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Update on the PANDA Cluster-Jet Target Activities in Münster and at COSY

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PANDA collaboration meeting, June 14-18, 2021

Overview of different activities

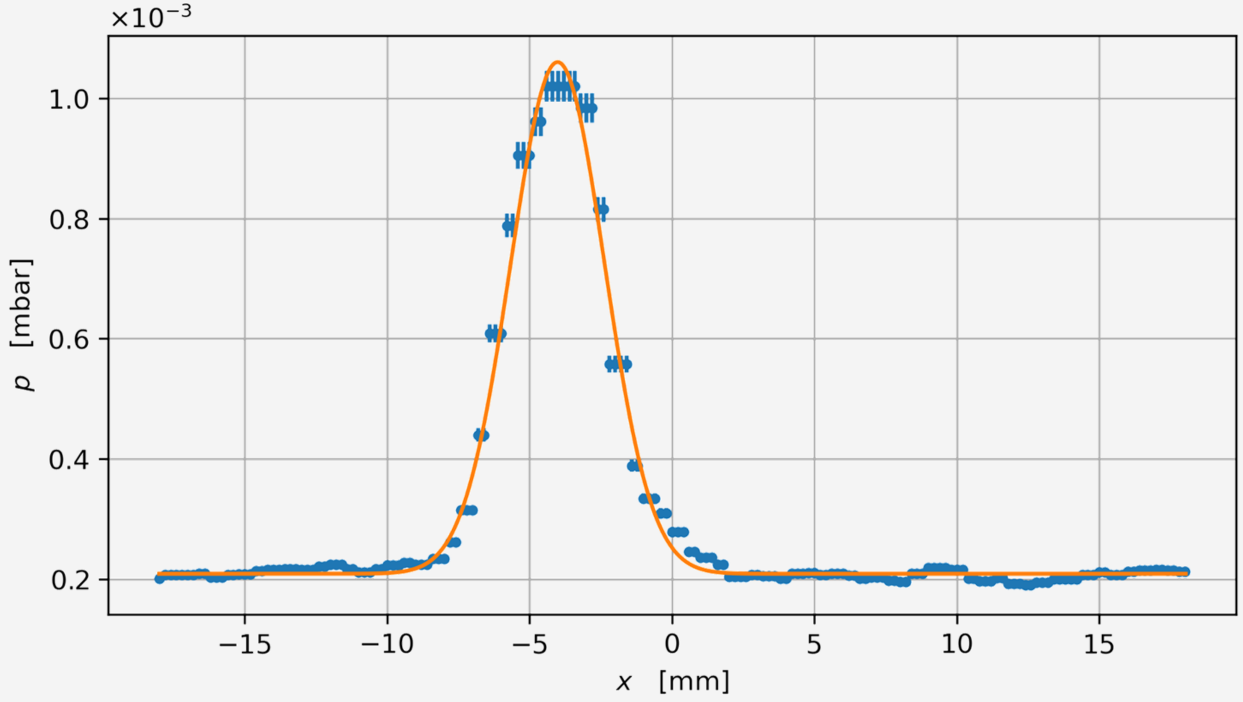
- Recent beam time at COSY in Jülich
  - Analysis of beam time results (P. Brand)
  - Simulation of beam dynamics with target interaction (H. Eick)
- Simulation of vacuum situation and cluster evaporation (B. Hetz)
- Studies on nozzle production, cluster formation, cluster velocity and cluster size distribution (S. Vestrick, M. Weide, C. Fischer and H. Eick)
- Development of a new beam dump with monitor systems (P. Brand and N. Humberg)
- Development of a cryopump for PANDA (C. Mannweiler and J. Runge)

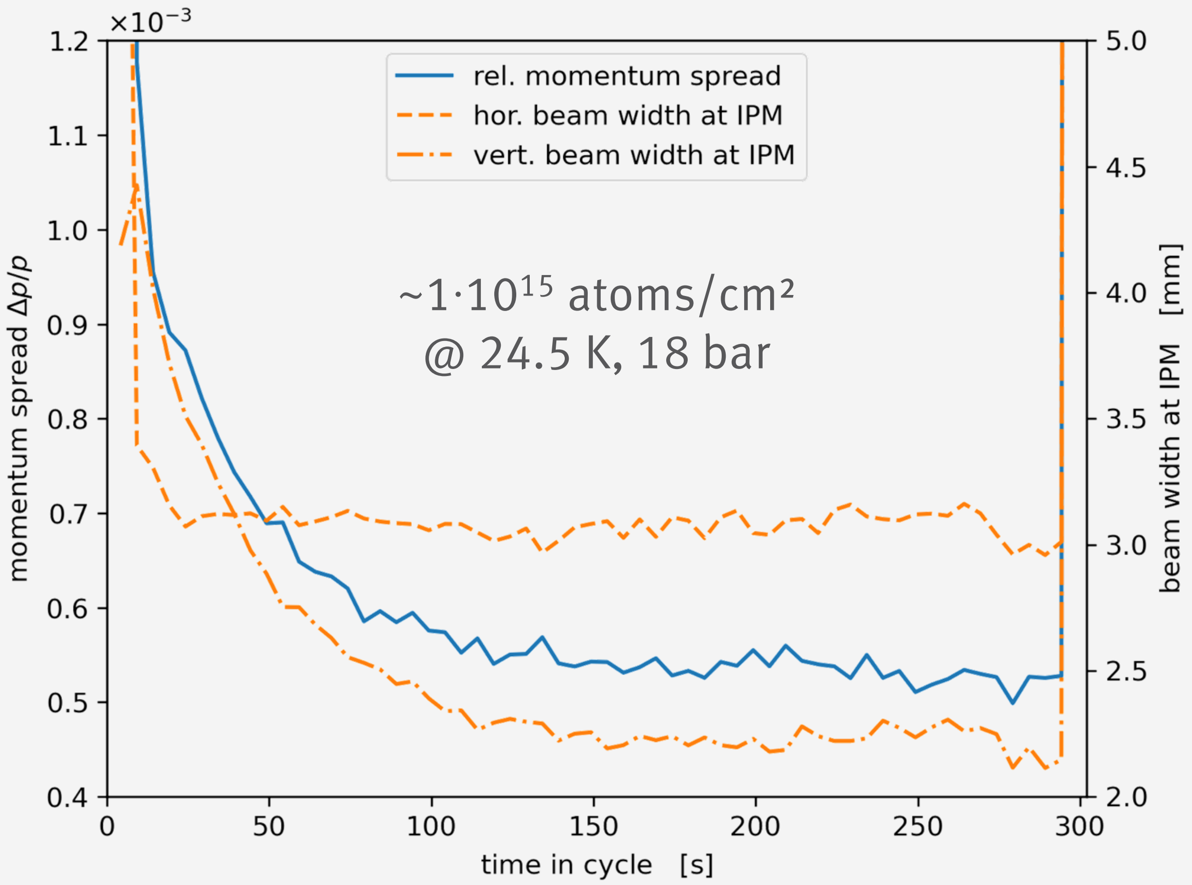
Beam time at COSY

- PANDA target is installed at COSY close to PANDA geometry
- Target influence on the COSY beam was studied in combination with stochastic cooling at 3.0 GeV/c
    - Measurement of beam lifetime and beam quality (momentum spread, beam size, …)
    - Different target thicknesses ($1 \cdot 10^{13}$ - $2.5 \cdot 10^{15}$ atoms/cm²)
    - Different proton beam intensities ($2 \cdot 10^{9}$, $5 \cdot 10^{9}$ and $1.5 \cdot 10^{10}$ stored protons)
    - Stochastic cooling was optimized for every setting (necessity was seen last beam time)
- Pion production at 800 MeV/c with different target thickness
    - Influence of target on physical data quality, measured with WASA FD

Beam time at COSY

Target profile @ 23 K, 18 bar
→ $2.5 \cdot 10^{15}$ atoms/cm² at IP





Simulation of beam dynamics with target interaction

MAD-X for simulating COSY ring

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Target simulation consisting of energy loss and small-angle scattering

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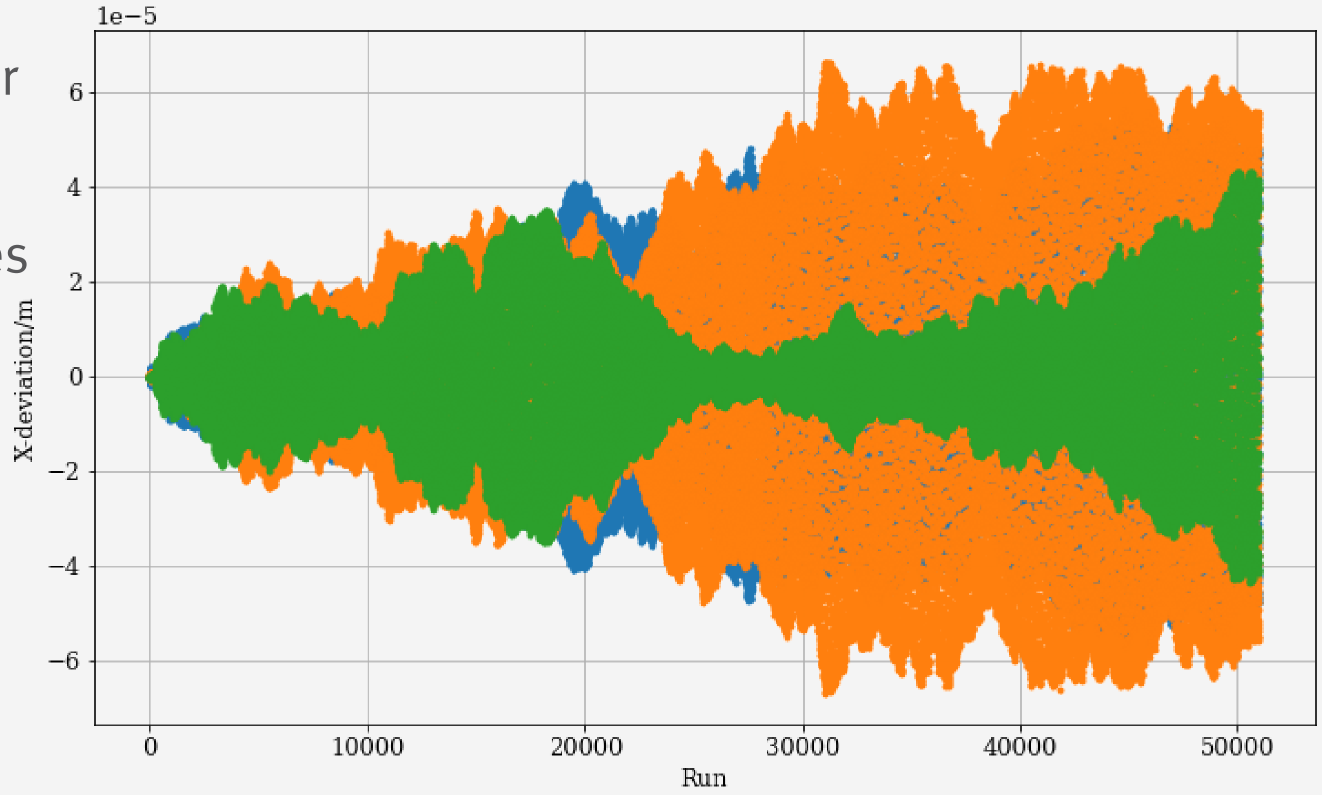
Compare beam expansion in vertical & horizontal directions and beam lifetime with measured cycles

Simulation of beam dynamics with target interaction

- Horizontal position referred to the ideal orbit for ~ 50000 runs
- 3 simulated particles with random energy losses & small-angle scatterings in each turn
- Starting point: reference orbit with reference momentum



Simulation of beam dynamics with target interaction

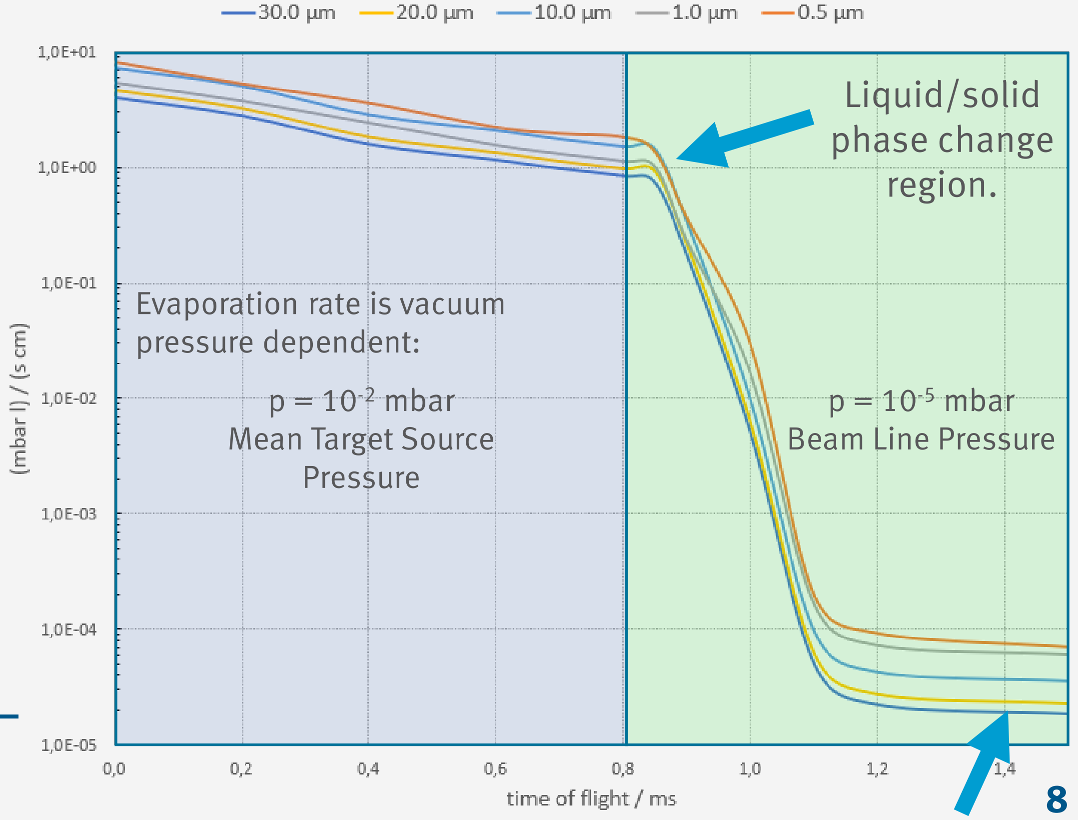
- During beam time various measurements were made, which are currently being simulated:
  1. Beam momentum of 3 GeV/c
  2. Beam momentum of 3 GeV/c + target on
  3. Beam momentum of 3 GeV/c + target on + HF on (+different voltages)
  4. Beam momentum of 3 GeV/c + target on + Barrier Bucket on
- Further steps: Predictions about the influence of the beam-target interaction on the circulating antiproton beam at HESR

Residual Gas Studies of Pellets and Clusters

- Measurements showed:
  PANDA Cluster-Jet cluster sizes are kind of 'tiny pellets'
  - Similar behavior of pellets and clusters in vacuum
  - Calculations of evaporation of liquid/solid droplets
- Assumption:
  - Sphere diameter › 10 µm: Single droplet train
  - Sphere diameter ‹ 10 µm: Target spot size in PANDA Jet geometry

→ Constant gas flow given by evaporating spheres inside PANDA jet beamline

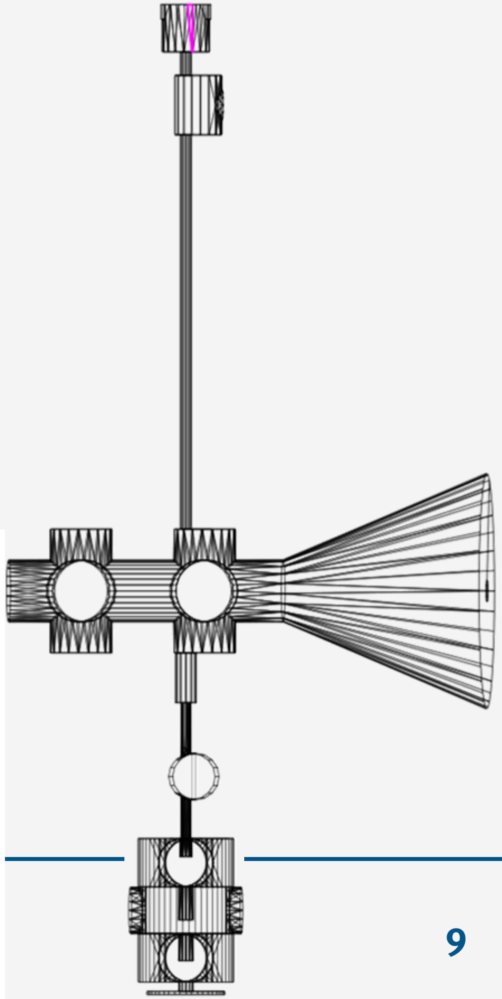
Gas flow of fixed target thickness but different sphere sizes



Constant gas flow near IP region

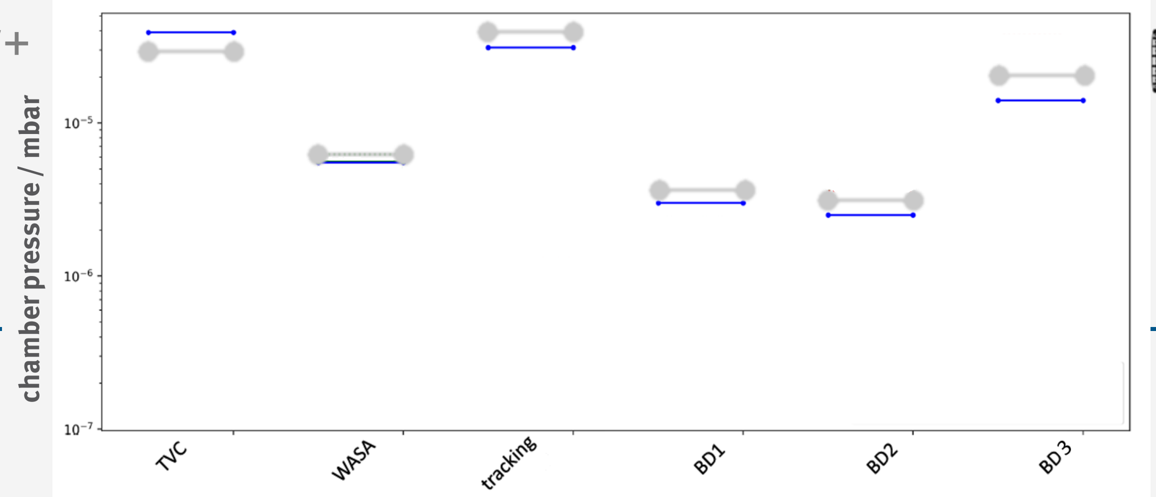
Residual Gas Studies of Pellets and Clusters

Molflow+ WASA/COSY model



- Molflow+ gas simulation:
  - with a detailed model of the COSY vacuum system incl. the jet beam line
  - with non simple pipe conductions, but Monte Carlo simulations
  - with results from residual gas calculations for target evaporation

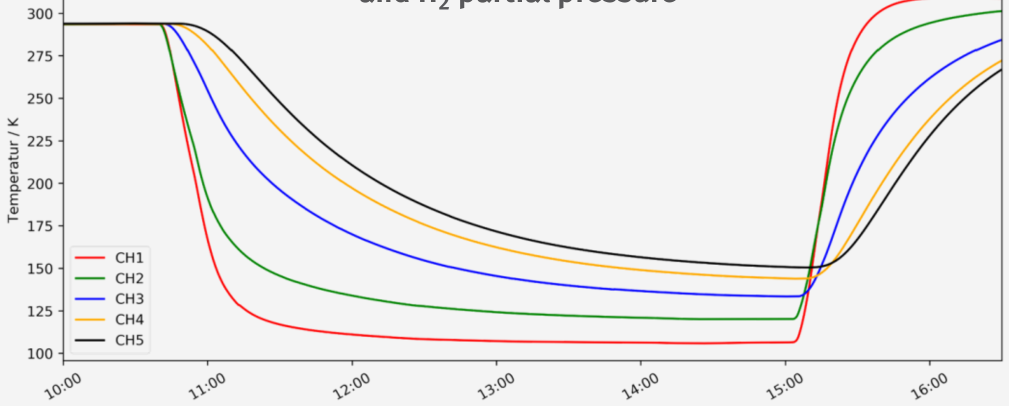
→ Good agreement of directly measured pressures at WASA/COSY and simulation results from Molflow+

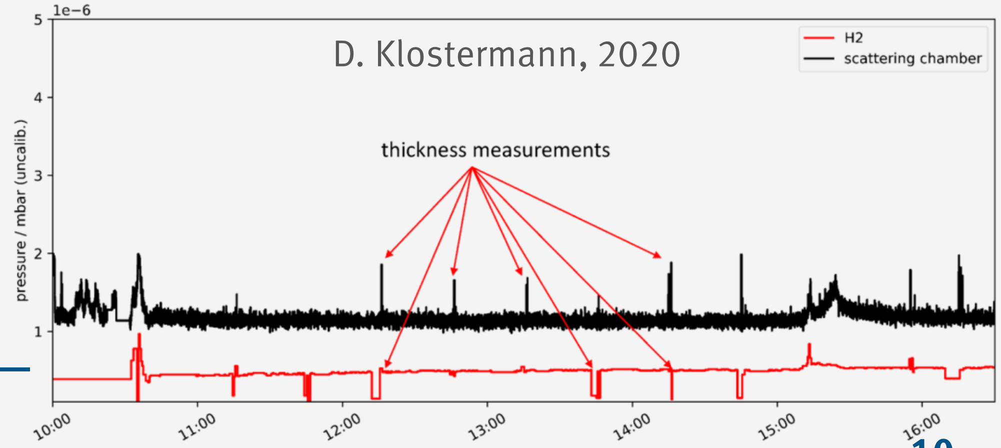


Residual Gas Studies of Pellets and Clusters

- Does the ambient temperature influence the sphere evaporation rate?
    - Studies done by former Master student at Münster Prototype target with a nitrogen cooled cluster-jet pipe, 1.2 m length before IP
    - Sphere evaporation calculations done with an assumed 300 K, 77 K and 4 K jet pipe.

Temperature change of jet pipe, and correpsonding change in absolute, and H_2 partial pressure

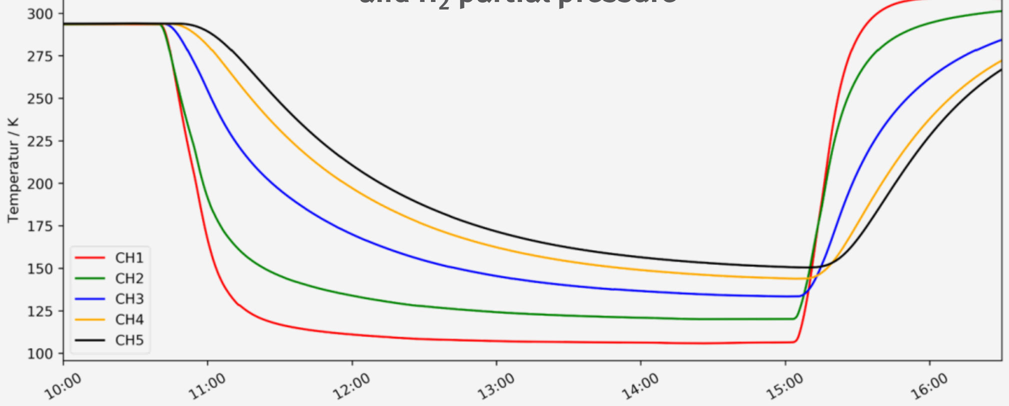


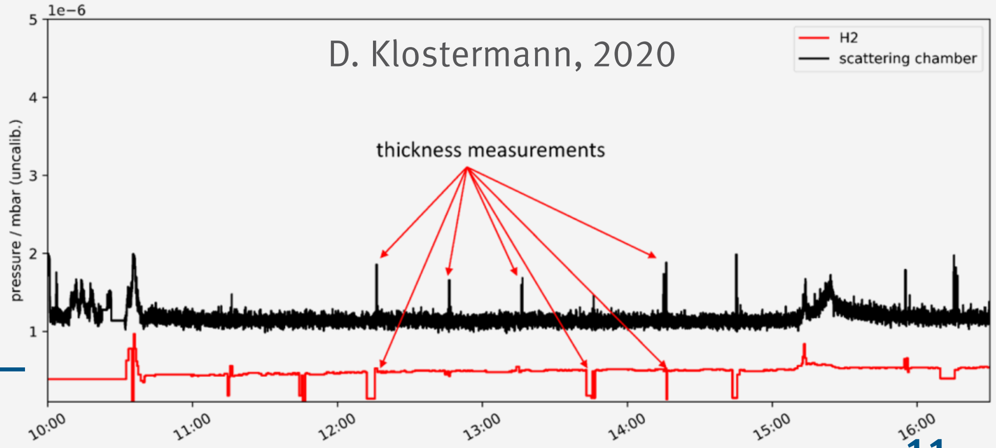


Residual Gas Studies of Pellets and Clusters

- Effects theoretical present. But minimal calculated effects for the 77 K do not justify a much more massive, cooled jet beam pipe. Furthermore, no positive effect directly visible at PANDA prototype.
- A 4 K beam pipe would theoretically improve the vacuum. Anyhow, a 4 K pipe would also work as cryopump, which would have a bigger effect

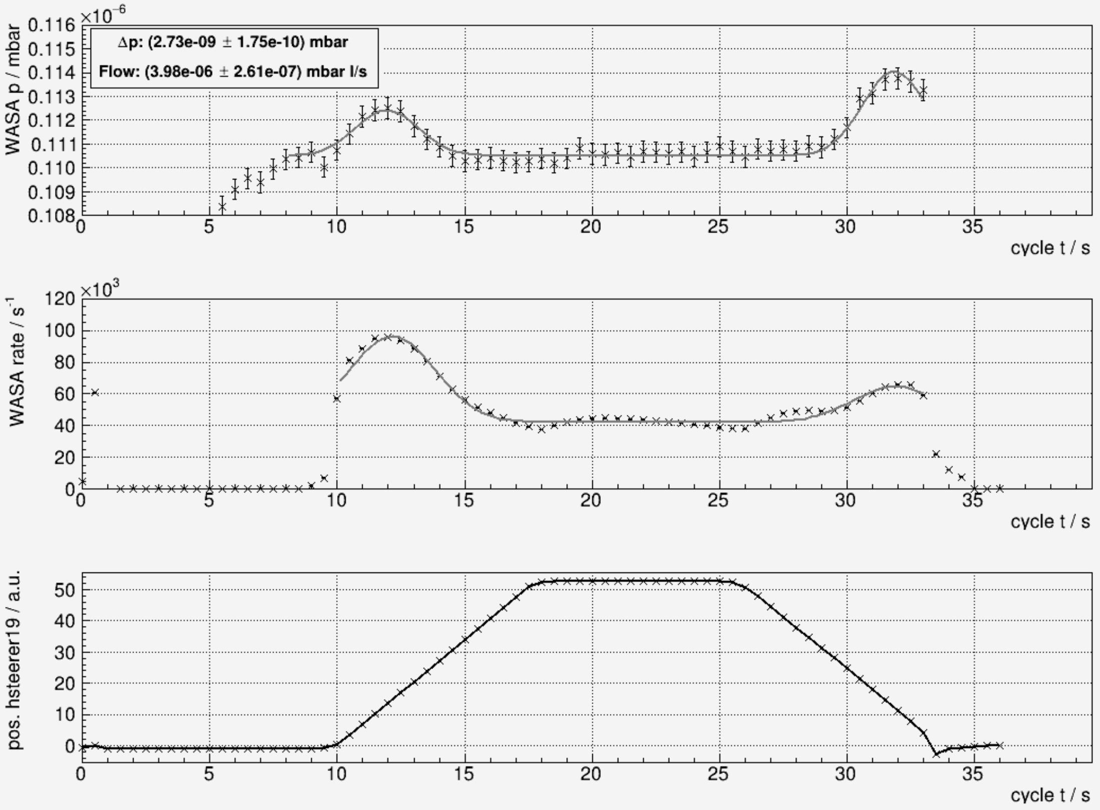
Temperature change of jet pipe, and correpsonding change in absolute, and H_2 partial pressure





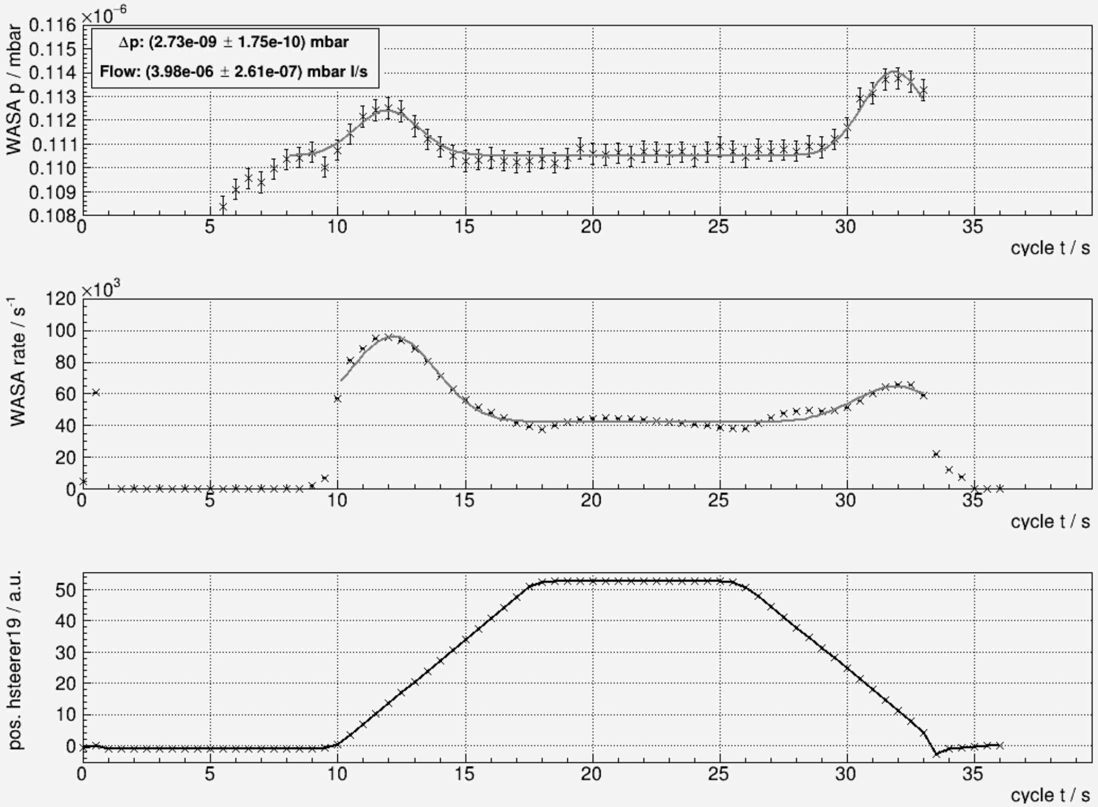
Residual Gas Studies of Pellets and Clusters

- Cluster evaporation by beam-target interaction seen at COSY:
  - Effect only visible for thin target (≈10^{13} atoms/cm²)
  - Pressure increase shows that only a fraction of deposited energy is used for evaporation
- Ion beam induced evaporation is not dominating for PANDA CJT operation



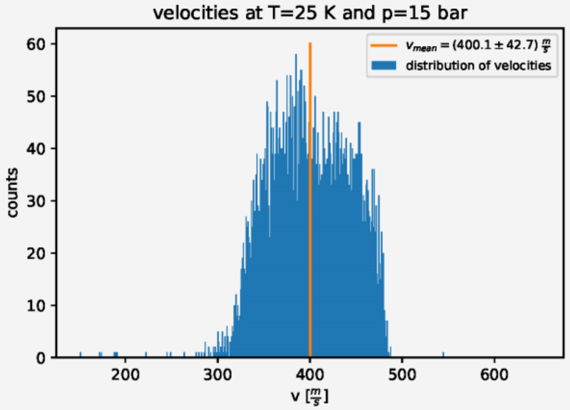
Residual Gas Studies of Pellets and Clusters

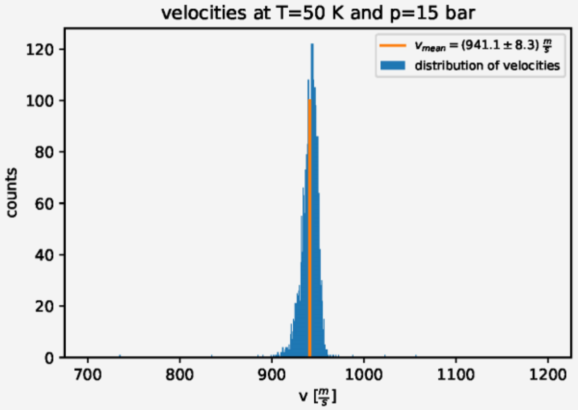
- Nevertheless, understanding important, e.g., for highest beam currents and big clusters/droplets
- Most energy escapes clusters via δ-electrons
  - Integration of energy deposition and escaping δ-electrons energy to cluster evaporation studies recently started
  - Simulation results can be checked with given COSY measurements



Further Measurements ongoing

- Galvanization process of copper nozzles is under further development
  - First improvements achieved, further optimizations in testing
- Investigation on cluster formation in dependence of stagnation conditions concerning velocity distributions
- Determination of cluster-size distribution
  - Shadowgraphy measurements in preparation





Conclusion

- Recent beam time at COSY with stochastic cooling finished successfully
  - Target thickness of up to $2.5 \cdot 10^{15}$ atoms/cm² reached
  - Results will be compared to MAD-X simulation → can be transferred to HESR simulations
- Detailed simulations of vacuum situation and cluster evaporation ongoing
  - Simulation are in very good agreement with measurements, evaporation is main contribution
- Studies on nozzle production, cluster formation and cluster size distribution ongoing