Münster PANDA Jet-Target Activities Report 03/2020

PANDA Collaboration Meeting 2020/1
GSI Darmstadt, Germany

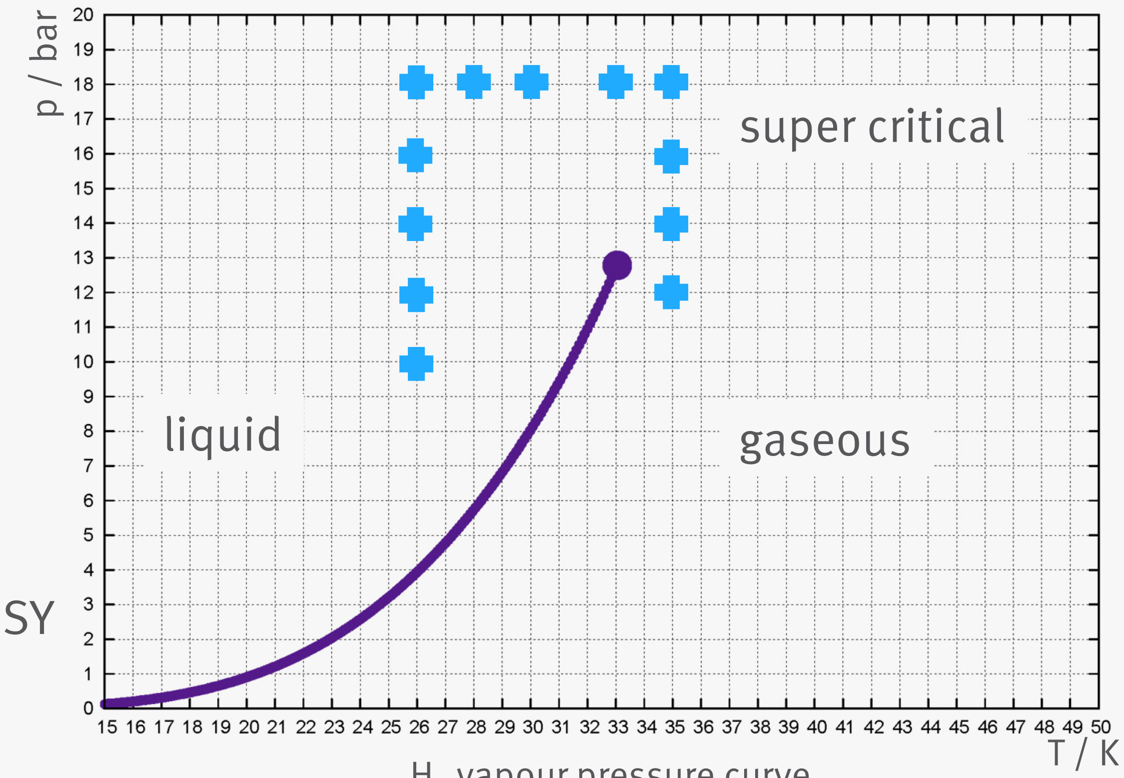
Benjamin Hetz
WWU Münster

Content

- Results of last year's COSY beam times
  - Beam quality
  - COSY beam influence on the jet beam
- Tests of a second, differential pumping stage for the source planned
- Vacuum simulation of HESR/PANDA vacuum
  - Different IP configurations
  - Influence of MVD inside HESR vacuum
- A cryopump for the HESR/PANDA beam line

Recapitulation: Measurements 08/2019 @ COSY

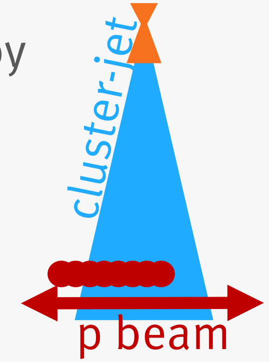
- ✚ 2 isotherm, 1 isobar measured:
  - ➢ Different cluster sizes
  - ➢ Different cluster production processes
    - From gaseous/supercritical/liquid phase of hydrogen
  - ➢ Everything in dependence of 3 proton beam currents
    - $(2 \times 10^{10} / 0.6 \times 10^{10} / 0.3 \times 10^{10})$ protons
  - ➢ Using stochastic cooling module of HESR installed at COSY
  - ➢ Using COSY barrier bucket

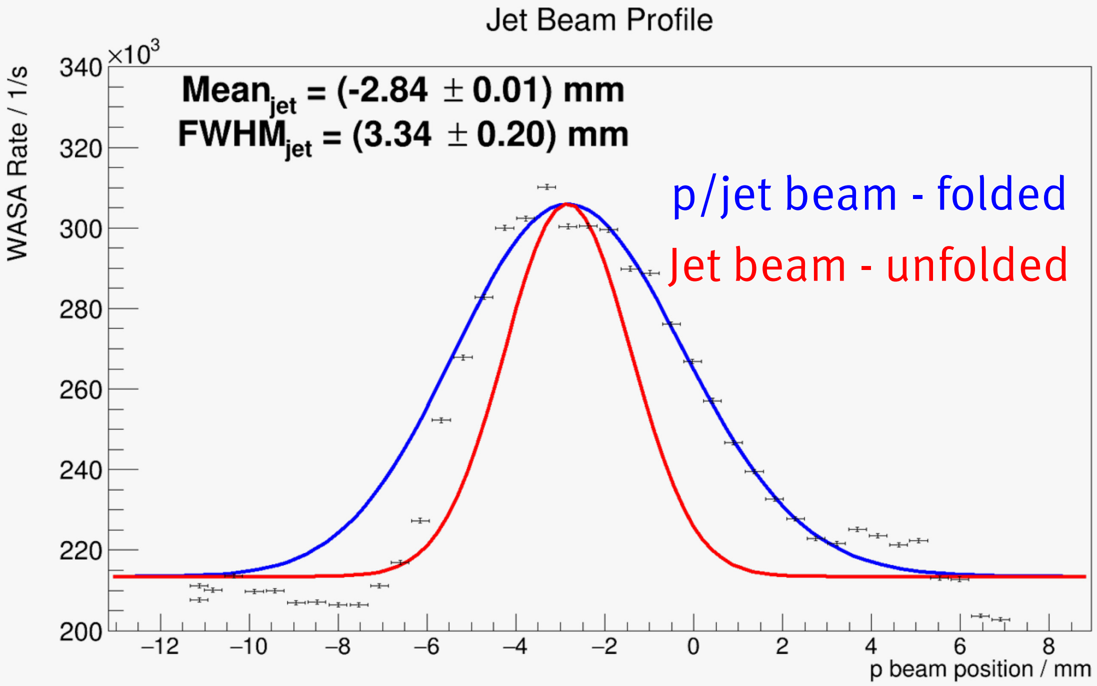


H_2 vapour pressure curve

Recapitulation: Measurements 08/2019 @ COSY

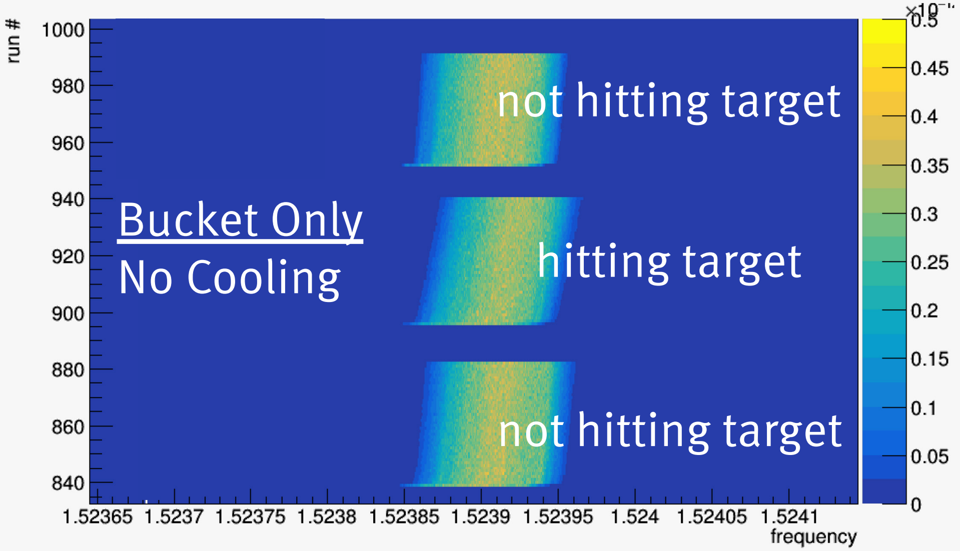
- Measurement of optimal beam-jet overlap by wobbling over the jet beam
- Measure WASA rate
  - ➢ Jet position inside pipe
- IPM giving COSY beam diameter
  - ➢ Unfolding -> jet diameter
  - ➢ Agrees with calculation and other means of jet beam measurements

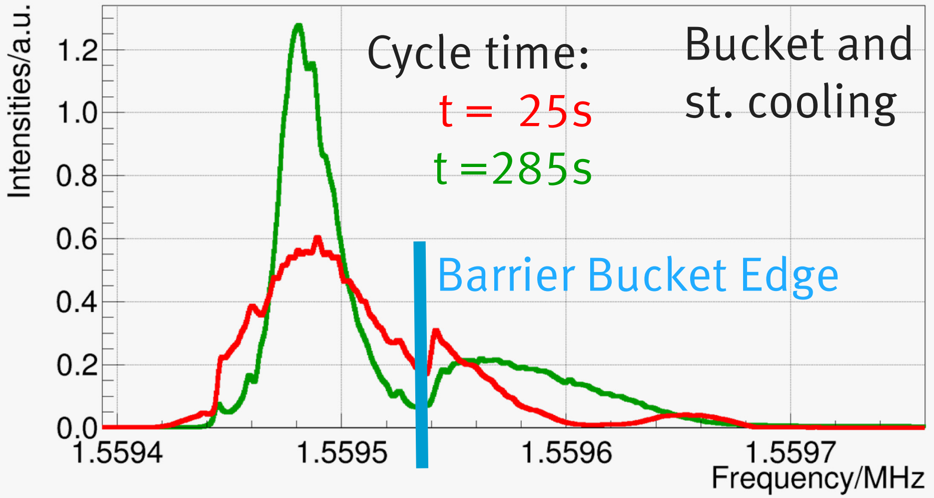




Recapitulation: Lateral Momentum Spectrum

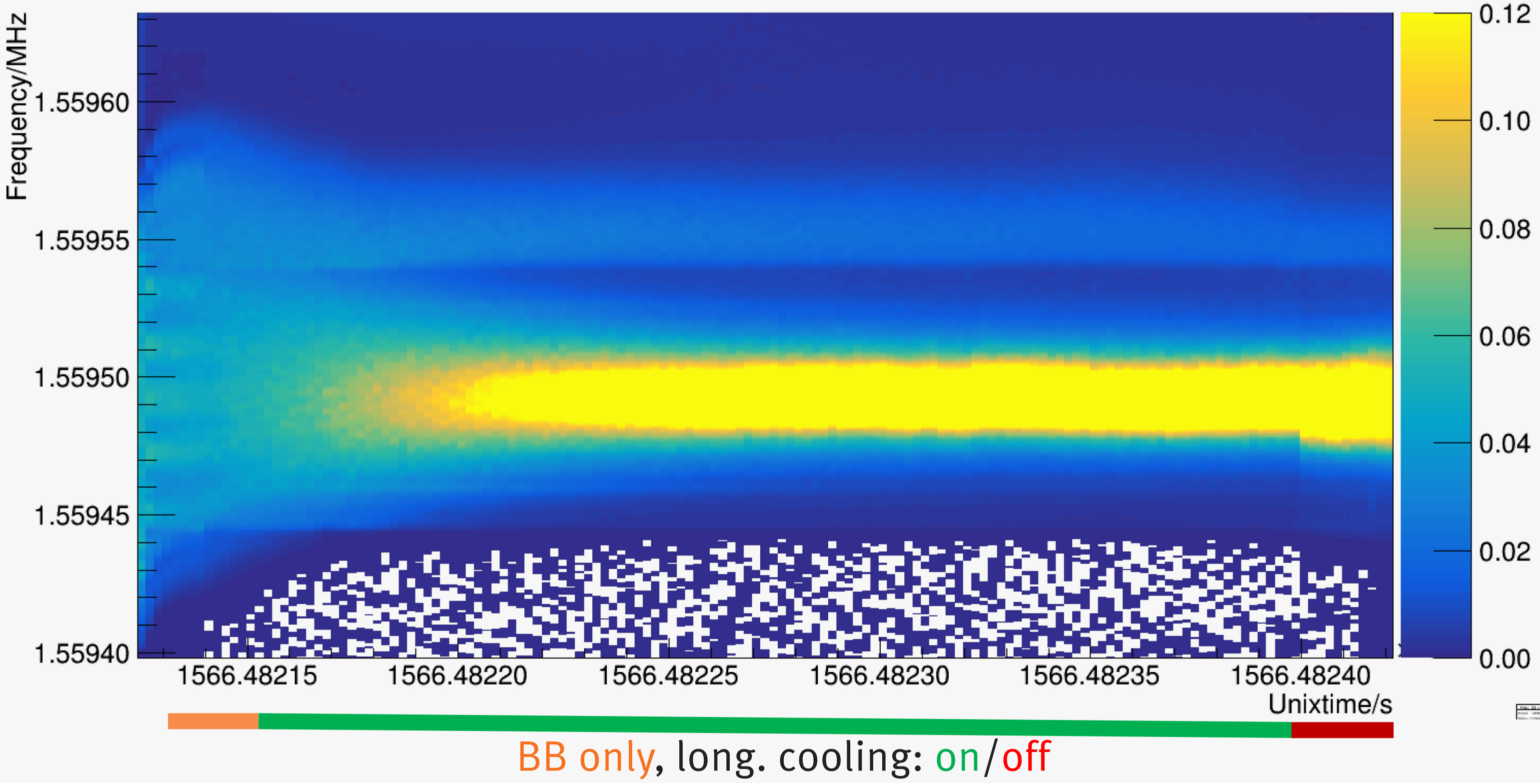
- Freq. spectrum measured using Schottky-Detector of HESR Pick-Up
  - Frequency -> lateral momentum
- Bucket only:
  - wide lateral spectrum
  - Spectrum shift due to energy loss if COSY beam is hitting target
- Bucket and stochastic cooling:
  - Lateral momentum width getting smaller and stable frequency
  - Particles outside of the barrier bucket:
    - Cannot be cooled optimal/sharp edge
    - HESR situation: Better bucket/more cooling power





Spectrum Analysis

- Beam acceleration
- Bucket on:
  Synchrotron oscillations visible
- Stochastic cooling on: decrease in lateral momentum spectrum width
- Comparison between spectrum with and without stoch. cooling:
  - ➢ signal suppression



Spectrum Analysis

- Reason for signal suppression is the feedback system created by the HESR-kicker/HESR-pickup/p-beam

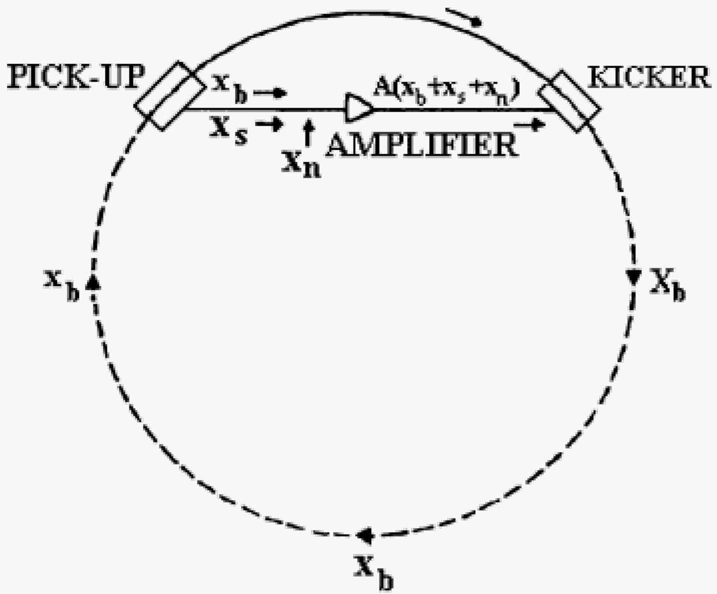
➢ Closed loop operation of cooling:

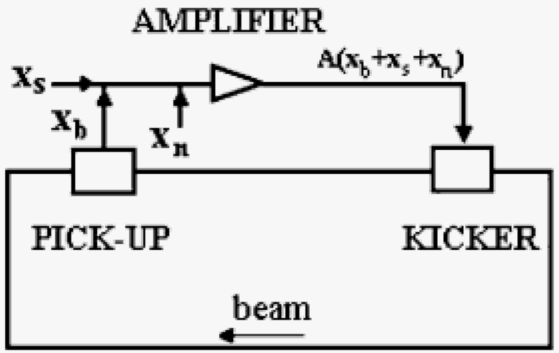
$$\underbrace{\left[1+\frac{S(\omega)}{1-S(\omega)}\right]}_{\text{shielding factor}}$$

- Shielding factor with dispersion-like term

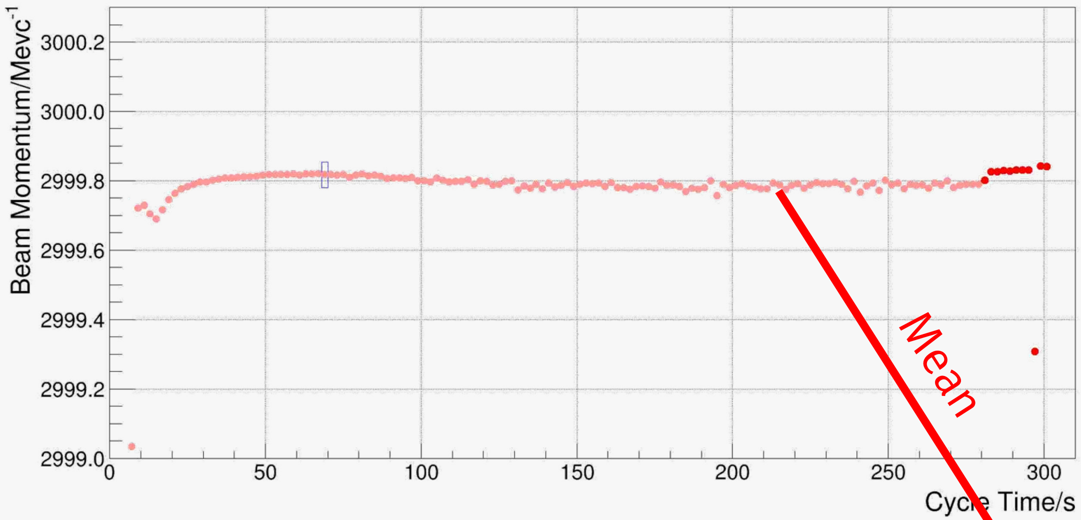
➢ True signal given by measuring with cooling turned off for only a short time in cycle

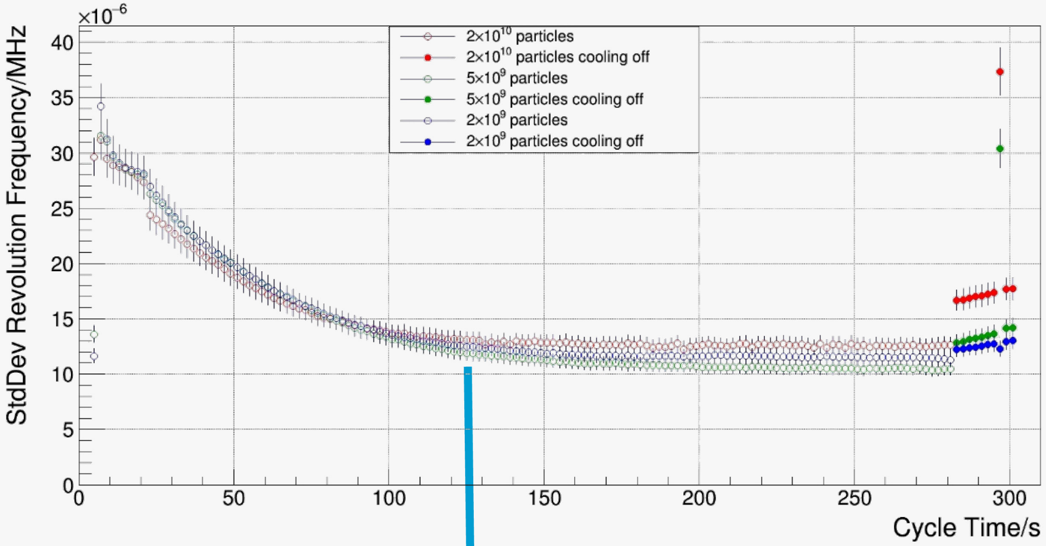
➢ Upcoming COSY beam times: In cycle measurements with pickup from ‘old’ COSY cooling system -› no closed feedback loop to HESR tanks



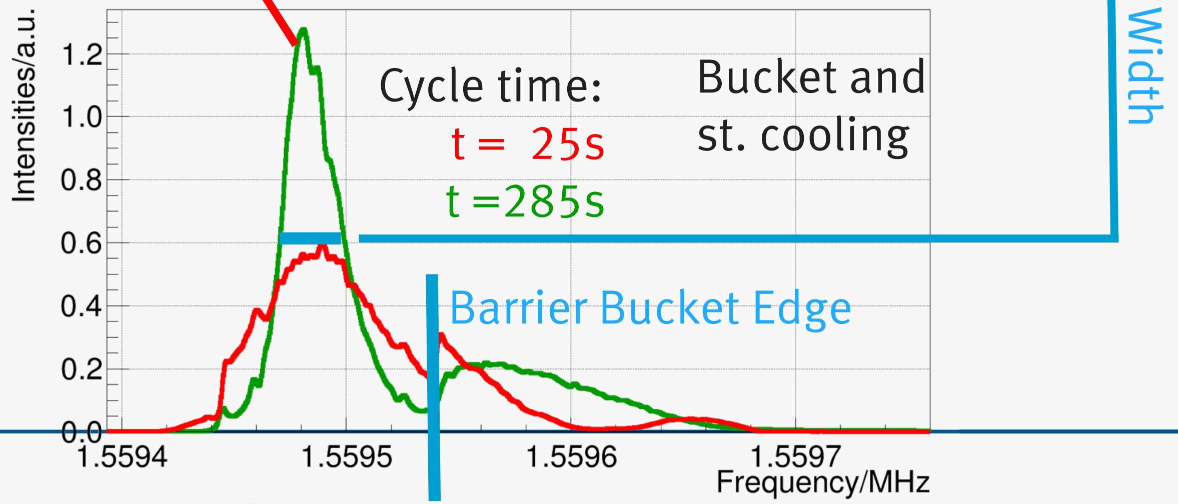


Beam Quality Measurements

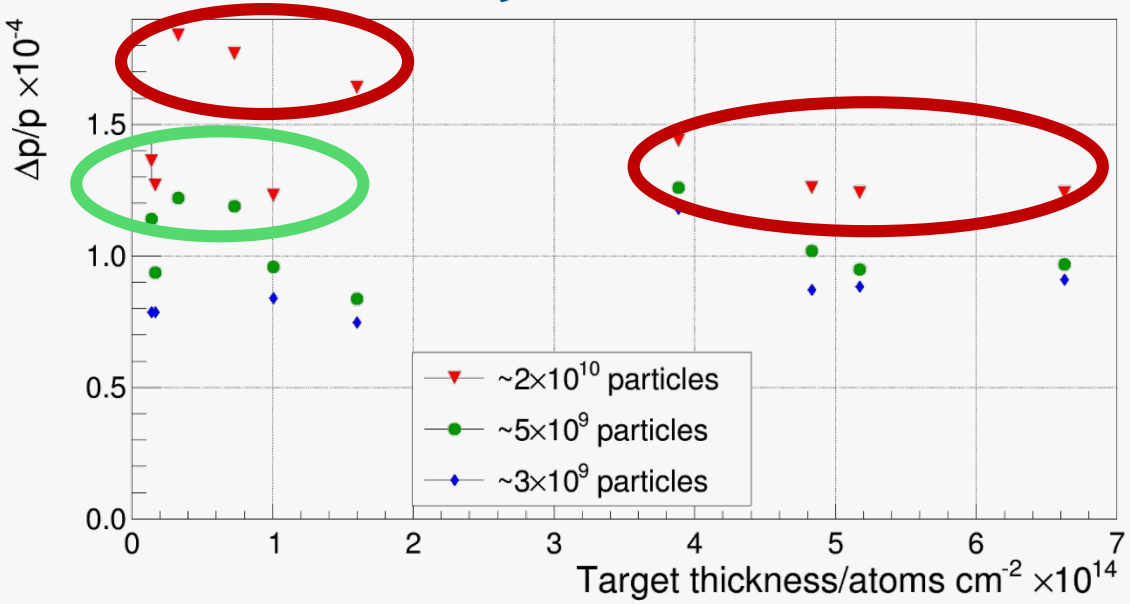


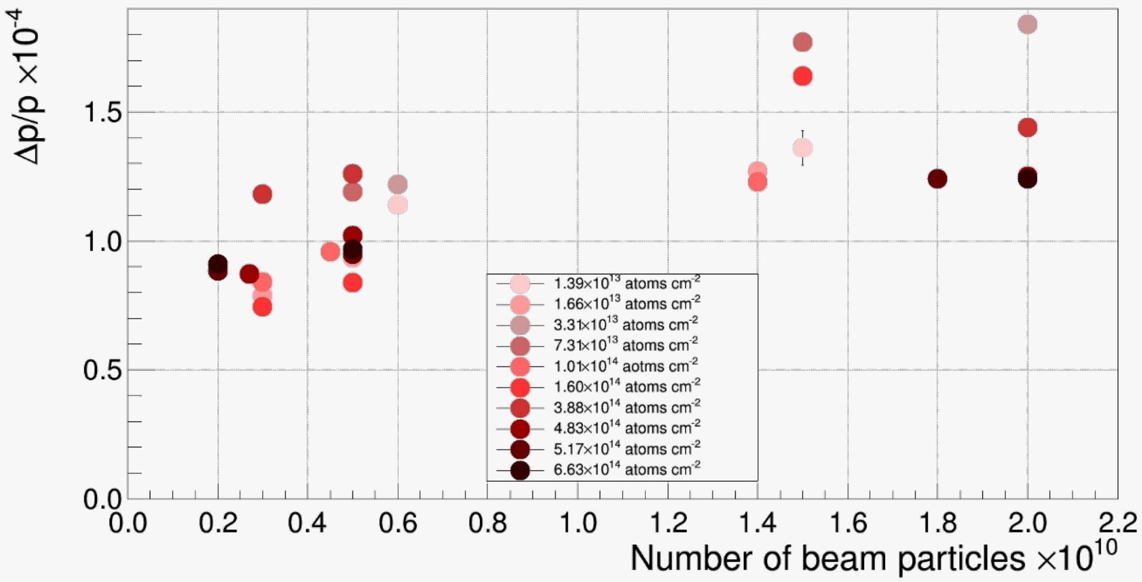


- Different target settings/thicknesses
- Different beam currents



Beam Quality Measurements Δp/p

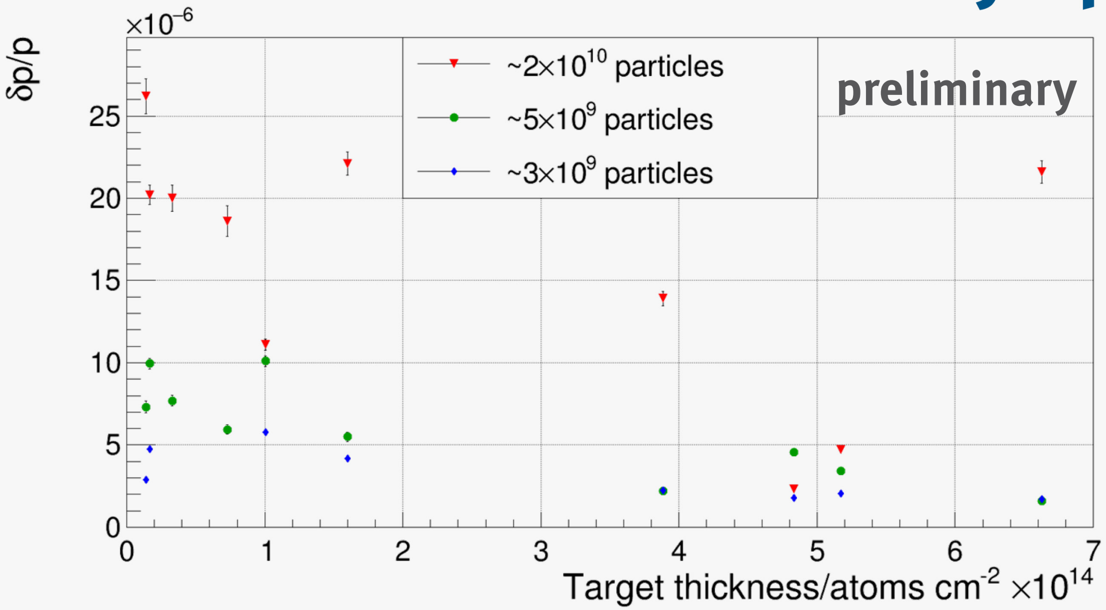


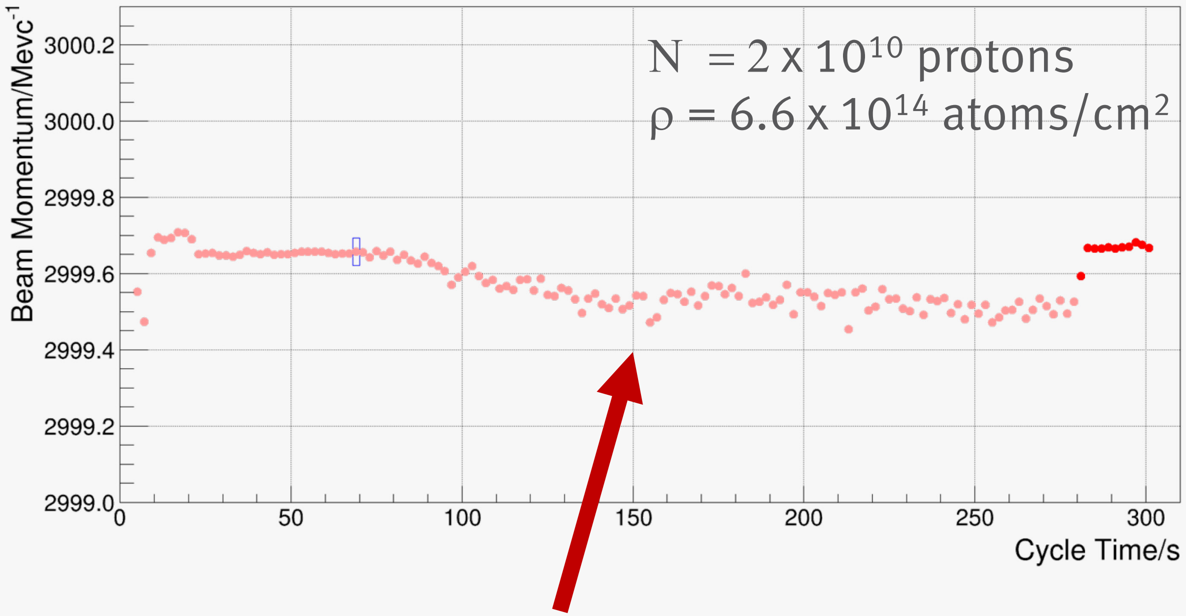


- ❖ More thickness -> smaller Δp/p value?
  - ➢ Effect clearly visible for high proton currents (red triangles)
  - ➢ Cooling adjustments for each p current/ target thickness setting necessary (red box bad/green good)

- ❖ More protons -> larger Δp/p value
- ✓ $\Delta p/p = 1.2 \times 10^{-4}$ at $\rho = 6.6 \times 10^{14}$ atoms/cm^2
- ✓ Measurements with higher target thicknesses will be done in 2020 COSY beam time
- ✓ Optimized stochastic cooling tank

Mean Momentum Stability δp/p





- Stochastic cooling was optimized for $\rho = 5 \times 10^{14}$ atoms/cm^2
  - $\delta p/p < 3 \times 10^{-6}$ (preliminary)
- **Next beam time:** Test with new auto tune function for stochastic cooling parameters and more precise manual tuning by cooling crew needed

- The need of optimal adjustment becomes obvious in the mean momentum stability

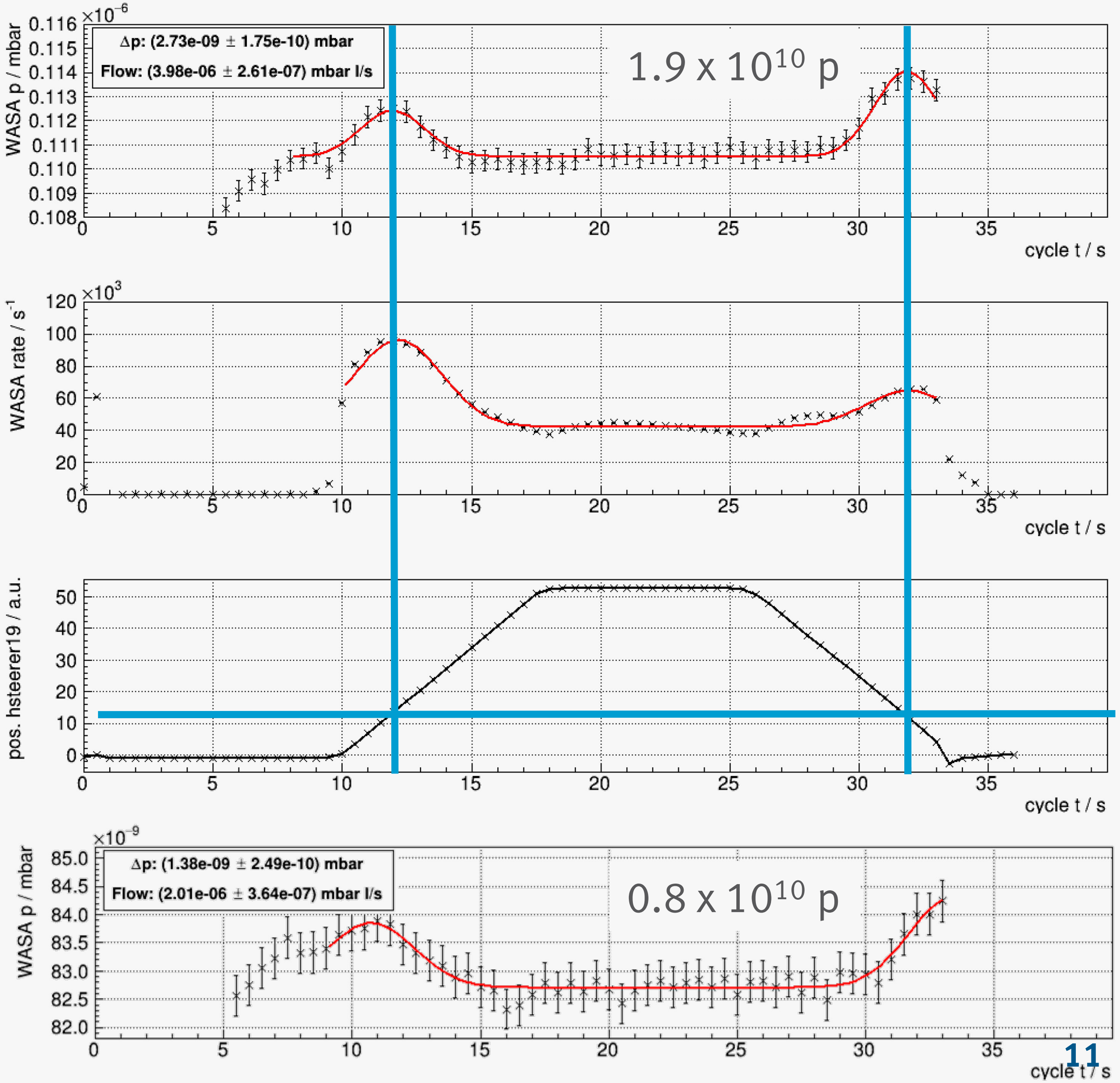
➢ Going to higher thicknesses to test if instability is an adjustment effect or if cooling test tank has reached its limit at COSY

Cluster Energy Deposition

- Proton beam horizontal wobbling over cluster-jet with low thickness -> small clusters
- During beam-target overlap:
  - Increase in pressure and detector rates
- Calculated energy deposition:
  - E_{dep} = 12 meV/atom (› E_{vdW} = 0.2 meV for H_2)
  - ➢ ‹ 2% of E_{dep} needed for “evaporation”

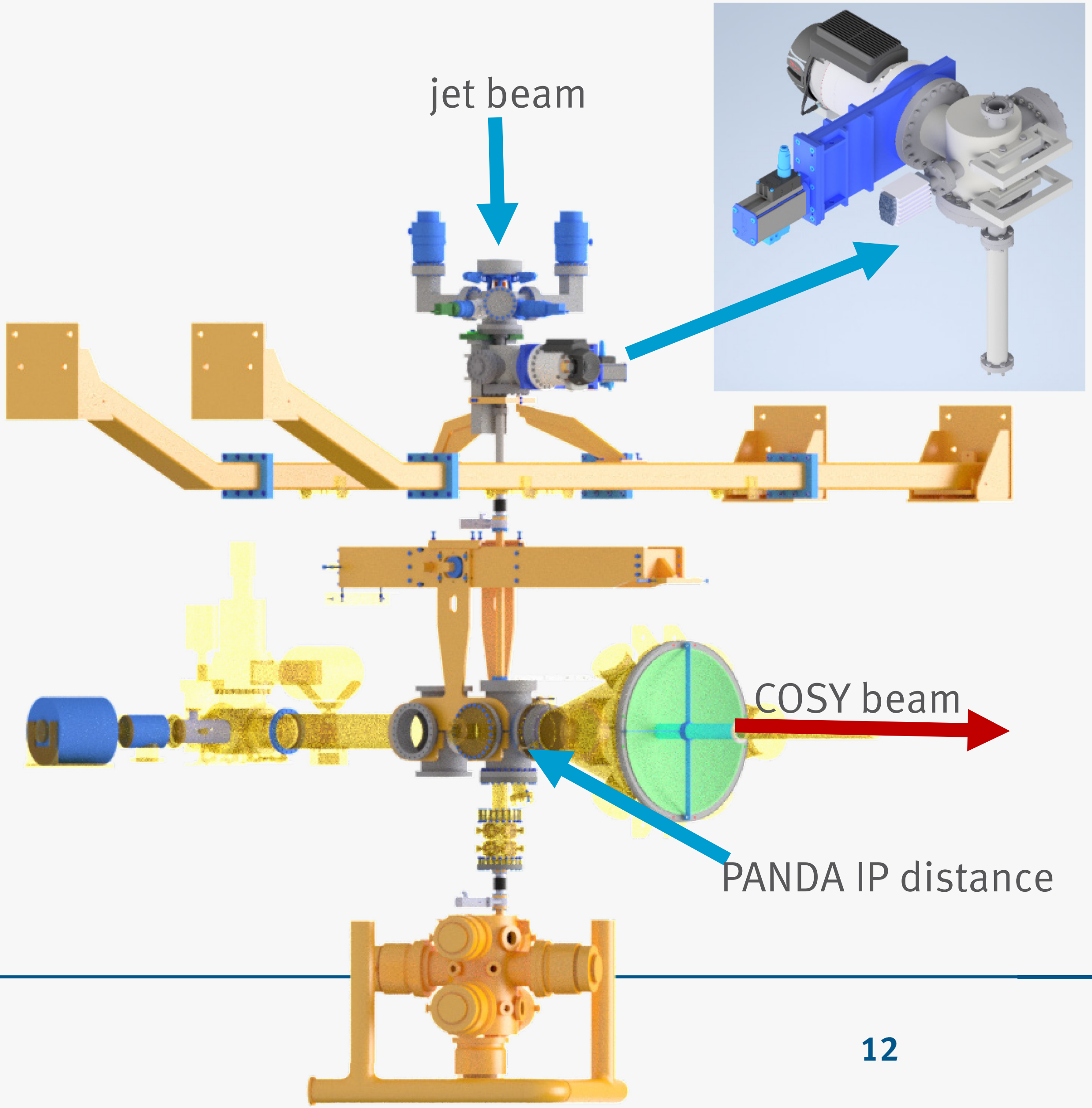
➢ Important to have a look at cluster sizes given by 10^{15} atoms/cm² thicknesses at next beam time

➢ Effect negligible at higher target thicknesses?



Residual Gas from Jet-Source

- Beam Dump not most important source of residual gas at IP (measured at Münster and COSY)
- Measurement of gas flow from jet source at COSY
- Production of secondary, differential pumping stage at jet-beamline connection point
  - Simple prototype for COSY operation
- Installation at next maintenance phase
- Test at next COSY beam time

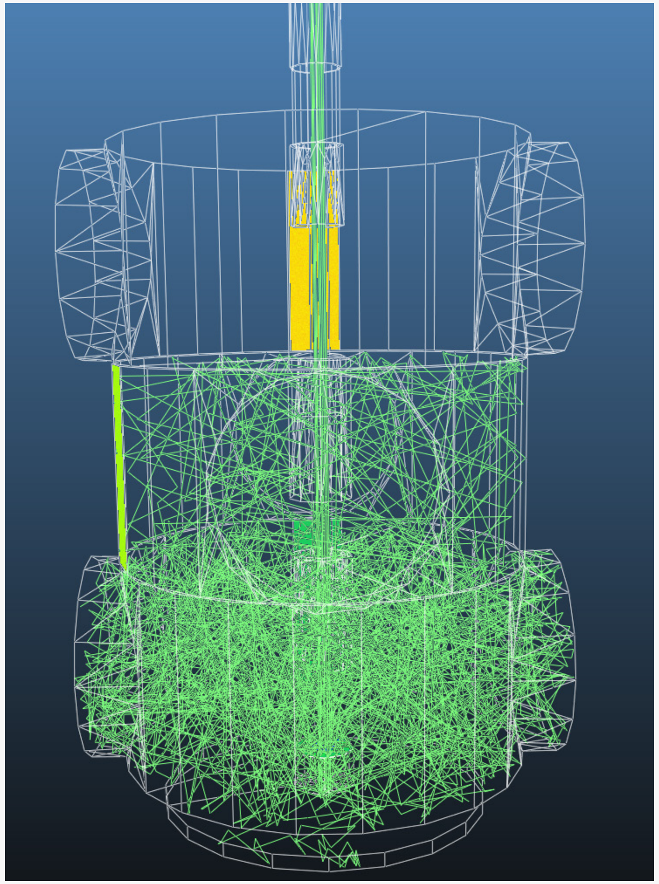


Residual Gas and Vacuum Simulation

- Residual gas background at interaction point not dominated by jet source and dump gas (back-)flows. Other sources for vacuum conditions?
- From interest vacuum measurements at COSY using the PANDA target at different stagnation points
- Need to understand vacuum situation by other means than simple geometrical simplifications of PANDA geometry and vacuum conductions and measurements
  - ➢ Use of MolFlow+ (molflow.web.cern.ch) for simulation of complex vacuum installations

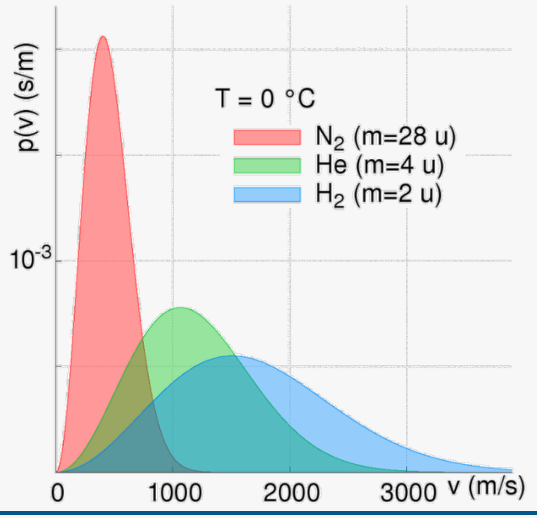
Residual Gas and Vacuum Simulation

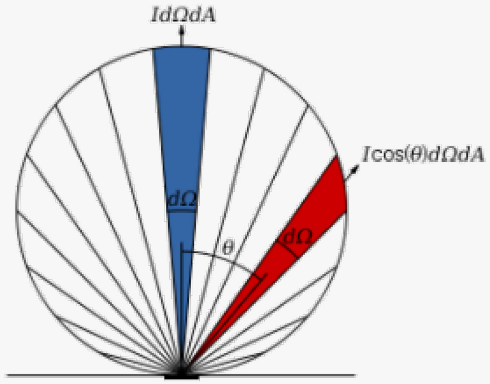
- Calculation of pressures, conductance by means of Monte Carlo test particles
  - Pressure is equivalent to number of wall hits at given gas velocity
  - No assumption of conductance of non simple forms because single particles (bunches) are tracked

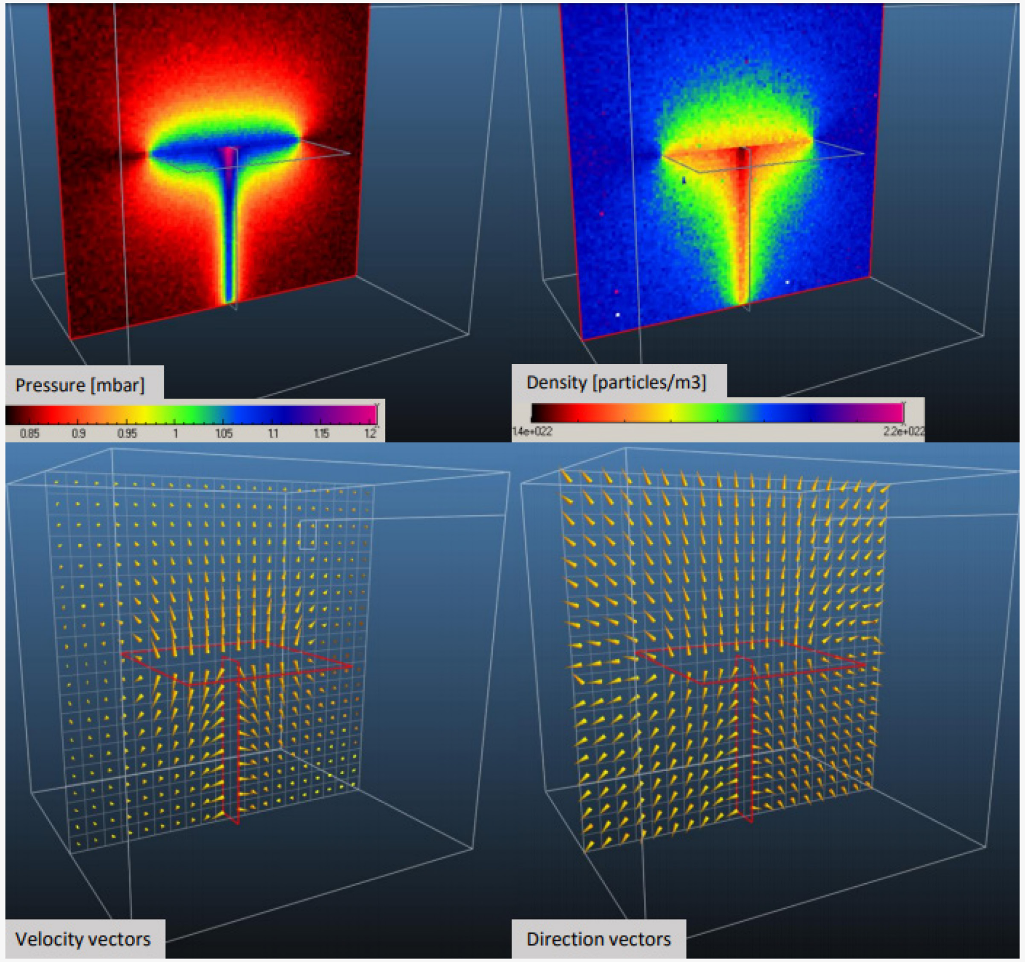


Residual Gas and Vacuum Simulation

- Realistic particle generation with correct Maxwell-Boltzmann velocity distribution
- Realistic rebound angle distribution on walls
- Temperature of gas variable, and non isotropic temperatures gradients on walls etc. possible

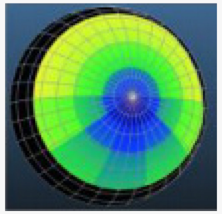


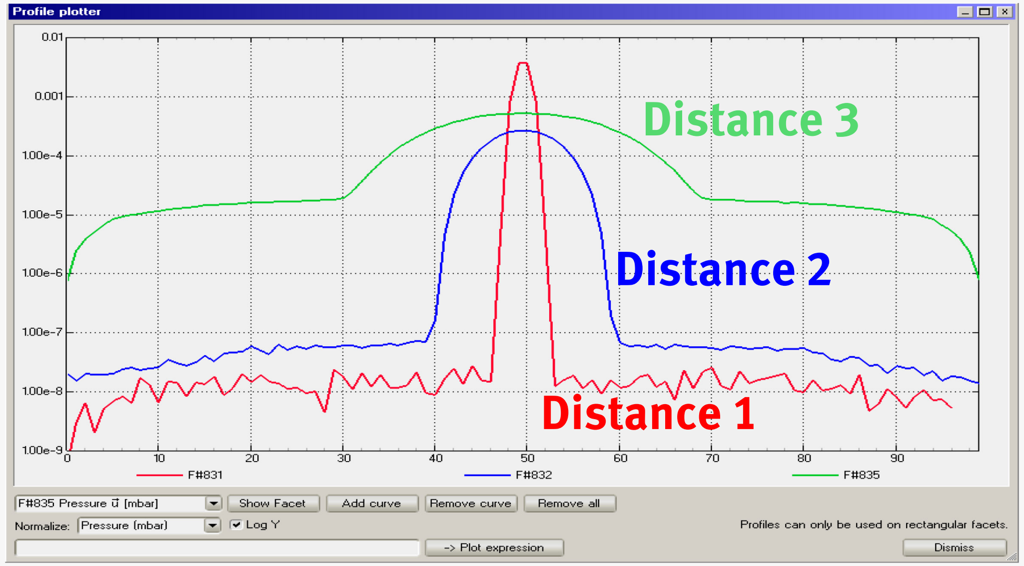


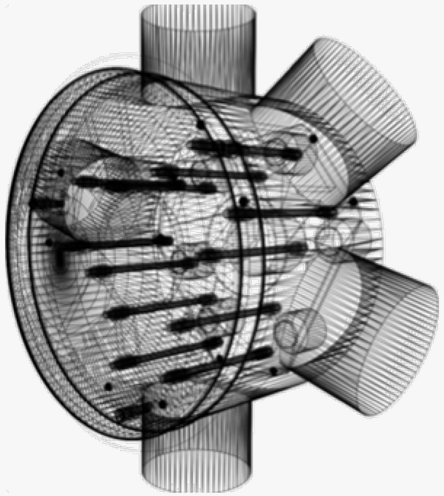


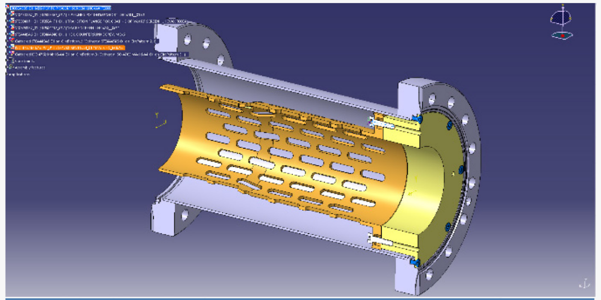
Residual Gas and Vacuum Simulation

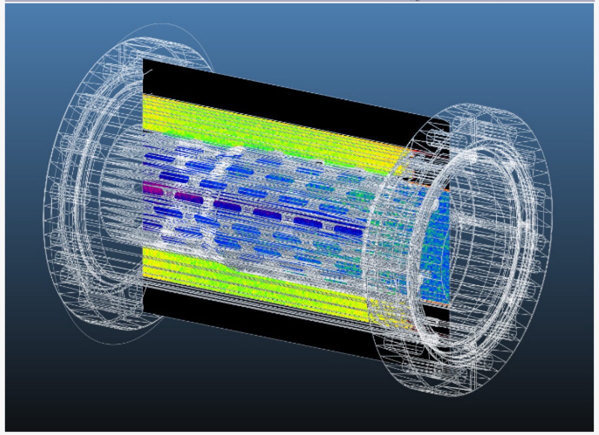
- Complex forms with correct conductance, temperatures etc. possible
- Direct import of CAD models
- Directed gas flows possible, creation of angular gas distribution maps
- Simulation of vacuum pump ports possible





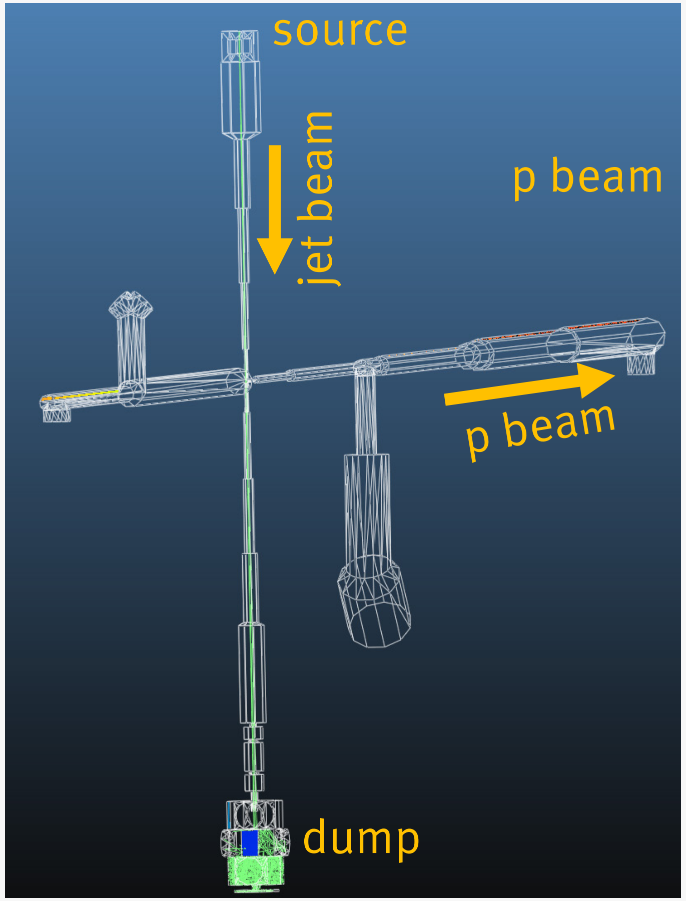




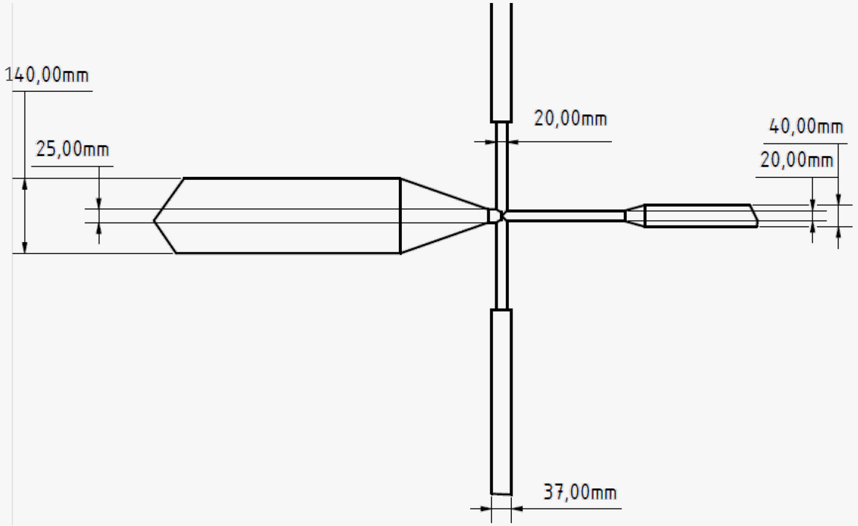


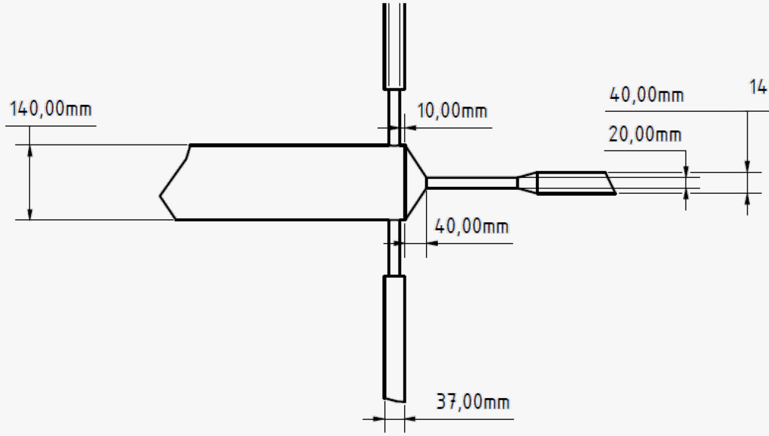
Simulation of PANDA Vacuum Situation

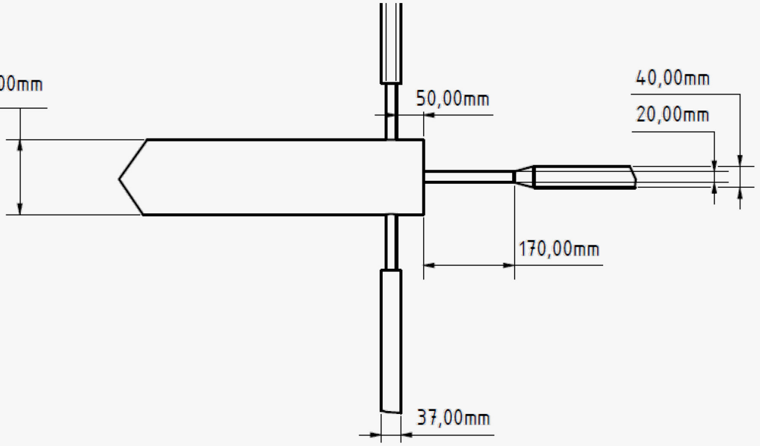
- Vacuum simulation of concrete PANDA system model
- With/without directed gas beam (no clusters!)
- Simulation studies of jet beam influence on vacuum by adding an “evaporation” mask to the gas beam
- Simulations agree with measurements of beam dump vacuum conditions and flows



Simulation of Different PANDA IP Configurations



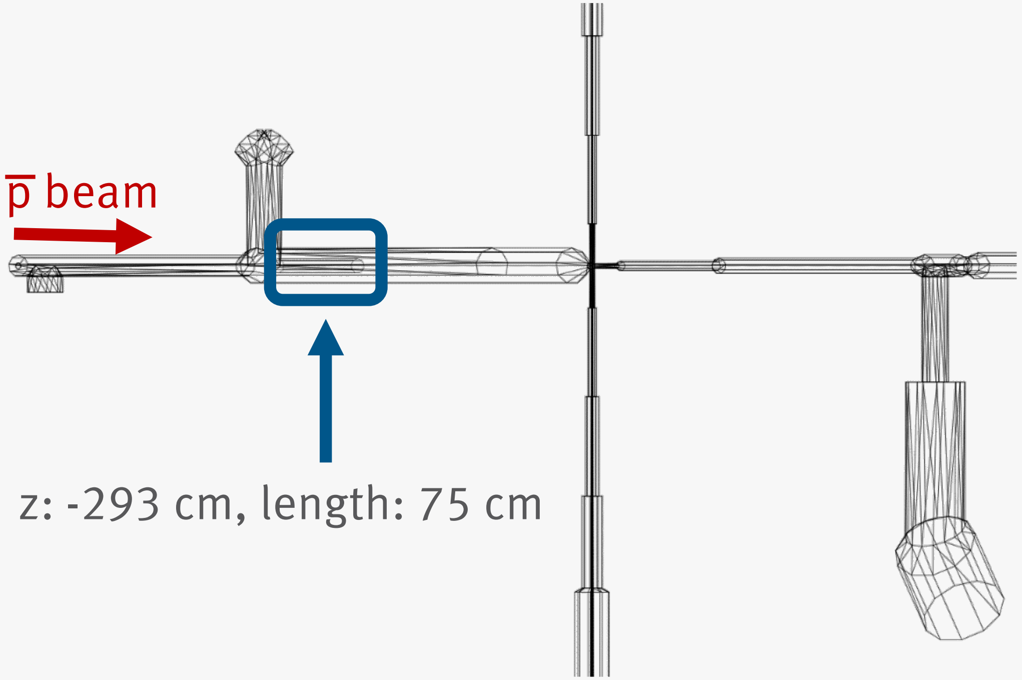




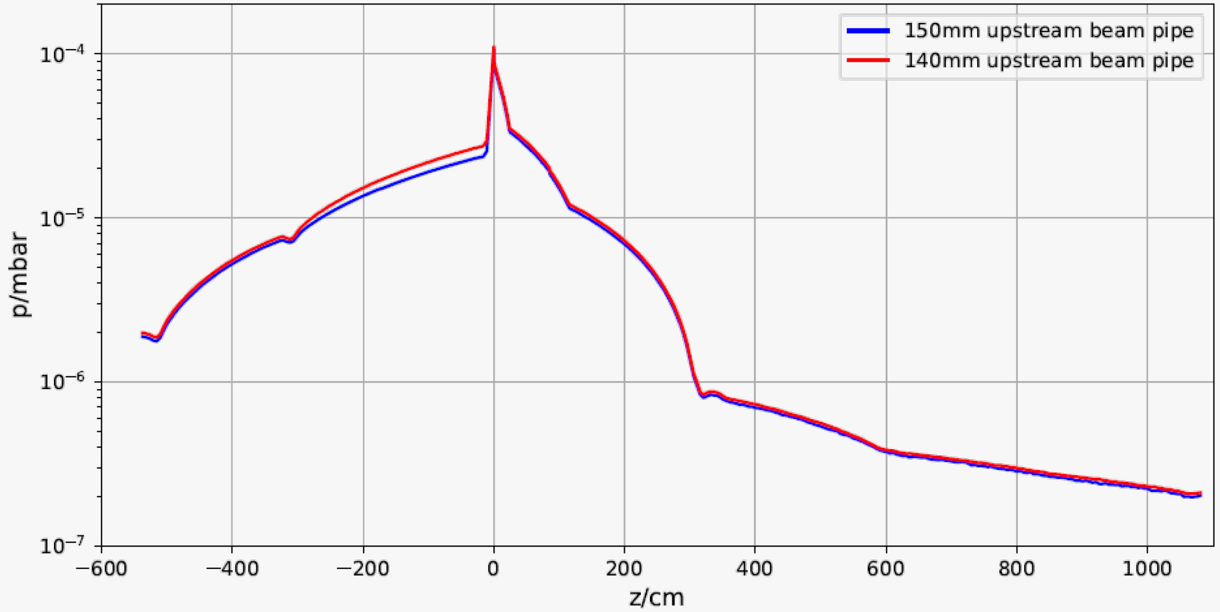
- Normal IP design (40mm/20mm)
- Big IP w/ Conus (140mm/20mm)
- Big IP w/o Conus (140mm/20mm)

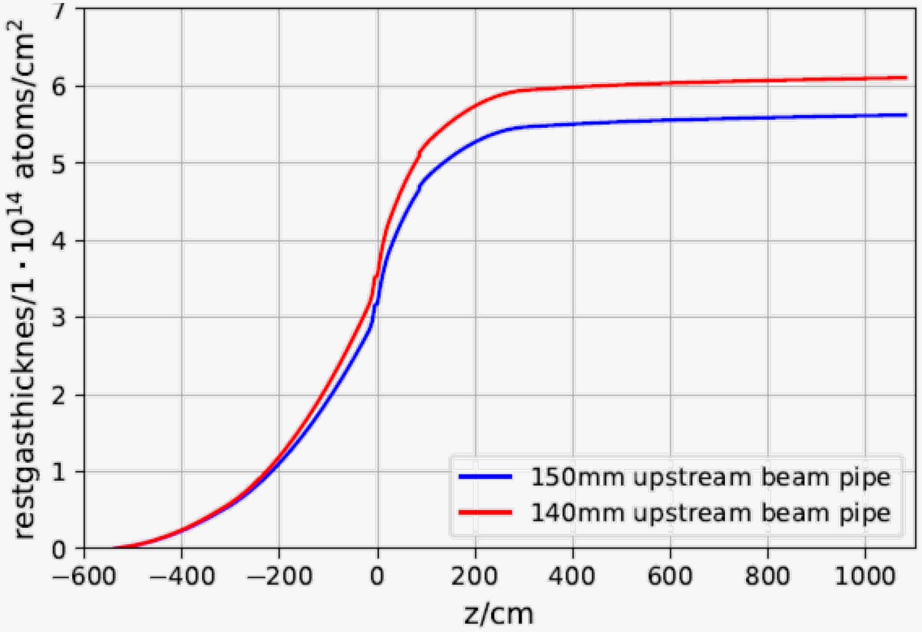
Simulation of Different PANDA IP Configurations

- Different IP configurations simulated with and without cryopump inside proton beam line
- Pumping speed of cryopump: 27500 l/s



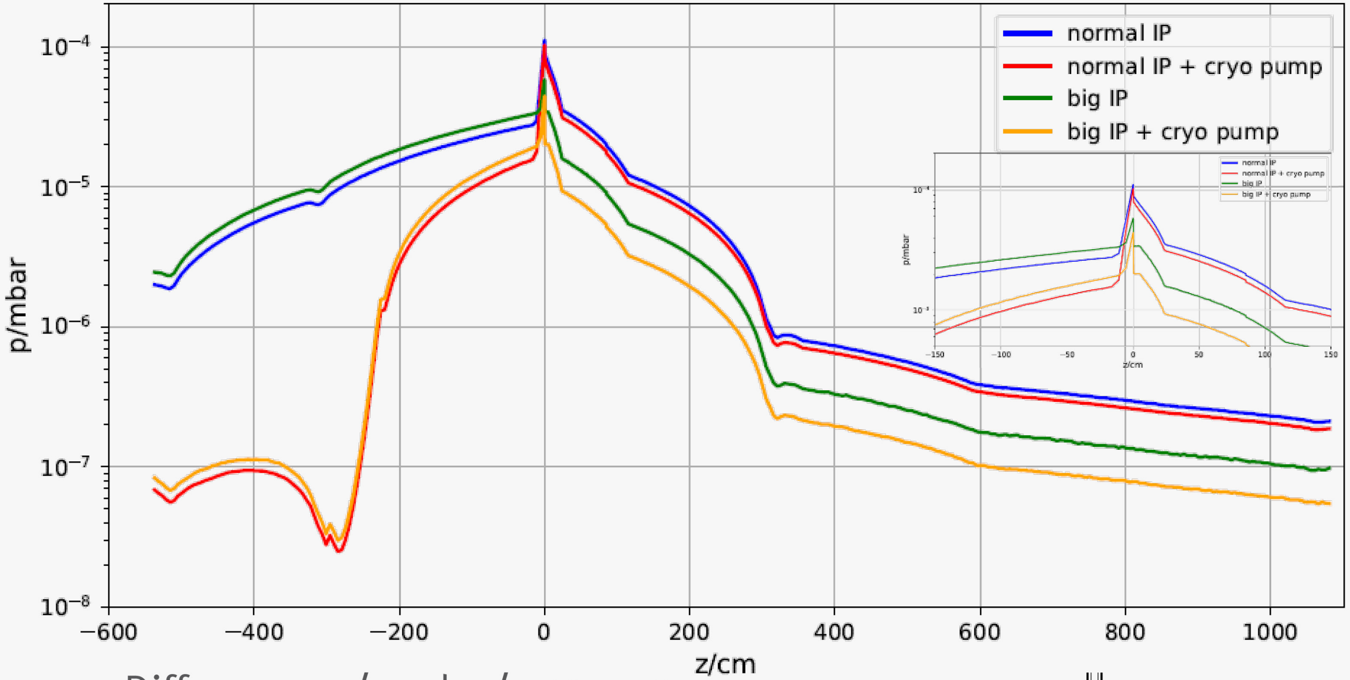
Simulation of Different PANDA IP Configurations

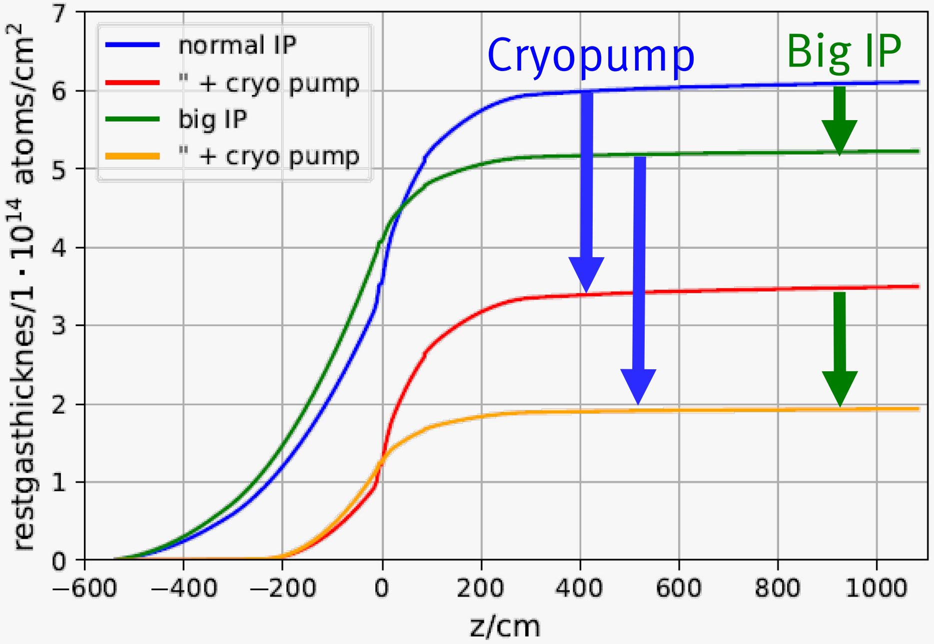




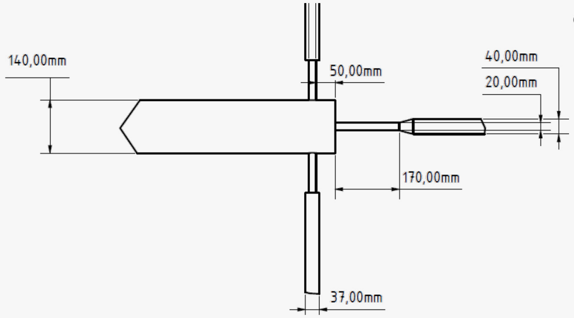
- Difference **without cryo pump**:
  - **140 mm** and **150 mm** upstream beam pipe
  - **Normal** IP design
- Small difference in pressure/integrated thickness
- Diameter effects on thickness at z › 0 cm:
  - Due to better conductance at z ‹ 0 cm
  - Less gas downstream

Simulation of Different PANDA IP Configurations



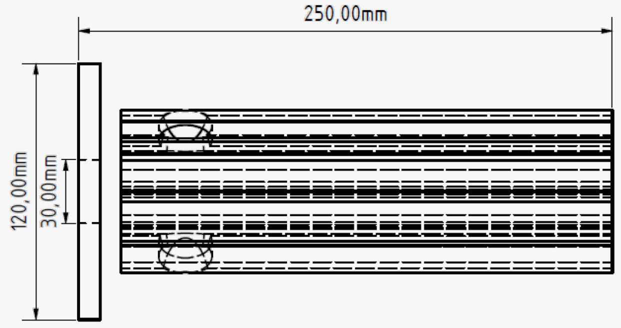


- Difference **w/** and **w/o cryopump**:
  - **140 mm** upstream beam pipe
  - Upstream pipe over IP

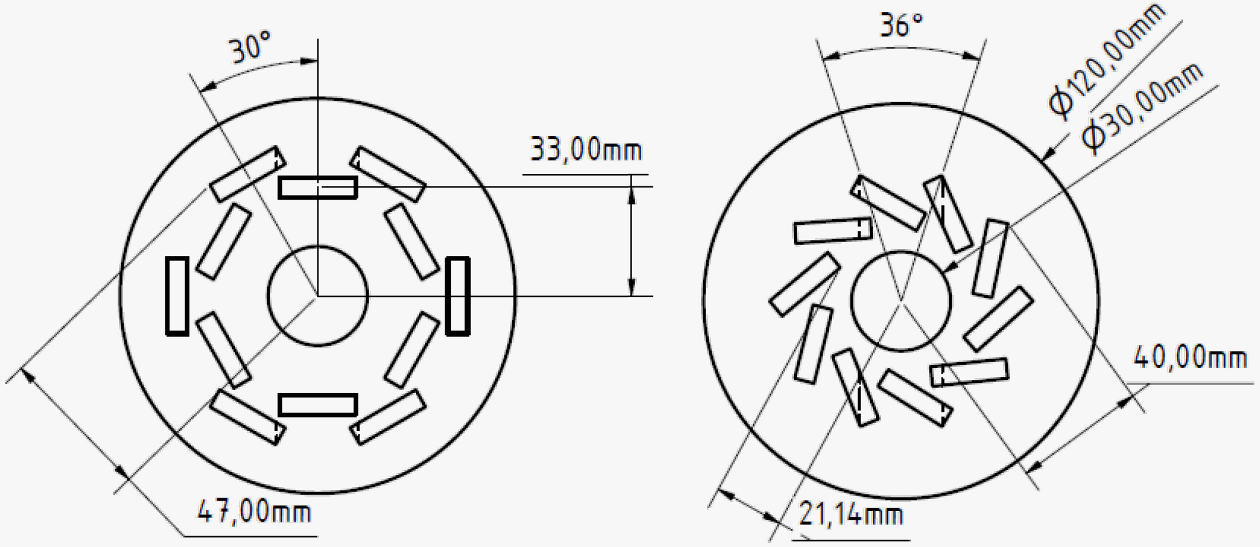


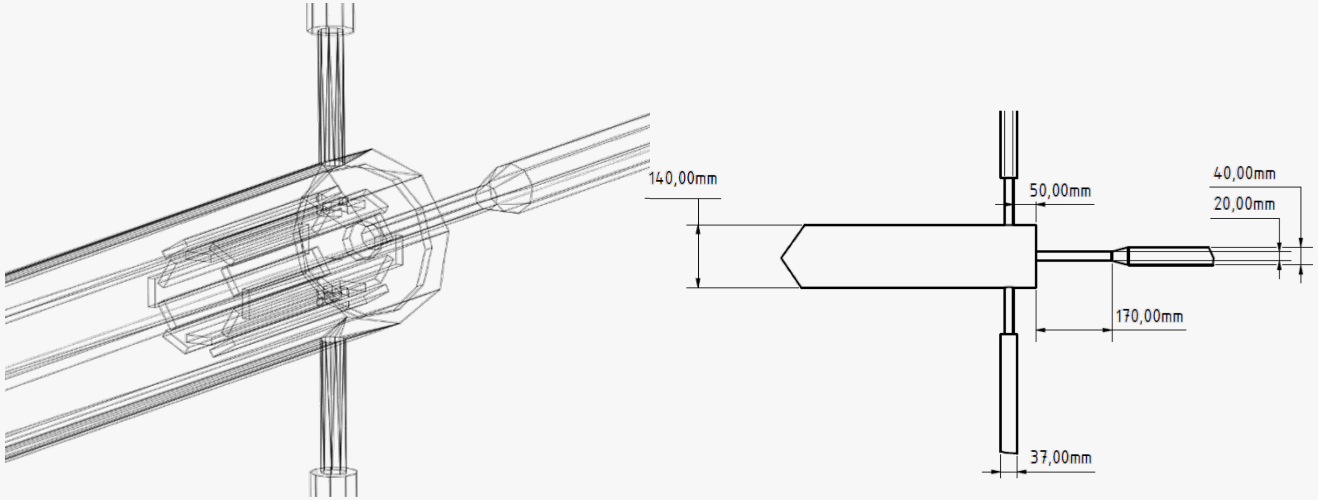
- For z > 0 cm:
  - Cryopump reduces thickness ~ρ=3 x 10^{14} atoms/cm^2
  - Big IP alone: ~ρ=1 x 10^{14} atoms/cm^2
  - Reduction is additive, not multiplicative

MVD Inside PANDA Beam Line

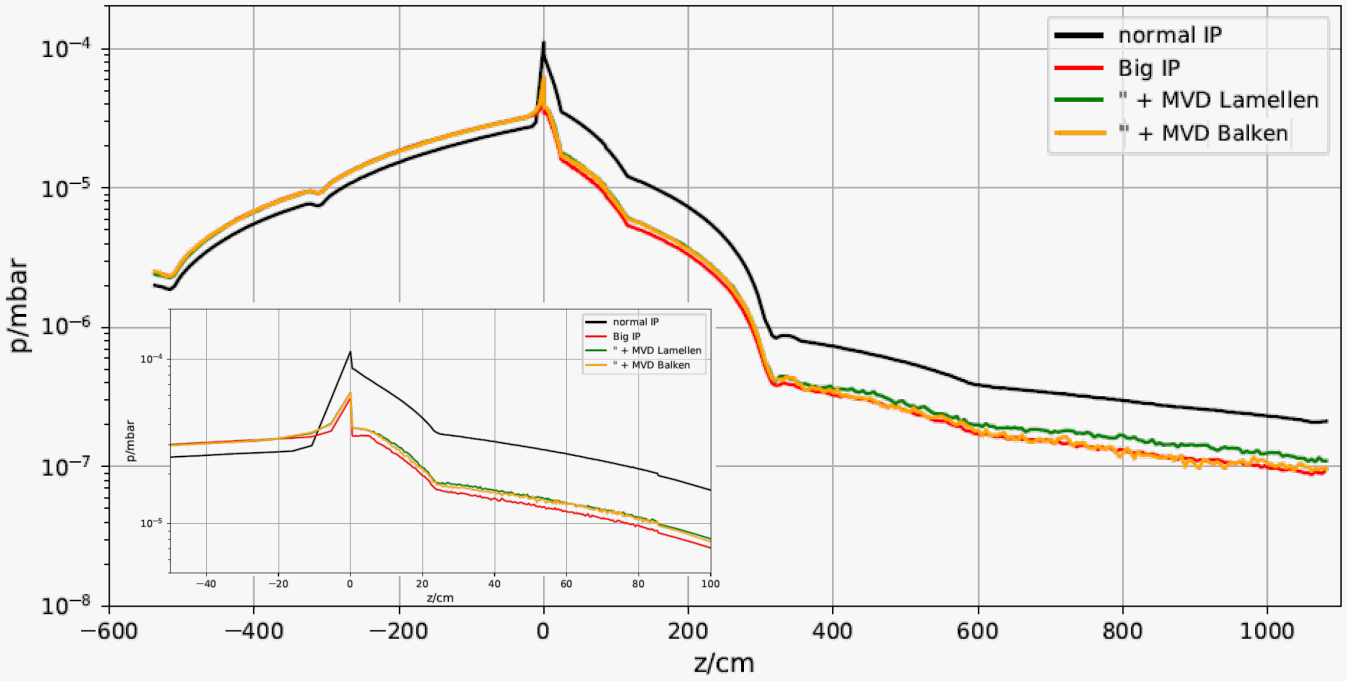


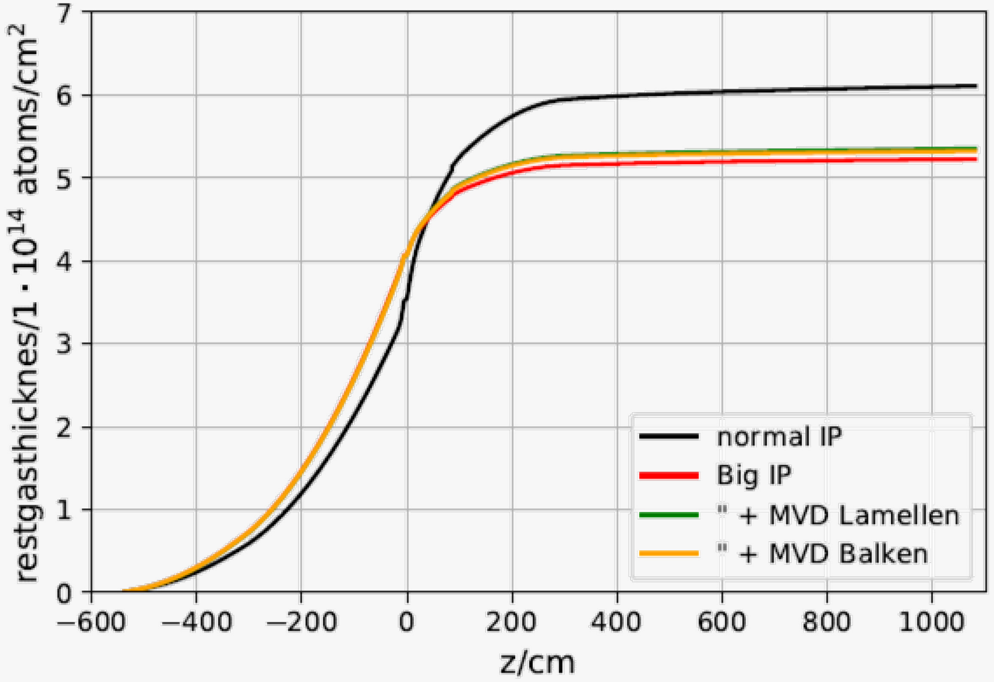
- Larger pipe -> MVD inside HESR vacuum
- Suggestions of possible MVD layouts by Miriam Fritsch
- Arbitrary geometries possible using Molflow+
- Does the MVD inside the beam line reverse all effects?





MVD Inside PANDA Beam Line



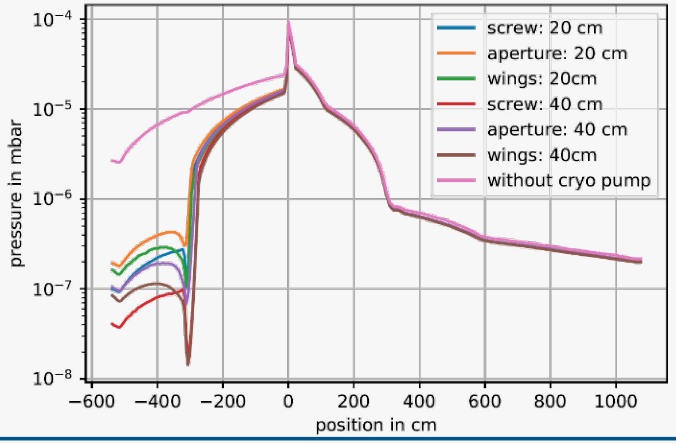


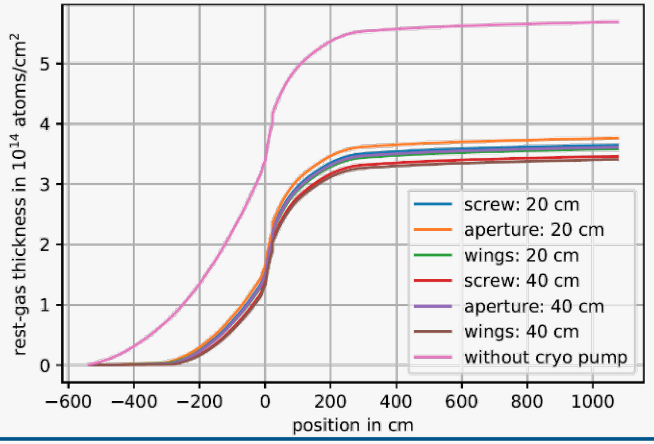
- Simulation show nearly no difference between beam pipe w/ and w/o MVD
- Also there is no big difference between both MVD designs

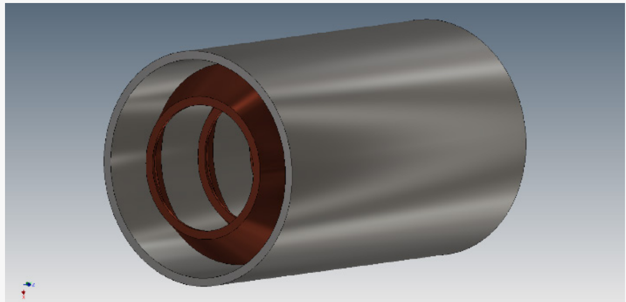
- Does the MVD inside the beam line reverse all effects?
  - ➢ **No** (negligible)

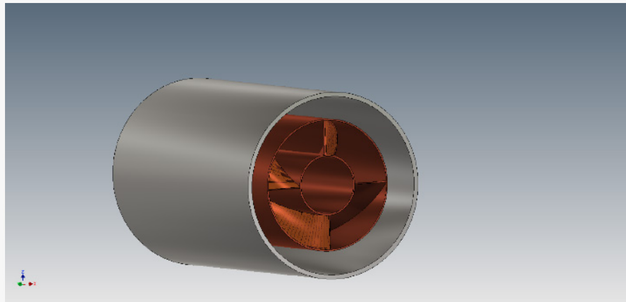
Developments of a Cryopump for PANDA

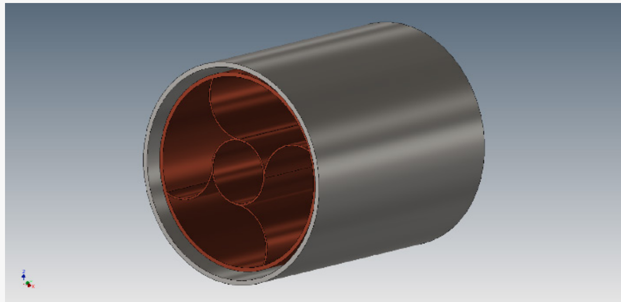
- Vacuum simulation showed the influence of a cryopump inside the beamline
- Christian Mannweiler, PhD student, started on this topic concerning:
  - ➢ Simulation of best charcoal sheet design for optimal pumping speed/size ration
  - ➢ Minimal temperature, insulation/shielding calculations and measurements
  - ➢ Calculations and measurements of impedances and influences on the $\overline{p}$-beam
  - ➢ Gas capacity and regeneration cycle frequency











Summary

- Results of last year's COSY beam times:
  - Lateral p-beam momentum resolution: $\Delta p/p = 1.2 \times 10^{-4}$ and
  - Mean momentum stability: $\delta p/p < 3 \times 10^{-6}$
    for $> 6 \times 10^{14}$ atoms/cm^2 possible
  - COSY beam influence onto the jet beam visible by pressure increase (minimal effect)
  - More test in upcoming (already granted) COSY beam times.
- Tests of a second, differential pumping stage for the source planed at COSY
- Vacuum simulation of HESR/PANDA vacuum using Molflow+:
  - Different IP configurations -> larger upstream pipe, cryopump inside HESR beam line
  - Influence of MVD inside HESR vacuum minimal
- Development and simulation of a cryopump prototype for PANDA started