Progress towards optically read out GEM-based TPC

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Motivation

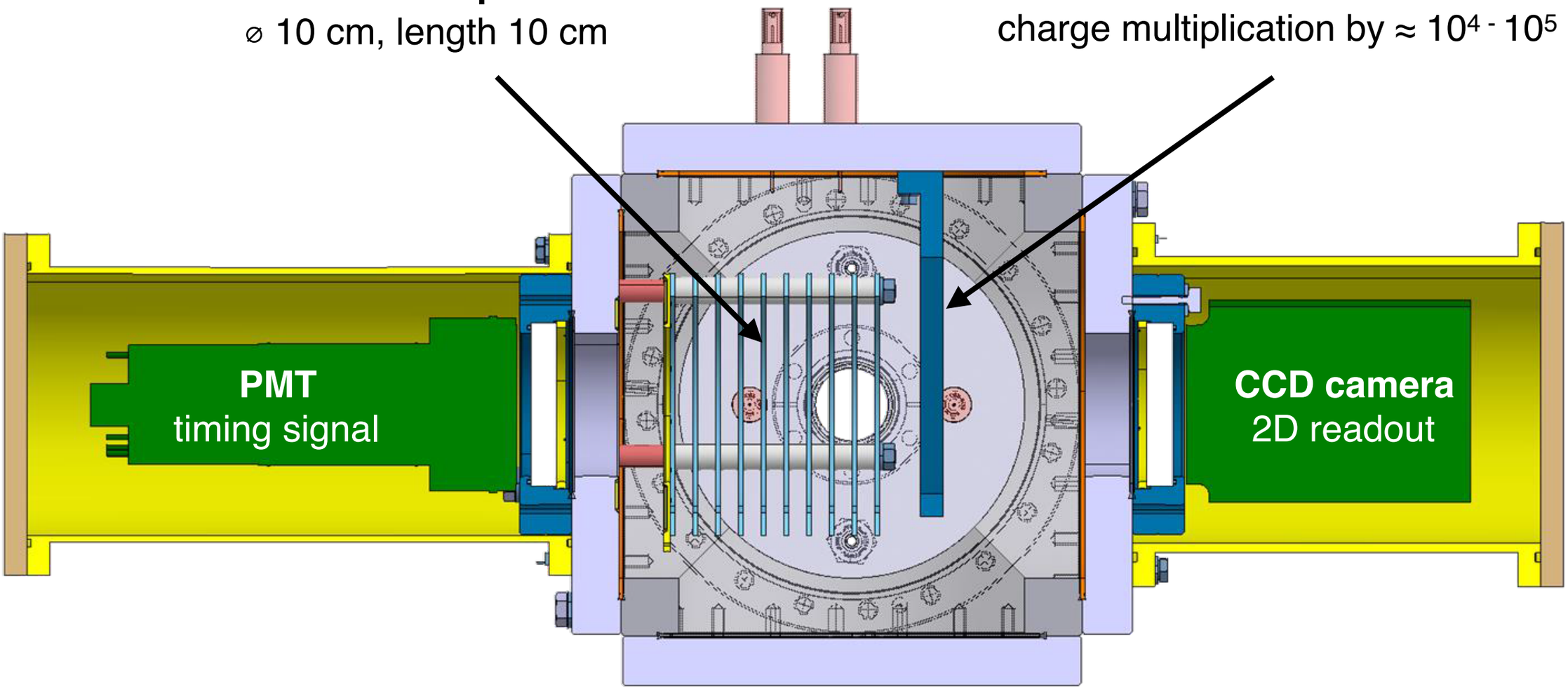
- Systematic studies of light yield and scintillation behaviour in different gas mixtures and pressure regimes
- Investigation of scintillation in sealed detectors

- Using optical readout for realising GEM-based TPC
- 3D event-reconstruction by combining CCD readout and timing signals from PMT

Setup 2D+1D

Field shaper
⌀ 10 cm, length 10 cm

Stack of 3 GEMs
charge multiplication by ≈ 10^4 - 10^5



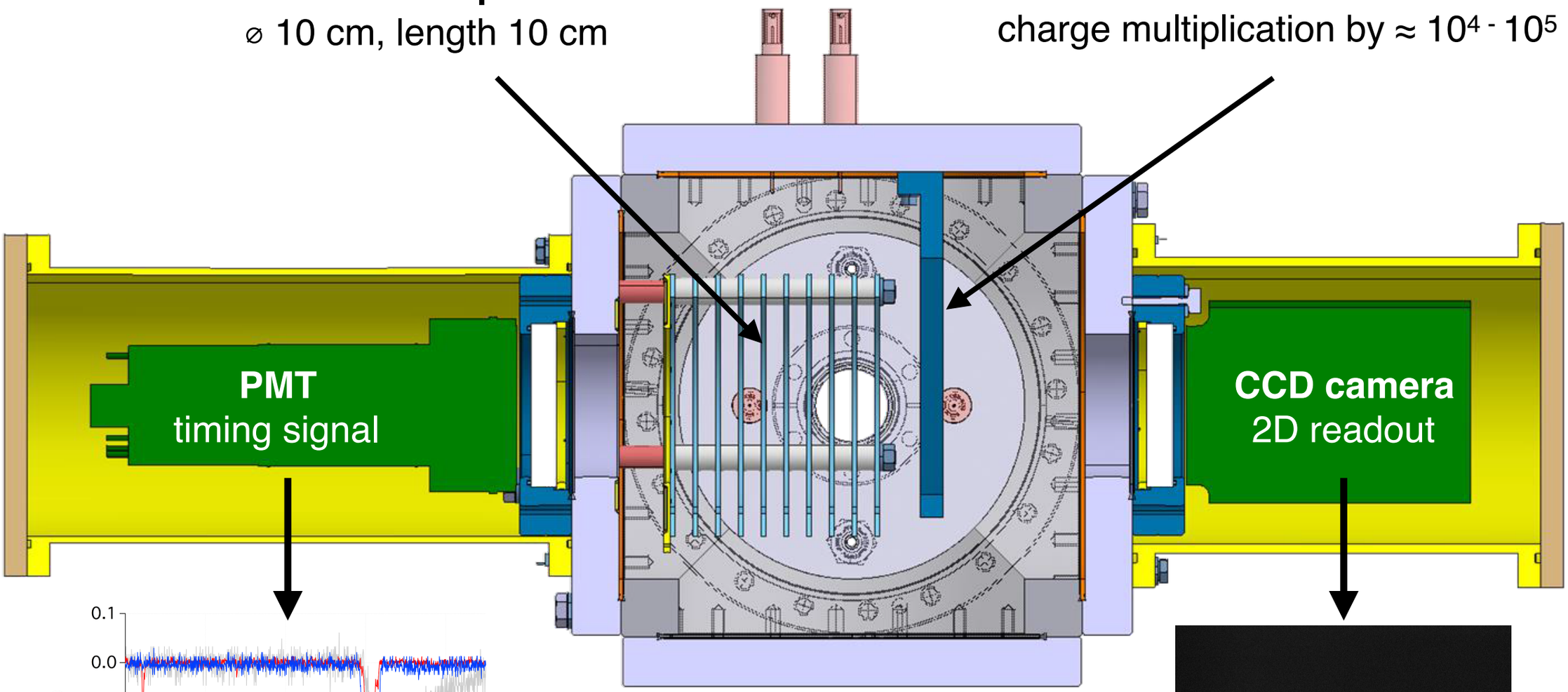
8000cm^3 vacuum-grade chamber
filled with Ar/CF_4 (80/20)

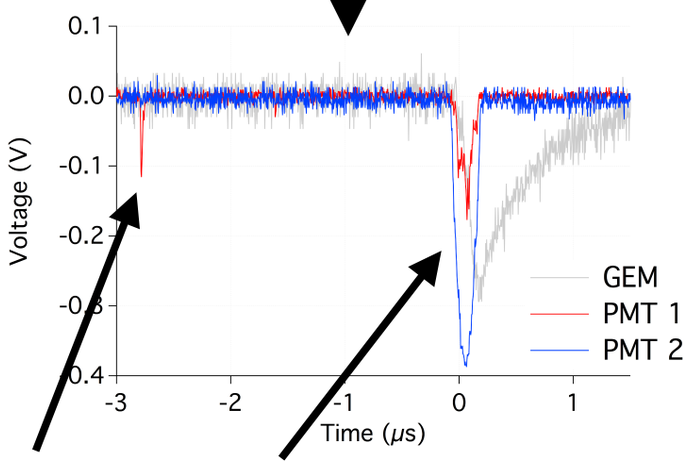
designed and developed by
D. Gonzales Diaz

Setup 2D+1D

Field shaper
⌀ 10 cm, length 10 cm

Stack of 3 GEMs
charge multiplication by ≈ 10^4 - 10^5





Primary / secondary scintillation

8000cm³ vacuum-grade chamber filled with Ar/CF_4 (80/20)

Optically read out α-track

Chamber

10^{-4}
mbar

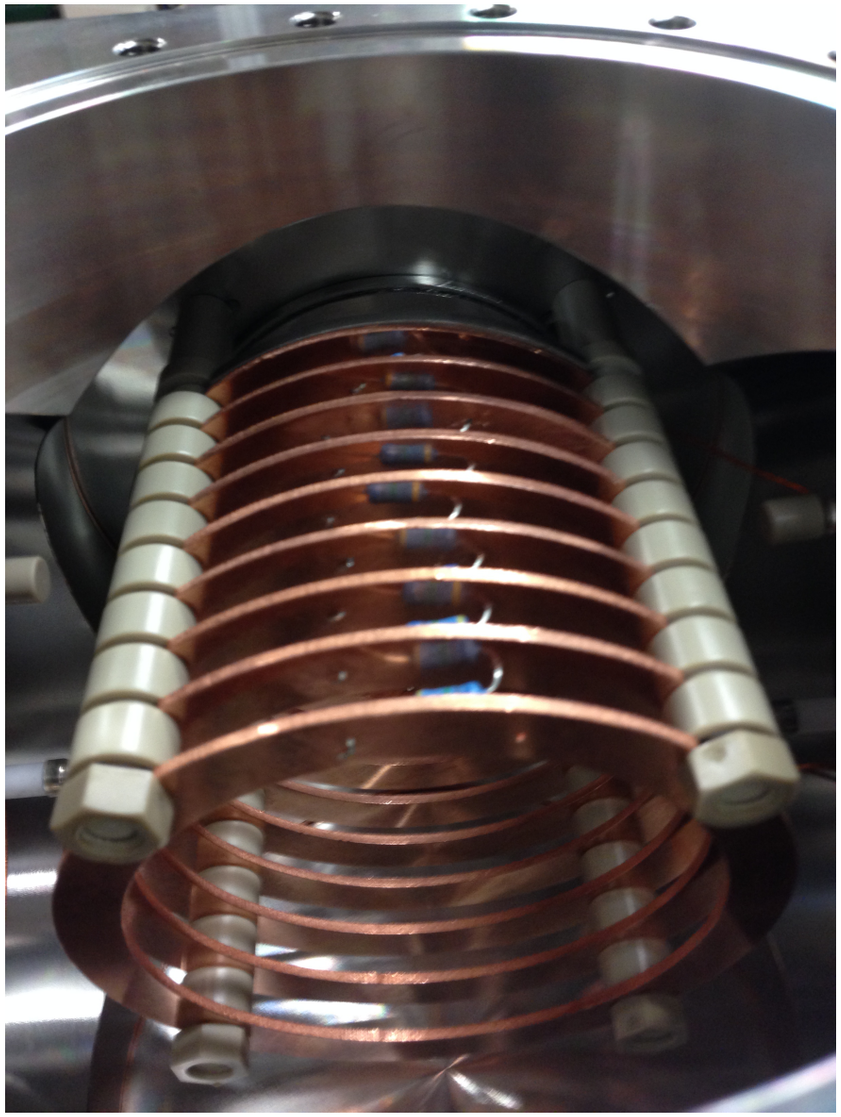
- Low outgassing components
- Allows for sealed operation and high gas purity

kHz
dark rate

- Excellent light tightness
- PMTs sensitive to small signals

500
V/cm

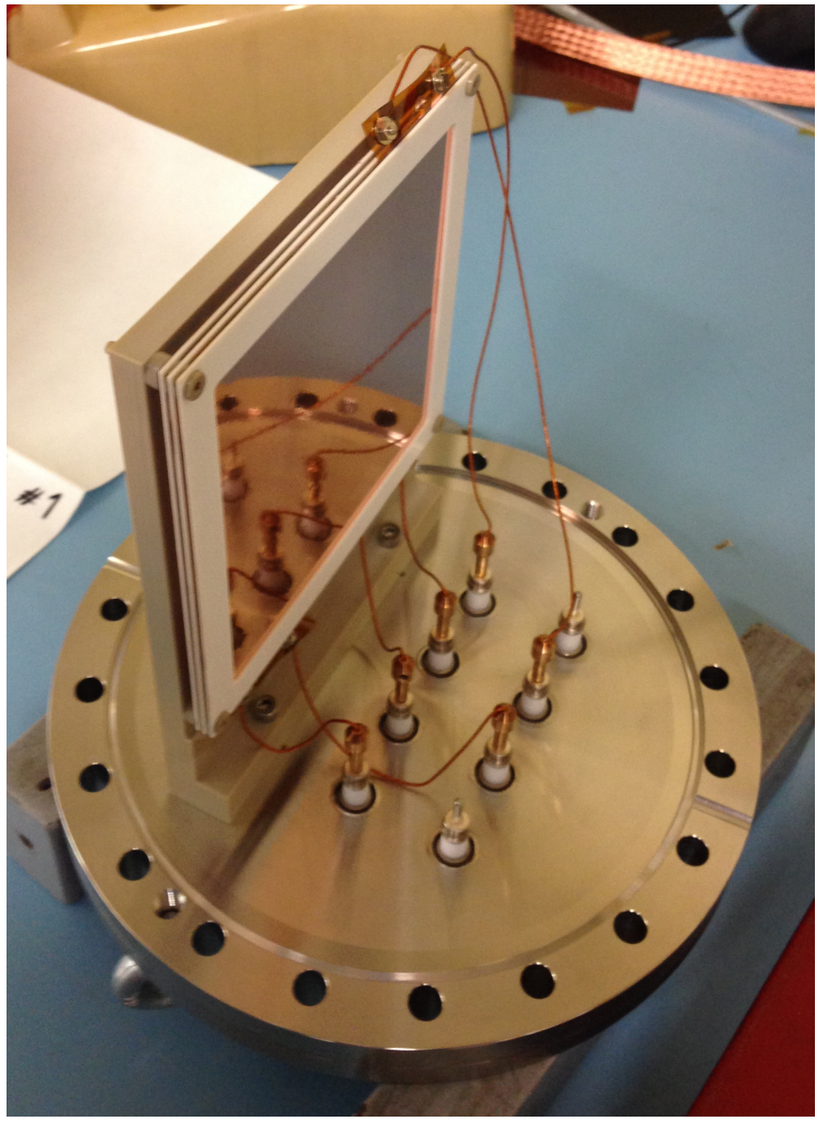
- Stable HV operation in Ar/CF_4 (80/20)
- Tested at fields up to 1000 V/cm



Field shaper

⌀ 10 cm, length 10 cm

Cu rings, PEEK rods

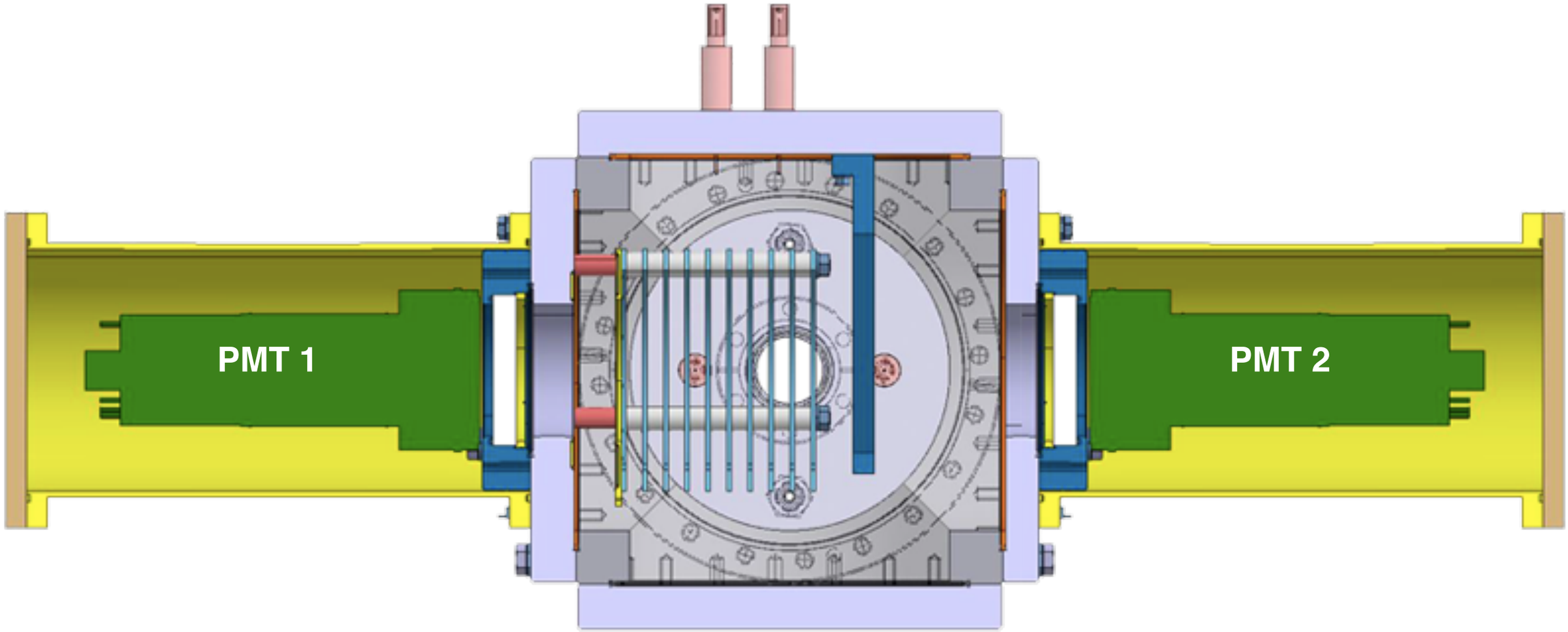


Triple GEM

10 x 10 cm^2

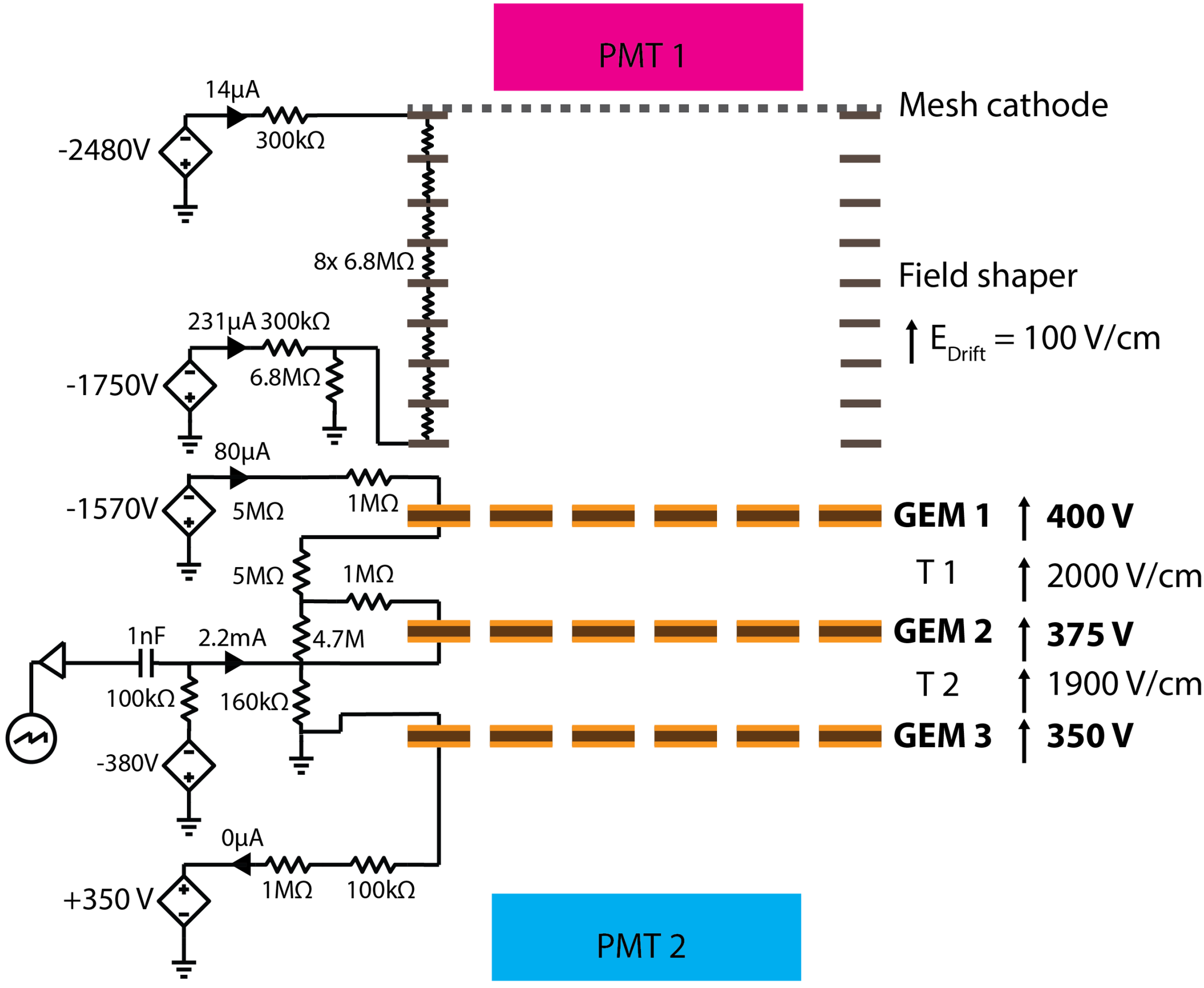
70 μm holes, 140 μm pitch

Setup - 2 PMTs



Ar/CF_4

80/20


PMT 1
14µA
-2480V
300kΩ
Mesh cathode
8x 6.8MΩ
Field shaper
E_{Drift} = 100 V/cm
231µA 300kΩ
-1750V
6.8MΩ
80µA
-1570V
5MΩ
1MΩ
5MΩ
1MΩ
1nF
2.2mA
4.7M
GEM 1
400 V
T 1
2000 V/cm
GEM 2
375 V
T 2
1900 V/cm
100kΩ
160kΩ
GEM 3
350 V
-380V
0µA
+350 V
1MΩ
100kΩ
PMT 2

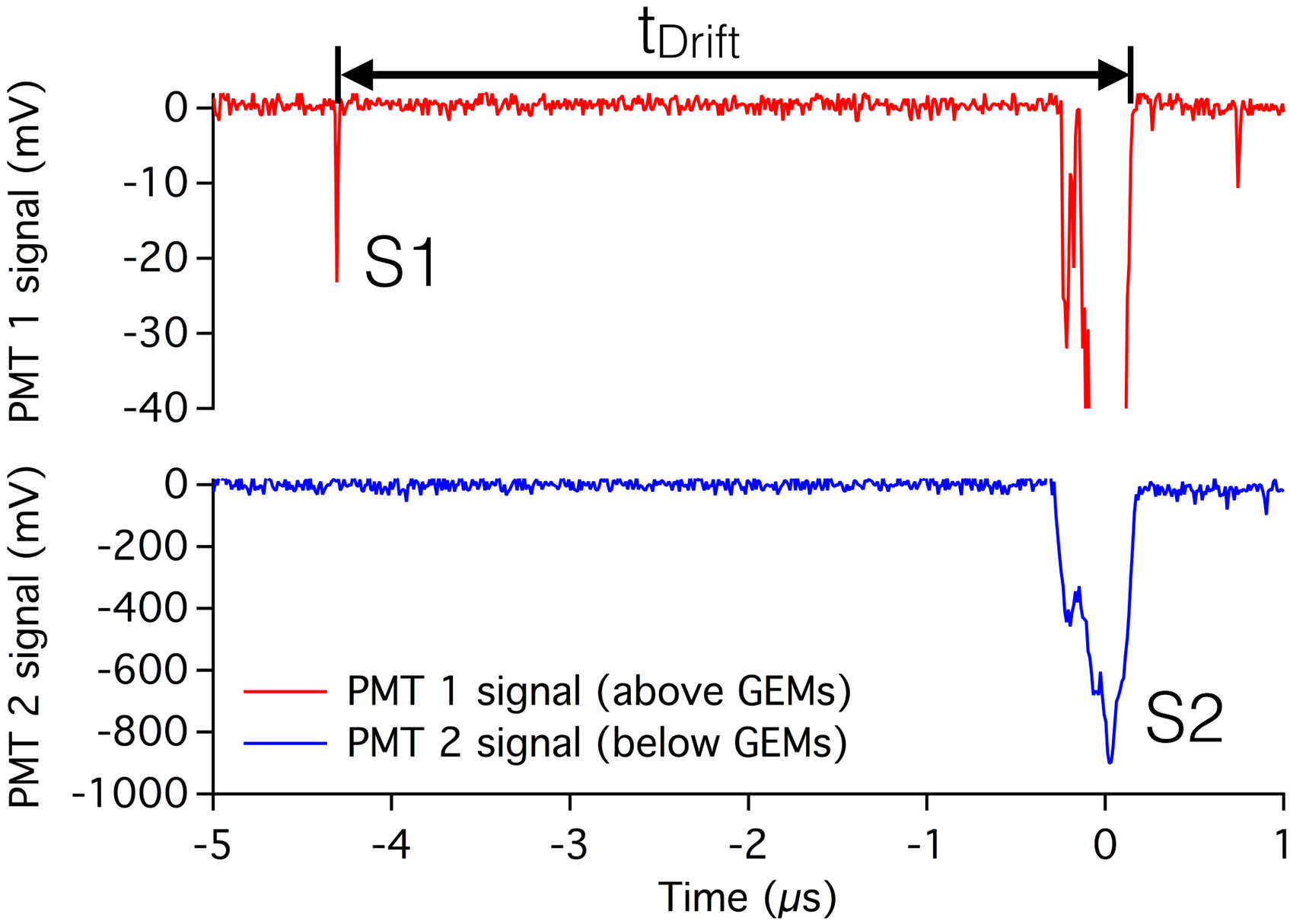
α tracks

Signal characteristics

$^{220}Rn \rightarrow {}^{216}Po$

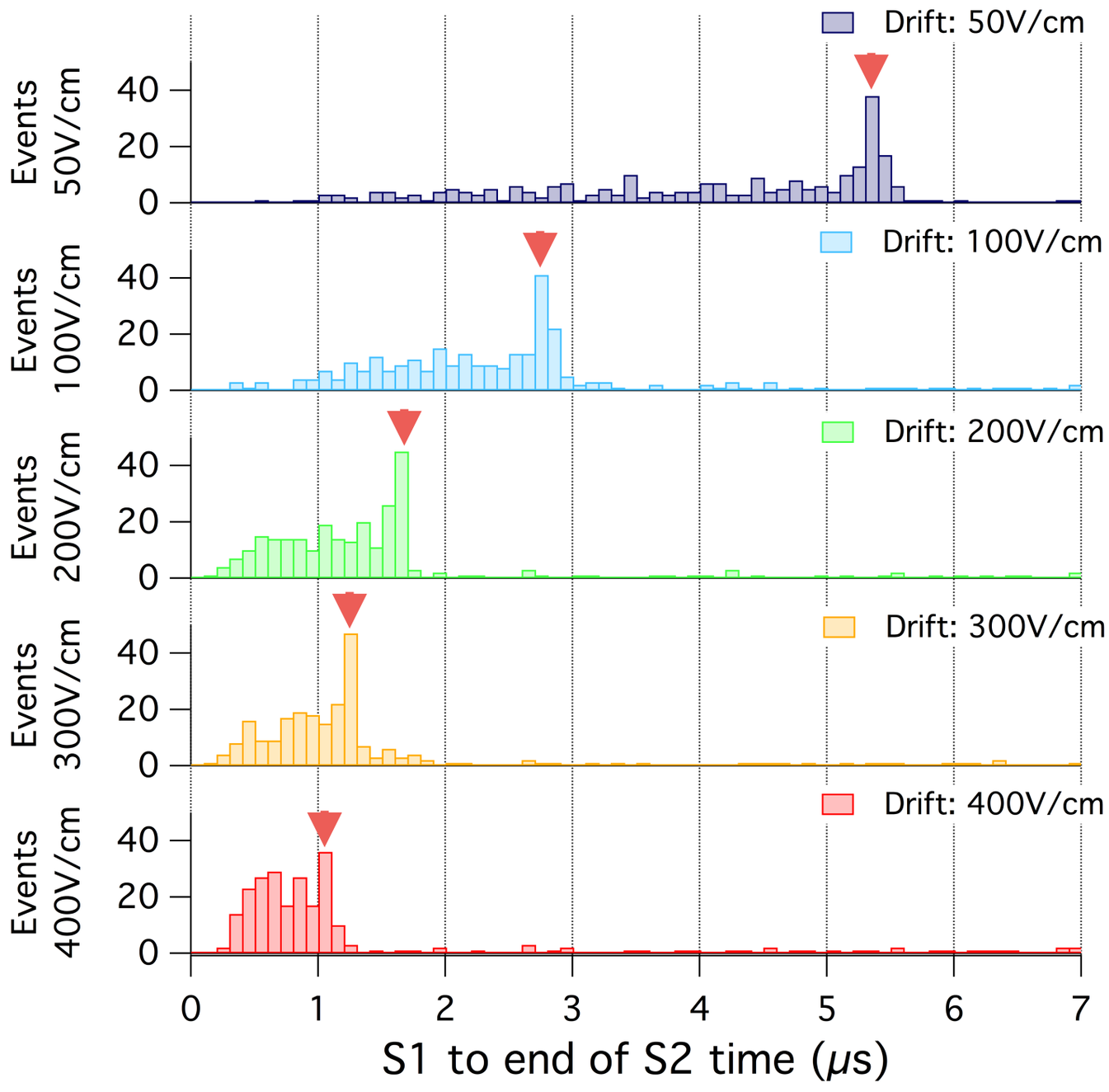
- Ar/CF_4 flushed through Rn source
- Rn decays in chamber via α-decay
- α-tracks are $\approx$ 8 cm long at 1 bar
- Double-α decay with λ = 140 ms

α signal

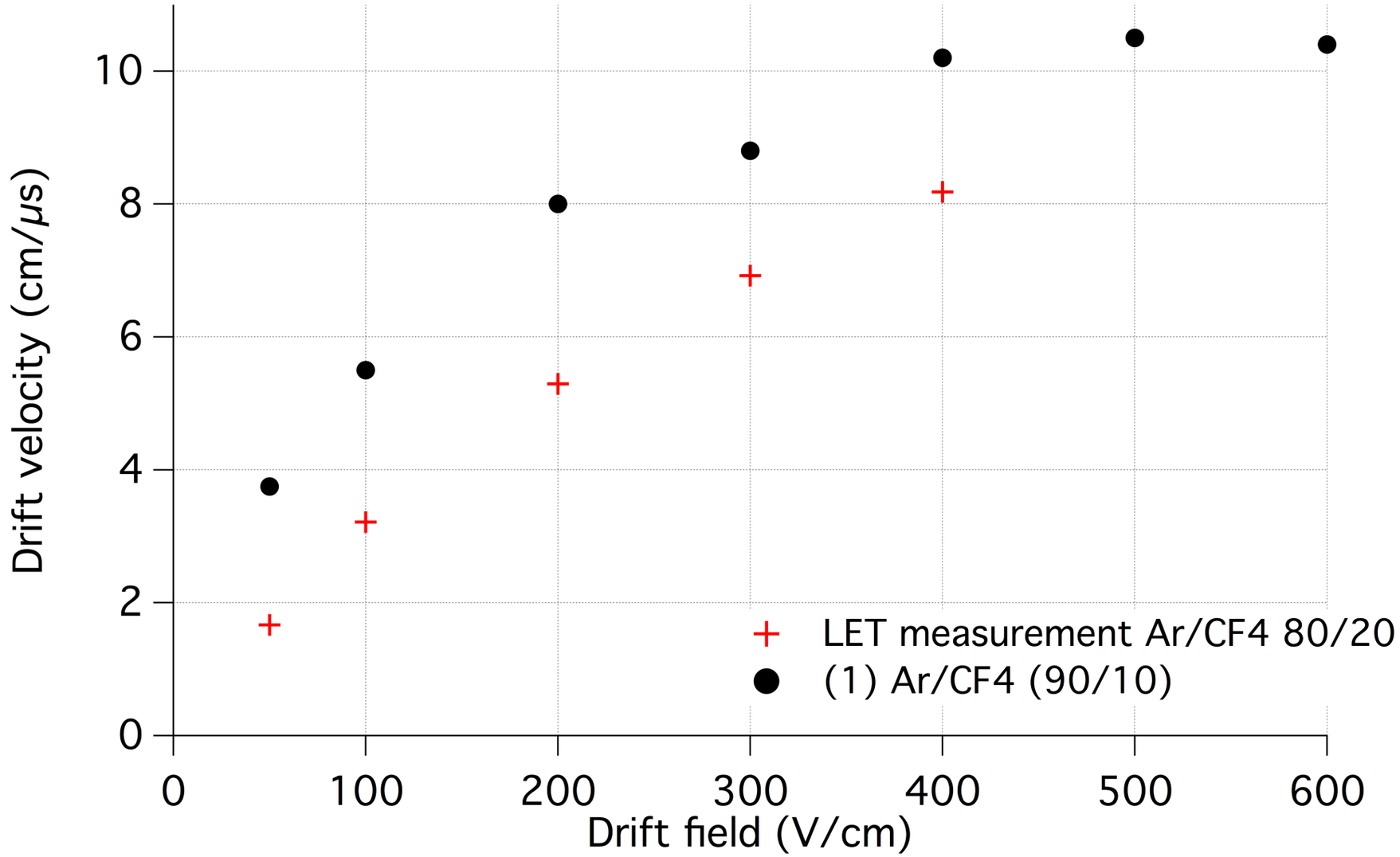


Primary (S1) and secondary (S2) scintillation of α-tracks

Maximum drift time



Drift velocity

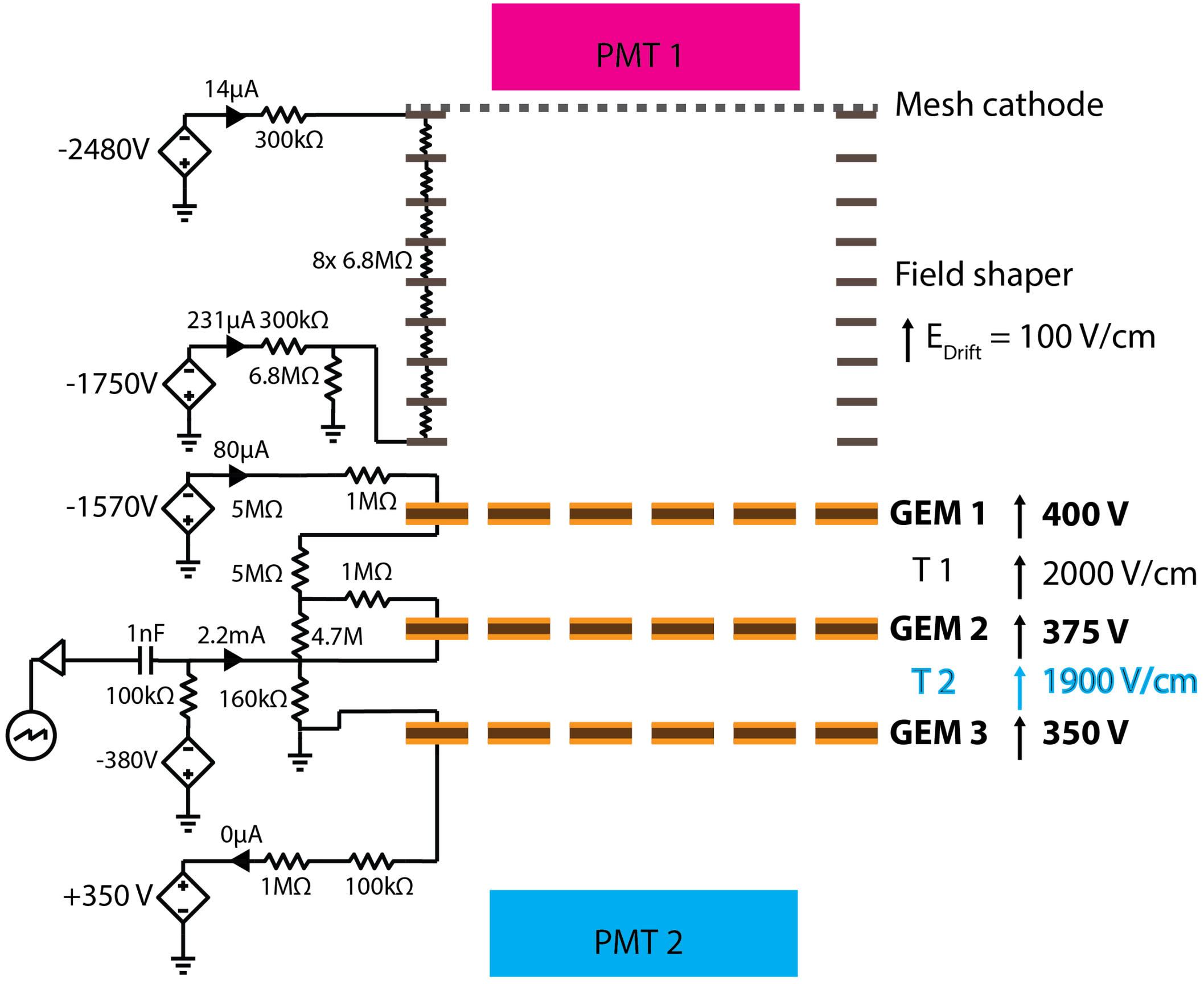


(1) Colas, P. et al. NIM 2002, 478, 215-219.

Possibly lower drift velocity due to gas impurities

α tracks

Signal origin and ion signals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160kΩ
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GEM 3
350 V
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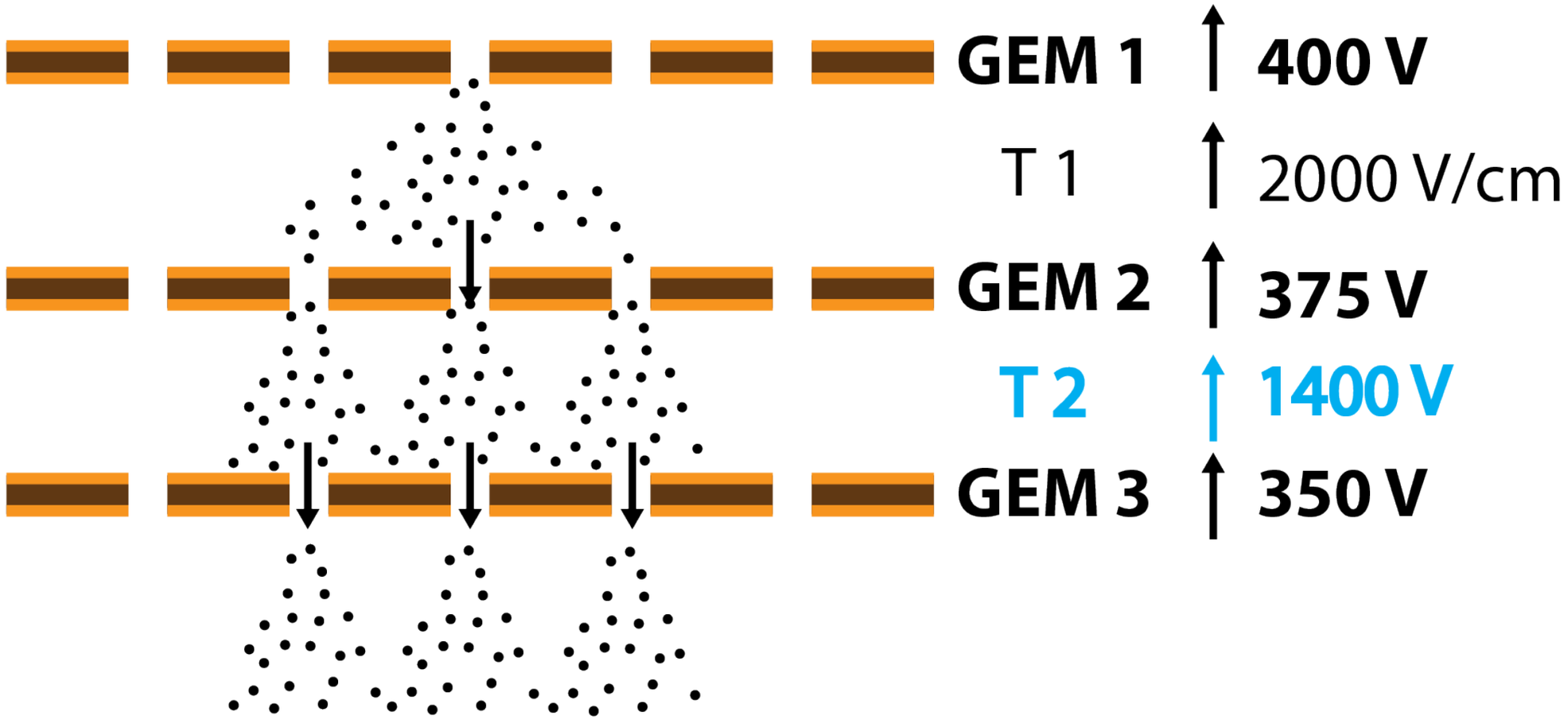
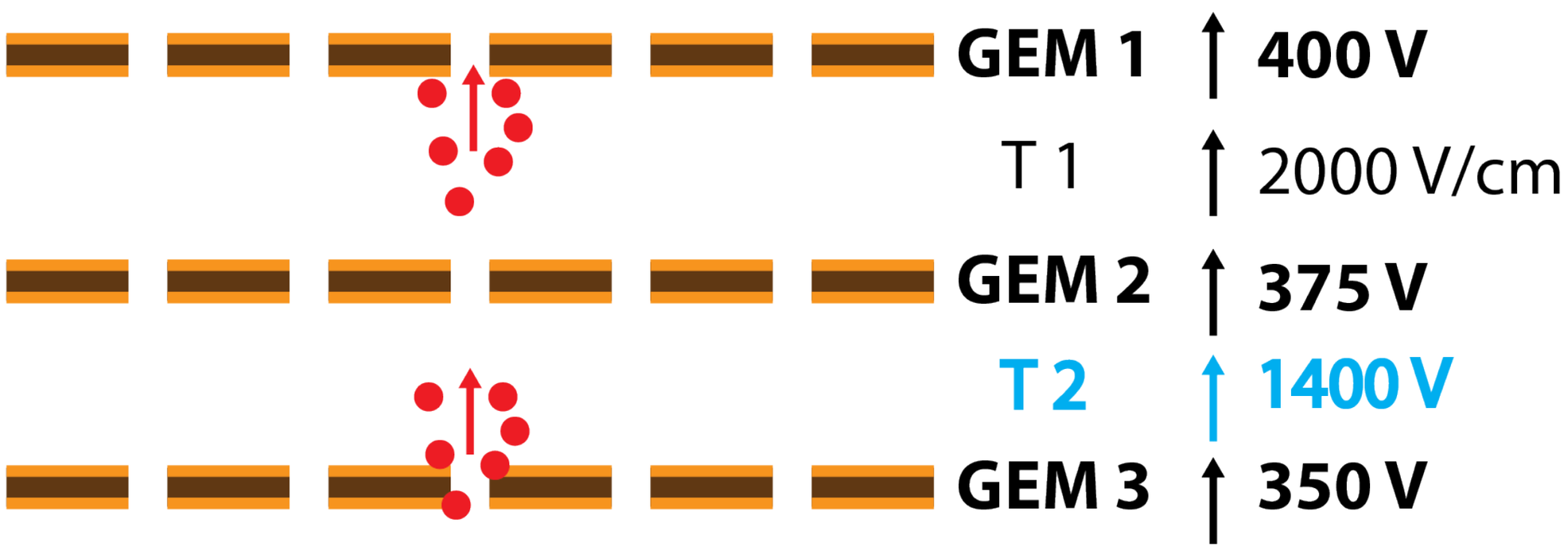
PMT 2

Signal origin - ions



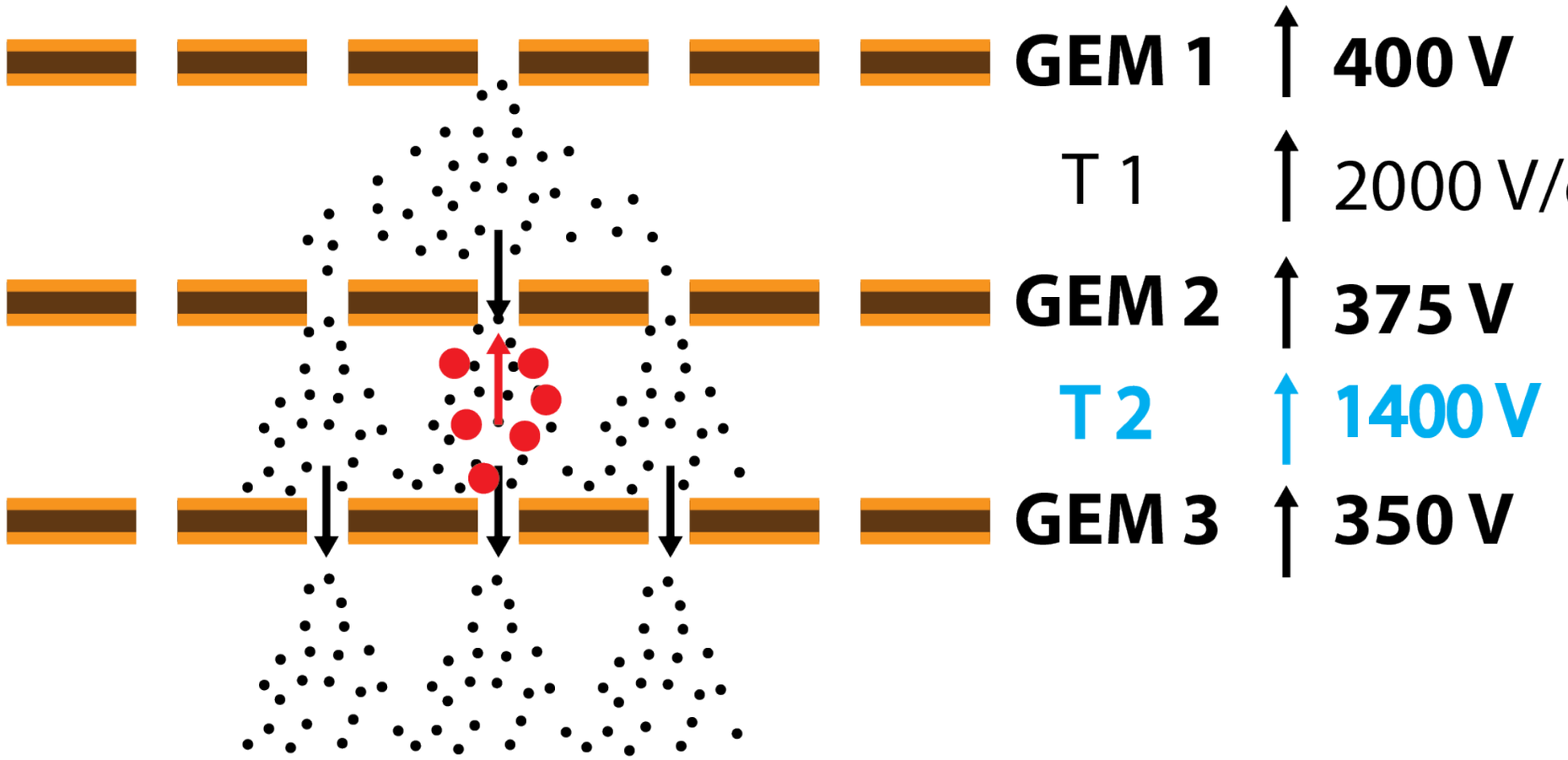
Asymmetric transfer fields
main signal from electrons

Signal origin - ions



Asymmetric transfer fields
ions drift upwards, take longer in T2

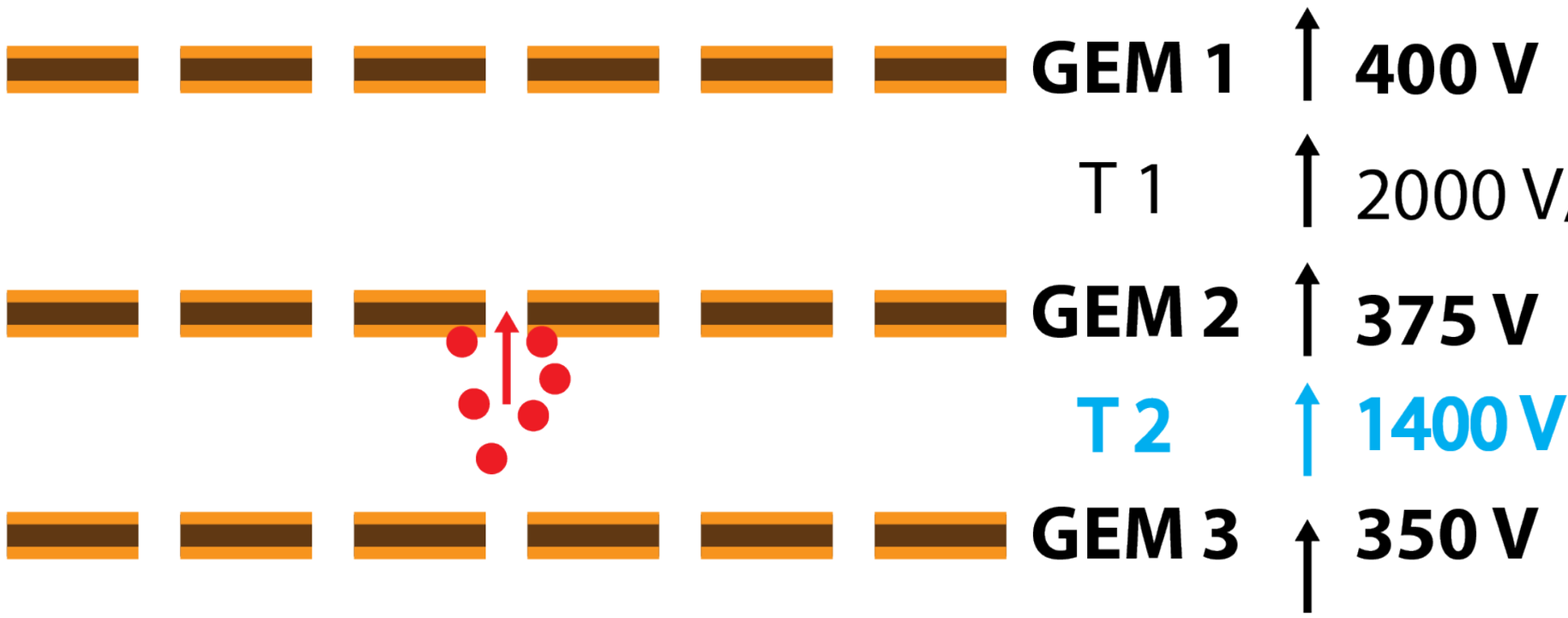
Signal origin - ions



Asymmetric transfer fields

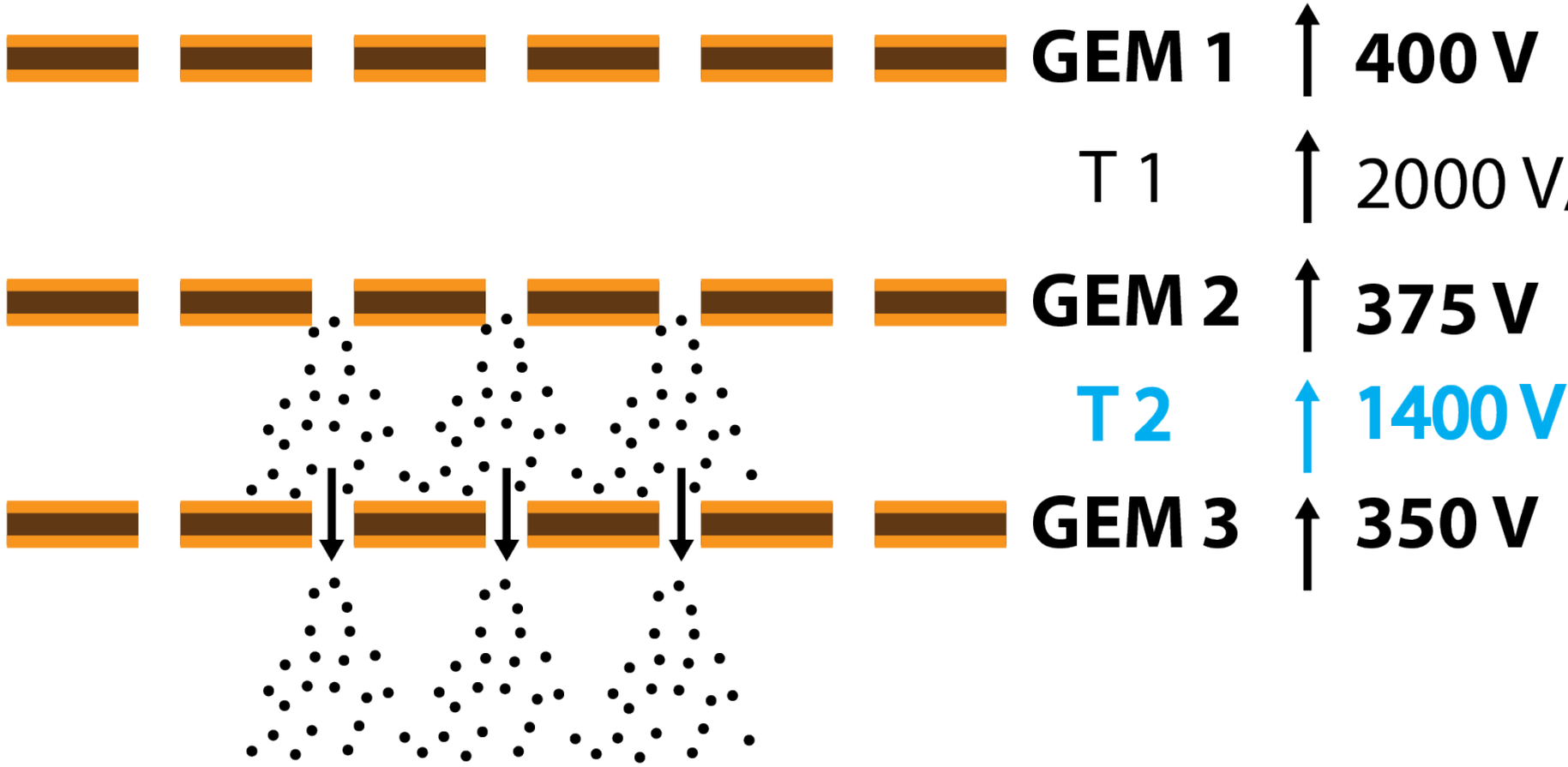
signal from electrons extracted by ions from GEM 2 in GEM 1

Signal origin - ions



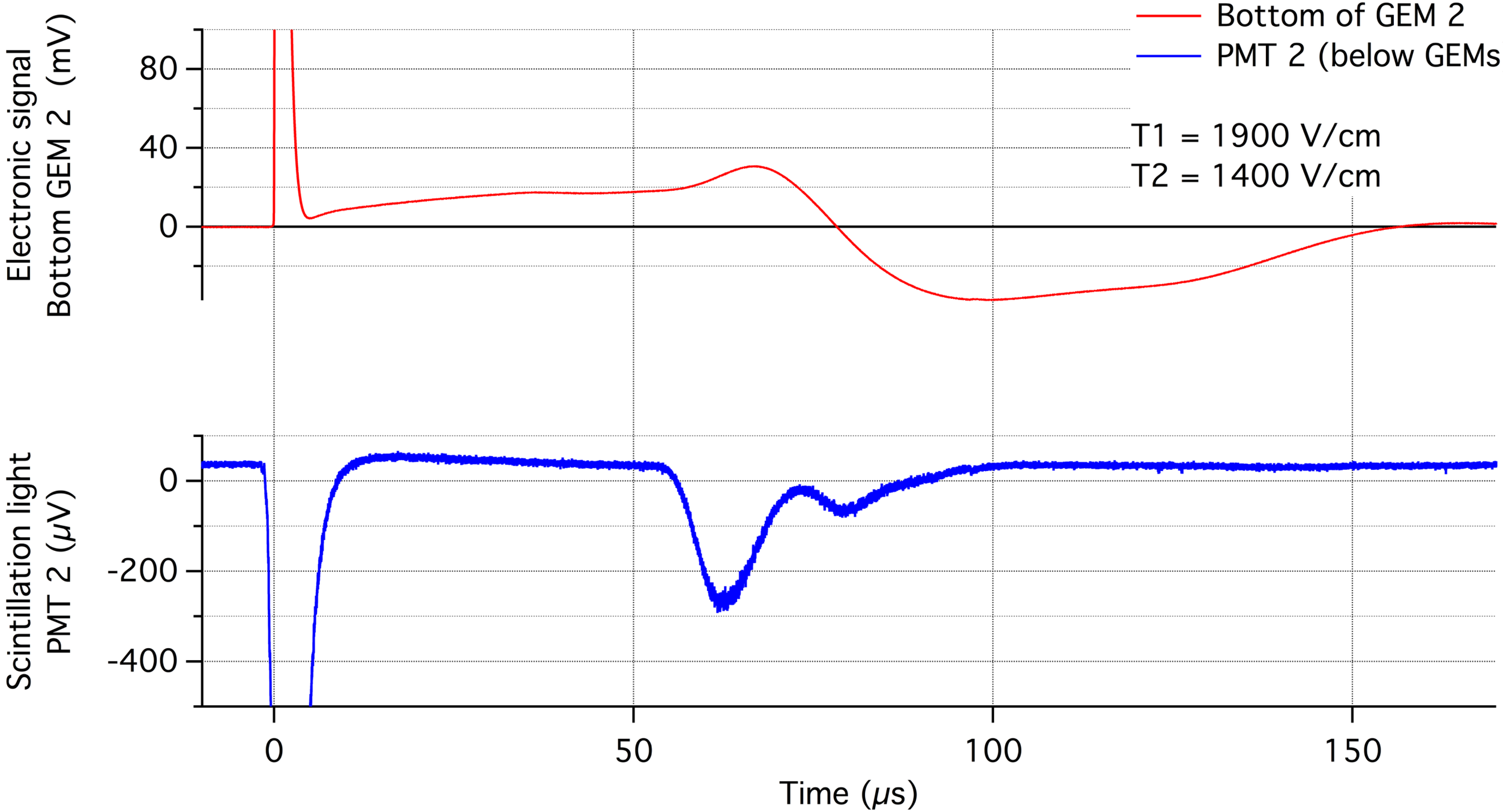
Asymmetric transfer fields
ions from GEM 3 move up to GEM 2

Signal origin - ions

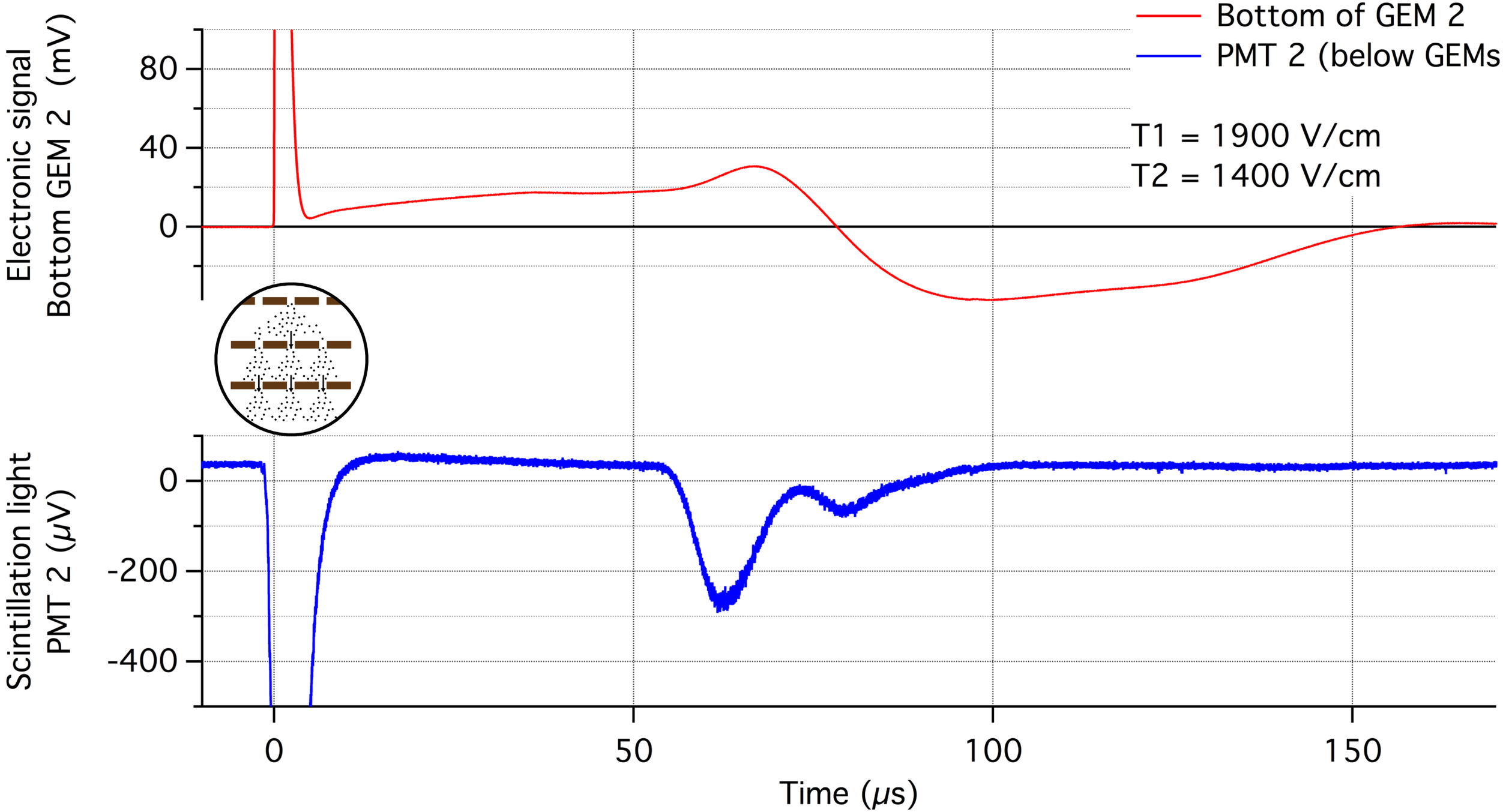


Asymmetric transfer fields
signal from electrons extracted by ions from GEM 3 in GEM 2

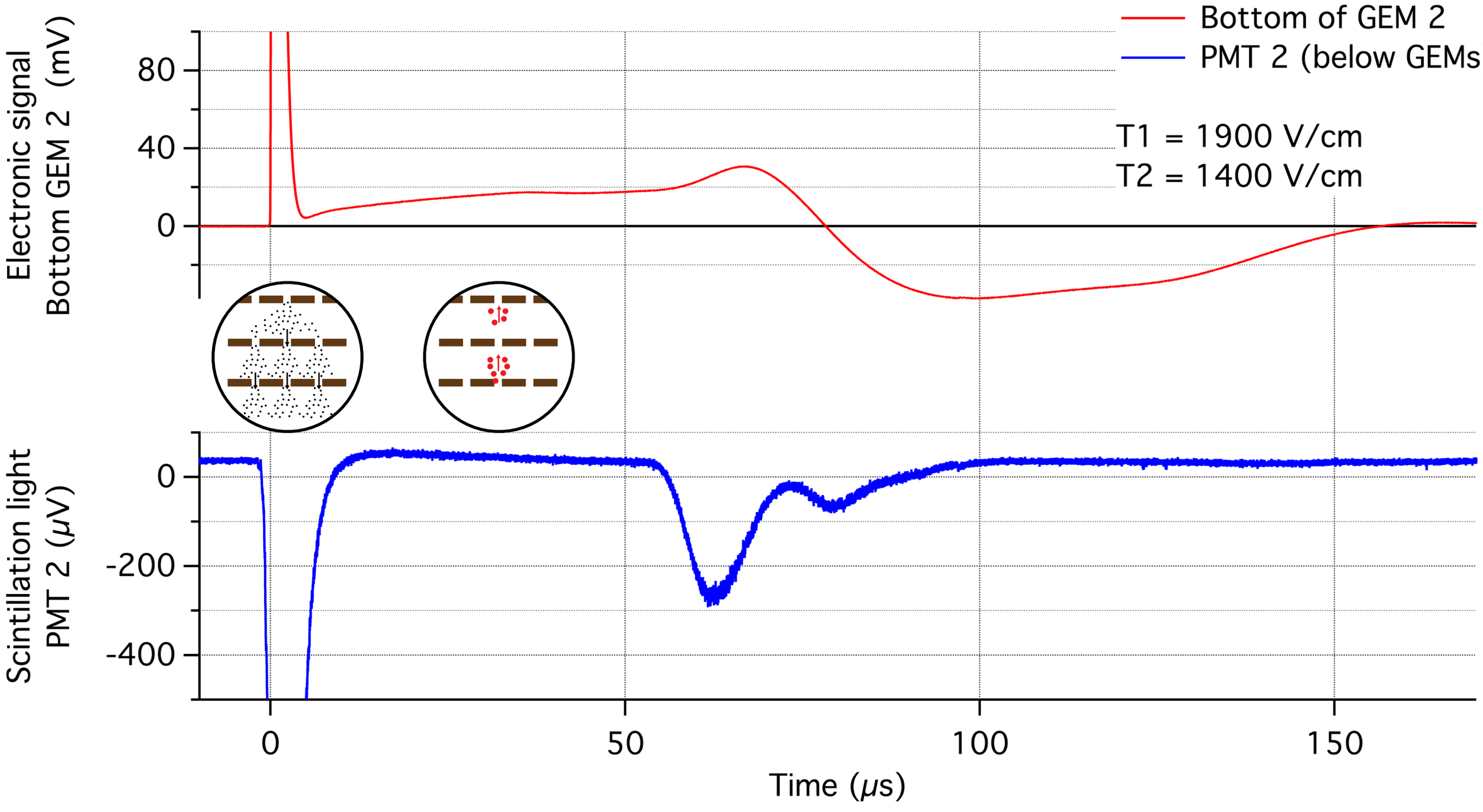
Signal origin - ions



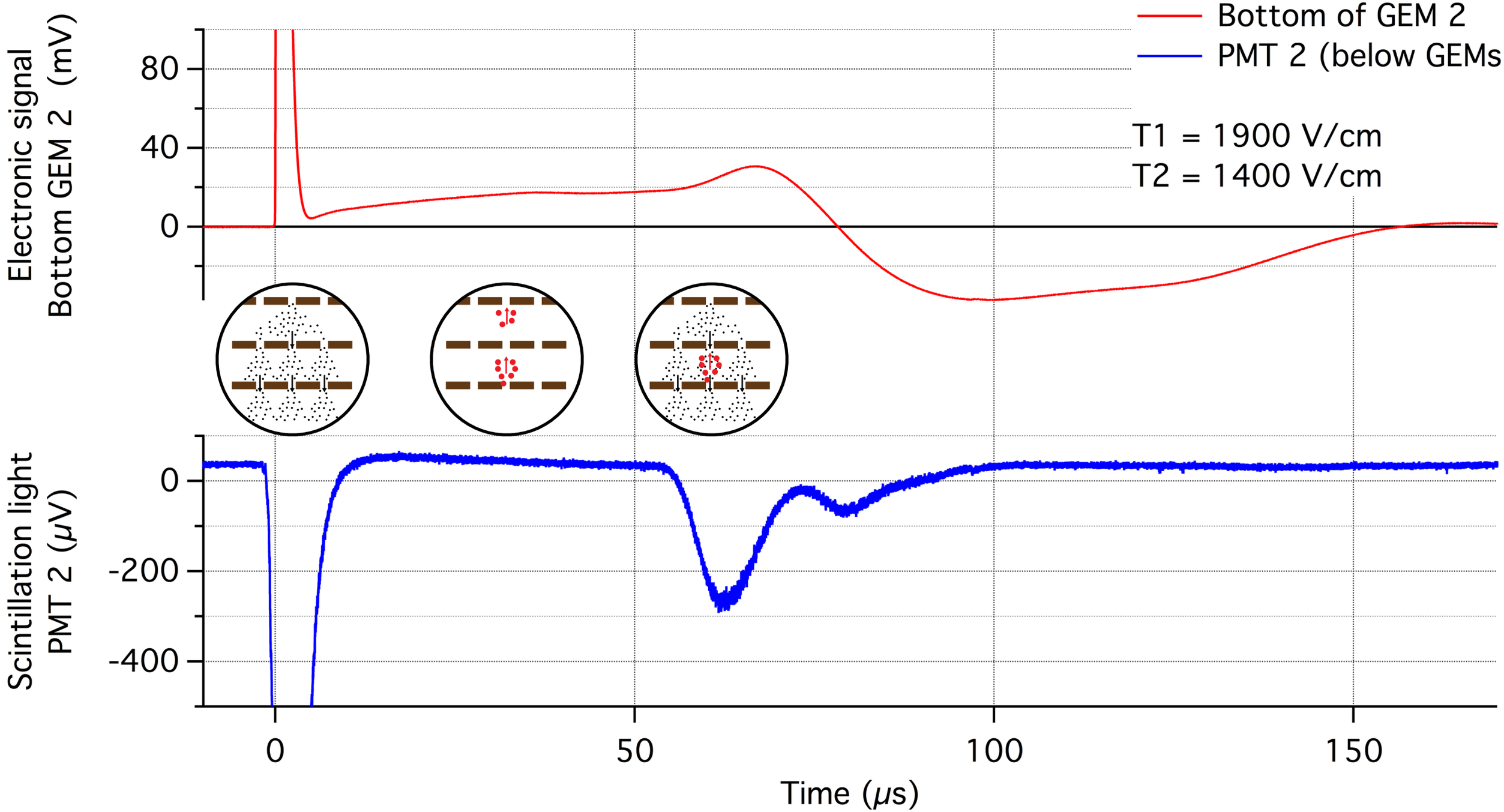
Signal origin - ions



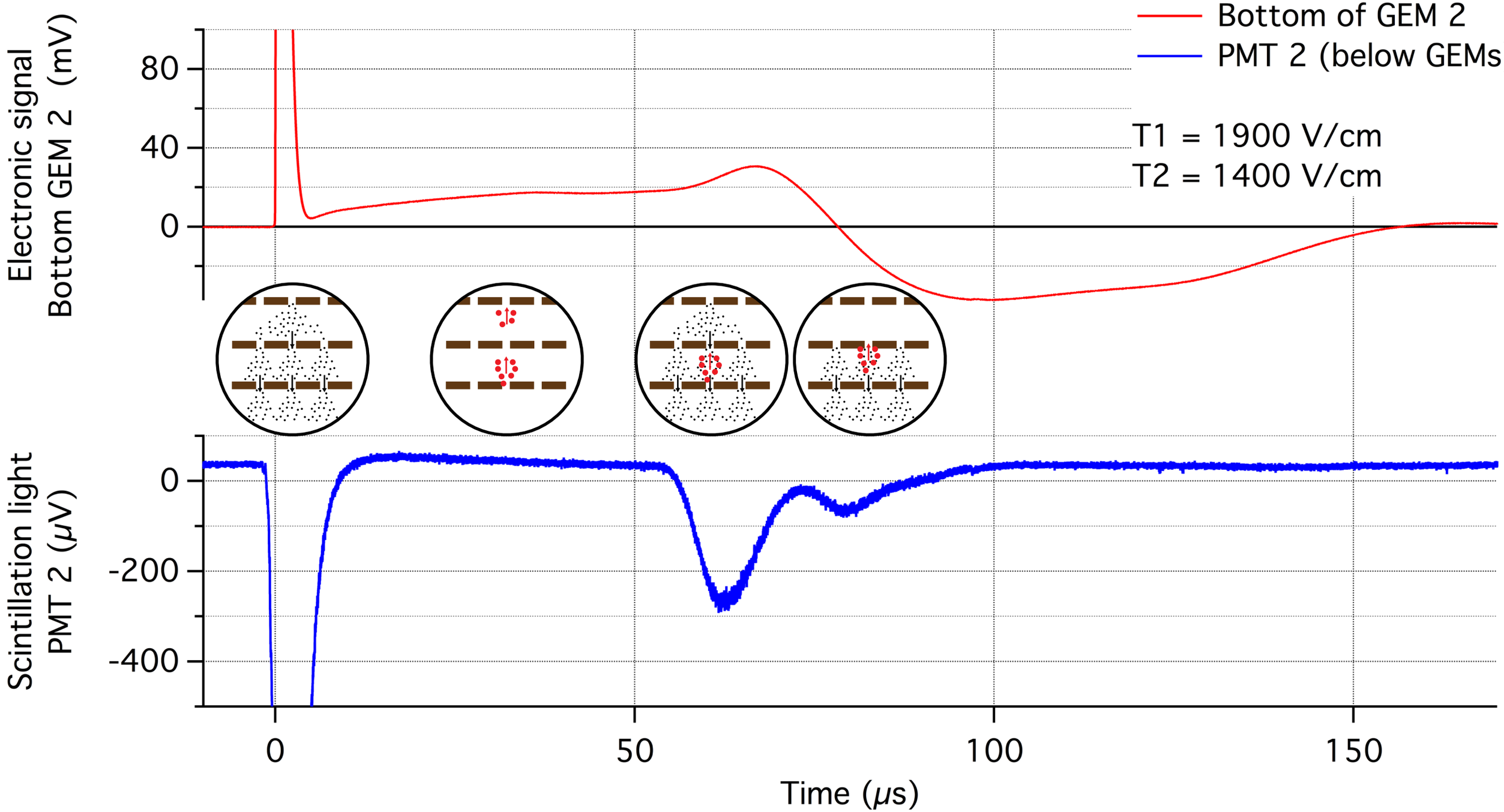
Signal origin - ions



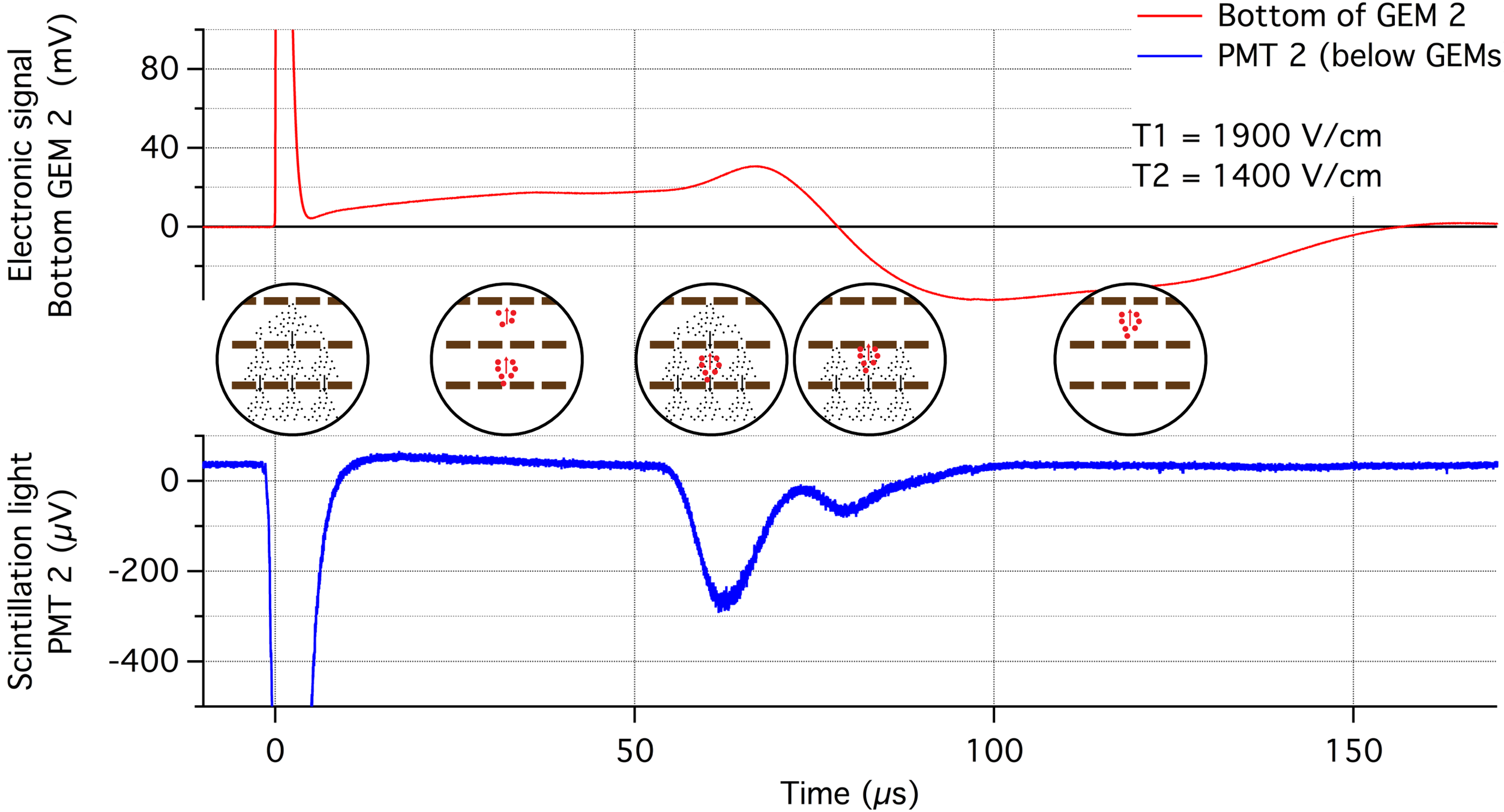
Signal origin - ions



Signal origin - ions



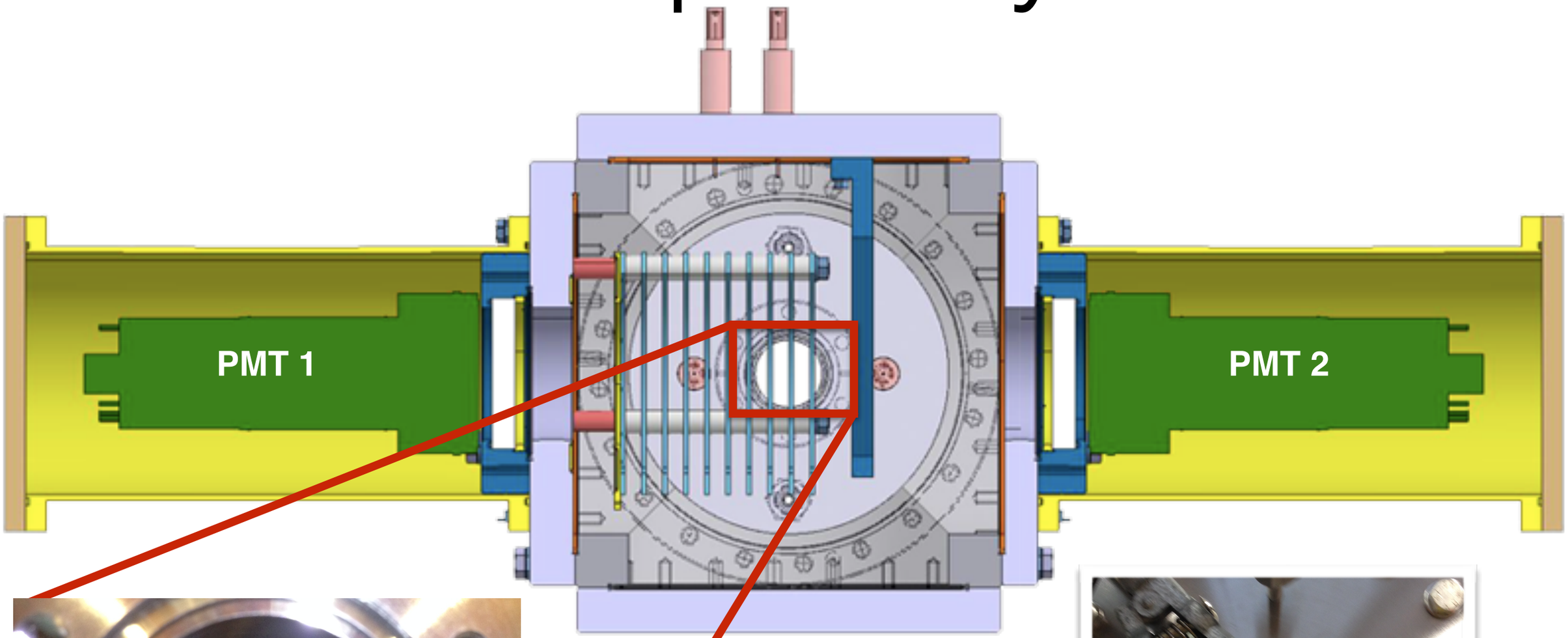
Signal origin - ions

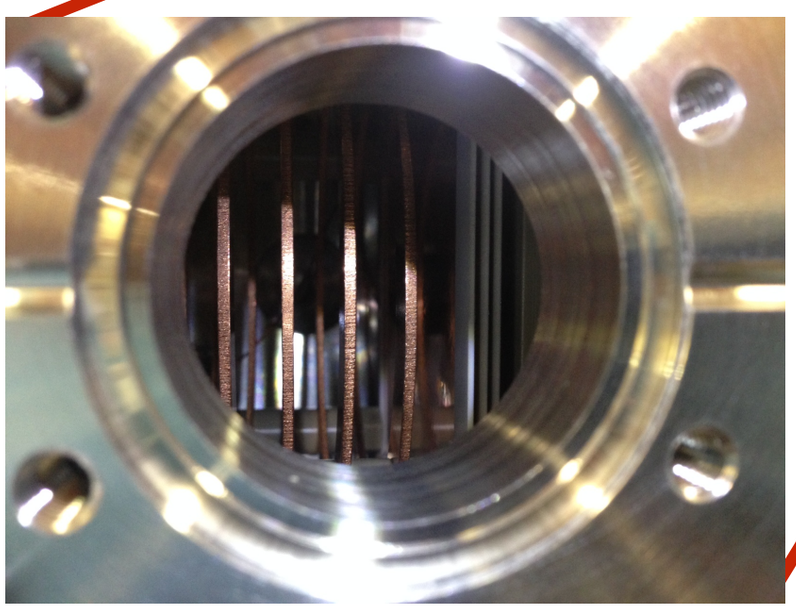


x-rays

Signal characteristics

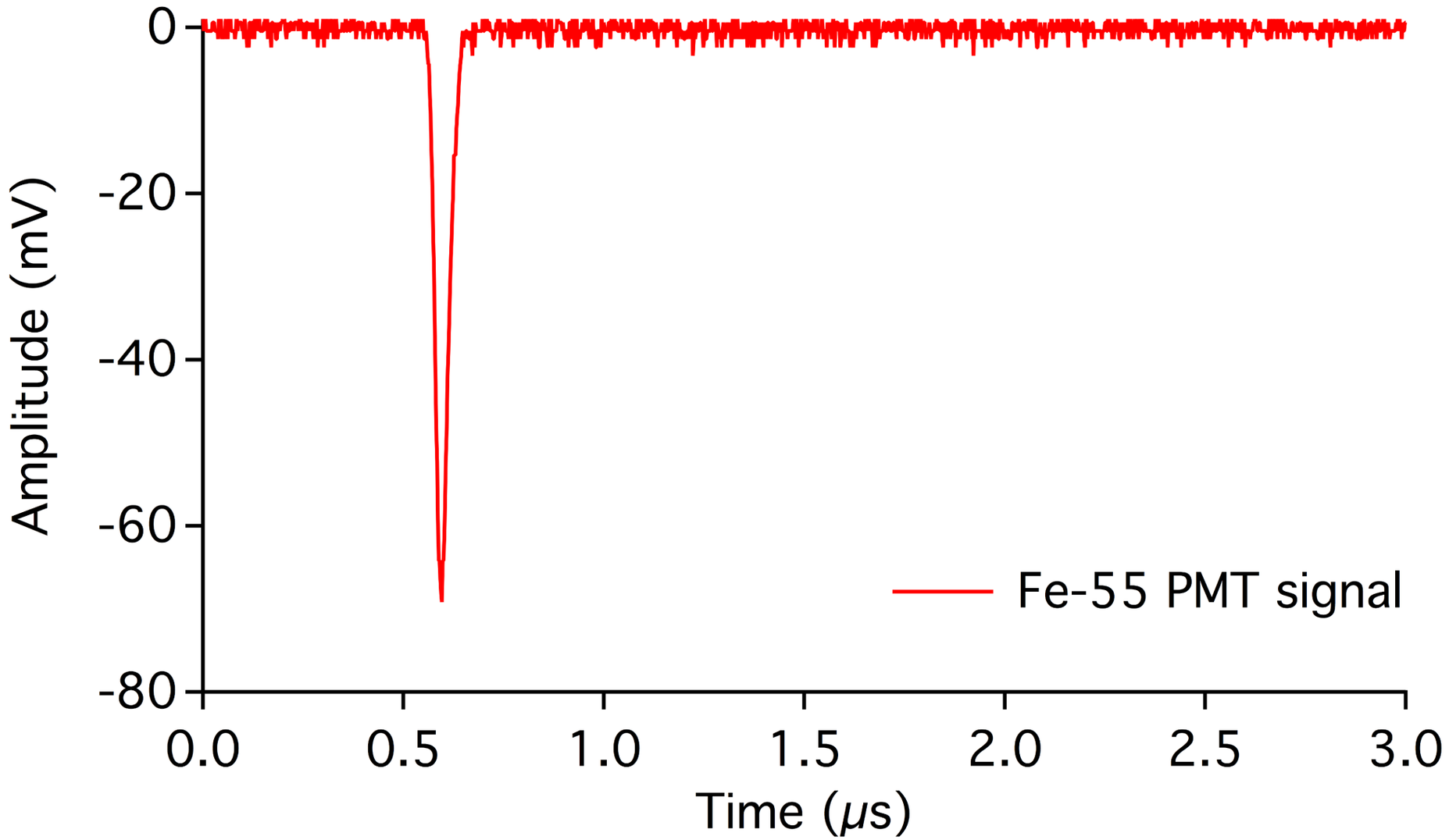
Setup x-rays





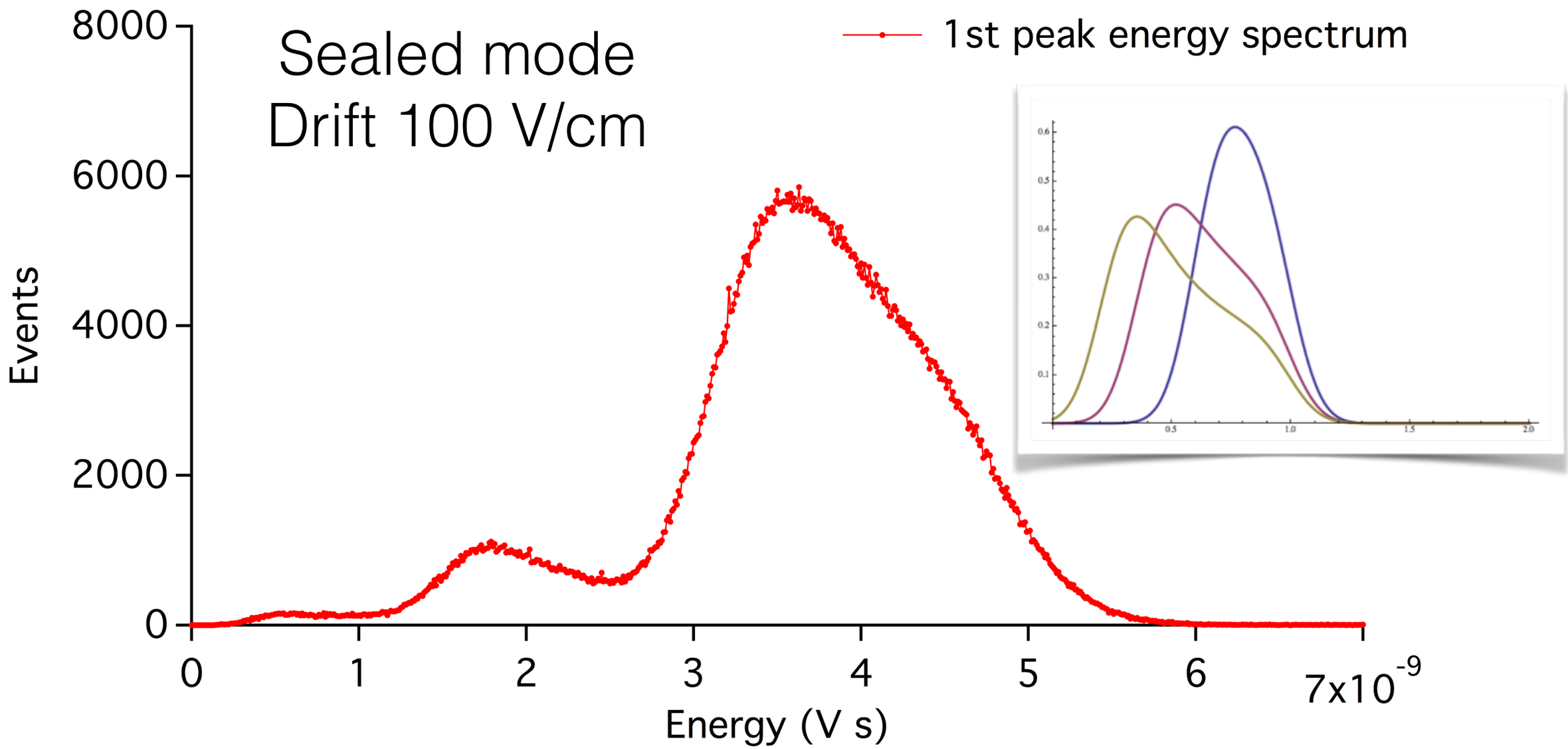
^{55}Fe source
(5.9 keV x-rays)

^{55}Fe signal



Secondary scintillation signal from PMT 2 (bottom of GEMs)

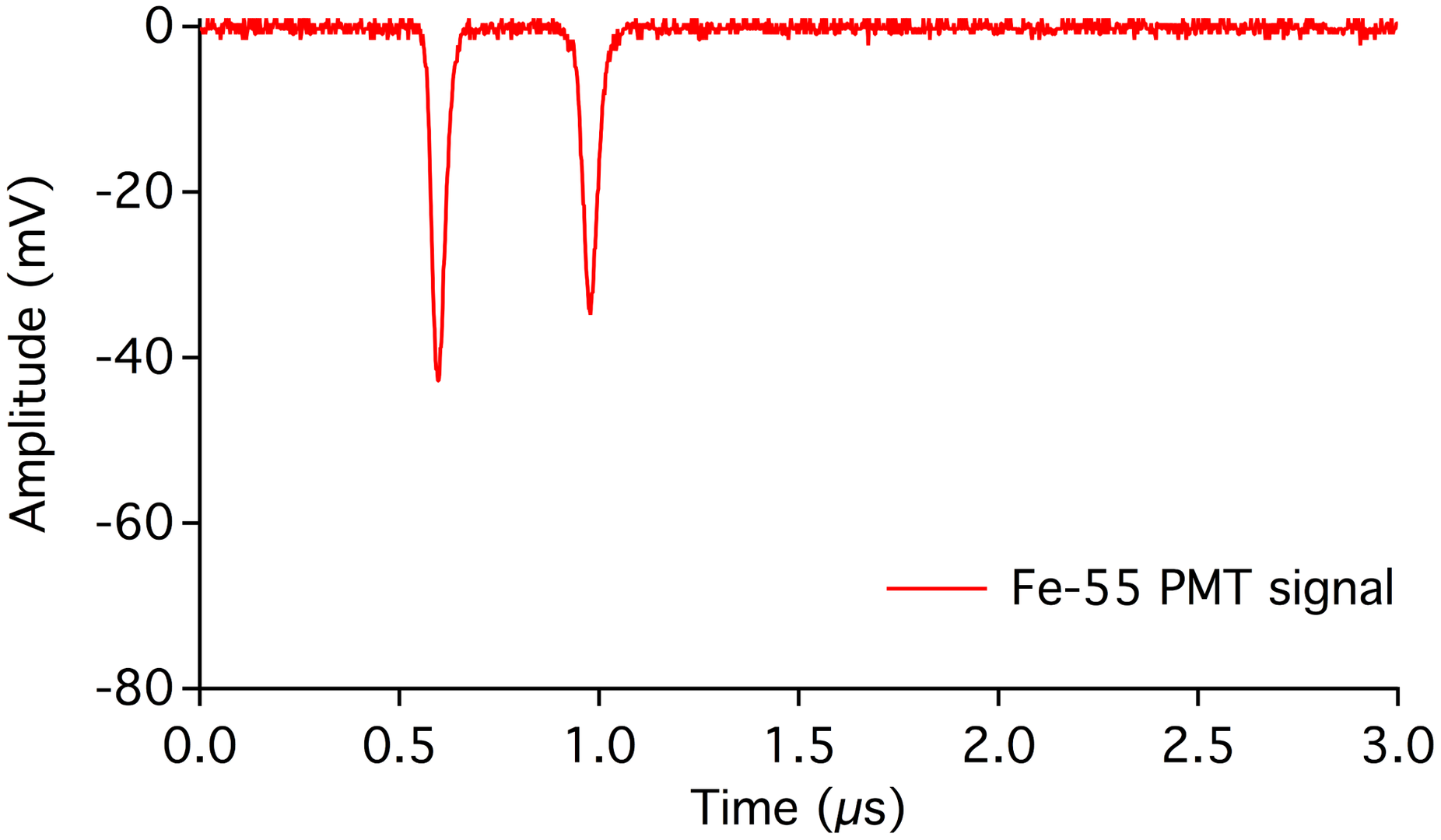
^{55}Fe spectrum



FWHM @ 5.9keV = 39%

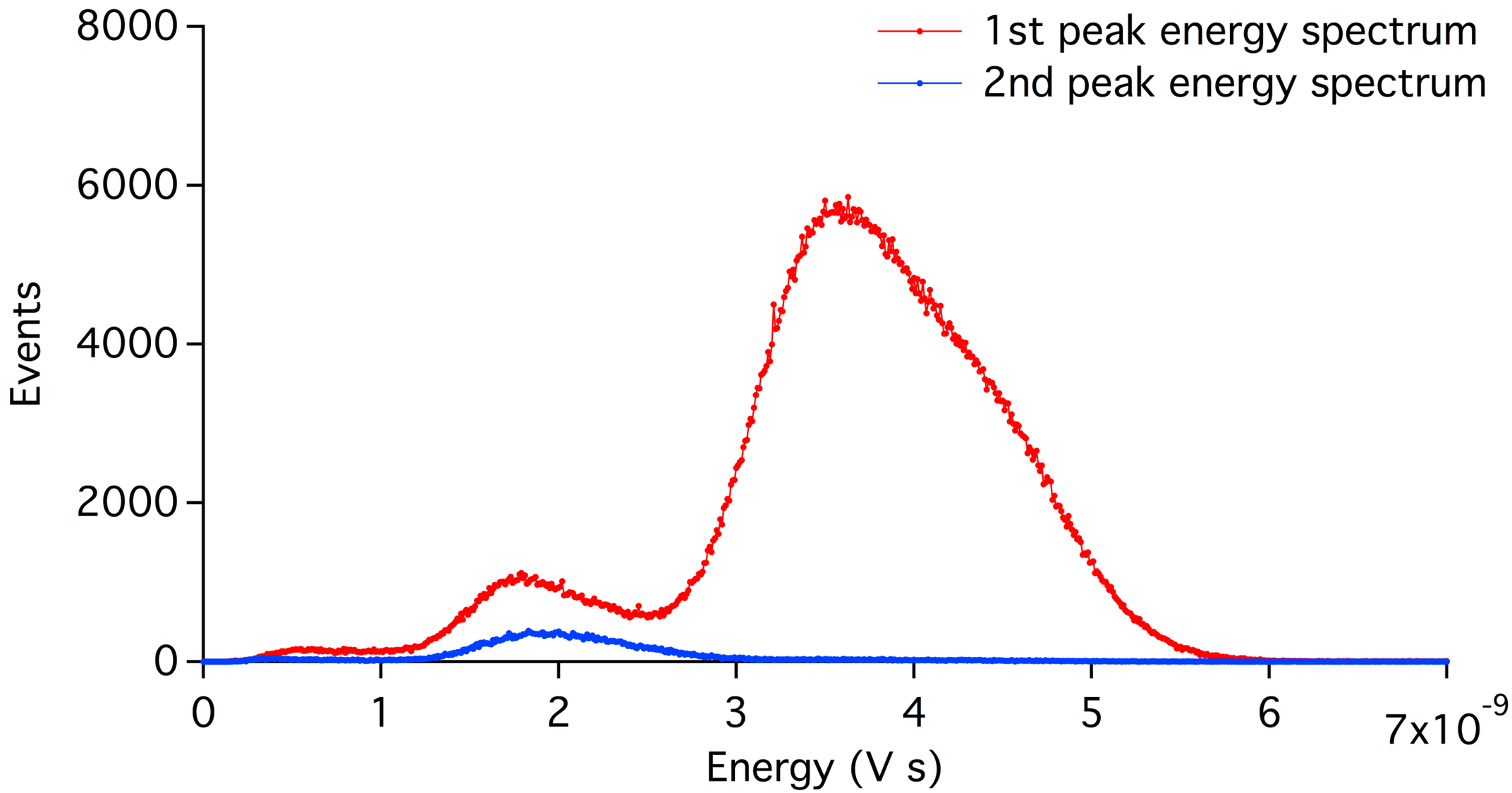
Escape peak amplitude 12% of amplitude of full energy peak

^{55}Fe signal



Secondary scintillation signal from PMT 2 (bottom of GEMs)

^{55}Fe spectrum



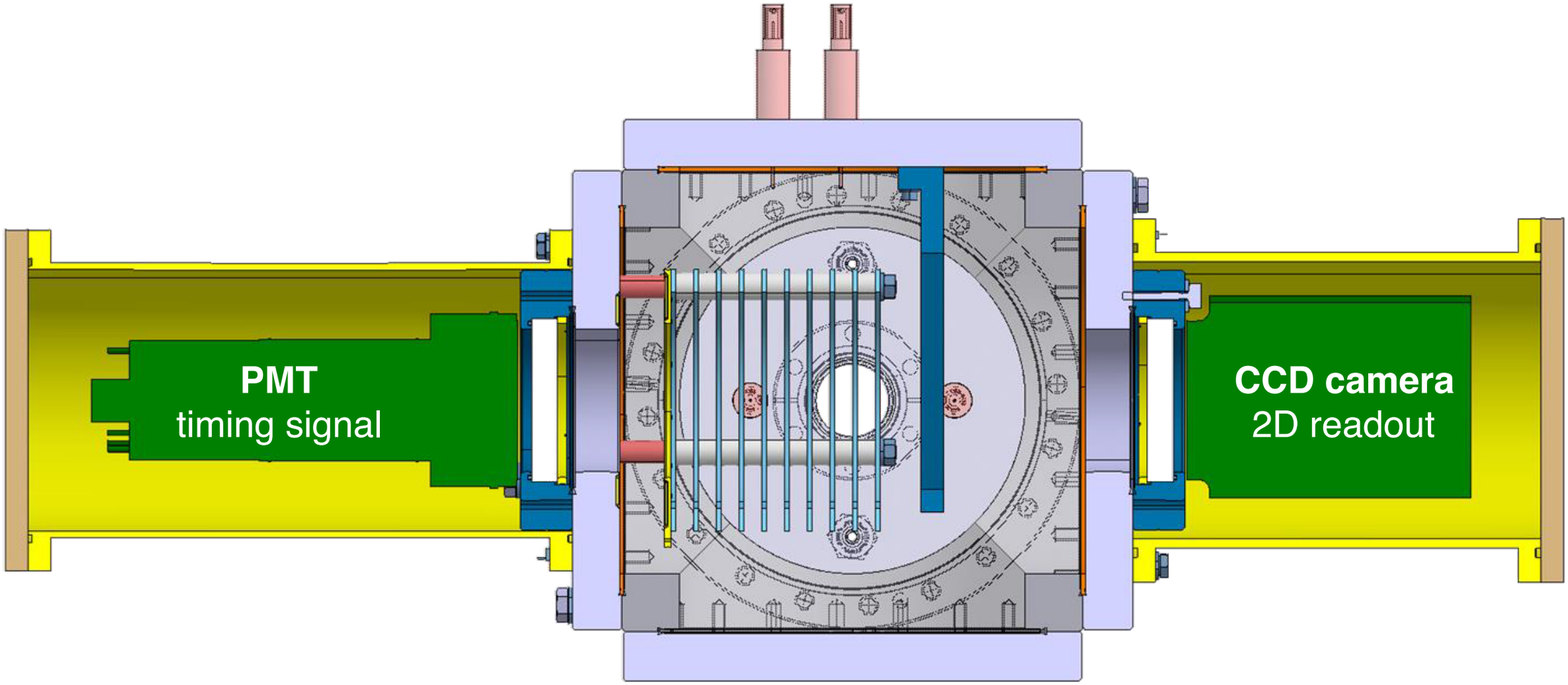
Re-emitted x-rays sometimes contained in drift volume

Summary

- Primary and secondary scintillation of α-tracks observed
- Ionisation profile visible in secondary scintillation
- Drift velocity scales approximately linearly with field

- ^{55}Fe spectra show gas impurity limited energy resolution
- Re-emitted 3 keV x-rays contained

Outlook



Outlook

High P

- Improved containment
- Enhanced primary scintillation

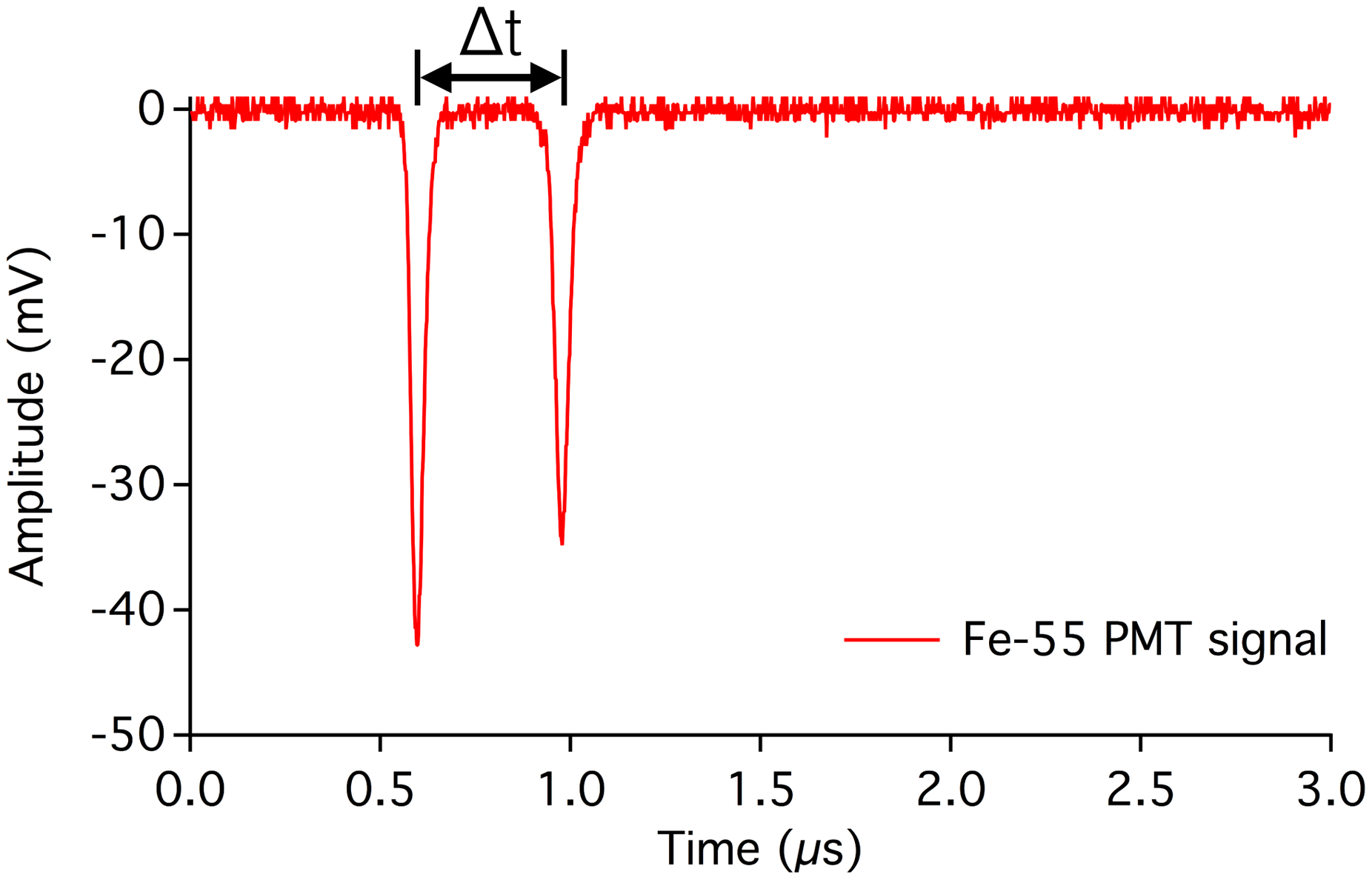
2D + 1D

- Event reconstruction from CCD image and PMT pulses

Gas

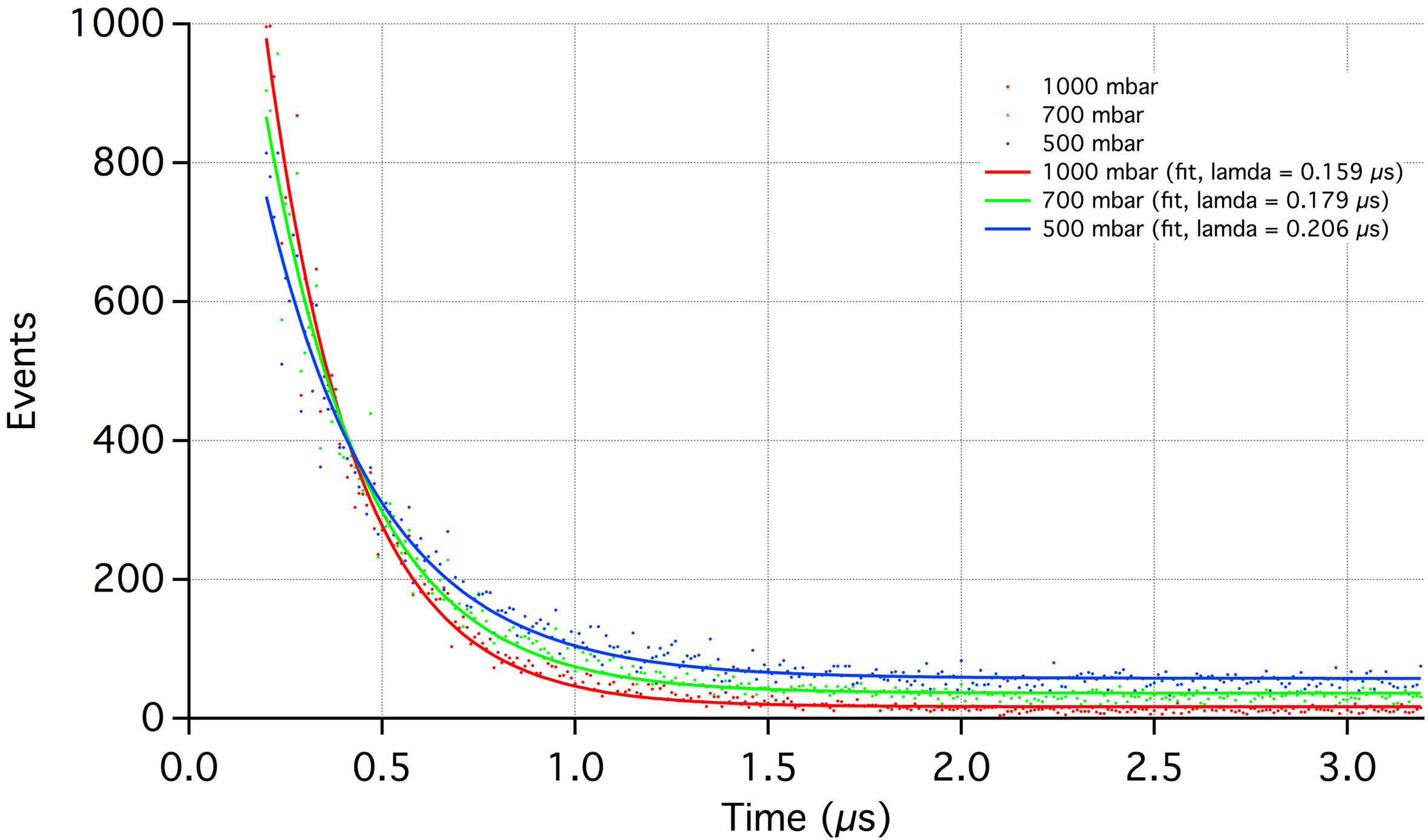
- Studying light yield of different gases and mixtures
- Scintillation in sealed mode

^{55}Fe signal



Secondary scintillation signal from PMT 2 (bottom of GEMs)

^{55}Fe signal


1000
800
600
400
200
0
Events
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time (μs)
1000 mbar
700 mbar
500 mbar
1000 mbar (fit, lamda = 0.159 μs)
700 mbar (fit, lamda = 0.179 μs)
500 mbar (fit, lamda = 0.206 μs)