‘JRA11 – Cryogenically cooled particle streams from nano- to micrometer size for internal targets at accelerators’

WP 29

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WWU

STRONG-2020 Kick-off meeting

October 23-25, 2019

Cryojet Project

- Participant institutions:
  - WWU(*) Westfälische Wilhelms-Universität Münster, **Germany**
  - GSI GSI Helmholtzzentrum für Schwerionenforschung, **Germany**
  - UU Uppsala University, **Sweden**

- Participants not receiving funds:
  - GUF Johann Wolfgang Goethe-Universität Frankfurt, **Germany**
  - HHUD Heinrich-Heine Universität Düsseldorf, **Germany**
  - INFNGE Istituto Nazionale di Fisica Nucleare Genova, **Italy**
  - SMI Österreichische Akademie der Wissenschaften, **Austria**
  - ITEP Institute for Experimental and Theoretical Physics, **Russia**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

Cryogenically cooled particle streams from nm to µm size for internal targets at accelerators

WP 29 objectives

- Significantly advance the science and technology of cryogenic target beams for various fields
  - Internal targets for accelerator experiments (FAIR, MESA, LEAF, ...)
  - Particle-laser interaction (ARCTURUS@HHUD, POLARIS@Jena, …)
- Development of advanced diagnostic tools
- Special focus:
  - Cluster Jet, Microjet, Pellet Beams
  - Low-Z elements (H_2, D_2) + heavier gases (N_2, O_2, Ar, Xe)
  - Boundary-free targets for hadron physics experiments
- Aim: Higher efficiency and performance of targets for future hadron physics facilities

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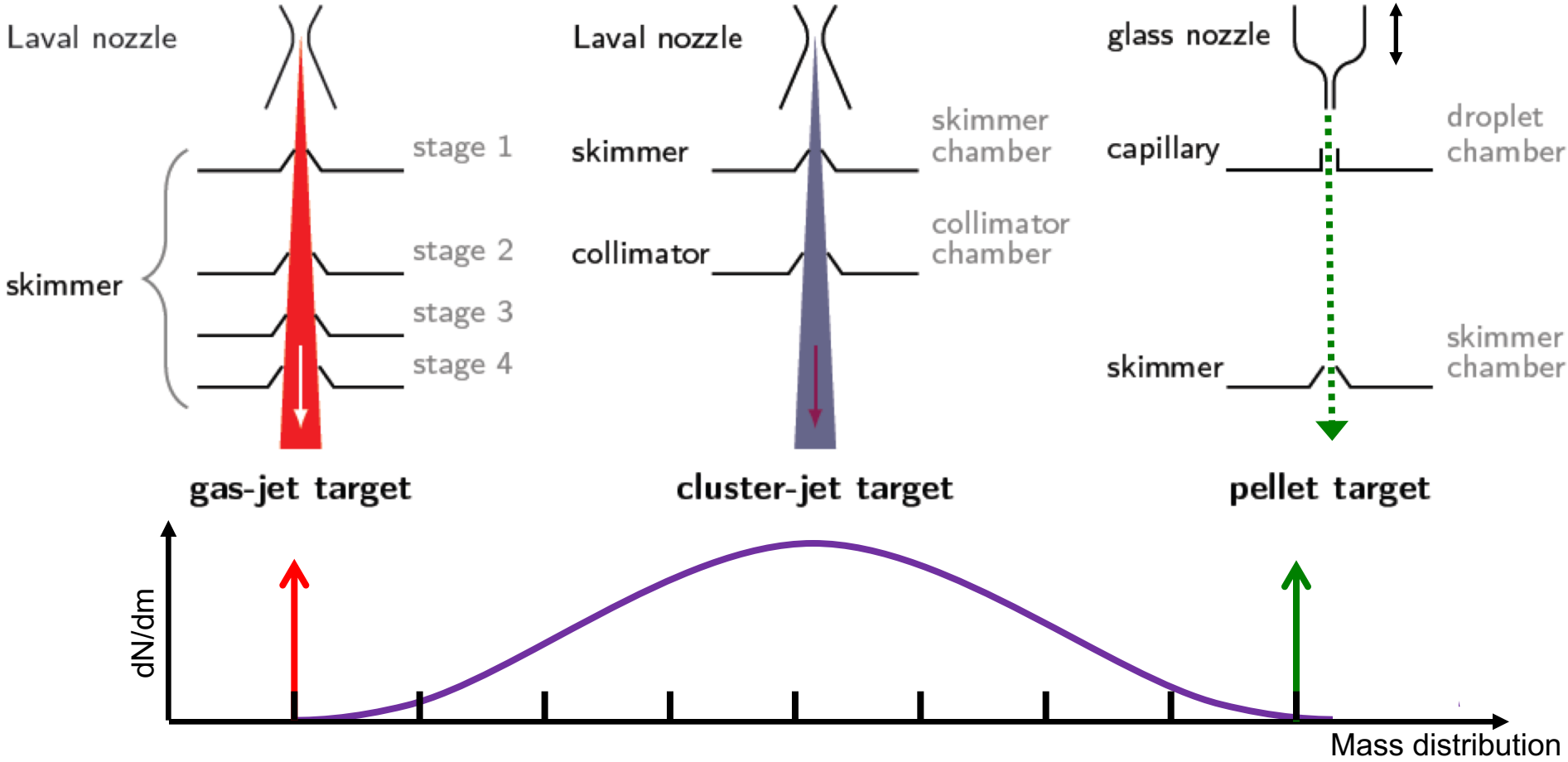
Production of gas, cluster, and droplet/pellet beams



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Cryogenically cooled particle streams from nm to µm size for internal targets at accelerators

WP tasks

- Cluster-jet beam studies
  - New nozzle production techniques
  - Studies on jet beams: highest performance and cluster formation
  - Laser-induced particle acceleration (H2 clusters and heavier gases)

- Cryogenic droplet beam target
  - Studies on droplet nozzles designs and efficiency
  - Measurements on long term stability
  - Investigations on high performance

- Pellet source studies
  - Development and studies with new pellet diagnostic systems
  - New nozzle and pellet production techniques

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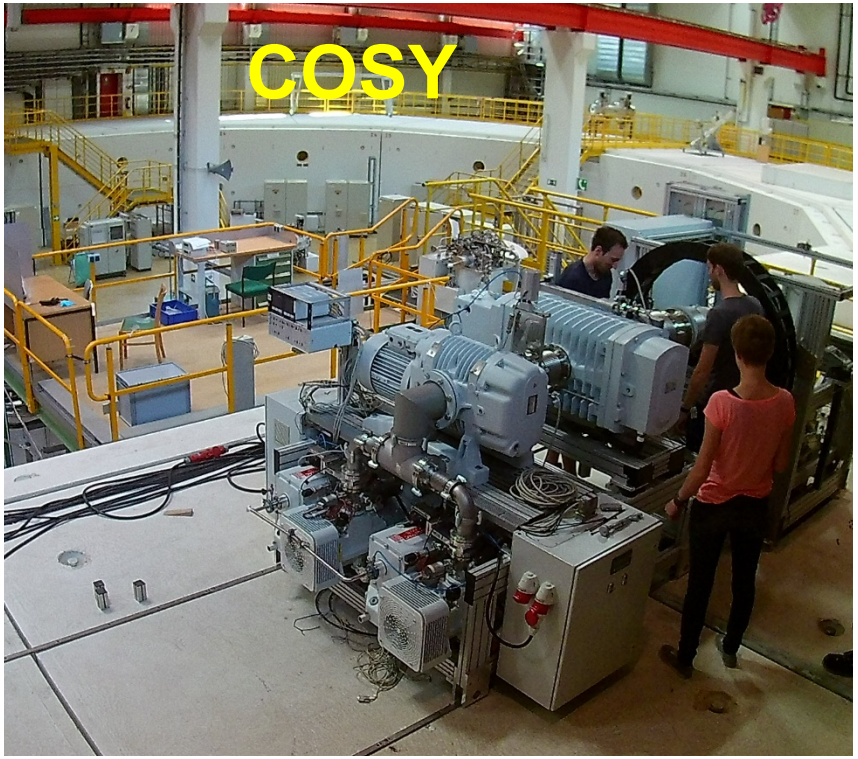
JRA11 : Update on progress

- Cluster-jet beam studies
  - Panda prototype target in operation at WWU
  - Final PANDA target and KOALA target in operation at COSY
  - Cluster target in operation at ARCTURUS laser at HHUD
  - Cluster target will be set into operation at GSI



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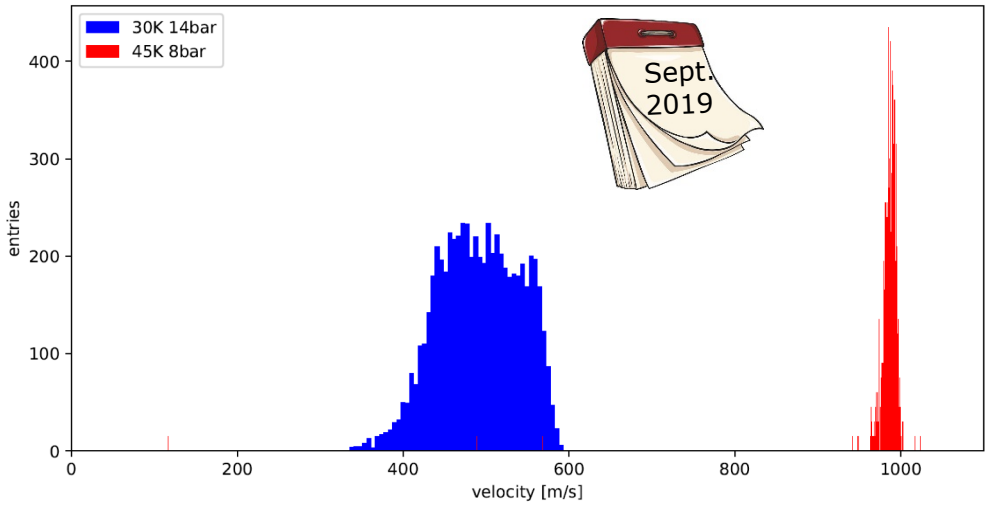
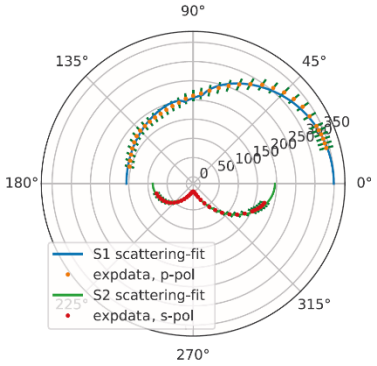
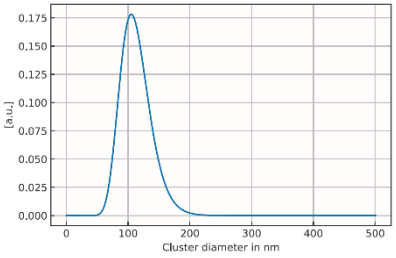
JRA11 : Update on progress

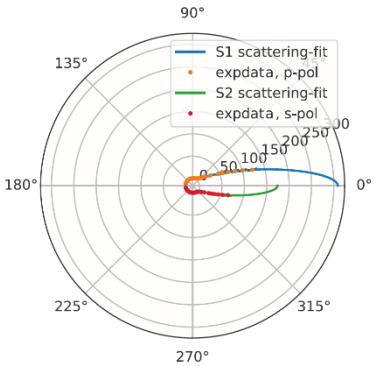
- Test of cluster-jet nozzles and measurement of cluster beam properties
  - Target thickness measurements (hydrogen)
  - Cluster nozzle tests and velocity distribution measurements via time-of-flight
  - Cluster size distribution measurements using Mie scattering
  - Cluster size and velocity distributions strongly depend on stagnation conditions / production process



Velocity distributions of hydrogen clusters







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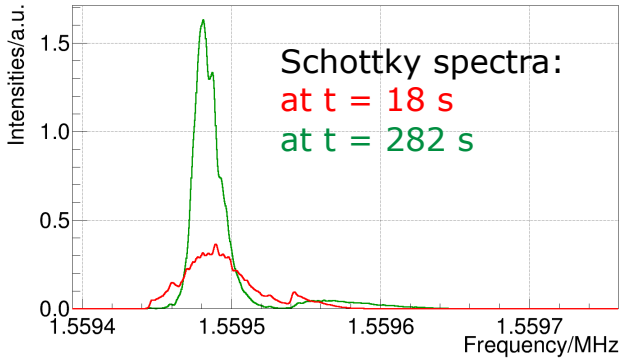
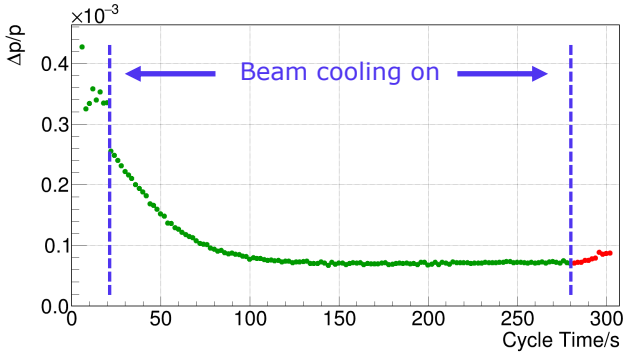
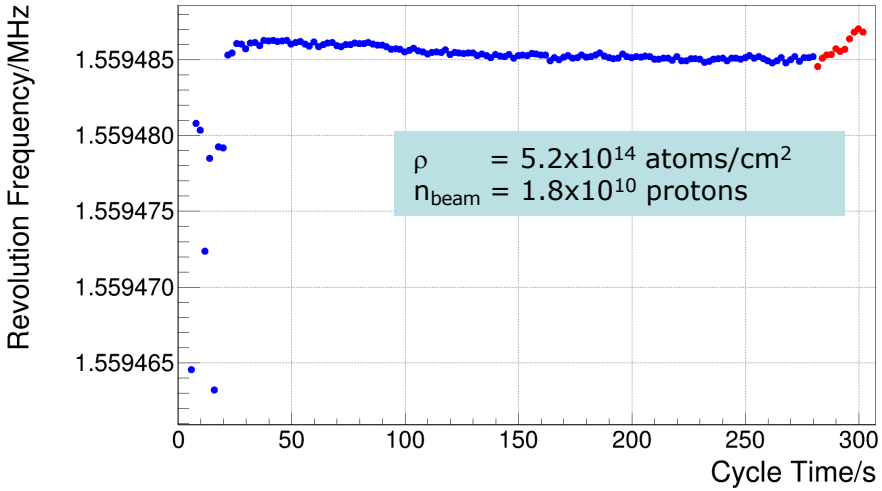
JRA11 : Update on progress

- Beam-target interaction studies at COSY
  - COSY beam time in August 2019 with PANDA hydrogen cluster target
  - Beam momentum p = 3.0 GeV/c
  - Studies on stochastic beam cooling at different target settings and COSY beam intensities







- Momentum resolution of $\delta p/p < 10^{-4}$
- Mean revolution frequency stable within $\delta f/f < 7 \times 10^{-7}$

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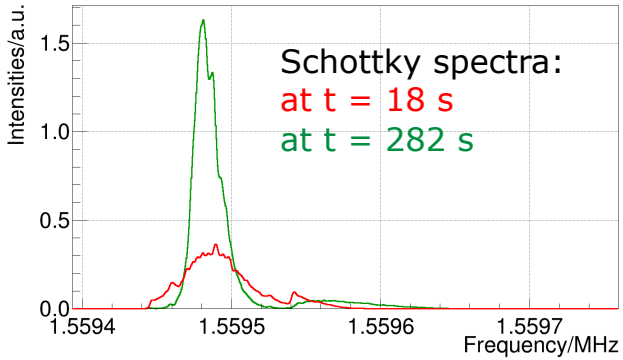

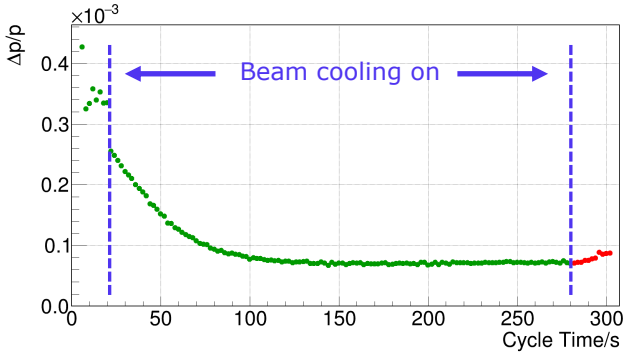

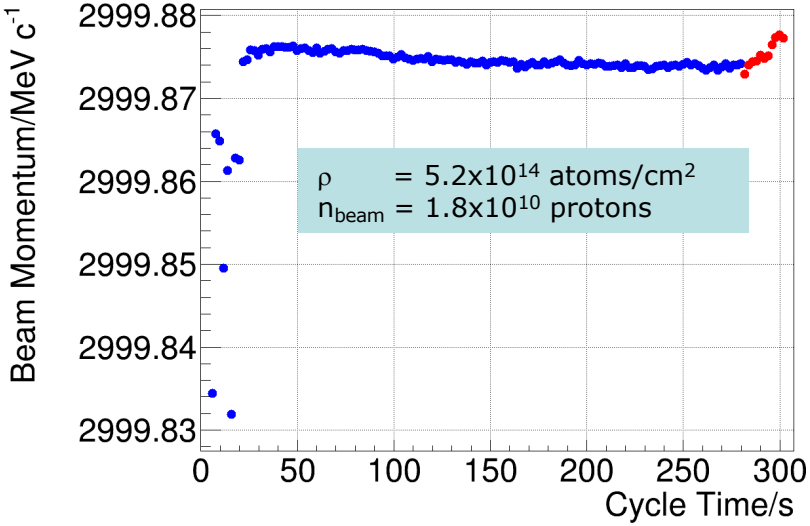

- Momentum resolution of $\delta p/p < 10^{-4}$
- Mean revolution frequency stable within $\delta f/f < 7 \times 10^{-7}$
- Mean momentum stable within 2 keV/c, i.e. $\delta p/p < 7 \times 10^{-7}$

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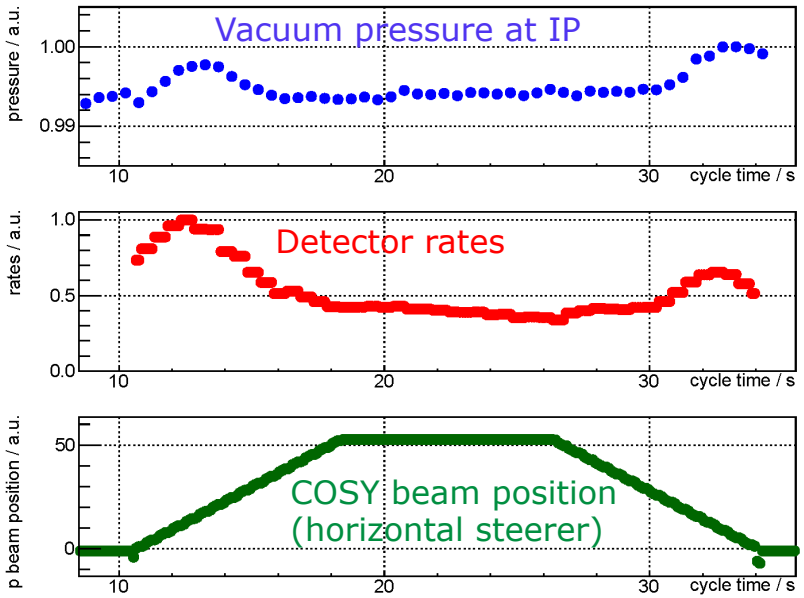
JRA11 : Update on progress

- Beam-target interaction studies at COSY
  - Studies on vacuum situation at interaction point and ion beam induced cluster evaporation
  - Accelerator beam life time studies in preparation



ρ = 1x10^{13} atoms/cm^2
T = 36 K, p = 12 bar
n_{beam} = 1.0x10^{10} protons

Measurement (left figure):

- COSY beam scans cluster beam via a steerer
- Event rate proportional to beam-target overlap
- Observation of ion-induced cluster evaporation
- Effect will be studied in more detail
  - Variation of target thickness
  - Variation of cluster size
  - Variation of COSY ion beam intensity

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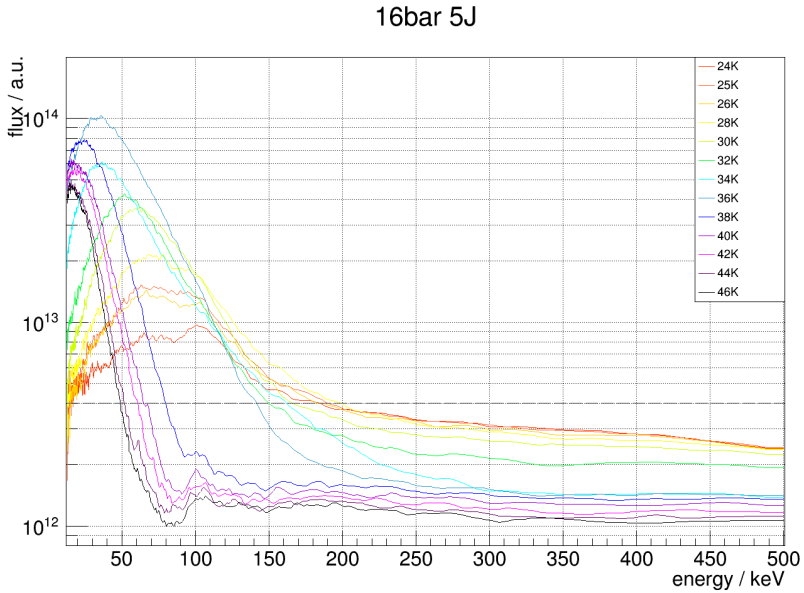
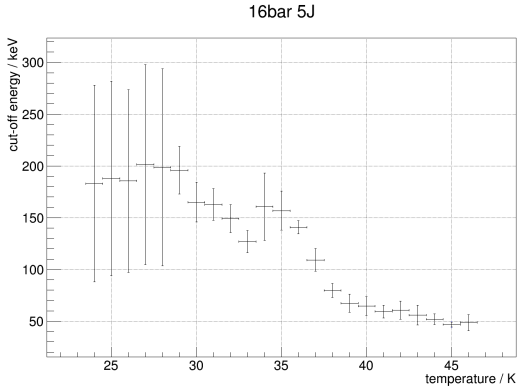
JRA11 : Update on progress

- Proton acceleration at the ARCTURUS laser in Düsseldorf
  - Interaction of 200 TW laser system with a hydrogen cluster beam
  - Variation of hydrogen cluster target parameter (nozzle temperature/pressure) → mean cluster size
  - Variation of laser energy
  - Observation of accelerated protons in combination with high shot-to-shot stability





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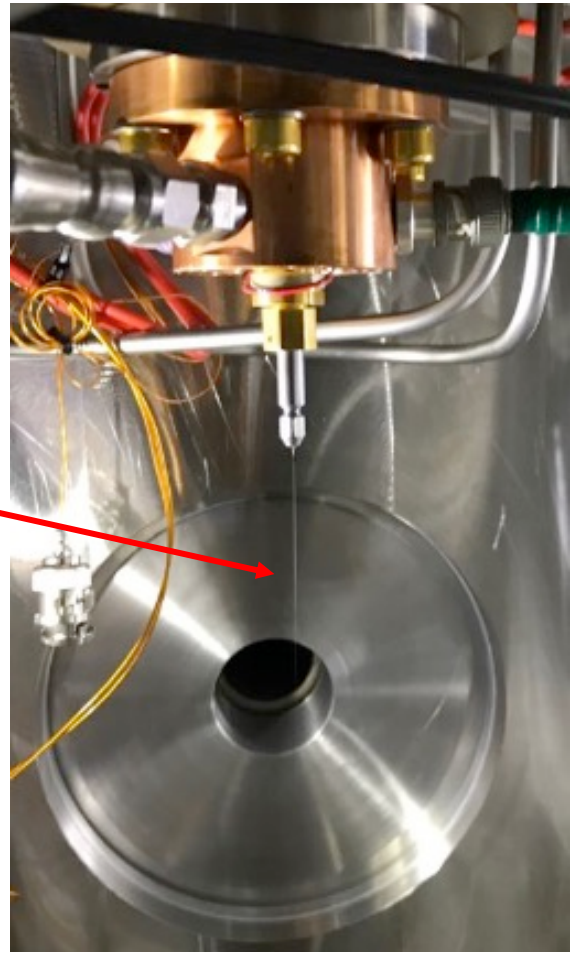
JRA11 : Update on progress

- Cryogenic droplet beam target
  - Droplet generator successfully set into operation at WWU
  - Optical diagnostic tools installed
  - Argon droplet generation
  - Measurement of velocity, size, distance of droplets
  - Test of nozzle designs and nozzle life time
- Gas purification and recoperation
  - Cluster/droplet/pellet targets require ultra-clean gases
  - Hydrogen: Palladium purifier
  - Heavier gases: Design of powerful purification system in progress (GSI)
  - Design studies on a recuperation system for rare and expensive gases at GSI



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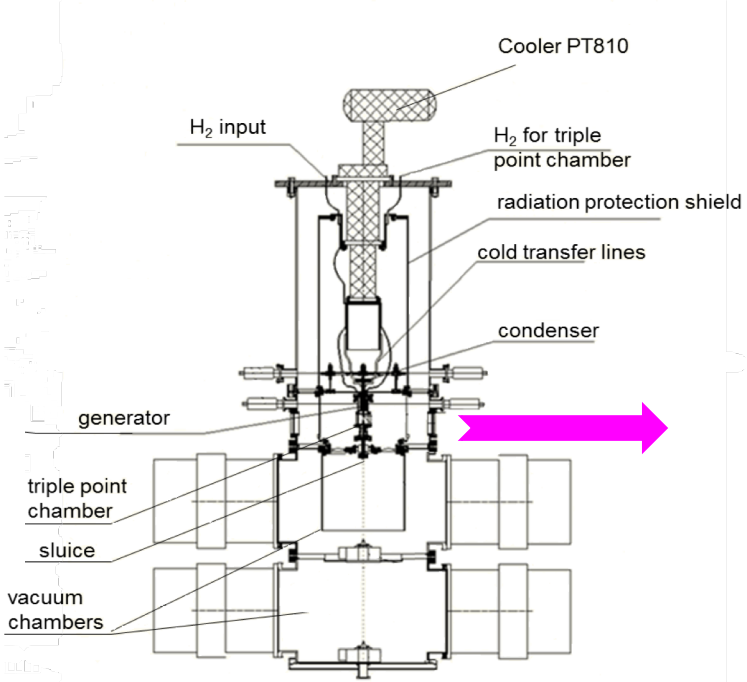
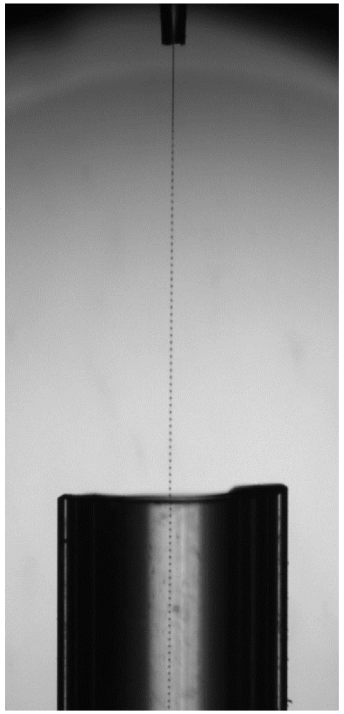
JRA11 : Update on progress

- Pellet source studies at ITEP using the PANDA pellet target prototype
  - Production of mono-dispers frozen hydrogen pellets





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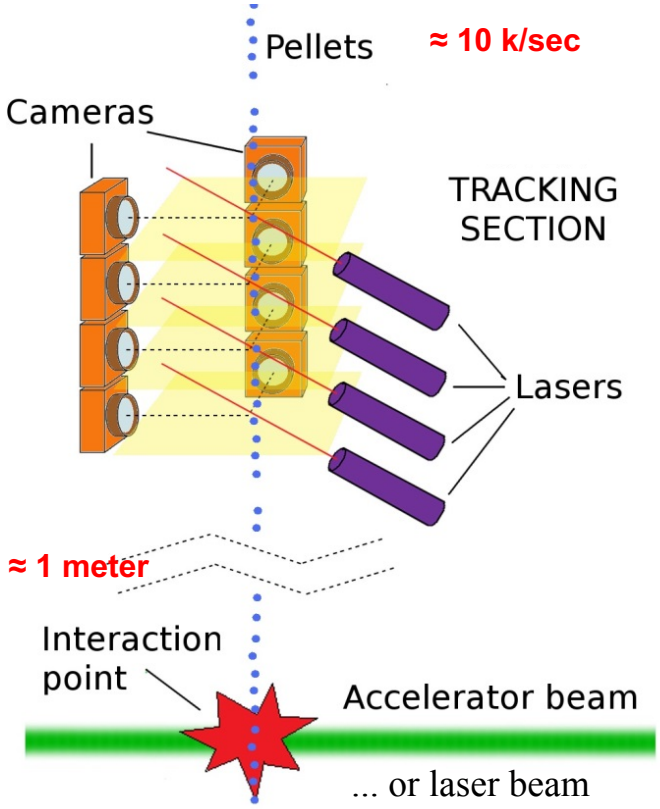
JRA11 : Update on progress

- Pellet target test station is currently set into operation at UU
- Device will be used for developments on a pellet tracking system
  - Predict ‘arrival’ of pellets 10 ms in advance
  - Aimed spacial resolution: 10 µm
- Application of a pellet tracking system
  - Target beam monitoring in hadron physics experiments
  - Triggering laser pulses for laser-induced hadron acceleration
- Hardware will be developed at UU
  - Detector configuration
  - Multi-camera operation
  - Readout system and software



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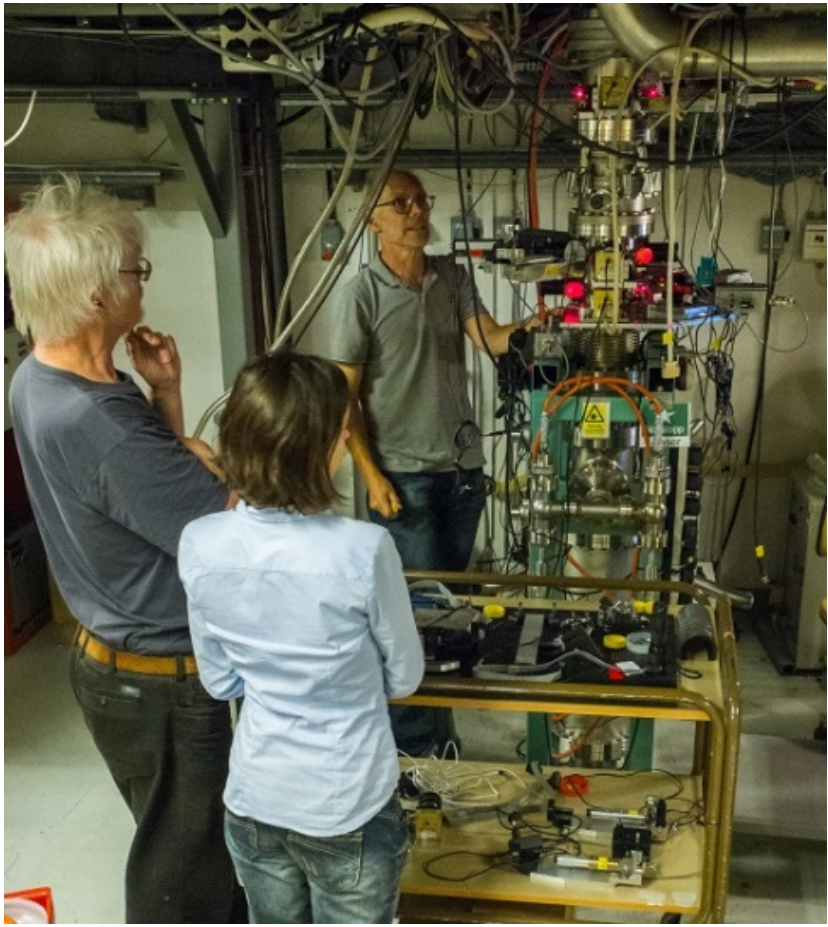
JRA11 : Update on progress

- Study of droplet generation via
  - Spontaneous breakup
  - Droplet generation via piezo excitation
  - Laser-induced droplet formation
- Investigate production of frozen H_2 fibers with, e.g., 15 μm diameter

Droplet chamber

Nozzle oscillation and Stroboscope: f = 67 kHz



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JRA11: Deliverables

- There are no deliverables due for Reporting Period 1 (18 months, June 2019-November 2020)

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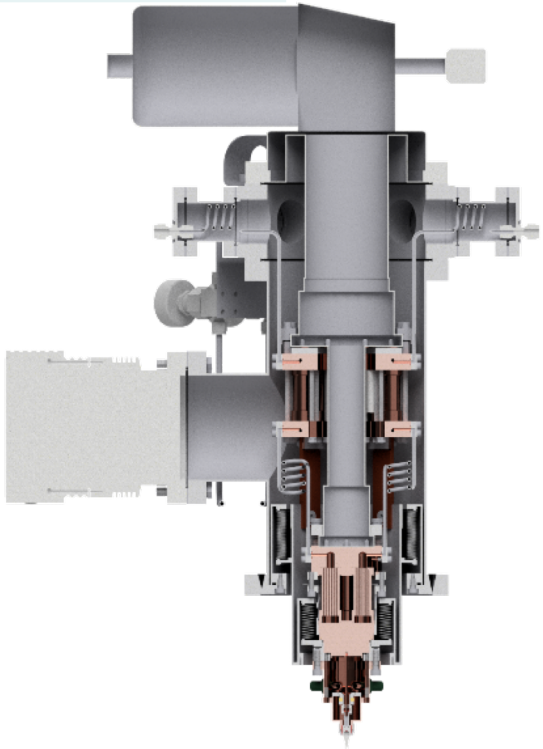
JRA11: Milestones

- MS68 has to be achieved M12 (May 2020)

Milestone number[18]	Milestone title	Lead beneficary	Due date (in months)	Means of verification
MS68	Setup of a droplet test device	16 - WWU	12	Successful operation of the droplet generator

- Advancement
  - First droplet target generator is already in operation
  - System is used for optimization studies on droplet generation and nozzle design
  - First studies with of Argon droplets already started
  - Hydrogen droplets will be investigated in a next step
  - Based on the received results, a new and optimized droplet generator will be build
- Expected delivery date
  - First milestone already achieved
  - Design of improved setup in preparation and will be set up in parallel to currend measurements



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Thank you very much....