First resolution test results of the Atomki nuclear nanoprobe

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Layout

Present arrangement (until mid 2018)

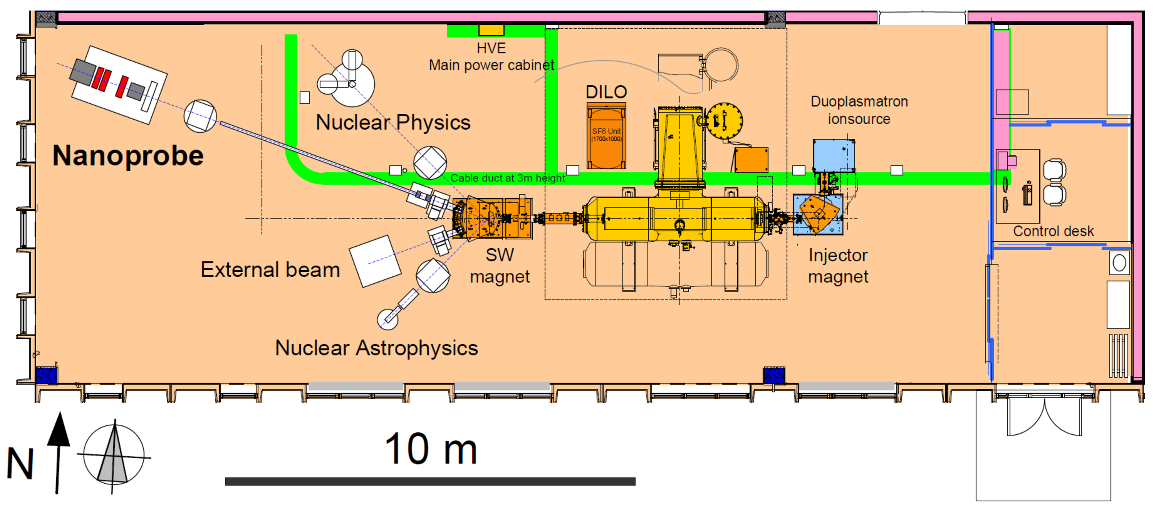
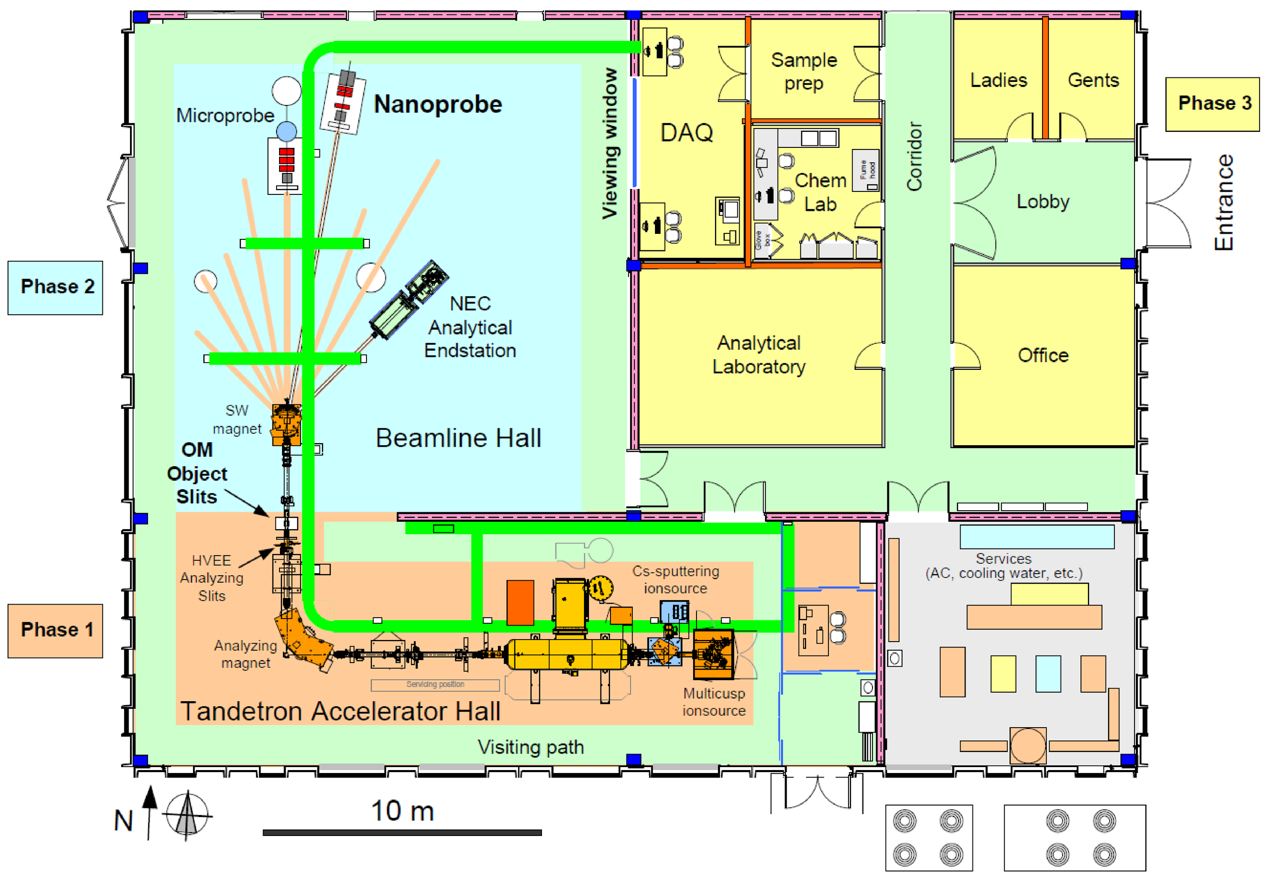


Photo of the present setup

Final layout (HVEE installation autumn 2018)



The present setup of the Tandetron Laboratory was completed with a single source injector (Model 358 duoplasmatron ionsource), and a switcher magnet. Due to financial reasons, the whole laboratory was planned to be equipped in several steps. The accelerator was positioned in the final place. In 'Phase 1' four beamlines were built [1] and have been used providing already several papers [2,3]. The nanoprobe was assembled in this temporary location for testing. The present results have been measured here. The final position of the nanoprobe will be in the 'Beamline hall' which is in 'Phase 2' of the building. ('Phase 3' will contain additional rooms, e.g. sample preparation, data acquisition, chemistry lab, etc.)

In the final layout the nanoprobe will be positioned as good as possible towards the Earth magnetic field to reduce beam deviation from the optical axis. The object distance will be much longer (about 12 m is planned instead of the present 6 m), and the object slits will be placed before the switcher magnet, thus slit edge scattering will be bent away.

Beam brightness measurements

For the brightness measurements we used the object and collimator slits made by Oxford Microbeams Ltd. The Y:X collimator ratio was 1:2, as we concluded from the WinTRAX calculations. The measurements were performed using several object and collimator combinations. The beam current was measured using a home-made mini Faraday-cup [4], with secondary electron suppression.

The measured beam brightness of the 358 ionsource and 2 MV Tandetron is: **0.75 Amp rad^{-2} m^{-2} eV^{-1}**

In Magurele (IFIN-HH, Romania) the specifications were: 0.6 guaranteed, 2 expected [5]. Their measured brightness is 2.5 Amp rad-2 m-2 eV-1 [6].

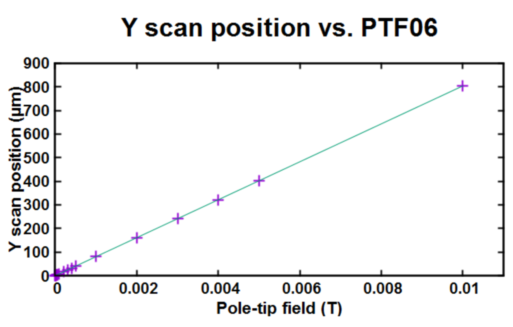
Brightness specifications of the Multicusp source [5]:

guaranteed	**8**	**Amp rad^{-2} m^{-2} eV^{-1}**
expected	**16**	**Amp rad^{-2} m^{-2} eV^{-1}**

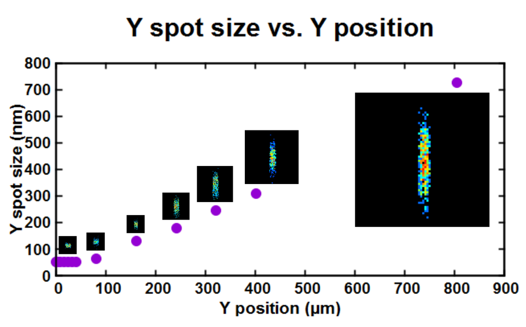
So we can expect x5 more current with the same slits using the planned very long object distance!

WinTRAX simulations

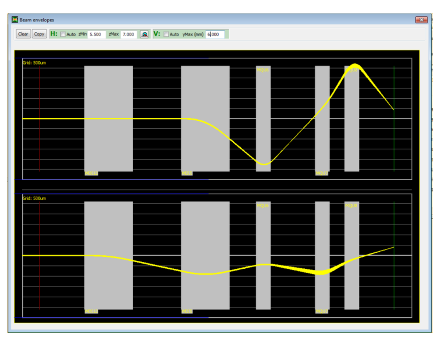
Various calculations have been performed with the WinTRAX software [7].



The beam scanning is perfectly linear up to 800 µm offset.



Up to 16 µm offset there is no degradation of the beam, but larger scans enlarge the spot.



In the Y direction the 'Dog-leg' scanning method is used.

Demagnification ratios were calculated for different working distances. 61 mm is the best compromise. Although 36 mm has larger demagnifications, but it is much more difficult to handle the samples. 61 mm will be also good to match the position of the X-ray detector. Demagnification ratios are also given for 61 mm working distance at two different large object distances.

Object distance: 6 m

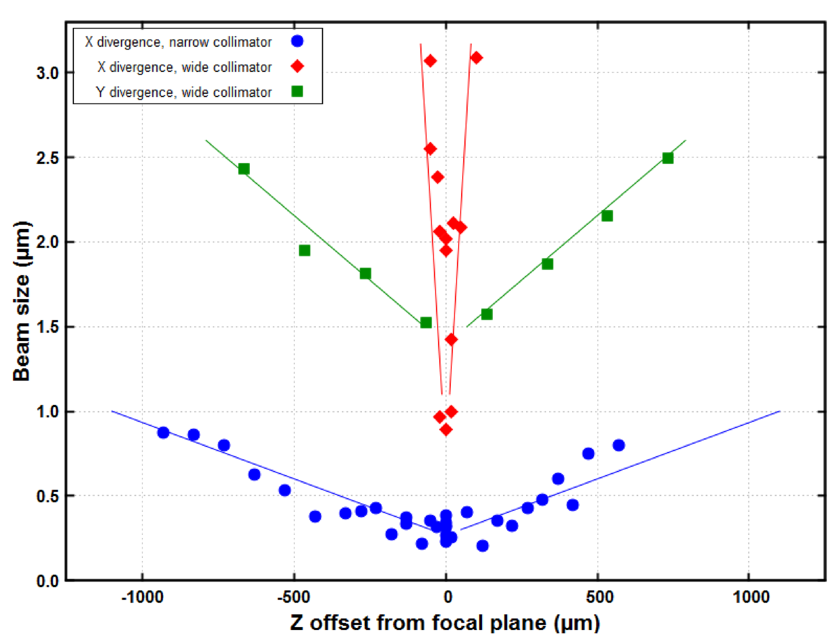
Demagnification	Working Distance (mm)		
	36	61	86
Dx	330	235	180
Dy	63	55	50

Working distance: 61 mm

Demagnification	Object Distance (m)		
	6	**12**	**14**
Dx	235	458	535
Dy	55	107	124

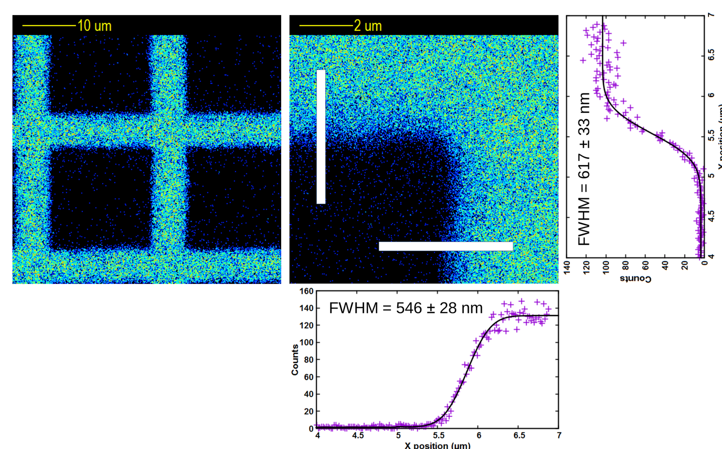
Beam divergence measurements

For the small divergence (small collimator slits) we only measured the X plane divergence, while for larger collimator slits we measured both X and Y. As expected, the accuracy of the target to be in focus of the beam is most sensitive in case of large collimator settings, and only in X. (See red symbols in the graph. The V-shaped lines are shown only to guide the eye.) In this case it is necessary to position the target into the beam focus with an accuracy of ~20 µm. This can be done easily, because in the microscope we can see that ~2 µm movement changes the optical image focus.



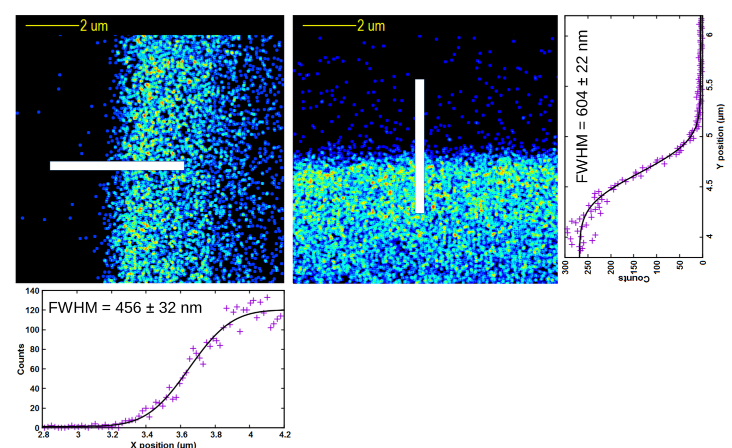
Beam size measurements

Cu grid 1000 mesh (off-axis STIM)



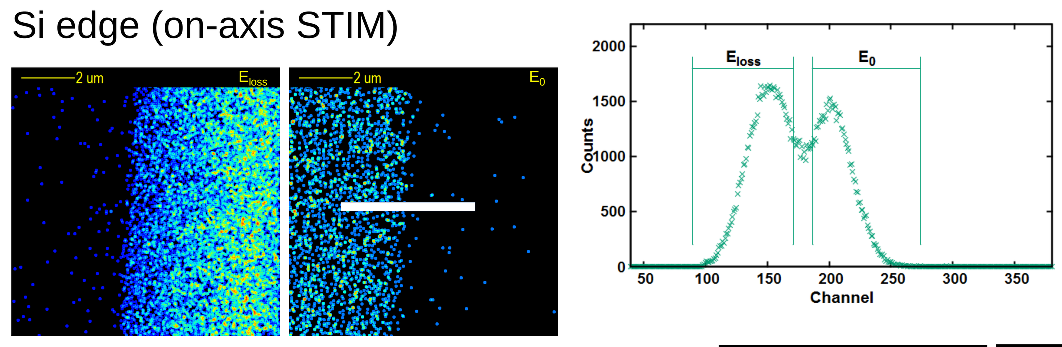
The Cu grid edge definition is not good enough for measuring ~100 nm spot sizes. So, we only use this grid for scan size calibration.

Si edge (off-axis STIM)

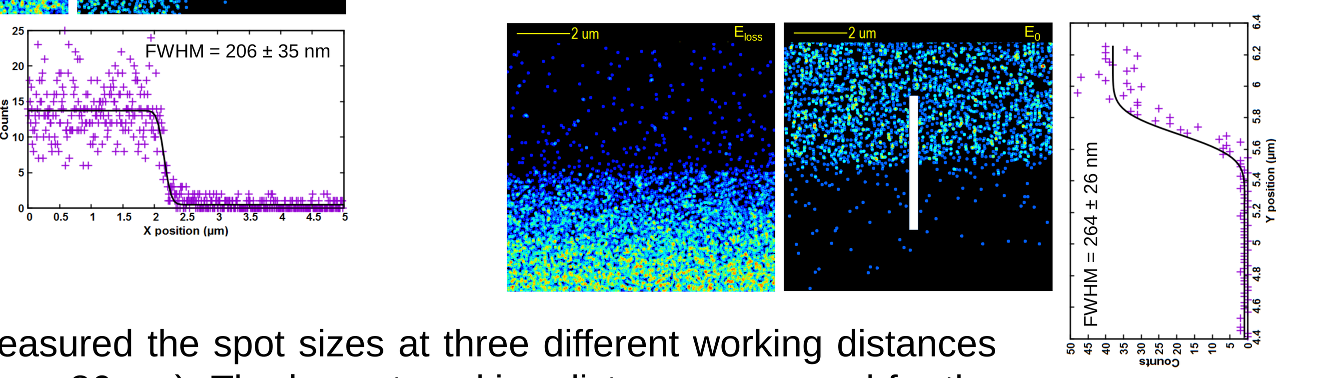


The edge of a freshly broken Si crystal is suitable, because the edge definition can be assumed to be atomic.

Si edge (on-axis STIM)



The beam scattered on the Si edge suffers energy loss. The unscattered beam is shown as E_0, i.e. incoming beam energy.



We have measured the spot sizes at three different working distances (36mm, 61mm, 86mm). The largest working distance was used for the initial beam tuning into the target chamber, and the quadrupole lens alignment. The smallest working distance did not require finer tuning in X and Y, only a very small amount of rotation misalignment was corrected. The spot sizes were measured at three different beam energies. Based on the required quadrupole currents for the used working distances, we have also calculated that He, C and O beams will be probably focusable.

Conclusions

The new nanoprobe setup at MTA Atomki is completed at its temporary location, and performing as planned. It is expected that at the final position the performance will be significantly better than now.

References:

[1] Rajta et al, NIMA 880 (2018) 125

[2] Gyürky et al, PRC 95 (2017) 035805

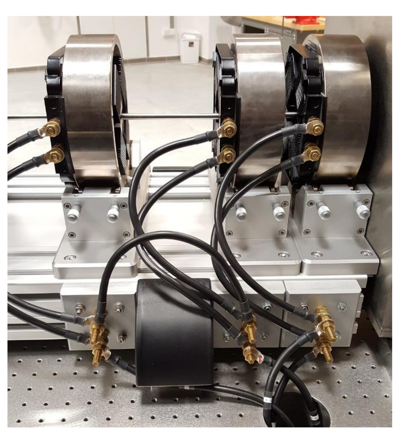
[3] Krasznahorkay et al, EPJ Web Conf. 142 (2017) 01019

[4] Bartha et al, NIMB 161-163 (2000) 339

[5] www.highvolteng.com

[6] Burducea et al, NIMB 359 (2015) 12

[7] www.microbeams.co.uk



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