Results from the test of sFLASH photon diagnostics using the FLASH FEL beam

FLASH beamtime KW 29-30 (23-24 July '09)

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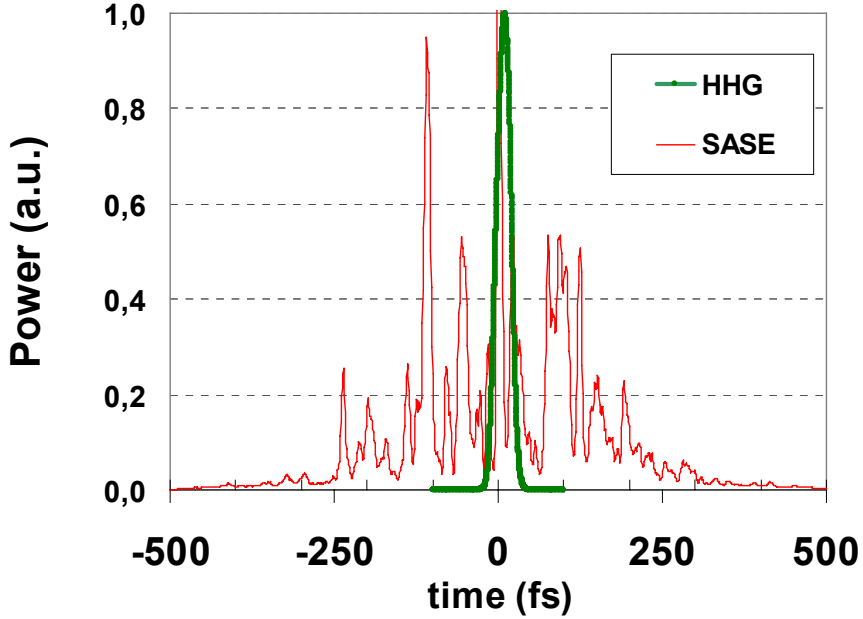
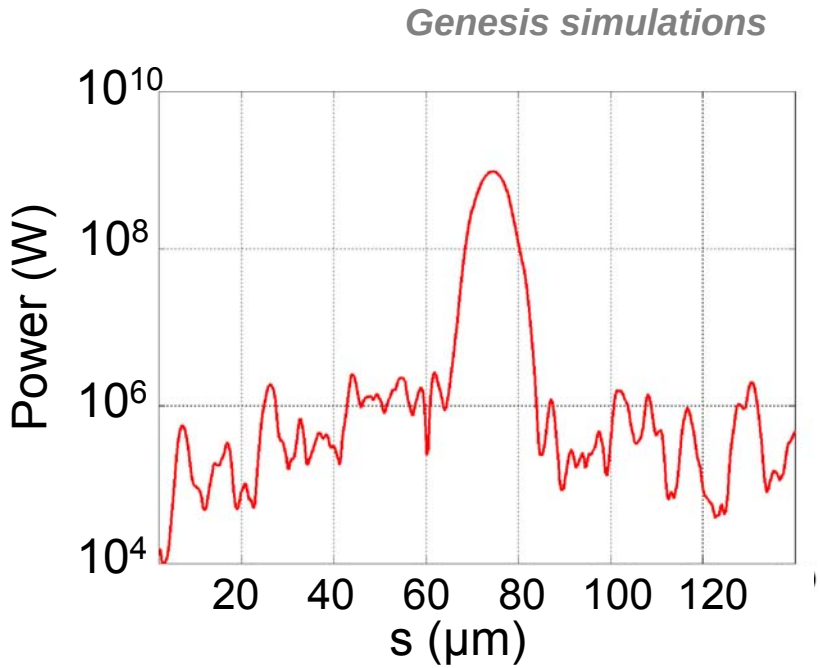
Outlook

- Why seeding?
- sFLASH within FLASH-upgrade`09
- Layout of sFLASH
- Photon diagnostics beamline
- Intensity monitor:
  - simulations and measurements
- Summary and plans

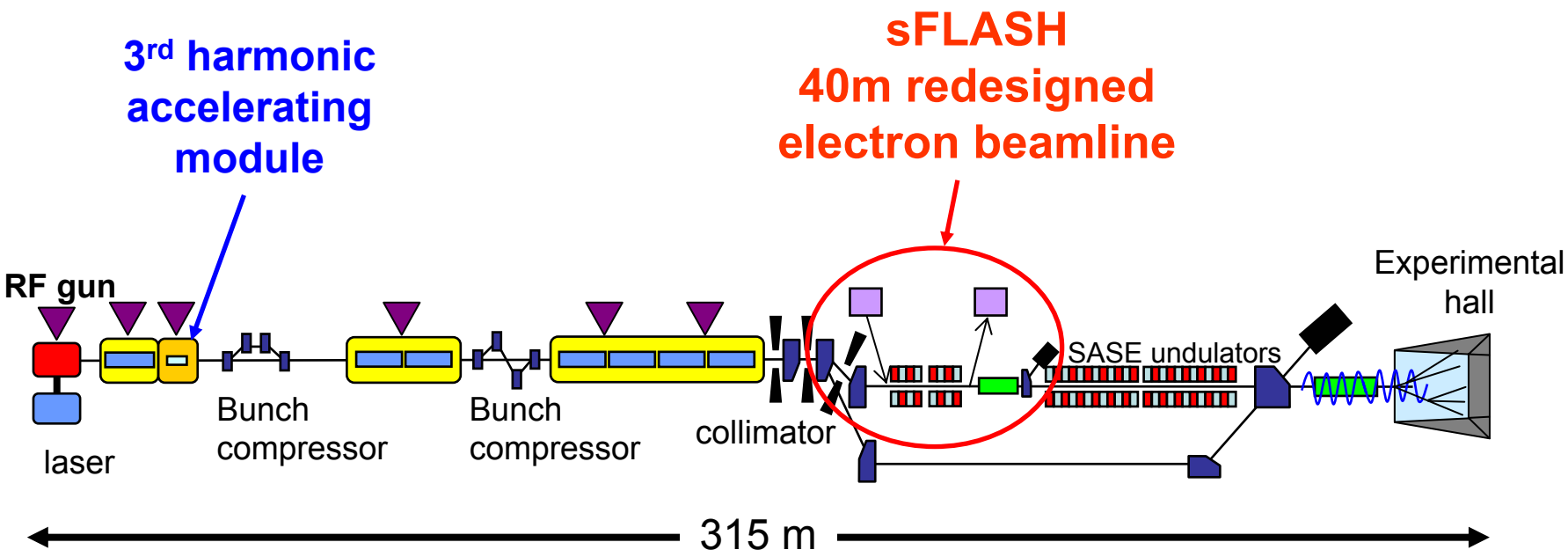
Motivation: why **direct** seeding?





- Longitudinal coherence
- Better intensity stability
- Temporal pulse shape control
- High precision synchronization for pump-probe experiments
- Additional experimental station

FLASH upgrade "for" sFLASH



3.9 GHz RF cavity: 200fs electron bunches, few kA peak current

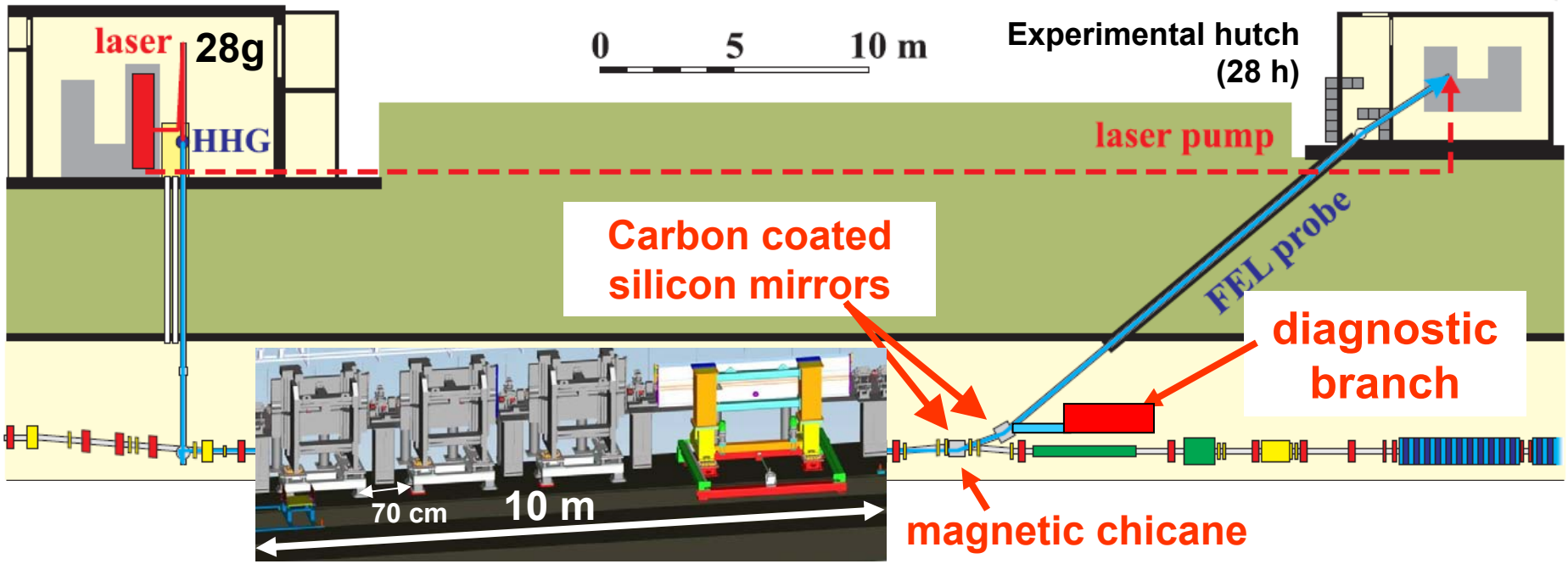
Beamline modifications to the section between the collimator and SASE undulators

sFLASH layout

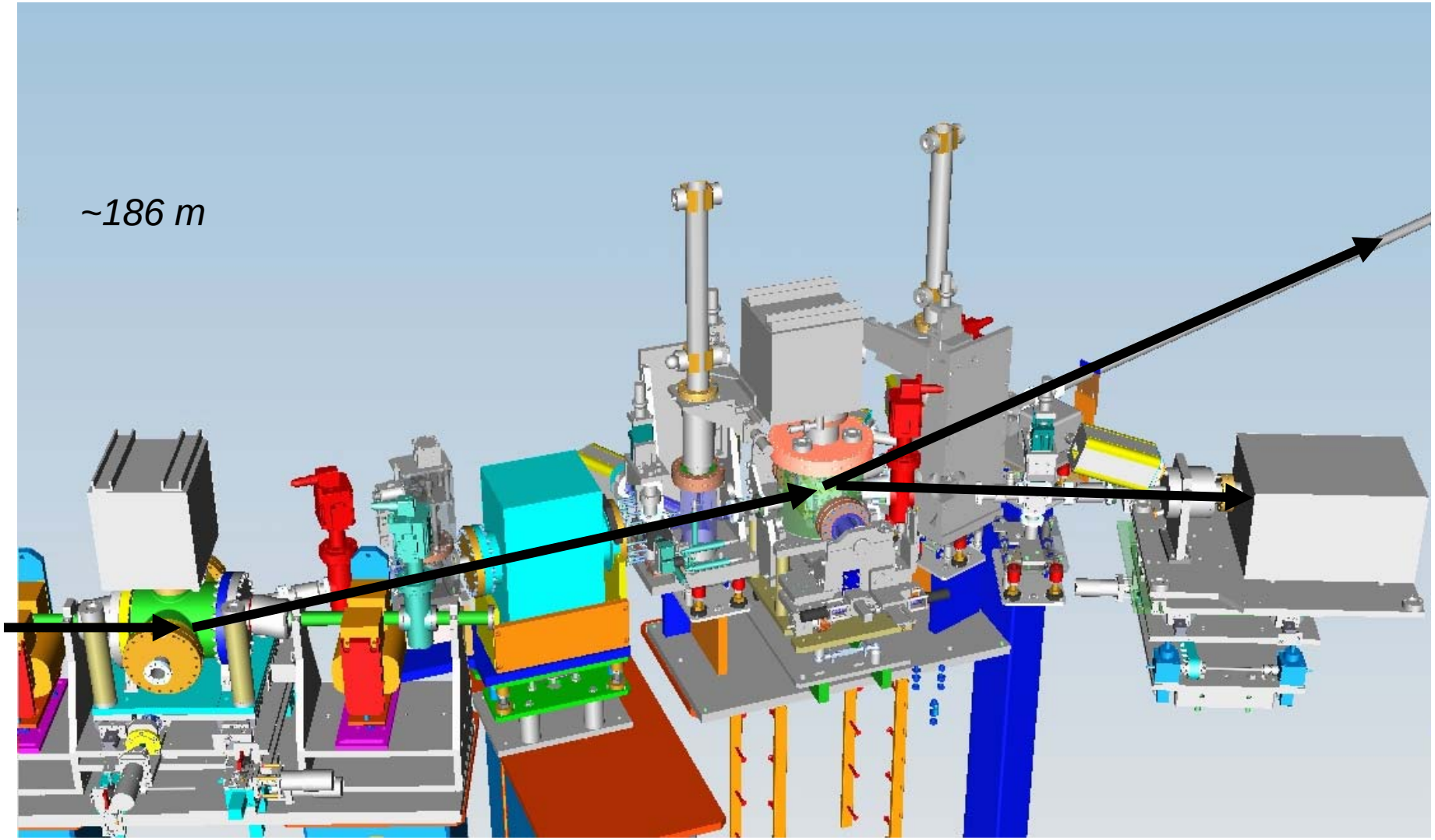
HHG-Laser system

- 35 mJ, 800 nm, 10 Hz, 35 fs (fwhm)
- 5-10 mJ HHG generation on gas target outside the tunnel
- multilayer mirrors at 13 and 30 nm

- 4 variable gap **undulators**:
  - 3 PETRA III (λ_u=31.4 mm, 2 m long)
  - 1 PETRA II (λ_u=33 mm, 4m long)
  - min gap ~ 9 mm
- phase shifters, additional steerers
- **intra-undulator diagnostics**

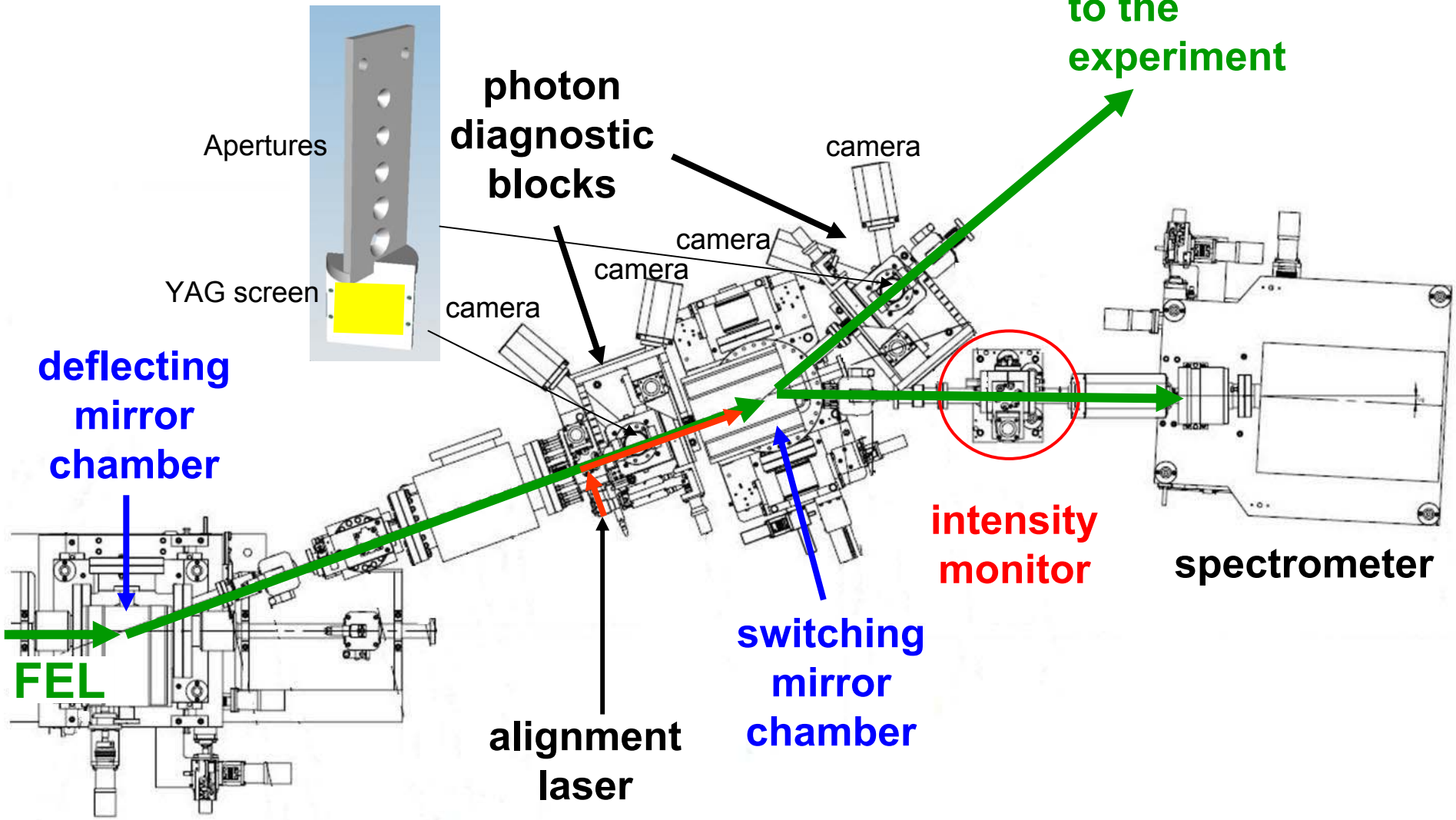


Photon beamline



Diagnostic branch

Inside the tunnel



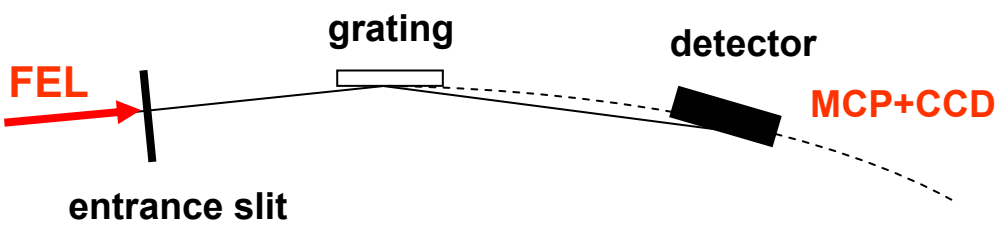
Grazing Incidence Spectrometer

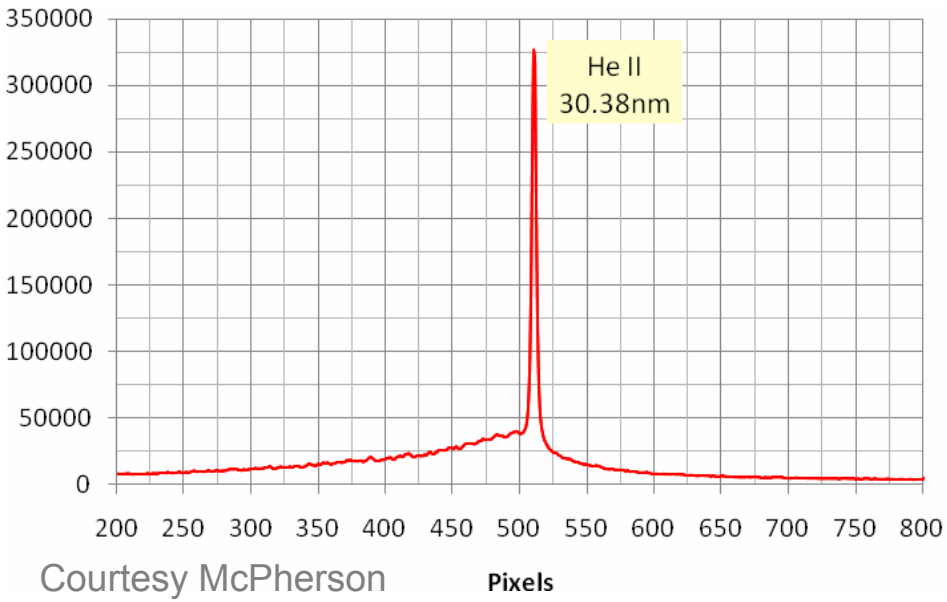
Purpose: matching undulator-HHG wavelength

Single-shot capability

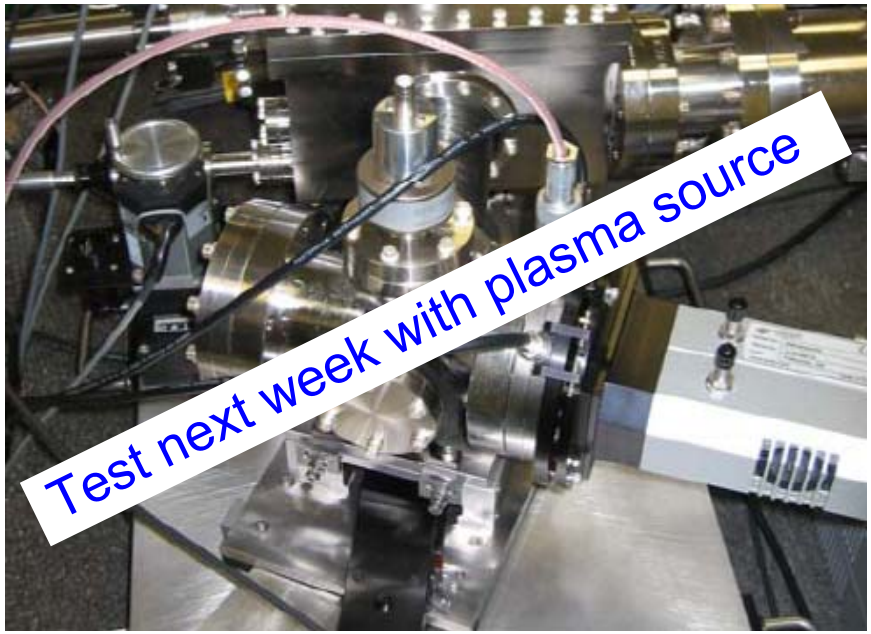
Resolution: $\lambda/\Delta\lambda = 1000$

Range: 1 - 35 nm





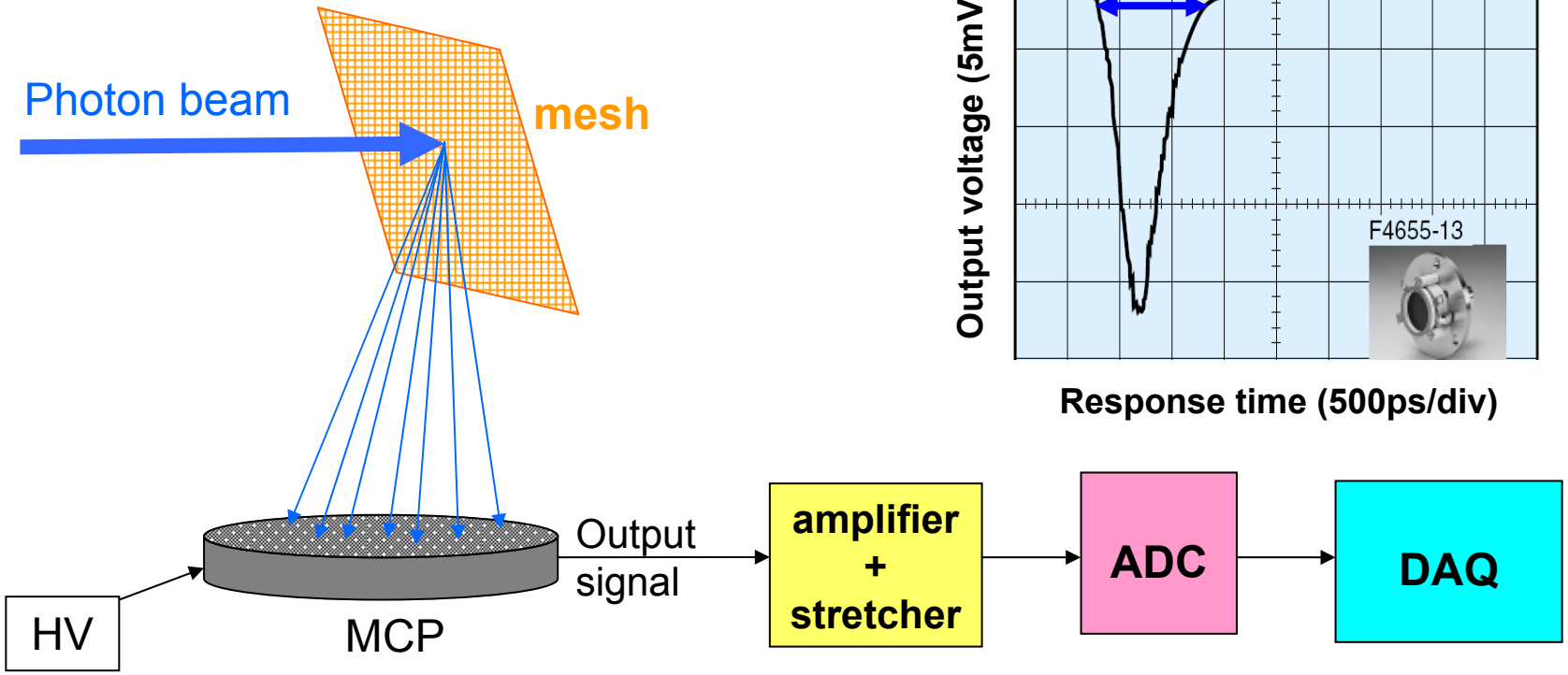
Courtesy McPherson



Intensity monitor

Purpose: to measure the gain curve of the seeded FEL

- detection of radiation scattered from a gold mesh with MCP
- cross calibration with gas monitor detector
- dynamic range ~10^4 per MCP (voltage)



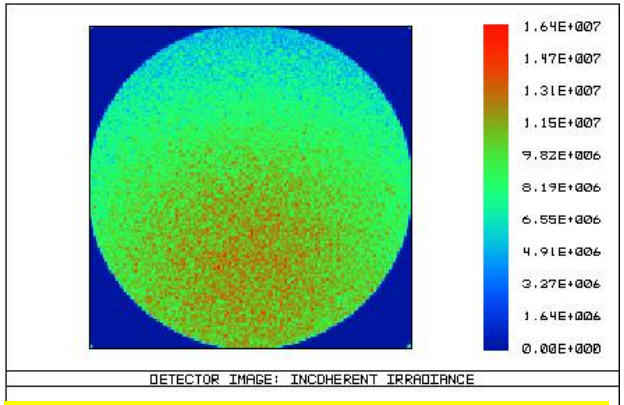
Final design

3 MCPs for wider dynamic range:

- 2 MCPs with hole on axis
- 1 MCP at 90°

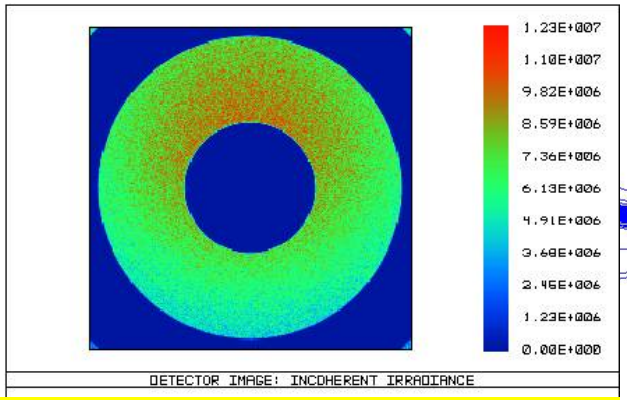
Mesh at 45 °

MCP 2

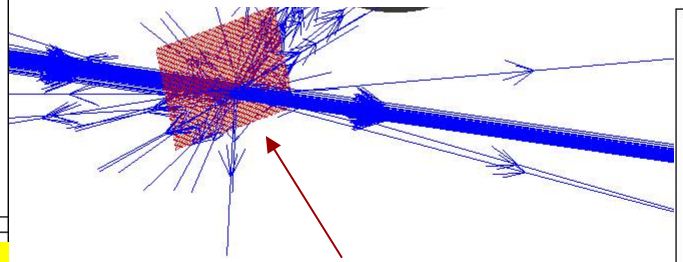


efficiency = 2.6 %

MCP 1

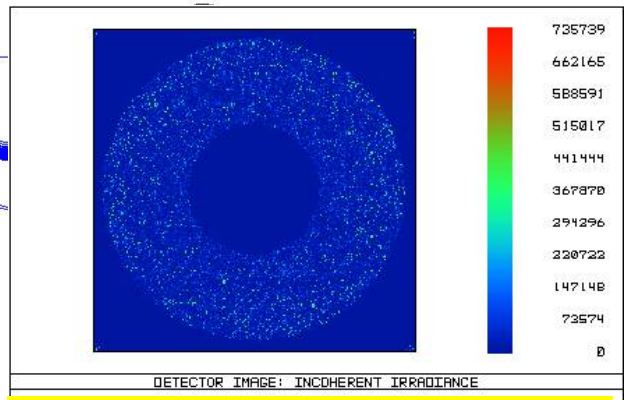


efficiency = 4.7 %



Gold mesh

MCP 3



efficiency = 0.04 %

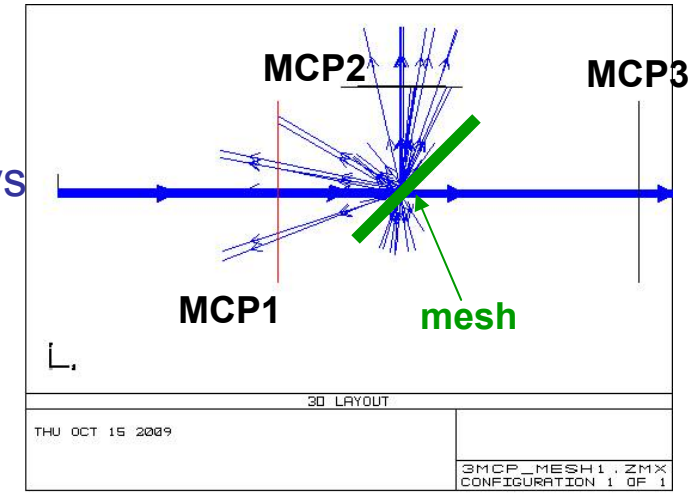
ZEMAX simulation

Source: 10^8 rays
500 μm FWHM
30 nm (41.3 eV)

Simulations at 30 nm

mesh: spacing = 0.25 mm, wire diameter = 0.06 mm, open area = 65 %

10^8 rays



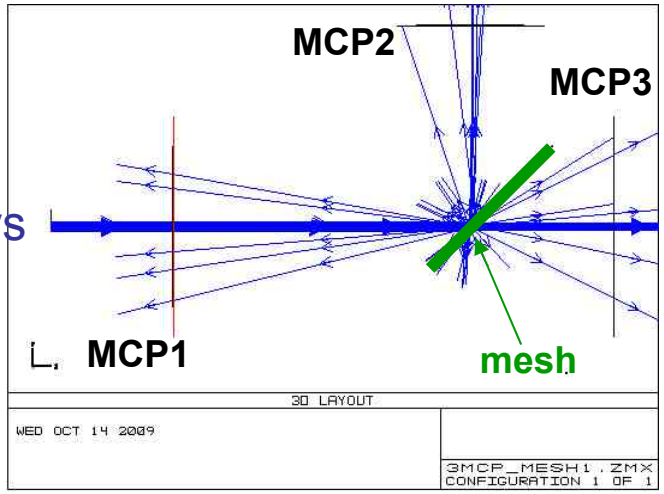
efficiency

MCP1 = 4.7×10^6 → 4.7%

MCP2 = 2.6×10^6 → 2.6%

MCP3 = 4.2×10^4 → 0.04%

10^8 rays



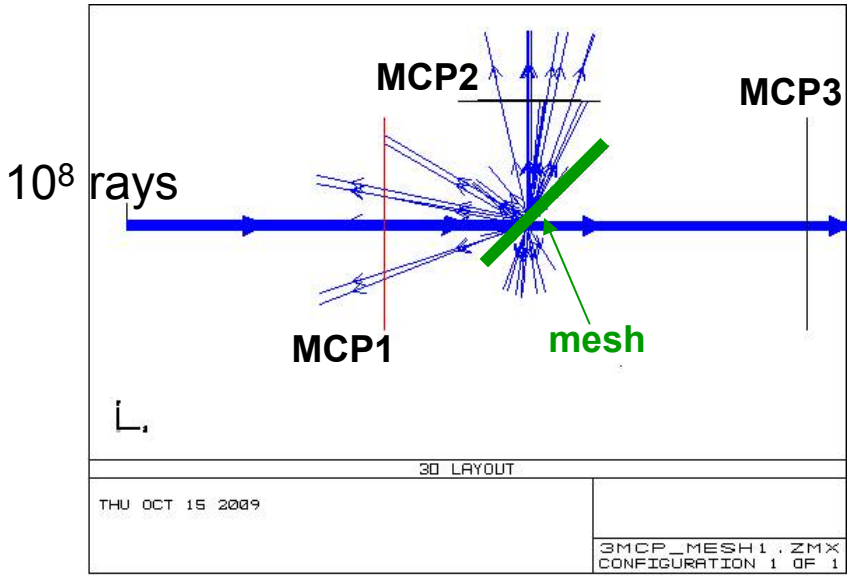
DIFFERENT CONFIGURATION

MCP1 = 1.5×10^6 → 1.5%

MCP2 = 1.1×10^6 → 1.1 %

MCP3 = 1.6×10^4 → 0.16%

Simulations at 30 nm



Mesh 1 (0.25 mm, Ø 0.06 mm, 65%)

MCP1 = 4.7×10^6 → ~4.7%

MCP2 = 2.6×10^6 → ~2.6%

MCP3 = 4.2×10^4 → ~0.04%

efficiency

SAME CONFIGURATION,

DIFFERENT MESH

Mesh 2 (0.011 mm, Ø 0.004 mm, 44%)

MCP1 = 6.3×10^6 → ~6.3%

MCP2 = 3.6×10^6 → ~3.6%

MCP3 = 6.7×10^4 → ~0.07%

two different meshes are mounted on a translation stage allowing to select the most suitable one depending on the photon flux

Mesh comparison at 13 nm

Starting with 10^8 rays

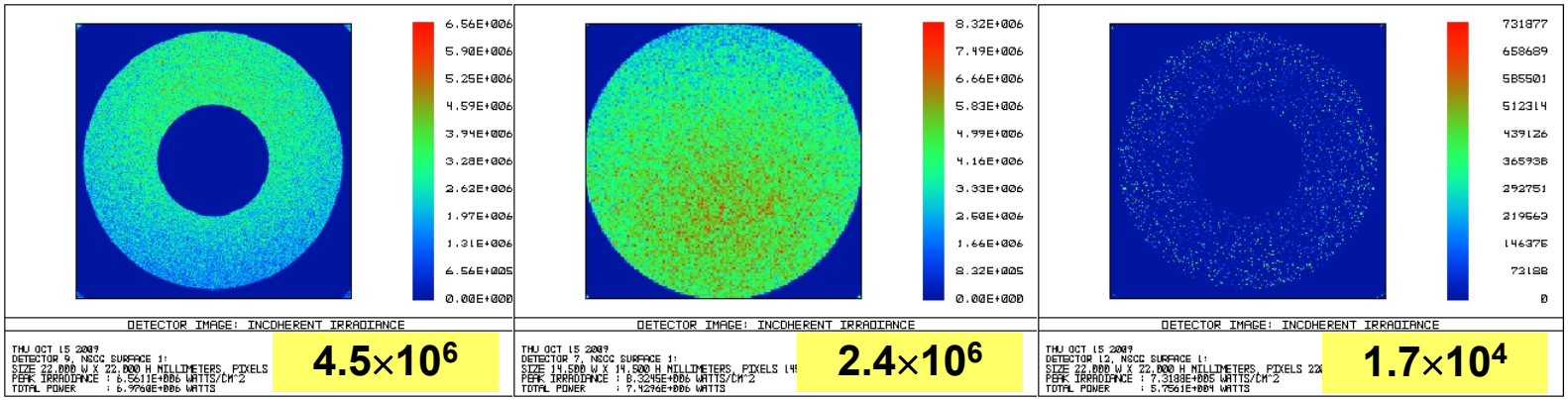
mesh 1

|↔| 0.25mm

Ø 0.06mm

Open area 65%

MCP 1 | MCP 2 | MCP 3



Efficiency:	4.5%	2.4%	0.02%

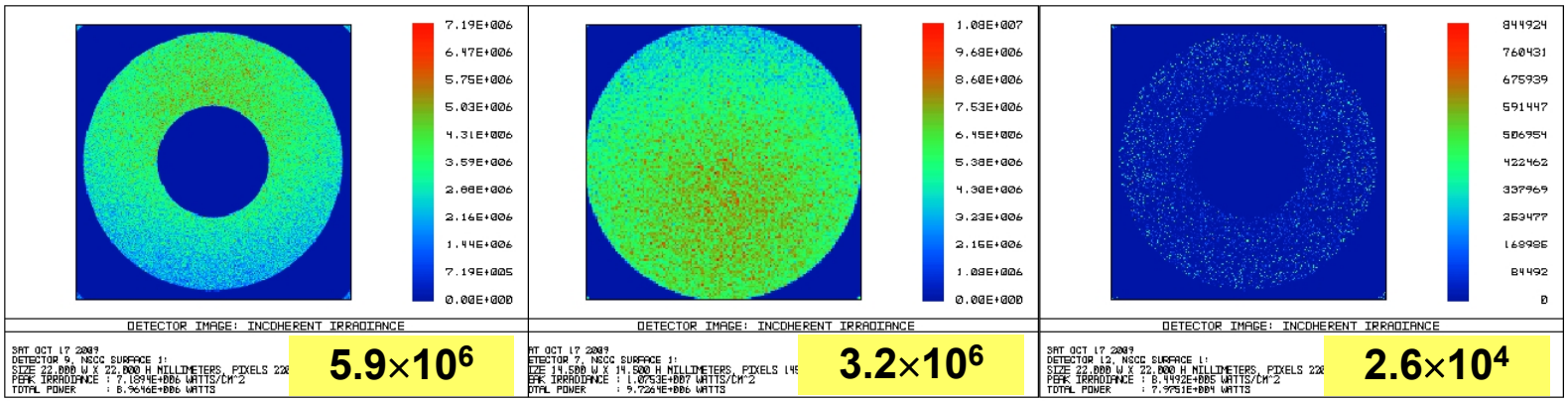
mesh 2

|↔| 0.011mm

Ø 0.004mm

Open area 44%

MCP 1 | MCP 2 | MCP 3



Efficiency:	5.9%	3.2%	0.03%

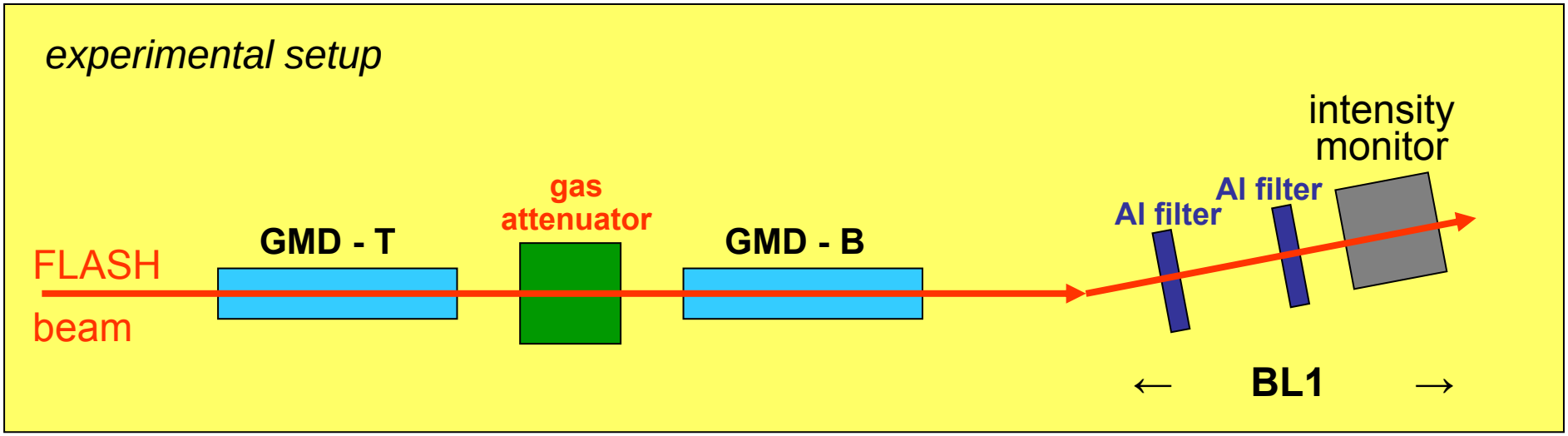
Calibration measurements

Measurements at BL1@FLASH ~ 500 μm spot size

λ = 13.7 nm

We simulated the amplification curve of sFLASH attenuating the SASE beam **from the μJ range down to the pJ range** by means of a combination of the gas attenuator and aluminum filters (thickness 200 and 137 nm).

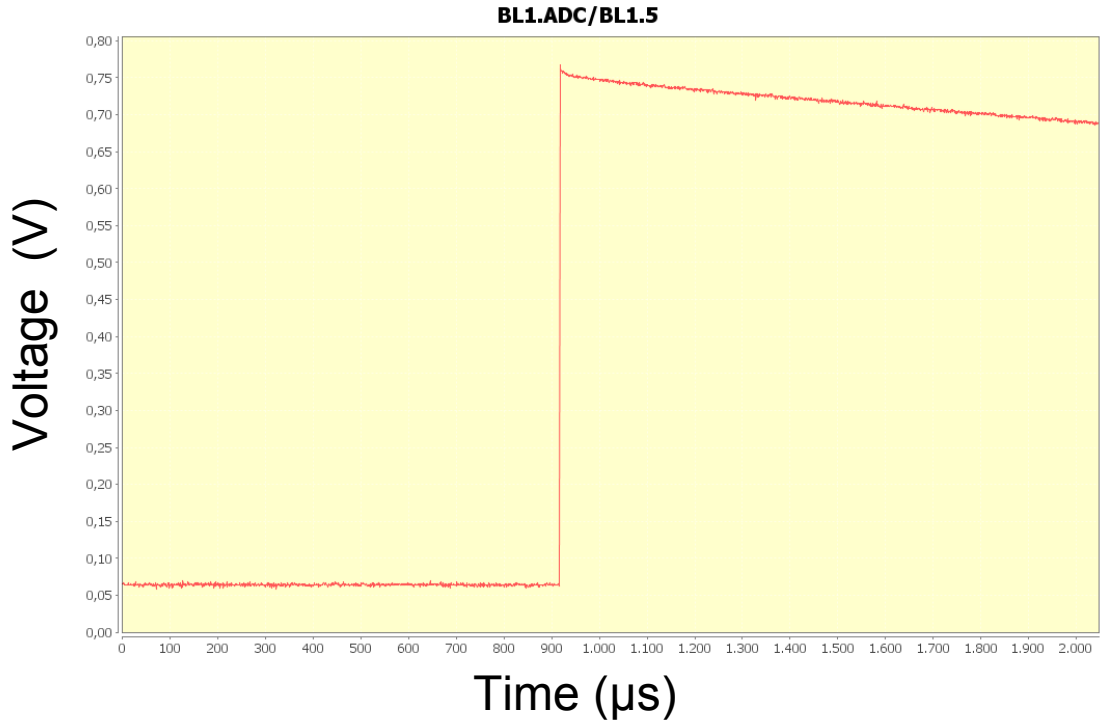
We measure the **spontaneous emission** from the undulators detuning SASE. This is similar to the starting point of the commissioning phase.



MCP signal

The short MCP signal (~1ns) is amplified, then stretched before entering the ADC

We measured the MCP output signal for different high-voltage settings

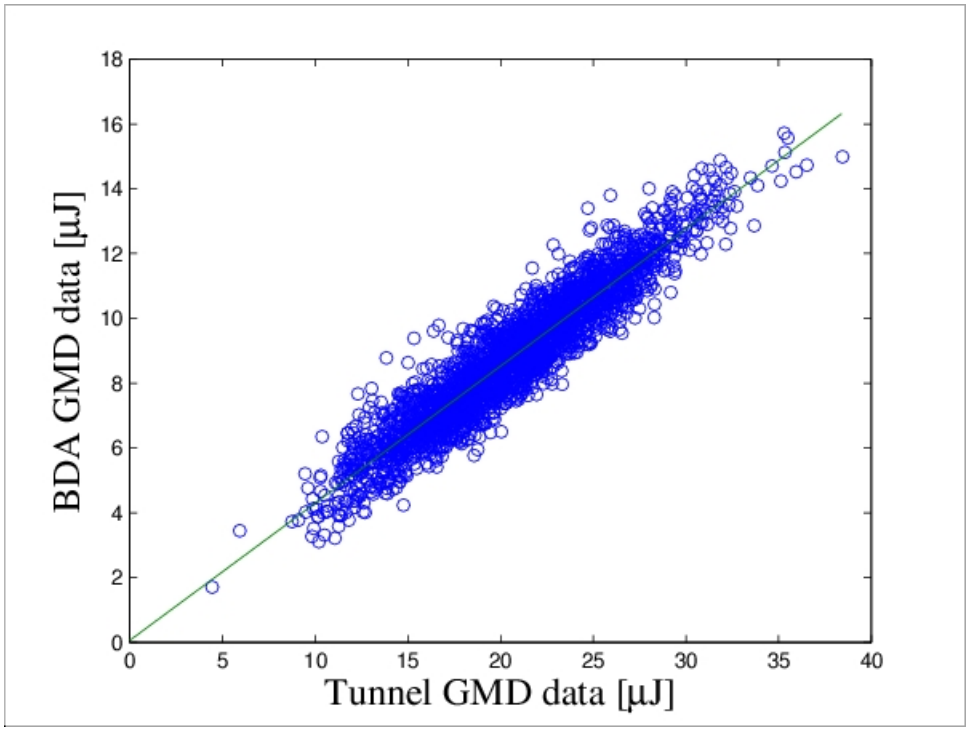


signal from the ADC as recorded by DAQ

GMD signal

we recorded the shot-to-shot energy of the pulses measured by the gas monitor detector

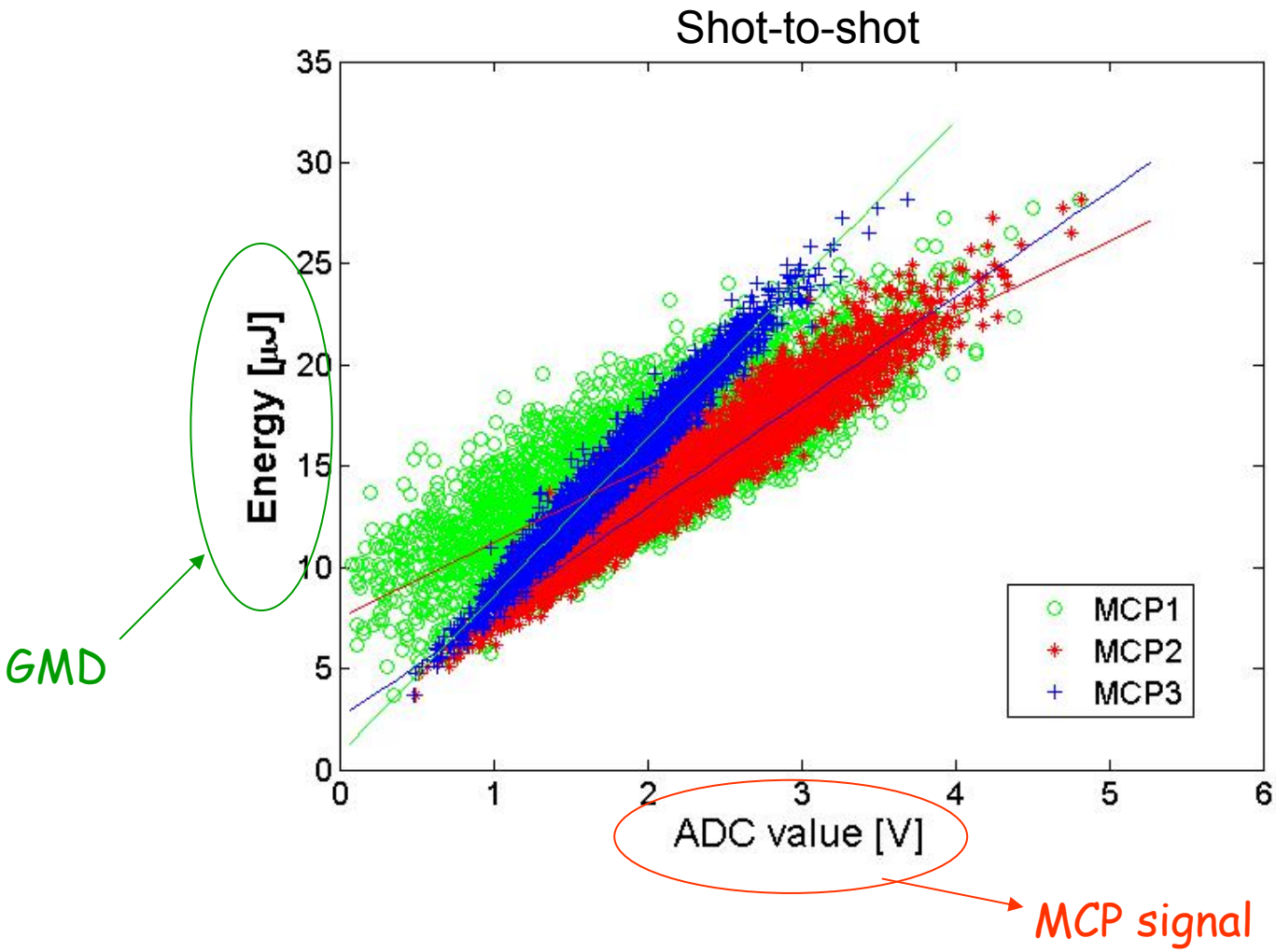
Correlation GMD tunnel with GMD BDA



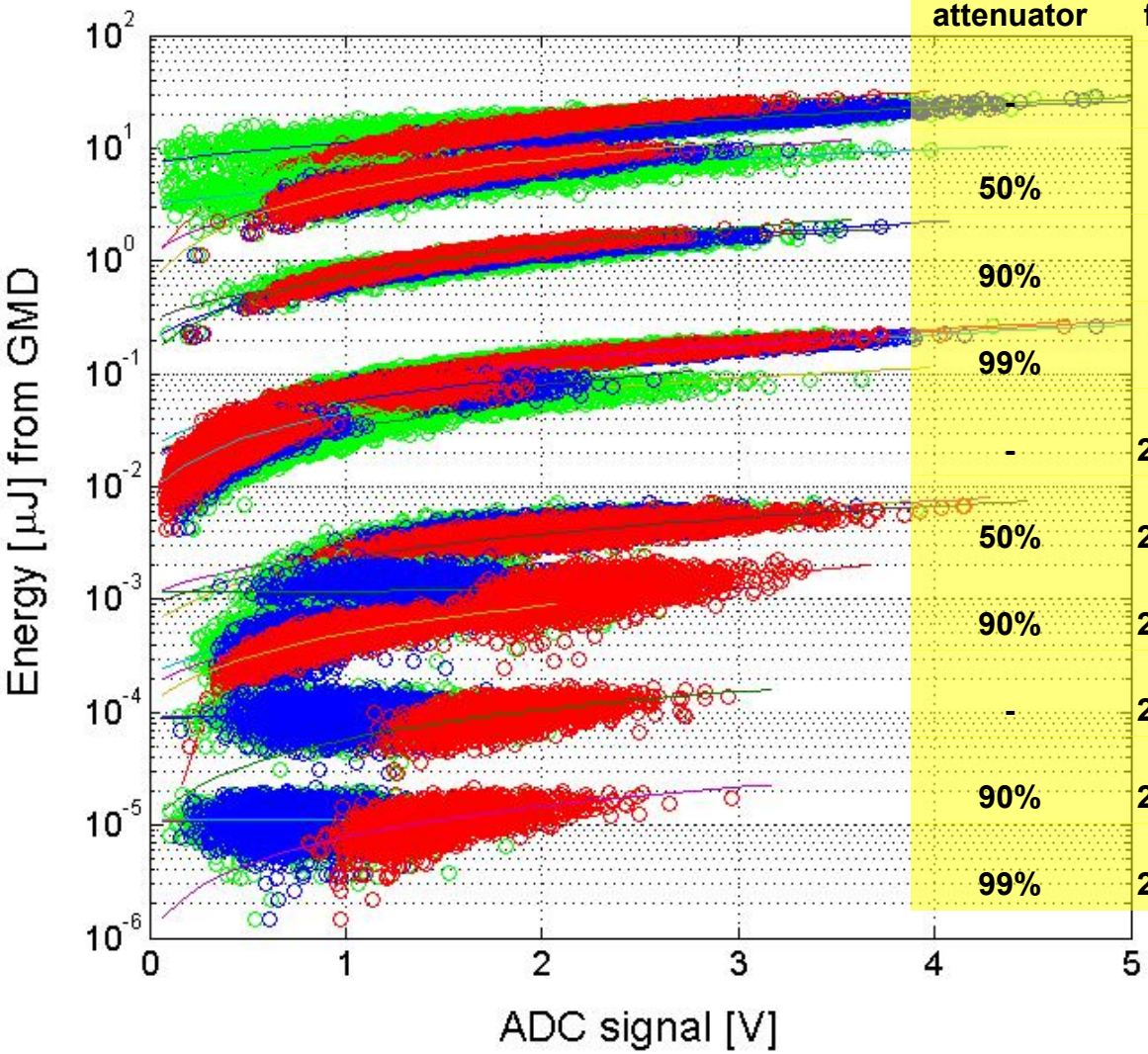
Precision of absolute energy calibration ~20%

Cross-calibration

For one voltage setting



Total dynamic range

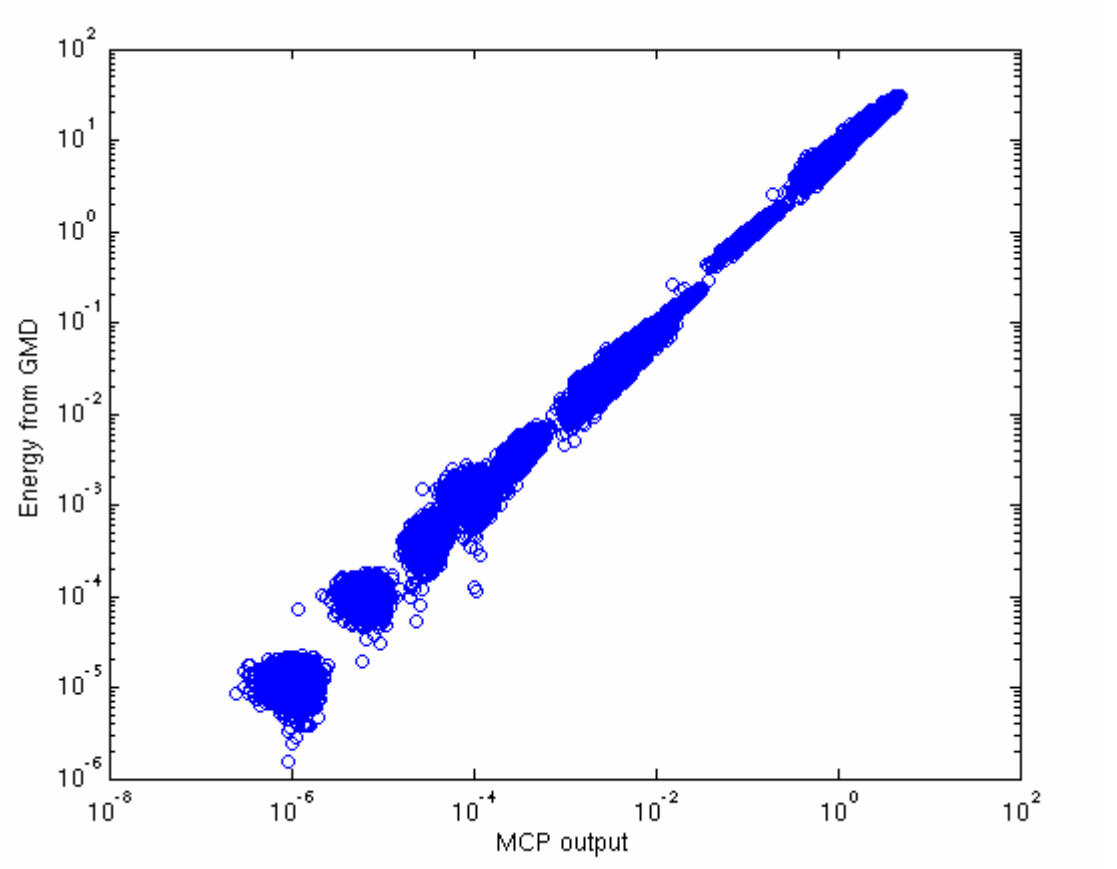


attenuation			Voltage (V)		
Gas attenuator	filter1	filter2	mcp1	mcp2	mcp3
-	-	-	930	1130	670
50%	-	-	970	1160	710
90%	-	-	1040	1235	790
99%	-	-	1110	1310	870
-	200nm	-	1350	1500	1050
50%	200nm	-	1350	1500	1050
90%	200nm	-	1500	1625	1190
-	200nm	130nm	1650	1710	1350
90%	200nm	130nm	1650	1710	1350
99%	200nm	130nm	1650	1710	1350

"normalization"

amplification factors estimated looking at regions where for different voltage settings we measured the same pulse energy

MCP 2



Conclusions

sFLASH:

- fully coherent beam with small SASE background
- high peak power operation ~ 1-2 GW
- variable bunch duration 20 - 40 fs (FWHM)
- temporal pulse shape control
- wavelength: 30 nm – 13 nm
- parasitic mode (hence parallel experiments)
- pump-probe experiments with fs synchronization

Photon diagnostics:

- shot-to-shot spectral measurements
- absolute calibration for measuring the gain curve (photon flux)

Acknowledgements

sFLASH team:

A. Azima, J. Boedewadt, F. Curbis, H. Delsim-Hashemi, M. Drescher, T. Maltezopoulos, V. Miltchev, M. Mittenzwey, J. Rossbach, R. Tarkeshian, M. Wieland (University of Hamburg, Germany)

S. Duesterer, J. Feldhaus, T. Laarmann, H. Schlarb (DESY, Hamburg)

A. Meseck (Helmholz-Zentrum Berlin, Berlin, Germany)

R. Ischebeck (PSI, Villigen, Switzerland)

S. Khan (DELTA, Dortmund)

S. Toleikis, DESY

M. Oja, University of Tartu

Thanks to many DESY groups:

HASYLAB, MPY, FLA, MCS, MIN, MKK, MVS …