Cluster Beam Shaping and Visualization

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Westfälische Wilhelms-Universität Münster

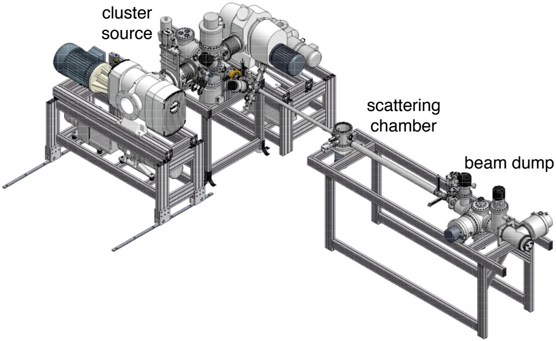
Bundesministerium für Bildung und Forschung

Cluster-Jet Target Prototype for $\overline{\text{P}}$ANDA

- Prototype built up in complete $\overline{\text{P}}$ANDA geometry

- Target material with purity of 9.0
- Target thickness:
  - $> 2 \times 10^{15} \frac{\text{atoms}}{\text{cm}^2}$
  - Adjustable by variation of pressure and temperature settings
  - Constant in time scales of at least several hours

$\longrightarrow$ **See talk of E. Köhler**

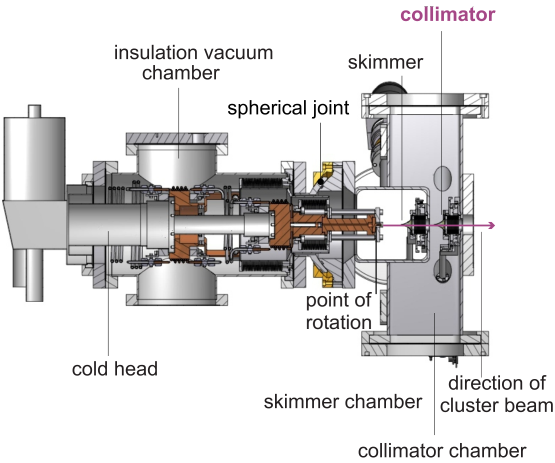


- Target size and shape variable by use of specially shaped collimators

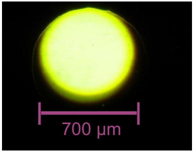
Variable Target Beam Size and Shape

Use of a collimator

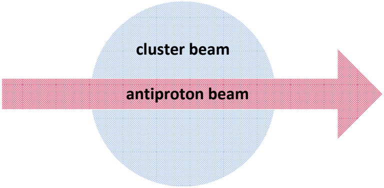
- Collimator installed behind the skimmer
- Cuts out a certain area of cluster beam
  $\Longrightarrow$ Shaping of cluster beam
- Collimator with different shapes are in use
  $\Longrightarrow$ a round and a slit collimator



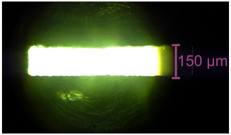
Specially Shaped Collimators



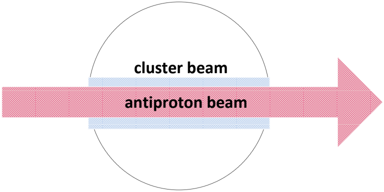
collimator with round orifice



$\Longrightarrow$ **Overlap of antiprotons and target beam small compared to the size of target beam**



collimator with slit orifice

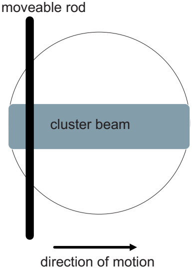


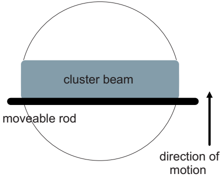
$\Longrightarrow$ **Target beam size as small as possible with same size of overlap region**

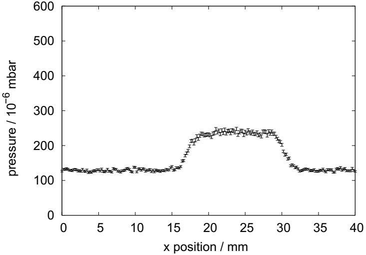
$\longrightarrow$ Reduction of background pressure

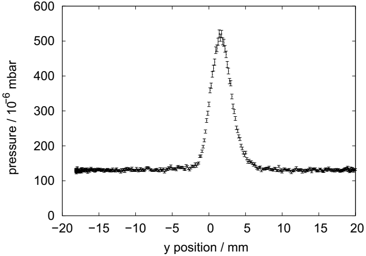
Studies on defined Cluster Beams

Determination of target position, size, shape and thickness





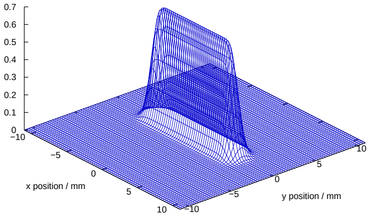




Studies on defined Cluster Beams

Fit function and assumed density distribution

- Target thickness $\rho_T \sim \frac{p_{sc}}{v_c}$
  - p_{sc}: Pressure increase in scattering chamber
  - v_c: Velocity of cluster $(200 - 1000\ \frac{\mathrm{m}}{\mathrm{s}})$
    (see A. Täschner et al., in proceedings of STORI'11 conference, PoS(STORI11)065)



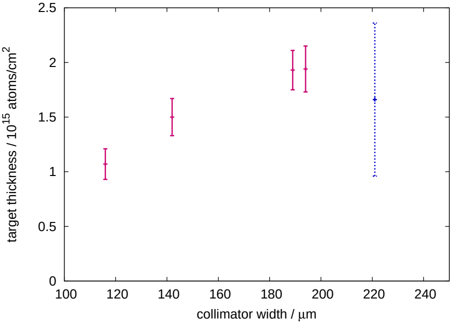
- Profiles can be described by a convolution of a rectangular and a Gaussian function

Assumed density distribution

$$\rho_T(x,y) = \rho_0 \cdot \frac{erf\left(\frac{\frac{1}{2}b_x - x}{s}\right) - erf\left(\frac{-\frac{1}{2}b_x - x}{s}\right)}{2} \cdot \frac{erf\left(\frac{\frac{1}{2}b_y - y}{s}\right) - erf\left(\frac{-\frac{1}{2}b_y - y}{s}\right)}{2}$$

- $erf(z)$: Error function
- s : Smearing factor $\sim$ FWHM of Gaussian
- b_x: Size of cluster beam in x-direction
- b_y: Size of cluster beam in y-direction

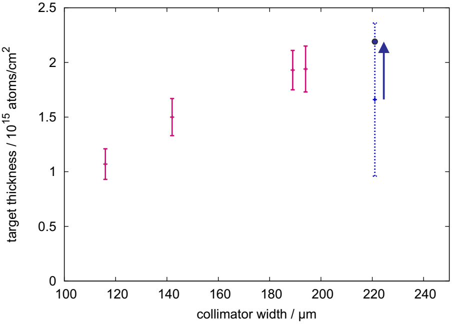
Target Thickness of defined Cluster Beam



- Analysis of 5 different slit collimators
  - Length: $\approx 780\ \mu\mathrm{m}$
  - Width: $116\ \mu\mathrm{m} - 194\ \mu\mathrm{m}$ (+)
  - $221\ \mu\mathrm{m} \times 580\ \mu\mathrm{m}$ (+)
- Target thickness $> 10^{15}\ \frac{\mathrm{atoms}}{\mathrm{cm}^2}$
- Smaller widths $\longrightarrow$ less thicknesses
- Thickness about $2.2 \times 10^{15}\ \frac{\mathrm{atoms}}{\mathrm{cm}^2}$ with a collimator with $221\ \mu\mathrm{m} \times 780\ \mu\mathrm{m}$

It is possible to achieve the same target thickness as measured with a round collimator!

Target Thickness of defined Cluster Beam



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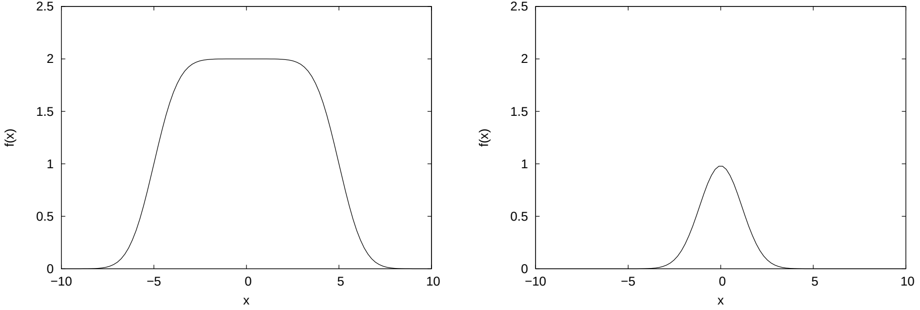
Size of Cluster Beam at the Interaction Point

Minimal size of the cluster beam at the IP is limited by FWHM of Gaussian

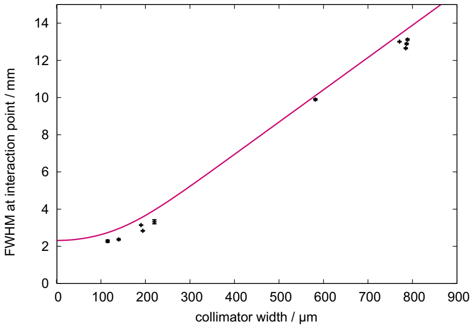
- $f(x,y) = \frac{erf(\frac{\frac{1}{2}b_x - x}{s}) - erf(\frac{-\frac{1}{2}b_x - x}{s})}{2} \cdot \frac{erf(\frac{\frac{1}{2}b_y - y}{s}) - erf(\frac{-\frac{1}{2}b_y - y}{s})}{2}$
- $b_x \approx s$: Smearing effects dominating $\longrightarrow$ impact on thickness

$b_x \gg s$ $\qquad$ $b_x \approx s$



Size of Cluster Beam at the Interaction Point

Dependency between cluster beam width and collimator width



- Expected theory curve at a constant $s = 1.38\,\mathrm{mm}$
- In good agreement with measurements
- Optimal collimator width around 200 $\mu\mathrm{m}$

Minimal cluster beam width about $2\,\mathrm{mm}$ (at the IP)

Signal to Background Ratio

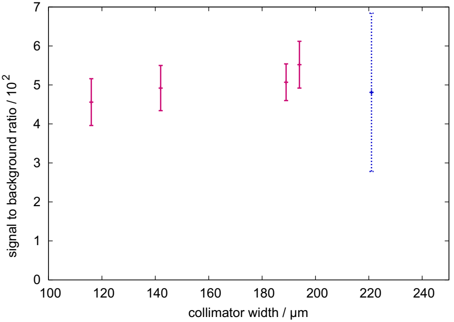
- Signal to background ratio is given by $r_{S/B} = \frac{\rho_T}{\rho_B}$
- Thickness of background: $\rho_B = \frac{p_B \cdot x}{k \cdot T}$ $(x = 1\,\mathrm{m}$

- Maximum signal to background ratio of 552 : 1
- Signal to background ratio of round collimator ($\varnothing\, 0.7\,\mathrm{mm}$) about 375 : 1

$\Rightarrow$ Improvement of about 50 %

- Geometrically expected: improvement by a factor of 2.5

$\Rightarrow$ Cause for deviation: residual gas comes directly from cluster source
$\longrightarrow$ Possible solution: installation of further orifices



Cluster Beam Shaping

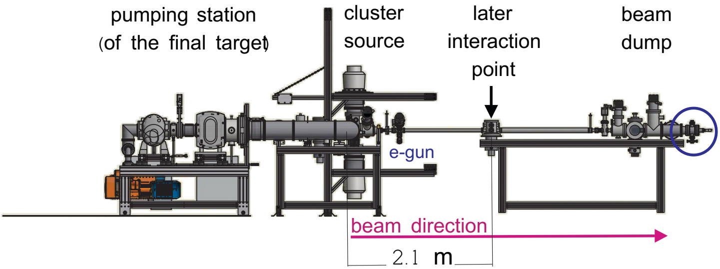
Summary

- Cluster beam can be shaped arbitrarily
  ($\rightarrow$ Can be visualized by a MCP detector)
- Target thickness in the order of $2 \times 10^{15}\ \frac{\mathrm{atoms}}{\mathrm{cm}^2}$ with a slit collimator
- Limitation of cluster beam size at IP

$\Rightarrow$ Minimal width currently about $2\,\mathrm{mm}$ (at the IP)

- Optimal collimator width around $200\,\mathrm{\mu m}$
- Signal to background ratio improved by $50\,\%$ compared to a round collimator

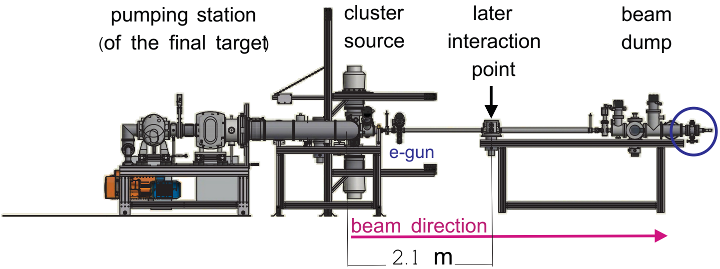
$\rightarrow$ Much more possible with a new pumping system



- Visualization of Cluster beam with MCP detector (**M**icro**C**hannel **P**late detector)

Visualization of the Cluster Beam

Overview



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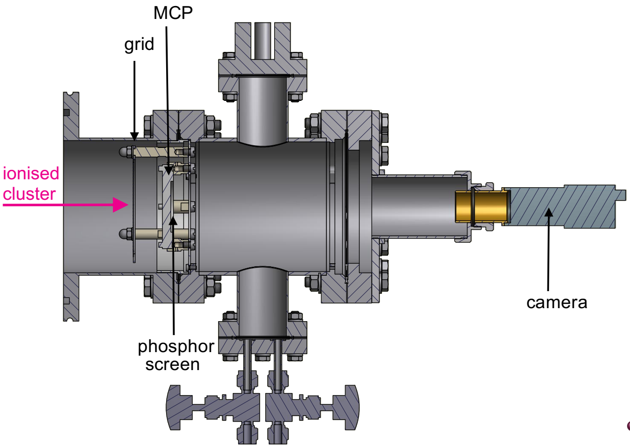
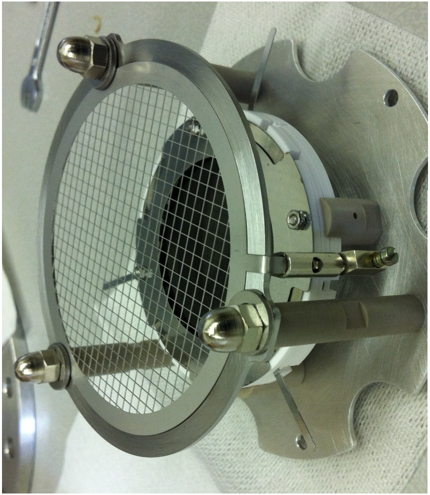
MCP detection system

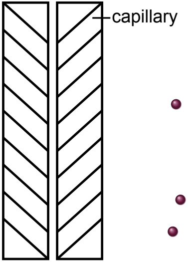
MCP Detection System

Overview



- **Grid** with 2.5 mm lattice spacing (electrically grounded)
- **Two MCPs** (chevron assembly, effective diameter of 40 mm)
  - each capillary works as independent secondary-multiplier
  - 1st MCP: max. $-4\,\mathrm{kV}$
  - 2nd MCP: max. $-2\,\mathrm{kV}$
- **Phosphor screen** (max. $3\,\mathrm{kV}$)





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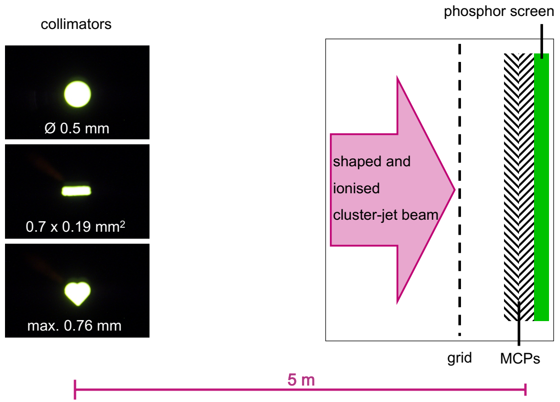
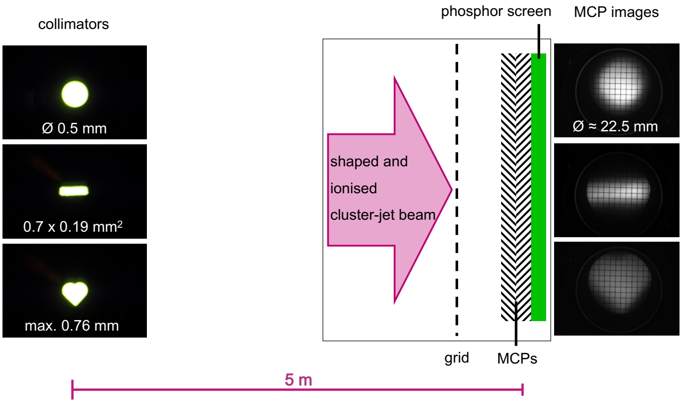
Direct Observation of the Cluster-Jet Beam

Microscopic View of Collimators and Resulting Images on MCP Detector

- Definition of target beam size and shape with collimators



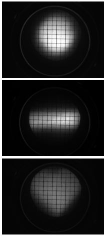
- Definition of target beam size and shape with collimators
- MCP images with expected beam shape and grid at approximately 5 m behind the collimator



Direct Observation of the Cluster-Jet Beam

Performance

- **Direct observation** of an ionized cluster-jet beam
  $\longrightarrow$ Cluster beam is very easy to shape with an orifice
- **Estimation of the cluster beam size** at the grid position
  $\longrightarrow$ Clearly visible grid structure (2.5 mm lattice spacing)



Direct Observation of the Cluster-Jet Beam

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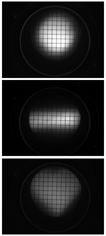

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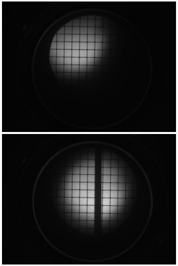
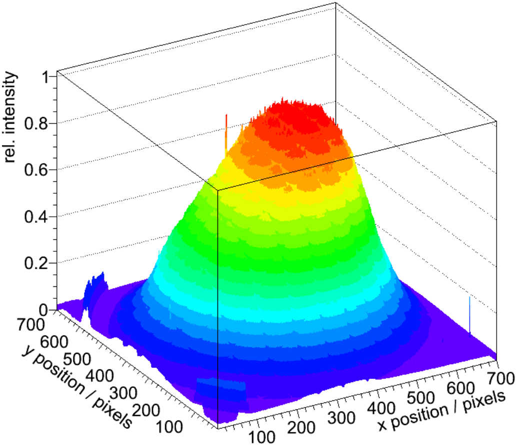


- **Identification** of cluster beam position and mechanical interferences

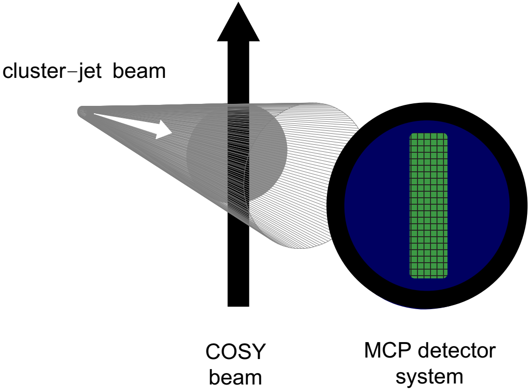
$\Rightarrow$New opportunity to run target beam adjustment checks during target operation

- The image intensity corresponds to the **relative cluster beam density distribution**



Visualization of the Beam and Target Interaction Region

at ANKE/COSY



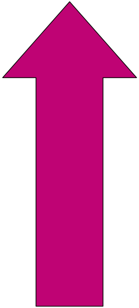
- Test measurements within 2 h
- COSY beam (2 GeV/c) passes the internal hydrogen (deuterium) cluster-jet target

⇒ **Ionization** of the cluster beam at the interaction zone

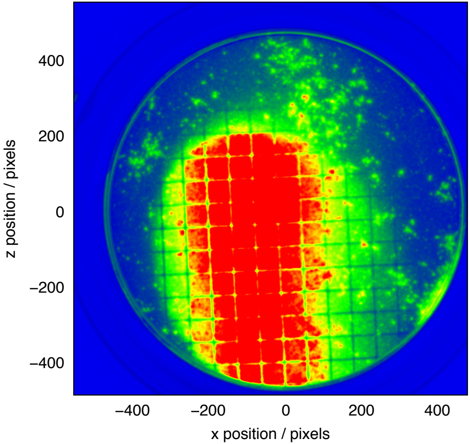
⇒ **Detection** of the ionized parts of the cluster beam at the end of the beam dump with MCPs

- Measurements during a cycle of the COSY beam: **Beam injection, acceleration, steerer magnet on/off**

Projection of the interaction zone **(in false colours)**
at COSY beam injection energies

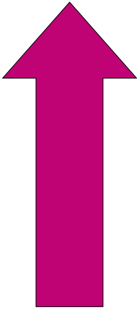


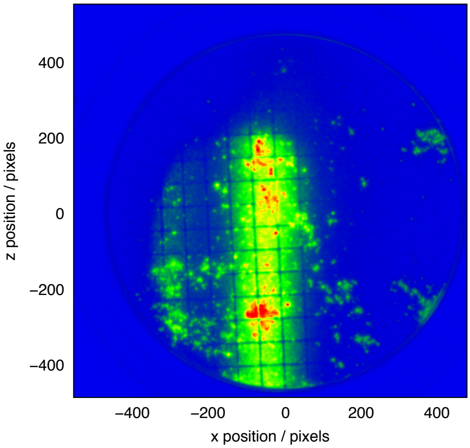
COSY beam direction



Visualization of the Beam and Target Interaction Region
at ANKE/COSY

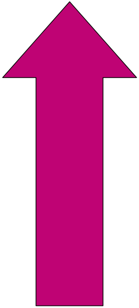
COSY beam after acceleration (2 GeV/c)
$\longrightarrow$ adiabatic cooling (reduced phase space)



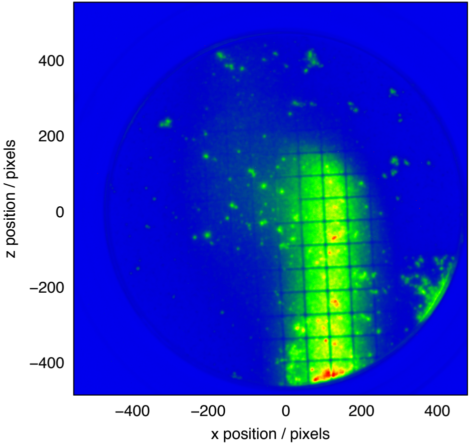


Visualization of the Beam and Target Interaction Region
at ANKE/COSY

Shift of the interaction zone
$\longrightarrow$ steerer magnet on

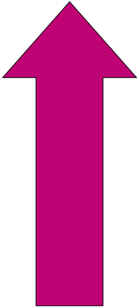


COSY beam direction

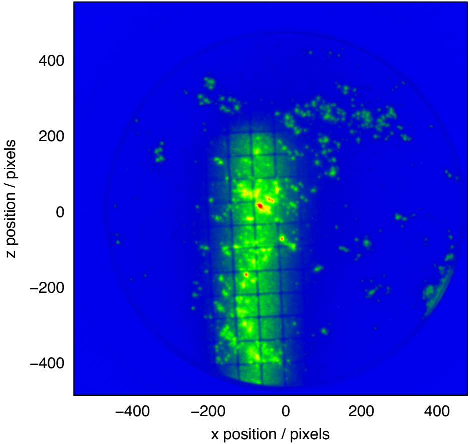


Visualization of the Beam and Target Interaction Region
at ANKE/COSY

Shift of the interaction zone
$\longrightarrow$ steerer magnet off



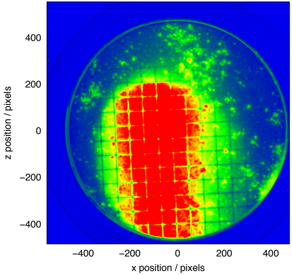
COSY beam direction

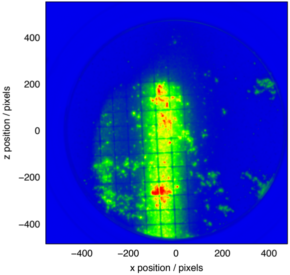


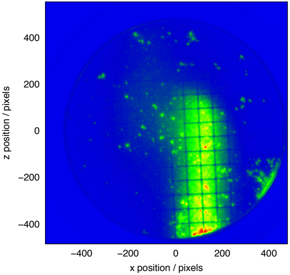
Visualization of the Beam and Target Interaction Region
at ANKE/COSY

$\Rightarrow$ **New possibility to monitor the interaction zone at internal target experiments**

$\longrightarrow$ **a diagnostic tool for quantitative vertex point studies**







Summary

- Target beam adjustment checks possible (during target operation)
  - Direct observation of the cluster beam (shape)
  - Estimation of target beam size (approximately 4.9 m after the nozzle)
  - Identification of cluster beam position and possible interferences
  - Image intensity $\widehat{=}$ relative density distribution
- Observation of beam and target interaction region
  - Successfully demonstrated at ANKE/COSY $\Longrightarrow$ New tool for $\overline{\text{P}}$ANDA

Outlook

- Estimation of the cluster mass
  - First tests with MCPs in combination with a deflecting field

$\Rightarrow$ See talk of E. Köhler

Thank you for your attention!

⋆ **And special Thanks to the ANKE/COSY Crew** ⋆

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