# Mejeriforskningens Dag

Concepts for Optimized and Innovative Applications
of Membrane Separation in Dairy Technology

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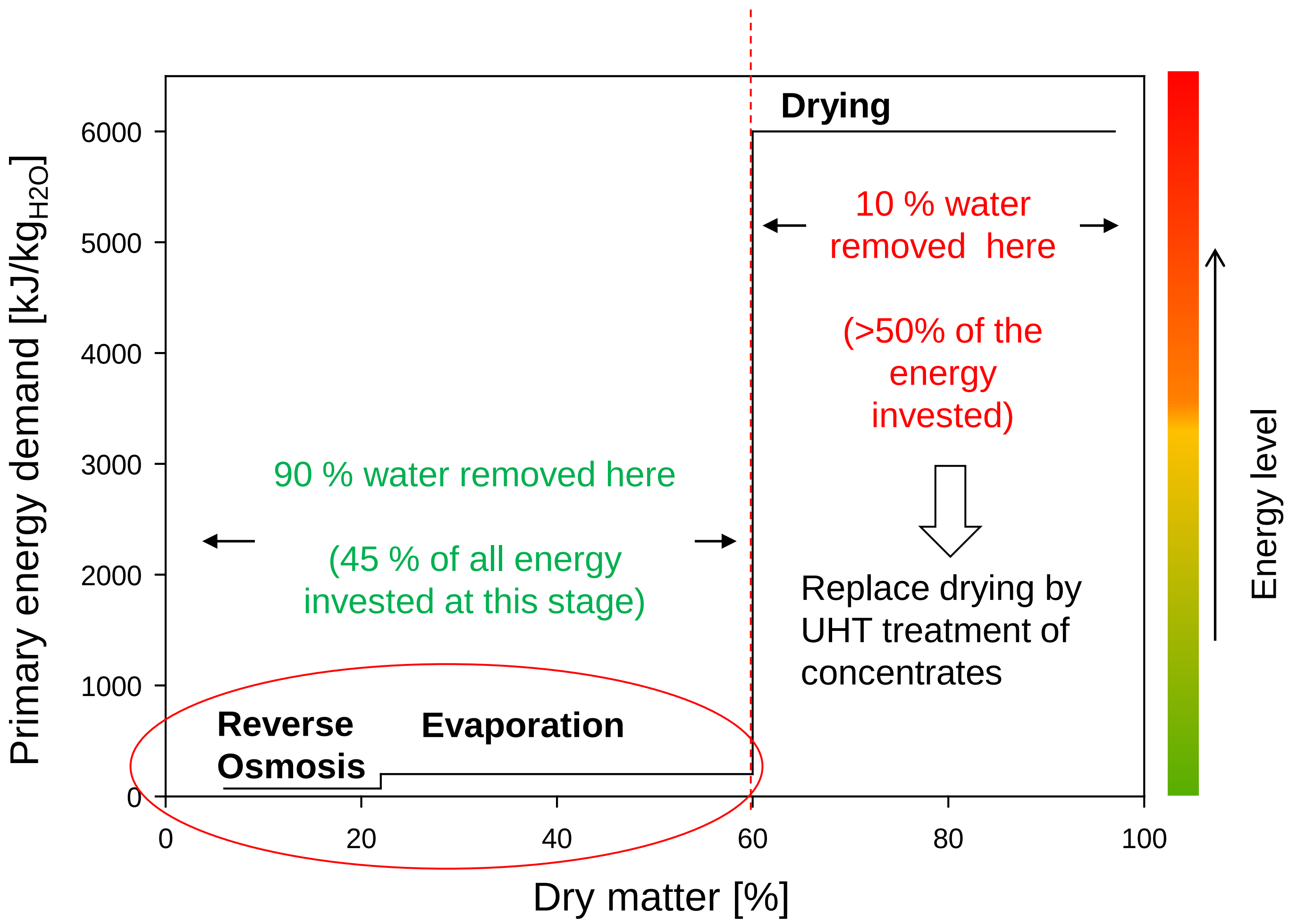
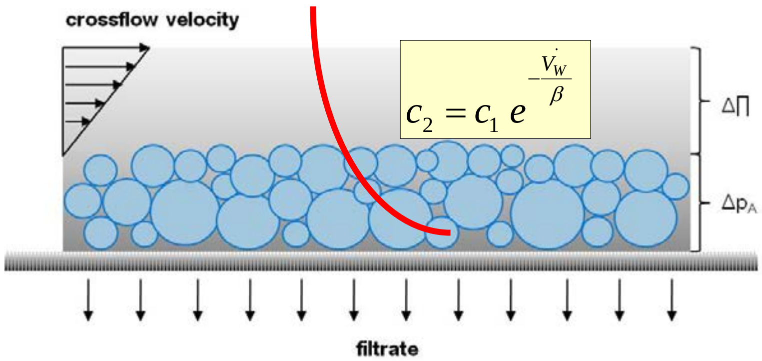
# Energy requirements for concentration and drying



# The concept: Separation of effects by using a membrane cascade

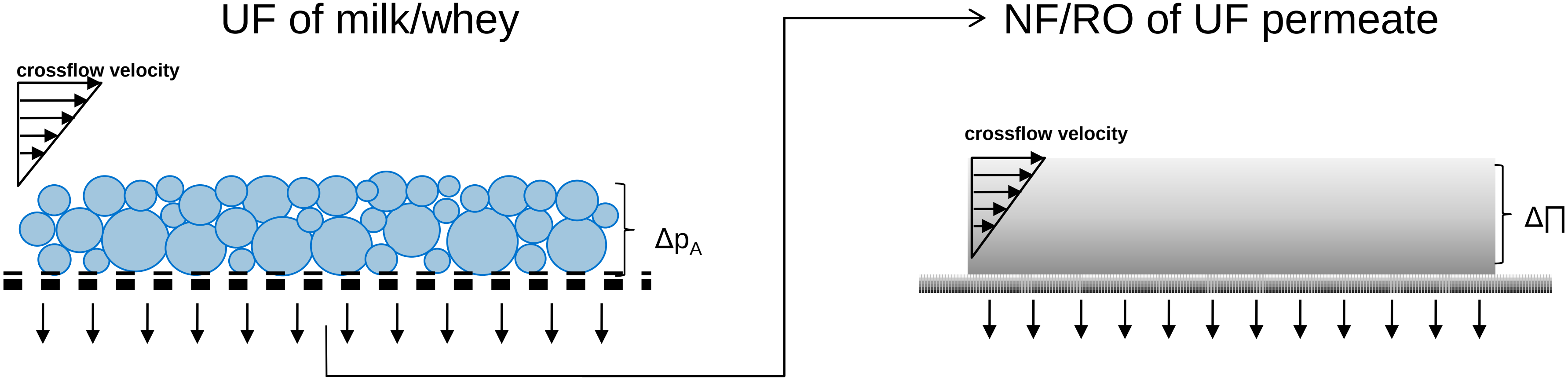
Flux reducing phenomena during RO/NF of milk/whey

- Concentration polarization layer
- Deposited protein layer




## UF of milk/whey

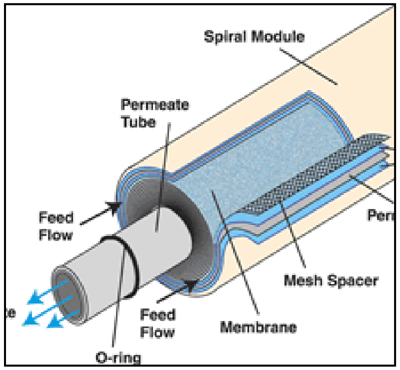
## NF/RO of UF permeate




- ✓ Concentration of proteins by UF at a low pressure level
- ✓ UF not affected by osmotic pressure

- ✓ Concentration of osmotically active solutes by RO w/o deposit formation → better investment of $\Delta p_{TM}$

# Extended processing scheme for the concentration of milk/whey using multiple membrane cascades




Skim milk/ Sweet whey

Conventional crossflow UF

Rotating (dynamic) UF

UF-Retentate

Milk serum

Reverse osmosis

Nanofiltration

NF-Permeate

RO-Polisher

RO/NF-Retentate

Skim milk/ Whey concentrate

Preservation

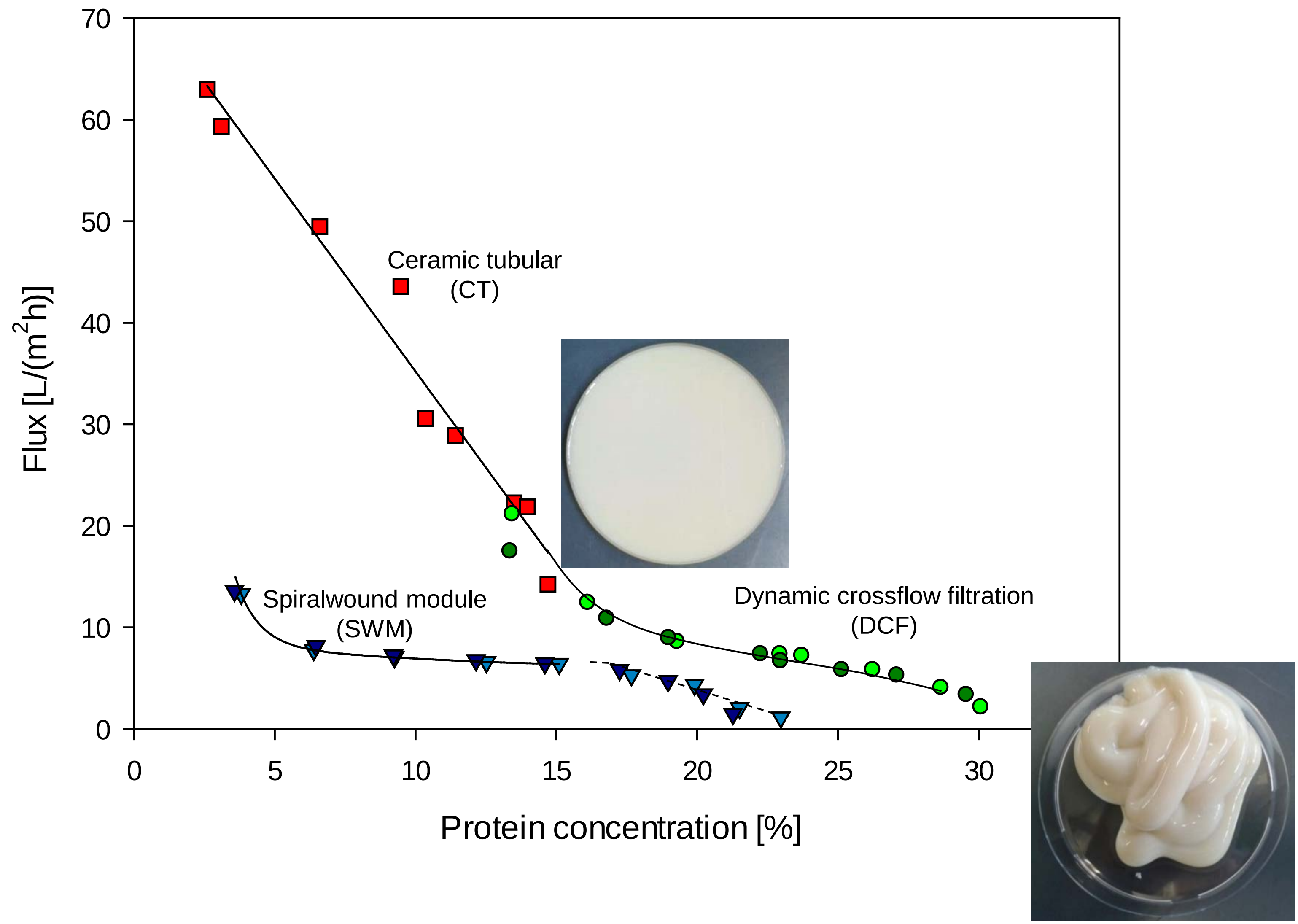
Drying

UHT-Treatment

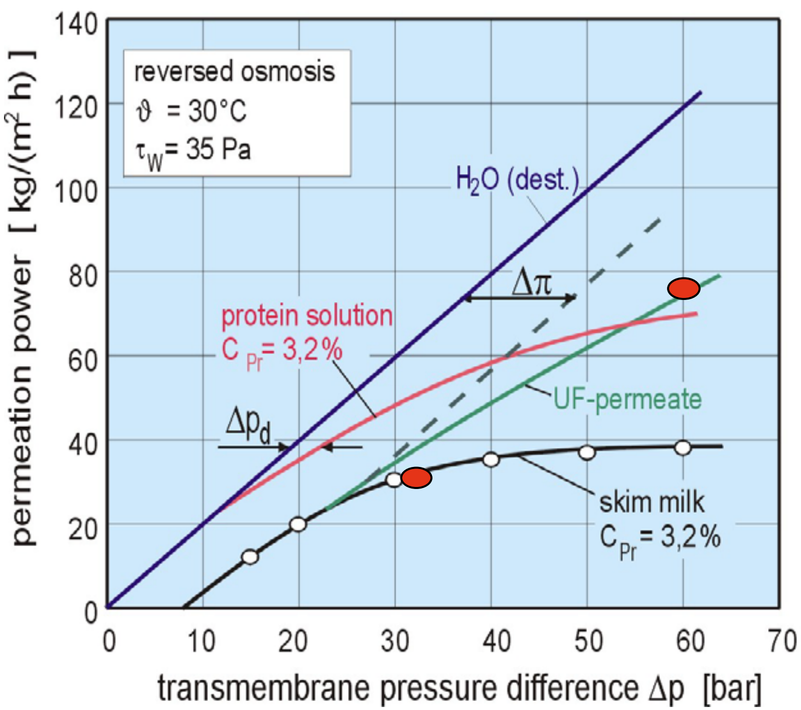
**Innovative features:**

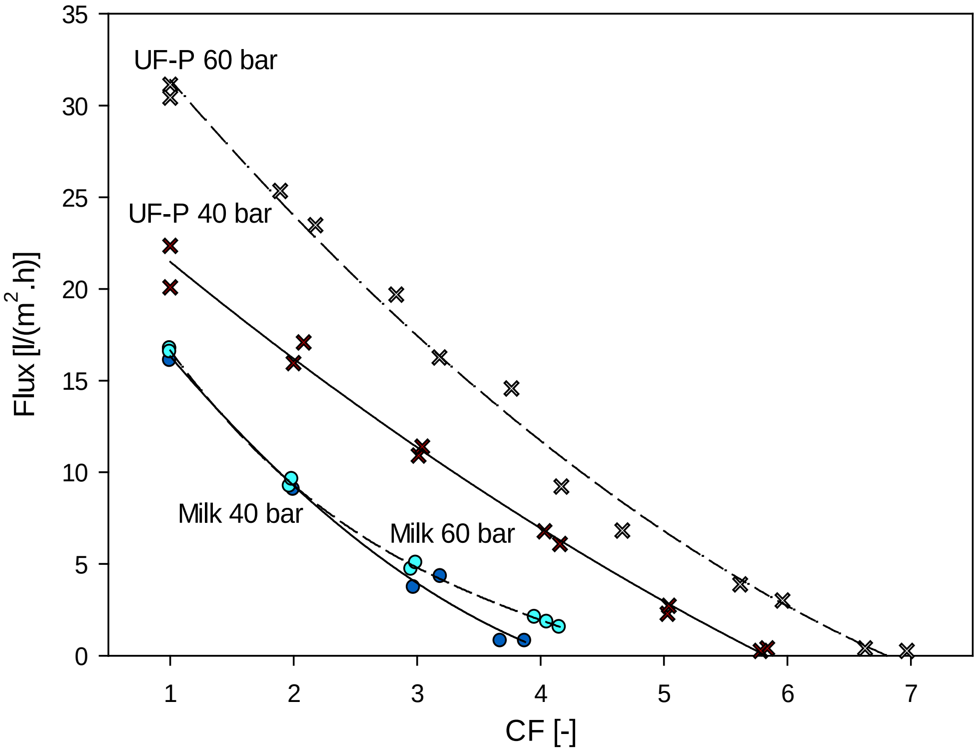
- High concentration of protein in DCF
- No protein deposits in RO
- High concentration of serum phase in NF/RO
- Reduced environmental impact
- Faster process

# Flux levels of different UF systems for milk protein concentration

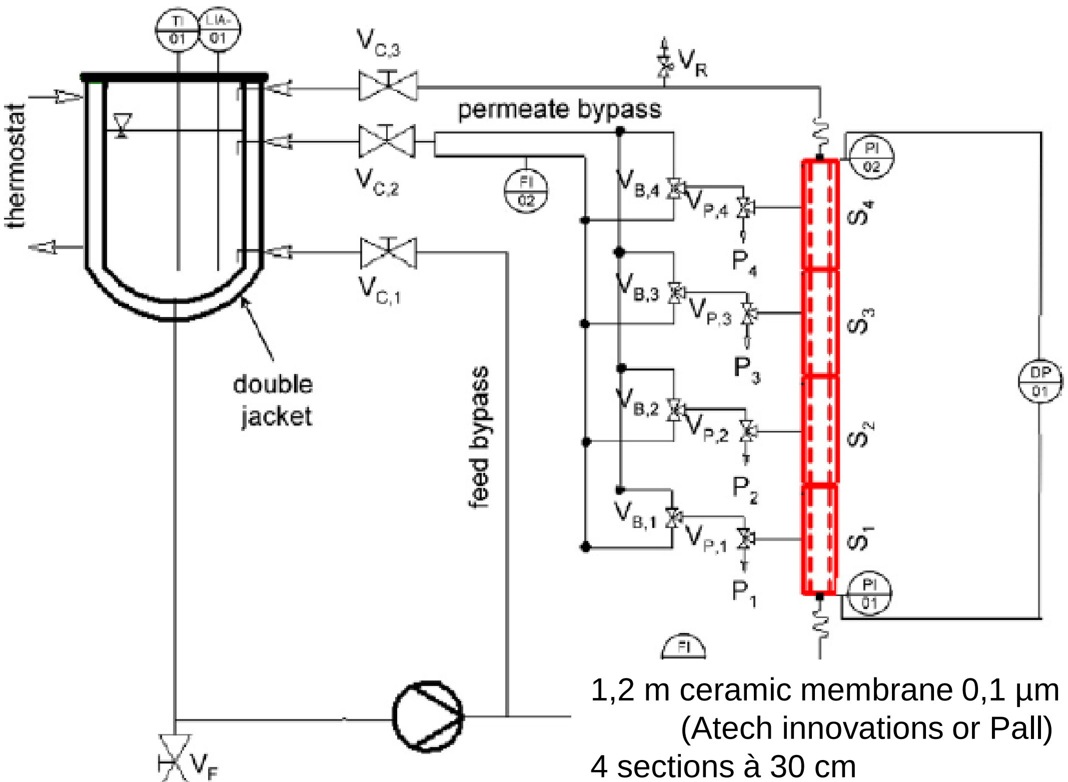


# Impact of transmembrane pressure on flux for skim milk and protein-free milk serum

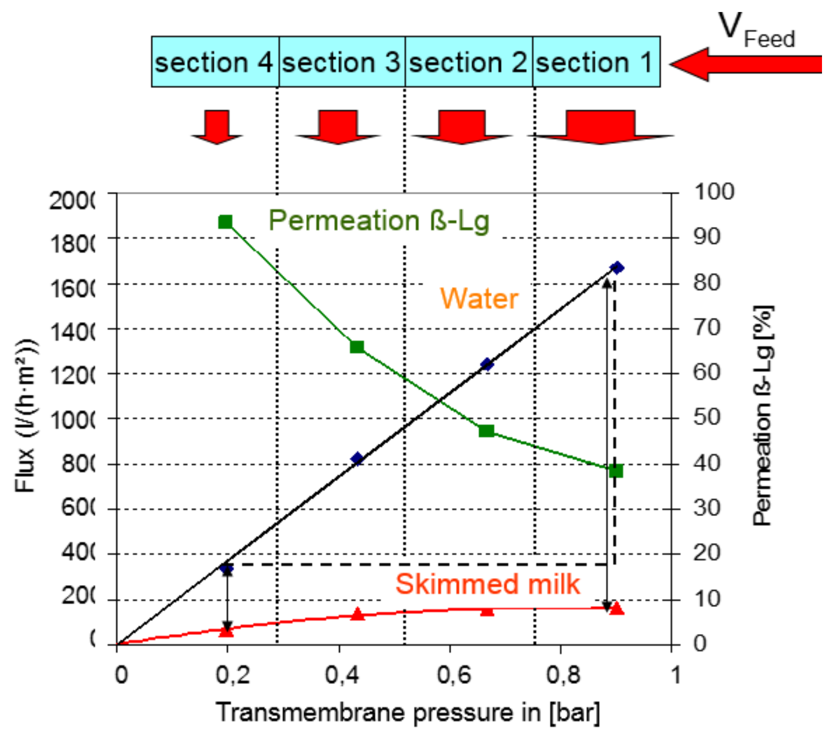


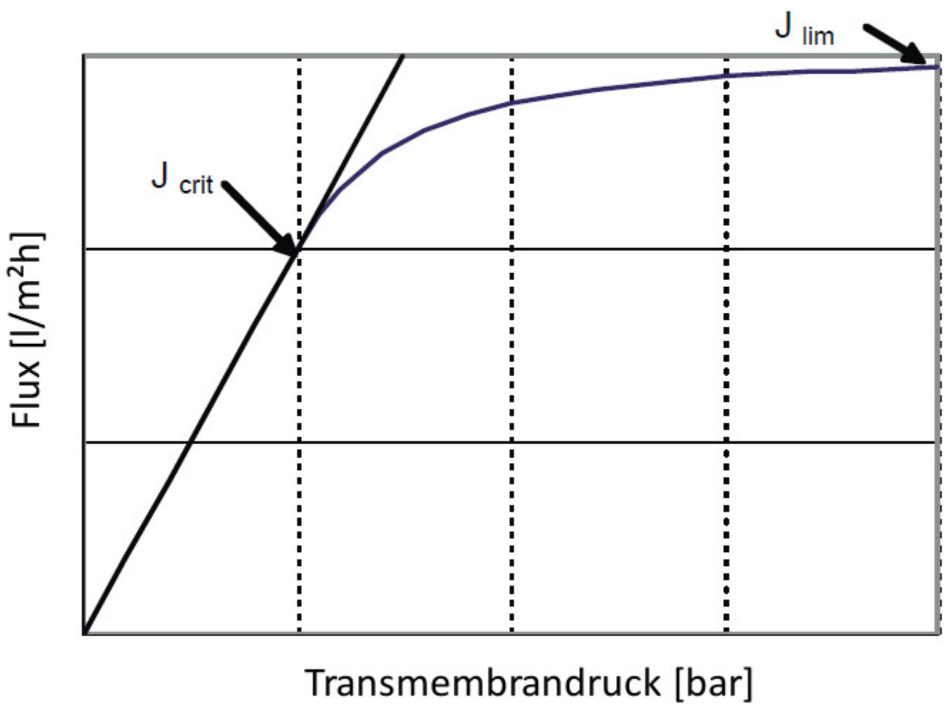
# Filtration plants for measuring the distribution of flux and protein permeation along a membrane

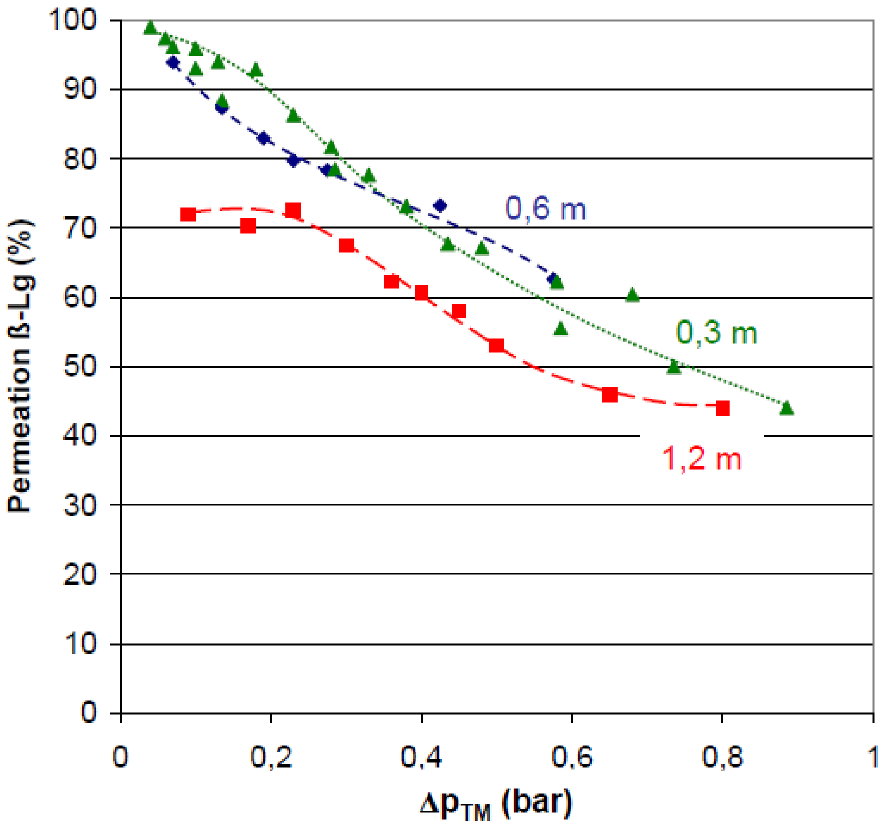



1,2 m ceramic membrane 0,1 µm
(Atech innovations or Pall)
4 sections à 30 cm



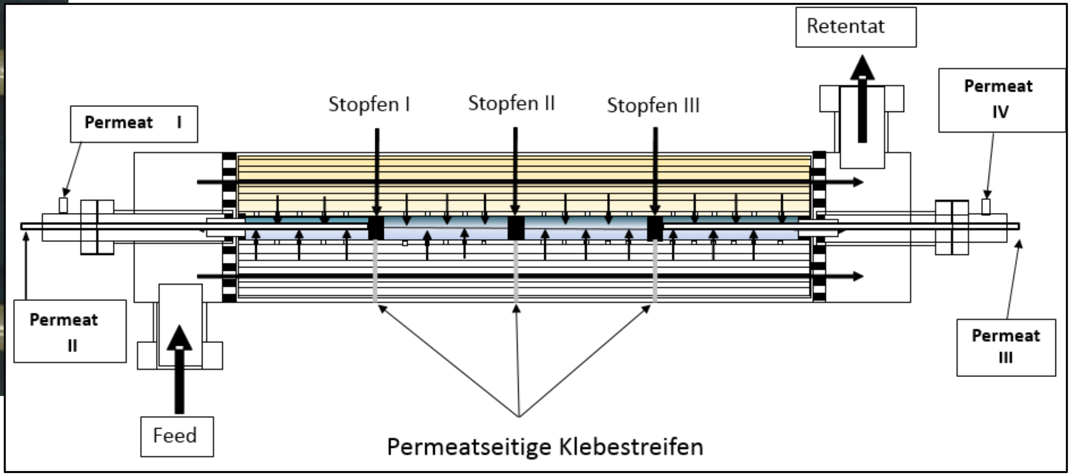
# Effect of transmembrane pressure in MF on flux and permeation using ceramic membranes



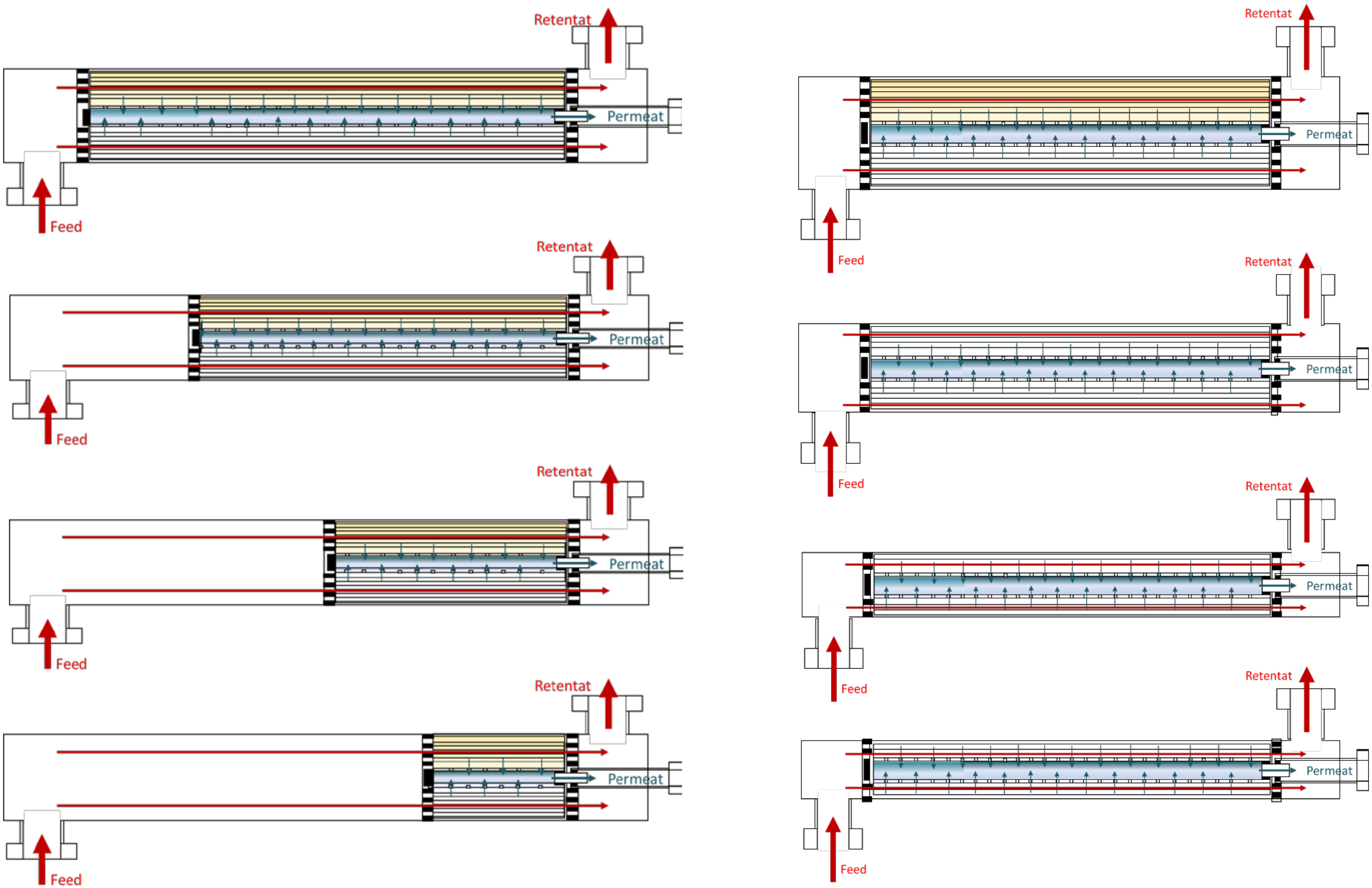

[Modifiziert nach Bacchin, 2004; Piry, 2011]

# Experimental SWM prototypes for the assessment of flux and deposit formation inside a industrial module

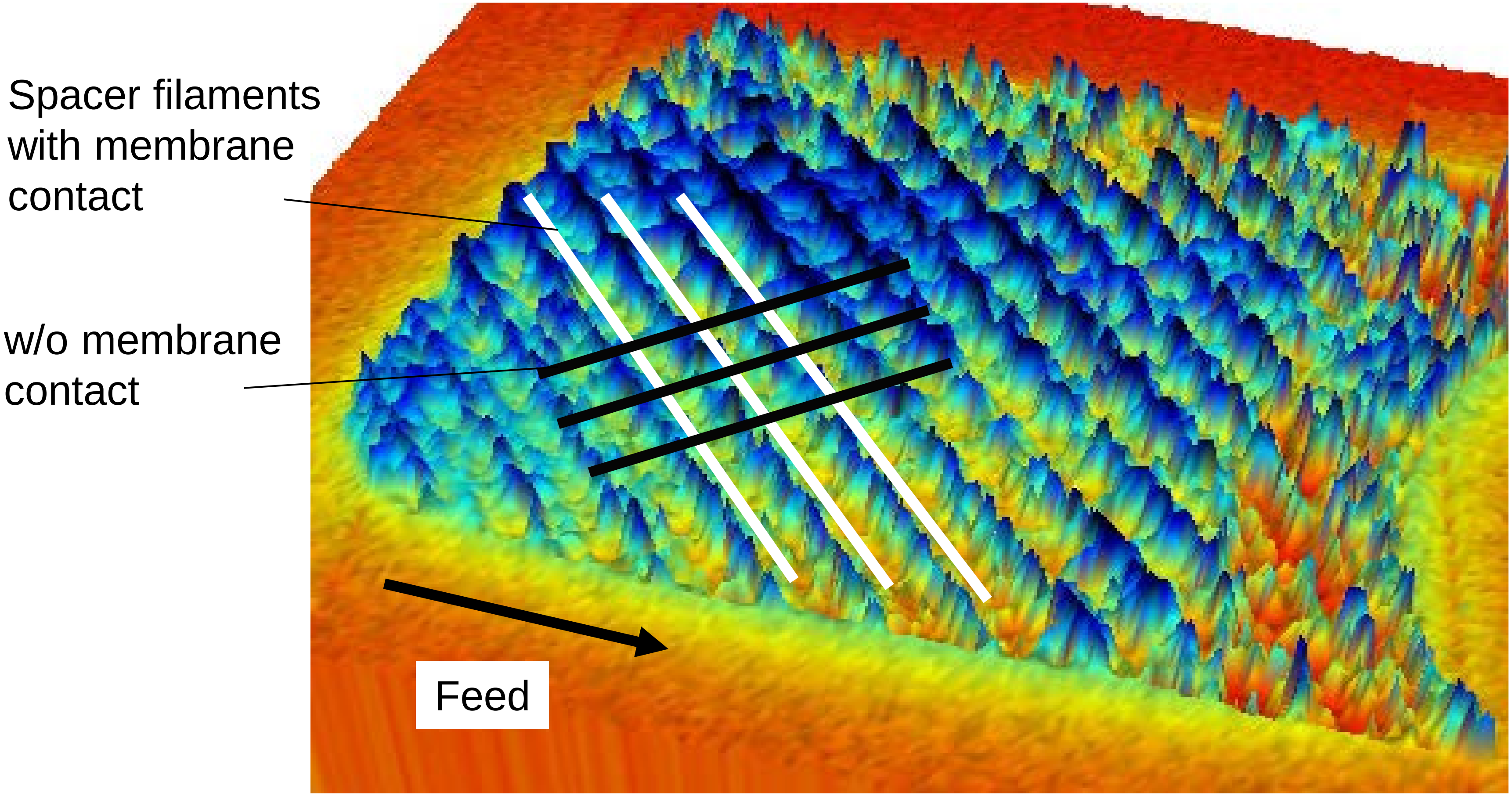


# Betrieb des sektionierten Moduls II: Technische Realisierung

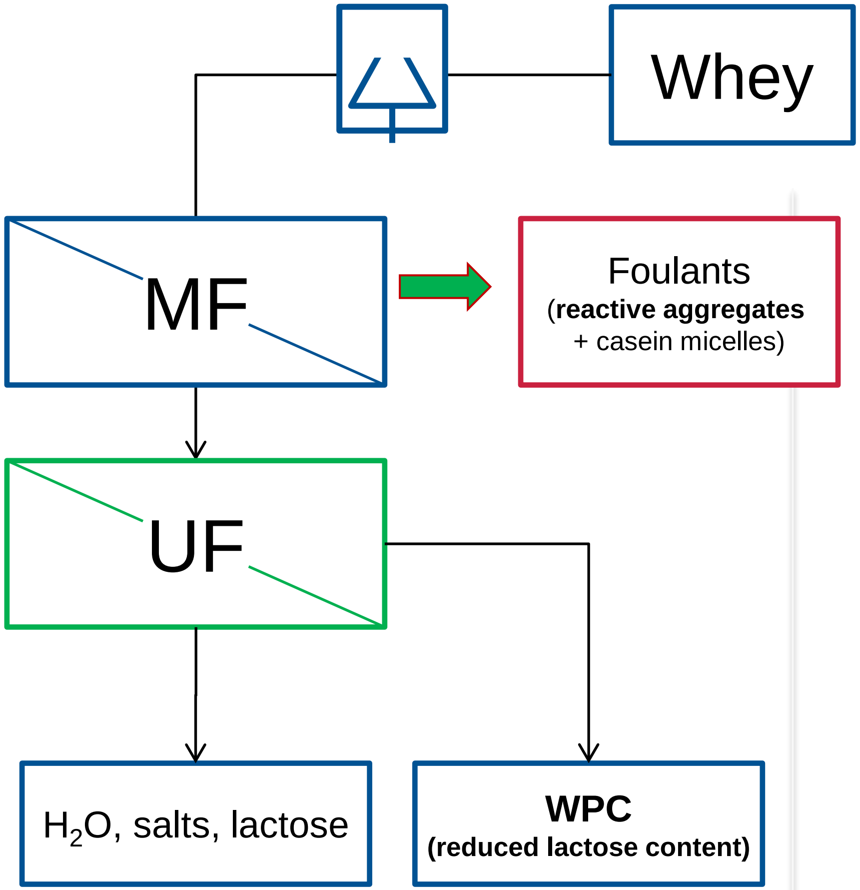
# Experimental SWM prototypes for the assessment of flux and deposit formation inside a industrial module

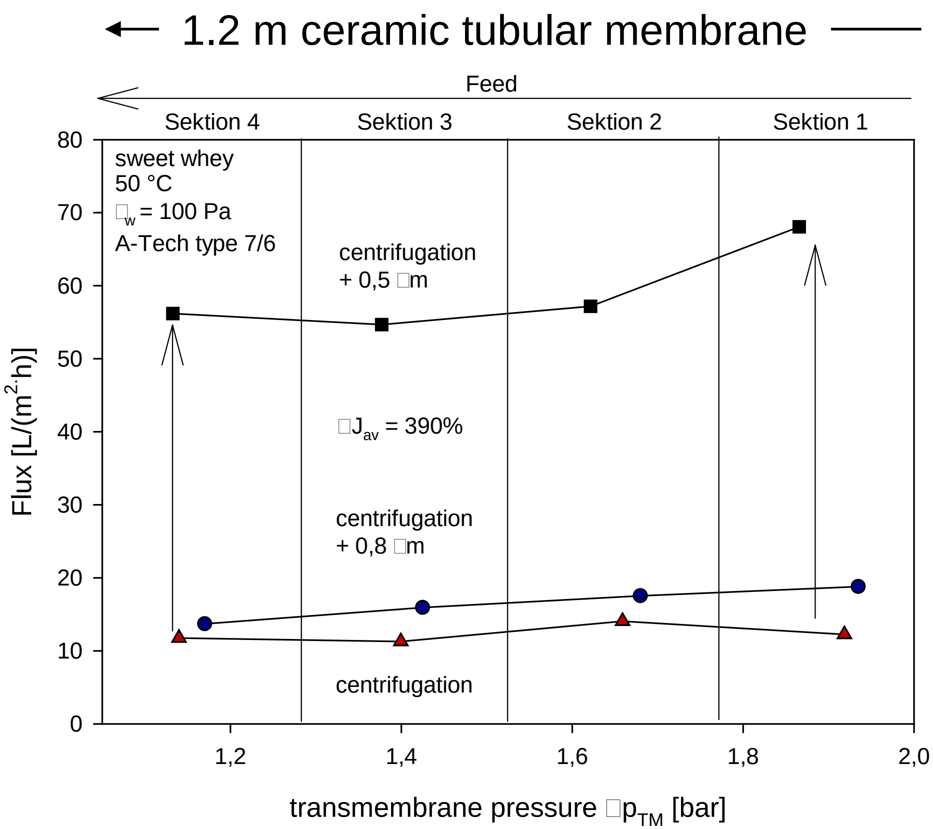


# Visualization of deposit formation on membrane surfaces by staining techniques



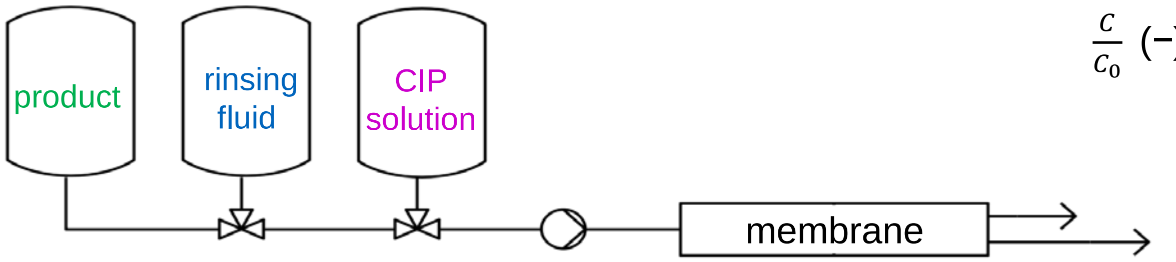
# Impact of upstream MF on steady-state flux for UF of whey

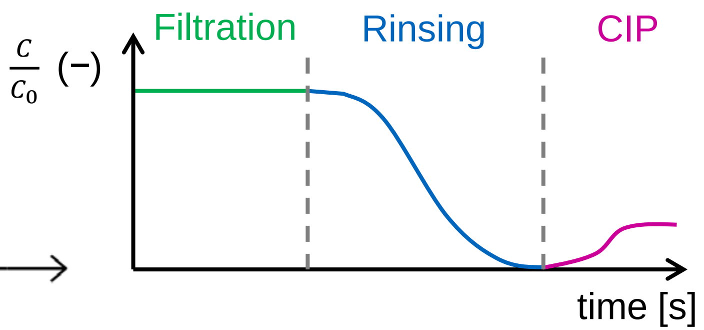



- MF leads to **increase** of steady-state UF-flux up to **400 %**
- Full transmission of whey proteins was found at ≥ 0.5 µm pore size

# Recording of rinsing processes as function of process conditions



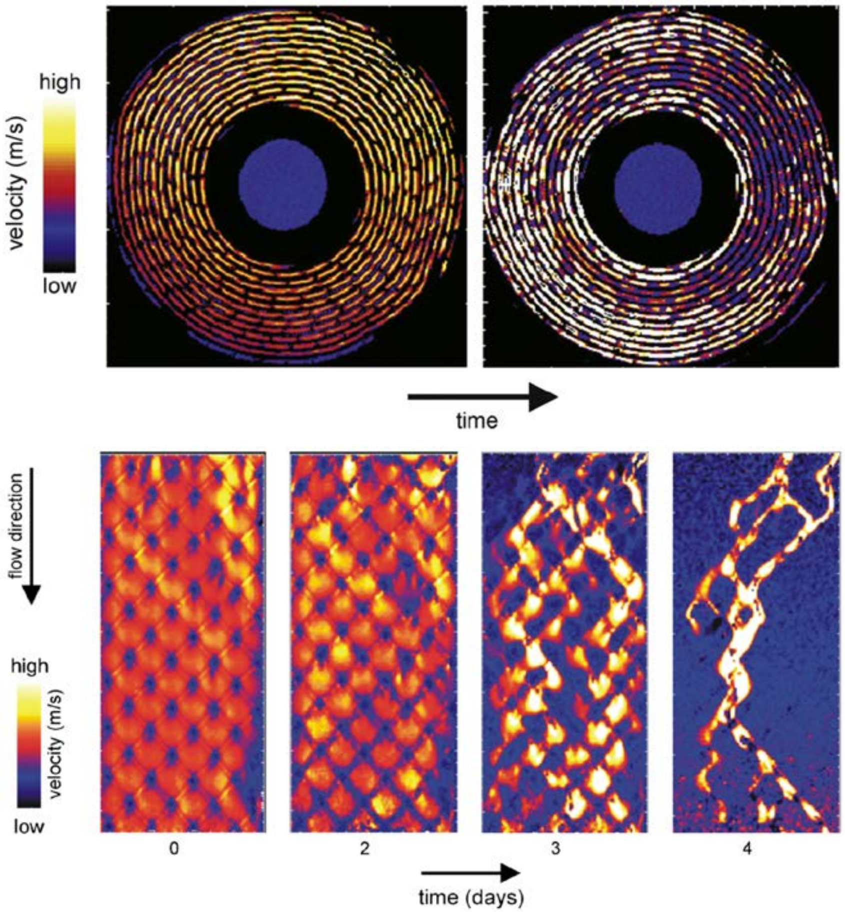




- Spacer size
- Viscosity
- Feed volume flow
- Transmembrane pressure
- Feed volume flow
- Viscosity
- SWM diameter

1. Feasible operating points
2. Optimal operating points
3. Rinsing characteristics

# Complexity of flow induced by fluidically demanding geometry of SWMs

according to Graf von Schulenberg et al. (2008)




Example:
Biofouling in SWMs

Visualization of superficial velocity components by NMR-microscopy

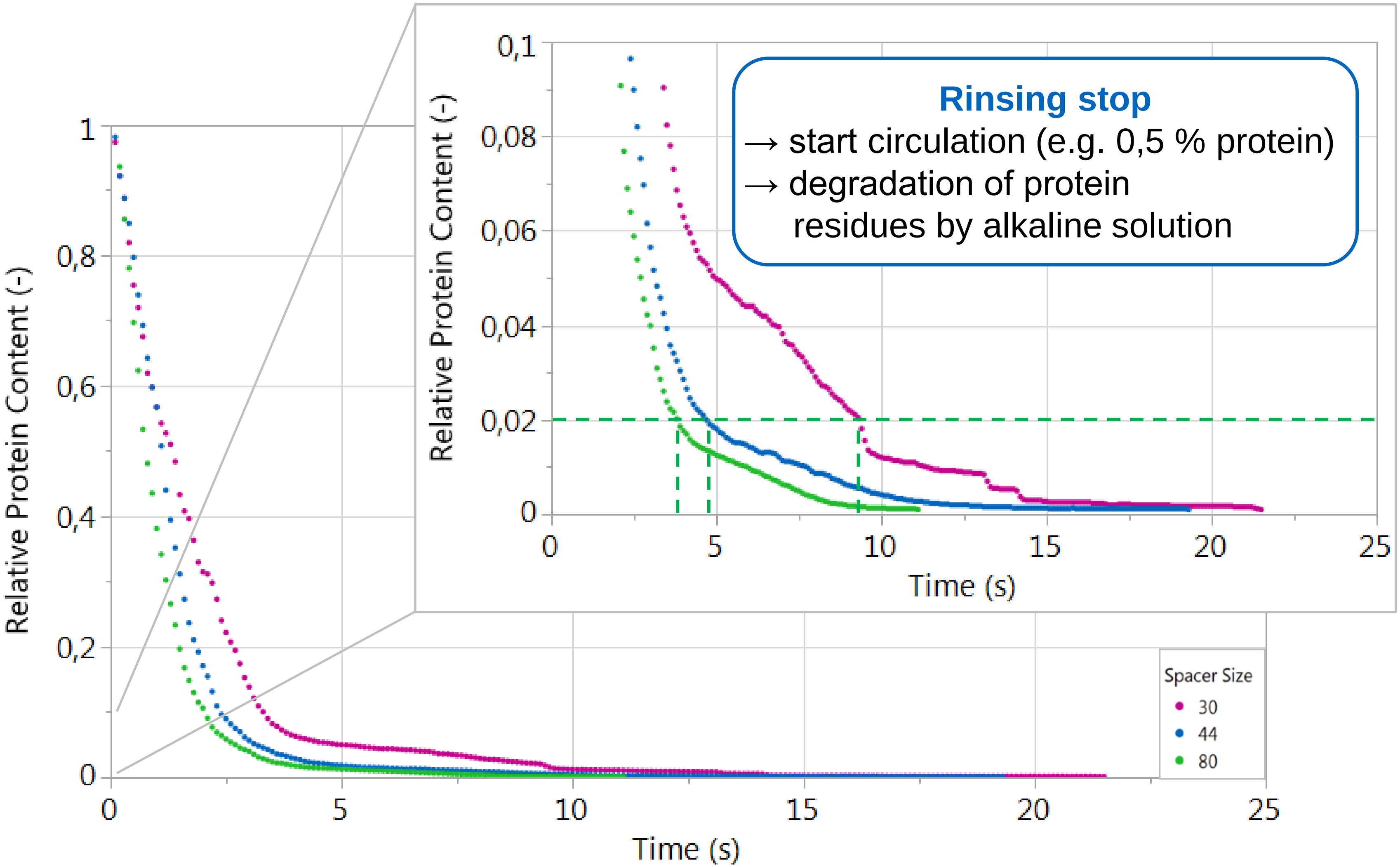
↓

→ without biofouling (left): even flow

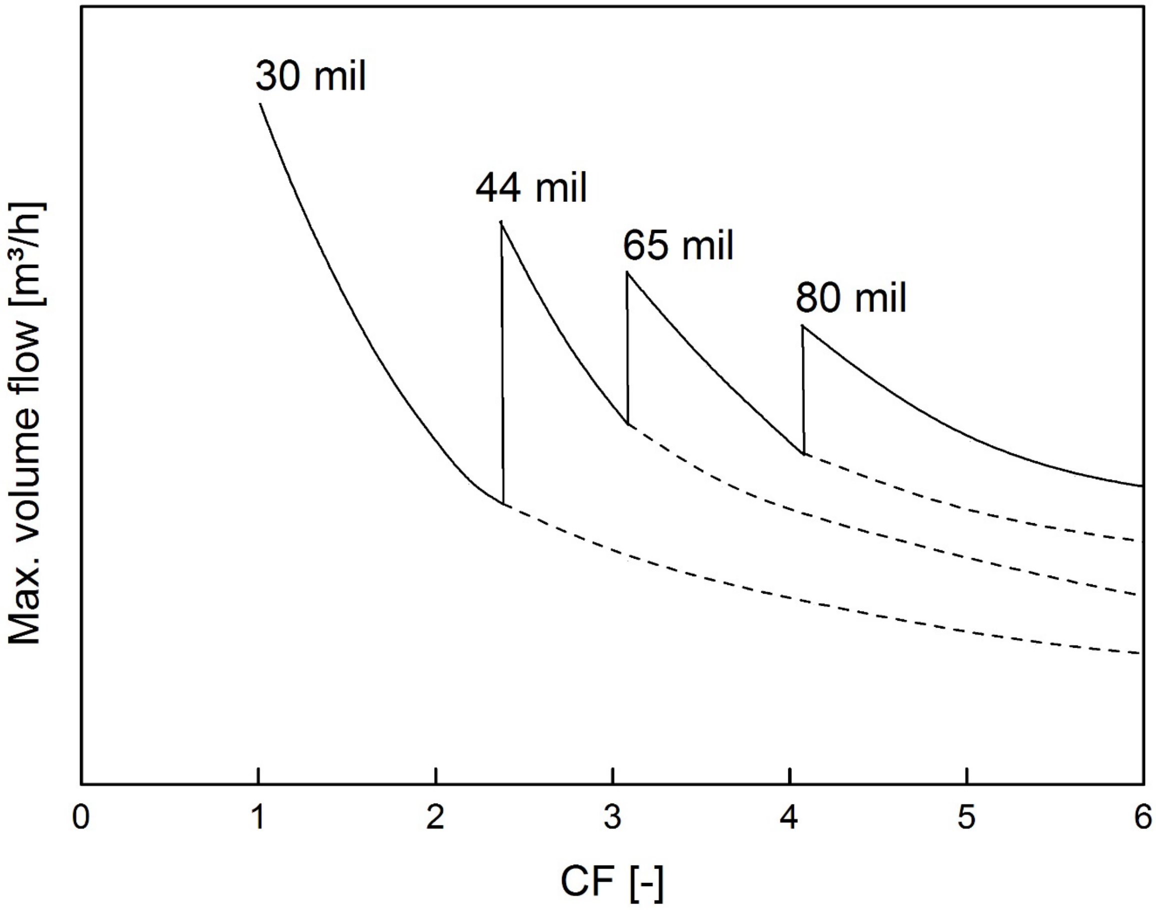
→ with biofouling (right): uneven flow

Complexity of flow:
Uneven flow in spacer-filled flat and curved channels.

# Rinsing stop according to predefined criteria

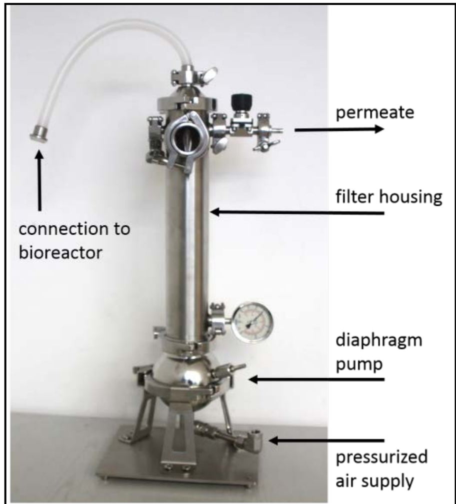


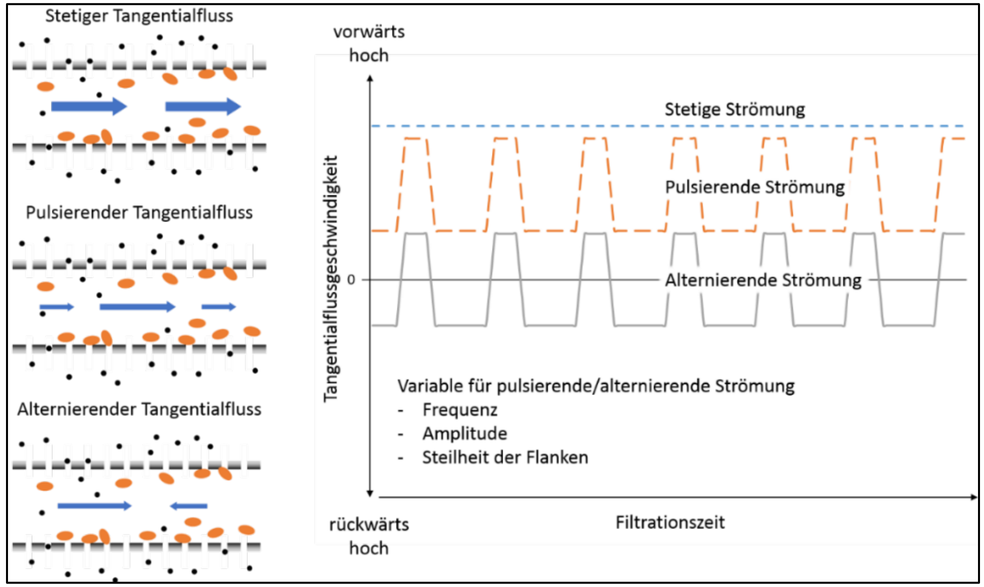
# Volume flow as a function of concentration factor and spacer geometry

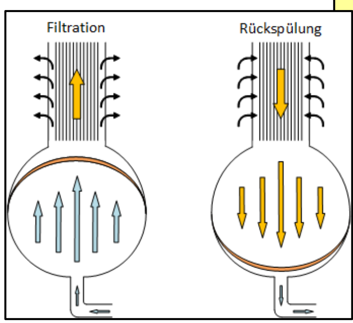



Should the spacer be selected based on flux, rinsing behaviour or other factors?

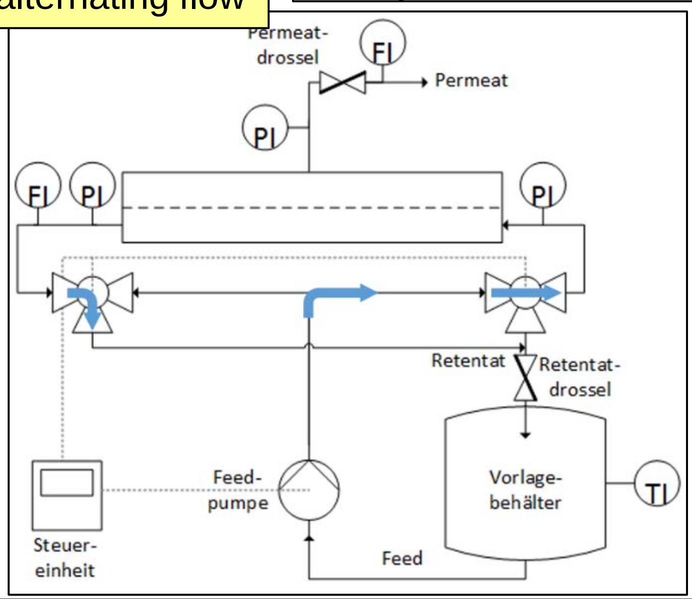
# Alternative processing modes in crossflow membrane technology



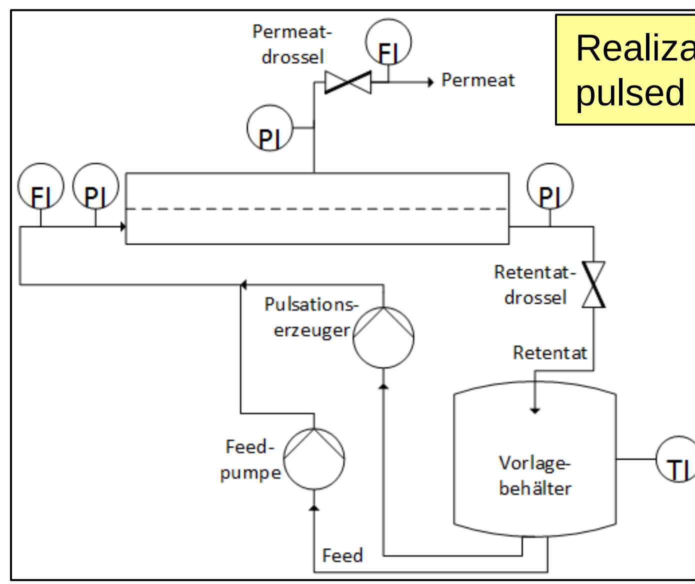



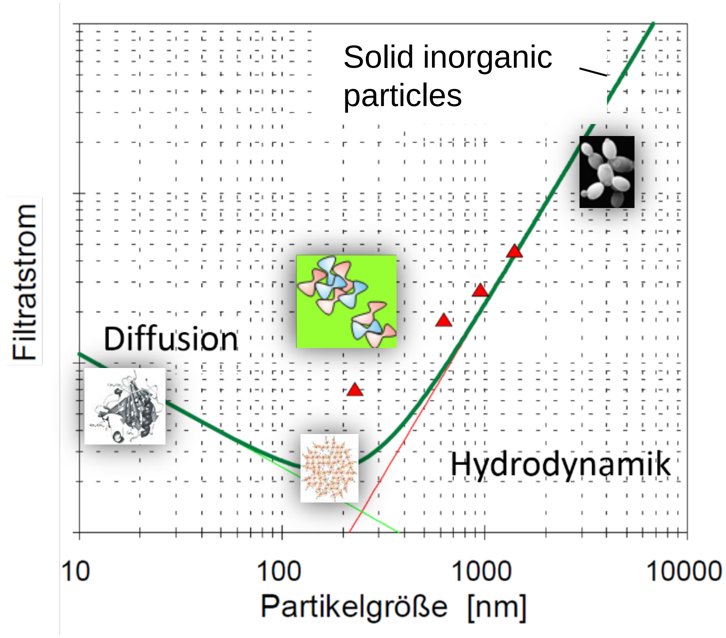

Realization of alternating flow

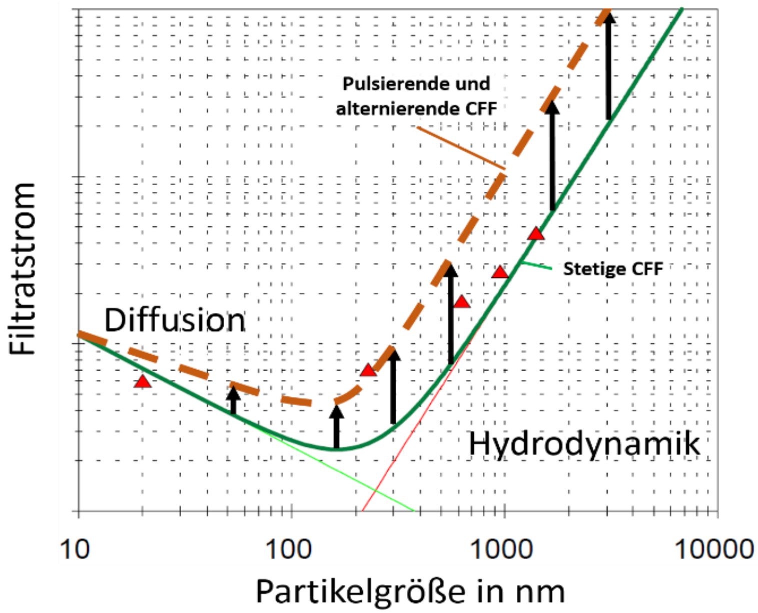


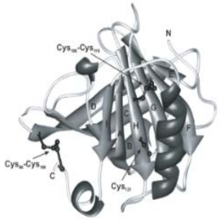
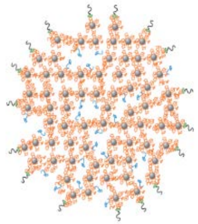
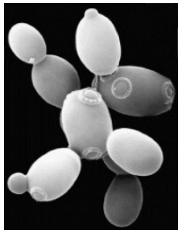
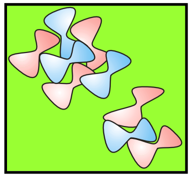

Realization of pulsed flow



# Alternative deckschichtabtragende Verfahrensweisen in der Crossflow-Filtration von Proteinen und Zellsuspensionen




| Molkenproteine | Caseinmicelle | *S. cerevisiae* | Molkenprotein-aggregate |
|---|---|---|---|
|  |  |  |  |
| < 10 nm | ca. 200 nm | ca. 5 µm | 10 nm – 20 µm |