Design and Analysis of a Halo-Measurement Diagnostics

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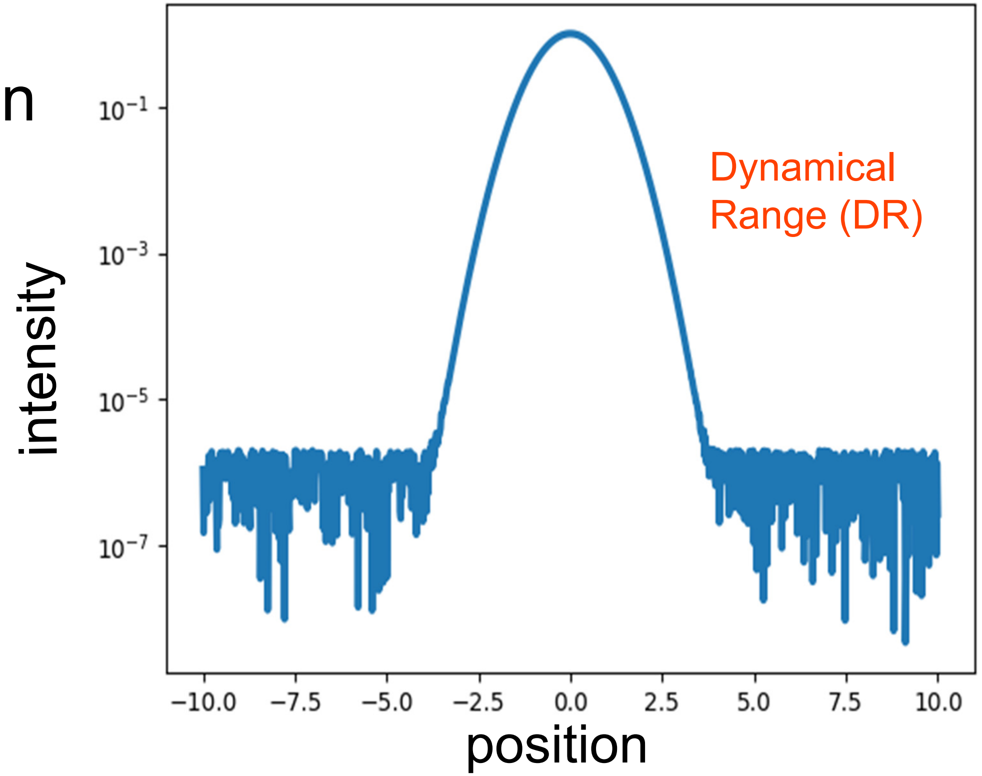
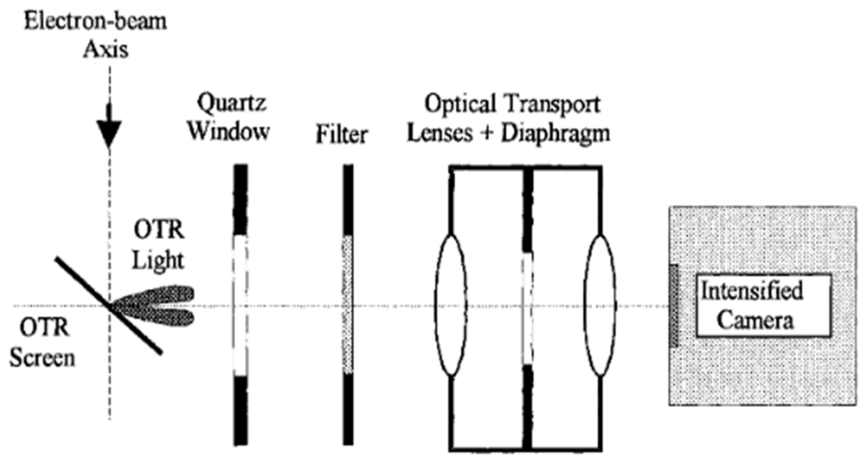
Why beam halo matters?

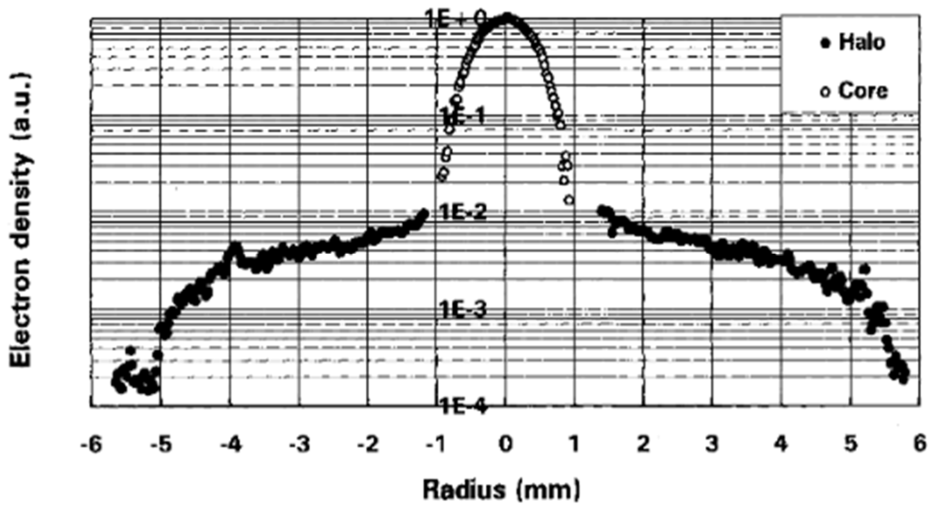
- Halo consists of faint particle distribution surrounding the core of the beam
- Particles in the halo generally do not participate in the front end application (e.g. in FELs, e-cooling, …)
- Halo ultimately limits an accelerator's performance (e.g. average current) due to resulting beam losses:
  - Beamline components activation, Hardware damage, SRF cavity quenching, etc.



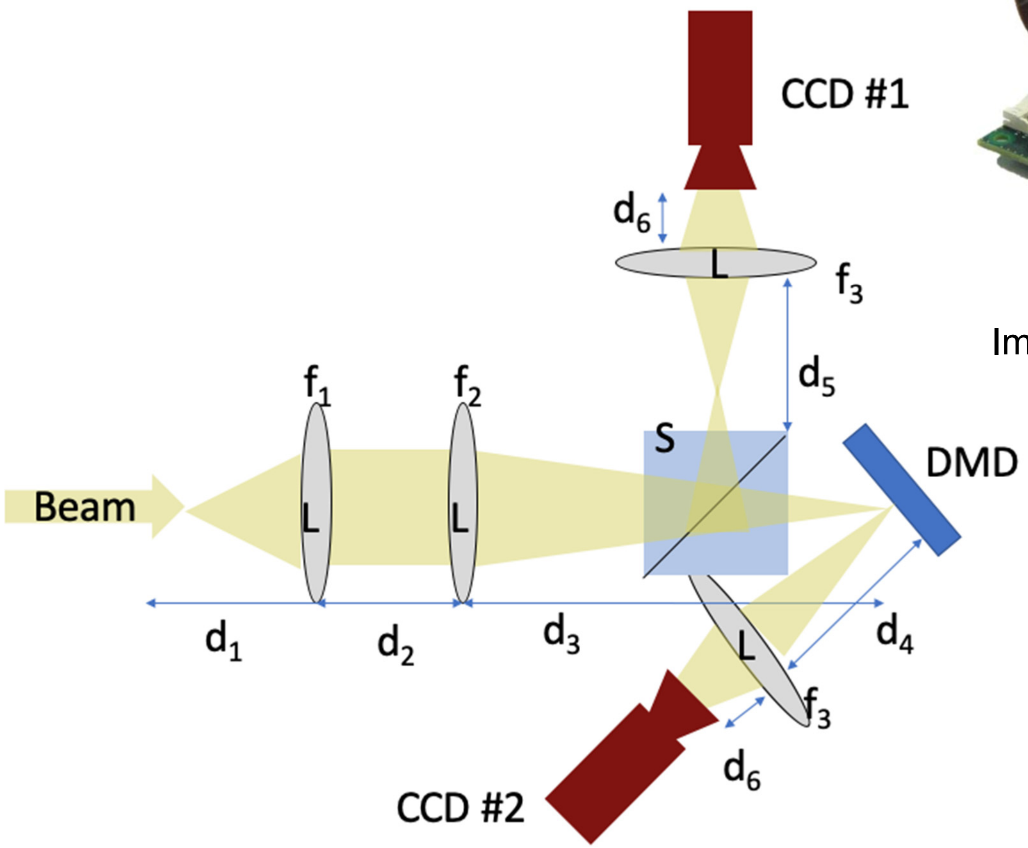
Techniques to measure halo distribution

- Coronographic method [G. Haouat, BIW94]
  - Image radiation produced beam
  - Mask the core of the distribution
- Method improved using a digital mask [J. Egberts, JINST 5 (2010)]
- Other approach include the imaging of core and halo on two separate CCD [P. Evtushenko, IPAC14]





Our approach: combining previous work



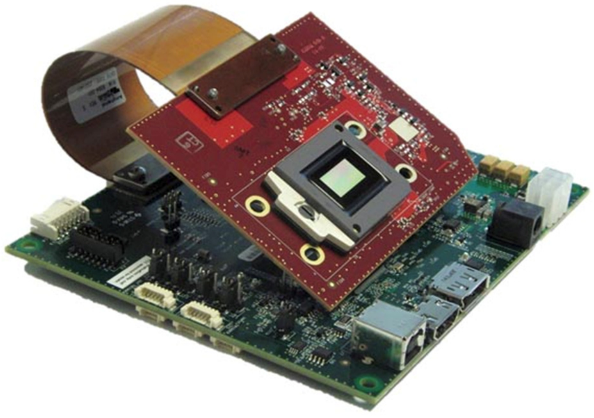


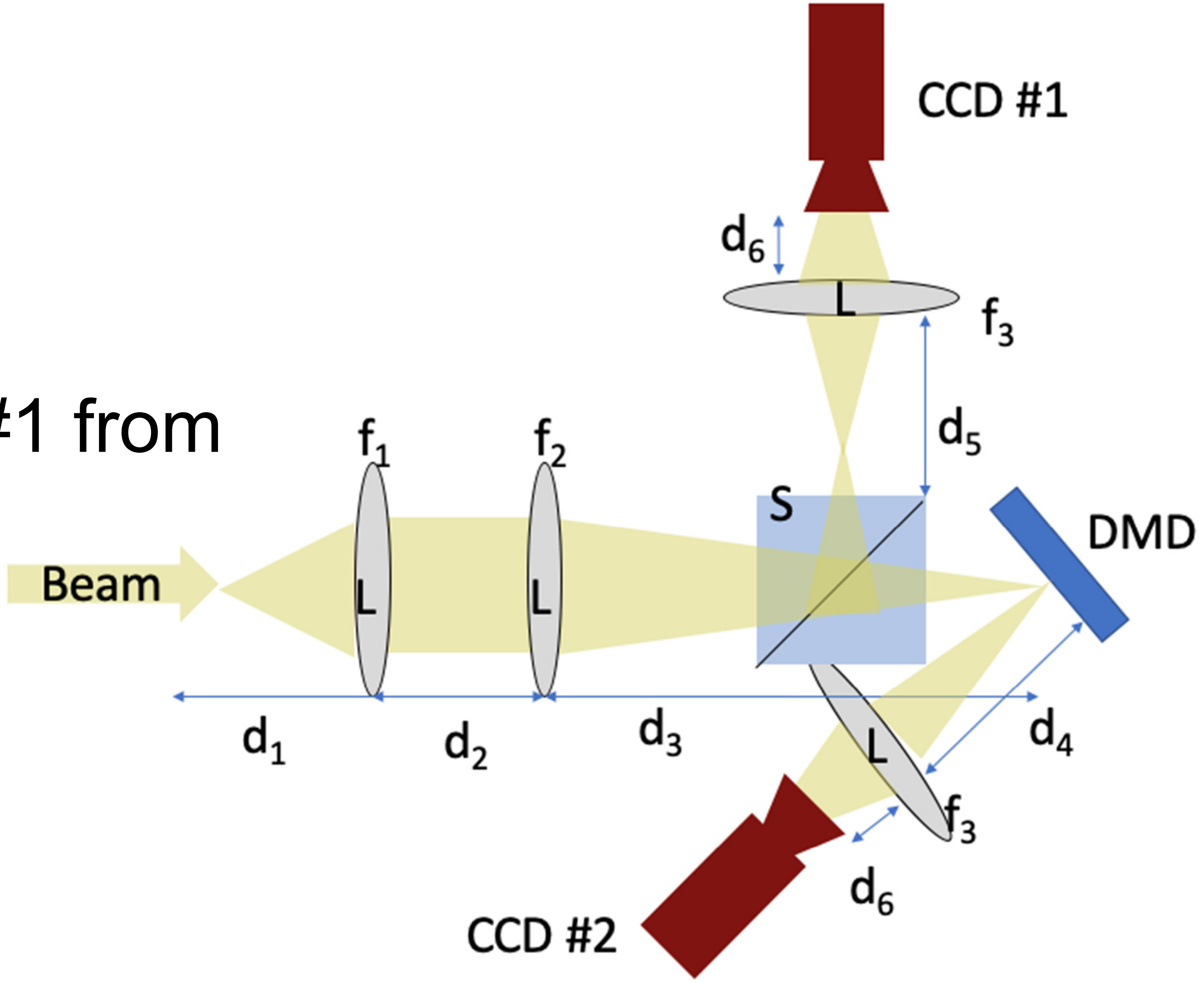
Image taken from DLi Webpage[1].

Specs	
Resolution	1920 px x 1080 px (~2 million mirrors)
Pitch/Angle Tilt	7.6 μm/12°
Active Array Size	8.1648 mm x 14.5152 mm

- Use a dual-detector system
  - Image core of beam on CCD#1
  - Image halo on CCD#2
- Halo selected by masking core using a DMD

Optical System I

- Beam is collimated by lens 1
- Beam is focused by lens 2
- Strikes beam splitter
- Half of beam focused on CCD#1 from lens 3
- Other half reflected by DMD
  - Core masked
- Focused on CCD#2 by lens 3

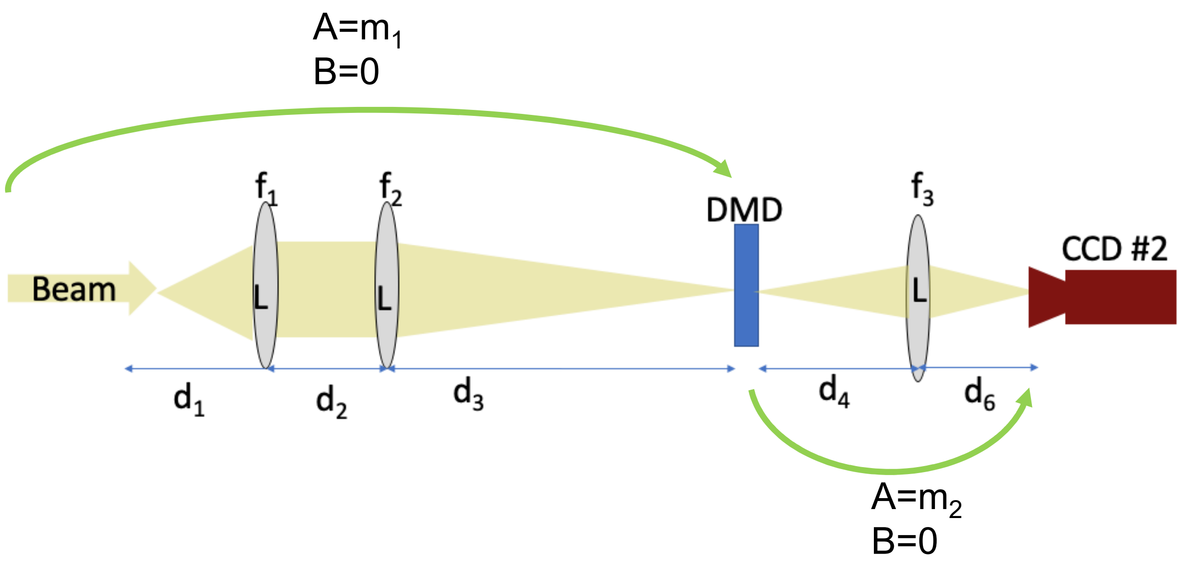


Optical System II

- Consider the unfolded system
- Use ABCD formalism

$$\begin{pmatrix} r \\ \theta \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} r_0 \\ \theta_0 \end{pmatrix}$$

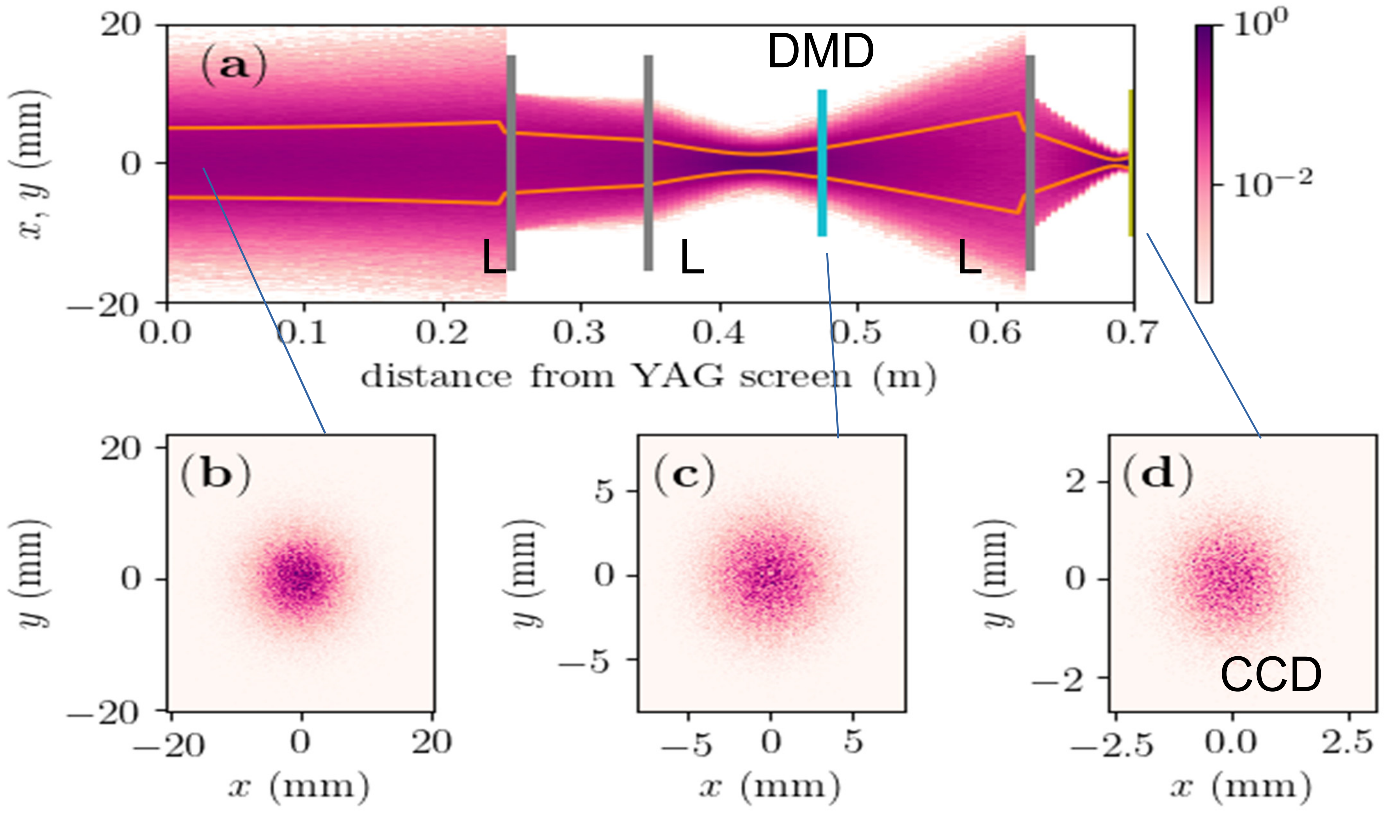
- To impose imaging condition *B=0* between required elements:
  - Source and DMD
  - DMD and CCD
- And associated magnification A=*m*



- Total magnification is set to $m_1 m_2 = \frac{1}{4}$ with $m_1 = m_2 = \frac{1}{2}$
- Consistent with mapping a 2-cm field of view into the DMD and CCD array

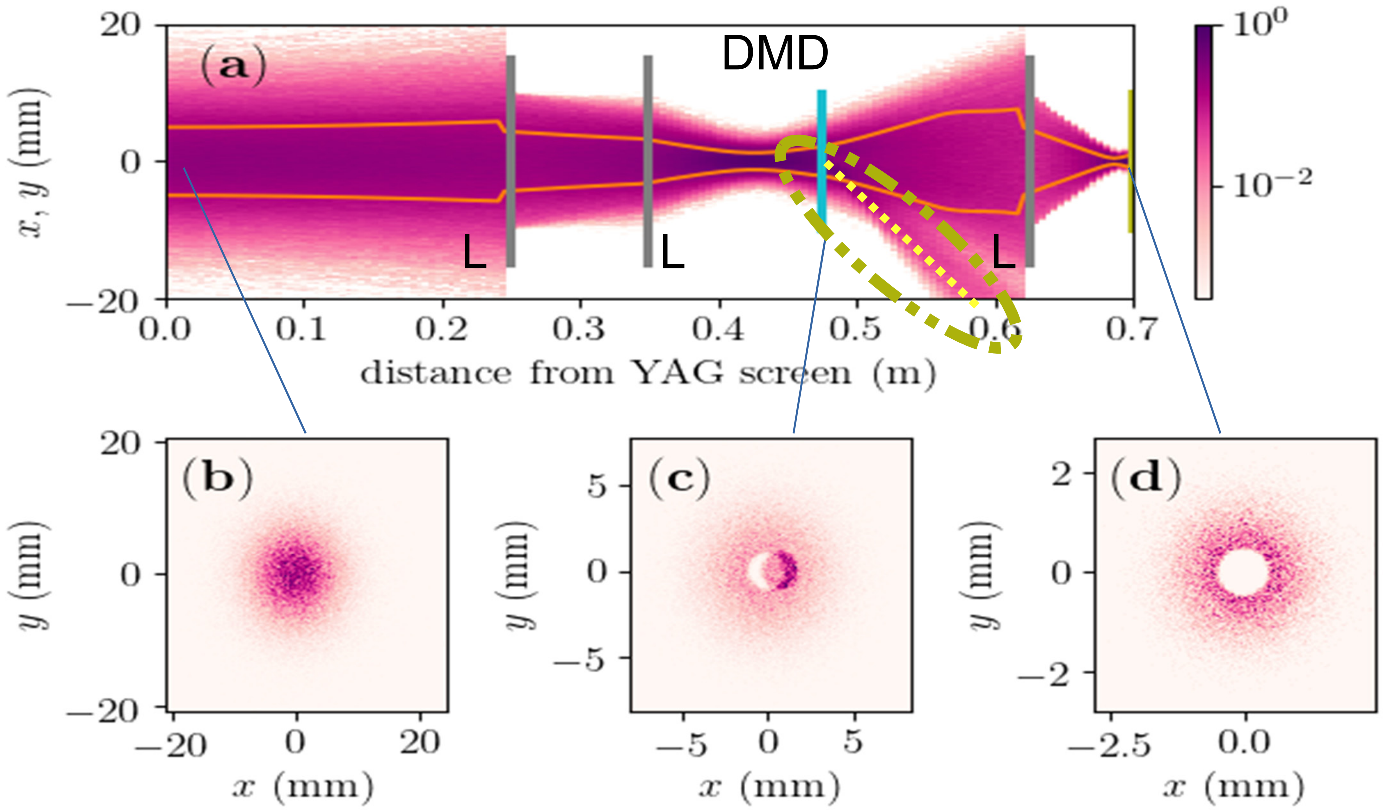
Simulations for the full beam

- Source assumed to be Gaussian
- Ray tracing performed with a python-based program



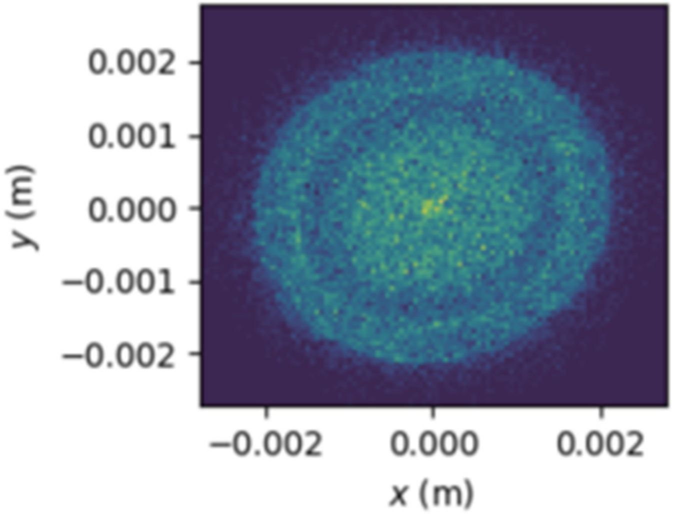
Simulations for the halo beam

- Core is masked using DMD (deflection)
- DMD simulated via the transformation $\theta \to \theta + 10^\circ$



Summary

- A halo-distribution diagnostics was developed
- System is presently being assembled
- Will be tested in an accelerator beamline at Argonne or Fermilab
- Ultimate goal is to characterize the halo formation in magnetized beam



Acknowledgements

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- [1]DLi LightCrafter 6500 Type S Product Page, Digital Light innovations, https://www.dlinnovations.com/products/dli6500-development-kit/#prettyPhoto
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