Recent Development of Diagnostics on 3rd Generation Light Sources

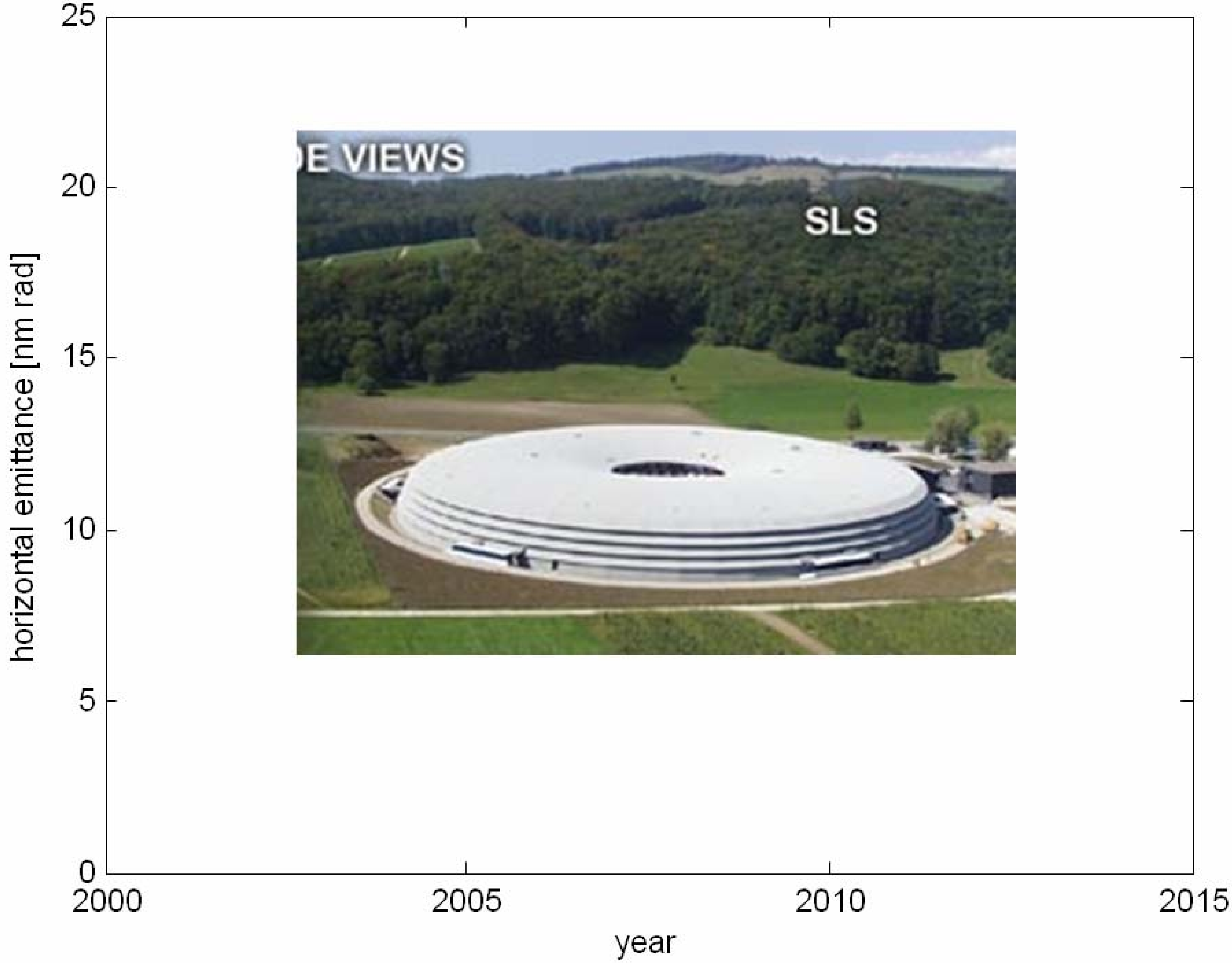
Guenther Rehm

Diamond Light Source

Outline

- Evolution of 3rd Generation Light Sources
- Diagnostics Requirements
- Electron Beam Position Monitors (EBPM)
- Emittance/Transverse Profile Monitoring
- Diagnostics for Top-Up
- Conclusions

Evolution of Horizontal Emittance



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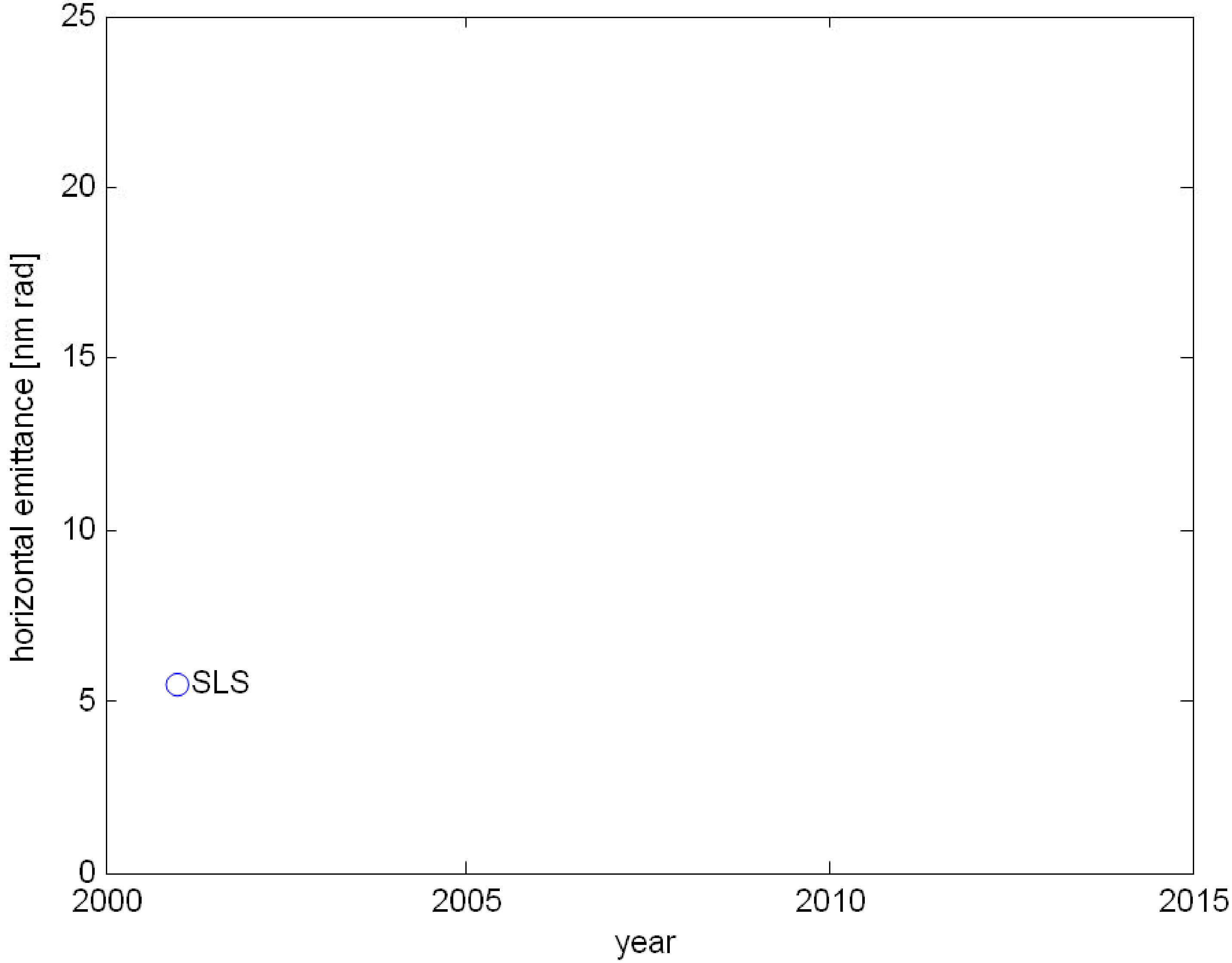

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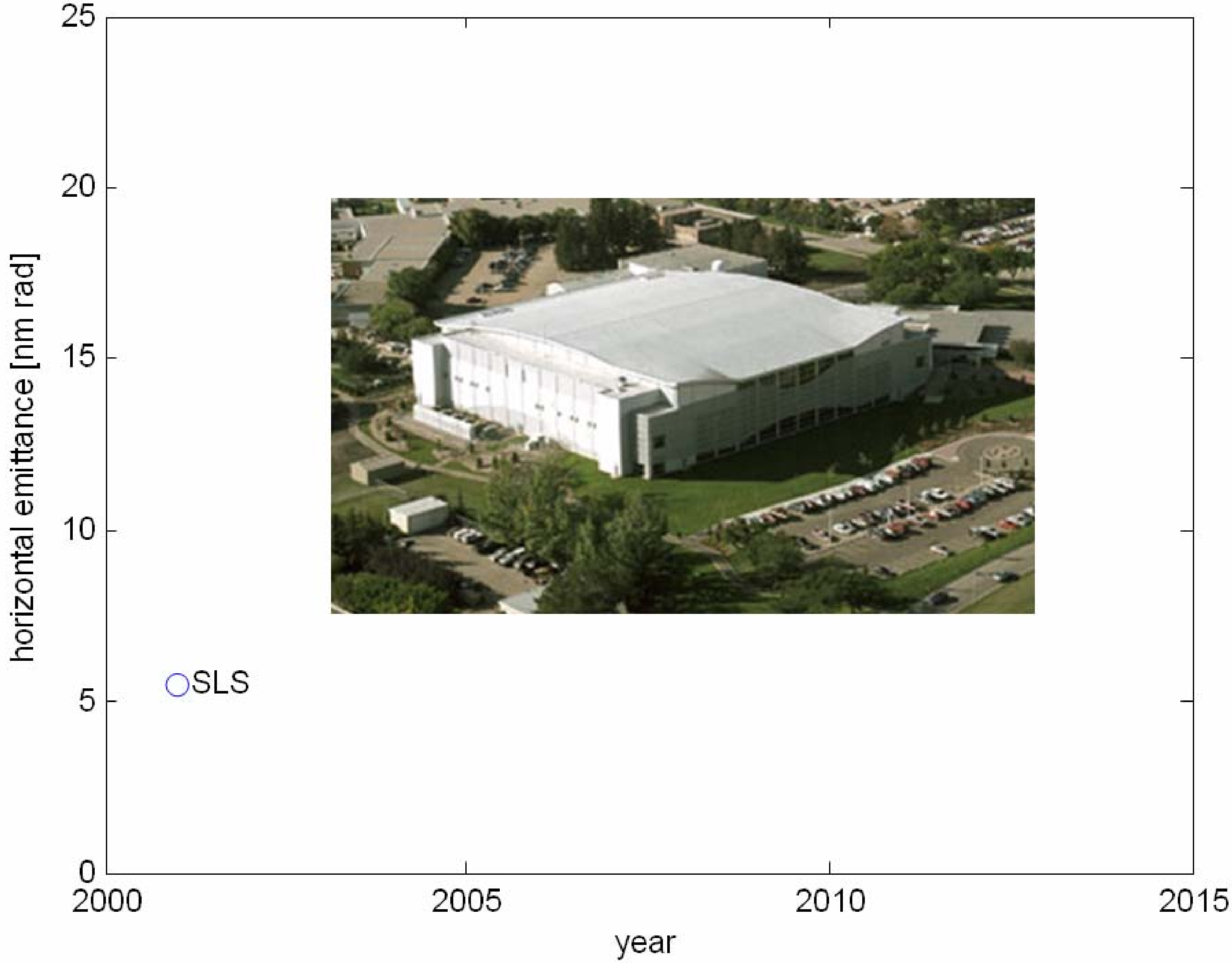

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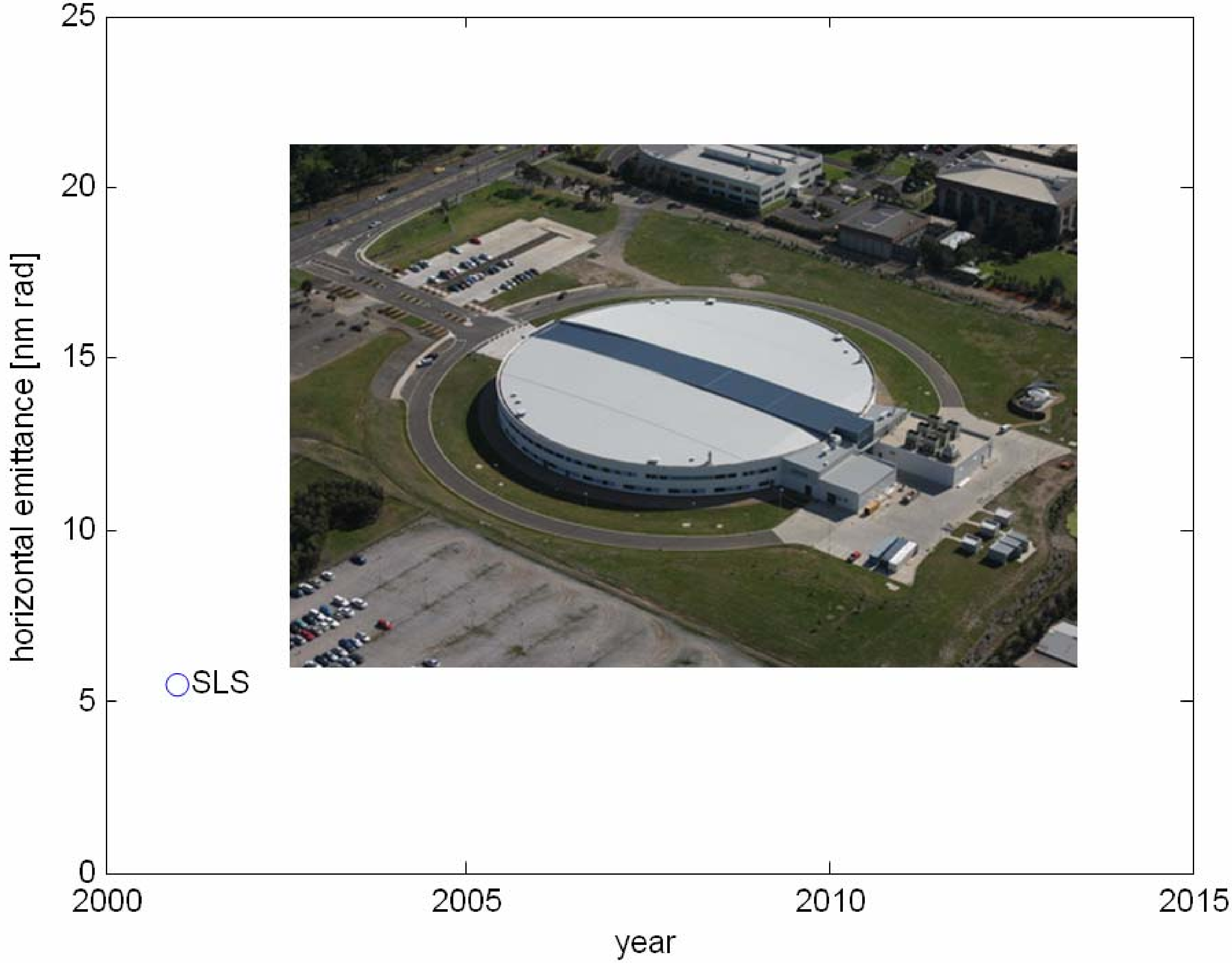

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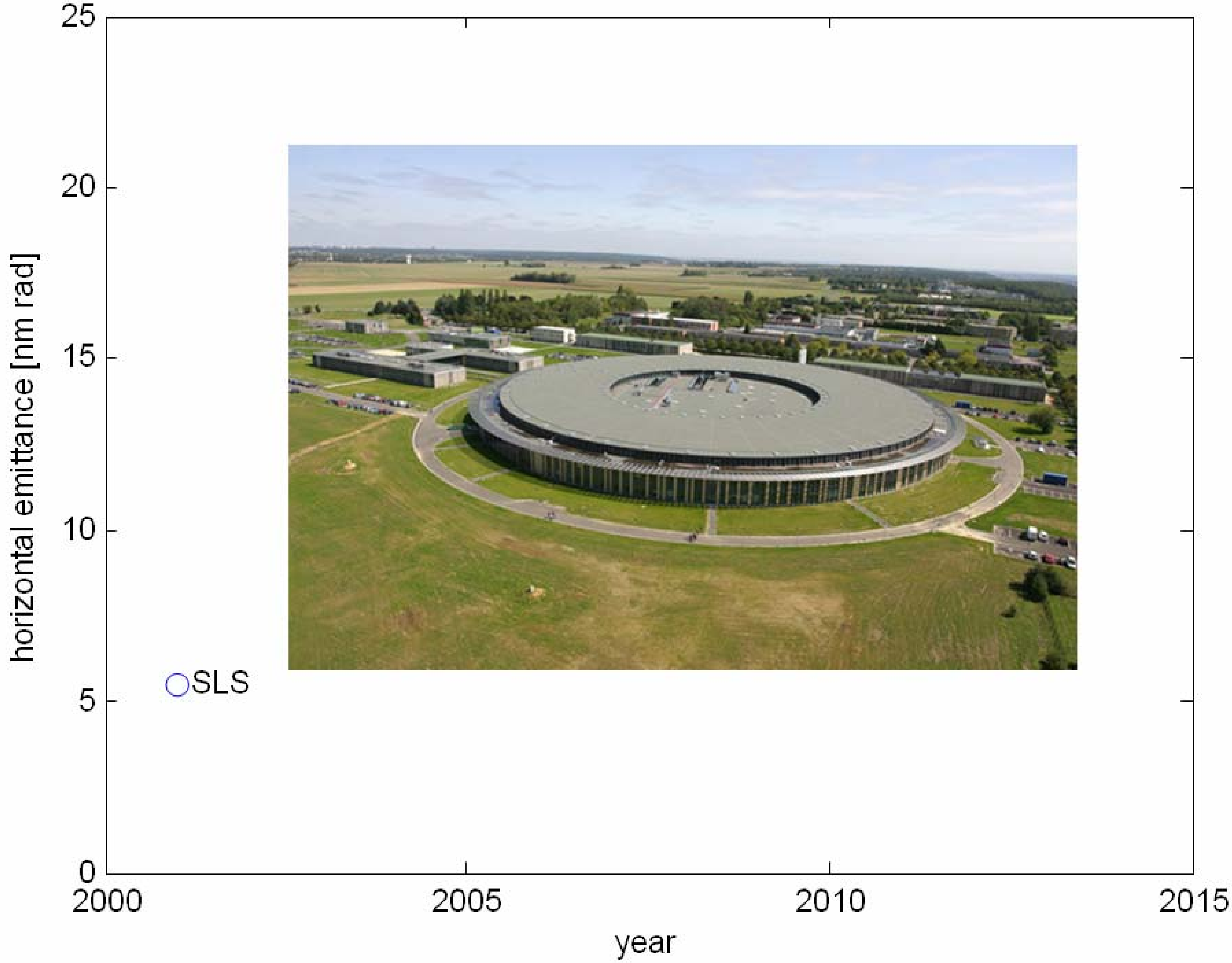

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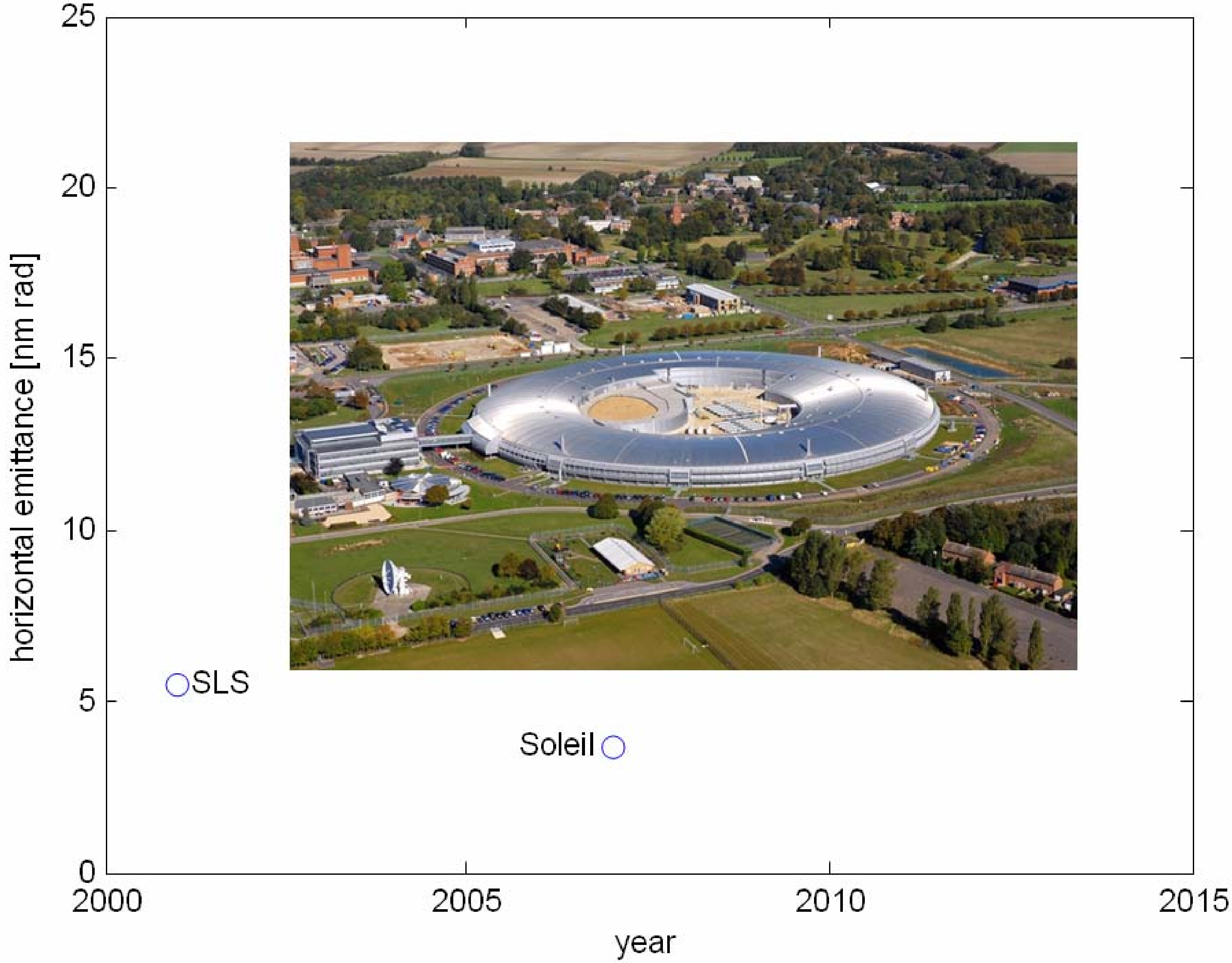

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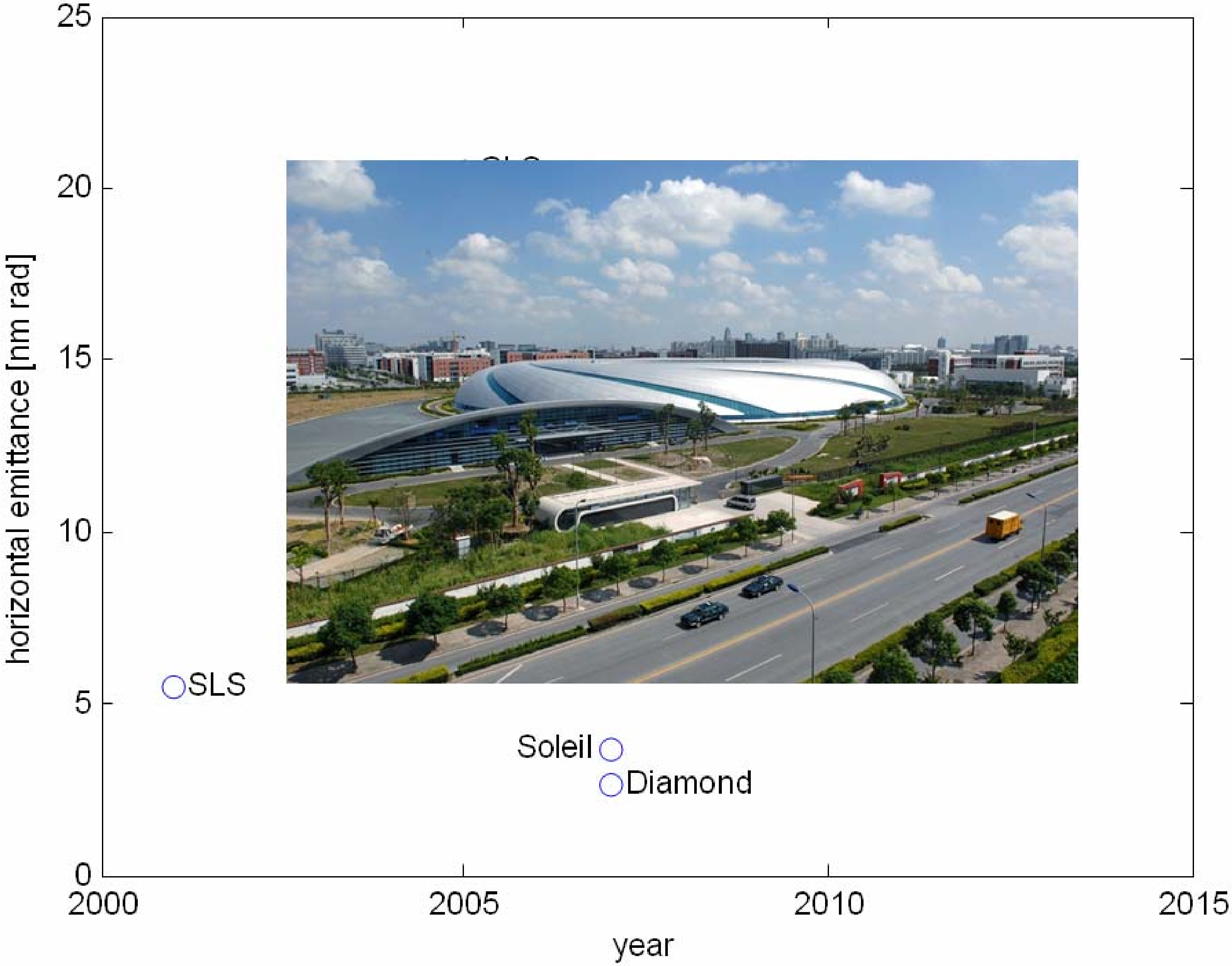

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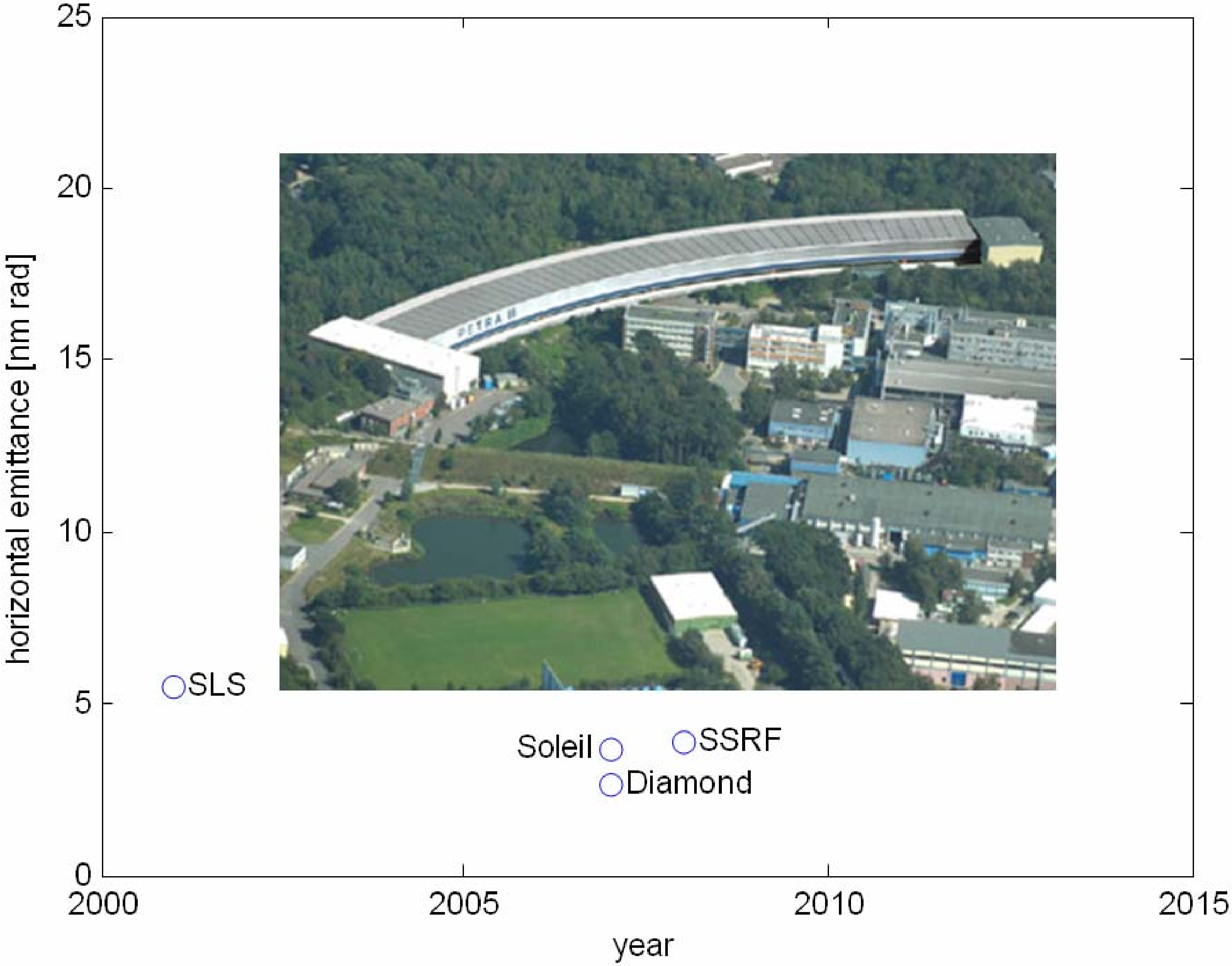

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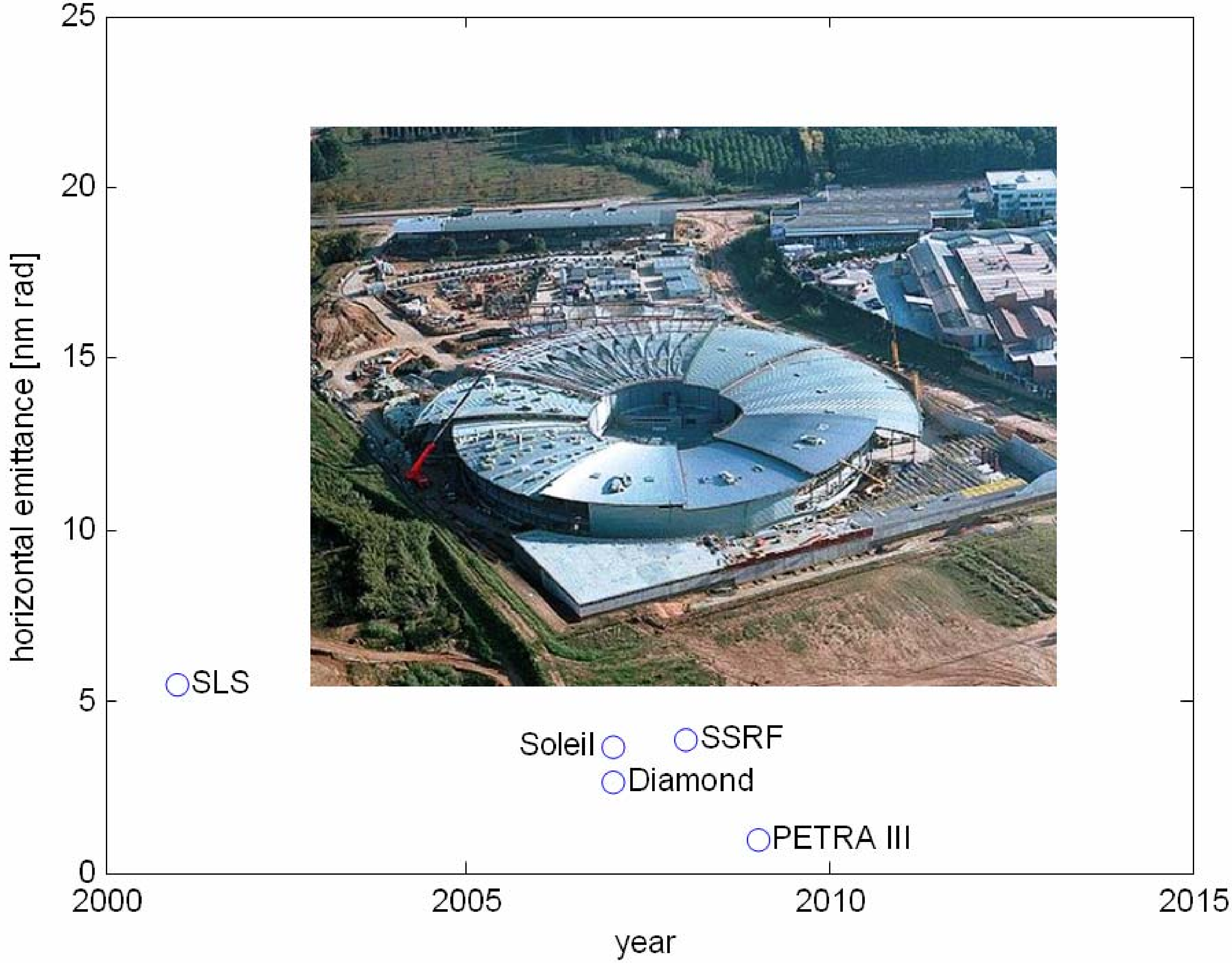

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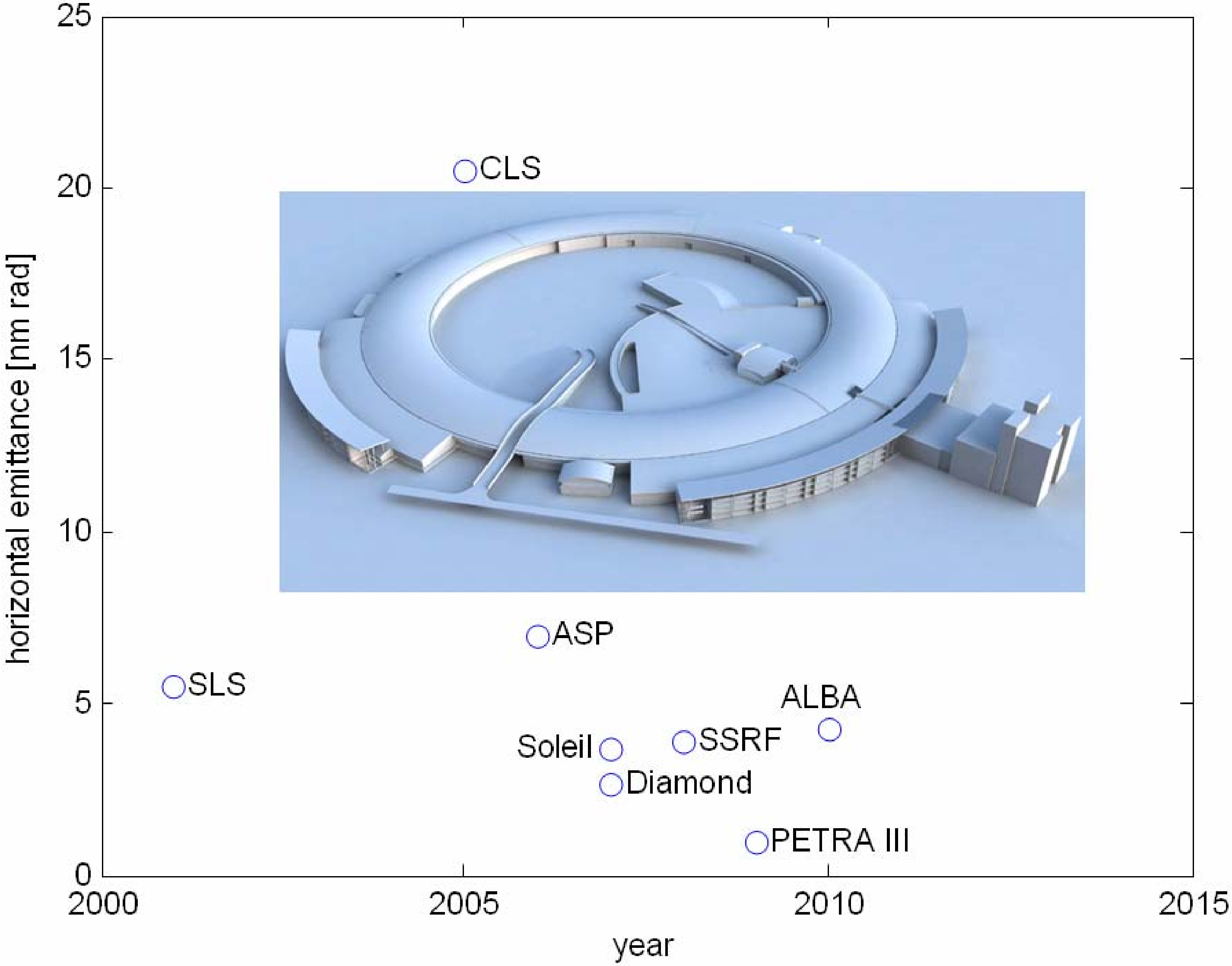

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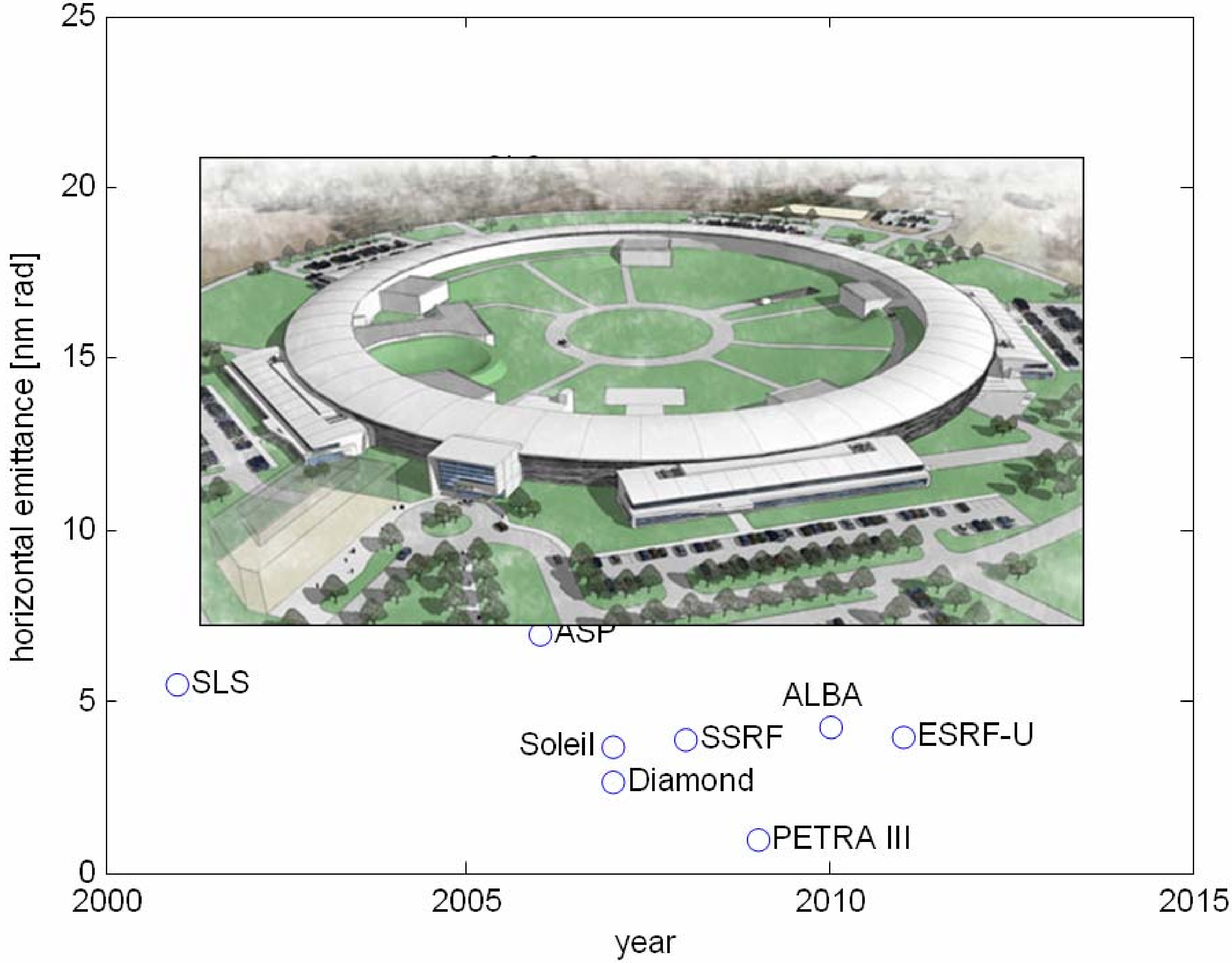

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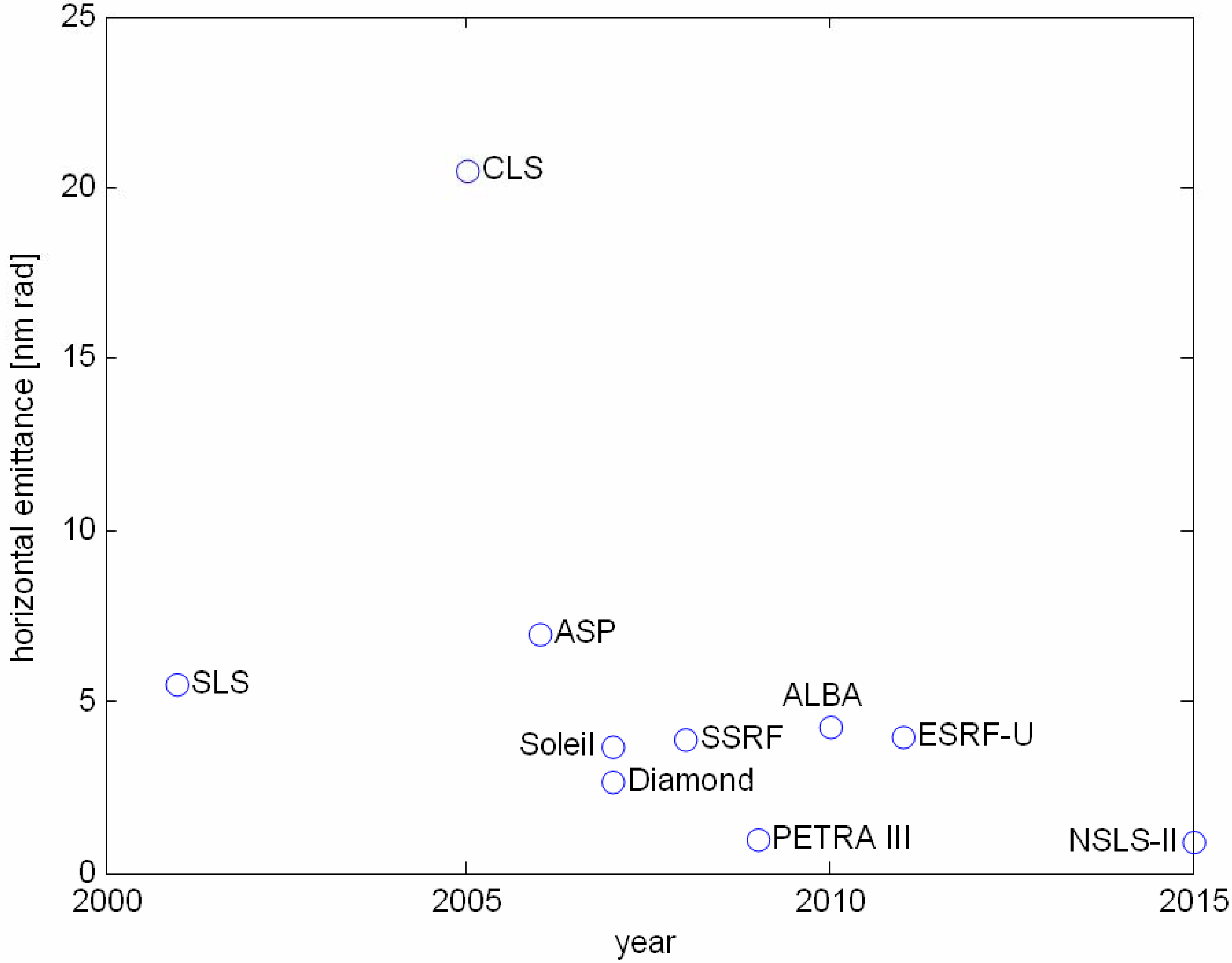
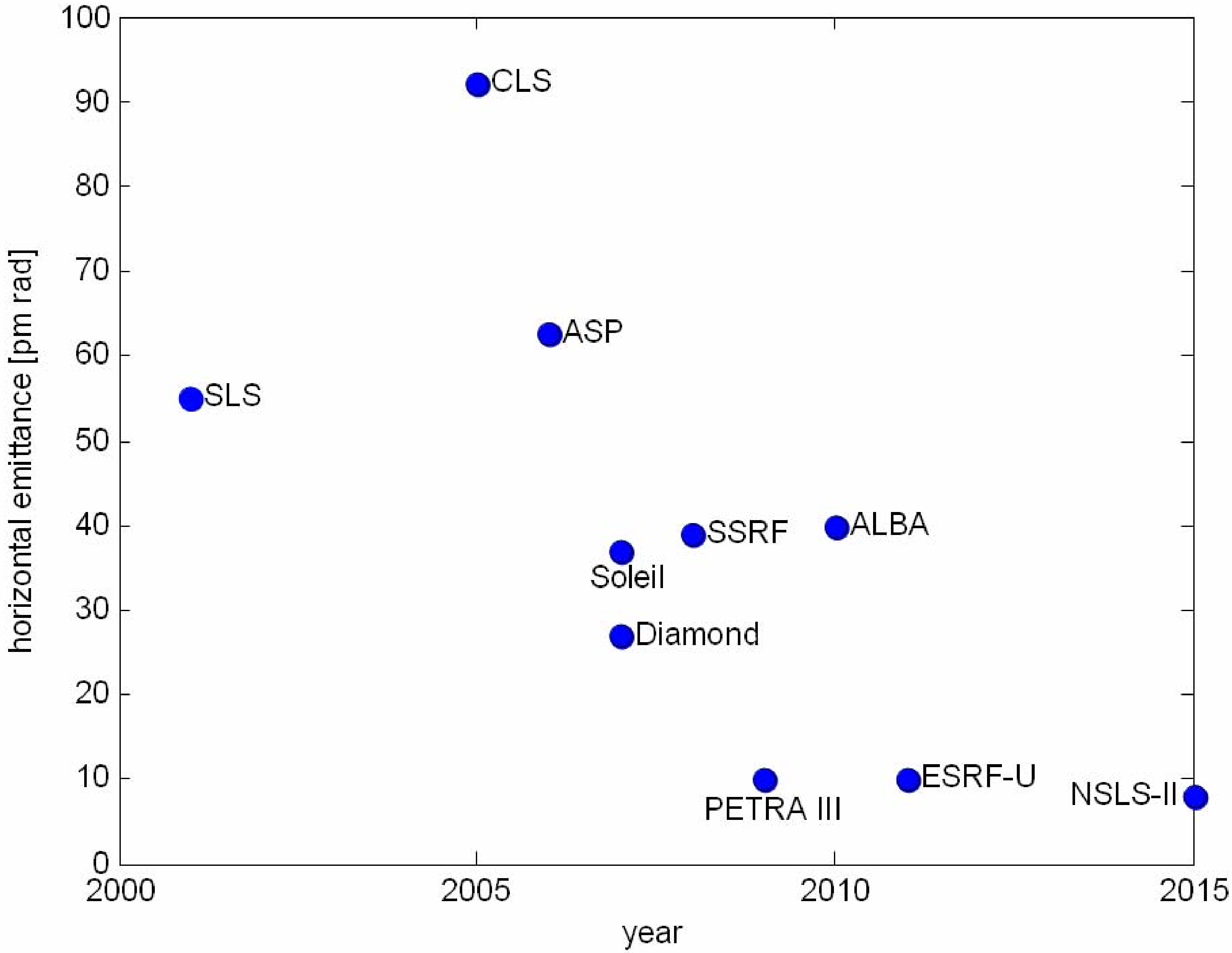


J. Bengtson, TUXM01

Evolution of Vertical Emittance



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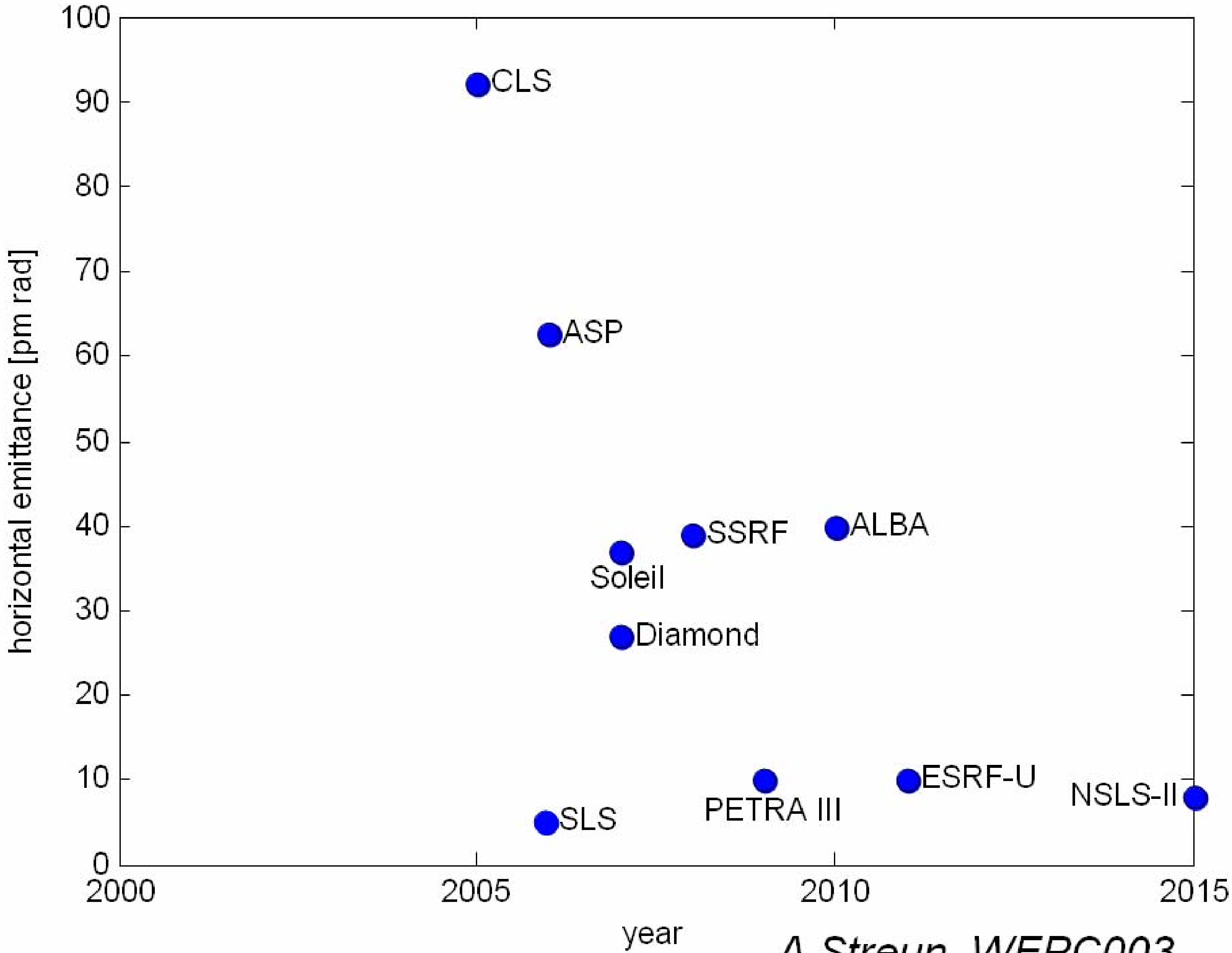
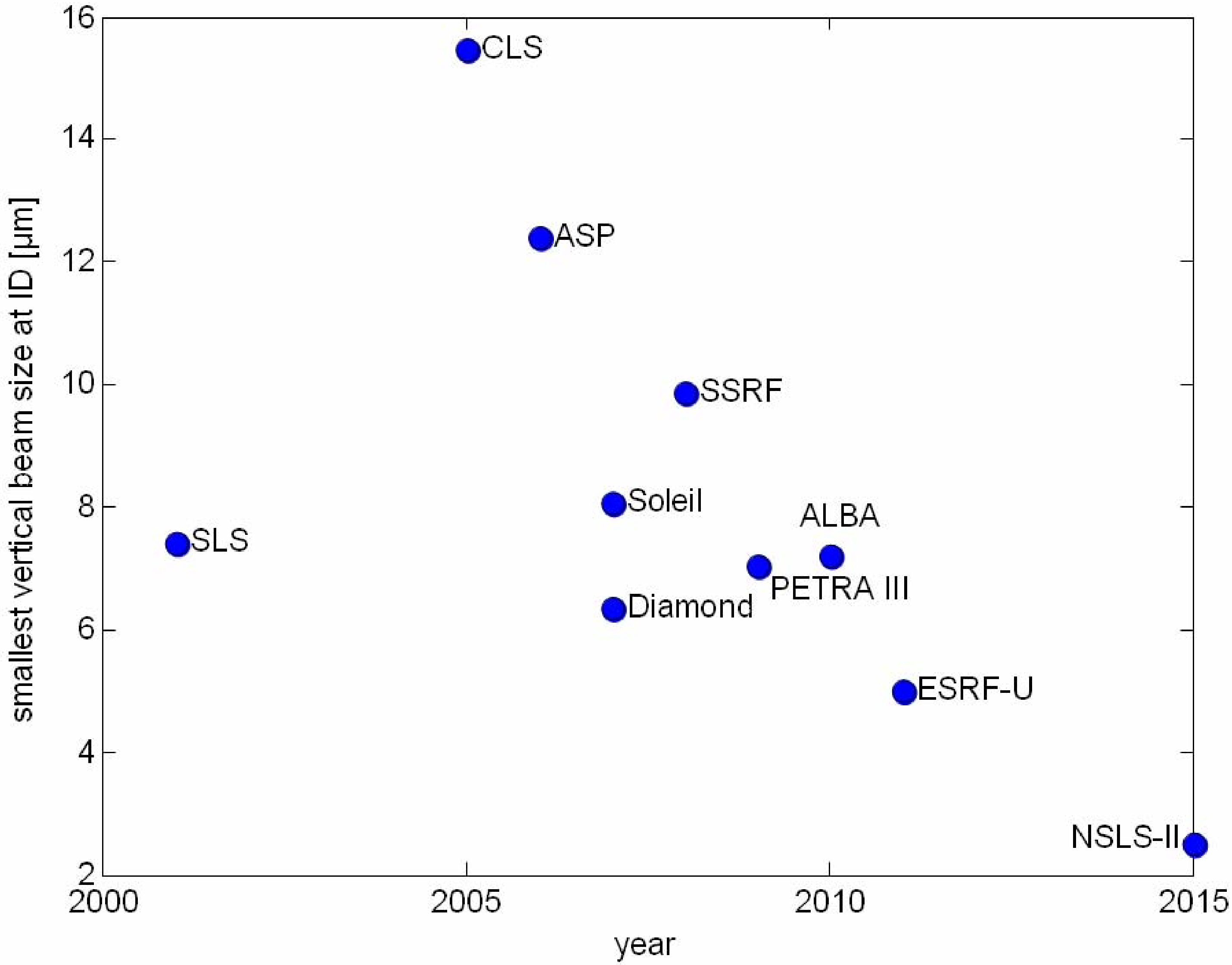


A.Streun, WEPC003

Evolution of Vertical Beam Size



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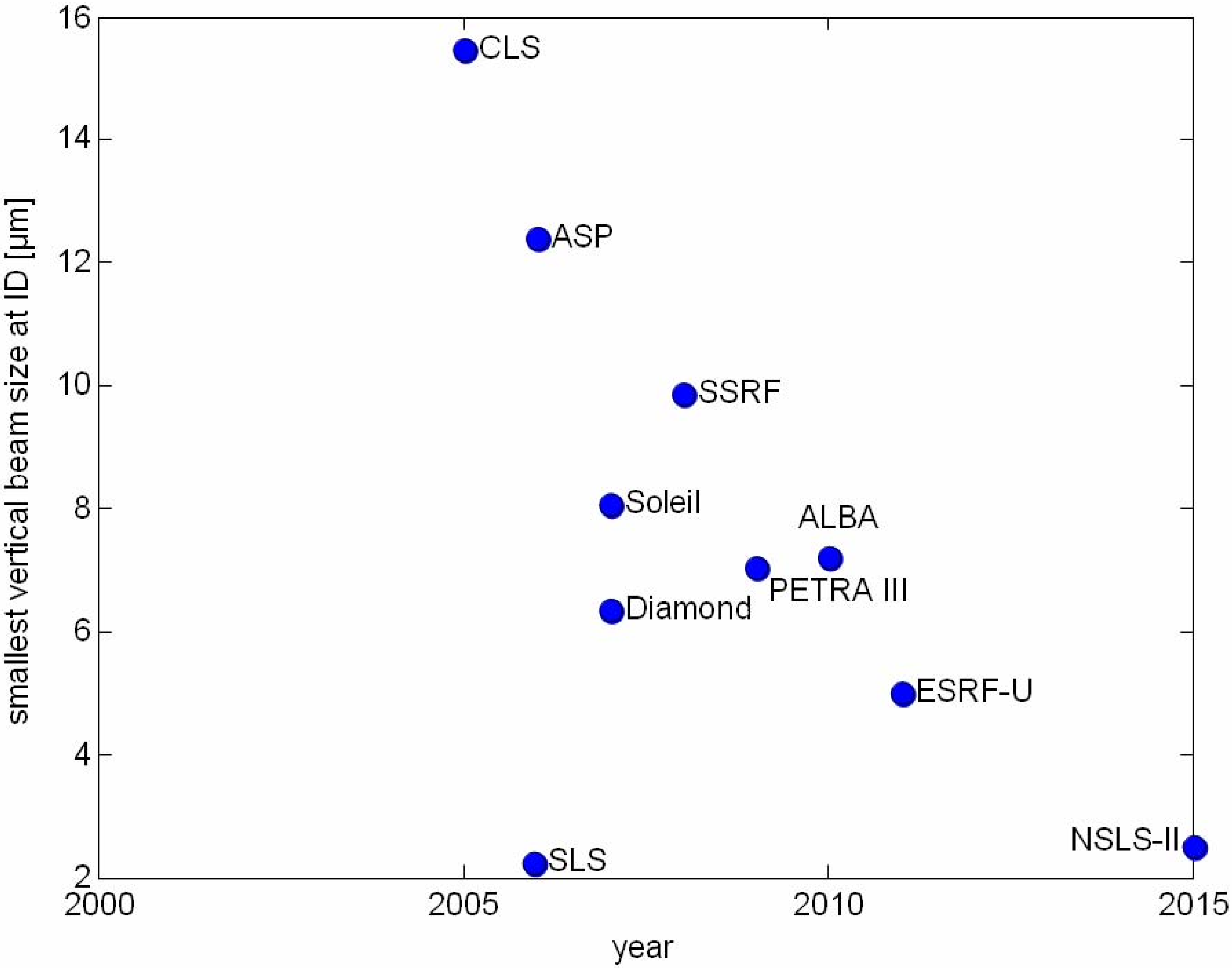
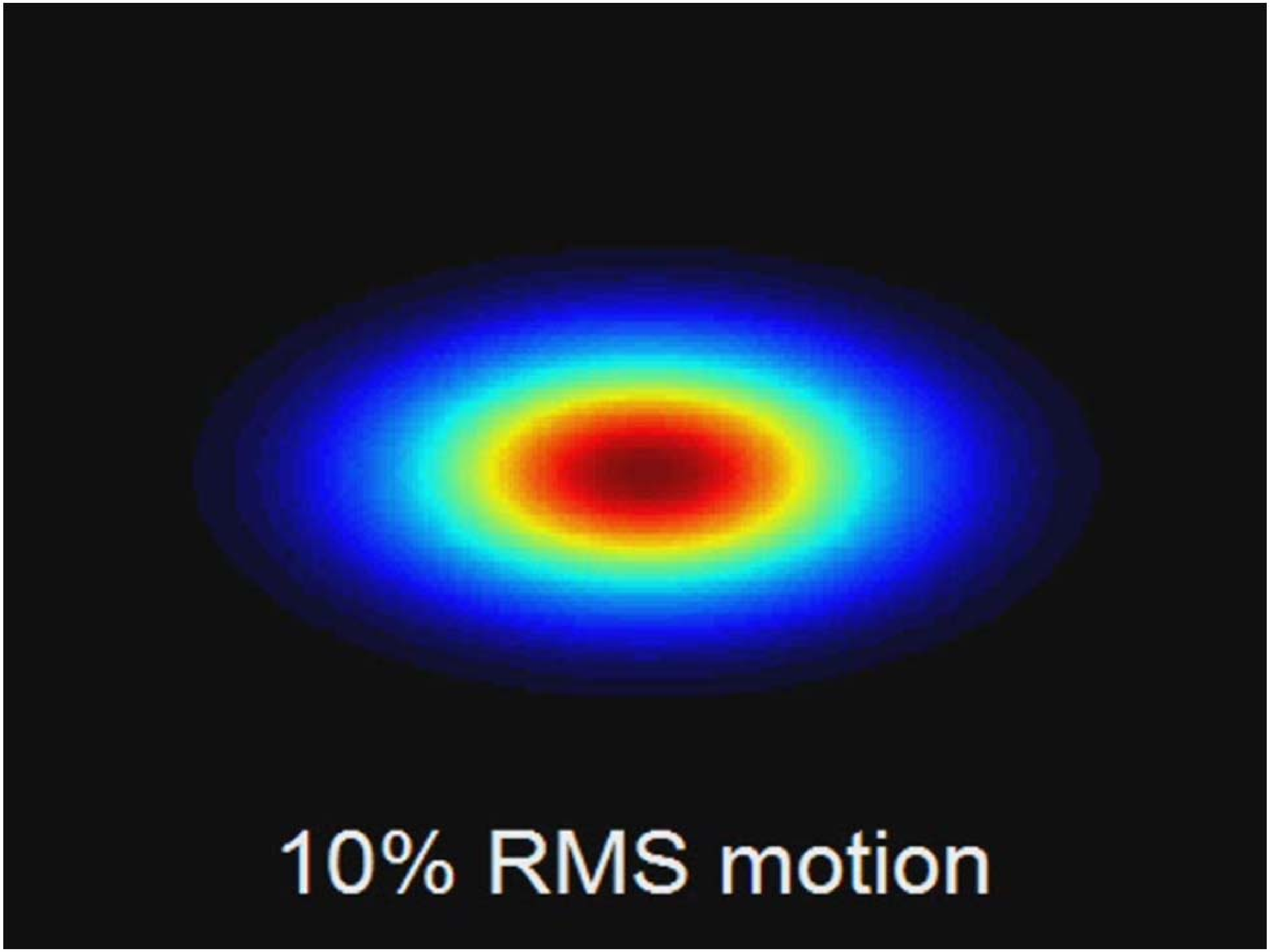


EBPM Requirements

- Typically 10 % of beam size for:
  - Resolution (RMS noise) in fast feedback bandwidth (1-2 kHz)
  - Stability (peak-peak over 24h)
  - Beam Current Dependence (peak-peak over range of decay)
- All in the range of 200-800 nm these days!

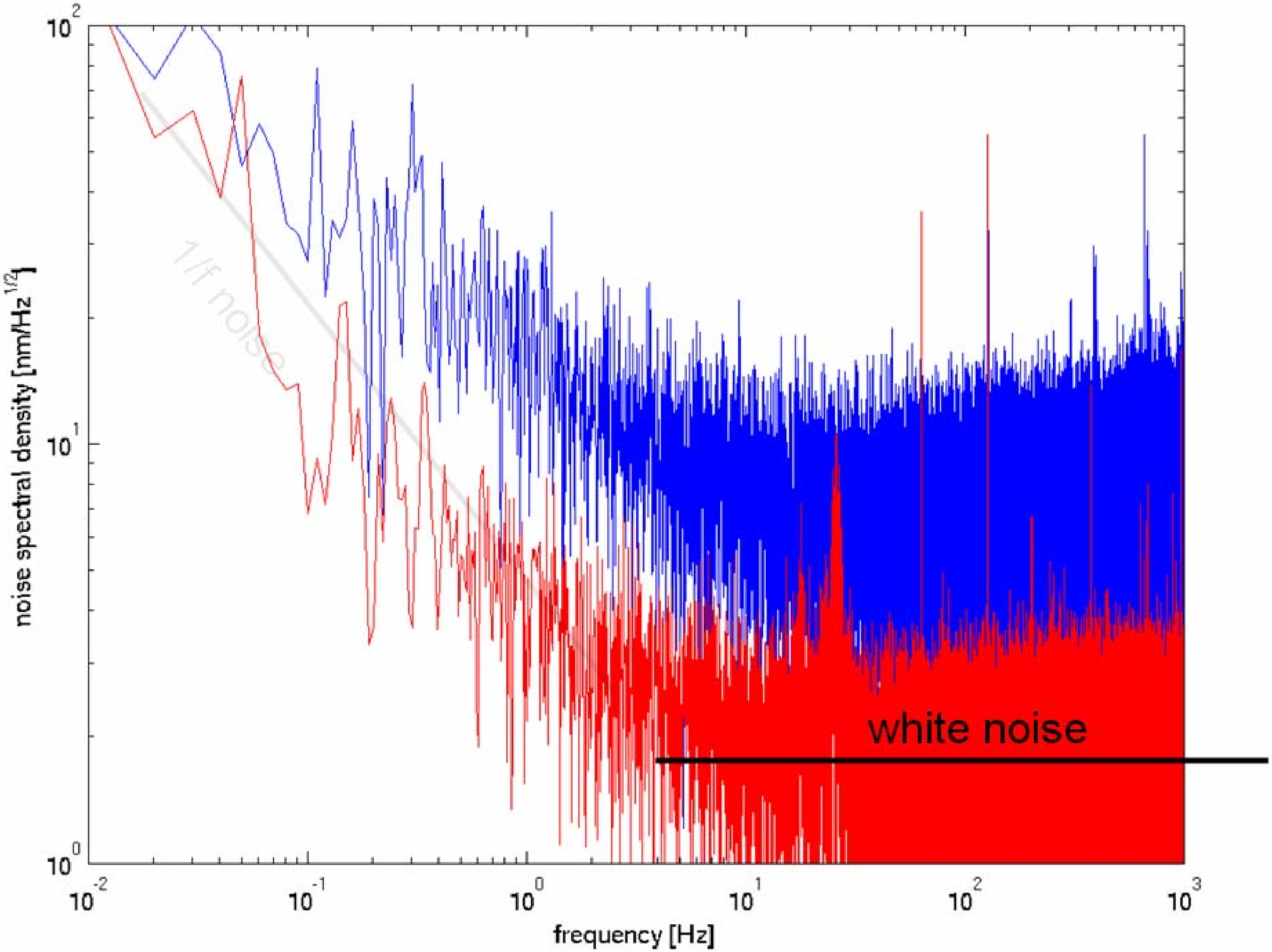
Stabilisation Target: Is 10% good?



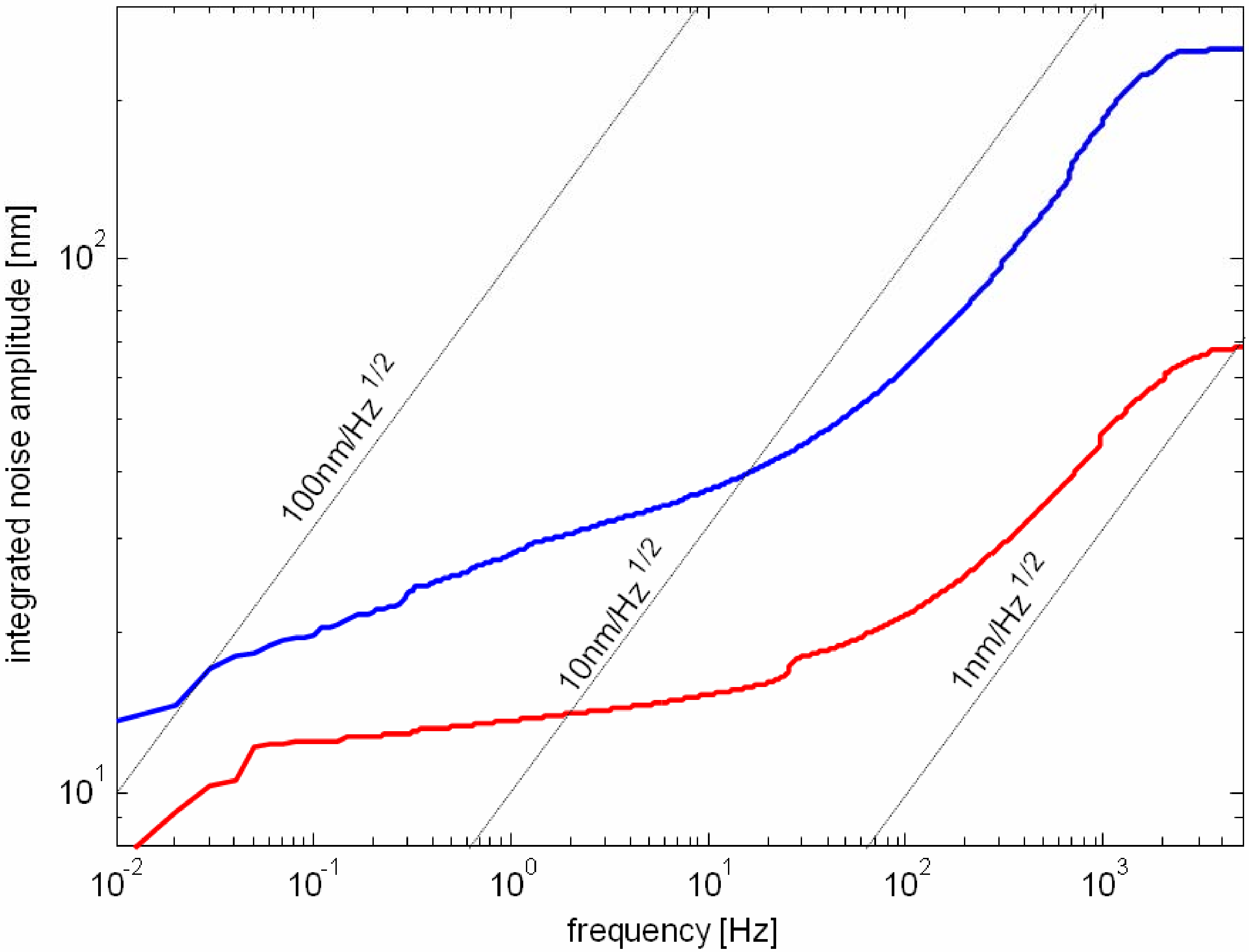
Resolution is not just *one* number!

- If EBPM noise is 'white' there is a noise floor at a certain spectral density:
  - Total noise amplitude will decrease with square root of bandwidth
- But in electronic systems we also observe a 1/f component in the noise spectrum
  - This means the above calculation does not hold for very low frequencies
  - We need to access EBPMs down to low frequencies

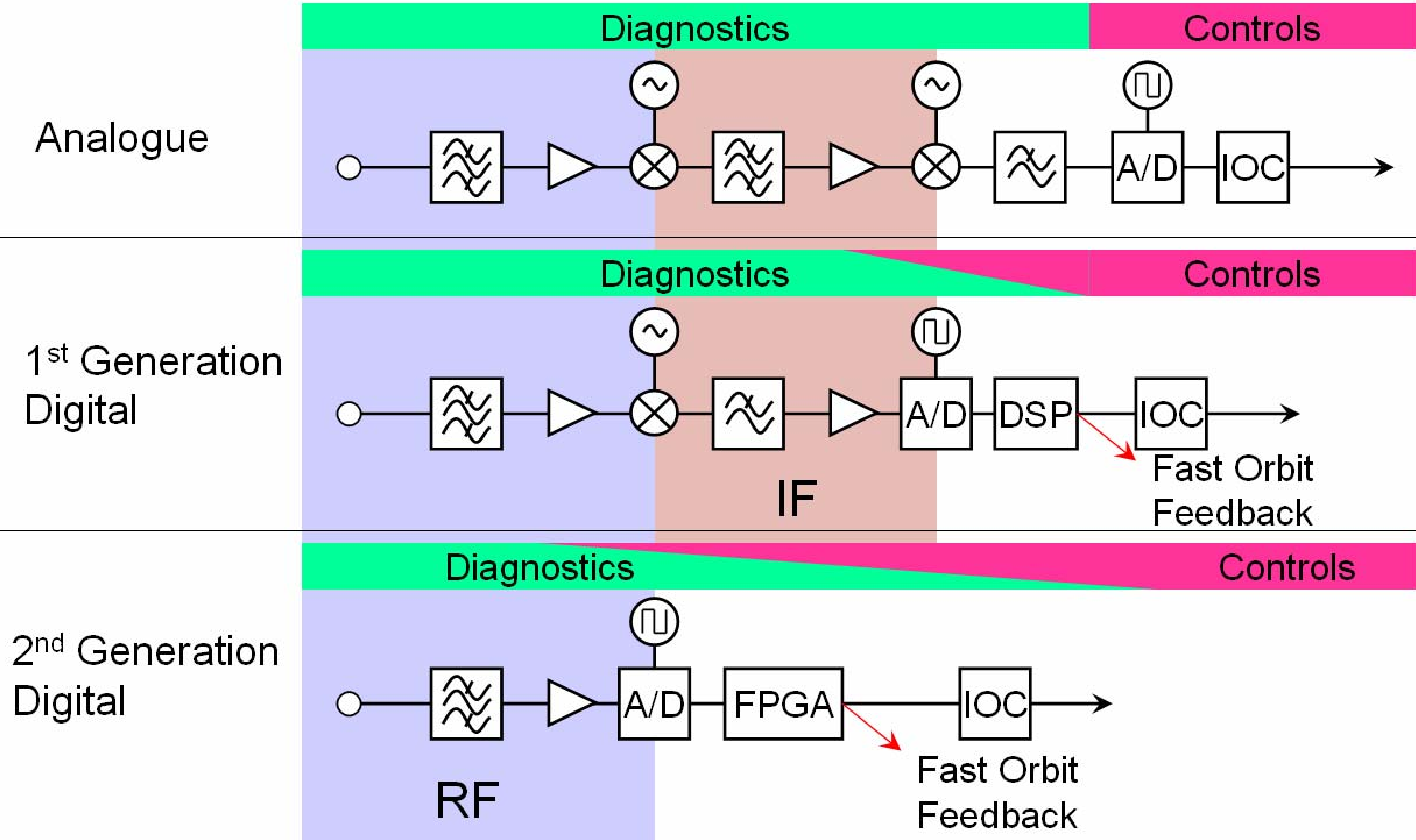
Spectral Noise Density of EBPMs



Integrated Noise Amplitudes



EBPM System Evolution



Who built *your* EBPM ?

- In the past, many light sources designed and built their own systems with considerable R&D: APS, ESRF, Spring-8, SLS
- Soleil and Diamond outsourced the development, collaborated with Instrumentation Technologies to produce *Libera Electron*
- ASP, SSRF and Elettra (for an upgrade) bought the same.
- ALBA and PETRA III (*TUPC111)* ordered an improved version called *Libera Brilliance*
- SLS (*THPC123)* and APS are looking into own new developments of ‘universal’ ADC / FPGA based systems

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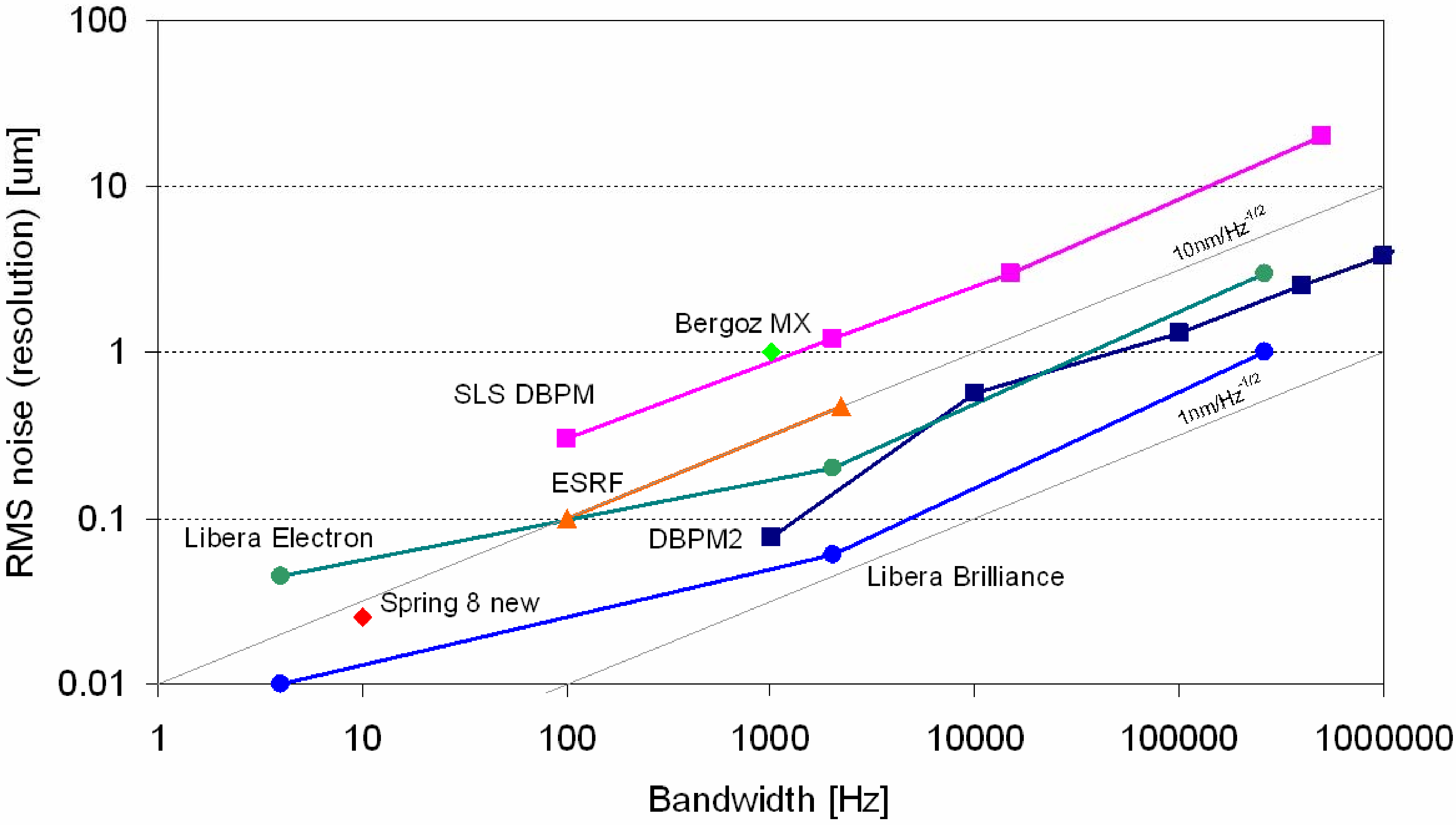
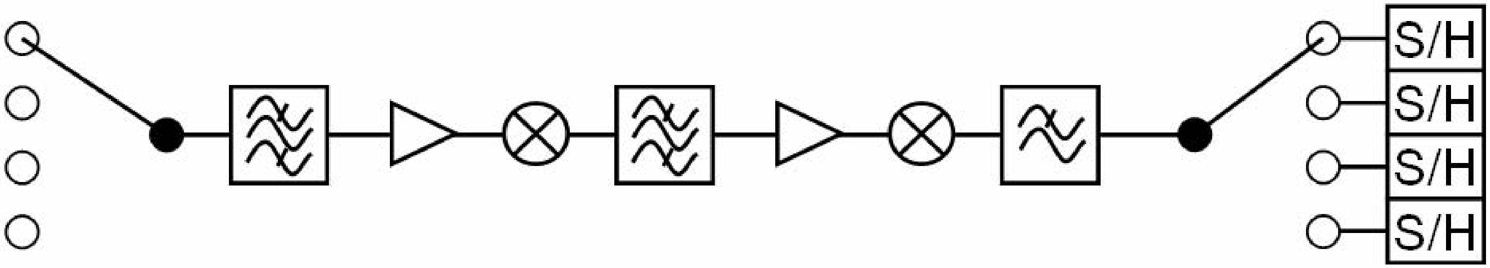
A rare concentration on one supplier, so far to the benefit of customers being able to share their firmware and software developments

EBPM Performance Comparison

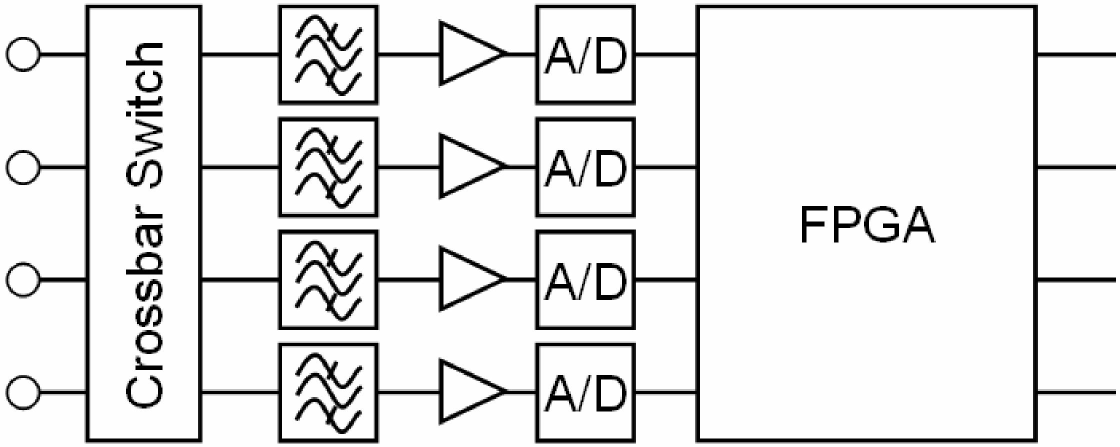


Achieving Stability

Multiplexed Analogue EBPM with on Detector Channel



Multiplexed Digital Four Channel EBPM



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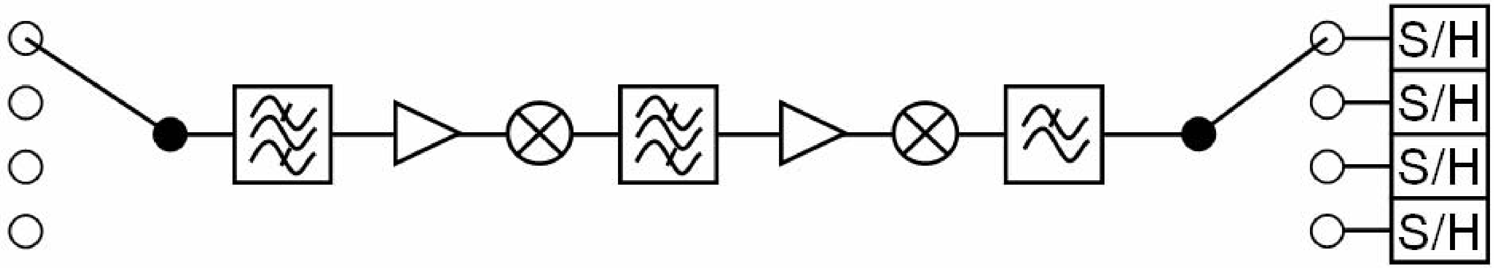

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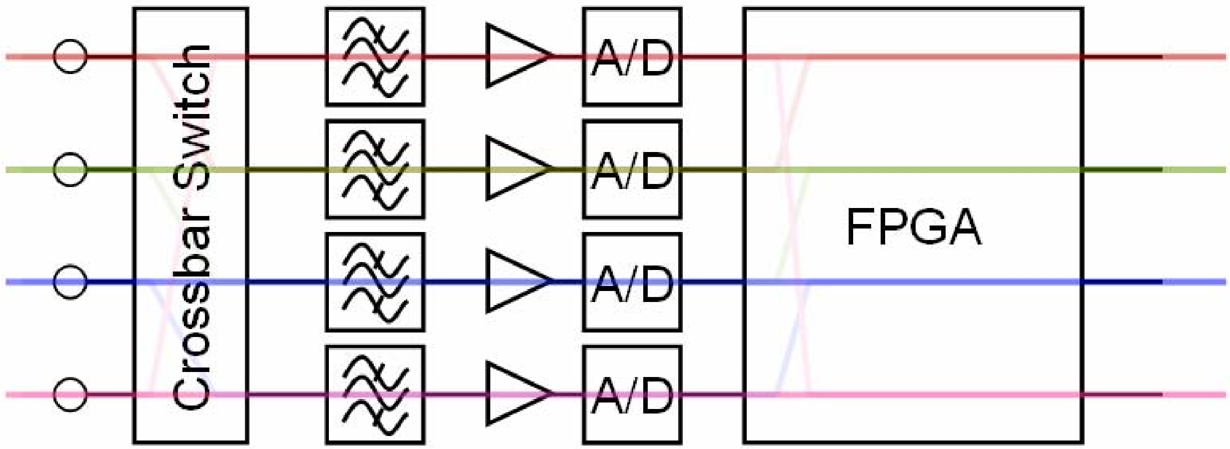
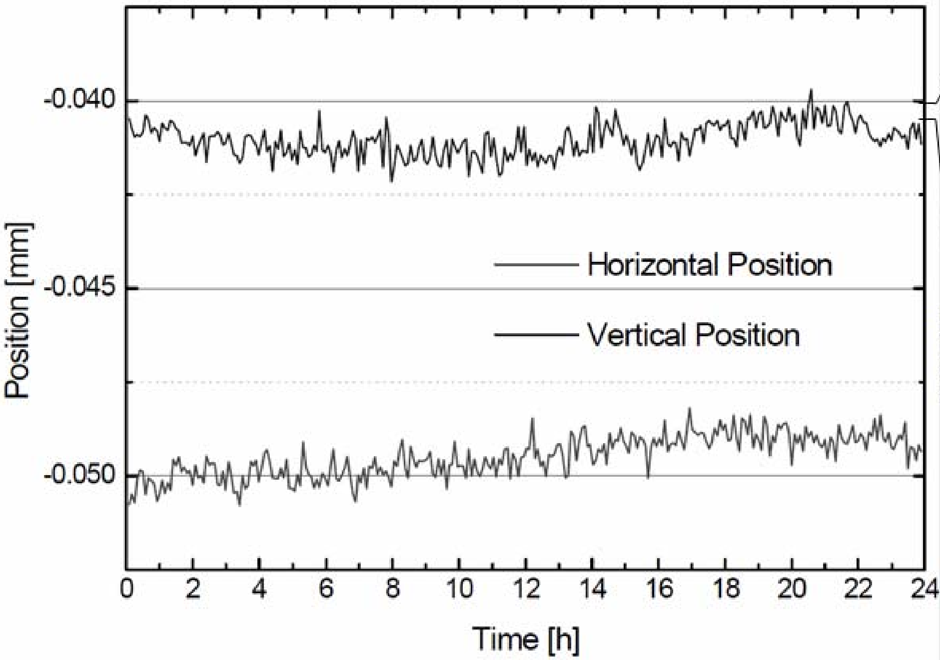
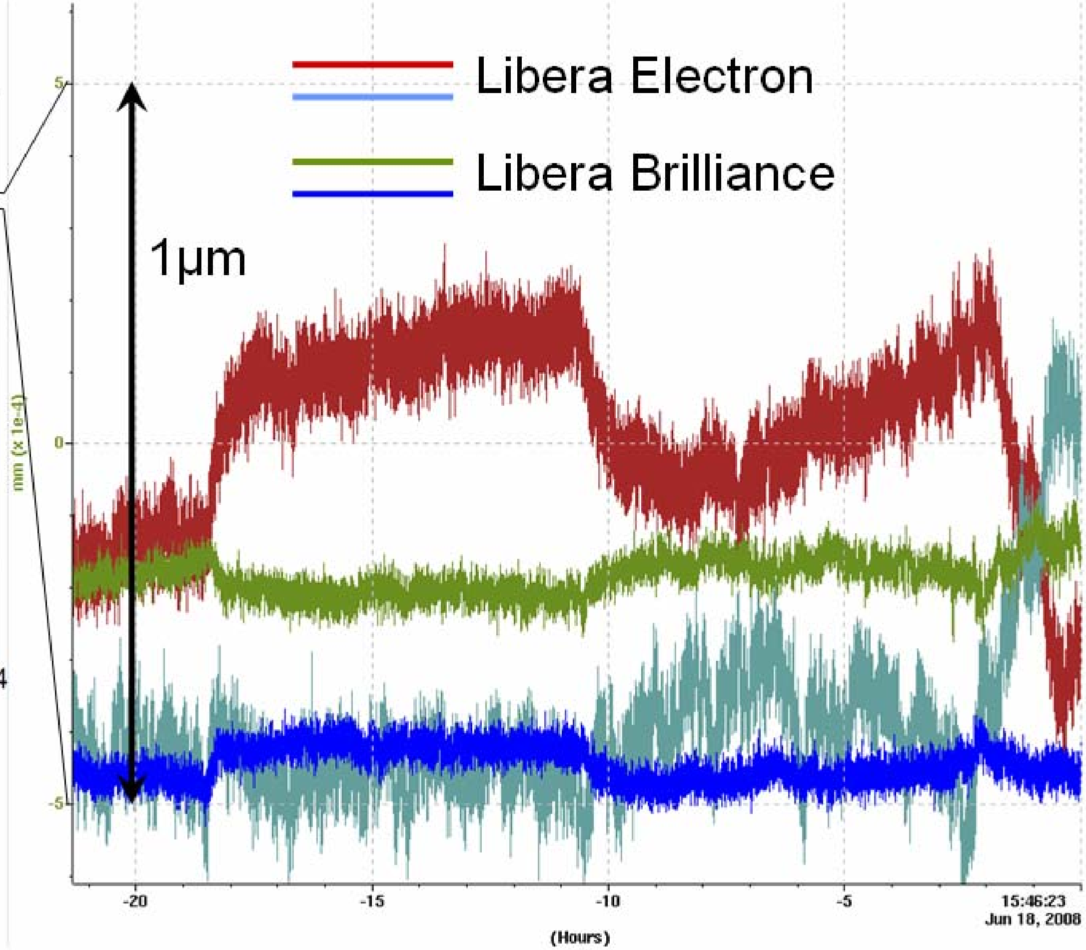


24h Stability Comparison



SLS BPM, *V.Schlott, DIPAC2001*

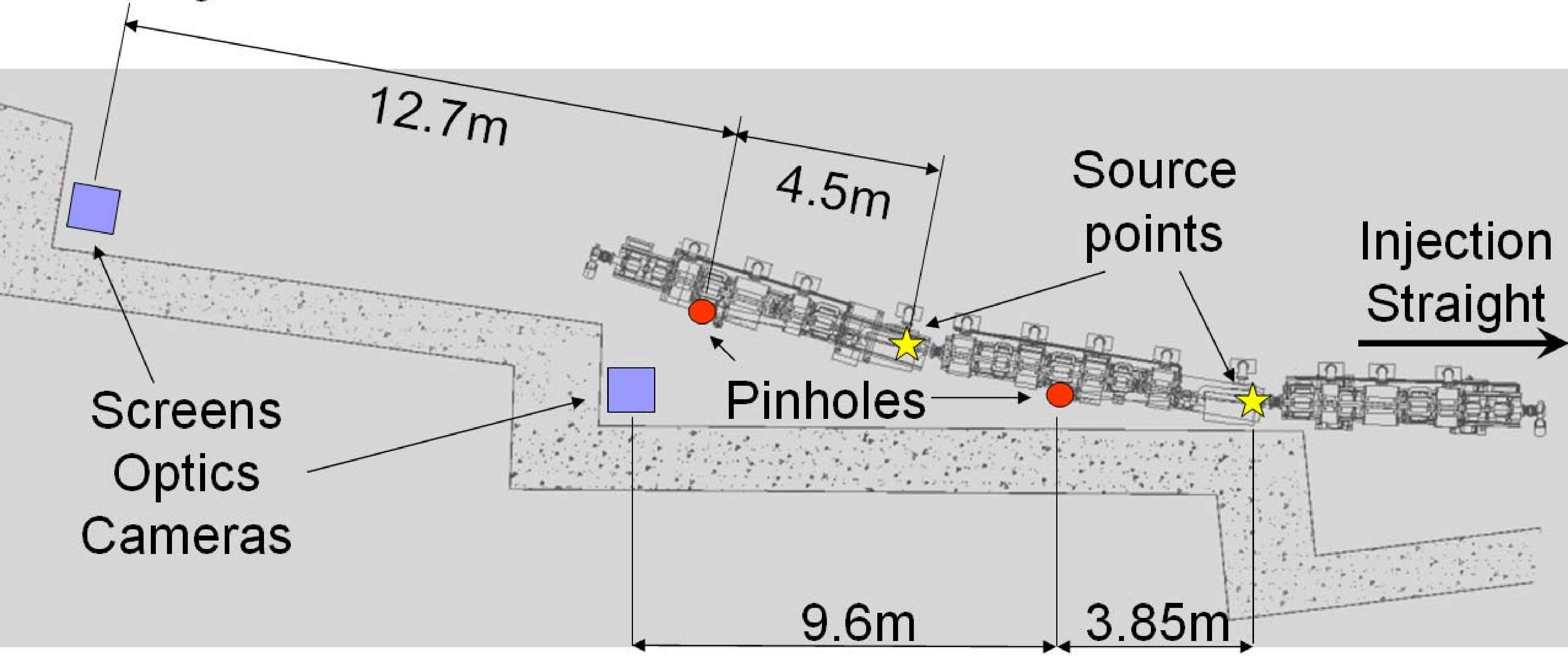


Test at Diamond,
not temperature stabilised

Emittance Measurement

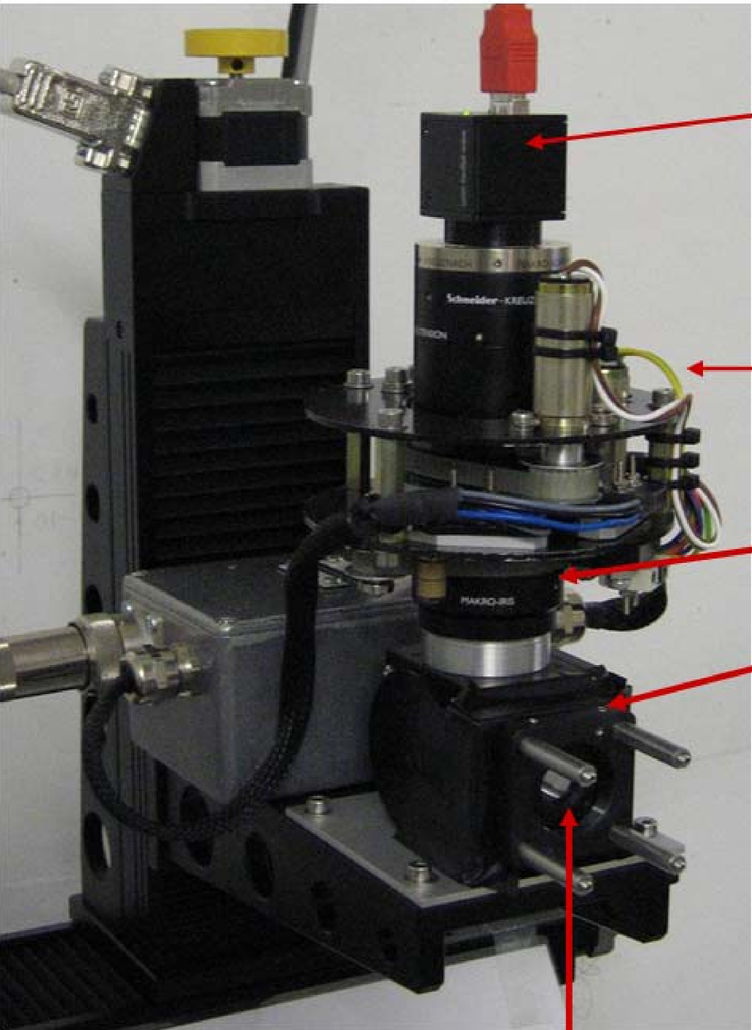
- Requires transverse profile and knowledge of Twiss parameters at source point
- Profile can be imaged at X-ray energies using:
  - ‘No optics’: Pinhole camera
  - Diffractive Optics: Fresnel Zone Plates
  - Refractive Optics: Compound Refractive Lenses
- Profile can be directly projected
- Profile can be inferred from distribution of vertically polarised visible light
- Profile can be probed: Laser wire

Example of Pinhole Camera Layout: Two Pinholes at Diamond



Diamond *C.Thomas, TUPC086*; ASP *M. Boland TUPC009*; Soleil *M. Tordeux DIPAC2007*;NSLS-II *I. Pinayev BIW2008*

Pinhole Camera in Air



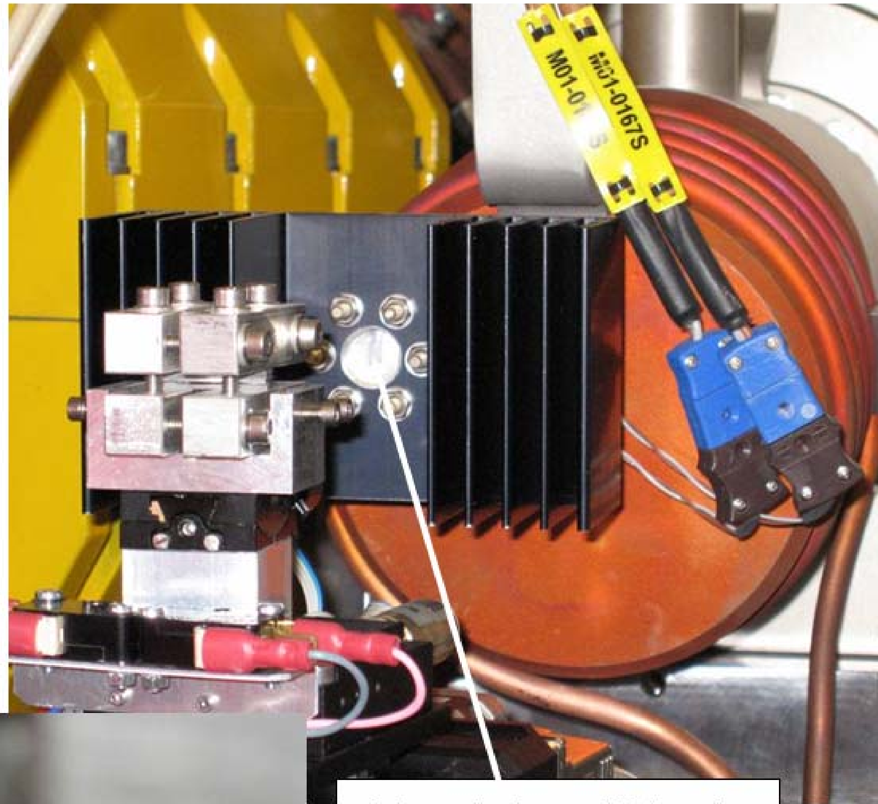
1024x768 CCD
4.65μm pixel

focus and iris
remote control

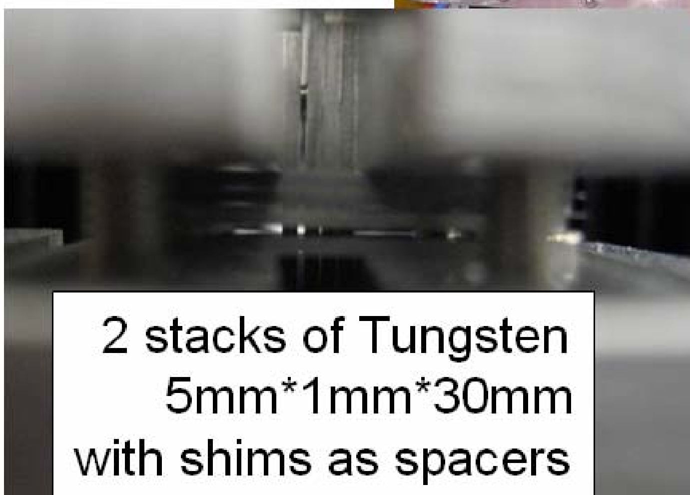
macro lens 1:1

mirror

$CdWO_4$ screen



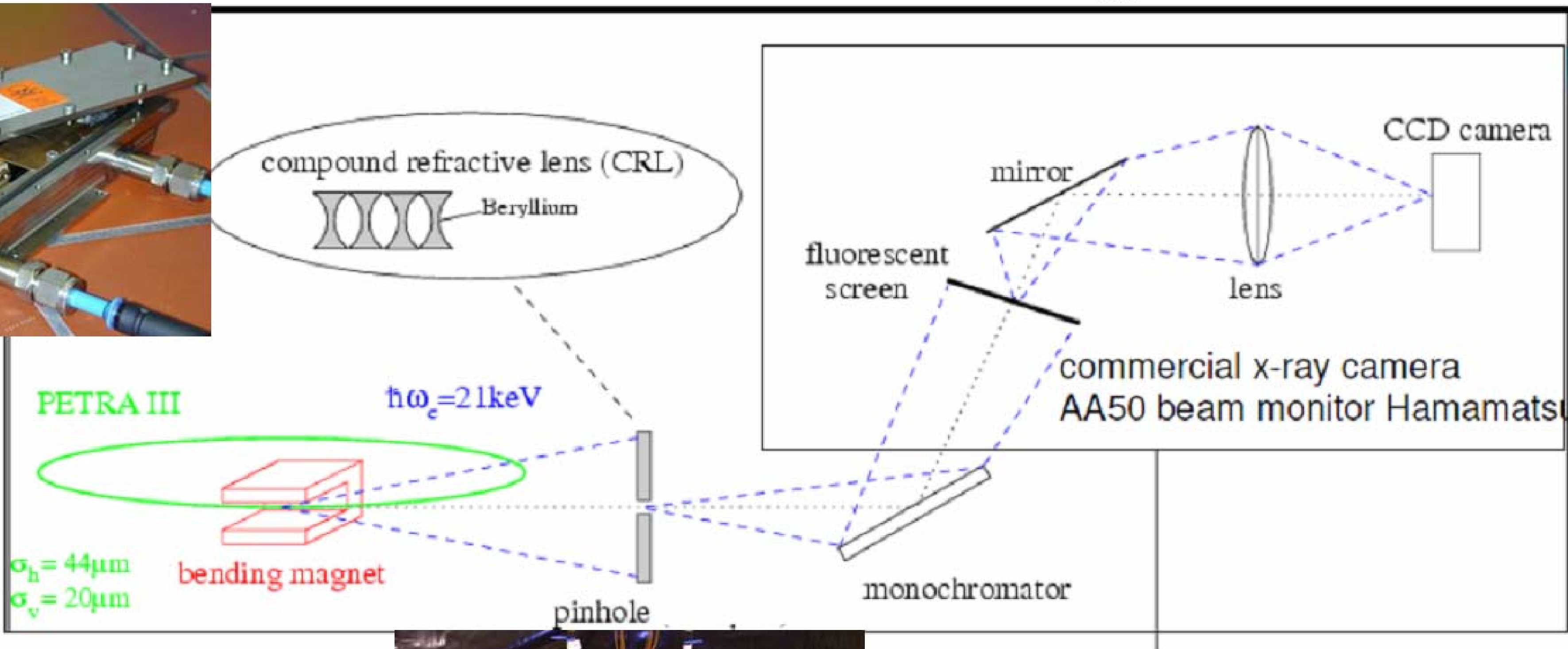
Aluminium/Steel
explosion bonded
flange as window

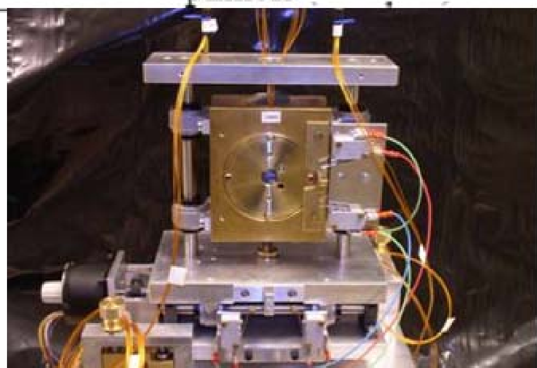


2 stacks of Tungsten
5mm*1mm*30mm
with shims as spacers

Pinhole and Compound Refractive Lens planned for PETRA III

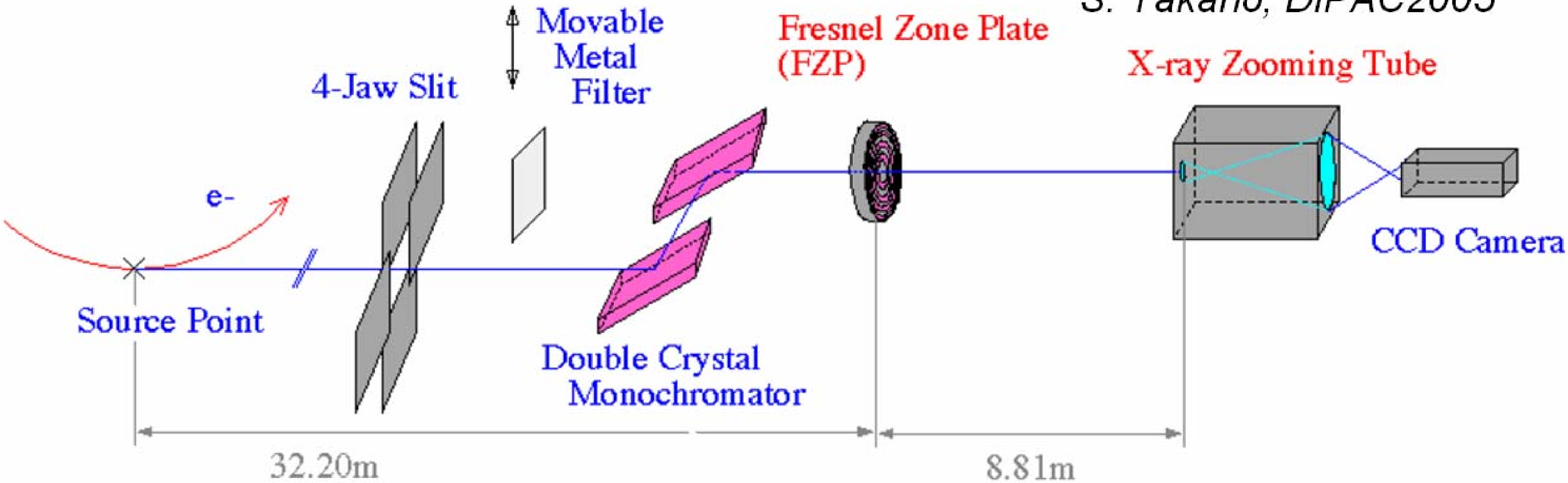
K. Wittenburg, BIW2008

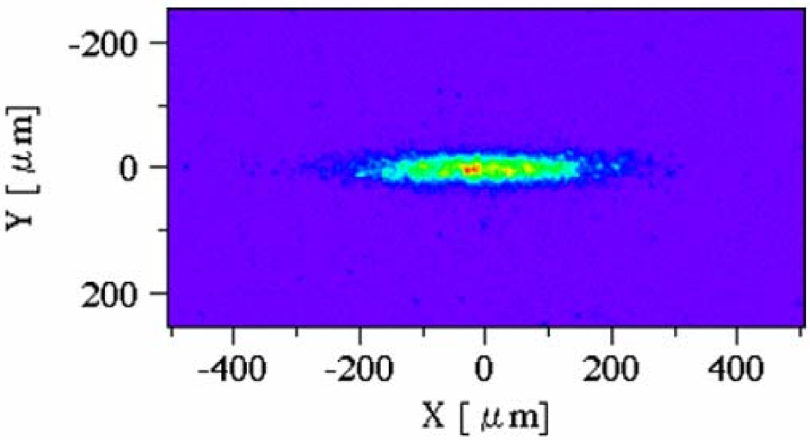


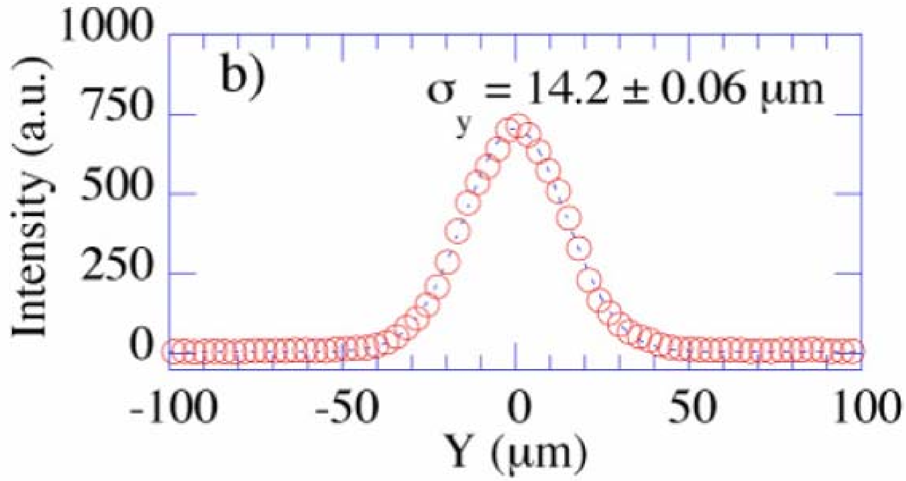


Fresnel Zone Plates at Spring-8

S. Takano, DIPAC2005



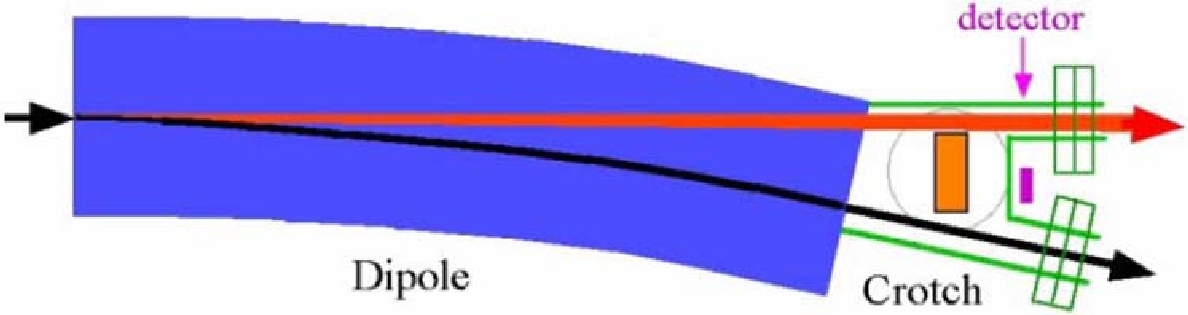




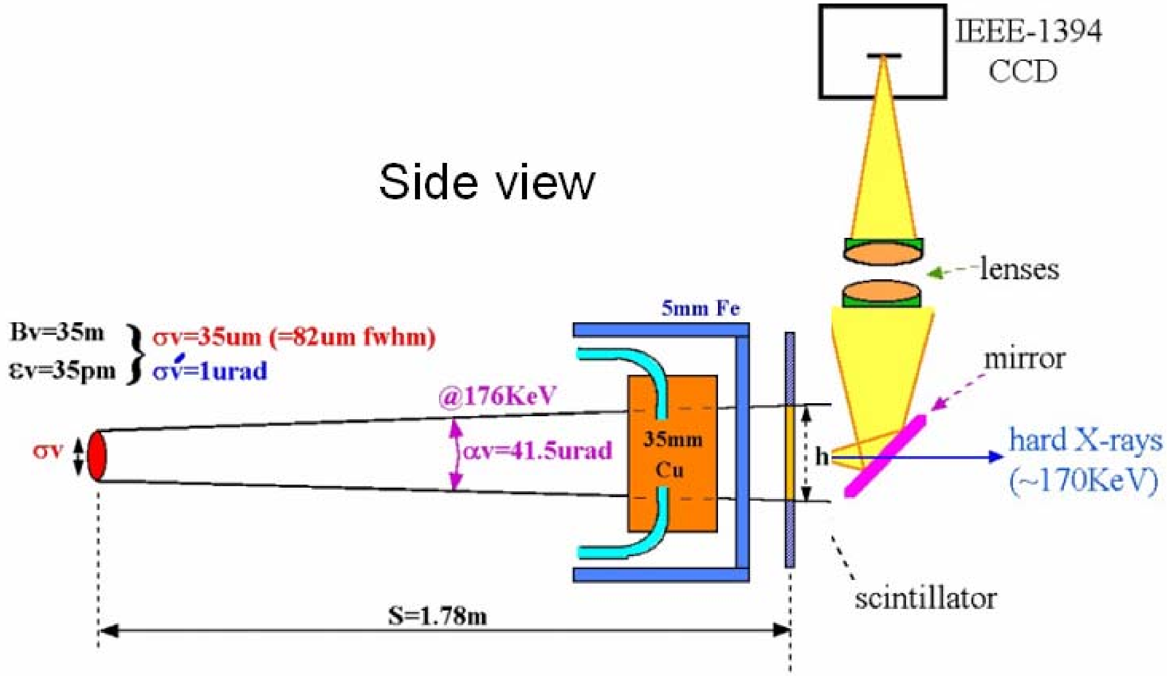
Direct Projection of Hard X-Rays at ESRF

K. Scheidt, DIPAC2007

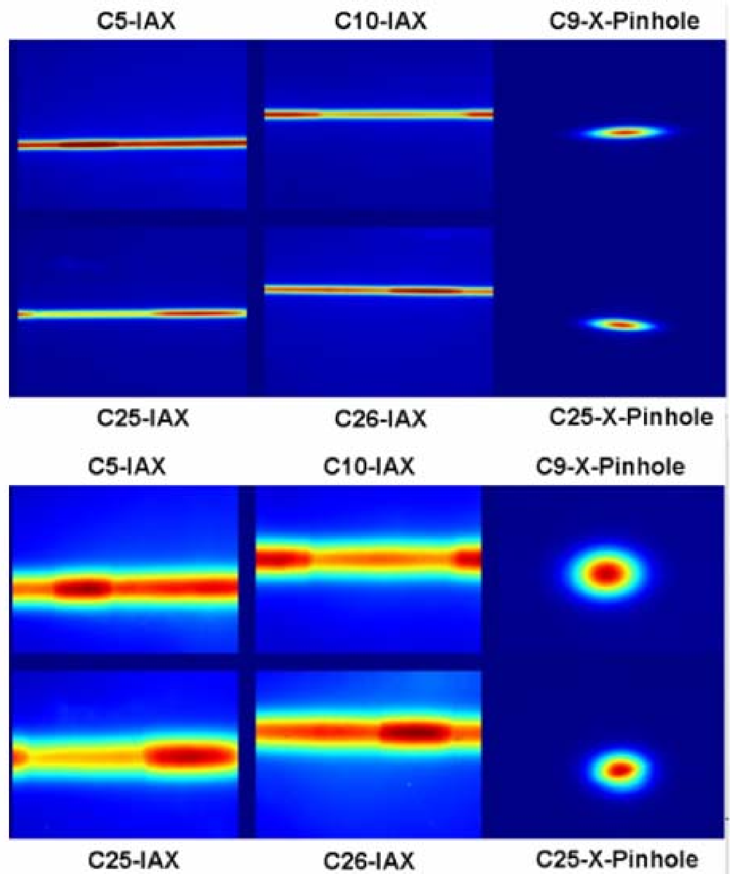
Top view



Side view



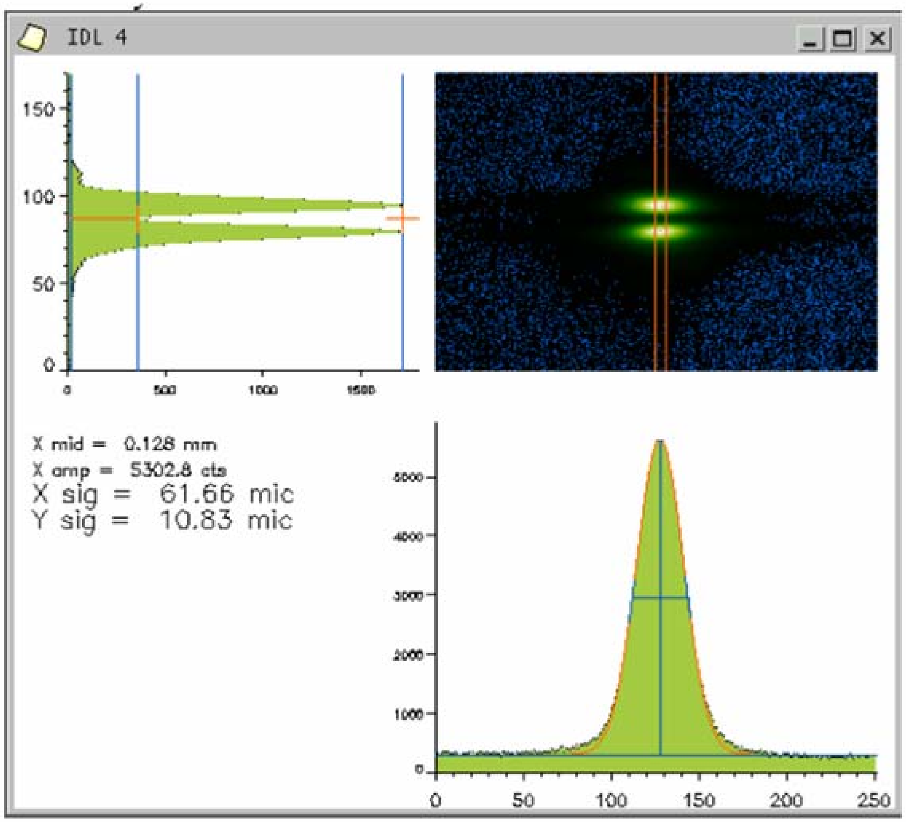
20 pm rad

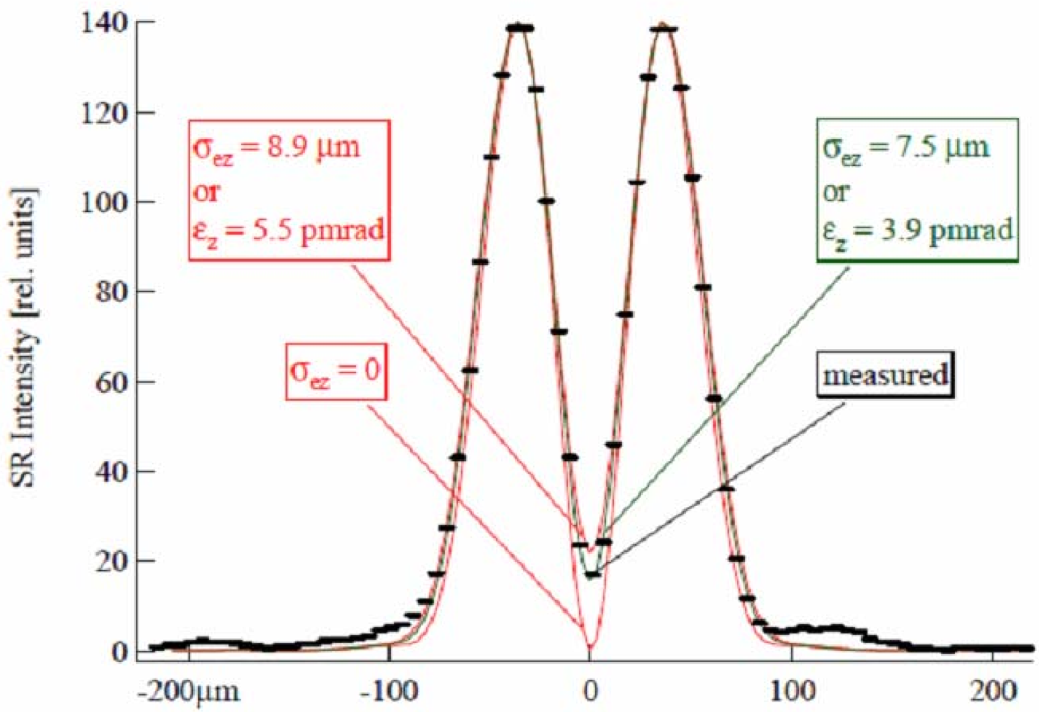


500 pm rad

SLS Measurements of Profile of Vertically Polarised Radiation

A. Andersson, DIPAC2007





Achieved Performance of Transverse Profile Measurements

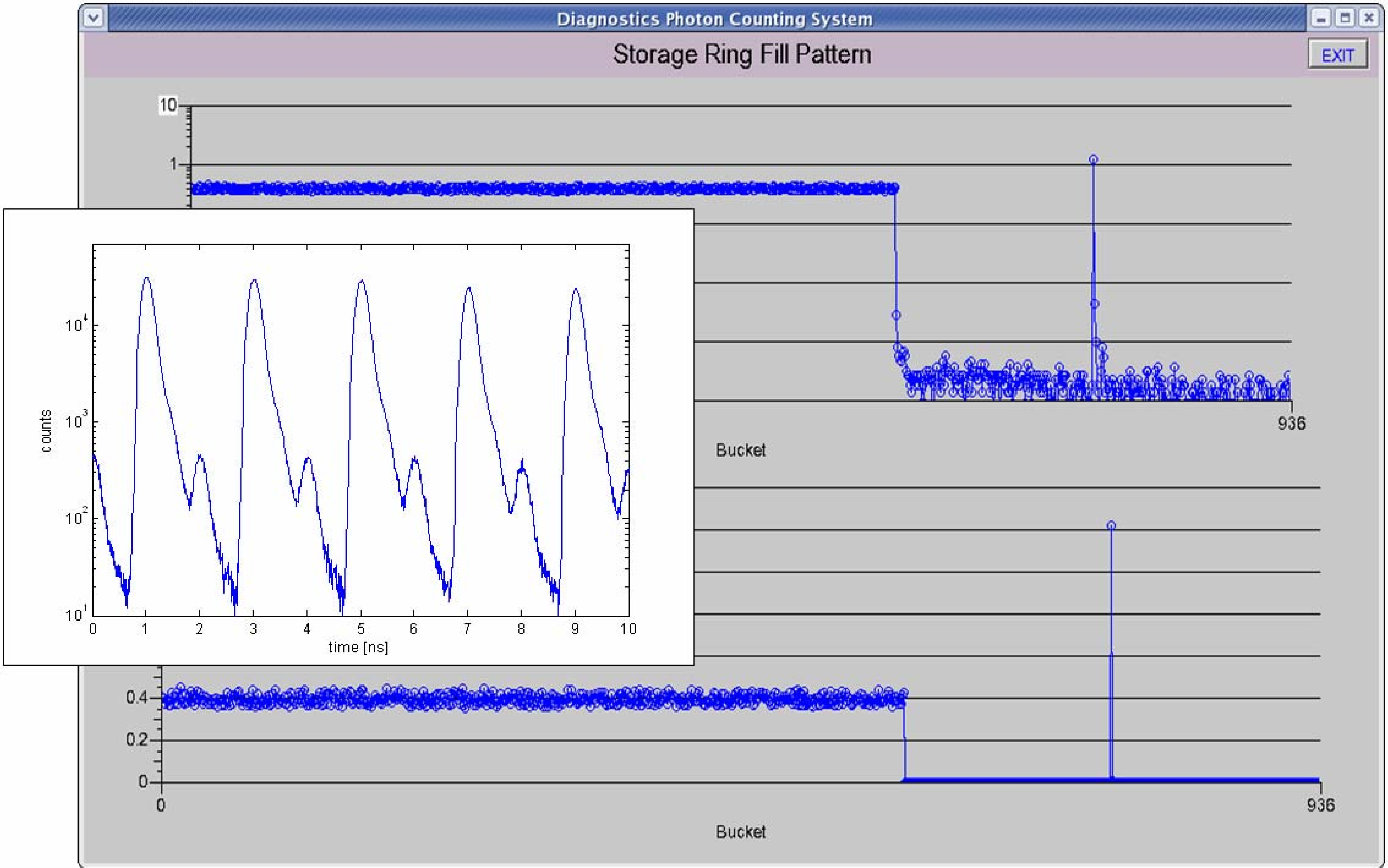
	type	Σ_0 [μm]	σ_y [μm]	σ'_y [μm]	ϵ_y [pm rad]
Spring-8	FZP	4.1	14.6	14	7
Diamond	Pinh. 1	3.9	7.8	6.8	2.2
Diamond	Pinh. 2	3.5	7.7	6.9	2.1
Soleil	Pinhole	5	19.8	19	4.7
ESRF	Project.	34	38.5	18	10
SLS	V. polar.	-	7.5	7.5	3.9
SLS	Pinhole	9	13.5	10	-

$$\sigma'_y = \sqrt{\sigma_y^2 - \Sigma_0^2}$$

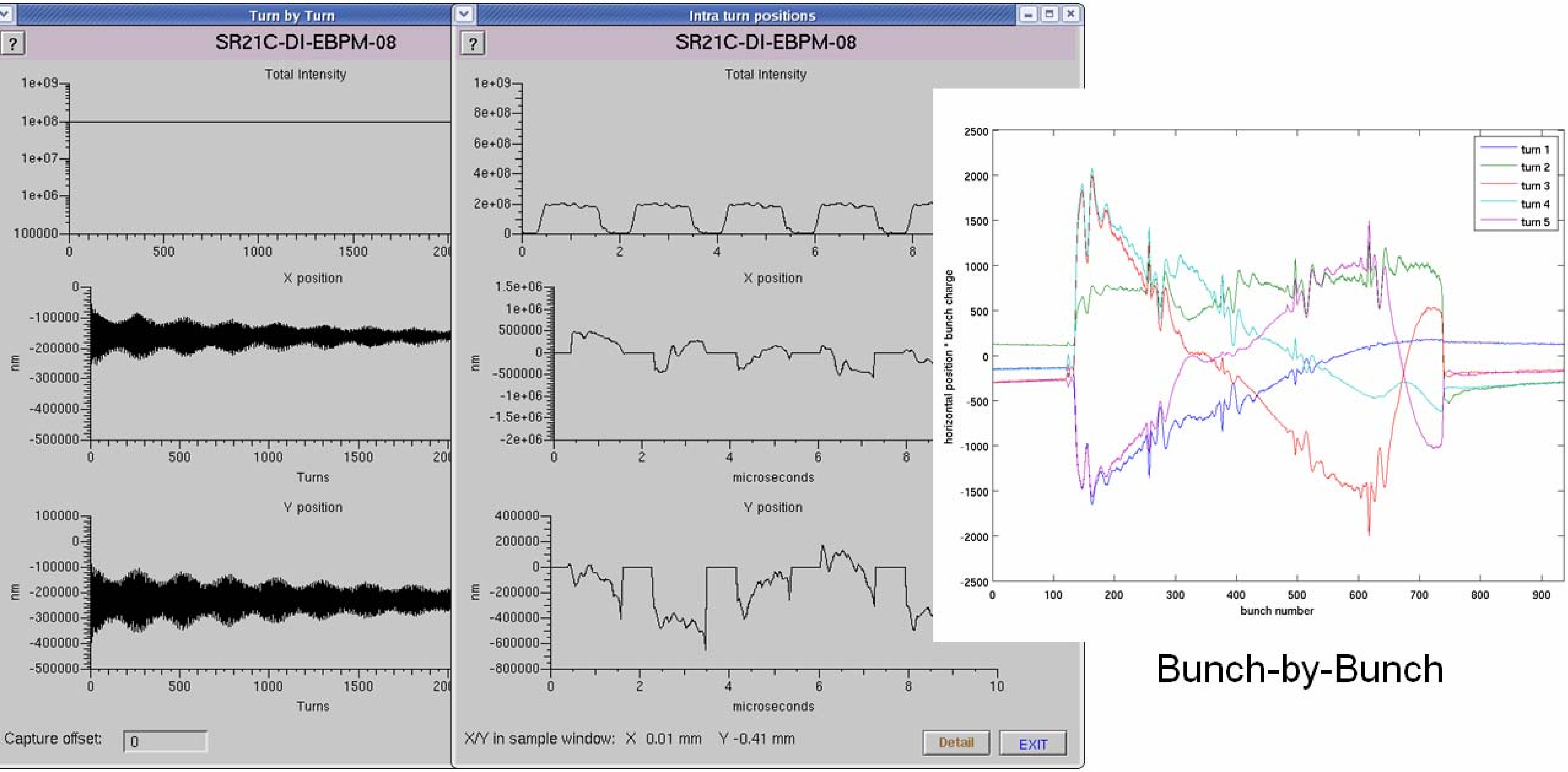
Diagnostics for Top-Up

- Basically no more than a PCT with readout synchronised to injection is needed
- Injection efficiency: synchronous readings of charge at various locations in the injector
  - ICTs are pushed to their limits for small charges (<100pC)
  - Striplines or other resonant pickups and dedicated electronics are better (*G. Naylor, DIPAC2007)*
- Some kind of measurement for Fill Pattern Feedback
- Diagnostics of beam perturbation from non closed injection kick:
  - Turn-by-turn EBPM are a good start, but might underestimate
  - Fast transverse imaging shows view of beamline

Fill Pattern from Time Correlated Single Photon Counting



Perturbation from Injection Kick: Turn-by-Turn and Faster

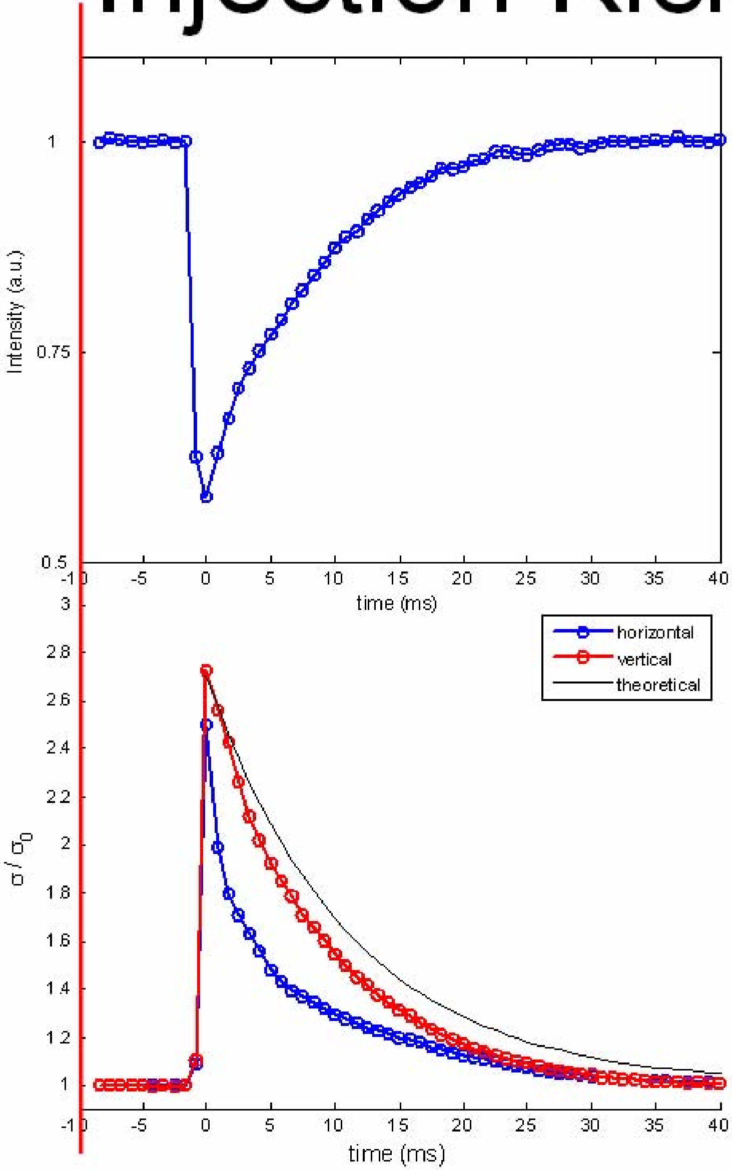


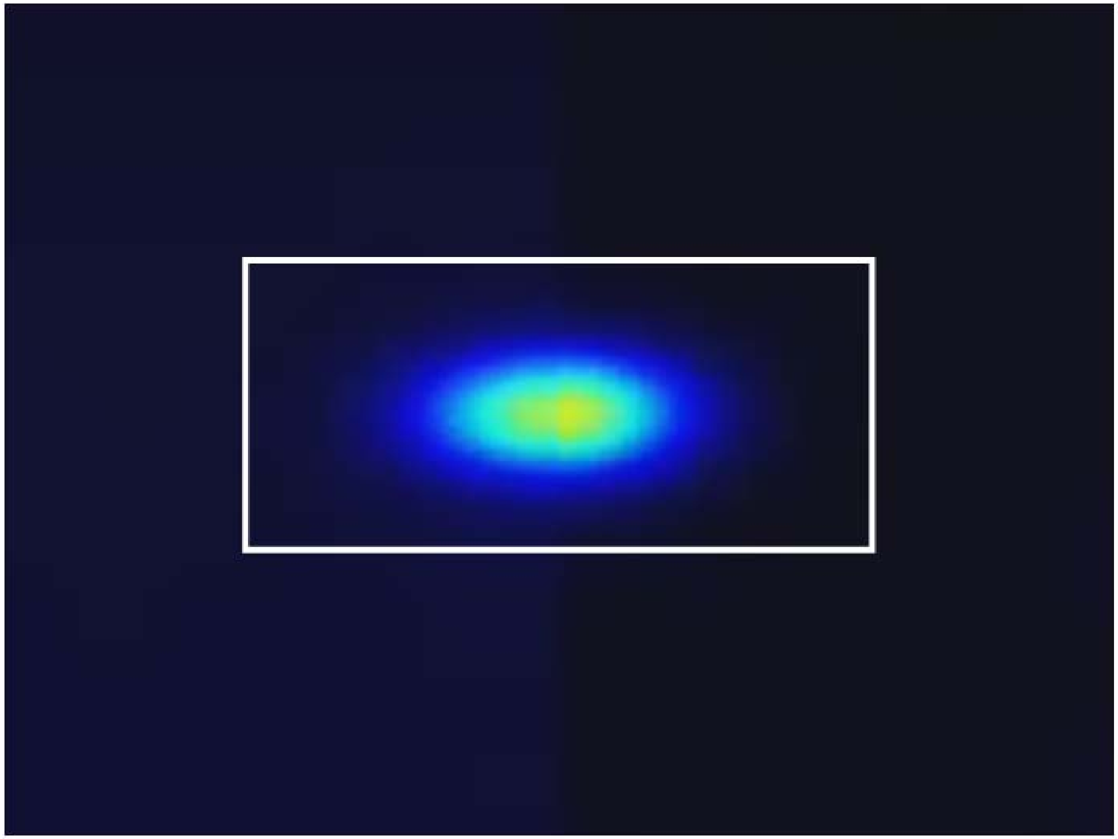
Turn-by-turn

Intra turn from EBPM

Bunch-by-Bunch

Fast Pinhole Camera Recording of Injection Kick Transient





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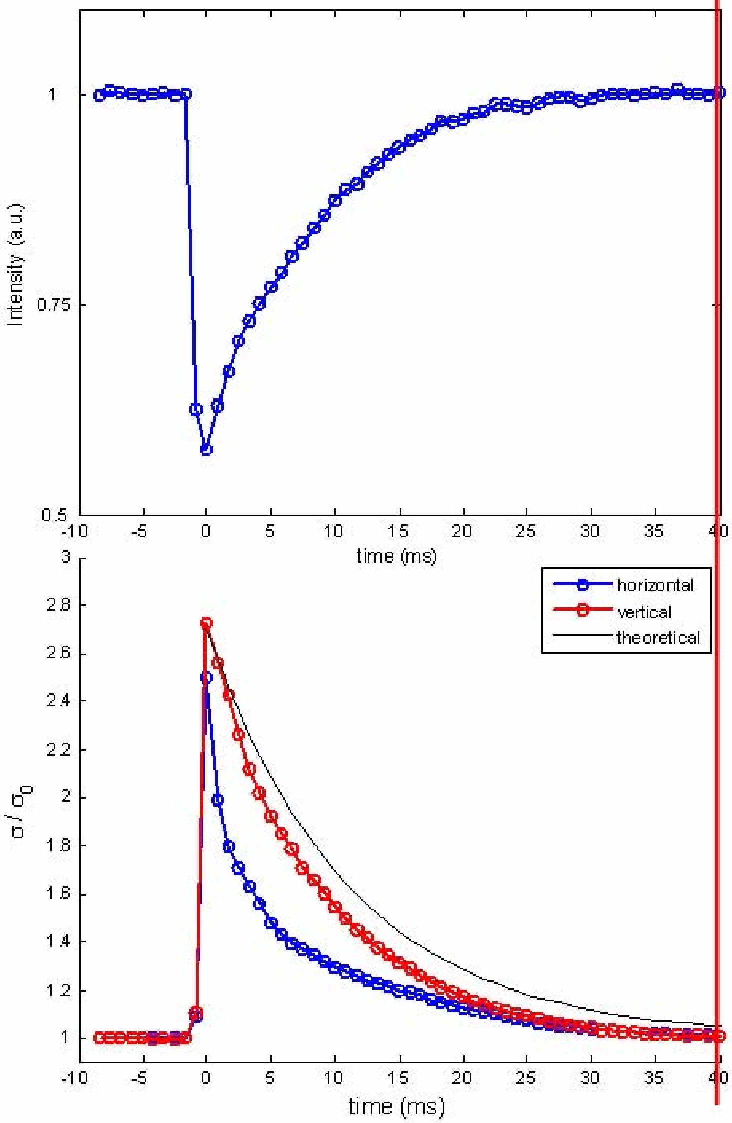
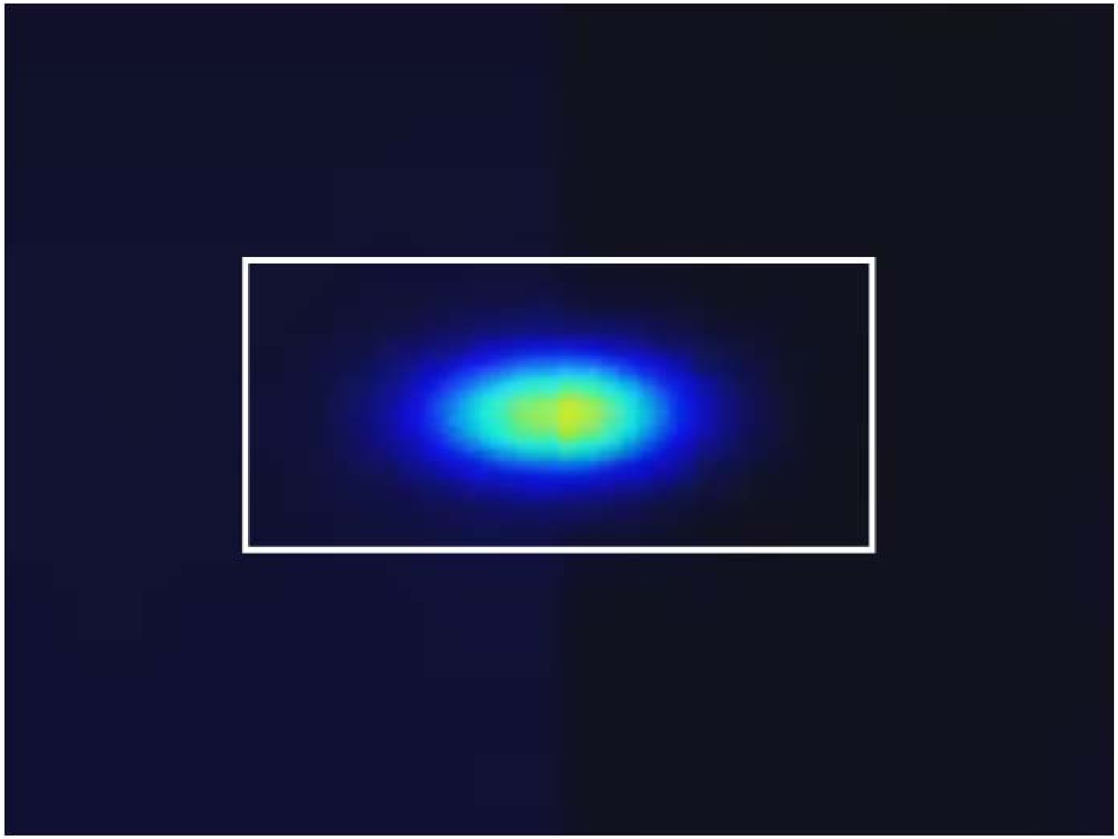




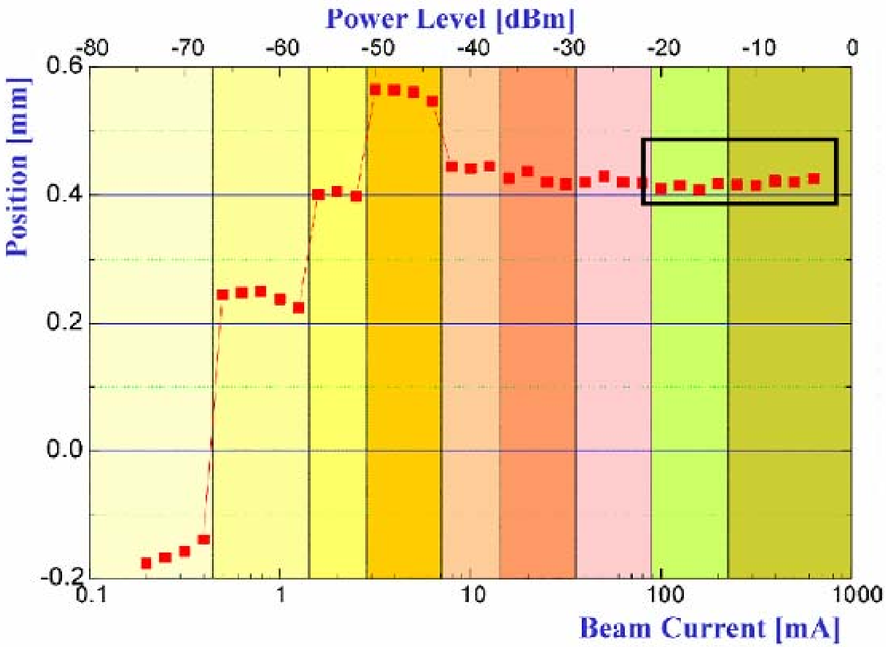
Summary

- EBPM evolution has led to ADC/FPGA based systems which keep up with tightening requirements
- Pinholes are still the favourite for emittance / transverse profile measurement, some new methods look promising
- Top-Up strictly requires few specific diagnostics, but measurement of fill pattern and injection kick perturbation are helpful

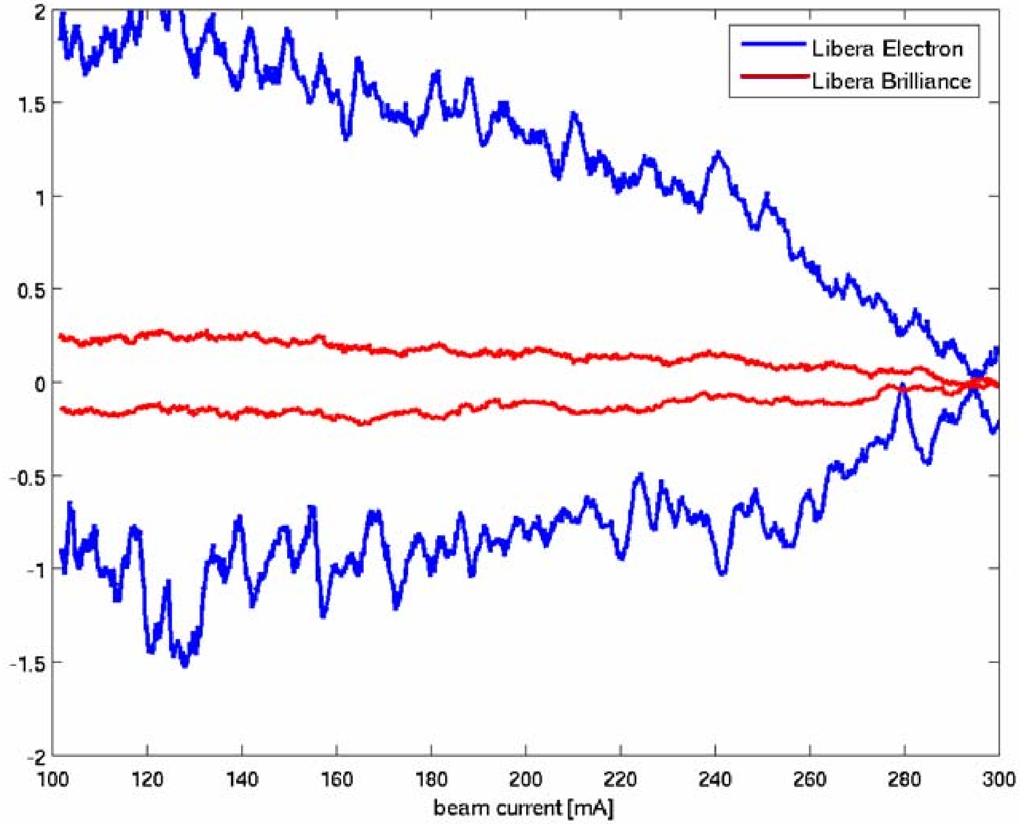
Acknowledgements

- ALBA: F. Perez, A. Olmos
- ASP: M. Boland, Y. Tan, M. Spencer
- Elettra: M. Lonza, M. Ferianis
- ESRF: K. Scheidt, E. Plouviez, G. Naylor
- NSLS-II: I. Pinayev, P. Cameron
- PETRA III: K. Wittenburg, G. Kube
- Soleil: J.-C. Denard, N. Hubert, M. Tordeux
- SLS: V. Schlott, M. Boege, T. Schilcher
- SSRF: Y. Leng, Y. Yan

Beam Current Dependence



SLS BPM, *V.Schlott, DIPAC2001*



Lab test at Diamond