Spectroscopy measurements on GEM discharges

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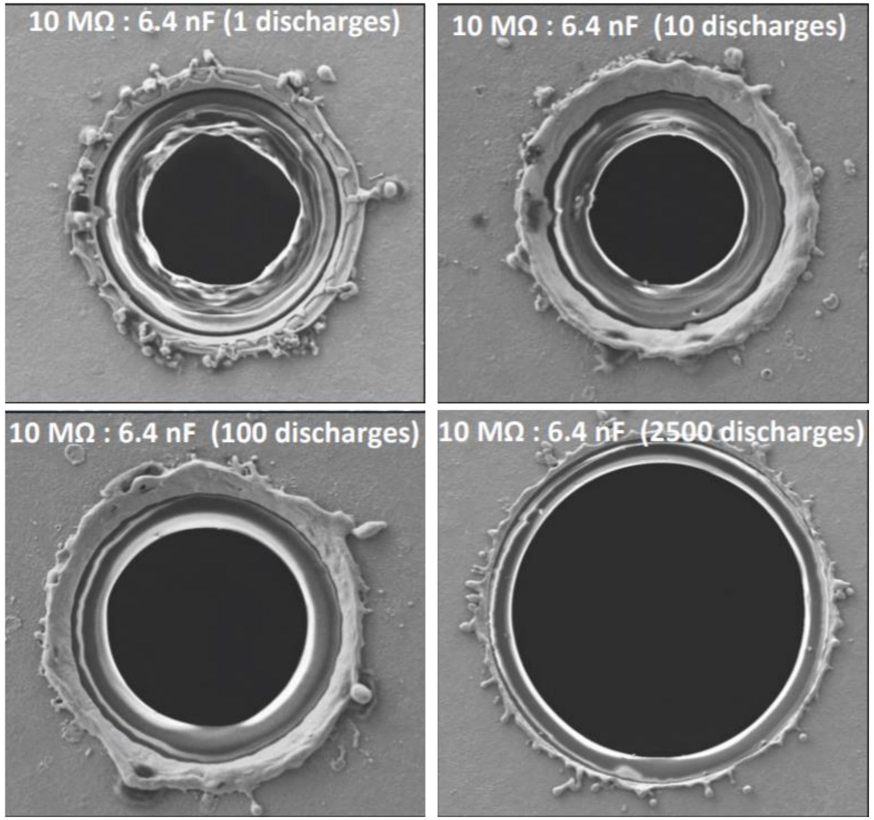
GEM discharges

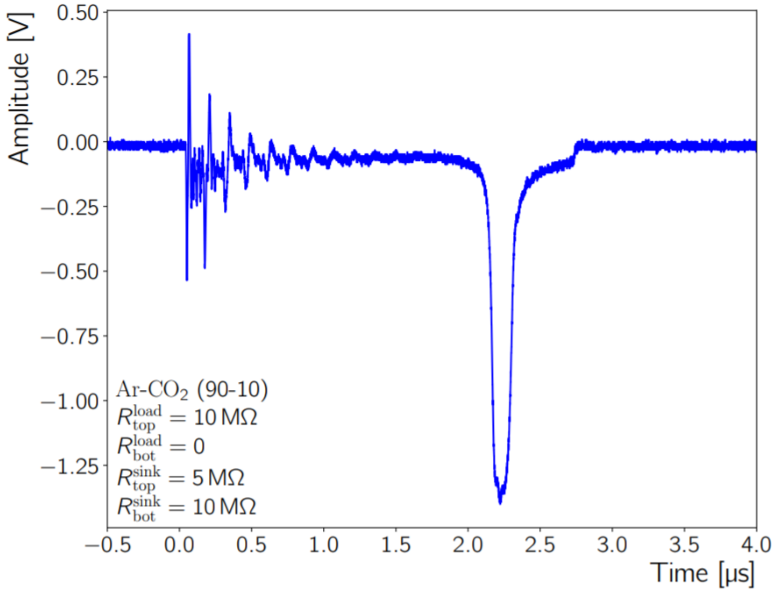
- Over the last two decades discharges in GEMs have been thoroughly studied in terms of their electrical properties
- Shown to damage and change geometrical structure of the involved GEM holes
    - ❑ J.A. Merlin, RD51 Collaboration Meeting 2018
- Methods have been developed to mitigate discharges during operation
    - RC components, gas, foil properties, etc.
    - ❑ S. Bachmann et al. NIM A 479 (2002) 294-308
    - ❑ P. Gasik et al. NIM A 870 (2017) 116
    - ❑ …



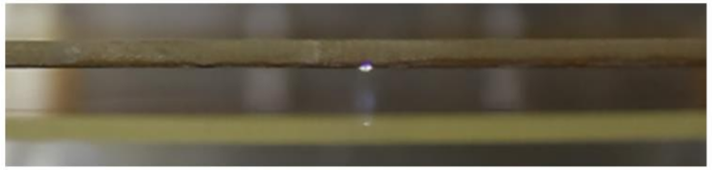
[J.A. Merlin, RD51 Collaboration Meeting 2018]

Secondary discharges

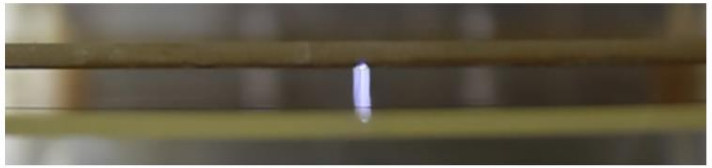
- Discharge in the transfer/induction gap appearing few µs after the primary spark
- Mitigation strategies established
    - ❑ L. Lautner, et al. JINST 14 (2019) no.08, P08024
    - ❑ A. Deisting, et al. NIM A 937 (2019) 168-180
- Formation mechanisms not fully understood
- Leading theory:
  Heating of the cathode after the primary discharge
    - ❑ A. Deisting, et al. NIM A 937 (2019) 168-180
    - ❑ A. Utrobicic, et al. NIM A 940 (2019) 262-273
- We try a new approach with optical spectroscopy



a) Primary discharge



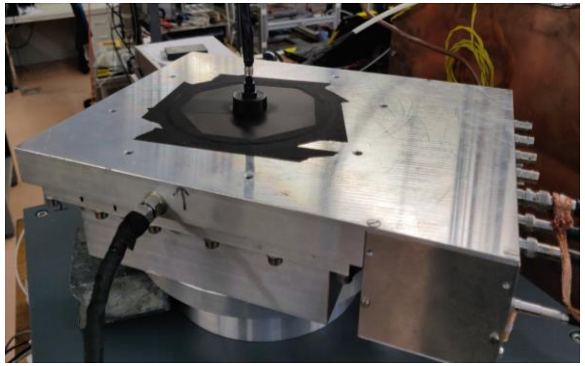
b) Secondary discharge

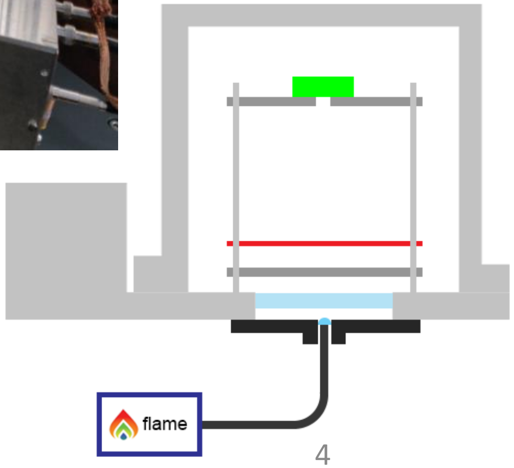


[A. Deisting, et al. NIM A 937 (2019) 168-180]

Optical spectroscopy

- Advantages of the method
  - Probing the region around the discharging GEM hole
  - Determine which elements are abundant in the region
  - Information concerning the temperature of the discharge
- Our setup
  - Mesh readout anode (transparency ~50%)
  - BOROFLOAT window (UV cut-off at ~300 nm)
  - Ocean optics Flame spectrometer, with courtesy GDD lab





Measurements

Studying light emitted by GEM discharges

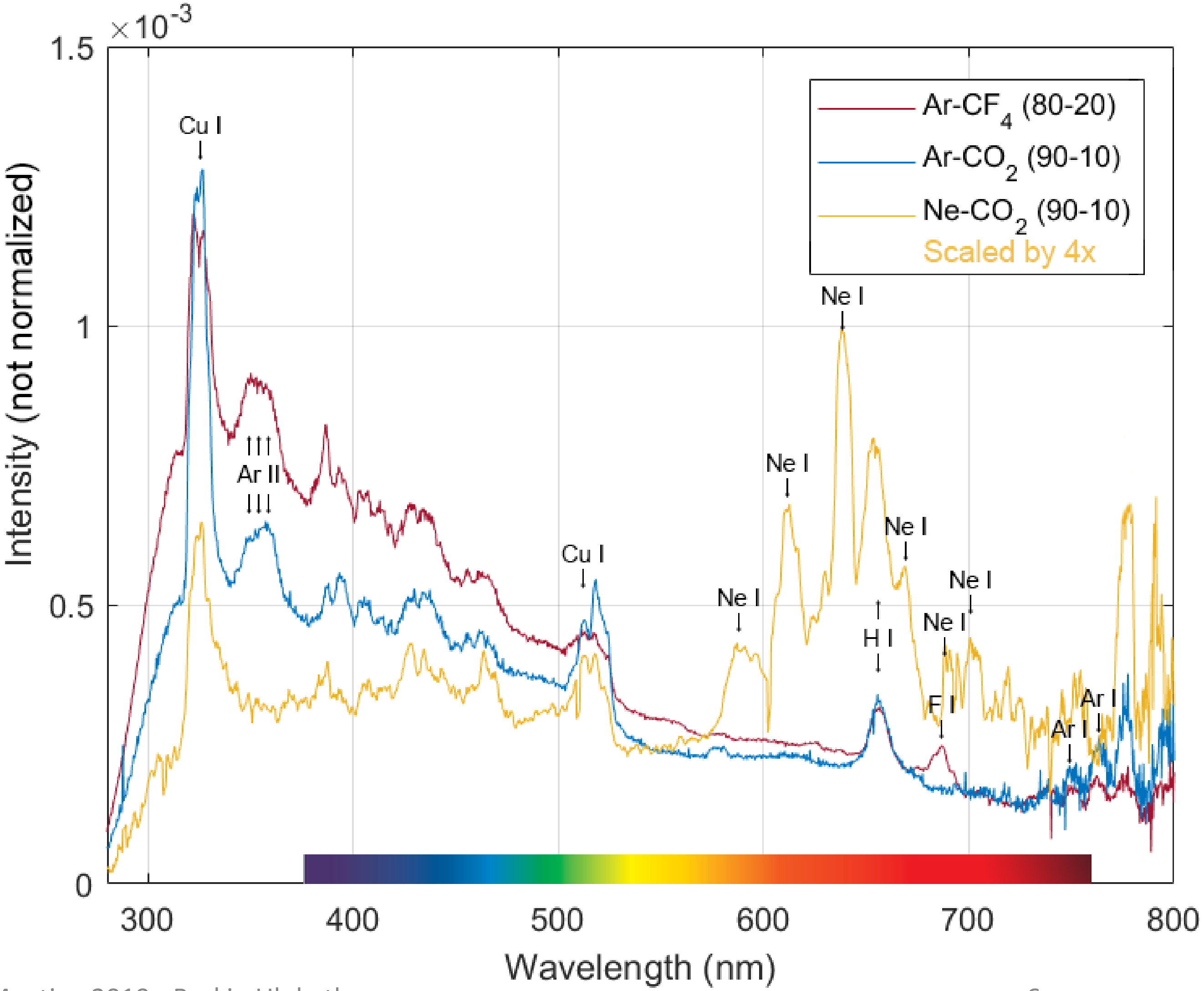
- Testing different gas mixtures
  - Ar-CO_2 ✓ Ar-CF_4 ✓ Ne-CO_2 ✓ Ar ✓
- Testing GEM foils with different material and geometric properties
  - GEM ✓ Single hole THGEM ✓ Single hole GEM (hammer) THGEM (hammer)

	Conductivity [10^6 S/m]	Work function [eV]	Melting point [°C]	Thermal conductivity [W/m*K]
Copper	58,7	4.7	1083	386
Aluminium	36,9	4.08	660	237
Molybdenum	18,7	4.5	2623	138
…	…	…	…	…

Standard GEM foil

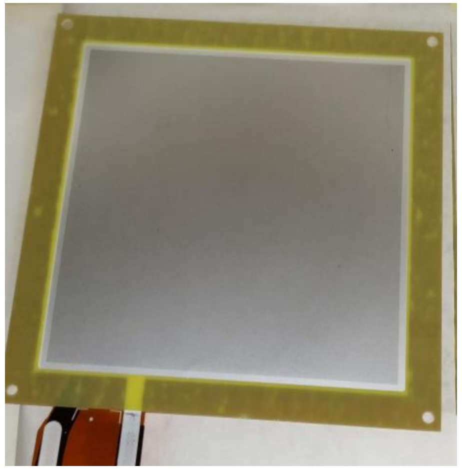
- Identifying the strongest emission lines of the used gas mixtures
- Copper emission lines
  - This is only possible if there are free copper atoms in the plasma

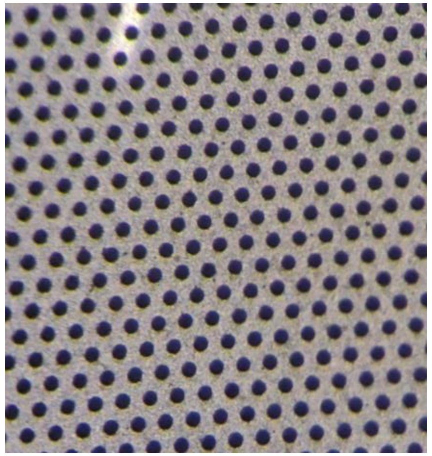
  → Evaporating the foil material

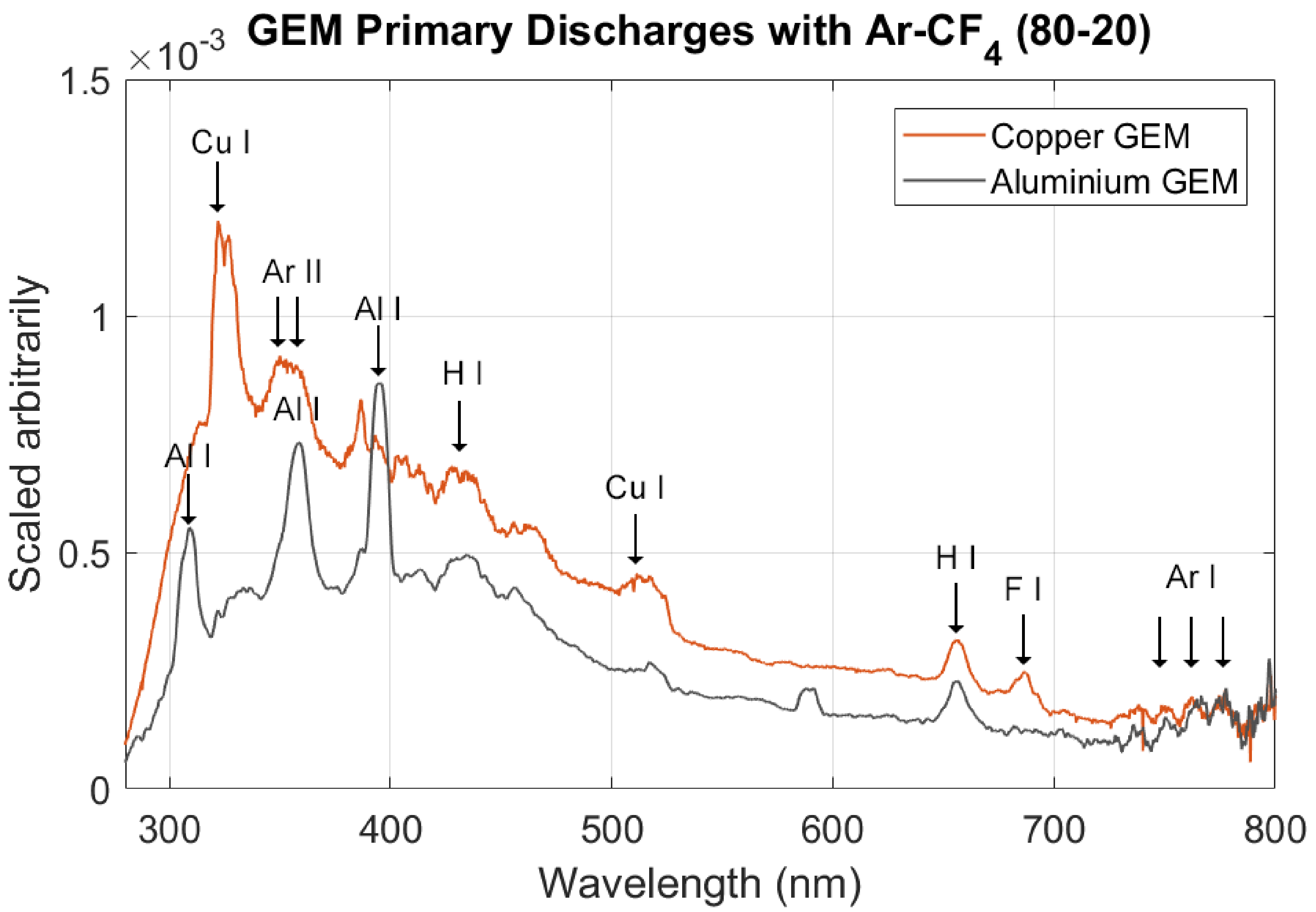


Aluminium GEM foil

- The peaks attributed to copper no longer evident
- Aluminium peaks are visible

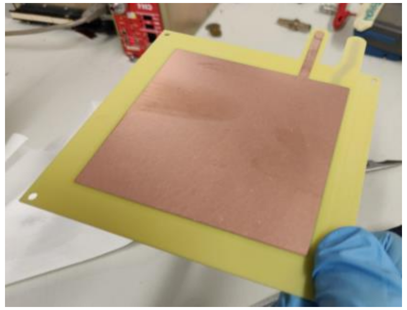


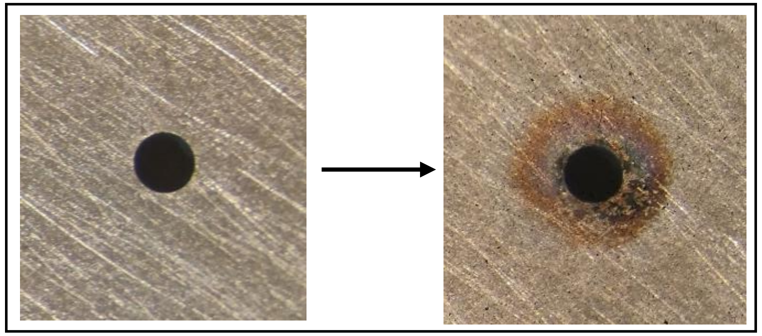


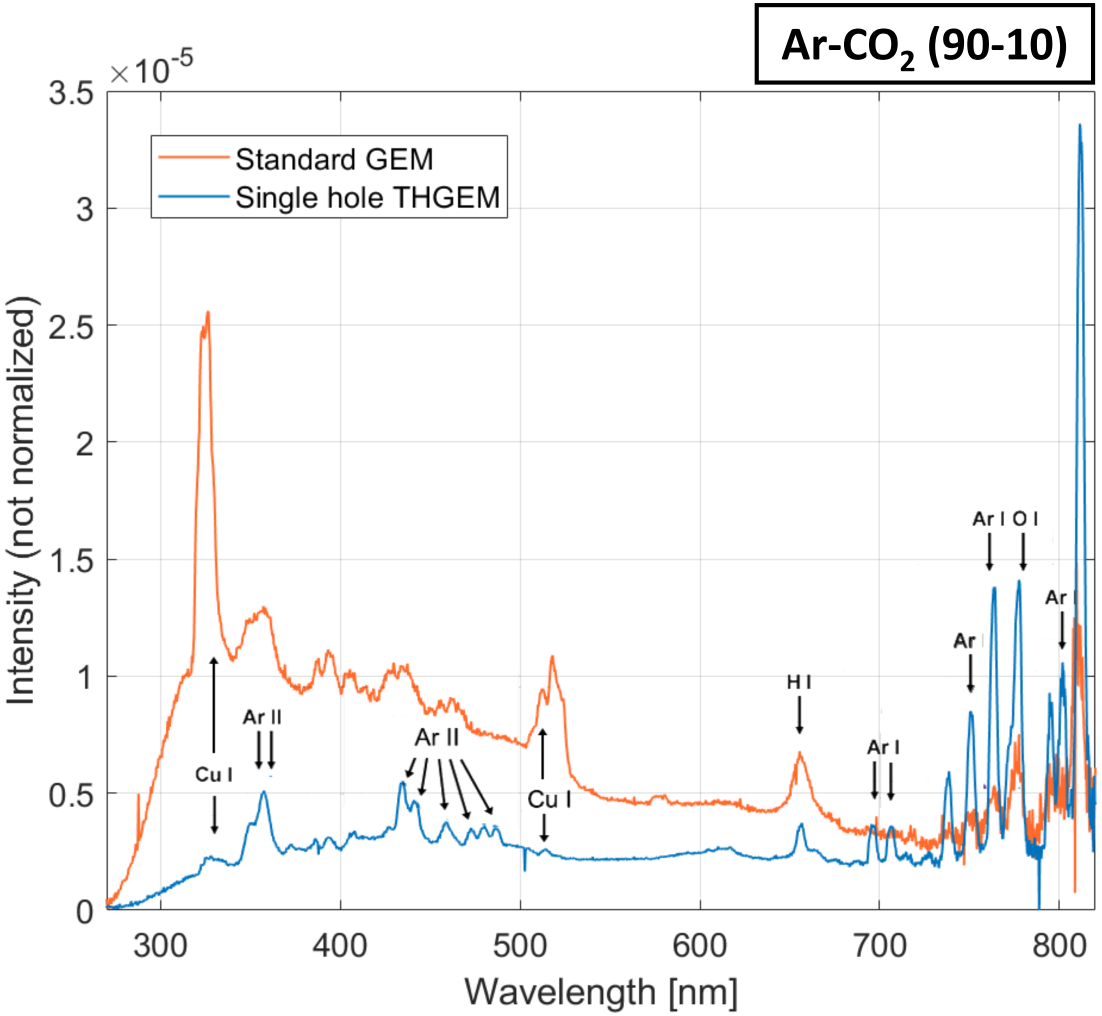


Single hole copper THGEM

- A major advantage of THGEM is their robustness against discharges
  - Can operate at higher discharge rate
  - More light = better spectrometer resolution
  - Easier to identify emission lines with the narrower peaks
- Copper peaks much weaker with THGEM
  - Less evaporation due to increased heat dissipation of the thicker copper layer

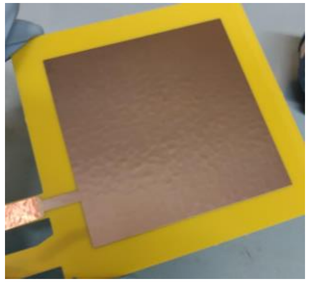


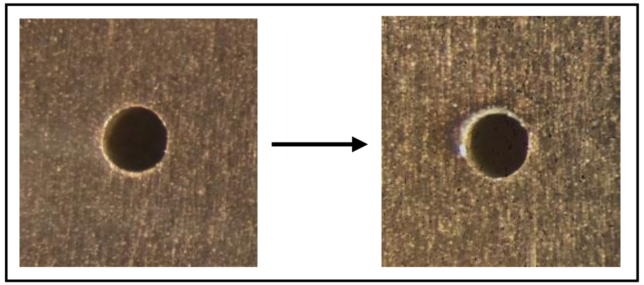




Single hole molybdenum THGEM

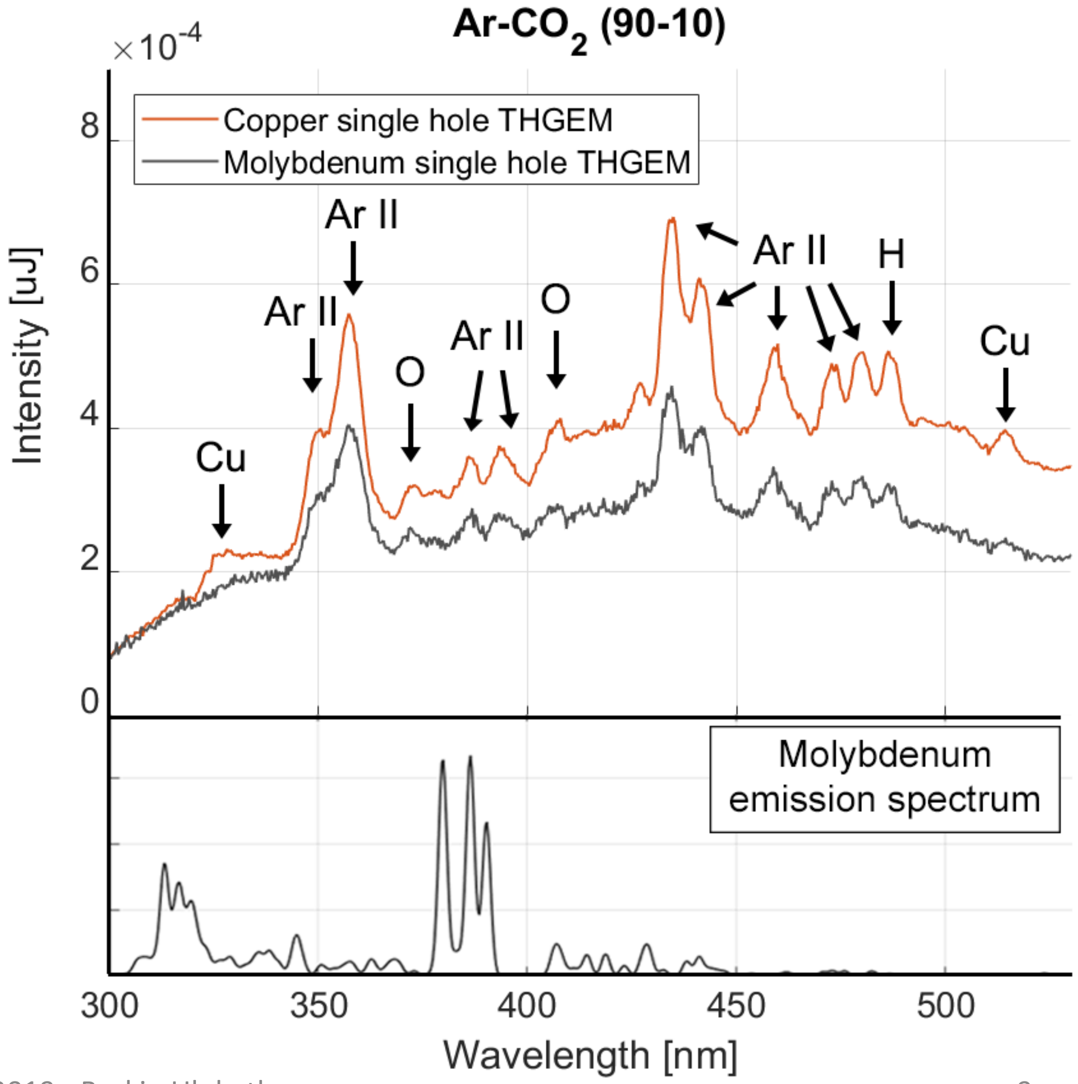
- Measurements triggered by discussions with V. Peskov
- Copper peaks no longer visible
- No molybdenum peaks observable
- No evident “burn” marks around the hole after the measurements





→ No evaporation?

	Copper	Molybdenum
Melting point [°C]	1083	2623

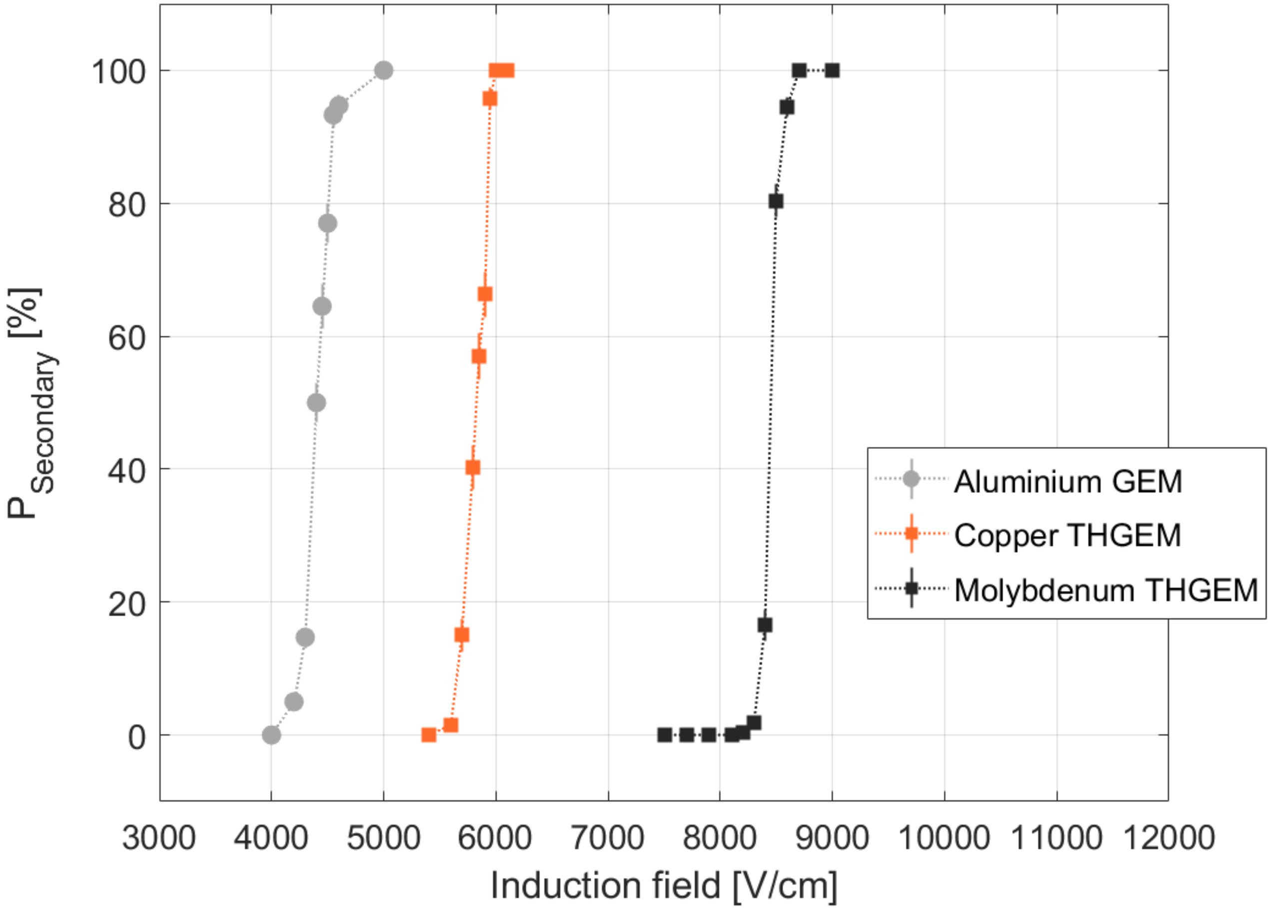


Stability against secondary discharges

- Secondary discharge probability:

$$P_{\mathrm{Secondary}} = \frac{\#\ \mathrm{secondary\ discharges}}{\#\ \mathrm{primary\ discharges}}$$

- Comparison with Alu-GEM not yet conclusive
  - Different hole geometry in GEM and THGEM
  - Questionable Alu-GEM quality
- Best comparison between copper and molybdenum single hole THGEMs
  - More systematic studies with the same hole geometry ongoing

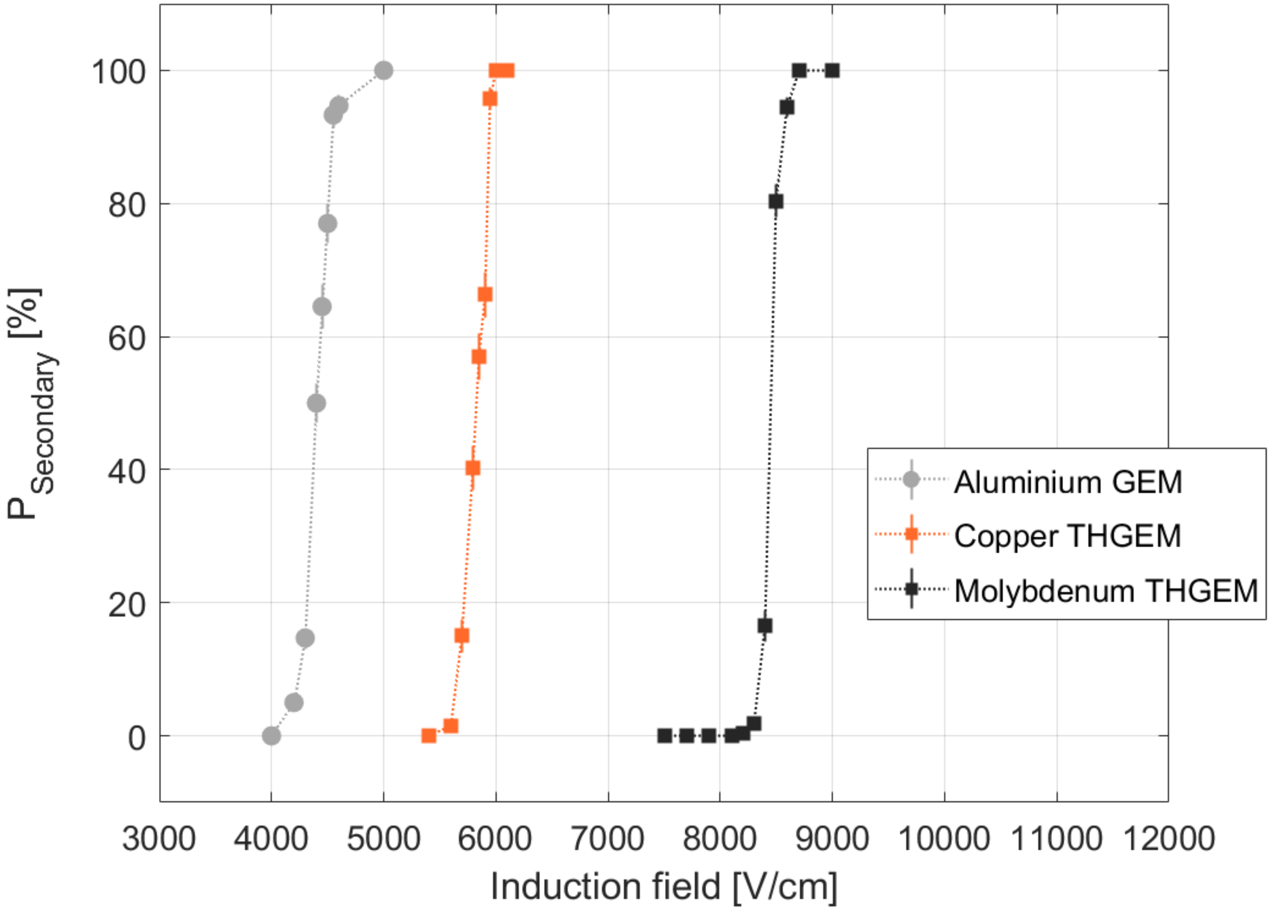


Stability against secondary discharges

- Material properties

	Conductivity [10^6 S/m]	Work function [eV]	Melting point [°C]	Thermal conductivity [W/m*K]
Cu	58,7	4.7	**1083**	386
Al	36,9	4.08	**660**	237
Mo	18,7	4.5	**2623**	138

- First hint of the material dependence



Summary

1. Spectroscopy can be used as a tool for studying discharges in MPGD structures
   - Materials abundant in the plasma after discharges can be identified
   - Direct observation of evaporated GEM foil material

2. Hints for the formation mechanism of secondary GEM discharges
   - Stability observed to scale with the melting temperature of the used conducting material
   - More measurements needed!

Outlook

- Systematic measurements with more electrode materials
  - Many thanks to Simon Williams (PCB LAB) for producing the exotic foils
- Higher resolution spectrometer
  - Determining the temperature of the created plasma
- Window with better cut-off (~200 nm)
- Spectroscopy lab at TUM is in preparations

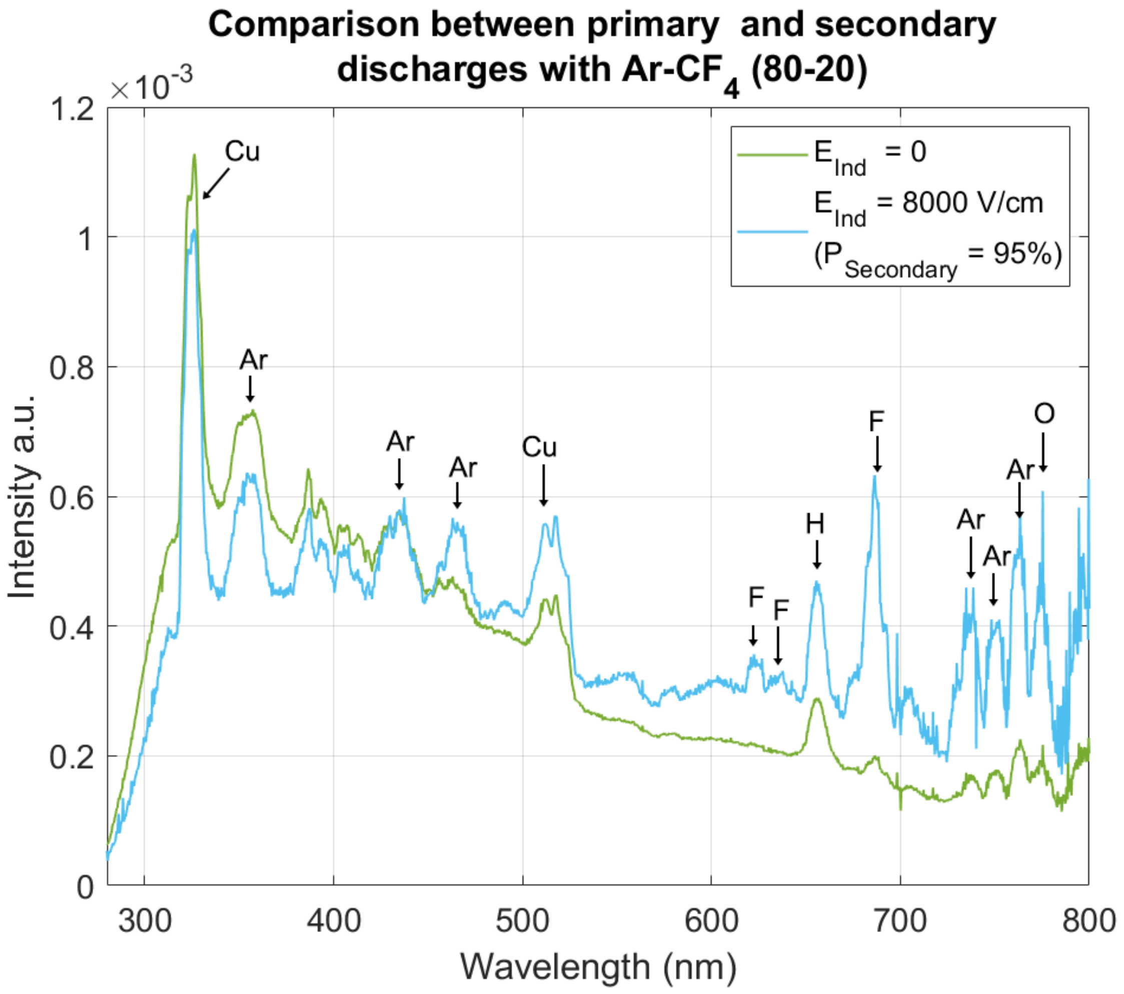
	Conductivity [10^6 S/m]	Work function [eV]	Melting point [°C]	Thermal conductivity [W/m*K]
Copper	58.7	4.7	1083	386
Aluminium	36.9	4.08	660	237
Molybdenum	18.7	4.5	2623	138
Tungsten	8.9	4.5	3422	174
Tantalum	7.6	4.22	3017	57.5
Stainless steel	1.37	4.4	1510	16.3

Available as of today!!

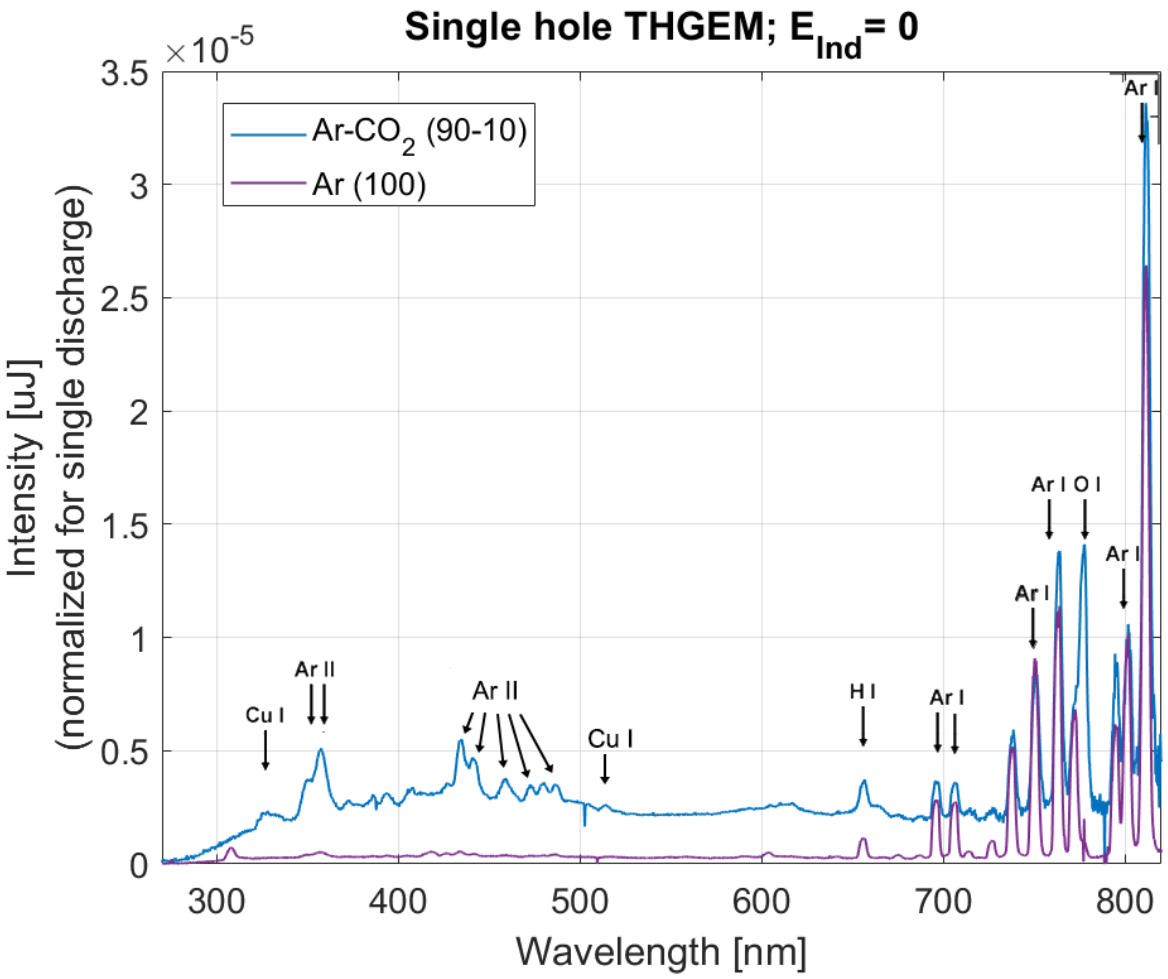
Thank you for your attention!

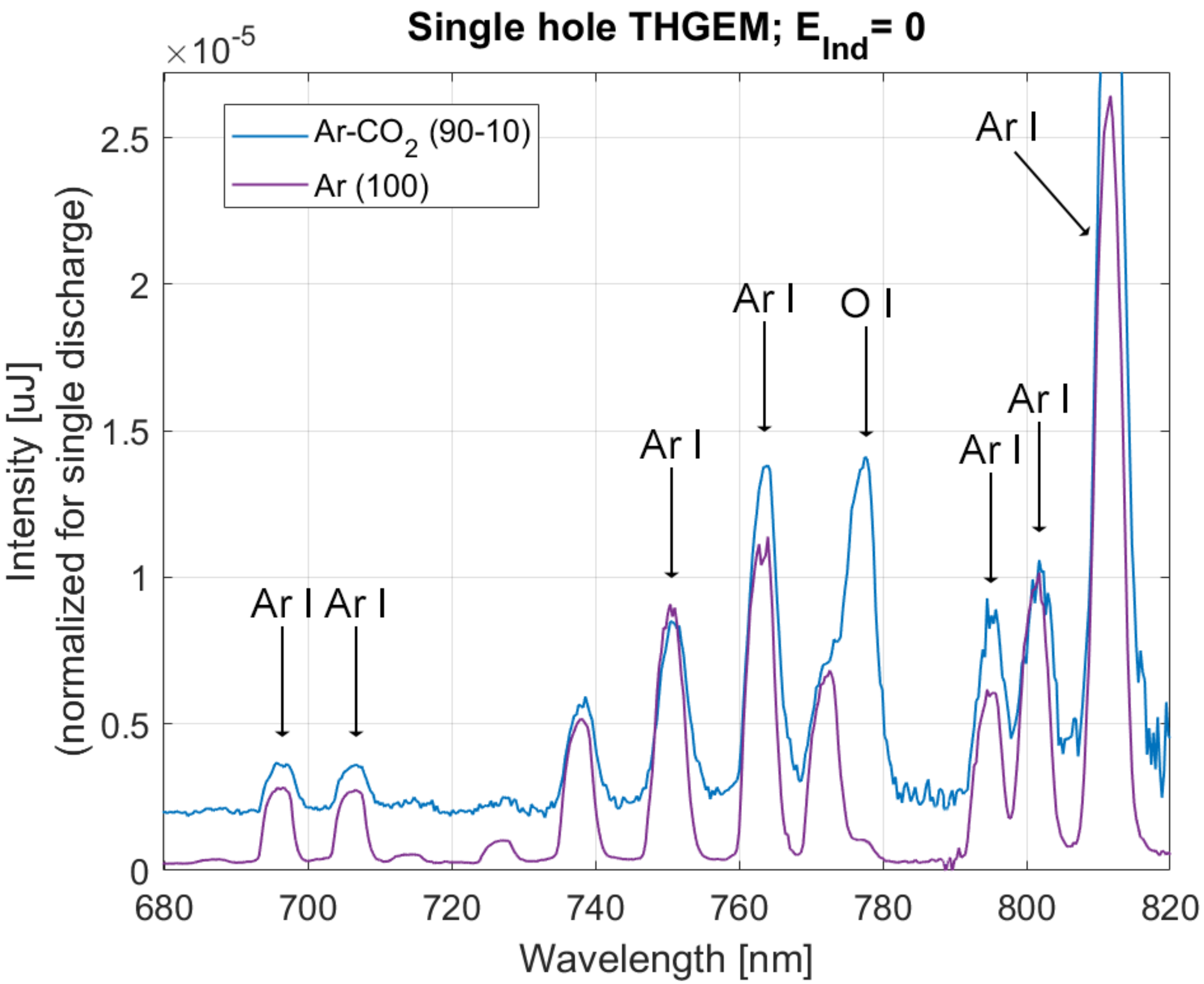
Spectrum of secondary discharges

- Same peaks observed with primary and secondary discharges
- Observed intensity of the peaks are different
  - Under investigation



Pure argon


Single hole THGEM; E_{Ind}= 0
×10^-5
Ar-CO2 (90-10)
Ar (100)
Intensity [uJ]
(normalized for single discharge)
Wavelength [nm]
Cu I
Ar II
Ar II
Cu I
H I
Ar I
Ar I
Ar I O I
Ar I
Ar I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