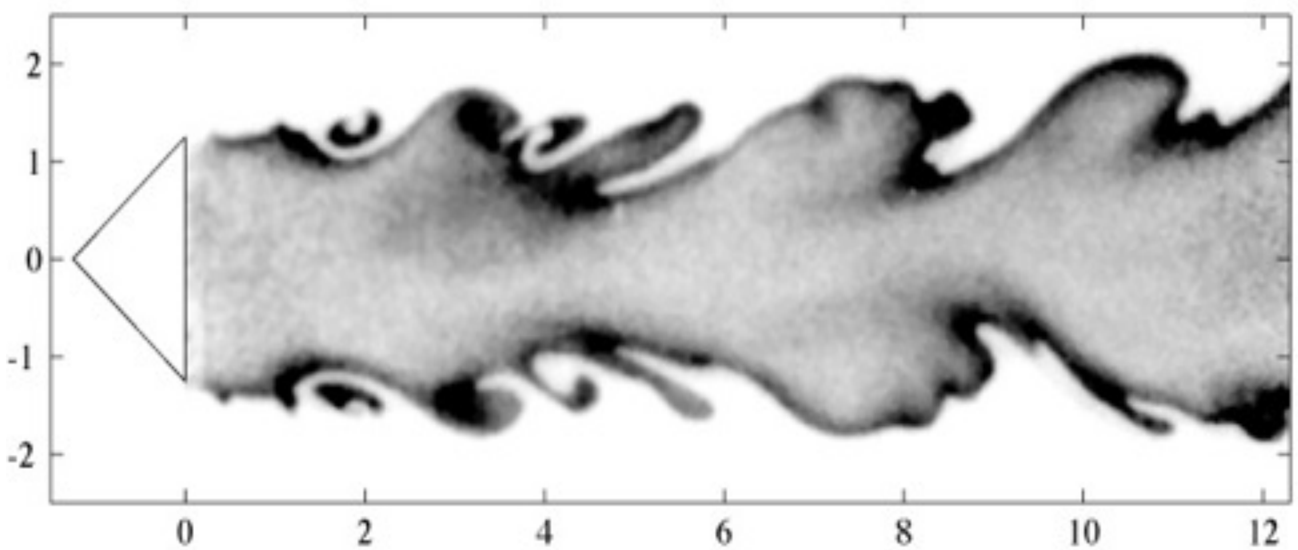
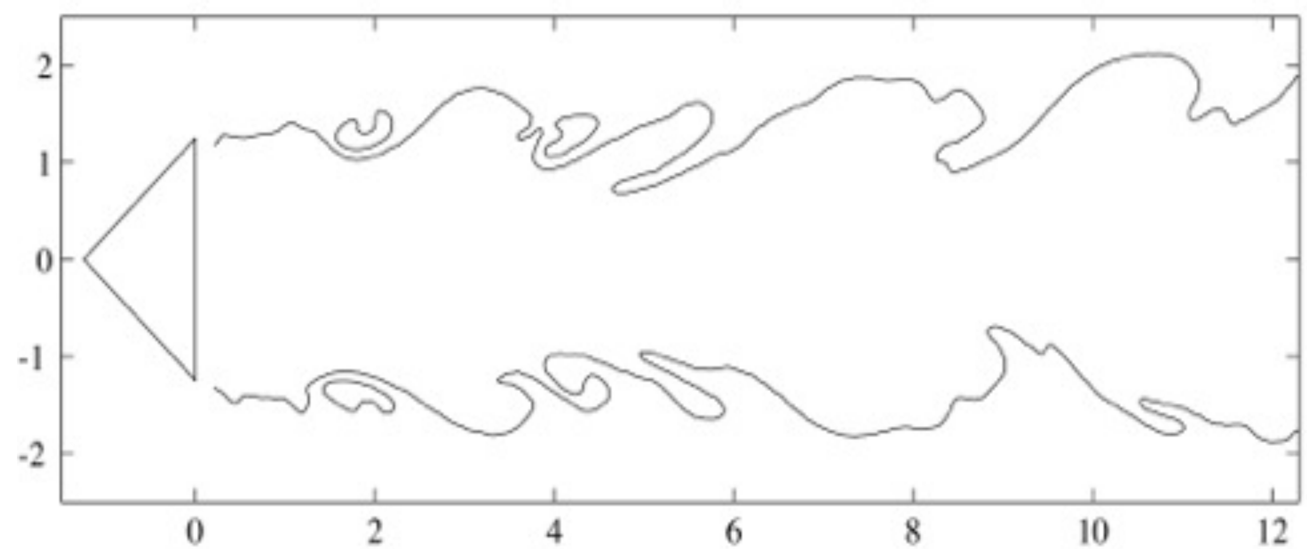
Développement d'un code Monte-Carlo pour le calcul intensif utilisant les spécificités de la méthode ERM

Olivier Gicquel, Ronan Vicquelin, Jean Taine

Phd Students : Y. Zhang, J. Kim, G. Wang, R. Goncalves dos Santos

Experimental data
(turbulent premixed propane / air V-shape flame)



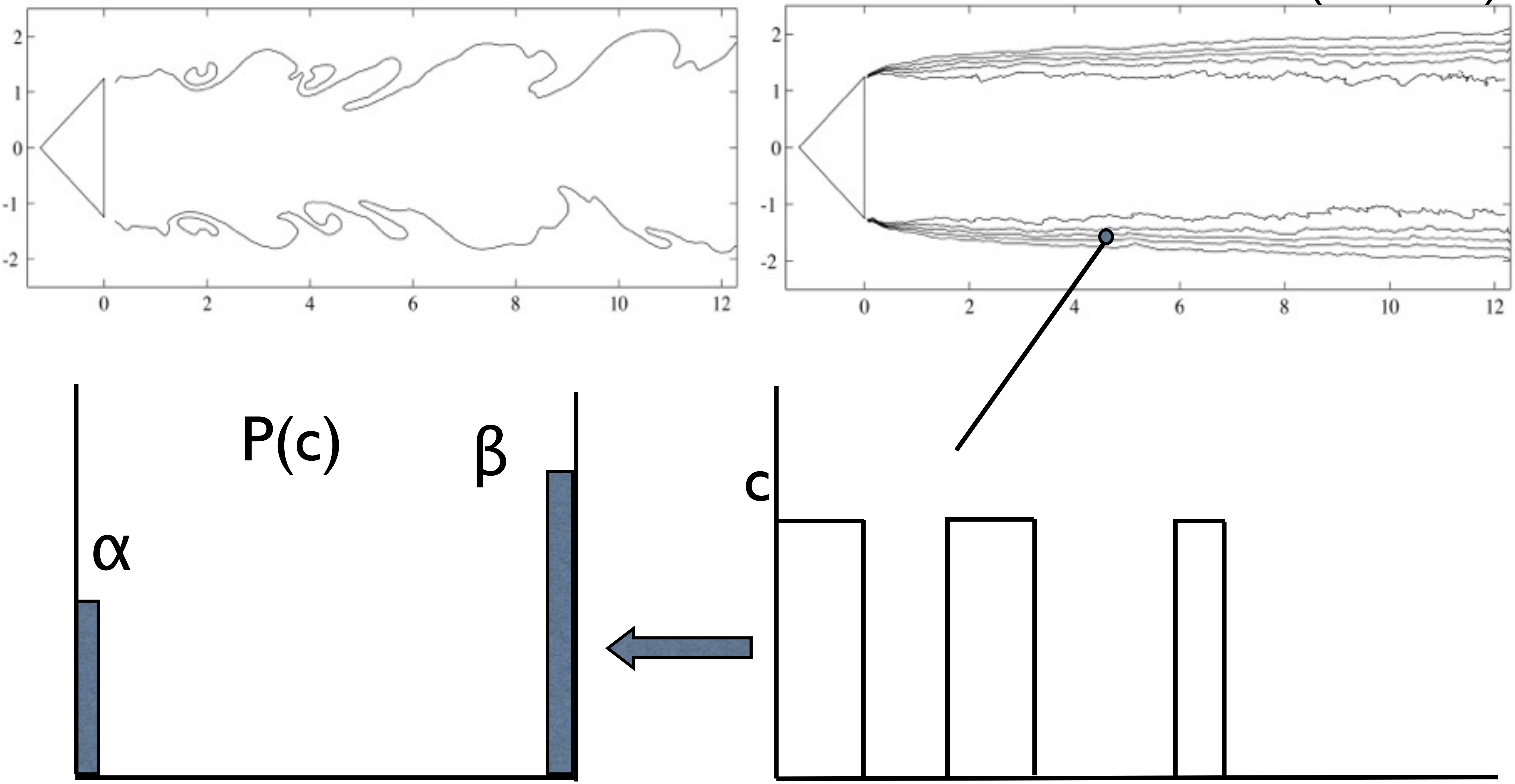


Flame visualisation using PLIF on OH radical

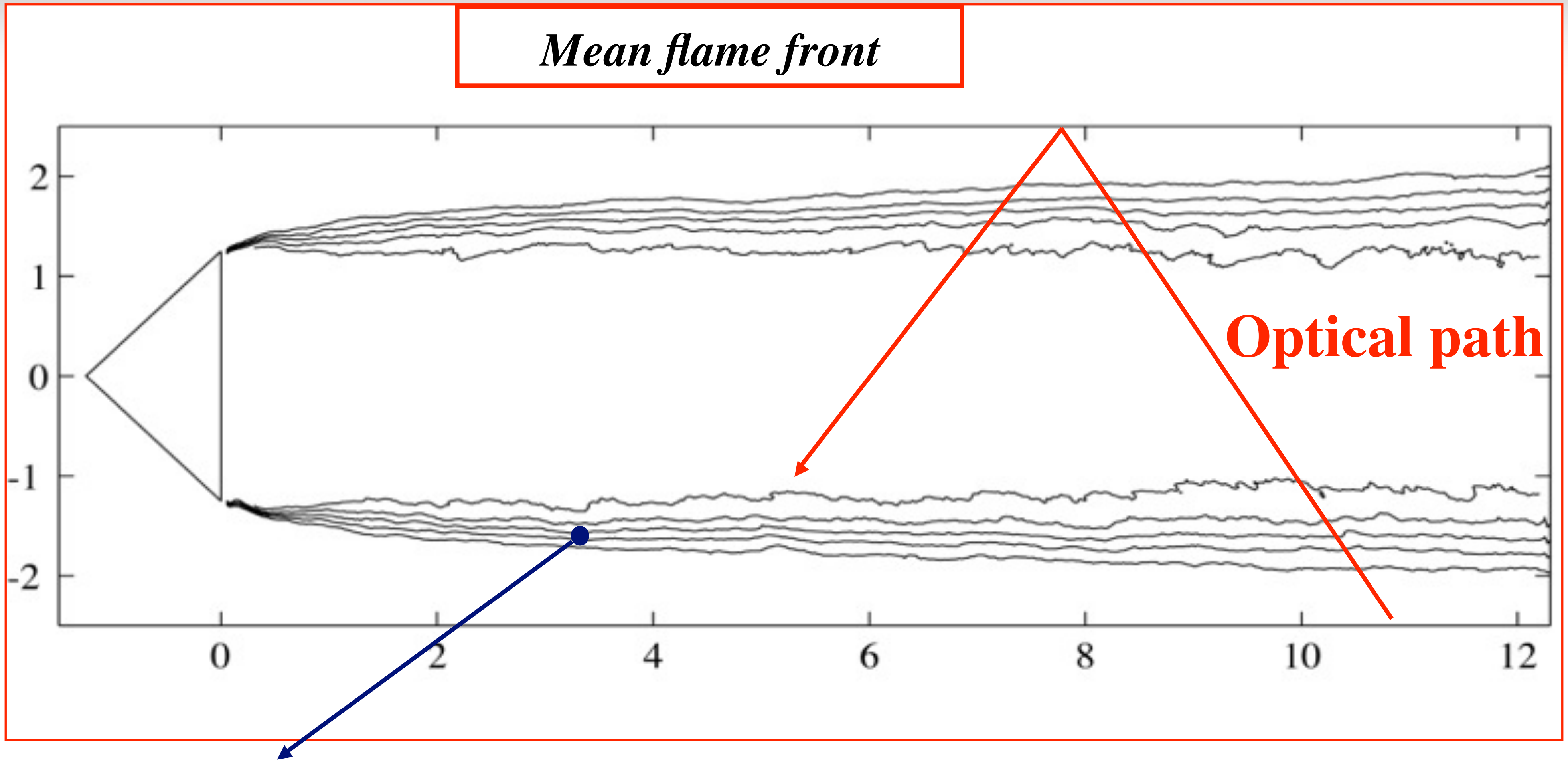
Extracted flame front

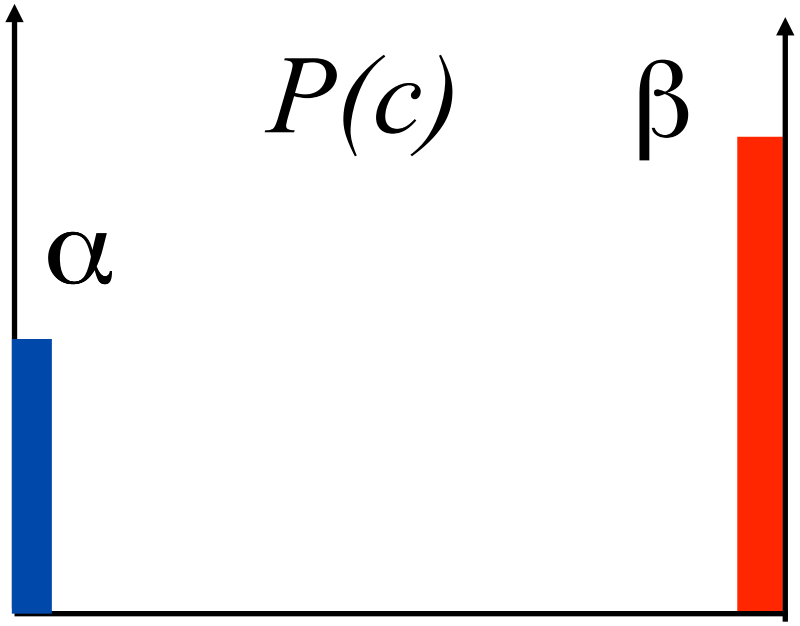
Knikker et al. (2000, 2004, 2006)

Instantaneous flame front — Mean flame front (RANS)



Mean temperature = probability to be in burnt gases!



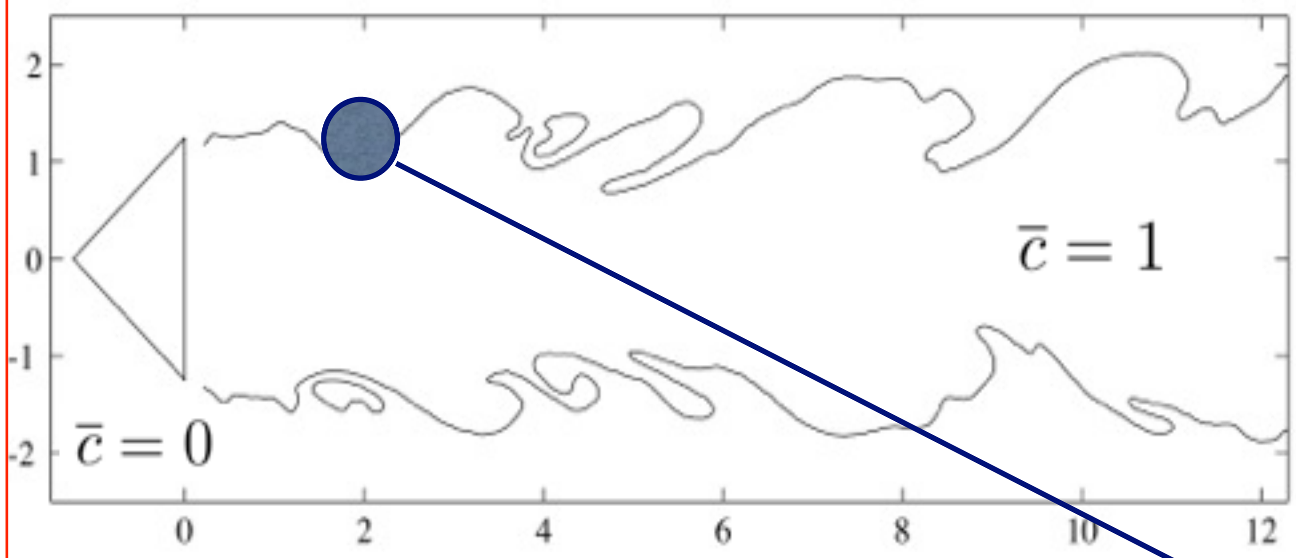


Averaging of radiative heat transfers along **instantaneous** optical paths

Models for cross-correlations!

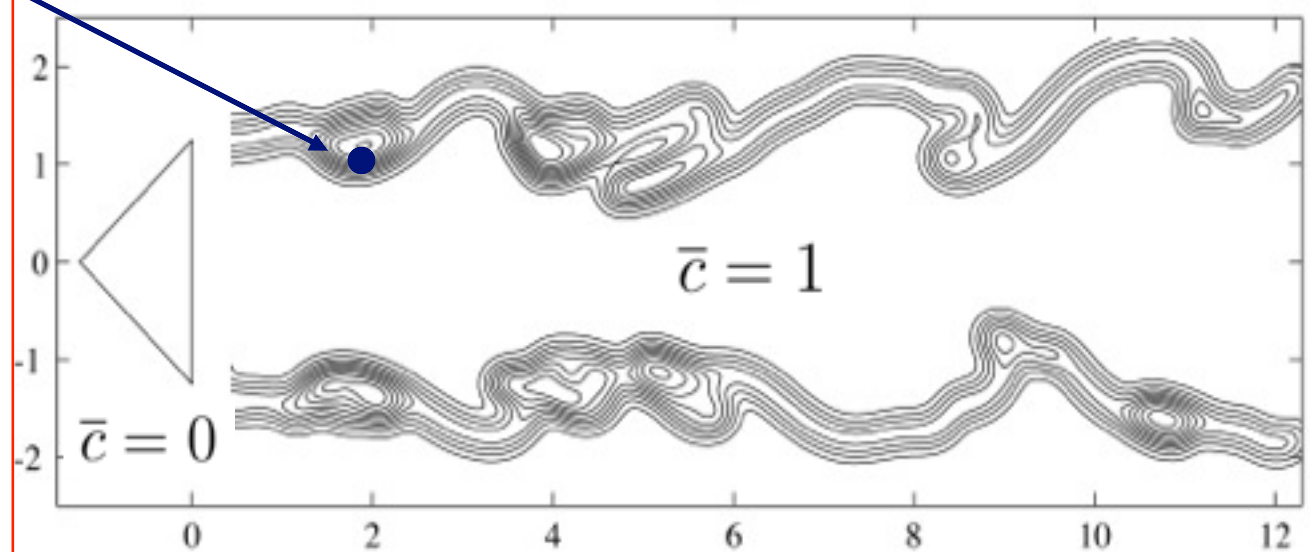
RANS versus LES simulations

LES framework



Local (weighted) average over a small volume

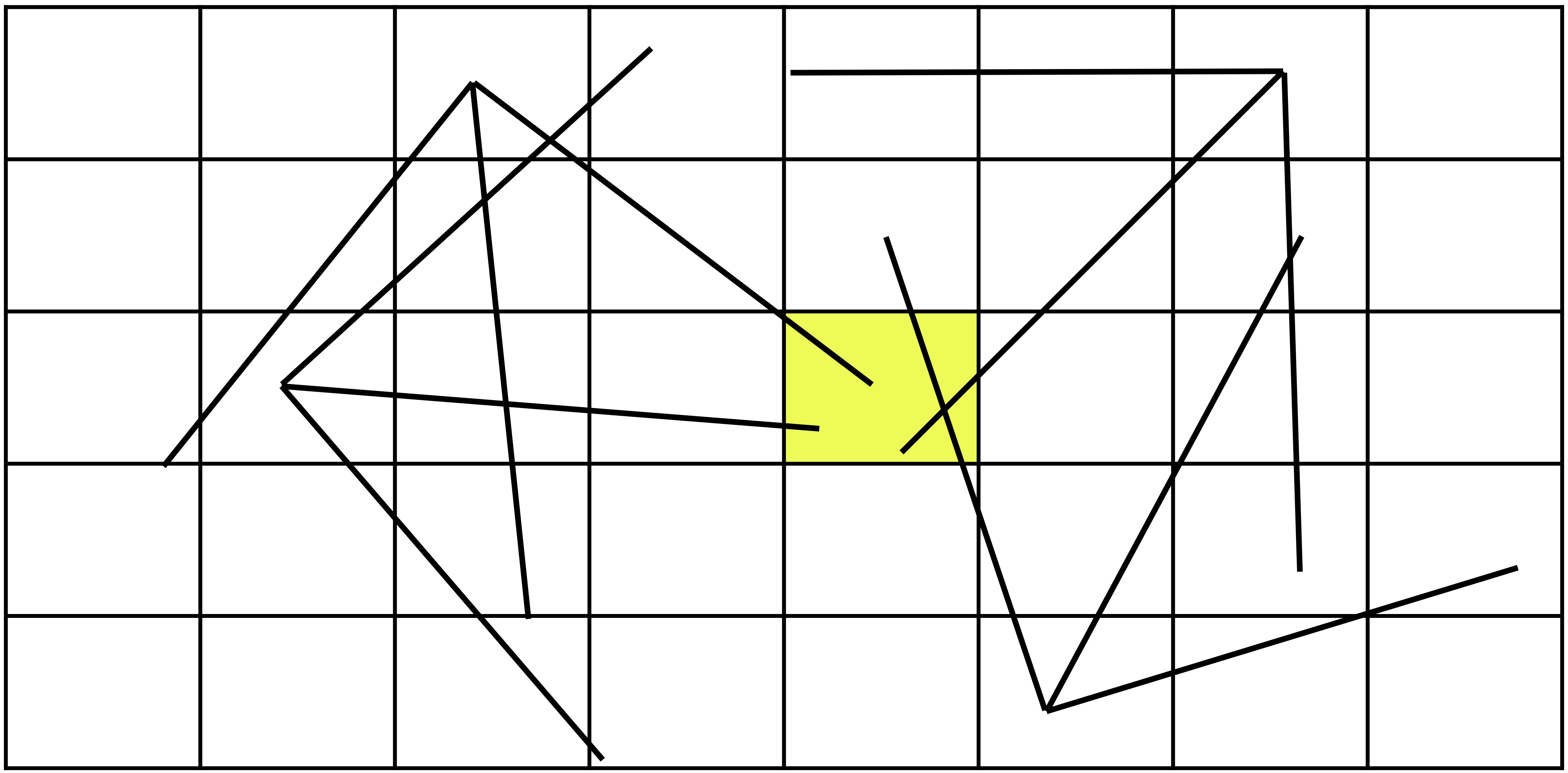
Fresh and burnt gas locations identified at the resolved scale level



Instantaneous filtered flame front (LES)

A dedicated Monte Carlo solver

Classical Monte Carlo approach



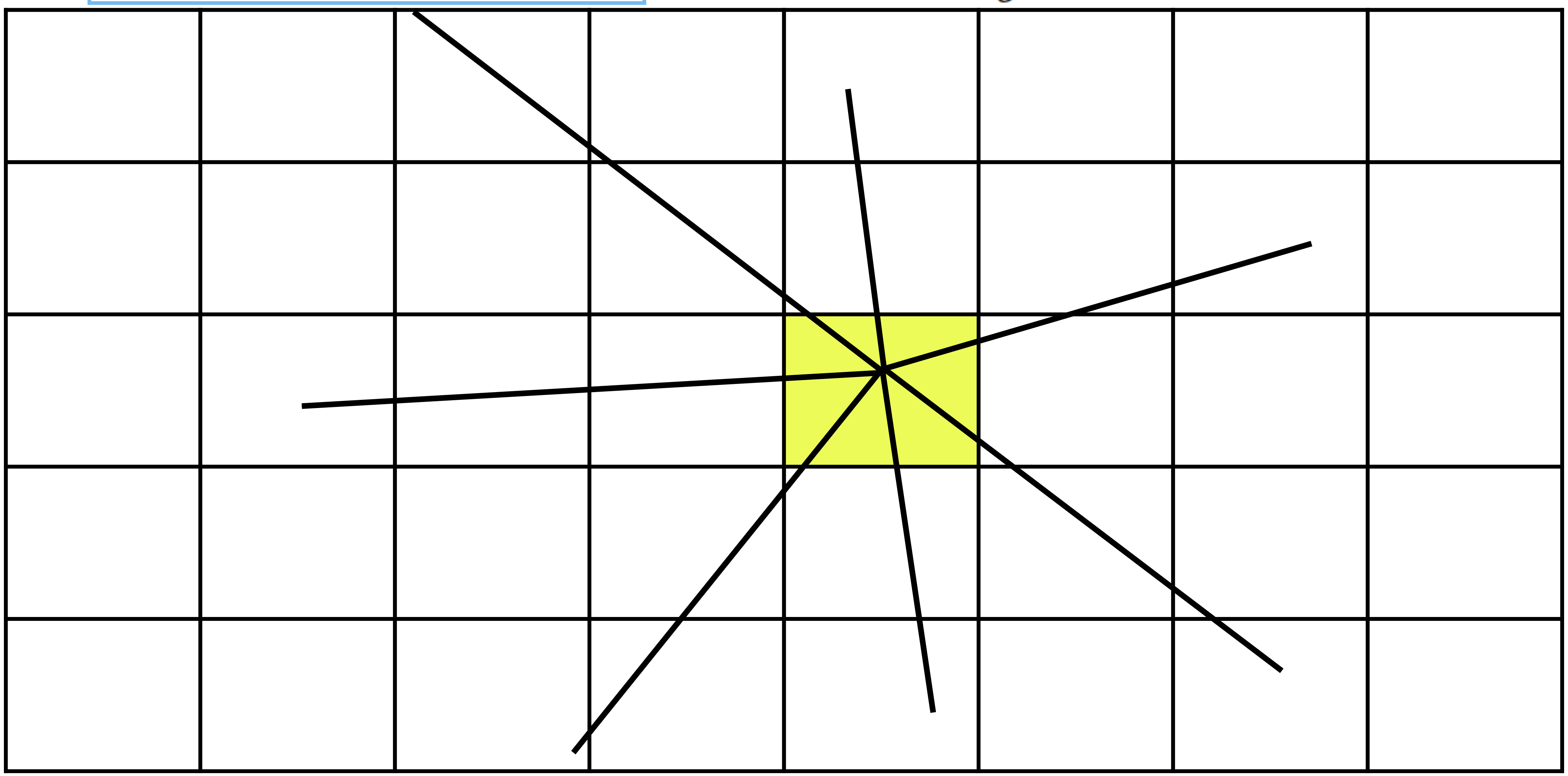
- Can not estimate the radiative power in a single point of the domain without performing a full simulation
- The convergence is a global converge
- The convergence is hard to optimize
- Problem of load balancing in massively large simulation
- Need a large amount of memory

A dedicated Monte Carlo solver

Reciprocal Monte Carlo approach ERM (L.Tessé et al)

$$P_i = \sum_{j=1}^{N_v+N_f} P_{ij}^{exch}$$

$$\frac{P_{ji}^{ea}}{P_{ij}^{ea}} = \frac{I_\nu^0(T_j)}{I_\nu^0(T_i)}$$



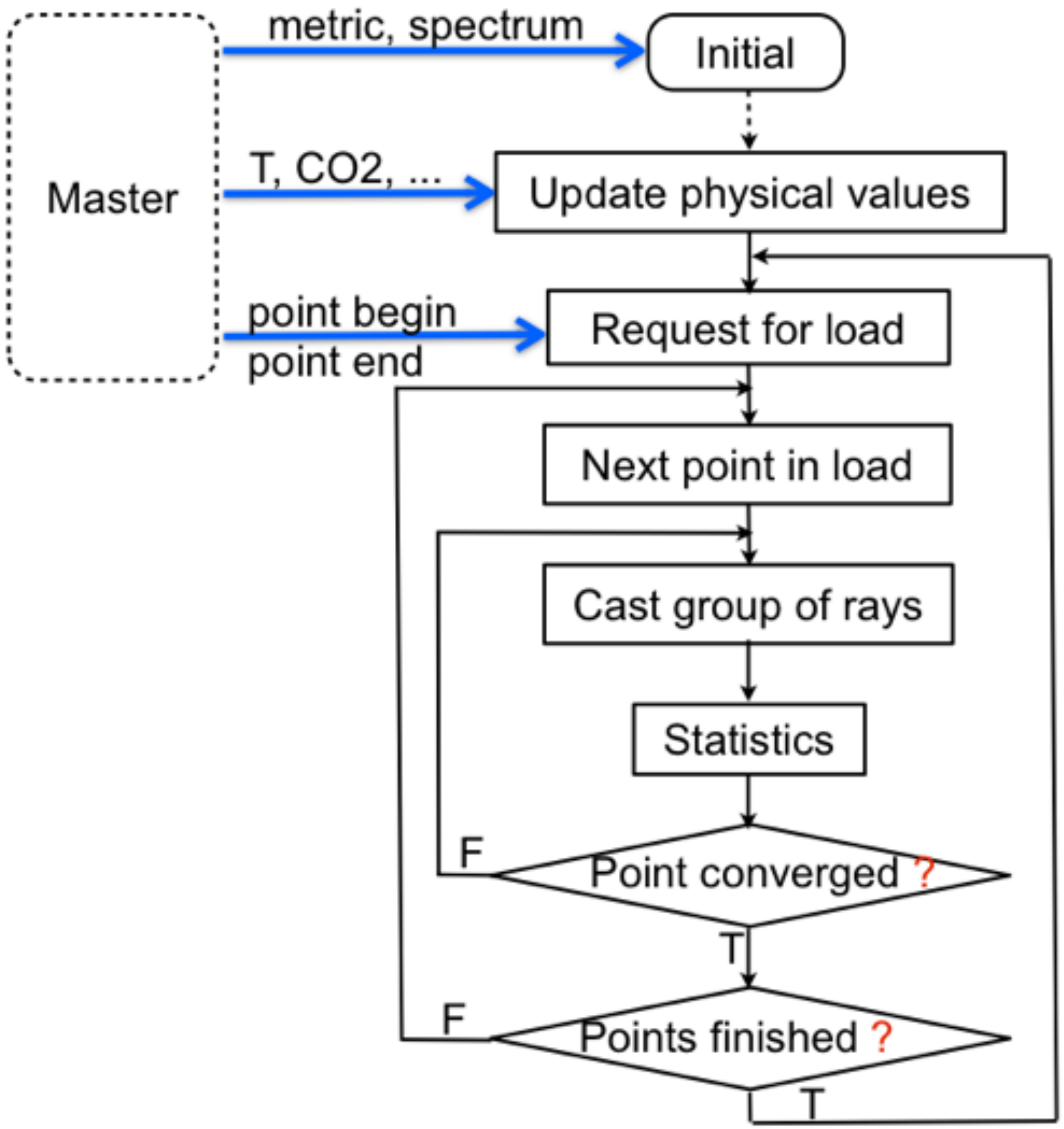
A dedicated Monte Carlo solver

Reciprocal Monte Carlo approach ERM

- **Estimation of the radiative power in a single point of the domain without performing a full simulation**
- **Possibility of a local convergence**
- **Very good scalability and load balancing**
- **Need only few memory**
- **Very accurate when there are large isothermal regions**

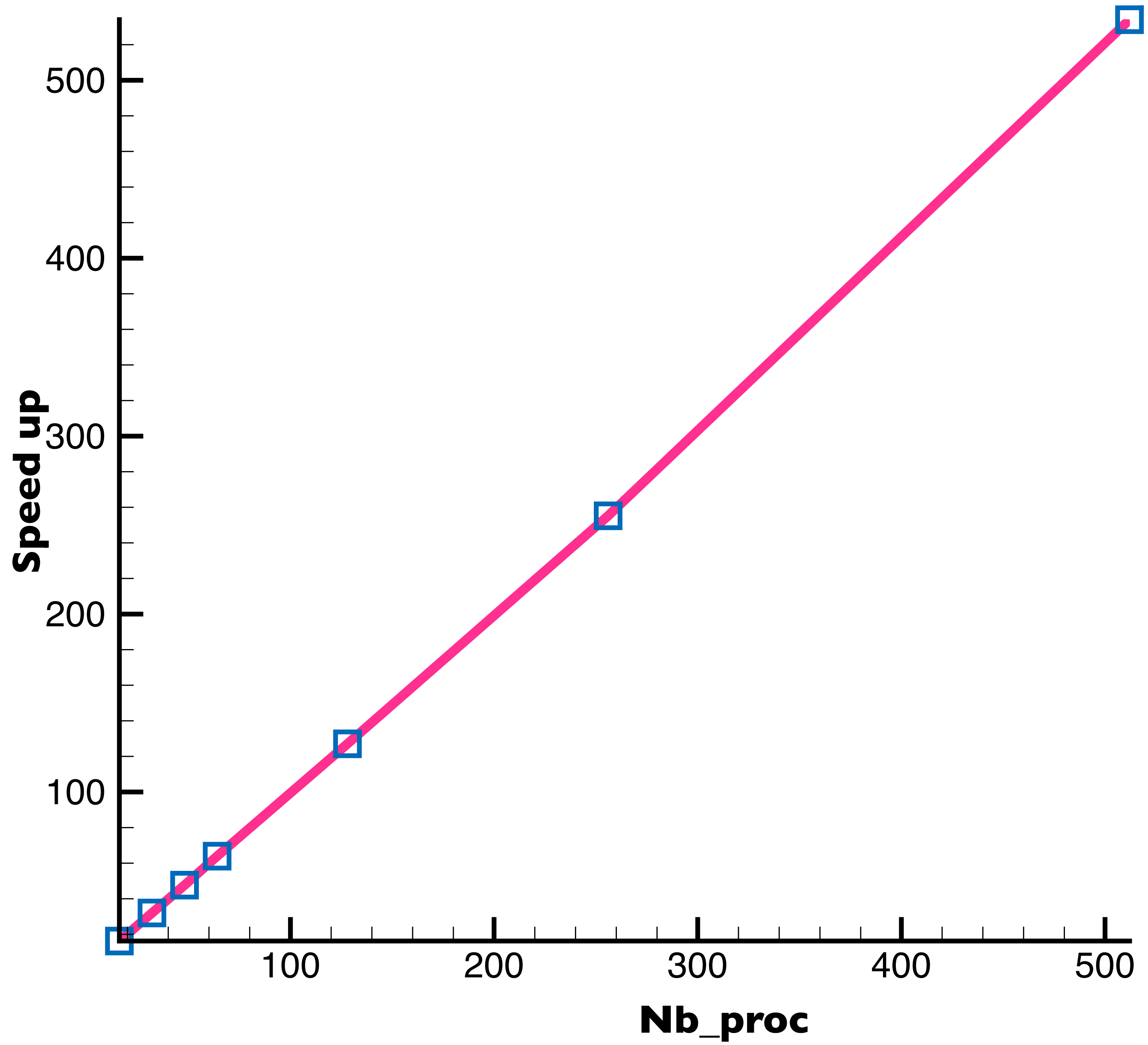
Few words about parallelisation

Monte Carlo code structure



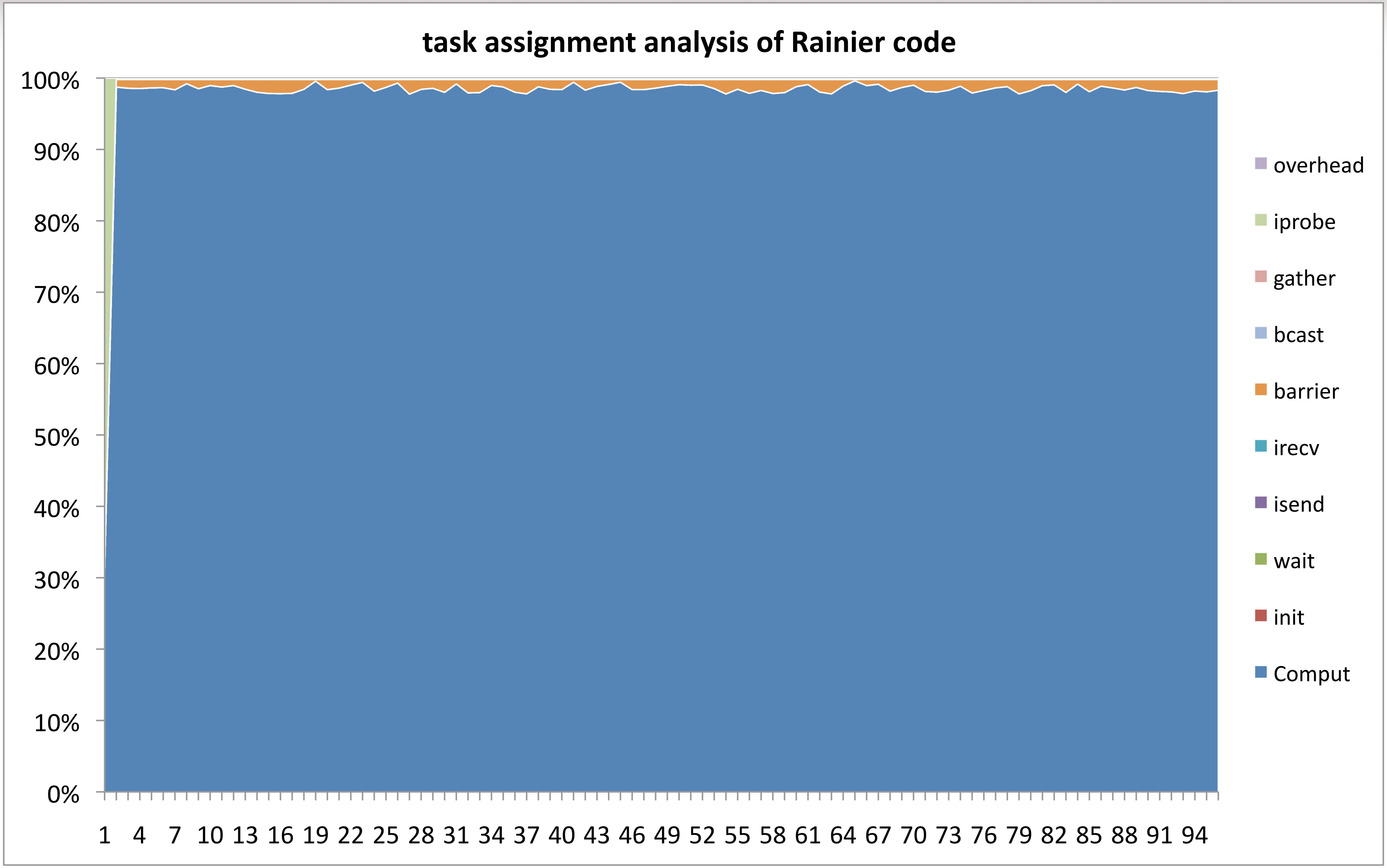
Few words about parallelisation

Monte Carlo code structure



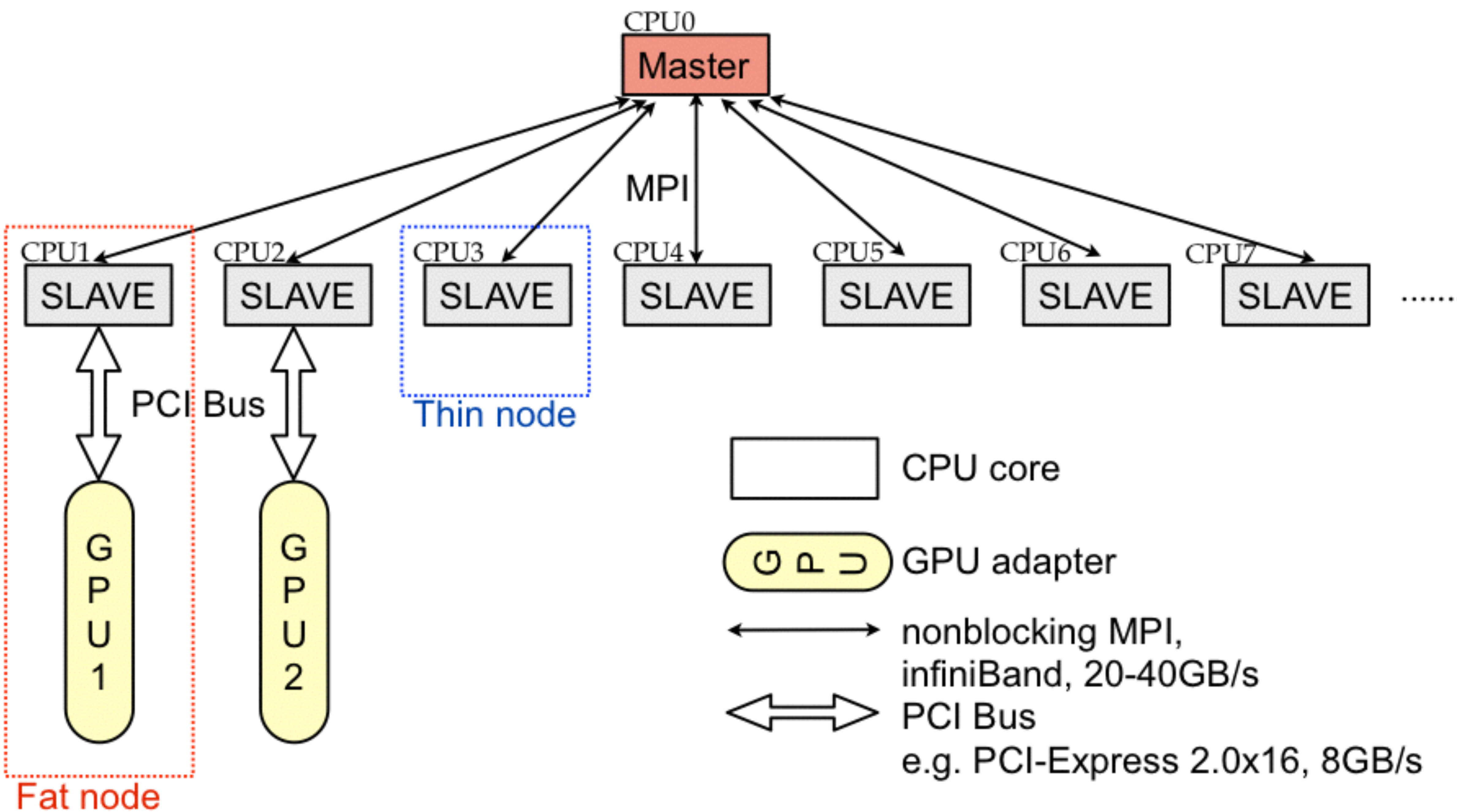
Few words about parallelisation

Monte Carlo code structure



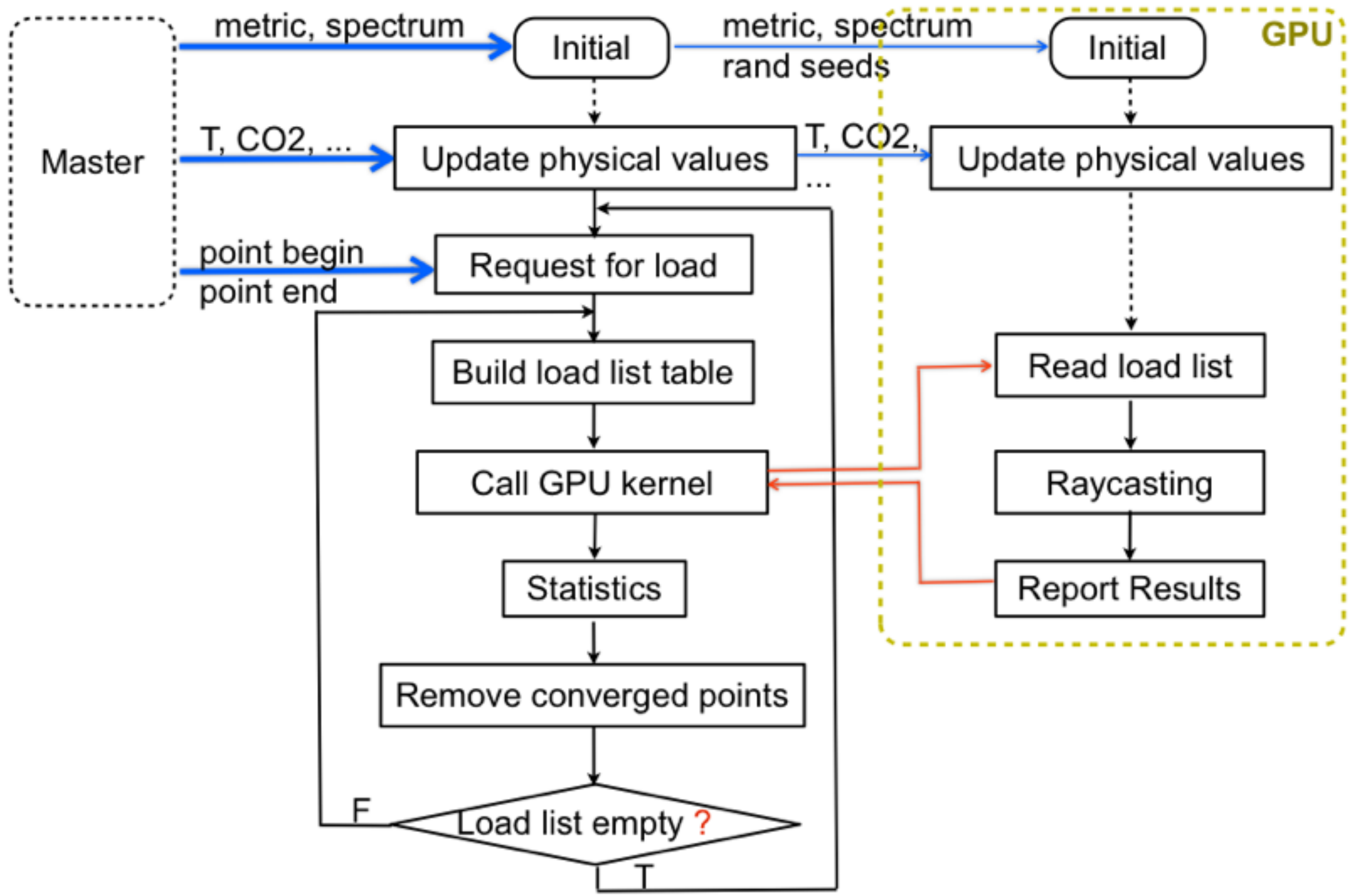
Few words about parallelisation

Hybrid parallelisation



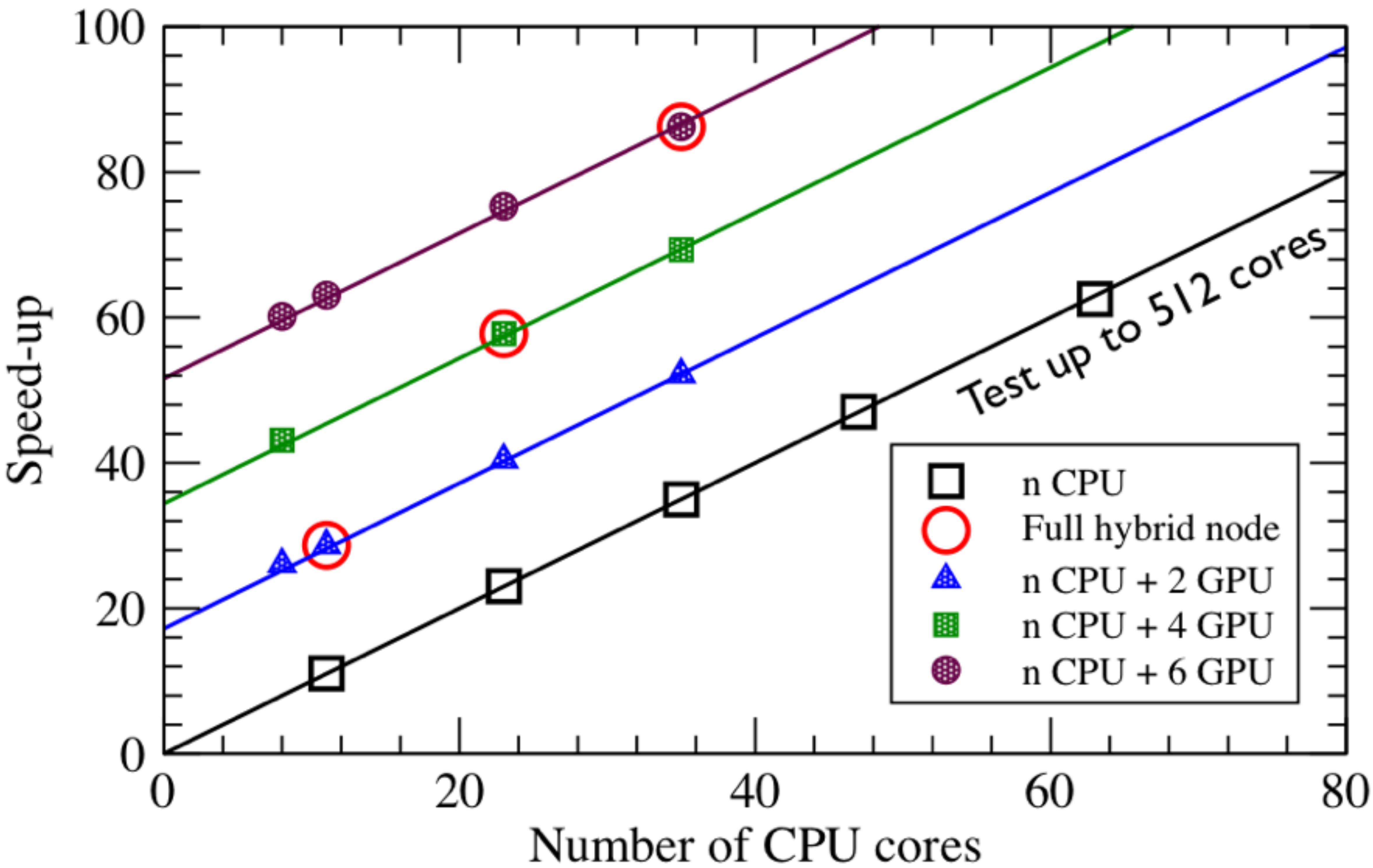
Few words about parallelisation

Hybrid parallelisation

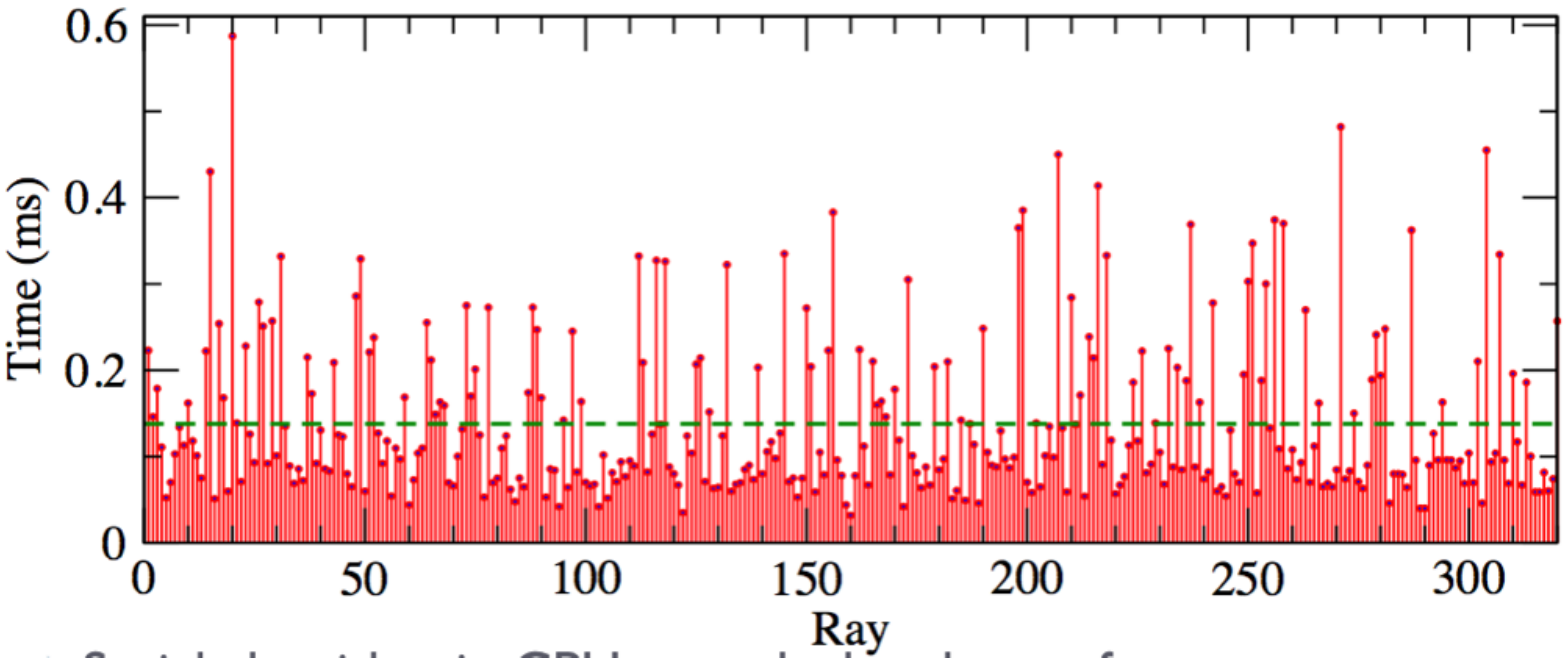


Few words about parallelisation

Hybrid parallelisation

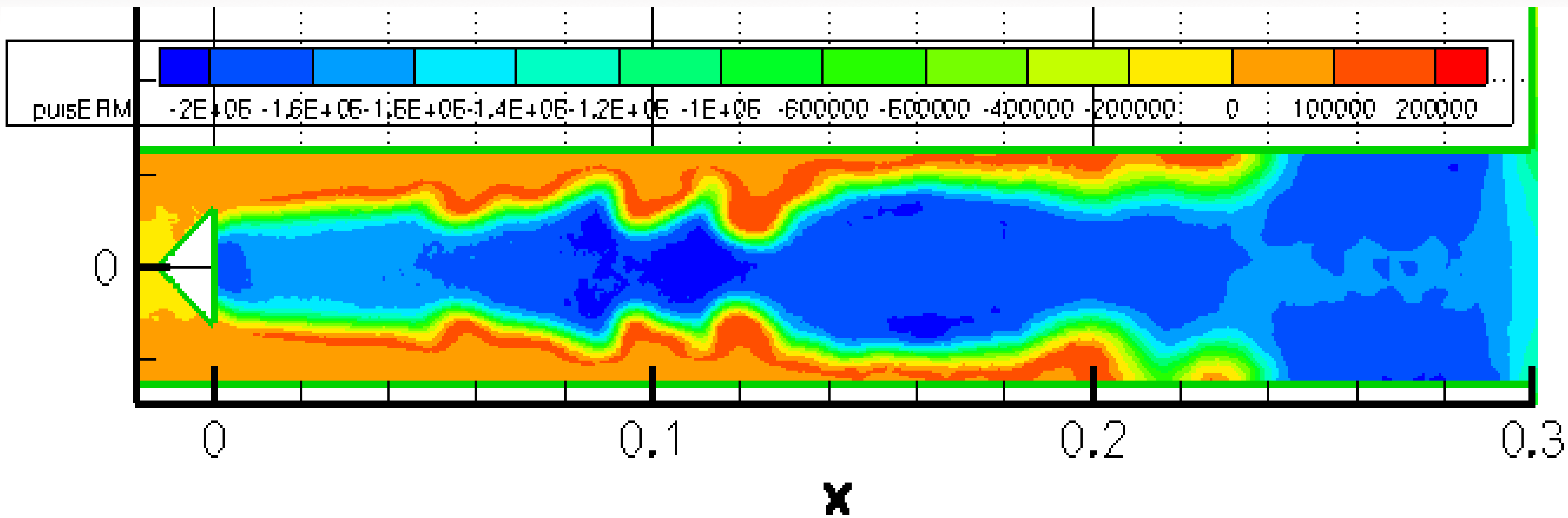


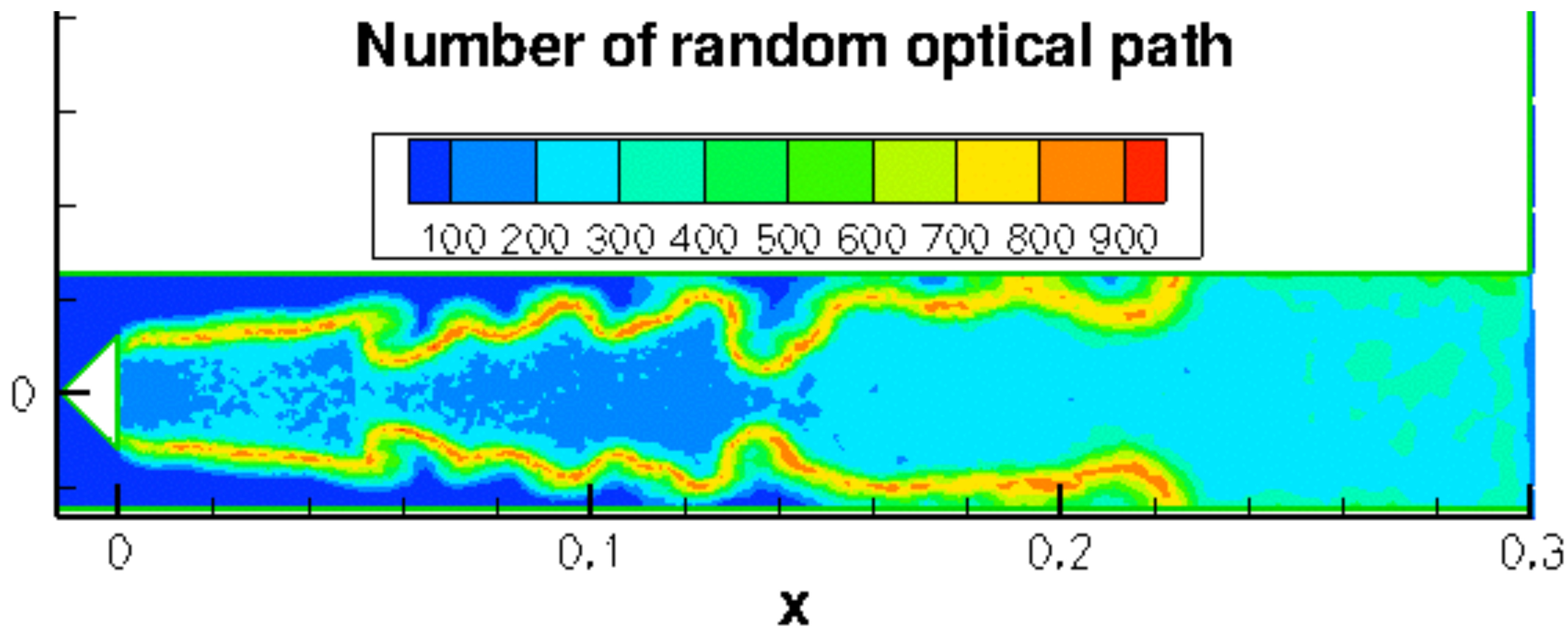
Load balancing with GPU



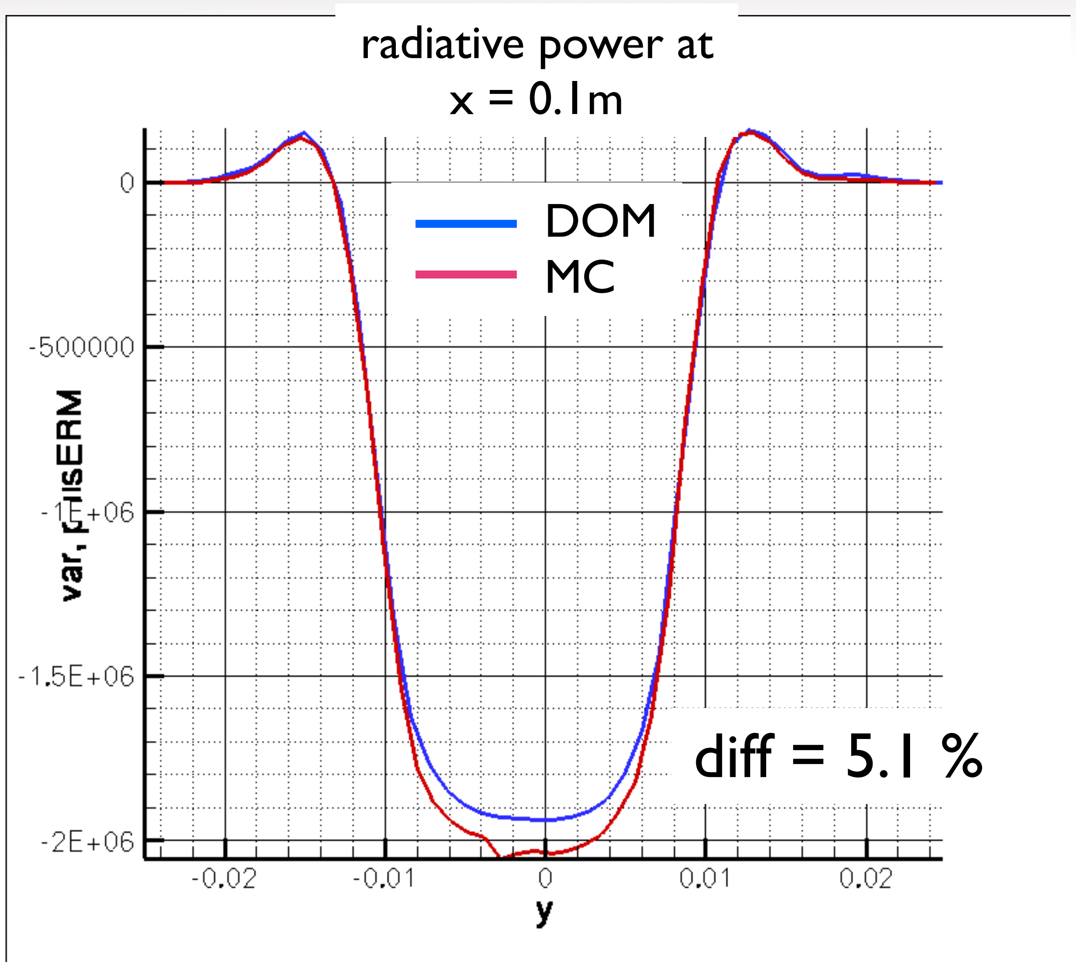
Optimization of the local number of realization

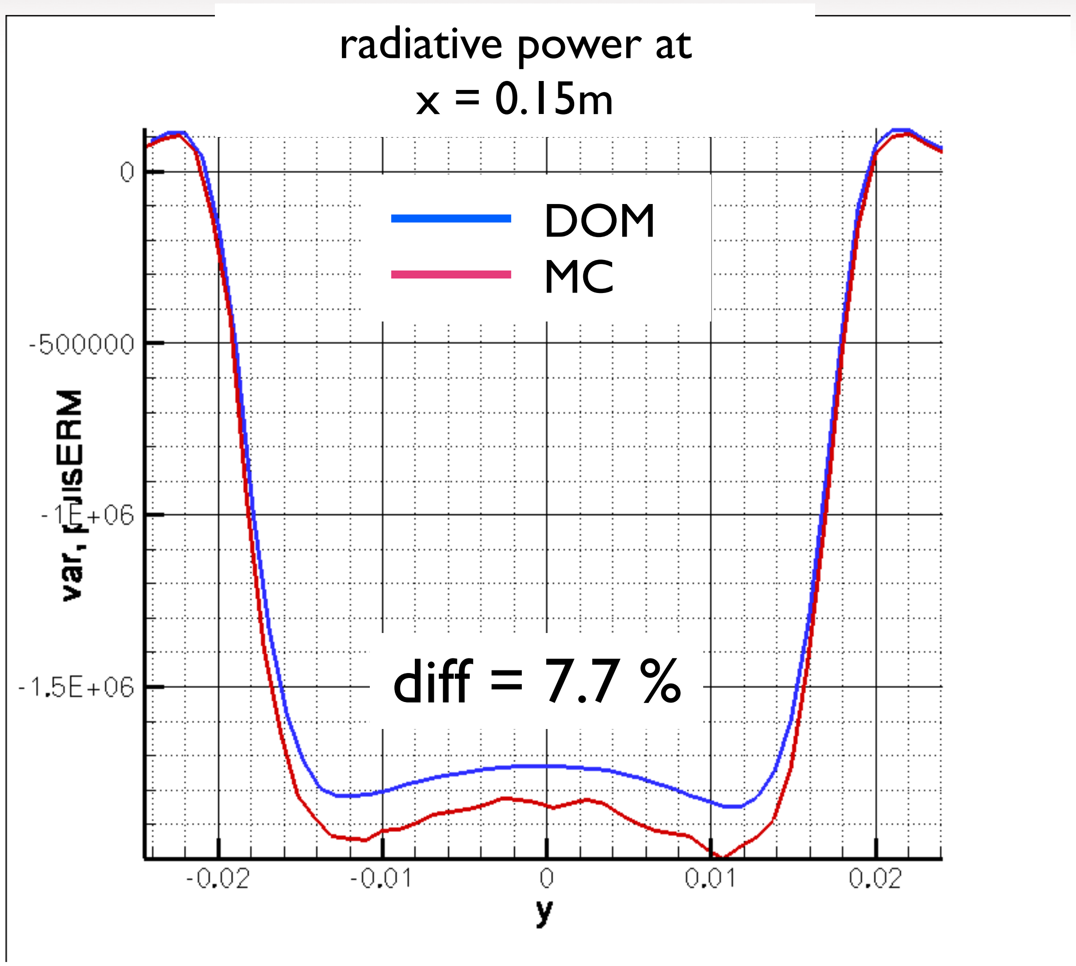
Typical results





Comparison with DOM



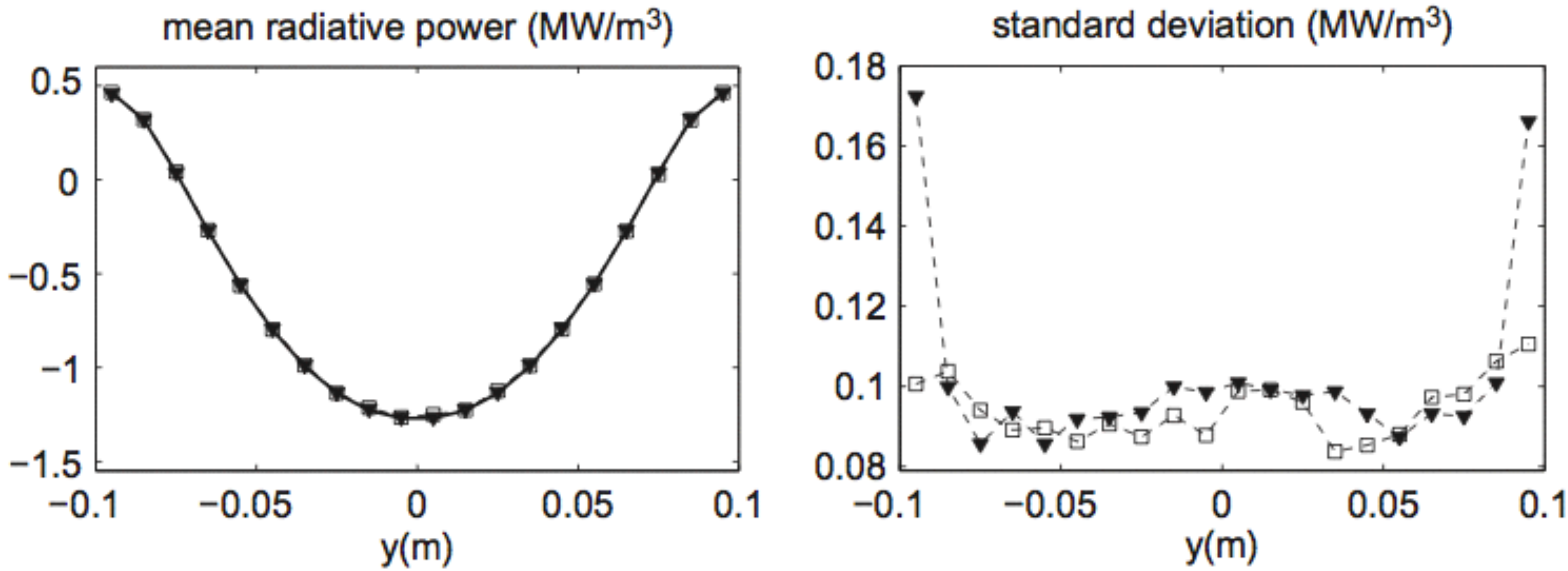


Mesh : 3.4million cells

Method	Nb_procs	optical paths	spectral bands	cpu time	memory
Domasium	72		36	2min	2G
monte carlo	72	1000_max	1022	18min	0.48G
domasium_bis	72		1022	56min	> 2G

Monte-Carlo optimisation (Level of importance)

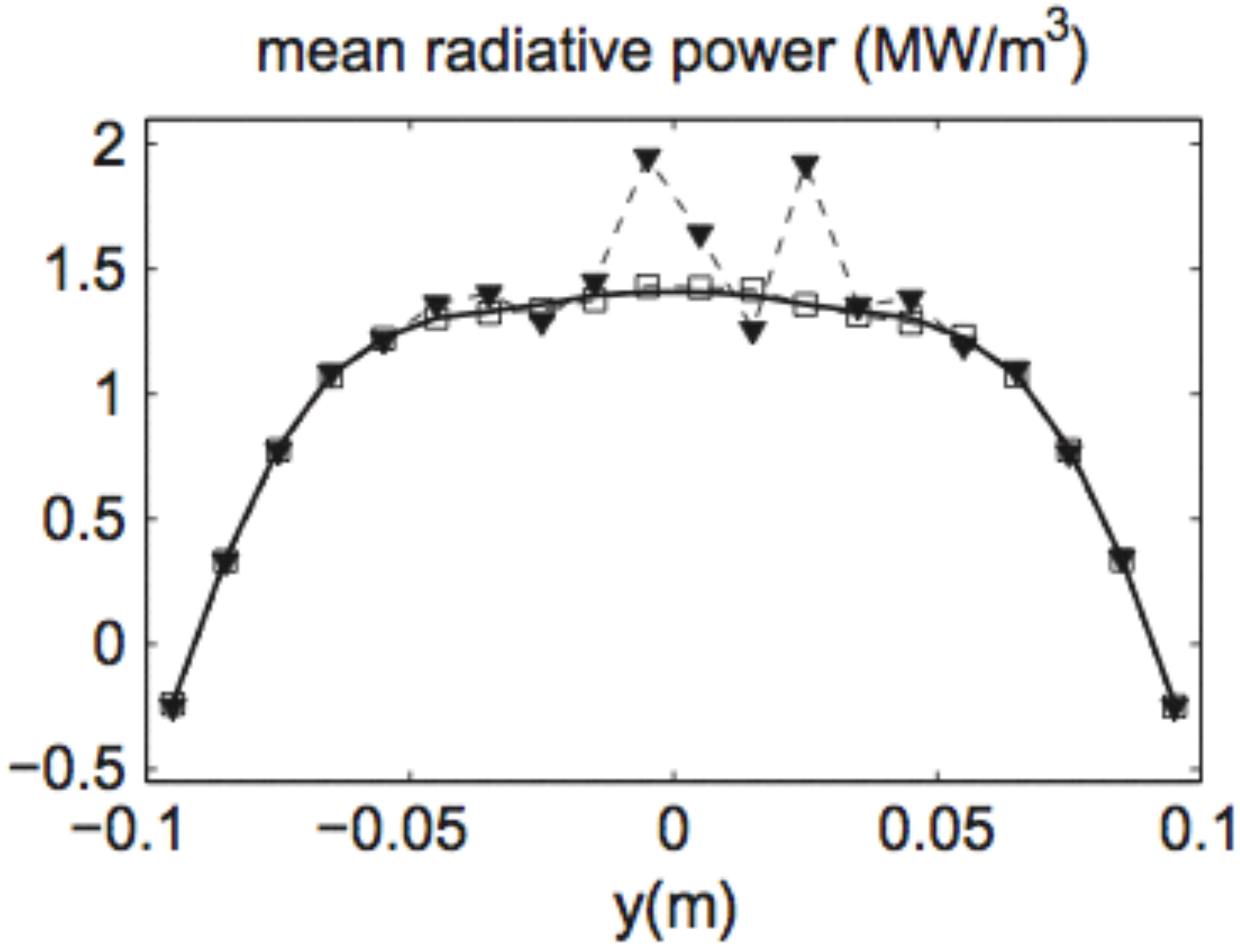
Avoiding the draw-backs of ERM

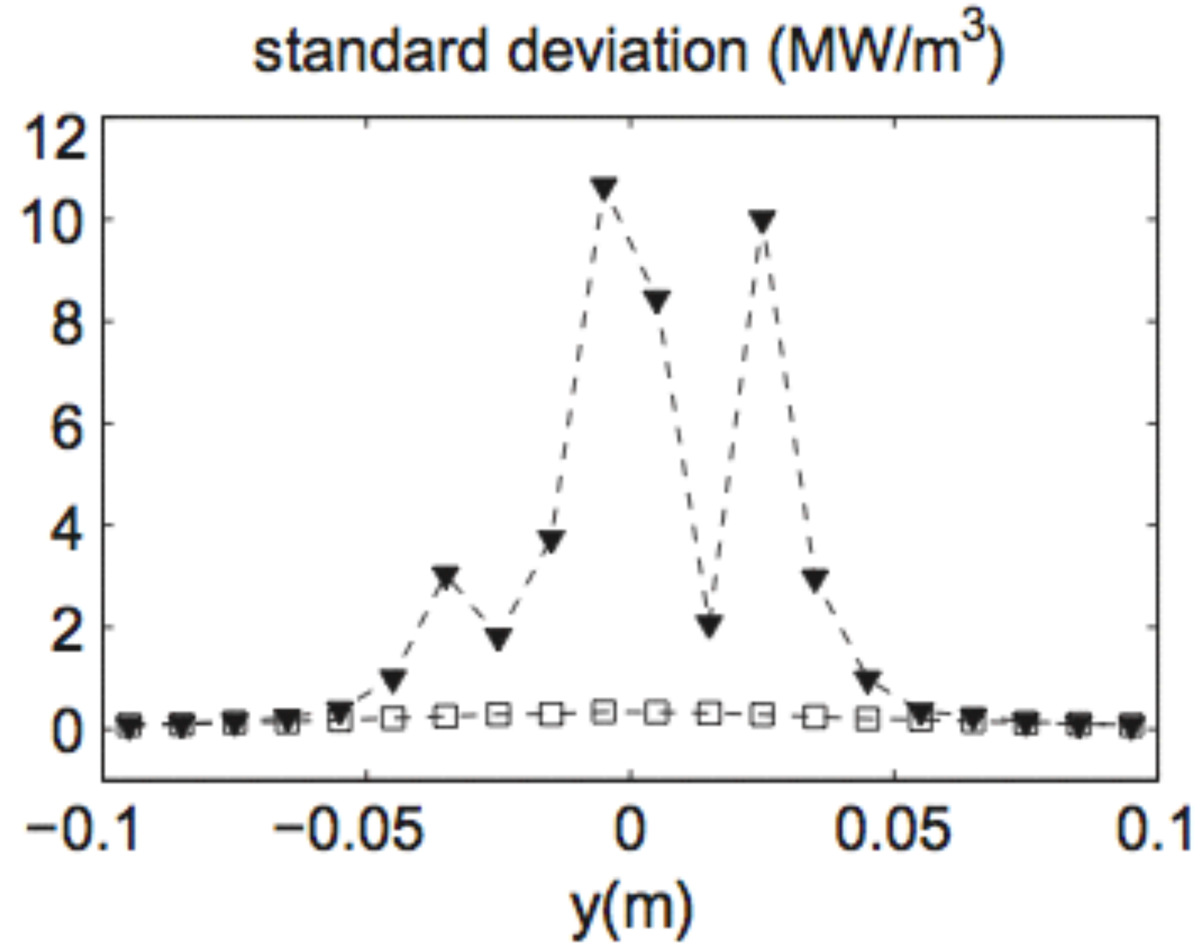


Gas : 2 500 K - Wall : 500 K

Monte-Carlo optimisation (Level of importance)

Avoiding the draw-backs of ERM





Gas : 500 K - Wall : 2 500 K

Monte-Carlo optimisation (Level of importance)

Avoiding the draw-backs of ERM

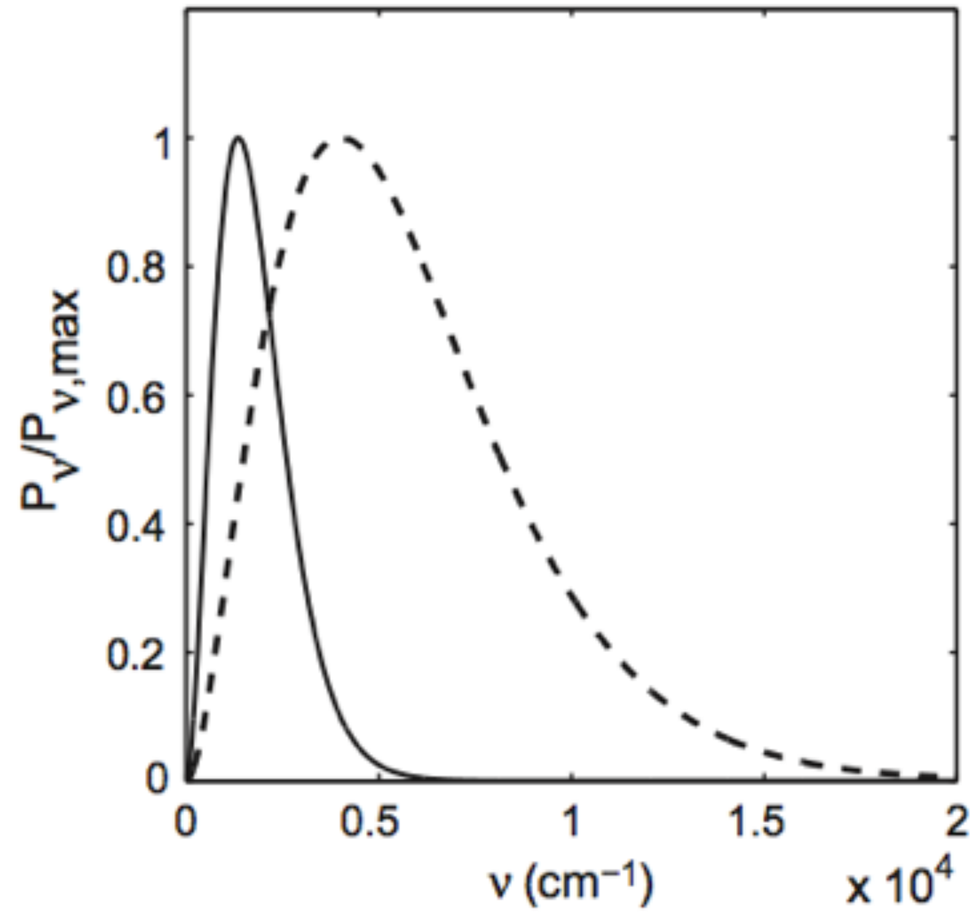


Fig. 3. Spectral emitted and absorbed power for a cell of temperature 700 (- - -) P^a_ν.

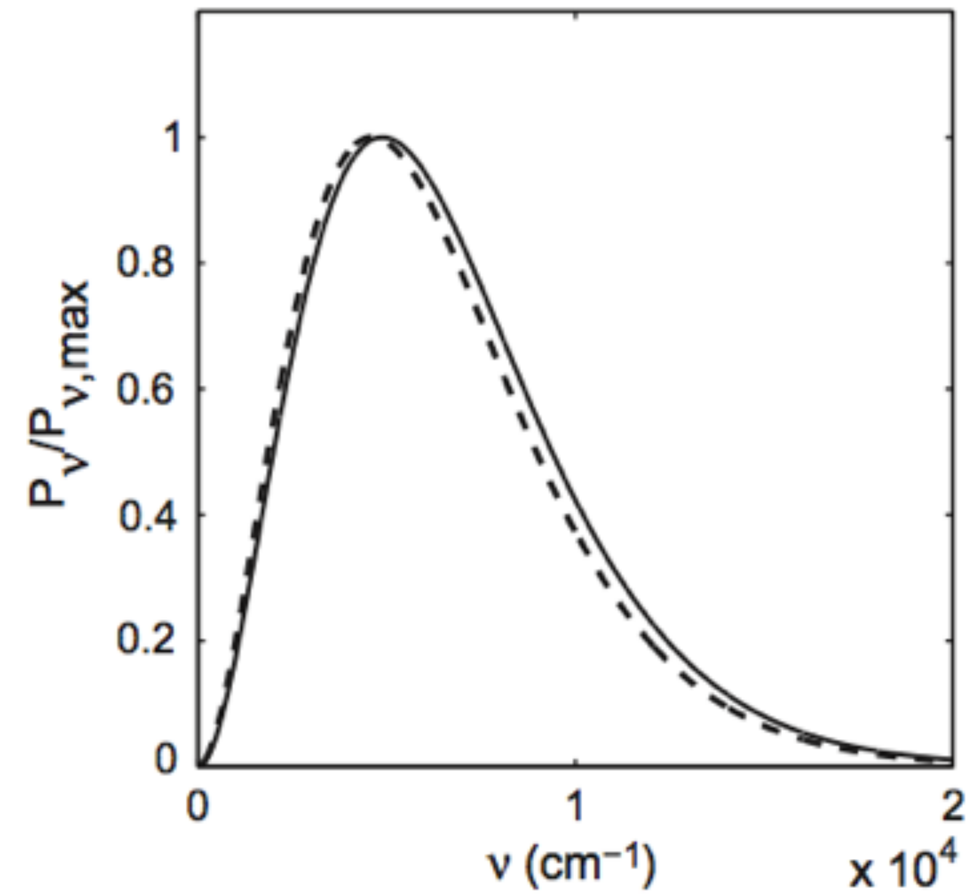
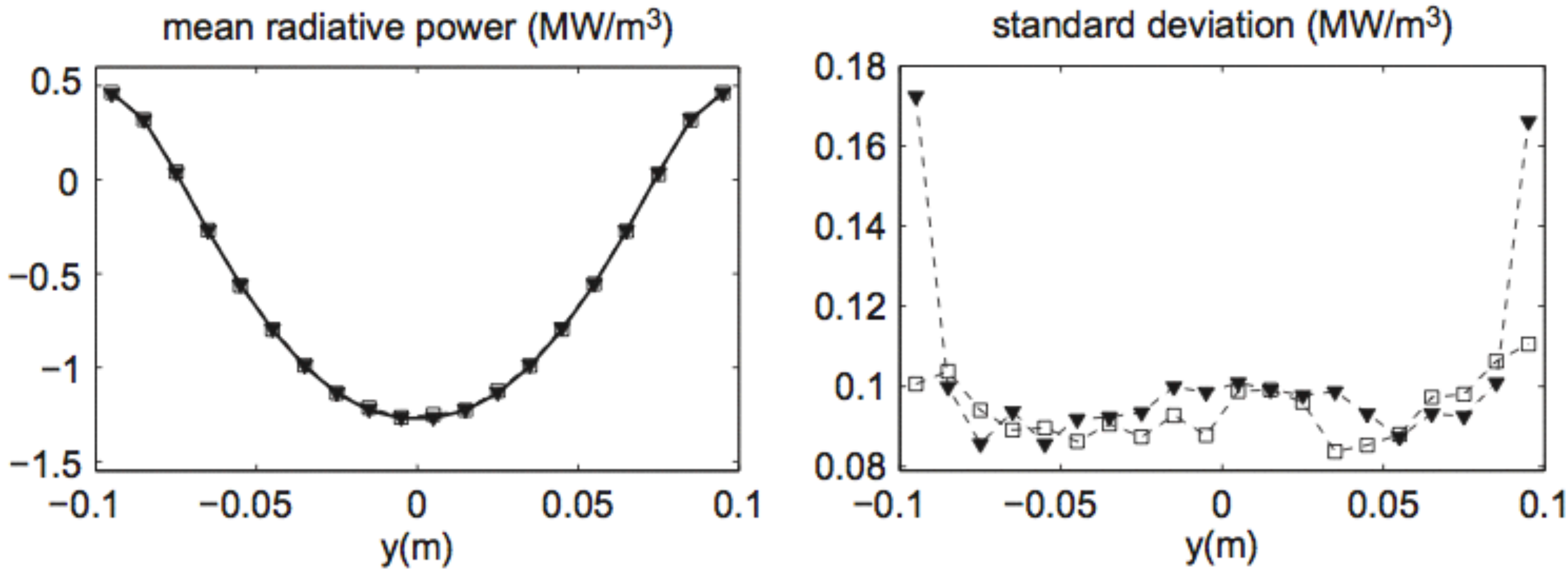


Fig. 4. Spectral emitted and absorbed power for a cell of temperature 2500 K; symbols as Fig. 3.

$$\widetilde{P}_{ij}^{exch} = \frac{P_i^e(T_{\max})}{N_i} \sum_{n=1}^{N_{ij}} \frac{I^\circ_{\nu_n}(T_i)}{I^\circ_{\nu_n}(T_{\max})} \frac{\kappa_{\nu_n}(T_i)}{\kappa_{\nu_n}(T_{\max})} \left[\frac{I^\circ_{\nu_n}(T_j)}{I^\circ_{\nu_n}(T_i)} - 1 \right] A_{ijn\nu_n}$$

Monte-Carlo optimisation (Level of importance)

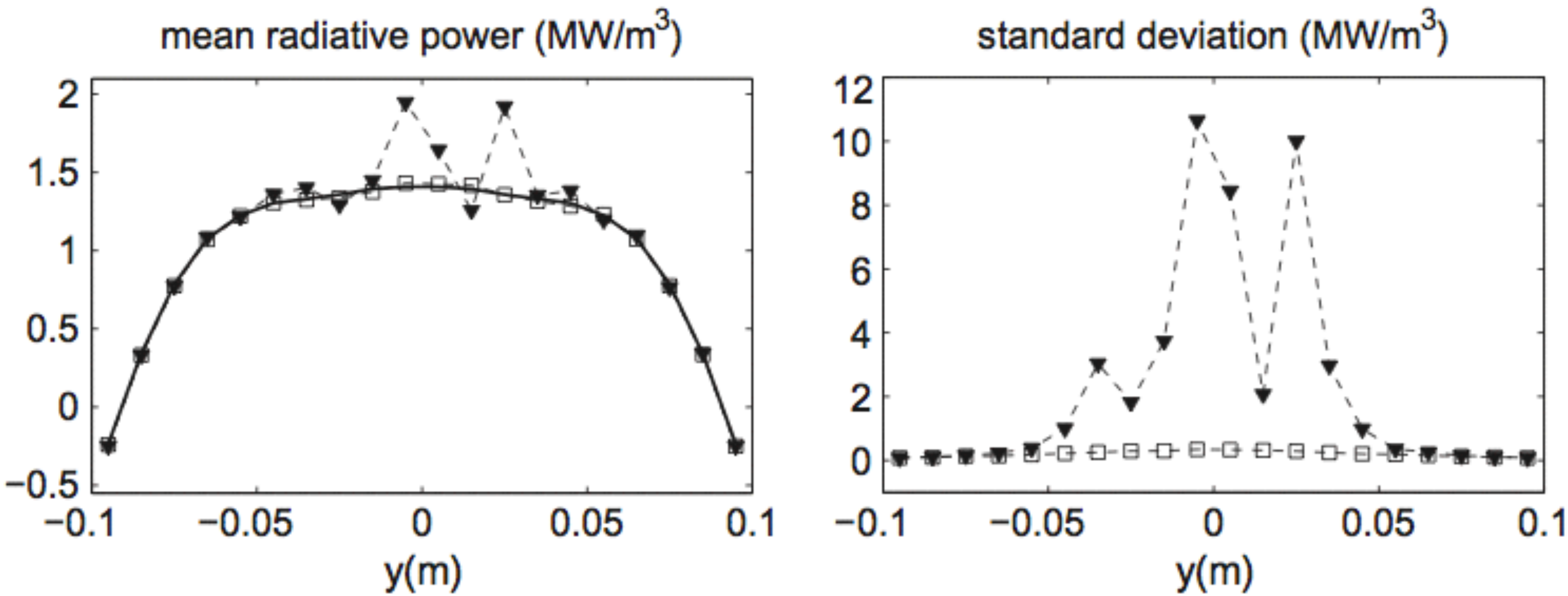
Avoiding the draw-backs of ERM



Gas : 2 500 K - Wall : 500 K

Monte-Carlo optimisation (Level of importance)

Avoiding the draw-backs of ERM



Gas : 500 K - Wall : 2 500 K

Fully coupled AVBP - Monte Carlo Simulation

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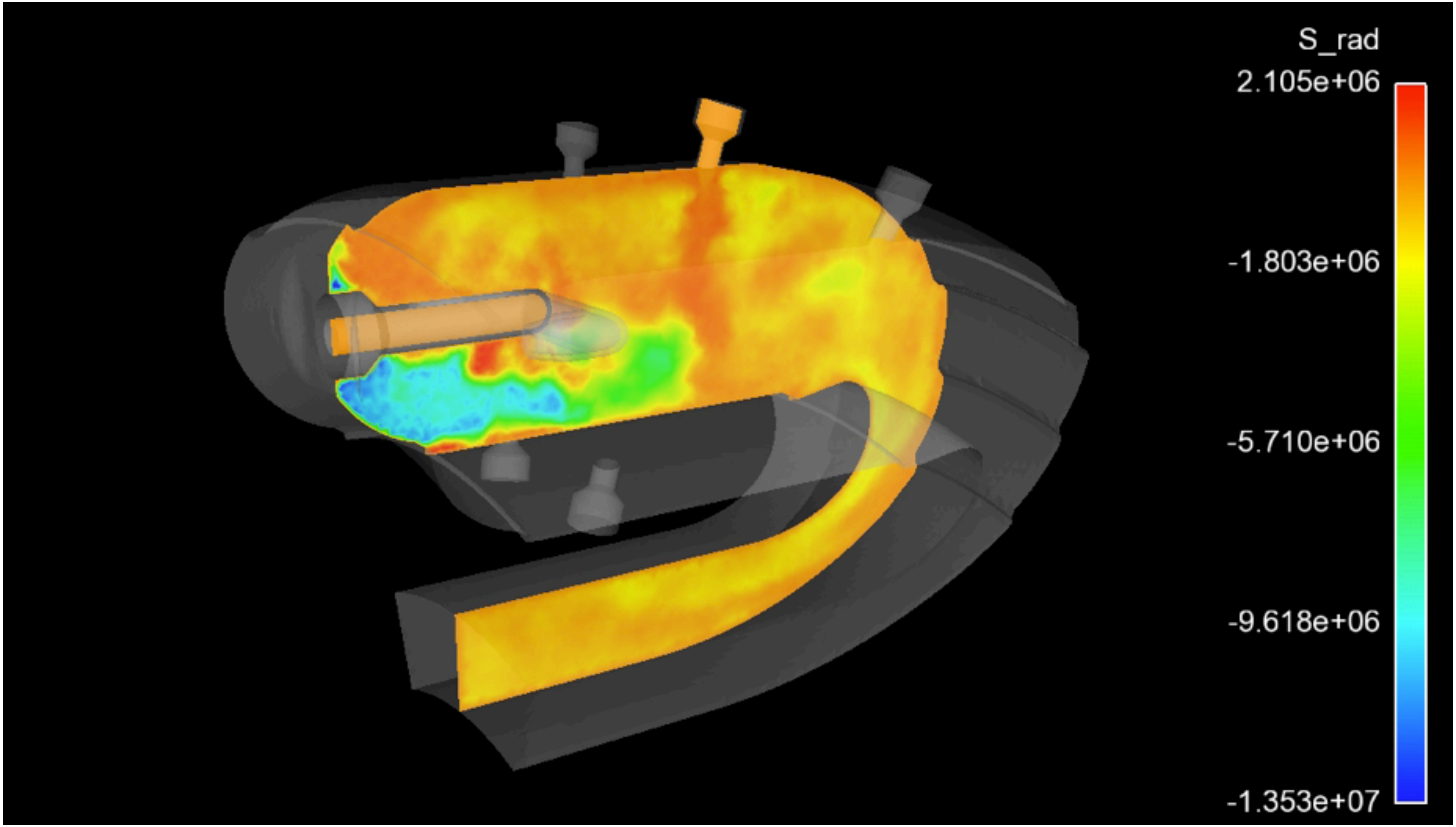
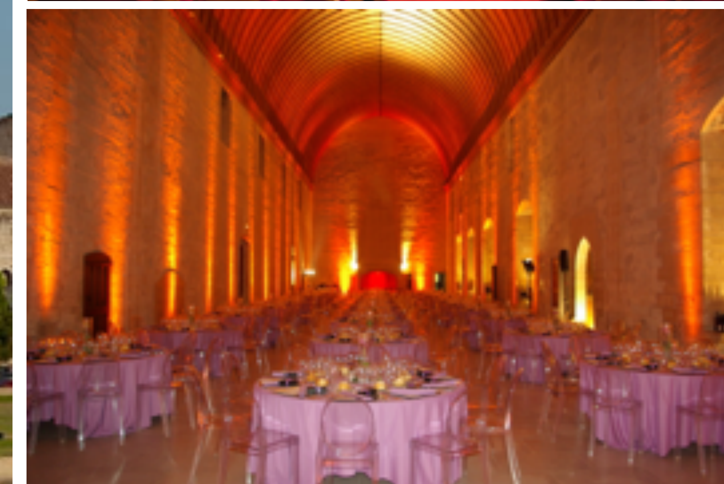


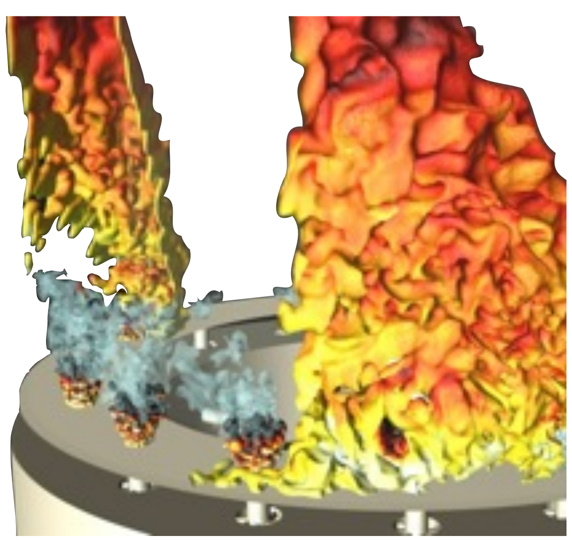
Final conclusion

- LES is a good framework to investigate Combustion - Radiation interaction
- Fully coupled simulations are available on gaz turbine geometries
- Dedicated solver are mandatory
- Radiation can change the conductive heat fluxes

Crucial need of experimental setups dedicated for both combustion and radiation

Accurate radiative boundary conditions





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