Development of the tracking detector for SuperNEMO and analysis of double-beta decay in ^{48}Ca using NEMO3 data

IOP 2013 - HEPP & APP Group Meeting, Liverpool

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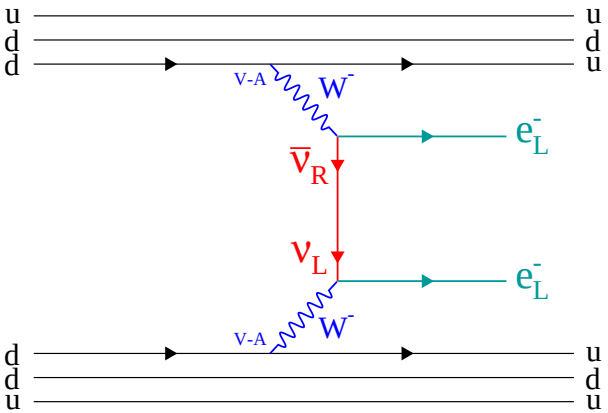
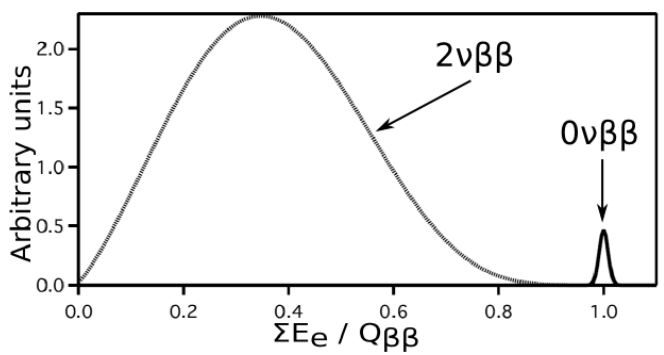
10 April 2013

Neutrinoless double beta decay

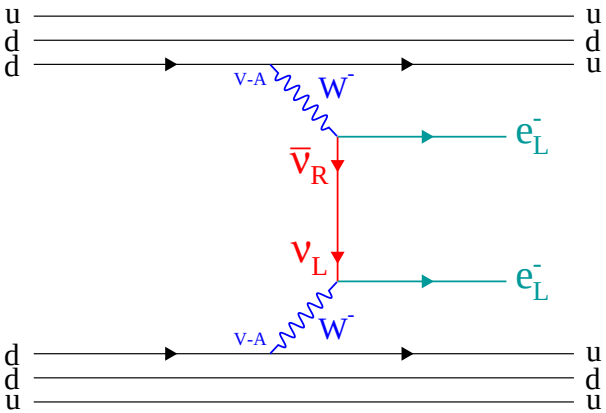


$$\left(T_{0\nu}^{1/2}\right)^{-1} \approx G_{0\nu} \left|M_{0\nu}\right|^2 \langle m_{\beta\beta} \rangle^2$$



- Allowed only if ν is Majorana ($\bar{\nu} = \nu$)
  - Only known channel to probe this property of νs
- Lepton number is violated ($\Delta L = 2$)
  - $\Delta L \neq 0$ processes required for leptogenesis
- Majorana mass term cannot come from the Higgs
  - Different mass origin from quarks and charged leptons
- $\langle m_{\beta\beta} \rangle = \sum U_{ei}^2 m_i$
  - Fix ν absolute mass scale

Neutrinoless double beta decay



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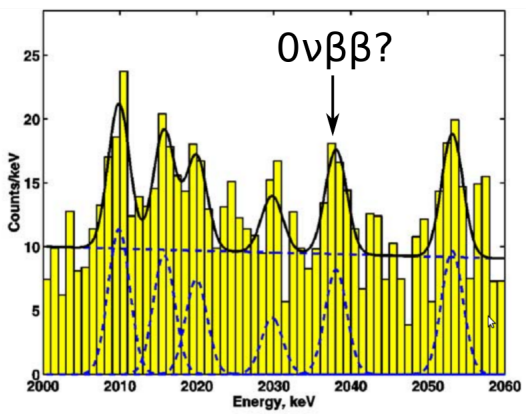

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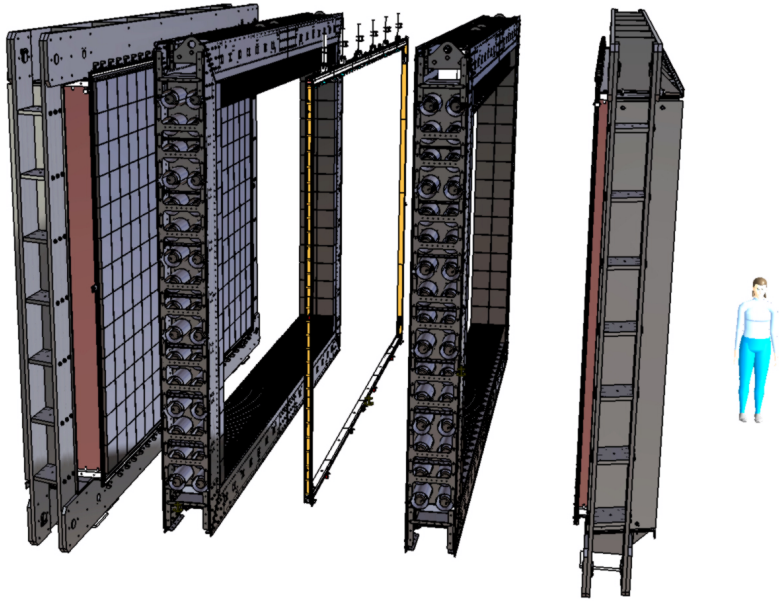
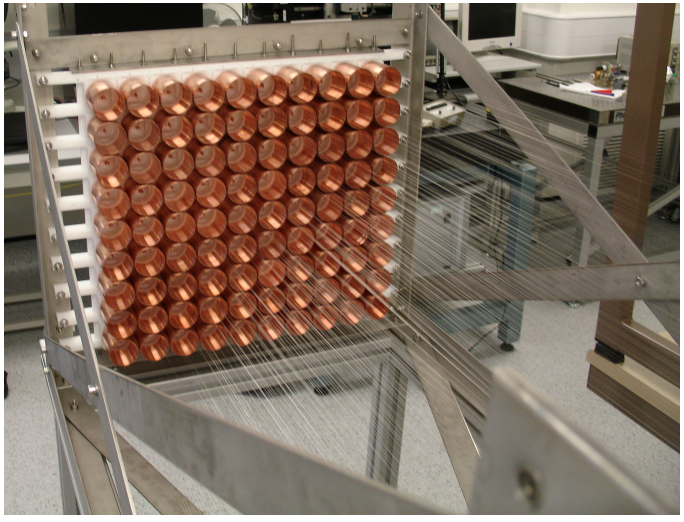
SuperNEMO

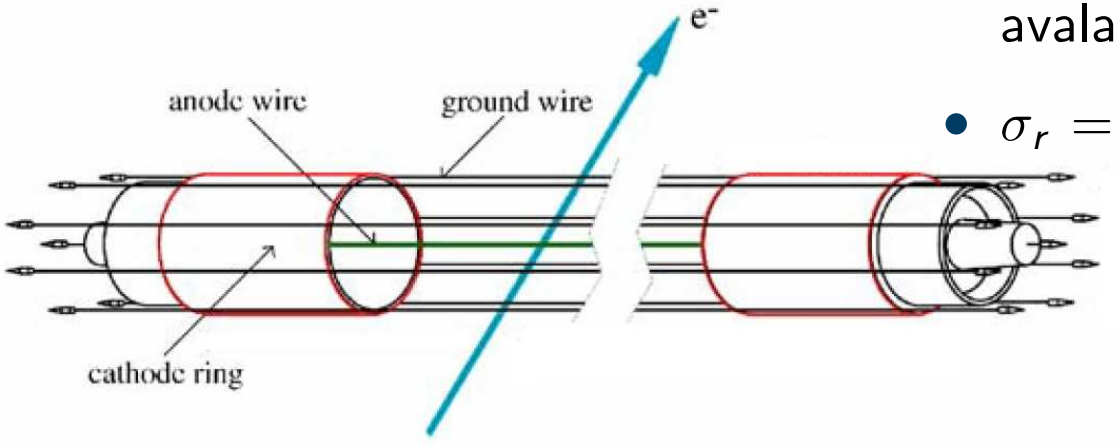
- Tracker + Calorimeter approach
- 20 modules
- 30% efficiency
- Resolution 4% FWHM at 3 MeV



	Demonstrator	Full scale
^{82}Se source	7 kg	100 kg
Geiger cells	2000	40000
Calorimeter modules	692	10000
$T_{1/2}$ sensitivity	6.6×10^{24} yr	10^{26} yr
$\langle m_{\beta\beta} \rangle$ sensitivity	200 - 400 meV	40 - 100 meV

SuperNEMO: Tracker

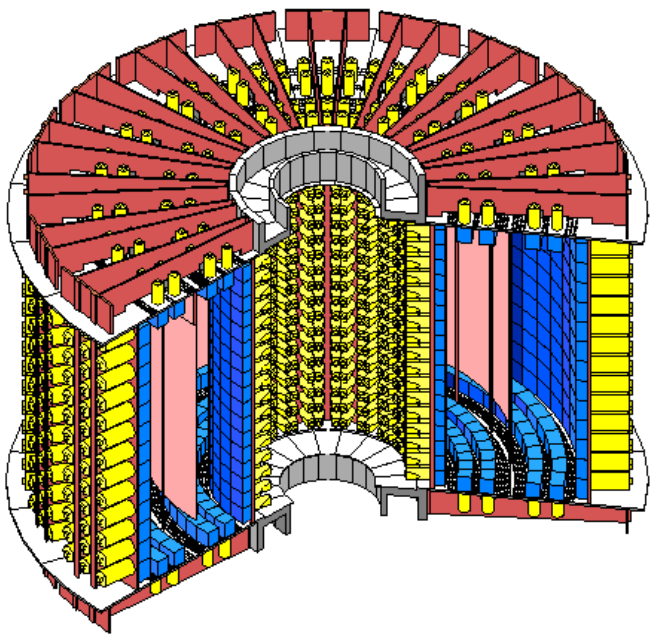


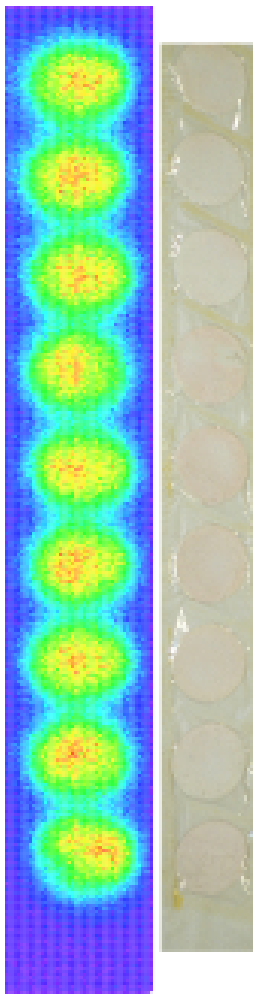


- Array of open Geiger cells
  - Approximately cylindrical electric field
  - Ionisation creates saturated avalanches
- Transverse radius given by e^- drift time
- Longitudinal position given by avalanche propagation time
- $\sigma_r = 0.7$ mm, $\sigma_Z = 1$ cm

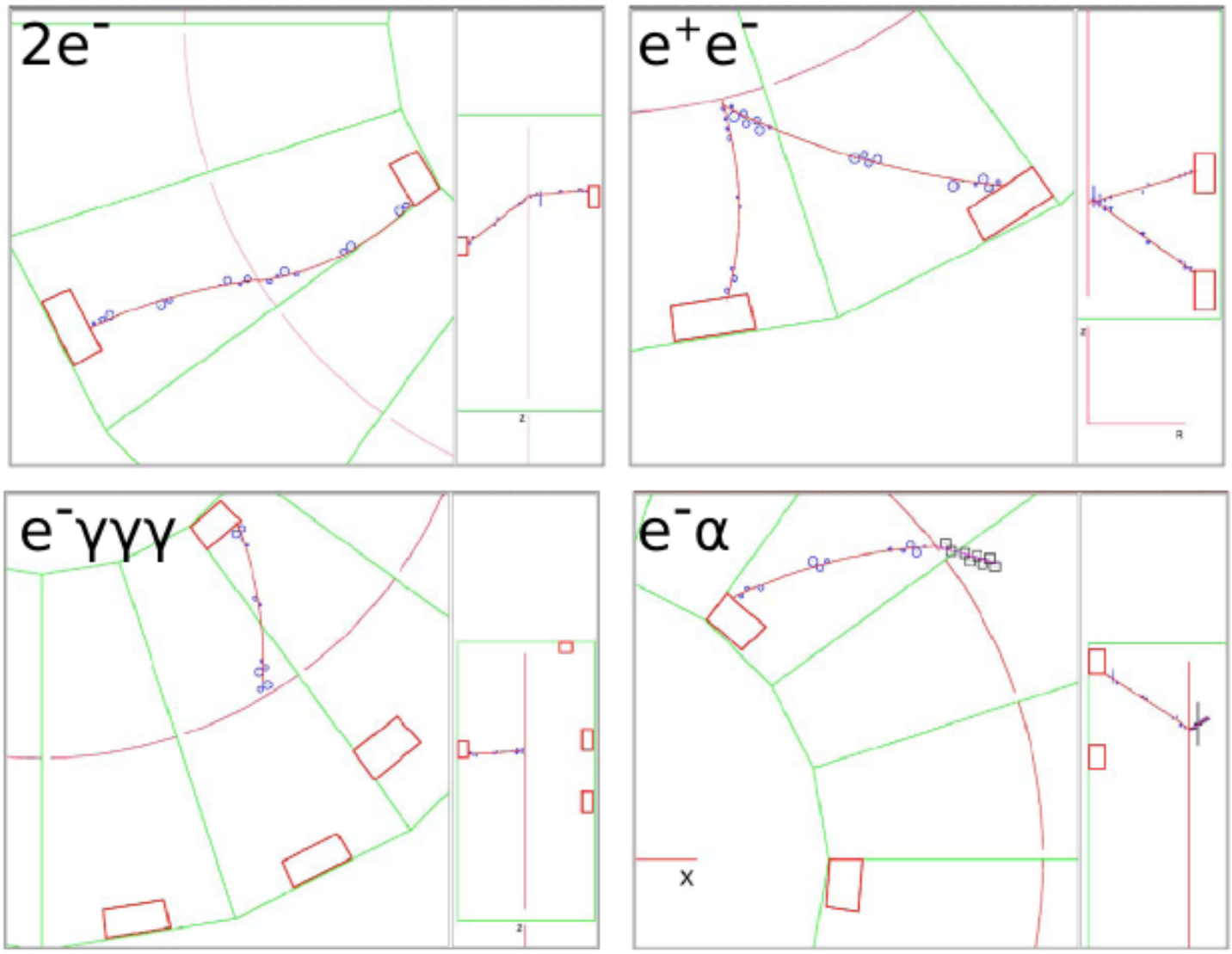
^{48}Ca double beta decay

- High Q-value: 4.27 MeV
  - Above most naturally occurring backgrounds
  - Phase space $\propto Q^5$
- In NEMO3:
  - 7g in 9 CaF_2 discs
  - $2\nu\beta\beta$ $T^{1/2}$ not yet published
- Also being measured by CANDLES
  - Japan based CaF_2 scintillator experiment
- Low natural abundance
- Enrichment is challenging
- Nuclear matrix element is small

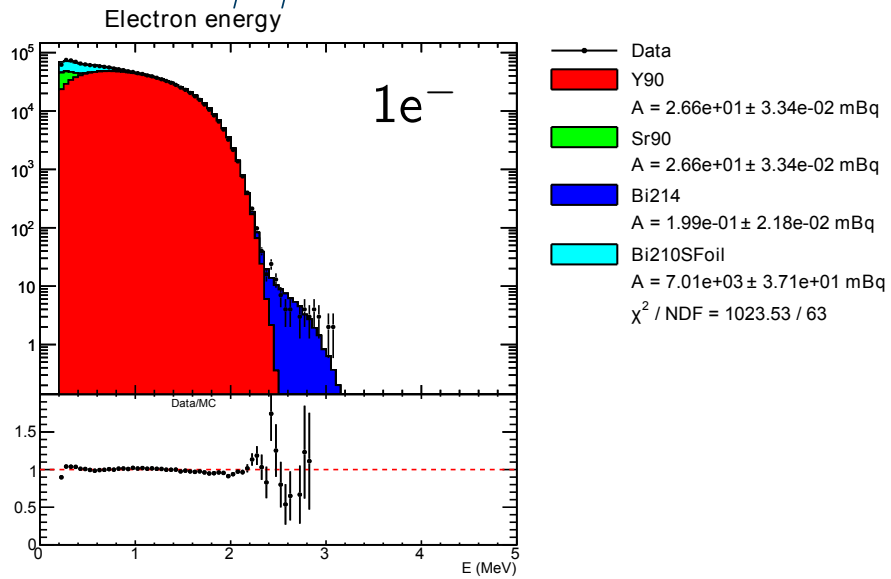




Signal identification and background discrimination



^{48}Ca $2\nu\beta\beta$ half-life measurement – Work in progress

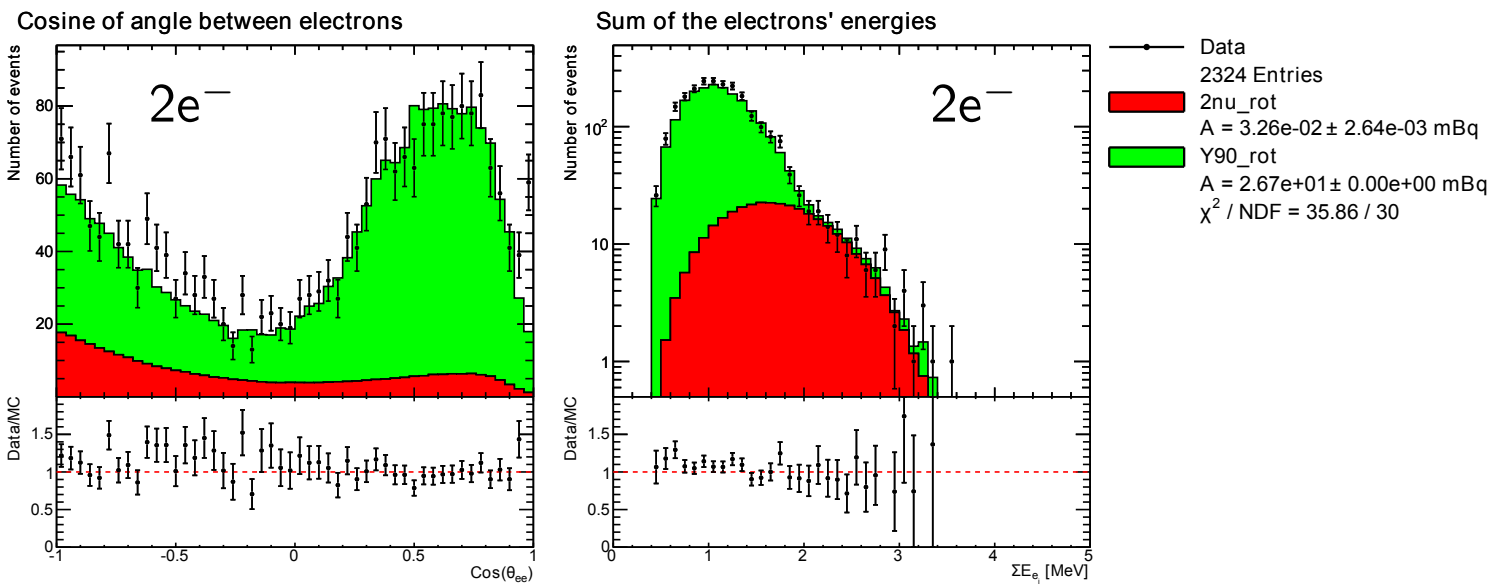


Runtime: 4.2 yr

$2\nu\beta\beta$ efficiency: 7.6%

Expect 10% statistical uncertainty

cf. TGV (2000) > 50%

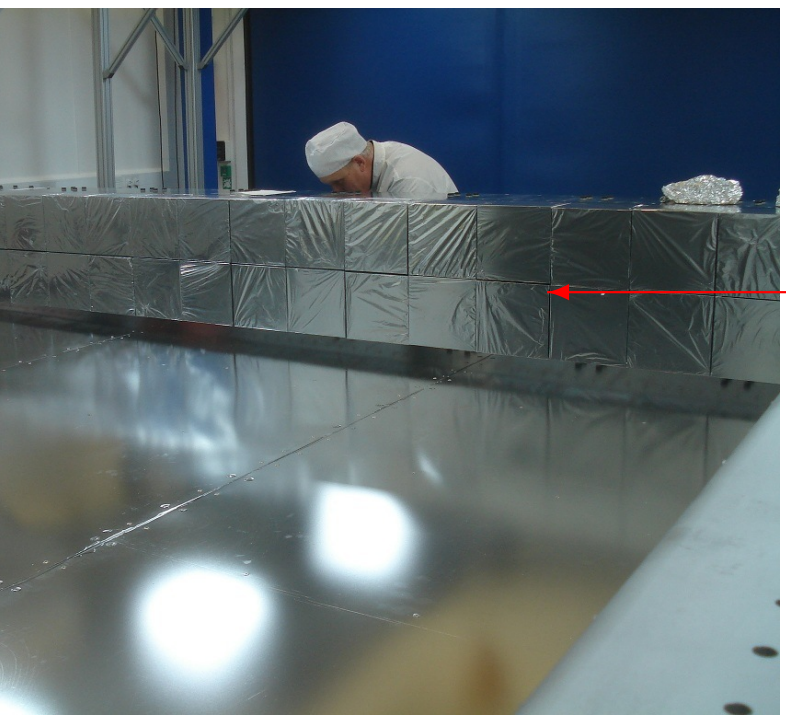


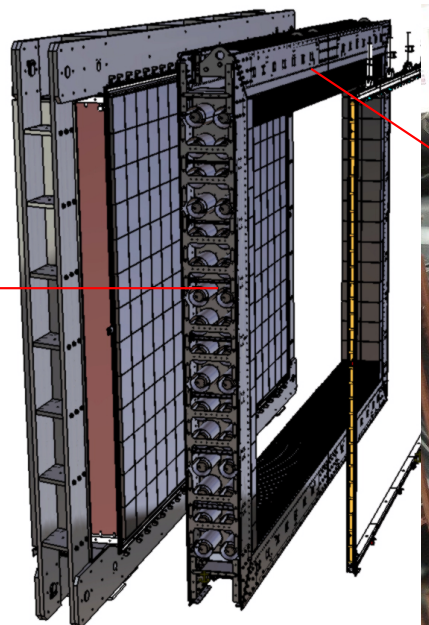
SuperNEMO tracker construction progress

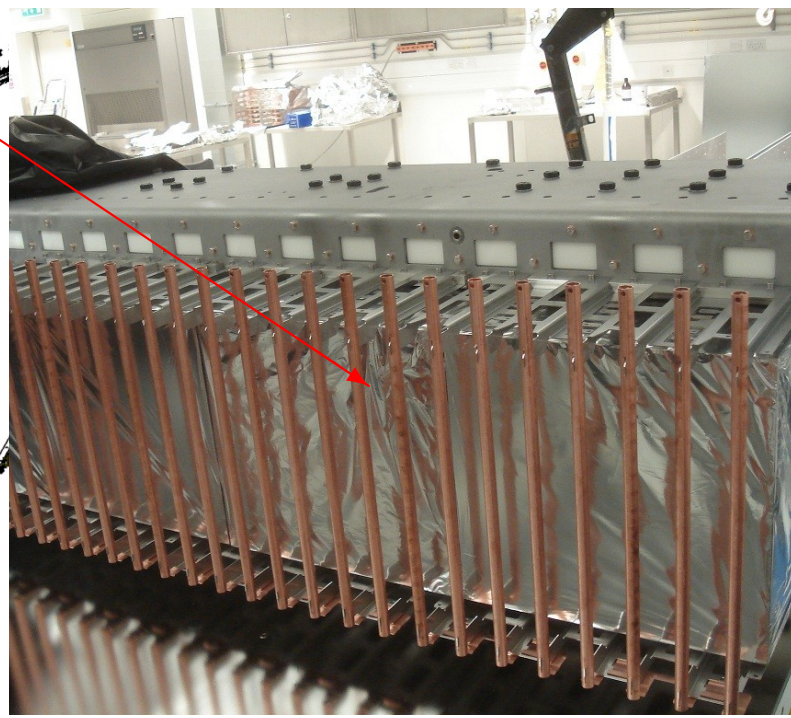
UCL/Mullard Space Science Laboratory, University of Manchester

- Ongoing/Next few months
  - First tracker C-section ($\frac{1}{4}$ tracker) frame built
  - Tracker cells to be shipped from Manchester and installed in the tracker frame
  - Surface commissioning
- **2013** Transport of tracker to the Laboratoire Souterrain de Modane and underground commissioning
- **2014** Integration of demonstrator module and commissioning
- **2014-15** Start background measurement and physics

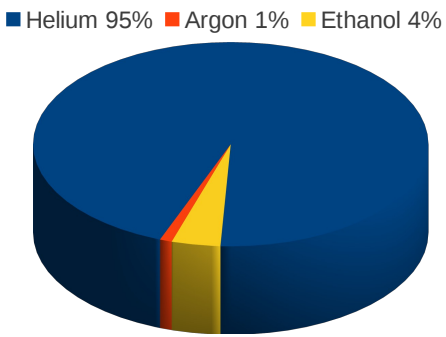
Tracker construction at Mullard Space Science Laboratory (UCL)



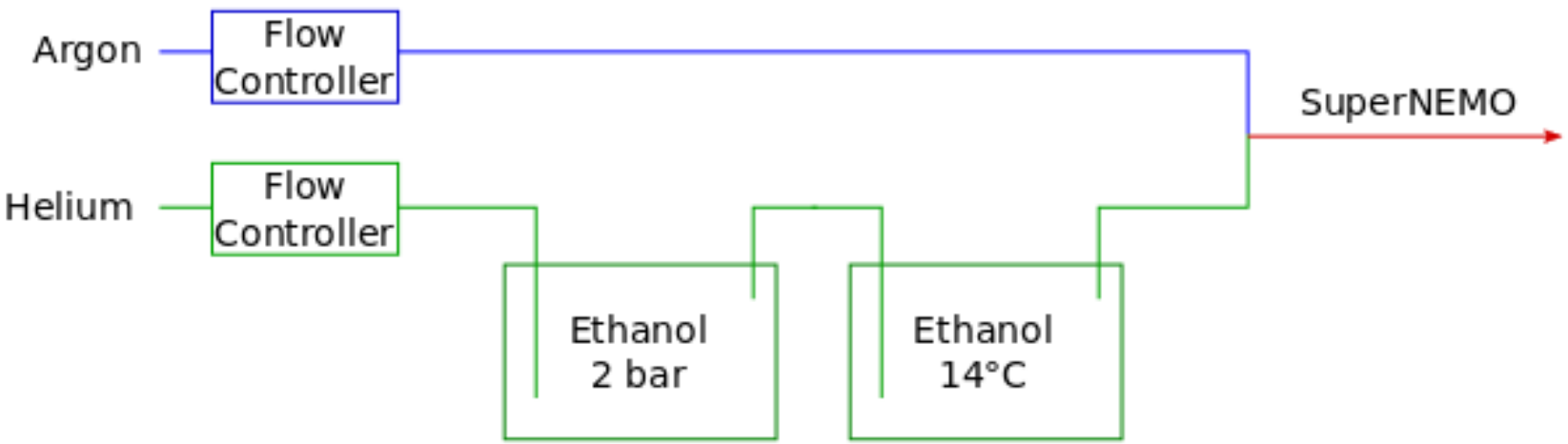


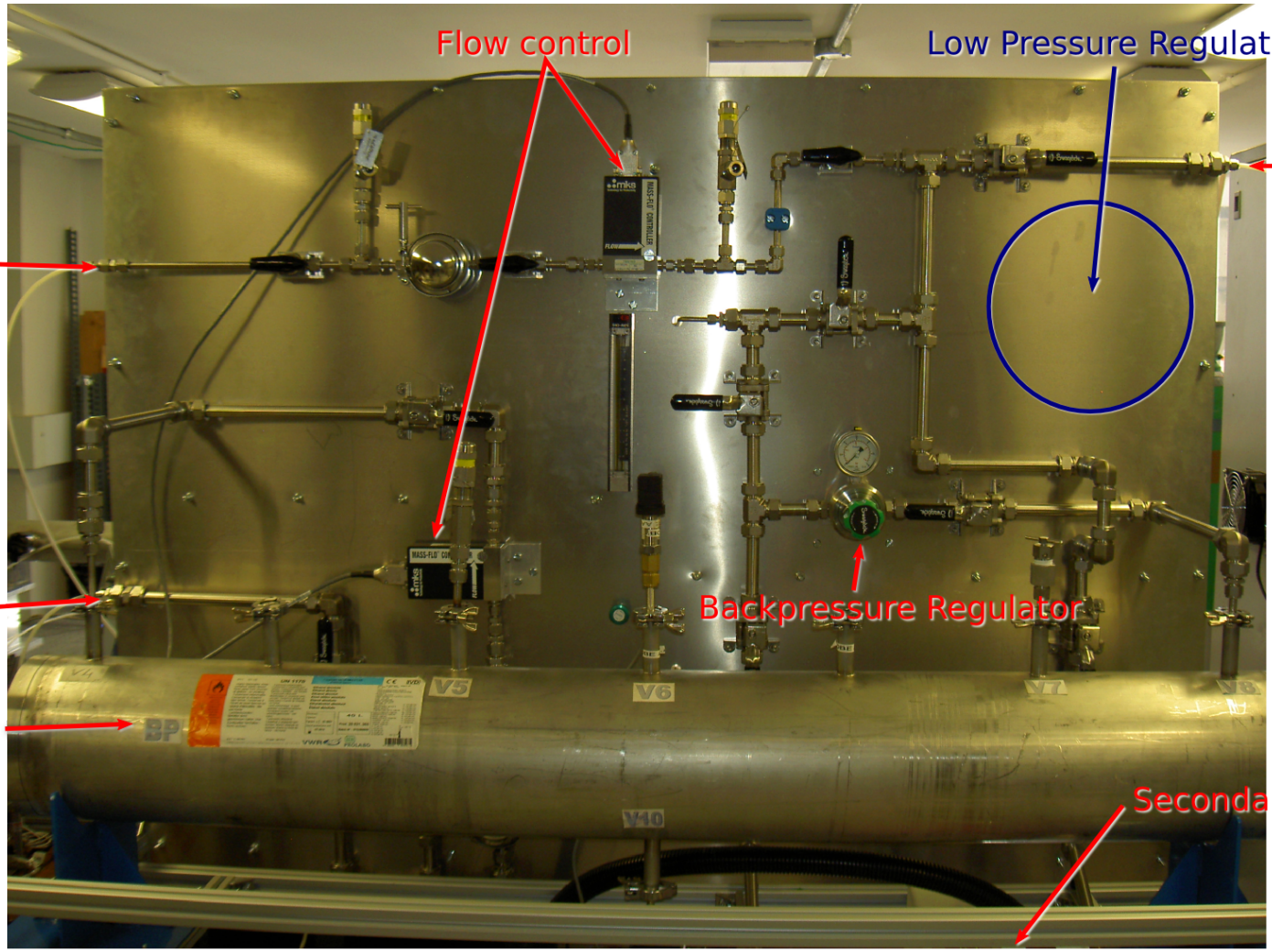


Gas system for the demonstrator module

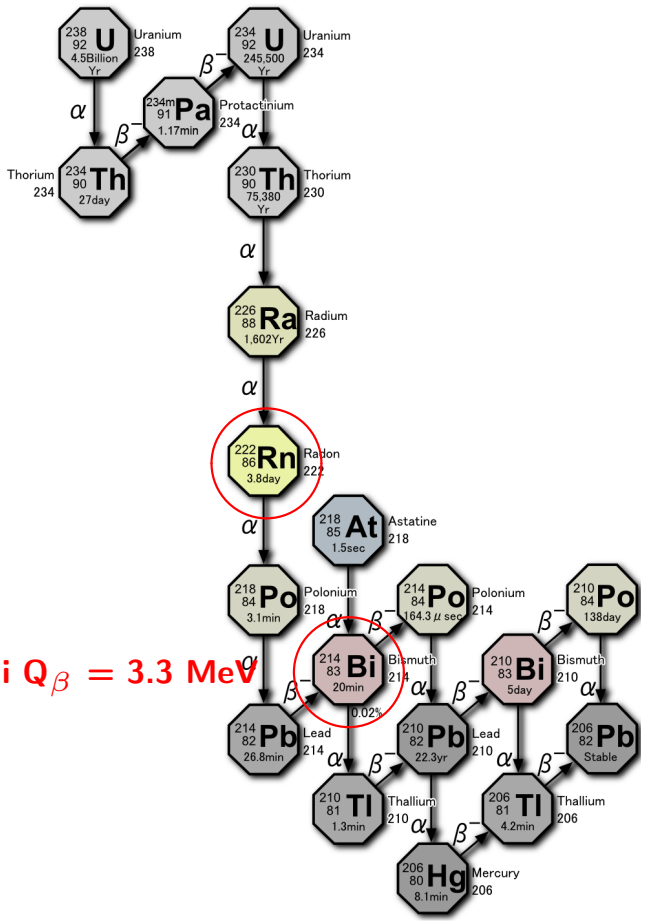


- Gas must be Radon *clean*
  - Careful selection of materials (*e.g.*, stainless steel pipe)
  - Capacity to run at a higher than baseline flow rate
- Tracker must be protected from over/underpressure

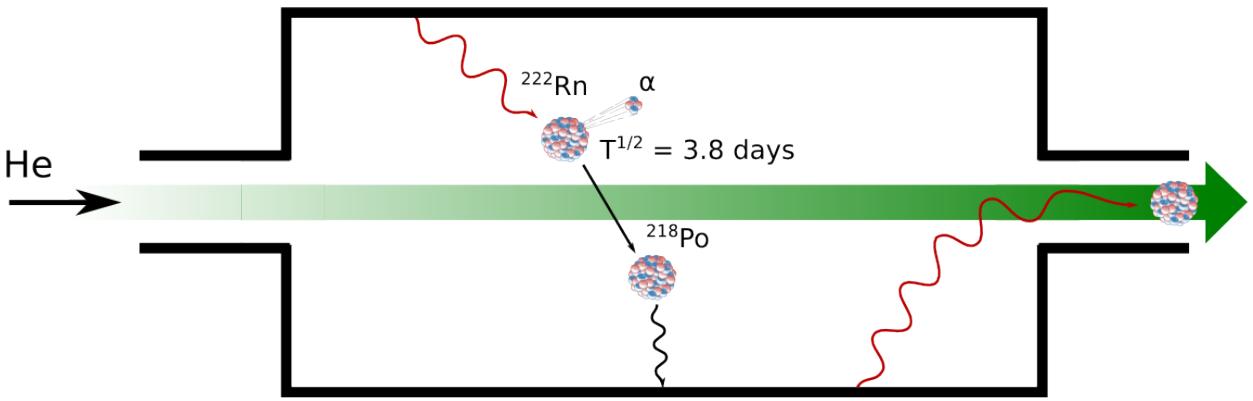


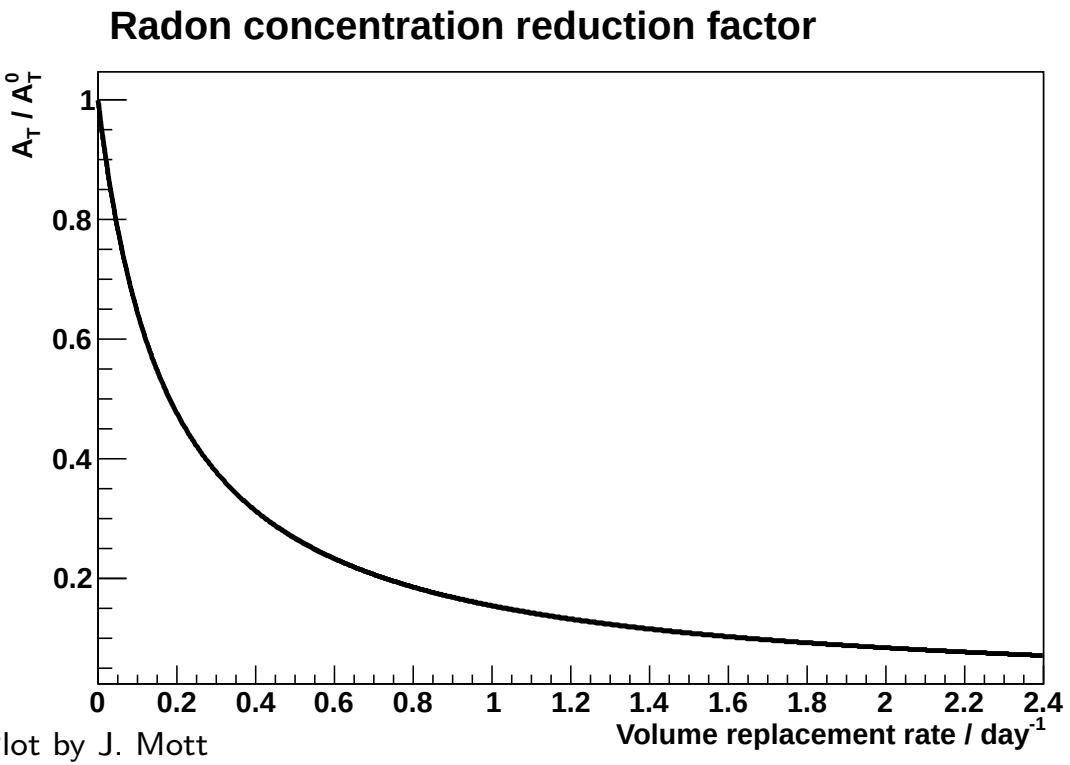

Flow control
Low Pressure Regulator
Output
Argon
Helium
Backpressure Regulator
Primary Bubbler
Secondary Bubbler

Flow rate study



^{214}Bi Q_β = 3.3 MeV

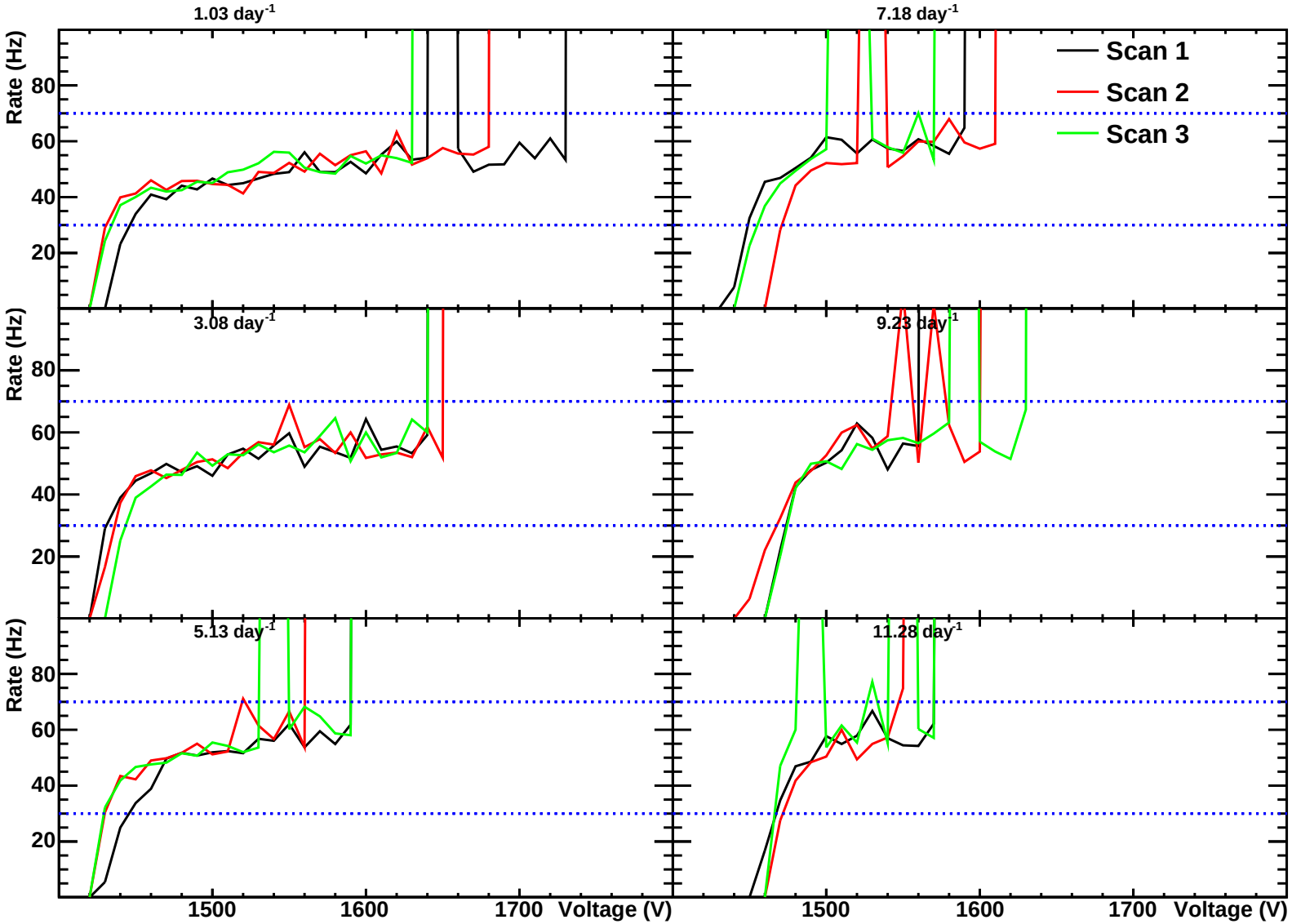


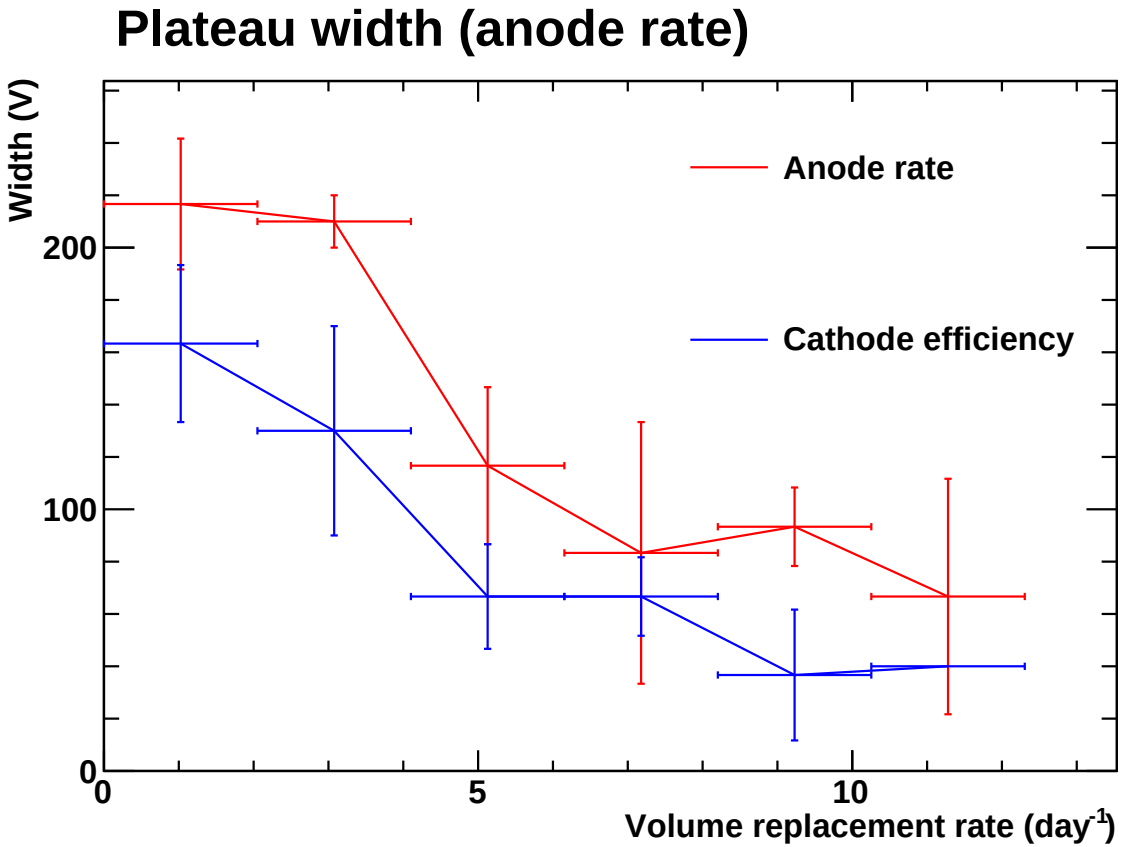


- At what flow rate does the tracker break down?

Plot by J. Mott

Plateau scans: Anode trigger rate





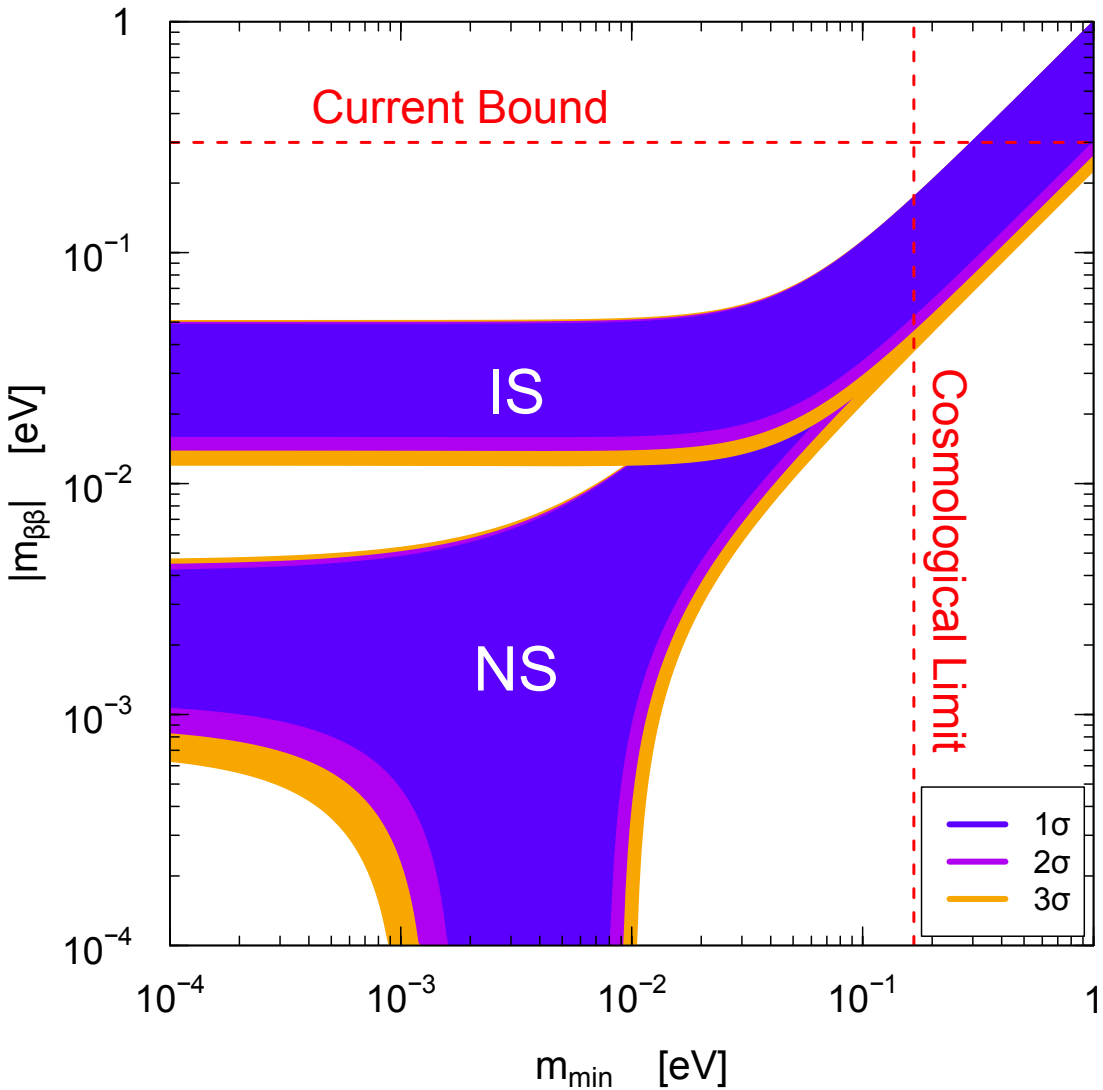
- Maximum volume change rate for Demonstrator is 2/day
- Caveats:
  - *Single* cell
  - Surface hit rate $\gg$ underground hit rate

The future

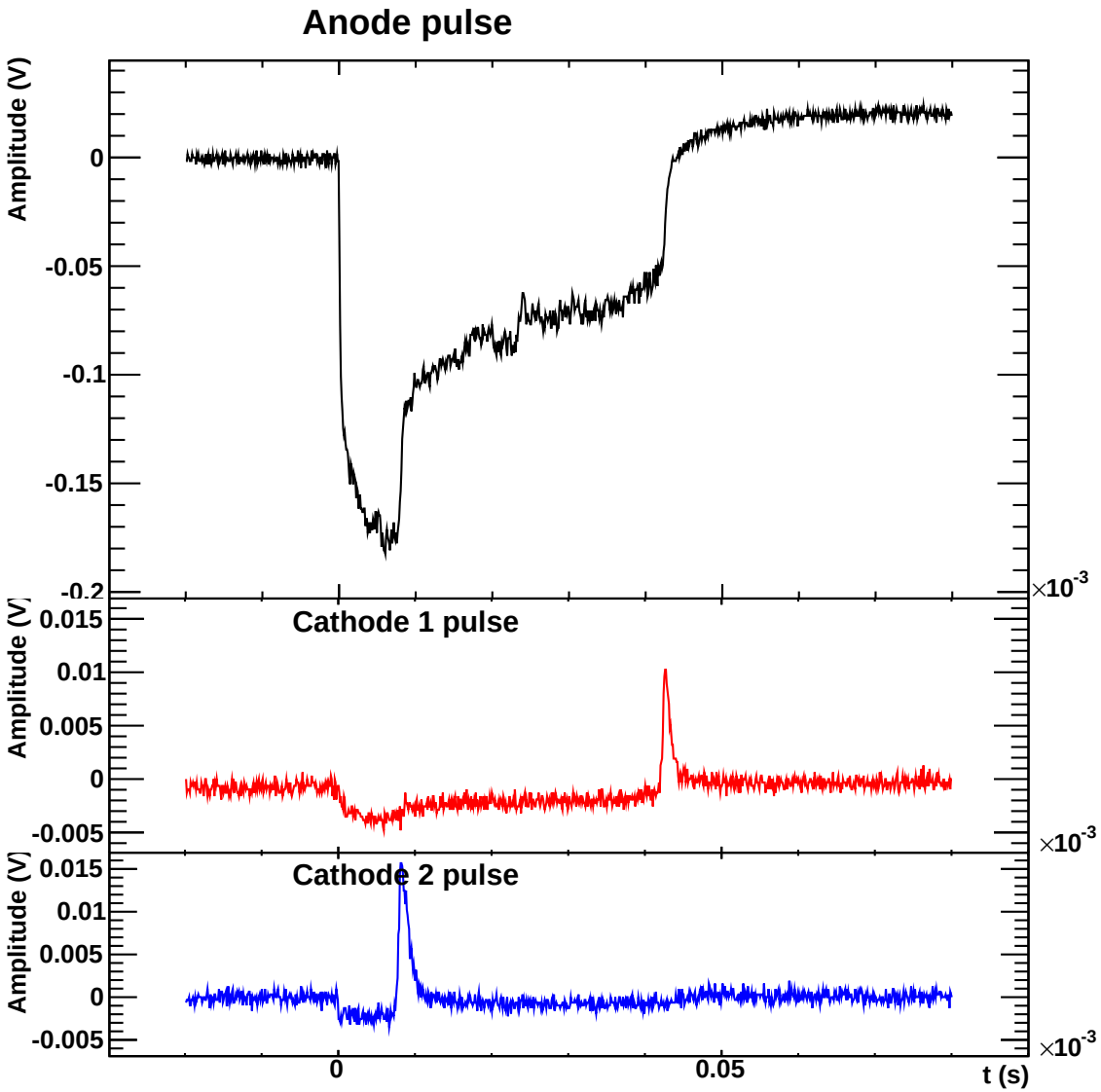
- Exciting times for double-beta decay
  - "Klapdor" claim is already being disputed (KamlandZen/EXO)
  - GERDA $0\nu\beta\beta$ unblinding in the Summer
- SuperNEMO Demonstrator module construction in progress
  - Heavy UK contribution
  - **Now** Building the tracker and surface commissioning
  - **2013** Underground commissioning
  - **2014-15** Start running

Supplementary slides

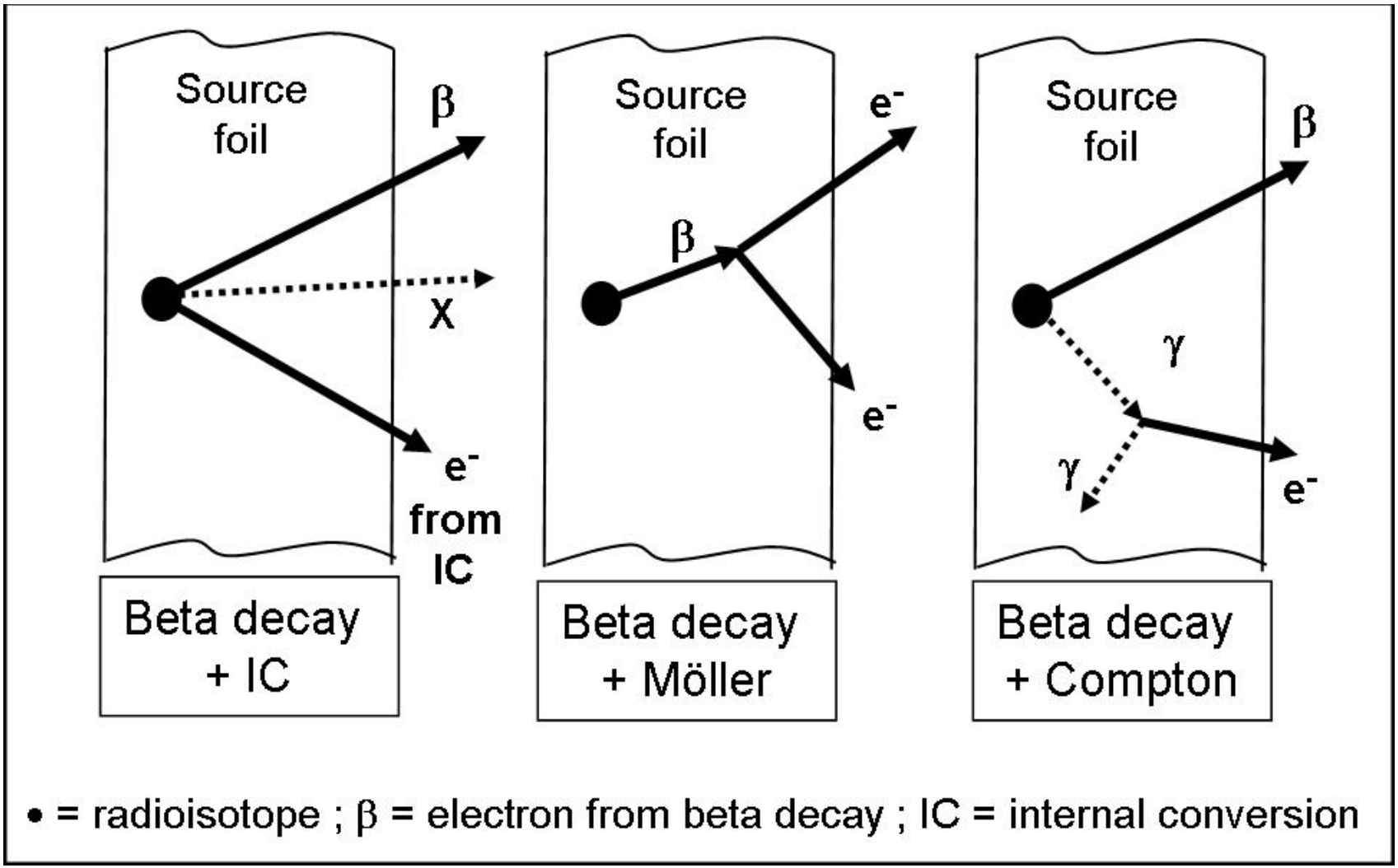
$\langle m_{\beta\beta} \rangle$ vs smallest ν mass



Tracker cell signal example



NEMO internal background production



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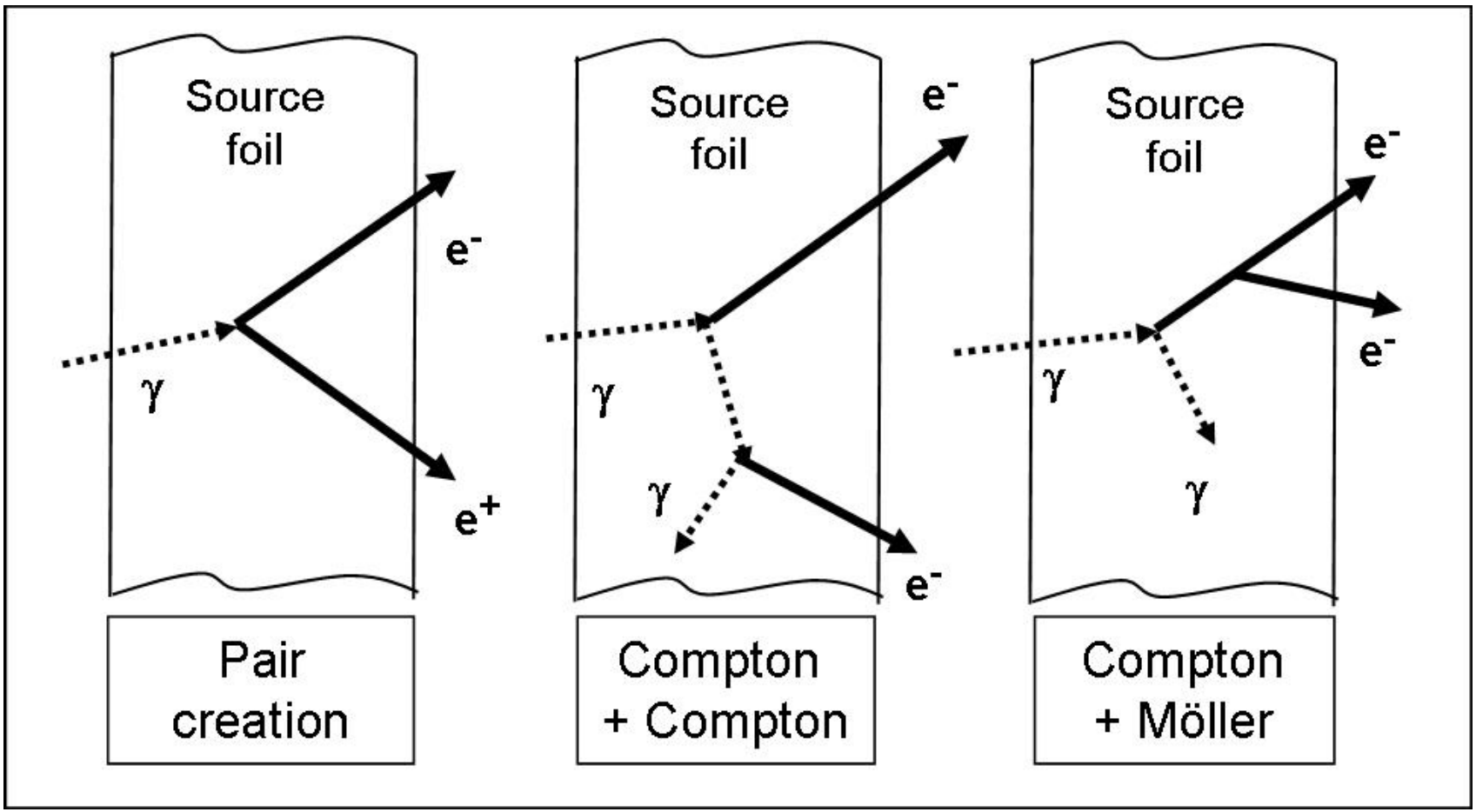
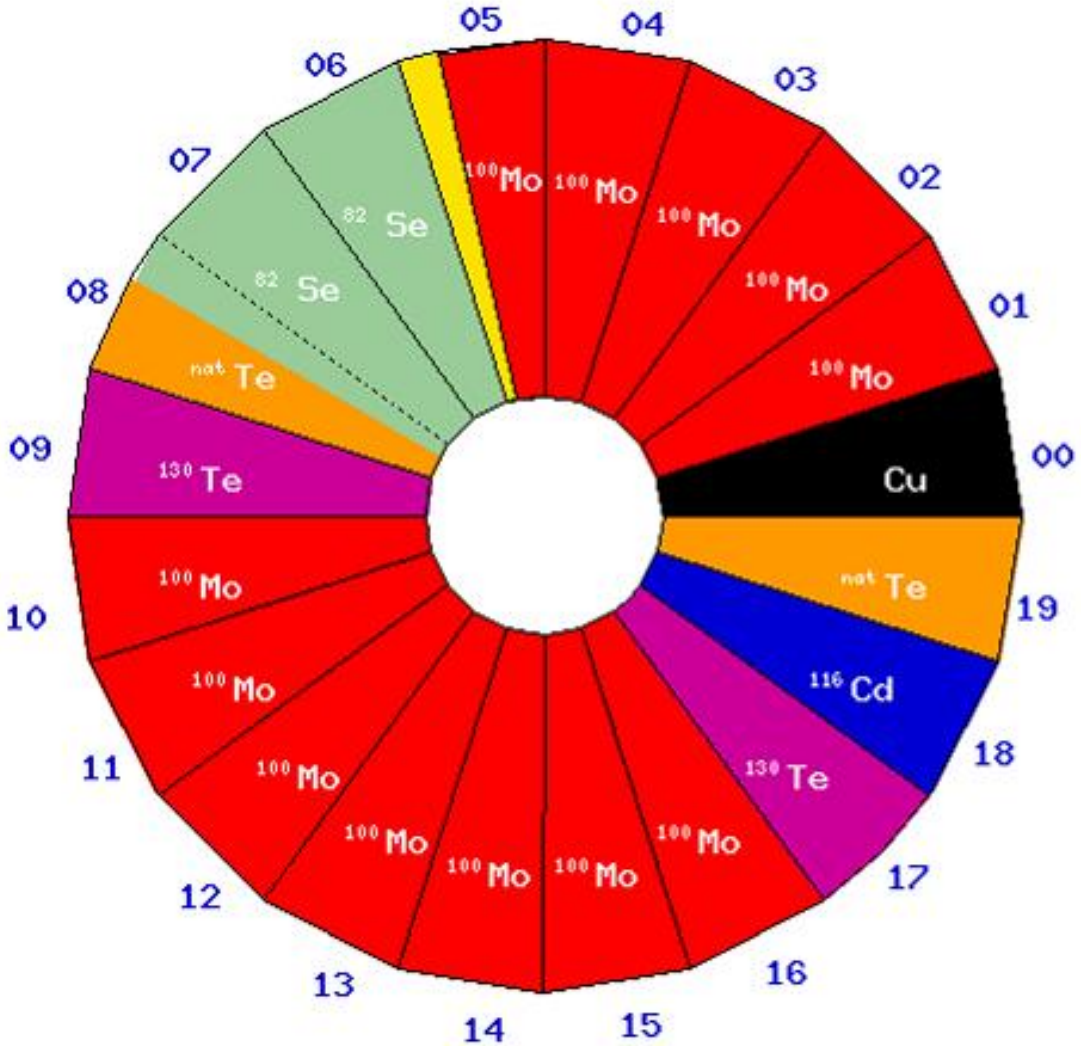


NEMO3 sources



Tracker wire ageing

- Single cell prototype was showing poor performance
  - Short Geiger plateau and prone to self discharge
  - *Noisy* pulses
- Ageing of the tracker is a known problem
- Deposits have been observed on wires after extended operation

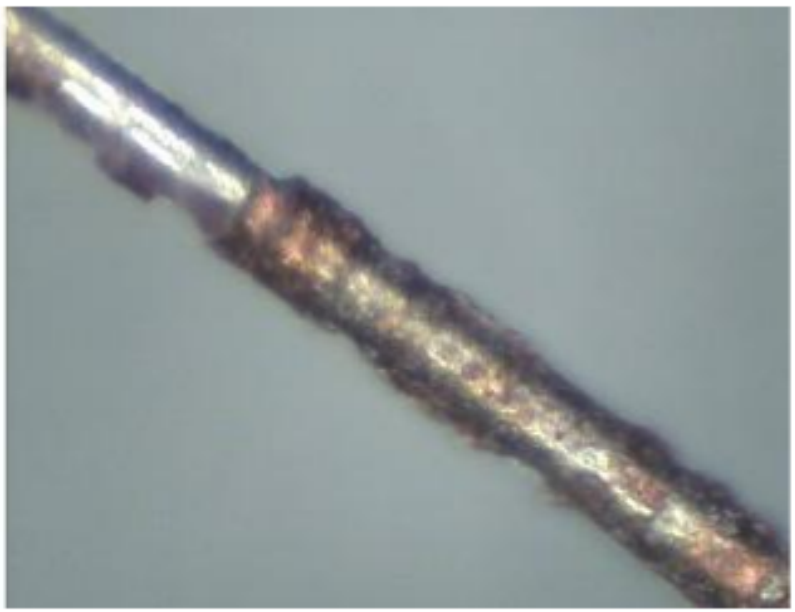
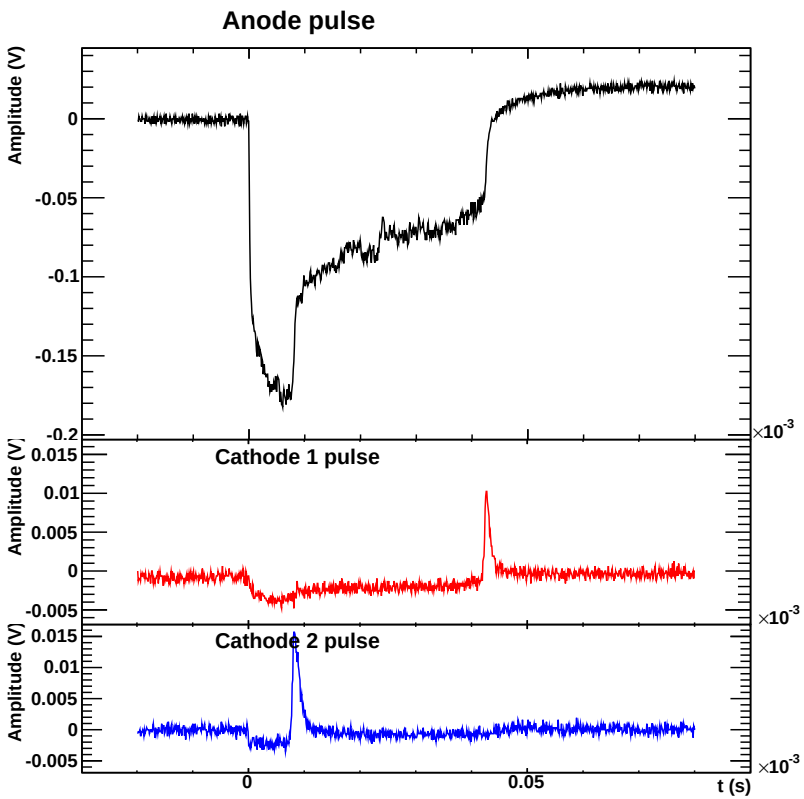


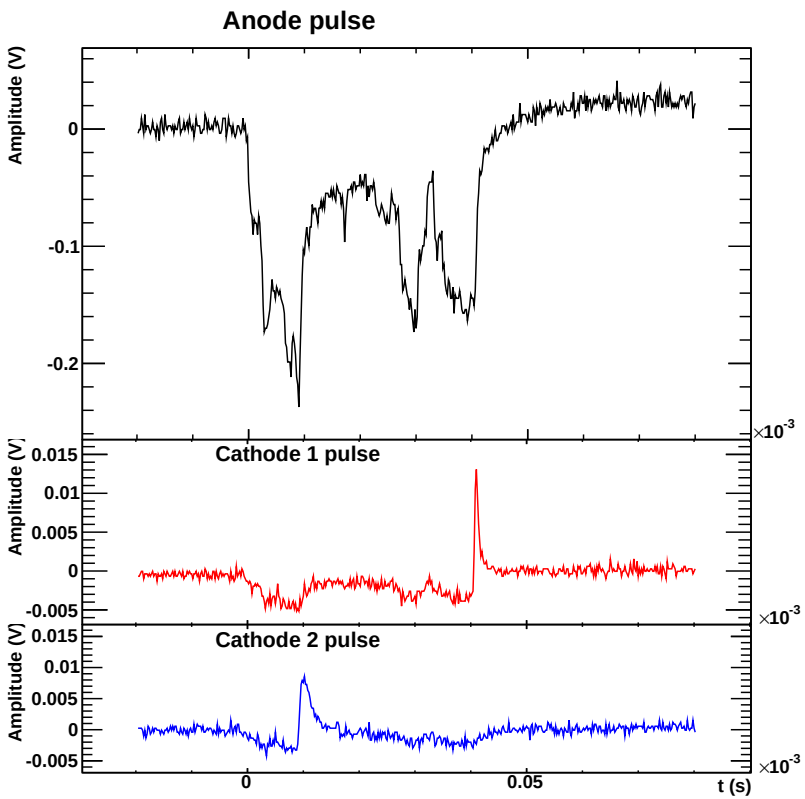
Photo – Manchester

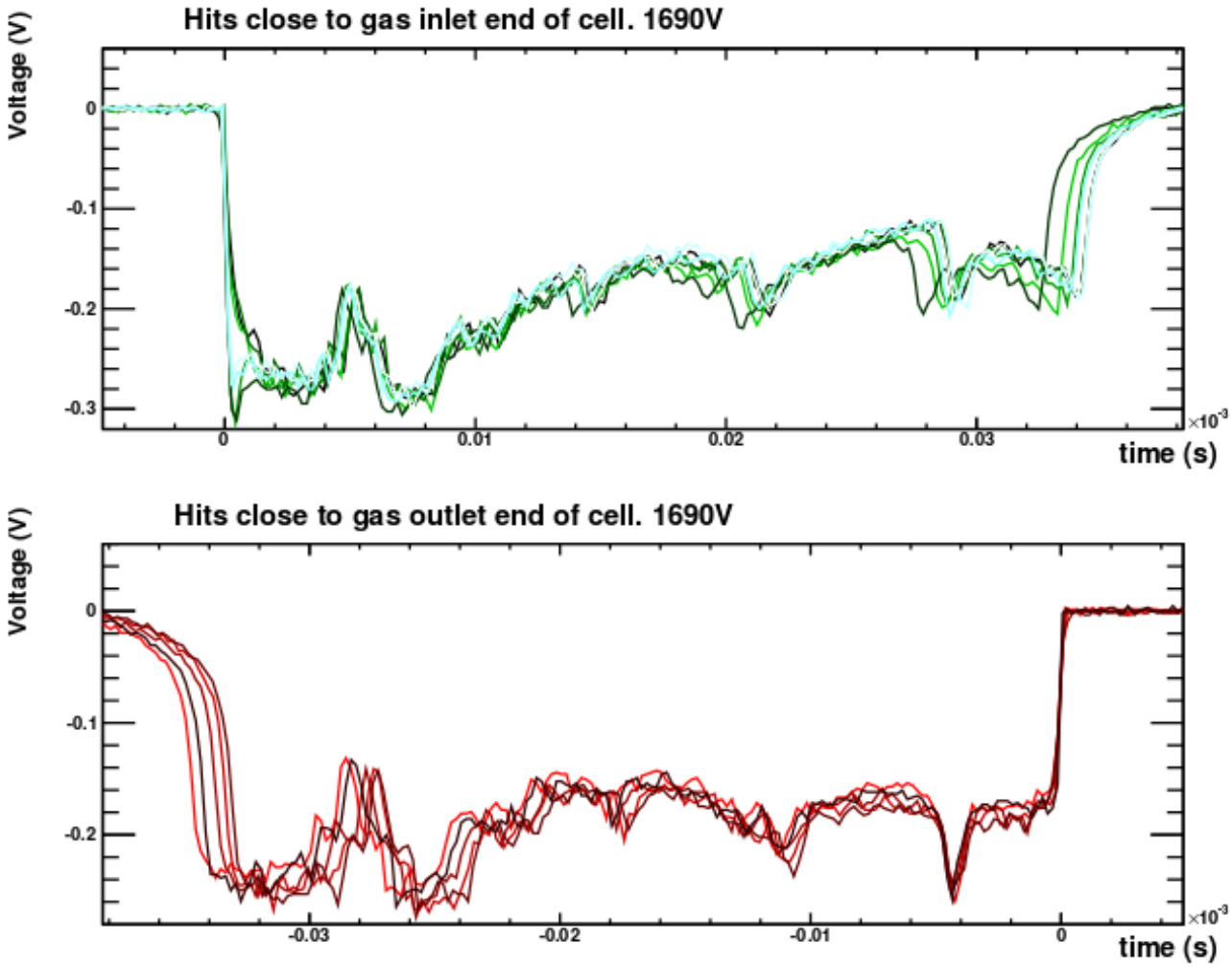
Tracker wire ageing

Typical anode pulse



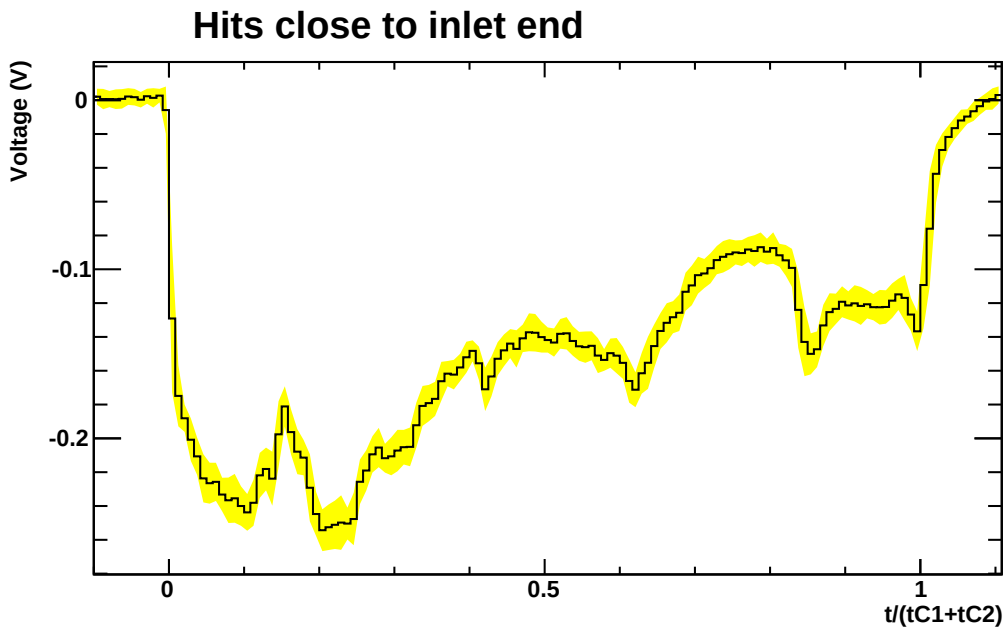
Noisy anode pulse

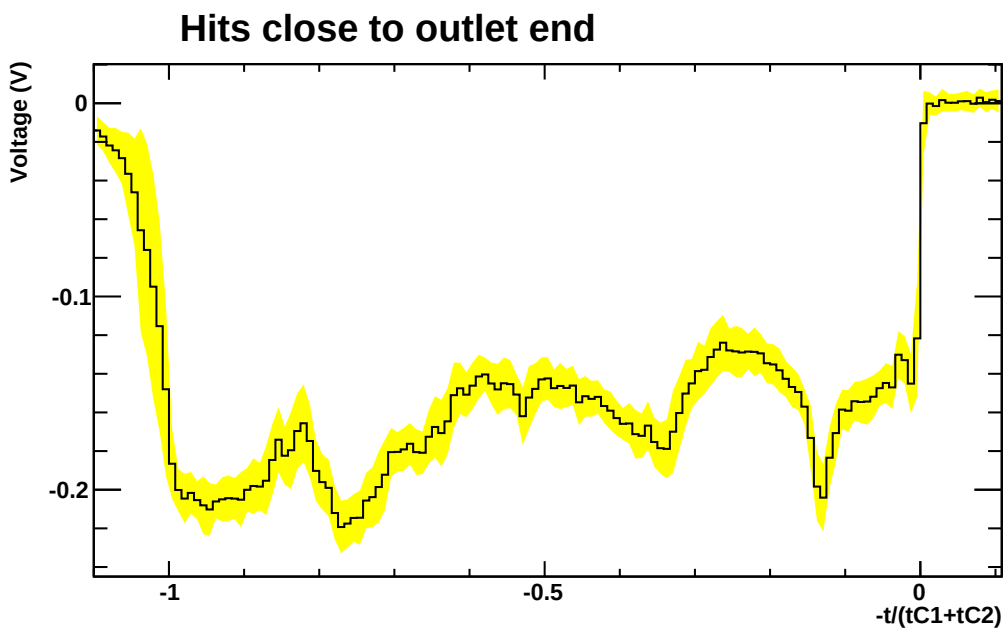




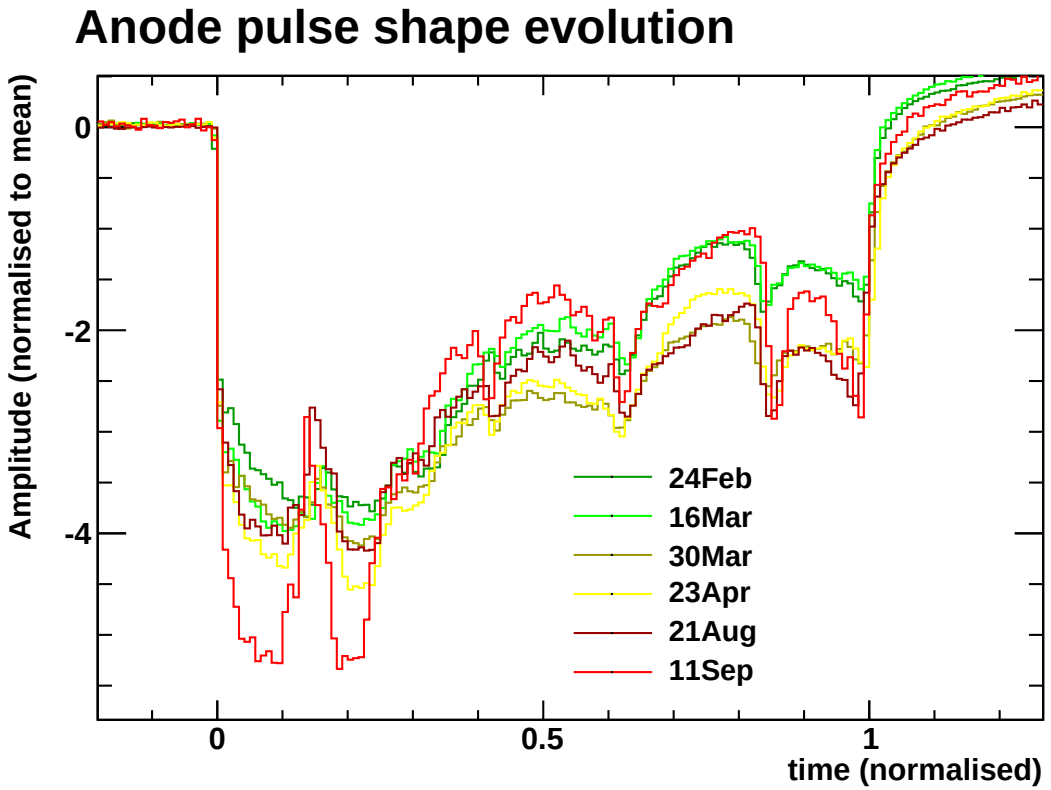
Look at long pulses, where a single "propagation front" travels the length of the wire. The noise is not random, it's a reflection of the wire's condition.

- Normalise time axis to total propagation time given by the cathode pulses
- Take average of ~ 5 pulses





Tracker wire ageing



- Progressive ageing of the tracker cell's anode wire is observed
- Need to investigate anti-ageing techniques, *e.g.*, adding H_2O to the gas
- Surface live time of the tracker must be minimised during commission