IROC Garfield++ simulations

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Introduction

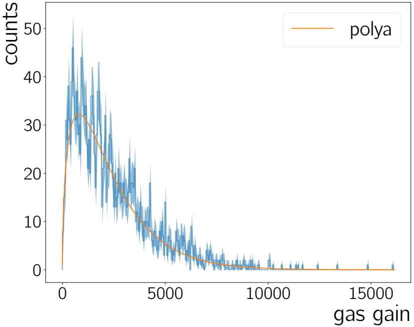
- Update on the simulation shown in the MPD meeting, week 13 (23.03.2020). See the slides in the backup.
- All the code for the following plots can be found here: `https://gitlab.cern.ch/adeistin/garfield-dune-hpgtpc-code/-/blob/master/README.md` – in case someone wants to play. The *readme* should help somewhat to get started. Contains:
  - ALICE ROC
  - Mock up RHUL HPTPC with three anodes
  - Pull and play with *cmake* (tested so far on Mac and the RHUL batch system – needs Garfield++)
- Today we show Ar-CO_2 (90-10) and P10 (Ar-CH_4 (90-10)) gain and signal simulation

Simulation set-up

- IROC geometry, three wire planes:
  - Anode wires, $\varnothing = 20\,\mu\text{m}$, pitch $2.5\,\text{mm}$, $V_{\text{anode}} = 1460\,\text{V}$
  - Cathode wires, $\varnothing_{\text{cathode}} = 75\,\mu\text{m}$, pitch $2.5\,\text{mm}$, $V_{\text{cathode}} = 0\,\text{V}$
  - Gating grid wires, $\varnothing_{\text{GG}} = 75\,\mu\text{m}$, pitch $1.25\,\text{mm}$, $V_{\text{GG}} = -70\,\text{V}$
- $400\,\text{V}\,\text{cm}^{-1}$ drift field
- The choice of constant voltages and changing pressure reflects the current work in the lab: *i.e.* pick a voltage setting ALICE used and see what one sees at high pressure. Last week's interesting talk showed anode voltage scans for constant pressure.
- Ar-CO_2 (90-10) and P10 at 750 torr and 1500 torr, 2250 torr, 3000 torr and 3750 torr – all at room temperature – with the Penning effect not included
- Used 100 clusters with 25 primary electrons each. Each cluster is located 1.1 cm above the GG wire plane and the cluster position is smeared with a Gaußian: In wire direction with $\sigma = 0.5\,\text{cm}$ and $\sigma = 0.2\,\text{cm}$ in the other two.
- The electron positions in a cluster are smeared as well with a Gaußian $\sigma = 0.05\,\text{cm}$ around the cluster centre.

Gas gain analysis, 1/3

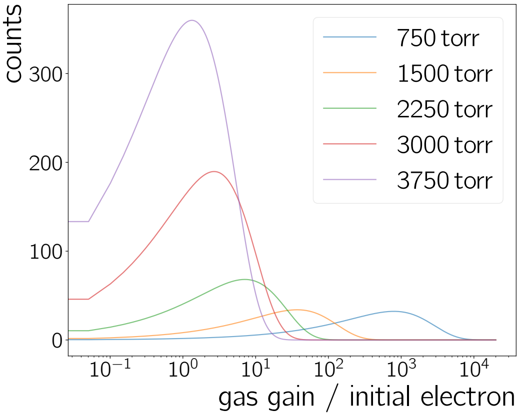
- Gas amplification simulated using the `AvalancheMicroscopic` class
- Histogramise the number of electrons produced for each primary electron
- Fit a Polya (see below)to parametrise the gain
- On the right is the example for 750 torr, Ar-CO_2



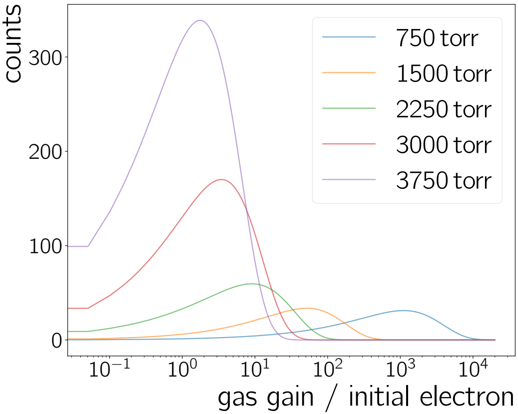
$$\theta = \left(\langle gain\rangle^2 - \sigma_{\text{gain}}\right)/\sigma^2_{\text{gain}} \tag{1}$$

$$P\left(G\right) = \frac{p_0}{\langle gain\rangle} \cdot \frac{\left(\theta-1\right)^{\left(\theta-1\right)}}{\Gamma\left(\theta-1\right)} \cdot \left(\frac{G}{\langle gain\rangle}\right)^{\theta} \cdot \exp\left(-\left(\theta-1\right)\cdot\frac{G}{\langle gain\rangle}\right) \tag{2}$$

Gas gain analysis, 2/3

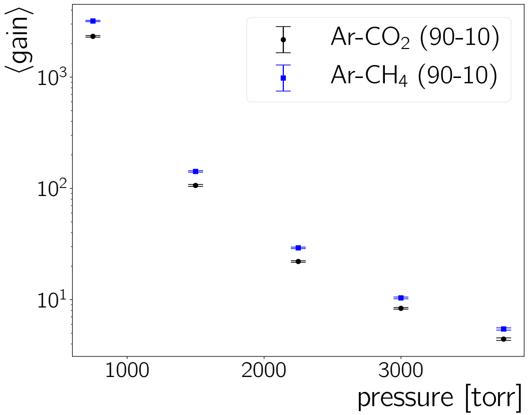


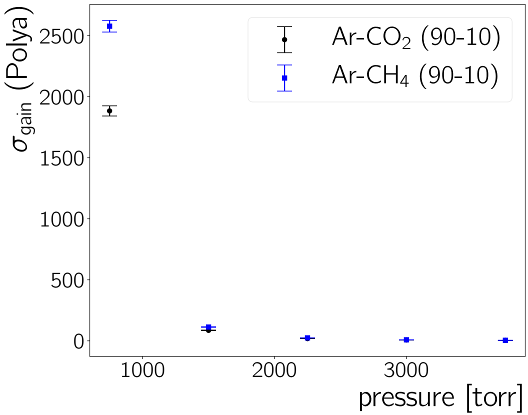
Ar-CO_2



Ar-CH_4

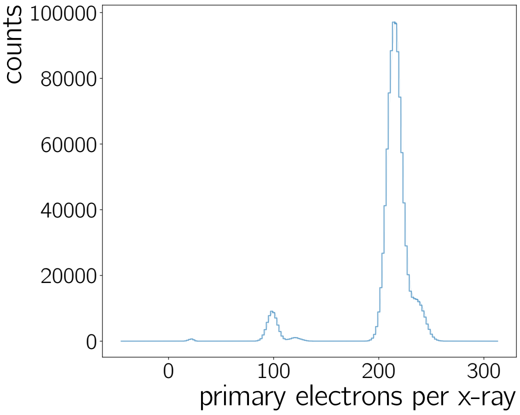
Gas gain analysis, 3/3



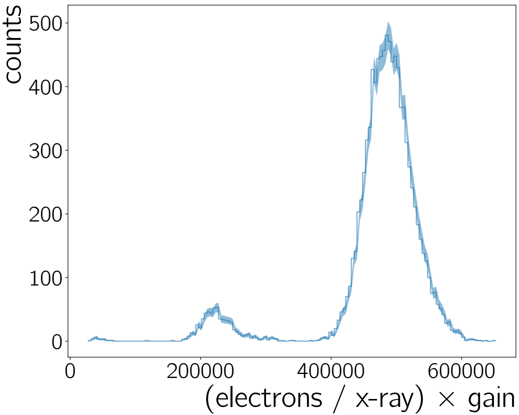


Gas analysis, comments

- Gains likely underestimated, slightly for Ar-CO_2, especially for the Ar-CH_4 (no Penning effect taken into account)
- Vanishing gain at higher pressures when the ALICE anode voltage is maintained
  - A large increase may not be feasible in order to ensure a safe operation of the chambers
  - Examining mixtures which provide a higher gain at lower voltage is a way out of this
- Will be interesting to compare to Brandon's results (last week's talk) since he used a different method in garfield++
- Having the parametrisation of the Polya at a gas and voltage setting ultimately allows to not simulate avalanches again (safes time), example on the next slide



primary electrons after 1000 ^{55}Fe x-ray interactions in the gas simulated with heed (Ar-CO_2 90-10, 750 torr)



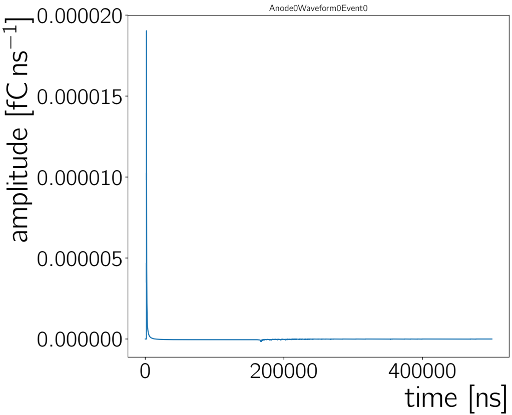
drawing primary electron numbers N_{primary} from the left distributions, followed by N_{primary} draws from a distribution based on the Polya

Signal simulations

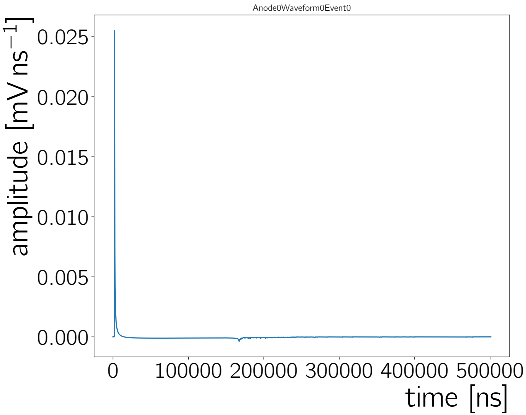
- Based on the gain simulation also a signal simulation can be run. It uses the same detector geometry and HV / gas-configuration file and runs on the output of the gain simulation
- *I.e* the initial electron positions are used to drift electrons / ions from there through the detector geometry
- Garfield++ records the signals. These are written out and can then be further processed. For example I convolve the signal with the same pre-amplifier response as we have seen last week, but external to garfield++
- PASA pre-amplifier response function:

$$R_{\mathrm{PASA}}(t) = 12.7\,\mathrm{mV\,fC^{-1}} \cdot \exp(4) \left(\frac{t}{160\,\mathrm{ns}}\right)^4 \exp\left(-\frac{4t}{160\,\mathrm{ns}}\right) \tag{3}$$

- One main question is what best to include in the final signals. I show on the next slides signals based only on the induced ion signal.



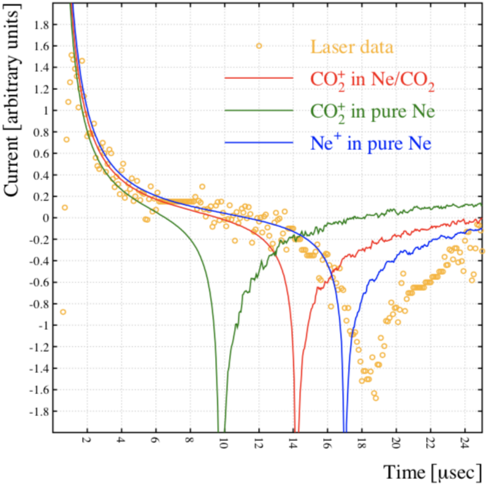
25 primary electrons in Ar-CO_2 90-10, 2250 torr



same as left, but convolved with the PASA response function

Signal simulations, comments

- Signal shape matches the ALICE measured signals, the scaling may be well off
- I have been using a default ion mobility file for CO_2 ions in CO_2.
- One for CO_2 ions in Ar would be needed for the Ar-CO_2 measurements and probably $CH_{4?}$ in Ar for P10.
- There is thus a caveat, since the signal height here is driven by gas gain and ion mobility.
- Nevertheless: I simulated 100 waveforms for each of the voltage and gas settings



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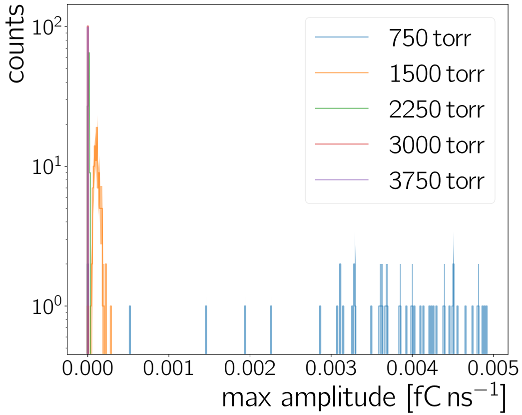
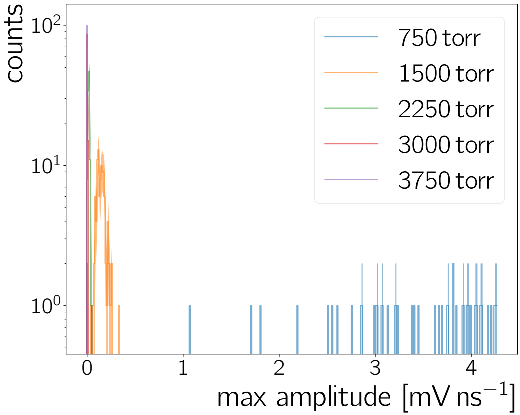
Signal analysis, Ar-CO_2

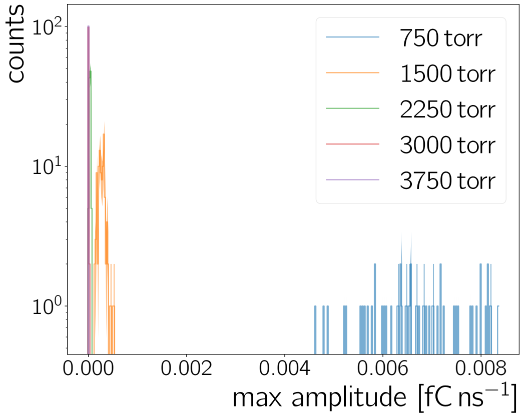


ion signal

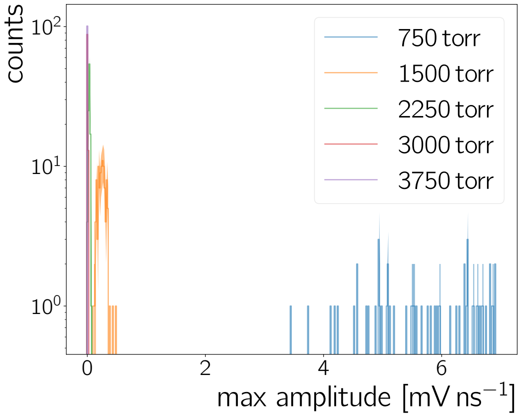


ion signal with PASA response

Signal analysis, Ar-CH_4



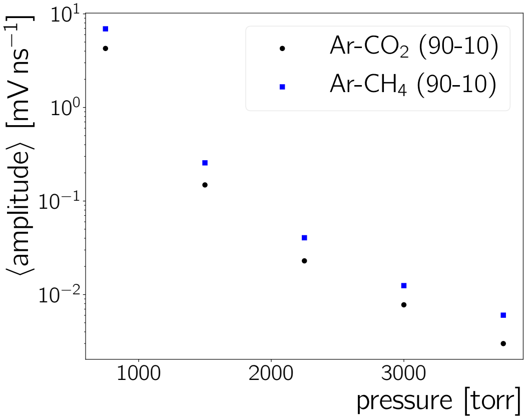
ion signal



ion signal with PASA response

Signal analysis

- The plots on the previous page are pulse height spectra, where the baseline and the largest value for each amplitude is calculated (the baseline is zero)
- Each waveform corresponds to 25 amplified primary electrons. *I.e* multiply the spectra by ~ 100 to get an idea for ^{55}Fe photon.
- The resulting amplitude spectra follow the expectation based on the Polya functions



On the right the mean value of these amplitude distribution vs pressure and $\langle gain \rangle$ from the Polya fits to the gain distributions is shown

Signal analysis

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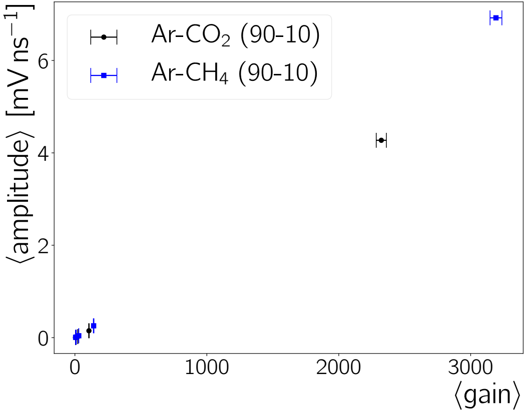


On the right the mean value of these amplitude distribution vs pressure and $\langle gain \rangle$ from the Polya fits to the gain distributions is shown

Summary

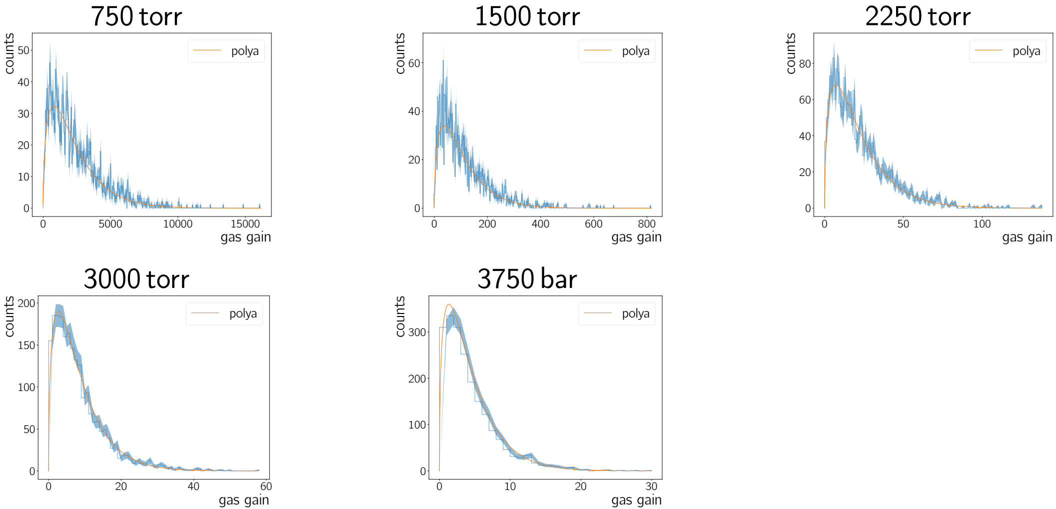
- Simulating the gas gain shows that it can be well parametrised by a Polya
- Amplitude spectra seem to follow the trend given by the Polyas as well

⇒ Increasing the statistics on both (especially on the latter) will allow to come up with a set of look-up functions for various gas and voltage settings, eliminating the need for extra run-time intensive garfield++ simulations in larger productions

- Unfortunately I did not yet run some configurations of last week's talk, but comparing both results will be a nice cross check, since we do not use the exact same garfield++ procedures
- The ultimate goal would be to compare to measurements in the lab – except for the preamp response functions we should have most things in hand to do this

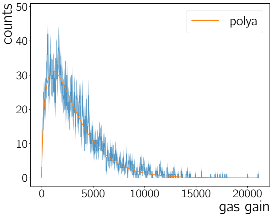
Backup

Gas gains, Ar-CO_2

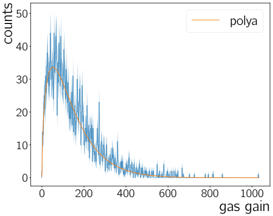


Gas gains, Ar-CH_4

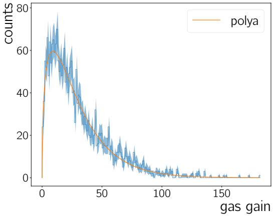
750 torr



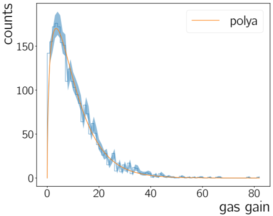
1500 torr



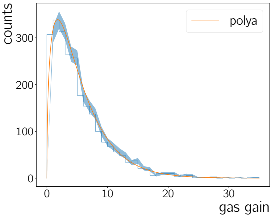
2250 torr



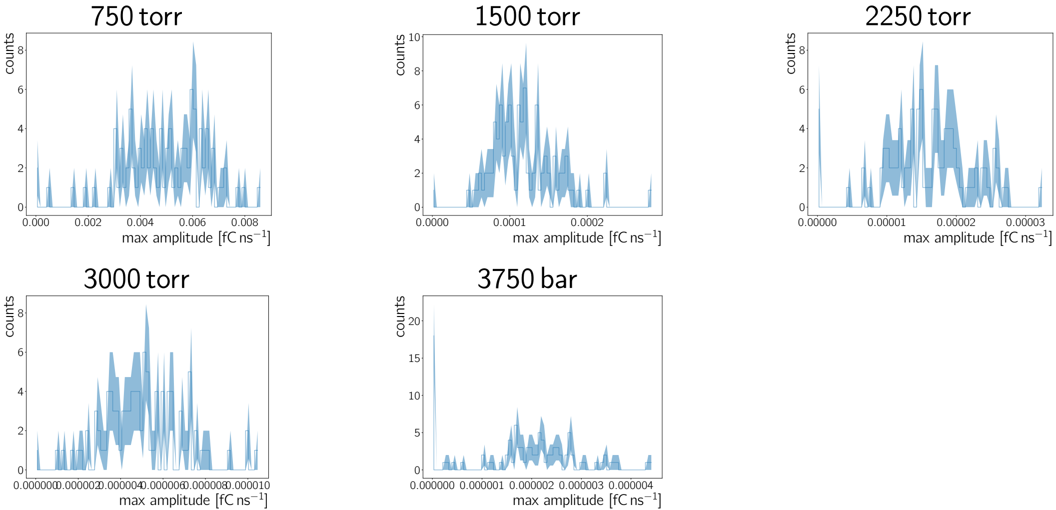
3000 torr



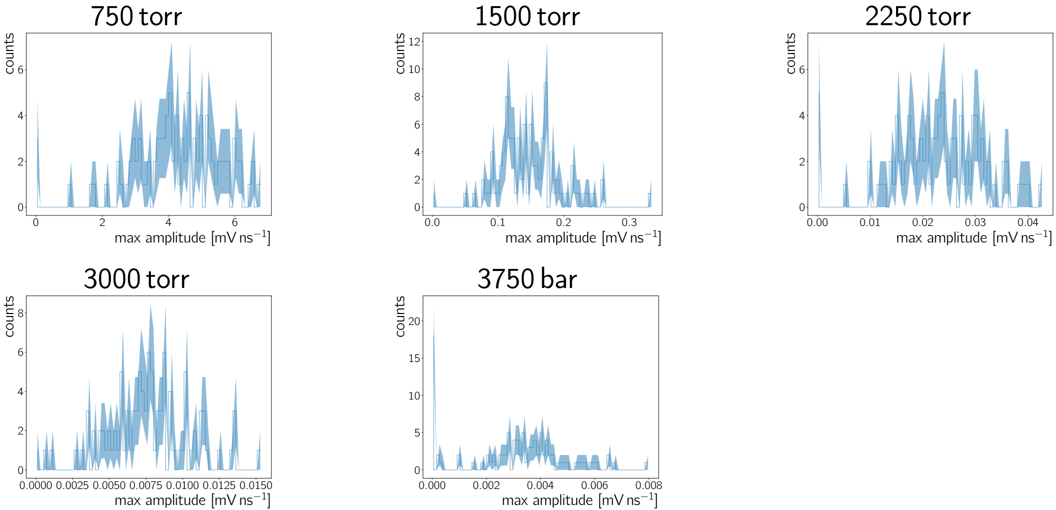
3750 bar



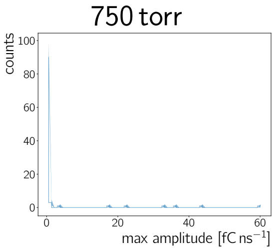
Amplitude spectra, ion signal, Ar-CO_2

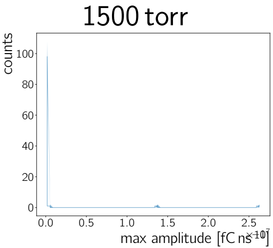


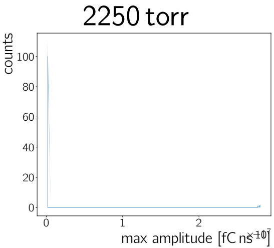
Amplitude spectra, ion signal $\times R_{\mathrm{PASA}}$, Ar-CO_2

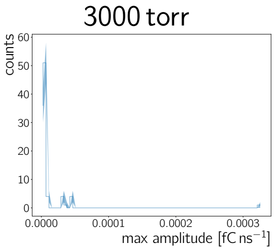


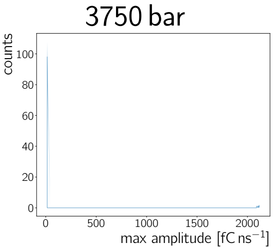
Amplitude spectra, ion and electron signal, Ar-CO_2



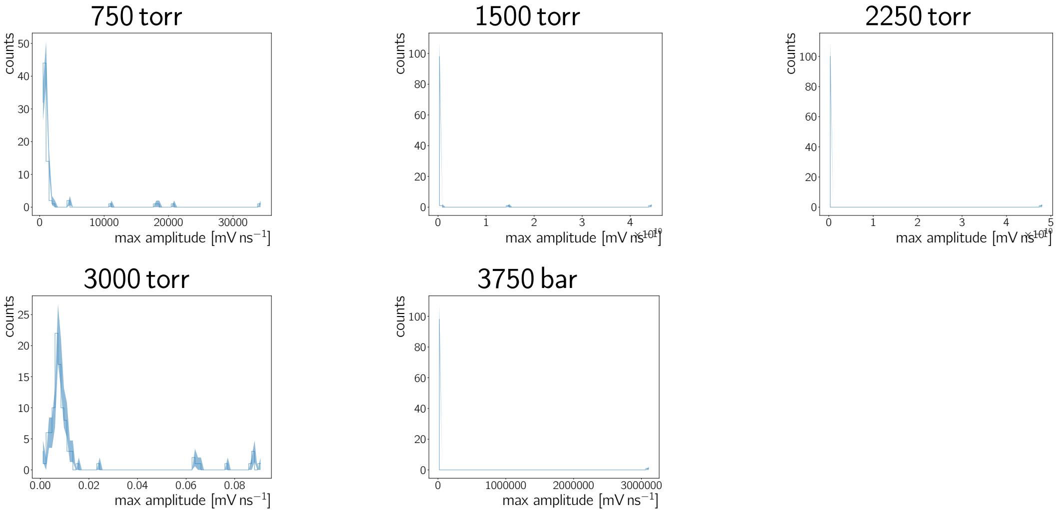




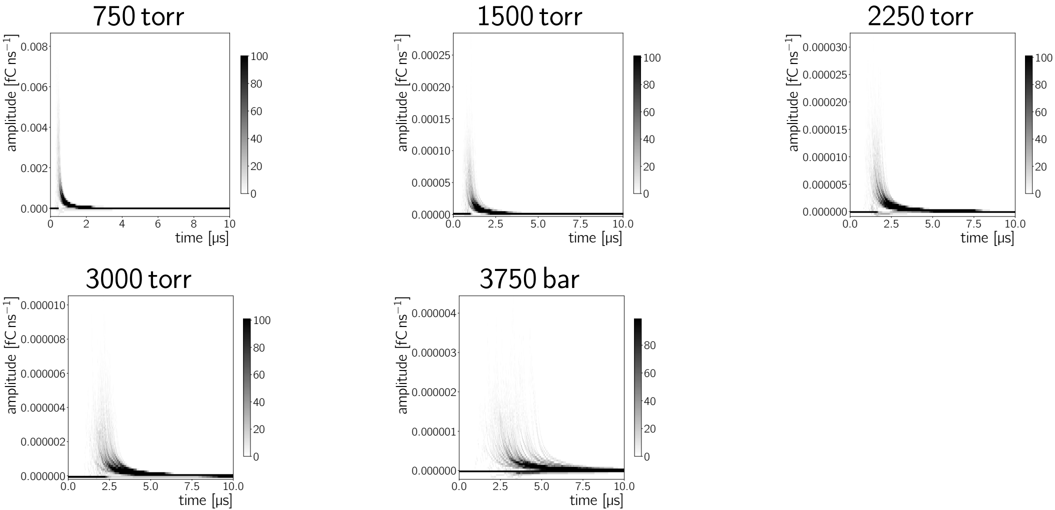




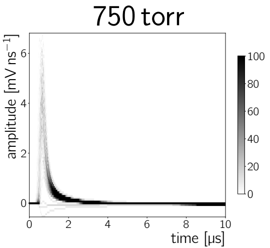
Amplitude spectra, ion and electron signal $\times R_{\mathrm{PASA}}$, Ar-CO_2

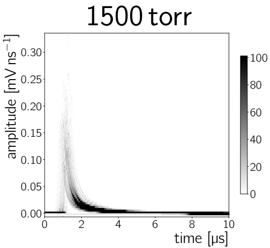


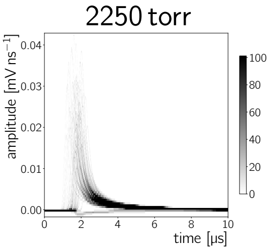
Waveform comparison, ion signal, Ar-CO_2

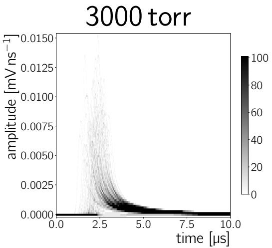


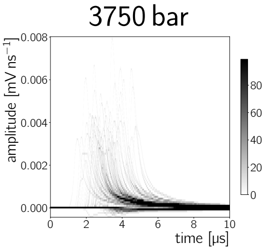
Waveform comparison, ion signal $\times R_{PASA}$, Ar-CO_2



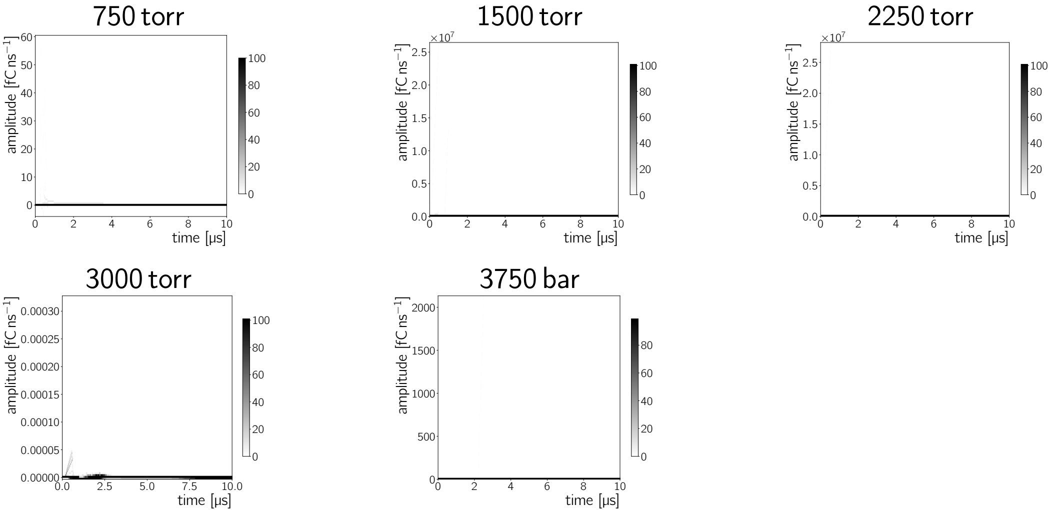




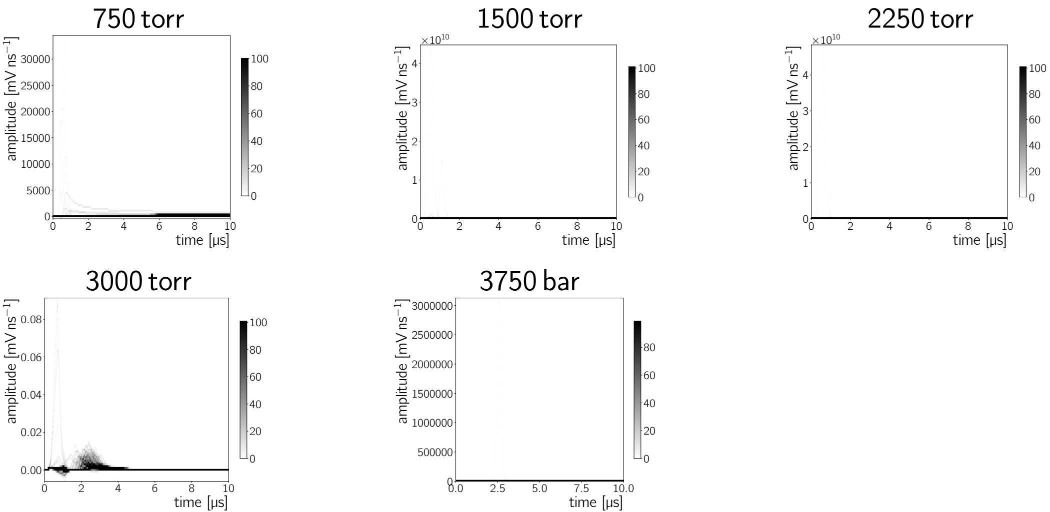




Waveform comparison, ion and electron signal, Ar-CO_2



Waveform comparison, ion and electron signal $\times R_{PASA}$, Ar-CO_2



Slides, 23.03.2020

Garfield++ simulation of an ALICE MWPC

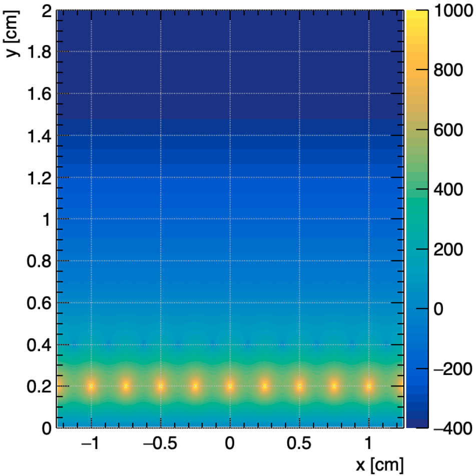
- To better understand the signals seen in the IROC (and later by the OROC) some simulations would be nice
- For this reason I am currently having a look into Garfield++ simulation
- There is an example for an ALICE MWPC (http://garfieldpp.web.cern.ch/garfieldpp/examples/alicetpc/) – on this one I based my code
- The problem with this example is that it does not have gas amplification in it
- The code lives on the CERN gitlab for now
- These slides are a short status update on these – **everything is very preliminary**

Strategy

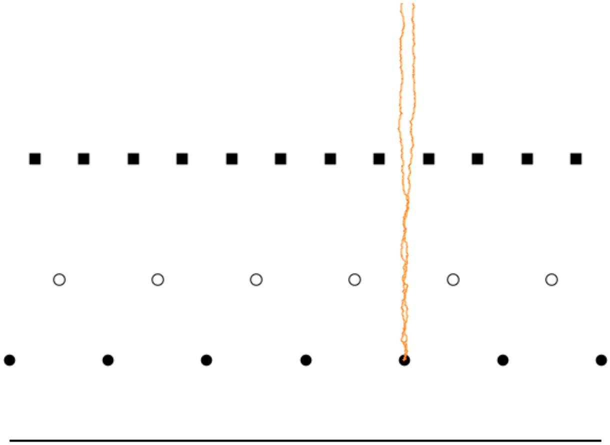
Since garfield can be a bit slow and memory usage intensive I split the simulation into two parts:

- a) Creating the avalanches from the initial electrons
- b) Drifting ions/electrons and calculate the signal
- In step b) the initial positions of the electrons from a) are used as the initial positions for the ion and electron drift
- Currently only 2 primary electrons are drifted in a purely ALICE TPC setting

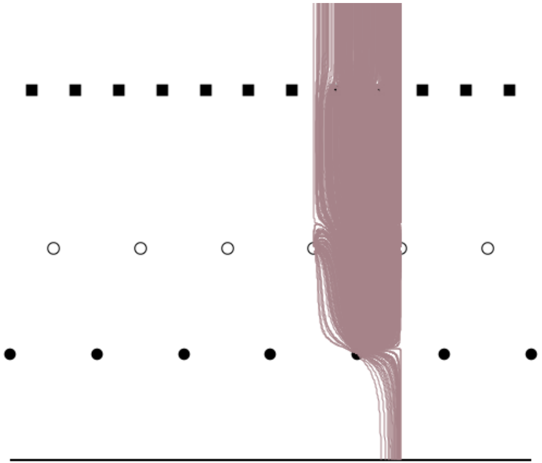
Electric field map



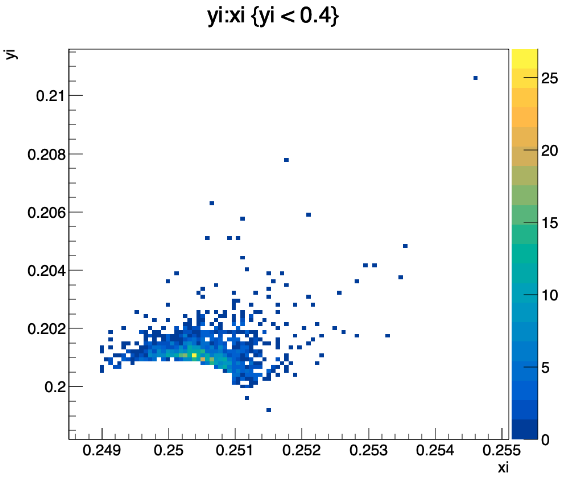
Electron drift



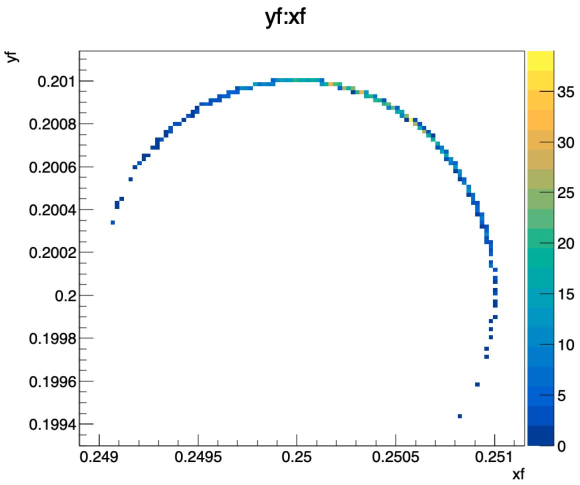
Ion drift



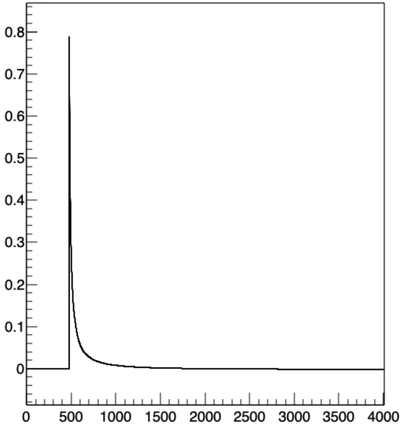
Electron initial positions close to a wire



Electron final positions



Summary



Time in ns on the horizontal axis, induced charge in arbitrary unit on the vertical

- So far all this looks reasonable
- I have to think a bit more about how to go from the raw induced signal to the signal (as shown on the left). This involves checking the signal transfer function provided does what I would like it to do
- Still on the list:
  - Implement this for the correct gas
  - ^{55}Fe as source of the signal
  - Large production of signals to run through a signal analysis