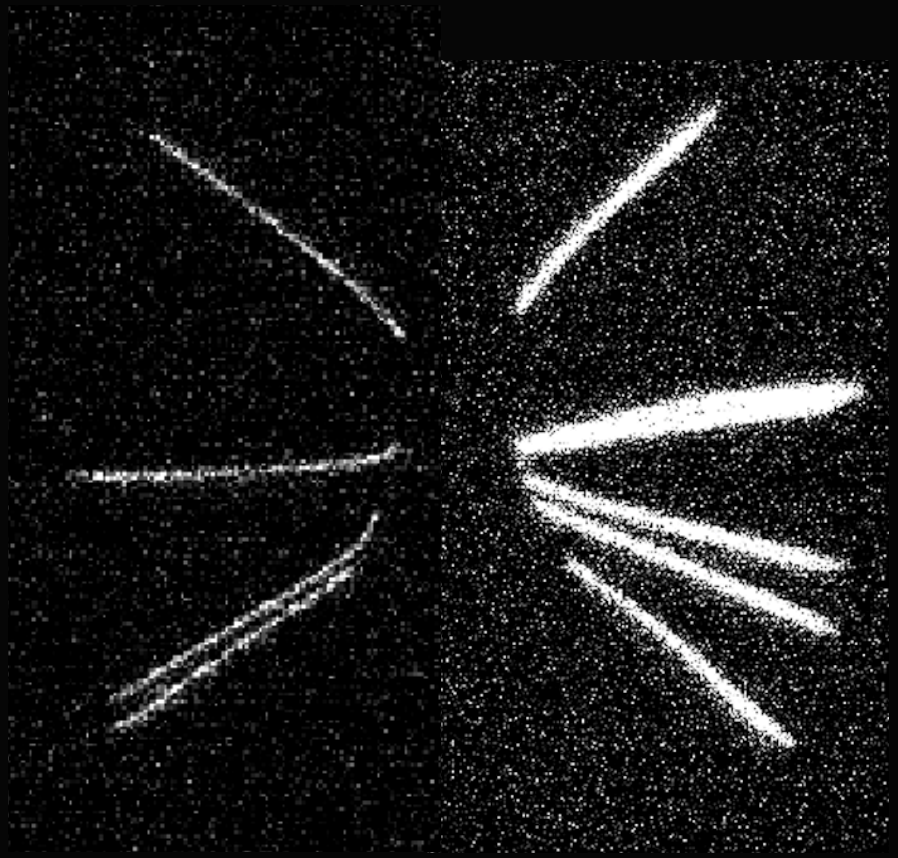
# INITIUM: an Innovative Negative Ion TIme projection chamber for Underground dark Matter searches



Many thanks to L. Passamonti, R. Tesauro and all the Technitians for their help!

.....it could really work??? (cit.)

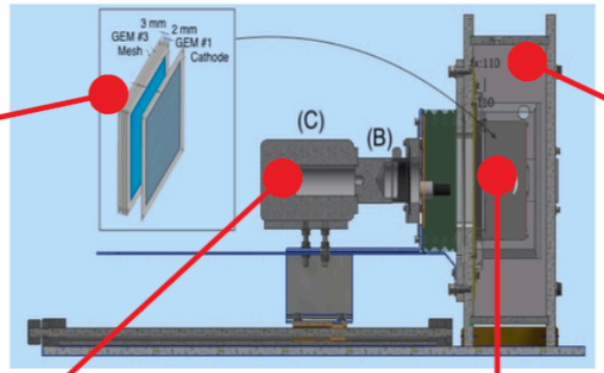
**The GSSI CYGNO group**

E. Baracchini, G. Dho, F. Di Giambattista, D. Marques, A. Prajapati, S. Torelli

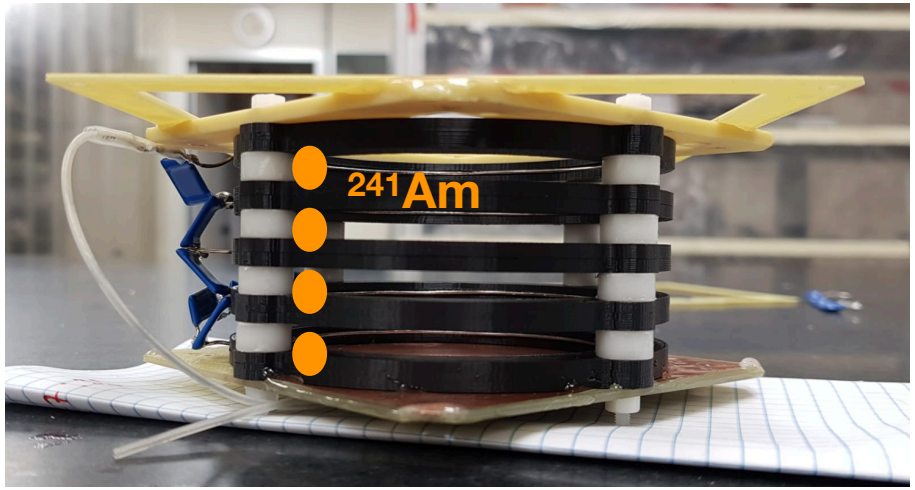
European Research Council
Established by the European Commission

# MANGO with field cage & $^{241}$Am source

GEMs:




Plastic gas-tight box




sCMOS Camera
Orca fusion C14440

2304x2304 pixels

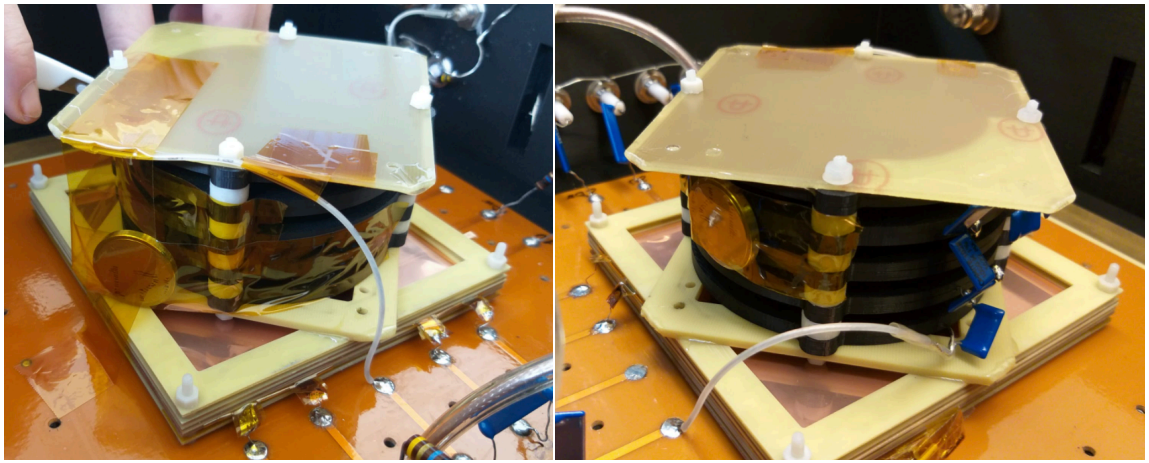
noise <1 ph/pixel

TPC volume:

Max volume 500 cm$^3$
(10x10 cm$^2$) area

He:$CF_4$ mixture 60/40

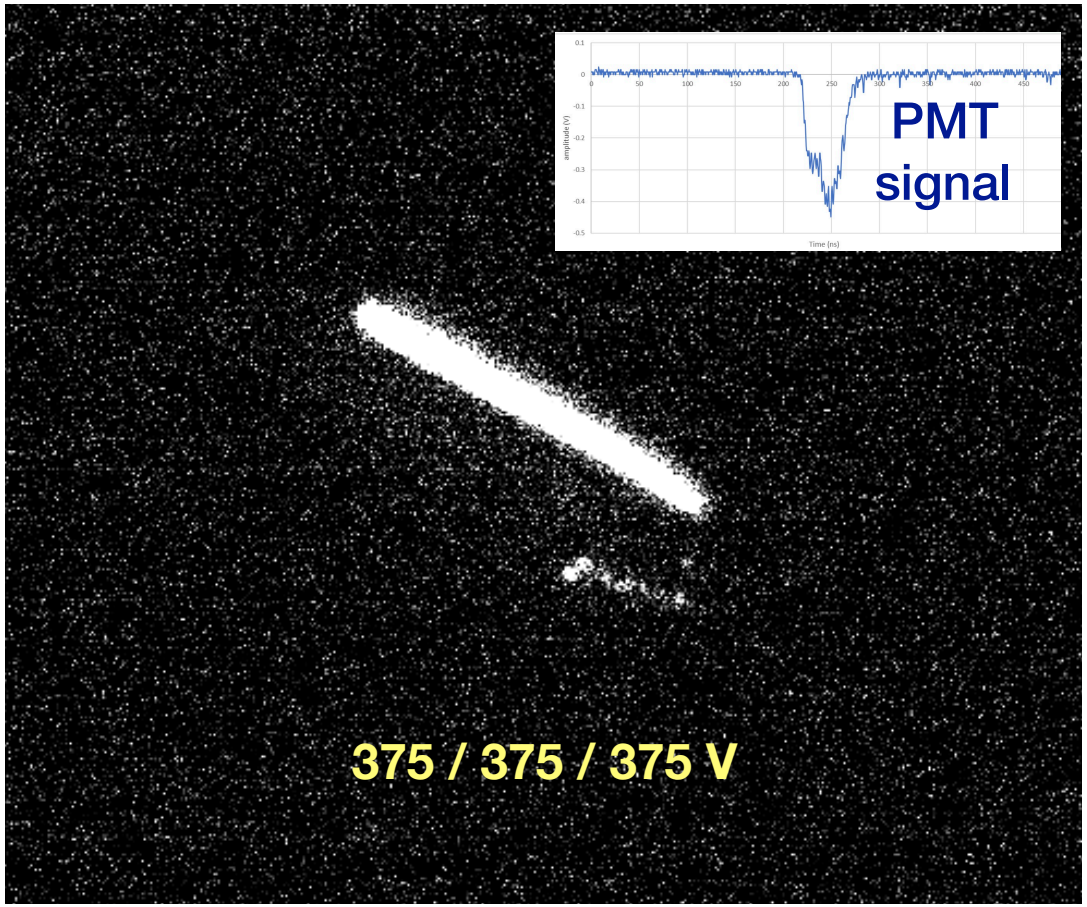
Atmosferic pressure



**Source distance from field cage varied depending on dinstance: track length cut varied accordingly (see later)**

# A first qualitative look by eye…

Electron drift (ED)




$He:CF_4$
60:40
1 kV/cm

0.88 atm

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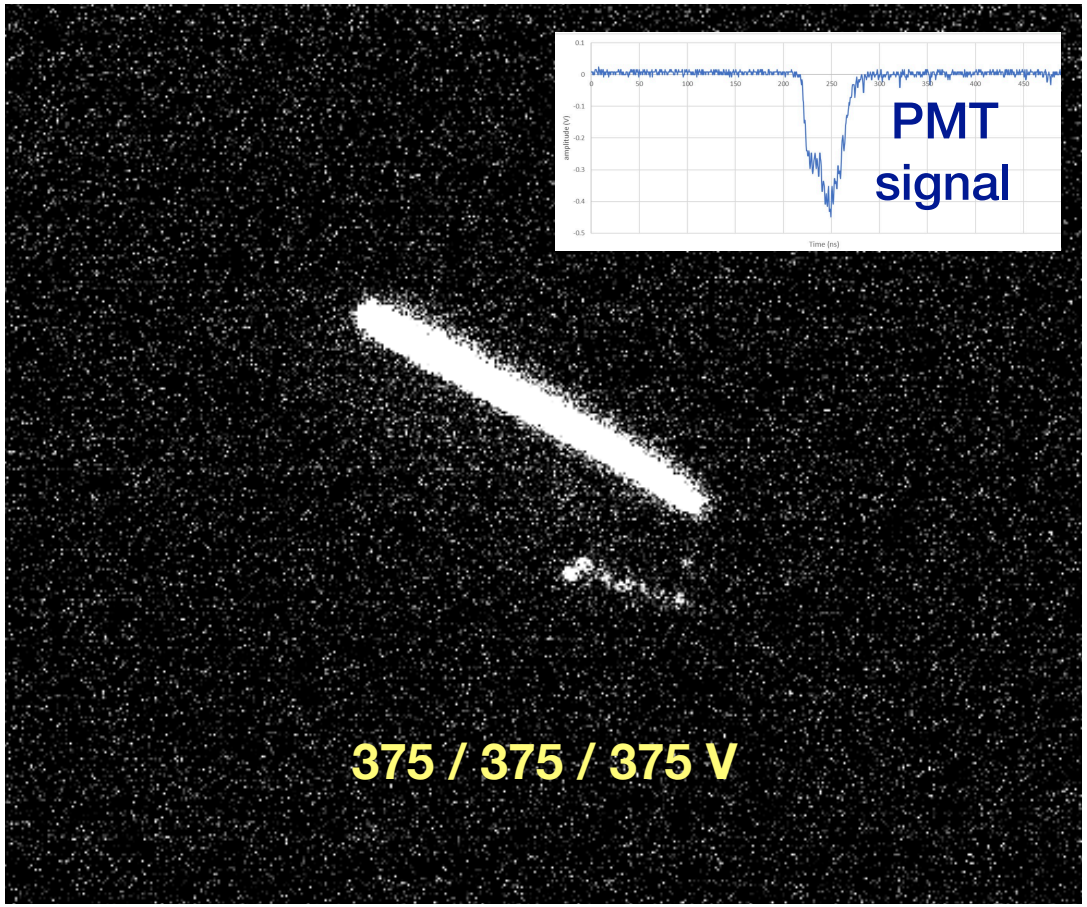
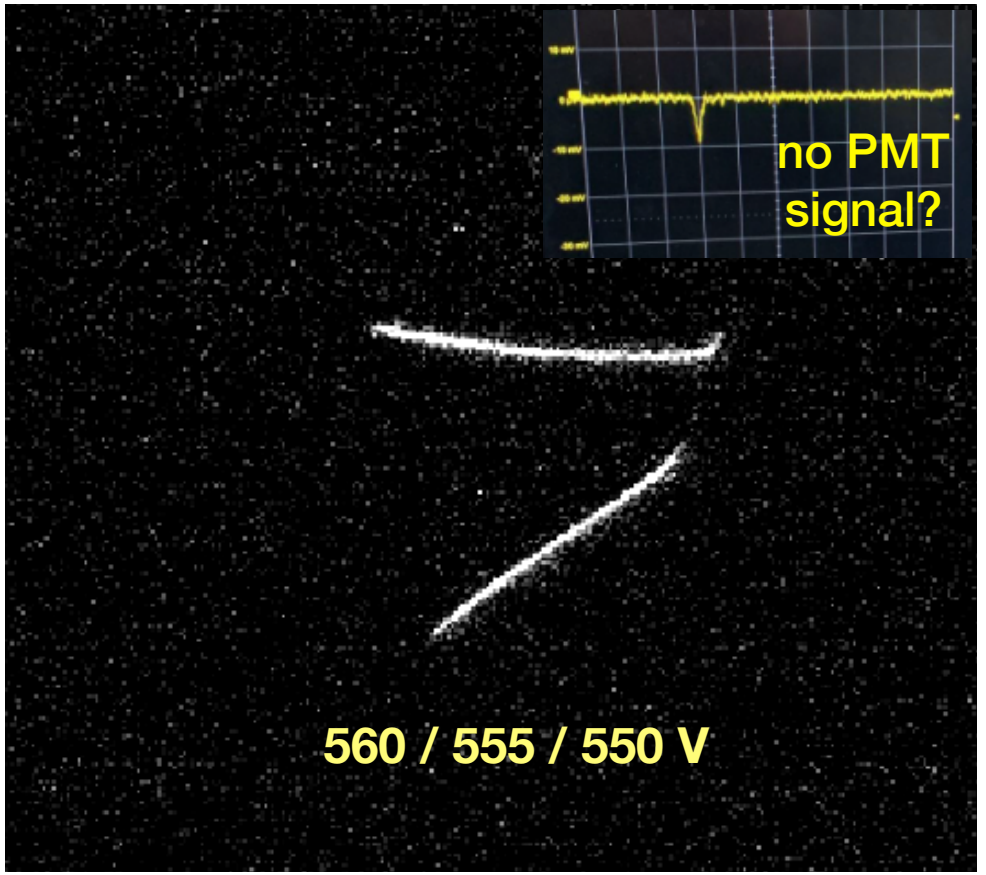
## Electron drift (ED)




$He:CF_4$
60:40
1 kV/cm

## Negative ion drift (NID)?



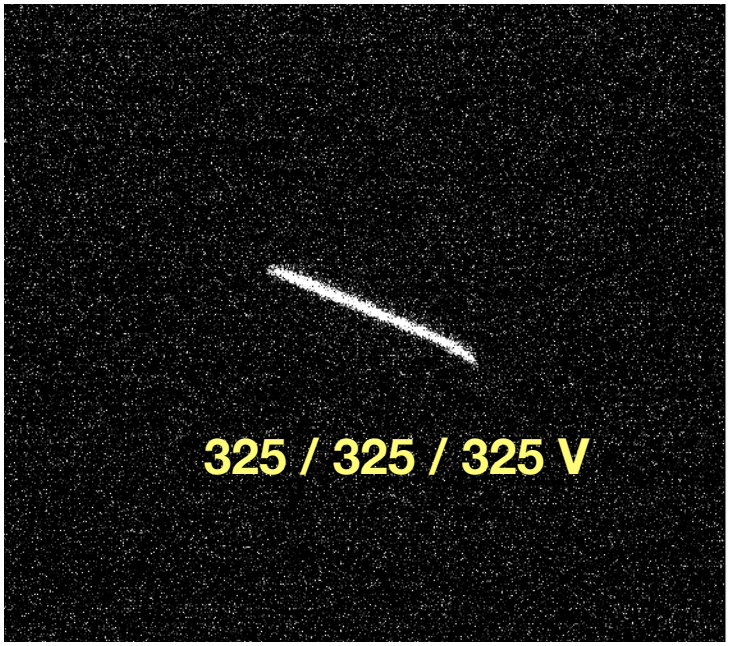

$He:CF_4:SF_6$
59:39.4:1.6
0.4 kV/cm

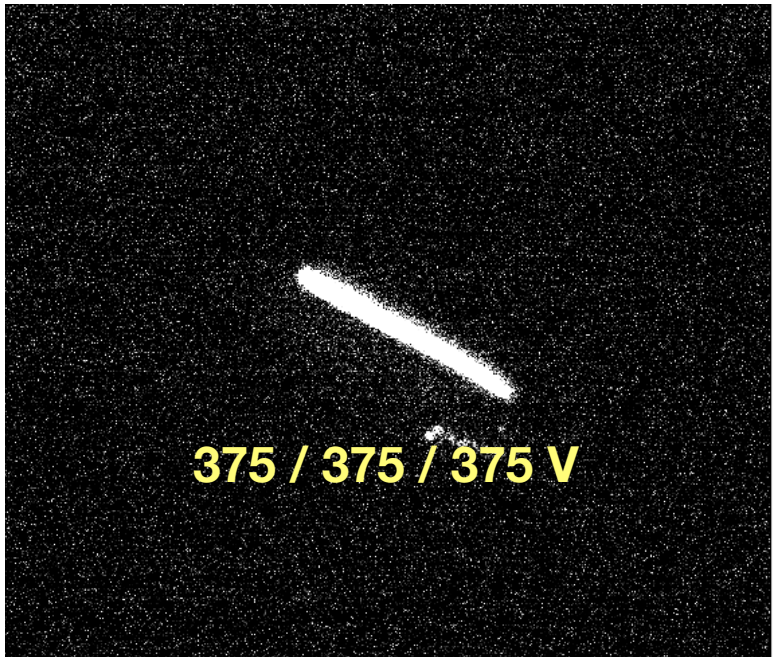
**0.88 atm**

Same mixture as published data with NITEC
at 0.8 atm (JINST 13(2018) 04, P04022)

# Qualitatively: diffusion depends on gain?

$He:CF_4$
60:40
1 kV/cm

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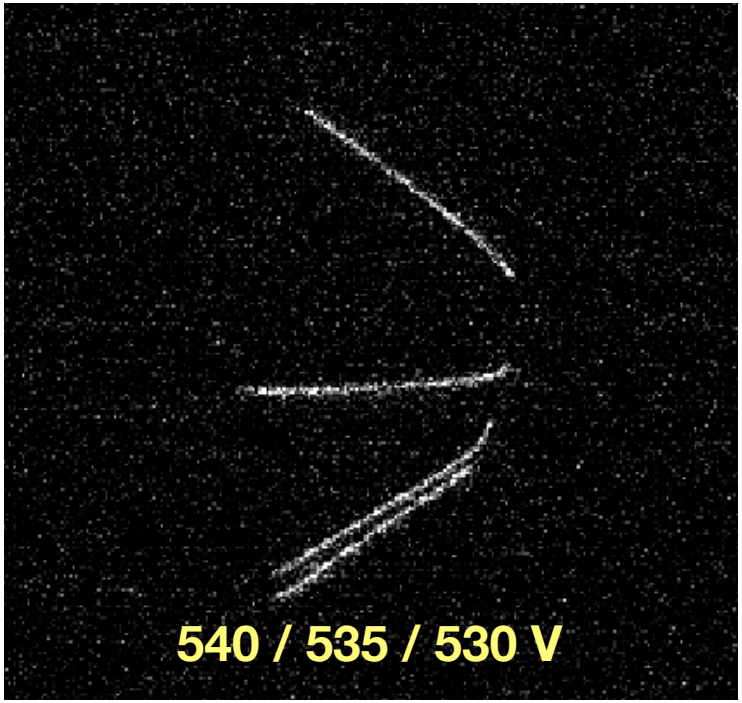


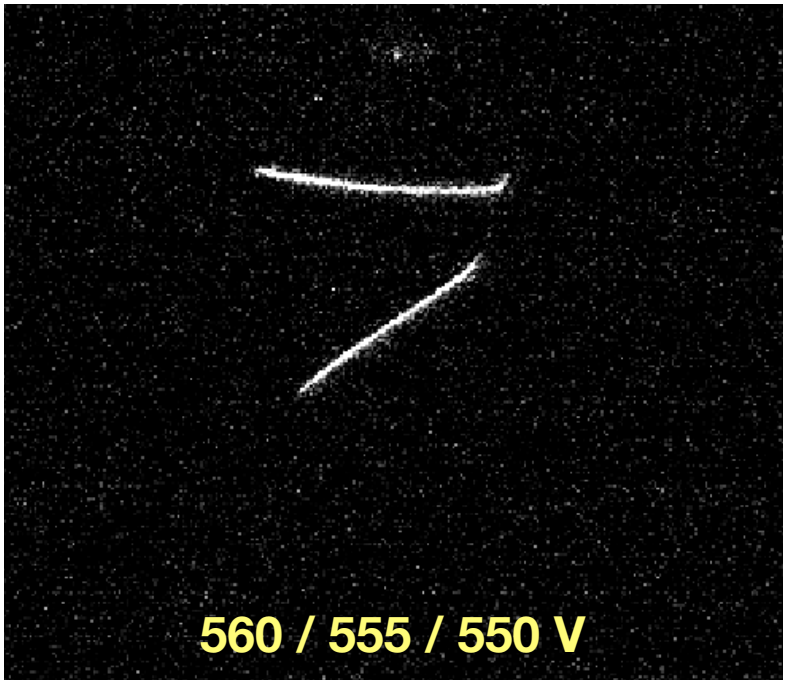

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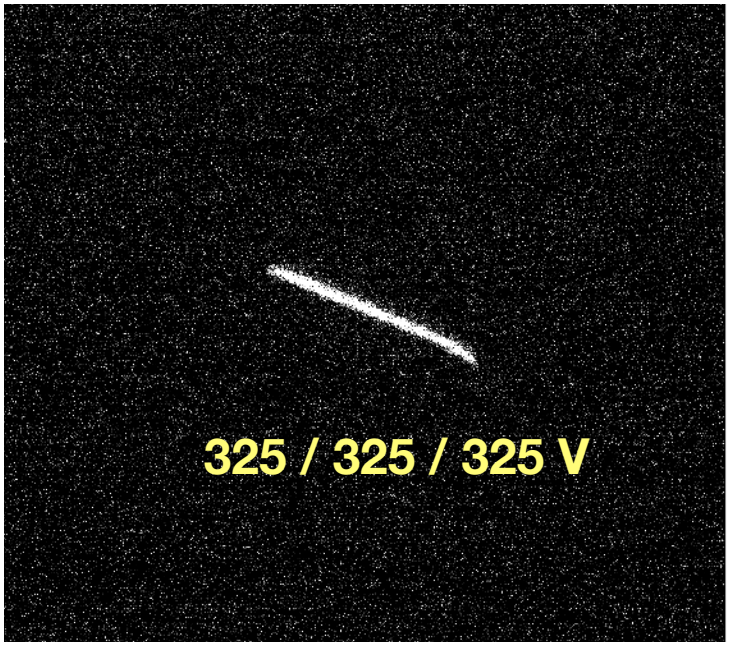
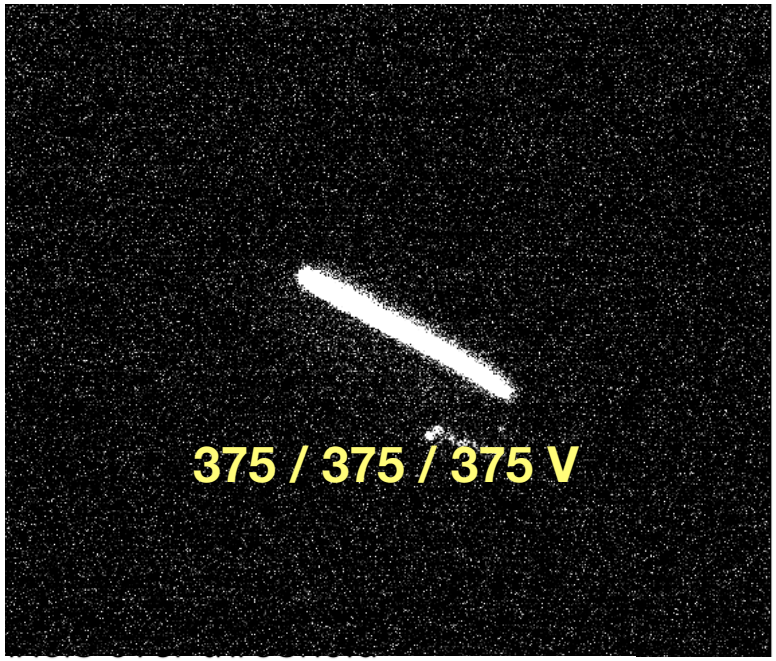
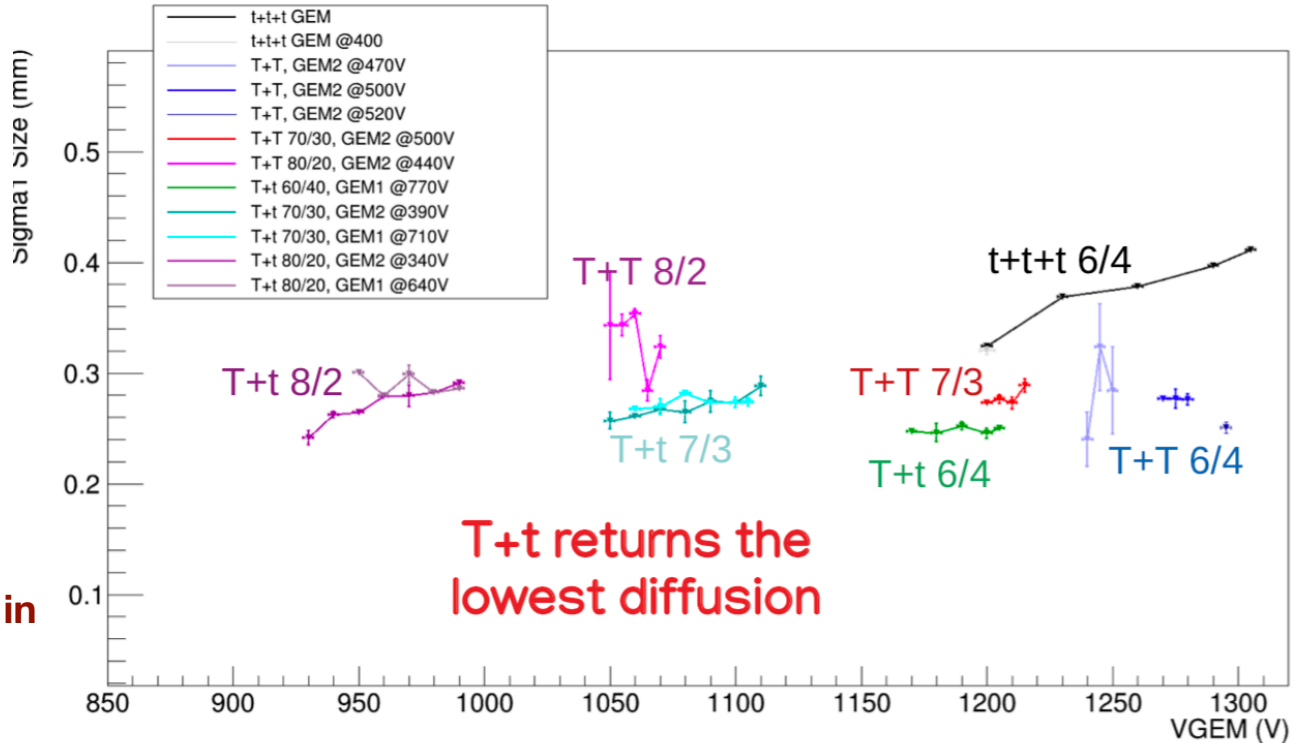


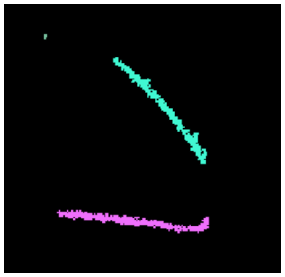

From Giorgio's studies on $^{55}Fe$ spot size of diffusion inside GEMs
± 1 um/V

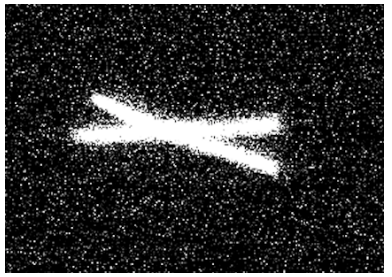
**Why? Charge modify field lines in GEMs gaps?**

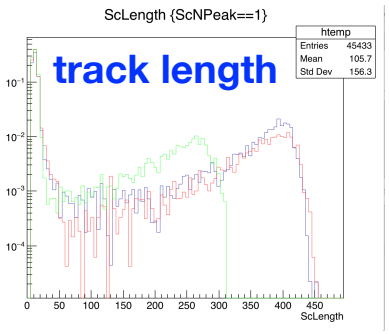


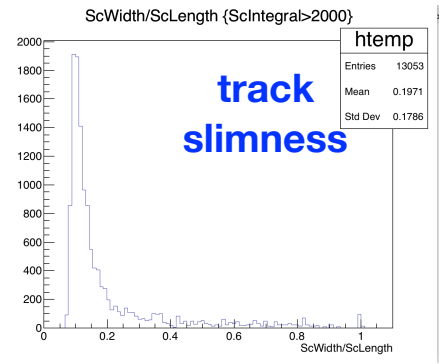
# Analysis strategy

- Track reconstructed with autumn2021 code
- Fit reconstructed tracks transverse profile (Flaminia's algorithm)
- Tracks selection:
  - track length > 150 (300) pixels (depending on source position)
  - track slimness < 0.3
  - # of peaks in the transverse profile == 1 (select single tracks)
  - Chi2/nDOF of transverse fit profile < 5 (remove additional multiple tracks)
- Sigma of track profile and track integral fitted with Gaussian to estimate diffusion and gain

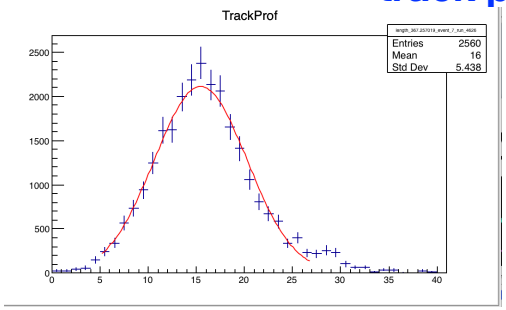


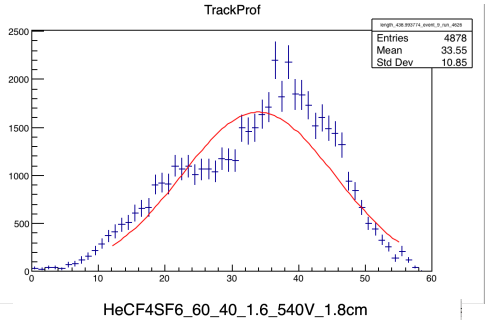


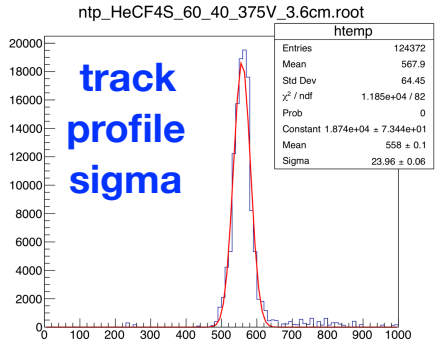


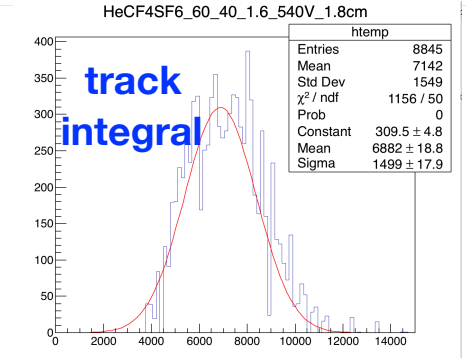




track profile



# Gain studies

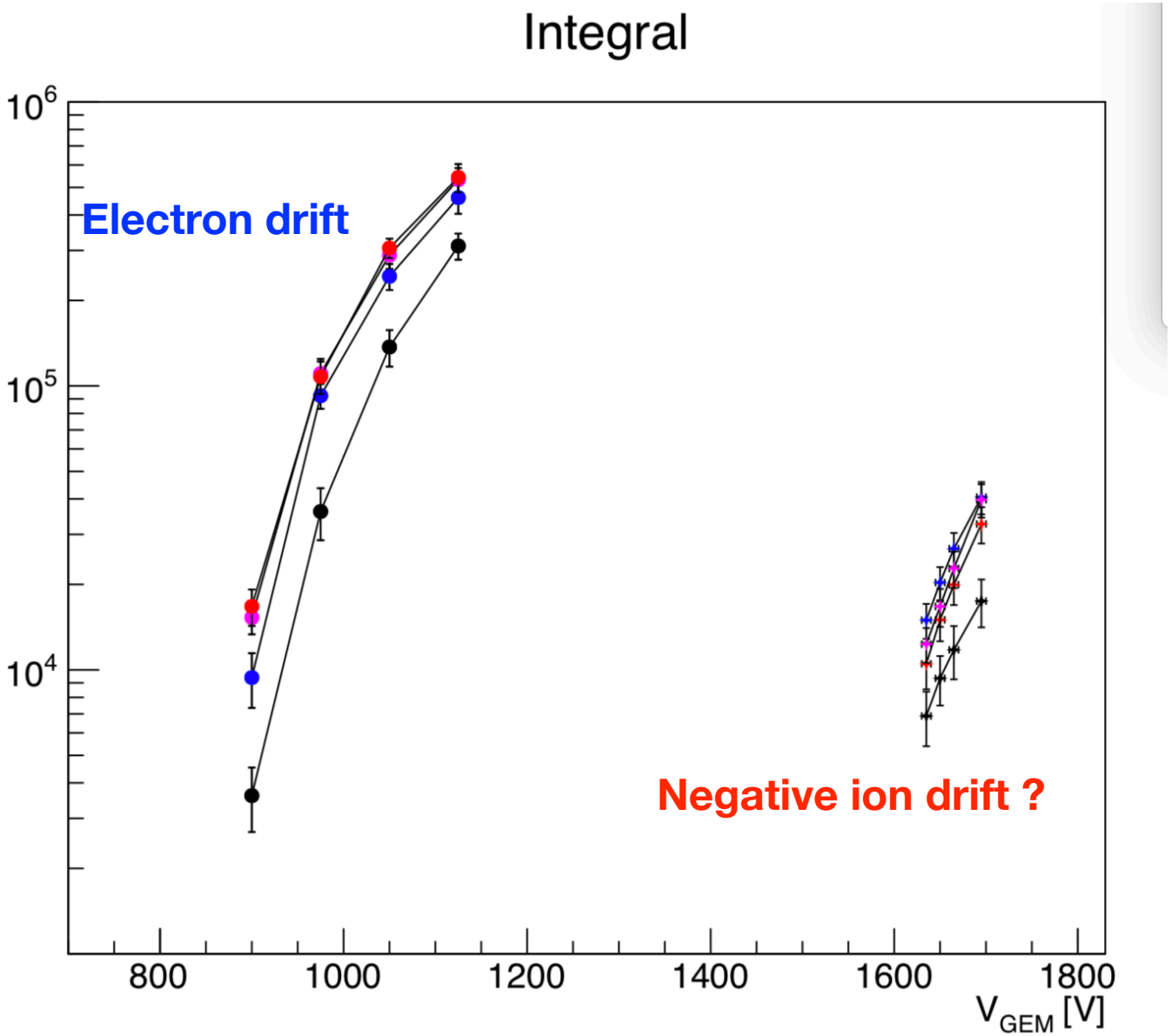
**N. B. 1.35 cm source position was considearbly further than the others, hence the lowest overall integral**

**1.35 cm**

**2.25 cm**

**3.15 cm**

**4.05 cm**



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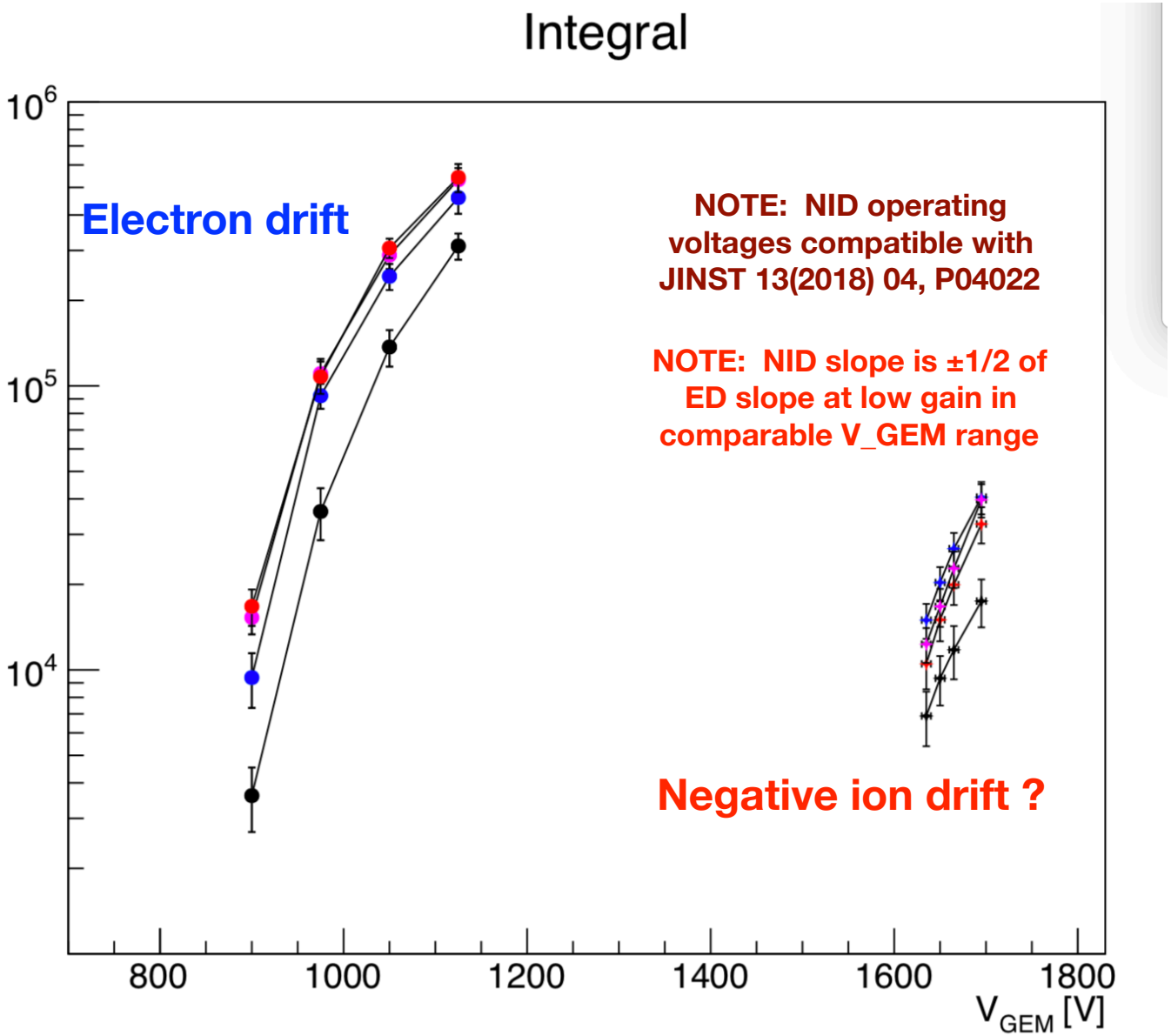
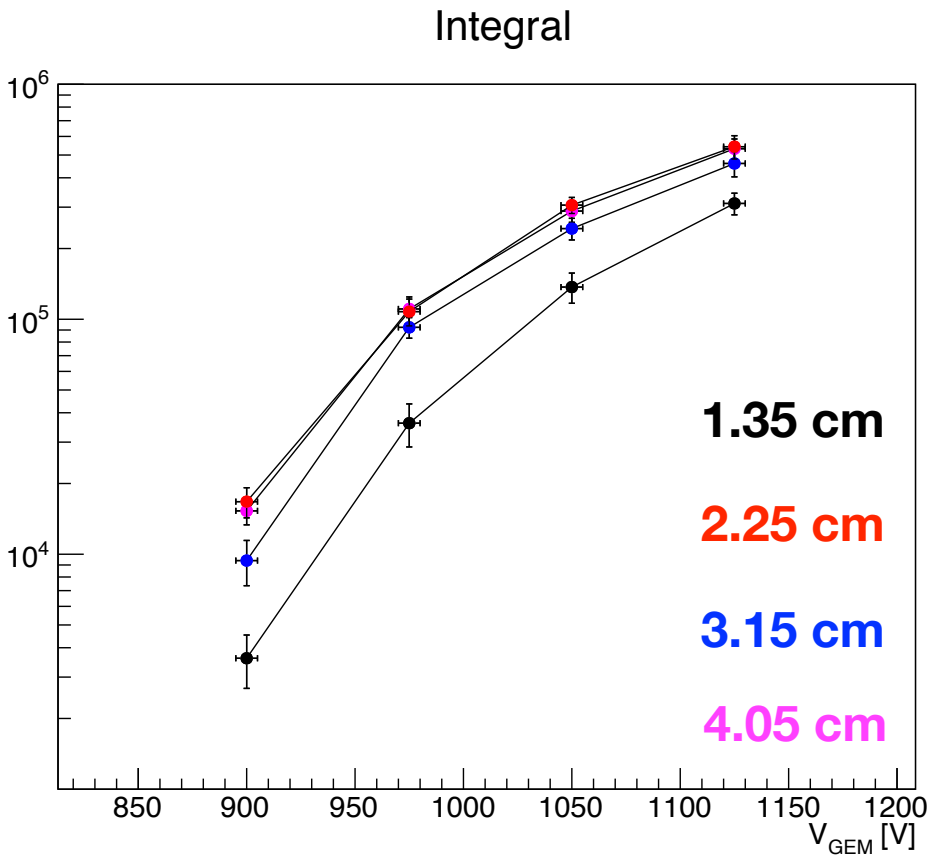
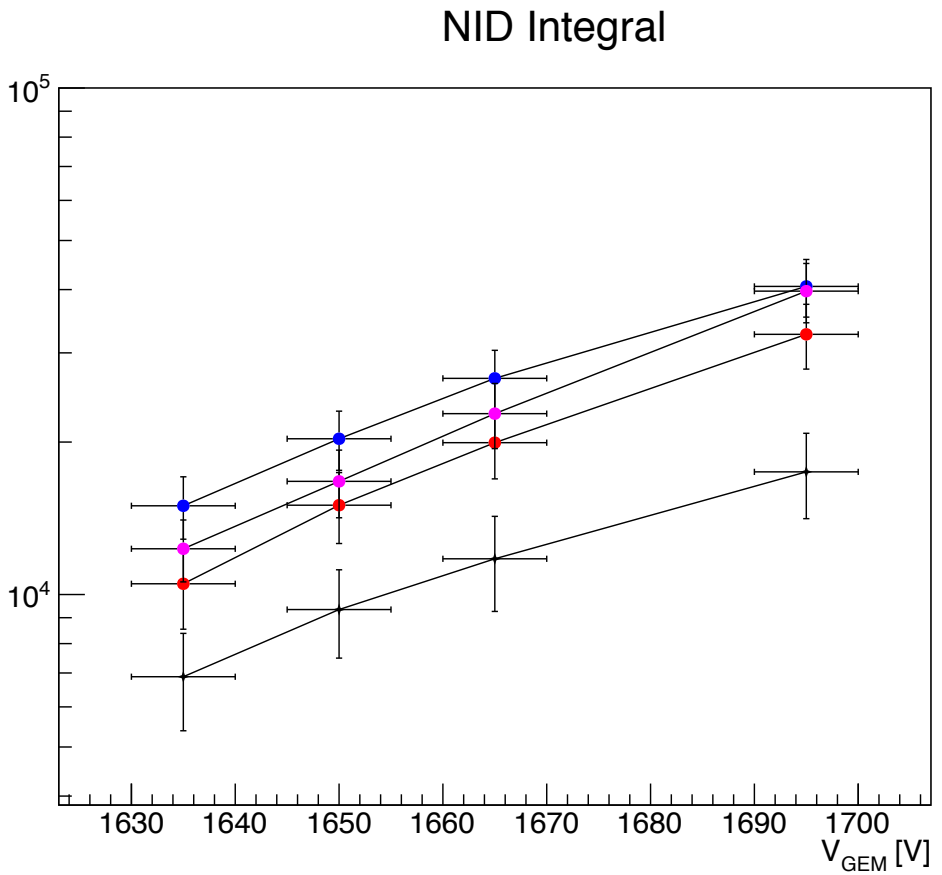


**N. B. 1.35 cm source position was considearbly further than the others, hence the lowest overall integral**

# Gain studies: zoom in



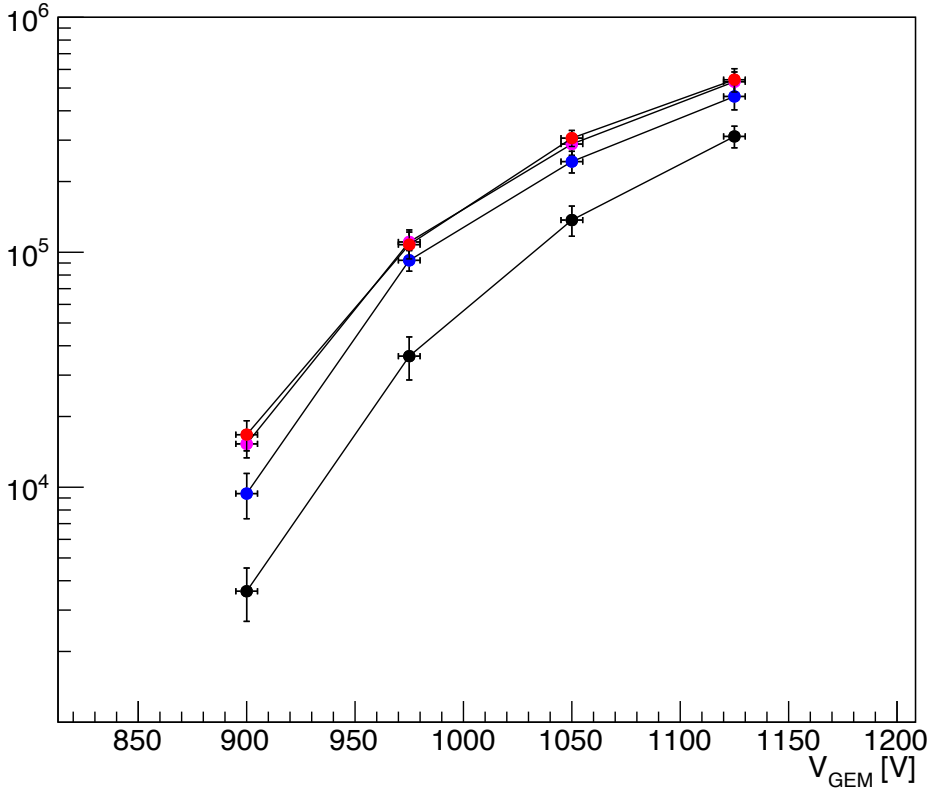

**Electron drift clearly shows saturation**

**Negative ion drift (?) shows gain consistent with exponential behaviour**

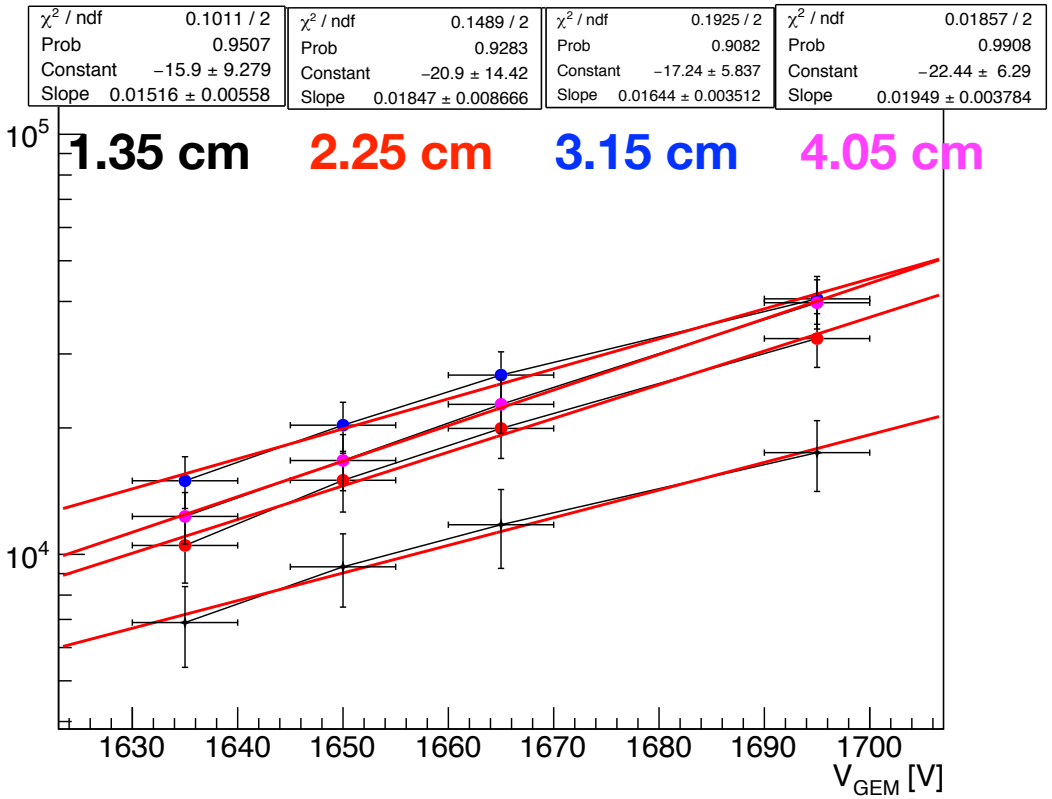
**N. B. 1.35 cm source position was considearbly further than the others, hence the lowest overall integral**

# Gain studies: zoom in

Integral



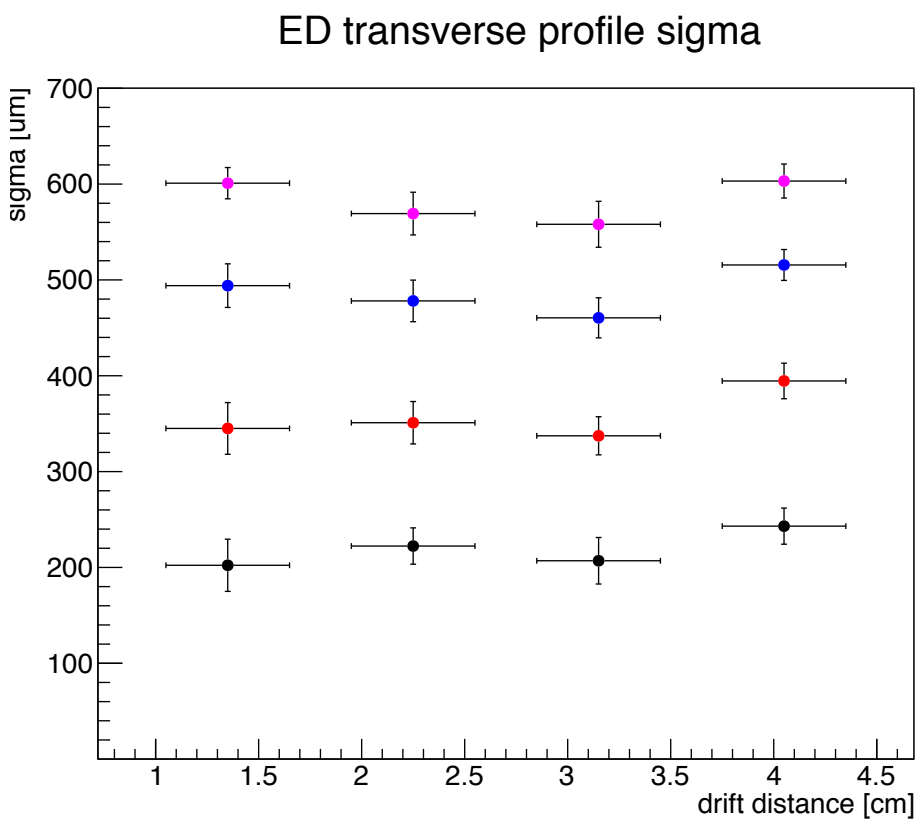

NID Integral



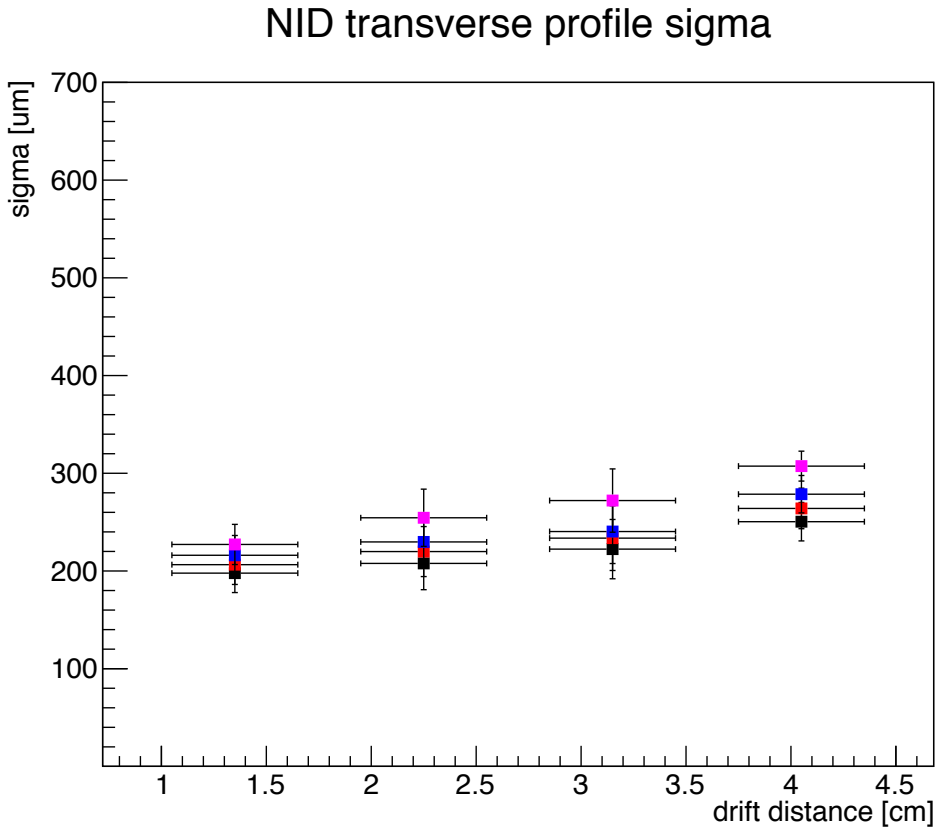

**Electron drift clearly shows saturation**

**Negative ion drift (?) shows gain consistent with exponential behaviour**

# Diffusion studies




900 V 975 V 1050 V 1125 V

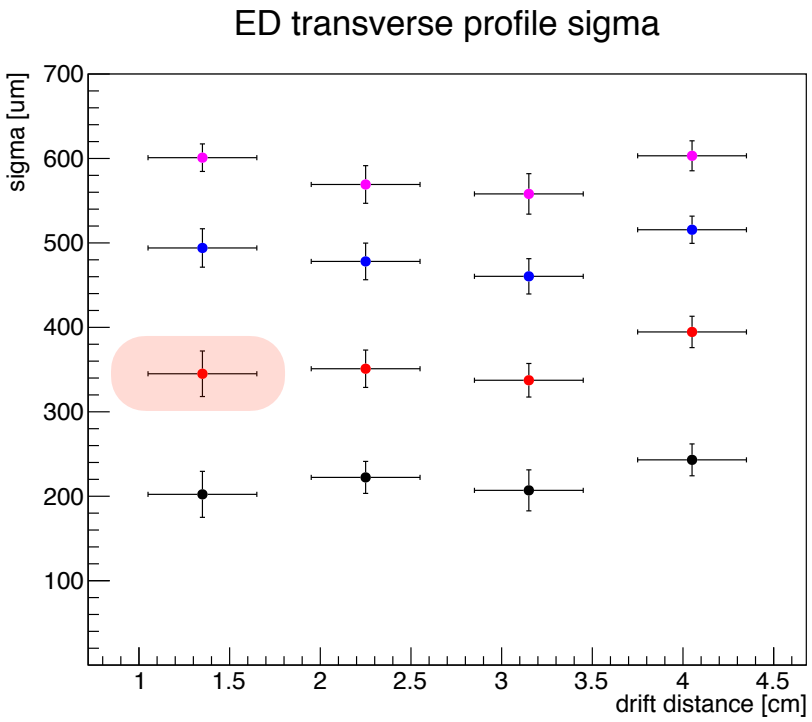


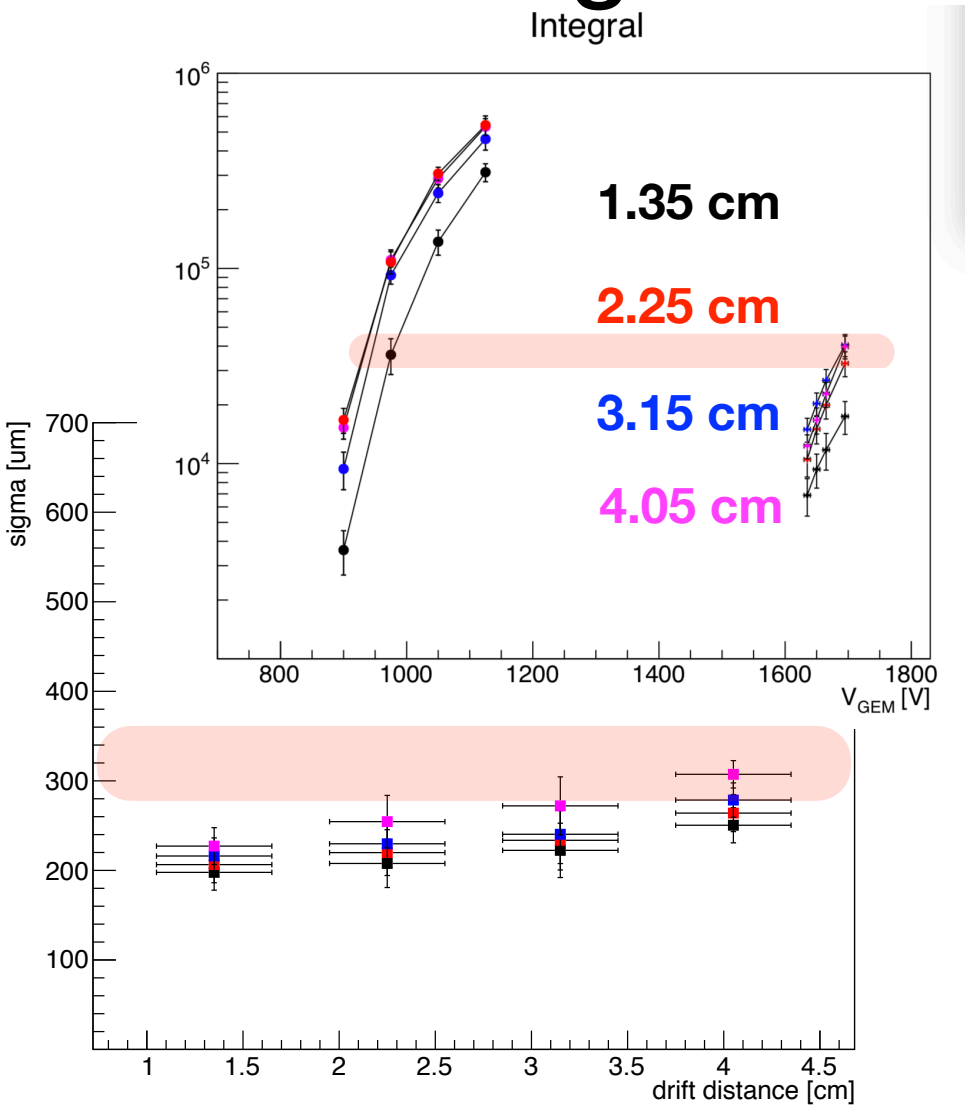

1605 V 1620 V 1635 V 1665 V

**Nearly instensitive to diffusion as a function of distance because dominated by difusion between GEMs**

# Diffusion studies: it is a matter of gain?

**Nearly instensitive to diffusion as a function of distance because dominated by difusion between GEMs**



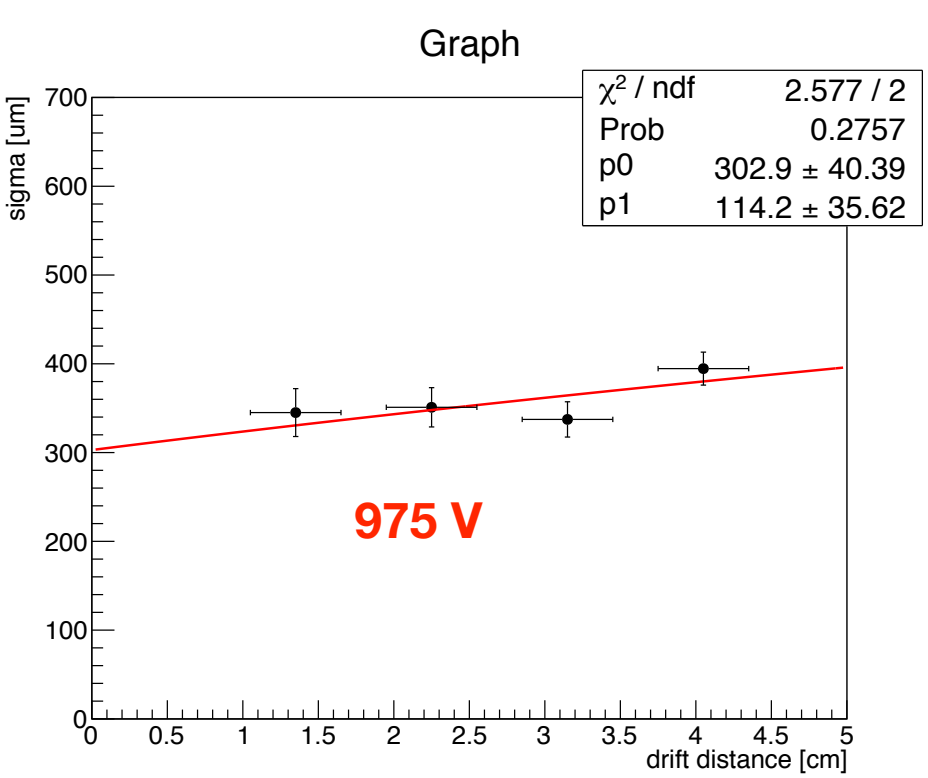

**900 V** **975 V** **1050 V** **1125 V**

**1605 V** **1620 V** **1635 V** **1665 V**

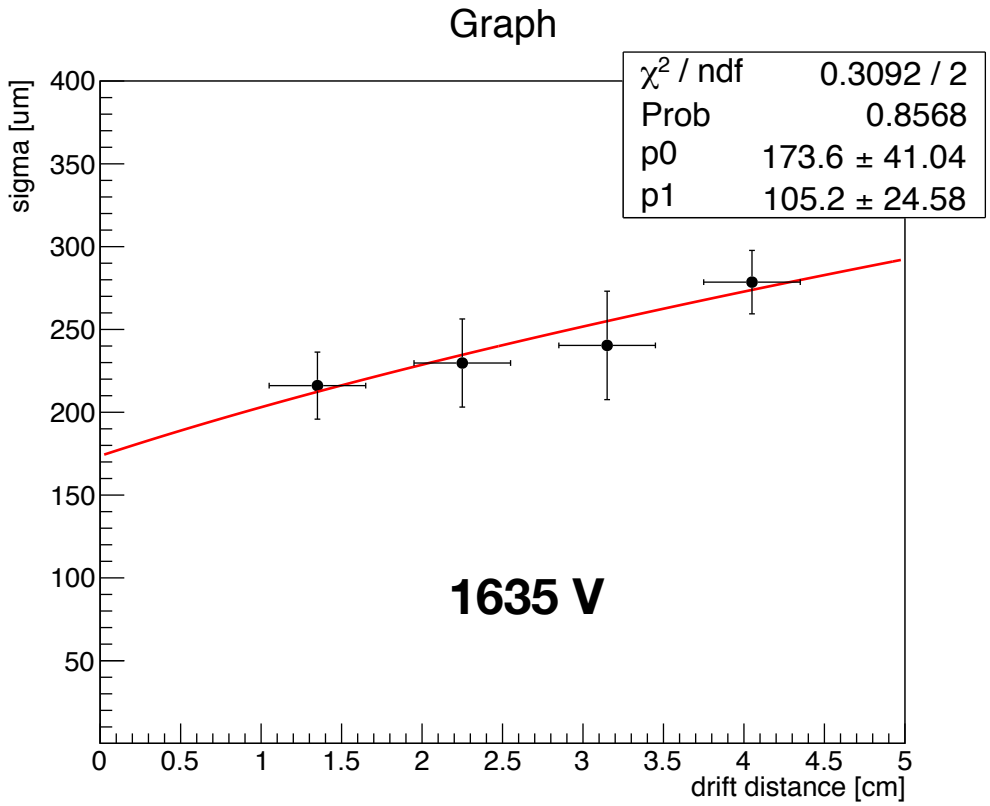
**975 V @ 1.3 cm gain compatible with 1665 V gain at 2.25, 3.15 and 4.05 cm**

# Diffusion coefficient (sigma_T) and constant term between GEMs (sigma_0)

**Electron drift**




**Negative ion drift ?**



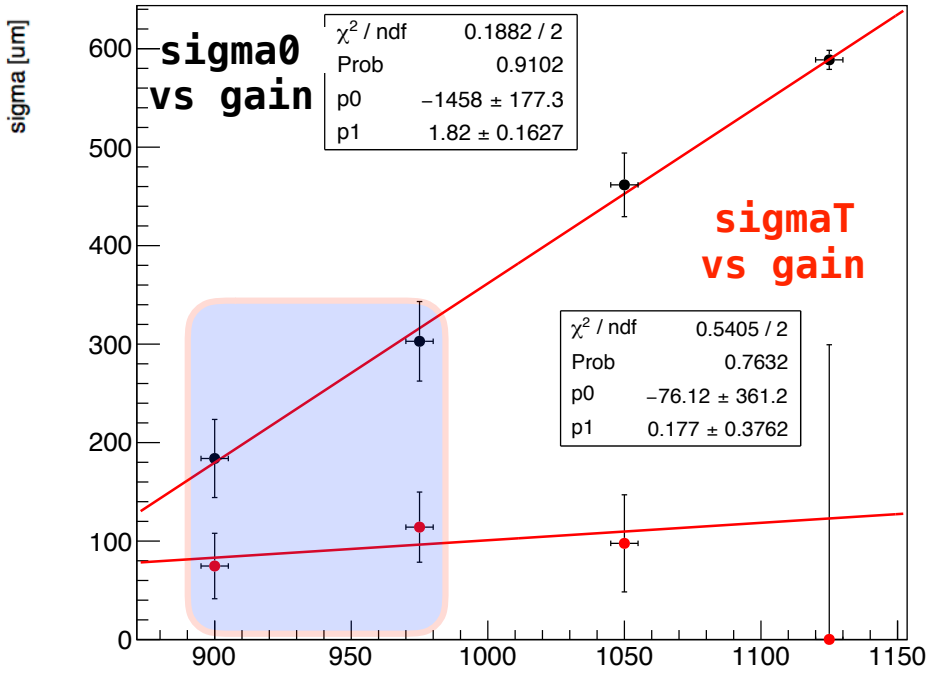

```
TMath::Sqrt(sigma_0^2 + sigma_T^2*x)
```

**Dominated by diffusion as a function of gain between GEMs?**
**..still showing different behaviours…**

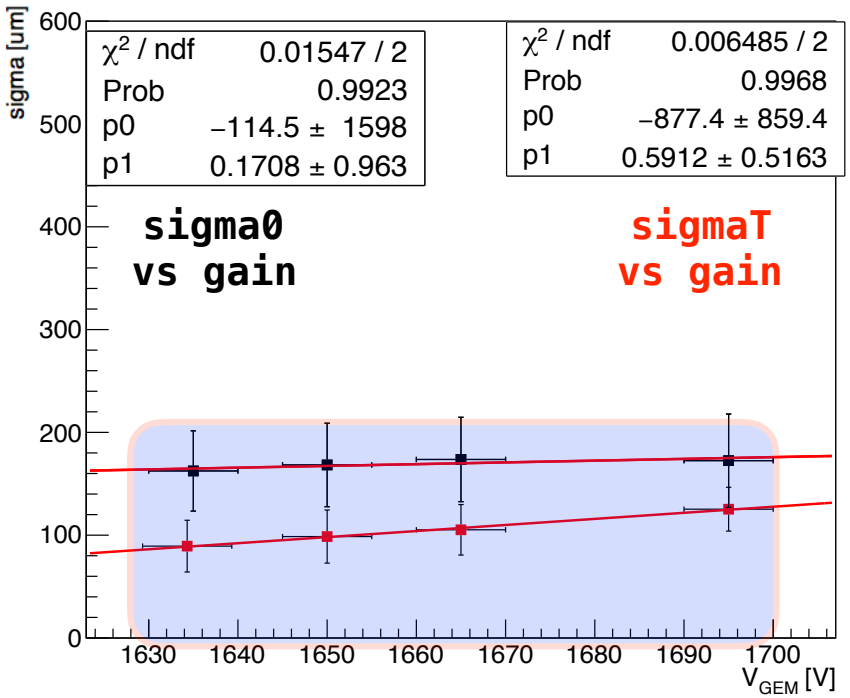
# sigma_T & sigma_0 versus gain

From Giorgio's studies on $^{55}Fe$ spot size $He:CF_4$ 60:40
sigma0 vs gain ± 1 um/V

## Electron drift




## Negative ion drift ?



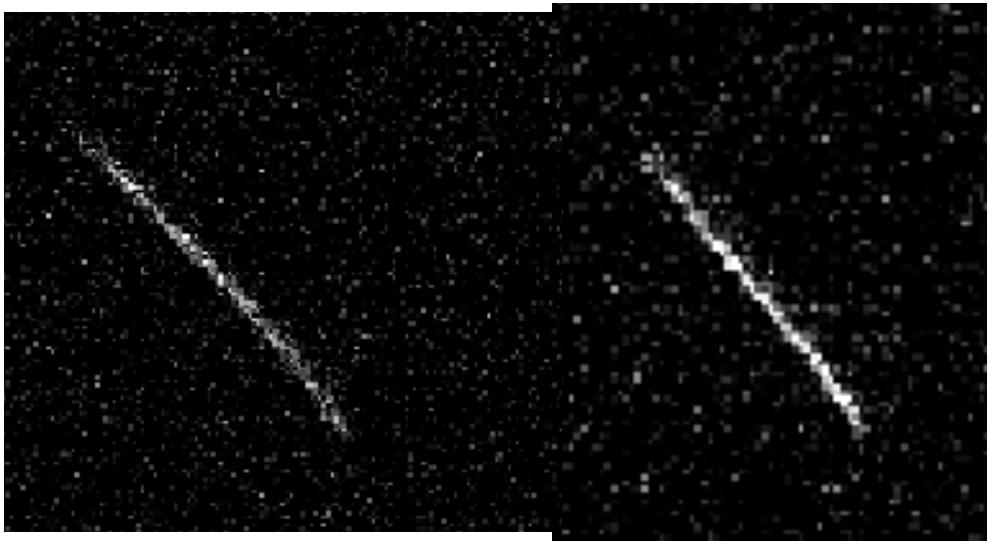

**same dV range**

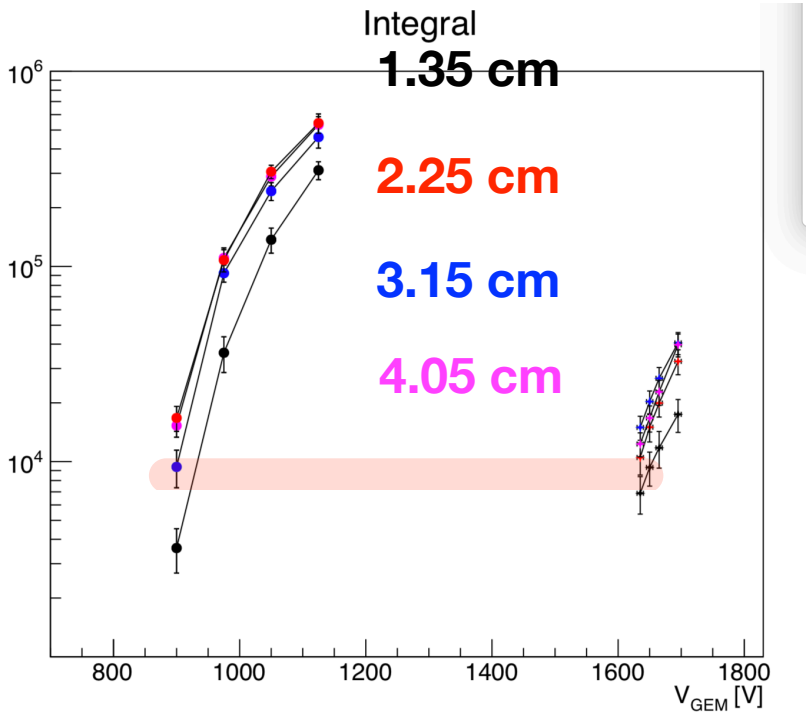
**electron drift less compatible with sqrt behaviour at larger gain**

**975 V @ 1.3 cm gain compatible with 1665 V gain at 2.25, 3.15 and 4.05 cm**

## Electron drift

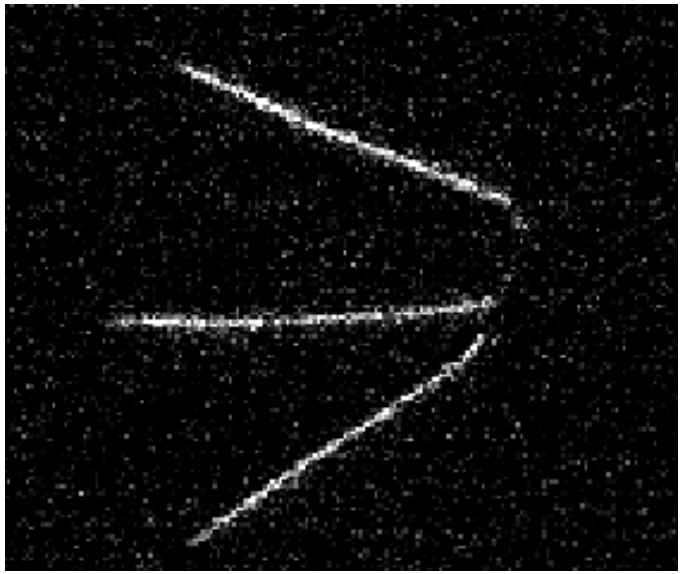
## Negative ion drift ?





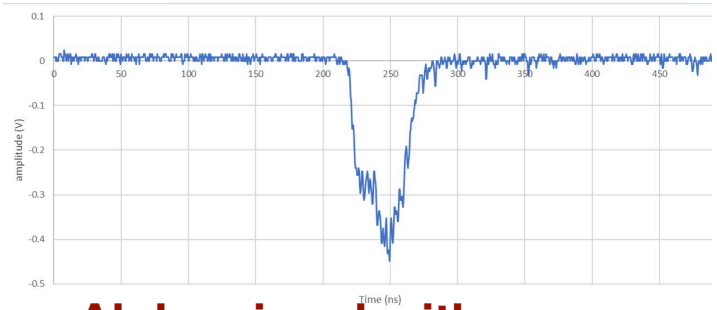

## Electron drift

## Negative ion drift ?

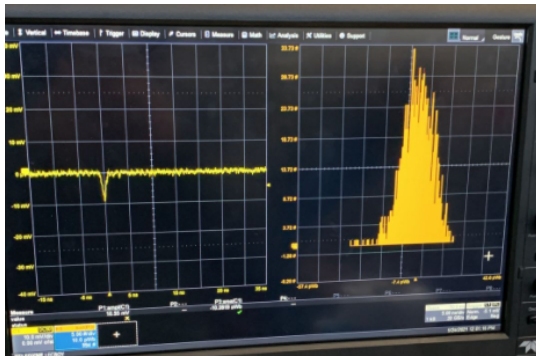


# The PMT issue

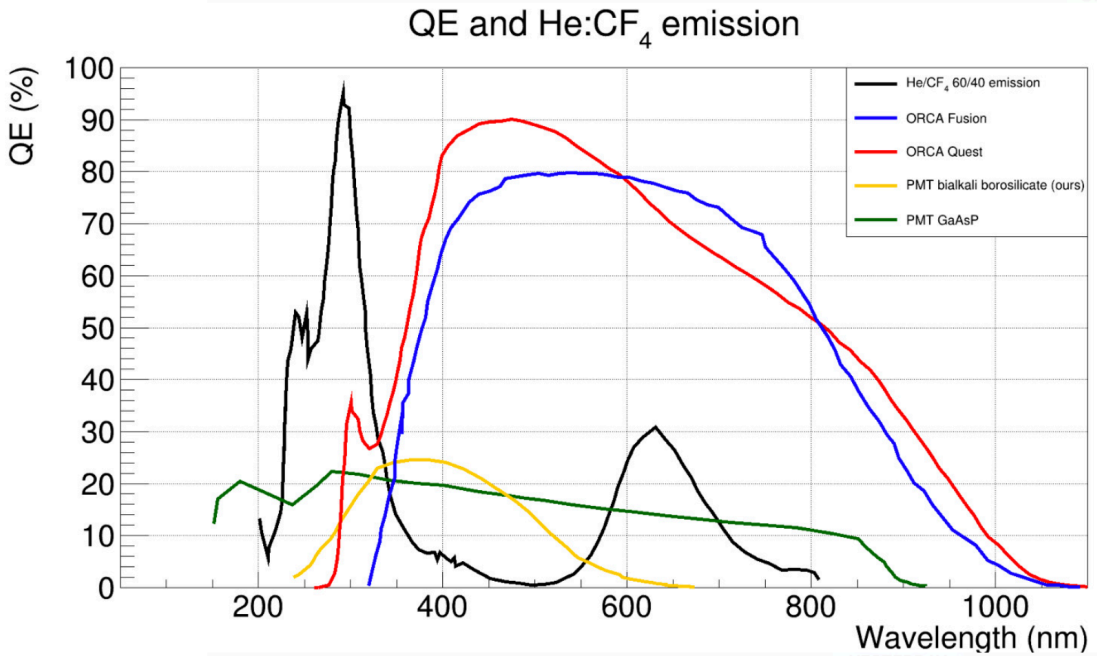
# No signals on PMT with NID! (but signals ok with electron drift….)




**Alpha signal with ED**

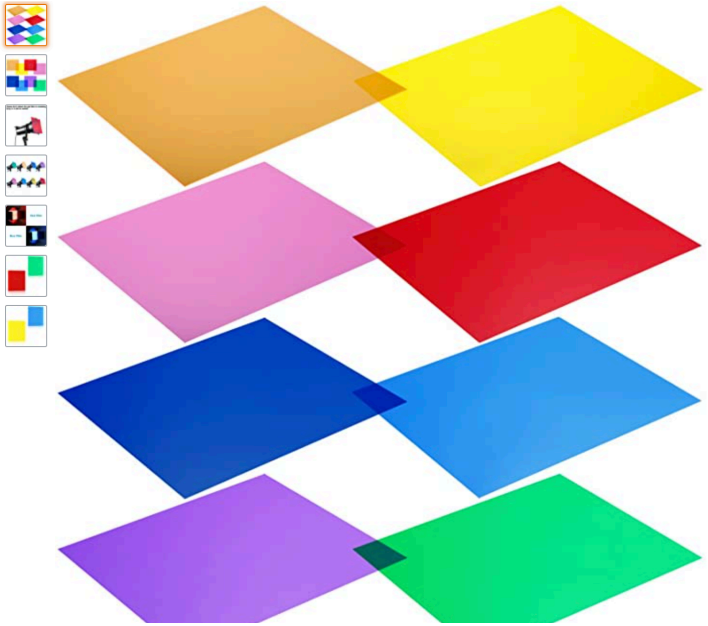


**Only noise: no rate increase with source**




**maybe SF6 is cutting low frequencies?**

# Filters studies



Neewer - Set di Filtri Gel trasparenti per la correzione del Colore per Luce Stroboscopica da Studio - 30x30cm 8pz - colori Rosso, Giallo, Arancione, Verde, Viola, Rosa, Blu Chiaro, Blu Scuro

Visita lo Store di Neewer

★★★★☆ 3.072 voti

Prezzo: 17,99€ ✓prime e Resi GRATUITI

Tutti i prezzi includono l'IVA.

Nuovo (6) da 17,99 € ✓prime

Taglia: **Confezione da 8**

| **Confezione da 8** | 11-Pack |
|---|---|
| 17,99 € | 18,49 € |
| ✓prime | ✓prime |

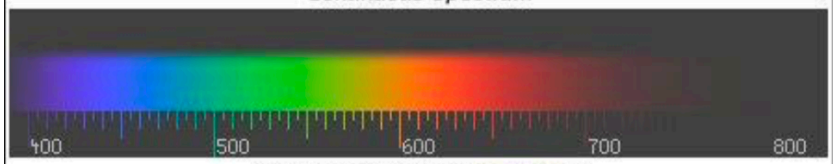
**Spedizione GRATUITA** con consegna presso **punti di ritiro.**

Dettagli

| | |
|---|---|
| **Marchio** | Neewer |
| **Descrizione rivestimento** | Rivestimento multiplo |
| **Tipo di effetto filtro foto** | Miglioramento |

| color | wavelength interval | frequency interval |
|---|---|---|
| red | ~ 625-740 nm | ~ 480-405 THz |
| orange | ~ 590-625 nm | ~ 510-480 THz |
| yellow | ~ 565-590 nm | ~ 530-510 THz |
| green | ~ 500-565 nm | ~ 600-530 THz |
| cyan | ~ 485-500 nm | ~ 620-600 THz |
| blue | ~ 440-485 nm | ~ 680-620 THz |
| violet | ~ 380-440 nm | ~ 790-680 THz |

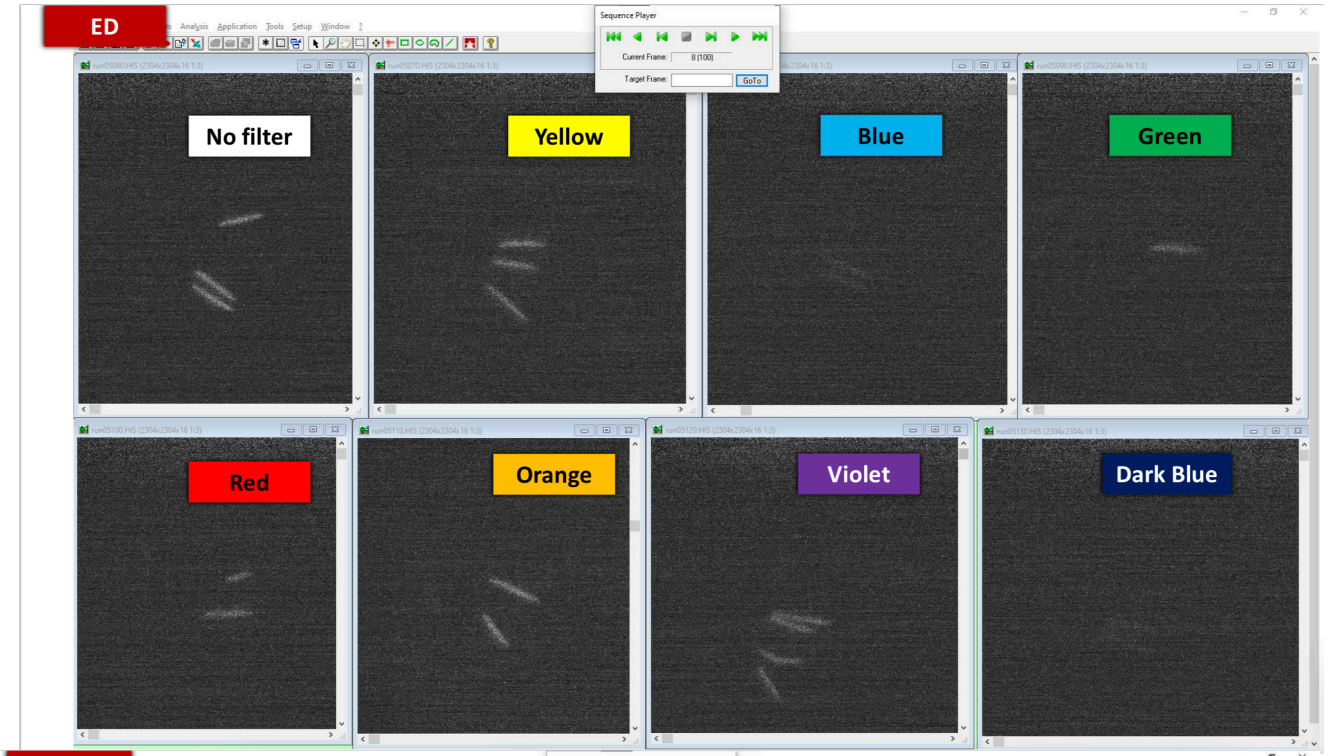
*Continuous spectrum*



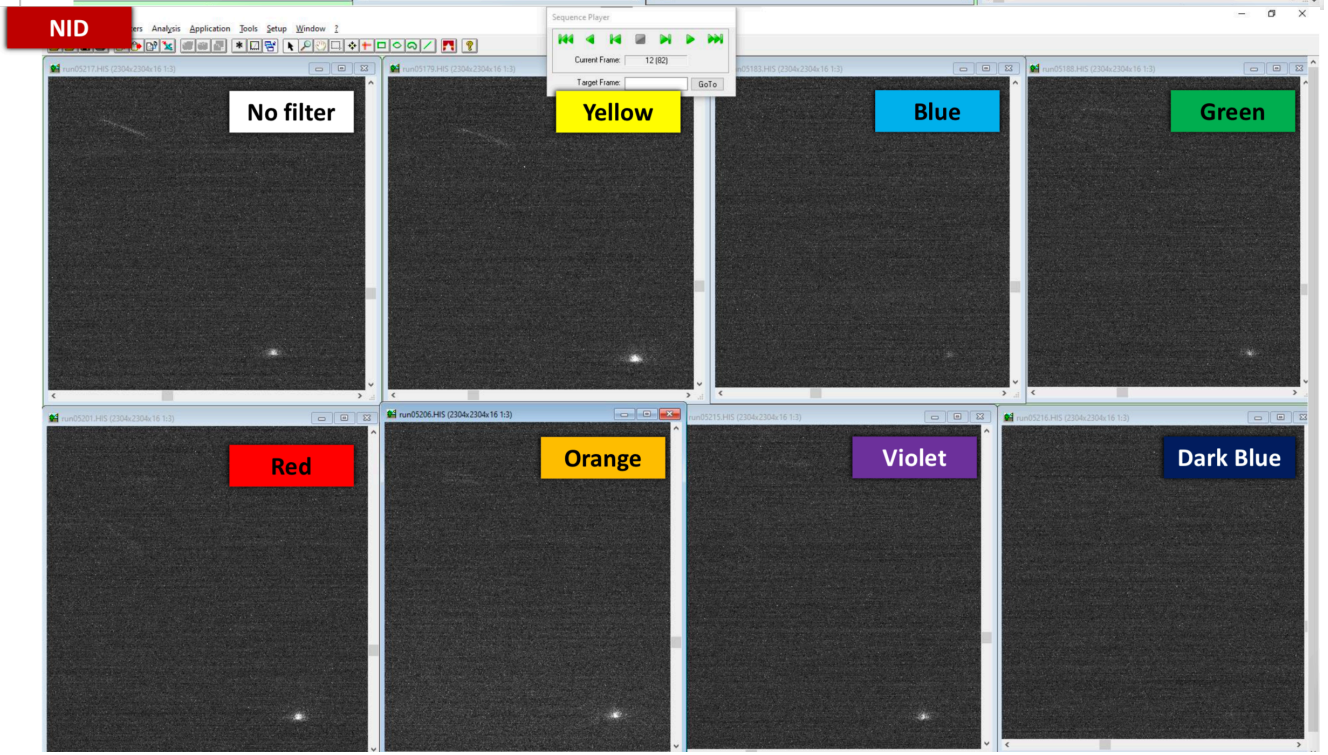

*Designed for monitors with gamma 1.5.*

**Red transmits only red frequencies and so on**

**ED behaviour consistent with expectations**




**NID seems more “dumped” than ED for orange filter….BUT there were some problems with gas mixture, so likely need to retake data**



# Conclusions & outlook

- He:$CF_4$:$SF_6$ 59:39.4:1.6 seems to behave differently from classical electron drift (ED)
  - Requires more than 70% larger GEM voltage to obtain comparable light yield
  - Gain vs $V_{GEM}$ dependence is 1/2 w.r.t ED
  - Gain does not saturate
  - Diffusion between GEMs is ± 170 um independent of gain (w.r.t. a 1.7 um/V dependence of ED)
  - Diffusion coefficient of ± 100 um/sqrt(cm) (ED data dominated by diffusion but typically 140 um/sqrt(cm))
  - Can't see signals on PMT at comparable light yield
  - Same mixture and same GEM voltages as data published with NITEC at only 10% larger pressure: GEM voltages compatible with E/p scaling
  - Several indication of negative ion drift behaviour

- Is it really negative ion drift (NID)? Further studies are required
  - Measure GEM charge signals with preamplifiers and demonstrate longer time development with NID?
  - Install longer ± 20 cm field cage "a la GIN"?
  - Study PMT light with a GaAs window PMT? (3 months delivery)

**Ideas for tests or improved analysis are more than welcome!!!**