Beam-Jet Interaction and Vacuum Effects from 08/2019 COSY Beam Time

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GSI Darmstadt, Germany

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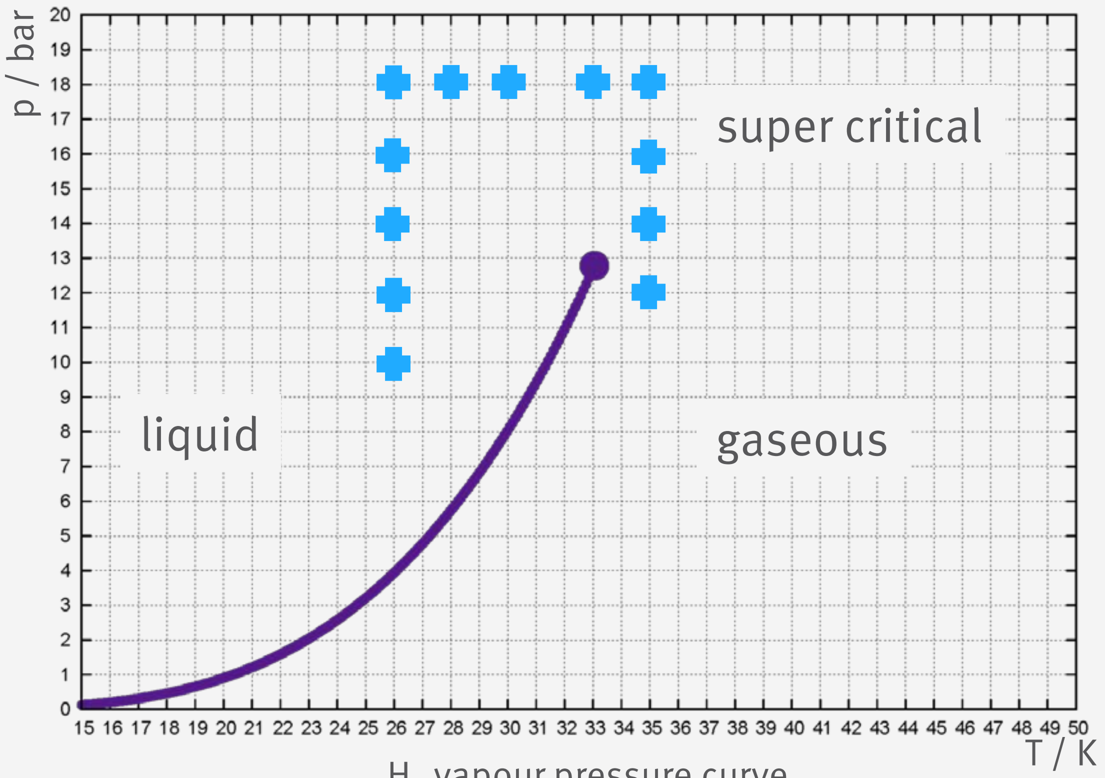
Measurements 08/2019 @COSY

- 2 isotherm, 1 isobar measured:
  - ➢ Different cluster sizes
  - ➢ Different cluster production processes
  - ➢ Systematic measurements:
    - signal/background ratio, residual gas, detector answers, cooling performance, long./trans. momentum spread, …
    - Everything in dependence of 3 p beam currents
      - ~ (2×10^{10} / 0.6×10^{10} / 0.3×10^{10}) protons
- First time: Systematic stochastic cooling measurements possible

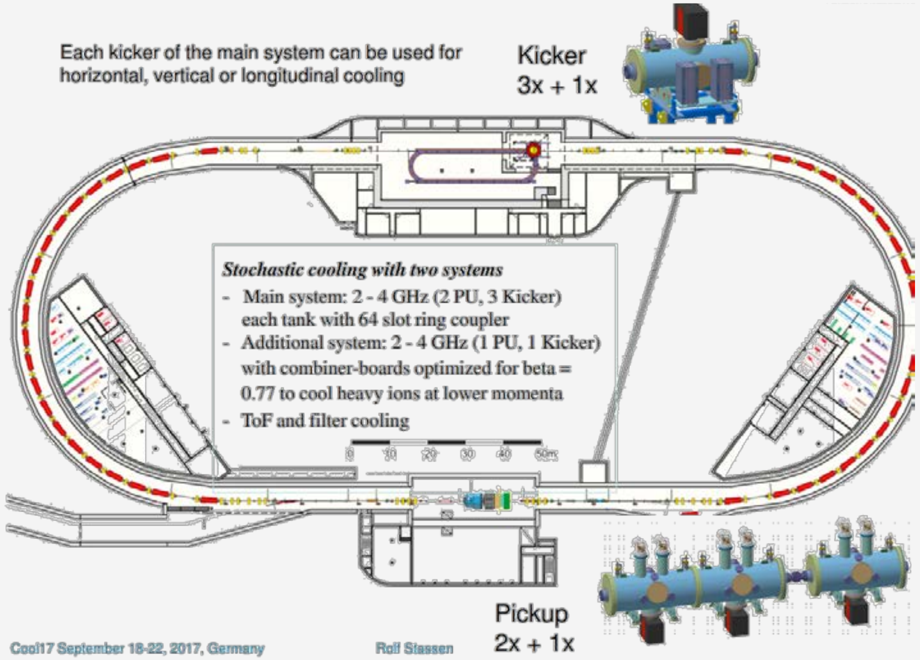
➢ Analysis ongoing, first results shown in the following

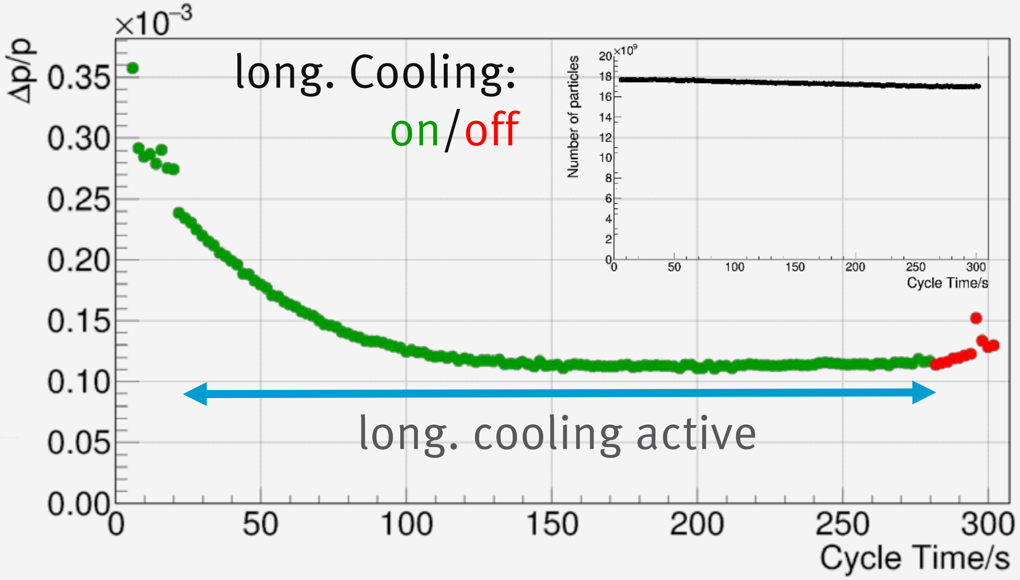


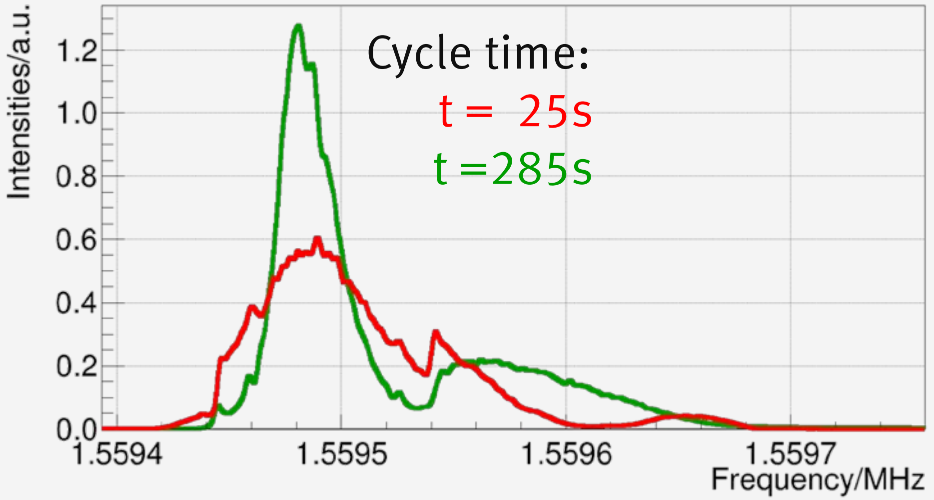
H_2 vapour pressure curve

Lateral Momentum Cooling

- Target: 5.2 x 10^{14} atoms/cm^2
- Barrier bucket and longitudinal cooling active
- ‹ 5% particle loss in 300s, 1.7 x 10^{10} protons injected
- dp/p = 1.2 x 10^{-4}
- COSY:
  1 x Kicker/ 1 x PU
- ➢ HESR:
  3 x Kicker /2 x PU

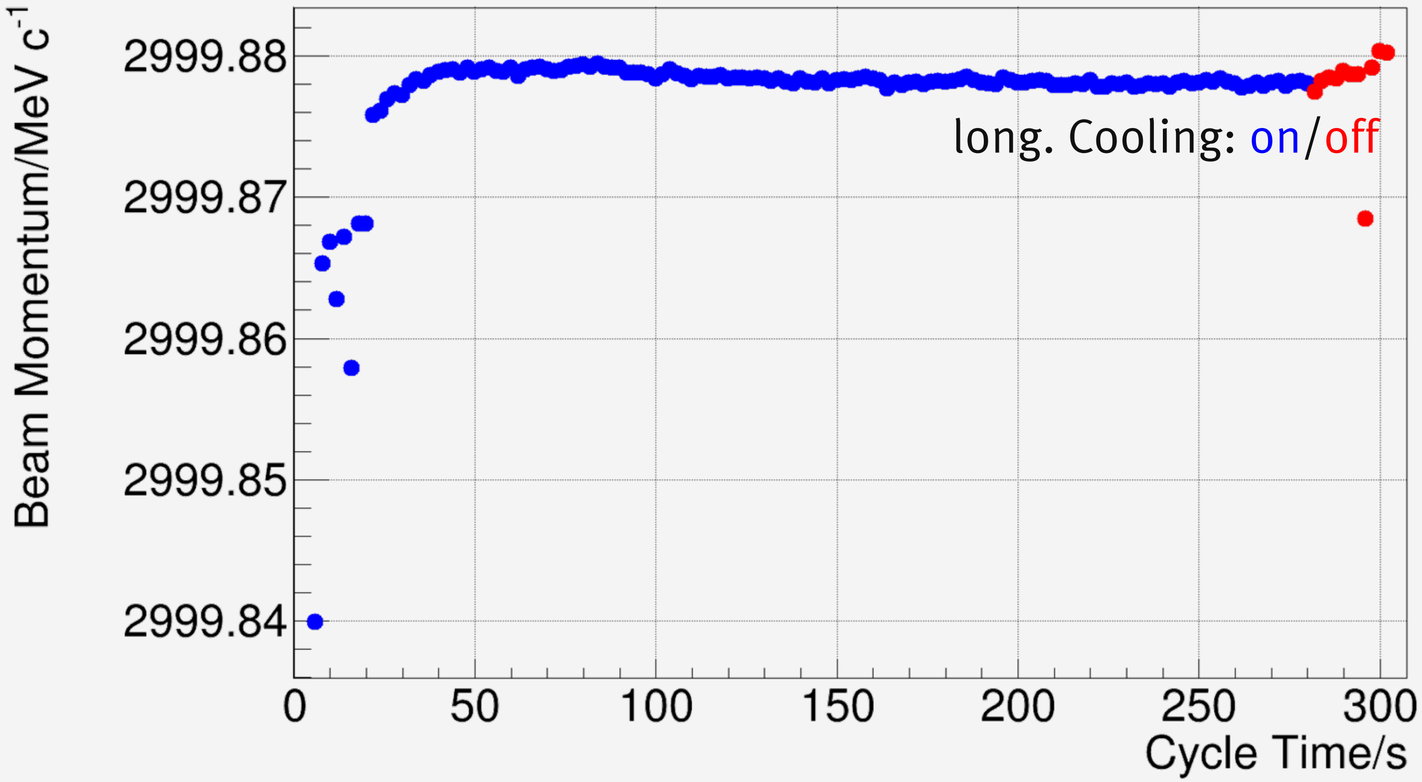






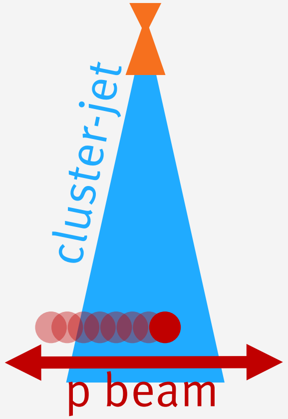
Momentum Stability

- Measured in August 2019 @COSY:
  - Target: 5.2×10^{14} atoms/cm^2
  - COSY: 1.7×10^{10} protons (~HR)
  - Momentum spread:
    dp/p = 1.2 x 10^{-4}
  - Mean momentum accuracy :
    $\delta p/p = 1.4 \times 10^{-7}$
- Assumed in [1] for resonance scans:
  - Total momentum spread:
    dp/p = 1×10^{-4} (HL) / *2×10^{-5} (HR)* / 5×10^{-5} (P1)
  - Accuracy in relative beam adjustment: *$\delta p/p = 10^{-6}$*
  - ✓ We are on a good way!



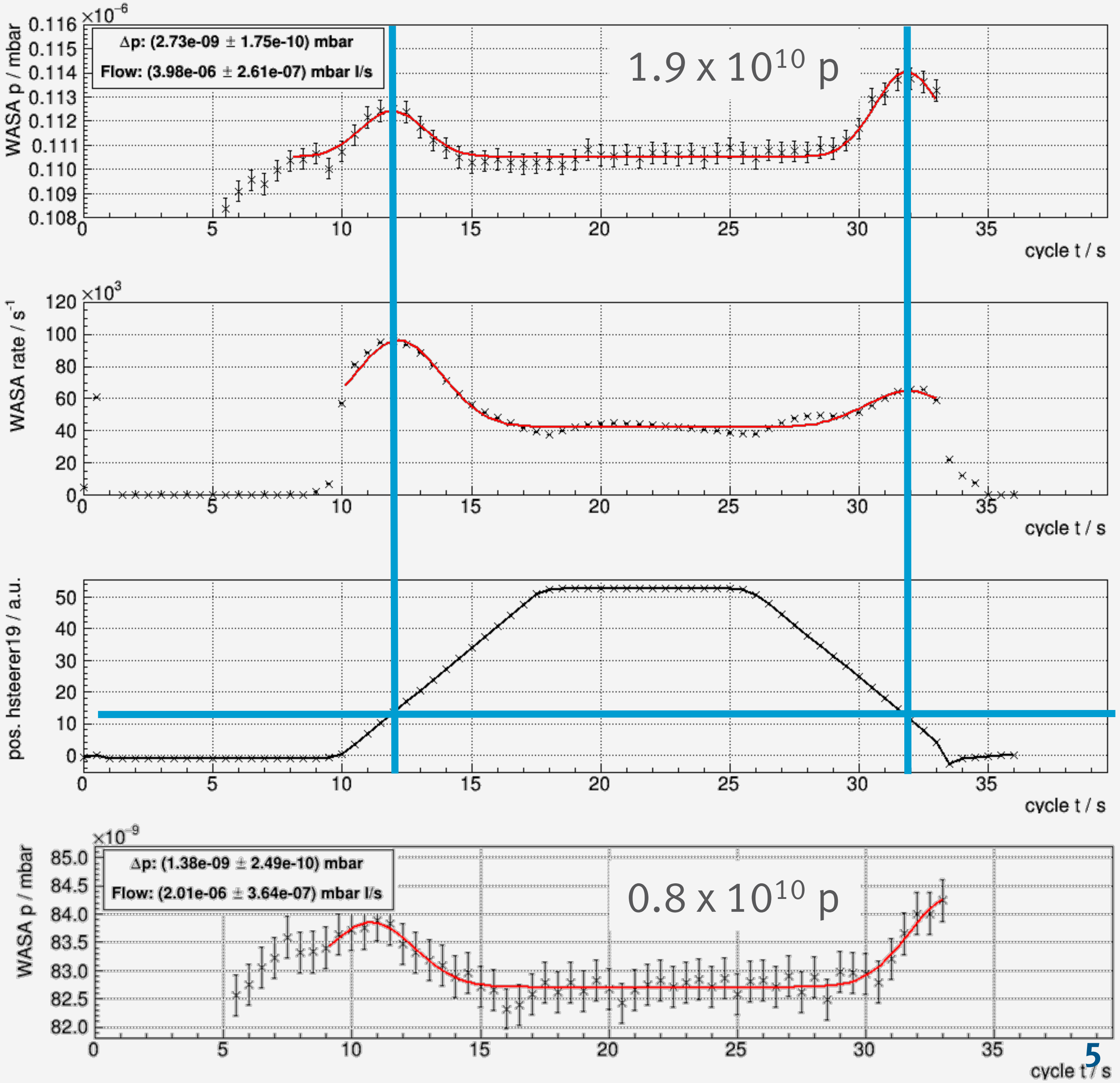
[1] Precision resonance energy scans with the PANDA experiment at FAIR, Sensitivity study for width and line shape measurements of the X(3872), DOI 10.1140/epja/i2019-12718-2

Cluster Evaporation



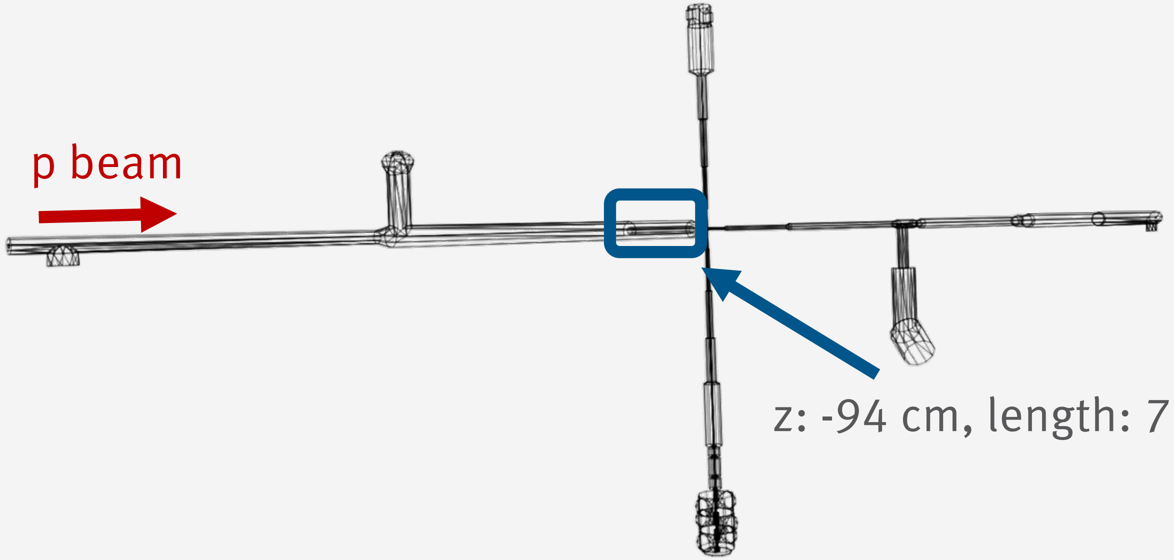
- Proton beam horizontal wobbling over cluster-jet
- Target thickness of 1 x 10^{13} atoms/cm^2 (very difficult to see at higher thicknesses)
- During beam-target overlap:
  - Increase in pressure and detector rates
  - Dependence of p beam current
- Bethe-Bloch, target thickness, pressure increase, pump configuration:
  - ➢ Cluster bonding energy: O(van der Waals)
- ➢ Analysis ongoing
- ➢ Need to have a closer look into in upcoming beam times

Beam-Jet Interaction and Vacuum Effects from 08/2019 COSY Beam Time

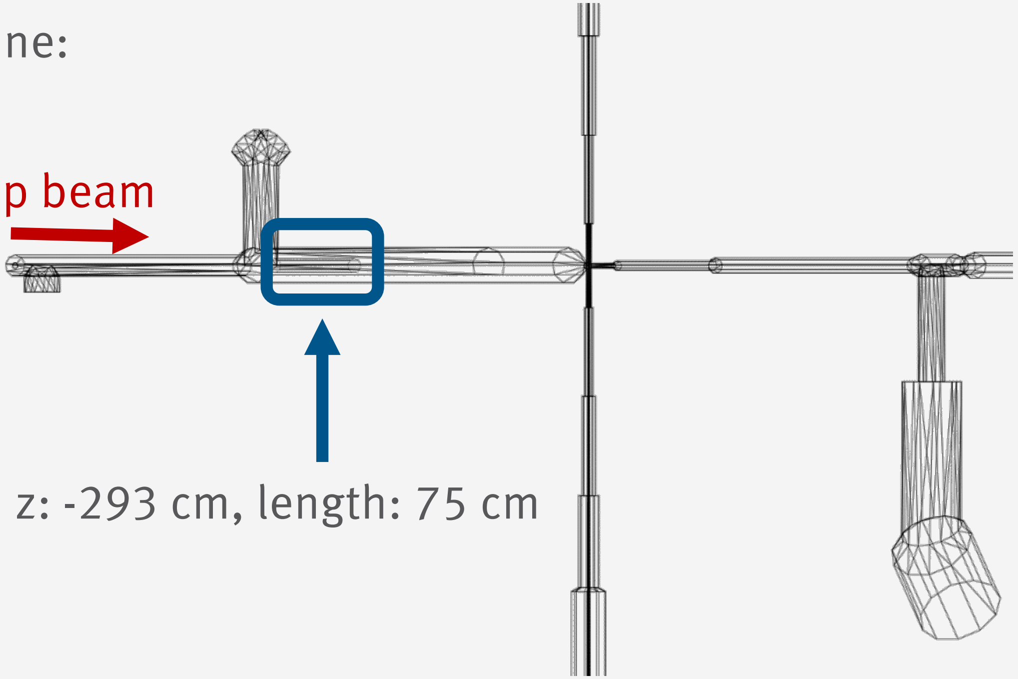


Vacuum Optimization at IP

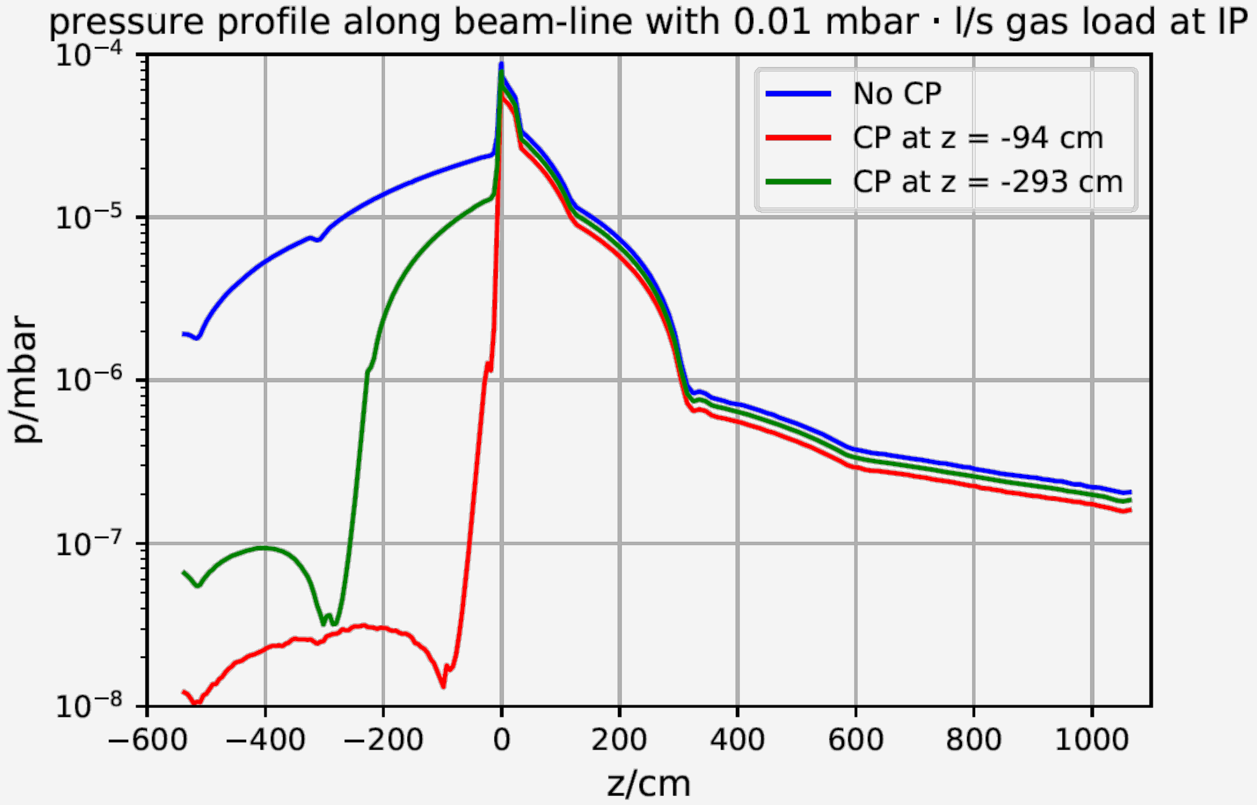
- Measurements at COSY and WWU Münster confirmed that the vacuum situation at the PANDA IP is a severe problem at PANDA
- At highest thickness of 2×10^{15} atoms/cm^2 residual gas flows of O(10^{-2} mbar l/s) into the PANDA IP
- A simple approach would be putting a cryo pump into the beam line:

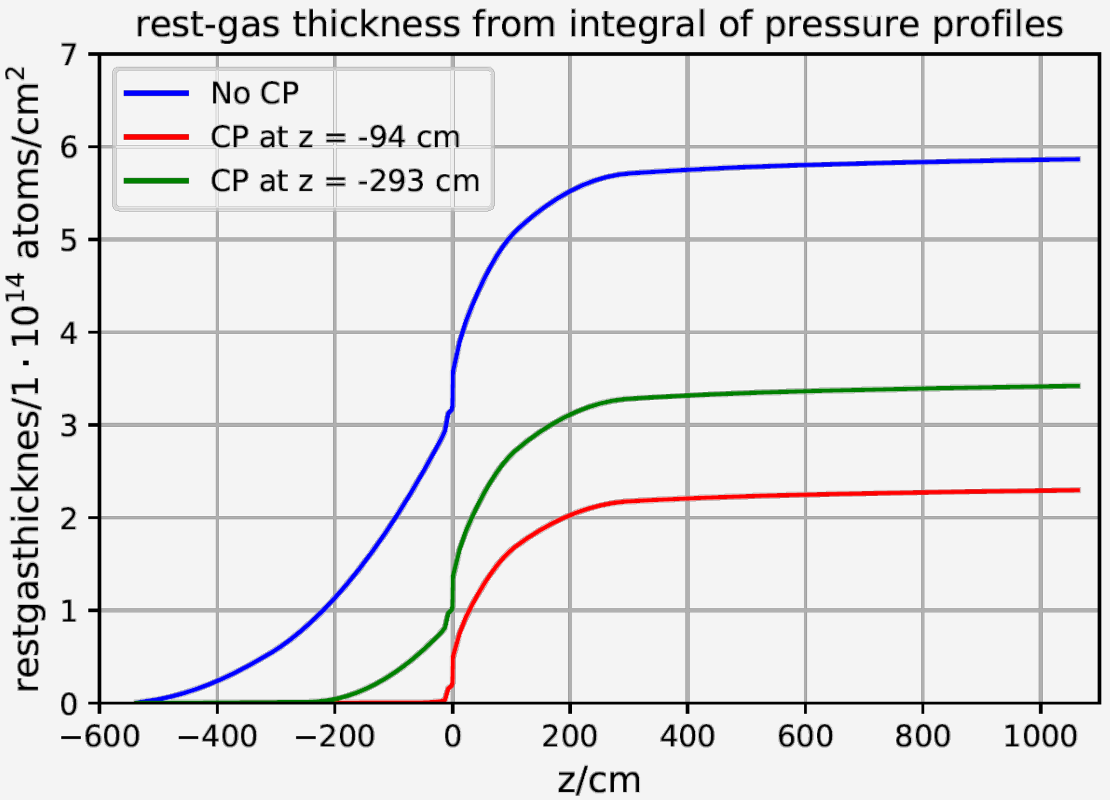


or



Vacuum Optimization at IP

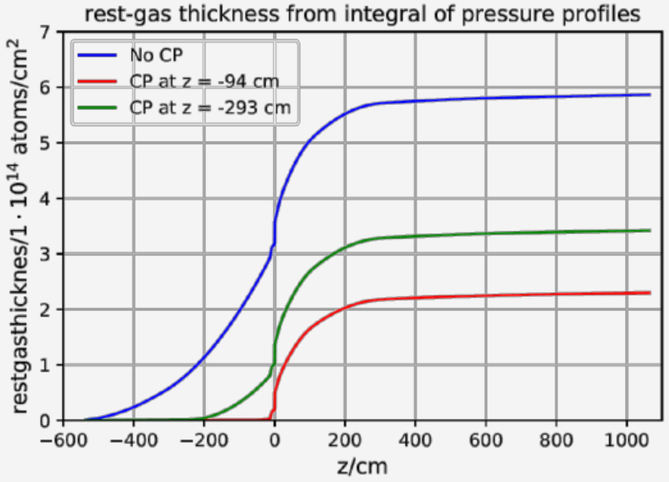




- A cryopump with a diameter of 60 mm, a length of 750 mm, and a pumping speed of 20 l/s cm^{-2} would reduce the integrated residual gas thickness by a factor of › 3, and extend beam lifetime.

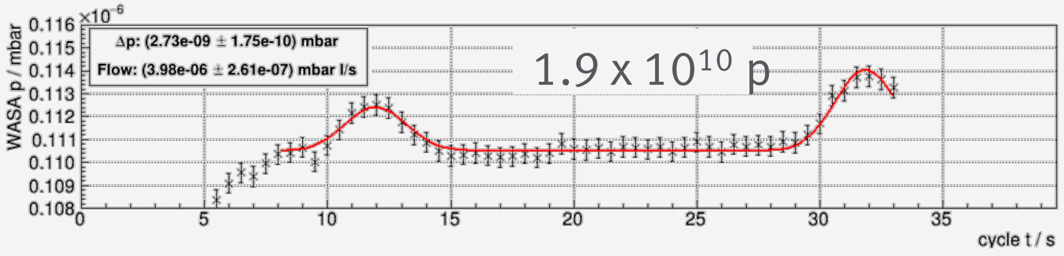
Vacuum Optimization at IP

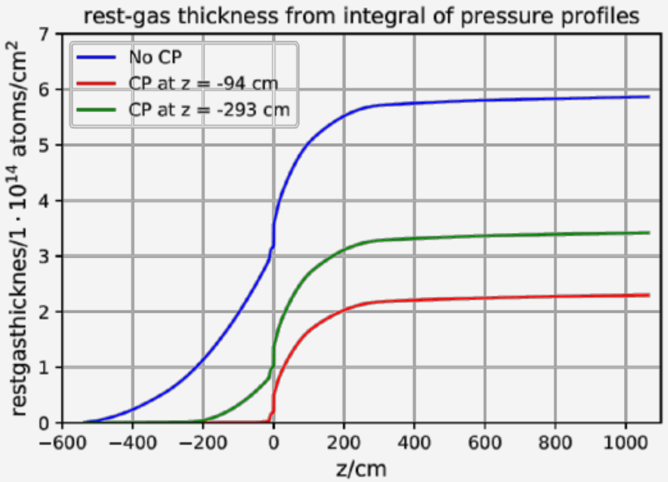
- Every minimization of pumping speed and/or PANDA beam pipe diameter would worsen the vacuum situation
- As shown, a cryo pump inside the beam pipe would be very beneficial
- Starting to prototype an optimal design, size, heat shielding, etc., would be a good idea for the PANDA vacuum conditions
- Münster could handle this task in future, having the possibilities to:
  - Do vacuum calculations, design studies, etc.
  - Having build cryo pumps in the past
  - Do measurements with a pump prototype at the PANDA Prototype in Münster and perhaps with the final PANDA target at COSY in future



Summary

- Measurements done at COSY and analysis ongoing:
    - 1 isotherm, 2 isobars of cluster conditions
    - cluster sizes/evaporation/vacuum influences
    - Beam-target interaction with trans./lateral stochastic cooling
    - First time: Systematic stochastic cooling measurements with target possible
- Excellent cooling performance with 5.2×10^{14} atoms/cm^2 target
- First time successful data taking of cluster evaporation process
- *Need to optimize IP vacuum*:
    - Idea presented of an internal cryo pump
    - Possibility to be build and tested at WWU Münster at the PANDA Prototype and final Target

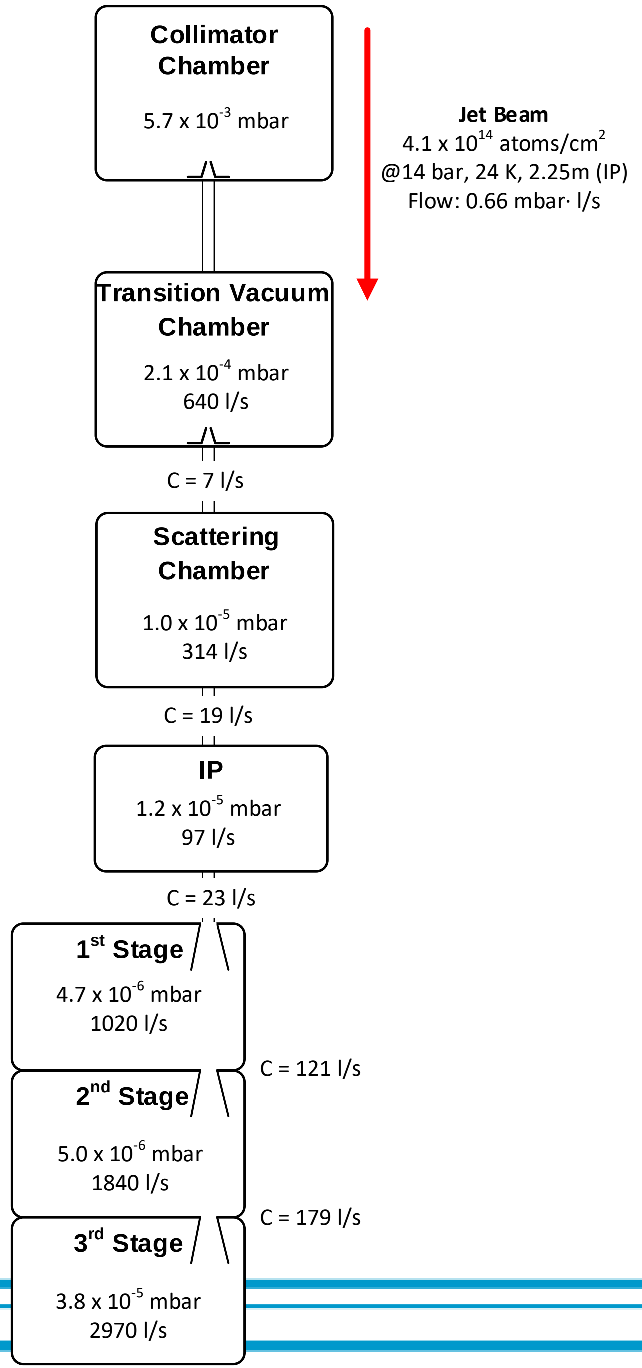




WESTFÄLISCHE WILHELMS-UNIVERSITÄT MÜNSTER

Vacuum Studies

- Hydrogen partial pressures with cluster beam on
  - 4.1×10^{14} H-atoms/cm^2 at PANDA IP
  - 2.25 m behind the nozzle
- Partial pressures from other gases and water completely negligible
- Pumping speed at IP in Münster corresponds to the one later at PANDA (~ 100 l/s)



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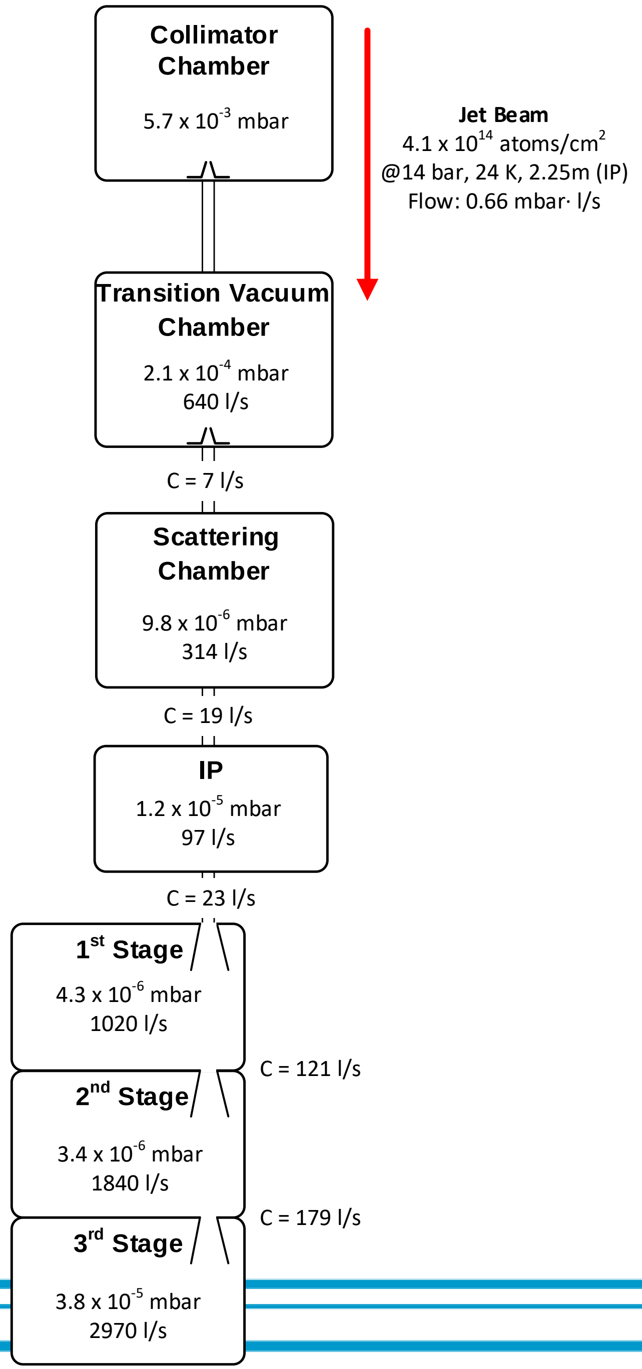
Vakuum Studies

- Study the effect of bouncing clusters or evaporation from clusters
  - Subtraction of back streaming **gas** from 3rd beam dump stage
    - Switch cluster beam off
    - Load 3rd beam dump stage with hydrogen gas so that the same pressure with cluster beam is obtained (i.e. $4x10^{-5}$ mbar)
  - Appreciable effect only in 2nd beam dump stage



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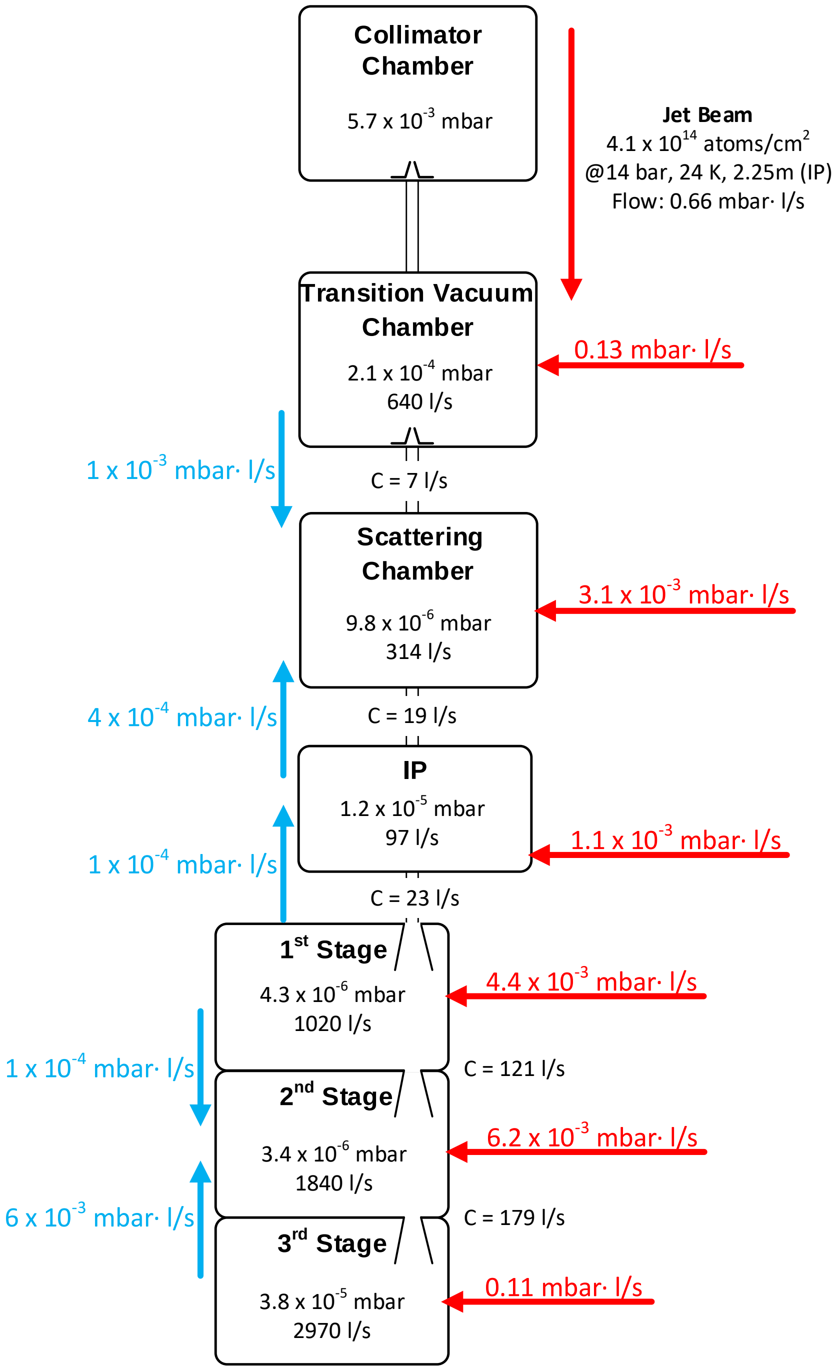
Vakuum Studies

- Obviously the obtained gas load to the IP result from
  - Gas load from neighbouring chambers
  - Conductance between the vacuum stages
  - Possible evaporation of gas from clusters
  - Possible bouncing clusters
- The last two contributions seem to be significant



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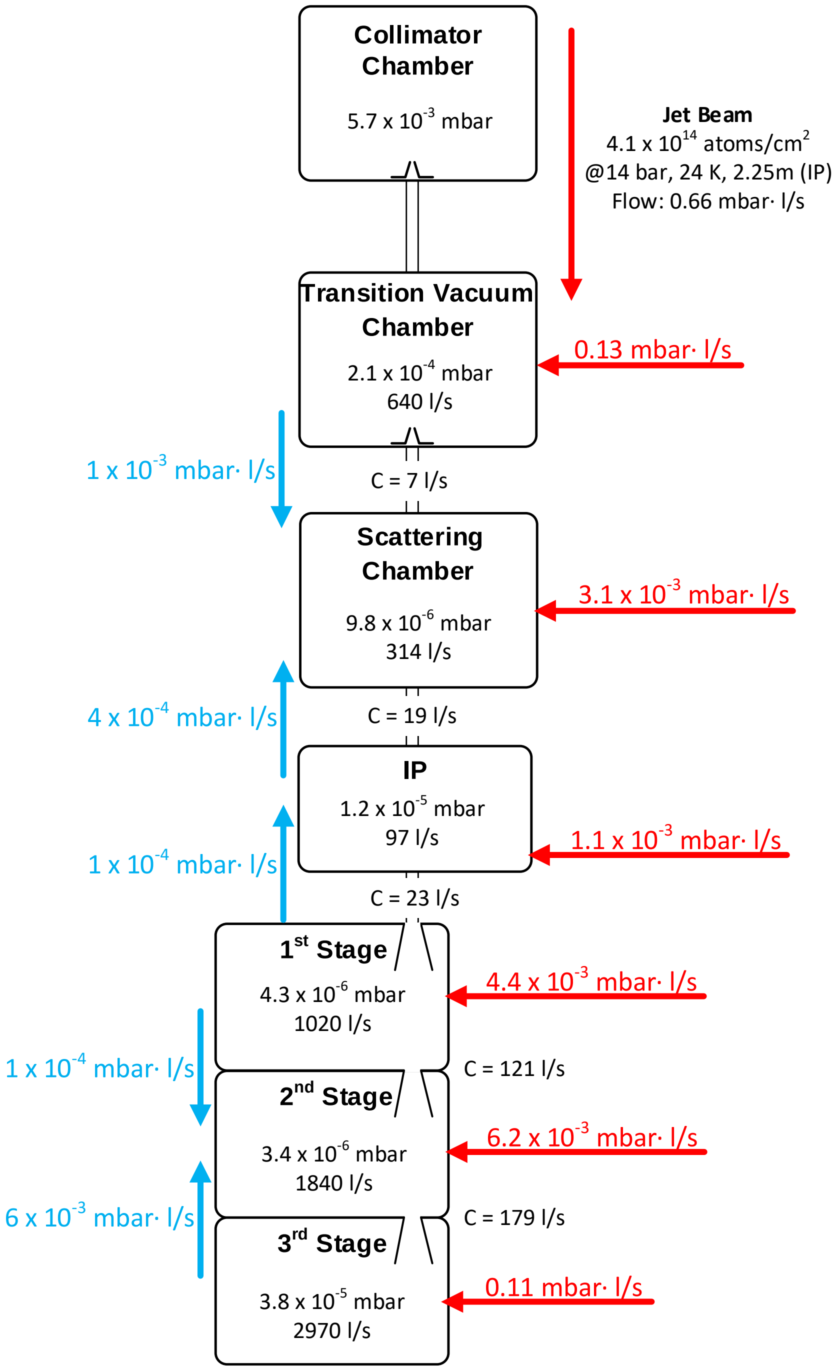
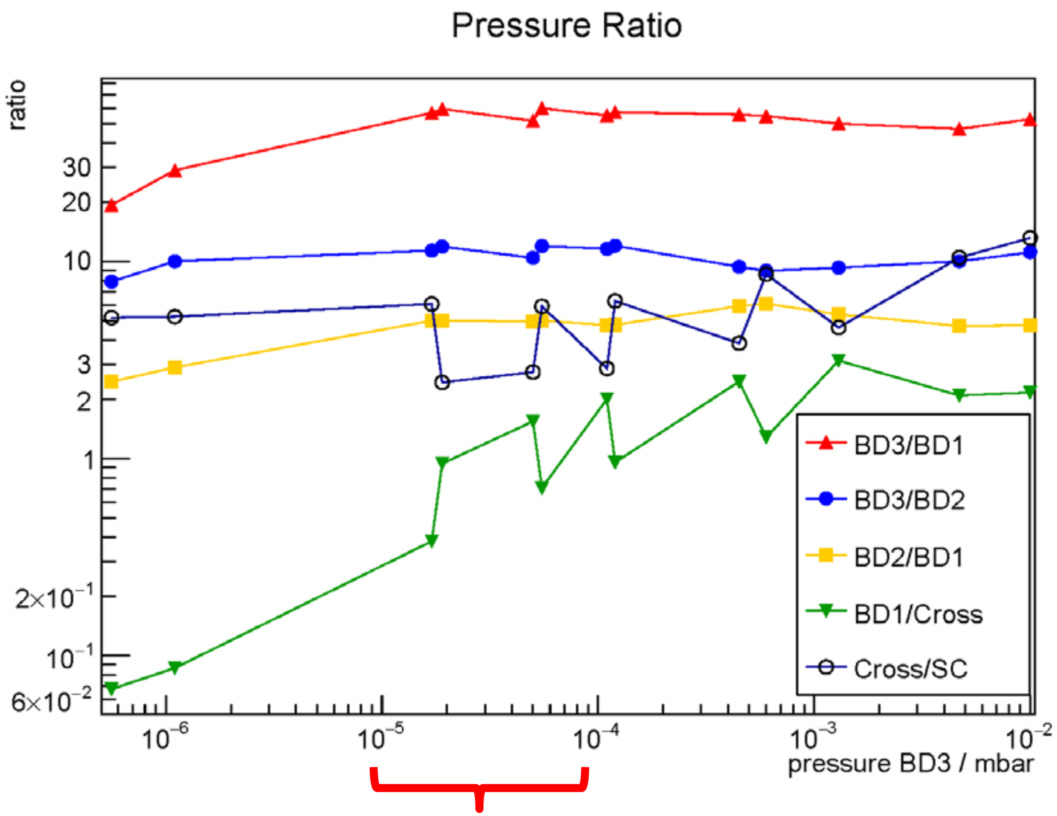
Vakuum Studies

- Further studies on this aspect in preparation
  - Variation of orifices (limitation by cluster beam size)
  - Variation of working points, i.e. stagnation conditions at the nozzle
- Estimation for given example measurement:
  - 1.2×10^{-5} mbar ≙ 6.4×10^{11} atoms/cm^3
  - 1 m of this pressure along the PANDA beam pipe corresponds to 6.4×10^{13} H-atoms/cm^2, i.e. 15.6% of the target thickness



Beam Dump Efficiency: Gas in Last Dump Stage



Relevant pressure range