Results with the Visible Light diagnostics with EBS now in full User-service mode

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Outline

1) The ESRF complex
2) The Visible Light Extraction system
3) Visible light characterization
4) Streak Camera measurements of stored and injected bunches
5) Conclusions

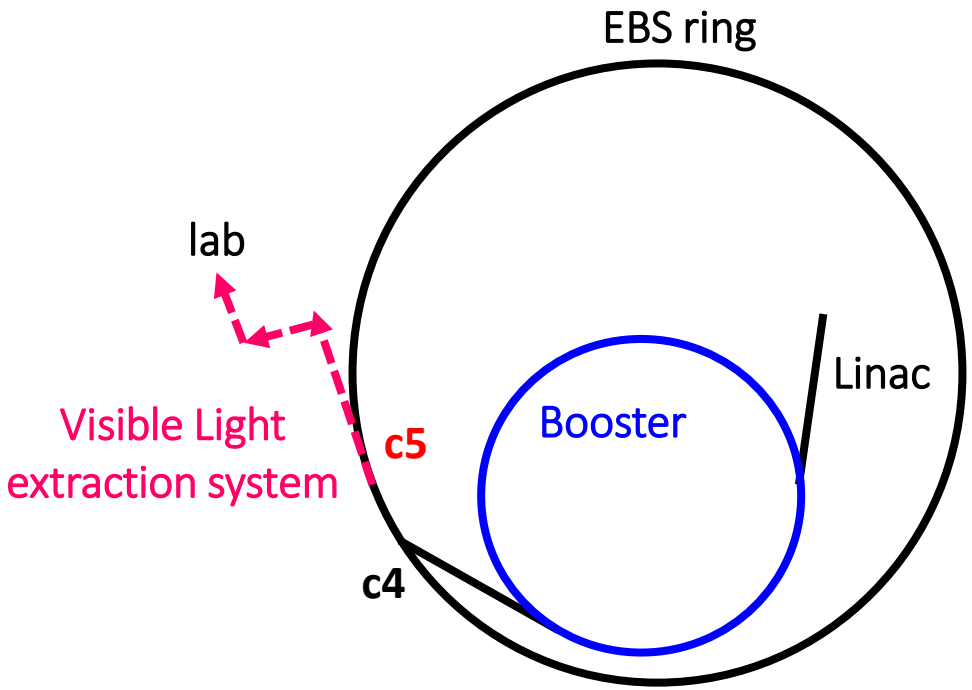
1) The ESRF complex

EBS parameters in User-mode:

- Circumference = 844 m
- Beam energy = 6 GeV
- Beam current = 200 mA
- Typical lifetime = 20h

At injection:

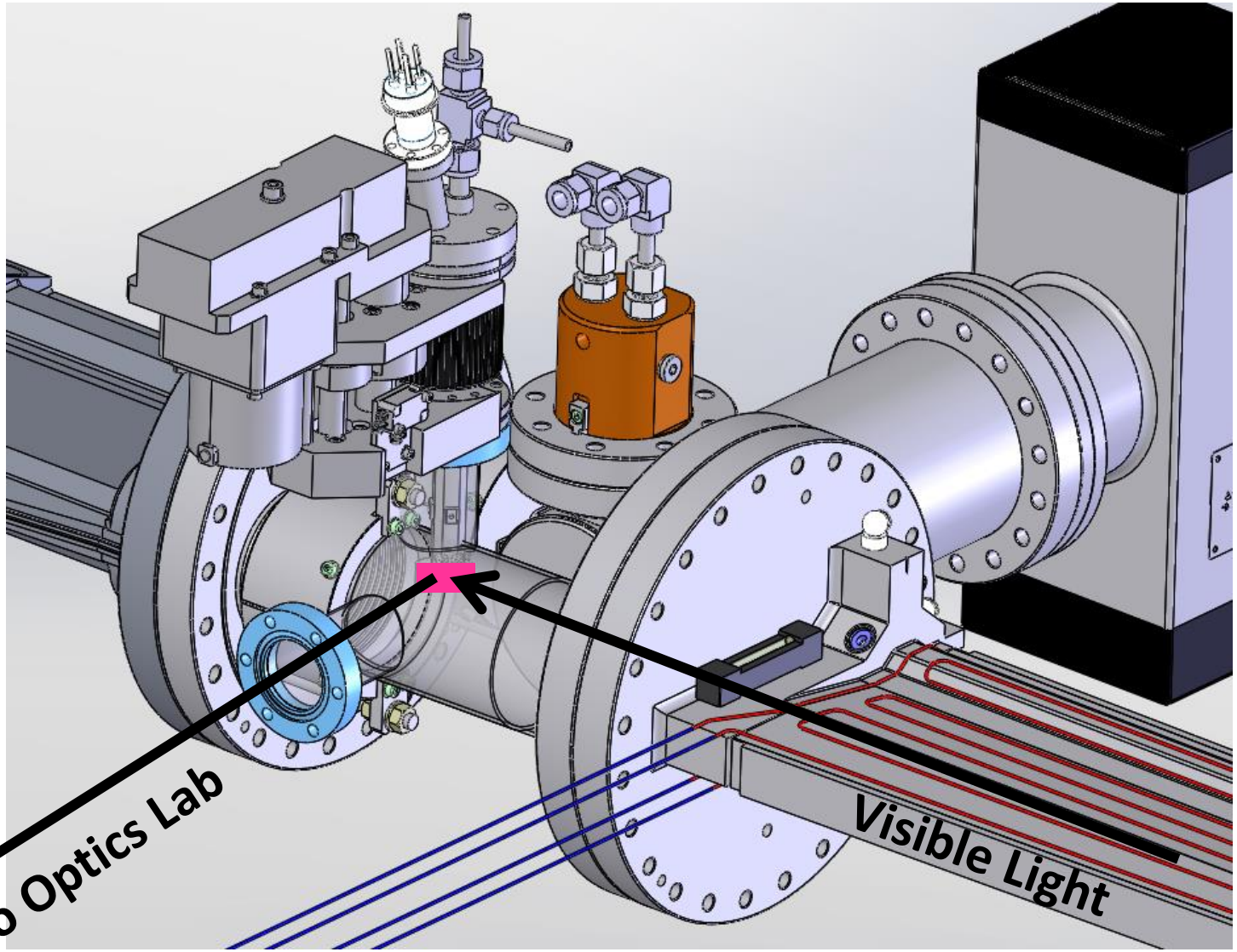
- 0.5 mA/shot
- ~ 80% injection efficiency



Visible Light Extraction system (cell 5):

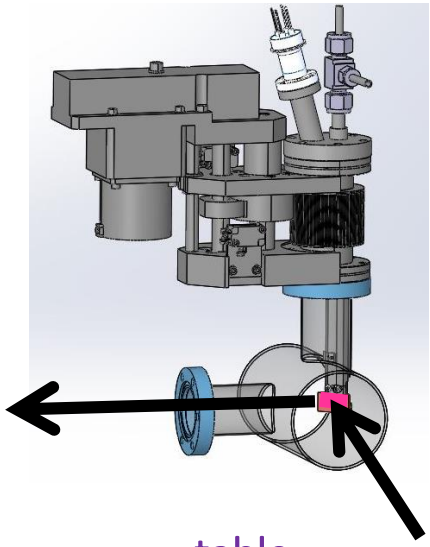
- Near the injection zone (cell 4)
- Allowing studies of both **EBS ring stored beam** and **injected beam (Booster)**

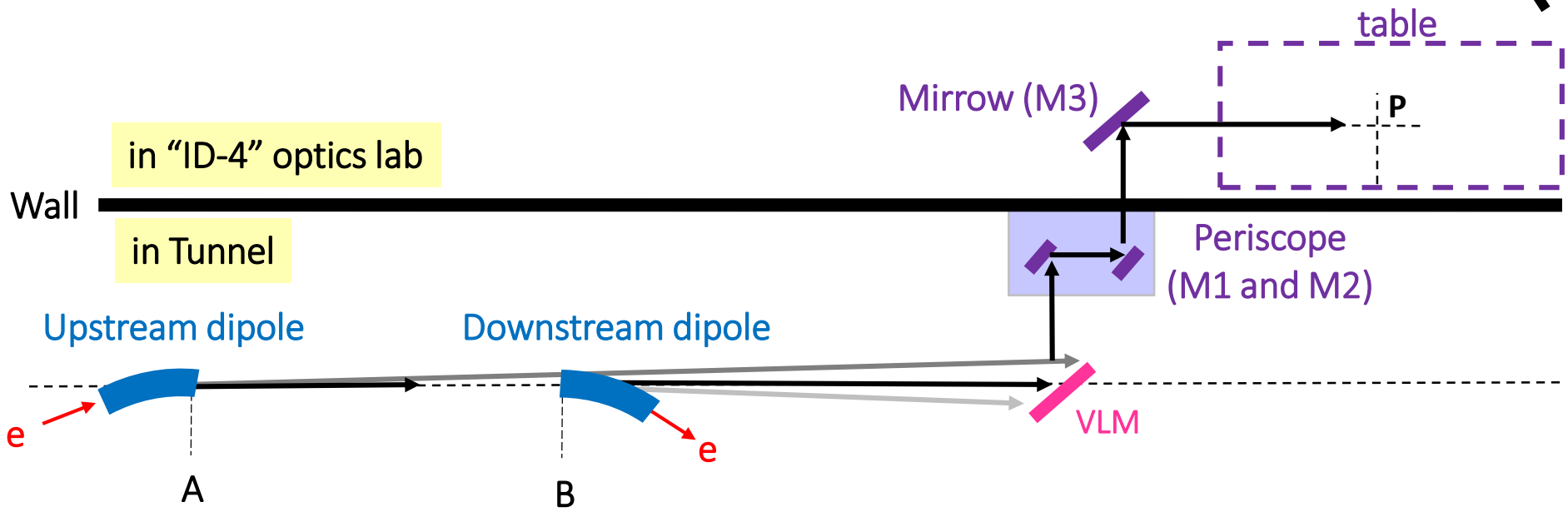
2) The Visible Light Mirror (VLM):



2) The Visible Light Extraction system

- Extracting light from the **Cell-5 dipole** to the optics lab (**ID-4**)
- Chicanes and radiation shielding well aligned since December 2020
- VLM mirror: 30 mm · 20 mm
- The VLM mirror can **be fully inserted** only **for low currents** (< 5 mA) due to the X-rays heat load



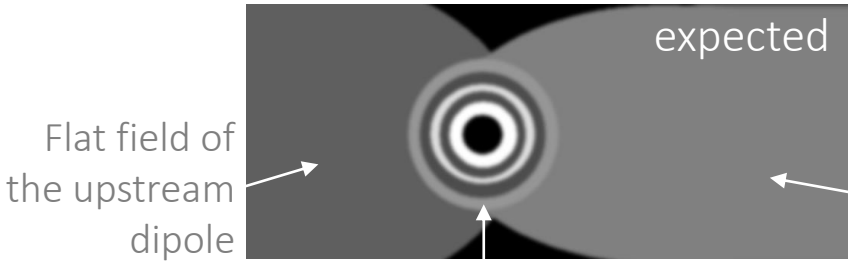


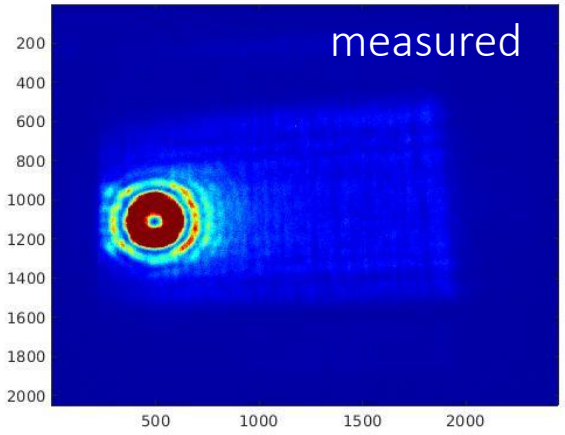
3) Visible Light characterization

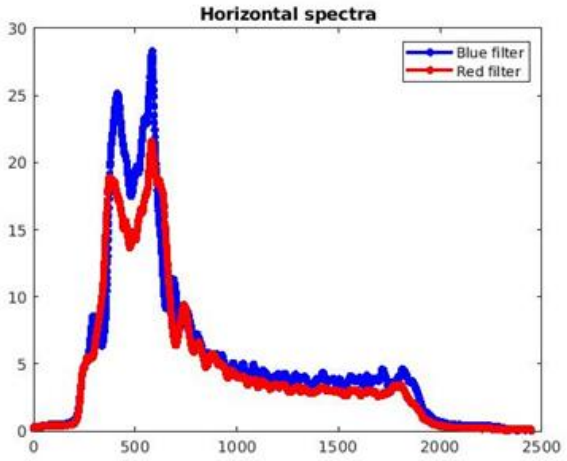
Machine Dedicated Time (MDT) performed with:

- **1 mA beam current:** the VLM **mirror** can **be fully inserted**
- no mirror surface deformation from the X-rays heat load
- flat field limited by absorber + vacuum aperture

- The full visible light cone corresponds to the expectations:



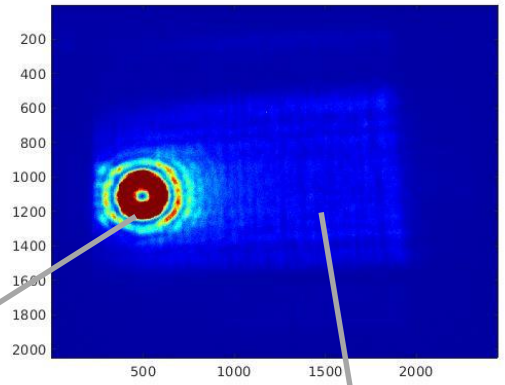




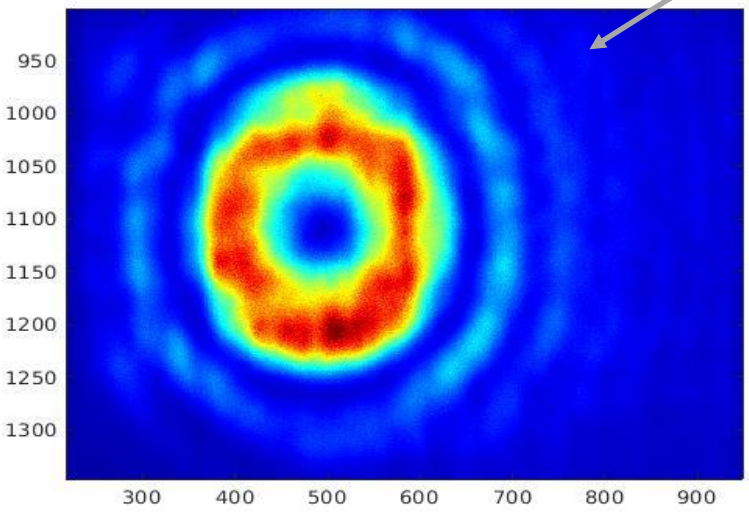
- The use of **different filters** allows to study the interference zone

3) Visible Light characterization

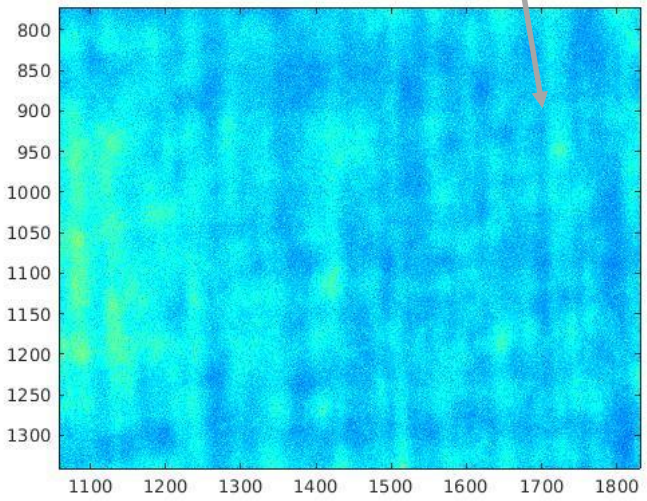
- Quality of the light-wavefront (absence of strong distortions):



a) interference zone
at different wavelengths



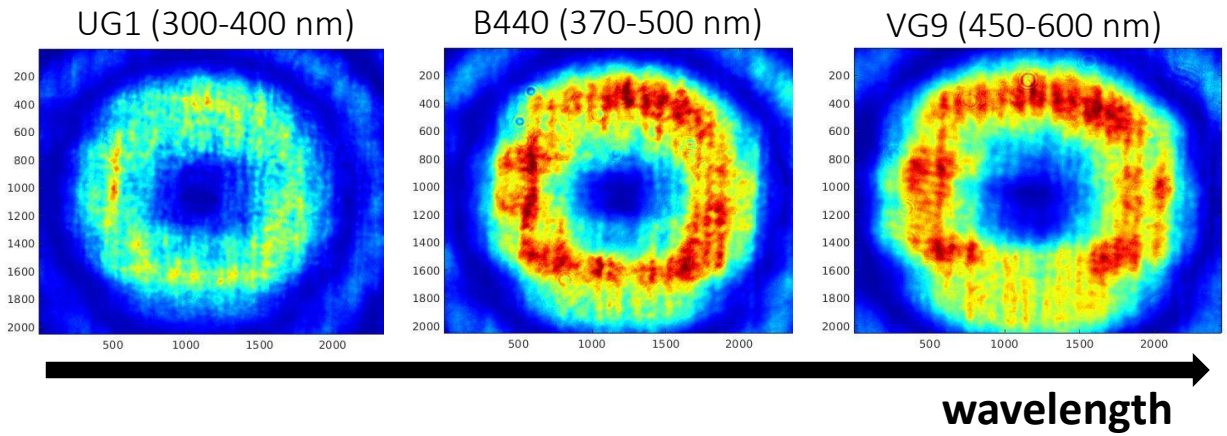
b) flat-field of the downstream dipole
(lens-achromat measurement
to verify the correct conjugate distances)

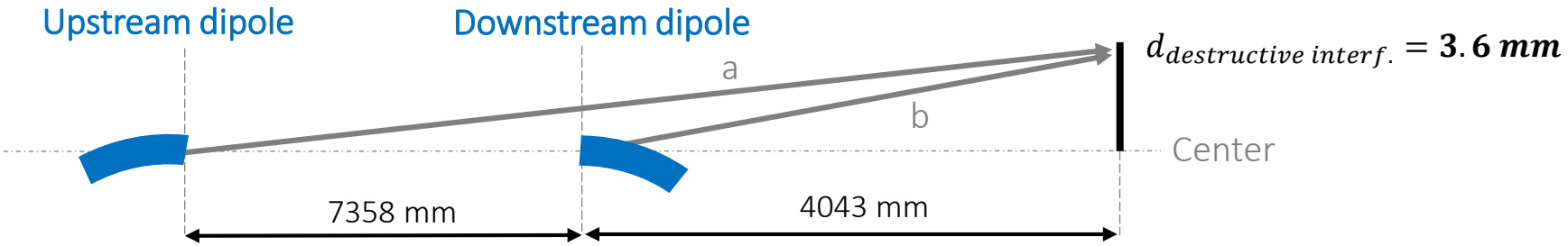


3) Visible Light characterization

a) interference zone: different filters, different wavelengths, different pattern width

For **lower wavelengths** the horizontal profile shows a **narrower width** of the constructive interference, as expected.





$d_{destructive\ interf.} = \mathbf{3.6\ mm}$

$$(a-b) = \frac{\lambda}{2} + n\lambda$$ for a destructive interference

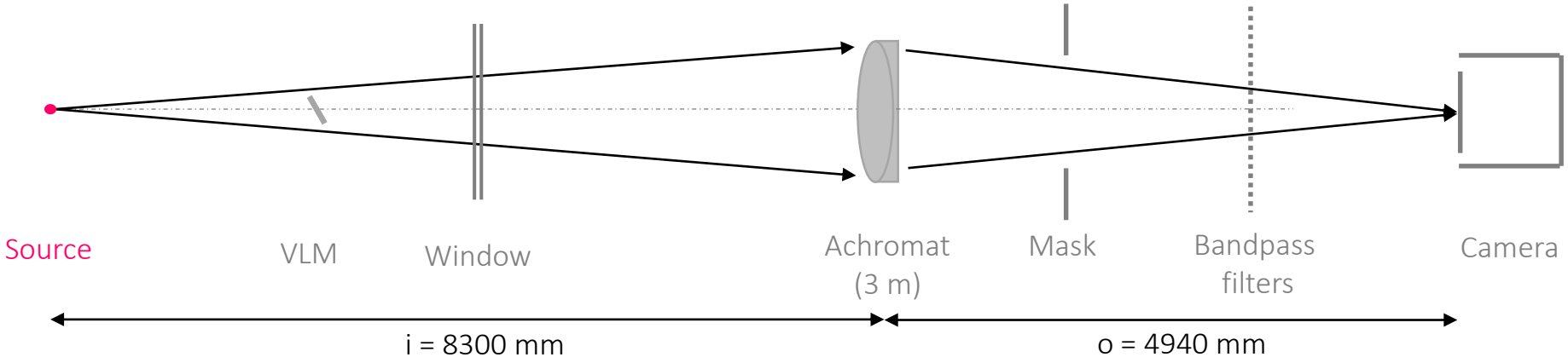
$$y_{min} = m\lambda\frac{D}{d} = m \cdot 440\ nm \cdot \frac{1}{3.7\ mrad} = \mathbf{3.57\ mm}$$

The measurements and the calculations agree.

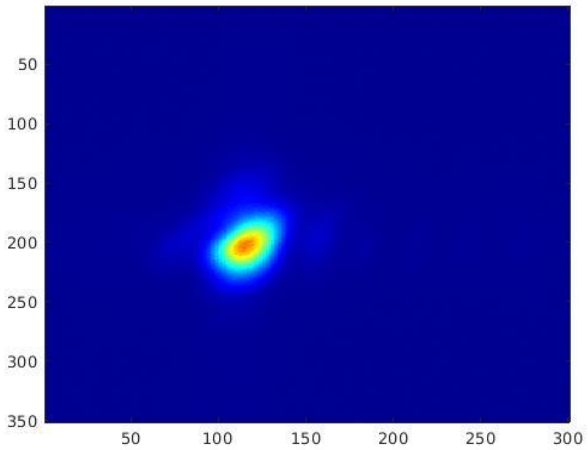
3) Visible Light characterization

b) flat-field of the downstream dipole (with a 3 m achromat)

- For beam current < 5 mA, the mirror can be **fully inserted**



Magnification factor $M = \frac{o}{i} = 0.595$



3) Visible Light characterization

b) flat-field of the downstream dipole (with a 3 m achromat)

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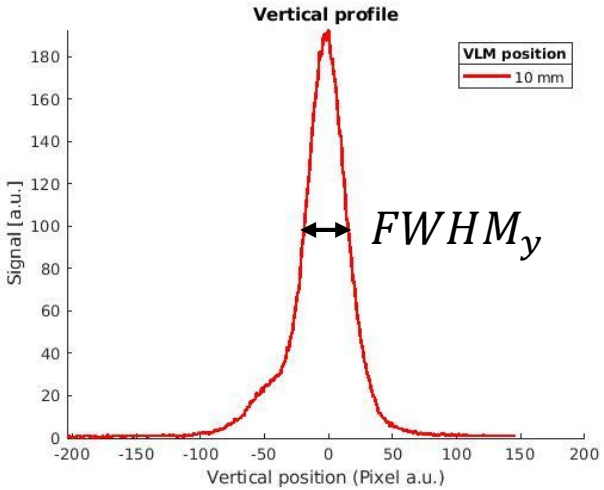
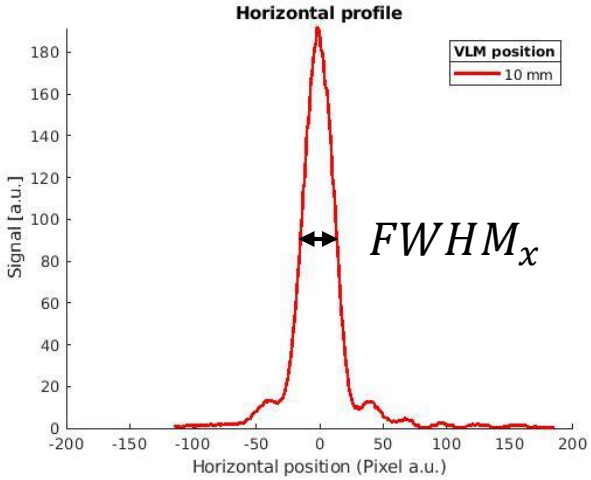




$$FWHM_y = \frac{spotsize \cdot resolution}{M} = \frac{35.13\ pixels\ \cdot 3.45 \frac{\mu m}{pixel}}{0.595} = 204\ \mu m$$

$$FWHM_x = \frac{spotsize \cdot resolution}{M} = \frac{27.50\ pixels\ \cdot 3.45 \frac{\mu m}{pixel}}{0.595} = 160\ \mu m$$

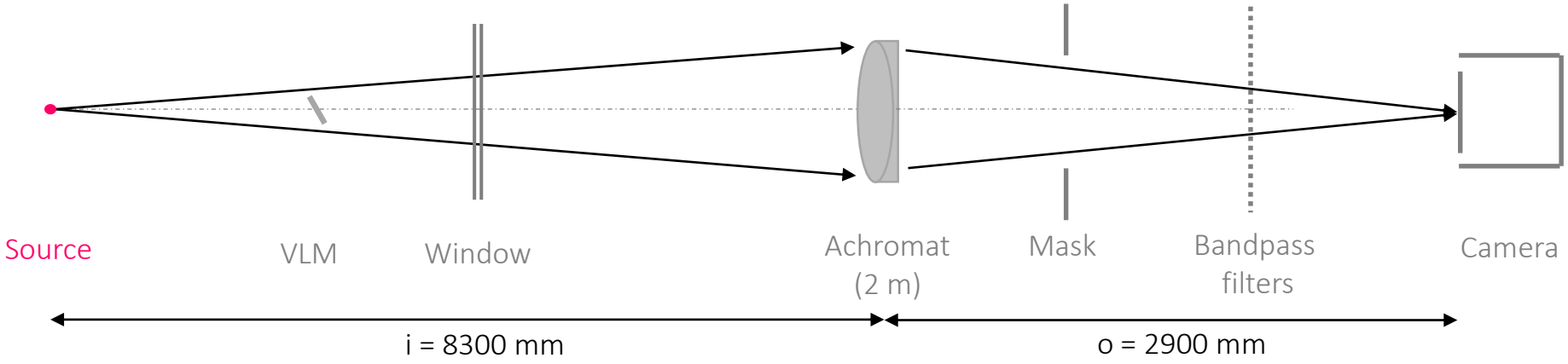
$$FWHM_{calculated} \cong \frac{\lambda}{a} = \frac{0.5\ \mu m}{3\ mrad} = 167\ \mu m$$

The measurements and the calculations agree (error < 20%).
No waveform distortions.

3) Visible Light characterization

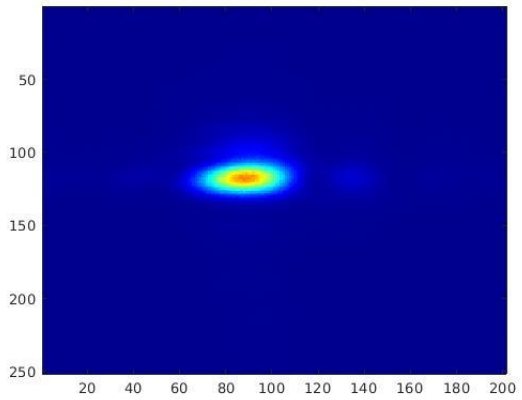
b) flat-field of the downstream dipole (with a **2 m** achromat)

- We applied vertically-limited masks (height: 1 cm, 1.5 cm, 2 cm, width: 3.9 cm)

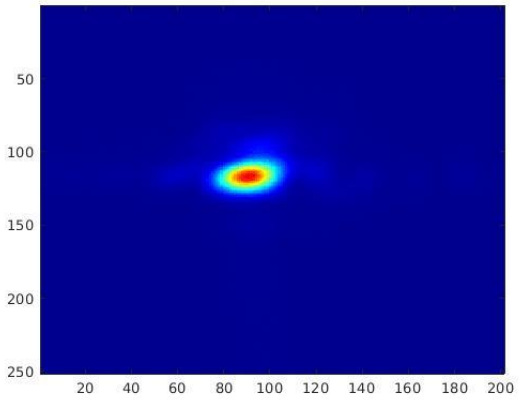


Magnification factor $M = \frac{o}{i} = 0.349$

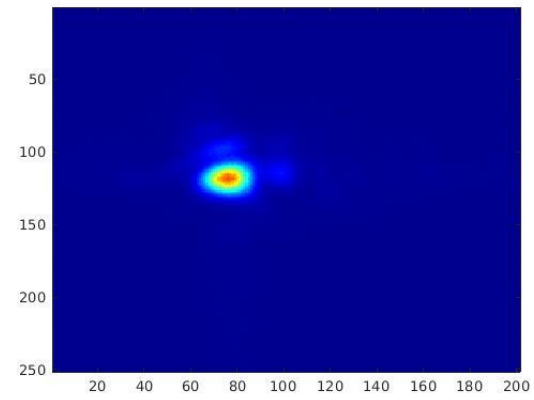
1 cm mask



1.5 cm mask



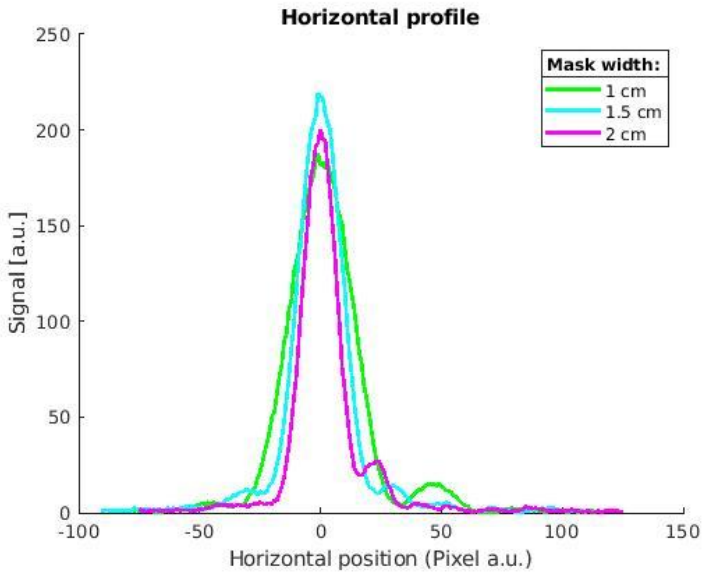
2 cm mask

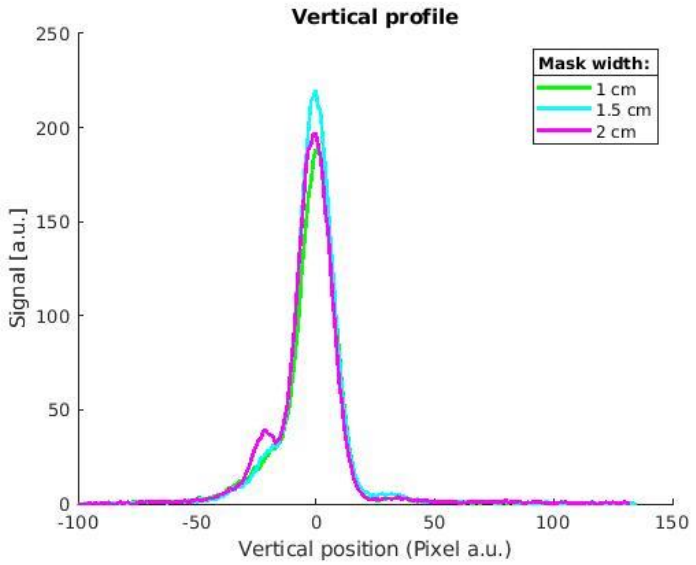


3) Visible Light characterization

b) flat-field of the downstream dipole (with a 2 m achromat)

- The larger the mask, the less diffraction limited in the horizontal axis
- No effect in the vertical axis





4) Streak Camera measurements

- Measurement performed with a **Streak Camera (SC)** to measure the **bunch length** of both the stored and the injected beam in EBS

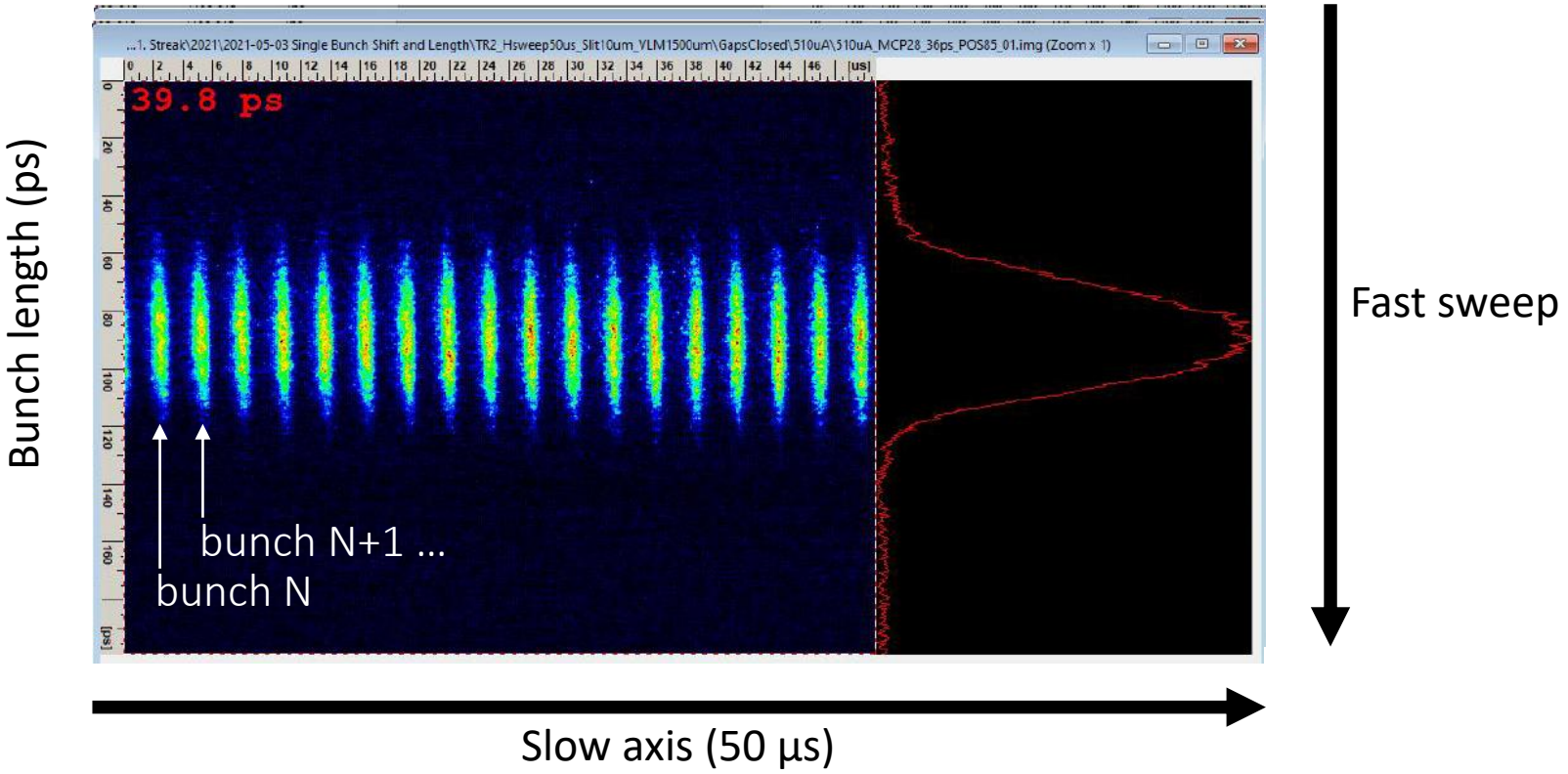
Universal streak camera,
(C10910 series, Hamamatsu)

SC parameters:

- Blanking amplitude: variable between 500 us and 5 ms
- Sweep speed: variable between 1 and 5
- Variable delay and trigger
- Vertical aperture of the slit: 0-200 um

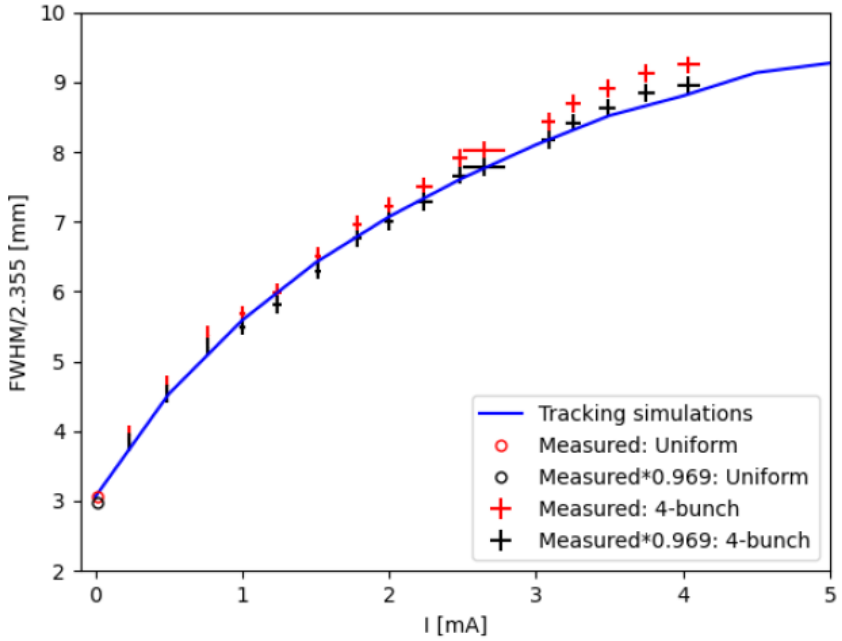
4.1) Stored-beam measurements

- Standard measurement performed at 0.5 mA per bunch
- Bunch length: 40 ps corresponds to 12 mm

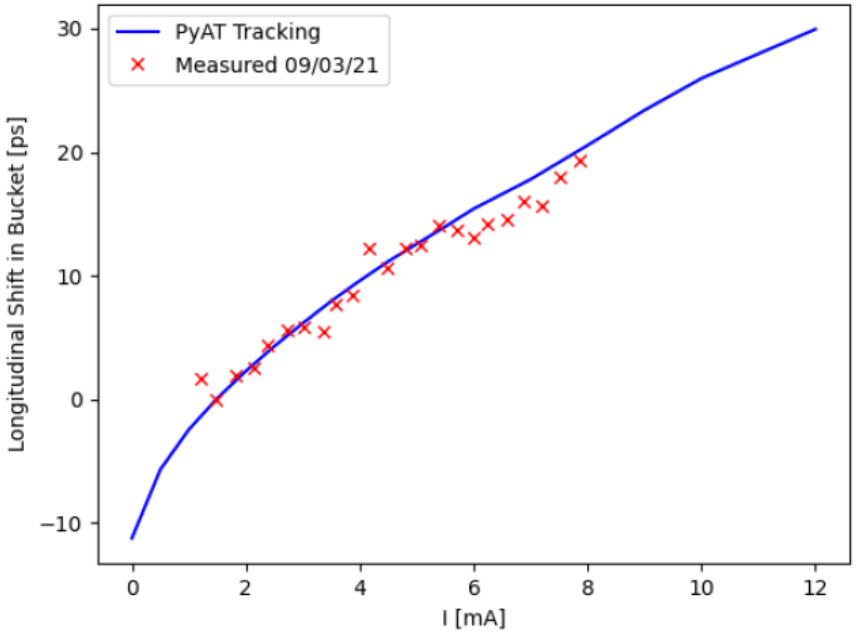


4.1) Stored-beam measurements

1) Bunch length as a function of the bunch current



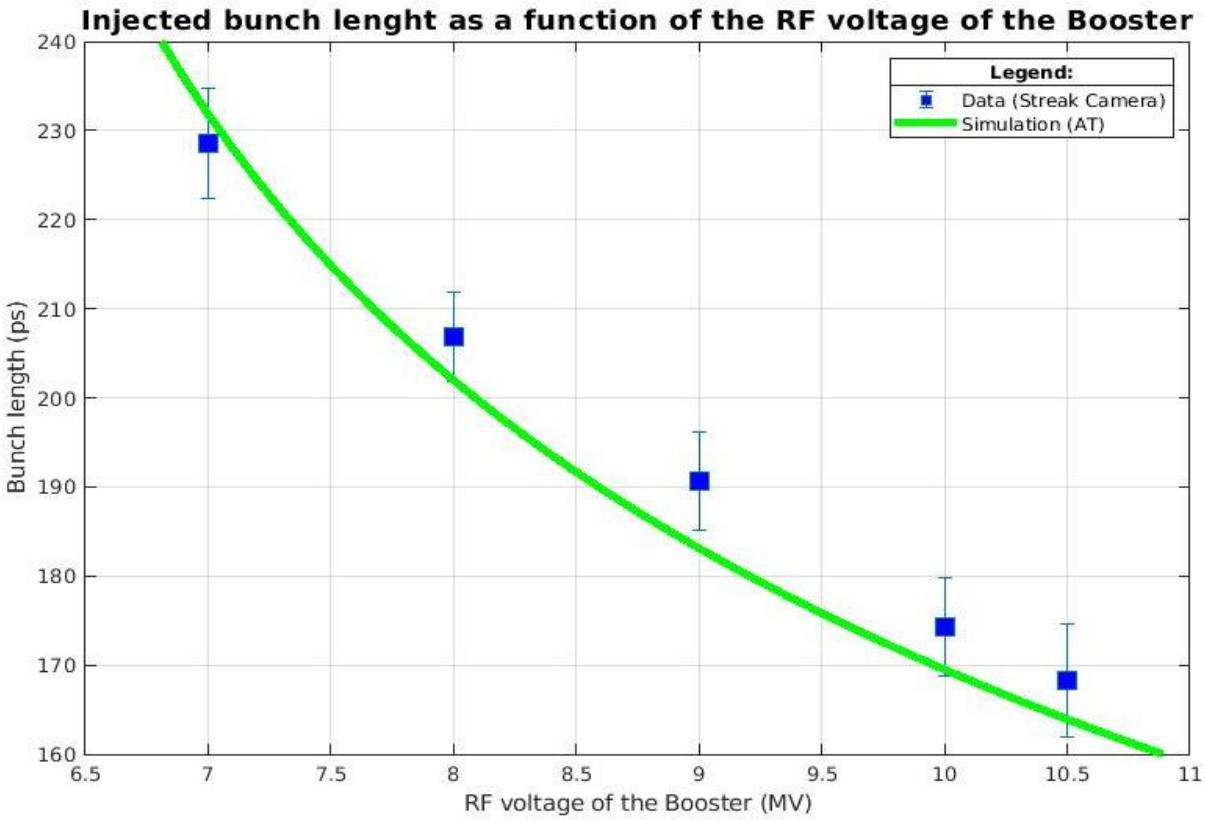
2) Bunch phase (longitudinal shift in bucket) as a function of the bunch current



L.R. Carter, E. Buratin, N. Carmignani, F. Ewald, L. Houmni, S. Liuzzo, T. Perron, B. Roche, S. White, ''*Single Bunch Collective Effects in the EBS Storage Ring*'', IPAC 2021

4.2) Injected-beam measurements

1) Bunch length of the injected beam as a function of the Booster RF voltage



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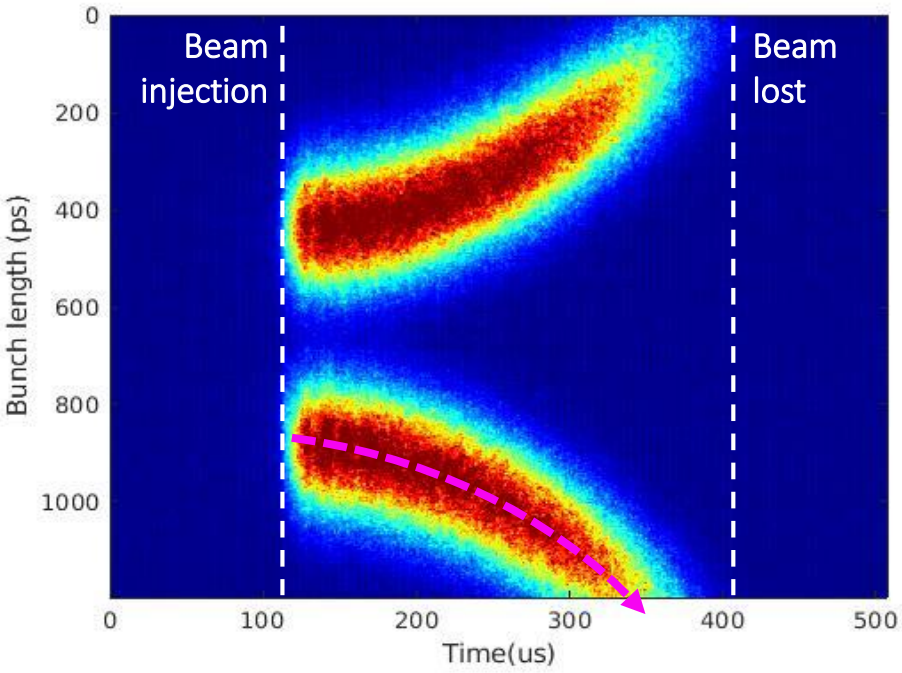
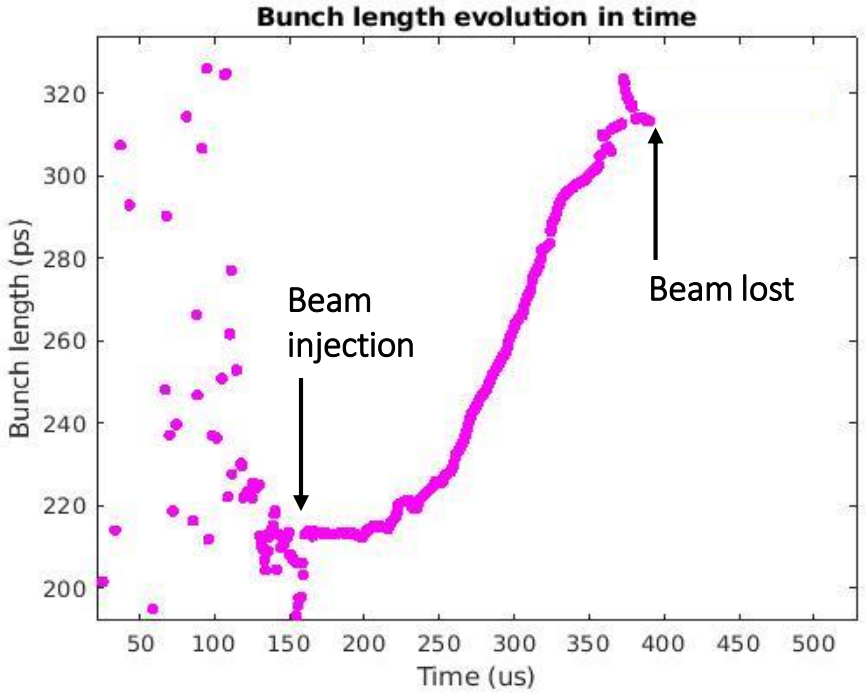
4.2) Injected-beam measurements

2) Longitudinal behavior at injection with RF off in EBS

- The fast sweep frequency (88 MHz) is one fourth of the RF master frequency (352 MHz), therefore its generates 2 streaks in the output image.
- The beam shifts position along the bucket
- The bunch length increases
- Beam lost in ~100 turns

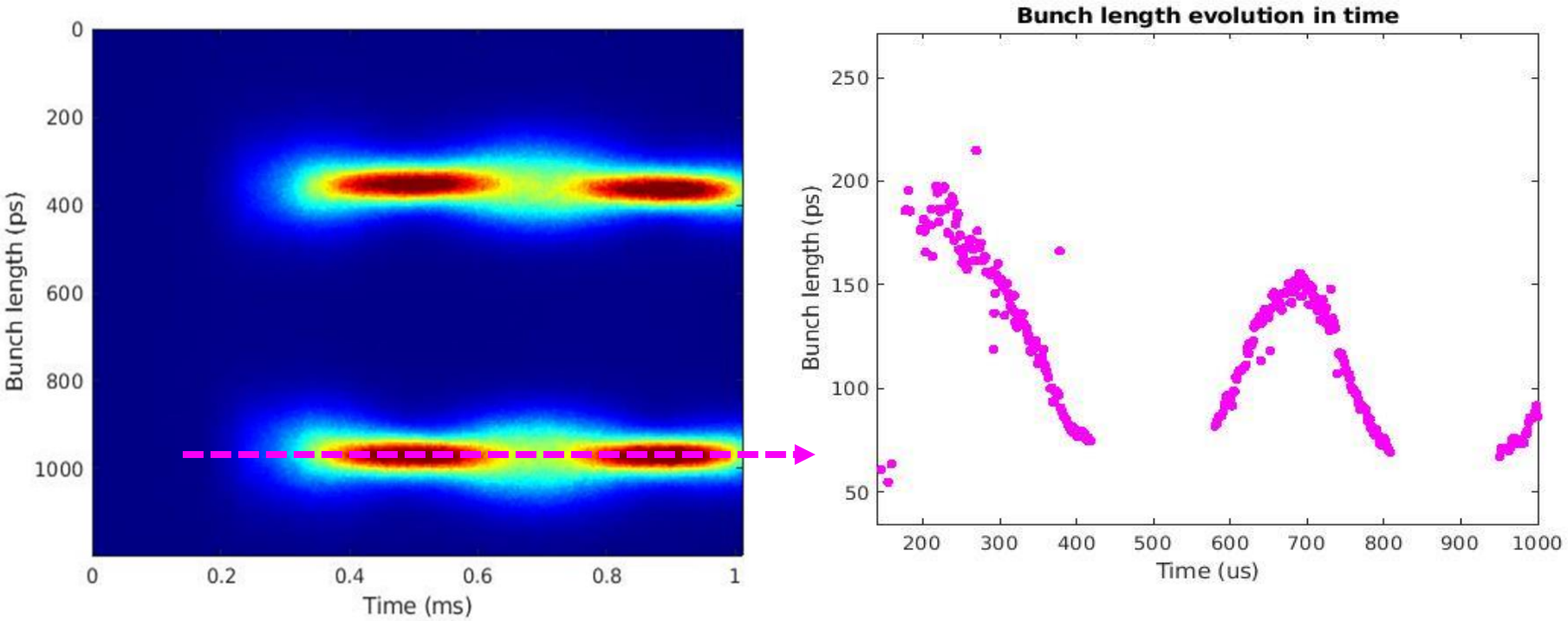




4.2) Injected-beam measurements

3) Longitudinal behavior at injection with RF on in EBS: beam stored

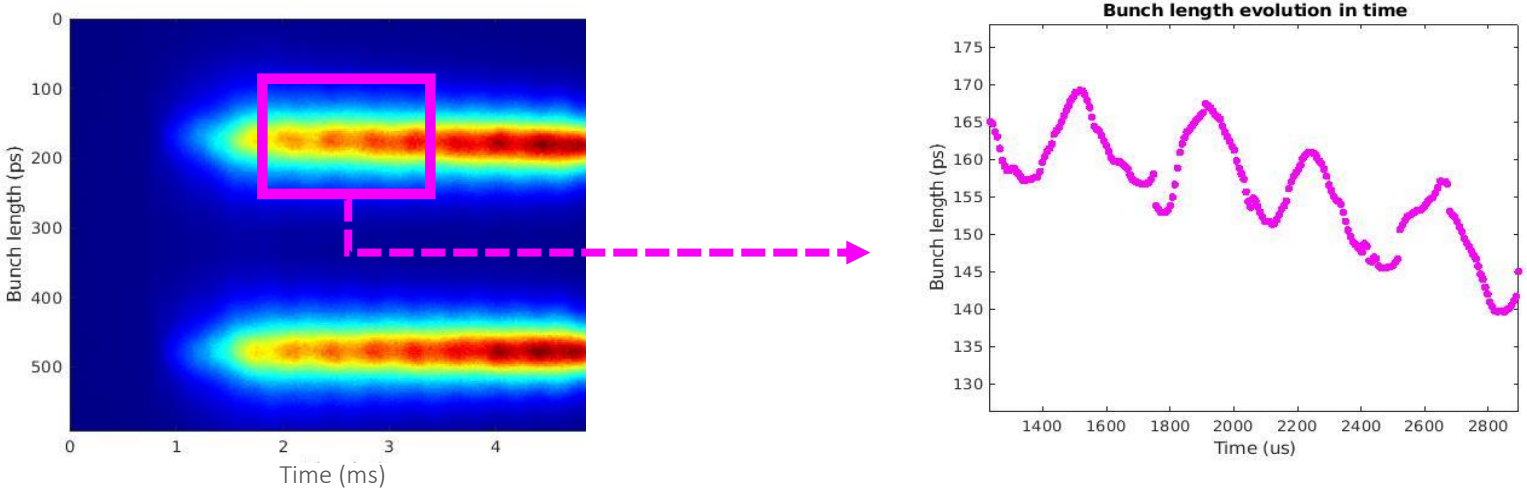
- 2 streaks generated due to the fast sweep frequency
- The bunch length oscillates
- Saturated signal



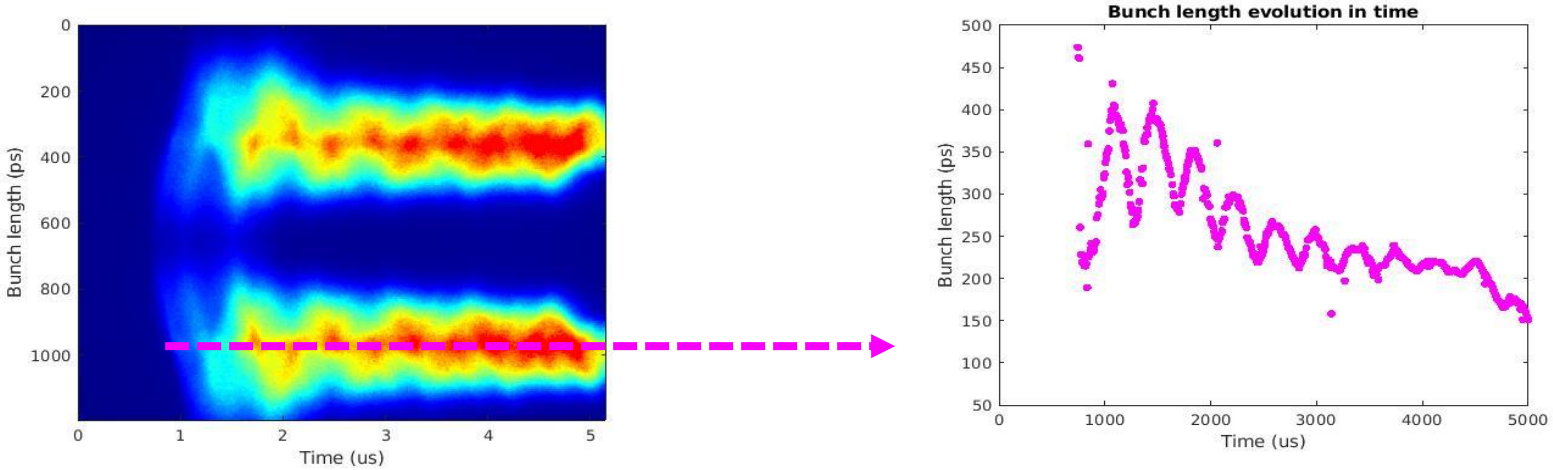
4.2) Injected-beam measurements

4) Longitudinal behavior: oscillations visible for few ms (0.4 ms apart)

- visible on Beam Loss Monitors (BLMs) as well!



5) Longitudinal behavior: degrading the phase, we see damped oscillations with a decreasing trend



5) Conclusions

The Visible Light Mirror (VLM) allows to extract the visible light from EBS. It has been completely and optimally aligned to obtain distortion-free light in a radiation-free laboratory.

We could characterize the light and detect the light from the 2 dipoles and their interference, with different filters and achromats.

We can measure the bunch length and the beam's longitudinal behavior with a Streak Camera, for both stored and injected bunches. The injected bunch length oscillates for few milliseconds, and this is also visible on the Beam Loss Detectors (BLDs) and on the Beam Position Monitors (BPM).

Next, we plan to install a gated **image intensifier** for transverse beam size measurements of the injected beam and a **PicoHarp photon-counter** for bunch purity measurements.

Many Thanks
for your Attention!