Overview of Bunch-Resolved Diagnostics for the Future BESSY VSR Electron-Storage Ring

HZB Helmholtz Zentrum Berlin

Gregor Schiwietz, Ji-Gwang Hwang,
Marten Koopmans, Markus Ries

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The BESSY VSR Project

See *Technical Design Study BESSY VSR*

Variable pulse-length **S**torage **R**ing

by A. Jankowiak et al. (June 2015)

BESSY VSR Project

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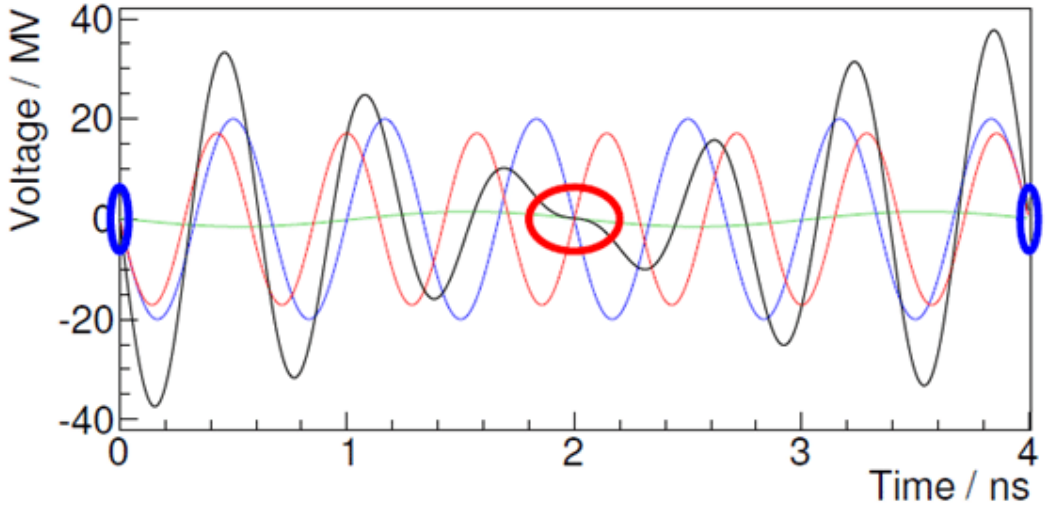
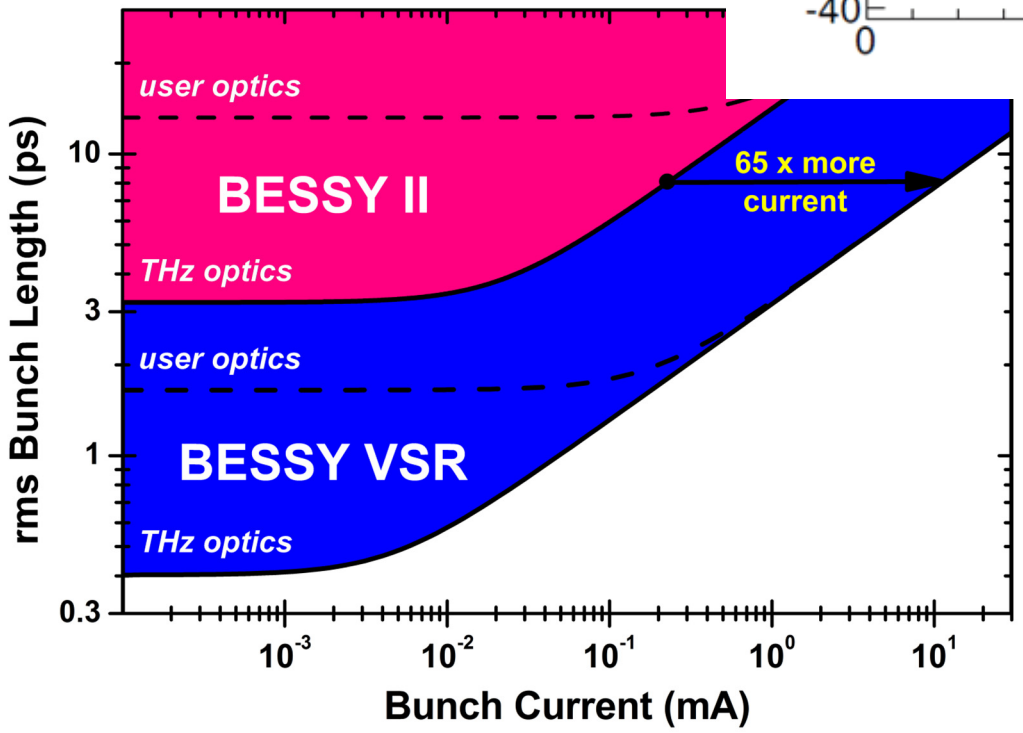
Superposition of RF at
0.5 GHz (BESSY II) and additionally
1.5 GHz plus 1.75 GHz, provided
by superconducting cavities
at high voltage,
leads to a beating pattern
of the effective electrical fields





BESSY VSR Project

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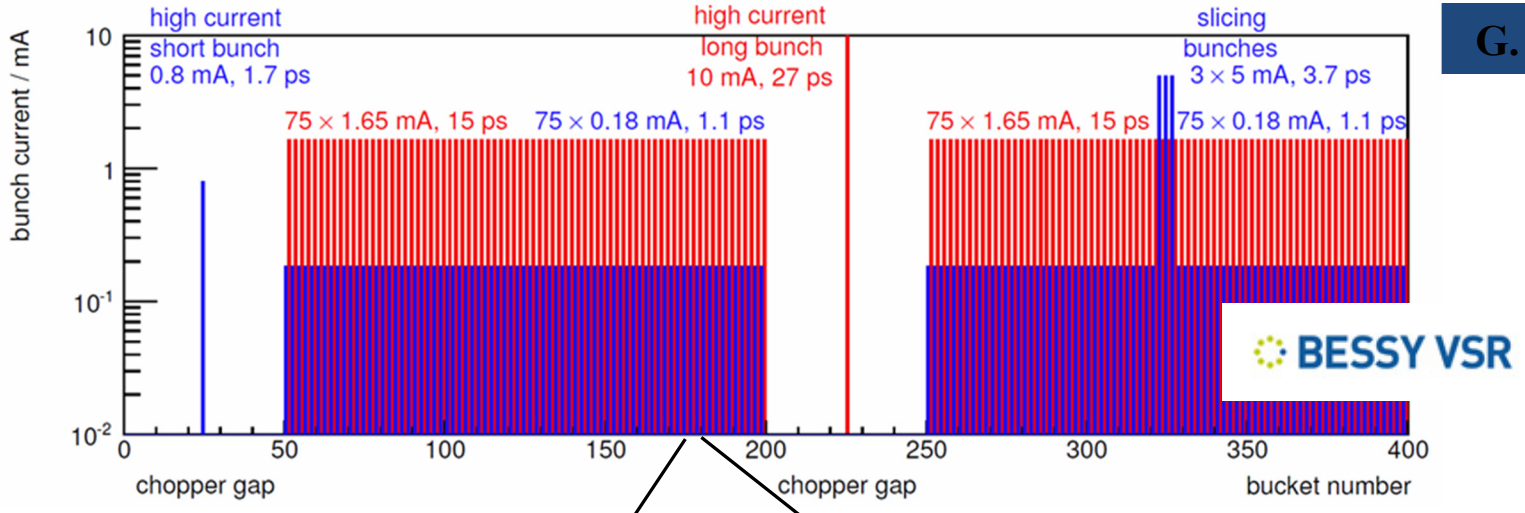

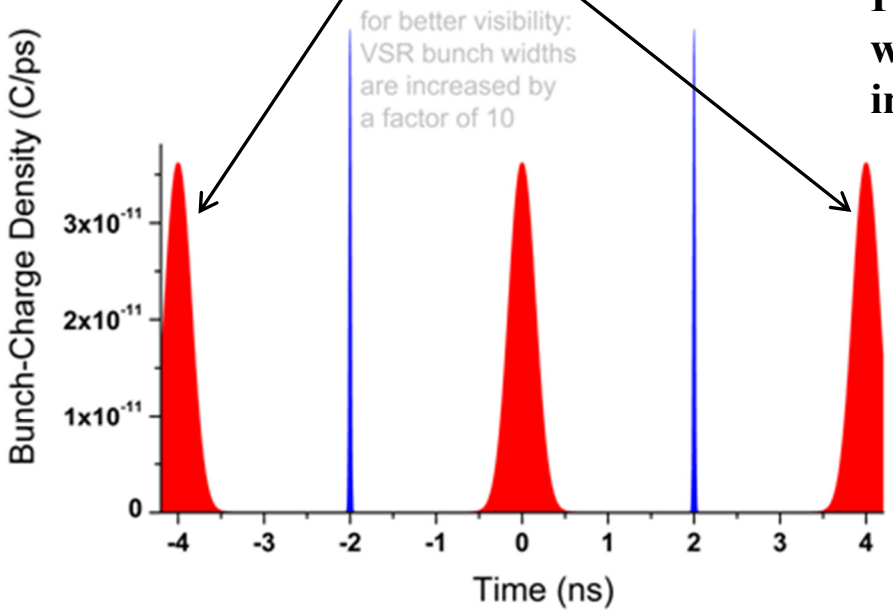

Possible BESSY-VSR timing pattern with gaps and bunches of different intensities and lengths.

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New Beamlines for Bunch-Resolved Optical Beam Diagnostics

Necessary Properties:

- **Nondestructive detailed (multi-parameter) diagnostics**
- **Robust 24/7 availability → dipole beamlines**
- **Bunch resolved operation**

Beamlines

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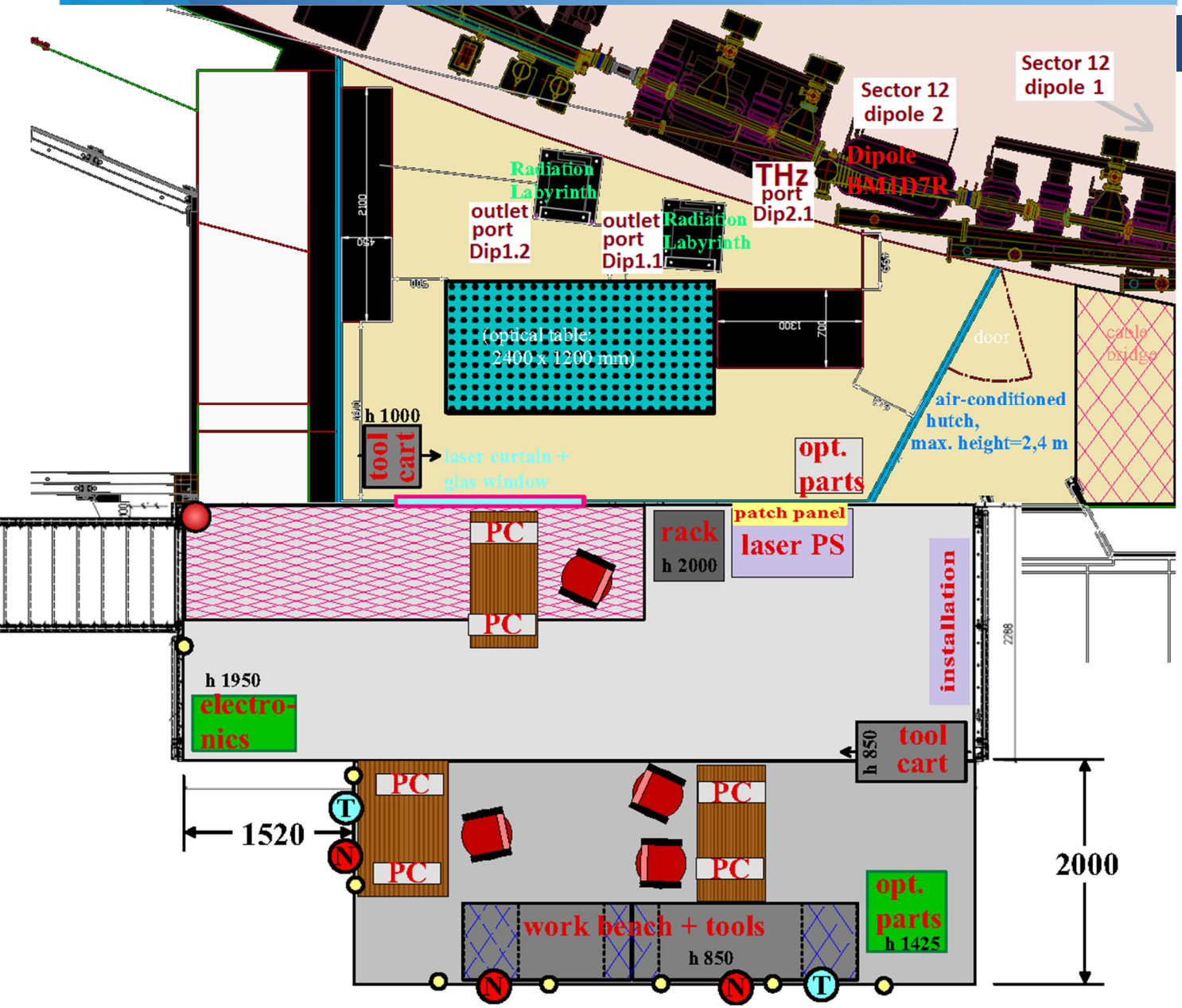

Dipole
BM2T6R

Schematic Top View

Transverse Beam Size:
Interferometry
(vs. geometrical Optics)

Interferometry

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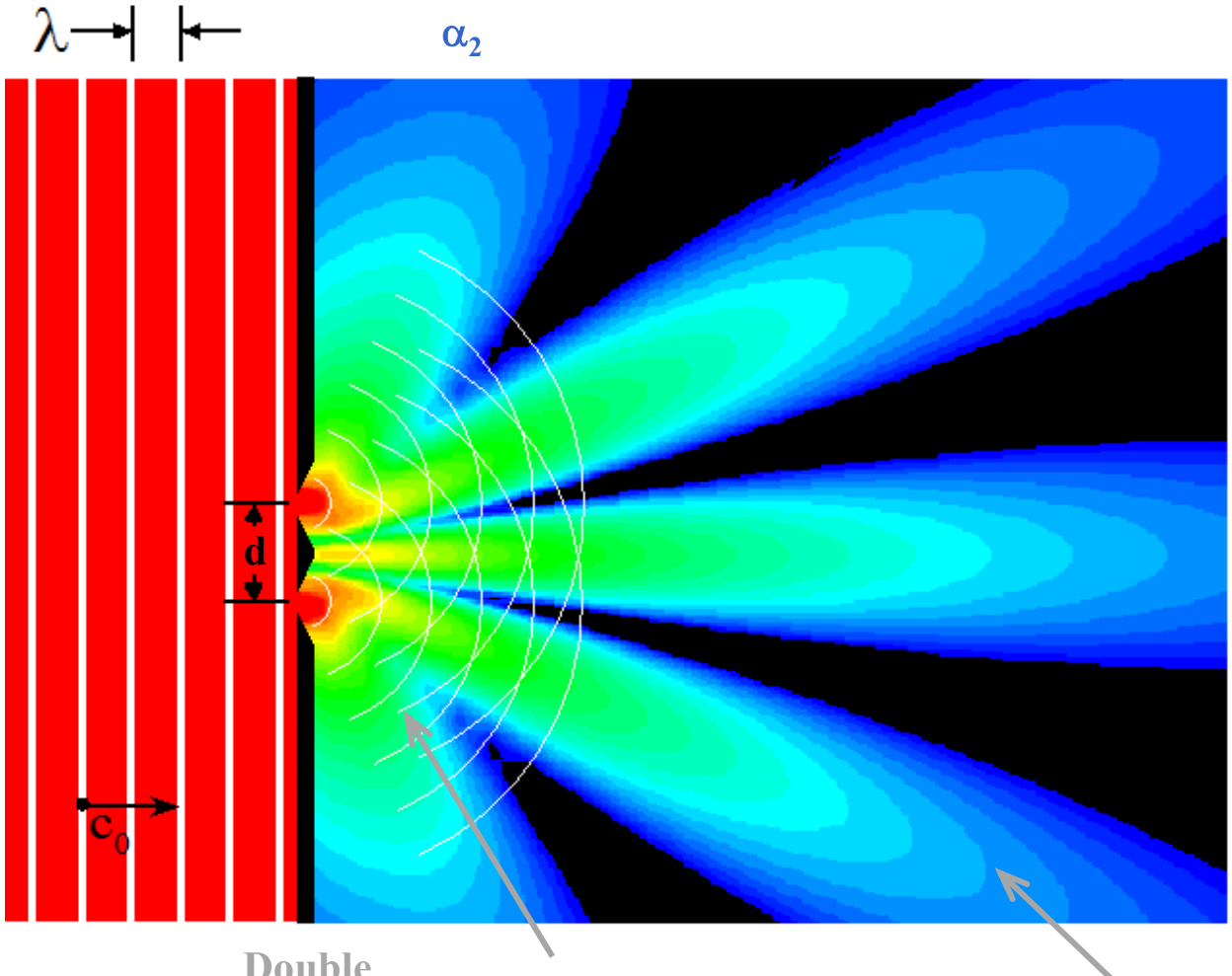

$$\sin \alpha_n = n \cdot \lambda / d$$

Interferometry

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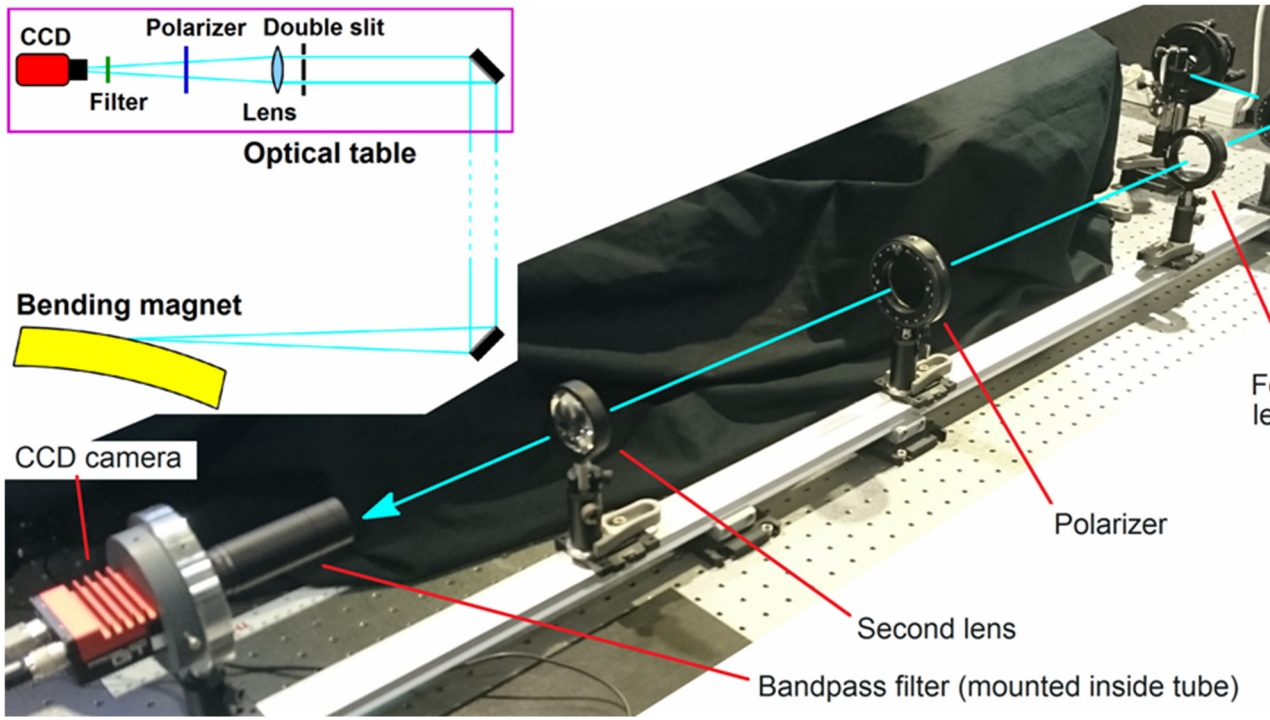
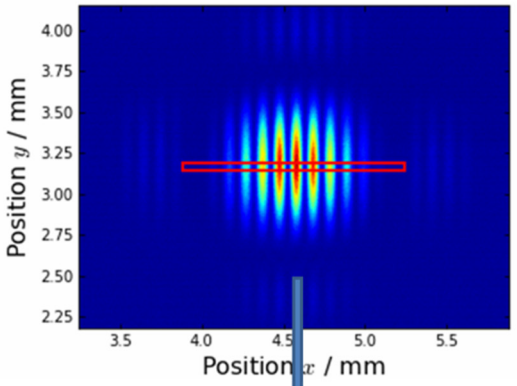
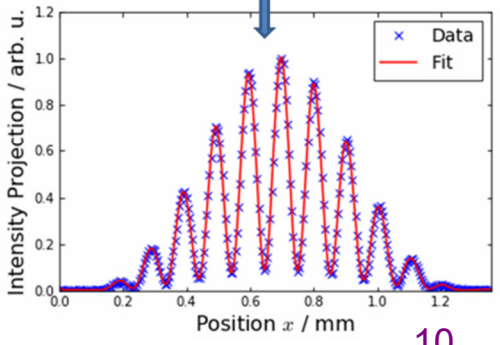


CCD Measurement





Master Thesis Marten Koopmans:
successful tests of double-slit method

see also T. Mitsuhashi in: Beam measurement
(ed. by S. Kurokawa et al., pp. 399–427, World Scientific 1999).

Scheme and photo of the optical Interferometric Beam-Size Monitor (IBSM)

Interferometry

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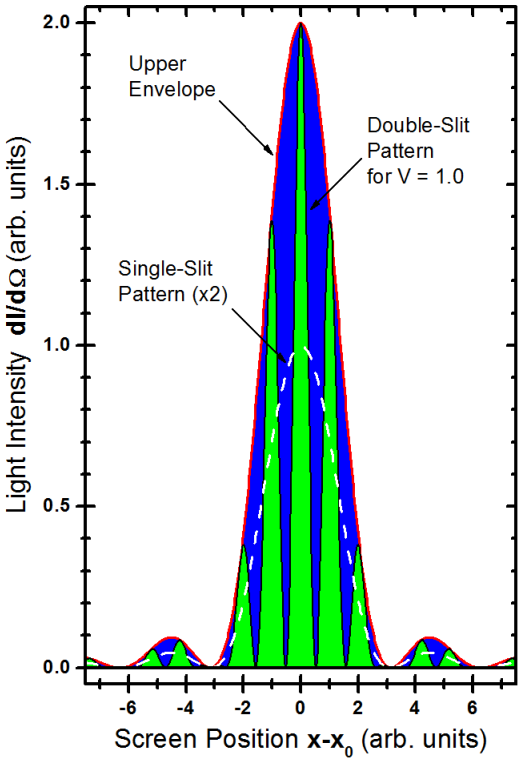
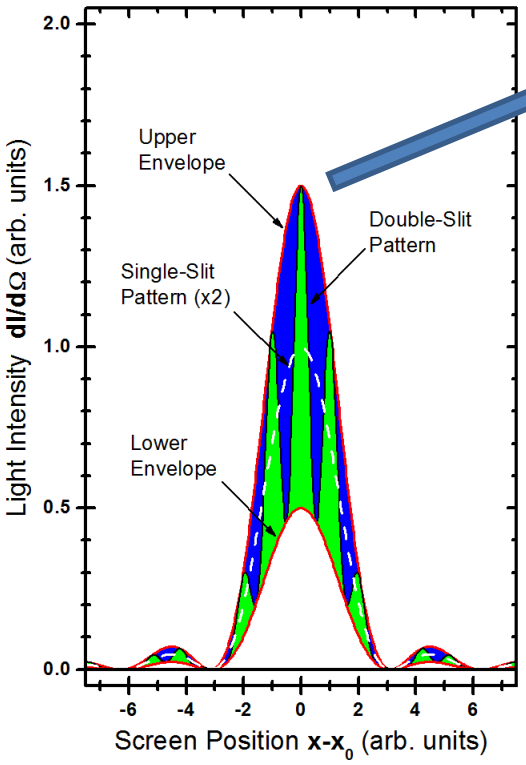
$$V \cong (I_{max} - I_{min})/(I_{max} + I_{min})$$

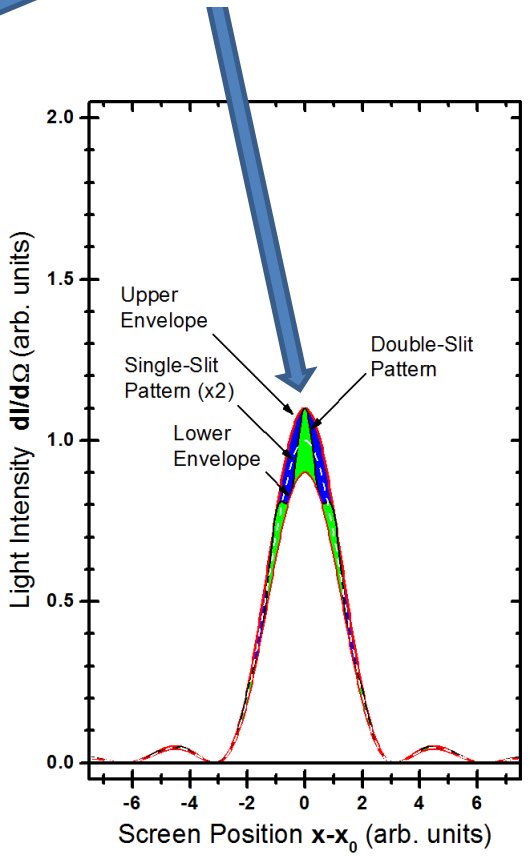


Full spatial coherence:
Point source visibility
V = 1.0



Reduced spatial coherence:
Visibility *V = 0.5*

Increase by a factor of *1.8* in σ



Reduced spatial coherence:
Visibility *V = 0.1*

Interferometry

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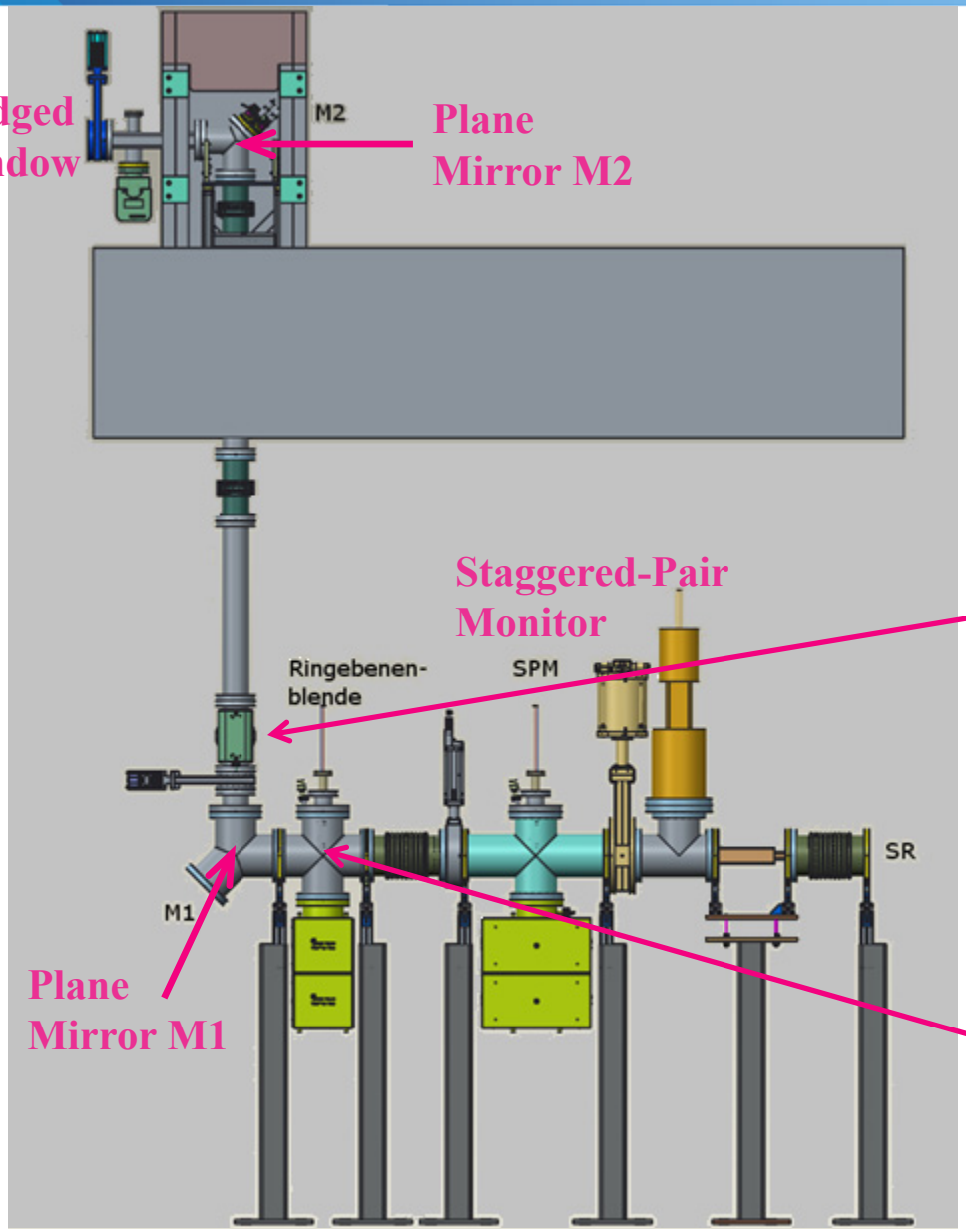

BM2T6R

Sector 12 Dip1.2:

Lateral Bunch-Size: Interferometry with ICCD

Selectable/retractable interference target plus retractable achromatic lens

X-Ray Blocking Baffle

Problems and Solutions

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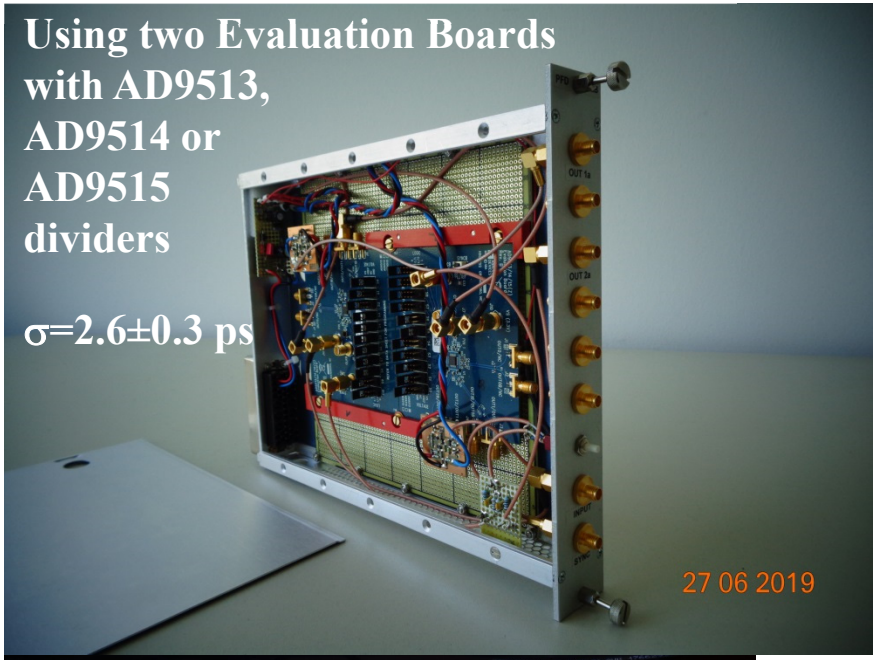
Fast gated Intensified CCD (ICCD), 4 channels
Exposure time: 200 ps to 80 s
Low jitter : < 10 ps rms
Multiple-gate repetition frequency: < 2.0 MHz
High dynamic Range: 14 bit

Needed: improved revolution trigger



Bunch Length:
High Time Resolution and 2D Streak-Camera Modes

Beamlines

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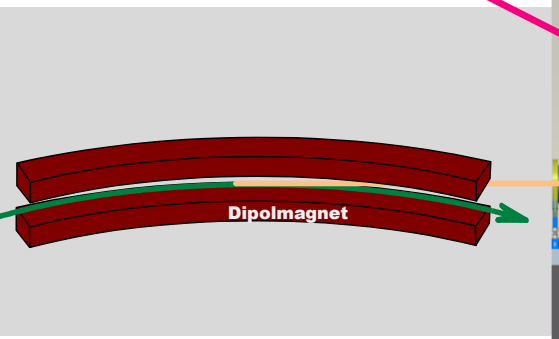
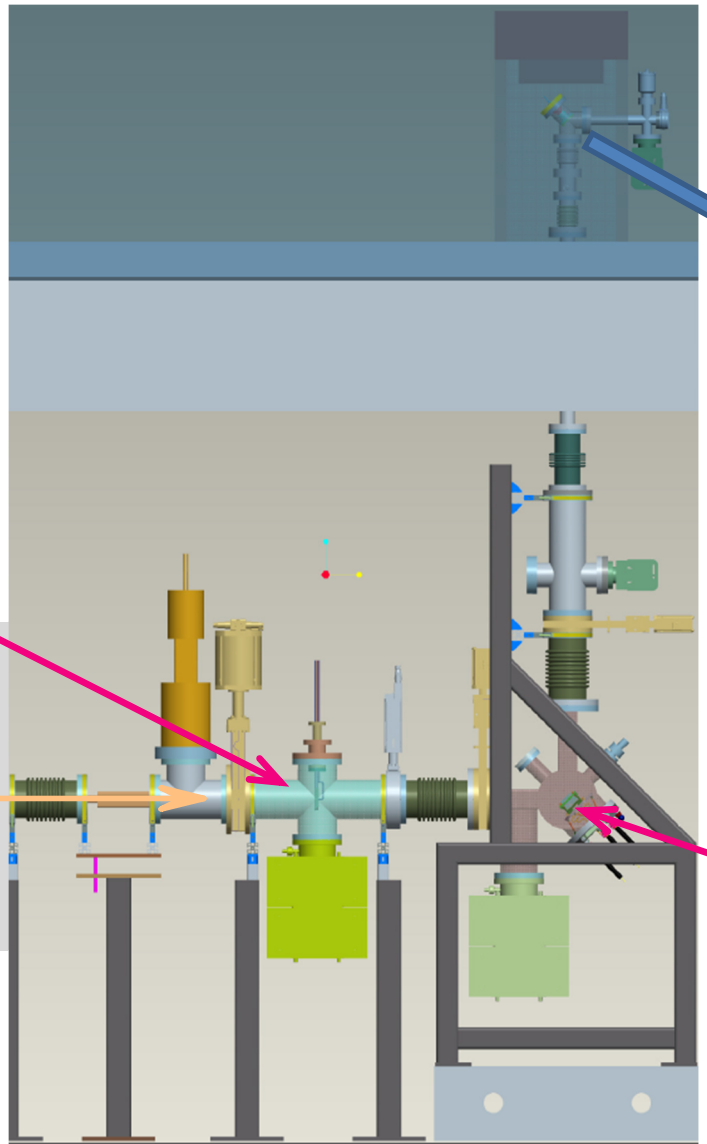
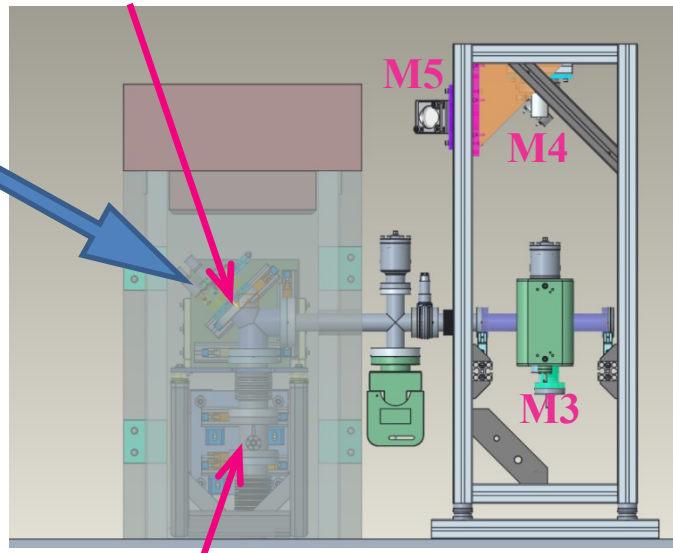
Sector 12 Dip1.1 - BM2T6R

Longitudinal Bunch Size

(timing:
streak Camera
etc.)







Toroidal Mirror M2

X-Ray
Blocking
Baffle

Intermediate
Focal Point
and Slit

Ellipsoidal
Mirror M1

Planar
Mirrors
M4&M5:
Select
transverse
direction

Beamlines

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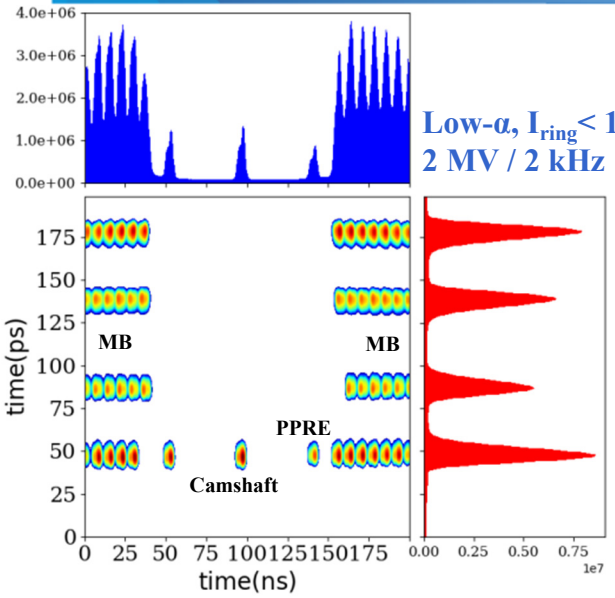
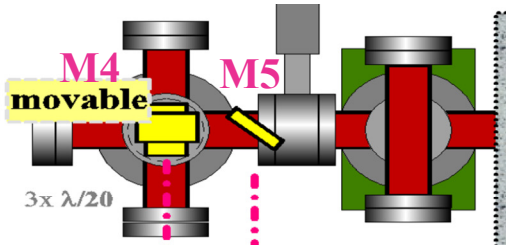
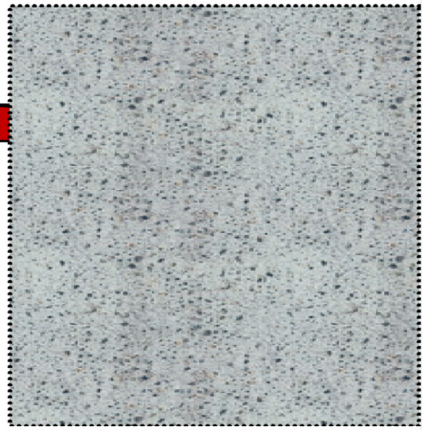


Low-α, I_{ring} < 15 mA
2 MV / 2 kHz

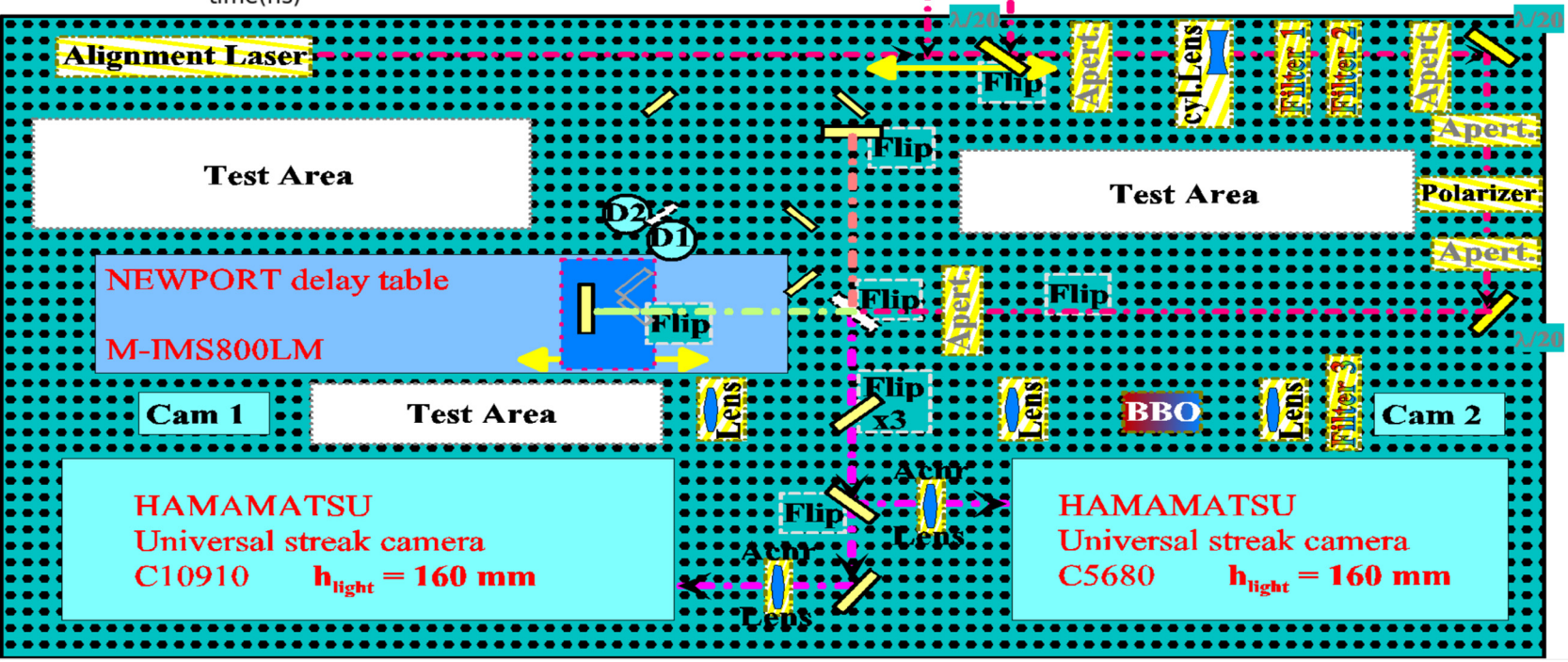
Select orientation of collimated light-beam





rotated beam (90°)

normal beam



Select wavelength, bandwidth and polarization

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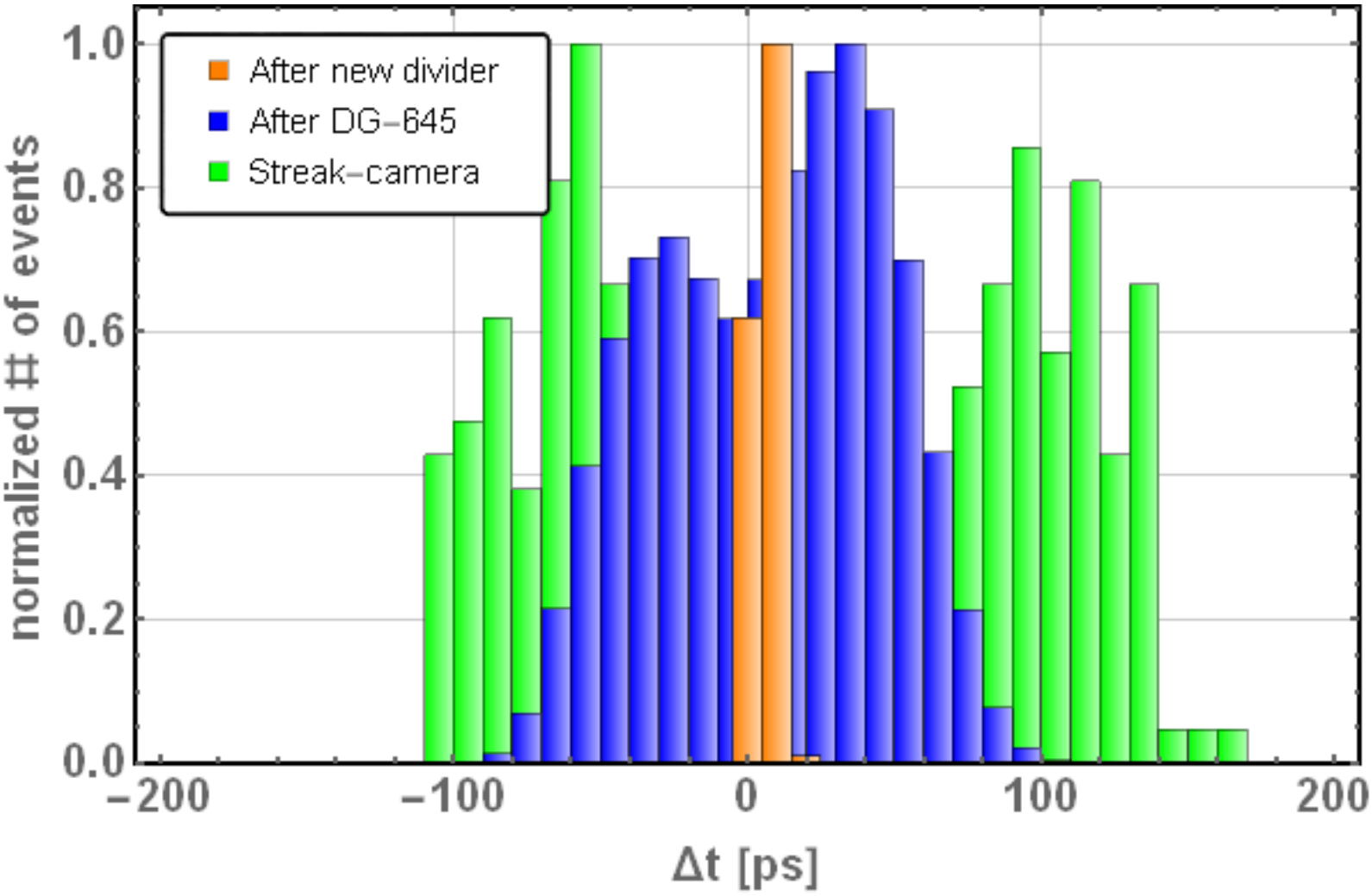
Temperature Stability of the Slow (Horizontal) Time Axis: Average over 40 hours



2D: time versus horizontal axis

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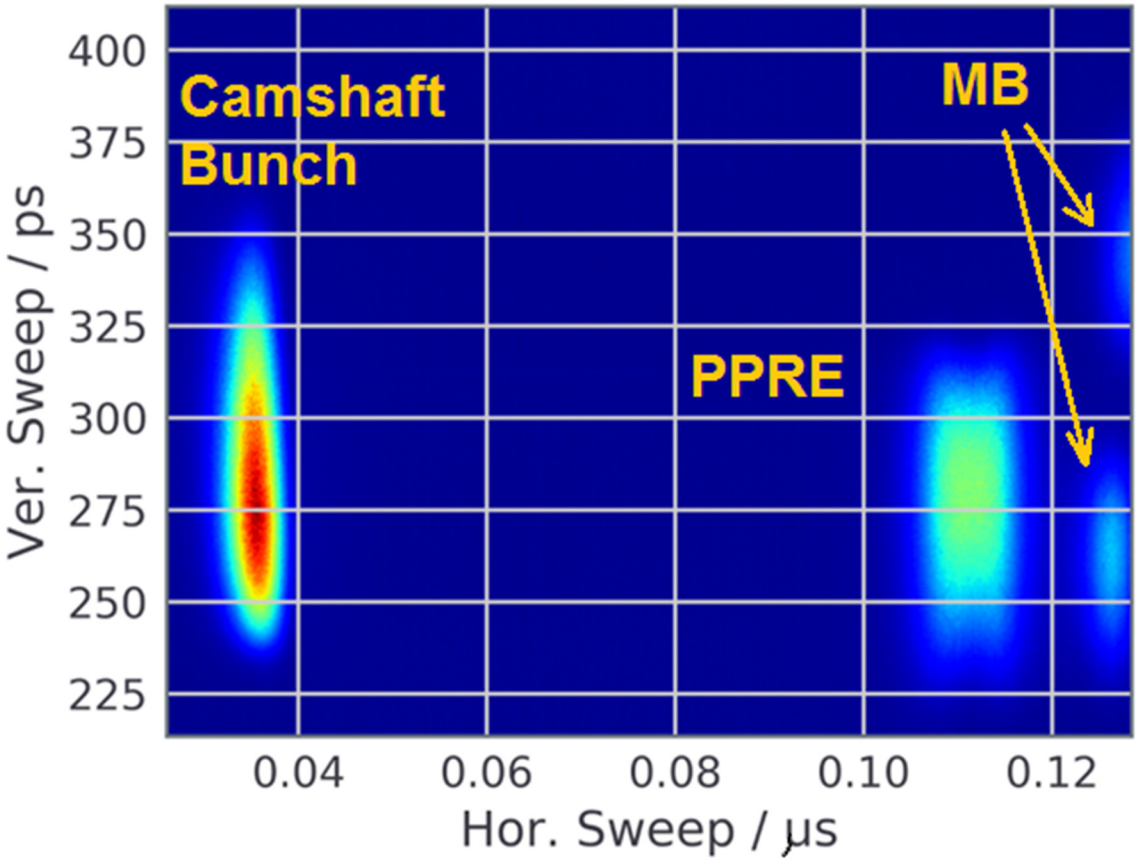
Standard BESSY-II user fill-pattern at top-up conditions near the center of the pseudo-single-bunch gap.



1 x Camshaft bunch
(with 4mA partial ring current)

1 x PPRE bunch
(3mA) for pulse picking by resonant excitation *

2 x MB bunch of the multi-bunch train (0.8 mA per bunch)

* K. Holldack et al.,
Nature Communications Vol. 5, 4010 (2014)

2D: time versus vertical axis

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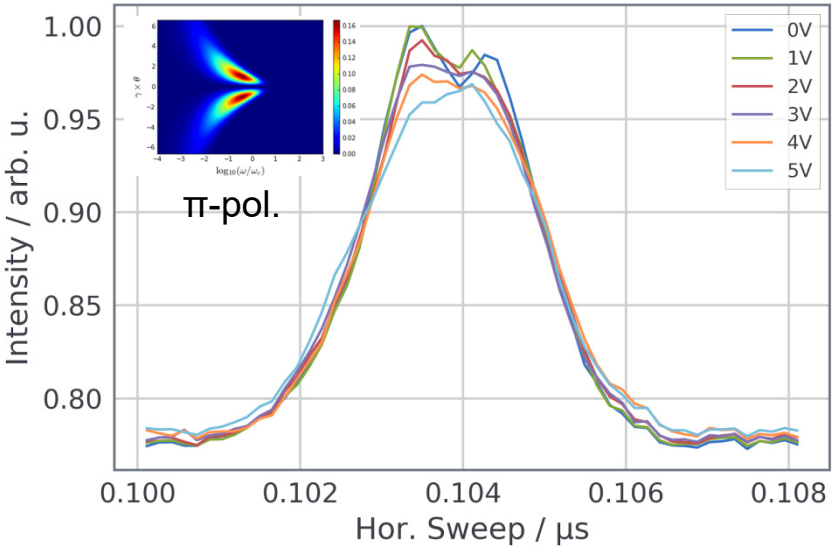
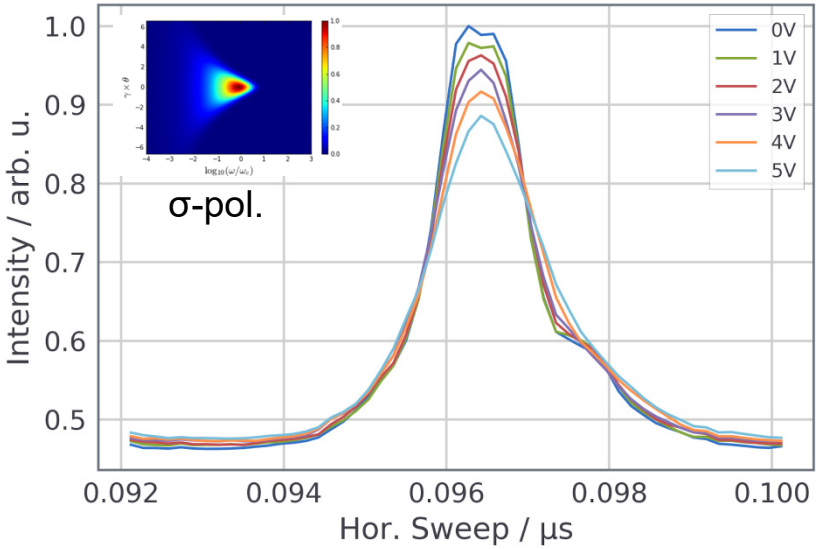
➢Profile of a single bunch for both polarizations as function of white-noise excitation





M. Koopmans et al., "Vertical Beam Size Measurement Methods at the BESSY II Storage Ring and their Resolution Limits", in IPAC'19 proceedings , Melbourne, Australia, May 2019, pp. 2491-2494. doi:10.18429/JACoW-IPAC2019-WEPGW012

For the X-ray-baffle method, see, e.g., J. Breunlin, Å. Andersson, N. Milas, Á. Saá Hernández, V. Schlott, NIM-A803, 55–64 (2015) and refs. therein.

Conclusions

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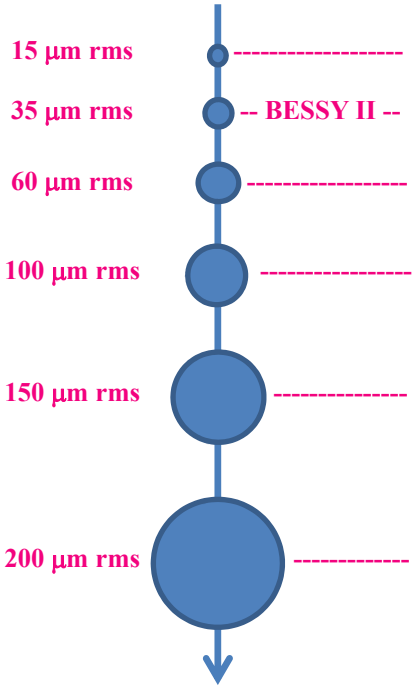
Lateral Beam Size



σ_y < 40 µm rms
→
X-ray-baffle interference

New beamline

25 µm rms
<
σ_x, σ_y
<
200 µm rms
→
Double-slit interference

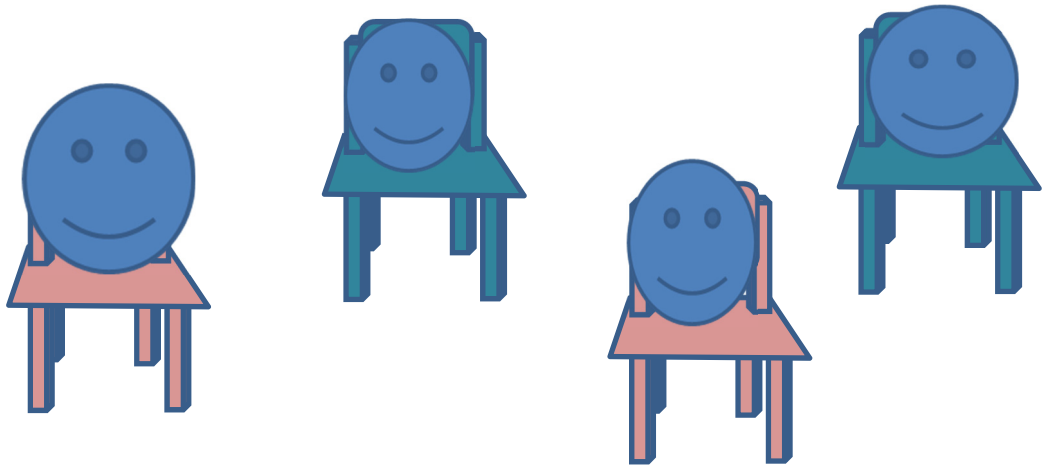
σ_x > 50 µm rms
σ_y > 70 µm rms
→
Geometrical imaging

(follows from Rayleigh's diffract. criterion or Abbe limit)

Longitudinal Beam Size (Bunch Length)

- **Time resolution Δt = 0.9±0.2 ps FWHM**
  @ 1000 synchro-scan sweeps per second
- **2D measurements** with high longitudinal and lateral resolution for *time vs. x* and *time vs. y* have been demonstrated
- **2D measurements in combination with interferometry** (X-ray-baffle method) have been demonstrated for *time vs. y*

Thank you for your attention !



For more information on BESSY II and BESSY VSR developments, please visit IBIC posters
MOPP026 (on a *new longitudinal kicker cavity* …) and
WEPP003 (on a *new button-type BPM* …)