Ejector Development Toolchain
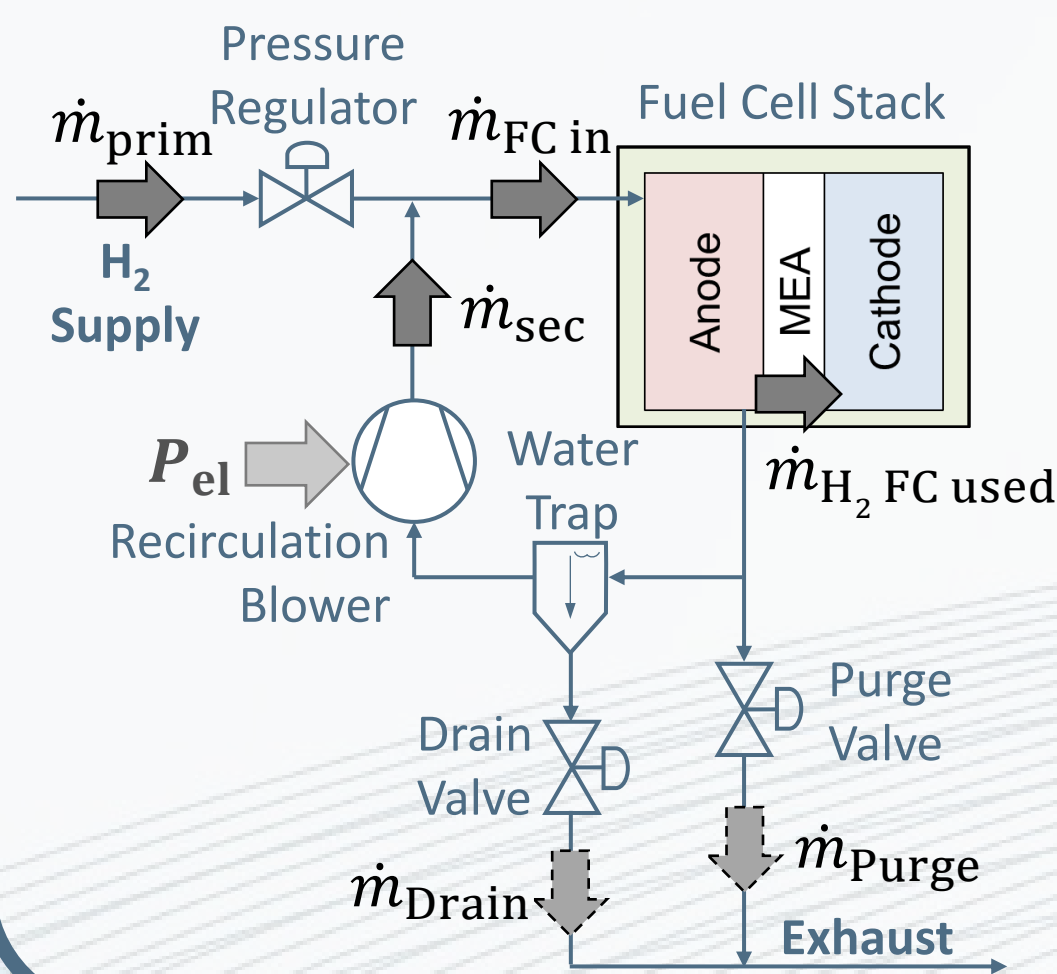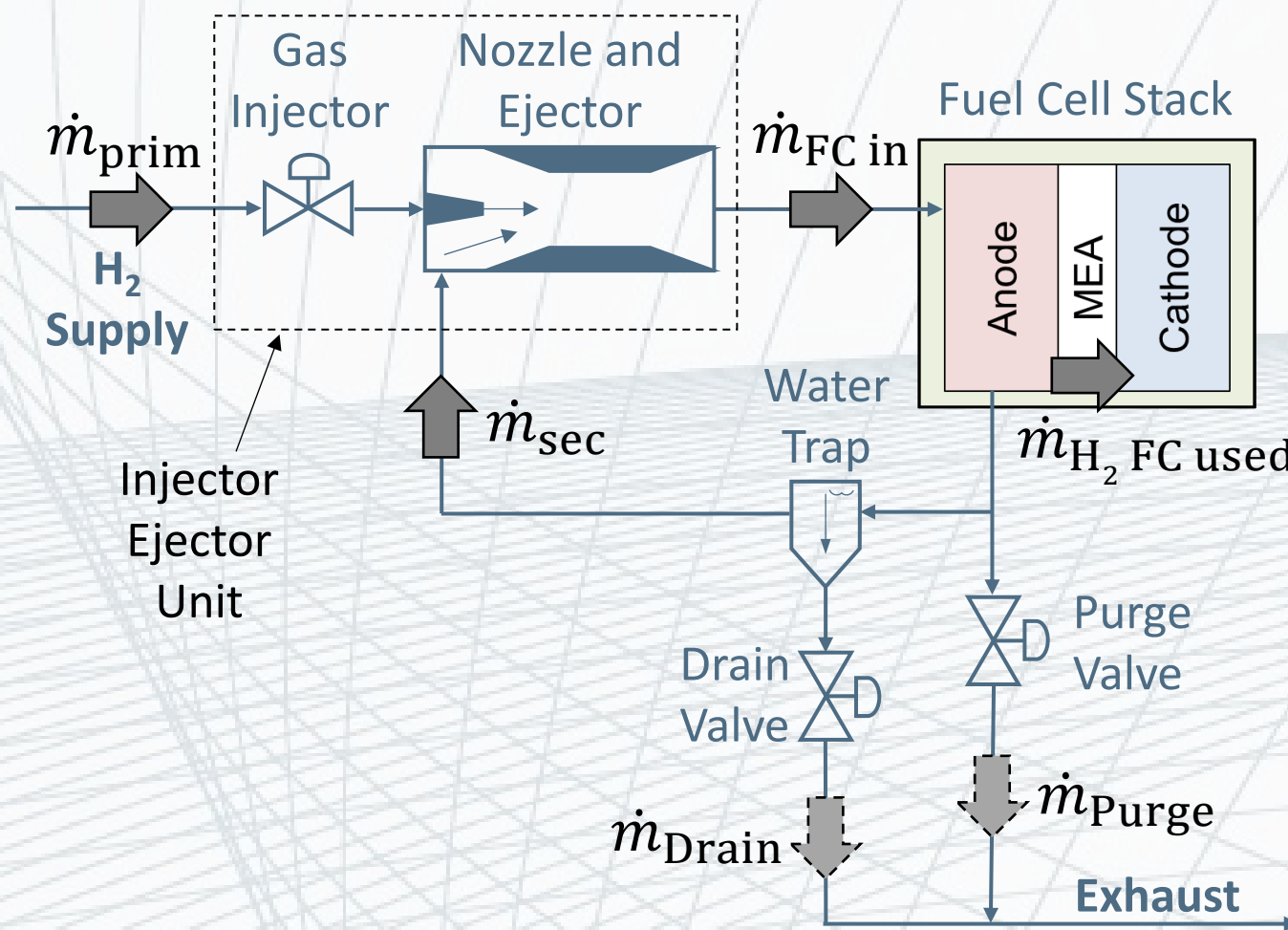## for Effective Passive Anode Recirculation in PEM Fuel Cell Systems

TU Graz

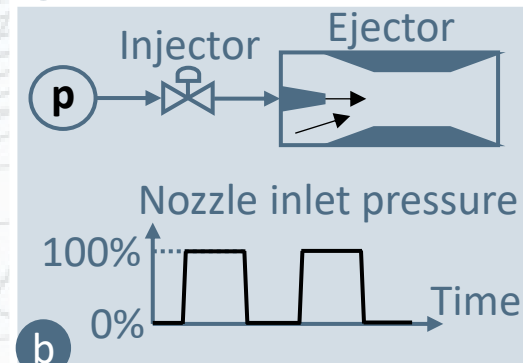**HyCentA — HYDROGEN CENTER AUSTRIA**

Active Recirculation

Pressure Regulator
$\dot{m}_{prim}$ $\dot{m}_{FC\,in}$ Fuel Cell Stack

H_2 Supply
$\dot{m}_{sec}$

Anode | MEA | Cathode

P_{el}
Recirculation Blower Water Trap $\dot{m}_{H_2\,FC\,used}$

Drain Valve Purge Valve

$\dot{m}_{Drain}$ $\dot{m}_{Purge}$ **Exhaust**

+	Controllability	−
+	Dimensioning	−
−	Energy Demand	+
−	Costs	+
−	Durability	+
−	Weight	+

Passive Recirculation

Gas Injector | Nozzle and Ejector

$\dot{m}_{prim}$ $\dot{m}_{FC\,in}$ Fuel Cell Stack

H_2 Supply

Injector Ejector Unit

$\dot{m}_{sec}$

Anode | MEA | Cathode

Water Trap $\dot{m}_{H_2\,FC\,used}$

Drain Valve Purge Valve

$\dot{m}_{Drain}$ $\dot{m}_{Purge}$ **Exhaust**

Control Strategies

Nozzle Inlet Pressure Control

Pressure regulator — Ejector
Nozzle inlet pressure
100% / 0% — Time (a)

Injector — Ejector
Nozzle inlet pressure
100% / 0% — Time (b)
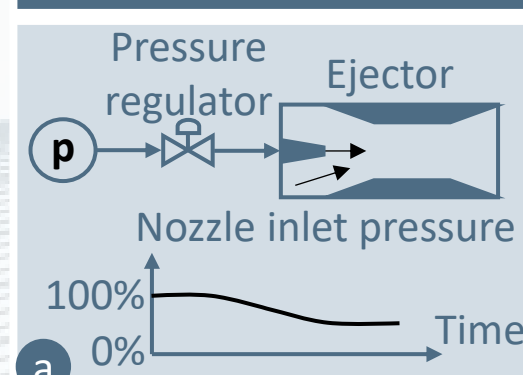
Nozzle Throat Area Control

Two or more coaxial nozzles in one nozzle
$A_t = A_{t1} + A_{t2}$ (c)
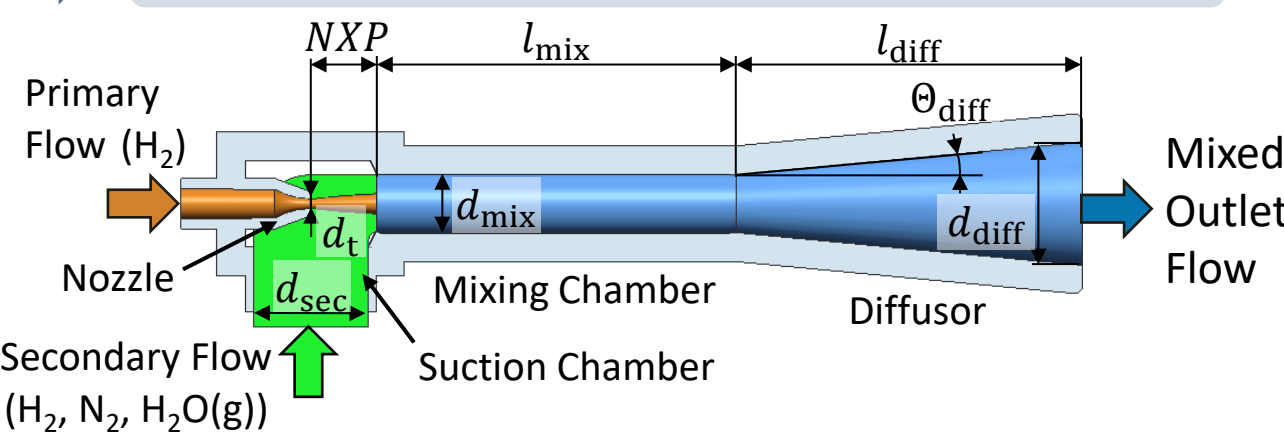
Movable needle in nozzle
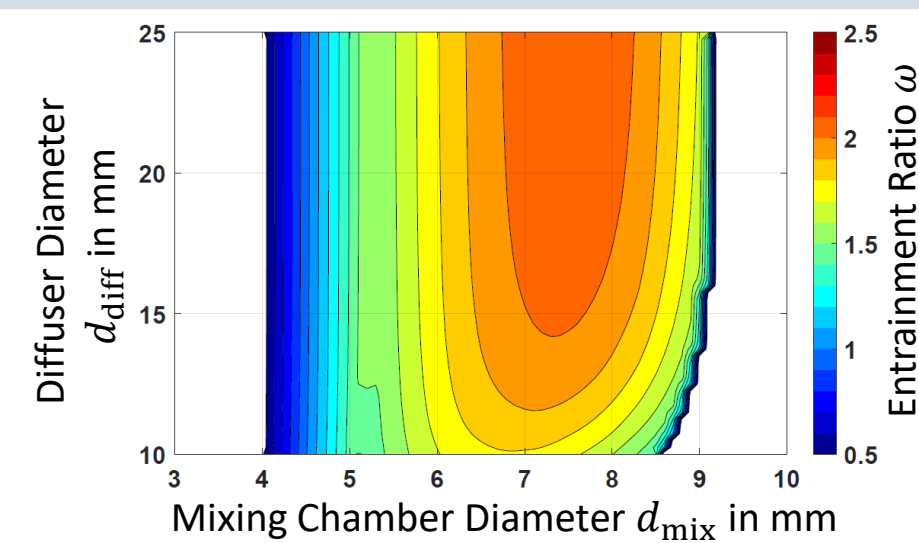$A_t = \frac{(d_t^2 - d_{t\,needle}^2) * \pi}{4}$ (d)
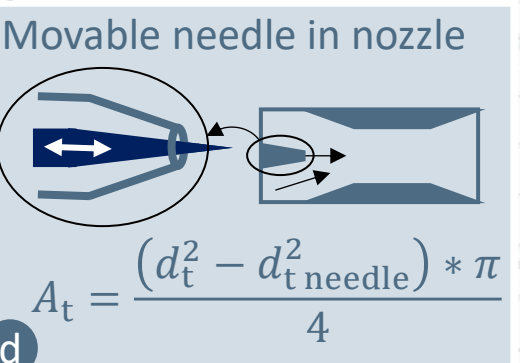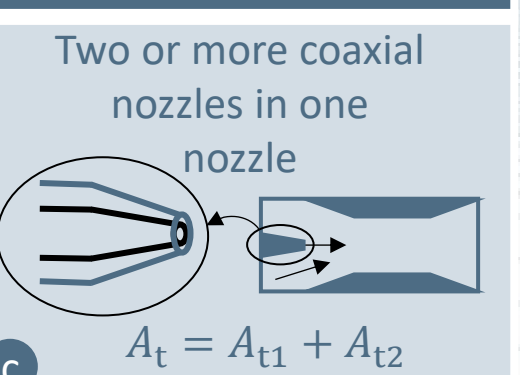
Development Toolchain

Base Calculation
> Definition of control strategy
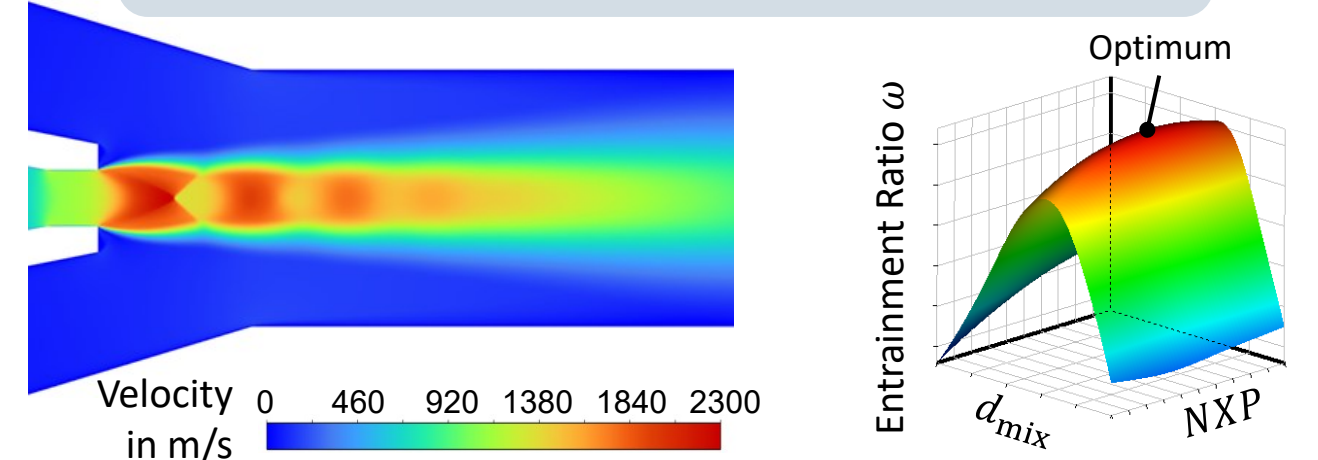> Definition of design boundaries
> First geometry estimation of ejector

Primary Flow (H_2)
NXP l_{mix} l_{diff}
Θ_{diff}
d_{mix} d_{diff}
Mixed Outlet Flow
Nozzle d_t
d_{sec}
Secondary Flow (H_2, N_2, $H_2O(g)$)
Mixing Chamber Suction Chamber Diffusor

1D Ejector SIM
> Stationary performance analysis
> Optimization of key geometry

Diffuser Diameter d_{diff} in mm
Mixing Chamber Diameter d_{mix} in mm
Entrainment Ratio ω

2D CFD Simulation
> Axisymmetric performance analysis
> Design of Experiments (DoE) geometry optimization

Velocity in m/s 0 460 920 1380 1840 2300
Entrainment Ratio ω Optimum d_{mix} NXP

1D Anode SIM
> Dynamic & transient analysis

Pressure vs Time
- Ejector outlet
- Fuel cell inlet
- Fuel cell average
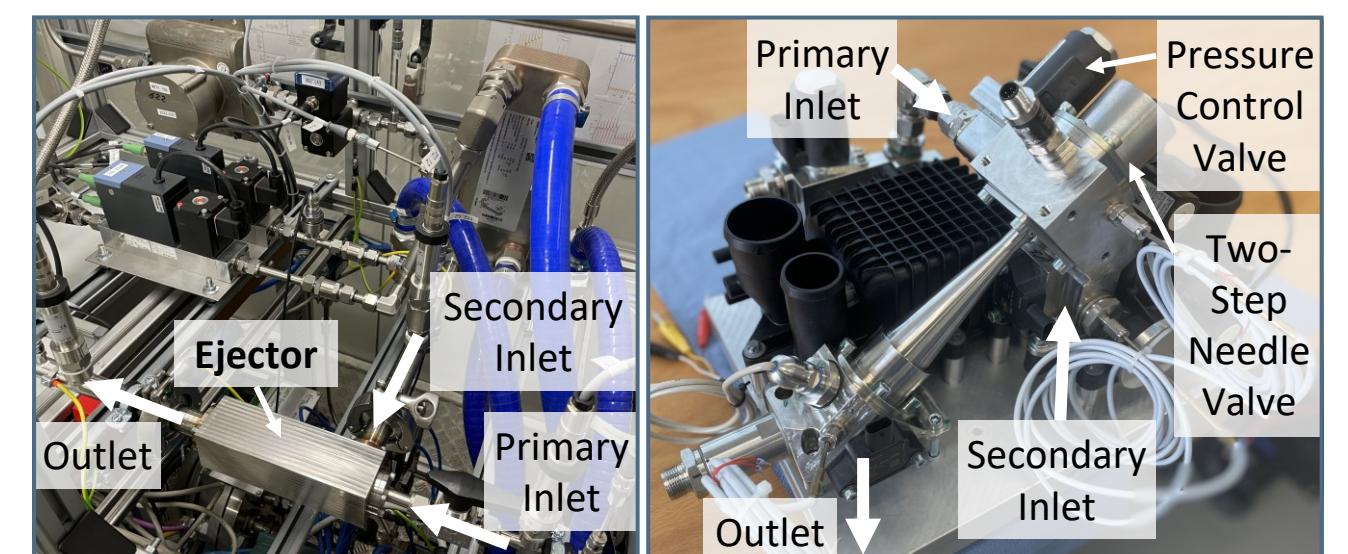- Fuel cell outlet
- Ejector sec inlet
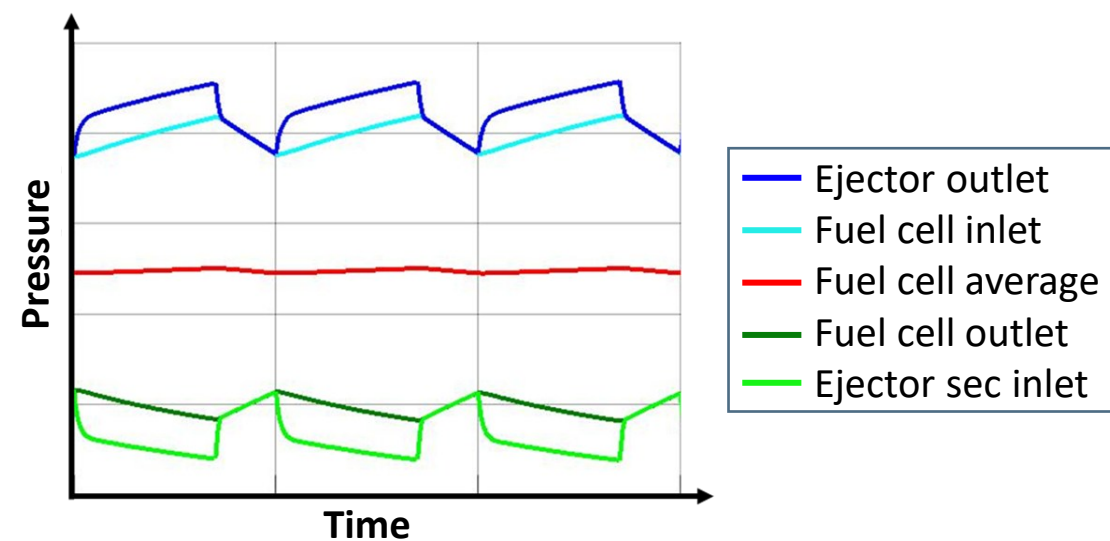
3D CFD Simulation
> Performance under realistic packaging constraints
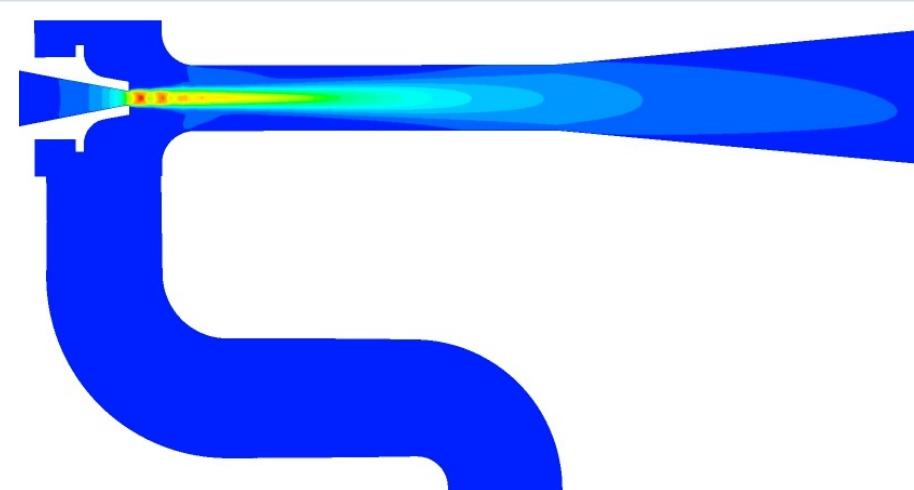
Experiment
> Verification & validation

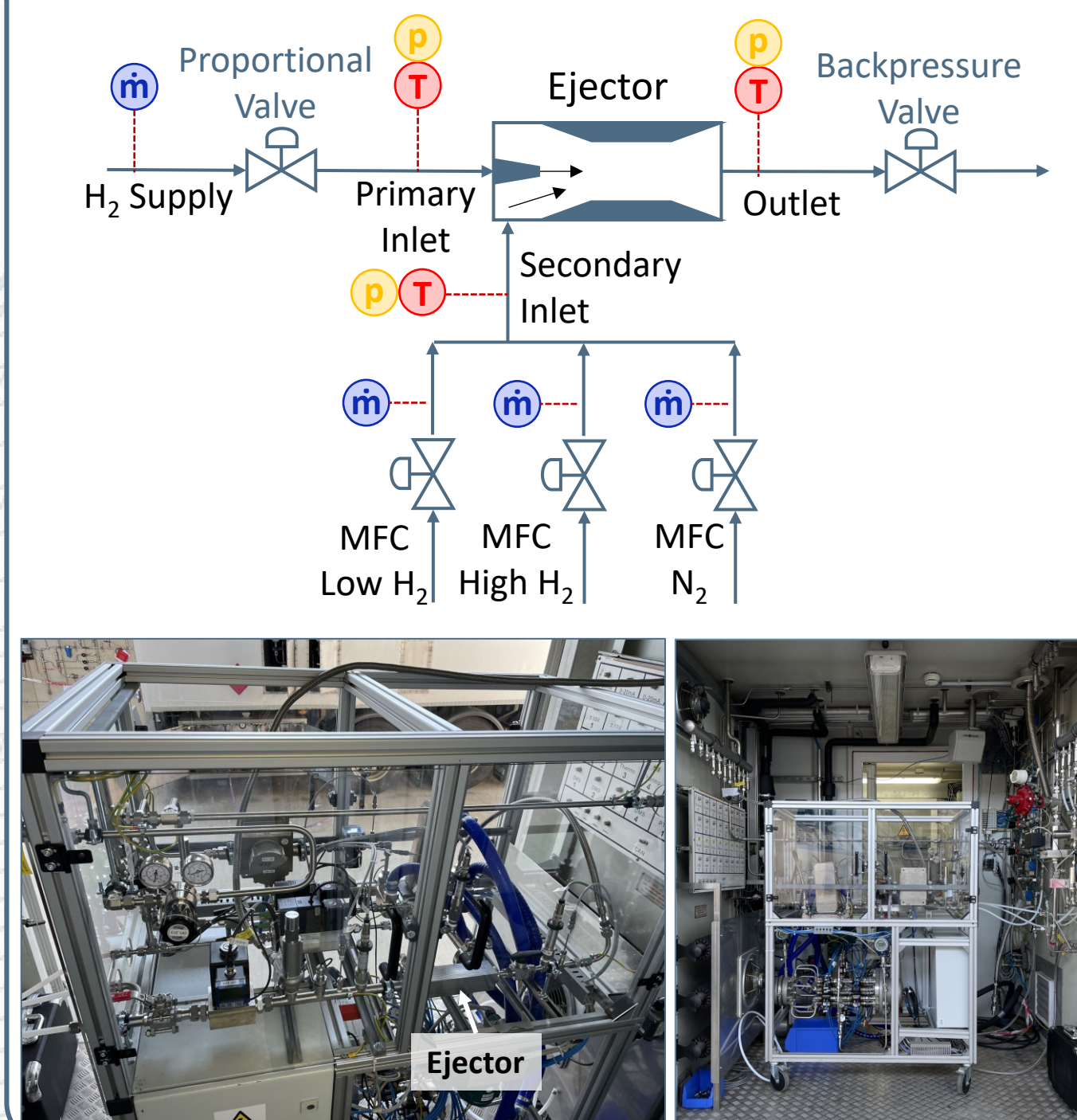Primary Inlet Pressure Control Valve
Ejector Secondary Inlet Primary Inlet Two-Step Needle Valve
Outlet Secondary Inlet Outlet

Simulation

Primary Inlet $\dot{m}_{prim}, T_{prim}$
Secondary Inlet $p_{sec}, T_{sec}, v_{sec\,H_2}$
Outlet p_{out}
Symmetry Axis

$p_{prim} = 8\,bar(a)$; $\Delta p = 0$ kPa
$p_{prim} = 8\,bar(a)$; $\Delta p = 40$ kPa
$p_{prim} = 8\,bar(a)$; $\Delta p = 55$ kPa

Velocity Magnitude in m/s 0 350 700 1050 1400 1750 2100 2450 2800

Experiment

Proportional Valve Ejector Backpressure Valve
H_2 Supply Primary Inlet Outlet
Secondary Inlet

MFC Low H_2 MFC High H_2 MFC N_2

Ejector

Validation

Secondary mass flow $\dot{m}_{sec}$ in g/s
Pressure difference Δp between ejector outlet and secondary inlet in kPa

- EXP: 5 bar(a)
- SIM: 5 bar(a)
- EXP: 8 bar(a)
- SIM: 8 bar(a)
- EXP: 12 bar(a)
- SIM: 12 bar(a)
- EXP: 16 bar(a)
- SIM: 16 bar(a)

Contact
Rafael Pinsker
HyCentA Research GmbH
Phone: +43 316 873 9500
Mail: office@hycenta.at

Publications