Tribology Campaign Results of Brake Emission Monitored by Proton-Transfer-Reaction Mass Spectrometry

February 17th, 2023

Set-up
A bit of background
Videos
Signal over time
Background
FM1 vs FM4
Gas emitted
Conclusion
Conclusion

Set-up

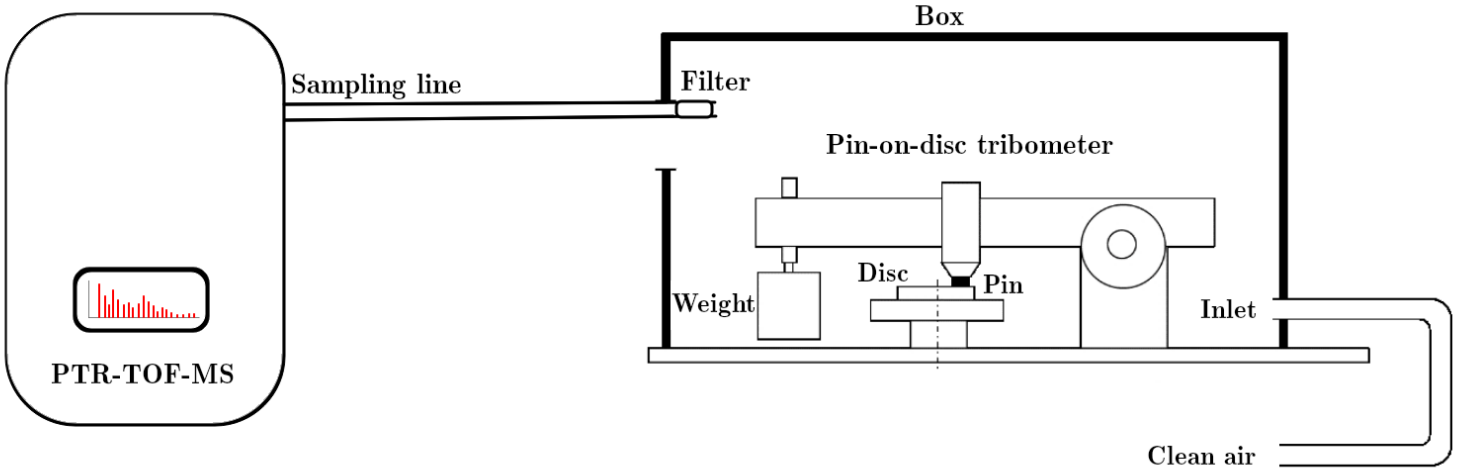


Figure: Experimental set-up (tribometer reproduced from Lyu Y Z et al, 2020 without permission).

Experimental conditions

- Two different materials: Low-Metallic Cu-free (FM1) and Non-Asbestos Organic (FM4)
- Contact pressure: 0.6 MPa to 1.1 MPa
- Velocity: $1\,\mathrm{m}\cdot\mathrm{s}^{-1}$ to $4\,\mathrm{m}\cdot\mathrm{s}^{-1}$

Tribology Campaign Results of Brake Emission Monitored by Proton-Transfer-Reaction Mass Spectrometry

Set-up
Experimental conditions
A bit of background
Videos
Signal over time
Background
FM1 vs FM4
Gas emitted
Conclusion
Conclusion

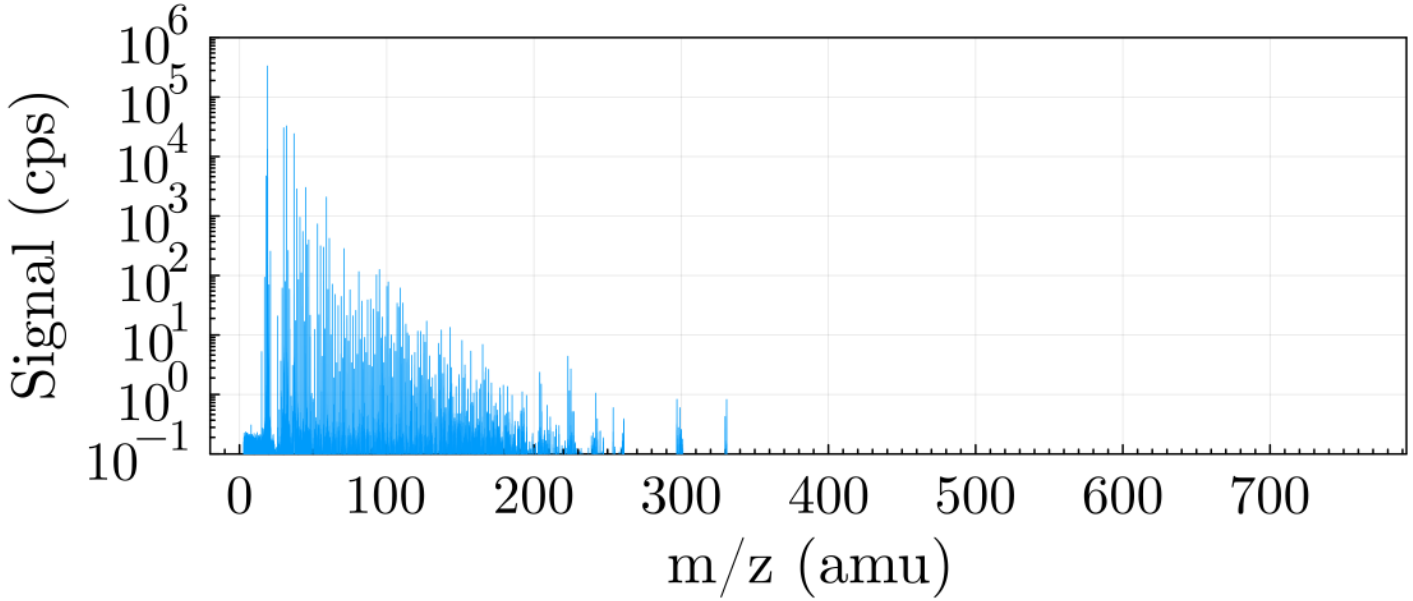
PTR-TOF-MS

FUSION Ionicon

- Chemical ionization by H_3O^+
- Proton transfer but also few charge transfer (quantified *ca* 5%)
- Spectra recorded up to $m/z = 770\,u$
- Detection sensitivity at the ppt (for common VOC)
- Resolution *ca* 8000

- For instance, it is possible to distinguish in mass between $C_6H_5H^+$ (77.039) and $C_3H_8O_2H^+$ (77.060)
but not between $C_6H_5H^+$ and $C_2H_8OSiH^+$ (77.042).
- Isotopic ratio sometimes helpful (but not always).

A typical mass spectrum



Tribology Campaign Results of Brake Emission Monitored by Proton-Transfer-Reaction Mass Spectrometry

Set-up

A bit of background

Videos

Signal over time

Background

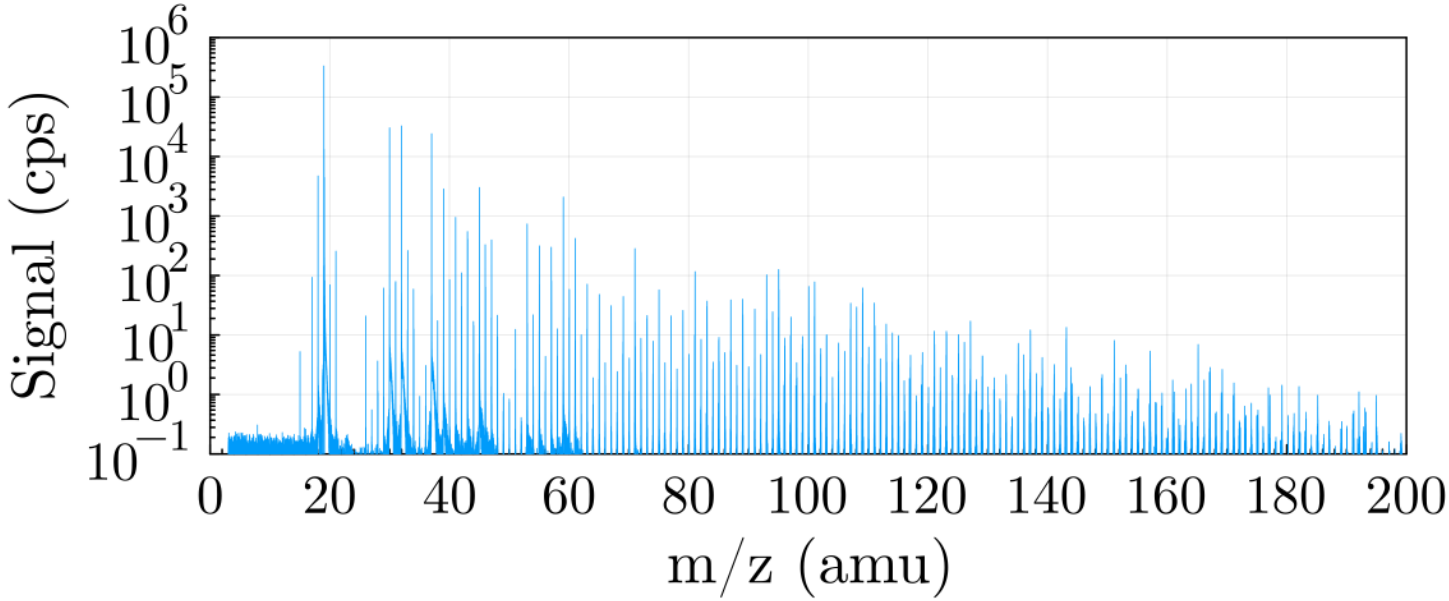
FM1 vs FM4

Gas emitted

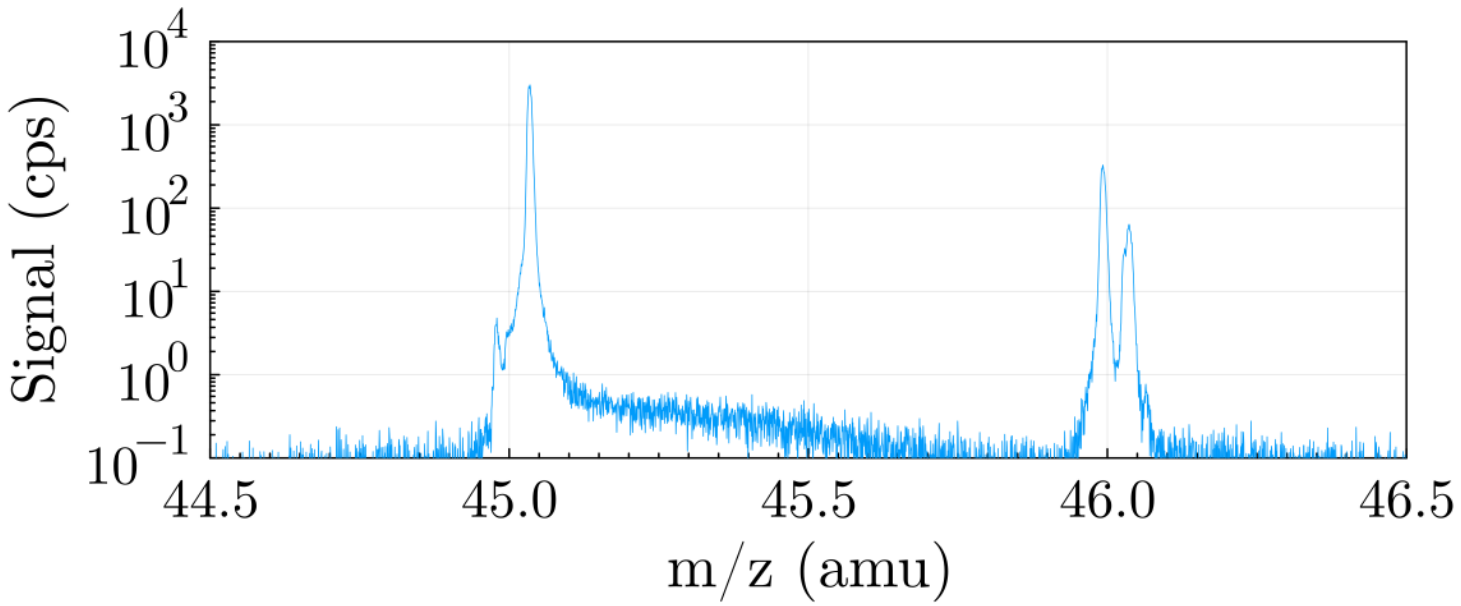
Conclusion

Conclusion

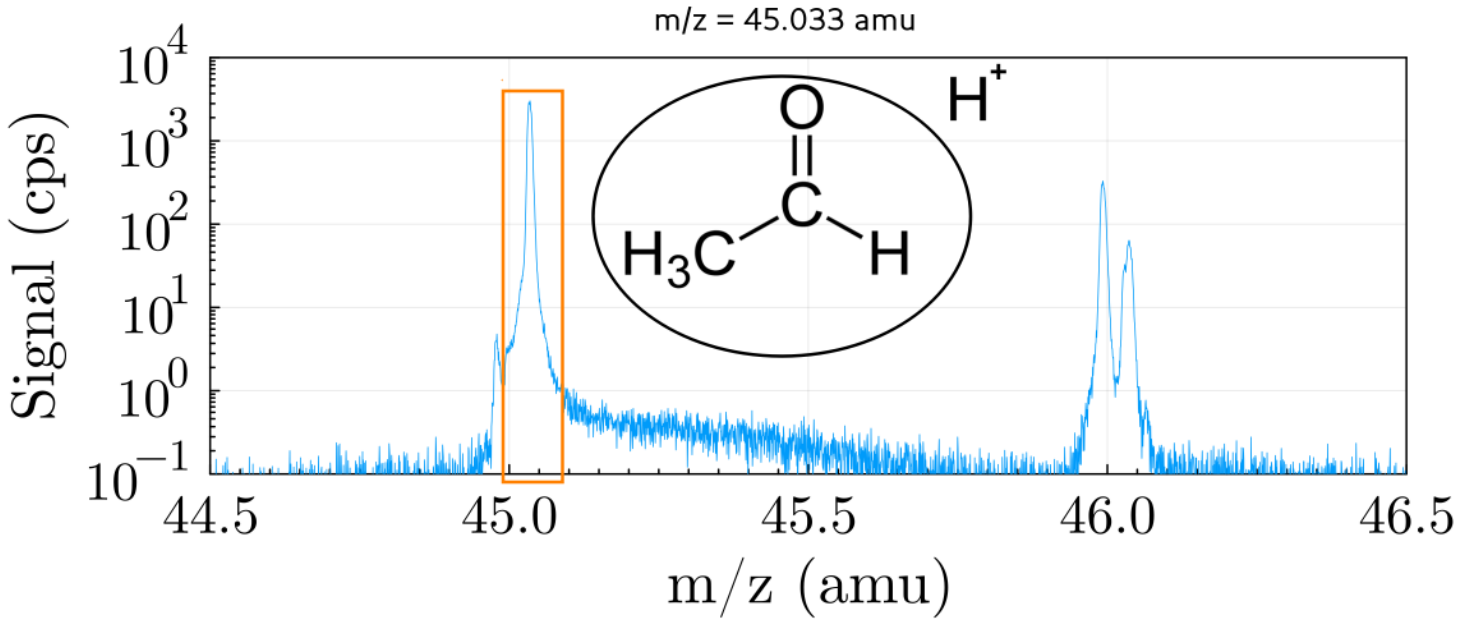
A typical mass spectrum



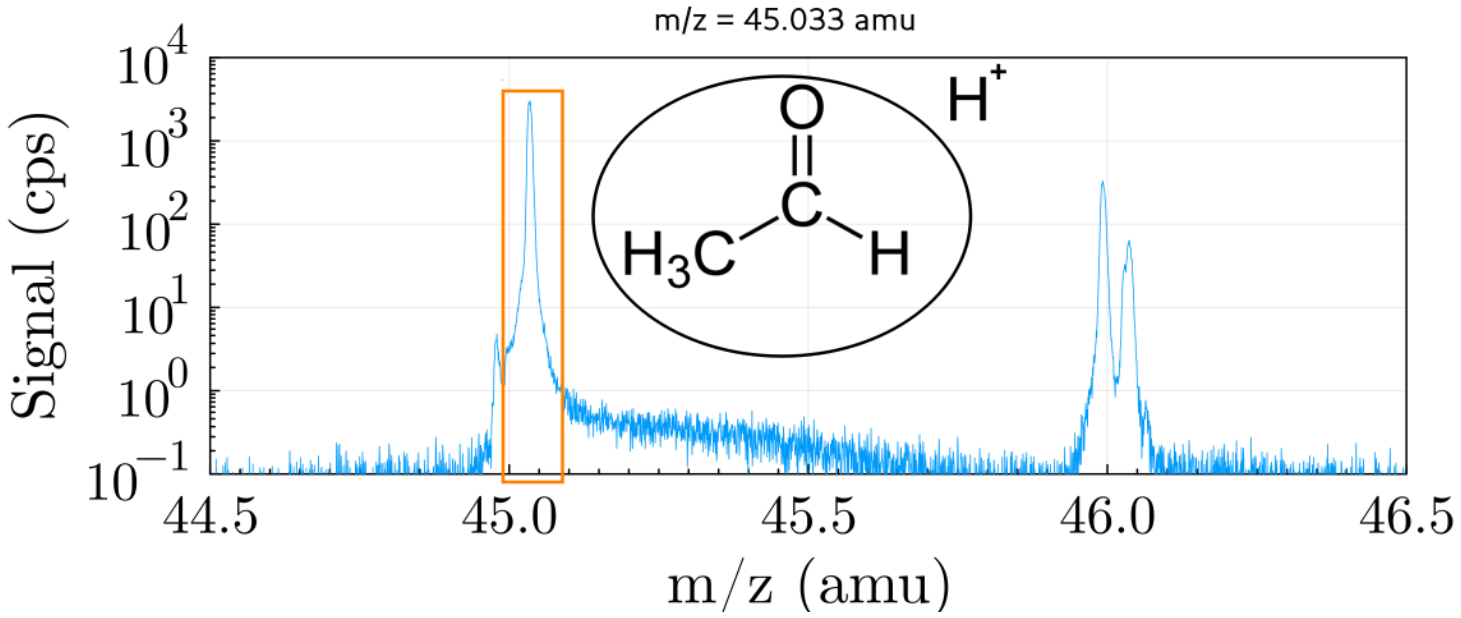
A typical mass spectrum

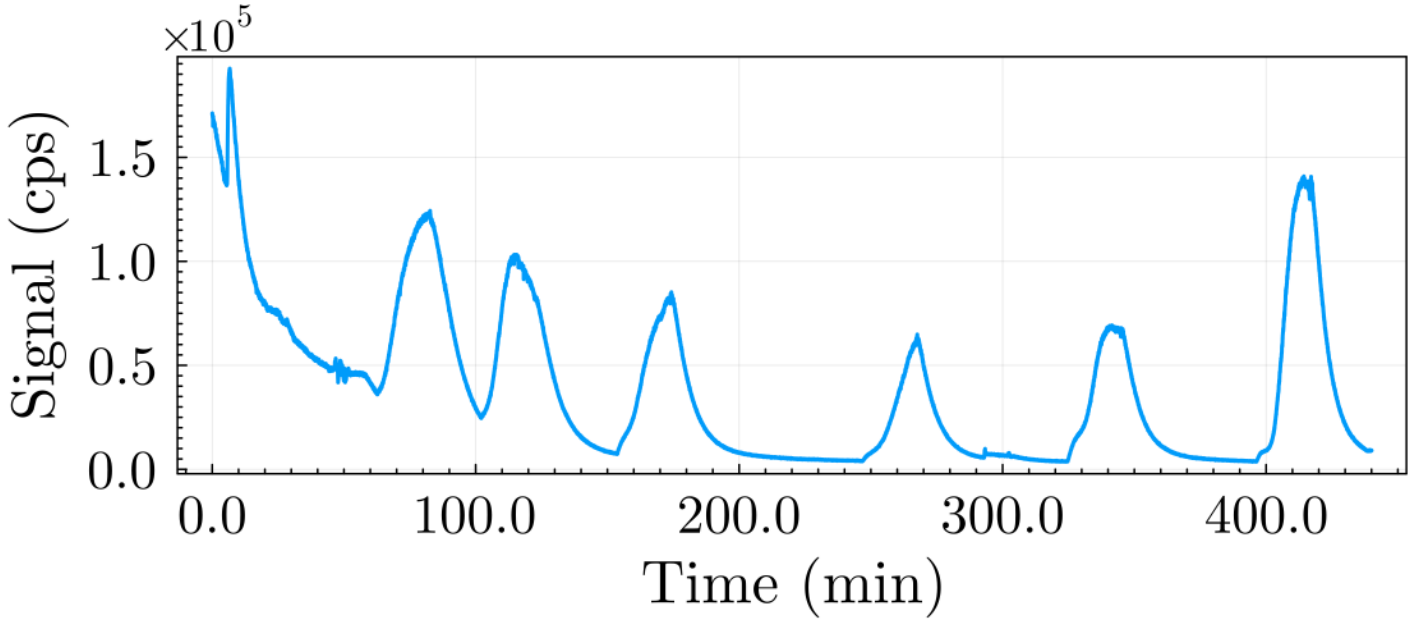


Acetaldehyde



Acetaldehyde





Tribology Campaign Results of Brake Emission Monitored by Proton-Transfer-Reaction Mass Spectrometry

Set-up

A bit of background

Videos

Signal over time

Background

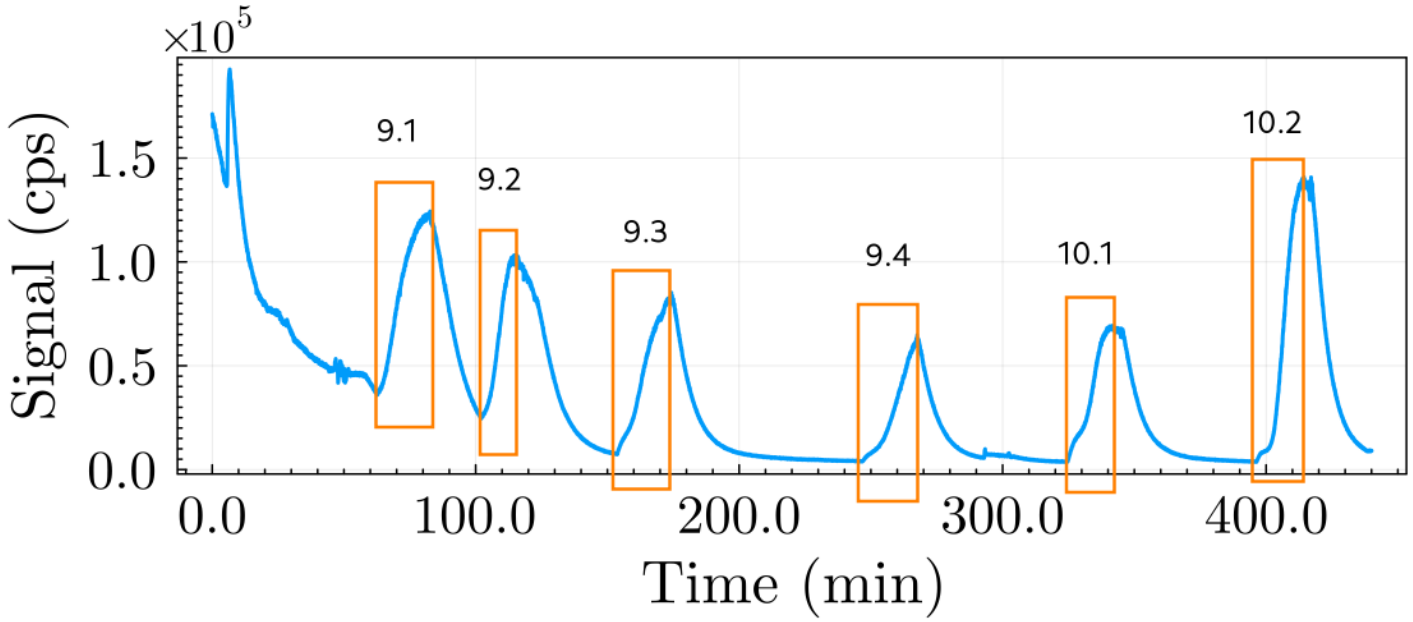
FM1 vs FM4

Gas emitted

Conclusion

Conclusion

Kinetic Trace



test number	9.1	9.2	9.3	9.4	10.1	10.2
Cp (MPa)	0.9				1.1	
velocity (m/s)	2	3	3	4	3	4

Tribology Campaign Results of Brake Emission Monitored by Proton-Transfer-Reaction Mass Spectrometry

Set-up

A bit of background

Videos

Signal over time

Background

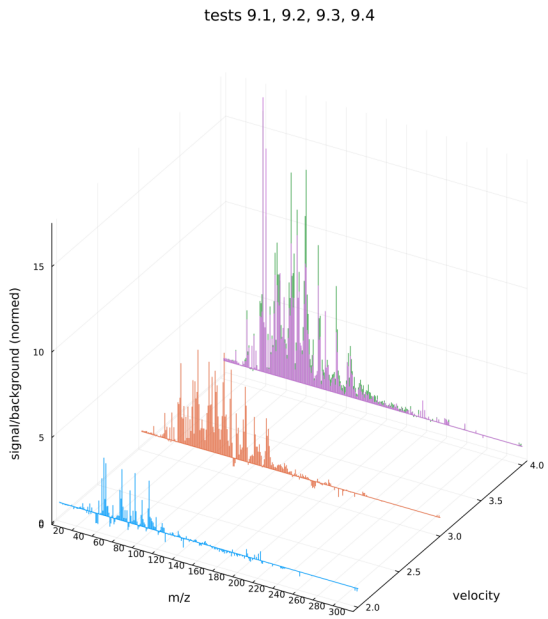
FM1 vs FM4

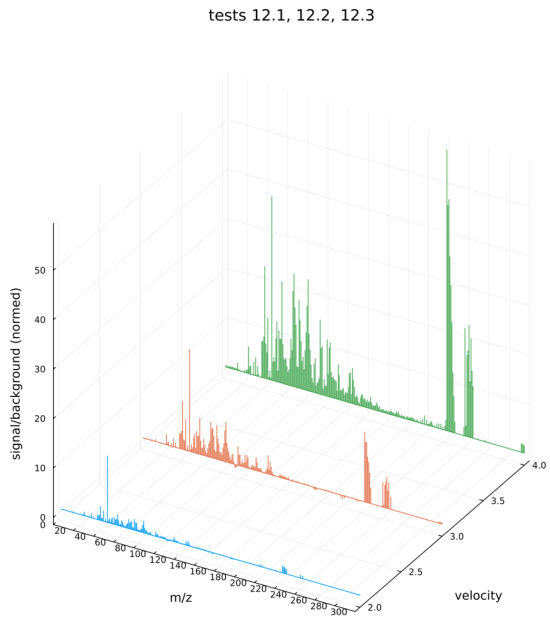
Gas emitted

Conclusion

Conclusion

FM1 vs FM4 - Cp = 0.9 MPa

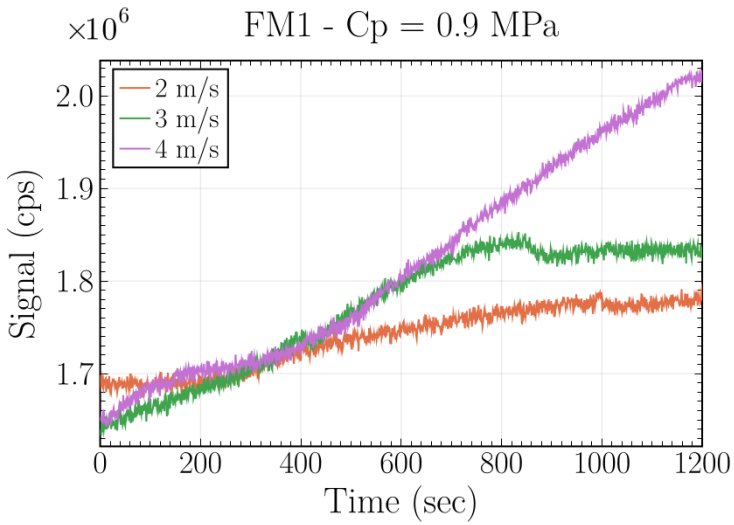


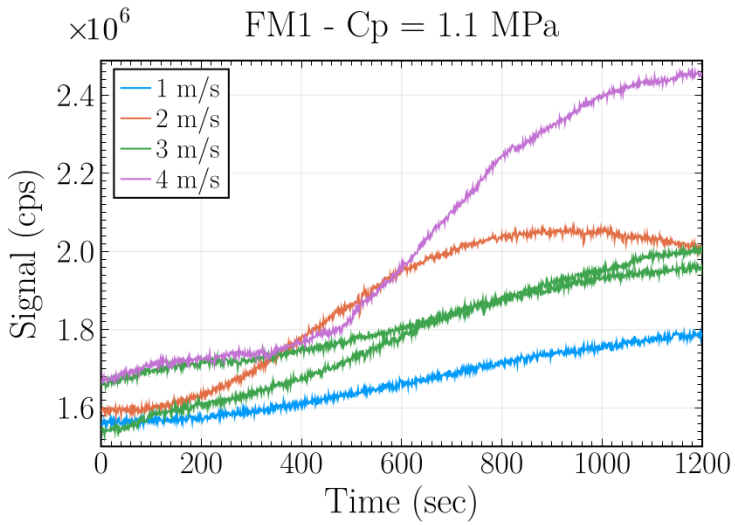


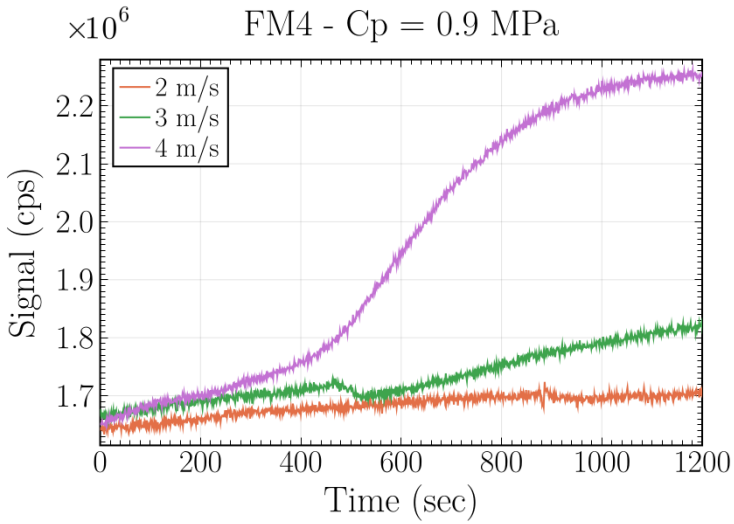
2 hours experiment - FM4: $Cp = 0.6\,\mathrm{MPa}$, $v = 4\,\mathrm{m}\cdot\mathrm{s}^{-1}$

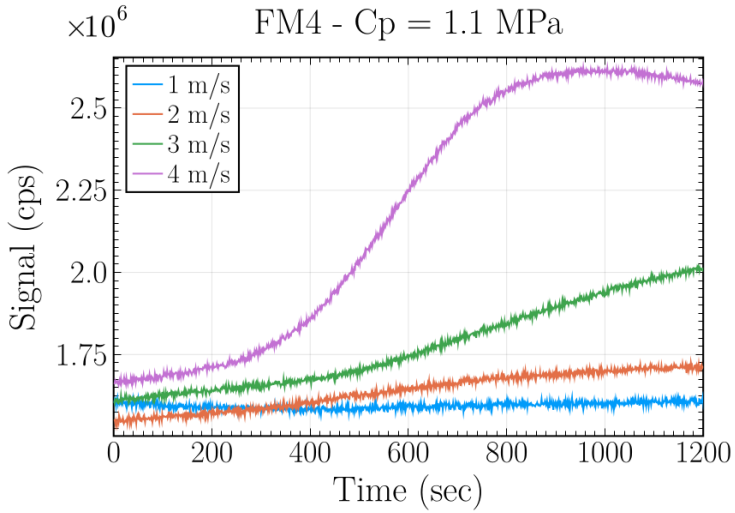
- We can see a "threeshold"
- Reaches a maximum and then saturates

Overall signal over time

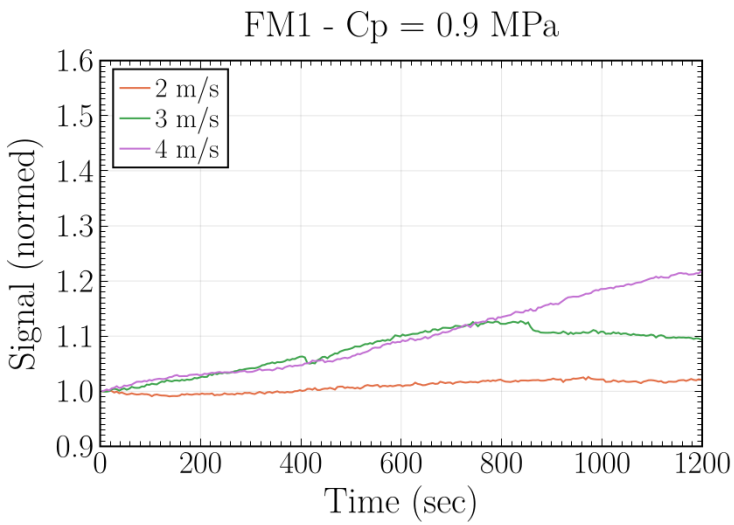


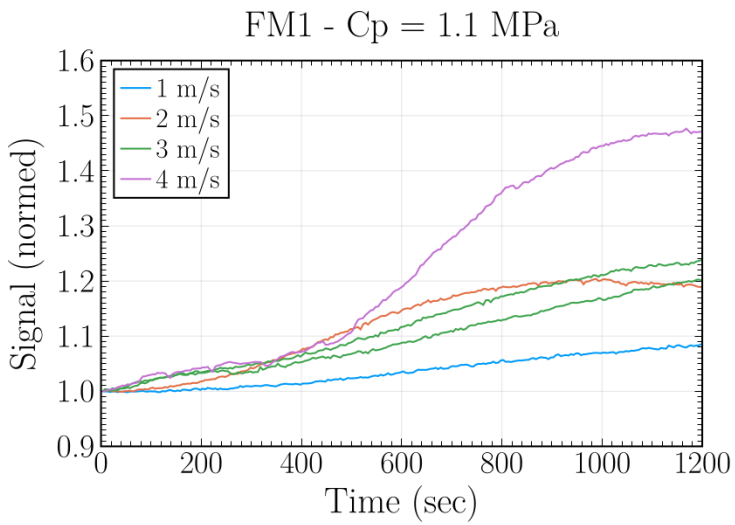


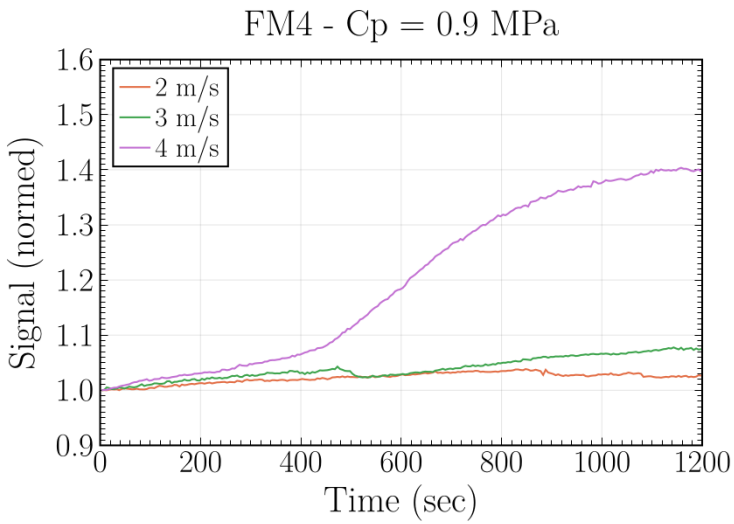


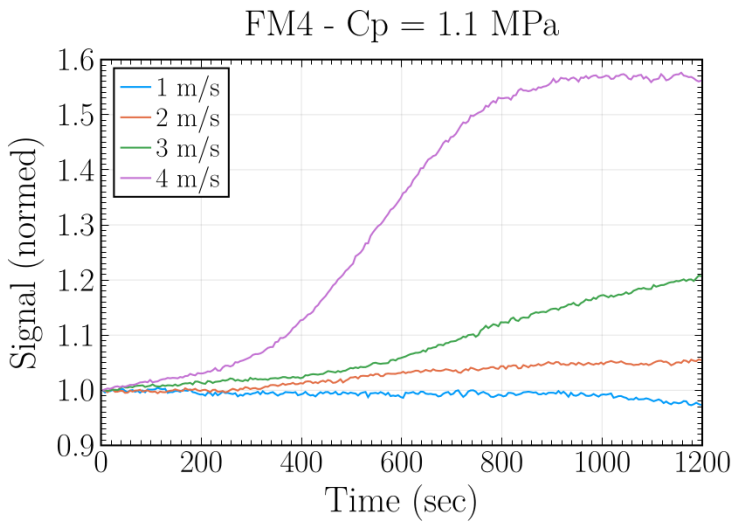


Overall signal over time (normalized)









Tribology Campaign Results of Brake Emission Monitored by Proton-Transfer-Reaction Mass Spectrometry

Set-up

A bit of background

Videos

Signal over time

Background

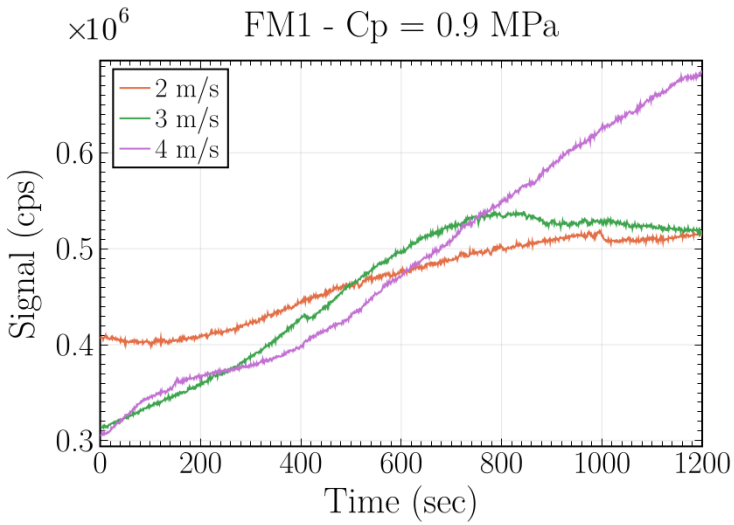
FM1 vs FM4

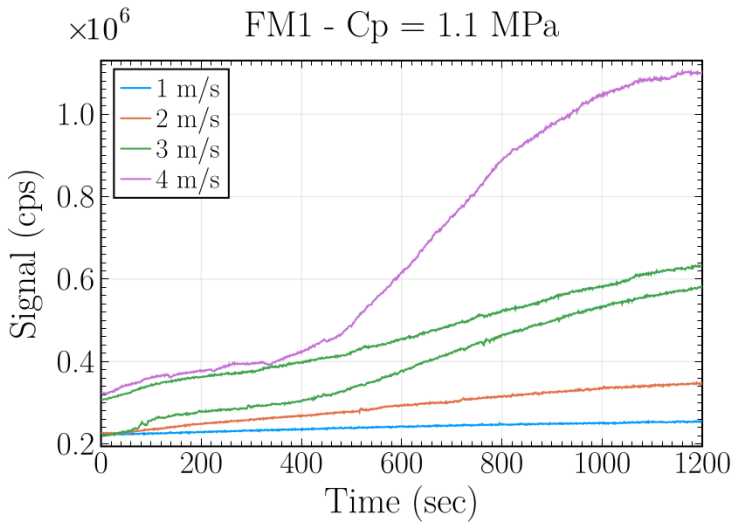
Gas emitted

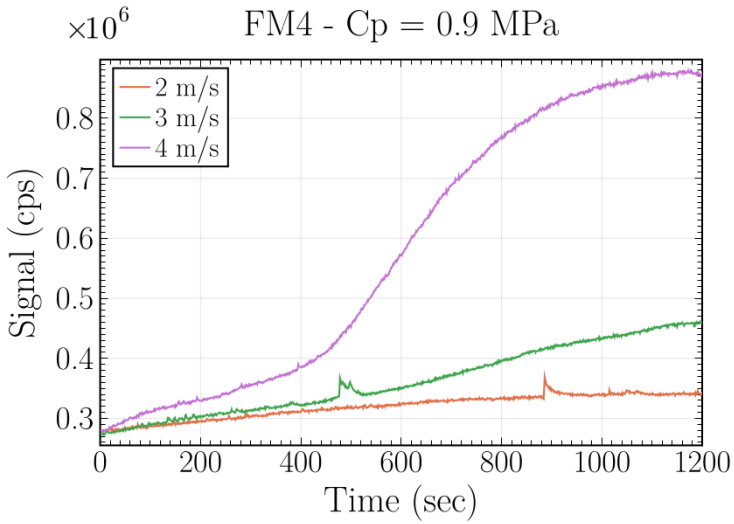
Conclusion

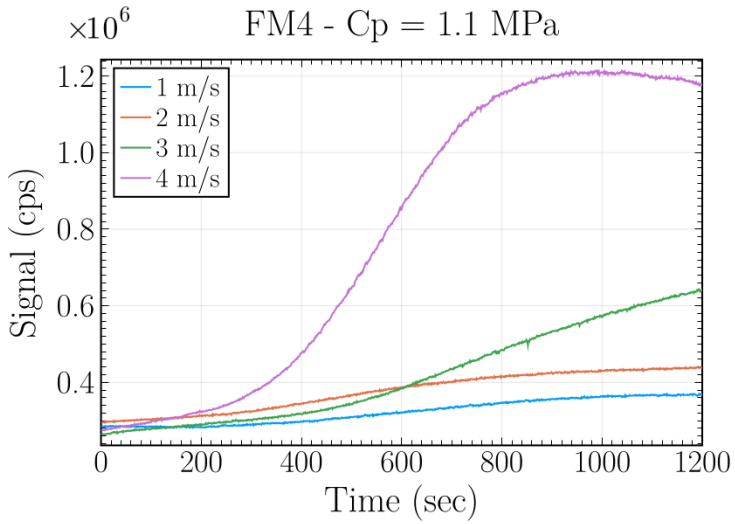
Conclusion

Signal over time (start at m/z=35)









Tribology Campaign Results of Brake Emission Monitored by Proton-Transfer-Reaction Mass Spectrometry

Set-up

A bit of background

Videos

Signal over time

Background

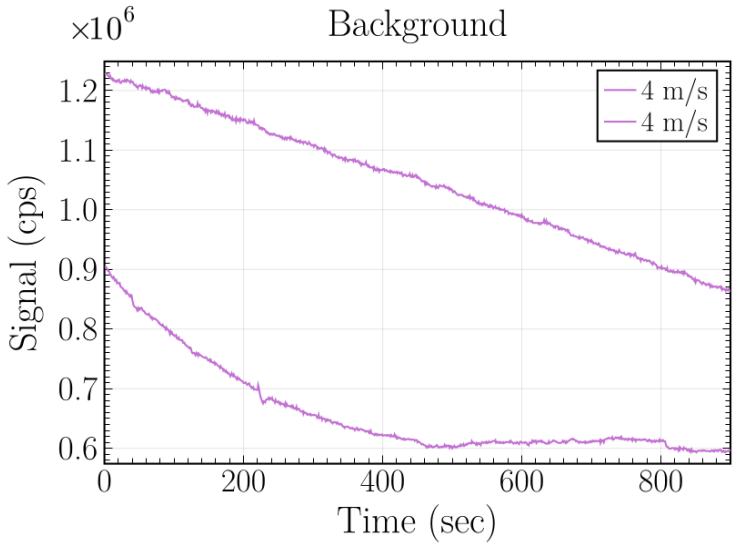
FM1 vs FM4

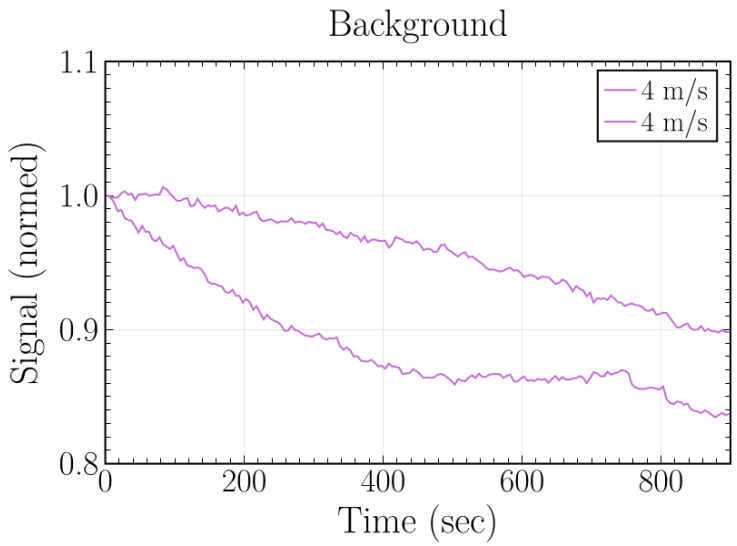
Gas emitted

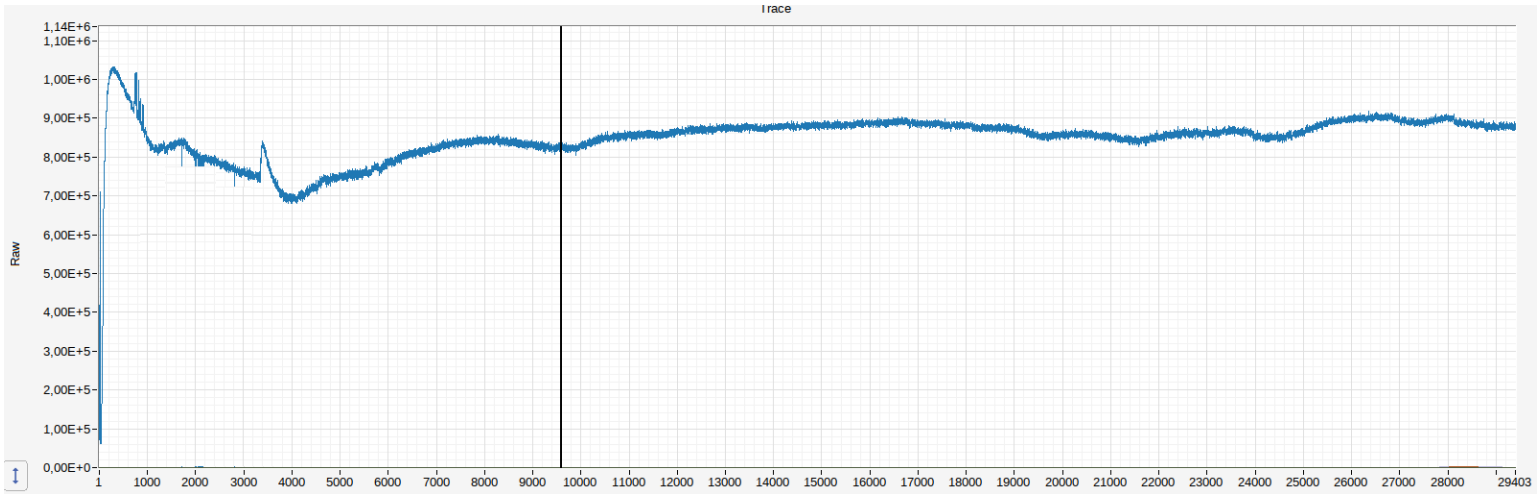
Conclusion

Conclusion

Background







Tribology Campaign Results of Brake Emission Monitored by Proton-Transfer-Reaction Mass Spectrometry

Set-up

A bit of background

Videos

Signal over time

Background

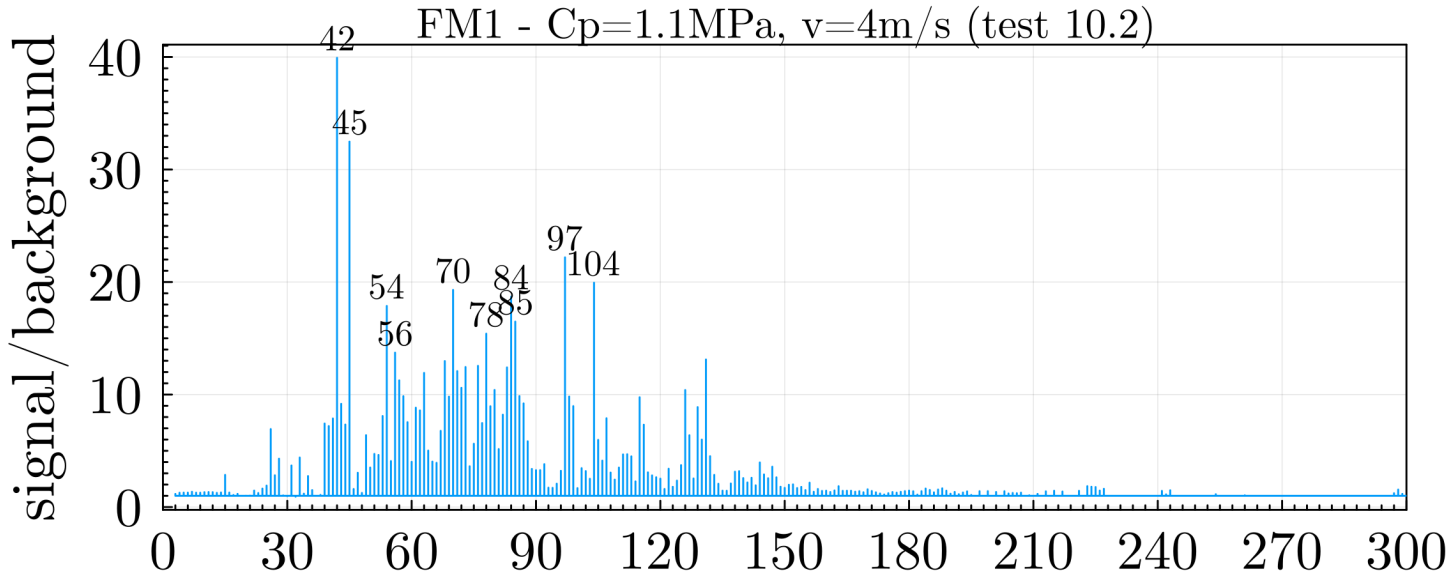
FM1 vs FM4

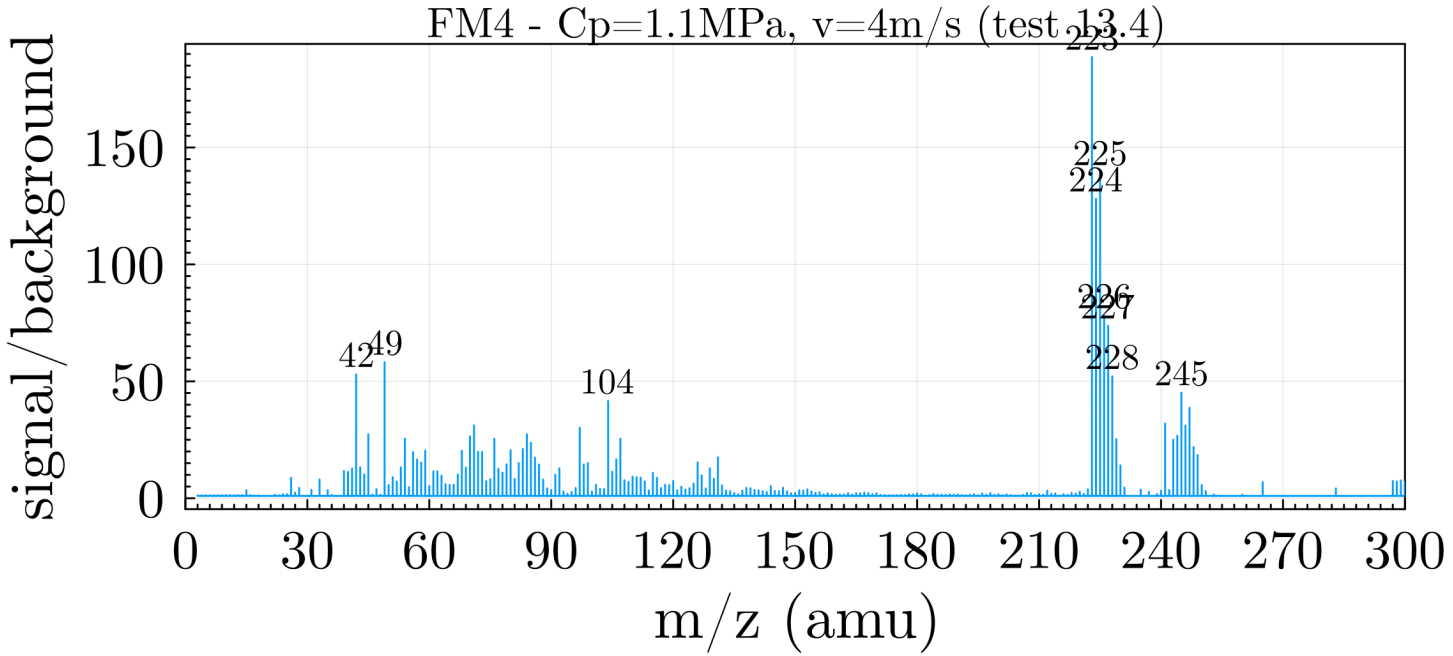
Gas emitted

Conclusion

Conclusion

FM1 vs FM4





Tribology Campaign Results of Brake Emission Monitored by Proton-Transfer-Reaction Mass Spectrometry

Set-up

A bit of background

Videos

Signal over time

Background

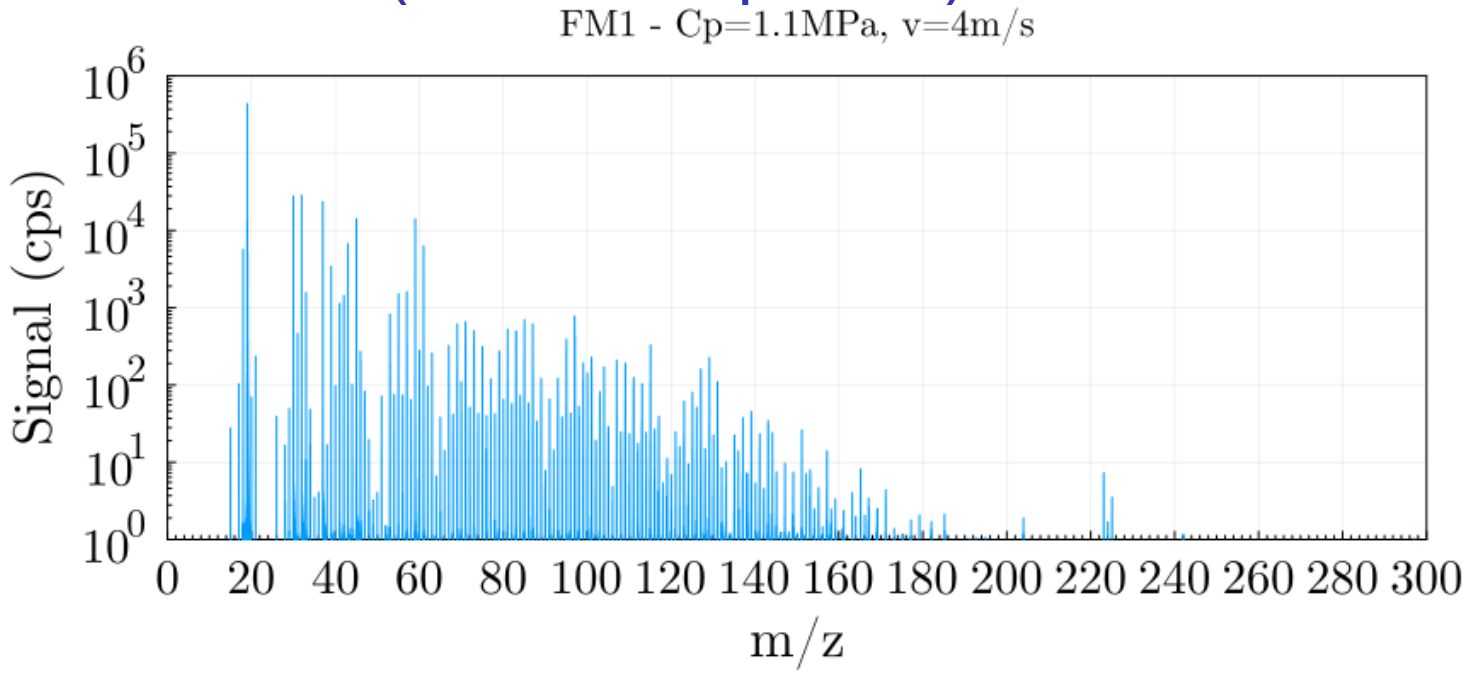
FM1 vs FM4

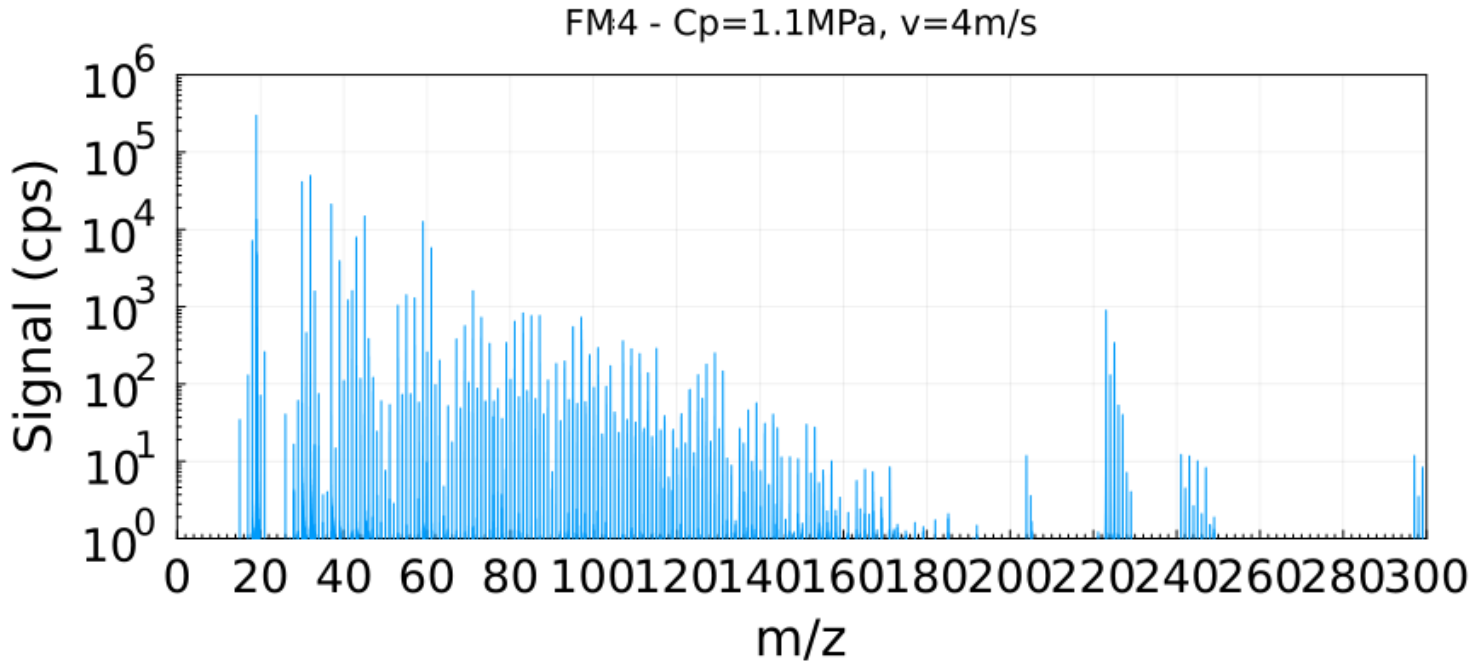
Gas emitted

Conclusion

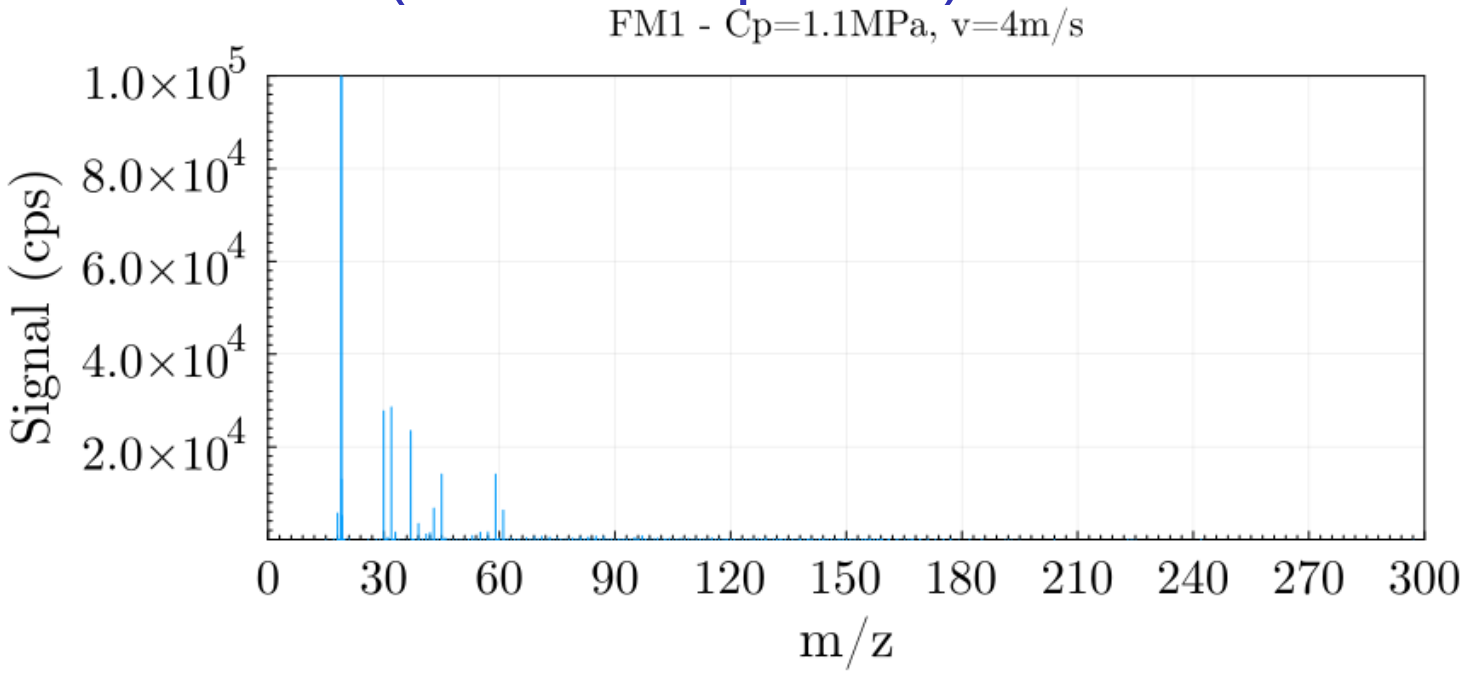
Conclusion

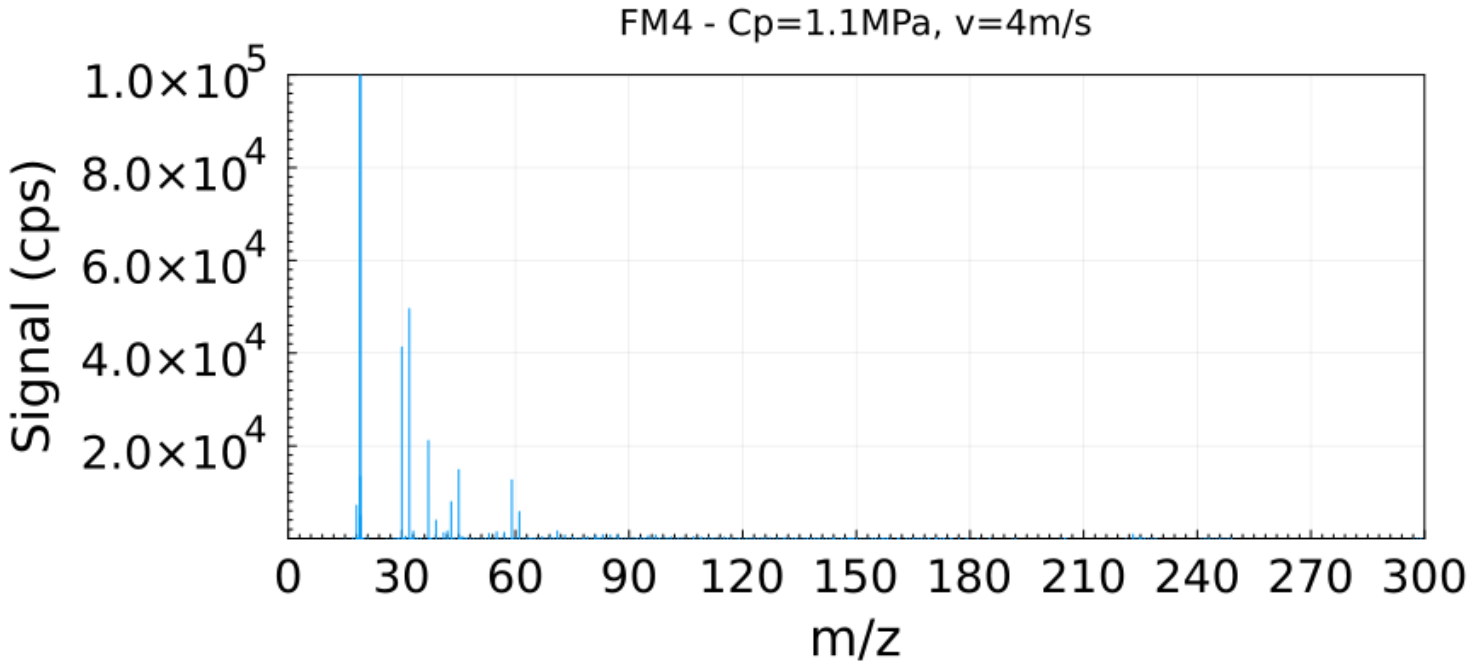
FM1 vs FM4 (absolute spectra)





FM1 vs FM4 (absolute spectra)





Tribology Campaign Results of Brake Emission Monitored by Proton-Transfer-Reaction Mass Spectrometry

Set-up

A bit of background

Videos

Signal over time

Background

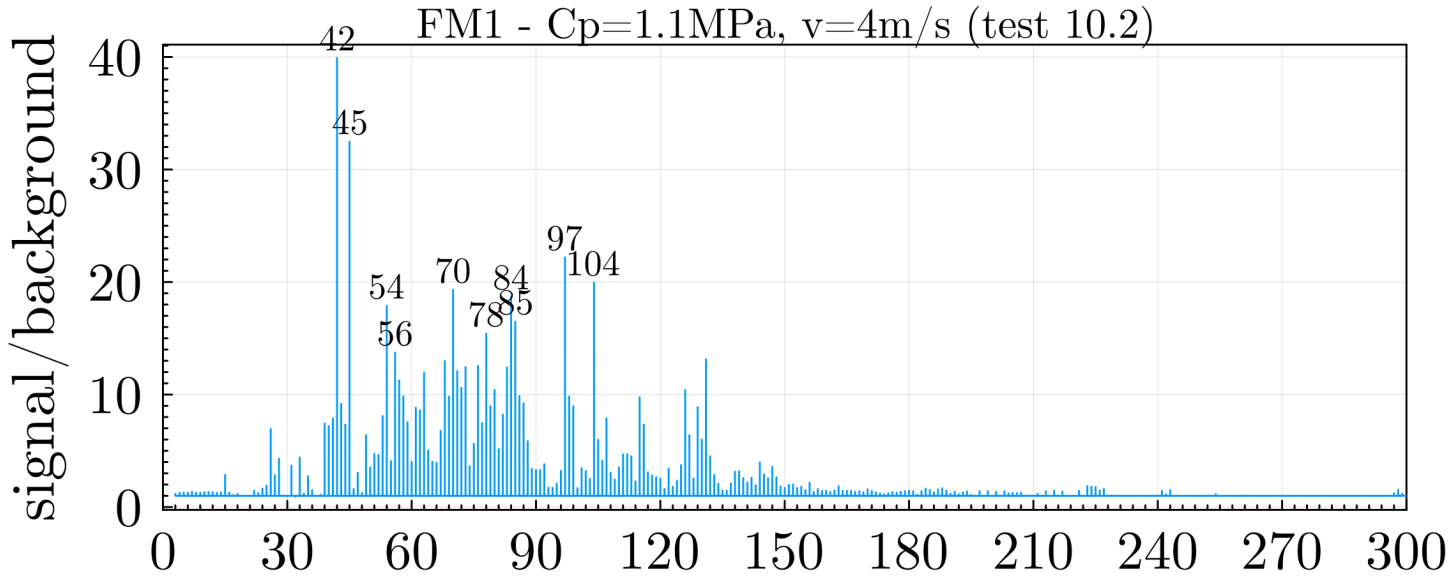
FM1 vs FM4

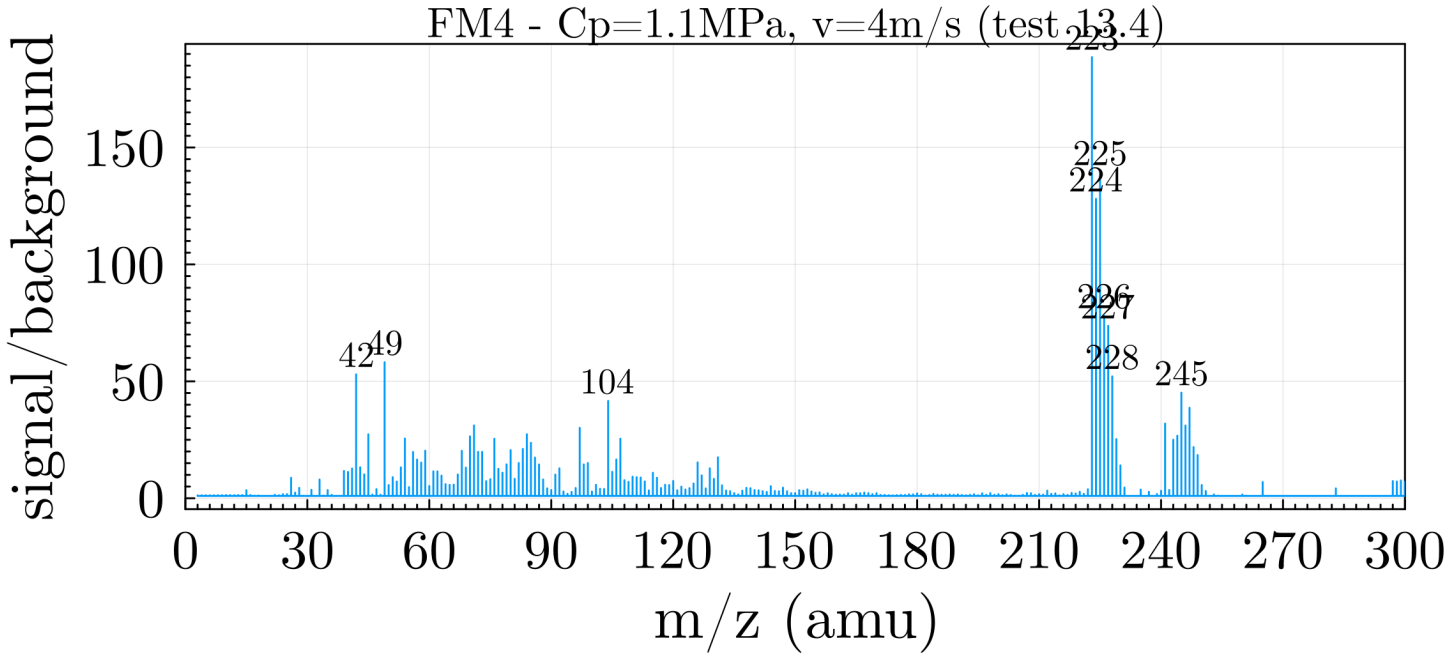
Gas emitted

Conclusion

Conclusion

FM1 vs FM4





Tribology Campaign Results of Brake Emission Monitored by Proton-Transfer-Reaction Mass Spectrometry

Set-up

A bit of background

Videos

Signal over time

Background

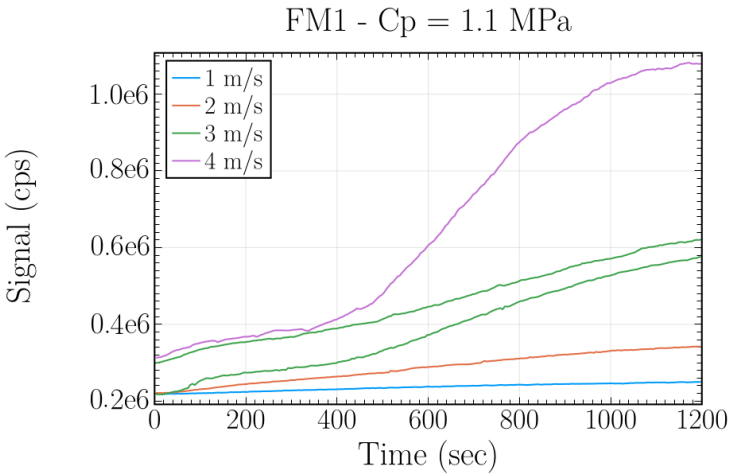
FM1 vs FM4

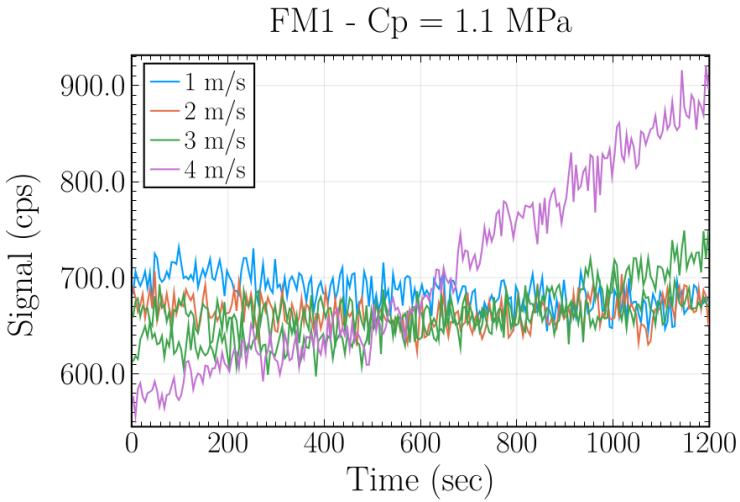
Gas emitted

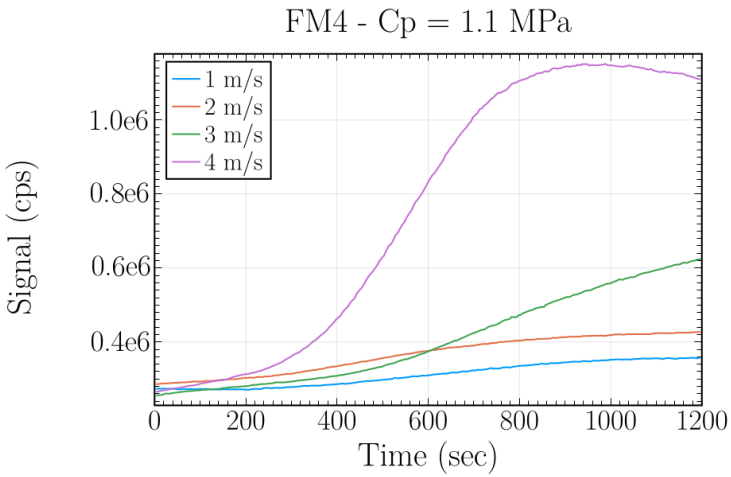
Conclusion

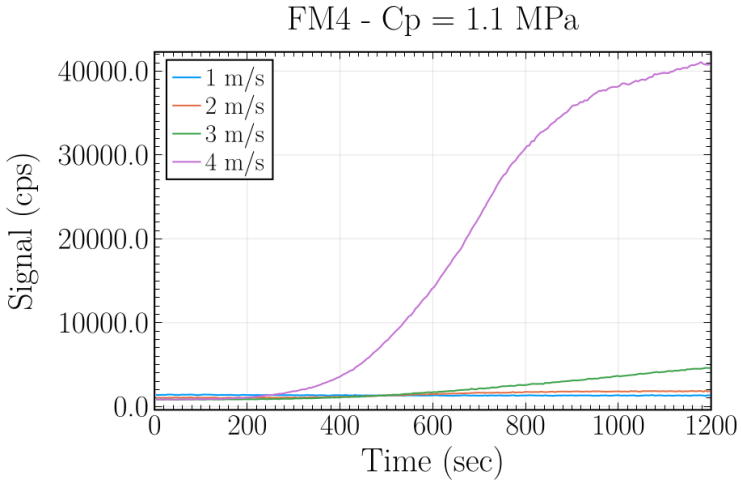
Conclusion

Group1 (35.5-130 amu) vs group2 (210-320 amu)

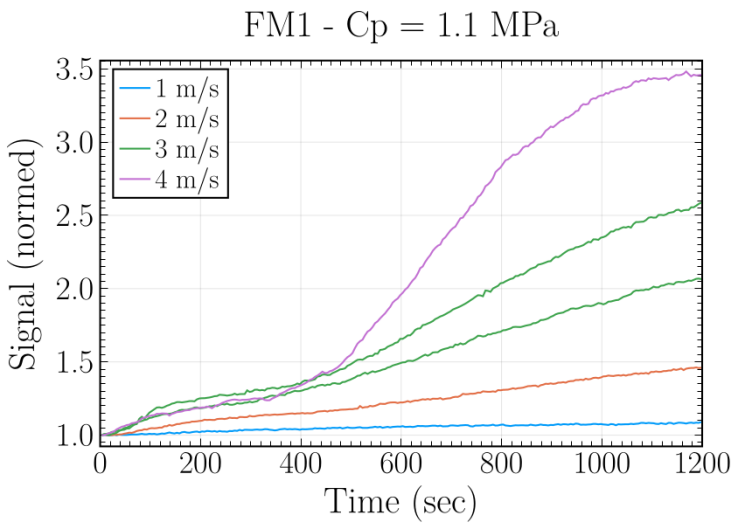


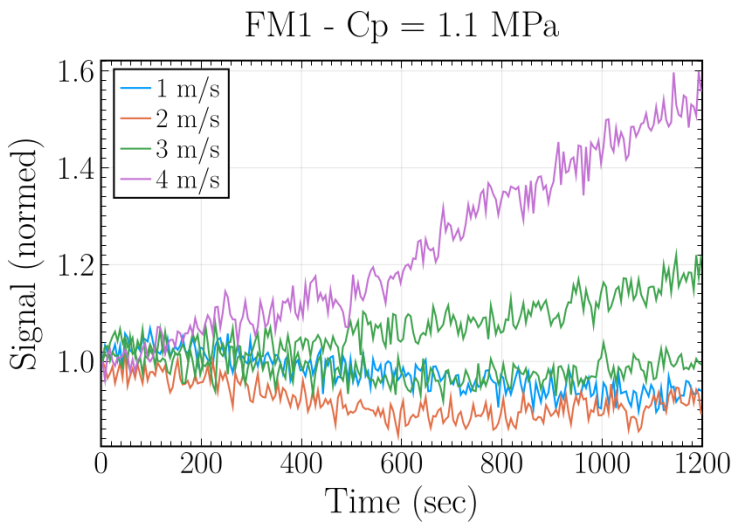


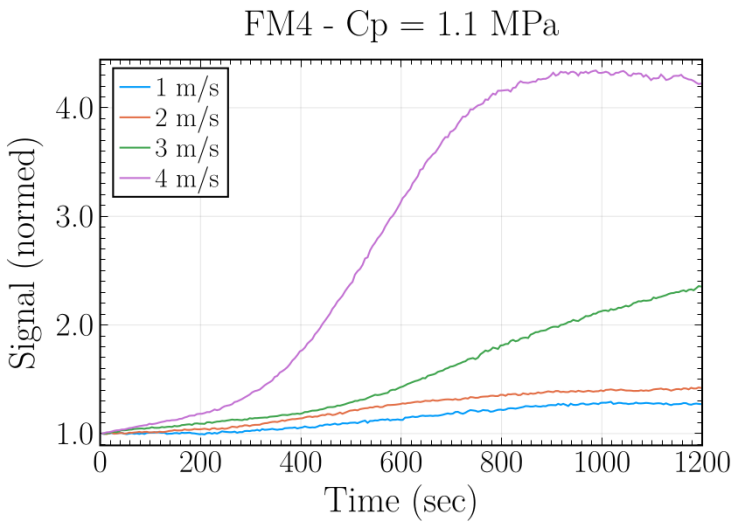


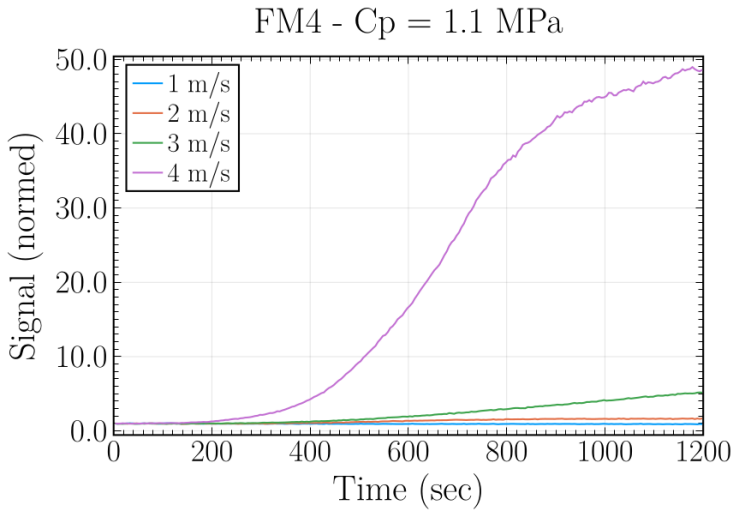


Group1 (35.5-130 amu) vs group2 (210-320 amu)









Gas emitted

- Hydrocarbon: C_3H_2, C_3H_4, C_4H_6, C_4H_8, C_5H_6, C_5H_8, C_6H_6, C_6H_{10}, C_7H_6, C_7H_8, C_7H_{12}, C_8H_{10}
- Hydrocarbon derivatives: CH_4O,C_2H_2O, C_2H_4O, $C_2H_4O_2$, C_2H_6O, C_3O, $C_3H_2O_2$, C_3H_4O, C_3H_6O, $C_3H_8O_2$, C_4H_6O, $C_4H_6O_2$, C_4H_8O, $C_5H_4O_2$, C_5H_8O, C_6H_4O, C_6H_6O, $C_7H_6O_2$, C_7H_8O, $C_7H_{14}O$, $C_9H_{16}O$
- Nitrile: C_2H_3N, $C_8H_{15}N$
- Likely to be some CH_4SH
- Siloxane (D3) $(SiO(CH_3)_2)_3$ (and another contribution yet to be identified)

And many other...

Tribology Campaign Results of Brake Emission Monitored by Proton-Transfer-Reaction Mass Spectrometry

Set-up

A bit of background

Videos

Signal over time

Background

FM1 vs FM4

Gas emitted

Conclusion

Conclusion

Left to be done

- Emission vs temperature
- Can we discriminate between different layers of materials?
- Investigate a bit more the reproducibility (background or FUSION effect)
- Absolute concentration estimation when possible (ppb vs ppt) and compute an emission rate
- Should the engine be accounted for?
- Look a bit closer to the charge transfer

Conclusion

- Several VOC emitted and identified
- Gas emission increase with Cp and v
- Siloxane are NAO fingerprint
- Regime change (according to temperature or layer ?)

Conclusion

- Several VOC emitted and identified
- Gas emission increase with Cp and v
- Siloxane are NAO fingerprint
- Regime change (according to temperature or layer ?)

- What about the correlation to the particles ?
- Your welcome to ask for datas, plots, and check the analysis
- I will put a first draft on Overleaf