

XFEL; FLASH

What's going on?

Report on XFEL Diagnostic Activities at FLASH

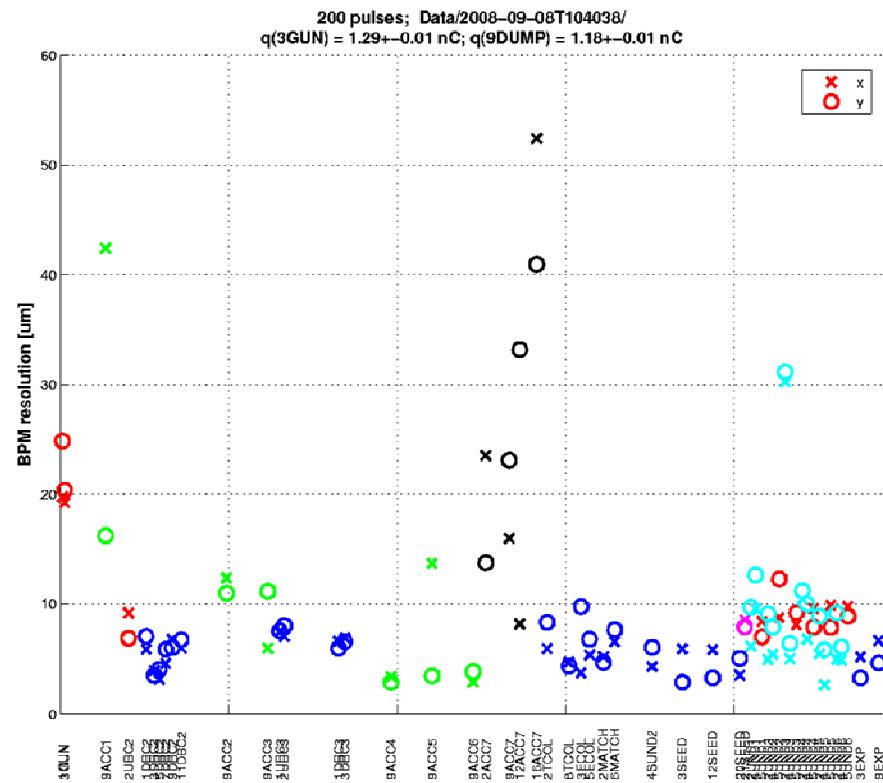
FLASH Seminar 11.11.08

**Many People's work presented by D.Nölle,
MDI, 9-2579**

Topics

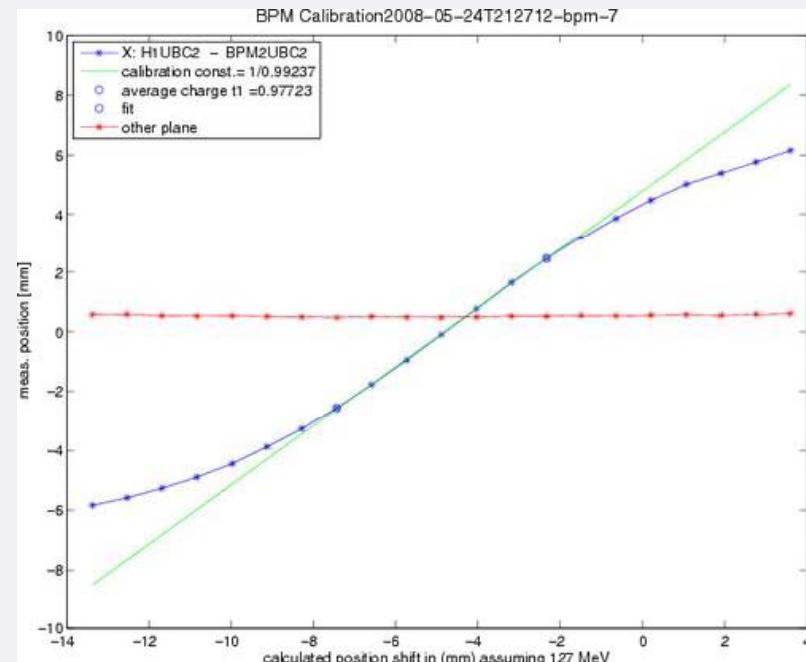
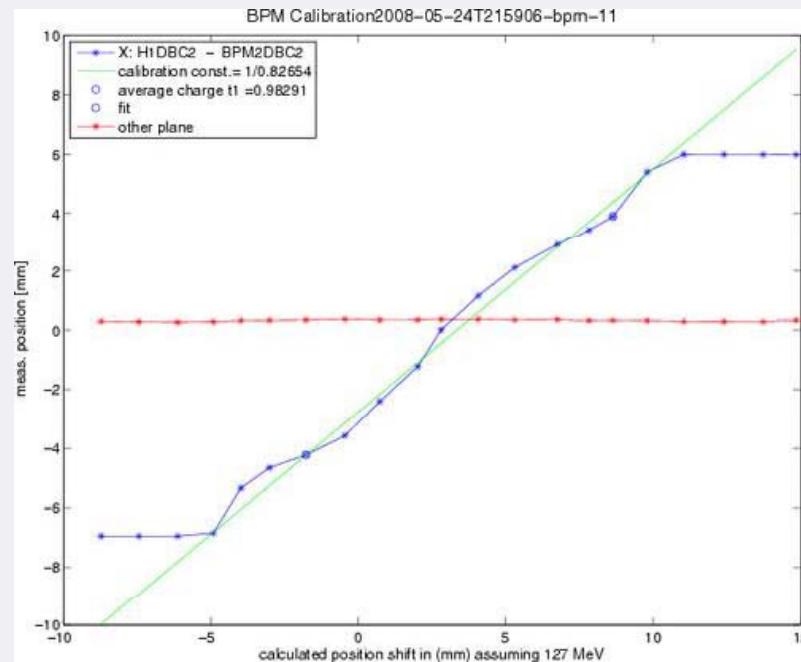
- **FLASH BPMs**
 - Revision of the Stripline BPM Electronics
 - Self Triggering for the Undulator BPMs
 - Recent Requirements: 0.1 nC Operation
- **FLASH Feedback**
 - Topology
 - Recent Results
- **XFEL**
 - Cavity BPM Program
 - Electronics Development
 - BPMs for the cold Modules
 - Feedback work
- **Dark Current Monitors**
 - Idea
 - Test in Zeuthen
- **Beam Loss Monitoring**
 - XFEL Tests
 - Dump Loss Monitoring

FLASH BPMs Status



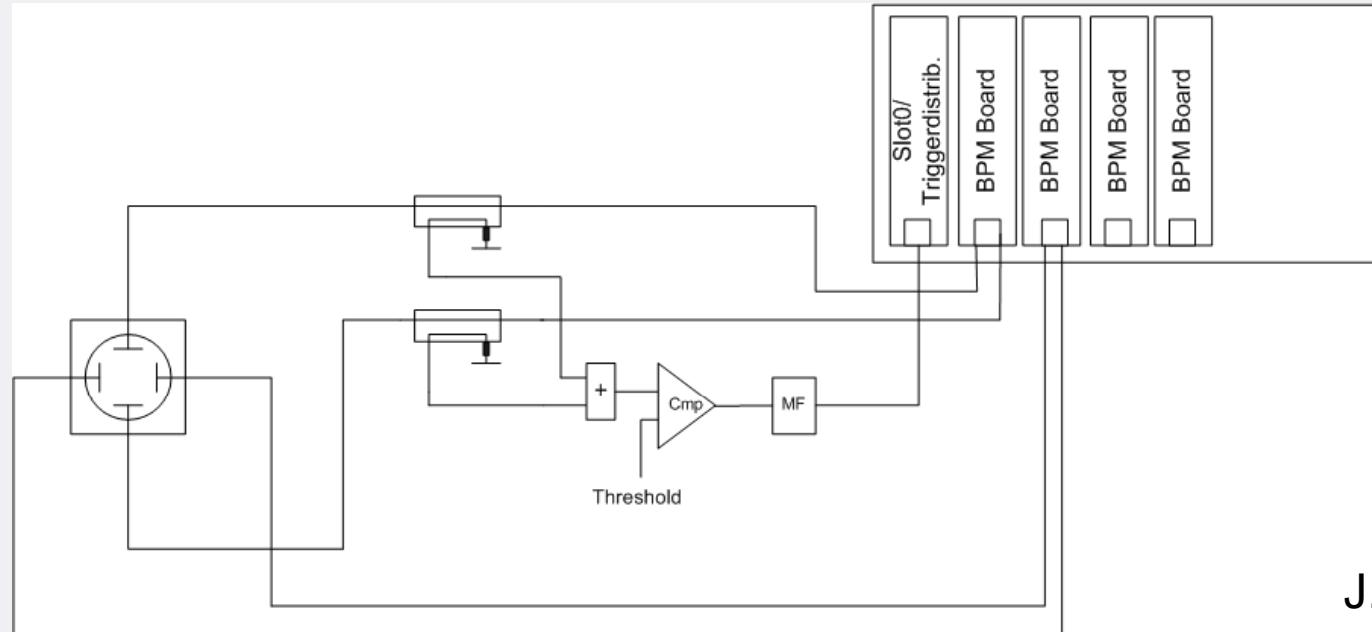
- Red: buttons:**
 - 34 mm, 20-30 μm Resolution, sensitive to timing
 - 10 mm, 10-15 μm Resolution, sensitive to timing
- Blue: Striplines**
 - 34/44 mm, Resolution below 10 μm
- Green: Cold BPMs Acc1 Reentrant, ACC2-6 Cavity BPMs (4-6 with a problem, that day)**
- Black: ACC7 BPMs with Frascati Electronics or HERA Electronics**
- Magenta: Undulator BPM with HERA Electronics (only 10 bunches)**
- Cyan: BPMs in the undulators**

Flash BPMs: Revision of the FLASH Striplines



- Exchange of Stripline Electronics by a revised version
- Improvements by Wolfgang Riesch (Zeuthen): „Riesch Electronics“
- Better linearity, less variation between the boards („standard“ Polyparameter)
- Similar resolution within the specs
- Exchange completed
- Required work with beam: Check calibrations and offsets

FLASH BPMs: Self Trigger



J. Lund-Nielsen

Upgrade: Add Self Triggering to Undulator BPMs

- FLASH Buttons are very sensitive to trigger/timing Jitter and Shifts ($O(1\text{ns})$)
- Idea: Use the beam to trigger the sample and hold
- Take a little portion of the signal of one BPM and trigger the entire crate
- Development almost ready (Remote Control of the Trigger Threshold)
- Need Beamtime to setup delay and test the system

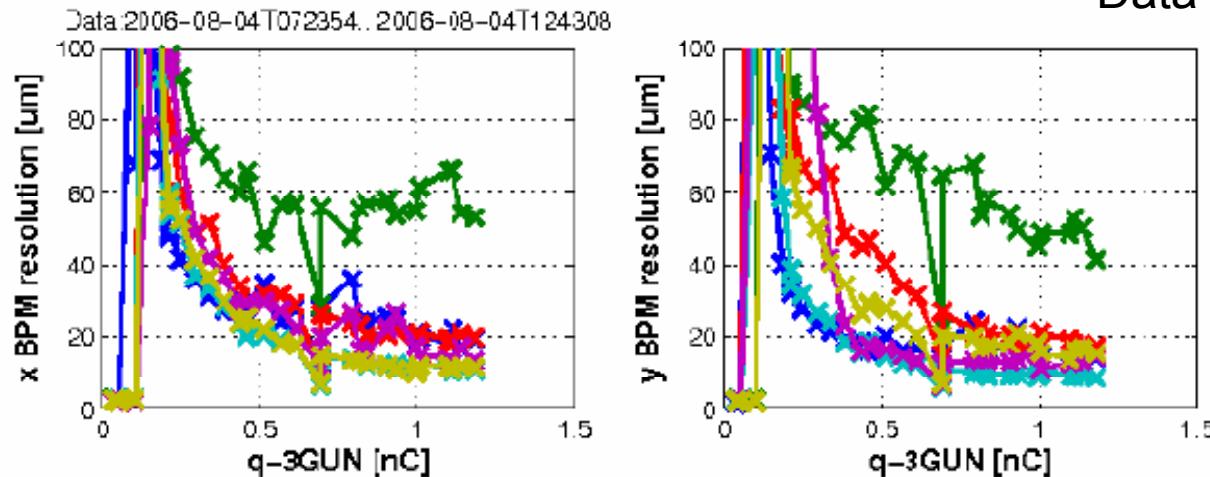
FLASH: 0.1 nC Operation

- Trend in FELs: Reduce Space Charge Effects by Low Charge Operation
- Signal from the BPMs gets smaller (Noise stays constant)
- Types with good Signal/Noise Ratio have advantages
- Problem with FLASH:
 - Button BPMs in the Undulator (Stripline OK)
 - Potential of Amplification almost exhausted
 - Averaging might bring some improvement (within a train)
 - Flash II should be equipped with Cavities

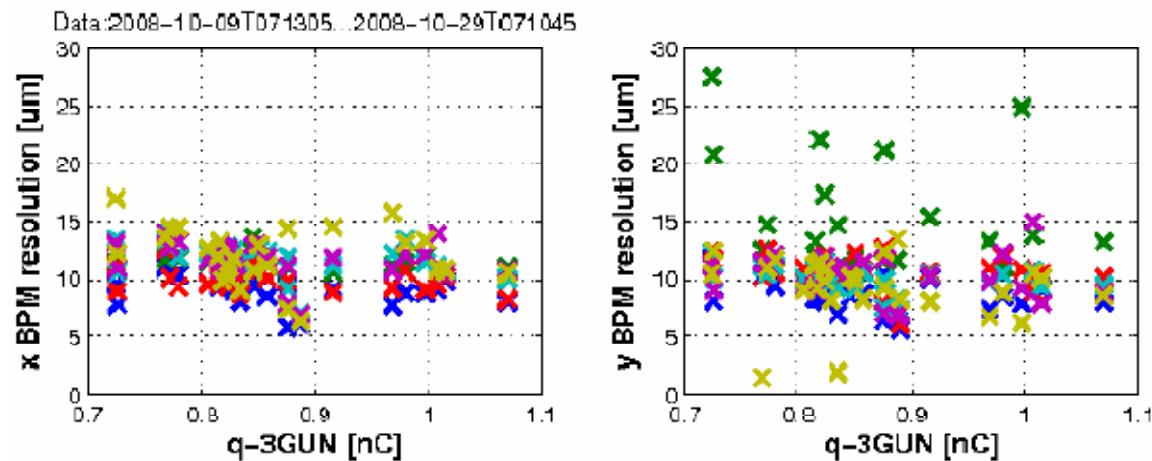
http://www.desy.de/~nicoleta/Links/FLASH_BPMs/2008.10.30_BPMmeeting_StatusResolution.pdf

BPM Resolution vs. Charge

Data by N.Baboi



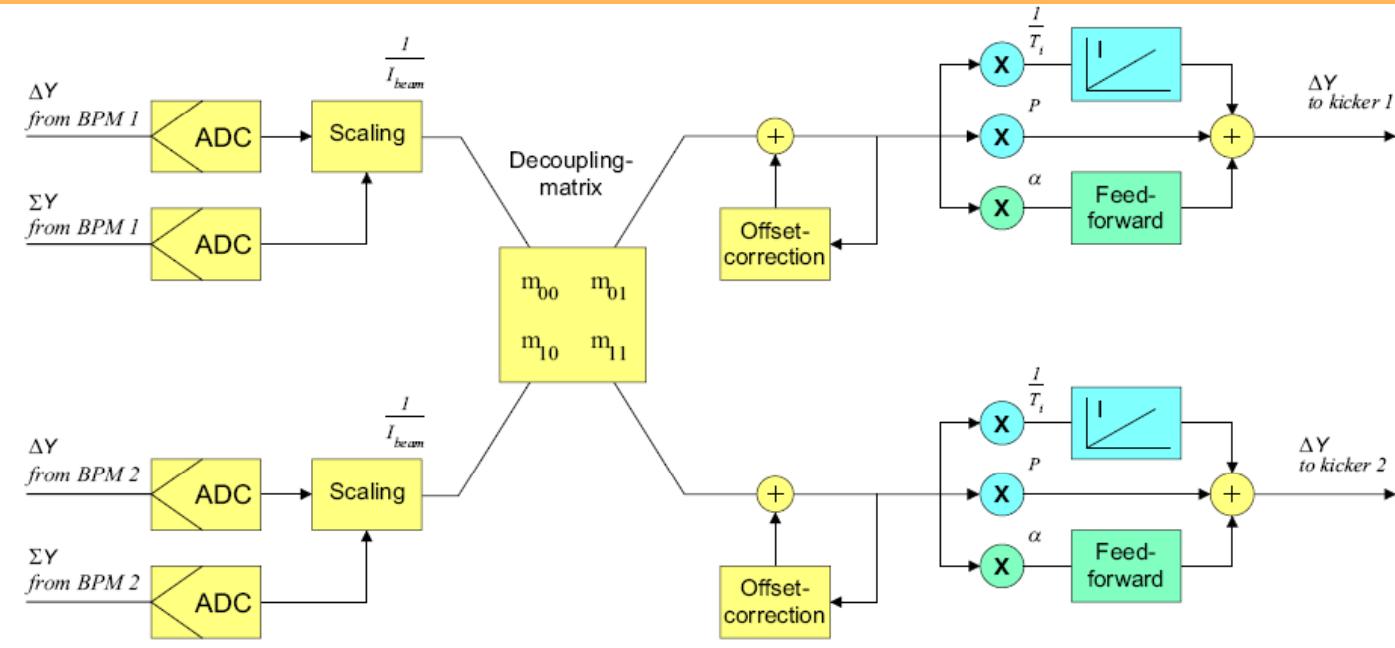
Old Data



Recent

Need to redo Res. vs. Charge Measurement, to see effect of improvement program and to check remaining options.

FLASH: Intra Bunchtrain Feedback

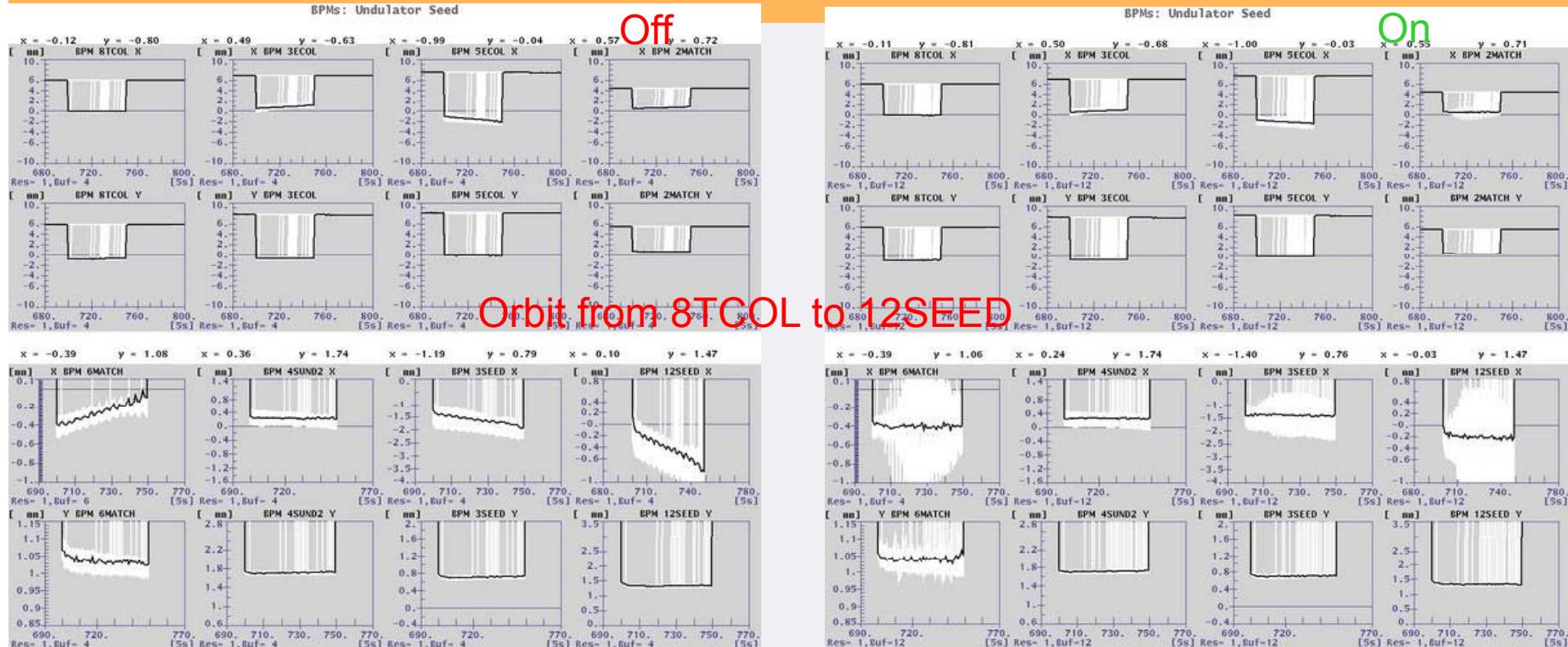


Scheme of the Intra Bunchtrain Feedback (IBFB)

- Use two downstream BPMs for correction
- Low Latency, suited for 1 MHz Operation
 - Standard Stripline Electronics with a fast Output Channel
 - Short Cables
 - Installation inside the Tunnel

J. Kluthe,
H.T. Duhme

FLASH: Intra Bunchtrain Feedback

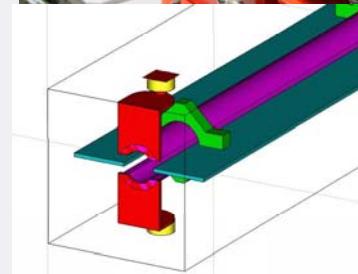


- Run at 552 MeV, 20 nm
- SASE @ 4 μ J, 50 bunches
- clear effect on orbit visible
- but no significant impact on SASE
- Need more experience with long bunch operation

FLASH: Intra Bunchtrain Feedback

Recent Steps:

- Test of a new Feedback kicker, designed by PSI
- 2 in Flash, work fine
- about 30% increase in kick strength



Drawing: M. Dehler

Status:

- System operational in expert mode
- Need to do control system integration
- should be tested more often
- S-FLASH: Shift of kickers and BPM implies modifications

XFEL BPMs @ FLASH

Due to the „same“ properties FLASH is an ideal test bed for XFEL BPM Hardware. (Problems: Space, Limited Vacuum Access, Users)

Therefore, we have several Prototype Projects:

- **BPMs for the Modules:**
 - Cold Button (DESY)
 - Reentrant Cavity BPM (Saclay)
- **High Precision BPMs**
 - Cavity BPMs
 - Resonant stripline BPMs
- **BPM Electronics**
 - Button BPM and Cavity BPM (to come)

XFEL BPM Specs

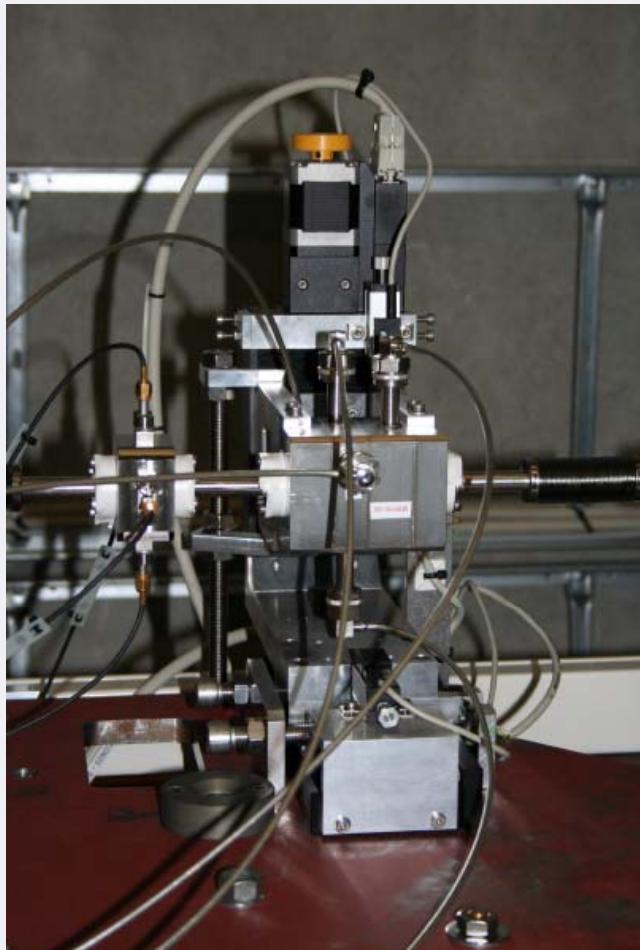
BPM Type	#	D	L	Type	SBR Res	Drift / Train	Drift over 1 hour	Drift over 1 week	Max. resolution range	Reasonable signal range	Linearity	x/y crossstalk	Charge dependence (Δx for $\Delta I = 0.1$)	Bunch to bunch crosstalk	Transverse alignment tol. (RMS)
		mm	c m		μm	μm	μm	μm	mm	mm	%	%	μm	μm	μm
Standard	3	40.5	4	Button	100	10	10	100	± 3.0	± 10	5	1	100	10	200
Standard	219	40.5	20	Button	50	1	5	50	± 3.0	± 10	5	1	50	5	200
Standard	6	100.0	20	Button	100	10	10	100	± 5.0	± 20	10	1	100	10	200
Cold	104	78.0	17	Button/ Re-entrant	50	1	5	50	± 3.0	± 10	10	1	50	5	300
Precision	12	40.5	20	Cavity	10	1	1	10	± 1.0	± 2	2	1	10	1	200
Precision	117	10.0	10	Cavity	1	0.1	0.1	1	± 0.5	± 2	2	1	1	0.1	50

Cavity BPM Program for XFEL

Single Bunch Resolution of 1 µm in the undulator and at some places

- **Only Cavity BPMs will do the job**
- **Need to Versions**
 - 10 mm for the Undulator Intersections
 - 40.5 mm for some special places (e.g. Feedback)
- **Not a Single Bunch Machine, but 200 ns Bunch Spacing**
 - Limitation in Q
- **Don't start from Zero!!**
 - Found the design by T. Shintake as our baseline
- **First Prototype 4.4 GHz installed in Flash since 1/07**
 - Good agreement between Theory (CST) and Measurement
 - Discrepancies understood
- **Second Prototype Series 3.3 GHz**
 - Currently in the Workshop

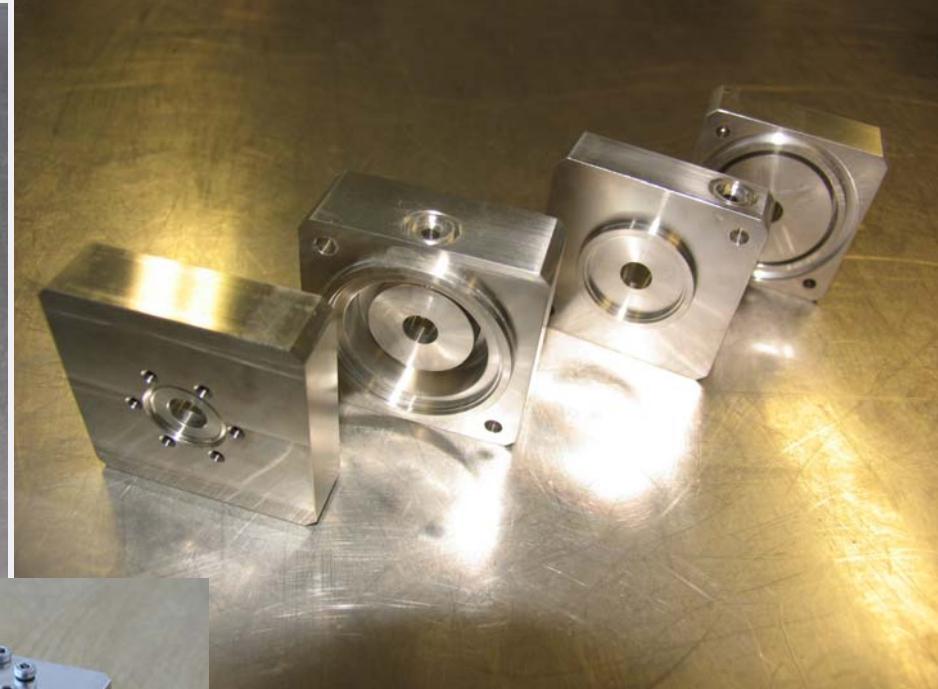
Cavity BPMs: Current Installation



Existing Test Facility before the undulator:

- **Currently:**
 - **4.4 GHz Cavity BPM**
 - **Diagnostic Cross Type Button**
- **Change in Winter**
 - **4.4 GHz C-BPM -> 3.3 GHz C-BPM**
 - **Try enlarged buttons for Diag Cross BPM**
- **Cable to Cryo-Annex**
- **Replacement in September Shutdown by Teststand between Undulator and FIR Undulator**

Photos of Cavity BPM before assembly

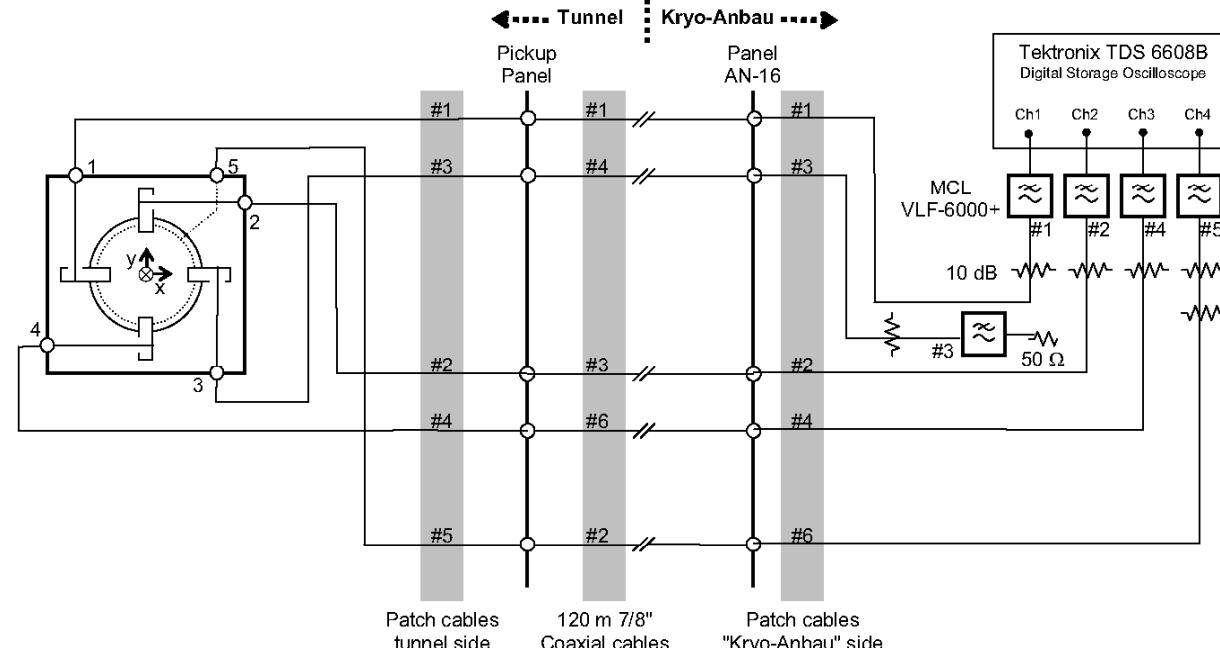


Dipole and Reference resonator with 4.4 GHz resonance of TM_{11} and TM_{01} respectively



Produced 3 Cavity BPM:
BPM I
BPM II
BPM III
D. Lipka, M. Siemens, S. Vilcins

Setup: Cables from the Undulator to Cryo Anbau



Reference resonator signal always on channel 4
 Free port terminated with 50 Ohm load
 Data taking of same bunch with Toroid and Button BPM
 Cable Length about 120 m

Fit function

To increase oscilloscope resolution for amplitude a fit is applied to the time signal, in addition resonance frequency and loaded quality factor is observed:

$$U(t) = U_{out} e^{-\frac{t-t_s}{\tau}} \cos(\omega_R t + \phi) \Theta(t_{trigger} + t_s)$$

$$\omega_R = 2\pi f_R$$

f_R resonance frequency

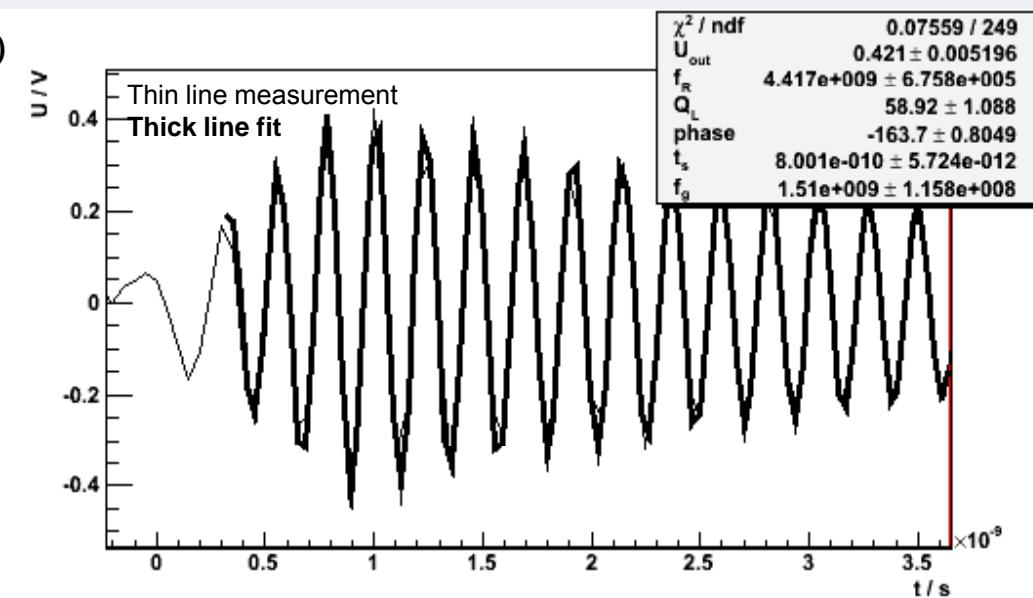
$$\tau = \frac{Q_L}{\pi f_s}, \text{ decay time}$$

Q_L loaded quality factor

$U_{out} \propto$ beam offset

ϕ phase offset

t_s end of transient oscillation

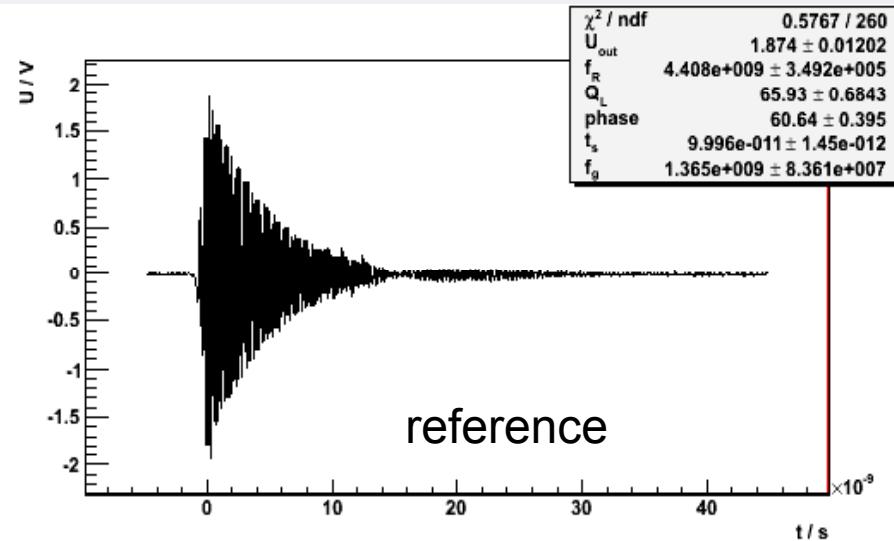
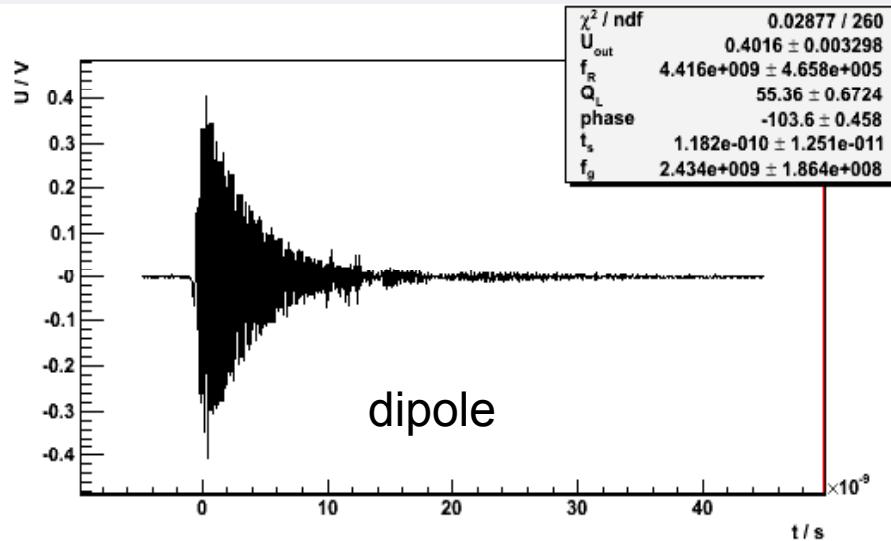


For time between $t_{trigger}$ and t_s
(transient oscillation):

$$U(t) = U_{out} e^{(t-t_s)f_g} \cos(\omega_R t + \phi)$$

f_g gradient frequency

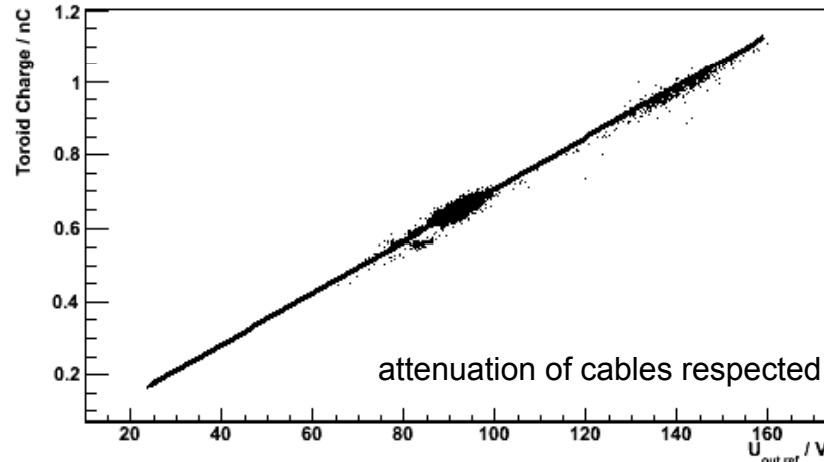
Fit maximum range



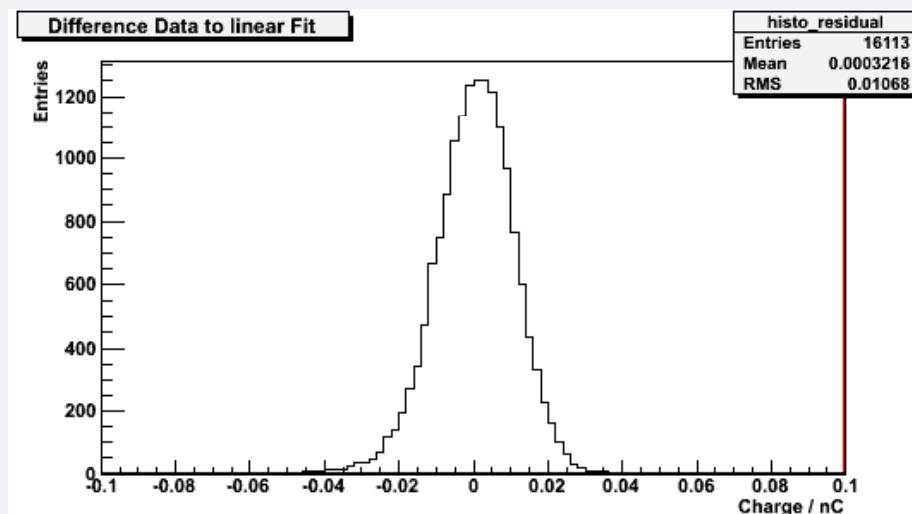
- $t = 14$ ns shows an additional oscillation: reflection between patch cable in tunnel (1.5 m long connected on BPM) and 7/8" coaxial cable
- therefore time of fit limited to $t_{\text{max}} = 13$ ns

Reference Resonator vs. Toroid

Beam charge change with Toroid compared to amplitude of Reference Resonator



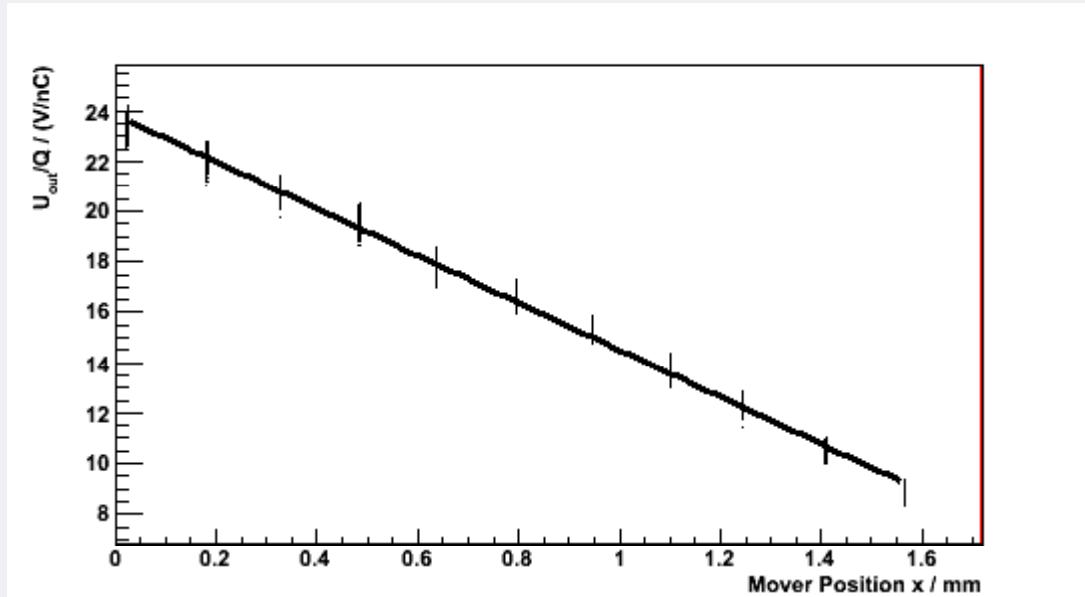
Statement: linear with $(141.6 \pm 1.7) \text{ V/nC}$



Difference between Linearity and Data:
11 pC (RMS),
Resolution of Toroid 5 – 10 pC
Resolution of Oscilloscope about 3 pC

Sensitivity

Charge calibrated Voltage vs. Mover Position

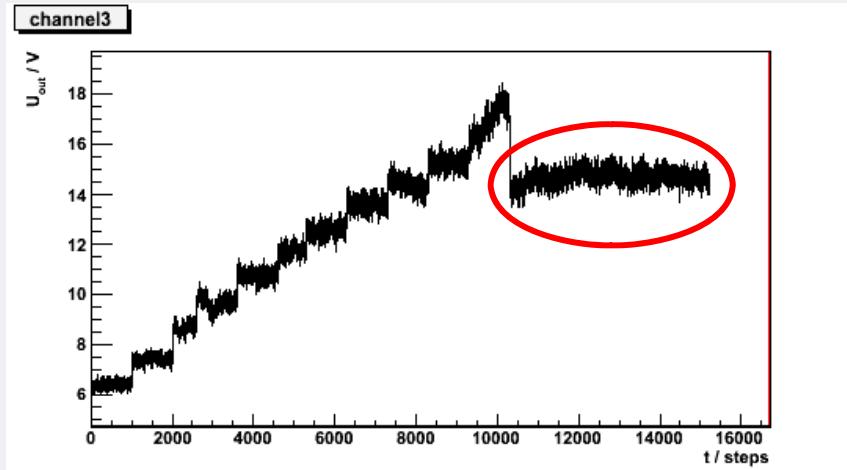


Measured Slope corresponds to Sensitivity of (9.737 ± 0.014) V/(mm nC)

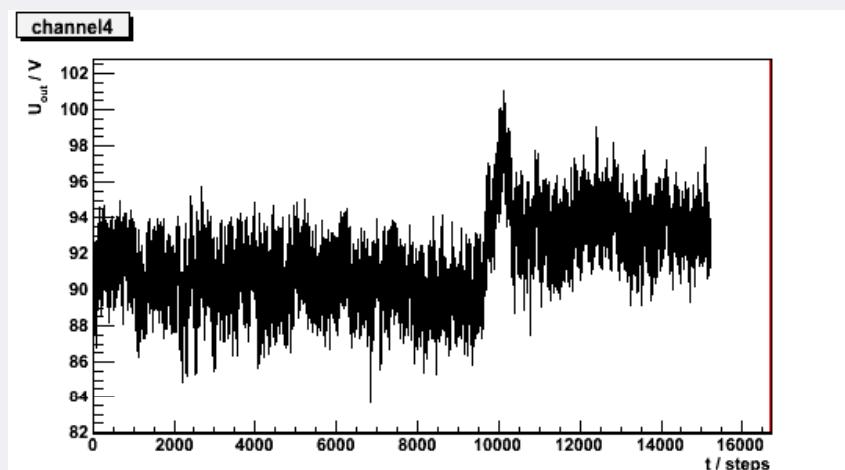
Simulated Sensitivity 9.8 V/(mm nC)

Dipole Resonator Voltage during FLASH-shift

Dipole Resonator



For comparison: Reference Resonator



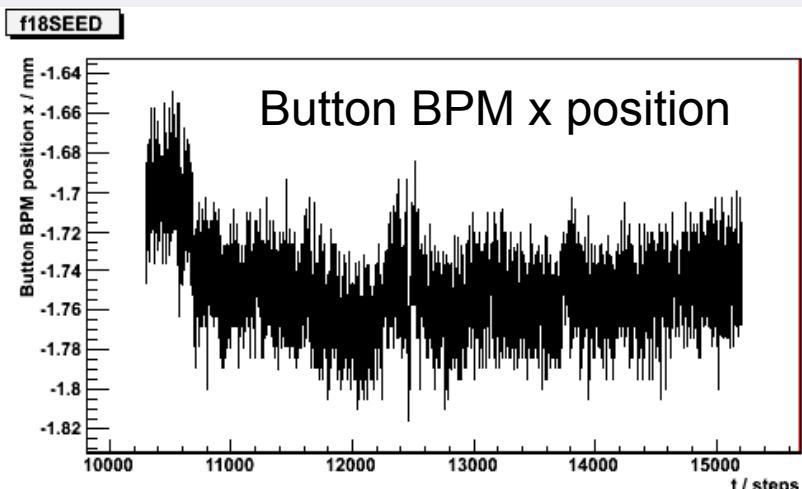
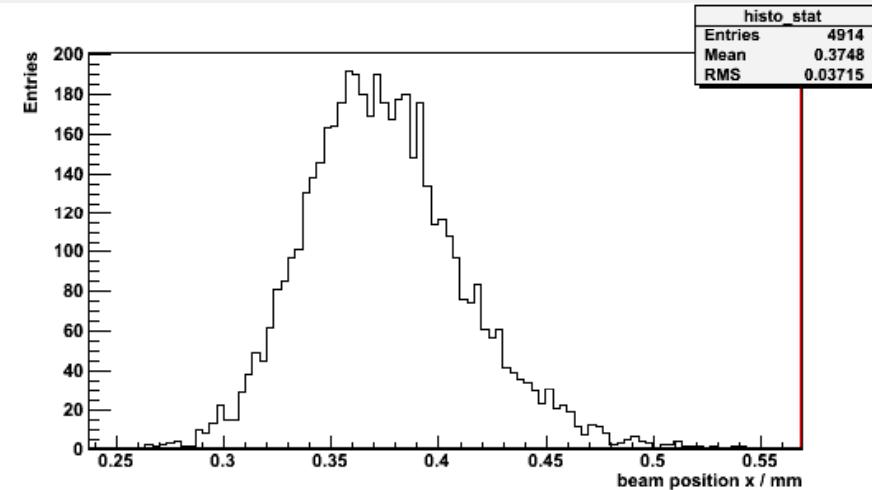
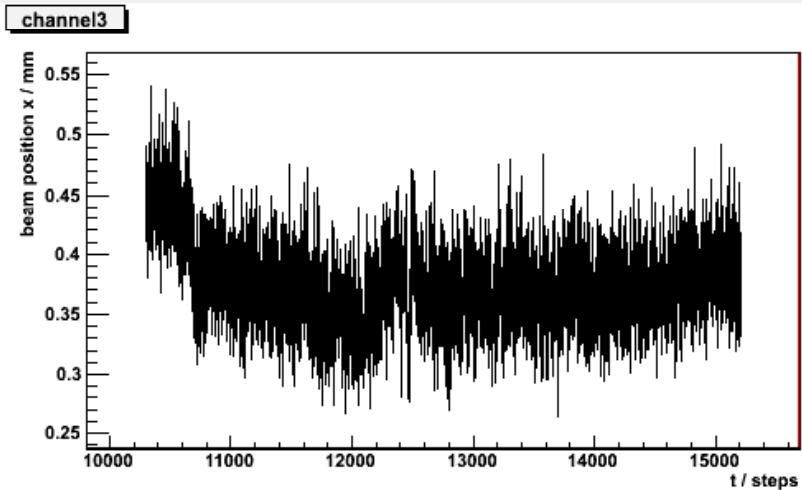
Mover Position changed in x; Mover Position y fixed at minimum amplitude for y
 First part (up to 10297 time steps) will be normalized with reference voltage (including charge normalization) and get a calibration of position → sensitivity

Other data to calculate position

Take last part of data set with

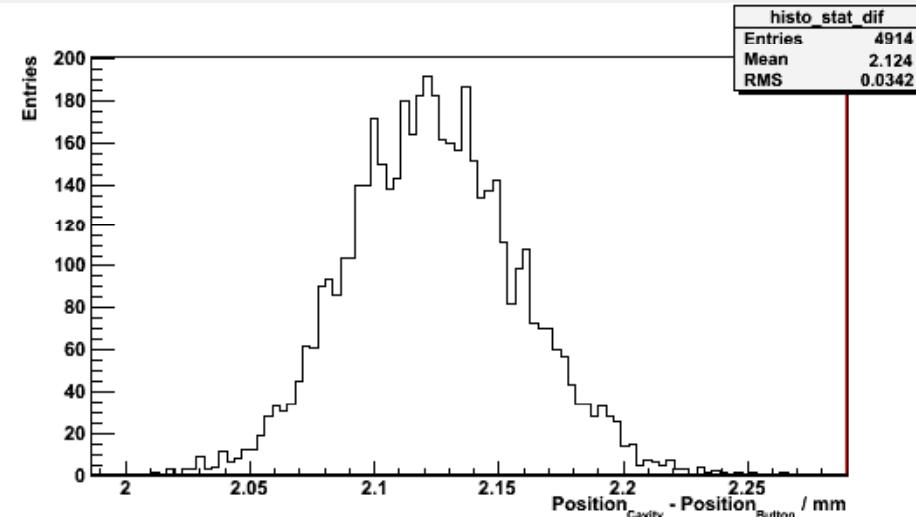
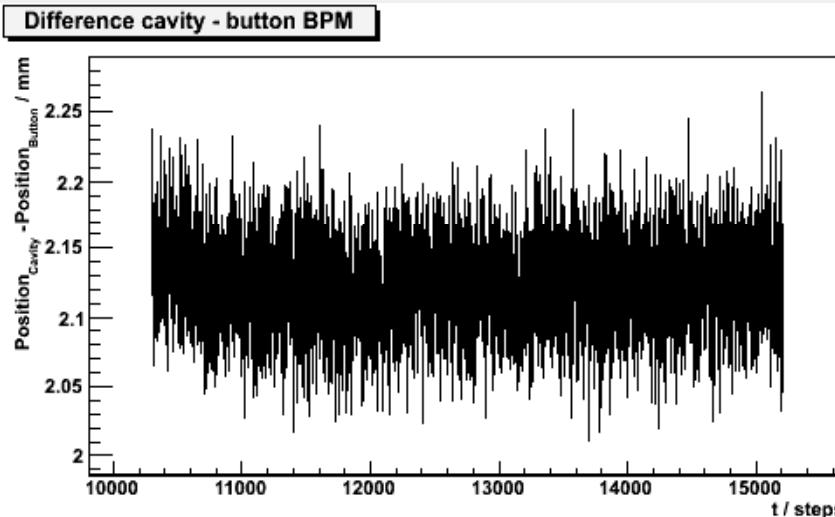
1. Reference resonator calibration = (141.6 ± 1.7) V/nC
2. Dipole resonator calibration = (9.737 ± 0.014) V/(mm nC) and calculate position

Beam Position in x from Cavity BPM



BPM at fixed position,
only drift between Cavity and Button
Measured beam position is changing
RMS of beam position is 37 μ m
Clear correlation between cavity and
button BPM

Difference Cavity and Button BPM



Difference should remove beam movement and jitter.

RMS of position decreased to $34 \mu\text{m} = \sqrt{(\text{Resolution(cavity)}^2 + \text{Resolution(button)}^2)}$

Resolution of Cavity BPM System

Setup includes thermal noise of cavity BPM, influence of monopole mode of cavity (shift with charge), influence of beam angle jitter, resolution of oscilloscope (improved with fit) and mover resolution

But:

Cavity BPM System consist of

1. Cavity BPM
2. RF front end (remove influence of monopole and beam angle)
3. Digitalization

All of these components will contribute to the system resolution. Up to now only point 1 is realized.

Frequency and loaded quality factors

Dipole resonator:
(time domain)

$$f_R = 4416 \pm 0.8 \text{ MHz}$$

$$Q_L = 59.1 \pm 1.4$$

NWA Measurement:

$$4414.5 \pm 0.6 \text{ MHz}$$

$$60.6 \pm 1.3$$

Expected:

$$4400 \pm 17$$

$$60$$

Reference resonator:

$$f_R = 4408 \pm 0.3 \text{ MHz}$$

$$Q_L = 67.1 \pm 0.8$$

$$4411.5 \pm 0.1$$

$$62.46 \pm 0.32$$

$$4400 \pm 16$$

$$62$$

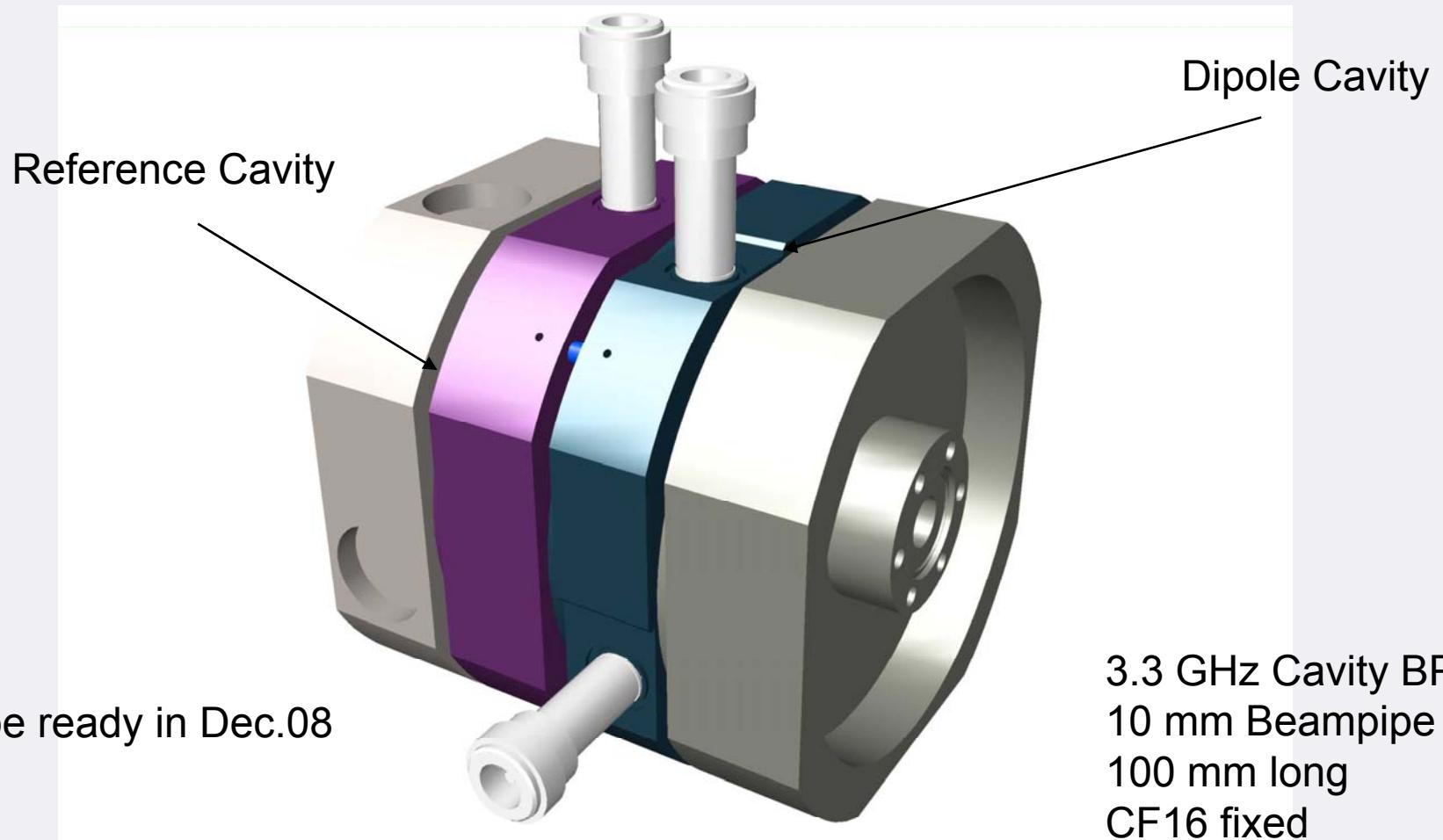
Design of the Cavity BPM is understood

Need to change Frequency to 3.3 GHz

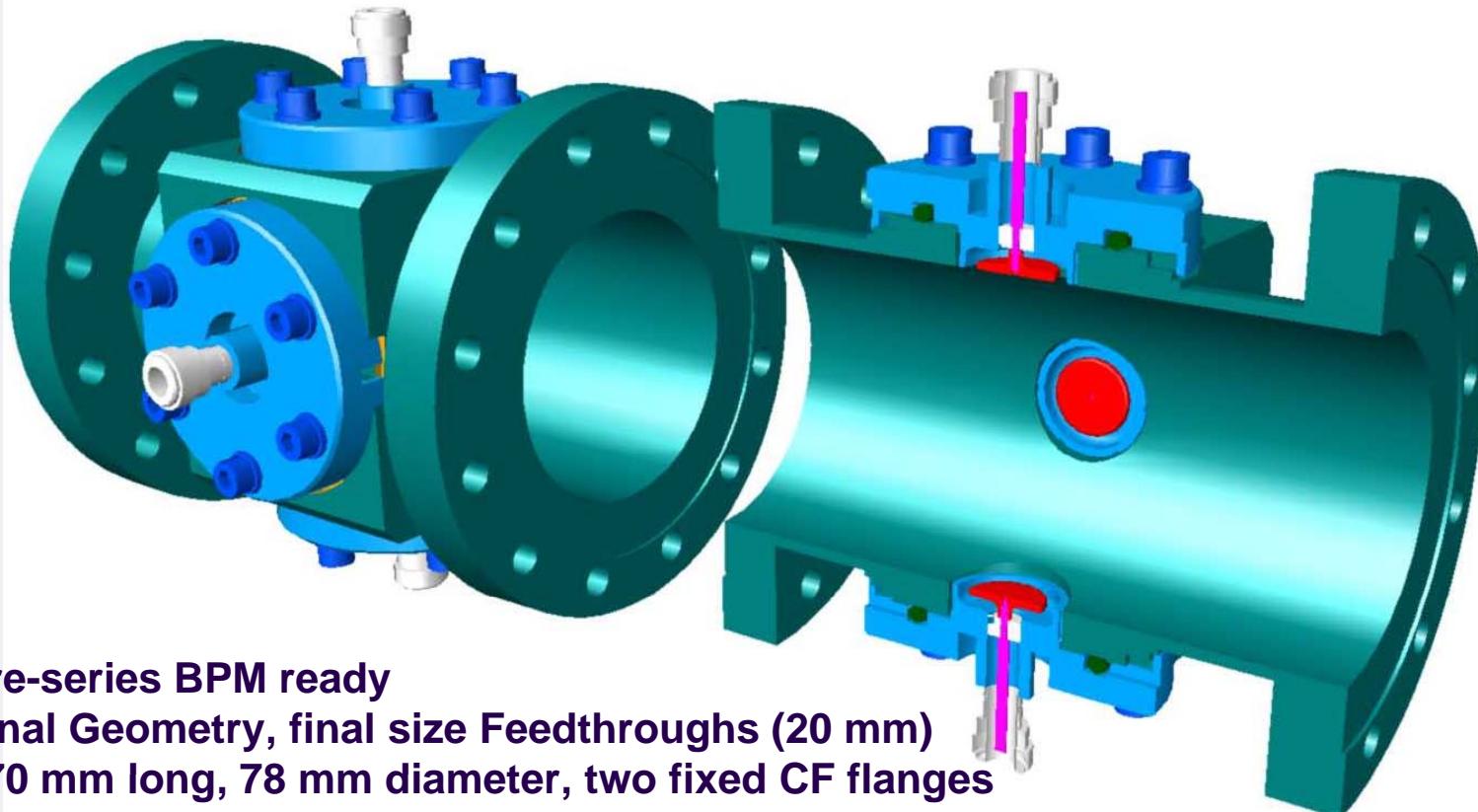
(same operation frequency for 10 mm and 40.5 mm beam pipe)

Next Step: 3.3 GHz Prototype for 10 mm Beam Pipe

3.3 GHz Prototype

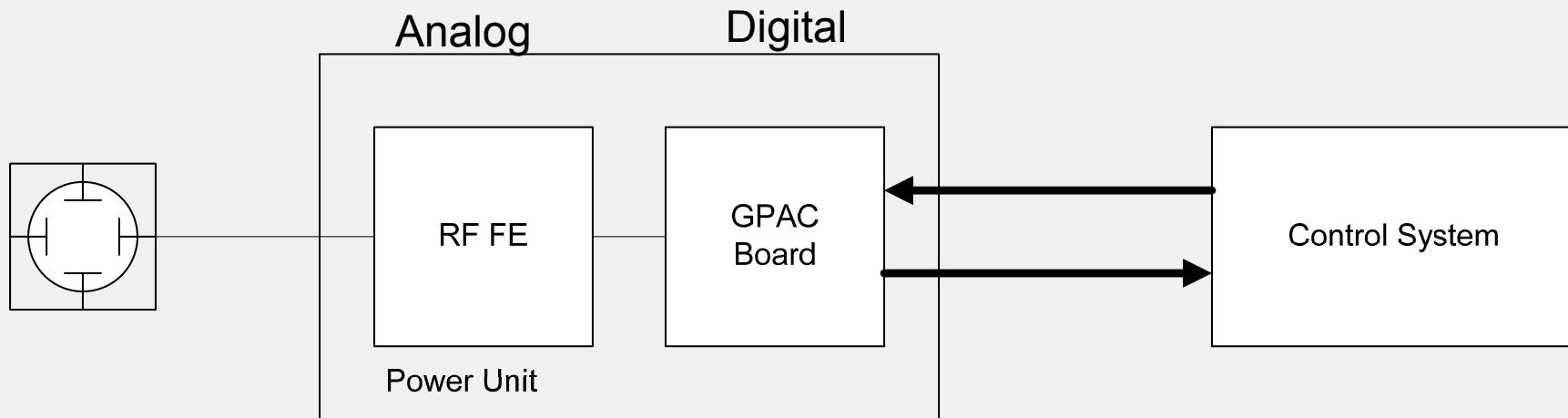


XFEL Cold BPM Prototype



- Pre-series BPM ready
- Final Geometry, final size Feedthroughs (20 mm)
- 170 mm long, 78 mm diameter, two fixed CF flanges
(Cavity flanges for cold versions)
- Test item for XFEL electronics
- Request for Shutdown planning: Keep Button and Reentrant Prototypes in ACC7 somewhere, where a 78 mm beam pipe is acceptable

XFEL BPM Electronics System Layout

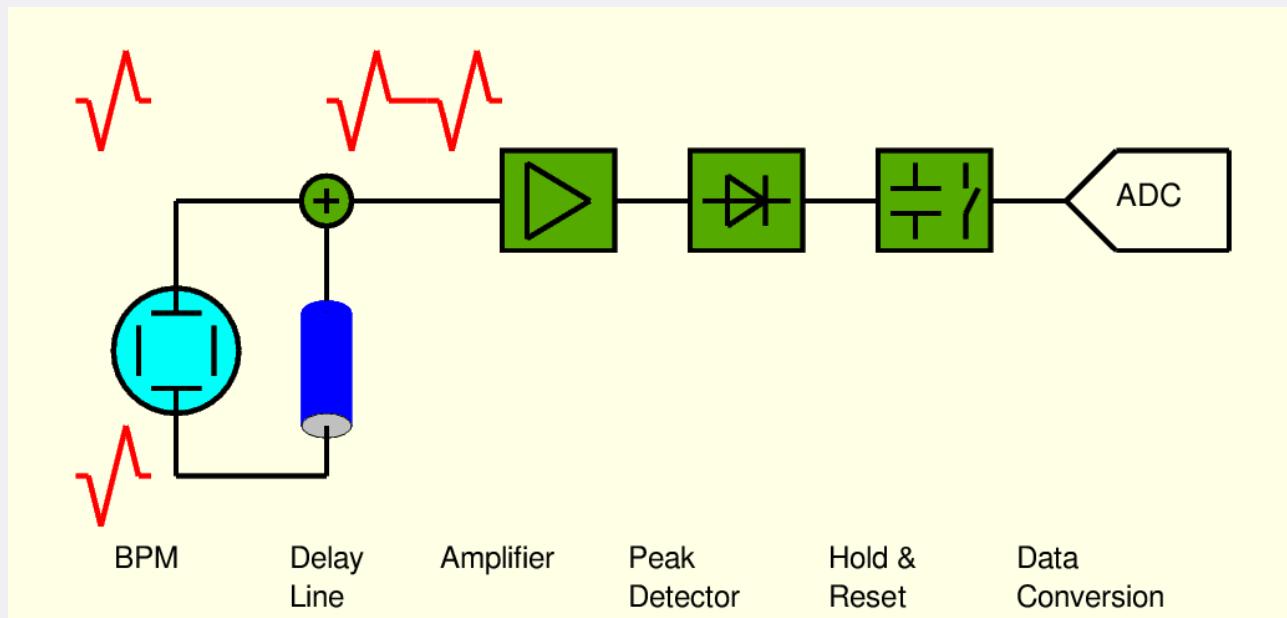


BPMs: Buttons; Reentrant; Cavity

Power Unit:

- **BPM Specific RF Front Ends (DESY, PSI, CEA)**
- **Common Digital Backend (GPAC from PSI)**
- **Common Interfaces to the Outside (Controls, Timing)**

XFEL BPM Electronics (Button)



- Design of the Button Electronics based on the successful HERA Scheme
- Signals will be added to single cable and processed by a single electronics channel
- Simple Peak Detection and Position Calculation by Difference/Sum
- Provides Charge Reading
- First Prototype ready, even with digital interface (RS232)
- Can be easily adapted to any digital backend.

Resolution: Button/Reentrant Dynamic Range (Charge) Data from 07

about 16 μm
with current prototype electronics

1.3 Resolutionmessung

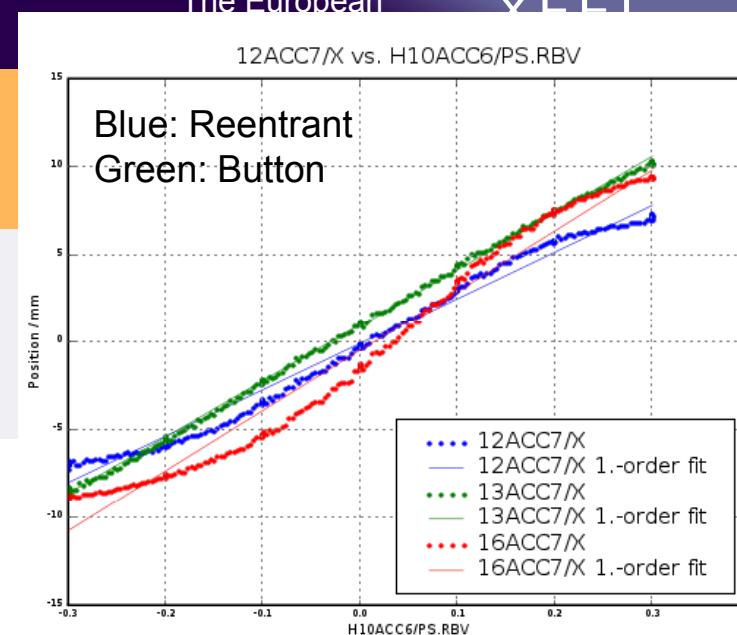
Alle Resolutions und Noises in RMS

Charge Attenuator	nC	dB	Resolution	Resolution	Resolution	Noise	Noise	Noise	Noise
			13ACC7	12ACC7	16ACC7	13ACC7X/13ACC7Y	12ACC7X/13ACC7X	13ACC7X/13ACC7Y	16ACC7X/13ACC7X
.			13ACC7	12ACC7	16ACC7	13ACC7X/13ACC7Y	12ACC7X/13ACC7X	13ACC7X/13ACC7Y	16ACC7X/13ACC7X
-			um	um	um	um	um	um	um
1.1	2		29.2	5.6	48.1	-	-	-	2007-01-11T200808
0.5	5		24.6	11.8	73.6	-	24	-	2007-01-11T201246
0.4	4		24.6	16.0	81.7	37	36	-	2007-01-11T201609
0.3	0		23.0	23.1	88.1	37	37	-	2007-01-11T201940
0.2	0		30.7	30.1	109	35	36	-	2007-01-11T202206

Button Prototype

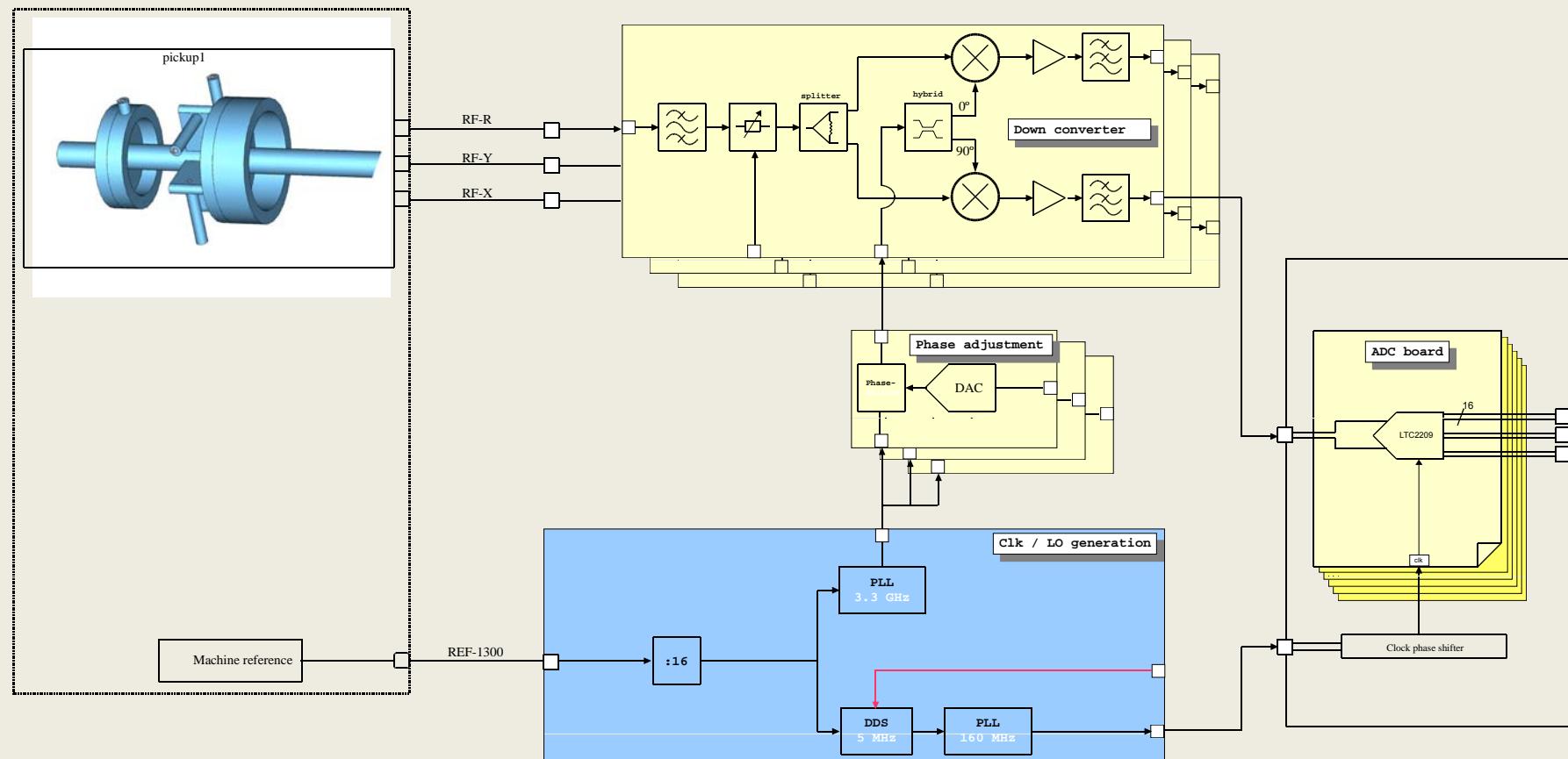
Reentrant (CEA)

Flash Stripline
(TTF 1 Electronics)



New measurements planned
next study period

RF Front-End Concept



XFEL BPM Tests @ FLASH

Upcoming Hardware Installations:

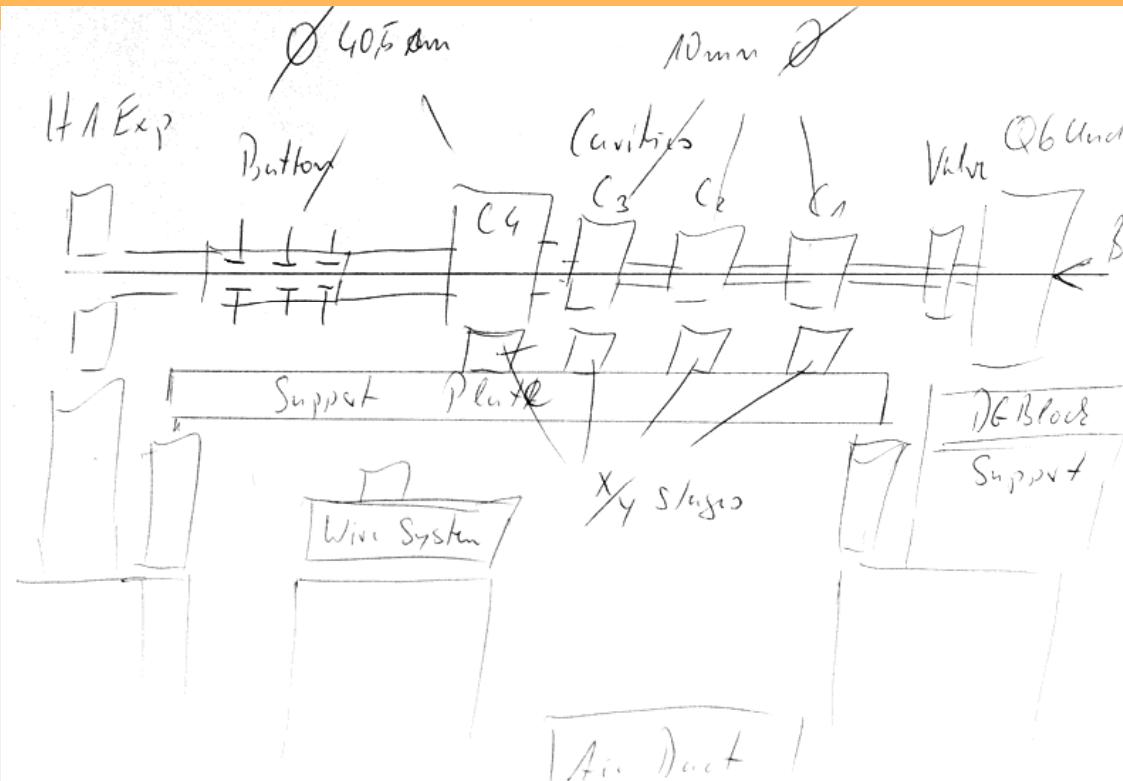
- Winter Maintenance (work on existing test area):
 - Replace Cavity BPM Prototype with final XFEL Frequency 3.3 GHz
 - Replace Button BPM (Undulator Cross type) by a version with enlarged button surface (eventually)
- Big September Shutdown 2009:
 - New test area between FEL and FIR Undulator
 - XFEL Cold BPM Prototypes in ACC7
 - Feedback BPMs for Intra Bunch Train Feedback (eventually, upcoming last week)

September Shutdown 2009: New BPM Test Facility

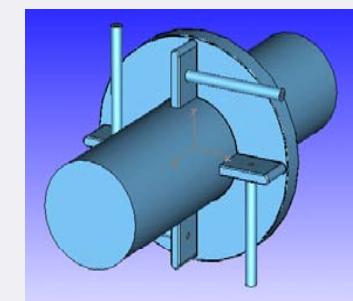
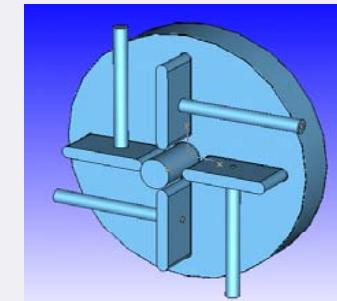
Why should it be between FEL and FIR Undulator:

- **Space of about 1 m,**
 - without impact on Beam optics
 - close to undulator, similar properties (beam size)
 - enough for cavity BPMs and Buttons
- **Only place for 10 mm vacuum chamber with movable BPMs**
 - without any risk for undulator
 - not in competition to S-Flash, LOLA or an undulator Upgrade
 - can stay for a while
- **Jump to higher vacuum cross section not critical**
 - Can integrate 40.5 mm Cavity BPM type to the set
- **Rather short cabling required (to build 49)**
 - But need some infrastructure there (timing signals, master frequencies)

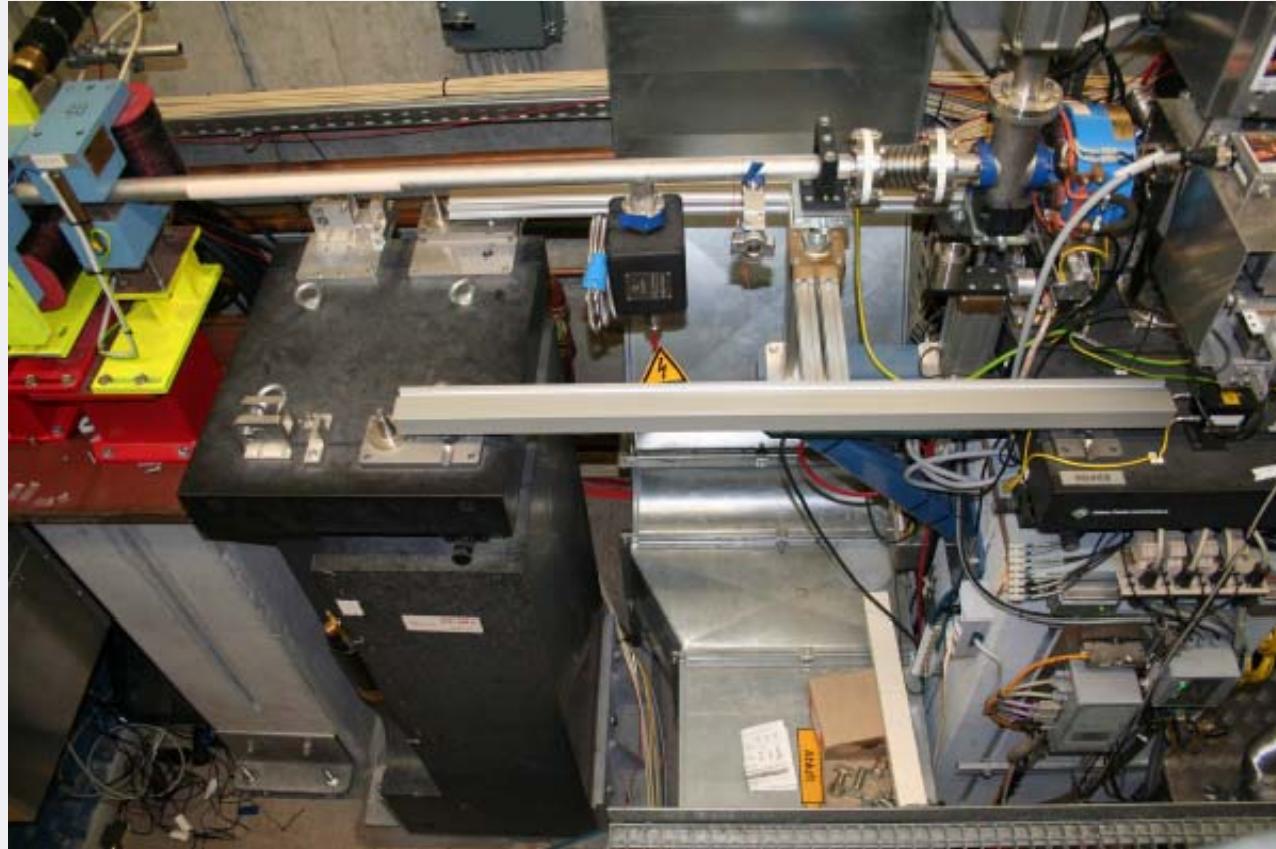
September Shutdown: New BPM Test Facility



- 3 10 mm BP 3.3 GHz Cavity BPMs in a row (drift) assembled on xy-stages
- 1 40.5 mm BP 3.3 GHz Cavity BPM on a xy-stage
- 1 40.5 mm BP 3 x Button BPM fixed
- This scheme enables resolution independent measurements



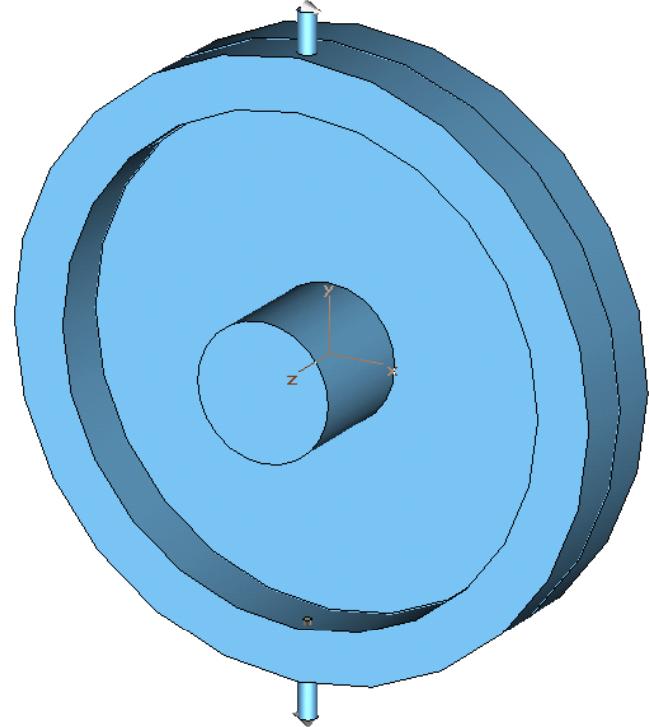
September Shutdown: New BPM Test Facility



Replace Beamline between FEL and FIR Undulator by a BPM Test Facility

Dark Current Monitor, Test @ PITZ

Modified Shintake BPM Reference Cavity for Dark Current Monitor (DCM)

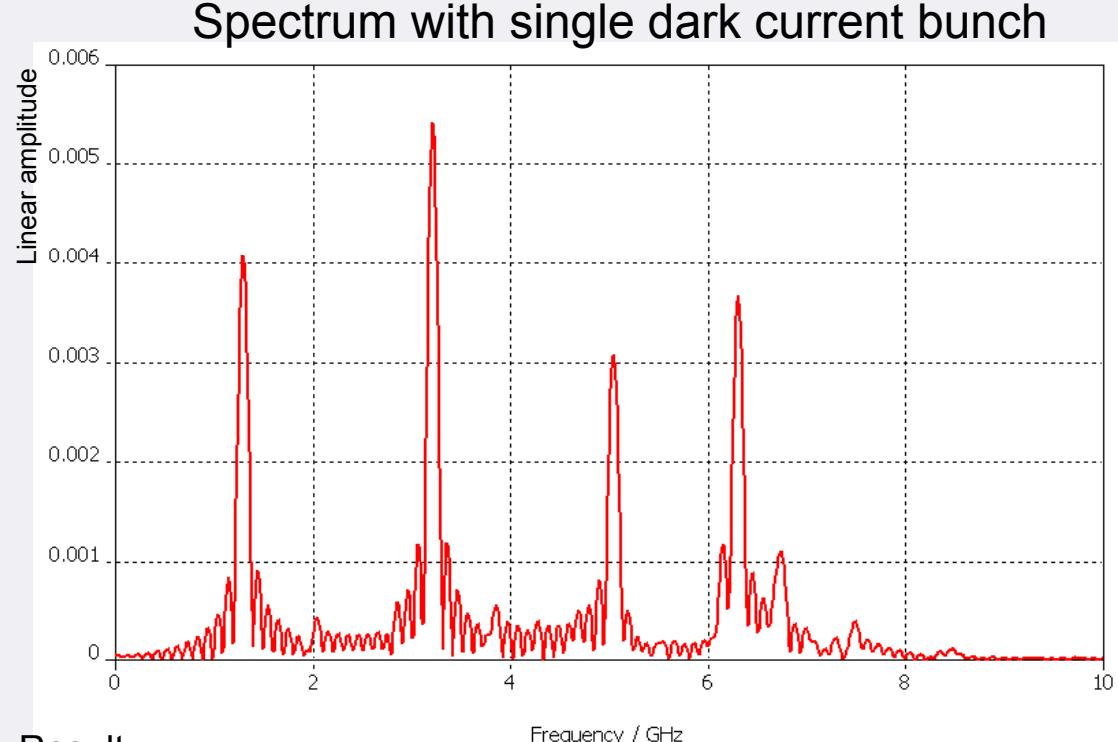


$$f_{01} = 1.3 \text{ GHz}$$

$$Q_0 = 6100$$

$$Q_{ext} = 220$$

$$\rightarrow Q_L = 212, \quad \tau = 52 \text{ ns}$$



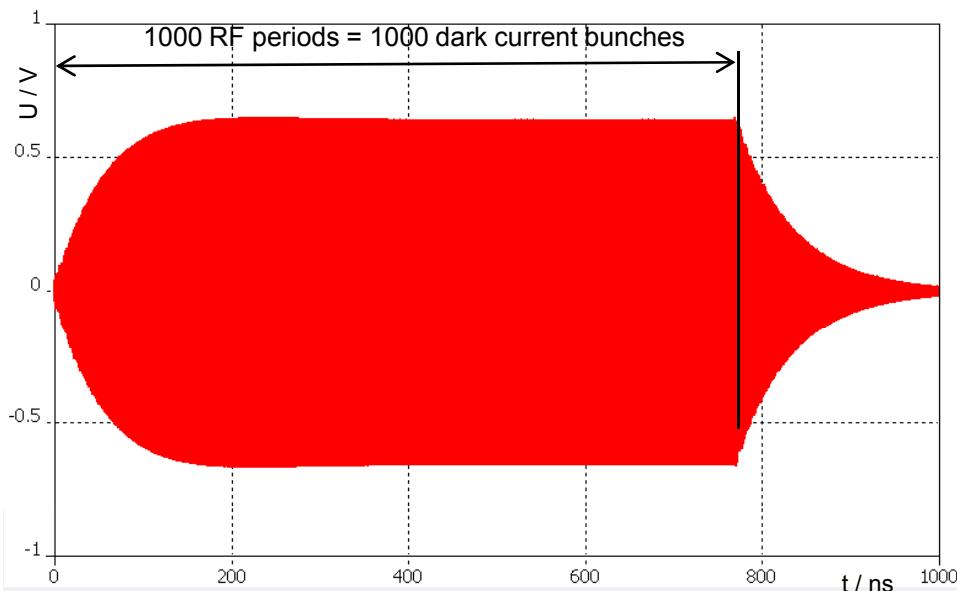
Result:

- Resonator thickness increased factor 2.6
- Resonator radius increased factor 1.07
- Kink length adapted to reach 1.3 GHz
- Feedthrough position adapted to reach smaller Q_{ext}

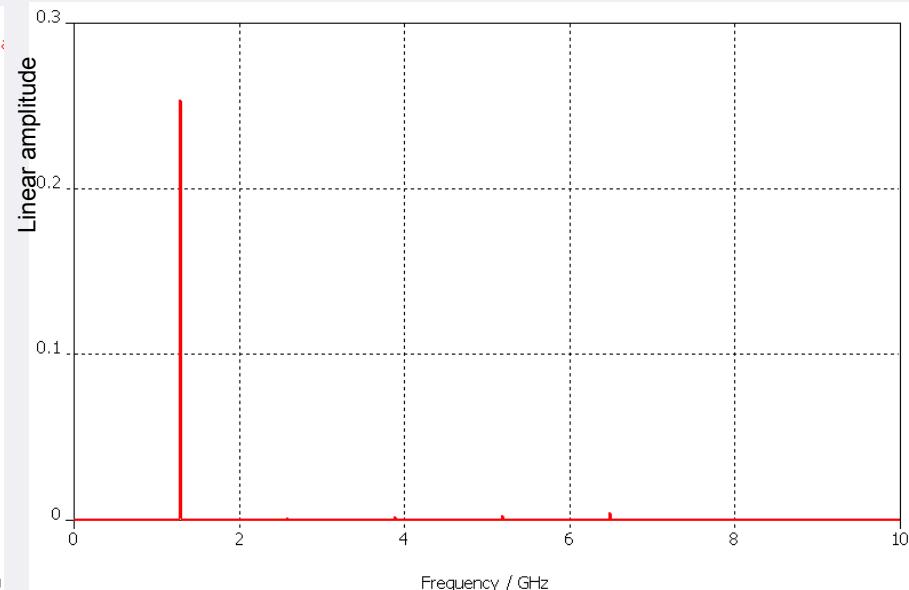
Simulation:
 $I_{darkcurrent} = 1 \text{ mA}$,
 $\sigma_z = 32 \text{ ps}$

Dark Current Monitor (II)

Time domain



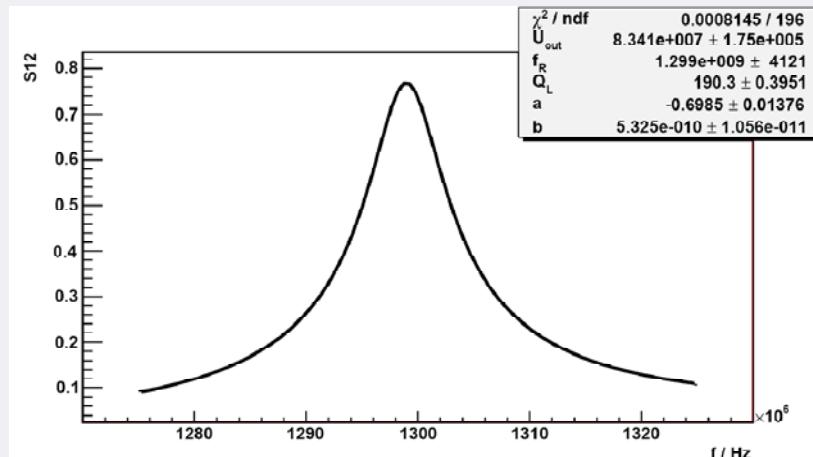
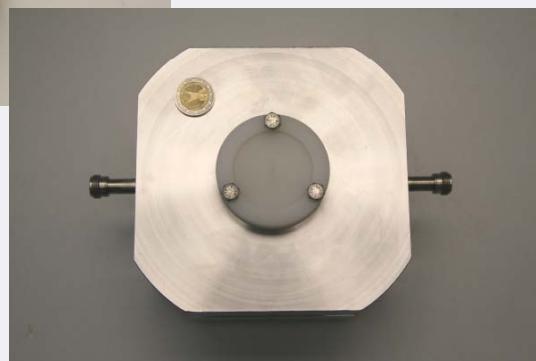
Frequency domain



Transient oscillation finished after 200 ns

Simulation: $I_{\text{darkcurrent}} = 1 \text{ mA}$, $\sigma_z = 32 \text{ ps}$

Dark Current Monitor (III)



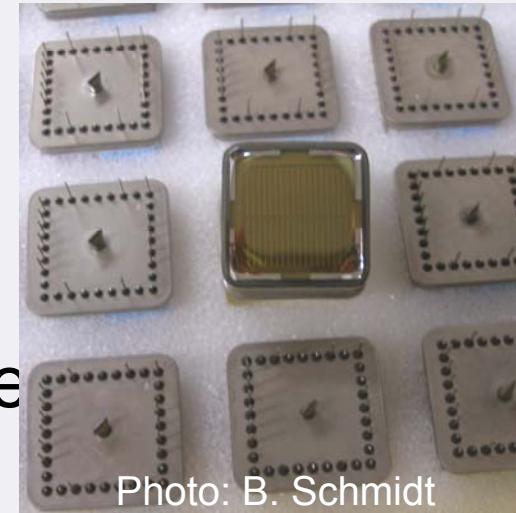
Ready since yesterday:
Spek:

- $f = 1.3 \pm 0.0014 \text{ GHz}$
- $\text{BW} = 6 \text{ MHz}$
- $Q = 205$

Expected Signal: 520 mV/1mA @ 32 ps Bunchlength

Beam Loss Monitors: Photomultipliers

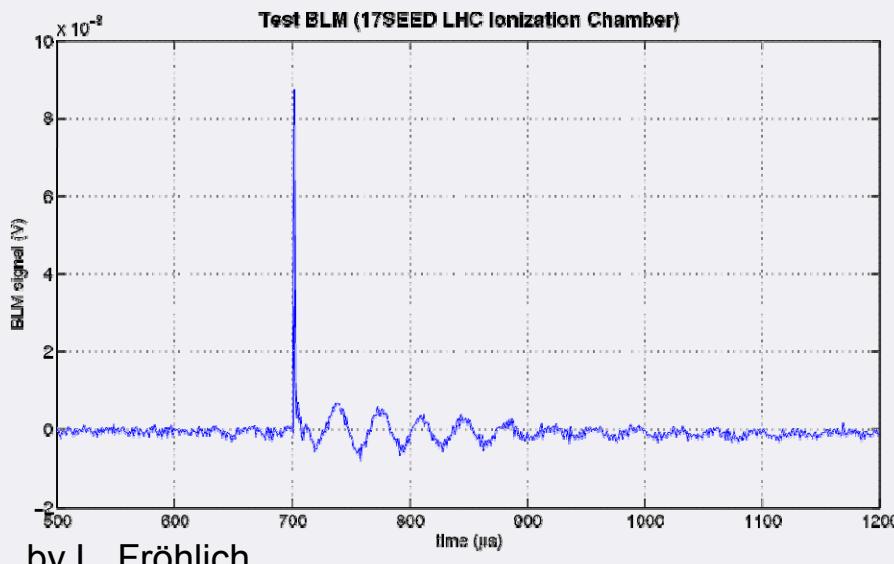
- Compact metal channel photomultipliers
 - Fast, not for high radiation areas
 - Test setup in preparation: Ch. Ge
Wilhelm
- PMTs with internal high voltage generation
 - Radiation hardness?
 - 1 PMT installed at BC2 since several months
- Usability of PMTs without scintillator



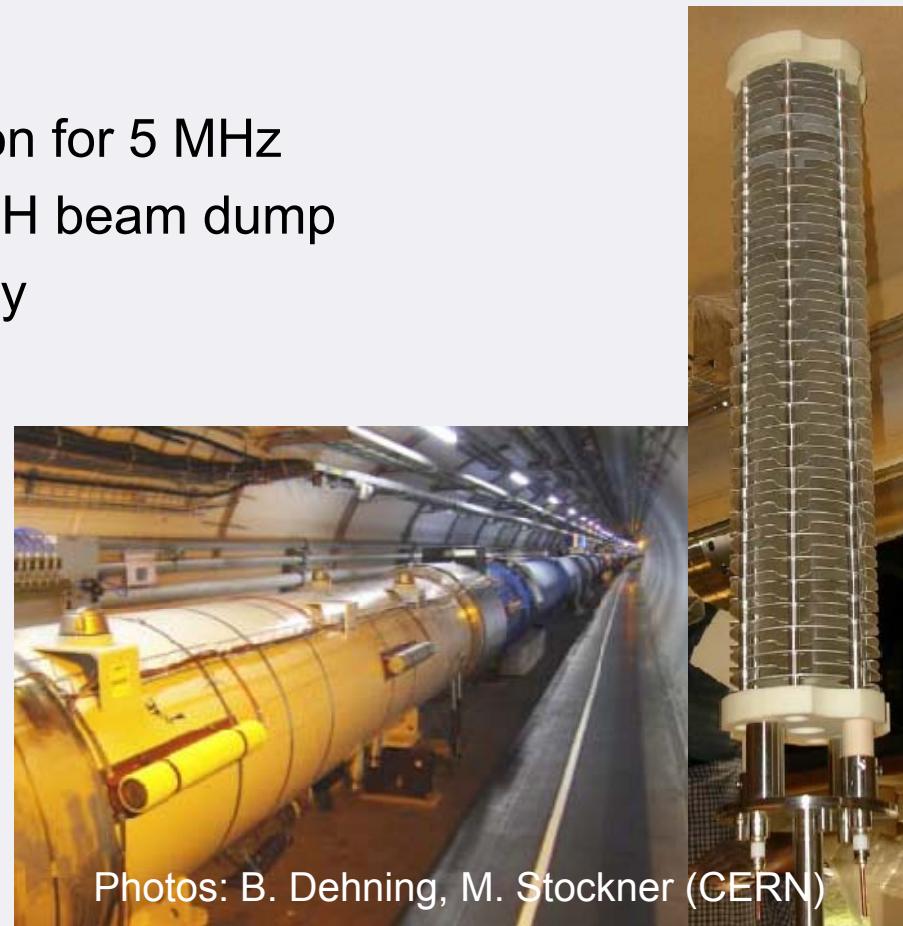
by L. Fröhlich

Beam Loss Monitors for the XFEL

- LHC ionization chambers
 - Radiation hard
 - No real single-bunch resolution for 5 MHz
 - Chamber installed near FLASH beam dump
 - Preamplifier to be added today



by L. Fröhlich



Photos: B. Dehning, M. Stockner (CERN)

Some Plans and Ideas

BPMs and TCA

- Current Prototype Board is feasible for digital communication
- Try communication with MCS4 AMC Board
- Get a BPM Prototype with full DOOCS integration
- Option for FLASH (II) not XFEL

Charge Monitoring at FLASH

- AMC based Fast ADCs get available
- Boards have sufficient FPGA Power on board
- Try to establish Toroid Readout System on AMC Basis
- To be used at FLASH and XFEL

Dark Current

- Test at PITZ
- But also useful for Dark Current control at FLASH