Secondary discharge mitigation by HV scheme optimisation

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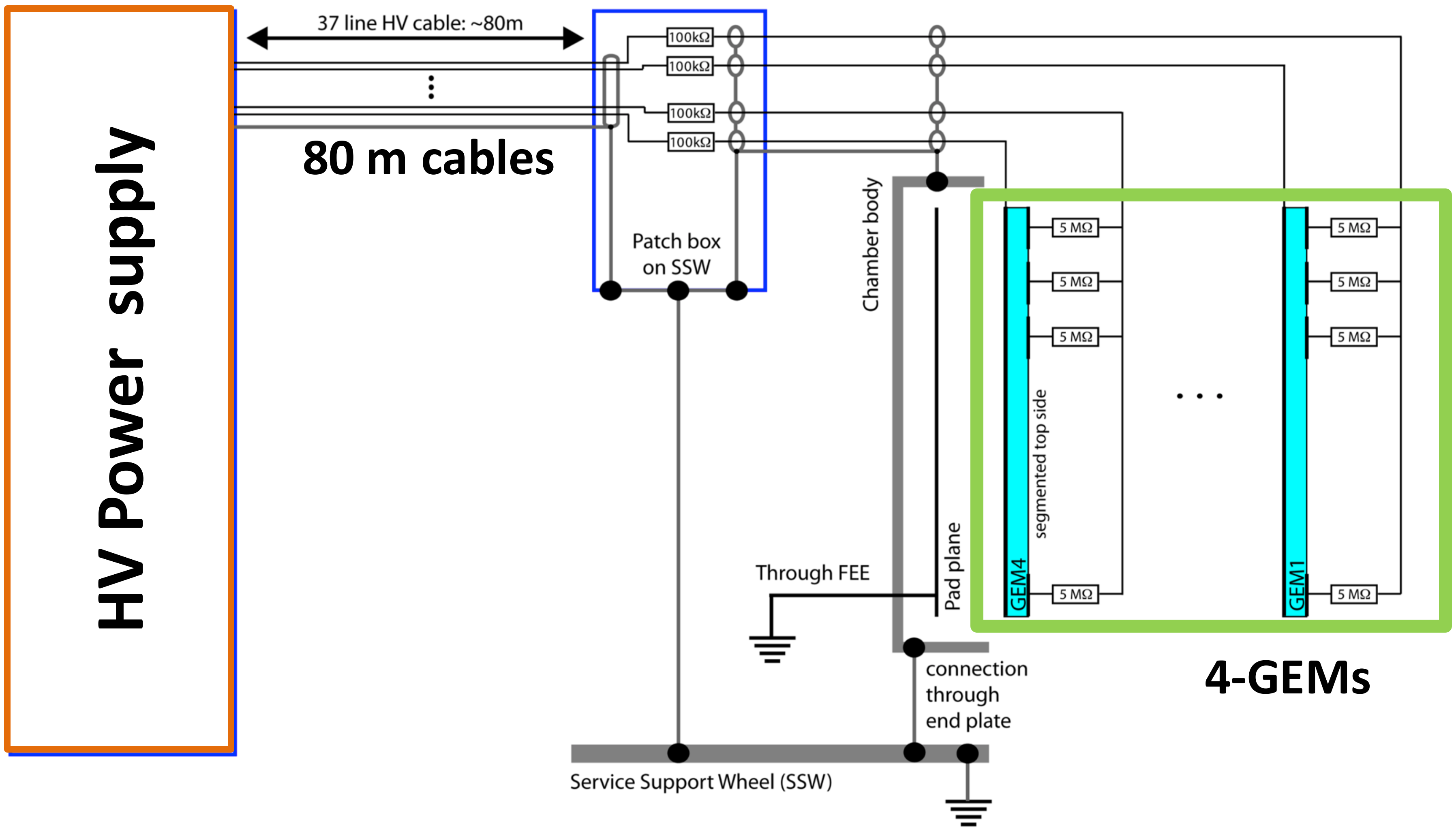
Motivation

- Secondary discharges appear shortly after primary discharges
- Large signal can be associated with a development of a spark between GEM and GEM/padplane
- See previous talks for physics introduction
- May be violent and harmful to hardware and electronics

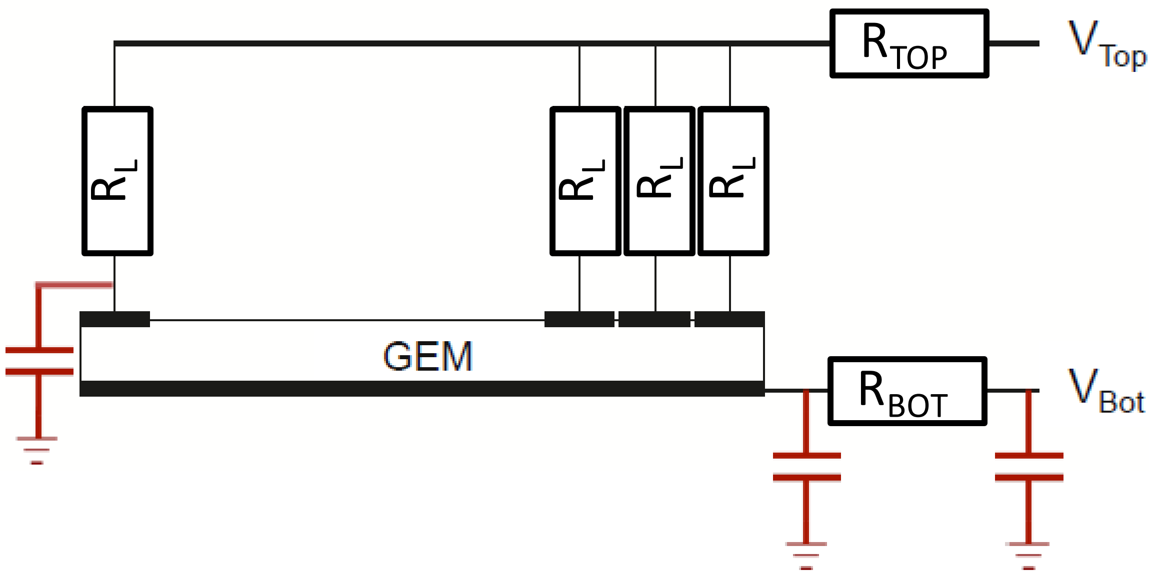
-> Avoid or mitigate secondary discharges

-> Optimise HV scheme

Upgraded ALICE TPC HV Scheme



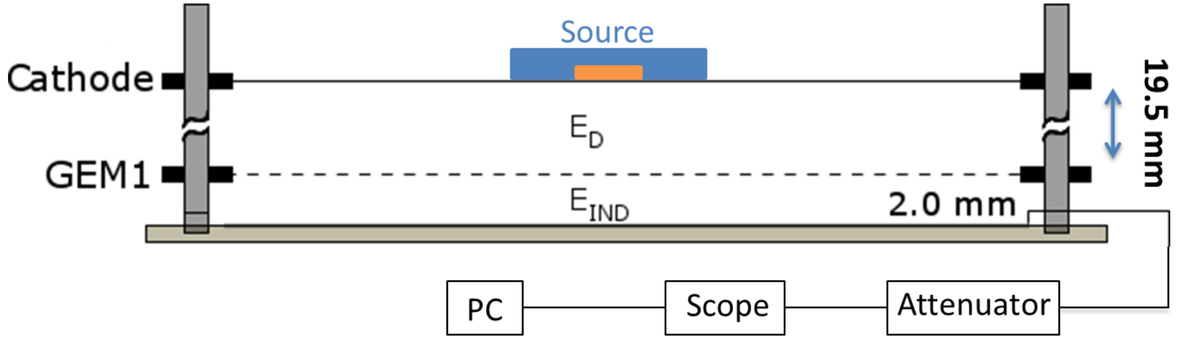
Optimising HV Scheme

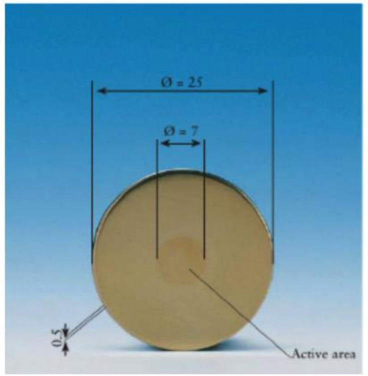


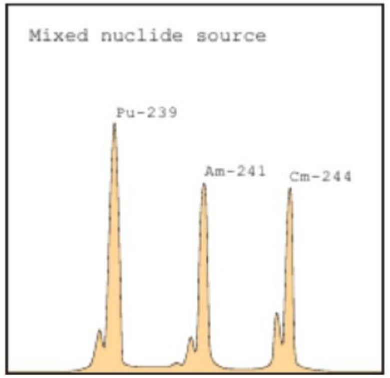
RC Elements in ALICE GEMs:

- Decoupling resistors R_{BOT} /R_{TOP} (1 per GEM side and HV cable)
  - Decouple HV supply line from a GEM electrode
  - Current choice: 100 kΩ; acceptable potential drop
- Parasitic Capacitance due to cables between
  - Power supply and decoupling resistors
  - GEM and decoupling resistors
- Loading resistors R_L (at top side)
  - Quenching sparks, reduce current, protect GEM segment
  - Reduce current flowing from the PS in case of a short
  - Voltage (thus gain) drop due to the (ion/electron) current
  - **Final choice:** 5 MΩ (for GEM1/2/3/4)

Experimental Setup







Mixed α-source (Pu, Am, Cm) shooting through 7 mm hole in the cathode
Rate ~550 Hz

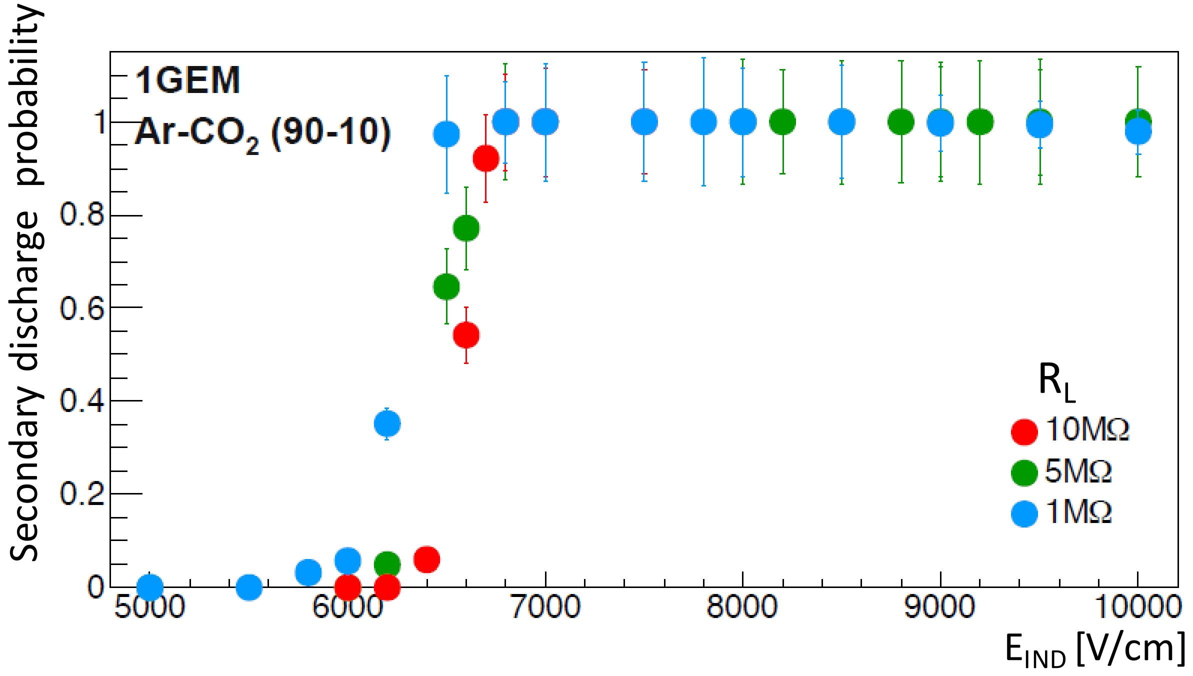
E_{DRIFT} = 400 V/cm (ALICE drift field value)

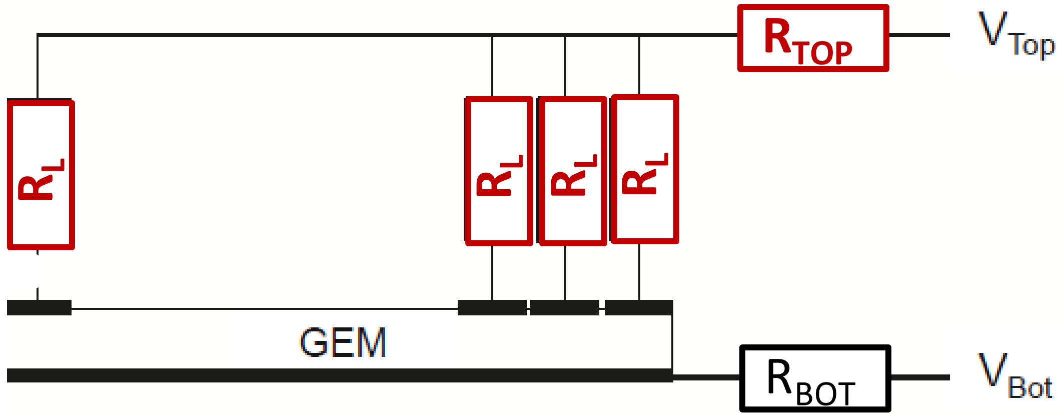
E_{IND} variable

Readout signals at the anode 34 dB attenuator and a scope

Operated in Ar-CO_2 (90-10) and Ne-CO_2-N_2 (90-10-5)

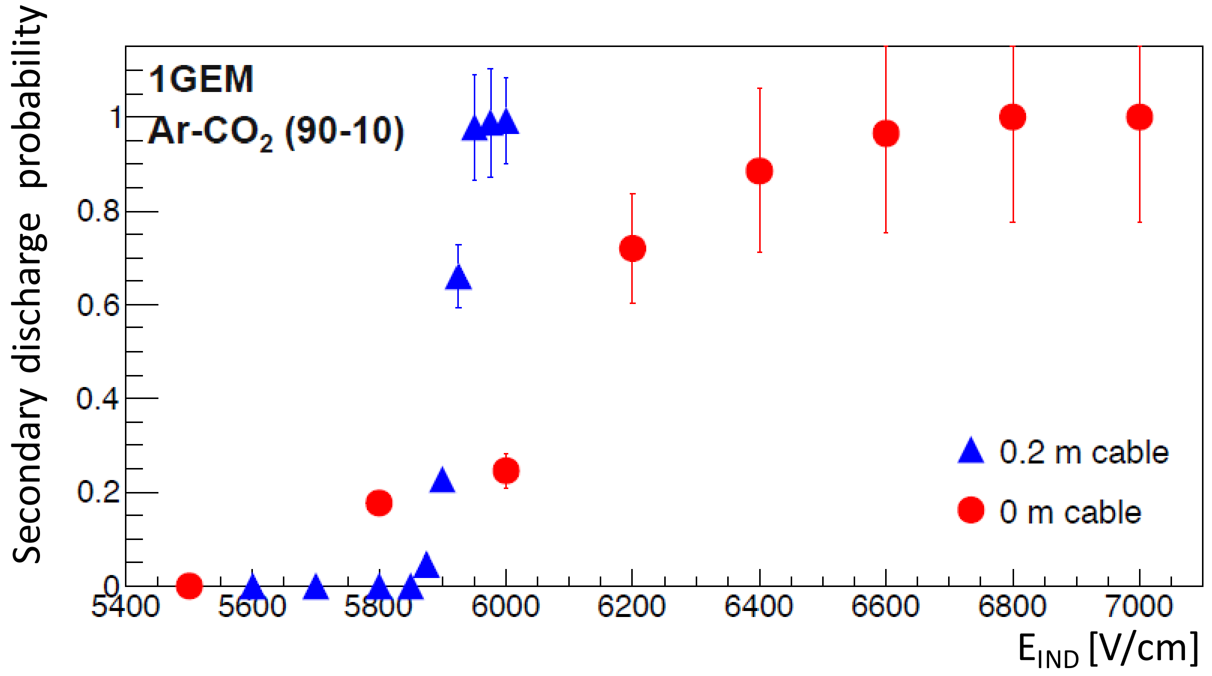
Parasitic Measurements in Ar-CO_2 (90-10)

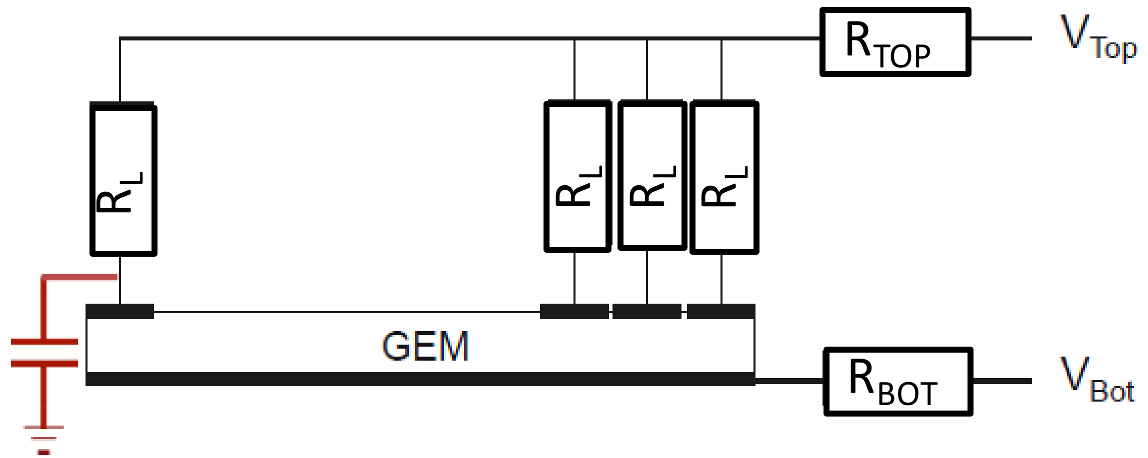




- Propagation probability does not depend on the loading resistor value
- Nominal value R_L = 5 MΩ

Parasitic Measurements in Ar-CO_2 (90-10)

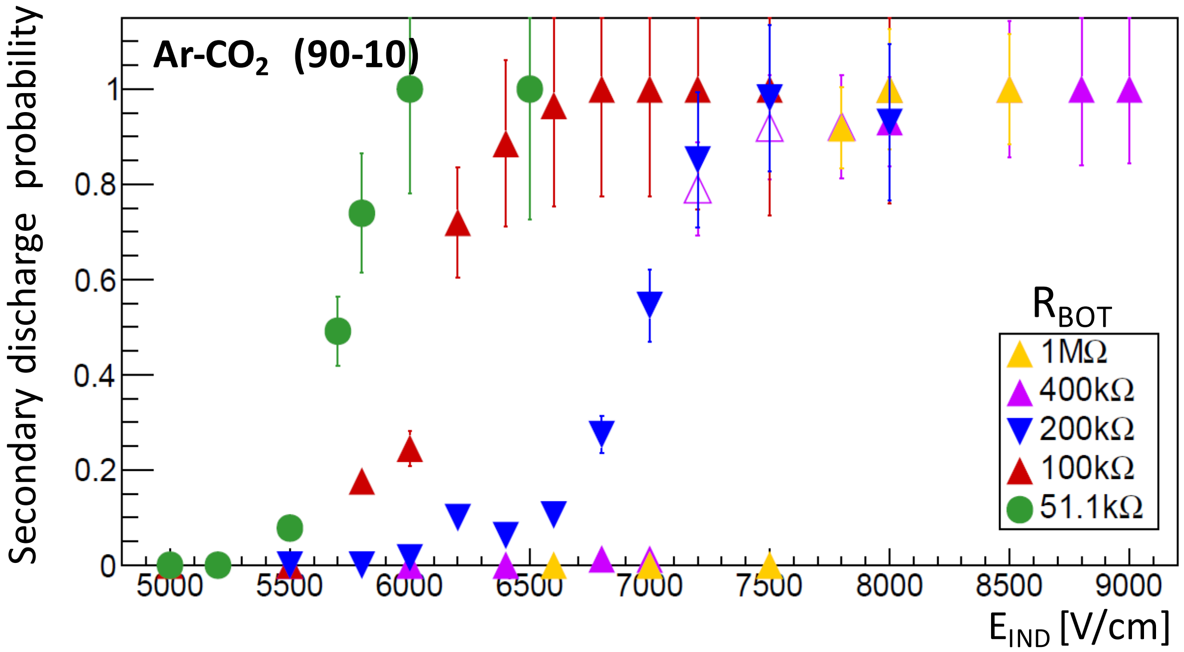


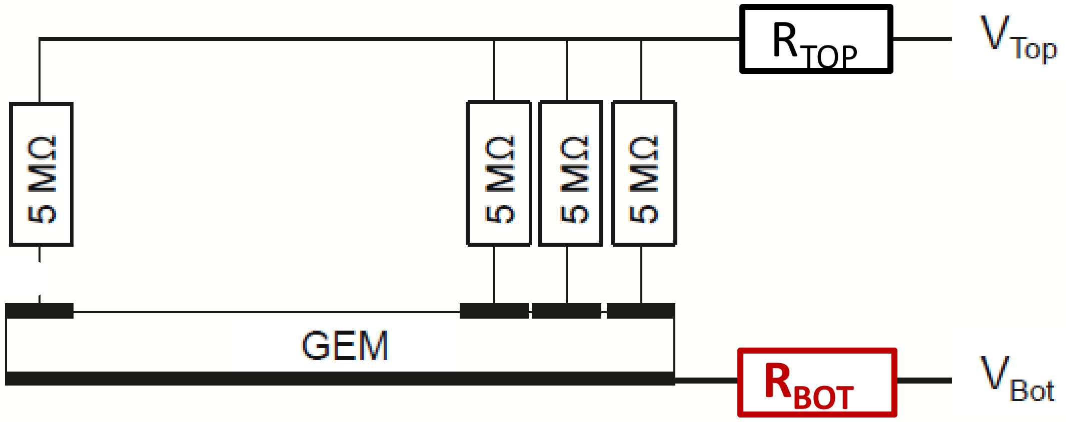


- Extra capacitance (e.g. cable) between the top loading resistor and the top GEM electrode may influence the propagation behavior
- Effect of an extra energy reservoir causes increase of GEM bottom voltage

=> Loading resistors soldered directly at GEM foil

Parasitic Measurements in Ar-CO_2 (90-10)

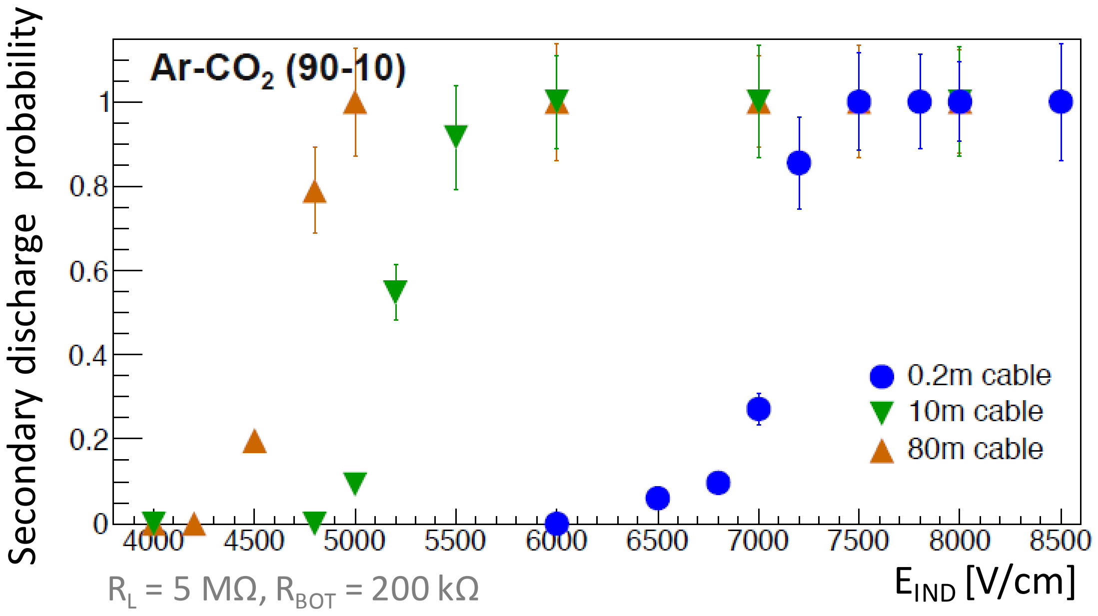


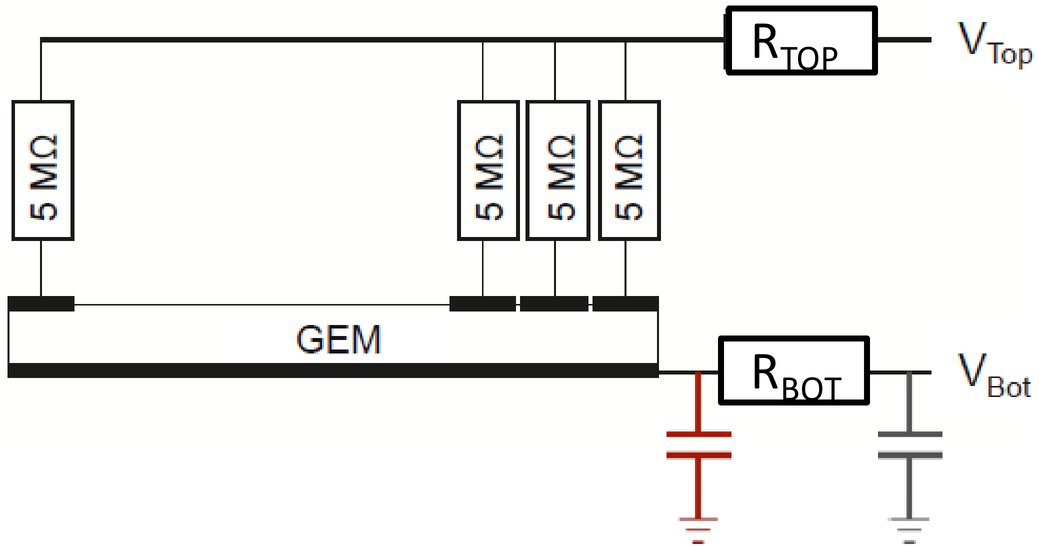


- Onset of propagation observed at higher E_{IND} for larger R_{BOT}
- Clear recommendtation to maximize R_{BOT}
- But high R_{BOT} leads to gain drop

$\Rightarrow$ Balance R_{BOT} between secondary discharge probability and gain drop

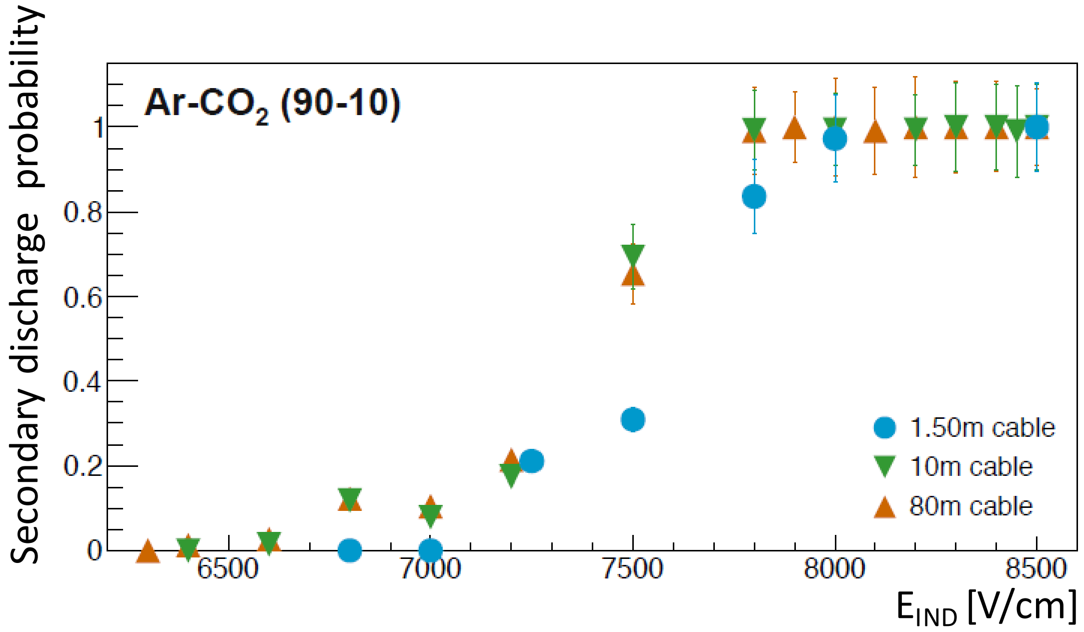
Parasitic Measurements in Ar-CO_2 (90-10)

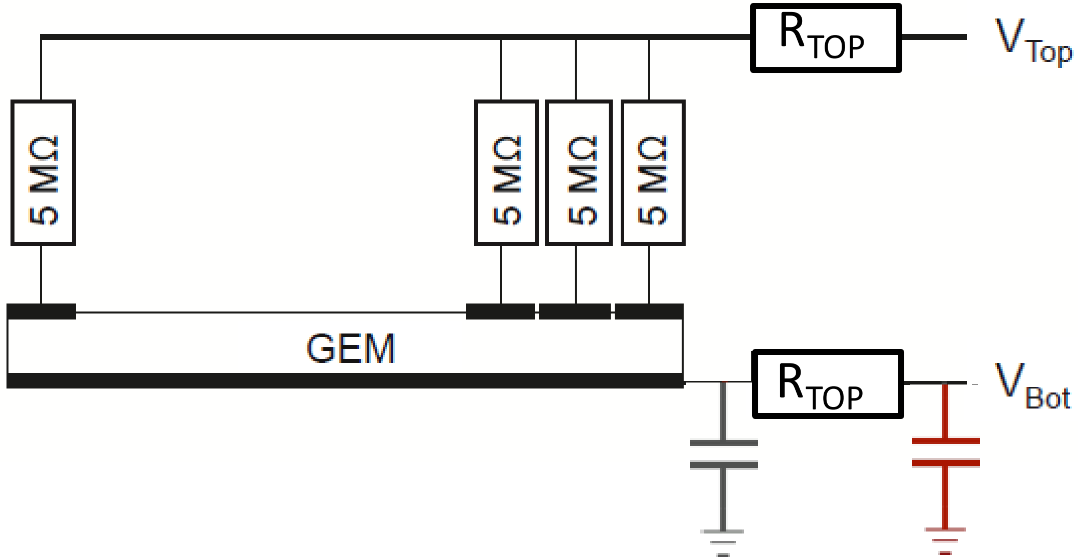




- Cables introduce parasitic capacitance
- Propagation probability increases with length of cable between R_{BOT} and GEM
- Effect of stored energy
- Necessary to install decoupling resistors close to chambers (clear preference R_{BOT} & R_{TOP} = 100 kΩ)

Parasitic Measurements in Ar-CO_2 (90-10)

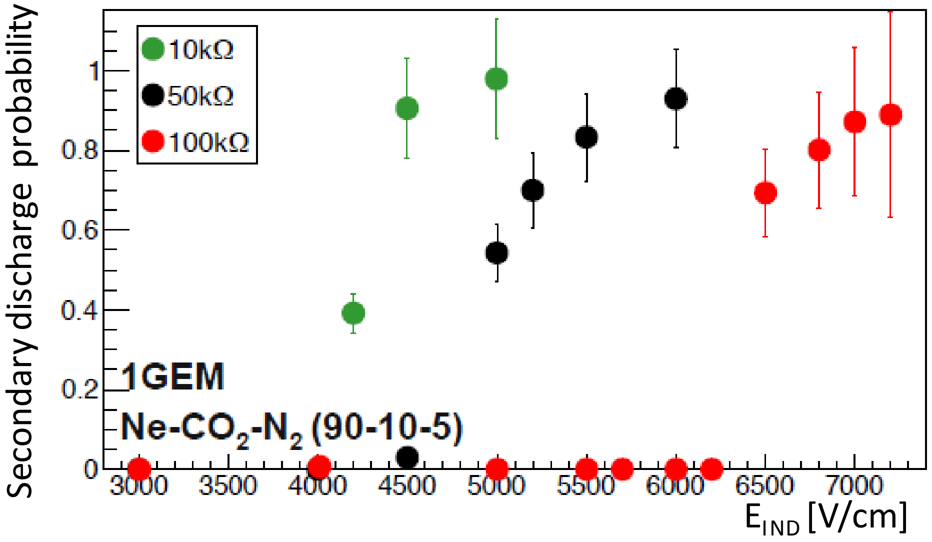


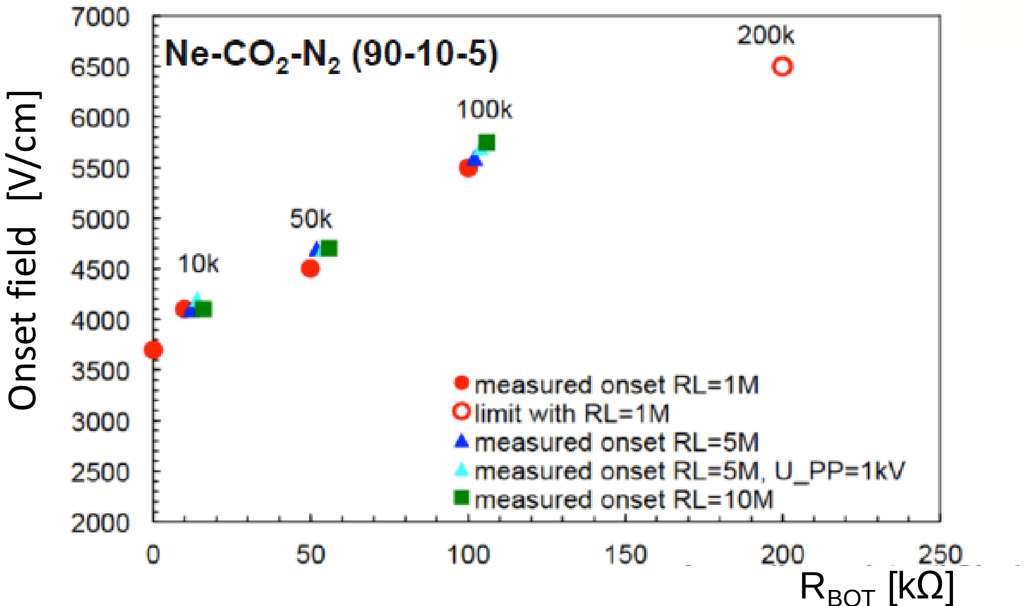


- Effect of decoupling resistor (R_{BOT} = 200 kΩ, R_L = 5 MΩ)
- Cable length (between the PS and R_{BOT}/R_{TOP}) does not influence the propagation probability

⇒ R_{BOT} decouples long cables well

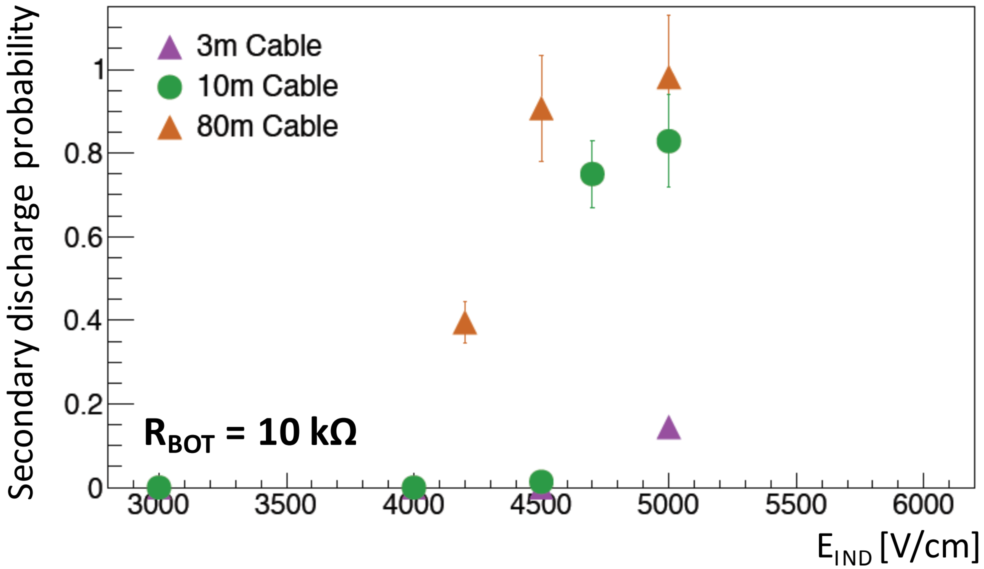
Measurements in Ne-CO_2-N_2 (90-10-5)



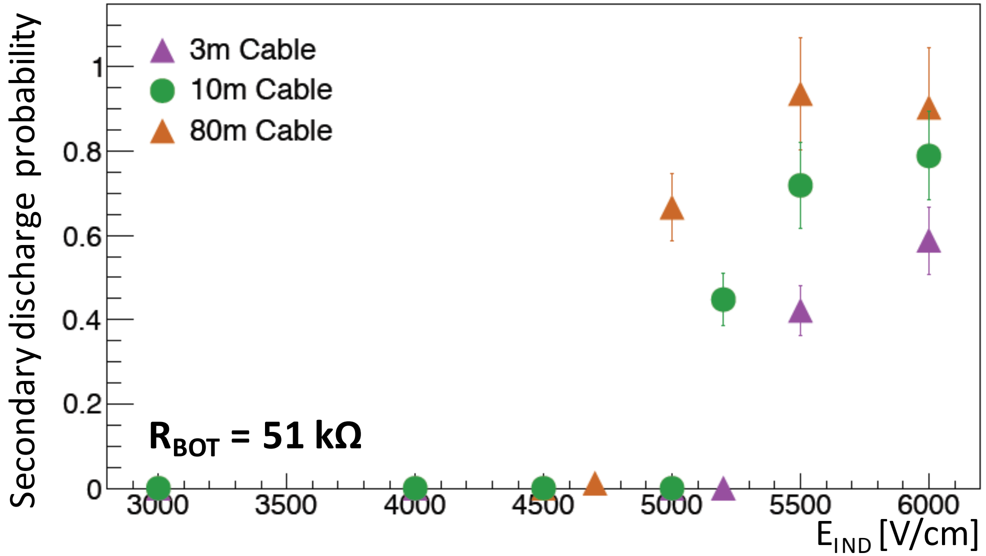


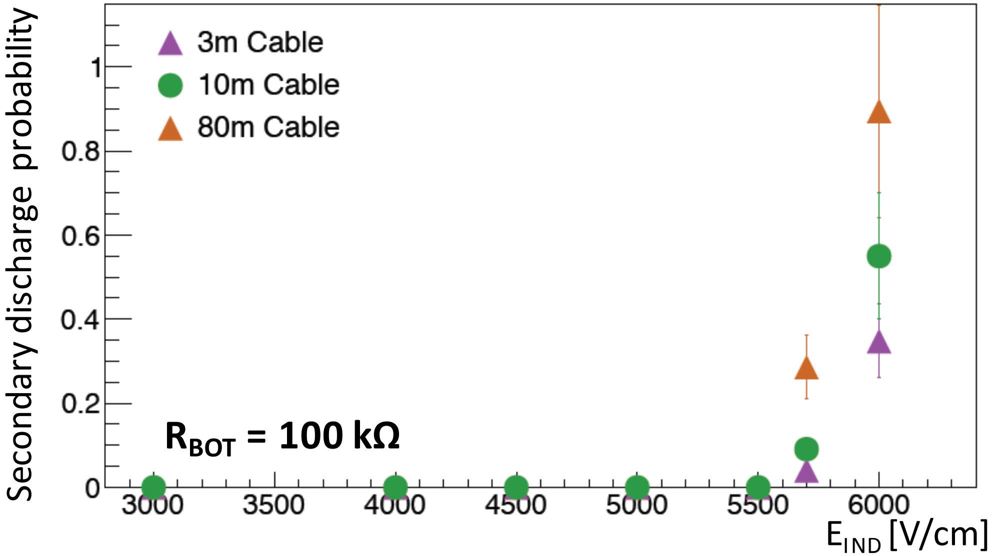
- Propagation curve measured in future ALICE TPC gas mixture
- 80 m cable from the power supply to simulate realistic conditions
- 1.5 m between R_{BOT} and GEM bottom
- Clear dependence on R_{BOT} value

Measurements in Ne-CO_2-N_2 (90-10-5)



- Visible dependence on cable length for low R_{BOT}
- Situation improves with larger R_{BOT}
- With R_{BOT} > 100 kΩ marginal dependency on the cable length
- Higher resistance clearly preferable

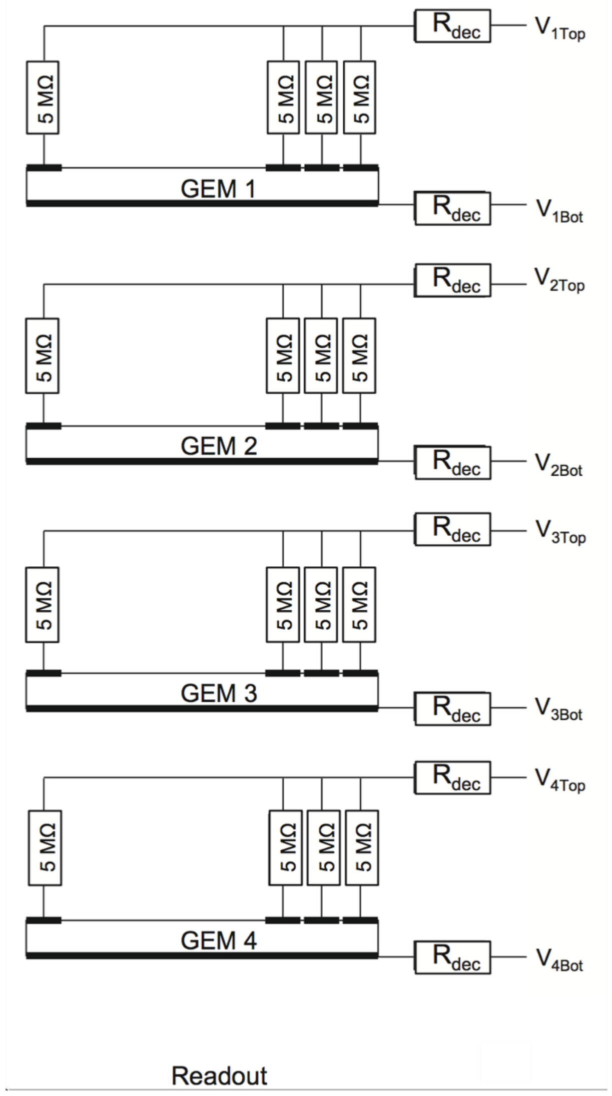




Summary I

- RC components clearly have a major influence on discharge propagation
- Solder R_L directly to GEM
- Choose high value of the decoupling resistance: R_{BOT} = 100 kΩ
  - Value of the resistor can be adjusted until final installation but also during the TPC operation
- HV settings with lower fields preferable
- Minimize cable length between the R_{BOT} and GEM (~2 m)

Application to 4-GEM Setup



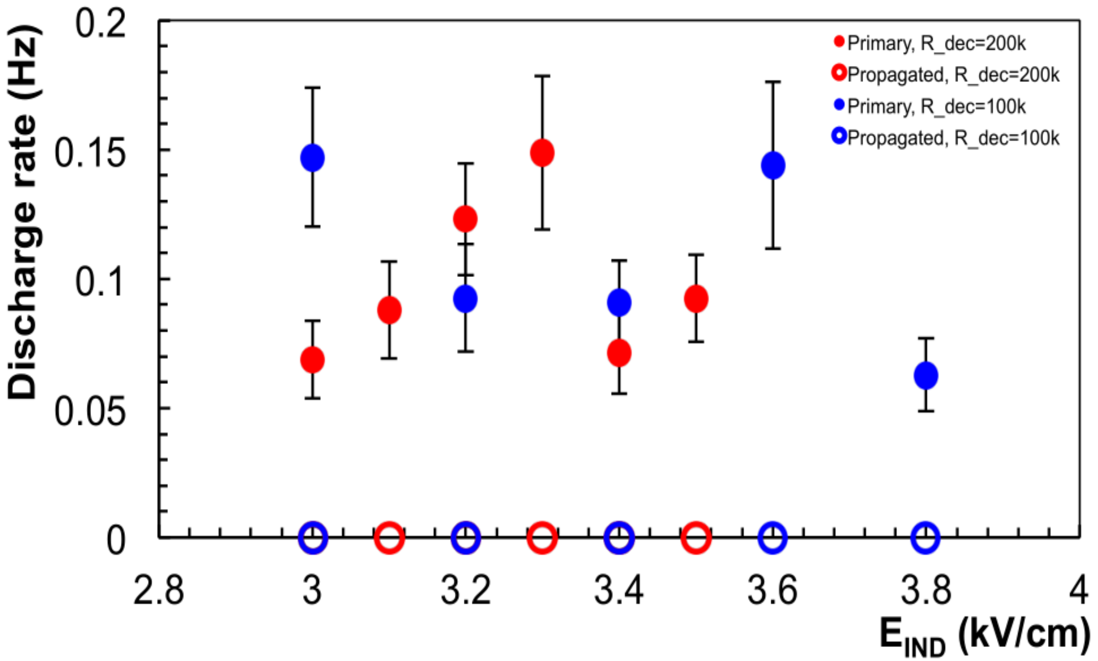
- So far all systematic measurements with 1-GEM setup
- Now: Application of "propagation-hardened" HV scheme on 4-GEM Setup

- Trigger sparks with ΔV_{GEM} > 380 V (much higher than nominal setting)

	GEM1	GEM2	GEM3	GEM4
ΔV_{GEM}	270 V	230 V	320 V	320 V
Field below GEM	3.5 kV/cm	3.5 kV/cm	0.1 kV/cm	3.5 kV/cm

Baseline ALICE settings

Application to 4-GEM Setup



- GEM 4 studies show that optimized HV scheme works as intended, no propagations to the readout plane
- However secondary discharges (in transfer gaps) still observed when primary discharge triggered in GEM 1/2/3
- Proper trip limits and 100 kΩ secure GEMs (no GEM was broken when $R_{BOT} > 0$)
- Further stabilisation by:
  - Reduction of transfer/induction fields (performance deterioration, higher ΔV_{GEM} necessary to compensate gain)
  - Increase R_{BOT} value for GEM 1/2/3 (200-500 kΩ) (gain drop is not an issue as the highest amplification occurs in GEM 4)

Summary II

- GEM 4 safe, propagation still visible in GEM 1/2/3

$\Rightarrow$ Solutions: higher R_{BOT}, lower E_{IND} (but lower E_{IND} necessitates higher ΔV_{GEM})

- Due to our rule set no GEMs were harmed during these studies

Next up:

- Measure multi-GEM propagation with final power supply and full-size IROC