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Quantitative analysis of gas circuit breaker physics through direct comparison of 3D simulations with experiment

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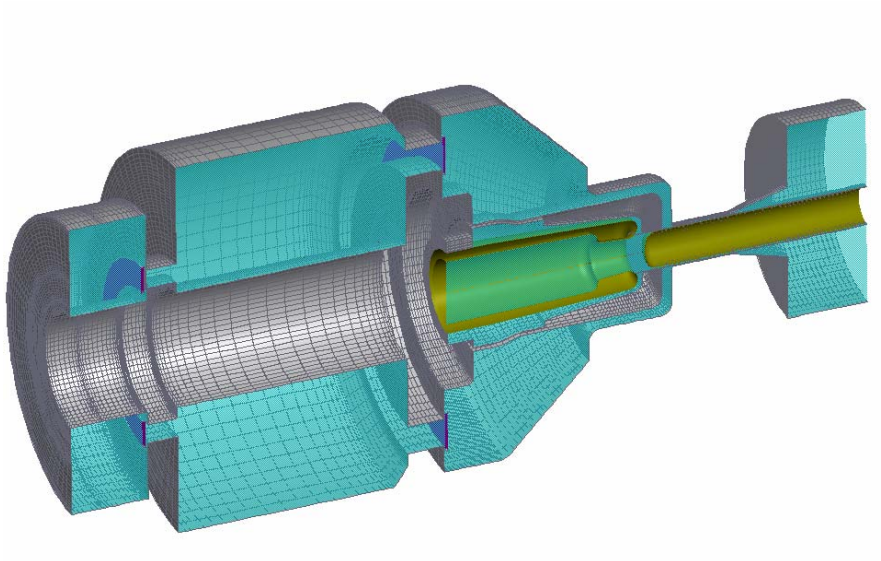
Introduction

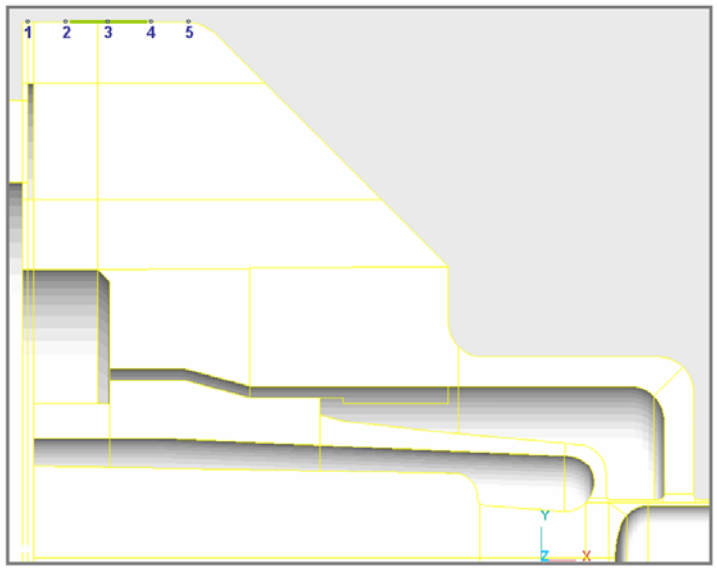
- We study interruption of short-circuit current in high-voltage gas circuit breakers
- Pressure produced by the arc is used to extinguish the arc, i.e. the self-blast principle
- We measure the pressure buildup using two spatially separated sensors
- The pressure and other measured quantities are compared to a 3D computational fluid dynamics (CFD) simulation

CFD simulation setup

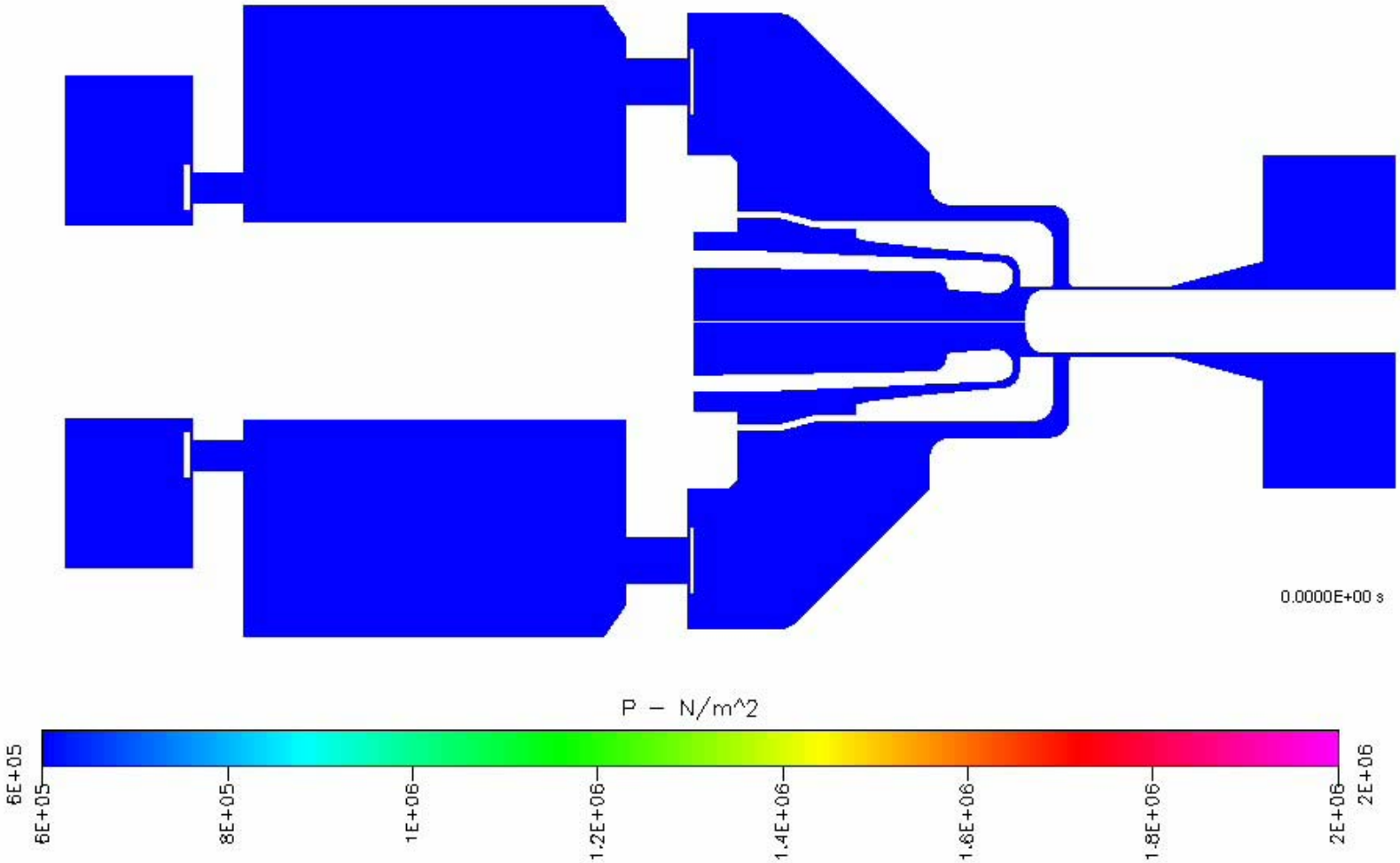


- Left-hand plot shows the grid used for the CFD simulation
  - A 180 degree cut is simulated
  - No turbulence is included

- Right-hand plot shows the heating volume and the positions where pressure is simulated
  - Position 3 is the actual sensor location

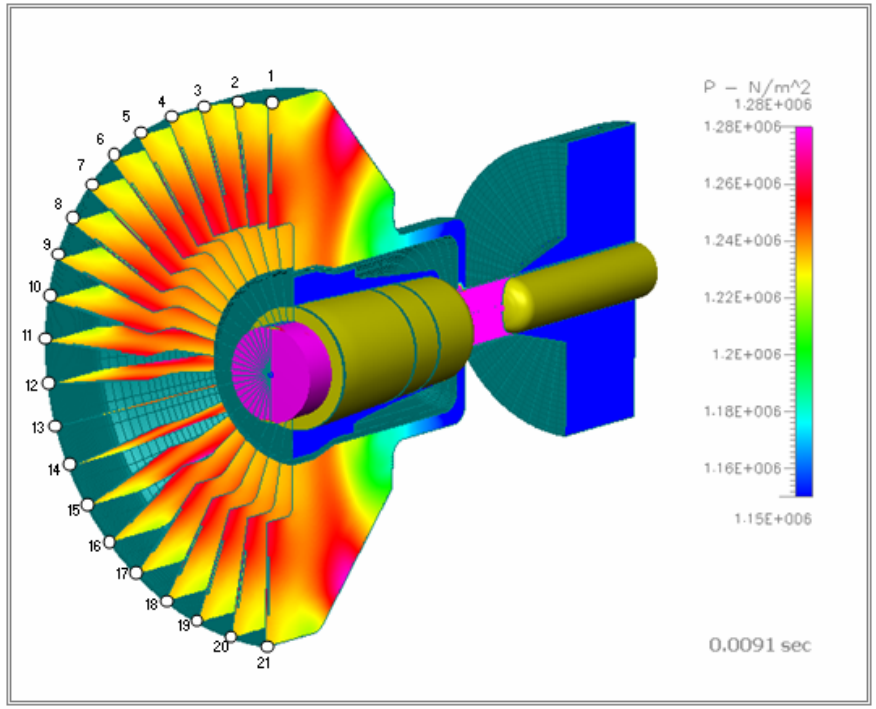


CFD pressure animation



Current interruption phases

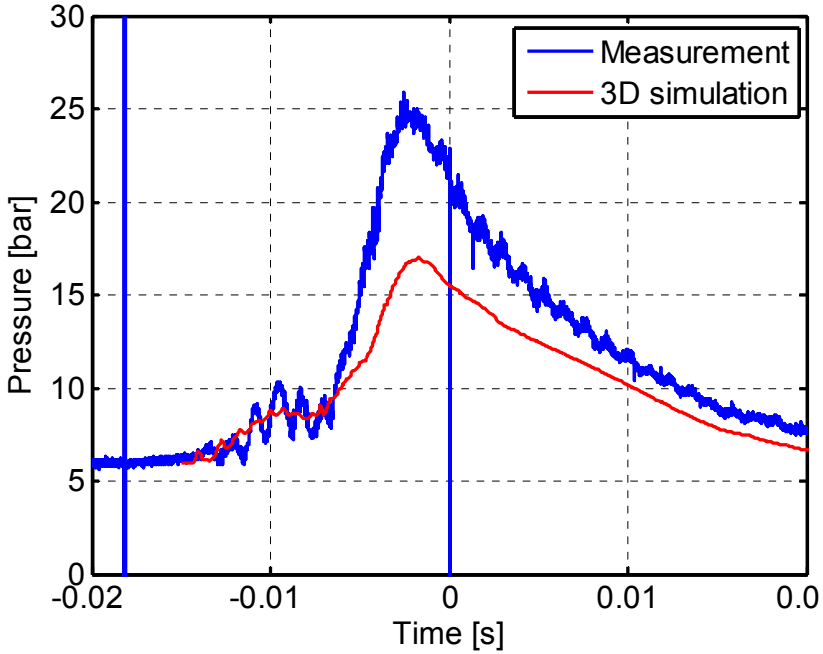
- Sequence of events
  1. Ablation controlled arc, backheating from arc zone to heating volume
  2. Flow reversal when the heating volume pressure equals the arc pressure
  3. Axially blown arc, flow from heating volume to arc zone
  4. Arc extinction

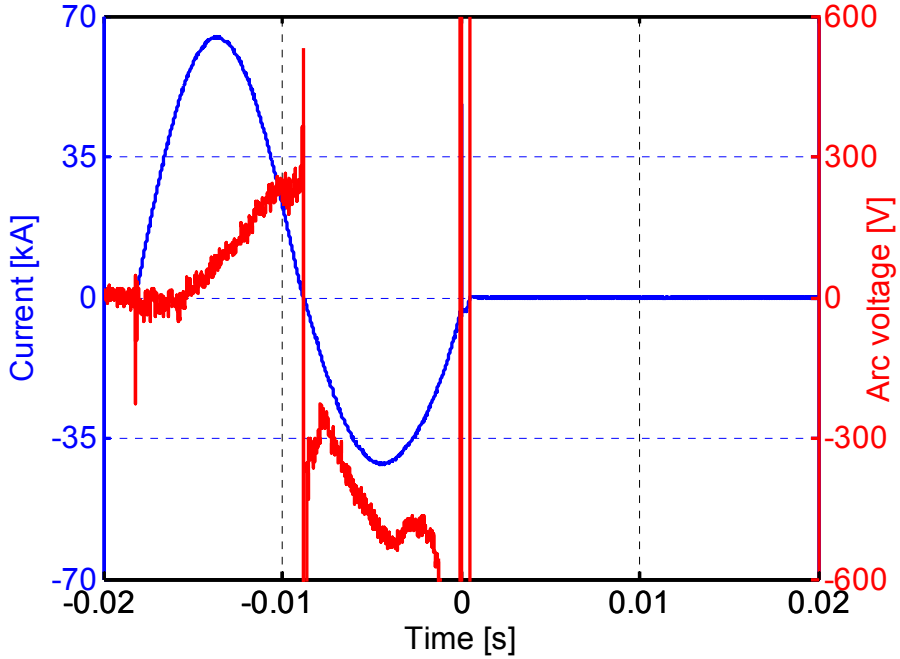


- Plot above shows pressure monitor points in the 3D simulation
  - Here, we analyze results from position 1 and 21

Heating volume pressure and arc parameters

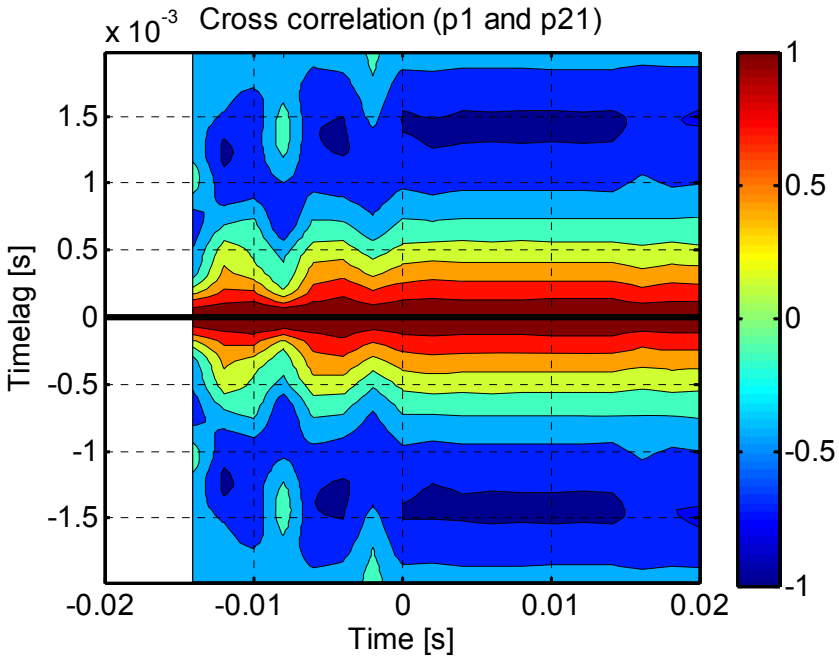
- Left: Heating volume pressure
- Right: Arc current and voltage

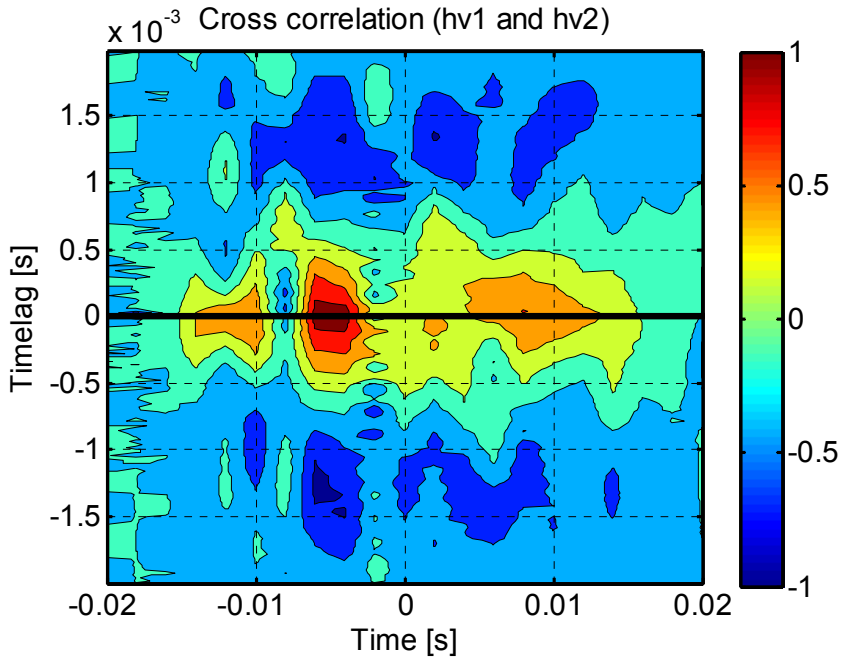




Transient between flow reversal and CZ

- A pressure transient a few ms before current zero (CZ) has been identified using cross correlation analysis
- The oscillation is between the arc zone and the heating volume

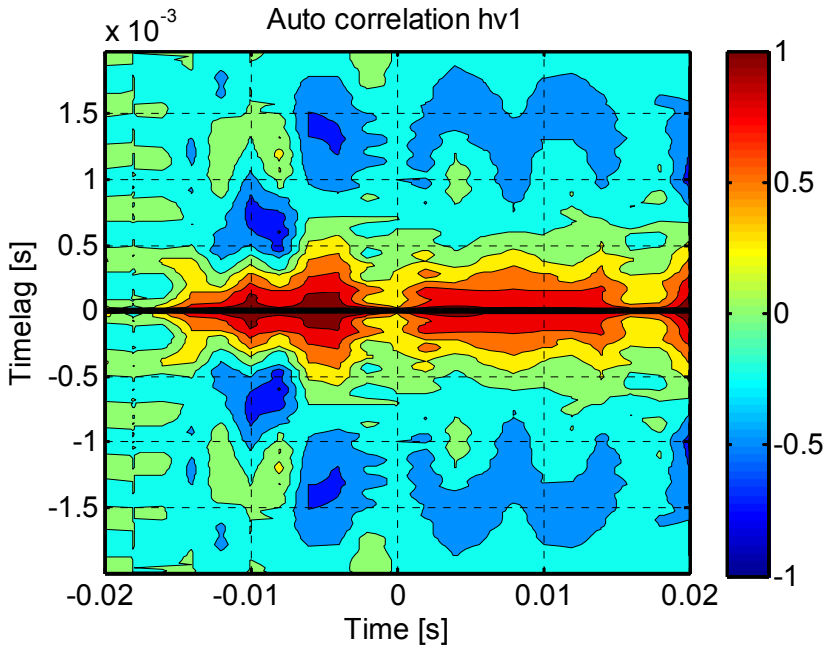


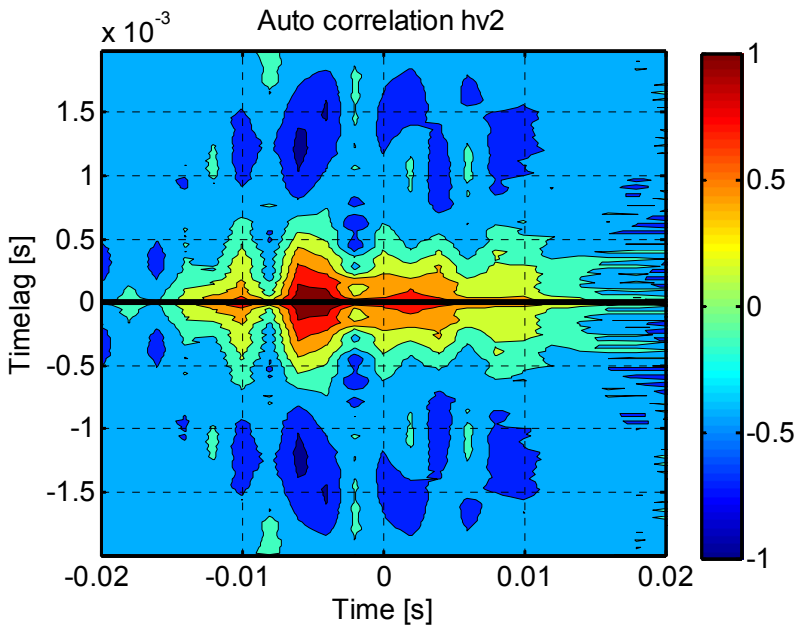


- Left simulations, right measurements

Early transient in heating volume

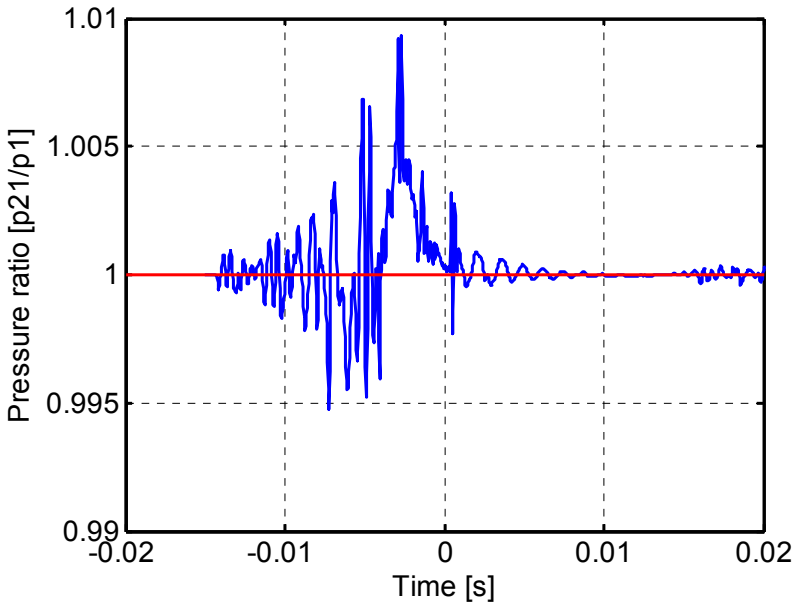
- Below we show auto correlation functions for both pressure measurements
- An oscillation is observed at -0.01 s with a period of about 1.7 ms at one sensor position (left-hand plot)

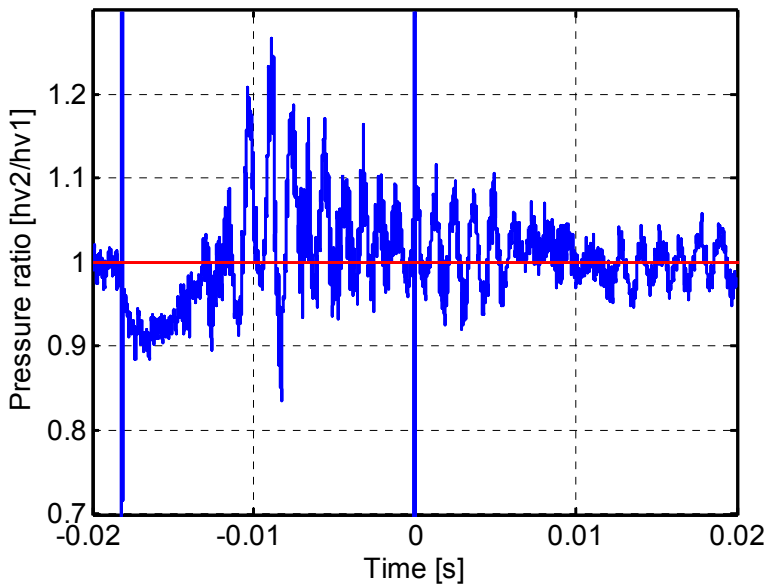




Pressure mixing

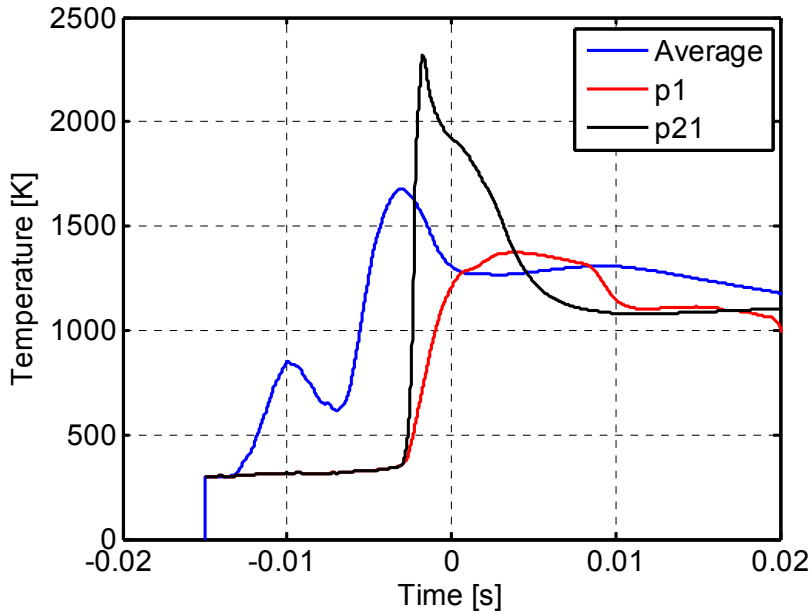
- The pressure ratio 180 degrees apart is used to gauge the uniformity of pressure
- Simulation (measurement) up to 1% (25%) difference, respectively

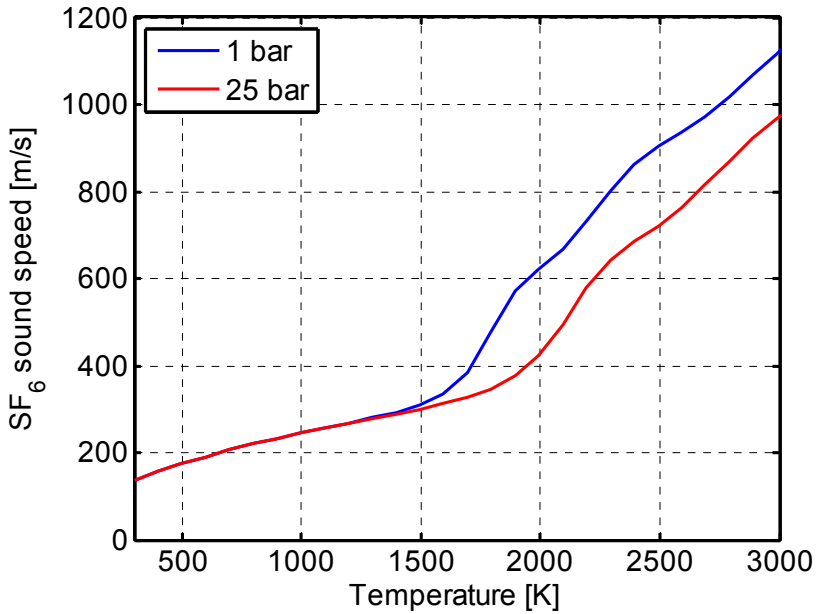




Temperature

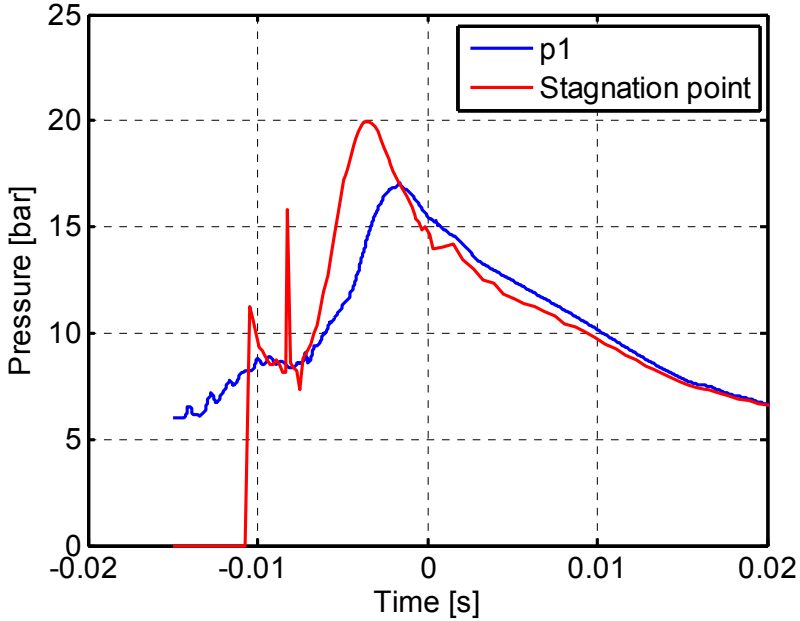
- Left: Temperature at sensor positions is very different after flow reversal
  - Average heating volume temperature reflects current behavior
- Right: With the sound speed of SF_6 and dimensions of the circuit breaker, cross correlation periods can be used to derive average temperatures

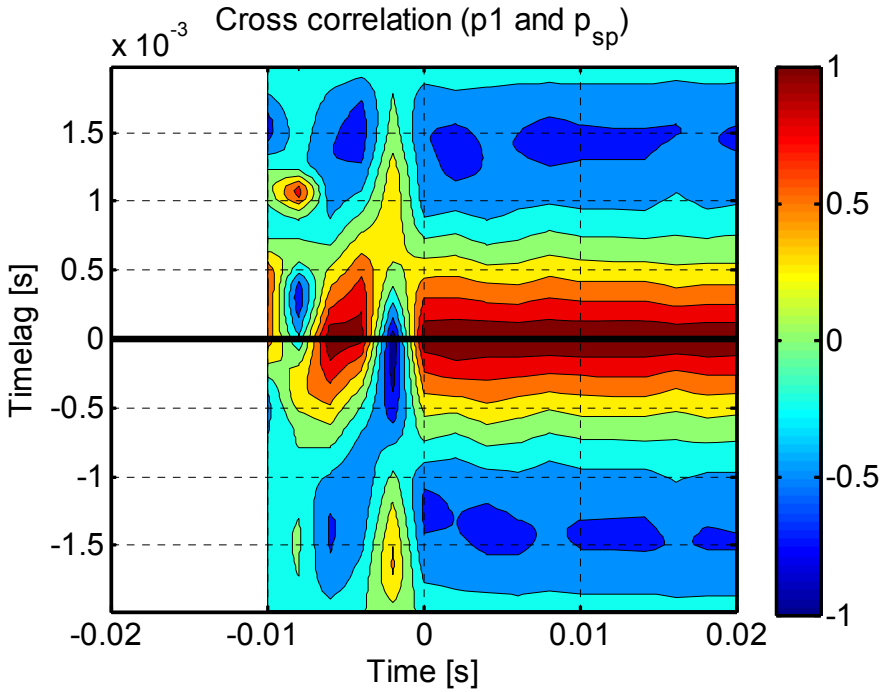




Pressure in arc zone and heating volume

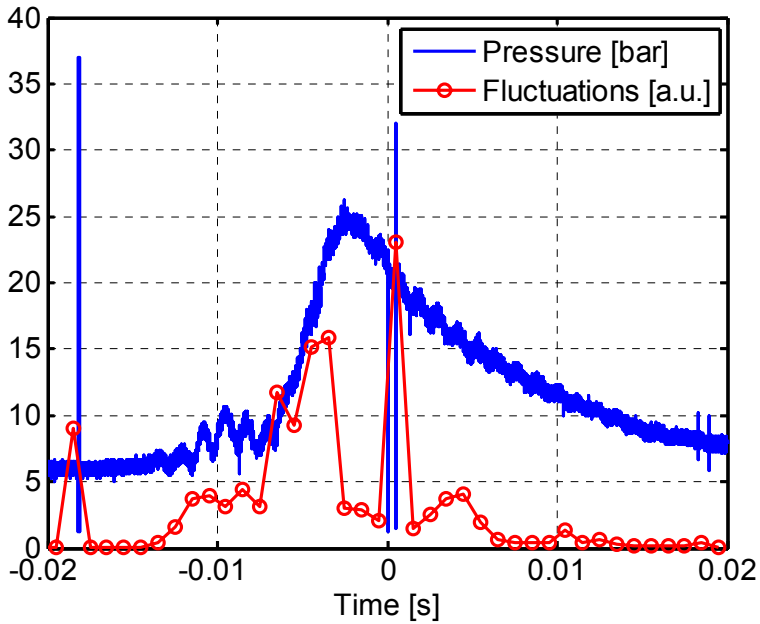
- Left: Simulated heating volume and arc zone pressure
- Right: Cross correlation of the pressures

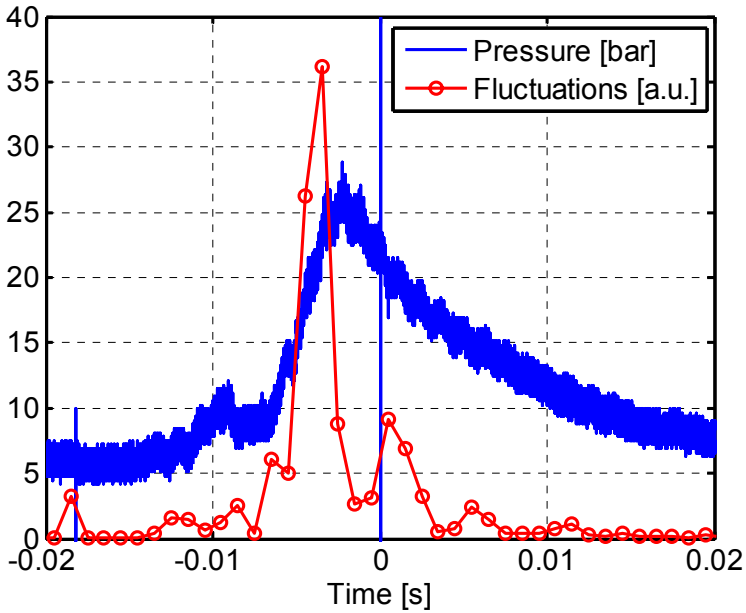




Pressure fluctuations

- Power spectra of the two pressure measurements integrated up to 20 kHz are shown below
- Most fluctuations during the final rise of the pressure





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