Westfälische
Wilhelms-Universität
Münster

Reliability Studies of the Nozzle/Piezo Units for the WASA-at-COSY Pellet Target

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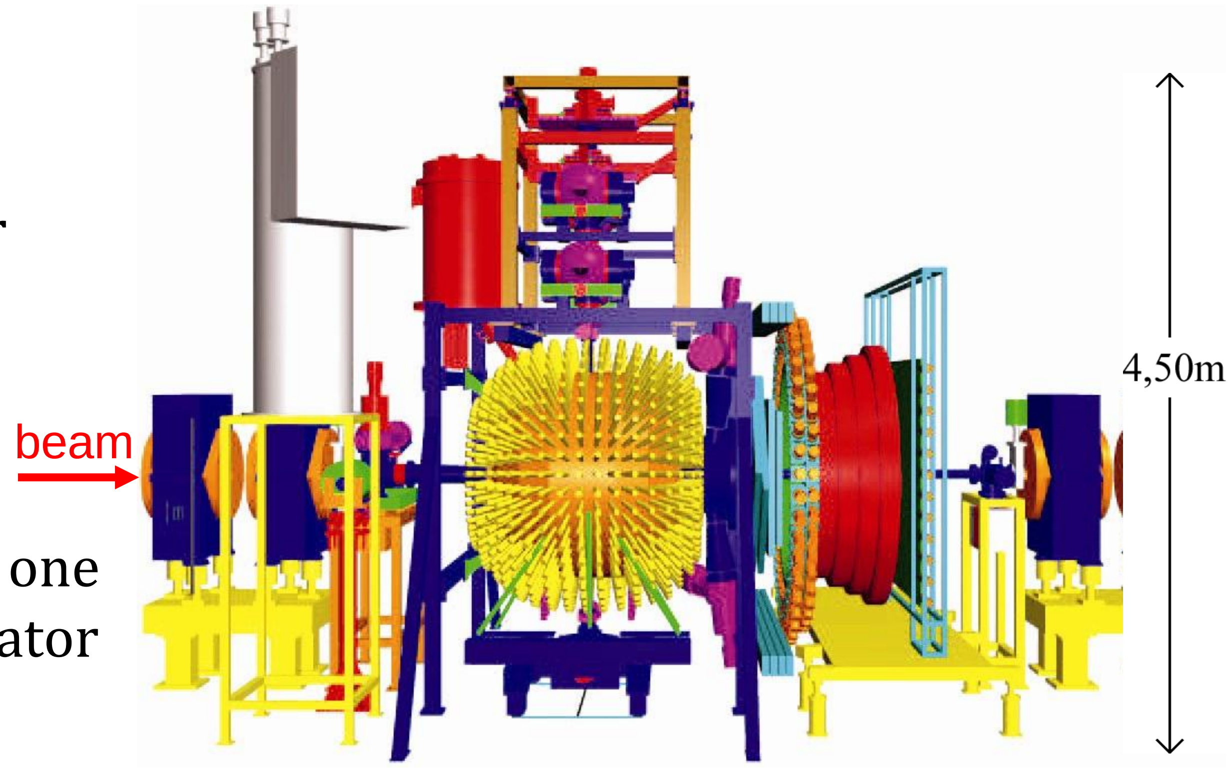
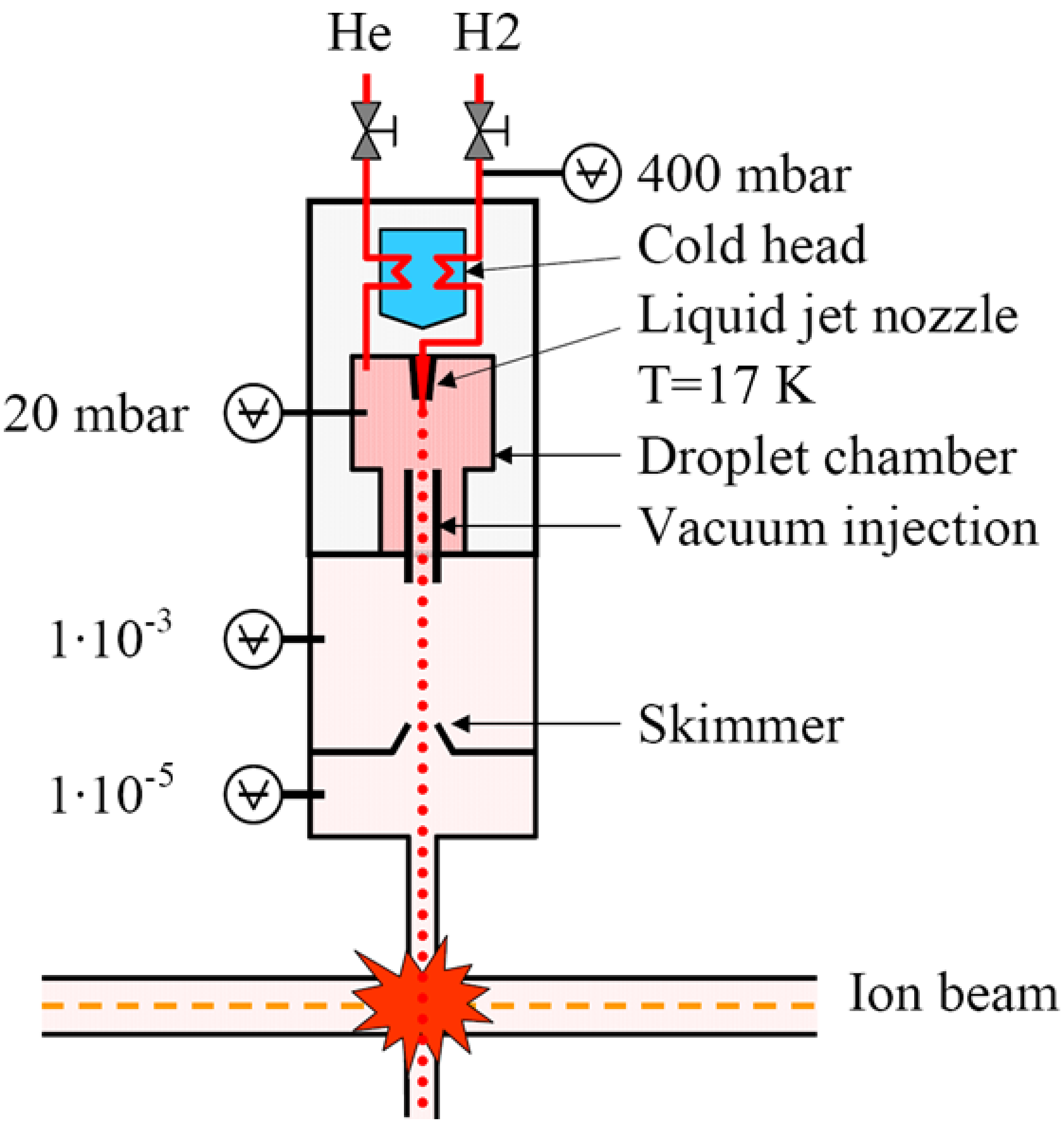
WASA – Wide Angle Shower Apparatus

- Constructed for production and decay studies of light mesons at the accelerator CELSIUS in Uppsala
- In operation at COSY accelerator in FZ Jülich since 2006
- Main components:
  - Forward detector
  - 4π central detector
  - Solenoid
  - Pellet target
- Pellet target: The only one operated at an accelerator

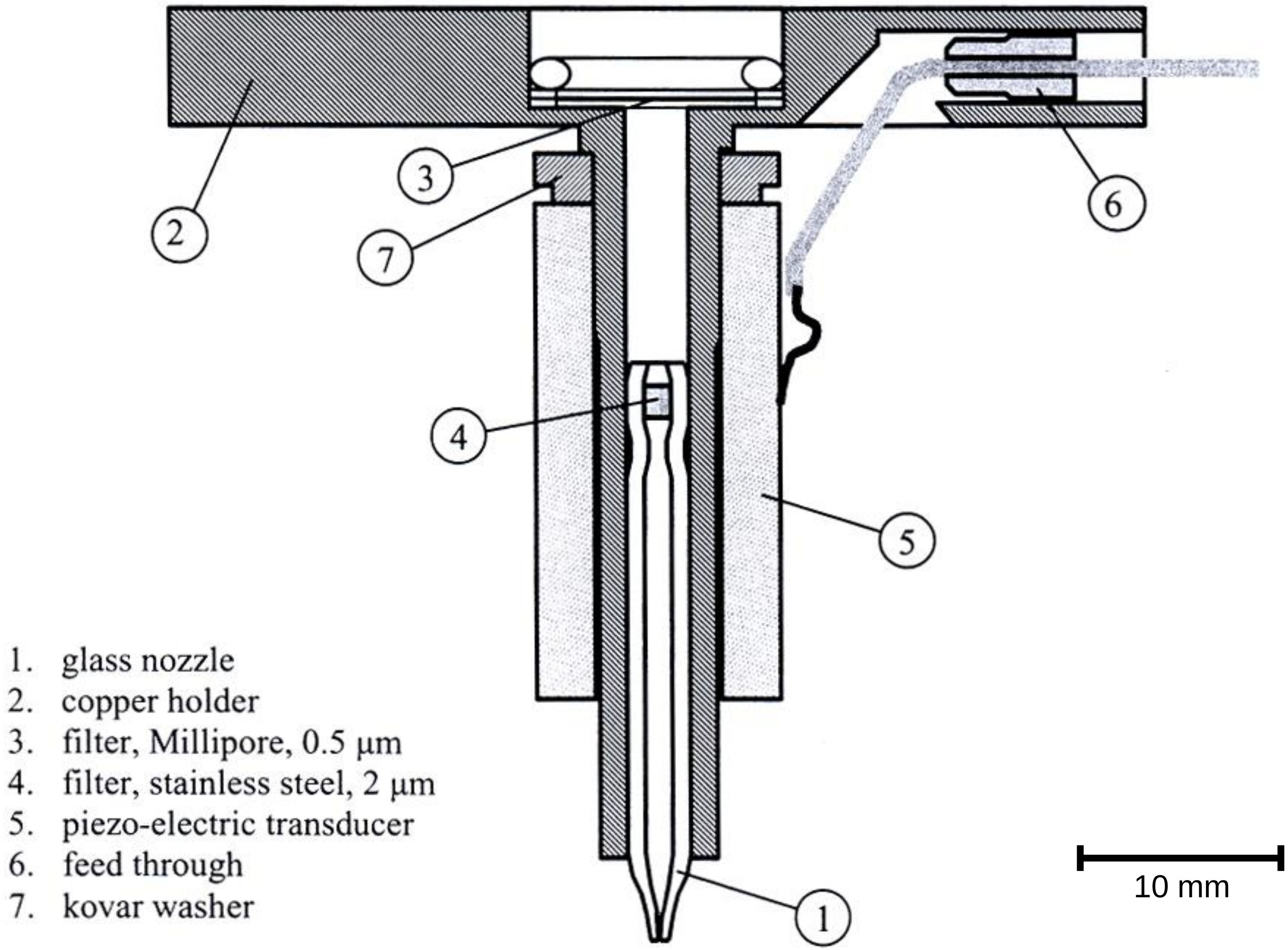


Pellet Target

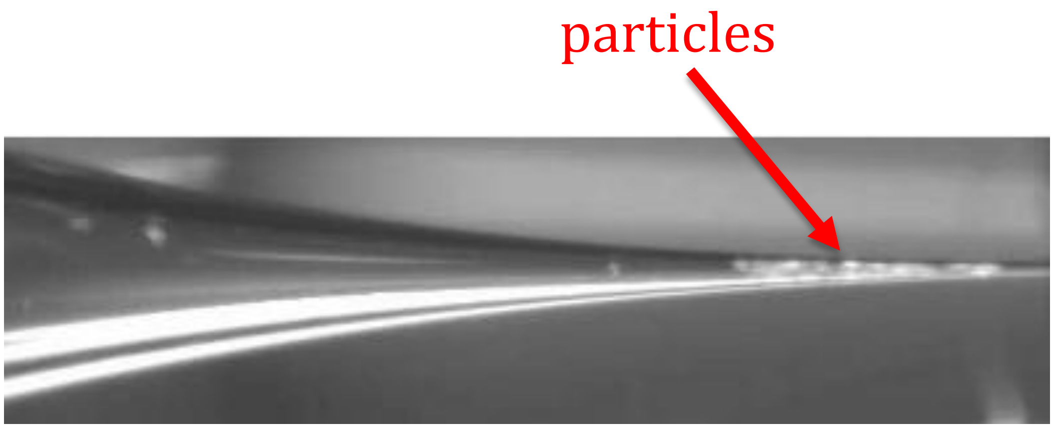


- Liquid hydrogen injected through nozzle into droplet chamber
- Droplet generation by piezo-electric transducer
- Vacuum injection via capillary tube
- Droplets freeze to pellets (Ø ≈ 25 µm) due to evaporation cooling
- Skimmer defines final pellet beam

Pellet Target – Nozzle



Nozzle Quality Assurance



- Lifetime limits of nozzles caused by:
  - Blocked nozzles
  - No working point for target operation
- Increase of lifetime improves the performance of the pellet target
- Nozzle production in FZJ including cleaning and quality checks already reduced nozzle blocking significantly

➔ Nozzle test station in Münster for additional quality and reliability checks before installation

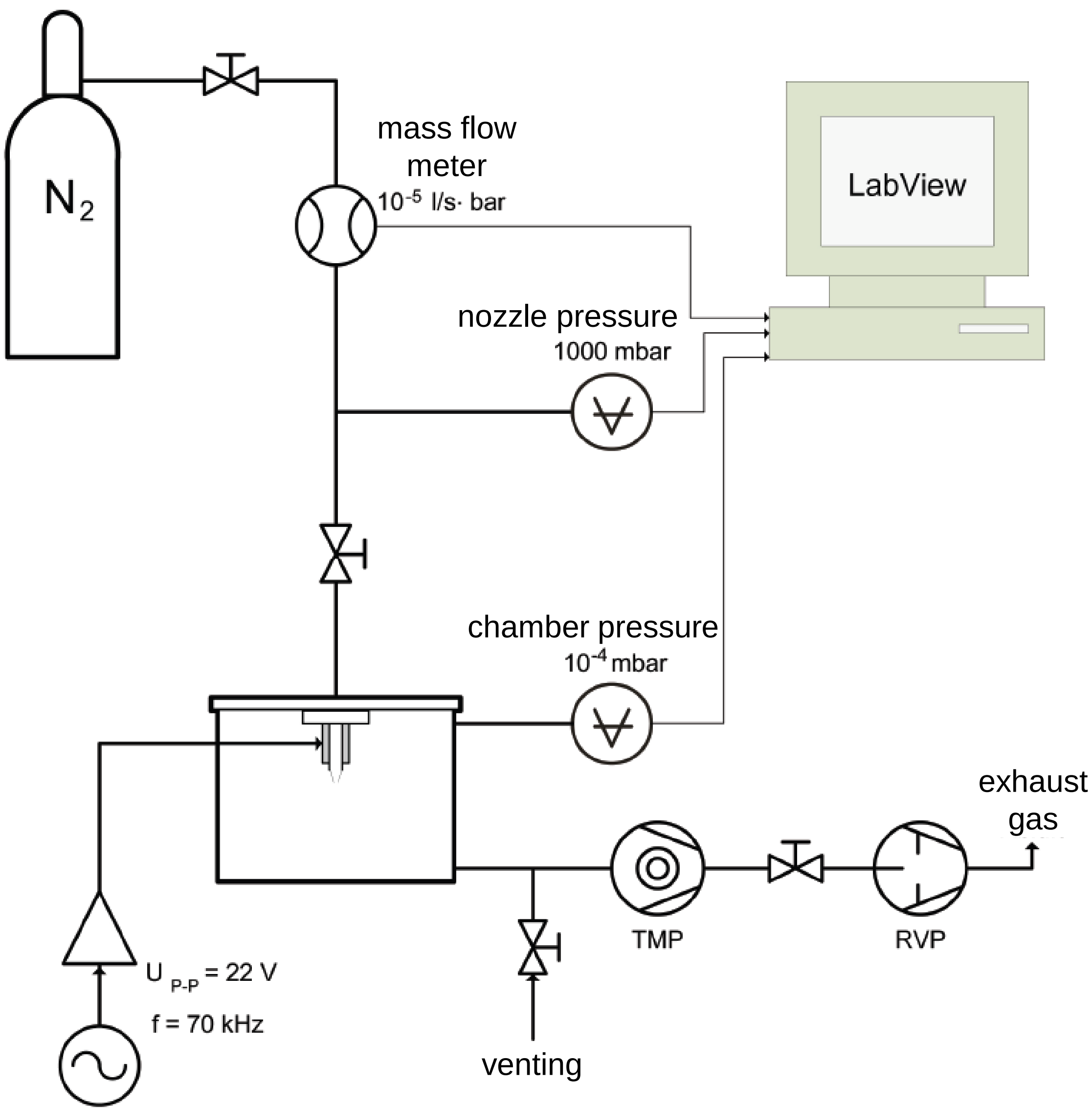
Investigation of Nozzle Blocking

- Possible reasons for nozzle blocking
  - Particle transport to nozzle tip by gas / liquid flow
  - Particles come off due to piezo vibration
  - Particles come off due to cryogenic temperature changes (300 K $\leftrightarrow$ 17 K)
  - Cryogenic liquid + piezo vibration: “ultrasonic bath effect”

➔ Stepwise approach to determine the responsible effect

- Here: Investigation of gas flow / piezo vibration

Nozzle Test Station Setup



Reliability tests:

- Nozzle gas flow test for one week without piezo
- Nozzle gas flow test for one week with piezo

➔ If the nozzle blocks, gas flow decreases to zero

- If not: installation in pellet target

- Results so far: nozzle, which passed two weeks test, was in target operation for two weeks without blocking

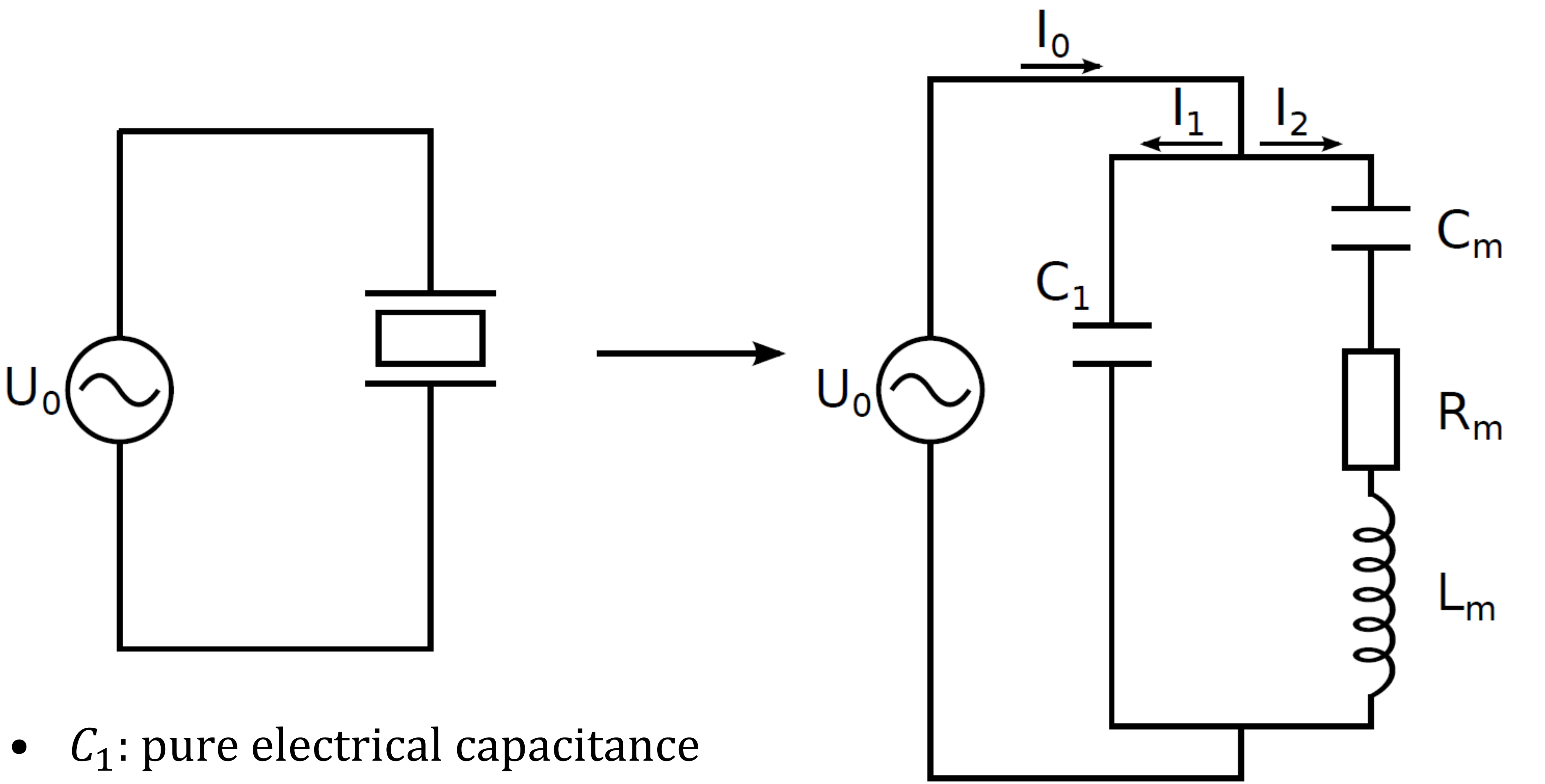
Pellet Target – Experiences

- Pellet target can only be operated at nozzle specific working points
  - ➔ Operation only possible at certain piezo frequencies which are temperature dependent
- Readjustment of the pellet target parameters are needed during the target operation

➔ Studies of the piezoelectric transducer coupled to the holder to understand these nozzle-holder unit specific characteristics

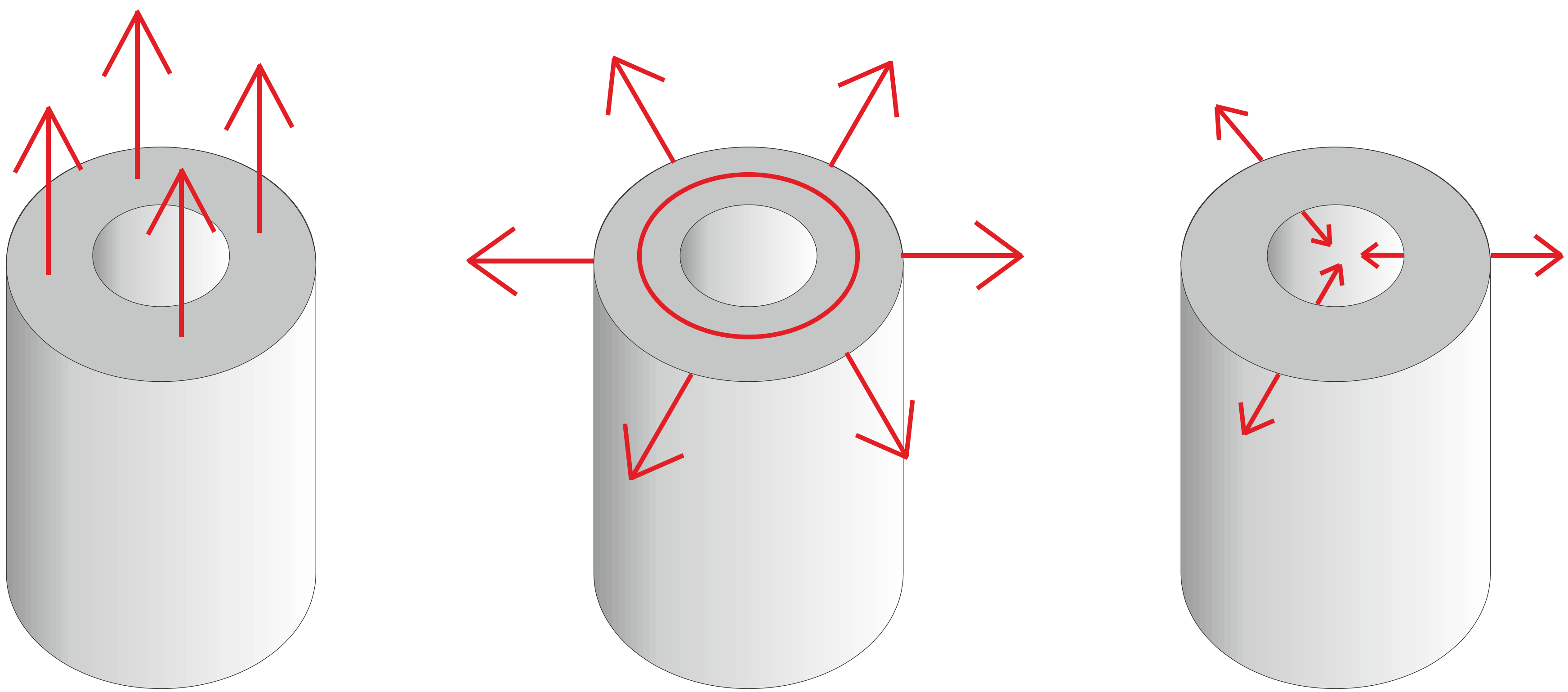
➔ If these properties are understood, changes to the WASA-at-COSY pellet target could be applied to improve the performance

- ➔ This is also interesting for future experiments like PANDA



- C_1: pure electrical capacitance
- X_m: description of the Piezo mechanic

  $R_m \leftrightarrow$ friction $C_m \leftrightarrow$ spring constant $L_m \leftrightarrow$ mass of the system



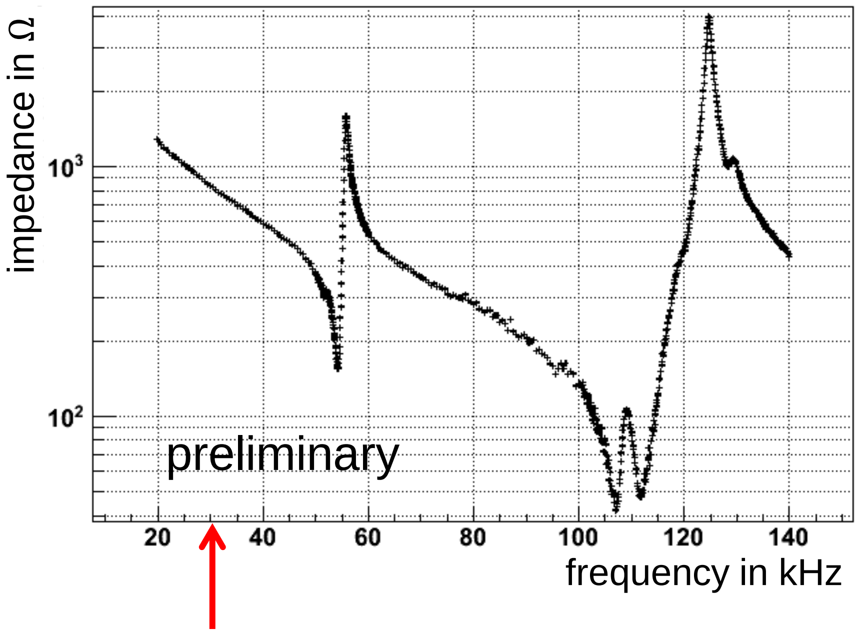
$f_l = (55.0 \pm 0.2)\text{kHz}$ $f_r = (99.5 \pm 1.1)\text{kHz}$ $f_t = (583.1 \pm 17.9)\text{kHz}$

- Three different modes possible: longitudinal (l), radial (r), thickness (t) oscillation

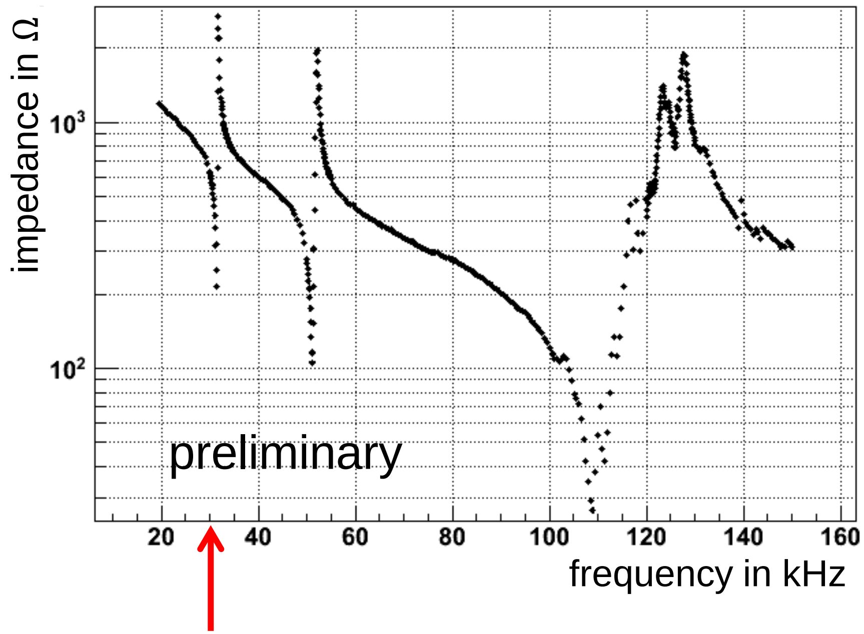
Impedance Measurements

- Resonances are measured via an impedance measurement

piezo



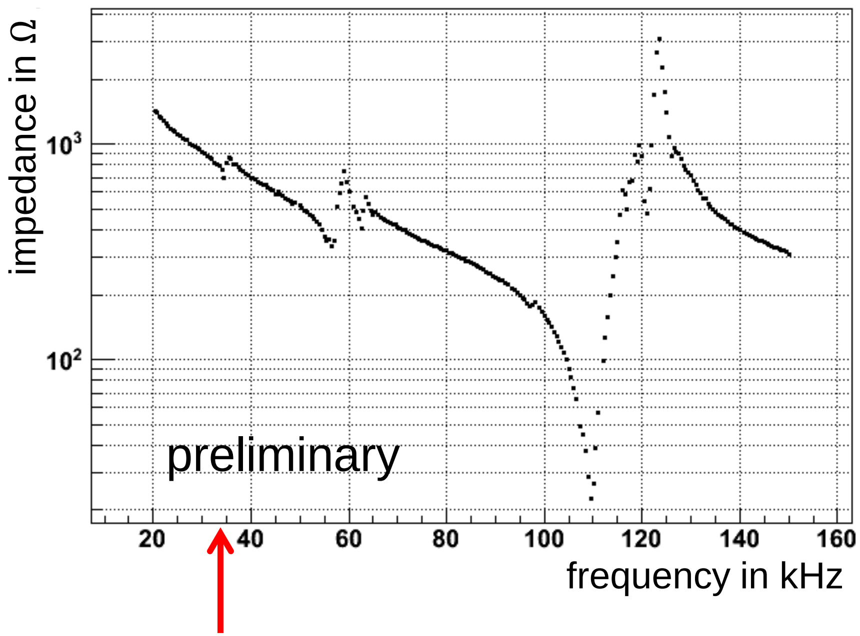
piezo mounted on holder (new)



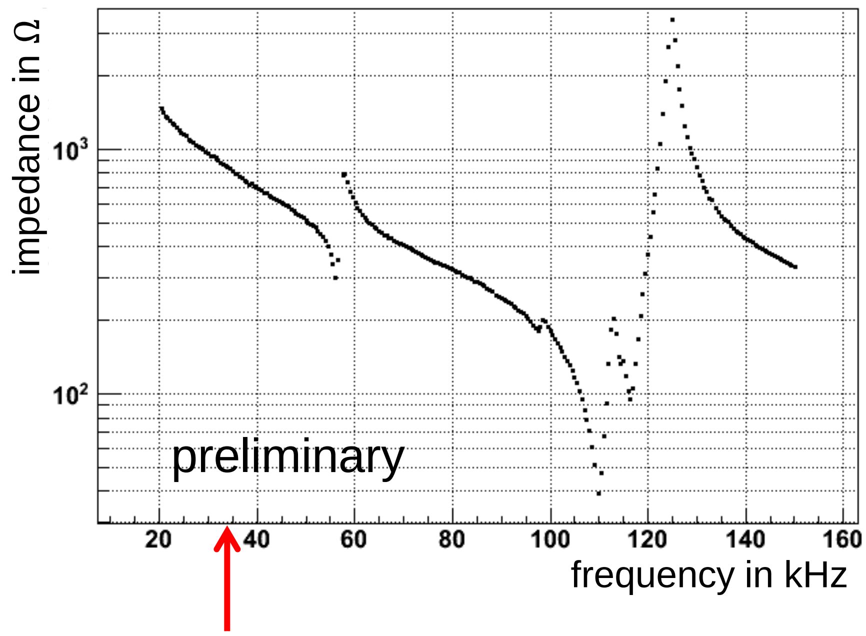
- Resonance at 50-55 kHz compatible with calculation
- Resonance at 105-110 kHz: possibly first harmonic
- Small resonance at 95-100 kHz compatible with calculation
- Additional resonance at about 30 kHz in coupled piezo-holder system

Impedance Measurements

piezo-holder unit no. 2

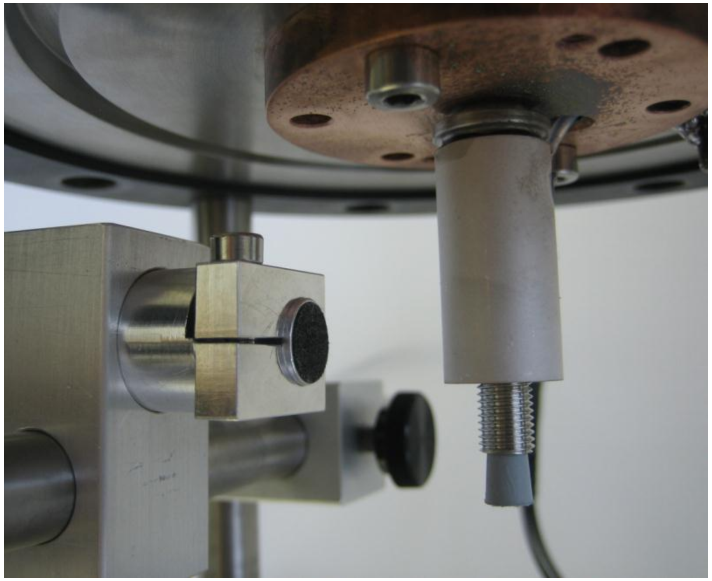


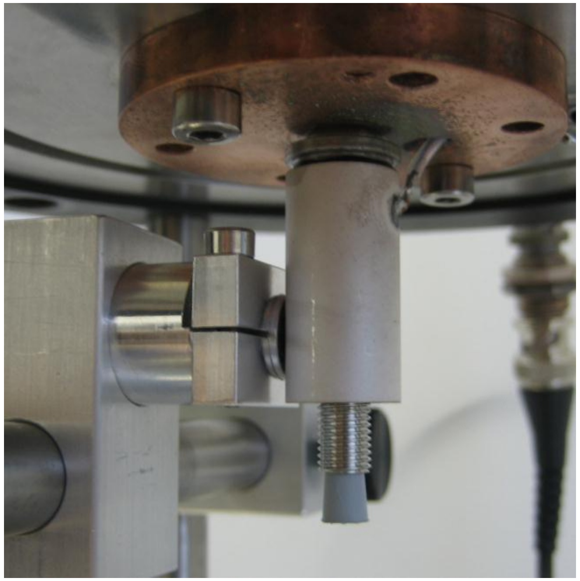
piezo-holder unit no. 8



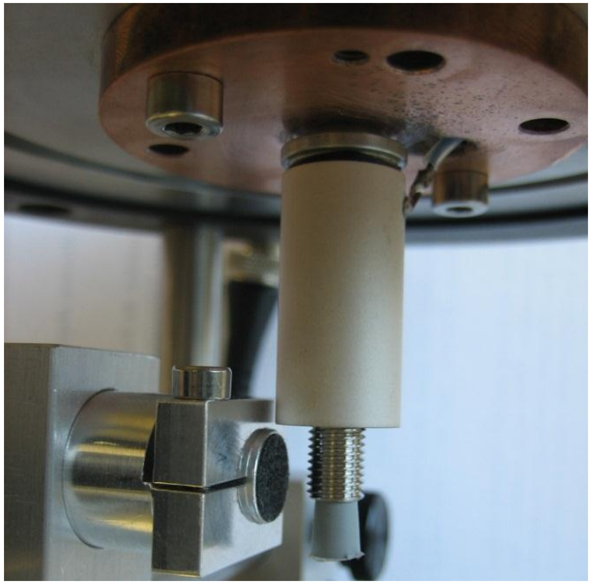
- Already used piezo-holder unit no. 2:
  - 30 kHz resonance significantly smaller compared to the new unit
- Piezo-holder unit no. 8:
  - 30 kHz resonance not visible at all
  - No working point during the last operation in the pellet target

Microphone Measurements

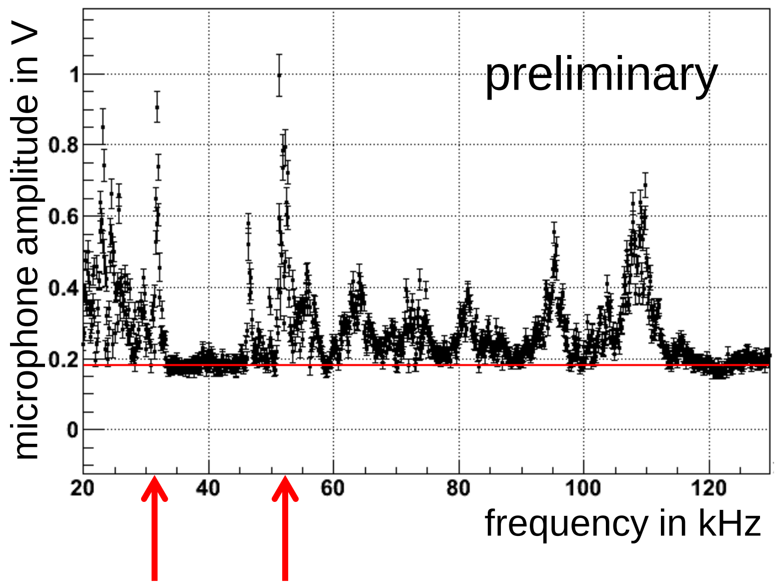




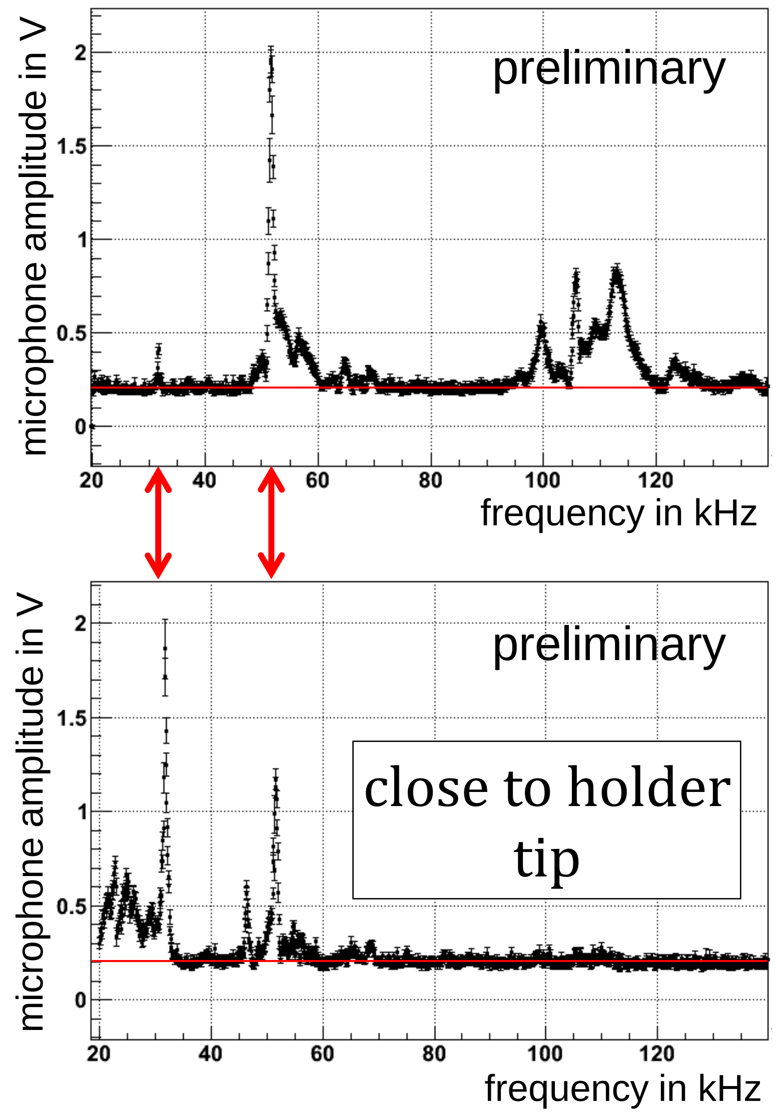
- Measurements of the resonances with microphone at three different positions:
  - A few centimeters beside the piezo
  - In contact with the piezo
  - Close to the holder tip



few cm beside piezo

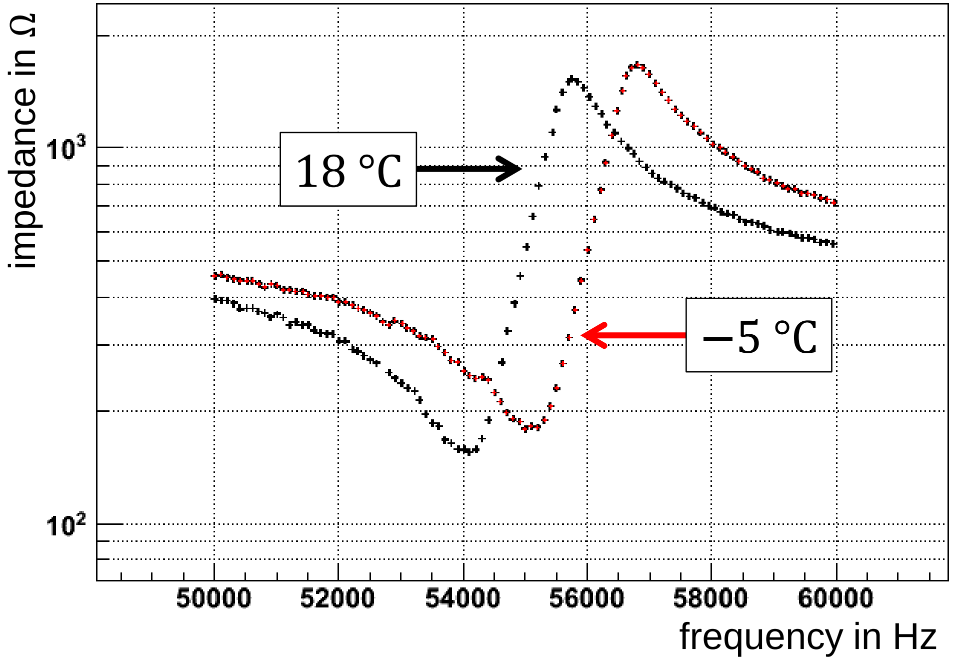


in contact with piezo



- 30 kHz resonance highest at holder tip, smallest in piezo contact measurement
- 55 kHz resonance always visible
- Signals measured only at certain frequencies

Temperature Dependency



- Measurement at room temperature and −5 °C:
  - Shift of 54 kHz resonance by (1357 ± 148)Hz expected
  - Shift by about 1100 Hz seen

Comparison to Pellet Target

- Expected shifts of the piezo resonances for operation at about 15 K:
  - Longitudinal mode: 55 kHz → 73 kHz:
    Delivers often the highest pellet rates
  - Longitudinal mode, first harmonic: 110 kHz → 128 kHz:
    Nice droplet beam observed
  - Radial mode: 100 kHz → 118 kHz:
    No definite statement possible
  - Nearly always nice droplets seen around 30 – 35 kHz, which is comparable to the seen piezo-holder unit resonance

Summary and Outlook

- Successful long term tests of nozzles: gas flow tests with and without piezo
  - If after passing the test a nozzle still blocks at WASA-at-COSY: Extend nozzle test station
- Effective droplet production only at certain frequencies
  - Piezo produces distinct resonance frequencies
- Quality check for piezo-holder units: Resonance at 30kHz

➔ Improvement of the pellet target performance

- Further improvement of pellet target performance (depending on the experimental needs):
  - Different piezo?
  - Change holder design?

➔ Additional frequencies for target operation