Design and Properties of a Target for the MAGIX Experiment

Silke Grieser

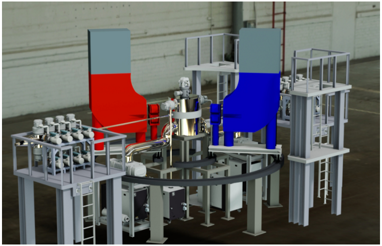
Westfälische Wilhelms-Universität Münster, Institut für Kernphysik

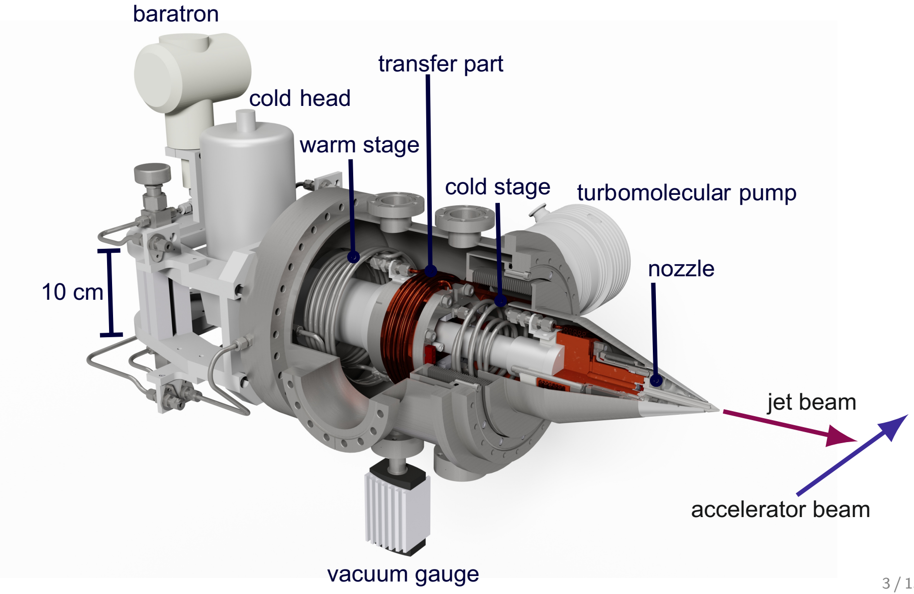
New Vistas in Low-Energy Precision Physics (LEPP), Mainz,
April 6th 2016

MAGIX @ MESA

Design Requirements for the Target

- Windowless target
- Minimize background interaction
- Different target material: H_2, O_2, ^3He, Xe, ...
- Pointlike interaction zone
- Target thickness constant in time
- Continuously adjustable and homogeneous spatial target density
- Target density: $O\left(10^{19}\right) \frac{\text{atoms}}{\text{cm}^2}$





baratron
transfer part
cold head
warm stage
cold stage
turbomolecular pump
nozzle
10 cm
jet beam
accelerator beam
vacuum gauge

- Volume flow q_V at normal conditions:

$$q_V = A^* \frac{p_0}{\sqrt{M T_0}} \frac{T_N}{p_N} \left(\frac{2}{\kappa+1}\right)^{\frac{\kappa+1}{2(\kappa-1)}} \sqrt{\kappa R}$$

  - A^*: Critical area of the nozzle
  - p_0 and T_0: Current pressure or temperature at the nozzle
  - p_N and T_N: Normal pressure and normal temperature
  - R: Universal gas constant
  - M: Molecular mass
  - κ: Heat capacity ratio

- Target density ρ_T:

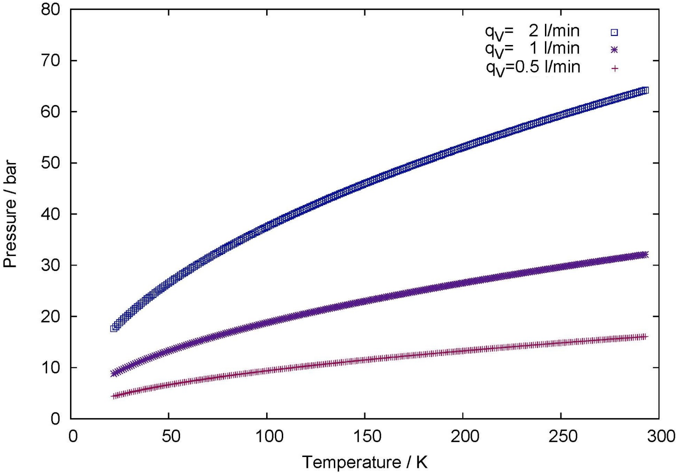
$$\rho_T = \frac{q_V \cdot N_A \cdot M_M}{A_{beam} \cdot v \cdot R \cdot T \cdot M_A} \cdot \varnothing_{beam}$$

  - A_{beam} and $\varnothing_{beam}$: Dimensions of the beam
  - N_A: Avogadro constant
  - M_M and M_A: mass of gas molecul and atomar constituent
  - v: Beam velocity

MAGIX @ MESA

Volume Flow and Density

- Stagnations conditions at the nozzle for a constant volume flow
  - Hydrogen
  - Nozzle diameter: $d = 30\mu m$

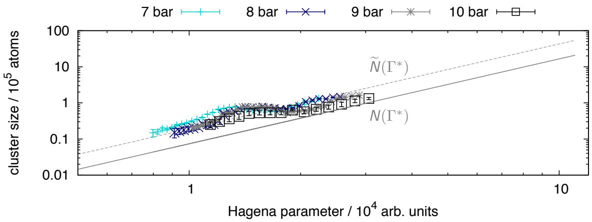


- Hagena parameter Γ^* provides an empirical access to the prediction of cluster sizes
- $\Gamma^* = \frac{\widehat{k} p_0 \left(\frac{0.74 d_n}{tan \alpha_{0.5}} \right)^{0.85}}{T_0^{2.29}}$
  - Gas dependent constant $\widehat{k}$
  - Stagnation pressure p_0
  - Temperature T_0 of the gas
  - Nozzle diameter d_n
  - Expansion half angle $\alpha_{0.5}$
- $\Gamma^* < 200$: flow without cluster formation
- $200 < \Gamma^* < 1000$: transition to cluster formation
- $\Gamma^* > 1000$: immense condensation of clusters

MAGIX @ MESA

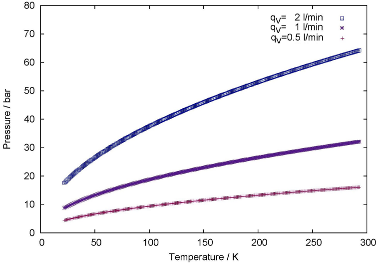
Hagena's scaling law

- Relation to the average cluster size N: Hagena's scaling law
- $N = A_N \left(\frac{\Gamma^*}{1000}\right)^{\gamma_N}$
  - Empirical Hagena parameter Γ^*, empirical values A_N and γ_N
- Esperanza Köhler, PhD thesis 2015, Münster



- Measured hydrogen cluster size as function of the Hagena parameter
- Grey solid line: Expected cluster size $N(\Gamma^*)$ (Hagena's scaling law)
- Grey dashed line: Fit $\tilde{N}(\Gamma^*)$ through the data
- Measured data and the predicted sizes agree by a factor of 2.6.

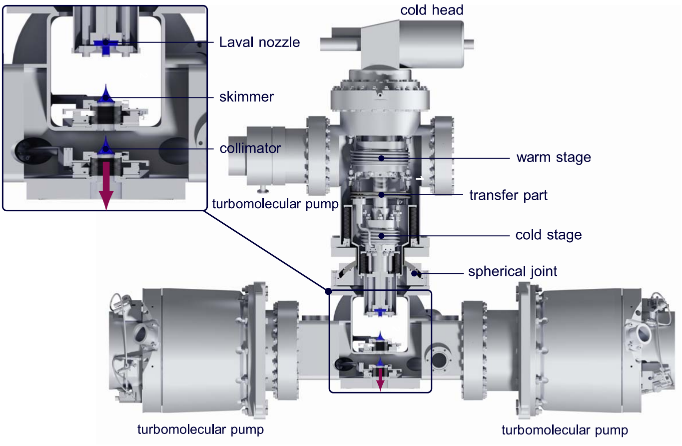
- Directed jet flow
- Variable size and shape of cluster beam
- Effective size of target beam as small as possible
  - Precise vertex reconstruction
  - Small influence on the vacuum conditions in the accelerator
- High density in a distance of more than 2m from the nozzle
- Measurement which shows the best stagnation conditions in regards to
  - Target size and shape
  - Vacuum conditions in the accelerator



MAGIX @ MESA

More elaborated Source Design

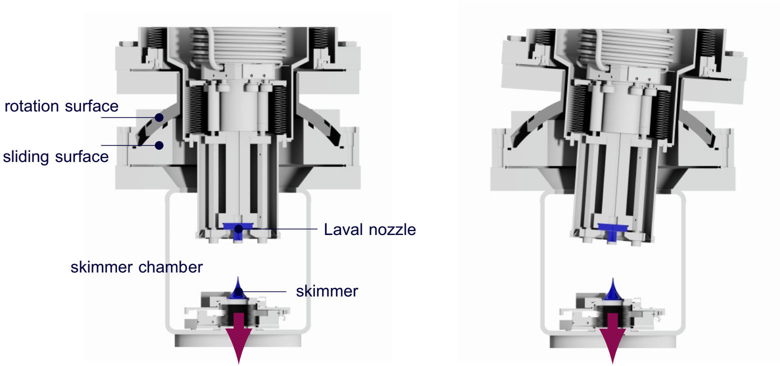
- Skimmer: Beam extraction and residual gas reduction
- Collimator: Size and shape of cluster beam

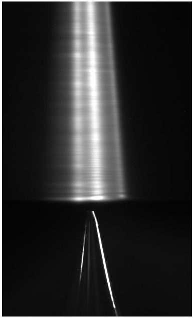


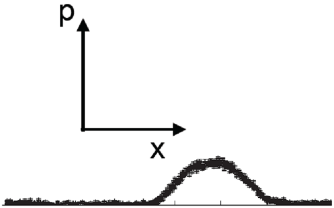
MAGIX @ MESA

More elaborated Source Design

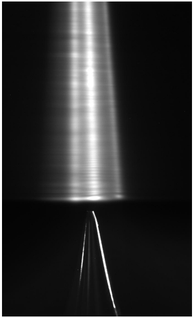
- Sperical joint to tilt the nozzle
- Narrowest inner nozzle diameter is point of rotation
- Extraction of highly intensive core beams

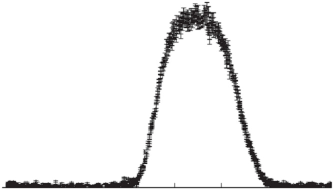




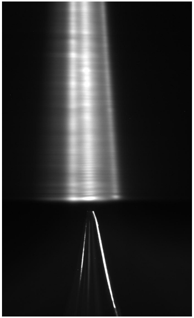


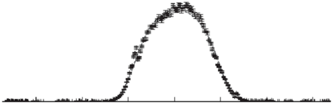
- Operation at highest densities → liquid H_2 at the nozzle inlet
- Beam structures → Highly intensive core beams
- Extraction of core beams by spherical joint





- Operation at highest densities → liquid H_2 at the nozzle inlet
- Beam structures → Highly intensive core beams
- Extraction of core beams by spherical joint

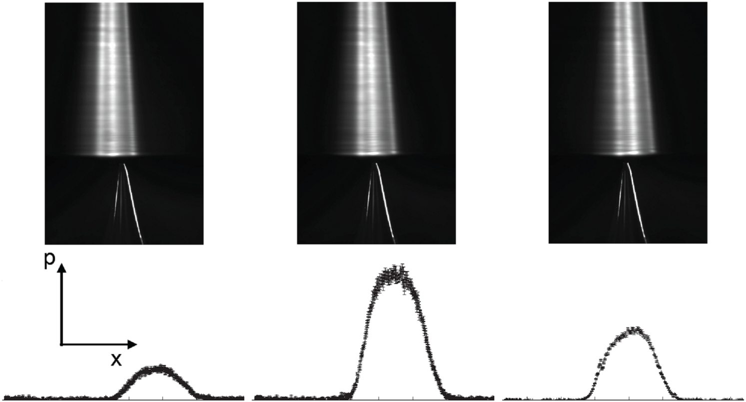




- Operation at highest densities → liquid H_2 at the nozzle inlet
- Beam structures → Highly intensive core beams
- Extraction of core beams by spherical joint

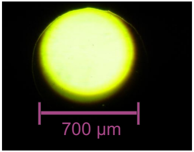
Cluster-Jet Target

Cluster source - **Beam structures**

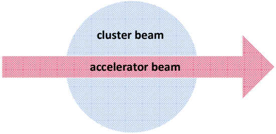


- Operation at highest densities → liquid H_2 at the nozzle inlet
- Beam structures → Highly intensive core beams
- Extraction of core beams by spherical joint

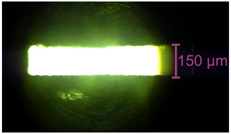
Specially Shaped Collimators



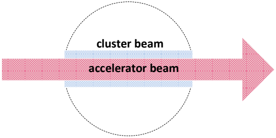
Collimator with round orifice



- Overlap between target beam and accelerator beam small compared to the size of the target beam



Collimator with slit orifice

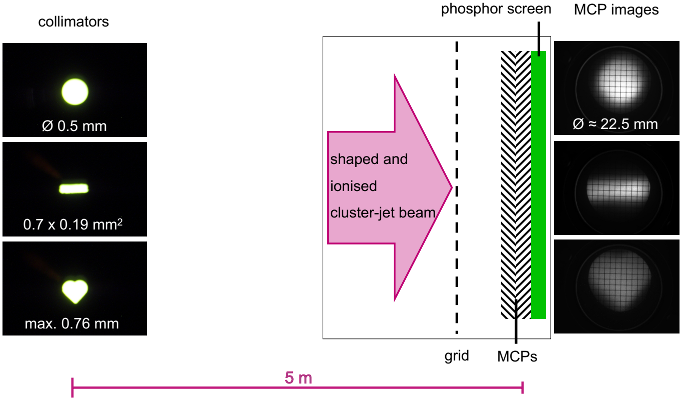


- Target beam size as small as possible at same overlap region with accelerator beam

  $\Rightarrow$ Improvement of vacuum conditions in scattering chamber

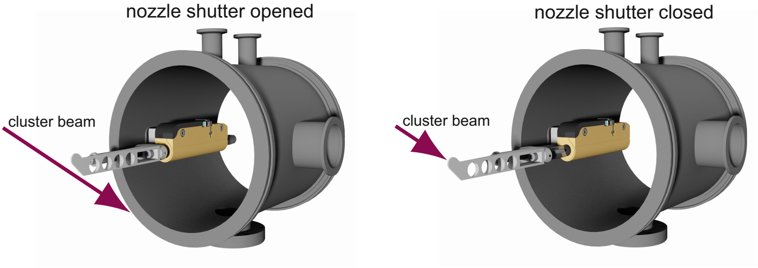
Microscopic View of Collimators and Resulting Cluster Beams on MCP Detector

- Definition of target beam size and shape with collimators
- MCP images with expected beam shape and grid at approximately 5 m behind the collimator



MAGIX @ MESA

Nozzle Shutter



- Useable as on/off switch
- A pulsed cluster beam is possible
  - ⇒ Reduced gas flow in interaction chamber
  - ⇒ Frequency of 10 Hz possible (limited by used linear motor)

MAGIX @ MESA

Summary & Outlook

- Gas-jet targets fullfil all the requirements for MAGIX @ MESA
  $\Rightarrow$ Gas-Jet Target will be set up

- Possibility to switch into cluster-jet operation
  $\Rightarrow$ High density is feasible
  $\Rightarrow$ Directed cluster beam
  $\Rightarrow$ Variable size and shape of cluster beam
  $\Rightarrow$ Improvements of vacuum conditions

- Nozzle shutter as on/off switch

- Target production in progress . . .

- Target ready in summer 2016