LEM gain measurement with muon tracks

ProtoDUNE DRA Meeting

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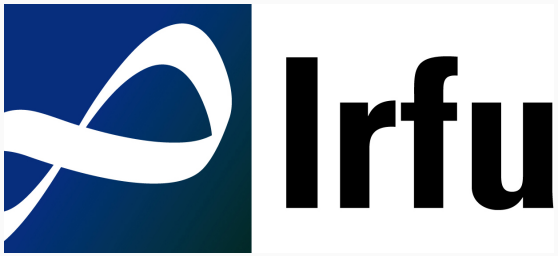
05/06/2020



Irfu - CEA Saclay

Introduction

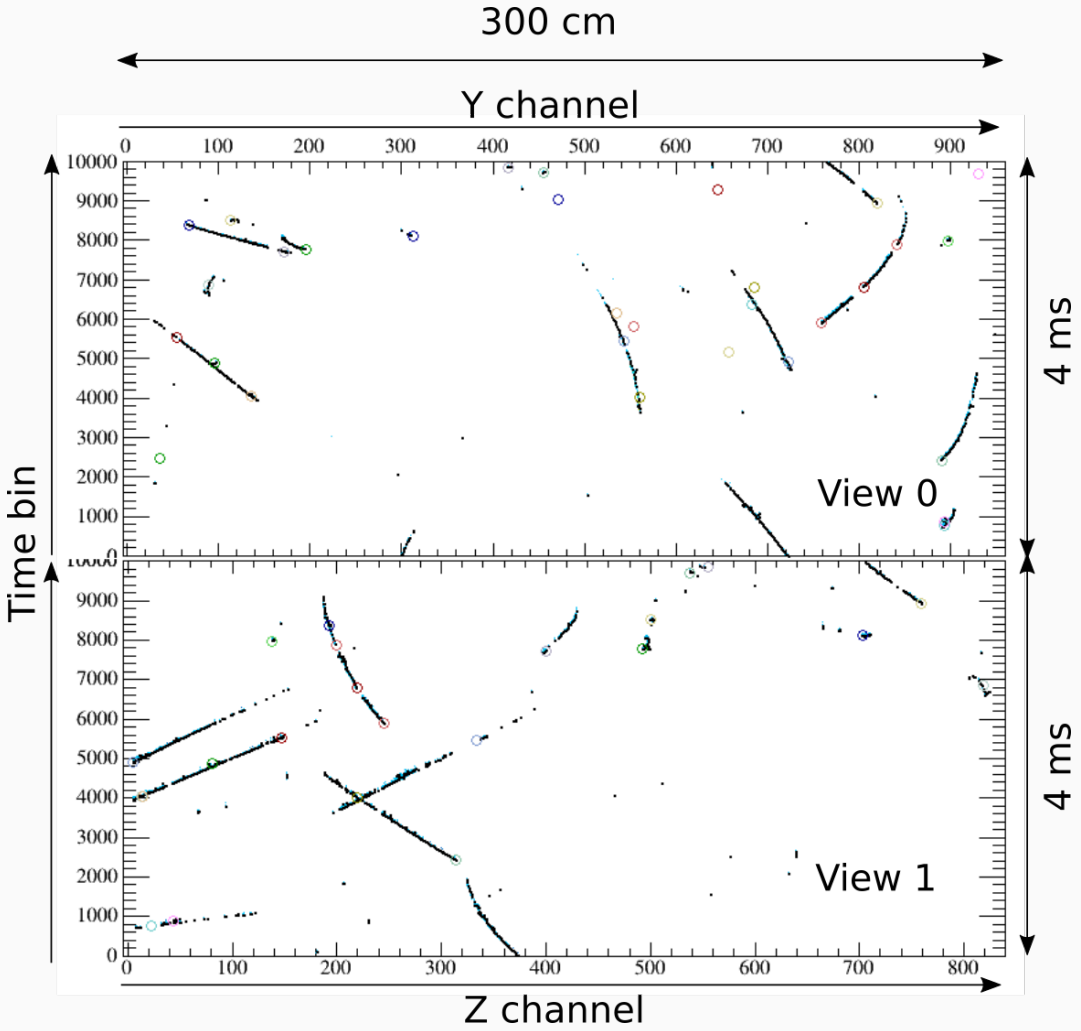
Data used for the analysis

run	date	nominal LEM voltage [kV]	Vcathode [kV]	Number of events
1262	2019-10-03	2.9	50	33377
1263	2019-10-03	3.0	50	18424
1267	2019-10-03	3.1	50	4505
1294	2019-10-04	3.2	50	29314
1323	2019-11-21	3.1	50	11464
1327	2019-11-21	3.0	50	11966
1337	2019-11-22	3.2	50	12063
1387	2020-01-13	3.1	50	4258
1401	2020-01-14	2.5	50	24378
1405	2020-01-14	2.7	50	18049
1407	2020-01-14	2.9	50	25497
1415	2020-01-14	3.0	50	4824
1410	2020-01-14	2.9	70	11889
1411	2020-01-14	2.9	90	11769

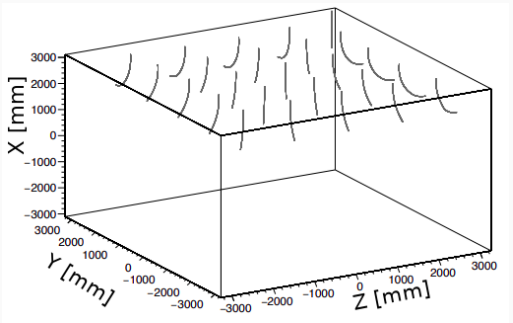
- Using data from 3 different months and exploring several LEM voltages
- Cathode potentials were explored in January
- Event windows last 4 ms
- Event trigger rate of 10 Hz

Reconstruction

Tracks are reconstructed with pandora by using **pddp_reco.fcl**



Reconstruction example for 1 CRP



Drift lines (L. Zambelli)

Apparent curvature of muons because of drift field inhomogeneities

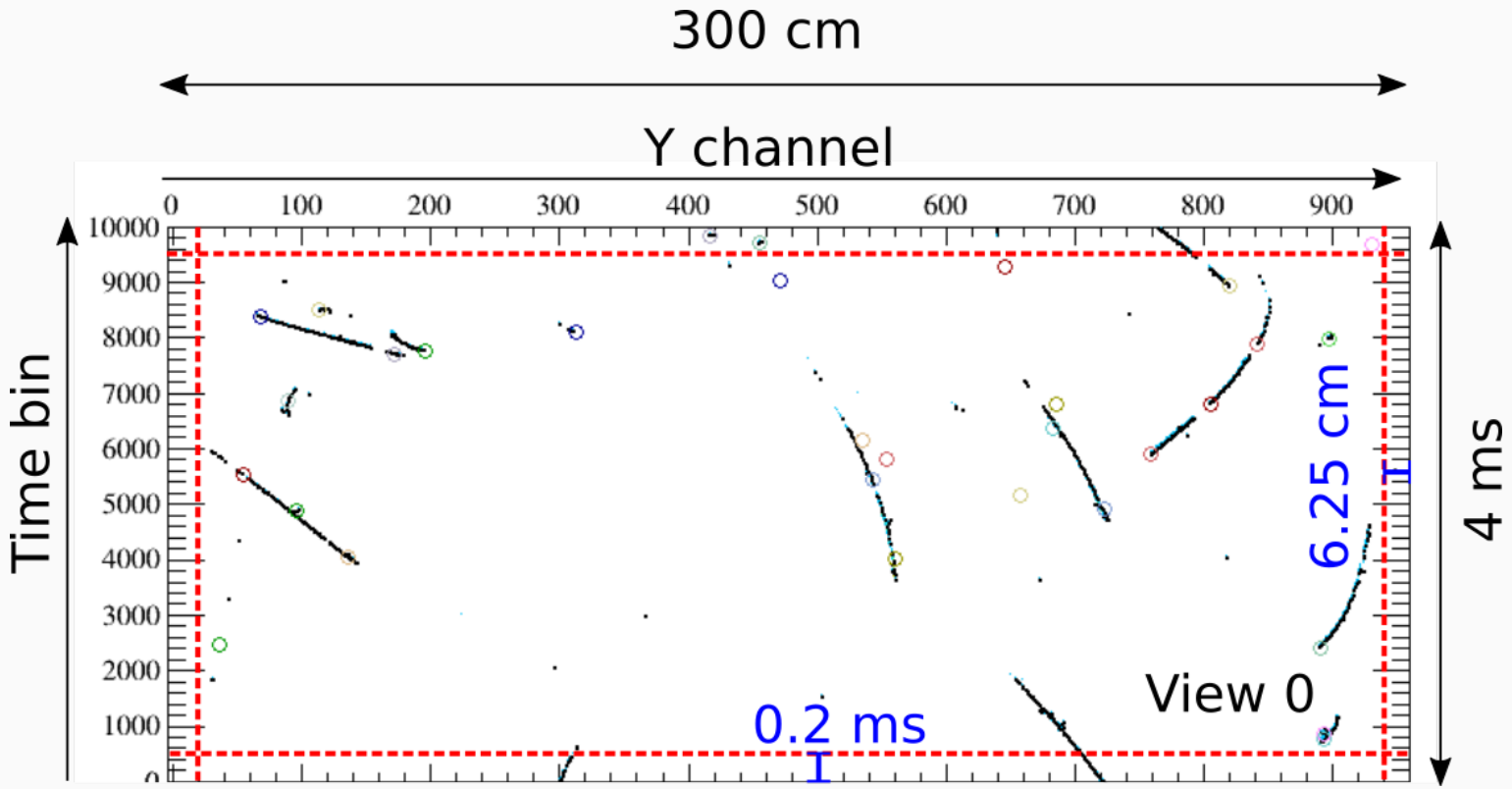
Analysis

Selections

Geometrical selection

Only tracks passing through the anode are kept by using cuts on the start of the track in space and time.

These cuts discard around 25 % of the tracks.

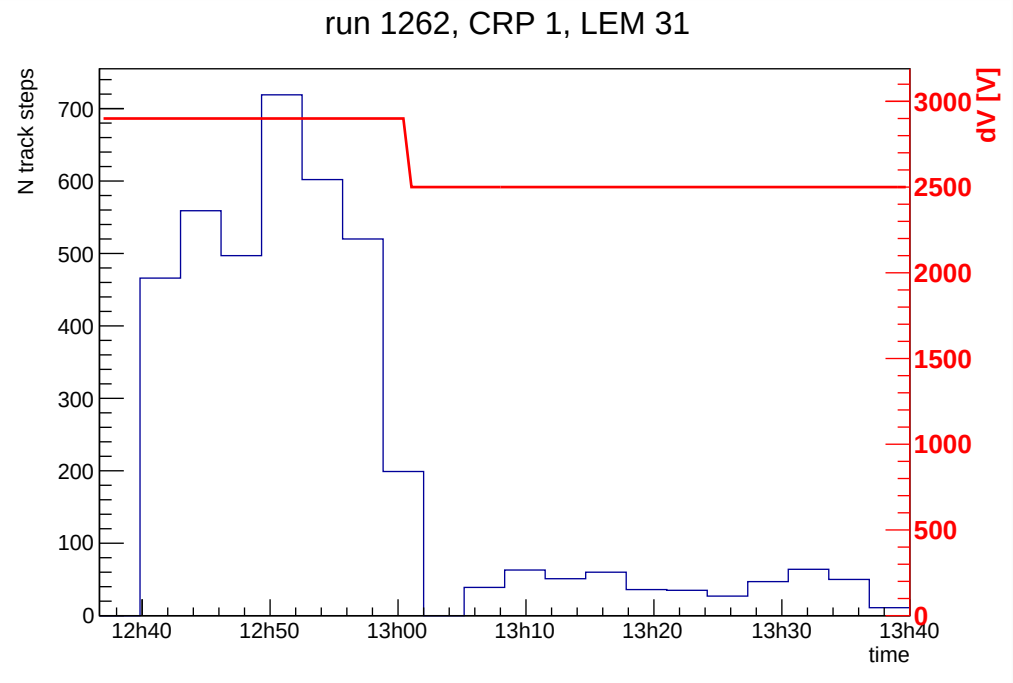


Selections

LEMs voltages

Hits detected below a given LEM are taken into account only if that LEM is at nominal voltage during that event.

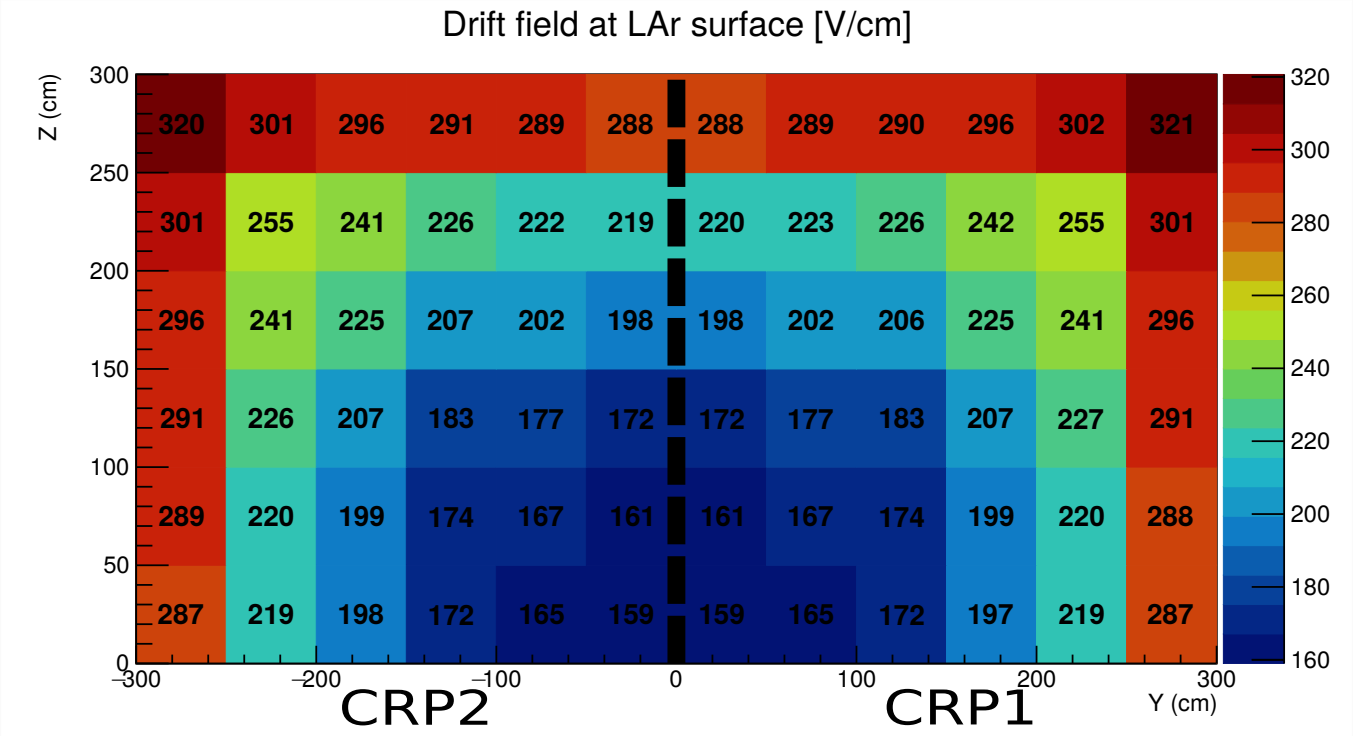
From 72 LEMs at nominal voltage in October to around 50 in January.



Example from voltage diminution during a run

$\rightarrow$ clear diminution of the number of tracks.

Taking into account the drift field

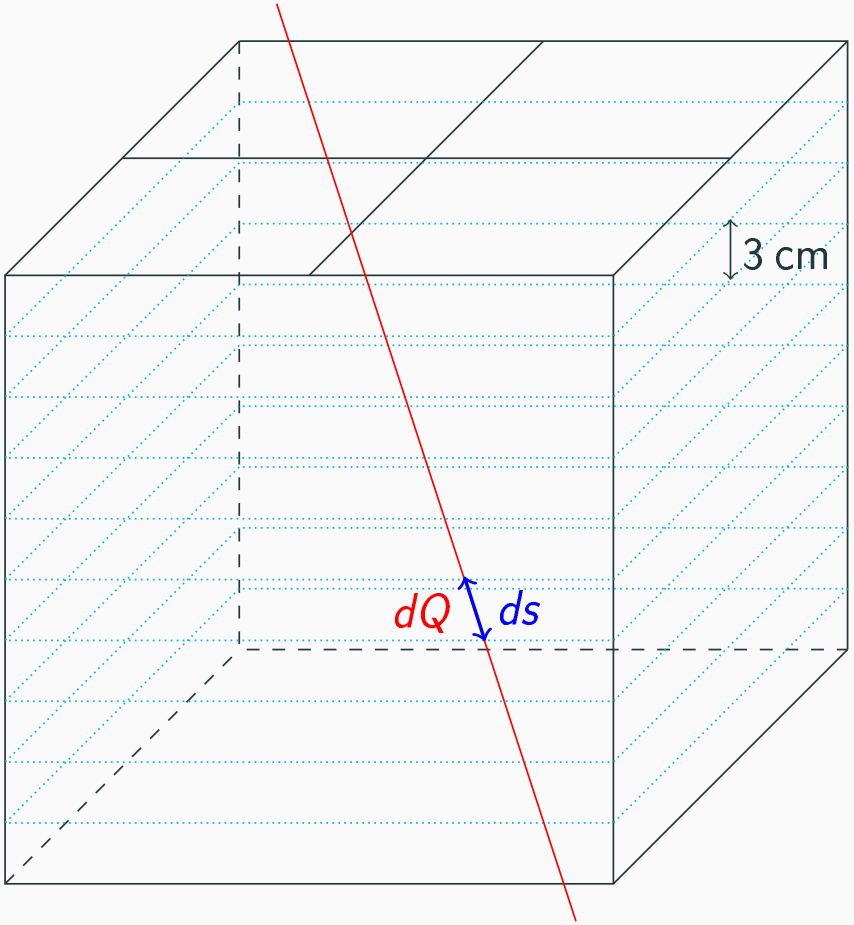


from Laura Zambelli's simulation

Partial recombination : $R = \frac{A}{1+\frac{\lambda}{\mathcal{E}}\frac{dE}{dx}}$

Larger charge collection is expected for LEMs on borders because of lower recombination.

Lifetime estimation for purity correction



Binning in depth of the detector

- For each track, ds and dQ are computed in each bin
- For each bin we compute $\left.\frac{dQ}{ds}\right|_{\text{MPV}}$
- Attenuation is deduced as $\left.\frac{dQ}{ds}\right|_{\text{MPV}}(\text{depth})$

Gain estimation

Gain estimation for each LEM

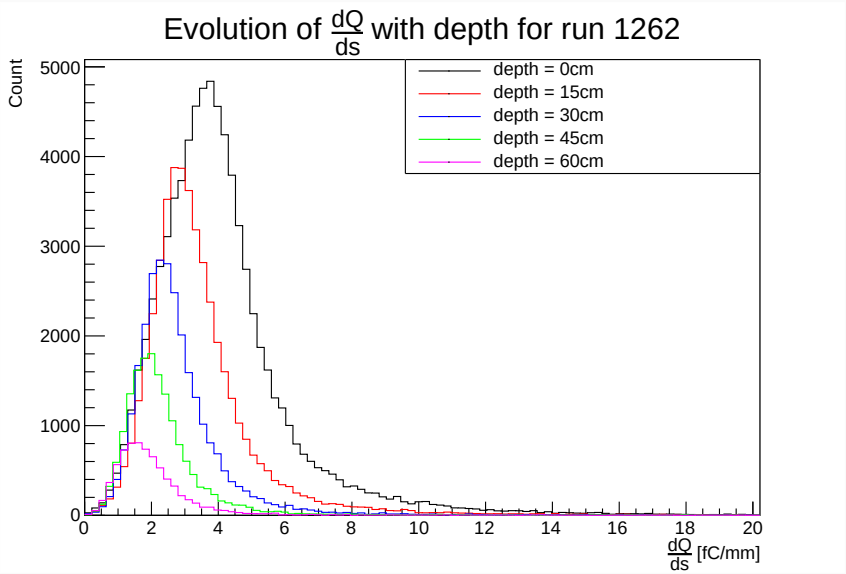
- Only the 5 first depth bins are kept : 15 cm $\rightarrow$ limits the purity and drift field corrections
- We correct dQ of each bin by previously fitted purity
- We correct local recombination due to local drift field
- $\left.\frac{dQ}{ds}\right|_{\text{MPV}}$ is computed and compared to theoretical value to get gain

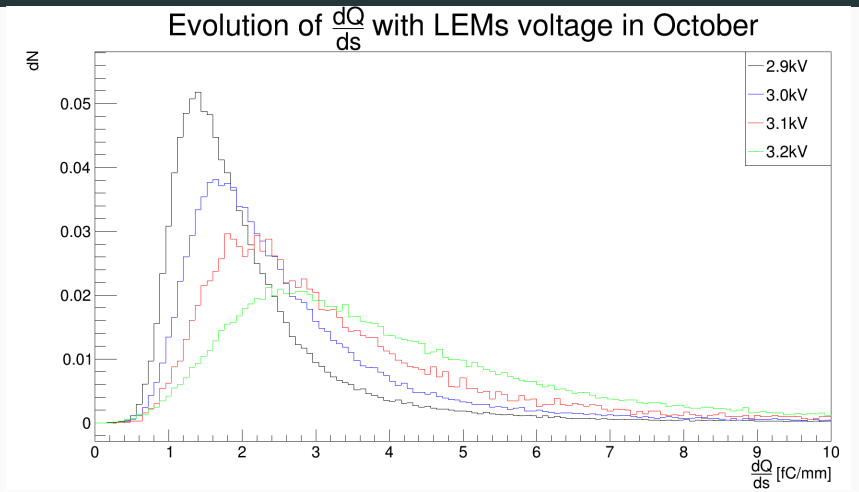
Overall CRP gain

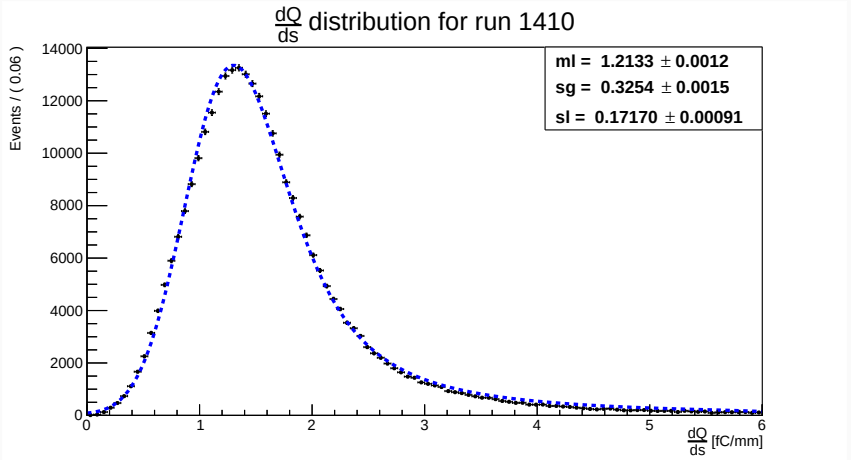
Overall CRP gain for a given voltage is estimated as mean gain of all LEMs at nominal voltage.

Results

$\frac{dQ}{ds}$ distributions



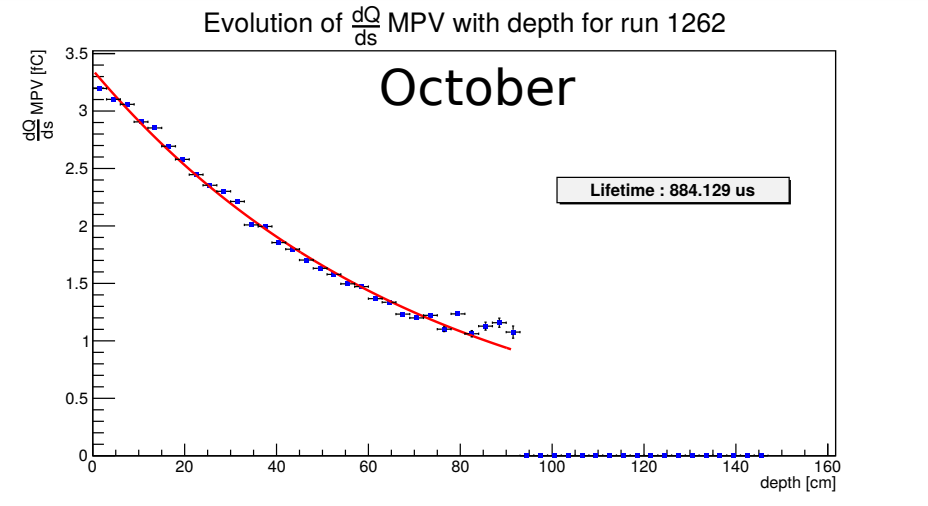


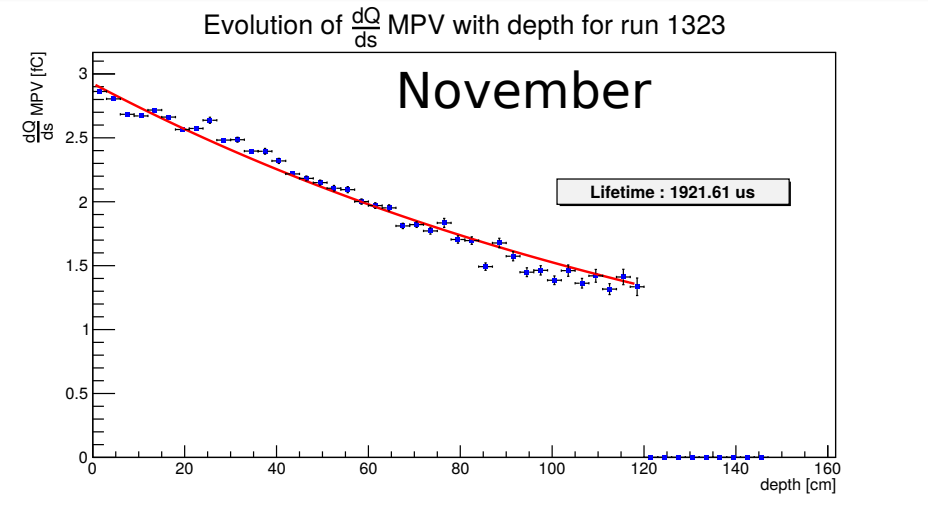


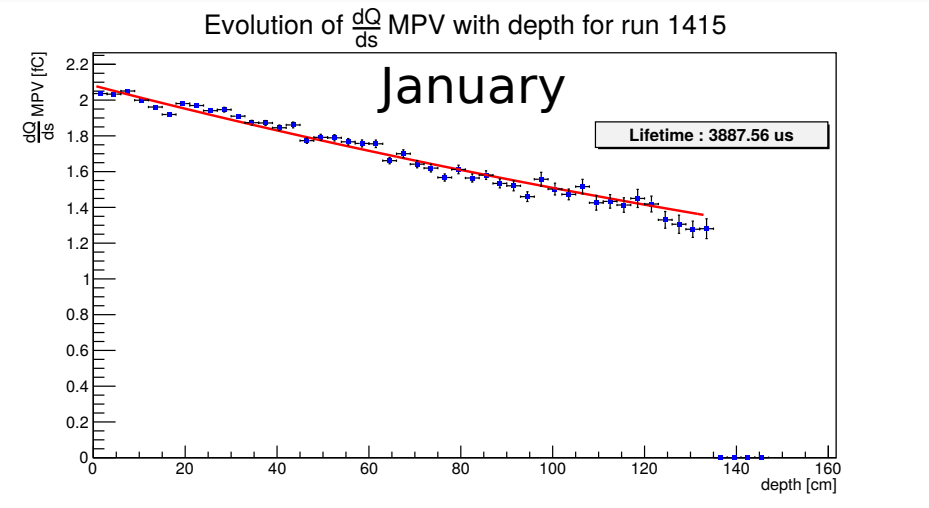
Fit of $\frac{dQ}{ds}$ distributions with the convolution of a gaussian and a Landau.

For a gain of 1 at $\mathcal{E} = 166\,\mathrm{V\,cm^{-1}} \rightarrow \left.\frac{dQ}{ds}\right|_{\mathrm{MPV}} = 0.8$

Lifetime results



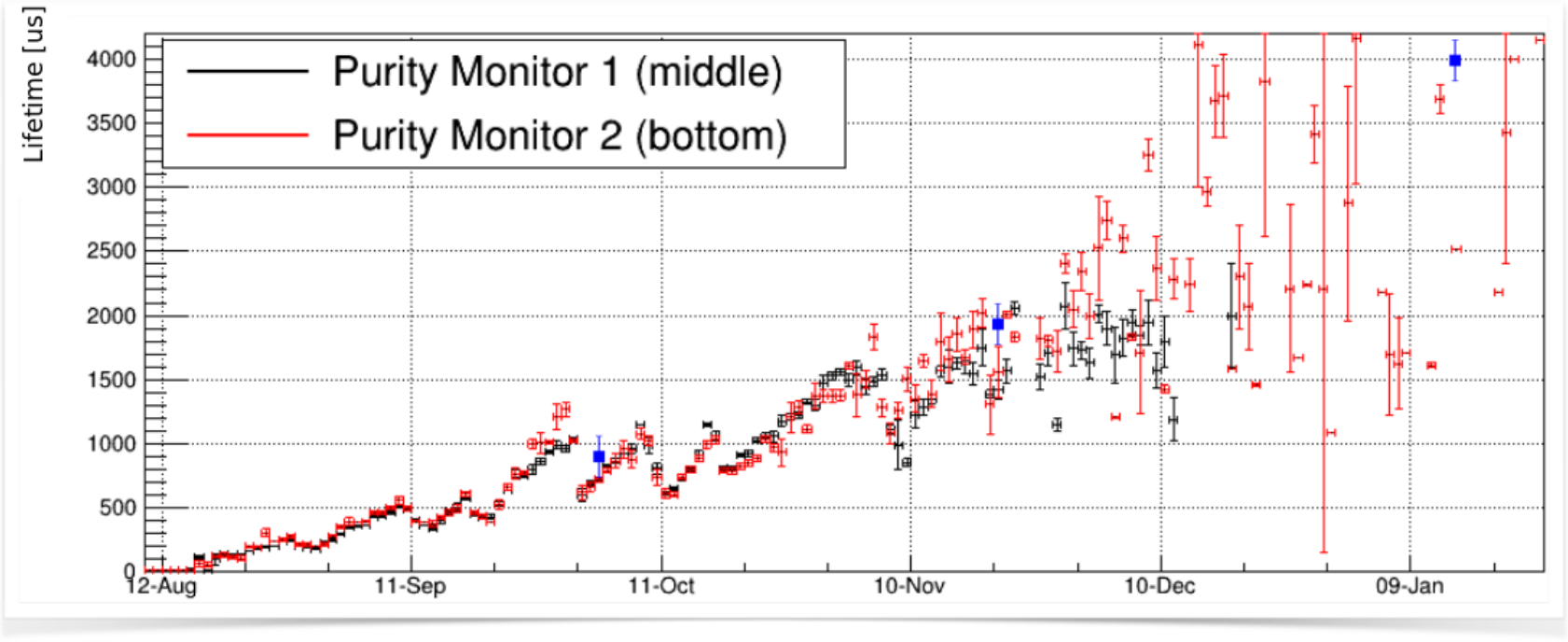




Fitted exponential decrease of $\left.\frac{dQ}{ds}\right|_{\text{MPV}}$ (depth).

Clear increase of purity with time

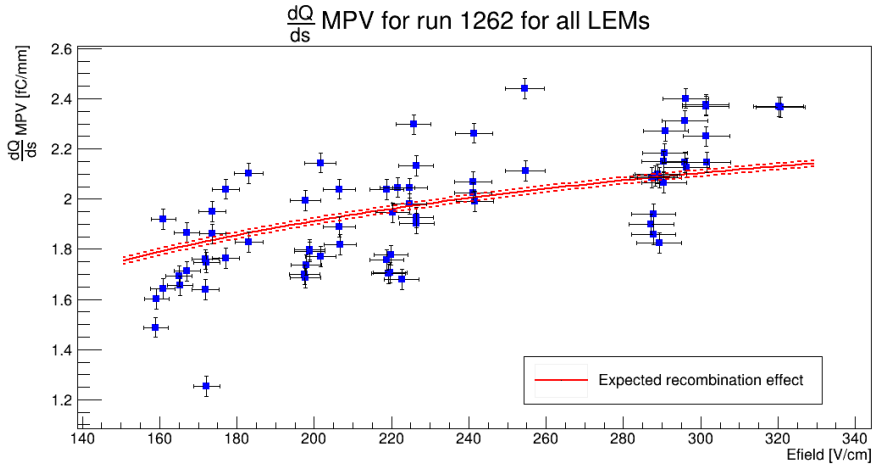
Lifetime results

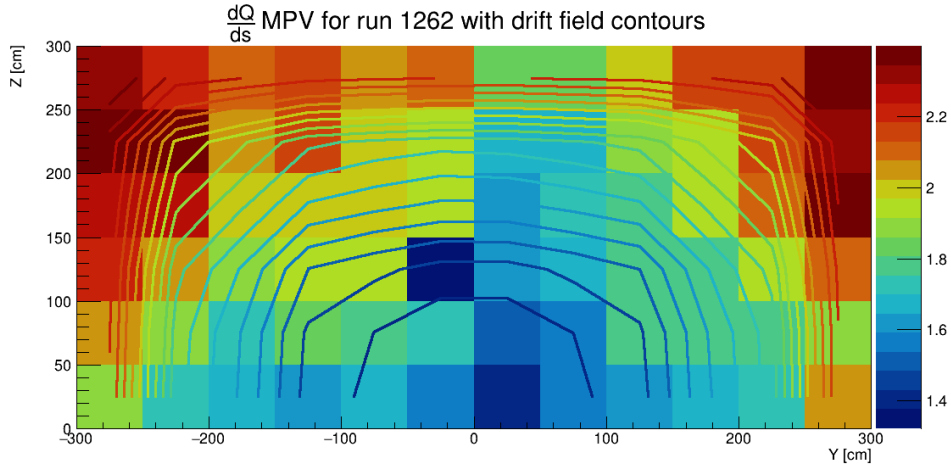


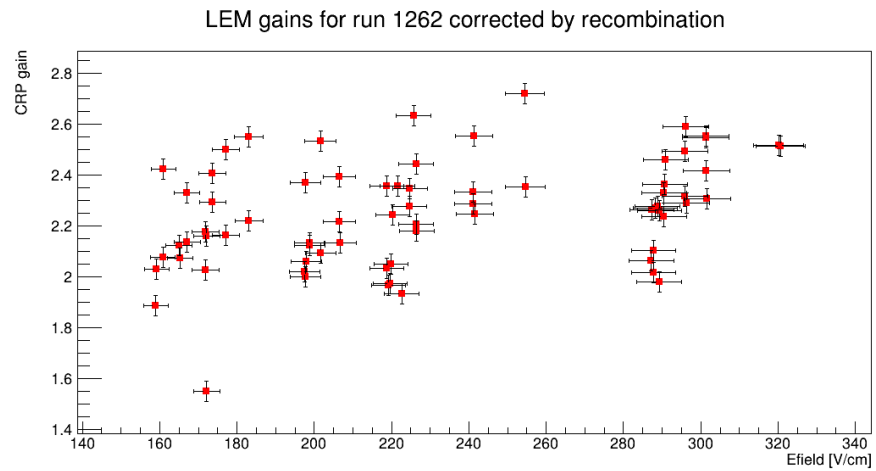
The fitted lifetimes for the 3 run periods (blue points) are fairly consistent with purity monitors data.

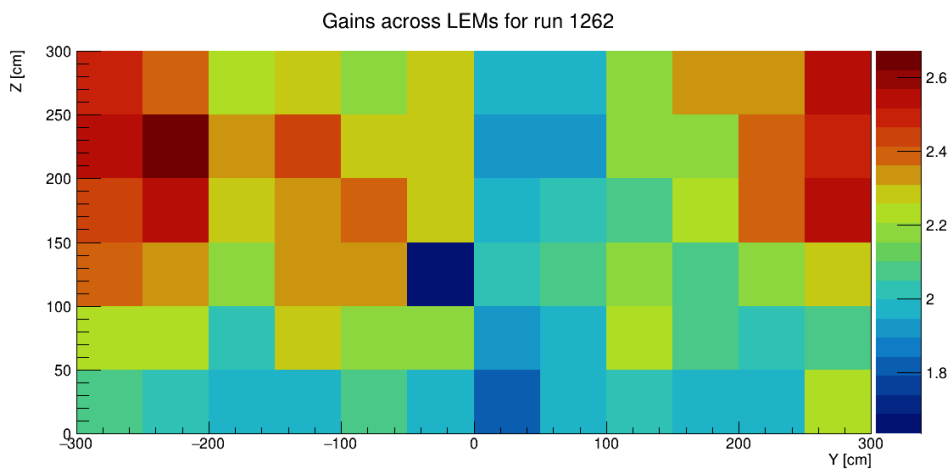
Errorbars correspond to the deviation measured for different runs.

Gains across LEMs









Errorbars are estimated by running the analysis 100 times on a random half of the data

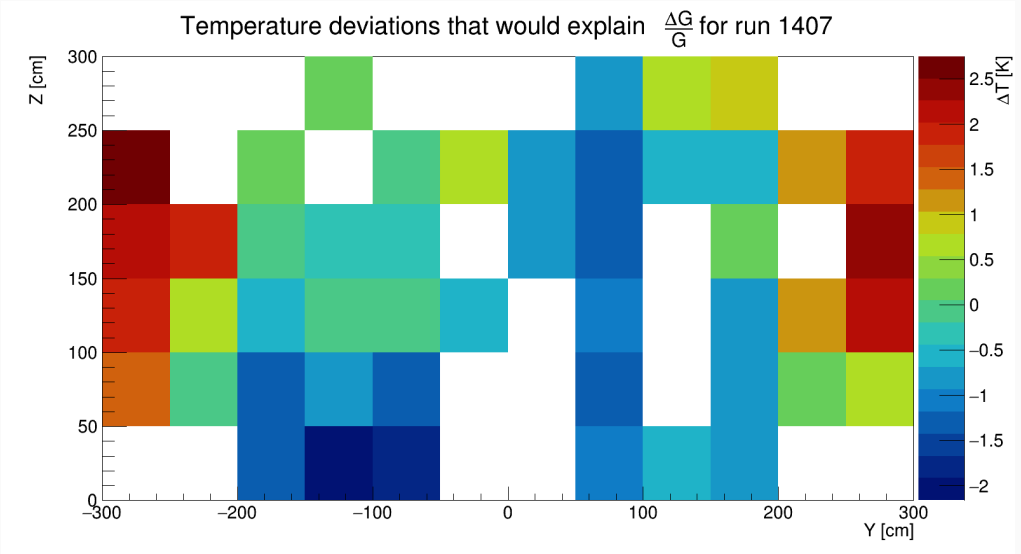
Accounting for recombination only partly explains gain inhomogeneities between LEMs

Could temperature differences explain gain inhomogeneities ?

$$G = C \exp\left(A\rho d \exp\left(-\frac{B\rho d}{V}\right)\right)$$

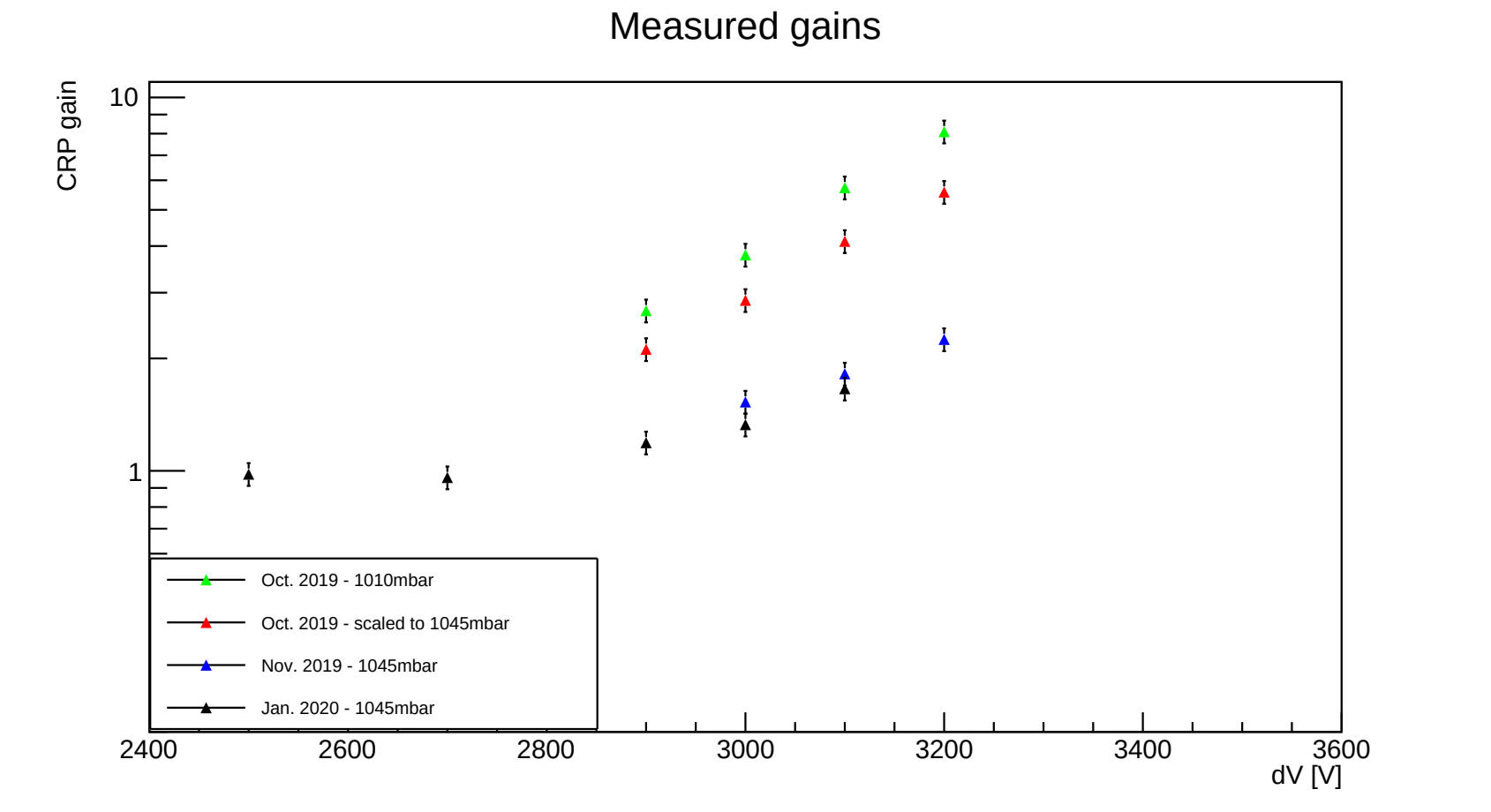
- A, B, C : coefficients
- V : voltage through LEMs
- ρ : gas density
- d : LEM thickness

- Converting $\frac{\Delta G}{G}$ to $\frac{\Delta(\rho d)}{\rho d}$
- Estimating the corresponding ΔT assuming fixed d



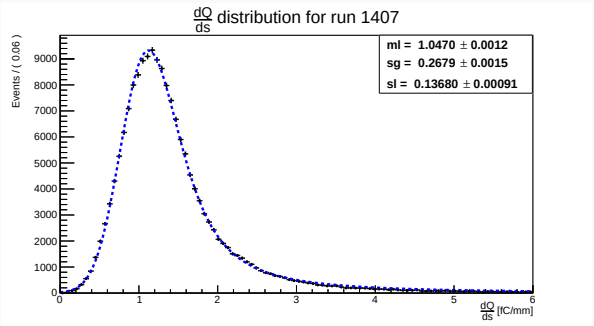
Small temperature differences between LEMs could explain the gain inhomogeneities $\rightarrow$ no T probe at the level of LEMs to check

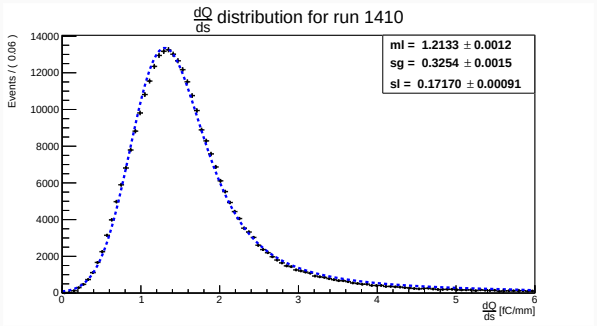
Evolution of gains with voltage

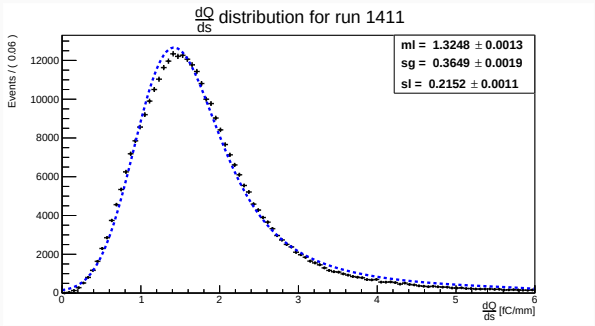


- Charging-up of LEMs with time as expected
- Increase of gain with dV
- Data for $dV < 2.9\,\mathrm{kV}$ analyzed carefully

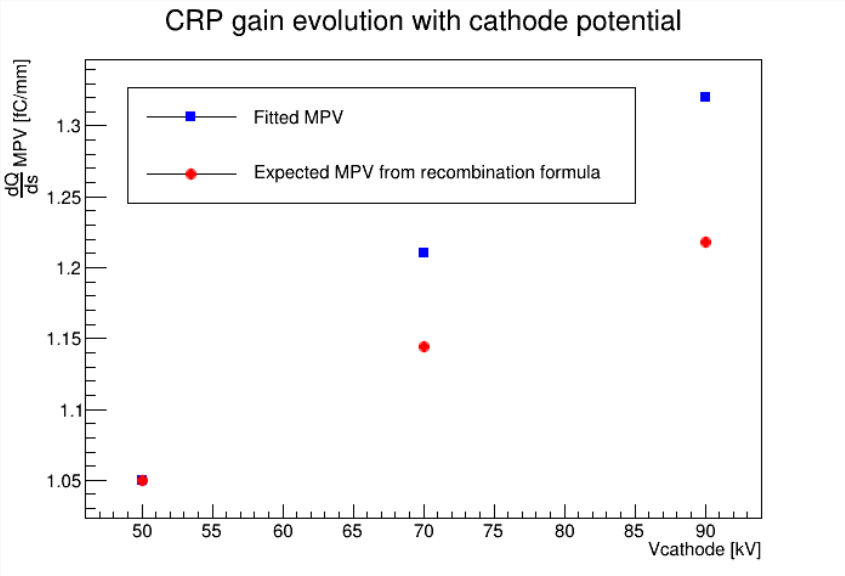
Evolution of gain with cathode voltage - Preliminary







$\frac{dQ}{ds}$ distributions fitted for the whole CRPs



Measured $\left.\frac{dQ}{ds}\right|_{MPV}$ seems to increase more rapidly with Vcathode than expected from recombination formula.

Conclusion

Conclusion

Summary

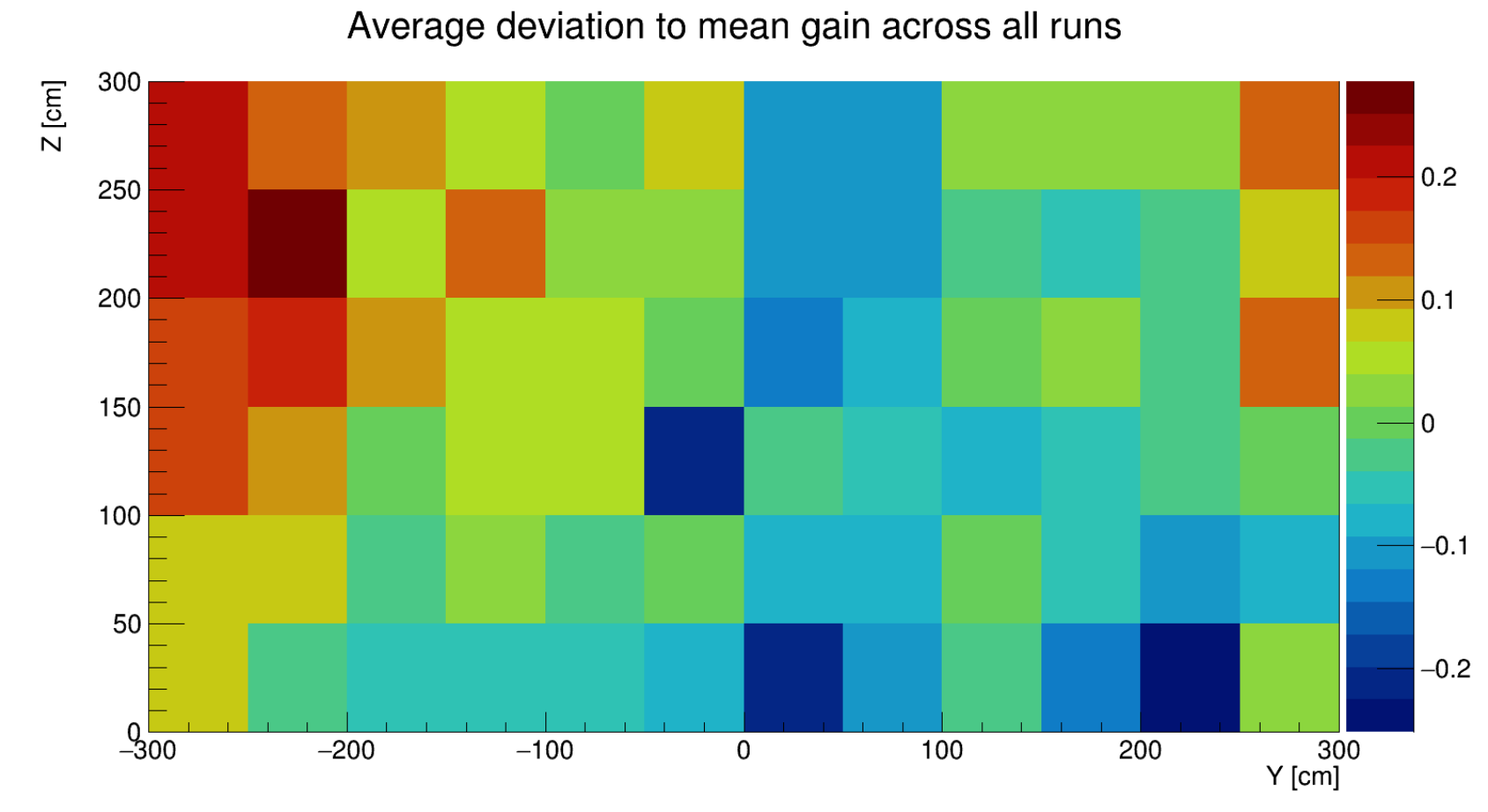
- Evaluation of purity seems consistent with purity monitors data
- The drift field inhomogeneities are visible on a LEM by LEM analysis
- There is a pattern in LEM gains $\rightarrow$ temperature explanation ?

How to improve ?

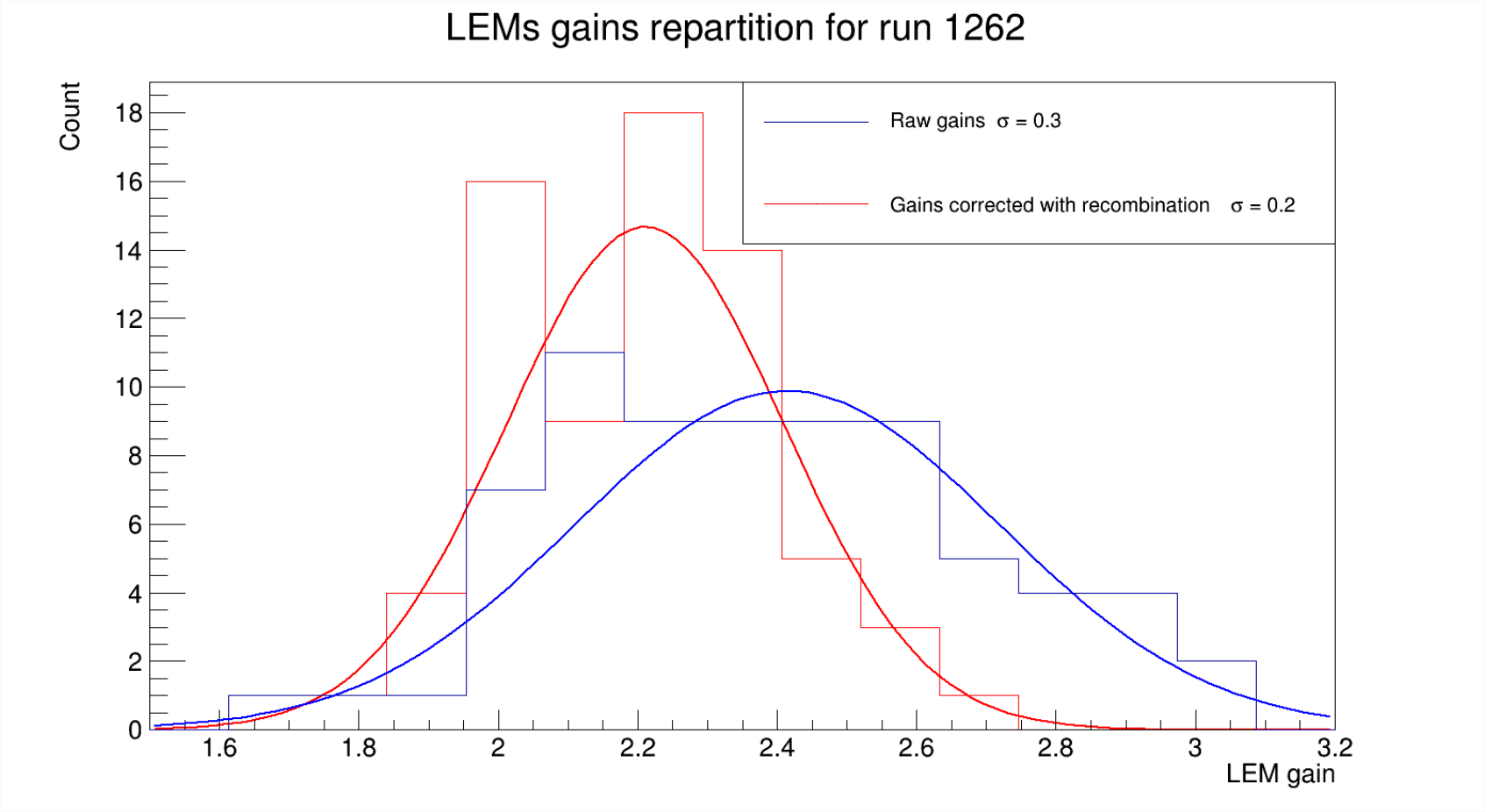
- Investigating low induction field data
- Correlate gain differences with LEMs thicknesses
- Understanding the evolution of gain with cathode voltage

Backup slides

Gains across LEMs



Gain dispersion



Spectra superposition