Richard Kesler

Richard Kesler is a research engineer with the Fire Safety Research Institute (FSRI), part of UL Research Institutes, based out of Columbia, Maryland, USA. He has worked to characterize the thermal and chemical properties of the fireground and understand how firefighting personal protective equipment performs under those conditions.

Richard served as a member of the Savoy (Illinois) Fire Department for more than 10 years, at ranks up to Assistant Chief. Richard holds a PhD in kinesiology and MS and BS degrees in bioengineering from the University of Illinois.

UL Research Institutes

Fire Safety Research Institute

ICEV vs EV

Chemical Characterization of Vehicle Fires

Richard Kesler
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Research Questions

What are the hazards associated with electric vehicle fires?

Do they differ from ICEVs?

How do the hazards vary by position?

Electric Vehicle Tests

Full-scale EV burns:

Large Fire Lab - Northbrook, IL

- Measurements of fire behavior
- Turnout gear swatches
- Sampling of smoke plume
- Operational level analysis

Methodology – Smoke Composition & Firefighter Exposure

e: Ref [1]

BTEX, Aldehydes, Metals, SO2, HCN, HF, HCL, Isocyanates, PAHs, Inhalable Particulate

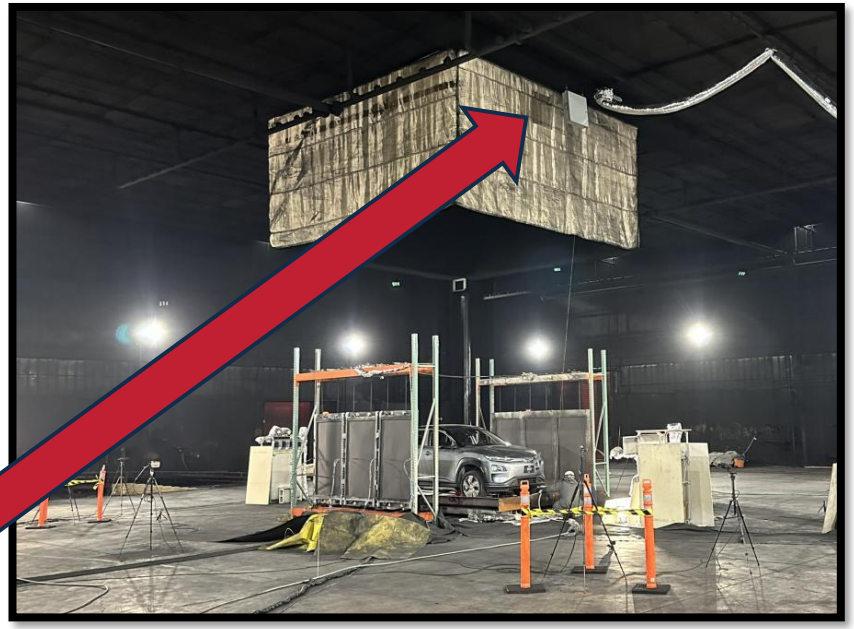
Methodology – Smoke Composition & Firefighter Exposure

e: Ref [1]

BTEX, Aldehydes, Metals, SO2, HCN, HF, HCL, Isocyanates, PAHs, Inhalable Particulate

Methodology – Smoke Plume

BTEX, Aldehydes, Metals, SO2, HCN, HF, HCL, Isocyanates, PAHs

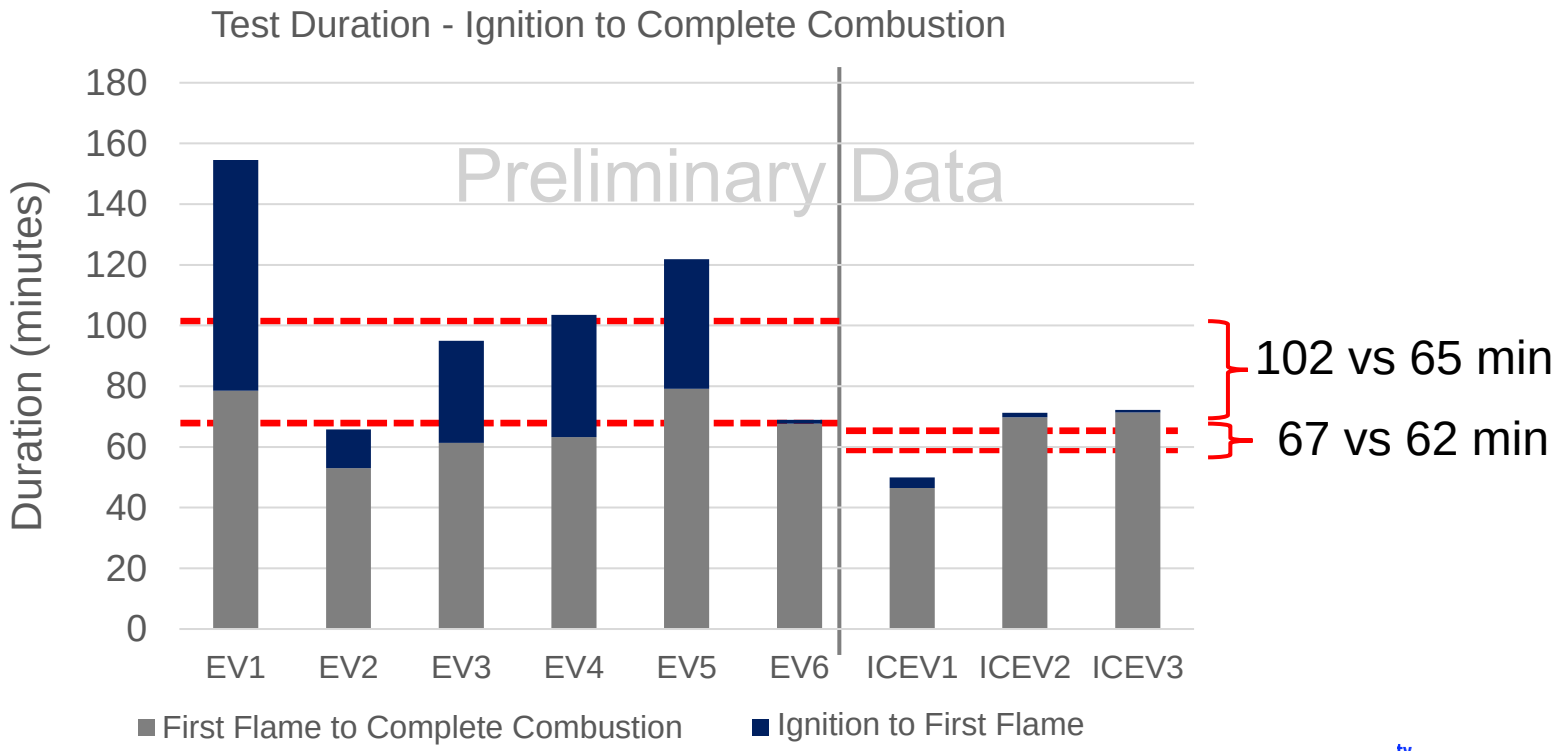


Vehicle Specifications

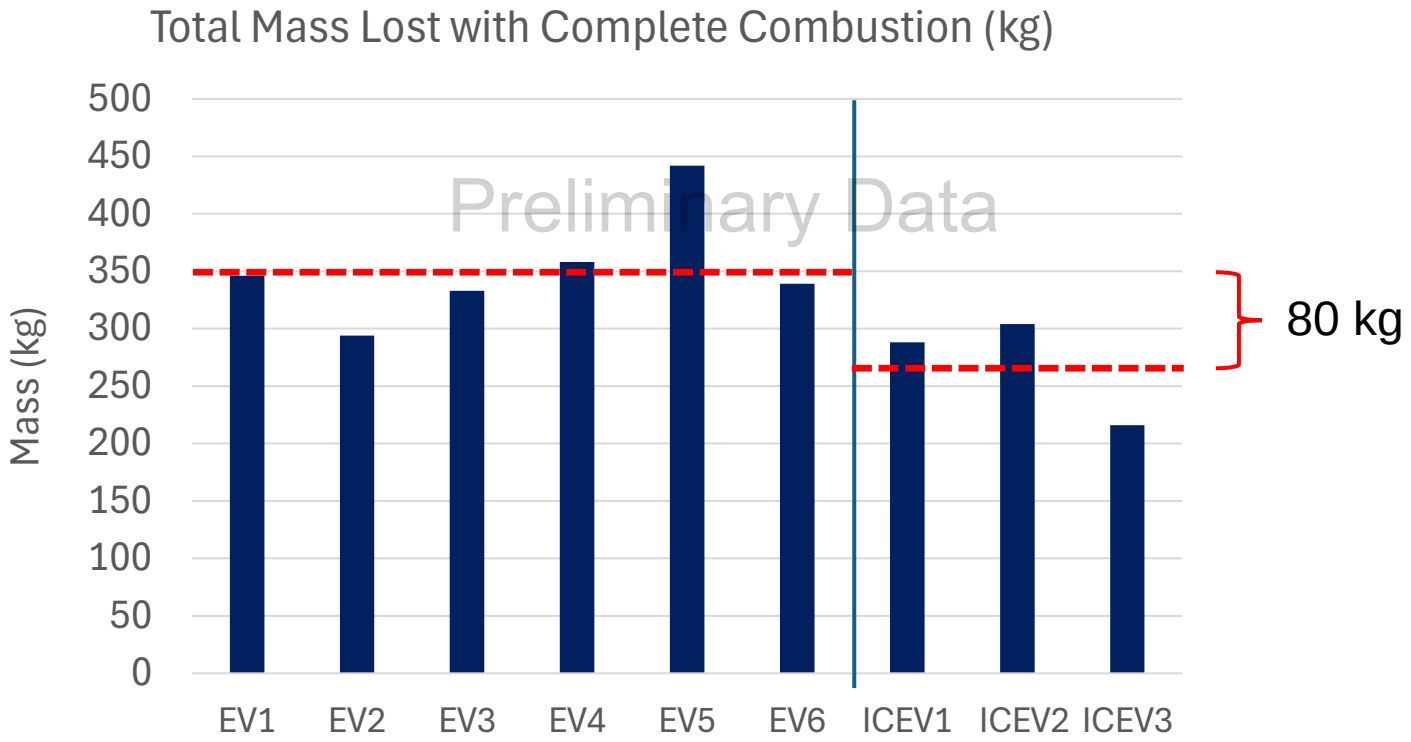
Designation	Make, Model, Trim	Year	Curb Weight (kg)	Fuel Capacity (L) or Battery Pack Charge (kWh)
EV1	Chevrolet Bolt	2022	1631	65 kWh
EV2	Nissan Leaf S	2019	1595	40 kWh
EV3	Hyundai Ioniq	2019	1448	28 kWh
EV4	Tesla Model 3 Long Range RWD	2023	1825	82 kWh
EV5	Ford Mustang Mach-E GT	2022	2256	91 kWh
● EV6	Hyundai Kona SEL Electric	2020	1689	65 kWh
▲ ICEV1	Hyundai Kona SEL	2020	1318	50 L (Gasoline)
△ ICEV2	Hyundai Kona SEL	2020	1318	50 L (Gasoline)
ICEV3	Toyota RAV4 XLE AWD	2019	1536	55 L (Gasoline)

Hummer EV:
212 kWh

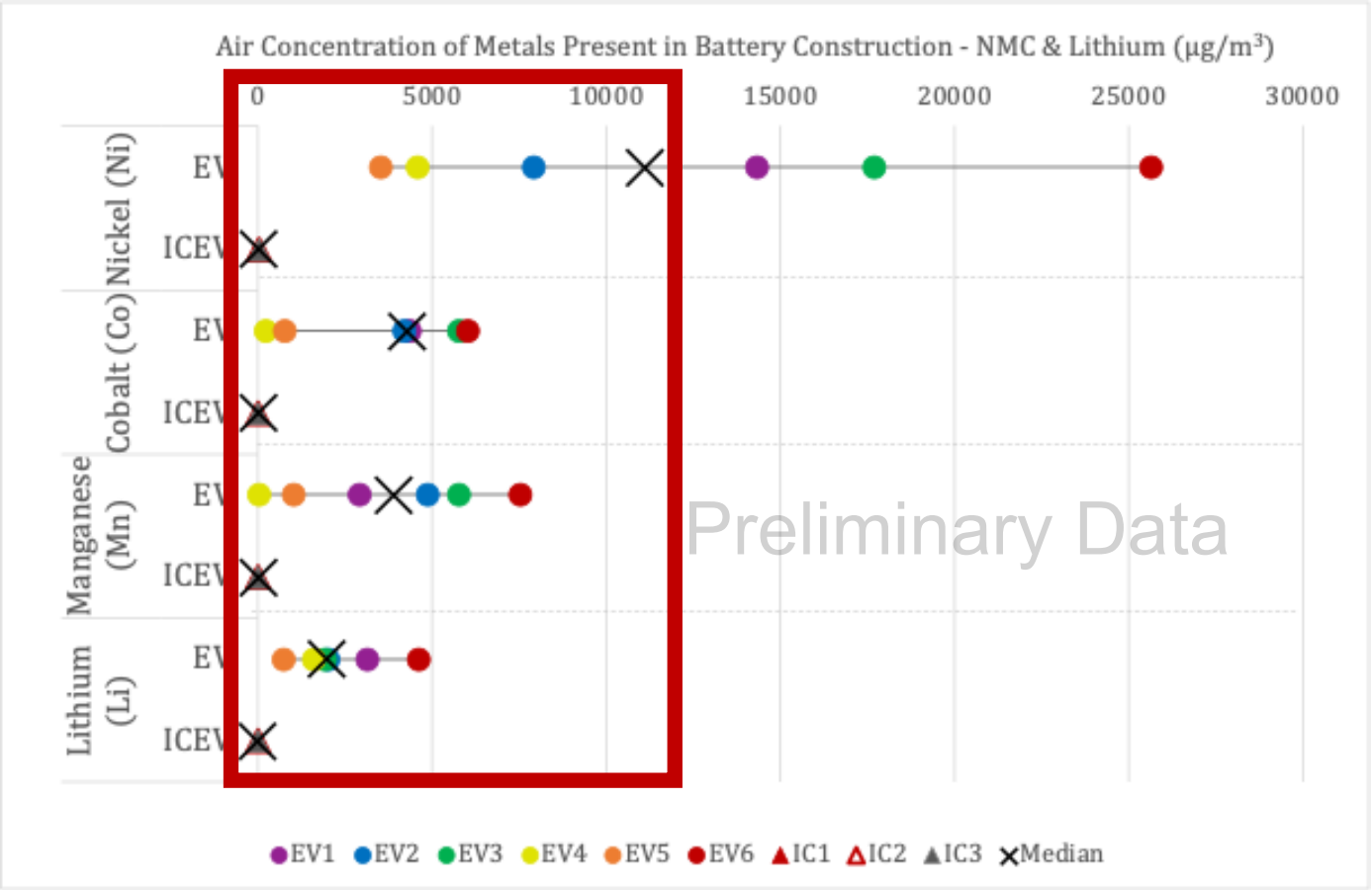
Timing


Test Duration - Ignition to Complete Combustion
Preliminary Data
Duration (minutes)
180
160
140
120
100
80
60
40
20
0
EV1
EV2
EV3
EV4
EV5
EV6
ICEV1
ICEV2
ICEV3
First Flame to Complete Combustion
Ignition to First Flame
102 vs 65 min
67 vs 62 min

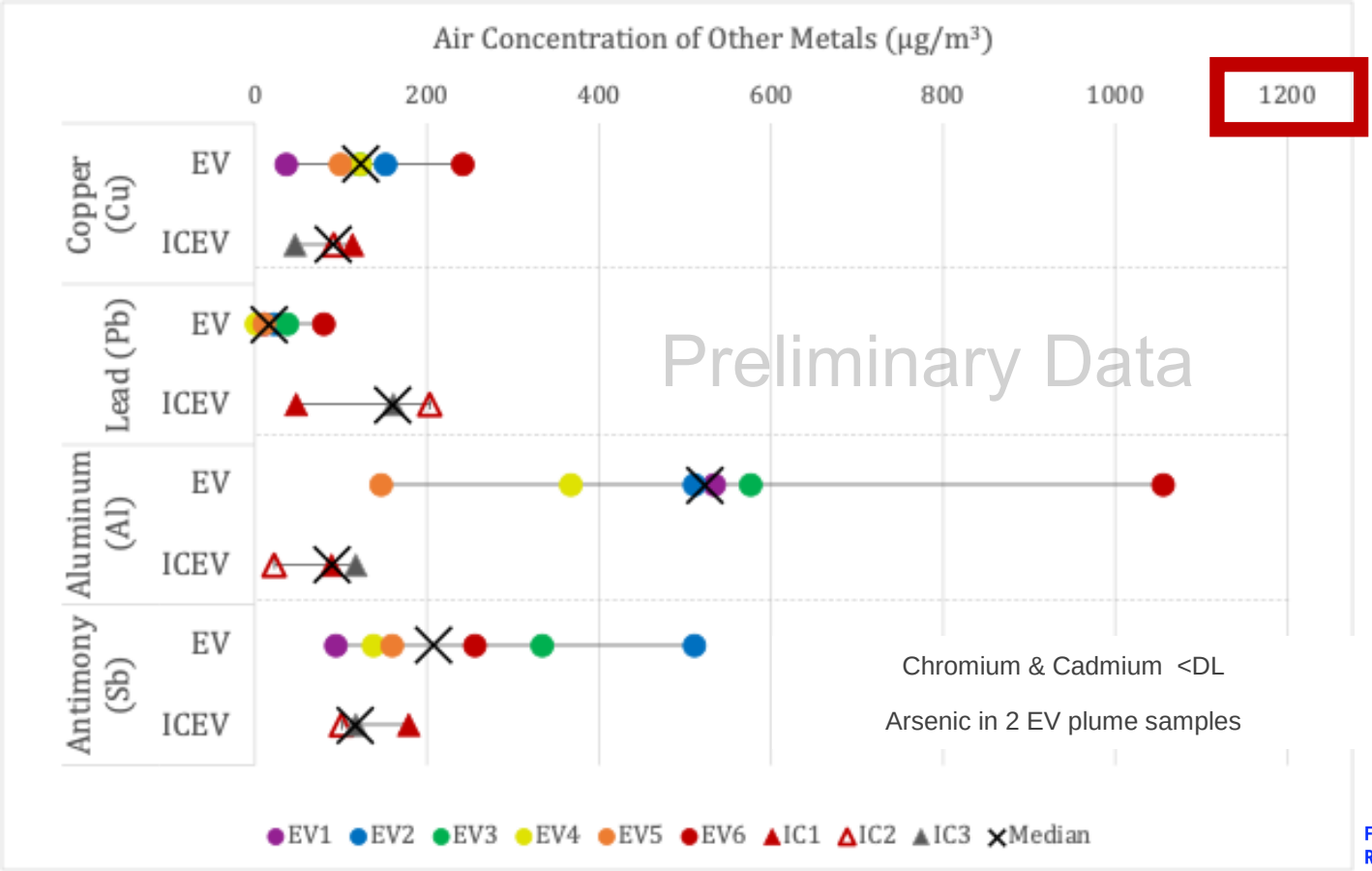
Mass Lost


Total Mass Lost with Complete Combustion (kg)
Preliminary Data
Mass (kg)
500
450
400
350
300
250
200
150
100
50
0
EV1
EV2
EV3
EV4
EV5
EV6
ICEV1
ICEV2
ICEV3
80 kg

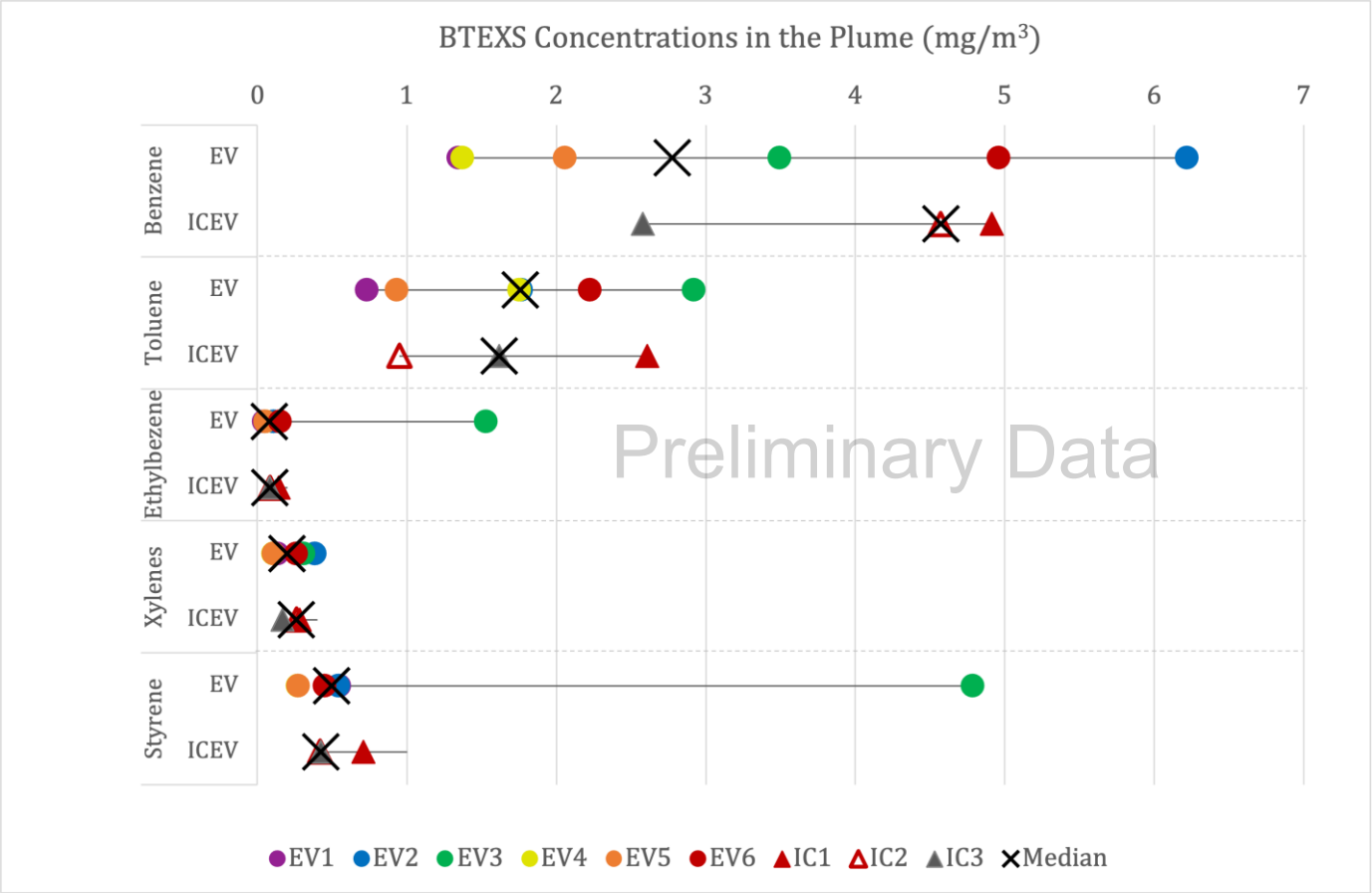
Metals – NMC + Li



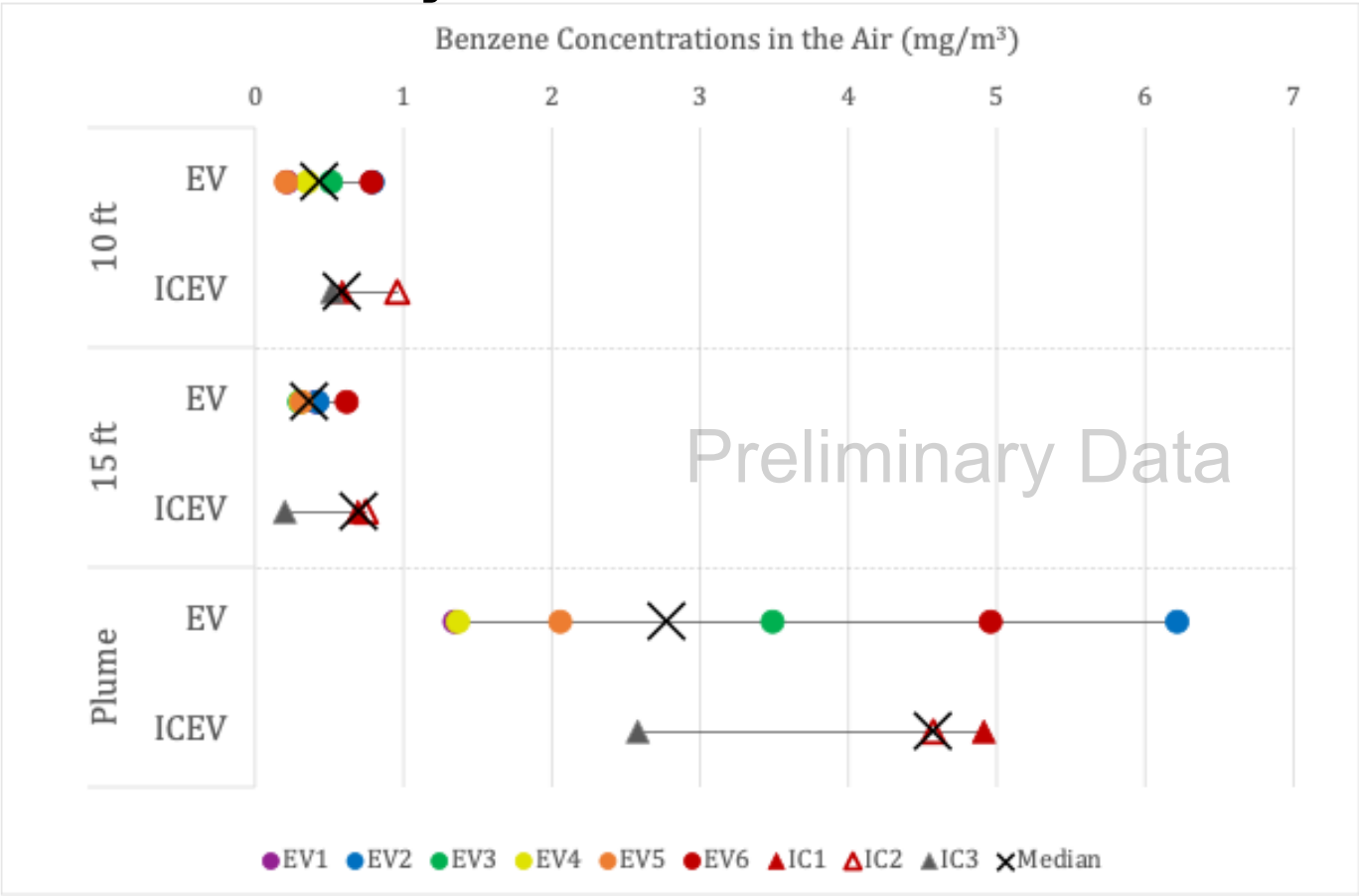
Metals - Others



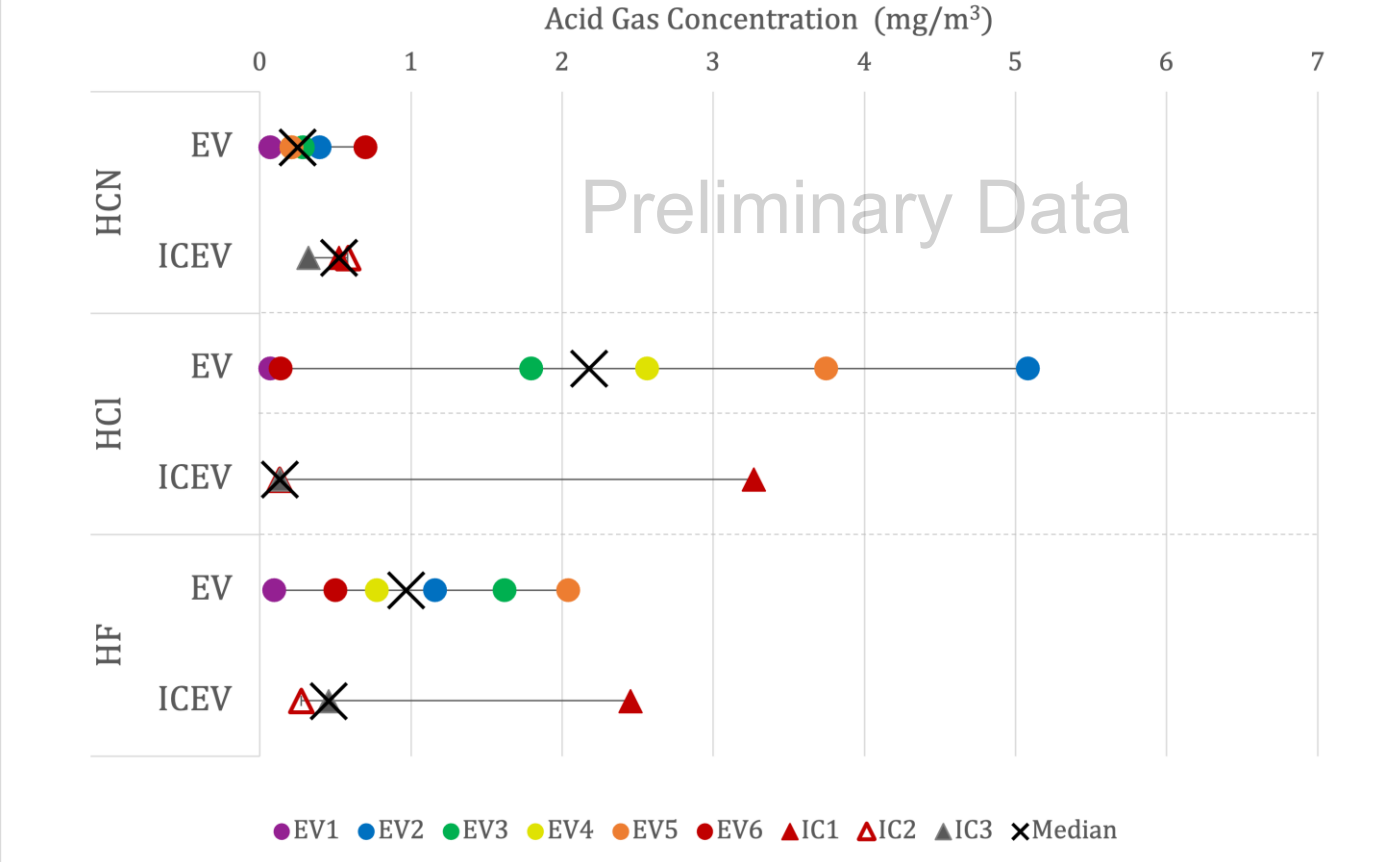
BTEXS - Plume


BTEXS Concentrations in the Plume (mg/m³)
0
1
2
3
4
5
6
7
Benzene
Toluene
Ethylbezene
Xylenes
Styrene
EV
ICEV
Preliminary Data
EV1
EV2
EV3
EV4
EV5
EV6
IC1
IC2
IC3
Median

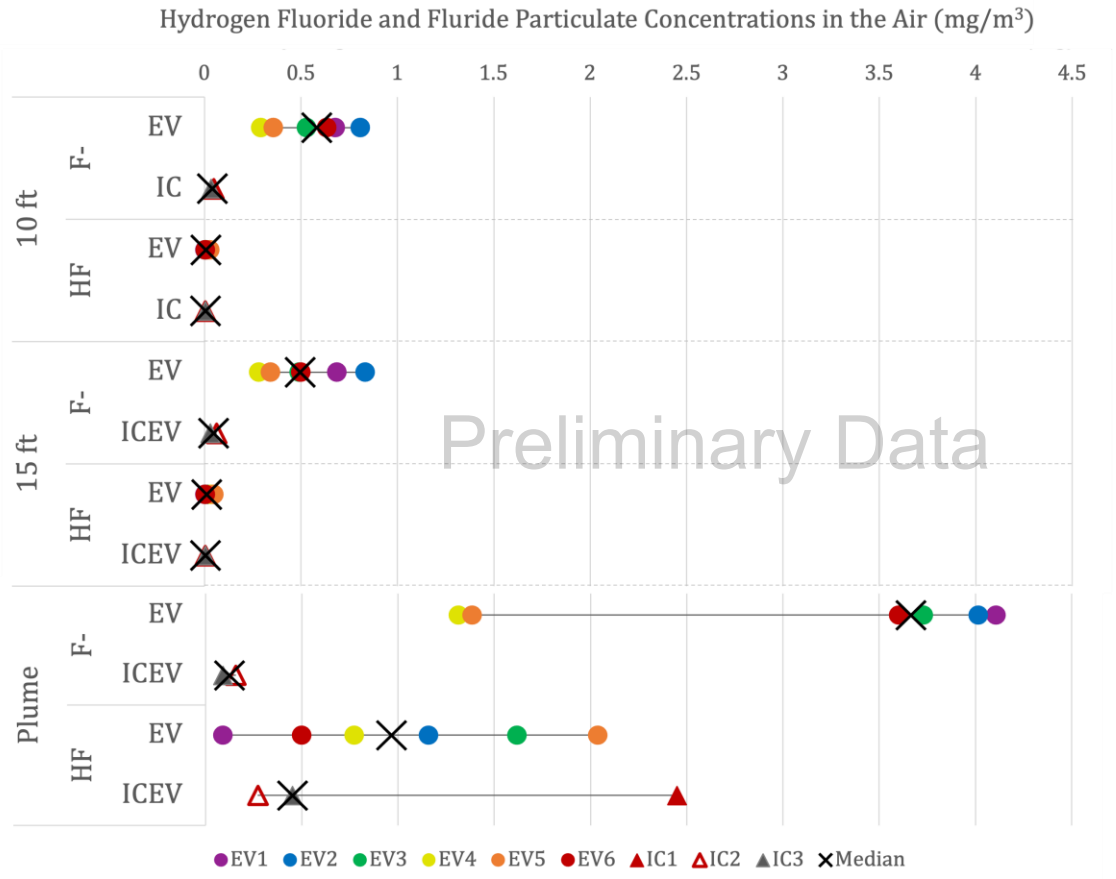
BTEXS – Benzene by location



Acid Gases


Acid Gas Concentration (mg/m³)
0
1
2
3
4
5
6
7
HCN
EV
ICEV
HCl
EV
ICEV
HF
EV
ICEV
Preliminary Data
EV1 EV2 EV3 EV4 EV5 EV6 IC1 IC2 IC3 Median

Acid Gases - Hydrogen Fluoride and Fluoride Ions



Silicone Samplers – Air Concentration Calculation

Compounds on Sampler (µg/g)

Sampler Mass (g)

Calculated air concentration (µg/m^3)

$$C_{air} = \frac{C_{sampler} * M_{sampler}}{R_s * A_{sampler} * T}$$

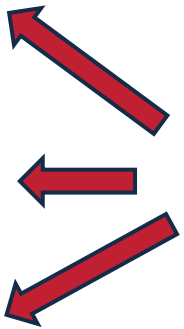
Normalized Sampling Rate (m^3/dm^2/day) (*Tromp, 2019*)

Sampler Surface Area (dm^2)

Total Sampling Time (fraction of day)

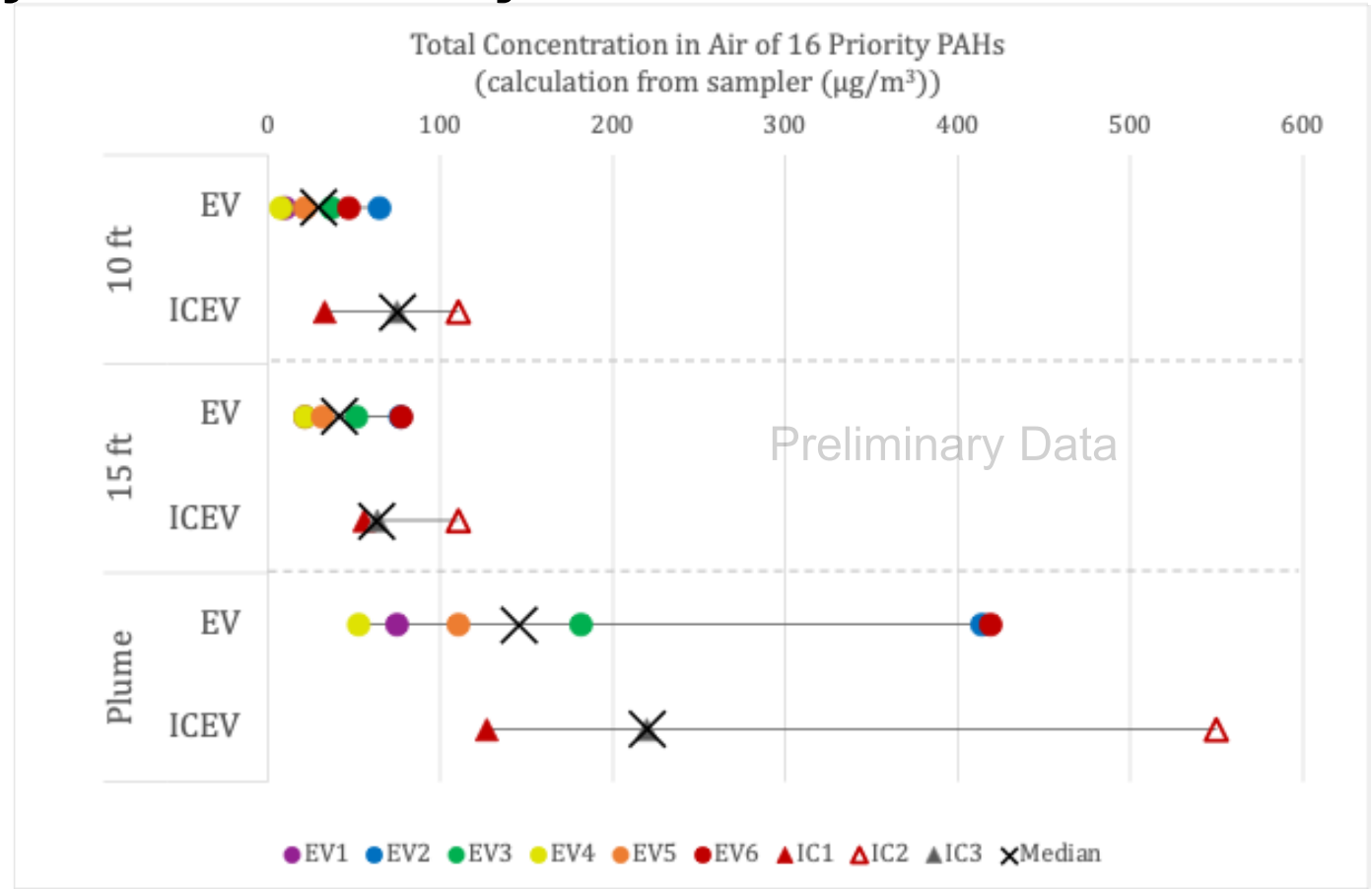
Polycyclic Aromatic Hydrocarbons

Compound	Abbreviation	Molecular Weight (g/mol)	IARC Group
Naphthalene	Nap	128.1	2B
Acenaphthylene	Acy	152.1	–
Acenaphthene	Ace	154.2	–
Fluorene	Fl	166.2	3
Phenanthrene	Ph	178.2	3
Anthracene	An	178.2	2B
Fluoranthene	Fla	202.3	3
Pyrene	Py	202.3	3
Benzo[a]anthracene	BaA	228.3	2B
Chrysene	Ch	228.3	2B
Benzo[b]fluoranthene*	BbF	252.3	2B
Benzo[k]fluoranthene*	BkF	252.3	2B
Benzo[a]pyrene	BaP	252.3	1
Benzo[g,h,i]perylene	BghiP	276.3	3
Indeno[1,2,3-cd]pyrene	IP	276.3	2B
Dibenz[a,h]anthracene	DBA	278.4	2A



10 are possibly, probably, or known carcinogens

Polycyclic Aromatic Hydrocarbons



Recap

- Similar burn duration – greater mass loss in EVs
- High levels of NMC – Li metals in EVs
- Acid gases similar across vehicles
  - Fluoride particulate elevated in EVs
- PAHs similar - slightly higher medians in ICEVs

Suppression Tests – Results Soon!

- ✔ Standard firefighting techniques
- ✔ EV specific techniques – blankets/under car nozzles/additives
- ✔ Water run-off

UL Research Institutes

Fire Safety
Research Institute

Thank you

Richard Kesler

Richard.Kesler@ul.org

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