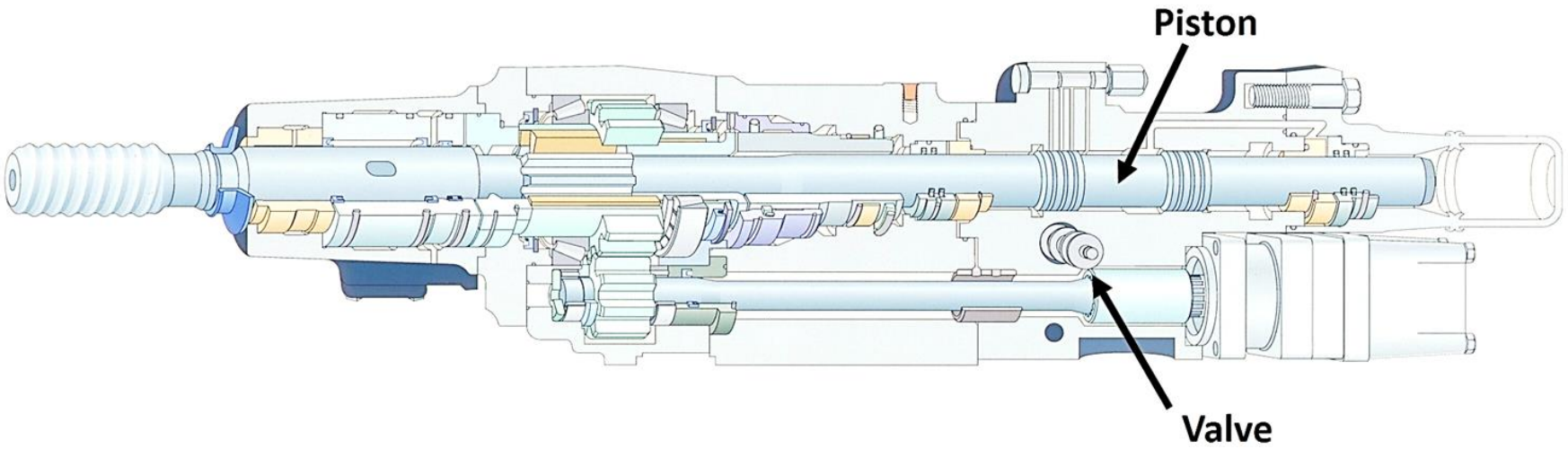
1D/3D CFD Co-simulation for Numerical Study of Caviation

Robert Braun, Linköping University
Marcus Jansson, Epiroc AB
Matts Karlsson, Linköping University

LINKÖPING UNIVERSITY

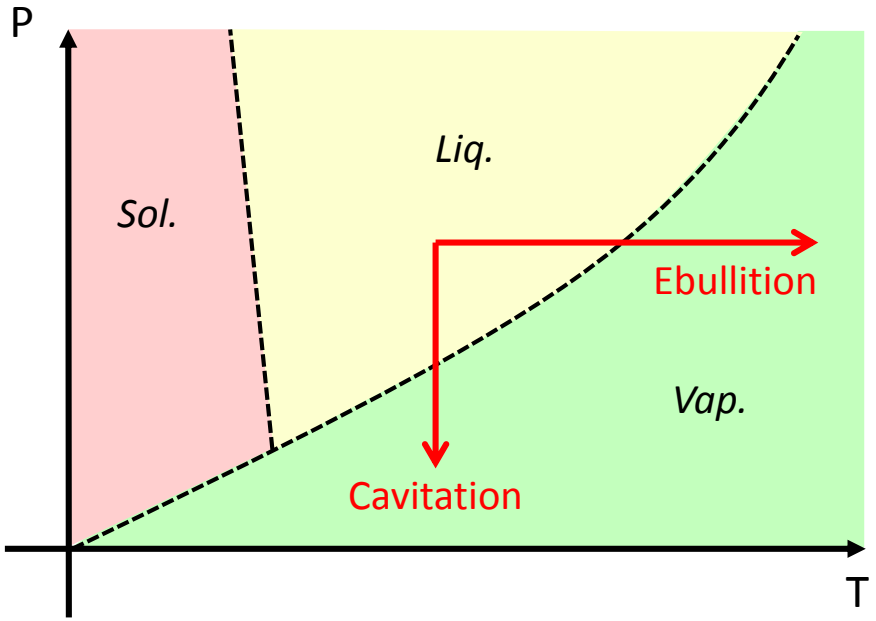
Background

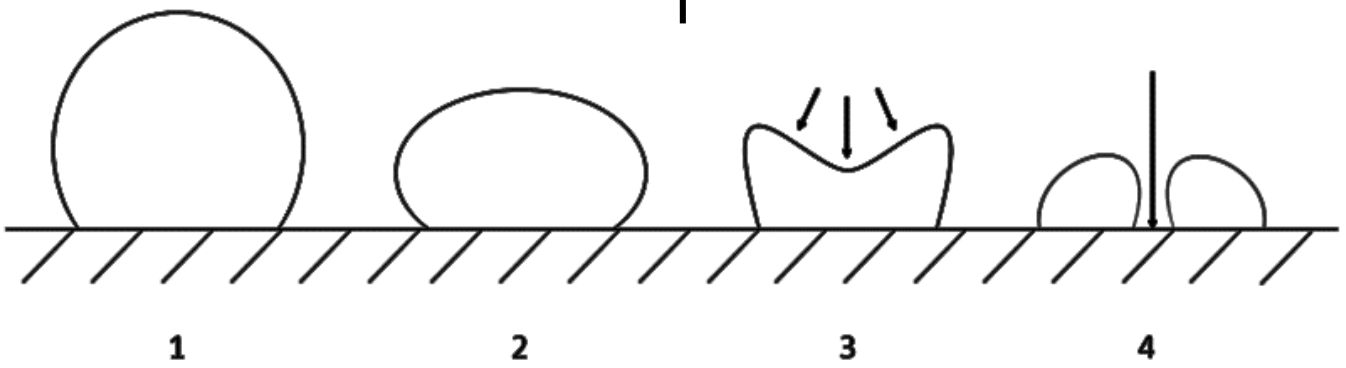
- Hydraulic rock drills
  - Rapidly changing fluid pressure



Cavitation

- Formation of vapour cavities due to large pressure transients
- May cause erosion





Cavitation erosion in hydrualic rock drills

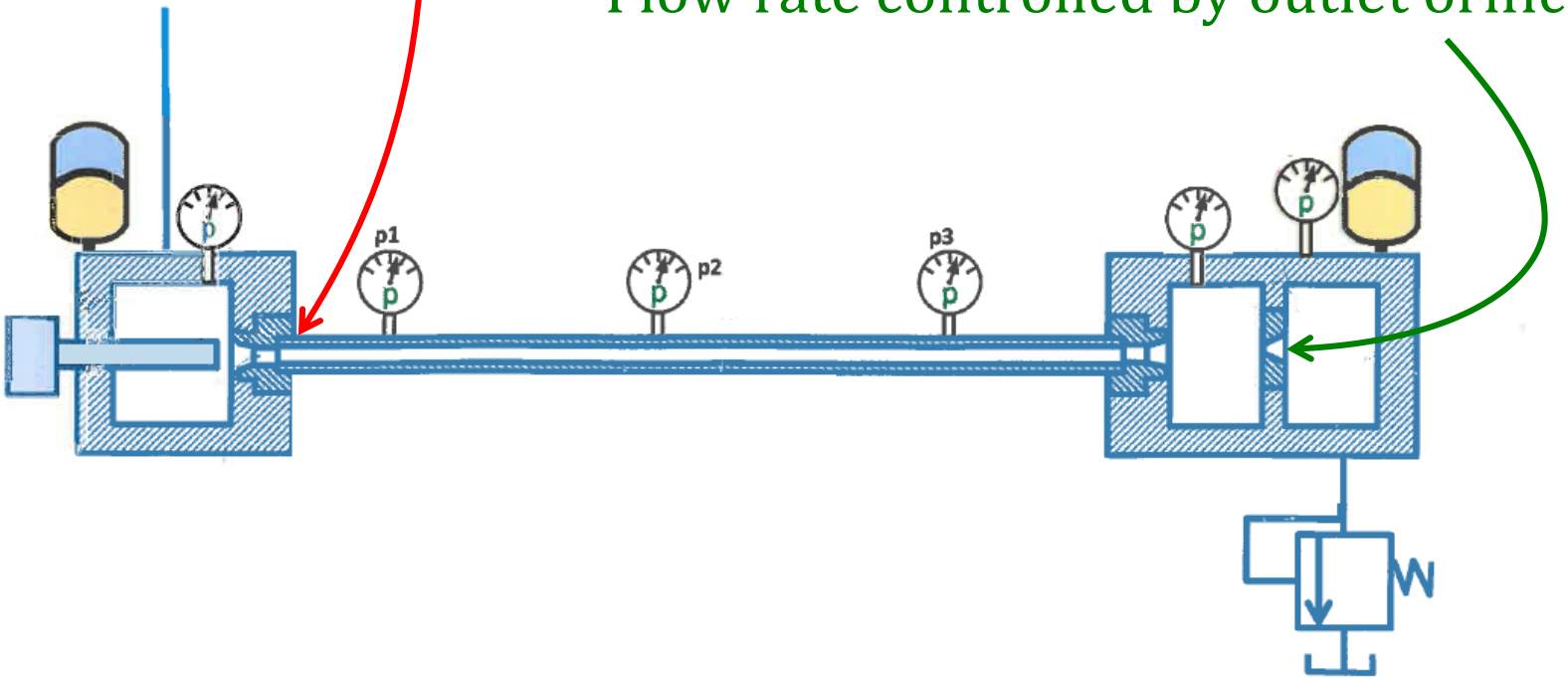
Cavitation is a major concern
- Reduced performance
- Shorter life-span

Important to predict cavitation
- Location
- Severity

Test rig

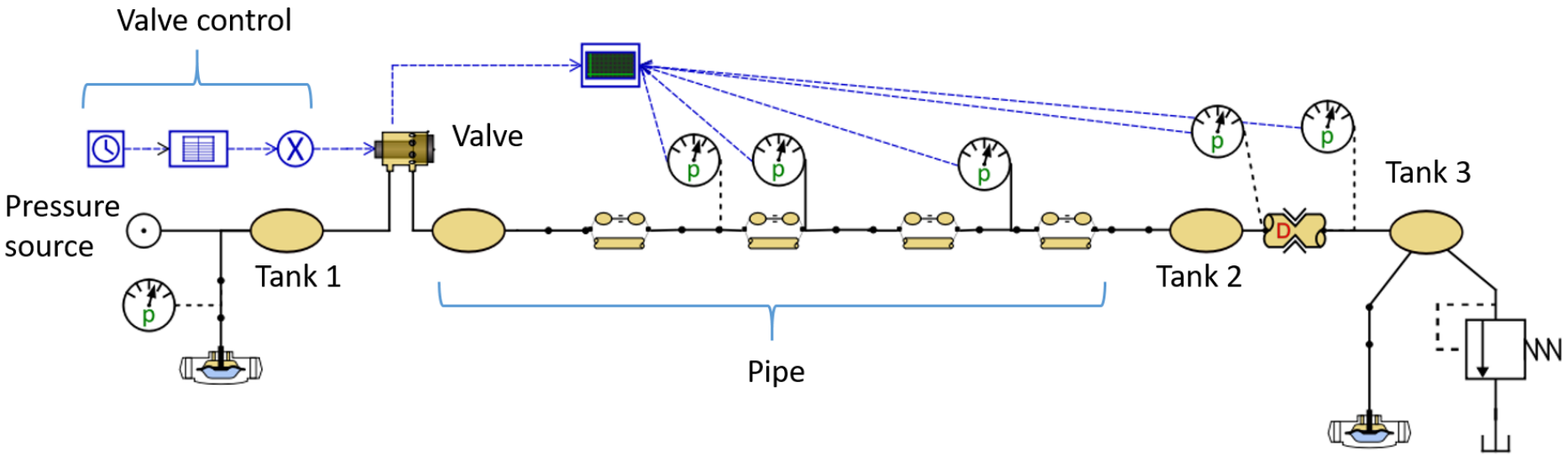
Cavitation induced by rapidly closing inlet valve

Flow rate controlled by outlet orifice



System Simulation Cavitation Model

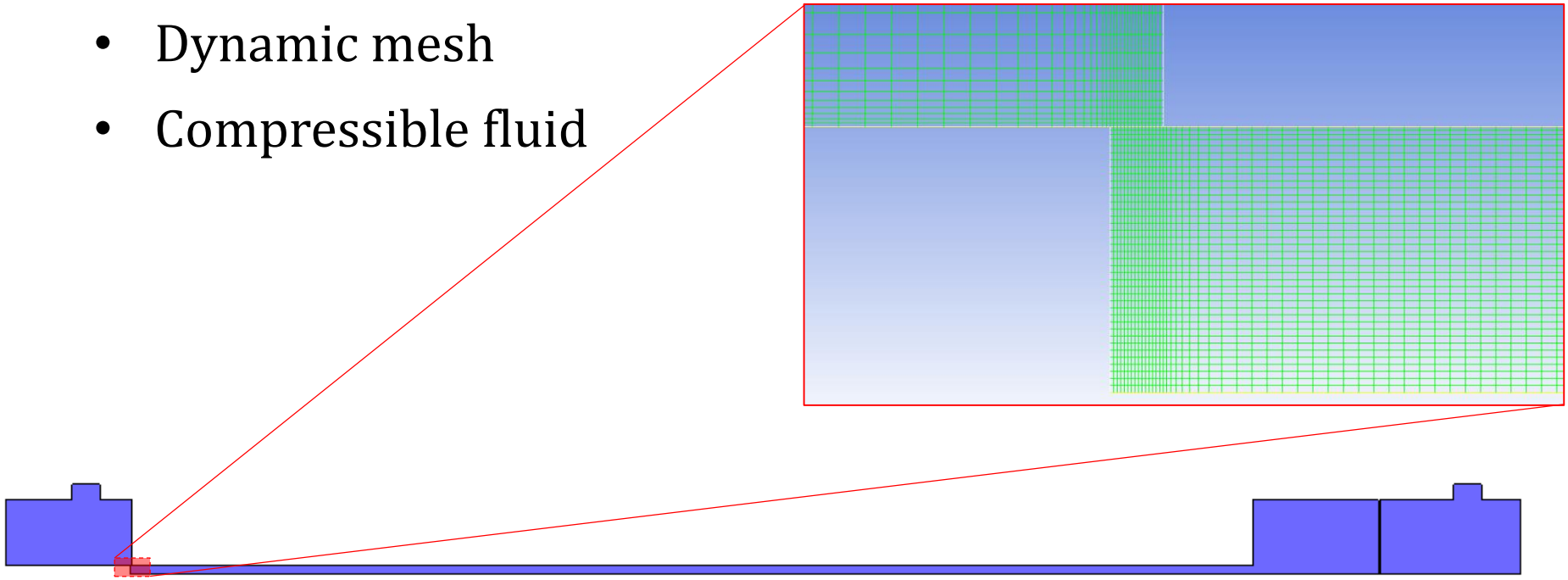
Hopsan simulation tool



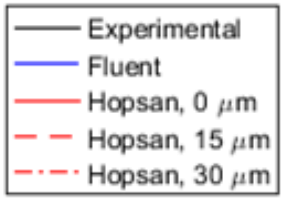
CFD Cavitation Model

Ansys Fluent

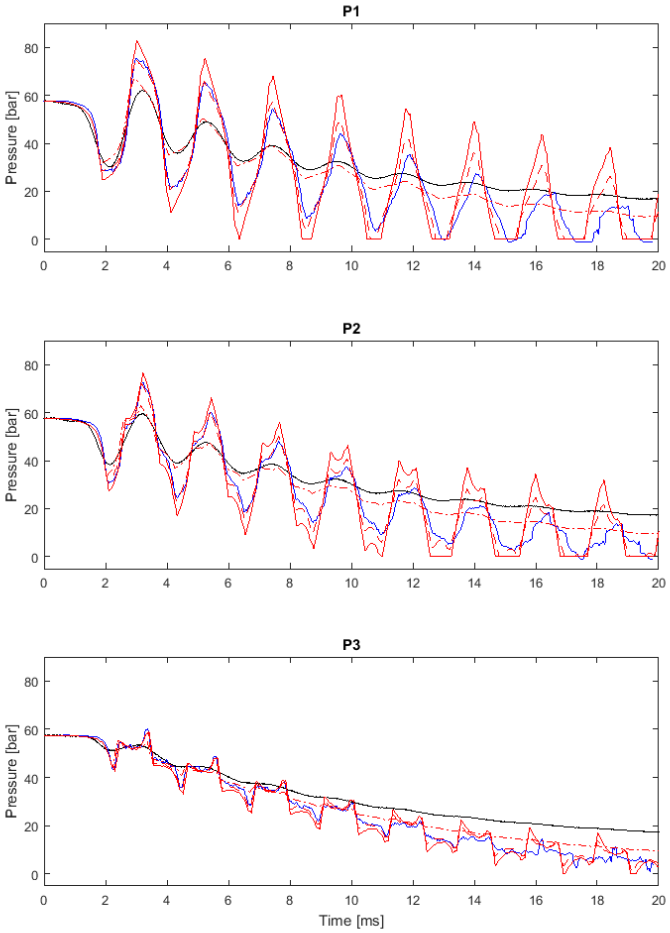
- Dynamic mesh
- Compressible fluid



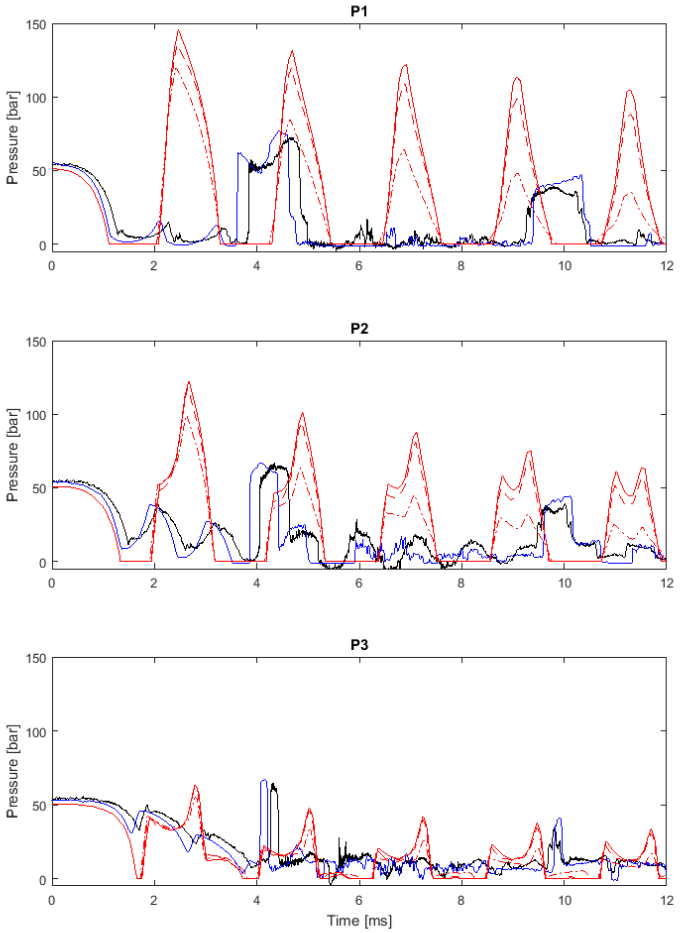
Simulation results



Without cavitation

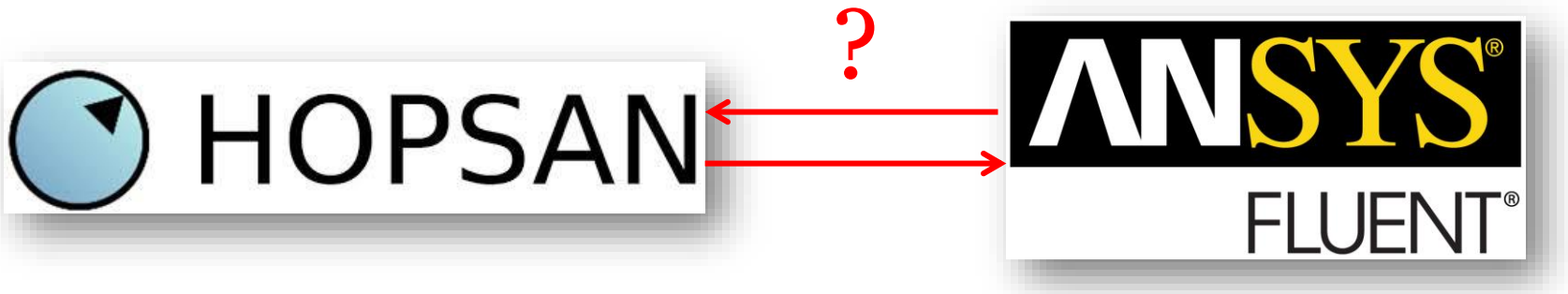


With cavitation



1D/3D Co-simulation

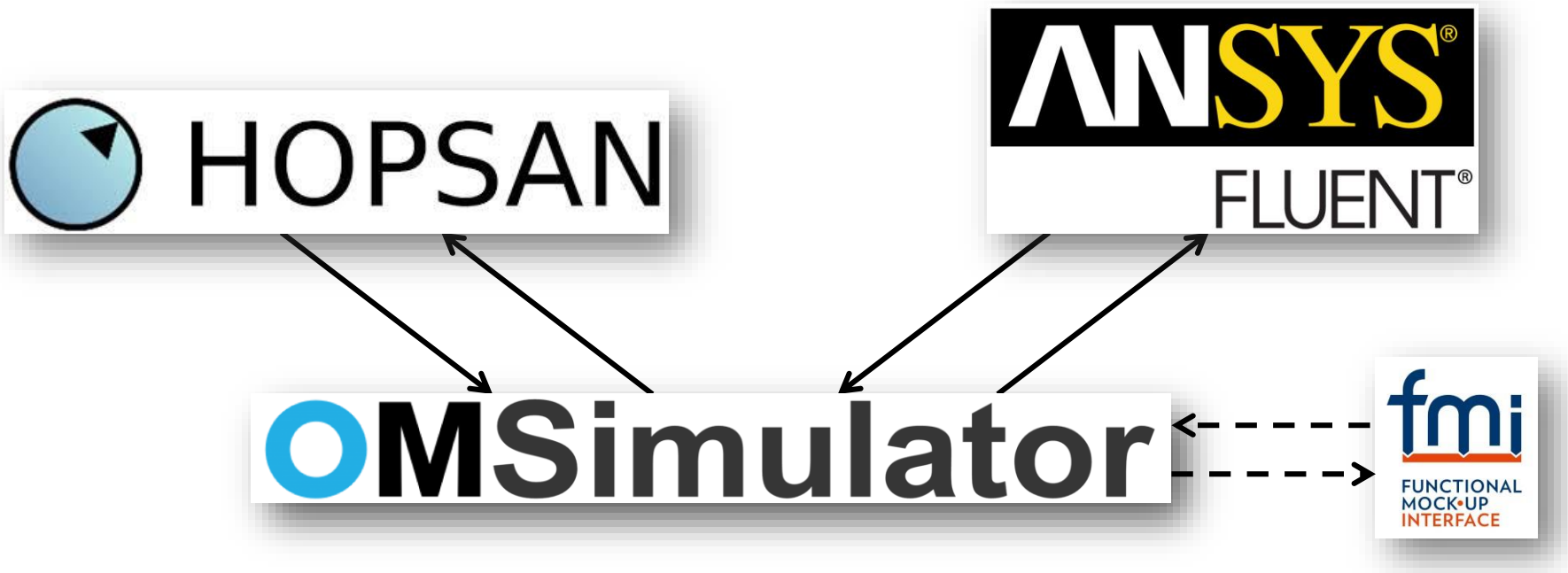
- Improved performance
- More accurate boundary conditions



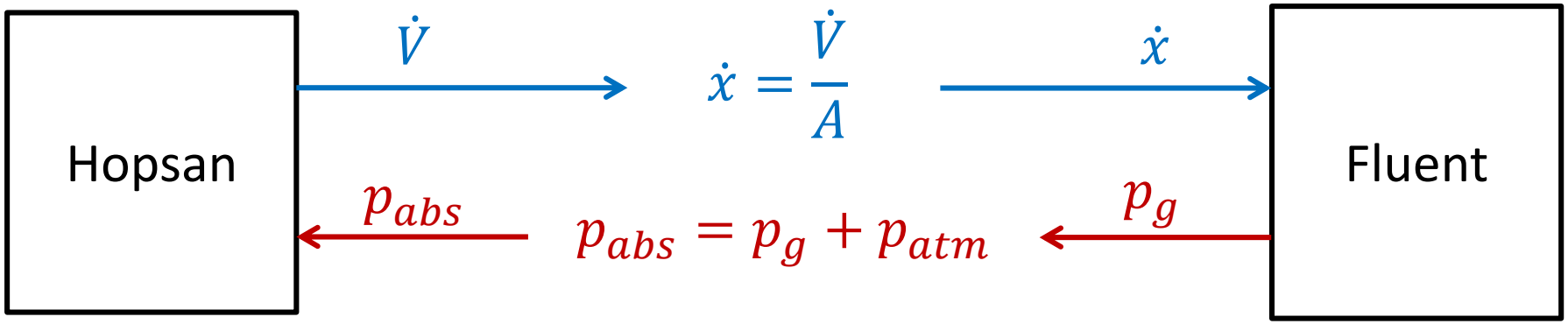
- Functional Mockup Interface?
- User-defined functions?
- External master simulation tool?

1D/3D Co-simulation Implementation

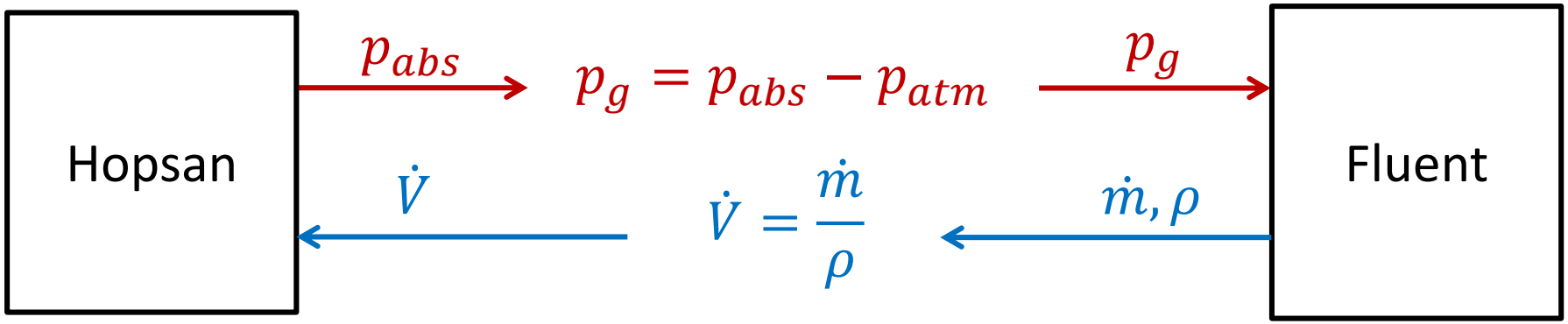
- TCP/IP sockets
- Busy-waiting synchronization



Velocity input interface



Pressure input interface



1D/3D Co-simulation Implementation

- Approach: User-defined functions (UDF)

```
DEFINE_PROFILE(tlm_input_velocity, thread, position)
{
   face_t f;
   real t = CURRENT_TIME;
   int n=0;
   real p=0;
   begin_f_loop(f, thread)
   {
      p += F_P(f,thread);
      ++n;
      double q,v;
      plugin->GetValueSignal(idq1, t, &q);
      v = q/0.031415;
      F_PROFILE(f, thread, position) = v;
   }
   end_f_loop(f, thread)
   p = p/n+1e5;
   plugin->SetValueSignal(idp1,t,p/n);
}
```

Input velocity

Output pressure

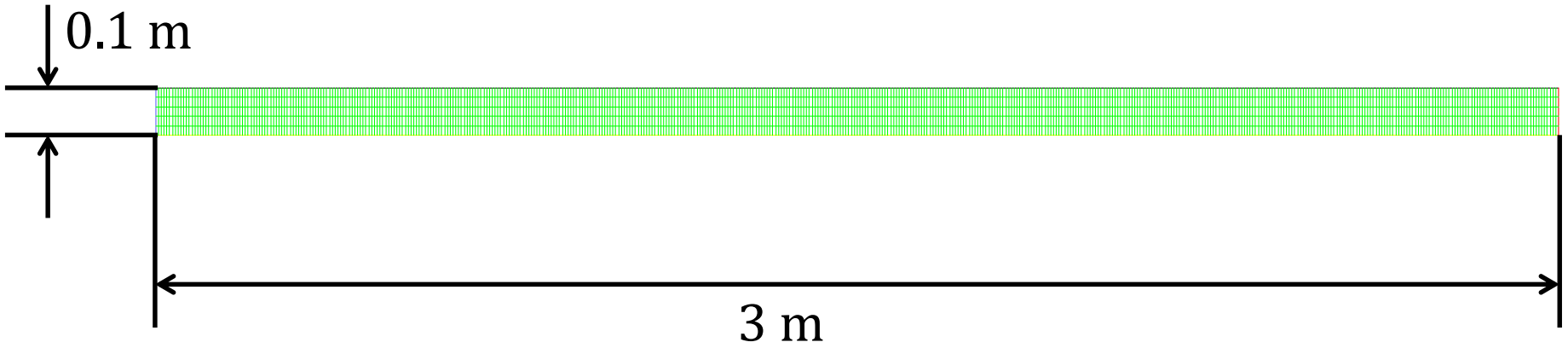
```
DEFINE_PROFILE(tlm_output_pressure, thread, position)
{
   face_t f;
   real t = CURRENT_TIME;
   double q = 0;
   begin_f_loop(f, thread)
   {
      real rho;
      rho = F_R(f,thread);
      q += F_FLUX(f,thread)/rho;
      double p;
      plugin->GetValueSignal(idp2, t, &p);
      p = p-1e5;
      F_PROFILE(f, thread, position) = p;
   }
   end_f_loop(f, thread)
   plugin->SetValueSignal(idq2,t,q);
}
```

Output flow

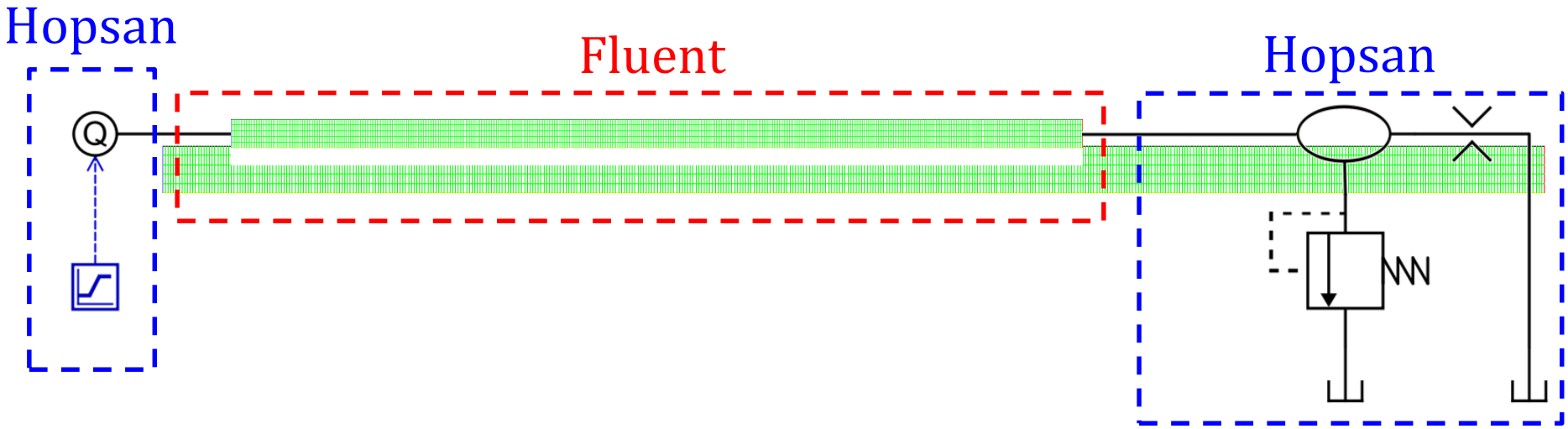
Input pressure

Verification model

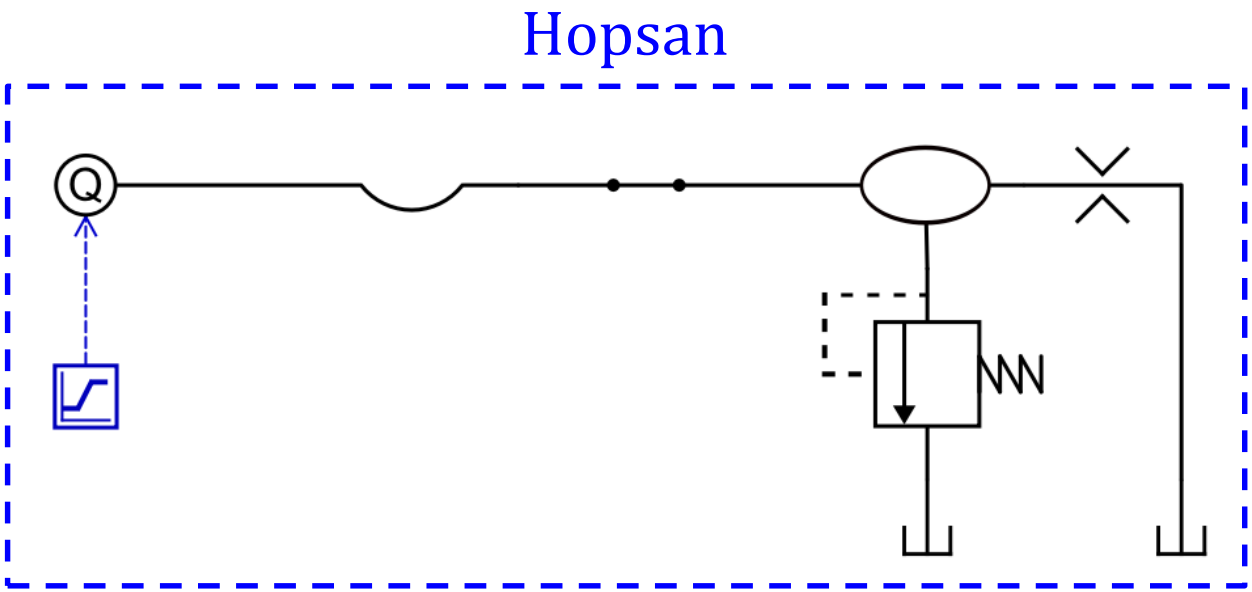
- 2D axisymmetric pipe model
- Static mesh
- Constant density



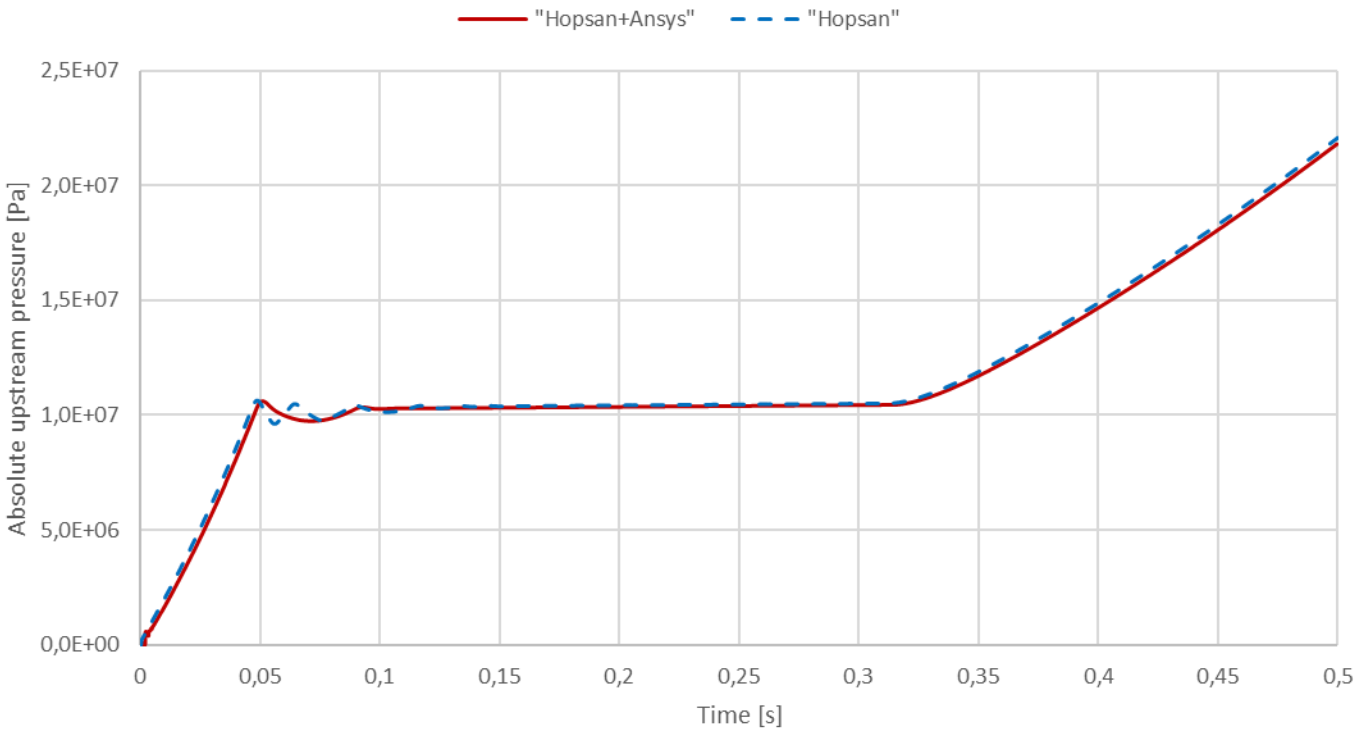
Verification Model



1D Reference Model

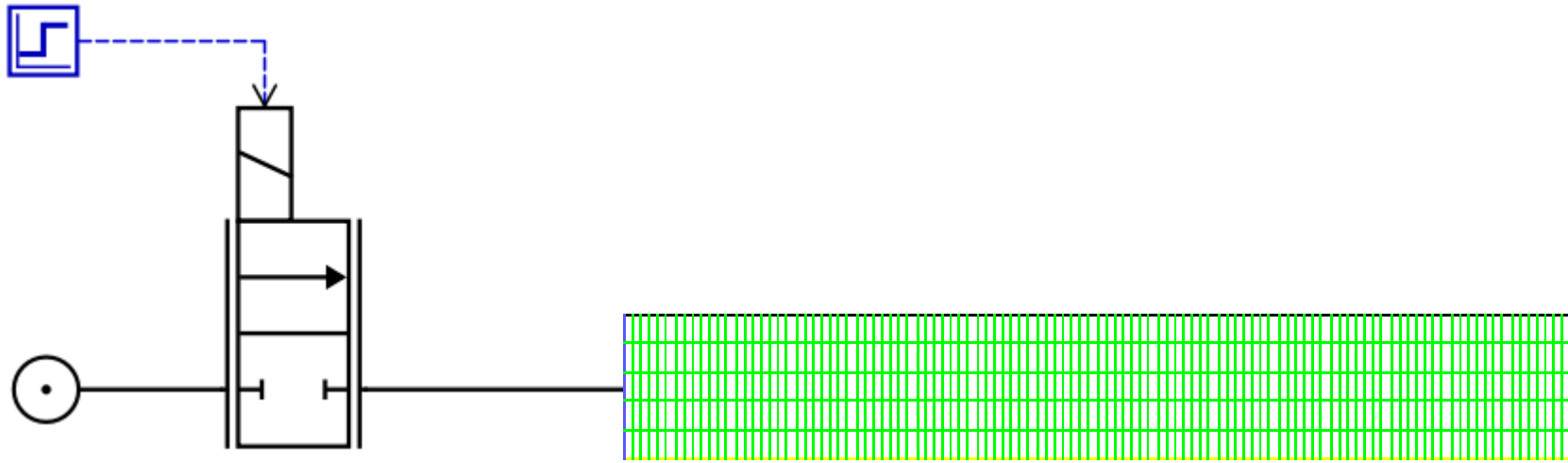


Verification results



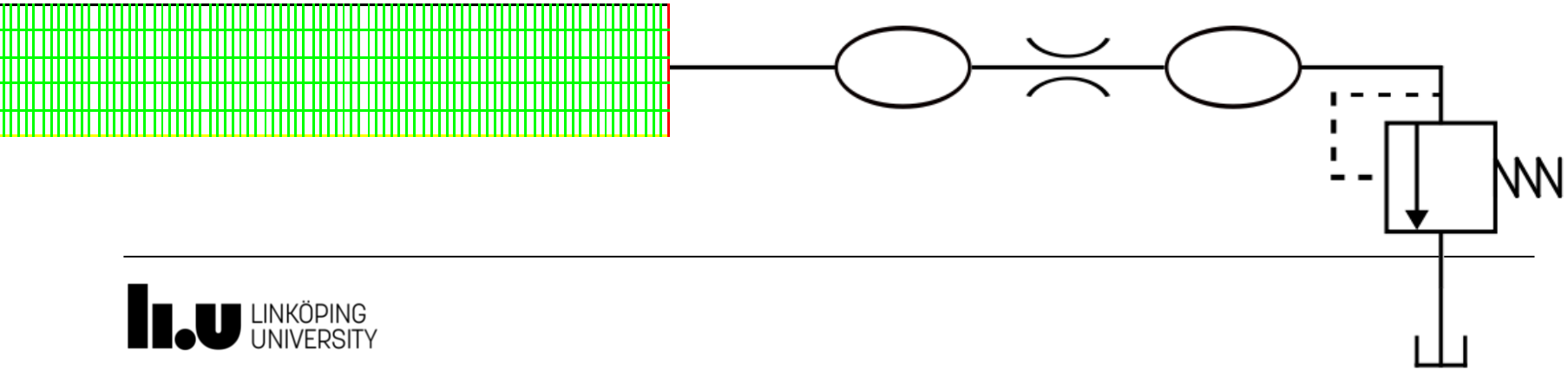
Co-simulation in caviatation study

- Approach 1: Inlet valve in Hopsan
  - Problem: Hopsan has no velocity profile (1D)
  - Multiple connections?



Co-simulation in caviatation study

- Approach 2: Downstream components in Hopsan
  - Details not of interest
  - Can improve performance



Co-simulation in caviatation study

- Approach 3: Better cavitation models in system simulation
  - CFD component in system model
    - Will decrease performance
  - Create simplified cavitation model based on CFD results

Remaining work

- Physical connection (TLM)
  - Improved numerical stability
- Compressible fluid
- Connect Hopsan to existing cavitation model

Thank you!

Questions?

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