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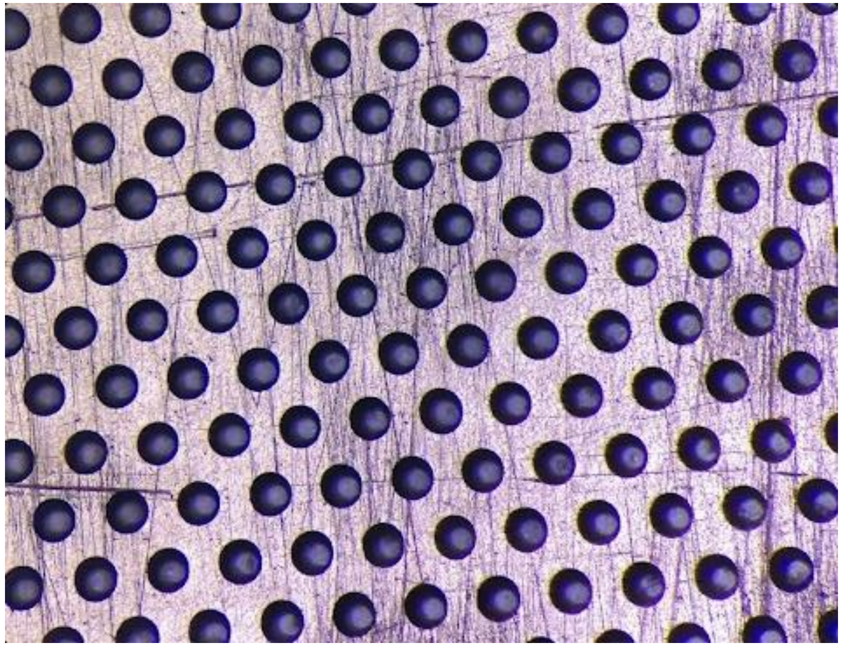
ISIS Neutron and Muon Source

Operation of the μRWELL detectors with ^{3}He-based gas mixtures

Raheema Hafeji
Davide Raspino
Erik Schooneveld
Nigel Rhodes



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MPGD2022, Dec 13, 2022

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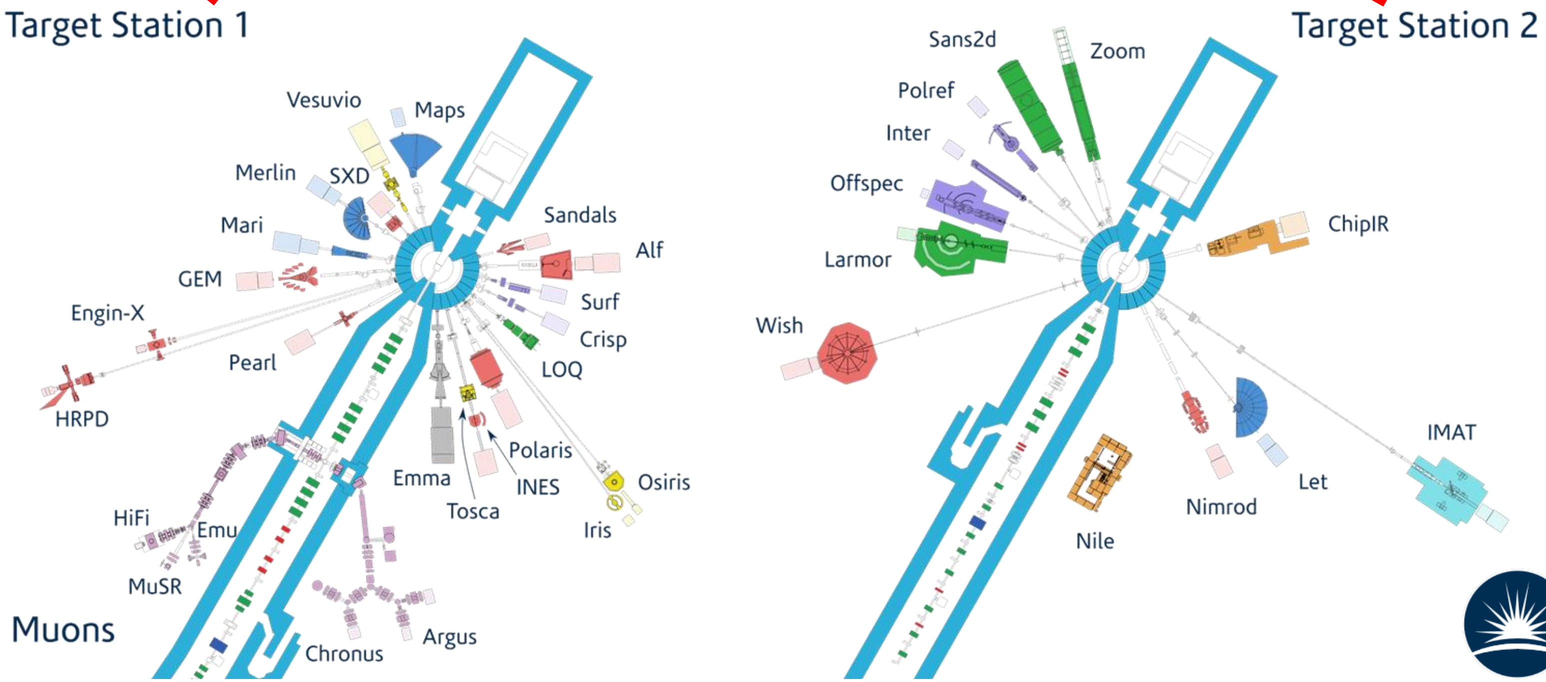

5 muon instruments
32 neutron instruments

Physics, chemistry, materials science, geology, engineering, and biology.

Endeavour program will expand ISIS capabilities to meet current and future challenges in areas such as Materials for the Future; Smart, Flexible and Clean Energy Technologies; Advanced Manufacturing; and Biosciences and Healthcare.

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Outline

- µRWELL
- $^3He\text{-}CF_4$ gas mixture
- Measurements and results
  - Gain
  - Rate Capability
- Conclusions and Future measurements

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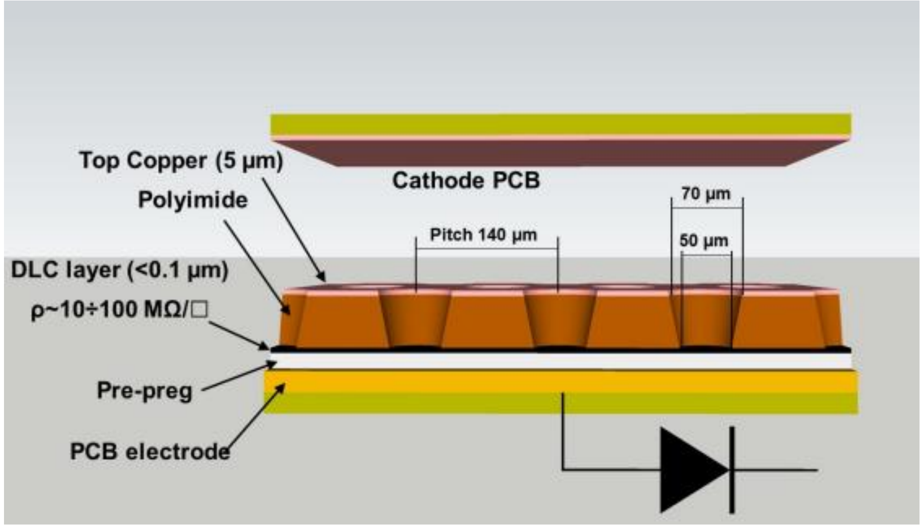
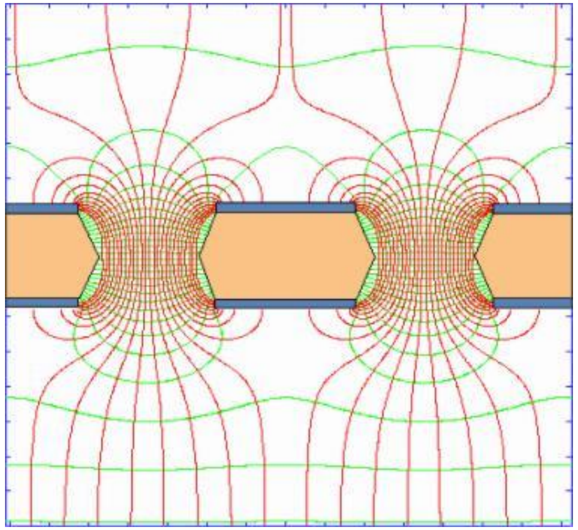
µRWELL vs GEM

- Solved major limits of operating GEMs in ^{3}He-CF_4 gas mixture
- Gain in a single stage comparable to the gain of a triple GEM
- DLC provides spark protection





G.Bencivenni et al., 2015 JINST 10 P02008.
https://doi.org/10.1088/1748-0221/10/02/p02008

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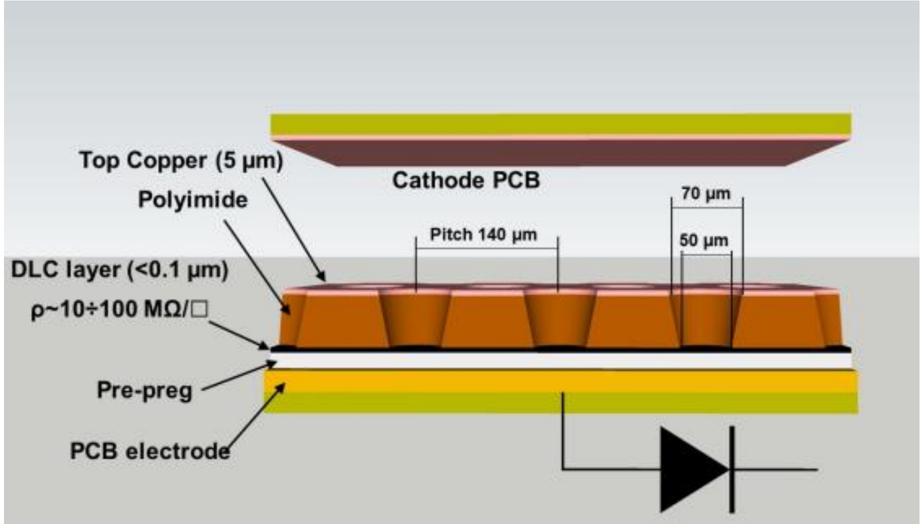
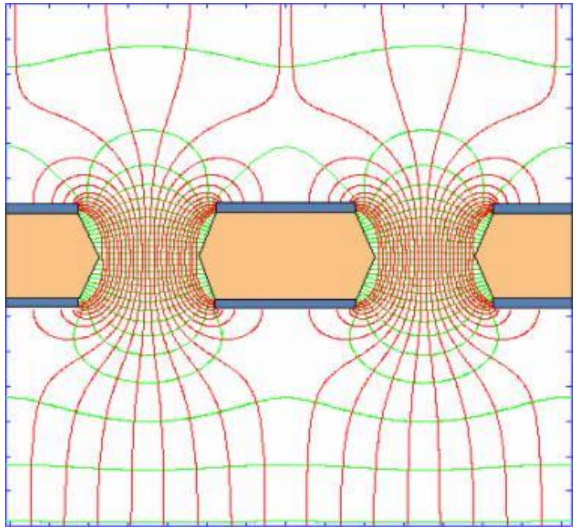
μRWELL vs GEM

- Solved major limits of operating GEMs in ^{3}He-CF_4 gas mixture
- Gain in a single stage comparable to the gain of a triple GEM
- DLC provides spark protection
- Lower rate capabilities than GEMs





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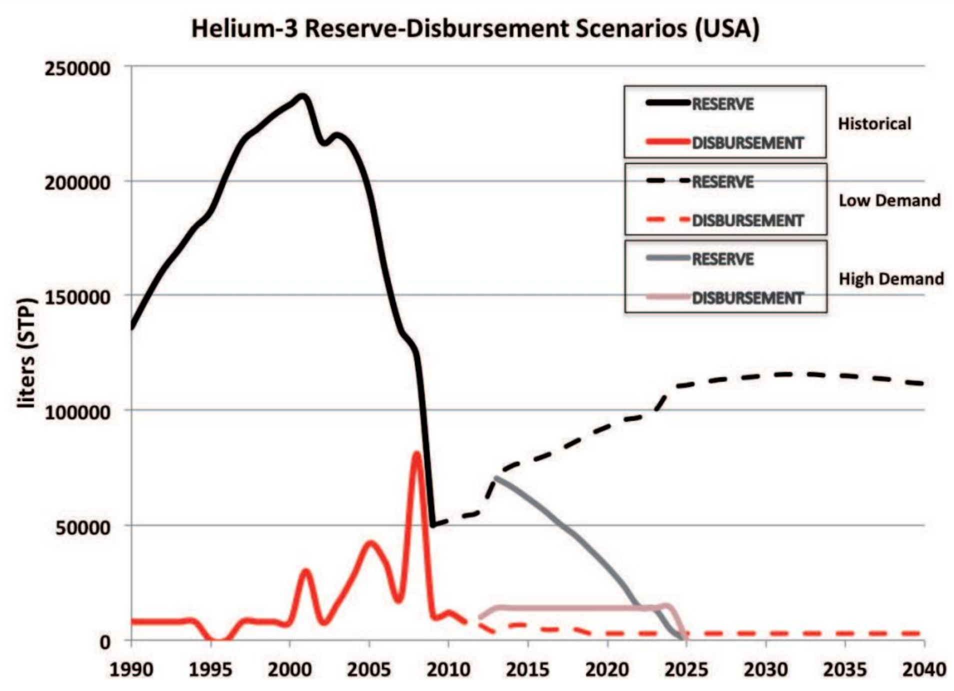
New ^{3}He detectors for neutron scattering

- 2009 increase cost of ^{3}He
- Very low availability
- Situation improving
- Budget and technical challenges for large area neutron detectors
- It can be recycled and reused indefinitely



Eur. Phys. J. Plus (2014) 129: 236

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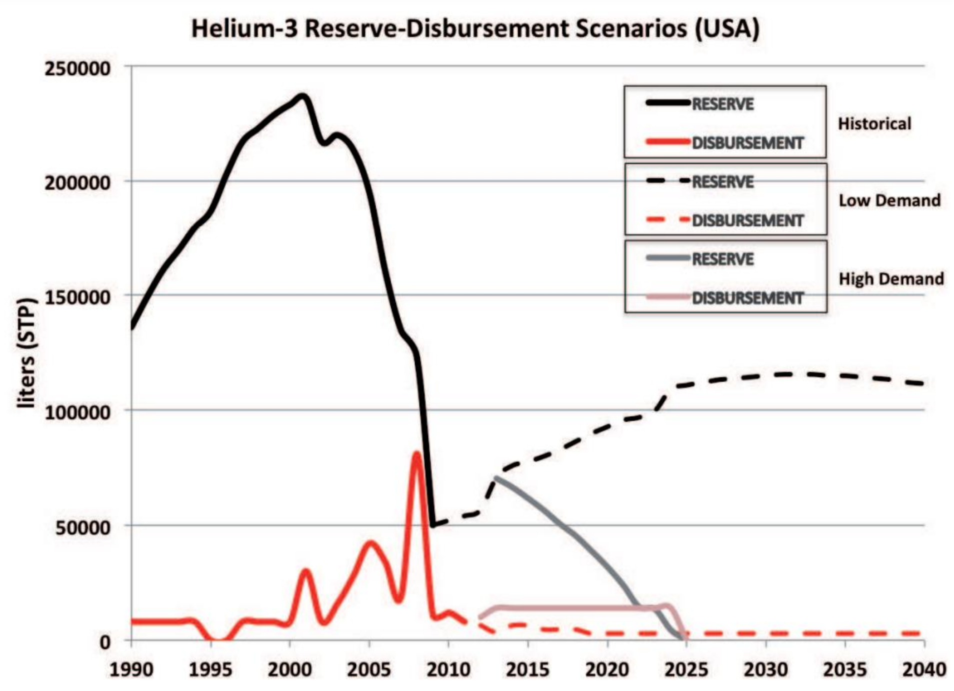
- High efficiency (> 70% at 25 meV)
- High rate (>1 MHz/full detector area)
- High spatial resolution (<1 mm FWHM)



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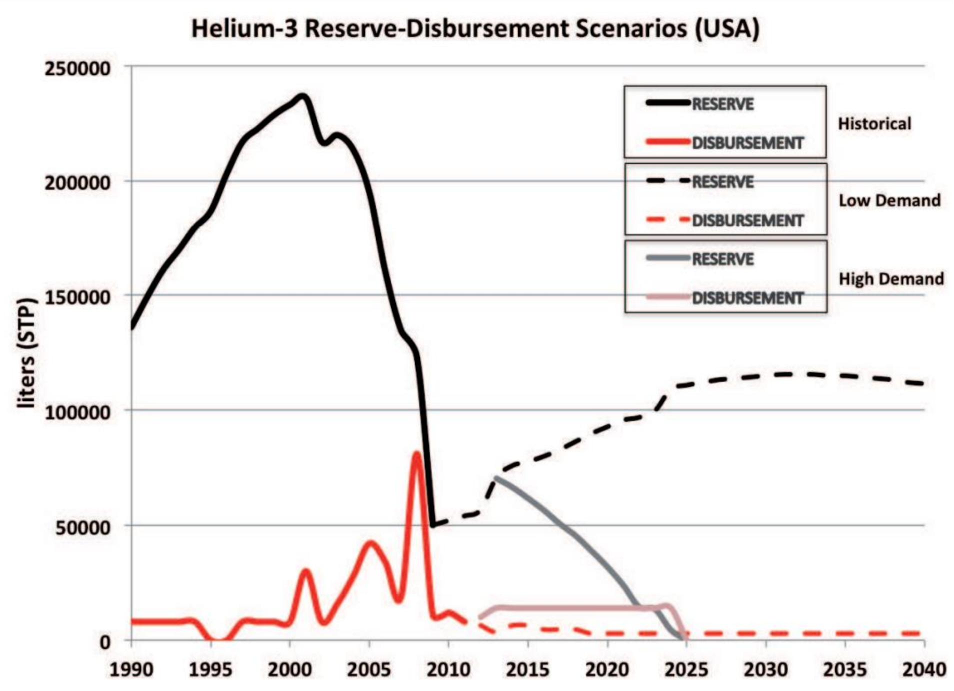
- MPGD ideal solution



Eur. Phys. J. Plus (2014) 129: 236

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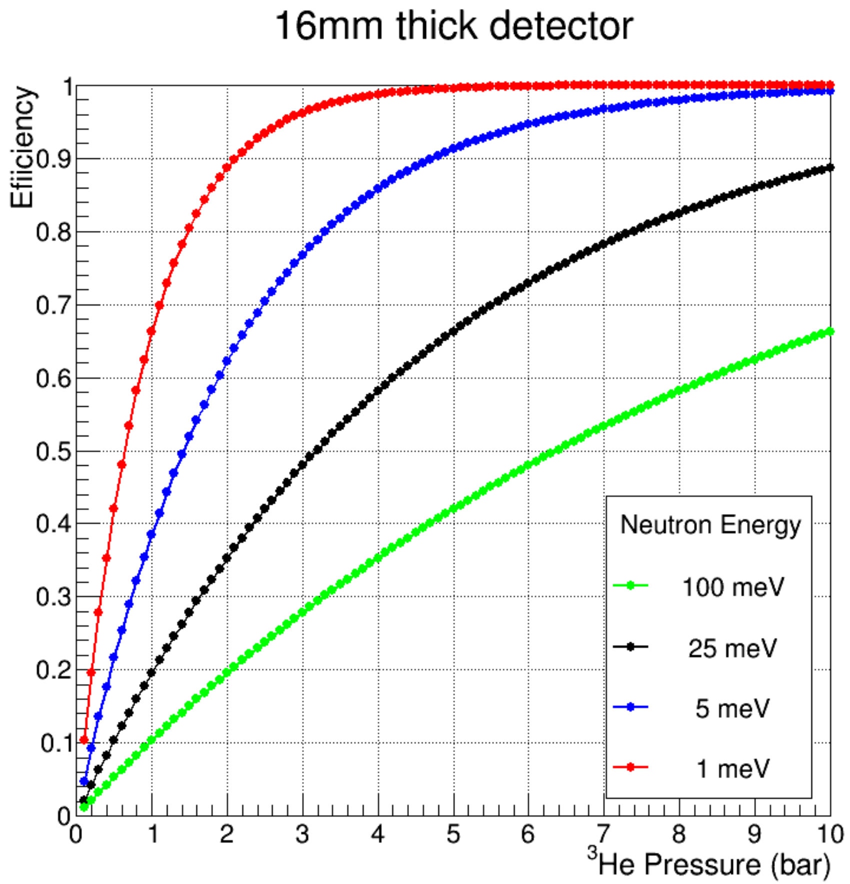
^{3}He/CF_4 gas mixtures

$n + {}^3He \rightarrow {}^3H + {}^1H + 764\ keV$

Efficiency = 1. – exp (- n·P·σ·d)

n = number density = 2.7 x 10^{19} /cm^3-bar
P = gas pressure [bar]
σ(λ) = cross section [cm^2] (function of λ)
d = gas depth [cm]



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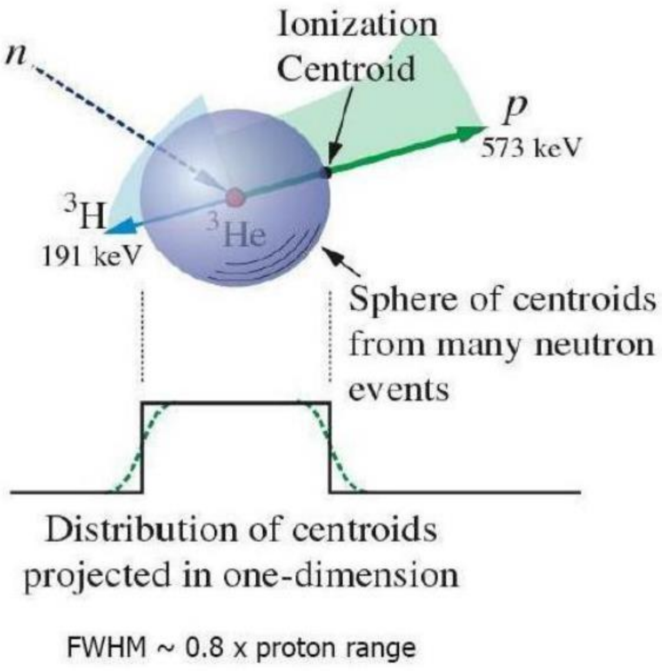

V. Radeka, DOE BES Neutron&Photon Detector Workshop, Aug 1-3, 2012

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K. Miuchi, et al. Nucl. Instrum. Meth A 517 (2004) 219–225.

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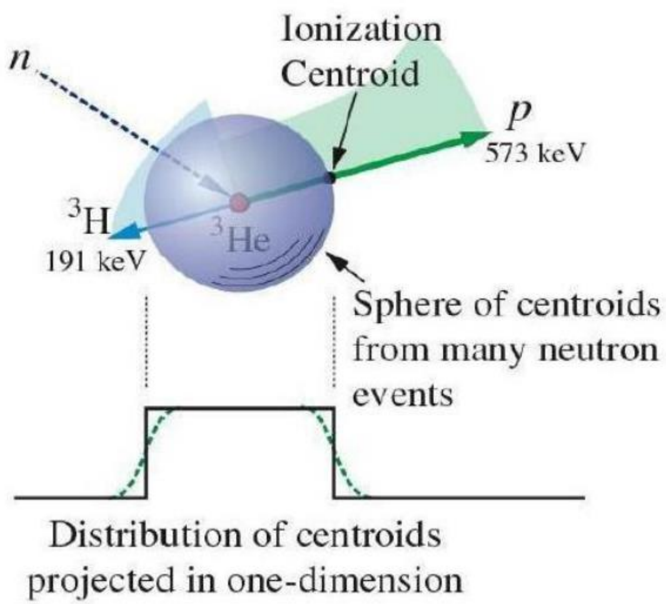
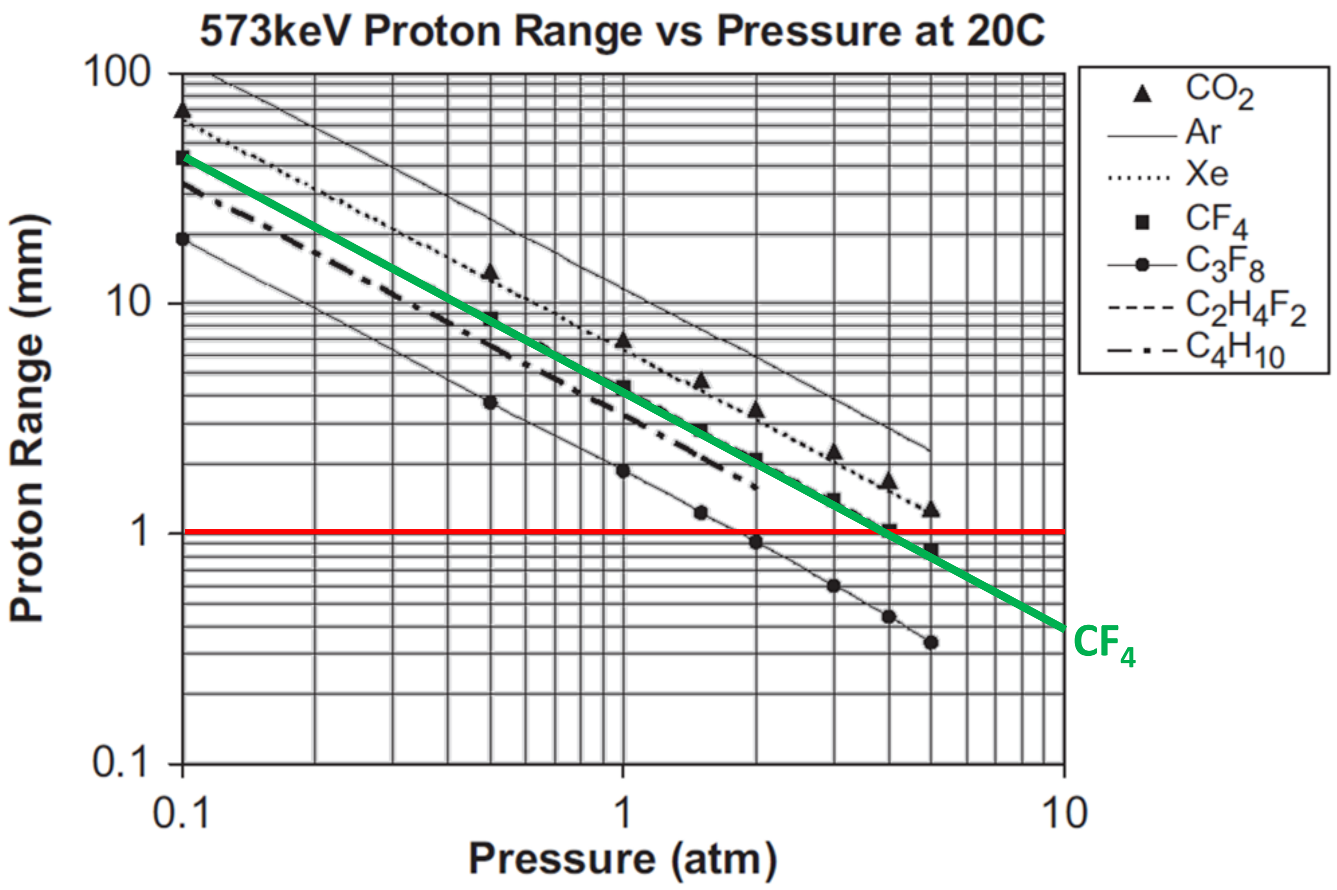


FWHM ~ 0.8 x proton range

V. Radeka, DOE BES Neutron&Photon Detector Workshop, Aug 1-3, 2012

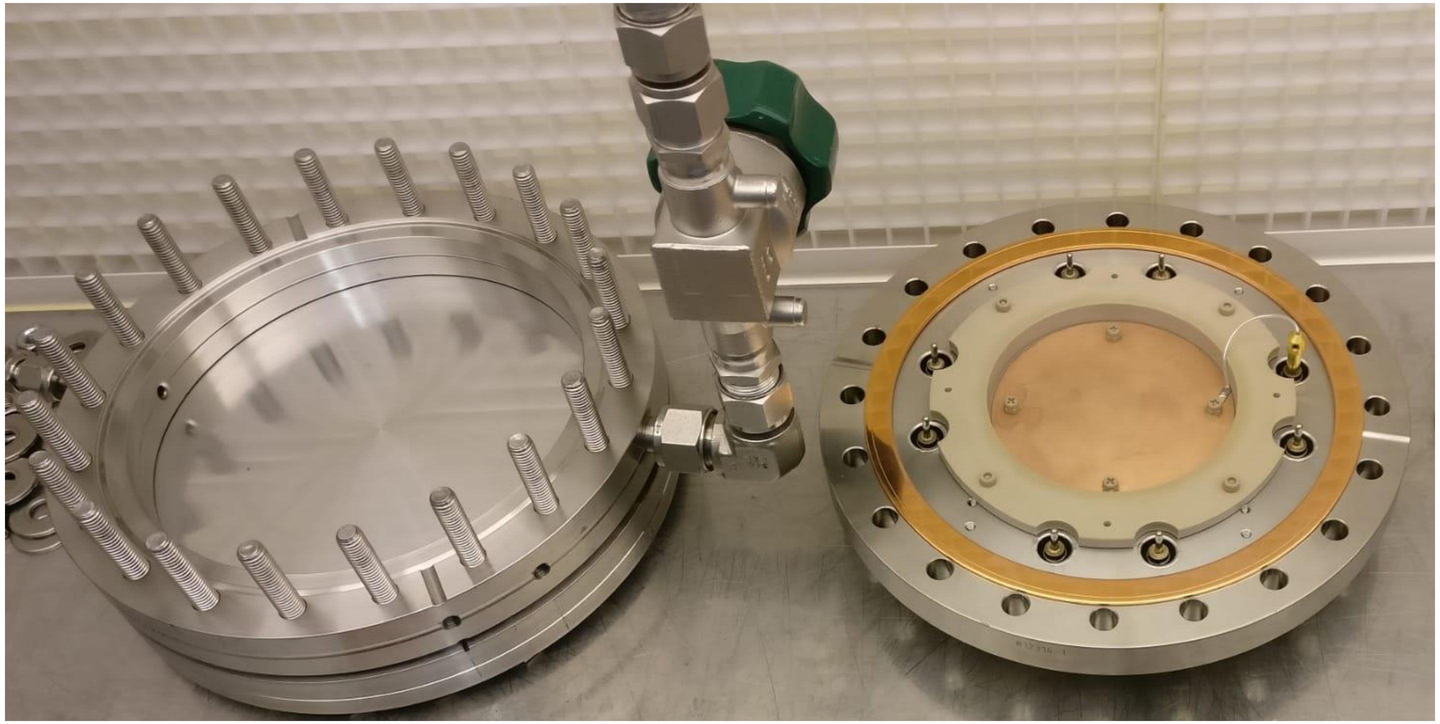


G.C. Smith et al.
doi:10.1016/j.nima.2012.01.035

µRWELL setup at ISIS

- Sealed vessel
- Certified up to 7bar

- 1bar ^3He
- 1 to 6 bar of CF_4 in step of 1.0 bar



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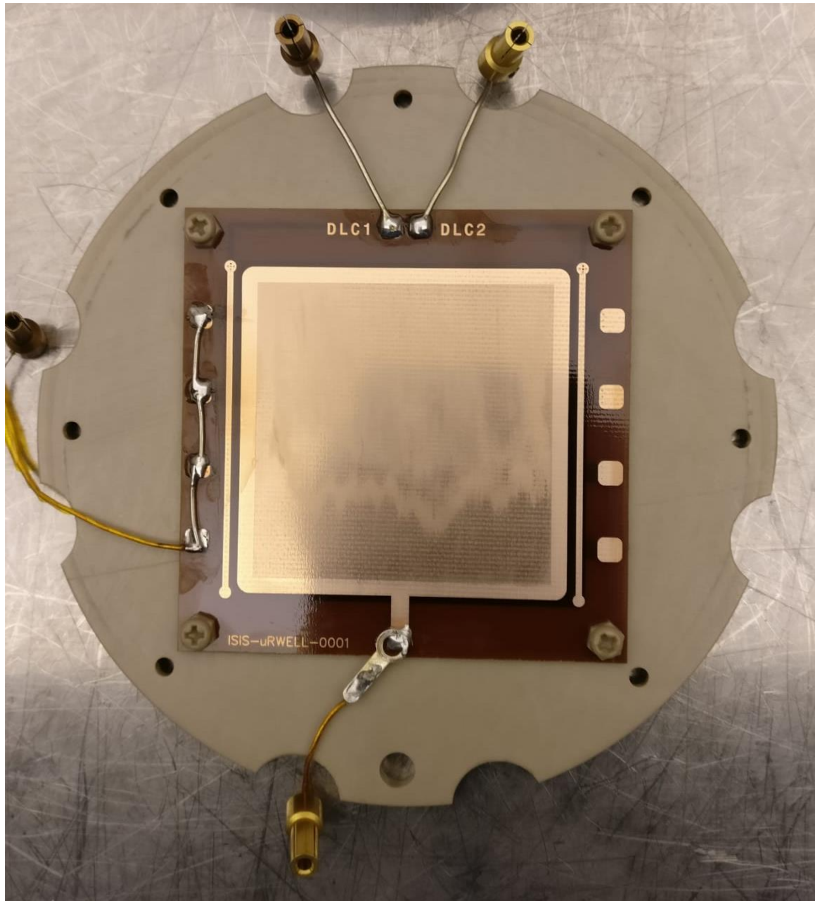
- Active area $50x50mm^2$
- DLC 80MΩ/□
- Anode segmented in four strips
- Joined together for this test

- Drift volume 16mm thick



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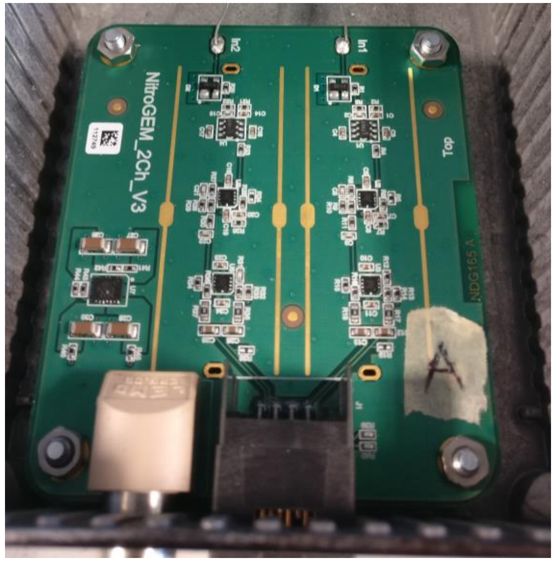
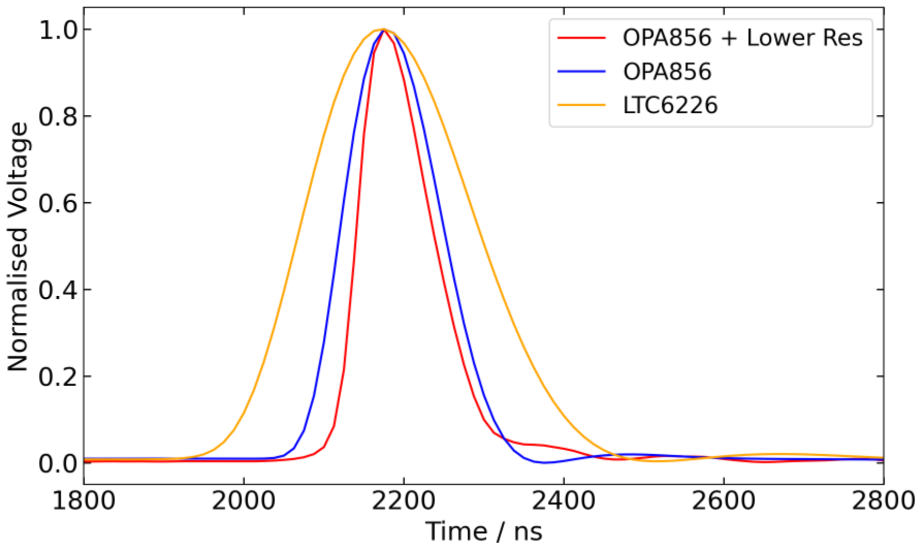
- Drift volume 16mm thick
- Bipolar preamp LTC6226/OPA856





Board (Op-amp + feedback res)	Width at 10% PH (ns)	Noise FWHM (mV)	PH Peak (mV)	S/N
LTC6226 + 27kΩ	413	51.7	~490	9.5
OPA856+ 15kΩ	226	16.1	~450	27.9
OPA856 +1.8kΩ	175	14.6	~430	29.5

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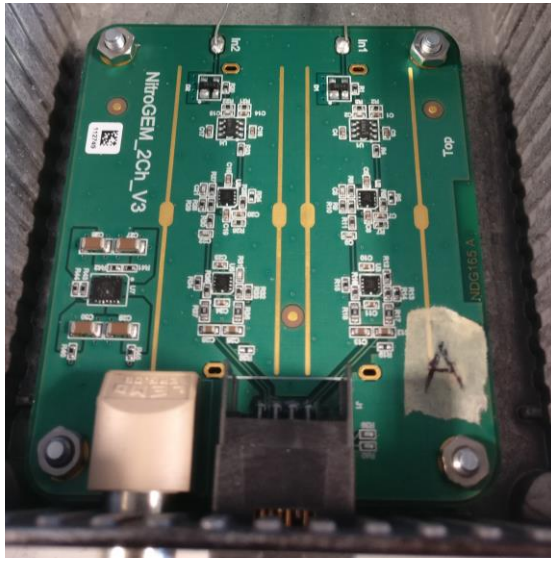

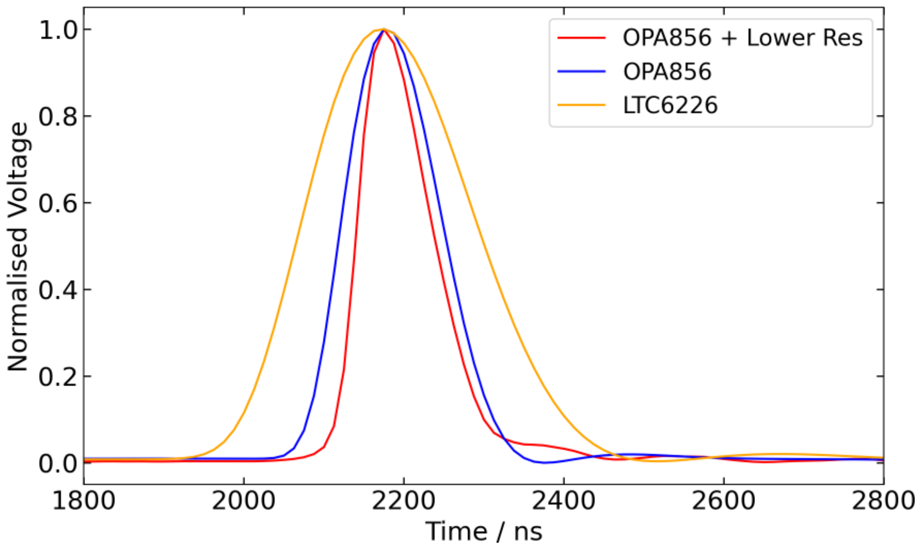

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PH spectrum

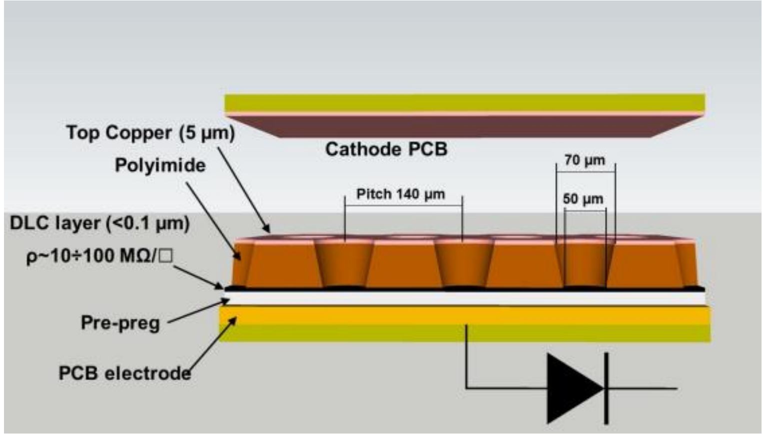
E_d = 1.875 kV/cm

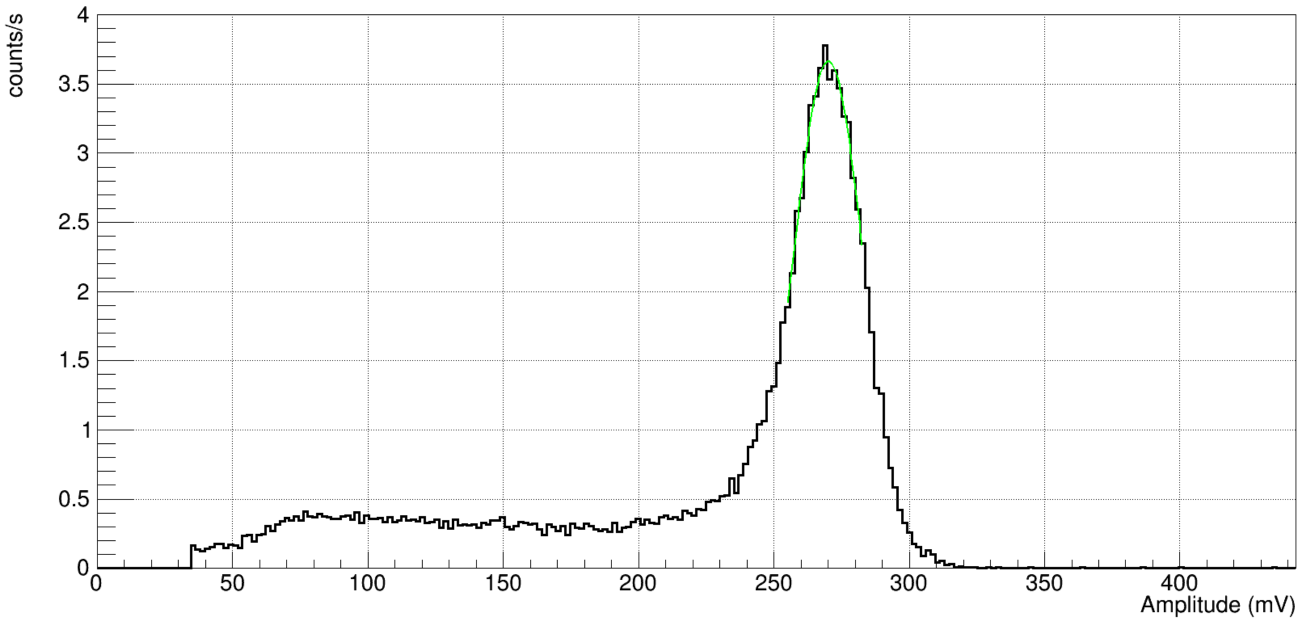
1 bar of ^3He and 1 bar of CF_4

$V_{\mu RWELL}$= 480 V

Primary Charge 2.26 fC

Gain ~10





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PH vs CF_4 Pressure and µRWELL voltage

1 bar CF_4

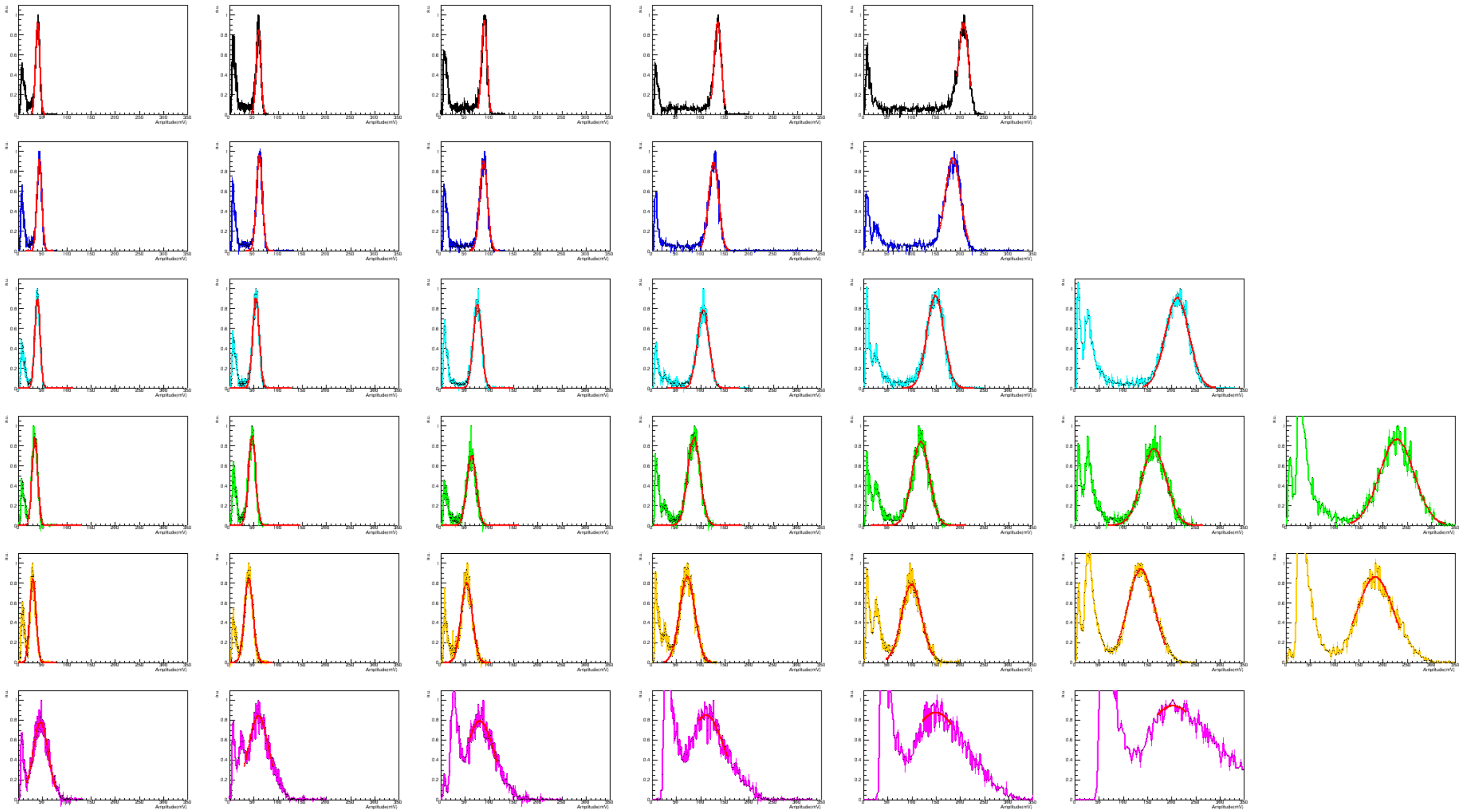
2 bar CF_4

3 bar CF_4

4 bar CF_4

5 bar CF_4

6 bar CF_4



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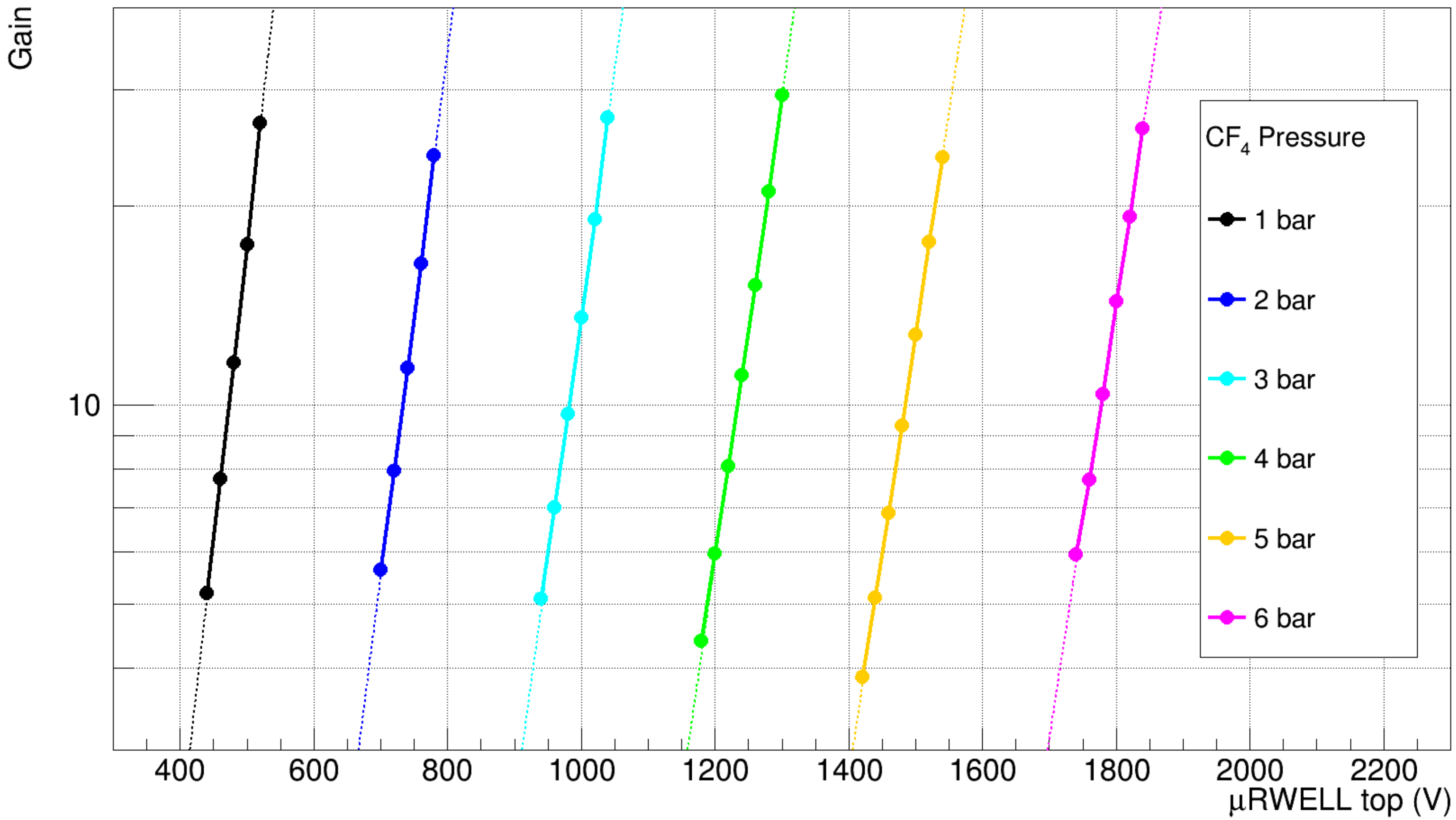
Gain Measurements

E_d=1.875 kV/cm

~280V/bar of CF_4



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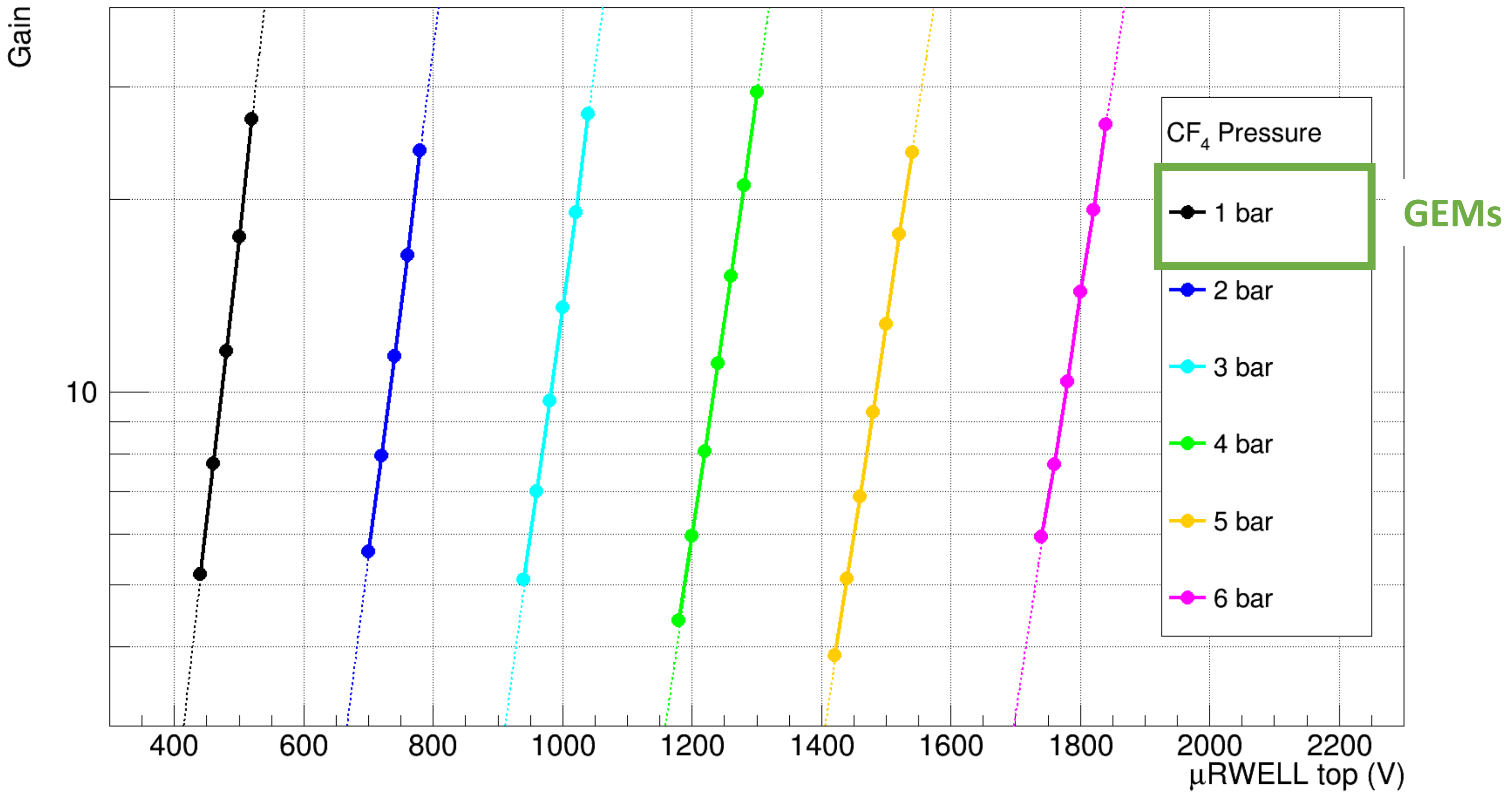

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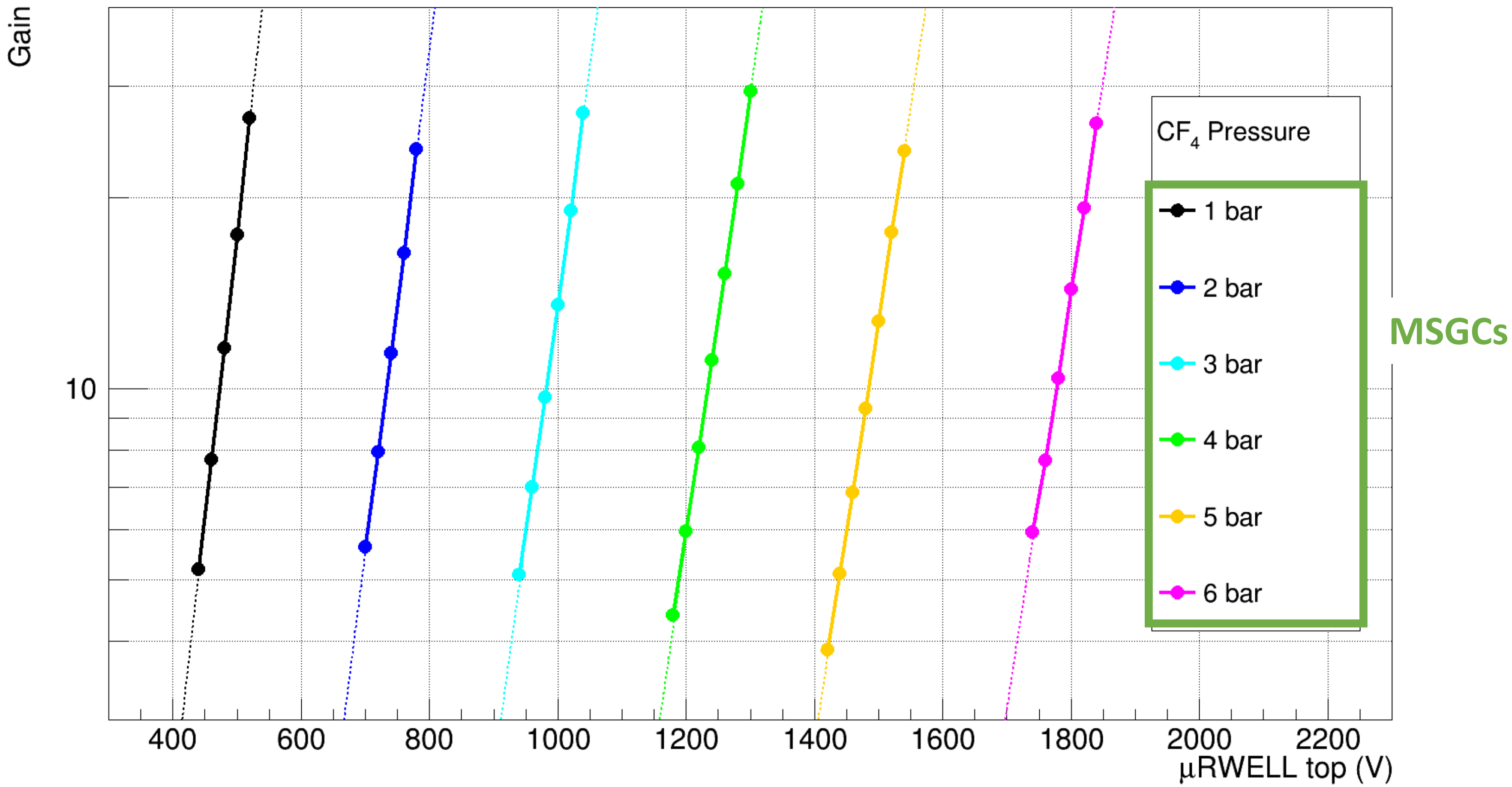


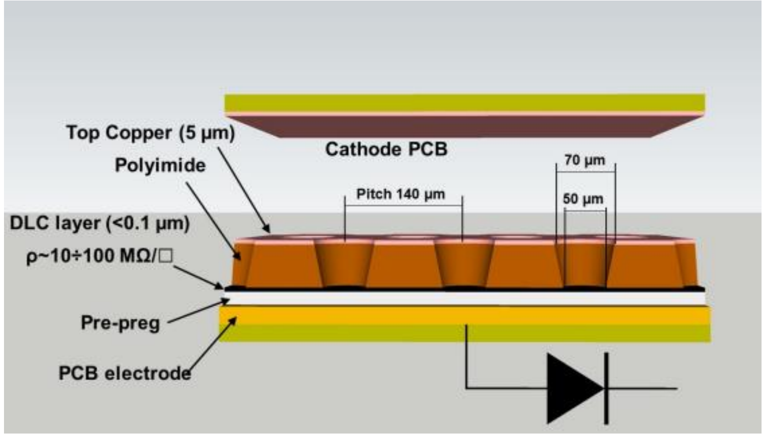
Scan in drift field

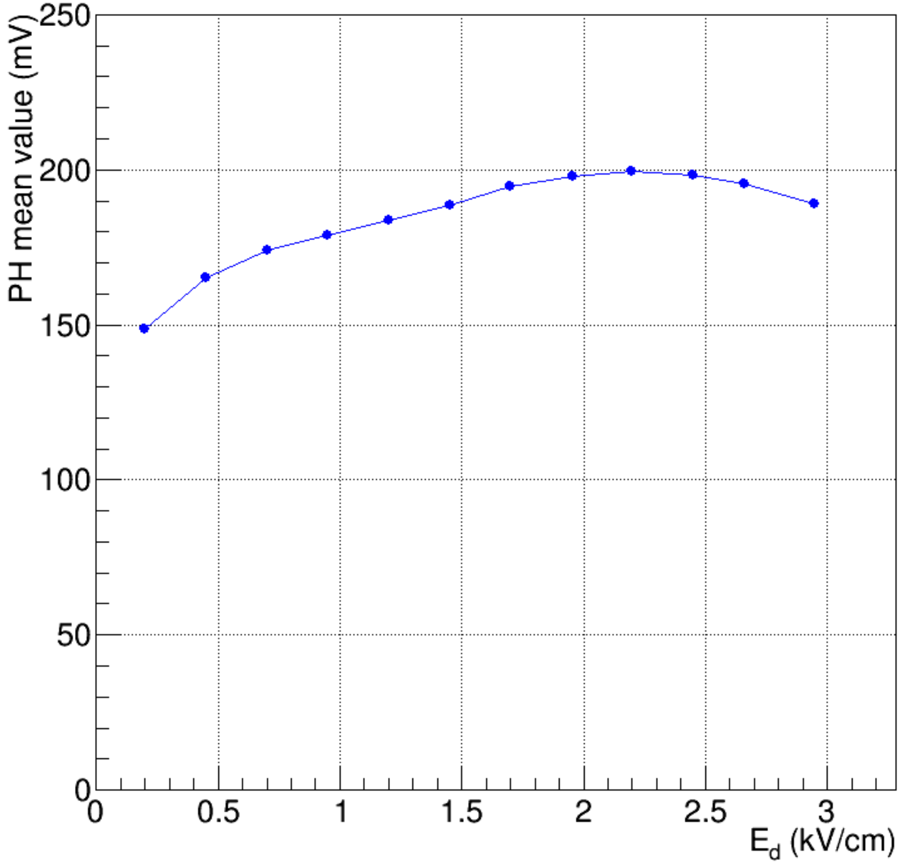
1bar ^3He +1bar of CF_4

$V_{\mu RWELL}$=500 V

Maximum moves to higher E_d by increasing the CF_4 pressure

Electron attachment vs electron collection in the holes





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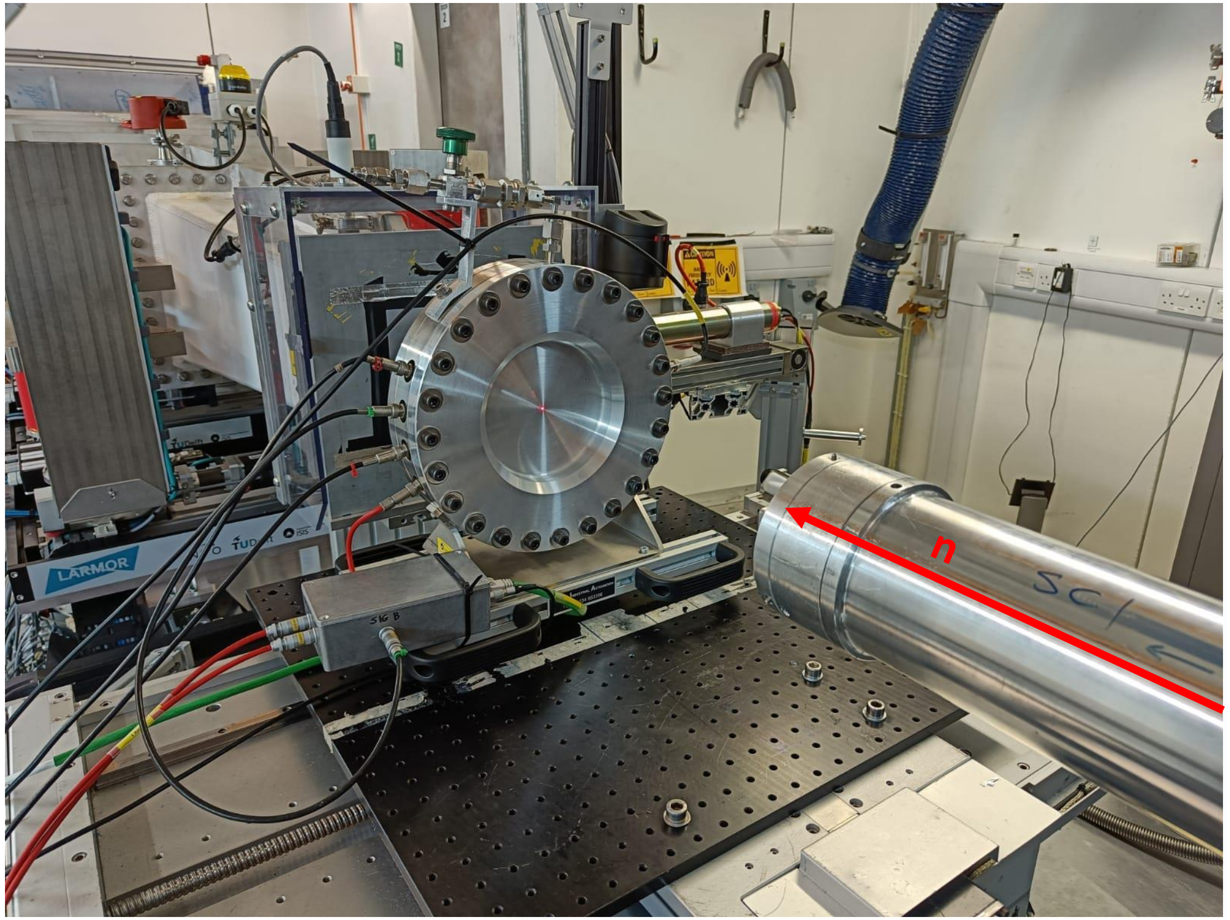
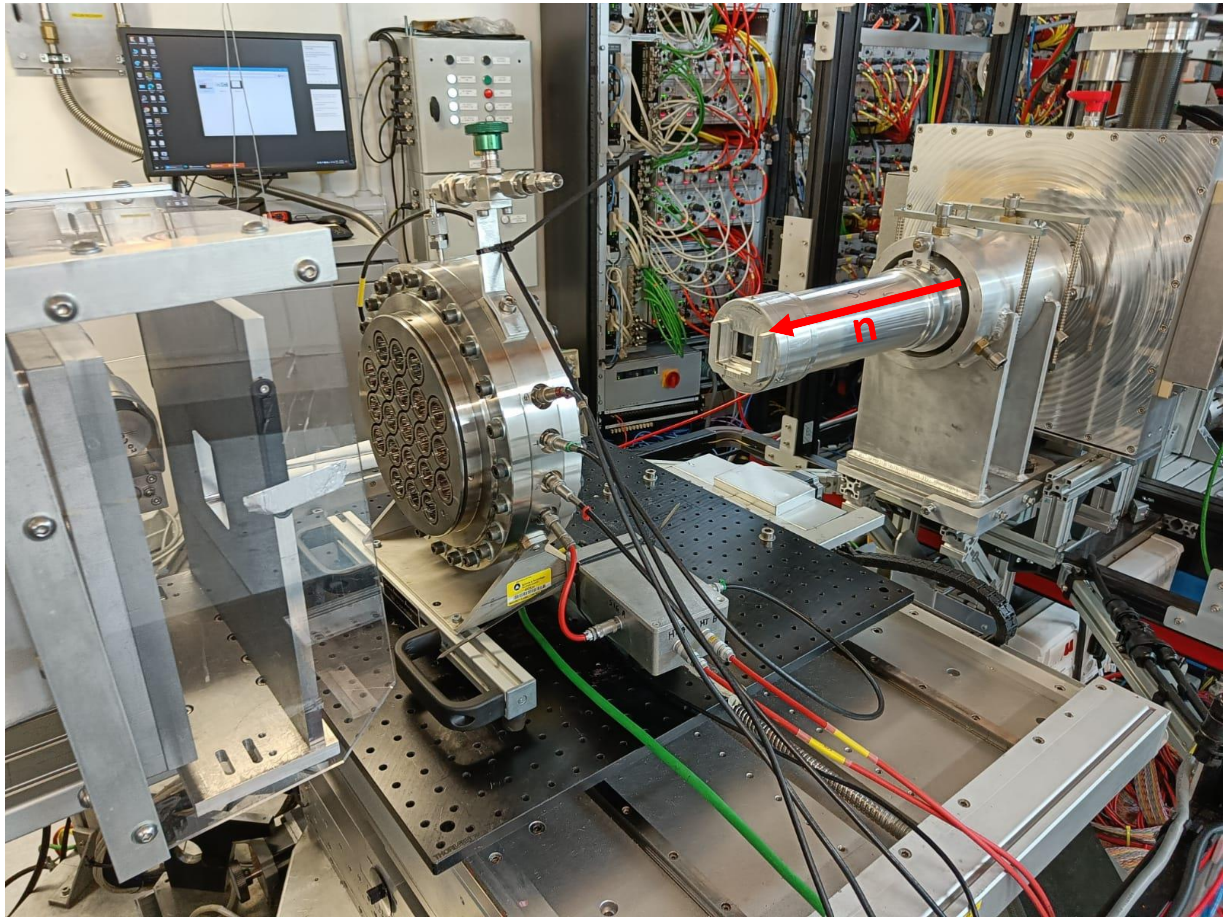
Rate Capability Test Setup





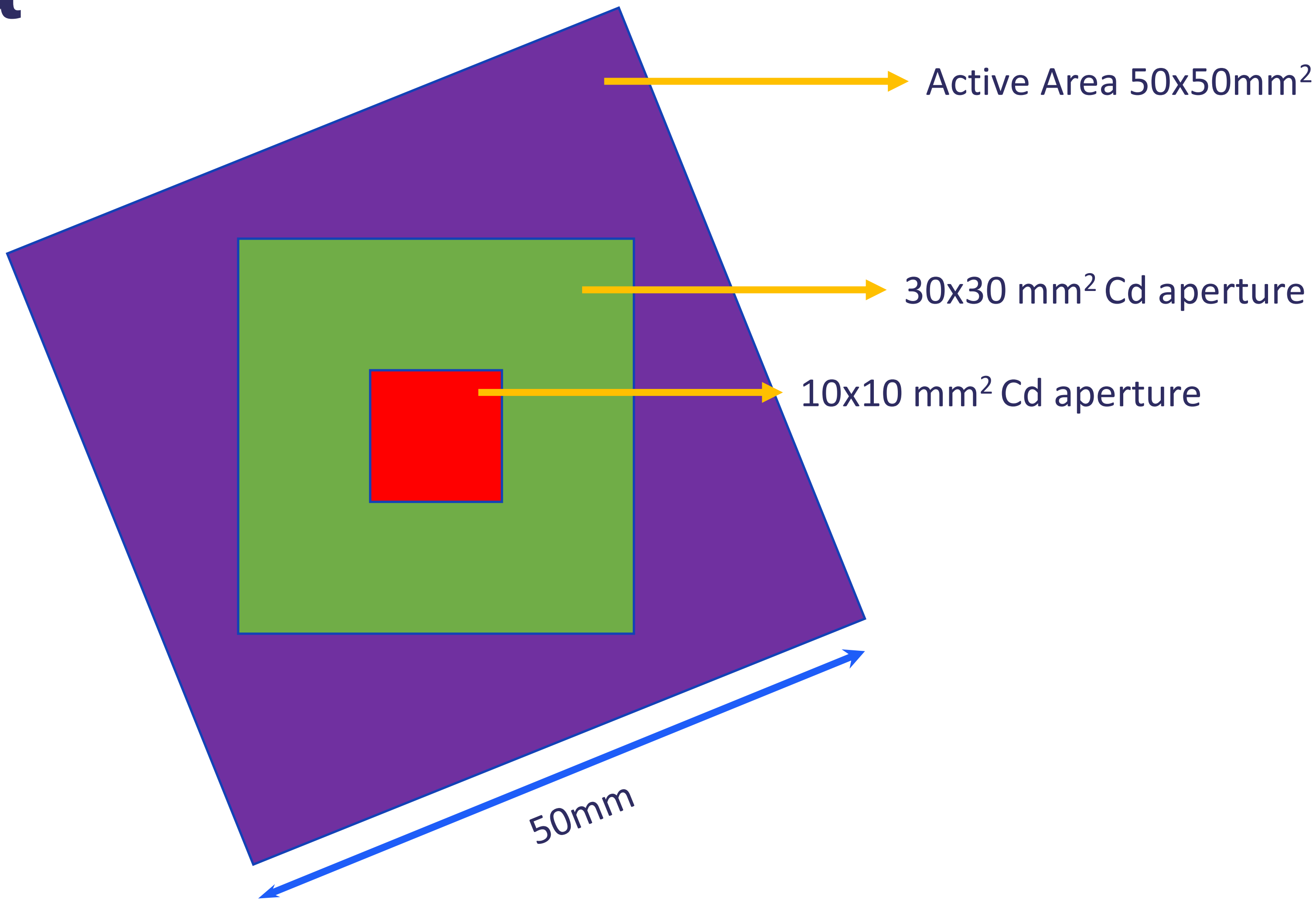
Larmor beamline at ISIS-TS2

Beam apertures and the detector active area

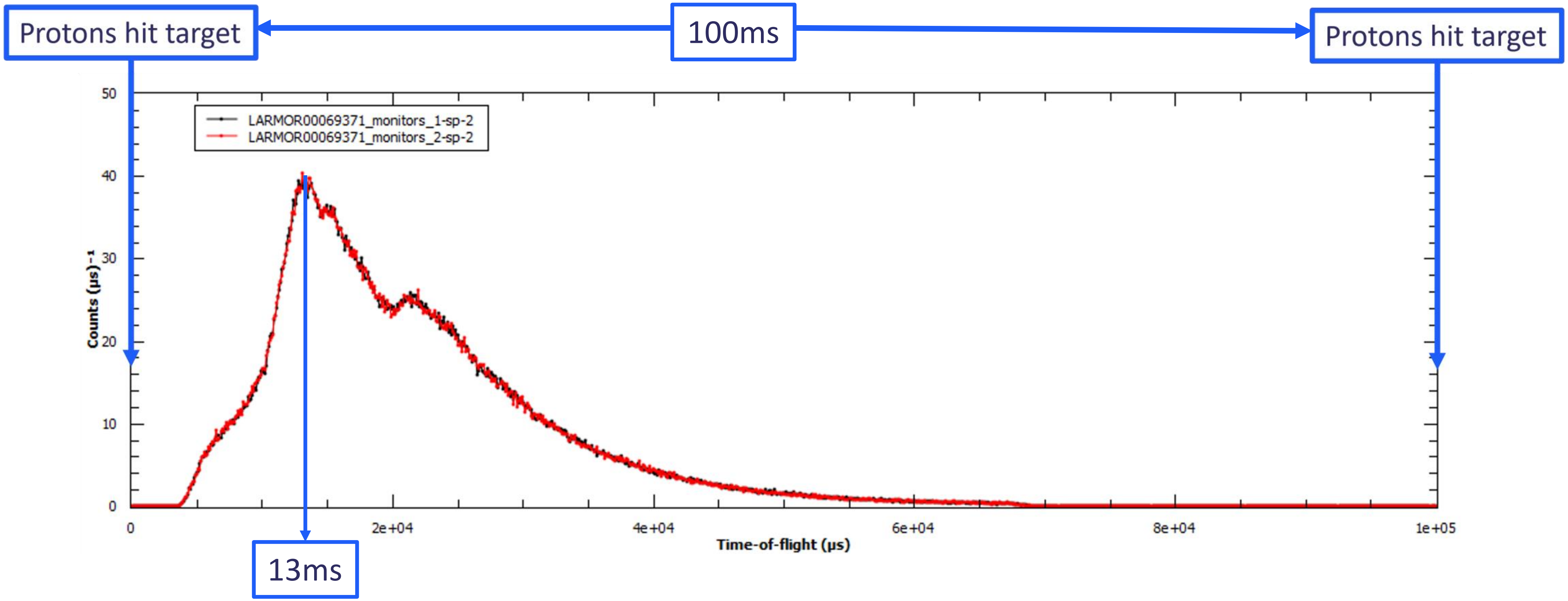
E_d=2 kV/cm

$V_{\mu RWELL}$=500V

1bar ^3He and 1bar CF_4

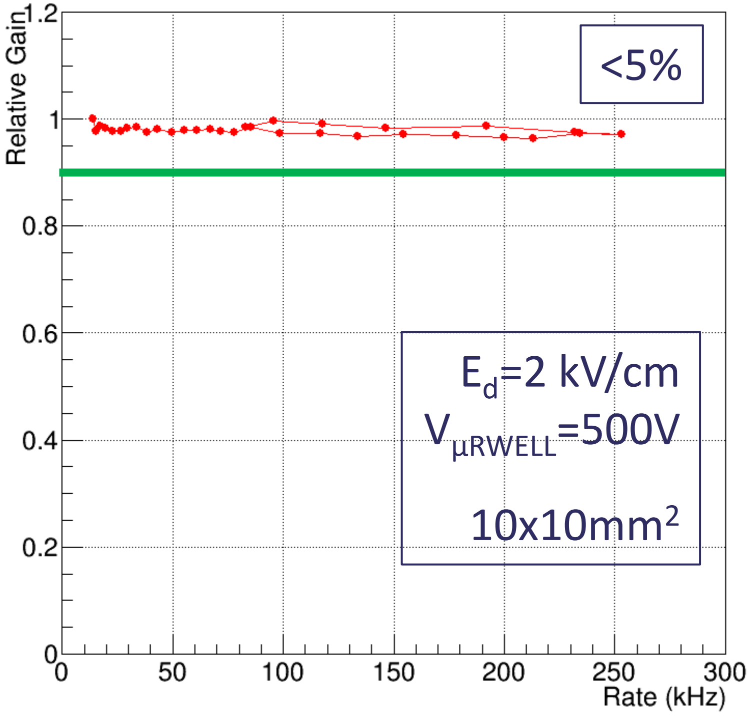


Neutron rate vs ToF



Gain vs Rate

Gain reduction less than **5%** up to **250kHz** with a 10x10mm^2



1bar ^{3}He and 1bar CF_4
E_d=2 kV/cm
$V_{\mu RWELL}$=500V

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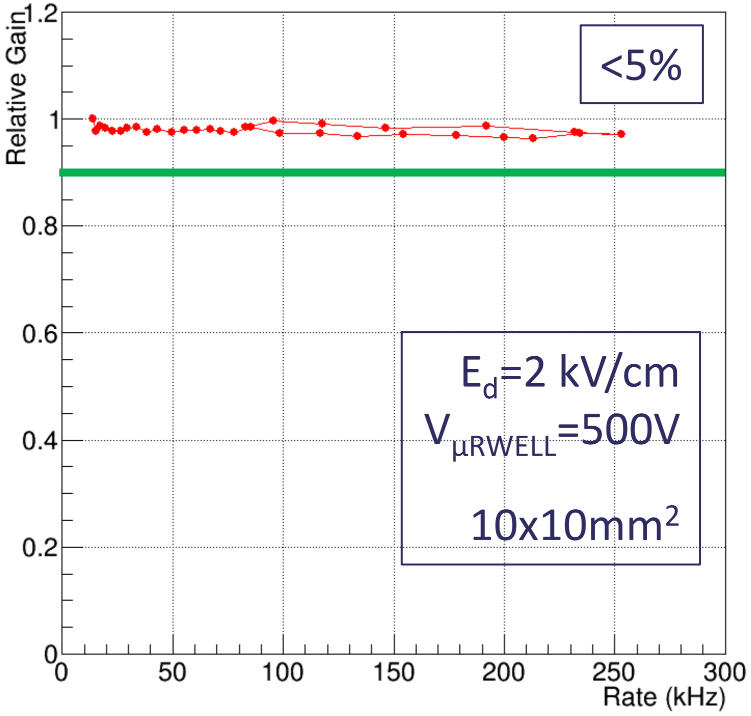
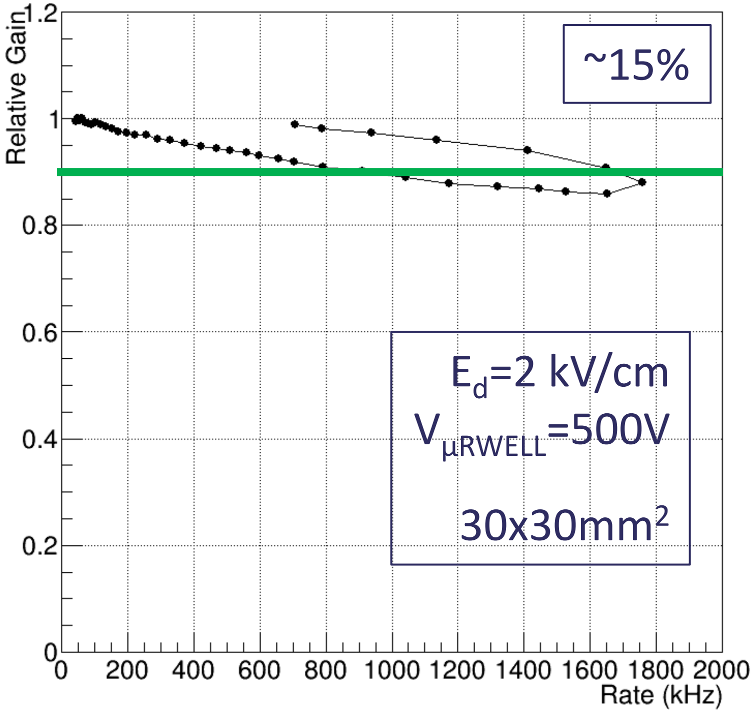
Gain vs Rate

Gain reduction less than **5%** up to **250kHz** with a 10x10mm^2

Gain reduction up to **15%** at a neutron rate of **1.8MHz** over 30x30cm^2

Gain does not follow the same pattern increasing and decreasing the rate on 30x30cm^2 beam





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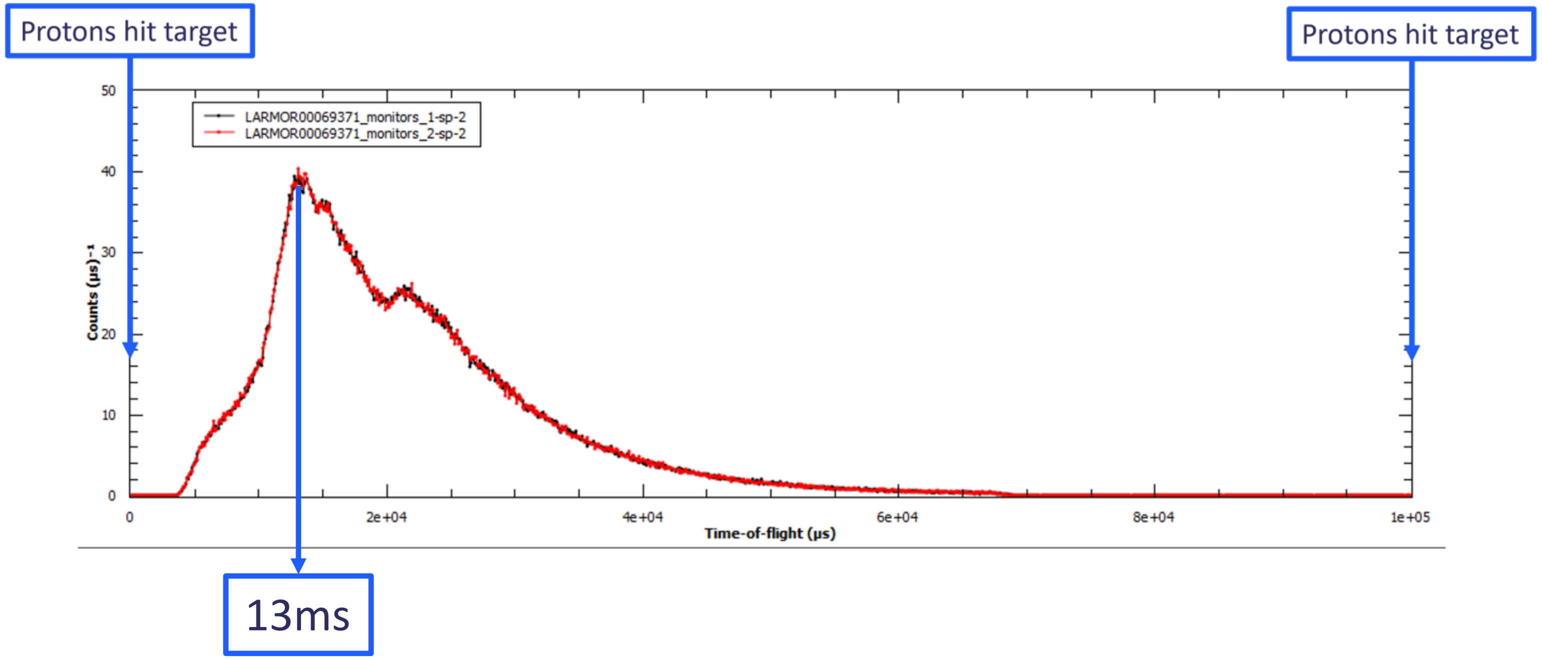
Beam time structure and gain variation



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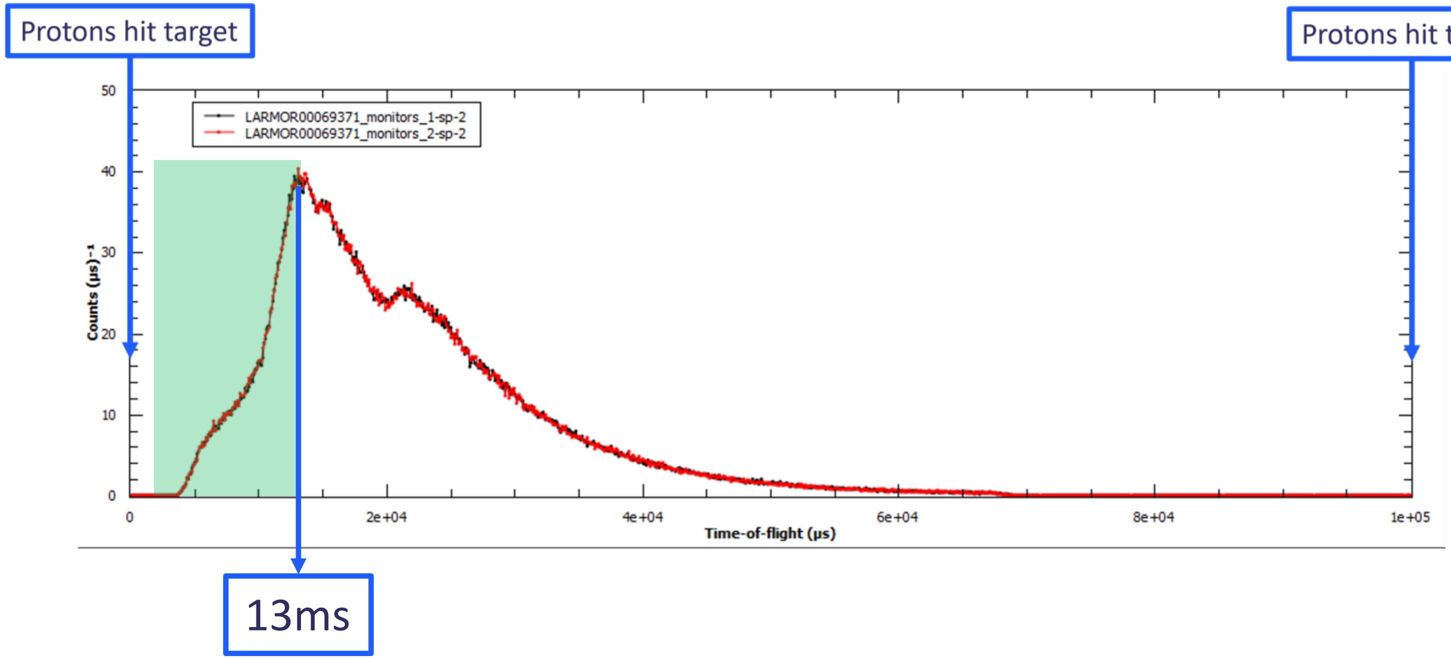

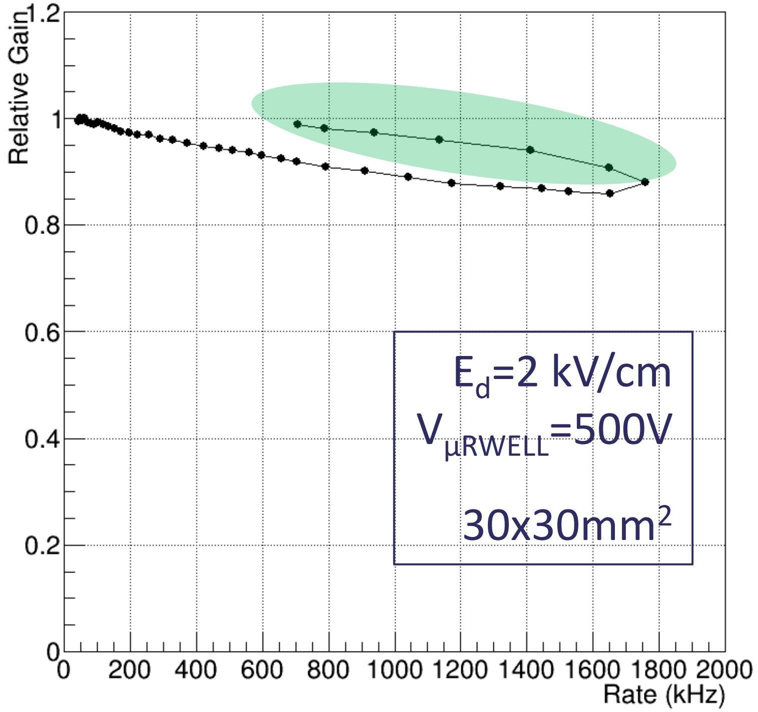

Beam time structure and gain variation

Protons hit target

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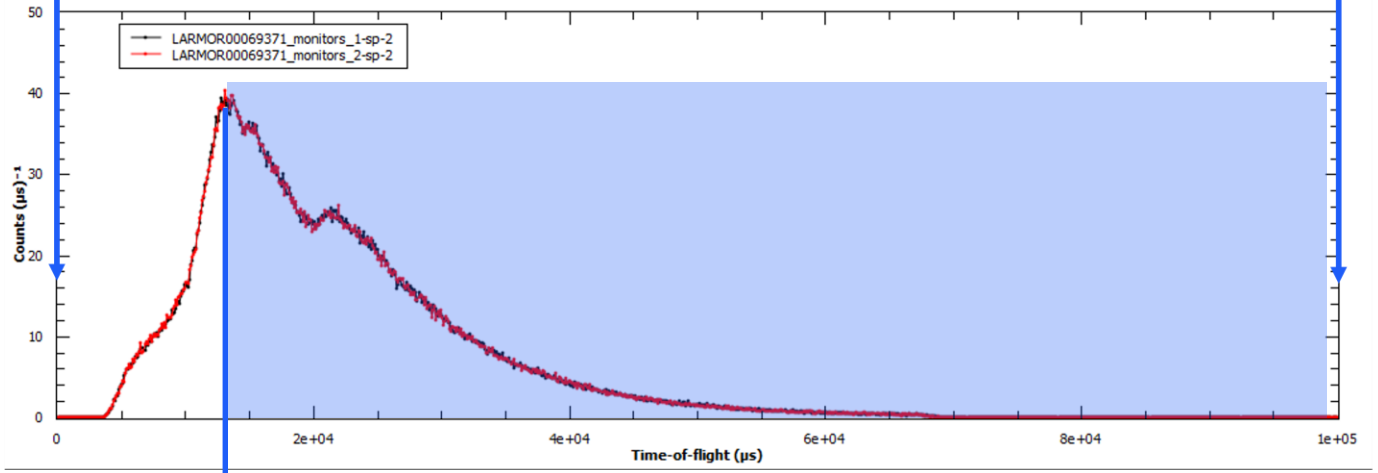
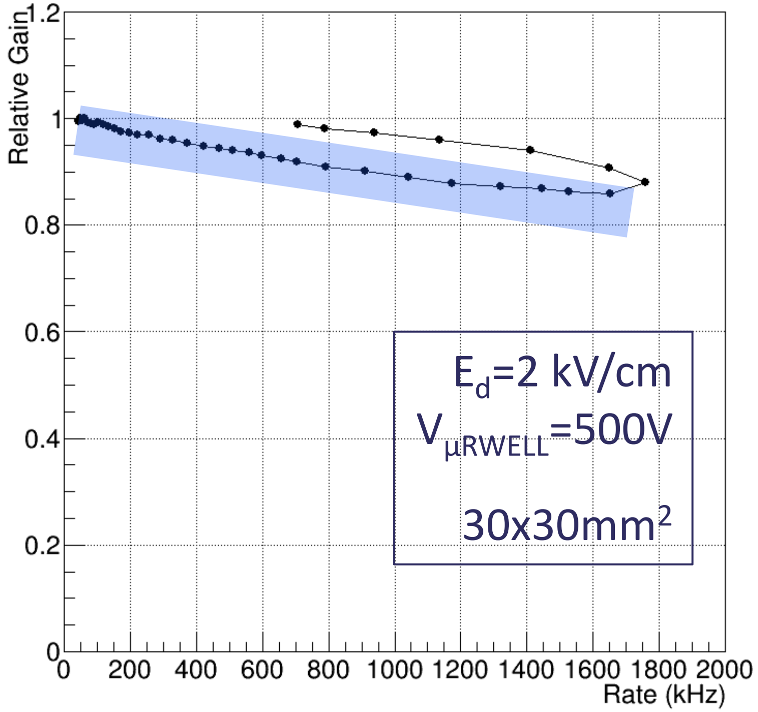


13ms

Too high DLC resistivity for this rate (80MΩ/□)

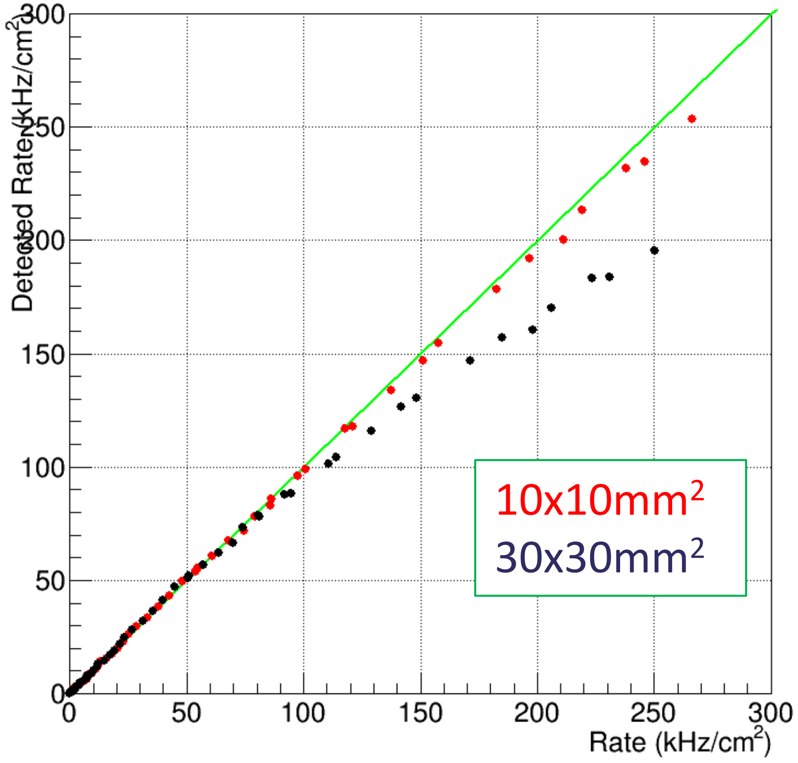


Rate/Unit area

Negligible rate loss up to **100kHz/cm²**

6% loss at **250kHz/cm²** on the 10x10mm²

17.5% loss at **250kHz/cm²** on the 30x30mm²



1bar ^3He and 1bar CF_4

E_d=2 kV/cm

$V_{\mu RWELL}$=500V

G. Bencivenni et al., 2019 JINST 14 P05014.
https://doi.org/10.1088/1748-0221/14/05/p05014

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Conclusions

- A new MPGD able to operate up to 6bar CF_4
    - Potential sub-millimetre position resolution
    - 2D readout
- Rate capability up to 100kHz/cm^2
- Five current ISIS instruments might immediately benefit from a detector with this performance

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Next Steps

- Measure the position resolution
- Evaluate µRWELLs layout to push the rate capability even further

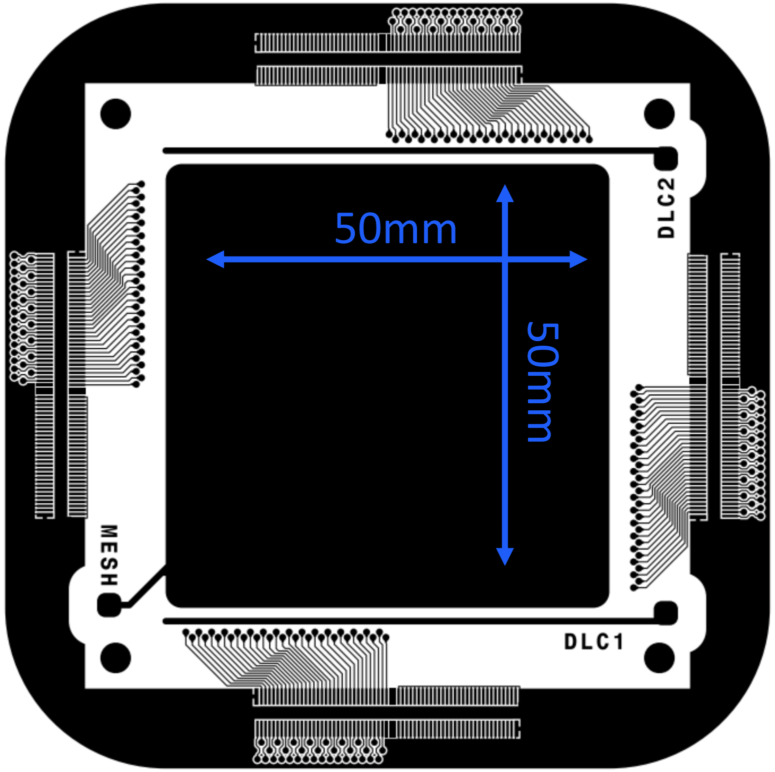
Next Steps

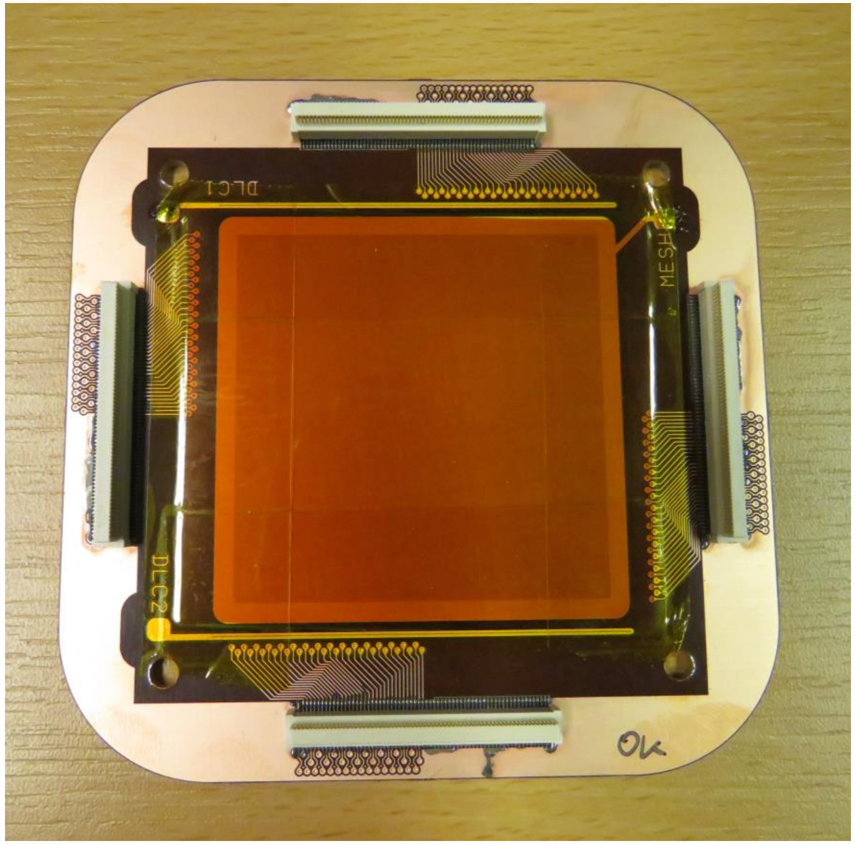
2D µRWELL

Measure position resolution
- as a function of CF_4 pressure
- as a function of neutron rate

128x128 XY strips

0.4mm pitch





Spares

Assembly procedure

Clean room class 100

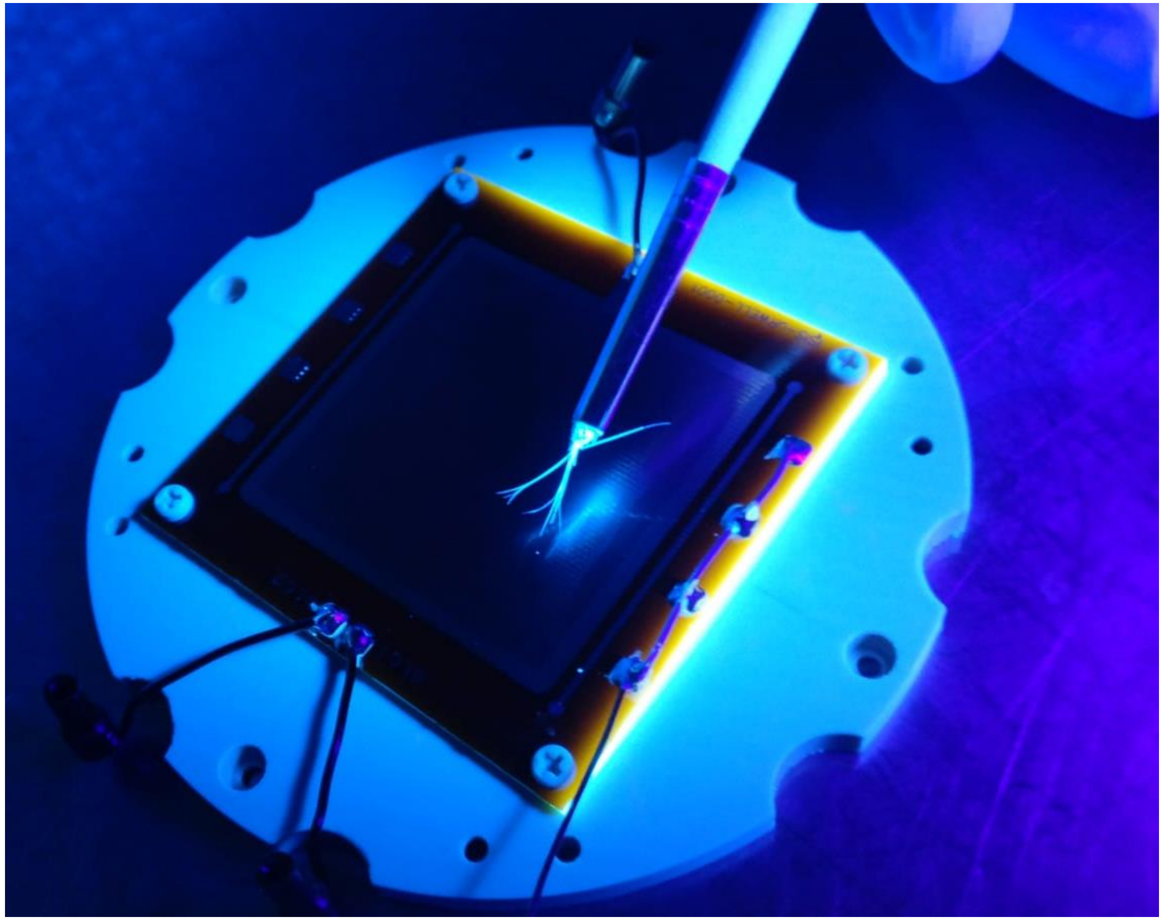
White and UV light to highlight specks of dust

Removed with brush and vacuum cleaner

Seal the volume and check the helium leak rate (10^{-10} mbar/l/s)

Bake at 100°C under vacuum (10^{-7}mbar) for +48h

Fill with the desired gas mixture



Materials
PEEK, copper, FR4, kapton, gold, ceramic

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