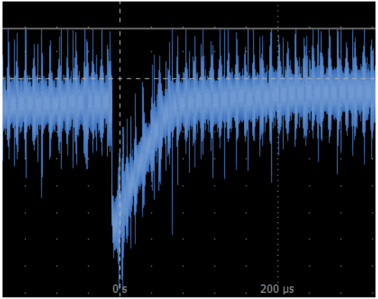
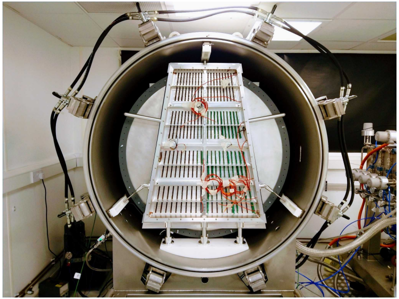
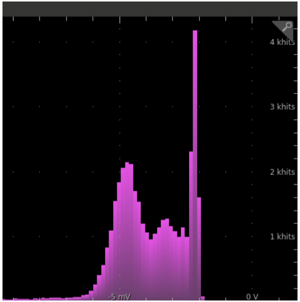
OROC Commissioning for high pressure, and measurements and simulation at 1atm in Ar-CO2

Harrison Ritchie-Yates, Alexander Deisting

ND-GAr: HPgTPC+ECAL Weekly Meeting, 14^{th} of December, 2020





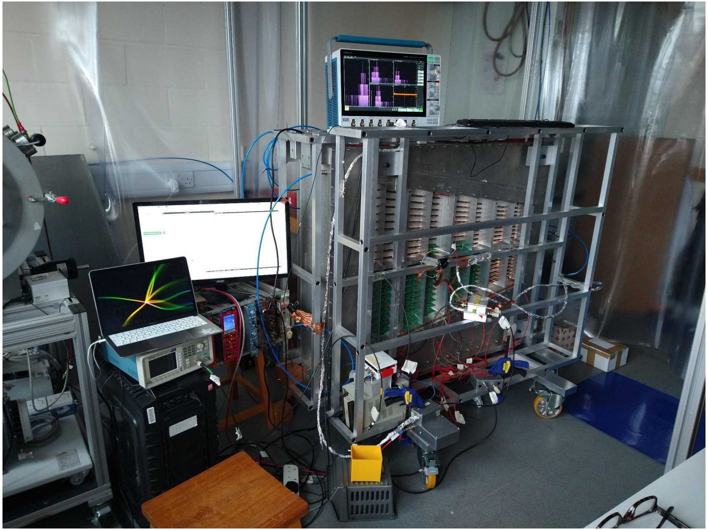


Introduction

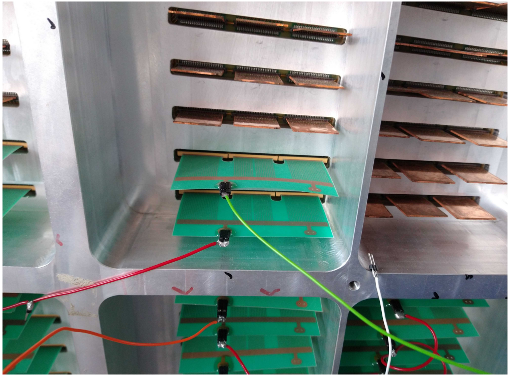
- We have been commissioning the OROC in a test box at Royal Holloway.
- We are running tests with Ar/CO2 90%/10% gas mix, using an Fe55 source.
- Reading only 1 channel, we have made our first gain measurements.
- Shown here are the test setup at Royal Holloway, the results of the test box commissioning, and a comparison with simulation.

Front and back of the OROC, showing the wires and pad planes, and the shortening cards for readout

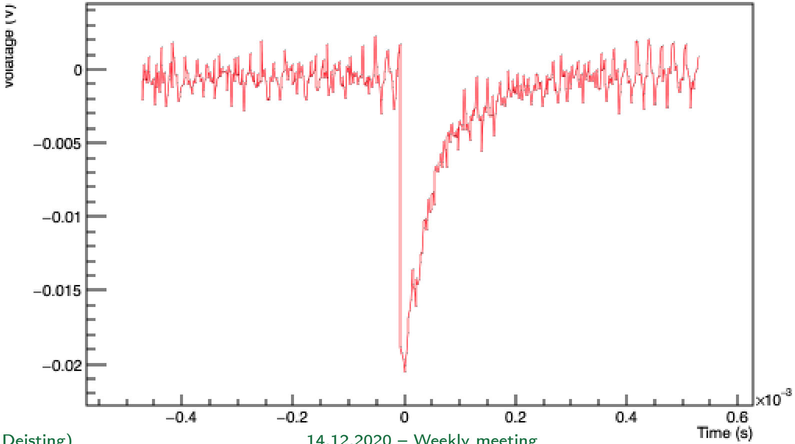
OROC test box setup at Royal Holloway



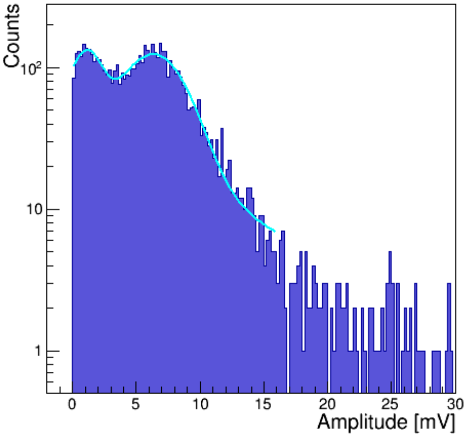
Reading out only 1 card via a Cremat CR-112 charge-sensitive preamp

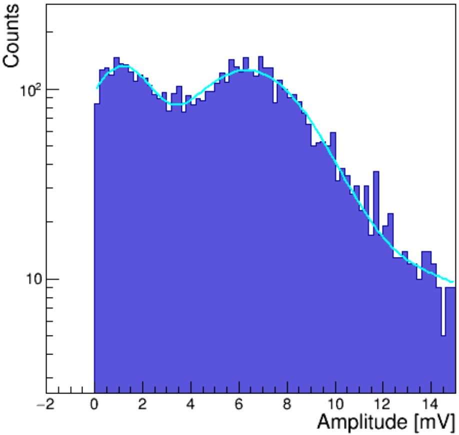


Typical signal waveform in Ar/CO2 90%/10%, using an Fe55 source, with cathode -4936 V, gating grid -120 V, Anode 1775 V

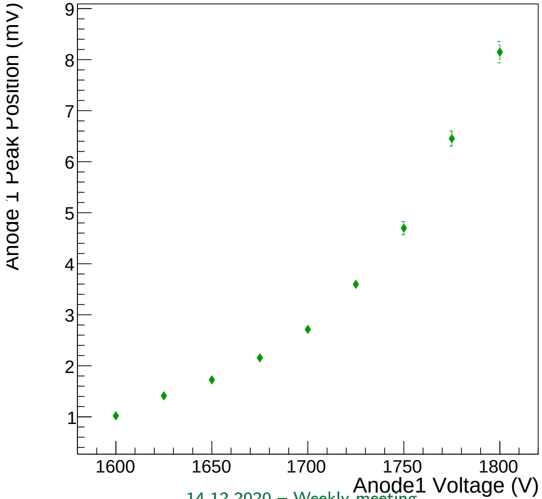


Amplitude spectra, Ar/CO2 90%/10%, using an Fe55 source, with cathode -4936 V, gating grid -120 V, Anode 1775 V

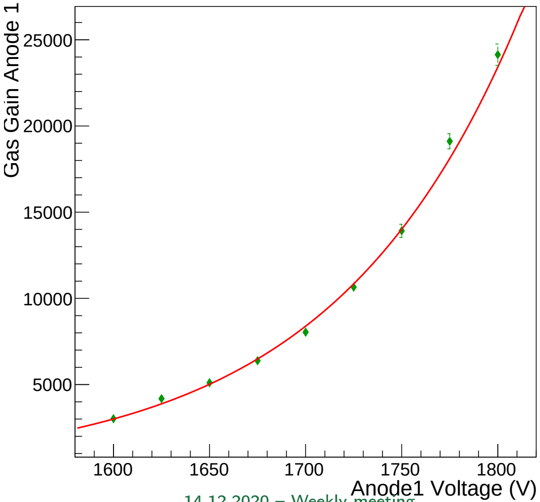




Peak position vs voltage Ar/CO2 90%/10%, Fe55 source, cathode -4936 V, gating grid -120 V



Gain vs voltage, Ar/CO_2 90%/10%, Fe55 source, cathode -4936 V, gating grid -120 V



Comparison to simulations

- The comparison will include the latest gas gain `garfield++` simulation results for an ALICE IROC in $Ar\text{-}CO_2$ (90-10) at atmospheric pressure.
- The OROC was operated with this mix and pressure we have been taking data with using the OROC in the 1 atm box.
- Still: These are IROC simulations. I started these simulations for our Fermilab colleagues and forgot to change back to OROC.
- Our Queen Marry colleagues (Takudzwa, Krzysztof, Linda, John) are joining the simulation effort for $\sim$2.5 months and we will have OROC simulations soon.
- More information on the simulation set-up can be found in previous talks, *e.g.* `https://indico.fnal.gov/event/44384/`

Summary: What do we do

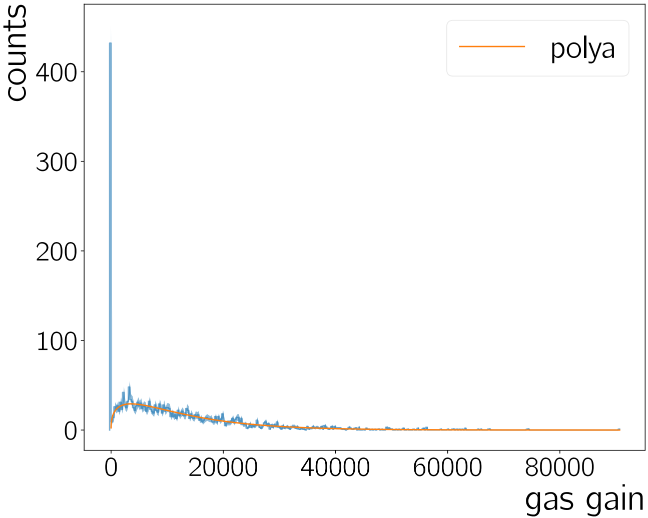
- We place a cluster of 25 primary electrons above the wire planes with some randomizing of this position
- `Garfield++` tracks the electrons through the amplification stage and does the gas amplification
- We check after each simulation how many electrons we got for each primary electron
- And then we repeat this step until we have enough statics

- With enough statistics we fit a Polya:

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

$$\theta = \left(\langle G \rangle^2 - \sigma_G \right) / \sigma_G^2 \tag{2}$$

- And extract the fit parameters $\langle G \rangle$, p_0 and σ_G and the χ^2 and N_{dof}.



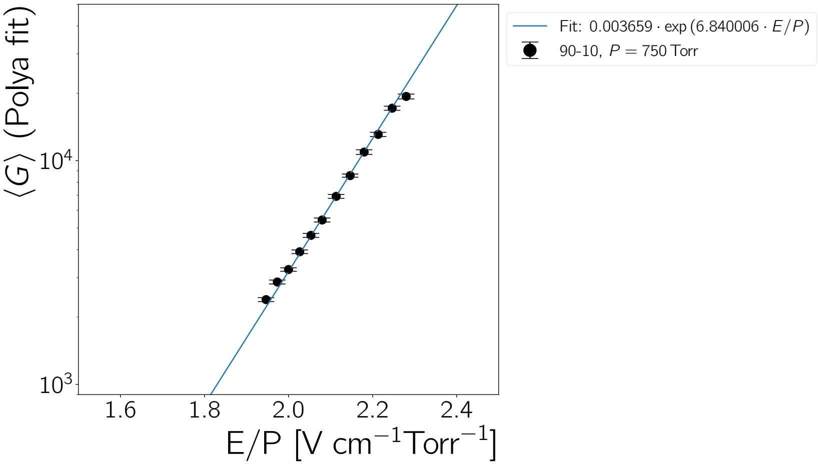
An example for the Polya fit (Eq. (1)) to a gas gain histogram from an $\mathrm{Ar}\text{-}\mathrm{CO}_2$ (90-10), $P = 750\,\mathrm{Torr}$ and $V_\mathrm{a} = 1660\,\mathrm{V}$ simulation.

Parametrising the simulated results

- As a result of many simulations at different voltage settings we get *e.g.* $\langle G \rangle$, E/P pairs
- We can attempt to describe the simulation results by some additional fits. For example an exponential as:

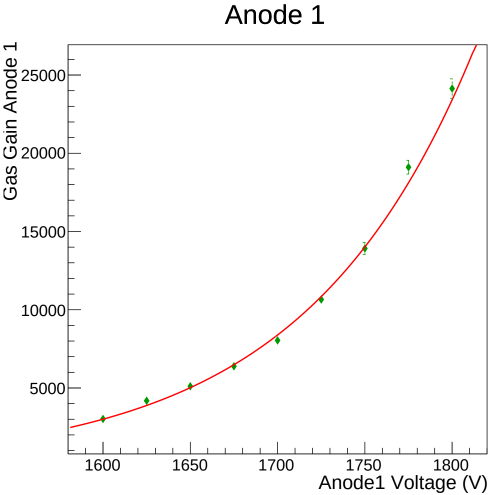
$$f_{\langle G \rangle}\left(\frac{E}{P}\right) = p_0 \cdot \exp\left(p_1 \cdot \frac{E}{P}\right) \tag{3}$$

- The result can be seen on the next slide
- Caveat: The plotting code had some problems with the highest gain events – so the $V_\mathrm{a} = 1685\,\mathrm{V}$ and $1710\,\mathrm{V}$ points may be slightly lower than actually predicted by `garfield++`.

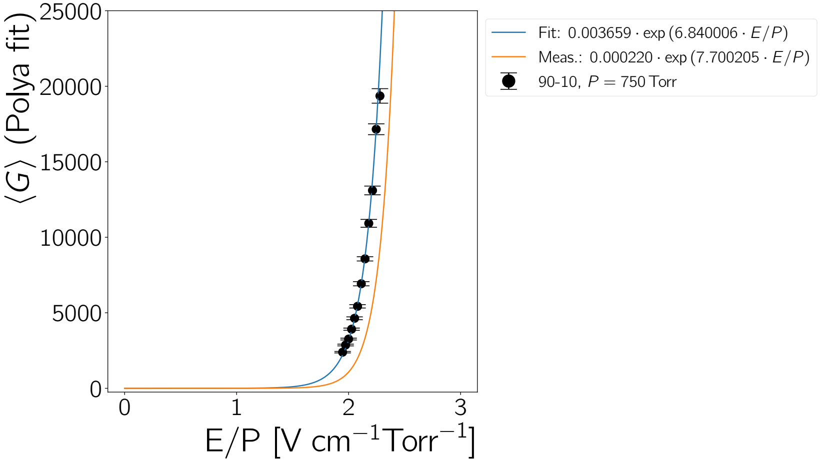


Points from an $\mathrm{Ar\text{-}CO_2}$ (90-10) simulation at $P = 750$ Torr with no Penning effect enabled. The line *Fit:* . . . is the result of a fit following Eq. (3) to the simulation.

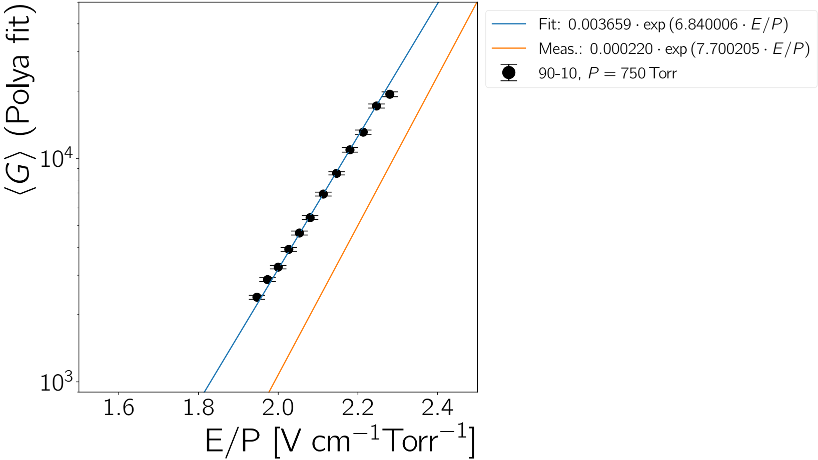
The measurement:



This has been done with the OROC at literally atmospheric pressure and an $Ar\text{-}CO_2$ (90-10) mix.



Points from an Ar-CO_2 (90-10) simulation at $P = 750$ Torr with no Penning effect enabled. The line *Fit:* . . . is the result of a fit following Eq. (3) to the simulation. The second line (*Meas.:* . . .) shows a parametrisation which has been fit to data measured with an OROC in the same mixture at atmospheric pressure.

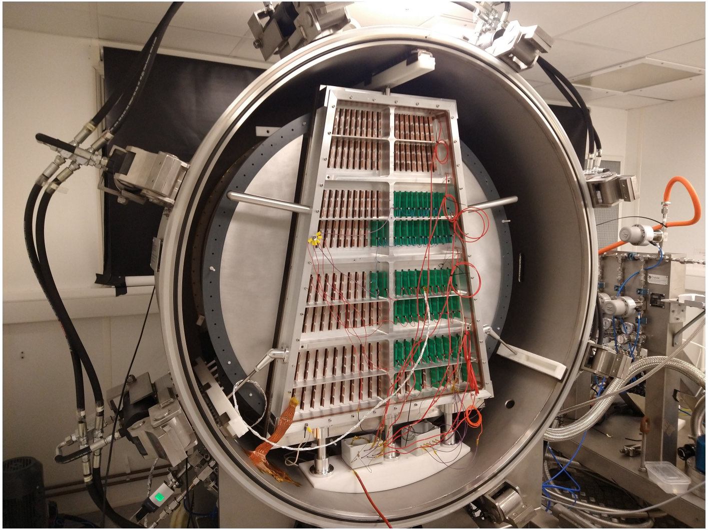


Points from an $\mathrm{Ar}\text{-}\mathrm{CO}_2$ (90-10) simulation at $P = 750\,\mathrm{Torr}$ with no Penning effect enabled. The line *Fit:* ... is the result of a fit following Eq. (3) to the simulation. The second line (*Meas.:* ...) shows a parametrisation which has been fit to data measured with an OROC in the same mixture at atmospheric pressure.

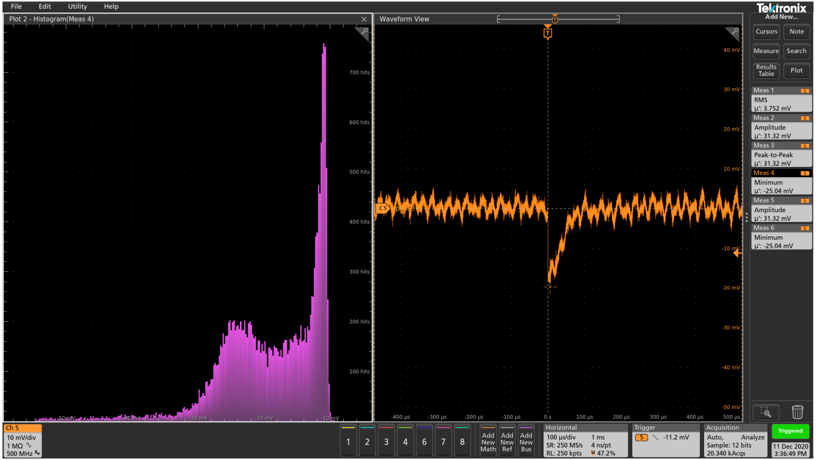
Simulation summary

- The χ^2/N_{dof} is not outrageously good for the fit to the simulation: 57.97/12.
- The slopes match in 10 % for the measurement and the simulation, the normalisation differs by $\sim$15.
- For an actual OROC simulation, the gain is expected to be lower, making the simulation move closer to the measurement data.
- On the other hand: There may have been issues with the gas quality. So a measurement with more pure $\mathrm{Ar\text{-}CO_2}$ (90-10) may yield a higher gain. (And an $\mathrm{Ar\text{-}CO_2}$ (90-10) where we have a high confidence in the mixing ratio.)
- Simulations by our QMUL collaborators as well as measurements in the HPTPC will tackle both ends of the problems with the current comparison.
- Our Fermilab colleagues will provide their gain curve, so we can add it to the plot and have an IROC to IROC comparison

OROC installed in HPTPC vessel



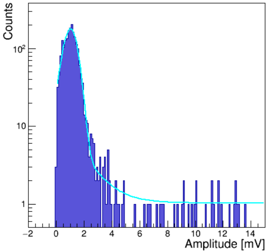
OROC in HPTPC vessel, first waveforms



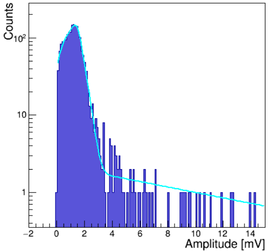
Extra Slides

Amplitude spectra, Fe55, cathode -4936 V, gating grid -120 V

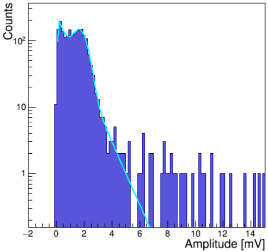
Anode 1600 V



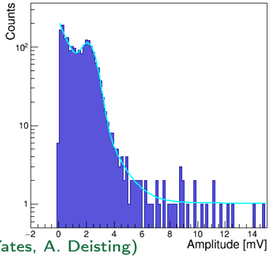
Anode 1625 V



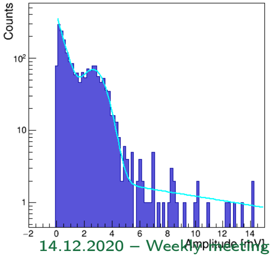
Anode 1650 V



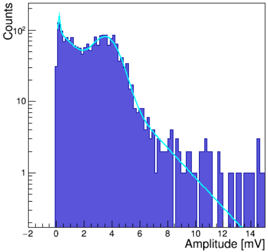
Anode 1675 V



Anode 1700 V

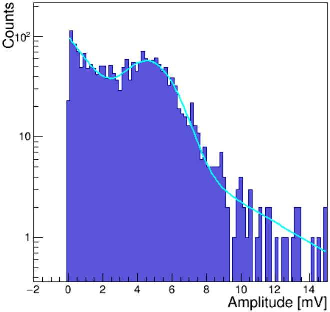


Anode 1725 V



Amplitude spectra, Fe55, cathode -4936 V, gating grid -120 V

Anode 1750 V



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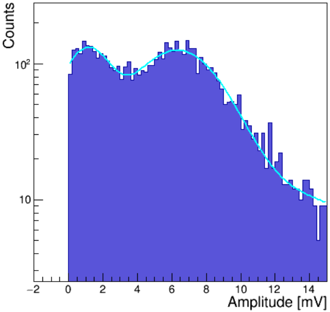
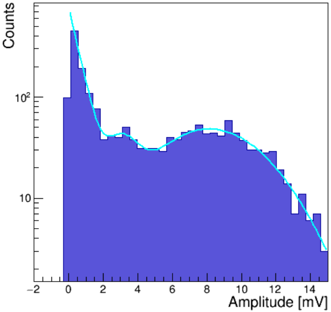
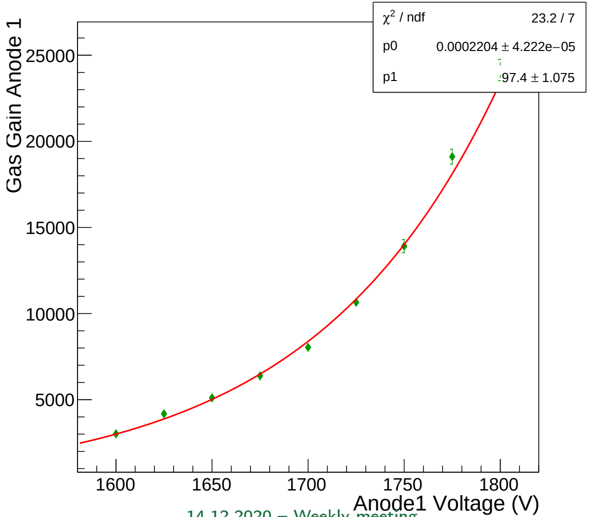


Anode 1800 V

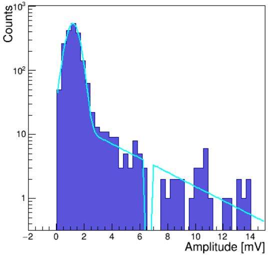


Gain vs voltage, Ar/CO2 90%/10%, Fe55 source, cathode -4936 V, gating grid -120 V



Amplitude spectra, Fe55, cathode -4936 V, gating grid -120 V

Anode 1600 V



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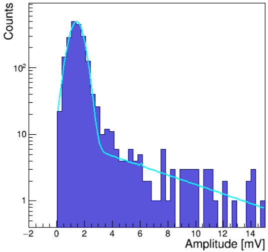
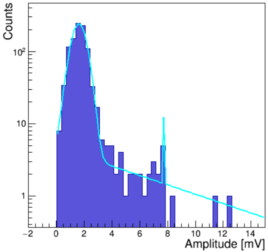


Anode 1650 V



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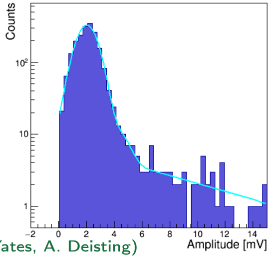
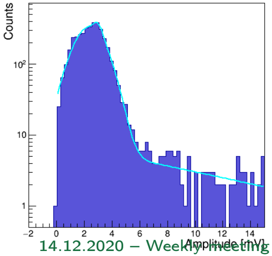
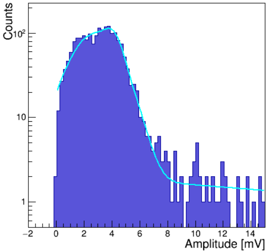


Anode 1700 V



Anode 1725 V



Amplitude spectra, Fe55, cathode -4936 V, gating grid -120 V

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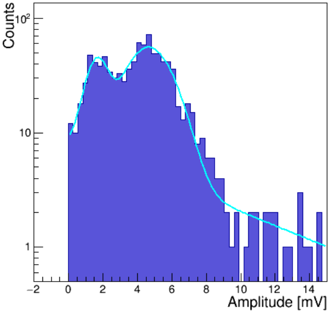

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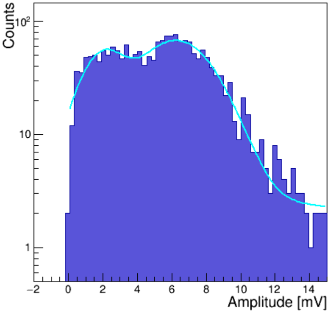
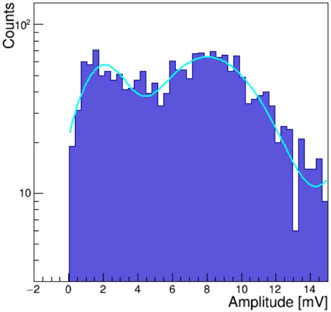
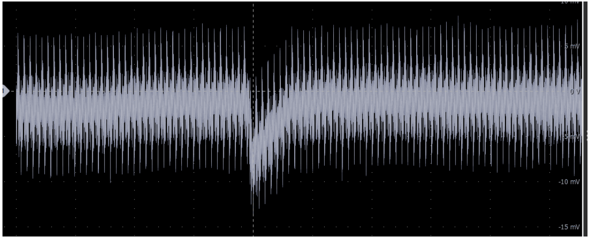
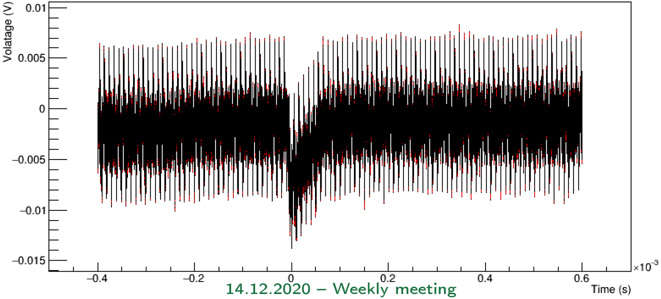


Anode 1800 V



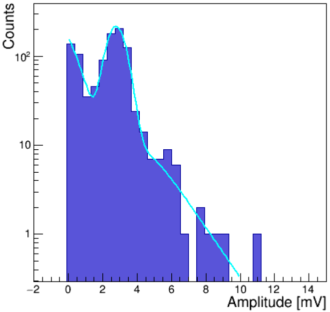
Signal with Fe55, as seen on the oscilloscope and as a root file



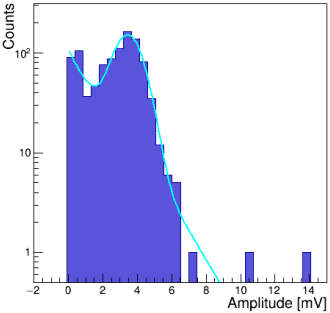


Amplitude spectra, Fe55, cathode -4936 V, gating grid -120 V

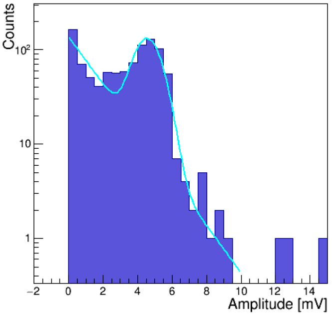
Anode 1650 V



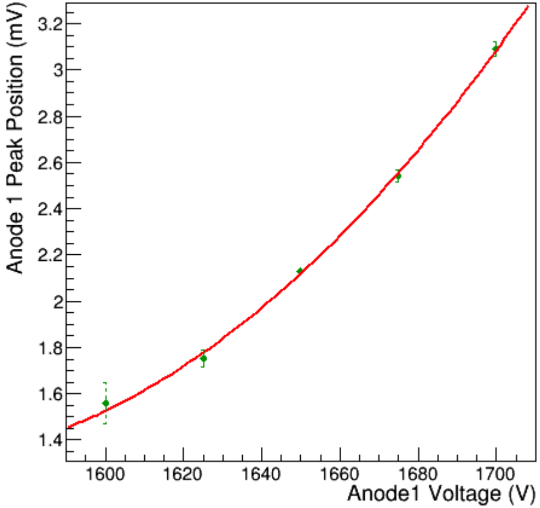
Anode 1675 V



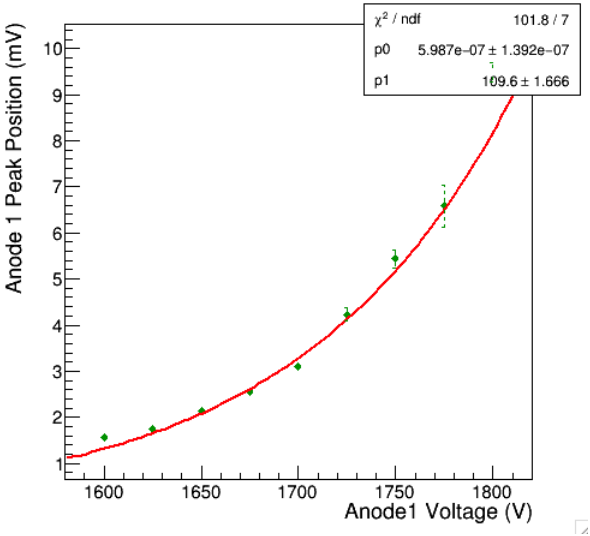
Anode 1700 V



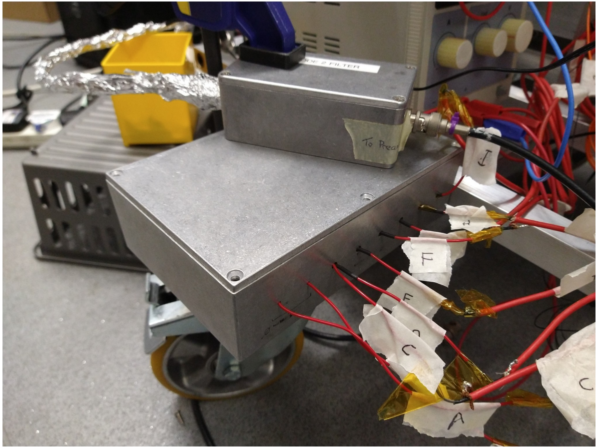
Peak position vs voltage, Fe55, cathode -4936 V, gating grid -120 V

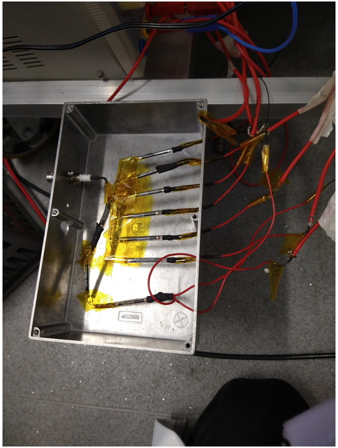


Peak position vs voltage, Fe55, cathode -4936 V, gating grid -120 V

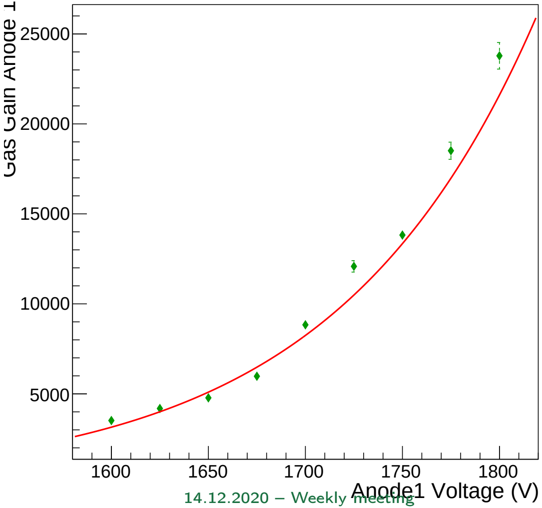


Anode distribution box pressure test

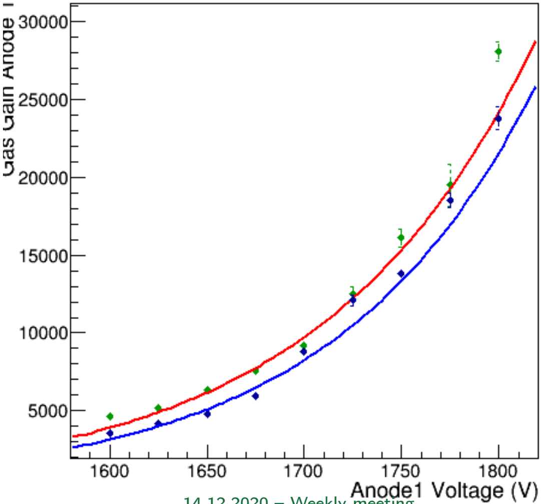




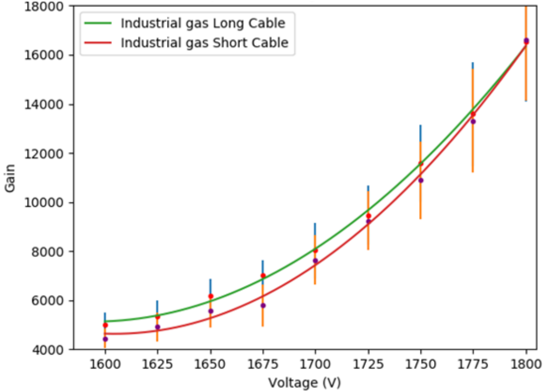
Peak position vs voltage, Fe55, cathode -4936 V, gating grid -120 V, using lower grade Ar/CO2 mix



Peak position vs voltage, Fe55, cathode -4936 V, gating grid -120 V, using lower grade Ar/CO2 mix

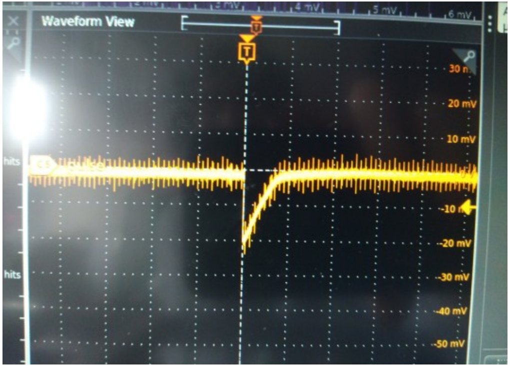


Peak position vs voltage, Fe55, cathode -4936 V, gating grid -120 V, using longer signal cable

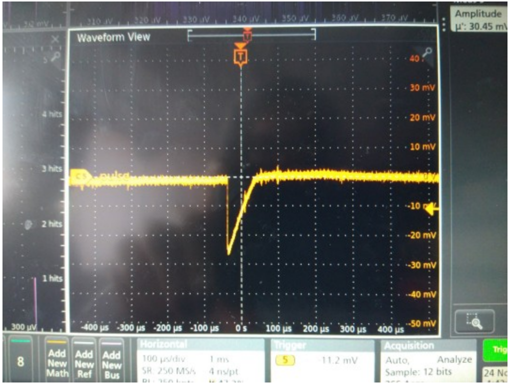


Comparison of noise with signal through feedthrough

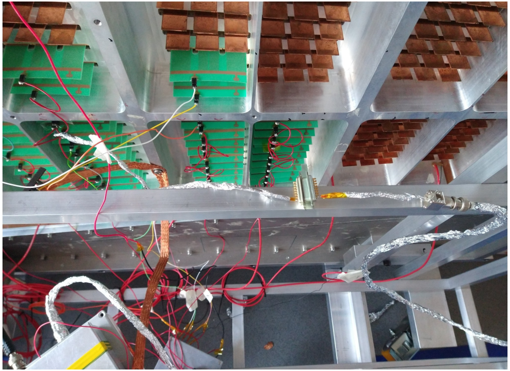
Without feedthrough

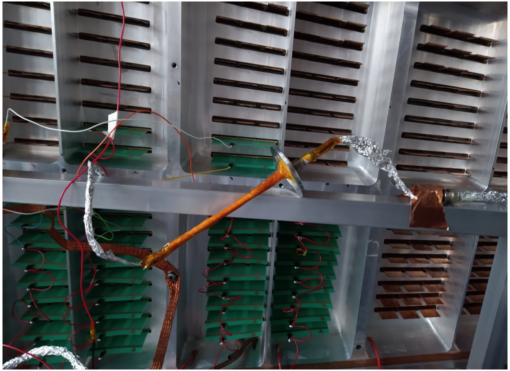


With dsub connector



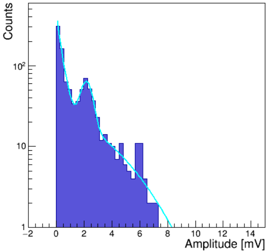
Reading out only 1 card via an HPTPC preamp



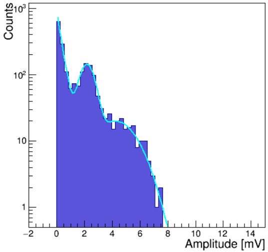


Amplitude spectra, Fe55, cathode -4936 V, gating grid -120 V

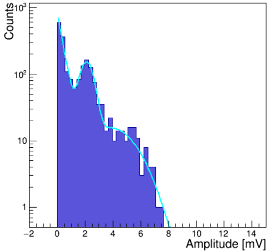
Anode 1600 V



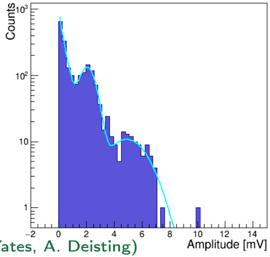
Anode 1625 V



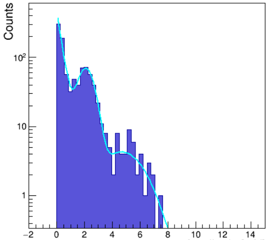
Anode 1650 V



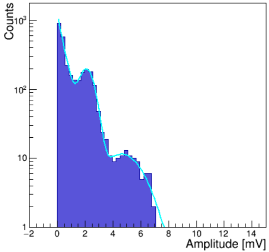
Anode 1675 V



Anode 1700 V

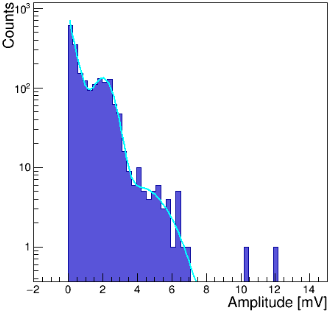


Anode 1725 V

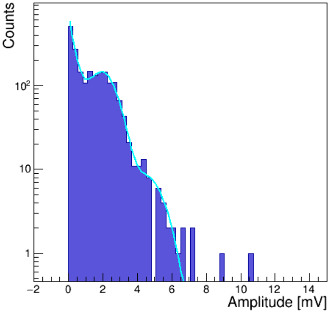


Amplitude spectra, Fe55, cathode -4936 V, gating grid -120 V

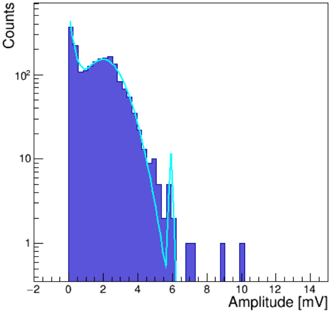
Anode 1750 V



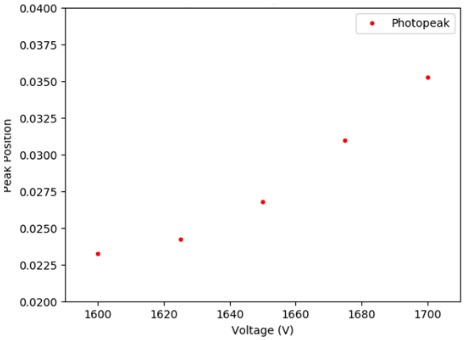
Anode 1775 V

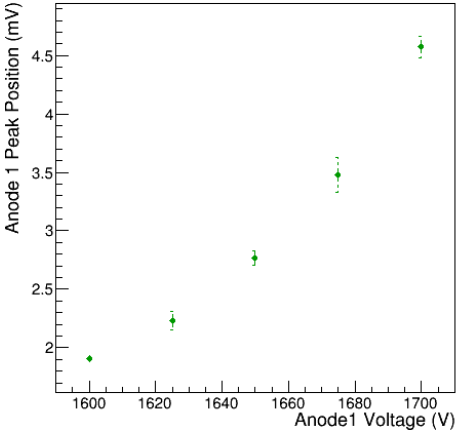


Anode 1800 V



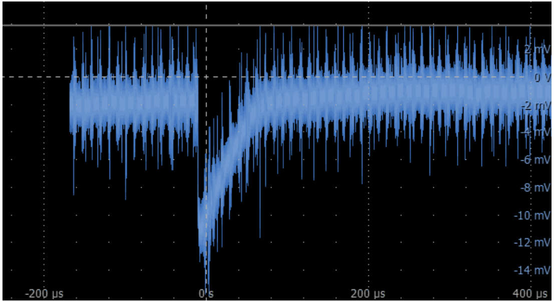
Comparing histograms made by oscilloscope and saved waveforms

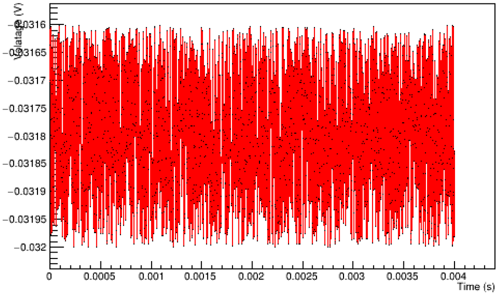




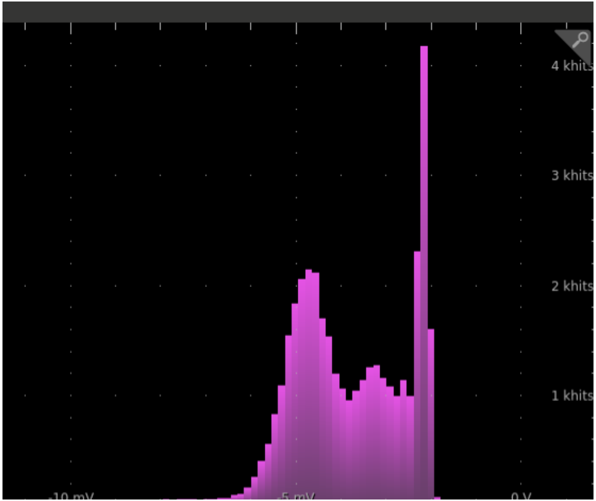
Signal with Fe55, cathode voltage -4936 V, anode 1700 V, grids -120 V

Issue with reading waveforms has been resolved

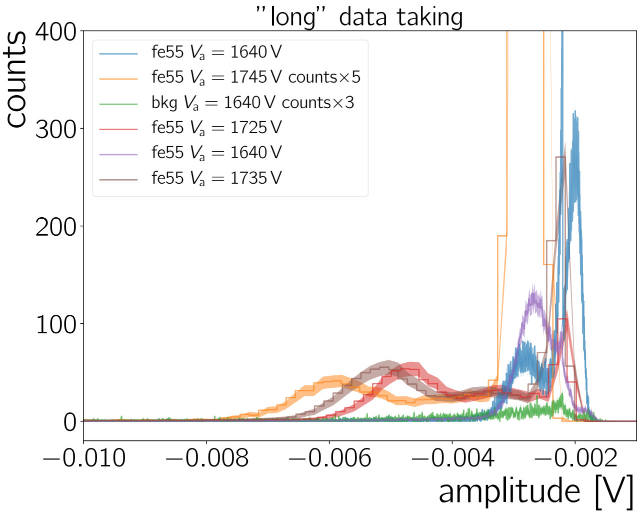




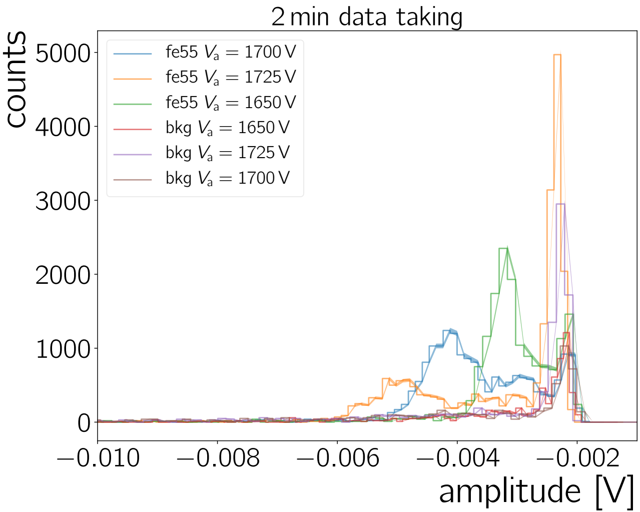
Amplitude spectrum with Fe55, cat -5000 V, an 1725 V, grid -90 V



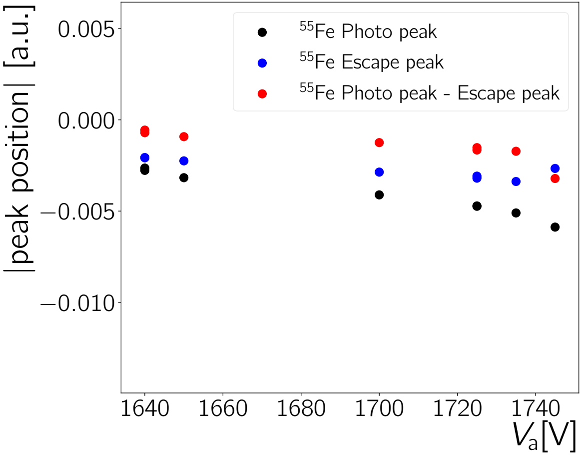
Amplitude Spectra with Fe55



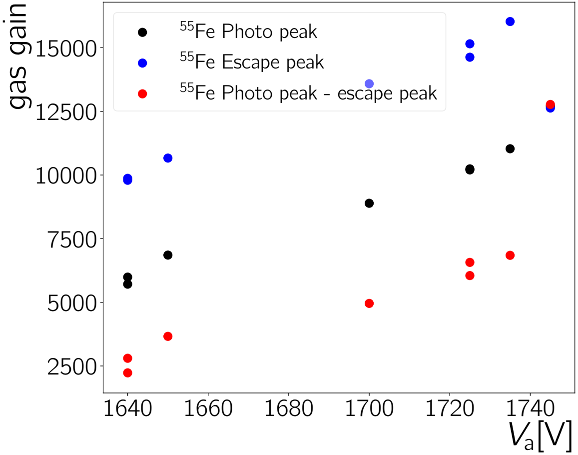
Amplitude Spectra with Fe55



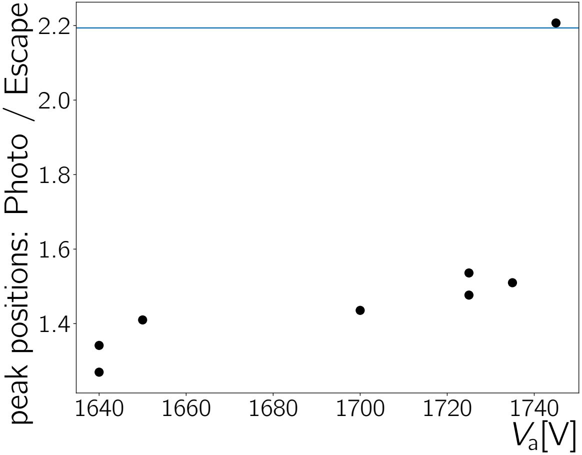
Peak position vs voltage with Fe55



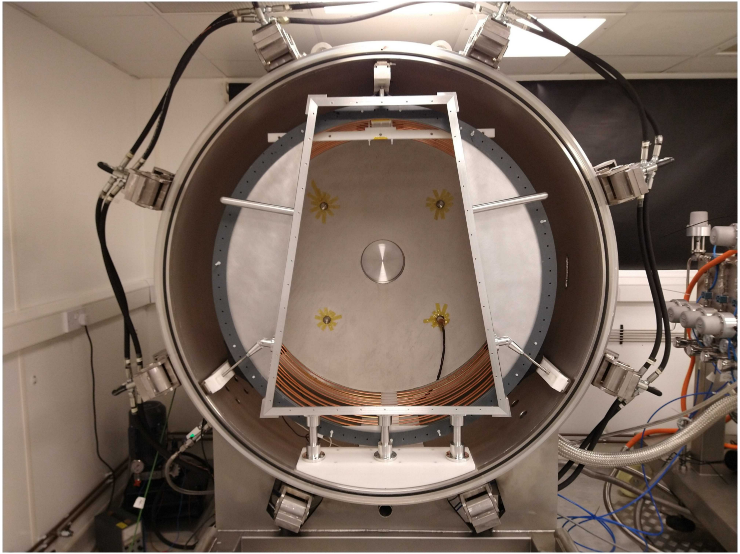
Gain vs voltage with Fe55



Ratio of photo peak to escape peak position



Current configuration inside the vessel



Hardware update, evacuated to 2.16e-6 barA, rate of rise improvement

Environmental data

Item	Value
Chamber pressure Manometer (BarG)	-0.30
Chamber pressure Pirani (BarA)	2.16e-06
Chamber pressure Chrono (BarA)	1.04
Ambient temperature (C)	16

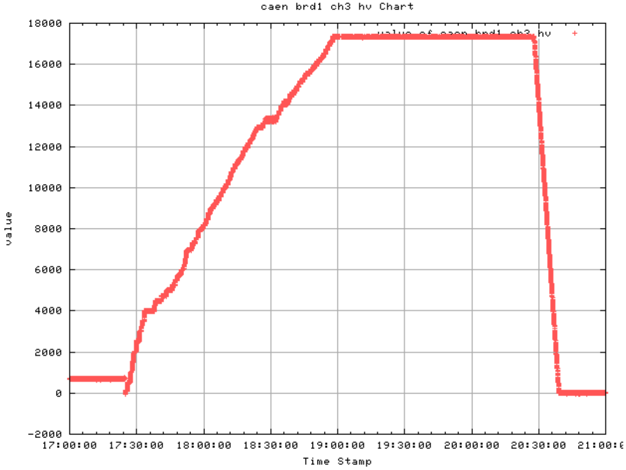
```
Pressure rise in bar per second: 5.22E-10
And in Torr l per second (assuming 850l): 3.33E-04
```

Hardware update, tested cathode to 17.4 kV with no issues

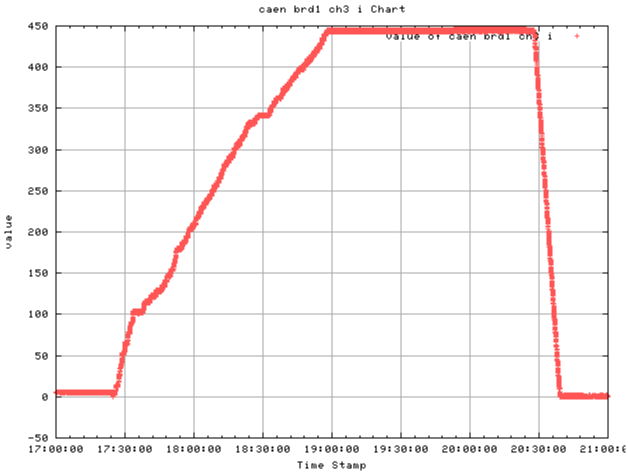
Control voltages

Item	Voltage [V]	Current [uA]	Set voltage [V]	Status
Anode 1	0.0	0.00	0.0	**DIS**
Anode 2	0.0	0.00	0.0	**DIS**
Anode 3	0.0	0.00	0.0	**DIS**
Cathode	17323.9	442.74	17400.0	**ON**

Hardware update, tested cathode to 17.4 kV with no issues



Hardware update, tested cathode to 17.4 kV with no issues



Drift voltage

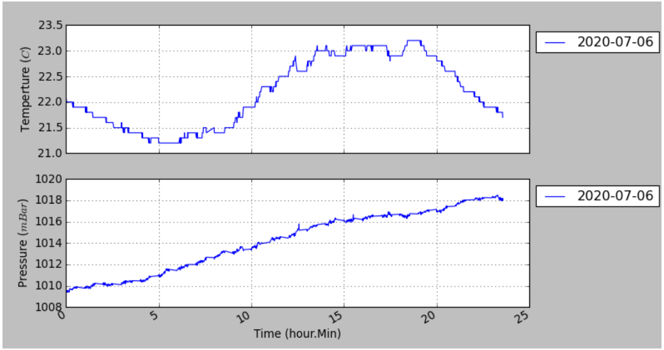
Alice E/p		Pressure (barA)	1	2	3	4	5	
400 V/cm								
		E/p	400 V/cm					
Drift region length	in mm	V/mm	40	80	120	160	200	V/mm
12 rings	435.6	Voltage	17424	34848	52272	69696	87120	V
8 rings	294.4	Voltage	11776	23552	35328	47104	58880	V
4 rings	153.2	Voltage	6128	12256	18384	24512	30640	V

HPTPC E/p		Pressure (barA)	1	2	3	4	5	
200 V/cm								
		E/p	200 V/cm					
Drift region length	in mm	V/mm	20	40	60	80	100	V/mm
12 rings	435.6	Voltage	8712	17424	26136	34848	43560	V
8 rings	294.4	Voltage	5888	11776	17664	23552	29440	V
4 rings	153.2	Voltage	3064	6128	9192	12256	15320	V

Drift voltage

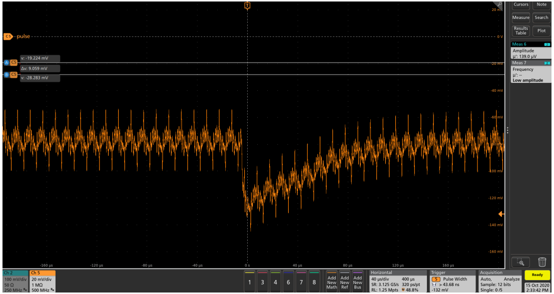
Lower E/p		Pressure (barA)	1	2	3	4	5	
100 V/cm								
		E/p	100 V/cm					
Drift region length	in mm	V/mm	10	20	30	40	50	V/mm
12 rings	435.6	Voltage	4356	8712	13068	17424	21780	V
8 rings	294.4	Voltage	2944	5888	8832	11776	14720	V
4 rings	153.2	Voltage	1532	3064	4596	6128	7660	V

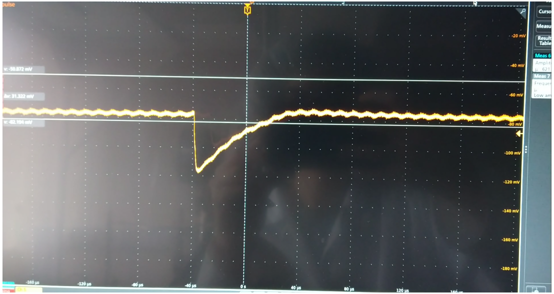
Pressure Monitoring (6th of July



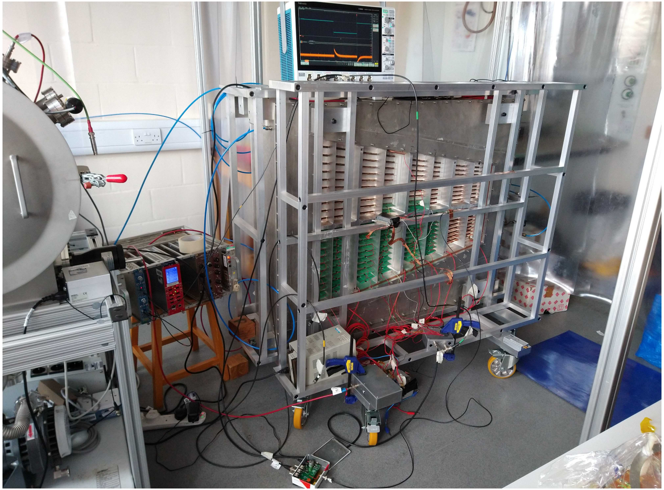
Signal with Cs137, cathode voltage -5000 V, anode 1750 V, grids -70 V

Similar amplitude signals from data with Cs137, before and after efforts to reduce noise

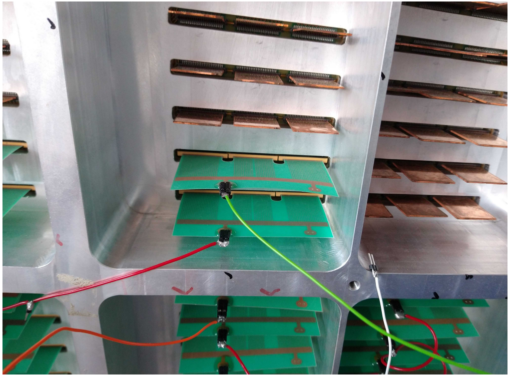




OROC test box setup



Reading out only 1 card via an HPTPC preamp



Signals with injected pulses look as expected

Other simulation settings:

parameter	value
anode voltage V_a [V]	1460
gating grid voltage V_{gg} [V]	-70
ΔV_{gg} [V]	90
temperature T [K]	293.1

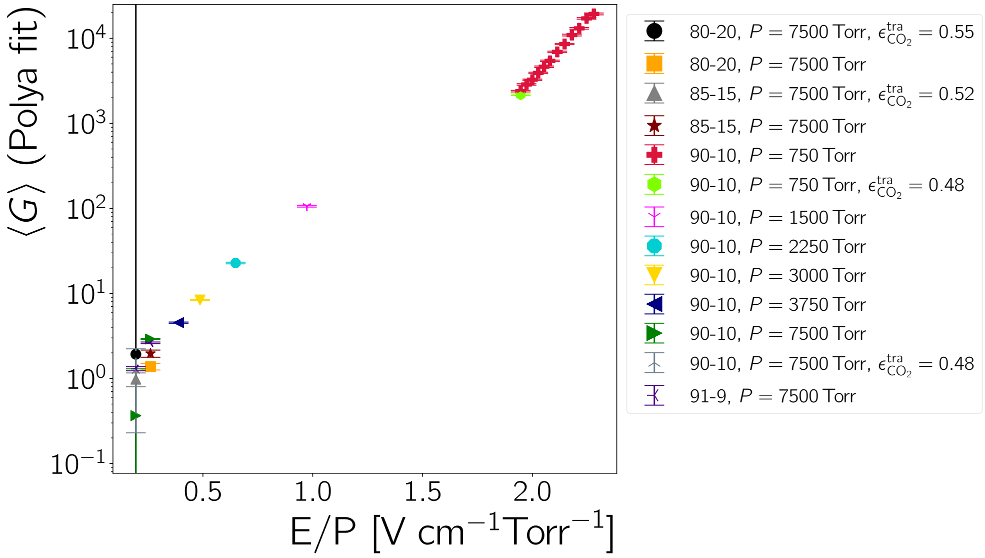
Table: Parameters which do not change from simulation to simulation. The readout chamber geometry corresponds to the geometry of an ALICE IROC.

mixture	P [Torr]	V_a [V]	Penning gas	Penning coef.	mobility data	ID
Ar-CO_2 (90-10)	750	1460	n.a.	n.a.	file I	ARCO2_4
Ar-CO_2 (90-10)	750	1480	n.a.	n.a.	file I	ARCO2_6
Ar-CO_2 (90-10)	750	1500	n.a.	n.a.	file I	ARCO2_7
Ar-CO_2 (90-10)	750	1520	n.a.	n.a.	file I	ARCO2_8
Ar-CO_2 (90-10)	750	1540	n.a.	n.a.	file I	ARCO2_9
Ar-CO_2 (90-10)	750	1560	n.a.	n.a.	file I	ARCO2_10
Ar-CO_2 (90-10)	750	1585	n.a.	n.a.	file I	ARCO2_11
Ar-CO_2 (90-10)	750	1610	n.a.	n.a.	file I	ARCO2_12
Ar-CO_2 (90-10)	750	1635	n.a.	n.a.	file I	ARCO2_13
Ar-CO_2 (90-10)	750	1660	n.a.	n.a.	file I	ARCO2_14
Ar-CO_2 (90-10)	750	1685	n.a.	n.a.	file I	ARCO2_15
Ar-CO_2 (90-10)	750	1710	n.a.	n.a.	file I	ARCO2_16

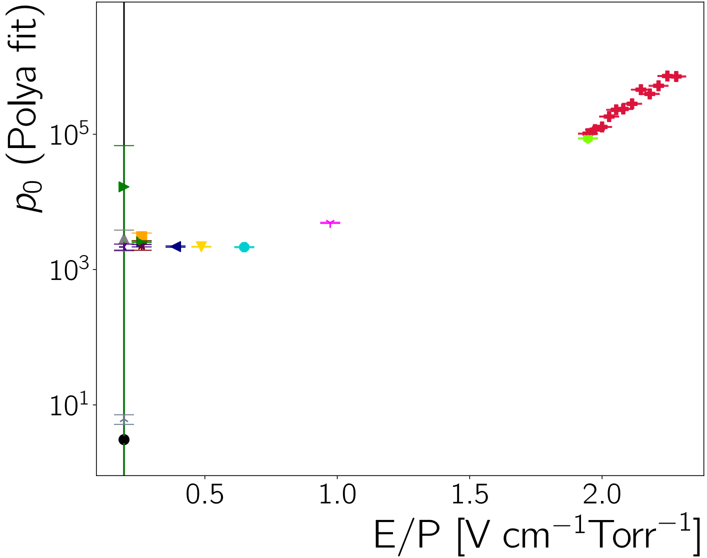
Table: Simulation settings for the simulation results shown in this talk: We list the gas mixture, pressures (P), anode voltage V_a, information about the Penning effect (*n.a.* Penning effect disabled, when the Penning effect was enabled the gas and the transfer efficiency for said gas is stated) and which ion mobility file has been used.

ID	mixture	$\langle G \rangle$	σ_G	p_0	χ^2/N_{dof}
ARCO2_4	90-10	2391.72 ± 49.11	1957.36 ± 54.61	102139.91 ± 1665.77	218.82/352
ARCO2_6	90-10	2867.05 ± 57.76	2362.71 ± 64.32	117277.88 ± 1859.53	268.77/354
ARCO2_7	90-10	3260.67 ± 58.69	2654.51 ± 65.13	128272.56 ± 1846.35	180.71/351
ARCO2_8	90-10	3914.65 ± 74.46	3162.15 ± 82.56	182730.52 ± 2808.38	210.35/354
ARCO2_9	90-10	4634.98 ± 94.95	3778.51 ± 105.62	229898.56 ± 3759.74	254.45/353
ARCO2_10	90-10	5428.15 ± 111.06	4520.69 ± 124.21	236668.88 ± 3759.25	205.49/352
ARCO2_11	90-10	6922.95 ± 138.39	5655.93 ± 153.77	282227.64 ± 4491.15	250.53/352
ARCO2_12	90-10	8570.85 ± 140.33	7068.38 ± 156.81	456458.98 ± 5876.61	188.22/352
ARCO2_13	90-10	10922.39 ± 260.04	9090.21 ± 290.19	394984.21 ± 7307.29	300.15/354
ARCO2_14	90-10	13100.28 ± 288.44	11161.43 ± 324.71	520867.27 ± 8642.97	230.02/351
ARCO2_15	90-10	17152.58 ± 359.45	14554.38 ± 404.46	726231.29 ± 11529.87	205.15/348
ARCO2_16	90-10	19359.01 ± 480.34	16037.52 ± 536.35	714389.28 ± 13856.16	234.70/302

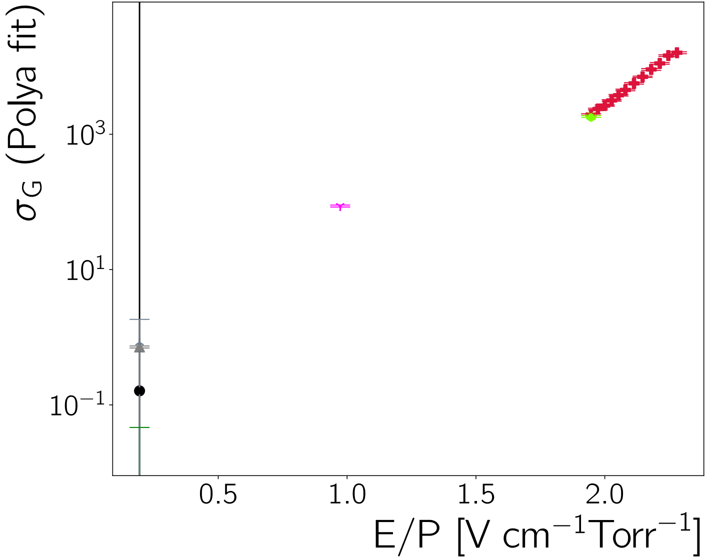
Table: Fit results of a Polya fit, *i.e* Equation (1) to the simulated data.



$\langle G \rangle$ (Polya fit)
10^4
10^3
10^2
10^1
10^0
10^{-1}
0.5
1.0
1.5
2.0
E/P [V cm^{-1}Torr^{-1}]
80-20, $P = 7500$ Torr, $\epsilon_{CO_2}^{tra} = 0.55$
80-20, $P = 7500$ Torr
85-15, $P = 7500$ Torr, $\epsilon_{CO_2}^{tra} = 0.52$
85-15, $P = 7500$ Torr
90-10, $P = 750$ Torr
90-10, $P = 750$ Torr, $\epsilon_{CO_2}^{tra} = 0.48$
90-10, $P = 1500$ Torr
90-10, $P = 2250$ Torr
90-10, $P = 3000$ Torr
90-10, $P = 3750$ Torr
90-10, $P = 7500$ Torr
90-10, $P = 7500$ Torr, $\epsilon_{CO_2}^{tra} = 0.48$
91-9, $P = 7500$ Torr

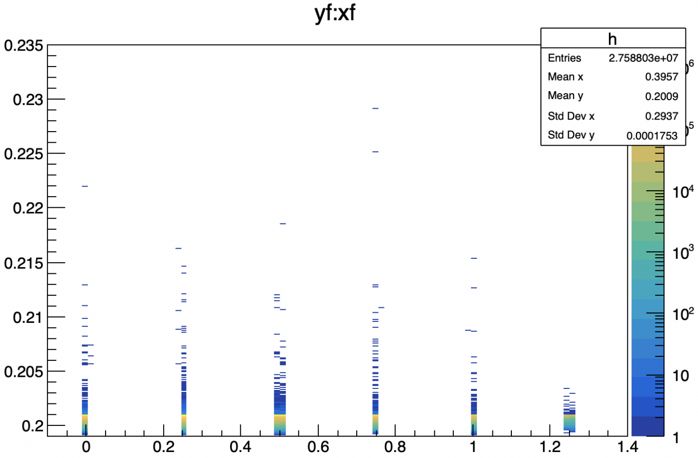


p_0 (Polya fit)
10^5
10^3
10^1
0.5
1.0
1.5
2.0
E/P [V cm^{-1}Torr^{-1}]

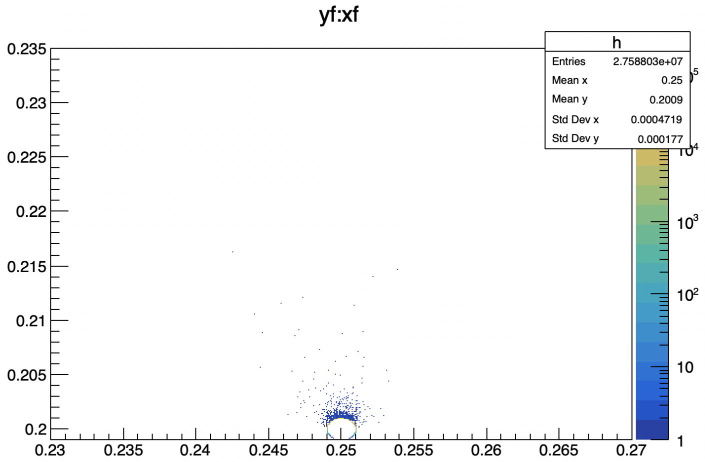


σ_G (Polya fit)
10^3
10^1
10^{-1}
0.5
1.0
1.5
2.0
E/P [V cm^{-1}Torr^{-1}]

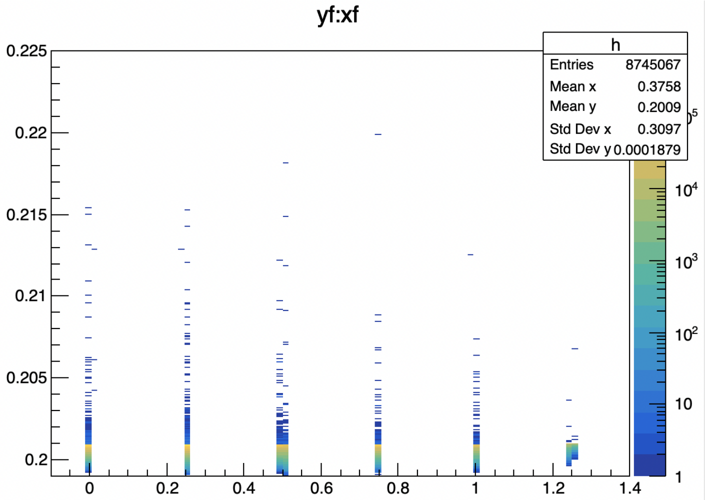
Where do the electrons go? ($V_a = 1660\,\mathrm{V}$)



Where do the electrons go? ($V_a = 1660\,\mathrm{V}$)



Where do the electrons go? ($V_a = 1520\,\mathrm{V}$)



Where do the electrons go? ($V_a = 1520\,\mathrm{V}$)