

# Volatility Characteristics of Electronic Cigarette Aerosols

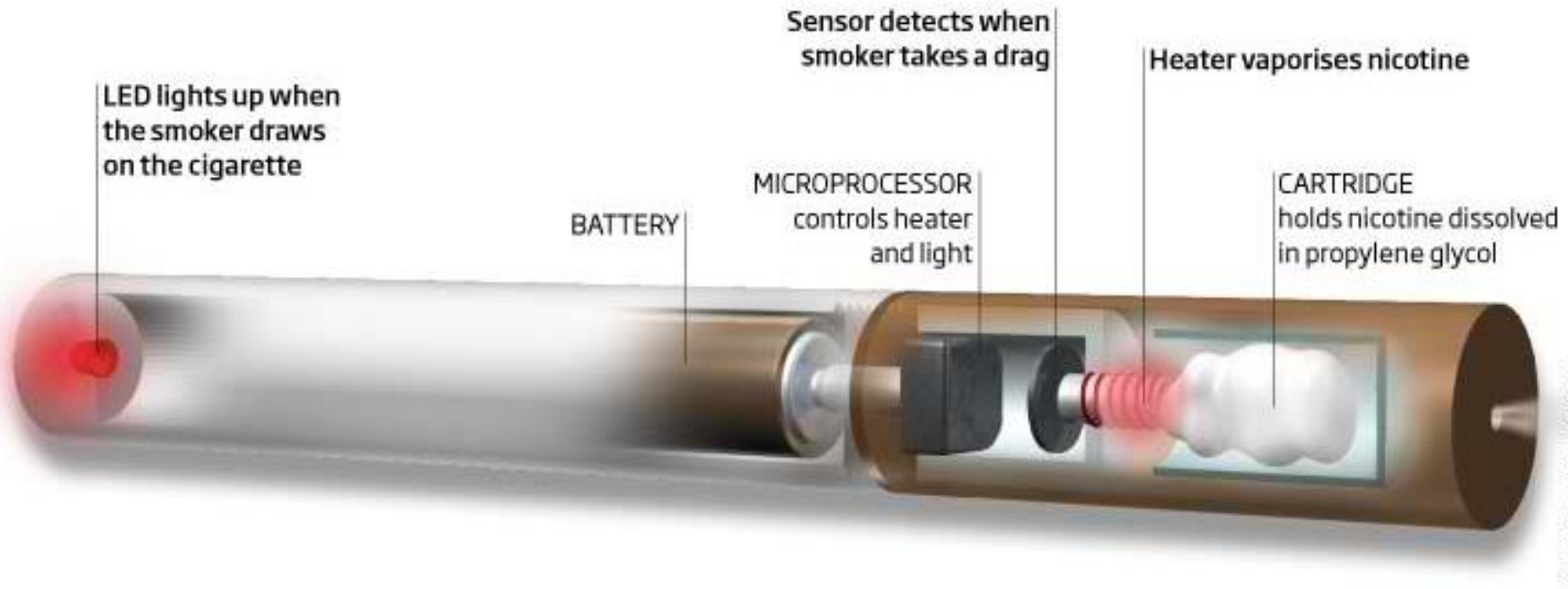
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# E-Cigarettes (“E-Cigs”) produce an inhalable aerosol by vaporizing a mixture of liquids

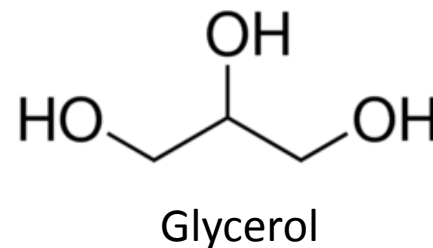


- Nearly all E-cigs use battery to power a heating coil in contact with a wicking material saturated with E-liquid
- Some are disposable.

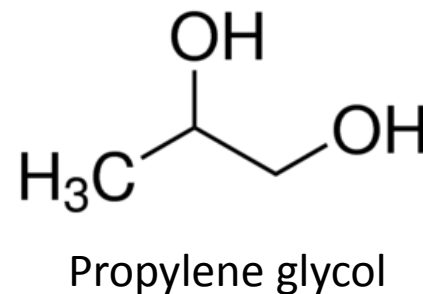


# Four standard “E-liquid” constituents

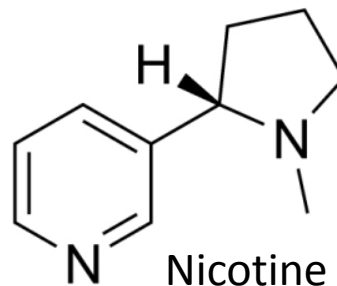
- Glycerol,  $\text{C}_3\text{H}_8\text{O}_3$ 
  - Produces aerosol that resembles smoke



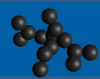
- Propylene Glycol,  $\text{C}_3\text{H}_8\text{O}_2$ 
  - Nicotine carrier, reduces viscosity



- Nicotine (0 – 24  $\text{mg}\cdot\text{mL}^{-1}$ )
  - Generally pharma grade



- Flavoring
  - FDA approved PG-based food flavoring



# E-cigs are emerging as a safe alternative to tobacco cigarettes

- Manufacturers claim E-cigs to be safe (no “toxic chemicals”)
- User perception of safety: **50% say “safer”** vs **2% say “less safe”** in the UK (<http://www.ash.org.uk/>)
- 2.5 million E-cig users compared to 45 million smokers in the U.S. (3 mil+ in the UK)
- 13% of high school students use E-cigs

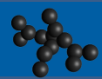


## Vaping risks: Chemicals used to flavour e-cigarettes could damage lungs in a similar way to tobacco

May, 2015 - <http://www.independent.co.uk/>

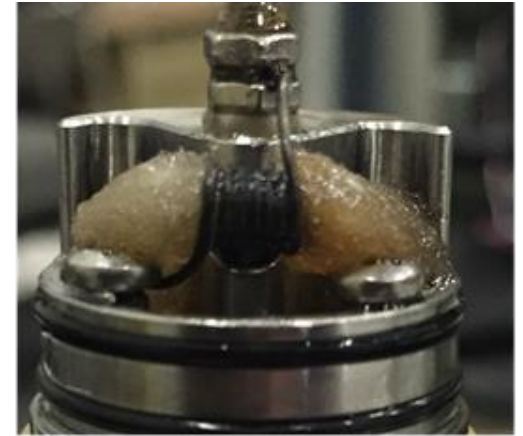


Of the 13 flavours tested in the research, five (including Hot Cinnamon Candies, Banana Pudding and Menthol Tobacco) changed cell viability, cell proliferation, and calcium signalling (calcium homeostasis is also affected by tobacco exposure) and were shown to be toxic in higher doses.



# Experimental objectives

- Construct apparatus that allows continuous, automated use of a typical E-cig
- Characterize size, concentration, and composition particles in E-cig aerosol
- Explore the impact of E-liquid additives and power on E-cig aerosol
- Determine temporal variability of aerosol properties



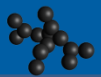
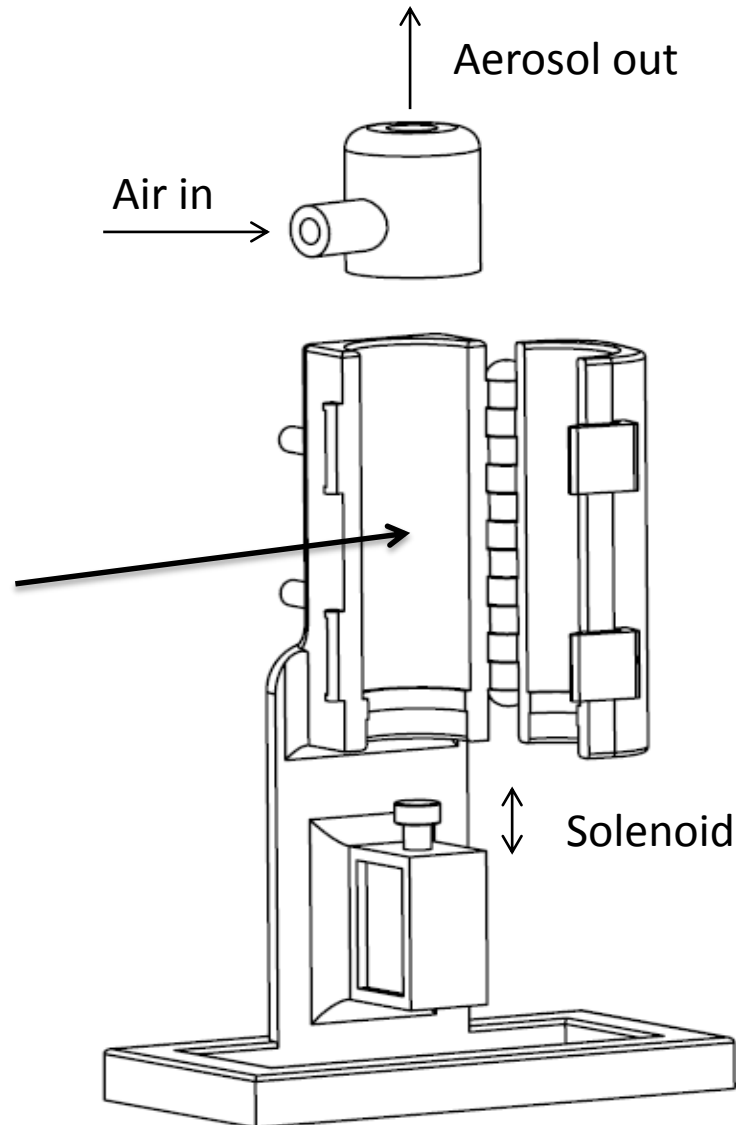
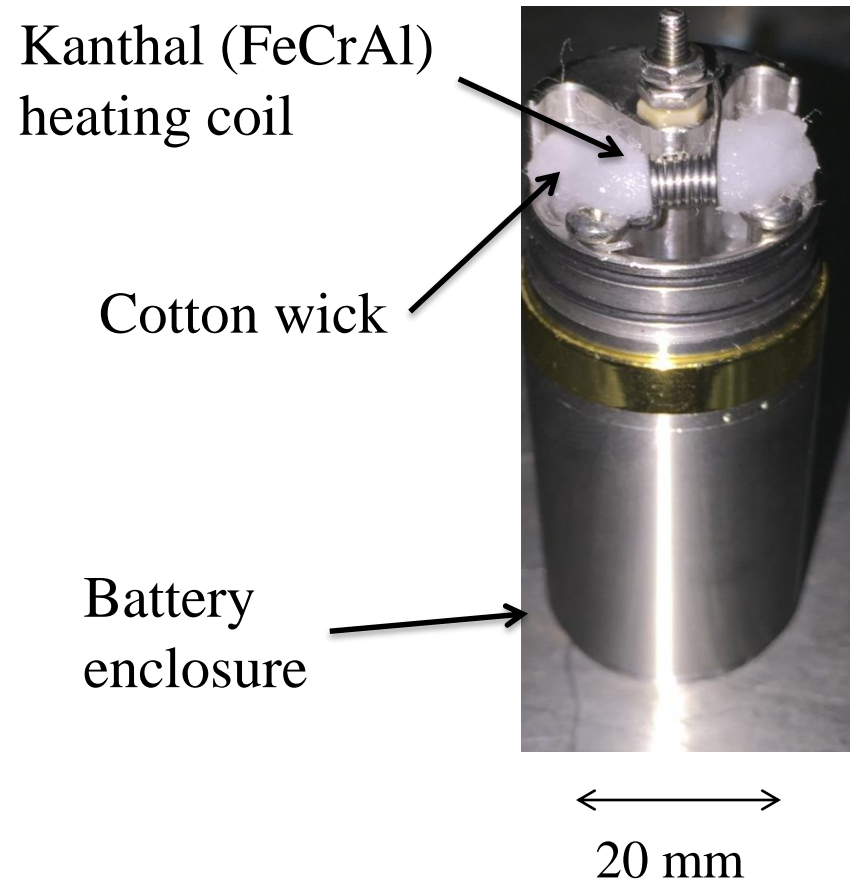
Dirty Coil: Pyrolyzed E-Liquid



Clean Coil



# Battery powered E-cig apparatus

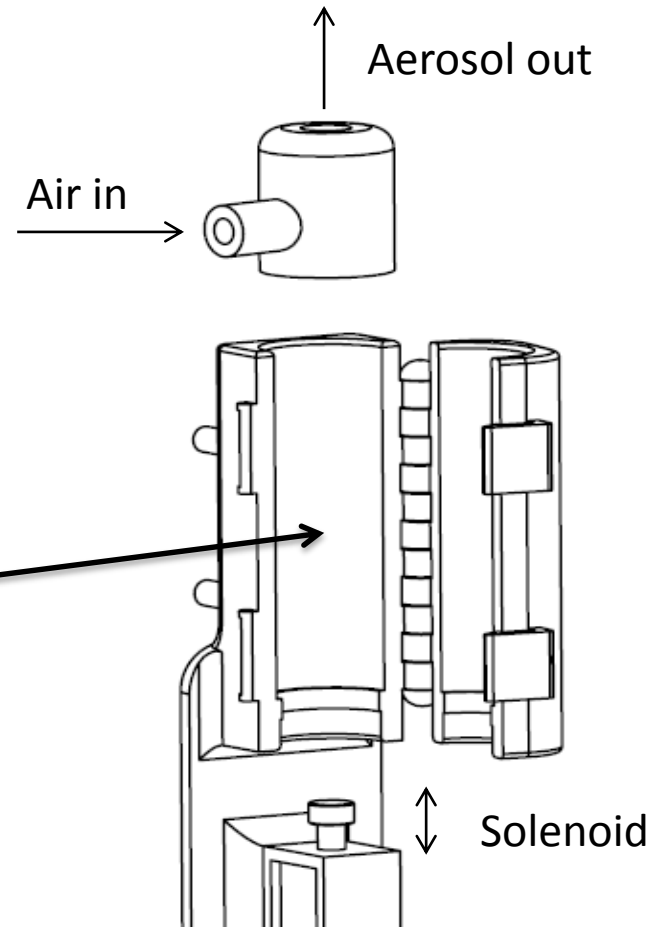


# Battery powered E-cig apparatus

Kanthal (FeCrAl)  
Heating Coil

Cotton Wick

Battery  
Enclosure

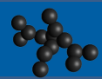
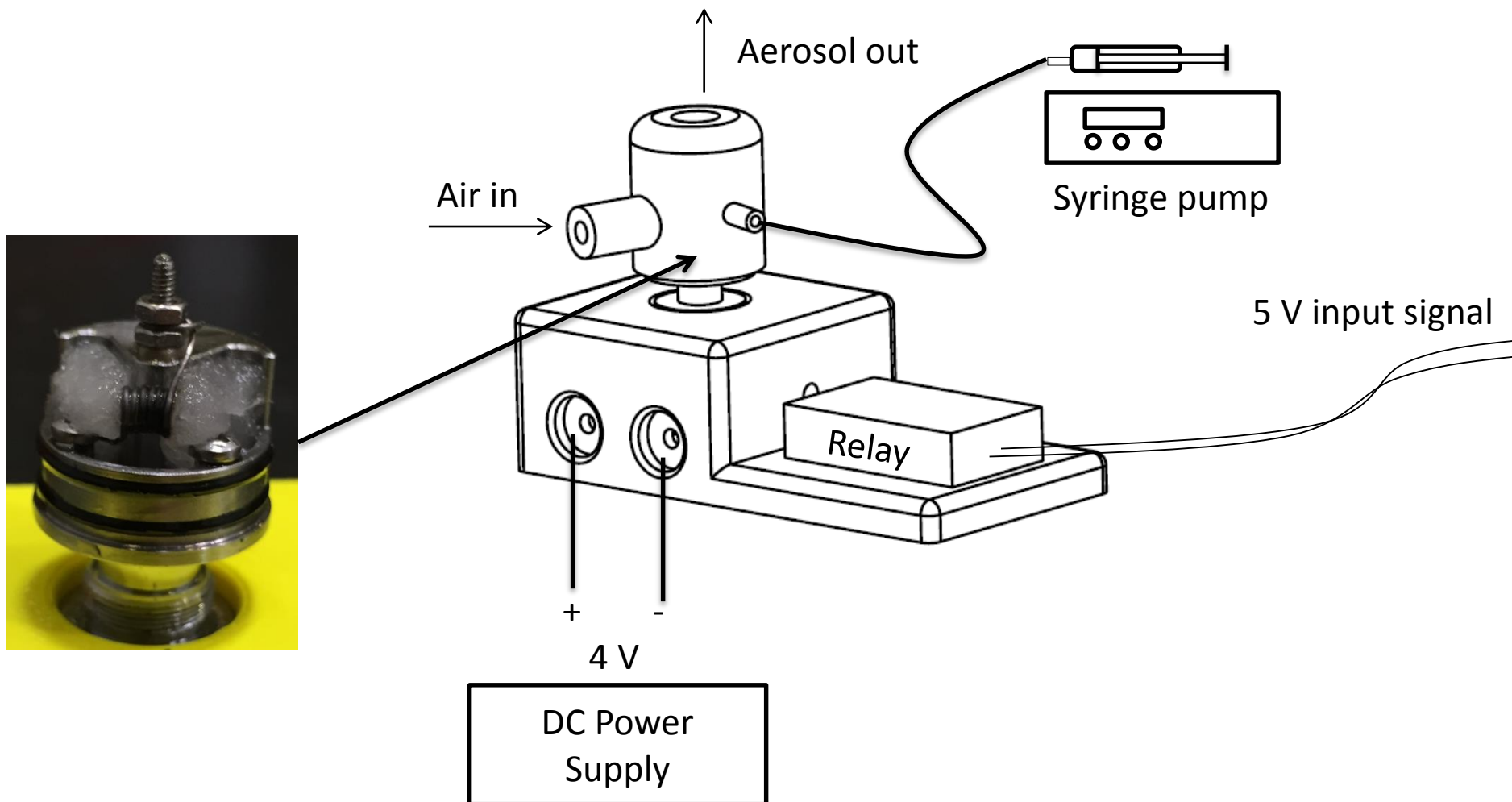


Primary limitations: battery life and  
E-liquid consumption (~ 10 puffs)

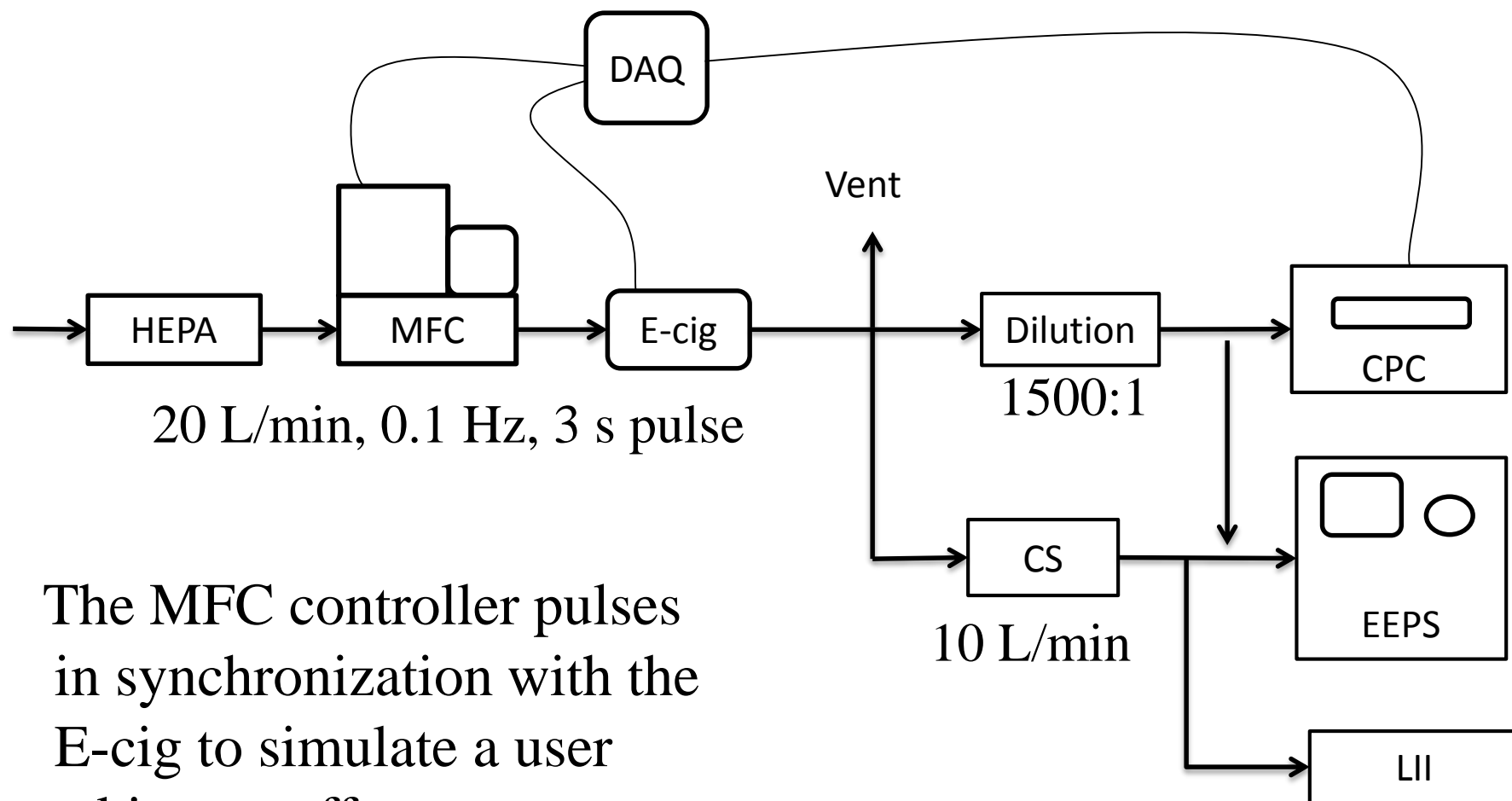




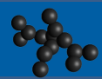
# E-Smoking Cycle Simulator (E-SCS™)



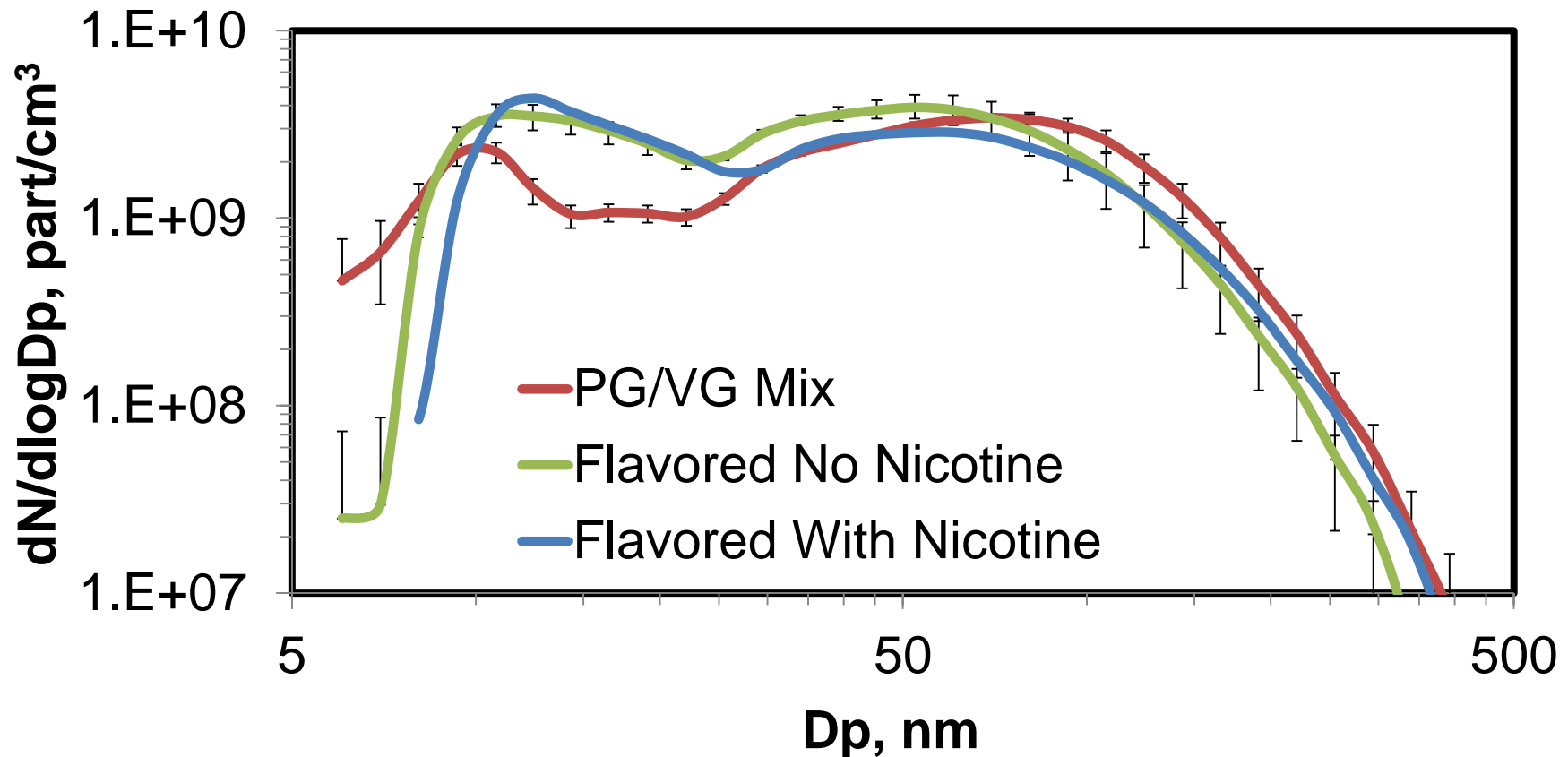
# Experimental apparatus and instruments



The MFC controller pulses in synchronization with the E-cig to simulate a user taking a puff



# Flavoring and nicotine content have little impact E-particle™ emissions

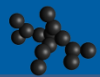


Concentrations  $\sim 1 \times 10^9$  particles/ $\text{cm}^3$   $\sim$  same as tobacco smoke

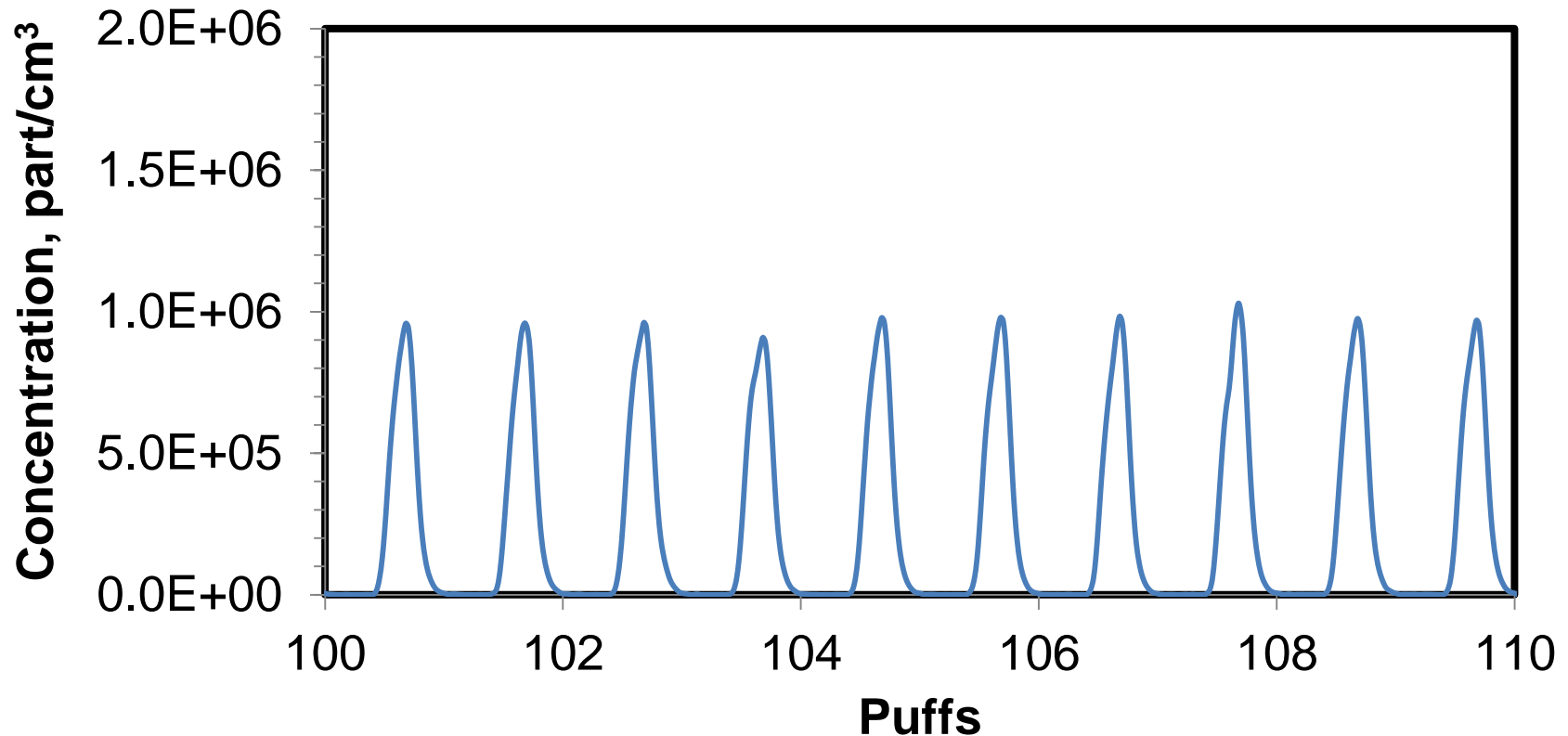


**The following slides all show  
“solid particles” measured  
downstream of a catalytic stripper**

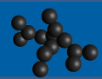
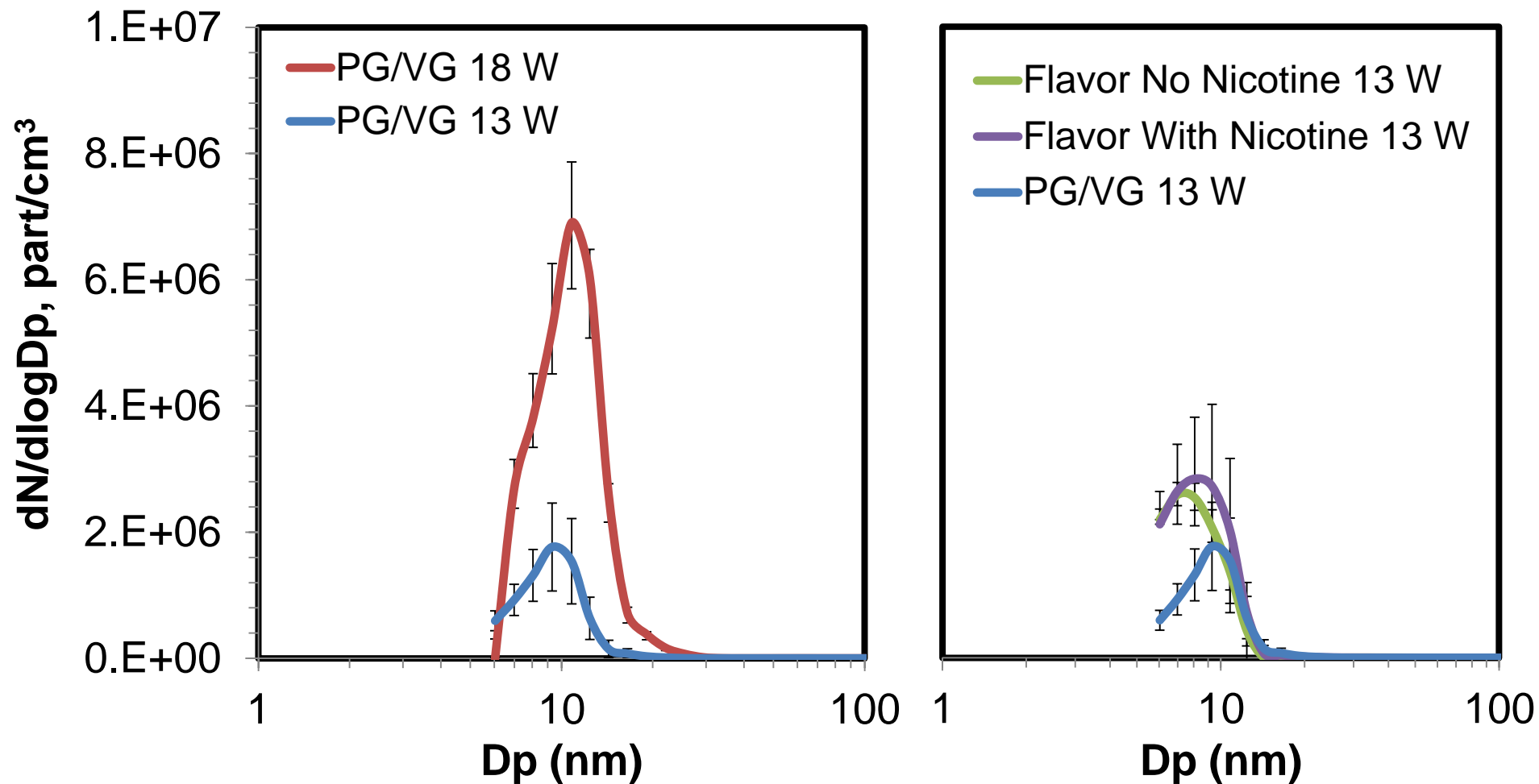
1. Averages of 10 puffs
2. Extended evaluation of the life of the coil



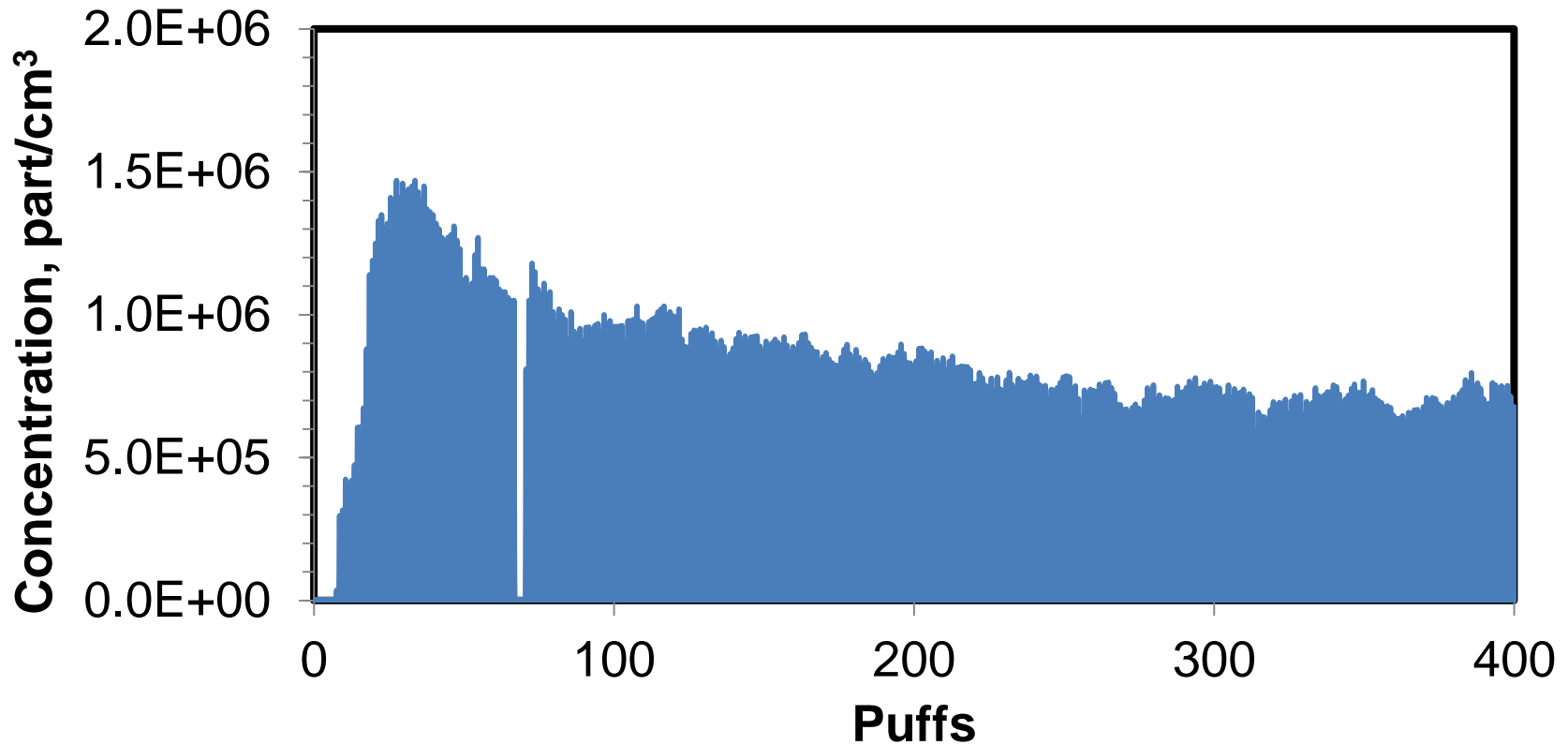
# Puff sequence shows highly repeatable solid E-particle emissions



# Increasing power increases solid particle emissions; flavoring has little effect



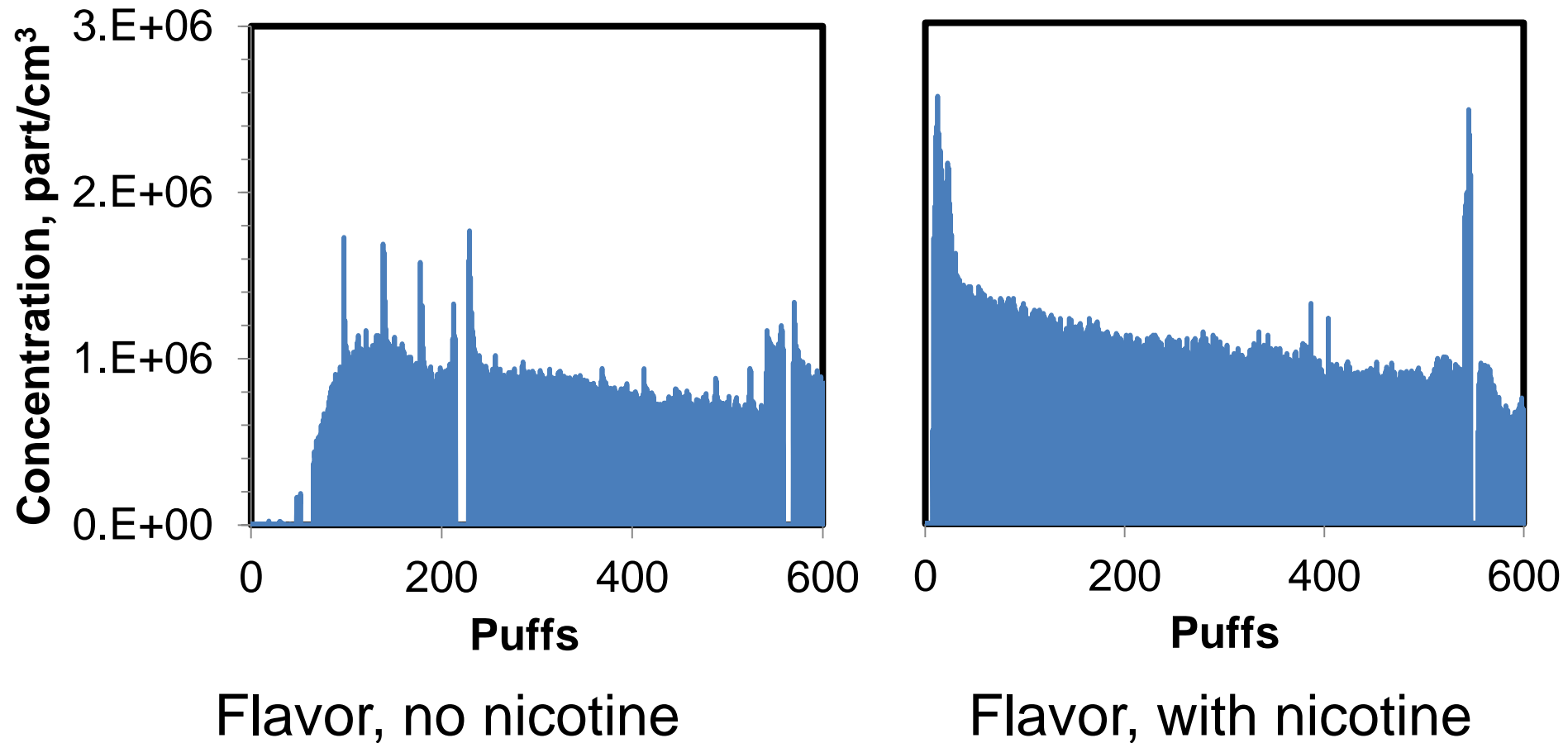
# 400 puffs shows solid particle emissions are relatively stable over coil life



Small variation likely due to inconsistent wick saturation

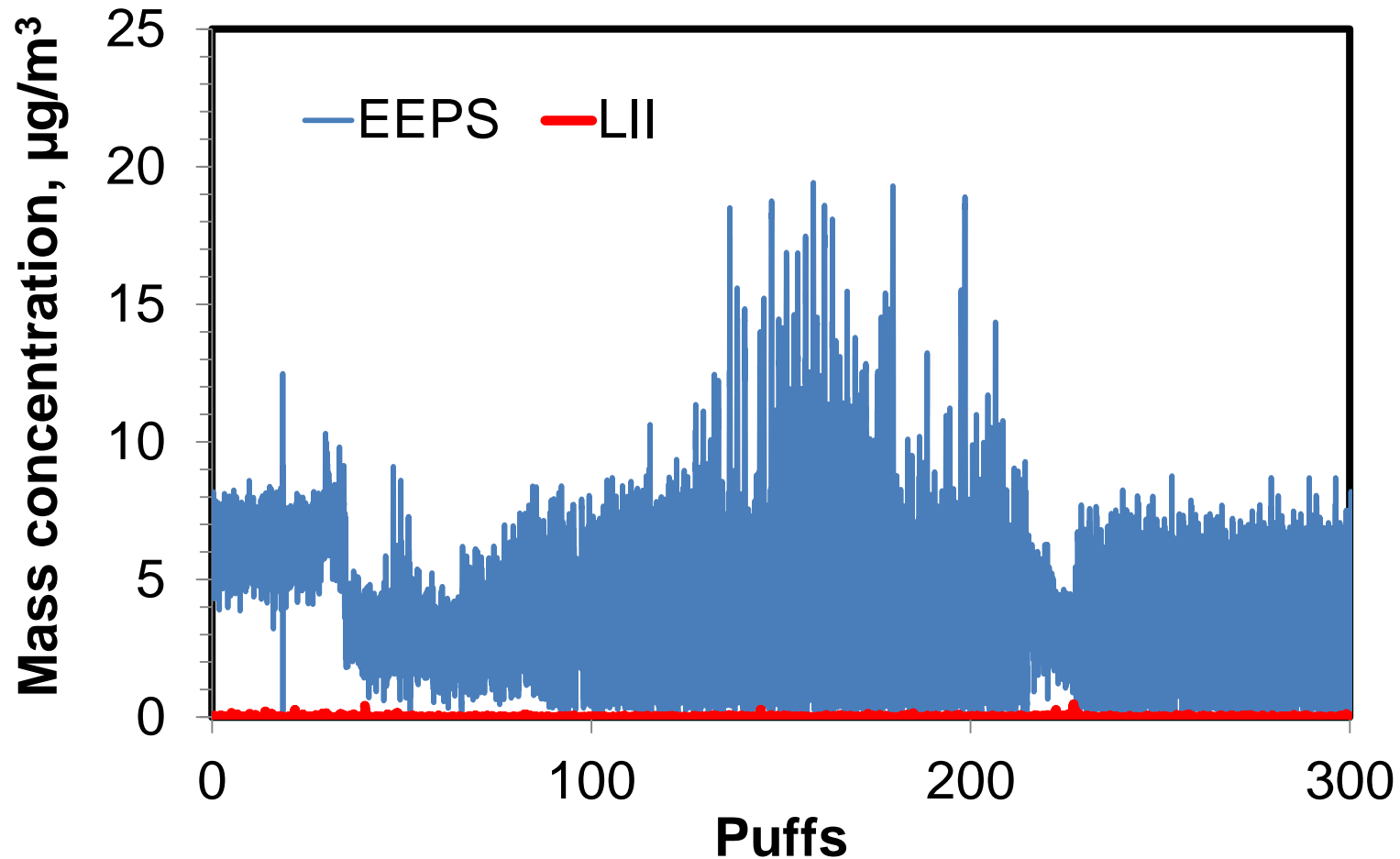


# Flavored E-liquids with and without nicotine show similar results to standard PG / VG

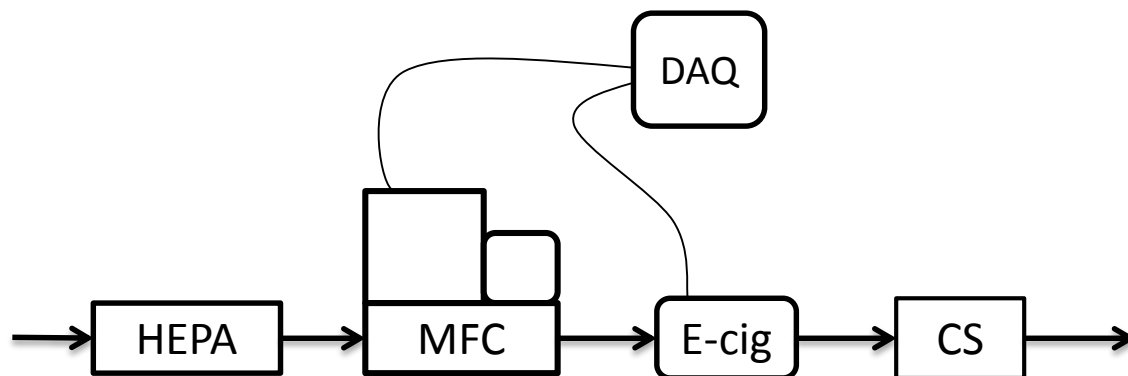




# LII does not respond to solid E-particles, suggesting they are not primarily carbon



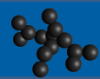
# Solid E-particles were collected on silver membrane filters for Laser Induced Breakdown Spectroscopy (LIBS) analysis



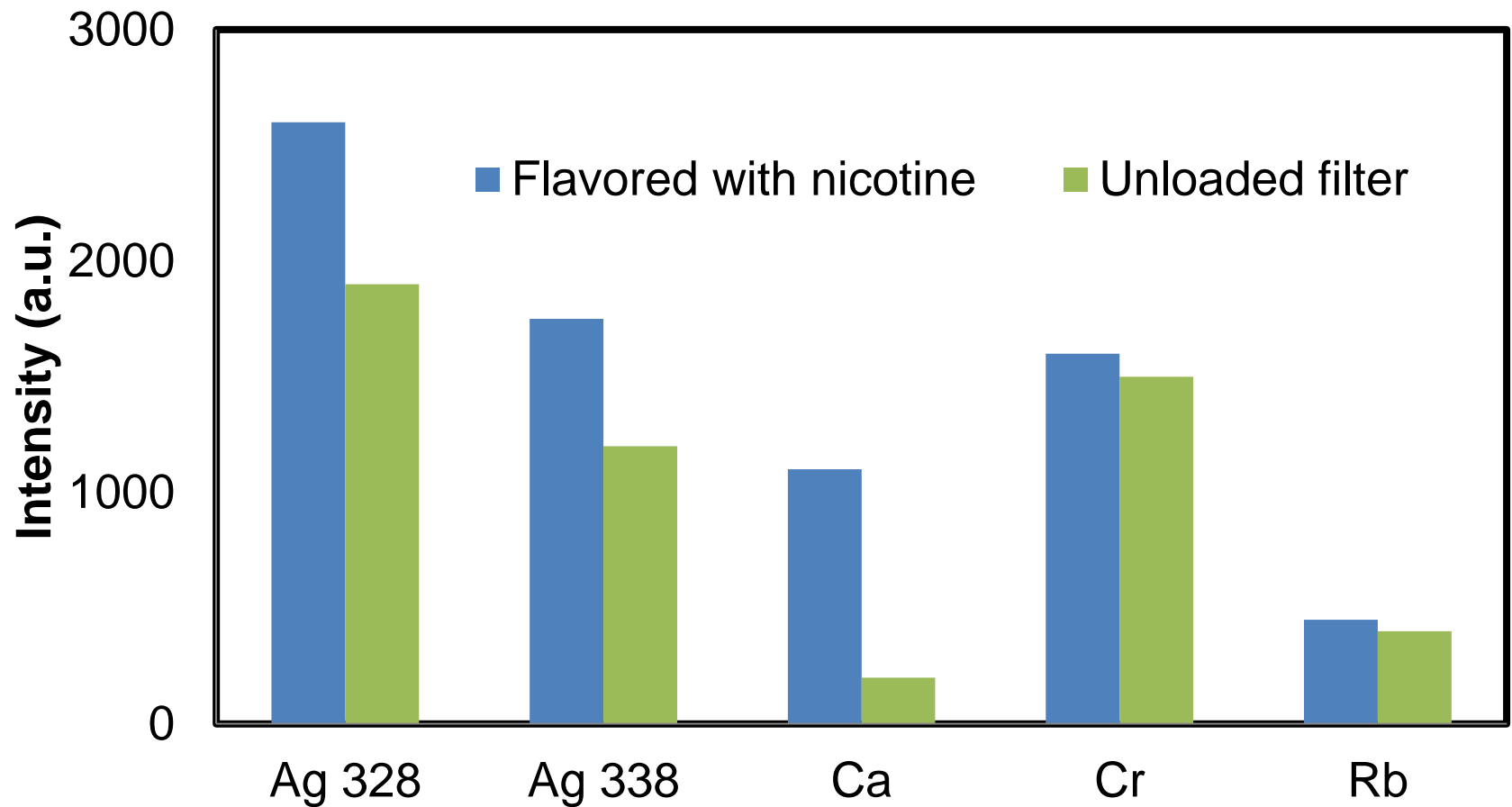
Filter Area = 0.128 cm<sup>2</sup>



- $\sim 3 \mu\text{g}/\text{m}^3$  for 3 seconds @ 2.6 L/min = 0.39 ng/puff
- 350 puffs
- $\sim 1 \mu\text{g}$  of solid particles per cm<sup>2</sup> of filter



# LIBS results not conclusive – only calcium identified above LOD



We thank TSI for loan of the LIBS for this work



# Summary

- Semi-volatile E-particles ( $\sim 60$  nm in size) are emitted in extremely high concentrations
- 10 nm solid particles are emitted in lower concentrations ( $1 \times 10^6$  part/cm<sup>3</sup>) and their composition is unknown
- Time (# puffs), E-liquid, flavoring, nicotine all had relatively little impact of solid and semi-volatile E-particle emissions
- Future work includes better LIBS analysis and FTIR detection of gases of interest (HCHO, N<sub>2</sub>O)

