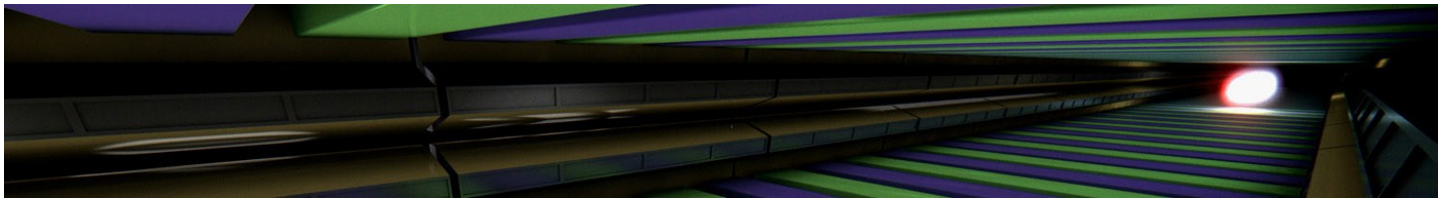
FEL
Beam
Dynamics



DESY

High-Level Anwendungen (Controls) bei XFEL/FLASH

T. Limberg

Gliederung

- Organisatorisches
- Werkzeuge und Konzepte
- Beispiele

Orga…

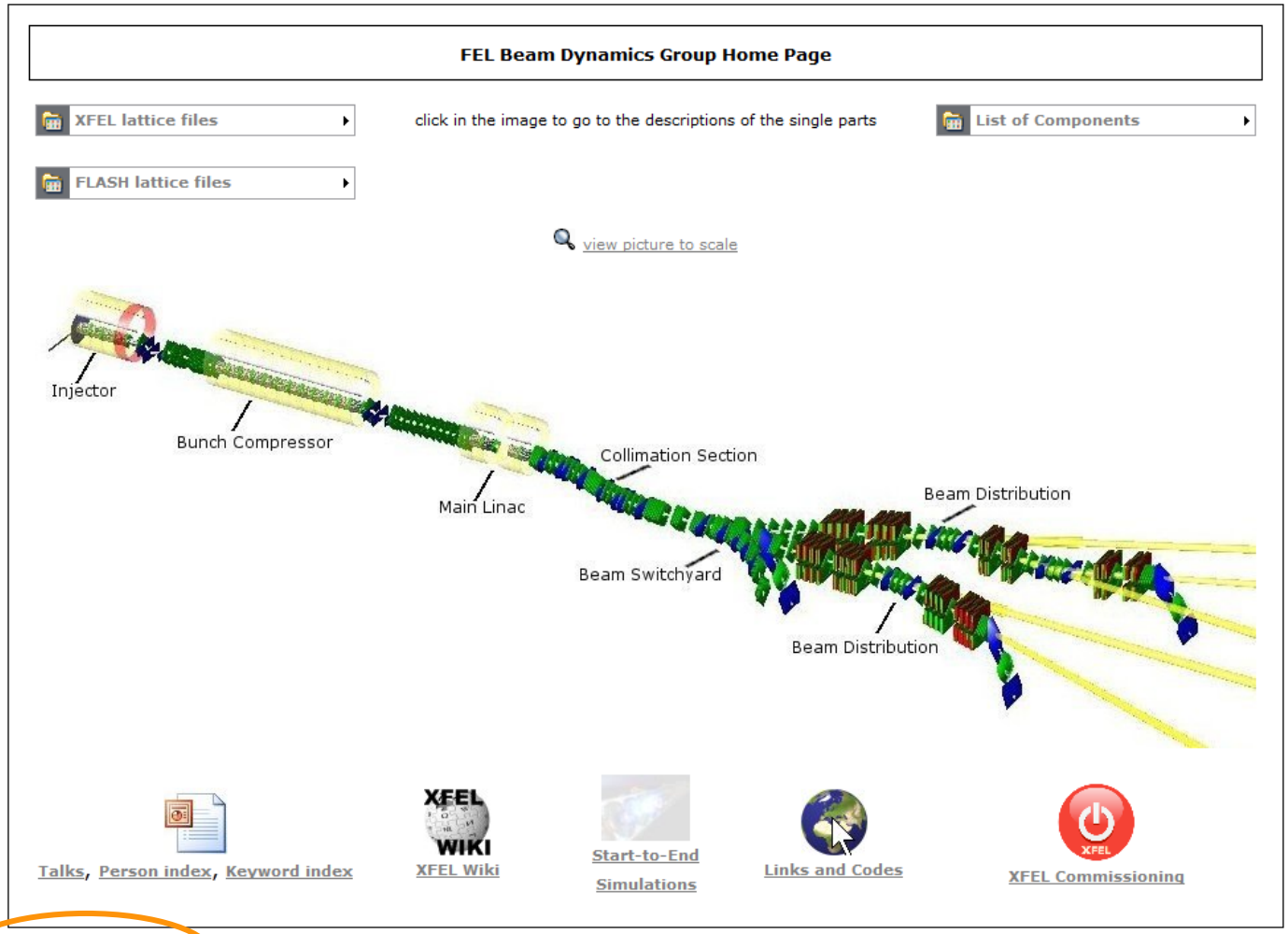
MCS-1
J. Wilgen

MCS-4
R. Kammering

MLC verantwortlich
für HLC: WD, TL

MPY
S. Meykopff

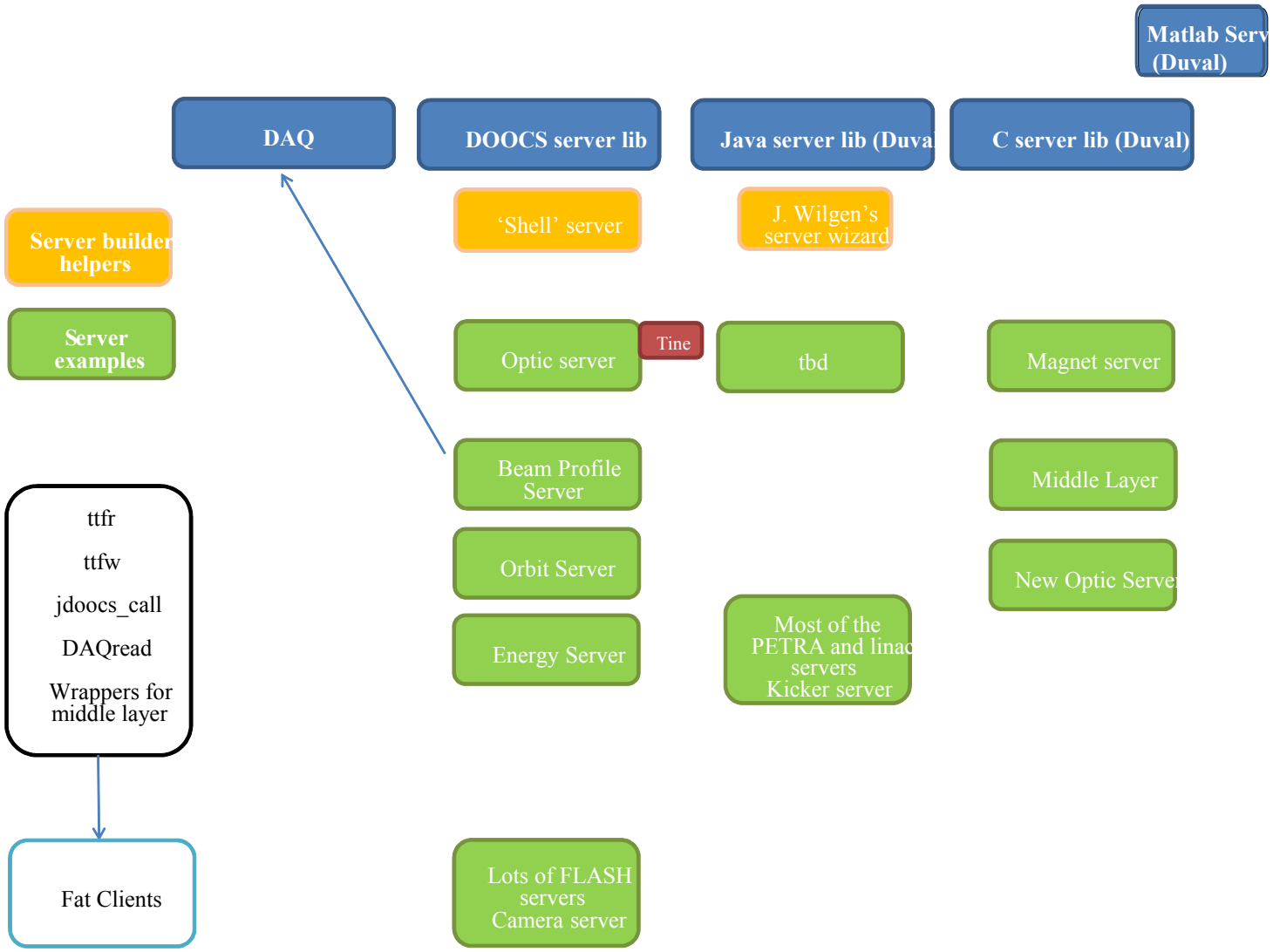
FEL Beam Dynamics Homepage



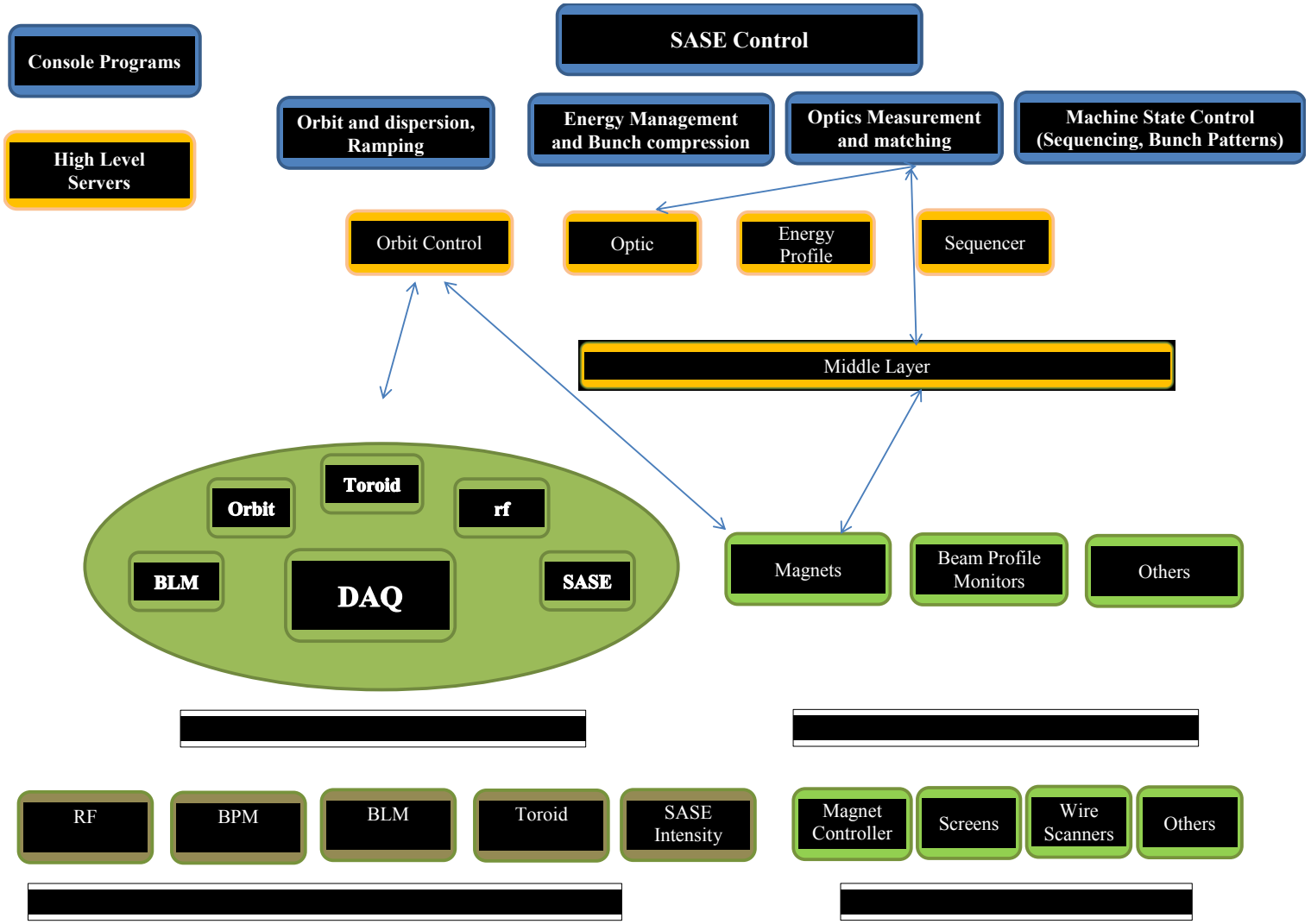
Aufgaben

- Oberflächen und Server zur Steuerung von Multikomponenten-Prozessen (z.B. Automatisierte Emittanzmessung)
- Unterstützung automatisierter Maschienenexperimente
- Hi-Level Post-Mortem Analyse

Was haben wir an Werkzeugen?



Kontrollsystem Ebenen



Beam Loss Monitor Middle Layer Server für FLASH

- Produced output data
  - For each BLM and each event, a time series which contains
    - The current data
    - A bunch-wise average, RMS, and a peak-hold value over the last N events
  - For each BLM, a summary of the current time series
    - Average, RMS, maximum and peak-hold of loss rates of bunch current, dark current, and total.
  - For each accelerator section a summary over all contained BLMs
    - Average, RMS, maximum and peak-hold of loss rates of bunch current, dark current, and total.

Matlab Middle Layer

List of Calls:

- **read_magnets**
- **set_magnets**
- **read_BPMs**
- **set_orbit**
- **read_toroids**
- **read_BLMs**
- **get_beam_profile**
- **get_longitudinal_profile**
- **read_rf**
- **set_rf**
- **set_energy**

Description of Calls:

[fields_and_currents, status, names, positions, error] =

read_magnets (id, further_specs)

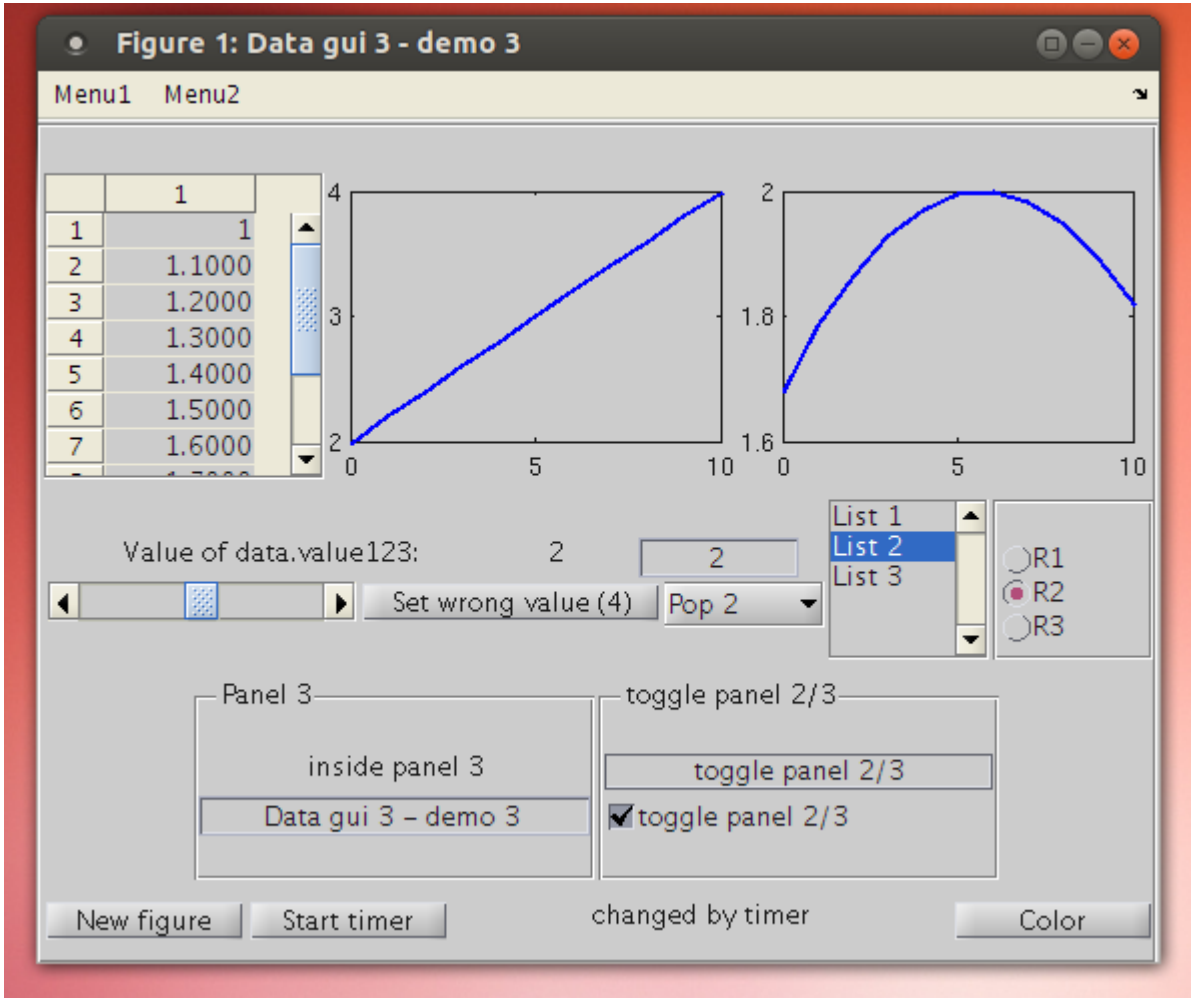
Generic names: 'Quad','Bend','Sext'

further_specs:

Name	Type	default	Comment
'ignore_if_off	Logical	1	Does not return switched off magnets

Matlab GUI Bibliothek

- axes
- checkbox
- edittext
- figure
- listbox
- menuitem
- panel
- popupbox
- pushbutton
- radiogroup
- slider
- statictext
- table
- togglebutton

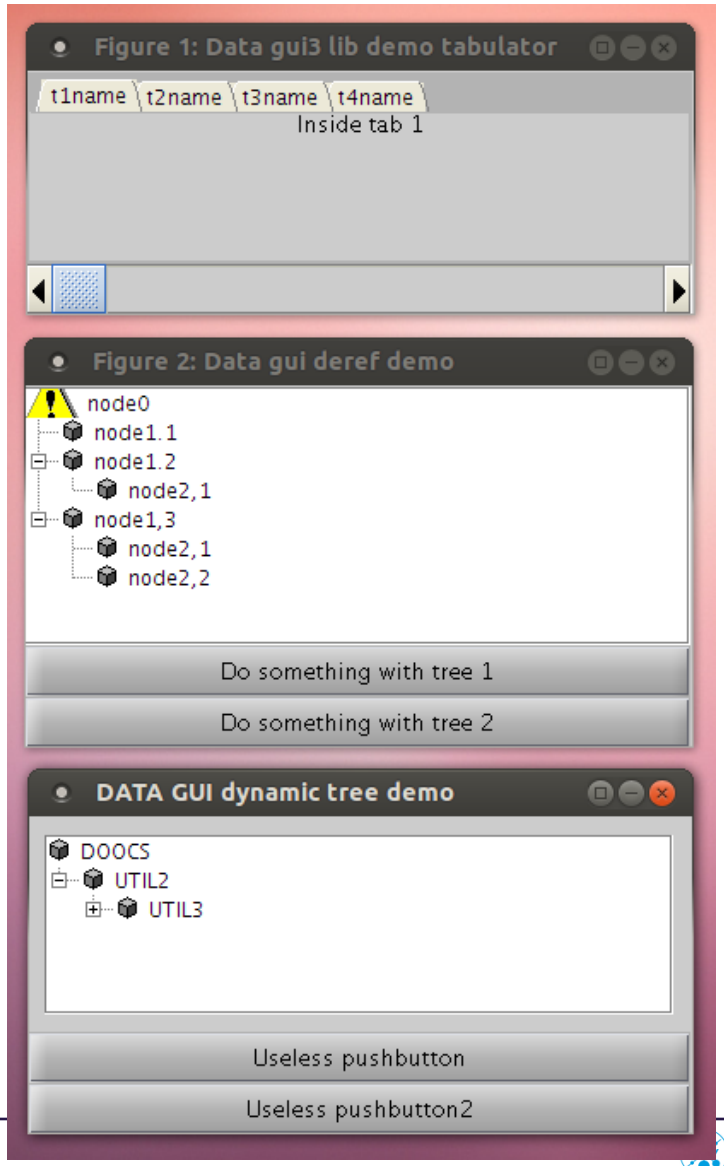


Matlab GUI Bibliothek

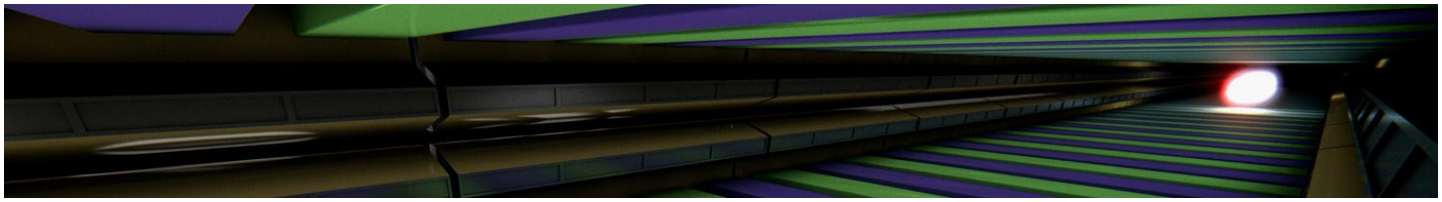
- deref
- timer
- tabgroup
- tree
- treedyn

Special GUI support:
- Continuouse slider
- Mouse wheel /
- Mouse button up/down
- Enter/Leave focus events

etc.



FEL
Beam
Dynamics

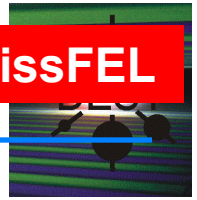


Matlab Toolbox ADAQA used for Emittance Measurements

Bolko Beutner, Rasmus Ischebeck

PSI / DESY / KIT Mini-Workshop on Longitudinal Diagnostics for FELs

Scan Framework



- These measurements need to be automatised for standard operation and commissioning, task are e.g.:
  - moving screens in and out
  - varying quadrupole settings
  - restore initial lattice configuration

- A successful measurement procedure (high level application) needs to be reliable, robust, and usable

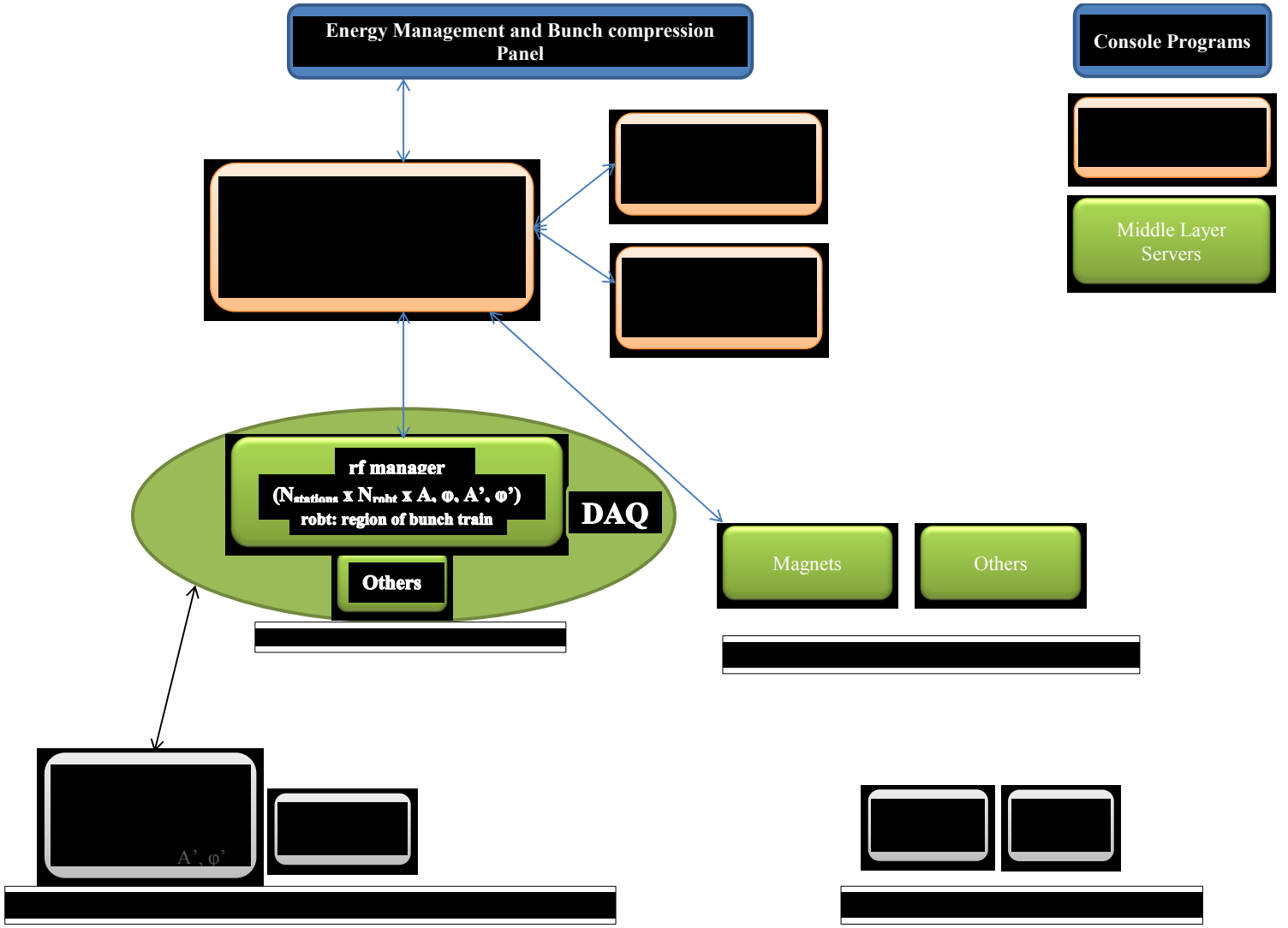
“Always have the operator at the end of the night shift in mind!”

- Accelerator operation in general relies on data acquisition and parameter scans
- In the various applications the requirements are actually quite similar

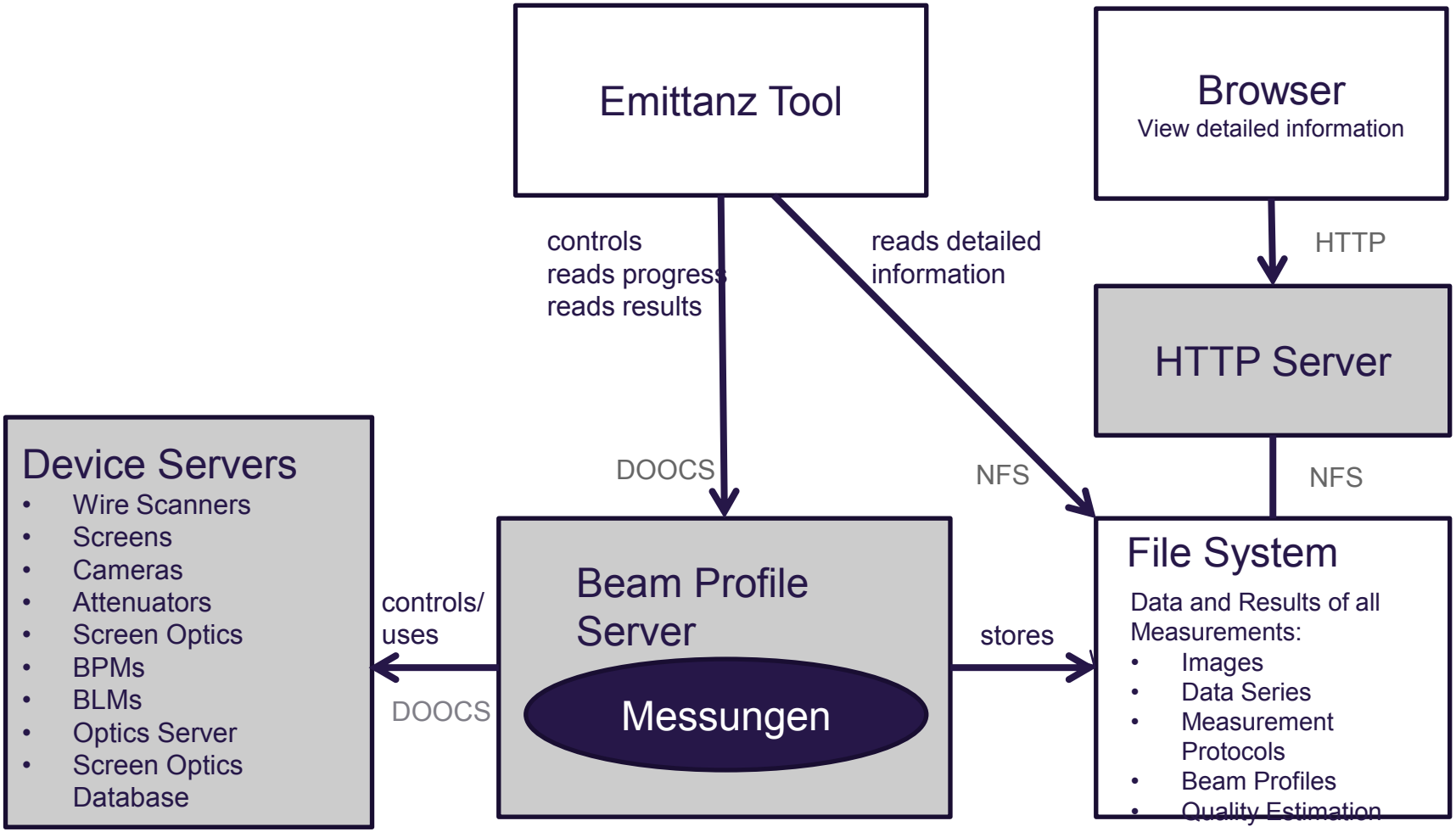
  ⇒ Tasks should be unified and standardised to prevent that every application developer “reinvents the wheel”

  ⇒ ADAQA - An Accelerator Data Acquisition & Analysis Framework

Beispiel Energie- und Kompressionsmanagement



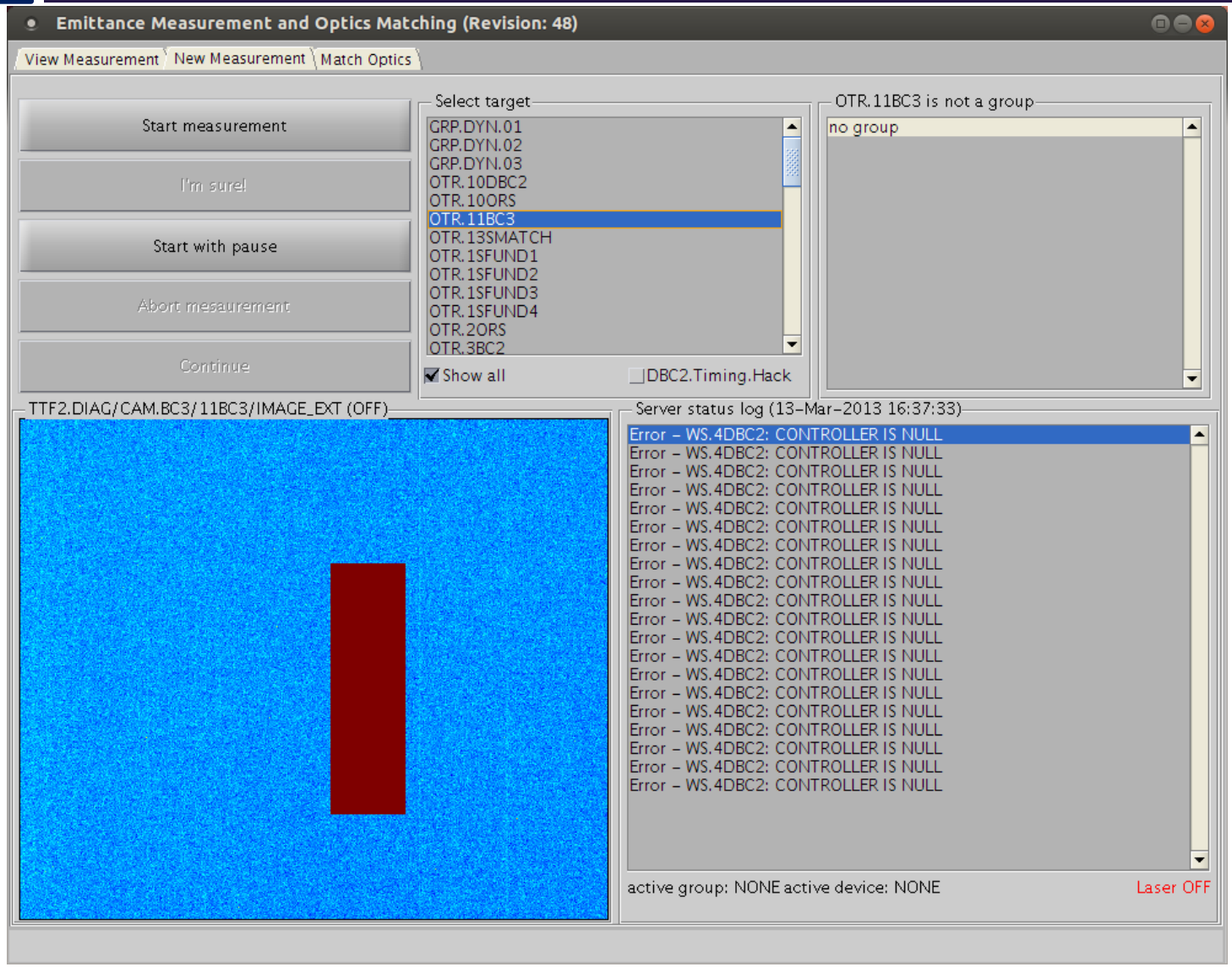
Emittanzmessung



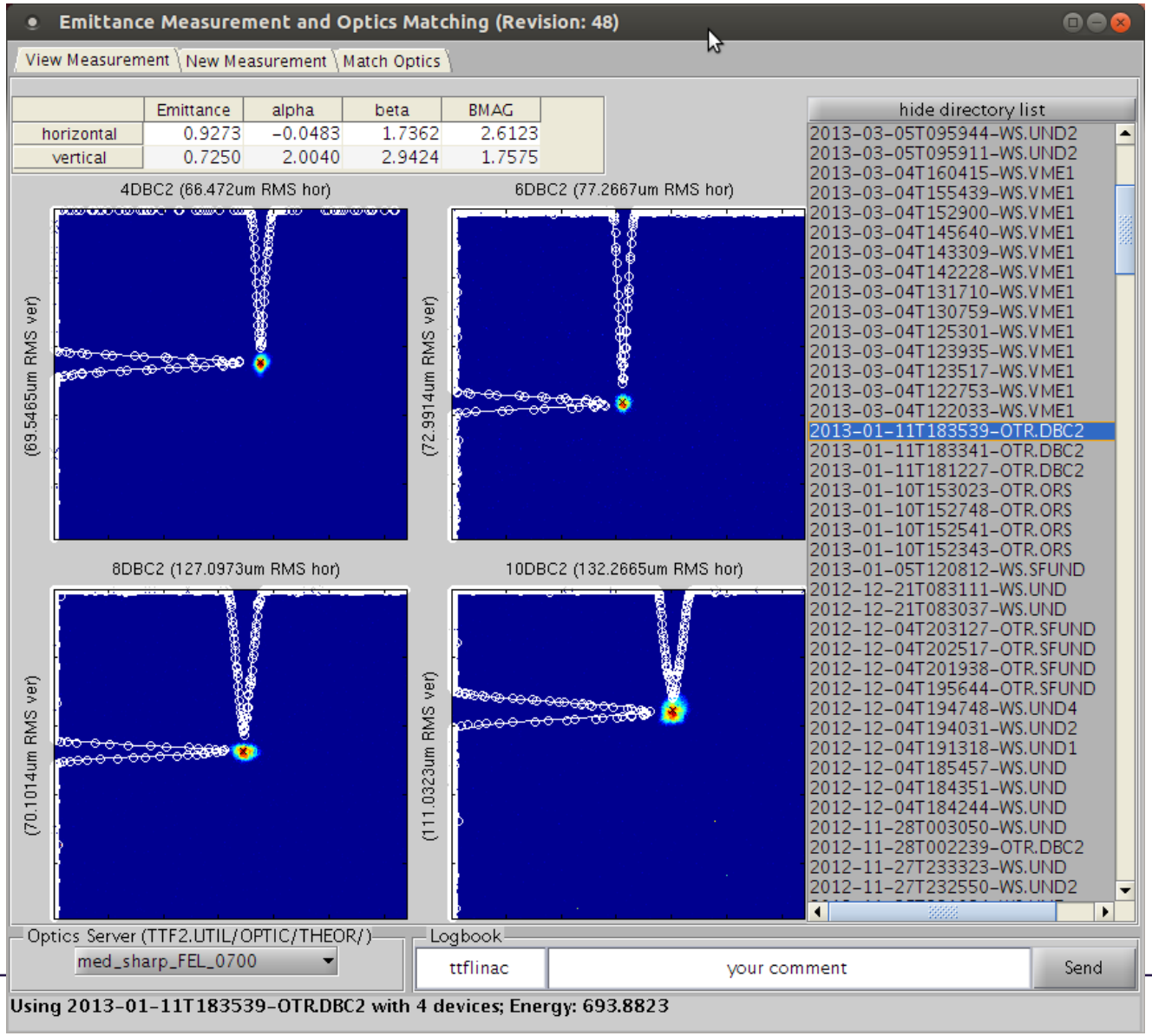
Undulator-Wire-Scanner Massnahmen

- Das Serverprogram der VME-Creates wurde überarbeitet.
  - Genaue Einmessung von Position und Fahrkurve bei Initialisierung.
  - Dadurch exaktes Anfahren beliebiger Positionen (+- 15um) möglich.
  - Verhalten zuverlässig und reproduzierbar.
  - Erhöhung der Fahrgeschwindigkeit, damit schnelleres Rein- und Rausfahren ermöglicht wird (noch in Arbeit).
  - Erkennbar, wann eine Initialisierung benötigt wird (Flag).
  - Hoffnung: Pro Server-Neustart nur noch einmal initialisieren.
- Bisher gute Erfahrungen/Tests mit neuem Server
  - Zuverlässigkeit wurde deutlich verbessert
  - Kein “Aufhängen” mehr beim Fahren.
  - Kein häufiges Initialisieren mehr nötig
- Einige Probleme werden noch untersucht
  - Einige WS (UND 5 + 6) halten Zielpositionen nicht.
  - Versprochene Max. Fahrgeschwindigkeit nicht erreichbar.
  - Motor bleibt bei vert. Scannern bei Initialisierung manchmal stehen.

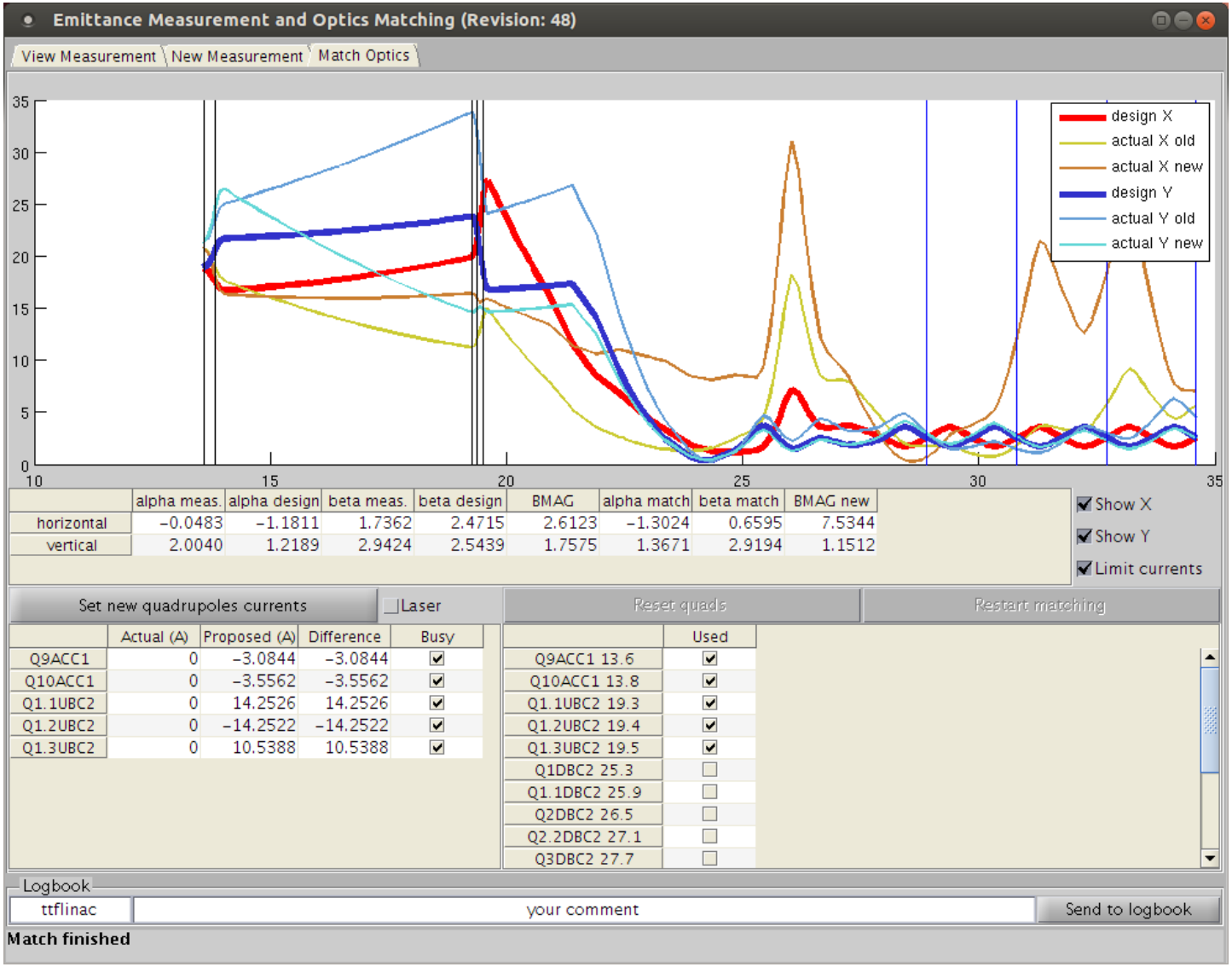
Emittanzmessung: NeueMessung



Emittanzmessung: Auswertung



Emittanzmessung: Optik einstellen

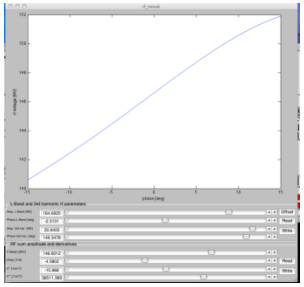


	alpha meas.	alpha design	beta meas.	beta design	BMAG	alpha match	beta match	BMAG new
horizontal	−0.0483	−1.1811	1.7362	2.4715	2.6123	−1.3024	0.6595	7.5344
vertical	2.0040	1.2189	2.9424	2.5439	1.7575	1.3671	2.9194	1.1512

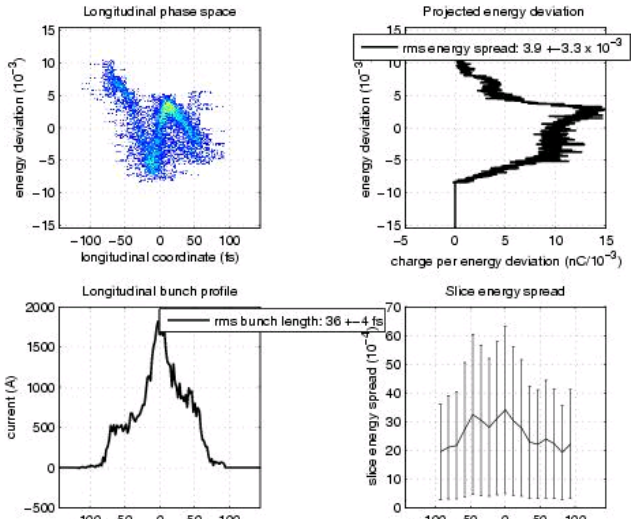
	Actual (A)	Proposed (A)	Difference	Busy
Q9ACC1	0	−3.0844	−3.0844	☑
Q10ACC1	0	−3.5562	−3.5562	☑
Q1.1UBC2	0	14.2526	14.2526	☑
Q1.2UBC2	0	−14.2522	−14.2522	☑
Q1.3UBC2	0	10.5388	10.5388	☑

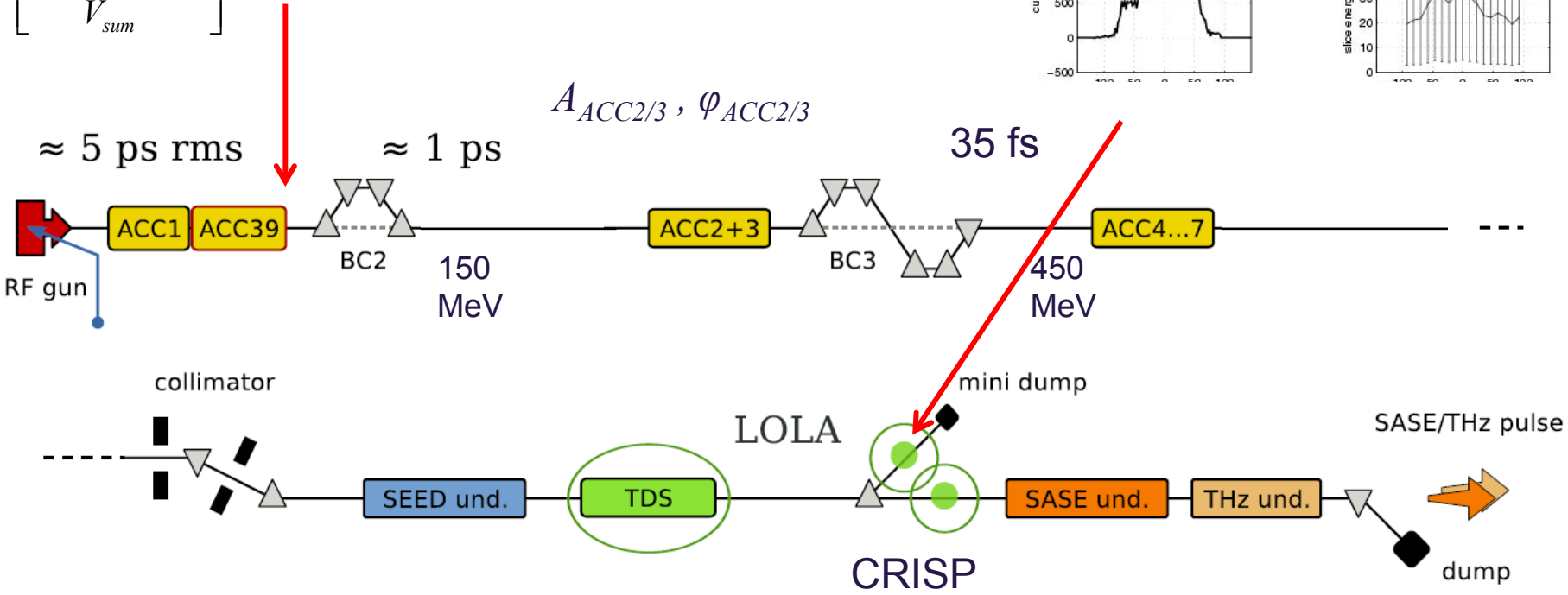
	Used
Q9ACC1 13.6	☑
Q10ACC1 13.8	☑
Q1.1UBC2 19.3	☑
Q1.2UBC2 19.4	☑
Q1.3UBC2 19.5	☑
Q1DBC2 25.3	☐
Q1.1DBC2 25.9	☐
Q2DBC2 26.5	☐
Q2.2DBC2 27.1	☐
Q3DBC2 27.7	☐

FLASH Bunch Compression Scheme

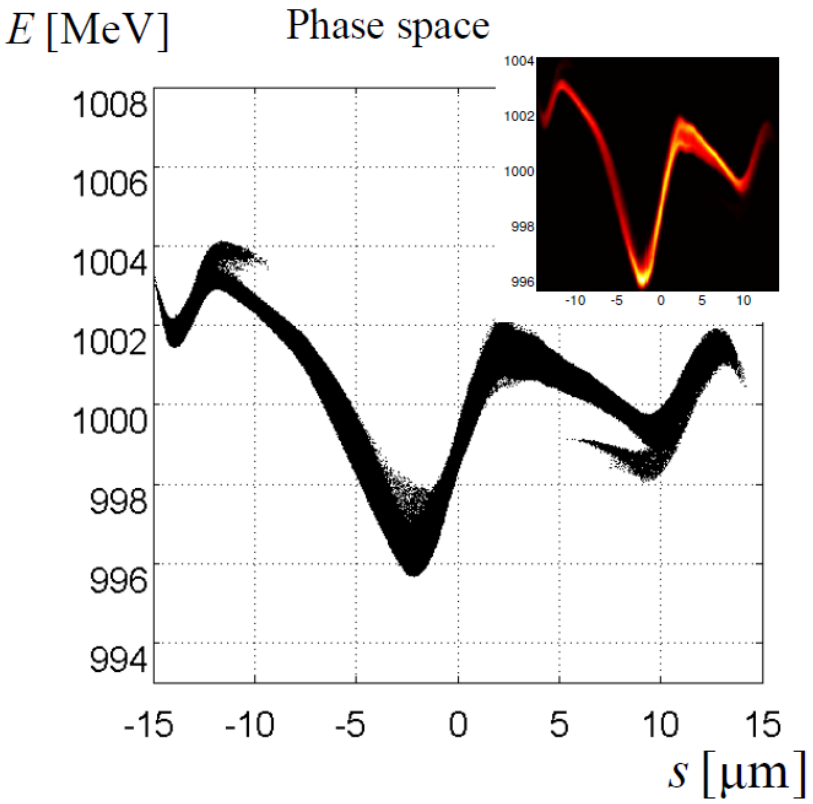


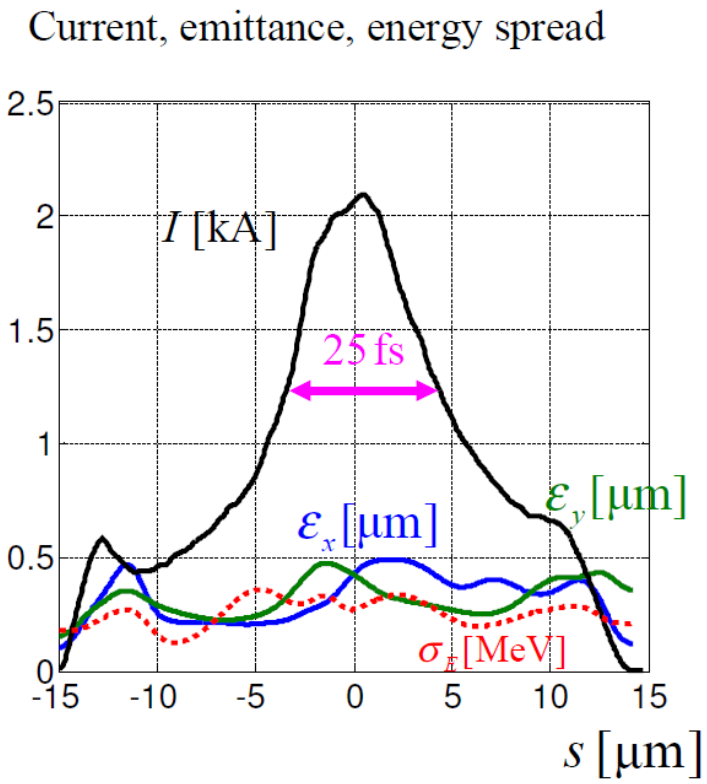
$$\begin{bmatrix} BeamEnergy \\ Chirp\,(V_{sum}{}') \\ V_{sum}{}'' \\ V_{sum}{}''' \end{bmatrix} = F(A_{ACC1}, \varphi_{ACC1}, A_{ACC39}, \varphi_{ACC39})$$





S2E with 100 pC Bunch Charge



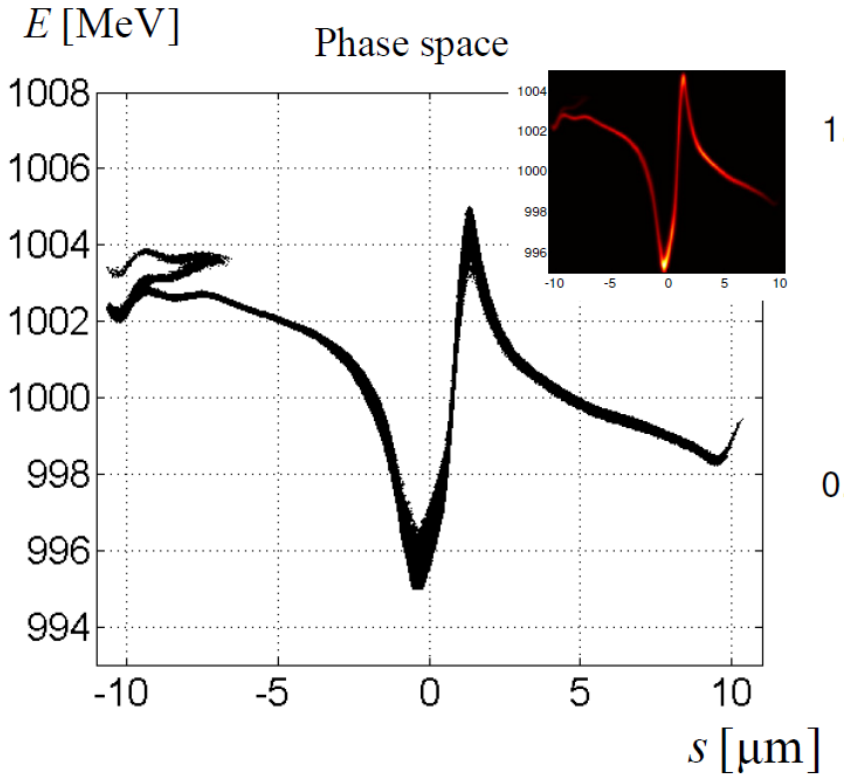


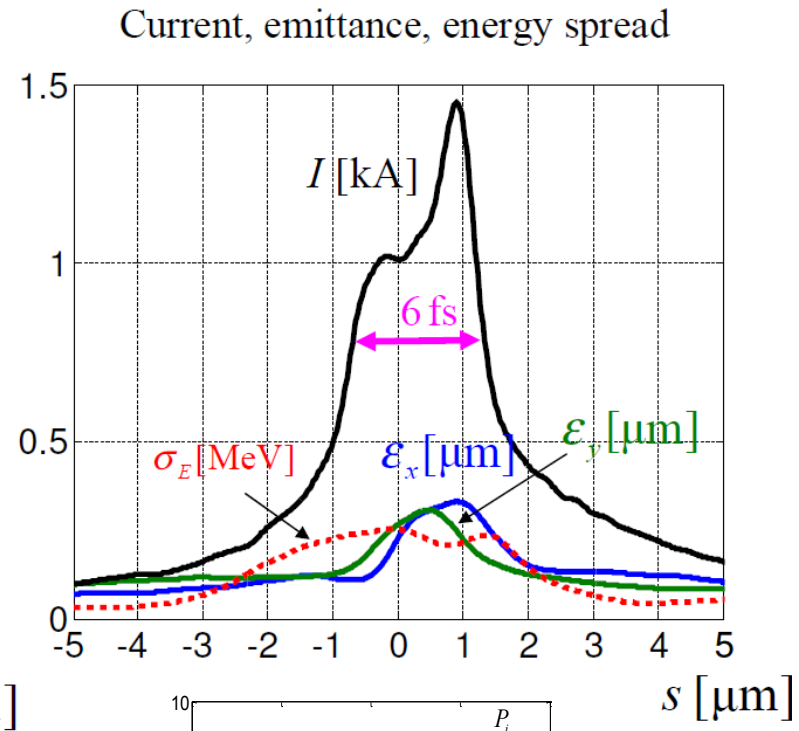
$$\varepsilon_x^{proj} = 2\,[\mu m]$$

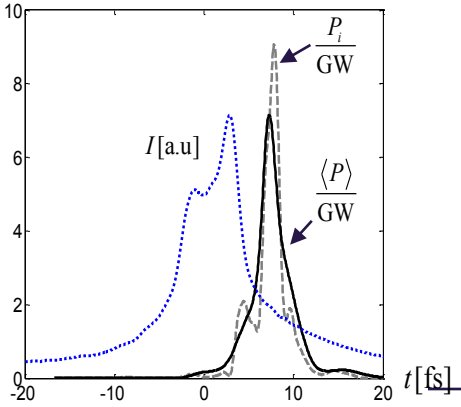
$$\varepsilon_y^{proj} = 0.6\,[\mu m]$$

Photon Pulse Length (FWHM) : 7 fs

S2E with 20 pC Bunch Charge

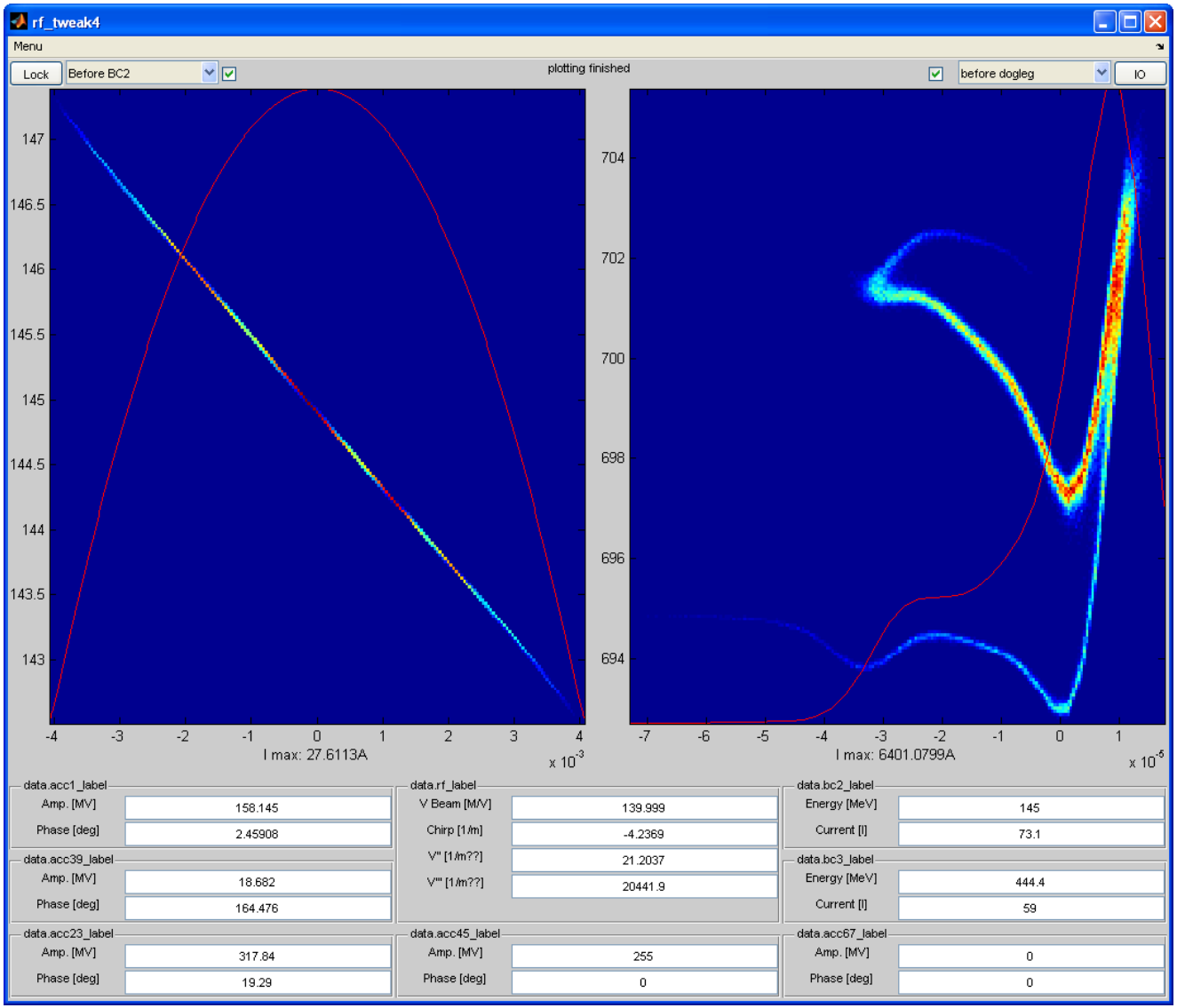






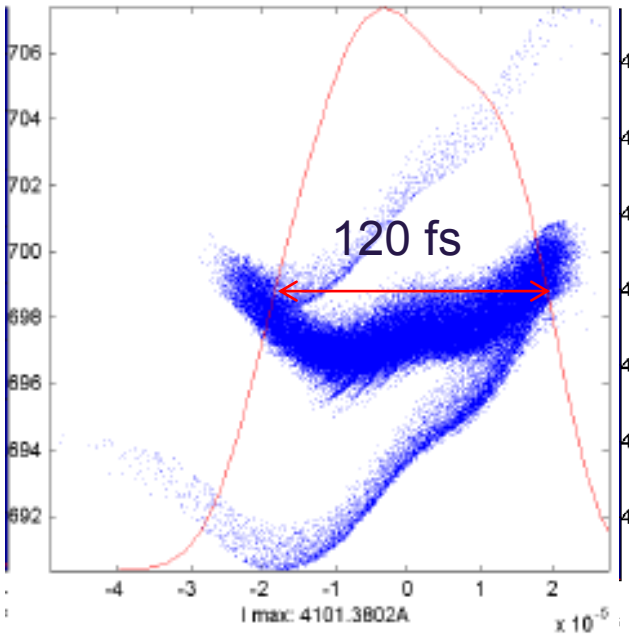
Photon Pulse Length (FWHM) : 2 fs

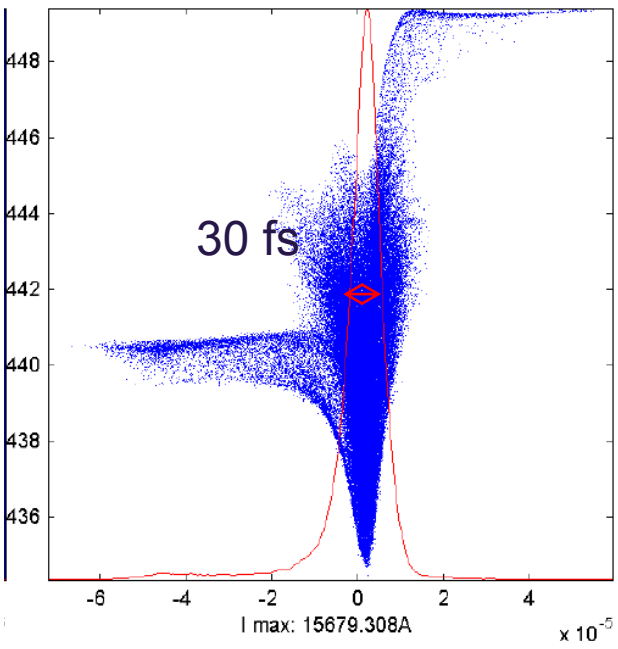
Fast Model for longitudinal Phase Space

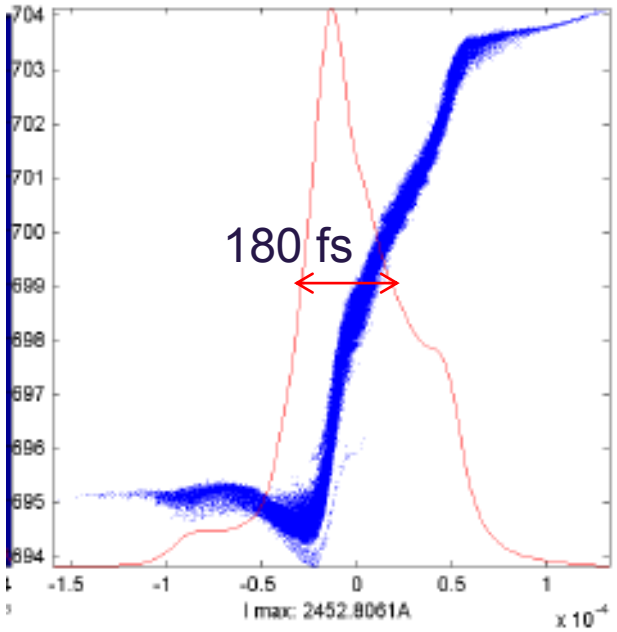


Bunch Shape after Compression vs. First Linac Section Chirp (500 pC)

Minimum bunch length limited
by non-linearities







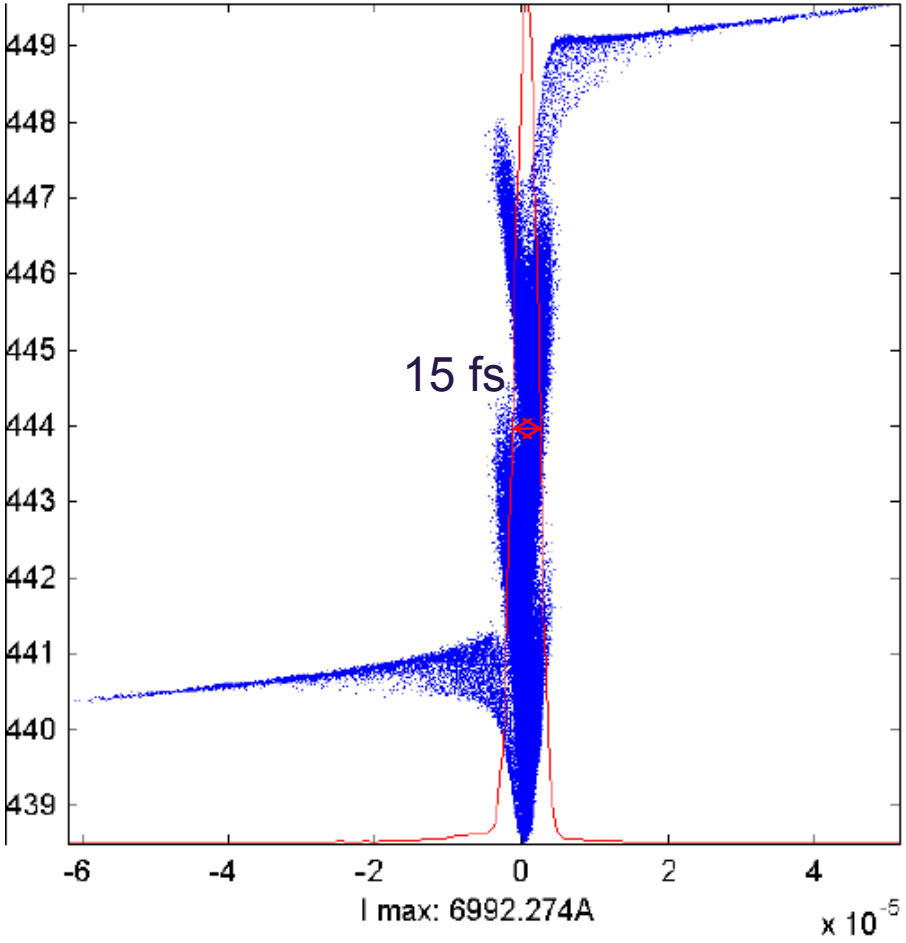
ACC1-Phase: 2.51 deg

ACC1-Phase: 2.6 deg

ACC1-Phase: 2.8 deg

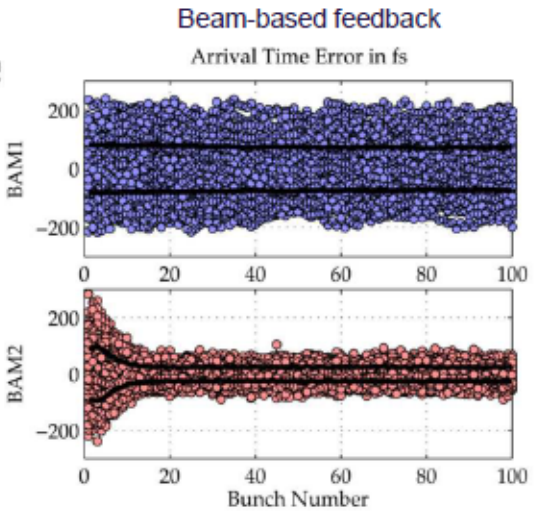
Stability and Tuning Issue

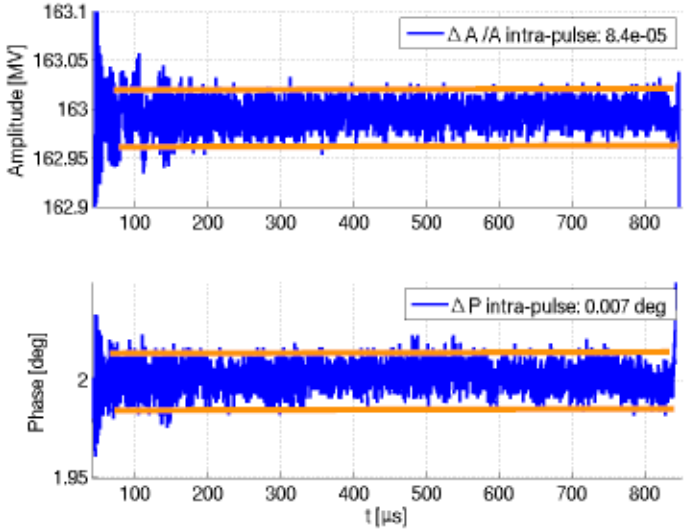
Bunch Shape after Compression (100 pC)



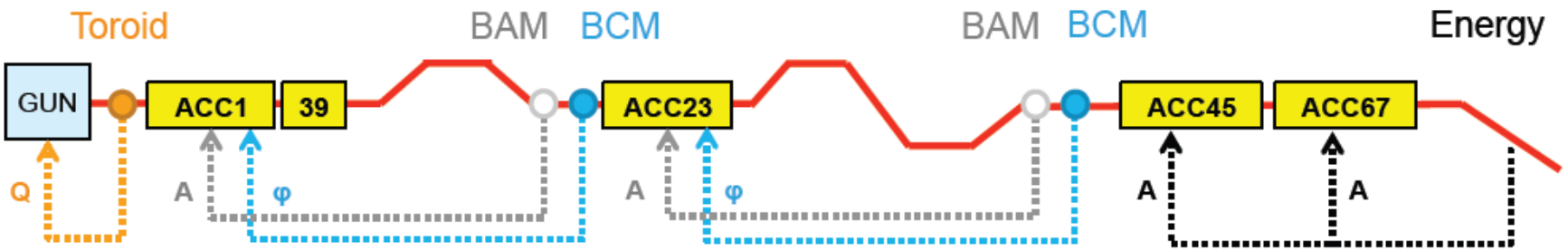
Measurements at FLASH

- Improvement of LLRF control performance
  - Beam-based feedback (tested at FLASH)
    - ➔ factor of 3 improvement in arrival time jitter
  - Cavity fundamental modes (tested at FLASH)
    - ➔ detection & filtering of 8π/9 and 7π/9 modes
  - $\Delta A/A < 9 \times 10^{-5}$, $\Delta\phi < 0.008$ deg. achieved

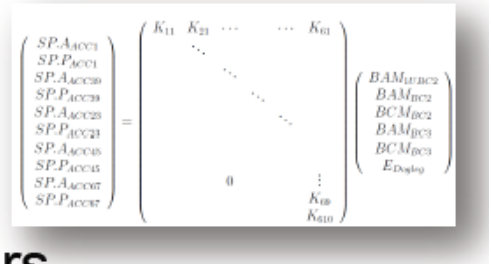




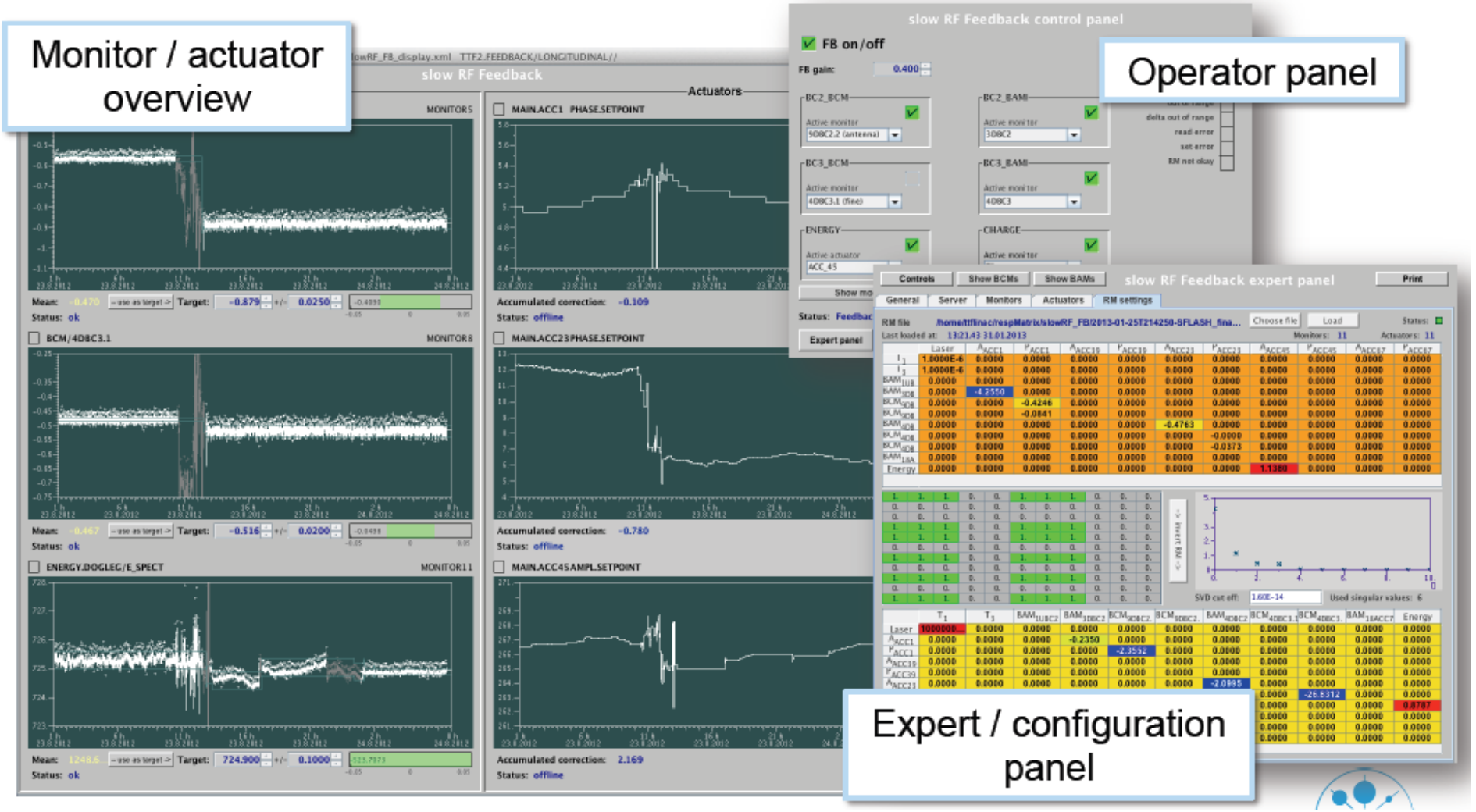
FLASH's slow longitudinal feedback (R. Kammering)



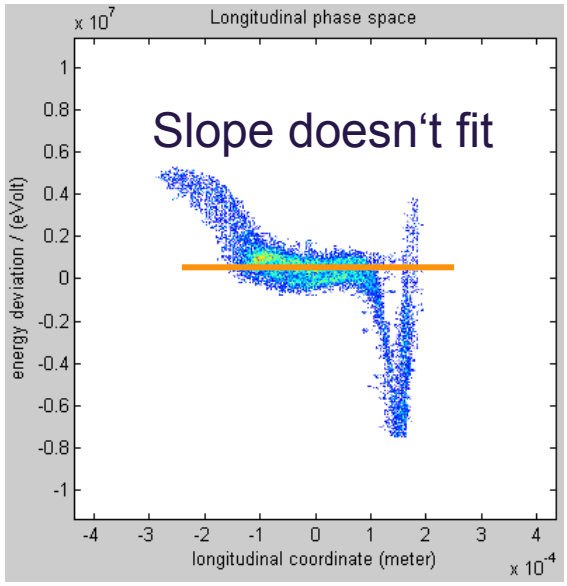
- PI controller, running up to 10 Hz
- DAQ attached DOOCS middle layer server
- Designed to run full coupled RM
- High flexibility in choice of monitors/actuators
- Robust operator interface
- Designed to be well scalable for XFEL needs

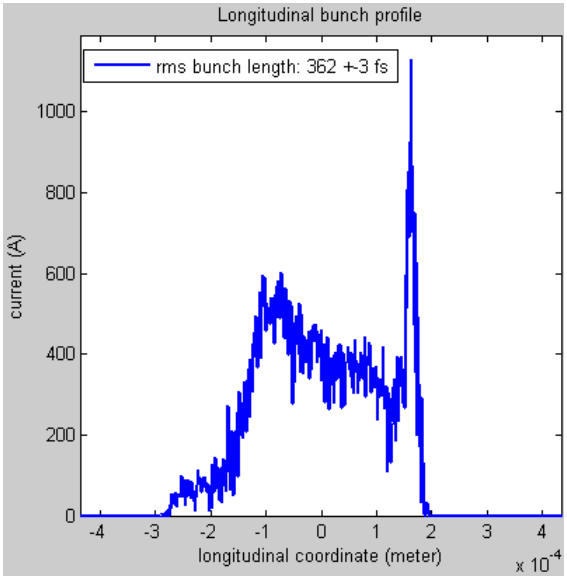


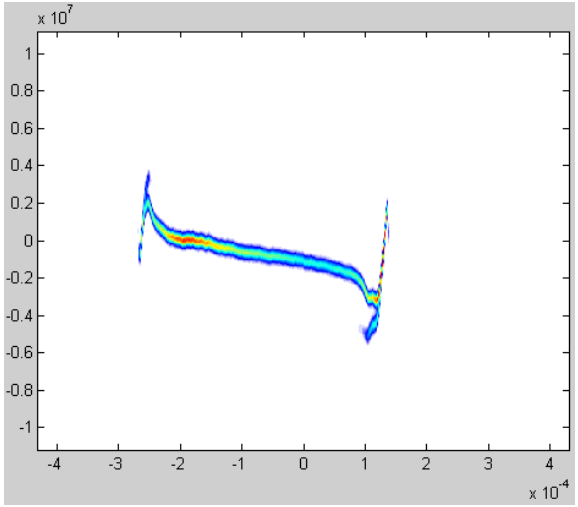
FLASH's slow longitudinal feedback

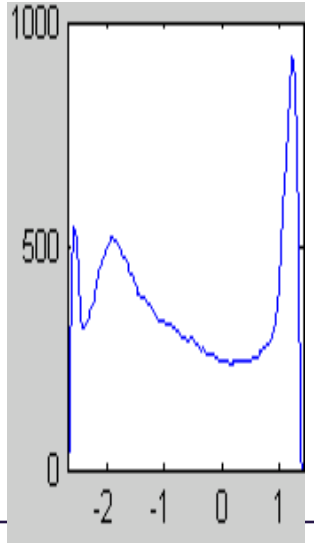


Kompressions-Studien: 1kA Spike









Tuning and characterization of short electron and FEL radiation pulses at FLASH during shifts 19(a)-21(m).01.2011

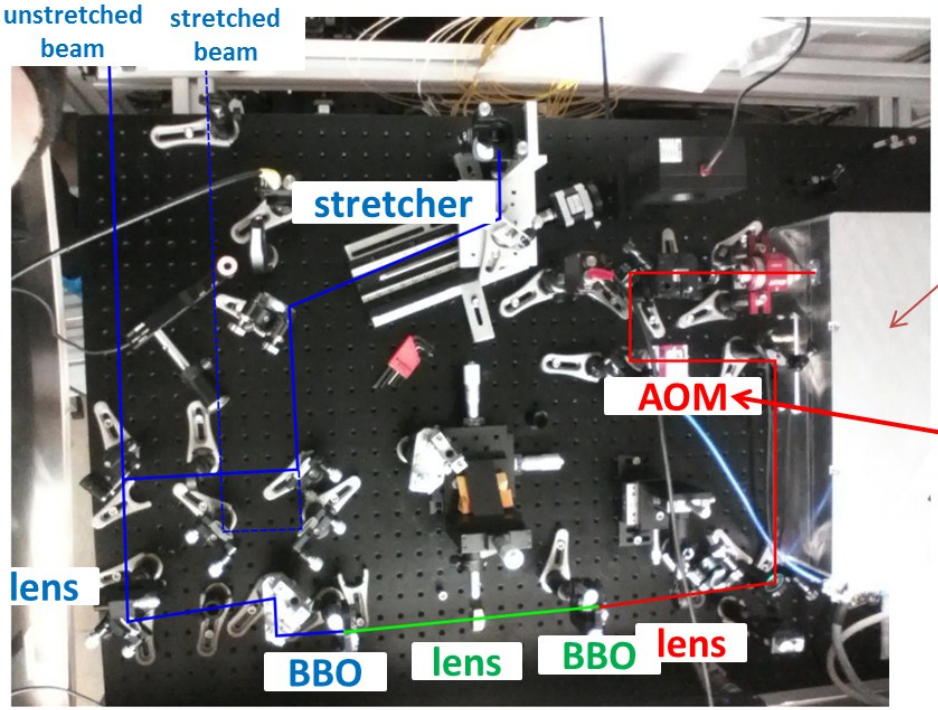
E. Schneidmiller and M. Yurkov (SASE & MCP)
C. Behrens, W. Decking, H. Delsim , T. Limberg, R. Kammering (rf & LOLA)
N. Guerassimova and R. Treusch (PGM & GMD)

Results from another shift block
(compiled by S. Schreiber (still preliminary))

	FEL Pulse duration in fs (FWHM)			
	0.5 nC	0.25 nC	0.15 nC	
Statistical method	100		35-40	
THz streak		50 – 70		Preliminary estimate
Spectrometer	100		20	20/-/3-4 spikes
Afterburner	170–200		25-70	FROG resolution 25 fs
	Estimate from electron pulse (FWHM, e^- length / 2)			
Coherent radiation			50	
LOLA	150	50 – 70	35	

- In general good agreement for the short pulses - within a factor of 2
- Larger uncertainties for longer pulses

New Laser System for short pulses (J. Roensch et. al, Uni HH)



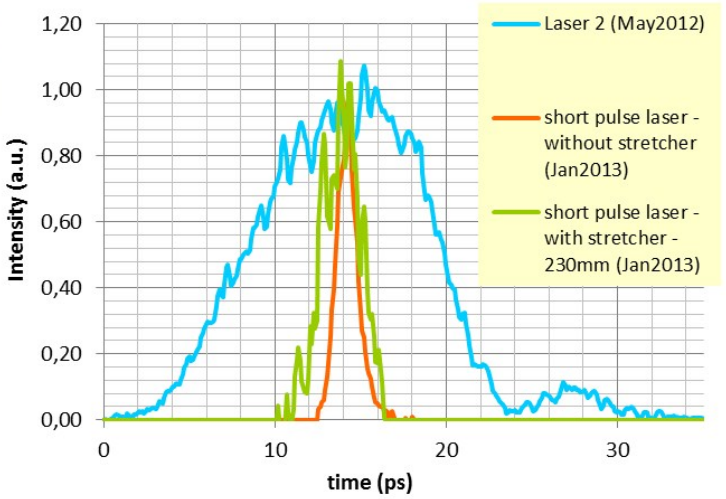
Amplified Laser System:

- Seed laser Origami 10 (OneFive)
  - 1030nm, 260mW, 54MHz, 400fs
- 2 stage amplifier (Amphos)
  - 1030nm, 10W, 1MHz, 800fs (10µJ)

AOM pulse picker (1MHz to 10Hz)
- allows pulse train operation

2 BBOs (forth harmonic)
- 1030nm -> 257.5nm
- (10% efficiency @ 10µJ) -> 1µJ

Streak camera measurement



Supported by BMBF under contract 05K10GU2 & FS FLASH 301

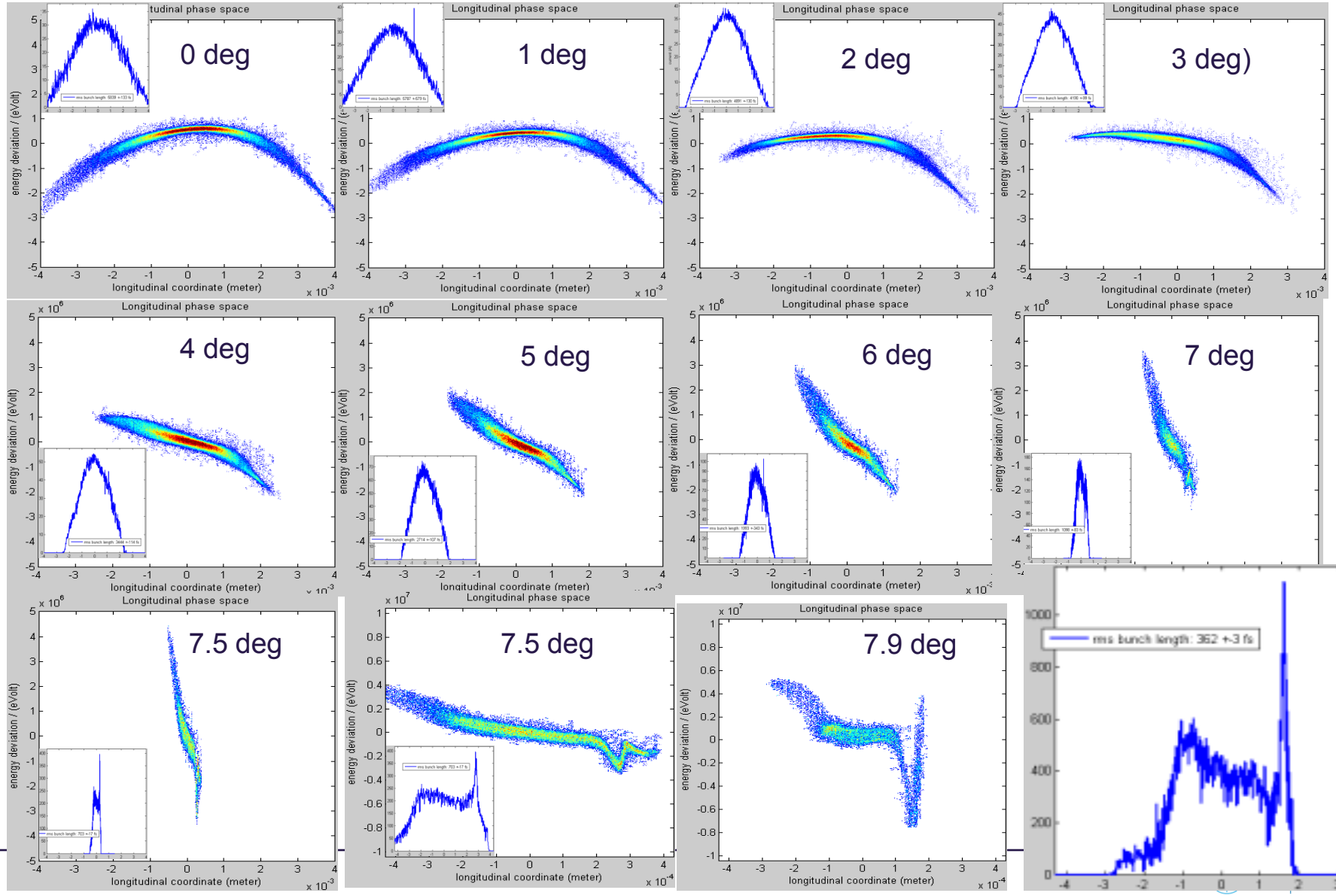

Danke für’s Zuhören!

Summary and Remarks

- The tools and methods to tune bunch length exist and have passed first tests
- Extensive feedback from users about photon beam quality is important
- An on-line photon pulse length and pulse shape measurement would be of great help

FEL Beam Dynamics

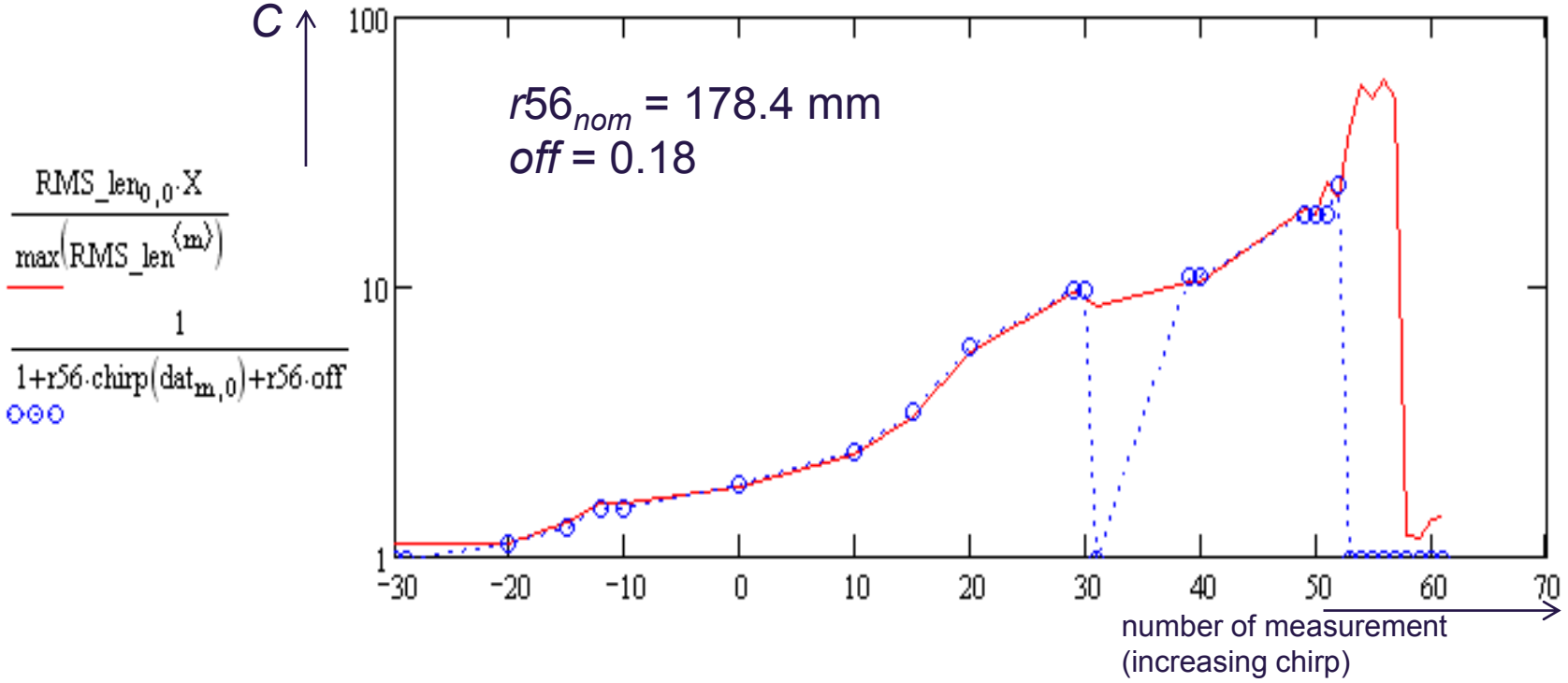
Longitudinal Phase Space and Profile vs. Energy Chirp (ACC1 phase monitored)



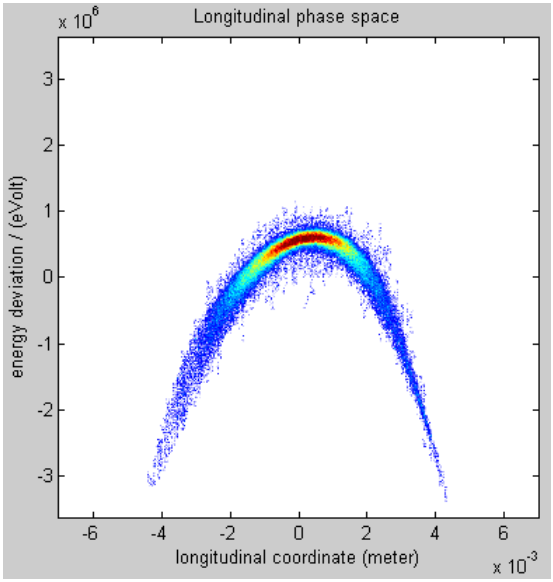
Measured and calculated compression factor (without self-effects)

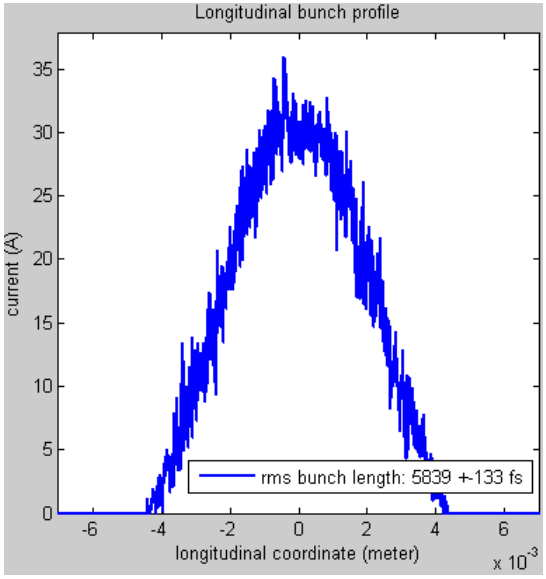
Small additional chirp and 10% correction of LOLA energy calibration:

M. Dohlus



On crest





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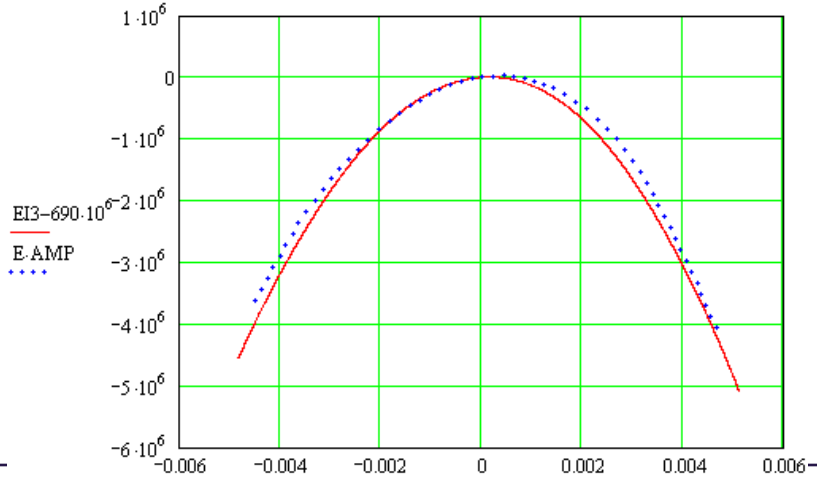
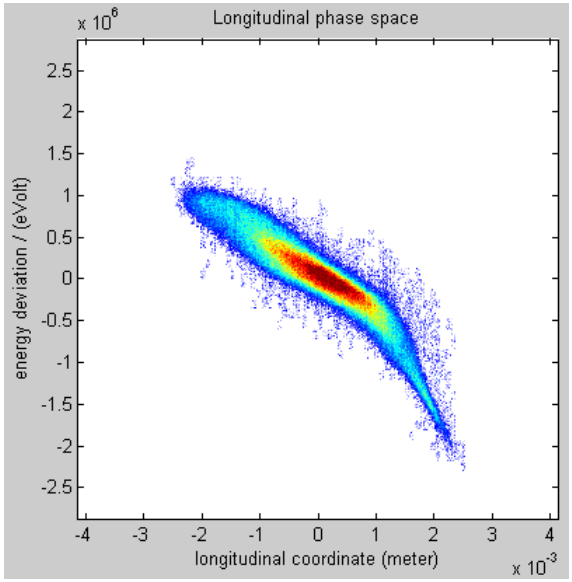
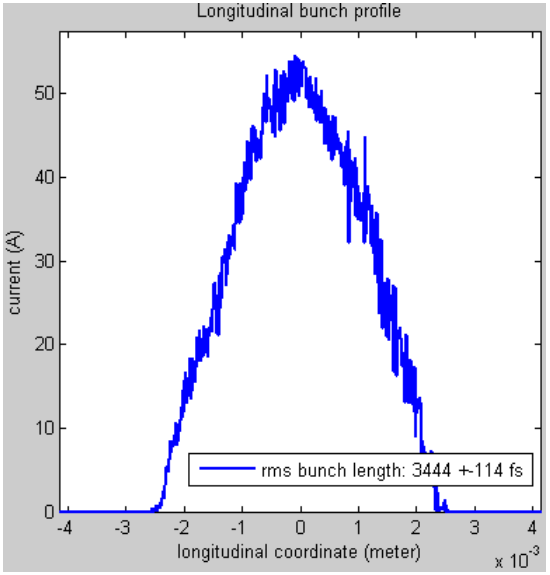
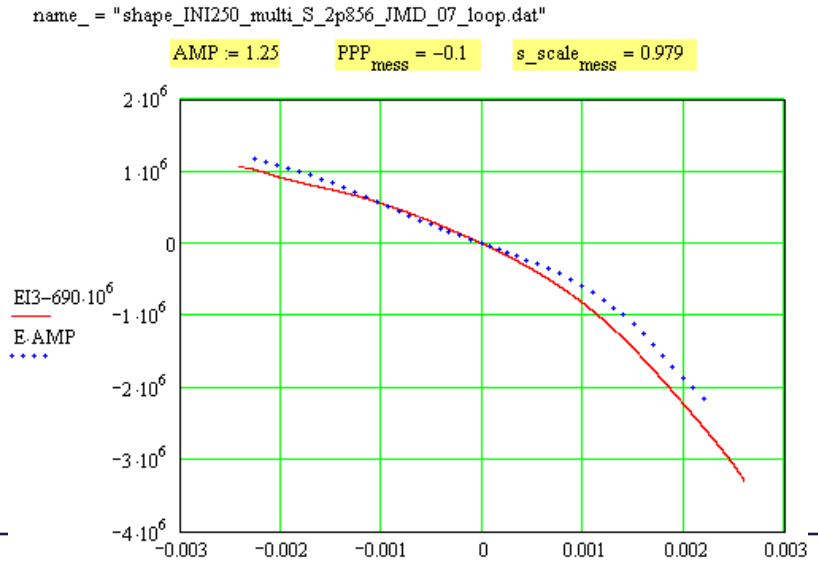
AMP := 1.25 $PPP_{mess} = -0.1$ $s\_scale_{mess} = 1.146$



Compressed to ca. 50 A

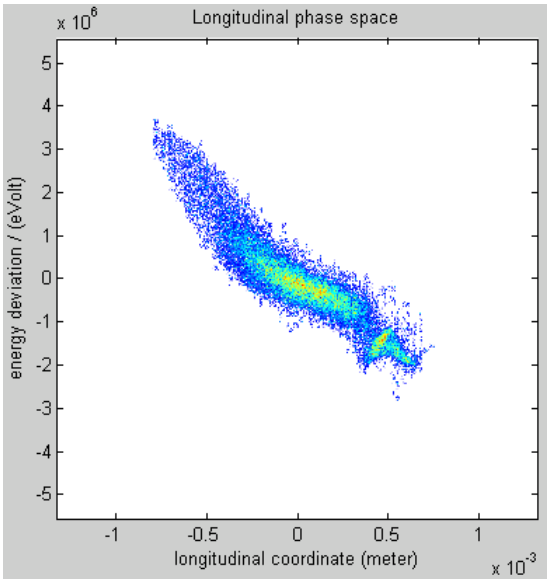


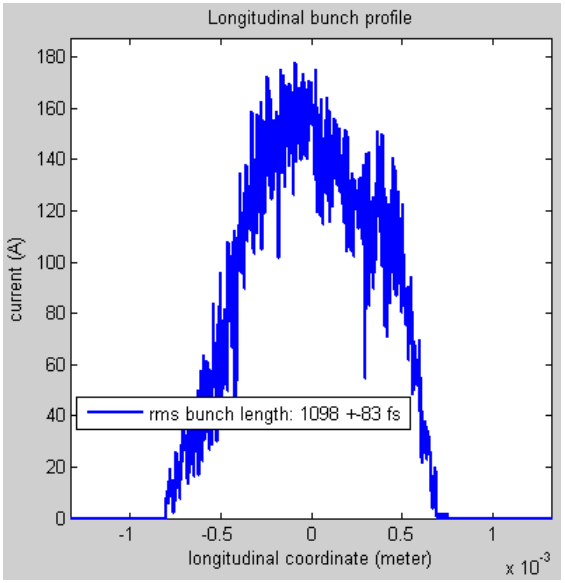


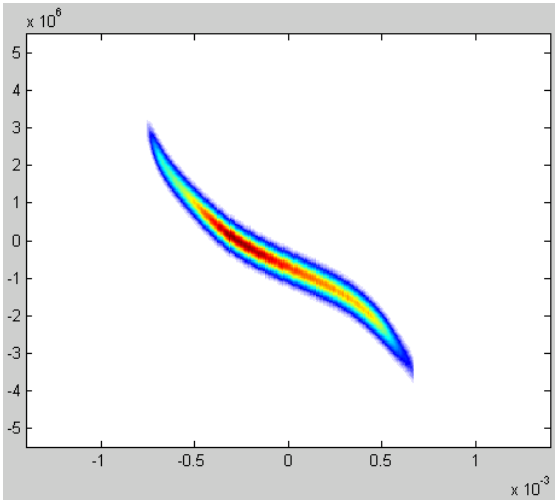


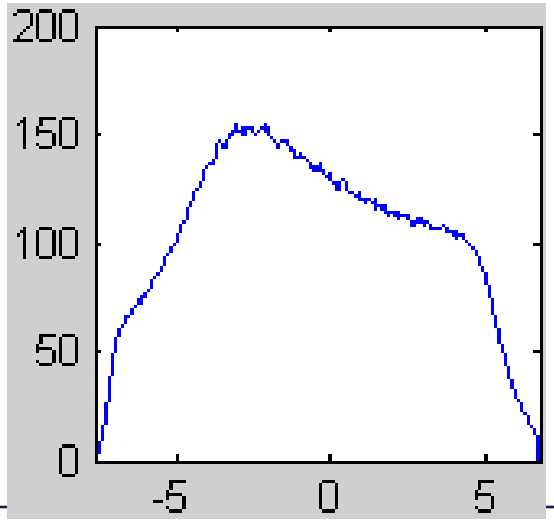
No self-effects

Compressed to ca. 150 A



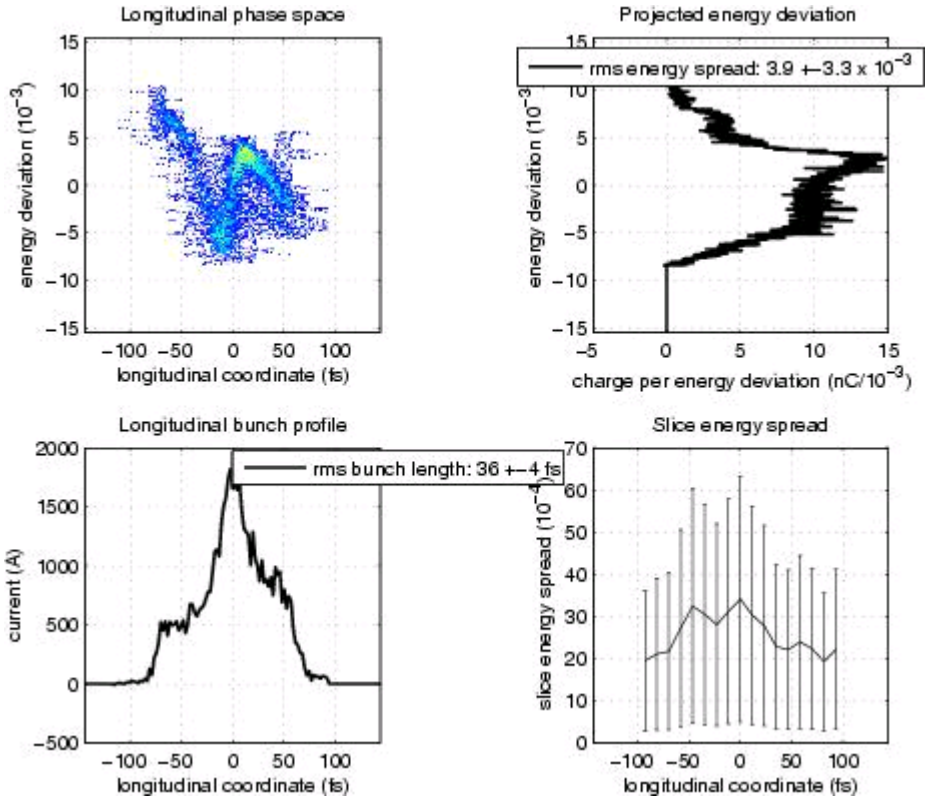






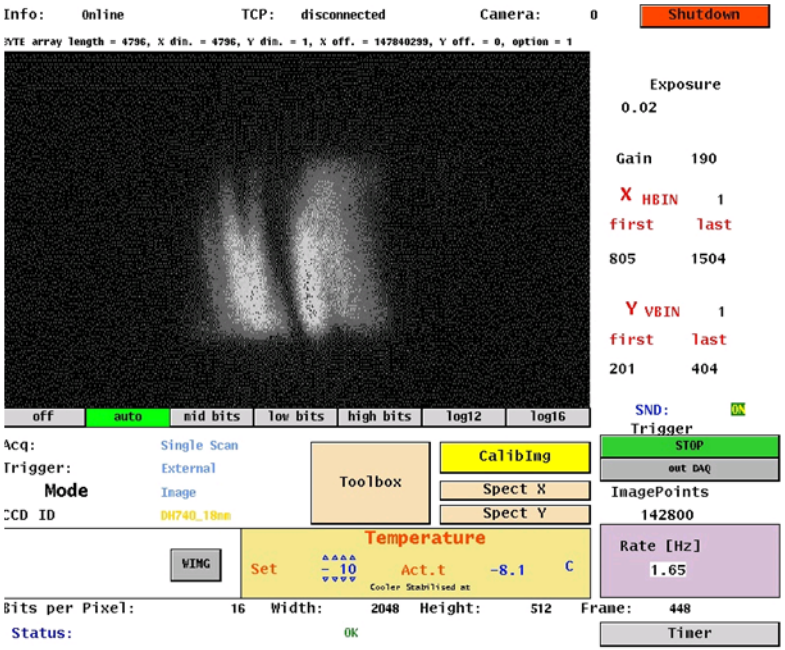
With self-effects

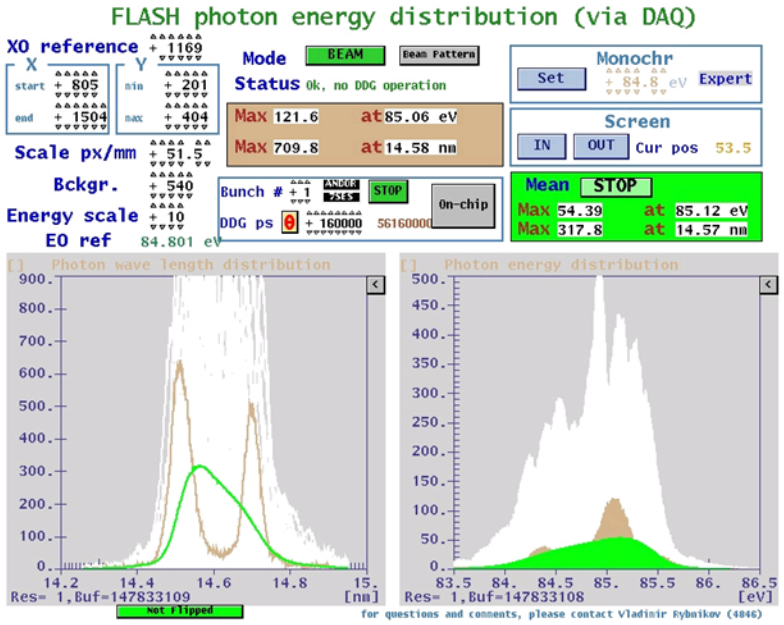
Bunch-Length-Tuning (differential): 150 pC



Bunch-Length-Tuning: Spectra and Statistics

- Statistical measurements agree qualitatively with spectral measurements .
- 150 pC sigma = 60% M = 2.8 T_rad ~ 15 fs (+10 fs + 7 fs)

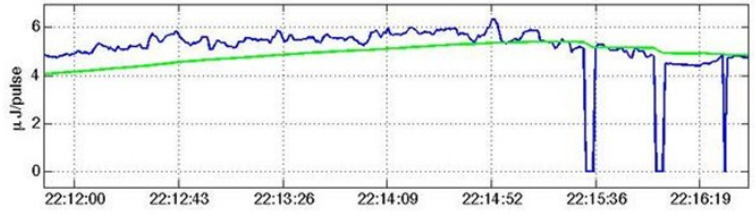


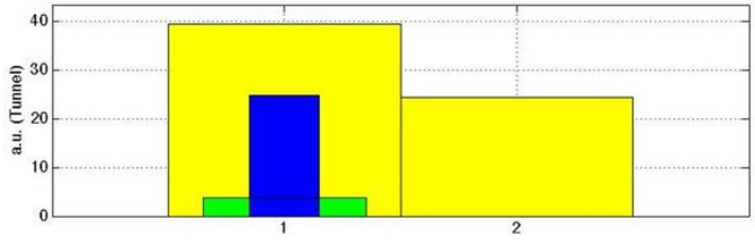


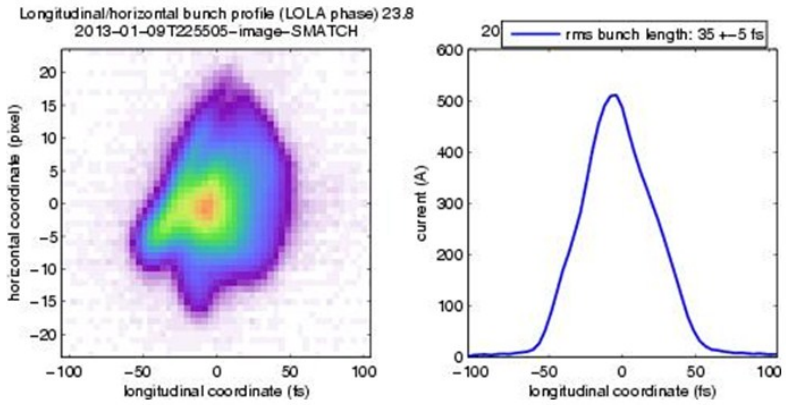
First Lasing

First SASE with short pulse injector laser:

- 9th & 11th of January 2013
- 5 uJ at 13,5 nm, bunch charge 35 pC

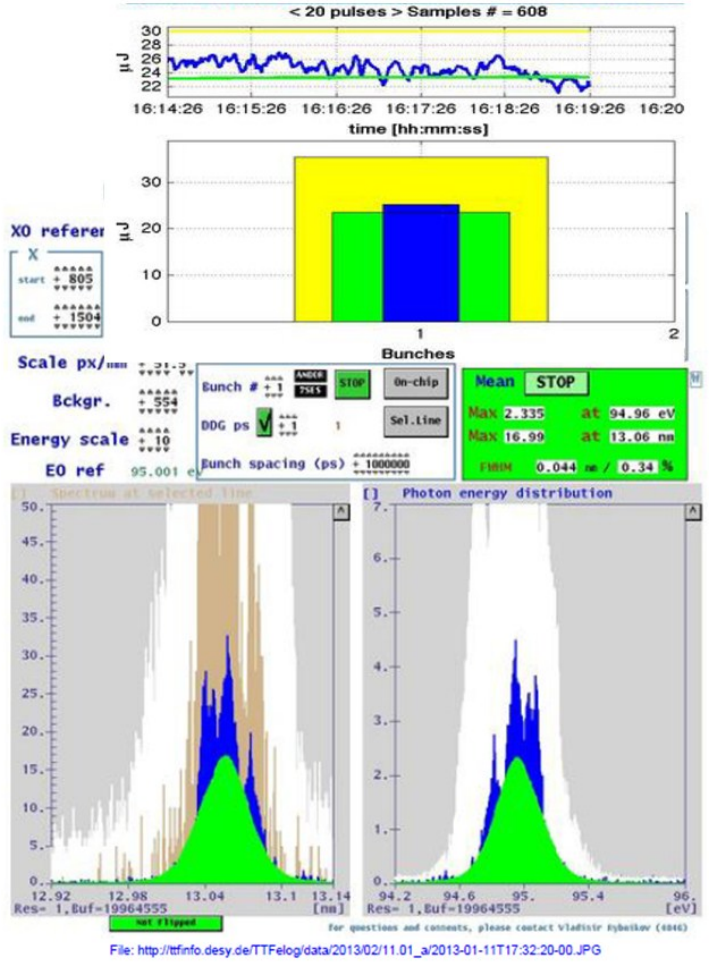






Supported by BMBF under contract
05K10GU2 & FS FLASH 301

- 25 uJ (GMD-T, 10/10 mm) at 13 nm, bunch charge 80 pC
  PG-measurement: Narrow bandwidth
  (0.34 % in linear regime, 0.42% at saturation)



Tuning Issues

- Longitudinal bunch shape changes with pulse train length, but LOLA can take only one bunch
  - Under study/development: UV Pockels cell
- Uncertainty in absolute rf phases
  - Beam Arrival-time Monitors help
- rf drifts
  - LLRF hardware and software upgrades improved situation significantly
- Instrumentation specified and designed for the original design charge of 1 nC

Peak Current for Short Pulses (Gaussian like)

Charge [pC]	Peak Current [kA] E-Bunch <100 fs FWHM	Peak Current [kA] E-Bunch <50 fs FWHM
1000	8.4	16.8
500	4.2	8.4
250	2.1	4.2
100	0.8	1.6

From S2E: At short bunches, peak currents of 2 kA already increase slice emittance.

From SASE Simulations: Peak currents of 1.5 - 2 kA needed for saturation (at least for the shorter wave lengths)

In the charge regime below 250 pC, SASE intensity and very short bunch length should go together