‚Options and performance of laser to RF conversion schemes‘

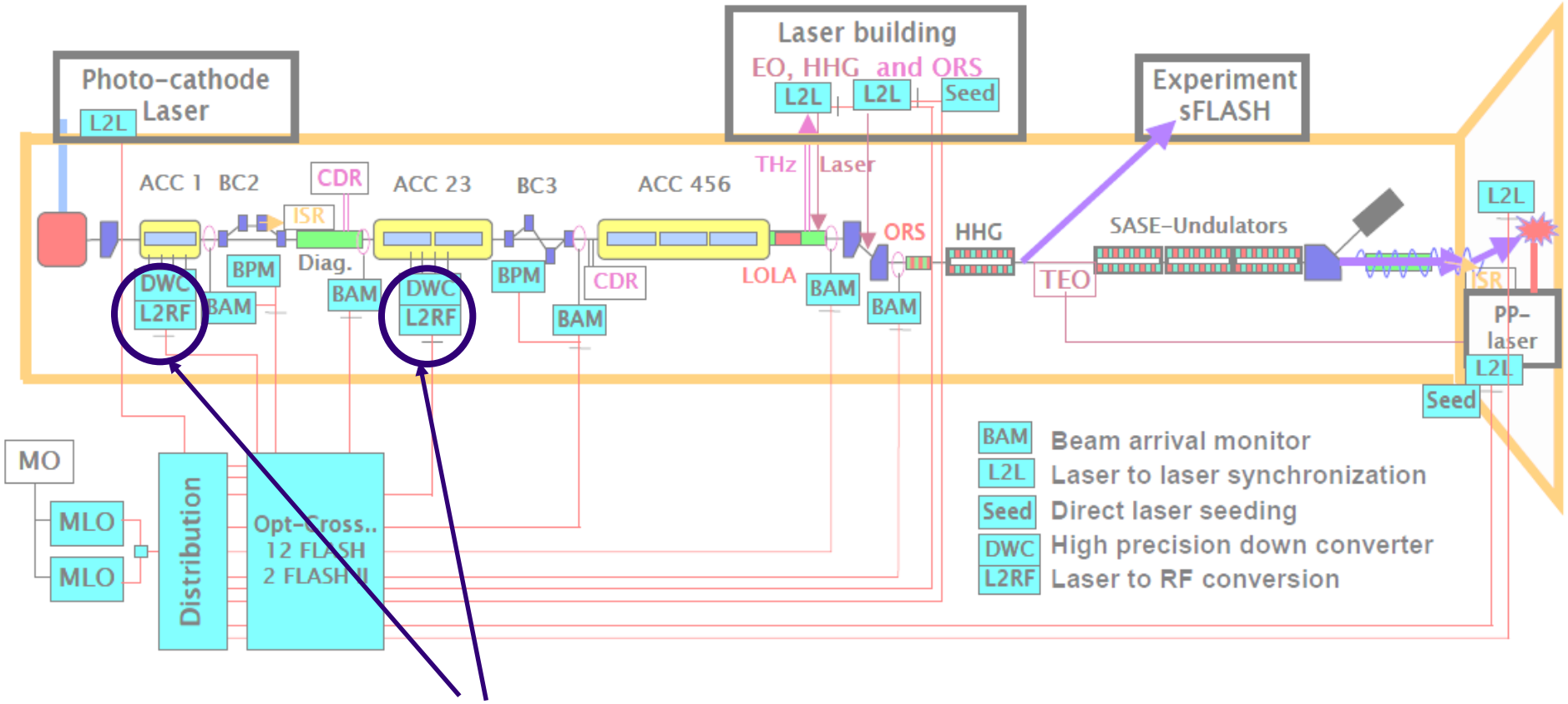
F.Ludwig (Presenter: P.Gessler) - DESY

Content :

- **Laser to RF Conversion**
  (M.Felber, B.Lorbeer, F.Ludwig, H.Schlarb - DESY)
- **High precision Down Converters**
  (M.Hoffmann, F.Ludwig, G.Moeller, S.Simrock - DESY,
  K.Suchecki - TU Warsaw,
  W.Jalmuzna - TU Lodz,
  H.Piel - Cryoelectra GmbH)
- **Beam Stability Update**
  (C.Gerth, F.Ludwig - DESY,
  C.Schmidt - TU Hamburg Harburg)
- **RF Master-Reference Update**
  (F.Ludwig, S.Simrock, H.Weddig - DESY,
  K.Czuba - TU Warsaw)

Laser Synchronization System at FLASH

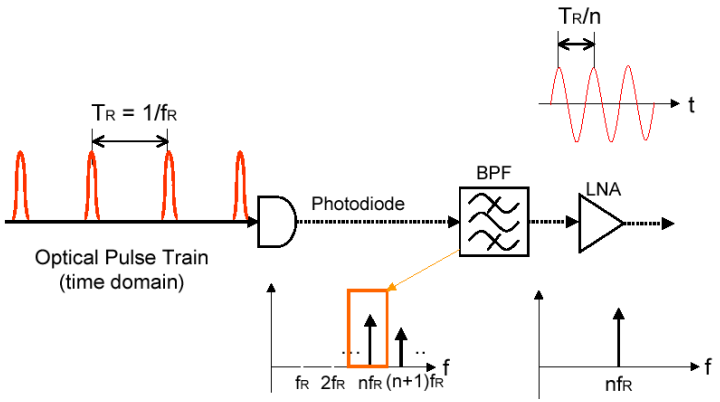
- Implementation of entire system 06/2008 - 2010

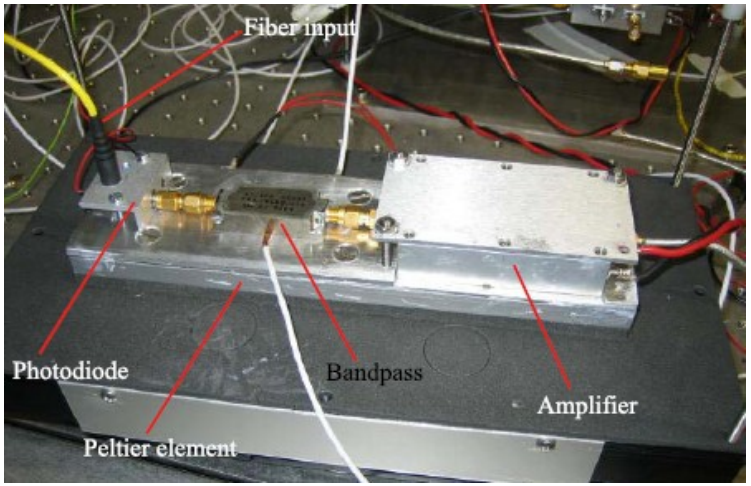


Laser to RF Conversion

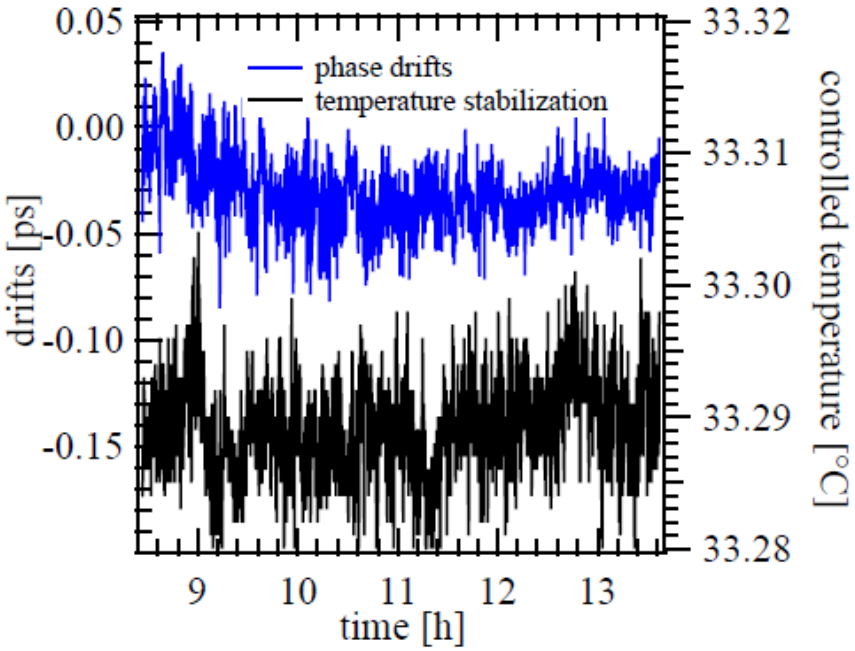
Laser to RF Conversion - Direct Photodiode Detection

- **Direct extraction to RF from a pulse train :**





- **Short-term and long-term performance :**

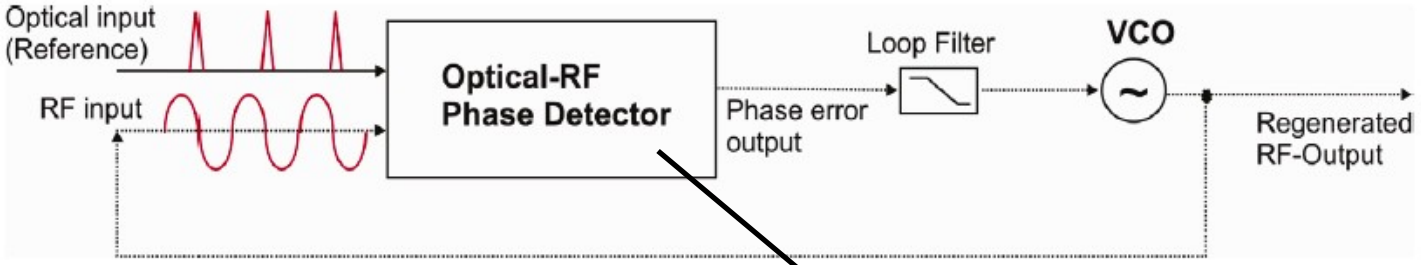


- 10fs-25fs(rms) jitter [1kHz-10MHz] @ 1.3GHz
- 80fs peak-to-peak long-term phase drifts
- AM to PM limitation (might be overcome)
  (Typical AM to PM conversion 1-10ps/mW)

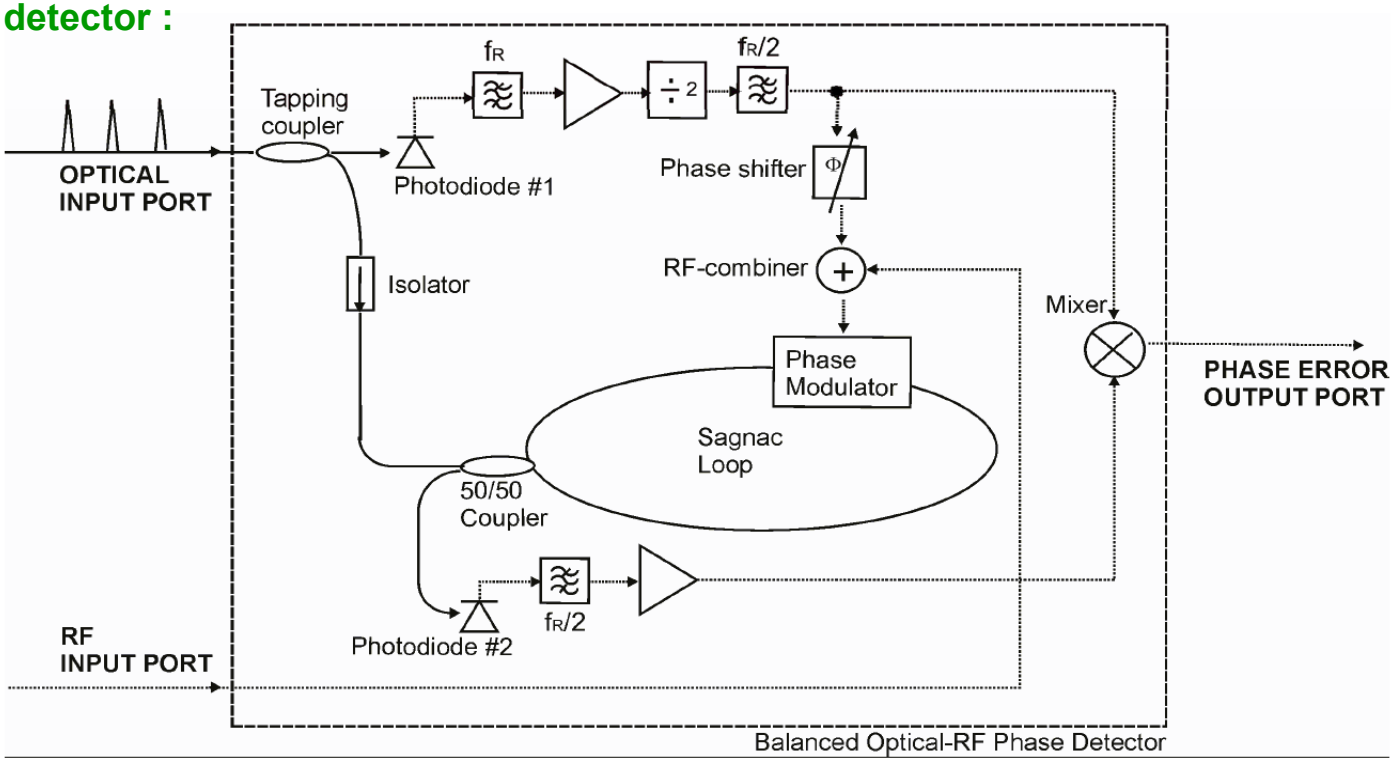
PAC07, `Noise and Drift Characterization of Direct Laser to RF Conversion Scheme`, B.Lorbeer et.al.

Laser to RF Conversion – Sagnac Loop

- **Phase-locked loop (PLL) :**

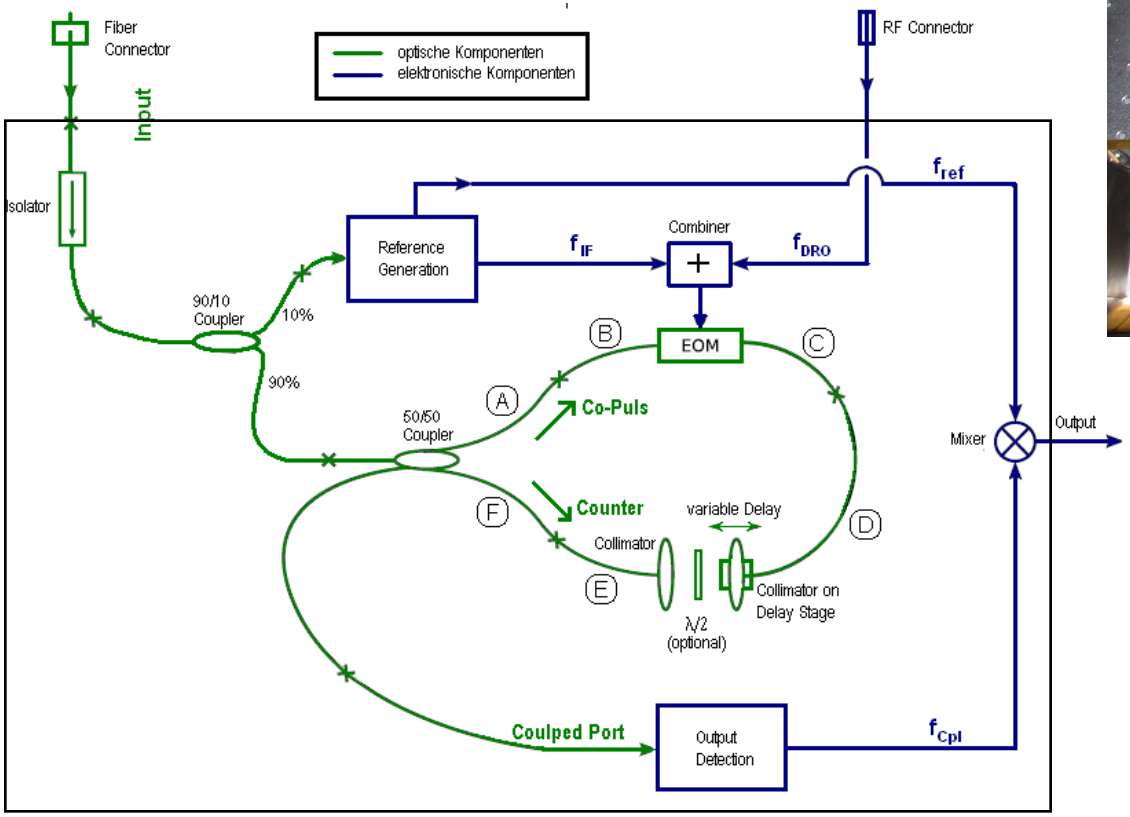


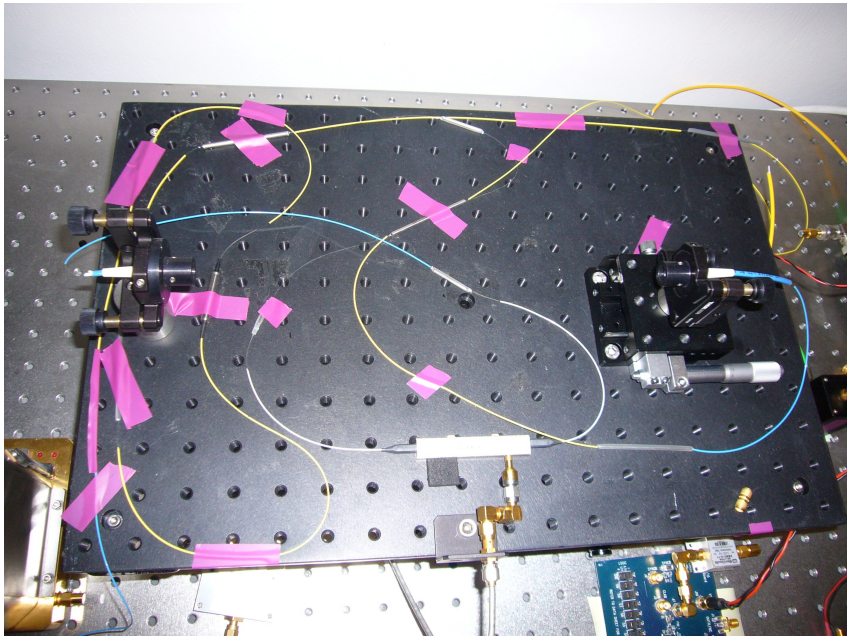
- **Optical to RF phase detector :**
  (Sagnac-loop)



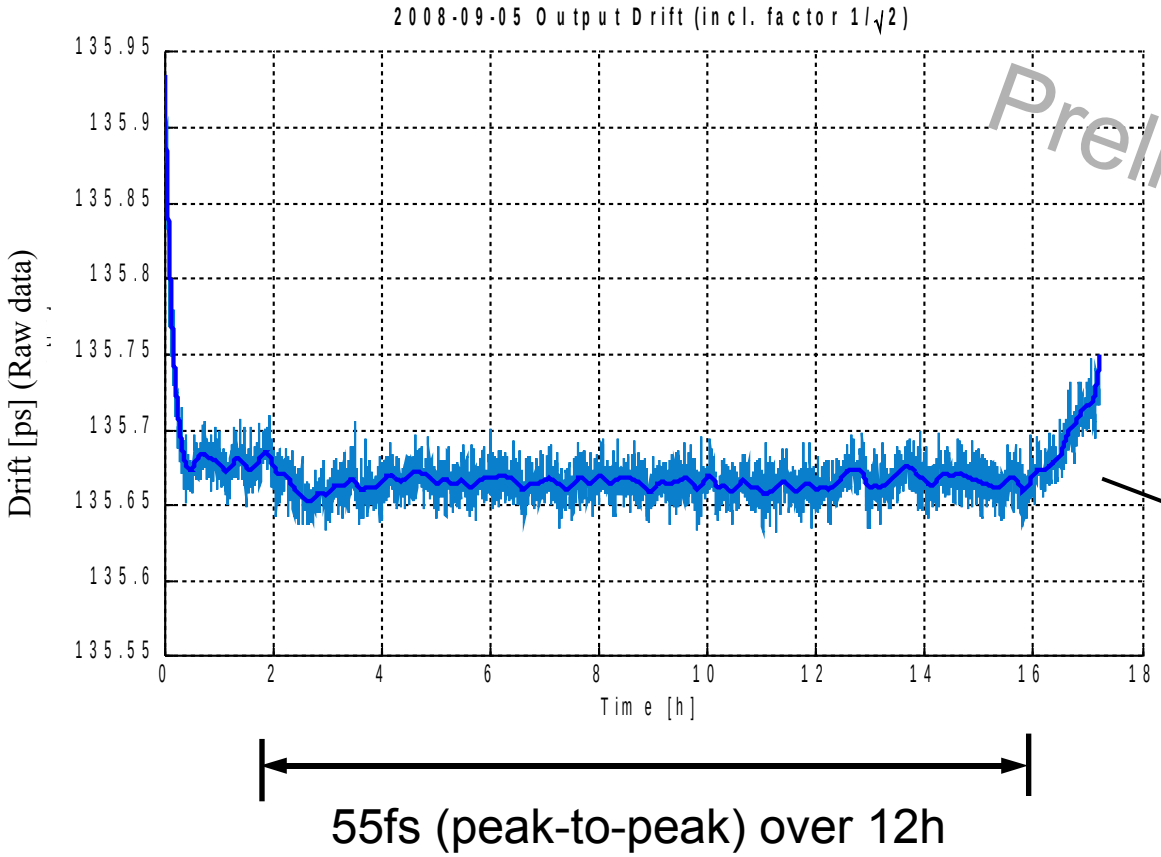
EUROFEL DS3.9, Delivery Report
01/2008, F.Ludwig et.al.

- Topology :


Fiber Connector
Input
optische Komponenten
elektronische Komponenten
RF Connector
Isolator
Reference Generation
f_{IF}
Combiner
f_{DRO}
f_{ref}
90/10 Coupler
10%
90%
B
EOM
C
A
Co-Puls
50/50 Coupler
Mixer
Output
F
Counter
variable Delay
Collimator
D
E
Collimator on Delay Stage
λ/2 (optional)
Coulped Port
Output Detection
f_{Cpl}

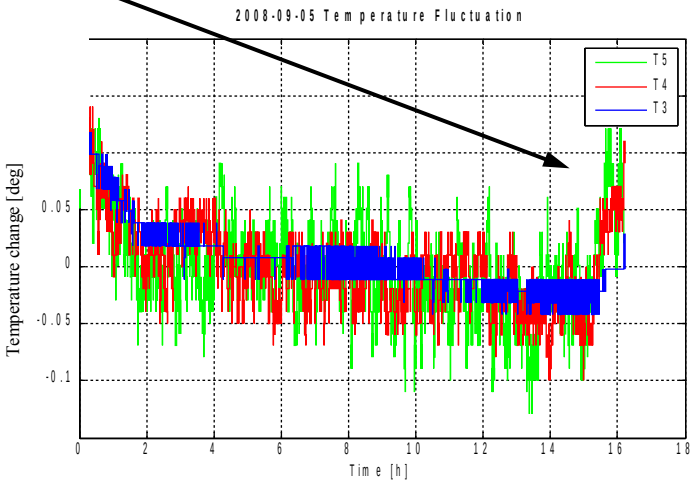


- Long-term stability: Sagnac loop vs. direct photodiode detection :



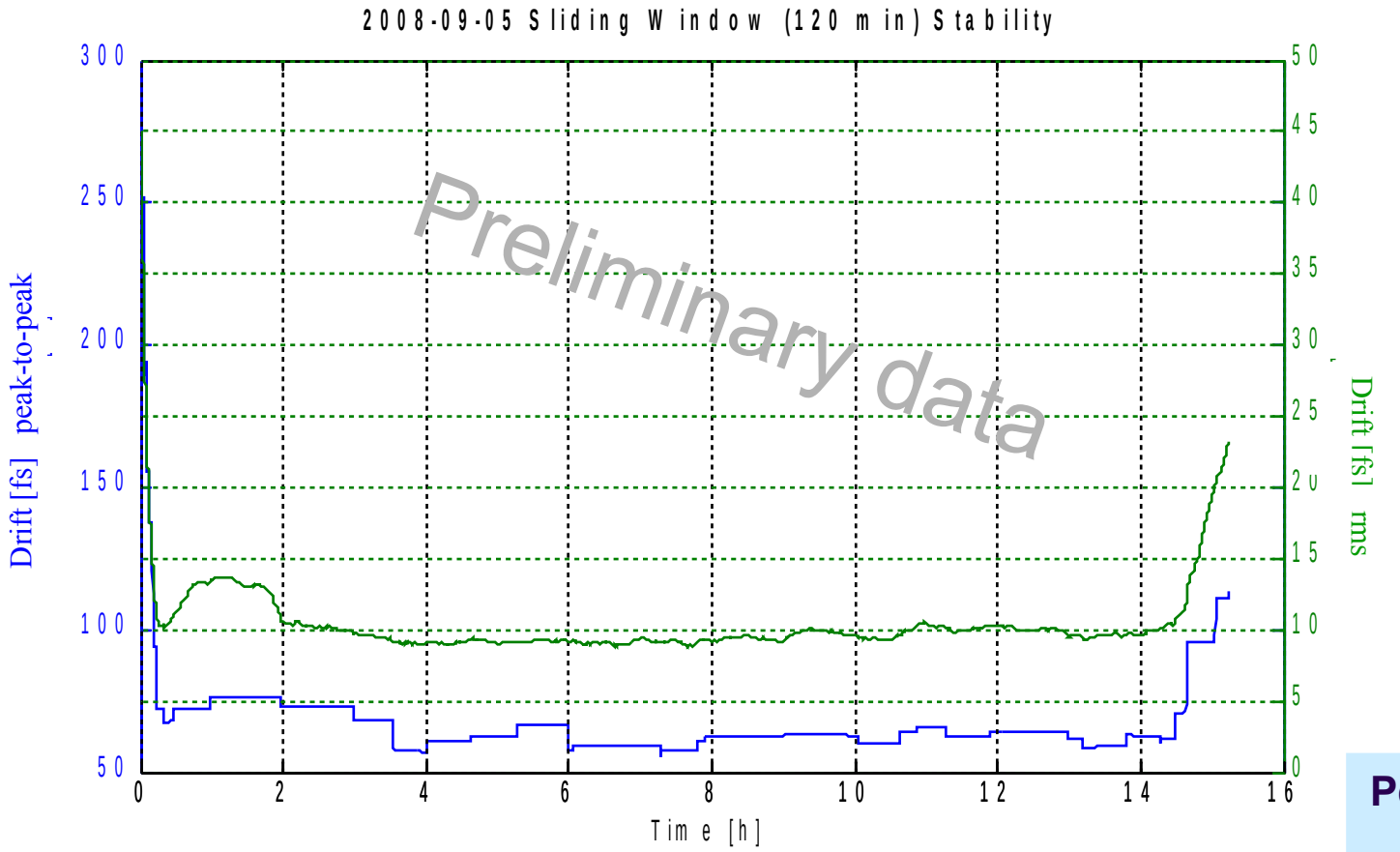
Preliminary data

Drift caused by temp. change



Laser to RF Conversion – Sagnac Loop

- Long-term stability: Sagnac loop vs. direct photodiode detection :

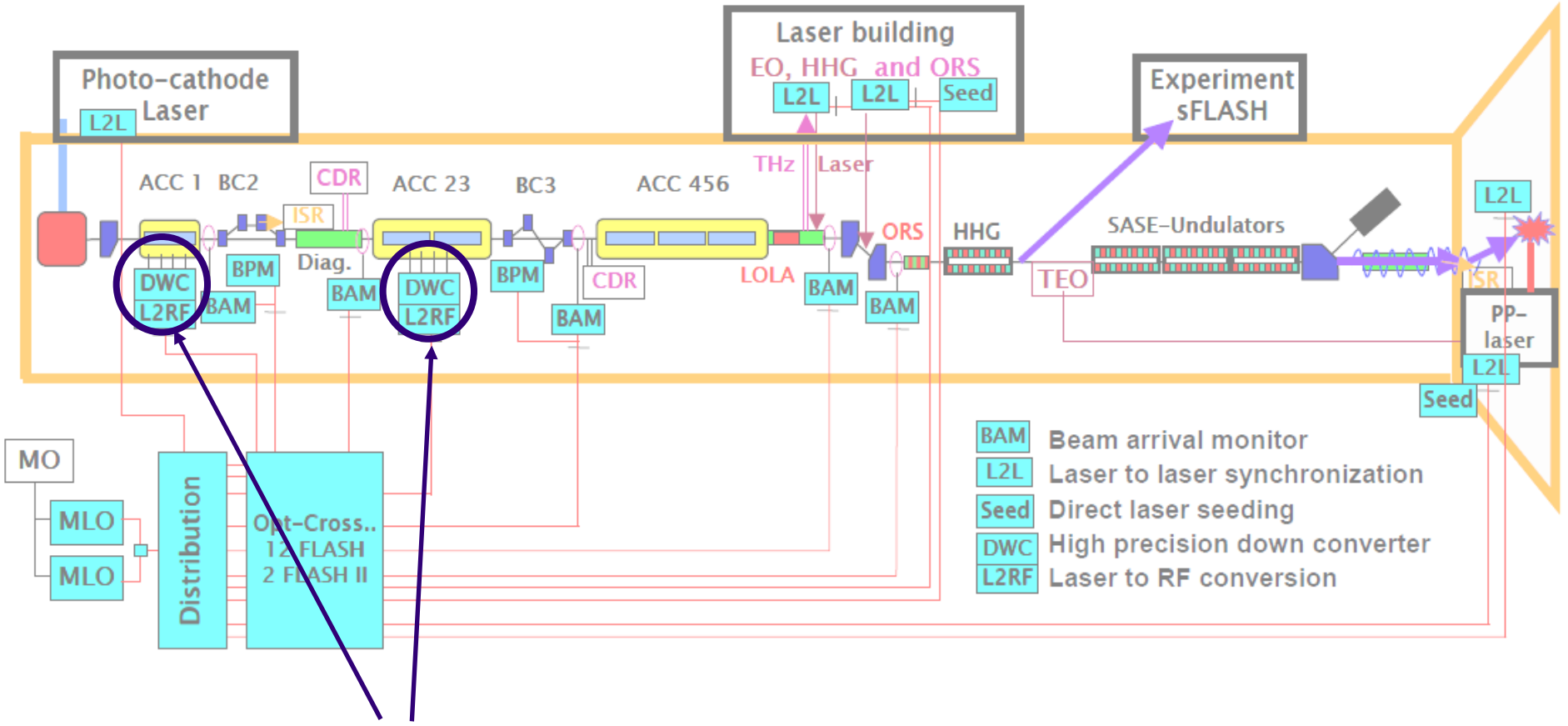


→ Next step: Beat 2 good Sagnac loops against each other

Performance over 12h:
- 10fs rms
- 33fs peak-to-peak

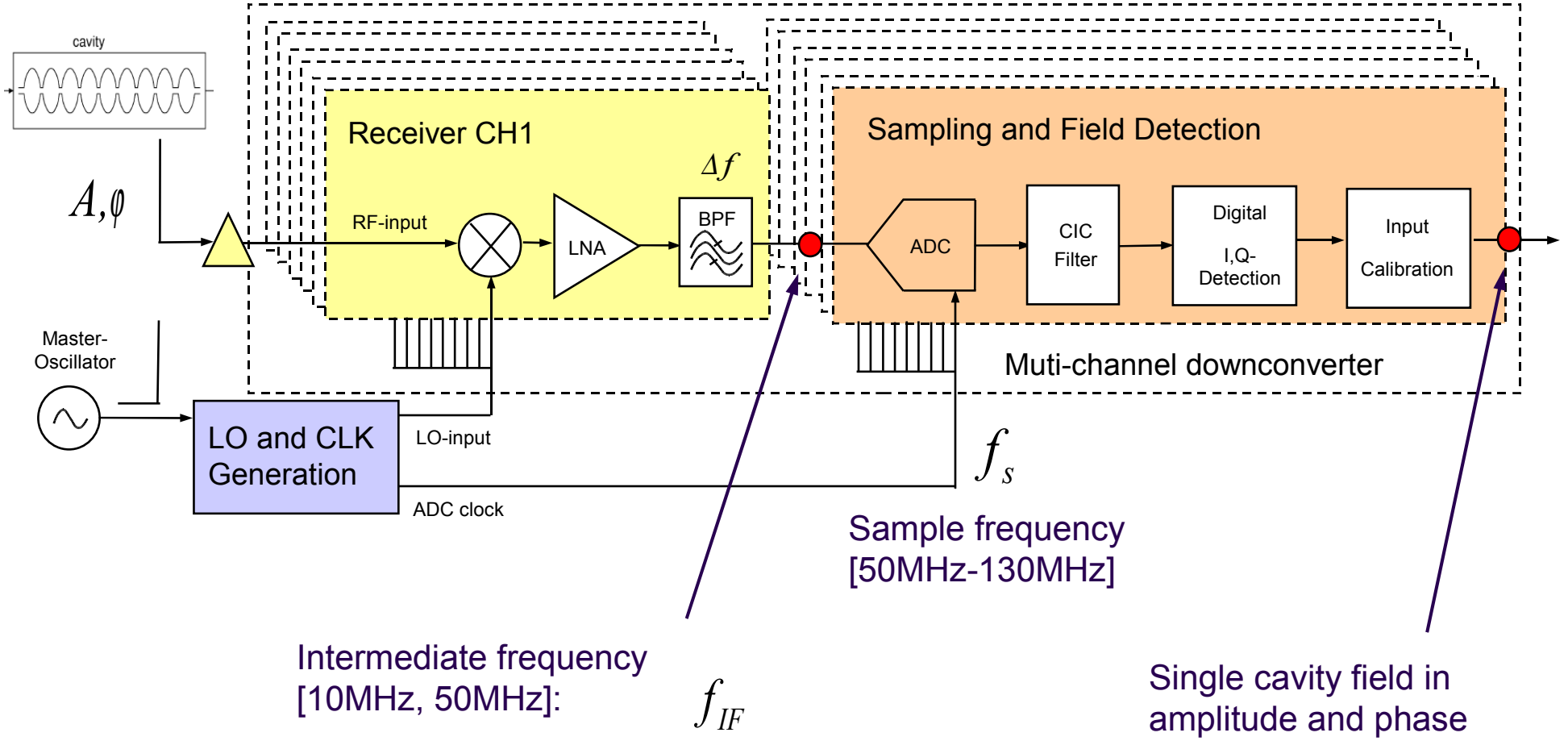
Laser Synchronization System at FLASH

- Implementation of entire system 06/2008 - 2010



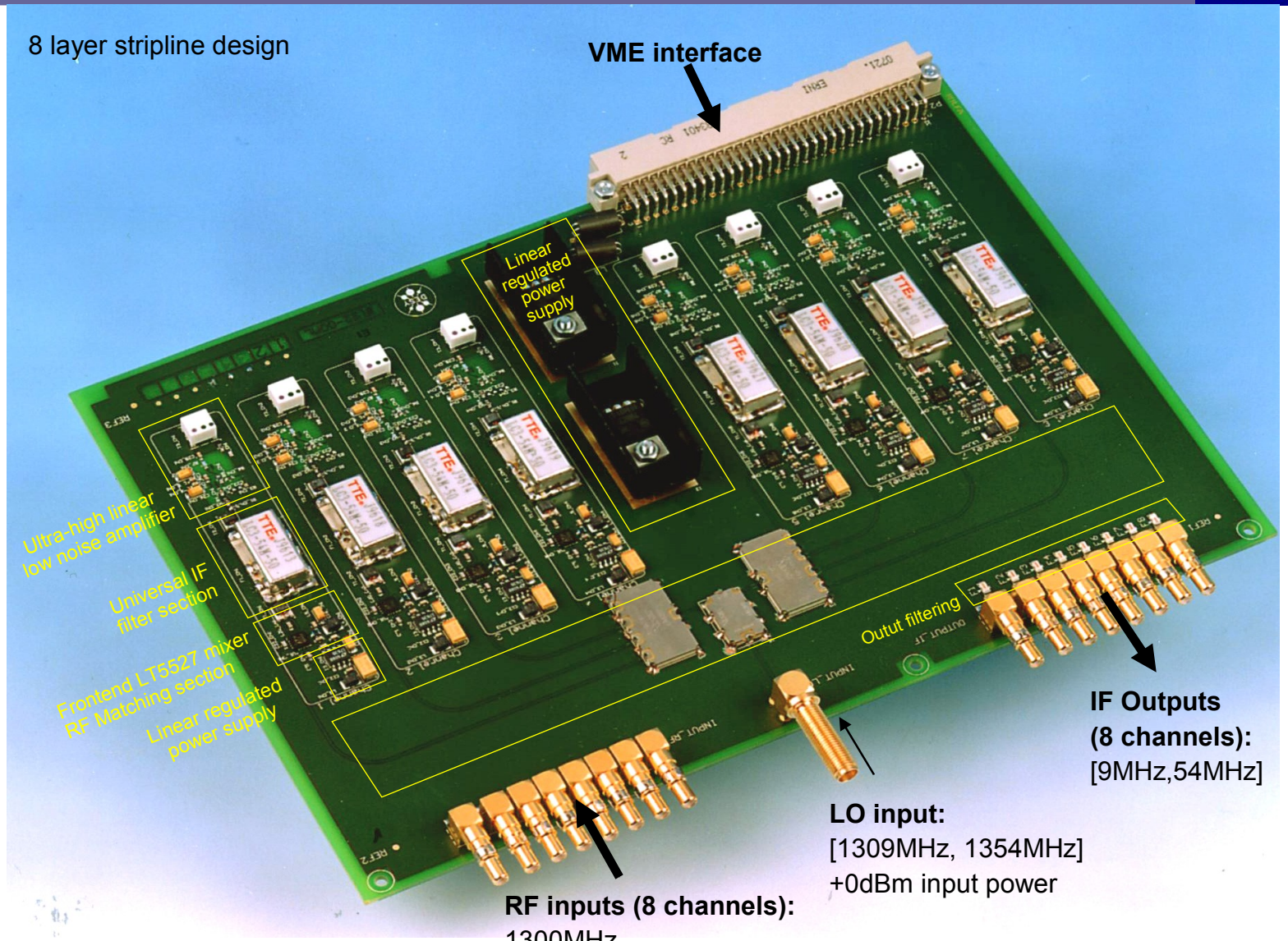
High precision down converter – cavity field and beam stability

- Down converters using the non-IQ-sampling scheme :



Beam Stability – Multi-channel Downconverter

8 layer stripline design



Beam Stability – Performance Tests at FLASH

- Stability lab results (single channel) :

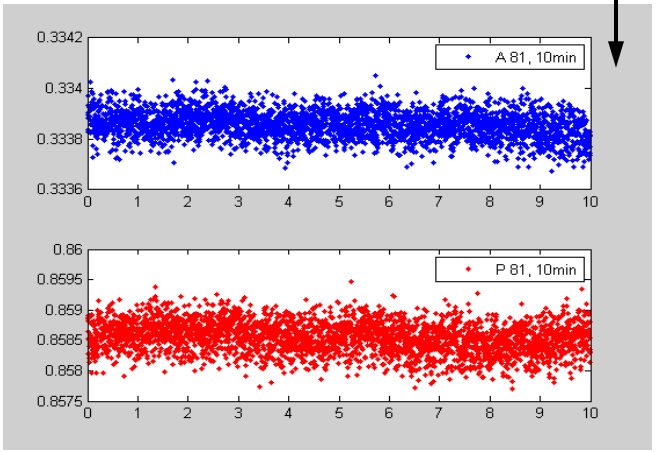
Short-term, bunch-to-bunch (800us) :
$\Delta A / A_{rms} = 0.015\,\%, \quad \Delta \varphi_{rms} = 0.0092\ deg$

Mid-term, pulse-to-pulse (10min) :
$\Delta A / A_{rms} = 0.016\,\%, \quad \Delta \varphi_{rms} = 0.0147\ deg$

Long-term, drifts (1hour) :
$\Delta A / A_{pkpk} = 0.09\,\%, \quad \Delta \varphi_{pkpk} = 0.05\ deg$

θ_A = 2e-3/°C, θ_P = 0.2°/°C

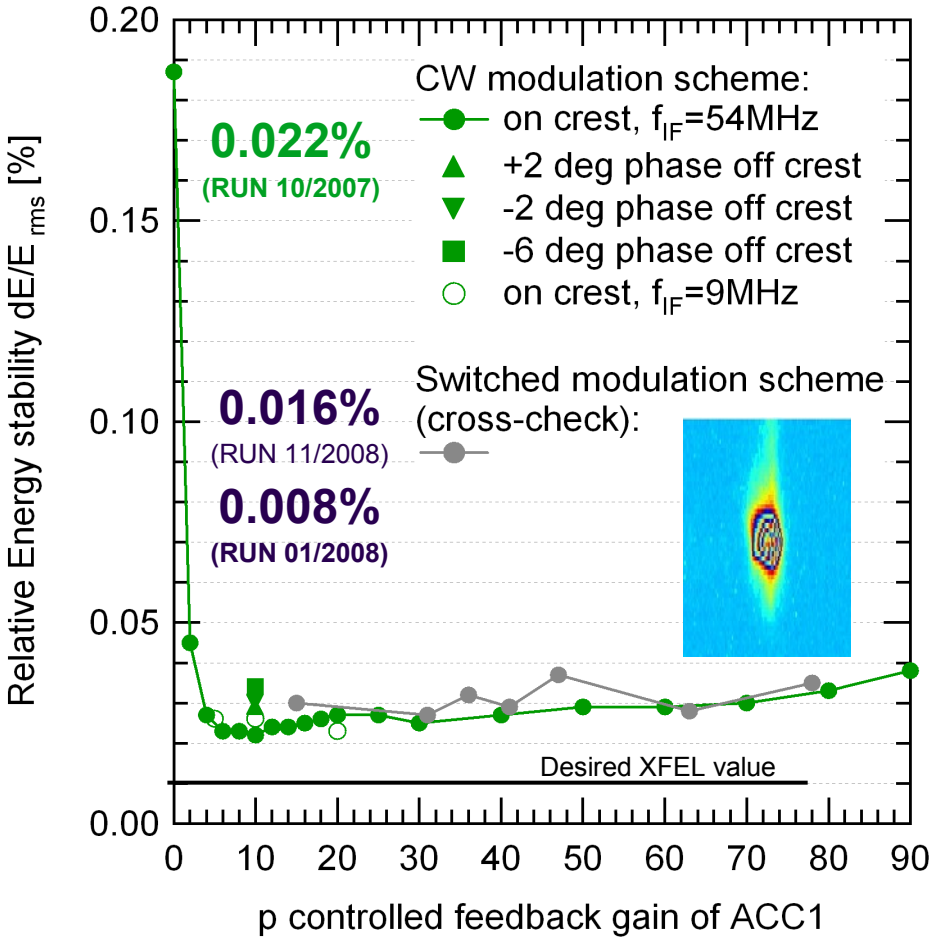
BW=1MHz
BW=1MHz



Parameter :

- VME active multi-channel receiver, Readout bandwidth 1MHz
- LO / IF leakage –72dB, Crosstalk –67...-70dB
- SIMCON DSP (14-Bit ADC)

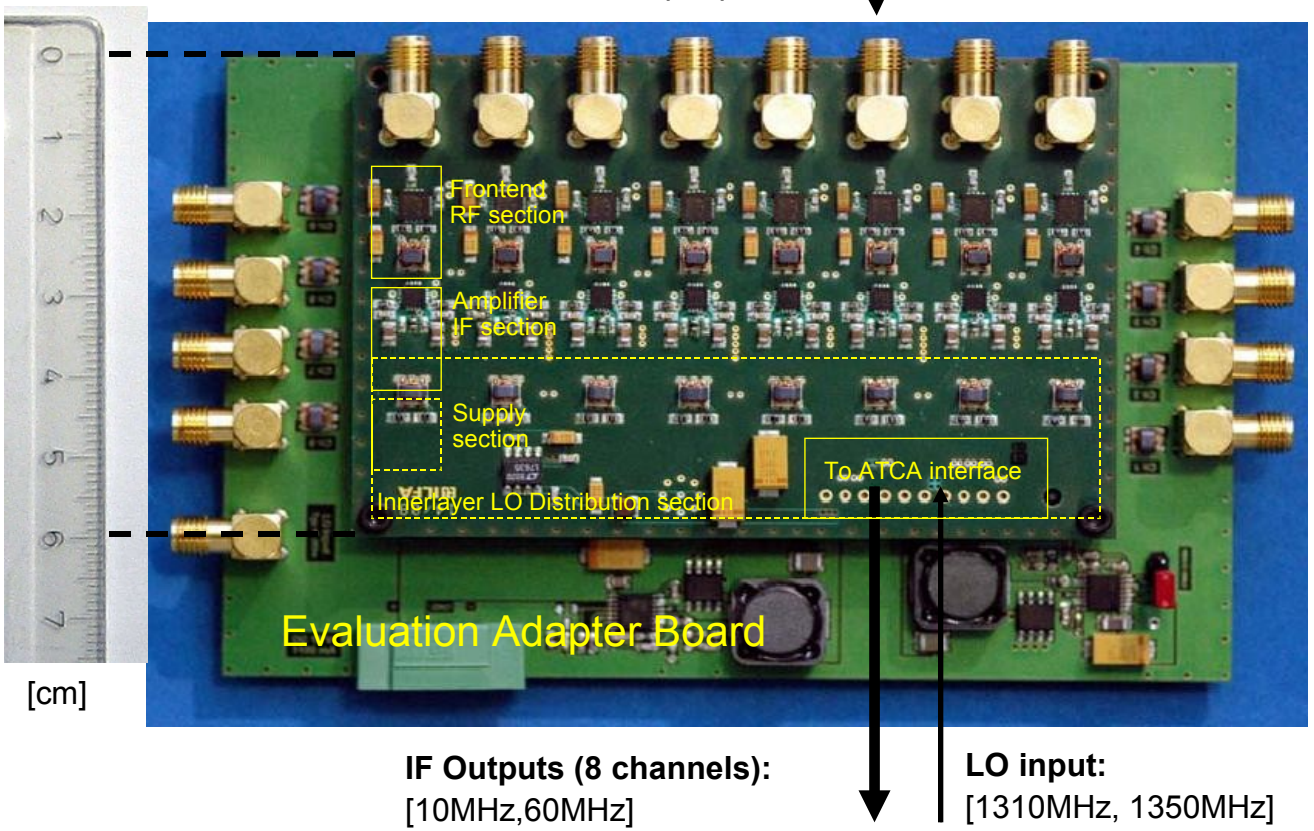
- Pulse-to-Pulse Beam Stability :



EUROFEL DS3.9, Delivery Report 01/2008, F.Ludwig et.al.

- Very compact **R**ear **T**ransition **M**odule (RTM) :

RF inputs (8 channels):
1300MHz, +0dBm input power



IF Outputs (8 channels):
[10MHz,60MHz]

LO input:
[1310MHz, 1350MHz]

Cryoelectra
Gesellschaft für kryoelektrische Produkte mbH

Receiver Type : LT5527 (Gilbert-Mixer)
RF: 1300MHz , <10dBm
LO: [1310MHz, 1350MHz], 10dBm
IF : [10MHz, 60MHz], diff. outputs

CHARACTERISTICS	RATING
IF Frequency, MHz	1 - 50
Conversion Loss, dB	-2 (typ)
Noise Figure (incl. the accessory card), dB	18 (typ)
IF Spurious Signals, dBc	<-60
IF Filter cut-off, MHz	60
IF Harmonic Distortion (IF < 15 MHz, RF input power < 0 dBm), %	1
IF Harmonic Distortion (IF > 30 MHz, RF input power < 9 dBm), %	0.25
Inter-Channel Crosstalk, dB	>65

Field Detection Methods and Status 12/08

- Downconverter Noise and Drift Sources :
  - LO-Generation, ADC Noise, Receiver and FPGA IQ Detection
  - Cable drifts
  - Microphonics from Vector-Sum Calibration caused by non-linearity, cross-talk, field-flatness

- Status of the Performance Evaluation

EUROFEL DS3.9, Delivery Report 01/2008 Section 1.5, F.Ludwig et.al.

Status of the Performance Evaluation: [10min, 1MHz]	Switched-modulation (existing at FLASH)	CW modulation (non-IQ-sampling)	Direct-sampling
Self test using the reference in Laboratory (Single channel, 8 channels to be done)	to be done	0.003% (PAC2007)[1]	to be done
Beam based in FLASH using SR-4BC2	0.016% (11/2008) [3]	0.022% (10/2007) [2]	to be done
2 DUT in FLASH using cavity probe splitting	0.016% (06/2008) [3]	to be done	to be done
Self test using the reference in FLASH (Single channel, 8 channels to be done)		0.016% (11/2007) [2]	0.022% (09/2008) [4]
Long-term operation at FLASH	YES	No	No
Calibration scheme tested in laboratory / FLASH	to be done	to be done	Reference tracking

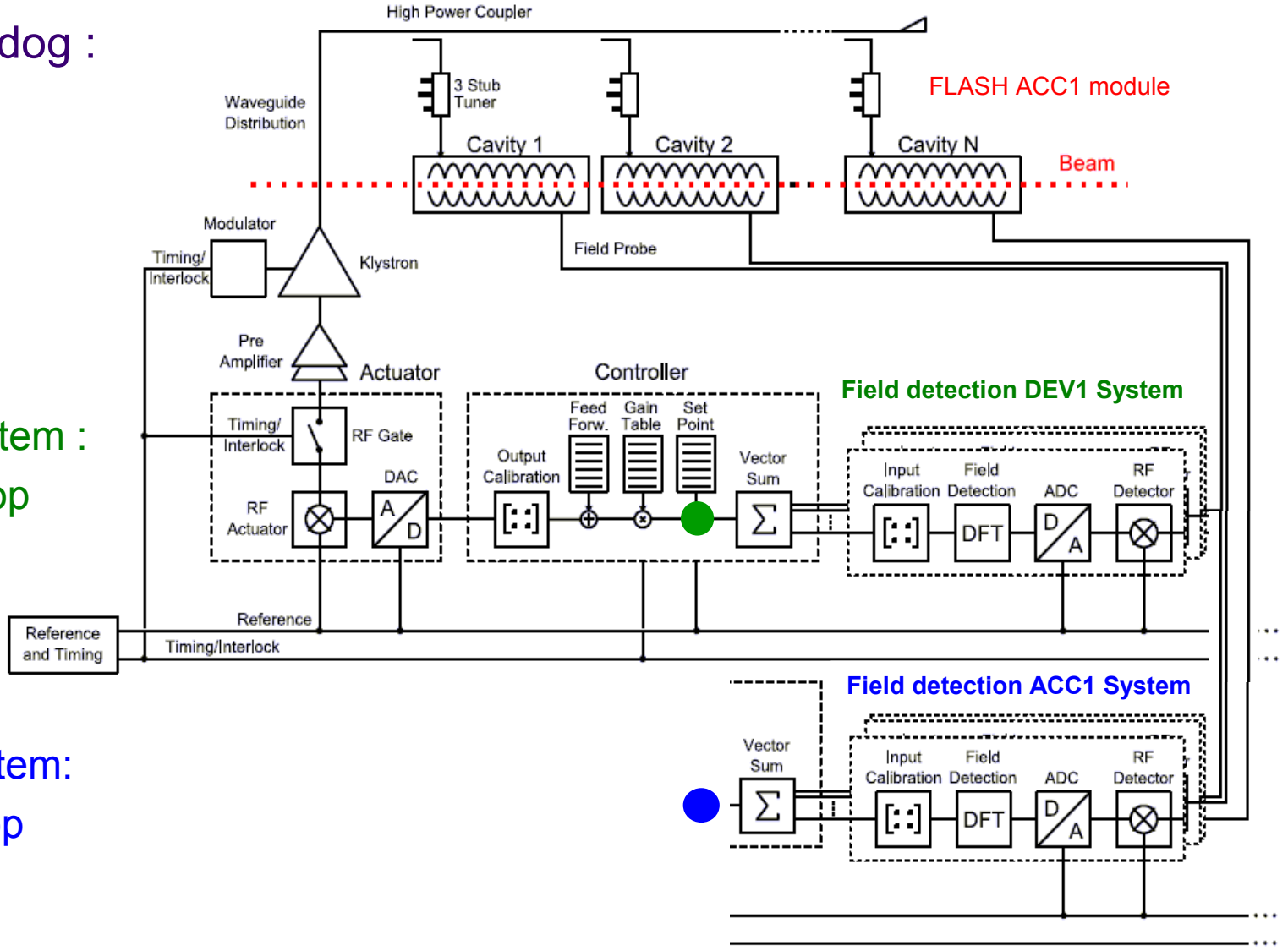
Confguration: **1:** Passive Receiver, 16-bit ADC ACB 2.1, **2:** Active Receiver, 14-bit ADC SIMCON 3.1
3: Active Receiver, 14-bit ADC FLASH Boards, **4:** 12-bit ADC, 200Msps

Beam Stability - Pulse-to-Pulse Fluctuations

- Noise watchdog :

- Regulation system :
  DEV1 close loop

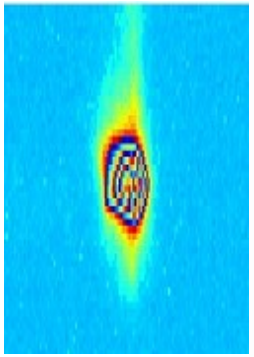
- Regulation system:
  ACC1 open loop

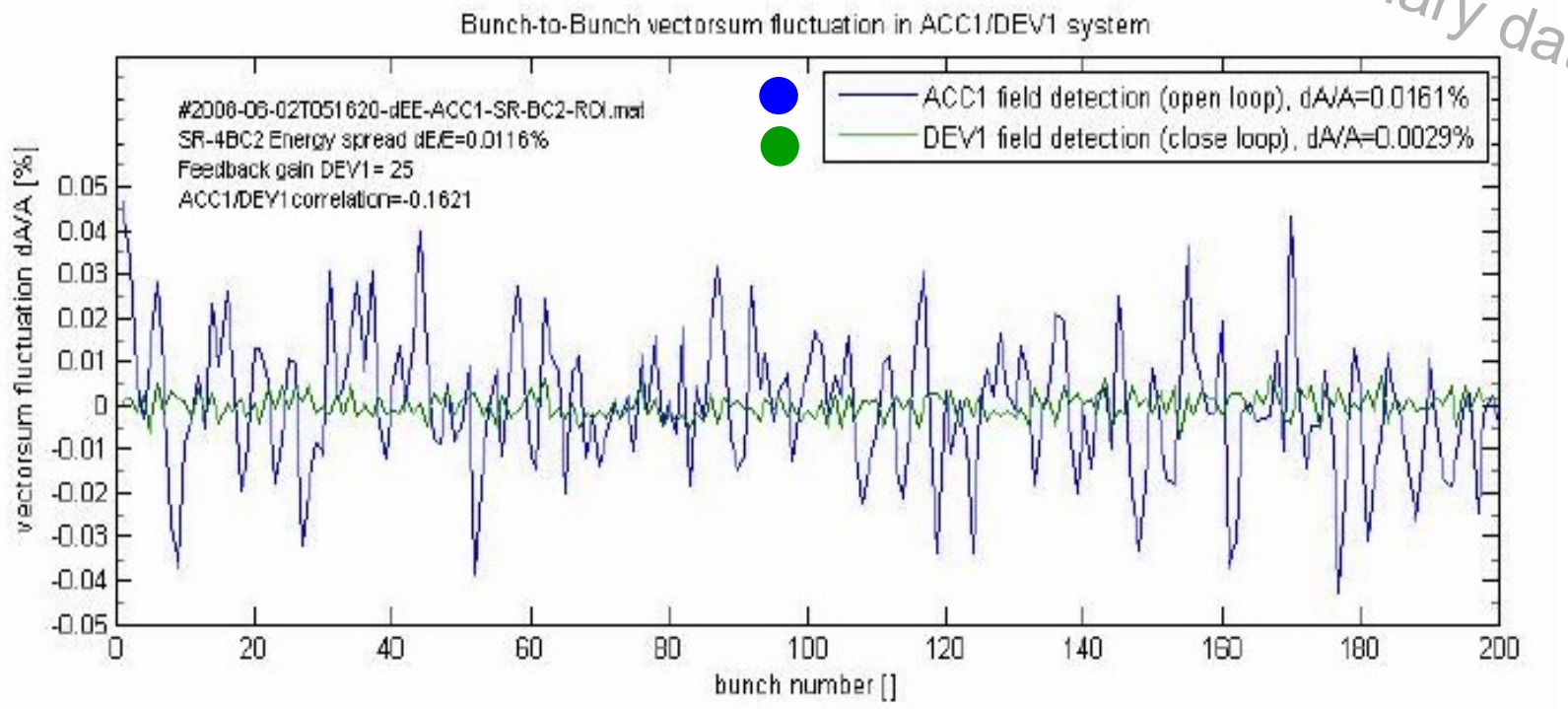


Beam Stability - Pulse-to-Pulse Fluctuations

- On-crest vector-sum fluctuations and beam energy spread :

Preliminary data





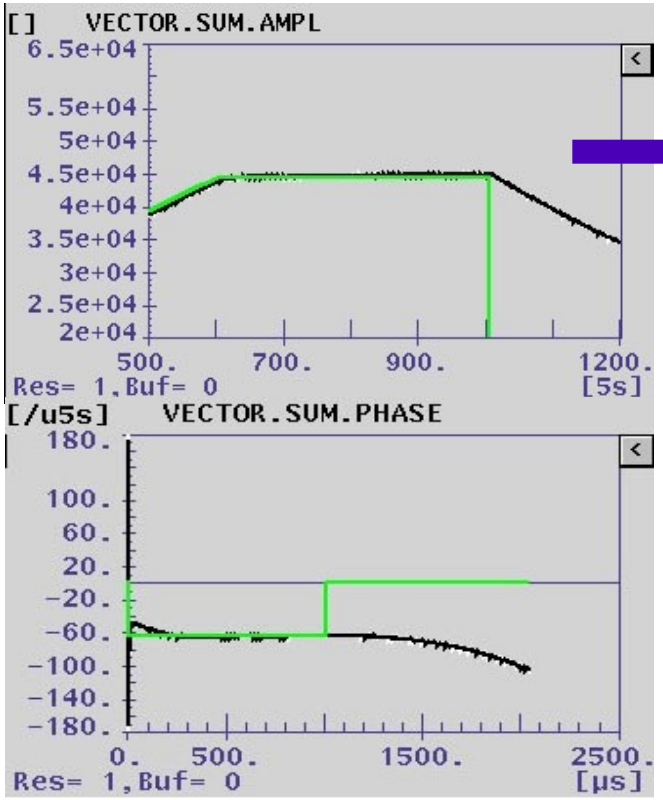
-> Field fluctuations of 0.016% are caused by 1/f-noise below 1kHz from field-detectors.

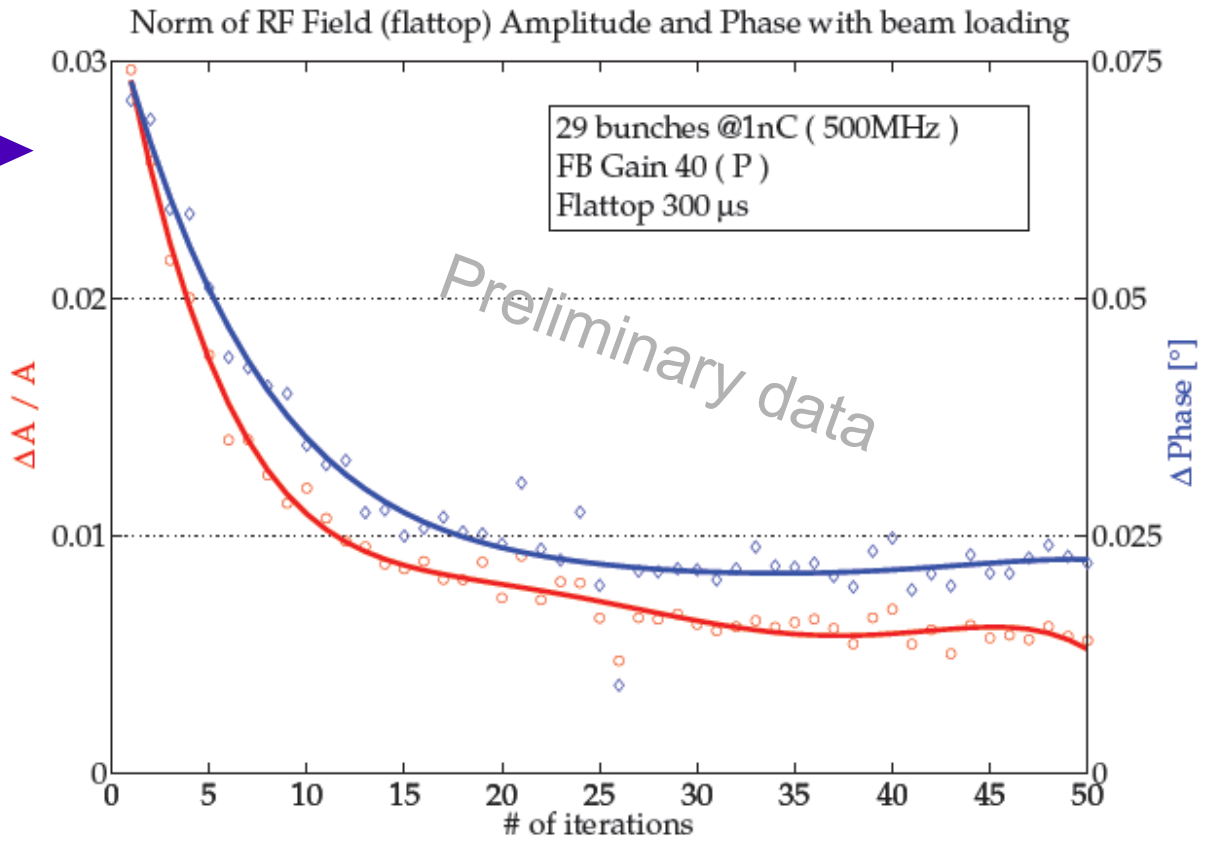
-> Fluctuations are in accordance to the beam energy spread of 0.0116%.

-> P-type controller and actuator chain worked fine on an scale 0.0029%.

-> **Optimize:** Vector-sum principe, LO-generation, receiver, ADCs and reference.

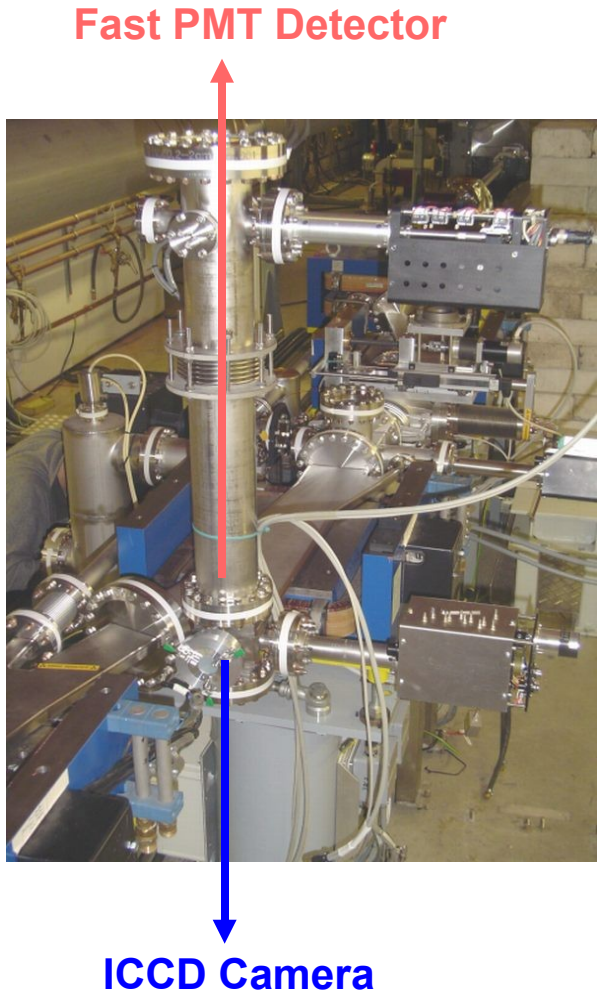
Cavity Field Flatness – Learning Feedforward

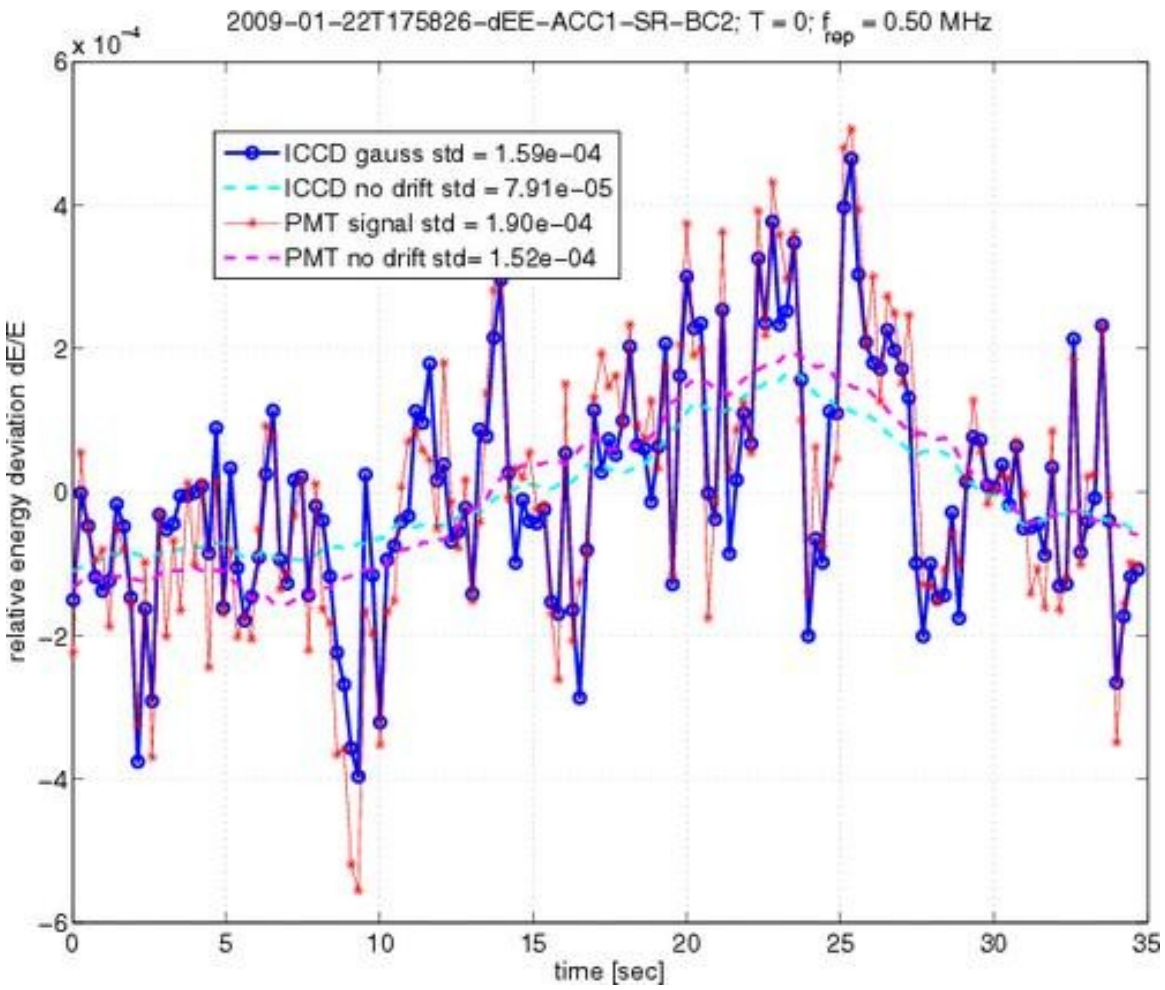




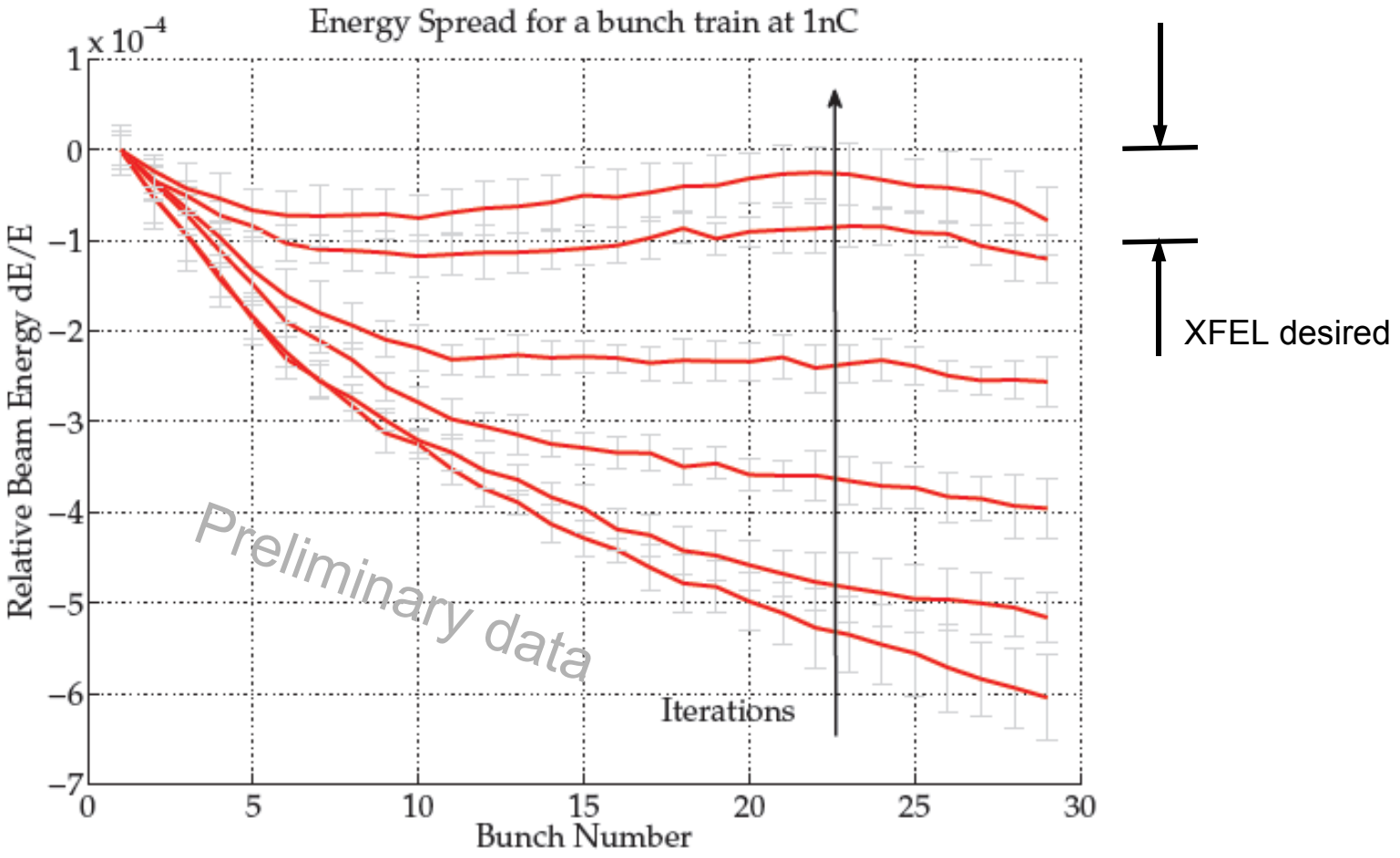
- Norm of RF amplitude and Phase errors during flattop
- Fast convergence and stable

- Energy beam stability ACC1 measured with SR ICCD camera and SR PMT





Beam Energy Flatness – Learning Feedforward



- Learning algorithm removes energy spread within 50 iterations
- Pulse to pulse fluctuations are mostly stochastic

Thanks for your attention !