Plume release CFD benchmark

Participants :

Air Liquide, CEA, JCR, NCSRD, PSA

Context

- Following B. Cariteau GAMELAN experiments
- Injections of helium in a closed/vented cavity
- Covered plume up to jet regimes of injection (1Nl/min up to 360 Nl/min) through 5mm up to 32mm diam.
- General good agreement between theory (Worster and Huppert) except at very low injection rates => unanswered questions
  - Is the assumed constant entrainment coef the problem ?
  - Are Ri dimensionless numbers appropriate to model the physics.

=> Need for a better understanding of the flow structure through CFD or new experiments

The modeled facilty GAMELAN

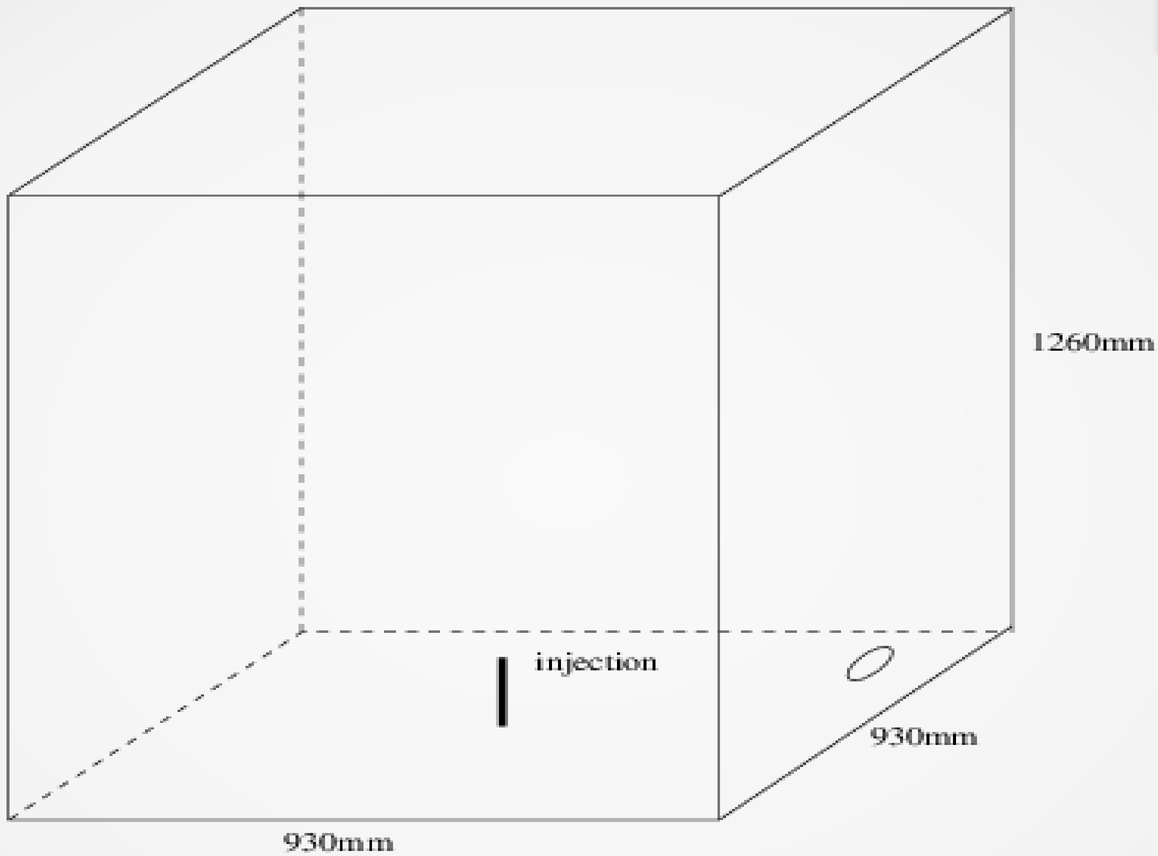
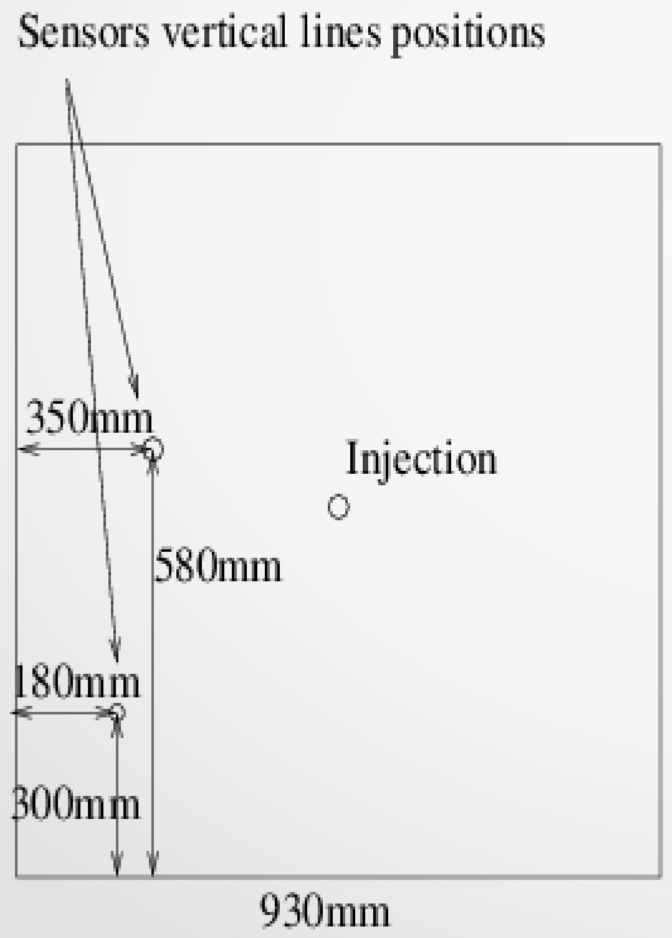
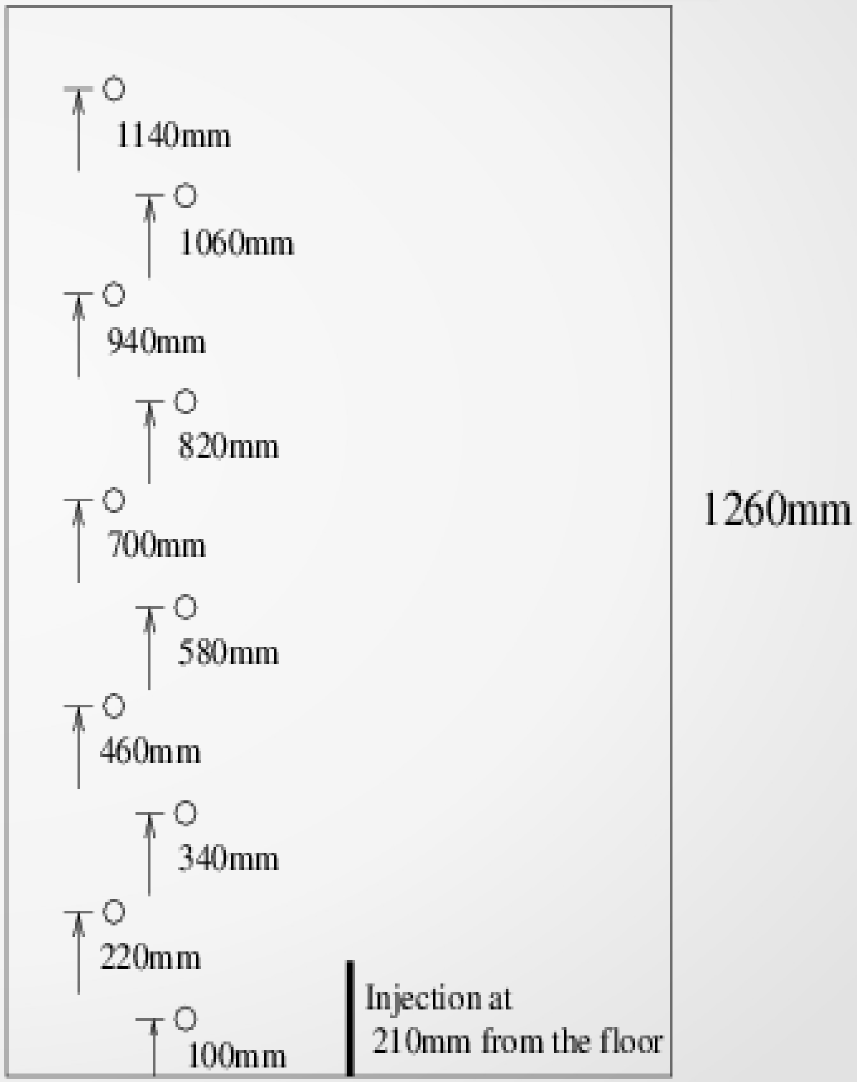


TABLE I: Experimental conditions.

D (mm)	Q_{he} (Nl/min)	Ri_0	l_m (m)	T (°C)	injection time (s)
20	4	3	0.03	19.5	1200

GAMELAN – sensors position





The physical models

- AL, CEA, PSA: Boussinesq approximation
- JCR: isothermal approach
- NCSRD: fully compressible equations

- L.E.S: (CEA) 2D axi approach. Smagorinsky $\mu_t = C_s^2 V_h \sqrt{S_{ij} S_{ij}}$

  Cs = 0.2
- Laminar approach (CEA, JCR): laminar viscosity and diffusivity but upwind scheme and limited spatial resolutions

The physical models

- RANS approach (AL, JCR, NCSRD, PSA)

TABLE II: k-ϵ parameters.

parameters	AL kϵ	AL realizable kϵ	PSA kϵ	NCSRD kϵ	JCR kϵ
Sc_t	0.7	0.7	0.7	0.85	0.7
C_μ	0.09	computed	0.09	0.09	0.09
$C_{1,\epsilon}$	1.44	1.44	1.44	1.44	1.44
σ_k	1	1	1	1	1
σ_ϵ	1.3	1.2	1.3	1.3	1.3
injection % turbulence	1%	1%	1%	?	5%

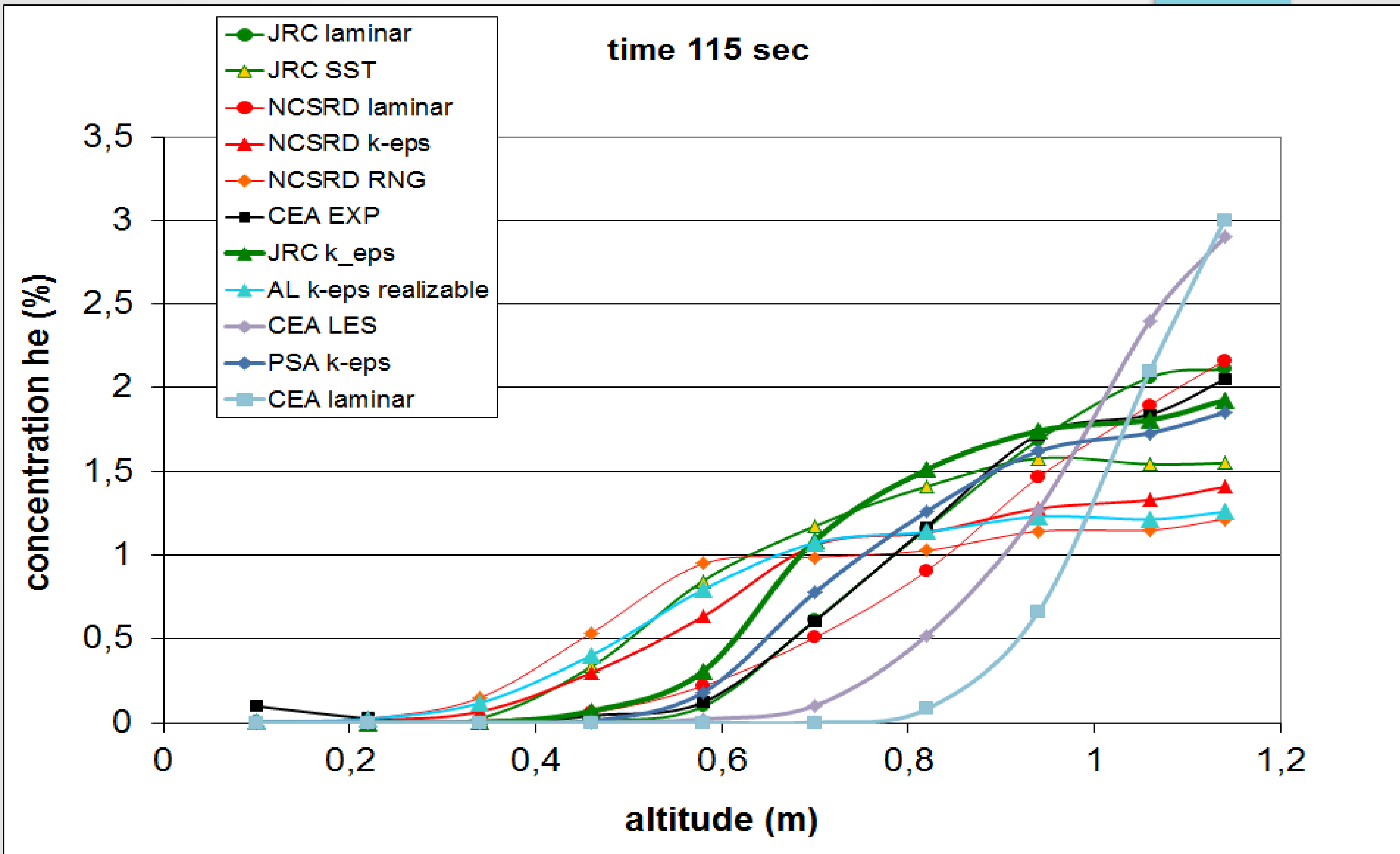
- RANS k-epsilon (NCSRD)

- SST (JCR)

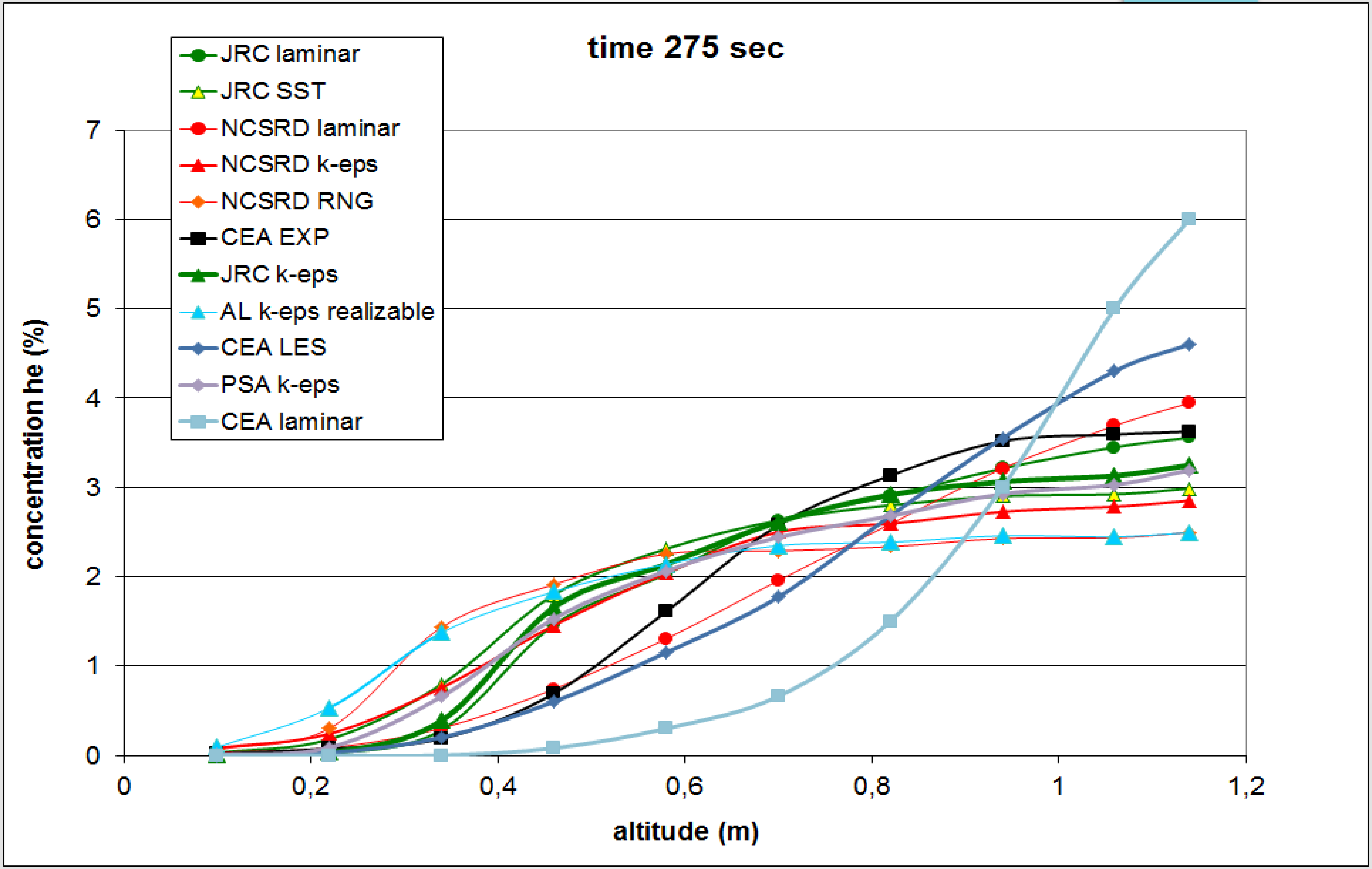
The numerical models

- CEA: Cast3M. Quadratic finite elements. Double projection. BDF2. Centered convection scheme. 10 nodes in the injection diam. 10000 nodes.
- AL: 3D, 8 nodes in the injection. 500000 nodes. BDF2 scheme. Fluent VF. Upwind.
- PSA : Fluent, 10 nodes in injection diam. 700000 nodes. SIMPLE solver. Euler scheme. Upwind.
- NCSRD : 2 cells in the source (new calculations since this paper). 25000 nodes. 3Rd order Quick.
- JCR :CFX. BDF2. Many tetraedral mesh tested.

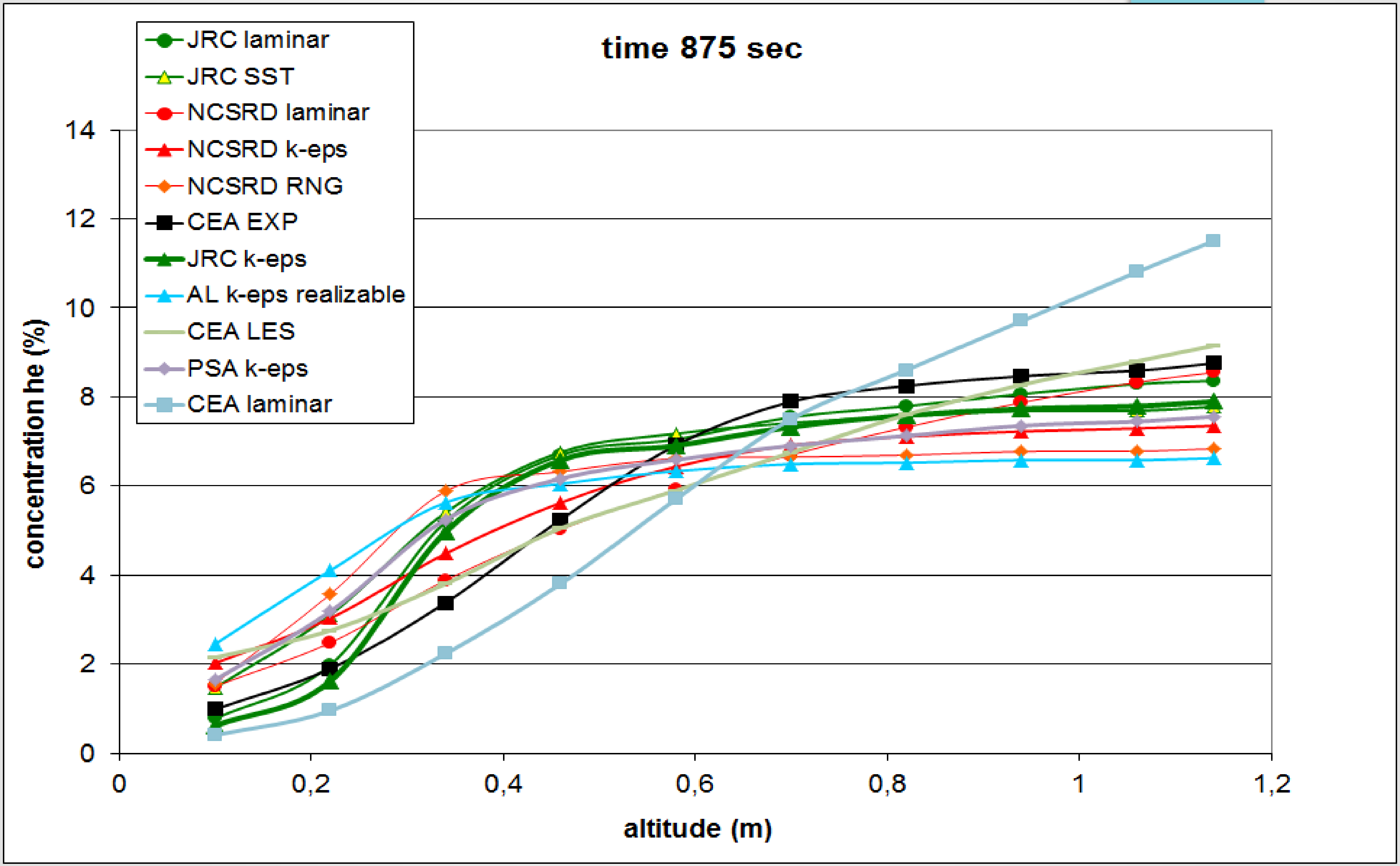
Results – C vertical profiles at 115s



Results – C vertical profiles at 275s



Results – C vertical profiles at 875s



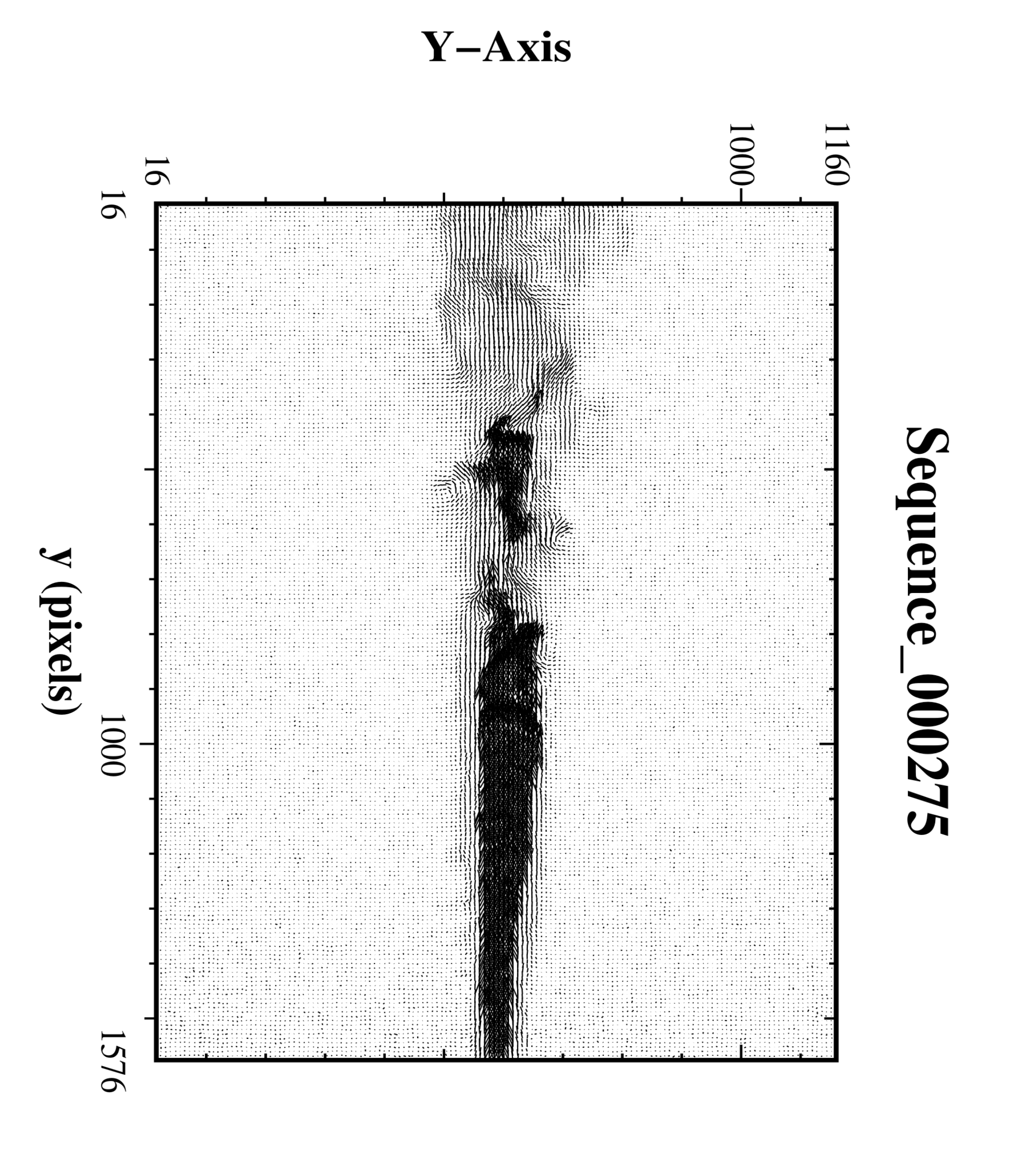
Concluding remarks

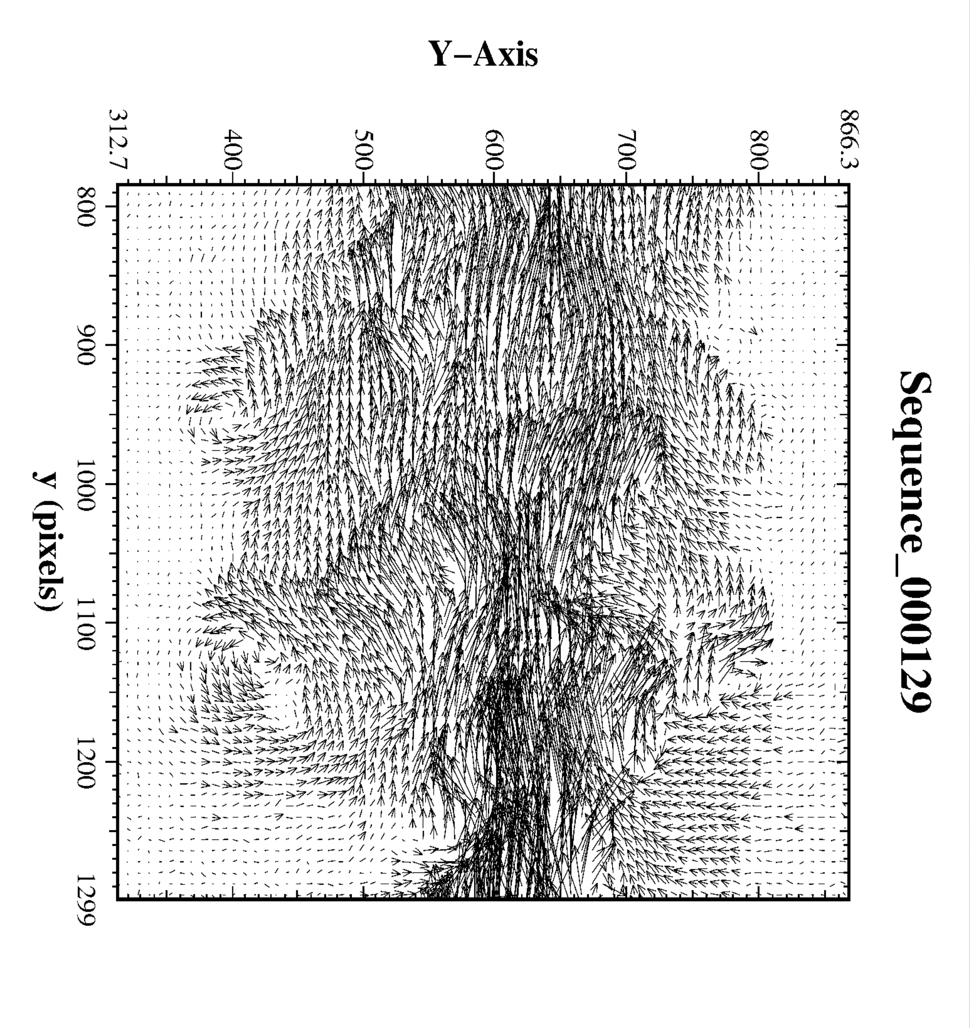
- RANS approach : too dispersive, too much diffusion leads to lower concentration at the top and higher concentration at the bottom of the cavity.
- Laminar approach : not really laminar, grid not fine enough, it is not DNS because of upwind scheme. Not diffusive enough because fluctuations and entrainment mechanism not well captured
- 2D-axi approach (LES) : not diffusive enough, axisymetry blocks the fluctuations along the axis of the jet.

Work in progress and perpectives

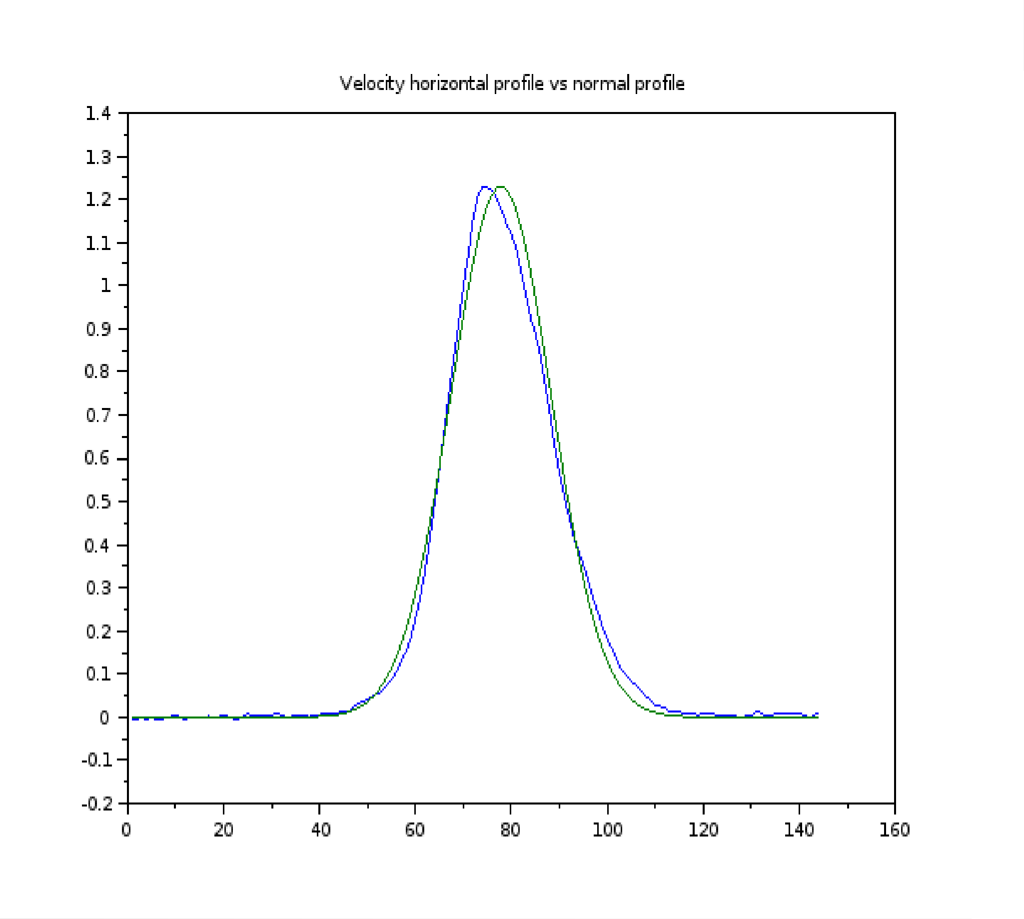
- UU made vey promissing 3D-LES calculations. Good agreement with experiments.
- Comparisons with new experiments are to be achieved. CEA has started a new GAMELAN set of experiments with PIV measurements
  - Gives access to velocity maps at the cavity scale
  - Acces to 3D components velocities in the jet with fine resolution (0.05 mm).

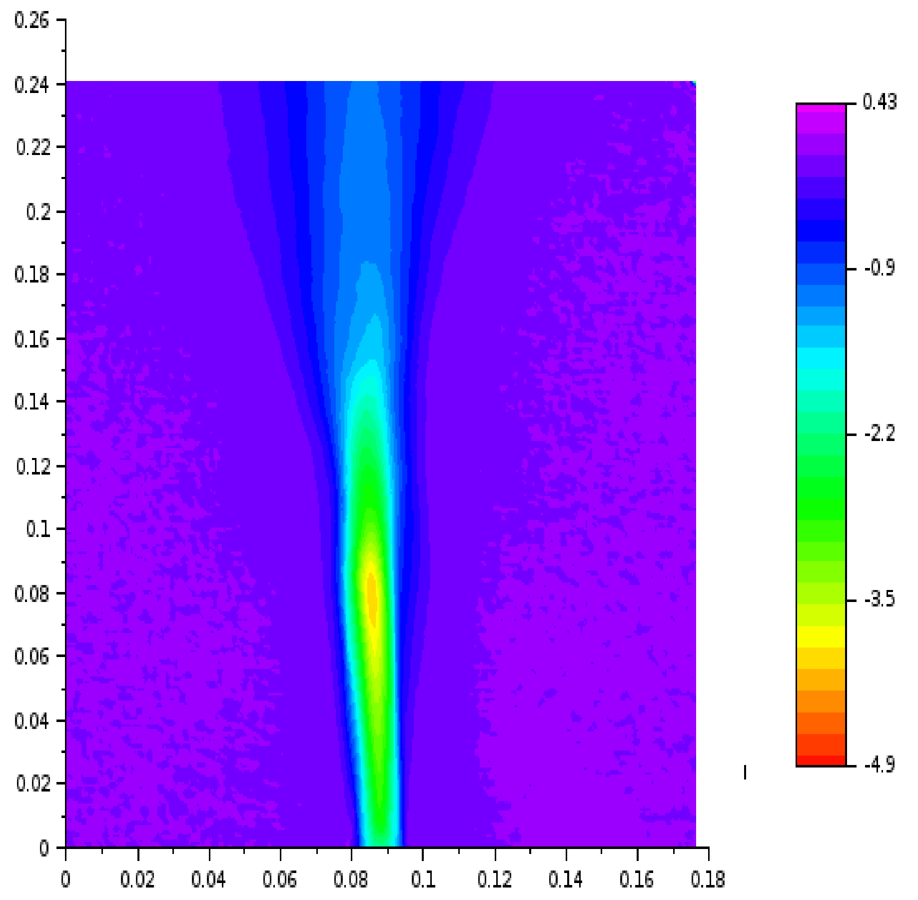
Future experimental validations





Mean values and entrainment





- Normal profile even at close distance will allow to calculate entrainment coef with vertical velocity.