CRP gain measurements from online reconstruction

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Introduction

- Feedback on LEM performance was daily required in order to evaluate the voltage configuration (e.g., raise dV across the LEMs)
- The PDDP raw data are continuously reconstructed on the online cluster machines (E. Pennacchio), these can be used to get a feedback on CRP gain
- Some caveats about absolute gain:
  - To calculate gain need to normalize by some expected charge value, which one typically takes to be MIP <dE/dx>
    - Sensitive high energy tail due to delta ray
    - Need to take into account recombination (drift field strength)
    - LAr purity effects: T0 can be obtained for certain track topologies

Cuts for track T_0 reconstruction

- To apply lifetime correction to the track need to correct the reconstructed track for the arrival time (T0) with respect to the trigger

1. For tracks left by comics before trigger, the T0 can be calculated if they exit on the side of the cathode from the apparent distance to the cathode ← not possible due to field cage HV issue (also low transparency of LAr)
2. For tracks from cosmics arriving after the trigger, T0 can be obtained from the apparent distance to the anode ← use only these
3. Also require the start point to be within area defined by CRP and not on the field cage wall (in which case the T0 cannot be calculated)

- Put a cut that the track start is > 10 cm from CRP and the walls to select only case 2

Expected MIP <dQ/dx>

- The strength of drift E-field is assumed 0.166 kV/cm
  - Rescaled for 50 kV from what was shown by F. Resnati at 120 kV cathode voltage

    ➔ v_{drift} = 0.8 mm/us (~1/2 of the drift velocity at 0.5kV/cm)

    ➔ Recombination factor = 0.55

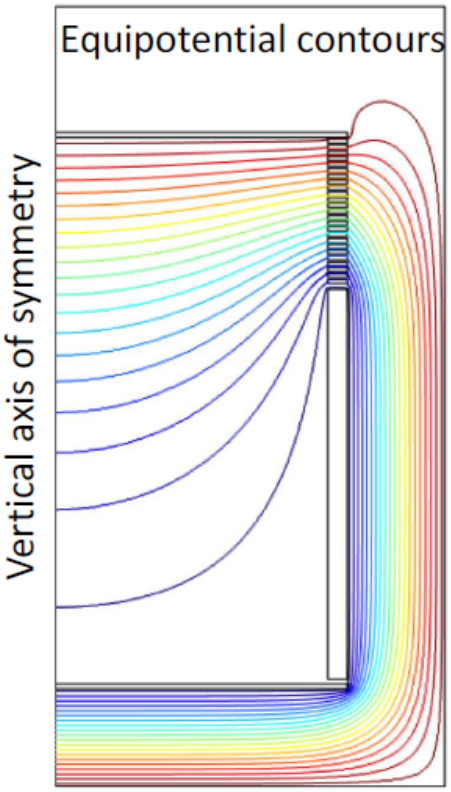
- The expected <dQ/dx> for MIPs

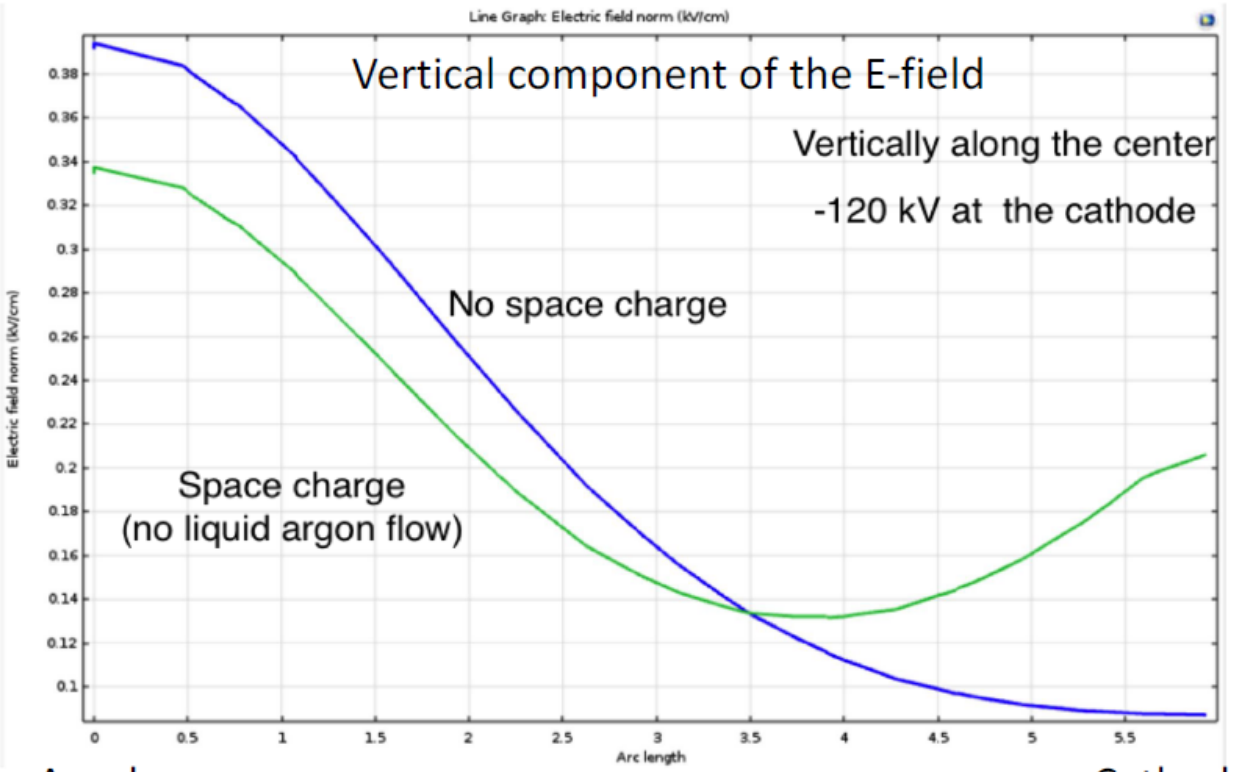
$$< dQ/dx >_{exp} = 0.8 \text{ fC/mm}$$

Electric field simulation

Simulation of F. Resnati from the report on HV problem

- Given our present understanding, the electric field in the drift volume has been calculated with and without space-charge (only the contribution from primary ionization, no from the ion back flow)





Selected runs

Pcryo = 1045 mb, grid 6 kV

runid	dataType	startTime	endTime	nbOfEvents	nL1	nL2	ErrorCode	
1153	cosmics	2019-09-13 11:55:00	2019-09-13 12:10:48	9383	2	4	0	
1212	cosmics	2019-09-18 16:22:44	2019-09-18 17:01:09	22922	2	4	0	dV = 2.9 kV
1214	cosmics	2019-09-18 17:22:42	2019-09-18 19:09:36	63947	2	4	0	
1217	cosmics	2019-09-18 20:14:24	2019-09-18 20:19:48	3156	2	4	0	dV = 3.0 kV
1219	cosmics	2019-09-18 20:37:06	2019-09-18 20:46:18	5416	2	4	0	dV = 3.1 kV

First check gain increase factor between different LEM dV settings

The extraction field varies, since grid voltage was kept constant

Selected runs

Selected here

Run no	LEM dV	Grid V
1262	2.9	5.5
1263	3.0	5.5
1265	3.1	5.5
1267	3.1	5.3
1272	3.1	5.0
1273	3.1	4.5
1275	3.2	4.5
1294	3.2	5.3

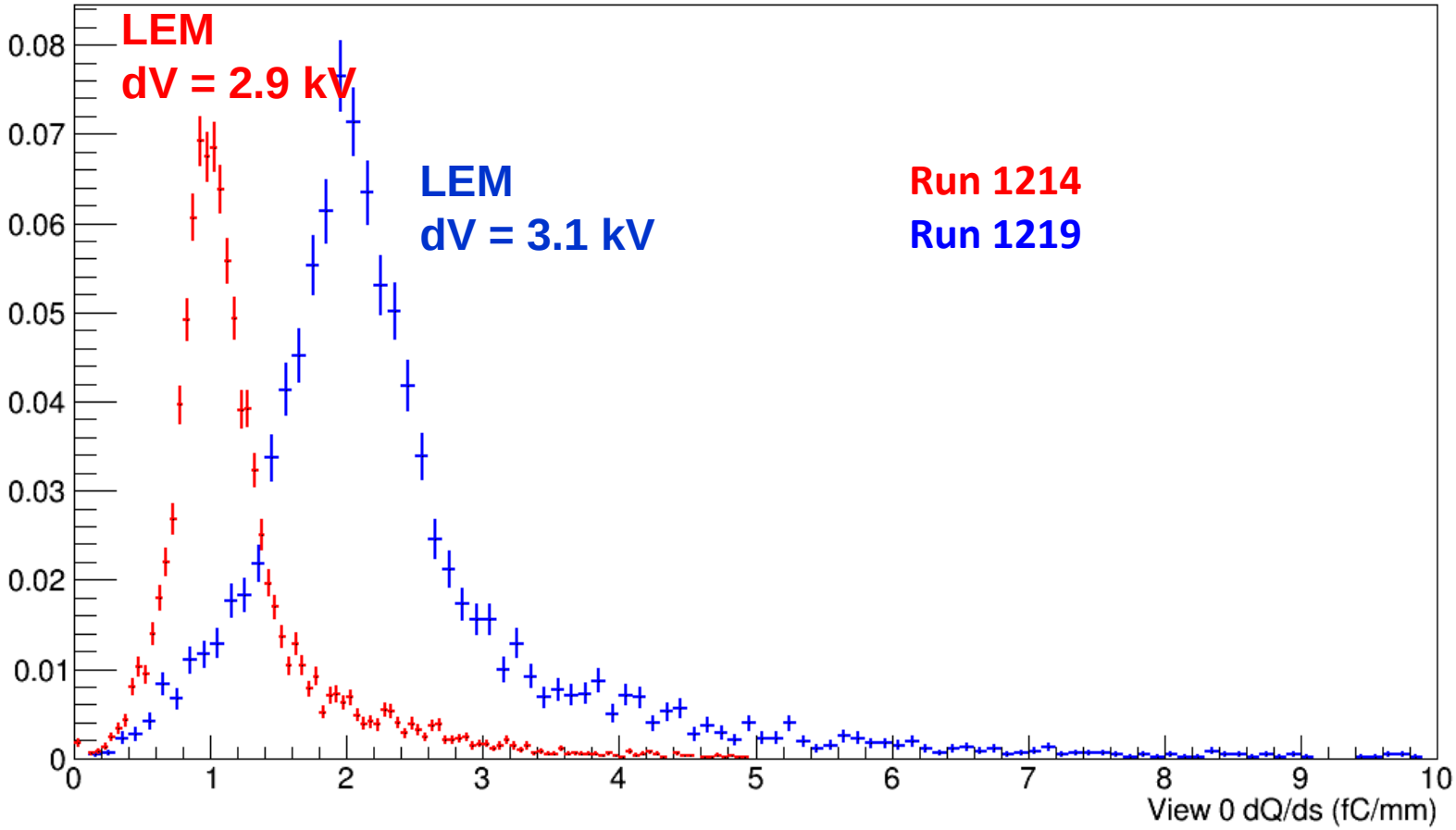
Pcryo = 1010 mbar

runid	datatype	startTime	endTime	nbOfEvents
1262	cosmics	2019-10-03 11:40:36	2019-10-03 12:36:28	33377
1263	cosmics	2019-10-03 12:48:21	2019-10-03 13:19:13	18424
1264	cosmics	2019-10-03 13:23:36	2019-10-03 13:33:48	6024
1265	cosmics	2019-10-03 13:47:17	2019-10-03 15:12:18	50852
1267	cosmics	2019-10-03 15:37:27	2019-10-03 15:45:05	4505
1268	cosmics	2019-10-03 15:51:24	2019-10-03 15:51:45	122
1269	cosmics	2019-10-03 15:53:31	2019-10-03 16:41:24	28618
1270	cosmics	2019-10-03 16:42:19	2019-10-03 16:42:43	164
1271	cosmics	2019-10-03 16:43:10	2019-10-03 16:57:34	8535
1272	cosmics	2019-10-03 17:01:26	2019-10-03 17:12:03	6283
1273	cosmics	2019-10-03 17:12:58	2019-10-03 17:19:05	3574
1275	cosmics	2019-10-03 17:32:59	2019-10-03 17:41:48	5198
1276	cosmics	2019-10-03 17:46:21	2019-10-03 18:02:22	9525
1294	cosmics	2019-10-04 13:46:39	2019-10-04 14:35:43	29314

Can get also a feedback for grid transparency effects

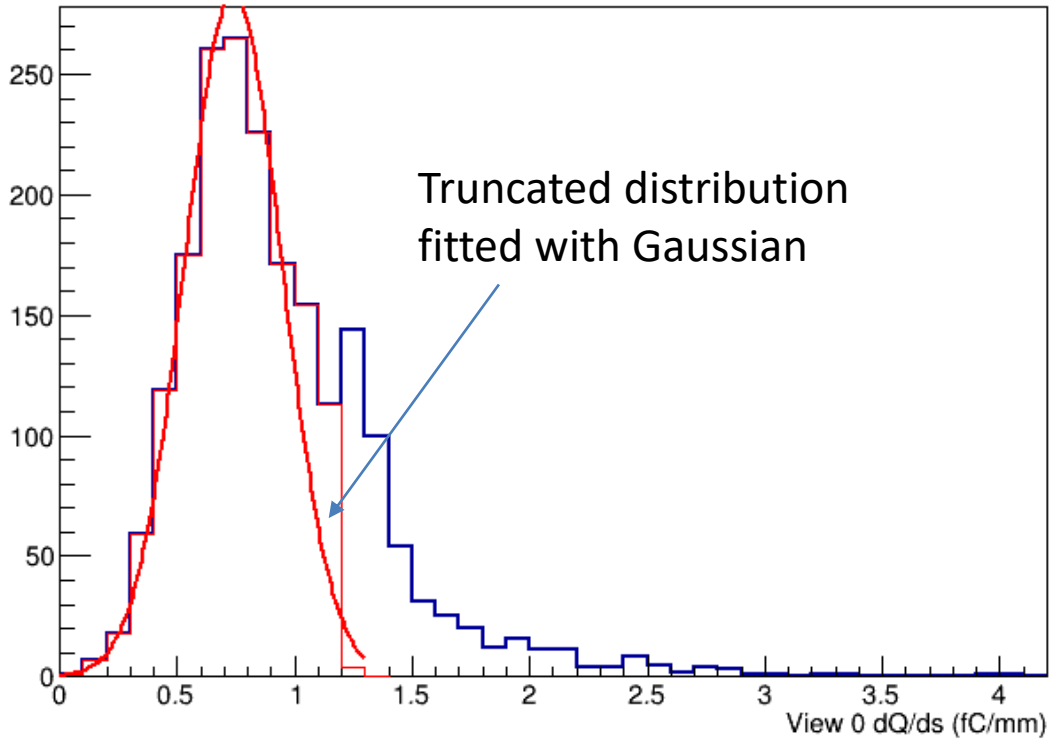
Example dQ/ds at different dV

Measured dQ/dx in one of the collection views of a CRP area for one of the CRP LEMs

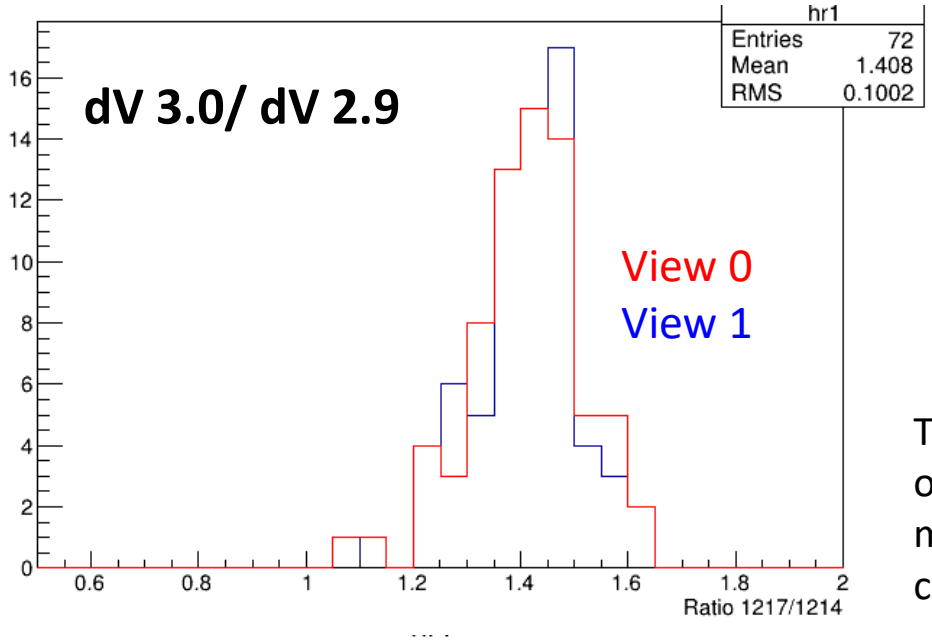


Comparing LEM gains

- To compare gains for each LEM between different runs
  - Truncate 20% of high Q tail
  - Fit Gaussian to get the mean of the truncated distribution, which is less sensitive to the high tail that would otherwise bias the mean

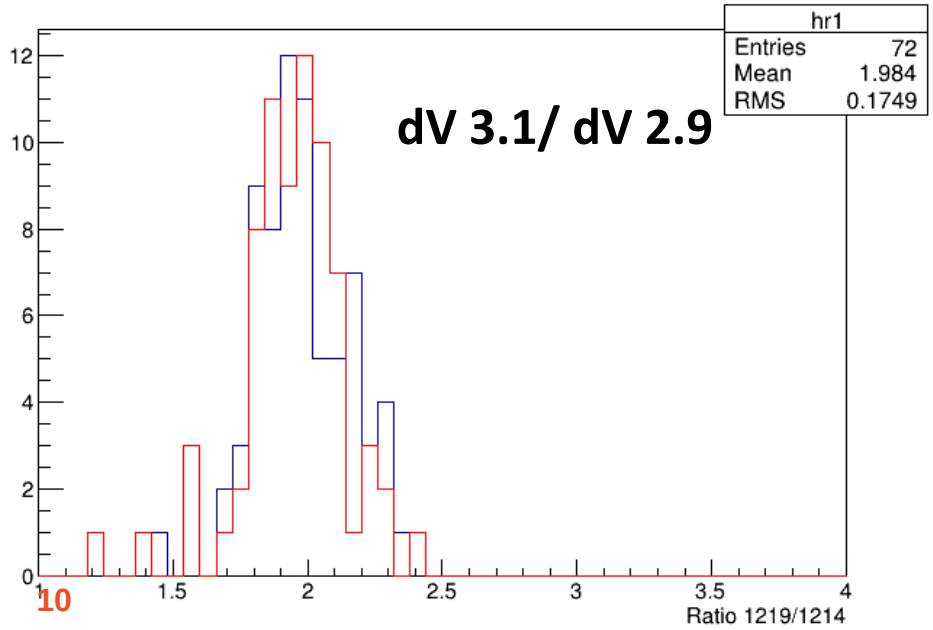


Comparison of 1214 to 1217 and 1219



Each entry in the histogram is the ratio of fitted truncated mean dQ/dx for a given LEM between two runs

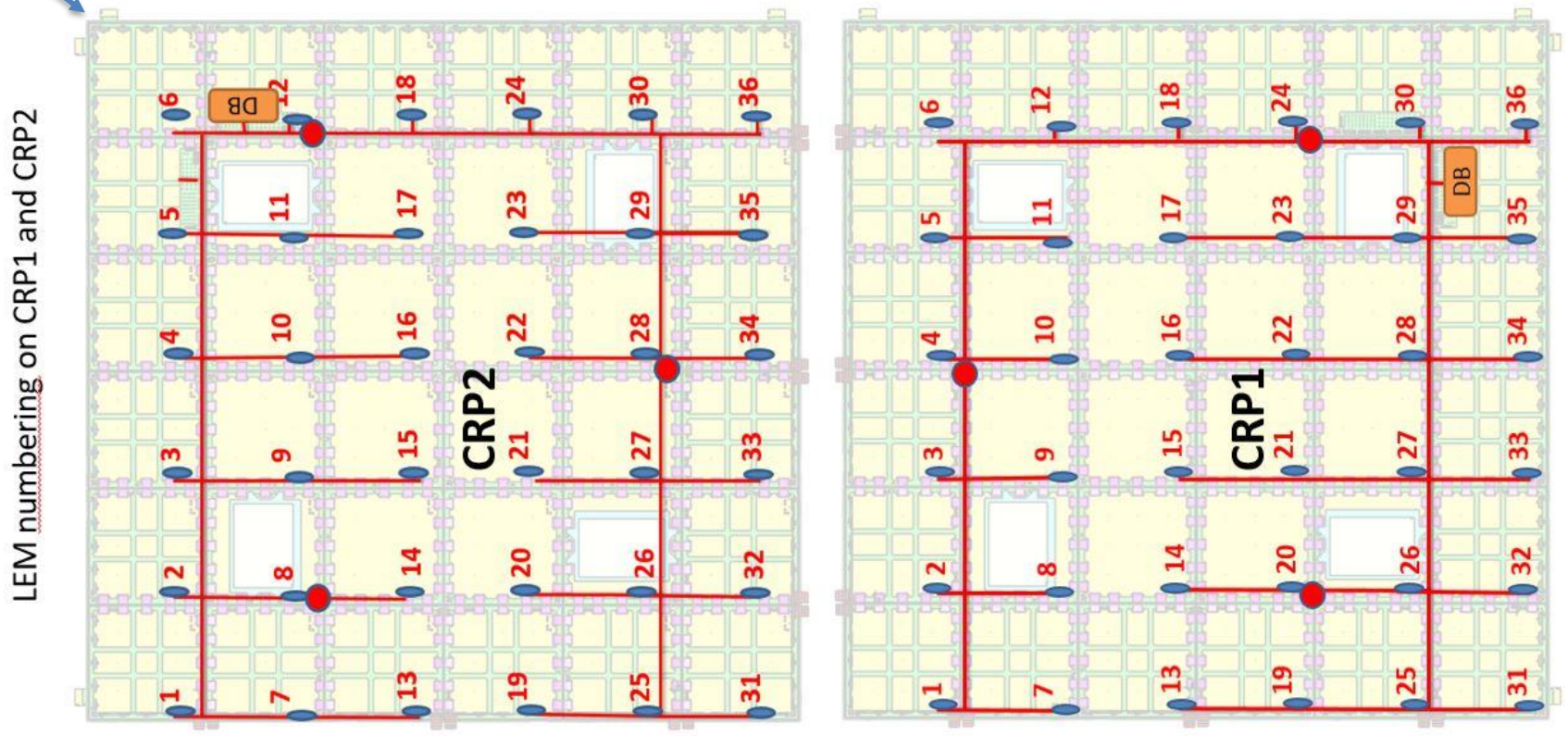
The measurements performed by the ETHZ were obtained at a pressure of 980mbar. Using 1045 mbar one gets lower gains (after complete charging up and with a 2.5kV/cm induction)



LEM dV	G 980 mb	G 1045 mb	GR/2.9 kV 1045mb	Measured
2.9	3.0	1.9	1.00	
3.0	4.2	2.5	**1.32**	**1.4**
3.1	6.2	3.4	**1.79**	**2.0**
3.2	9.5	4.8	2.53	
3.3	15.3	7.0	3.68	
3.4	25.9	10.8	5.68	
3.5	46.1	17.2	9.05	

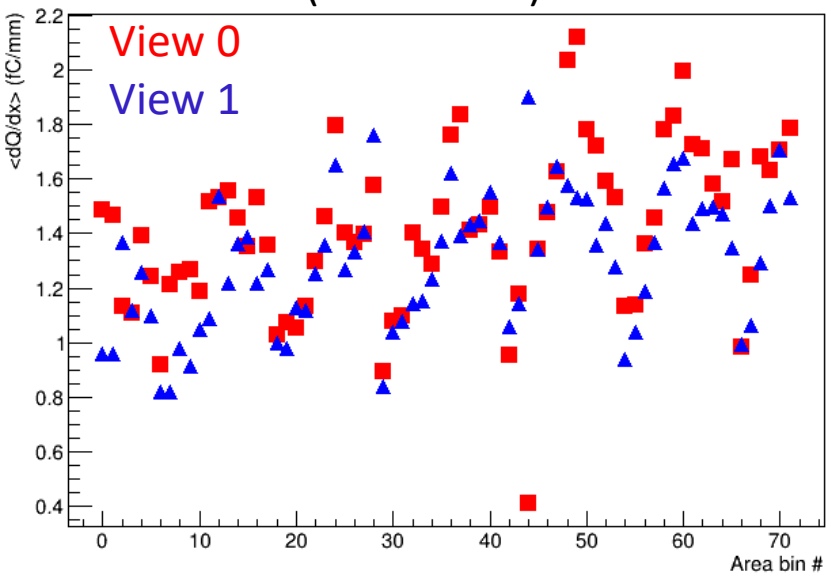
LEM numbering convention

Beam line

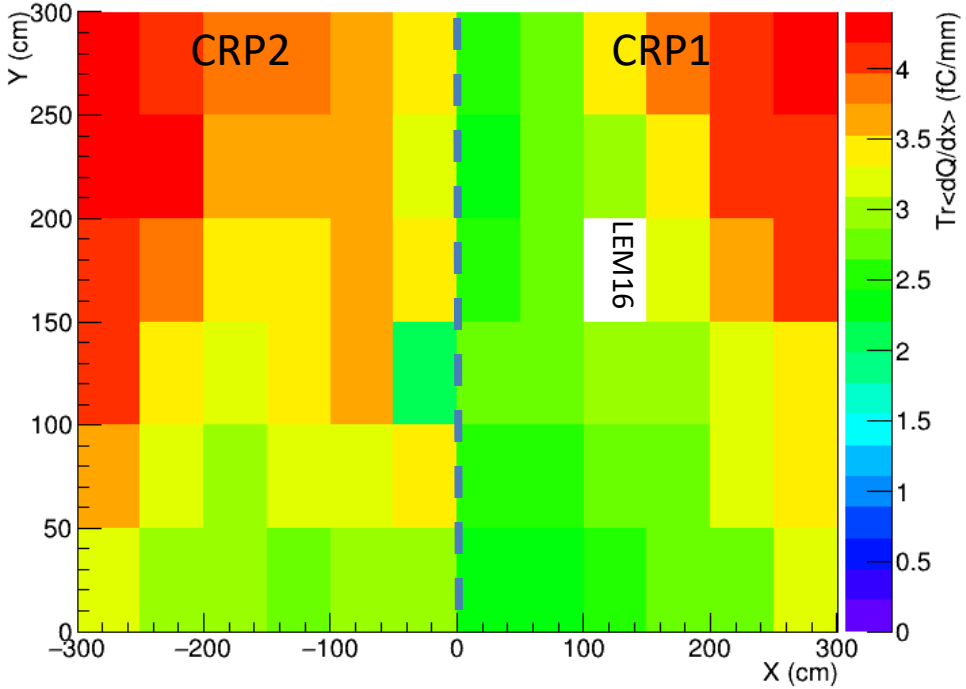


Fitted truncated <dQ/dx>

Run 1219 (dV = 3.1kV)

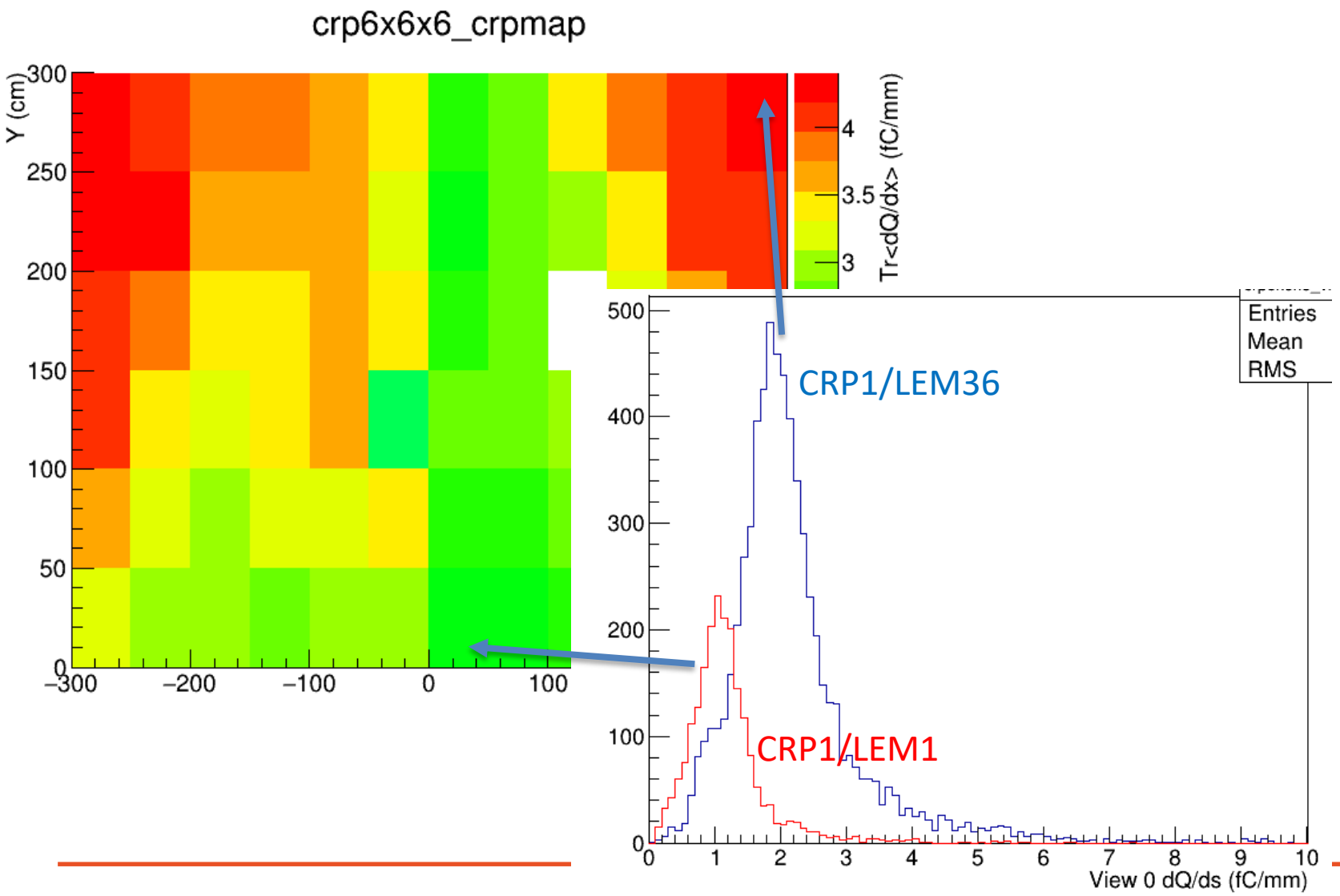


Sum of mean values of dQ/dx from each view binned in 50x50 cm2

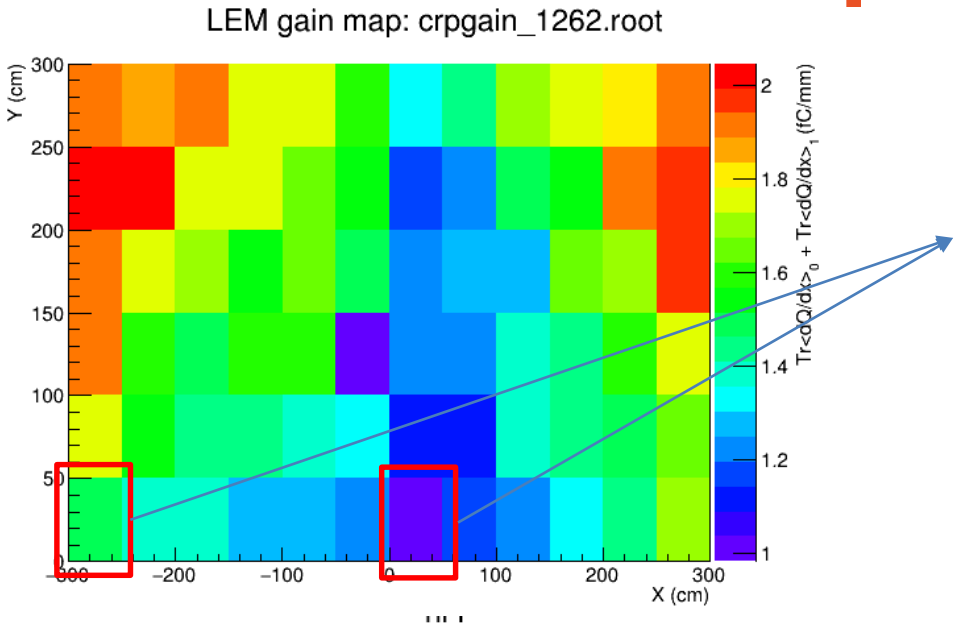


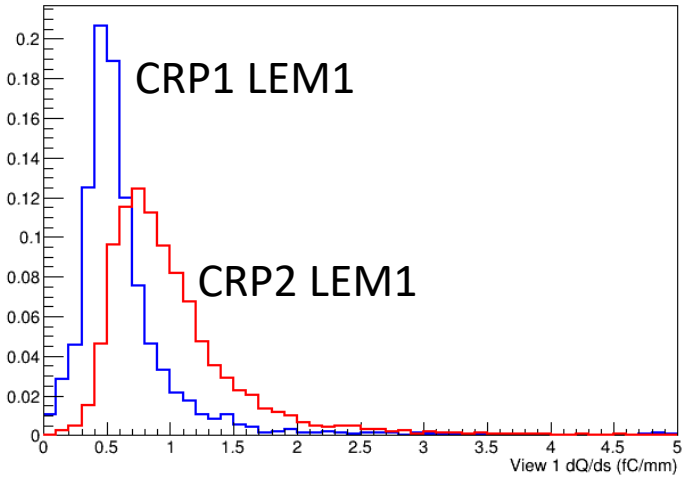
There is a non-uniformity in between LEM gains
Will discuss more this point later

CRP gain map: run 1219

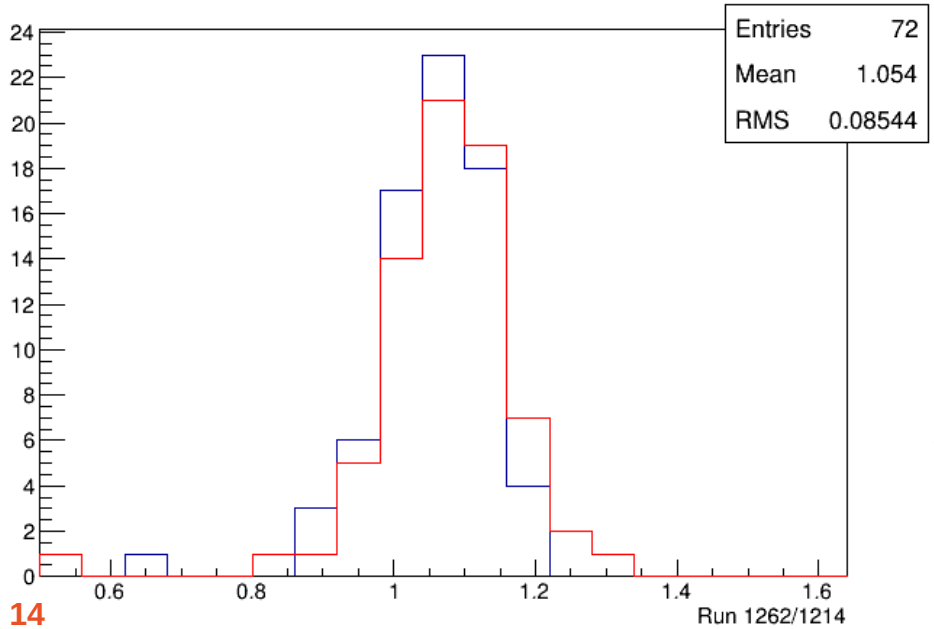


Run 1262 & compare to 1214





Same LEM dV = 2.9 kV

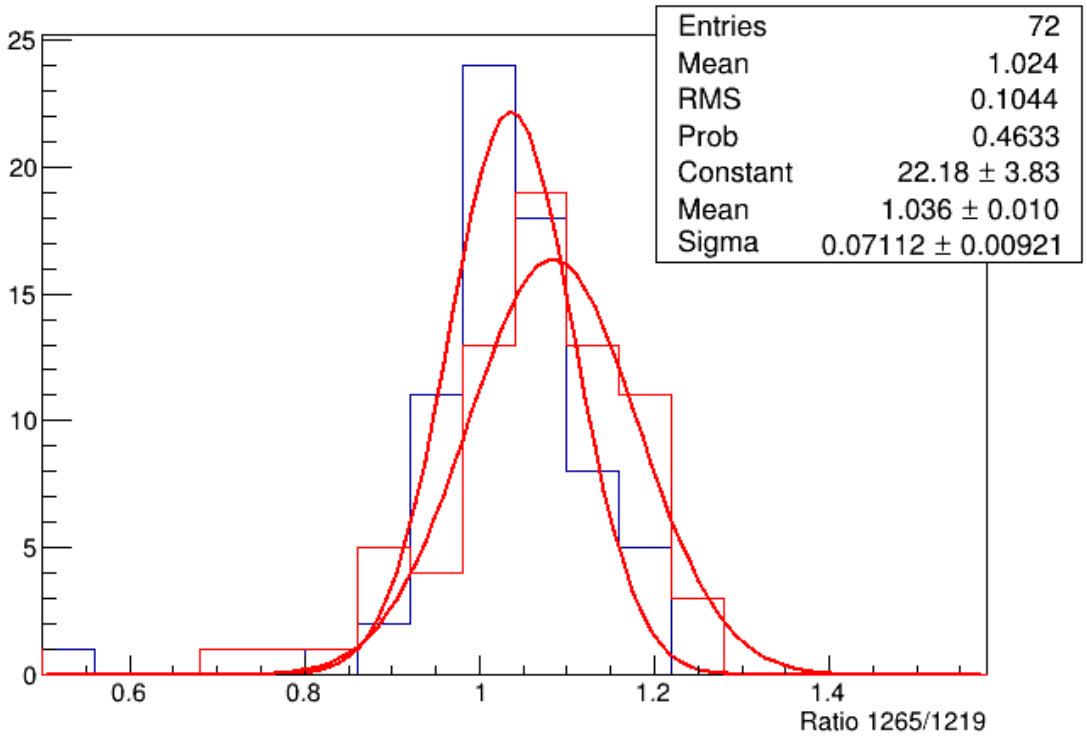


Although the pressure is lower for 1262 (1010 mbar) than 1214 (1045 mbar) the grid voltage is also lower 5.5 kV (6.0 kV) for run no 1262 (1212)
So the grid transparency cancels out the gain increase due to lower pressure

The fitted <ratio> is higher by about 7%
→<gain ratio> 1.07

Run 1265 comparison to 1219

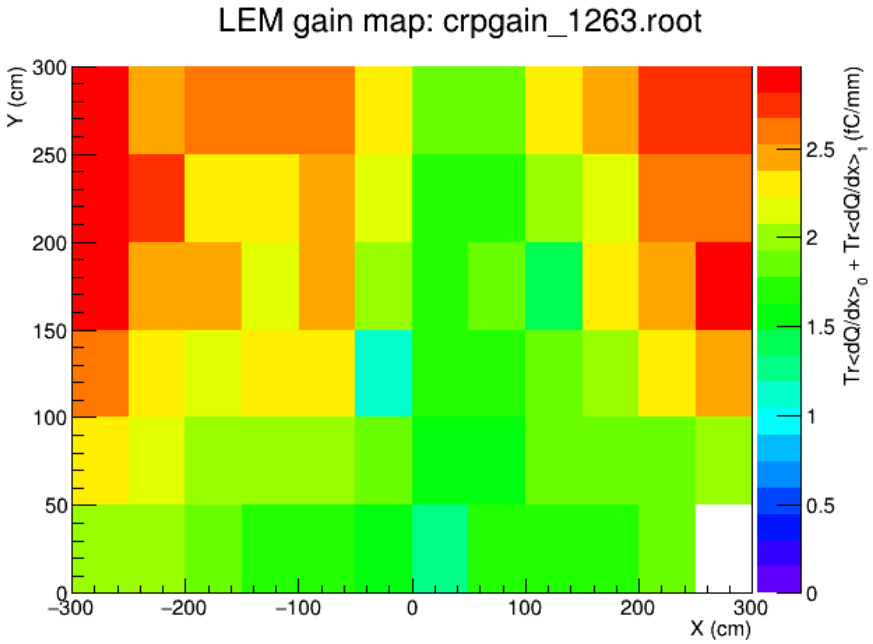
1219 dVlem = 3.1 kV, Vgrid = 6.0 kV, P = 1045 mbar
1265 dVlem = 3.1 kV, Vgrid = 5.5 kV, P = 1010 mbar

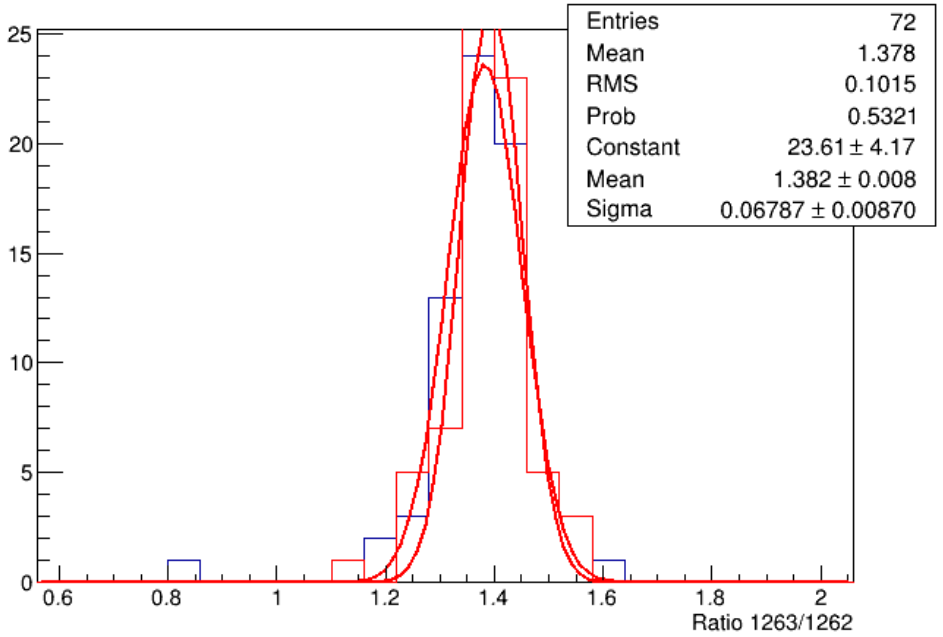


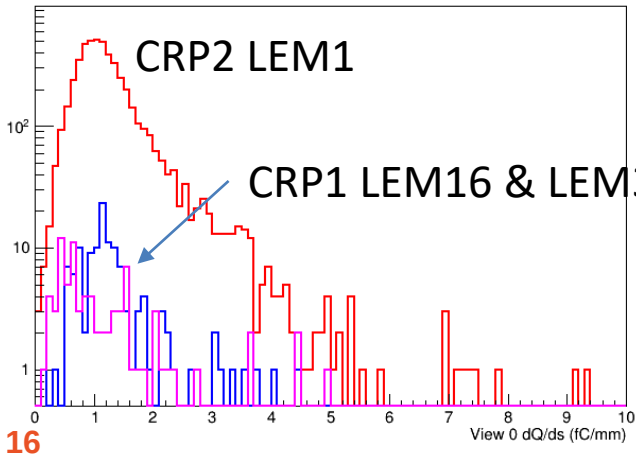
The average ratio for two views is 1.06
Same as before although the grid transparency is decreased due to lower dVgrid

Run 1263/1262

dV = 3.0 kV / dV = 2.9 kV



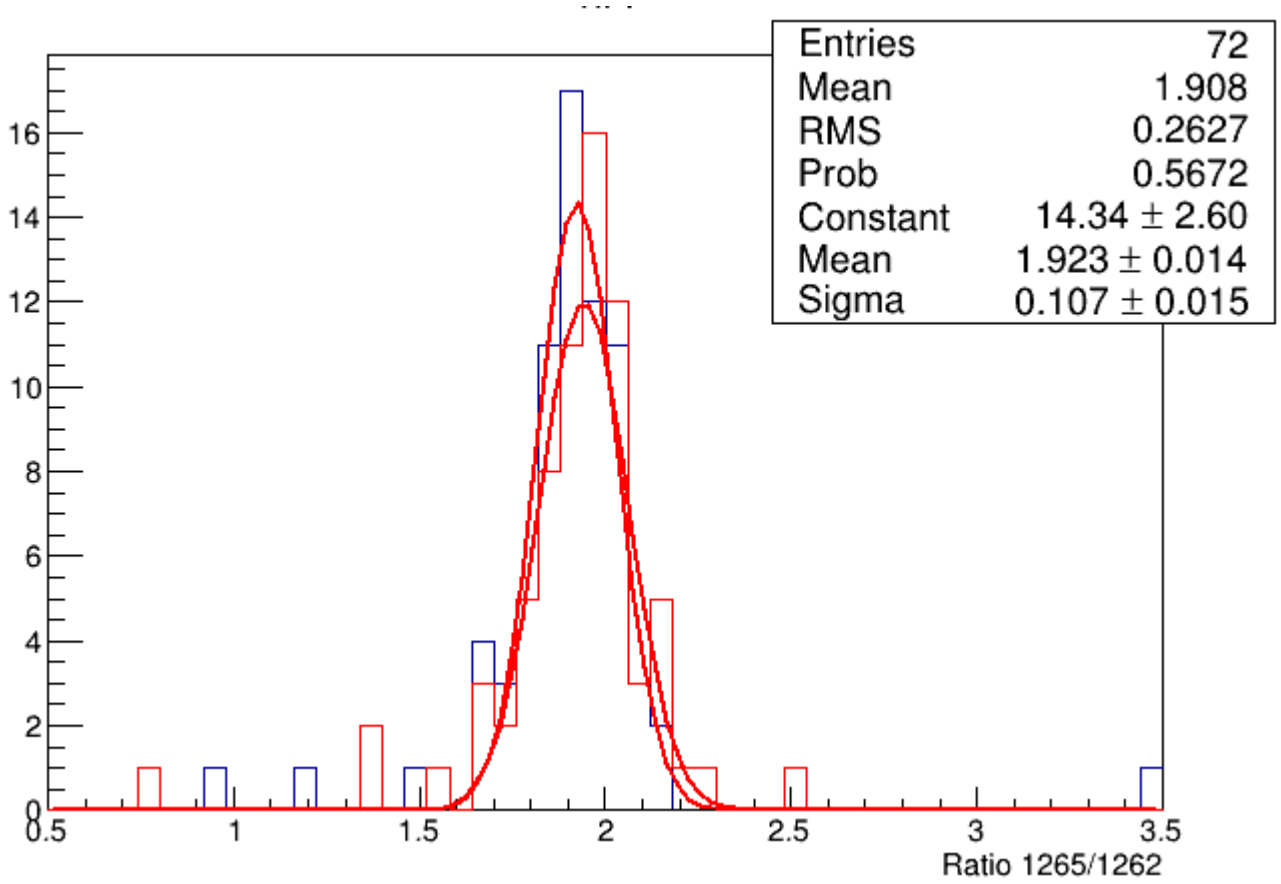




The increase in LEM gain is 1.39

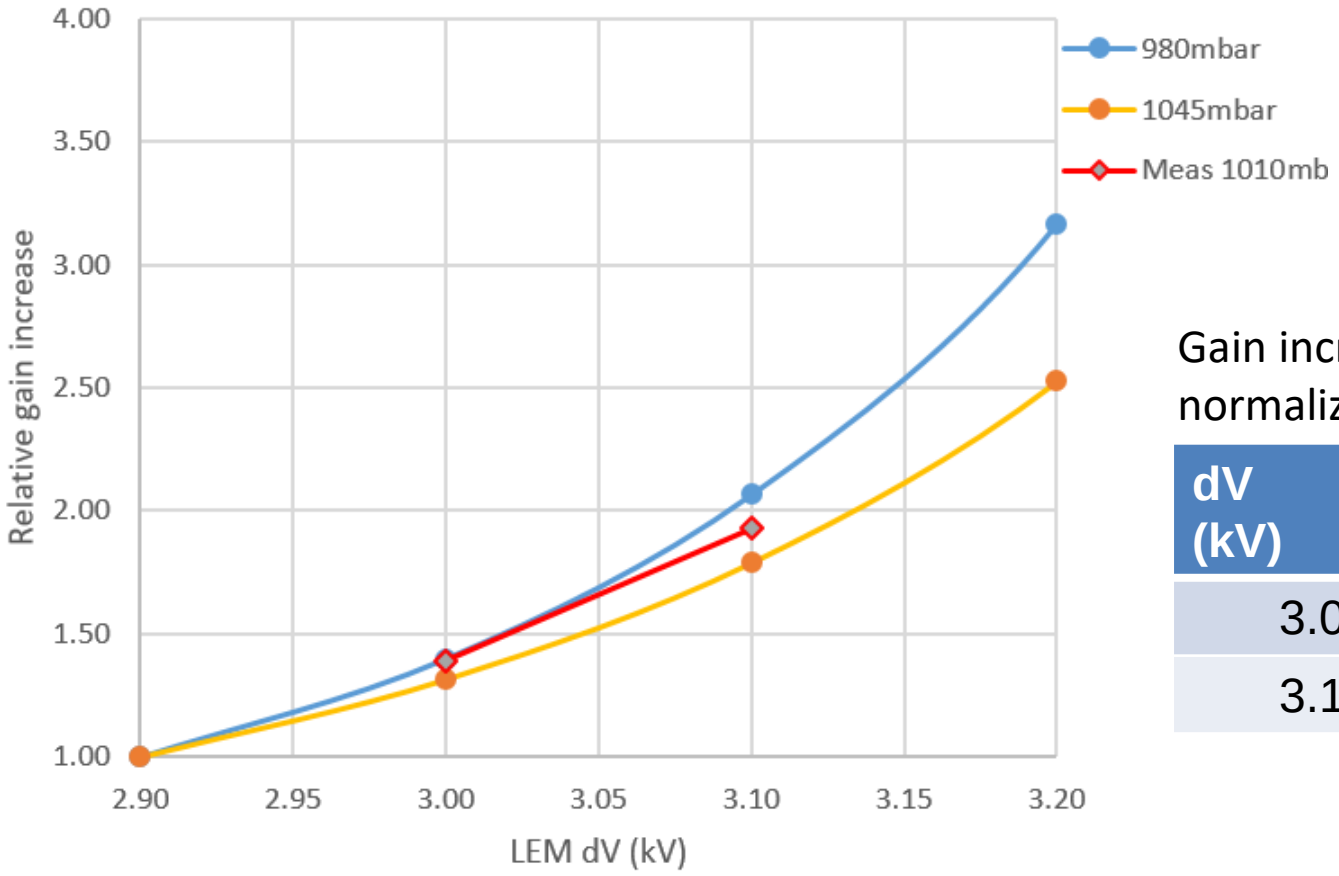
Run 1265/1262

dV = 3.1 kV / dV = 2.9 kV



The increase in LEM gain is 1.93

Relative gain increase



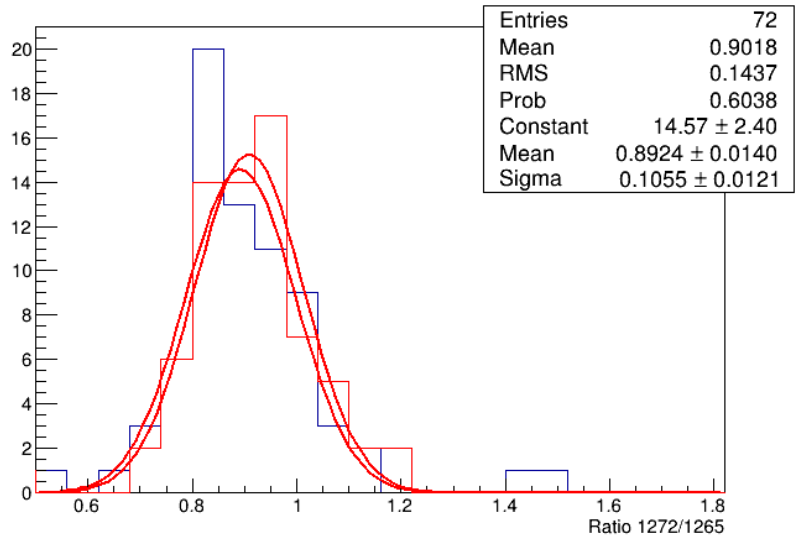
Gain increase at 1010 mbar normalized to dV = 2.9kV

dV (kV)	Ext data	PDDP data
3.0	1.36	1.39
3.1	1.94	1.93

Grid extraction efficiency

Run no	LEM dV	Grid V	Grid-LEMB dV	Ratio to 1265
1265	3.1	5.5	1.9	1
1267	3.1	5.3	1.7	0.97
1272	3.1	5.0	1.4	0.90
1273	3.1	4.5		

Error is ~0.01

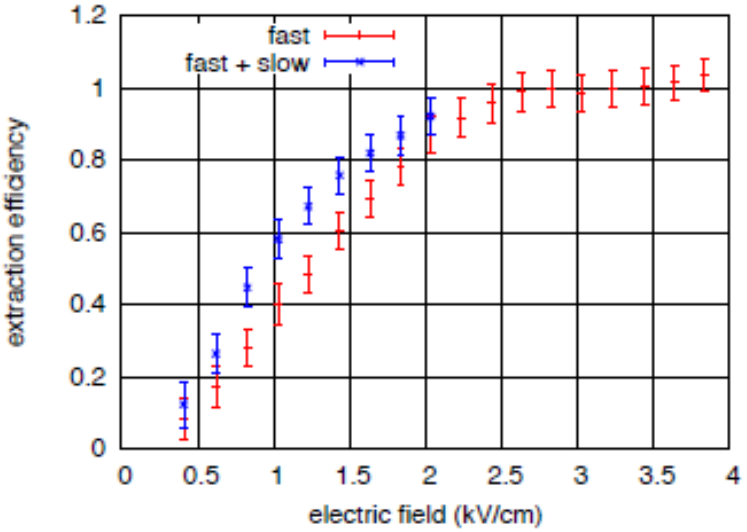


Have very small statistics of usable tracks
Somehow track reconstruction is failing here

Going from dVgrid of 1.9 to 1.4 decreases the grid transparency by about 10%

Extraction efficiency

From Gushchin et al paper



$$E_{ext} = \frac{\Delta V}{D}\left(\frac{1}{\varepsilon_l/\varepsilon_g + d_l/D\,(1-\varepsilon_l/\varepsilon_g)}\right)$$

D = 1.0 cm

dl = 0.7 cm, liquid level above grid

$\varepsilon_l/\varepsilon_g$ = 1.5

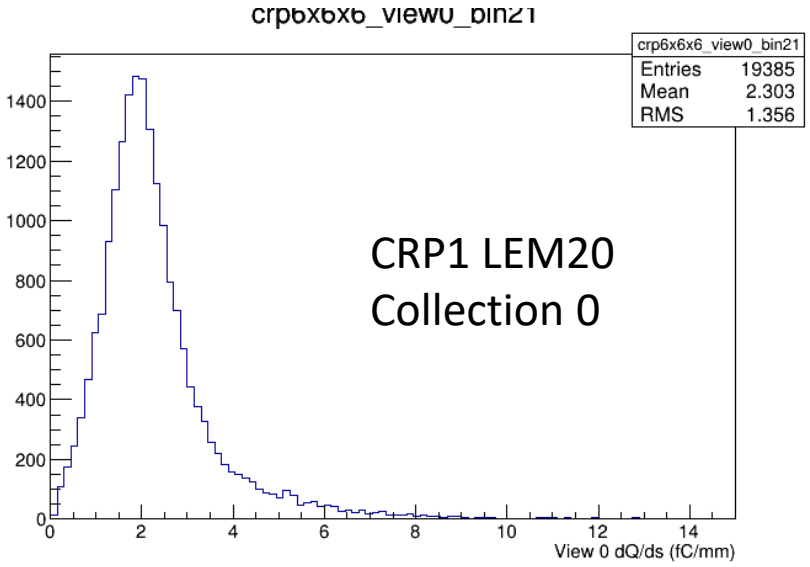
Perform linear interpolation between the points to get “expected” efficiency

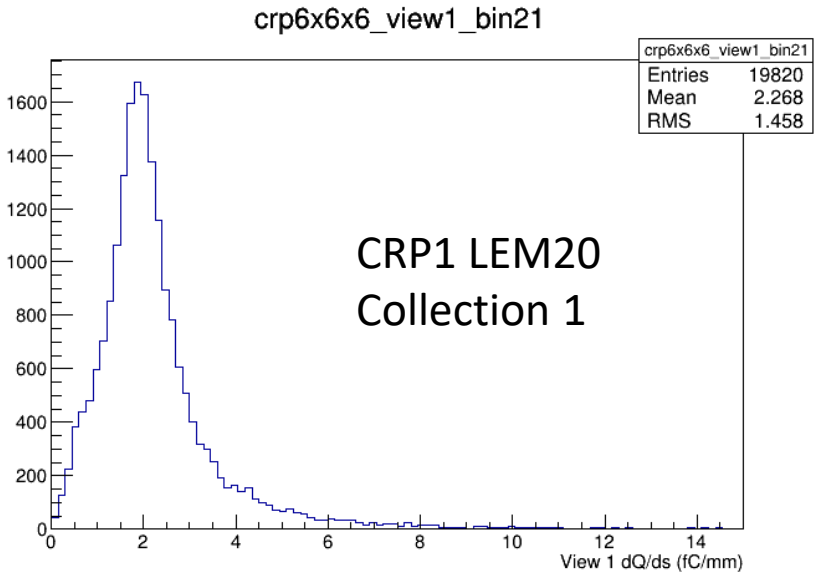
DeltaV (kV)	Eext (kV/cm)	Efficiency	Ratio to dV = 1.9
2.4	2.09	0.94	1.14
1.9	1.65	0.82	1.0
1.7	1.48	0.77	0.94 (*0.97*)
1.6	1.39	0.74	0.90
1.4	1.22	0.68	0.83 (*0.90*)

The drop in extraction efficiency is larger than what we see in the data

LEM abs gain at dV=3.2: back-of-envelope

Run 1294





Expected charge assuming quenching for 0.16 kV/cm

$$< \mathrm{dQ/dx} >_{\mathrm{exp}} \; = 0.8 \text{ fC/mm}$$

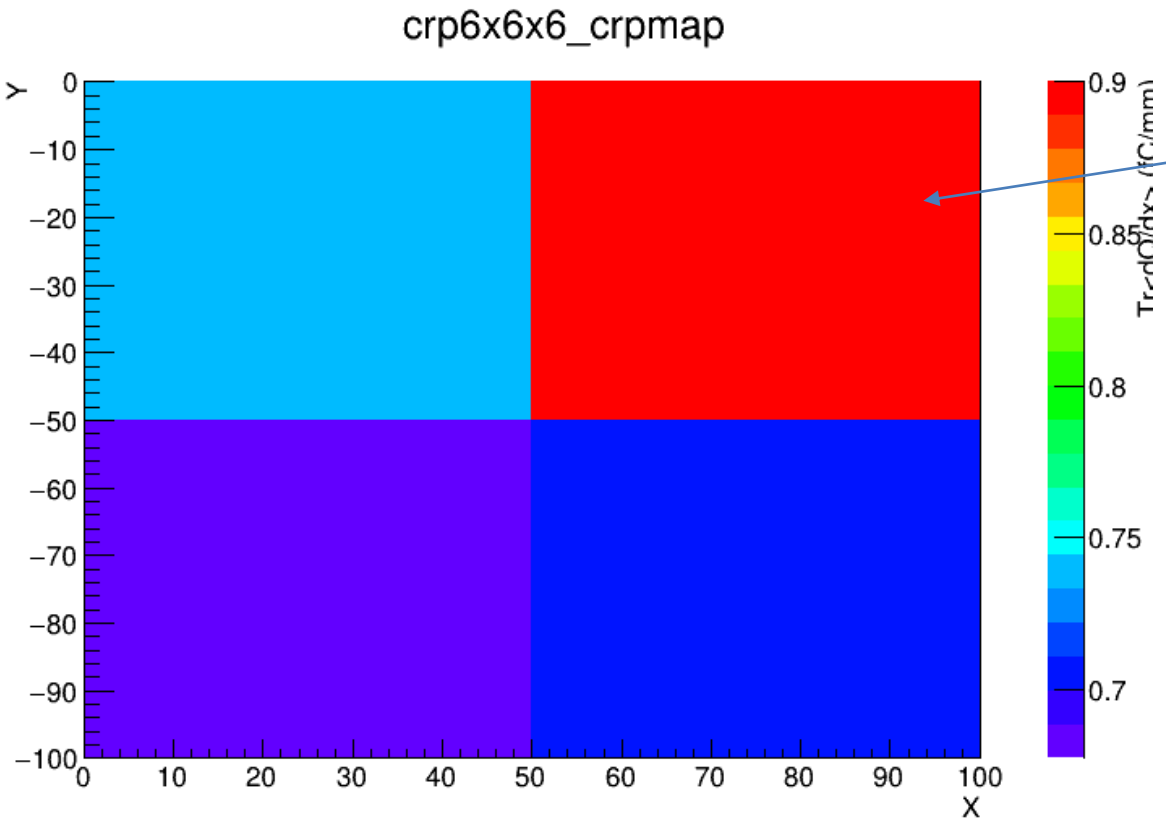
The mean* per view x Nviews / MIP dQdx / Grid ext efficiency factor (assumed to be 0.74 at dV ext = 1.6 kV):

LEM gain = 2.3 / 0.8 x 2 / 0.74 = 7.8

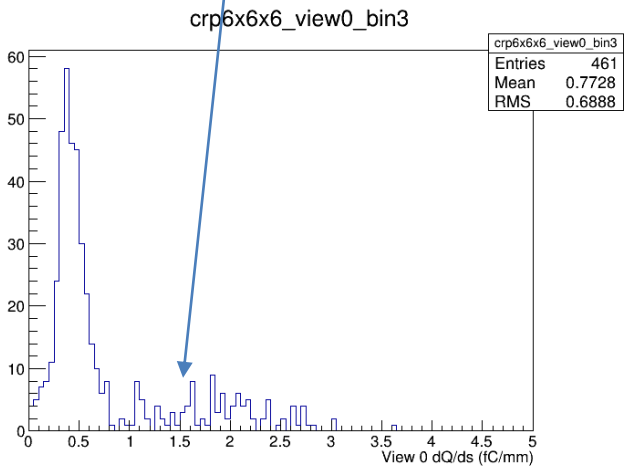
*the mean is sensitive to reconstruction effects
(e.g., treatment/reconstruction of delta rays)

CRP4

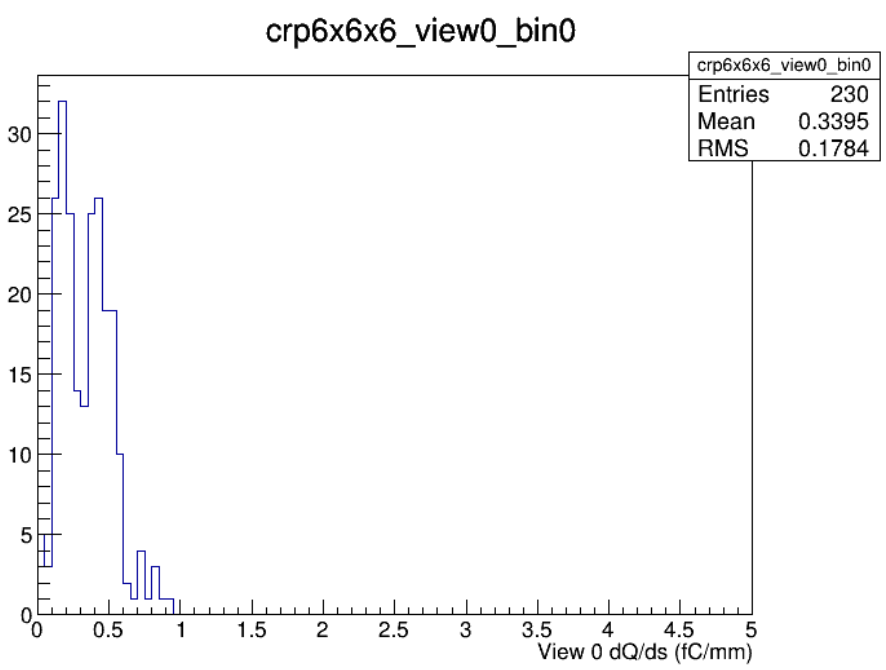
Run 1187 with 4 kV on the grid
The statistics is very low. Only about 40 tracks could be used for the analysis
Similar as before look in bins of 50 x 50 cm2 CRP area

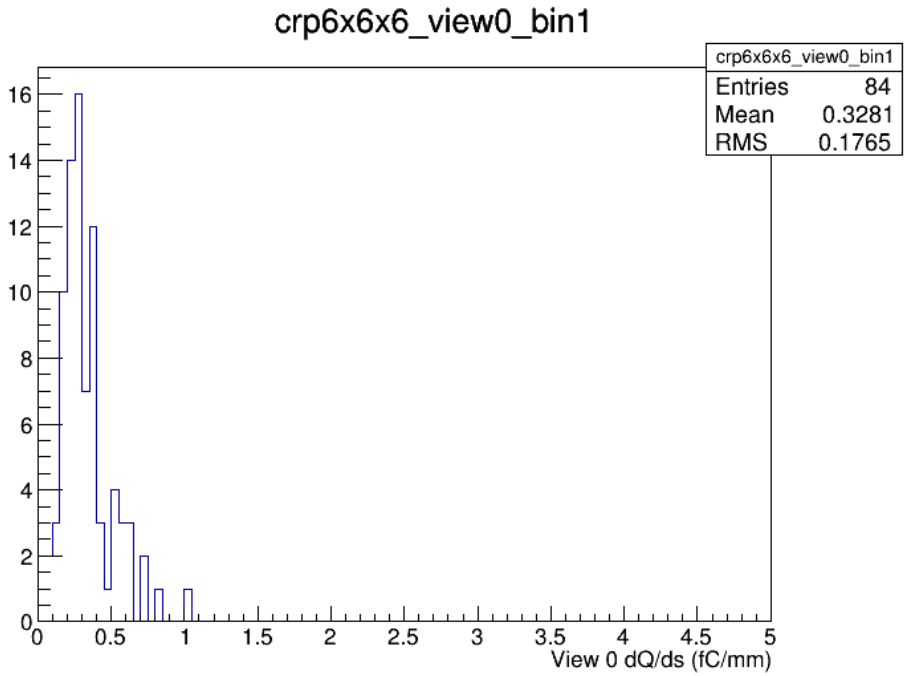


This is probably due to noise activity



CRP4





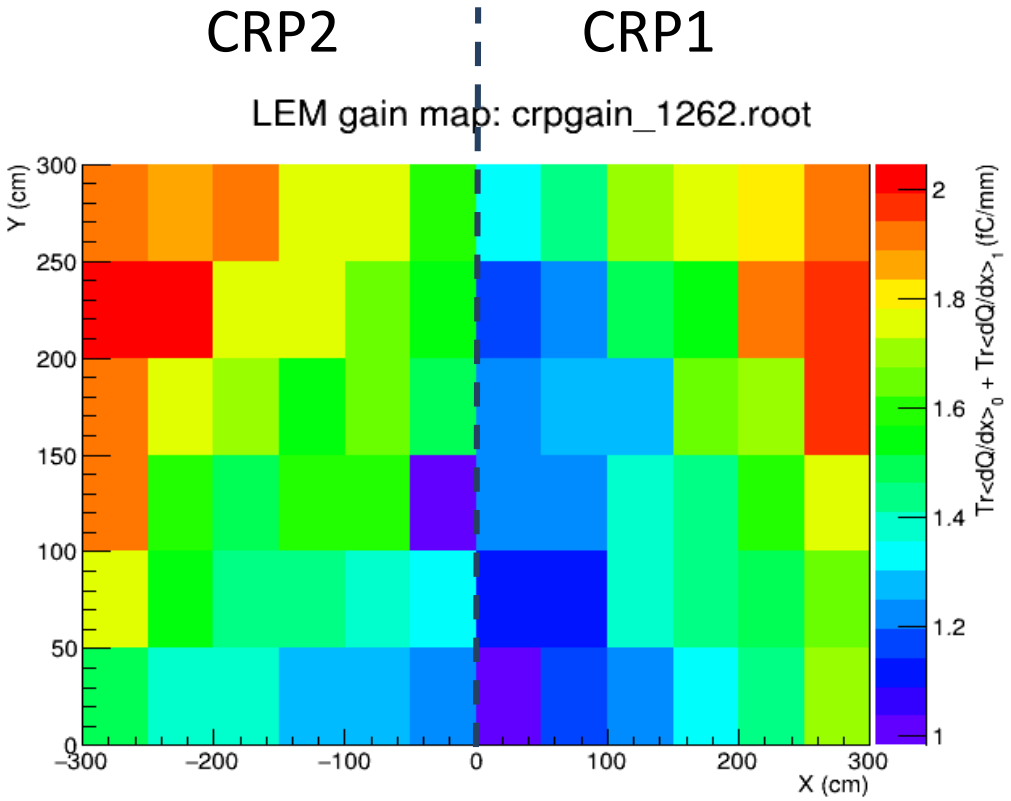
If one takes the expected mean MIP charge

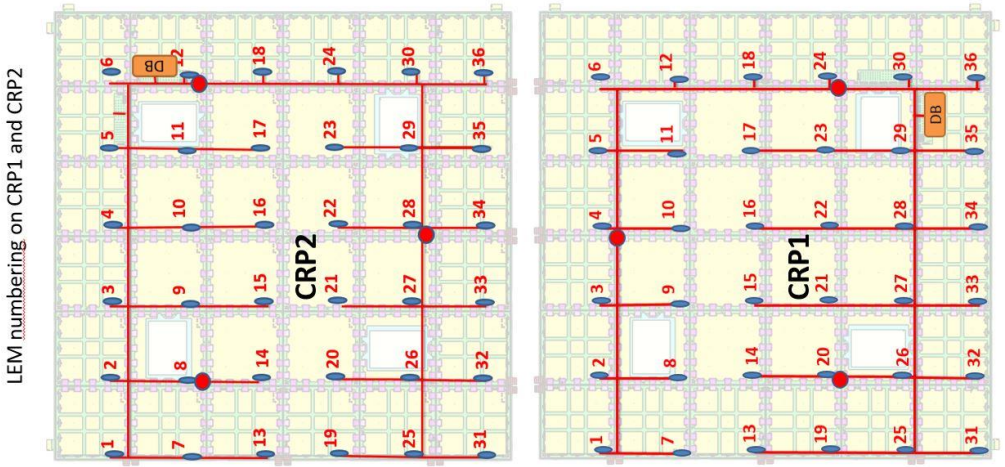
$$< \mathrm{dQ/dx} >_{\mathrm{exp}} \; = 0.8 \text{ fC/mm}$$

Then per view one should expect 0.4 fC/mm

The mean <dQ/dx> we see are between 0.34 – 0.38 per view

CRP gain map



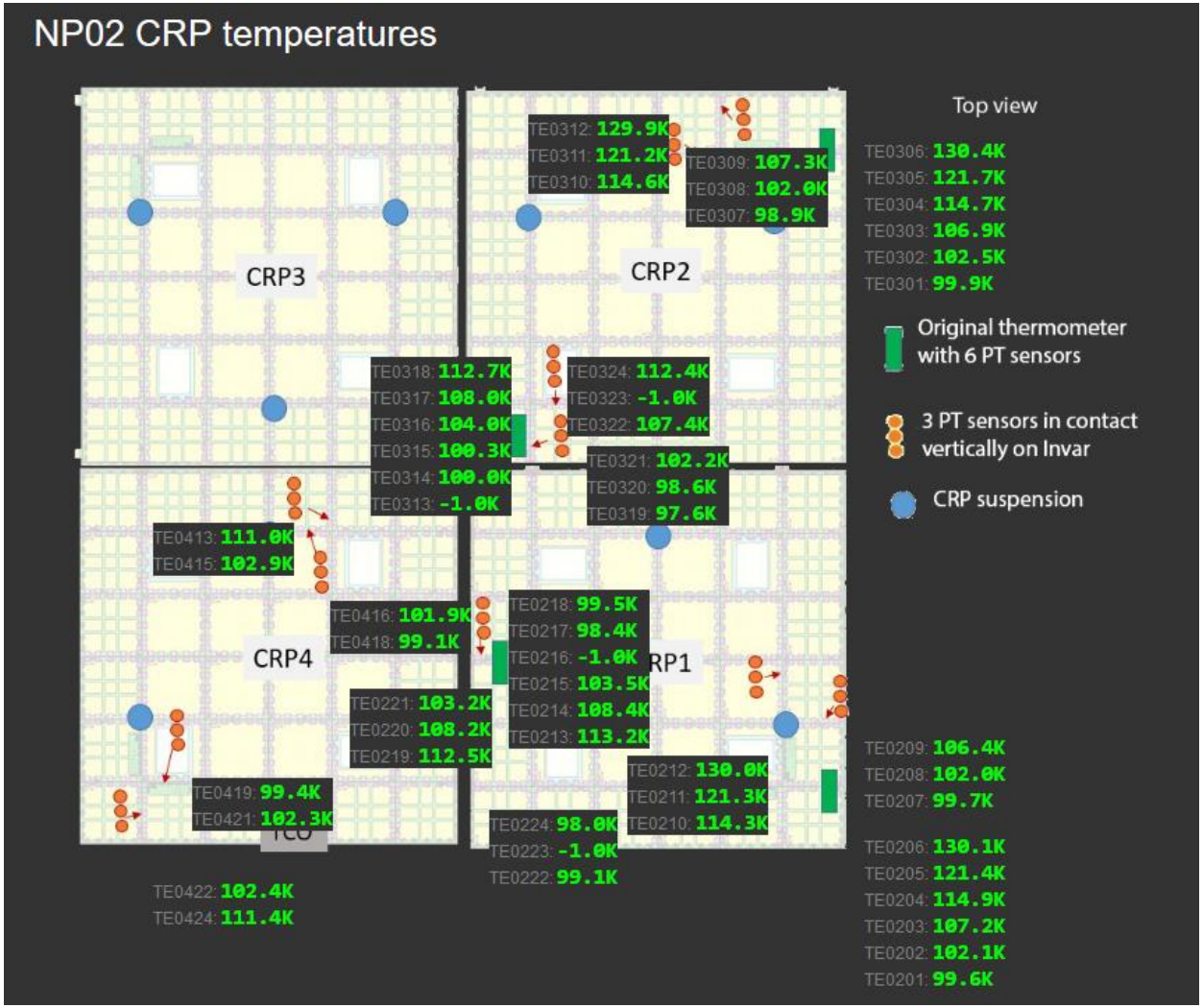


The corners with highest gain are the closest to the distribution boxes in both CRPs
But the current must be appreciable in order to generate significant voltage drop on the conductors

Maybe related to the gas temperature
➔ Temperature hotter in the CRP corners (gas is less dense → more gain) than in the middle

Note that the CRP T probes are not connected during data taking since they introduce very large noise
However, they have been reconnected recently to check the bubbling

CRP temperature probes



Conclusions

- The gain increase in LEM as a function of dV appears to be consistent with past measurements

- There is a non-uniformity in LEM gain across CRP
  - This is caused by external factors (i.e., not LEMs themselves)
  - The effect of grid transparency is too small to explain such large variations
  - One candidate is the gas temperature: to be checked now that the probes are connected