Swimming pools water circulation optimization with CFD

From competition lap pools to freeform recreational pools

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SAFETY, QUALITY, HEALTH icspsRome2013

1) Water Treatment

2) CFD application to swimming pools, our experience

3) 3D simulations: dye test

4) Development of accessories

1. Water treatment

- Circulation
- Filtration
- Oxidation and disinfection

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2. CFD application to swimming pools, our experience

Why CFD in swimming pools ?

Large amount of fluid in movement / Foresee and optimize the circulation

Analytical solution of fluid dynamic equations is possible only for very simple cases. Otherwise : need of CFD, Computational Fluid Dynamics.

The geometry is divided in small cells and for each cell simplified equations for velocity, pressure, temperature, etc. are solved.

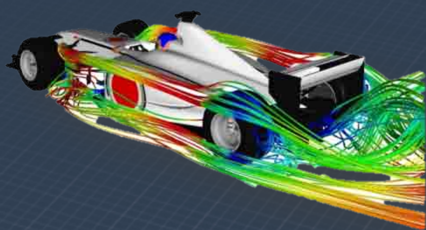
We run models up to 4M cells. The calculation time is ~1 week (HW with 64Gb RAM, 24 parallel CPUs). > 3years of experience, mainly w/ COMSOL Multiphysics (4.3).

Attention has to be paid to reach a physical solution.

SIMULATION

VALIDATION

RELIABLE
AND ACCURATE
RESULTS



3. 3D simulations: dye test

The aim is to simulate the DYE test before the pool construction

Reference EN 15288-2:2009 Swimming pools Part 2: Safety requirements for operation

2D and 3D CFD simulations applied to a pool can provide important pieces of information about the circulation.

The 3D simulation of an entire pool (in particular in presence of overflow gutter) represents a challenging project.

Convergence is reached through small steps such as increasing slowly the flow rate, using numerical stabilization methods or starting from laminar solution.

In fact 3D CFD in swimming pools is characterized by:

- large volume combined with relative little flow;

- small inlet diameter compared to the pool volume;

- mostly laminar but partly turbulent flow.

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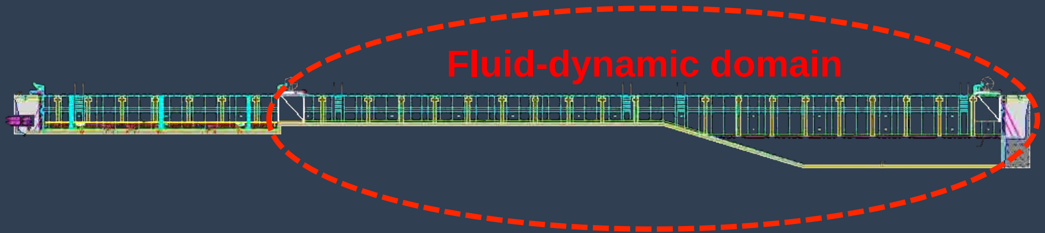
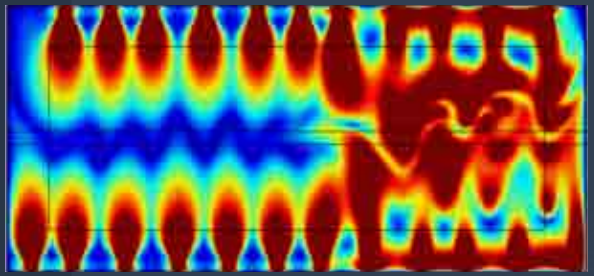
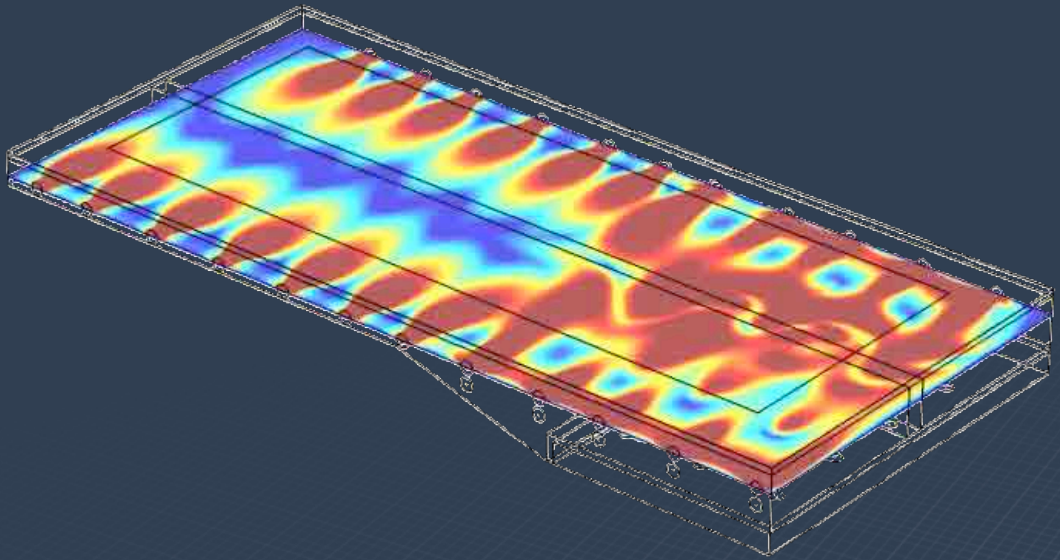
3. 3D simulations: dye test

1st example: Windsor (CA) pool 71x25 m. Simulations are performed on the competition section (50x25 m). Depth from 2 to 5 m with a 30° slope.







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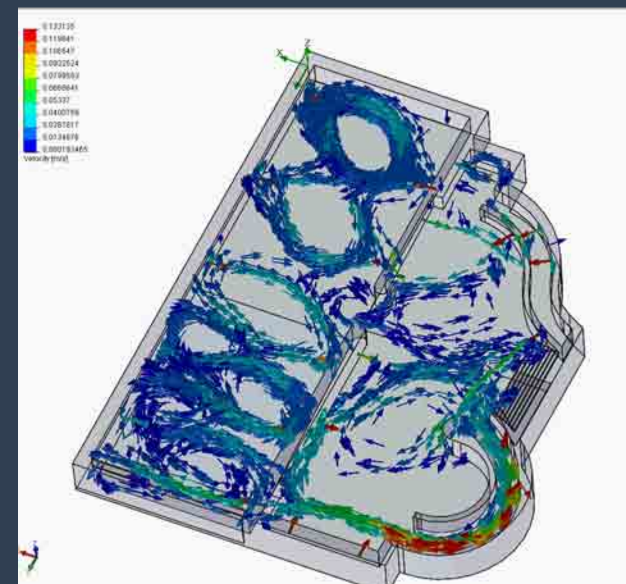
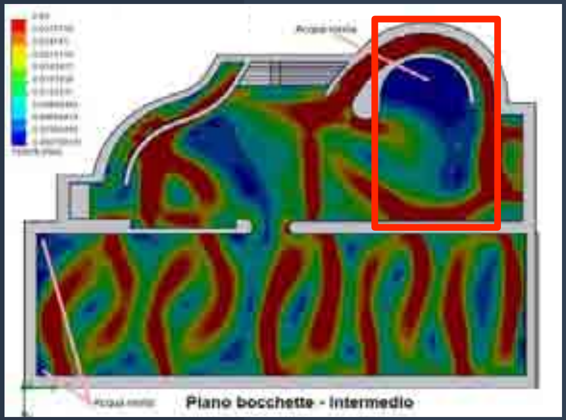
3. 3D simulations: dye test

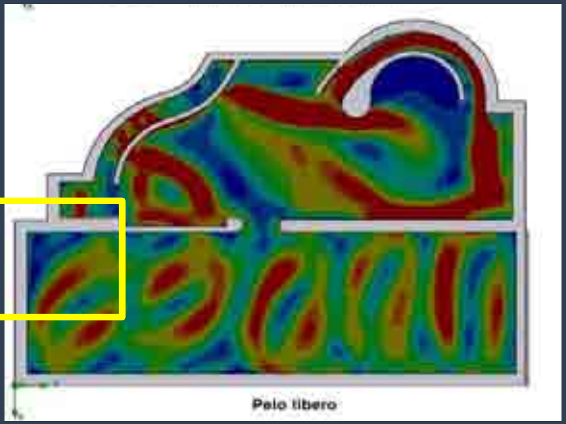
2nd example: Tours Aquatic Center pool (FR)

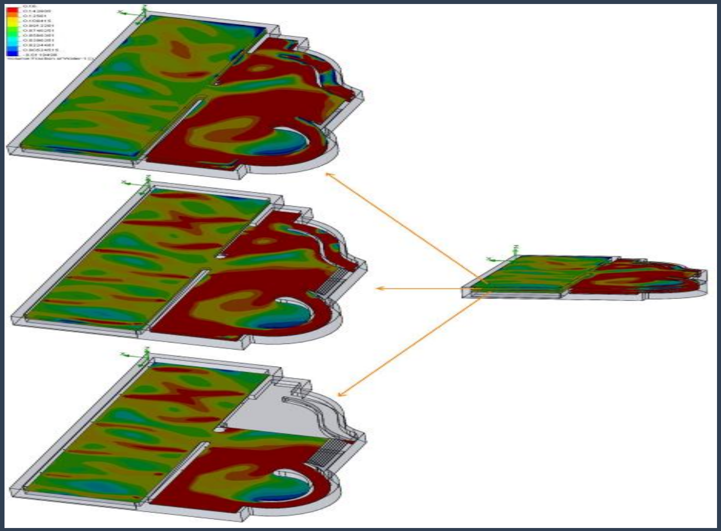


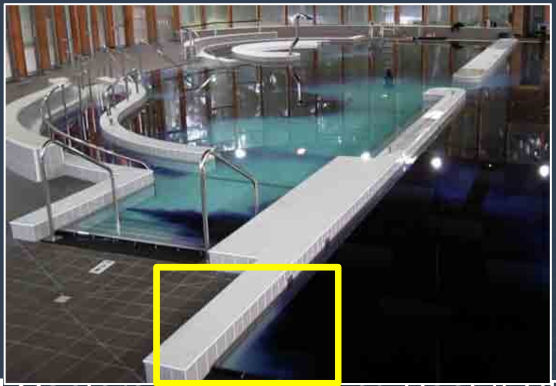
3. 3D simulations: dye test

Direct relationship between the CFD velocity field
… and the dye test results









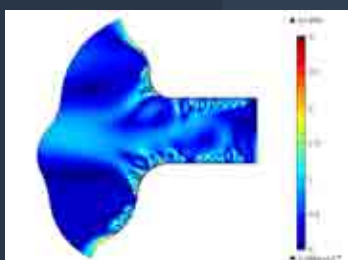
3. 3D simulations: dye test

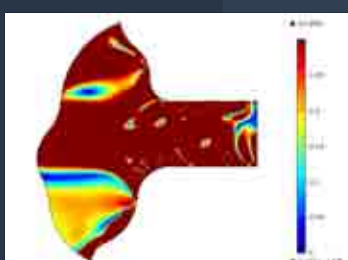
3th example: Wet'n'Wild Wave Pool, Sydney (AU) : 100x60 m

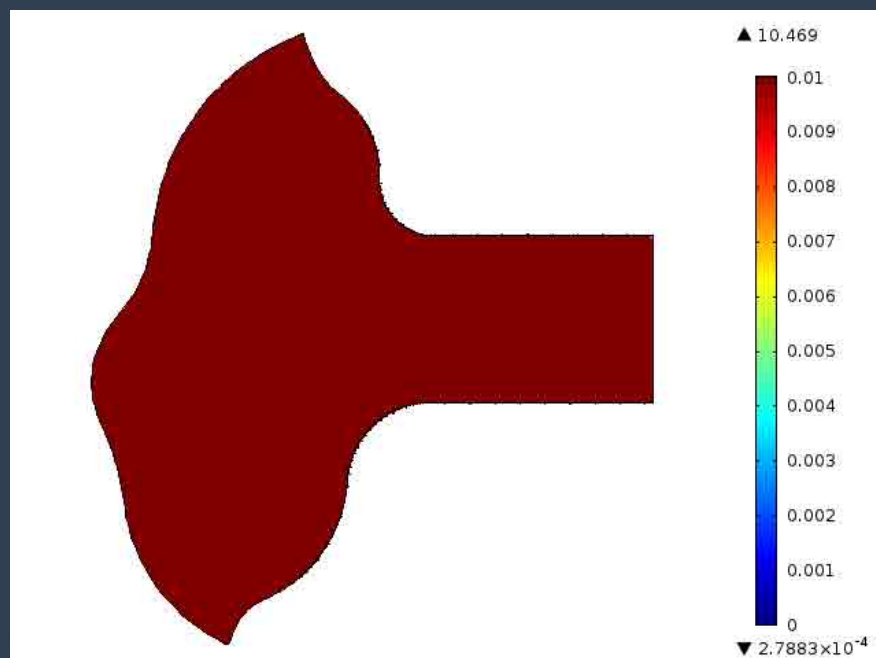
3. 3D simulations: dye test

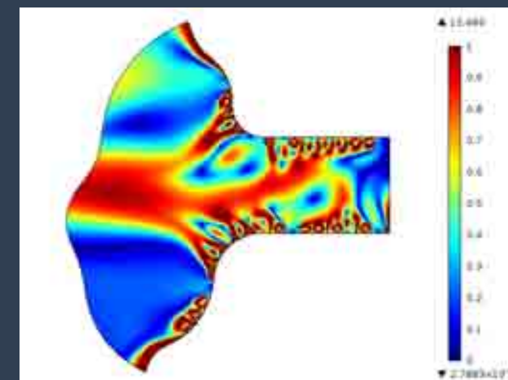
3th example:
CFD help during contract definition

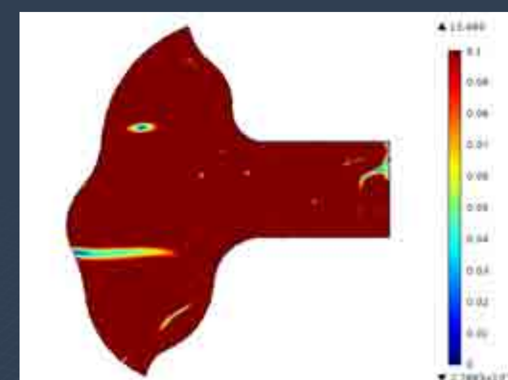
Red zones represent velocity greater than 0.01 m/s (36 m/h)











4. Development of accessories

1. **Wall inlets present a large number of advantages in terms of flow circulation maintenance, costs and execution time.**

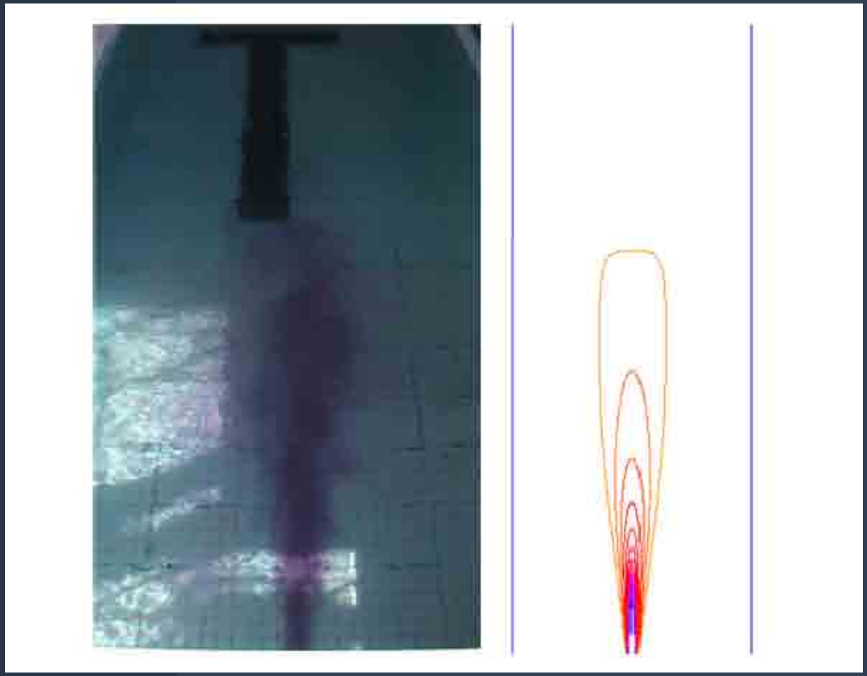
2. **Using staggered wall inlets (DIN 19643) further reduces the inlet number but it is important to guarantee that the flow reaches the opposite wall to pass the DYE TEST.**

3. **To reach this goal the flow exiting the inlets was appropriate but sometime disturbing the swimmers especially in the second lane.**

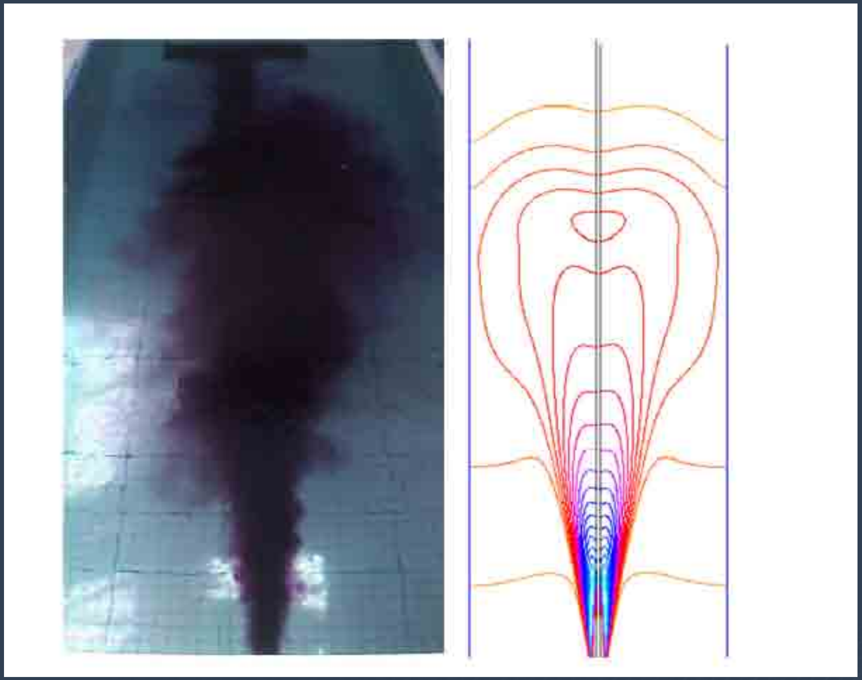
4. **The capability to guarantee high performance and low swimmers interference was a challenging point.**

4. Development of accessories

For turbulence there are available different models: the validity of selected model (revised k-ω*) and simulations settings was verified through color tests.



In the first instants the color diffuses only in the high velocity zones, that is the first 3-7 meters depending on flow rate.

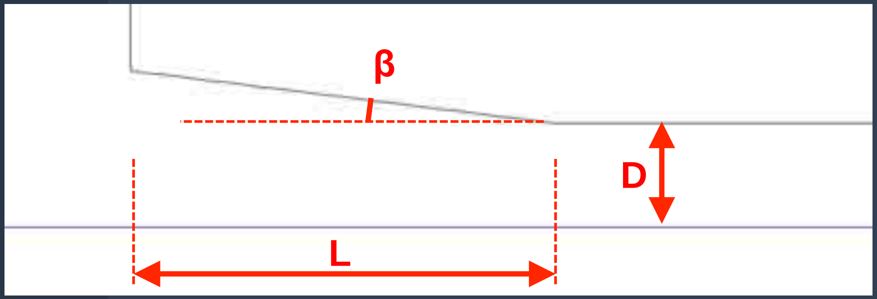


Then turbulent diffusion distribute the color in a wider region. The same applies for disinfection products.

***D.C. Wilcox, Turbulence Modeling for CFD, 2nd ed., DCW Industries, 1998.**

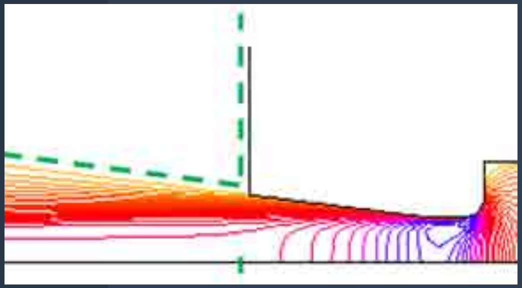
4. Development of accessories

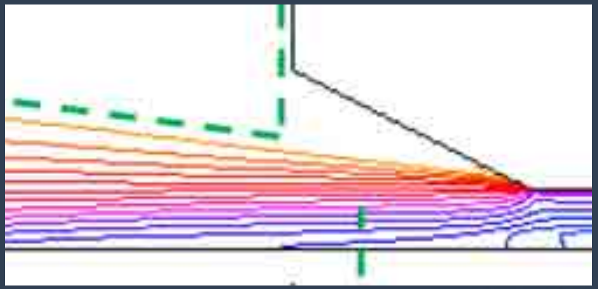
Axisymmetric simulations of the internal inlet geometry were performed. We deeply investigated the diverging cone, which has a fundamental importance.

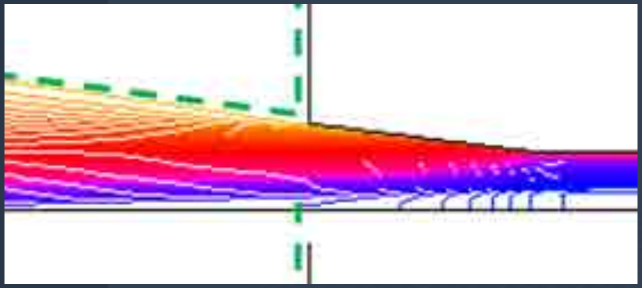


We tested several configurations varying 3 main parameters: D, β, L.

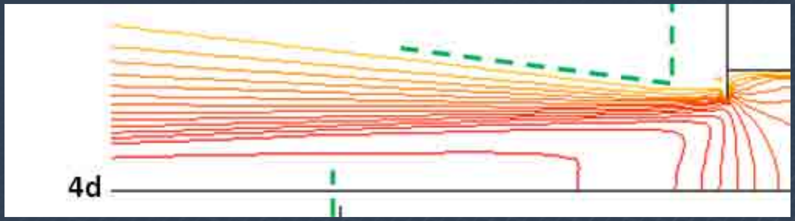
Examples are reported below. The pictures report half of the inlet (Velocity field)







RESULT: the exiting water jet has a preferential angle of about 16°



4. Development of accessories

We investigated the force of the jet with dedicated experimental tests. In this way we identified low and high energy regions depending on the flow rate. The optimal flow rate for reaching the opposite wall and avoid interference was also obtained.

Wall inlet

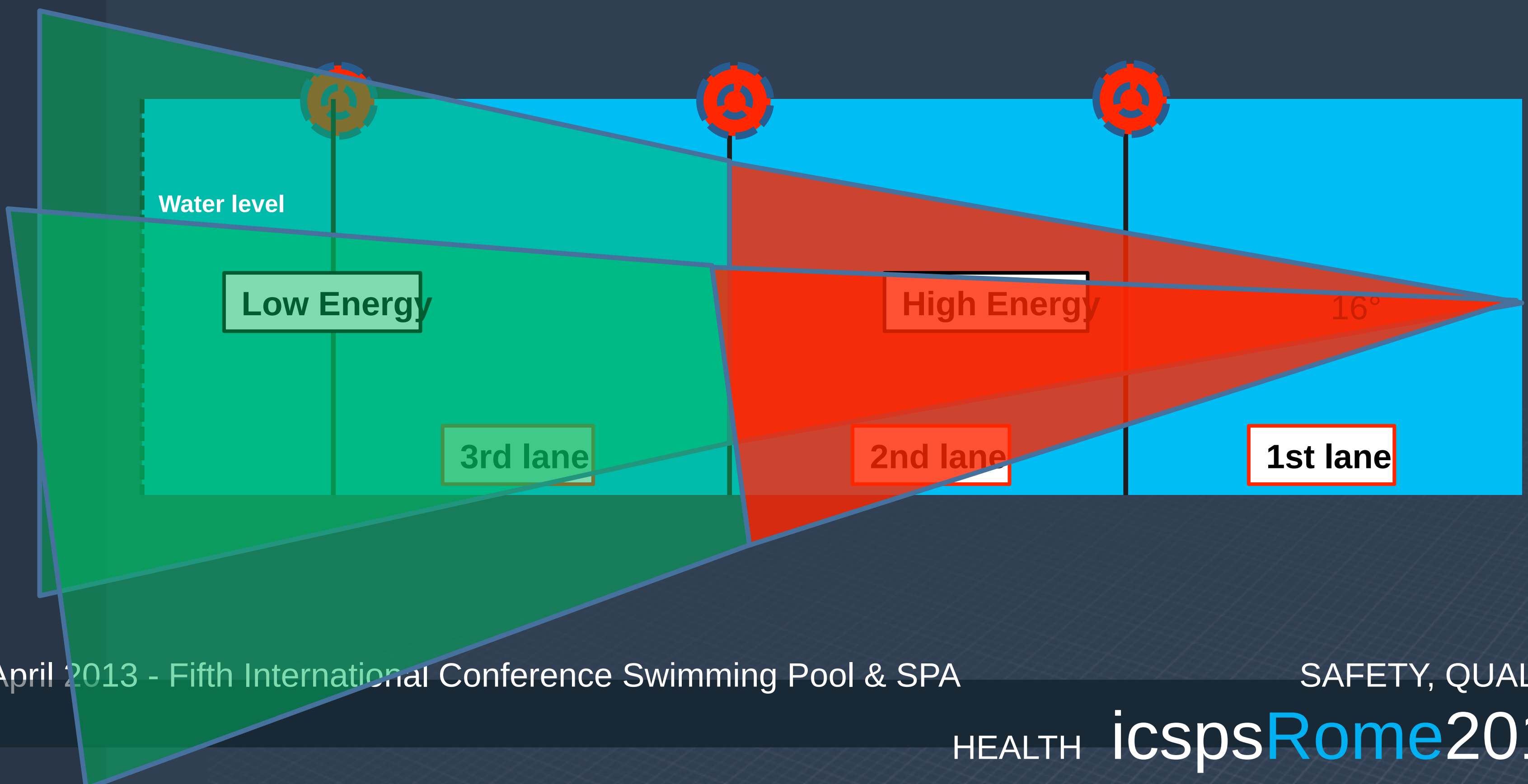
Force measurements

Distance measurements

4. Development of accessories

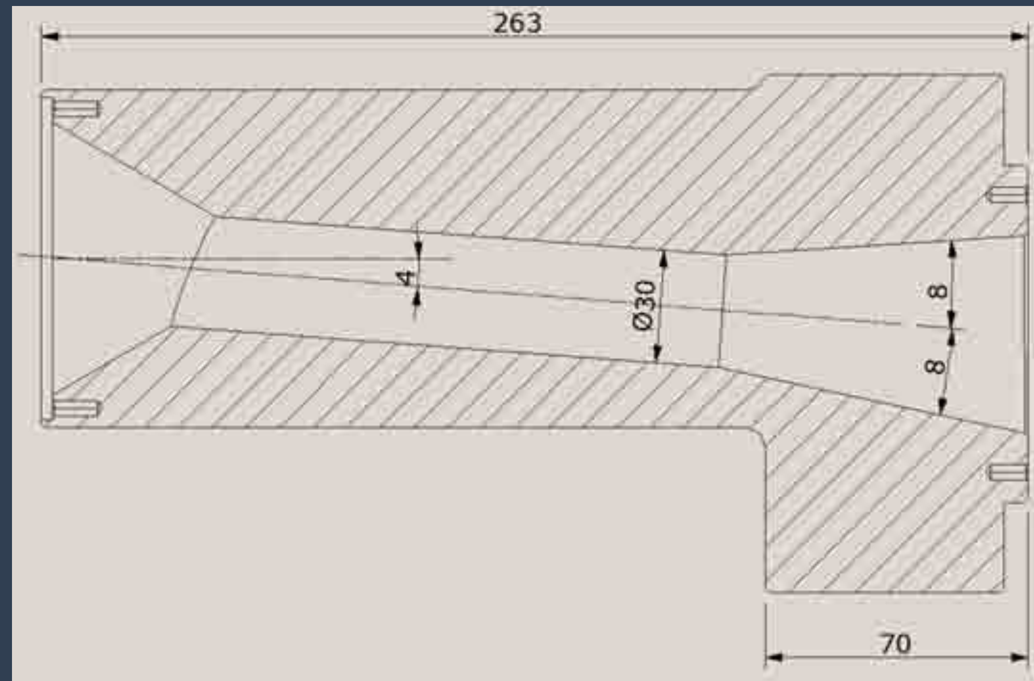
If we consider a 16° jet angle we can **explain** the swimmer interference on the **second lane**, which is still an high energy region.

In particular a 4° inclination downward moves the high energy regions far from the swimmers.



4. Development of accessories

The new wall inlet design takes into account all the investigated parameters.



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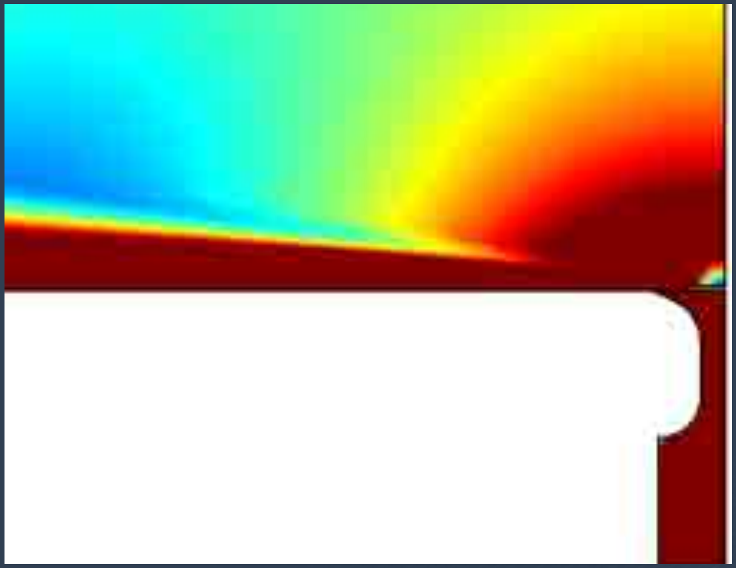
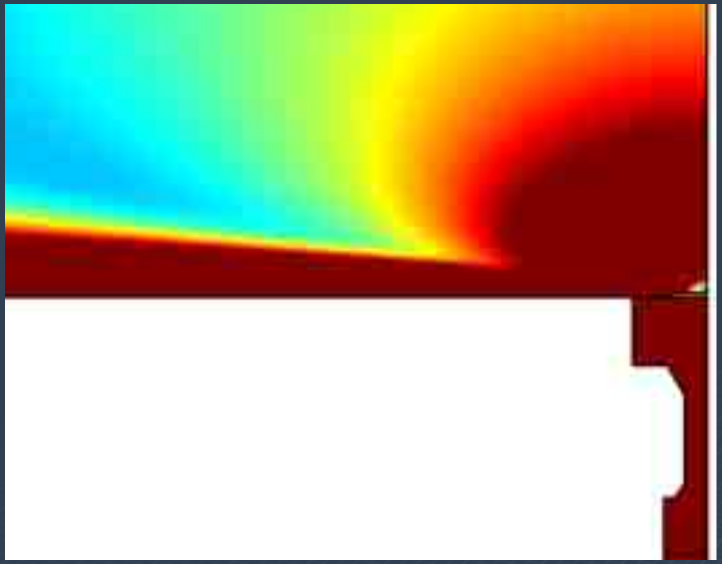
4. Development of accessories

Example of floor inlet design-to-cost optimization

… we used CFD (model comparison) and only 1 prototype

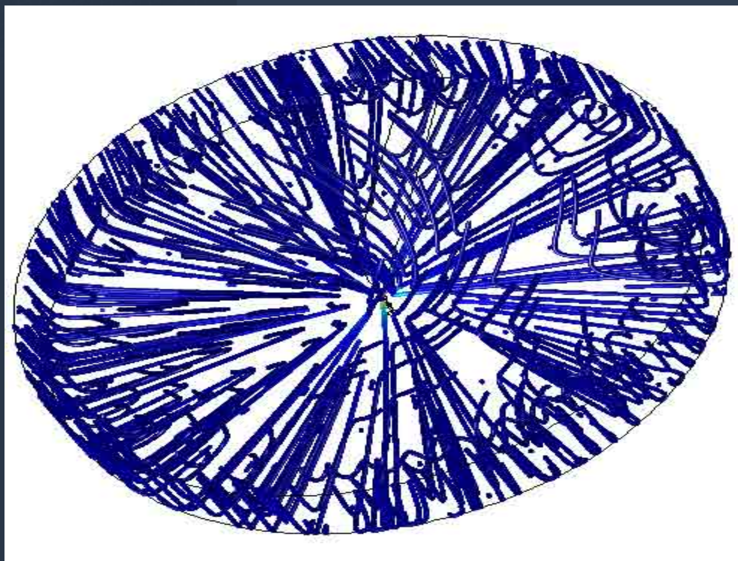


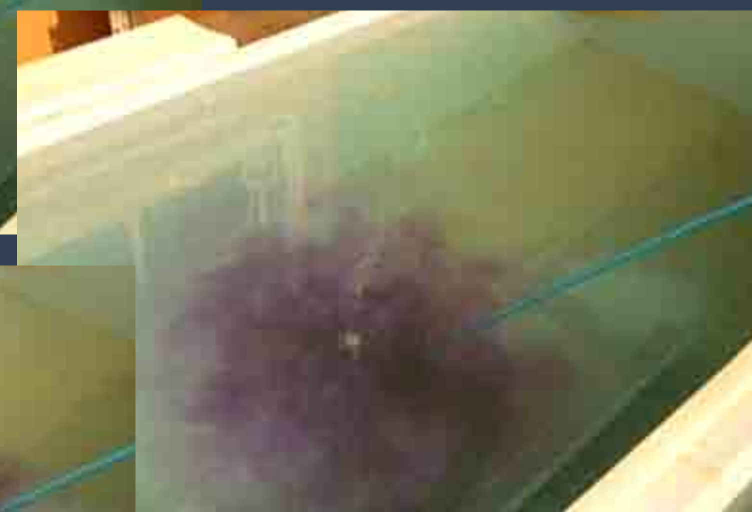


4. Development of accessories

The result is a floor inlet:

- More compact
- Easier to install
- With reduced pressure drops





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