The University Of Sheffield.

Towards CYGNUS: A directional WIMP detector

Callum Eldridge

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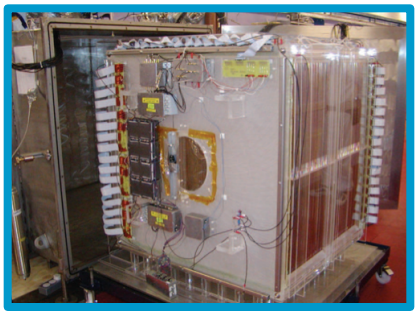
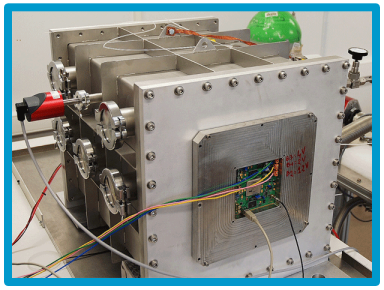
CYGNUS Proto-collaboration

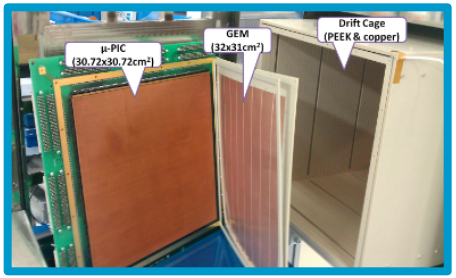
- 5 current generation detectors
- ~80 scientists
- 15 institutions
- 8 countries
- First meeting in 2007
- Recent RnD grants in Italy, Japan and Australia



DRIFT

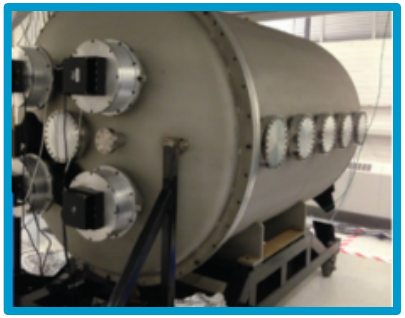


MIMAC



NEWAGE

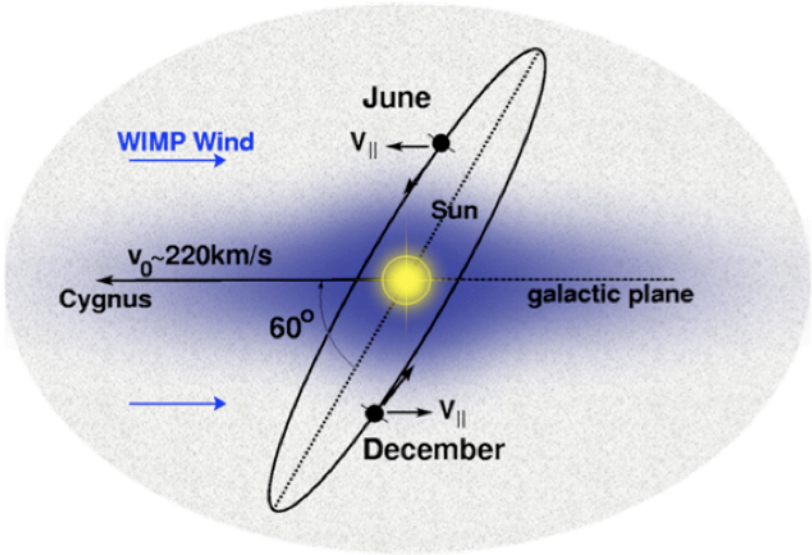
D^3

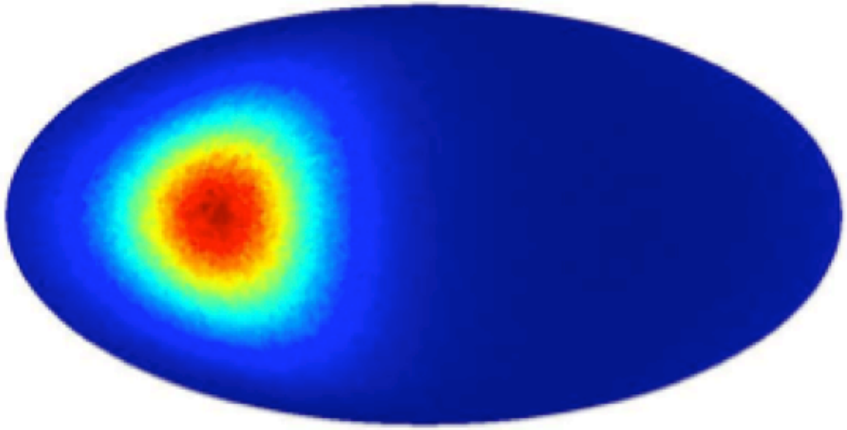


DMTPC

WIMP Wind

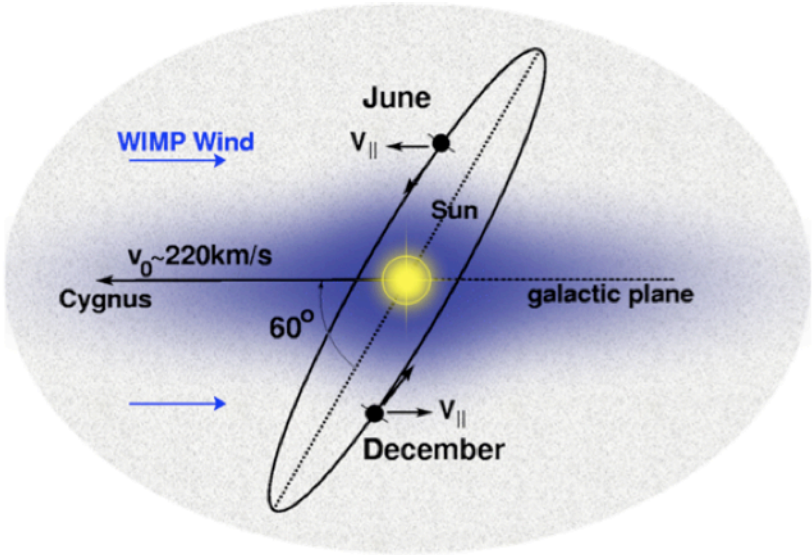
- Movement of Sun relative to dark matter halo
- Signal is from approximate direction of Cygnus Constellation

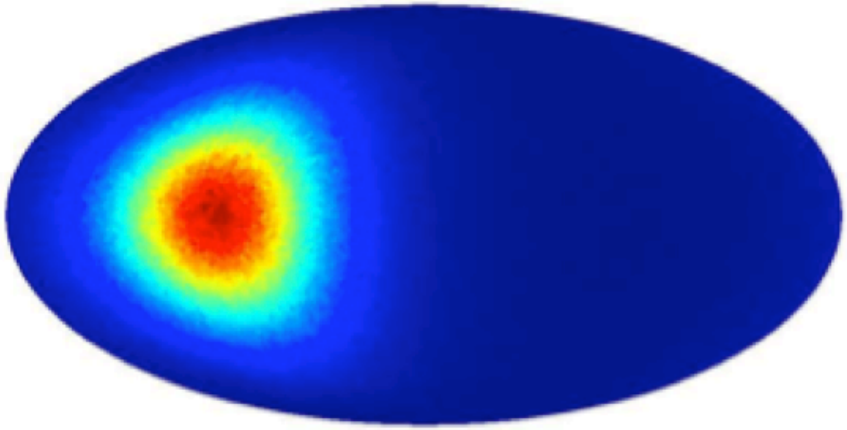




WIMP Wind

- Directionality gives a clean discovery parameter
- Can probe below neutrino floor





CYGNUS-1000

- Need capability to resolve recoil tracks
  → low pressure gas TPC
  (there are some other options –ask me at the end)
- Consequently very low fiducial mass/volume
  (~1 ton / 1000 m^3 at 50 Torr SF_6)
- Fluorine target: CF_4 or SF_6

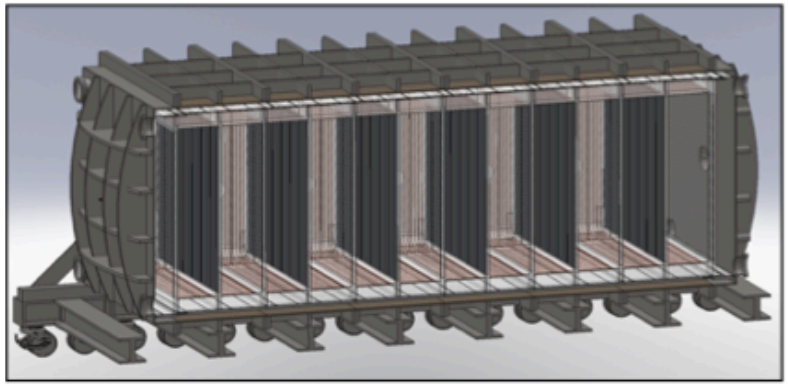
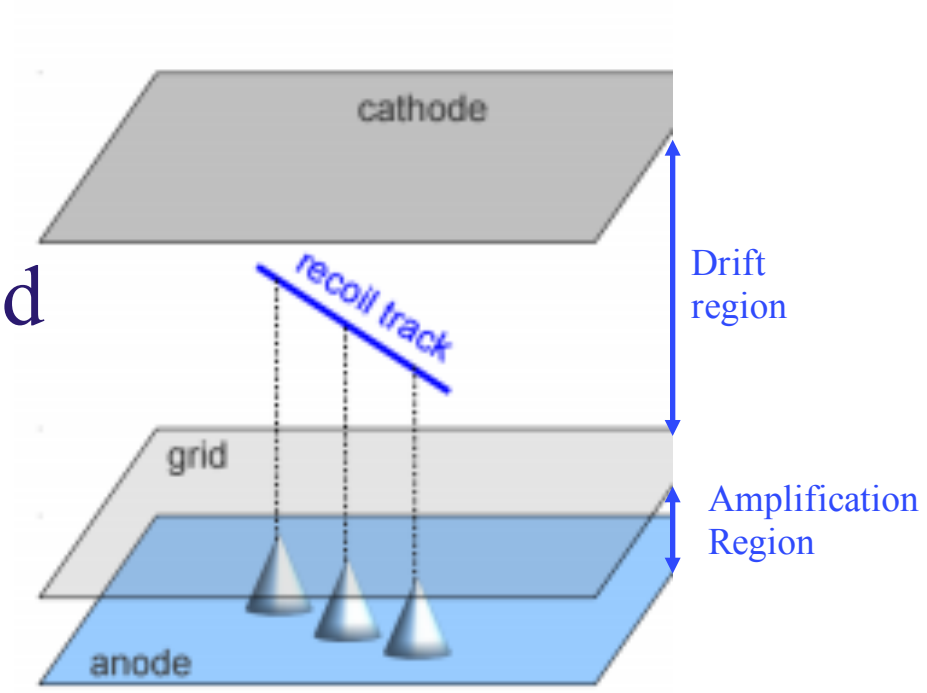


Diagram: Schematic for DRIFT-III

TPC basics

- Ionising particle creates track
- Charge cloud is drifted to the anode
- Signal is read out at the anode



TPC Instrumentation

- Ultimately limiting factor is cost
- Trade off between fiducial mass and resolution
- Must be robust

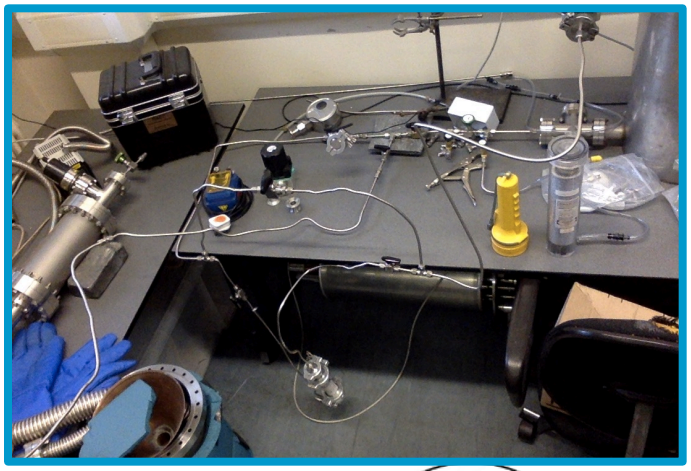
Readout type	Dimensionality	Segmentation ($x \times y$)
planar GEM	1-d (z)	10 cm × 10 cm
large pixels	1-d (z)	3 mm × 3 mm
wires	2-d (yz)	1 m wires, 2 mm pitch
optical CMOS	2-d (xy)	200 μm × 200 μm - t.b.d.
resistive strip Micromegas	3-d (xyz)	1 m strips, 200 μm pitch
pixel ASIC	3-d (xyz)	200 μm × 200 μm

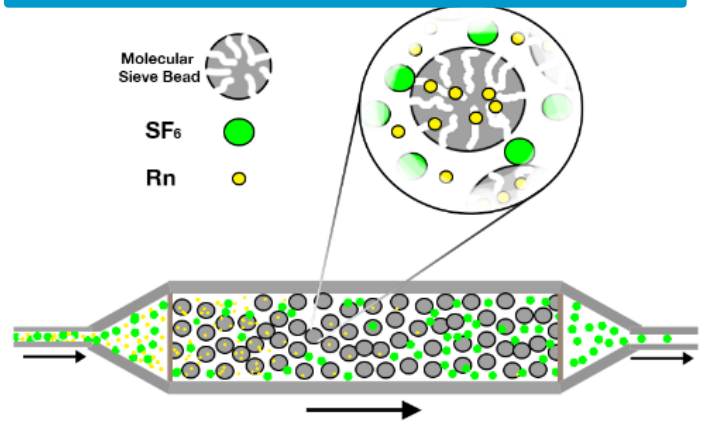
SF_6

- Negative ion drift – reduced diffusion allows larger volume detector
- High fluorine content – lots of target nuclei
- Non-toxic – makes operation in mines easier
- Minority carriers – fiducialisation

Sheffield – Radon removal in SF_6

- Vessel of proposed size requires gas re-circulation
- Radon = large source of background
- Molecular sieve traps radon

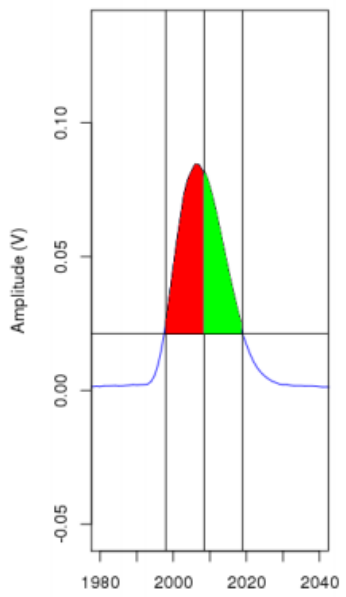


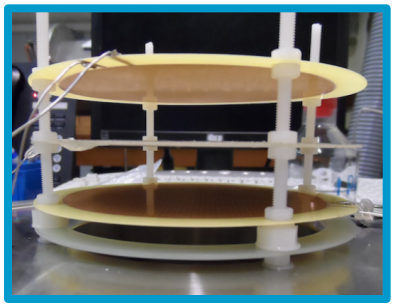


A.C. Ezeribe et al. 2017 JINST 12 P09025

Sheffield – head/tail in SF_6

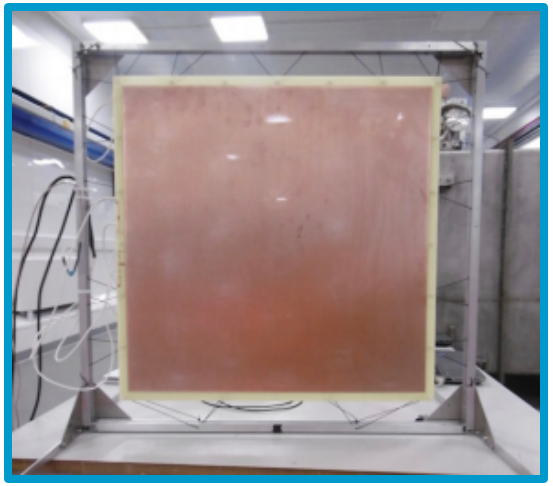
- Slowing of recoil nucleus produces a “Head” & “Tail” to charge cloud
- Enables determination of track direction
- Demonstrated with neutron recoils in for first time SF_6

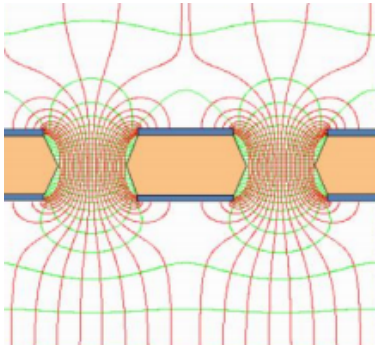




Sheffield – Large Area ThGEM

- Cheap, robust, large area readout?
- 1D – only get head/tail
- But we can combine with other, less robust readouts

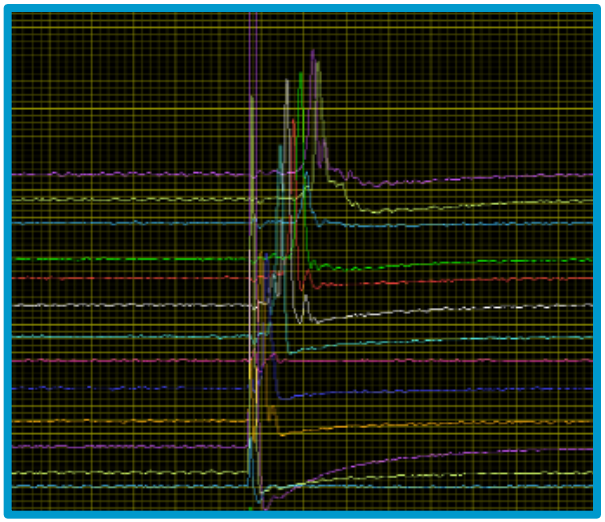


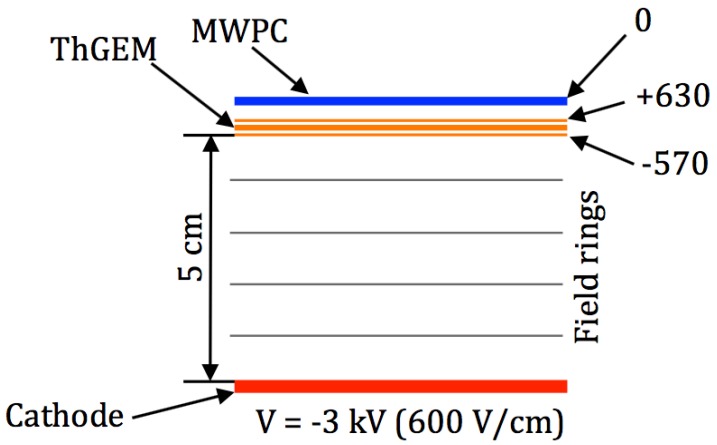


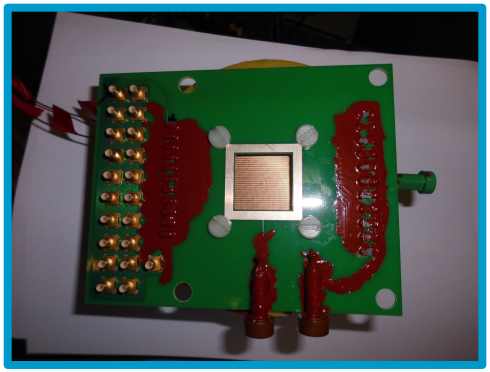
J. Burns et. al. 2017 JINST 12 T10006

Sheffield – ThGEM/Wire hybrid

- Charge amplification across thGEM
- Wires used to readout signal

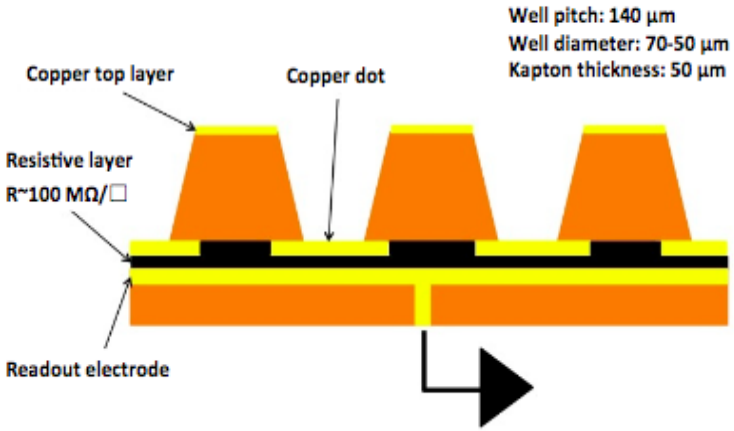


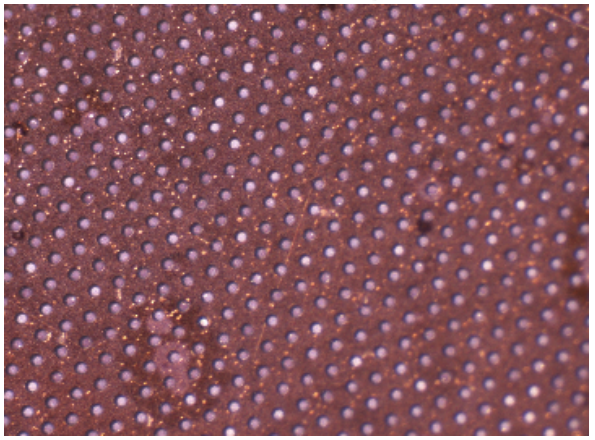




Sheffield – μRWELL

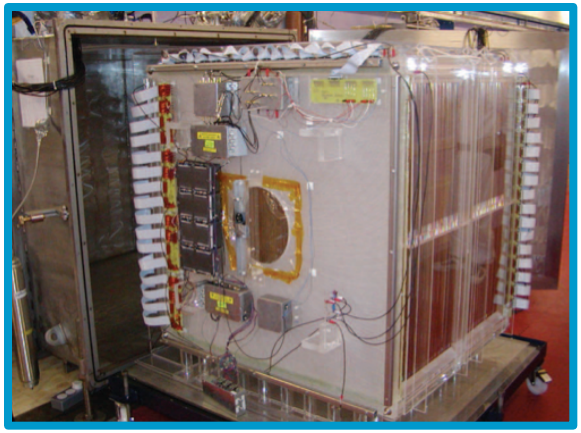
- Fabricated by CERN
- Strip readout
- Similar to thin GEM technology
- Resistive layer and backing board hopefully make it fairly robust

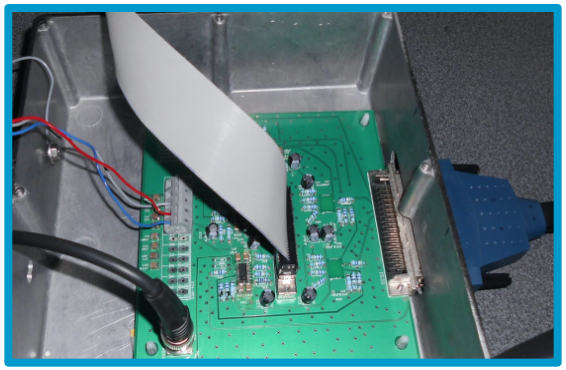




Sheffield – Other work

- DRIFT- head/tail + axial sensitivity in CS_2+CF_4+O_2
  (J.B.R. Battat et. al. 2016 JINST 11 P10019)
- Background simulations for CYGNUS-1000
- Multiplexing demonstration
  A. C. Ezeribe et. al. arXiv:1711.00943





CYGNUS KM

- ~3 m^3 vessel deployed in Kobe/Kamioka, Japan
- Also used as demonstrator for readout technologies
- 18 ‘windows’ to mount readouts
  - ThGEM
  - µRWELL
  - Optical
  - Pixel chips
  - MWPC
  - MicroMegas

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To Discover And Understand.

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(BACKUP) Other directional detection techniques

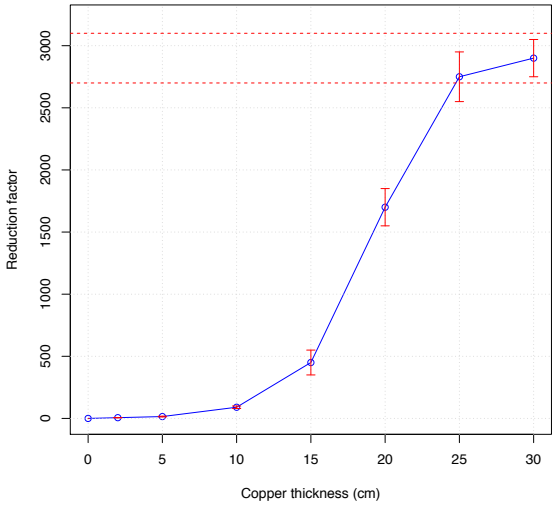
- Nuclear emulsions
- Columnar recombination – (Xe)
- Anisotropic scintillators – ($ZnWO_4$)
- Planar graphene target
- Carbon nanotubes
- DNA/RNA strands

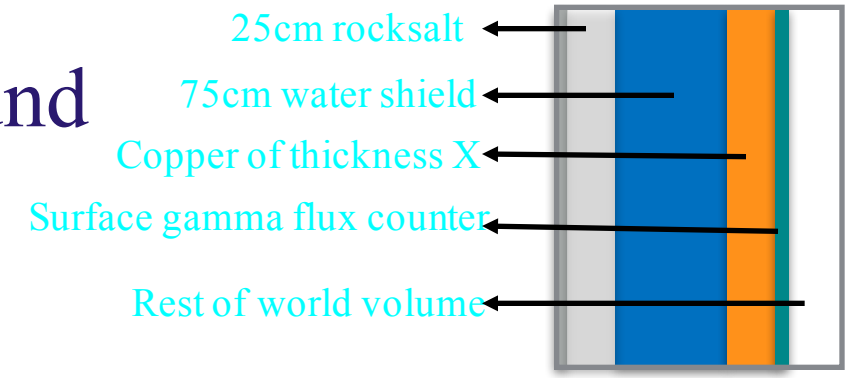
Cygnus 1000 vessel considerations

- Background Sources – magnitude, type
  - Rock
  - Vessel
  - Radon
- Material – strength, background, outgassing
  - Acrylic
  - Steel
  - Copper
- Shielding – neutrons, gammas, location
  - Water
  - Acrylic
  - Vessel material
- Shape – available space, maintenance, cost
  - Distributed
  - Modular
  - Single vessel

Sheffield – Background simulations

- Model gamma and neutron creation and propagation
- Lots of competing considerations
- Aim for ~one background event /year





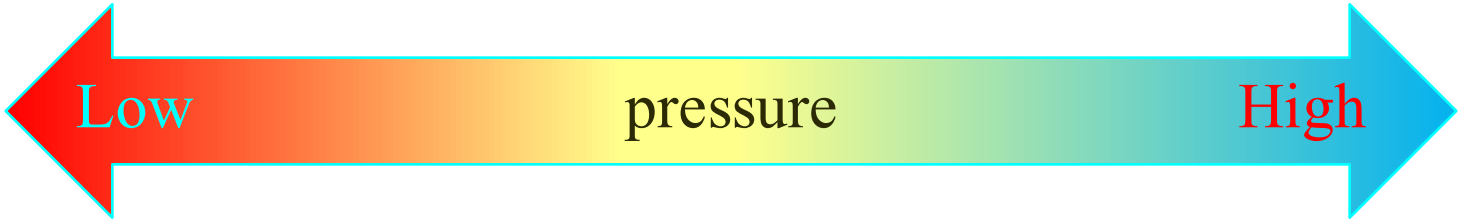
Gas - Pressure

+Lower gas impurity

+Longer recoil track length

-More Impurities

-Shorter recoil track length



-More Expensive vessel

-Less fiducial mass/volume

+Cheaper vessel

+More fiducial mass/volume

Science goals

- Robust confirmation of WIMP discovery above neutrino floor (DAMA?)
- Discovery of WIMP below neutrino floor (1-1000 GeV)
- Discover WIMP streams (Sagittarius stream?)
- Solar neutrino observatory

Contents

- WIMP wind & need for directional detection
- The CYGNUS-1000 detector
- TPC's general points
- Current work at Sheffield

