RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

ONERA
THE FRENCH AEROSPACE LAB

The UNREAL (Unveiling nucleation mechanism in aircraft engine exhaust and its link with fuel composition) project: Results from simulation chamber and oxidation reactor experiments

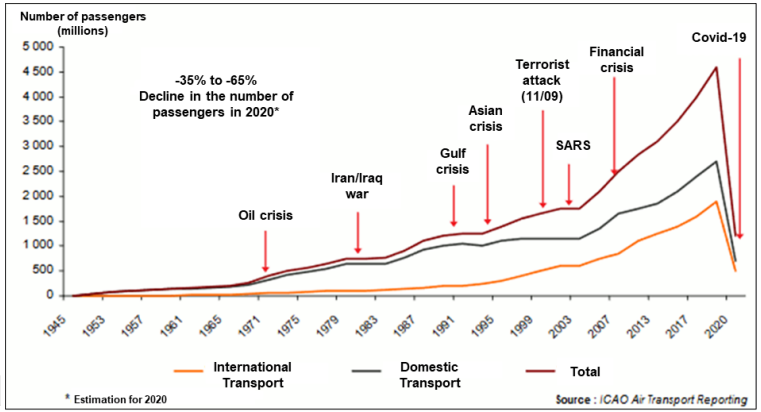
I.K. Ortega, M.Cazaunau, A. Farah, A. Singh, N. Karoski, R. Barrellon-Vernay, J. Duplissy, A. Bergé, J. Brito,A. Berthier, D. Delhaye, J.-E. Petit, A. Albinet, M. Sicard, Y. Carpentier, B. Raepsaet, F. Ser, M. Kulmala, V. Riffault, C. Focsa, and J.F. Doussin

lisa
PhLAM Physique des Lasers Atomes et Molécules
ARMINES
INAR
LSCE
INERIS
AGENCE NATIONALE DE LA RECHERCHE ANR

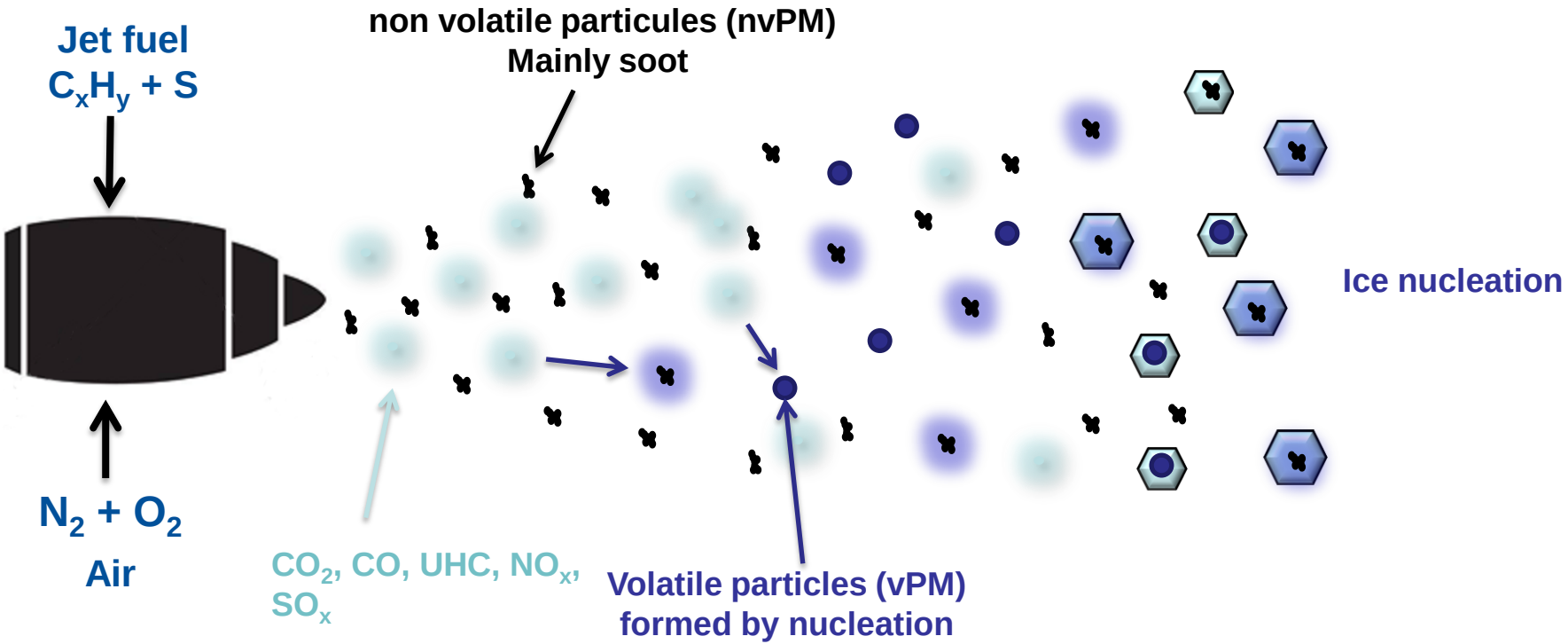
Context

Aviation sector emissions

- Sector in expansion before COVID19
- Big concern about aviation emissions air quality and climate
- Emissions reduction: use of sustainable aviation fuels (Synthetic kerosene, low CO_2 fuels, hydrogen…)



Context : Aircraft engine emissions



UNREAL project

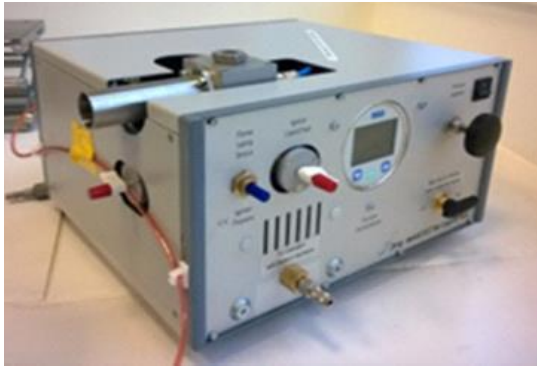
Unveiling Nucleation mechanism in aiRcraft Engine exhAust and its Link with fuel composition

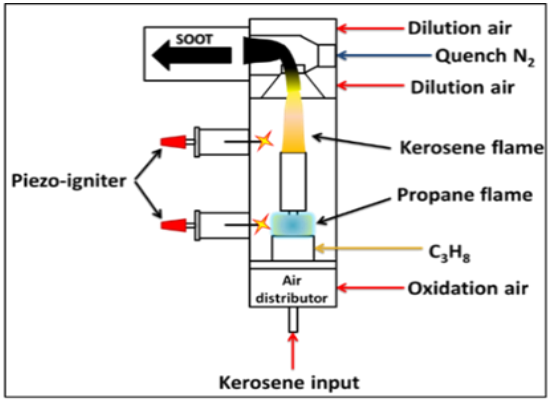
UNREAL

@AnrUnreal

- Project funded by ANR (1/1/2019 to 31/12/2022)
- **Main objectives:**
  - To determine the mechanism behind vPM formation in the engine exhaust and if there is a link with fuel composition
  - To establish a sampling protocol for vPM measurements that can be used in certification processes
  - To determine the impact of fuel chemical composition on the physico-chemical properties of vPM and nvPM

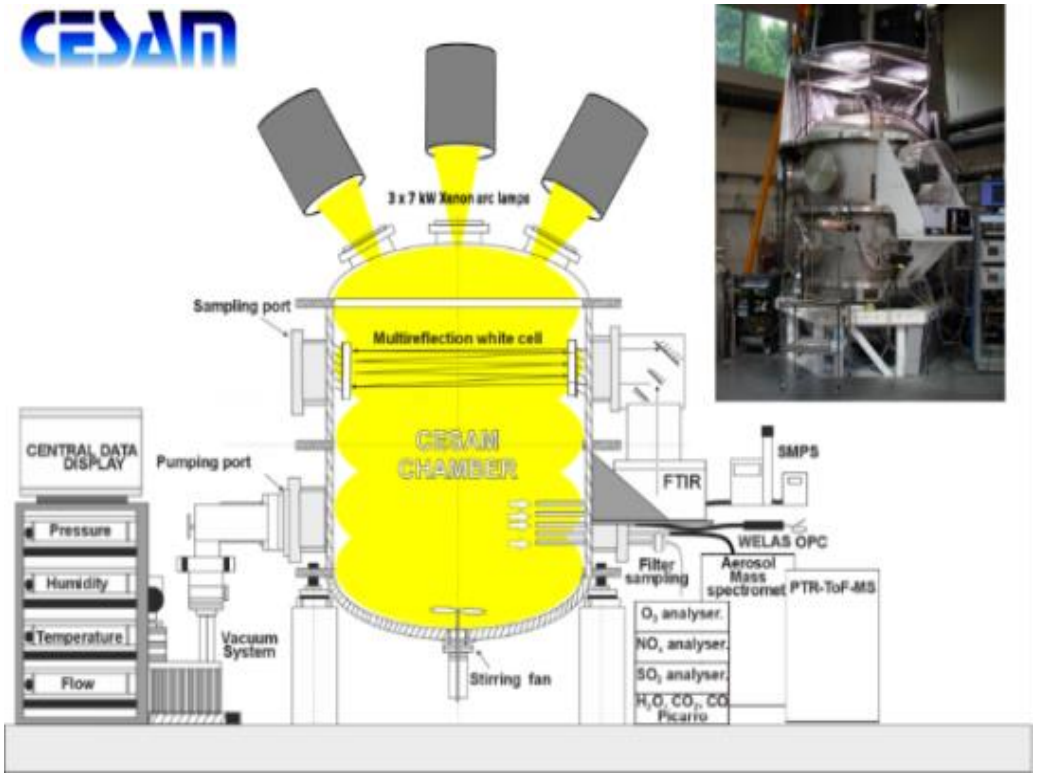
Liquid CAST generator (Jing ltd.)





- Able to work with any liquid fuel
- Fuel impact on emissions well captured respect other combustion sources
- Emissions chemical composition close to the one found in real engines
- Low fuel consumption (10 ml per hour of test)
- Jet A-1, AtJ, AtJ / Jet A-1 blend 30:70

CESAM chamber

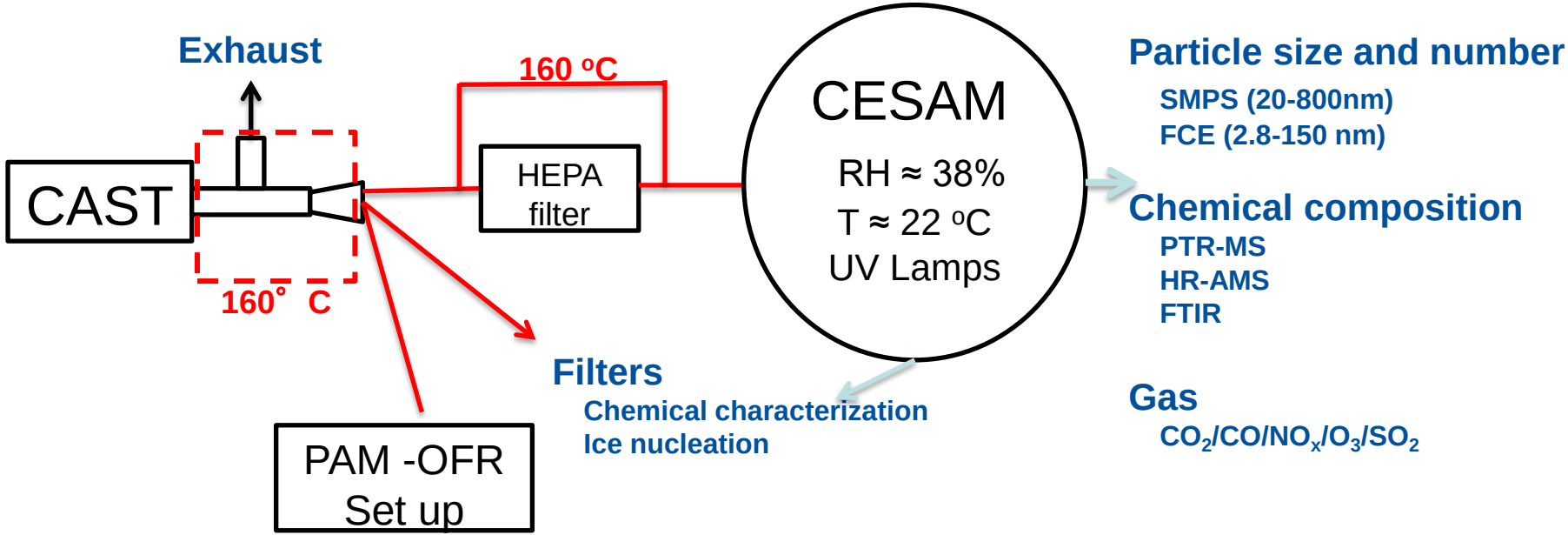


- 4.2 m^3 stainless steel atmospheric simulation chamber.
- Evacuable down to a few 10^{-7} atm
- Temperature controlled between +15° C and +60° C
- High power xenon arc lamps which provide realistic sun irradiation
- Long lifetime for submicron particles (up to 4 days)
- Controlled RH
- Equipped with a comprehensive sets of analytical instruments

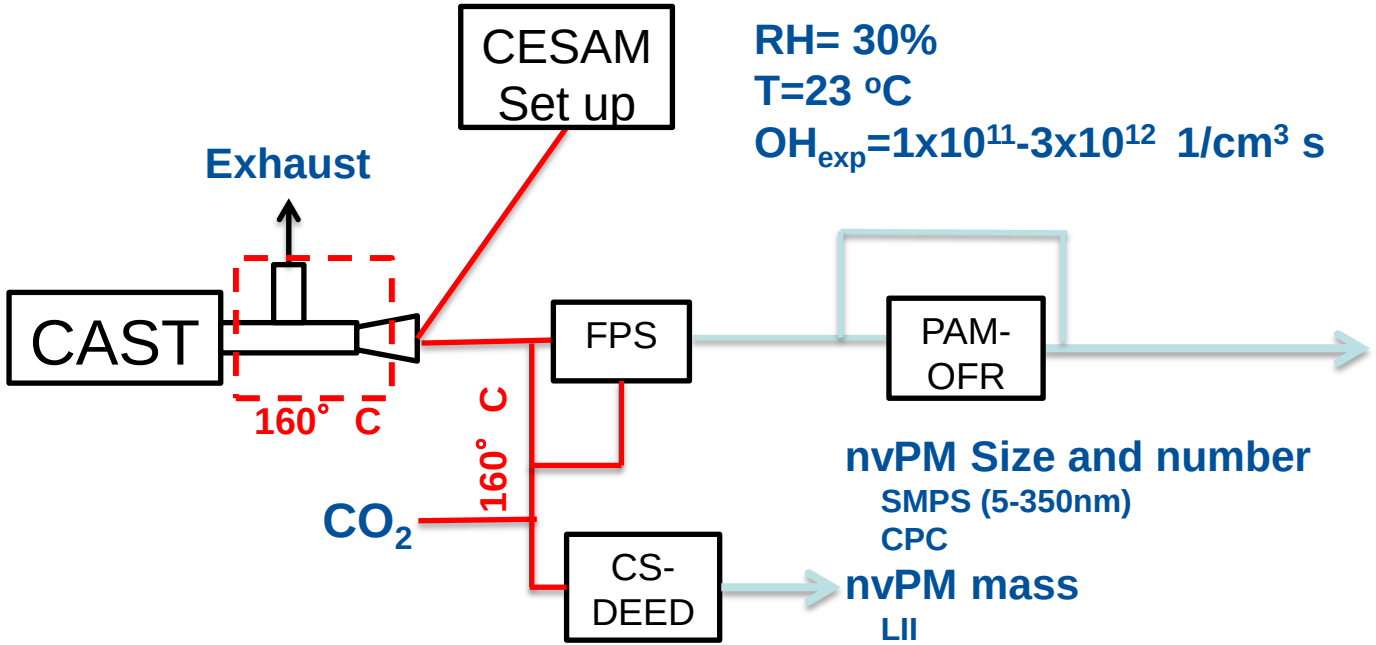
Potential Aerosol Mass – Oxidation Flow Reactor

- Small dimensions (13 L) and transportable oxidation reactor
- Continuous flow conditions (dynamic system)
- Controlled RH
- Aging from 1 to 30 days in about 1 min (using OH reactivity)
- Connected to comprehensive sets of analytical instruments with automated switching before and after aging

Experimental set-up, Atmospheric chamber



Experimental set-up, PAM flow reactor



RH= 30%
T=23 °C
OH_{exp}=1x10^{11}-3x10^{12} 1/cm^3 s

nvPM Size and number
- SMPS (5-350nm)
- CPC

nvPM mass
- LII

Gas
- CO_2

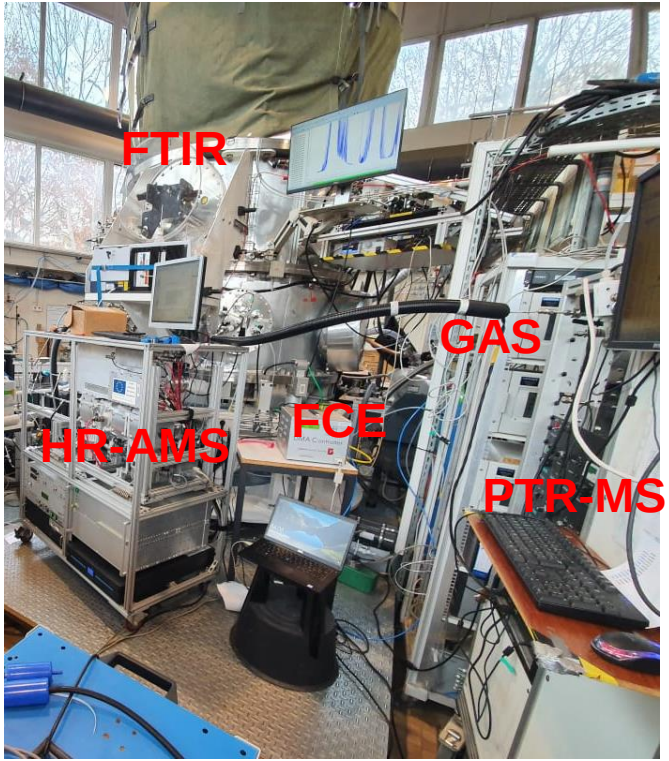
Particle size, number and mass
- SMPS (20-800nm)
- CPC
- CPMA
- TEOM-50
- AE33

Chemical characterization
- PTR-MS
- ACSM / HR-AMS
- Filters

Gas
- CO_2/CO/NO_x/O_3/SO_2

Experimental set-up

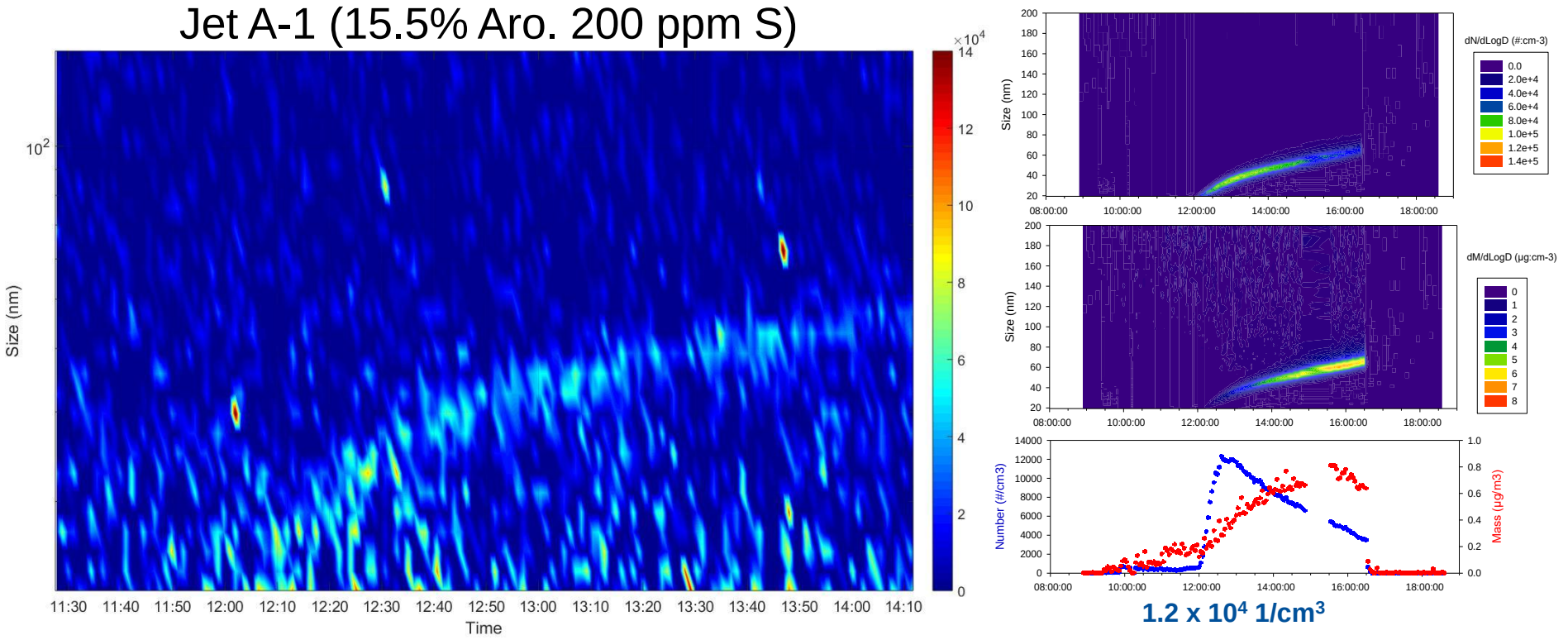
Experimental set-up



Experimental protocol

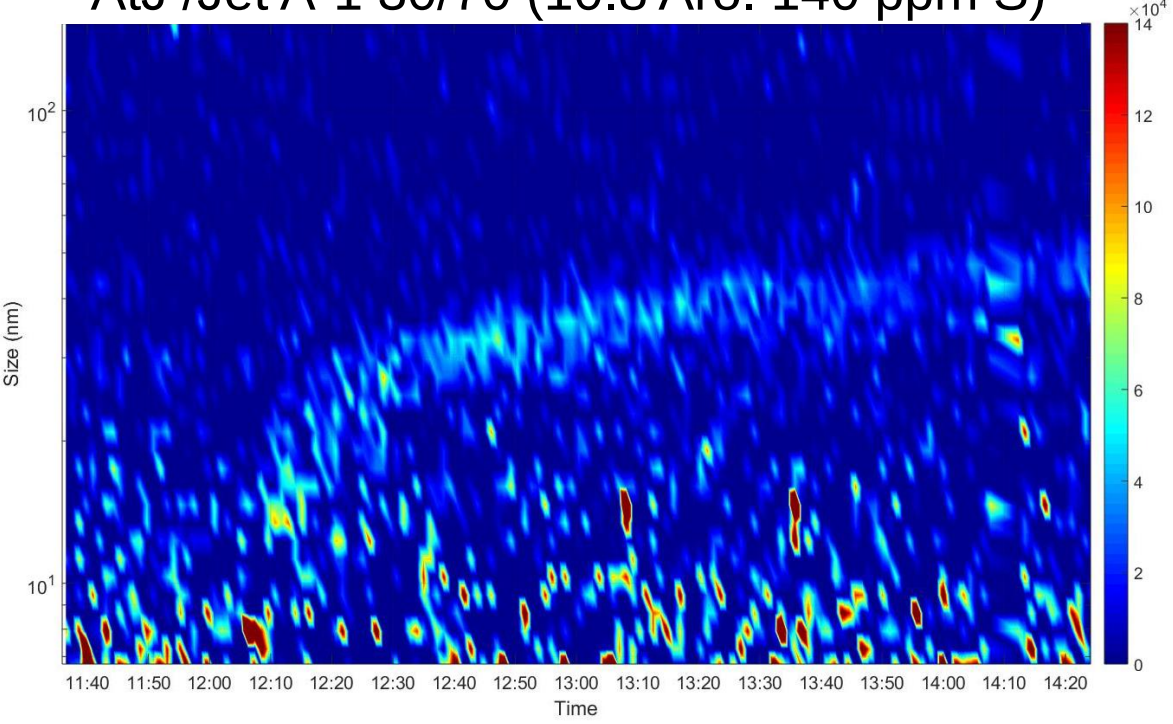
- Limit of soot amount in the chamber to avoid contamination
- Two types of experiments:
  - Injection of gases gases (HEPA filter)
  - Sequential injection gases and then soot
- Injection under dark conditions, lights on after stabilization
- PAM experiment in parallel mainly with soot + gases (only 2 runs with gases only)
- Fuel tested: Jet A-1, AtJ, AtJ / Jet A-1 blend 30:70

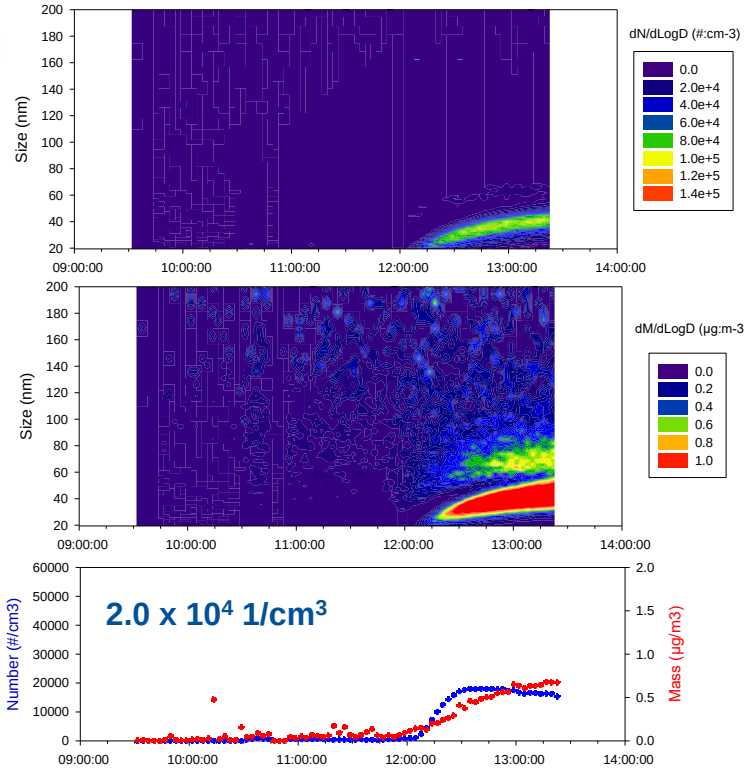
PRELIMINARY Results, Gas only injection (FCE + SMPS)



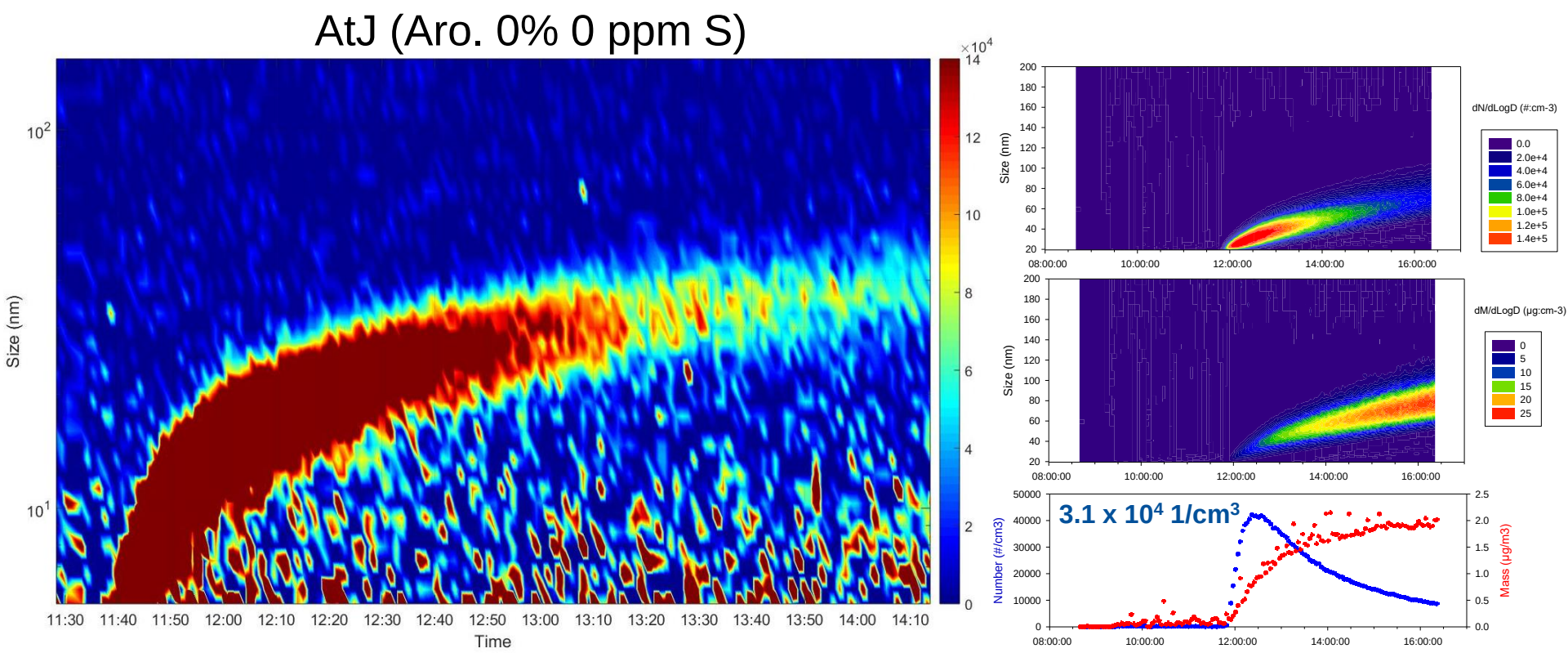
PRELIMINARY Results, Gas only injection (FCE)

AtJ /Jet A-1 30/70 (10.8 Aro. 140 ppm S)

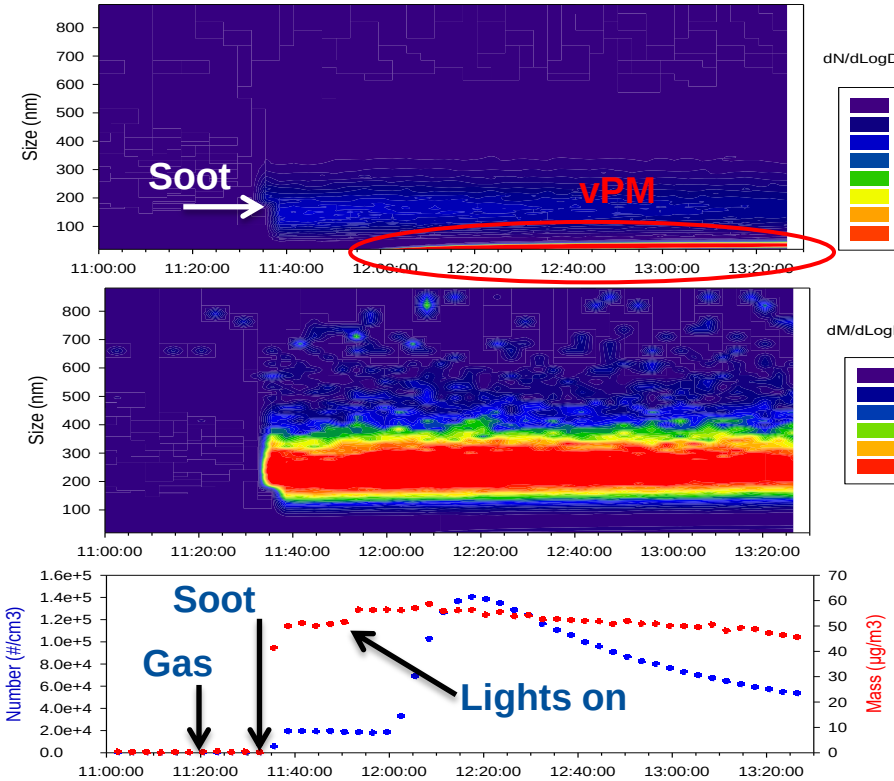




PRELIMINARY Results, Gas only injection (FCE + SMPS)

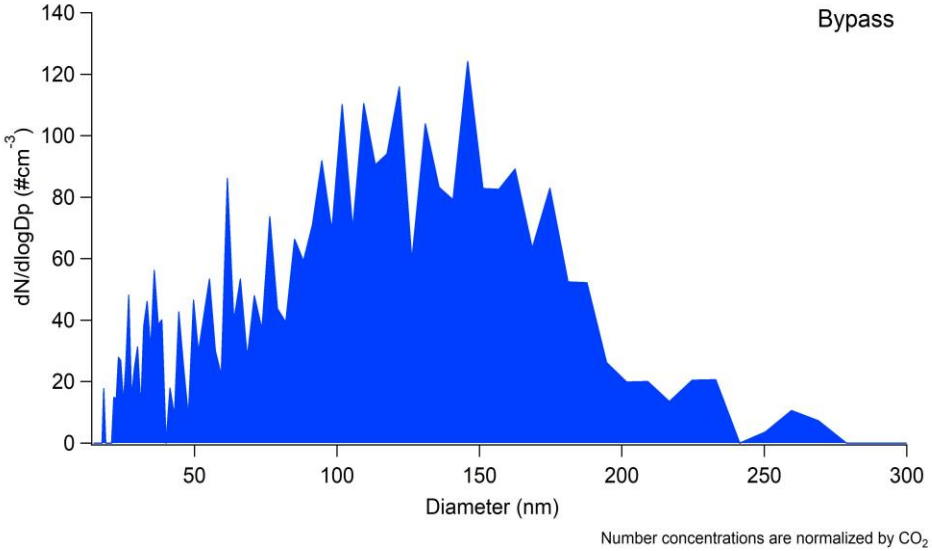


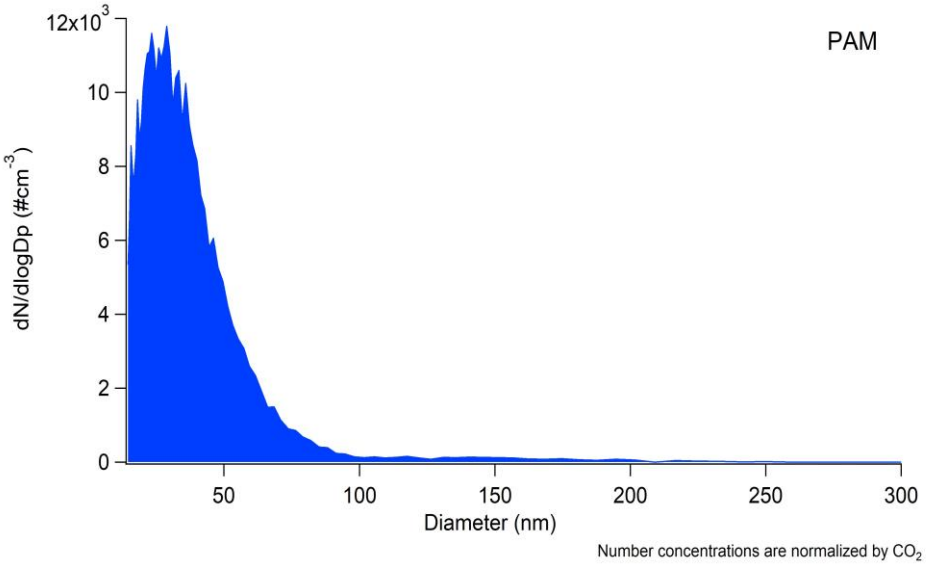
PRELIMINARY Results, Gas + soot injection (SMPS)



- Injection of gases only followed by 10 s injection of soot + gases (Jet A-1)
- Lights on after stabilization
- Just after lights were switched on, increase in mass but not in number → condensation on soot
- Around 12 min after lights on, particle number increases → vPM formation
- vPM formed are small →no significant contribution to total mass

PRELIMINARY Results, Gas only PAM flow reactor





Background particles coming from the line

Particles formed after PAM (~1.2 x10^4 1/cm^3)

Results summary

- We observed particle formation with all fuels gas only experiments for chamber and PAM

- We observed as well particle formation in some cases with Soot + gases

- AtJ produces almost 3 times more particles than Jet A-1(gas only experiments)

- Suplementary slides

Second UNREAL campaign, Fuel Matrix

Fuel	Aromatic content (%)	Sulfur content (ppm)
Jet A1 ref	16	4
Jet A1 High aro	23	4
Jet A1 High S	16	3000
Jet A1 High aro & S	23	3000
Jet A1 (A1)	15,5	200
AtJ (B1)	0	0
Jet A1/AtJ blend (E5)	10,8	140