Focusing properties of X-ray radiation channeling at the exit of a MCP

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Layout

* introduction
* about MCPs
* experimental data: BESSY & Elettra
* conclusions and perspectives

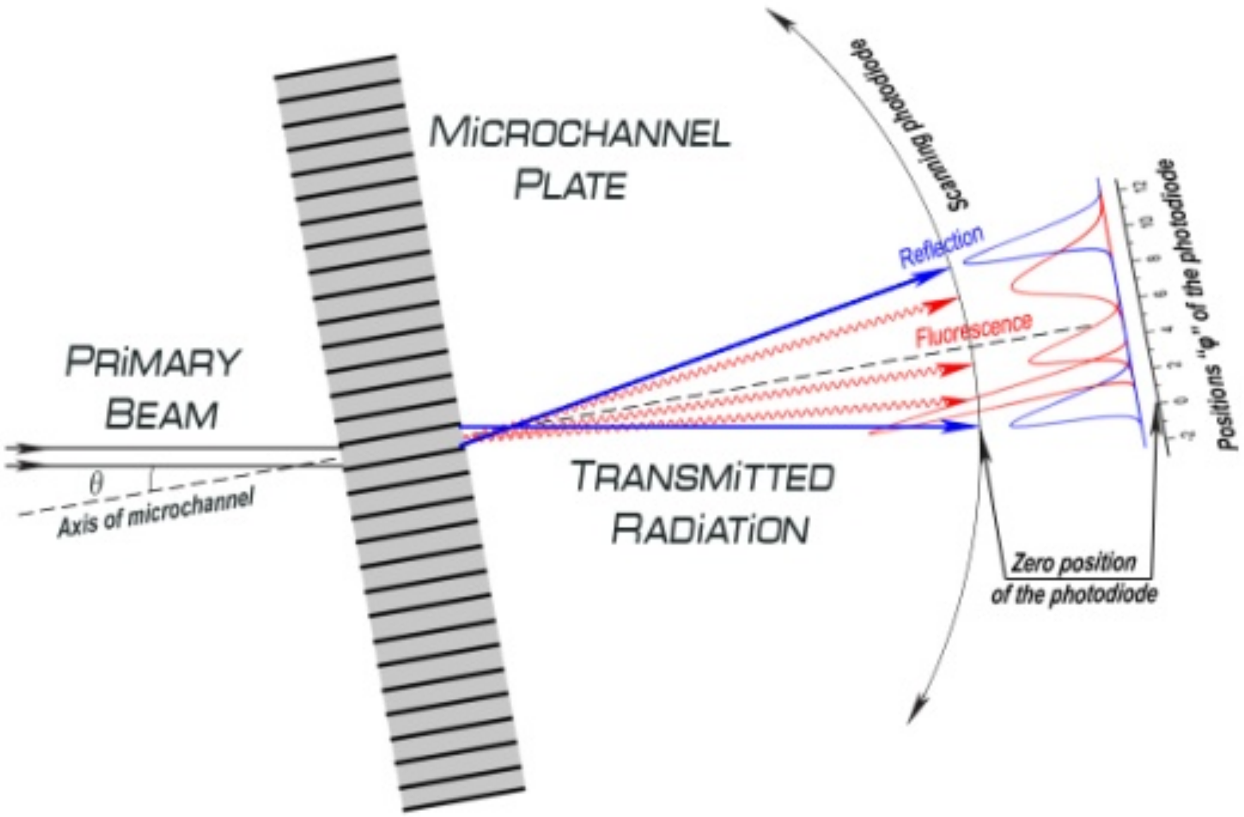
Introduction

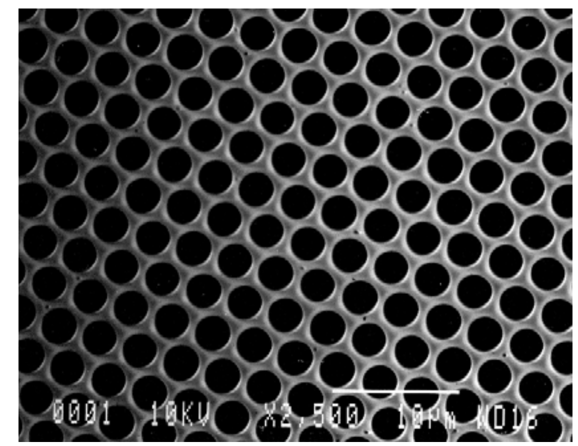
- *Capillary optics is one of the fastest growing optical technologies because of its superior capacity of generating high flux density x-ray beams in the μm - and sub μm range, their gain, high spatial resolution and high temporal resolution. Actually, channeling based devices may guide and shape a X-ray beam and control intensity, spot size, divergence and spatial distribution.*

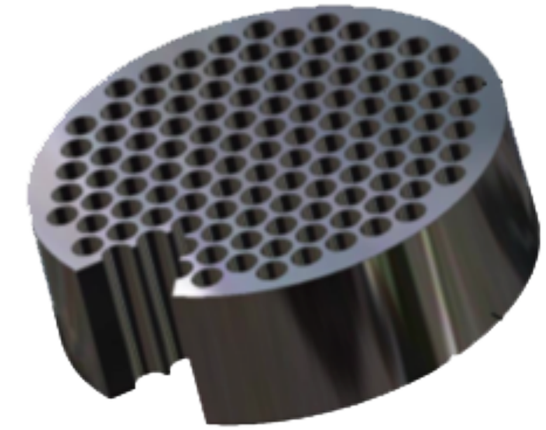
- *A polycapillary device consists of large and low weight optics made by an array of a large number of small hollow glass tubes of circular or squared shape. Hollow cylindrical microcapillaries work also as waveguides for X-ray radiation. The optic collects radiation emerging from a X-ray source within a large solid angle and guides radiation in order to have a focused or a parallel beam.*

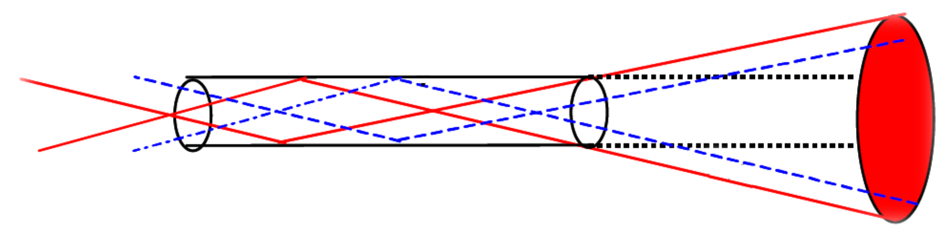
- *Based on experimental and theoretical data, the study of the channeling phenomenon may gives unique information on the nature of X-ray wave interaction and propagation of radiation. Indeed, both experimental and theoretical data point out the presence of propagation radiation modes in such glassy waveguides and the interference between incident and reflected (fluorescence) waves inside microcapillaries.*

Micro-Channel Plates





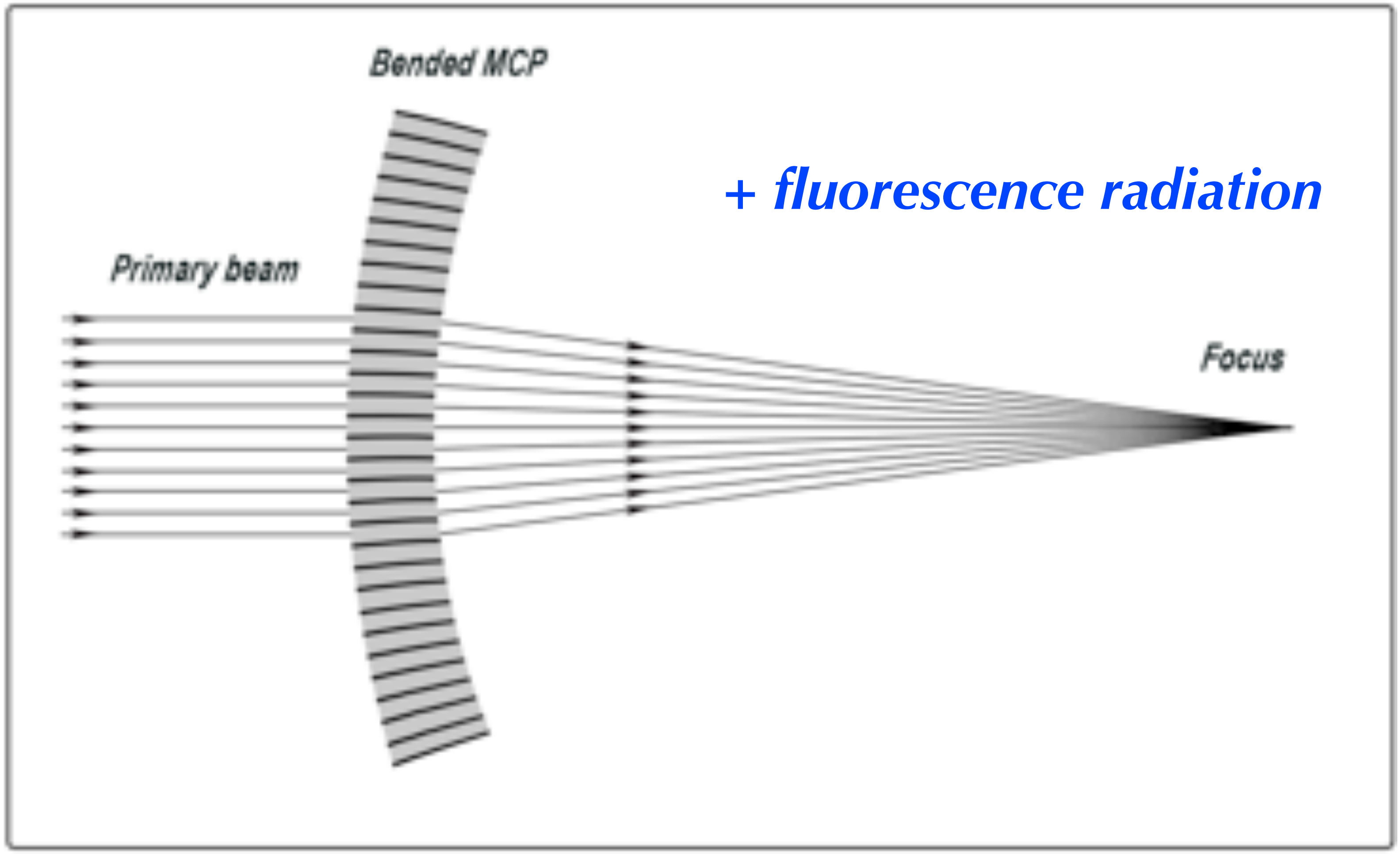




We present here experimental data on the transmission of synchrotron radiation, in a wide energy range, collected at the exit of micro-channel plates (MCP). We have studied both energy and angular distribution spectra of X-ray for large MCPs (20 mm and 33 mm of diameter) with a thickness of ~0.3 mm, characterized by long micro-channels with a length-to-diameter ratio ~80:1 (~12-13 mrad).

MCPs have spatial regular empty channels with a hexagonal symmetry in the transverse cross-section. Micro-channel walls are oriented parallel to the normal of the MCP surface, a diameter of 3.4 μm and a pitch size of 4.2 μm.

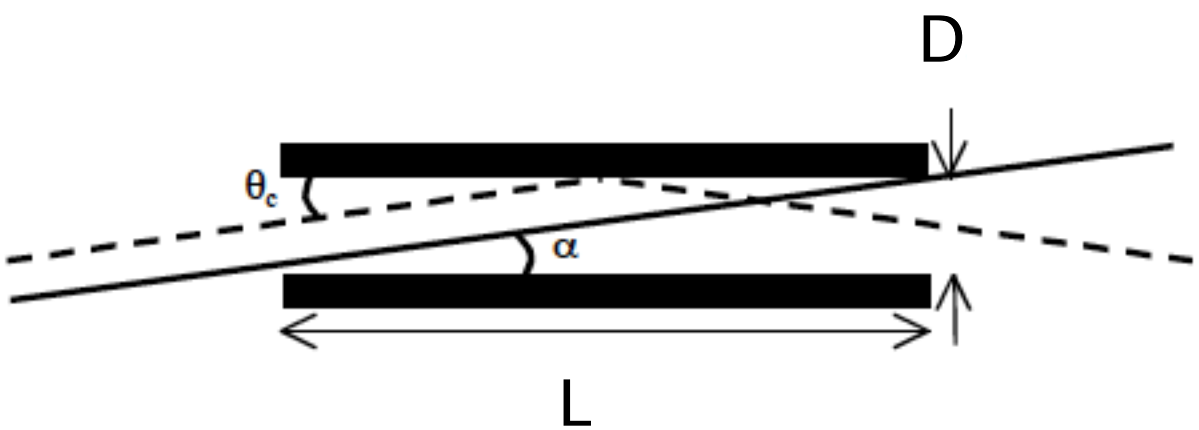
High density fluorescence beam

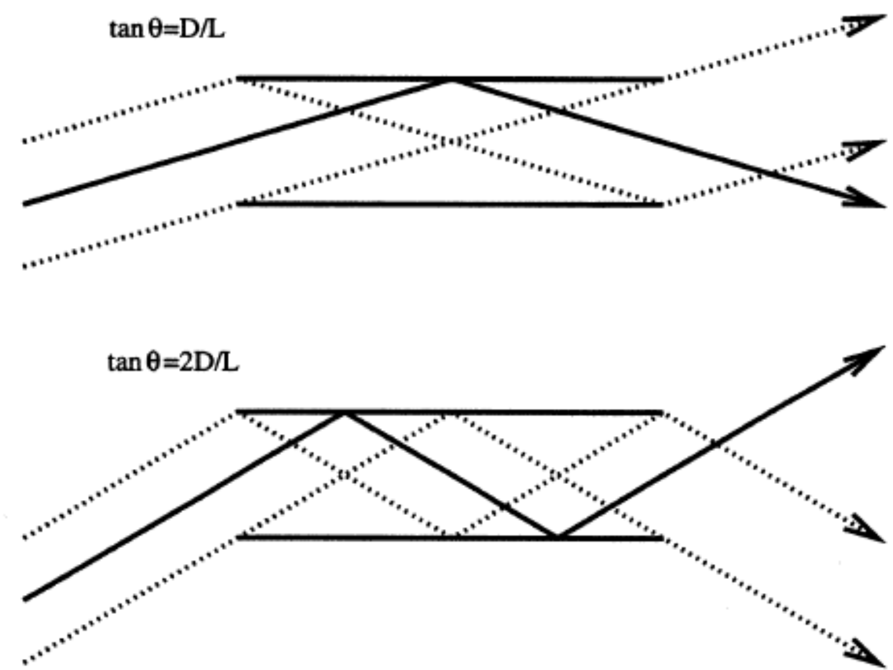


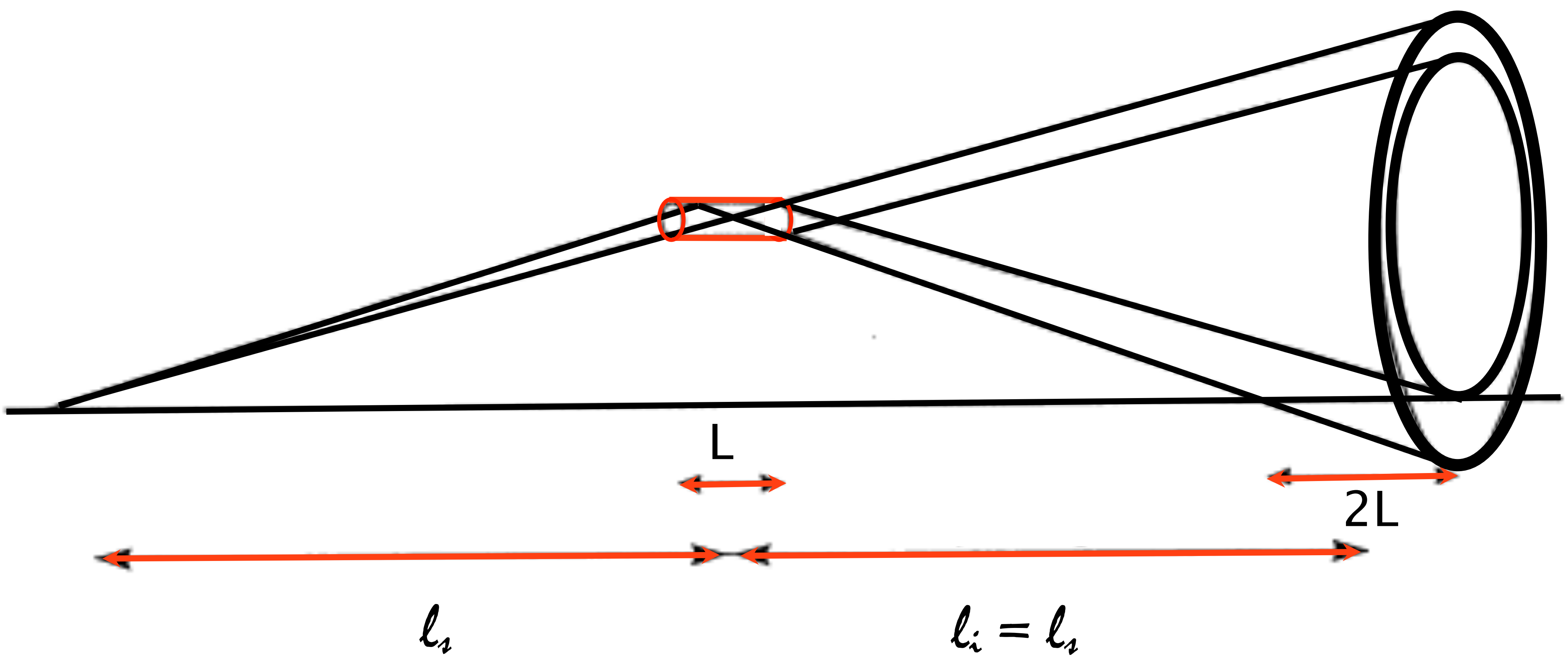
The microchannel plate system can be applied to focus and collimate radiation in a wide energy range, including x-rays. The optics can provide a large effective low weight device and may be ideally considered for several applications, e.g., due to broadband characteristics they are potential devices for micro beam X-ray fluorescence and scanning microscopy.

On the base of experimental (and theoretical) data we may imagine applications as x-ray devices particularly for dedicated extreme focusing of radiation.

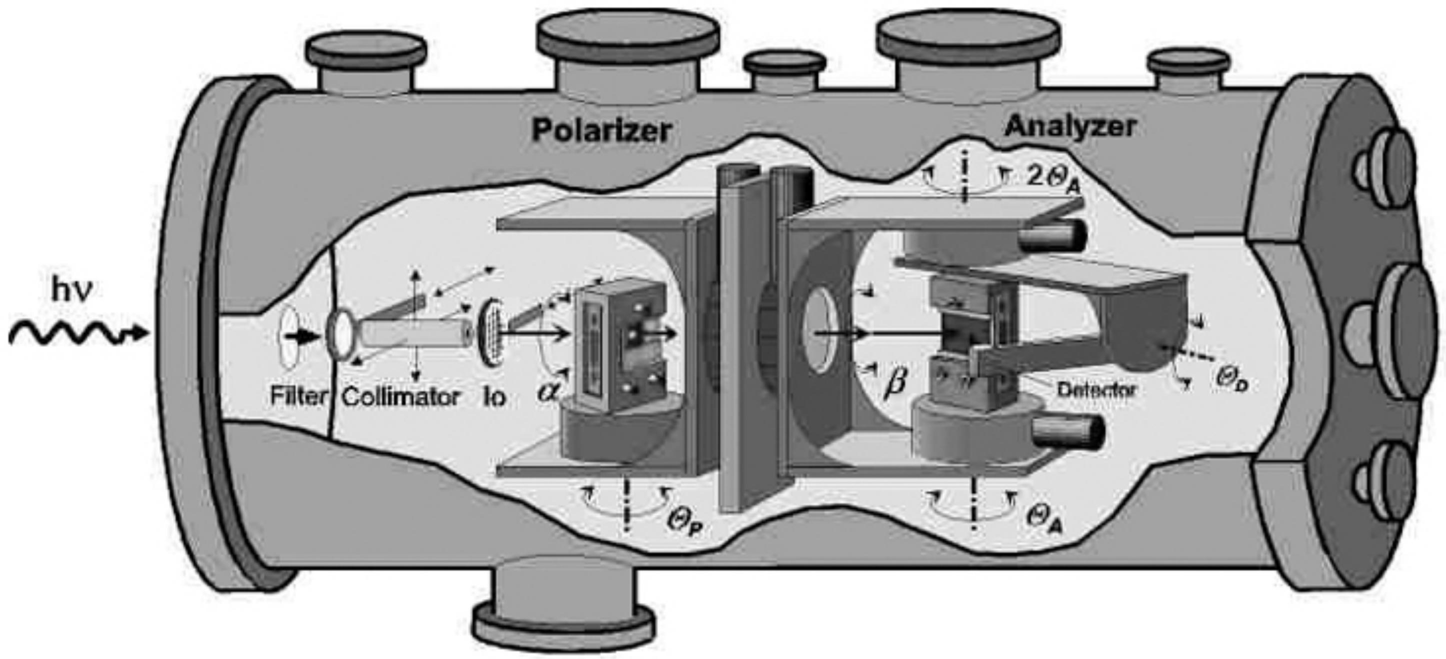
Focusing efficiency

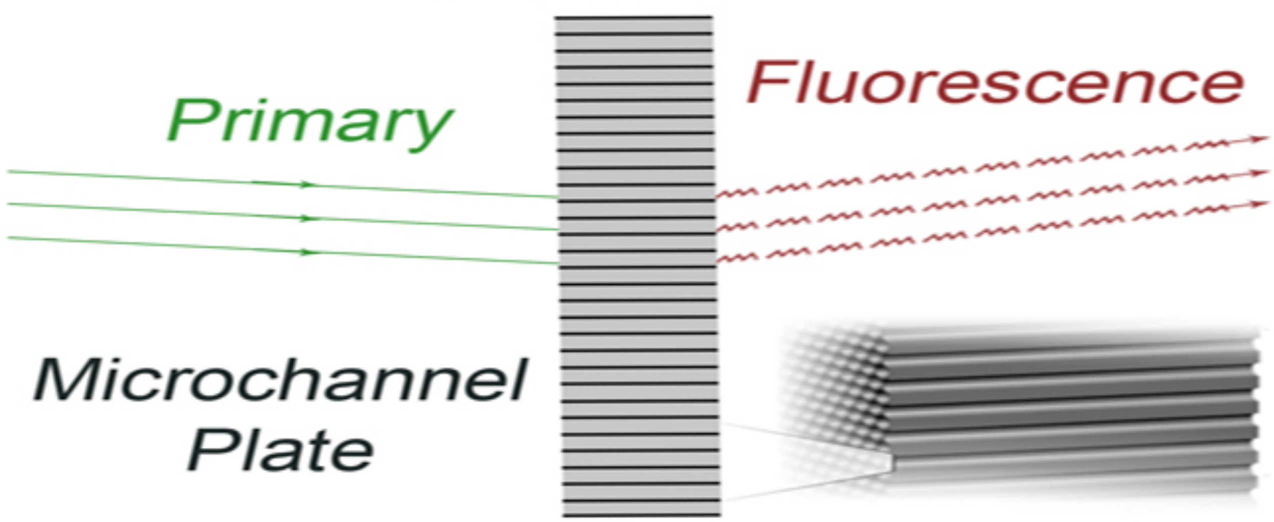


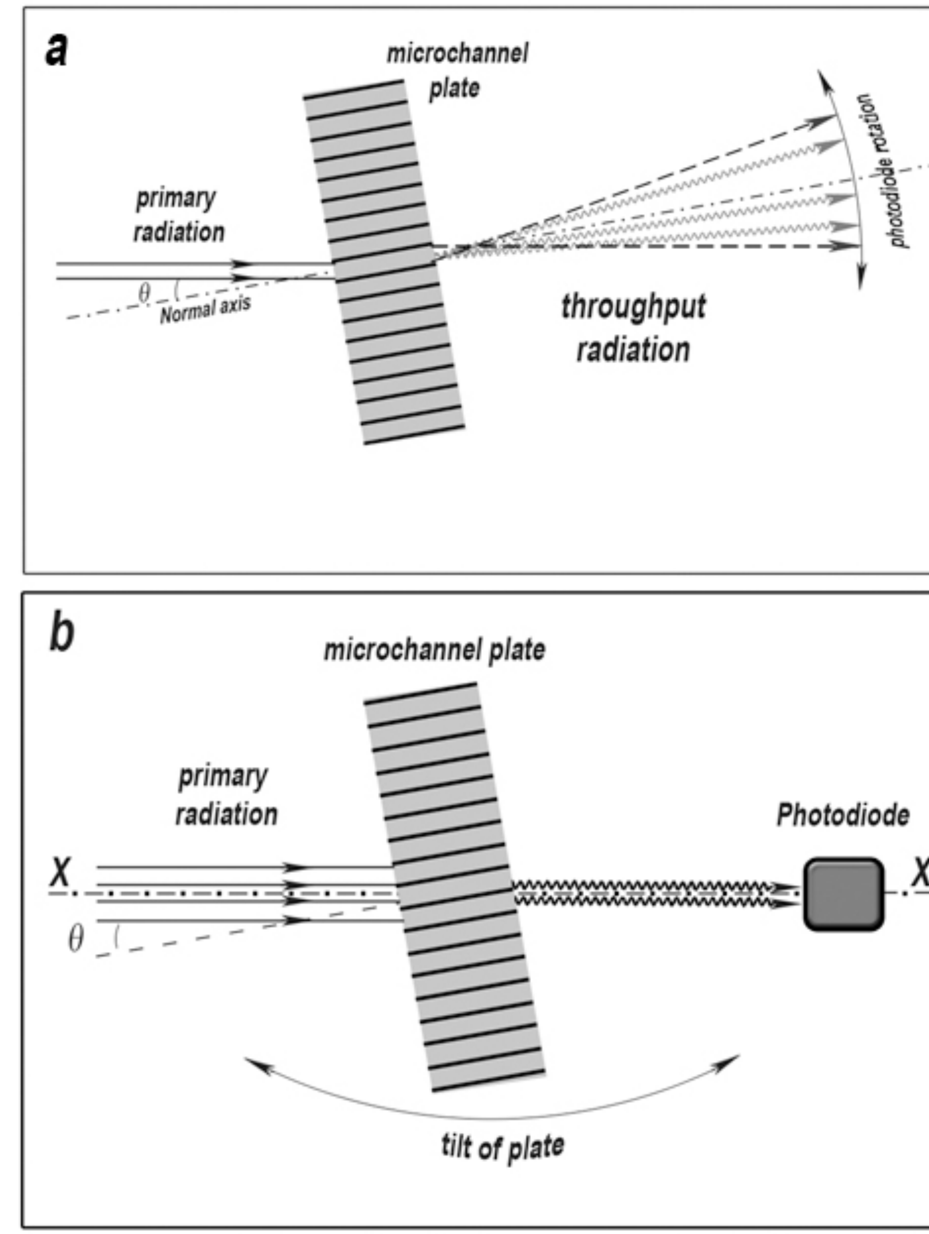




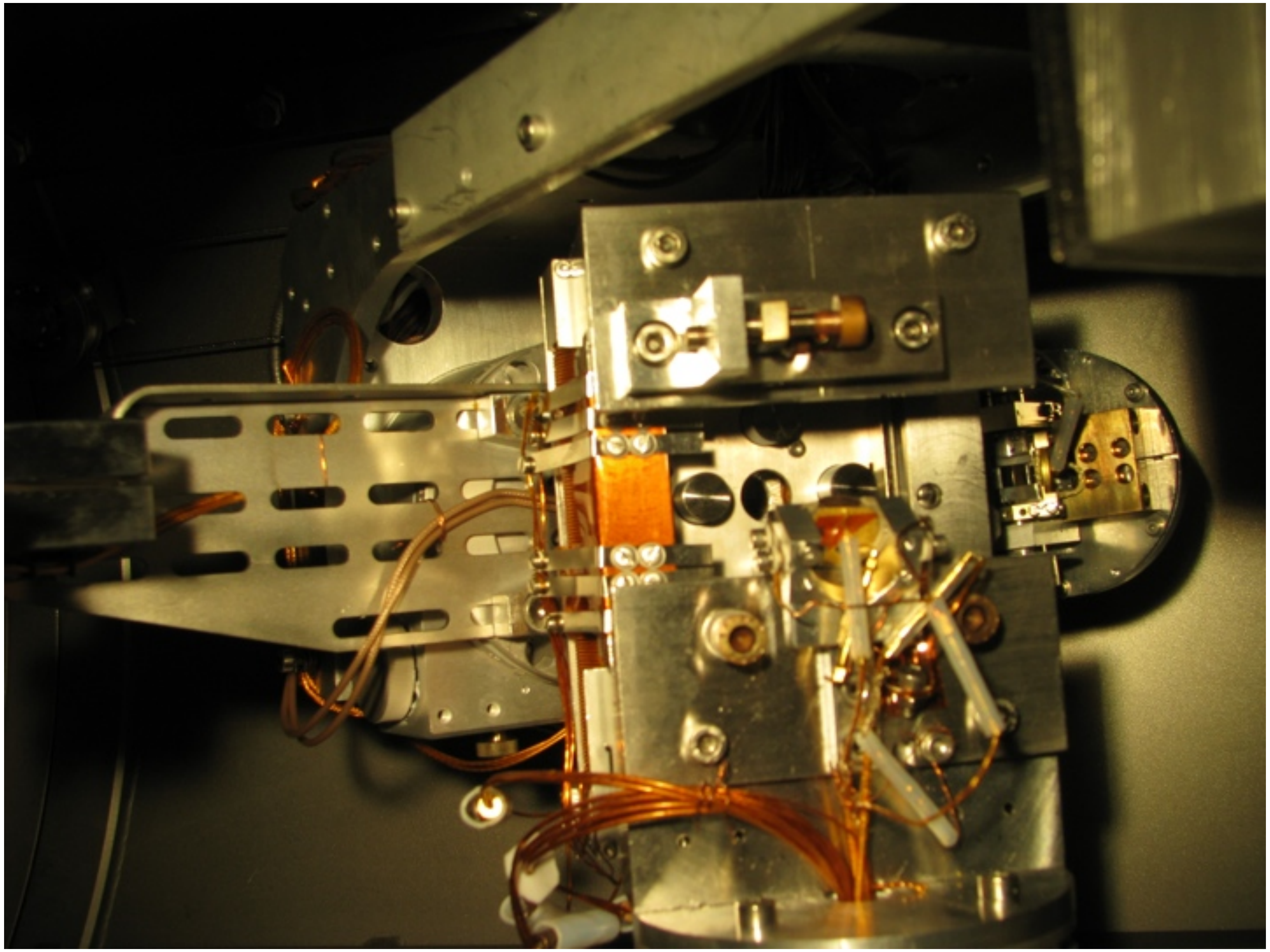
Experimental Layout







(top right) the layout of the rotational alignment of the photodiode at the exit of the MCP, (bottom right) the rotational geometry of the MCP for the zero position of the photodiode. The grazing angle between the incident primary beam and the microchannel walls of the MCP may change while rotating the MCP around the " θ " axis. In the transmission geometry the primary beam size was 60x60 μm. Data have been collected by a photodiode with a circular diaphragm of 200 μm and the distance between the sample and the photodiode was 145 mm.



Next Step: EU funded Project no. 20120188@BESSY

Channeling through hollow policapillary structures probed by radiation at the condition of anomalous dispersion probed by Si L- and O K- absorption edges.

Reflectometry at the Optics Beamline at BESSY II

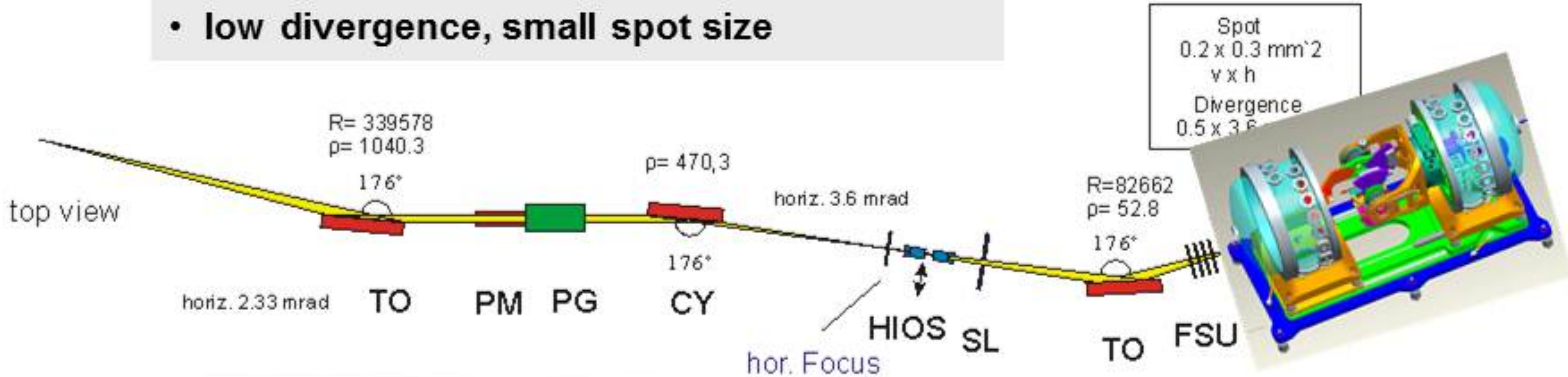
Metrology of in-house produced gratings and more

Reflectometry

- „at-wavelength“ metrology
- quality control
- in-house R&D
- user operation
- short-term access

Collimated PGM

- 10 - 2000 eV
- moderate resolution 10.000 (@500 eV)
- polarization linear/elliptical
- higher order light suppression
- low divergence, small spot size



4 circles goniometer
for large samples (~20 mm)

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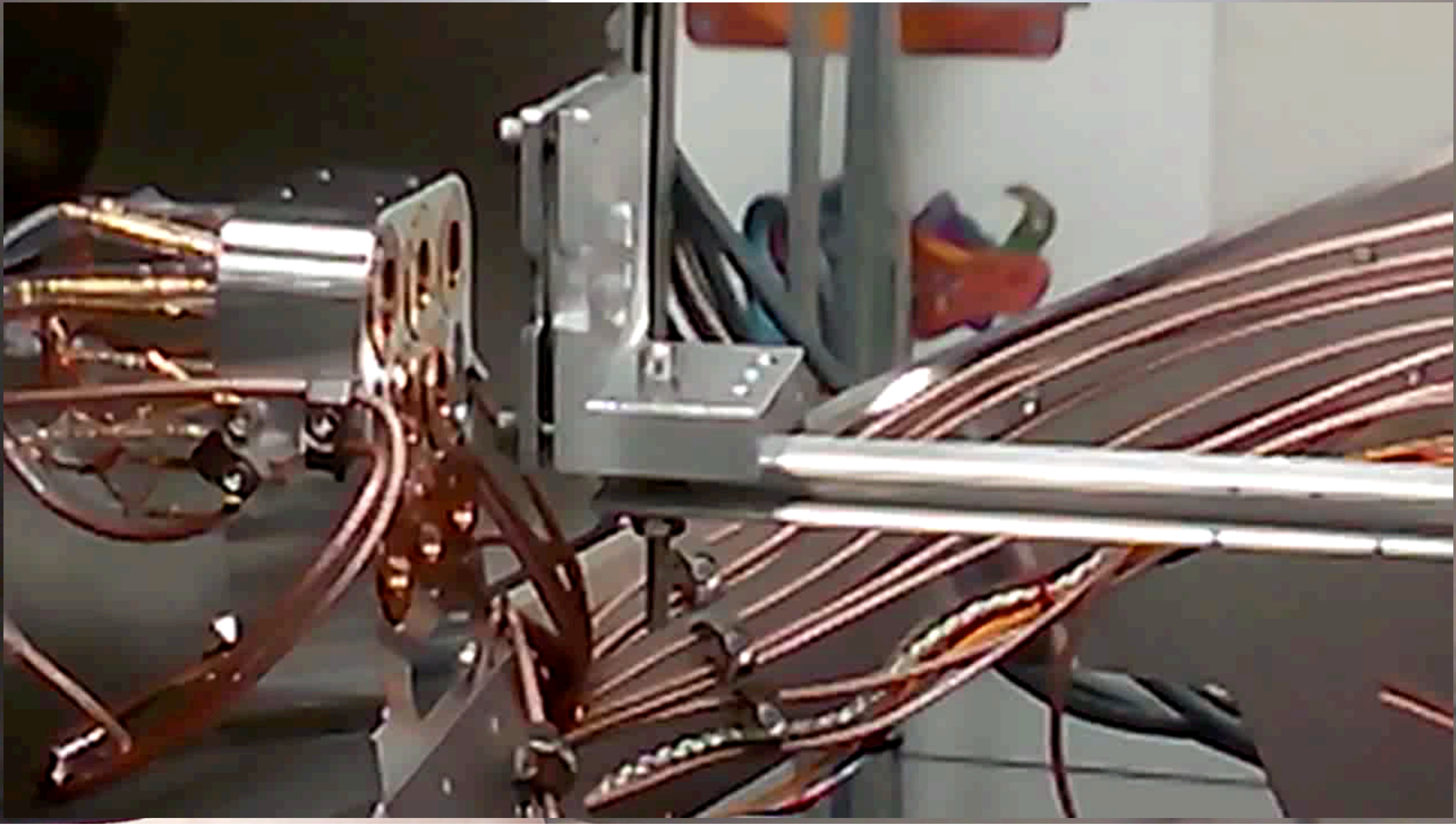

distance ~310 mm

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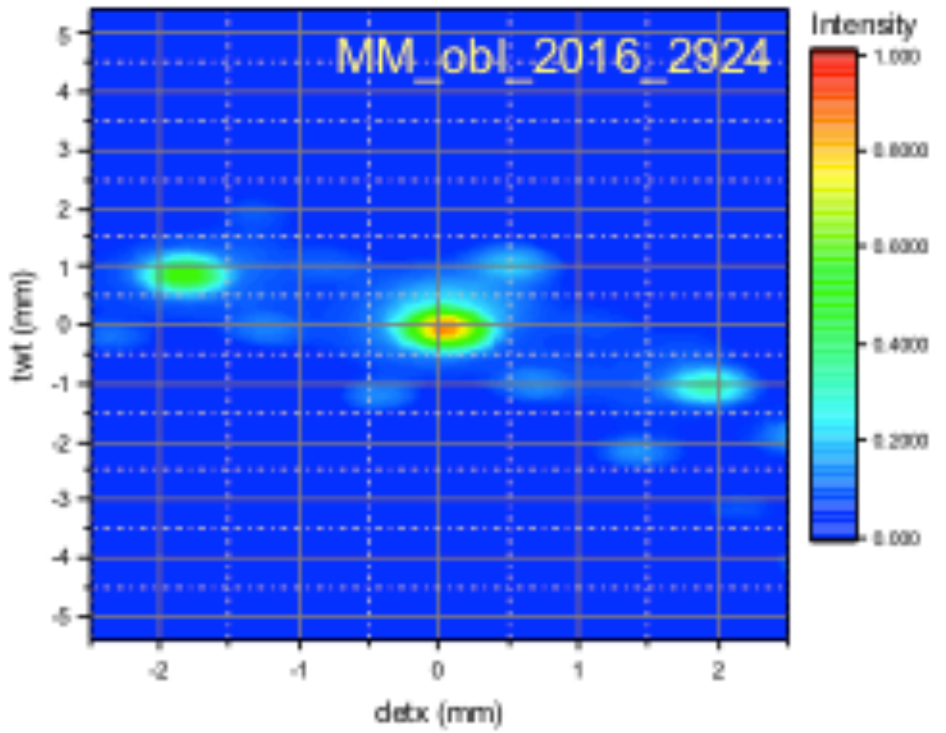
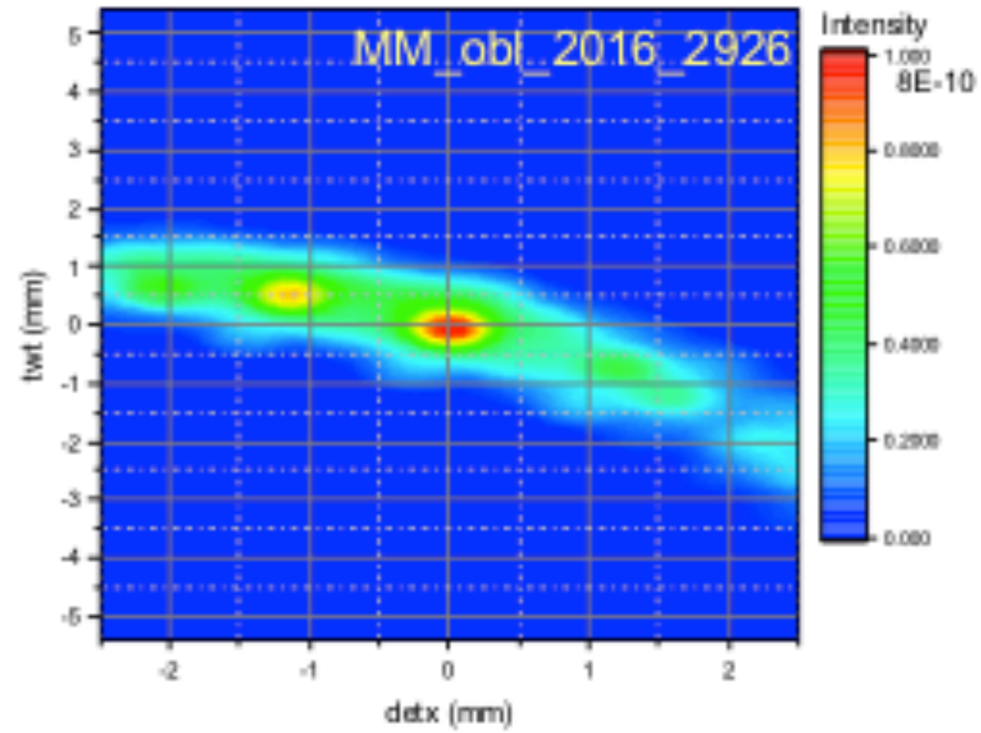
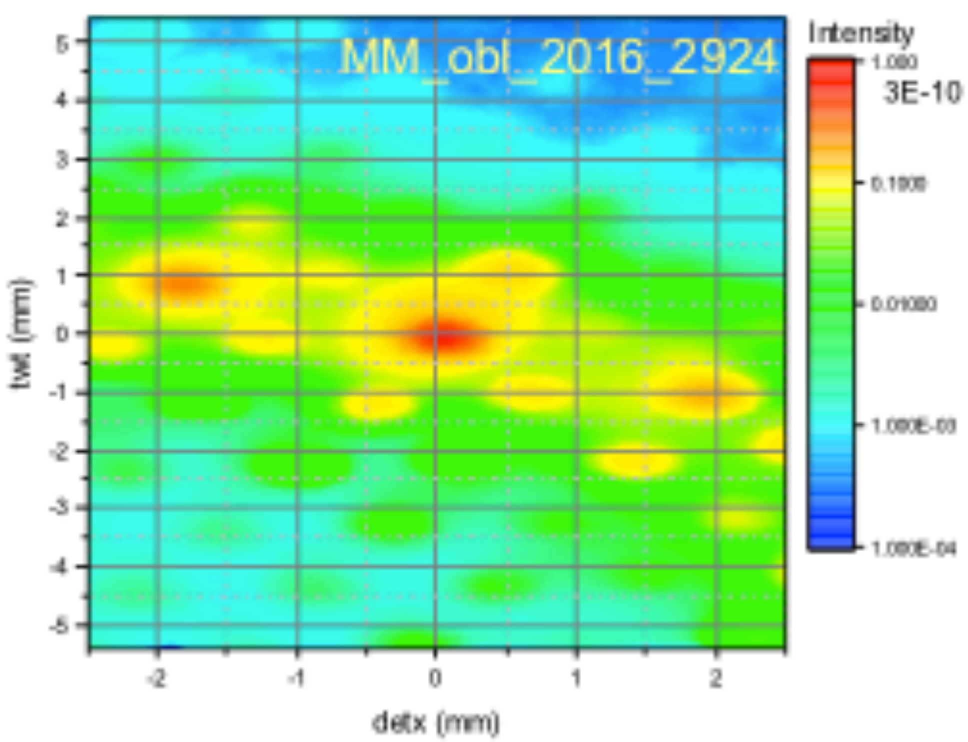
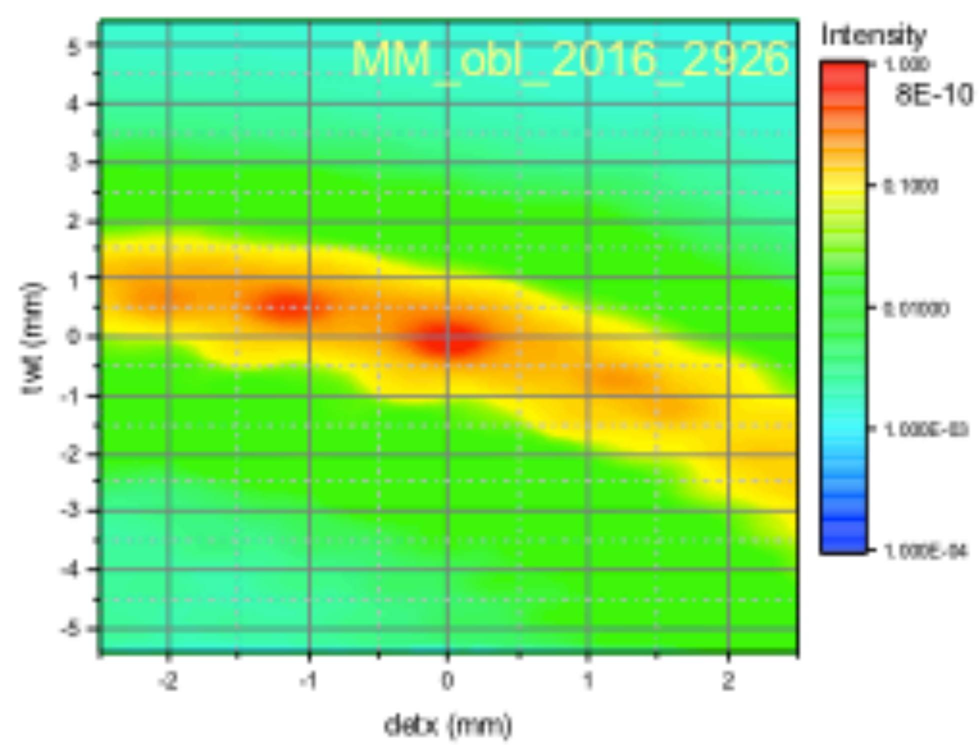
2D scan 2θ vs. detector



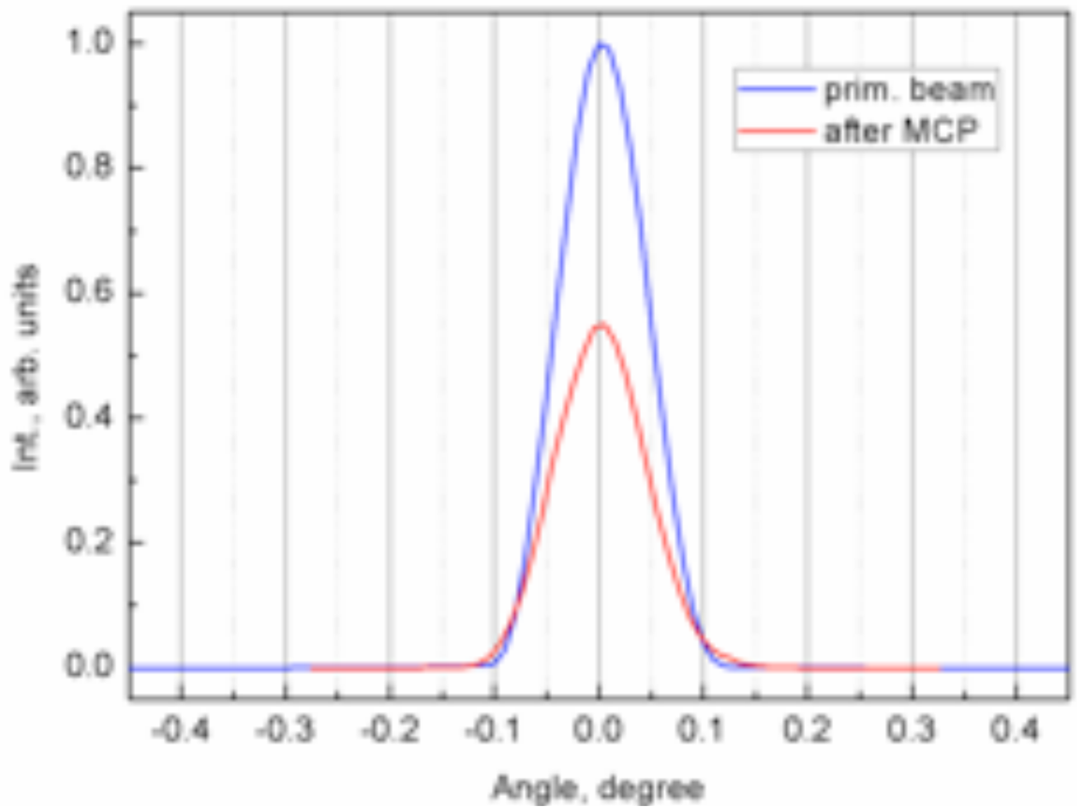


Black MCP 3.4 μm
E~88 eV
slit 100 μm





Black MCP 3.4 μm
E~138 eV
slit 100 μm

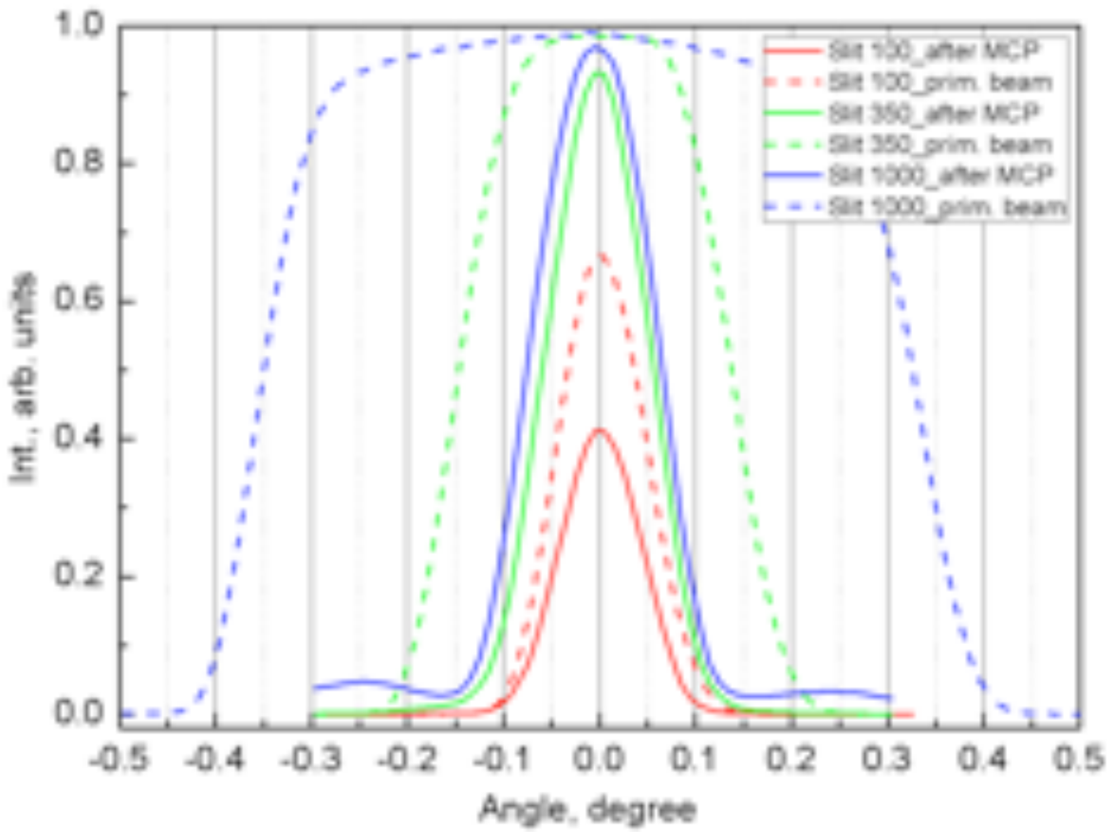


Angular scans of the detector

vertical slit 100 µm

E=1800 eV

MCP 3.4 µm



Angular scans of the detector

E=100 eV

vertical slit 100, 350, 1000 µm

MCP 3.4 µm

Transmission from ~60 % to > 20%

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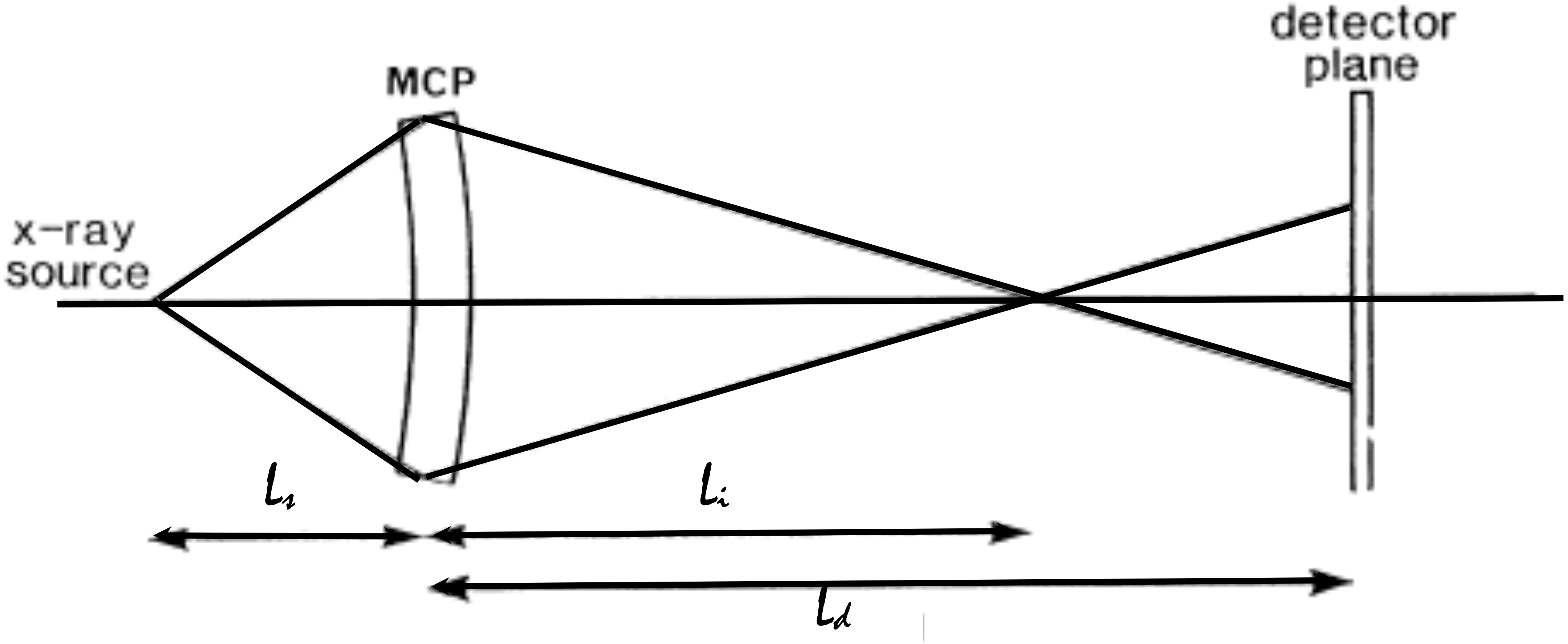
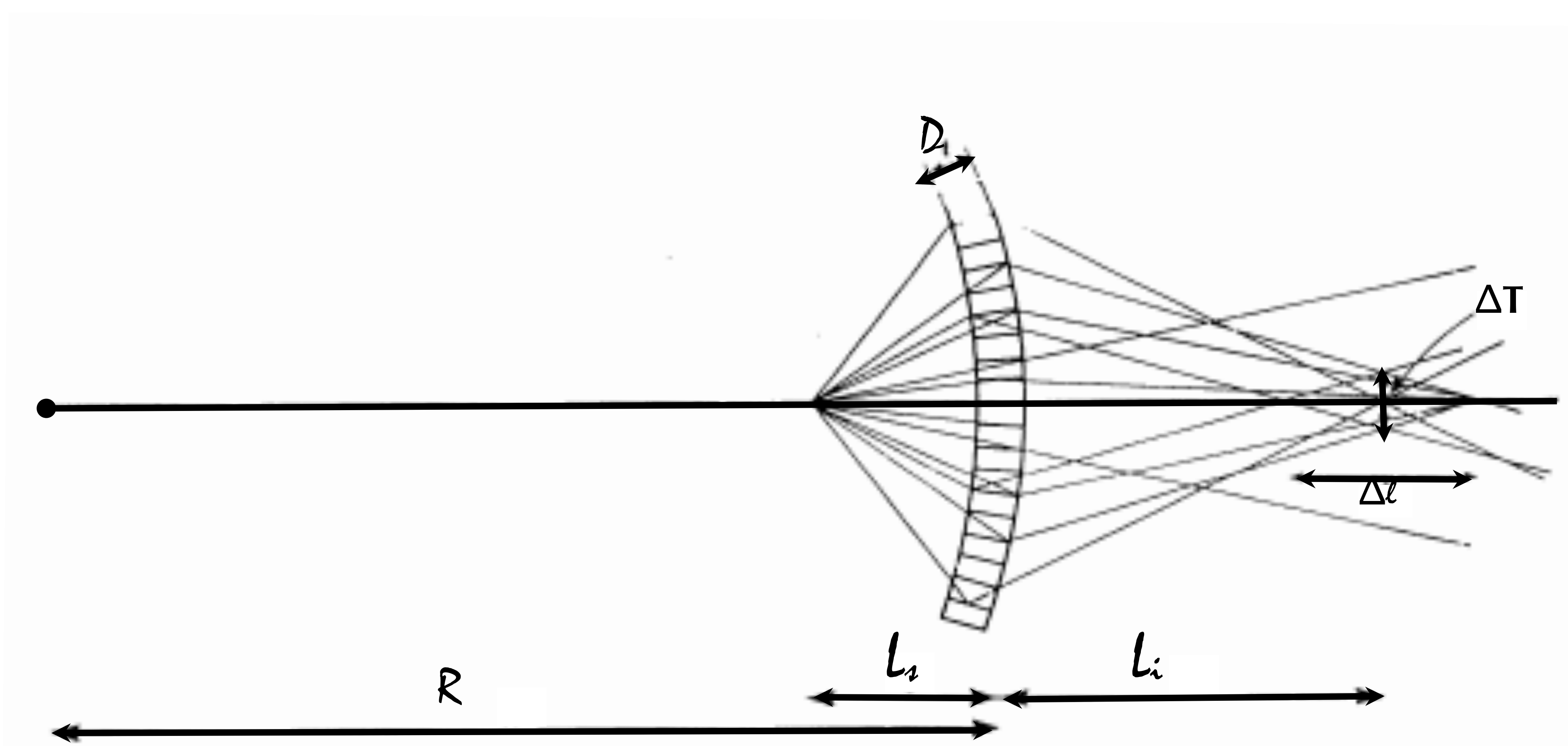
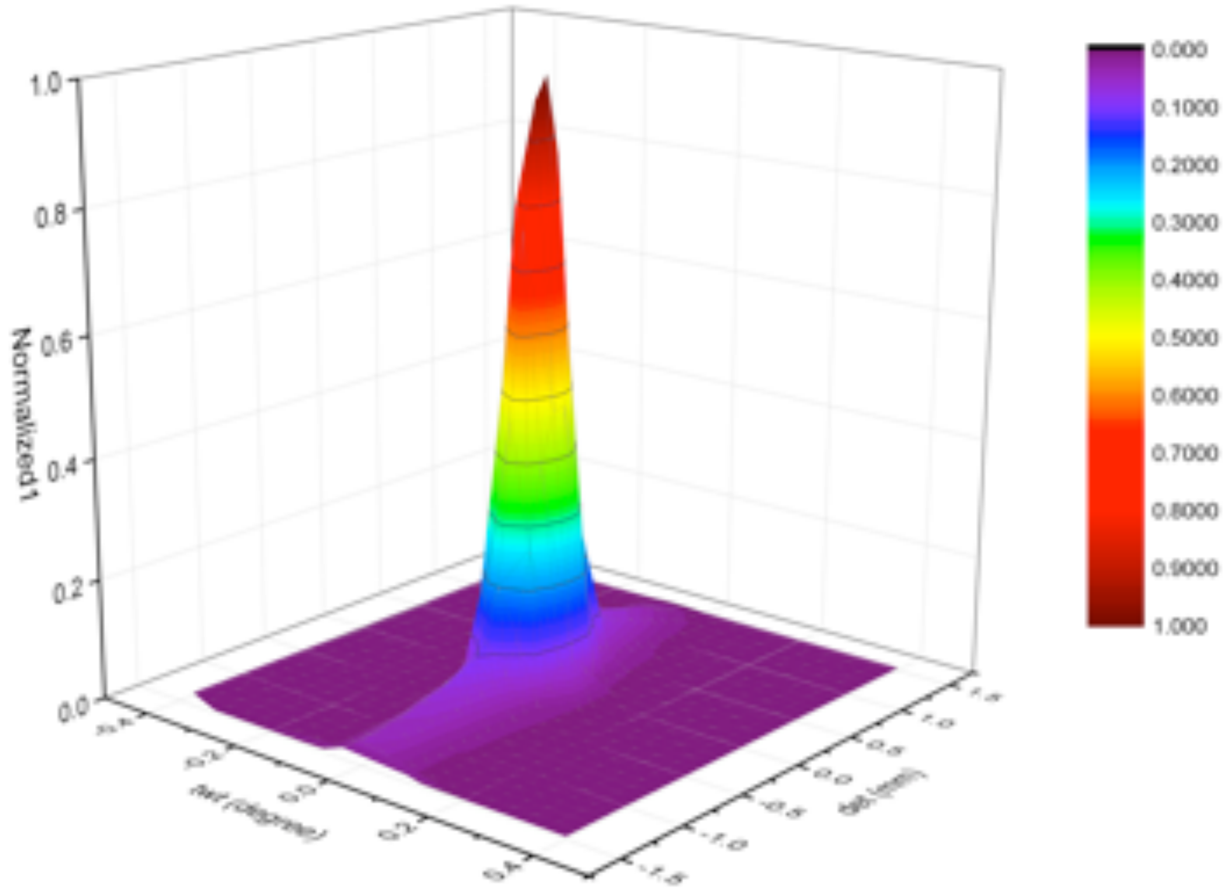
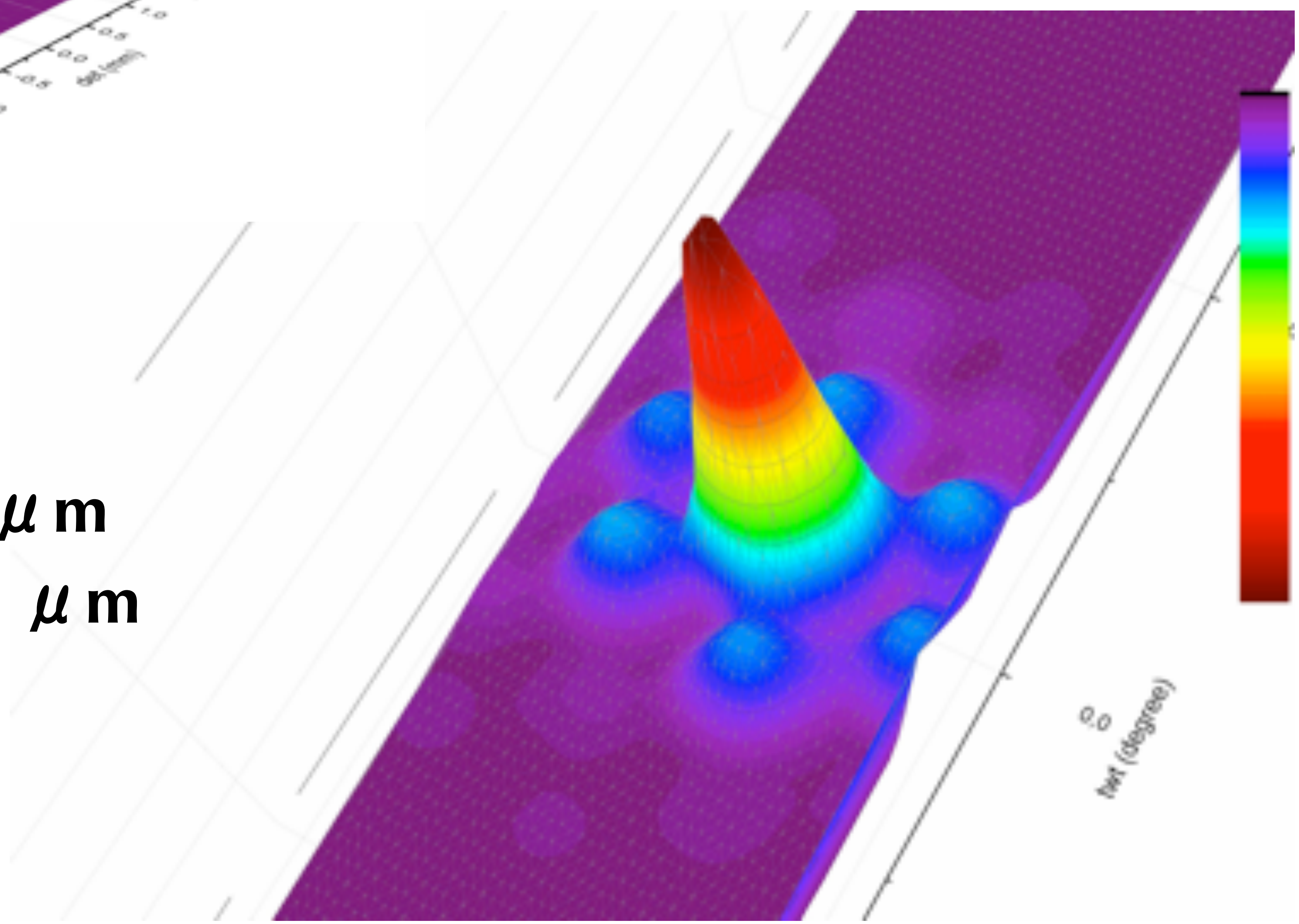






E=138 eV, Slit=100 μm
angular mesh



White MCP - 3.4 μm
E=138 eV, Slit=100 μm
angular mesh

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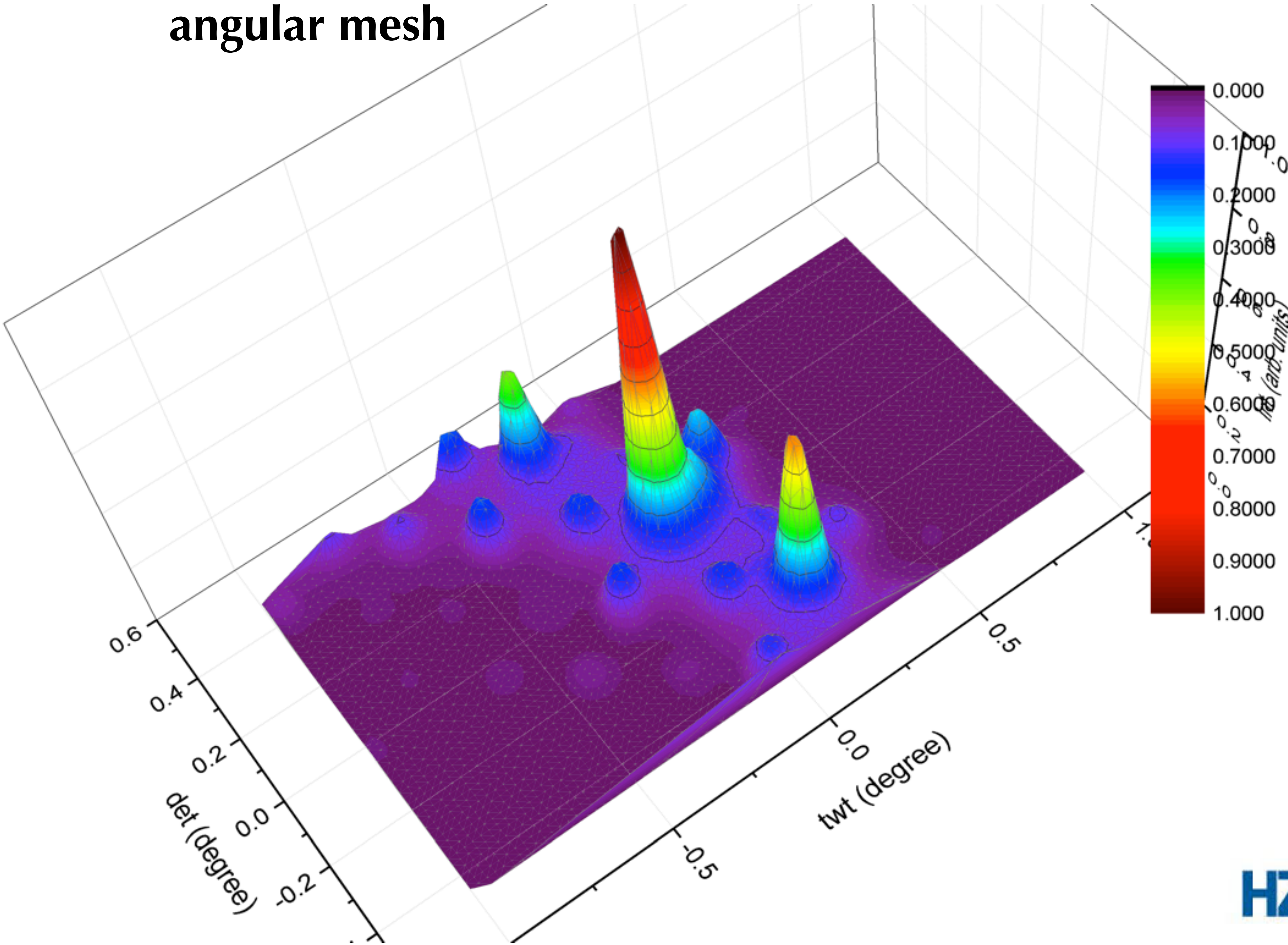
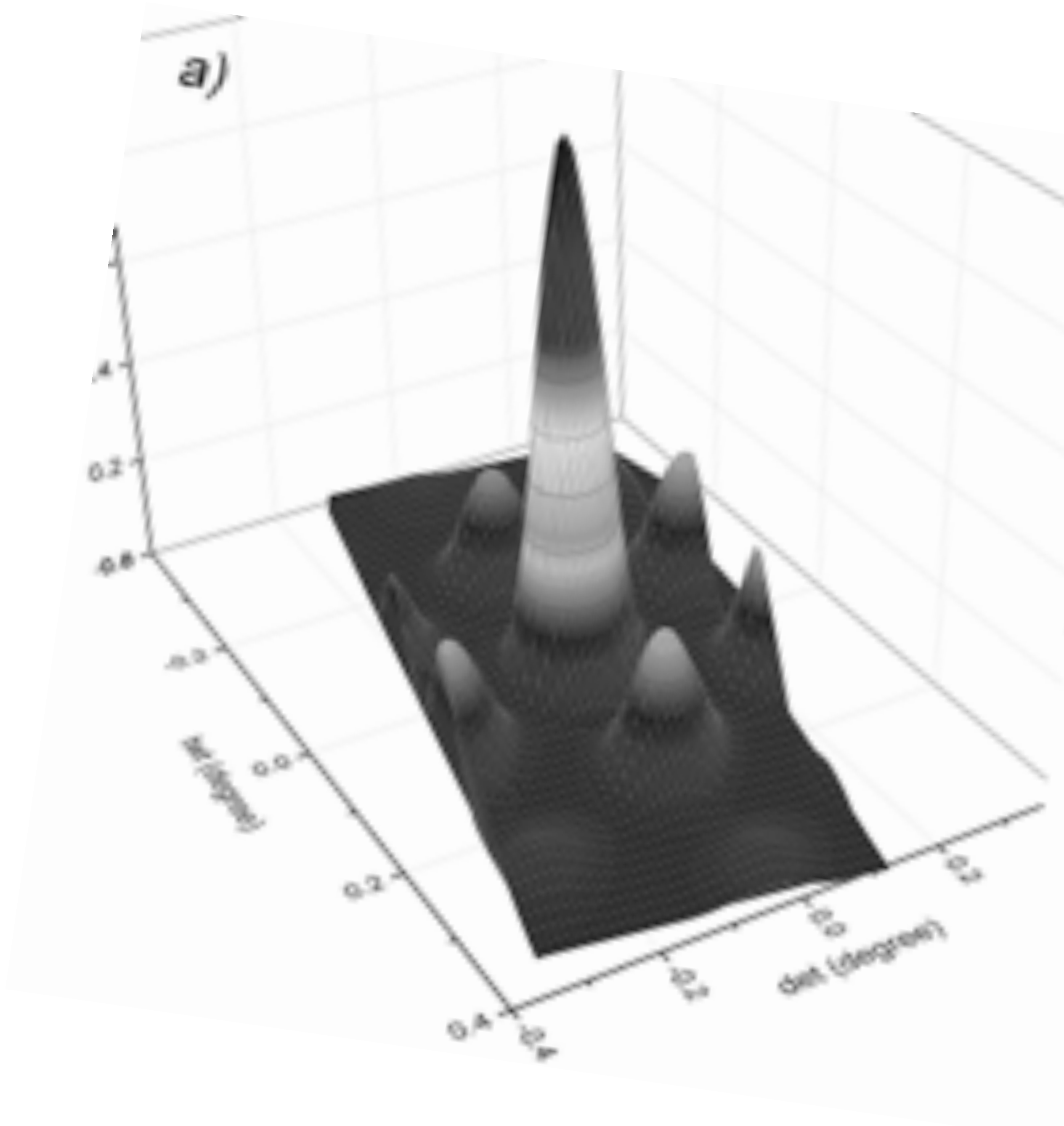
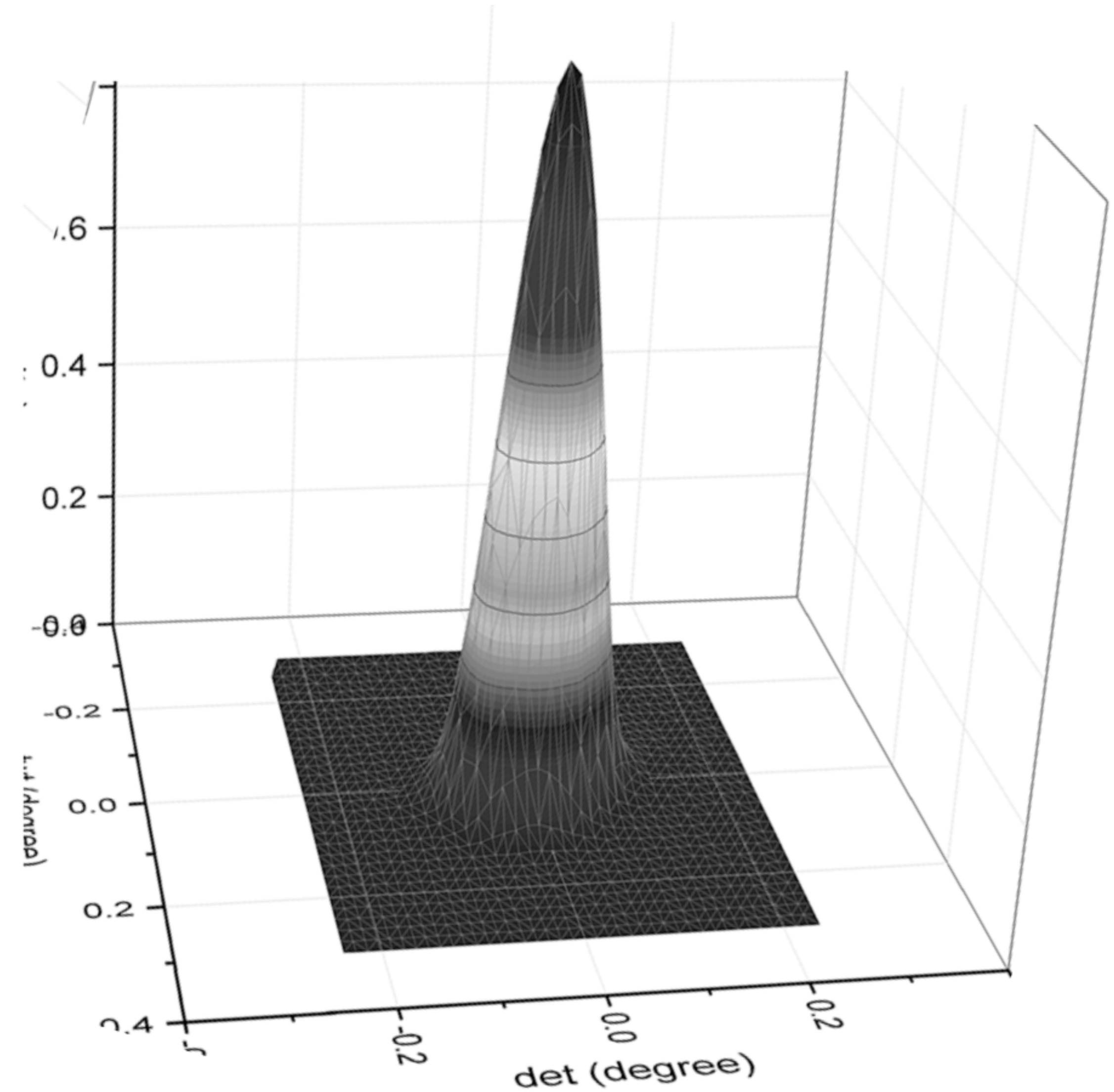
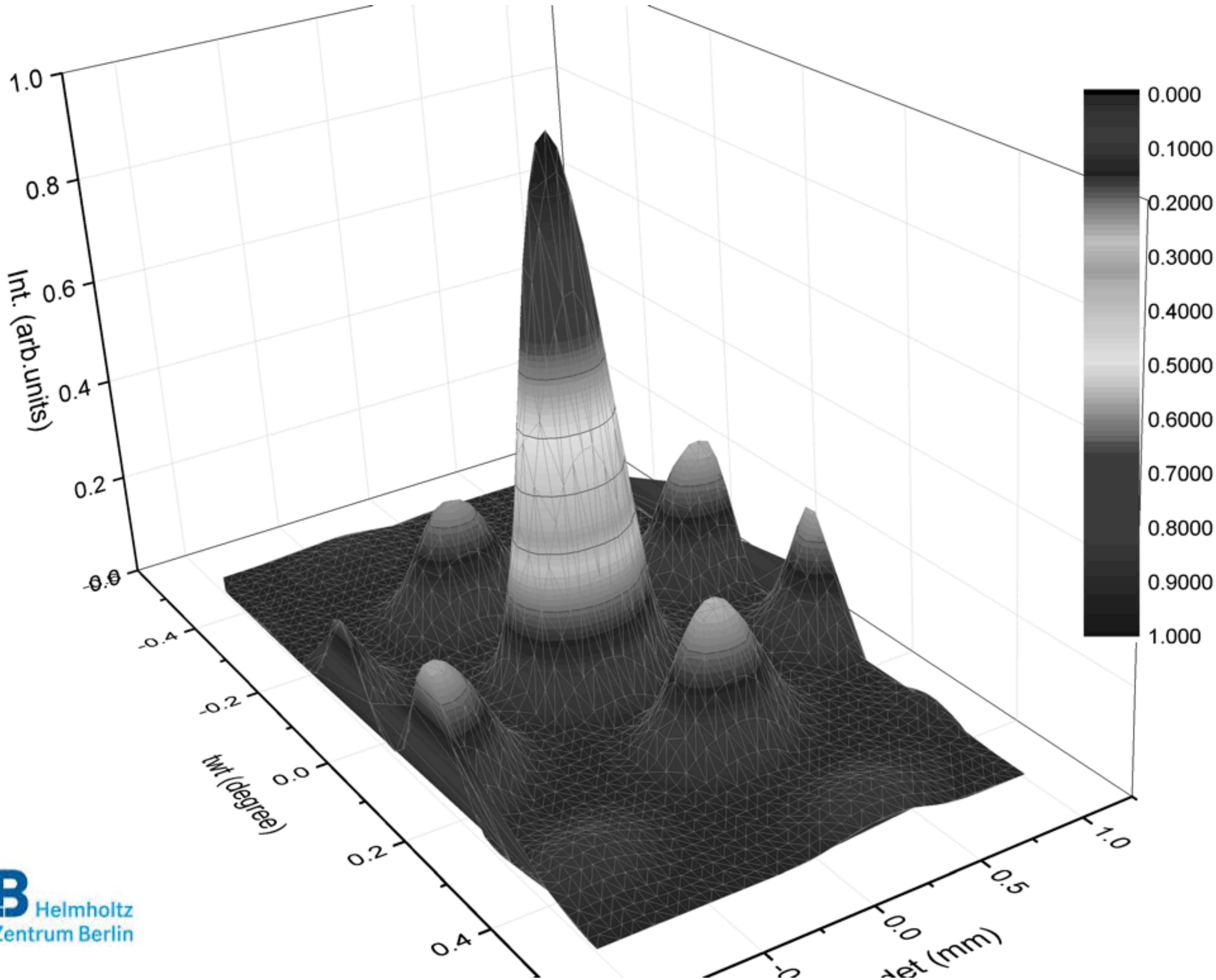
Black MCP - 3.4 μm
E=88 eV, Slit=100 μm
angular mesh





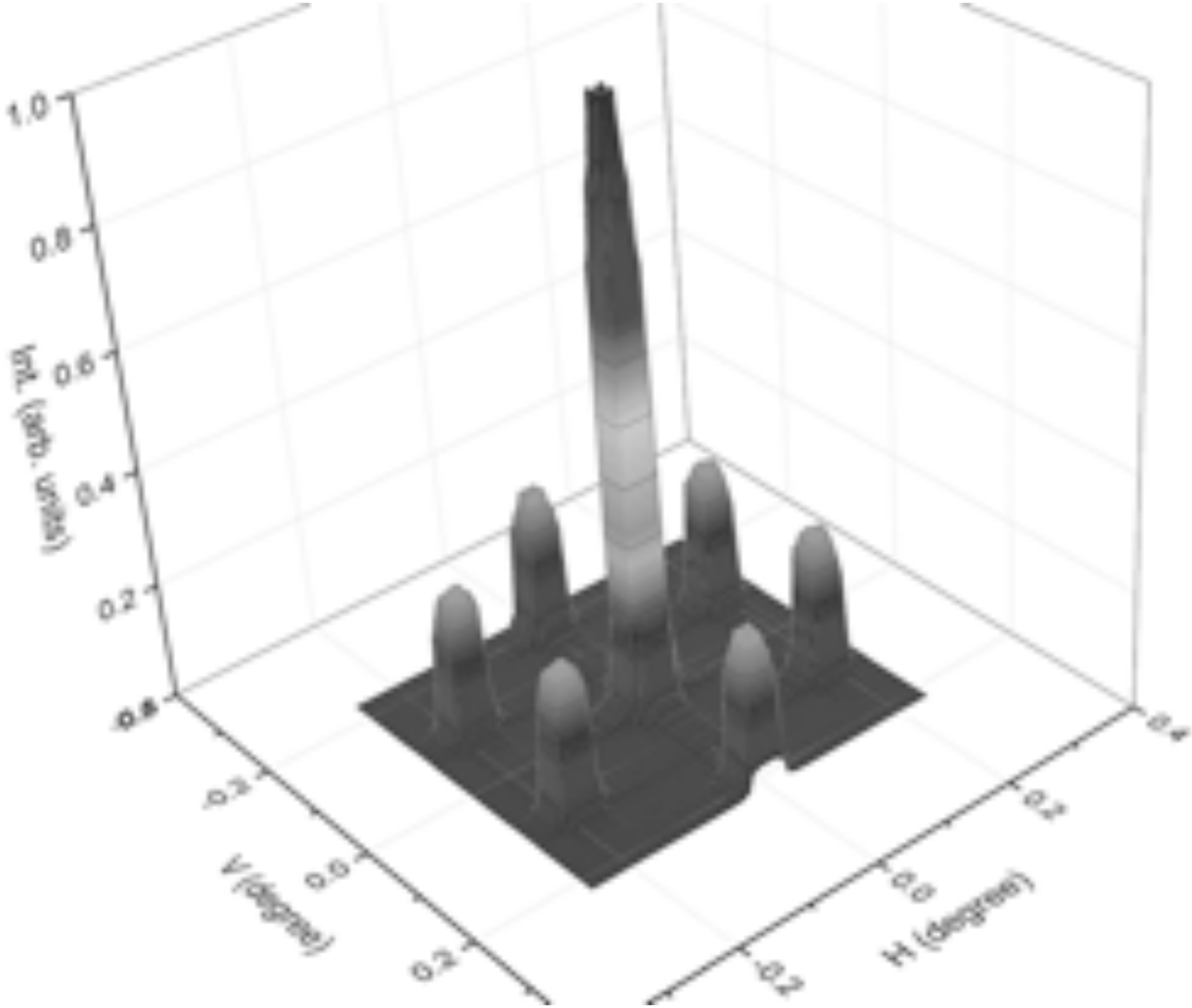


The experimental angular distribution of the radiation transmitted through a MCP with microchannels of 3.4 μm of diameter at 100 eV (left) and 1800 eV (right).



1.0
0.8
0.6
0.4
0.2
0.0
Int. (arb.units)
-0.4
-0.2
0.0
0.2
0.4
twt (degree)
0.0
0.5
1.0
det (mm)
0.000
0.1000
0.2000
0.3000
0.4000
0.5000
0.6000
0.7000
0.8000
0.9000
1.000

Diffraction model at far zone



Theoretical angular distribution of the transmitted radiation (90 eV) by a flat MCP with microchannels of 3.4 μm of diameters.

CiPo beamline@Elettra

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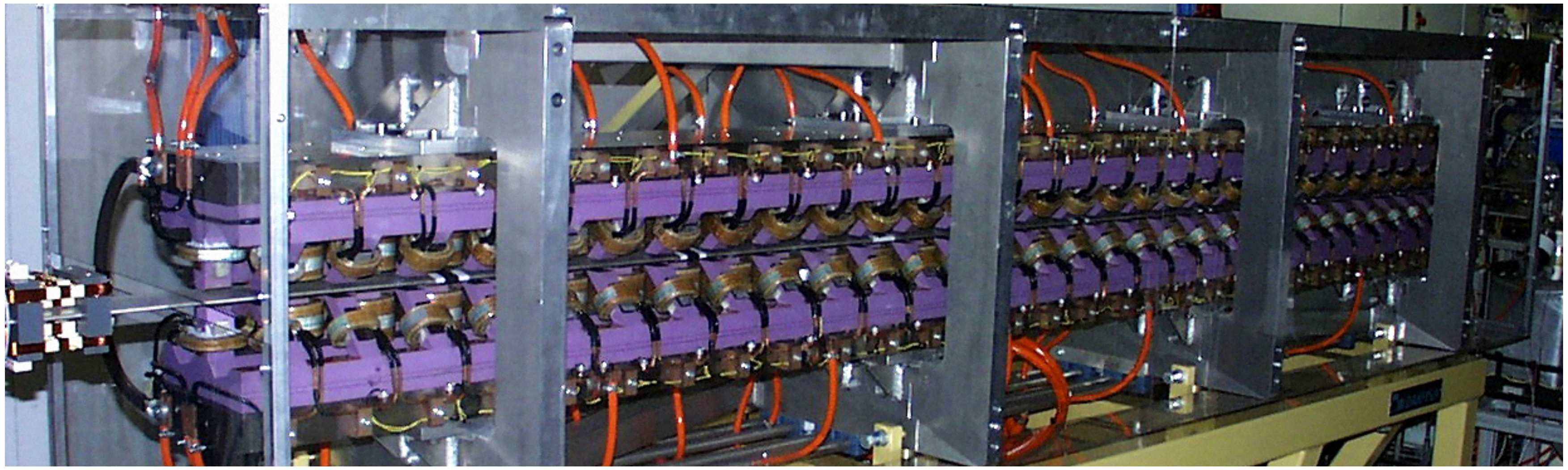
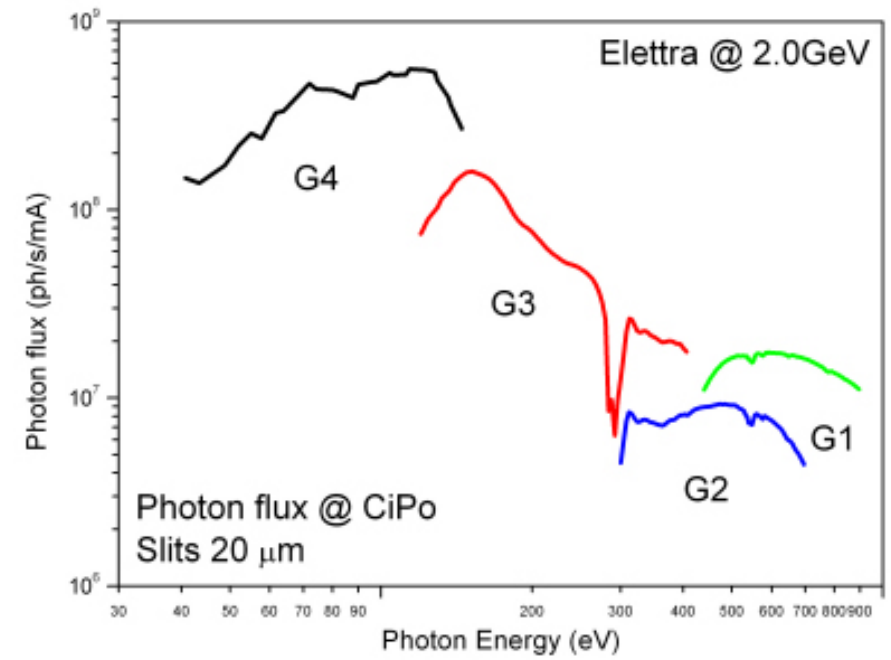
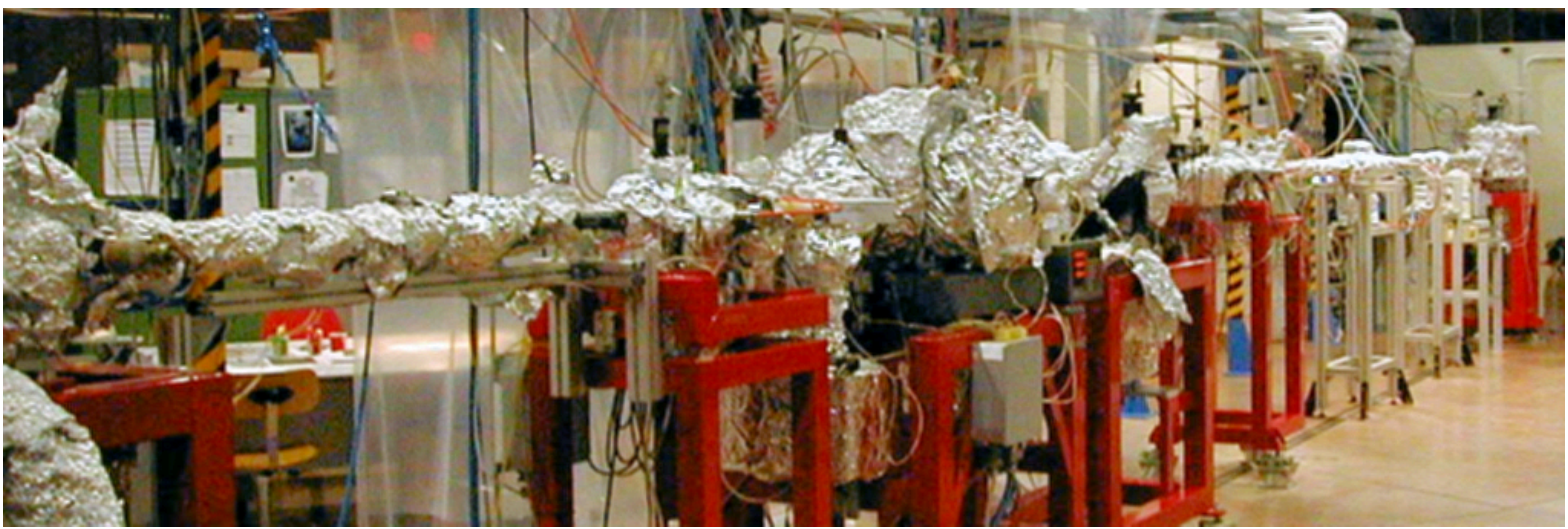


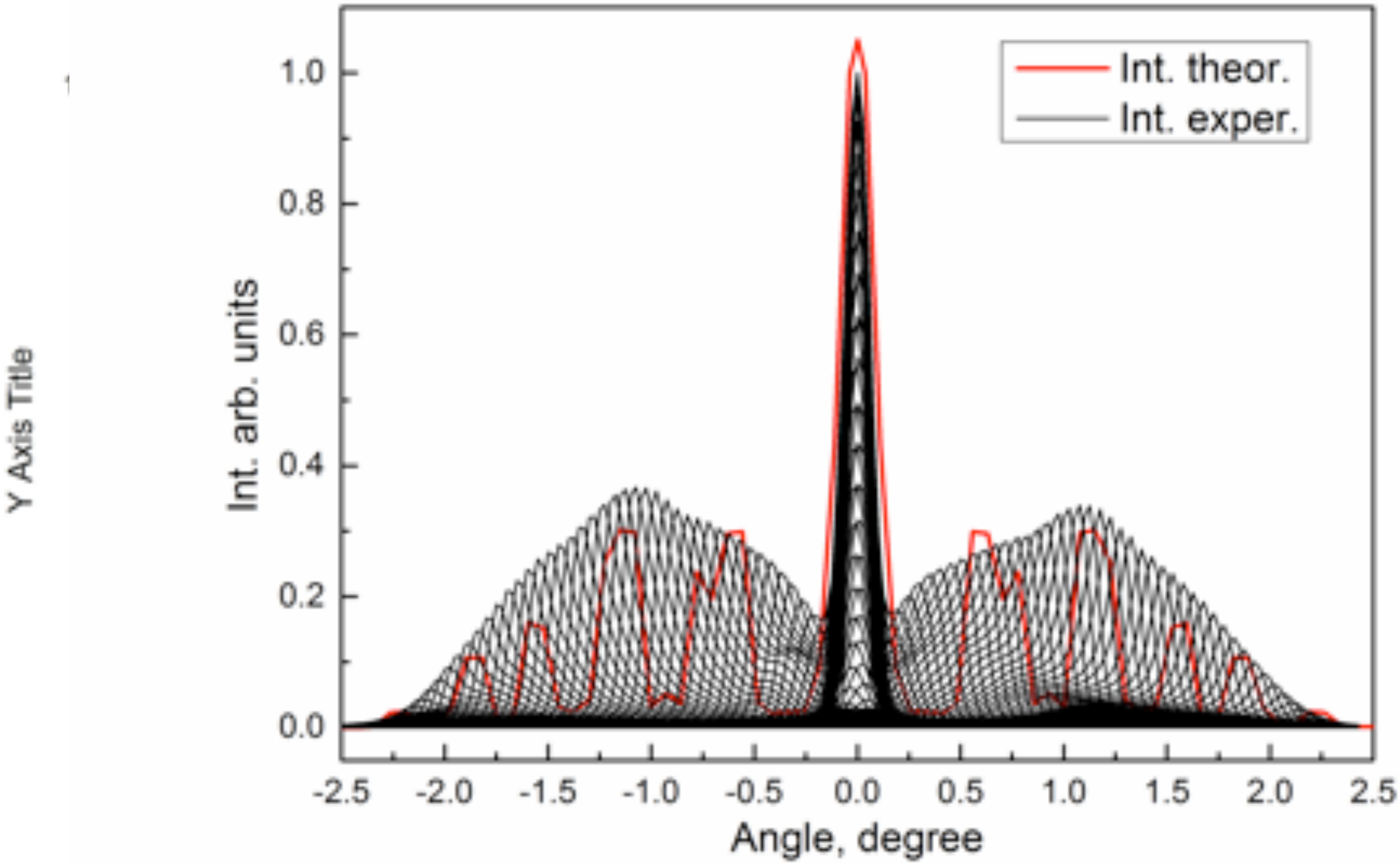
- *source: elettromagnetic elliptical wiggler*
- *SGM monochromator (~40-900 eV)*
- *IRMA HV experimental chamber*





CiPo beamline@Elettra

The angular map of the same white MCP (3.4 μm) collected at 700 eV. On the x-axis the angular scan of the device while on the y-axis is given the vertical scan of the detector (2.5 x 2.5 deg).



Coherent and incoherent components of a synchrotron radiation spot produced by separate capillaries

Sultan B. Dabagov, Augusto Marcelli, Violetta A. Murashova, Nikita L. Svyatoslavsky,
Rustem V. Fedorchuk, and Mikhail N. Yakimenko

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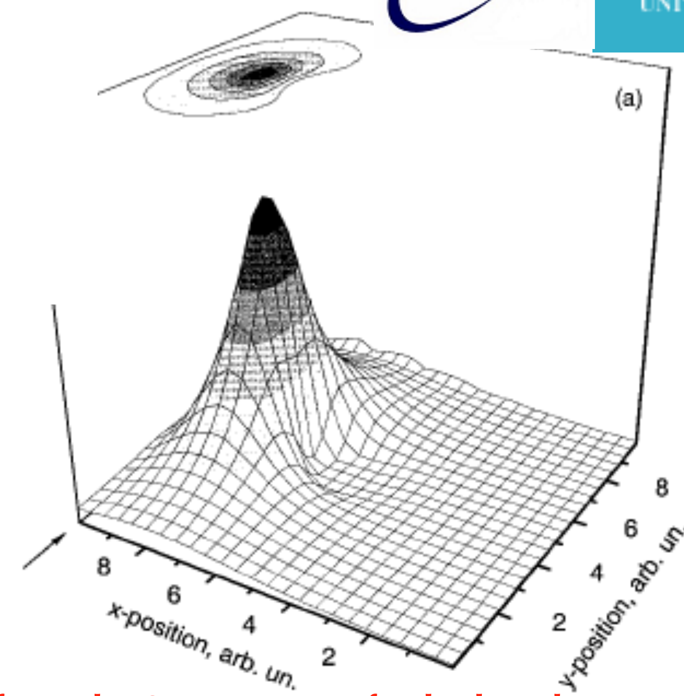
The experimental observation of interference in x-ray radiation traveling through capillaries demonstrates the presence of a coherent component superimposed on the incoherent diffuse radiation.
The coherent component is usually is negligible but with new SR sources this portion may represent a substantial contribution. The observation of wave phenomena in the redistribution of the emission from a capillary structure is a complex task. An improved transmission of the coherent contribution appears possible through the optimization of the diameter; length; curvature radius, number of channels and symmetry of the system.
The enhancement of the coherent contribution could be also obtained through alternative orientations of the devices. The presence of the mode propagation for x-rays in capillaries/ channels is valid and may have applications
in x-ray microscopy and imaging using coherent x-ray sources.



SR beam from the S-60 source of Lebedev Phys. Institute

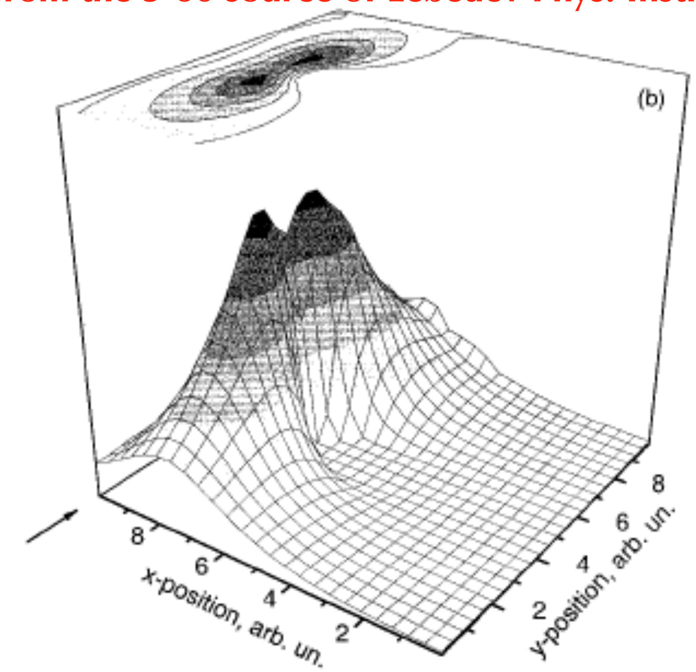


Fig. 1. Typical x-ray distributions inside a curved capillary for the first (main) two modes. The intensity of the distribution for the mode $m = 1$ is increased 10 times for comparison.

Although limited, the experimental results pointed out the existence of interference phenomena for SR propagation through capillaries/channels that are significantly larger than the wavelength of the radiation.

Conclusions

- MCPs are extremely interesting and flexible soft & hard x-ray devices
- Experimental data can be collected with easy layouts (in air and in vacuum)
- Characterization of focusing properties needs time and dedicated optical layouts
- MCPs have potentials for many applications
- Promising opportunities to manipulate coherent sources

Thanks for the attention

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