Status of the Electron Beam Transverse Diagnostics with Optical Diffraction Radiation at FLASH

M. Castellano, E. Chiadroni, A. Cianchi,
K. Honkavaara, G. Kube

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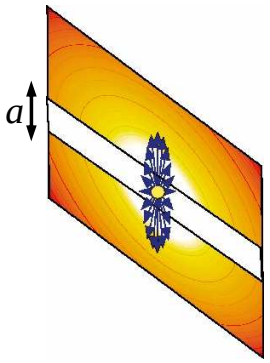
Diffraction Radiation Theory

- DR is produced by the interaction between the EM fields of the traveling charge and the conducting screen



- The radiation intensity is $I \propto e^{-\frac{2\pi a}{\gamma\lambda}}$
- DR impact parameter is $\frac{\gamma\lambda}{2\pi}$ ➔ if a

$$\begin{cases} >> \frac{\gamma\lambda}{2\pi} & \text{No radiation} \\ \cong \frac{\gamma\lambda}{2\pi} & \text{DR} \\ << \frac{\gamma\lambda}{2\pi} & \text{TR} \end{cases}$$

- Excellent candidate to measure beam parameters **parasitically**

Diffraction Radiation Diagnostics

- Low γ, λ of the order of *mm* ➔ Coherent Diffraction Radiation

  ➔ Longitudinal diagnostics*

*** M. Castellano et al.**, Phys. Rev. E 63 (2001)
*** E. Chiadroni**, "*Bunch Length Characterization at the TTF VUV-FEL*", PhD Thesis, Univ. of Rome "Tor Vergata"

- Large γ of the order of 10^3 ➔ Optical Diffraction Radiation

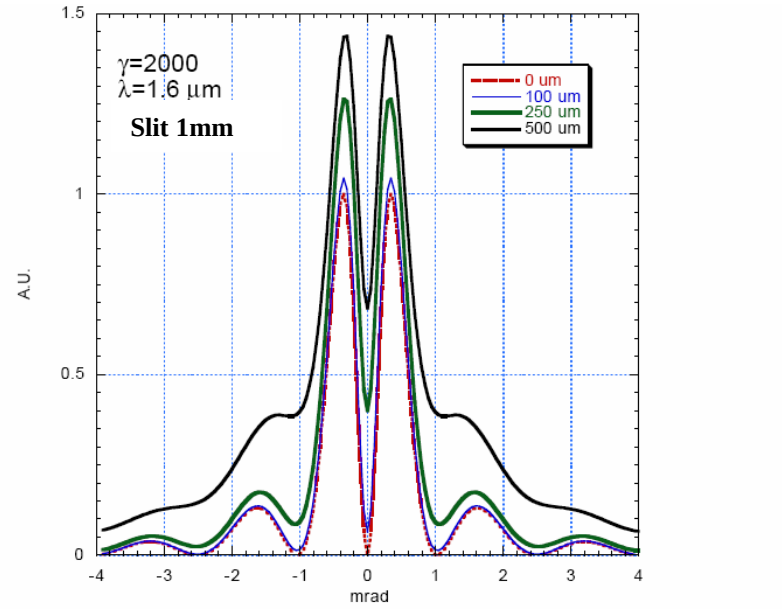
  ➔ Transverse diagnostics**

  - Position
  - Angular divergence
  - Transverse dimensions
  - Emittance

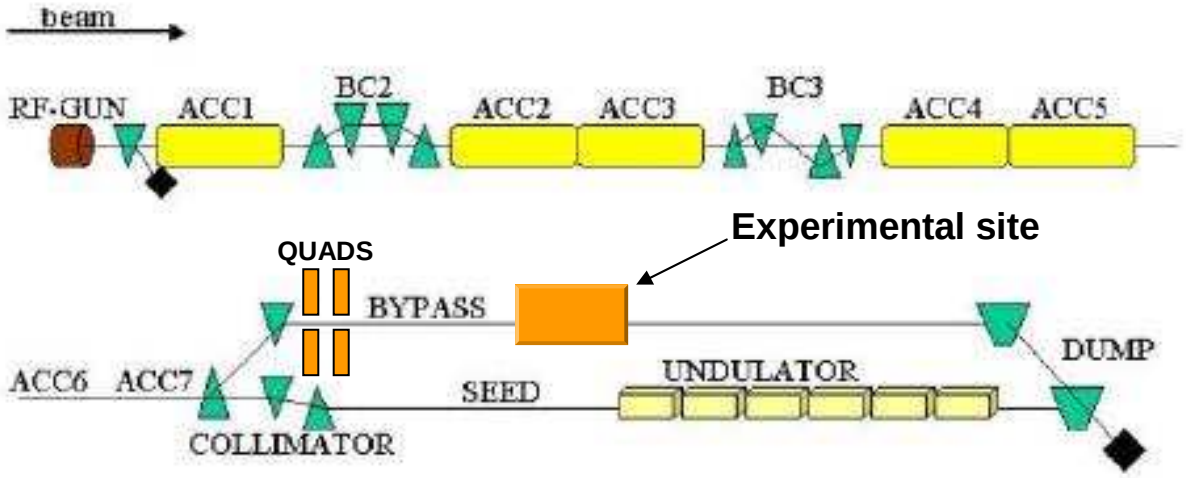
**** M. Castellano**, "*A New Non Intercepting Beam size Diagnostics Using Diffraction Radiation from a Slit*",
Nucl. Instr. And Meth. in Phys. Res. A394, 275, (1997)
**** P. Karataev et al.**, "*Beam-Size Measurement with Optical Diffraction Radiation at KEK Accelerator Test Facility*",
Phys. Rev. Lett. 93, 244802 (2004)

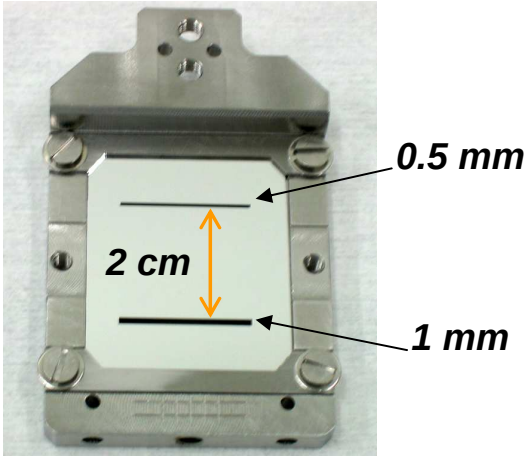
Beam Transverse Diagnostics with ODR

ODR angular distribution gives information on the transverse beam size: increasing σ_y both the peak intensity and the central minimum increase



The Experiment

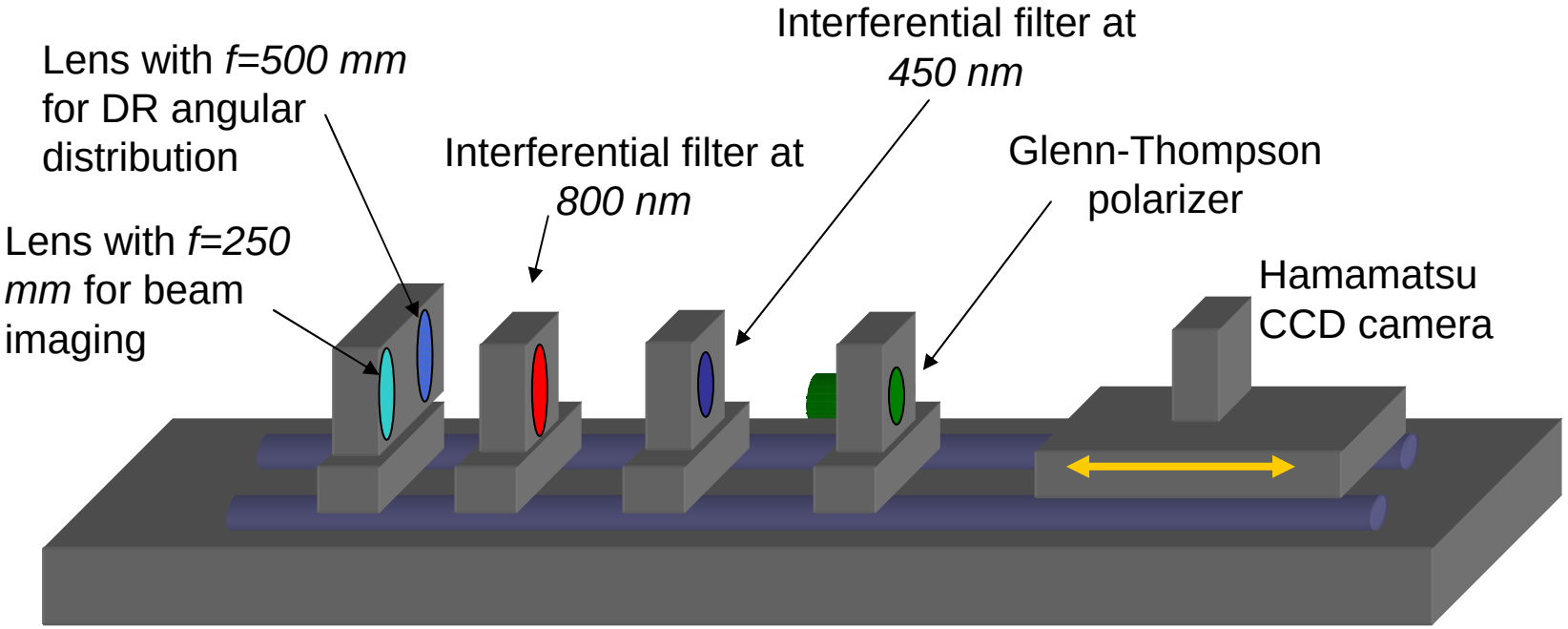




FLASH is a good test facility for several reasons:

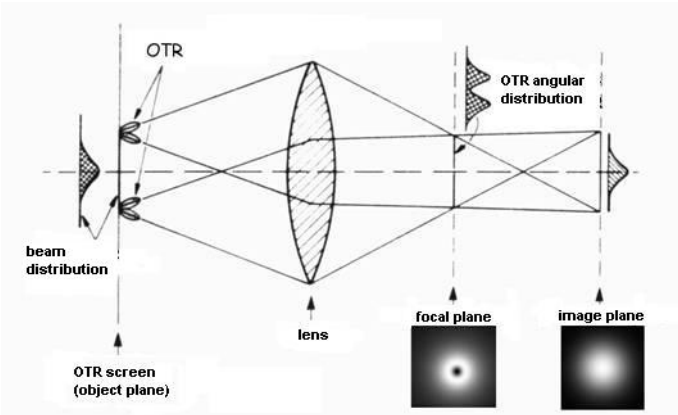
- High energy, up to *1 GeV*
- Up to 30 bunches per macropulse
- Repetition rate 5 Hz

Optical System

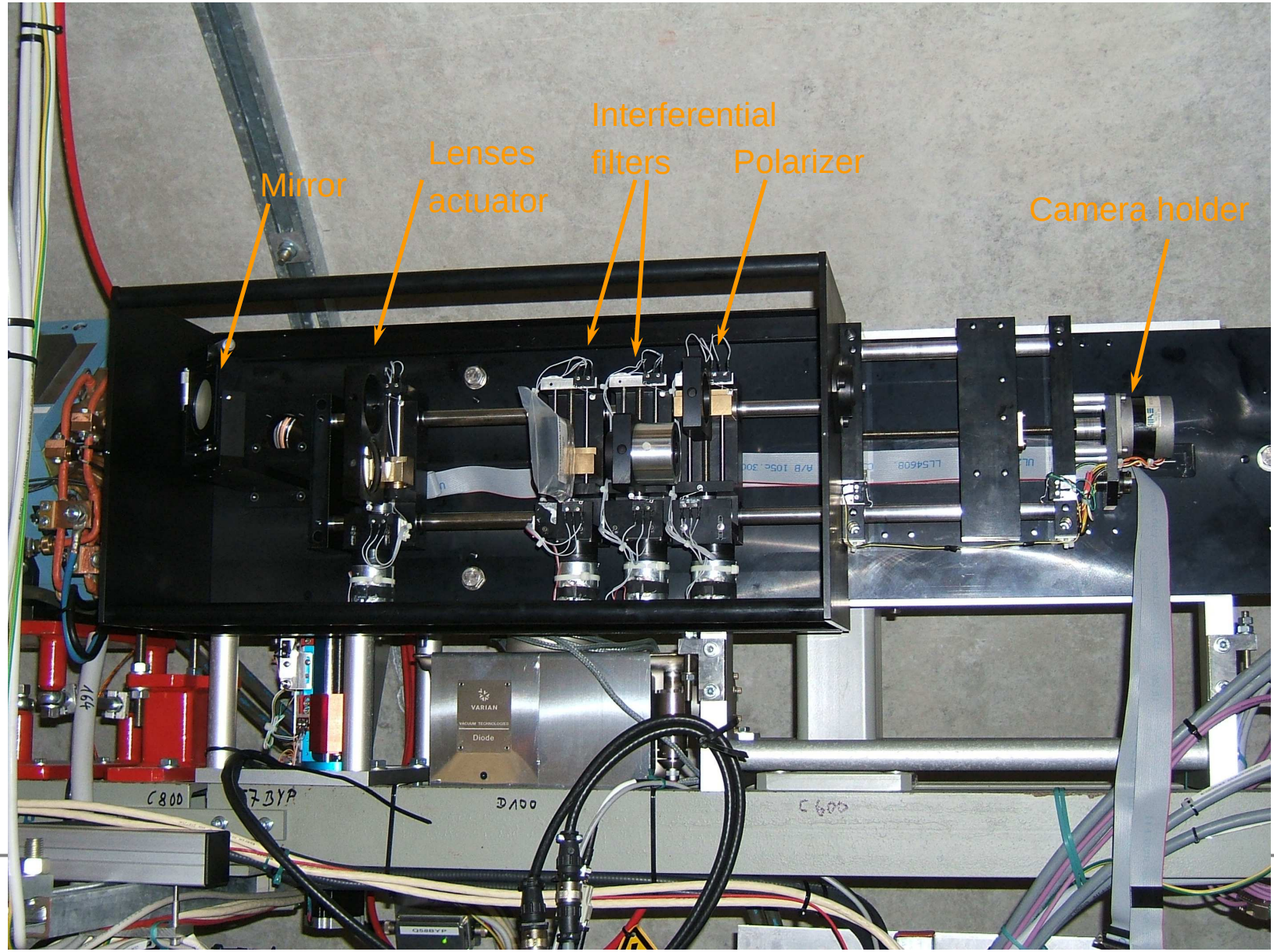


High Sensitivity Hamamatsu Camera

- High quantum efficiency
- Air Cooling -55˚C
- Long exposure time up to 2 hours



Experimental Setup



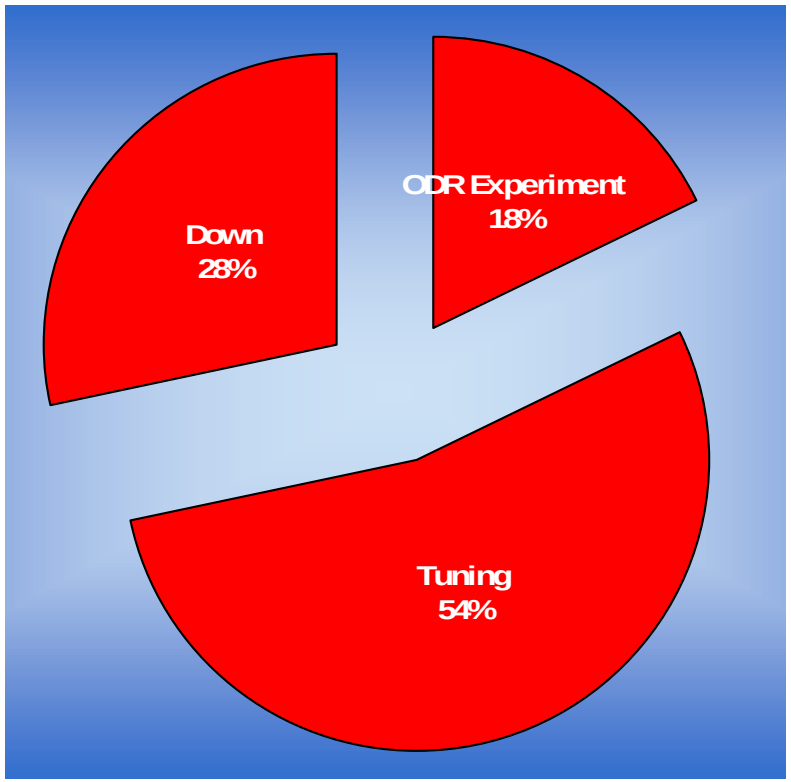
Acquisition System

- The optical system is controlled by electronic box placed in the tunnel
- This is a quasi-standard FLASH electronic box, using can-bus modules, partially integrated in linac control system
- The more accurate stepper motors for the target and the camera position, as well as the camera, are controlled via Firewire by industrial PC

Time Shift Usage

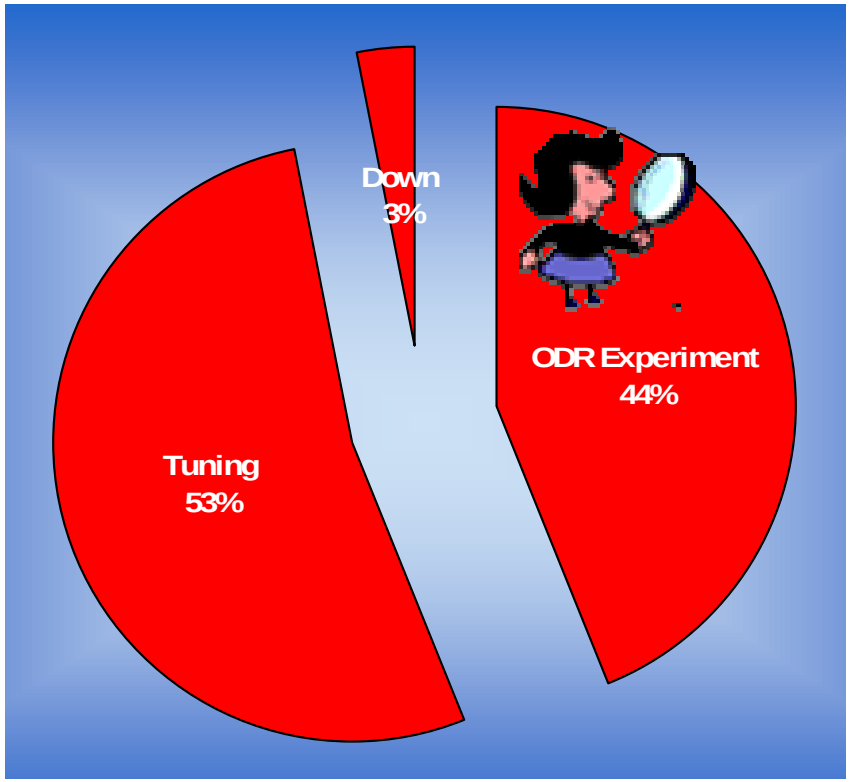
1st Period: Week 10

4 shifts equivalent

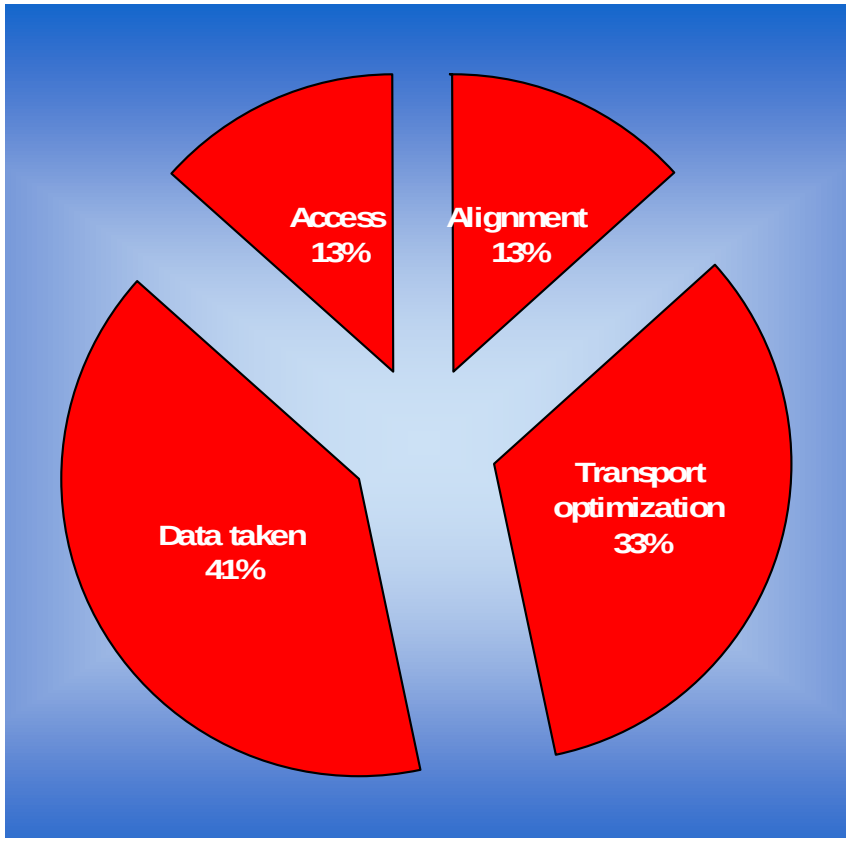


2nd Period: Week 13

6 shifts equivalent



Details of Measurement Time



2 Periods of Measurements

- **1st Period, Low Energy: *480 MeV***
  - First tests of the whole apparatus: non-perfect alignment
  - First observation and understanding of the background
  - Rough energy measurement with OTR

- **2nd Period, High Energy: *620 MeV***
  - Background subtraction
  - First measurements with *1 mm* slit in

Critical Issues

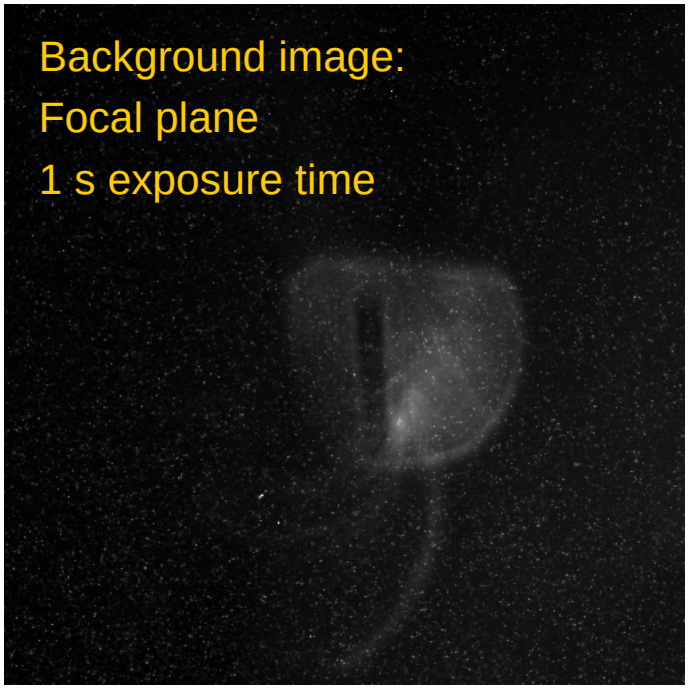
- Synchrotron radiation background coming from the dipole and quads
  - Not optimized optics in the by-pass

- Due to multiple scattering in the line, the background produces an image of the target ➔ the background comes with the beam!!
  - It must be subtracted playing with the steerer

- Severe X-rays background which does not allow to integrate over a long time
  ➔ Optimization of the beam transport: Low charge, High # of bunches

- Low electron beam energy

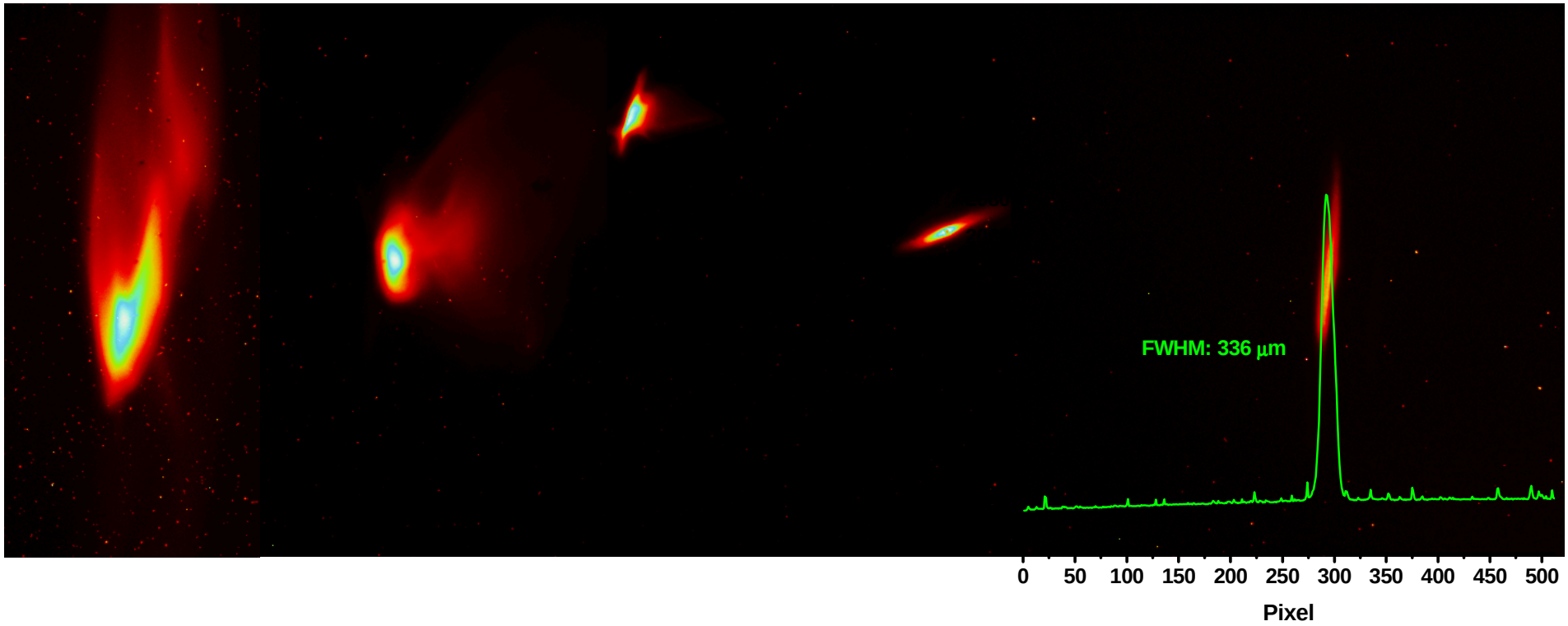
- Large and unstable beam
  ➔ *1 mm* slit



The Beam (I Period)

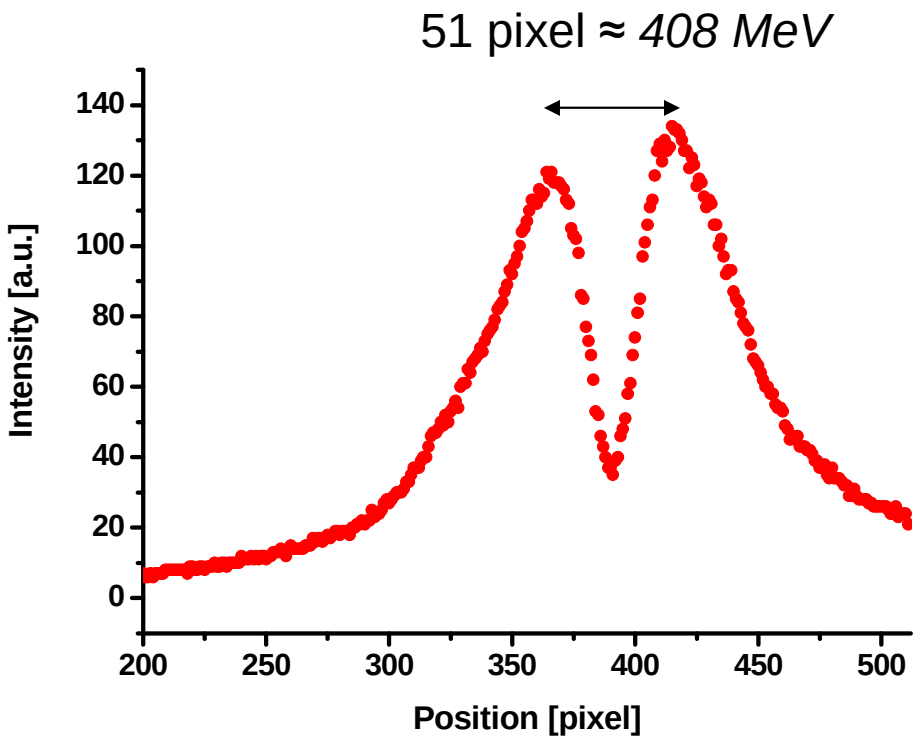
Initial conditions

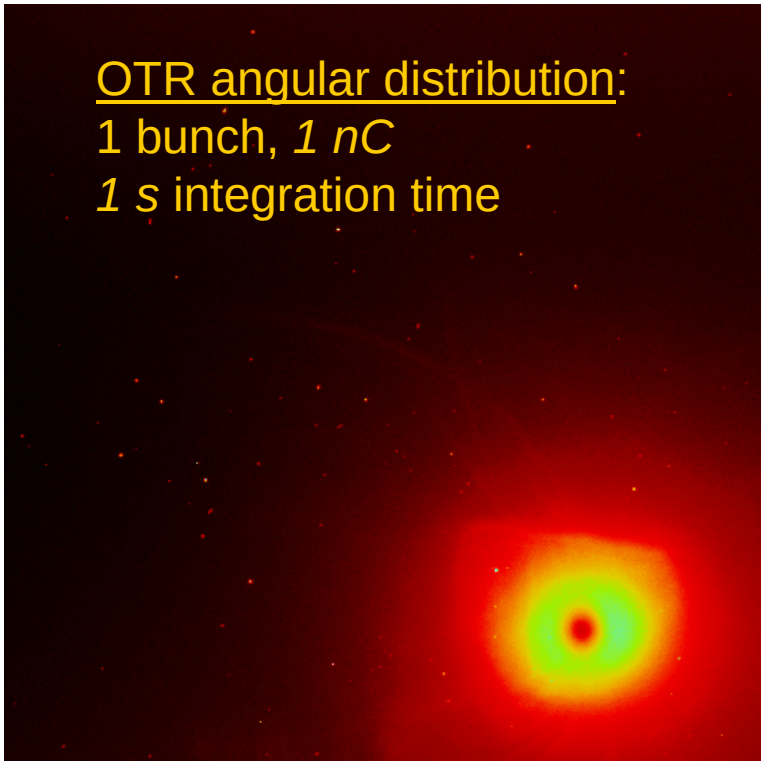
After some tuning



Beam Energy Measurement

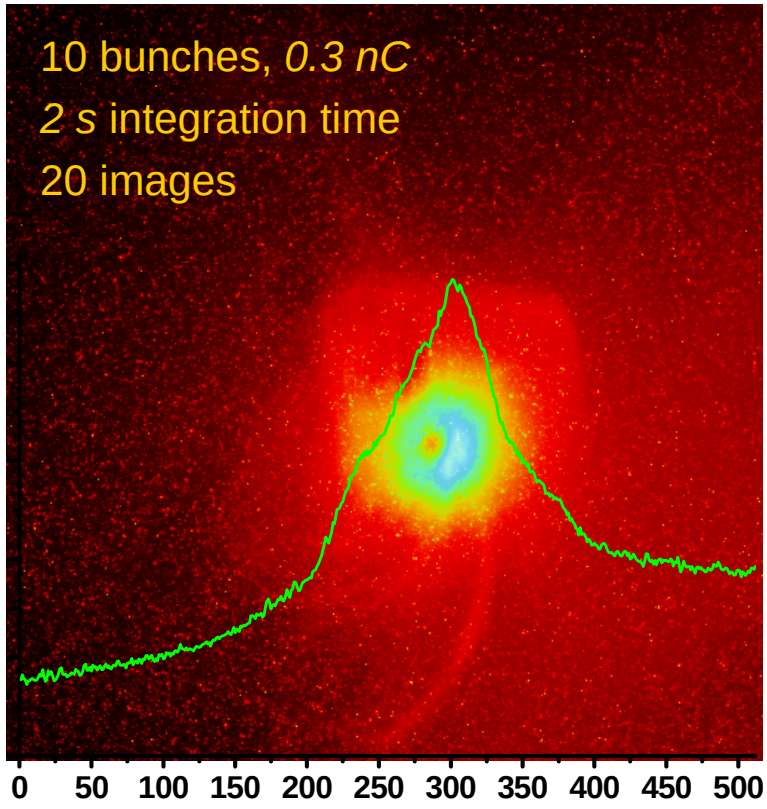
A rough energy measurement has been done by measuring the aperture of the OTR angular distribution cone ➔ The agreement with the energy measured by the FLASH team is within 20%.



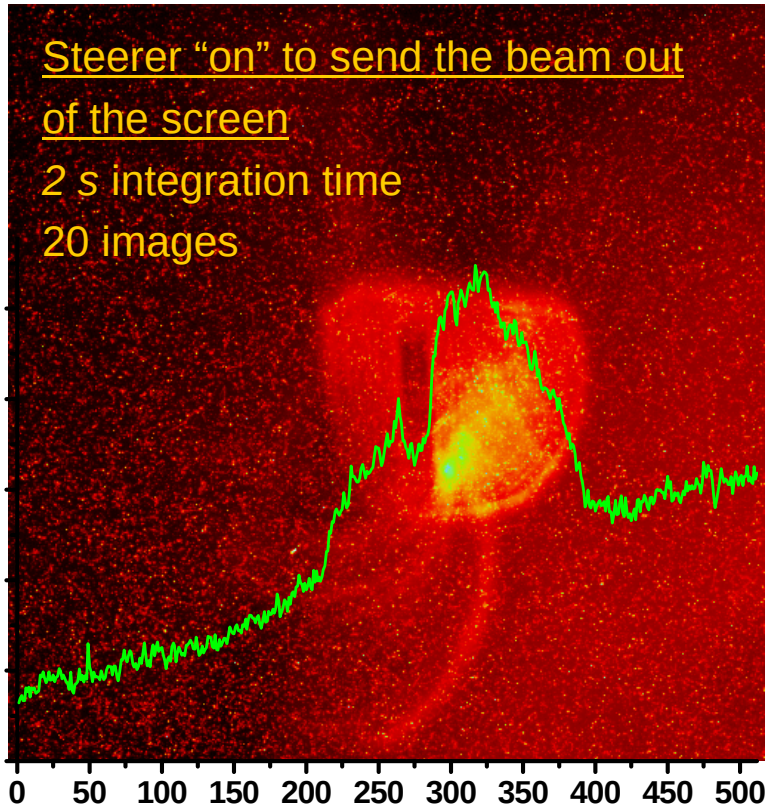


Background Subtraction (I)

LabView tool to remove hot spots and subtract background

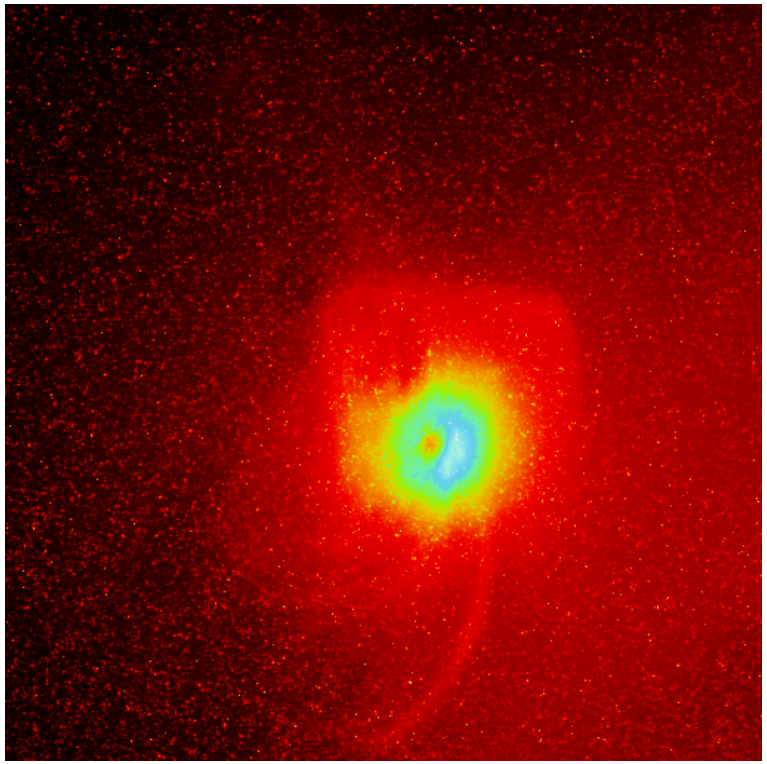


OTR angular distribution and background

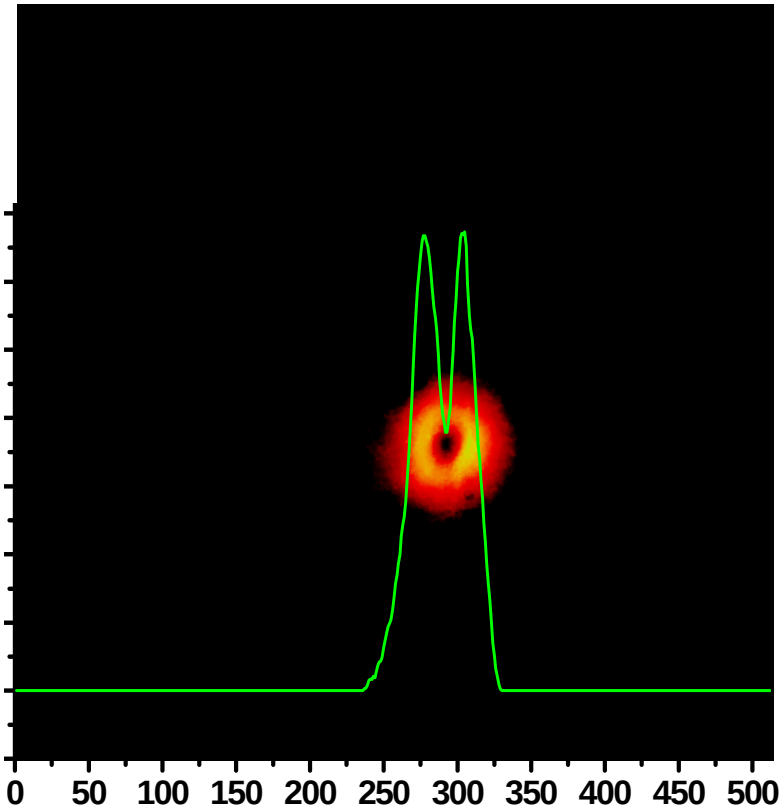


Background image

Background Subtraction (II)



Before background subtraction

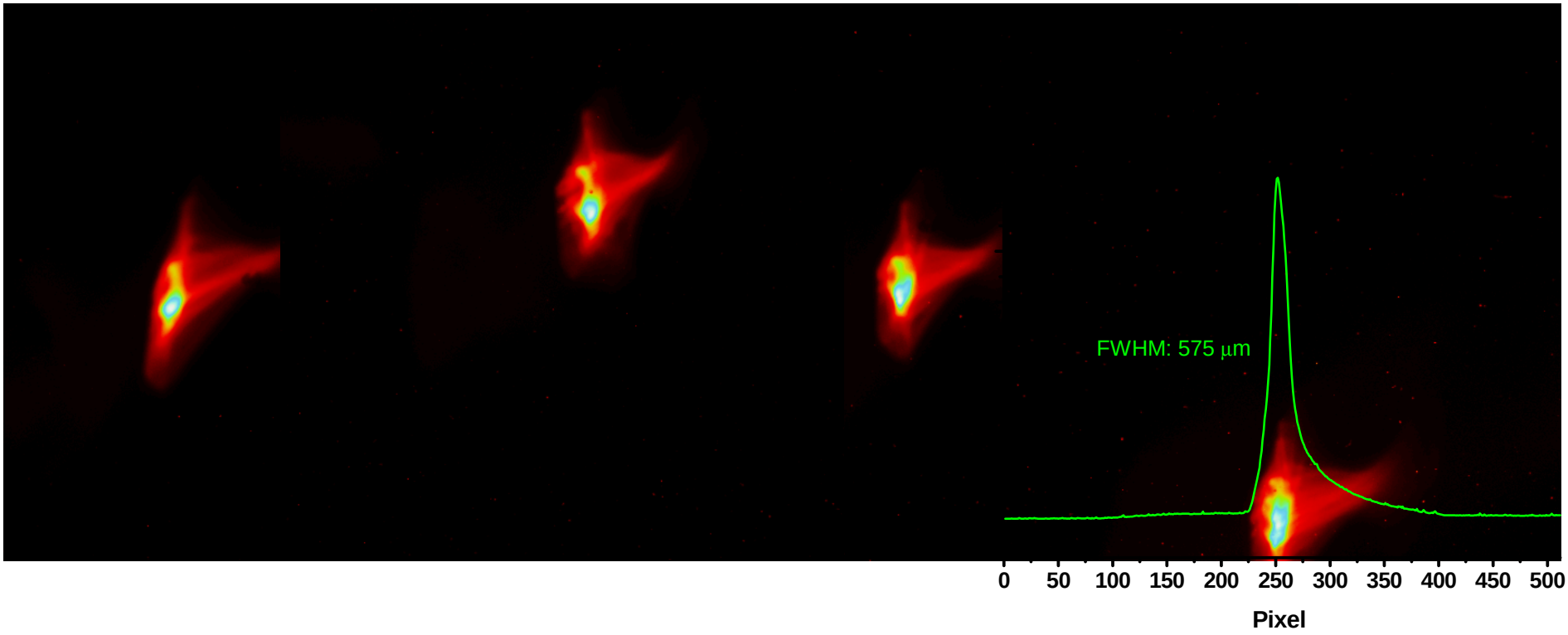


OTR angular distribution after background subtraction

The Beam (II Period)

Initial conditions

After some tuning

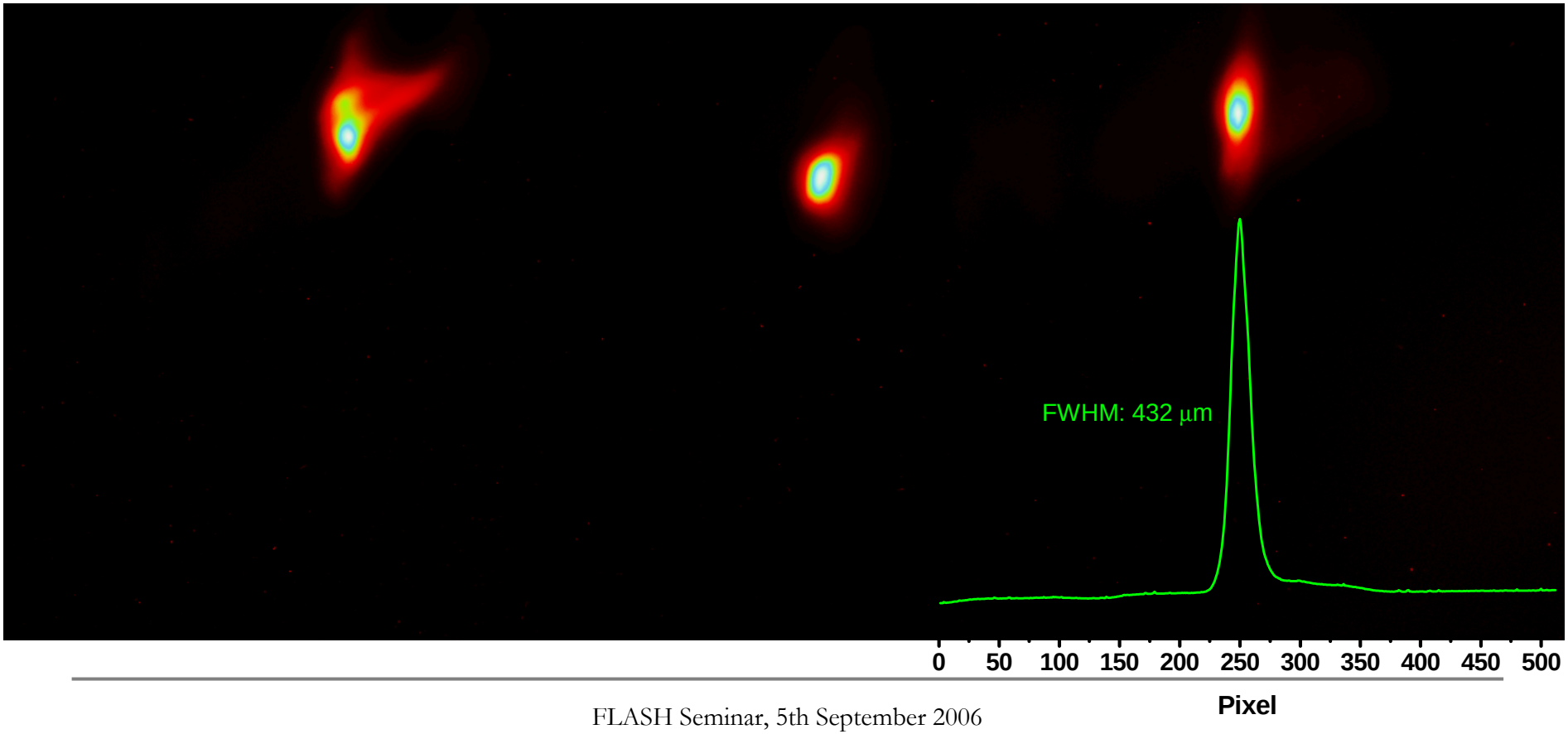


The Beam (II Period)

The Following Day

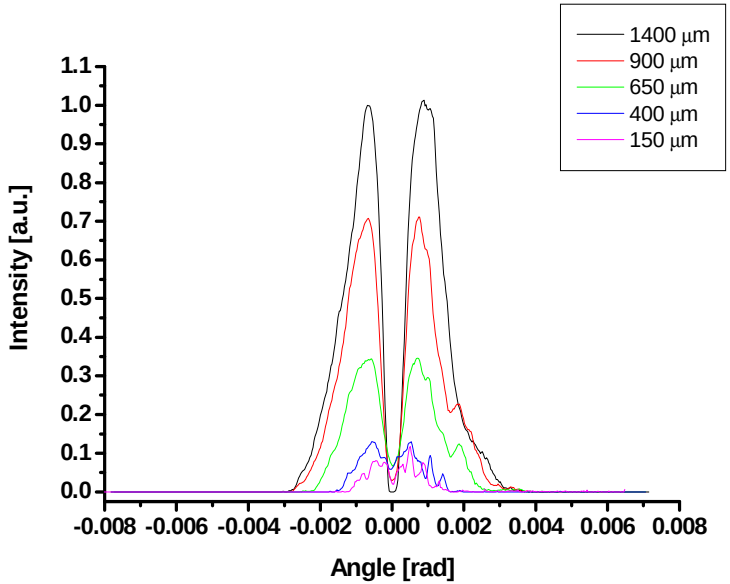
Initial conditions

After some tuning

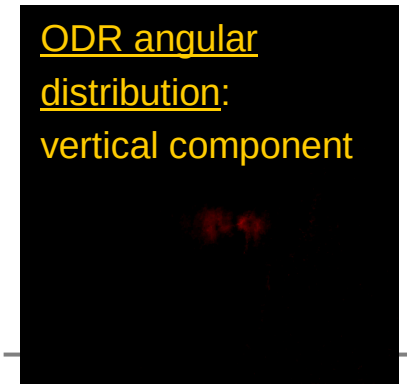


From OTR to ODR

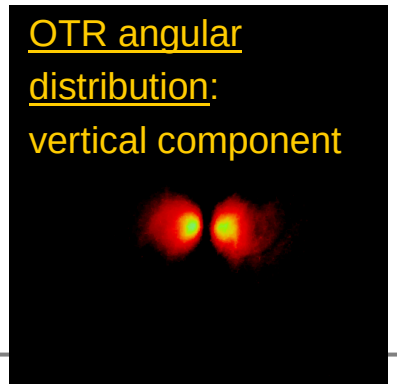
- Moving the vertical steerer (V41)



ODR angular distribution: vertical component



OTR angular distribution: vertical component



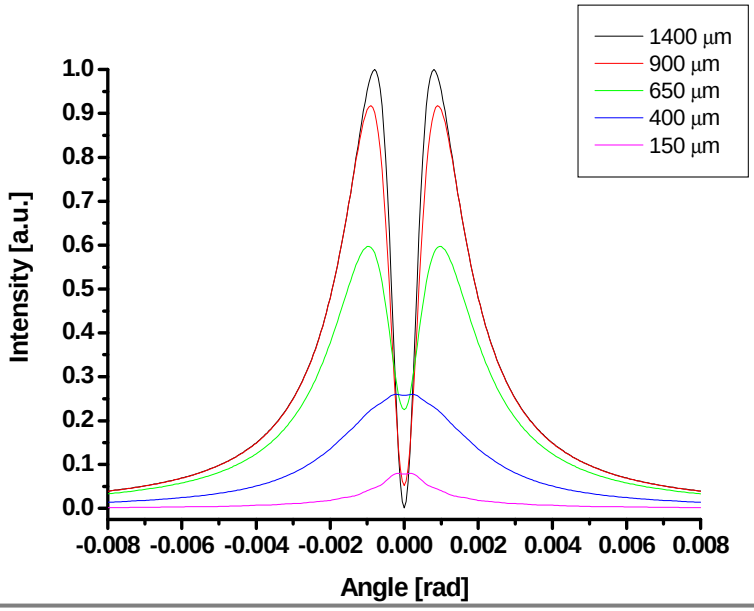
Beam transport optimization:

- *0.3 nC*
- 25 bunches
- *1 s* exposure time

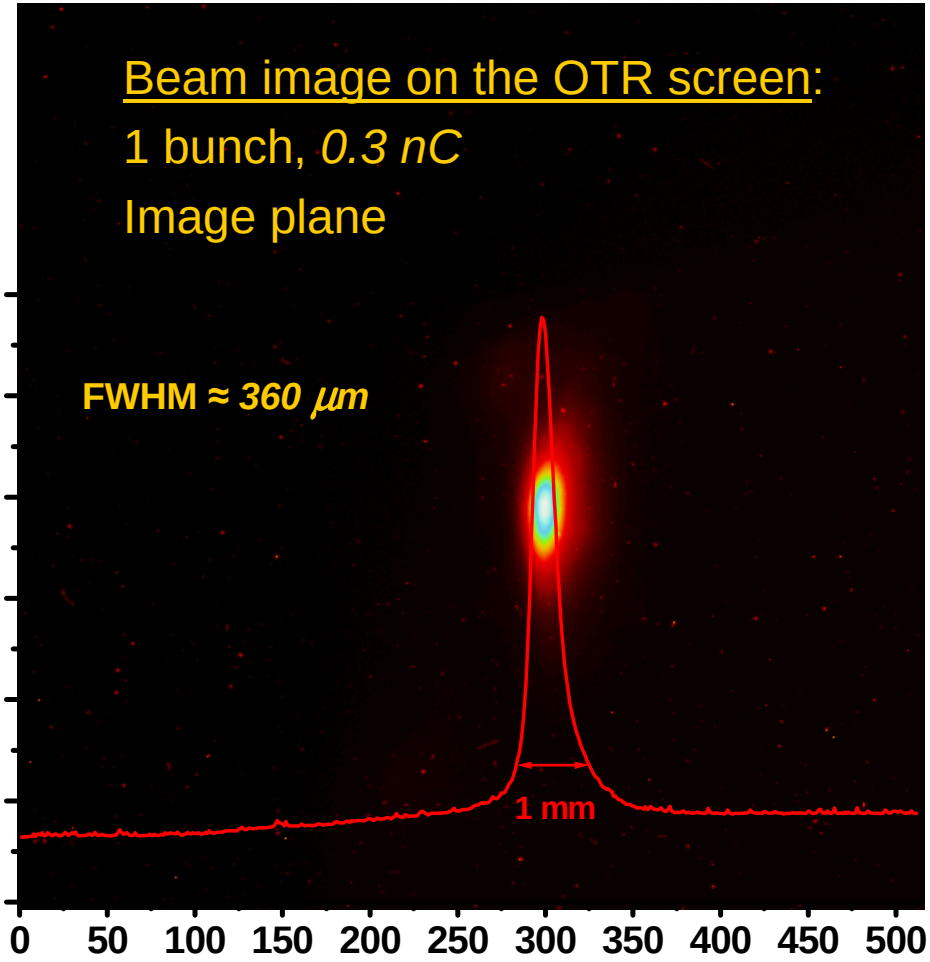
Optics optimization:

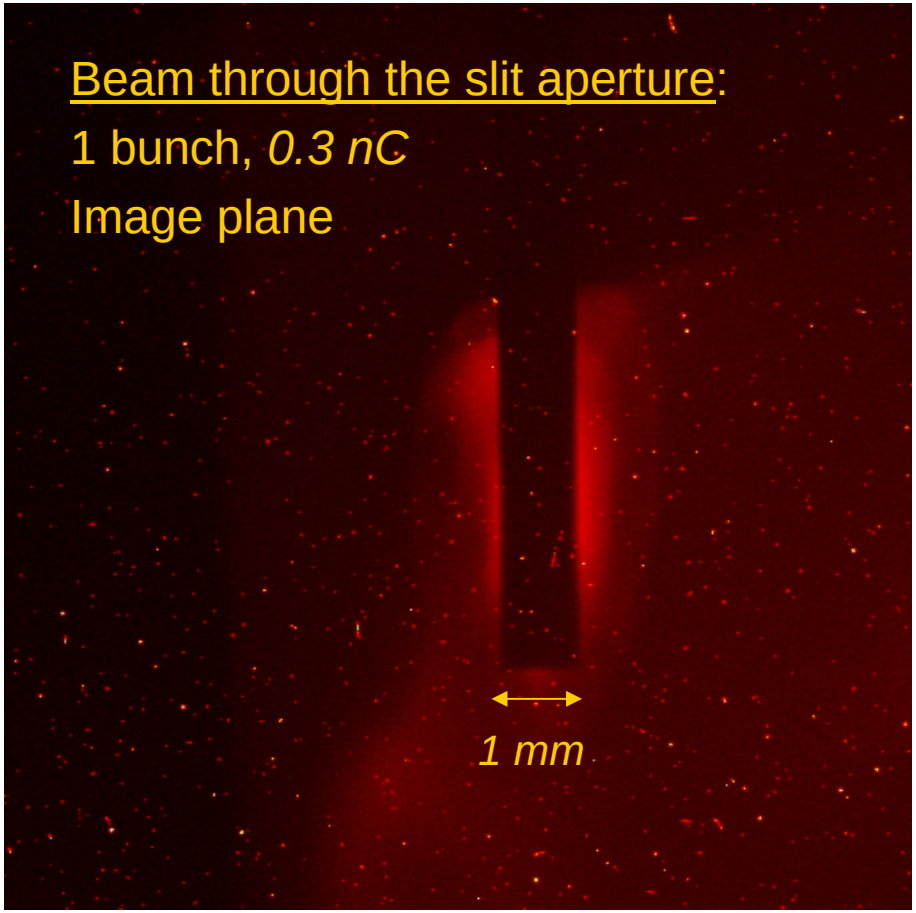
- *800 nm* interferential filter in
- polarizer in

- Simulating the slit insertion



The Best Beam





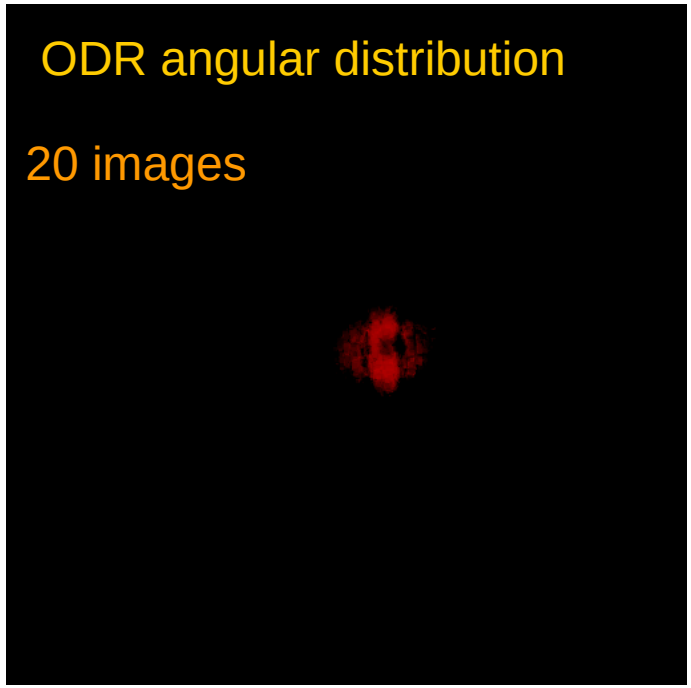
ODR Evidences

Beam transport optimization:

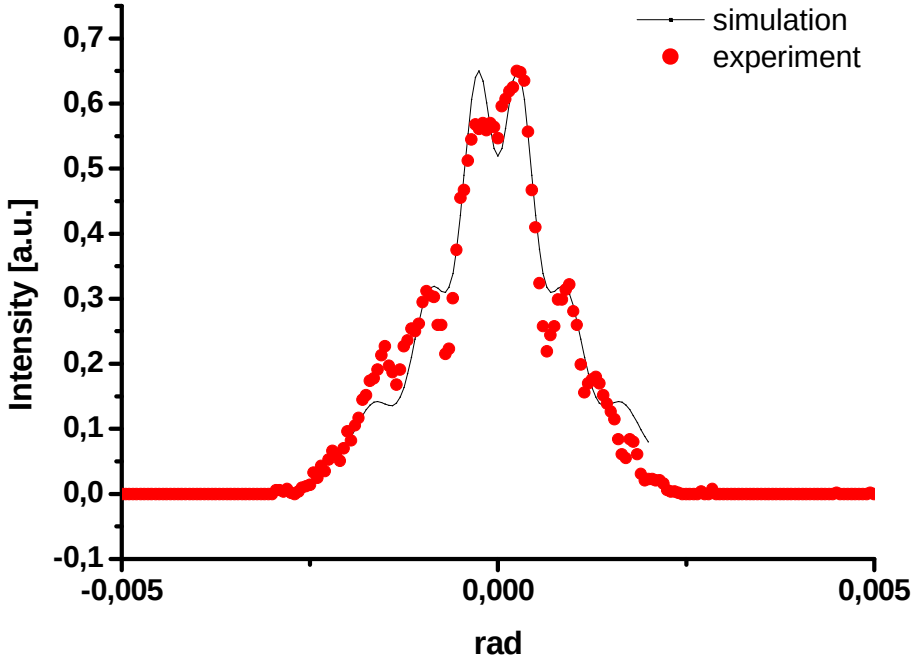
- *0.3 nC*
- 10 bunches
- *2 s* exposure time
- E_{beam} = *620 MeV*

Simulation parameters:

- *a = 1mm*
- σ_y = *150 μm*
- σ'_y = *0*
- E_{beam} = *620 MeV*



Projected ODR profile



Conclusions

- Commissioning of the ODR experiment at FLASH started
- First test of the CCD camera and the experimental setup done
- First measurements have shown a **dramatic background** which, together with **low energy** and **large and unstable beam**, makes **ODR detection difficult**
- An off-line software tool has been developed to filter x-ray and subtract background ➔ processed images give **interesting results**
- **Qualitative agreement between measurements and simulations**

Outlook

- **October '06**, *3 weeks shut-down*
  - Installation of a new target
  - shielding from SR
  - careful alignment of the whole system

- **January '07**, *Measurement shifts*
  - *700 MeV* electron beam energy
  - smaller and more stable beam ➔ *0.5 mm* slit ?
  - quasi-online background subtraction
  - better shielding of the CCD camera

- **Spring '07**
  - Shut-down to install the last module (ACC6)

- **Autumn '07**
  - *1 GeV* electron beam energy ➔ last measurements

THANKS TO …

…FLASH shift crews

…Rossano Sorchetti and Luciano Cacciotti (LNF-INFN)

…Ben Polzin

… Federica Stella and Vittorio Merlo

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