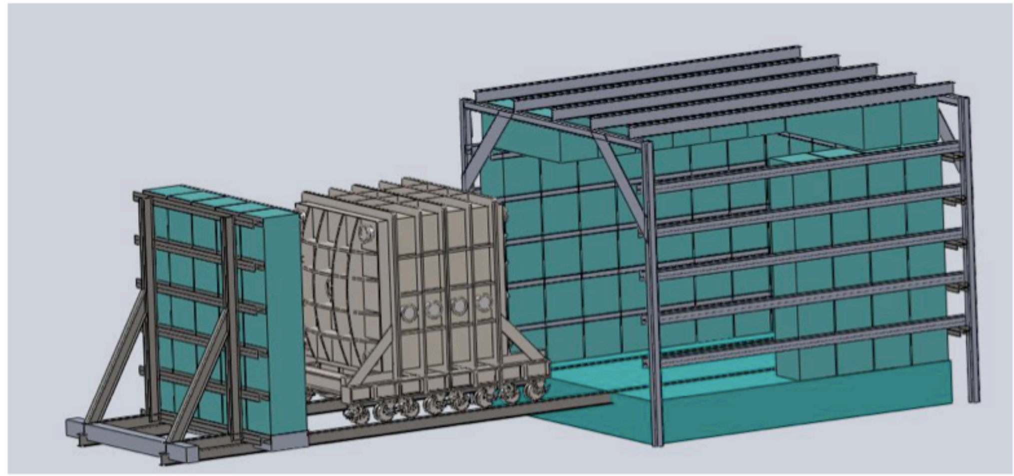
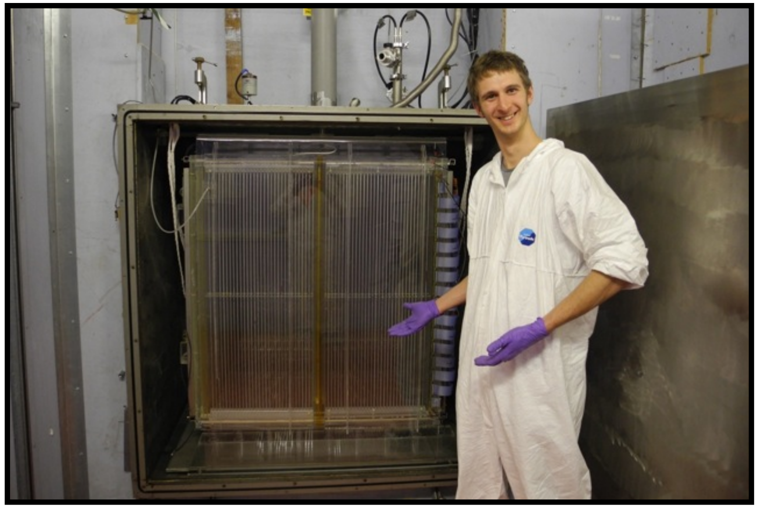
The DRIFT Directional Dark Matter Experiments....



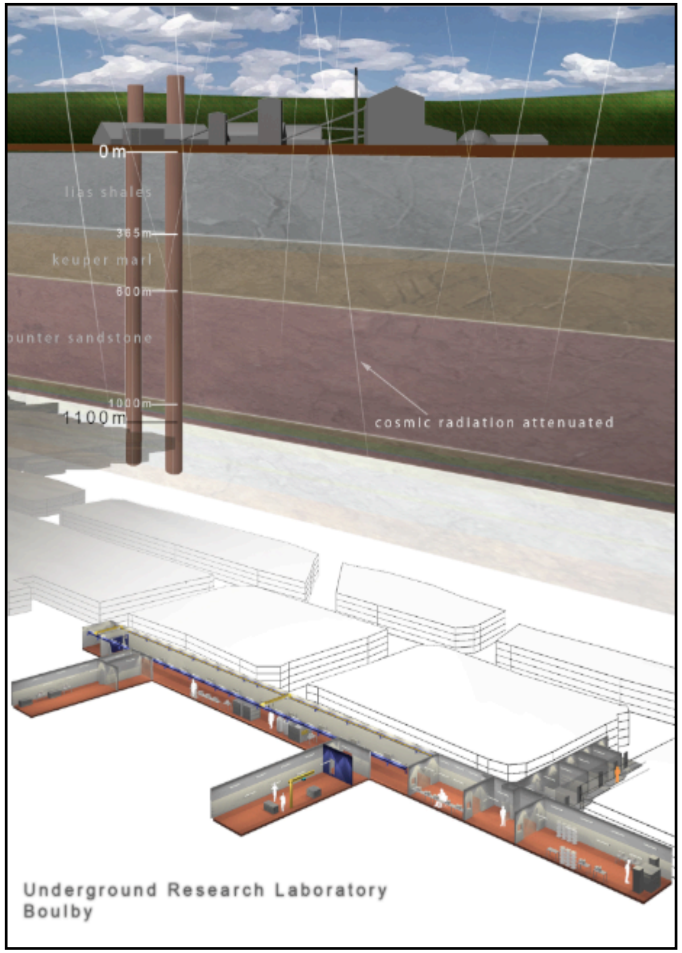
Neil Spooner, University of Sheffield
DRIFT collaboration, Boulby
(Occidental, UNM, USC, Sheffield, Edinburgh, STFC)

- DRIFT IIa-d
- DRIFT IIe - scale-up tests
- DRIFT III - $24m^3$
- Tonne-scale



Boulby Mine - Palmer Laboratory

- Current site (1.1 km deep) in salt rock
- Deeper excavation underway to 1.4 km depth
- Suitable for a large TPC!



Boulby - Current Status of Projects

Palmer Laboratory now funded under STFC-Futures programme

DRIFT-IId

SKY0,1

DM-ICE17

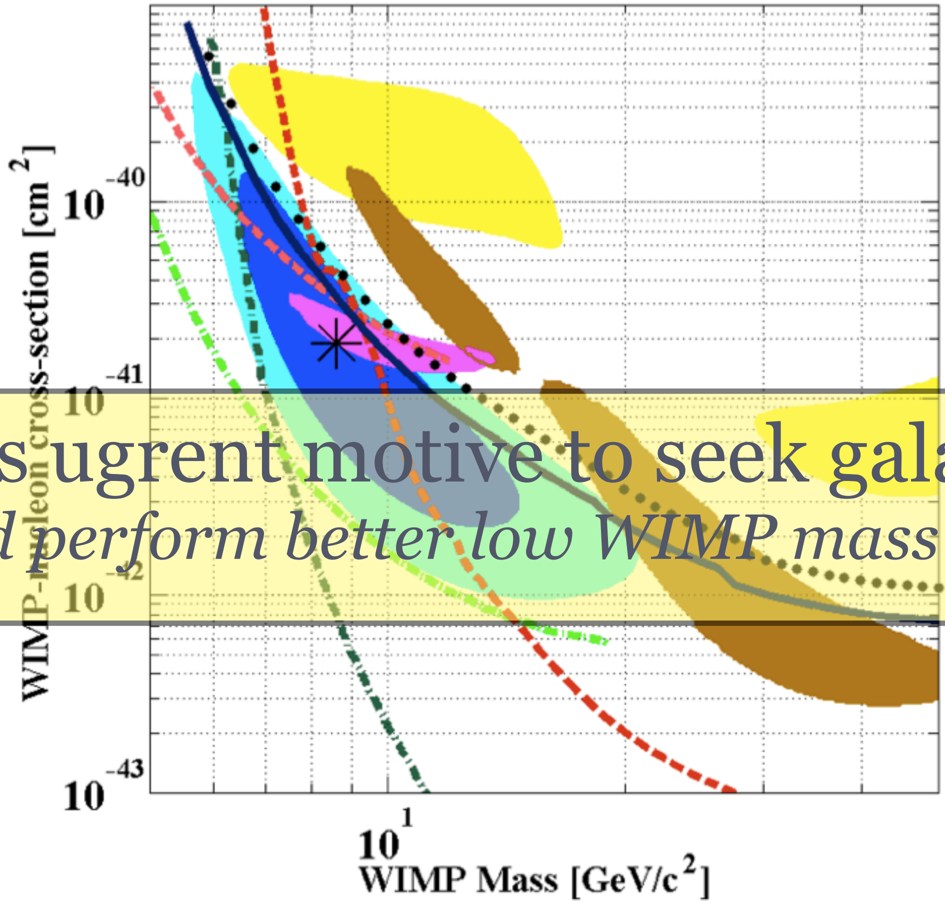
PROJECTS

- **DRIFTIId, DRIFTIIe (under construction), DRIFTIII (new lab)**
- **SKY0, SKY1 (climate change)**
- **DM-ICE test stand**
- **Project Deep Carbon (carbon sequestration and muon tomography)**
- **Extreameophiles**
- **Low background studies, radon facility**

ZEPLIN III now closed, DRIFTIId continuing, DRIFTIIe under construction

Excitment and Confusion in WIMP World

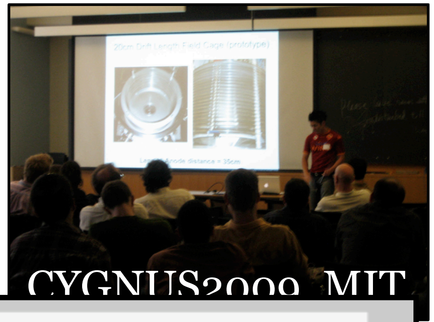
- Currently 6 direct search experiments see events above expected background - DAMA/LIBRA, CoGENT, CRESST, CDMS/Edelweiss
  and three/four claim detection of WIMP DM



There is ugrent motive to seek galactic signals
and perform better low WIMP mass searches

- There is also indirect claimed evidence, e.g. the spectrum of gamma rays from the region surrounding the Galactic Centre peaks at a few GeV, consistent with a ~7-10 GeV dark matter particle annihilating largely to leptons

CYGNUS Workshops 2007-2009-2011-2013..



CYGNUS 2007

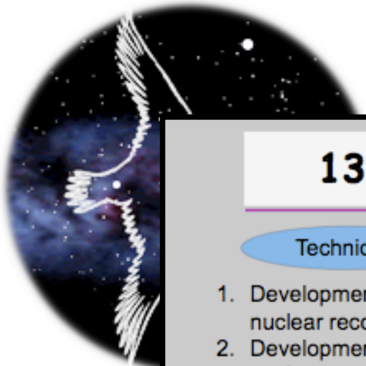
First Workshop on Directional Detection of Dark Matter

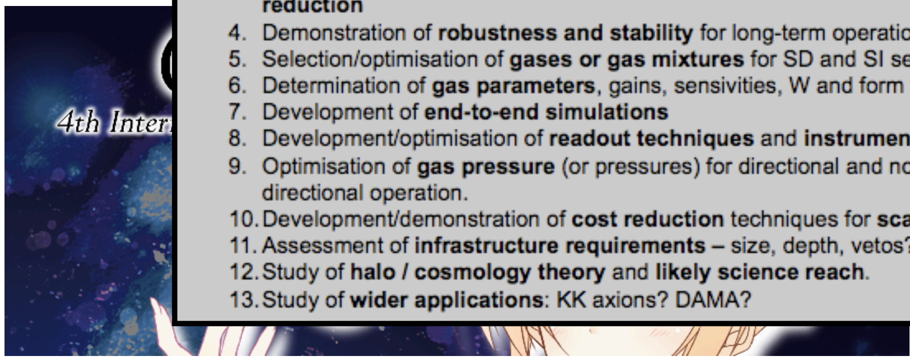
22-24 July 2007

Boulby Underground Laboratory, UK

ILIAS-N3 - advanced detectors meeting

CYGNUS 2009





13 Directional R&D Challenges

Techniques | Implementation | Theory

1. Development/demonstration of **directional sensitivity** for low energy nuclear recoils
2. Development/demonstration of **head/tail discrimination** for low energy nuclear recoils
3. Development/demonstration of **background discrimination** and **reduction**
4. Demonstration of **robustness and stability** for long-term operation
5. Selection/optimisation of **gases or gas mixtures** for SD and SI sensitivity
6. Determination of **gas parameters**, gains, sensivities, W and form factors
7. Development of **end-to-end simulations**
8. Development/optimisation of **readout techniques** and **instrumentation**
9. Optimisation of **gas pressure** (or pressures) for directional and non-directional operation.
10. Development/demonstration of **cost reduction** techniques for **scale-up**
11. Assessment of **infrastructure requirements** – size, depth, vetos?
12. Study of **halo / cosmology theory** and **likely science reach**.
13. Study of **wider applications**: KK axions? DAMA?

International Journal of Modern Physics A
Vol. 25, No. 1 (2010) 1–51
© World Scientific Publishing Company
World Scientific
www.worldscientific.com

THE CASE FOR A
DIRECTIONAL DARK MATTER DETECTOR AND
THE STATUS OF CURRENT EXPERIMENTAL EFFORTS

S. AHLEN,[1] N. AFSHORDI,[23,31] J. B. R. BATTAT,[*,15] J. BILLARD,[11]
N. BOZORGNIA,[3] S. BURGOS,[21] T. CALDWELL,[15,22] J. M. CARMONA,[12,13]
S. CEBRIAN,[12,13] P. COLAS,[4] T. DAFNI,[12,13] E. DAW,[26] D. DUJMIC,[15] A. DUSHKIN,[2]
W. FEDUS,[15] E. FERRER,[4] D. FINKBEINER,[6] P. H. FISHER,[15] J. FORBES,[21]
T. FUSAYASU,[16] J. GALAN,[12,13] T. GAMBLE,[26] C. GHAG,[5] I. GIOMATARIS,[4]
M. GOLD,[18] H. GOMEZ,[12,13] M. E. GOMEZ,[7] P. GONDOLO,[29] A. GREEN,[20]
C. GRIGNON,[11] O. GUILLAUDIN,[11] C. HAGEMANN,[18] K. HATTORI,[10]
S. HENDERSON,[15] N. HIGASHI,[10] C. IDA,[10] F. J. IGUAZ,[12,13] A. INGLIS,[1]
I. G. IRASTORZA,[12,13] S. IWAKI,[10] A. KABOTH,[15] S. KABUKI,[10] J. KADYK,[14]
N. KALLIVAYALIL,[15] H. KUBO,[10] S. KUROSAWA,[10] V. A. KUDRYAVTSEV,[26]
T. LAMY,[11] R. LANZA,[15] T. B. LAWSON,[26] A. LEE,[15] E. R. LEE,[18] T. LIN,[6]
A. TAKEDA,[28] T. TANIMORI,[10] K. TANIUE,[10] A. TOMAS,[12,13] H. TOMITA,[1]
K. TSUCHIYA,[10] J. TURK,[18] E. TZIAFERI,[26] K. UENO,[10] S. VAHSEN,[14]

White Paper
112 authors

International Journal of Modern Physics A Vol. 25, No. 1 (2010) 1–51

*Institute of Particle and Nuclear Studies, KEK, Tsukuba, Japan
[10] Kyoto University Kitashirakawa-oiwakecho, Sakyo-ku, Kyoto, 606-8502, Japan
[11] Laboratoire de Physique Subatomique et de Cosmologie, Université Joseph Fourier Grenoble 1, CNRS/IN2P3,

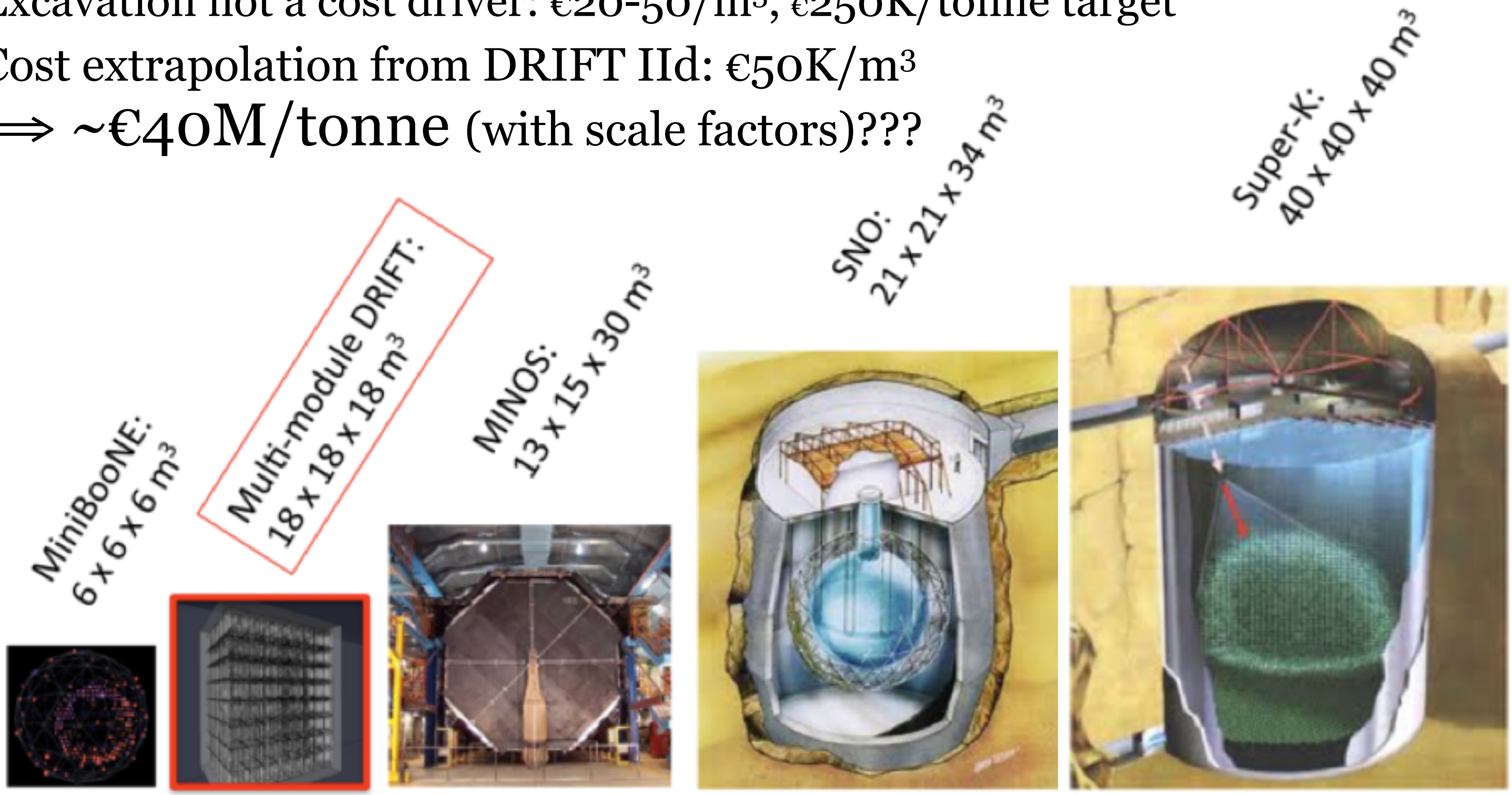
Towards Tonne Scale

- A 1 Tonne target is not unimaginable - target (10keV Thresh, 0 bg) would give 10^{-10}pb (raw) & >10^{-9}pb (halo) SI sensitivity.
- Vol = 2,500–10,000m^3 (160-40 Torr).
- 1/30th-1/120th volume of LNGS
- 4/3^{rds} – 1/3rd the size of MINOS

Excavation not a cost driver: €20-50/m^3, €250K/tonne target

Cost extrapolation from DRIFT IId: €50K/m^3

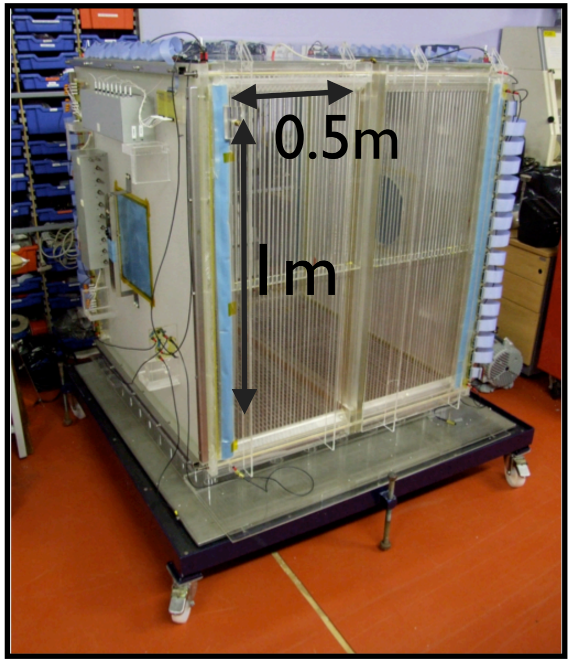
⇒ ~€40M/tonne (with scale factors)???

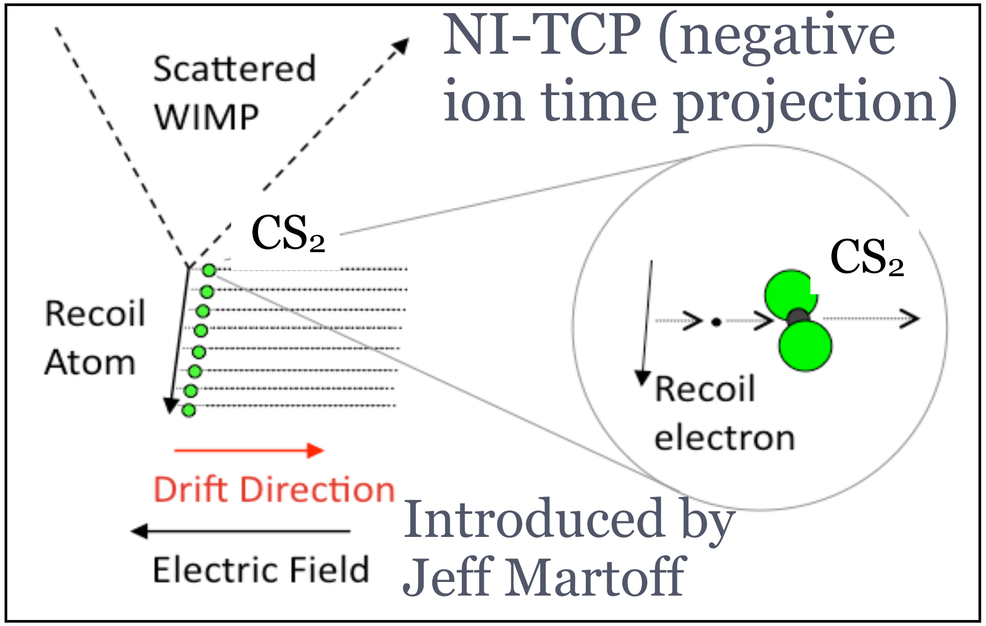


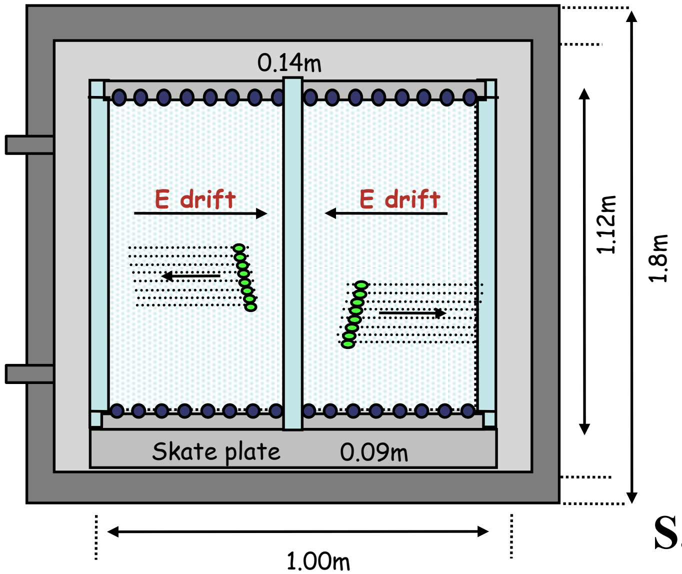
DRIFT History

- DRIFT is a proven directional detector
- Operational in the Boulby Mine since 2001
- DRIFT-I, DRIFT-IIa, DRIFT-IIb, DRIFT-IIc and DRIFT-IId

DRIFT II Concept







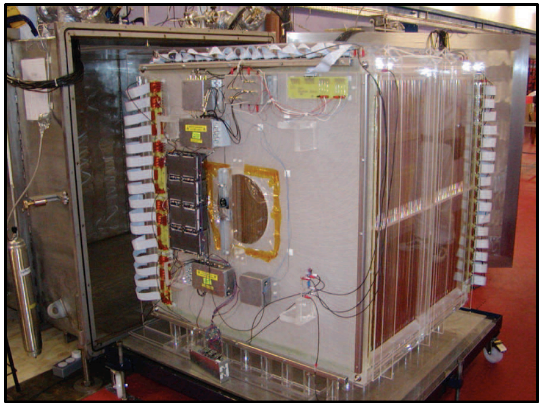
- 1 m^3 active volume - back to back MWPCs
- Gas fill 40 Torr CS_2 => 167 g of target gas
- 2 mm pitch anode wires left and right
- Grid wires read out for Δy measurement
- Veto regions around outside
- Central cathode made from 20 μm diameter wires at 2 mm pitch
- Drift field 624 V/cm
- Modular design for modest scale-up

S. Burgos et al., Nucl. Instr. Meth. A 584, 114 (2008)

DRIFT IIa-d Summary

- Operational in the Boulby Mine since 2001
- DRIFT-I, DRIFT-IIa, DRIFT-IIb, DRIFT-IIc, DRIFT-IId
  - Low threshold potential (< 3 keV, S-recoil)
  - Directional signatures (and 3D reconstruction)
  - Head-tail (sense) is feasible, and verified by theory
  - Radon backgrounds (RPR) understood reduced
  - *Fiducialisation via minority carriers works*
  - *Thin cathode works*
  - Neutron backgrounds understood
  - Stable and safe operation with CS_2 and CF_4
  - Competitive SD WIMP-P limits with directionality

BIG PROGRESS in the last 2 years

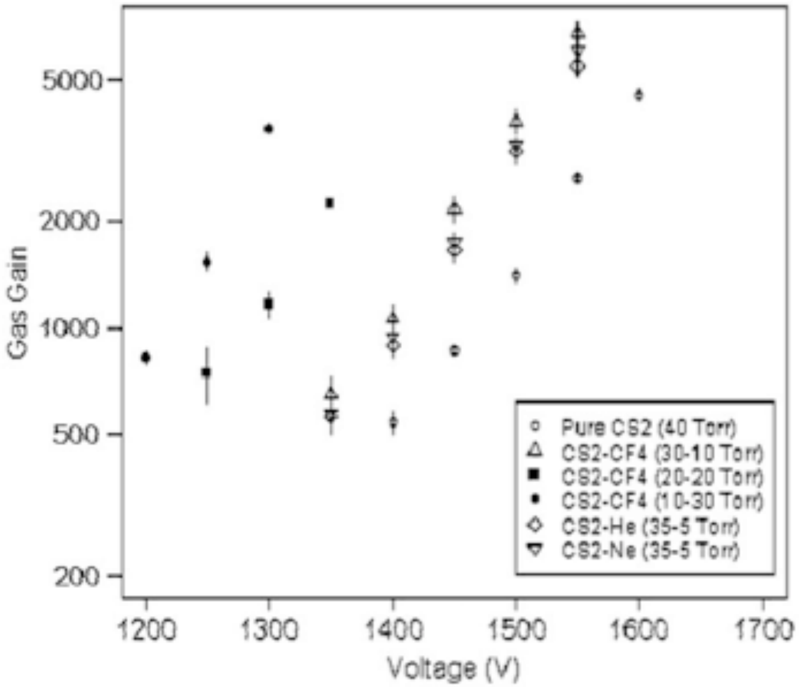


B. Morgan, A.M. Green and N.J.C. Spooner, Phys Rev D71 (2005) 103507
P. K. Lightfoot, N. J. C. Spooner et al., Astropart. Phys. 27 (2007) 490
S. Burgos et al., Astropart. Phys. 28 (2007) 409
N.J.C. Spooner, J. Phys. Soc. Japan, 76 (2007) 11101
E. Tziaferi et al., Astropart. Phys. 27 (2007) 326
K. Pushkin et al., (2008) arXiv:0811.4194
S. Burgos et al., Nucl. Instrum. and Meth. in Phys. Res. A 584 (2008) 114
S. Burgos et al., JINST 4 (2009) P04014
S. Burgos et al., Nucl. Instrum. and Meth. in Phys. Res. A600 (2009) 417
S. Burgos et al., Astroparticle Physics 31 (2009) 261
N.J.C. Spooner et al. Astroparticle Physics 34 (2010) 284
E. Daw et al, sub Astroparticle Physics (2011) - arXiv:1012.5967

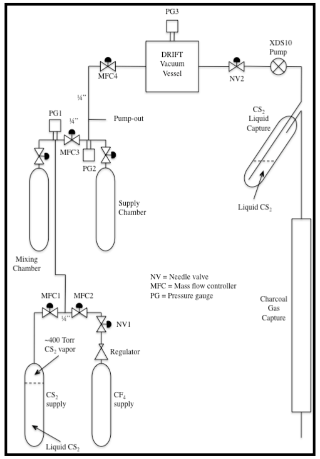
→ Ready for new experiment DRIFT III Module - $24m^3$

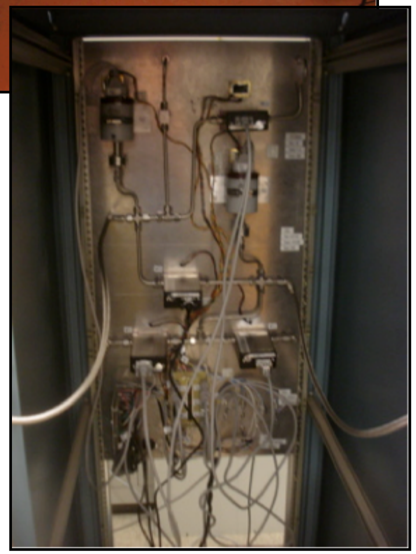
DRIFT IId Tech Highlights - Gas Physics

- CS_2 is an amazing gas!
- Measured ionization, gain, drift velocity and diffusion in various CS_2 gas mixtures **with CF_4 and now O_2 minority carrier**
- CS_2 works with only 5% concentration
- DRIFT-IId new set-up with $CS_2/CF_4/O_2$



CS_2/CF_4 gain vs mixture



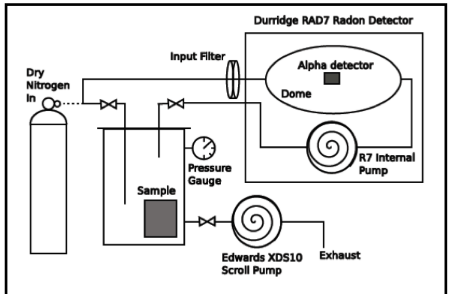


DRIFT IId Tech Highlights - Radon

- Radon mitigation by acid cleaning

- Radon mitigation by material selection and emanation studies

sensitivity ~ 1mBq



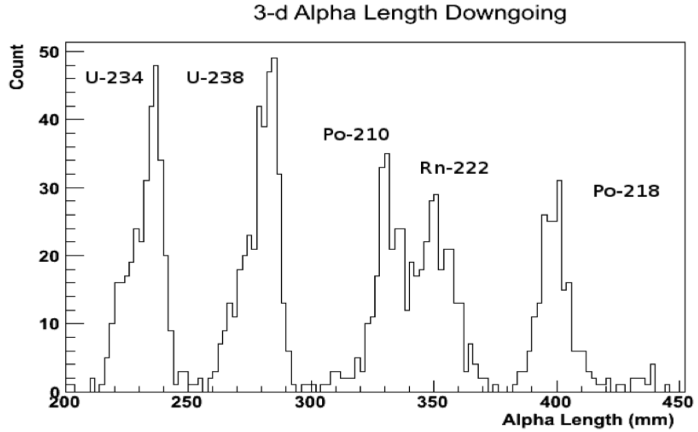
Radon emanation screening apparatus

- Internal radon assay by alpha particle range

Sample	Rn emanation (atoms/s)	Scaling & notes
Nitrile O-ring	0.0602 ± 0.0068	$\times 0.5$.
Black HV cables	0.1069 ± 0.0134	None, full set tested.
Rubber bungs (old)	0.0333 ± 0.0027	$\times 2$ and $\times 0.718$. $\frac{1}{2}$ number of bungs.
Aluminized Mylar	0.0076 ± 0.0046	$\times 2$. Sample was $\frac{1}{2}$ cathode area.
Electronics boxes [1]	0.05 ± 0.01	None
FEP ribbon cables [1]	0.00 ± 0.02	None
PTFE signal cables [1]	0.00 ± 0.02	None
Total	0.258 ± 0.034	GPCC implied rate: 0.277 ± 0.017

Detector materials present during April 2012 run

Sample	Rn emanation (atoms/s)	Scaling & notes
Nitrile O-ring	0.0602 ± 0.0068	$\times 0.5$.
White HV cables	0.0053 ± 0.0019	None, full set tested.
20 silicone bungs	0.0129 ± 0.0015	$\times 0.718 \pm 0.028$.
Aluminized Mylar	0.0076 ± 0.0046	$\times 2$. Sample was $\frac{1}{2}$ cathode area.
Electronics boxes [1]	0.05 ± 0.01	None
FEP ribbon cables [1]	0.00 ± 0.02	None
PTFE signal cables [1]	0.00 ± 0.02	None
Total	0.136 ± 0.031	GPCC implied rate: 0.151 ± 0.013

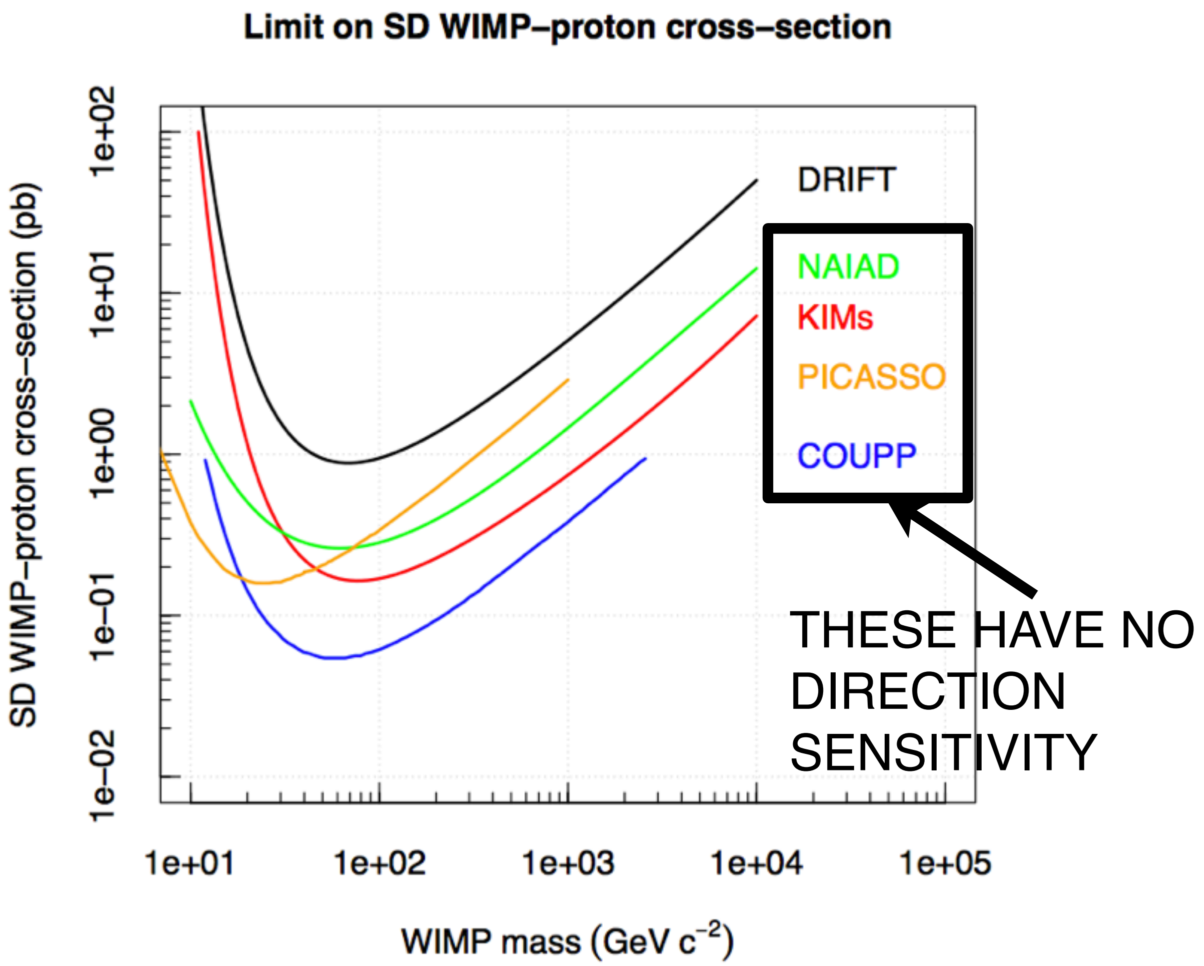


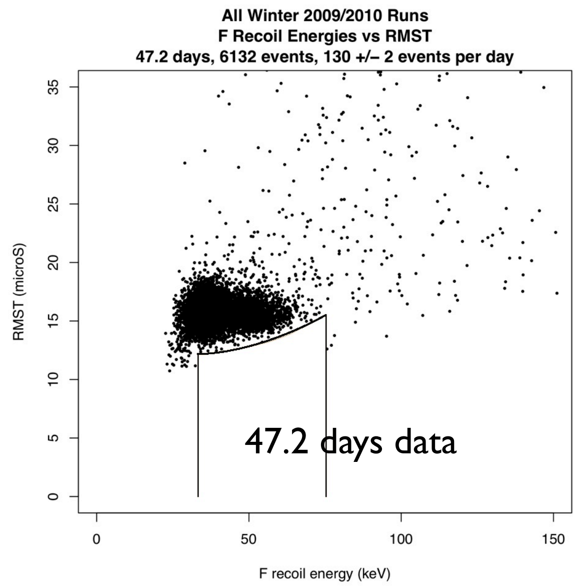
Isotope	Dirty	Clean
^{234}U	12 ± 2ppt	$\leq 2 \pm 0.3$ppt
^{238}U	260 ± 31ppb	1.2 ± 2.4ppb

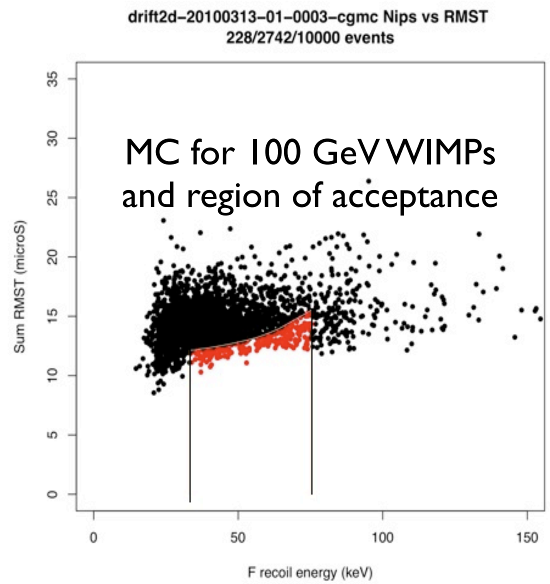
Together, these reduced the RPRs by 96% relative to D-IIa rate

SD Limit from 47.2 days

- 30 Torr -10 Torr CS2-CF4,
- MC simulation calibrated by neutron data
- No compromise on directional sensitivity
- Signal region chosen for zero events (<u>unblind</u> analysis)





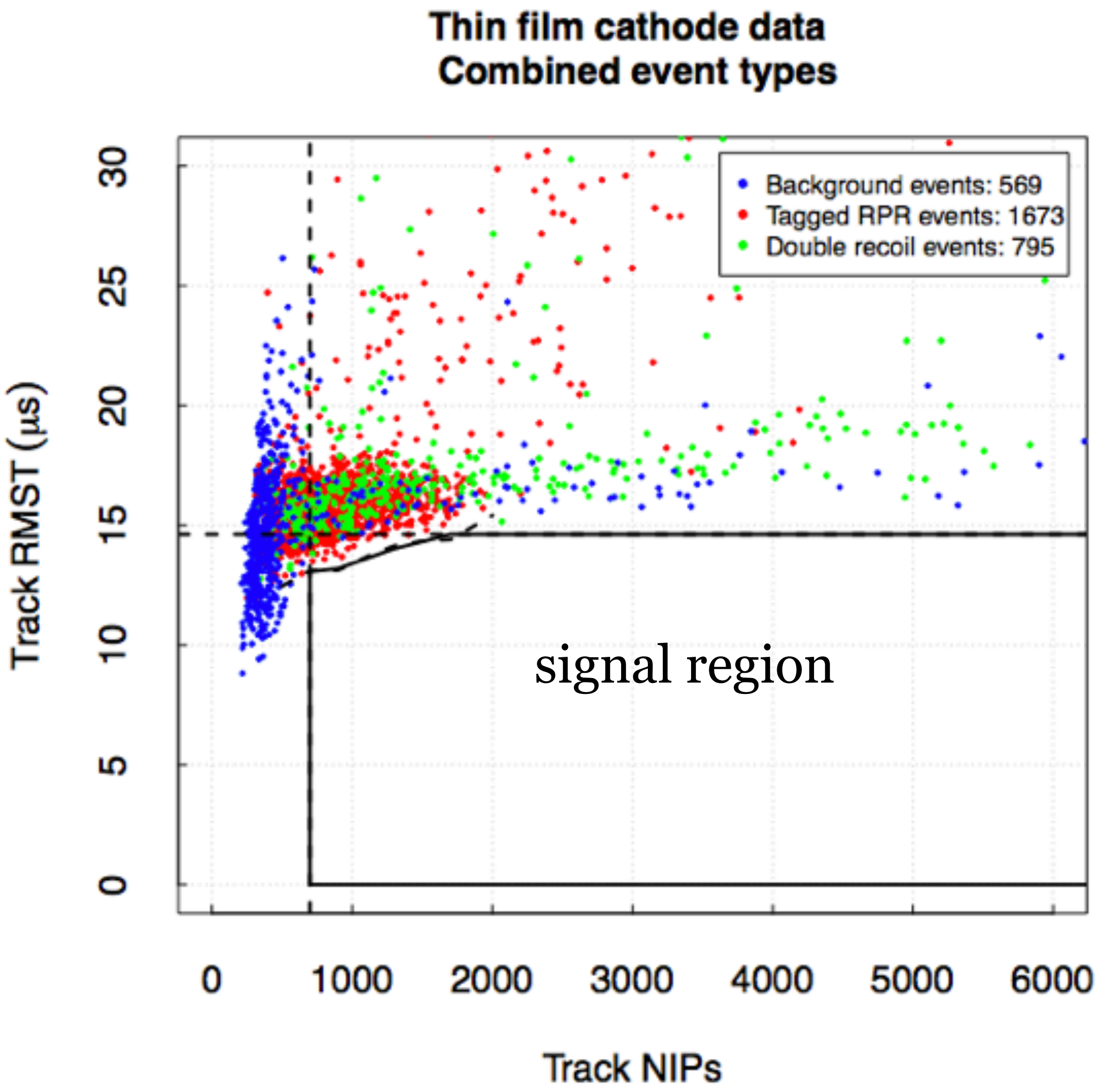


DRIFT IId
Recent Advances/Upgrades

- Opertaion with multiple target gases - CS_2 is an amazing gas!
- Radon mitigation - factor x ~500 reduction from DRIFT IIb

  - Introduce texturised thin film cathode for radon progeny recoil tagging
  - Introduce fiducialisation with minority carrier using O_2
  - Improve electronics and analysis
  - Introduce blind analysis

BLIND Analaysis Test



Unblind Analysis

↓

blind Analysis

PhD Thesis
Mark Pipe

DRIFT IId - 0.9μm Central Cathode

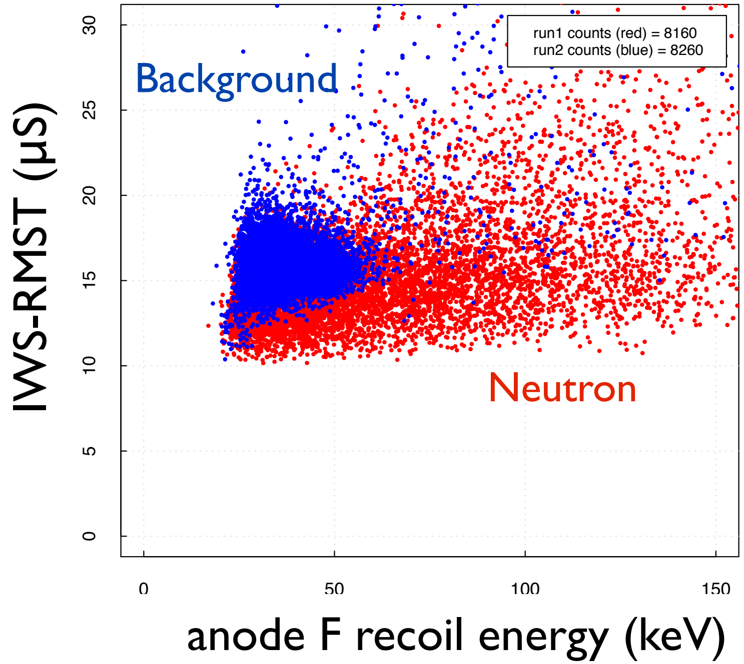
Use of multi-panel 0.9μm thick DRIFT cathode

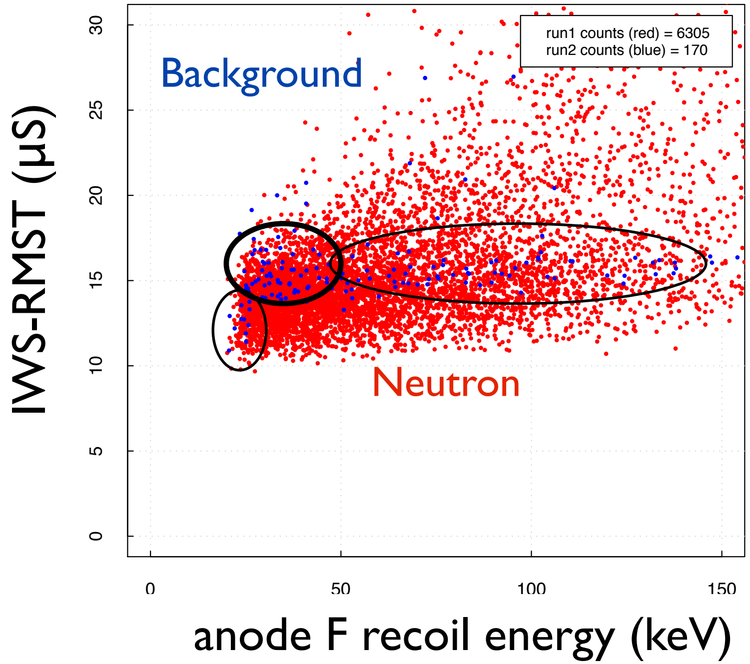
cathode tested at full voltage (32.5kV)

Running stably since installation

DRIFT IId - 0.9μm Central Cathode

20 μm wire cathode → 0.9 μm film cathode





New upgrade to thin (alpha transparent) cathode shown to suppress background by another x15-30

But other smaller backgrounds are now revealed that account for the lower difference seen compared to expectation of ~ x40 (LEAs, betas...)

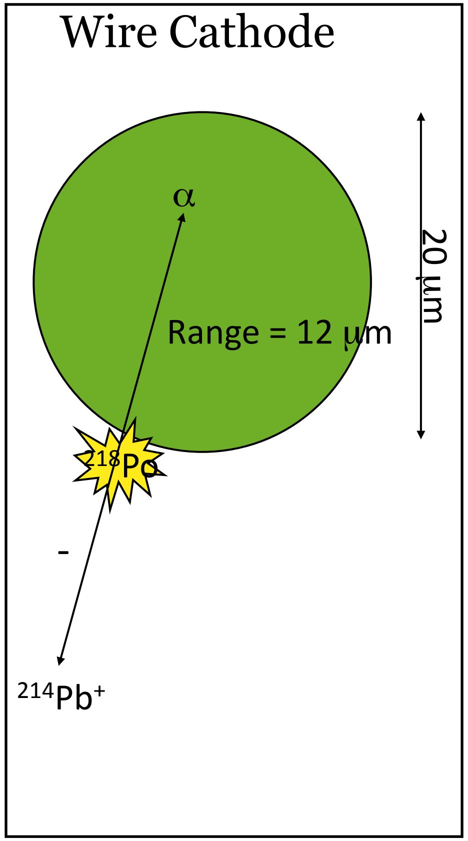
→ Texturised thin cathode

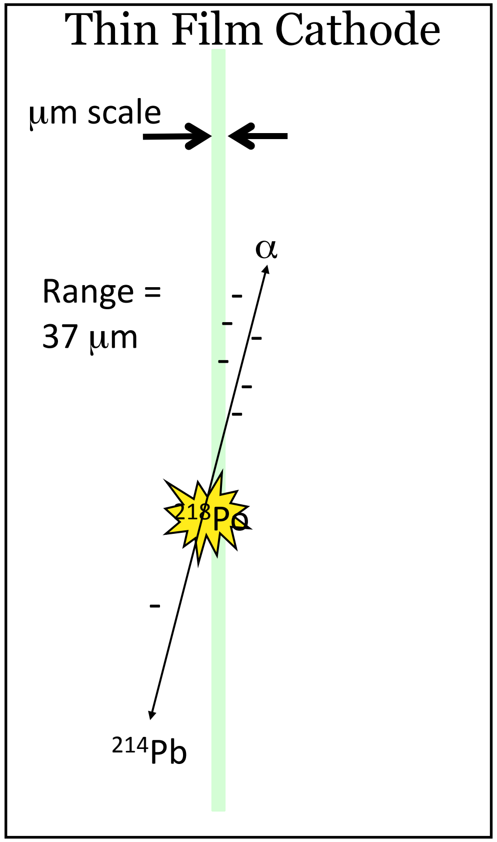
→ Minority carrier fiducialisation

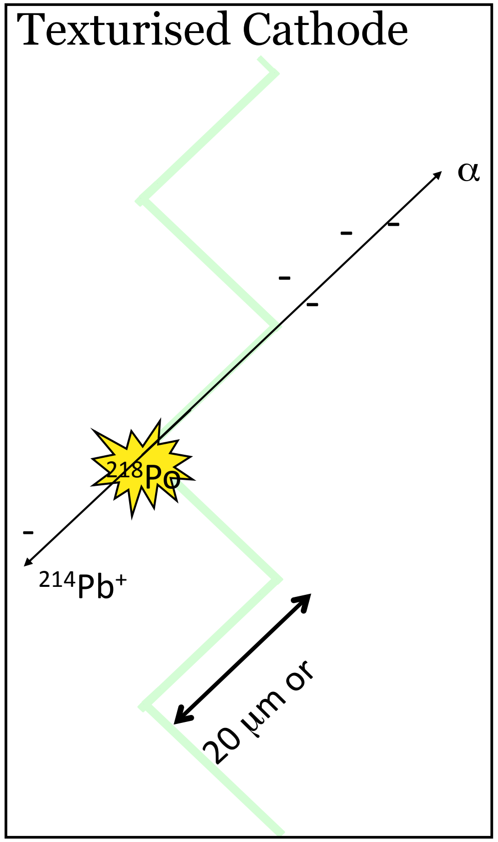
DRIFT IId Texturised Cathode Instal

Wire Cathode → Thin Cathode → Thin Texturised Cathode

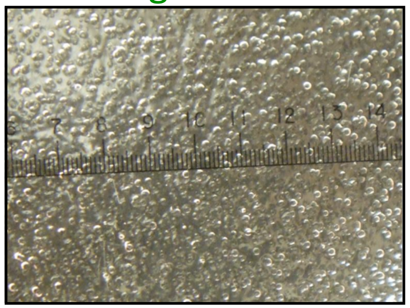
~500 RPRs/day ~100 RPRs/day nitric etch ~2 RPRs/day ~0.01? RPRs/day







- Texturizing 0.9 micron thin film is really difficult!!
- 0.9 micron texturized thin film deployed on DRIFT-IId in Boulby in May 2013.
- Awaiting results…

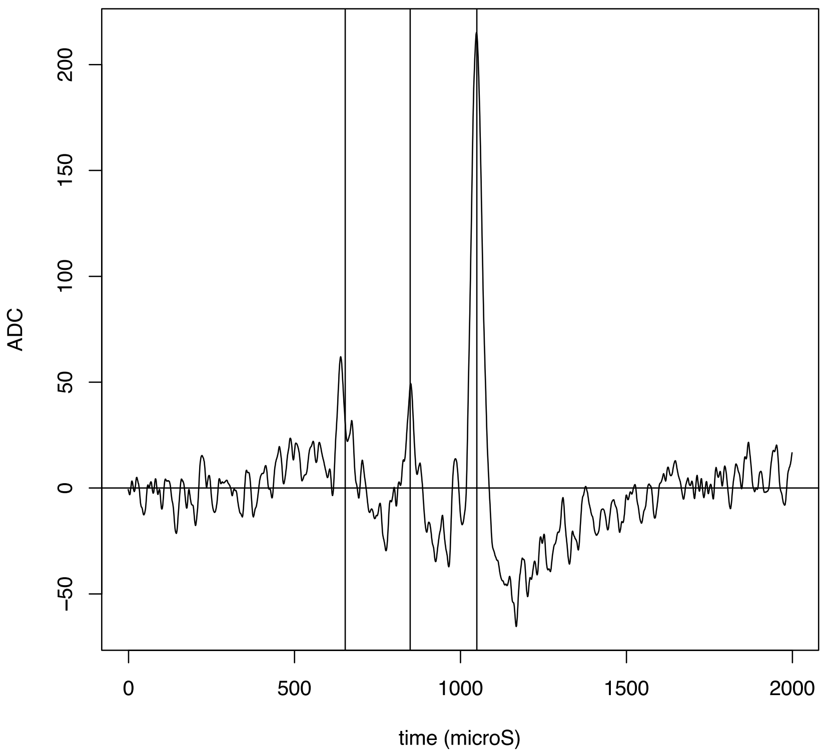


Give the alphas **no** place to hide in a **texturized** aluminized Mylar thin film

DRIFT IId Fiducialisation Instal

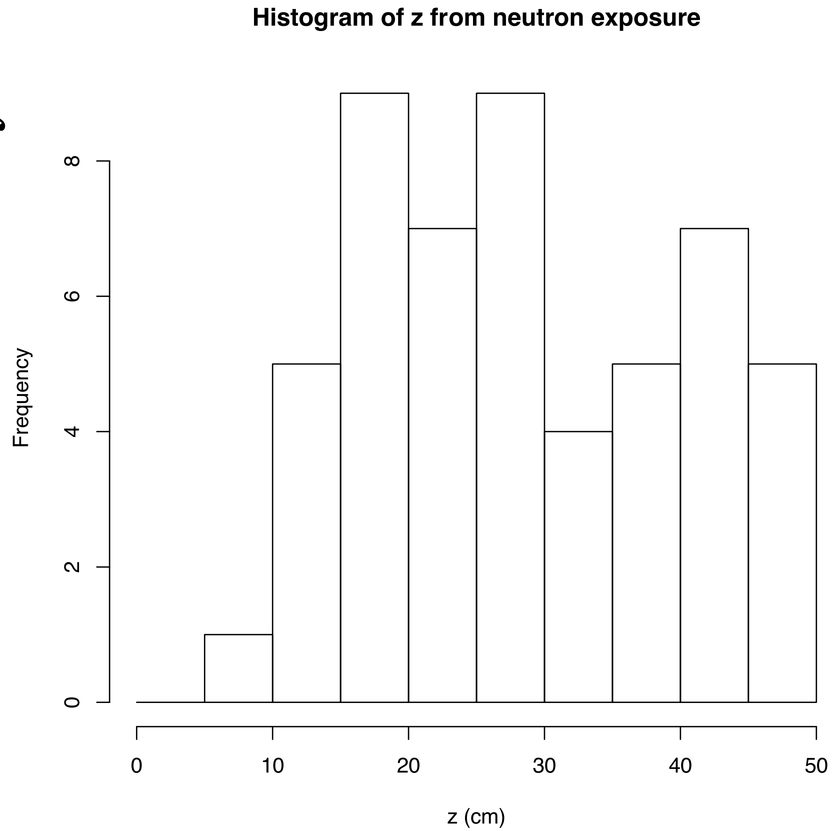
Before O_2 Fiducialisation

WIMP efficiency ~5%



After O_2 Fiducialisation

WIMP efficiency ~90%?

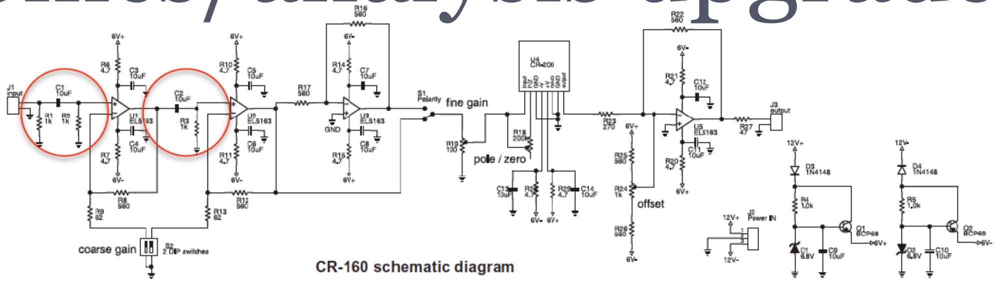


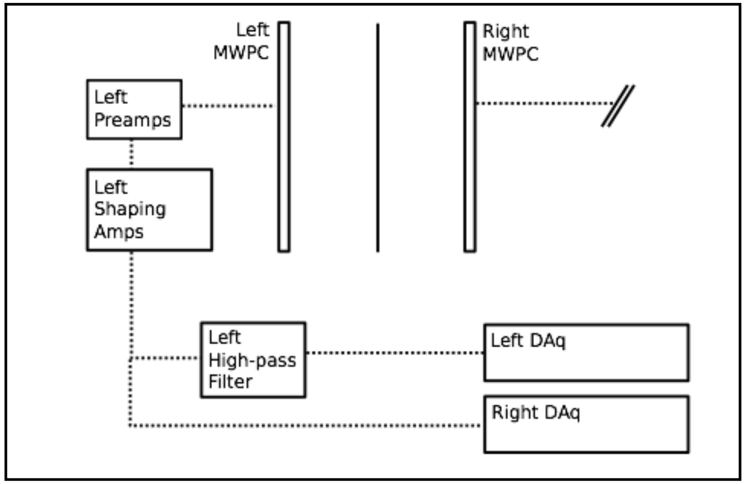
Nuclear Recoil Efficiency

Depth in DRIFT IId

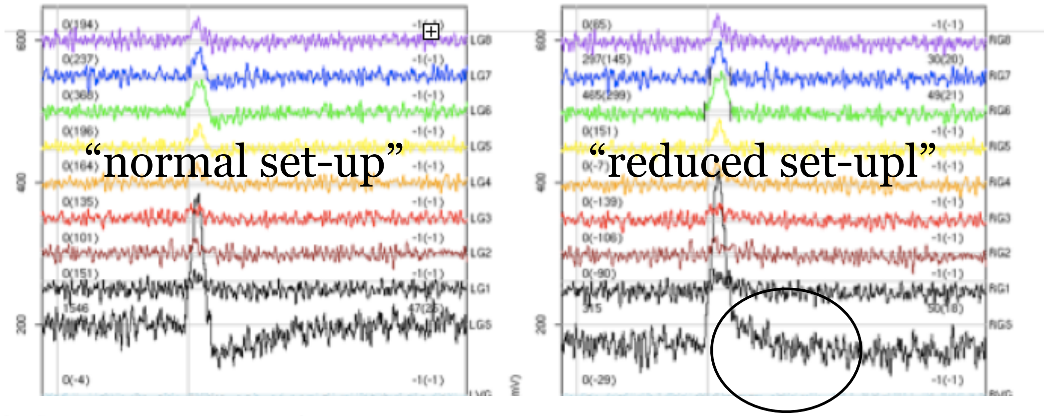
DRIFT IId Electronics/analysis upgrades

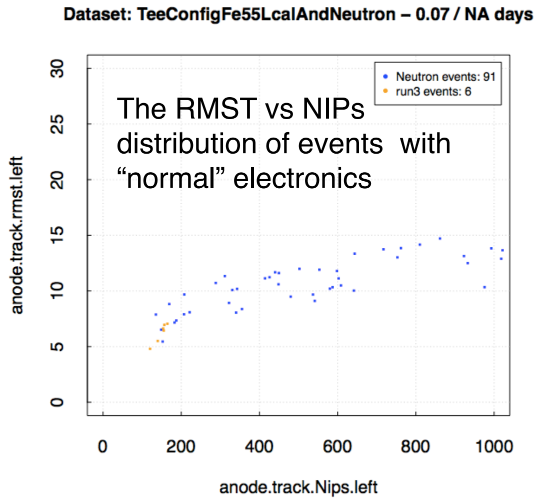
Aim: remove pulse shaping and introduce filtering in software: lower noise, better PSD for track reconstruction and background rejection

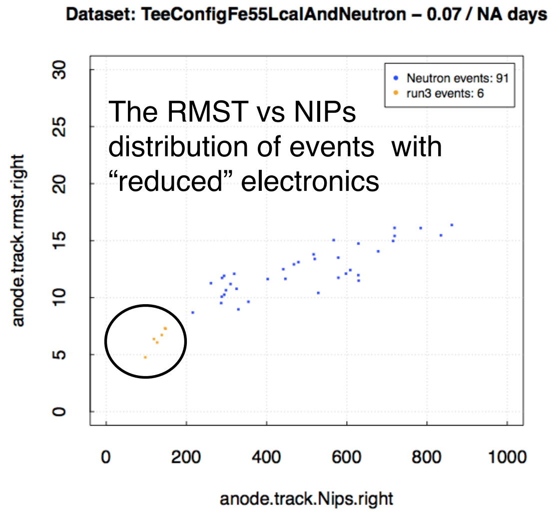




- Current IId electronics uses Cremat pre-amps and shapers plus filters

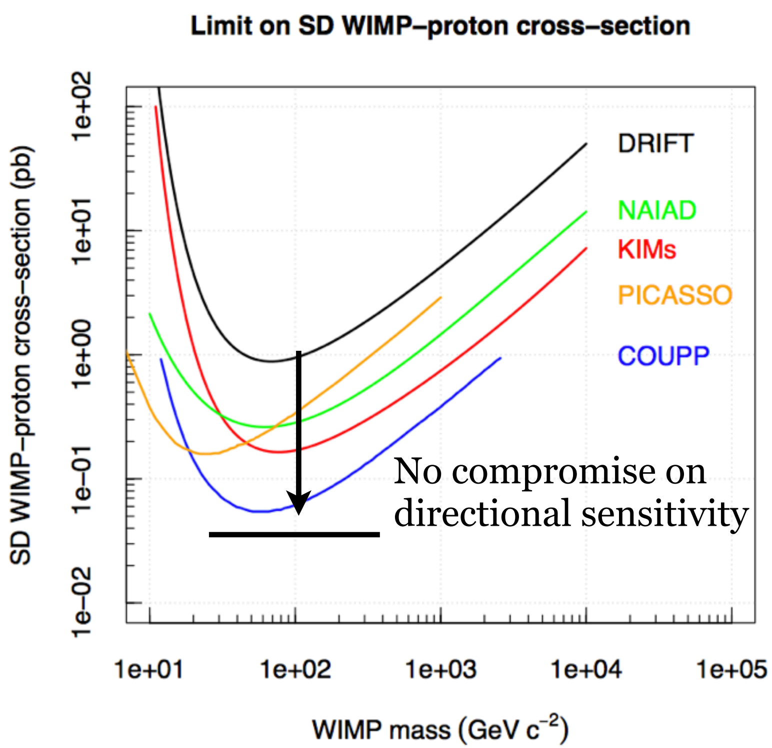






- Analysis shows imroved separation of RPRs from neutron-induced recoils

DRIFT IId Sensitivity Prediction Now



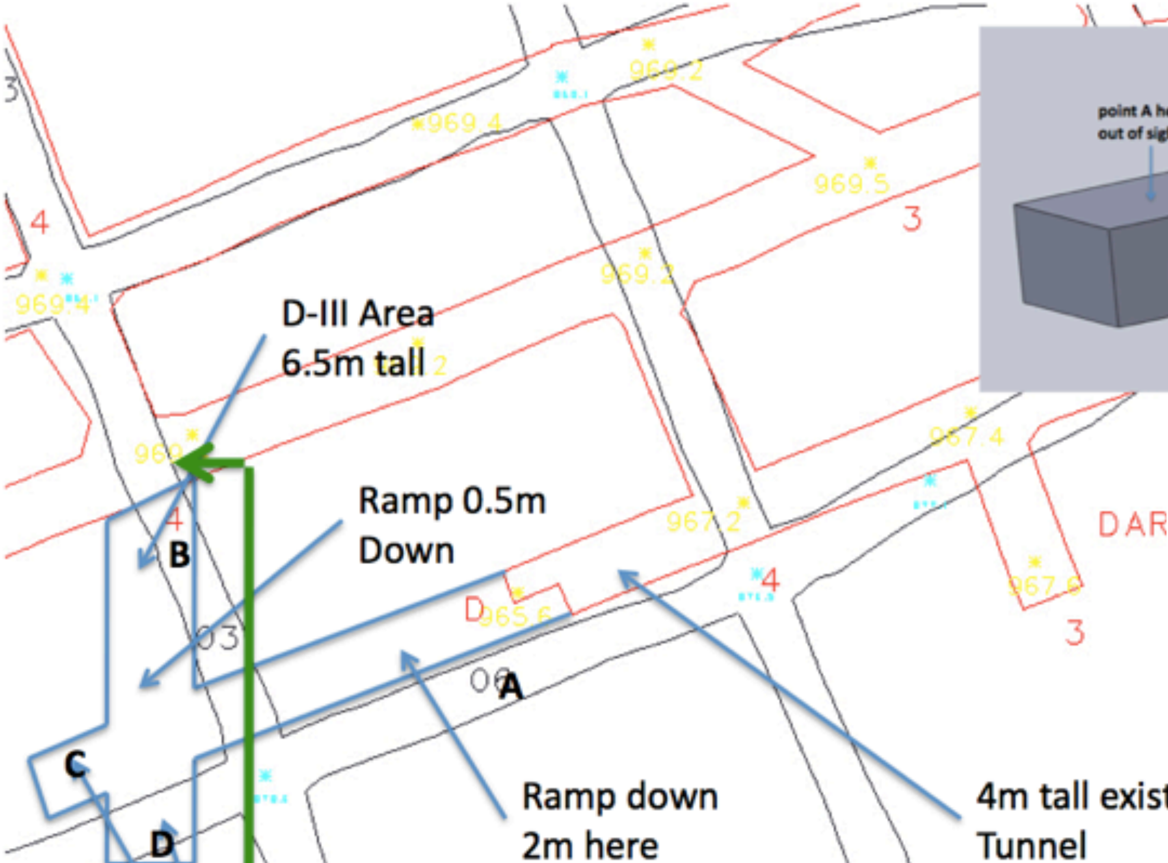
Points to DRIFT III scale-up (24m^3)

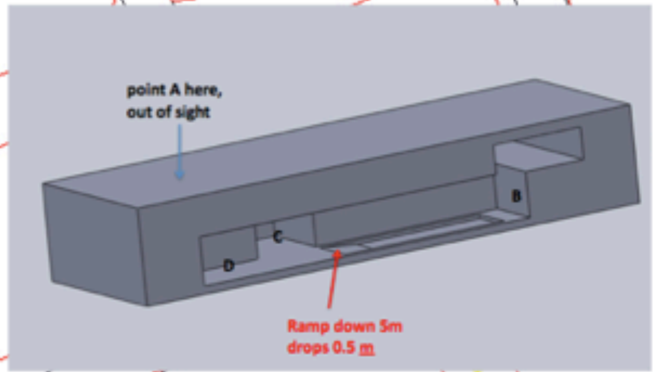
DRIFT IIe demonstrator under construction to test DRIFT III features

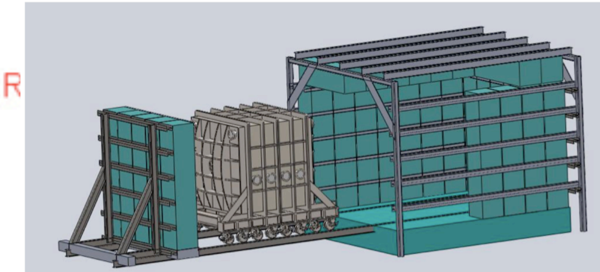
- New low radon emanation materials
  expect ×10 reduction in intrinsics radon background
- New texturised central cathode
  expect ×40 reduction in intrinsics RPR background
- New O_2 fiducialisation
  expect ×20 increase in fiducial volume
- New analysis/electronics
  expect improved patricle ID
- 0.02pb limit projected assuming RPRs have same distribution
- DRIFT II is then volume limited not background limited

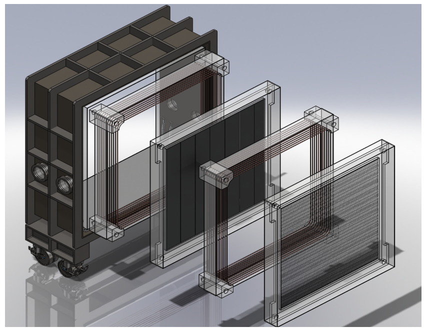
DRIFT III Proposed - New Lab

- New underground lab for DRIFT III module to be built for us by CPL









DRIFT IIe
Test-Bed for DRIFT III

DRIFT IId

→

DRIFT IIe

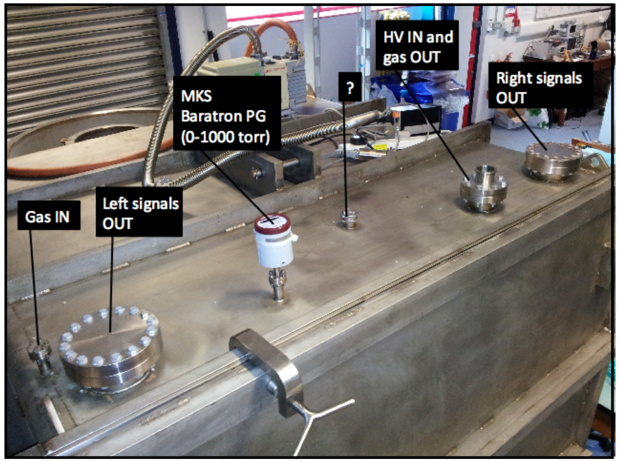
DRIFT IIe incorporates tests of all major components needed for DRIFT III

- Vessel with reduced outgassing and leaks
- Simpler shielding
- New robust, low radon MWPC cage and cathode engineered for 2 x 2m
- New simpler gas system with multiple new gases
- Introduction of gas recirculation and radon scrubbing
- Addition of minority carrier gives pre-signals to allow full 3D fiducialisation
- New Shielding
- New electronics allows all wire readout at reduced cost (**test of 3 DAQ concepts**)

DRIFT IIe + DRIFT IId to operate together -> 2 m^3

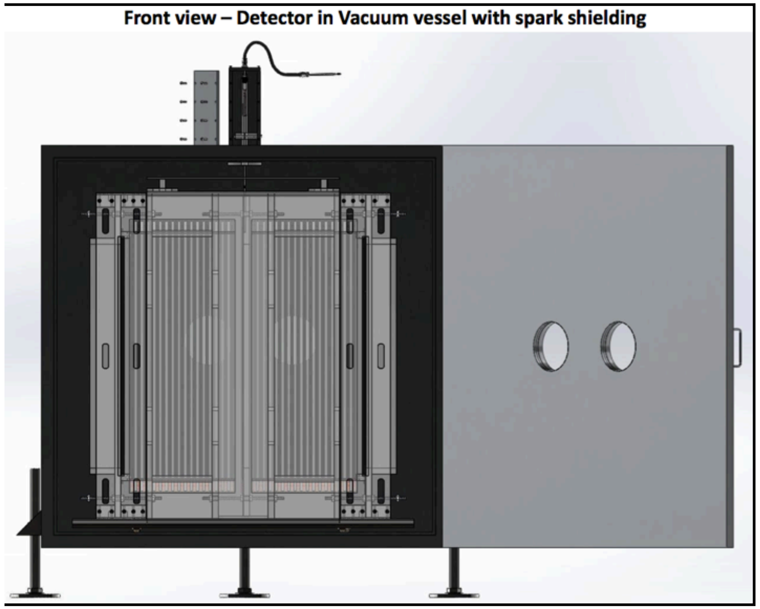
DRIFT IIe - Vessel

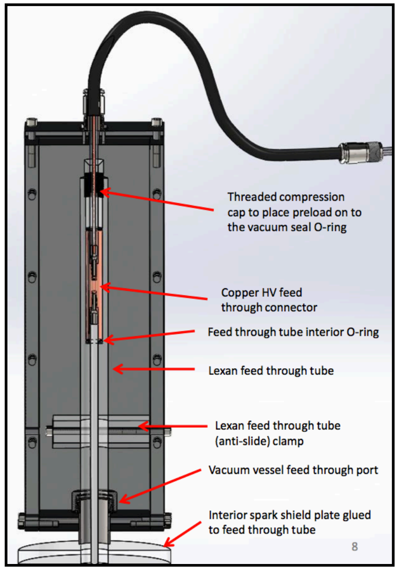
- Leaves Sheffield
- Arrives underground

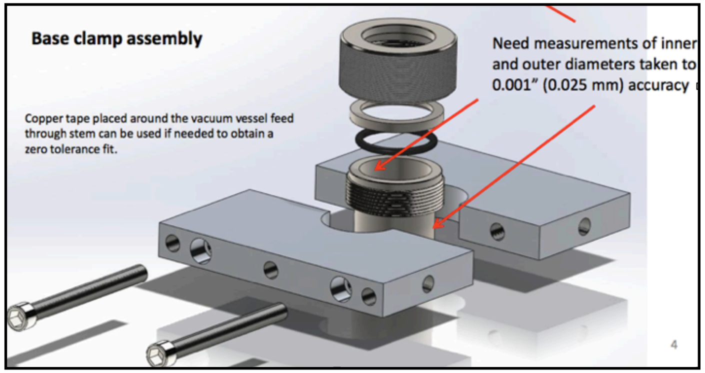


- Installed in shielding March 2012
- Top plate details

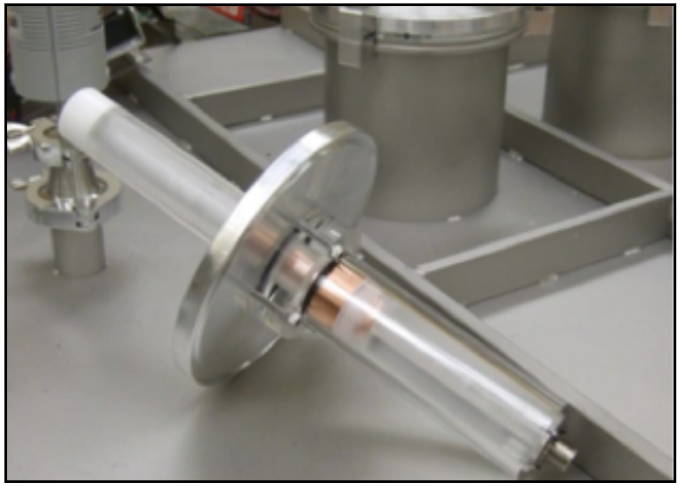
DRIFT IIe - High Voltage Feeds

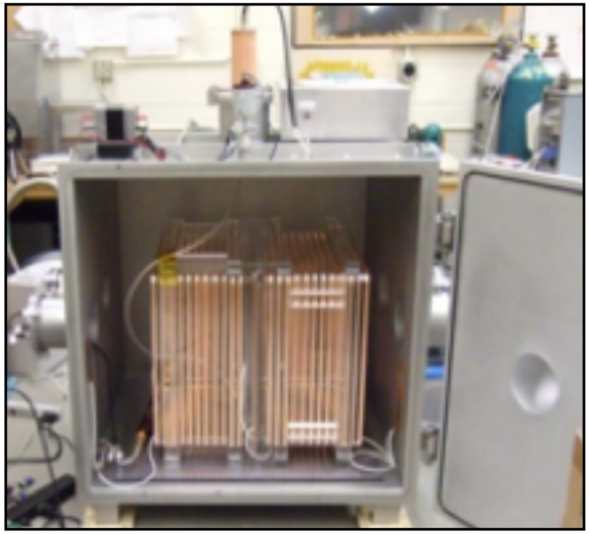






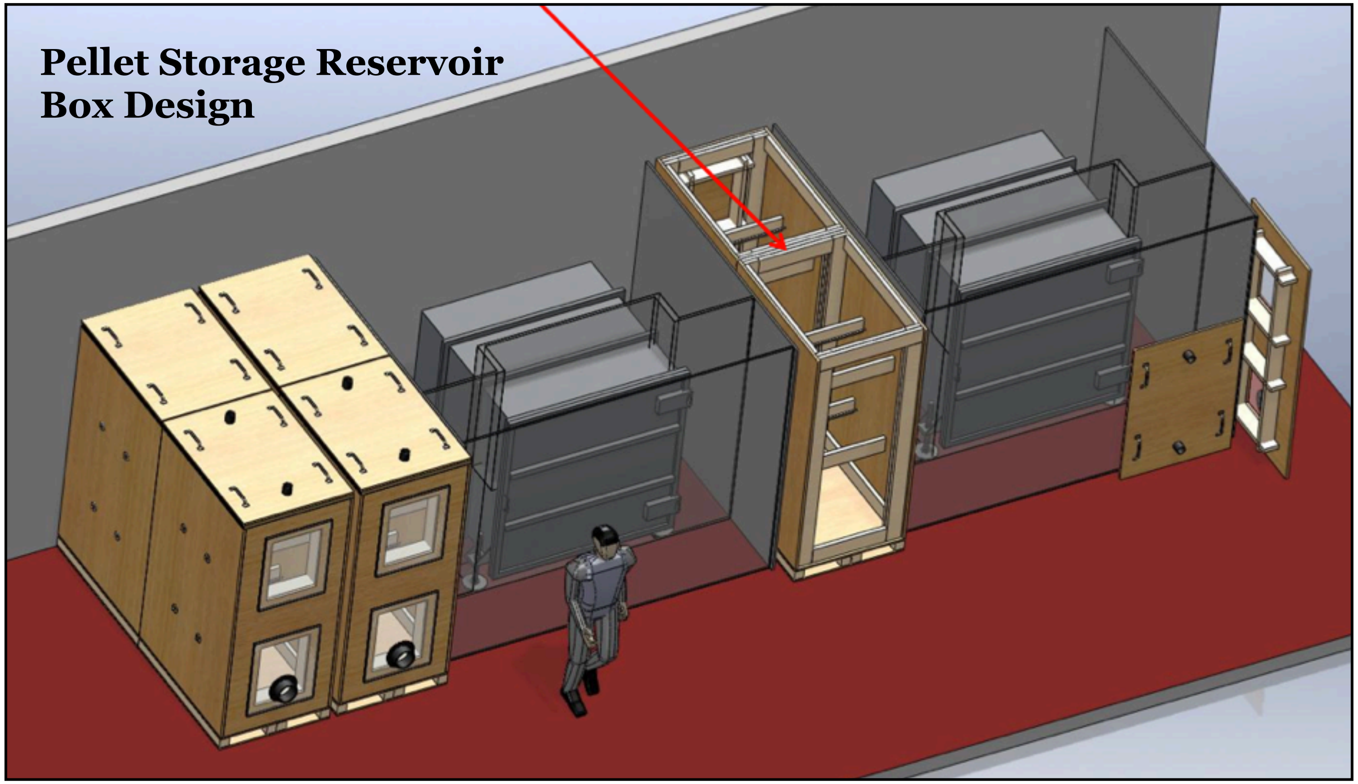
- Designed by UNM and tested on mini-DRIFT at UNM





DRIFT IIe - Shielding

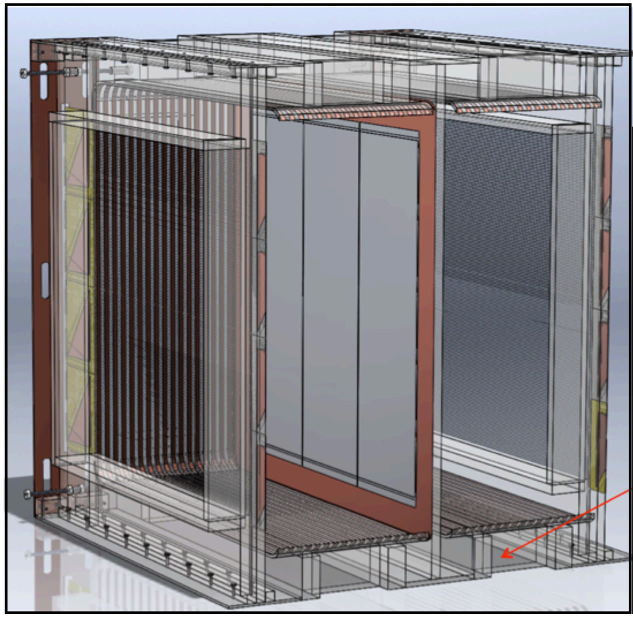
Frame surfaces pushed together with foam gasket in between them. After the frames are compressed together with C-Clamps, bolt holes are drilled and threaded bolt, nut and washers attach the two pellet storage box halves. Open front allows carpenters easy access to the interior during this joining operation.

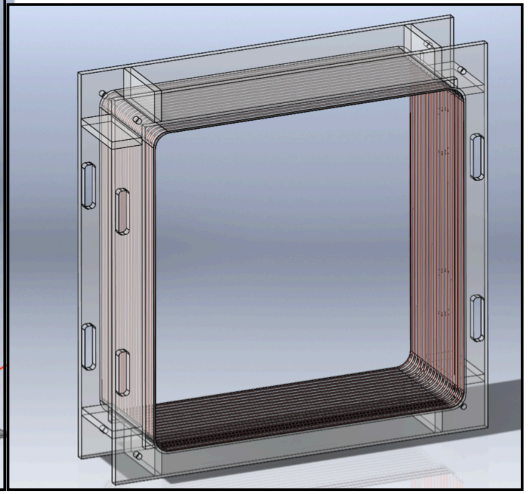


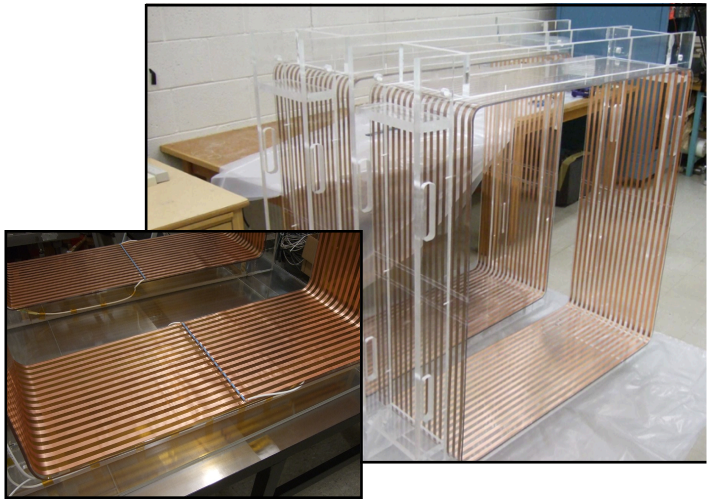
Polypropylene shielding, consisting of pellets is used to shield the DRIFT detector. Neutrons are readily absorbed by hydrogen atoms.

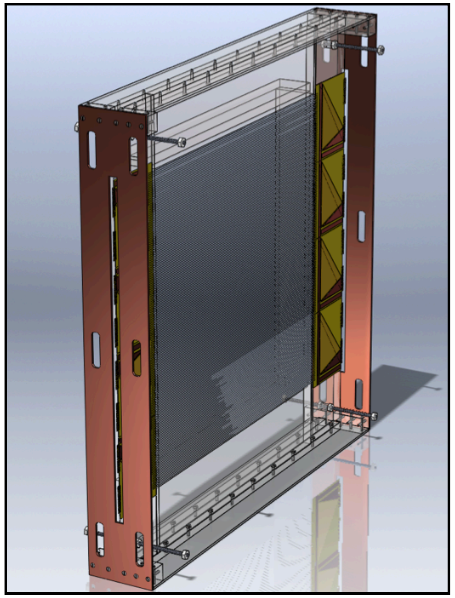
DRIFT IIe - Detector, Field Cage, MWPC

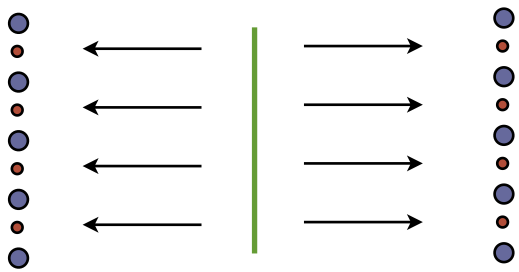
Field cages: We have 56Meg 5KV resistors (18 x 56M = 1.01 Gohm) ready for installation upon approval from the Occi EM simulation team.



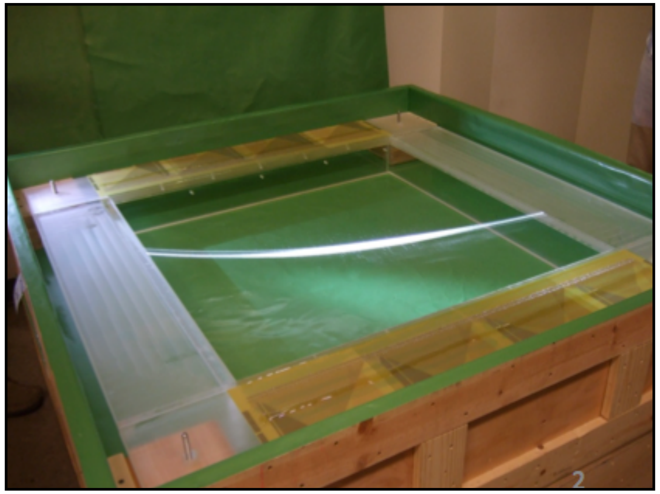








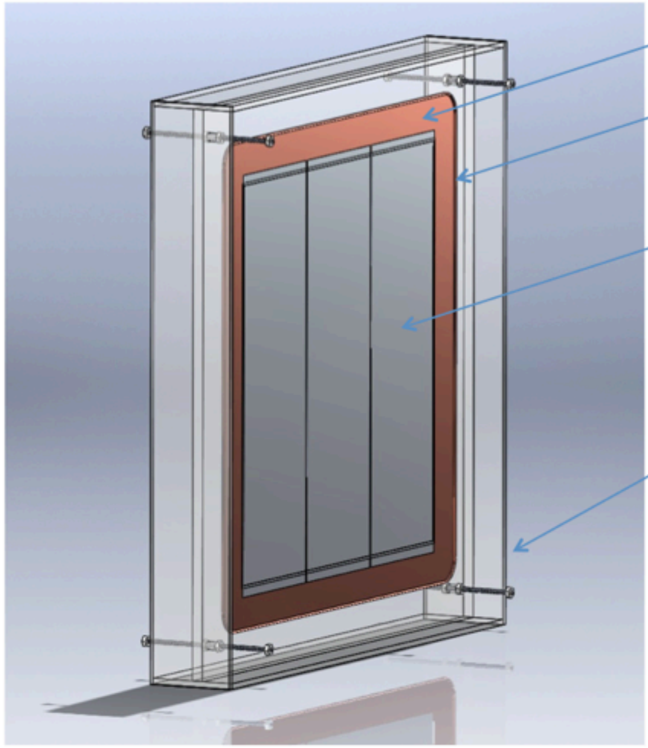
Each new MWPC has 914 alternating anode and field wires spaced 1 mm apart. The anode wires are at ground while the field wires are at -900 V.

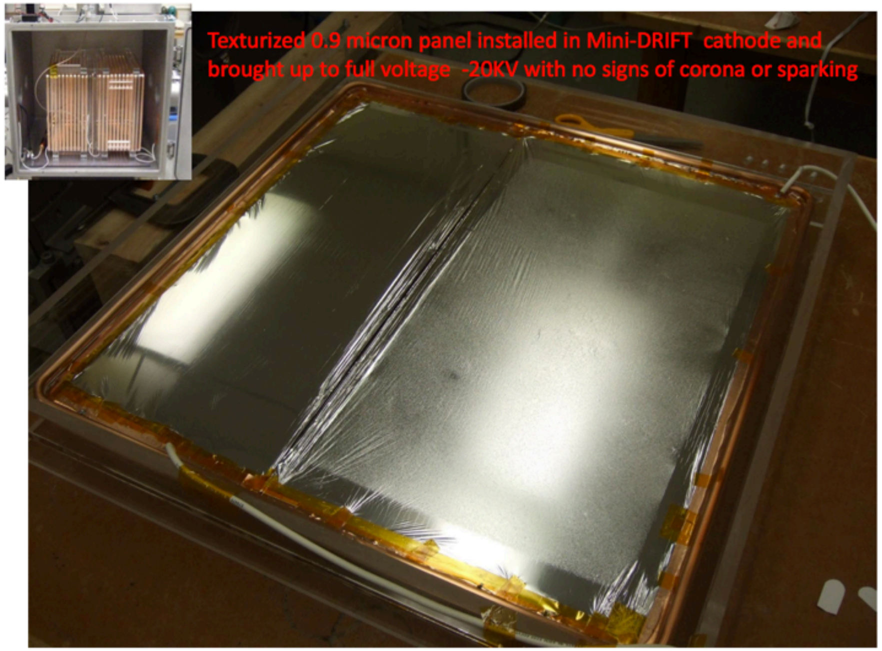


DRIFT IIe - Texturised Central Cathode

Cathode

Ver3.0 same as Ver2.0

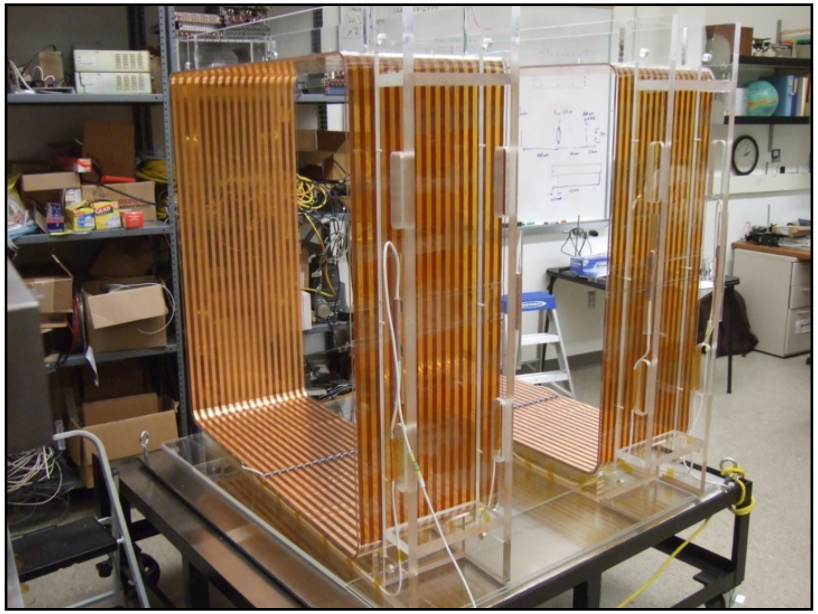
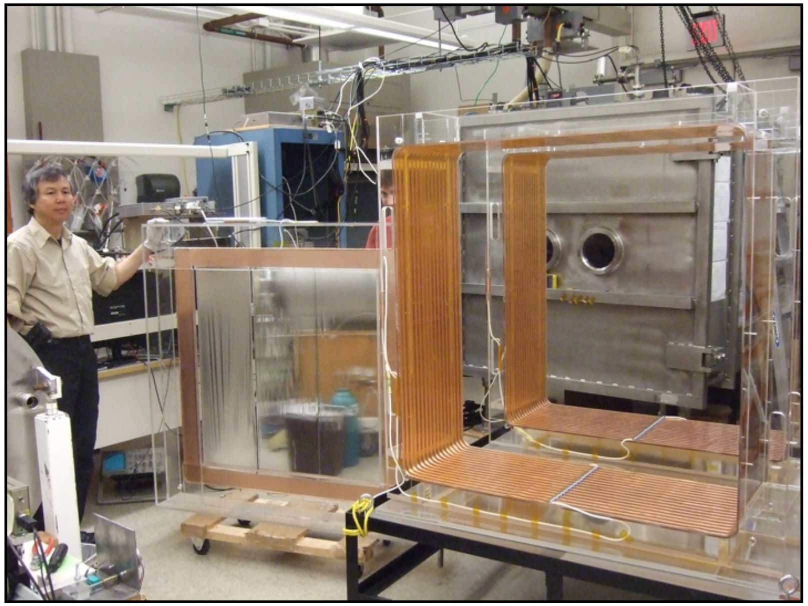
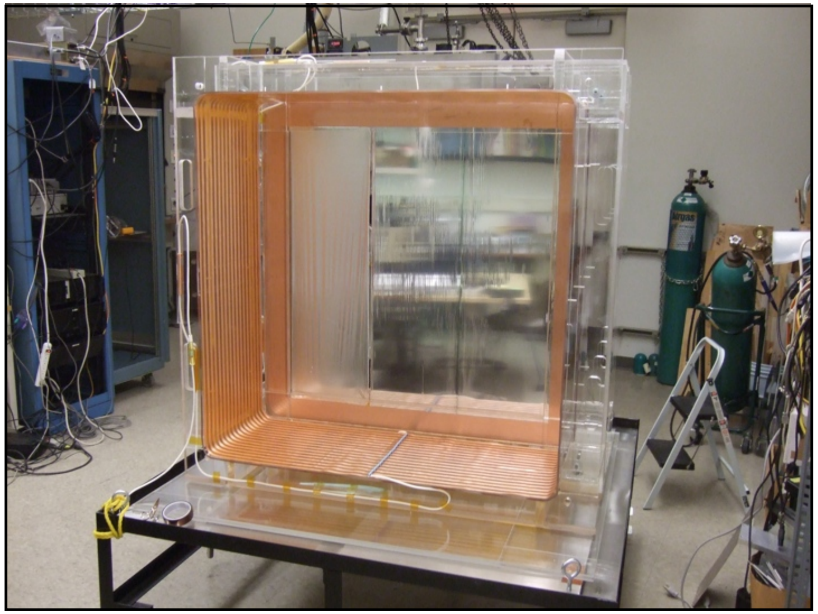
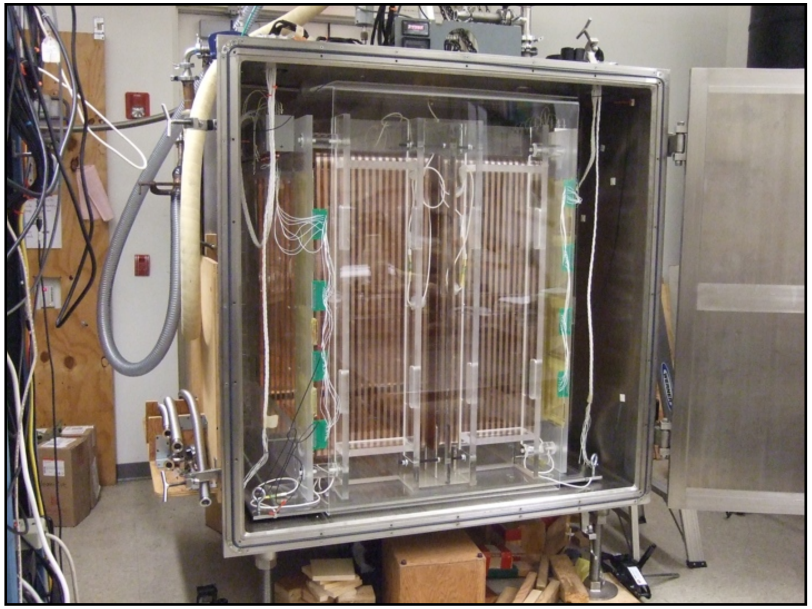




Cathode assembly weight: 99 pounds

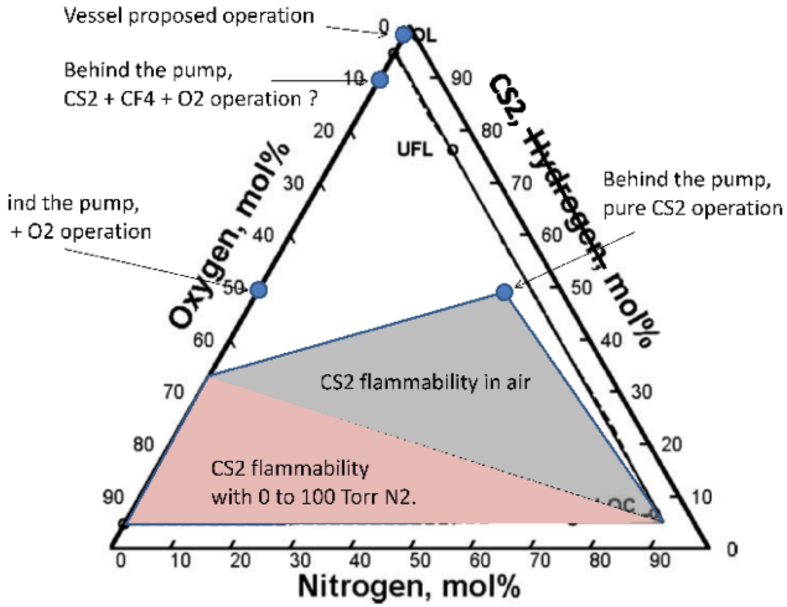
- Cathode thin film at ~33kV
- Currently being tested in DRIFT IId

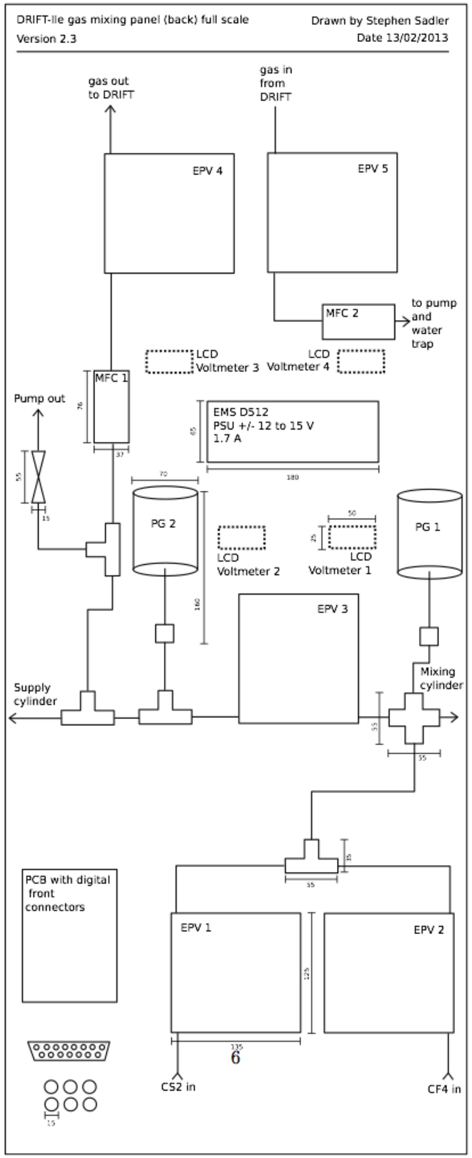
DRIFT IIe - Surface Assembley

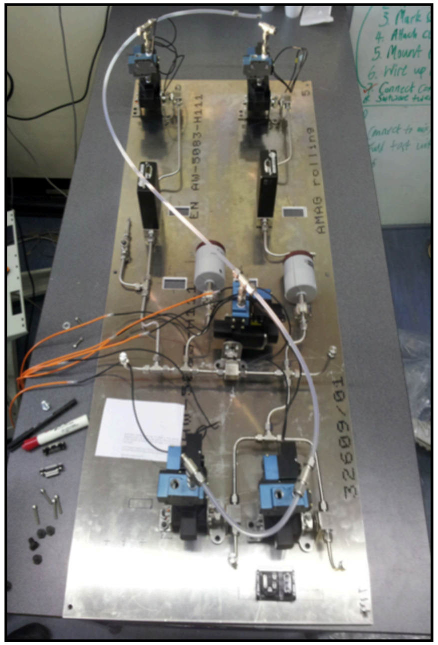





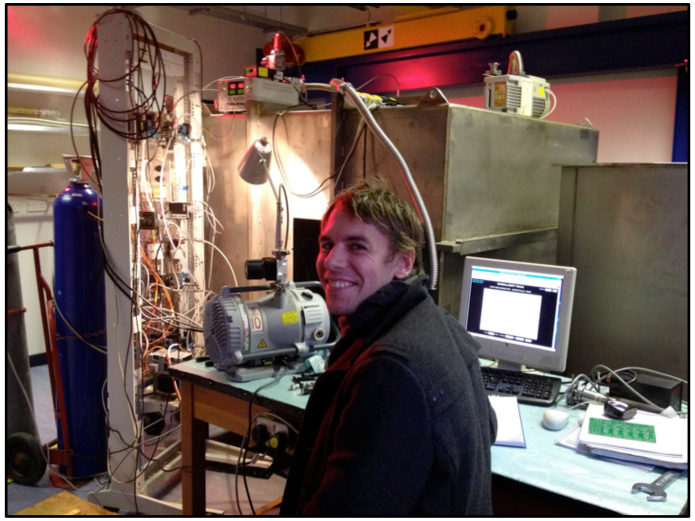
DRIFT IIe - Gas Supply - $CS_2/CF_4/O_2$

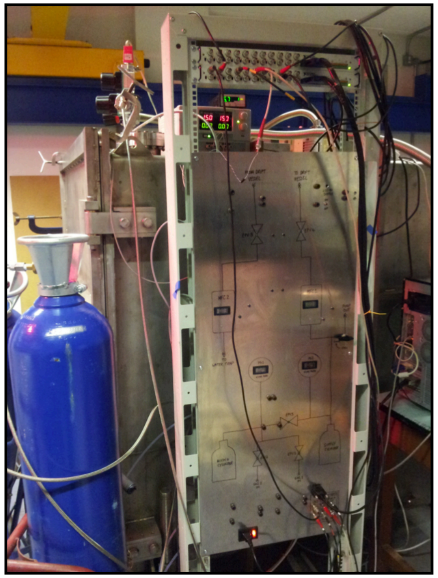
- Significant safety issues solved - now assembled underground, test on DRIFT IId
- Designed and built at Sheffield





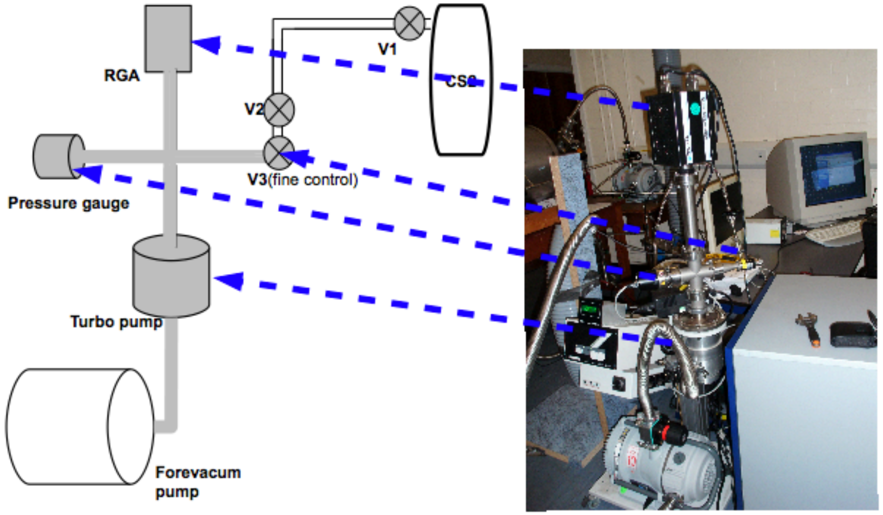


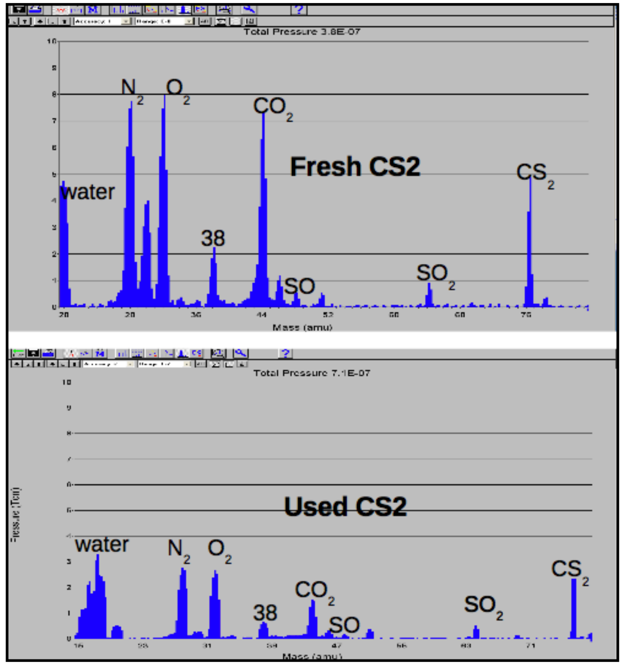




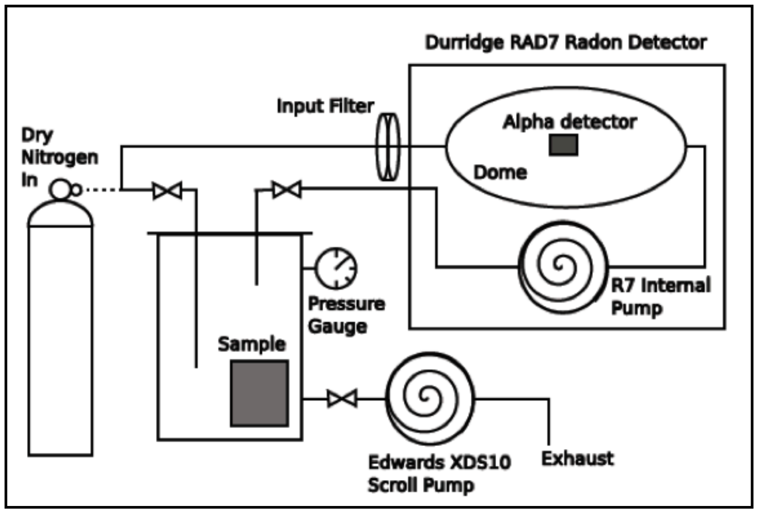
DRIFT IIe - Gas R&D - Recirculation

- Residual Gas Analyser R&D to examine gas contamination
- Aim to establish reduced or zero gas flow
- Currently being tested in DRIFT IId



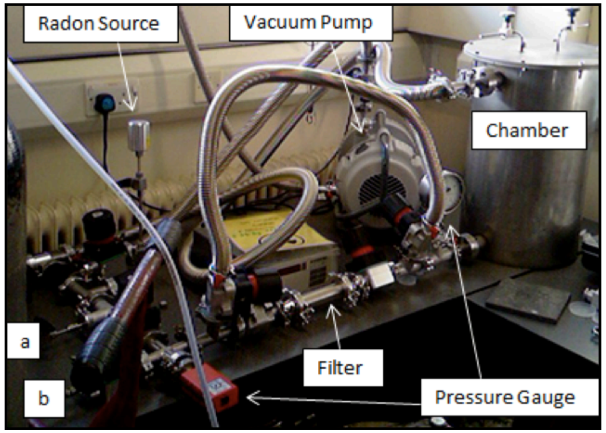


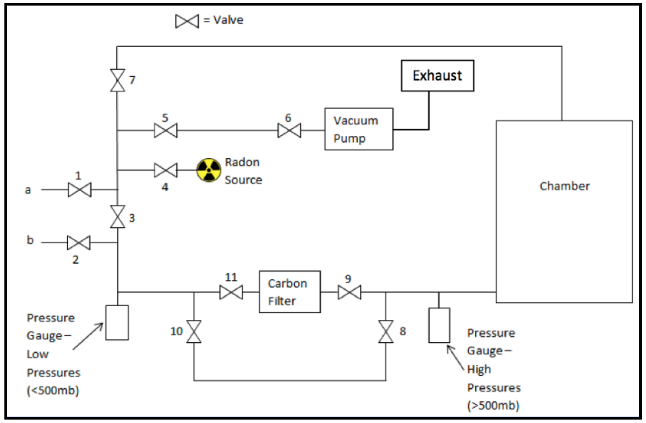
- Radon Emanation of Materials

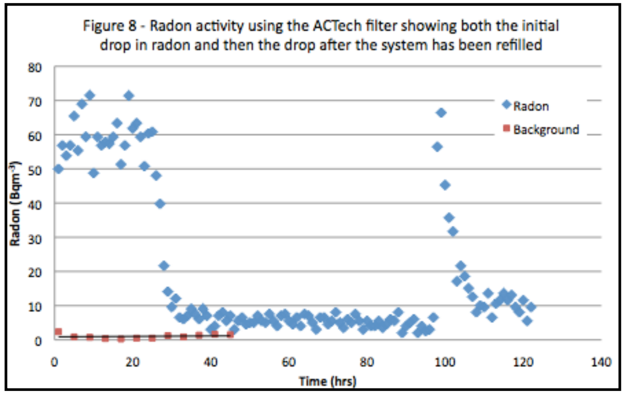


DRIFT IIe - Gas R&D - Radon Srub

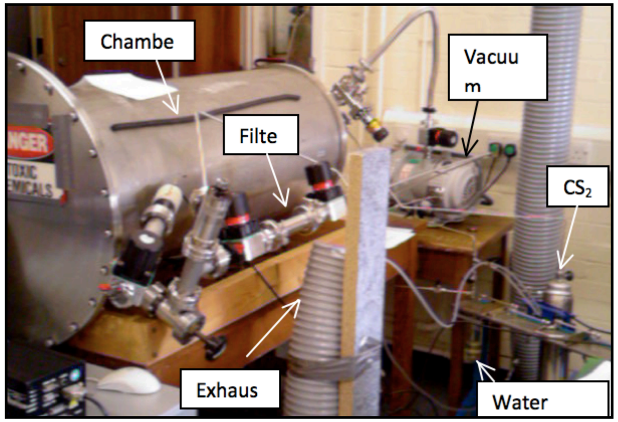
- Radon scrub R&D - aim to find best filter for radon that does not disturb CS_2
  - Plot shows effect on radon of ACTtech carbon

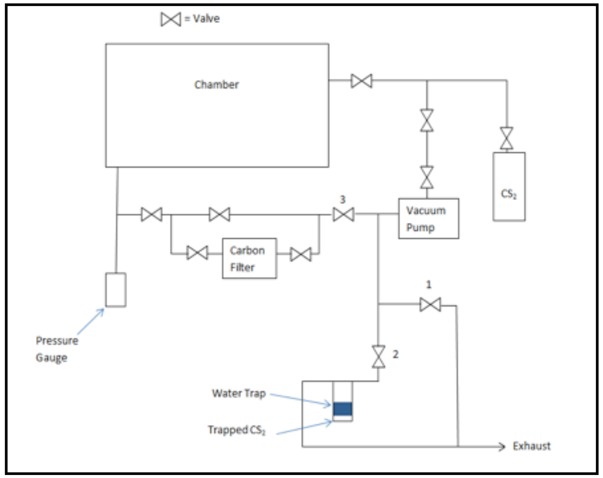


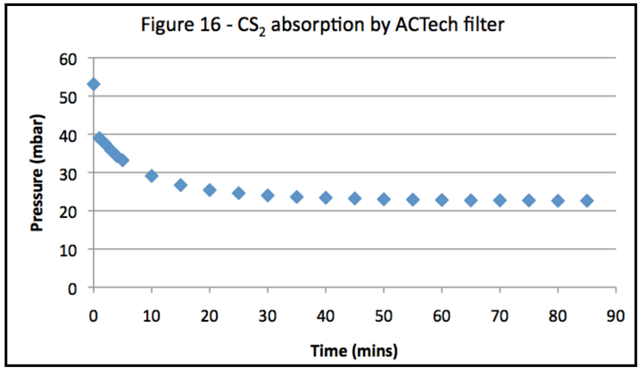




- Gas purity scrub R&D - aim to elliminate gas flowing - prevent “bad gas” build up by re-circulation through filters and traps
  - Plot shows CS_2 mainly passes through ATCtech carbon



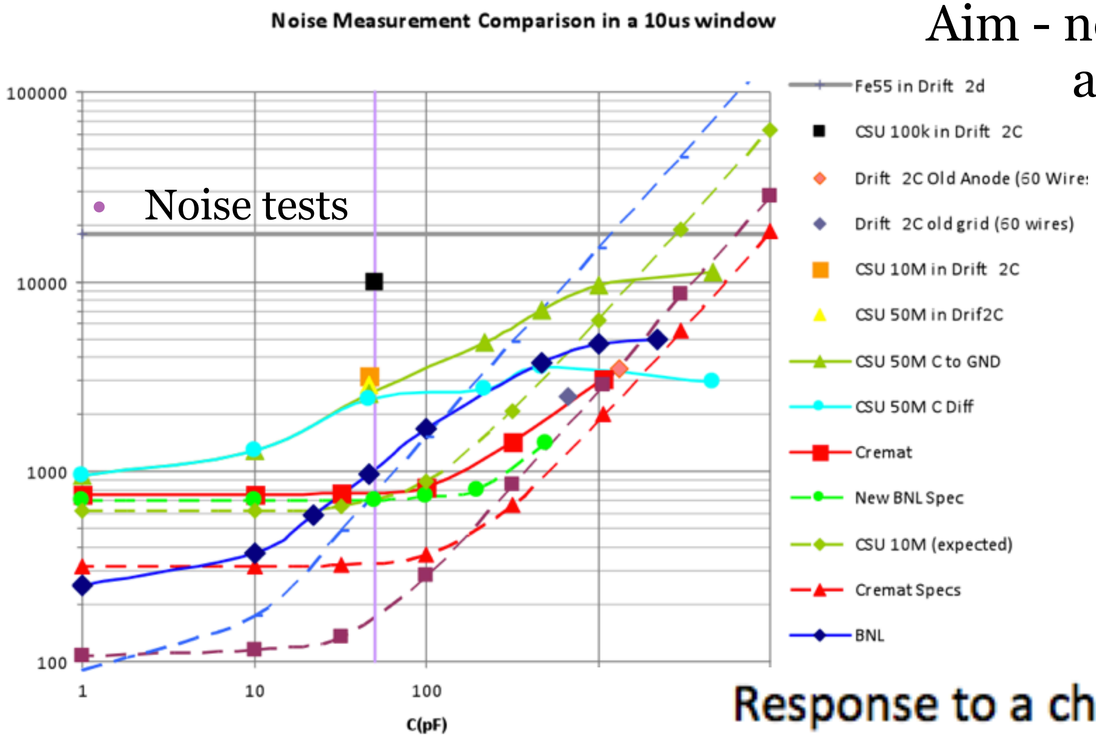




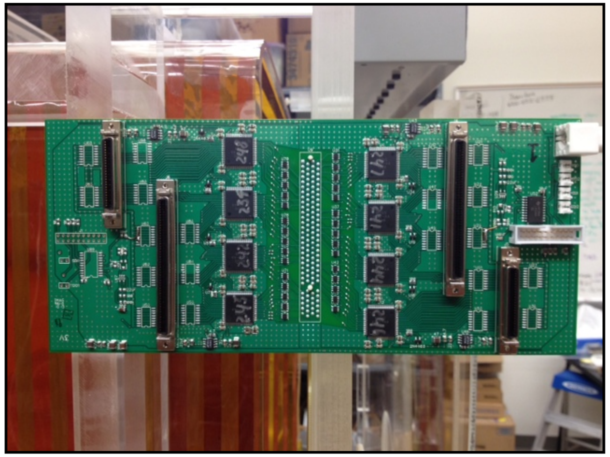
DRIFT IIe - Electronics Front End, BNL

Aim - noise reduction of x4 over DRIFT IId all wire readout (not grouped)

- Noise tests



- Based on MicroBooNE chips



BNL Specs

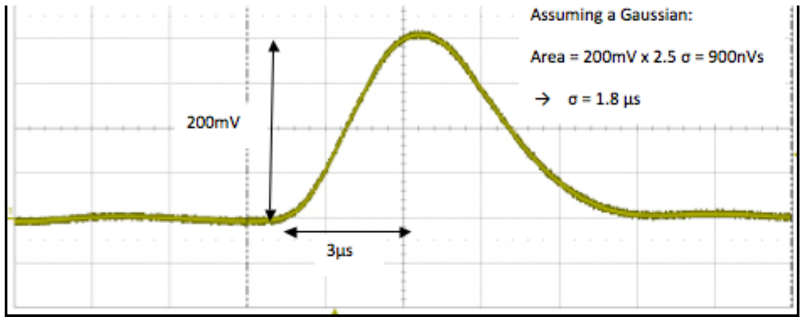
Gain:	5 to 25 mv/fC
Peaking time:	.5 to 3µs
Shaping time:	.3 to 1.8µs
ENC:	150e- at 0pF (.025fC)
ENI:	5pA - 30pA
Output:	.2 to 1.6 V
Max charge:	28 to 140 fC
Max current:	12 to 360 nA
Max output Load:	250Ω || 400pF

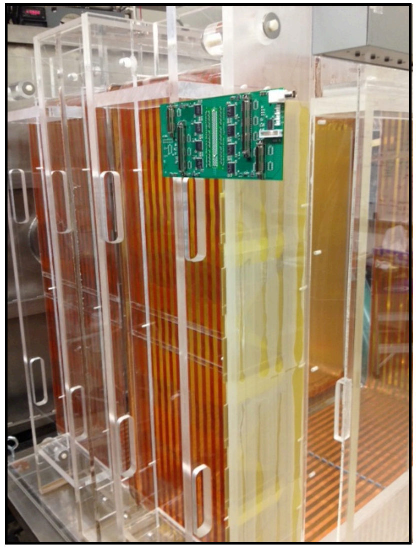
Response to a charge impulse

(Gain = 25mv/fC, τ_p = 3µs)

$q_{injected}$ = 200pF x 0.04V = 8fC

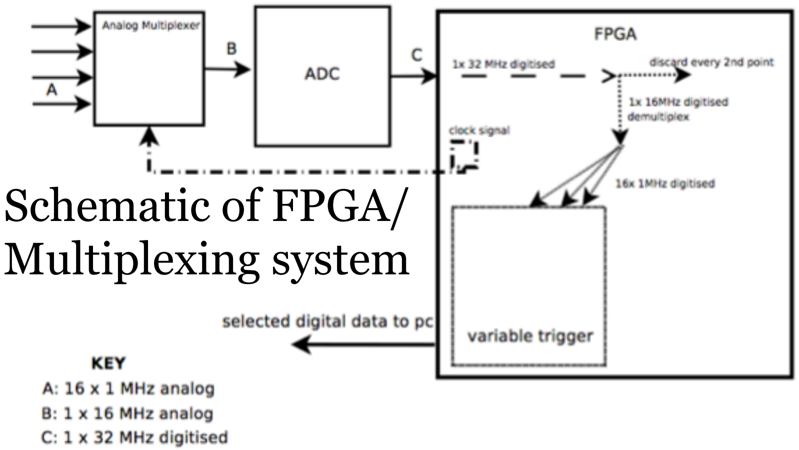
$q_{measured}$ = 200mv / (25mv/fC) = 8fC



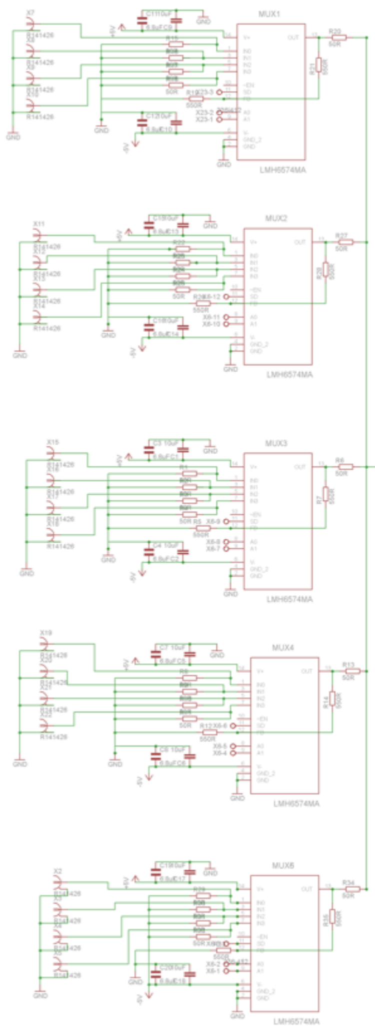


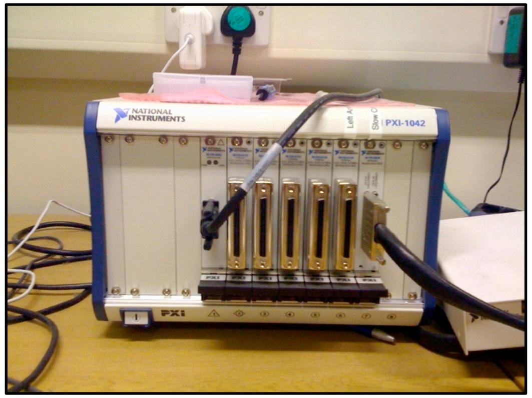
DRIFT IIe - DAQ (1) - Multiplex (Shef)

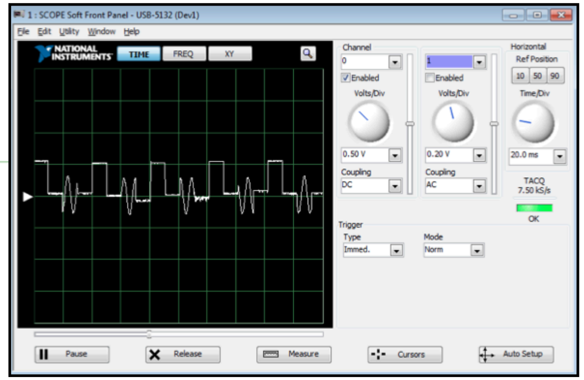
- Aim to make use of slowness of DRIFT charge
- Use 50 Mhz NI ADC and Multiplex 20:1
- Saves costs by x 20



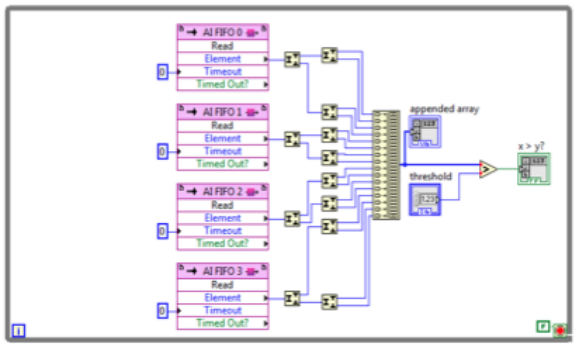
- Schematic of FPGA/ Multiplexing system



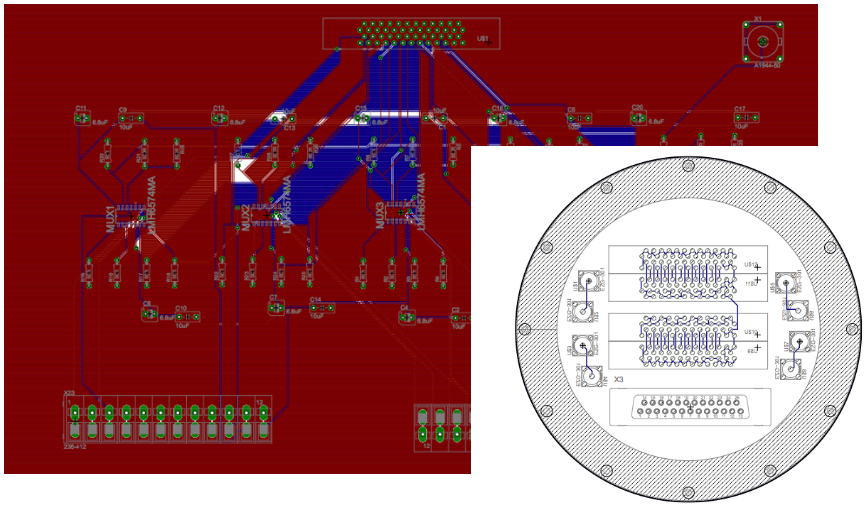




LabView FPGA code for reading analog inputs

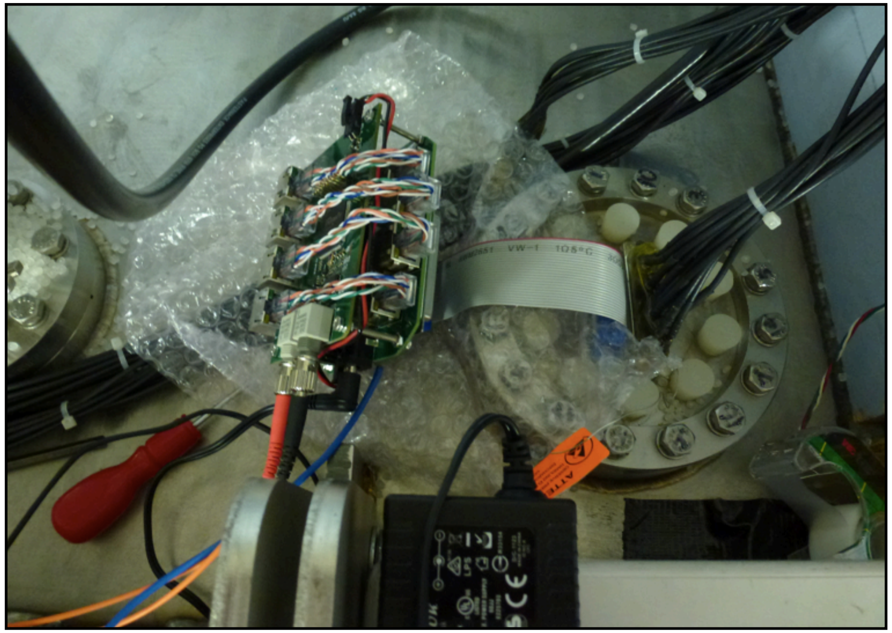


- PCB and flange designs

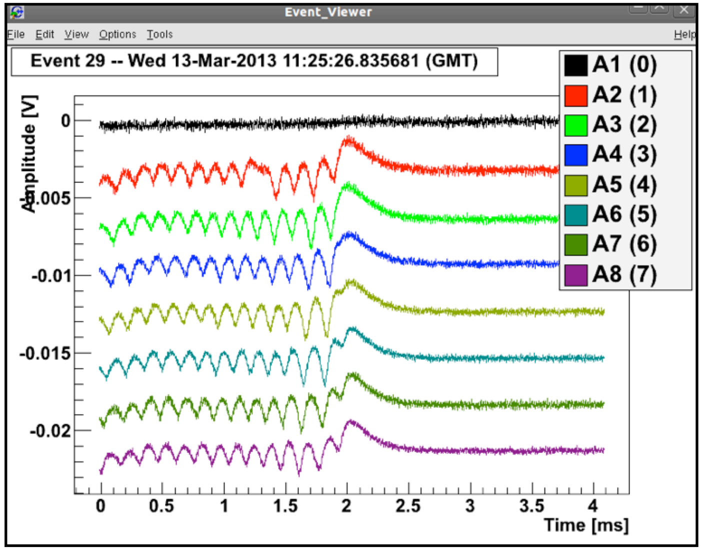


DRIFT IIe - DAQ (2) - Edelweiss (Oxford)

- Aim to test ready-made Edelweiss electronics for DRIFT (Hans Kraus)



- First test of 8 channels on DRIFT IId worked well

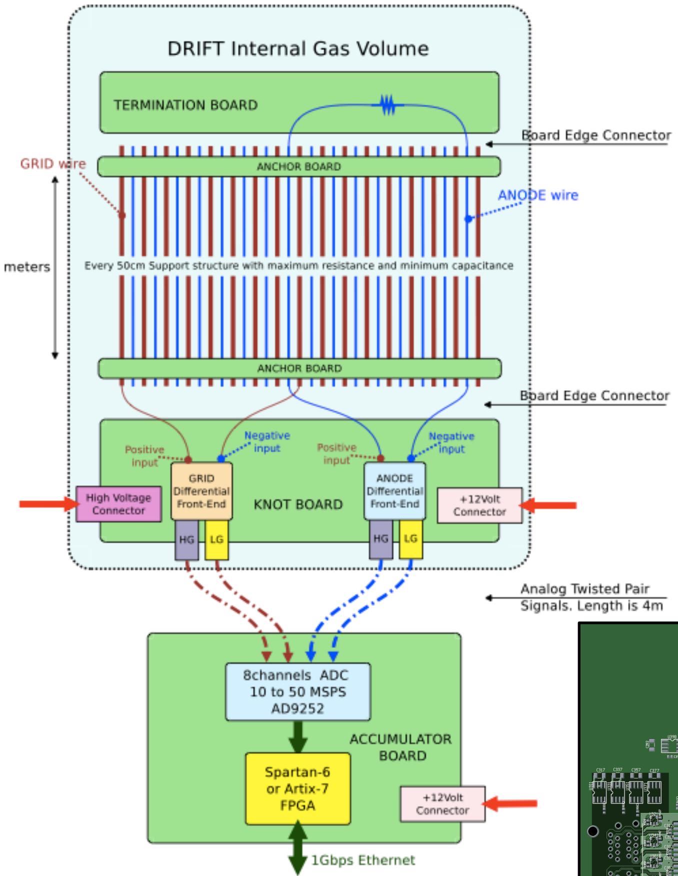


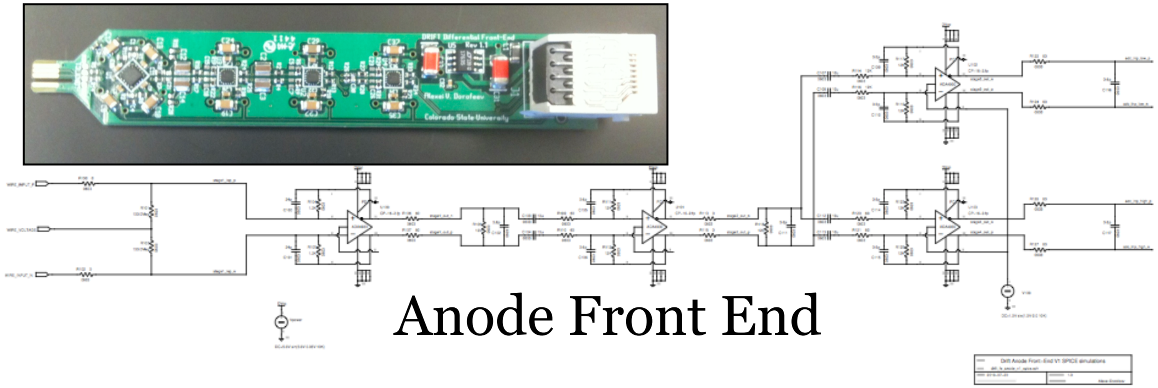
Front-end DAQ (ADC): this is based on an analogue front-end chip that contains 8 channels, each comprising a low-noise amplifier, a variable gain amplifier, a 3-pole anti-aliasing filter and a 14-bit adc. In addition, there is a high-pass filter and a sampling rate of 10 MHz is easily achieved. This allows implementation of a single channel at a cost of approximately **£25 per channel**

Processing of front-end ADC data: this is a (large) FPGA with enough resources. It reads the ADC front ends (26 signals per 8-channel ADC chip) and incorporates some level of digital filtering, interfaces user commands to the ADC chip, controls a memory chip to buffer data during data bursts and interfaces to the optical fibre link. The memory chip requires nearly 50 connections, but has enough storage capacity that it might be possible to actually realize a deadtime-free system. At a push it would be possible to connect up to 5 ADC chips, giving 40 readout channels on.

USB interface and optical fibre link: this is an optical fibre receiver (the counterpart to what is on the DAQ board), an FPGA, an

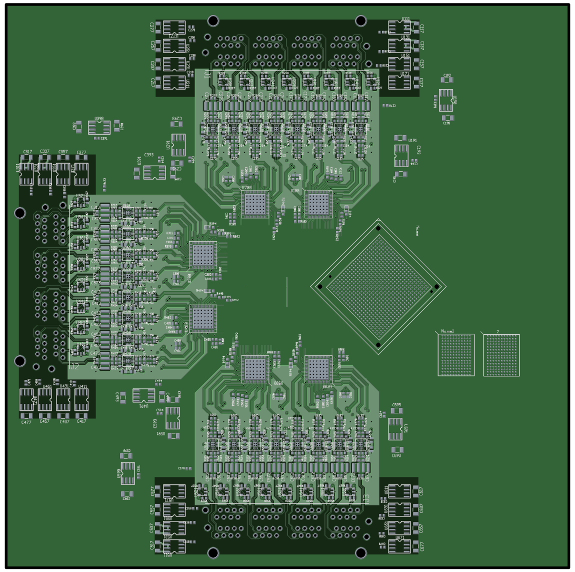
DRIFT IIe - DAQ (3) - Accumulator (CSU)





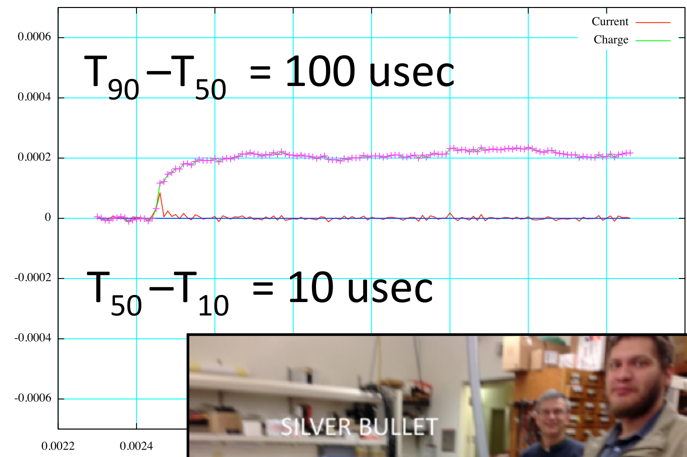
Anode Front End

More than 1GhZ Differential opamp: ADA4930. High Supply transient rejection rate, fully balanced input. Low and High gain channels (ratio is 200).



DIGITIZATION BOARD. READS OUT 96 WIRES WITH DIFFERENTIAL FE. WILL BE USED ON FRIFT-IIe.

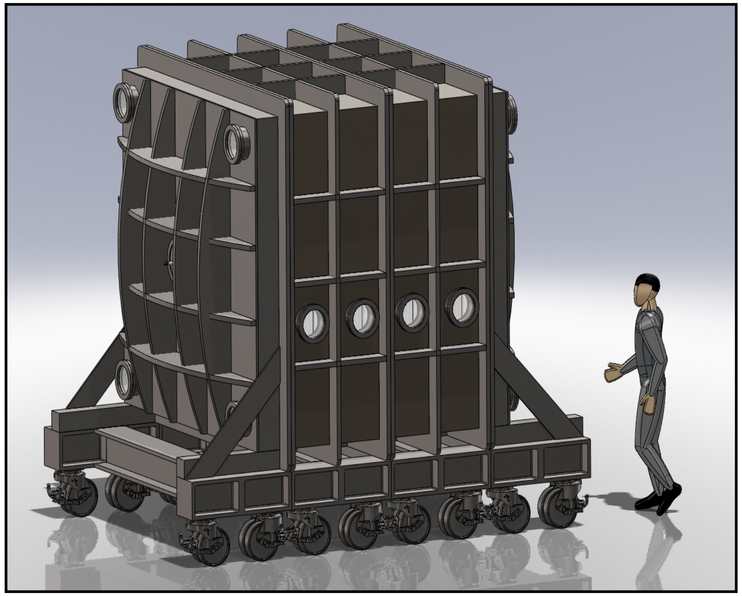
Charge Integral at wire, TrgCh, OUT9

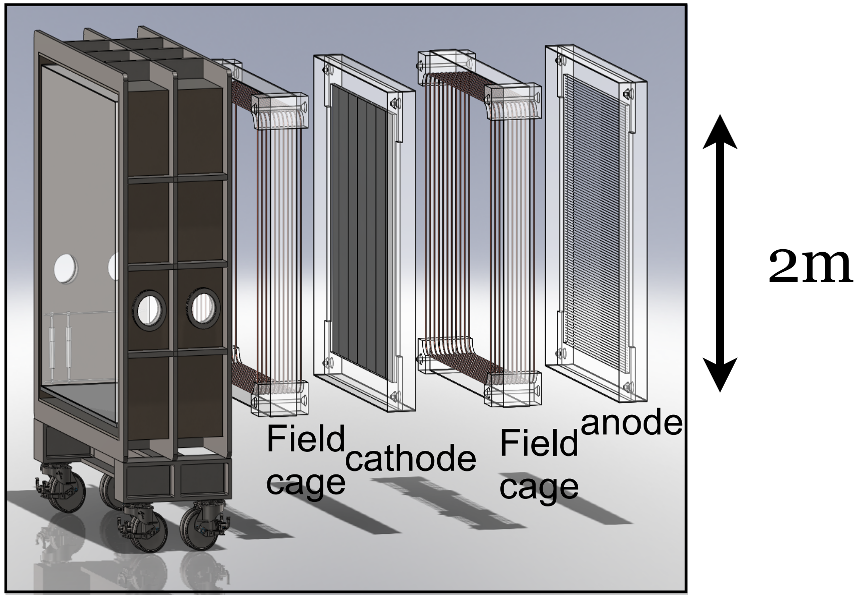


DRIFT IIe + DRIFT IId

DRIFT III

DRIFT III Modules





- 2 modules of 2 x 2m, total 8 m^3, 10x DRIFT II, robust engineering
- Nitric acid process cleaning and radon emanation selection
- MWPCs look "both ways" - doubles volume per per wire
- reduced tension simplifies engineering (no strongback)
- CS_2 -ve ion plus CF_4 plus O_2 (different target mixes)
- Texturized thin central cathode (0.9 μm), partial segmentation
- Every-wire readout for lower noise (better particle ID)
- Full fiducialization of events with O_2, x, y, z

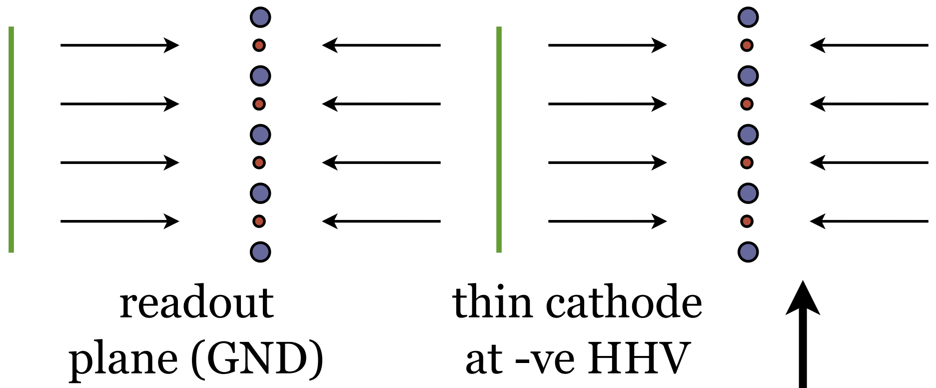
DRIFT III Readout

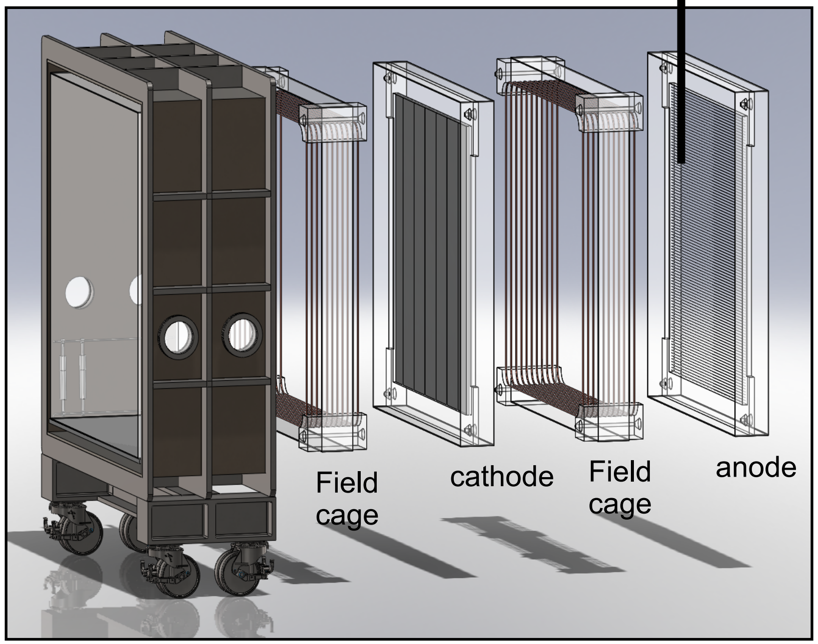
Sense plane

- Transparent readout plane to sense two sides (eliminates the mechanical support "strong back")
- 20 µm diameter stainless steel wires on a 2 mm pitch
- X-wires, Y-veto strip
- alternate grid wires, 1mm pitch
- Head-Tail sensitivity
- 2D readout but with 3D side veto

Cathode

- 70 kV with well-engineered field cage and high-voltage system; diffusion (reduced by 40% c.f. DRIFT II)
- Texturised thin film
- Partial segmentation



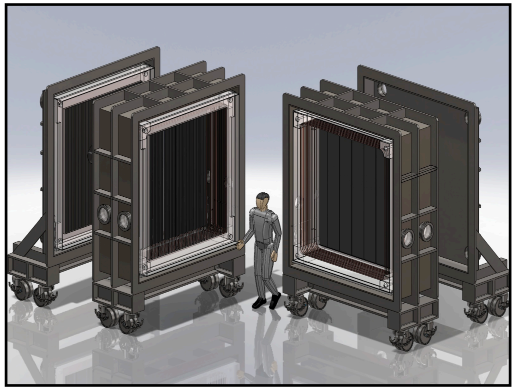


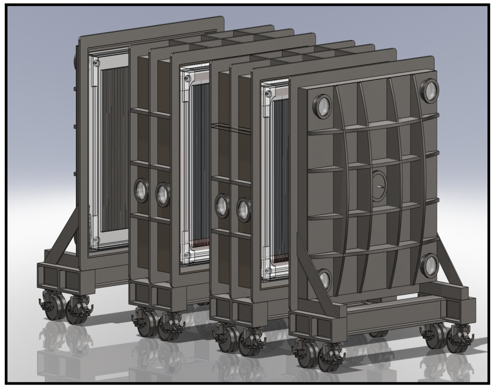
DRIFT III Scale-up

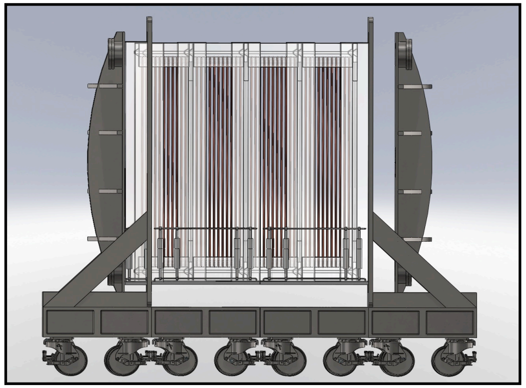
- Two modules composed of 8 m³ footprint ~6 m by 3 m.

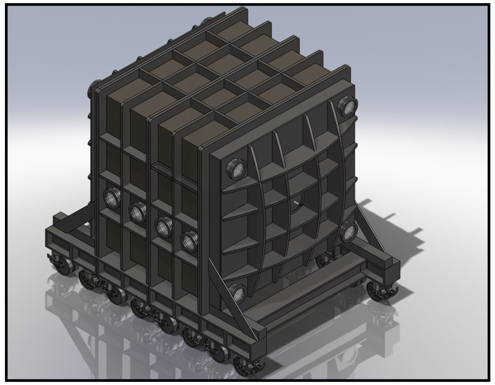
- Modular design to allow approach to ton-scale
- 4 kg target - 24 m³

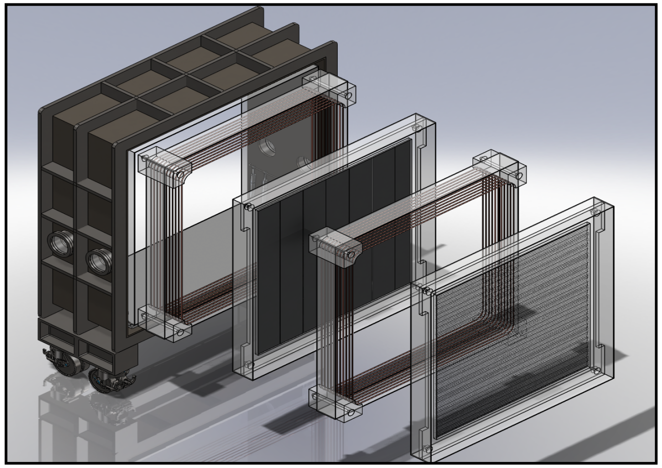
- 250 of 4 kg modules gives 1 ton would fit into a standard DUSEL module or 500m tunnel at Boulby

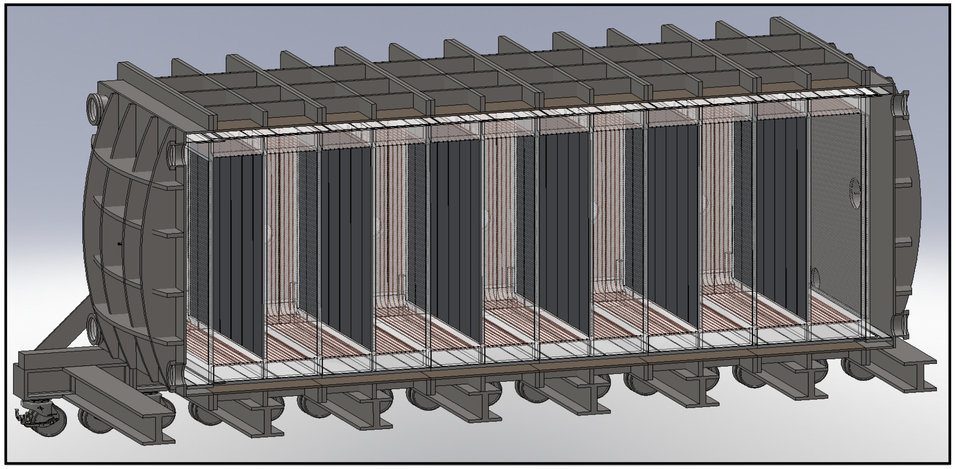






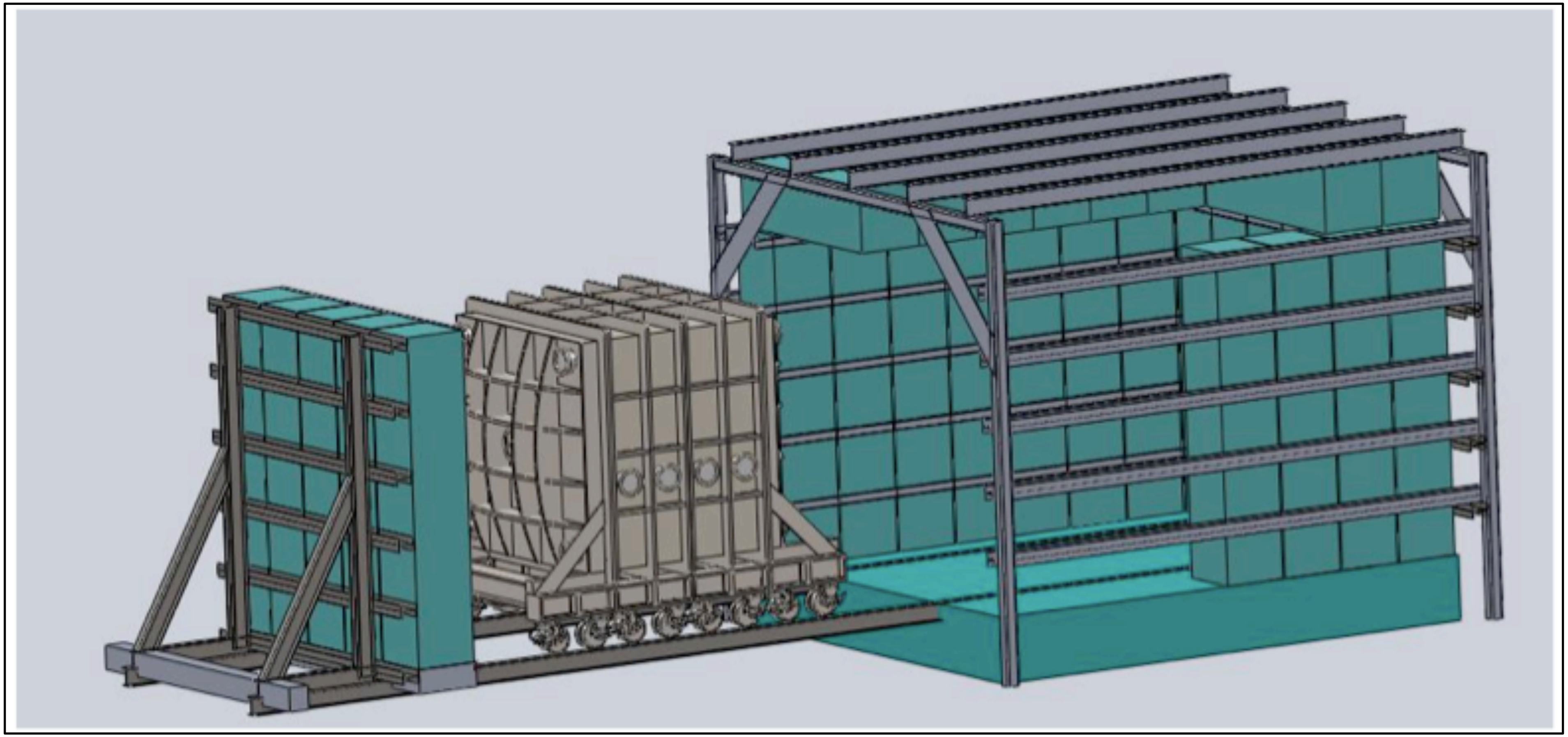






- Preference for CH-based material

DRIFT III Shielding



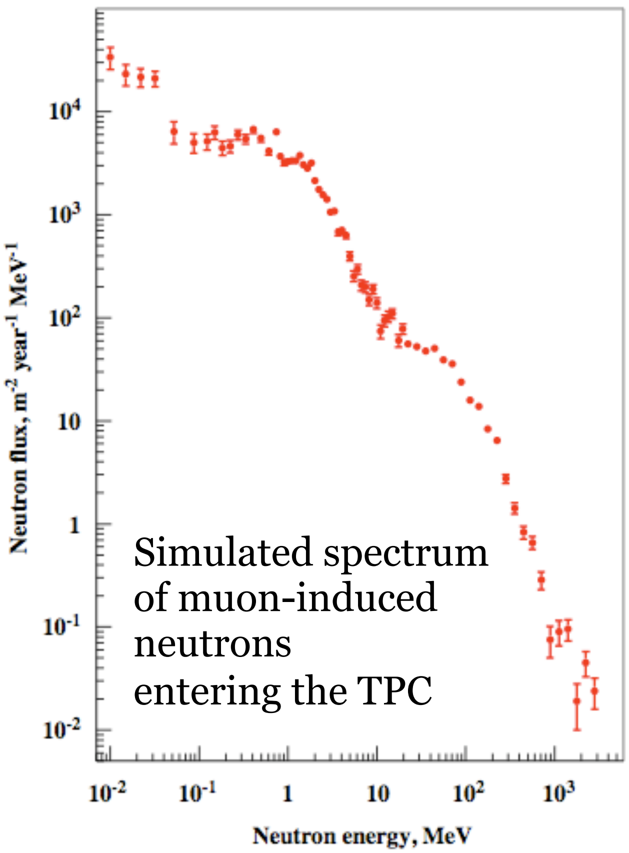
- neutron shielding   Water shielding   CH pellet shielding
- No gamma shielding needed

Neutron Summary for DRIFT III

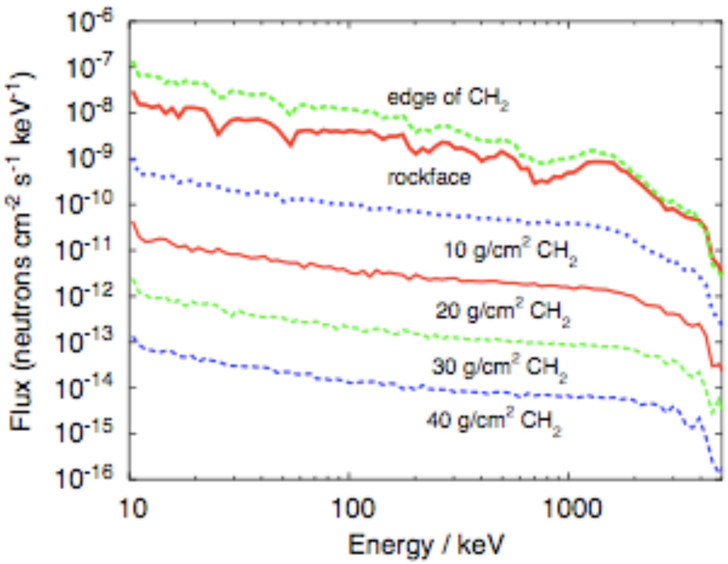
- Total neutron rates from Muons, Rock, Detector

e.g. see M.J. Carson et al NIM A 546 (2005) 509–522

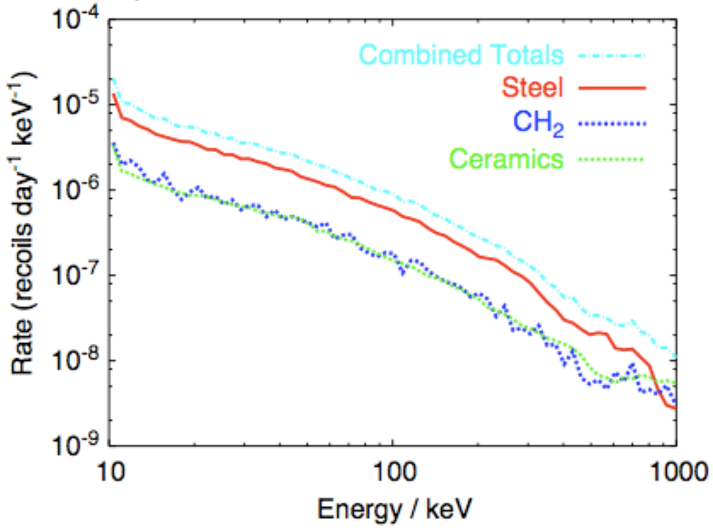
(1) Muon neutrons



(2) Rock neutrons



(3) Detector neutrons



Neutron Summary

Assumptions

Includes 40 g cm^{-2} CH_2 shielding against rock neutrons (estimates)

Result (prelim estimates)

see M.J. Carson et al NIM A 546 (2005) 509–522

Estimated neutron backgrounds per year at 10-50 keV recoil energies

		kg	Rock	Muons	Detector	Total
	DRIFT II	0.167	0.01	0.12	0.06	0.19
	24 m^3 (as multiple DRIFT IIs)	4.00	0.24	2.88	1.56	4.68
DRIFT III	24 m^3 using steel, no muon veto	*4.00*	*0.20*	*2.00*	*1.50*	*3.70*
DRIFT III	24 m^3 acrylic, no muon veto	*4.00*	*0.20*	*<1.00*	*<1.00*	*<0.4*

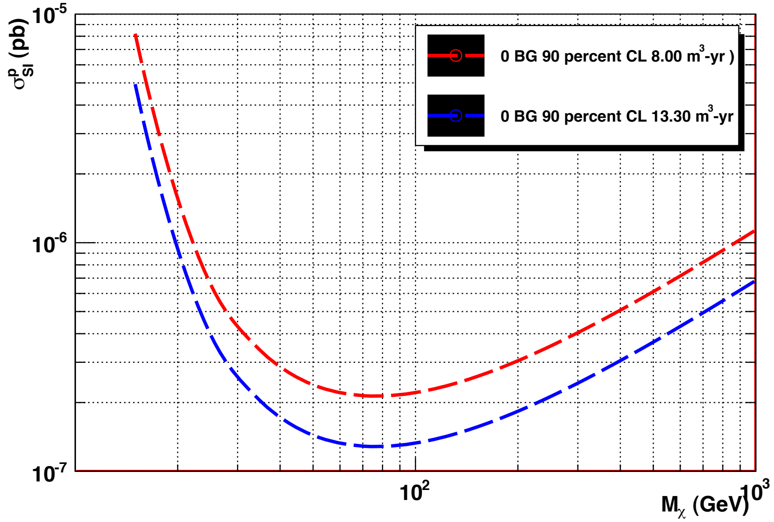
Conclusion for DRIFT III.1 module (prelim):

- Requires 40 gcm^{-2} CH neutron shielding (like DRIFT II)
- Steel construction just about alright

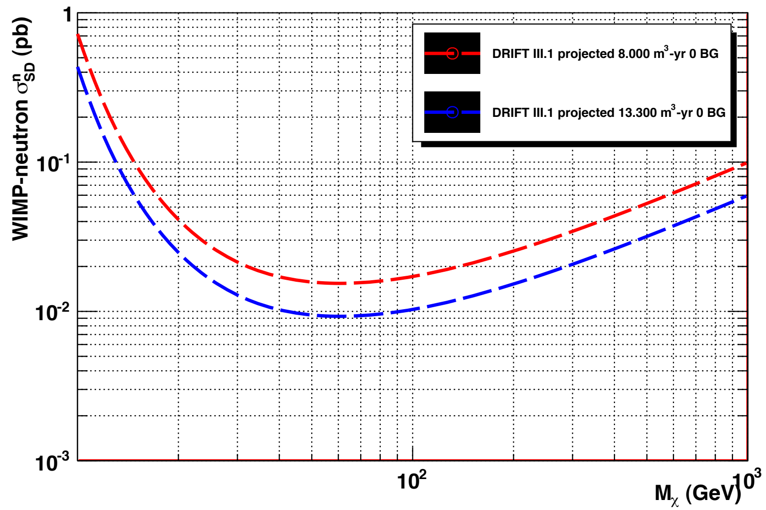
  optimization, selection, internal CH?
- No need for muon active veto at Boulby for single module

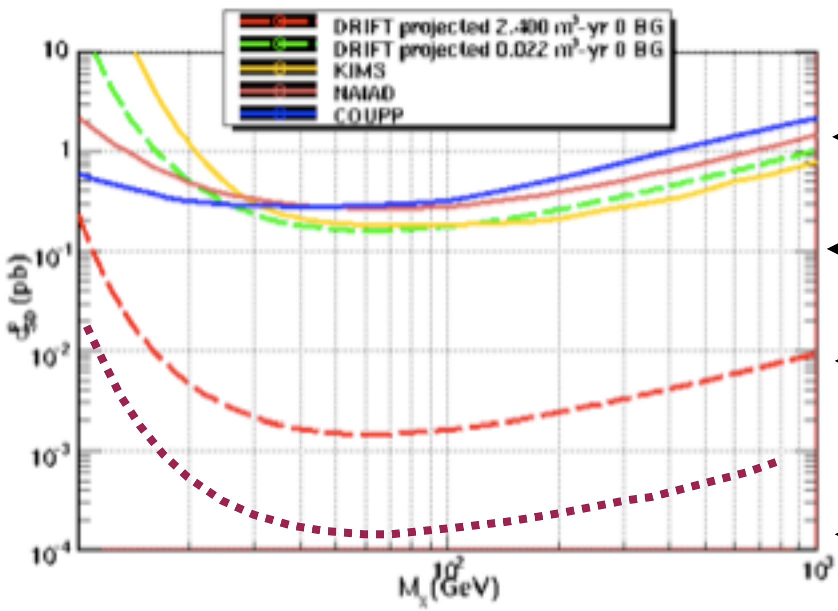
SD Sensitivity of DRIFT IIe, DRIFT III.1

(1) Expected SI sensitivity
DRIFT III.1 8.0 m3-yr, 0 bkg (red)



(2) Expected SD-n sensitivity
DRIFT III.1 8.0 m3-yr, 0 bkg (red)





(3) Expected WIMP-proton spin dependent sensitivity

current limits

DRIFT IIe - 10 day run, zero background prediction

DRIFT III.1 8.0 m3-years, zero background prediction

DRIFT III 1 year run

Conclusion
Paths to Bigger DM Detectors?

The final route to a definitive detection is not clear, but more than one technique will be essential

Best at Scalability of Target Mass?

Best at Finding a Signal?

Best at Background Rejection?

Gas Directional