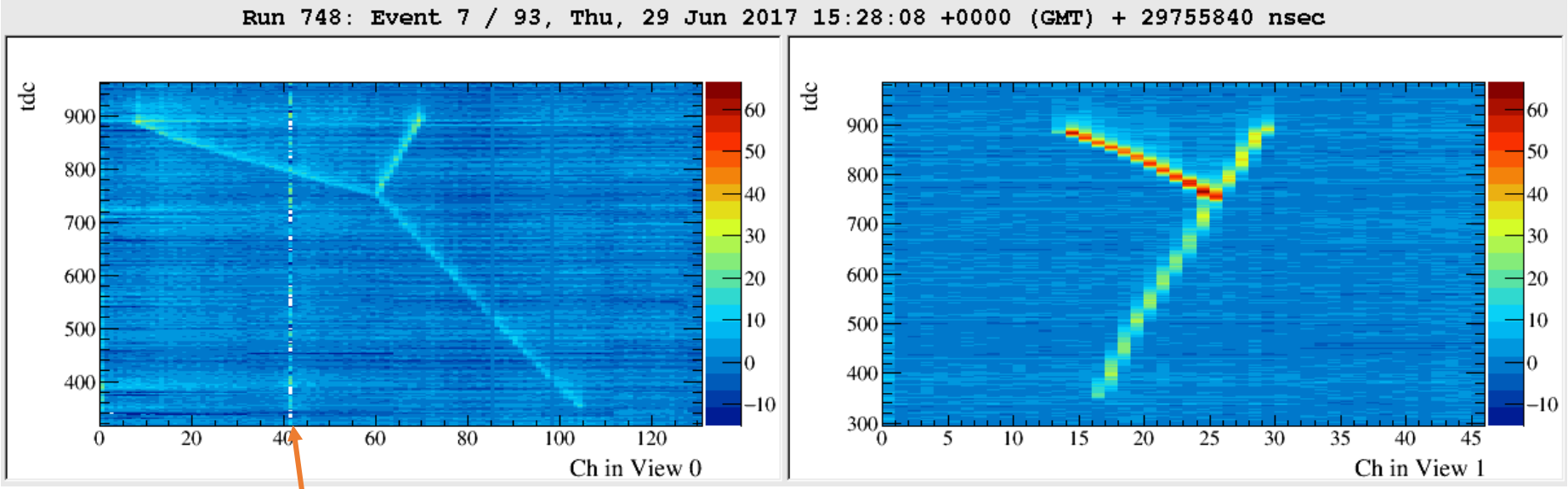
Preliminary considerations for 311 charge readout analysis

WA105 SB meeting

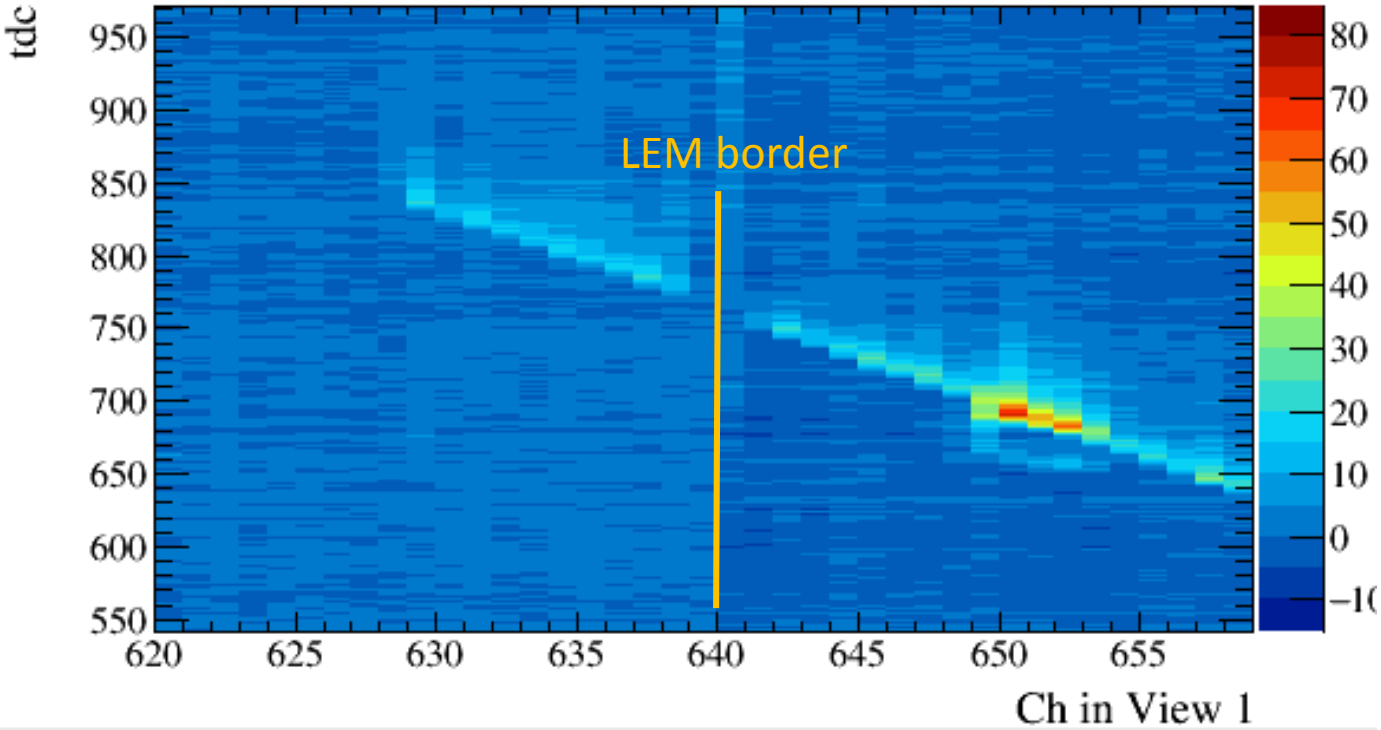
05.07.2017

A candidate for a hadronic interaction in 3x1x1?



Known bad channel due to an electrical coupling with one of temperature probes on the CRP

Charge screening by LEM borders

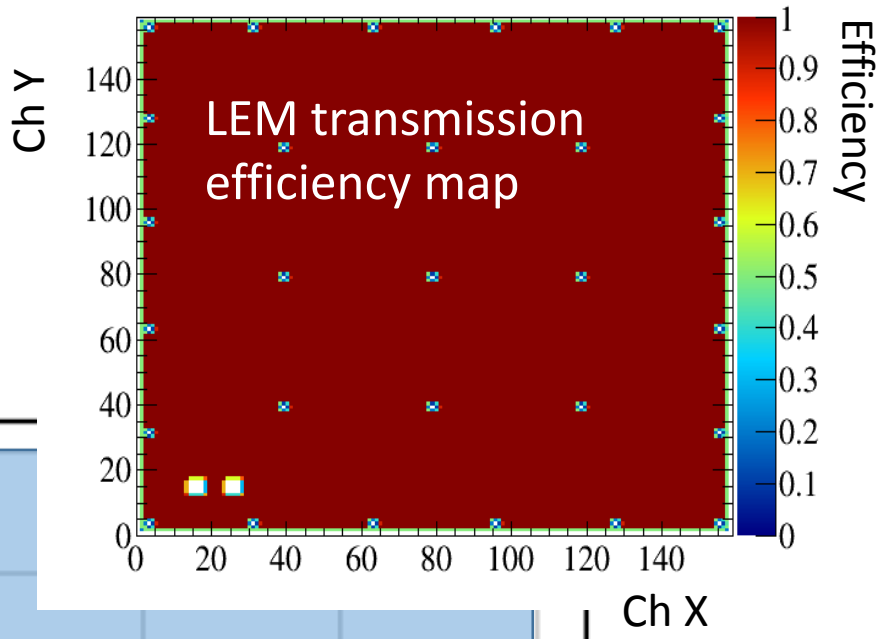


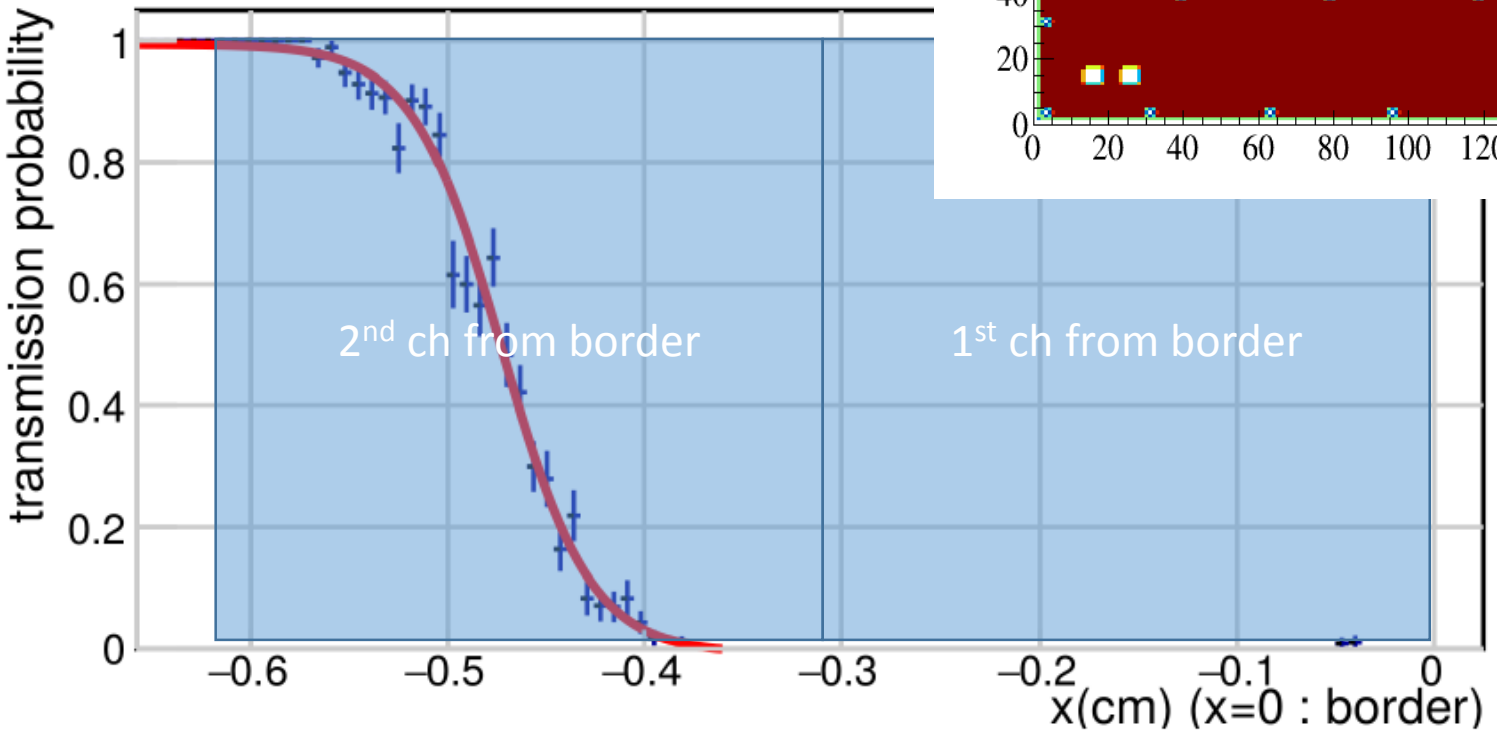
Gaps in the tracks of about 2-4 channels due to LEM borders

The last and the first channel of the anode do not see any charge due to the 2 mm FR4 border and 2 mm Cu rim around the edges of each LEM

Should start to see “complete” charge depositions only $\geq 3^{rd}$ channel from border

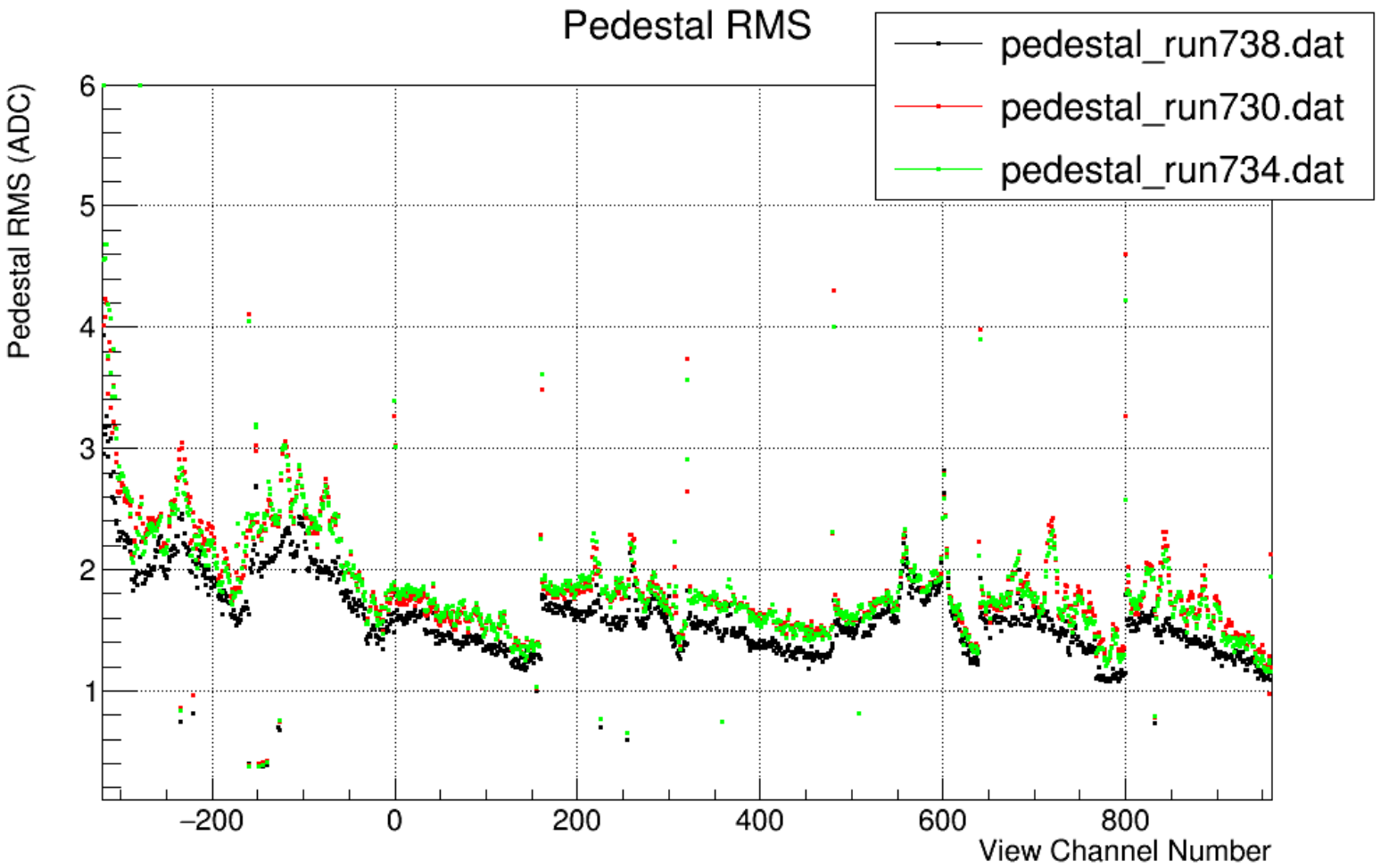
From P. Cotte's ANSYS studies of the LEM electron transparency





The 1st channel from the border is blind: the transmission probability is 0
The 2nd channels should see about ~0.5 of the full charge

Noise during data taking (HV LEM ON)

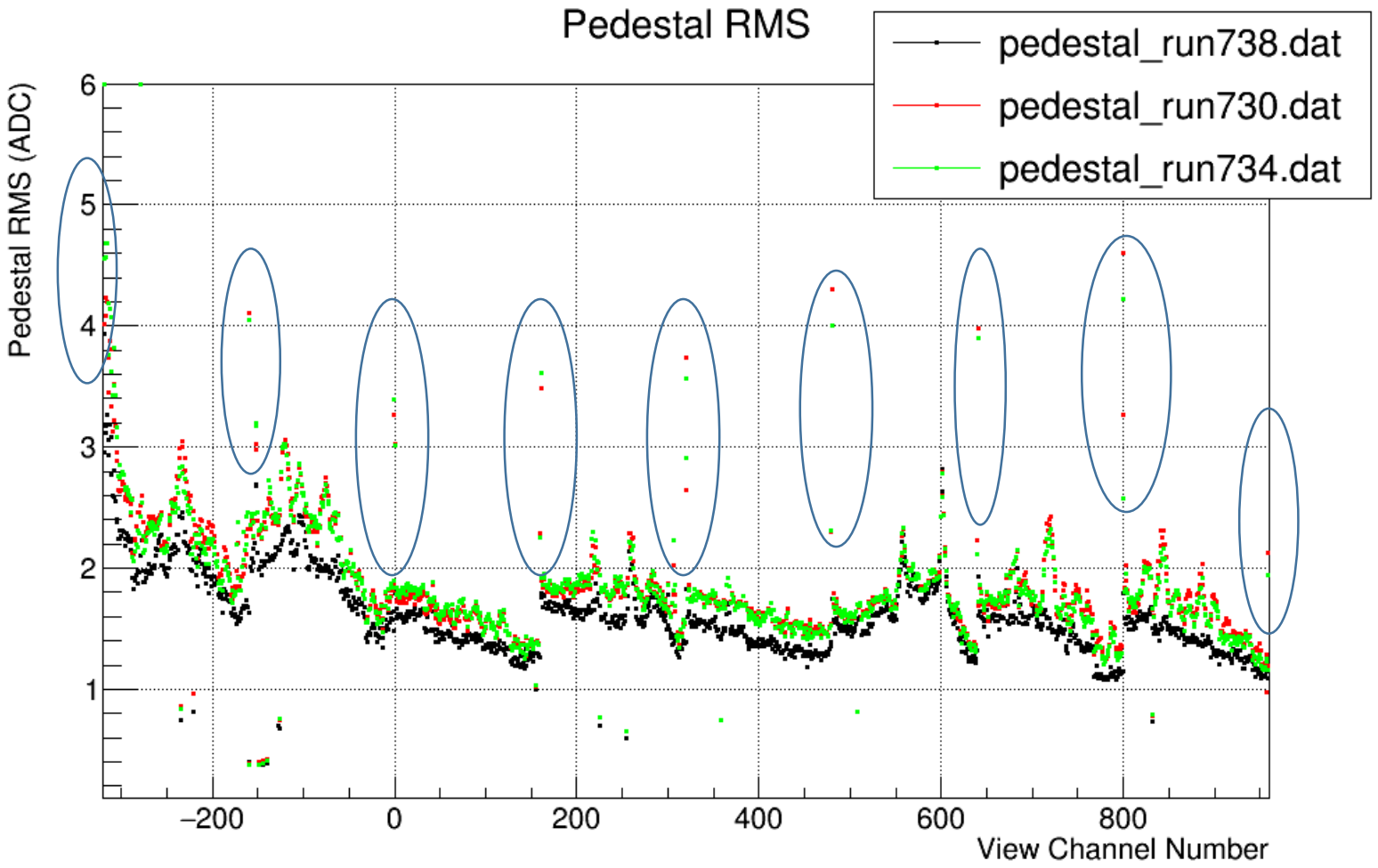


Black points with HV and VHV OFF: run taken after runs 730 and 734

Green / red measured from pedestal samples during operation. These were taken with random trigger

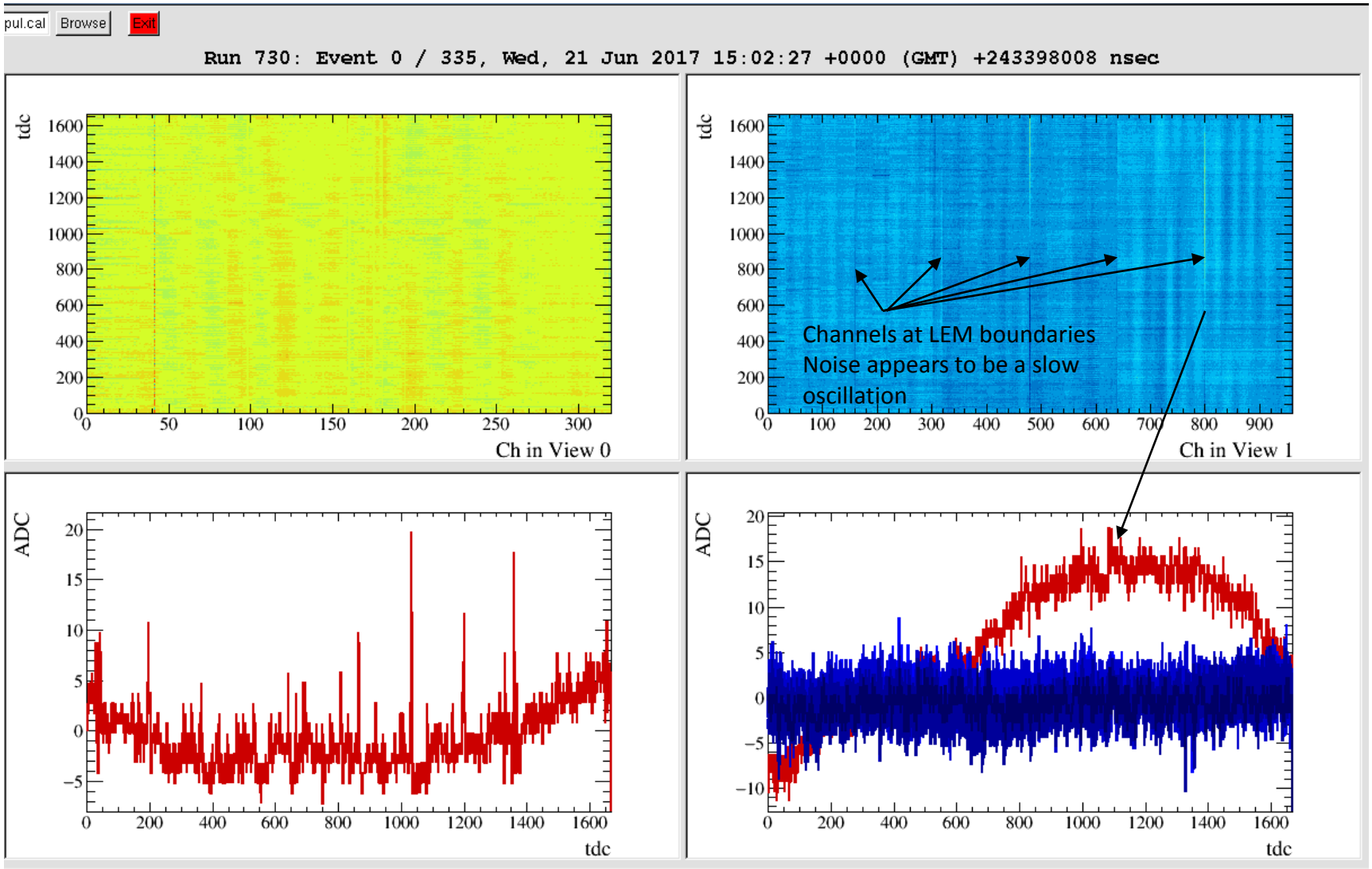
LEMT/B = 0.2/3.1 kV, grid = 4kV, Cathode = 37 kV

Noise at LEM borders



The spikes in noise match the LEM 0.5 m boundaries;
Occur at first ch of a given anode and last ch of previous anode

Noise at LEM borders



The frequency of the slow oscillations is around 1 kHz

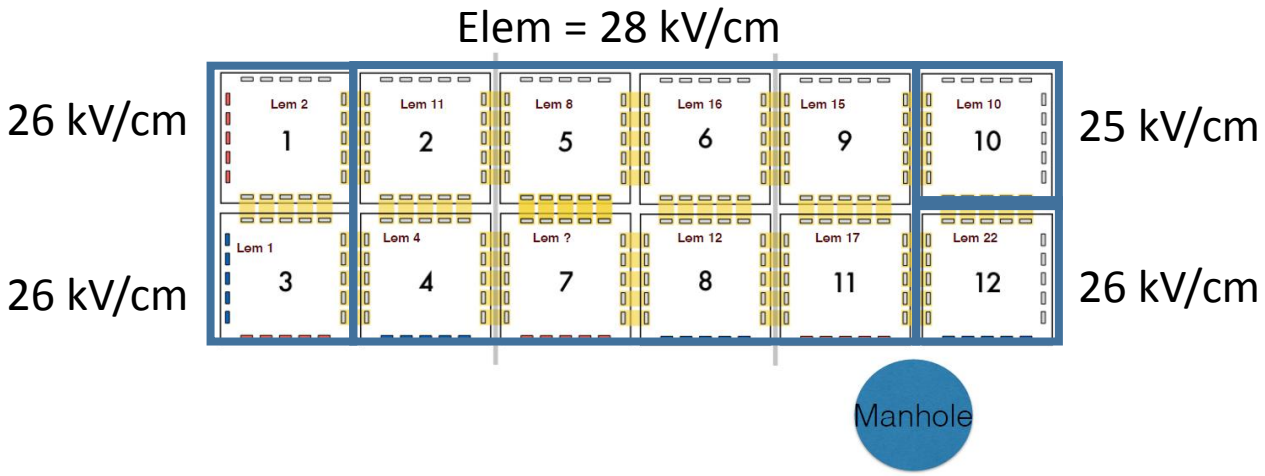
Masking non-functioning / noisy channels

- A list of non-functioning channels has been updated with recent measurements (see elog 266)
- In total 17 channels were observed to not respond correctly to injected pulses
  - 1 channel (view 0 ch 41) appears to be in short with T probes → high noise
- In addition for reconstruction need to mask the anode channels at the LEM borders: 2 channels / LEM / view x 2 views = 4 channels / 50x50 cm2
- Similar to pedestal, channel mask file is defined in $THEDATAFILES/chmasked/chmasked
- In hit reconstruction masking of the channels and pedestal subtraction is enabled with PARA_CALI [1, 1, 0] (see collab meeting presentation)

Preliminary look at Run 748 data

Some of the relevant conditions for this run

```
Run 748
HV:
LEM T 0.2kV
LEM B 3.0 kV
LEM01 B 2.8 kV
LEM03 B 2.8 kV
LEM12 B 2.8 kV
LEM10 B 2.7 kV
GRID 4.5 kV
CATH 41.0 kV
```



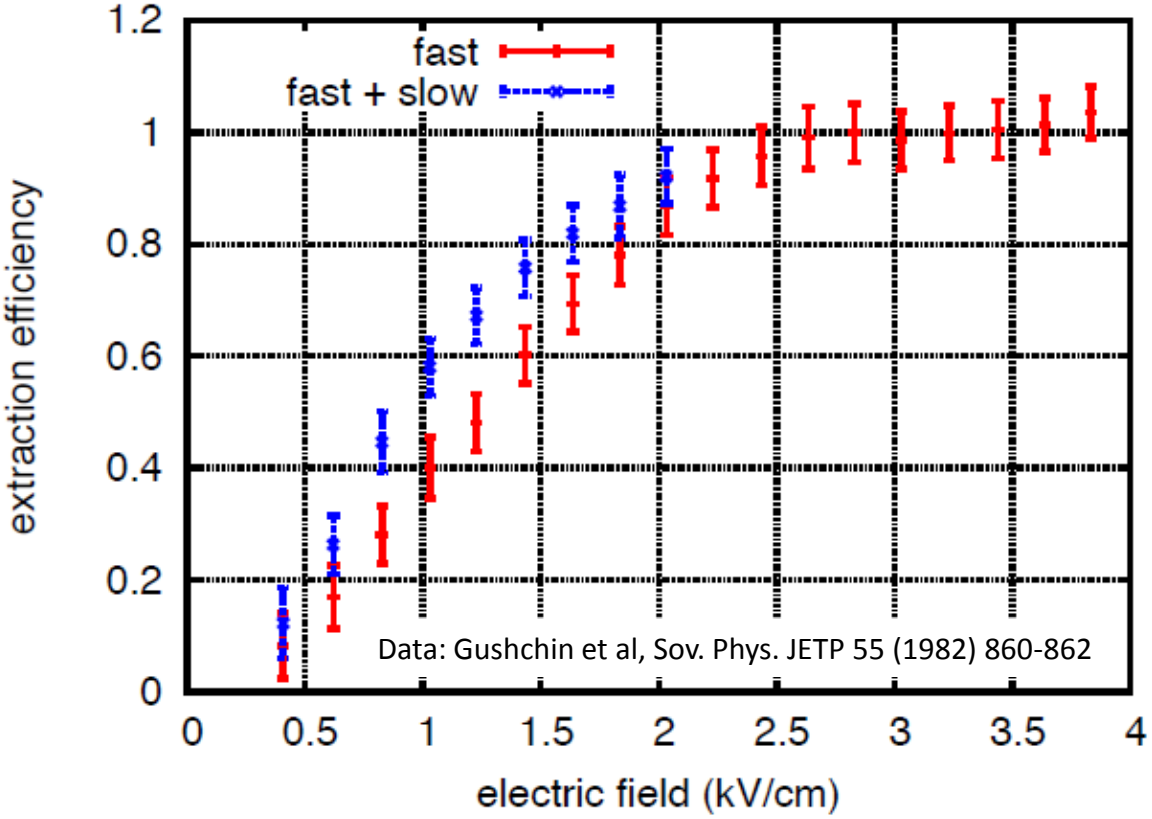
➔ Grid $\Delta V = 1.5$ kV for central LEMs

➔ Induction field 1.0 kV/cm

➔ LEM field 28 kV/cm (2,4-9,11), 26 kV/cm (1,3,12), 26 kV/cm (10)

Grid extraction efficiency

Fig. 22 from TDR



"Fast" < 0.1 us extraction
"Slow" extracted ≥ 100 us

Ideally want to be in the region of $E_{lar} \geq 2.5$ kV/cm

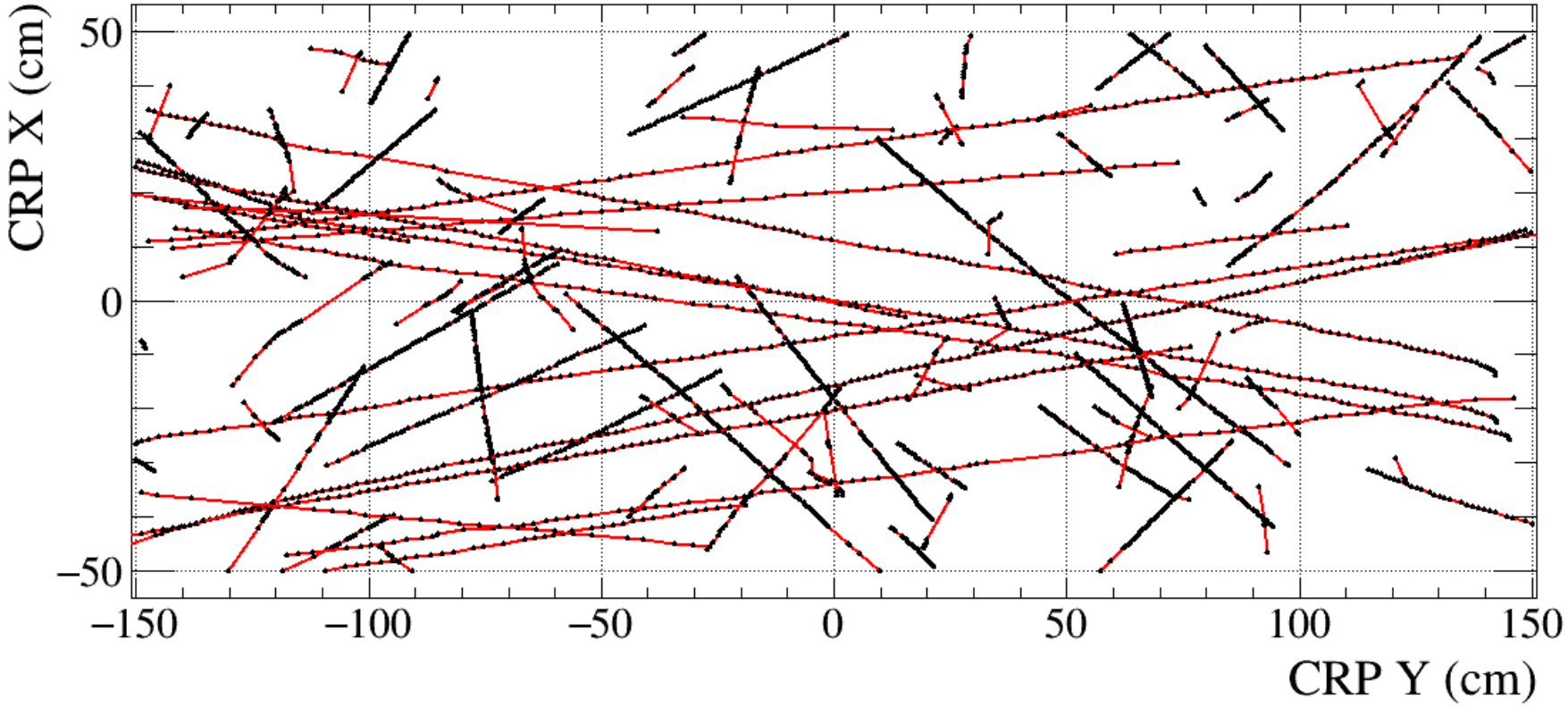
- No "slow" contribution
- Extraction is ~100%

➔ $\Delta V \sim 3$ kV with respect to the LEM bottom electrode

Taking $\Delta V = 1.5$ kV and assuming LAr level is ~5 mm above the grid
$E_{lar} = 1.2$ kV/cm ➔ extraction efficiency for "fast" contribution ~0.5

Reconstructed tracks in CRP projection after view merging (run 748)

Black points are registered hits in view 0

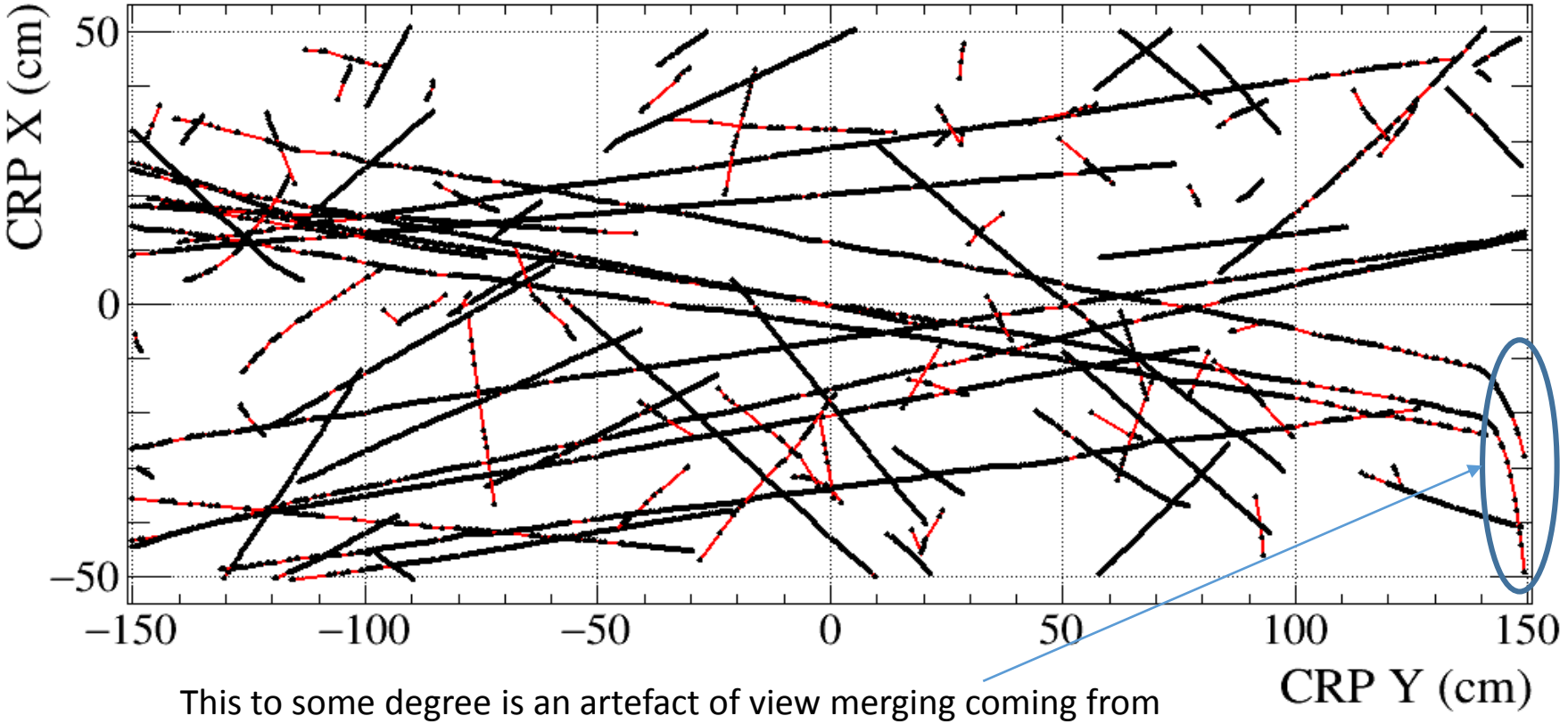


Long tracks traversing the detector are triggered by CRT
Short tracks are fragments of other cosmics entering detector within +/- readout window

Reconstructed tracks in CRP projection after view merging (run 748)

Black points are registered hits in view 1

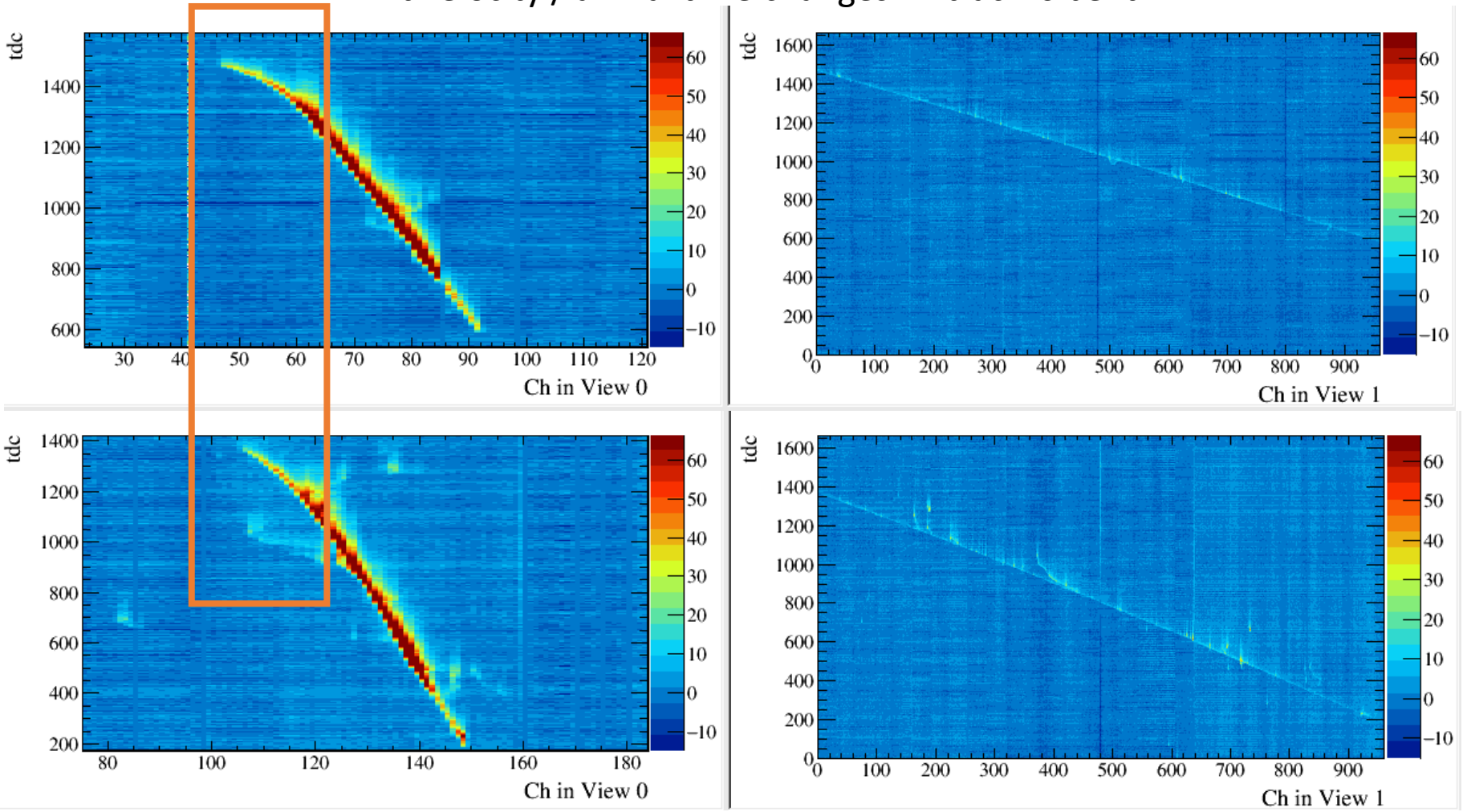
More hits than in view 0 due to larger dimension and favourable trigger selection



This to some degree is an artefact of view merging coming from extrapolating X coor'd (from view 0), which changes slope (dz/dx) rapidly for some tracks as shown in the next page

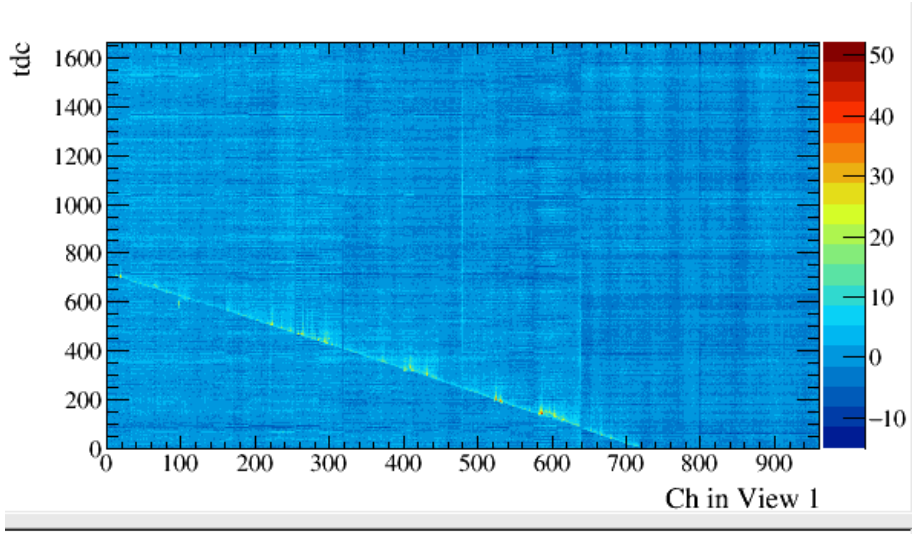
Distorted tracks in raw data

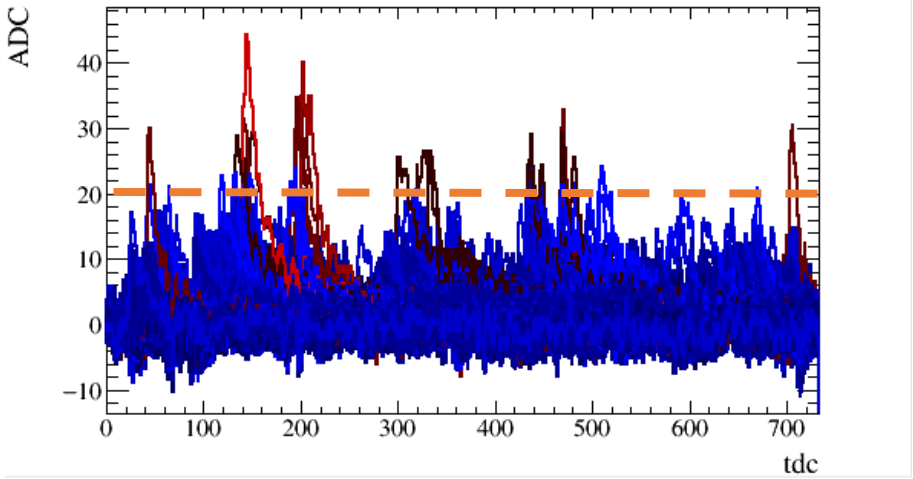
Drift velocity / arrival time changes → track is bent



Drift field distortion? To be investigated further …

Quick order of magnitude check

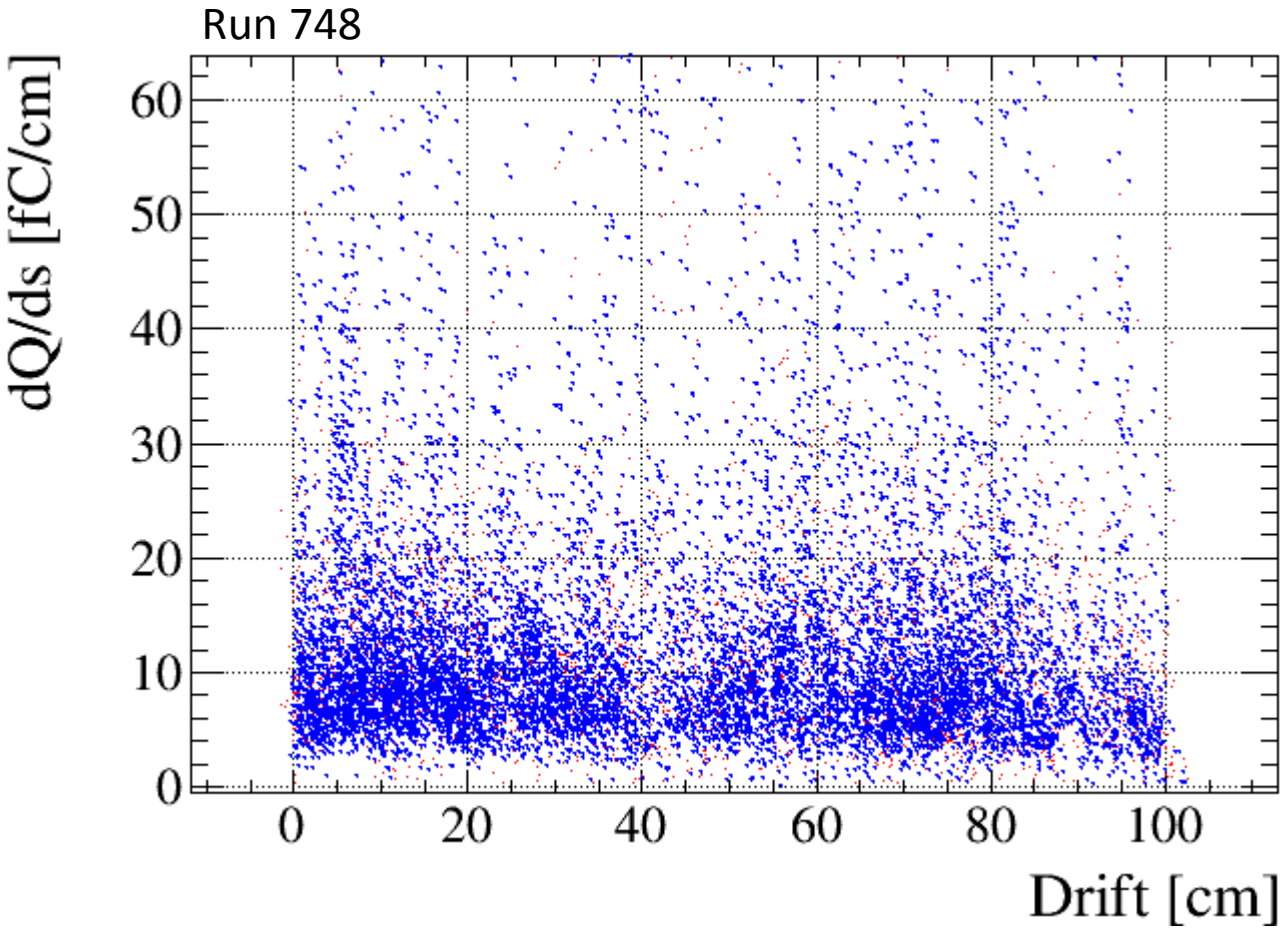




For nearly horizontal tracks that go close to parallel to 3m strips, can get a quick order of magnitude idea of the charge loss

20 ADC corresponds to 3 fC
(cf. p. 58 SPSC-SR-206)
Charges seen by pre-amplifiers are <3 fC
Or normalizing by channel pitch <10 fC/cm

dQ/ds in each collection view

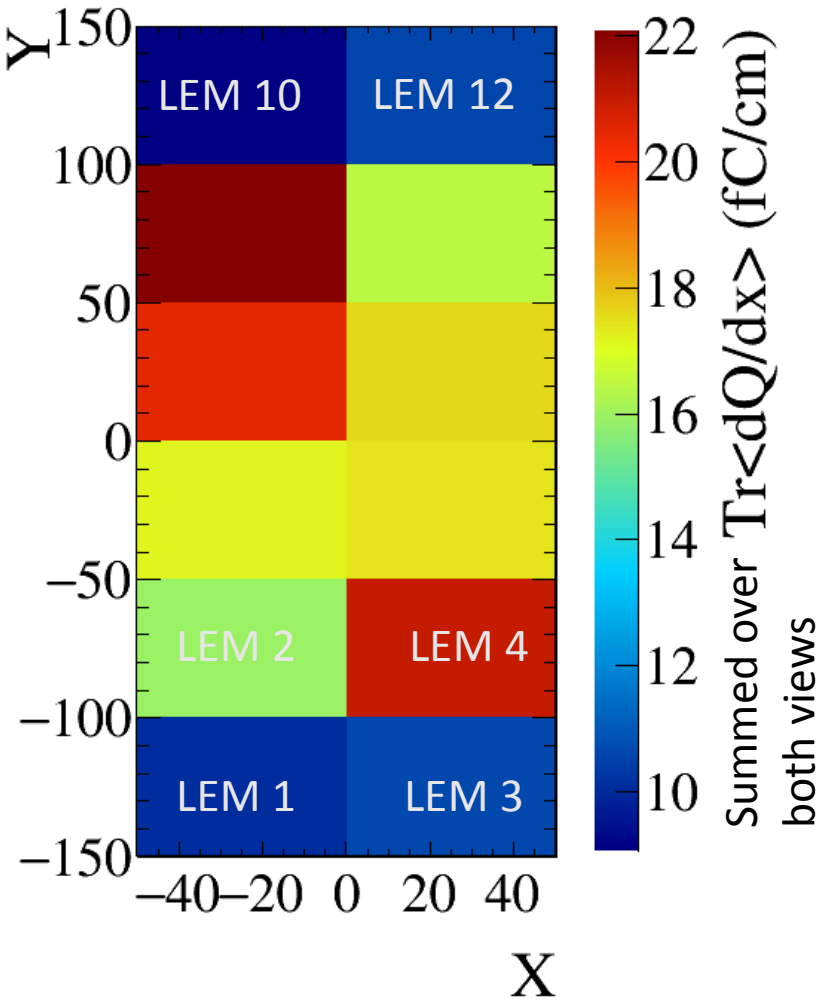


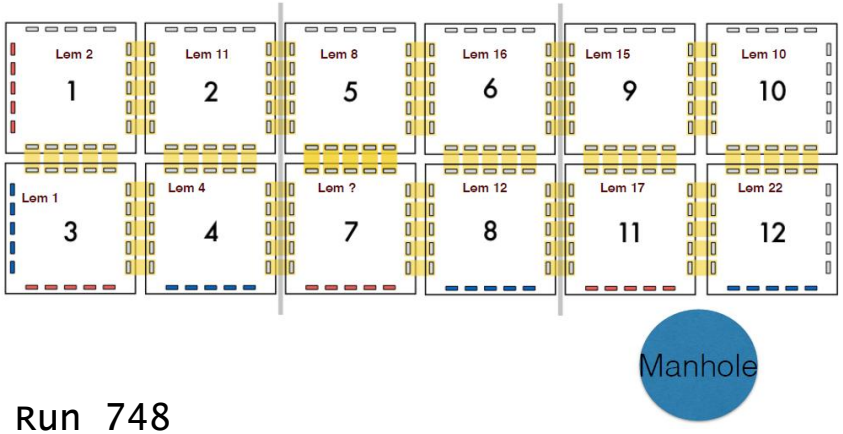
Collection view 0
Collection view 1

ds is the effective pitch in 3D

No substantial attenuation over the drift → good purity
To be checked with a precise fit …

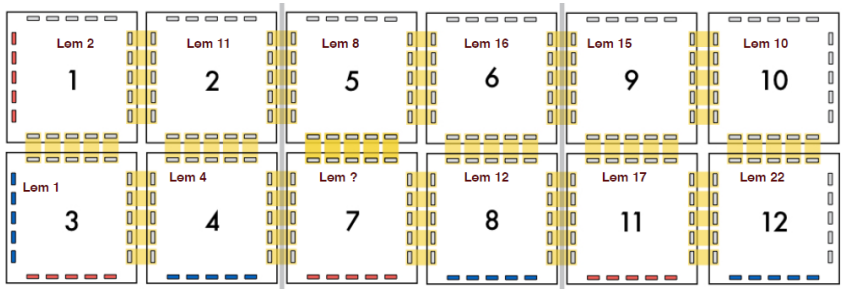
From truncated mean
with 30% on the tail



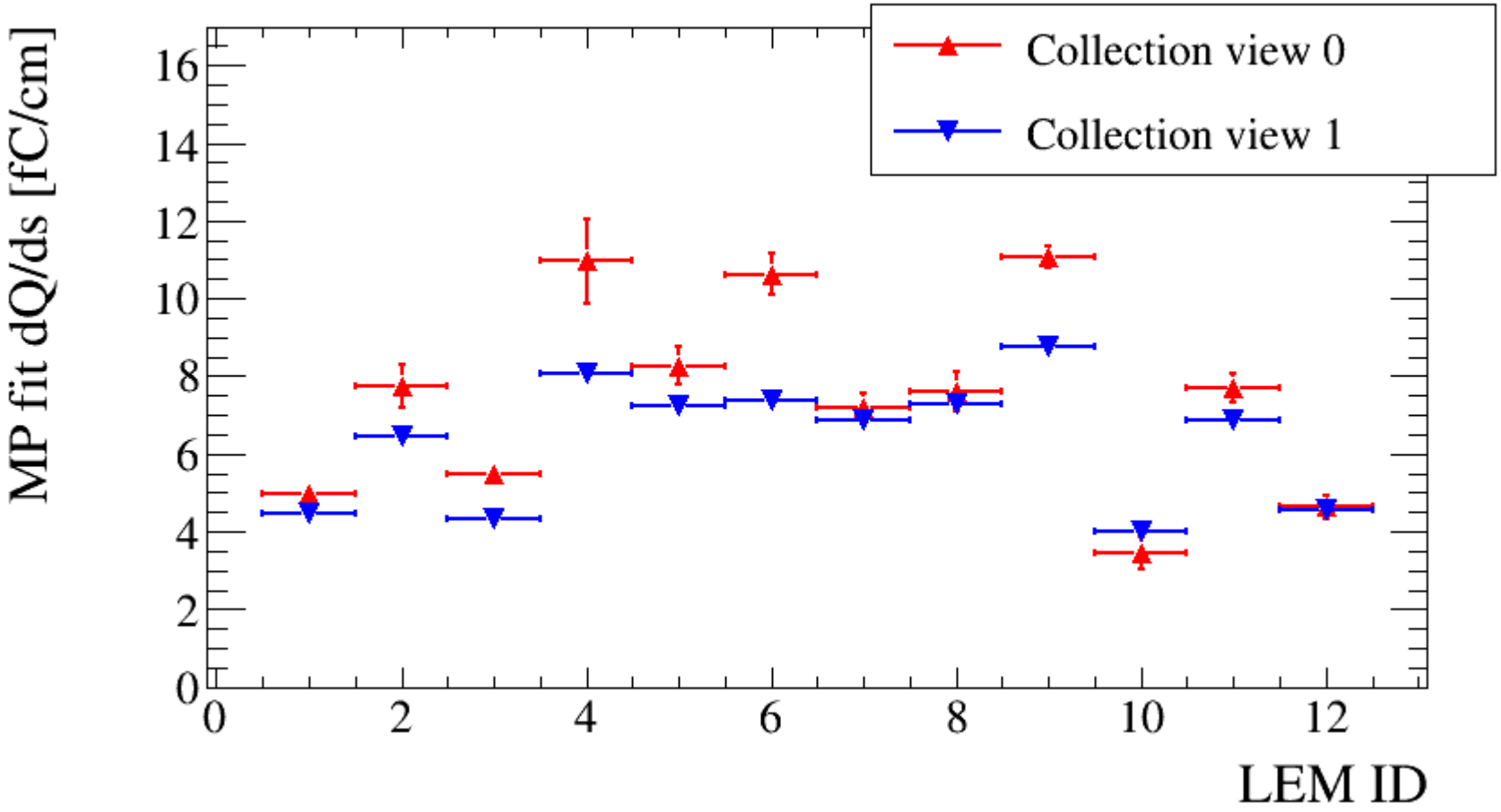


Run 748
HV:
LEM T 0.2kV
LEM B 3.0 kV
LEM01 B 2.8 kV
LEM03 B 2.8 kV
LEM12 B 2.8 kV
LEM10 B 2.7 kV
GRID 4.5 kV
CATH 41.0 kV

Lower gain is seen in the LEM at borders. Qualitatively consistent with the fact that these LEMs were operated with lower field values during this run



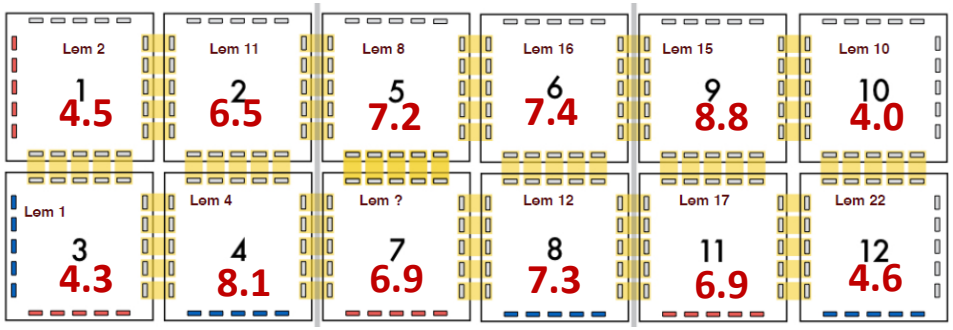
Fitted MPV Run 748 for different LEMs



MPV from fit of convolution of Gaussian with a Landau function

Fitted MPV dQ/ds from collection view 1 in each LEM [fC/cm]

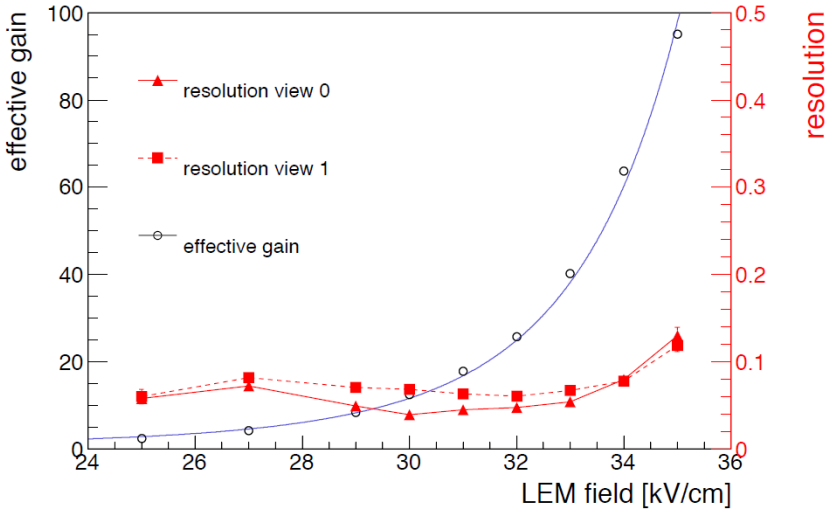
LEMF	Fitted MPV dQ/ds_1 [fC/cm]
1	4.5 +/- 2%
2	6.5 +/- 2%
3	4.3 +/- 2%
4	8.1 +/- 2%
5	7.2 +/- 2%
6	7.4 +/- 2%
7	6.9 +/- 2%
8	7.3 +/- 2%
9	8.8 +/- 2%
10	4.0 +/- 5%
11	6.9 +/- 3%
12	4.6 +/- 3%



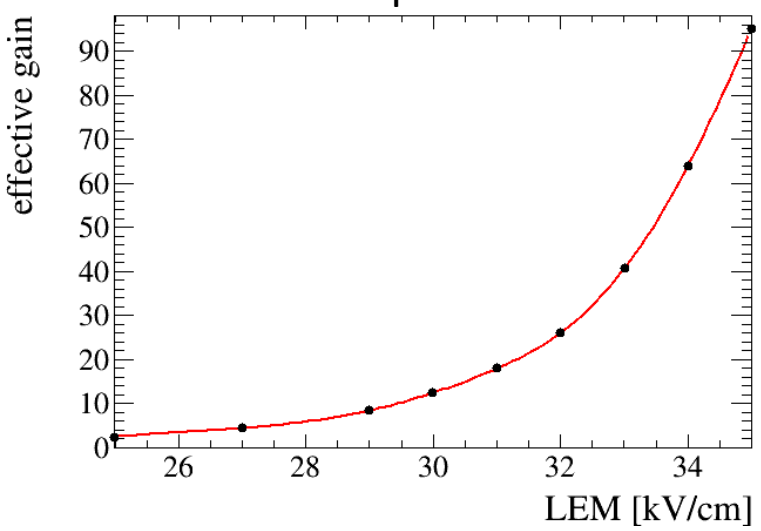
- The stat error is ~2% for the collection view 1
- LEM 1, 3, 12 at 26 kV/cm gains look to be within ~3% from each other
- LEM 10 at 25 kV/cm gain is lower by ~10% compared to 1,3, and 12
- LEMs 5-8 at 30 kV/cm have the same gain within ~4%
- LEM 4 and 9 at 30 kV/cm are on the higher end while LEM 2 and 11 are at the lower end
  - Interestingly the LEM 2 and 4 and LEM 9 and 11 are the pairs next to the border LEMs at lower field

Gain vs LEM field

Fig 51 from TDR



A digitized copy of the image used for interpolation



LEM field [kV/cm]	Eff gain in 3L	3L frac increase	dQ/ds_1 [fC/cm]	311 frac increase
25	2.4	-	~4.0	-
26	3.5	1.46	~4.5	~1.13
28	5.9	1.69	~7.2	~1.60

Expected charge yield: "back of the envelope calculation"

Take gain $G \approx 5.9$ at 28 kV/cm (no pressure / temperature corrections …)
Charge is evenly shared between two collection views: $f_{share} = 0.5$
Electron extraction efficiency: $f_{ext} \approx 0.5$
Take $dQ_{CR}/ds \approx dQ_{mip}/ds$ for cosmics to be consistent with the "3L" gain normalization

Since the cosmic muons that cross the chamber are minimum ionising particles the average charge deposition along a track, predicted by the Bethe-Bloch formula and accounting for electron-ion recombination [21] is $\langle \Delta Q/\Delta s \rangle_{MIP} = 10$ fC/cm. By using the sum of the collected charge per unit length on both views we hence define the measured effective gain by:

$$G_{eff} = \frac{\langle \Delta Q_0/\Delta s_0 \rangle + \langle \Delta Q_1/\Delta s_1 \rangle}{\langle \Delta Q/\Delta s \rangle_{MIP}} \qquad (2.3)$$

Cantini, C. *et al.* JINST 10 (2015) no.03, P03017

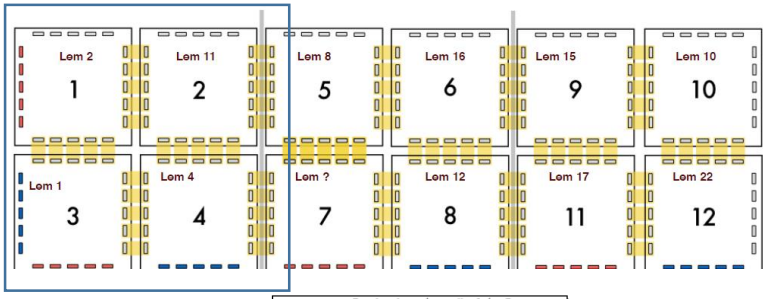
Note however cosmics are on average 4 GeV/c: dE/dx > MIP

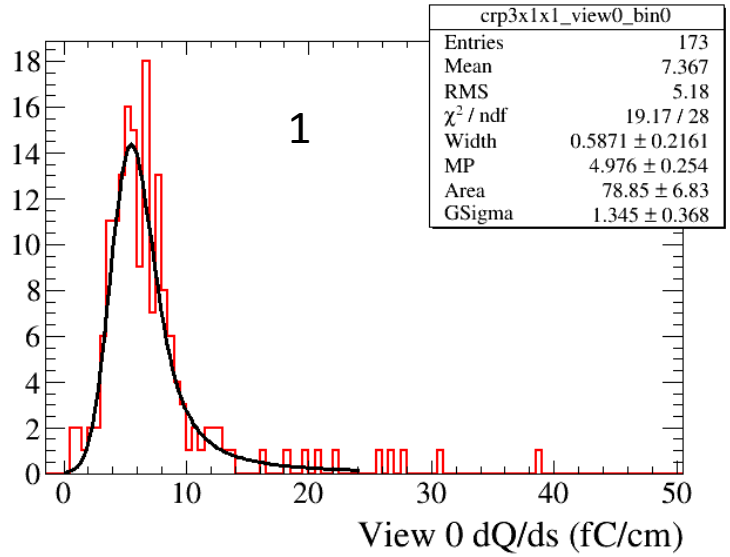
Expect signals:

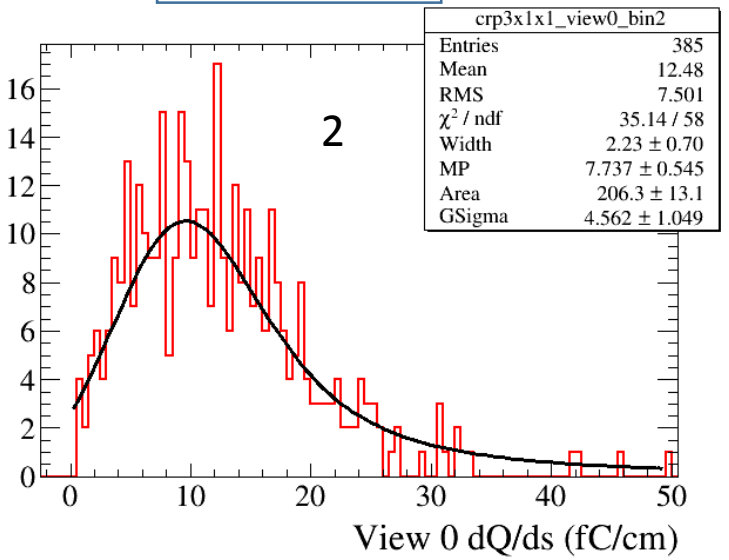
$$< dQ/ds >_{view} = f_{share} \times G \times f_{ext} \times dQ_{CR}/ds = 14 \text{ fC/cm}$$

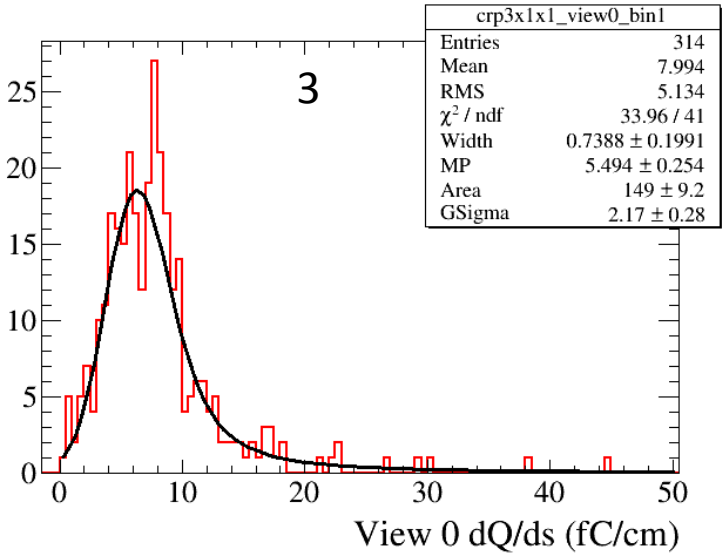
Some inefficiency due to low induction field should also be considered …

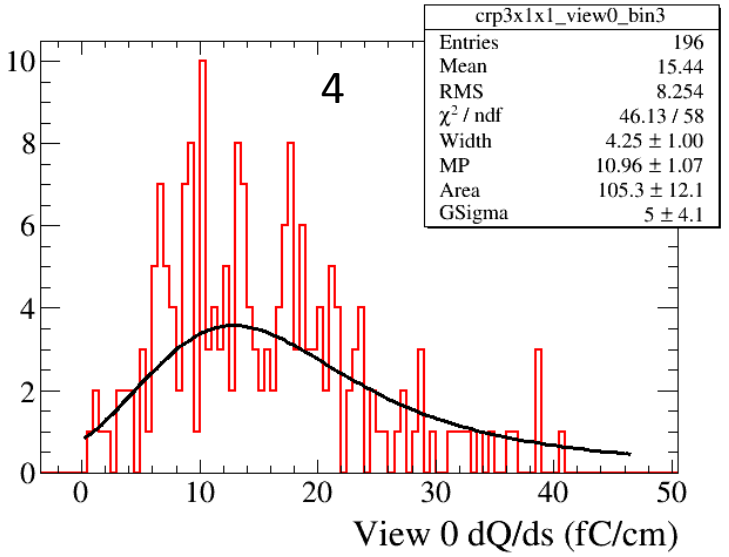
dQ/dx view 0


Lom 2
1
Lom 11
2
Lom 8
5
Lom 16
6
Lom 15
9
Lom 10
10
Lom 1
3
Lom 4
4
Lom ?
7
Lom 12
8
Lom 17
11
Lom 22
12

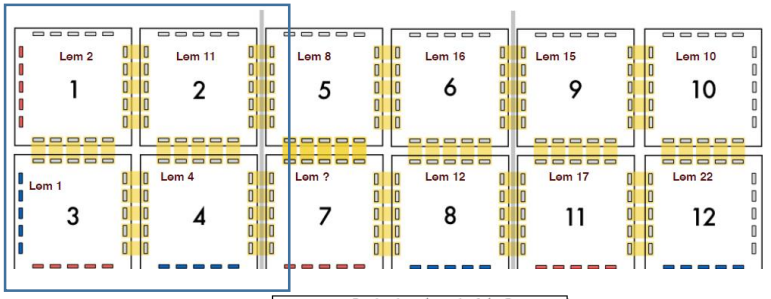

crp3x1x1_view0_bin0
Entries 173
Mean 7.367
RMS 5.18
χ² / ndf 19.17 / 28
Width 0.5871 ± 0.2161
MP 4.976 ± 0.254
Area 78.85 ± 6.83
GSigma 1.345 ± 0.368
1
View 0 dQ/ds (fC/cm)


crp3x1x1_view0_bin2
Entries 385
Mean 12.48
RMS 7.501
χ² / ndf 35.14 / 58
Width 2.23 ± 0.70
MP 7.737 ± 0.545
Area 206.3 ± 13.1
GSigma 4.562 ± 1.049
2
View 0 dQ/ds (fC/cm)


crp3x1x1_view0_bin1
Entries 314
Mean 7.994
RMS 5.134
χ² / ndf 33.96 / 41
Width 0.7388 ± 0.1991
MP 5.494 ± 0.254
Area 149 ± 9.2
GSigma 2.17 ± 0.28
3
View 0 dQ/ds (fC/cm)


crp3x1x1_view0_bin3
Entries 196
Mean 15.44
RMS 8.254
χ² / ndf 46.13 / 58
Width 4.25 ± 1.00
MP 10.96 ± 1.07
Area 105.3 ± 12.1
GSigma 5 ± 4.1
4
View 0 dQ/ds (fC/cm)

dQ/dx view 1


Lom 2
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Lom 11
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Lom 8
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Lom 16
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Lom 15
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Lom 10
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Lom 1
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Lom 4
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Lom ?
7
Lom 12
8
Lom 17
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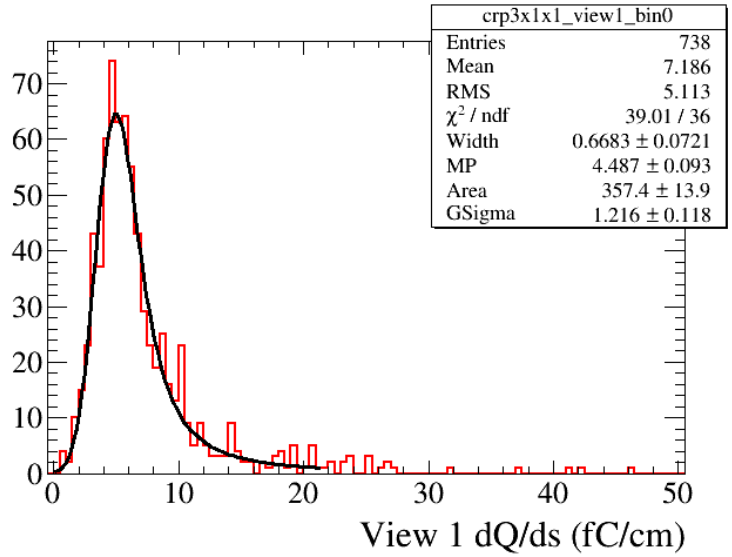
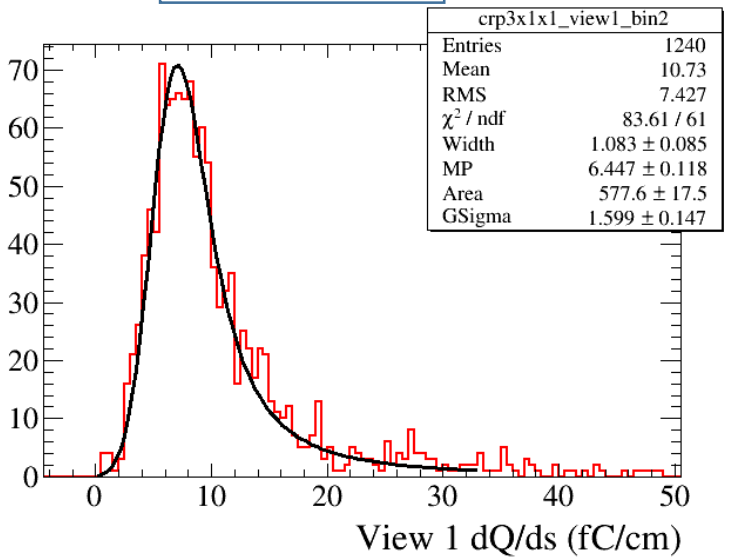
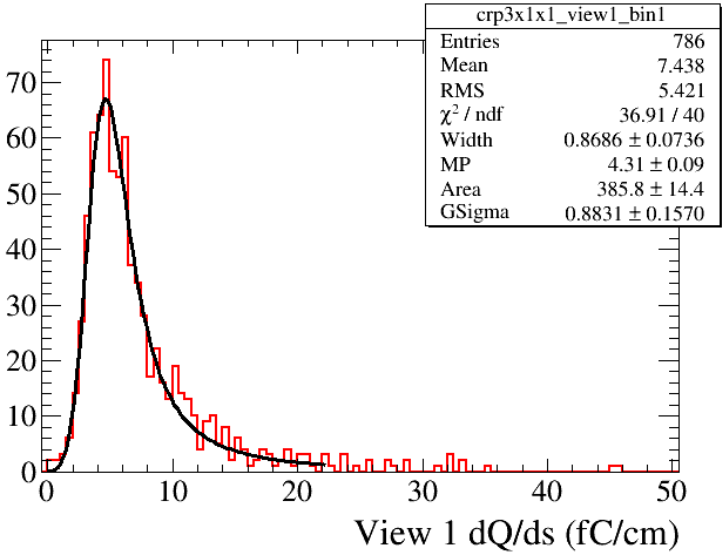
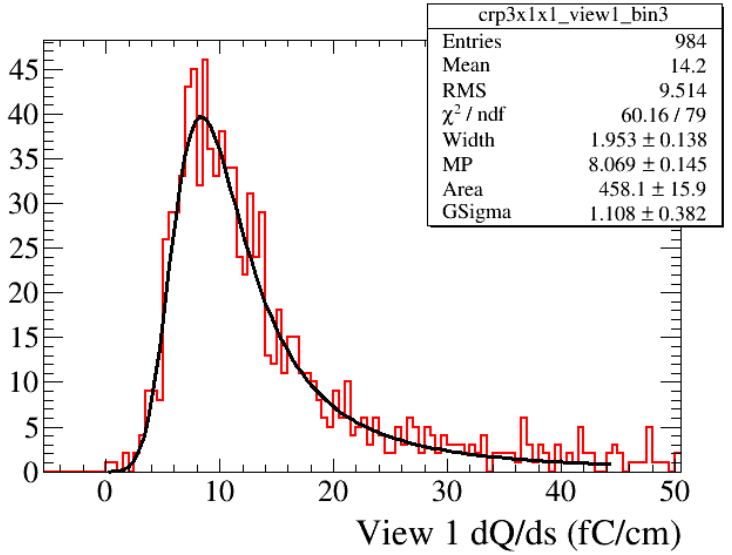
Lom 22
12

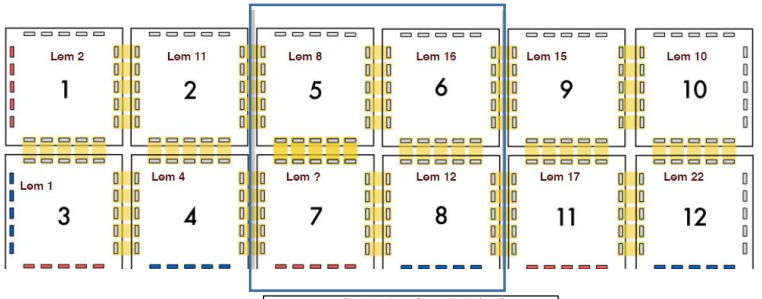

crp3x1x1_view1_bin0
Entries 738
Mean 7.186
RMS 5.113
χ² / ndf 39.01 / 36
Width 0.6683 ± 0.0721
MP 4.487 ± 0.093
Area 357.4 ± 13.9
GSigma 1.216 ± 0.118
View 1 dQ/ds (fC/cm)


crp3x1x1_view1_bin2
Entries 1240
Mean 10.73
RMS 7.427
χ² / ndf 83.61 / 61
Width 1.083 ± 0.085
MP 6.447 ± 0.118
Area 577.6 ± 17.5
GSigma 1.599 ± 0.147
View 1 dQ/ds (fC/cm)


crp3x1x1_view1_bin1
Entries 786
Mean 7.438
RMS 5.421
χ² / ndf 36.91 / 40
Width 0.8686 ± 0.0736
MP 4.31 ± 0.09
Area 385.8 ± 14.4
GSigma 0.8831 ± 0.1570
View 1 dQ/ds (fC/cm)


crp3x1x1_view1_bin3
Entries 984
Mean 14.2
RMS 9.514
χ² / ndf 60.16 / 79
Width 1.953 ± 0.138
MP 8.069 ± 0.145
Area 458.1 ± 15.9
GSigma 1.108 ± 0.382
View 1 dQ/ds (fC/cm)

dQ/dx view 0


Lom 2
1
Lom 11
2
Lom 8
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Lom 16
6
Lom 15
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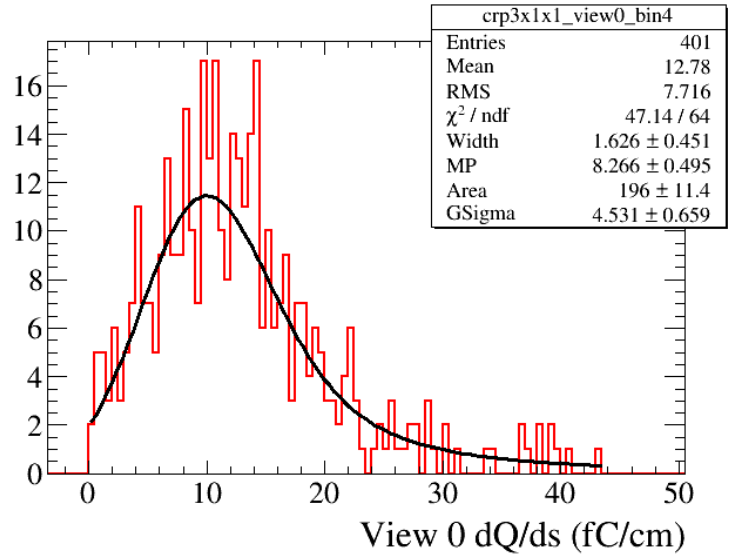
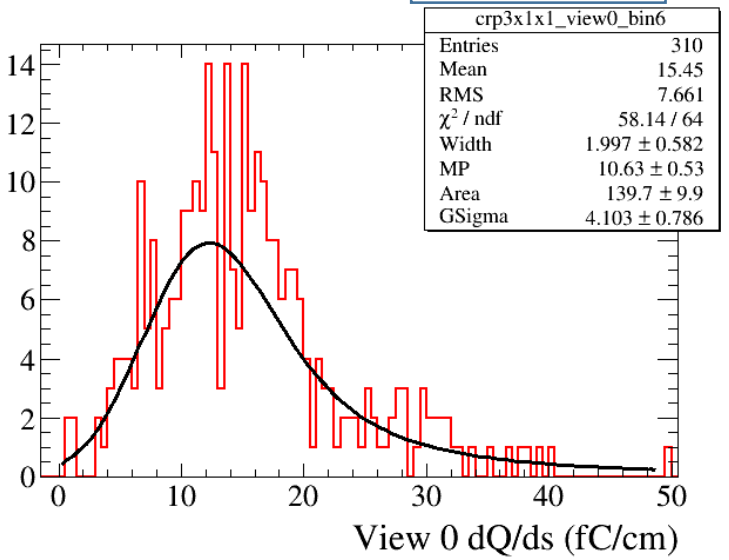
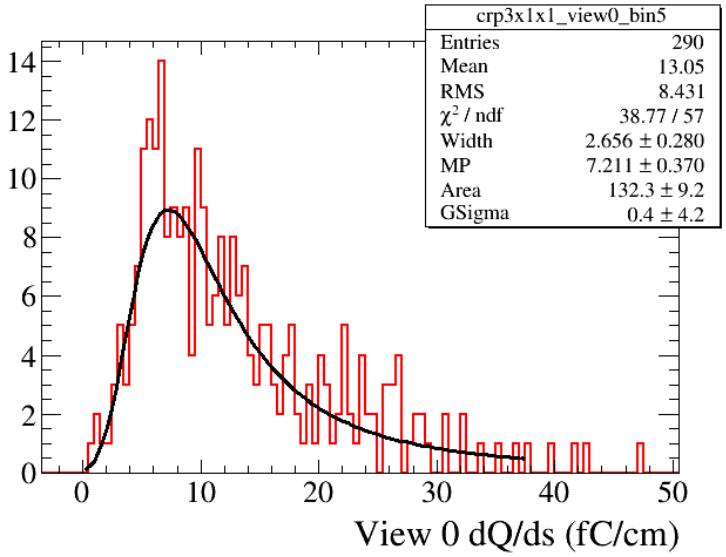
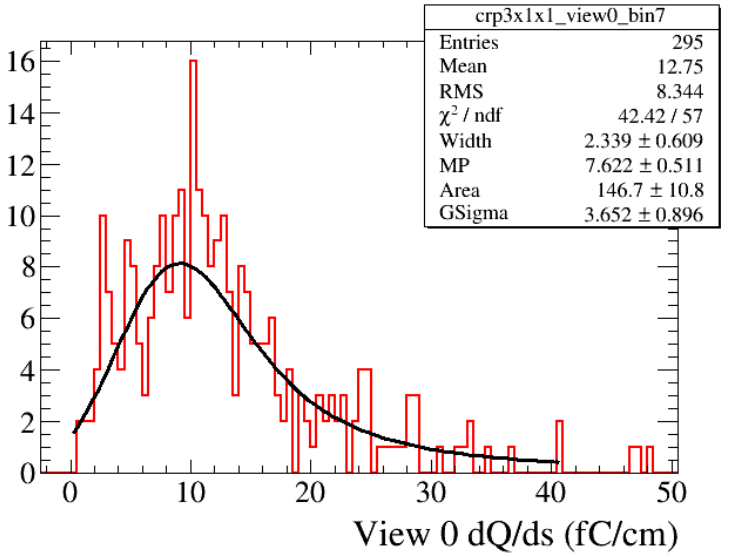
Lom 10
10
Lom 1
3
Lom 4
4
Lom ?
7
Lom 12
8
Lom 17
11
Lom 22
12

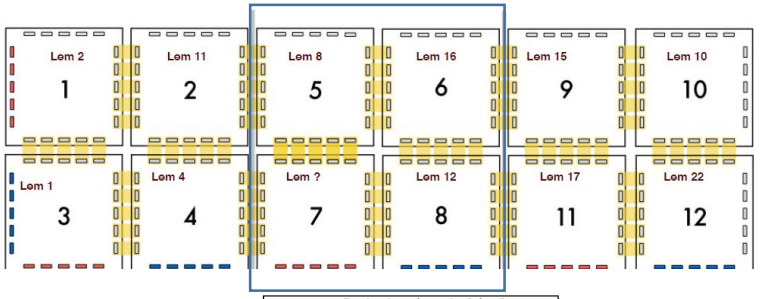

crp3x1x1_view0_bin4
Entries 401
Mean 12.78
RMS 7.716
χ² / ndf 47.14 / 64
Width 1.626 ± 0.451
MP 8.266 ± 0.495
Area 196 ± 11.4
GSigma 4.531 ± 0.659
View 0 dQ/ds (fC/cm)


crp3x1x1_view0_bin6
Entries 310
Mean 15.45
RMS 7.661
χ² / ndf 58.14 / 64
Width 1.997 ± 0.582
MP 10.63 ± 0.53
Area 139.7 ± 9.9
GSigma 4.103 ± 0.786
View 0 dQ/ds (fC/cm)


crp3x1x1_view0_bin5
Entries 290
Mean 13.05
RMS 8.431
χ² / ndf 38.77 / 57
Width 2.656 ± 0.280
MP 7.211 ± 0.370
Area 132.3 ± 9.2
GSigma 0.4 ± 4.2
View 0 dQ/ds (fC/cm)


crp3x1x1_view0_bin7
Entries 295
Mean 12.75
RMS 8.344
χ² / ndf 42.42 / 57
Width 2.339 ± 0.609
MP 7.622 ± 0.511
Area 146.7 ± 10.8
GSigma 3.652 ± 0.896
View 0 dQ/ds (fC/cm)

dQ/dx view 1


Lom 2
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Lom 11
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Lom 8
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Lom 16
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Lom 15
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Lom 10
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Lom 1
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Lom 4
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Lom ?
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Lom 12
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Lom 17
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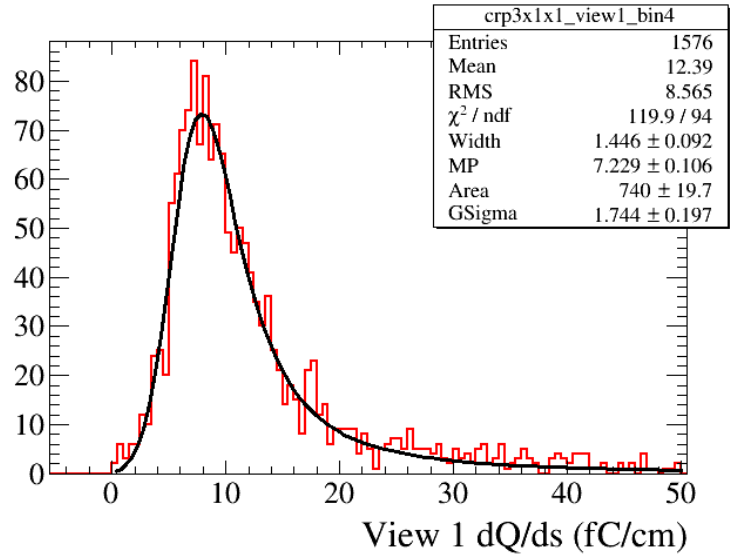
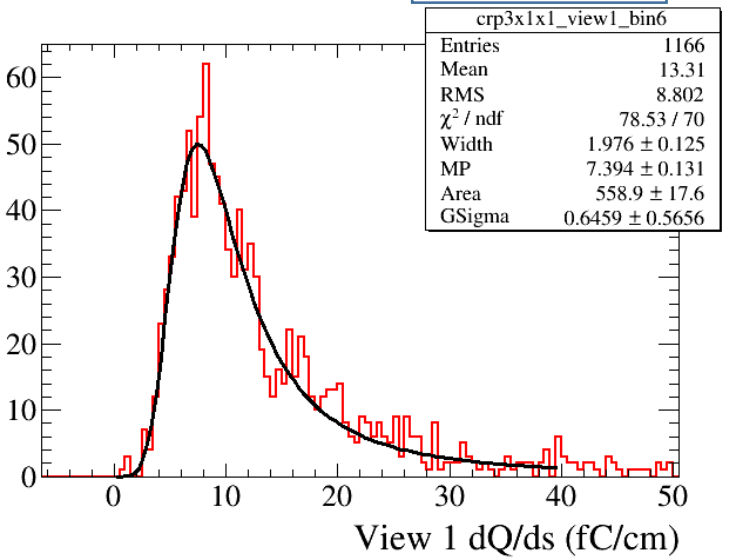
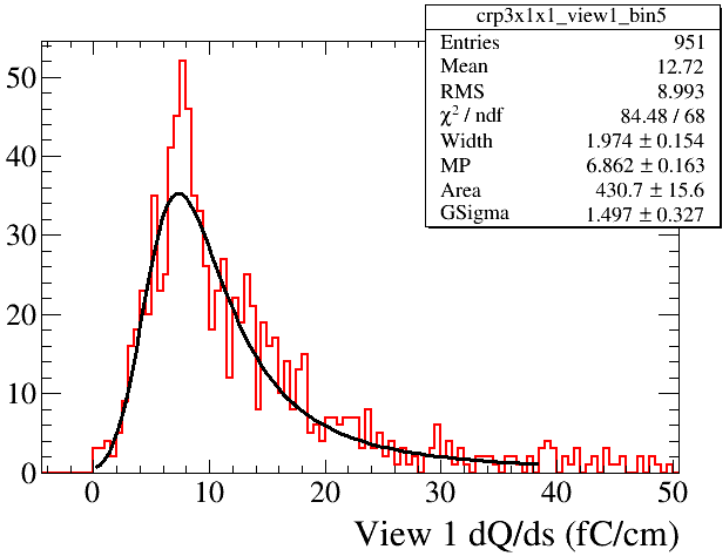
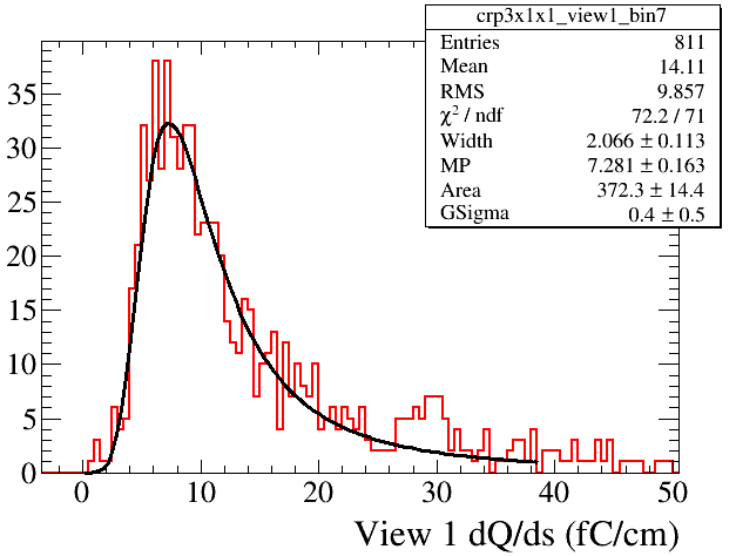
Lom 22
12

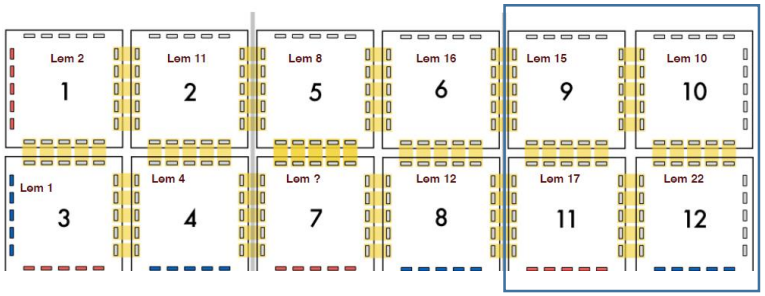

crp3x1x1_view1_bin4
Entries 1576
Mean 12.39
RMS 8.565
χ² / ndf 119.9 / 94
Width 1.446 ± 0.092
MP 7.229 ± 0.106
Area 740 ± 19.7
GSigma 1.744 ± 0.197
View 1 dQ/ds (fC/cm)


crp3x1x1_view1_bin6
Entries 1166
Mean 13.31
RMS 8.802
χ² / ndf 78.53 / 70
Width 1.976 ± 0.125
MP 7.394 ± 0.131
Area 558.9 ± 17.6
GSigma 0.6459 ± 0.5656
View 1 dQ/ds (fC/cm)


crp3x1x1_view1_bin5
Entries 951
Mean 12.72
RMS 8.993
χ² / ndf 84.48 / 68
Width 1.974 ± 0.154
MP 6.862 ± 0.163
Area 430.7 ± 15.6
GSigma 1.497 ± 0.327
View 1 dQ/ds (fC/cm)


crp3x1x1_view1_bin7
Entries 811
Mean 14.11
RMS 9.857
χ² / ndf 72.2 / 71
Width 2.066 ± 0.113
MP 7.281 ± 0.163
Area 372.3 ± 14.4
GSigma 0.4 ± 0.5
View 1 dQ/ds (fC/cm)

dQ/dx view 0


Lom 2
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Lom 11
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Lom 8
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Lom 16
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Lom 15
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Lom 10
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Lom 1
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Lom 4
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Lom ?
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Lom 12
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Lom 17
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Lom 22
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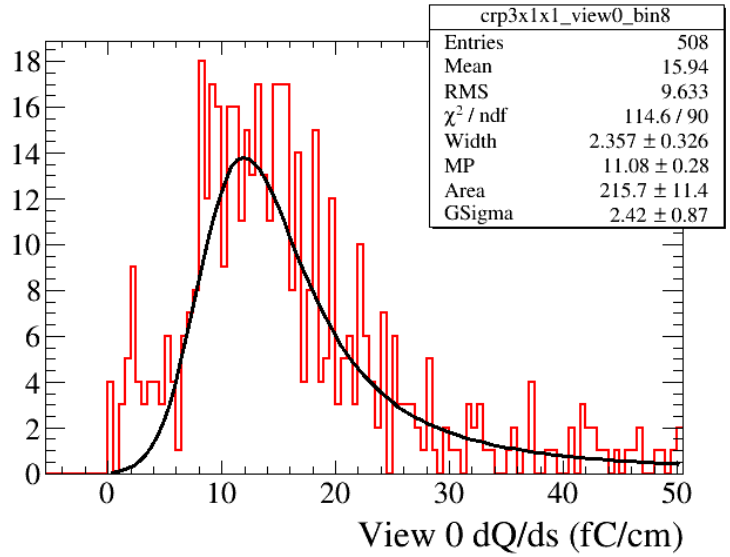
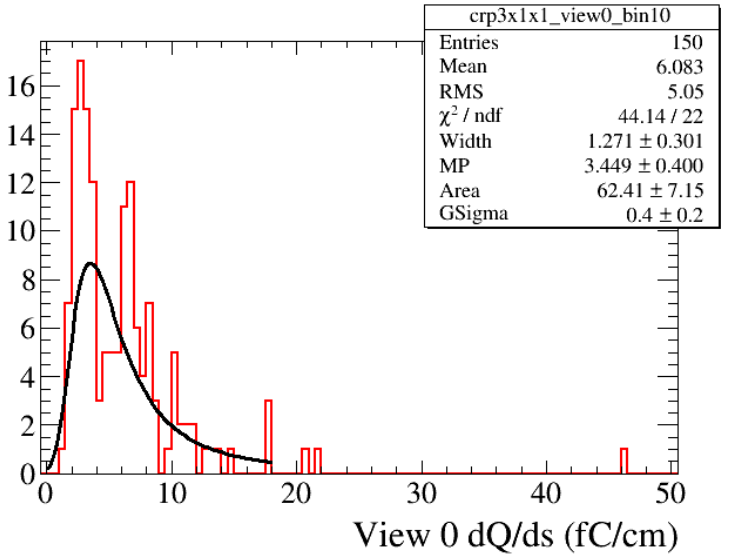
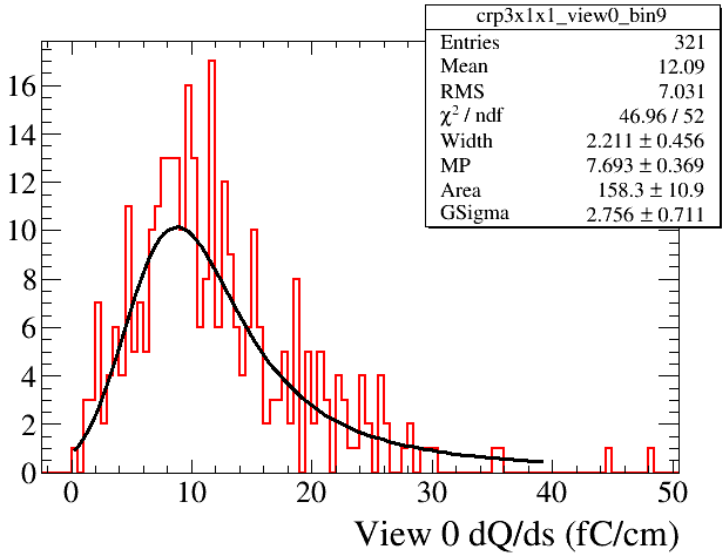
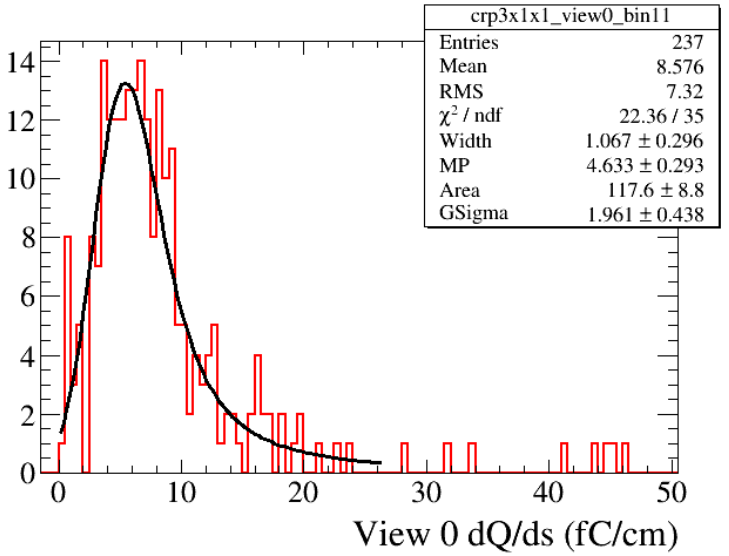
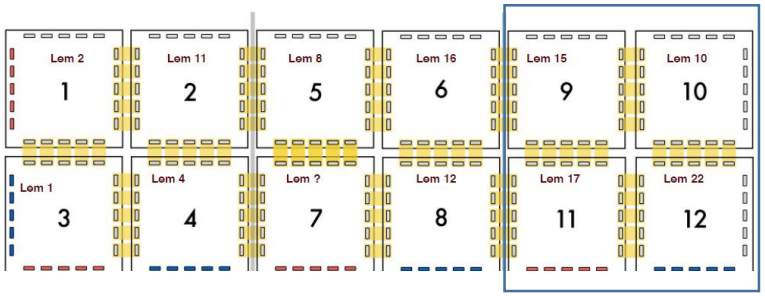

crp3x1x1_view0_bin8
Entries 508
Mean 15.94
RMS 9.633
χ² / ndf 114.6 / 90
Width 2.357 ± 0.326
MP 11.08 ± 0.28
Area 215.7 ± 11.4
GSigma 2.42 ± 0.87
View 0 dQ/ds (fC/cm)


crp3x1x1_view0_bin10
Entries 150
Mean 6.083
RMS 5.05
χ² / ndf 44.14 / 22
Width 1.271 ± 0.301
MP 3.449 ± 0.400
Area 62.41 ± 7.15
GSigma 0.4 ± 0.2
View 0 dQ/ds (fC/cm)


crp3x1x1_view0_bin9
Entries 321
Mean 12.09
RMS 7.031
χ² / ndf 46.96 / 52
Width 2.211 ± 0.456
MP 7.693 ± 0.369
Area 158.3 ± 10.9
GSigma 2.756 ± 0.711
View 0 dQ/ds (fC/cm)


crp3x1x1_view0_bin11
Entries 237
Mean 8.576
RMS 7.32
χ² / ndf 22.36 / 35
Width 1.067 ± 0.296
MP 4.633 ± 0.293
Area 117.6 ± 8.8
GSigma 1.961 ± 0.438
View 0 dQ/ds (fC/cm)

dQ/dx view 1


Lom 2
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Lom 16
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Lom 10
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Lom 1
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Lom 4
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Lom ?
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Lom 12
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Lom 17
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Lom 22
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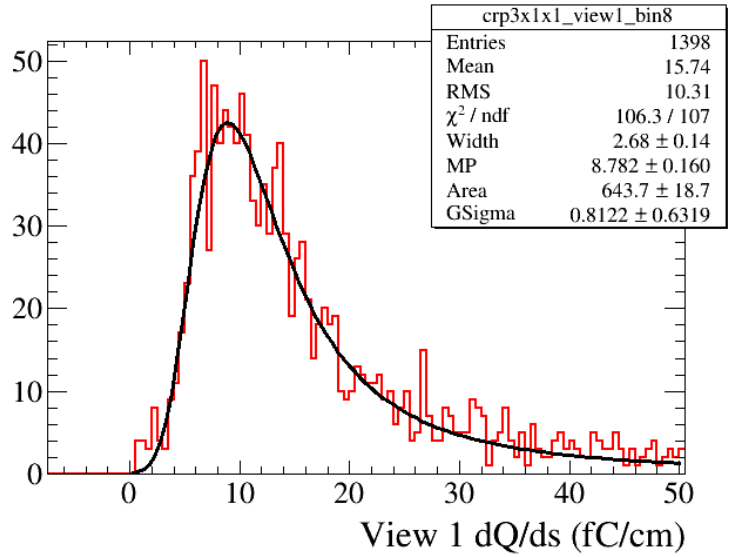
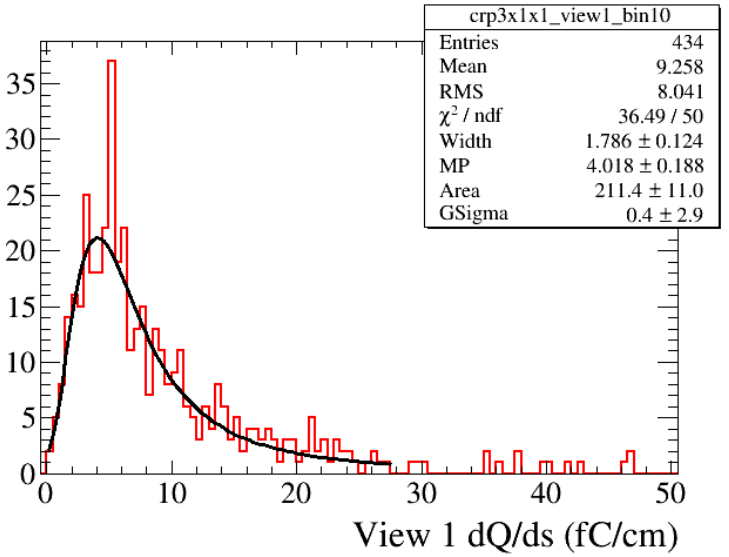
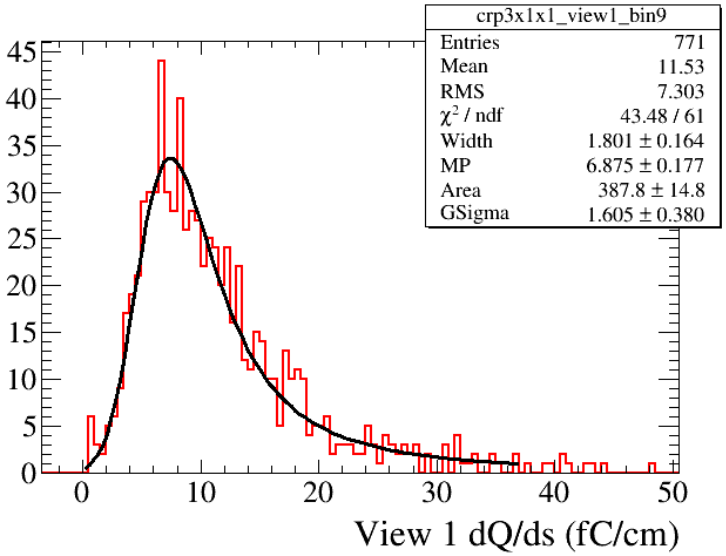
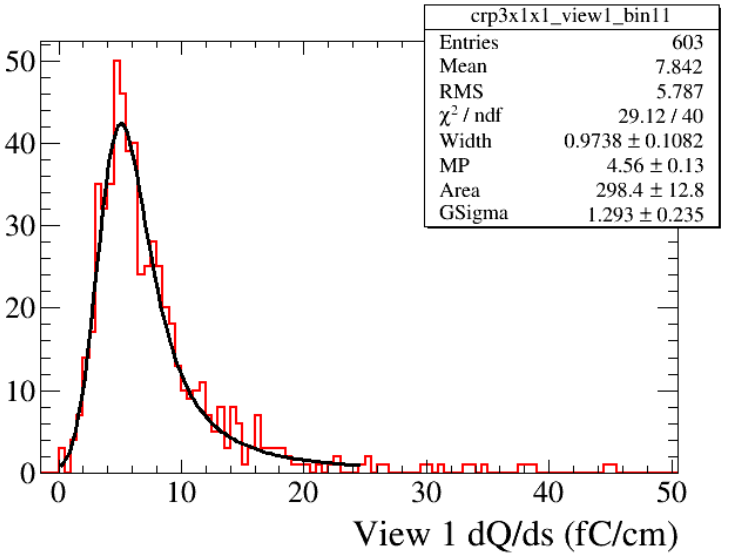

crp3x1x1_view1_bin8
Entries 1398
Mean 15.74
RMS 10.31
χ² / ndf 106.3 / 107
Width 2.68 ± 0.14
MP 8.782 ± 0.160
Area 643.7 ± 18.7
GSigma 0.8122 ± 0.6319
View 1 dQ/ds (fC/cm)


crp3x1x1_view1_bin10
Entries 434
Mean 9.258
RMS 8.041
χ² / ndf 36.49 / 50
Width 1.786 ± 0.124
MP 4.018 ± 0.188
Area 211.4 ± 11.0
GSigma 0.4 ± 2.9
View 1 dQ/ds (fC/cm)


crp3x1x1_view1_bin9
Entries 771
Mean 11.53
RMS 7.303
χ² / ndf 43.48 / 61
Width 1.801 ± 0.164
MP 6.875 ± 0.177
Area 387.8 ± 14.8
GSigma 1.605 ± 0.380
View 1 dQ/ds (fC/cm)


crp3x1x1_view1_bin11
Entries 603
Mean 7.842
RMS 5.787
χ² / ndf 29.12 / 40
Width 0.9738 ± 0.1082
MP 4.56 ± 0.13
Area 298.4 ± 12.8
GSigma 1.293 ± 0.235
View 1 dQ/ds (fC/cm)