Application of Diamond and Sapphire Sensors at FLASH: First Results

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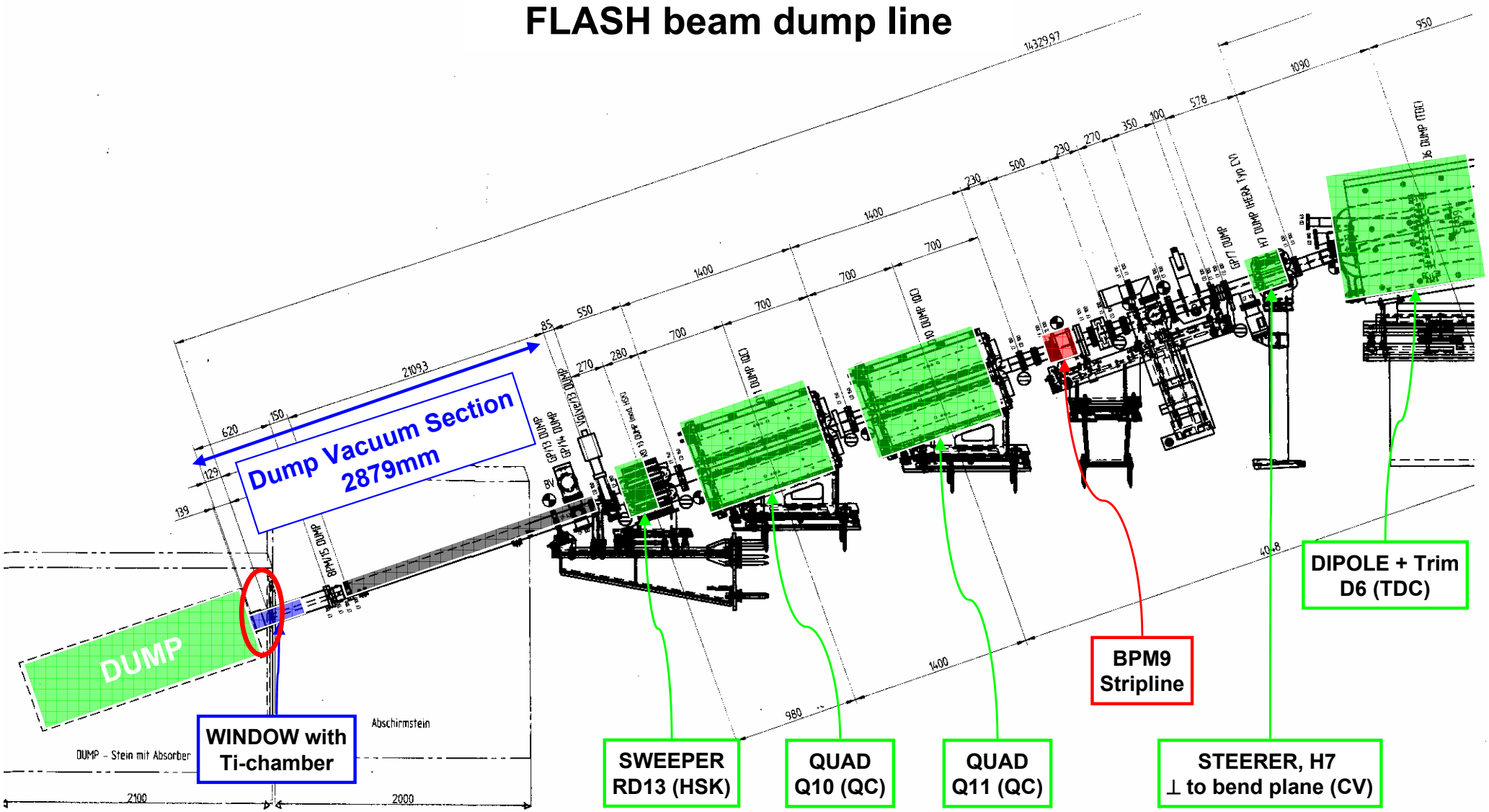
Overview

- Beam Halo Monitor system
  - Position
  - Sensors
  - System description
- Simulation
- 9 mA run
  - Results
- Additional investigation of the sensors
- Summary

Beam Halo Monitor system

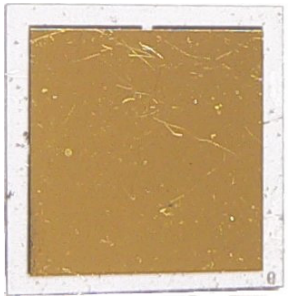
Position

FLASH beam dump line

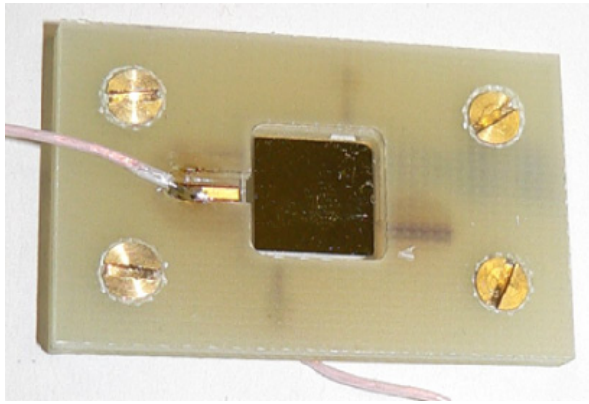


Sensors

1. pCVD diamond produced by Diamond Detectors Ltd.
   Dimensions 10×10×0.3 mm^3
   Metallization: 50/50/200 nm Ti/Pt/Au



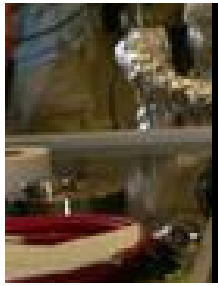
2. Single crystal sapphire (Al_2O_3) produced by CRYSTAL GmbH
   Dimensions 10×10×0.5 mm^3
   Metallization: 50/50/200 nm Al/Ti/Au



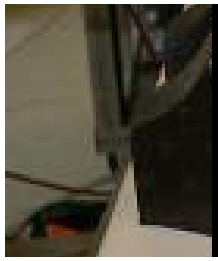
The sensors are operated like solid-state ionization chambers

System description

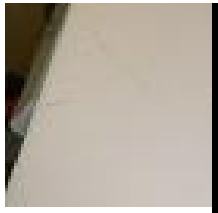
UR (diamond #13)

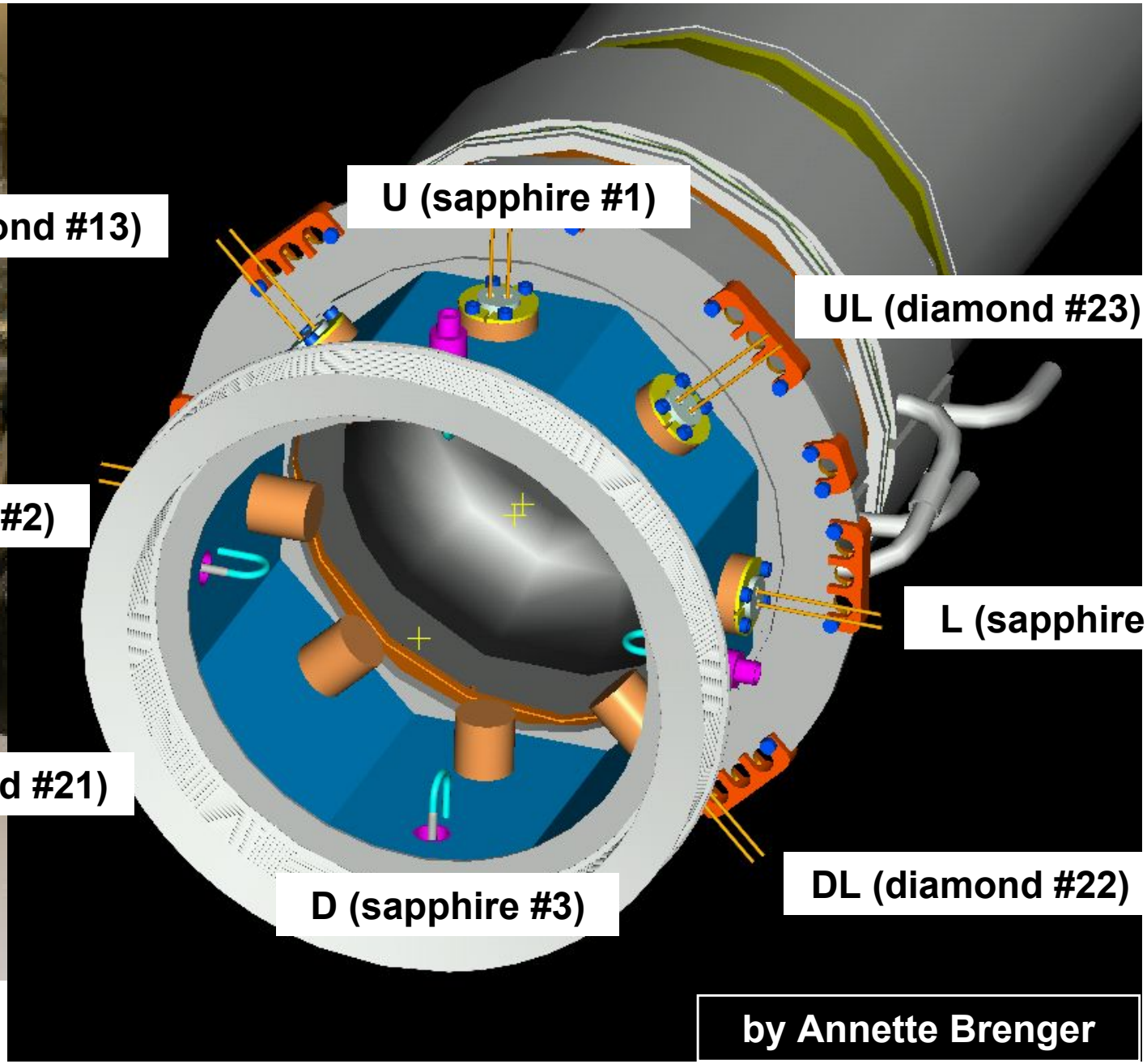


R (sapphire #2)

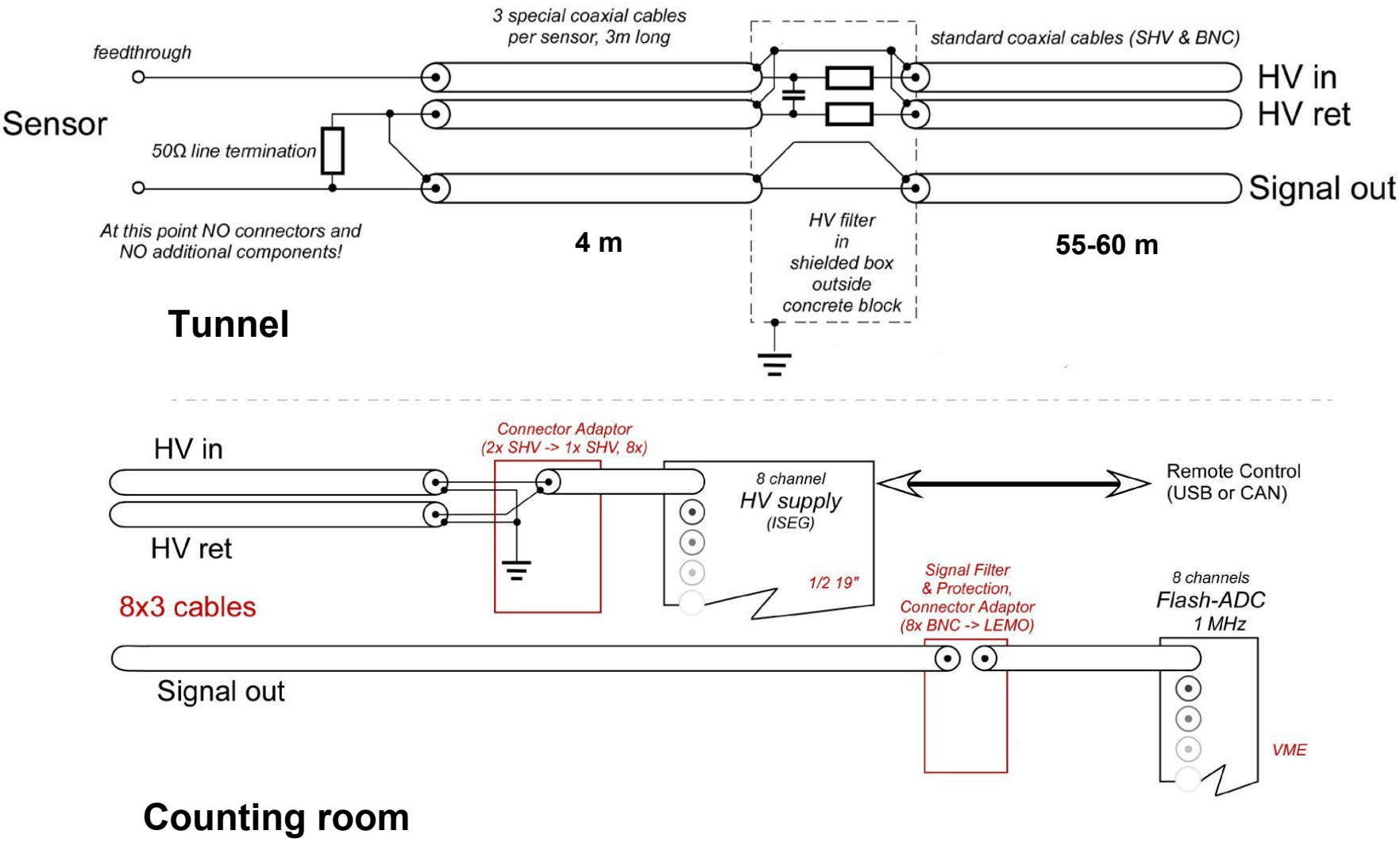


DR (diamond #21)





Bias voltage feed and signal readout

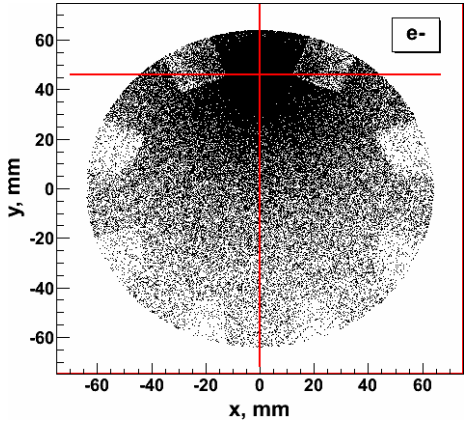


Simulation

by Andriy Ushakov

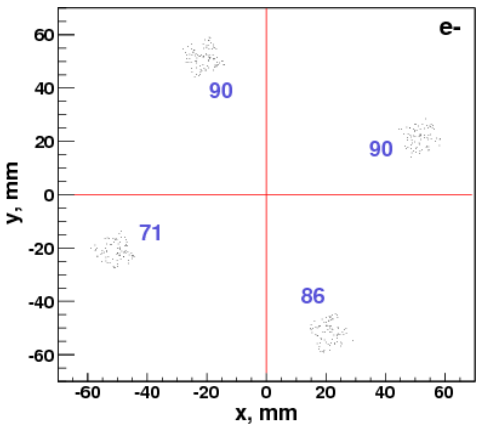
"Pencil-like" beam down to the exit window
10^6 primary electrons

46 mm offset

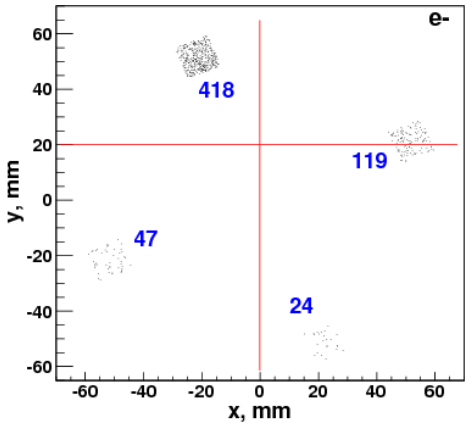


Electron distribution in the sensor plane

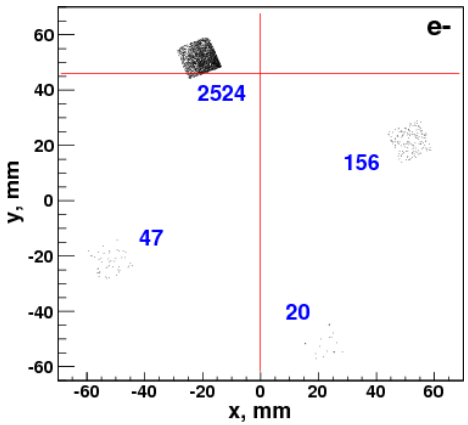
Number of the electrons crossing the sensors



Centered



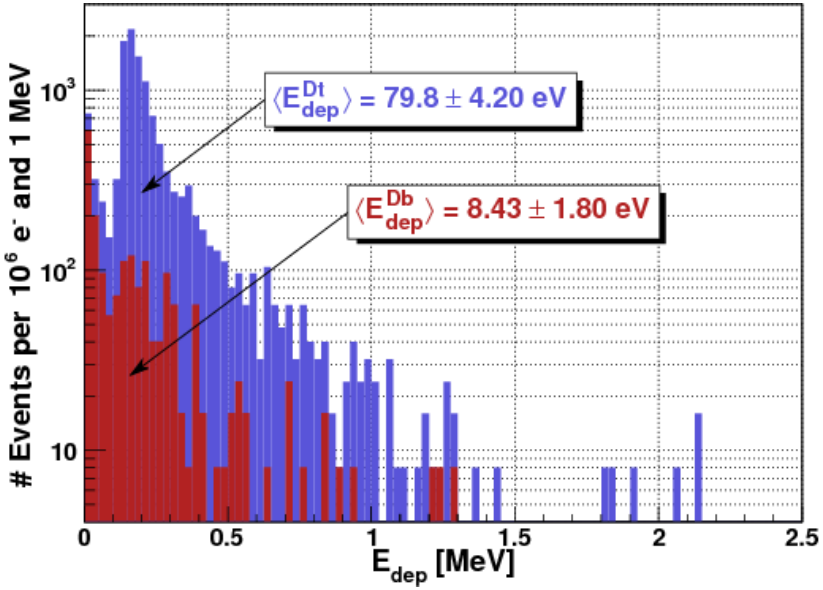
20 mm offset



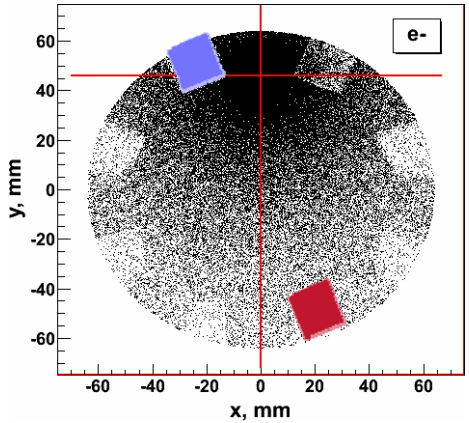
46 mm offset

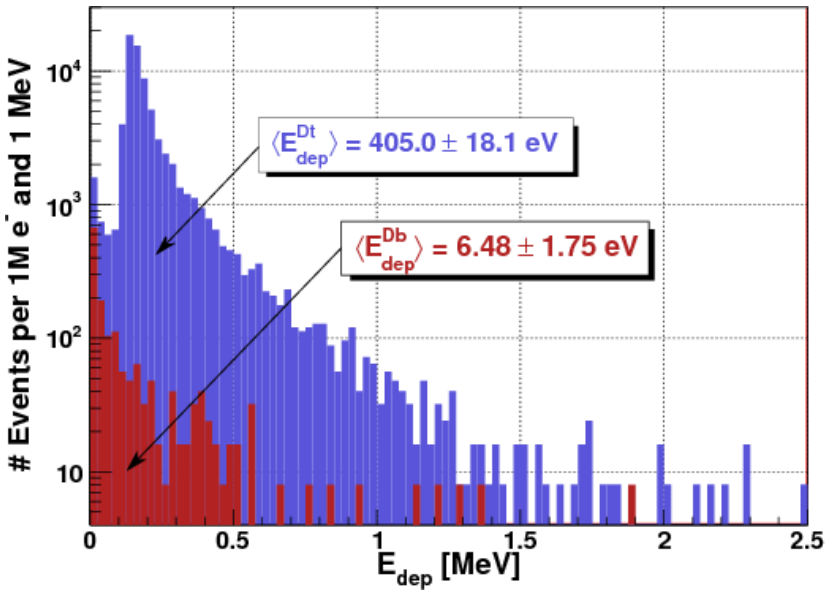
http://flash.desy.de/sites/site_vuvfel/content/e403/e1642/e71562/e71563/infoboxContent71573/TESLA-FEL2010-02.pdf

Energy deposition for the top and bottom sensors



20 mm offset





46 mm offset

9 mA run

A test run in order to achieve the new regime of the machine:

Energy	**1 GeV**
Bunch repetition rate	**3 MHz**
Bunch charge	**3 nC**
Full bunch train	**800 μs**

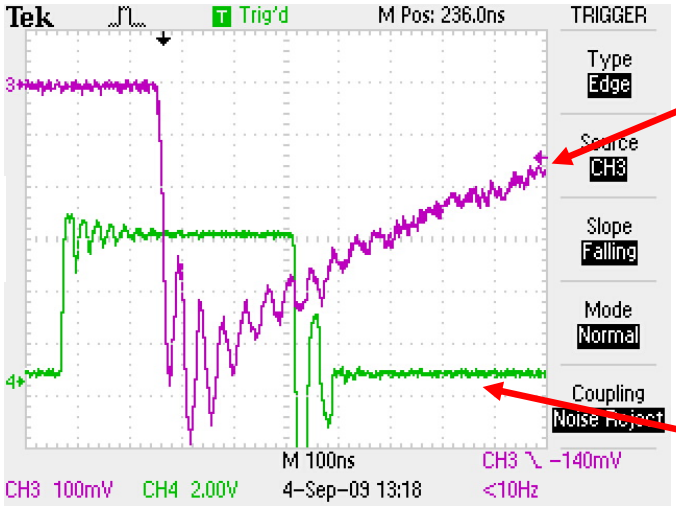
The BHM functioning proof in two stages:

1. **Beam steering period (20 min) with single bunch & increased sweeping radius**

2. **Normal multi-bunch machine operation**

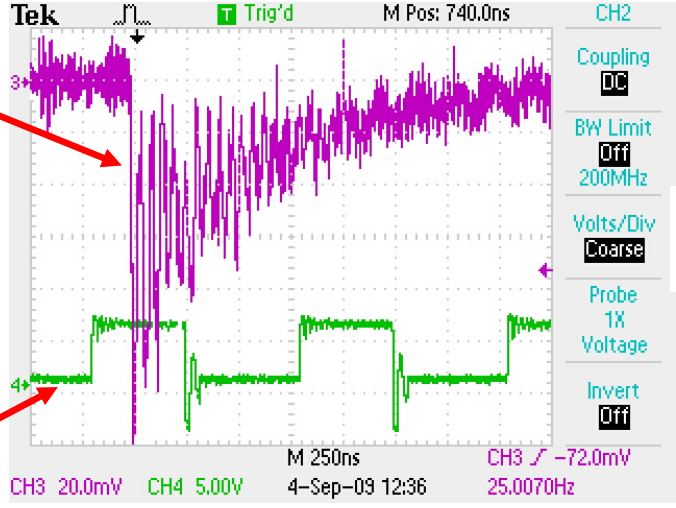
Results

100 mV/div
100 ns/div



Signal

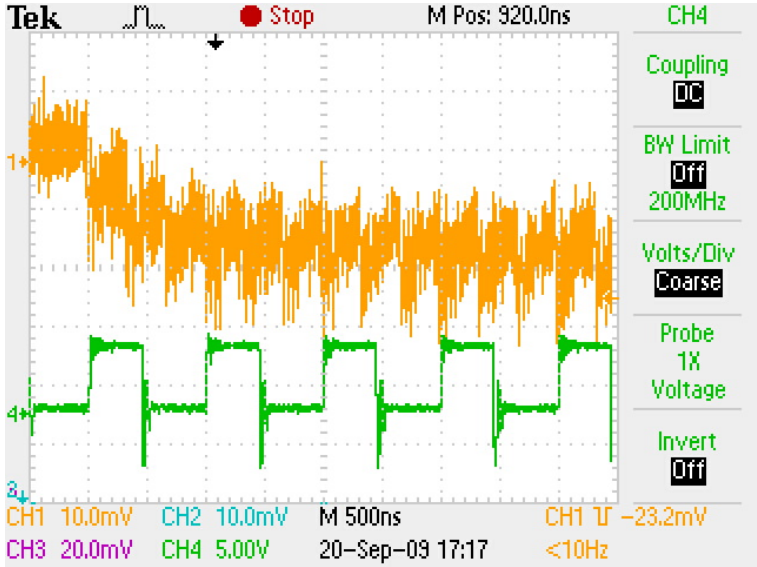
Clock



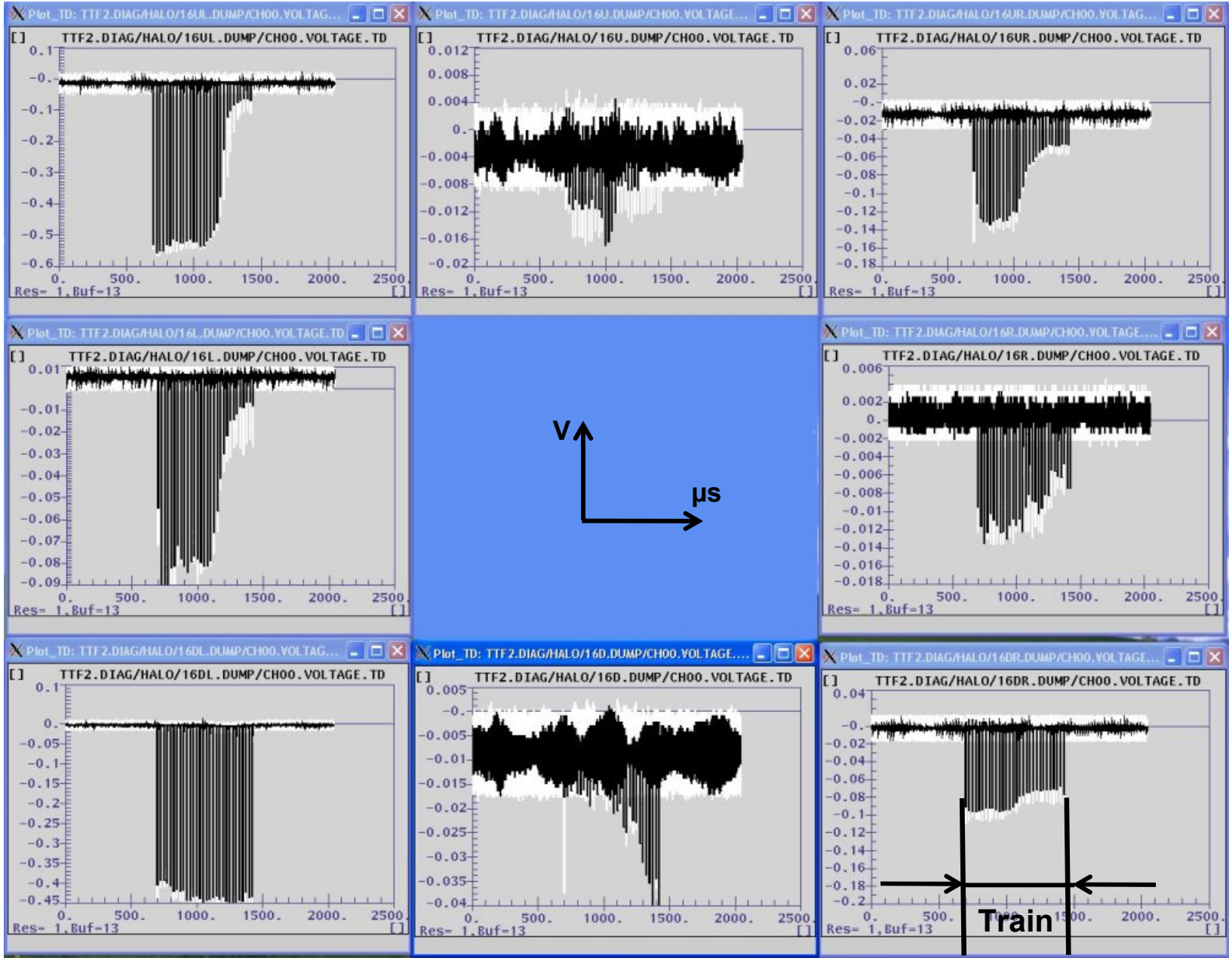
20 mV/div
250 ns/div

Analog signals from a diamond (left) and a sapphire (right) as a response to a single bunch
No amplification

10 mV/div
500 ns/div

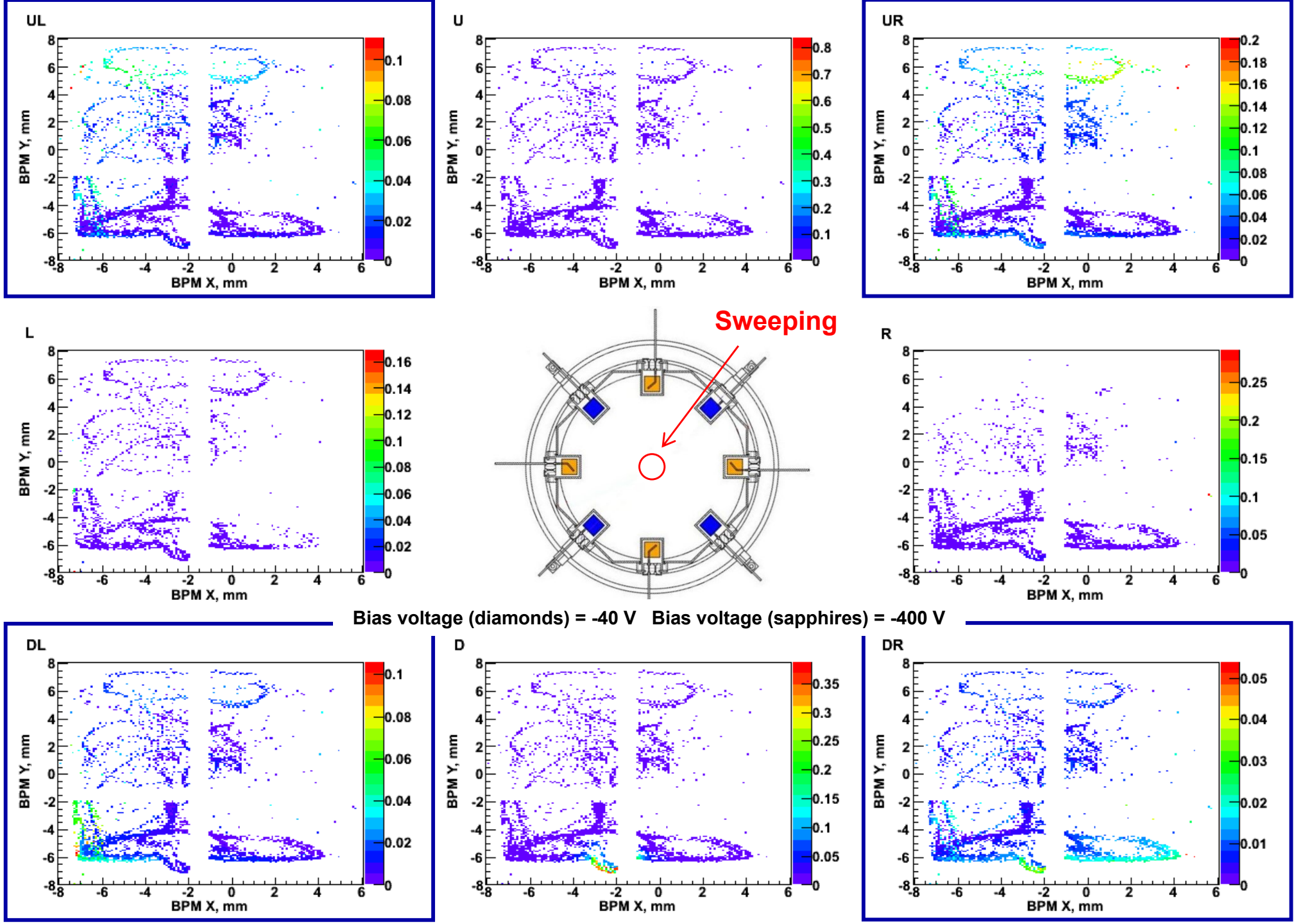


Analog signal, response to many bunches
Bunch repetition rate 3 MHz

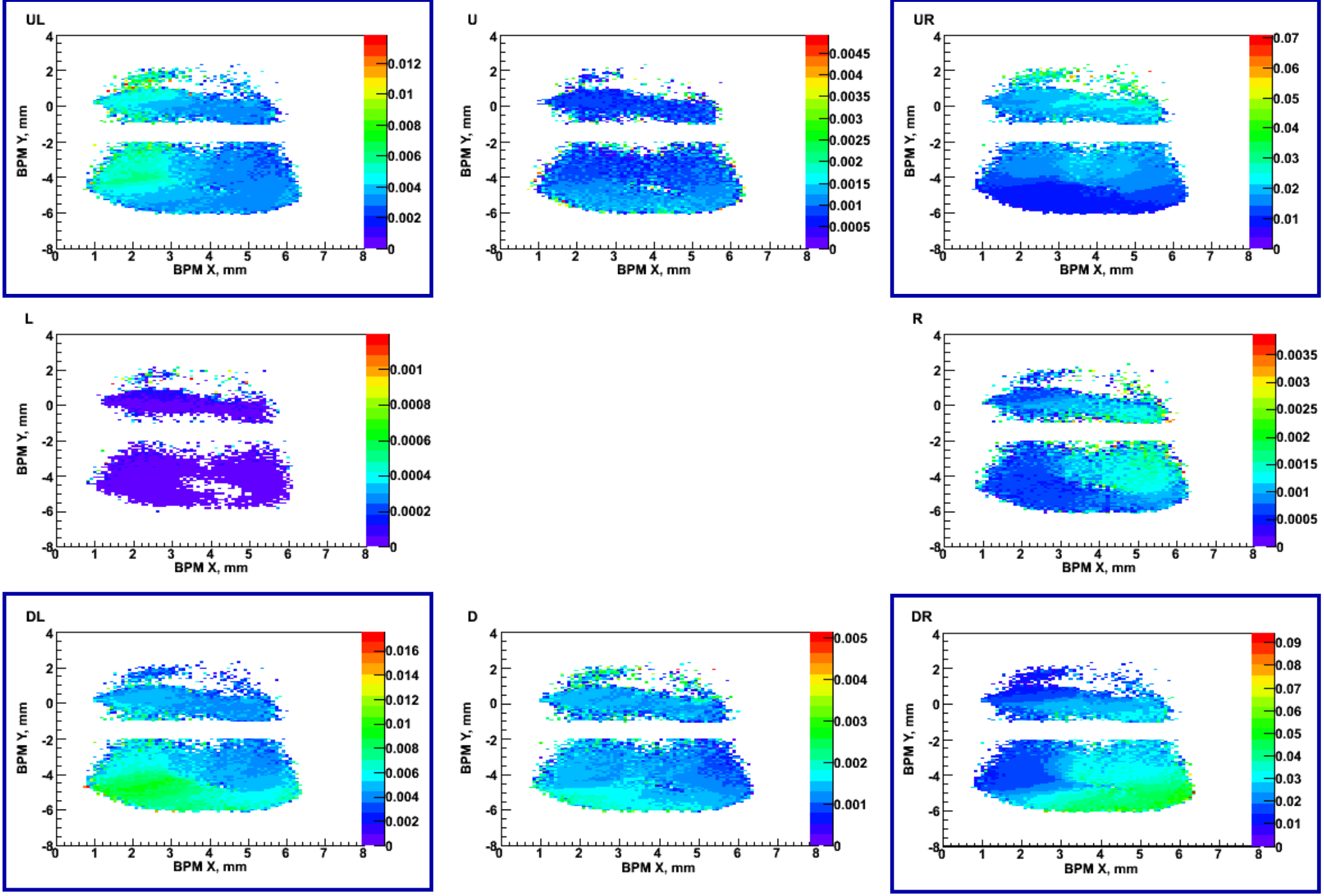


Bias voltage (diamonds) = -100 V Bias voltage (sapphires) = -200 V

Signals from the BHM sensors (digital, 1 train of 30 bunches)



Average signal size (V) (per 1 nC) as a function of beam position (by "in-air" BPM). Beam steering period of ~ 20 min, increased sweeping

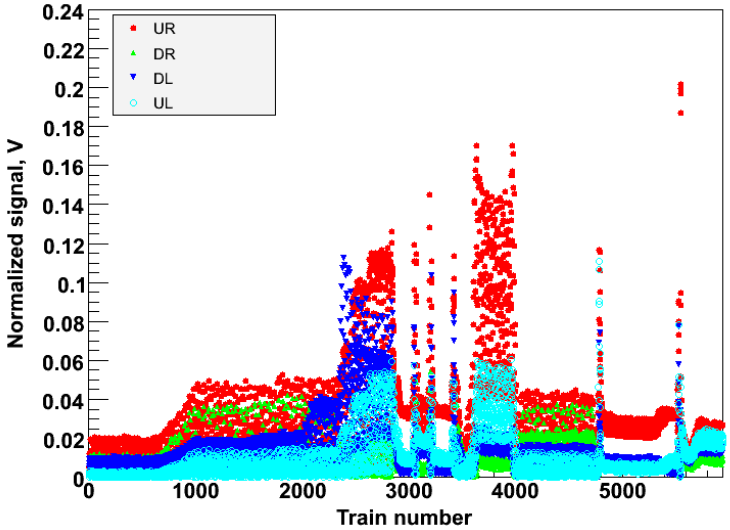


Bias voltage (diamonds) = -40 V Bias voltage (sapphires) = -400 V

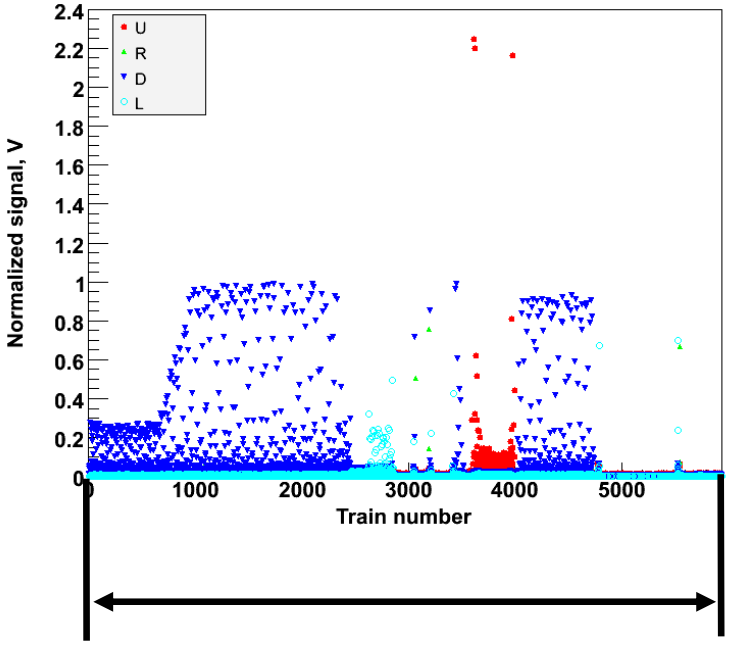
Average signal size (V) (per 1 nC) as a function of beam position (by "in-air" BPM). Normal multi-bunch machine operation

Signals over time during the beam steering period

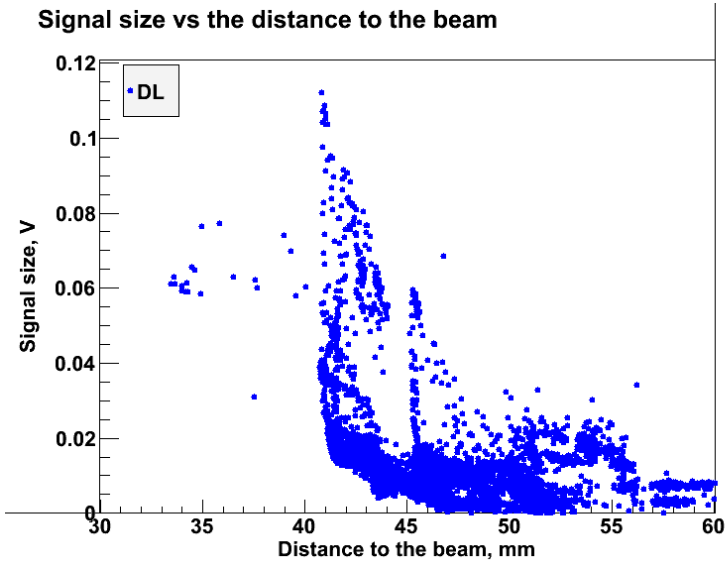
Signals from the BHM sensors (diamonds)

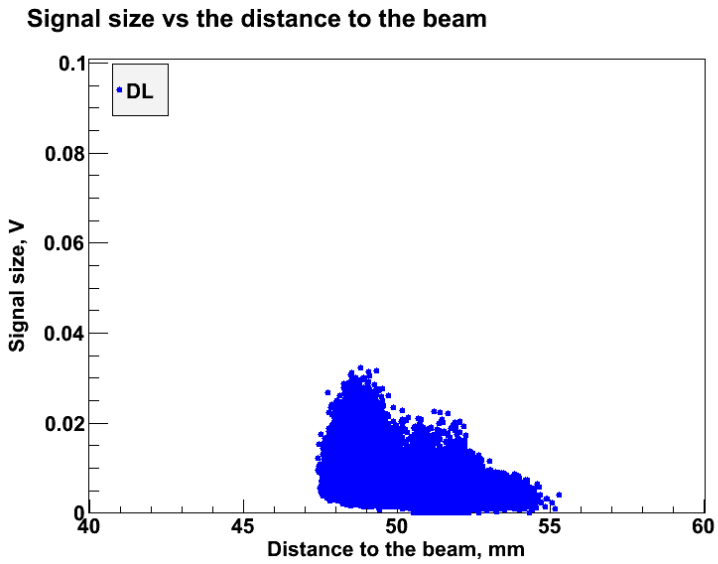


Signals from the BHM sensors (sapphires)

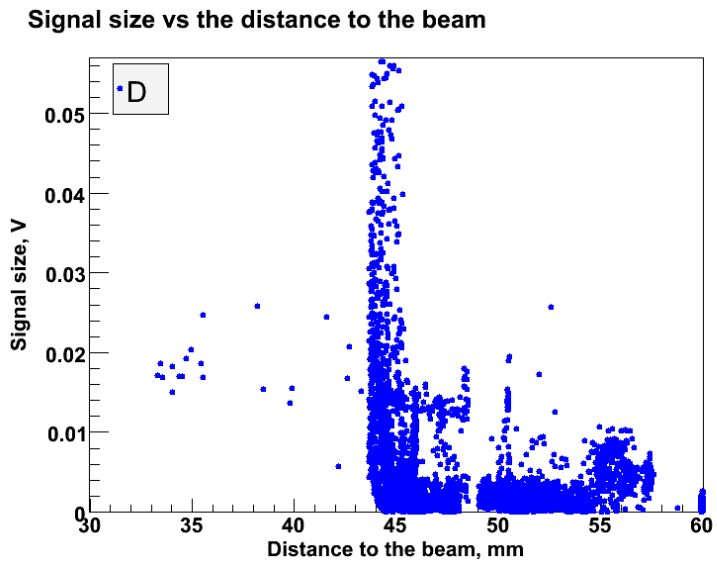


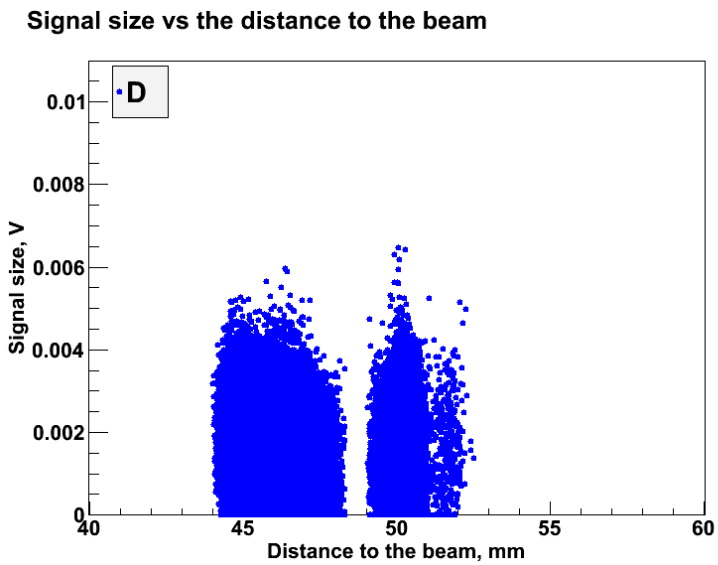
~ 20 min





Diamond

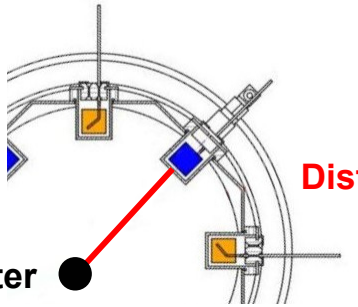




Sapphire

Beam steering period

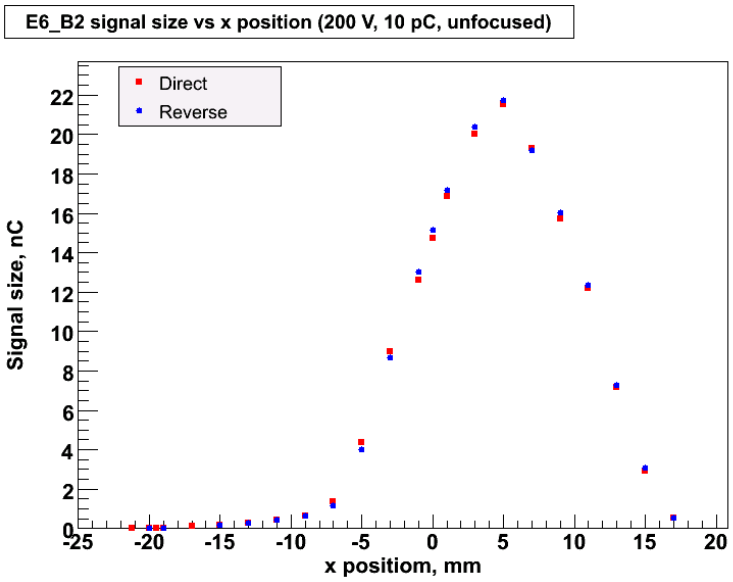
Normal machine operation



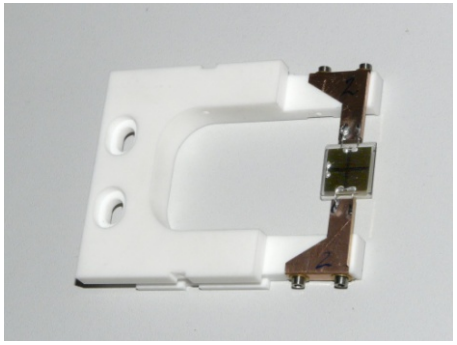
Distance to the beam

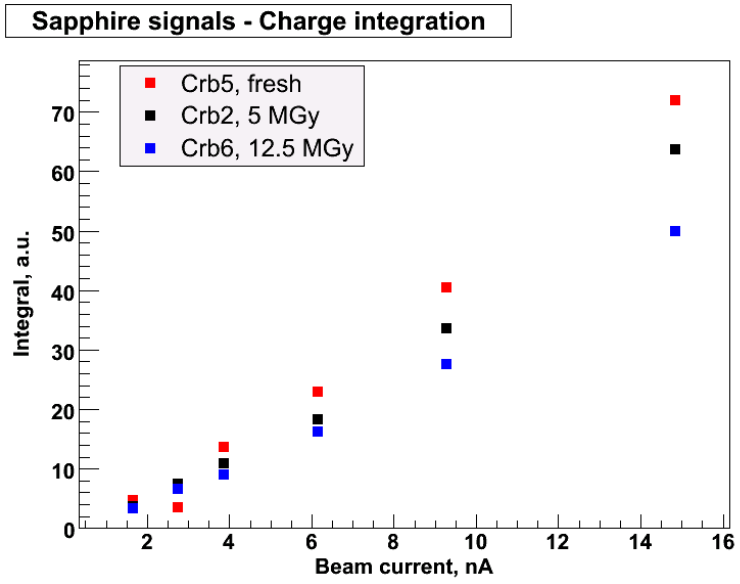
Beam center

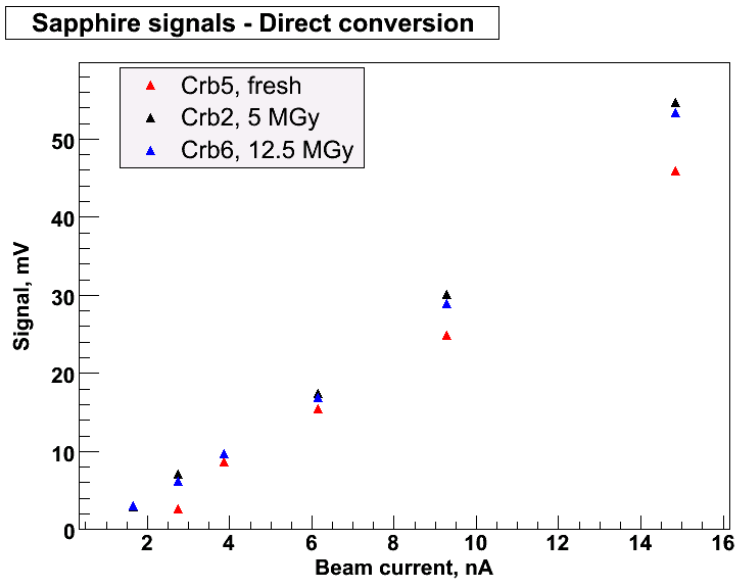
Additional investigation of the sensors



PITZ facility (Zeuthen)
14 MeV electrons
Moving a diamond sensor through the beam
Charge integration







ELBE facility (FZD Rossendorf)
20 MeV electrons
The sensor is in the center of the beam

Signal observation without shaping/amplification

Summary

1. 4 pCVD diamond sensors and 4 artificial sapphire sensors are used for the Beam Halo Monitor system at FLASH

2. All sensors were operational during the test run

3. The sensor response depends on the beam position

4. The sapphires are less sensitive than diamond enhancing the dynamic range

5. The signal amplitude from sapphires does not decrease with accumulated dose

6. The sensors survived bunch charges up to 1 nC

7. The long term performance of the sensors will be investigated

8. The system may become a part of the FLASH run control

9. Similar systems might be helpful at other places e.g. XFEL