Discharge studies with single GEMs

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7th of June, 2016

Outline

This talk is a continuation of the results presented by Piotr during the last RD51 mini week

Reminder:

- GEM biasing in the future ALICE TPC
- Set-up of the discharge propagation measurements
- First study: Influence of the powering scheme on the occurrence of discharges

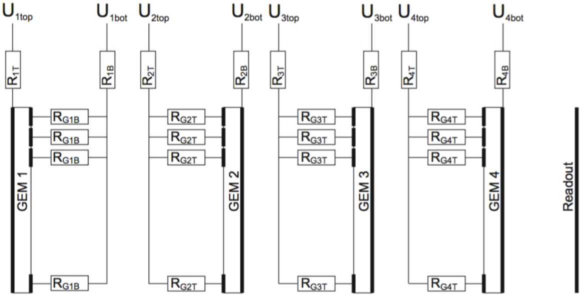
New Measurements:

- Different gas mixtures

Further studies with the standard powering scheme:

- GEM bottom at GND potential
- Different induction gap length and different drift length
- Studies with a large pitch foil

Former biasing scheme of GEMs (ALICE)



- Sectorised sides: Powered with loading resistors
- GEM2 to GEM4: Sectorised side faces the drift cathode (To avoid spark propagation)
- GEM1: Non subdivided side faces the drift cathode
  - → Minimise distortions in case of a short
  - → Cover electrode functionality
- GEM1 setting was changed due to the outcome of this discharge studies

Question: How do the different GEM settings (GEM1 vs GEM2 to GEM4) compare in terms of discharge propagation?

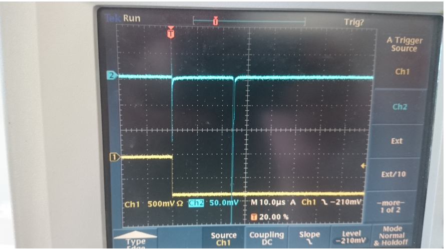
Set-ups in Munich and CERN – 1/2

The studies presented here were done in Munich and at CERN, with almost similar settings:

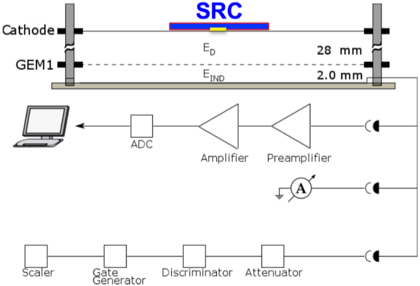
	Munich	CERN
α-Sources	Pu, Am, CM (570 Hz) mounted in the cathode PCB Rn (15 Hz) in the detector volume	 Rn (14 Hz)
Gas:	$Ar-CO_2$ (90-10) (70-30) $Ne-CO_2$ (90-10) $Ne-CO_2-N_2$ (90-10-5)	$Ar-CO_2$ (90-10)
H_2-O / O_2 (@ 10 L h^{-1})	0.02 ppmV/10 ppm	160 ppmV/?
d_{drift}	29.5 mm, 39.5 mm	26.7 mm, 13.9 mm

In both cases standard GEMs with a distance of 2 mm to a readout plane were studied. (At CERN additional studies for different drift lengths, induction gap and a large pitch foil have been made.)

Set-ups in Munich and CERN – 2/2

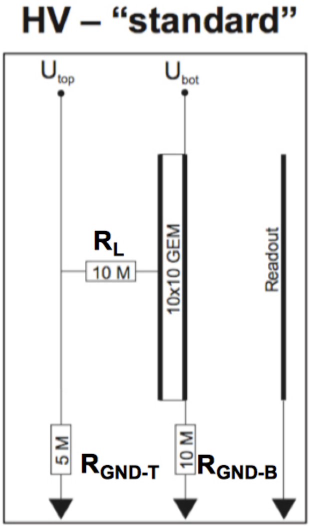


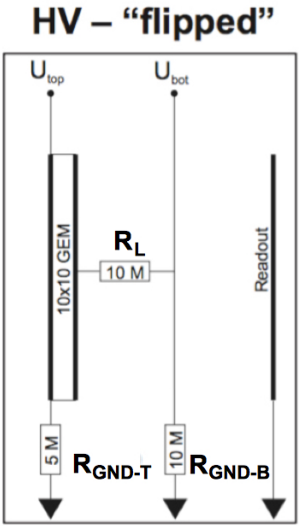
- Signal from the readout plane
  - → First: A bipolar primary discharge
  - → Second: An unipolar secondary discharge
- Gate signal



- Signals are counted by NIM logic with corresponding discriminators (Thresholds are tuned based on the scope signals)
- To avoid counting the secondary discharge as a primary one, a gate is used
- Discharge signals are recorded for further analysis

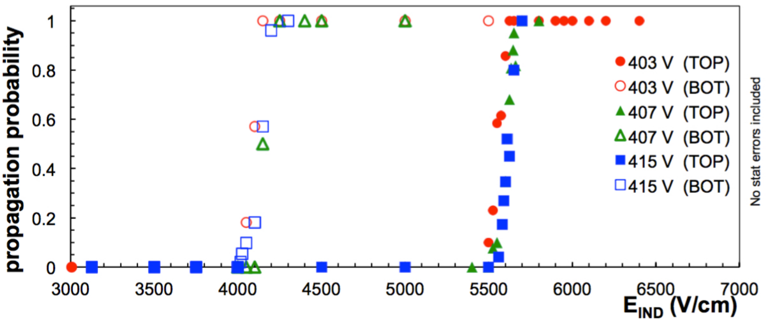
Standard vs Flipped





Flipped- vs Standard-configuration

Ar-CO_2 (90-10), R_L = 10 MΩ, INDEP. HV, $R_{GND-T/B}$ = 5/10 MΩ



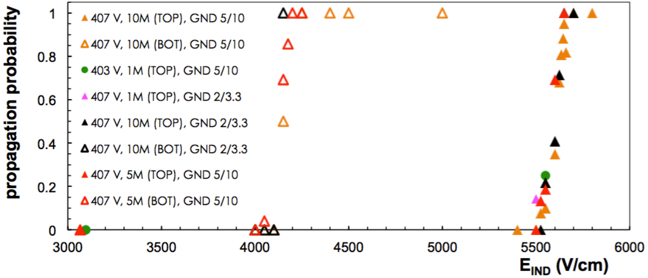
Top: Standard-config.

Bot: Flipped-config.

- Drift distance: 29.5 mm
- ΔV_{GEM} range may be to small to see an effect

- Standard-configuration: Onset of secondary discharges @ $\sim 5.5\,\mathrm{kV\,cm^{-1}}$
- Flipped-configuration: Onset of secondary discharges @ $\sim 4\,\mathrm{kV\,cm^{-1}}$
- No dependence on ΔV_{GEM} visible

Further studies: Different resistors



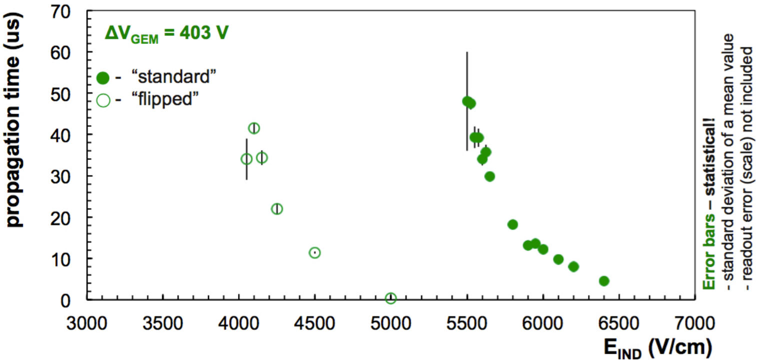
Top: Standard-config.

Bot: Flipped-config.

- Drift distance: 29.5 mm
- $R_{\mathrm{L}}/R_{\mathrm{GND\text{-}B}}/R_{\mathrm{GND\text{-}T}}$

- Same onset fields observed as in the previous measurements
- No significant change with different resistors was found $\rightarrow$ Resistors only influence the loading behaviour of the GEM, but not the energy stored in the GEM and hence not the discharge probability
- Adding capacitances (to simulate long cables) doesn't change the picture
- Powering the GEM with a resistor chain yields an higher onset field in case of the Standard configuration

Last reminder: Propagation time



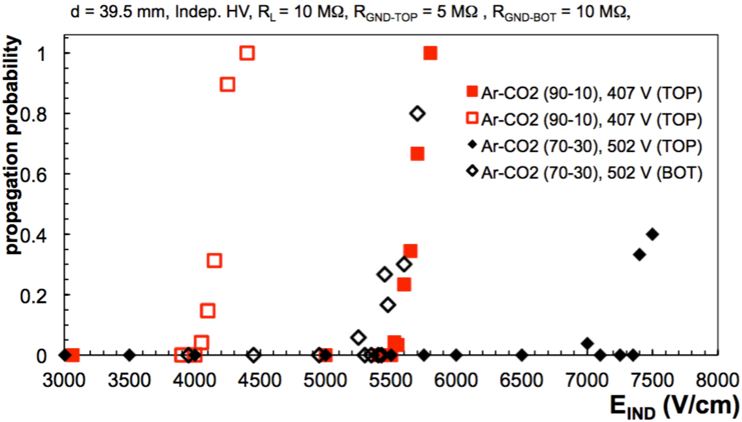
- Dependence on the induction field well visible

Discharges in different gas mixtures

Still: Standard- vs Flipped-configuration

Measurements shown so far: Ar-CO_2 *(90-10)*

Ar-CO_2 (70-30)



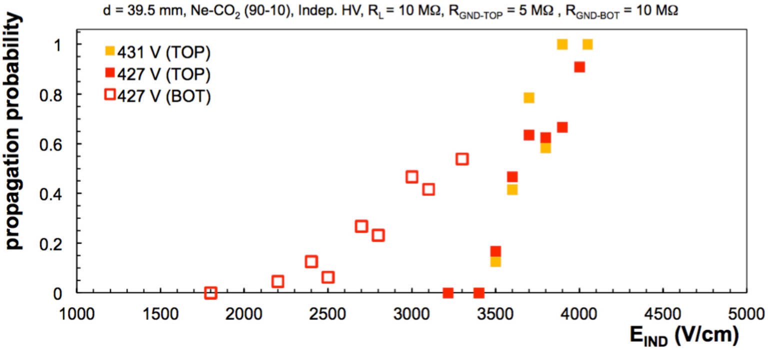
Top: Standard-config.

Bot: Flipped-config.

- 100 V more across the GEM
- Less steep curves

- Later onset of the secondary discharges (Standard-config: $\sim 7\,\mathrm{kV\,cm^{-1}}$, flipped-config: $\sim 5.3\,\mathrm{kV\,cm^{-1}}$)

Ne-CO_2 (90-10)

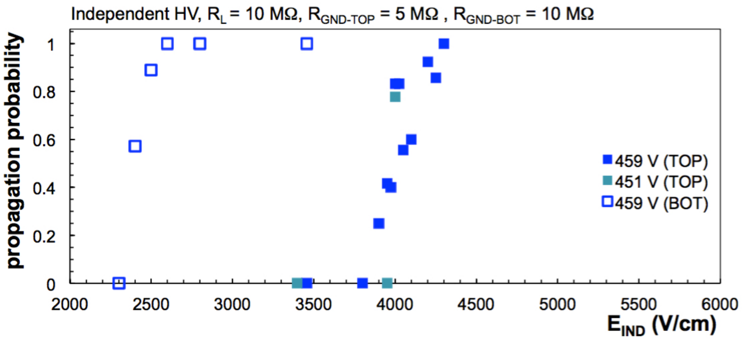


Top: Standard-config.

Bot: Flipped-config.

- Earlier onset of the secondary discharges (Standard-config: $\sim 3.4\,\mathrm{kV\,cm^{-1}}$, flipped-config: $\sim 2\,\mathrm{kV\,cm^{-1}}$)
- Far less steep curves

$Ne\text{-}CO_2\text{-}N_2$ (90-10-5)



Top: Standard-config.

Bot: Flipped-config.

- Earlier onset of the secondary discharges (Standard-config: $\sim 3.8\,\mathrm{kV\,cm^{-1}}$, flipped-config: $\sim 2.4\,\mathrm{kV\,cm^{-1}}$)

Summary so far: – 1/2

	Ar-CO_2 (90-10)	Ne-CO_2-N_2 (90-10-5)	Ne-CO_2 (90-10)	Ar-CO_2 (70-30)
SF (%)	101-104	115	107	126
ΔV_{GEM} (V)	403-415	459	427	502
GAIN (with E_{IND} = 3 kV/cm)	200-300	610	690	415
P(spark)	10^{-4}	10^{-4}	10^{-4}	10^{-4}
Propagation onset "standard"	5.5 kV/cm	3.8 kV/cm	3.4 kV/cm	7 kV/cm
Propagation onset "flipped"	4 kV/cm	2.4 kV/cm	2 kV/cm	5.3 kV/cm
Propagation slope	|	/	/	/
Signal (1st/2nd)	0.3/2.8 V	0.4/1.2 V	0.75/0.6 V	0.4/4 V
d_{source} (mm)	29.5	39.5 mm	39.5 mm	39.5 mm

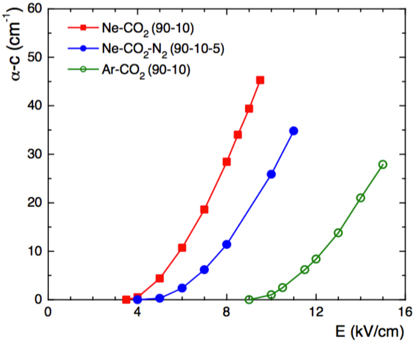
Footnote:

- Discharge probabilities in Ar-CO_2 (90-10) at 38.5 mm drift length differs not from the shorter value

Summary so far: – 2/2

- Lower onset of secondary discharges for the 'flipped' setting
- The onset filed strength follows qualitatively the first Townsend coefficient – but starts at far lower values
- No simple dependence of the onset on ΔV_{GEM}, the resistors and the capacitance found
- Different behaviour of the onset while the GEM was powered with a resistor chain, suggests a dependence on the HV supply

– First Townsend coefficient –



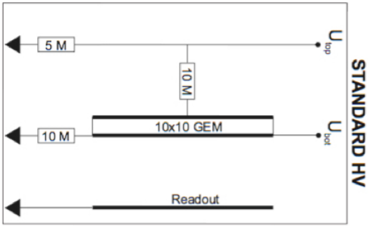
Further studies with the standard configuration

1. Question: Does the potential change of the bottom GEM side during the primary discharge trigger the secondary discharge?

Standard HV supply vs $V_{\mathrm{GEMB}} = \mathrm{GND}$ – Settings:

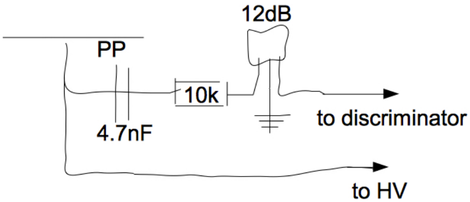
Standard

- See picture
- Discharges go after attenuation with a 12 dB attenuator and a 10 kΩ resistor (or 10 MΩ) to the discriminator/scope



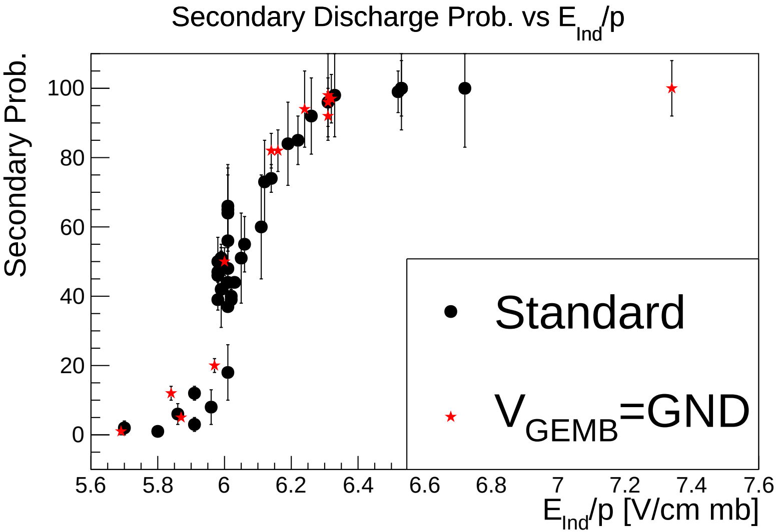
$V_{\mathrm{GEMB}} = \mathrm{GND}$

- Lower side of the GEM grounded
- Readout plane on HV
- Decoupling of the signal via a 4.4 nF capacitor, further readout as the standard readout



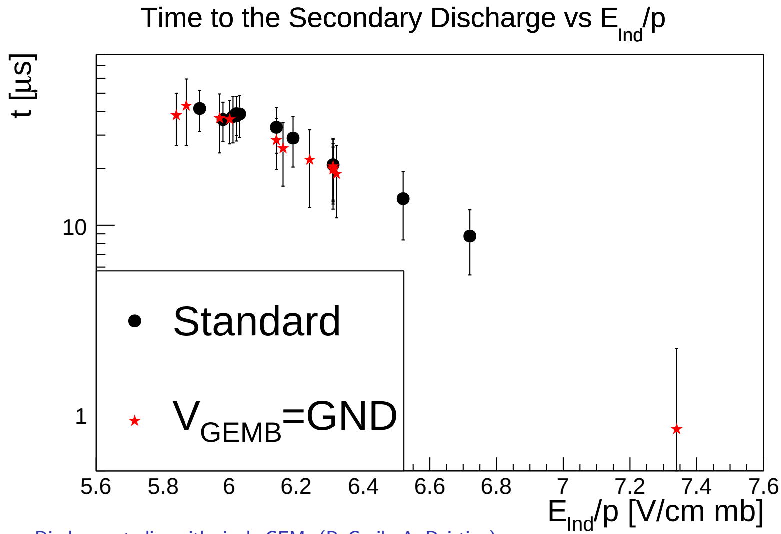
The following: Measurements with a standard GEM in $\mathrm{Ar}\text{-}\mathrm{CO}_2$ (90-10) with an induction gap of 2 mm and a drift distance of 26.7 mm.

Secondary discharge probability



- The standard HV settings and the $V_{\mathrm{GEMB}} = \mathrm{GND}$ show the same steep onset as seen before
- There is no difference visible between the two settings
- The onset is at a higher voltage as compared to previous results

Time between discharges



- The time between discharges for both settings shows the same trend
- The trend is as expected from previous measurements

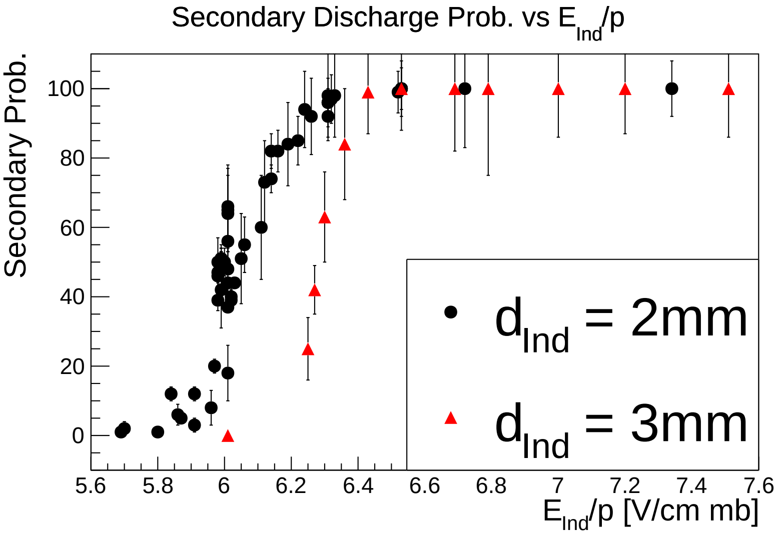
⇒ Comparing standard- and GND-HV settings: No differences visible

⇒ However differences between standard GEMs visible as compared to Munich

Further studies with the standard configuration

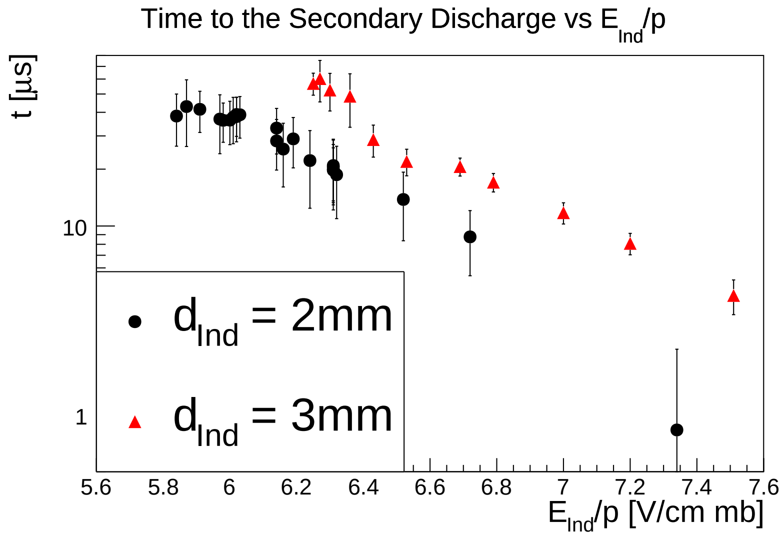
2. Question: How does the length of the induction gap influence the discharge behaviour?

Secondary discharge probability



- $d_{\mathrm{Ind}} = 2\,\mathrm{mm}$: All previous points are shown
- $d_{\mathrm{Ind}} = 3\,\mathrm{mm}$: Only the $V_{\mathrm{GEMB}} = \mathrm{GND}$ setting was measured
- The onset of the secondary discharges moves to higher fields
- This change is smaller as the difference in the CERN and Munich results for $d_{\mathrm{Ind}} = 2\,\mathrm{mm}$

Time between discharges



- The measured points for $d_{\text{Ind}} = 3\,\text{mm}$ move as expected from the secondary discharge probability

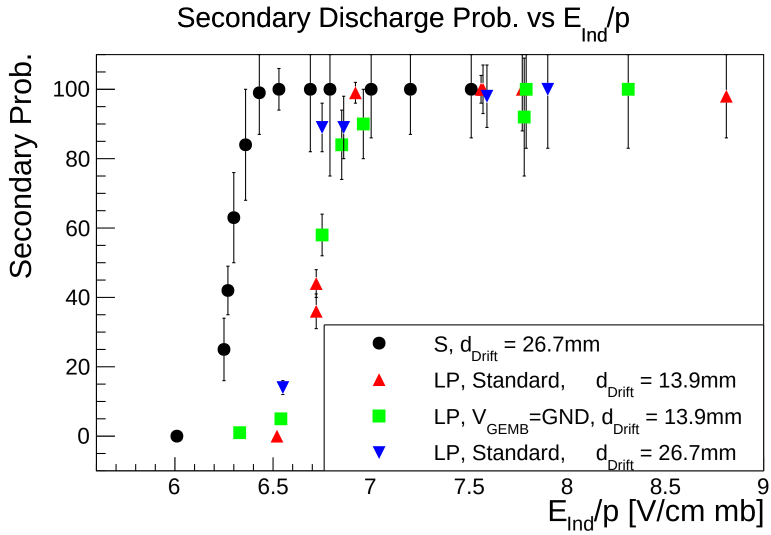
In addition:

- Amplitude of the secondary discharge doubles with the increased gap
- Trend of this amplitude with E_{Ind} not yet conclusive (CERN/Munich measurements)

Further studies with the standard configuration

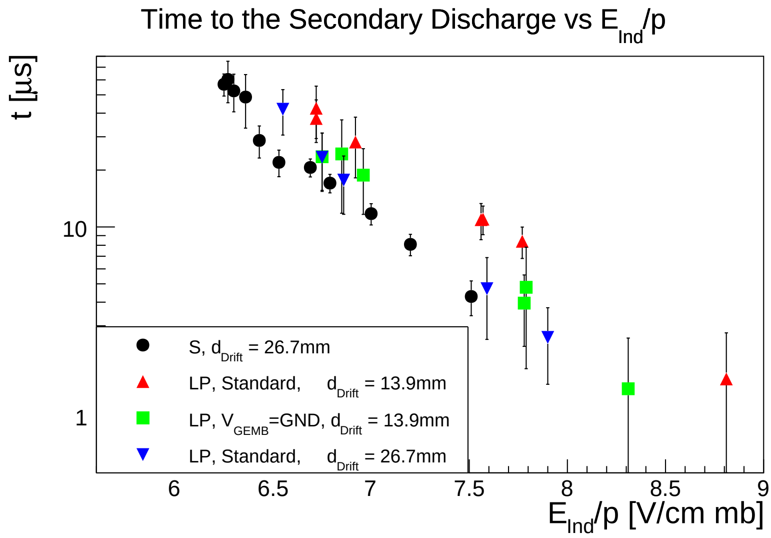
3. Question: Does a large pitch (LP) foil behave similar?
4. Question: Is there an influence of the drift gap?

Secondary discharge probability



- As comparison: Standard (S) GEM at $d_{\mathrm{Ind}} = 3\,\mathrm{mm}$ and standard HV config.
- LP GEM: Onset of the discharges occurs at higher induction fields
- No difference for different drift lengths and HV settings
- Difference S vs LP GEM is smaller as the difference between CERN and Munich S GEM results

Time between discharges



- Also here: The points for different LP measurements don't show different behaviour
- The overall change for the time between discharges, behaves as it did for previous measurements: As the onset shifts to higher fields, the time distribution does as well.

Summary of the CERN studies

GEM type	S	S	LP	LP
Primary discharge probability ($\mathcal{O}$)	10^{-3}	10^{-3}	10^{-2}	10^{-2}
d_{Ind} [mm]	2	3	3	3
d_{Drift} [mm]	27.7	26.7	26.7	13.9
V_{GEMB}	HV(GND)	GND	HV	HV(GND)
Onset E_{Ind} $\left[\mathrm{V\,cm^{-1}\,mbar^{-1}}\right]$	5.7(5.7)	6.2	6.6	6.6(6.6)
Signal ($1^{\mathrm{fst}}/1^{\mathrm{snd}}$) [V] – HV-config:	-0.18/-1.5		-0.18/-4.7	?[2]/4.7
GND-config:	-0.18/-3.4	-0.3/-1.1[1]		-0.18/4.7

Footnotes:

1: Corresponding measurements made with different attenuation

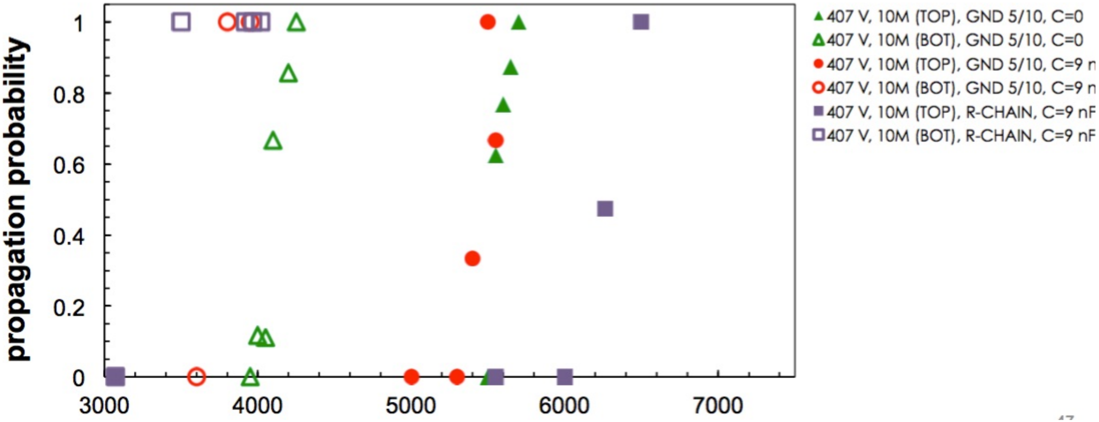
2: Non constant behaviour of the primary voltage

Combined Conclusions

- The onset of the secondary discharges depends on the induction field – so far no other dependency has been found
- This includes studies of the absolute potential on the GEM, drift-field (200-600 $\mathrm{V\,cm^{-1}}$) and -length studies, and studies of the ΔV_{GEM} ($410\,\mathrm{V} \pm \mathcal{O}(\%)$)
- The exact position of this onset seems to change from foil to foil
- The field for the onset depends on the induction gap (Threshold value increases with the gap)
- The time between primary and secondary discharge depends exponentially ($\sim \exp(-c_1 \times (E_{\mathrm{Ind}} - c_2))$) on the induction field, where c_2 depends on the onset field
- Different gas mixtures lead to a different slope of the onset

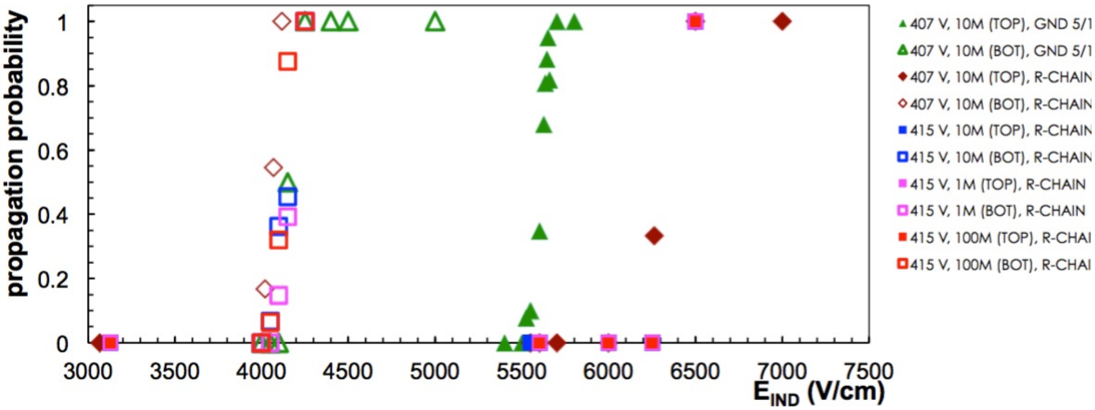
Backup

Simulating long cables: Capacitances to ground



- To simulate long cables capacitors were added
- No changes observed with the standard config., but lower onset seen in case of the flipped config.

Observation while powering the GEM with a resistor chain



- In case of the flipped configuration nothing changed
- For the standard configuration the onset shifts to higher fields!

Determination of the plotted parameters

Probabilities:

- Primary ("lower case 1"):

$$Pr_1 = \frac{(scaler\ counts)_1}{rate \times time}, \quad \Delta Pr_1 = Pr_1 \times \sqrt{\left(\frac{\Delta rate}{rate}\right)^2 + \frac{1}{(scaler\ counts)_2}}$$

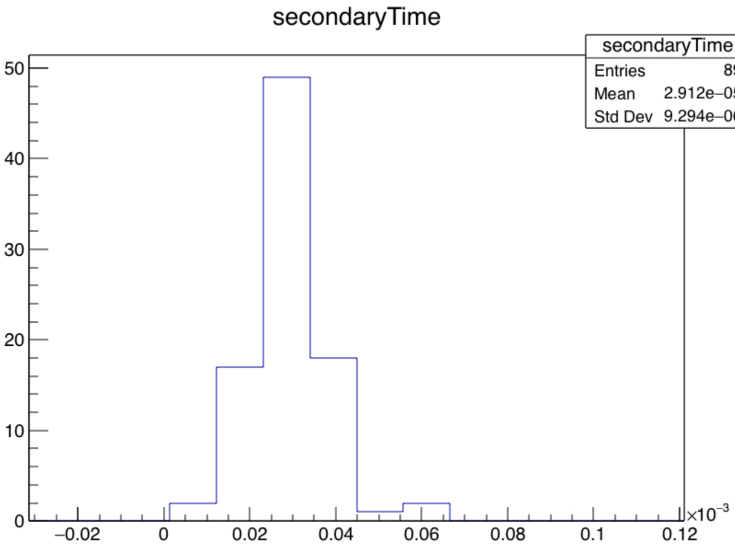
- Secondary ("lower case 2"):

$$Pr_2 = \frac{(scaler\ counts)_2}{(scaler\ counts)_1}, \quad \Delta Pr_2 = Pr_2 \times \sqrt{\frac{1}{(scaler\ counts)_1} + \frac{1}{(scaler\ counts)_2}}$$

Times:

- Average time between discharges := Mean of the "Time between discharges distribution" (Example on the next slide)
- Error given in plots showing the time is the standard deviation of the "Time between discharges distribution"

Example: "Time between discharges distribution"



Settings:

$$\Delta V_{GEM} = 406\,\mathrm{V}$$

$$E_{\mathrm{Drift}} = 400\,\mathrm{V\,cm^{-1}}$$

$$E_{\mathrm{Ind}} = 5943\,\mathrm{V\,cm^{-1}}$$

FYI:

Time lower than 0.2 μs

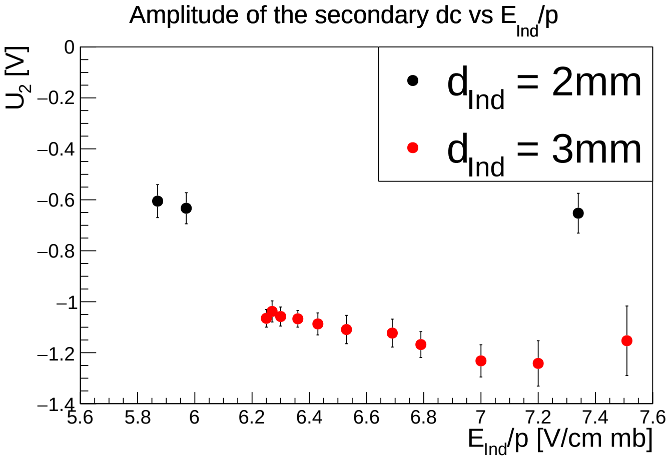
$$\Delta V_{GEM} = 419\,\mathrm{V}$$

$$E_{\mathrm{Drift}} = 400\,\mathrm{V\,cm^{-1}}$$

$$E_{\mathrm{Ind}} = 6990\,\mathrm{V\,cm^{-1}}$$

have been observed.

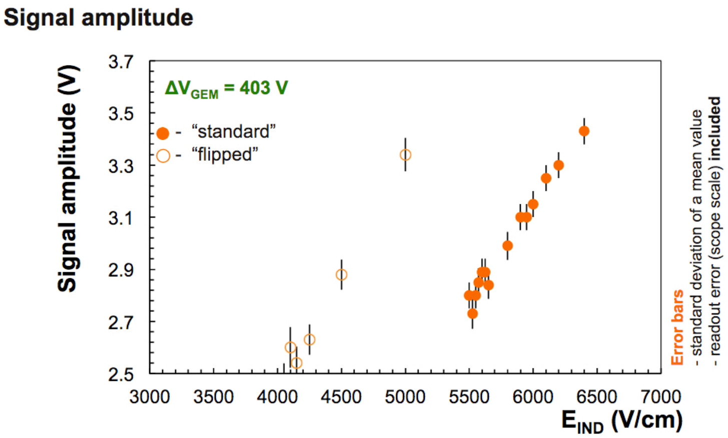
Amplitude of the secondary discharge – 1/2



- Points recorded during the $V_{\mathrm{GEMB}} = \mathrm{GND}$ measurements are shown
- Furthermore: Points with a different attenuation were rejected
- The amplitude of the secondary discharge roughly doubles with the increased induction gap

But: Different trend with induction field observed in Munich

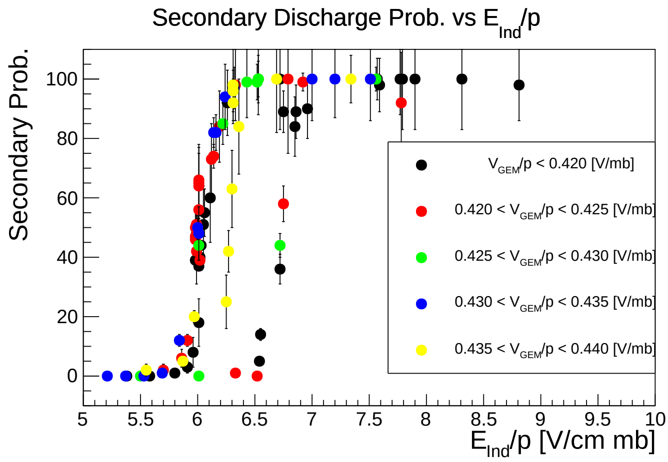
Amplitude of the secondary discharge – 2/2



Results in Munich:

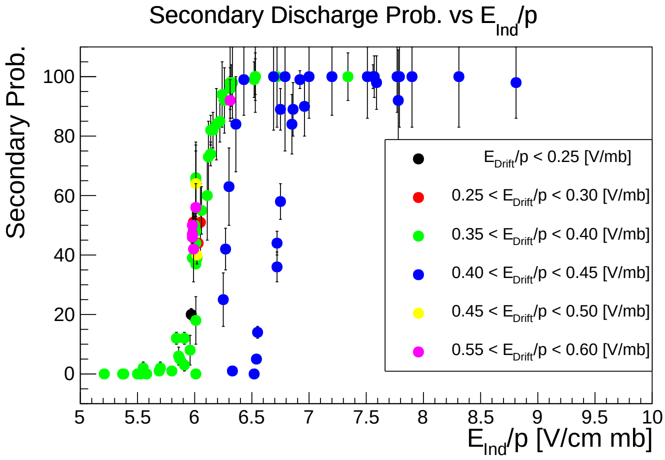
- Except of the onset field, the amplitudes in the flipped/non flipped configuration behave similar
- Amplitudes increase with the induction field
- Differences between measurements (CERN/Munich) still to be resolved

Secondary discharge probability for different GEM voltages



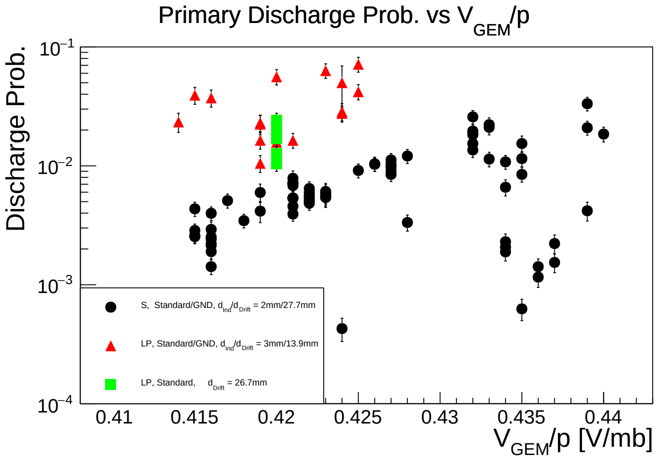
- As observed in Munich: No dependence of the discharge probability (time between discharges) of the GEM voltage observed

Secondary discharge probability for different drift fields



- Studied with the standard GEM and and the 2 mm gap
- No dependence observed
- The same is true for e.g. the time between discharges

Primary discharge probability of all measurements



- Clearly a higher primary discharge probability with the LP
- A high amount of outliers → not explained yet
- Outliers only visible in this plot – no influence on other measurements found