Sub-ps *(and sub-micrometer)* ***developments at ELETTRA***

Mario Ferianis

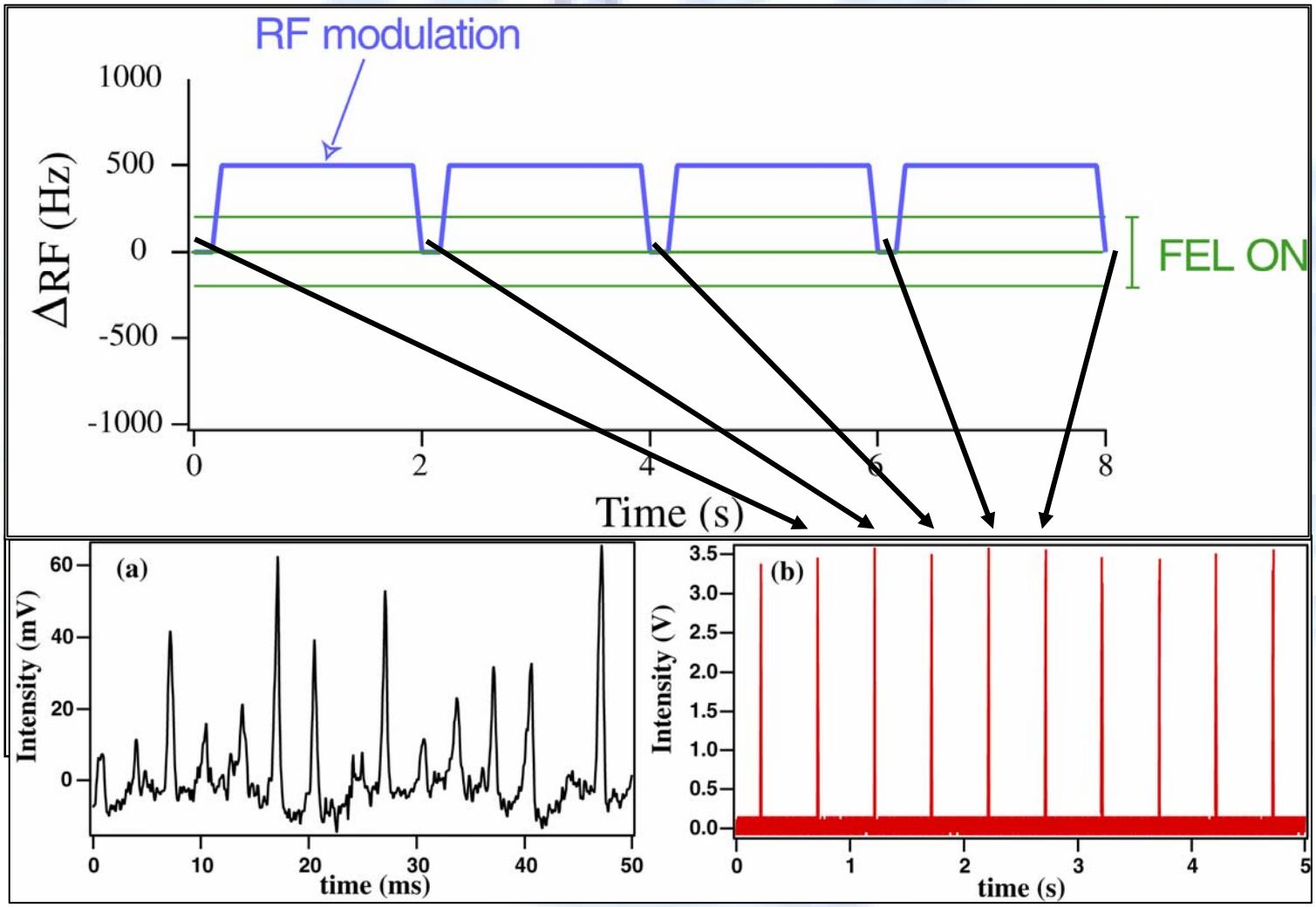
SINCROTRONE TRIESTE, Italy

The ELETTRA laboratory

- ELETTRA is a **3rd generation synchrotron** light source in Trieste (I)
  - since 1993
  - up to 6000 user hours/year
- **1GeV LINAC + 2.4GeV Storage Ring**
- **~ 20 active beam lines:**
  - Insertion Devices and Bending
  - Soft X-rays, VUV-UV, VIS (diagnostics), IR
- Technical Optimization Study (in collaboration with LBL, MIT & SLAC) underway for **a seeded FEL, based on the upgrade of the existing LINAC**
  - **new Photo-cathode GUN**
  - **energy up to 1.2GeV**
  - **FEL 1: 100÷40nm**
  - **FEL 2: 40÷10nm**

Storage Ring Free Electron Laser:

4 bunches spaced by **216ns**=roundtrip time of the optical cavity



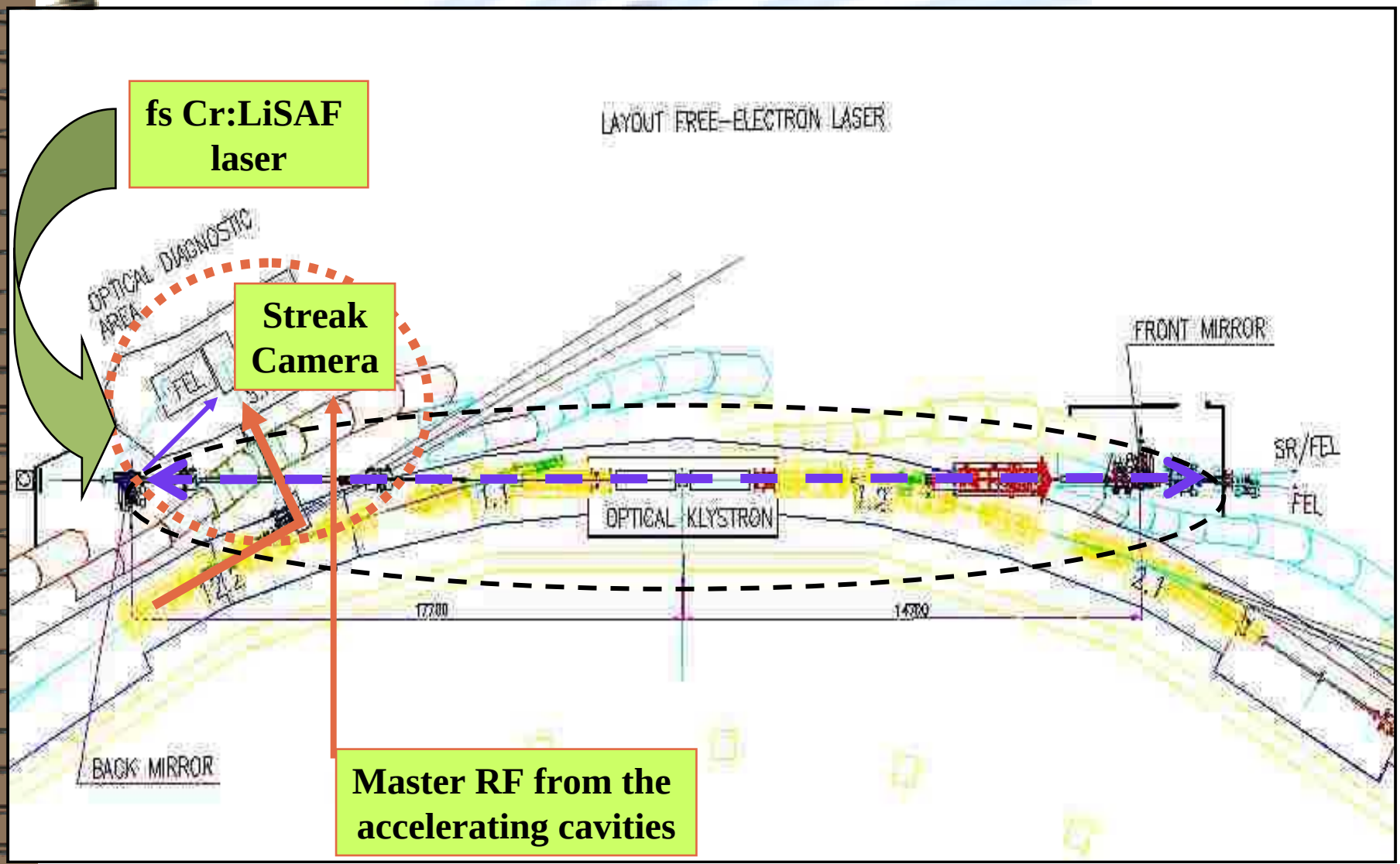
Free running **Q-Switch**

courtesy: G. De Ninno

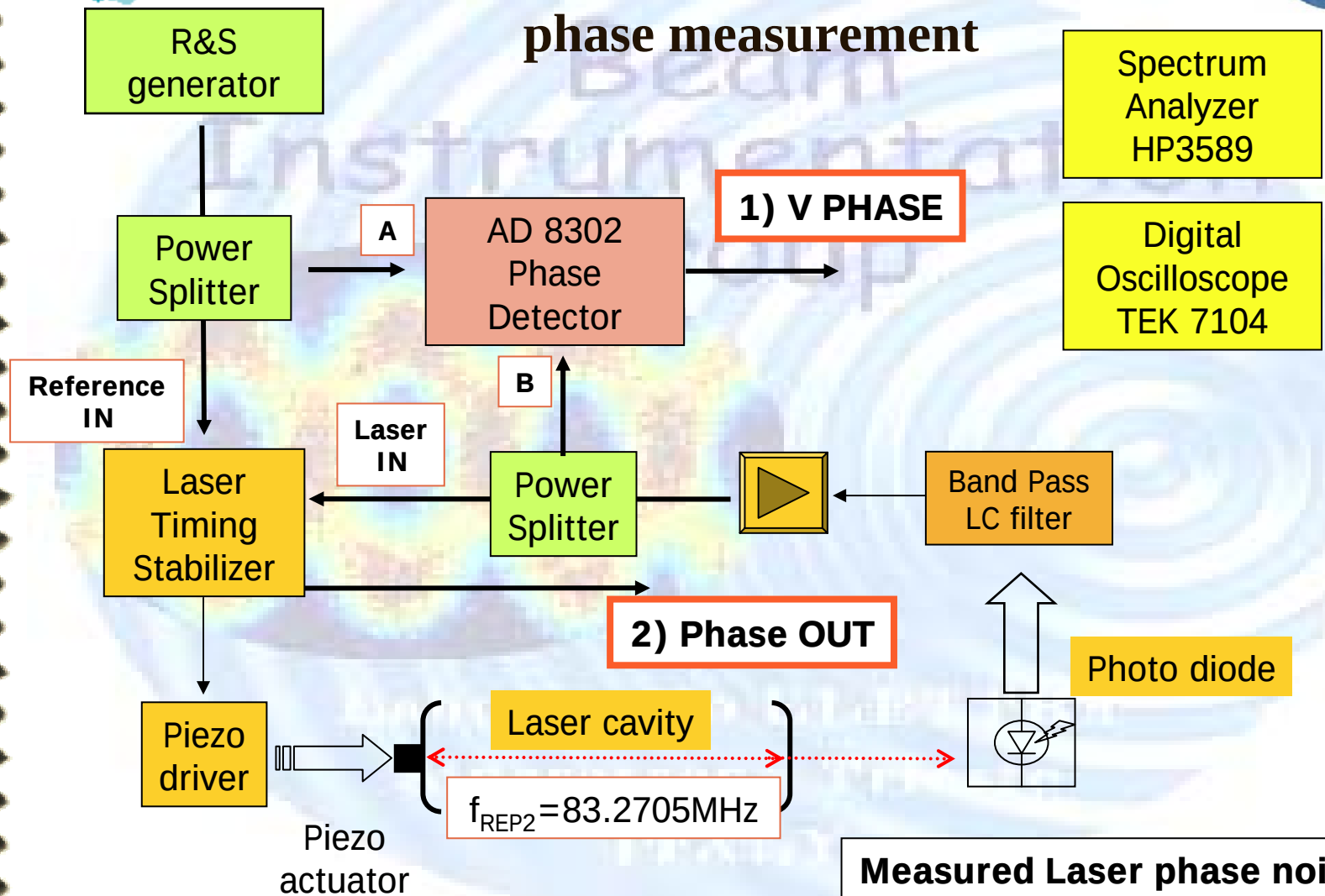
Need for synchronization

- Up to now most of the experiments have been using the average photon flux
- In a "*pump-probe*" scheme, one pulse excites the sample whereas the second one "*takes the picture*"
- Different combinations of the available sources (SR, SR-FEL, external fs Lasers) can be used: *we need to synchronize at the "pico second" level*
- As an experiment, we lock a fs laser to the electron bunches of the Storage Ring, by using a low jitter *(<1ps$_{RMS}$)* electronic module.
- To check for jitter (short term) and stability (long term) between sources
- To implement high resolution phase measurement

Lay out of section 1 of the ELETTRA Storage Ring with diagnostics Optical Laboratory

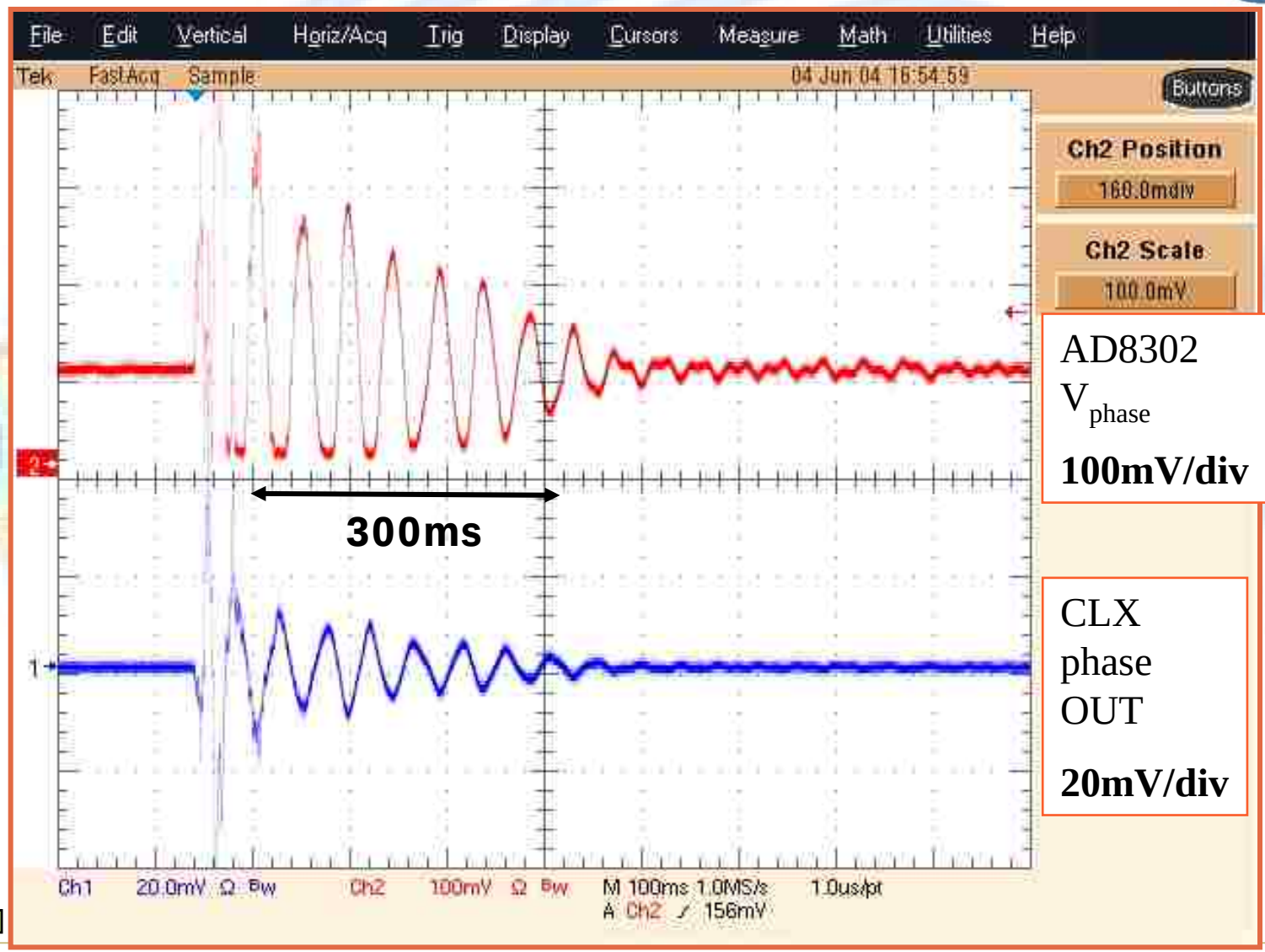


Minimizing locked laser phase noise
Redundant high resolution phase measurement



Measured Laser phase noise: 0.1ps$_{RMS}$

Locked laser damping time to an external kick

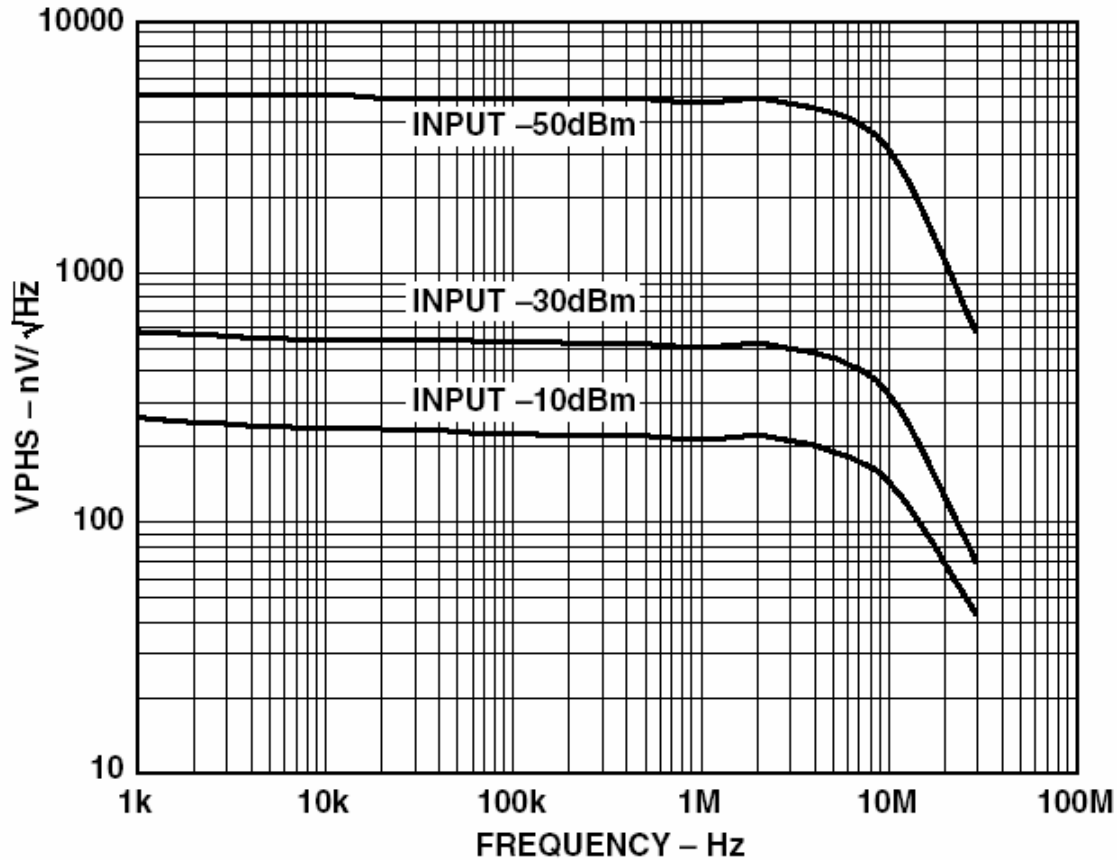


AD8302
V_{phase}
100mV/div

CLX
phase
OUT
20mV/div

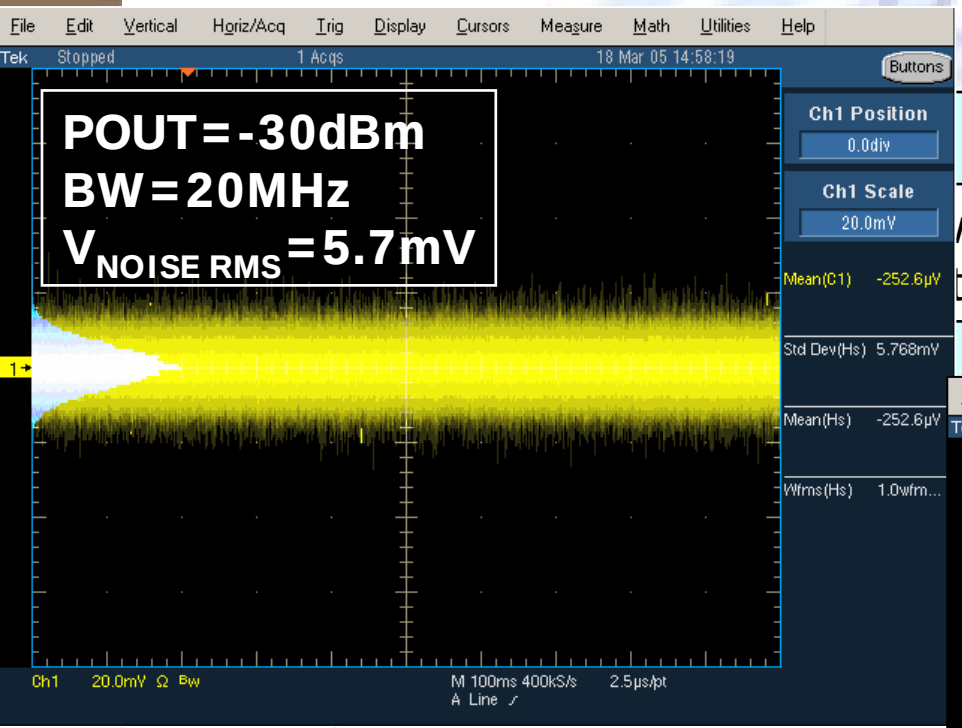
Noise Spectral Density

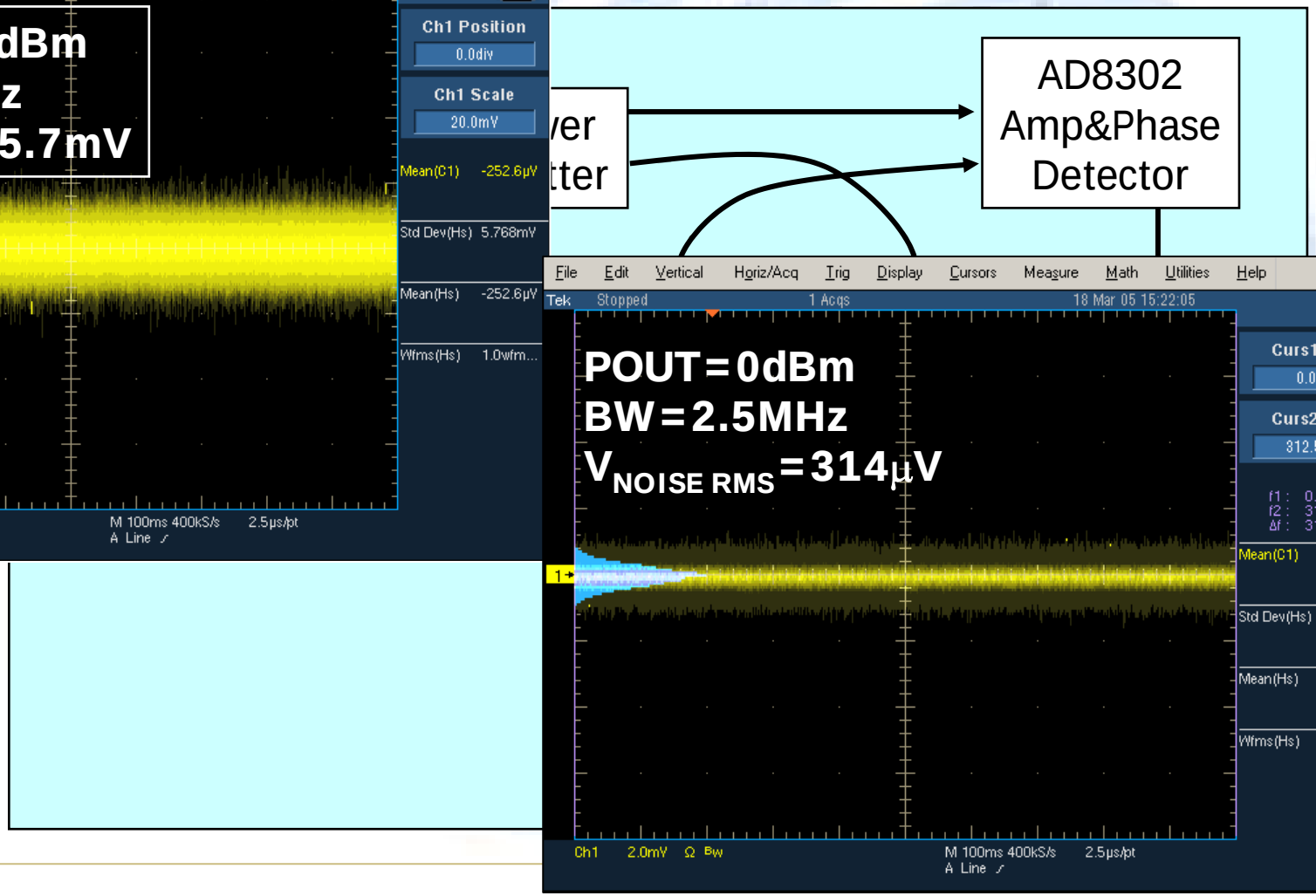
Analog Devices data sheet, Phase Detector AD8302



TPC 41. VPHS Output Noise Spectral Density vs. Frequency, P_{INPA} = –30 dBm, P_{INPB} = –10 dBm, –30 dBm, –50 dBm, and 90° Input Phase Difference

Noise measurement set-up
Phase Detector AD8302 (0÷2.7GHz)



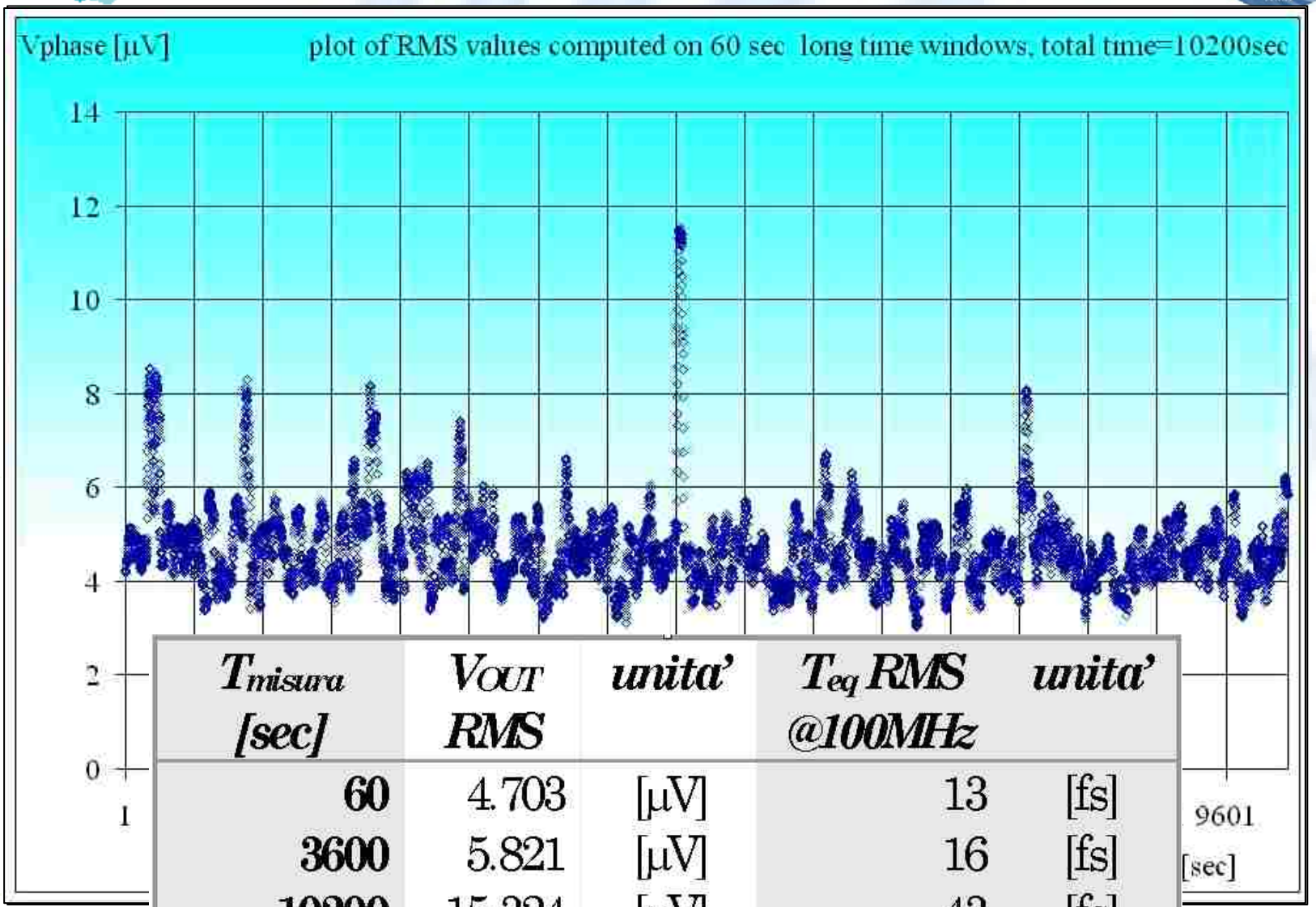


Measured data on
Noise amplitude (RMS) vs. Bandwidth
(BW=1GHz, 20MHz, 2.5MHz)
V_{PH} scaling=10mV/deg

Input level [dBm]	**Measurement bandwidth**			
	Full scope ***BW=1GHz***	BW limit ***BW=20MHz***	LP filter ***BW=2.5MHz***	DVM $7^{1/2}$ bits ***BW=1Hz***
-30	5.9mV 0.59deg	5.7mV 0.57deg	4.43mV 0.44deg	-
0	450µV 0.045deg	407µV 0,040deg	**314µV** **0,031deg**	4.7µV 0,47mdeg

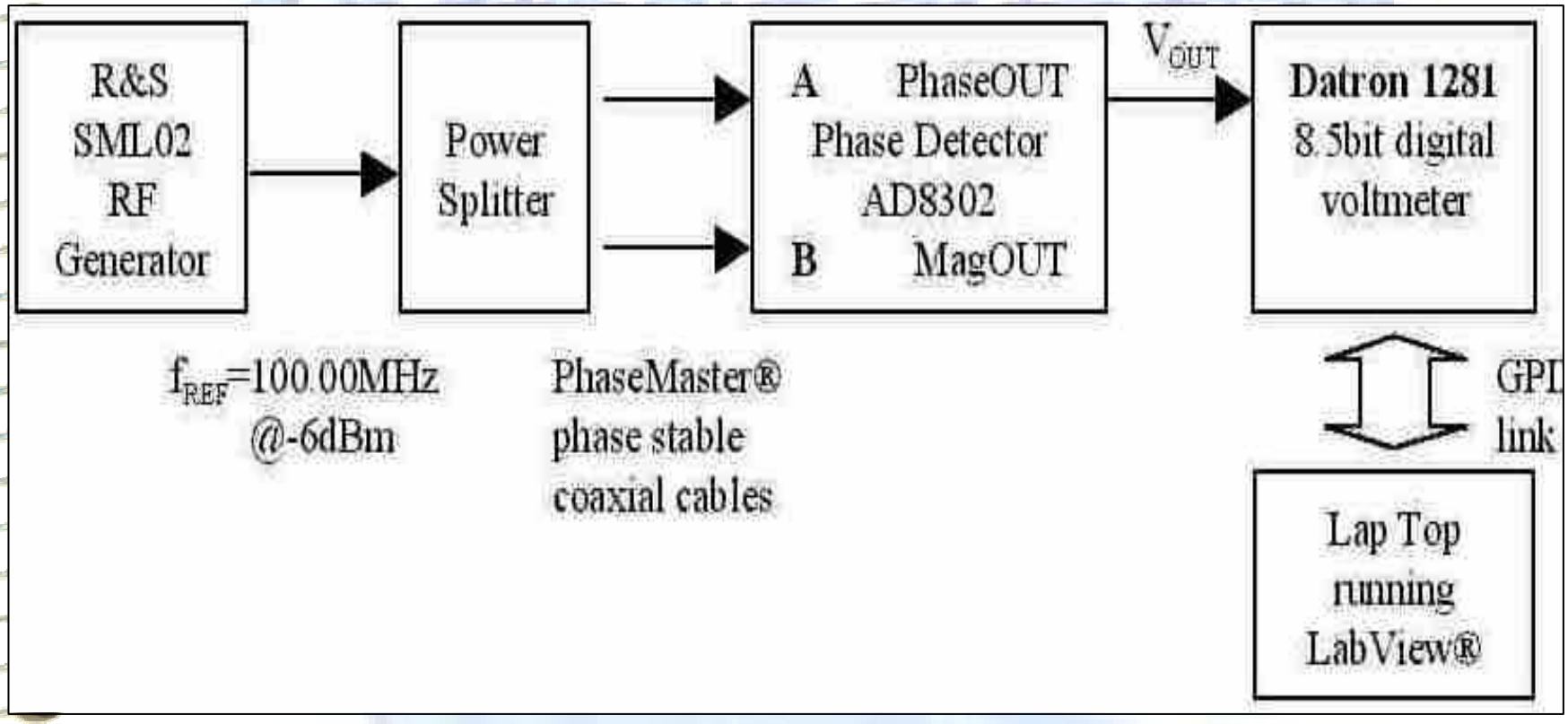
Stability tests on AD8302: data @1Hz on DVM

10mV/deg ⇒ 10μV=1mdeg (100MHz...2.7GHz)

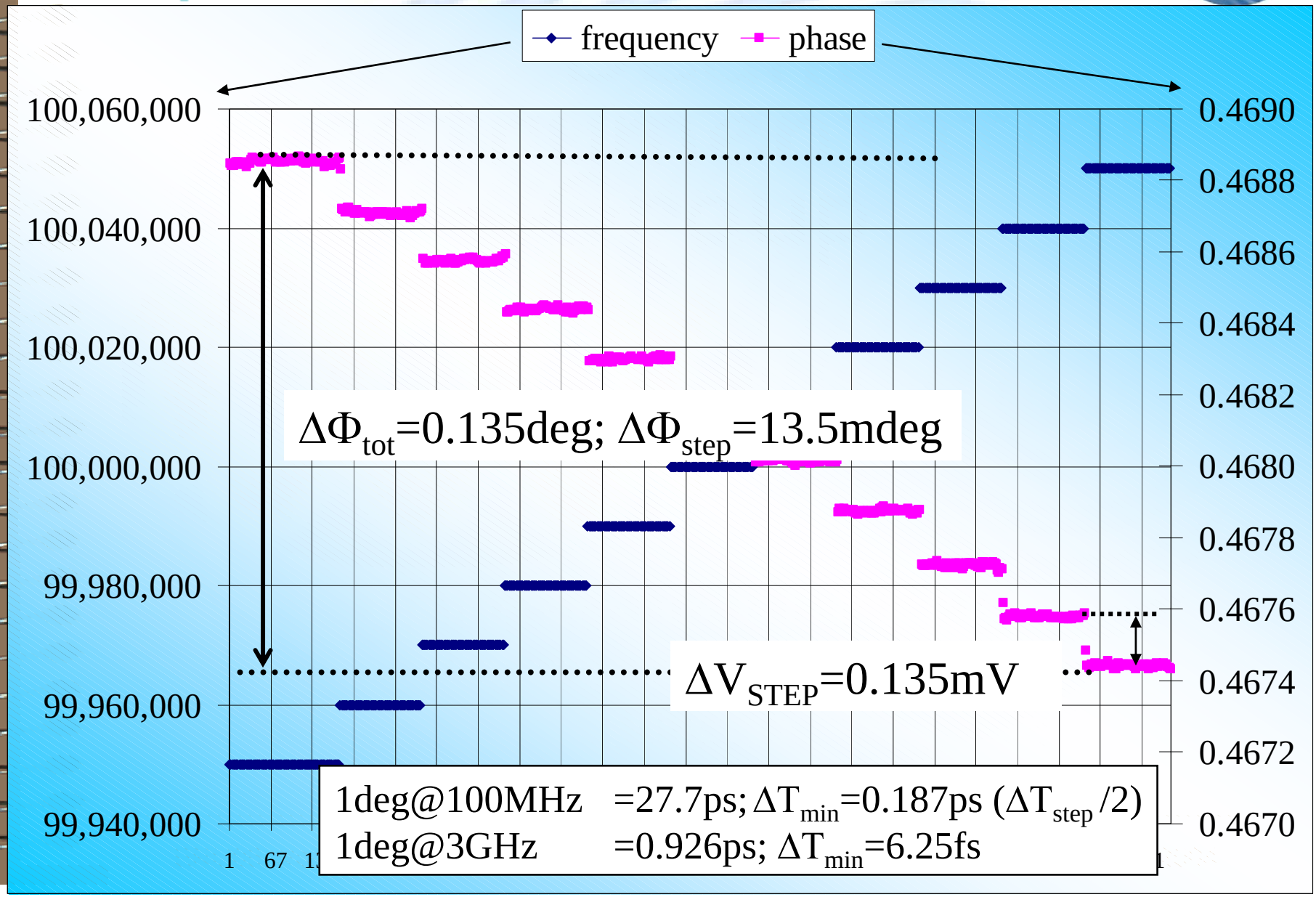


T_{misura} [sec]	V_{OUT} RMS	unita'	T_{eq} RMS @100MHz	unita'
60	4.703	[μV]	13	[fs]
3600	5.821	[μV]	16	[fs]
10200 (≈3hours)	15.324	[μV]	43	[fs]

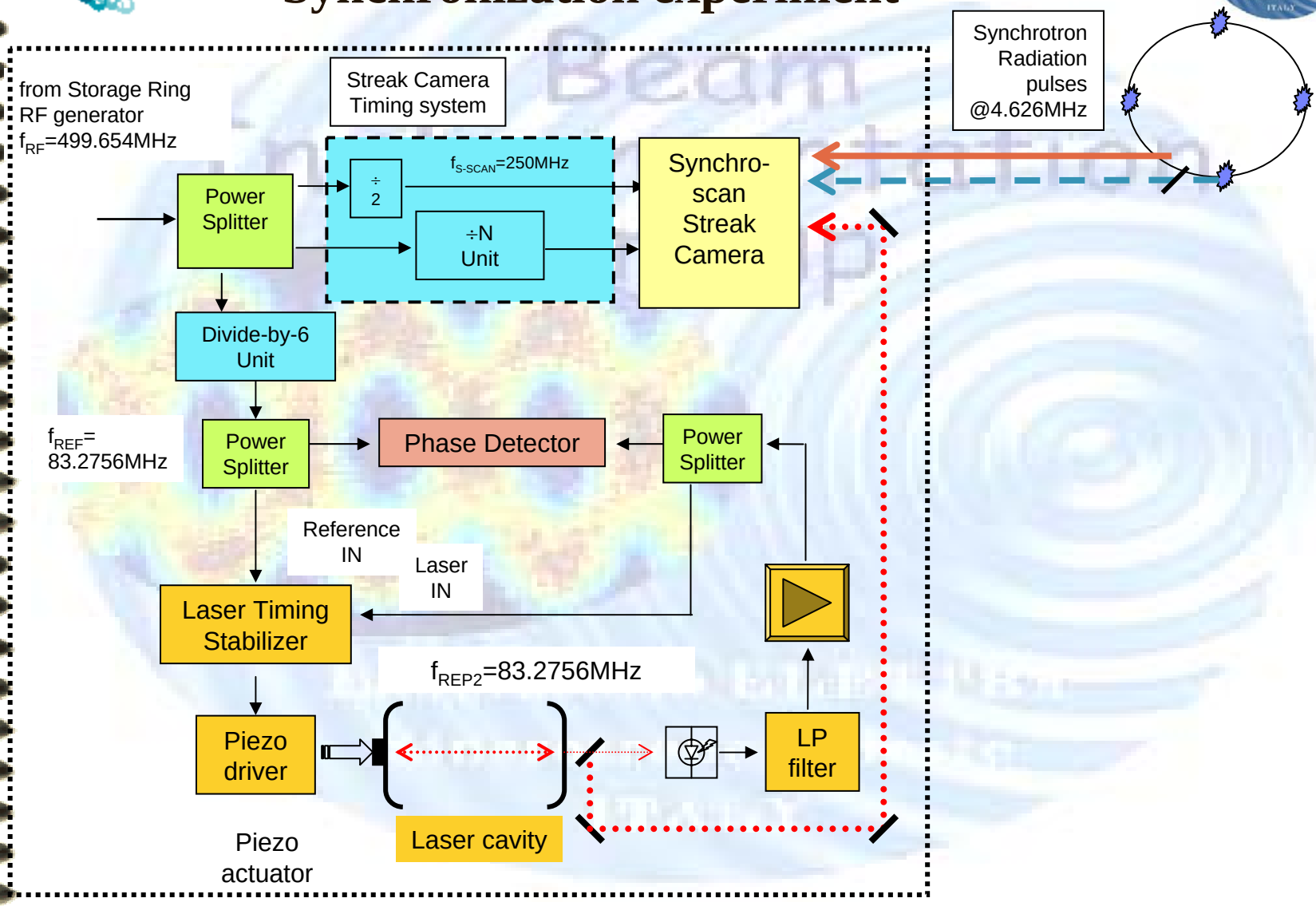
Resolution measurement set-up
Phase Detector AD8302 (0÷2.7GHz)



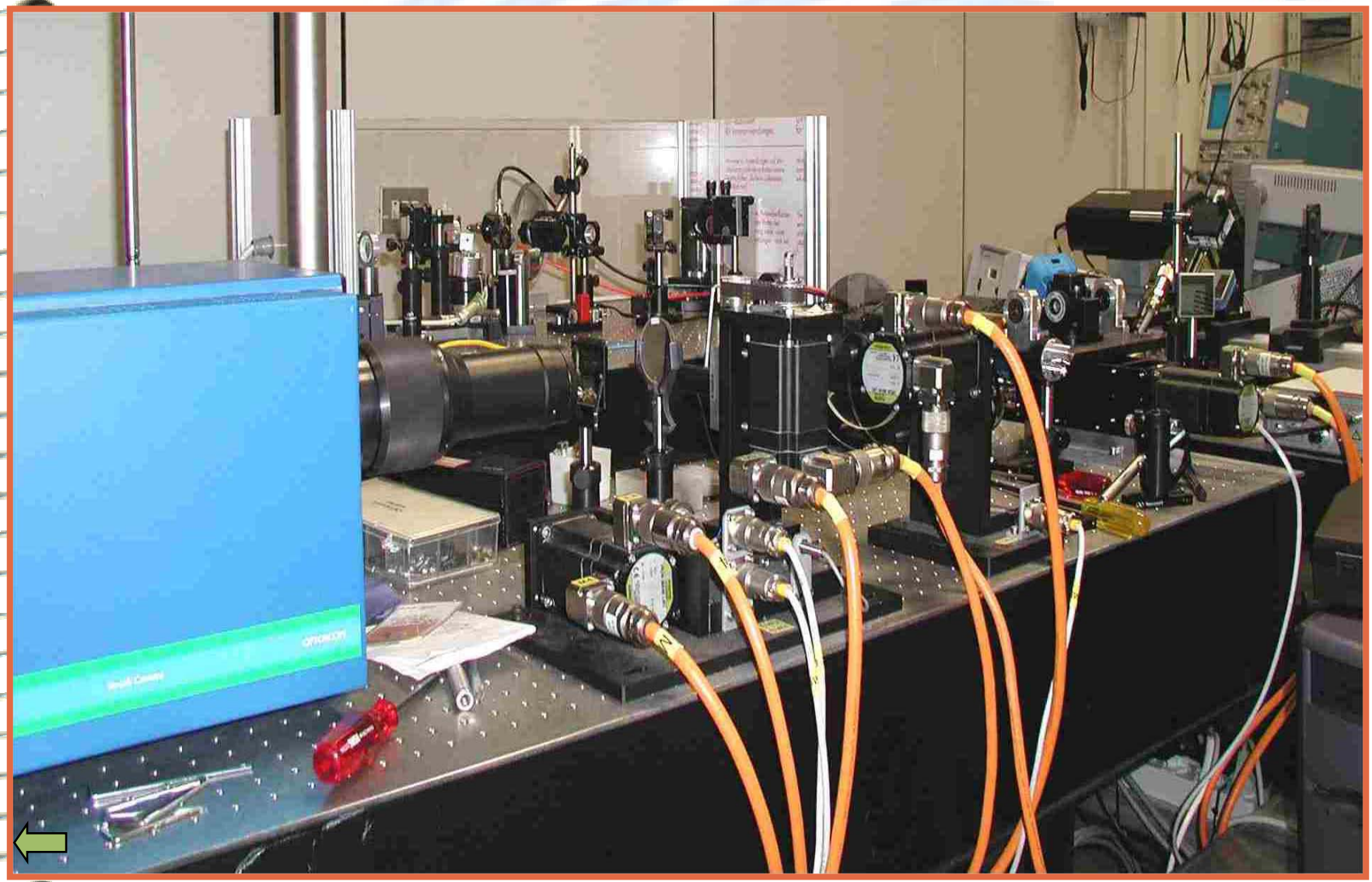
V_{phase} vs. frequency @100MHz: ΔF_{tot}=100kHz $\Rightarrow$ $\Delta\Phi_{TOT}$=0.135deg



Final configuration for the Synchronization experiment



Streak Camera and Cr:LiSAF laser in the diagnostics Optical Laboratory



Storage ring vs. external Laser frequencies

f_{RF}=499.654MHz

Multi Bunch
1 bunch / 2ns

÷5

$f_{REP1}=f_{RF}\div 5$ = 99.9308MHz

t_{LASER} = 10.006ns ⇒
1 laser pulse / 5 bunches

Coincidence laser on same bunch: every 5 revolutions (864/10 = 86.4ns)

4-Bunch SR-FEL
1 bunch / 216ns

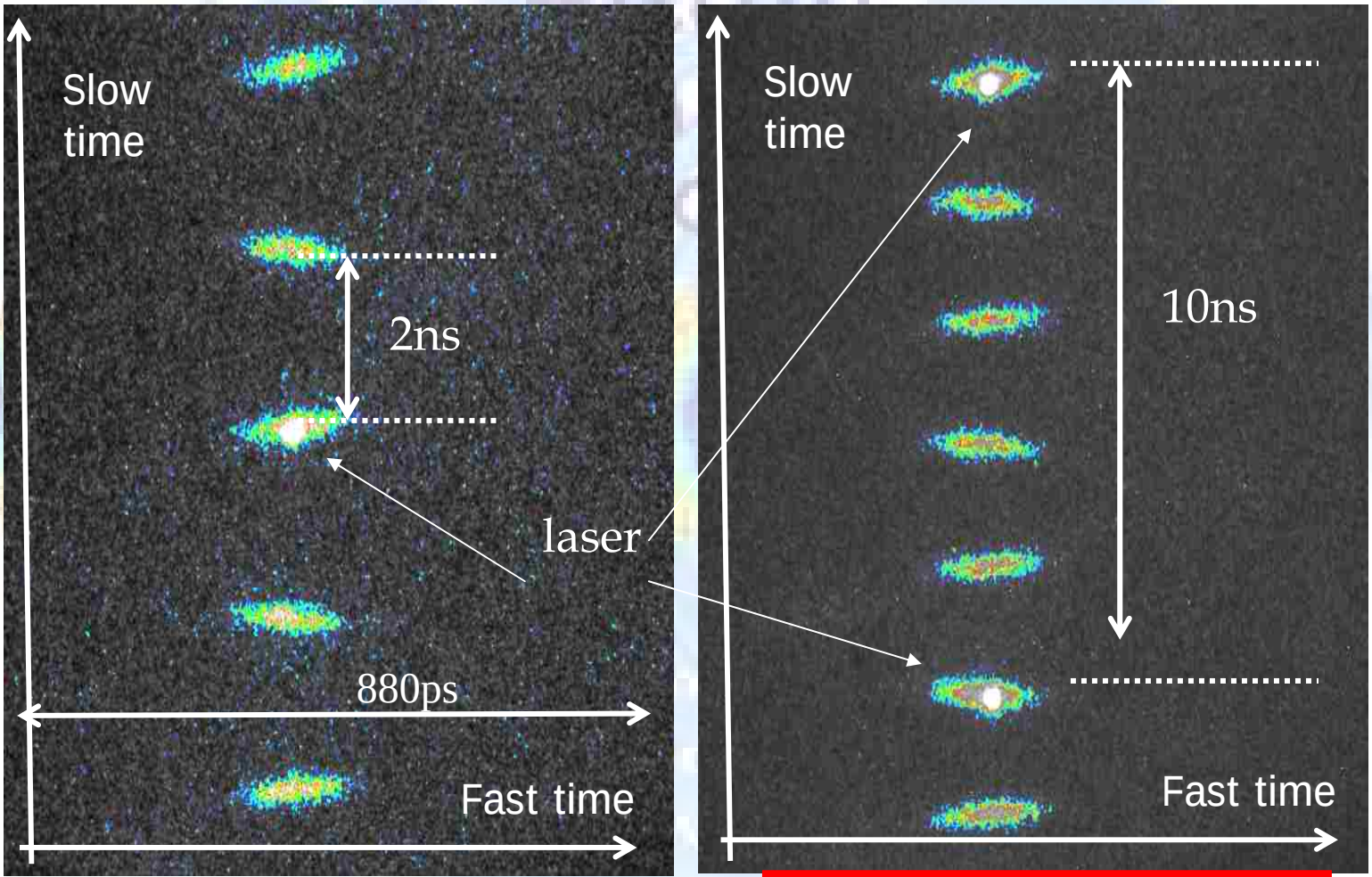
÷6

$f_{REP2}=f_{RF}\div 6$ = 83.2756MHz

t_{LASER} = 12.006ns ⇒
18 laser pulses / bunch (4B)
(12ns*18=216ns)

Coincidence laser on same bunch: at each turn

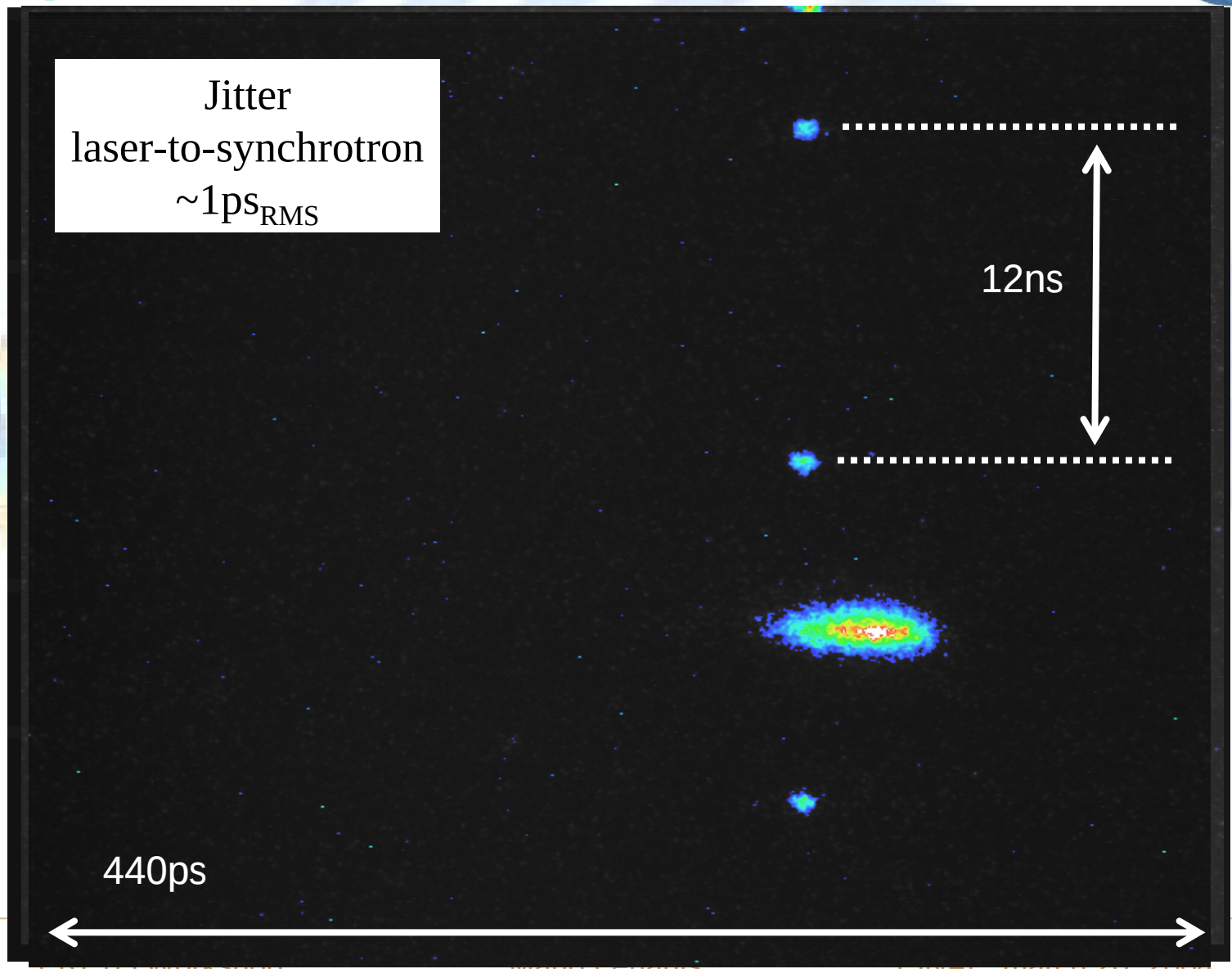
Two streak camera acquisitions (synchroscan): Multi Bunch beam + laser



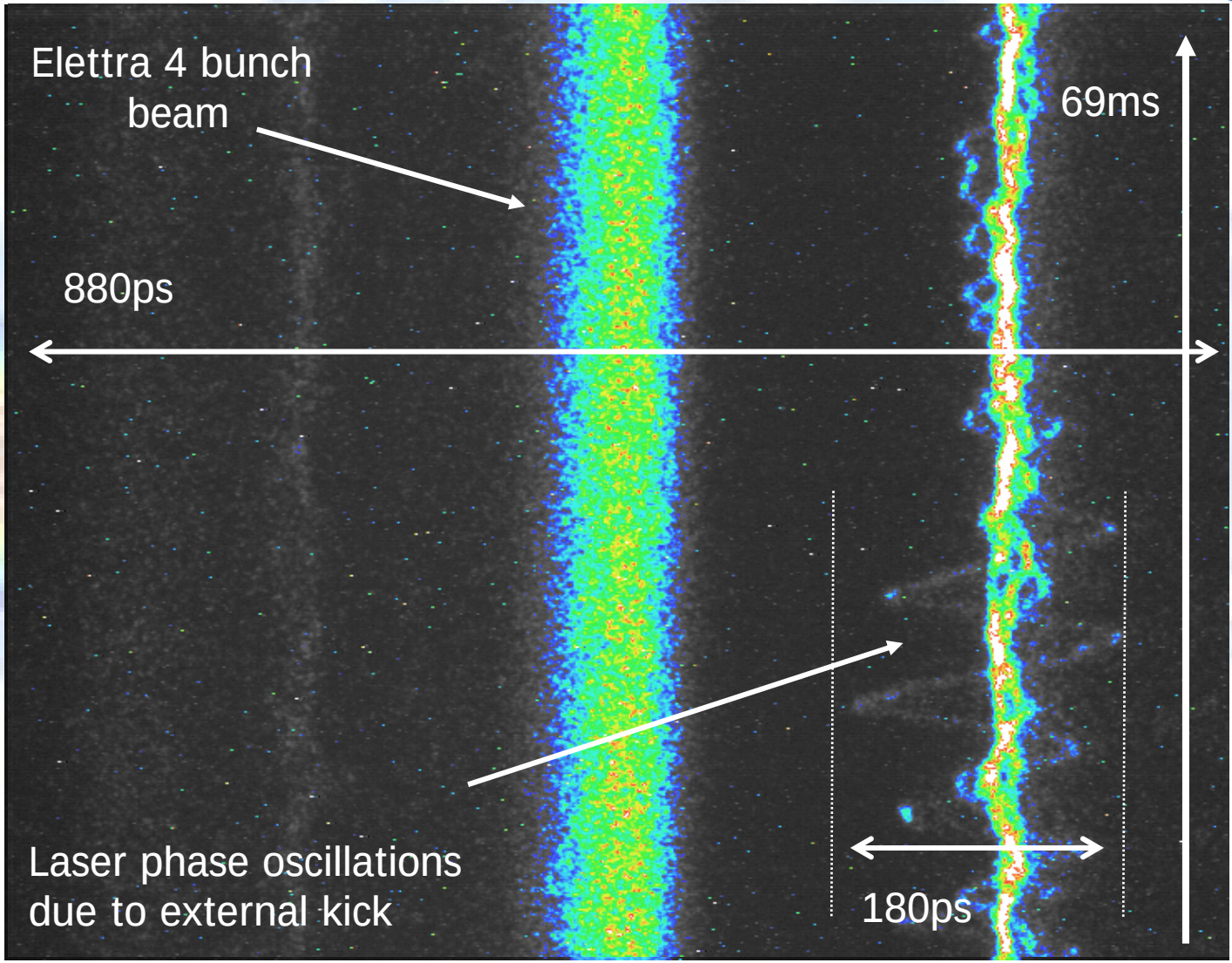
$f_{REP1}=f_{RF}\div 5 = 99.9308\text{MHz}$

4 Bunch beam (216ns/bunch)
+ laser@83.275MHz (12ns)

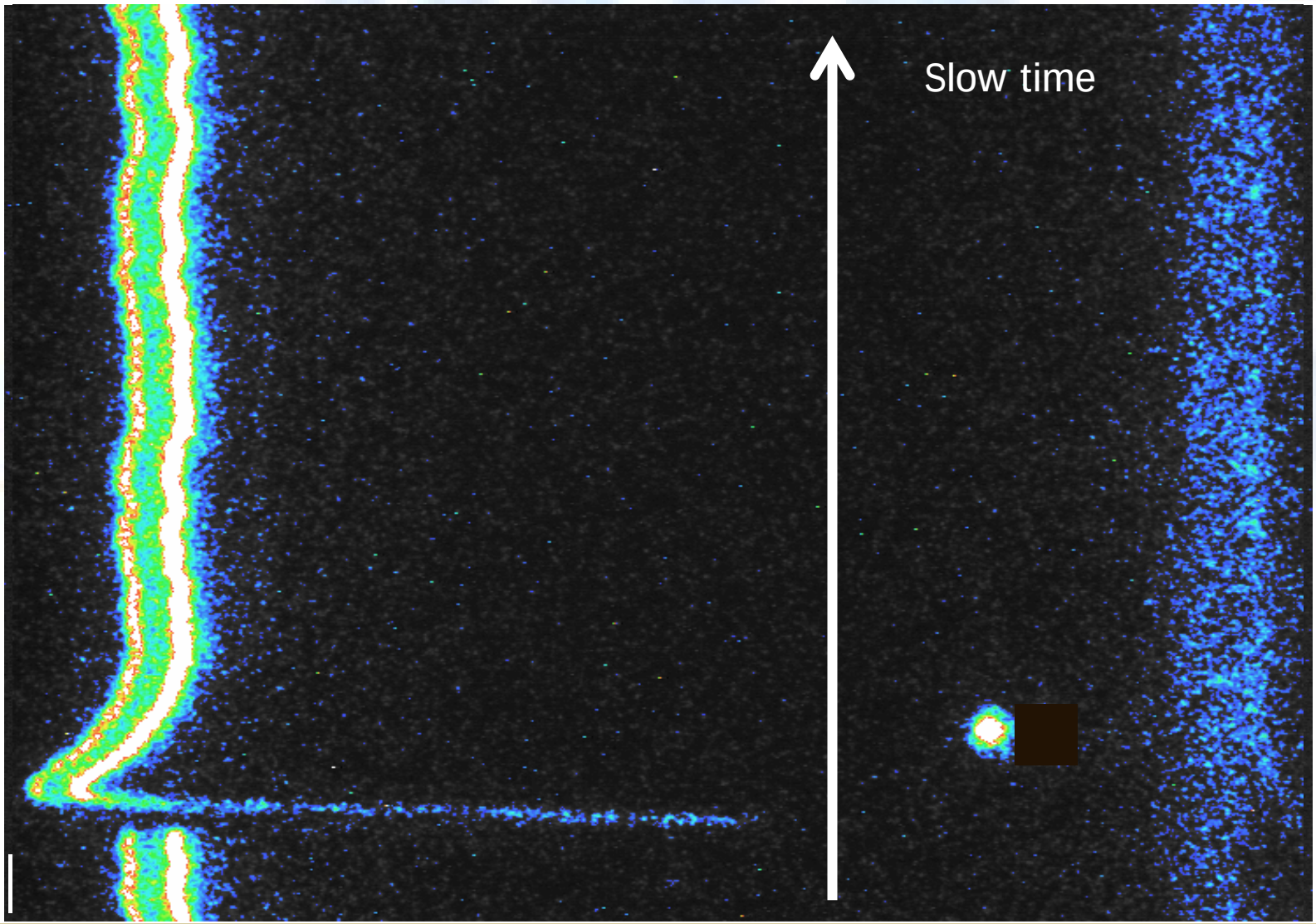
$f_{REP2} = f_{RF} \div 6 = 83.2756MHz$



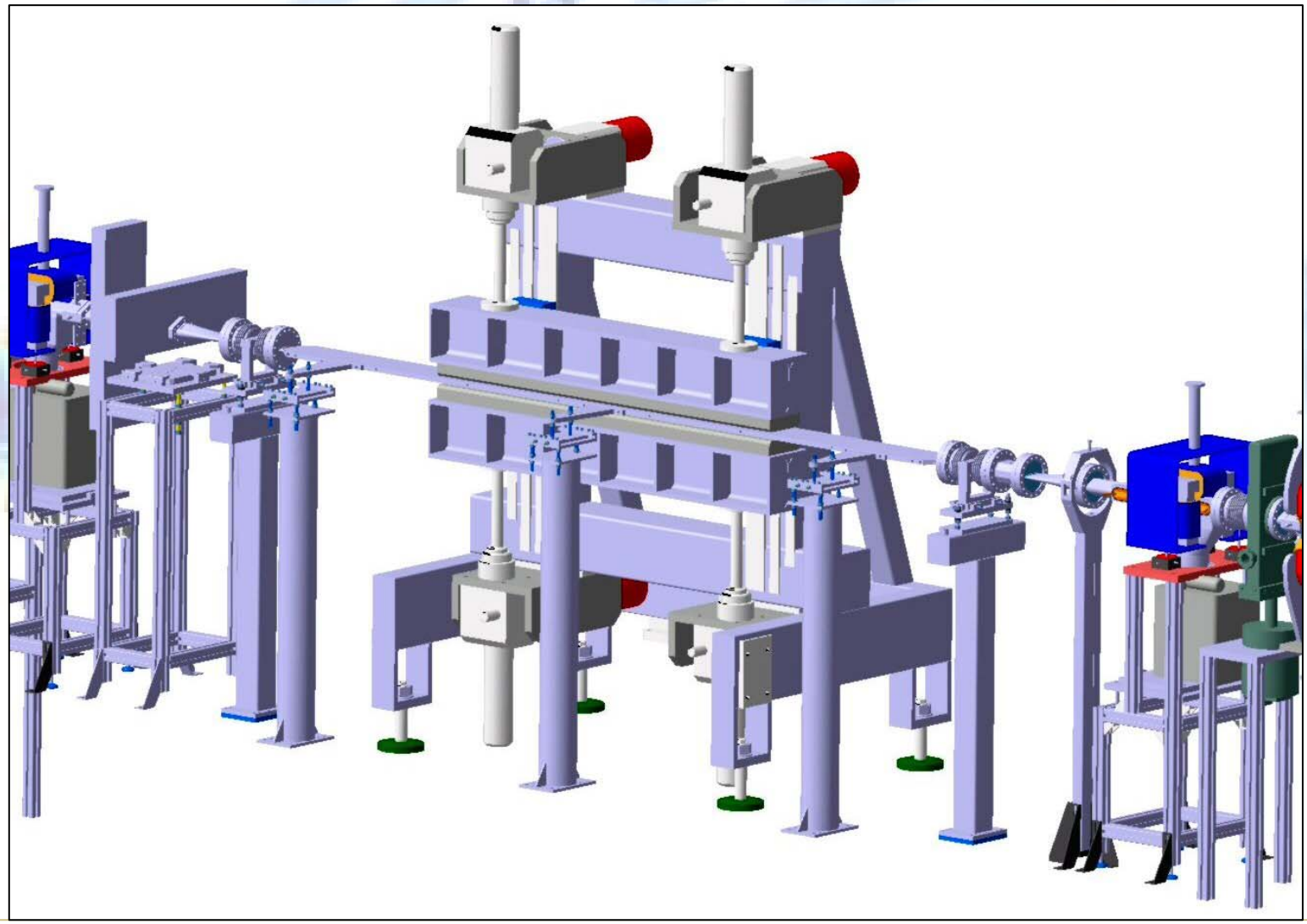
Long time (69ms) acquisitions: 5 accumulation



All three sources...

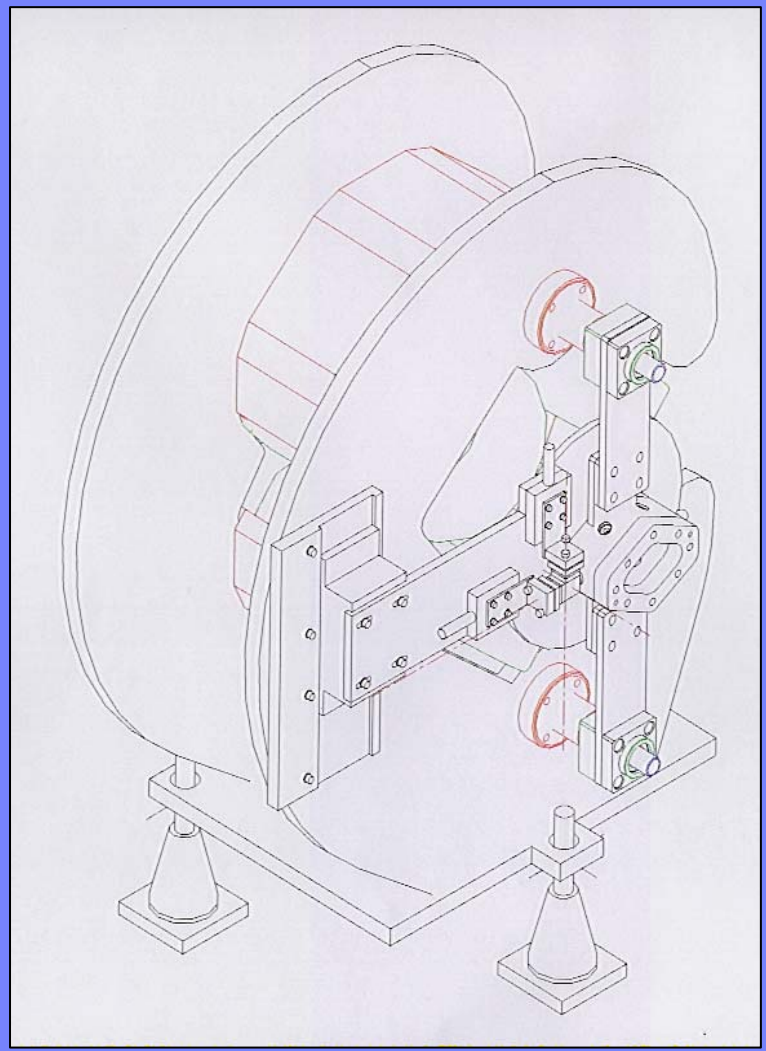


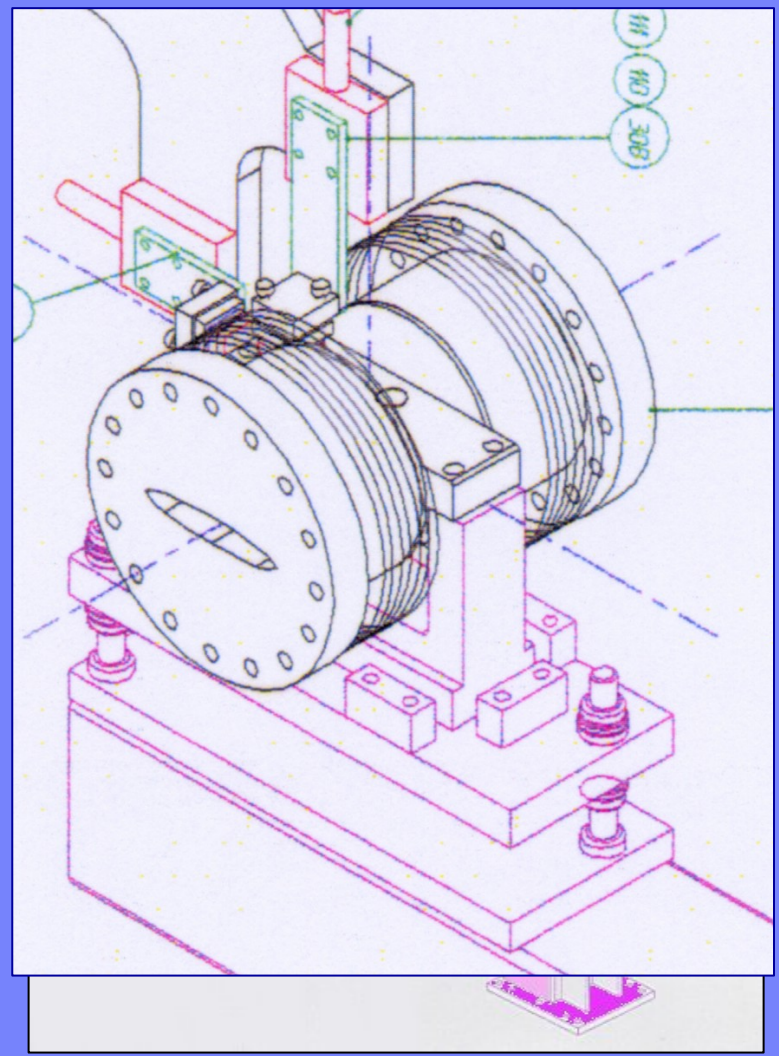
Beam Orbit stabilization at the center of the Insertion Device straight section



LEFT: std BPM mounted to the Q-pole faceplate

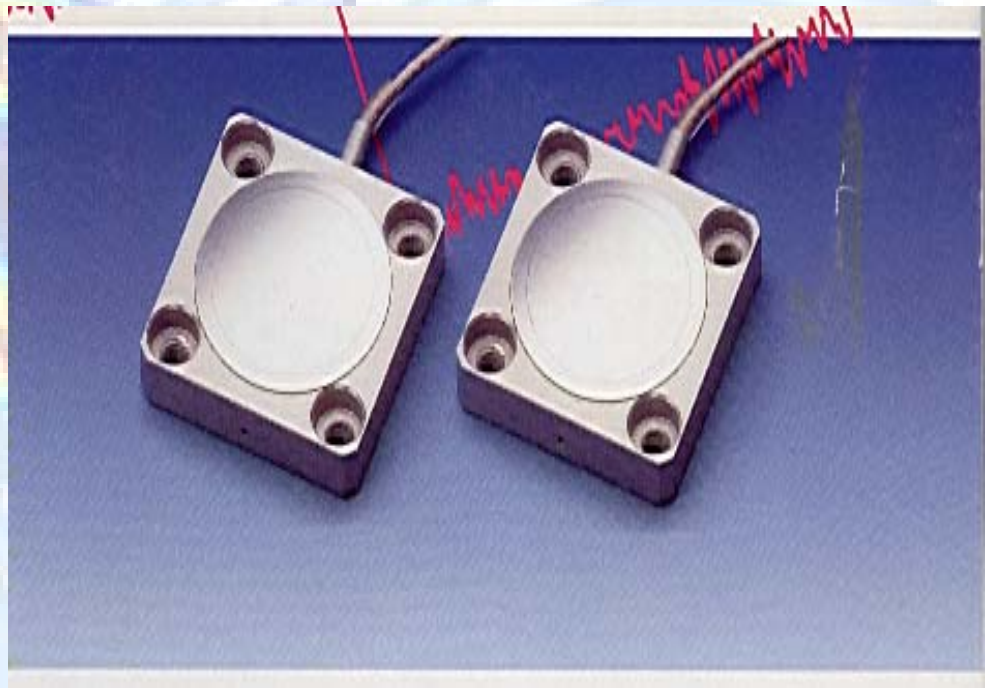
RIGHT: new LGBPM indep. Support+ref column



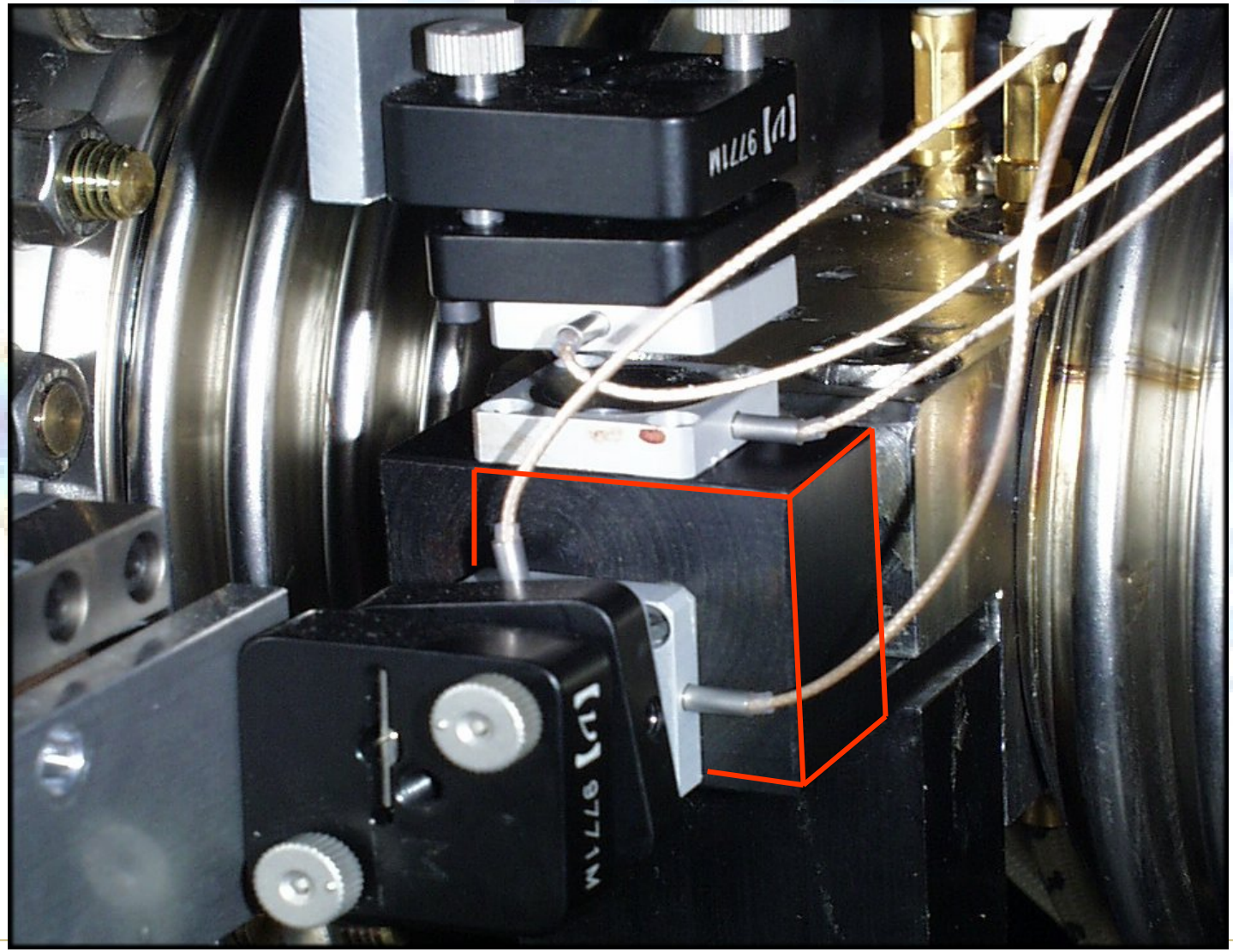


Capacitive Sensor specifications (by Physik Instrumente)

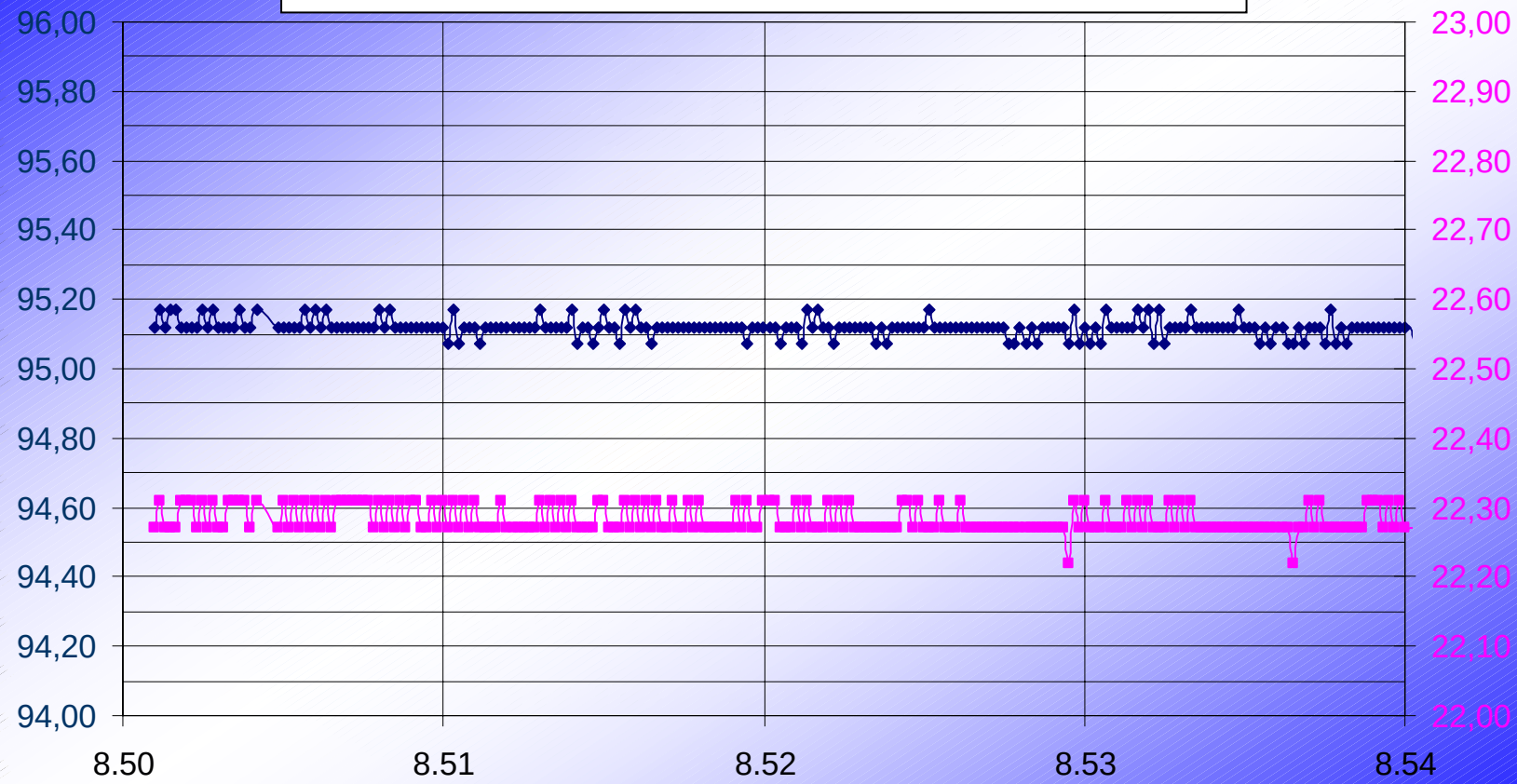
- It provides sub-nm resolution over a 300μm range
- It's linear: <0.05%
- Low temp drift: -30ppm/°K
- It has 3 kHz bw
- It provides a non-contact measure



Two pairs of Capacitive Sensors monitoring the X&Y position of Low Gap BPM

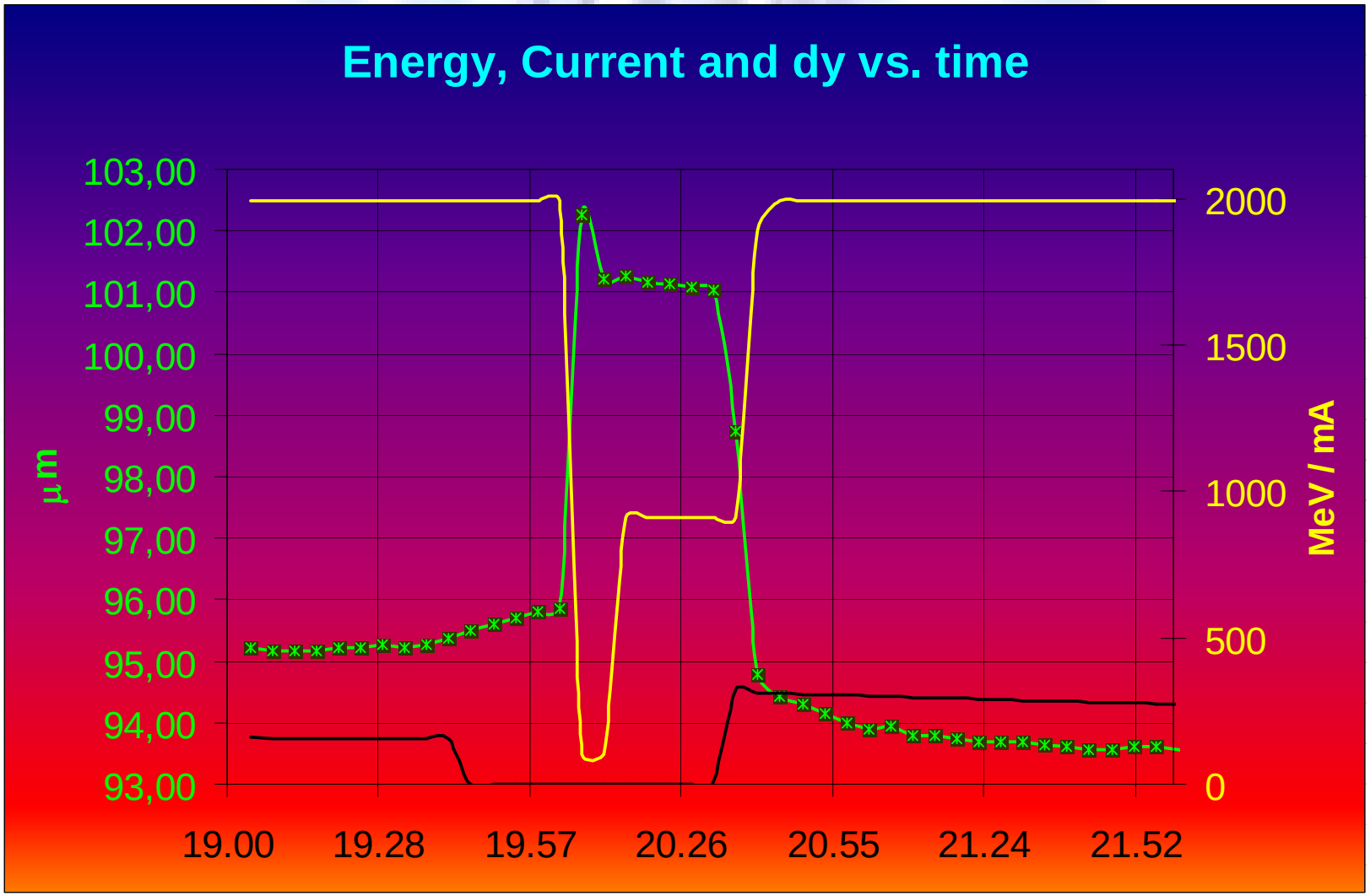


Noise on real position readings in the machine tunnel at 1Hz

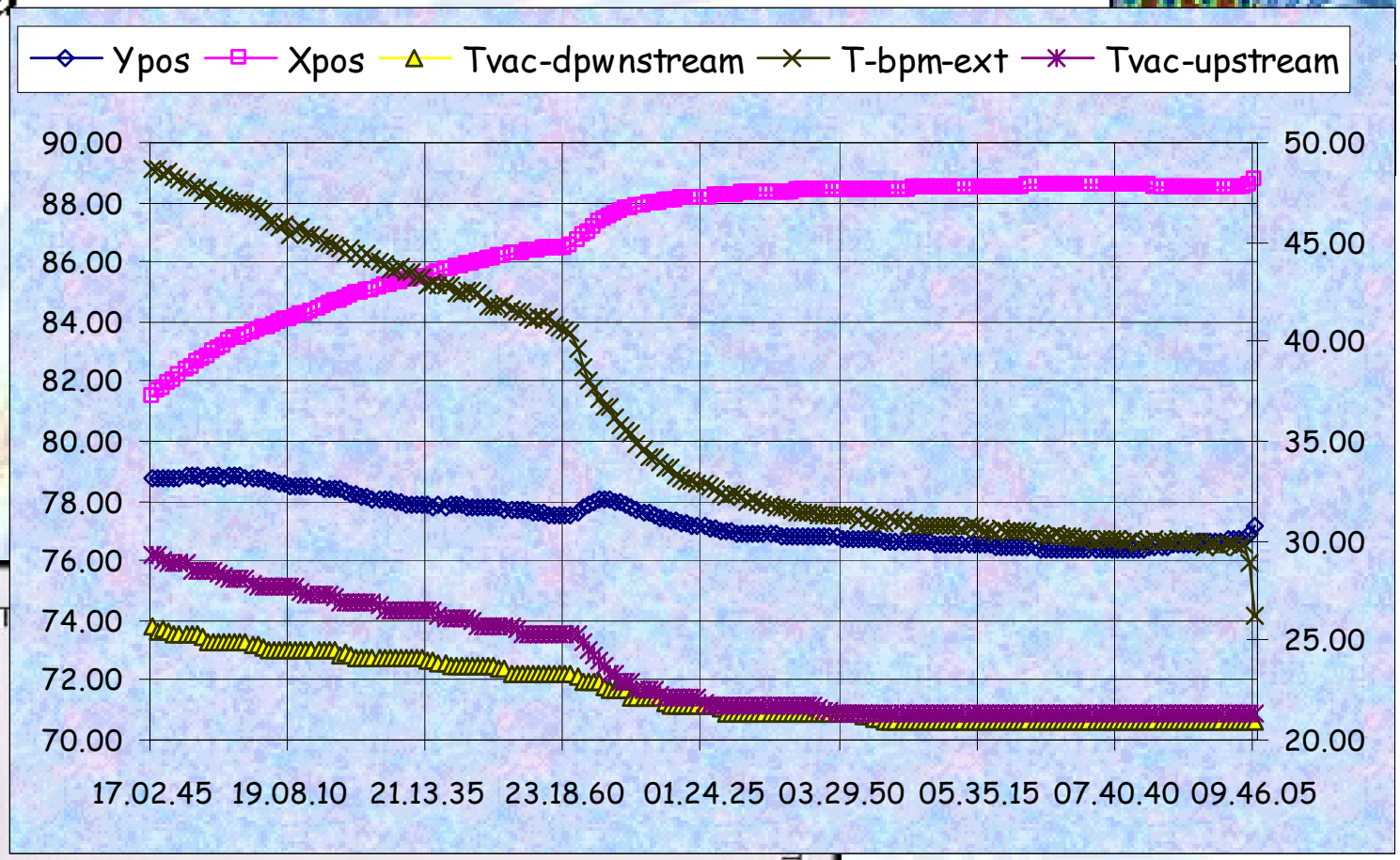


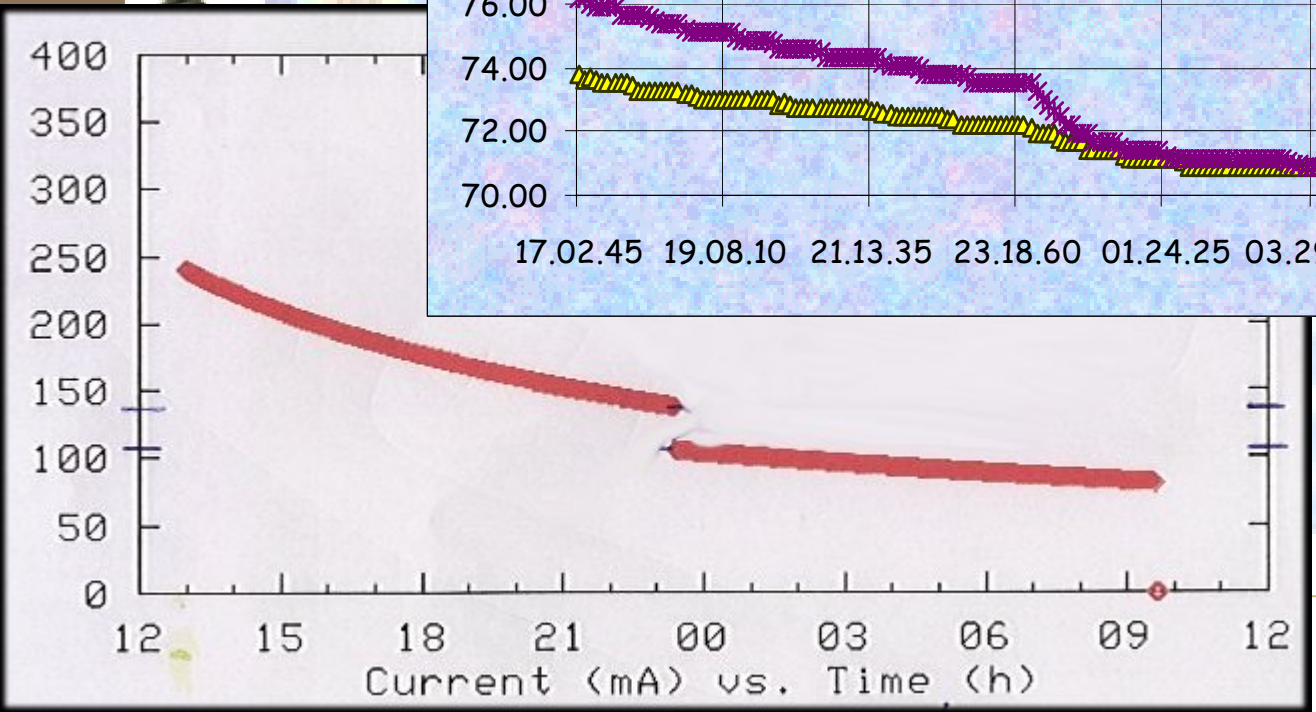
y_{RMS} = 30nm ; $y_{pk\text{-}pk}$ = 100nm

Drift of the Low Gap BPM vertical pos. during re-fill of the Storage Ring

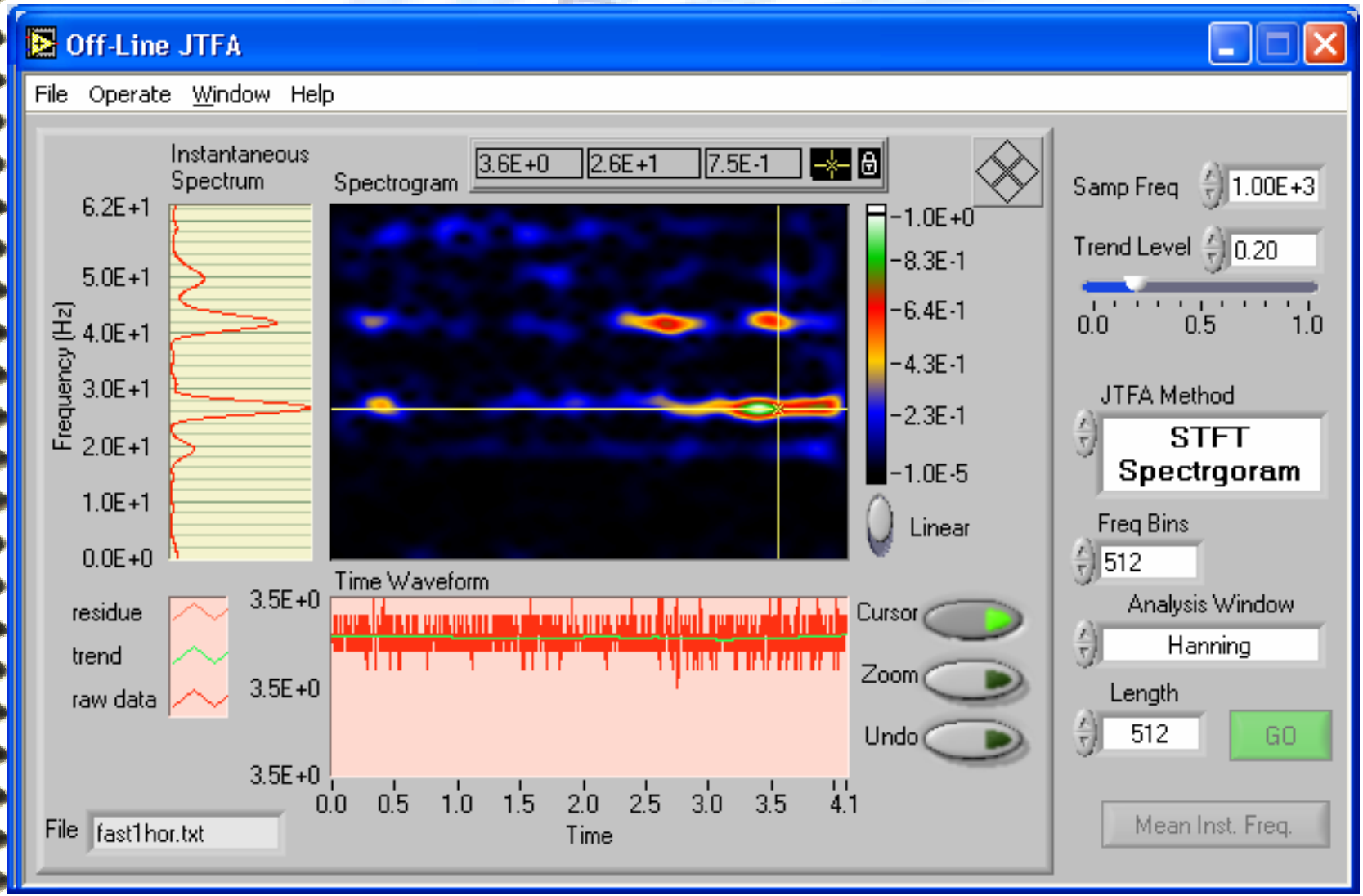


RUN 71; 12-13/04/01

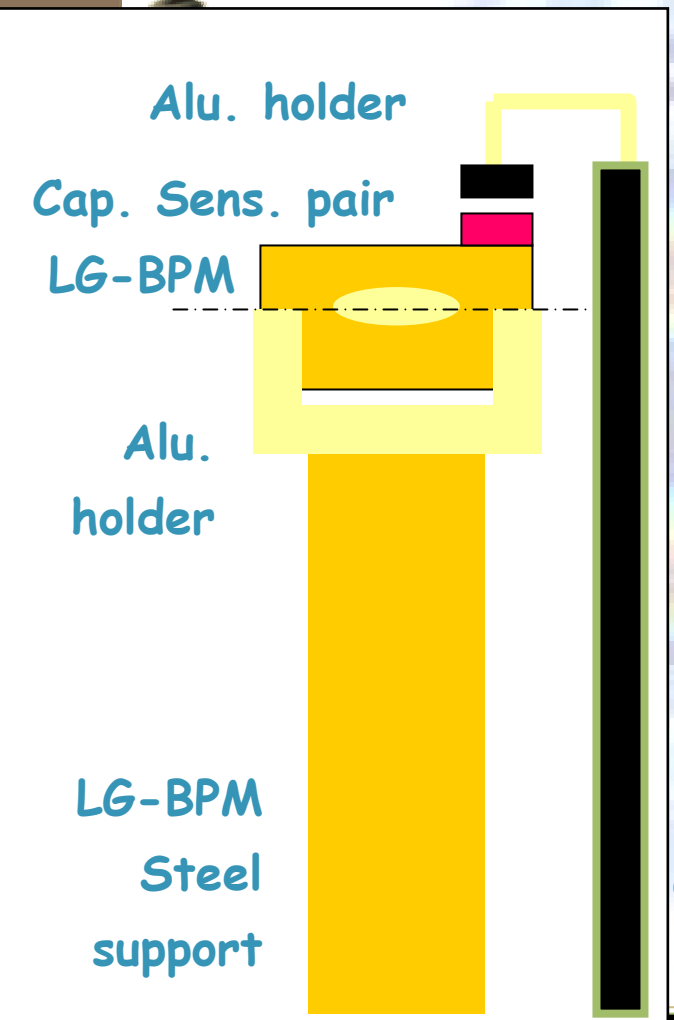




Joint Time Frequency Analysis based on LabView tool



Model of the Support System: vertical axis

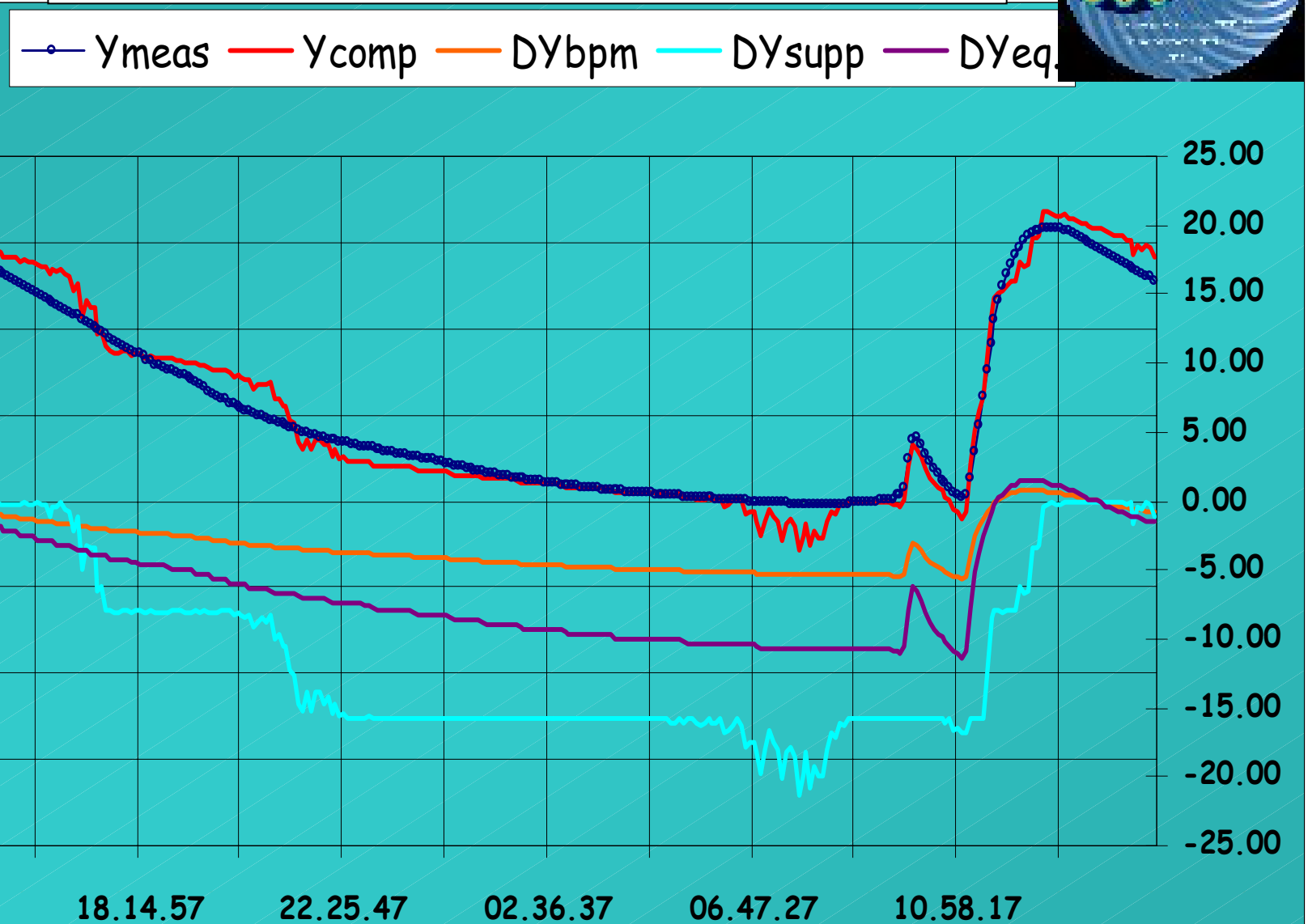


α carb. fiber	=	$-0.1\mu m/(m^oC)$
α steel	=	$18\mu m/(m^oC)$
α aluminum	=	$22\mu m/(m^oC)$
$L_{support}$	=	1.1m
$h_{LG-bpm}/2$	=	0.025m
h_{holder}	=	0.01m

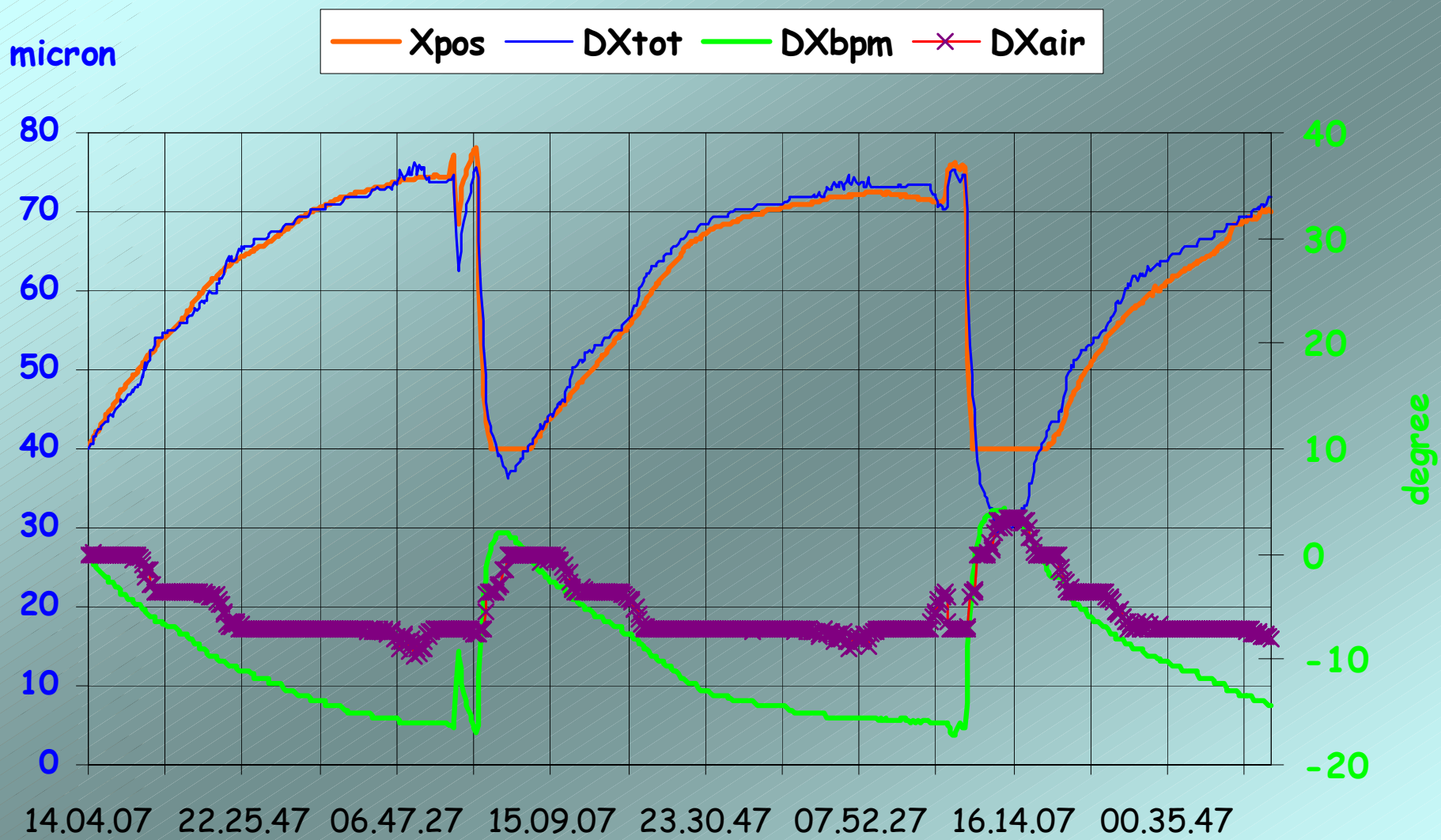
$$\Delta L = \Delta T_{air} * L_{supp.} + \Delta T_{BPM} * (h_{BPM} + h_{eq.})$$

Carbon Fiber
Reference Column

Measured ΔY vs. Computed ΔY



Measured ΔX vs. Computed ΔX



M. Ferianis

October 2000