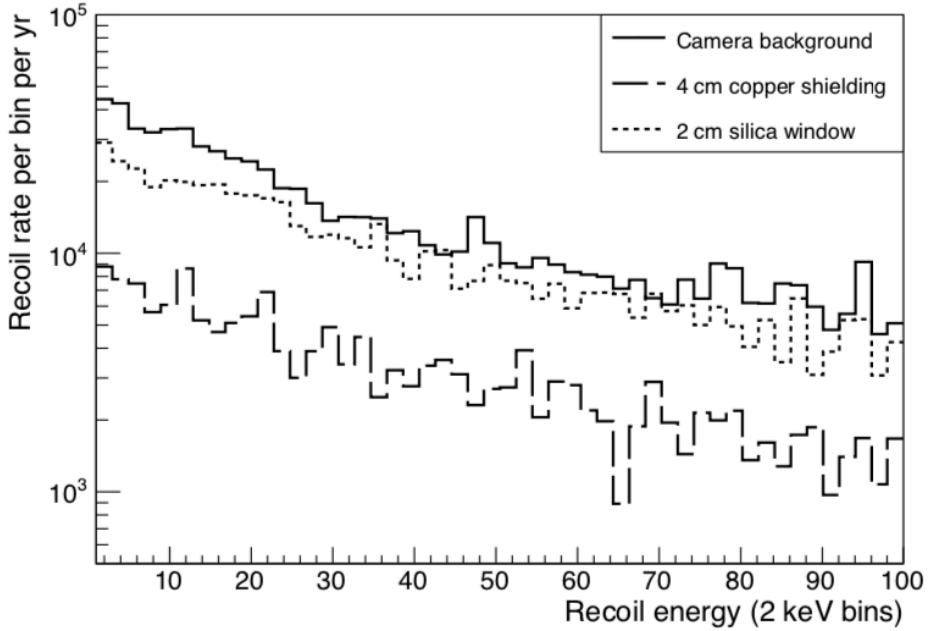


Figure 9.3: Gamma recoil rates, between 1 and 100 keV, for a single camera with no shielding, a 4 cm thick copper shield and a 4 cm thick copper shield with a 2 cm thick silica window.

Electron Discrimination Simulations

- Geant4, Garfield, SRIM etc…
  electron and nuclear recoil, tracks

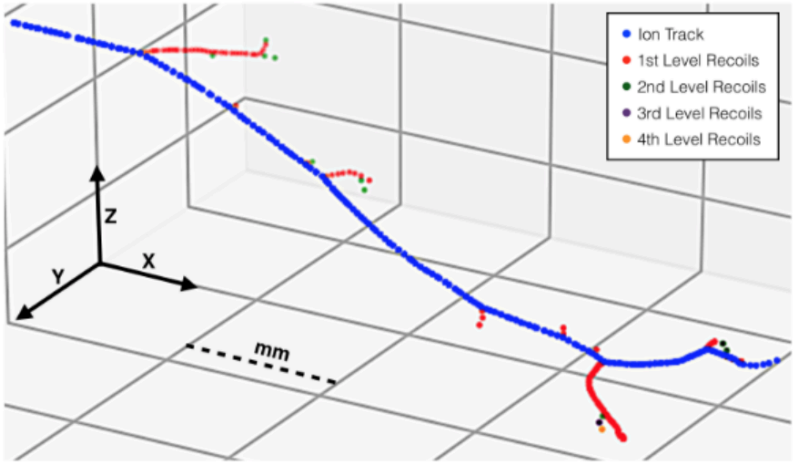
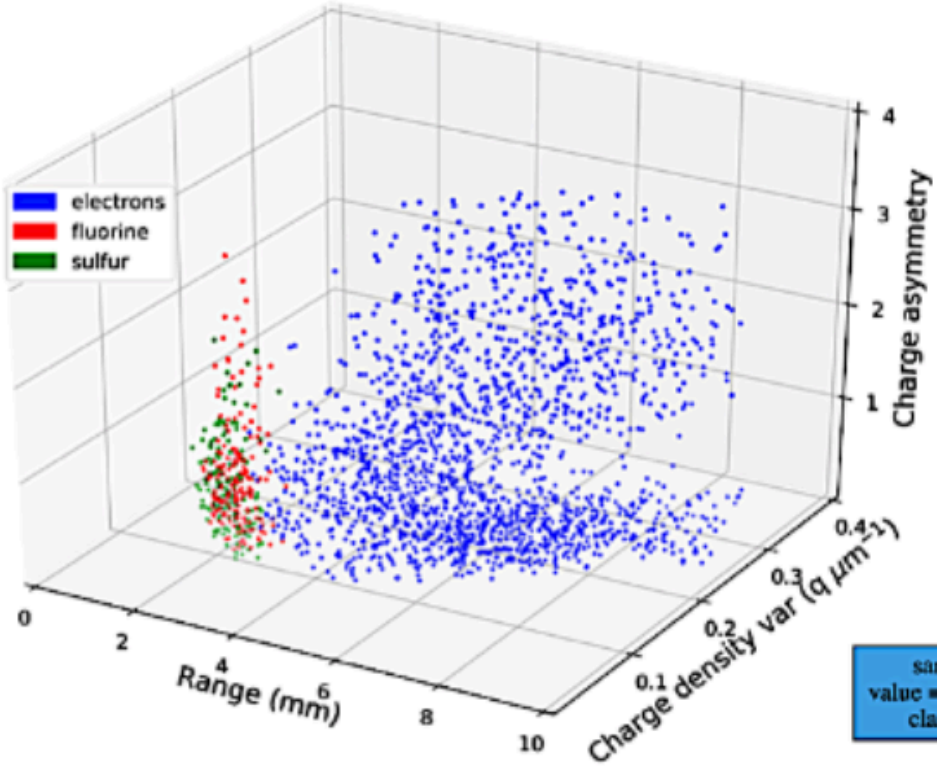
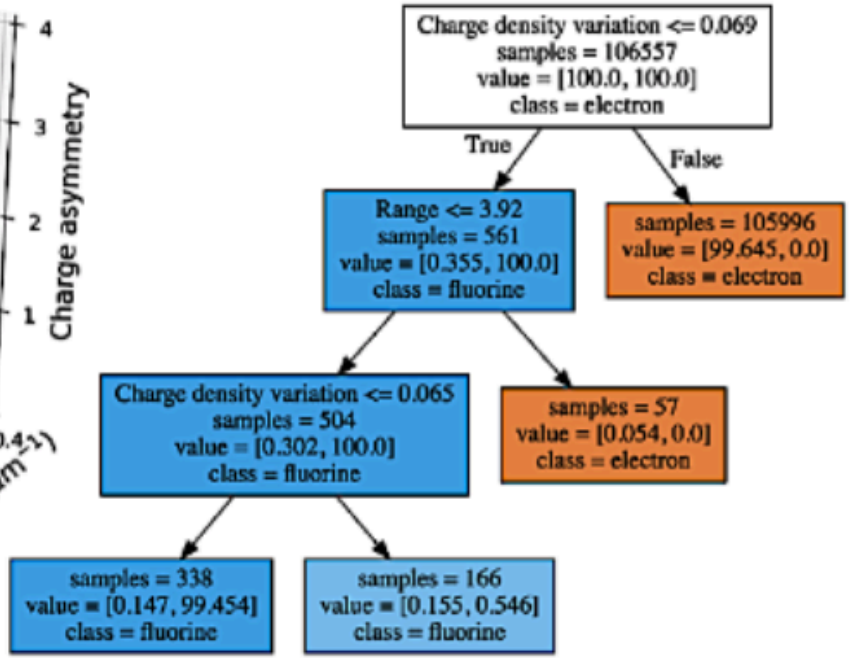


Figure 26. Ionised electrons, form the primary, 1st, 2nd, 3rd and 4th level of recoils, for a 50 keV_r fluorine track in 20 Torr of SF_6 gas.





Electron Discrimination Simulations

- Geant4, Garfield, SRIM etc…
  electron and nuclear recoil, tracks

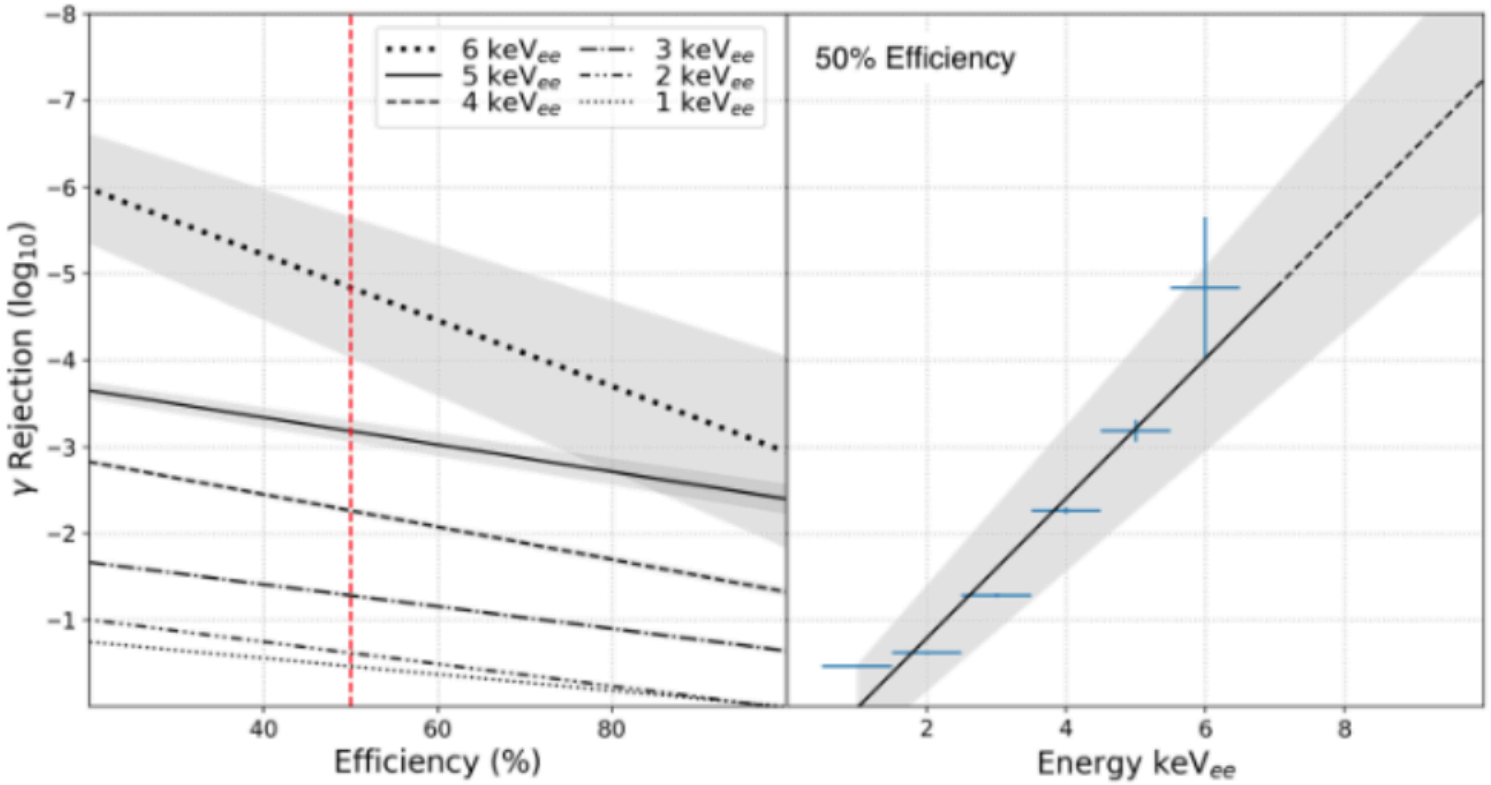


Figure 31. Gamma rejection for a 600 μm readout resolution and 25 cm diffusion. Left: as a function of efficiency for recoil energies between 1-6 keV$_{ee}$. Right: as a function of recoil energy (1-10 keV$_{ee}$). The grey band represents one sigma deviation.

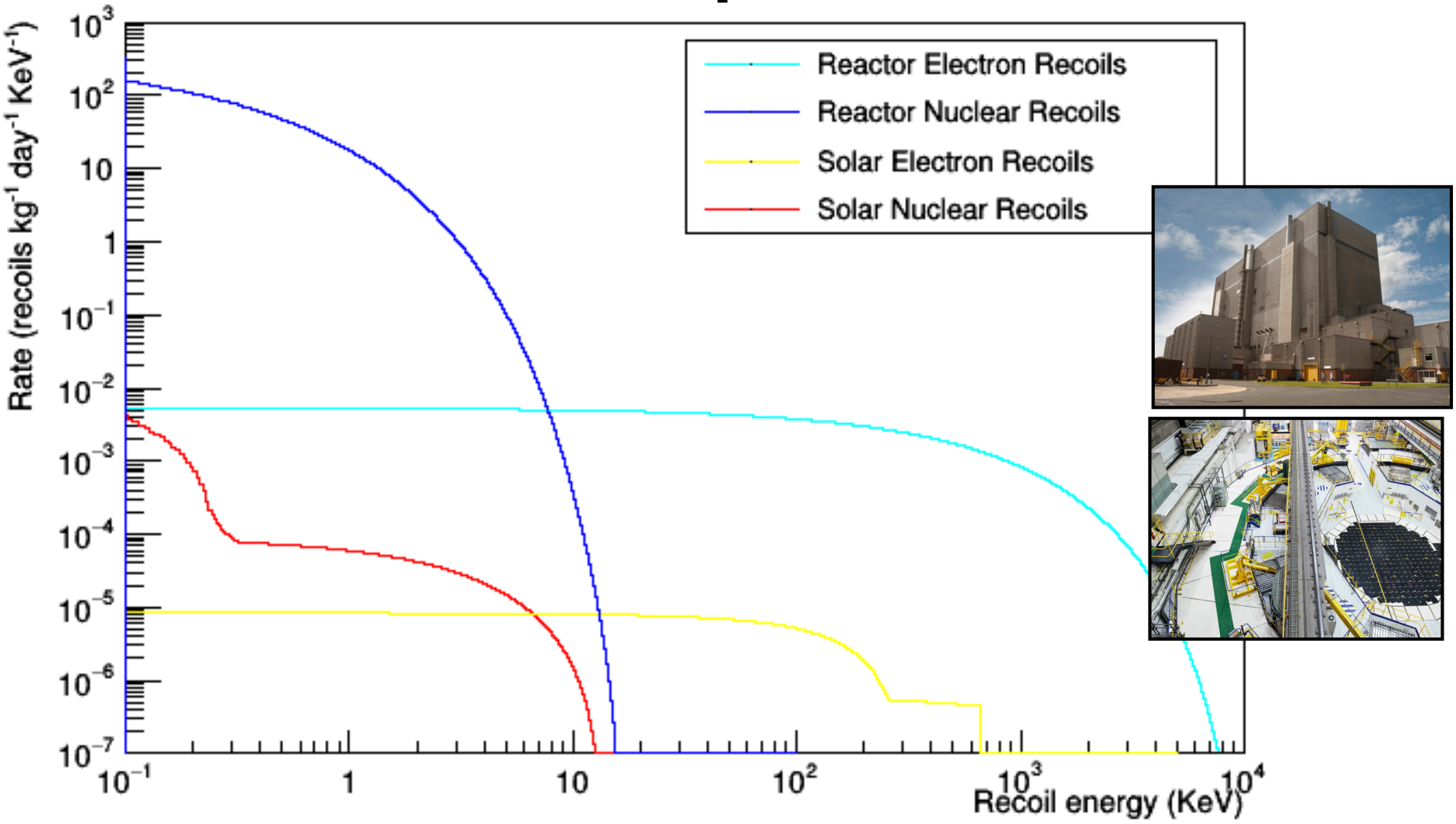
Coherent Neutrinos in CYGNUS

Fluorine in SF6 at 10m from a single reactor

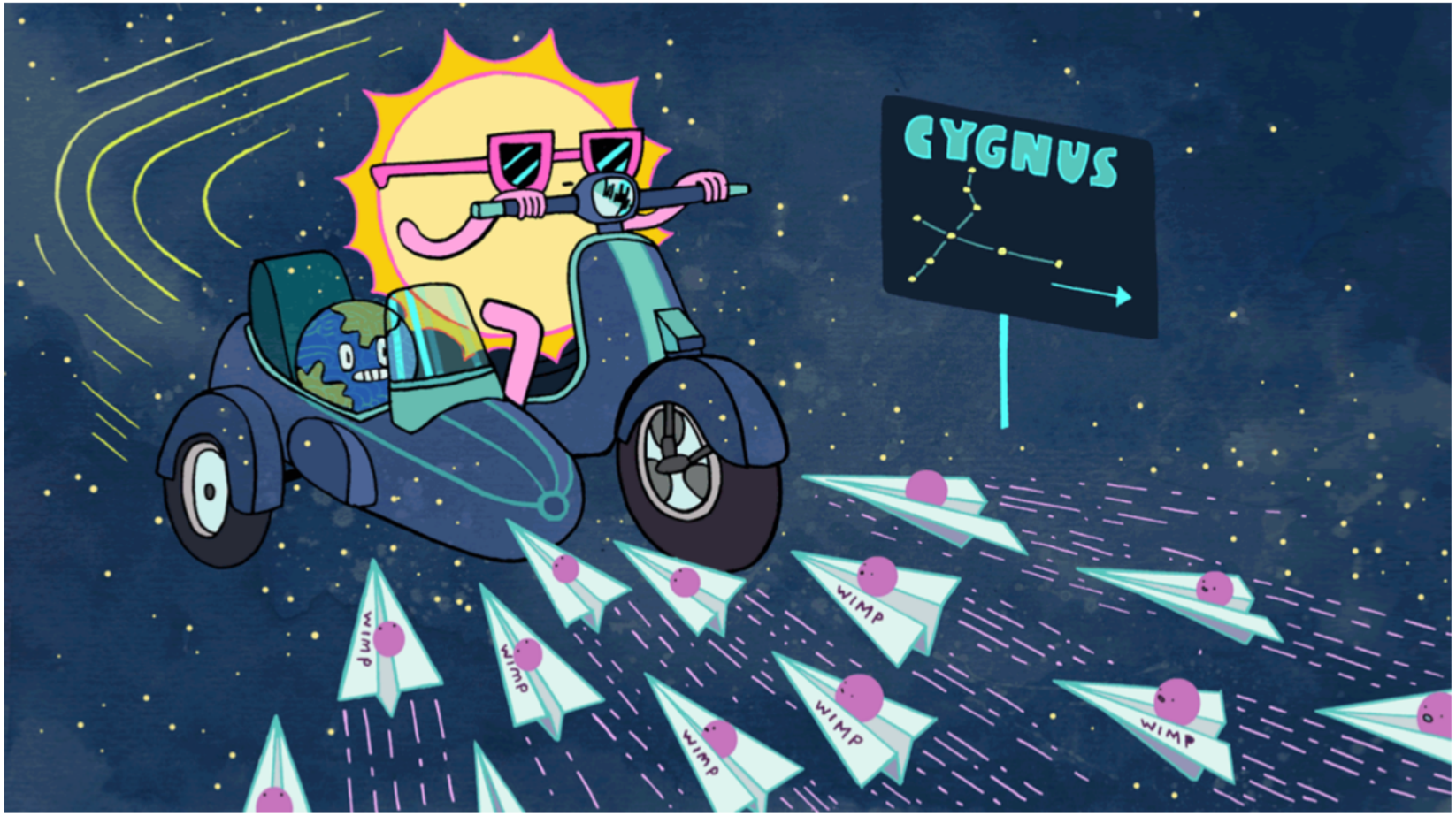
Electron and nuclear recoils c.f solar

Callum Eldridge

Hartlepool Estimates



Questions…



http://www.symmetrymagazine.org/article/wimps-in-the-dark-matter-wind