HSE
Occupational Health and Safety

Quantification of inhaled soot mass using Pathfinder coupled results

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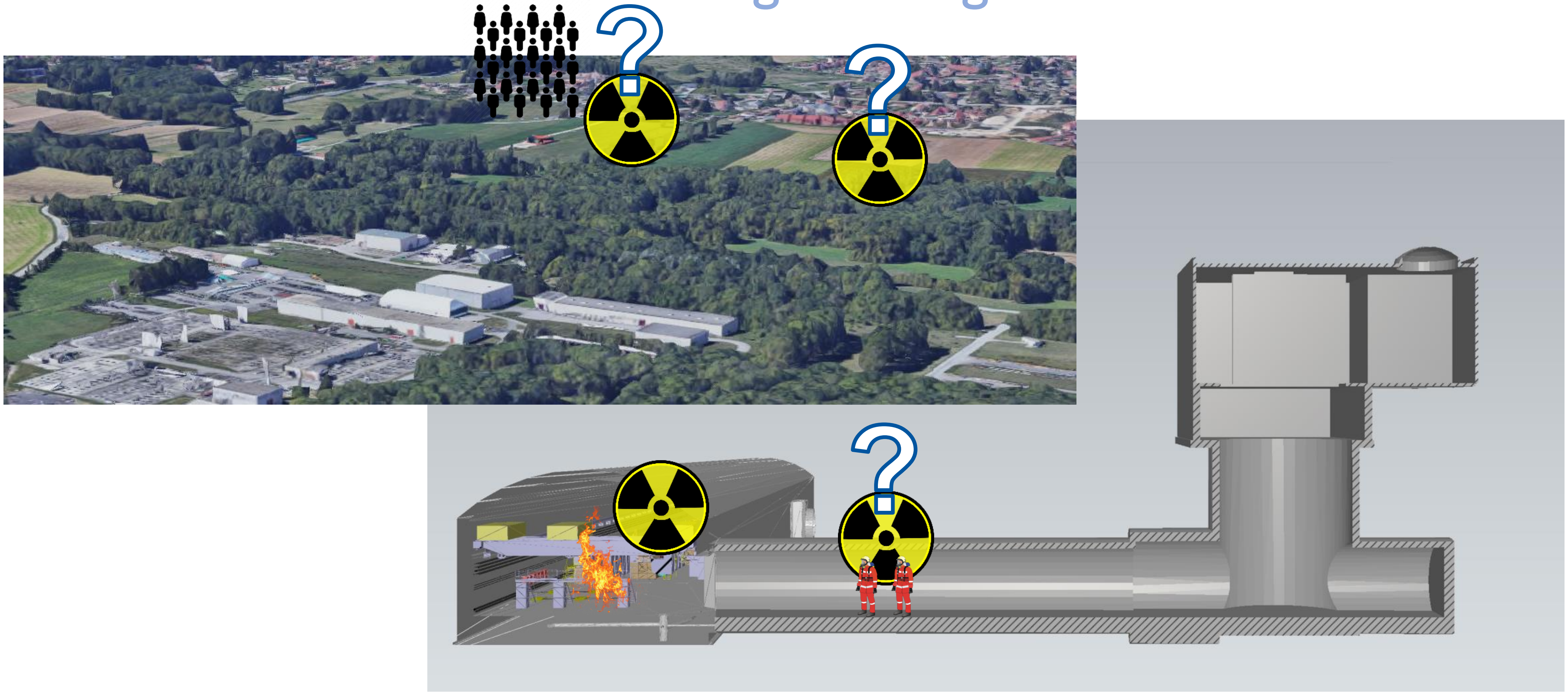
FIRIA - Fire Induced Radiological Integrated Assessment



Joint effort of the **HSE** Unit

Chair of project steering board: B. Delille (HSE DH)

Project Manager: S. La Mendola
Deputy PM: O. Rios

OHS | RP | FRS

Fire engineers

HSE
Fire Safety Engineering Team

RP physicists
&
Environmental protection specialists

Fire officer

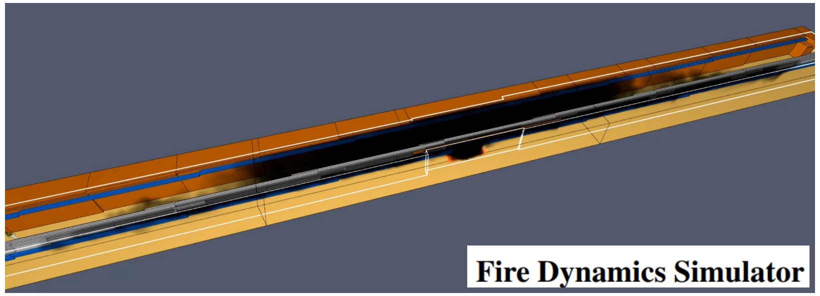
Support of the **IT department** for the use of the HPC cluster

Tech Student/PhD for dispersion

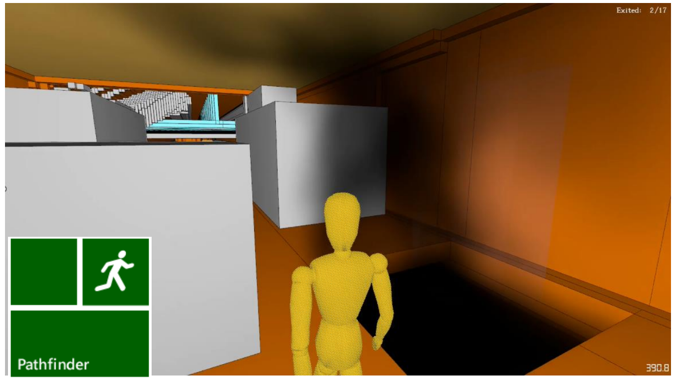
CFD cooperation with EN-CV CFD Team

- **Multidisciplinary project** launched in early **2018** by the HSE Unit for a duration of **3.5 years**
- In March 2020 a **second phase** was financed upon presentation of a project proposal to MTP 2021-2025 → **project extended beginning 2025**

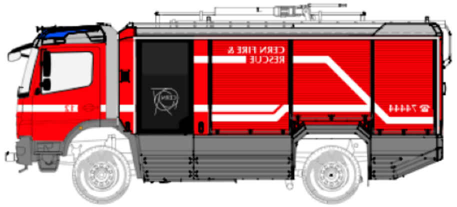
Fire modelling / smoke transport



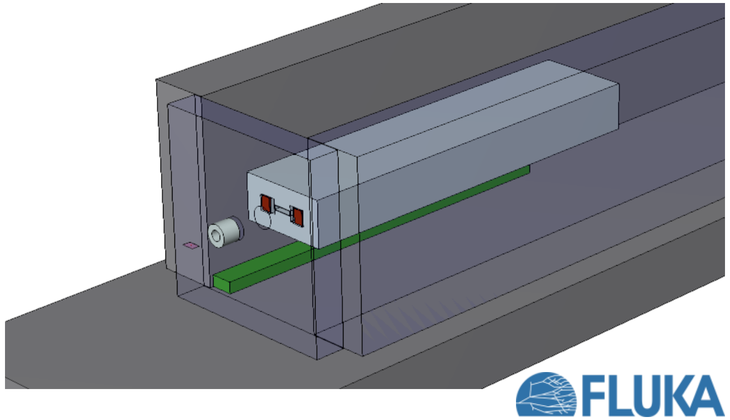
Life safety for occupants



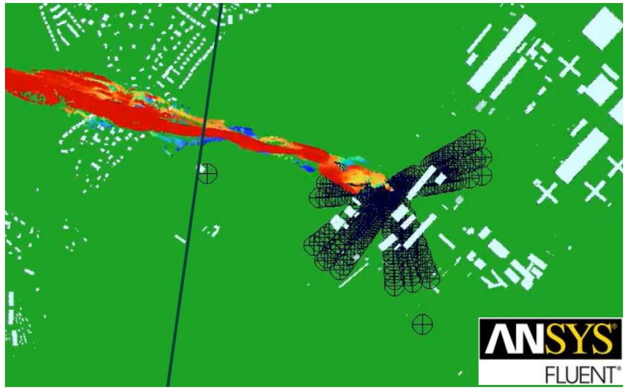
Input for fire intervention tactical plan



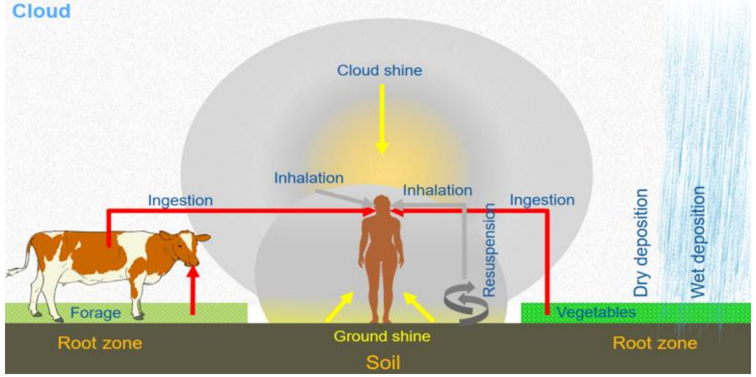
RP radionuclide inventory



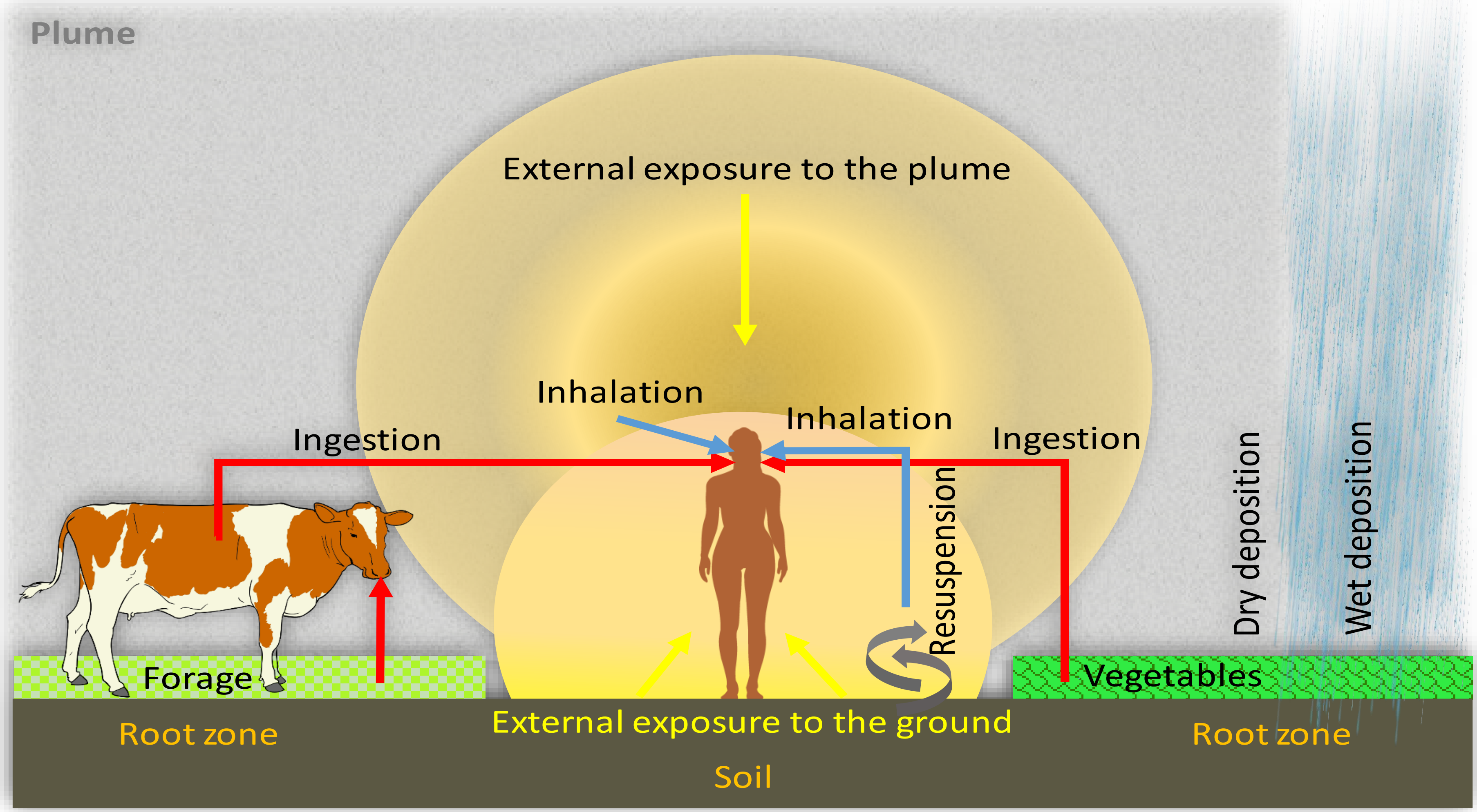
Environmental dispersion



Radiological environmental impact assessment



Assessment of effective dose



Assessment of effective dose

Methodology for inhaled soot

- We have a model to calculate:
  - Effect of inhaled toxic gases and visibility on *occupants* (FS)
  - Effect of radioactive gases and soot particles on *bystanders* (standing still) (RP)
  - Effect of direct radiation on *occupants* (RP)
- We need a model for the RP effect of inhaled radioactive gases and soot particles!

Methodology for inhaled soot

1. Calculating the time-dependent concentration of soot in every point with FDS → 2. Importing the data in Pathfinder which outputs the encountered concentration → 3. After running evacuation simulations, calculating the inhaled amount of soot → 4. Assessing the amount of radionuclides inhaled (Bq inhaled) → 5. Converting the activity to a committed dose (Sv)

Methodology for inhaled soot

- New model based on existing calculation tools:
  - Evacuation: Pathfinder gives us output on:
    - Amount of soot present per timestep (visibility)
    - Amount of CO present per timestep (CO volume fraction)
- Specific activity for soot → $a_s = \frac{1}{Y_s} a_{fuel}$, only used for particles deposited on soot (liquid/solid state)
- Radioactive gases (iodine etc) can be scaled with CO

Methodology for inhaled soot

- Amount of soot present per timestep (visibility)

$$S = \frac{C}{K_m \rho \chi_s}$$

$$\frac{\rho_0 T_0}{T} = \rho$$

S	Point-specific visibility	m
C	Non-dimensional constant characteristic of the type of object being viewed	-
K_m	Mass specific extinction coefficient	m^2/kg
ρ	Density of smoke	kg/m^3
χ_s	Soot mass fraction	kg/kg
ρ_0	Density of smoke (air) at T_0	kg/m^3
T_0	Ambient temperature	K
T	Point-specific temperature	K

Methodology for inhaled soot

- Amount of CO present per timestep (CO volume fraction)

$$f_{co} = \frac{\rho_{smoke}}{\rho_{co}} \chi_{co}$$

$$f_{co} = \frac{W_{smoke}}{W_{co}} \chi_{co}$$

f_{CO}	CO volume fraction	m^3/m^3
ρ_{smoke}	Smoke density	kg/m^3
ρ_{CO}	CO density	kg/m^3
χ_{CO}	CO mass fraction	kg/kg
W_{smoke}	Molar mass of smoke	g/mol
W_{CO}	Molar mass of CO	g/mol

Methodology for inhaled soot

- Using Pursers model, which is used to calculate inhalation of CO and can be used for soot:
- Scaling with soot:

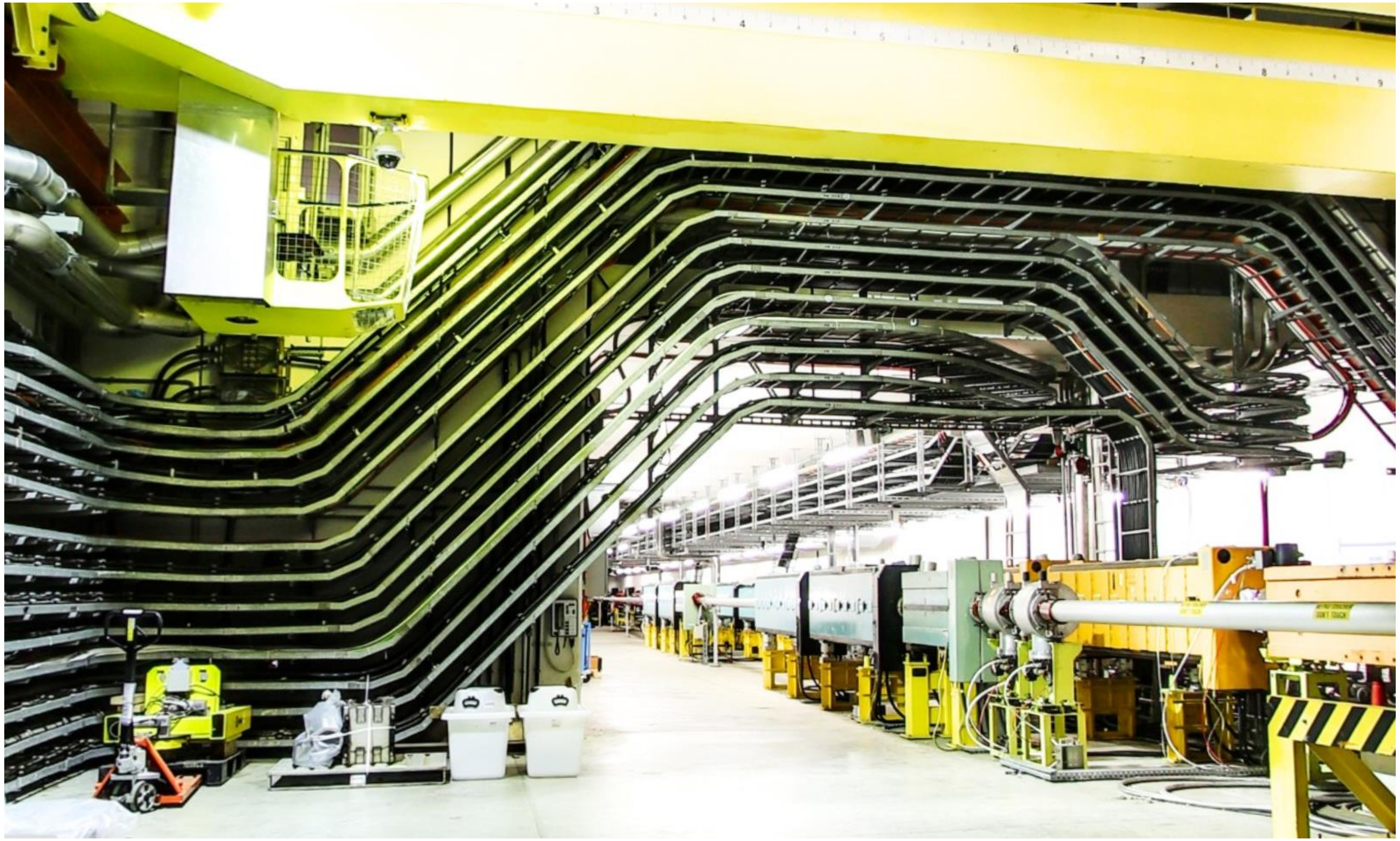
$$A_{i,Bq} = \frac{1}{Y_S} a_{fuel} \sum V_{CO_2} RMV_{mass} \chi_s \Delta t$$

- Scaling with CO:

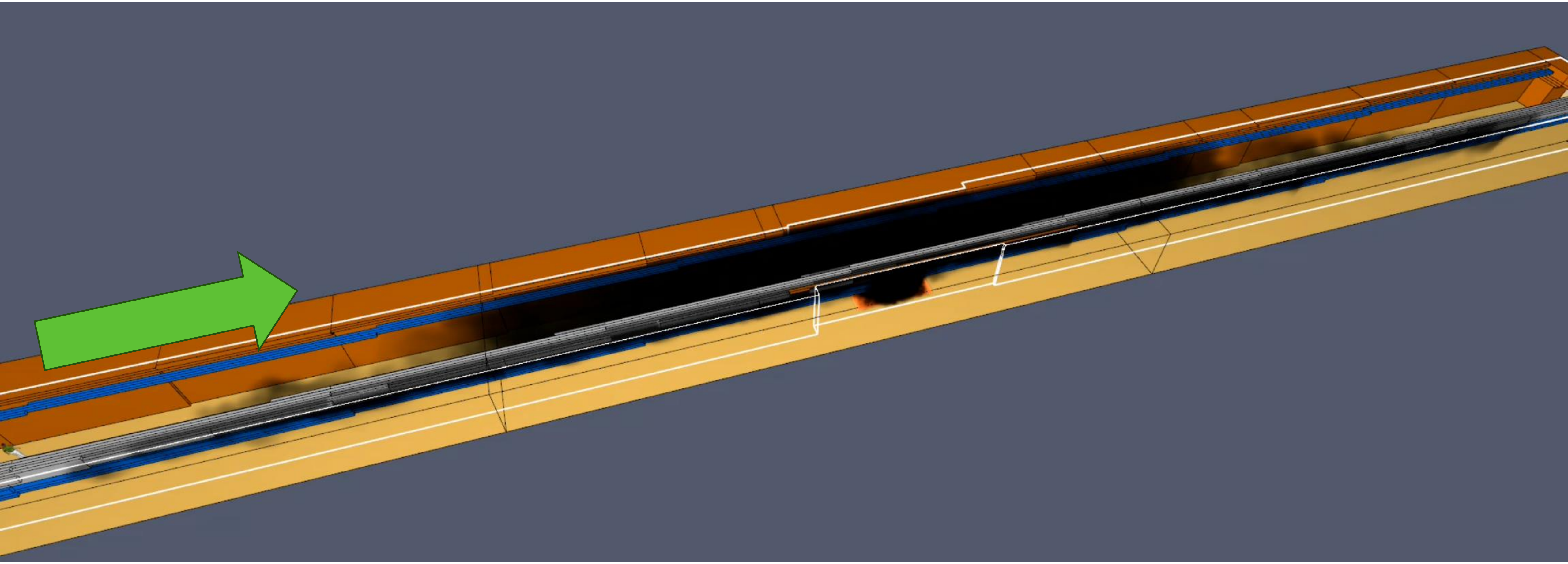
$$A_{i,Bq} = \frac{1}{Y_{CO}} a_{fuel} \sum V_{CO_2} RMV_{mass} \chi_{CO} \Delta t$$

$A_{i,Bq}$	Committed dose due to inhalation	Bq
Y_S, Y_{CO}	Soot yield, CO yield	kg/kg
a_{fuel}	Specific activity of the fuel	Bq/kg
V_{CO_2}	Multiplication factor due to hyperventilation	-
$\mathrm{RMV_{mass}}$	Respiratory minute volume - mass	kg/s

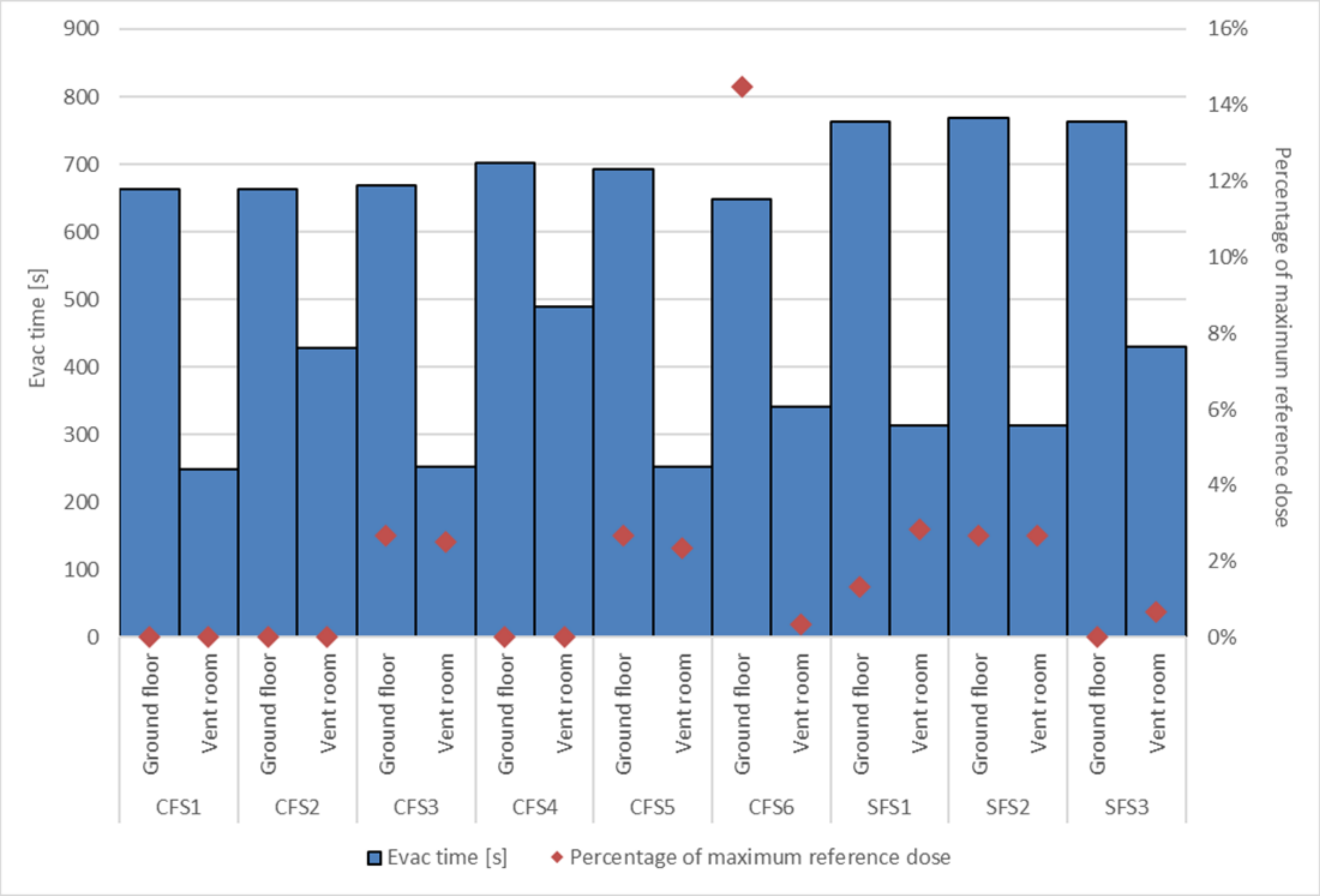
Example



Example



Example


900
800
700
600
500
400
300
200
100
0
Evac time [s]
16%
14%
12%
10%
8%
6%
4%
2%
0%
Percentage of maximum reference dose
Ground floor
Vent room
CFS1
CFS2
CFS3
CFS4
CFS5
CFS6
SFS1
SFS2
SFS3
Evac time [s]
Percentage of maximum reference dose

Conclusion

- Novel methodology allows to quantify the effective dose due to inhalation, with moving agents.
- This methodology is highly scaleable to other properties, whether gases, liquids or solids – imagine lead content in the fuel, asbestos content,...
- Post-processing is still time consuming.
- It would be beneficial to add this functionality as a built-in property in FDS & Pathfinder
  - This requires more flexibility on the definition of PLOT3D properties and more flexibility on the interlinking of them.

Thank you for your attention!

Questions?