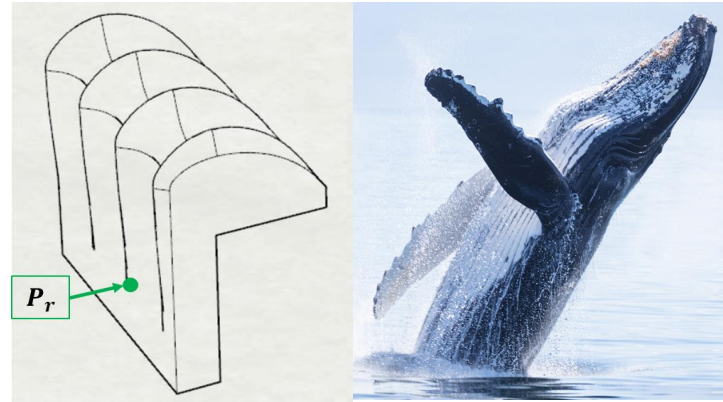


Apprentissage adaptatif, Conception biomimétique pour l'Optimisation de la forme des déversoirs

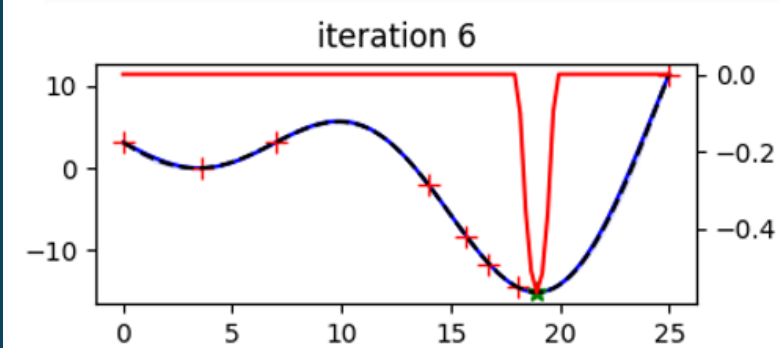
Fatna Oukaili (LNHE - EDF R&D)
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Y. Bercovitz, C. Goeury, F. Zaoui,
T. Fonty, G. Coulaud (EDF R&D)

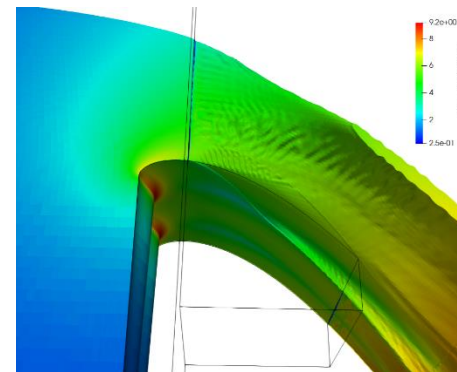
Conception biomimétique



Optimisation par Apprentissage adaptatif

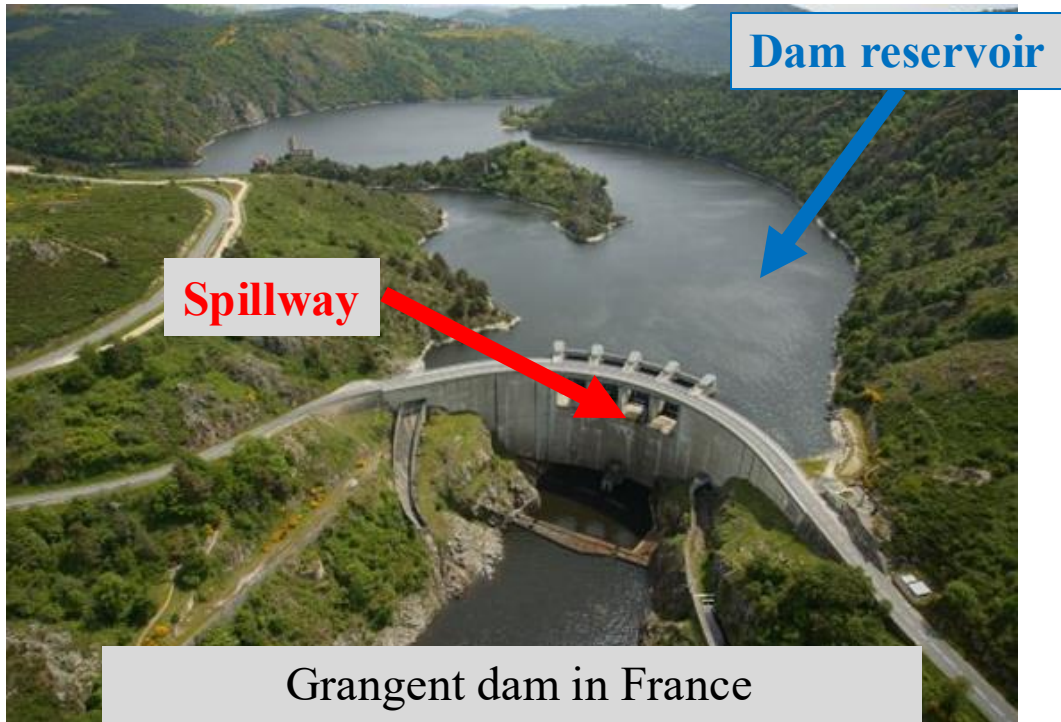


Déversoirs à formes optimales



Context & Objectives

➤ Spillways ensure dams safety during floods



November 2009 flood at Grangent dam



March 2007 flood at Hautefage dam

Motivations

- ❖ EDF aims to **improve spillways** design to make **them safer and more efficient** to cope **with exceptional floods**



Malarce dam Piano-key spillway



Morning glory bell-mouth

Shape Optimisation Objective

➤ Improve weir discharge capacity

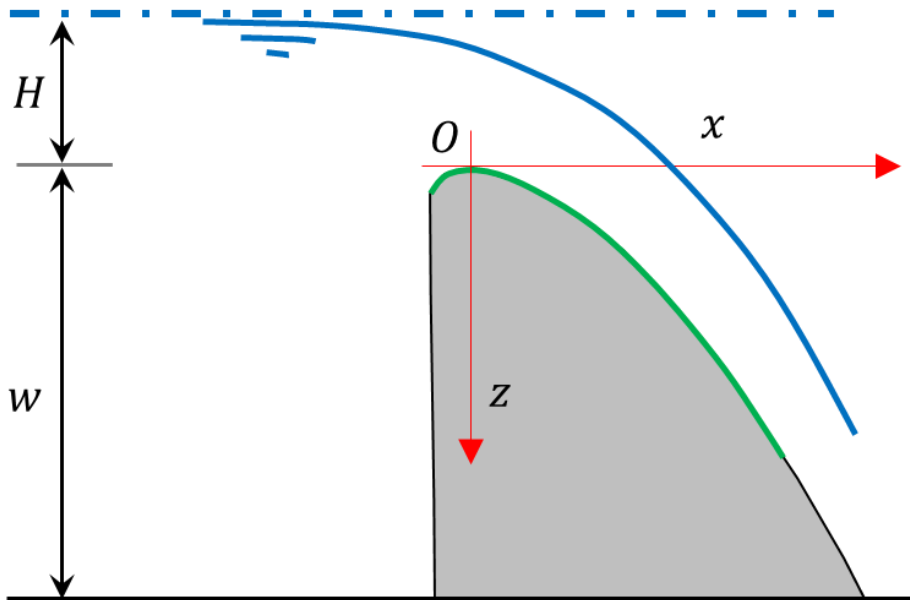
Water discharge capacity of the weir is expressed by the law

$$Q = C_d b \sqrt{2gH^3}$$

C_d = discharge coefficient

H = head discharge

w = weir height

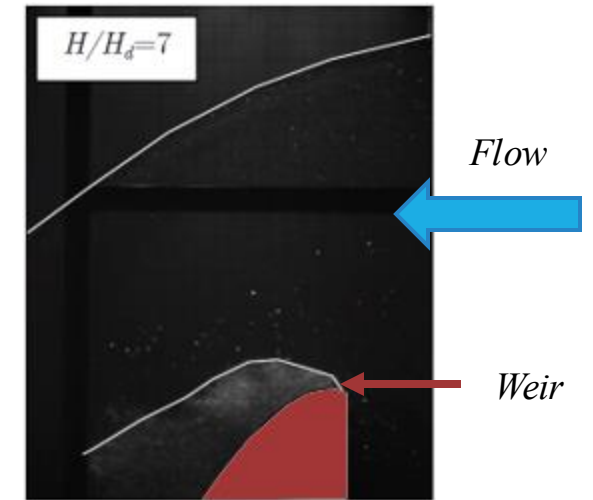


(Hager et Vischer, 1999)

➤ Limit the appearance of negative pressure values along weir crest

Flow separation over a standard weir (Erpicum et al. 2018)

➡ discharge capacity drop

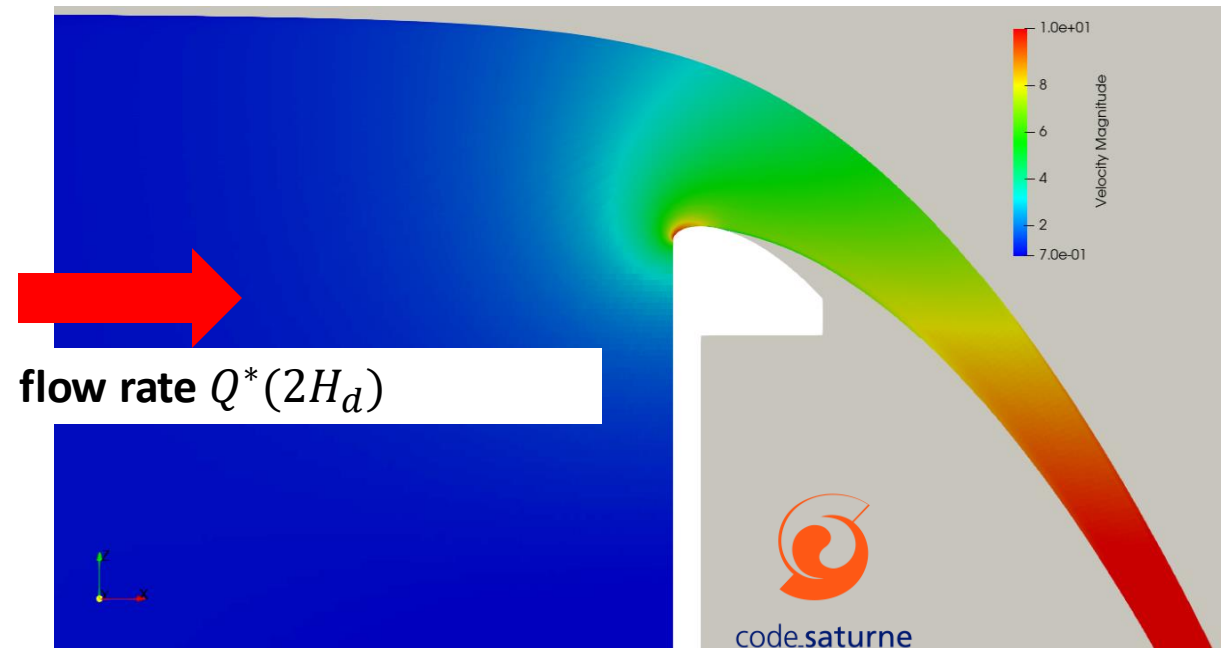


Cavitation damage on Karun dam (Bouvard, 1997)



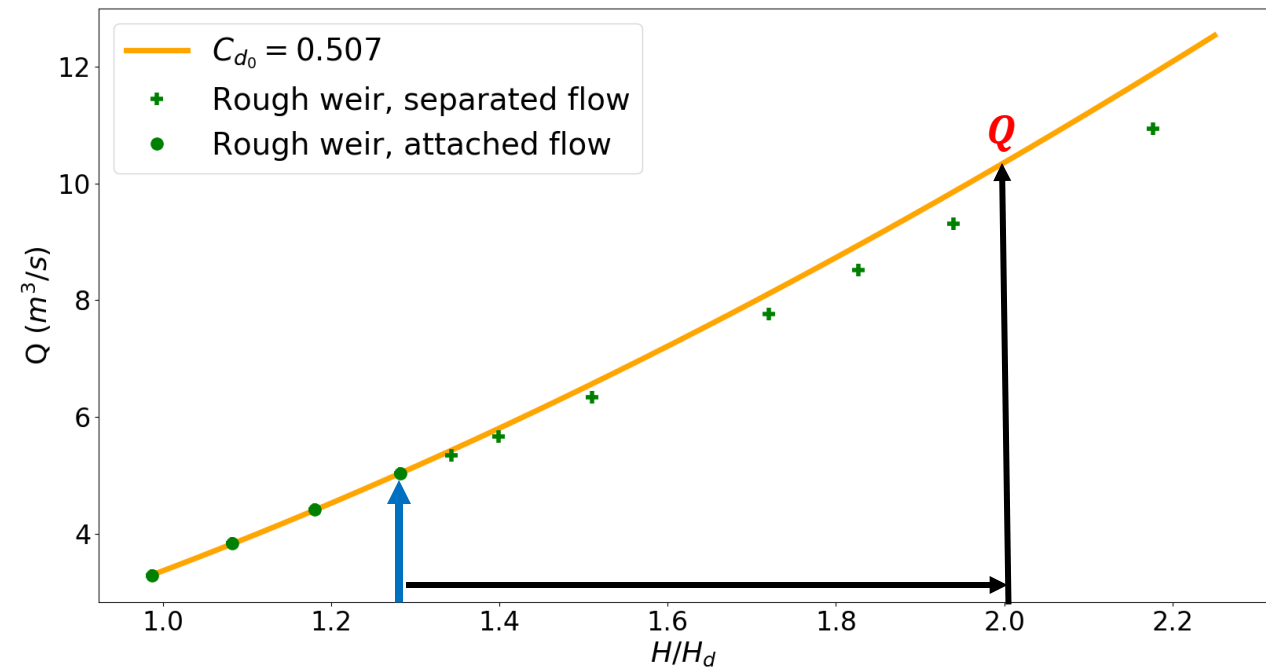
Bio-inspired spillways design

- Improve the evacuated flow
- limiting negative pressure & delaying flow detachment



*flow rate over a standard weir of a head design equals to $H_d = 1\text{ m}$

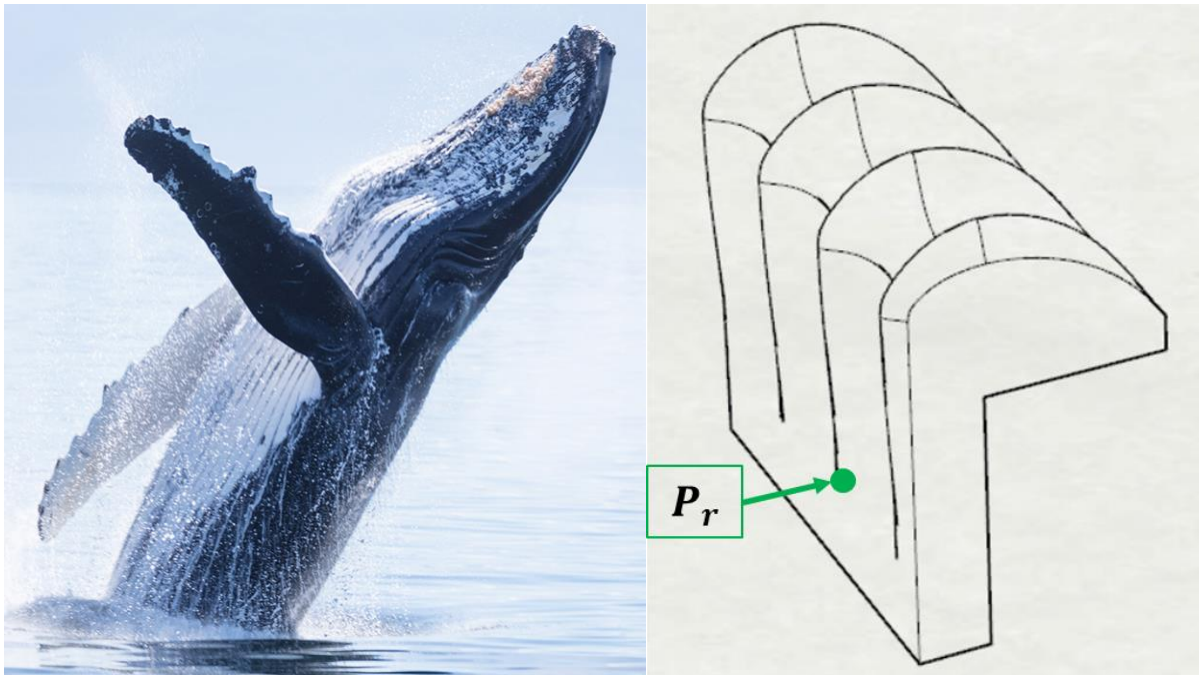
- Minimise
$$\begin{cases} H(d) = H_{simu} \\ f_{pw}(d) = \frac{0,01 \int_{S^+} p^2 ds + 1 \int_{S^-} p^2 ds}{S} + 2(1 - \frac{A_w}{S}) \end{cases}$$
 where A_w is weir wet surface



Head-flow rate law $Q = 0,495b\sqrt{2gH^3}$

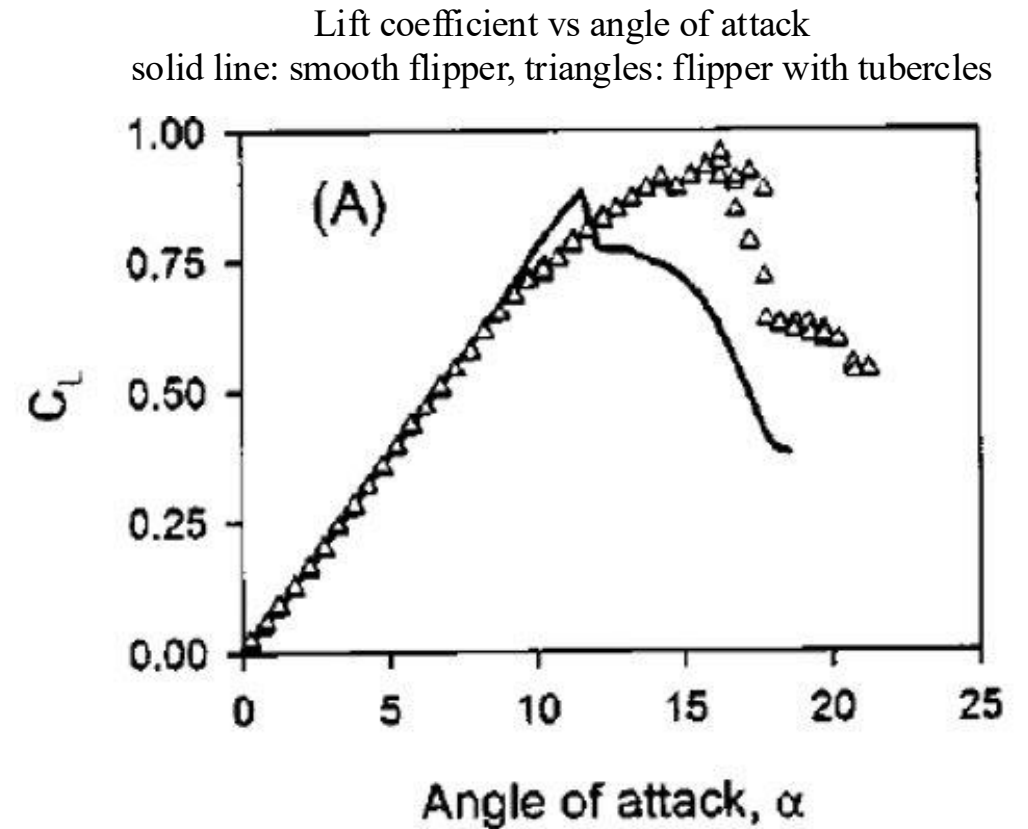
Bio-inspired spillways design

- Improve the evacuated flow
- limiting negative pressure & delaying flow detachment



Humpback whale weir

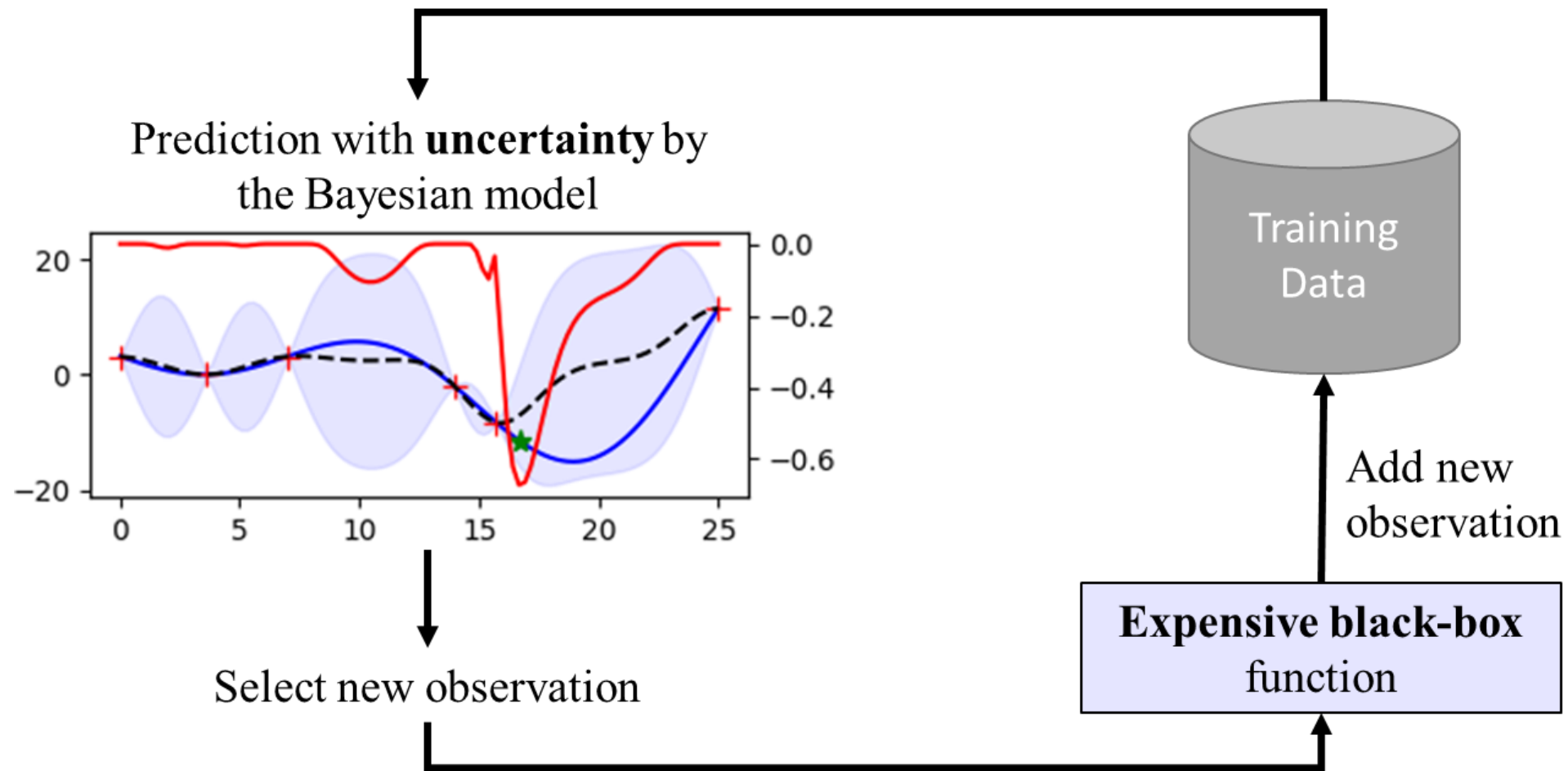
- ❖ They increase by 40% the stall angle



Optimisation methodology

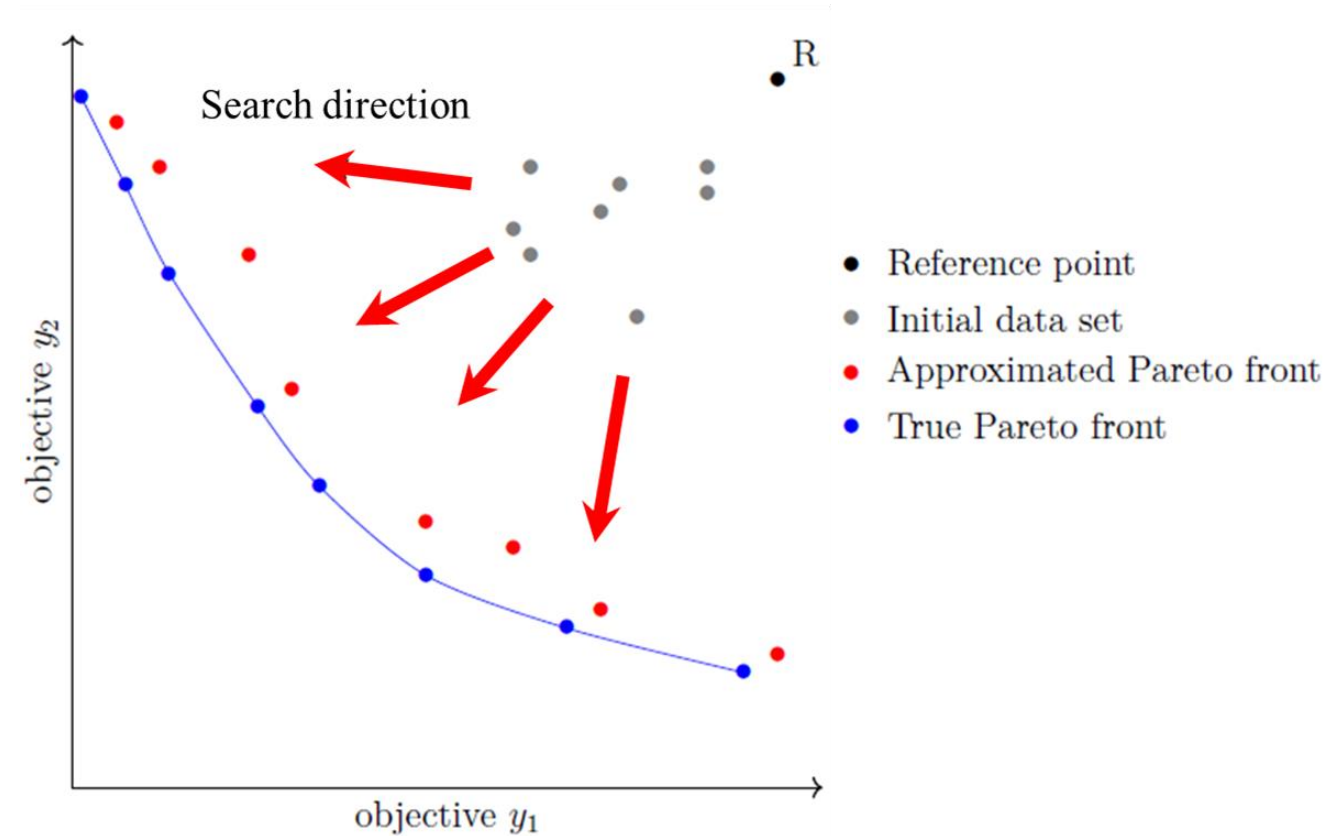
Overview of Bayesian optimisation

- Adapted for black-box expensive numerical models
- Achieve a sample-efficient optimisation



Shape optimisation of Humpback whale weirs

Optimisation results

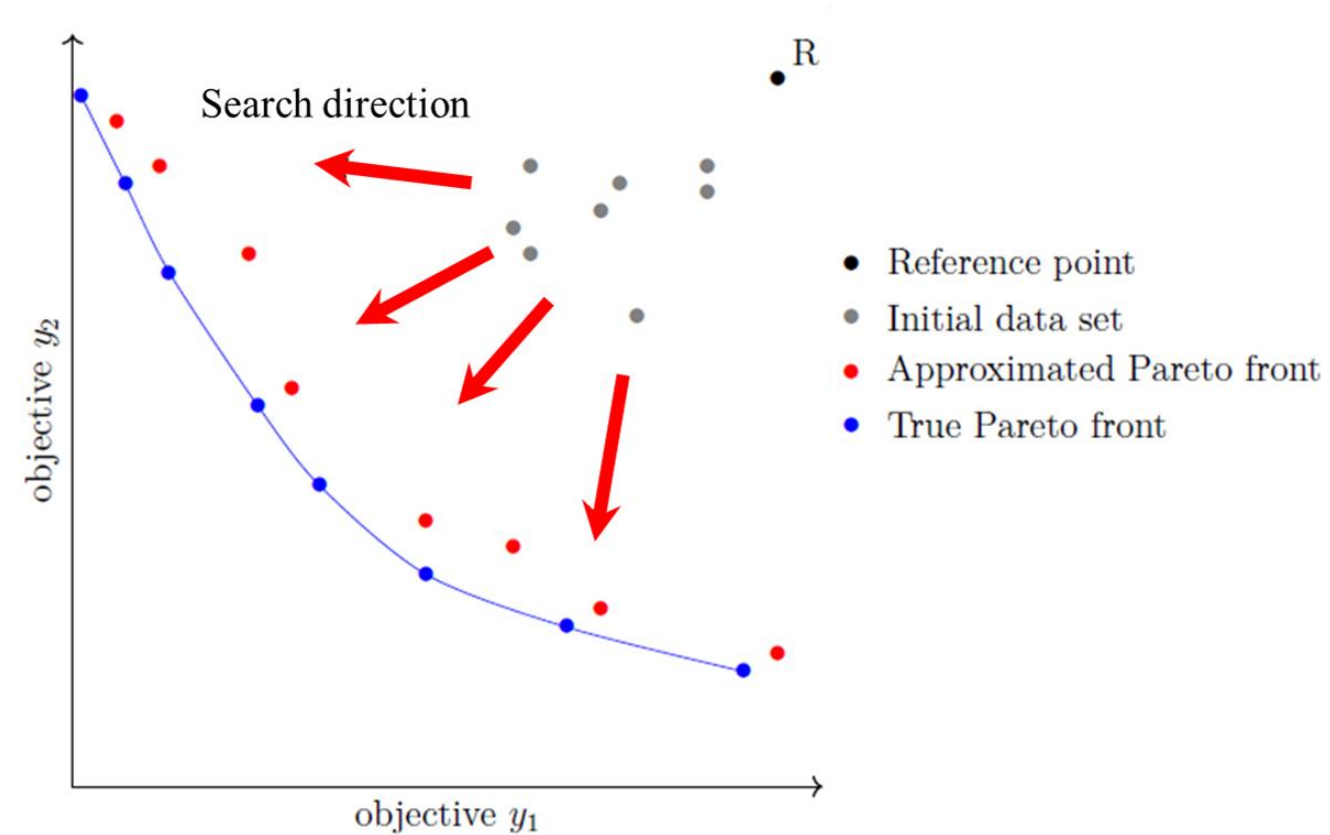
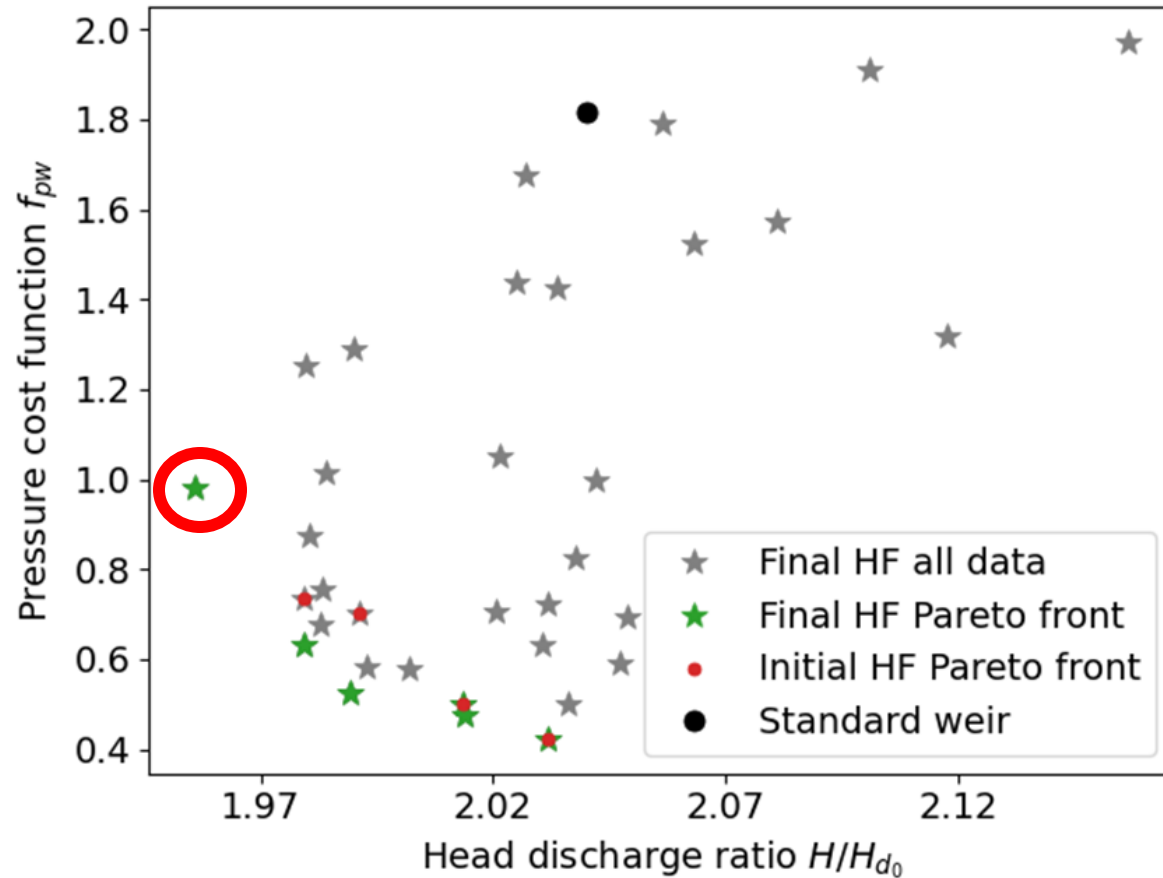


➤ Minimise
$$\begin{cases} H(d) = H_{simu} \\ f_{pw}(d) = \frac{0,01 \int_S^+ p^2 ds + 1 \int_S^- p^2 ds}{s} + 2\left(1 - \frac{A_w}{s}\right) \end{cases}$$

where A_w is weir wet surface

Shape optimisation of Humpback whale weirs

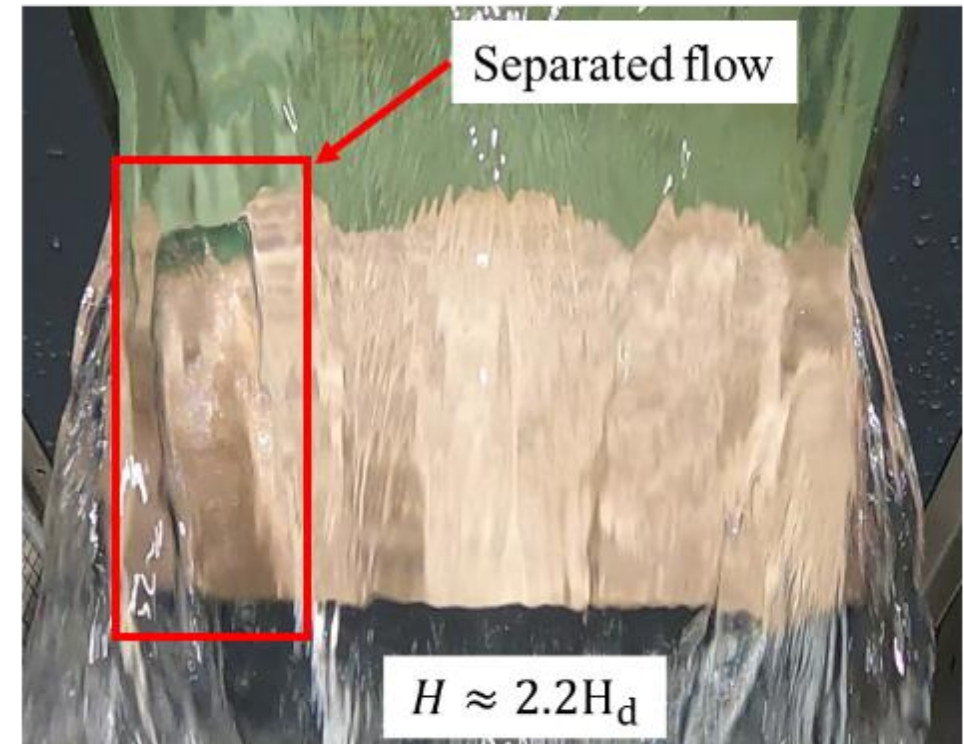
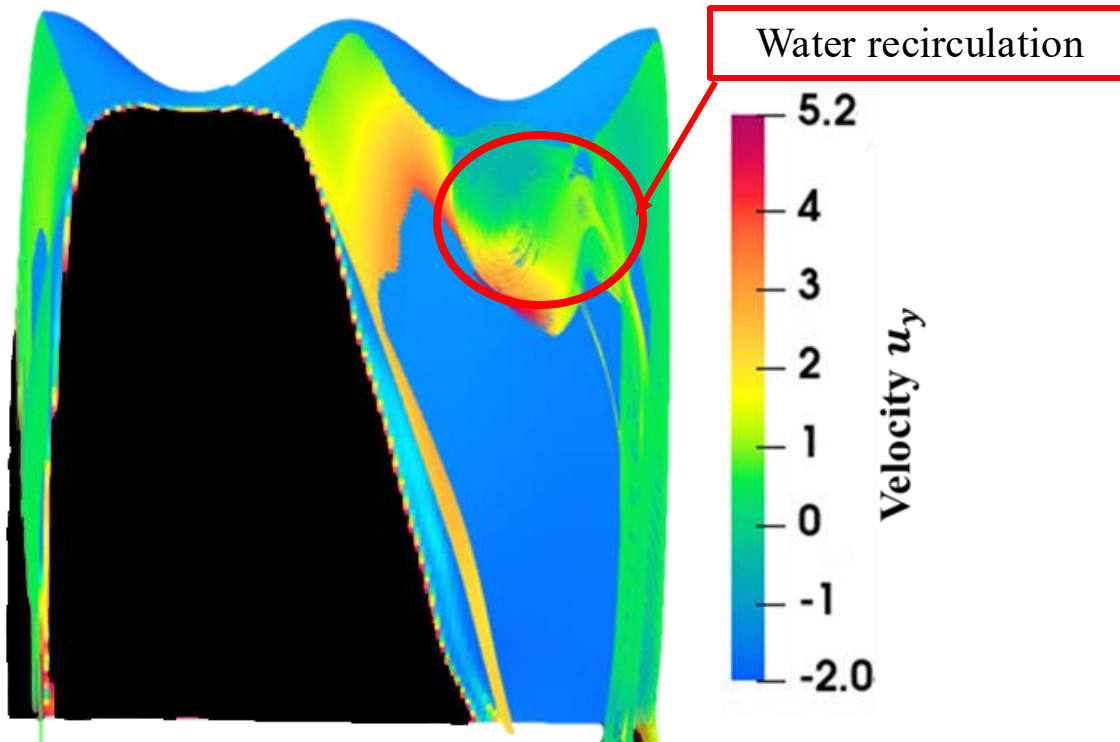
Optimisation results



	Initial data	Initial cost (user hours)	Added data	Additional cost (user hours)
High fidelity	15	52.5	8	28
Low fidelity	30	15	34	17

Shape optimisation of Humpback whale weirs

- The flow stays attached for high head ratios thanks to water recirculation in the through



Some concluding remarks

- The optimisation chain is adapted to industrial and complex applications
- Adaptive learning based on Gaussian process is adapted for costly black-box codes
- The possibility to test and study complex hydraulic structures and improve their performances
- Experimental studies confirmed the gain obtained numerically in terms of flow detachment

