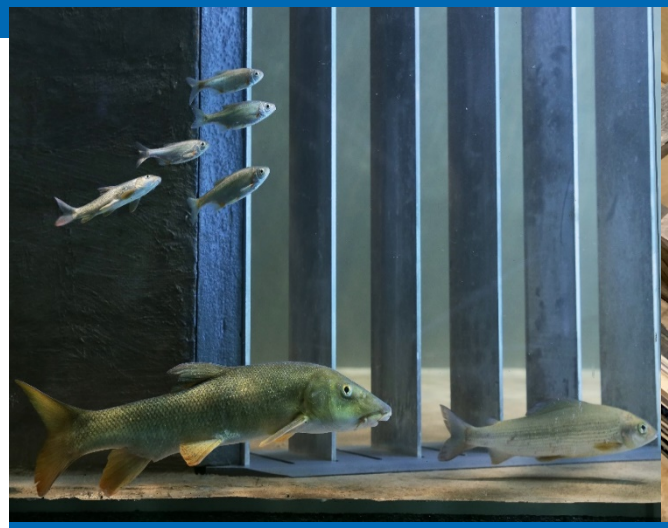
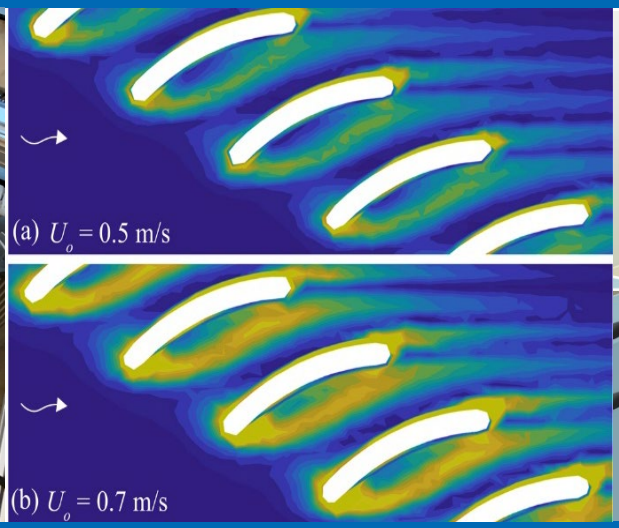
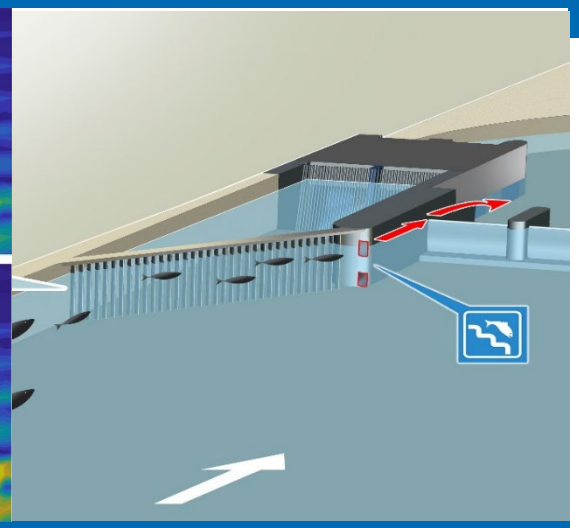






Ergebnisse des EU Horizon 2020 Projektes „FITHYDRO“

Fischschutz und Fischabstieg an großen Wasserkraftanlagen:

Erfahrungen und Wissen teilen, organized by ICPR

September 16, 2021

Dr. Ismail Albayrak, Prof. Dr. Robert Boes, Dr. David Vetsch, Dr. Claudia Beck, Dr. Julian Meister, Anita Moldenhauer, Claudia Leuch, Stephan Kammerer, Cristina Rachelly, Reza Maddahi, Dr. Armin Peter (FishConsulting), Dr. Oliver Selz (Eawag)

Laboratory of Hydraulics, Hydrology and Glaciology VAW, ETH Zurich

Outline

- Introduction
  - FIThydro
  - VAW projects in FIThydro
- Curved-Bar Rack - Bypass System
  - Overview
  - Head-loss
  - Live-fish tests
  - Pilot project
- Conclusions

Introduction: FIThydro

Fishfriendly Innovative Technologies for Hydropower (FIThydro)

26 Partners: 13 research, 13 industry from 10 EU countries

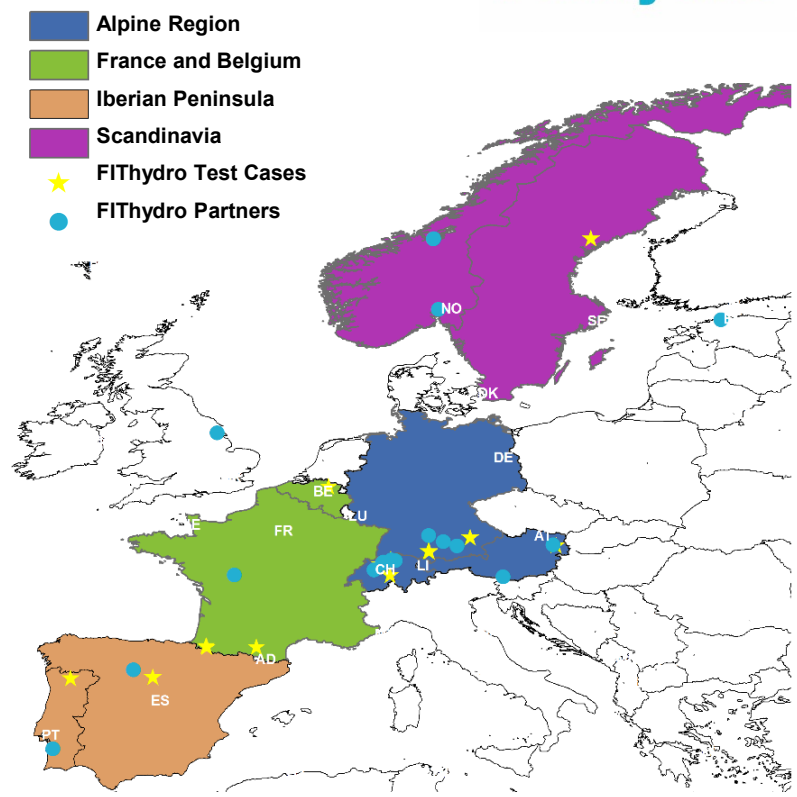
Project aim at:

- Development of cost-efficient environmental solutions for sustainable and fish friendly hydropower by investigating mitigation measures and strategies
- Development of decision support tools for commissioning and operating hydropower plants by use of existing and innovative technologies

Budget: 7.2 Mio. €

FIThydro project website: www.fithydro.eu

FIThydro WIKI: https://www.fithydro.wiki



FIThydro Partners & Test Cases

This project is Funded by the Horizon 2020 Framework Programme of the European Union Grant Agreement number 727830

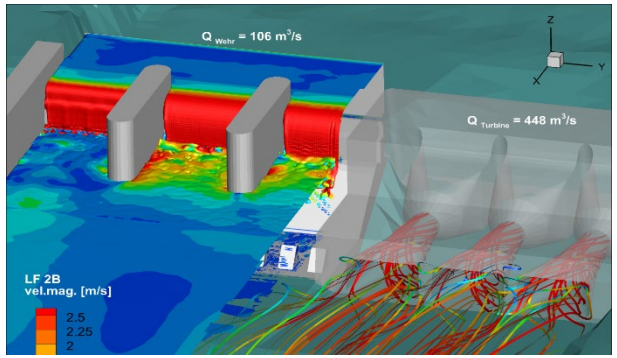
Introduction: VAW projects in FIThydro

Field studies

Bannwil Hydropower Plant (Q_{design} = 450 m^3/s)

Spillway and Turbine Fish Passages

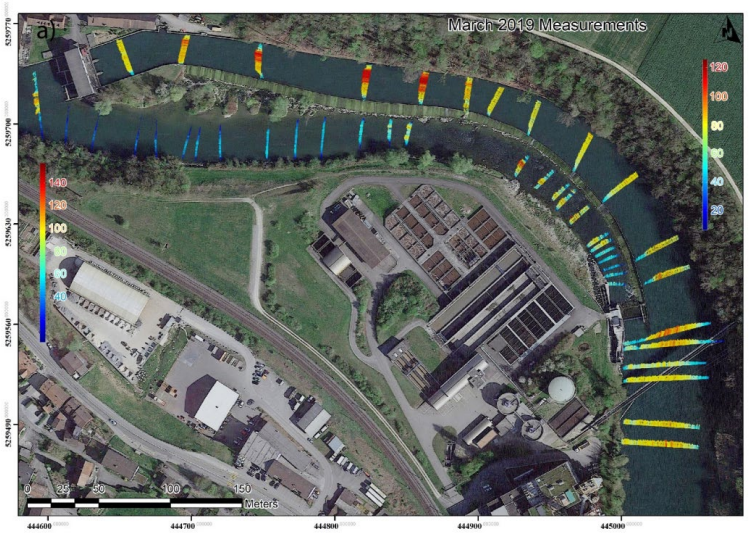
Development of Curved-Bar Rack-Bypass System



https://www.fithydro.wiki/index.php/File:Test_case_presentation_Bannwil_HPP.pdf

Schiffmühle Hydropower Plant (Q_{design} = 108 & 14 m^3/s)

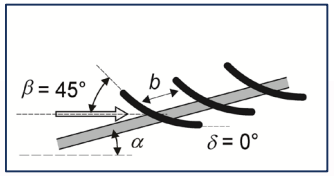
Horizontal Bar Rack – Bypass System
Vertical slot and nature-like fish ways
Bedload diversion using vortex tube

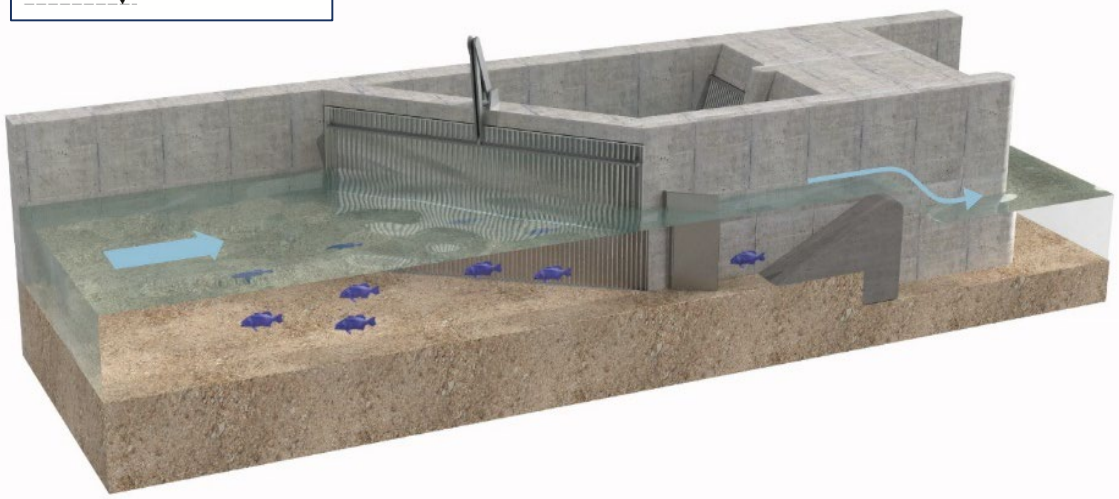


https://www.fithydro.wiki/images/Test_case_presentation_Schiffmühle.pdf

Introduction: VAW projects in FIThydro

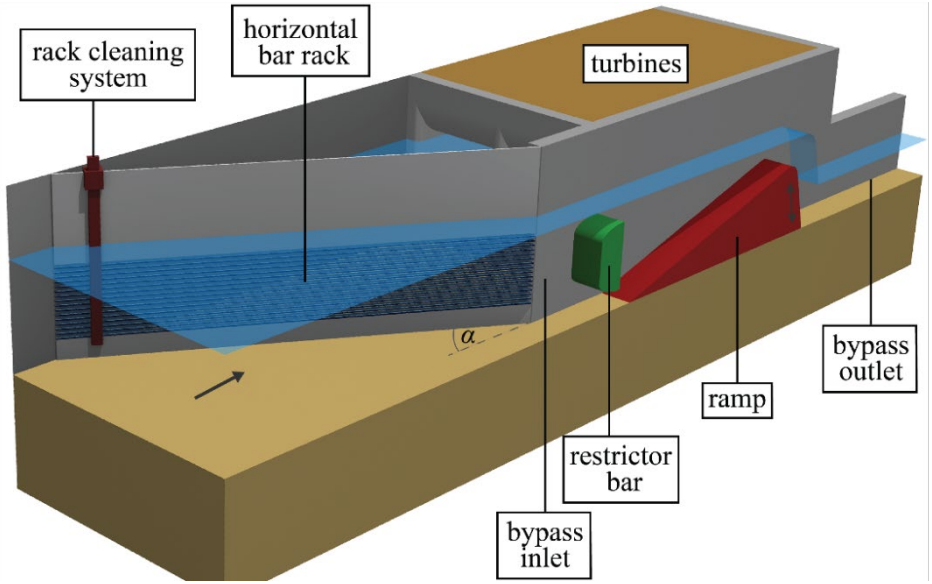
Laboratory studies





Fish Guidance Structure (FGS) with Vertical Bars
«Mechanical behavioural barriers»

Curved-Bar Rack-Bypass System (CBR-BS)
for small-to-large HPPs



FGS with Horizontal Bars
«Physical barriers»

Horizontal Bar Rack-Bypass System (HBR-BS)
for small-to-medium size HPPs with Q_d < 100 m³/s

PhD thesis of Dr. Claudia Beck

PhD thesis of Dr. Julian Meister

Curved-Bar Rack – Bypass System: Overview

«Mechanical behavioural barriers»
Clear bar spacing: 25 - 100 mm (50 mm recommended)
Rack angle ≥ 30°

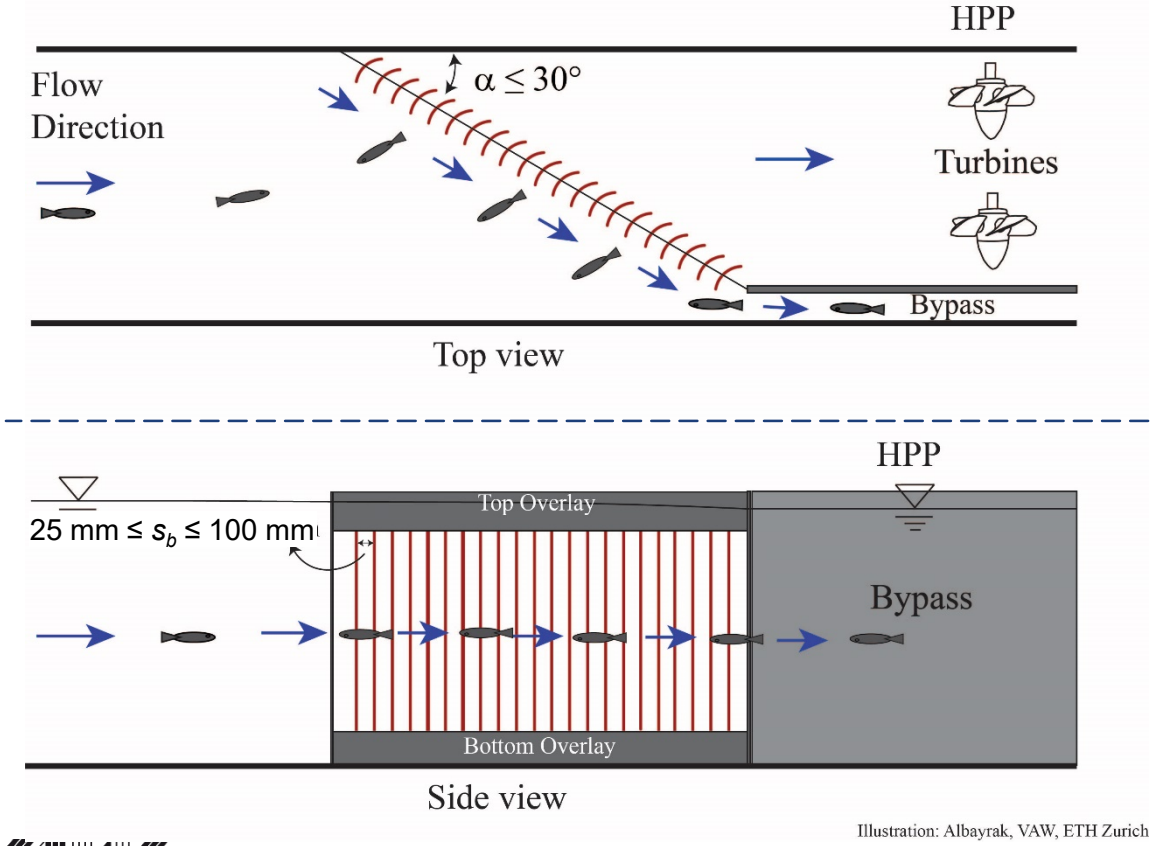
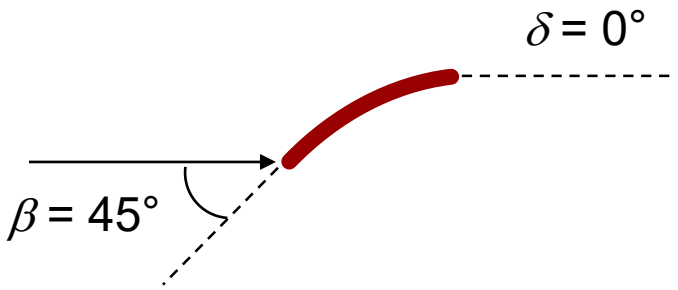
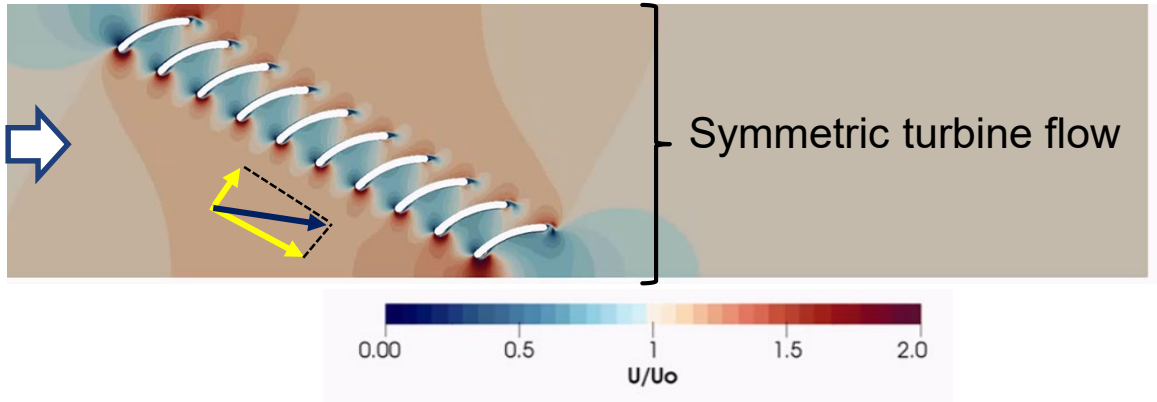
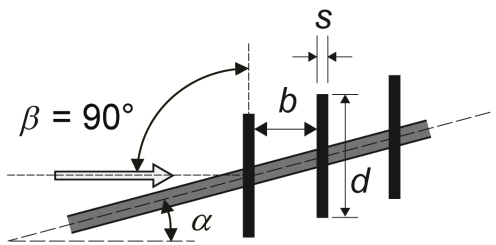


Illustration: Albayrak, VAW, ETH Zurich

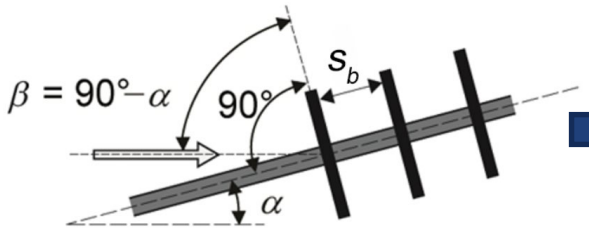




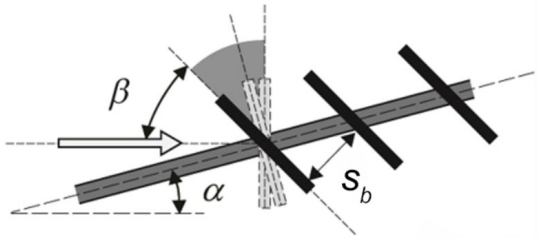
Curved-Bar Rack – Bypass System: Head loss



Louvers

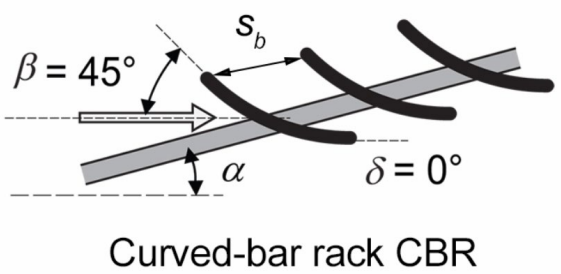


Angled bar rack



Modified angled bar rack

2015, VAW



Curved-bar rack CBR

2021, VAW

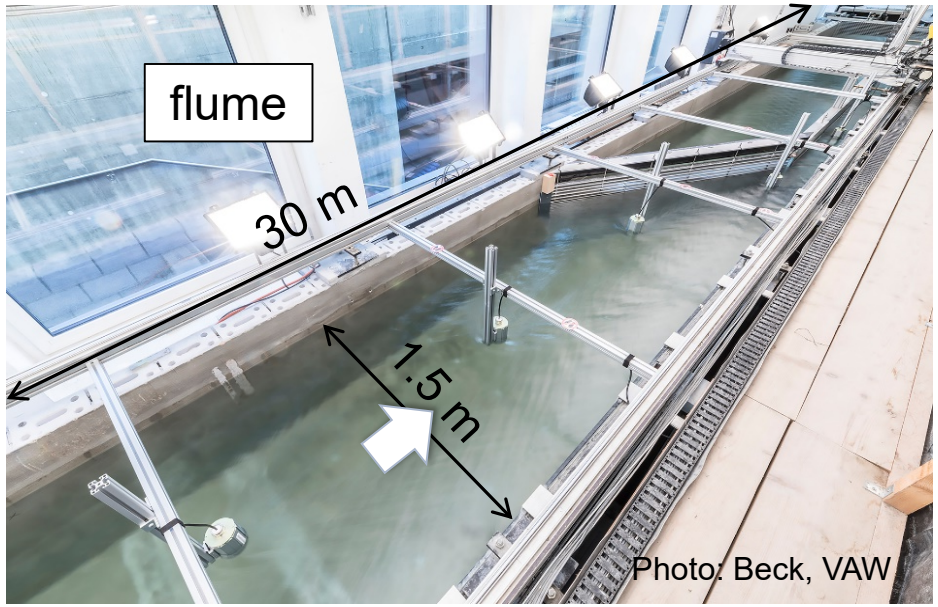
Head loss reduction

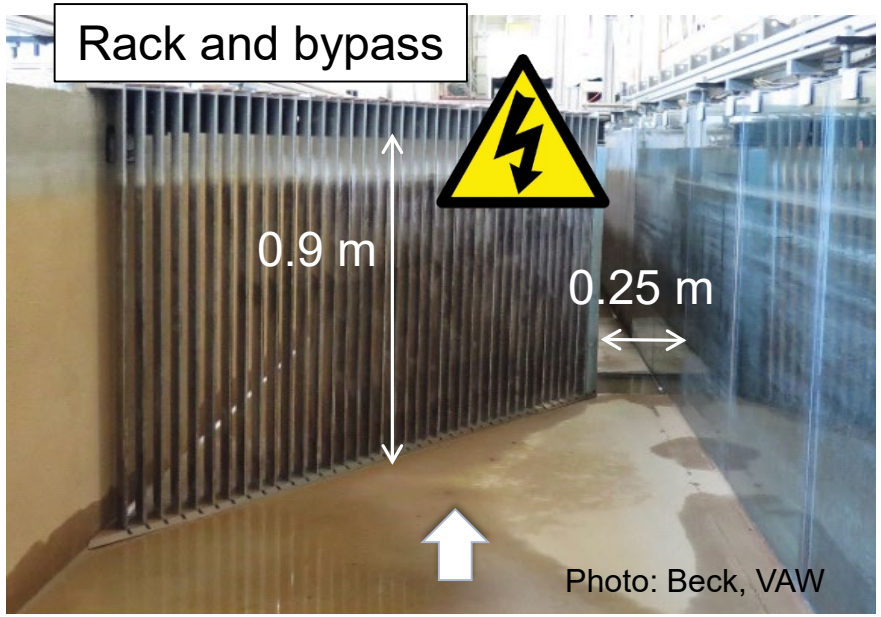
Example: rack angle, α = 30°, clear bar spacing, s_b = 50 mm:

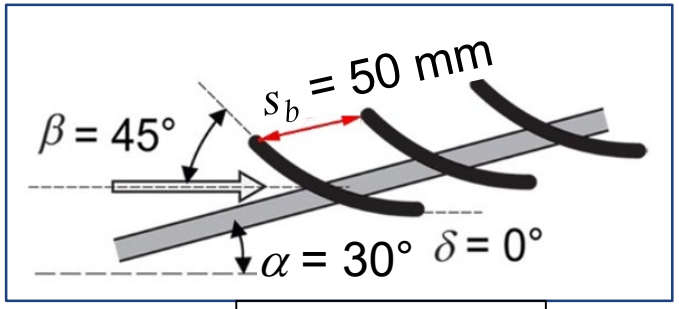
ξ_R = 14 → ~ξ_R/5 = 2.6 → ~ξ_R/20 = 0.6

Curved-Bar Rack – Bypass System: Live-fish tests

Etho-Hydraulic Laboratory Flume

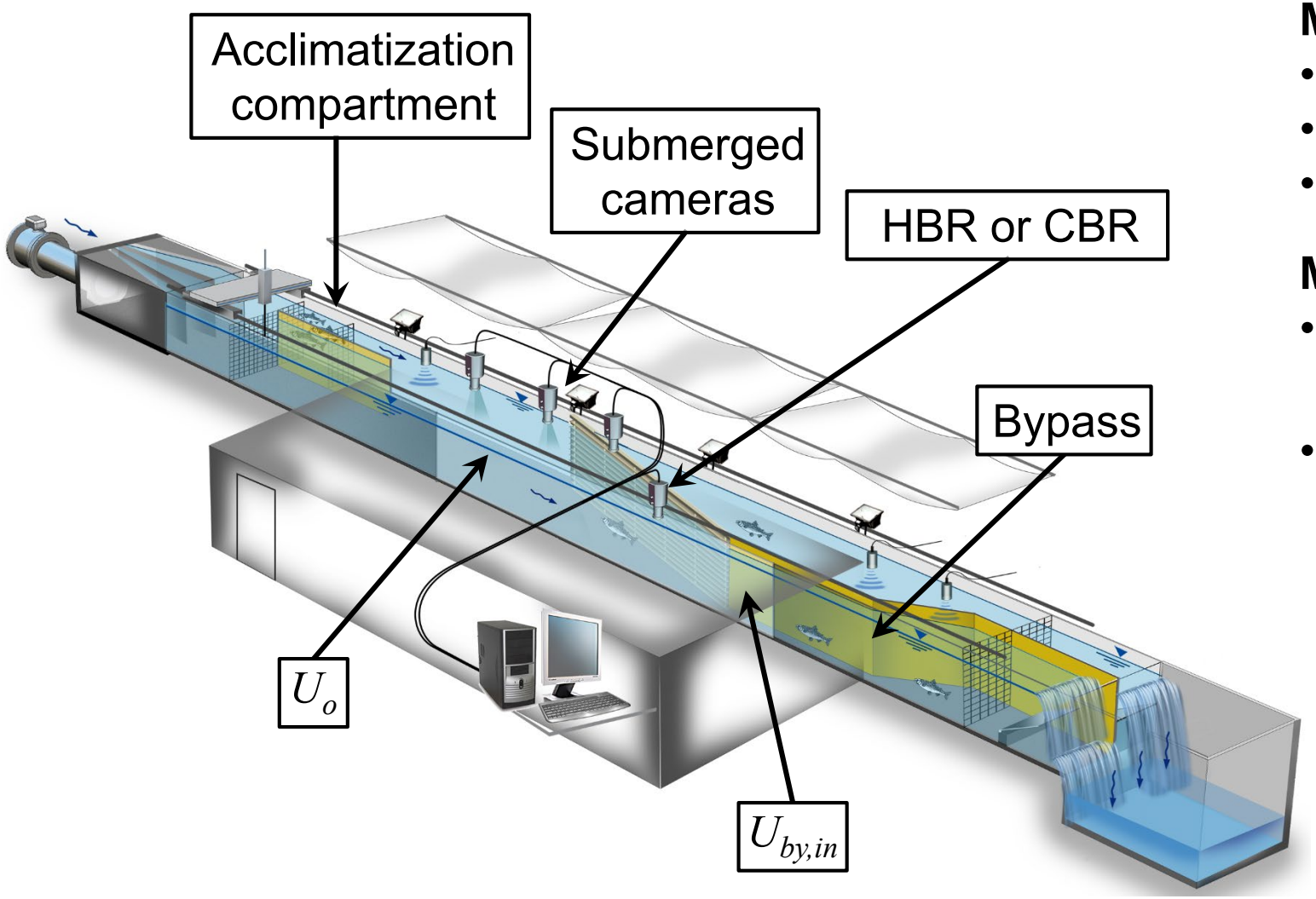






d_b = 100 mm

Curved-Bar Rack – Bypass System: Live-fish tests



Main objectives

- Fish behavior at CBR-BS
- Guidance & protection efficiencies
- Effect of hydraulic parameters

Main parameters

- Approach flow velocity
  $U_o = 0.5, 0.7$ m/s
- Velocity ratio
  $VR = U_{by,in} / U_o = 1.2, 1.4$

Tested fish species

Spirlin (Schneider), Barbel (Barben), Nase (Nasen), Brown trout (Bachforellen), Atlantic salmon parr (Atlantischen Lachs Parr), European eel (Europäischen Aalen)

Curved-Bar Rack – Bypass System: Live-fish tests

1. Line 1 not passed
2. Line 2 not passed

not willing to migrate, excluded from data analysis

3. Bypass passage (passed line 3)
4. Rack passage
5. Refusal (passed line 2, but did not pass rack or bypass after 30 min.)

Fish guidance efficiency

$$FGE = \frac{N_{bypass}}{N_{total}}$$

Fish protection efficiency

$$FPE = \frac{N_{bypass} + N_{refusal}}{N_{total}}$$

Curved-Bar Rack – Bypass System: Live-fish tests

Results

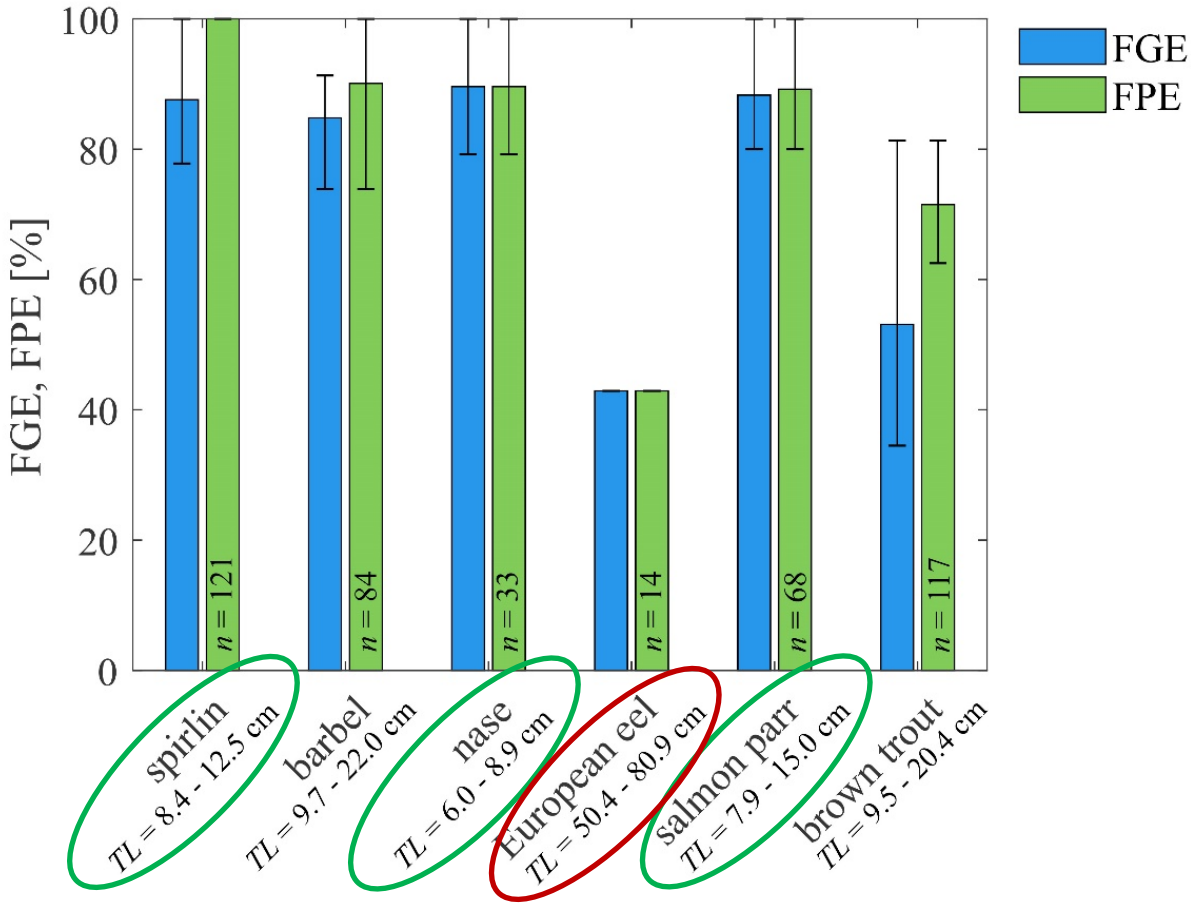
- 220 tests
- 639 fish tested
- 527 active fish

$$\mathrm{FGE} = \frac{N_{\mathrm{bypass}}}{N_{\mathrm{total}}}, \qquad \mathrm{FPE} = \frac{N_{\mathrm{bypass}} + N_{\mathrm{refusal}}}{N_{\mathrm{total}}}$$

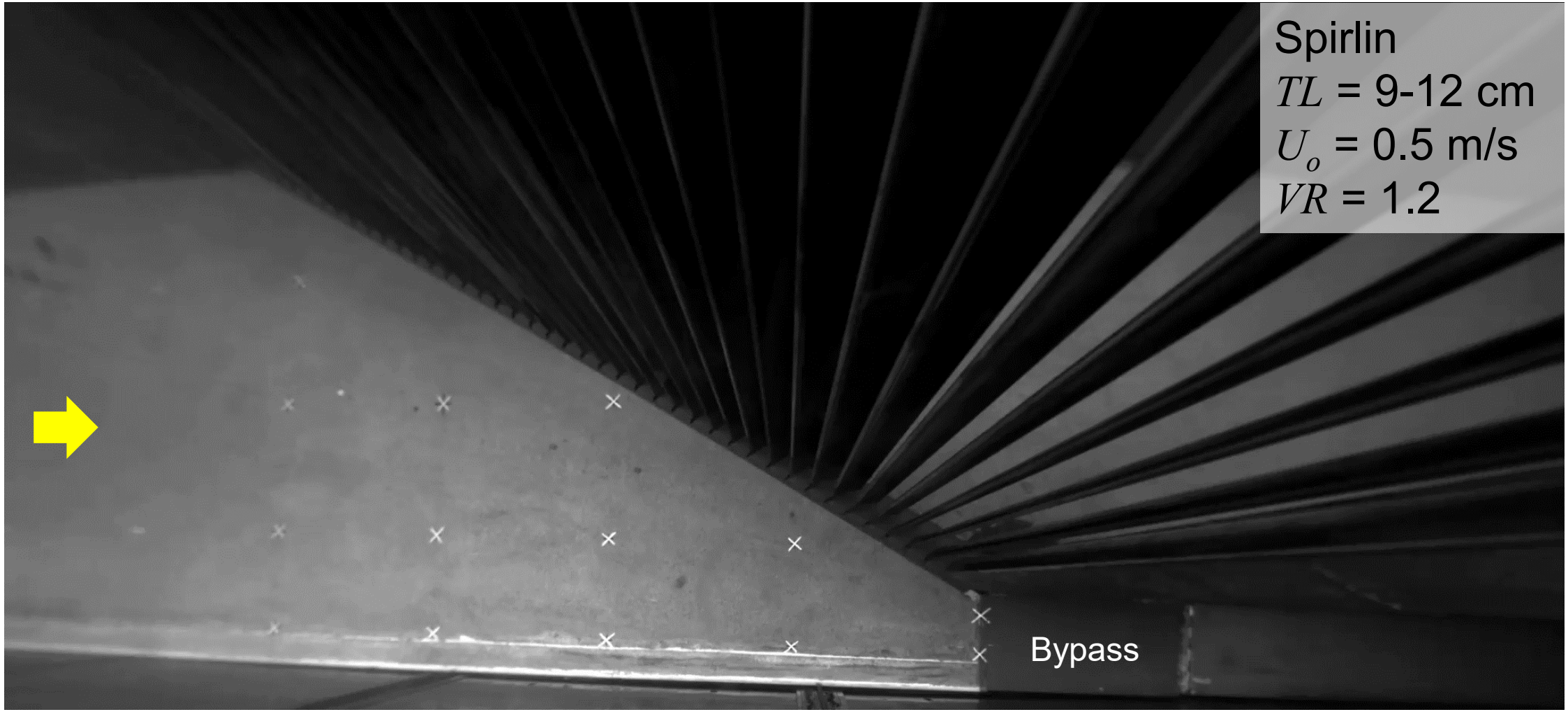
- FGE > **85%** for spirlin, barbel, nase & salmon parr
- FGE < 60% for eels and brown trout

- FPE > **90%** for spirlin, barbel, nase & salmon parr
- FPE < 70% for eels and brown trout

Efficiencies averaged over all tested flow conditions:



Curved-Bar Rack – Bypass System: Live-fish tests



Curved-Bar Rack – Bypass System: Live-fish tests

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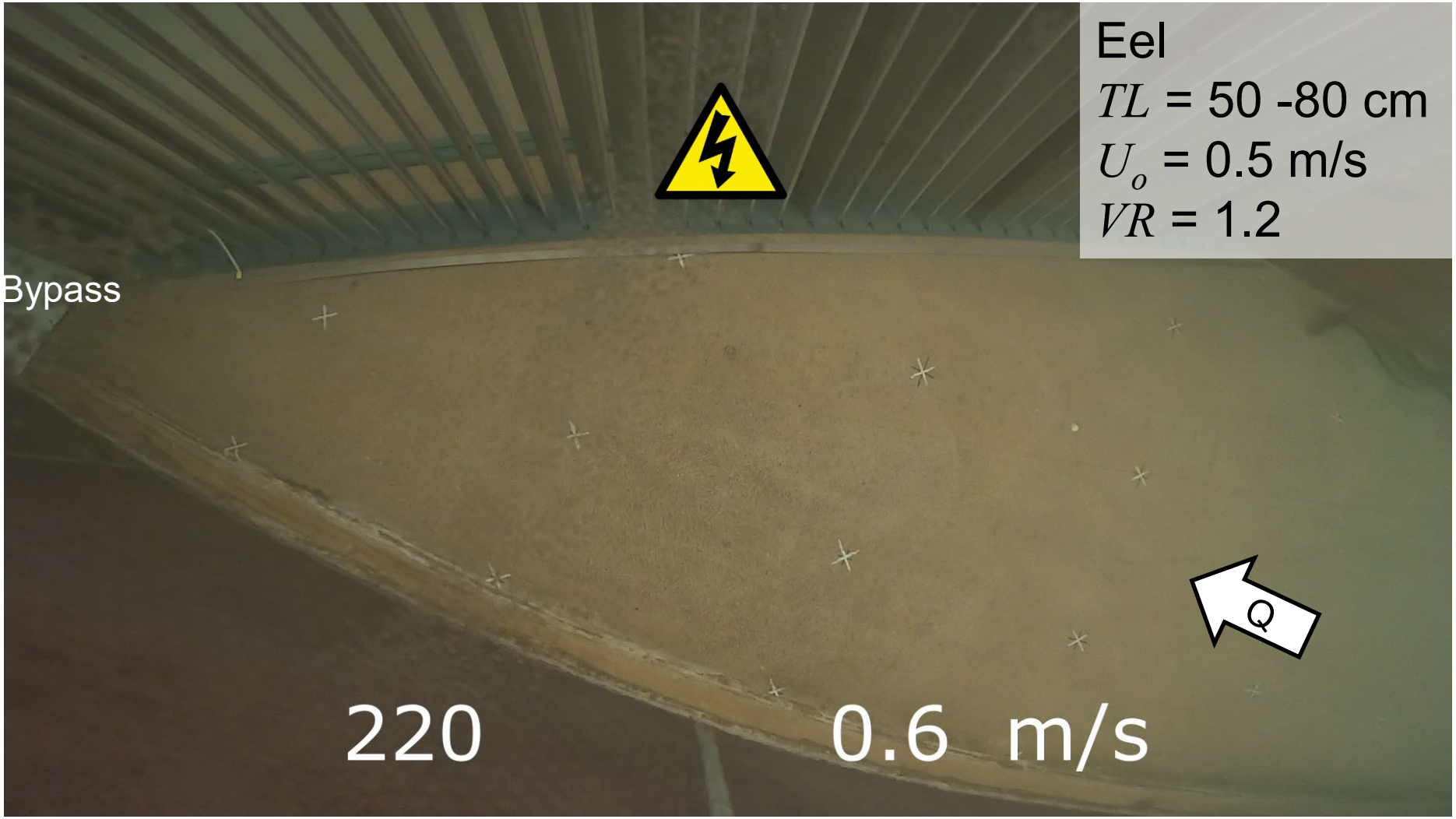
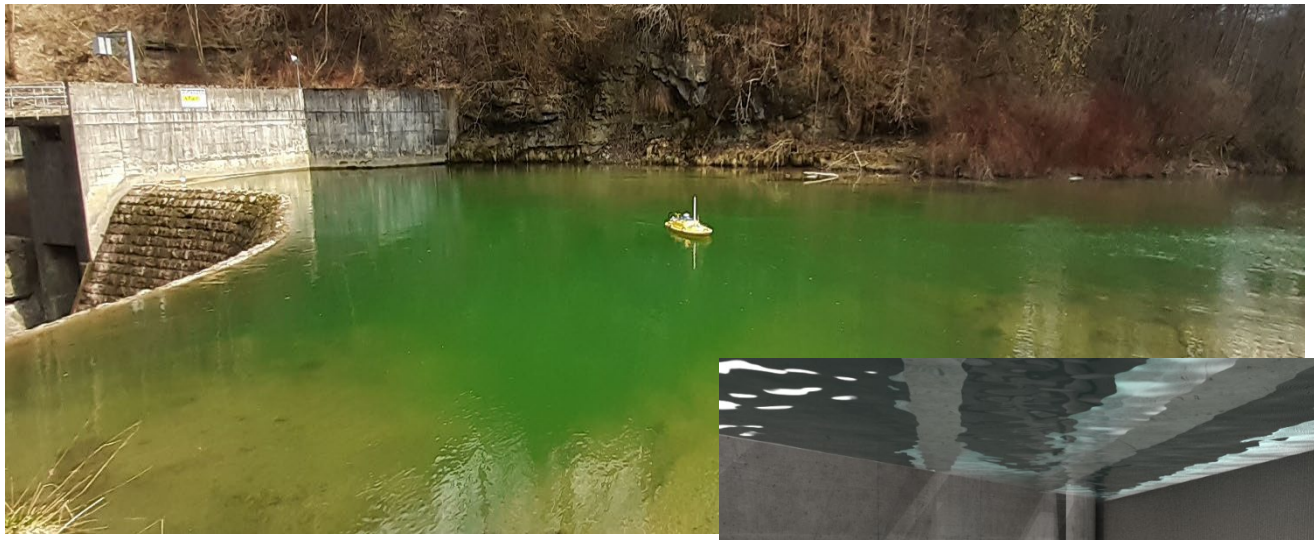
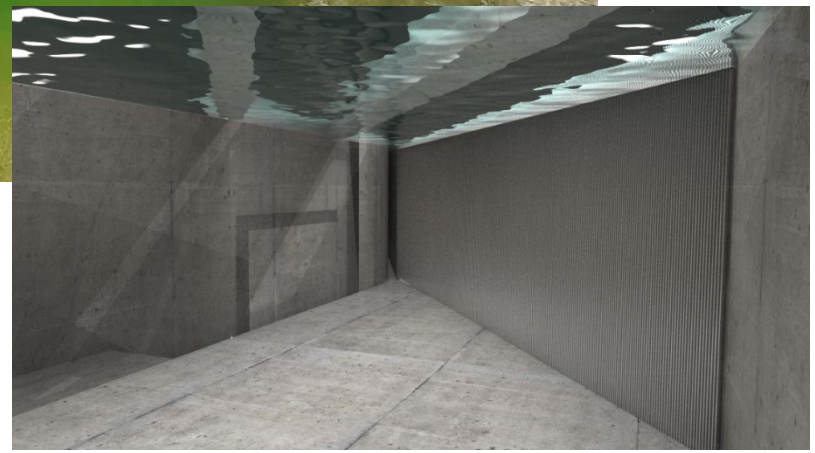


Curved-Bar Rack – Bypass System: Pilot project

First CBR-BS at Herrentöbeli Hydropower plant on River Thur, Switzerland, in preparation for 2022





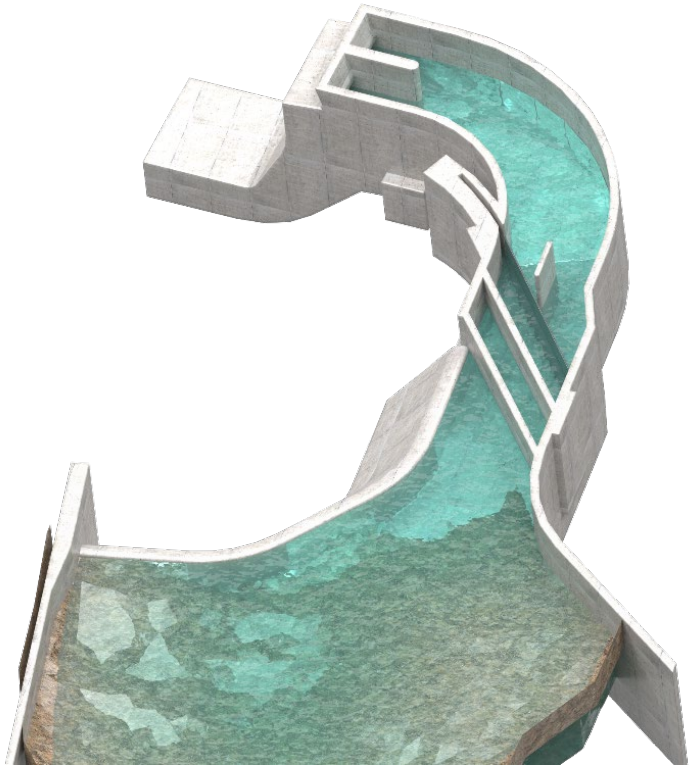


Photo & Illustrations: VAW, ETHZ

https://www.ee-news.ch/de/article/45713/sak-im-kraftwerk-herrentobeli-an-der-thur-wird-die-eth-zurich-den-neu-entwickelten-fischleitrechen-zum-ersten-mal-im-feld-testen

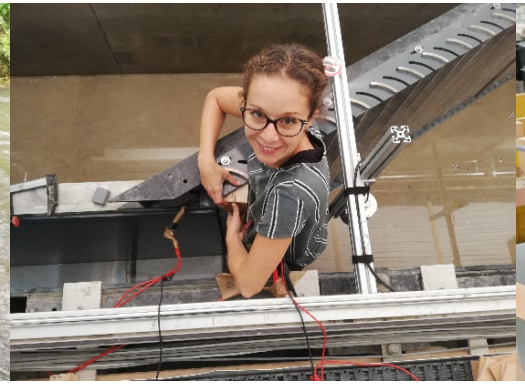
Conclusions

- Many measures available for safe downstream fish passage
- **HBR-BSs** are **state-of-the-art** downstream passage facilities for HPP with Q_d < 100 m^3/s
- **CBR-BSs:** Novel curved bar shape greatly improves the hydraulic performance
  - Flow straightening effect → **symmetric turbine admission → lower head losses**
  - Live-fish tests proved **the behavioural barrier effect** of this fish guidance system
- **CBR-BS** have a large potential to protect and guide fish at HPPs and water intakes with **minimal impact on operation & production**
- **Prototype tests** will start **in 2022**
- **Electrification** of CBR & HBR potentially **increase FPE/FGE**

Thank you for your attention!

Questions?





FIThydro

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für Wirtschaft, Bildung und Forschung WBF
Staatssekretariat für Bildung, Forschung und Innovation SBFI

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