

Instrumentation Activities at the SwissFEL Injector Test Facility

Rasmus Ischebeck, for the SwissFEL Team

SwissFEL

- > SwissFEL: X-ray laser for hard X-rays (0.1 to 7 nm)
 - > Construction has started in the Würenlingen forest
 - > First user beam in summer 2017
- > SwissFEL features
 - > Normal-conducting linac with 100 Hz repetition rate
 - > Low slice emittance: 180 to 340 nm
 - > Two bunches for two beamlines (separated by 28 ns, Phase 2)
 - > Low charge: 10 to 200 pC
 - > Short bunches: 600 as to 30 fs
 - > Good stability: RF phase stability of 0.02° , achieved with solid-state modulators

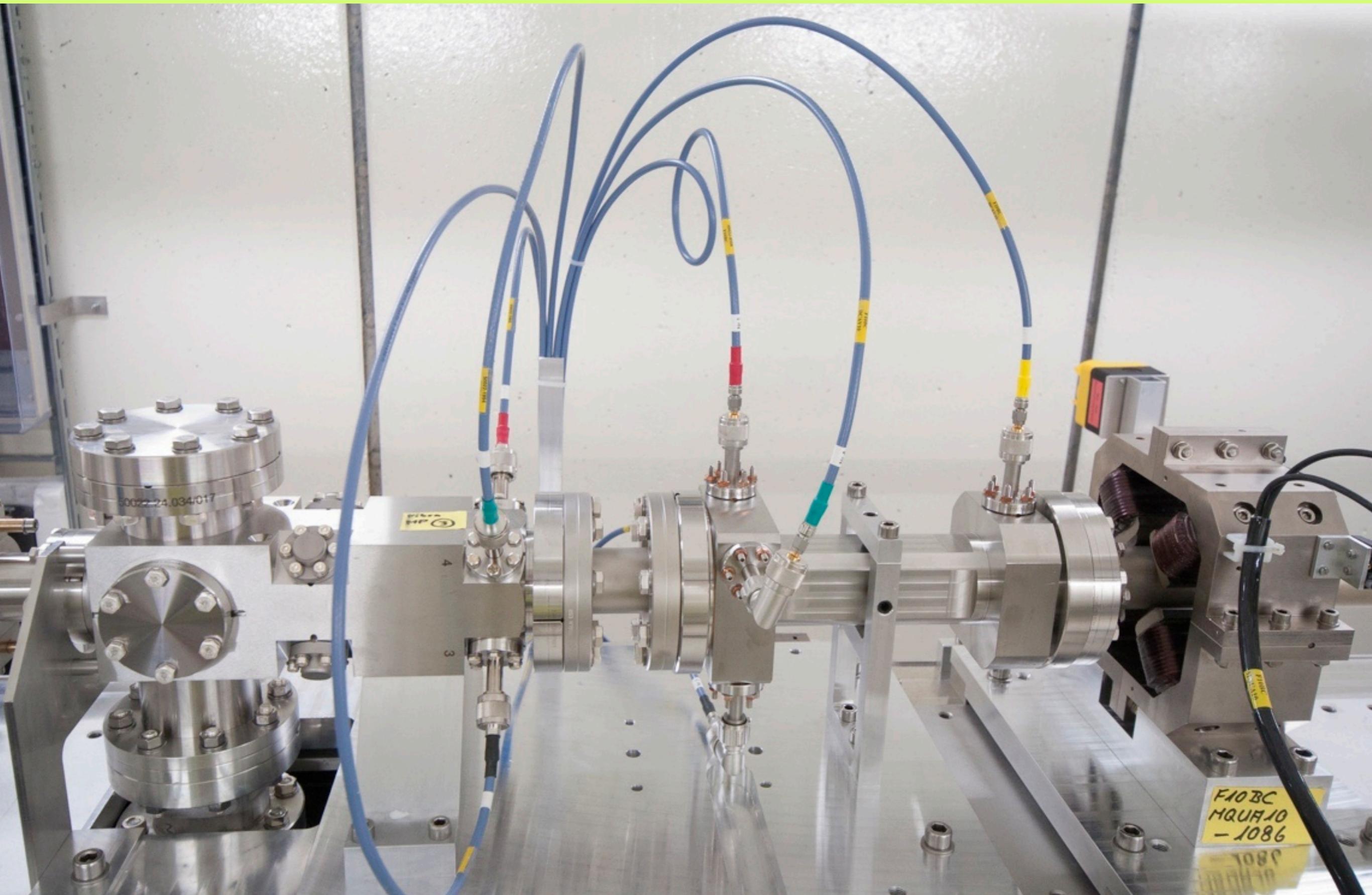


Instrumentation at the SwissFEL Injector Test Facility

- > Beam Position Monitors
- > Charge Monitors
- > Profile Monitors
 - > Screen Monitors
 - > Wire Scanners
 - > Synchrotron Radiation Imager
- > Time-Resolved Measurements
 - > Arrival Time Monitor
 - > Compression Monitor
 - > Electro-Optical Monitor
 - > Transverse Deflecting Cavity
- > Optical Spectrum of Transition Radiation

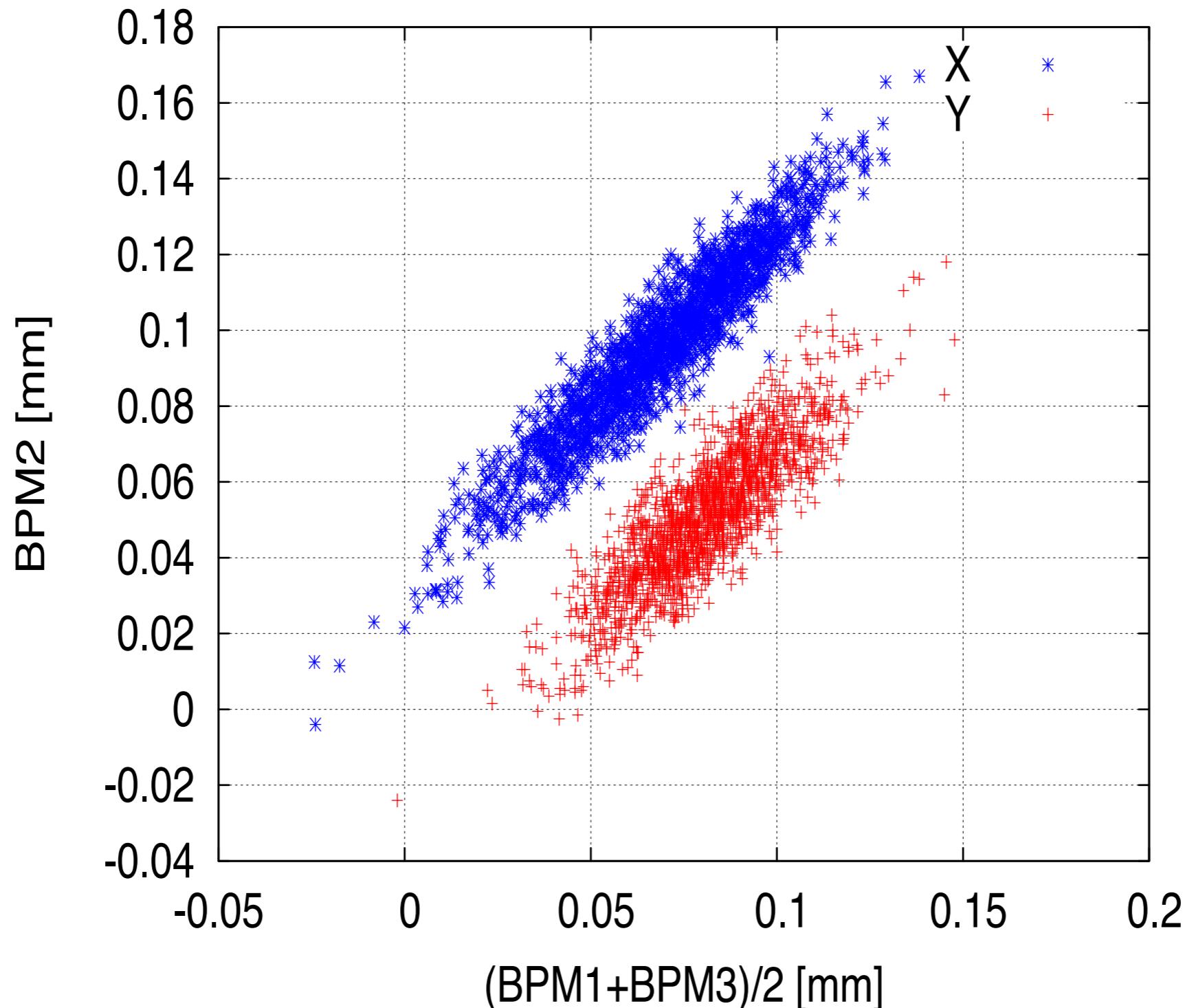


Beam Position Monitors



Beam Position Monitors

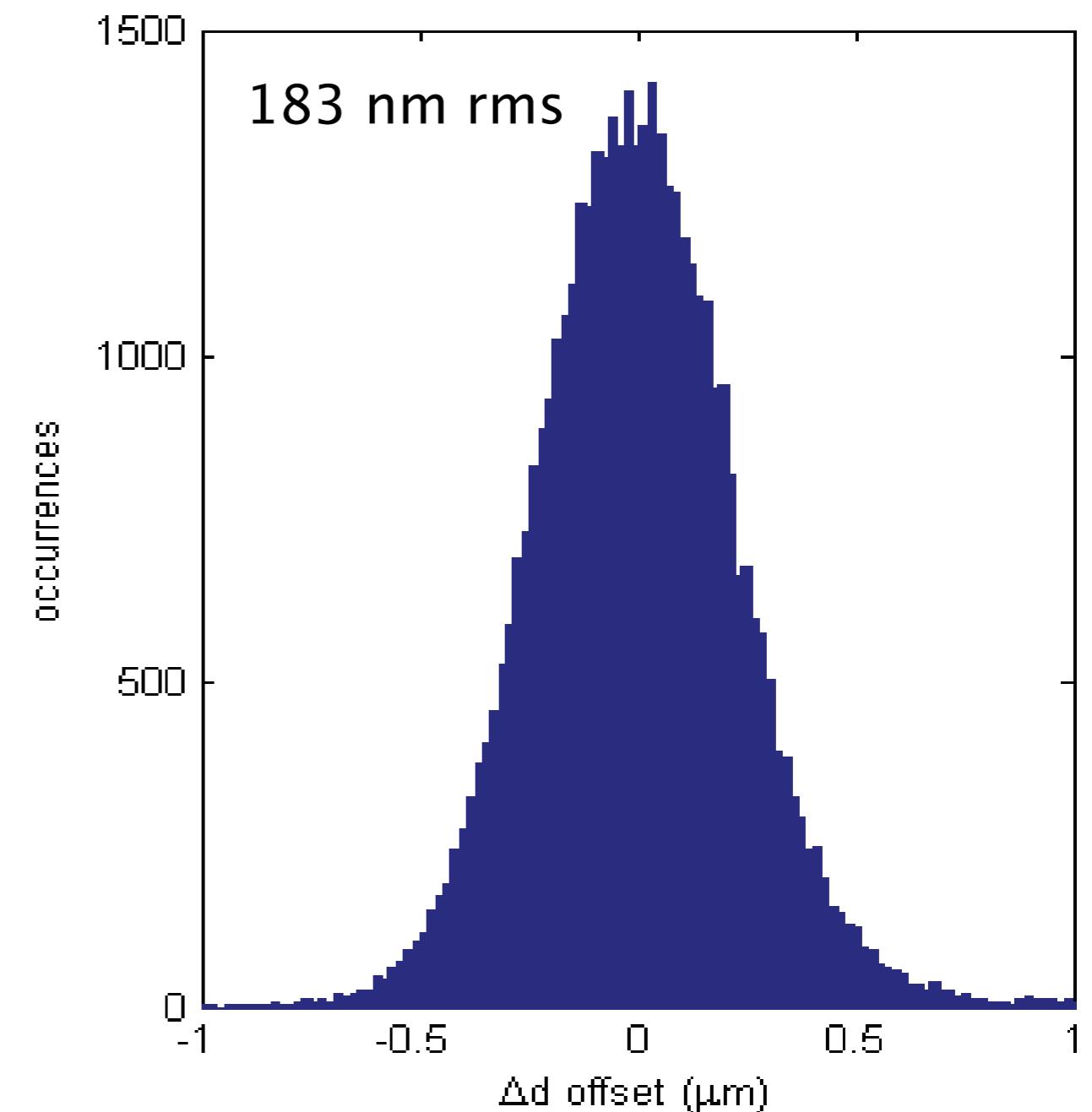
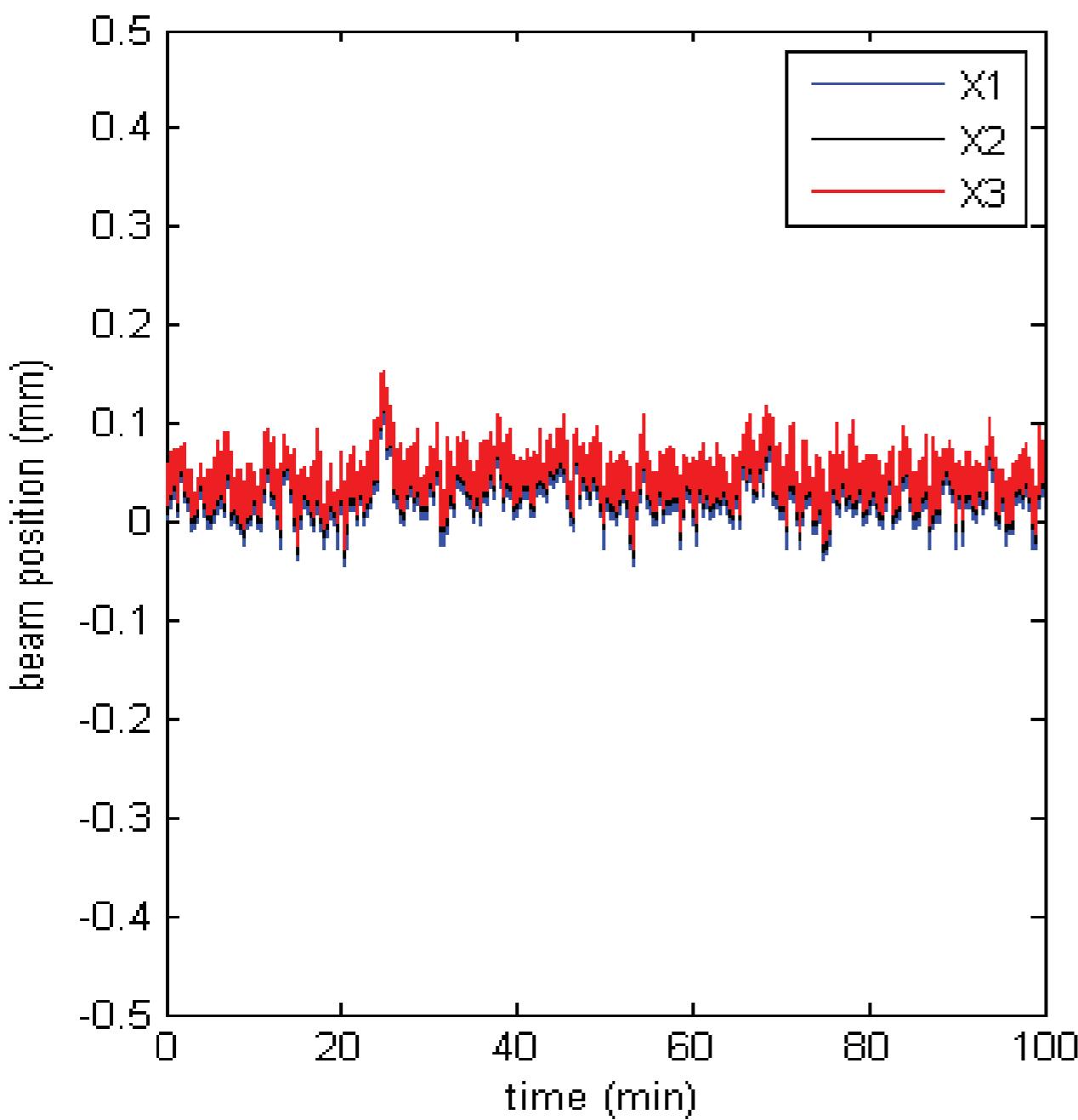
- > Resolution determined by comparing three adjacent BPMs
- > 7 μm rms for charges between 5 and 1000 pC



Cavity Beam Position Monitors

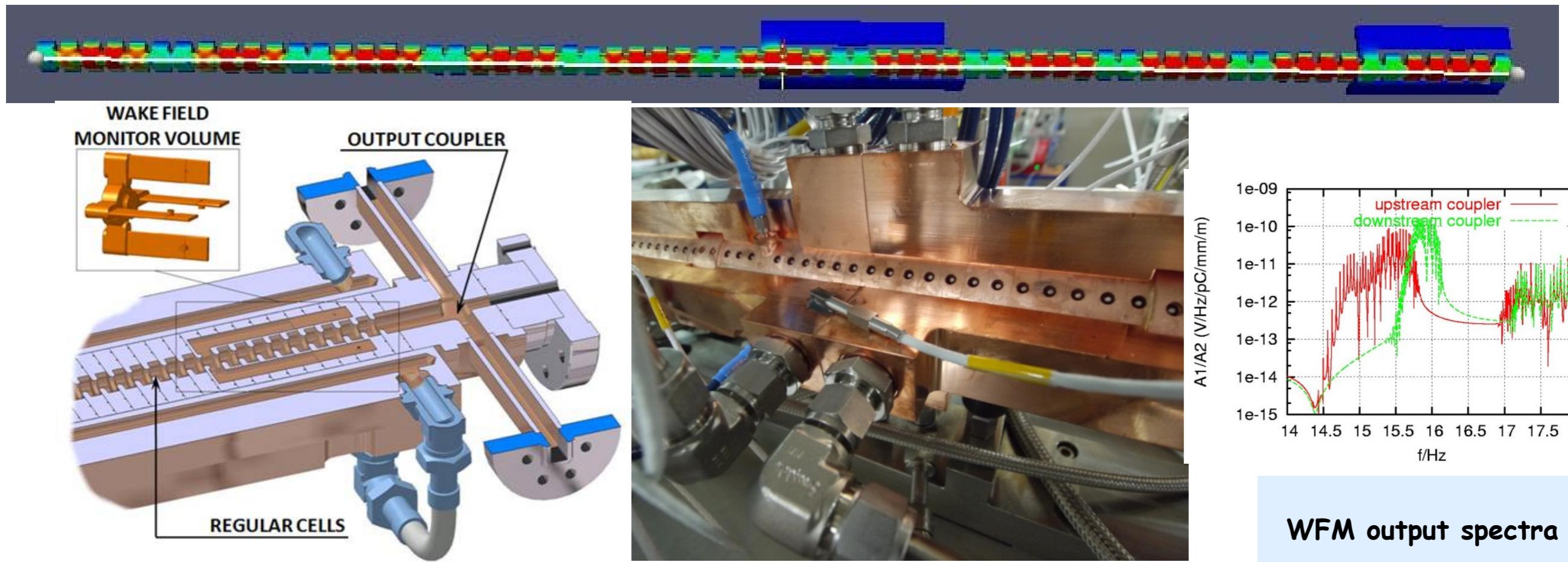
- > SwissFEL will use only cavity beam position monitors
- > The same electronics as for the European XFEL will be used
- > Sub-micrometer resolution has been demonstrated

☞ TUPC25



Position Measurement: Wakefield Monitor

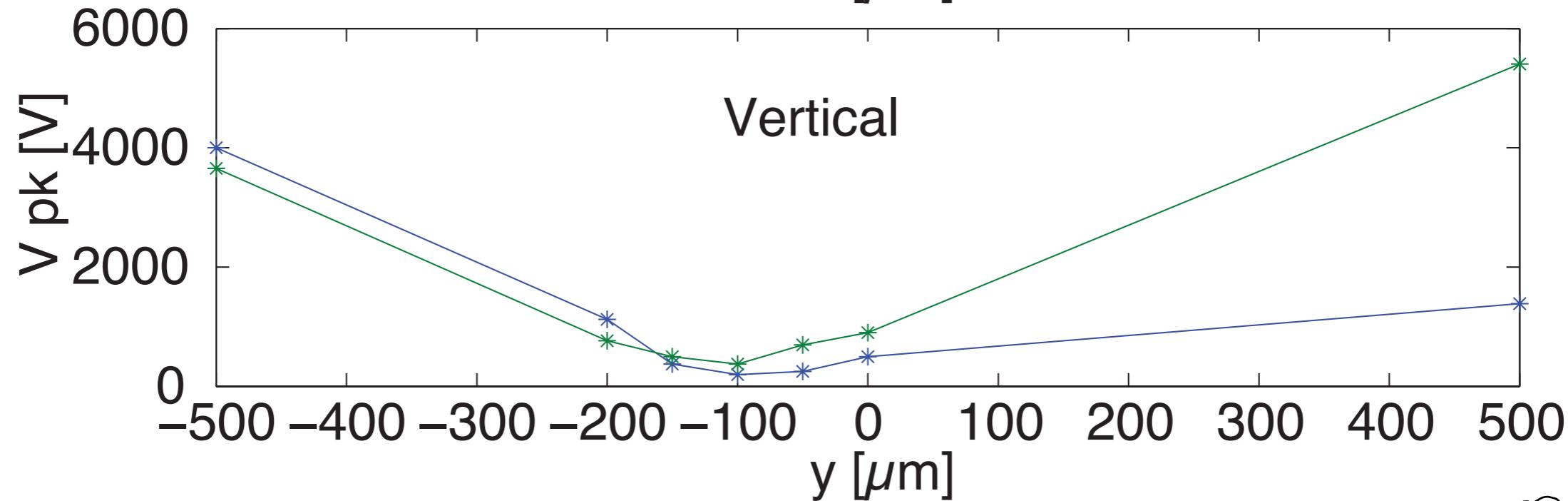
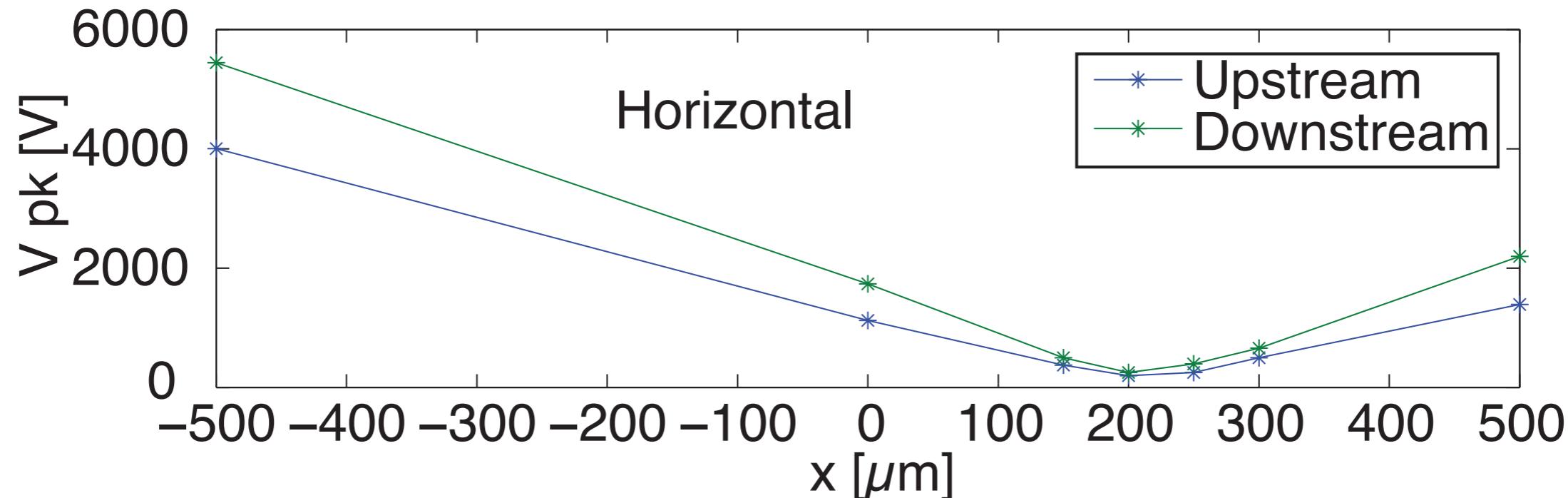
- > Position in X band linearizing cavity is important to reduce effects of wake fields
- > Wake fields can be measured directly



- > Outcoupling of wakefields at frequencies $> 10 \text{ GHz}$ requires special care in
 - > couplers
 - > cables
 - > data acquisition

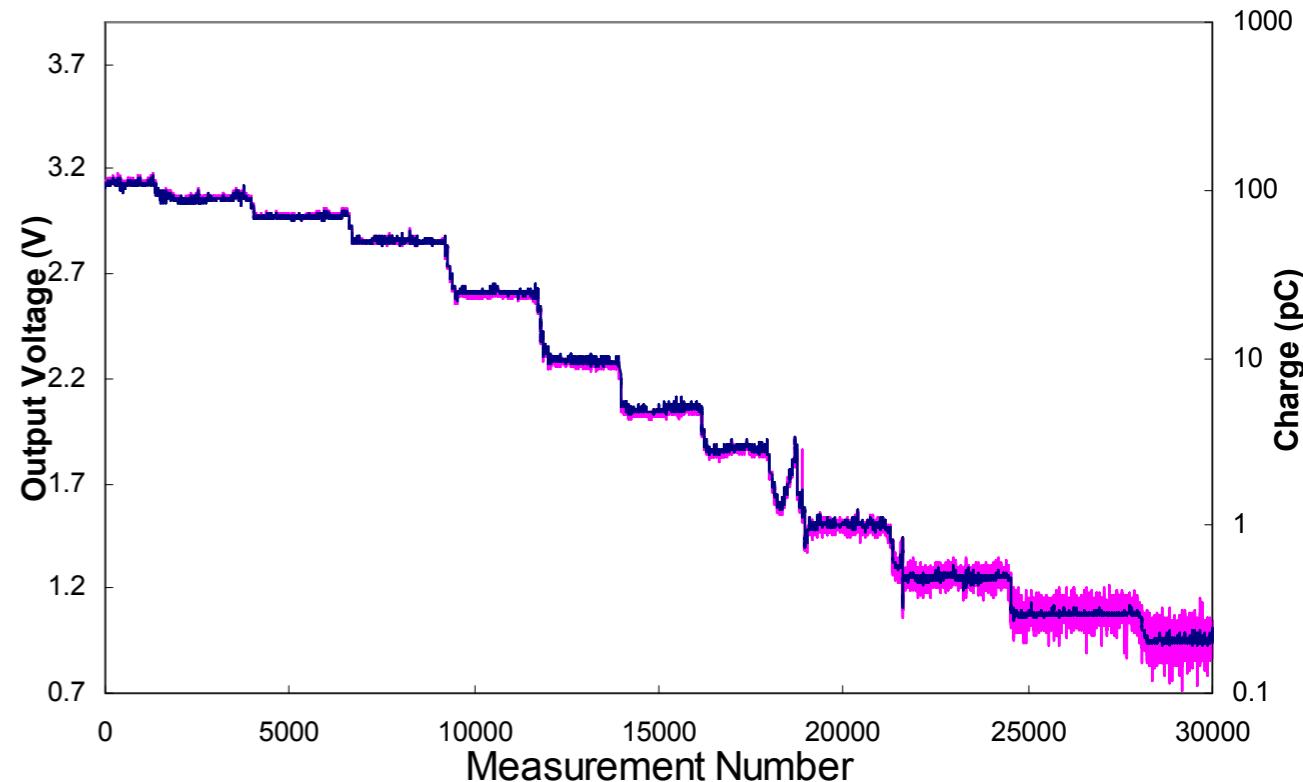
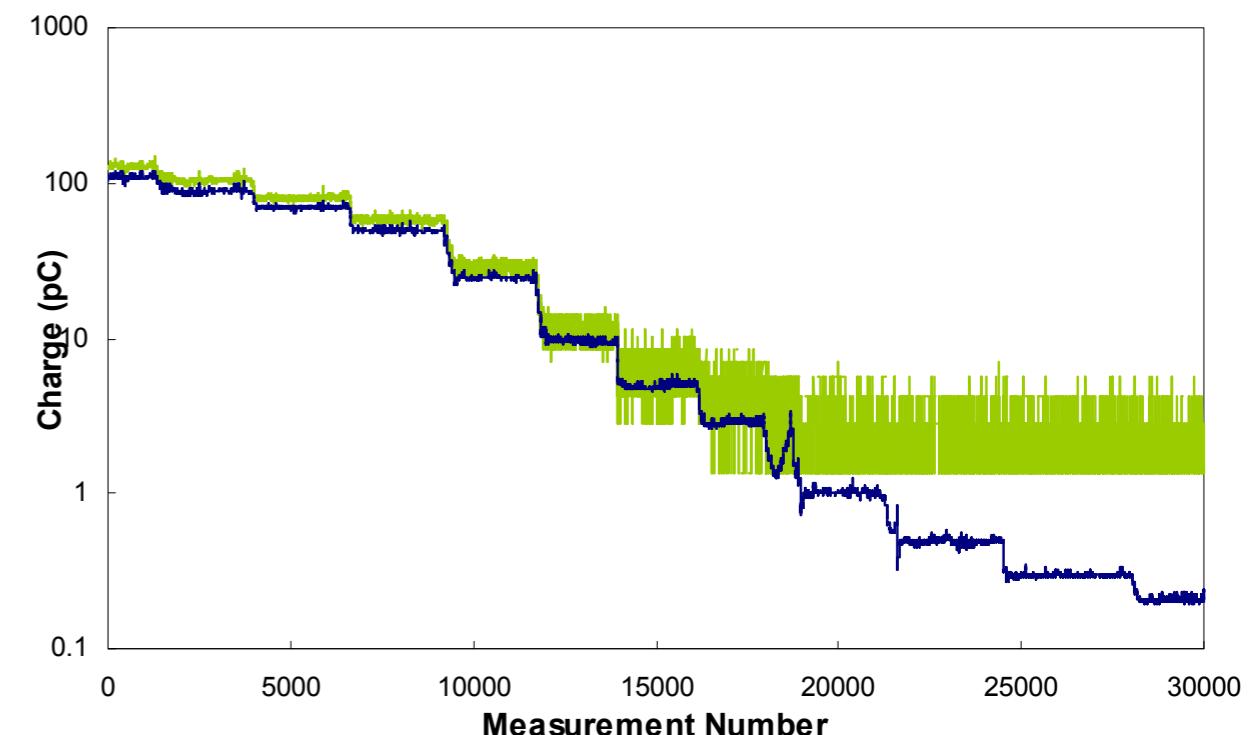
Position Measurement: Wakefield Monitor

- > Measured signal as a function of offset, measured by resonant strip line BPMs
- > Observed offset compatible with mechanical alignment tolerances



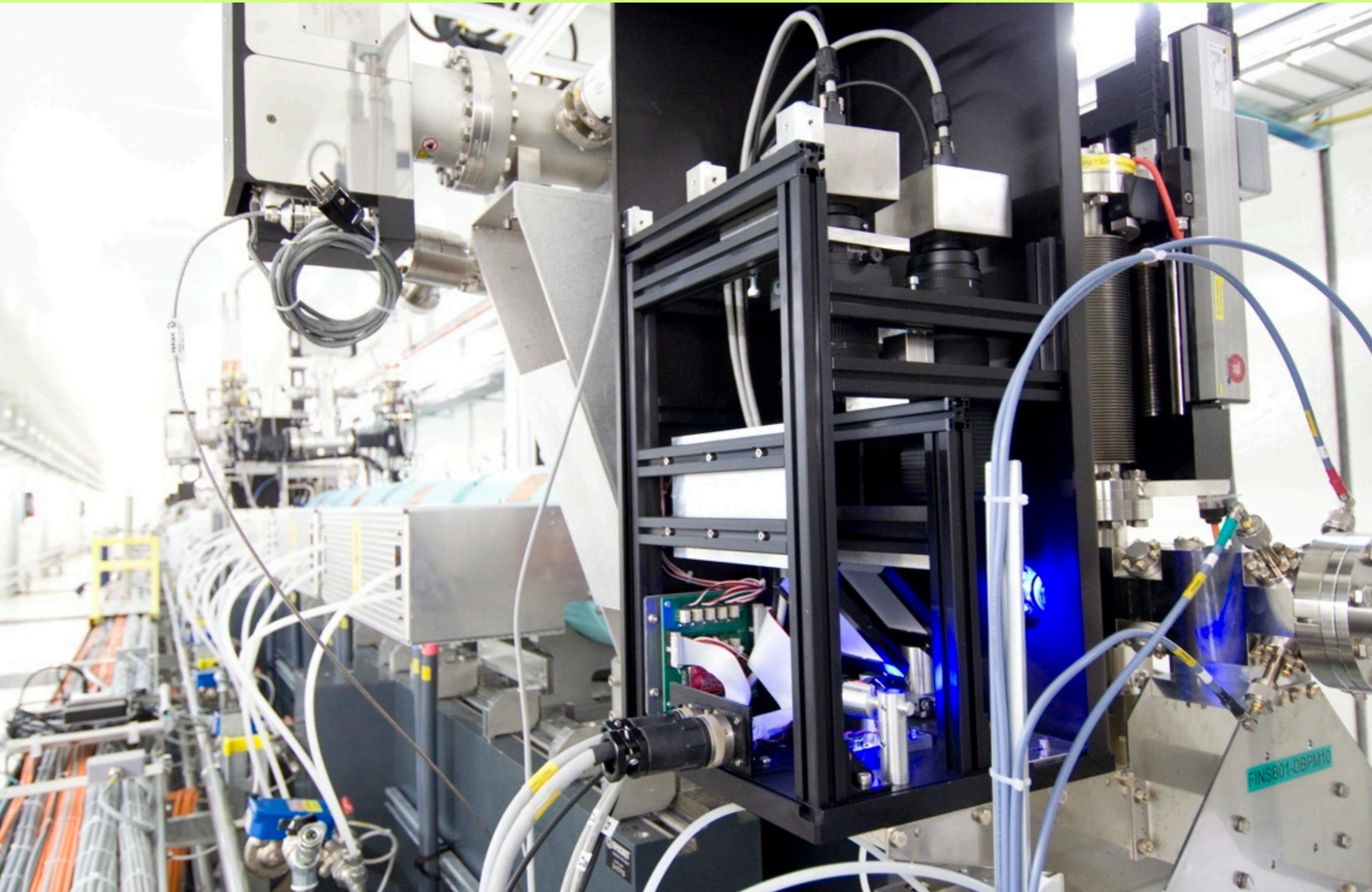
Charge Monitors

- > Absolutely calibrated integrating current transformers
- > New and improved model shows superior noise at low charge
- > Resolution: 1% at 120 pC

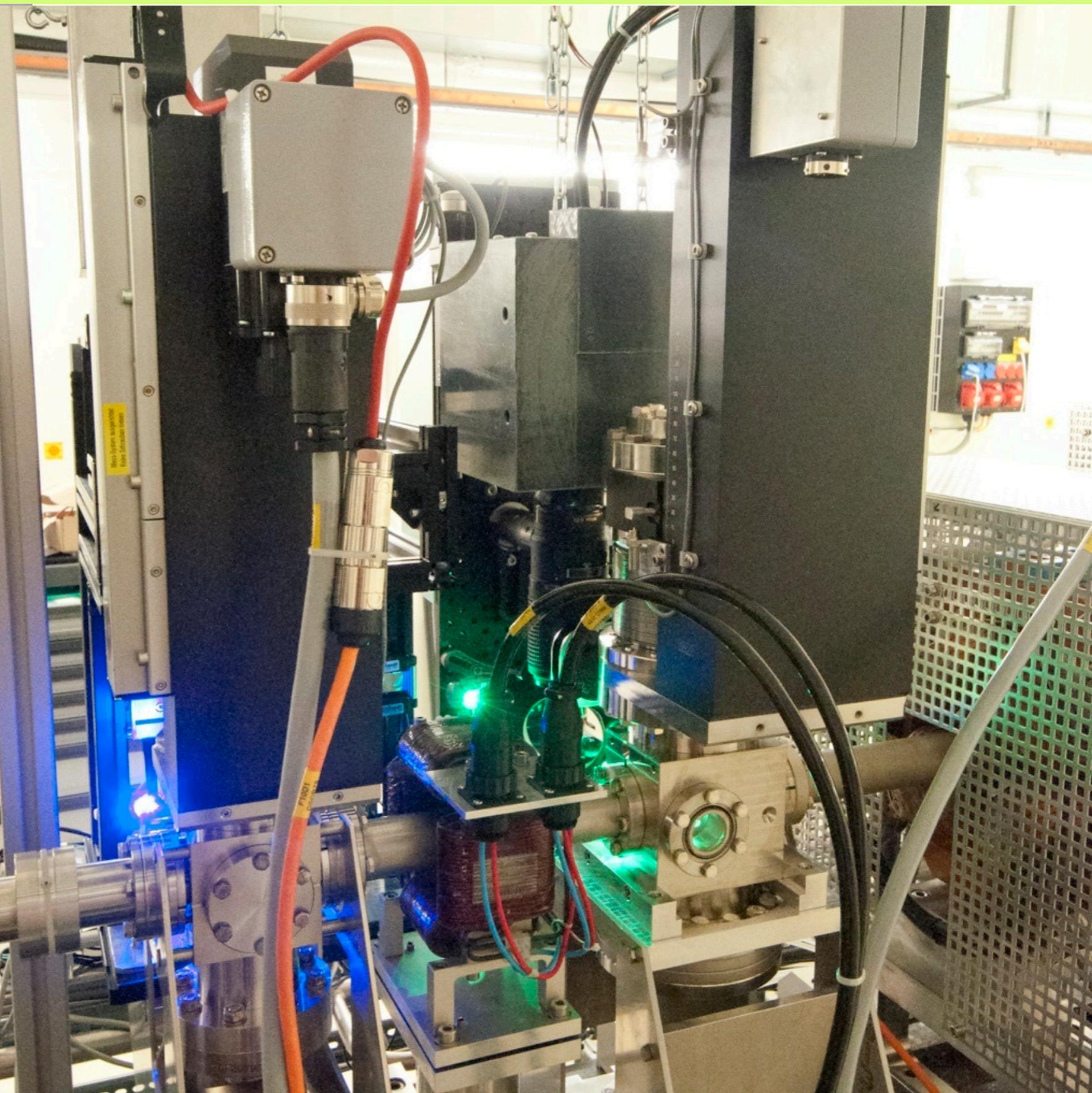
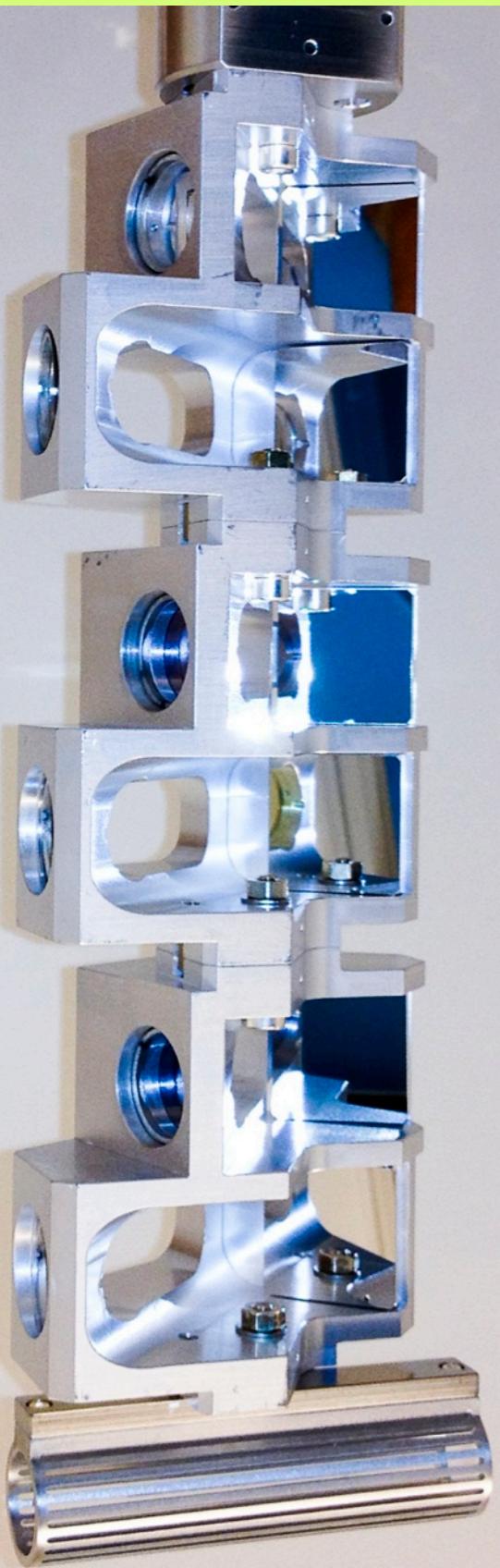


👉 Marquee Exhibitor Area

Transverse Profile: Screen Monitor

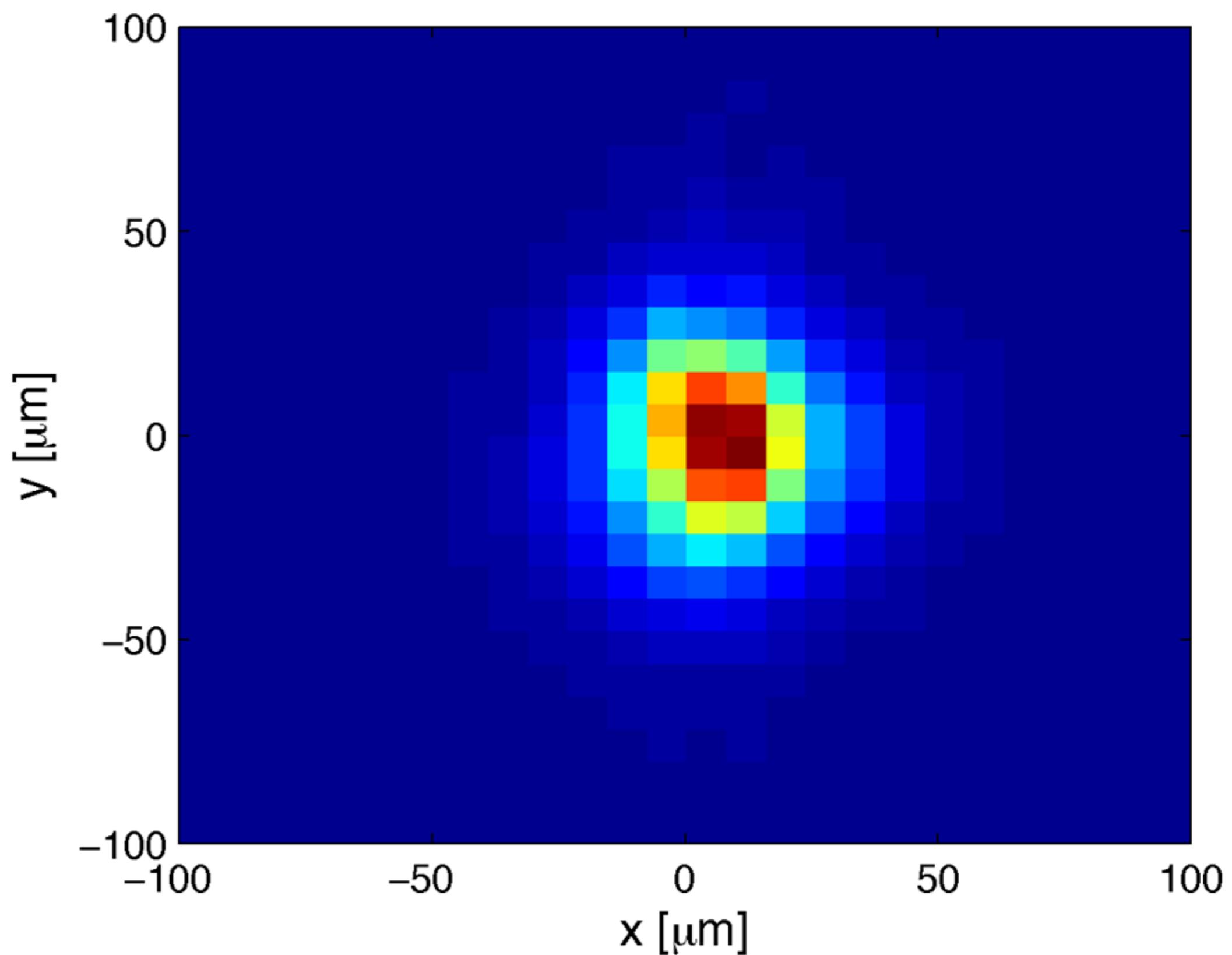


Transverse Profile: Screen Monitor



Transverse Profile: Screen Monitor

- > Measurement of small beams
- > Optical resolution (ISO 12233): 8 μm
- > Beam sizes down to 10 μm measured

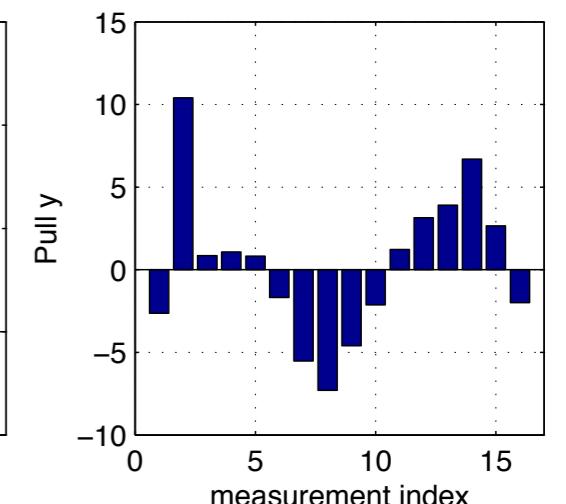
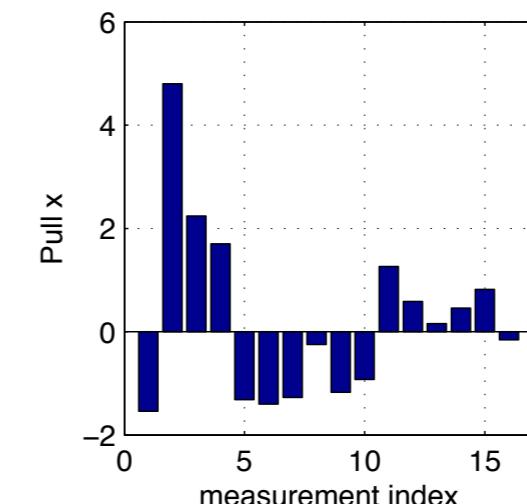
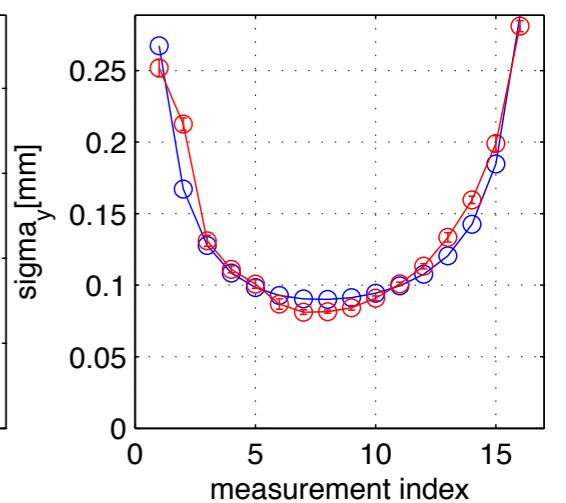
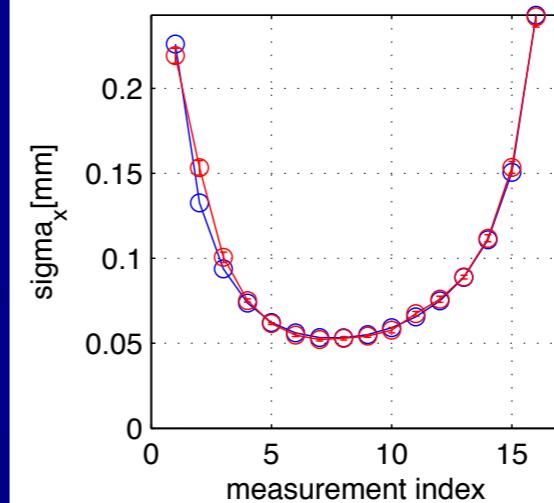
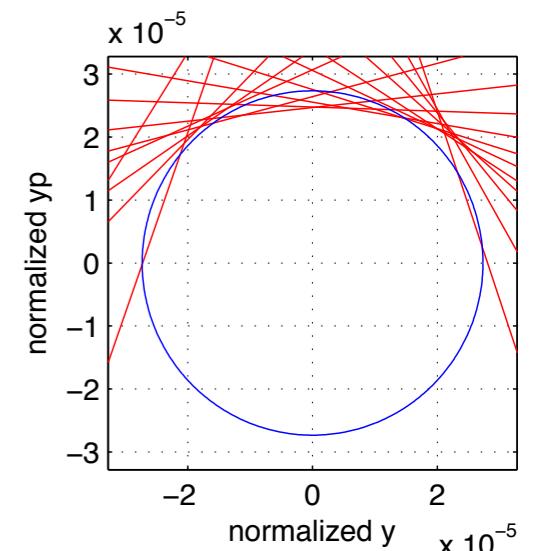
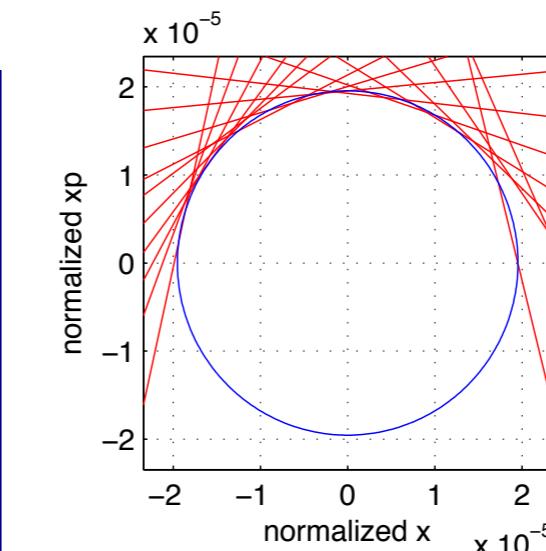
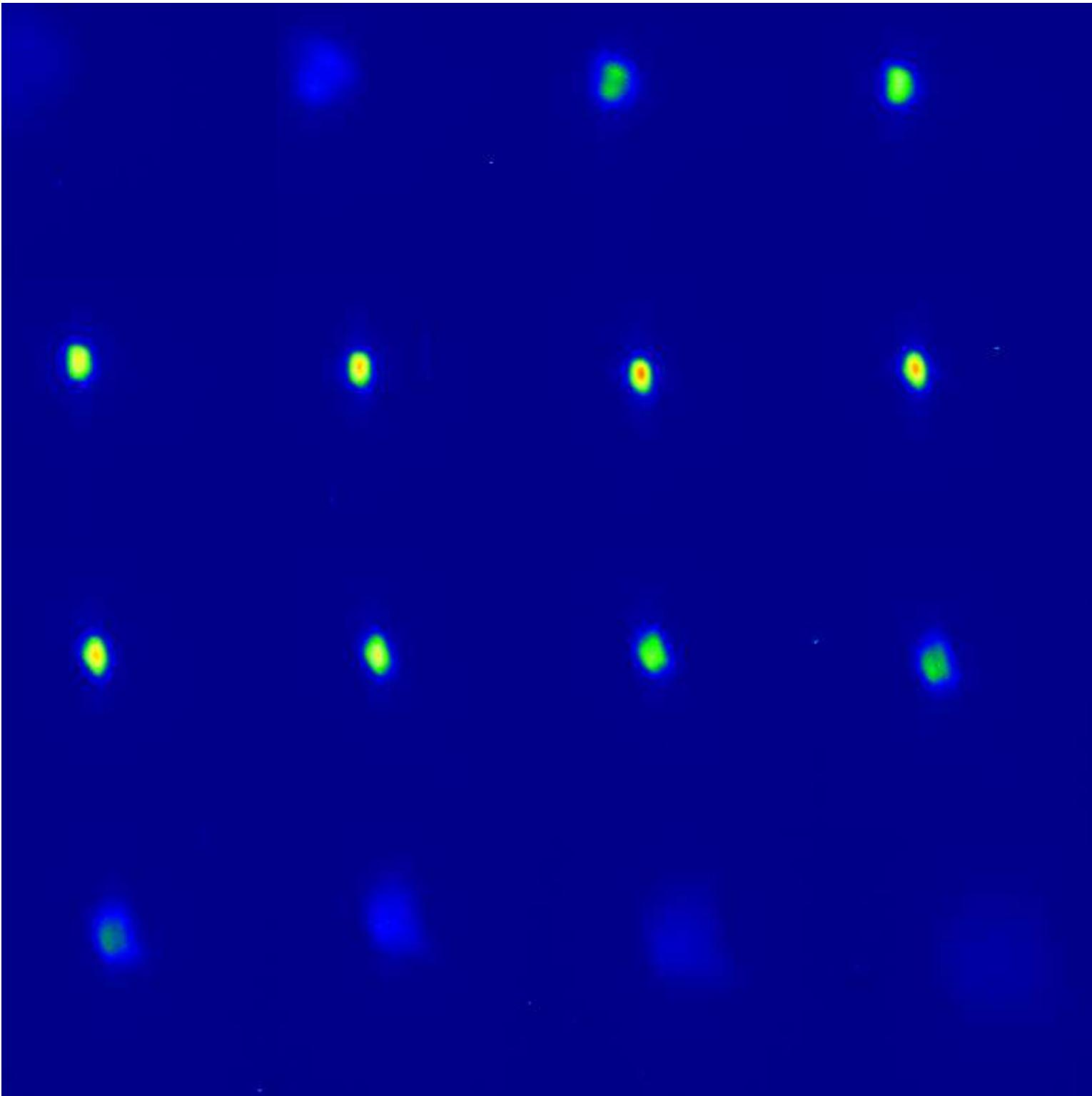


Transverse Profile: Screen Monitor

- > Measurement of small beams
- > Optical resolution (ISO 12233):
8 μm
- > Beam sizes down to
10 μm measured



Transverse Profiles: Quadrupole Scan



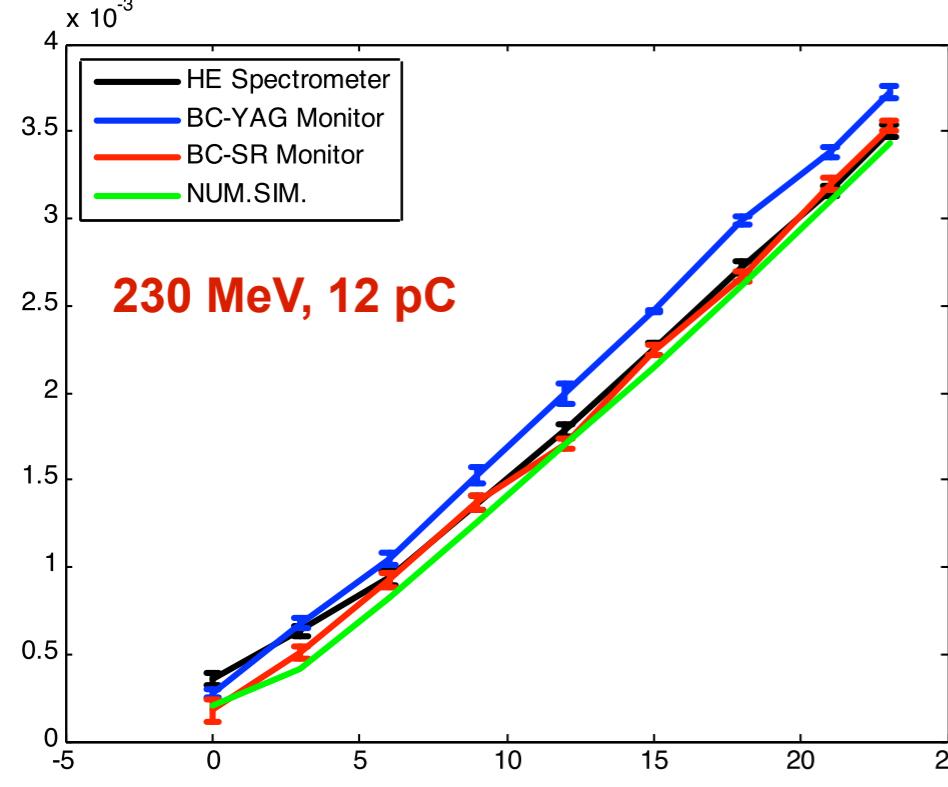
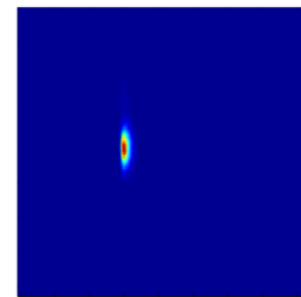
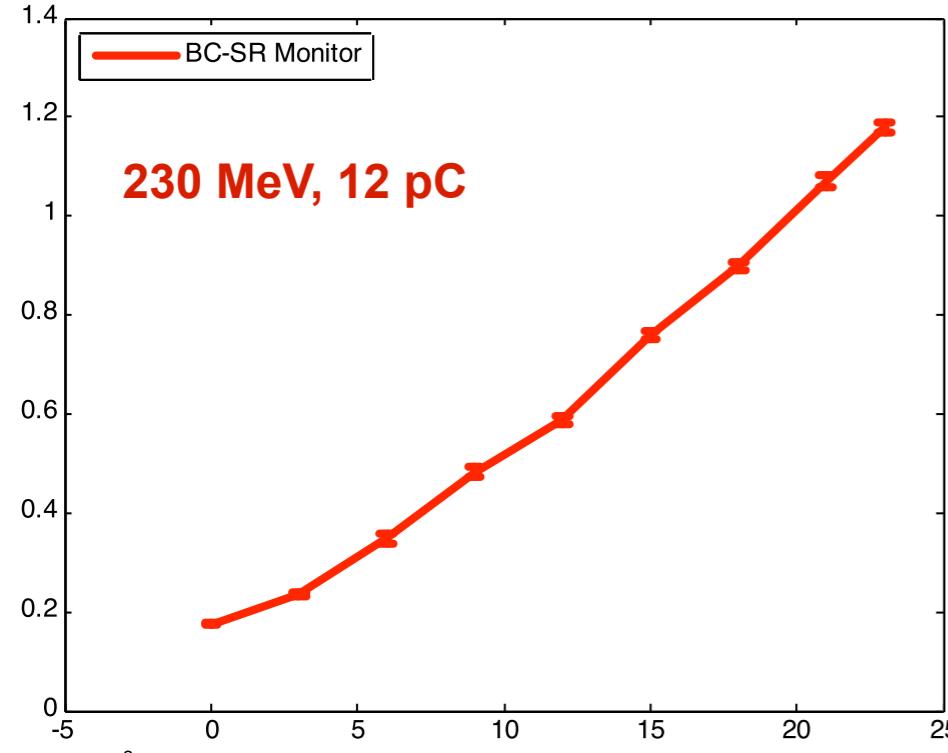
Synchrotron Radiation Imager



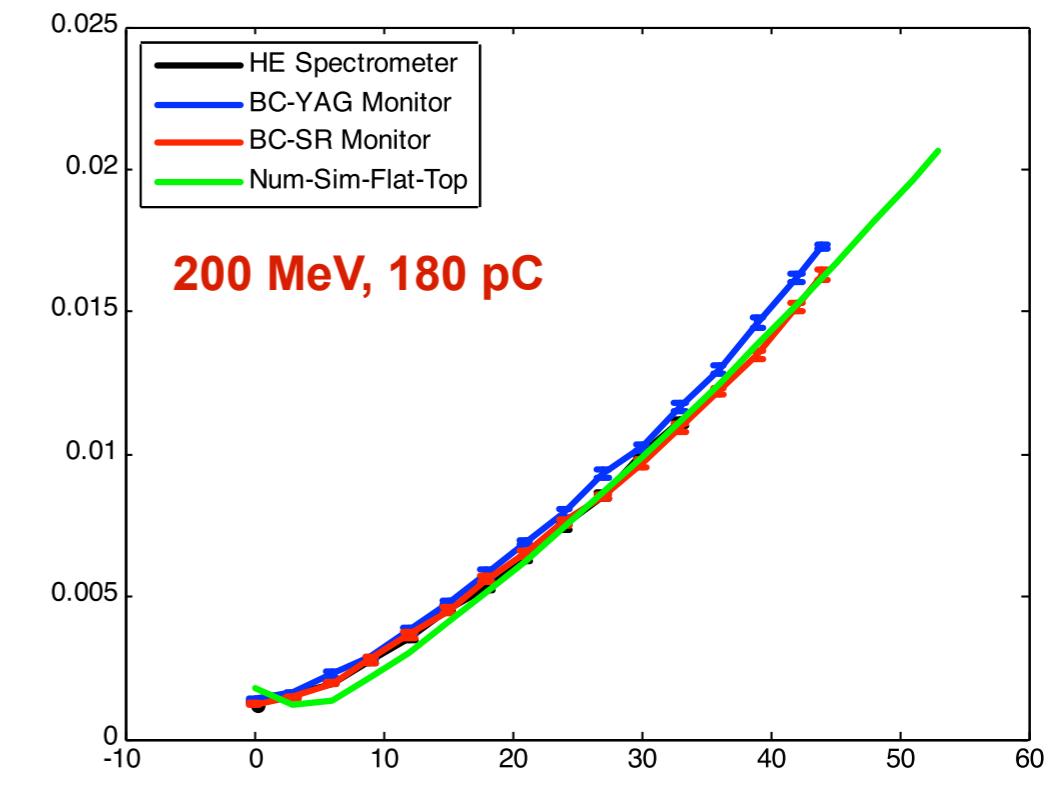
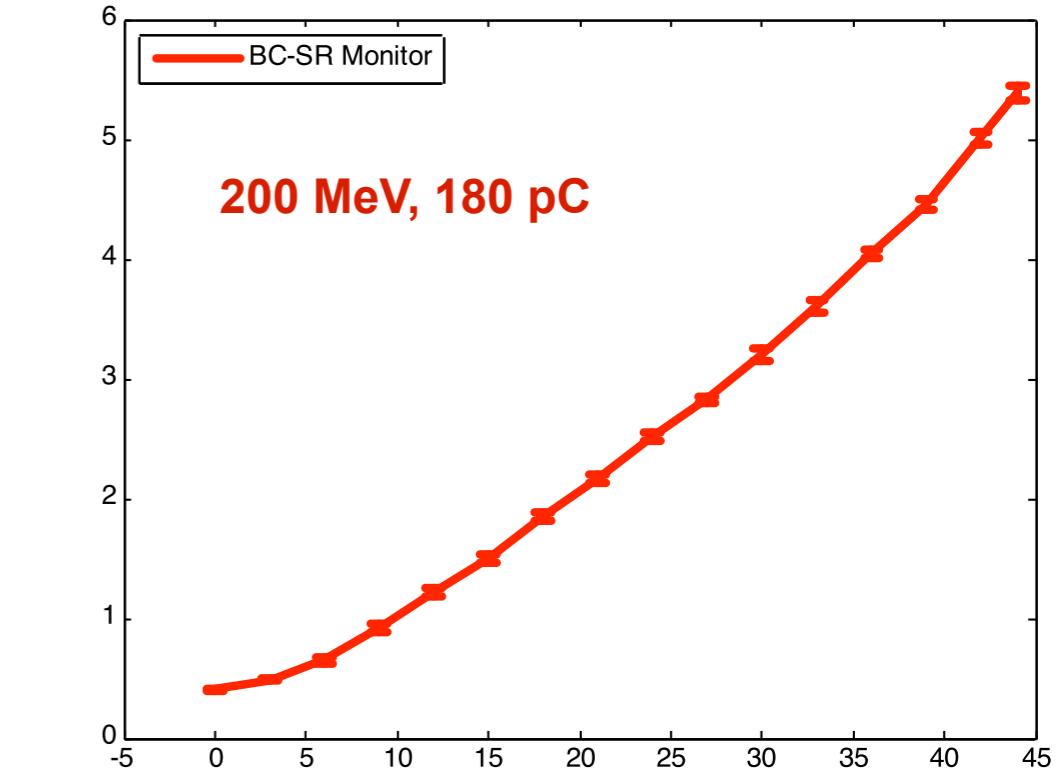
Synchrotron Radiation Imager

Prototype Results - 250 MeV Injector Test Facility (SITF)

👉 TUPF08



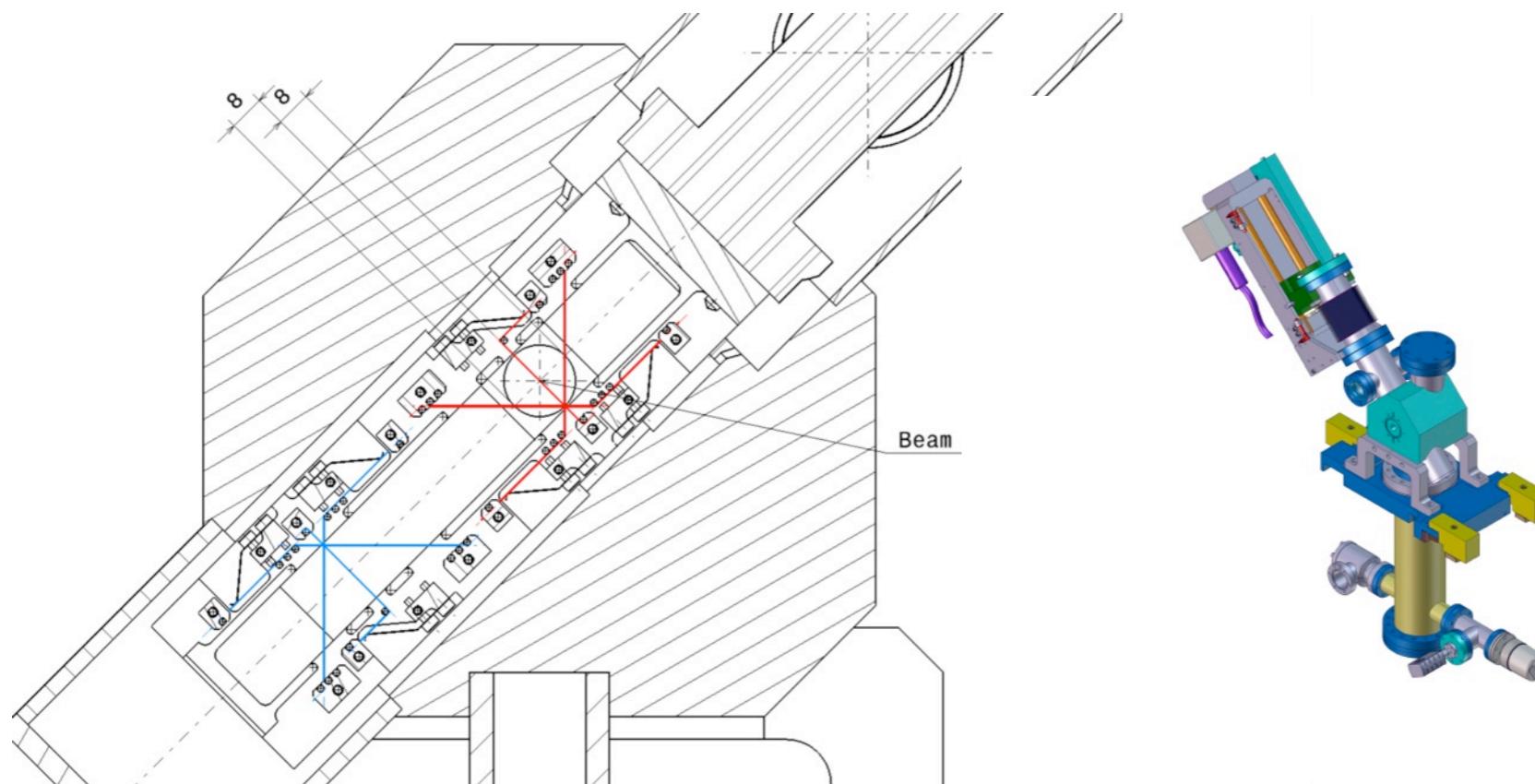
12 pC, SR Monitor images,
0- 23 deg OFF RF Crest



Wire Scanners

- > SwissFEL version:
 - > Inserted at 45° → measurement of horizontal beam size possible
 - > Can be used in a quasi-parasitic mode

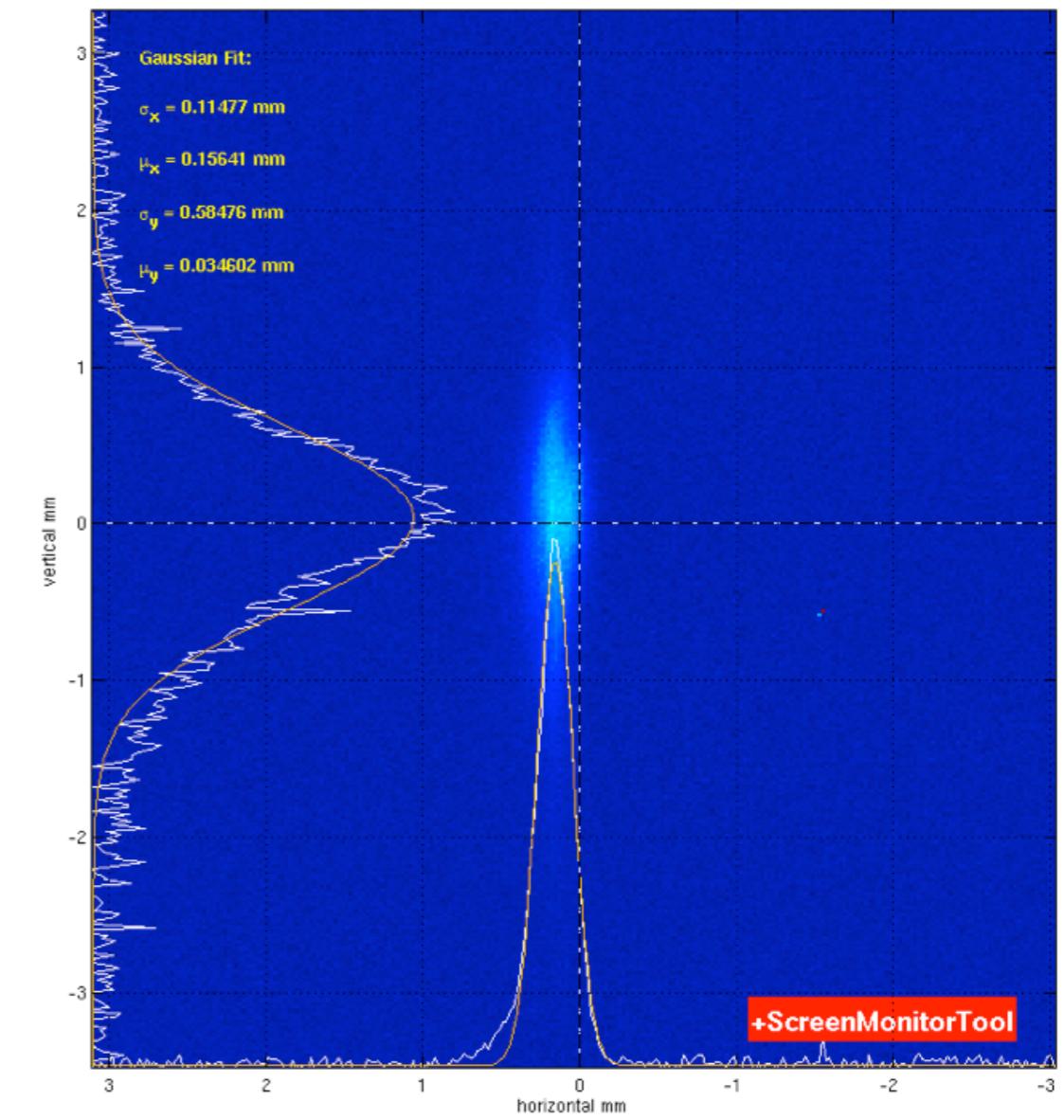
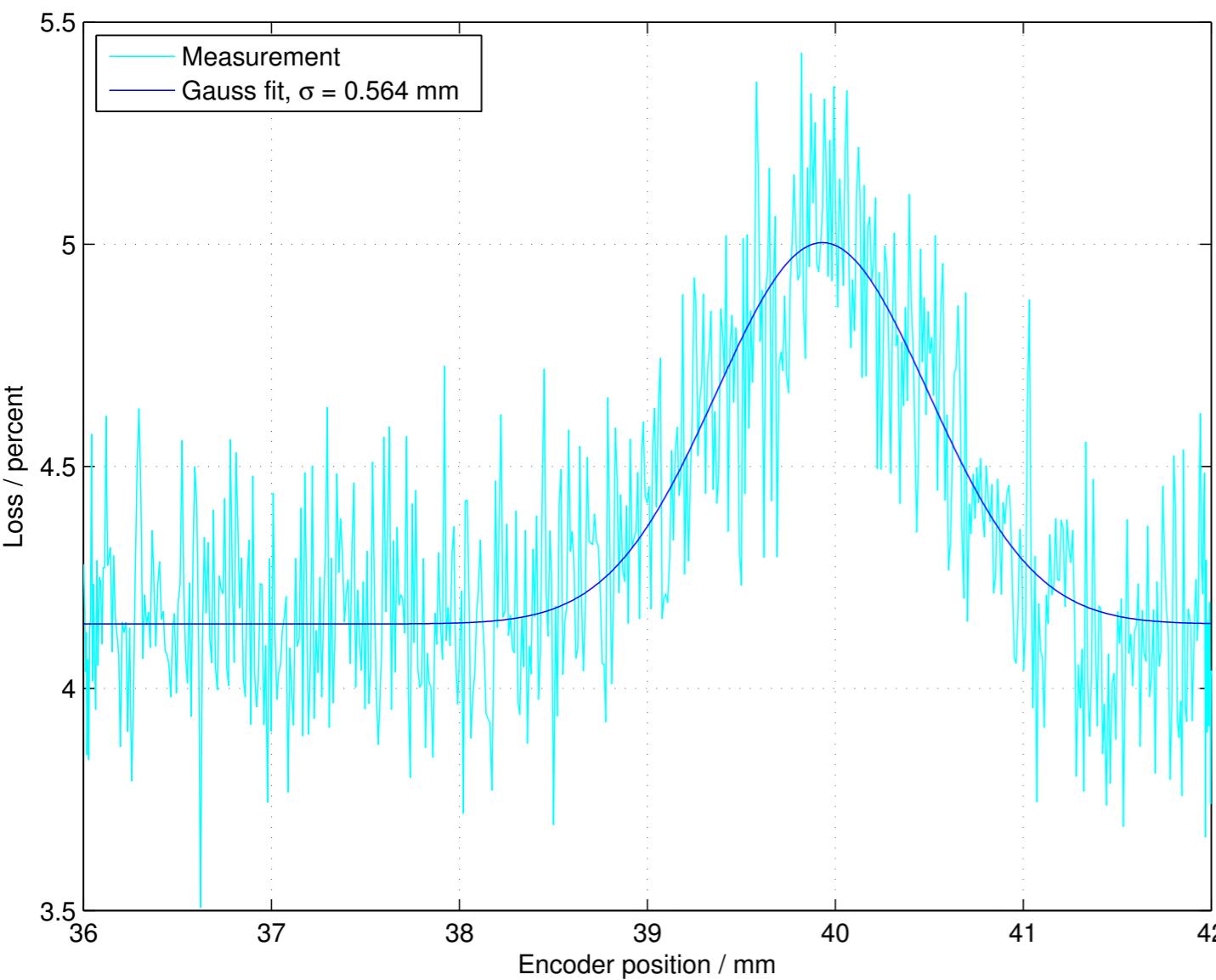
Technical Realization



3 different pin positions \leftrightarrow 3 different Wire separations (8, 5 or 3.5 mm) \leftrightarrow 3 different scan time (for a fixed wire velocity)

Wire Scanners

- > Wire scanners installed at all screen stations > 100 MeV
- > Measurements performed with horizontal wire:
 - > Charge measurement before and after wire
 - > Using beam synchronous data acquisition for encoder and charge (BPMs)
 - > Comparison to OTR measurements

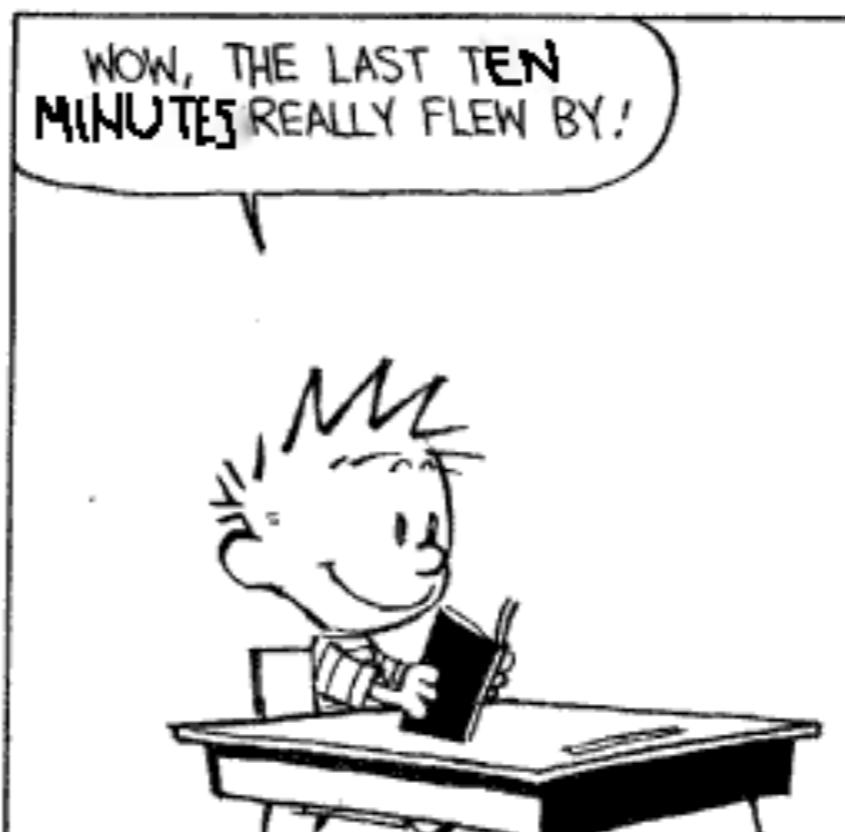
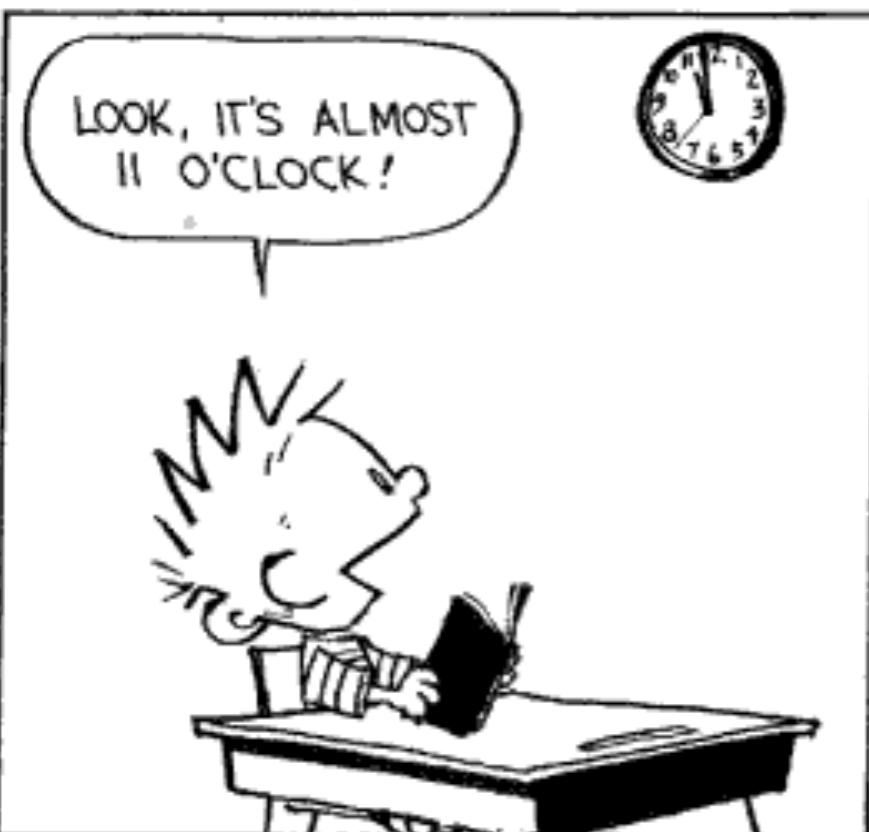


Instrumentation at the SwissFEL Injector Test Facility

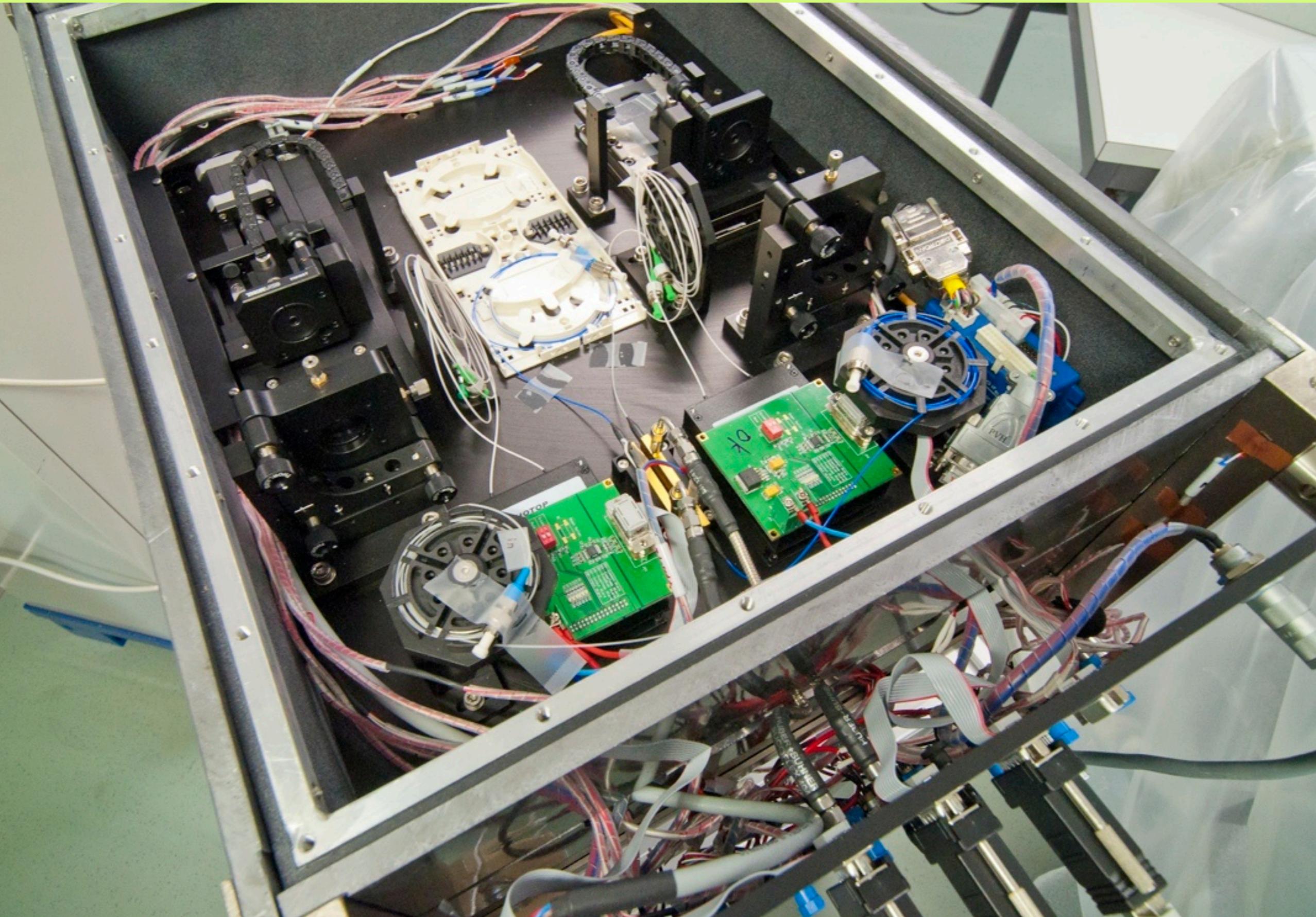
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Time-Resolved Measurements

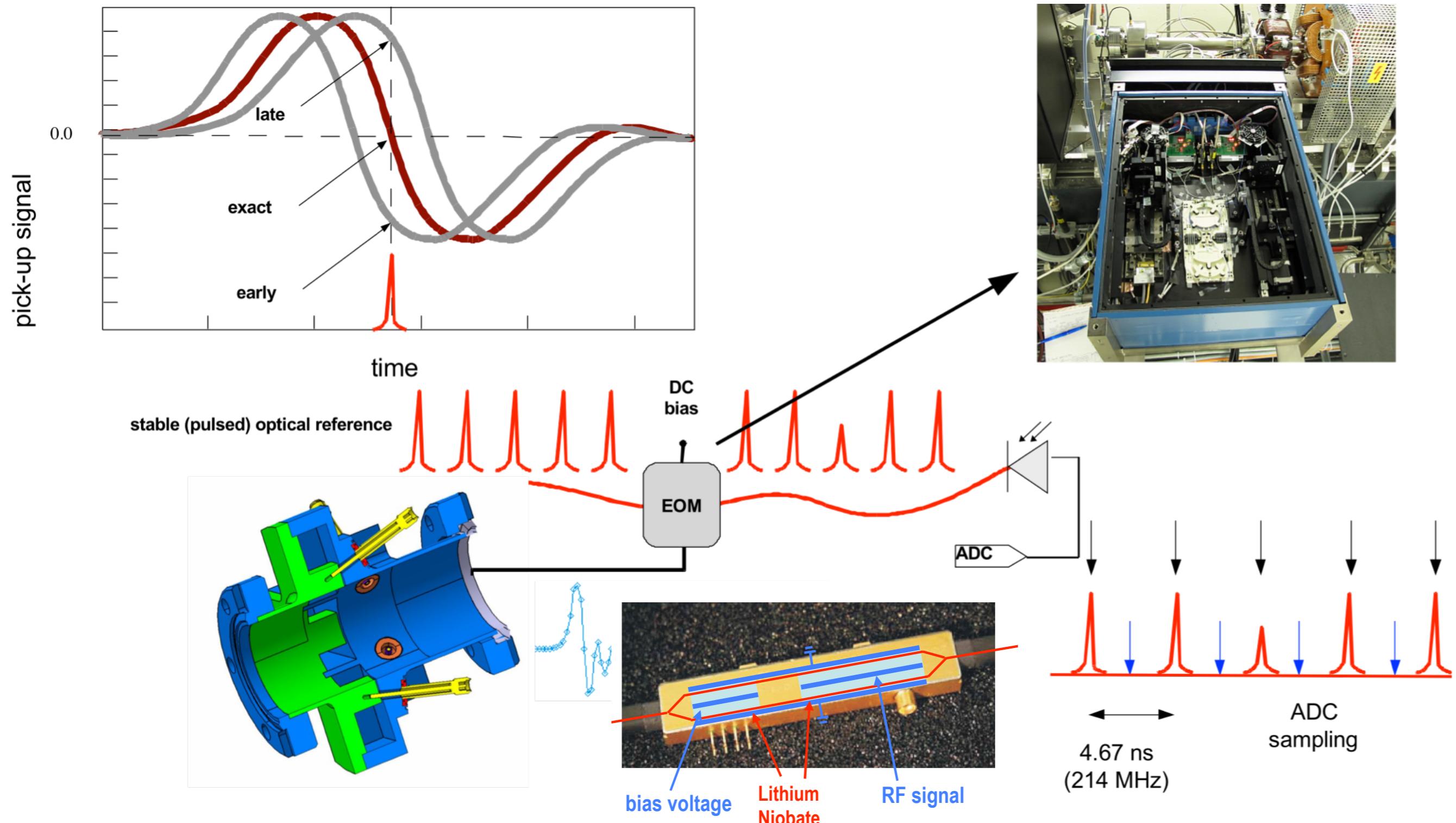


Bunch Arrival Monitor



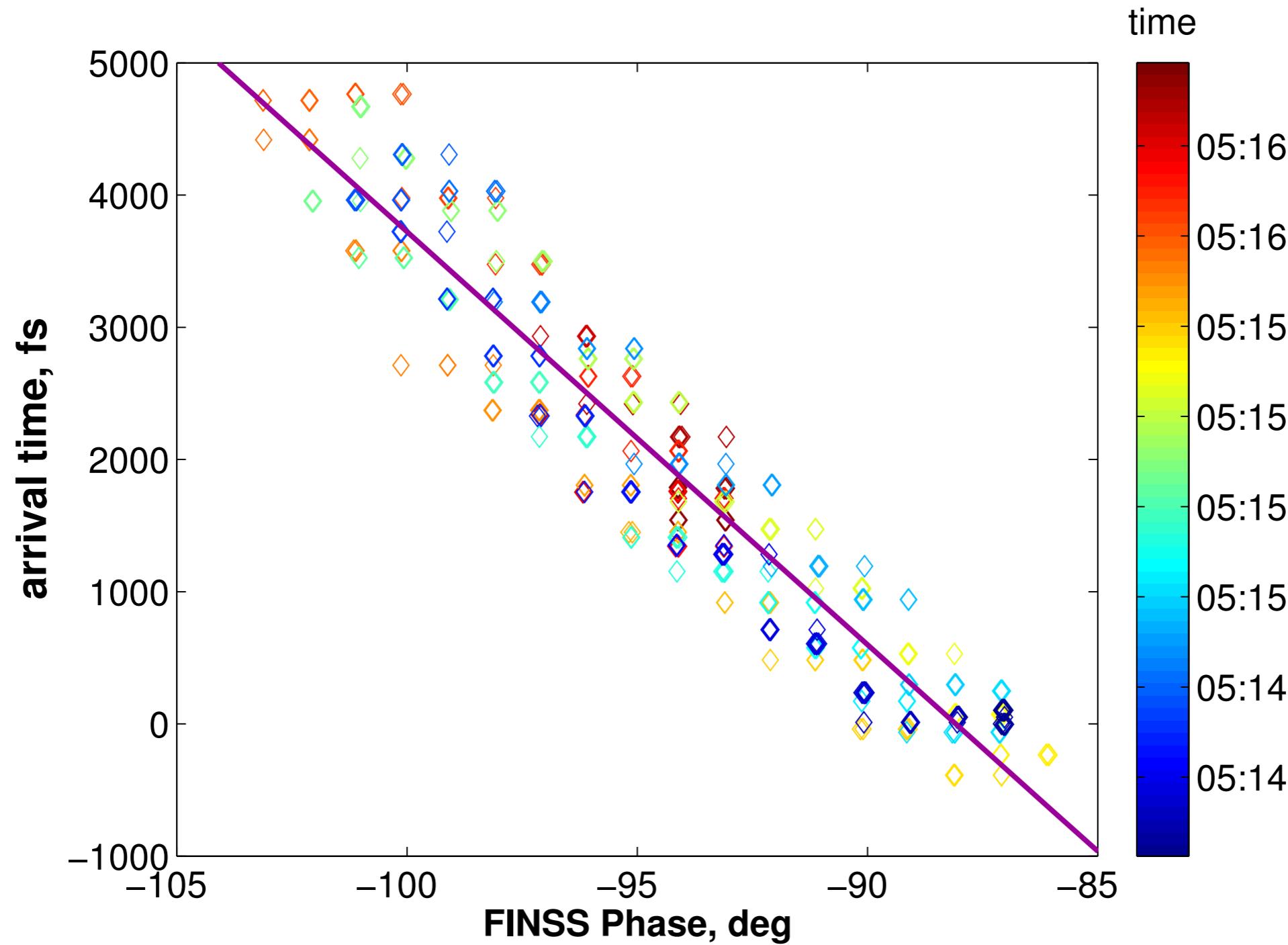
Bunch Arrival Monitor

> Arrival time signal generated at pickup is transferred onto an electro-optical modulator

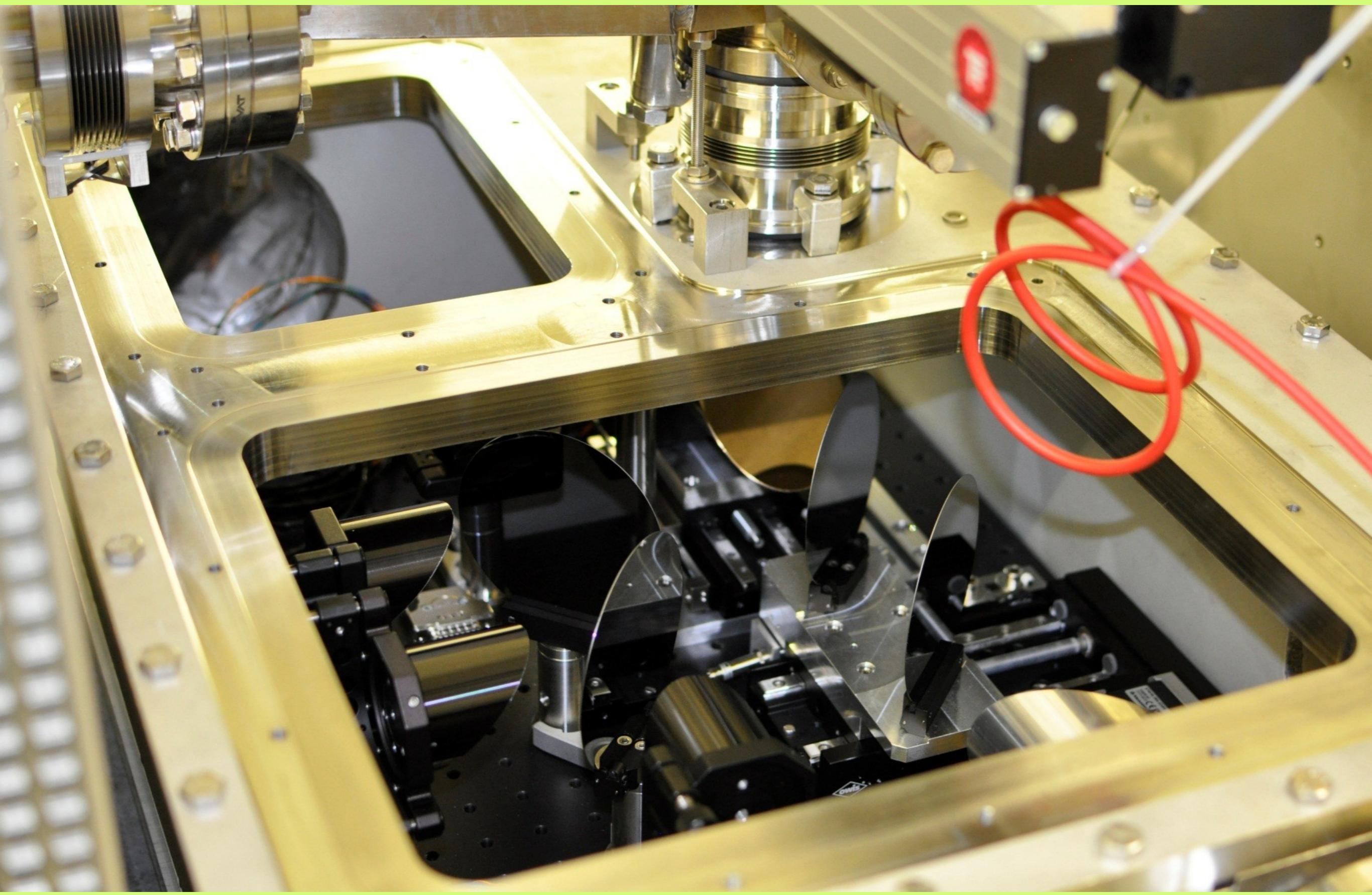


Bunch Arrival Monitor

- > Dependence of arrival time on gun phase
- > Resolution of BAM: 18 fs rms

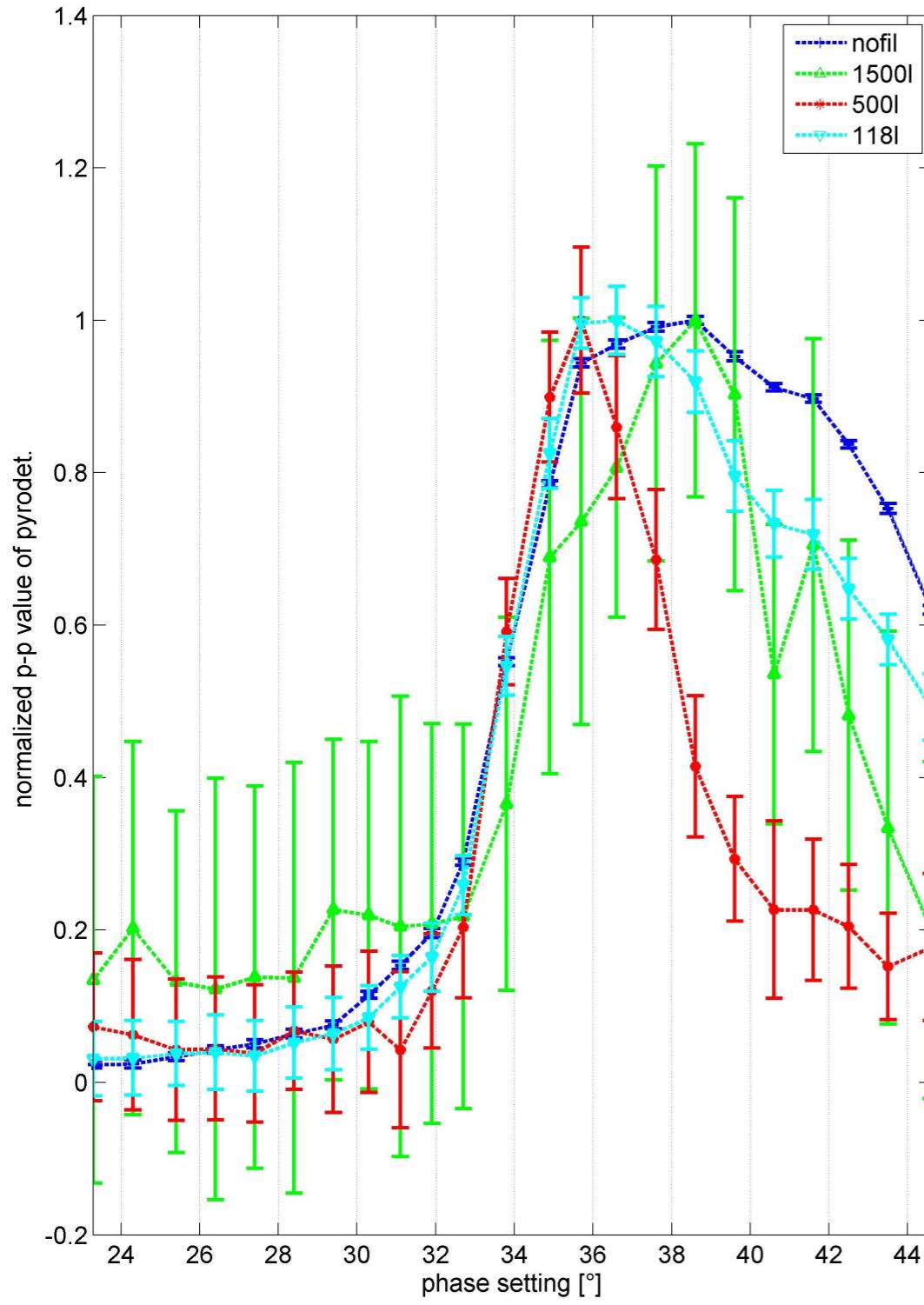


Form Factor Monitor

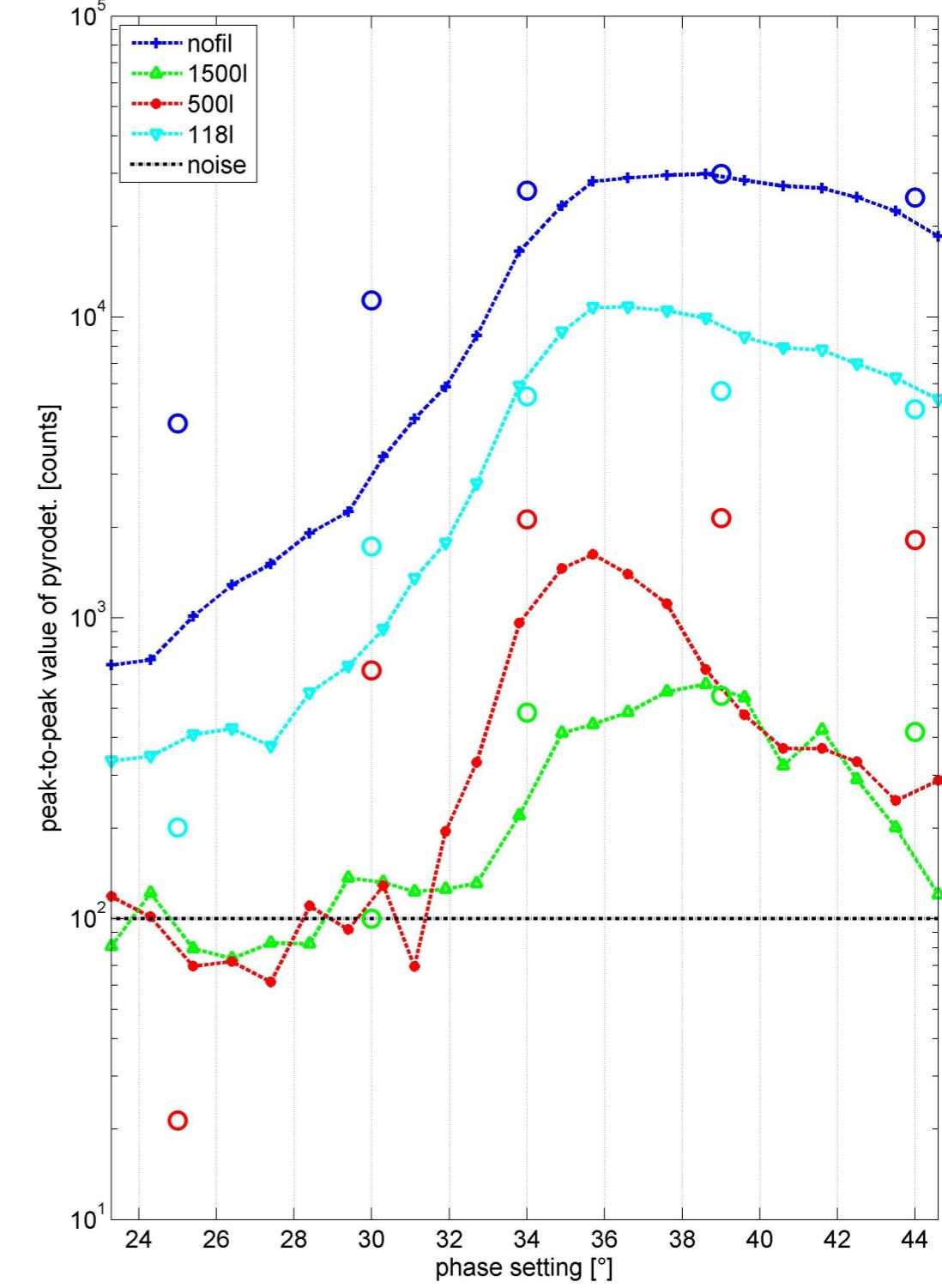


Form Factor Monitor

Normalized signals from pyros with different filters

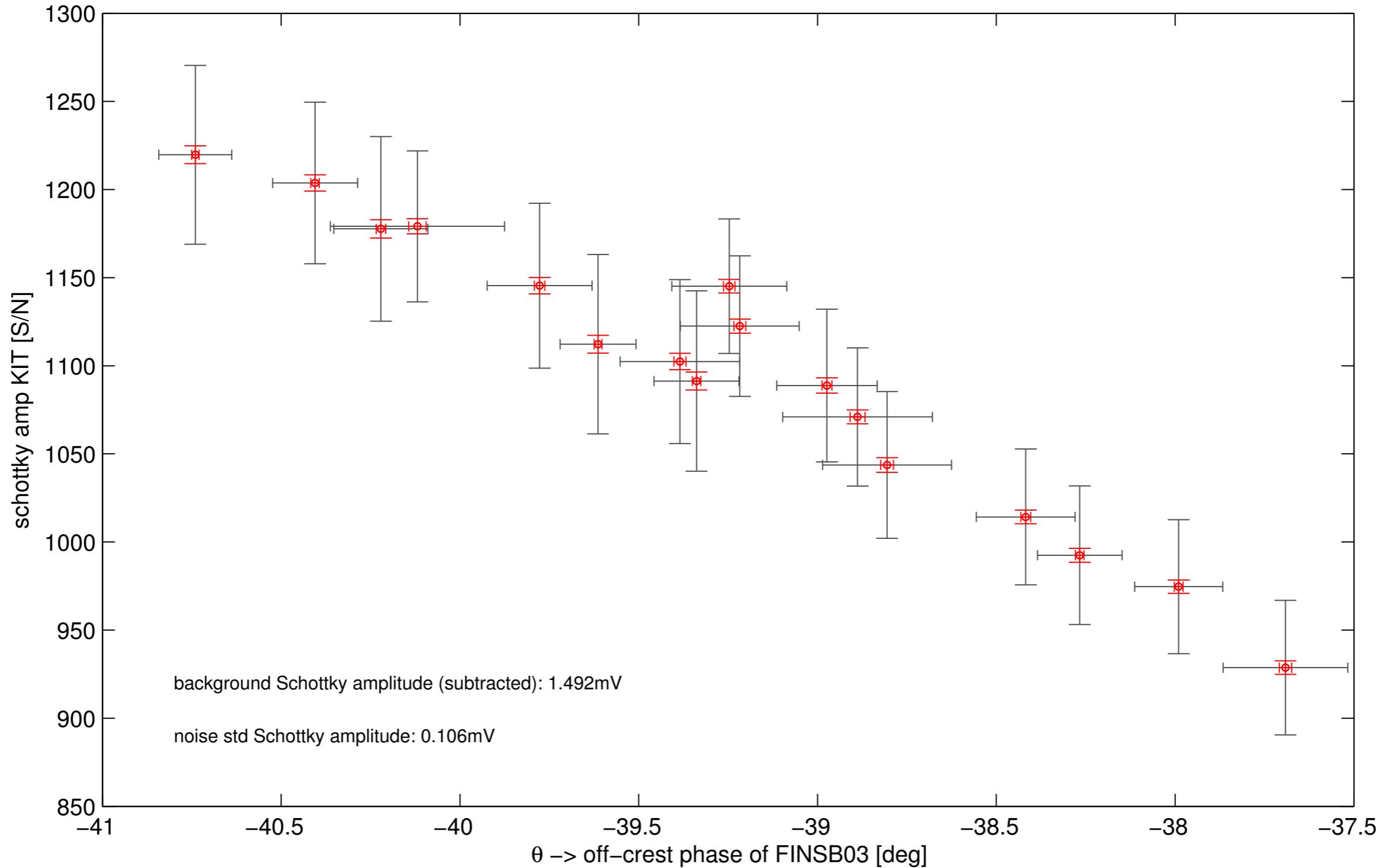


Pyro signals compared to expected response

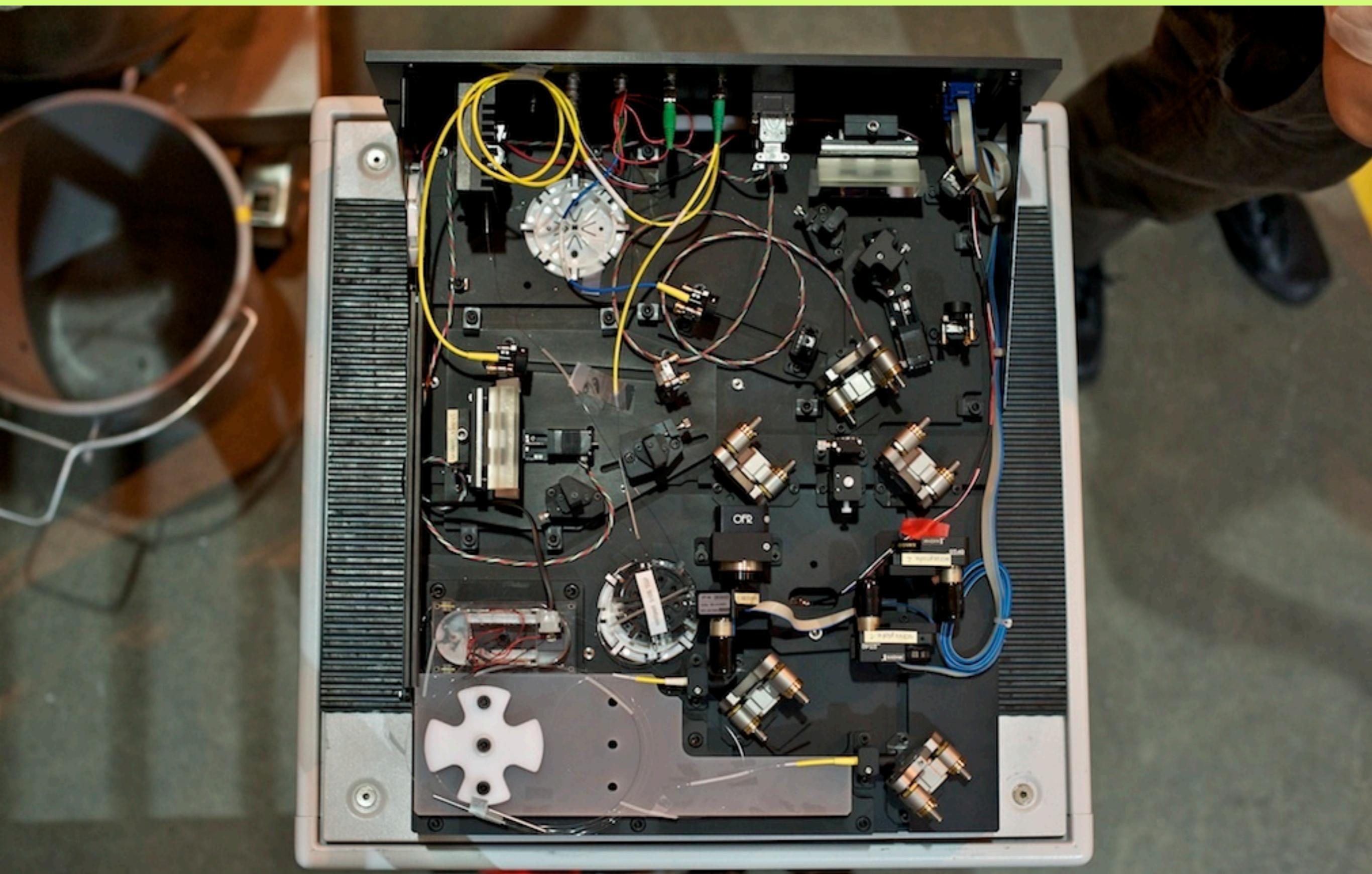


Form Factor Monitor

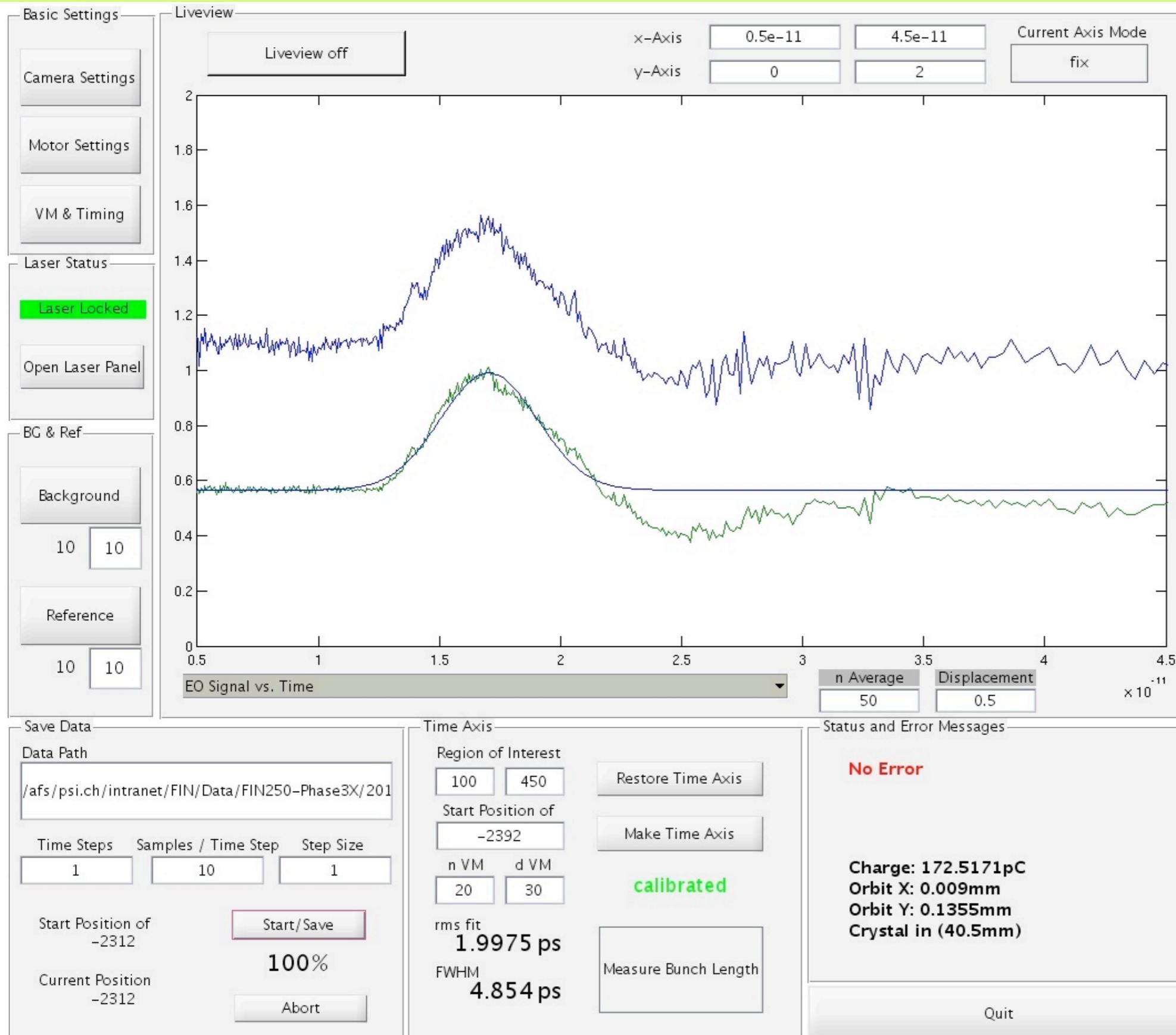
> New detector with improved signal-to-noise at 10 pC bunch charge  WEPC36



Electro-Optical Monitor



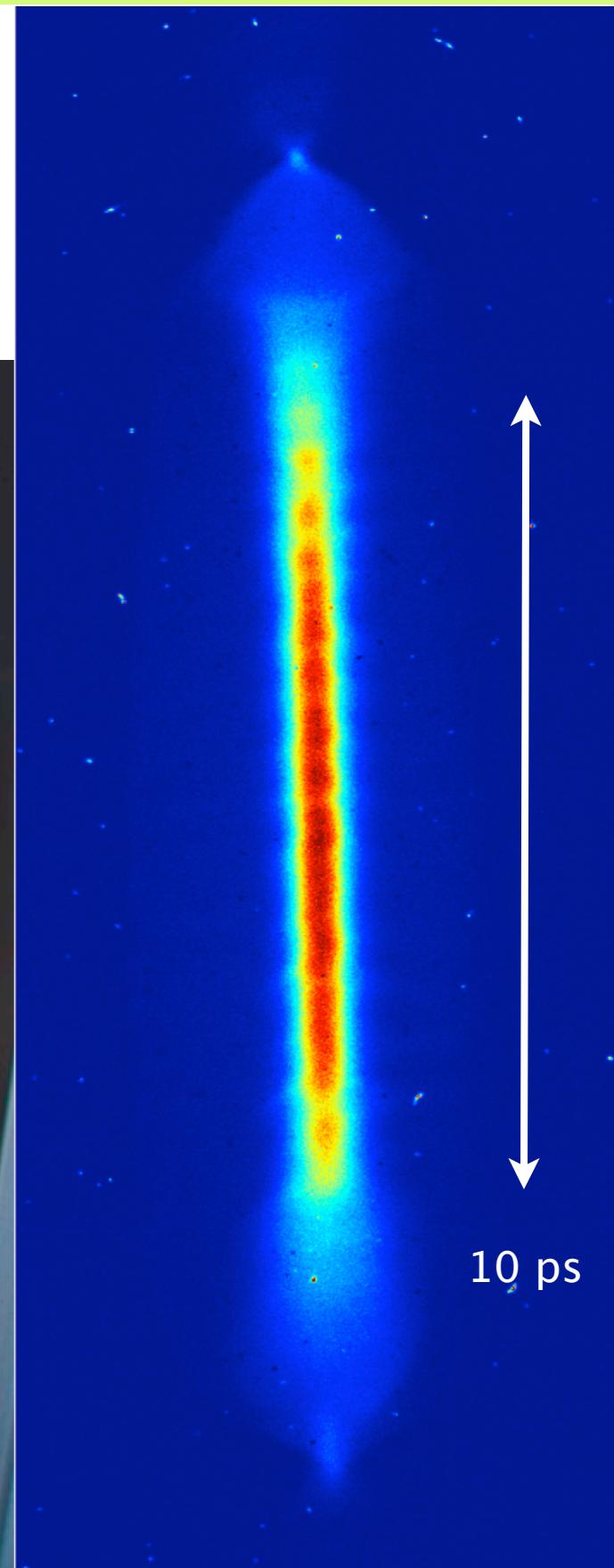
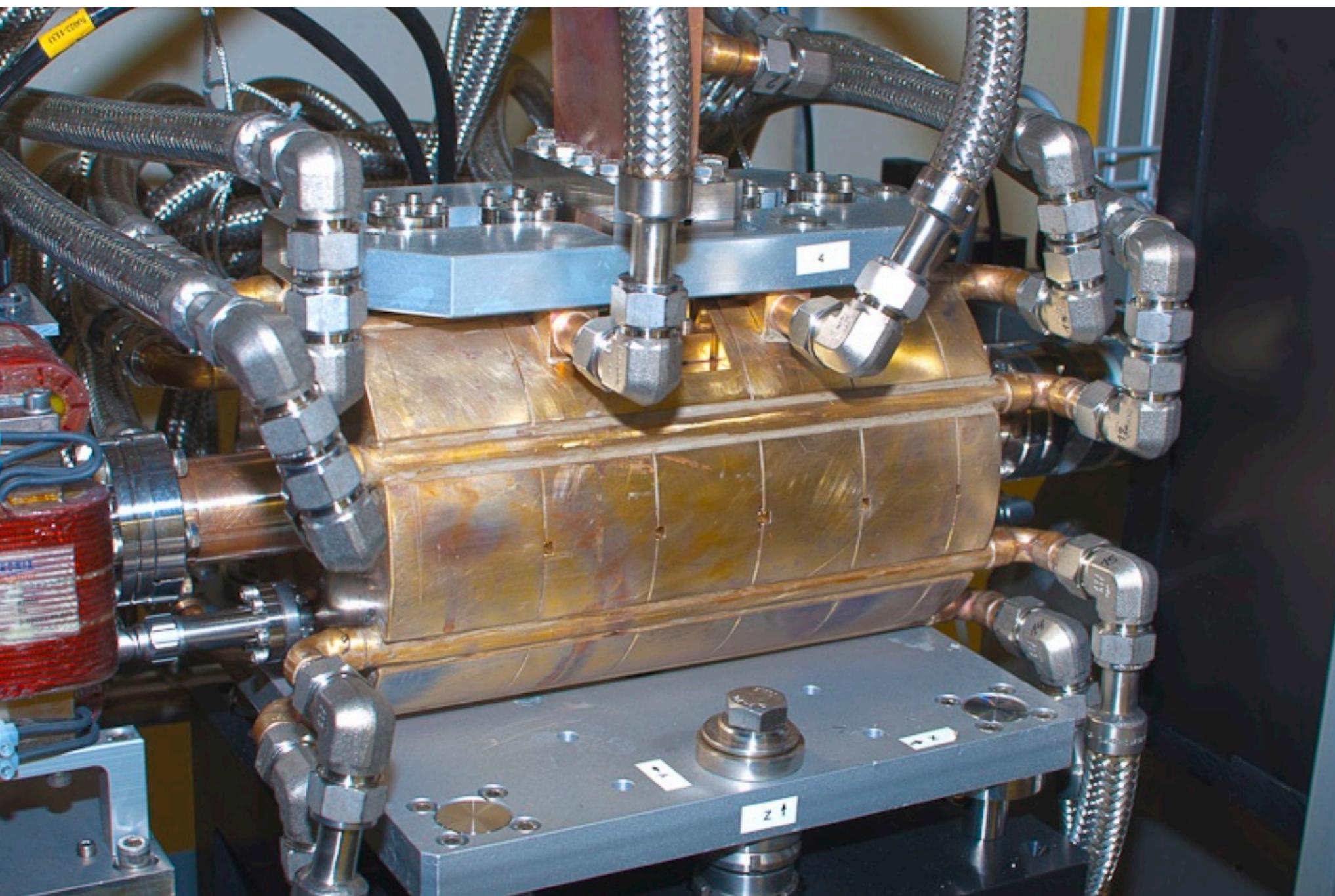
Electro-Optical Monitor



WEPC37

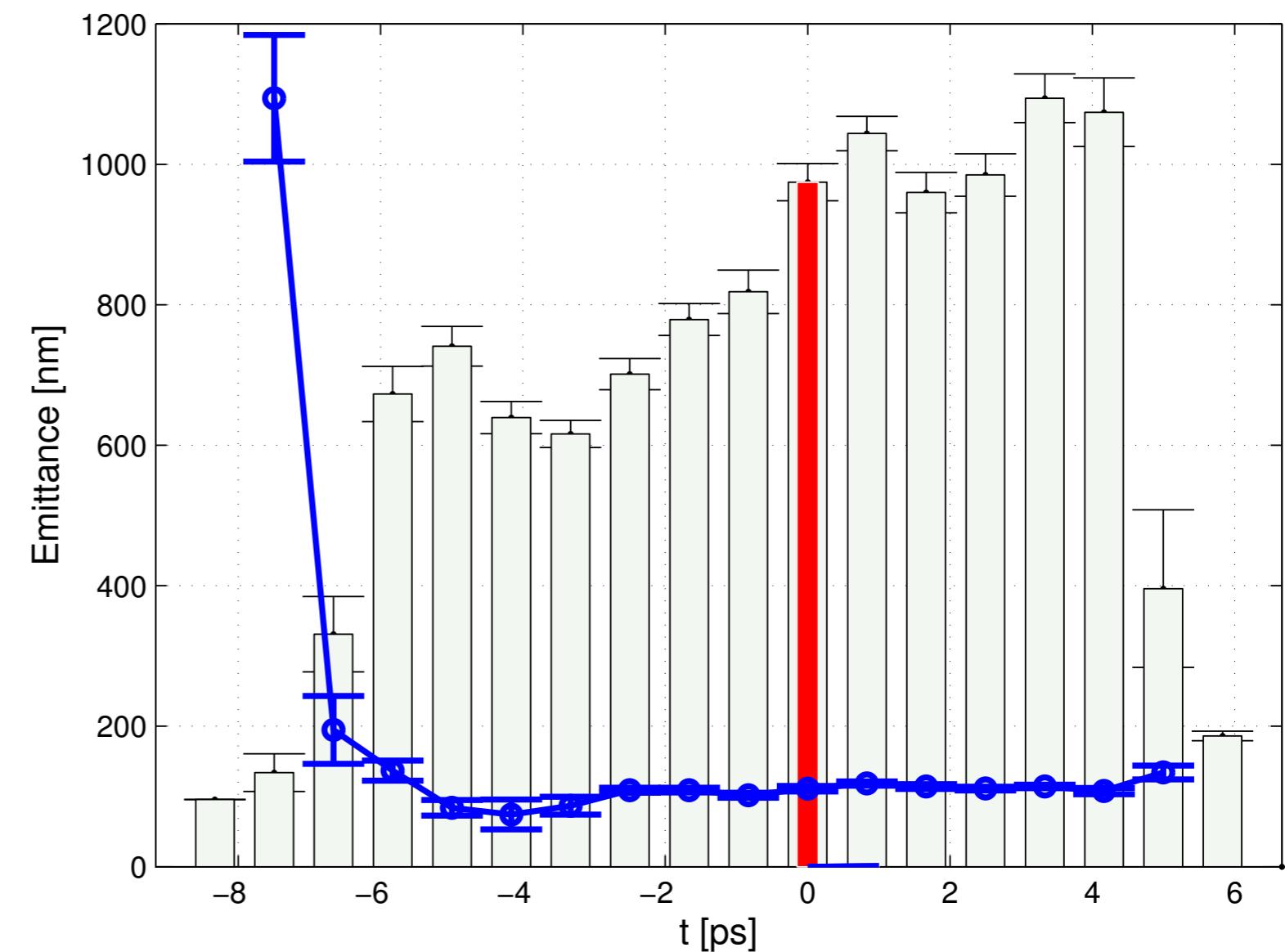
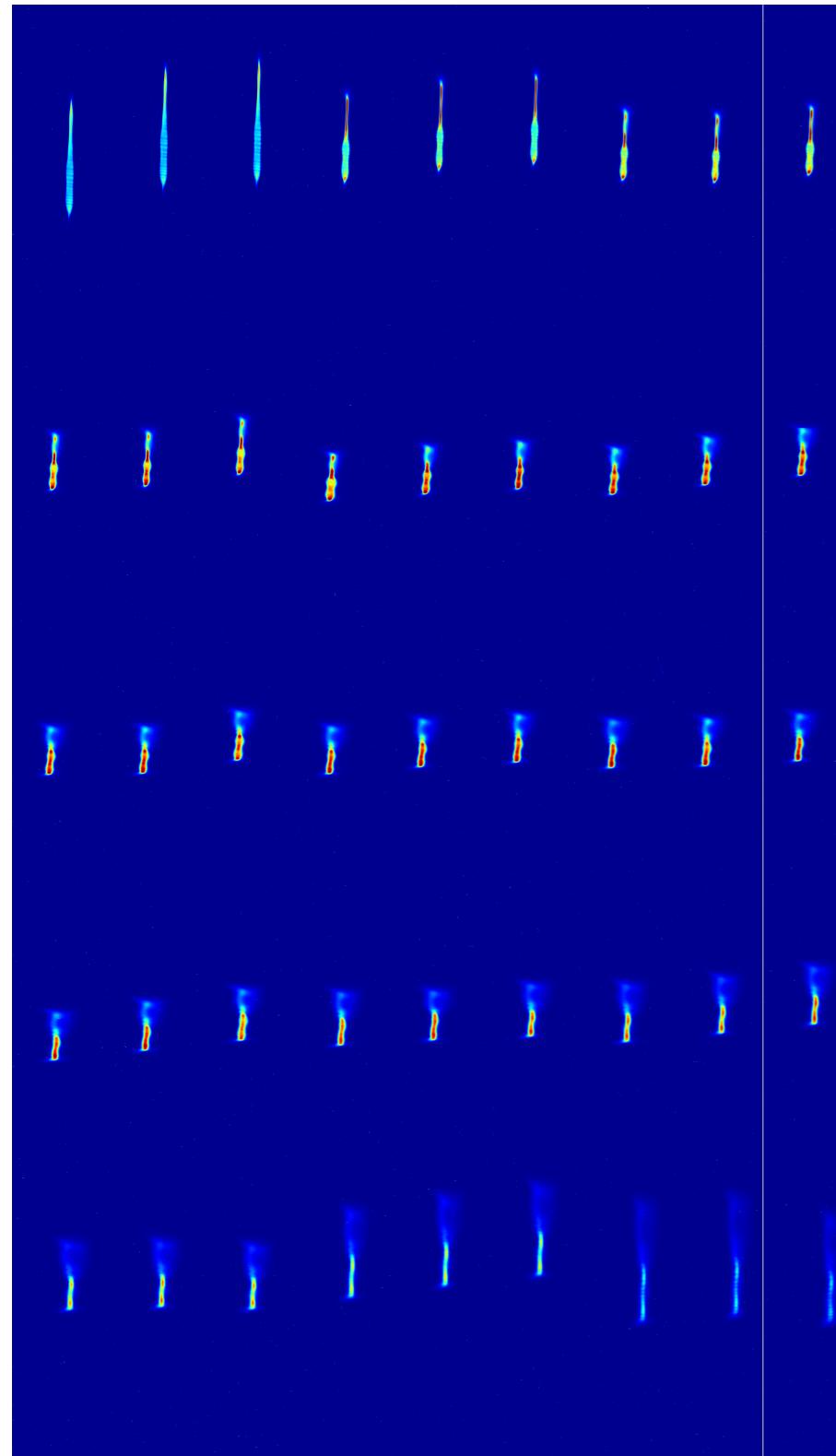
Direct Streaking of the Electron Beam

- > Requires integrated transverse field of several MV
- > Use transverse deflecting RF structure, powered by klystron
- > Two-dimensional measurements possible



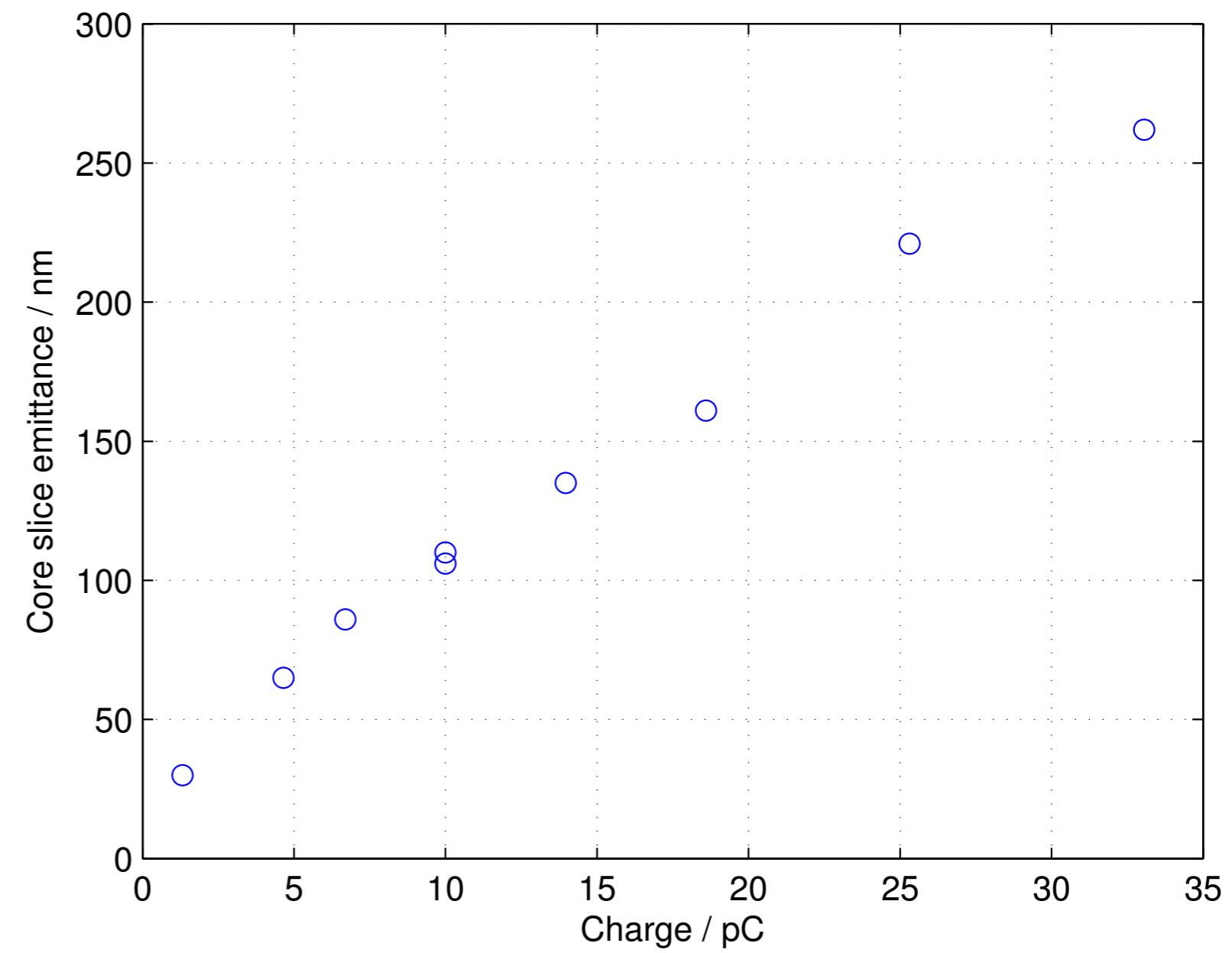
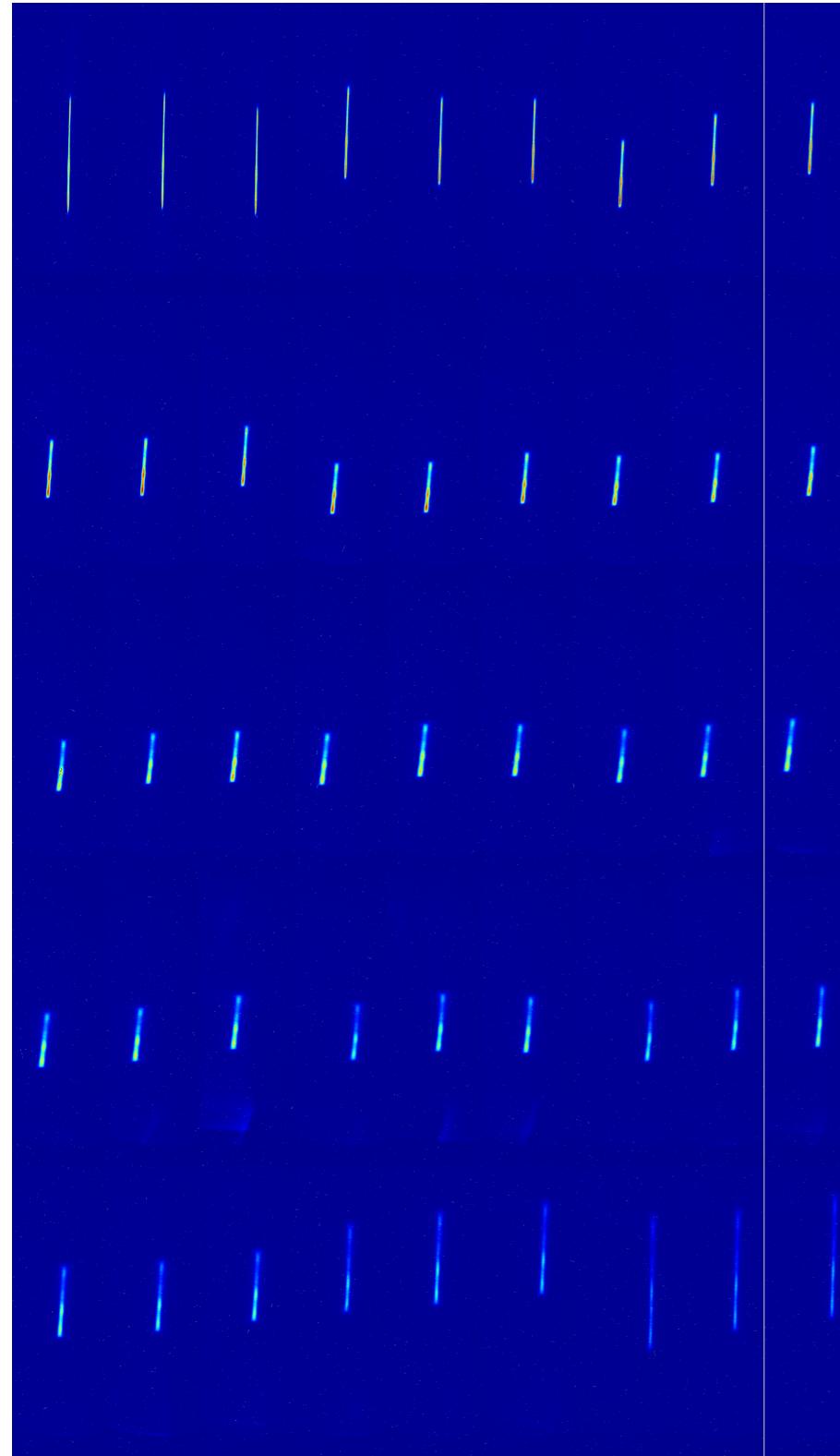
3-Dimensional Measurements

> Reconstruction from a series of 2-d measurements: Slice emittance



3-Dimensional Measurements

> Slice emittance measurement of a 1.3 pC beam

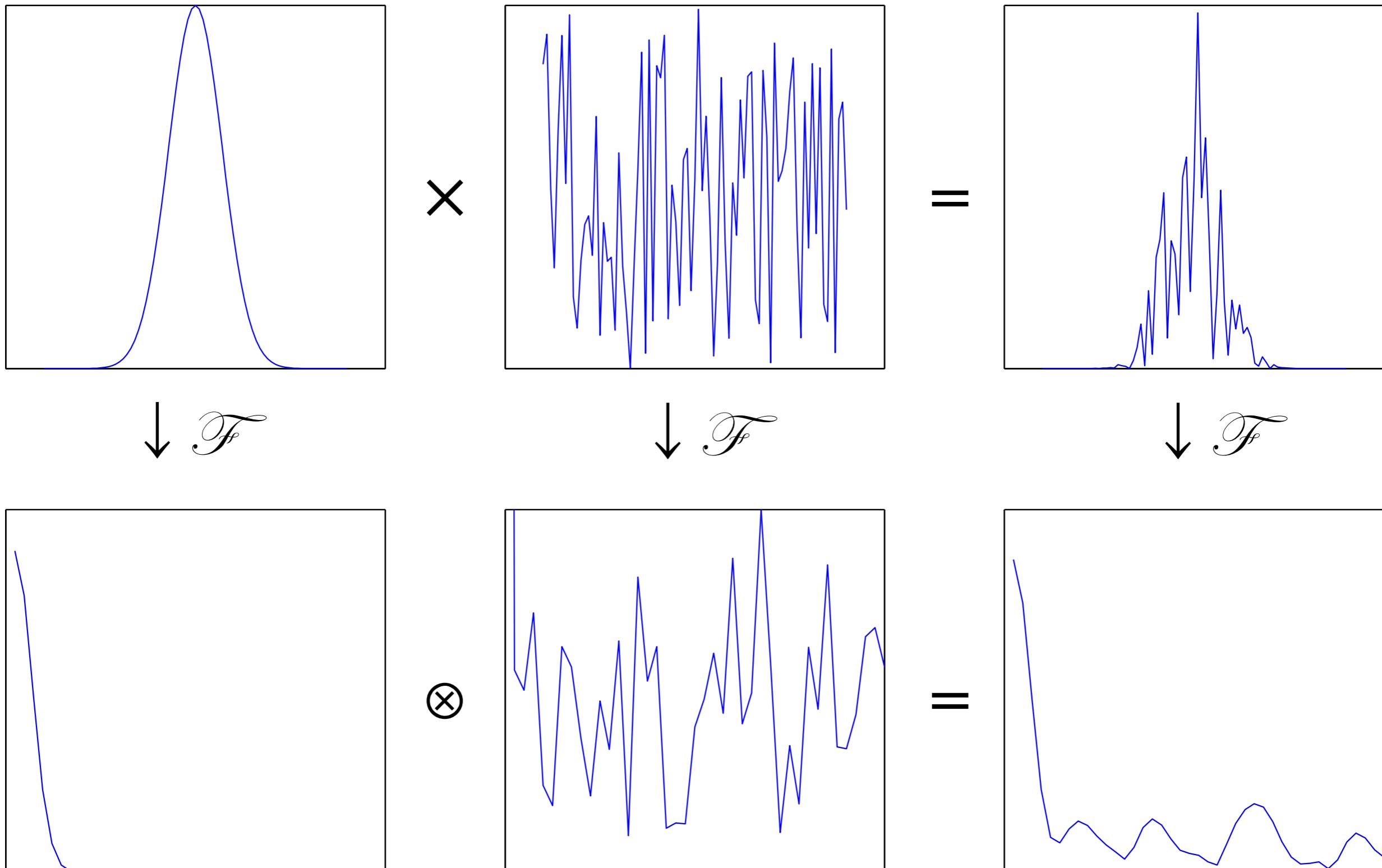


Instrumentation at the SwissFEL Injector Test Facility

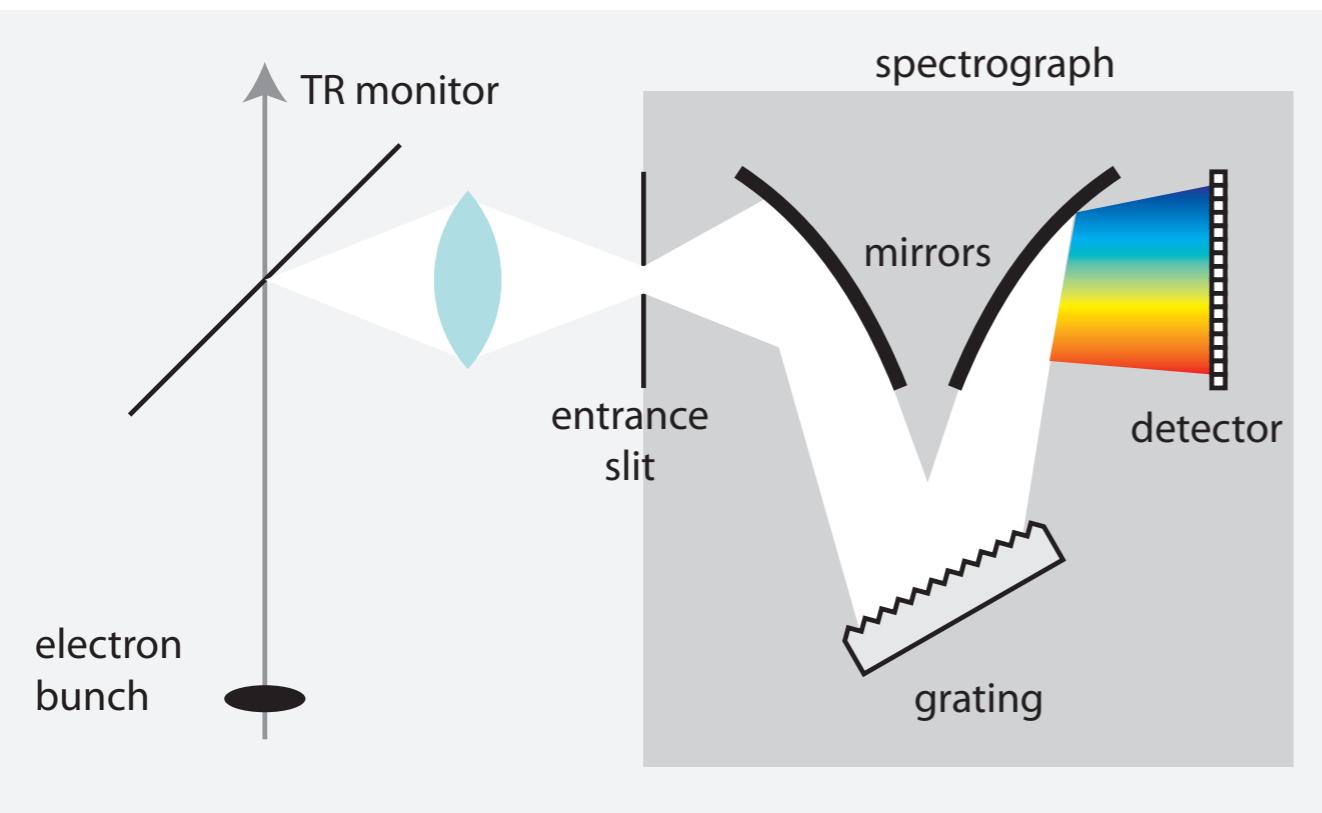
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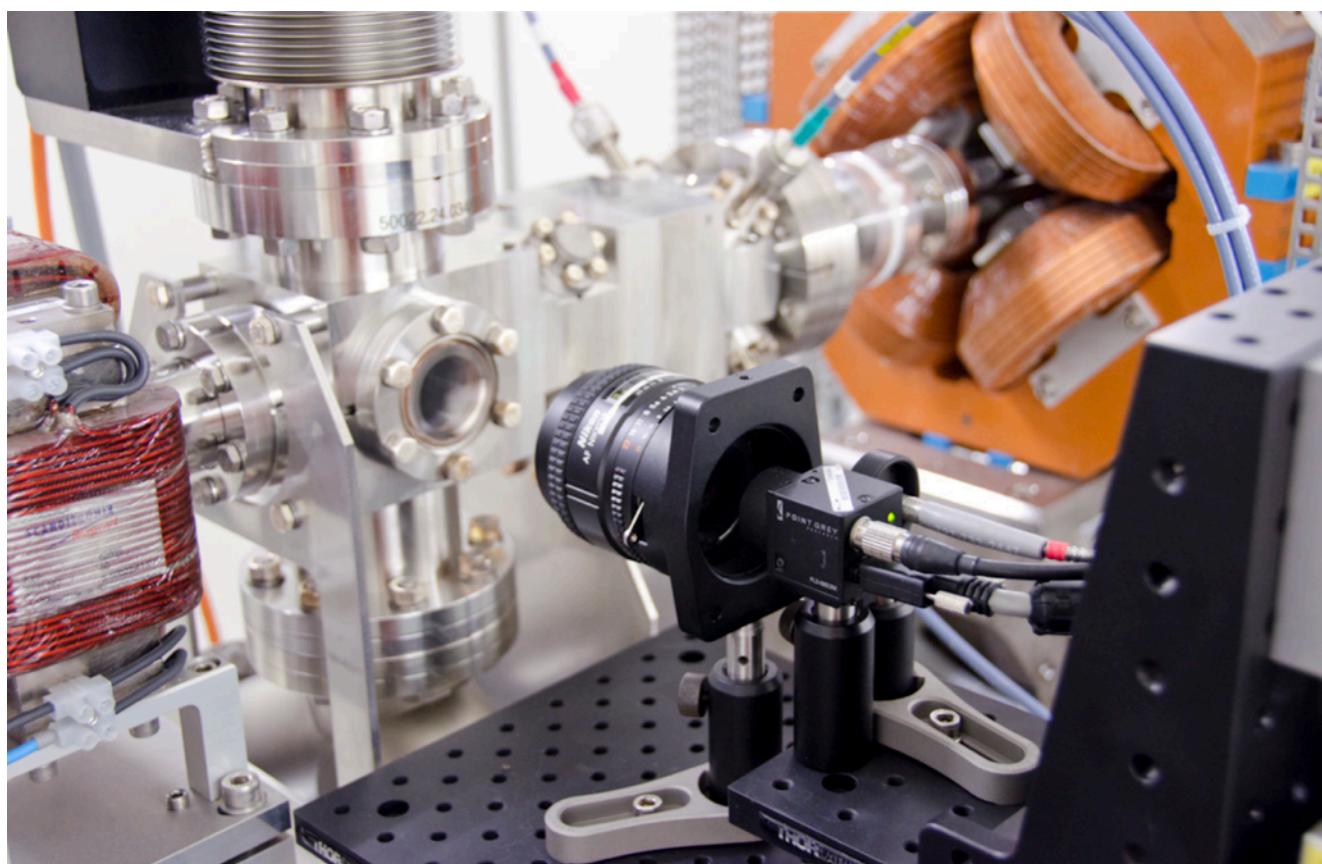
Optical Spectrum of Transition Radiation



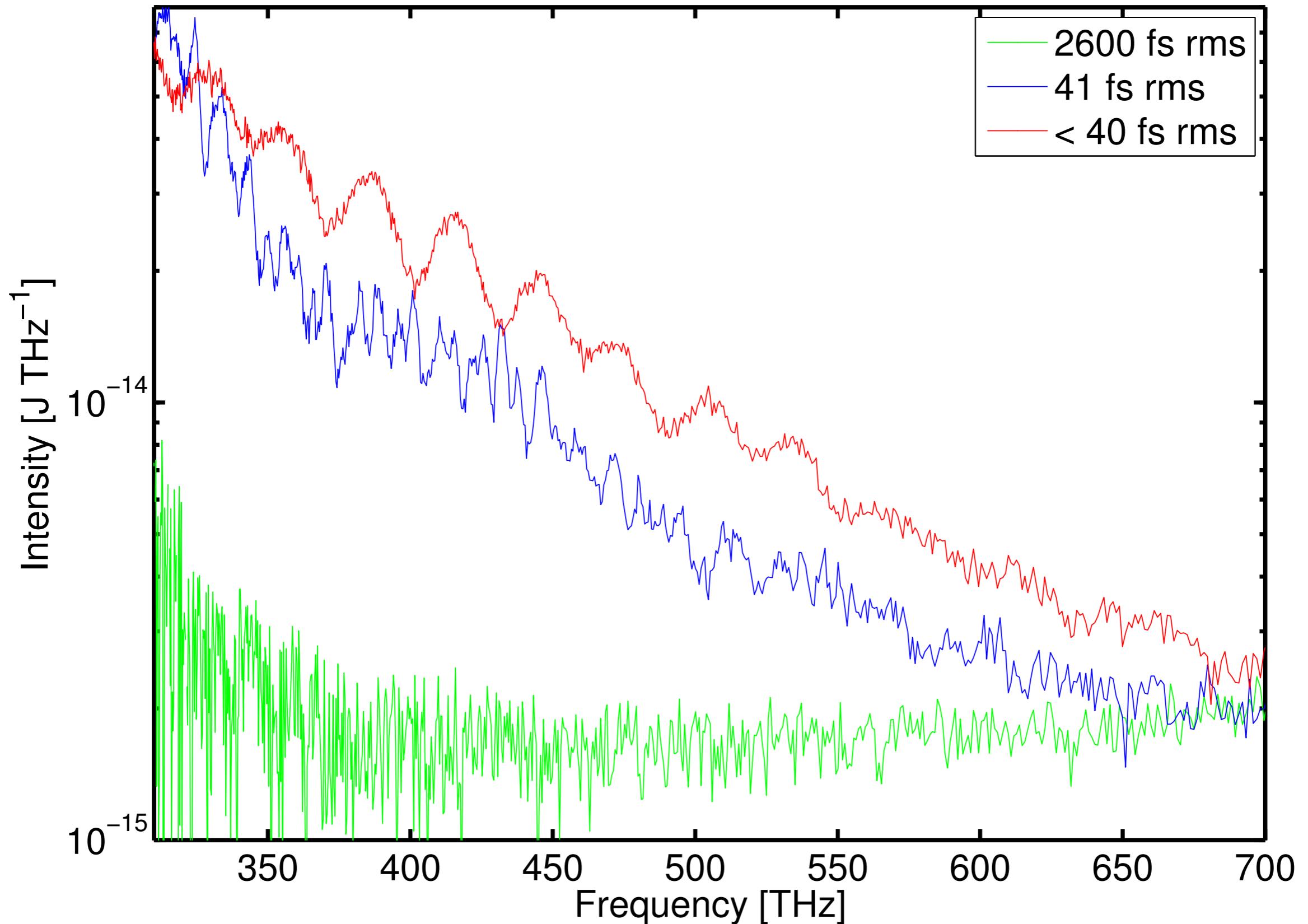
Optical Spectrum of Transition Radiation



- > Experimental Setup in the SwissFEL Injector Test Facility
- > Transition radiation from aluminum coated silicon screen
- > Focusing with lens, now replaced by mirror
- > Commercial spectrometer with wide spectral range from 320 to 700 THz



Optical Spectrum of Transition Radiation



Instrumentation Activities at the SwissFEL Injector Test Facility

Rasmus Ischebeck, for the SwissFEL Team

- > Thank you for slides, graphics, photos and plots provided by:
 - > Vladimir Arsov
 - > Simona Bettoni
 - > Bolko Beutner
 - > Micha Dehler
 - > Antonio Falone
 - > Franziska Frei
 - > Ishkhan Gorgisyan
 - > Yevgeniy Ivanisenko
 - > Boris Keil
 - > Florian Löhl
 - > Gian Luca Orlandi
 - > Marco Pedrozzi
 - > Peter Peier
 - > Patrick Pollet
 - > Eduard Prat
 - > Thomas Schietinger
 - > Volker Schlott
 - > Bennie Smit
 - > Markus Stadler
- > Slides available at: <http://people.web.psi.ch/ischebeck>



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