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## Session C8: Development of Criteria for the Design and Dimensioning of Fish- Friendly Intakes for Small Hydropower Plant

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**1**

Pour mieux affirmer ses missions, le Cemagref devient Irstea

**Pôle Ecohydraulique ONEMA – IRSTEA – IMFT (Toulouse)**

**2**

**Institut P' de Poitiers**

# Development of criteria for the design and dimensioning of fish-friendly intakes for small hydropower plant

COURRET D<sup>1</sup>, LARINIER M, DAVID L<sup>2</sup> and CHATELLIER L<sup>2</sup>

Several studies funded by :



## Context in France

- **Downstream migration is taking into account for :**
  - **Salmon : smolts (+ adults)**
  - **Sea trout : smolts + adults**
  - Can have a lot of hydropower plants on their migration route
  - **Silver eels**
  - Suffered high mortality
  - **Brown trout at medium or high head hydropower plant**
- **A lot of small hydropower plants on migration route (old mills)**
  - Run-of-river operation
  - Turbine discharge mostly  $< 50 \text{ m}^3/\text{s}$ , some between  $50 - 100 \text{ m}^3/\text{s}$
  - A few big plants :
    - » Dordogne and Garonne river :  $300-500 \text{ m}^3/\text{s}$
    - » Rhine and Rhone river :  $1000 - 1500 \text{ m}^3/\text{s}$

**Smolts : (12) 15 - 20 (22) cm**



**Silver eels :**

- Male 30-45 cm

- Female 50-90 (110) cm



# Brief overview of solutions and ONEMA positions

## 4 main types of solutions

- **Fish friendly turbine** (VLH, Screw) → Good solutions, but limited to low height dam and discharge, mostly for new equipment, not really cost-effective on existing plant
- **Behavioral device** (sound, light, electricity) → No system approved until now, except light to attract smolts
- **Targeted shutdown of turbines** → Foreseen for eels at biggest dams where other solutions are not feasible, difficult to define, ongoing research
- **Material barriers which can induce both behavioral or physical effects :**
  - Louver → Not implemented due to maintenance constraints
  - Surface guiding wall with bypasses → Reserved to biggest dams (1 case)
  - **Bypass in association with trashrack → Main solution implemented at small plants in France**

# Studies conducted

- **1992 – 2005** : Assessment of the efficiency of bypasses in association with existing trashracks (EDF R&D – CSP – Cemagref)
- ➔ A satisfactory solution in some cases
- ➔ But difficulties to obtain regularly good efficiencies, especially for eels



Halsou

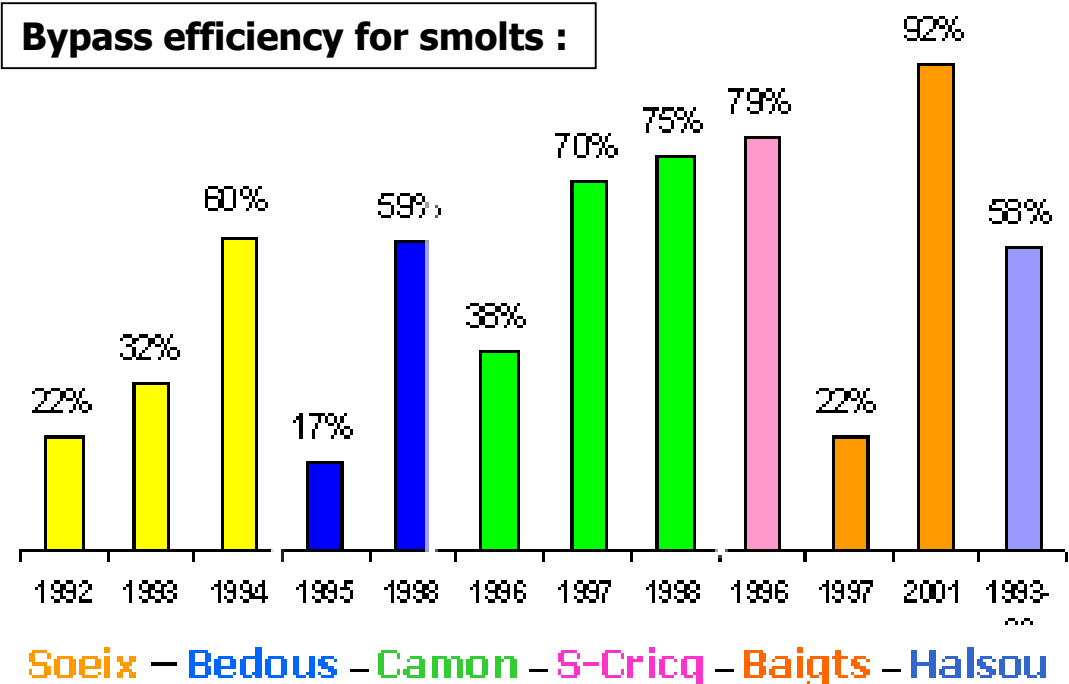


Baigts

### Bypass efficiency for silver eels :

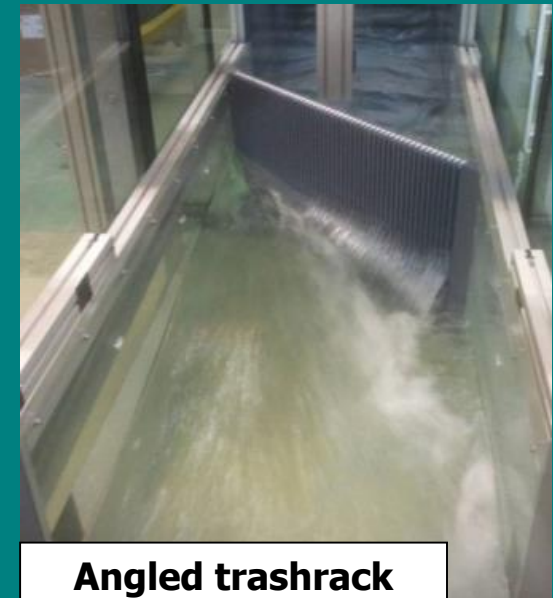
- Baigts :  $\approx 20\%$  (surface), very low (bottom)
- Halsou : 56 – 64 %

### Bypass efficiency for smolts :



## Studies conducted

- **2007-2008** : Synthetize the feed-back of all efficiency assessment and intake design in France and abroad (mainly USA) to define criteria for systems of racks and bypasses with high efficiency (> 90%)
  - So-called "fish friendly intakes"
  - Production of a technical guide in 2008
  
- **2010 – Until now** : hydraulic studies, mainly on down-scaled physical model + numerical simulation :
  - Characterize head-losses through racks in fish-friendly configurations
  - Verification of guiding conditions and adaptation of criteria
  - Precise criteria for the design of bypasses (attractivity in function of position, flow, ...)



**Angled trashrack**

## 3 fundamentals functions

### 1) Stop fish and avoid their passage through turbine

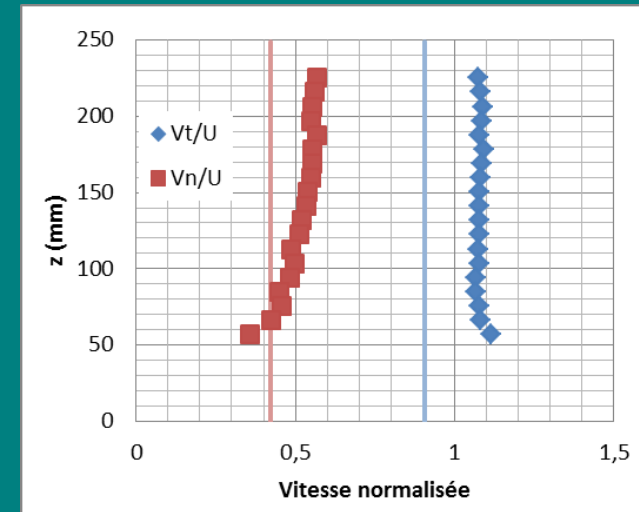
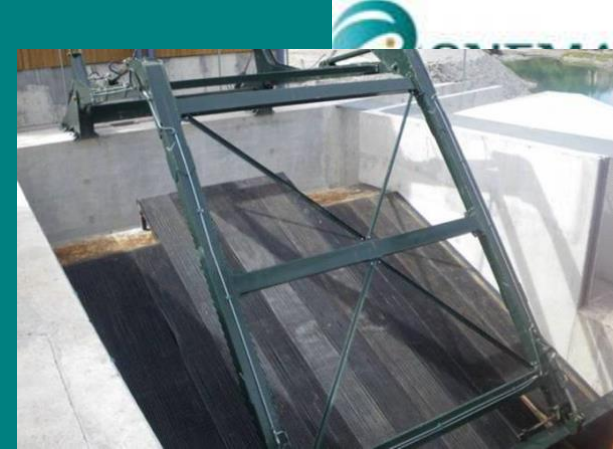
- **Smolts :**
  - Possible to obtain good efficiency with a behavioral effect
  - Bar spacing :  $\leq 25$  mm
- **Silver eels :**
  - Necessity to install a physical barrier : bar spacing  $\leq$  head diameter
  - Bar spacing : 15 - 20 mm to stop eels longer than 50 - 60 cm
- **Velocities upstream the rack low enough to :**
  - Allow fish swimming during the time necessary to find bypasses
  - Do not induce rapid passage through or impingement of fish against the rack
  - Normal velocity (flow divided by the wetted rack surface)  $\leq 50$  cm/s for eels and smolts
  - Give a minimal surface of the rack for a given turbine discharge : at least 2 m<sup>2</sup> of rack for 1 m<sup>3</sup>/s of turbine discharge



### 3 fundamentals functions

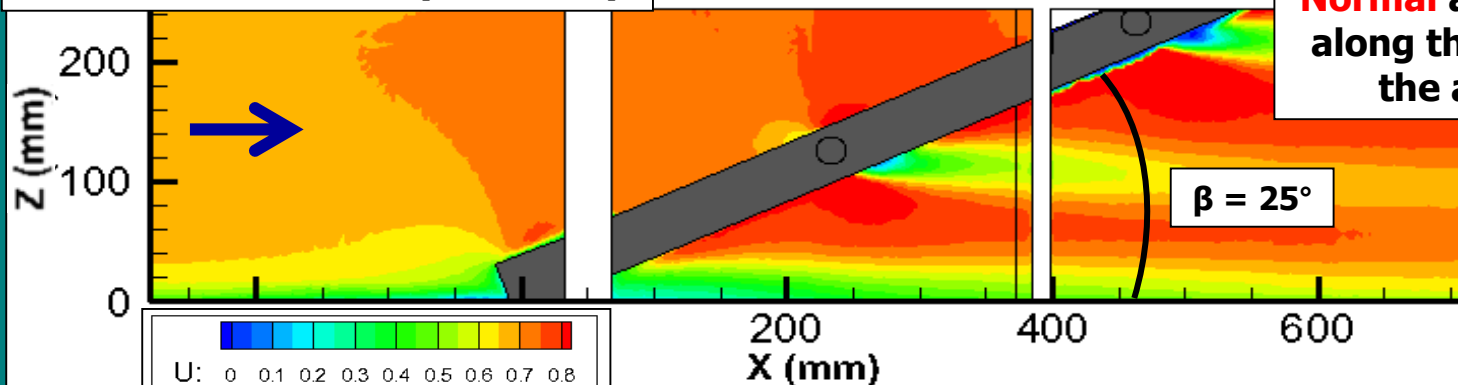
#### 2) Guide fish towards bypasses → Inclined trashrack perpendicular to the flow :

- Moderate acceleration of velocities along the rack ( $\approx +10\%$  at the top of the rack)
- Minimal inclination at  $\beta \leq 26$  to obtain  $V_t \geq 2 V_n$  and guide fish to the surface
- Approach velocity acceptable up to  $\approx 0.80$ - $0.85$  m/s à  $\beta = 26^\circ$  → higher inclination in case of higher velocities



**Normal and tangential velocity along the rack (normalized to the approach velocity)**

**Measured velocities (side view)**

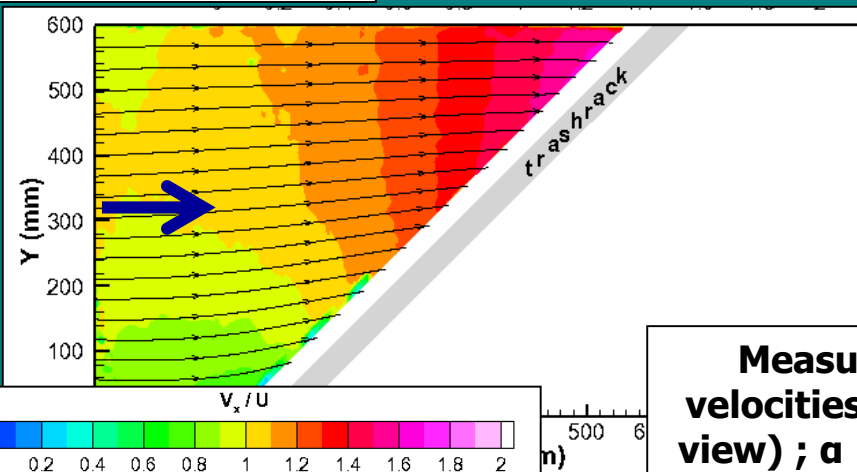


# 3 fundamentals functions

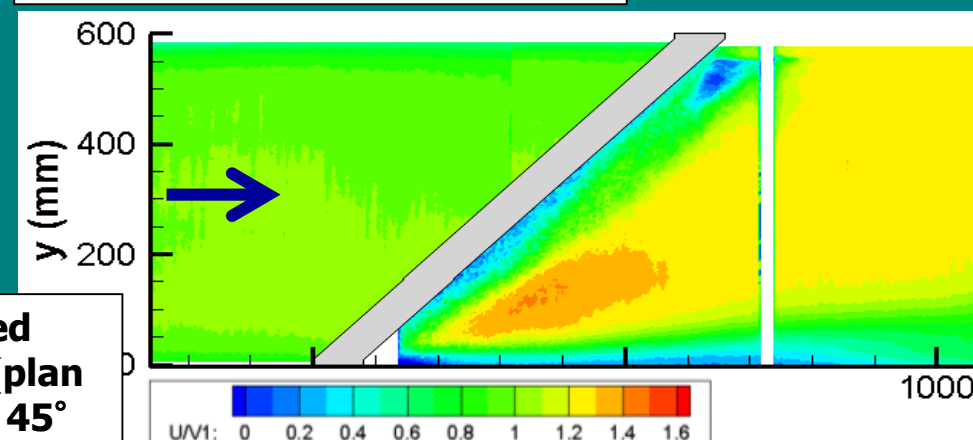
## 2) Guide fish towards bypasses → Angled vertical trashrack :

- Minimal angle  $\alpha \leq 45^\circ$  to obtain  $V_t \geq V_n$
- Conventional rack (bar perpendicular to the rack axis)
  - Flow acceleration along the rack + head-losses increasing with angulation
  - Approach velocity acceptable limited to 0.5 m/s at  $\alpha = 45^\circ$  → Low gain on acceptable approach velocity with an increase of the angulation
- Rack with streamwise bars (experimental configuration)
  - Homogeneous velocities upstream the rack + reduction of head-losses
  - Approach velocity acceptable up to 0.6 m/s à  $\alpha = 45^\circ$  → higher angulation in case of higher velocities, but solution to find to clean the rack

**Conventional rack**



**Rack with streamwise bars**



**Measured velocities (plan view) ;  $\alpha = 45^\circ$**

### 3 fundamentals functions

#### 2) Guide fish towards bypasses → Angled vertical trashrack :

- Angled rack with horizontal bars are interesting :
  - no installation in France ; several installations in Deutschland and Sweden
  - Looking for studies and feedback on this configuration
  
- Rack in bank alignment are favorable configuration for fish guidance



# 3 fundamentals functions

## 3) Downstream transfer of fish → Inclined rack

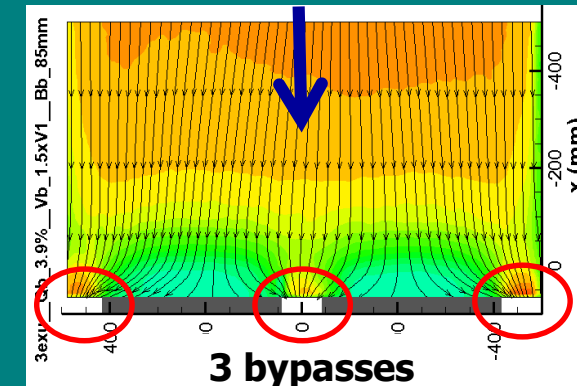
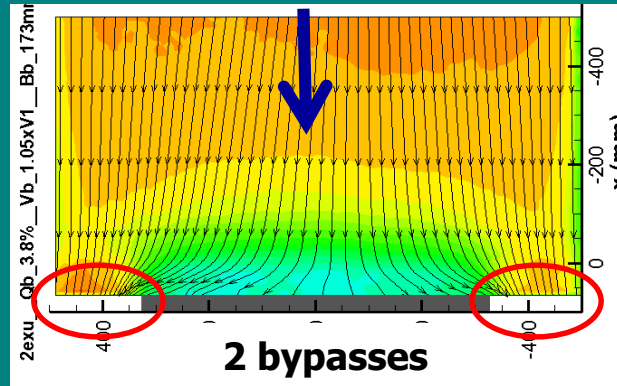
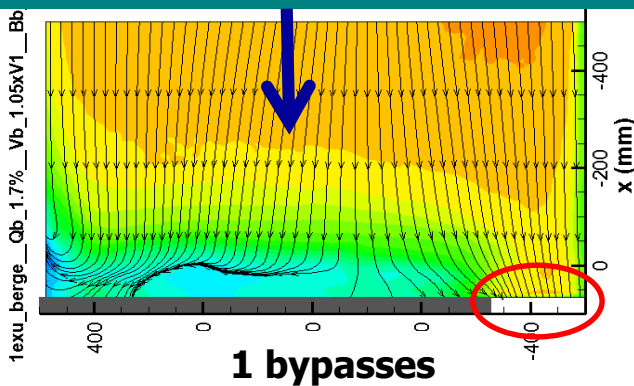
- Surface bypasses at the top of the rack
- Criteria to determine bypass number and flow :
  - Velocity at the bypass entrance  $V_b = 1.1 V_A$
  - Minimal dimensions recommended : 1 m wide ( $B_b$ ) and 0.5 m deep ( $H_b$ )
  - Obstruction of the top of the rack, between bypasses, over the same depth → to generate transversal velocities
  - Maximal distance between bypasses : 4-5 m → Determination of the number of bypasses  $N_b$

→ From 5-6% of turbine discharge for small intakes, down to 2-3% for intakes  $> 50 \text{ m}^3/\text{s}$



$$Q_b = V_b * H_b * (N_b * B_b)$$

Near surface velocities (plan view) at the top of inclined rack ;  $\beta = 26^\circ$



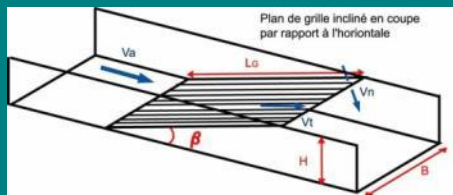
## 3 fundamentals functions

### 3) Downstream transfer of fish → Angled rack

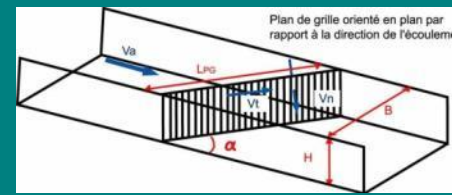
- **Bypass positioned at the downstream end of the rack**
- **Not a complete set of criteria nowadays :**
  - Surface bypass : as deep as possible, ideally same depth as the intake → high flow ; difficulties to create a such deep bypass on existing site
  - Interrogation about bottom bypass, notably for eels :
    - » Sensible to clogging and difficult to clean
    - » Necessity ? → Eels seem to prospect all the water column if they are stopped by the rack.
  - Velocity at the bypass entrance  $V_b$  of about velocities at the downstream end of the rack :
    - »  $V_b = 1.7 V_A$  for a “conventional” angled rack à 45° → high flow
    - »  $V_b = 1.0 V_A$  for a angled rack with streamwise bars
    - » Criteria for an angled rack with horizontal bars and rack in bank alignment ?

# Head-losses and clogging issues

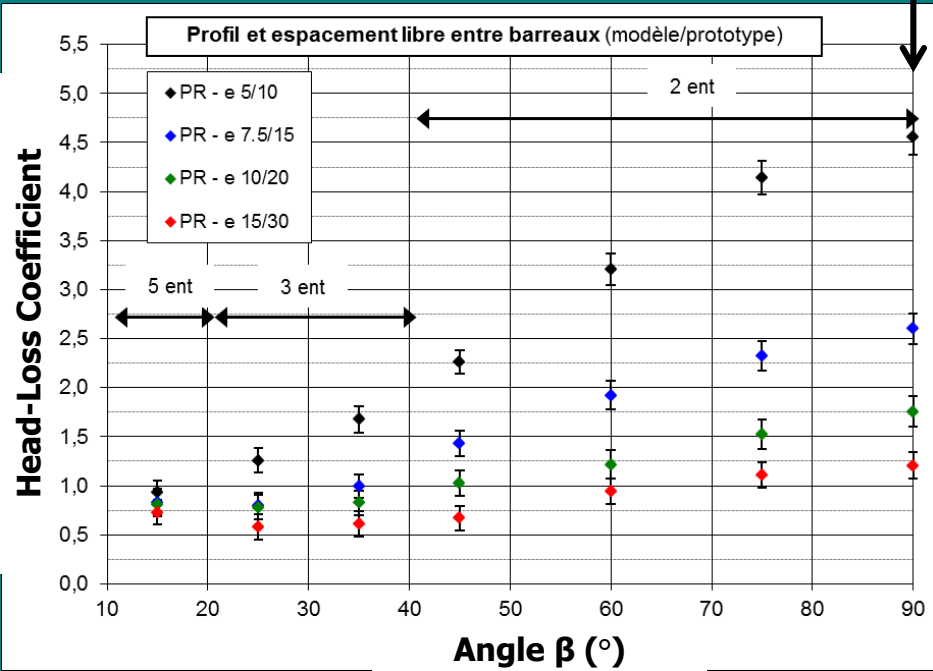
- Experimental measurement of head-losses
  - Existing formulae not adapted to fish-friendly configurations
- Production of new formulae (Raynal et al. 2013)



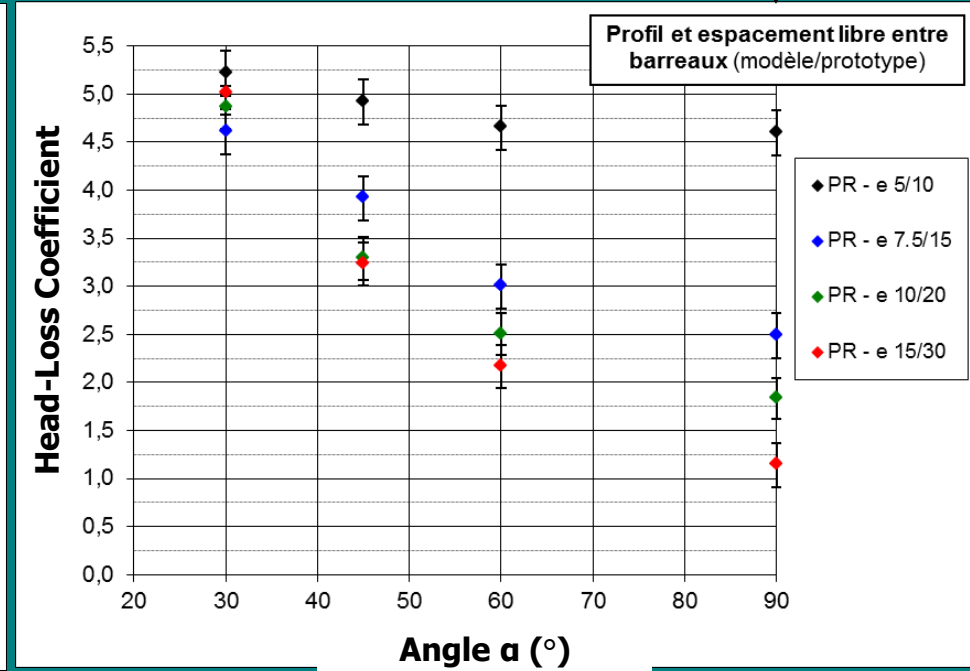
**Vertical**



**Perpendicular**



**Decreasing head-losses with inclination**



**Increasing head-losses with angulation**

## Conclusions

- **Preference for inclined rack :**
  - Lower head-losses
  - Compatible with high approach velocity
  - Existing solutions for rack cleaning → Except for deep intakes and long racks
  - Bypass design criteria well-defined
  - But not adapted to forebay with water level fluctuations
- **Angled rack reserved to deep intakes, or intake with fluctuating water levels, or in bank alignment**
  - « Conventional » rack constraining (head-losses, admissible approach velocity)
  - Rack with stream-wise bars → interesting solution, trashrake design to find
  - Rack with horizontal bars ? → Feed back in Deutschland and Sweden
  - Design criteria for bypass to complete
- **Absolute necessity to adapt the trashrake**
- **Feed back to acquire on operation and biological efficiency (ongoing)**

Thank you for your attention



4 bypasses