Measuring small beam size using Optical Diffraction Radiation

Summary of the tests performed at Cornell and KEK

M.Bergamaschi[2], L. Bobb[1,4], M. Billing[3], J. Conway[3], **R.Kieffer[2]**
P.Karataev[1], T.Lefevre[2], S. Mazzoni[2], T. Nobuhiro[5], J.Shanks[3]

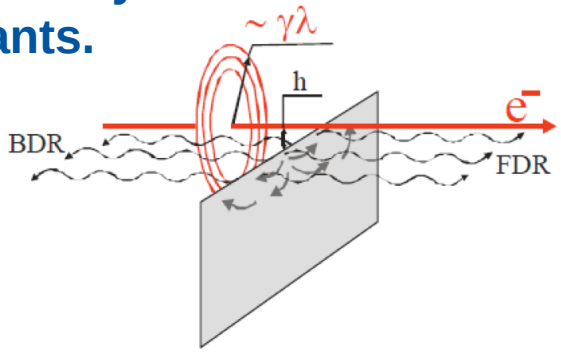
1. John Adams Institute at Royal Holloway, Egham, Surrey, United Kingdom
2. CERN European Organisation for Nuclear Research, CERN, Geneva, Switzerland
3. Cornell University, Ithaca, New York, USA
4. Diamond Light Source, Oxfordshire, UK
5. Accelerator Test Facility KEK, Tsukuba Japan

Overview

- Introduction to ODR
- Cornell CESR experiment for ODR target development and optimization.
- KEK ATF2 ODR-OTR experimental station for small beam size measurement.
- Conclusions

Introduction to ODR

Optical diffraction radiation (ODR) is emitted when the coulomb field of charged particle beam crosses a boundary between two mediums with different dielectric constants.

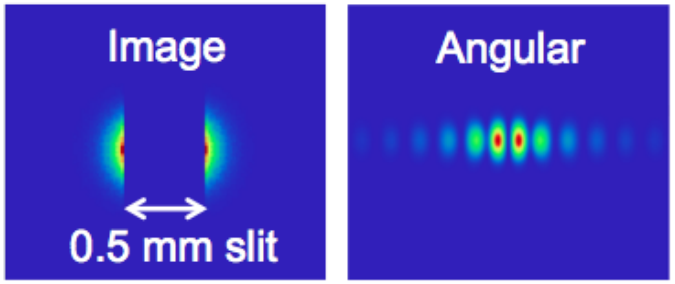


This effect appends on both sides of the target:

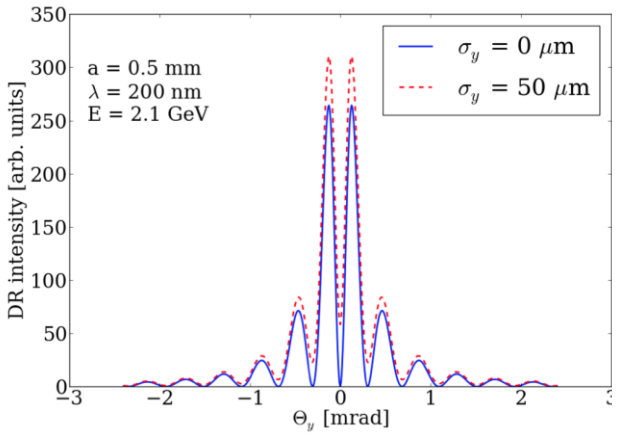
- Backward diffraction radiation (BDR)
- Forward diffraction radiation (FDR)

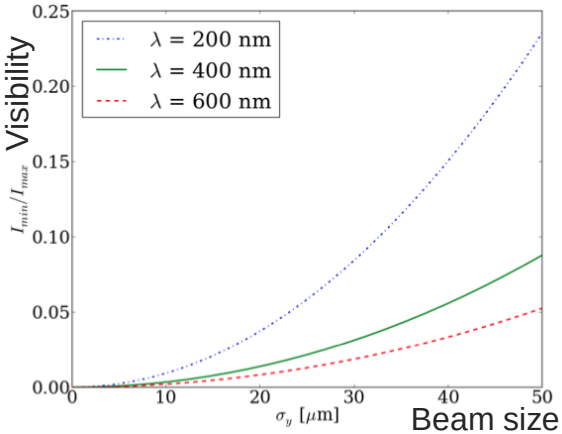
While the target image have no beam size sensitivity, **the angular distribution** of the BDR is **sensitive to beam size.**

Single particle images



ODR model beam size simulations (L. Bobb)



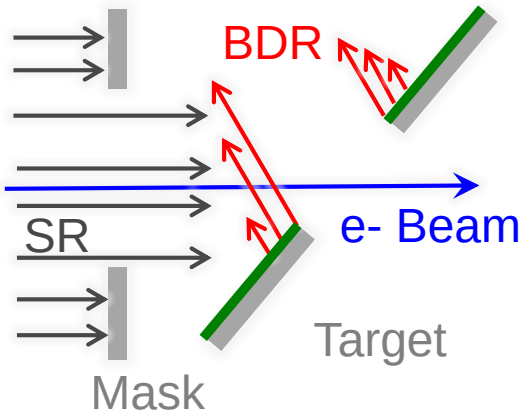


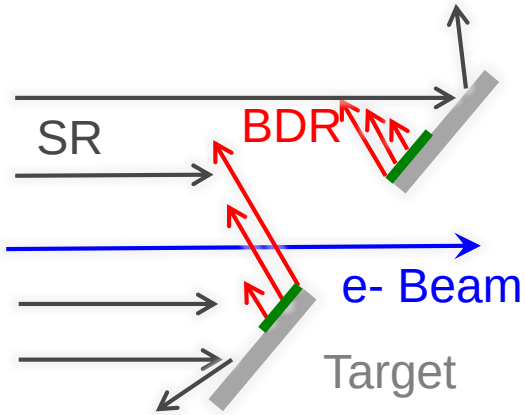
Noise contribution for ODR

The main noise contribution to the observed BDR pattern comes from the synchrotron radiation (SR)

- SR can be reduced by **using a mask** upstream the target.
- SR can also be reduced by **limiting the reflective** surface of the target to the BDR emission area.

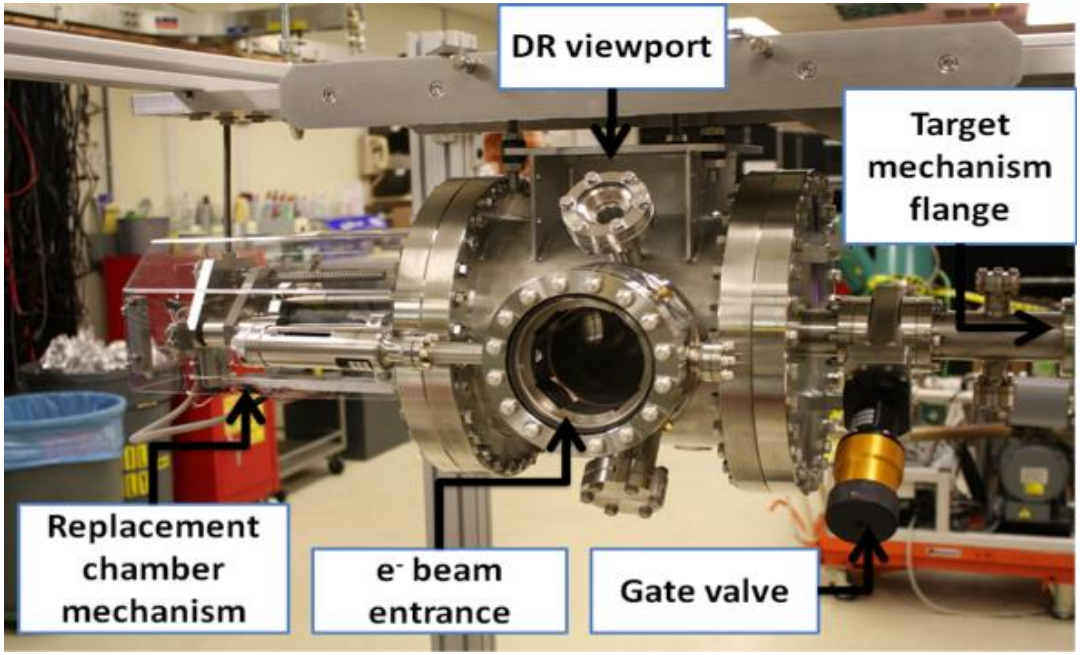
Both techniques where tested at Cornell 2015-2016

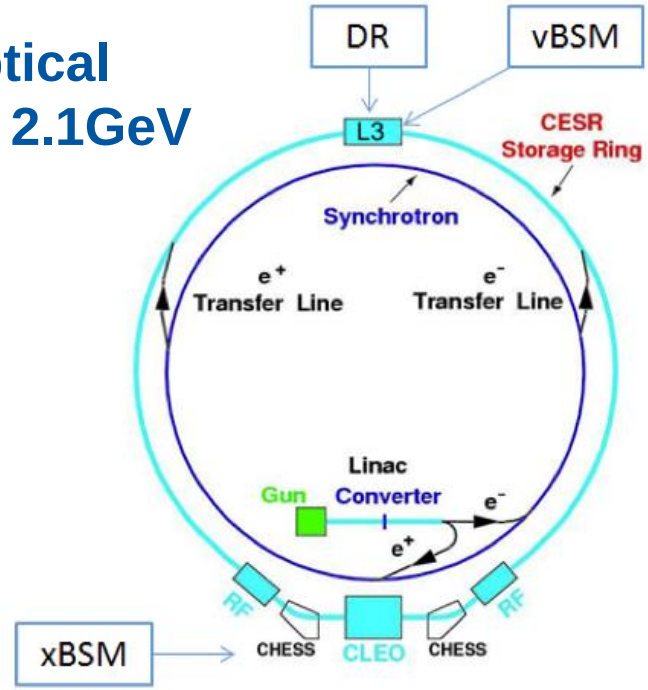


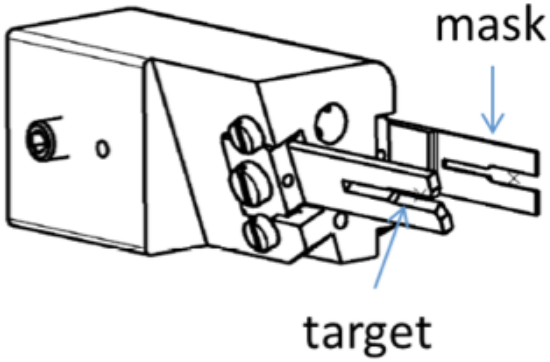


The ODR experiment @ CESR Cornell

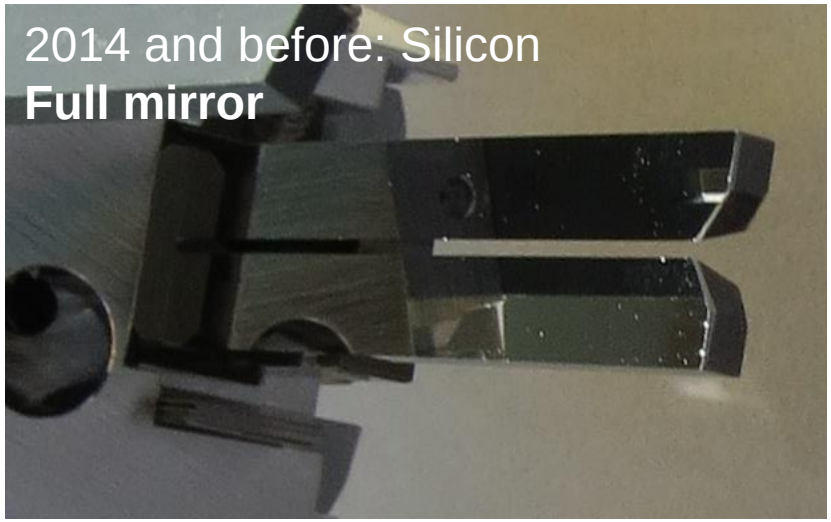
Non invasive beam size measurement using Optical Diffraction Radiation visibility technique with a 2.1GeV electron beam. (since 2012)

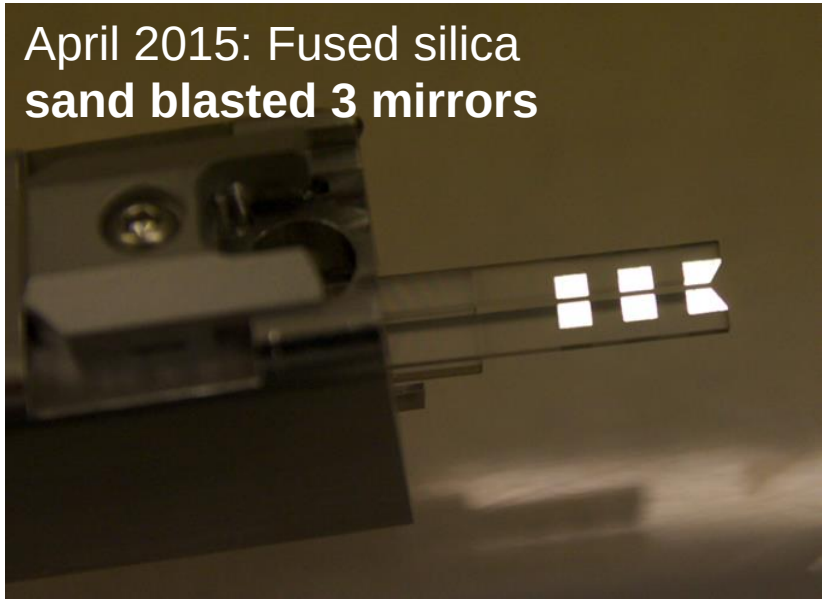


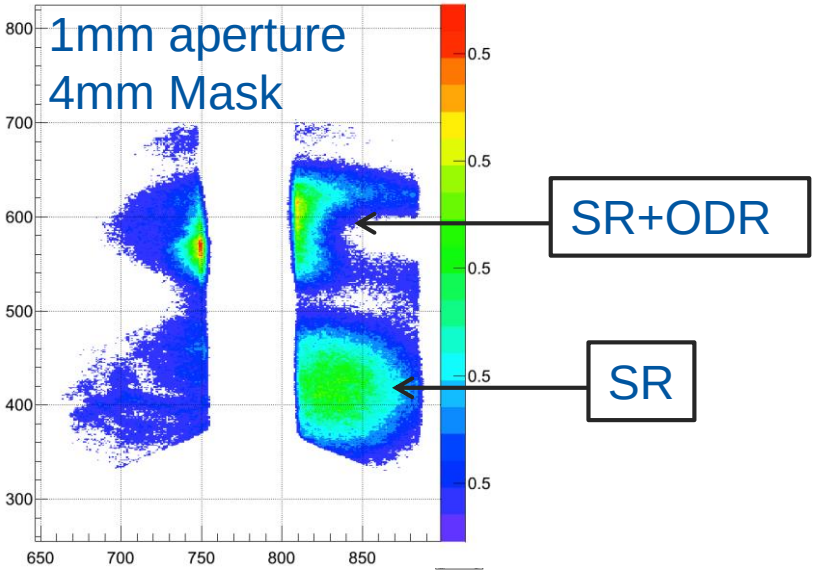


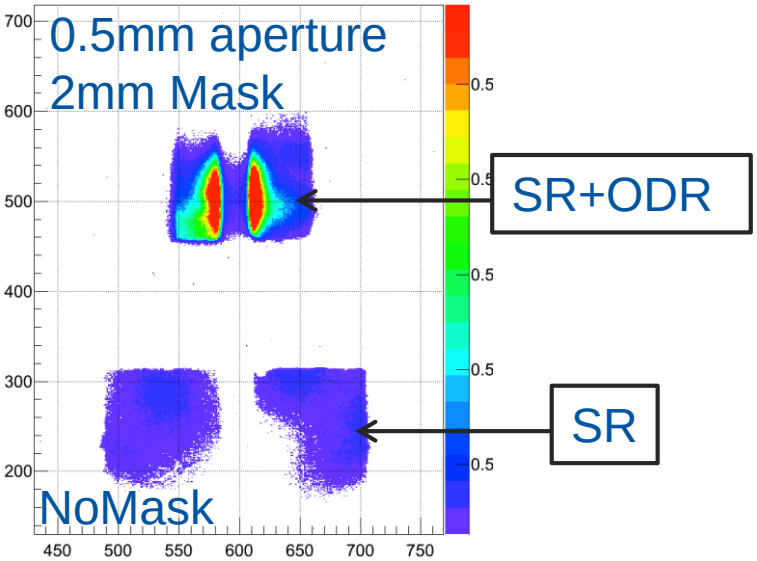


Improvement on the SR/DR ratio

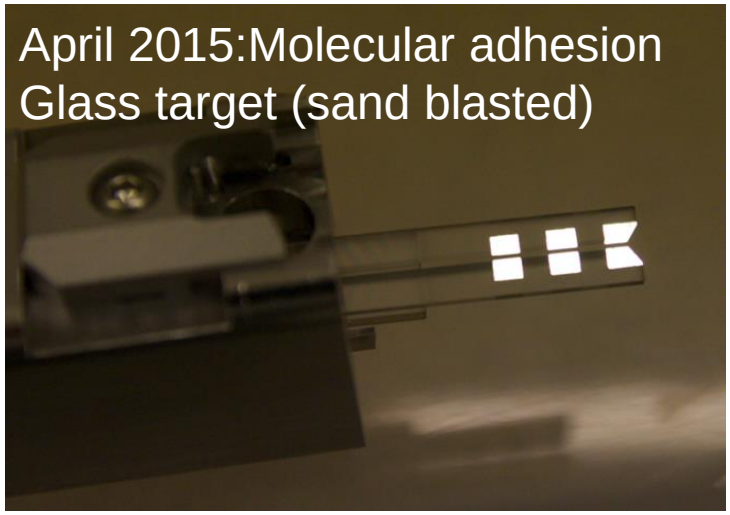


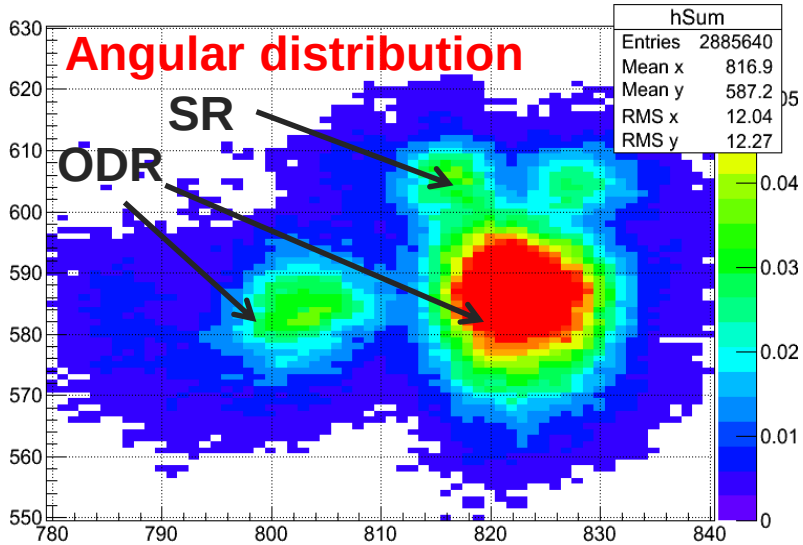


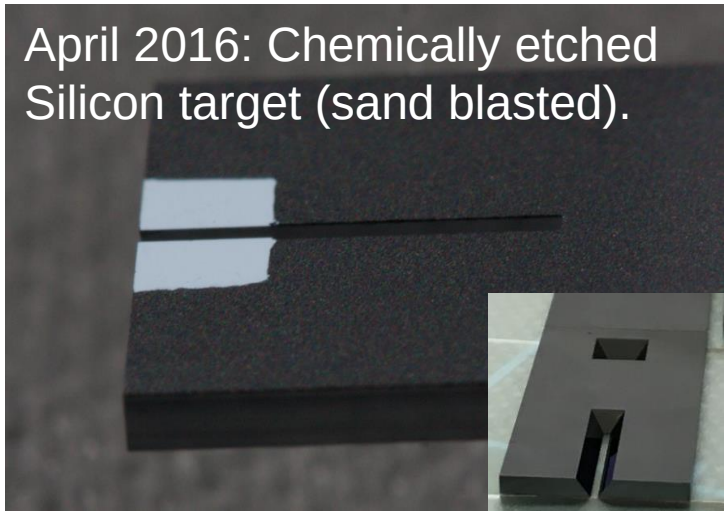


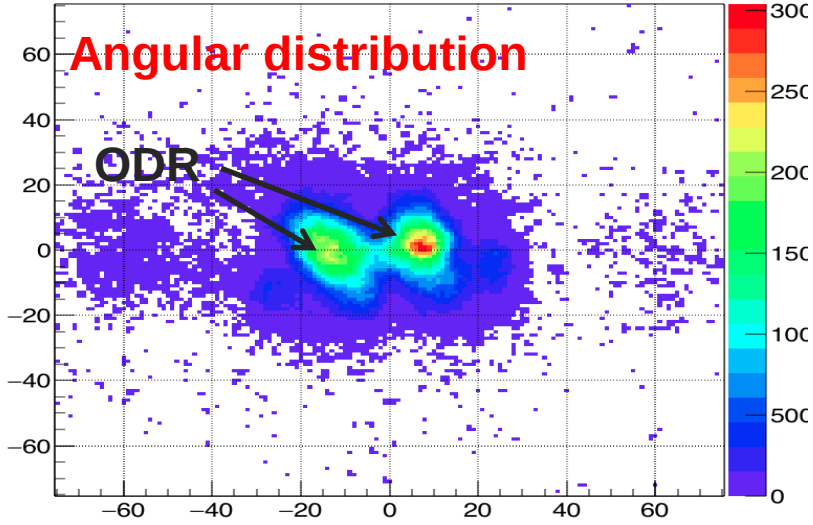


Refurbishing again for a single mirror target





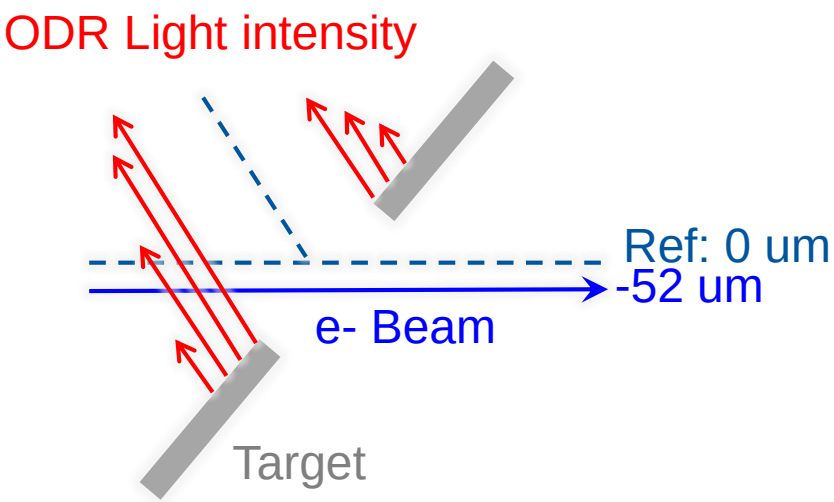


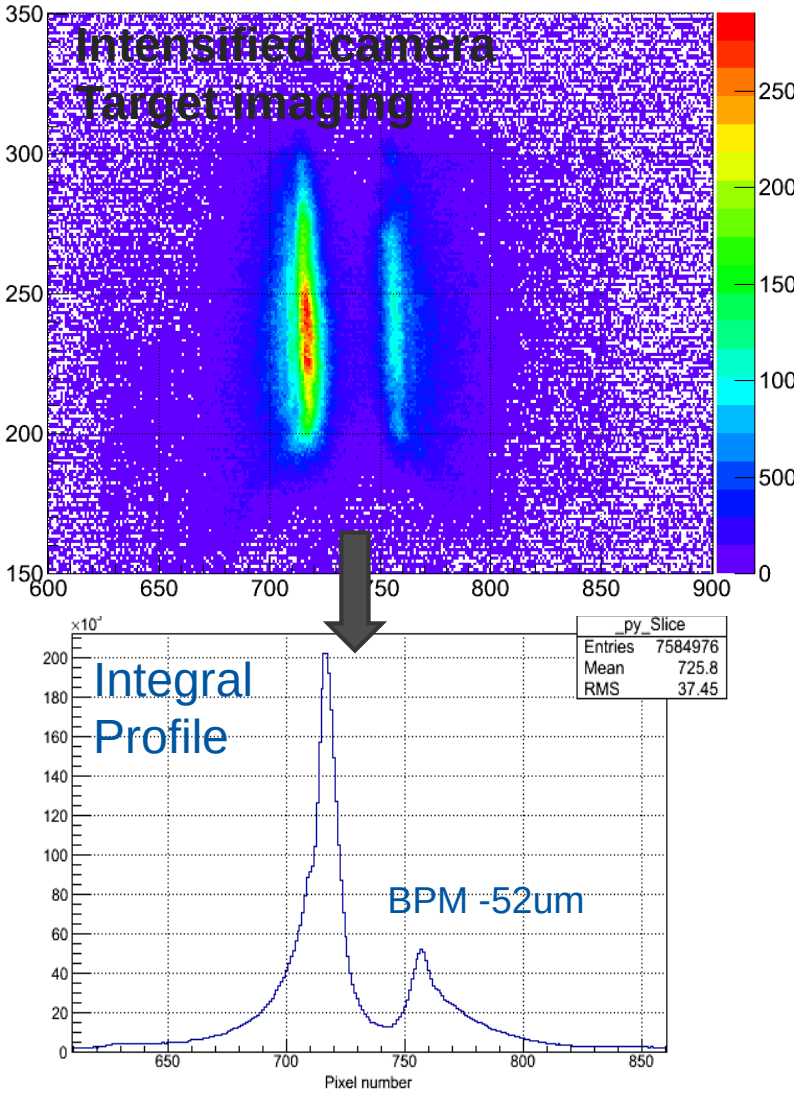


Imaging ODR profile Asymmetry

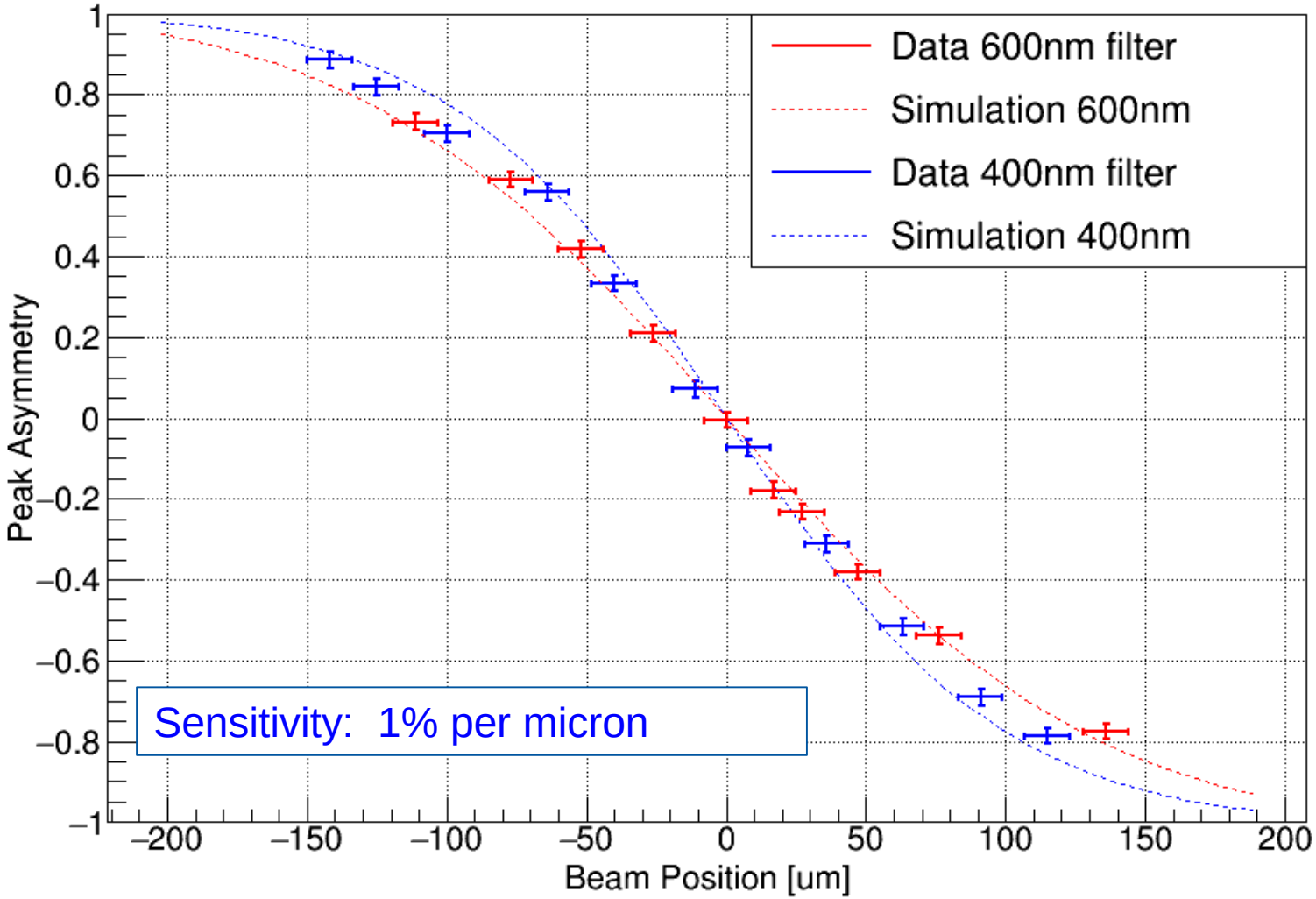
ODR profile asymmetry can be used to center the beam precisely into the slit aperture.

This could be used as **beam position monitoring** technique .





Imaging ODR profile Asymmetry



Asymmetry= (Max Peak Left - Max Peak Right)/(Max Peak Left + Max Peak Right)

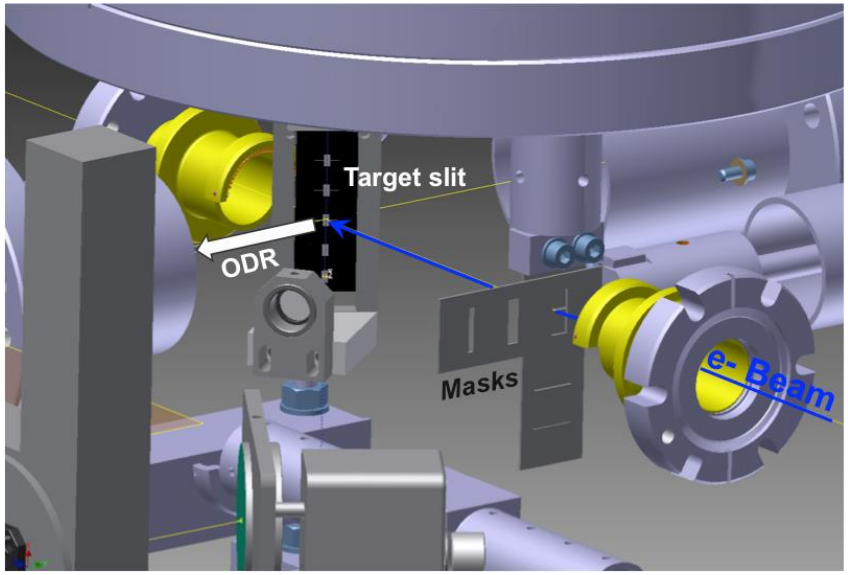
Conclusion about the target R&D @ CESR

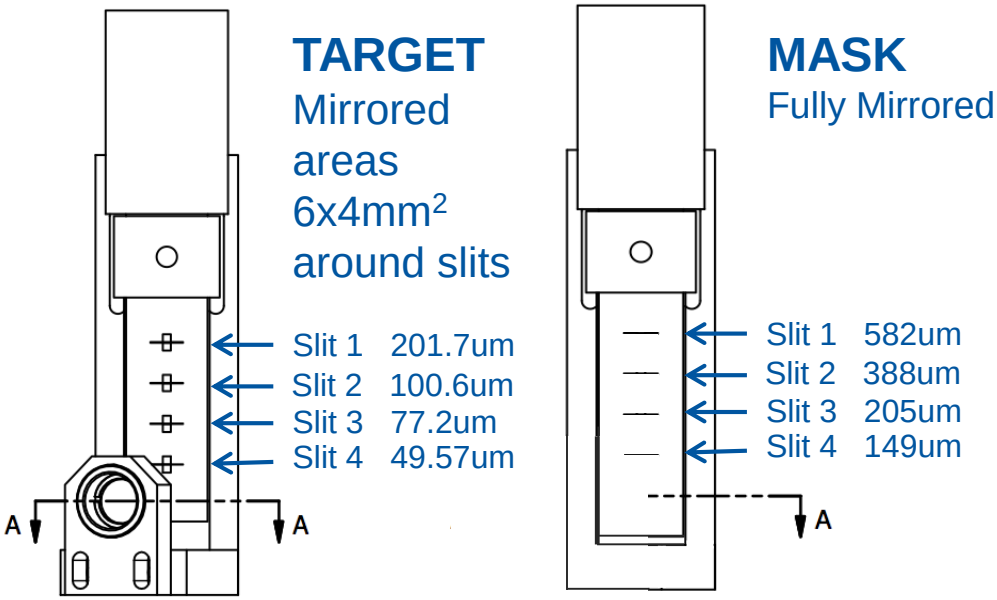
- The SR/DR ratio is improved by reducing the mirrored area thanks to the diffusive effect of sand-blasting. Using a mask upstream also helps to shield from SR.

- The angular distribution was quite asymmetric due to a co-planarity offset. It was found to be very difficult to produce a fork shaped target with a sufficiently good co-planarity (<20nm).

The ODR-OTR experimental station in KEK-ATF2

The new tank was installed in February 2016 on the virtual interaction point of the ATF2 beam line.

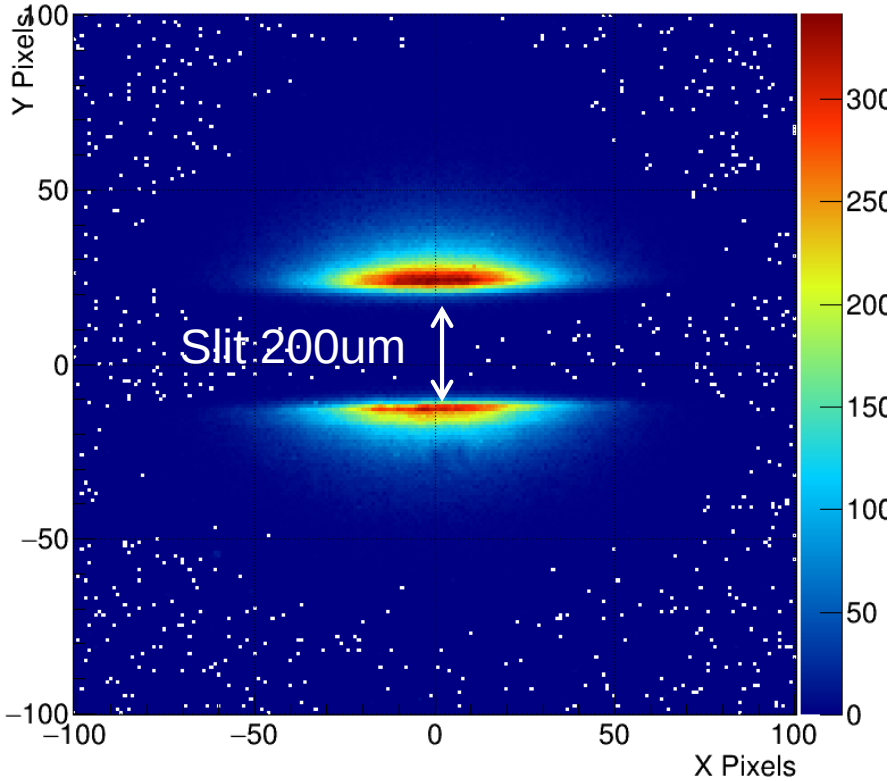




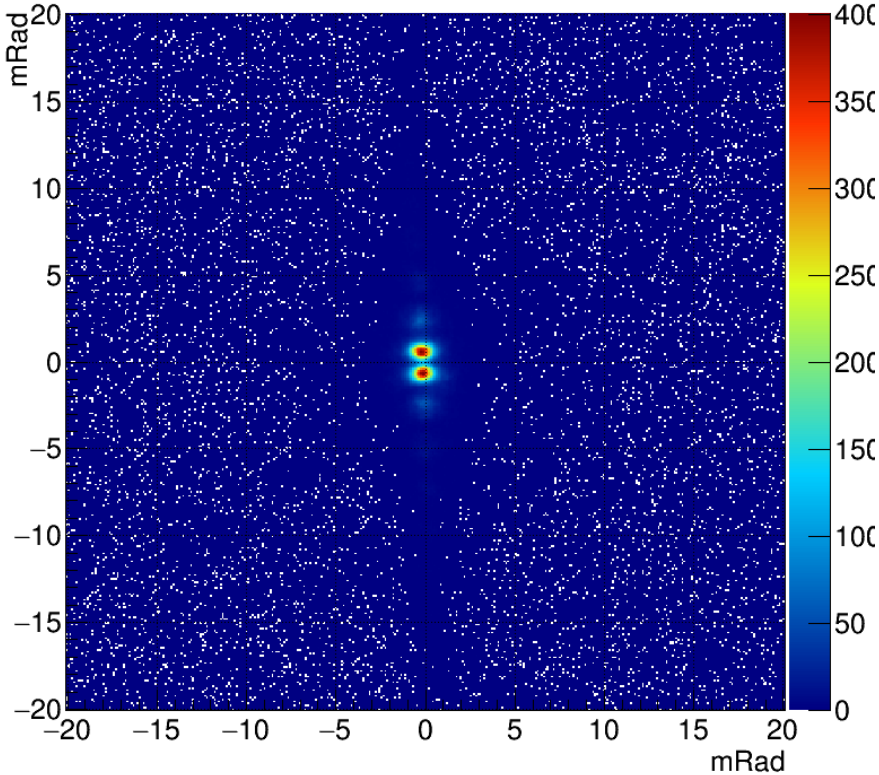
- The target and mask were made by chemical etching of silicon wafers.
- The sand-blasting technique was used to reduce mirrored area.
- Very good co-planarity between slit sides **(measured < 20 nm).**

The ODR-OTR experimental station in KEK-ATF2

Target Image

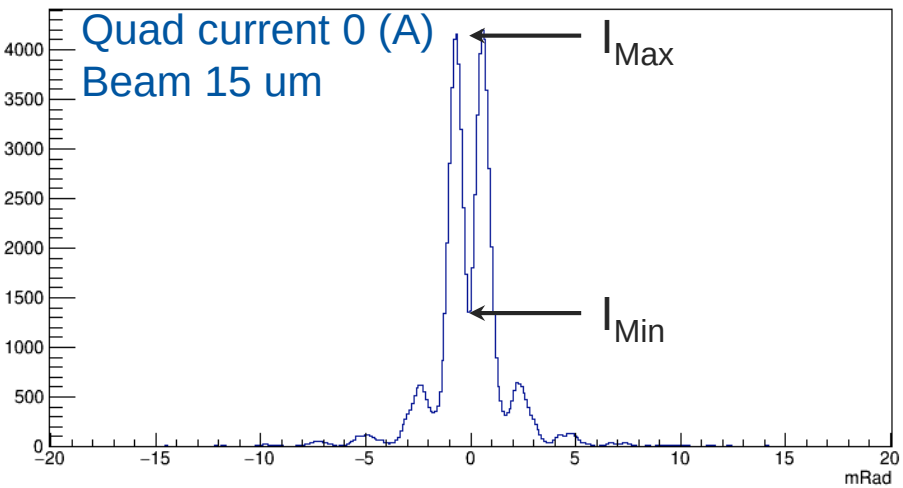


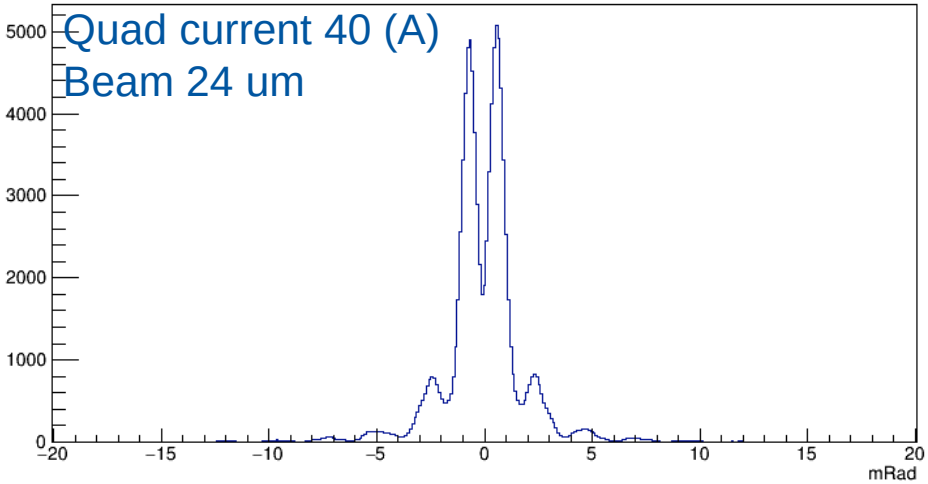
Angular distribution



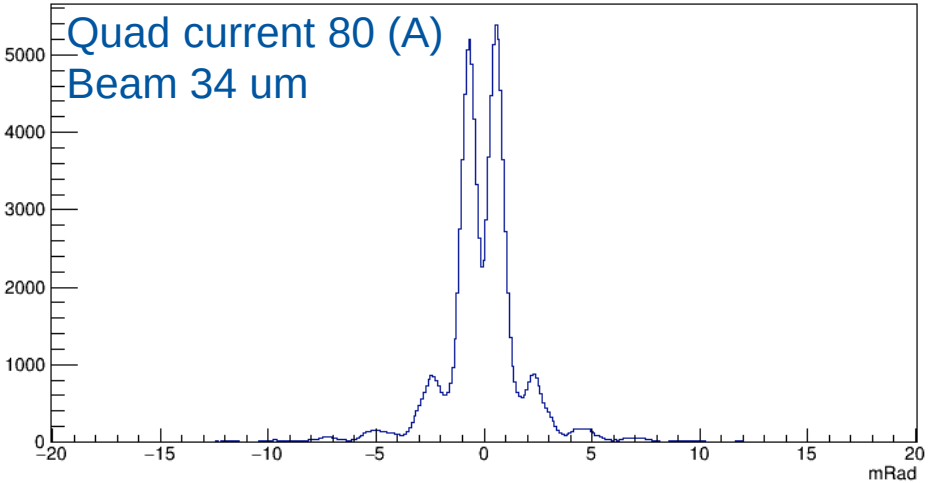
Two scientific cameras triggered to acquire synchronously the target image and angular distribution (beam splitter).

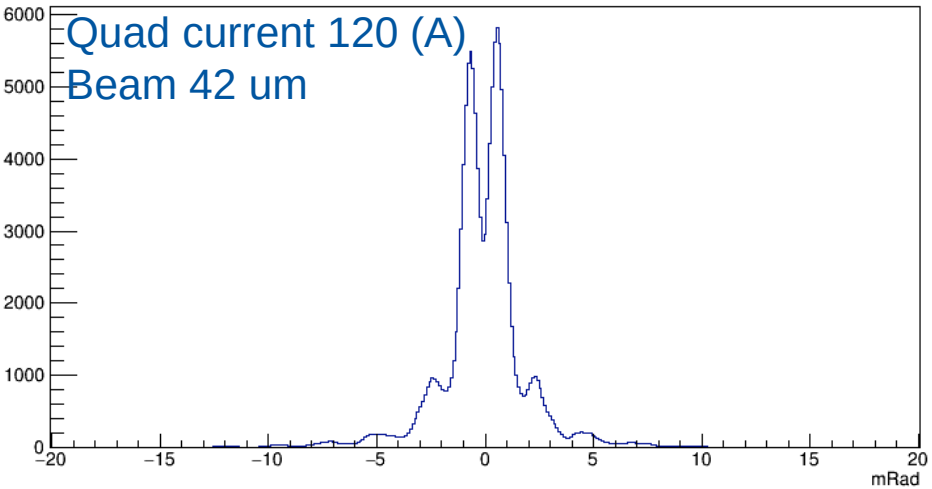
ODR angular visibility : quad scan





Visibility = I_{min} / I_{Max}



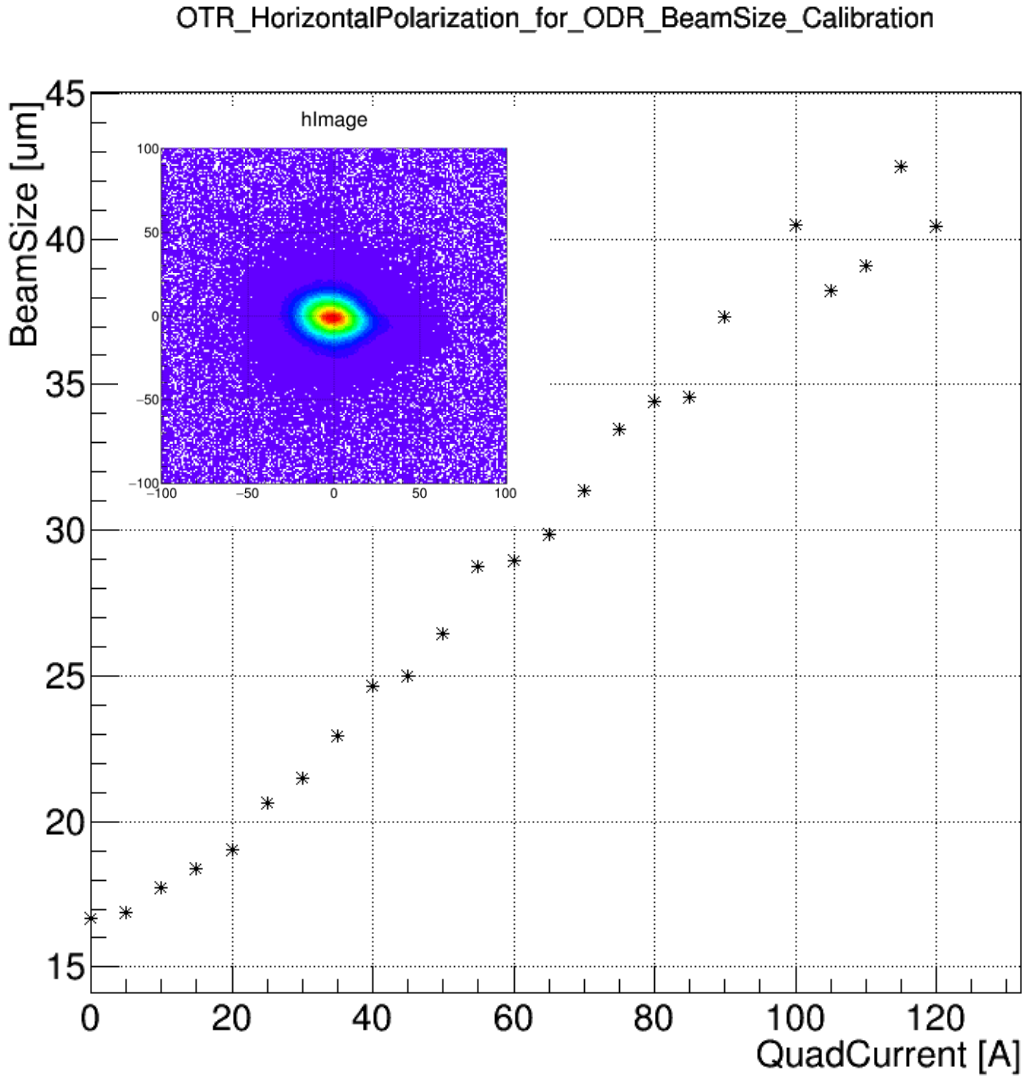


OTR beam size calibration

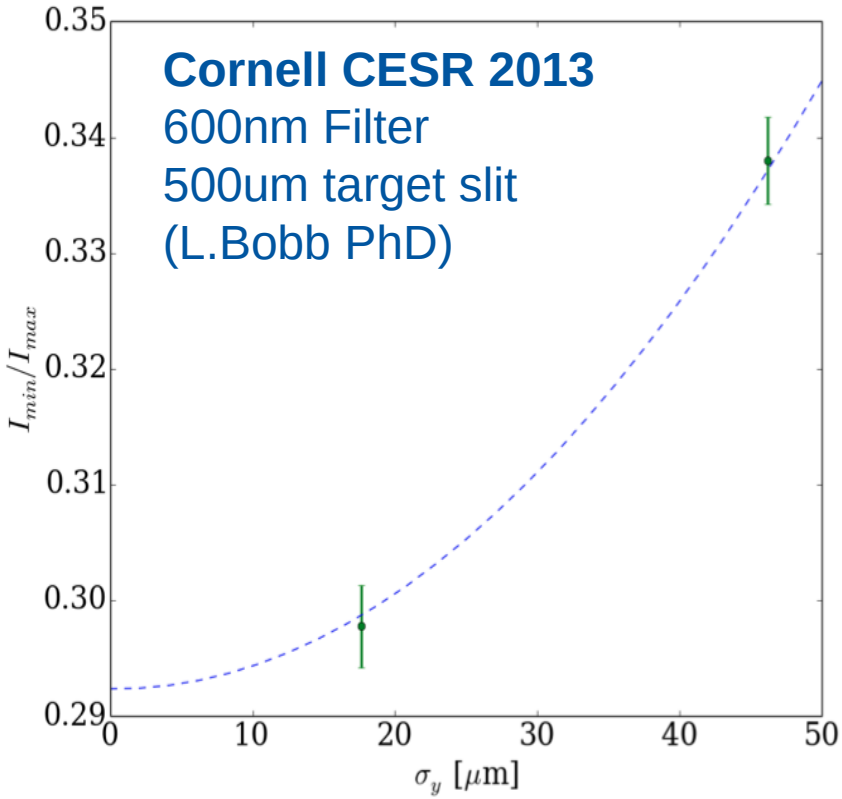
The side mirrors of the ODR slit were used to record reference OTR beam size measurement.

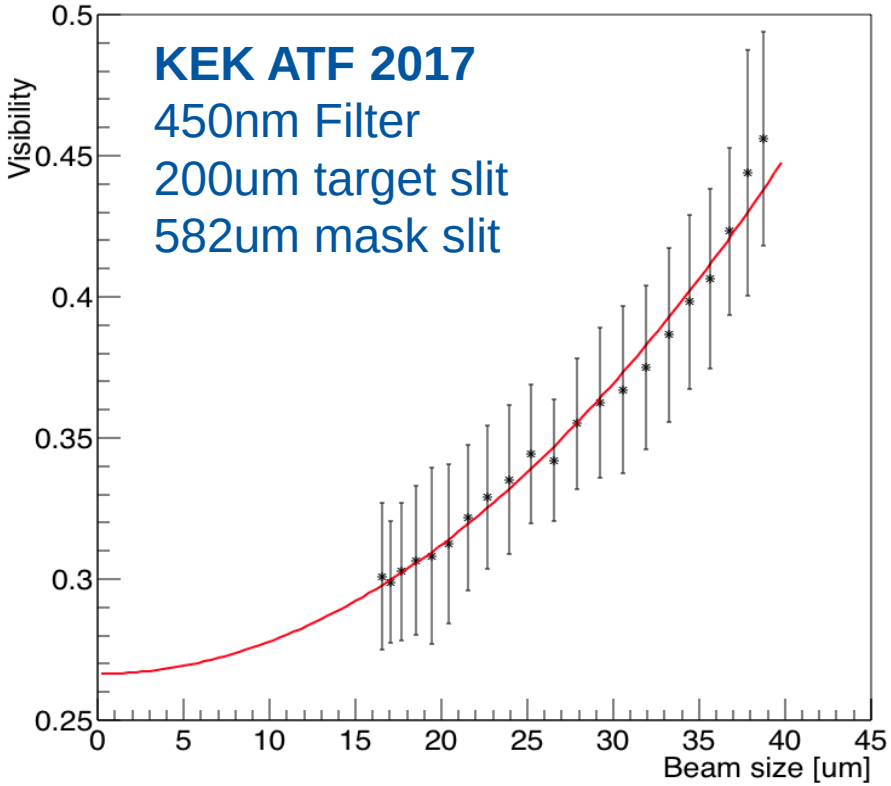
This could be done in CLIC/ILC using pilot beam (no target damage).

Then ODR can then be used for full beam charge.



ODR angular visibility for beam size measurement





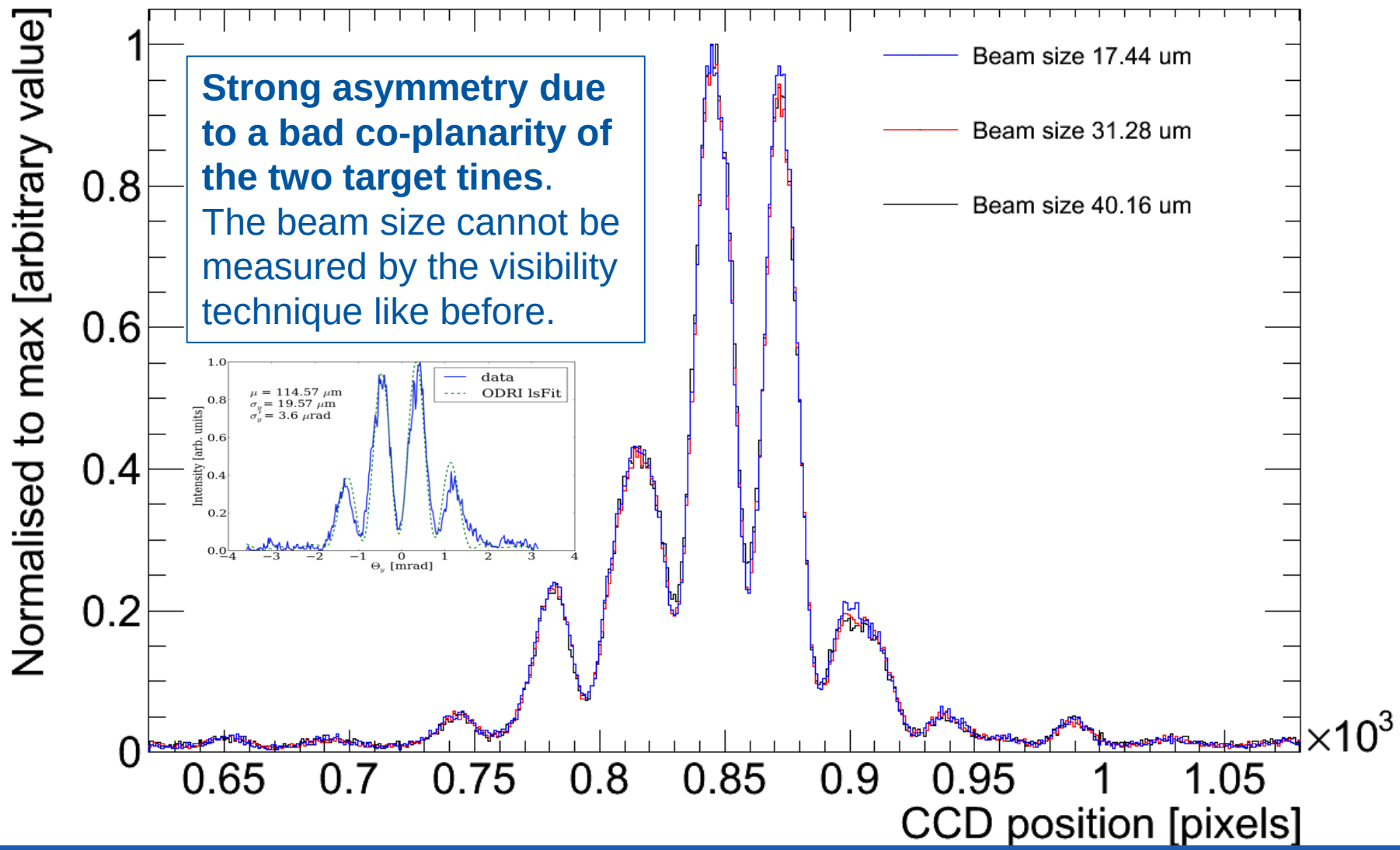
Visibility = I_{min} / I_{Max}

Conclusion & perspectives

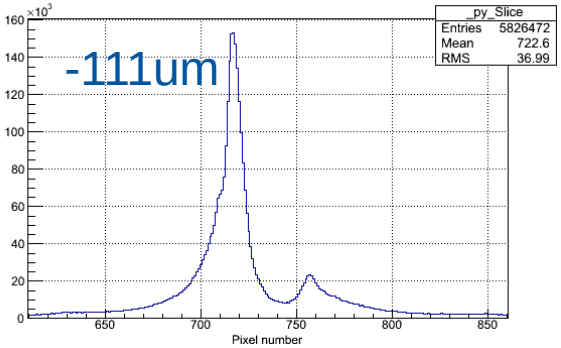
- 2016 was a very successful year of ODR commissioning and operation in ATF.
- Very promising results and good angular data was recorded. Data analysis is still ongoing.
- 2017 will be dedicated to the observation of ODR in the UV optical range. UV is optimized for small (<15um) beam size measurement.
- A tank is being produced to put the optical lines in an Argon flushed atmosphere. It should be up and running for the spring ATF2 shifts.

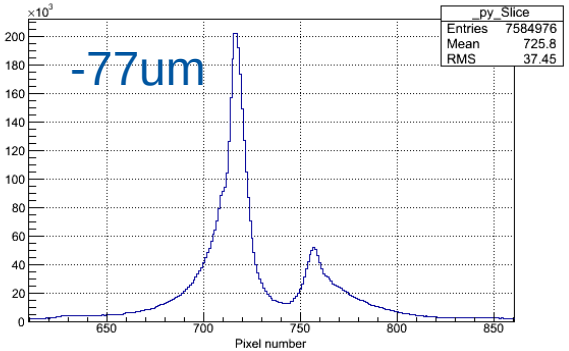
Thanks for your attention !

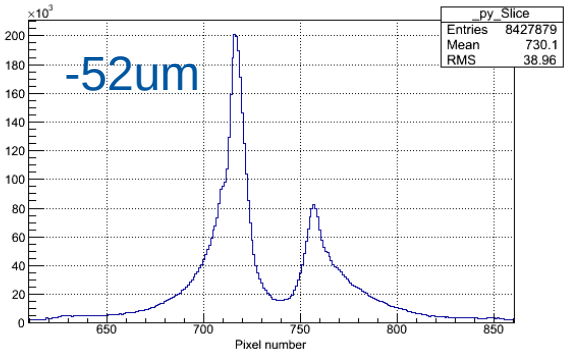
ANGULAR Beam Size scan Mirror3 @ 400nm 0.5mmSlit & 1mm Mask ODR-Interference CESR

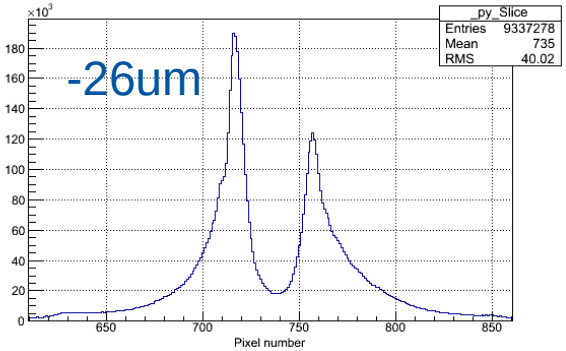


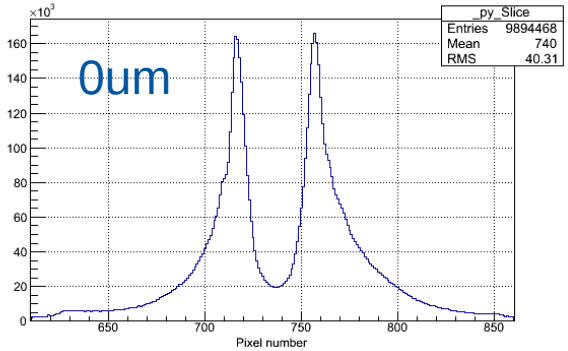
Imaging ODR profile Asymmetry CESR

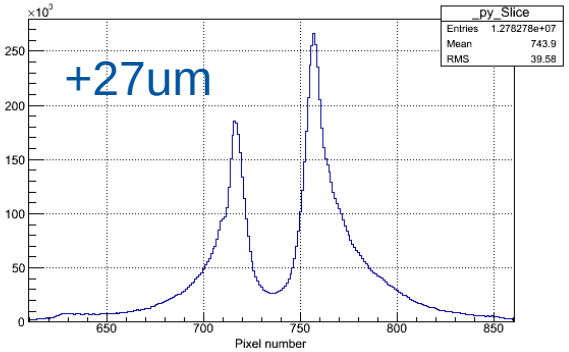


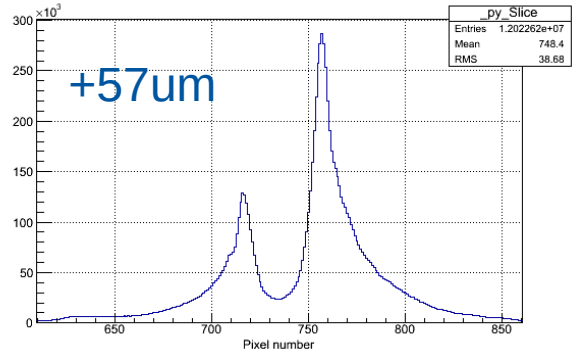


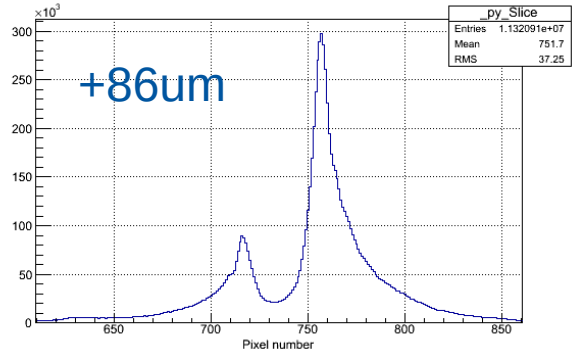


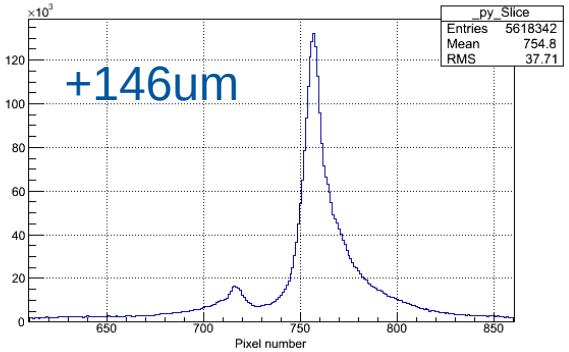












Conditions: Filter 600 nm, beam size: 23.7 um, target with single mirror (no