# A POWER SWITCHING IONIZATION PROFILE MONITOR (3D-IPM).

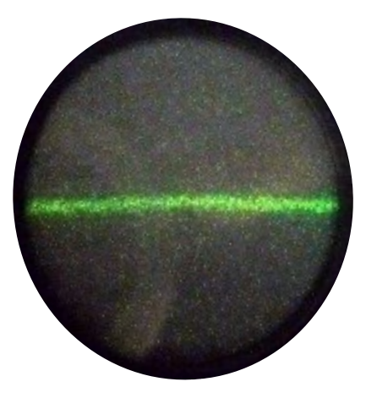
**H. Breede,**
**L. V. Vu, M. Sachwitz, H. Grabosch,**
**DESY, Zeuthen, Germany**

## Introduction

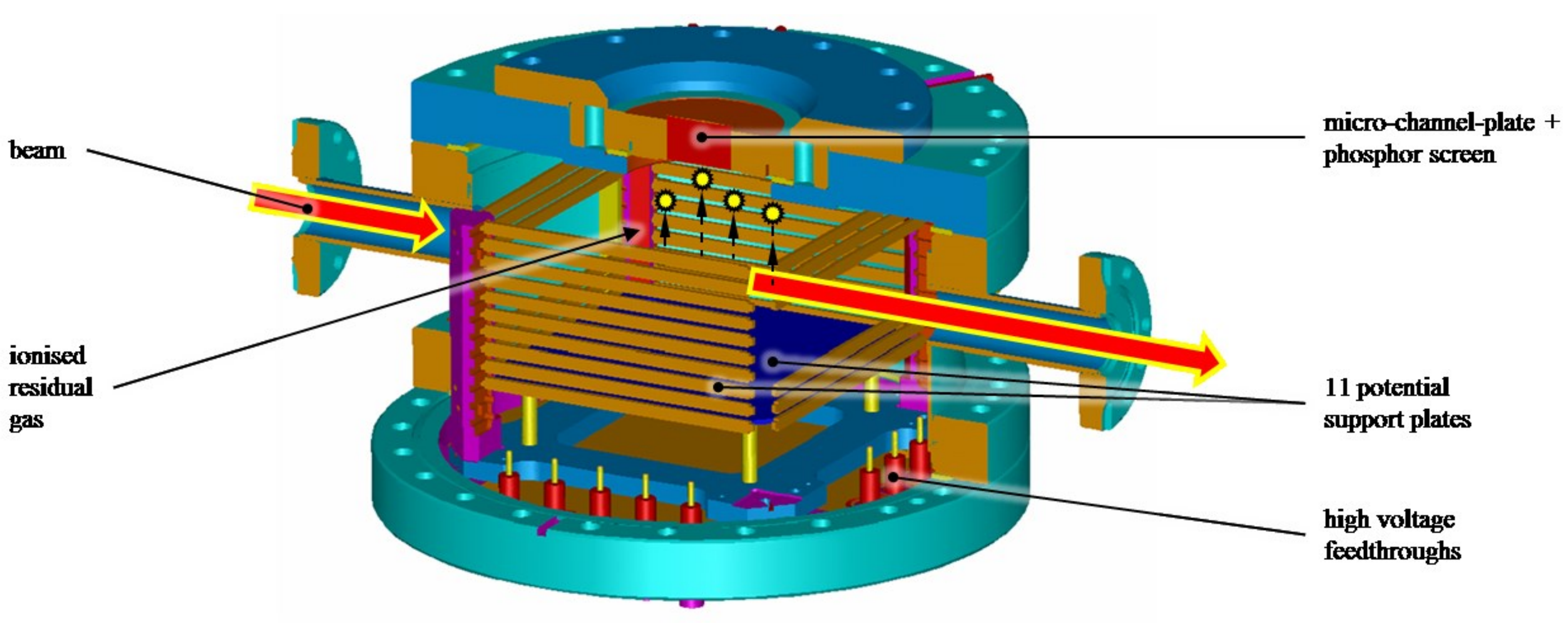
To ensure smooth operation of the free electron laser FLASH at DESY Hamburg, numerous detectors are necessary for the precise measurement of the electron and laser beam. The great advantage of the here described Ionization Profile Monitor (IPM) is the uninstructive determination of the position and intensity distribution of the laser beam.

### Measuring principle of an Ionizing Projection Monitor (IPM)

The FLASH laser beam has a variable wavelength from 4.1 to 45 nm, and is located in an Ultra High Vacuum (UHV) beam pipe. Despite the vacuum a certain amount of residual gases still remain. If the laser beam hits a residual gas atom, it becomes ionized and electrons and ions are created. By means of a homogeneous electric field, these electrons and ions can be accelerated in a rectilinear way towards a micro-channel plate (MCP). Here, the impacting particles create an avalanche of secondary electrons in the micro tubes of the MCP, and are visualized on the phosphor-screen. This results in an image of the intensity-dependent laser beam profile (see Figure below).



## Conventional Set Up



approx. 400 x 300 x 200 mm for 2D-measuring

The figure upper shows an IPM module for the laser beam position measurement as implemented in FLASH. Problems and disadvantages of this design are the following

- **large size**
- **2 detectors needed** for monitoring horizontal and vertical parameters
- **costly high voltage** feedthroughs ($U_{max}$ = 3'000 V)
- **uncertainty** concerning the homogeneity **of** the **electric field**
- can't take a look on the bunches, **temporal resolution: 1 ms**

## New Design

- **unification** of the horizontal an vertical monitors **by alternating** the **electric field**
- **shielding** of the area of interest to ensure an optimal homogenous electric field
- **compact design** permits **low voltage** (U_max = 800 V)
- low voltage consequences
  - **easier to handle & manufacture**
  - **easier to switch**
  - **cost effective**
- **5** potential-support-**planes**
- **simulation** & analysis **of electric field &** resulting **particle trajectories** with FEM
- FEM offers
  - **optimization of** the **voltage** values **for** linear particle trajectories and **accurate beam imaging**
  - **recursive determination of** the **beam positon**
- **temporal resolution on the order of 100 ns** by using a fast resolving screen

## Design Description

- Unification of the separate horizontal and vertical monitors with an alternating homogeneous electric field.
- A special cage protects the area of interest from electrical stray fields to ensure an optimal homogenous electric field.
- Decreasing the size of the device to 203 mm x 218 mm x 246 mm while at the same time reducing the applied electrical voltage with the appropriate low cost feedthroughs.
- With the Finite Element Method (FEM) a comparison of different residual gas particles is performed concerning their trajectories in the electric field.
- This procedure offers an optimization of the design by simulating the trajectory of the particles in the electrical field with the deflection caused by the inhomogeneity of the field. Varying the CAD monitor model helps finding out the best possible determination of the laser beam position.

### Device Specifications

- 2x grid bonded in a ring washer by Precision Eforming
  - MN49 bonded to 20mm SS Frame
- a pulse generator for generating an alternating orthogonal electrical field
  - A-GBS-MATRIXPULS 1x25 by GBS ELEKTRONIK GmbH
  - with a frequency of 100 kHz [8]
- 2x micro-channel-plate and P47 phosphor screen assembly by HAMAMATSU
  - F2222-27P227 [4]
  - Emission range 375 - 600 nm

### Optical Limits of Measurements

The chosen parts leads to a signal intensity of 48,11% because of unavoidable transmission and response losses.
The lower table shows the relative spectral emission, transmission and spectral response of the chosen parts and the optical system.

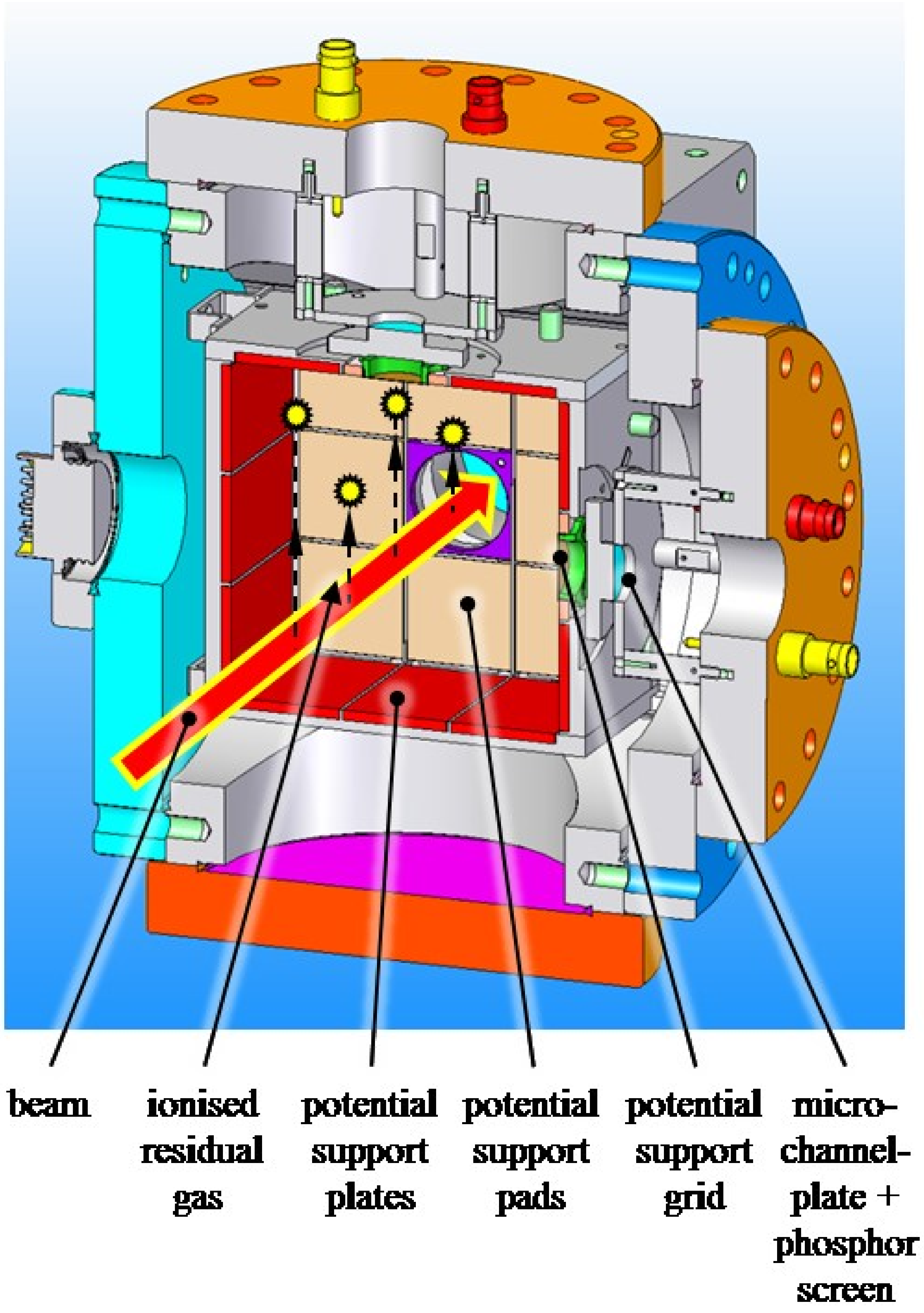
| | Phosphor-screen Hamamatsu F2222-27P227 | Inspection Glass Vacom VPCF40DUVQ-L-BBAR2 | Objektive Schneider Kreuznach Makro-Symmar 5.8/80 | Camera Basler acA2500-14gm | relative Light-absorption with Makro-Symmar and AcA2500-14gm |
|---|---|---|---|---|---|
| wave-lengh in nm | rel. spectral emission in 1 | rel. transmission in 1 | rel. transmission in 1 | rel. spectral response in 1 | rel. trans-mission of light relating 25 nm |
| 350 | 0,00 | 0,90 | 0,00 | 0,00 | 0,00 |
| 375 | 0,10 | 0,90 | 0,66 | 0,00 | 0,00 |
| 400 | 0,70 | 0,90 | 0,85 | 0,48 | 6,43 |
| 425 | 0,95 | 0,90 | 0,95 | 0,56 | 11,37 |
| 450 | 0,95 | 0,90 | 0,95 | 0,60 | 12,18 |
| 475 | 0,80 | 0,90 | 0,96 | 0,61 | 10,54 |
| 500 | 0,70 | 0,90 | 0,97 | 0,61 | 9,32 |
| 525 | 0,55 | 0,90 | 0,97 | 0,60 | 7,20 |
| 550 | 0,35 | 0,90 | 0,97 | 0,58 | 4,43 |
| 575 | 0,22 | 0,90 | 0,97 | 0,55 | 2,64 |
| 600 | 0,12 | 0,90 | 0,97 | 0,50 | 1,31 |

**Relative signal intensity of the beam photo relating to the sender: 48,11%**

### Temporal Resolution

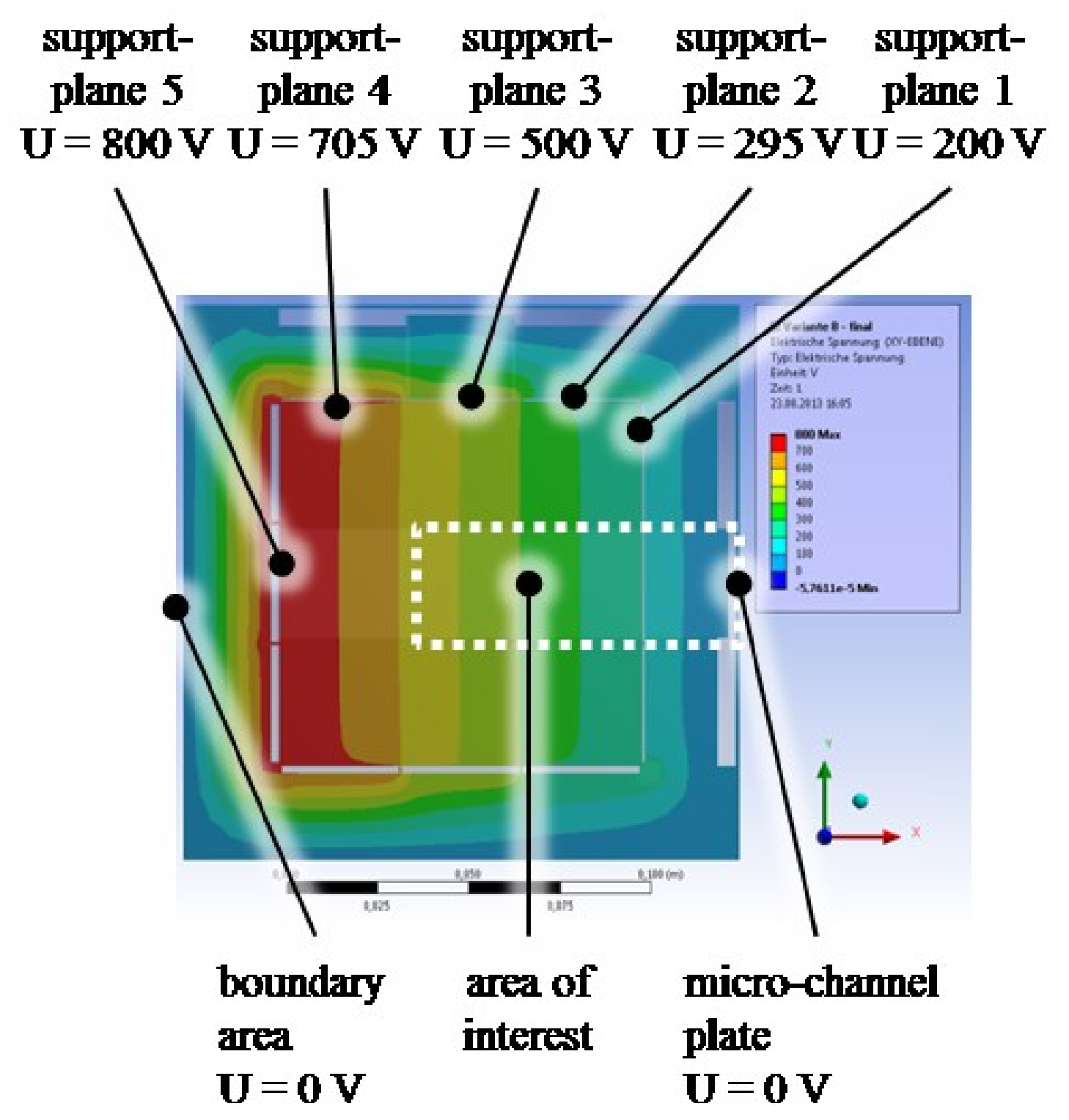
The selected camera offers a shutter frequency of 12 pictures. This means that 12 times per second the position and the profile of the beam can be measured. The time between the horizontal and the vertical measurements of the profile is limited to the time of fly of the ions and the intensity of light of the screen. A $N^{2+}$ Ion needs 1 µs from the middle of the assembly to the screen. The intensity of the light is unknown and it has to be tested. Certainly, the shutter time is much longer than the time of fly. But a shutter time of 400 µs is realistic, resulting in a complete profile measurement of the beam every Millisecond.

## New Design



203 x 218 x 246 mm mm for 3D-measuring

## FEM ANALYSIS



Simulation studies performed with the ANSYS 14.5 workbench module package proved the potential ratios, as can be seen in the upper Figure, to be optimal for a homogeneous electric field and hence for a straight flight of particles. Since the MCP has a diameter of merely 20 mm, only in the marked "area of interest" the electric field must be homogeneous. Also, the expected beam variation in X or Y is below ± 5 mm. Homogeneity in a larger space does not result in a higher spatial resolution.

## Conclusion

The first prototype of a 3D-IPM is currently under construction and will be completed and tested in 2014. Before any test with a toggling electrical field, there will be tests with a rigid field. First practice tests are planned in 2015 at FLASH in DESY Hamburg site.

The special cage is visualized in the Figure below.