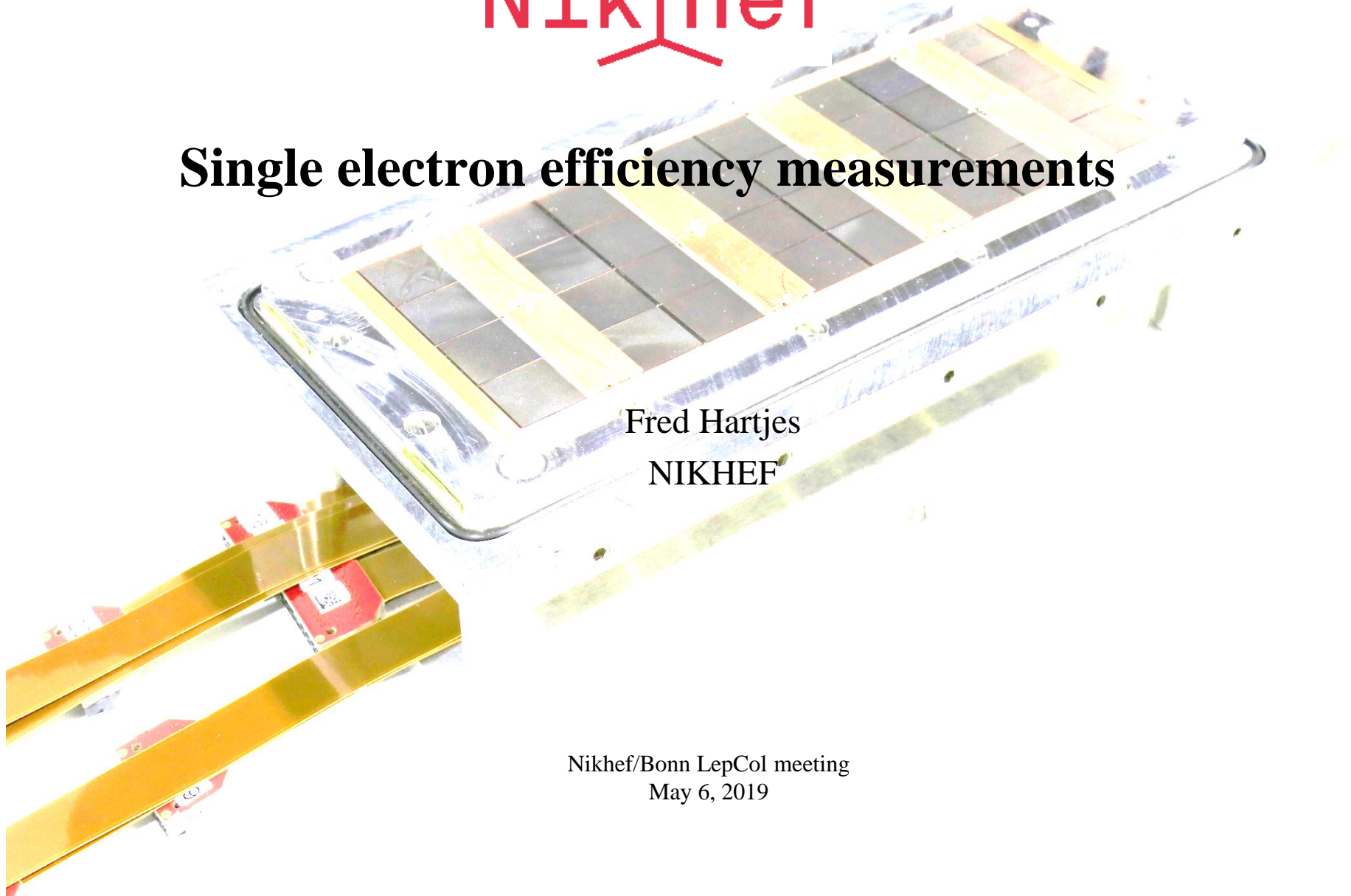




Single electron efficiency measurements

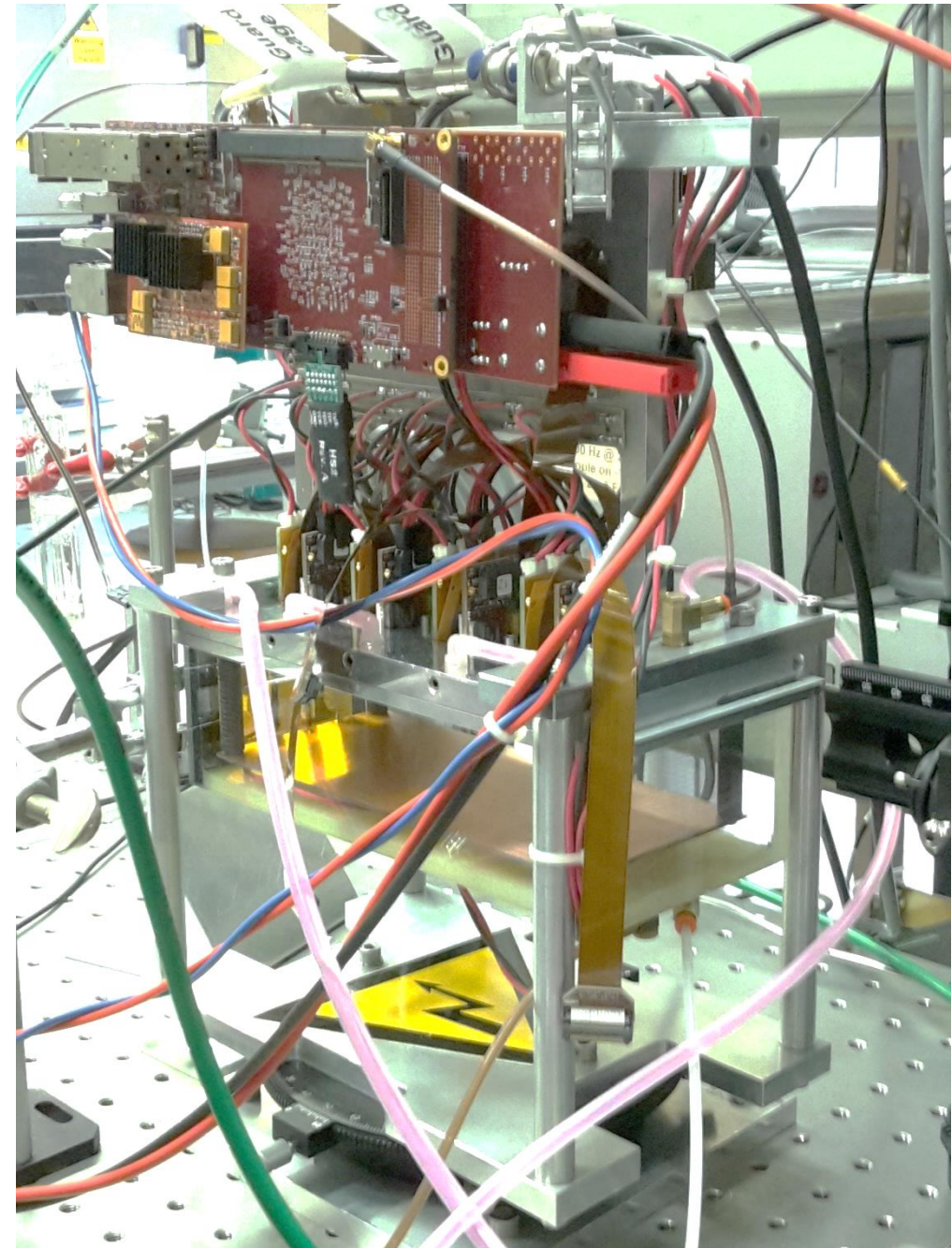
Fred Hartjes
NIKHEF

Nikhef/Bonn LepCol meeting
May 6, 2019



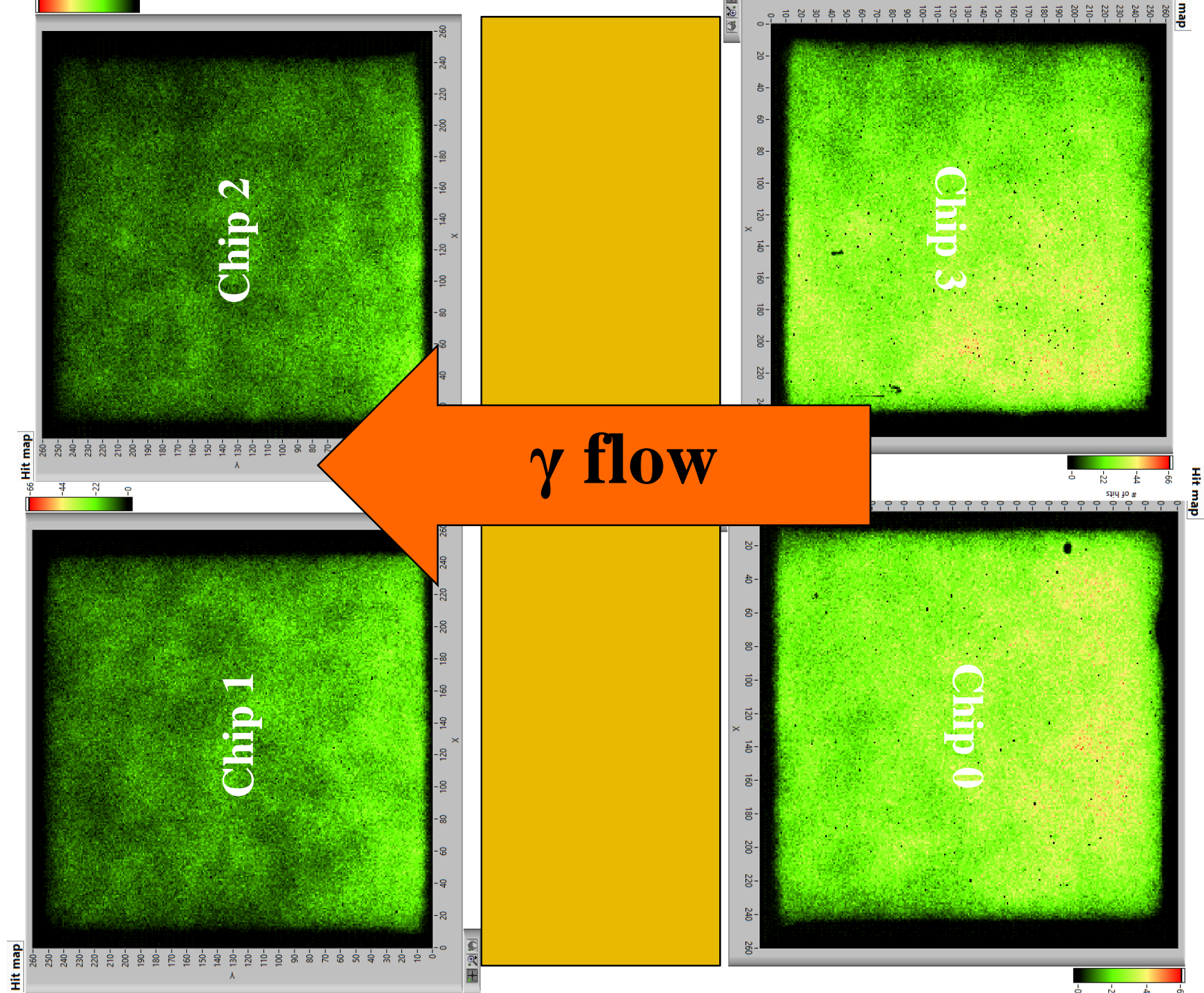
Single electron efficiency with ^{55}Fe source

- Source Fe-55-04
 - 5.6 keV gamma
- Expecting with Ar a peak of ~ 220 e $^-$ and a second peak at ~ 110 e $^-$ (escape peak)
- 3 gas mixtures tried
 - T2K
 - T3K (3% iC $_4$ H $_{10}$)
 - 18% iC $_4$ H $_{10}$ + Ar
- Done for 8 – 9 different grid voltages, 170 s per run
- Cluster tracing by finding hits within -40 to 400 ns window from 1st hit
- Cluster rate 25 – 100 Hz depending on chip position
 - => I_{grid} \sim 10 pA/chip
 - => hardly voltage drop across the protection layer



Hitmaps at $V_{\text{grid}} = -320 \text{ V}$

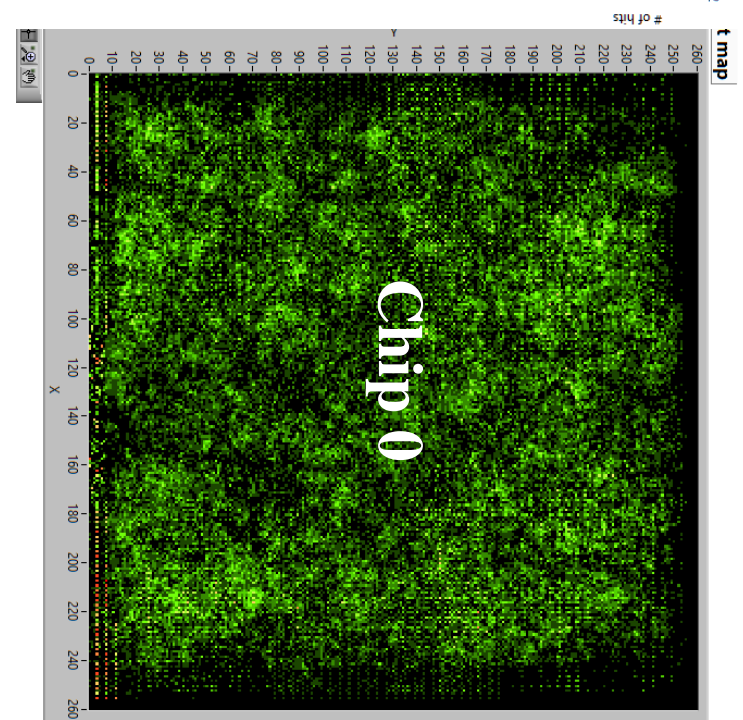
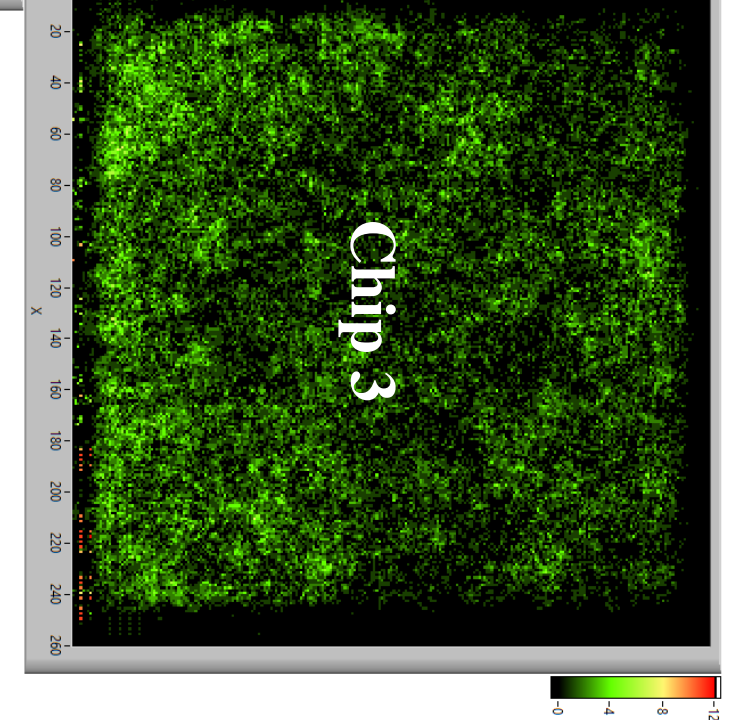
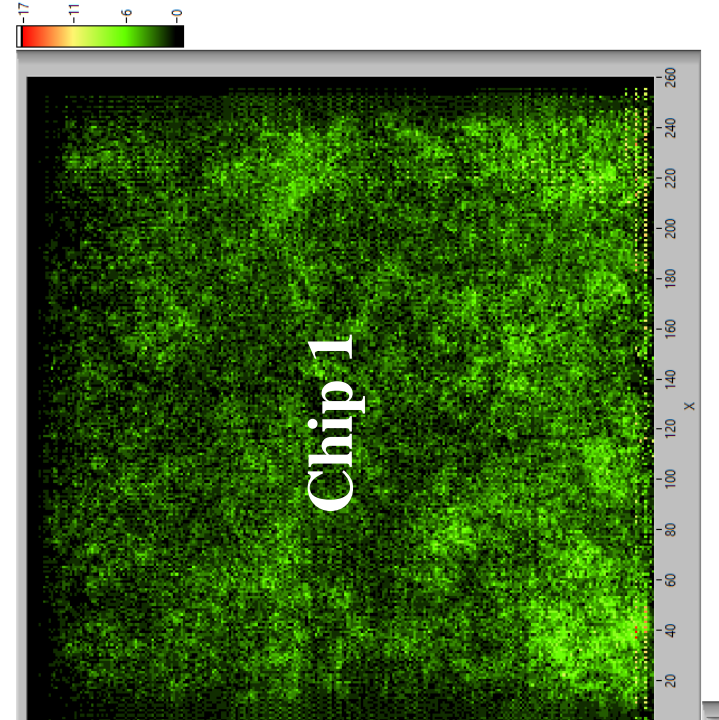
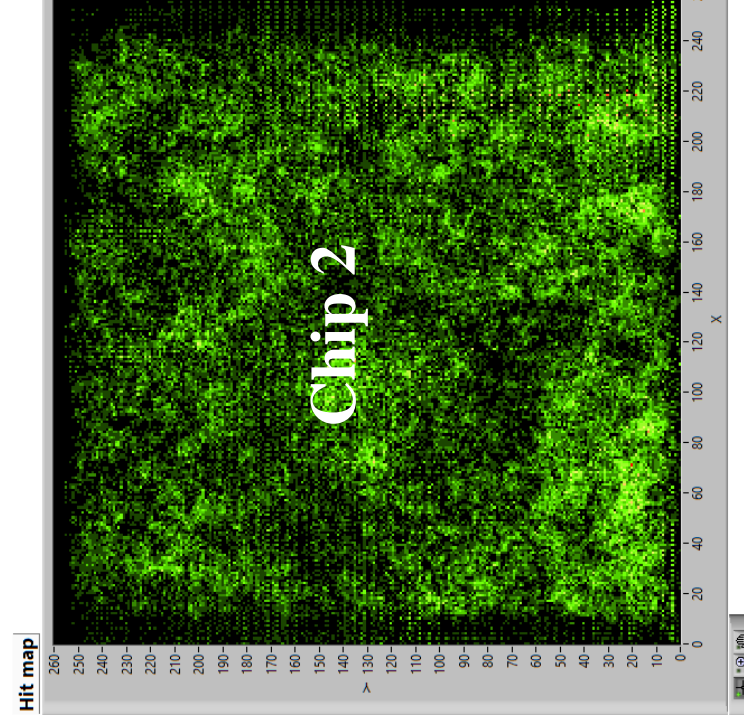
- T2K gas
- Using ^{55}Fe source
- 5 micro discharges during 170 s
- Identical Z scale for all plots



Hitmaps at $V_{gid} = -350 \text{ V}$

■ No ^{55}Fe source

■ 16 micro discharges during 170 s



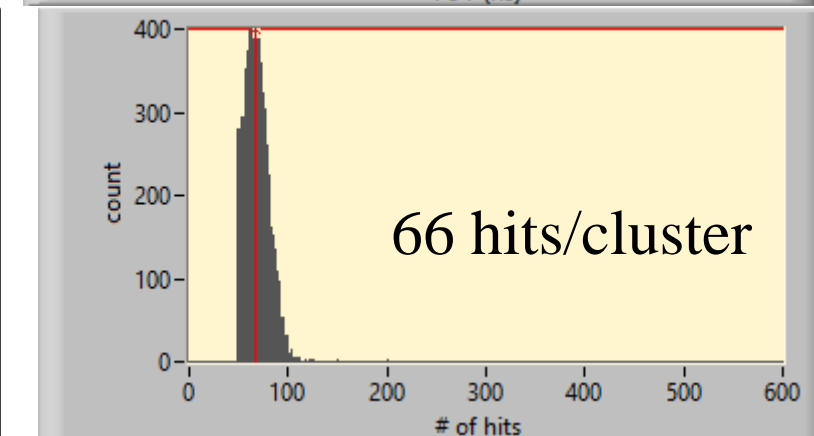
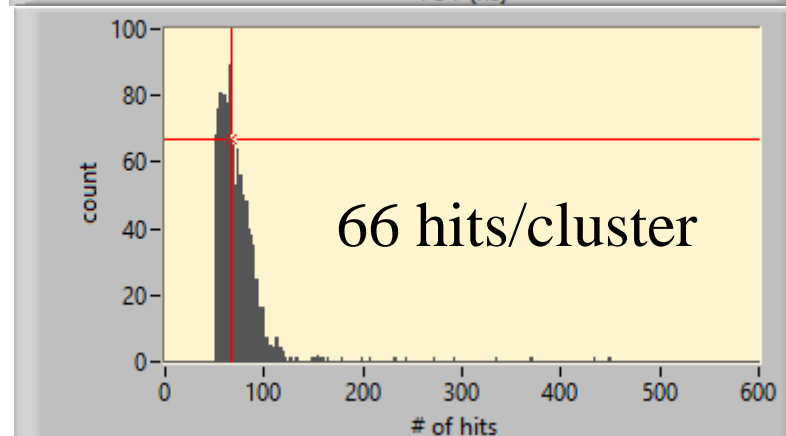
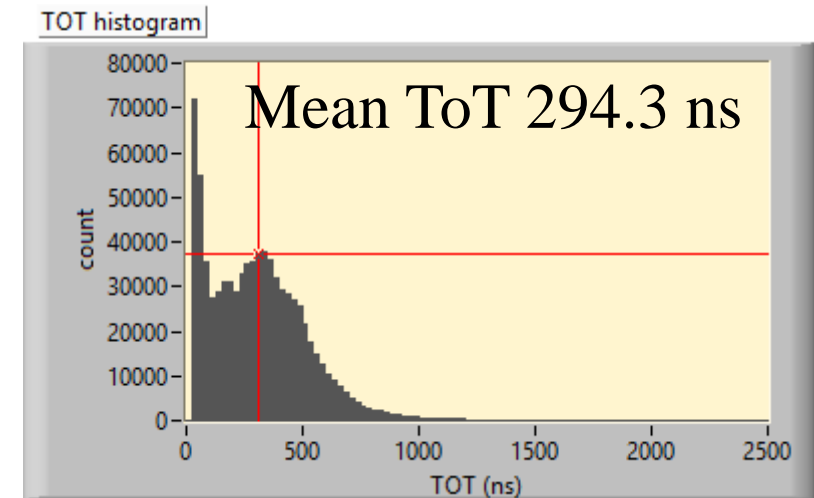
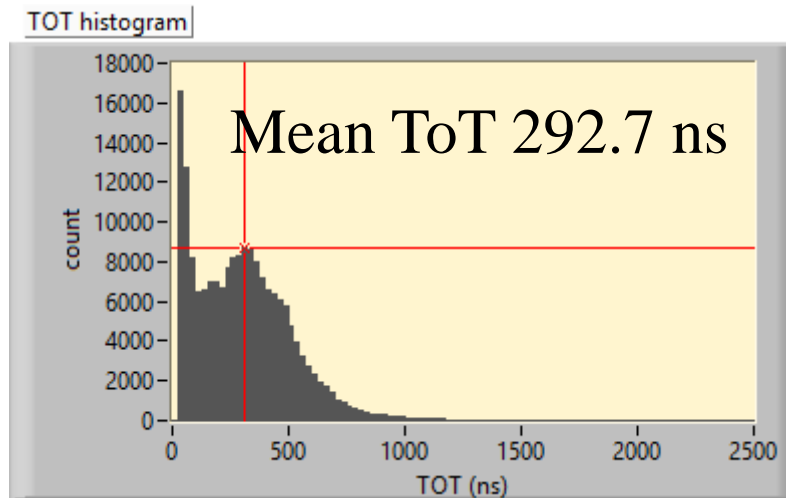
Measurements with iC4H10/Ar 18/82

^{55}Fe measurements with Ar/ $i\text{C}_4\text{H}_{10}$ 82/18 $V_{\text{grid}} = -340 \text{ V}$

- One micro discharge

Chip 2

Chip 0

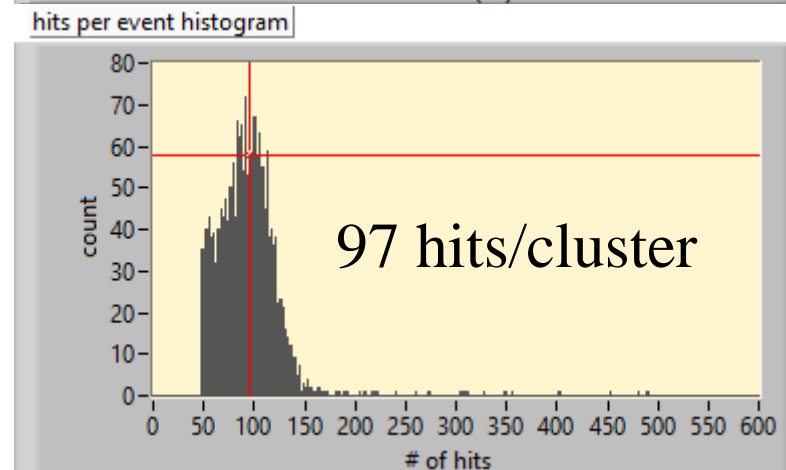
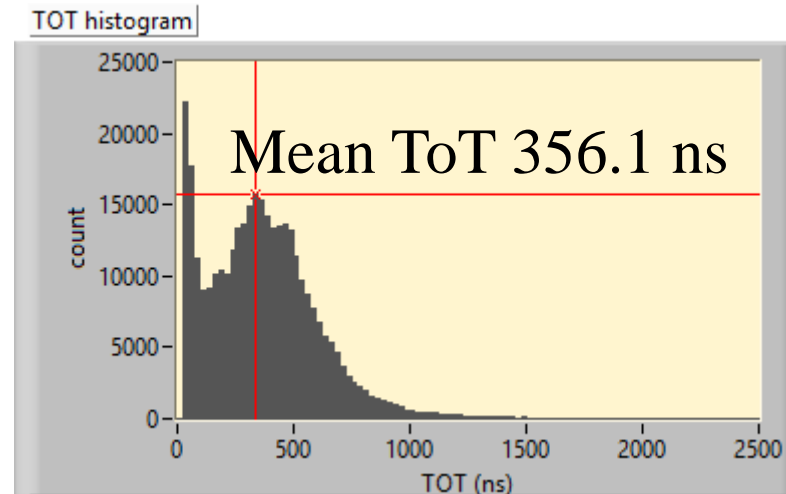


55Fe measurements with Ar/iC₄H₁₀ 82/18

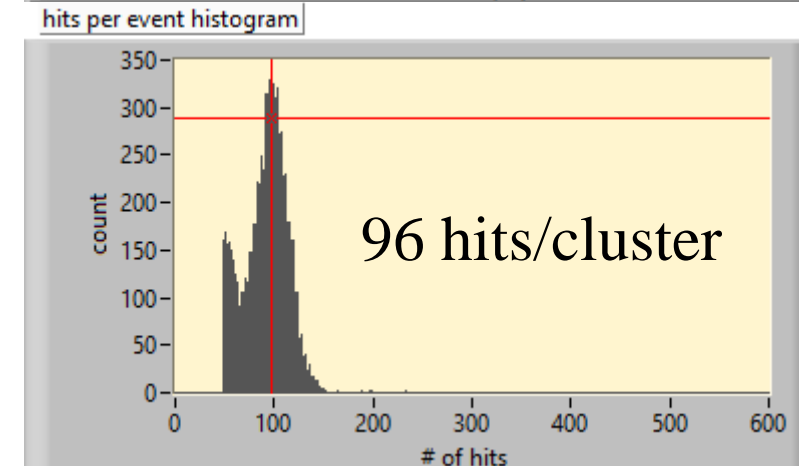
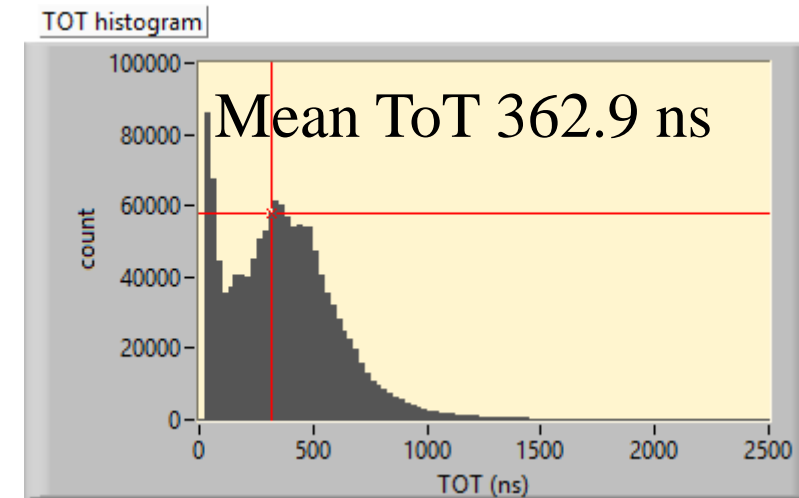
Vgrid = -350 V

- No micro discharge

Chip 2



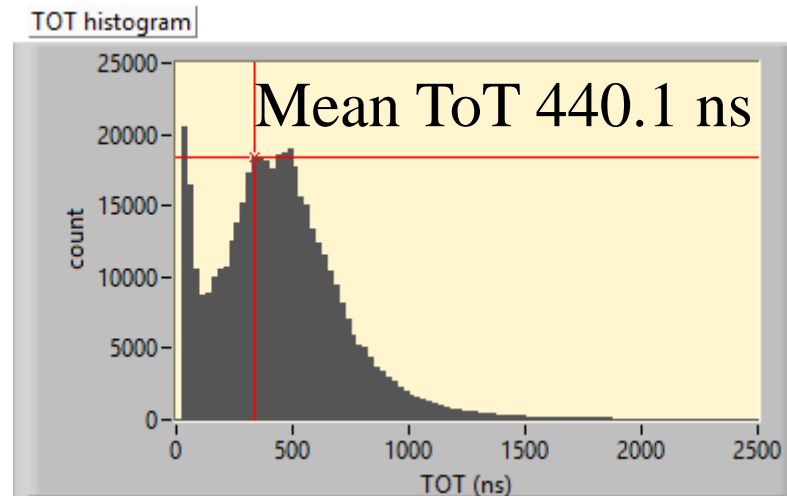
Chip 0



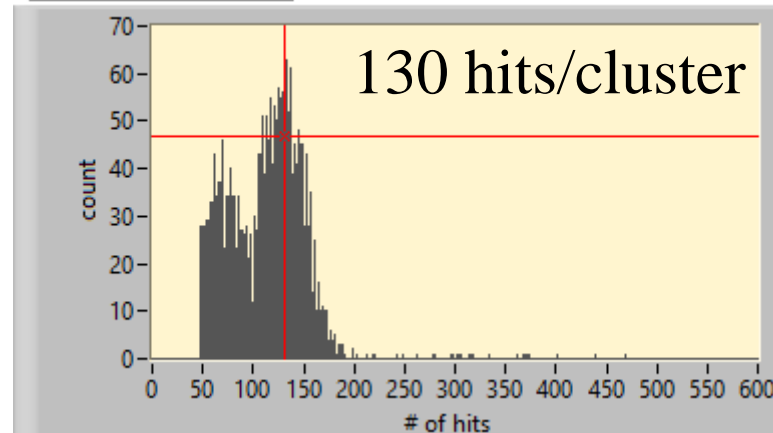
^{55}Fe measurements with Ar/ $i\text{C}_4\text{H}_{10}$ 82/18 $V_{\text{grid}} = -360 \text{ V}$

- No micro discharges

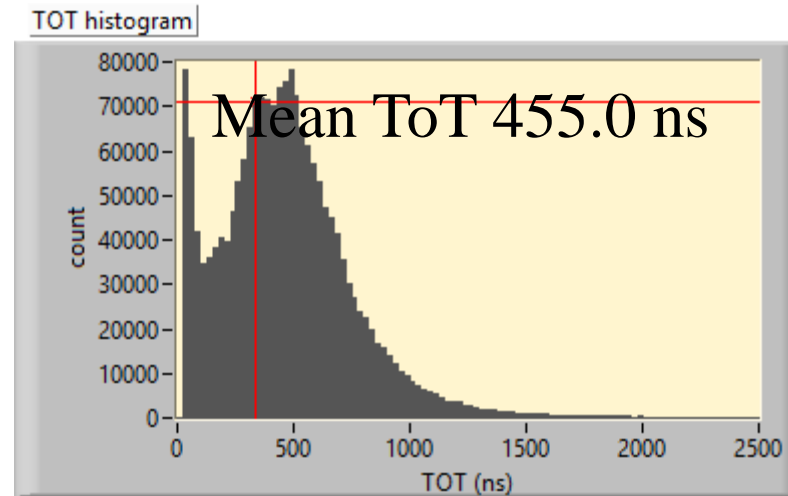
Chip 2



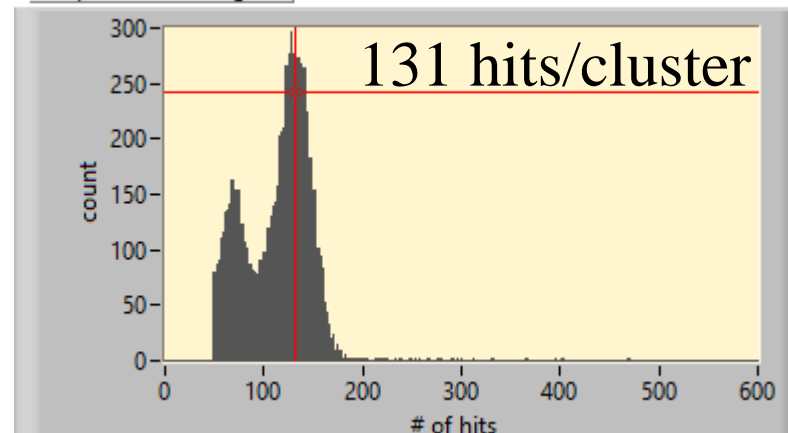
hits per event histogram



Chip 0



hits per event histogram

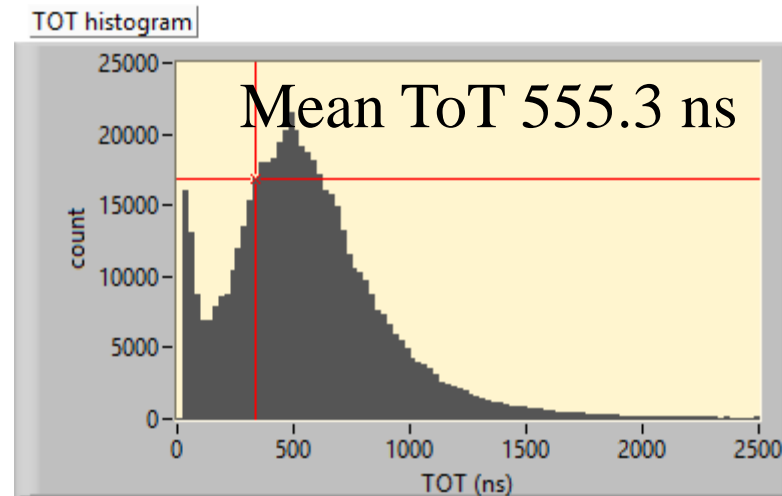


55Fe measurements with Ar/iC₄H₁₀ 82/18

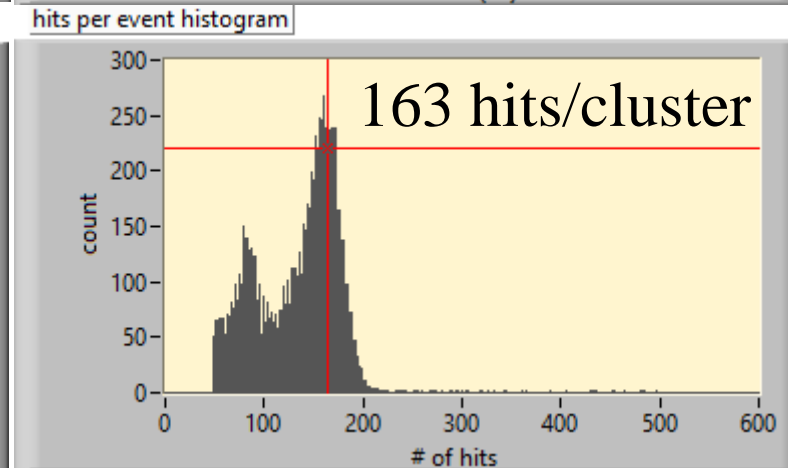
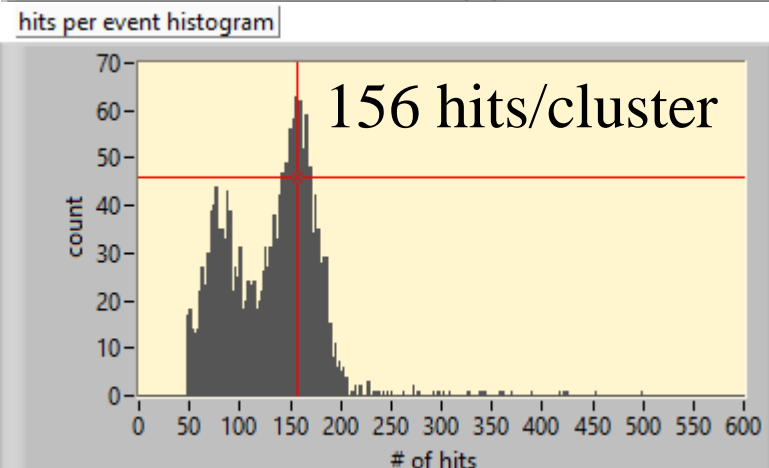
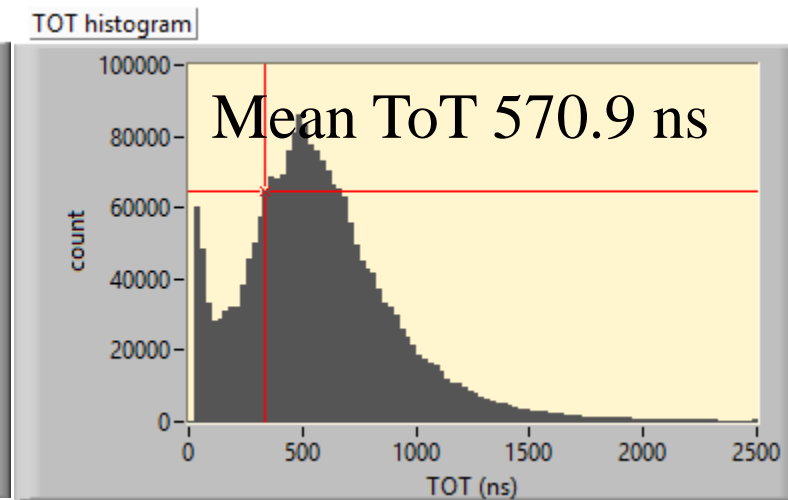
Vgrid = -370 V

- No micro discharges

Chip 2



Chip 0

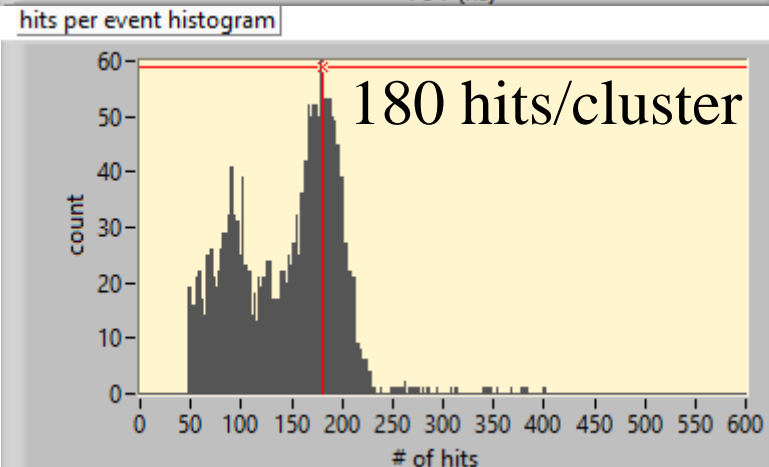
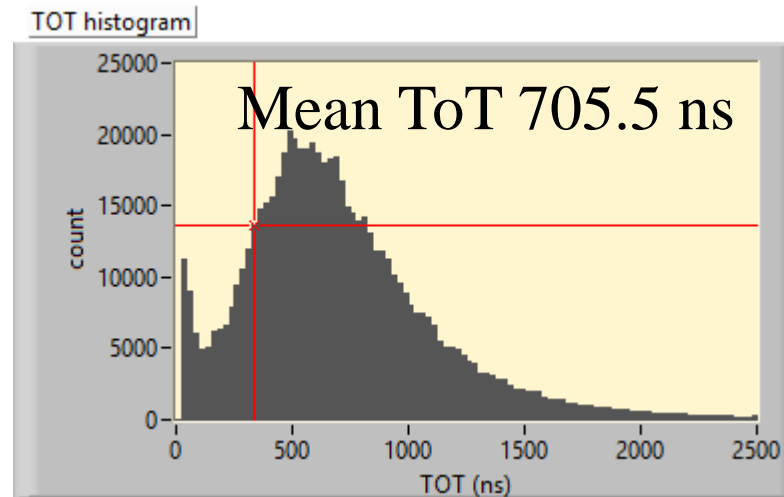


55Fe measurements with Ar/iC₄H₁₀ 82/18

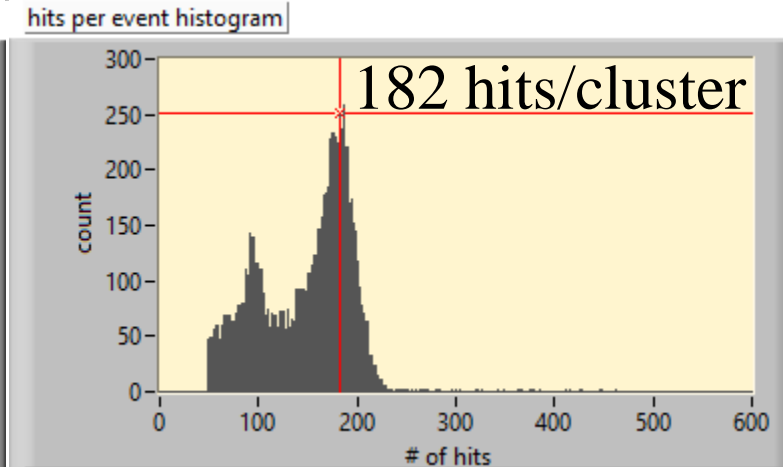
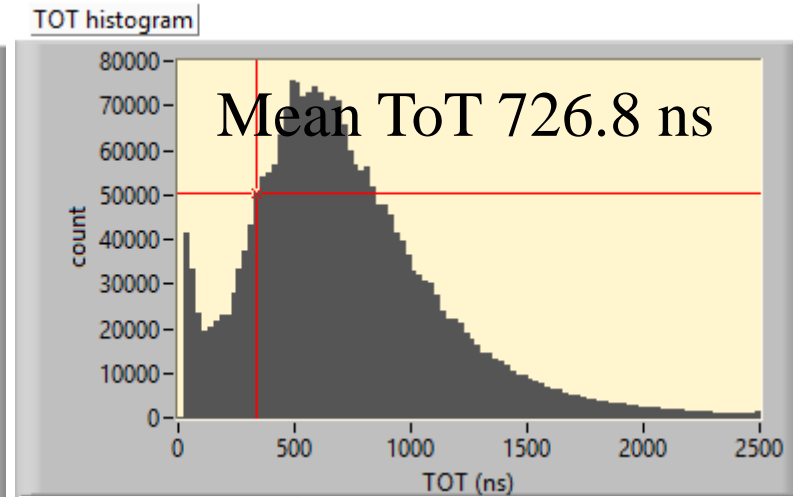
Vgrid = -380 V

- No micro discharges

Chip 2



Chip 0

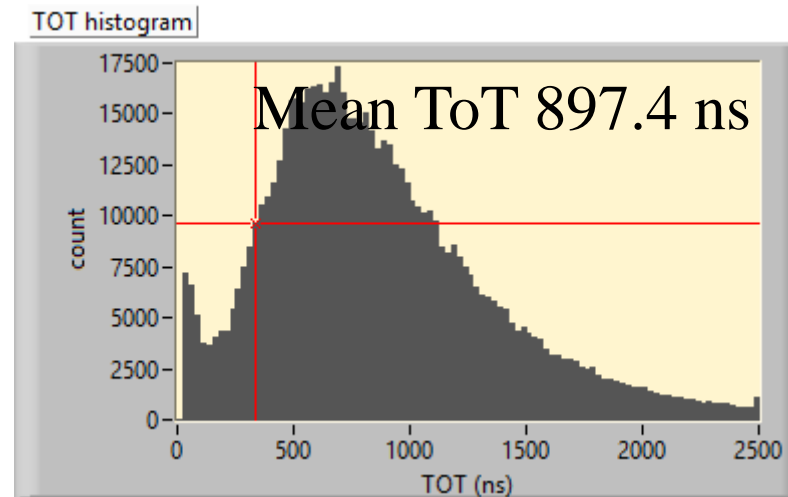


55Fe measurements with Ar/iC₄H₁₀ 82/18

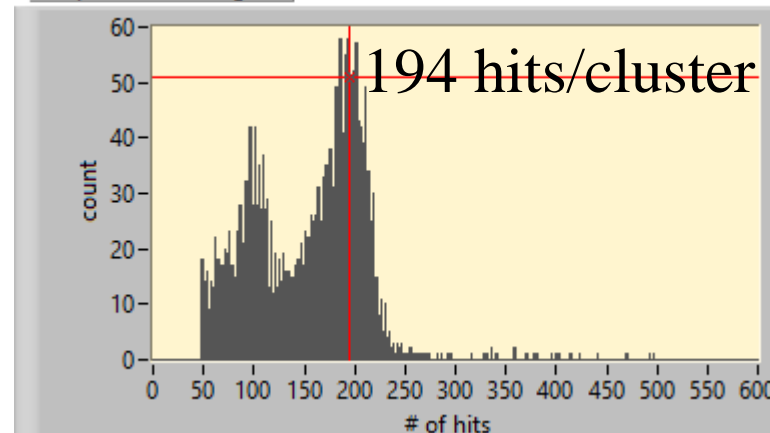
Vgrid = -390 V

- One micro discharge

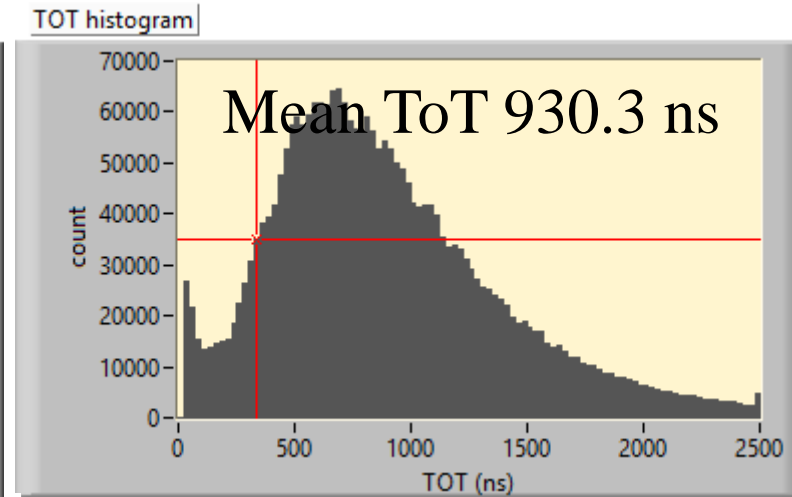
Chip 2



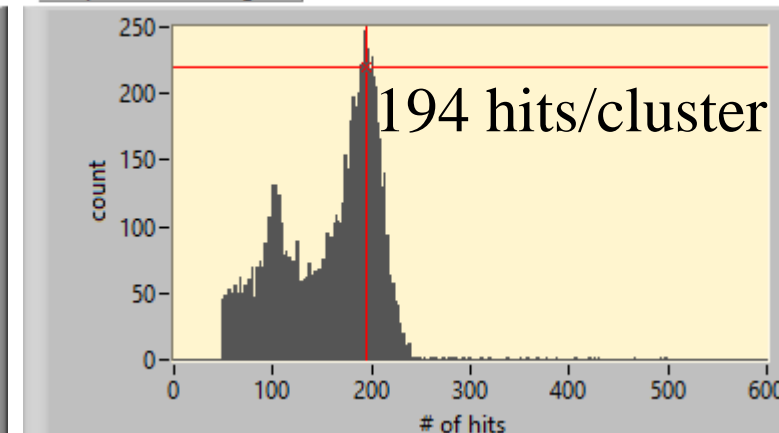
hits per event histogram



Chip 0



hits per event histogram

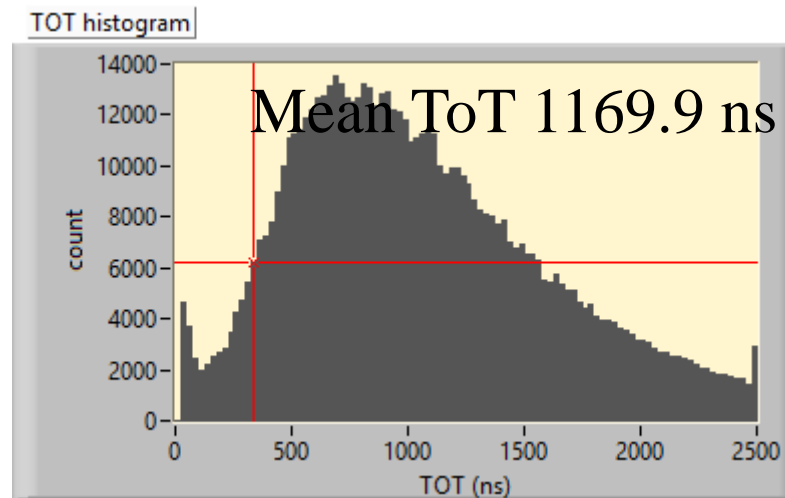


^{55}Fe measurements with Ar/ $i\text{C}_4\text{H}_{10}$ 82/18

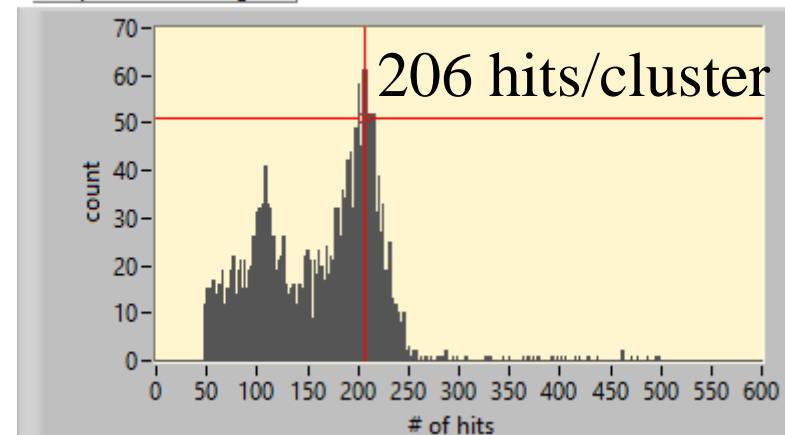
$V_{\text{grid}} = -400 \text{ V}$

- One micro discharge

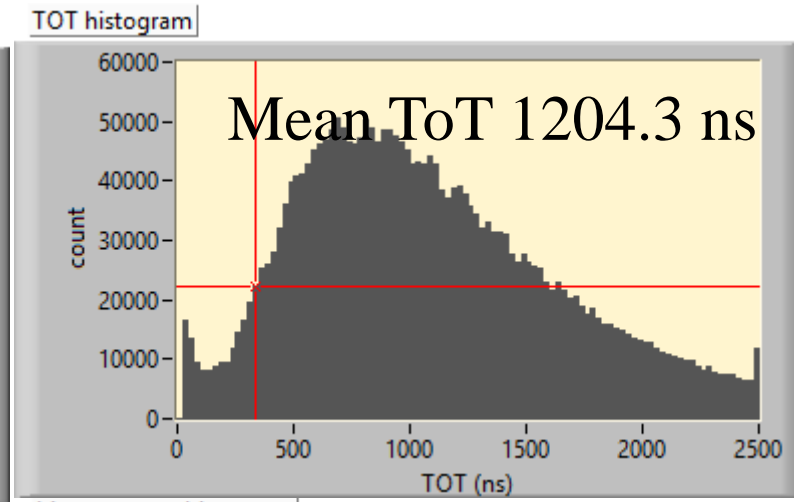
Chip 2



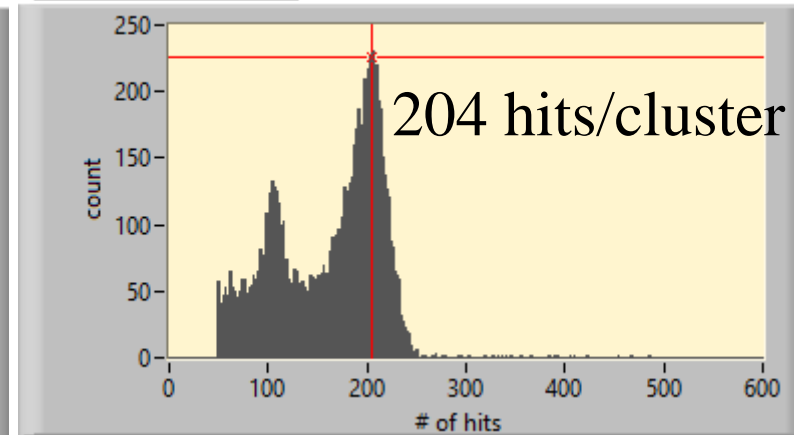
hits per event histogram



Chip 0



hits per event histogram

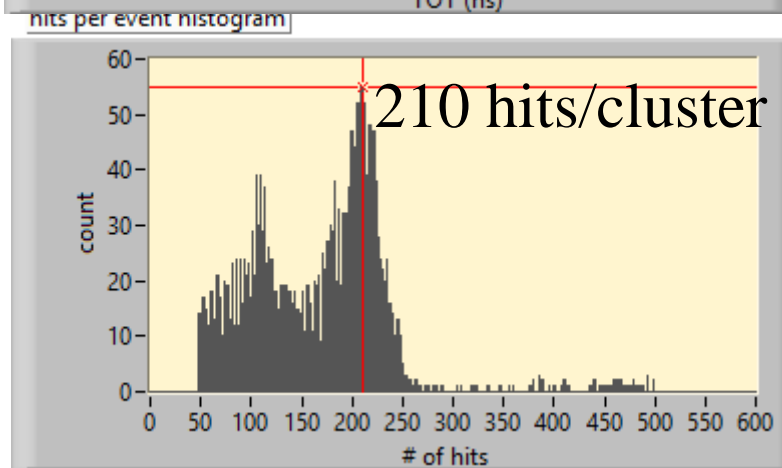
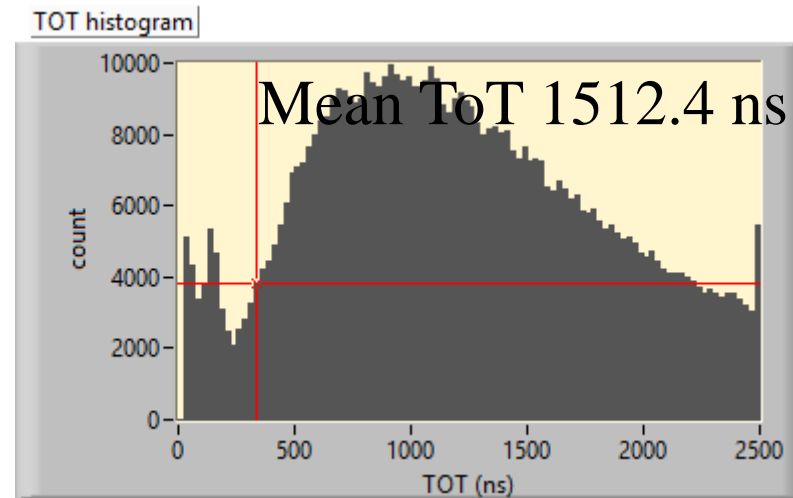


^{55}Fe measurements with Ar/ $i\text{C}_4\text{H}_{10}$ 82/18

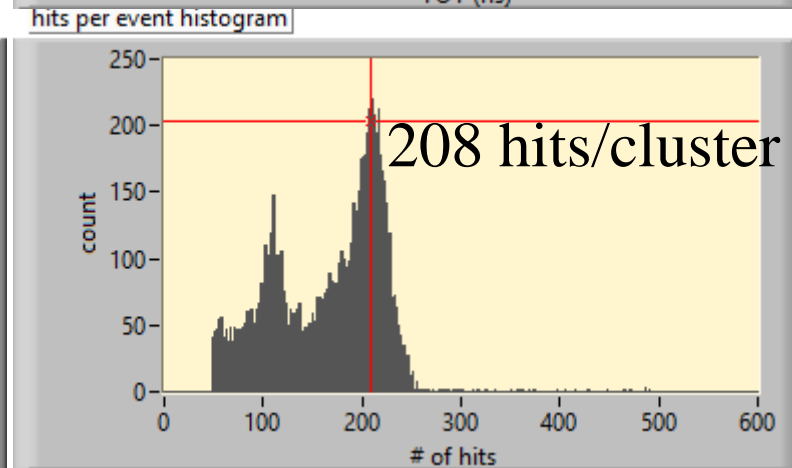
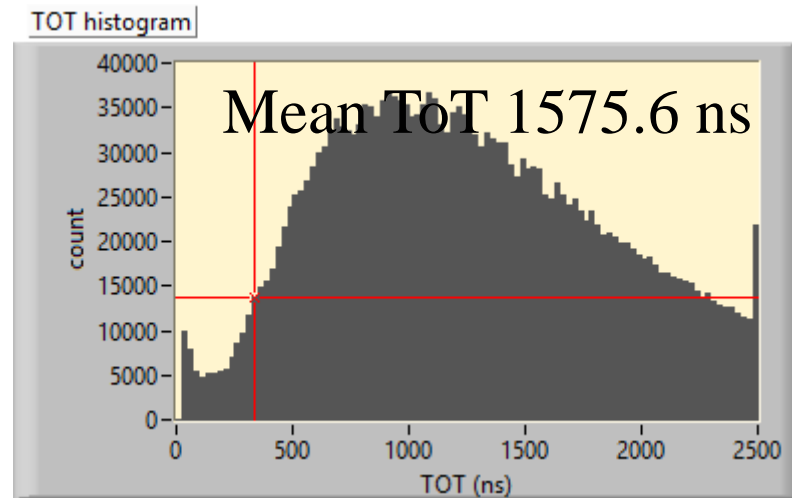
$V_{\text{grid}} = -410 \text{ V}$

- Two micro discharges

Chip 2



Chip 0

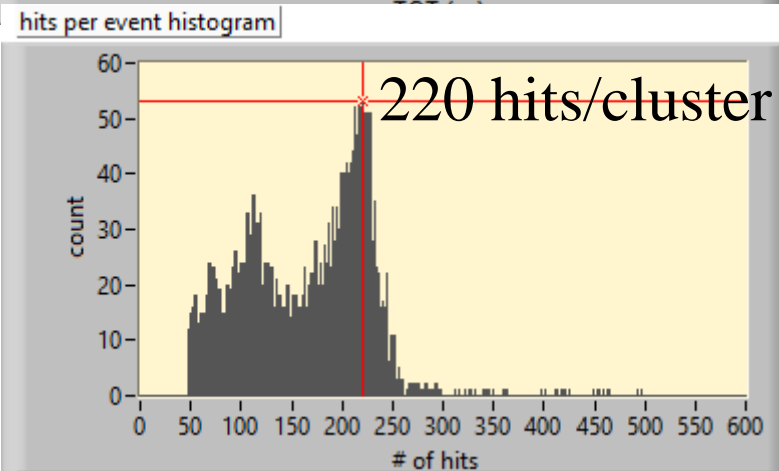
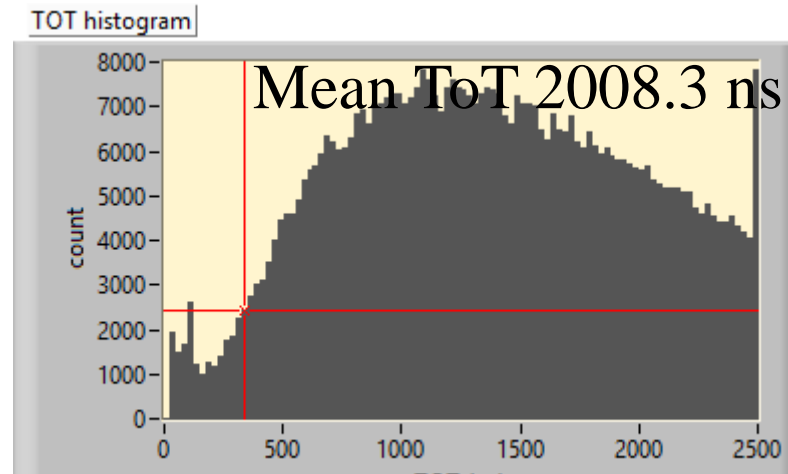


^{55}Fe measurements with Ar/ $i\text{C}_4\text{H}_{10}$ 82/18

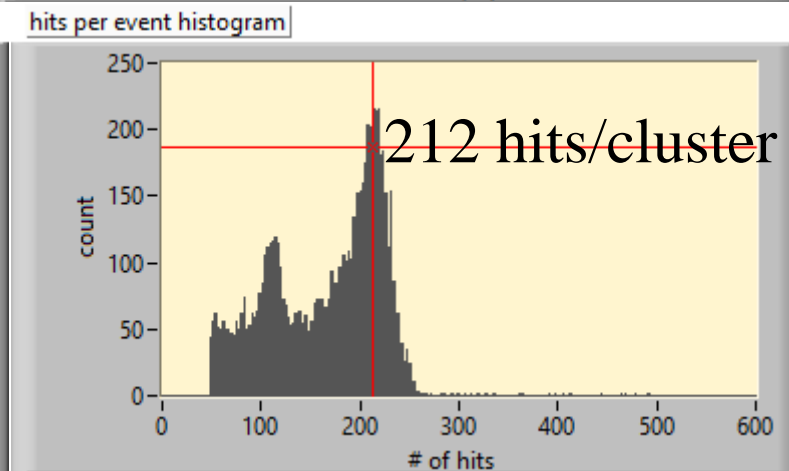
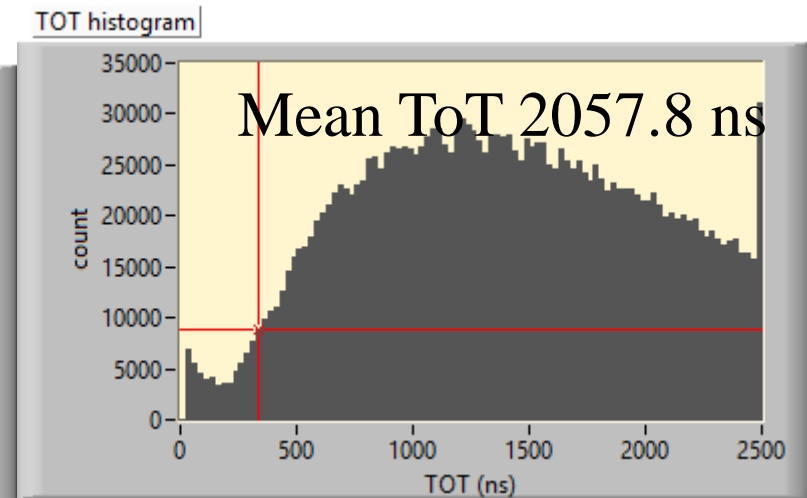
$V_{\text{grid}} = -420 \text{ V}$

- No micro discharges

Chip 2

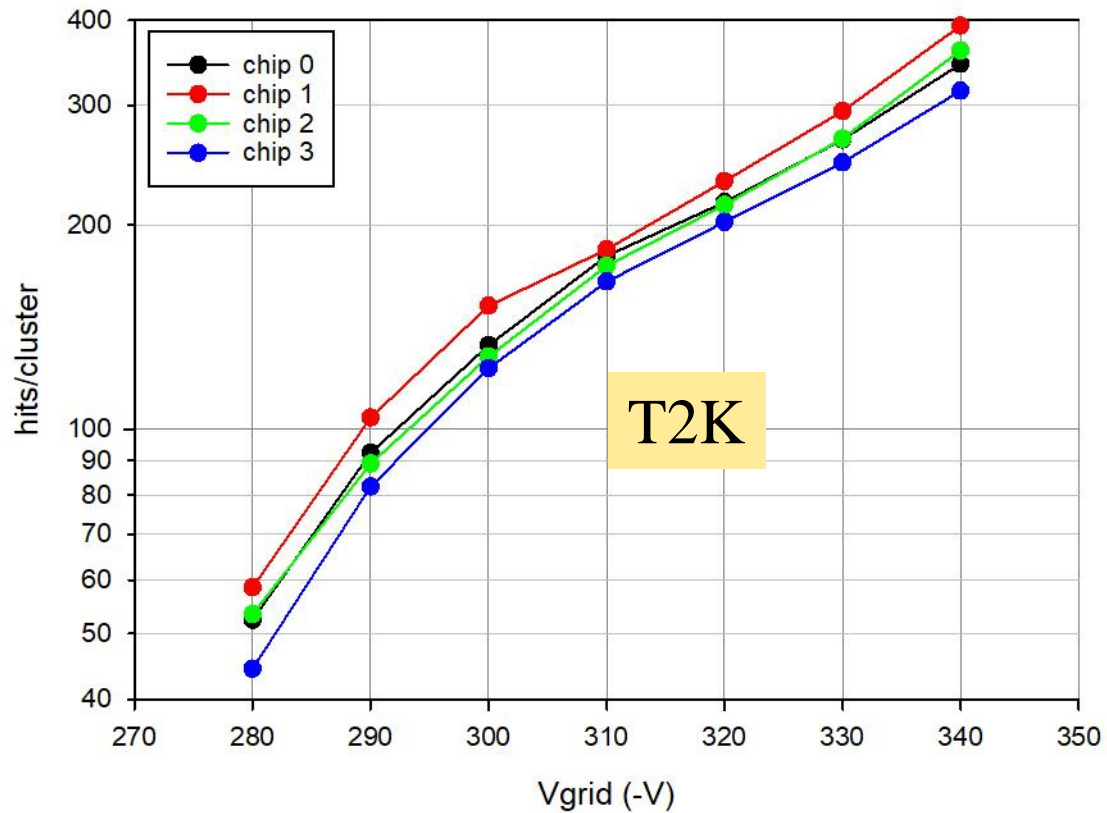


Chip 0



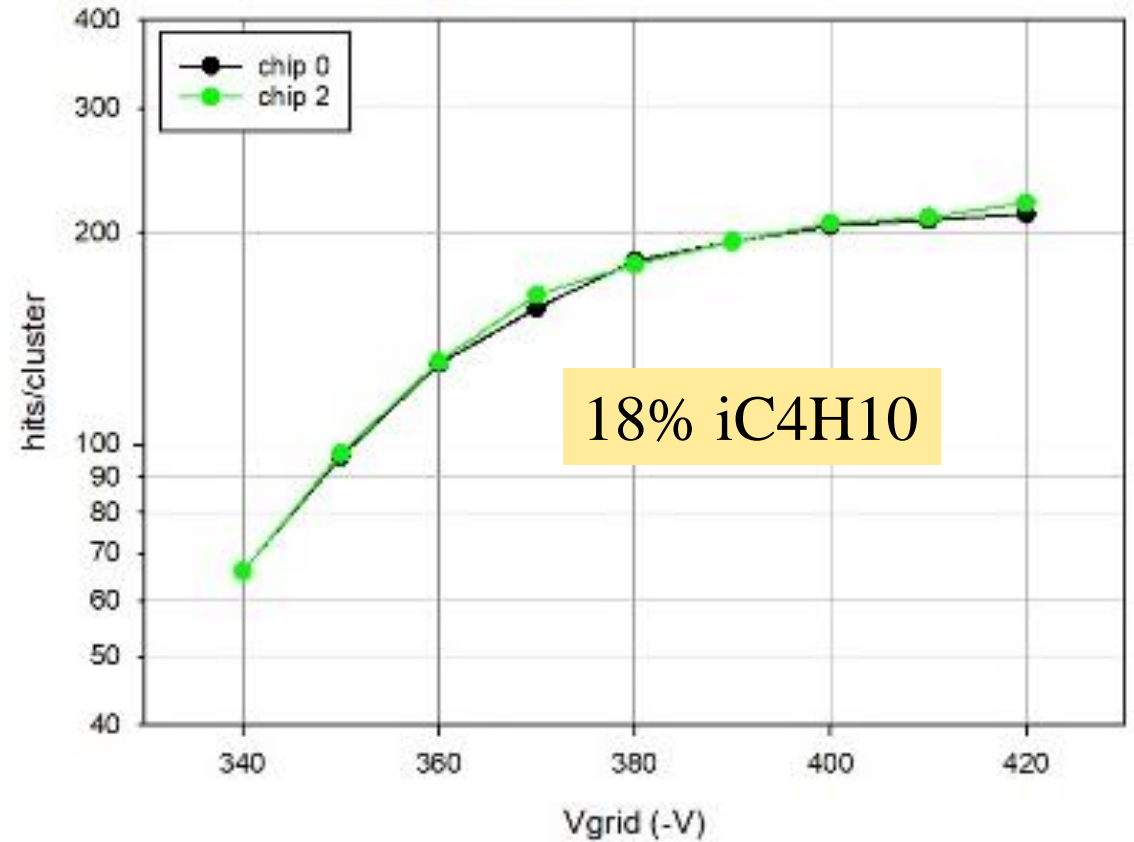
Comparison hits/cluster

QUAD 13 hits/cluster vs Vgrid
55Fe irradiation



QUAD 13 hits/cluster vs Vgrid
55Fe irradiation

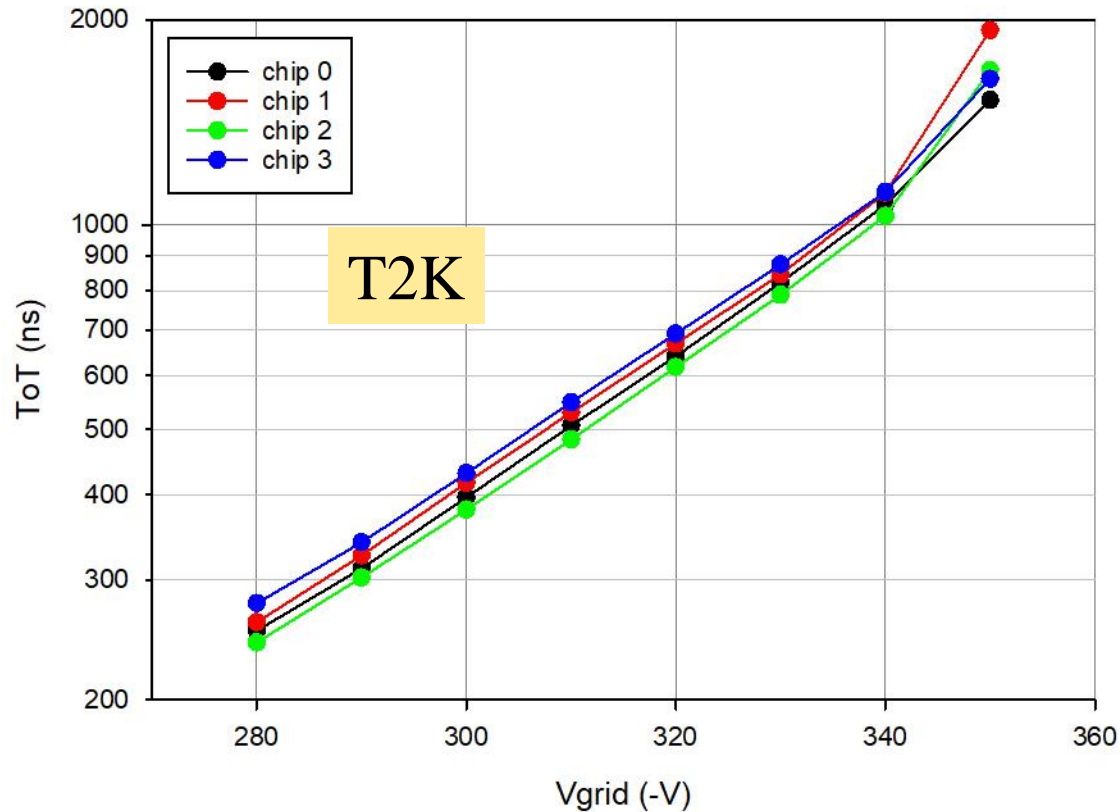
Data 30 - 4 - 2019
Ar/iC4H10 82/18



Comparison mean ToT

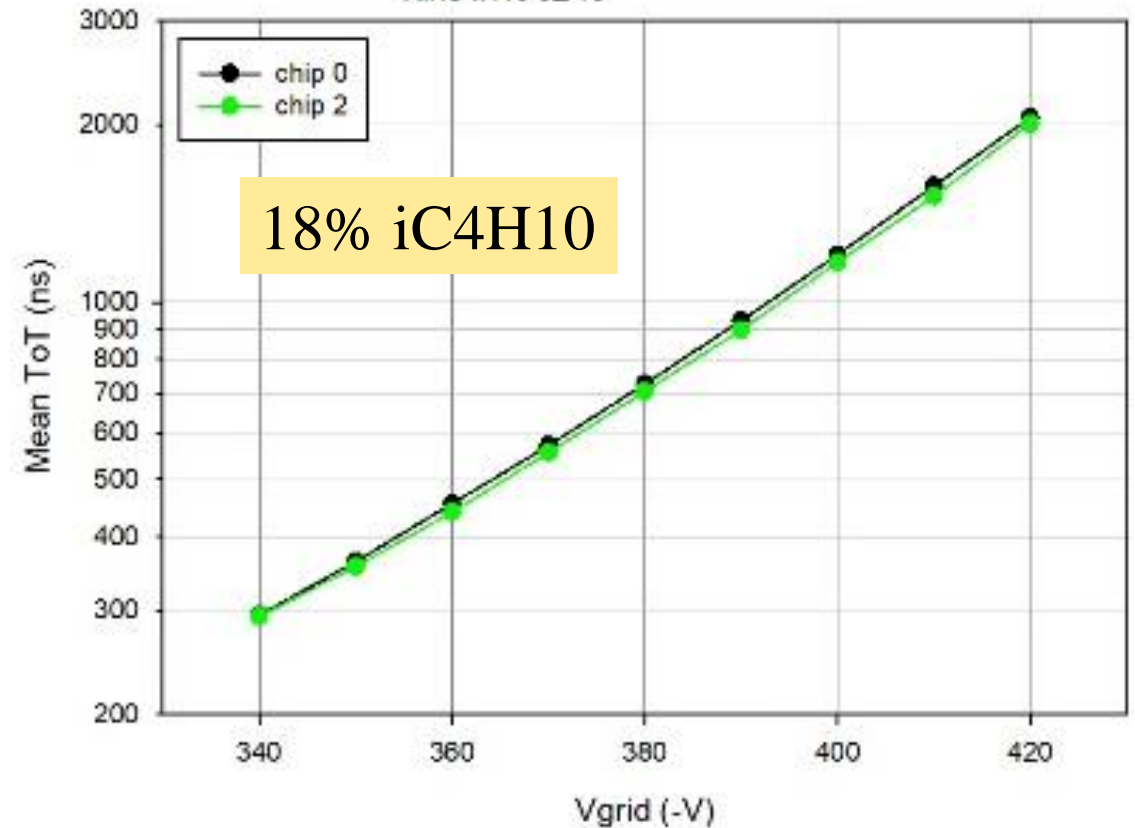
- ToT for laser measurements ~20% lower
 - ^{55}Fe values affected by pile-up?

QUAD 13 ToT vs Vgrid
 ^{55}Fe irradiation



QUAD 13 ToT vs Vgrid
 ^{55}Fe irradiation

Data 30 - 4 - 2019
Ar/iC4H10 82/18



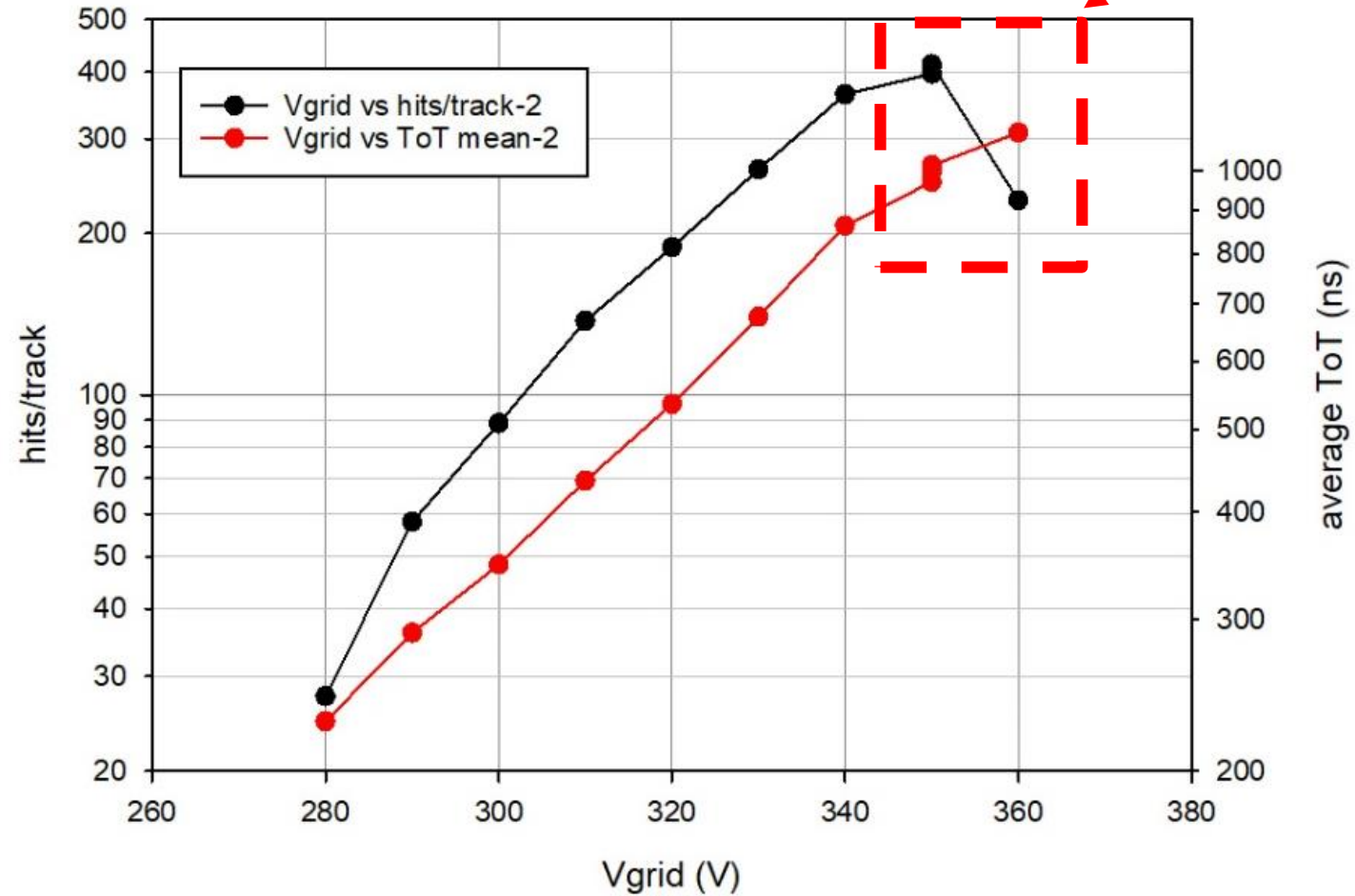
Laser measurement using T2K gas

Hits/track and ToT vs Vgrid

■ No plateau

2D Graph 1

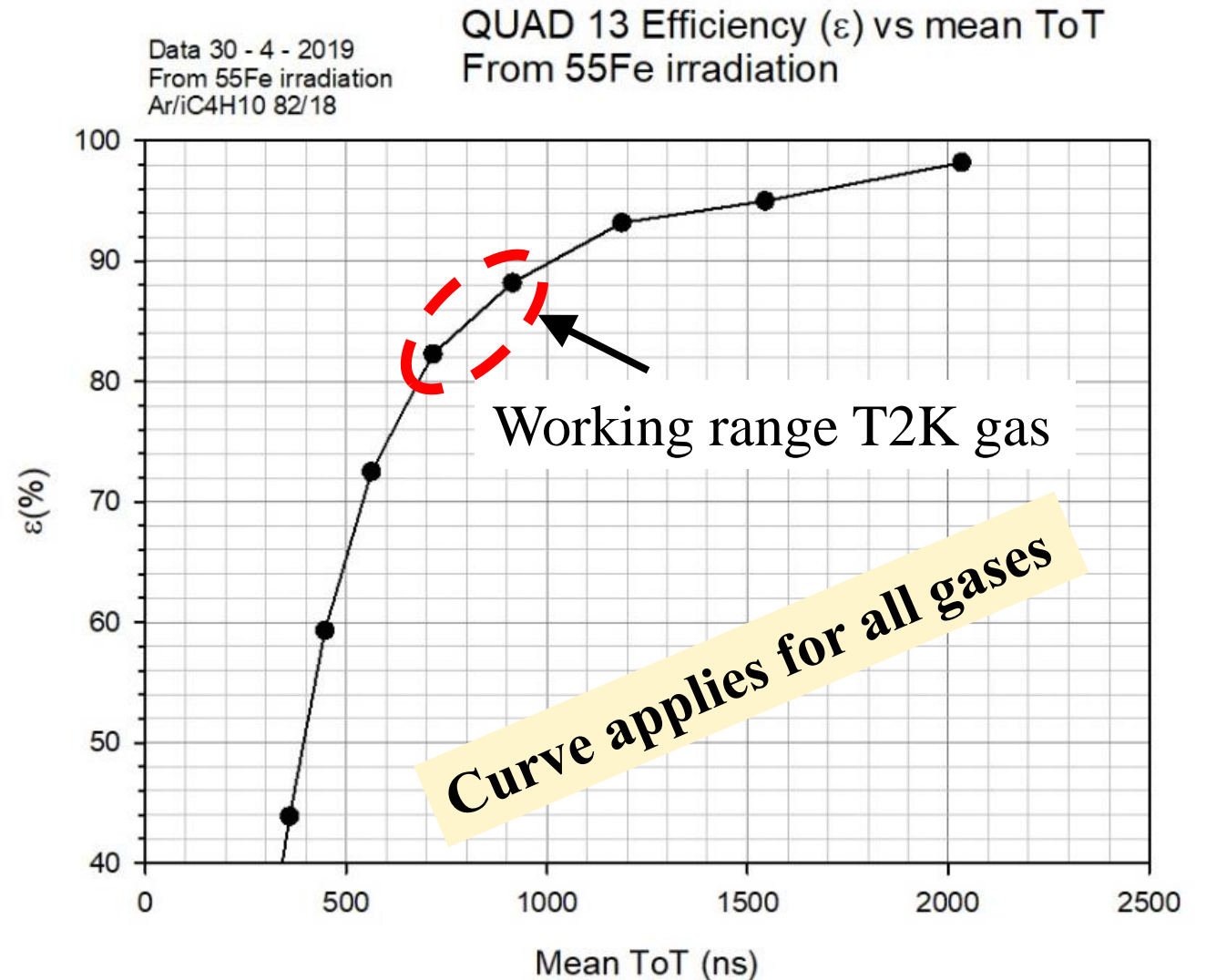
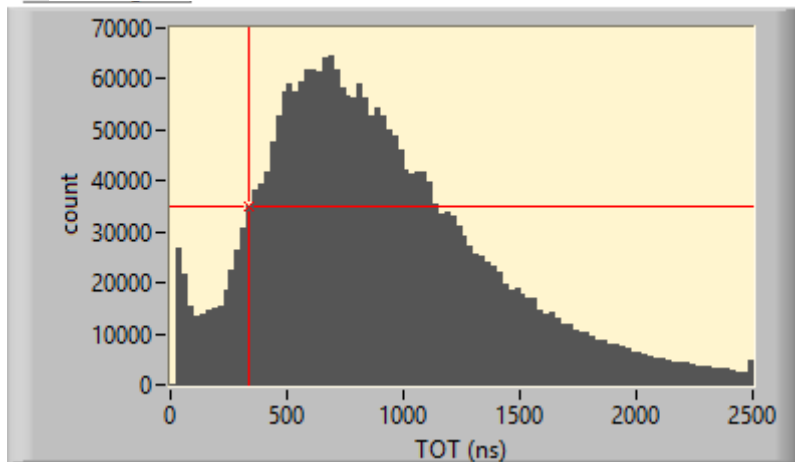
Messy region



Deduced from 18% iC_4H_{10} measurements: Single electron efficiency vs mean ToT

- For Mean ToT = 1000 ns we have 90% SE efficiency
- During testbeam:
- **Look at mean ToT => SE efficiency**

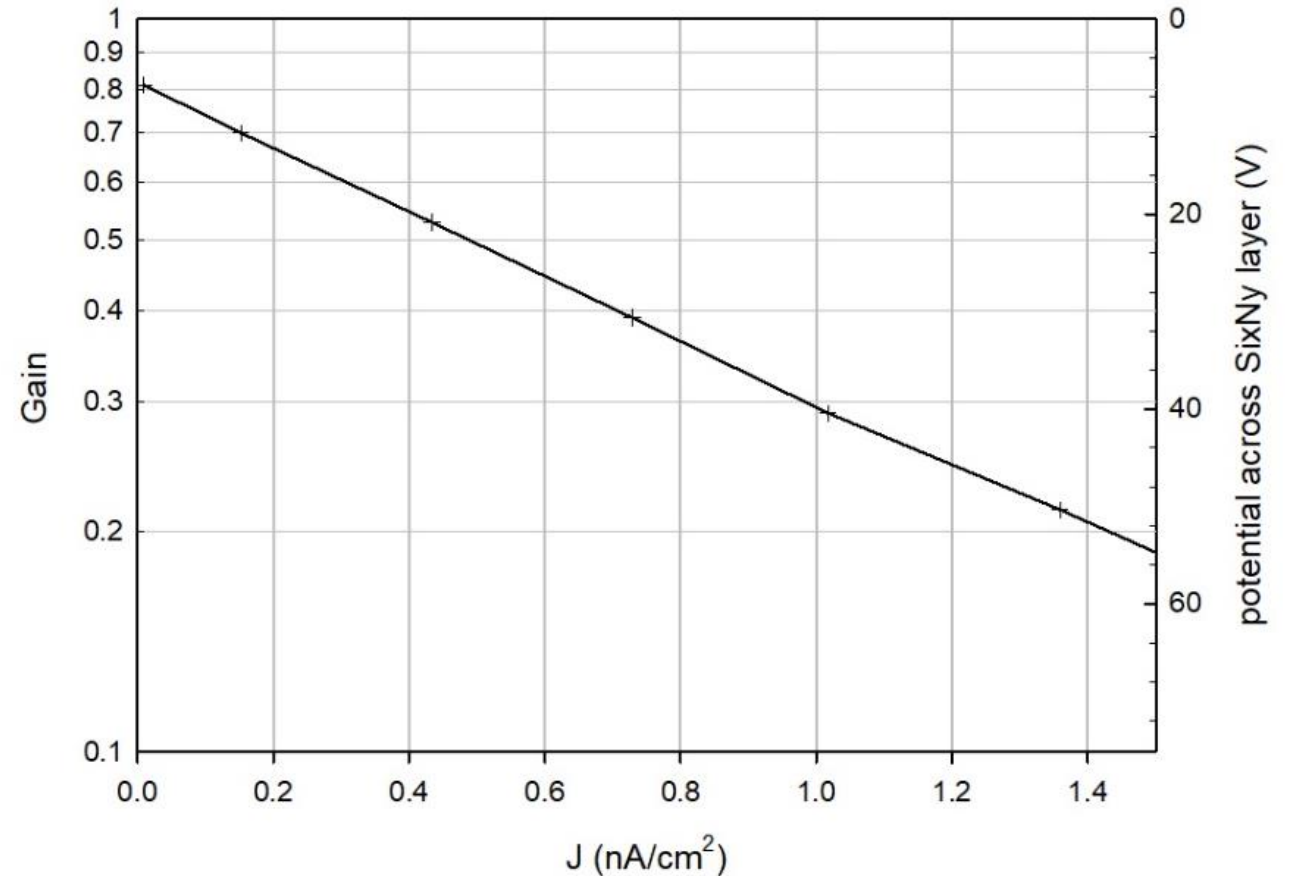
TC Example ToT spectrum



- During testbeam we may easily have **30 – 40 V potential drop** across protection layer
- => we need an extended working range

Gain vs grid current density (J)

Timepix3 with water probe
 4 μm SixNy
 Production May 2018
 Assuming gain slope 0.0306 V^{-1}
 25-3-2019



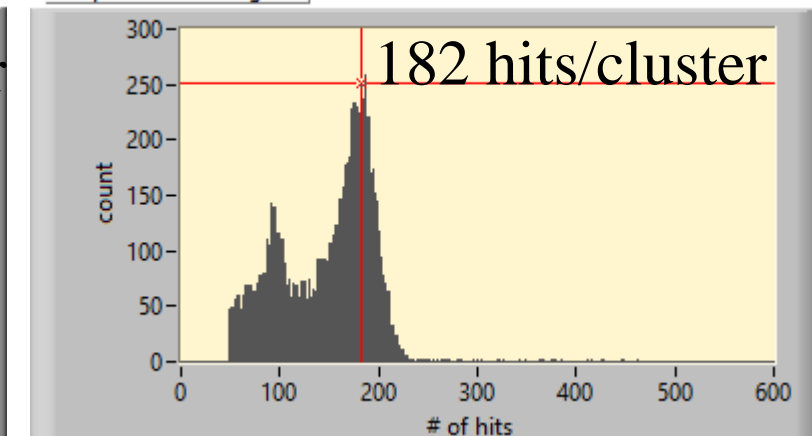
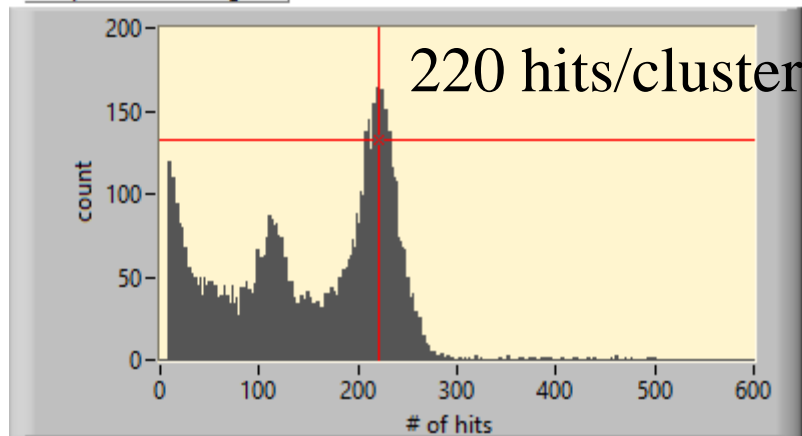
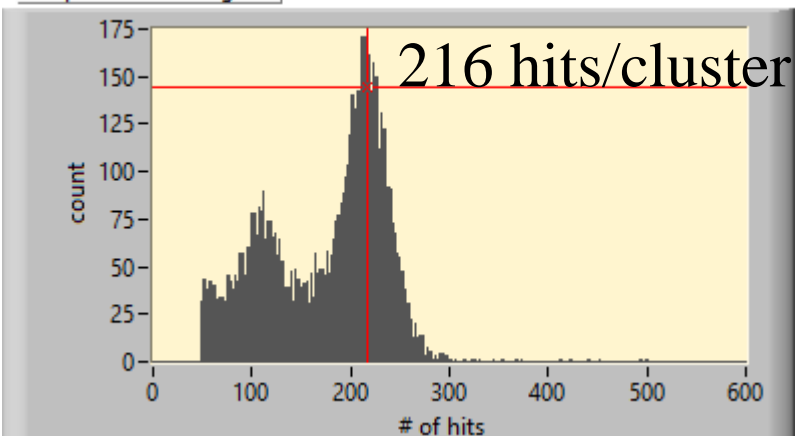
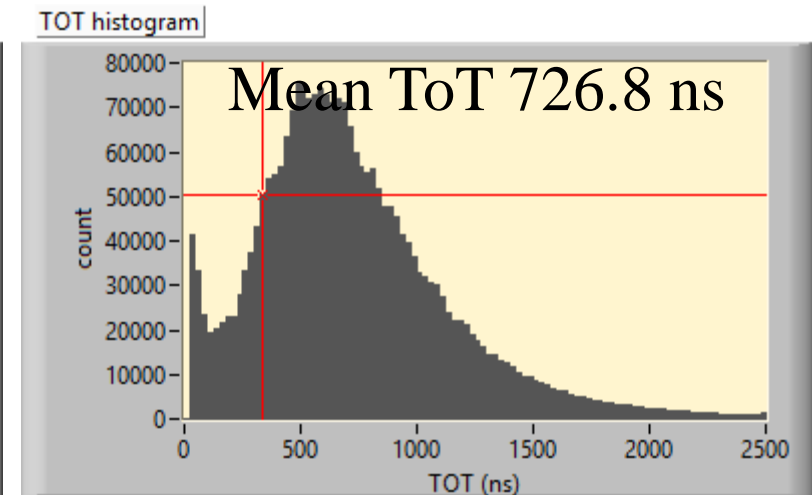
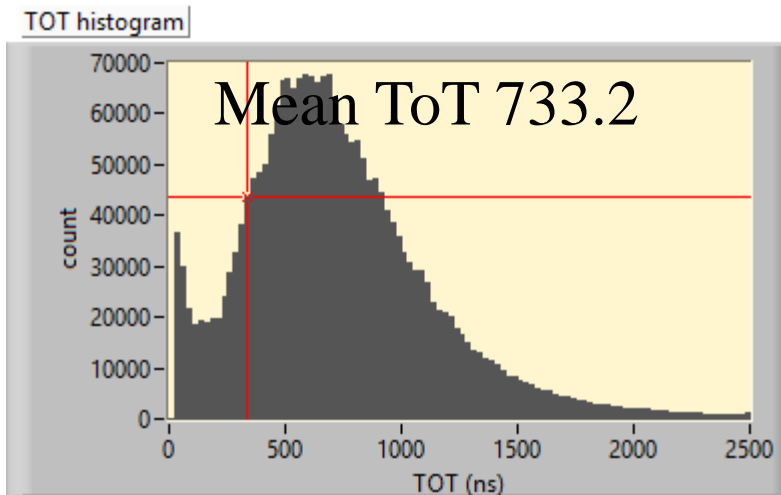
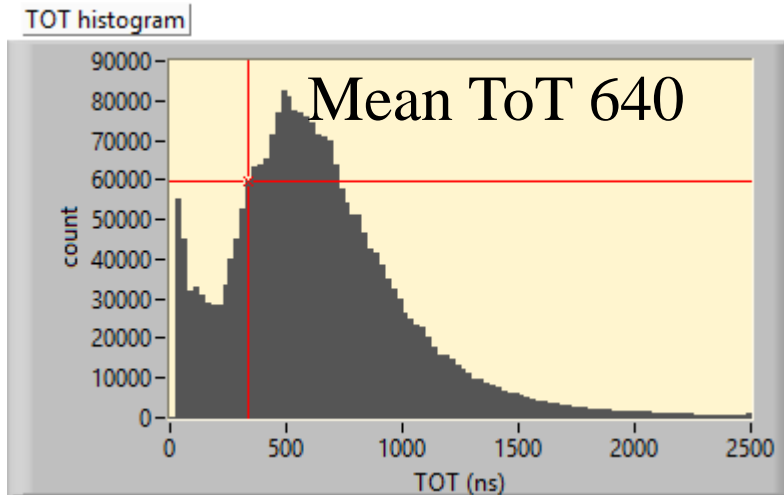
Comparison of 3 different gases for chip 0 at mean ToT = 640 – 730 ns

■ => single electron efficiency 77 – 84%

T2K -320 V

T3K -320 V

18% iC4H10 -380 V



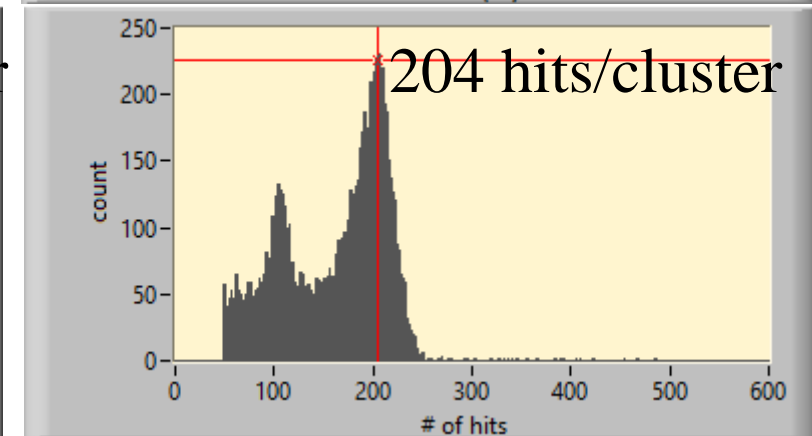
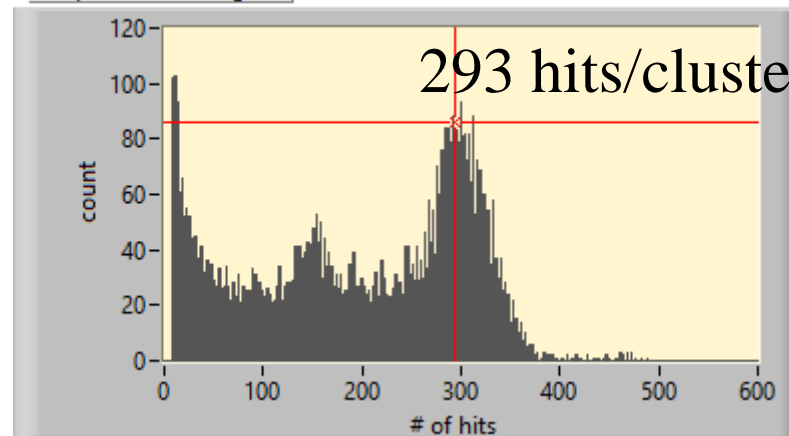
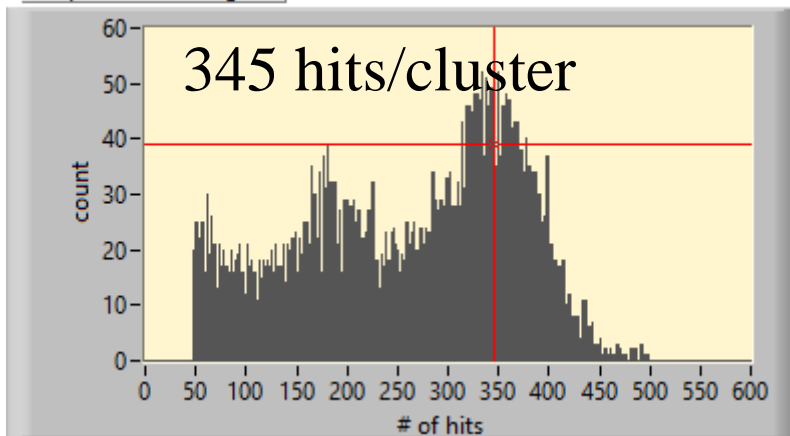
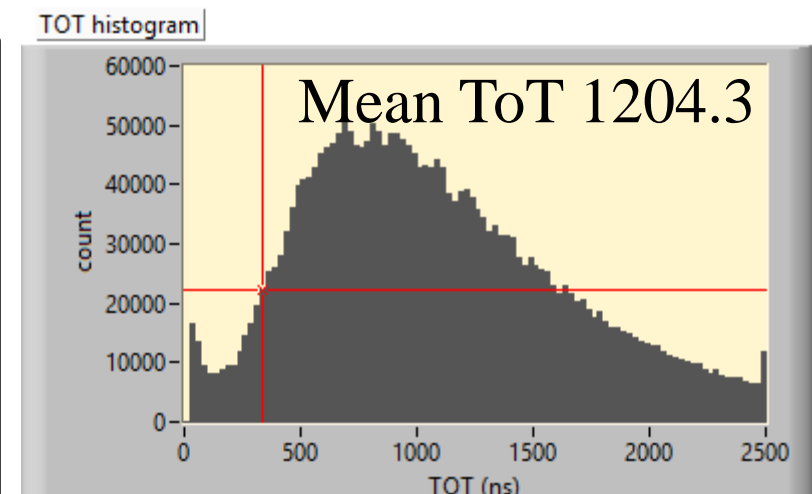
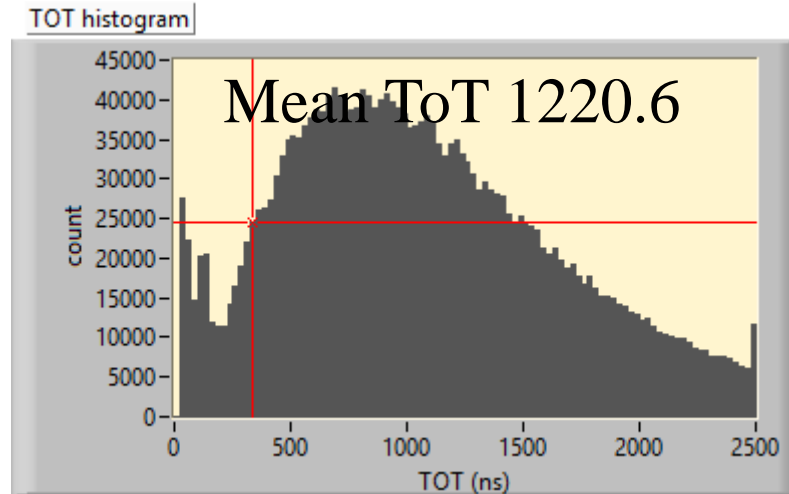
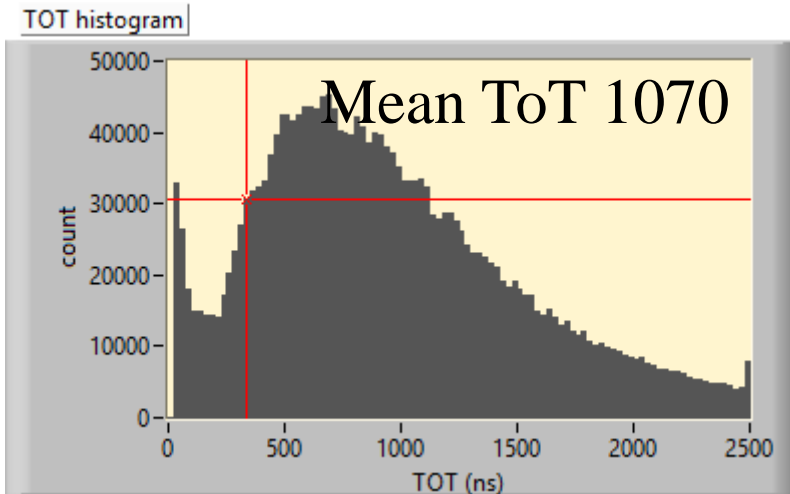
Comparison of 3 different gases for chip 0 at mean ToT = 1000 – 1200 ns

■ => single electron efficiency 90 – 93%

T2K -340 V

T3K -340 V

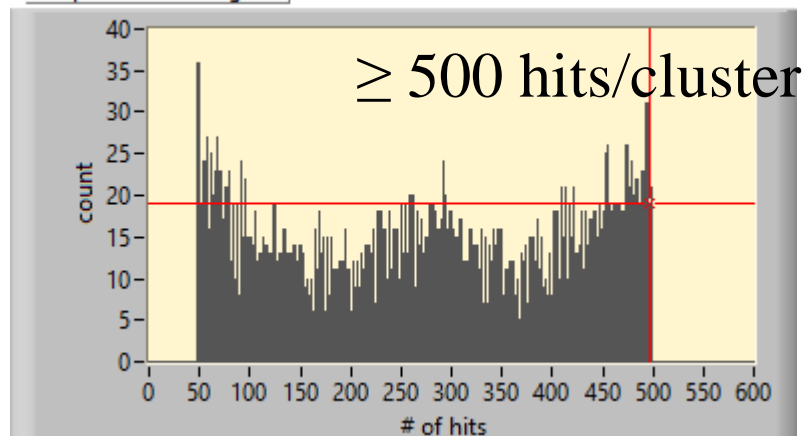
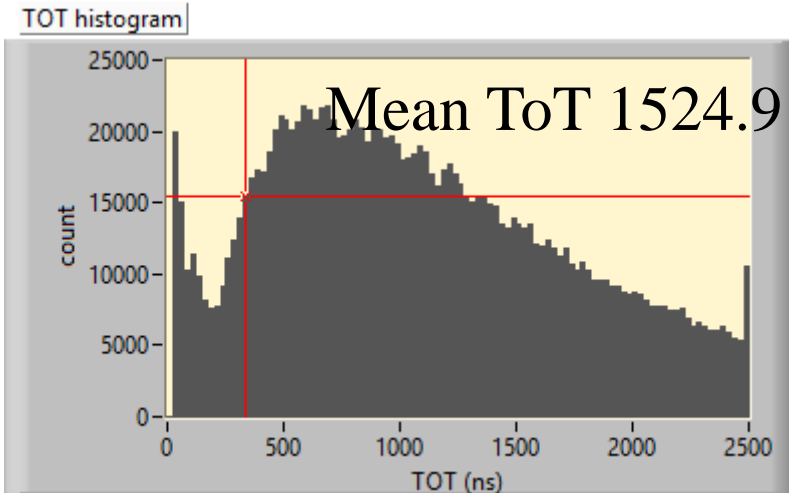
18% iC4H10 -400 V



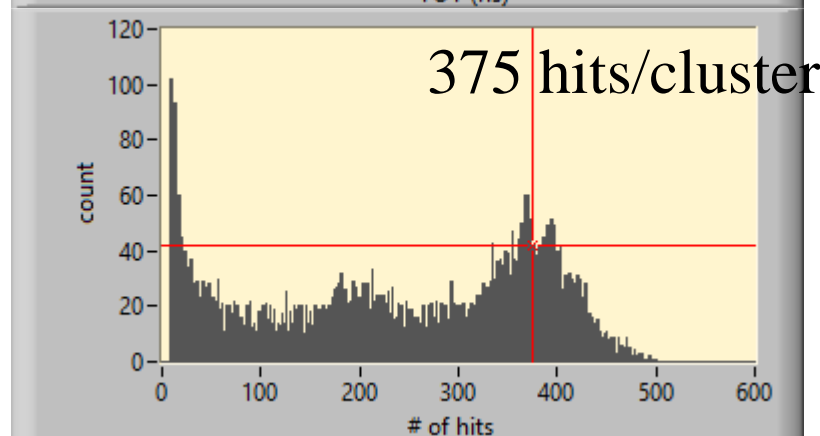
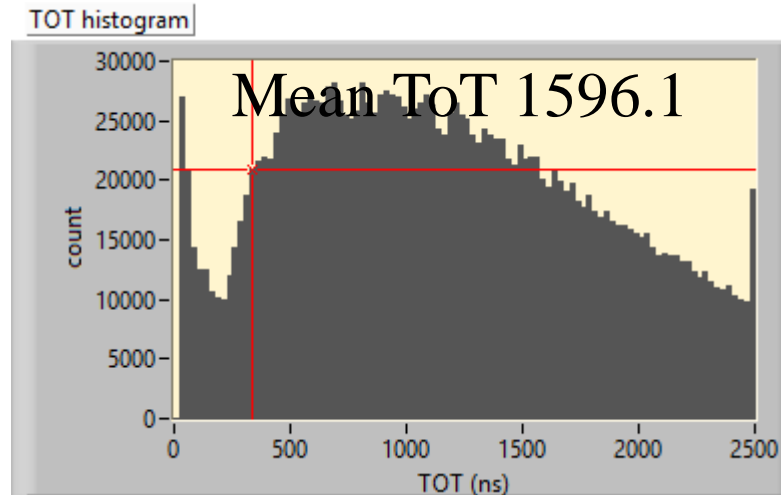
Comparison of 3 different gases for chip 0 at mean ToT = 1525 – 1600 ns

■ => single electron efficiency 95 %

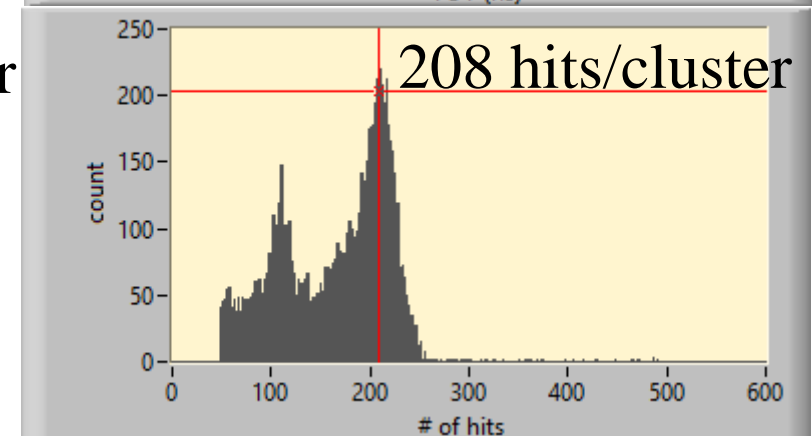
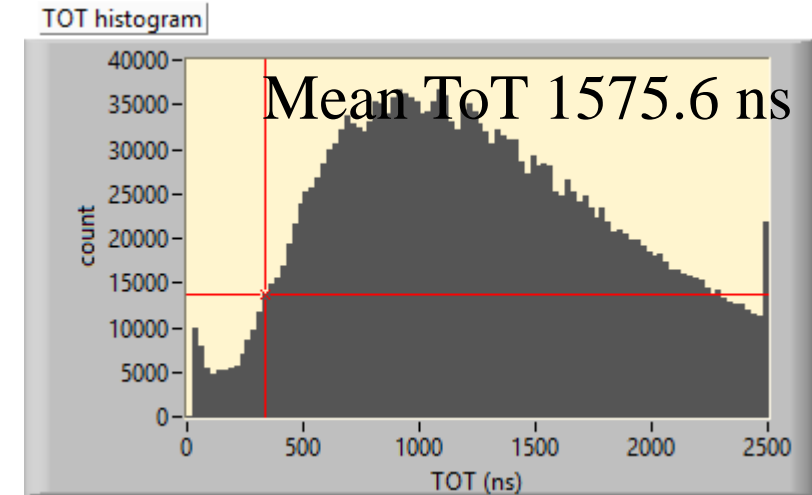
T2K -350 V



T3K -350 V

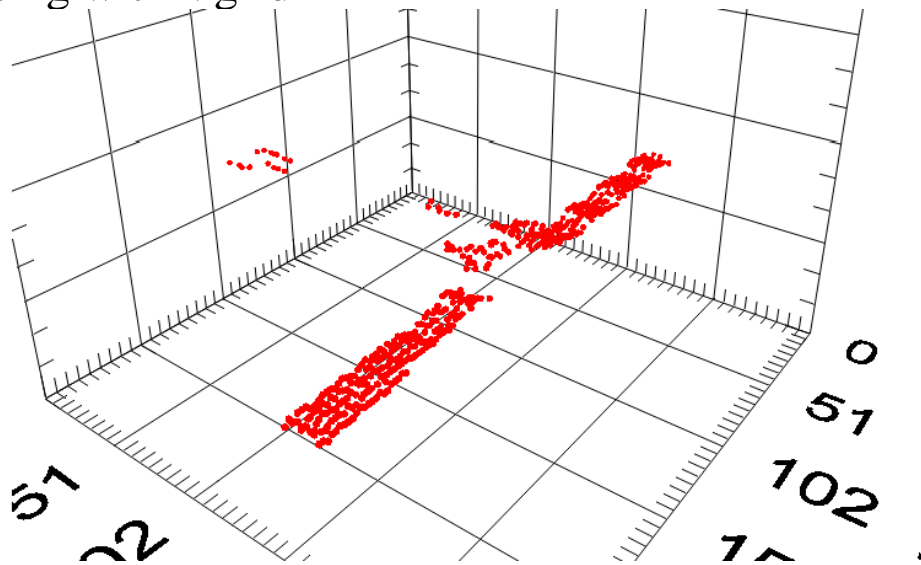


18% iC4H10 -410 V

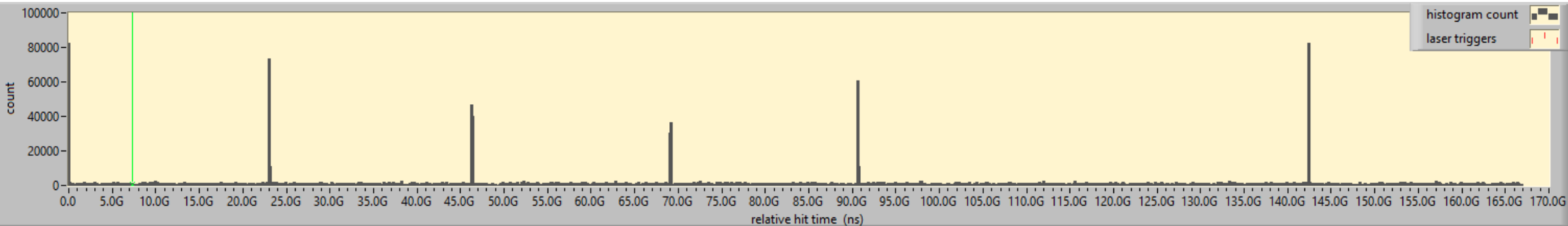
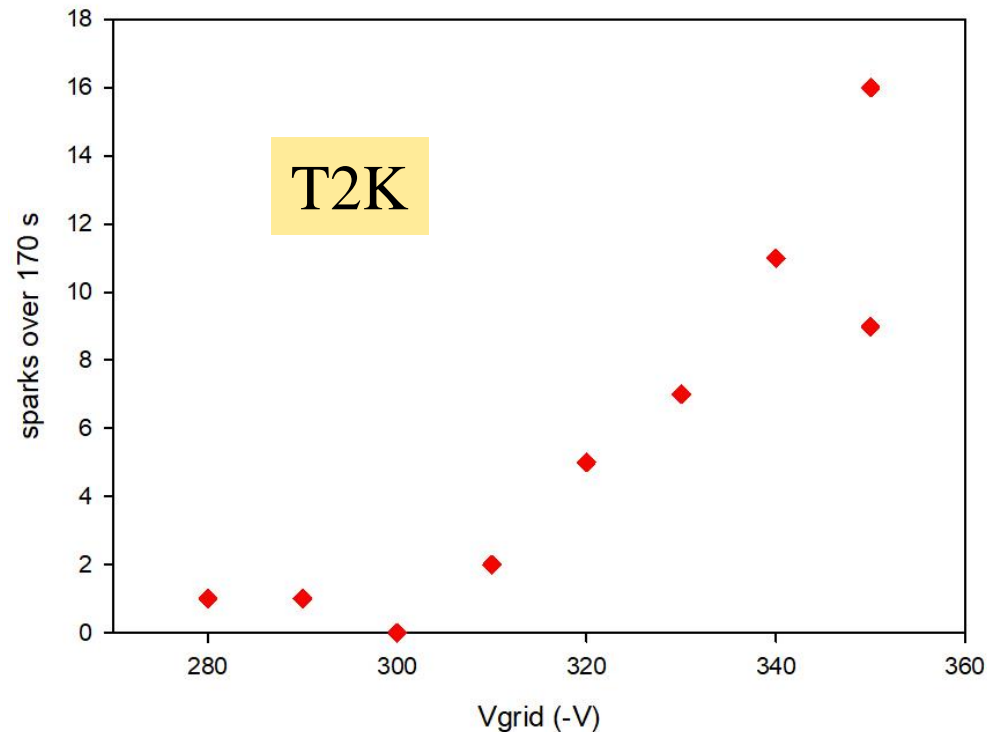


Micro discharges

- Occurring quite frequently
- Show themselves as ~50 events of ~530 hits each, separated by $409.6 \mu\text{s} \Rightarrow 20 \text{ ms}$ dead time
- **Not visible** on the current monitor of the HV supply
- Hitting all pixels on all 4 chips simultaneously
- Rate increasing with Vgrid

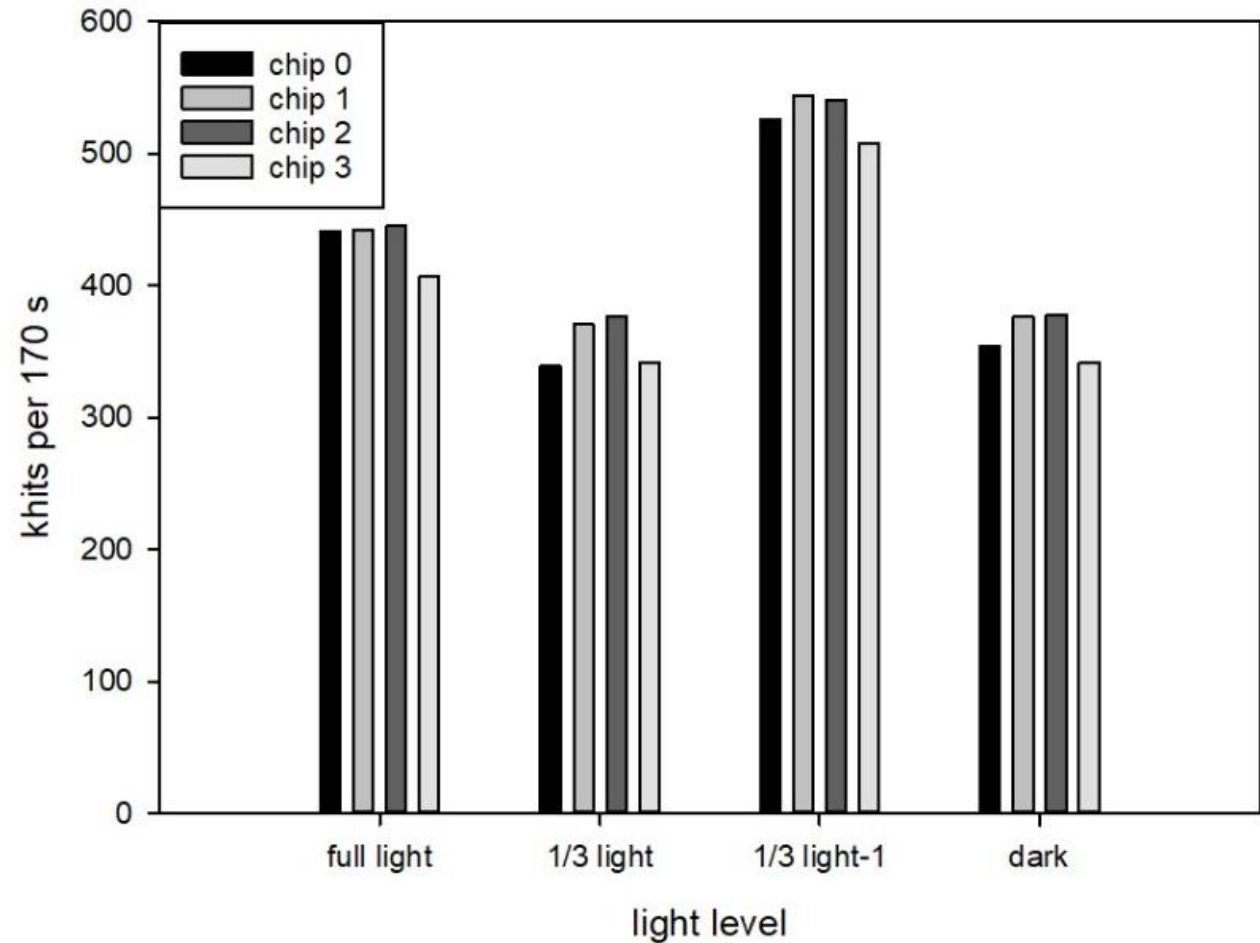


Spark frequency vs Vgrid
QUAD 13



Sensitivity to environmental light

- Hit rate in T3K gas without source at $V_{\text{grid}} = -340 \text{ V}$
- Measured with
 - All lights on
 - 1/3 lights on (the ones near the corridor wall)
 - In almost complete darkness
- => **no obvious correlation with environmental light level**

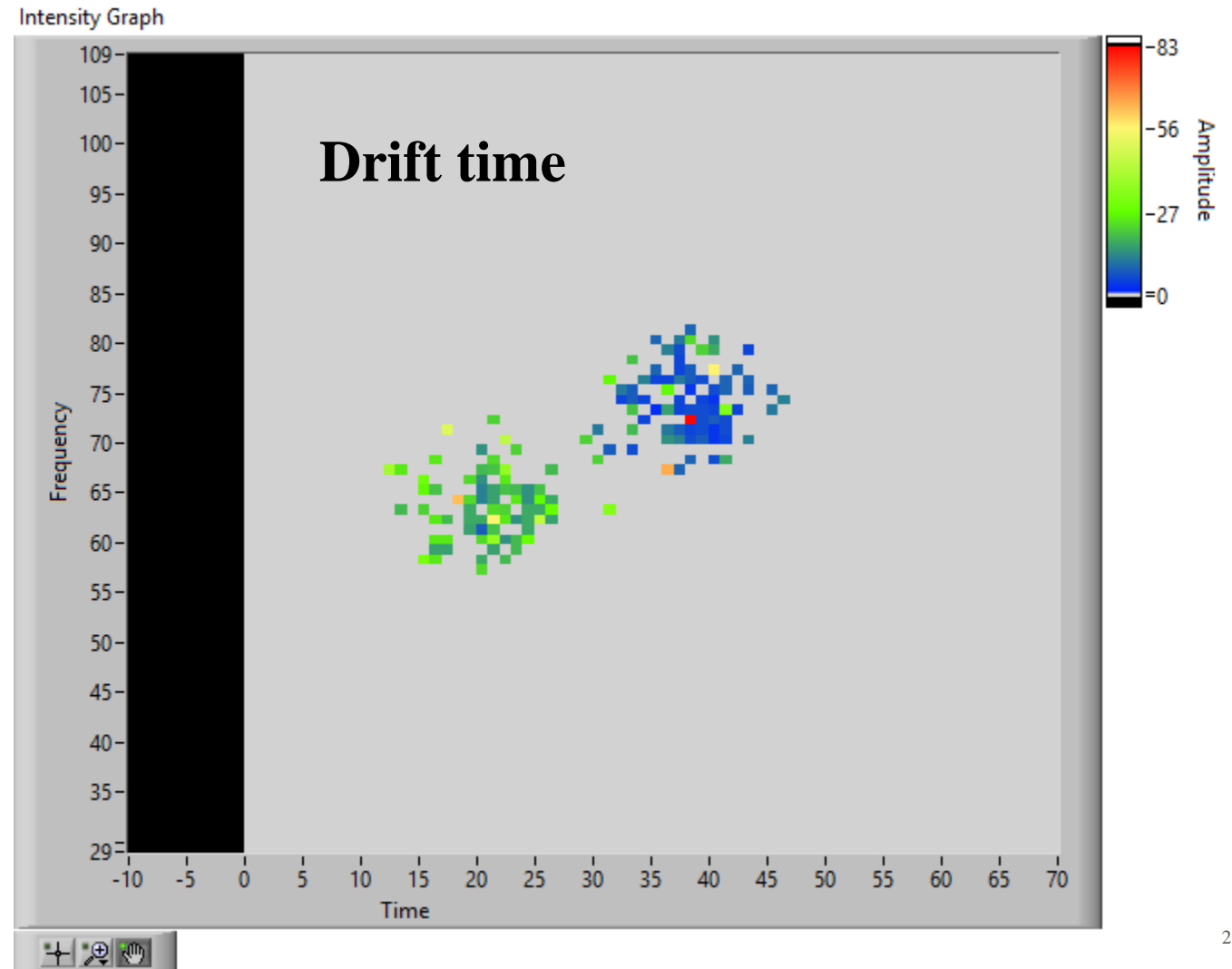


Conclusions efficiency / secondary emission measurements

- **Using well quenched gas (18% iC₄H₁₀)** gives excellent results
 - Good plateau on expected level (210 e.) => comfortable working point
 - Limited sparking: **5 micro-discharges** during Vgrid scan of 25 min
 - Good for dE/dX
- **Using T2K gas with 2% iC₄H₁₀** the performance of the present TPX3 with InGrid is problematic
 - Have to work on steep part of efficiency curve => very sensitive for rate effects
 - Many secondary emission hits, easily exceeding 100% at reasonable efficiency
 - Frequent sparking: **36 micro-discharges** during Vgrid scan of 22 min
 - Not suited for reliable dE/dX
- **Using T3K (3% iC₄H₁₀)** secondary emission is about reduced by a factor of 2
 - We would need ~ 10 % iC₄H₁₀ to bring the secondary emission down to an acceptable level (T9K)
- **Secondary emission** depends on
 - Amount of quencher in the gas
 - Distance anode – grid
 - Material/surface treatment of the grid (Cu is much better than Al)

Just some fun: two events almost simultaneously

- Event 982
- Ar/iC4H10 82/18
- Chip 2
- 400V
- Close to the grid



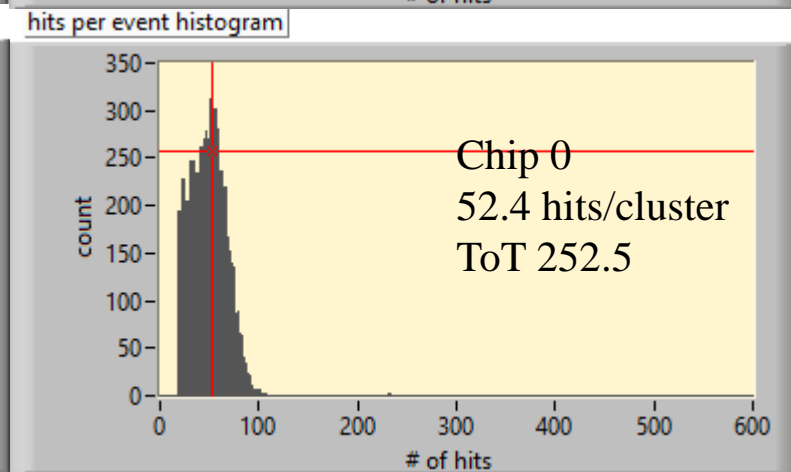
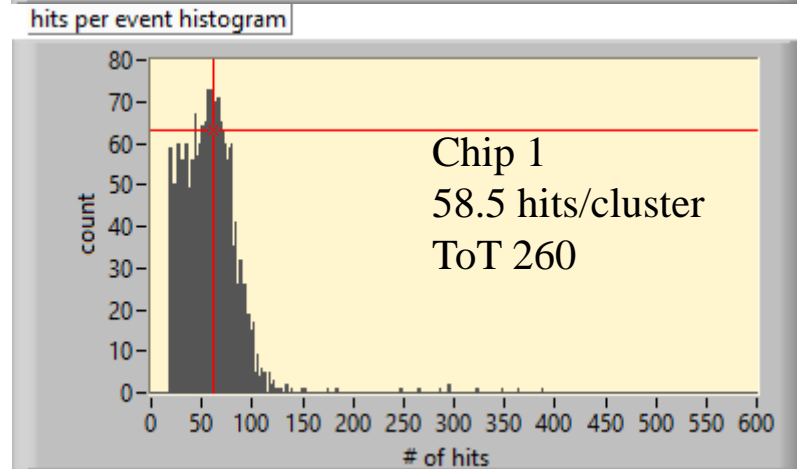
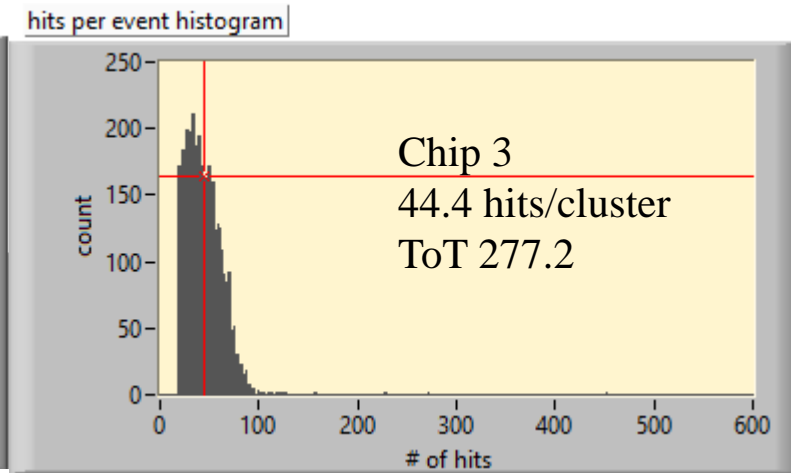
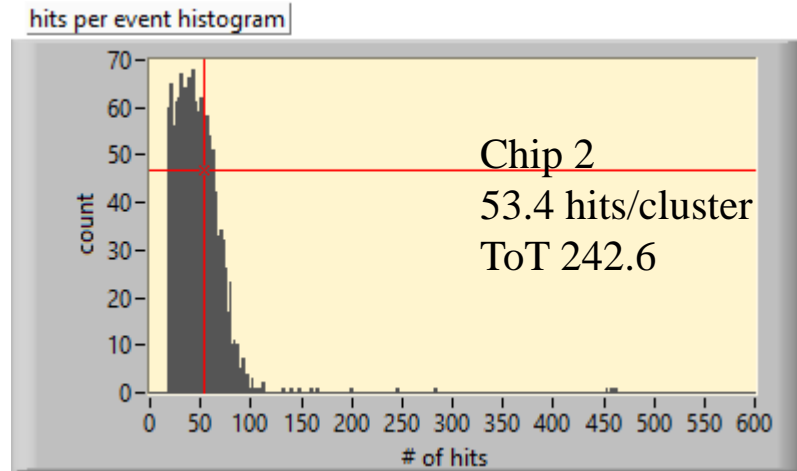
Reference

T2K

(iC4H10/CF4/Ar 2/3/95)

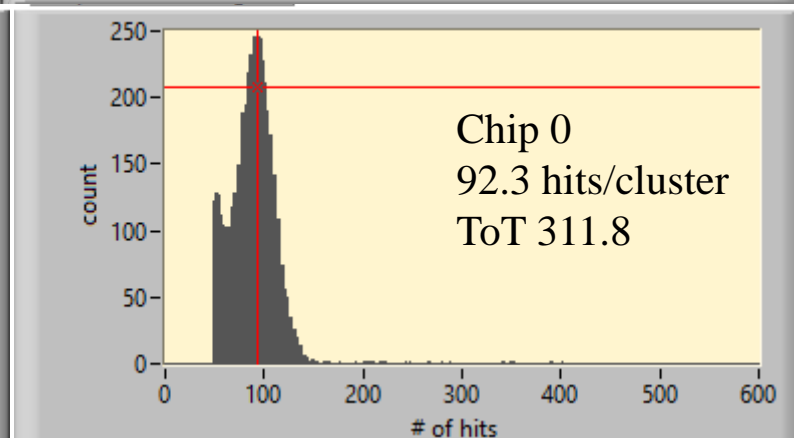
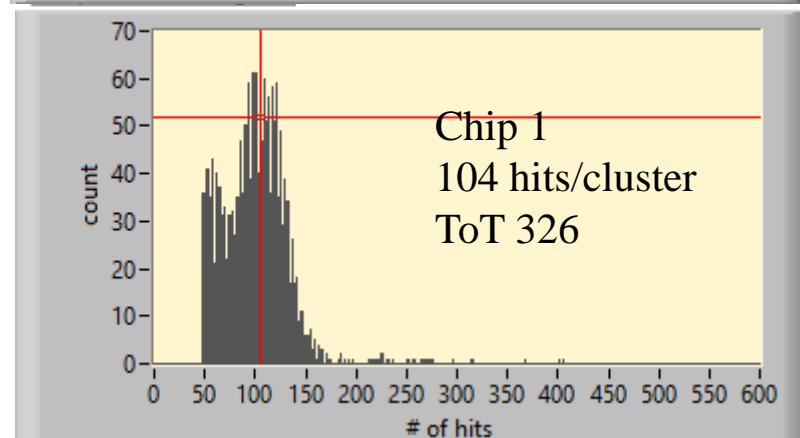
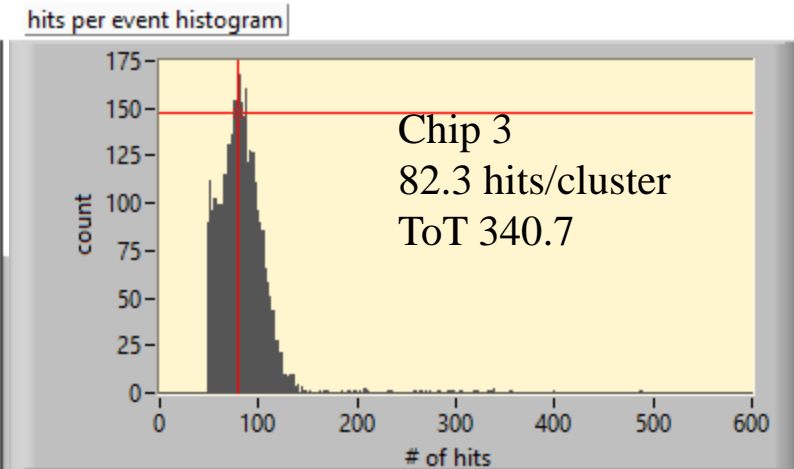
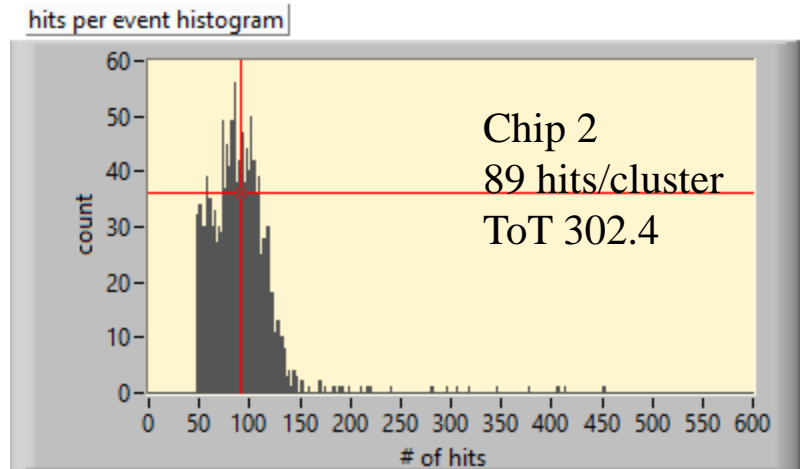
280 V

- 1 micro discharge



290 V

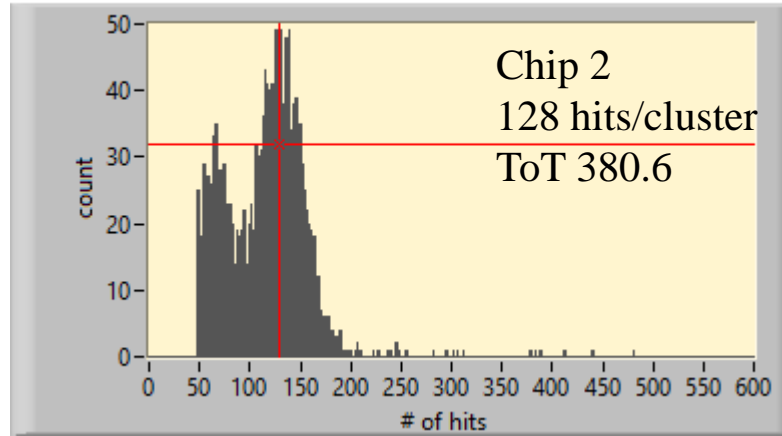
- 1 micro discharge



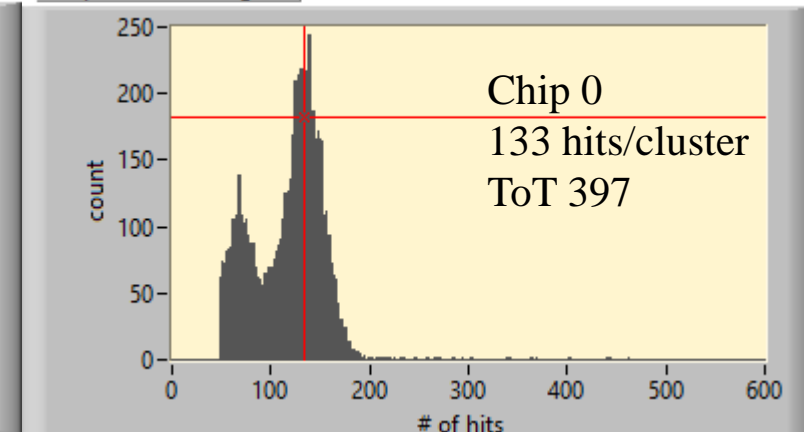
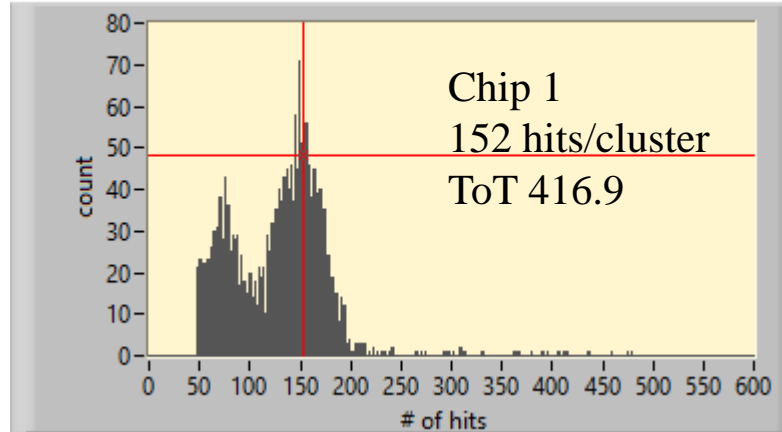
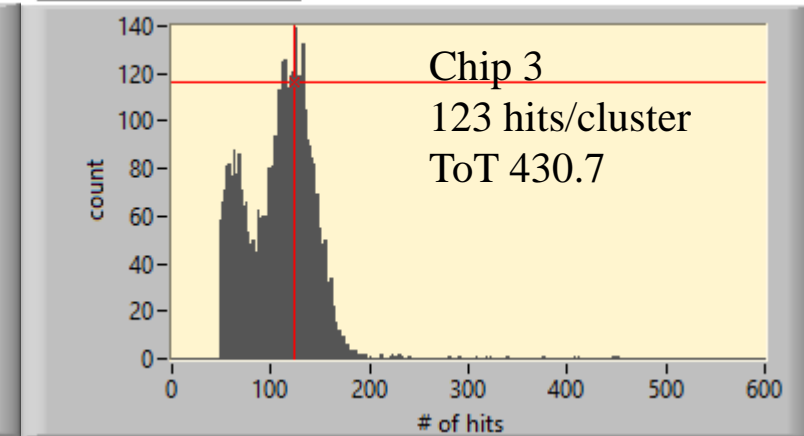
300 V

- No discharges

hits per event histogram



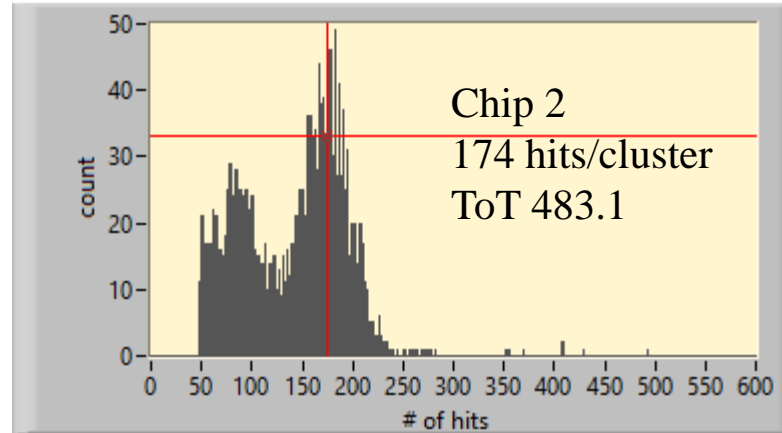
hits per event histogram



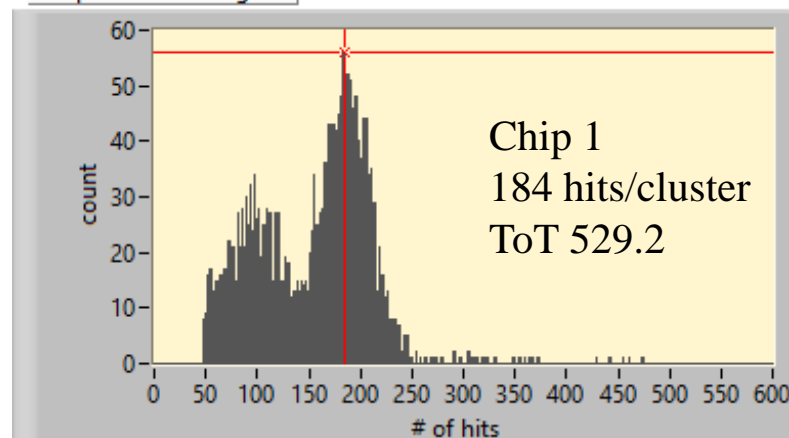
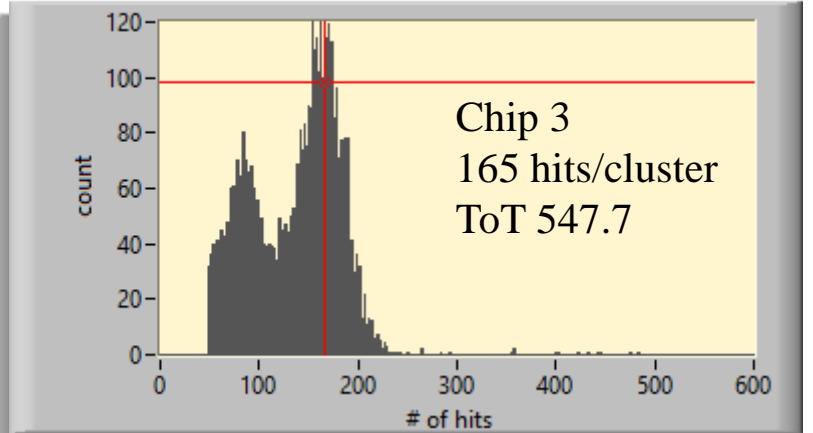
310 V

- 2 micro discharges

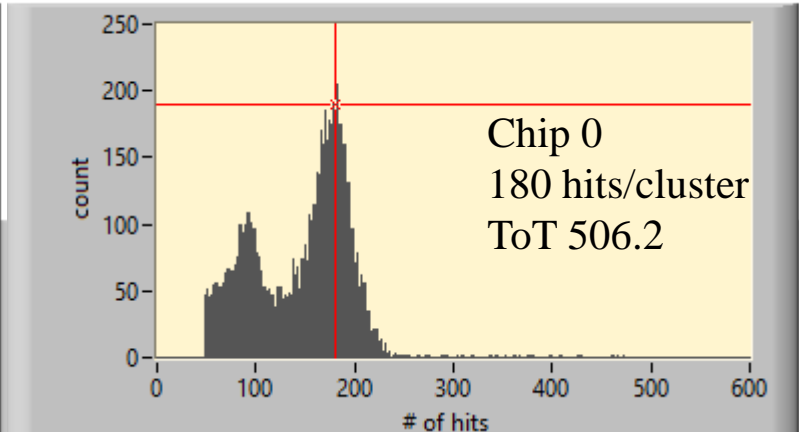
hits per event histogram



hits per event histogram

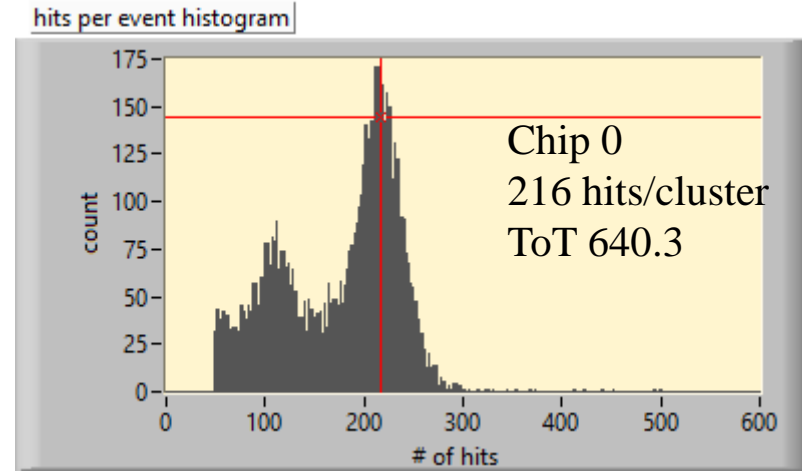
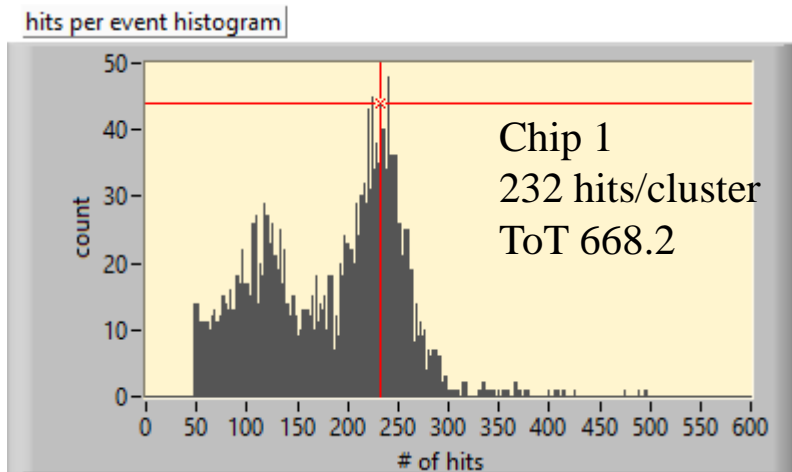
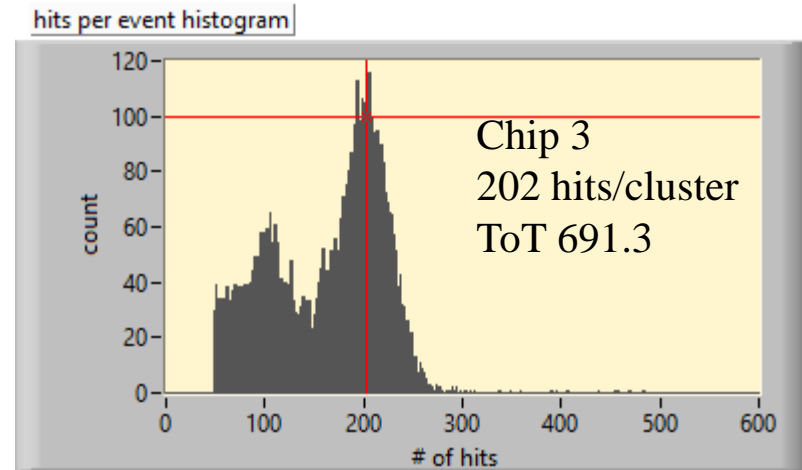
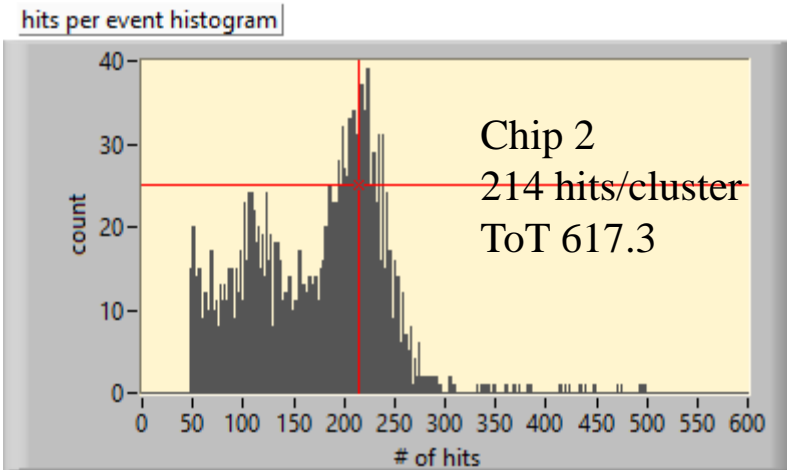


hits per event histogram



320 V

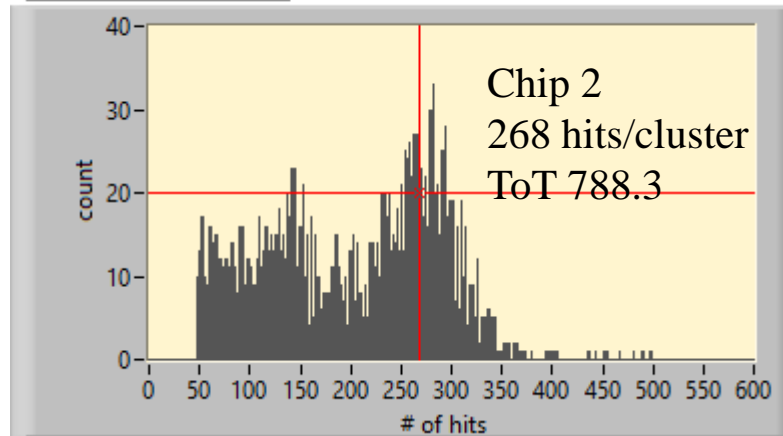
- 5 micro discharges



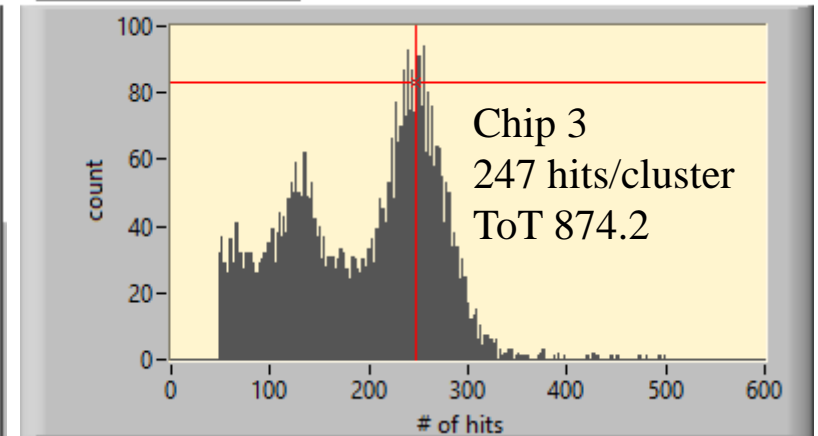
330 V

- 7 micro discharges

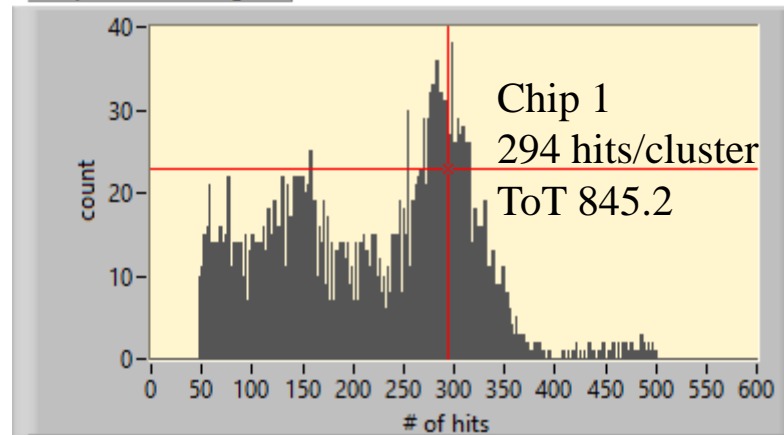
hits per event histogram



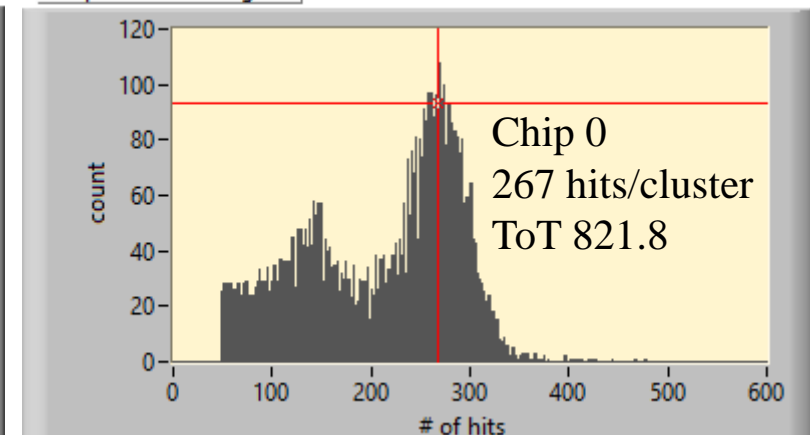
hits per event histogram



hits per event histogram



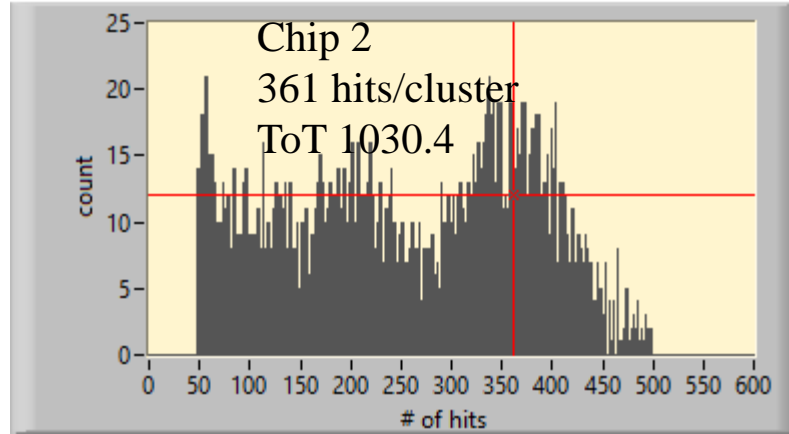
hits per event histogram



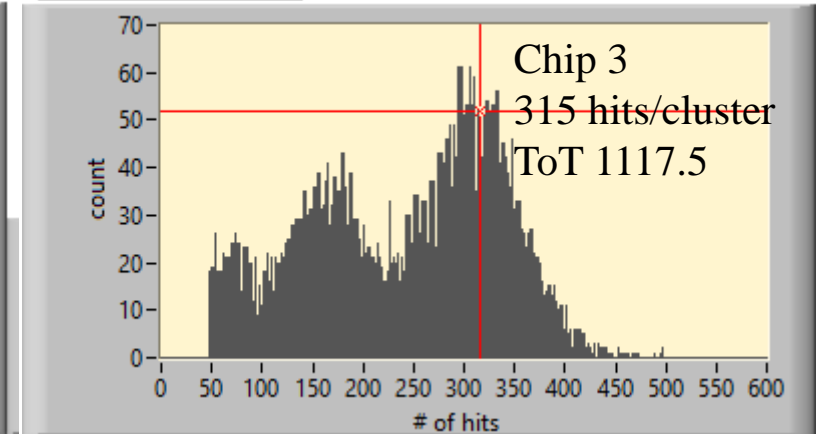
340 V

- 11 micro discharges

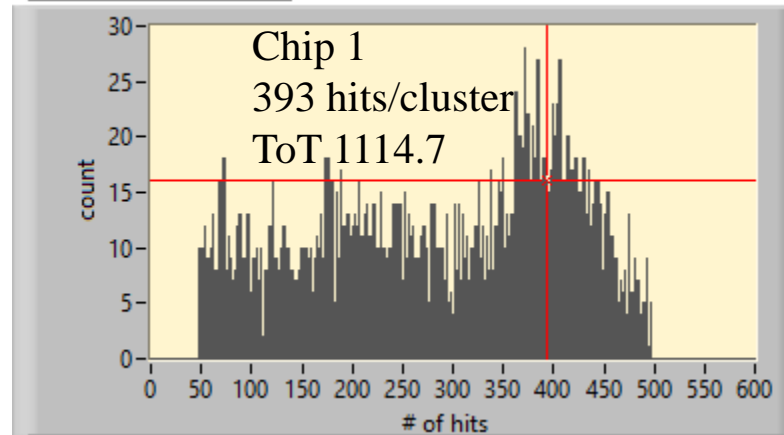
hits per event histogram



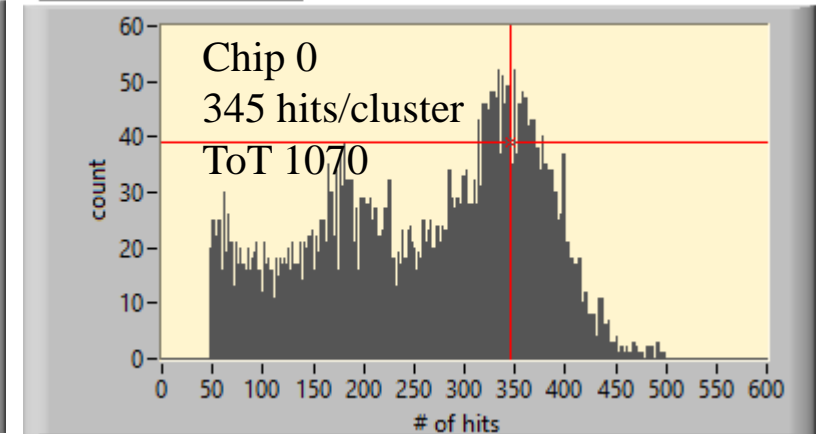
hits per event histogram



hits per event histogram

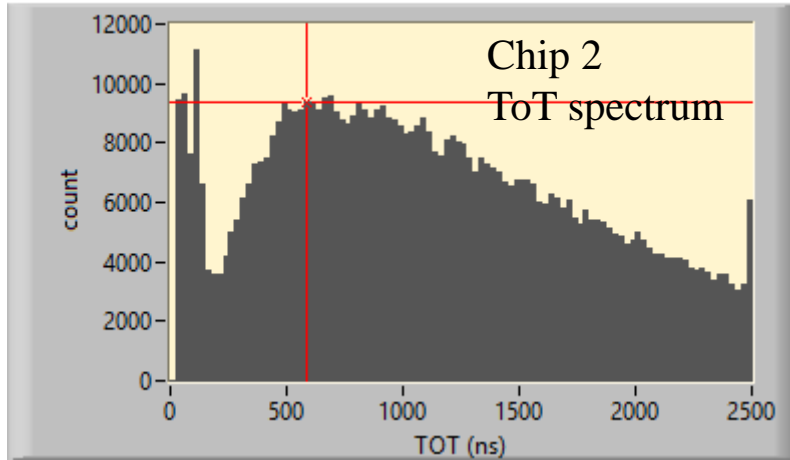


hits per event histogram

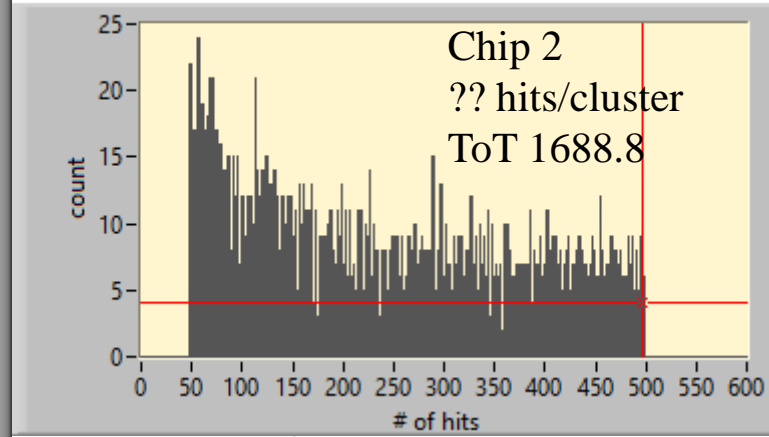


350 V

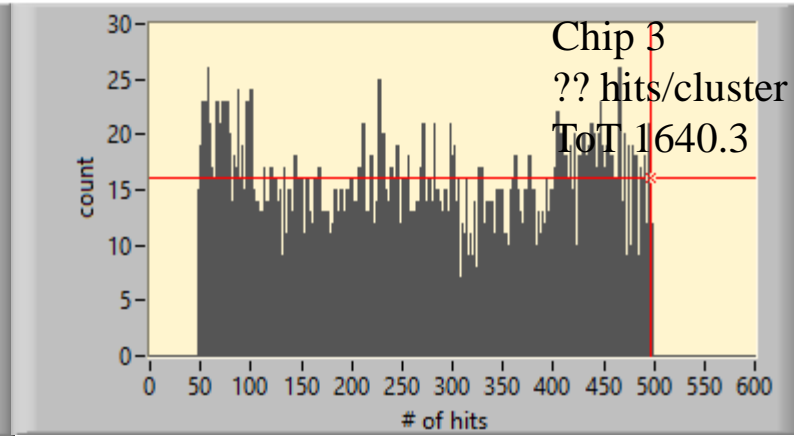
TOT histogram



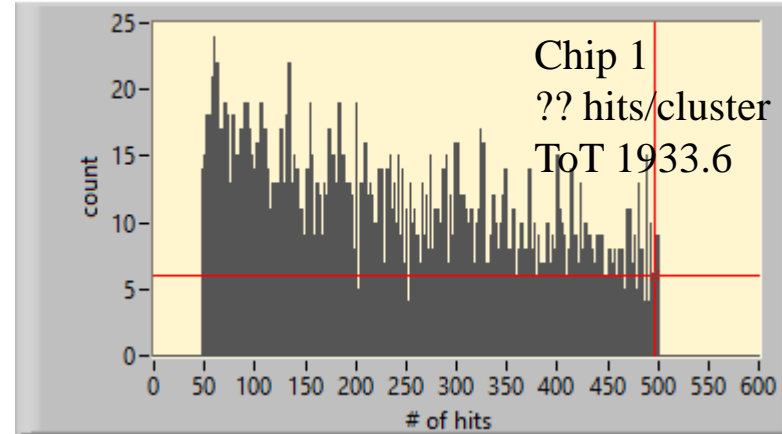
hits per event histogram



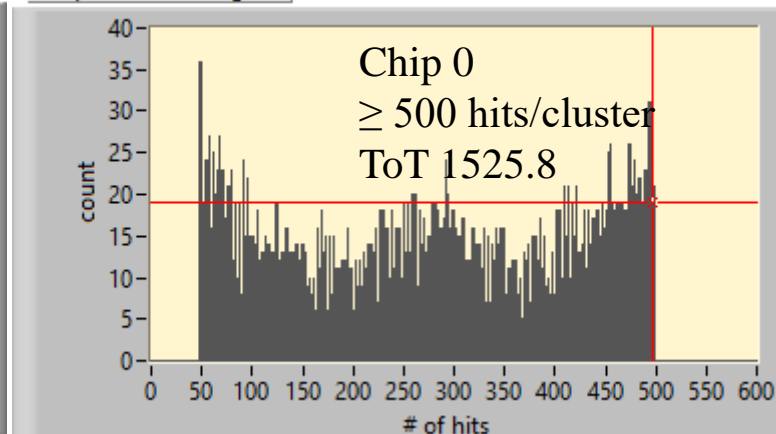
hits per event histogram



hits per event histogram



hits per event histogram

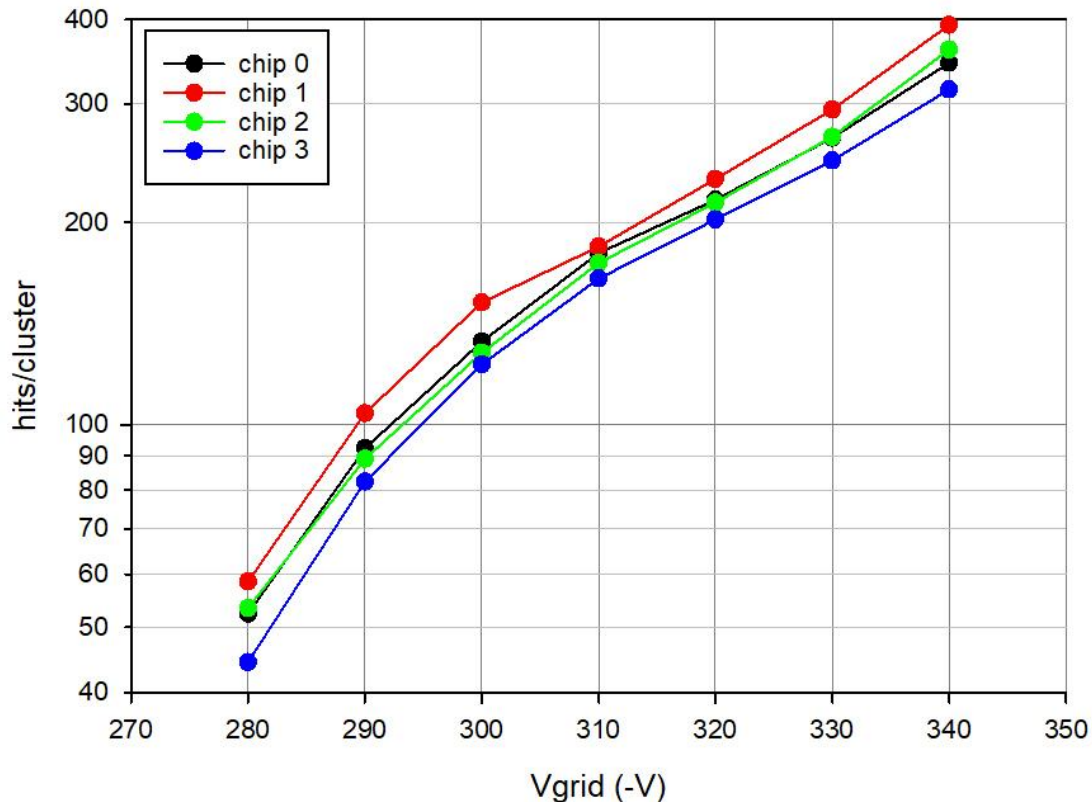


■ 9 micro discharges

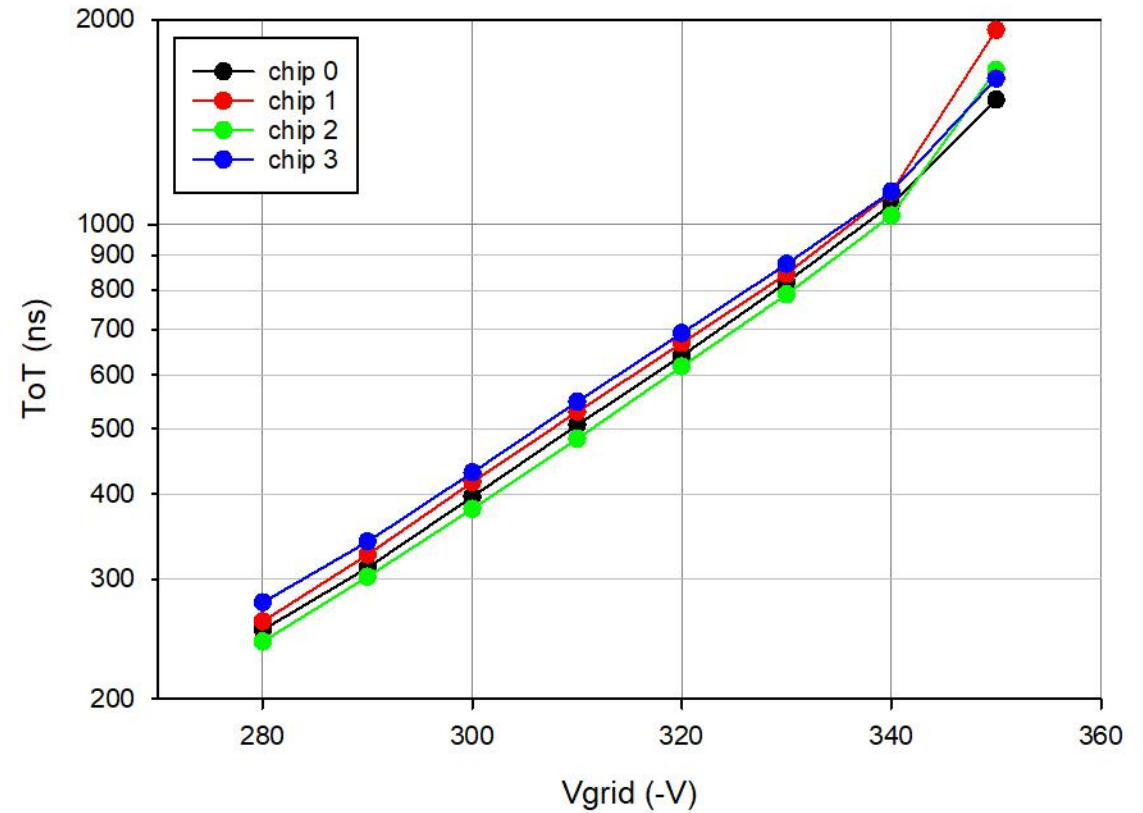
No plateau visible in hits/cluster

- Results agree with laser measurements
- Above 320 V much more hits than the number of primary electrons
- Possible cause: **secondary emission** from the grid by UV light from the avalanche
- May be solved by more quencher in the gas (iC4H10)

QUAD 13 hits/cluster vs Vgrid
55Fe irradiation

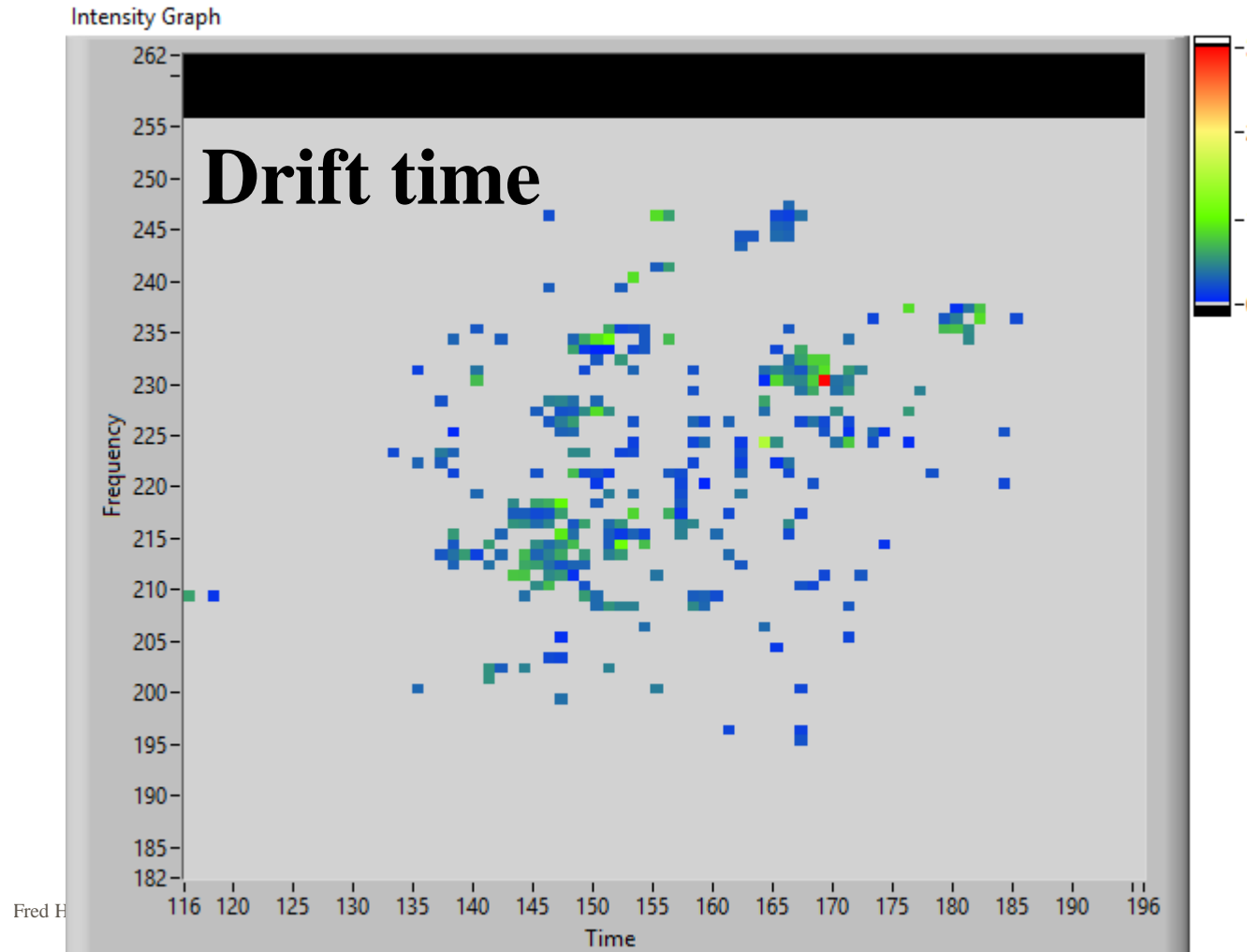
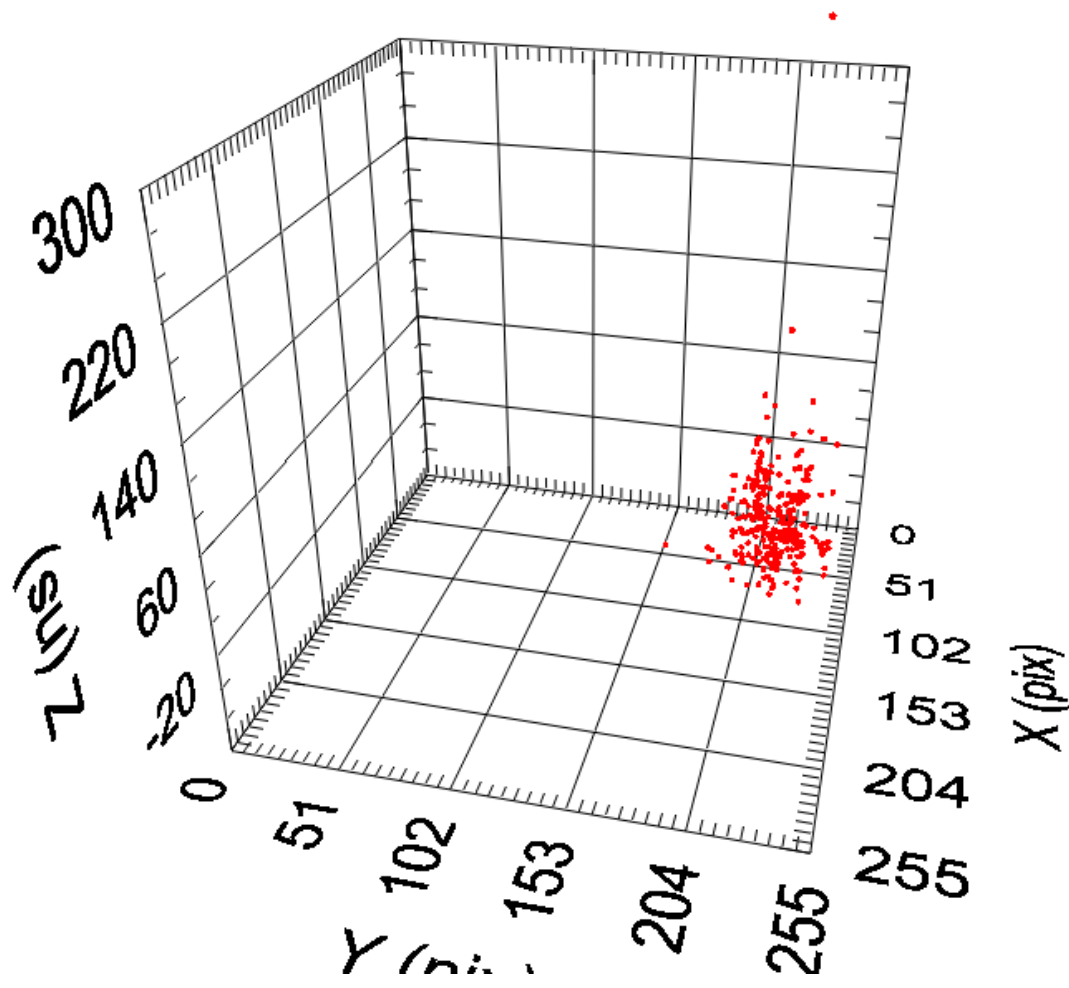


QUAD 13 ToT vs Vgrid
55Fe irradiation



- NO ToT correction
- 288 hits
- 215 neighbours
- **Tendency of clustering**

Event at $V_{grid} = -350$ V

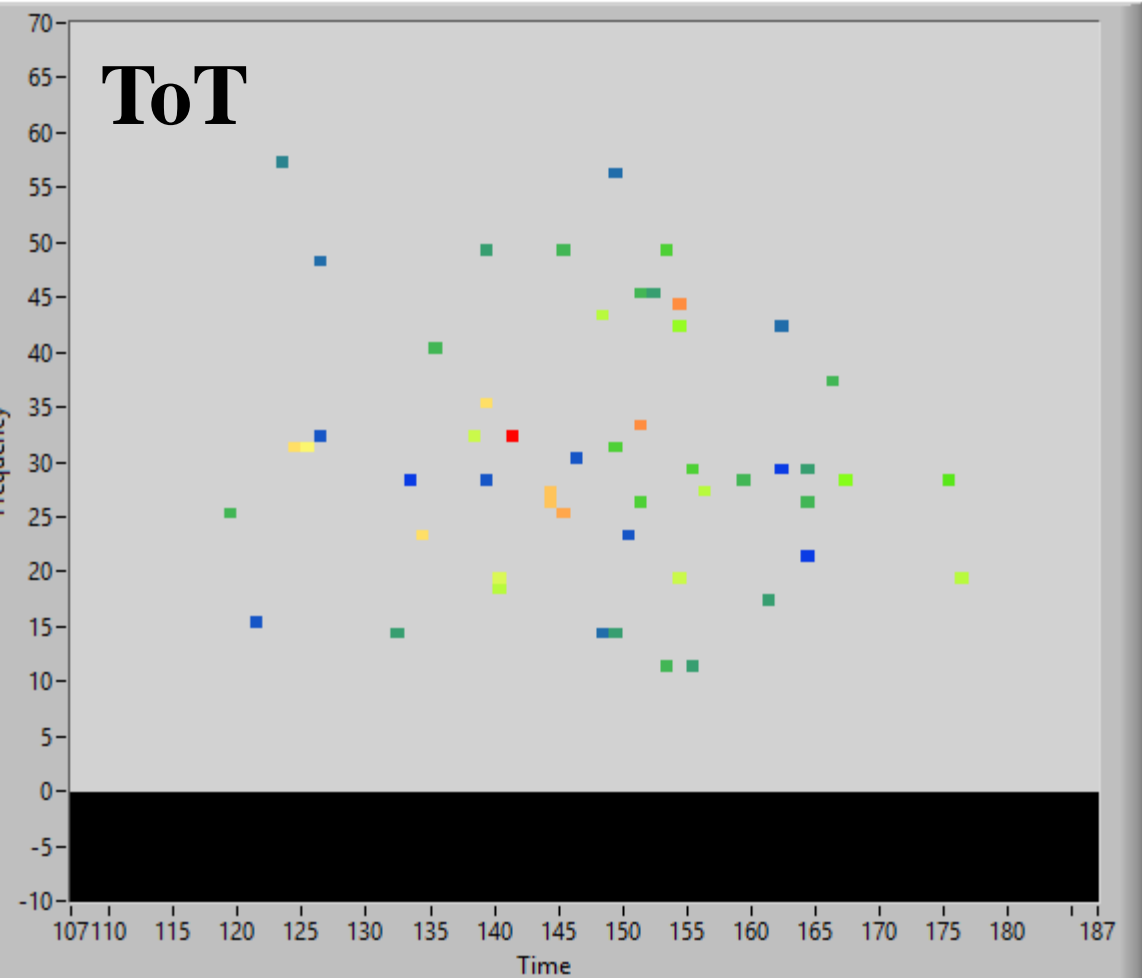


Events

$V_{\text{grid}} = -280 \text{ V}$

52 hits, 5 neighbours

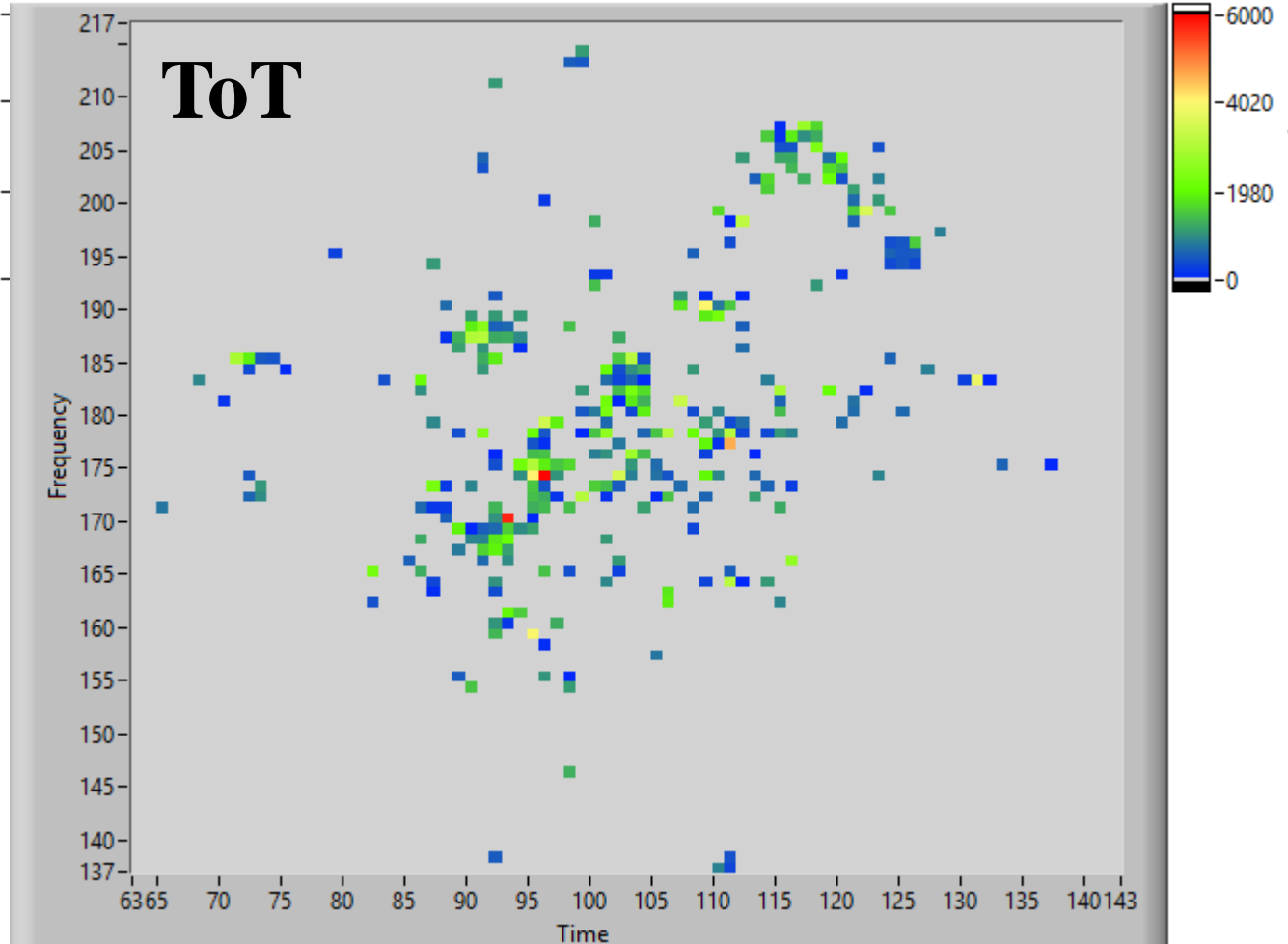
Intensity Graph



$V_{\text{grid}} = -350 \text{ V}$

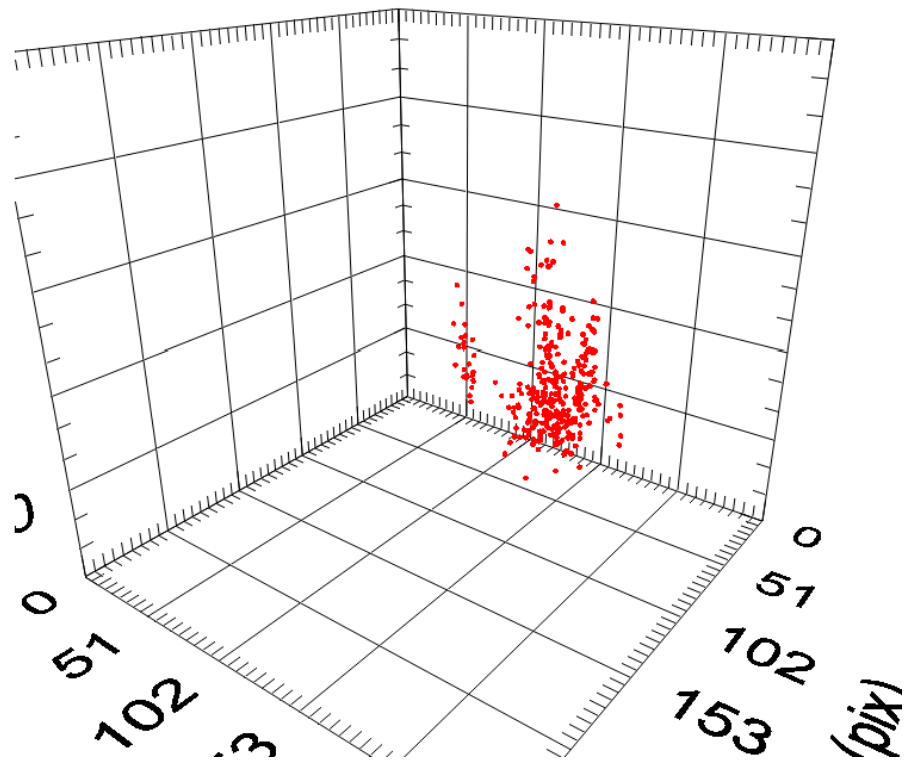
338 hits, 239 neighbours

Intensity Graph



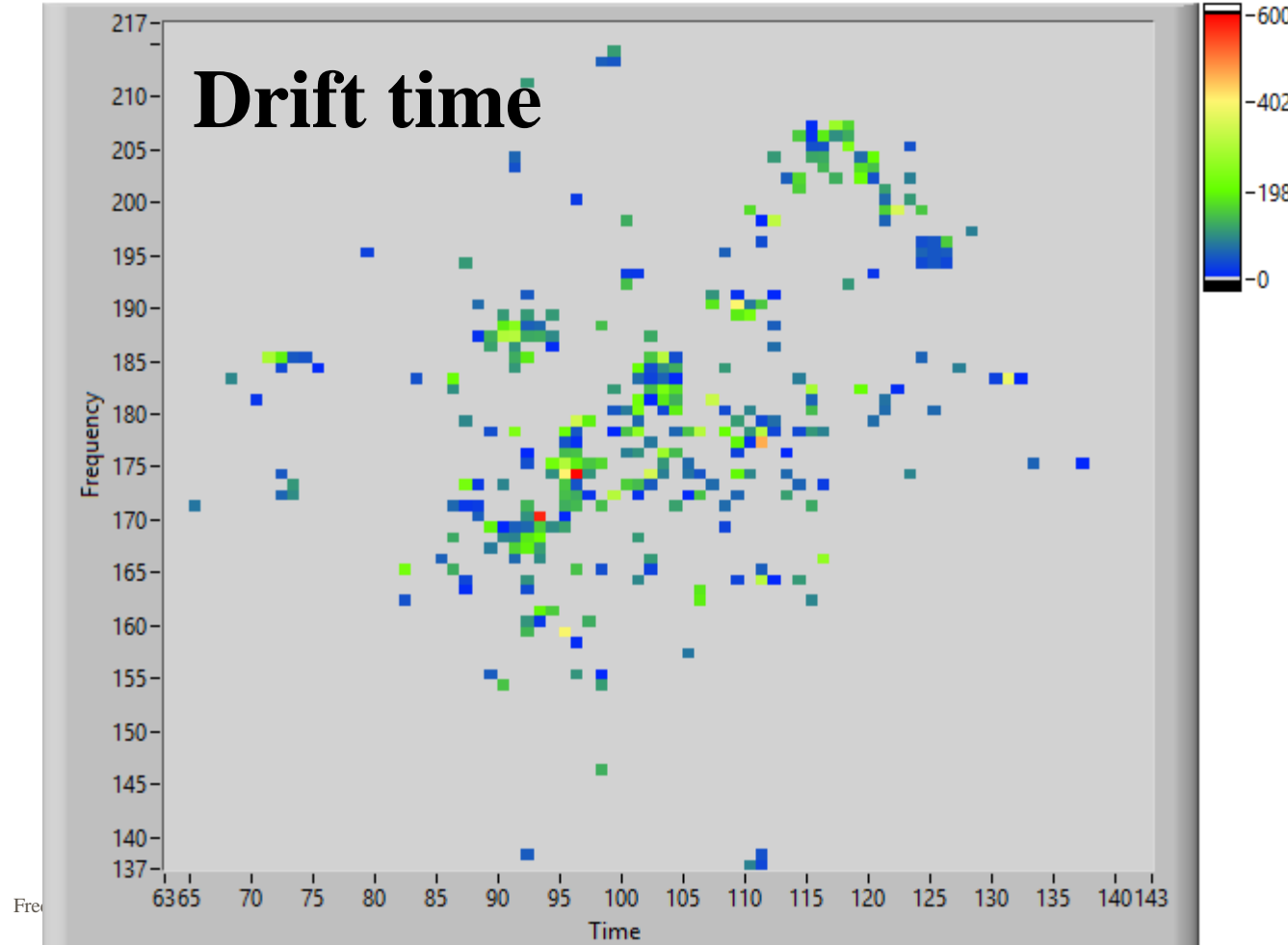
$V_{\text{grid}} = -350 \text{ V}$
338 hits, 239 neighbours

Event display



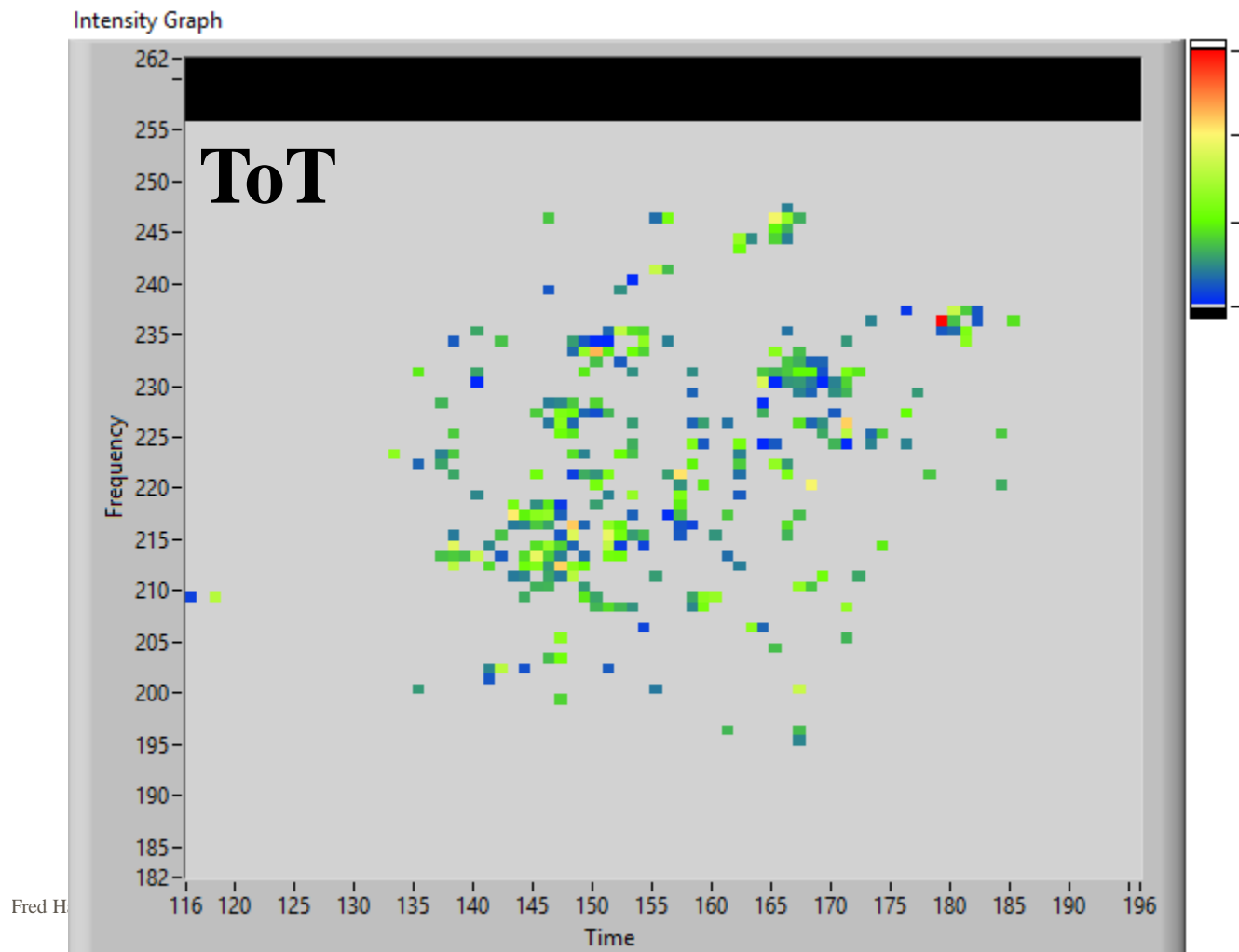
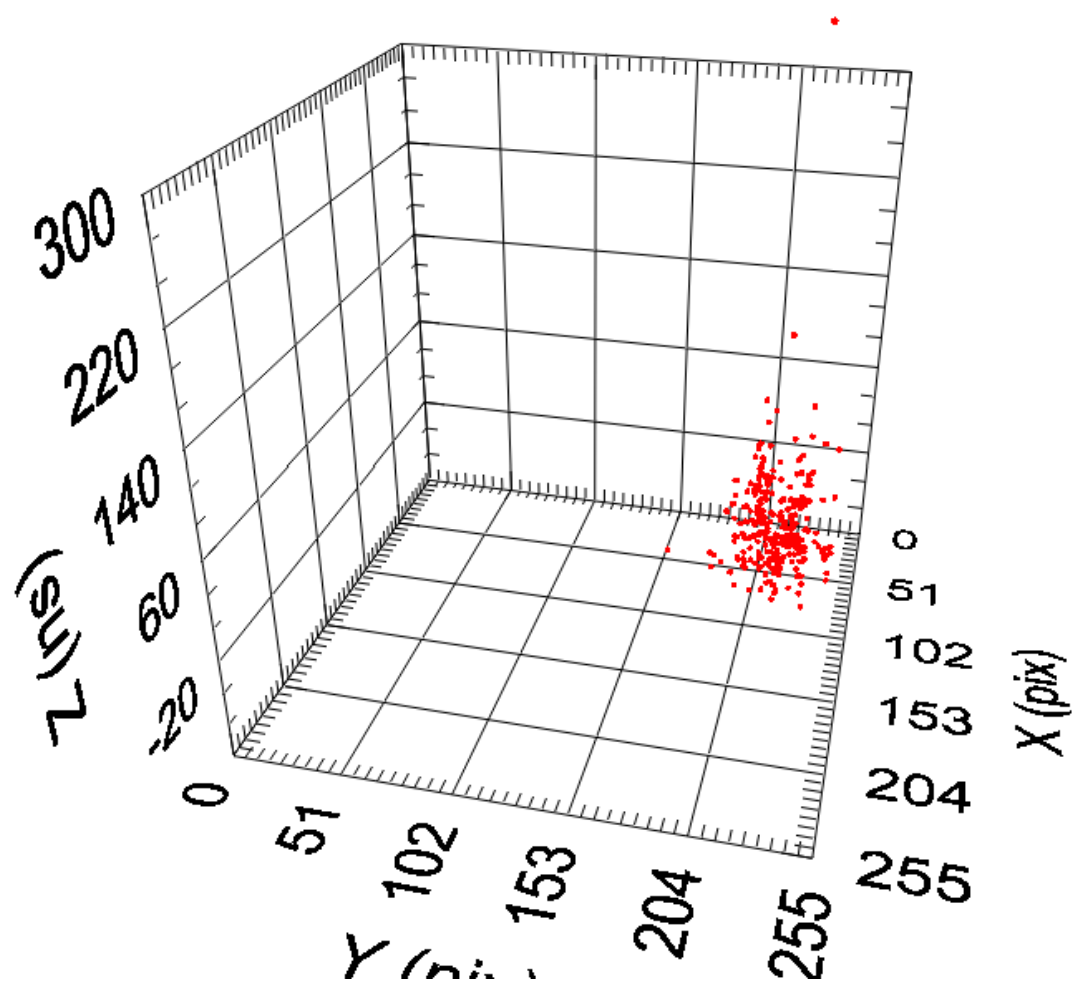
$V_{\text{grid}} = -350 \text{ V}$
338 hits, 239 neighbours

Intensity Graph



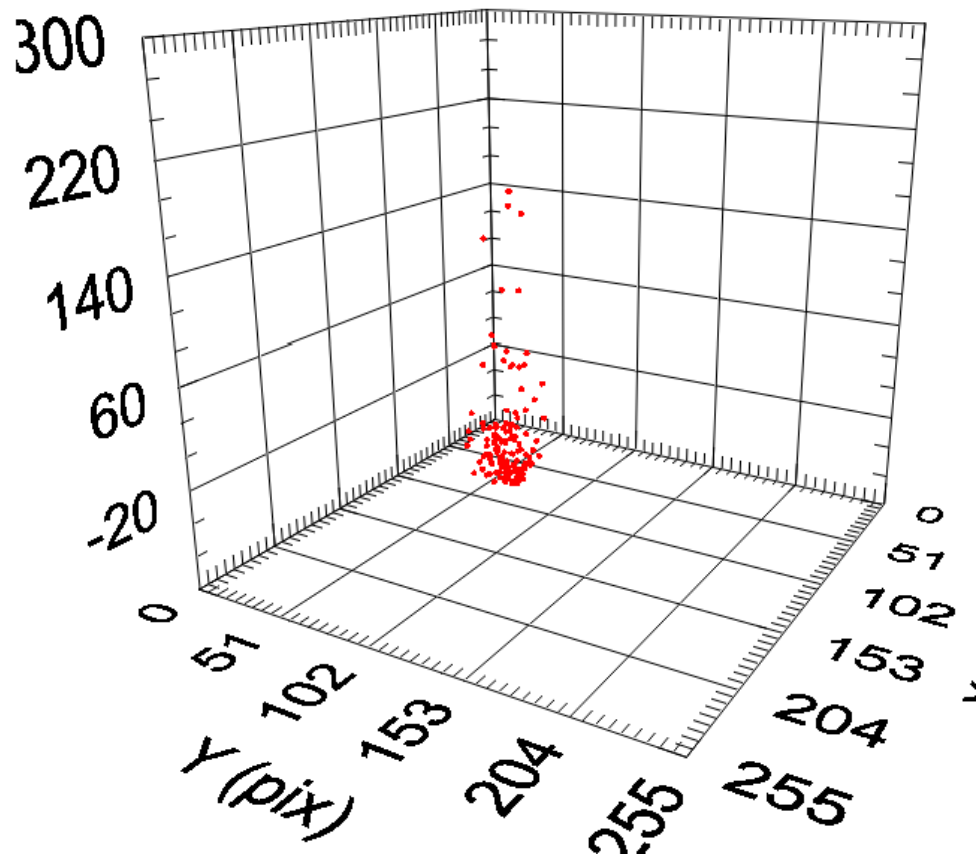
- NO ToT correction
- 288 hits
- 215 neighbours
- **Indication of clustering**

Event at $V_{grid} = -350$ V

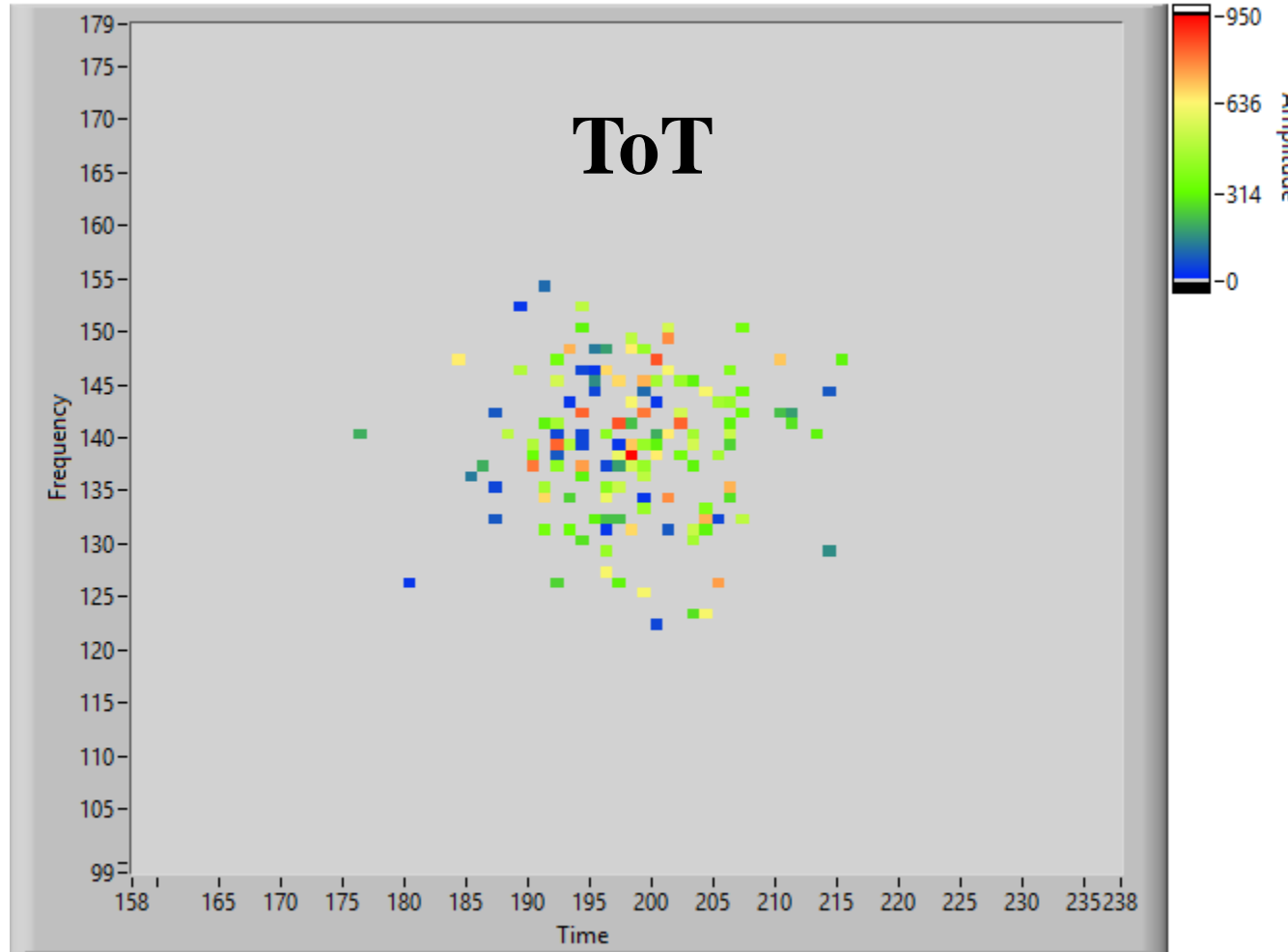


- NO ToT correction
- 134 hits
- 59 neighbours
- **NOT many pairs of high/low ToT**

Event at $V_{\text{grid}} = -300 \text{ V}$

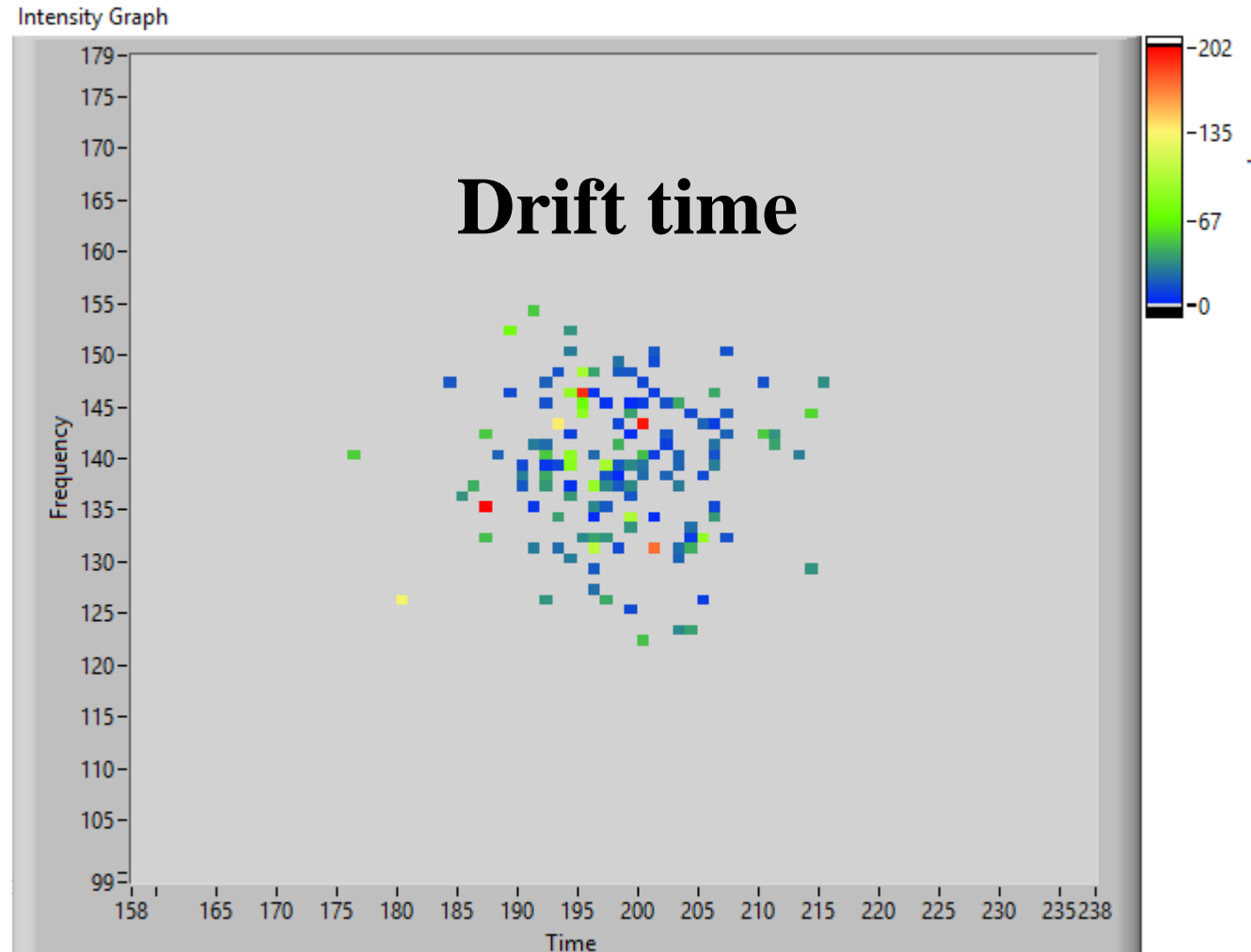
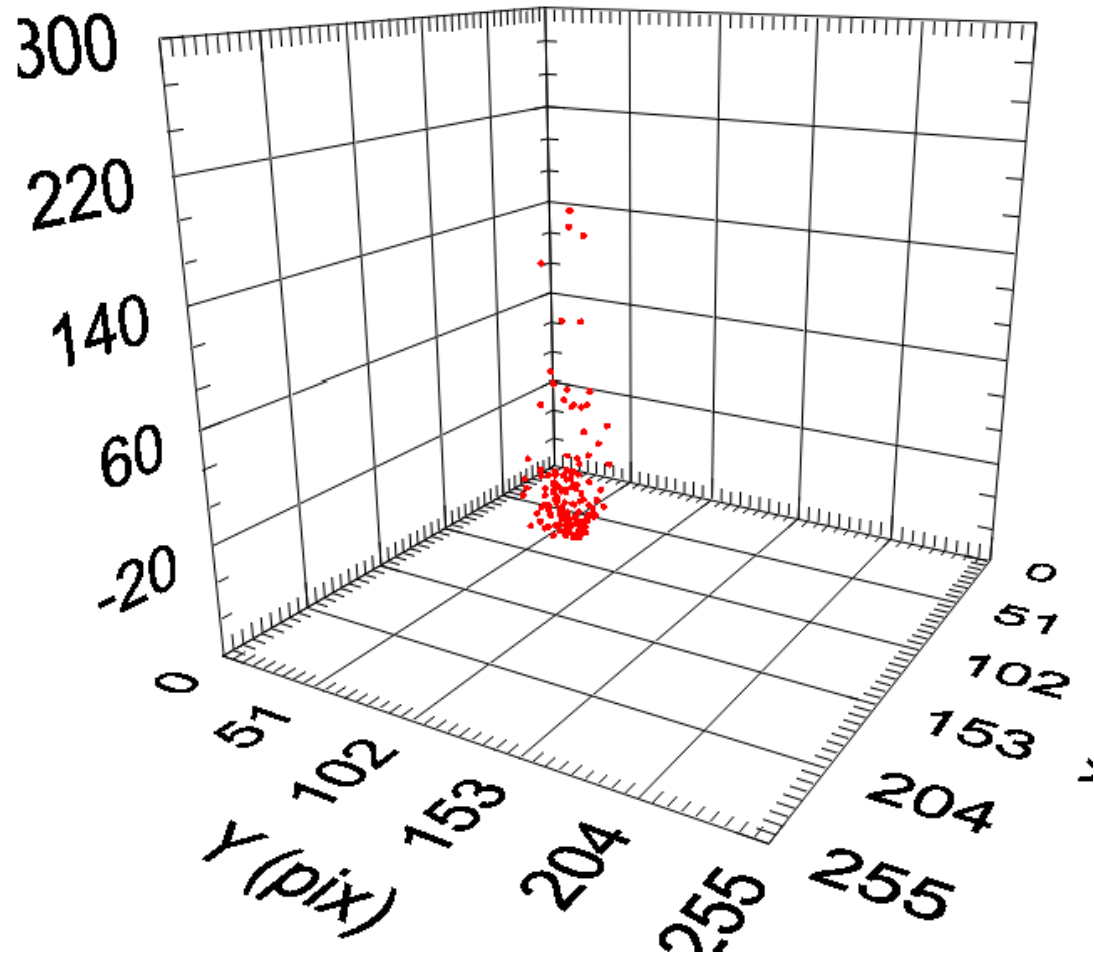


Intensity Graph



- NO ToT correction
- 134 hits, 59 neighbours
- **No unexpectedly large drift times**
 - Large drift times are related to small ToT

Event at $V_{\text{grid}} = -300 \text{ V}$



T3K

(iC4H10/CF4/Ar 3/3/94)

55Fe measurements with T3K

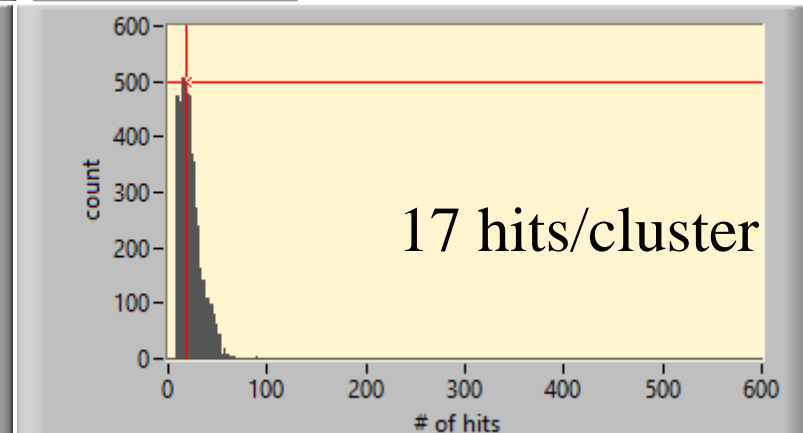
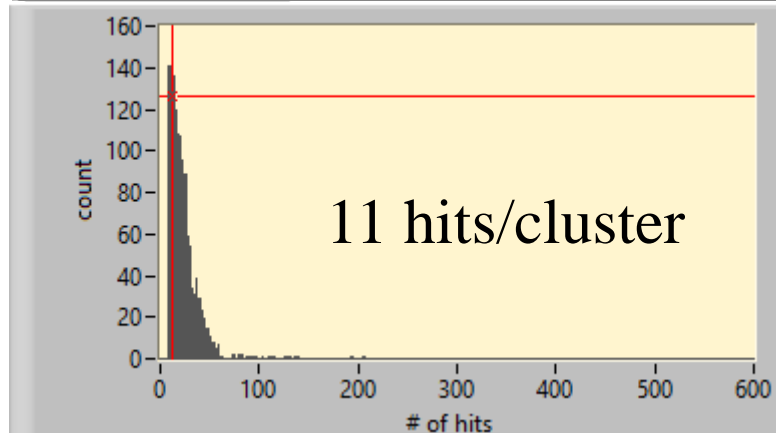
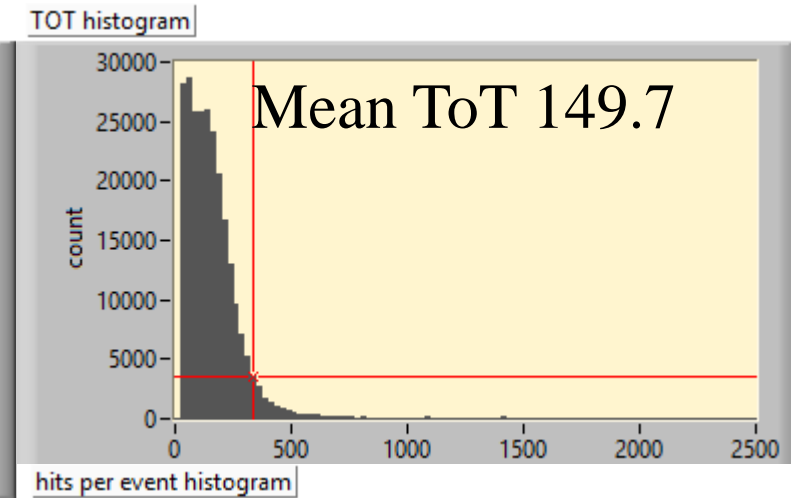
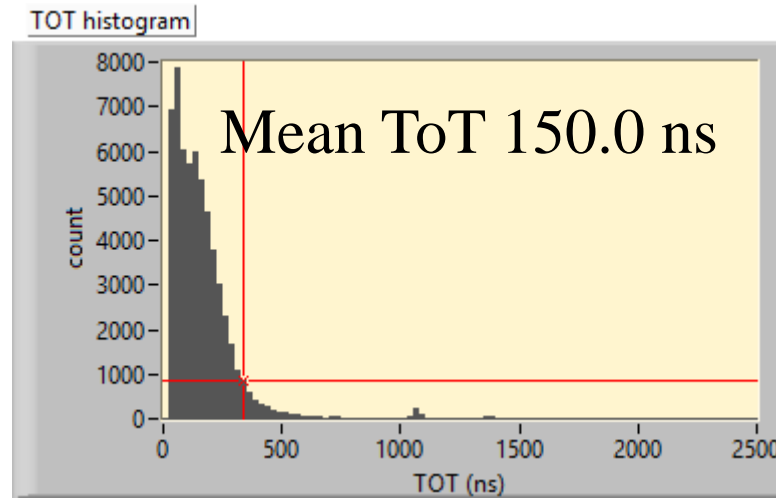
Vgrid = -280 V

- No micro discharges

Chip 2

Chip 0

Increased threshold



55Fe measurements with T3K

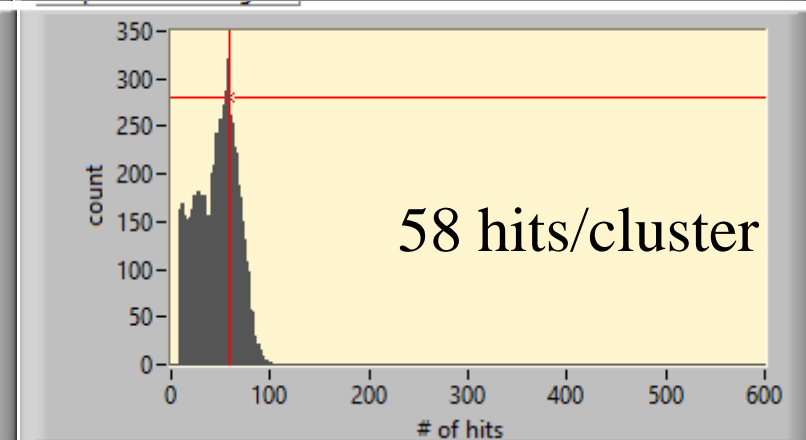
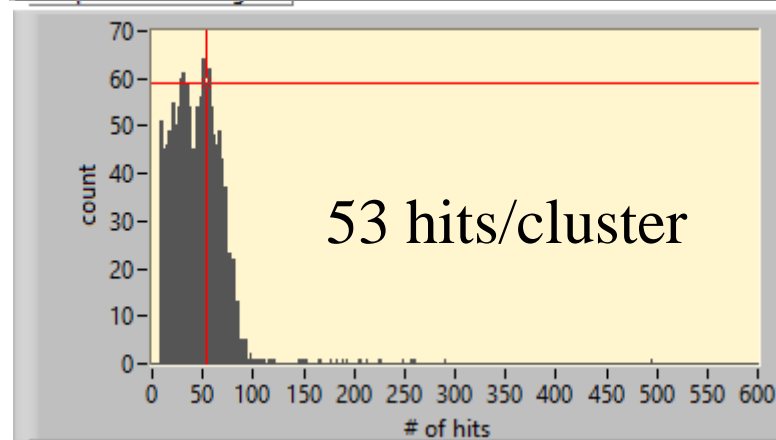
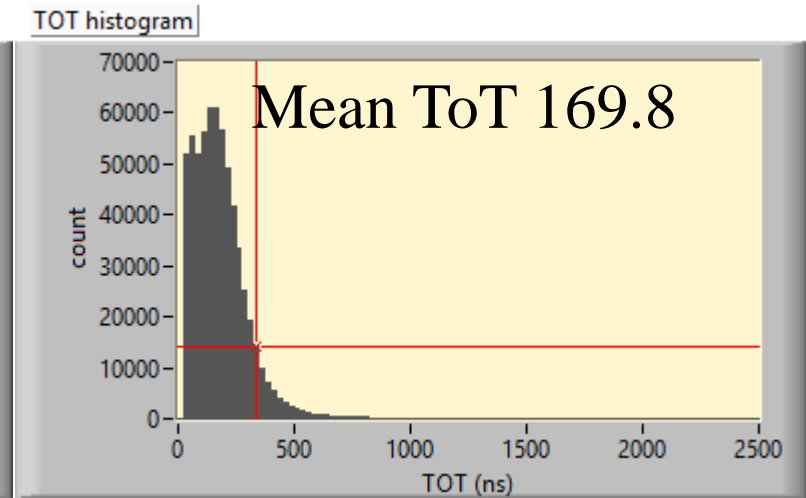
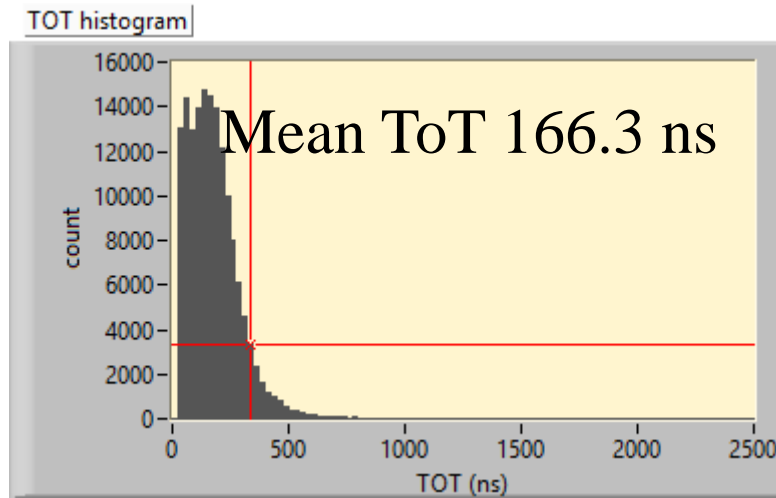
Vgrid = -290 V

- No micro discharges

Chip 2

Chip 0

Increased threshold



55Fe measurements with T3K

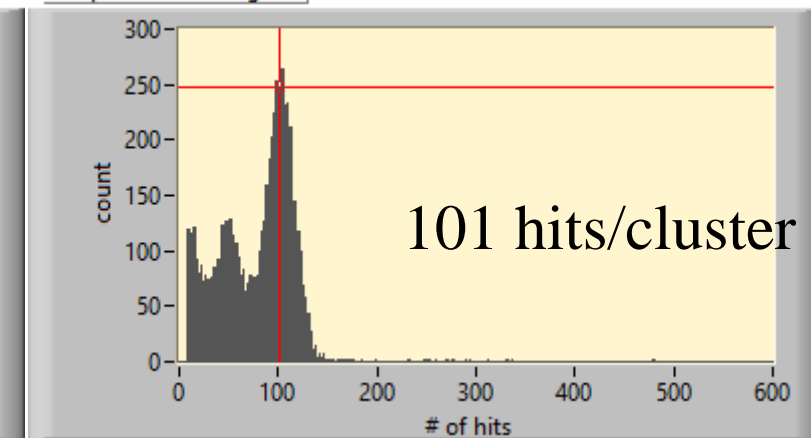
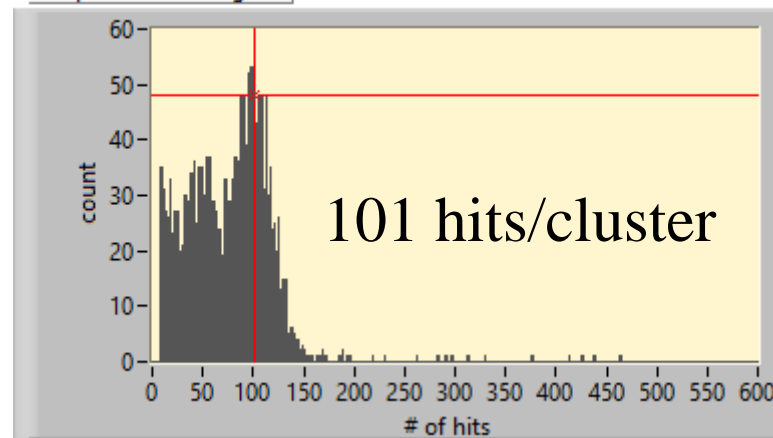
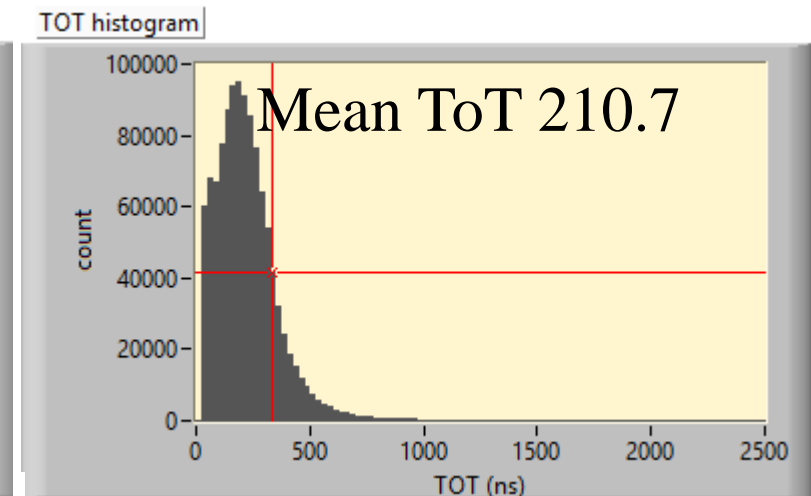
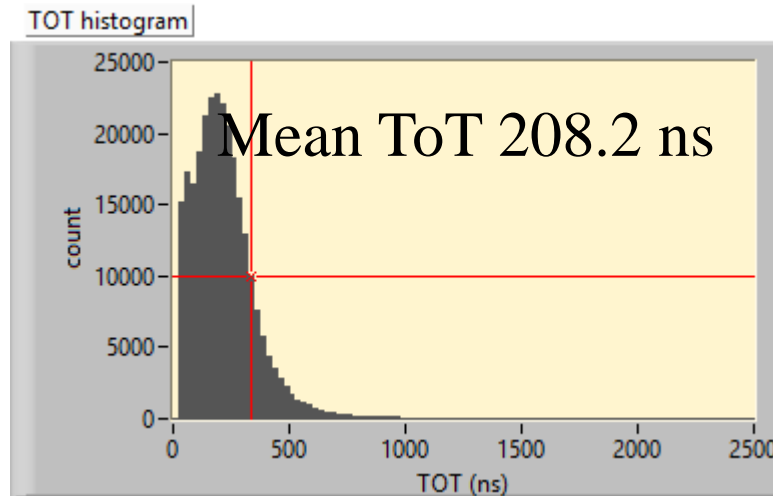
Vgrid = -300 V

- No micro discharges

Chip 2

Chip 0

Increased threshold



55Fe measurements with T3K

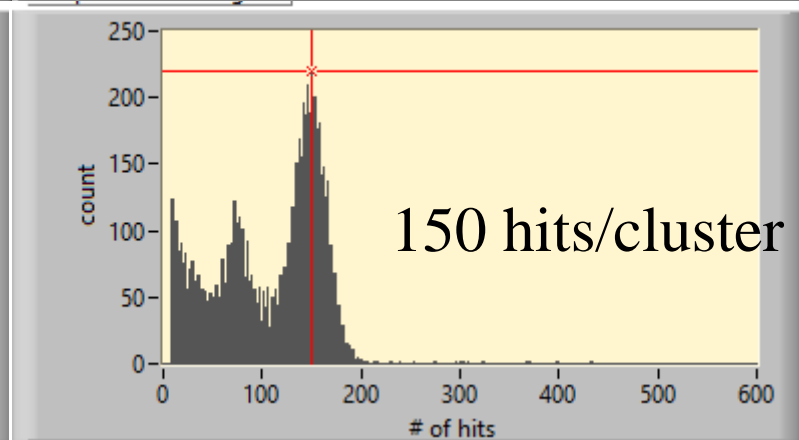
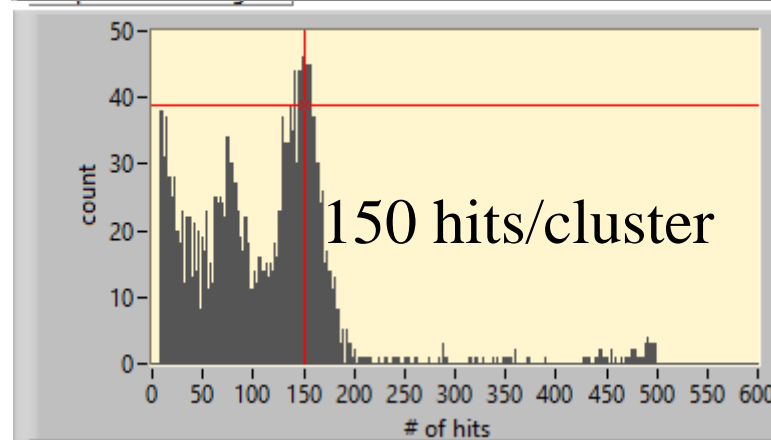
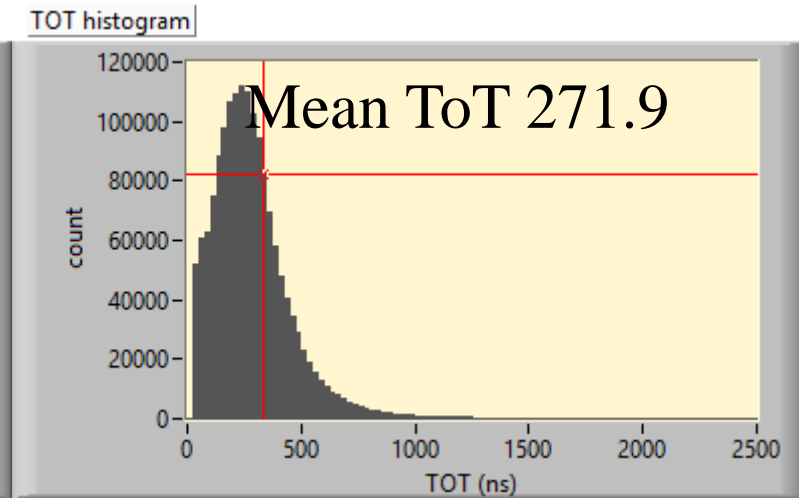
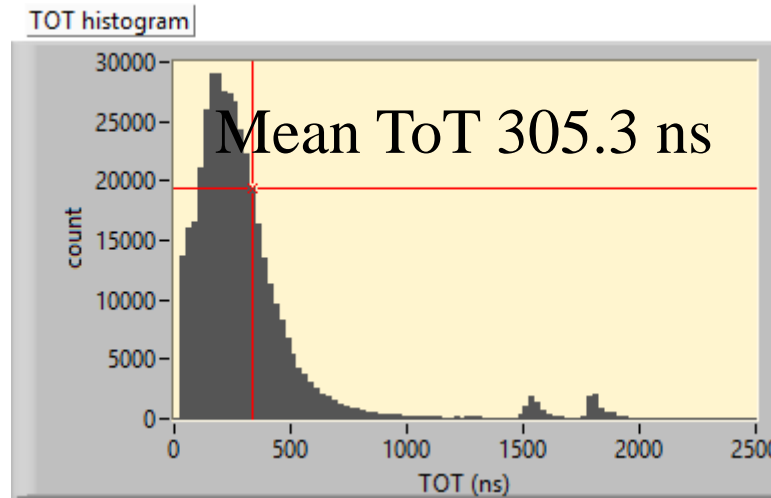
Vgrid = -310 V

- One micro discharge

Chip 2

Chip 0

Increased threshold



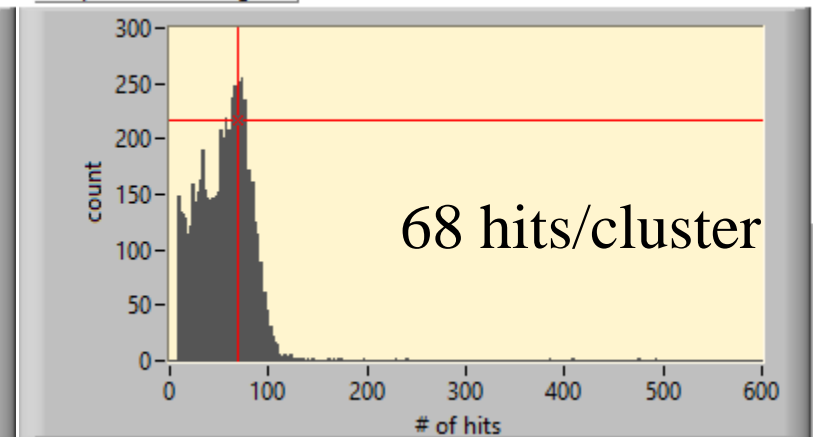
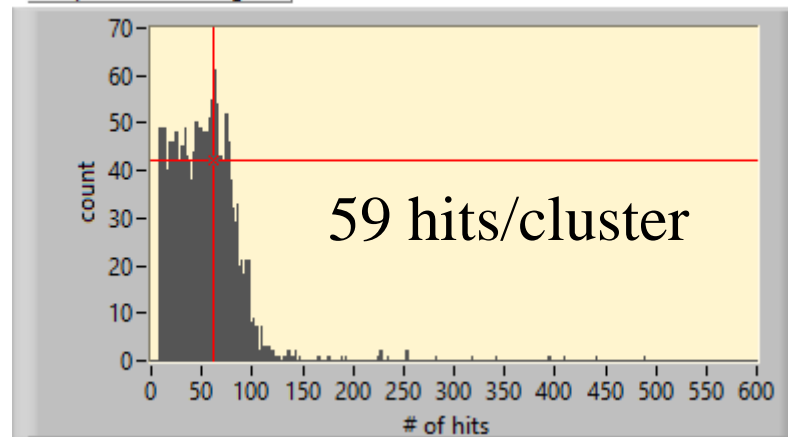
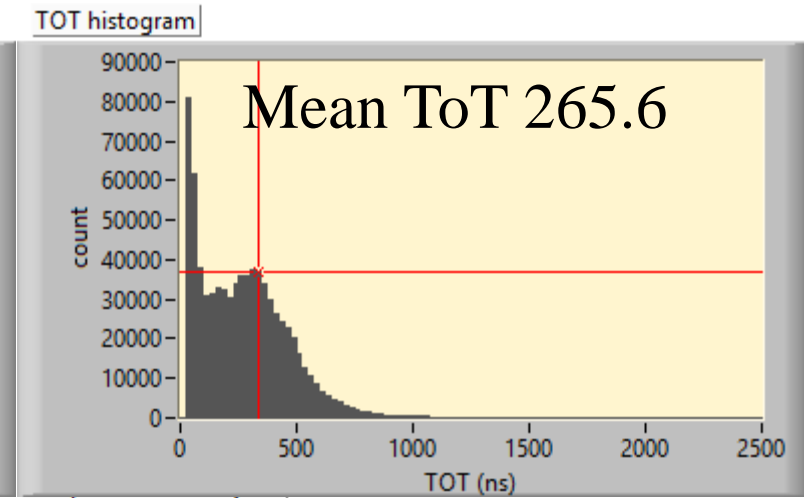
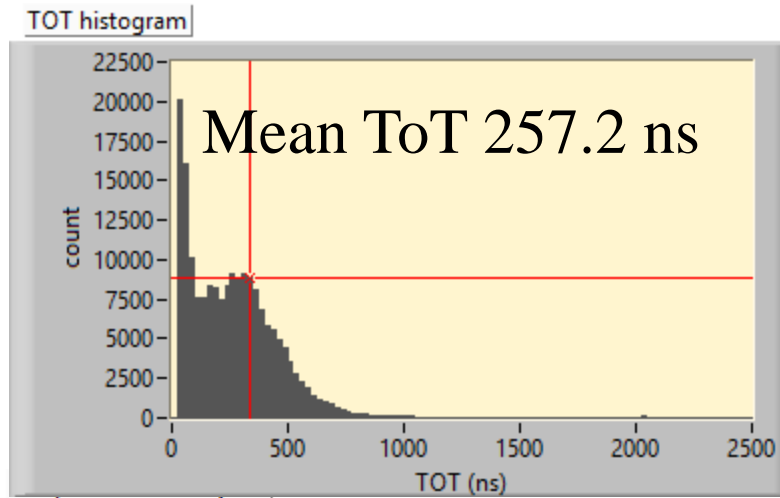
^{55}Fe measurements with T3K

Vgrid = -280 V

- One micro discharge

Chip 2

Chip 0



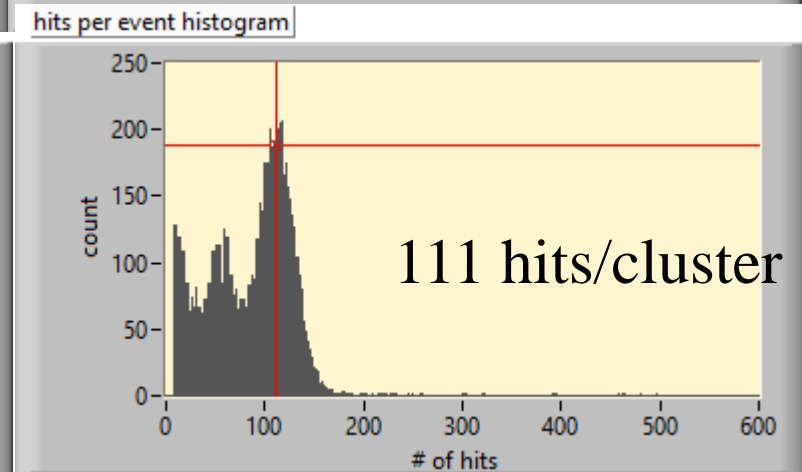
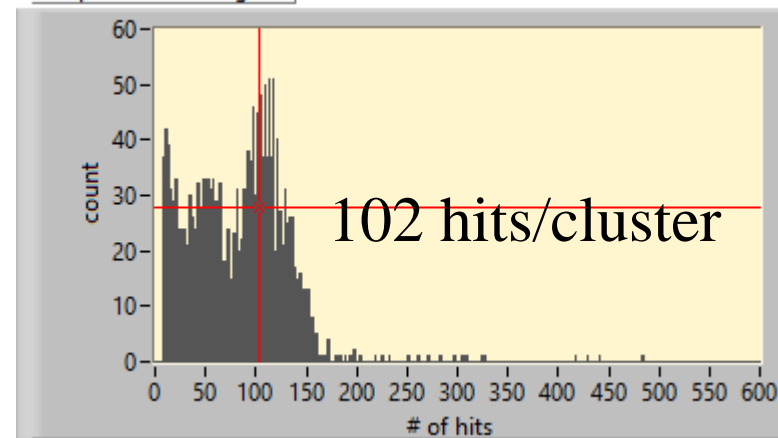
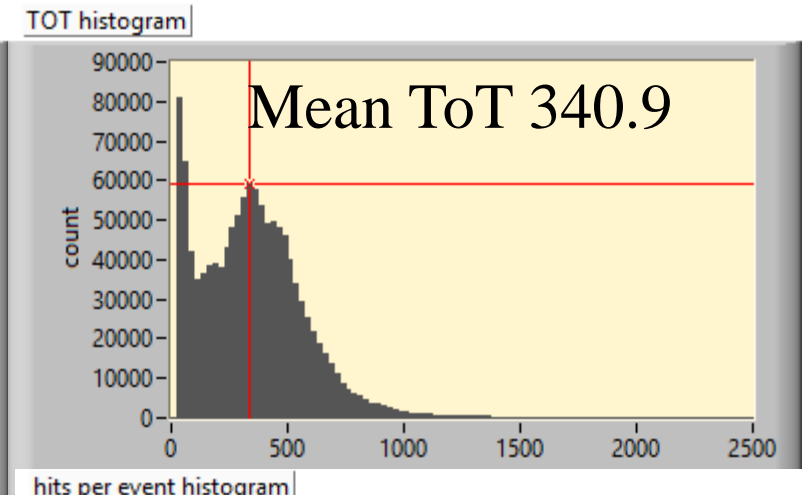
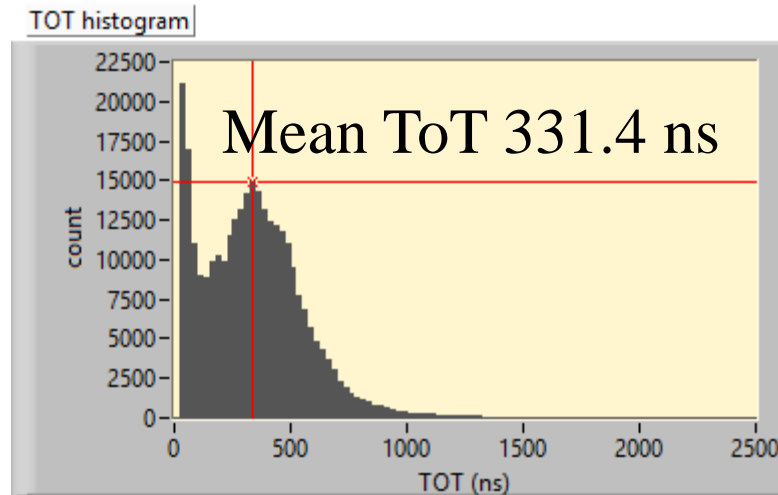
55Fe measurements with T3K

Vgrid = -290 V

- Two micro discharges

Chip 2

Chip 0



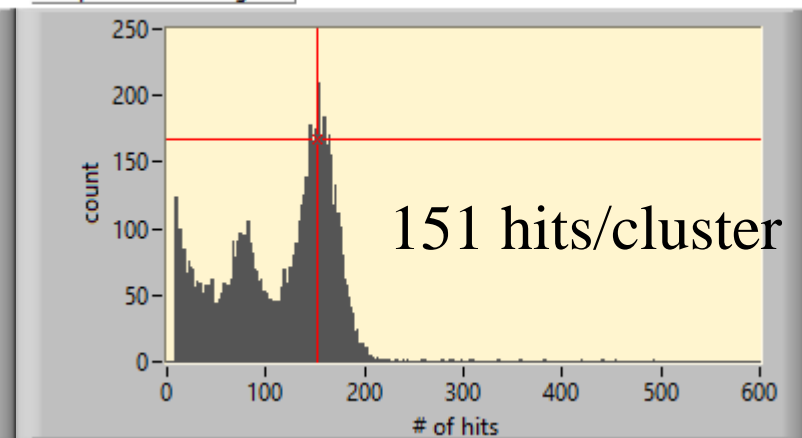
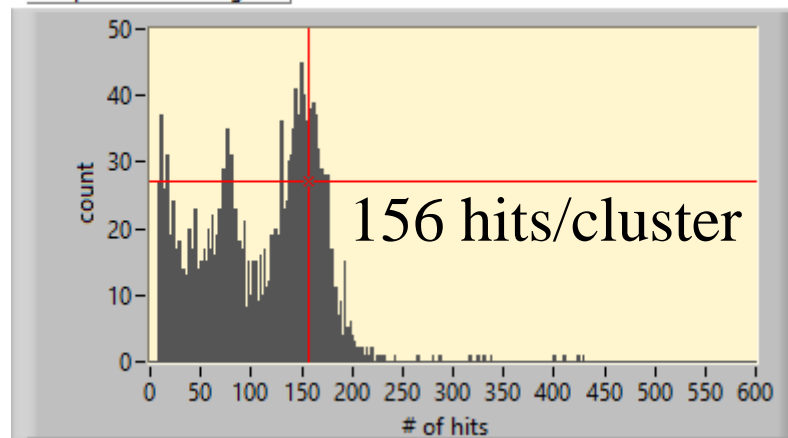
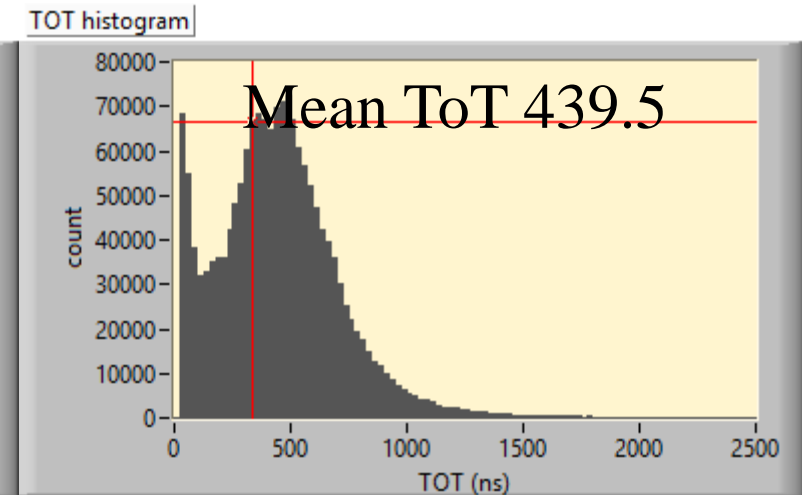
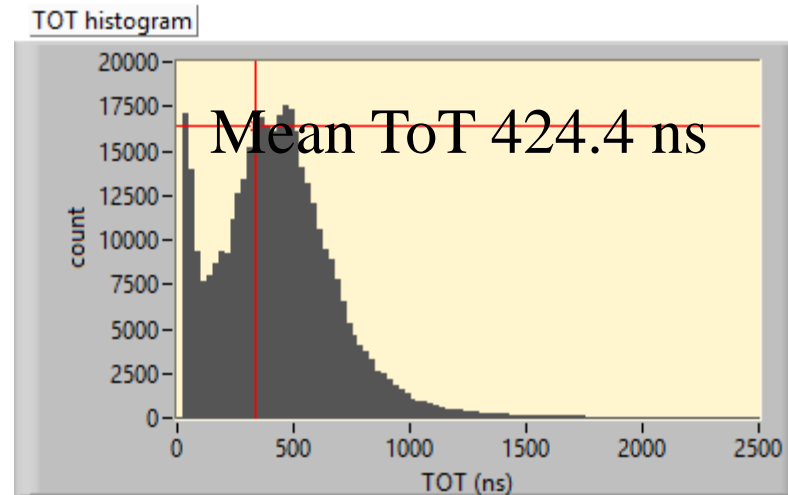
55Fe measurements with T3K

Vgrid = -300 V

- No micro discharges

Chip 2

Chip 0



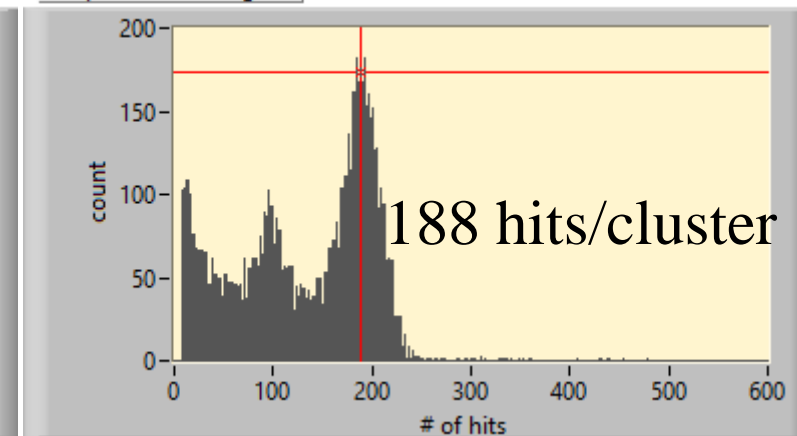
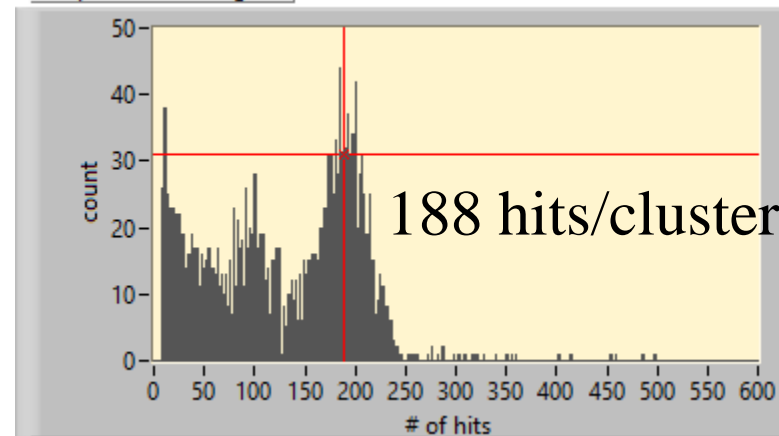
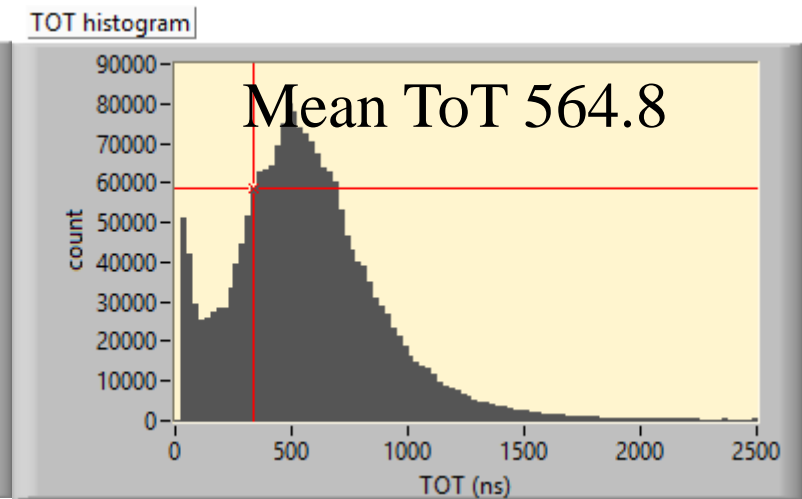
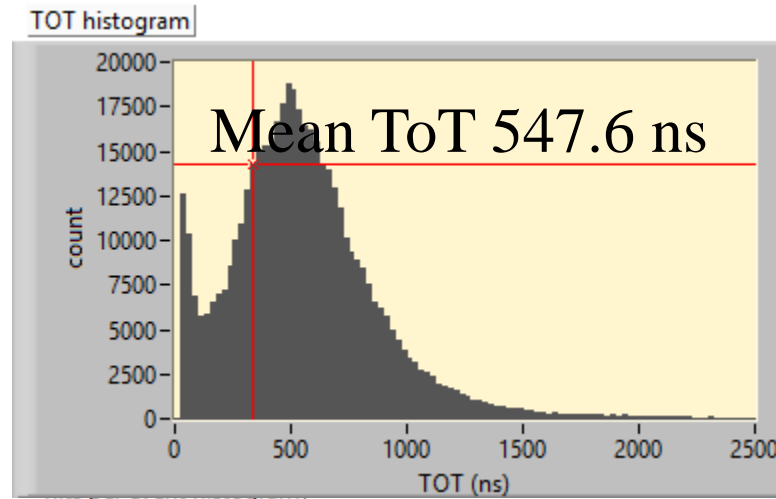
^{55}Fe measurements with T3K

Vgrid = -310 V

■ One micro discharge

Chip 2

Chip 0



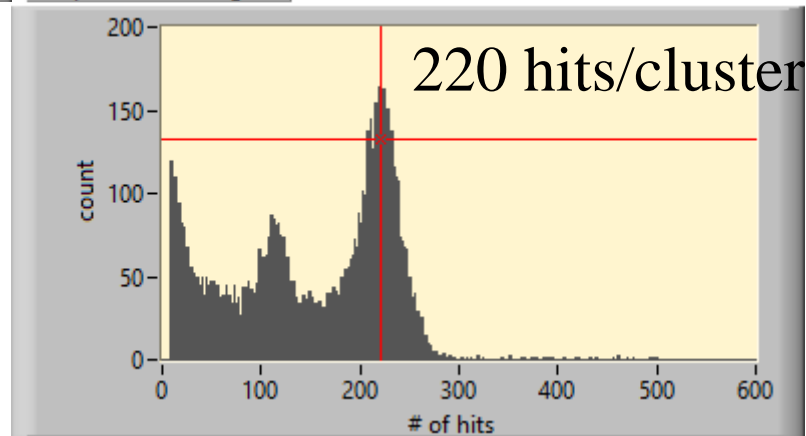
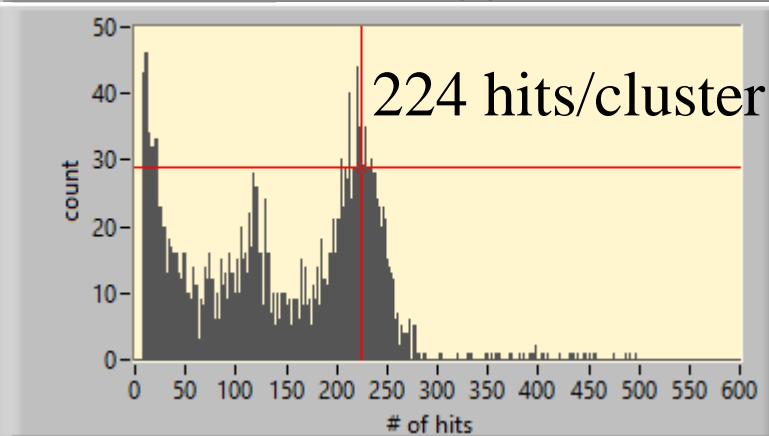
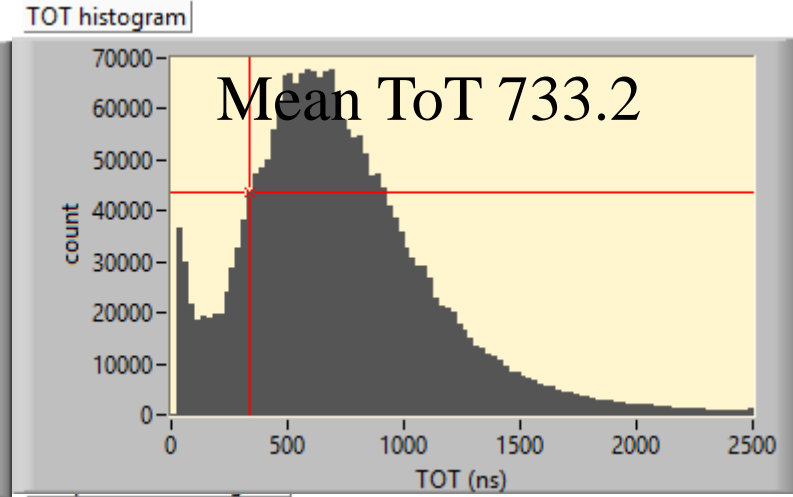
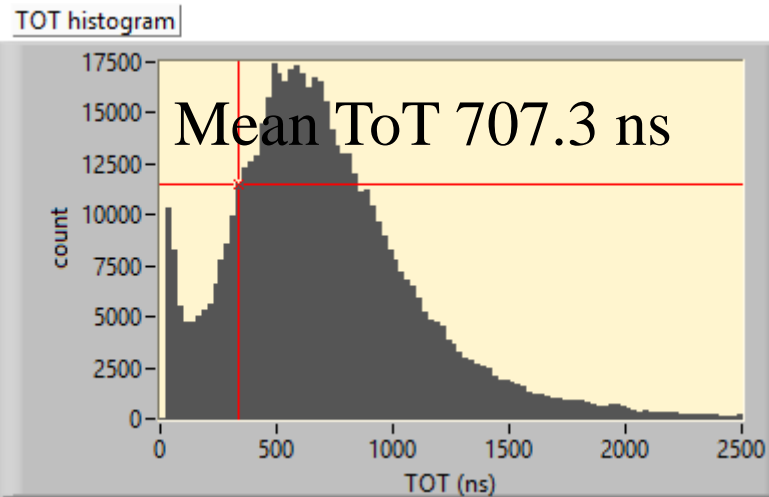
^{55}Fe measurements with T3K

$V_{\text{grid}} = -320 \text{ V}$

- Seven micro discharges

Chip 2

Chip 0



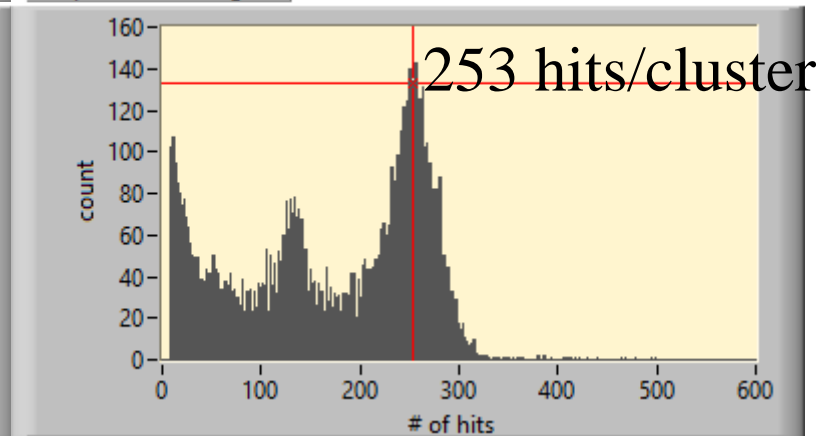
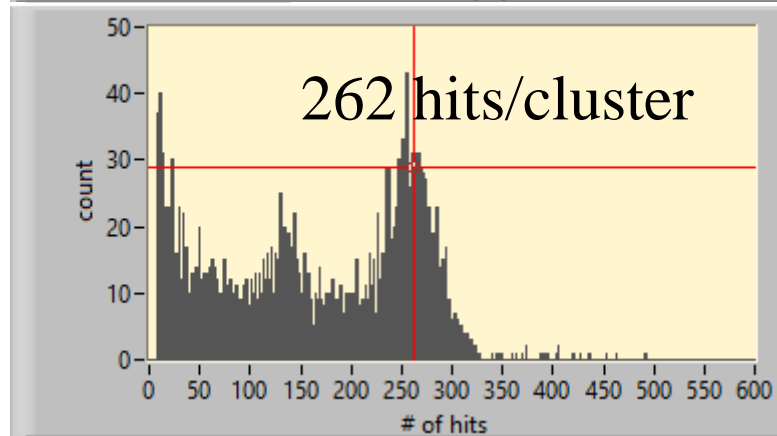
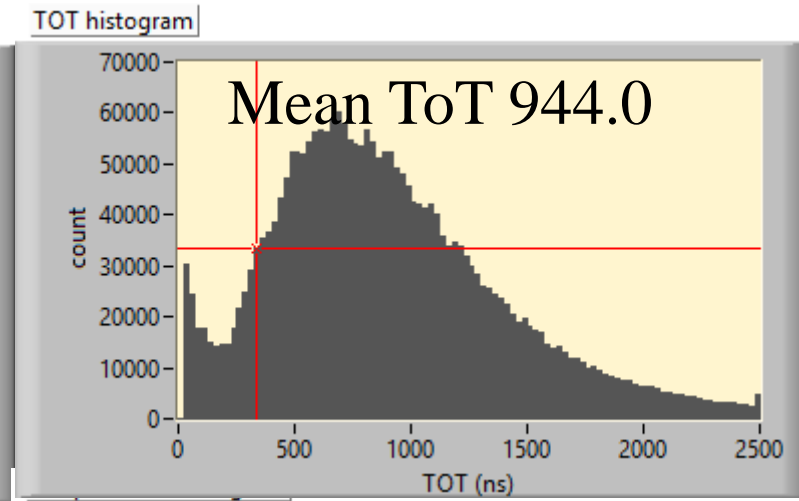
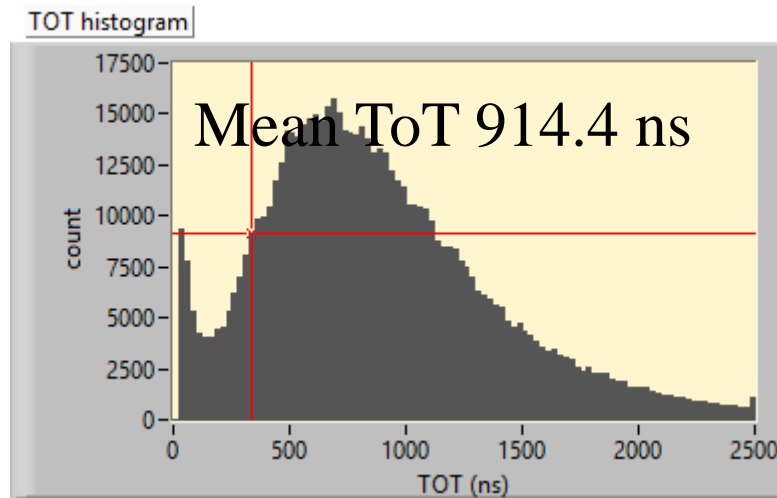
^{55}Fe measurements with T3K

Vgrid = -330 V

- Five micro discharges

Chip 2

Chip 0



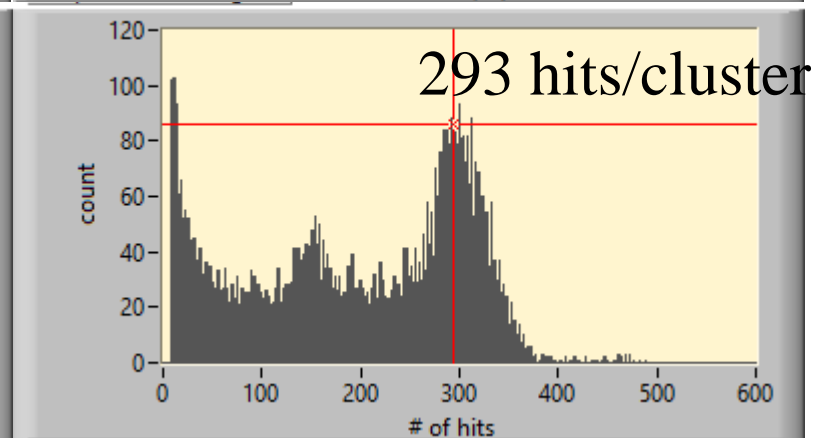
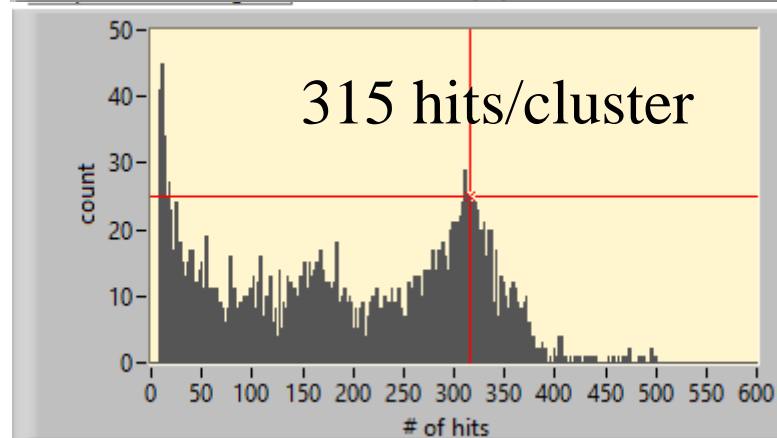
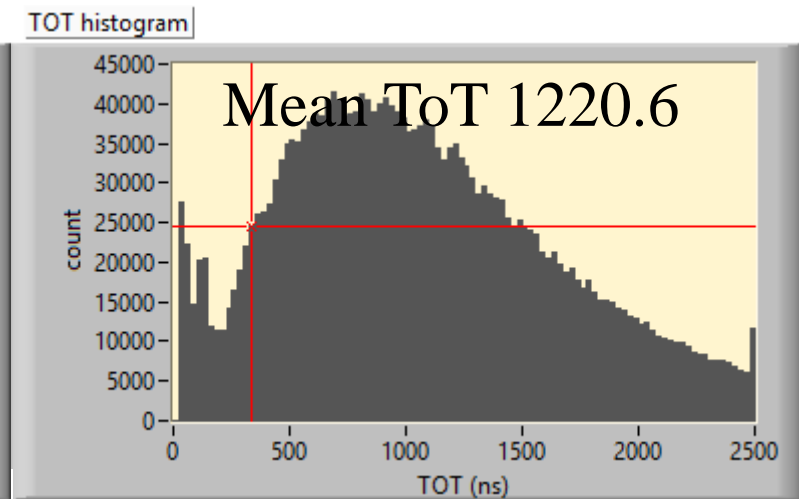
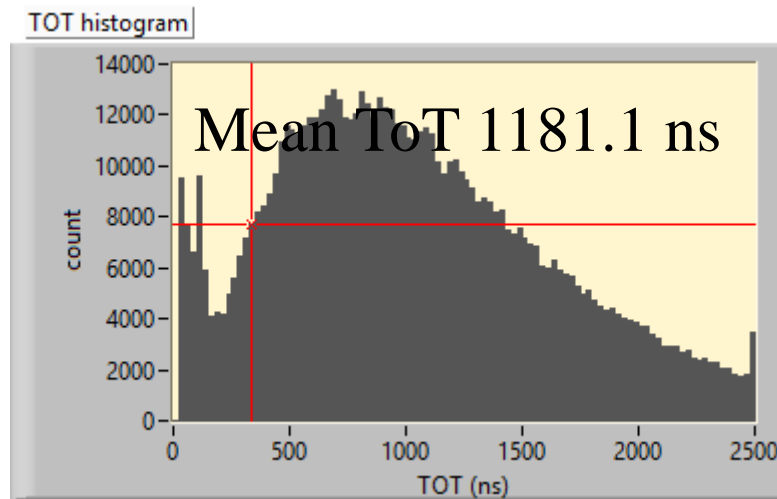
^{55}Fe measurements with T3K

$V_{\text{grid}} = -340 \text{ V}$

- Five micro discharges

Chip 2

Chip 0



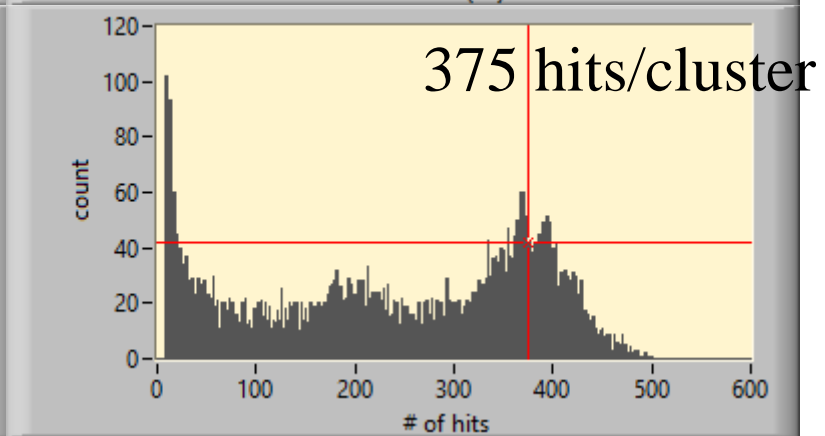
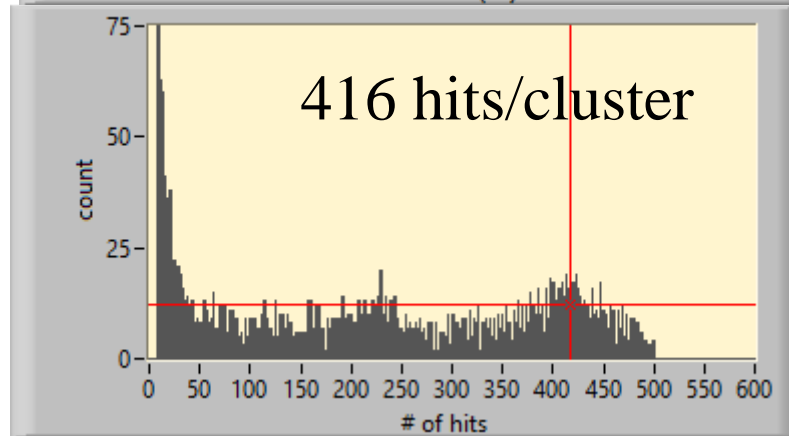
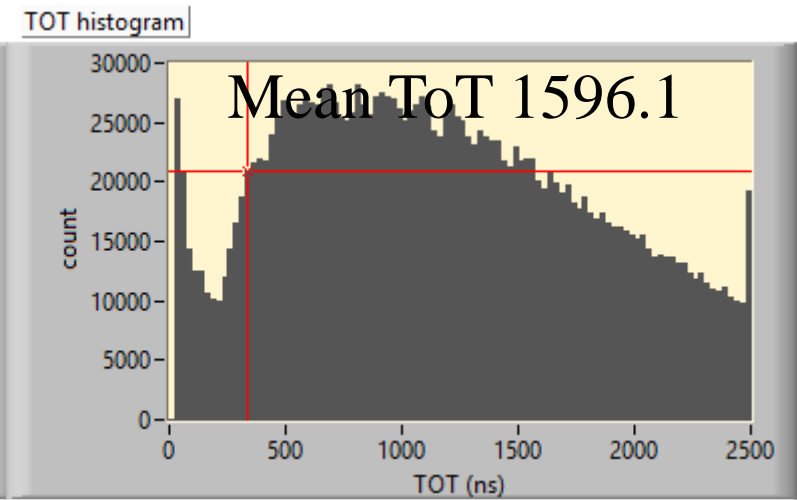
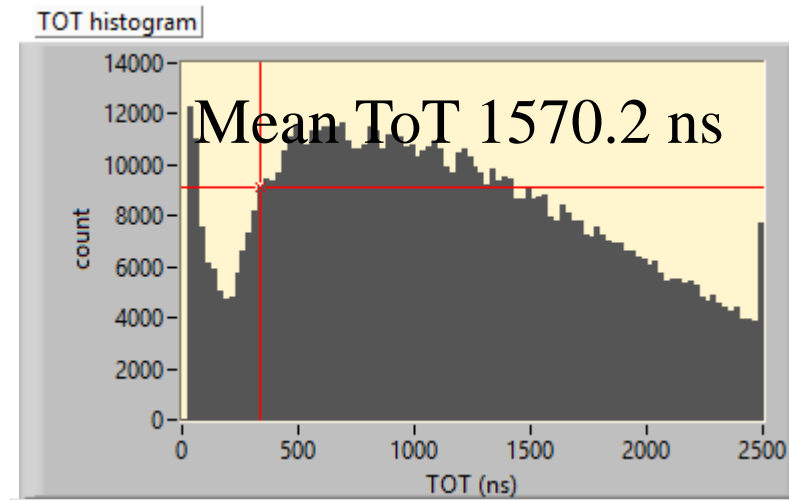
^{55}Fe measurements with T3K

$V_{\text{grid}} = -350 \text{ V}$

- Eight micro discharges

Chip 2

Chip 0



^{55}Fe measurements with T3K

$V_{\text{grid}} = -360 \text{ V}$

- Eleven micro discharges

Chip 2

Chip 0

