Simplified readout for CYGNUS-TPC:

a massive directional dark matter detector

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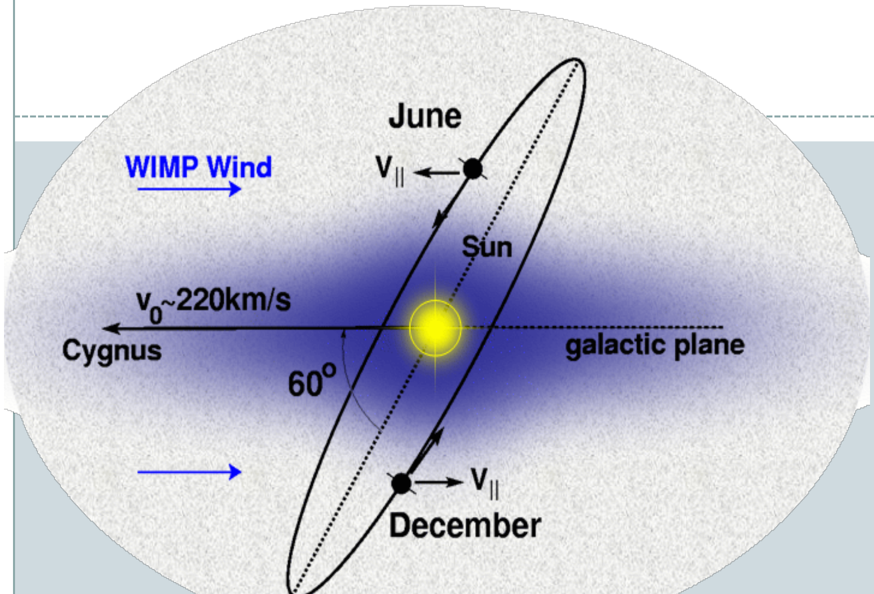
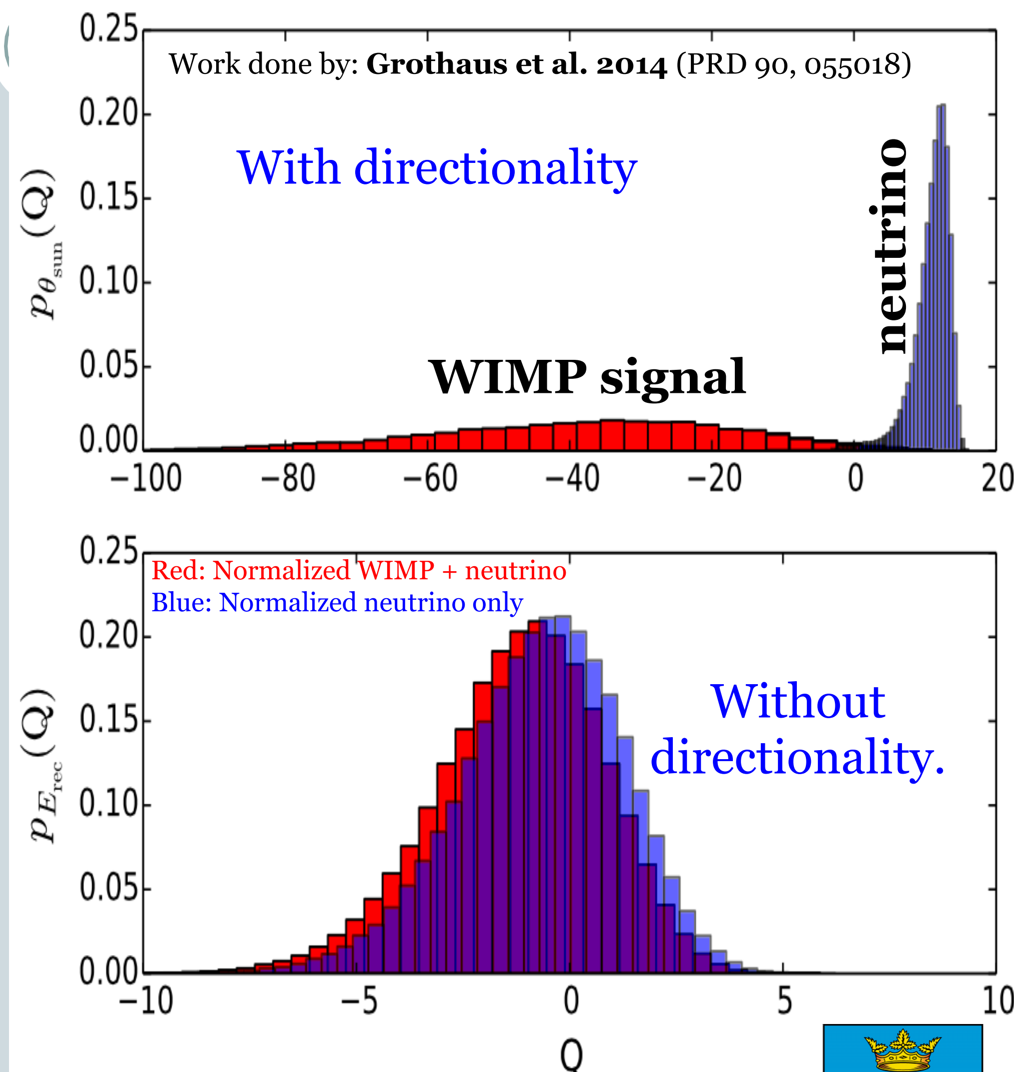
Our Motivation



https://www.hep.shef.ac.uk/research/dm/drift.php

- WIMP wind coming from CYGNUS
- WIMP induced recoil tracks should point back to CYGNUS
- Will need massive (in tons) directional detector to be able to go beyond the neutrino floor.
- Plus enough physics run time.
  See: O'Hare et al. (2015) PRD 92, 063518.
- No "neutrino floor" for directional DM detectors **Grothaus et al. 2014.**



- Study done for 6 GeV WIMP in CF_4 TPC

Plans for CYGNUS-TPC

Los Angeles, USA
June 2015.

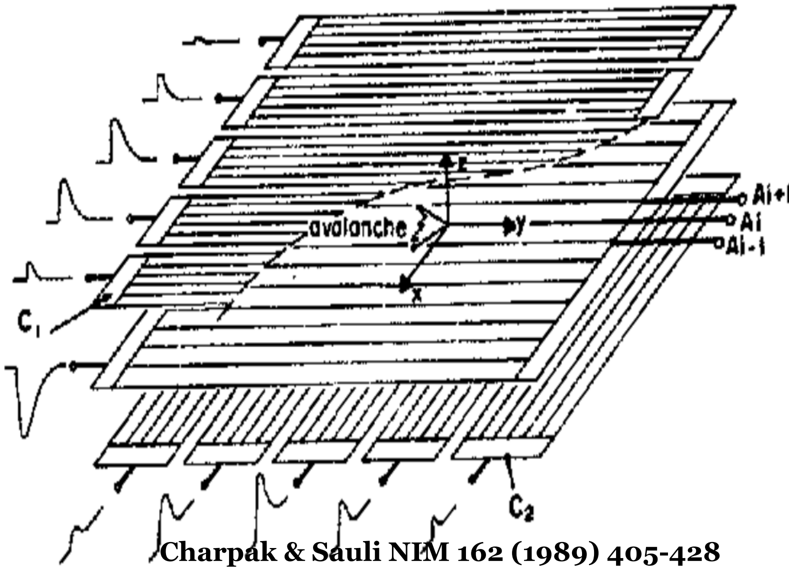
Next worshop:
7-8 April 2016,
Italy.

Lots of phone meetings.

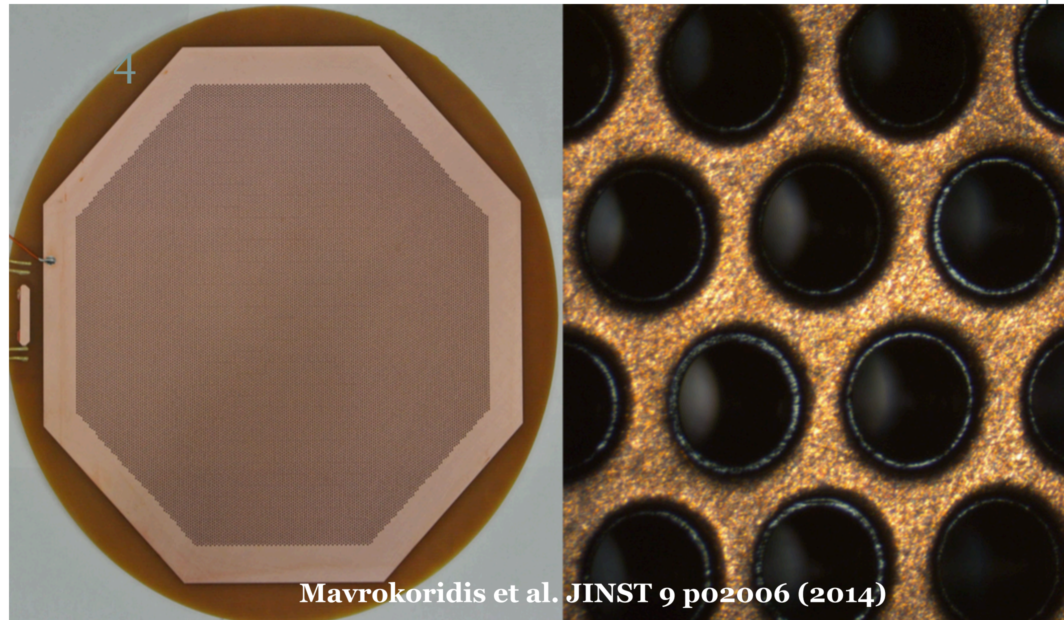
Boulby, UK
Jan. 2016

CYGNUS-TPC WORKSHOP 2016.

Possible readout for CYGNUS



Charpak & Sauli NIM 162 (1989) 405-428

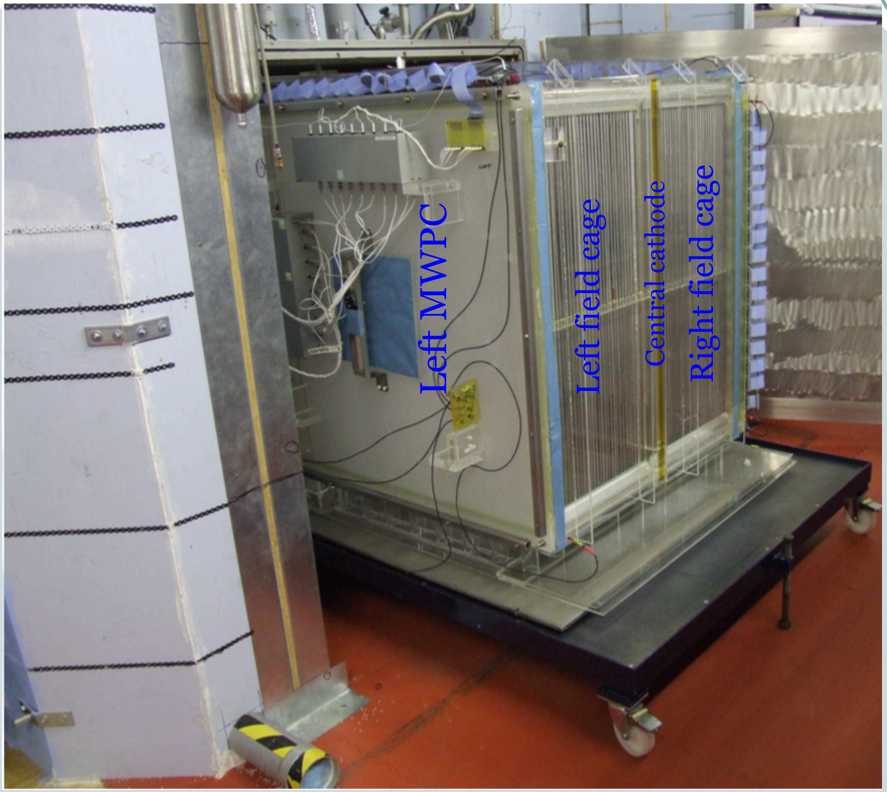


Mavrokoridis et al. JINST 9 p02006 (2014)

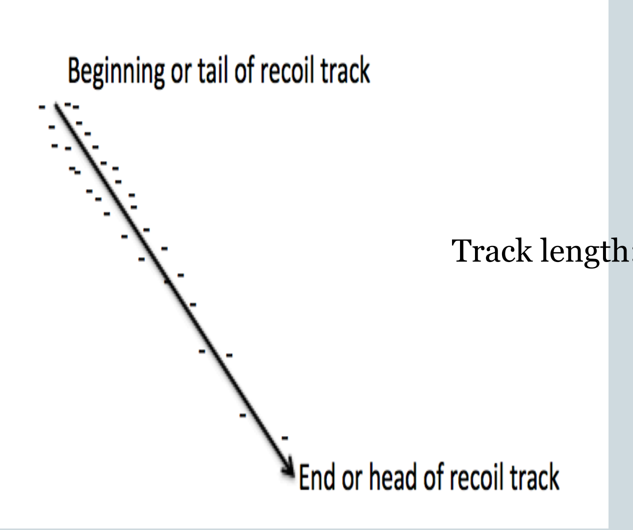
- Conventional MWPC: limited to ~1 mm resolution in x-direction.
- More wires: means more money for readout electronics.
- Robust, good gas gain: $10^4 - 10^6$ in pure CF_4.
- Configuration can be double ThGEM or tripple ThGEM.
- Can be mesh based: Micromegas etc.

- Any favored readout for CYGNUS should be sensitive to signal head-tail effect.

DRIFT-IId DETECTOR AND HEAD-TAIL



- Fiducial volume: 0.8 x 0.8 x 0.8 m^3.
- Fiducial mass: 137 g.
- Gas: 30:10:1 Torr of CS_2:CF_4:O_2 gas mixture.
- Drift field: ~600 Vcm^{-1}.



Track length: 2 -10 mm

- Consists of two back-to-back gas TPC
- One 1 m^2 central cathode, two 1 m^2 MWPC readouts.

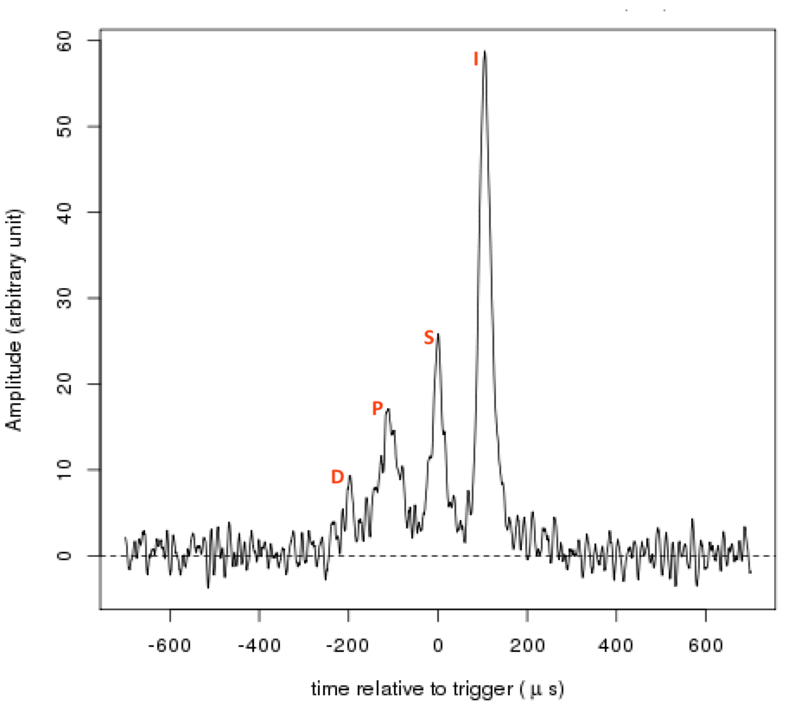
For details on HT measurement in DRIFT-IId: **AstroPart. Phy. 31 (2009) 261-266**

Fiducialisation in DRIFT

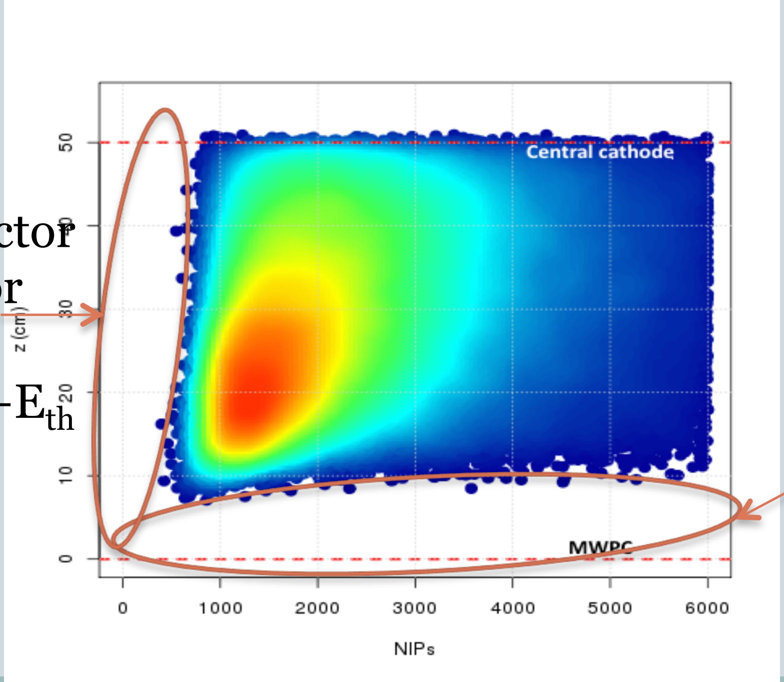
- Added 1 Torr of O2 in 30+10 Torr of CS2+CF4 gas mixture.
- This results to three minority carriers and one main charge cloud.

$$z = (t_I - t_P)\left(\frac{v_I v_P}{v_P - v_I}\right)$$

See: **Battat et al. 2015 PDU 9-10, 1-7.**



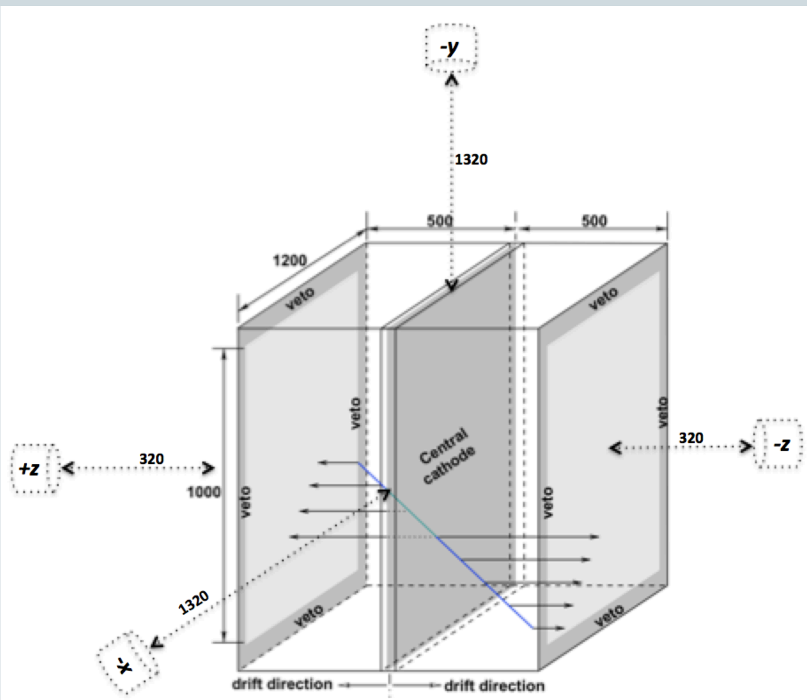
Due to detector efficiency for low energy events in z +E_{th}

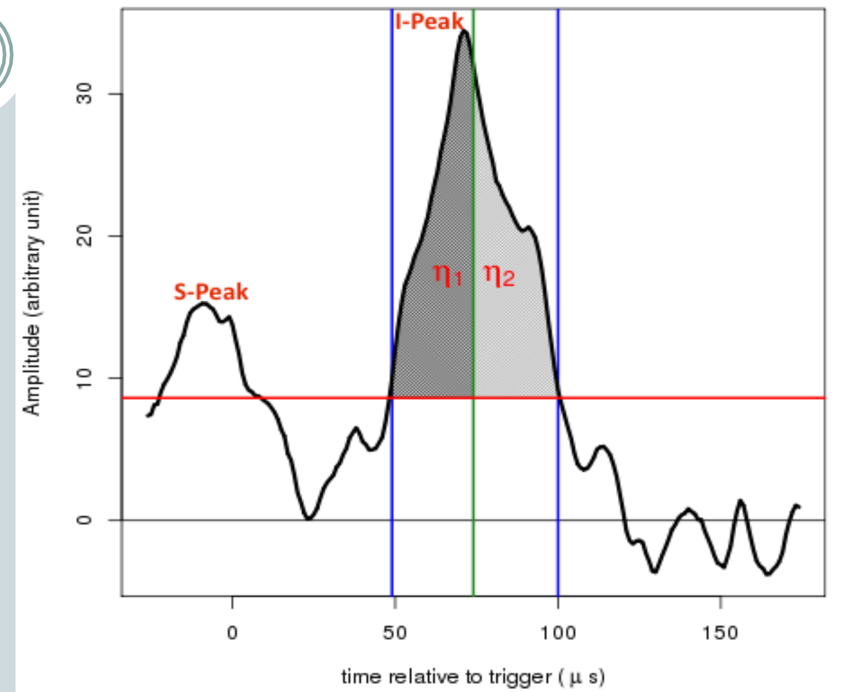


Low-z unfiducialised events were rejected in analysis. Low-z events are unfiducialised due to lack of peak separation.

Directionality after fiducialisation

- DRIFT-IId was exposed to fast neutrons from Cf-252 source from different directions.
- Measured asymmetry in charge distribution along recoil tracks known as HT effect.

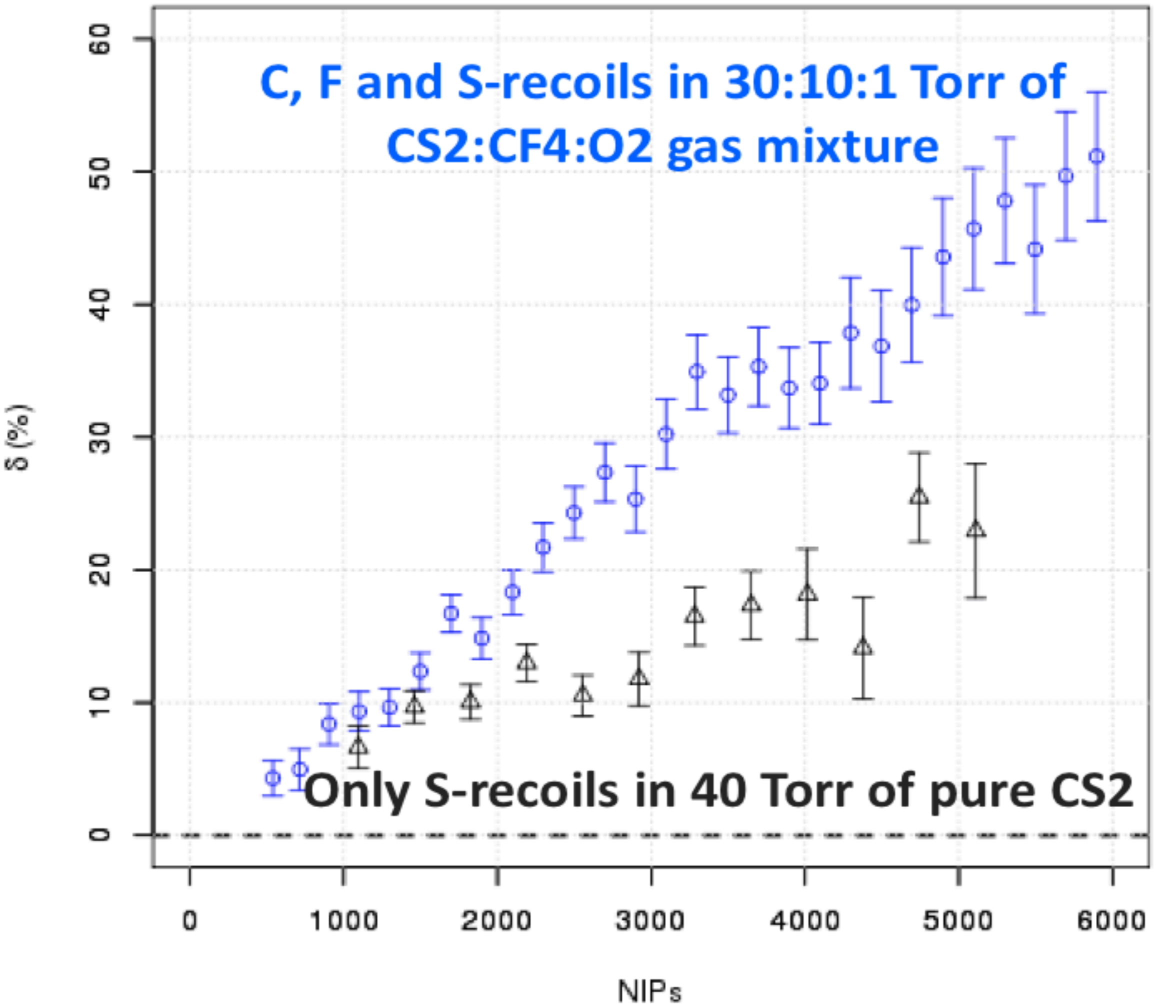




- More charge in the beginning (TAIL) than the end (HEAD) of nuclear recoil tracks. See: **AstroPart. Phy. 31 (2009) 261-266.**
- When η_1 is the TAIL and η_2 is the HEAD of a recoil track, HT asymmetry parameter α is:

$$\alpha = \frac{\eta_1}{\eta_2}$$

Head-tail results



$$\delta = \left[\frac{200\left|\langle\alpha_L\rangle - \langle\alpha_R\rangle\right|}{\langle\alpha_L\rangle + \langle\alpha_R\rangle}\right]_{op}$$

- Sensitive to HT at lower energy compared old result from only S-recoils is due to lower analysis threshold.

- 50 keV fluorine equivalent recoil energy is 1055 NIPs.

See: **Hitachi RPC 77 (2008) 1311-1317**

For the pure CS_2 results, see: **AstroPart. Phy. 31 (2009) 261-266**

Neutron events for 3-sigma H-T

- HT significance was computed for different numbers of events and was used to put a constraint on the number of neutron events required for HT detection.

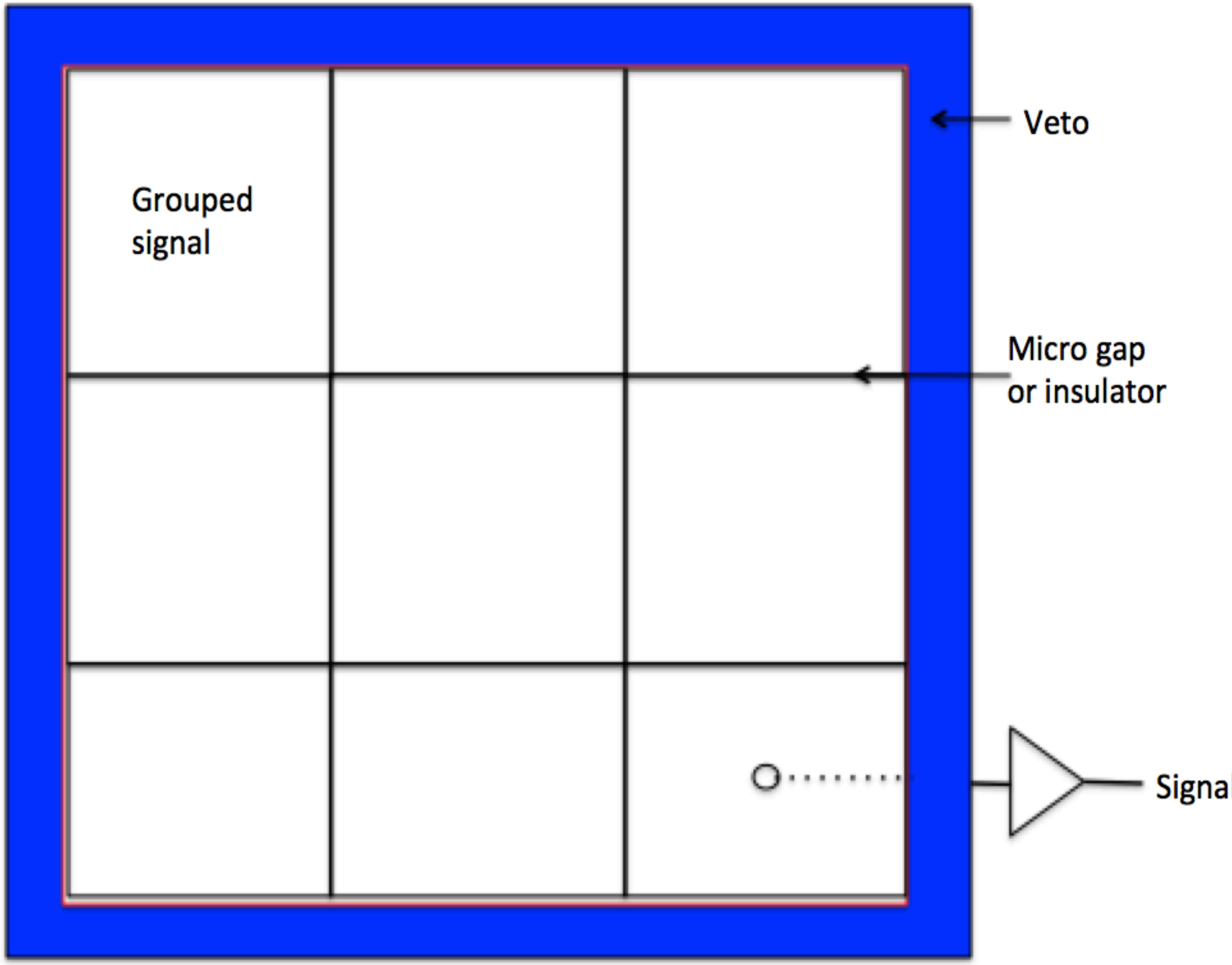
- Considering only events from the optimal directions (+z and –z runs).

- It was found that ~320 neutron events will be enough for 3-sigma head-tail detection.

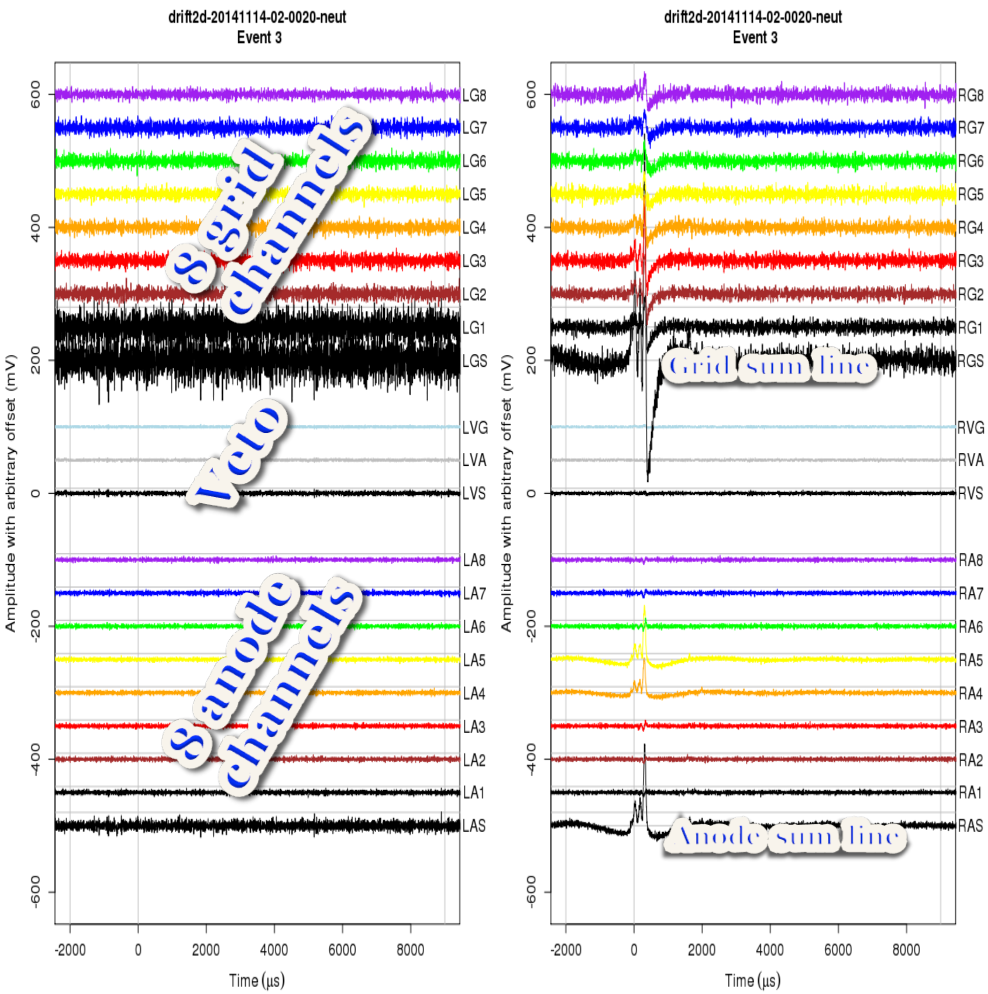
- MC will be required to estimate the number of events for a given mass of WIMP that will produce this result.

Can reduce cost of readout

- Can group signal even with ThGEMs.
- Though, smaller gaps will increase the capacitance.
- Micro gaps needed for alpha discrimination.
- Can include fiducialisation and retain head-tail.



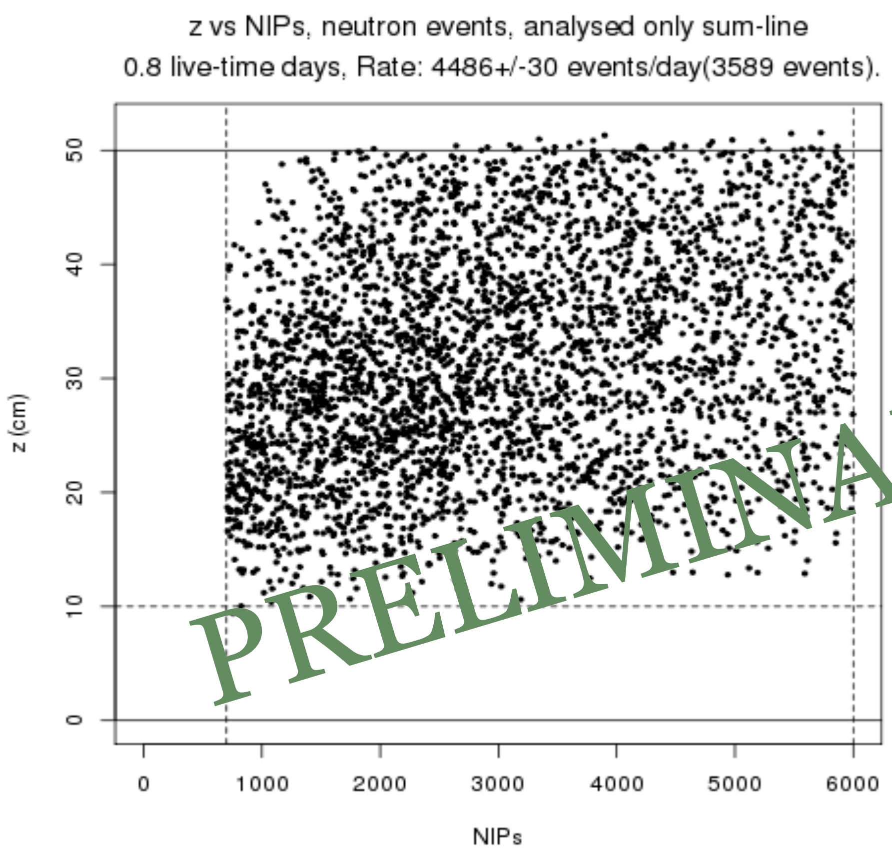
Test analysis for a simplified readout

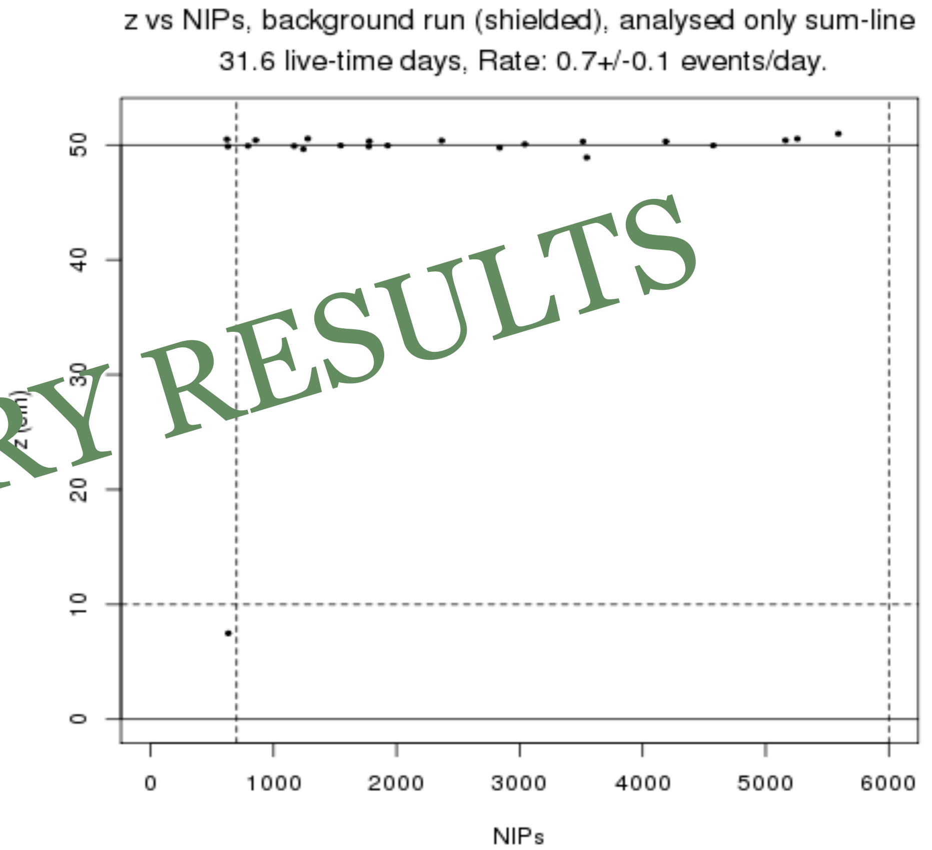


Normal DRIFT DAQ configuration.

- MWPC in the simplified mode:
- Grouped **all** 448 anode wires and
- Grouped **all** 448 grid wires in DRIFT.
- Reduced the number of readout channels to 4 and the vetos.
- One anode, one grid channel from each detector.
- Analyzed neutron events and
- Background events in this new grouped data mode.
- Turned off number of hits cut (can be active in analysis of Cygnus data).

Results: simplified readout analysis





- ❑ Still sensitive to neutron induced recoils.
- ❑ No background event seen over 31.6 live-time days, gammas and electron recoils may show up for longer runs.
- ❑ Optimization of this method requires more work.

CONCLUSION

- Preliminary results suggest that the simplified and low cost readout could work for massive directional dark matter detectors for instance CYGNUS-TPC.
- This can be achieved without compromising the detector's head-tail sensitivity.
- It can also be fiducialised using existing technologies.
- Though gamma events and electron recoils are potential problems of this new set-up.