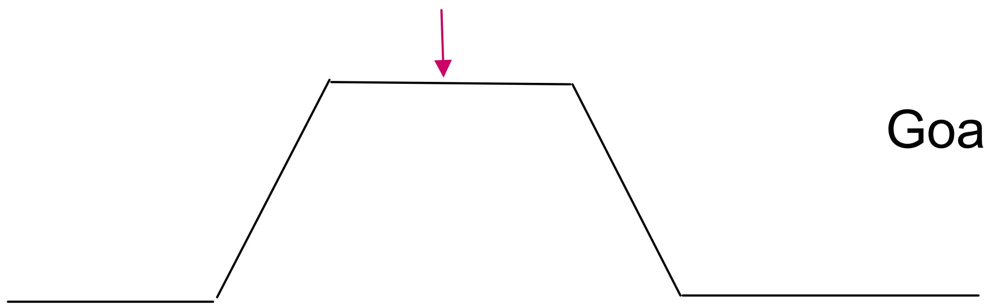
BC2 Chicane BPM Commissioning

01-12-09

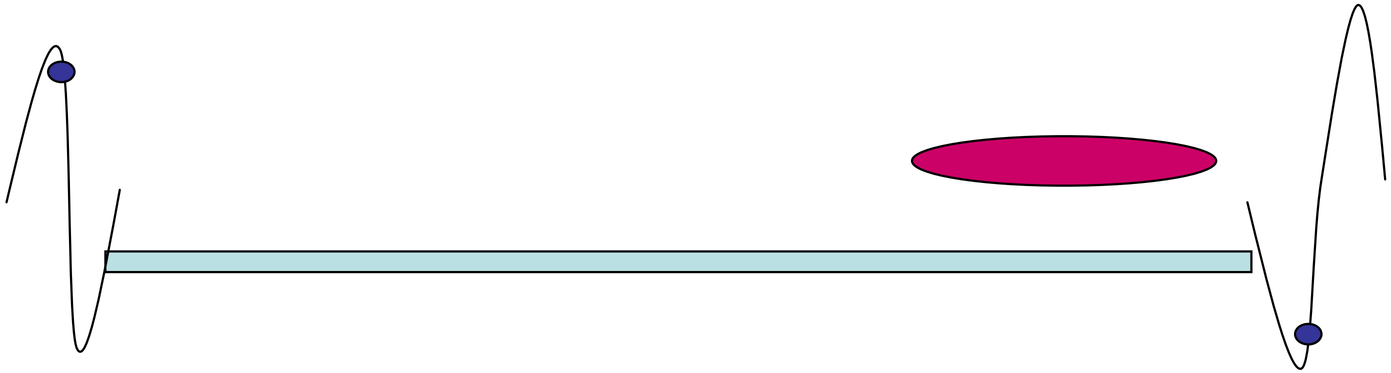


Goals: < 5 um resolution
over 10 cm range
robust operation
for all beam shapes

7 Independent BC2 Energy Stability/Position Measurements

Measurement System	**Position resolution**	**Energy resolution**	**Dynamic range**
In-loop Vector Sum (drifts)	70 µm	2e-4 $\pm$ 1e-2	10 cm
Out-of-loop Vector Sum (drift-free)	70 µm	2e-4	10 cm
BC2 BPM 1.3 GHz front-end	25 µm	7e-5	80 mm
Photomultiplier Tube Monitor	15 µm to 30 µm	4e-5 to 9e-5	2 mm
BC2 BPM 10.4 GHz front-end	(3 µm to) 5 µm	1e-5	2 mm
BC2 BPM optical front-end	2 µm	6e-6	1 mm
time-of-flight with 2 BAMs	(6 fs)	(1e-5) anticipated	

BC2 BPM Beam Position Measurement Basics



left = (R16 – R56)*dE/E
right = (R16 + R56)*dE/E

sum = 2*R16*dE/E
diff = 2*R56*dE/E

arrival = sum/2
position = diff/2

If both signals increase or decrease, you have an arrival time change

If the signals go in opposite directions, you have a position change

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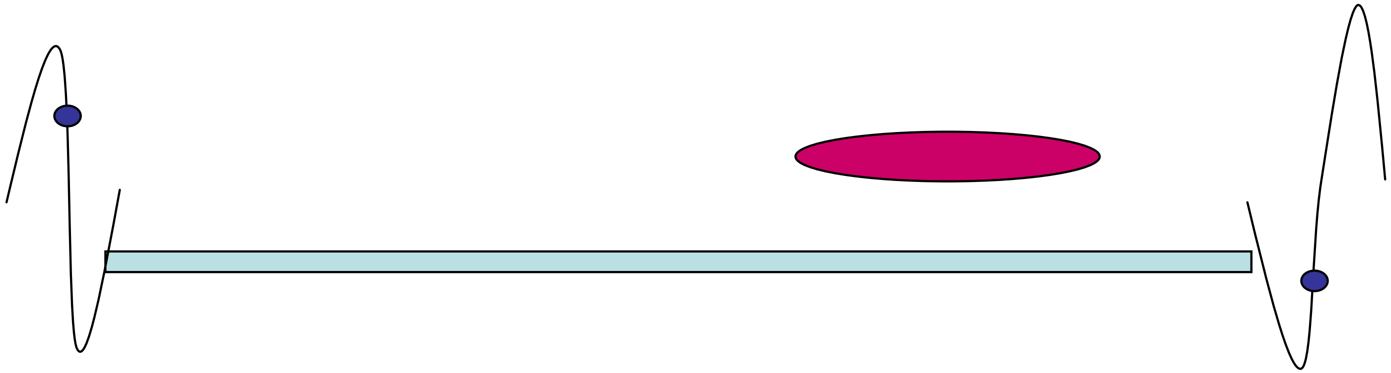

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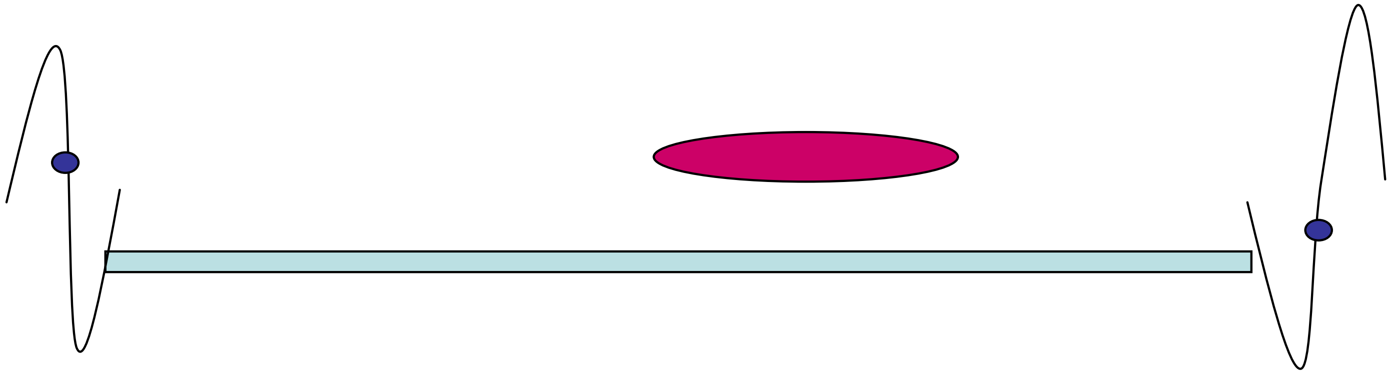

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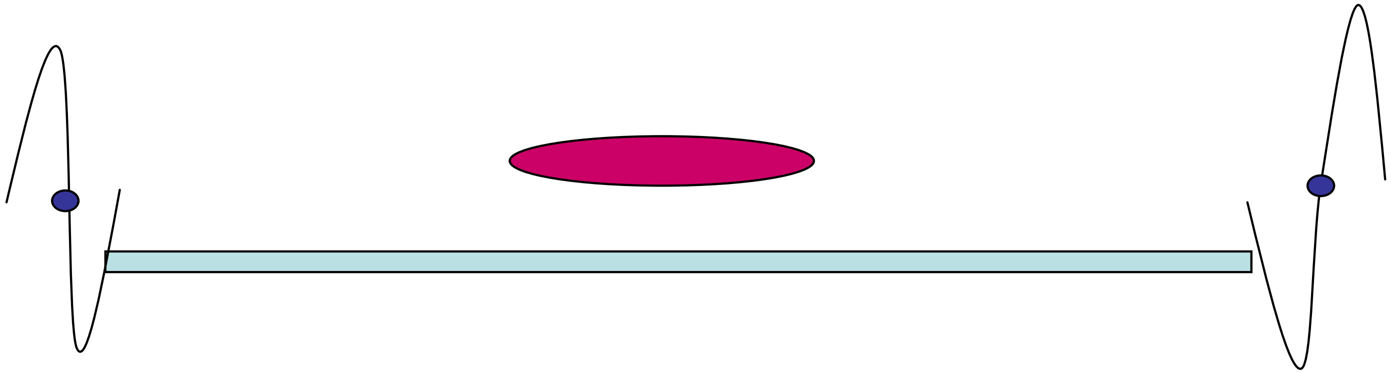

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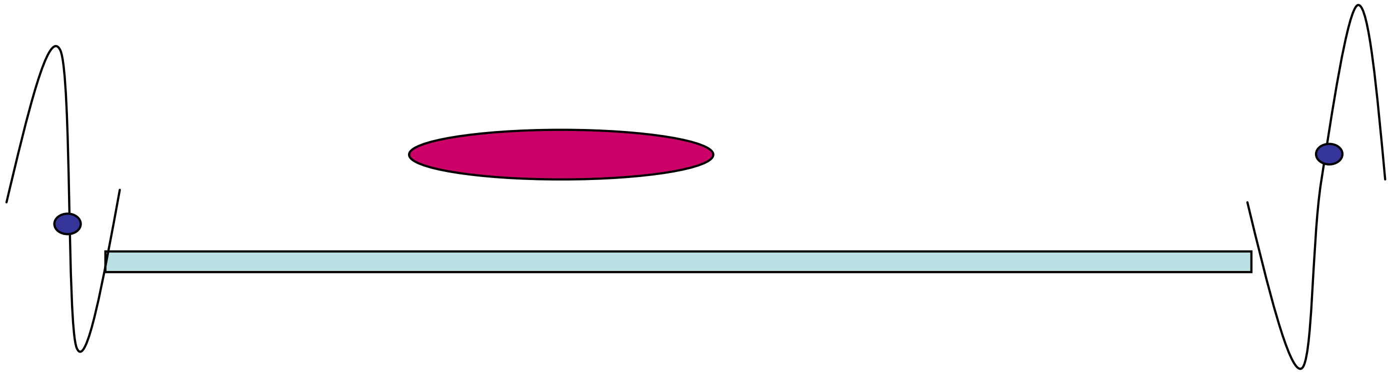

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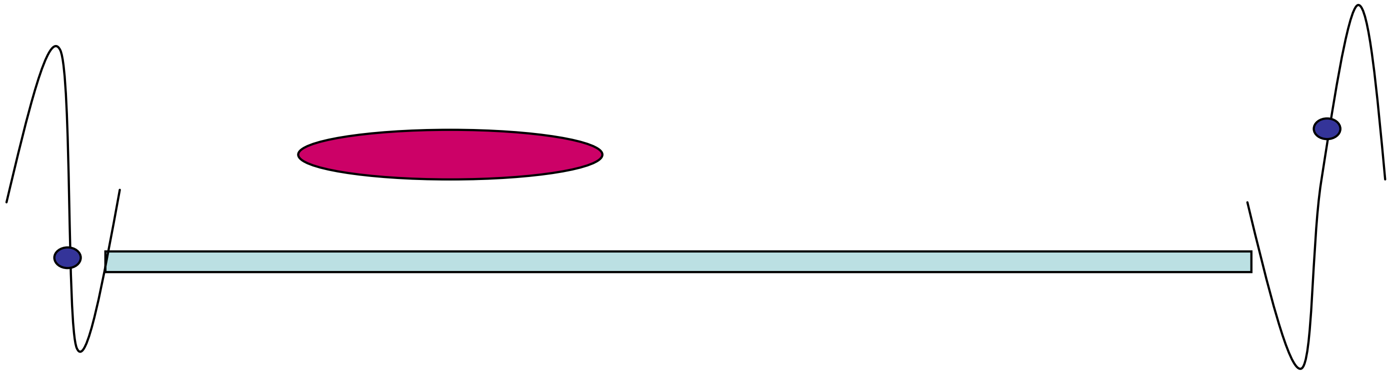

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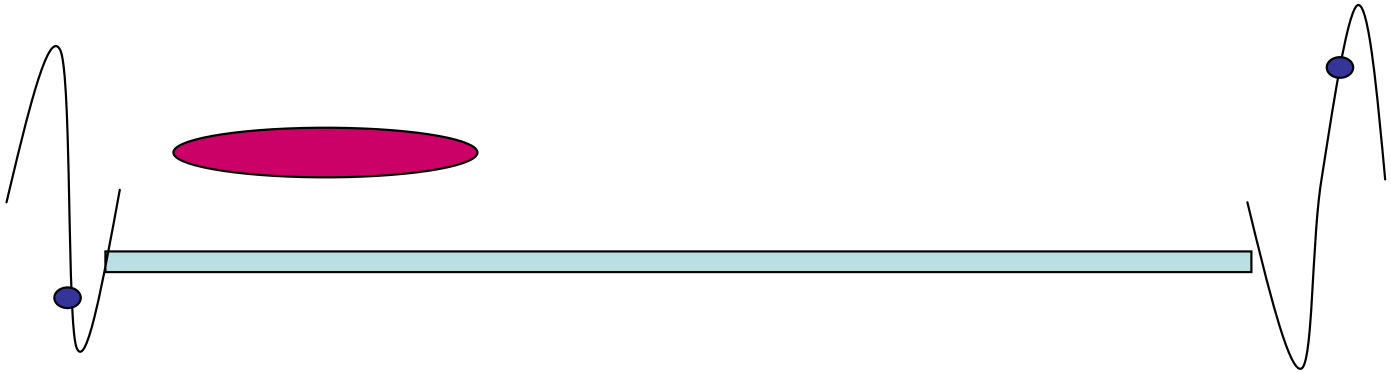

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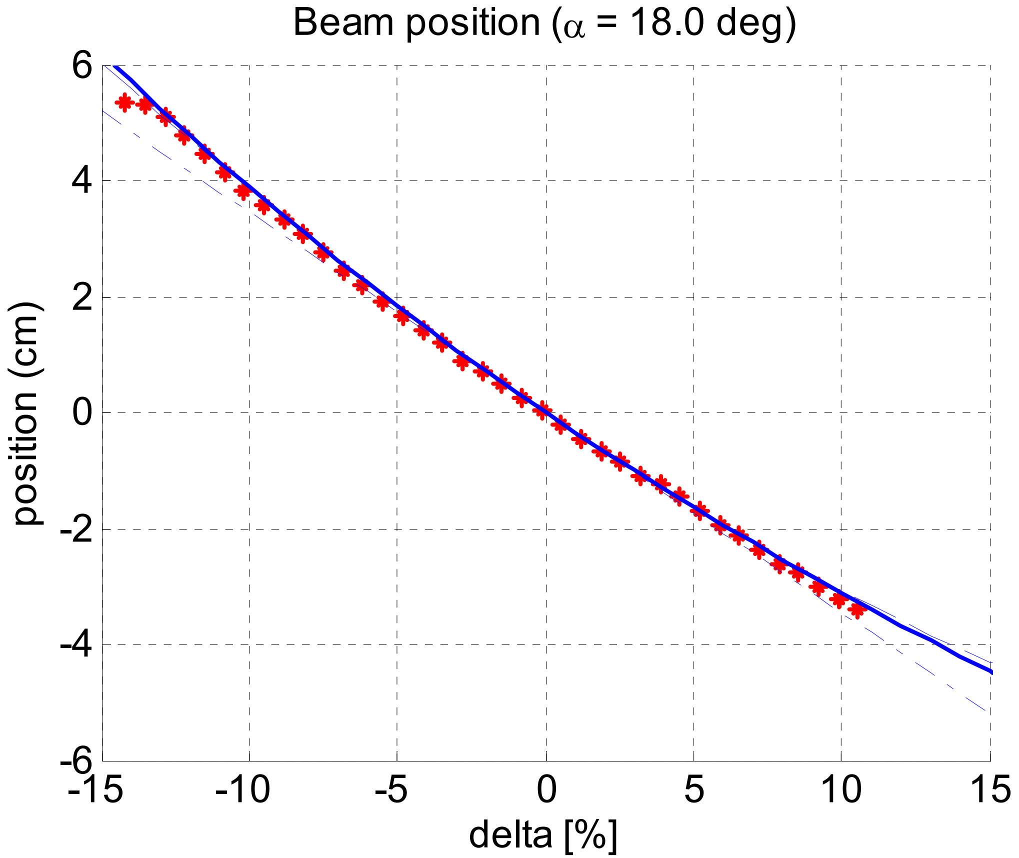
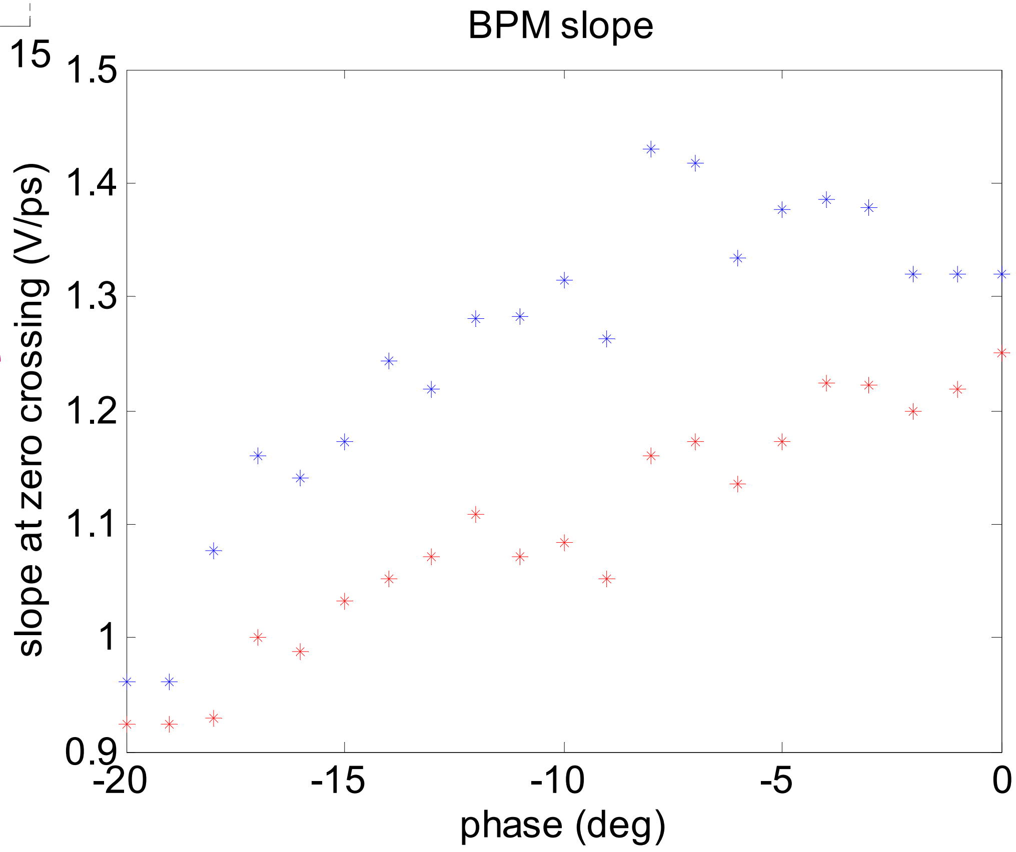


R16
T166
R3666

Measured using an oscilloscope

full measurement range



Weak dependence of signal slope on beam width

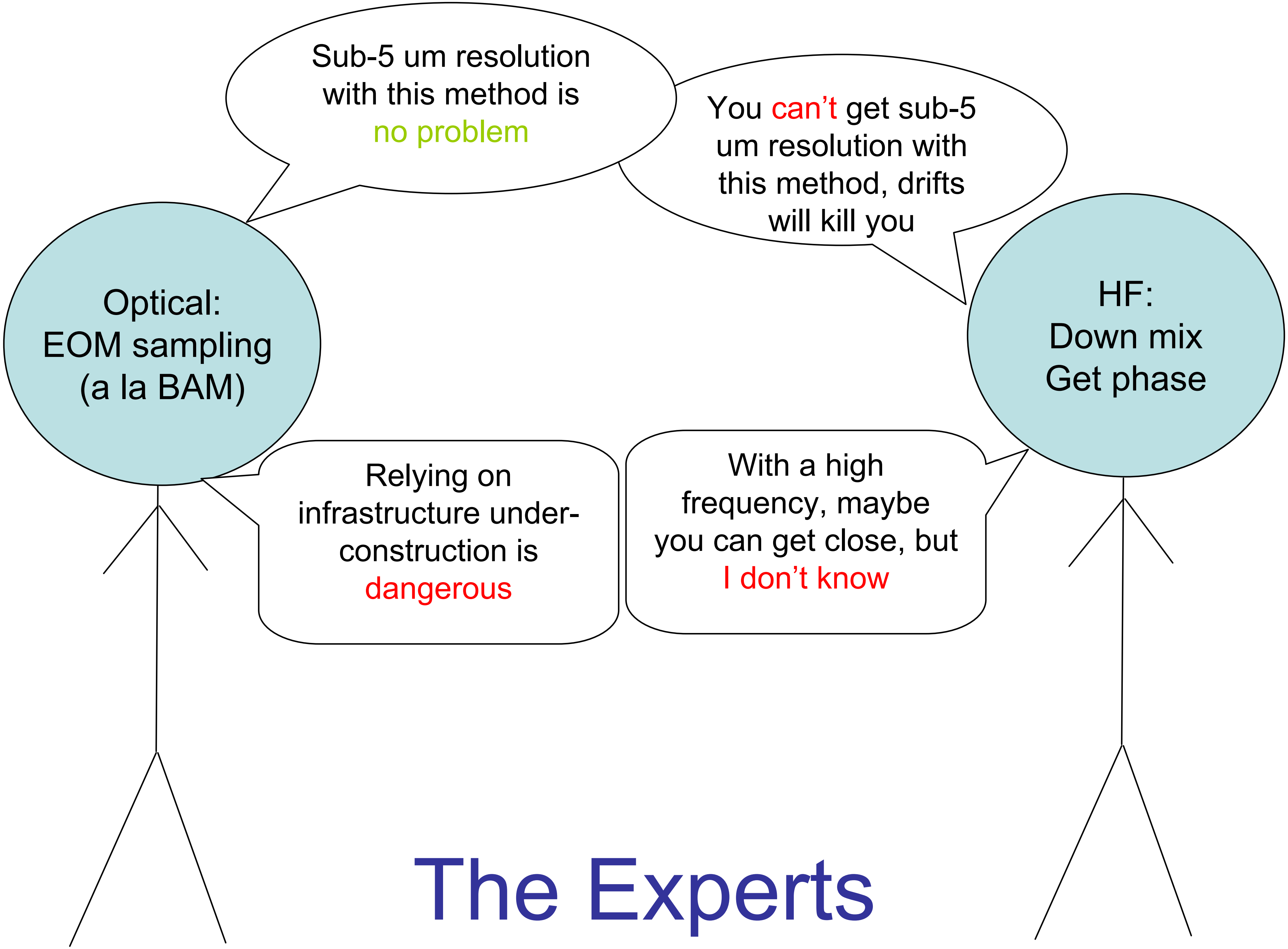
BPM Front-end

Strategies:

Low resolution Measurement helps put High resolution Measurement in range	Monitor can be periodically calibrated with a phase shifter

Tactics:

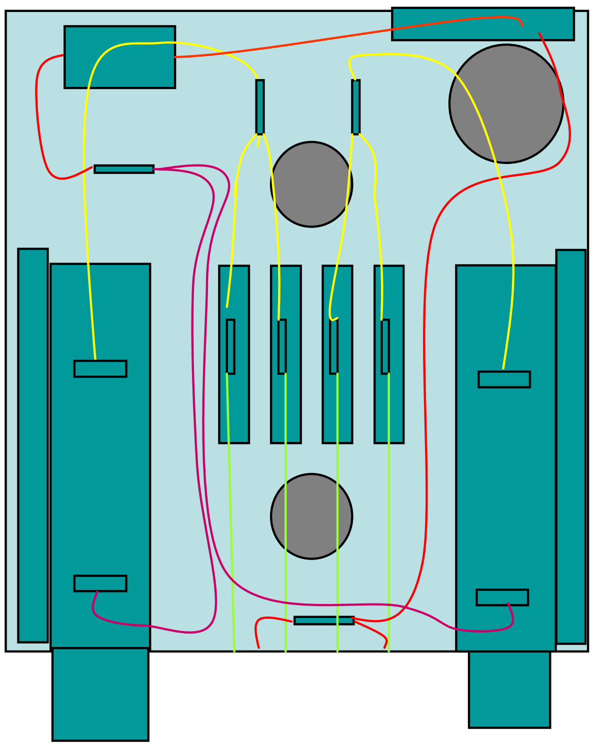
Optical method: EOM sampling (a la BAM)	HF method: BP Filter Down mix get phase


Sub-5 um resolution with this method is no problem
You can't get sub-5 um resolution with this method, drifts will kill you
Optical: EOM sampling (a la BAM)
HF: Down mix Get phase
Relying on infrastructure under-construction is dangerous
With a high frequency, maybe you can get close, but I don't know

The Experts

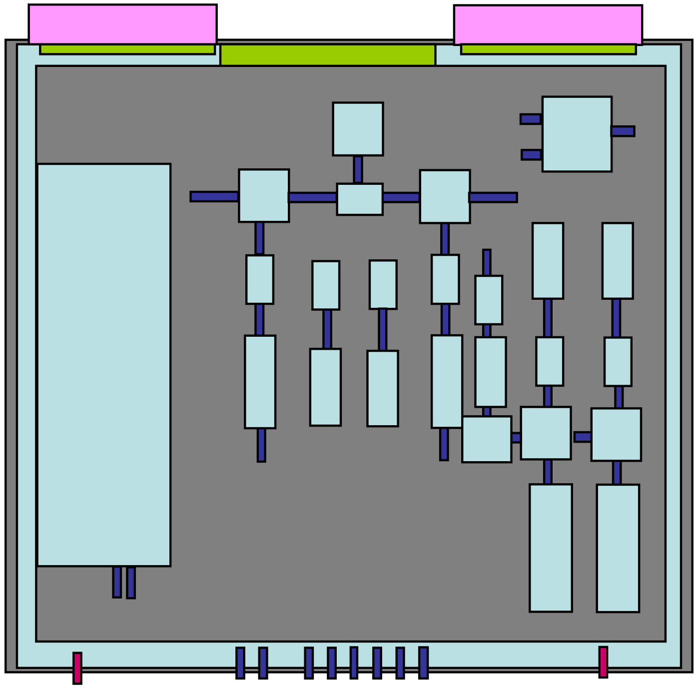
3 different front-end chassis constructed and commissioned

1
EOM



1 layer
not actively thermally stabilized
Short lifetime delay stages
5 um resolution

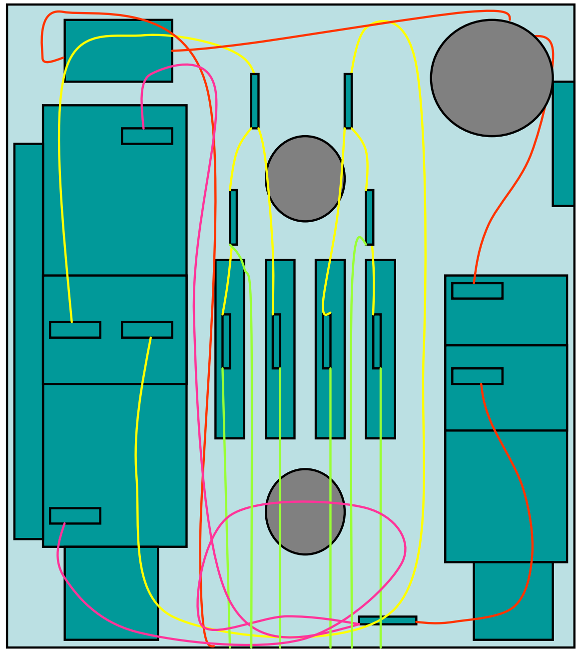
2
HF



2 layers
Actively thermally stabilized
Easy to construct
5 um resolution

Out-of-tunnel

3
EOM



2 layers
Actively thermally stabilized
Tedious to construct
2 um resolution

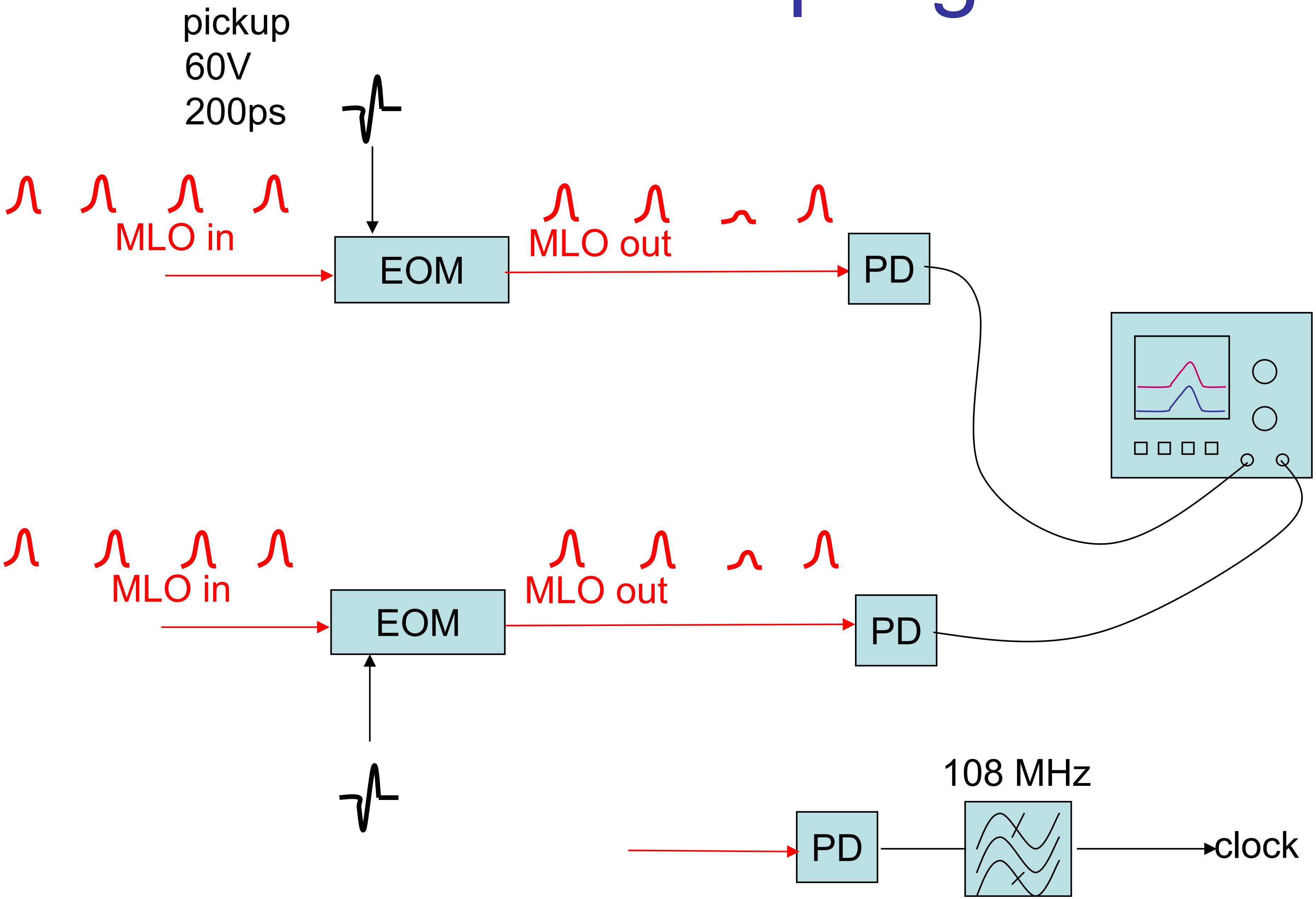
In Tunnel

1 pickup : 4 distinct front-ends

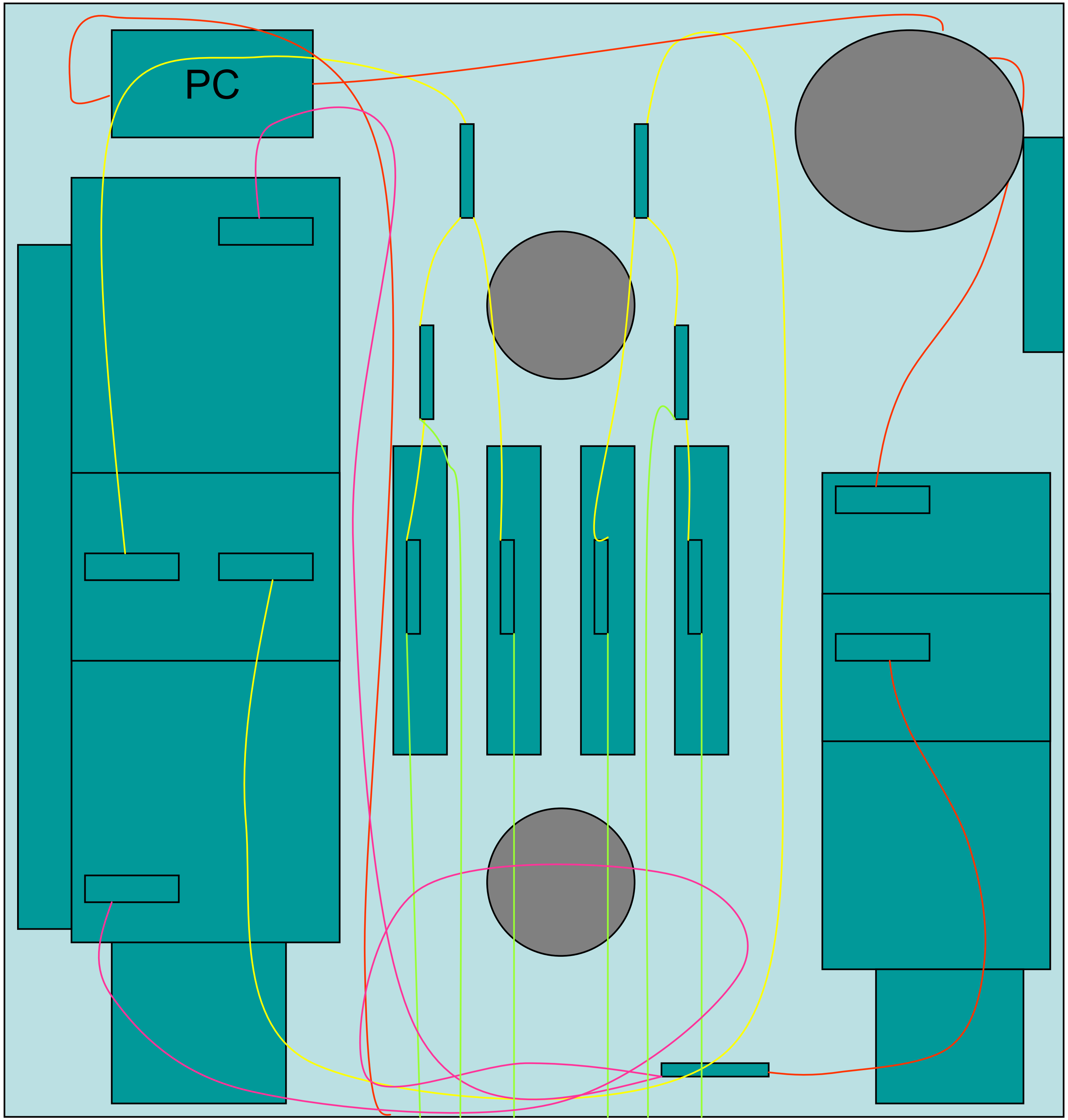
	HF		Optical	
	Downmixing at 1.3 GHz	**Downmixing at 10.4 GHz**	**EOM sampling with attenuated signal**	**EOM sampling with limited signal**
Resolution	~25 µm	~5 µm	~25 µm	~2 µm
Moving parts?	no	yes	yes	yes
Infrastructure required	MO, 2 VMs, VME: ADC, DAC		MLO, VM, fiber links, piezo drivers, motors, Beckhoff, VME: ADC, DSP, DAC	
ADC	Struck 108 MHz Good for this application only 40 bunches at a time		In-house 108 MHz with extras Nightmare clock bucket jumps gets whole bunch train	
Cost	10,000 EUR		30,000 EUR	

MO = Master HF Oscillator
MLO = Master Laser Oscillator
VM = Vector Modulator
EOM = Electro-Optical Modulator

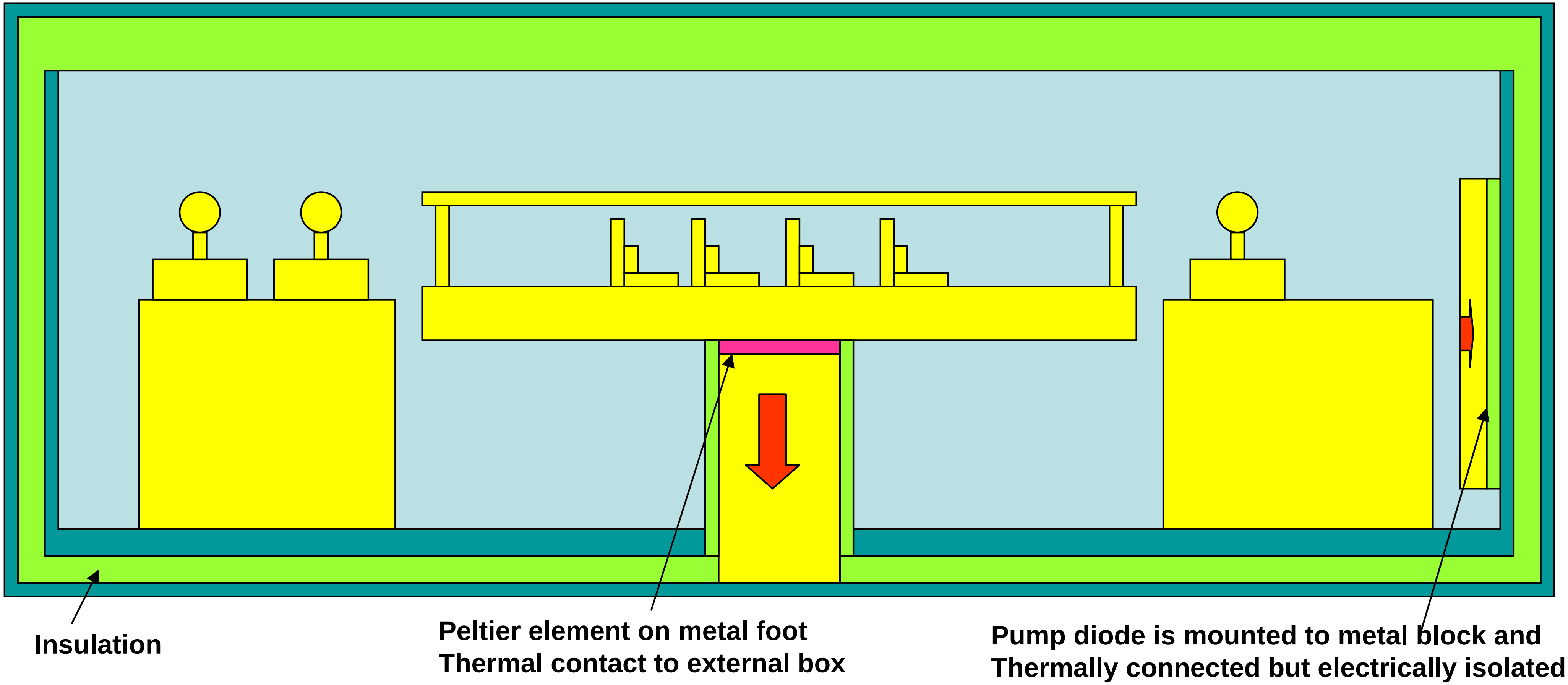
EOM sampling



EOM
EBPM
Front
End

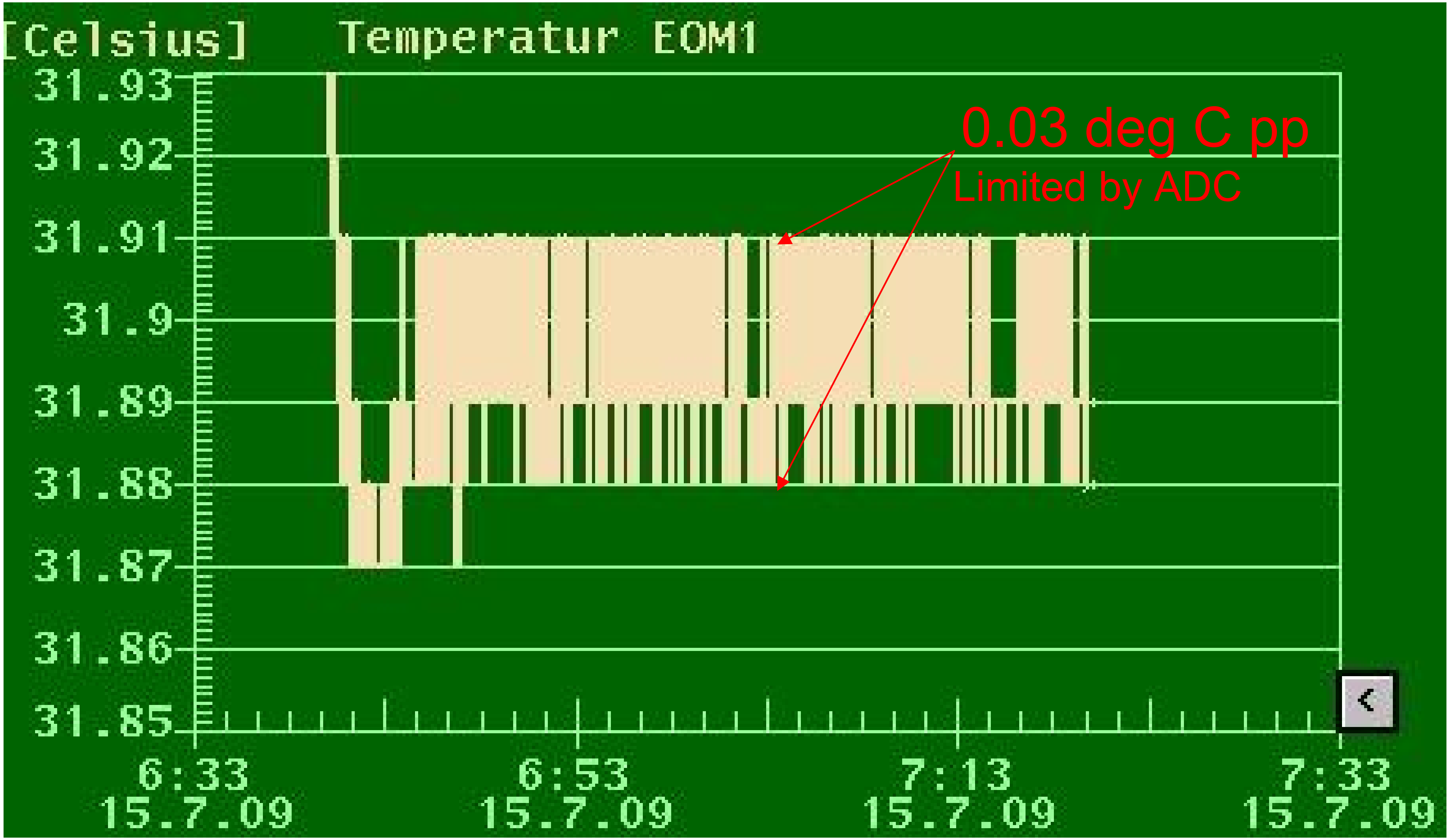


Thermal Stability



1 m fiber drifts 5-10 um / deg C
~8 m fiber in box
0.8 um drift /0.01 deg C

Thermal stability



Thermal stability

Recovery from maintenance day : 12 hours

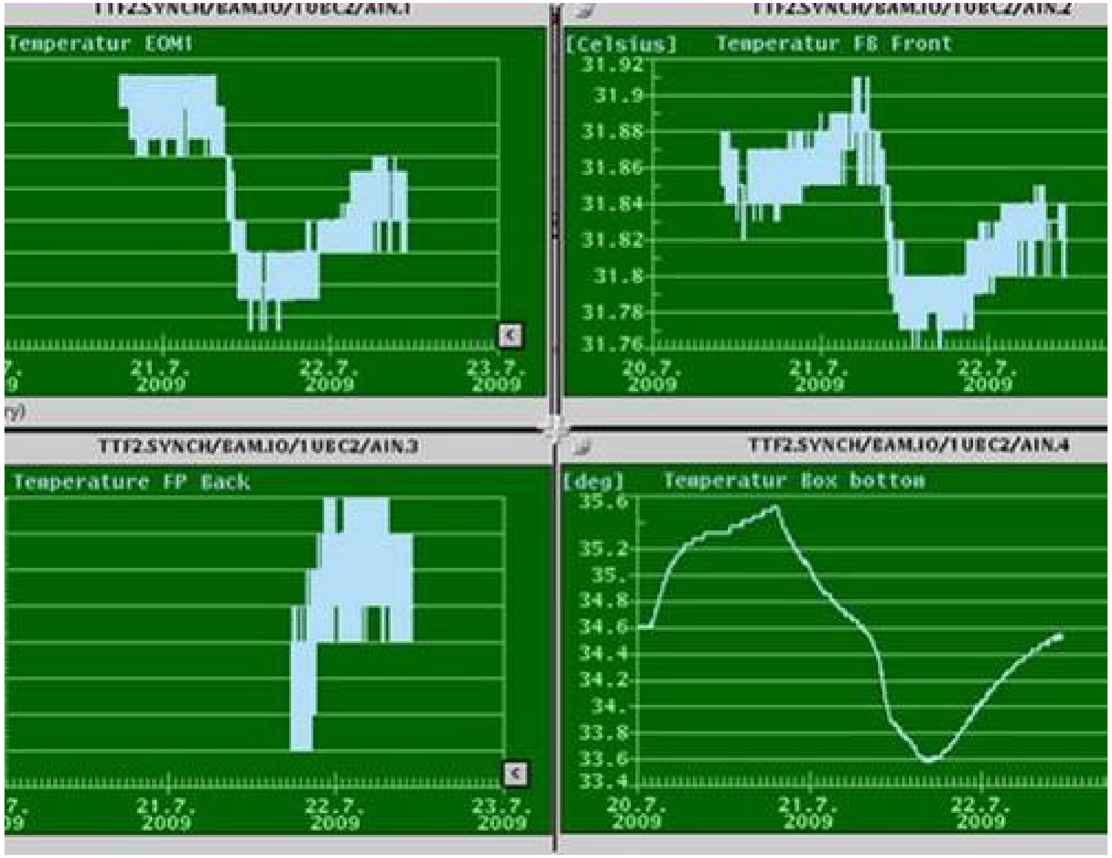


Plate temperature changes are ~6% of outer box changes

0.12 degree change shown

Inner box floor temperature tracks tunnel temperature

2 degree change shown

Optical front-end commissioning process

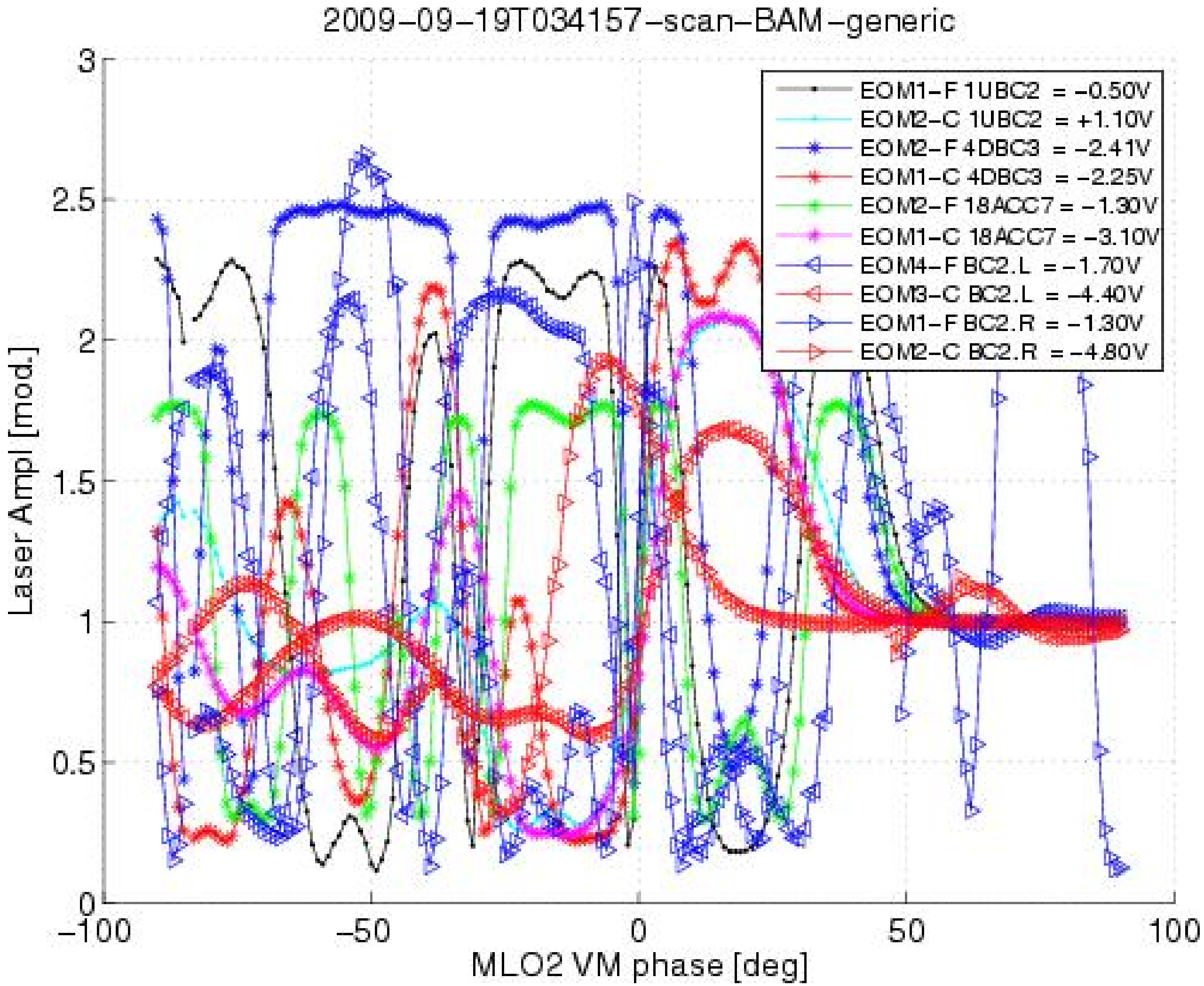
- ~12 hour process repeated for each of 4 EOMs

  -Find signal
  -Adjust cable lengths (tunnel access)
  -Calibrate
  -Set up motor feedback

- Complicated by ADC clock bucket jumps
  -Every few hours or more
  -Requires resetting board until correct bucket is found for all channels

Finding the sample position

Adjusting cable lengths ~ 4 hours per signal + tunnel access



Calibration and Resolution

- Out of Tunnel

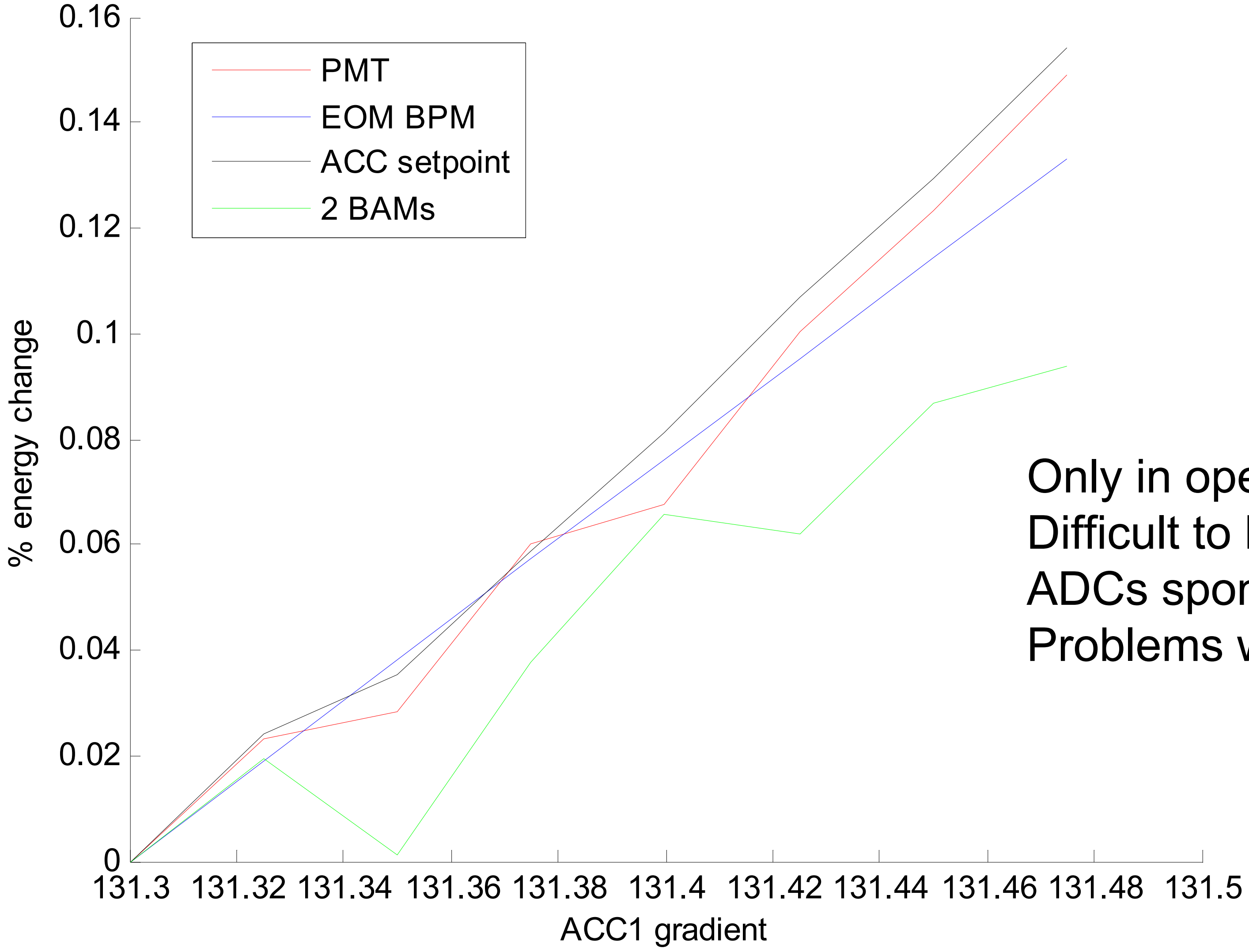
$\boxed{\text{17 fs resolution} \Downarrow \text{3 um resolution}}$ = 55 fs/% modulation * 0.3 % amplitude detection noise

- In Tunnel (short cables => drift free)

$\boxed{\text{10 fs resolution} \Downarrow \text{2 um resolution}}$ = 35 fs/% modulation * 0.3 % amplitude detection noise

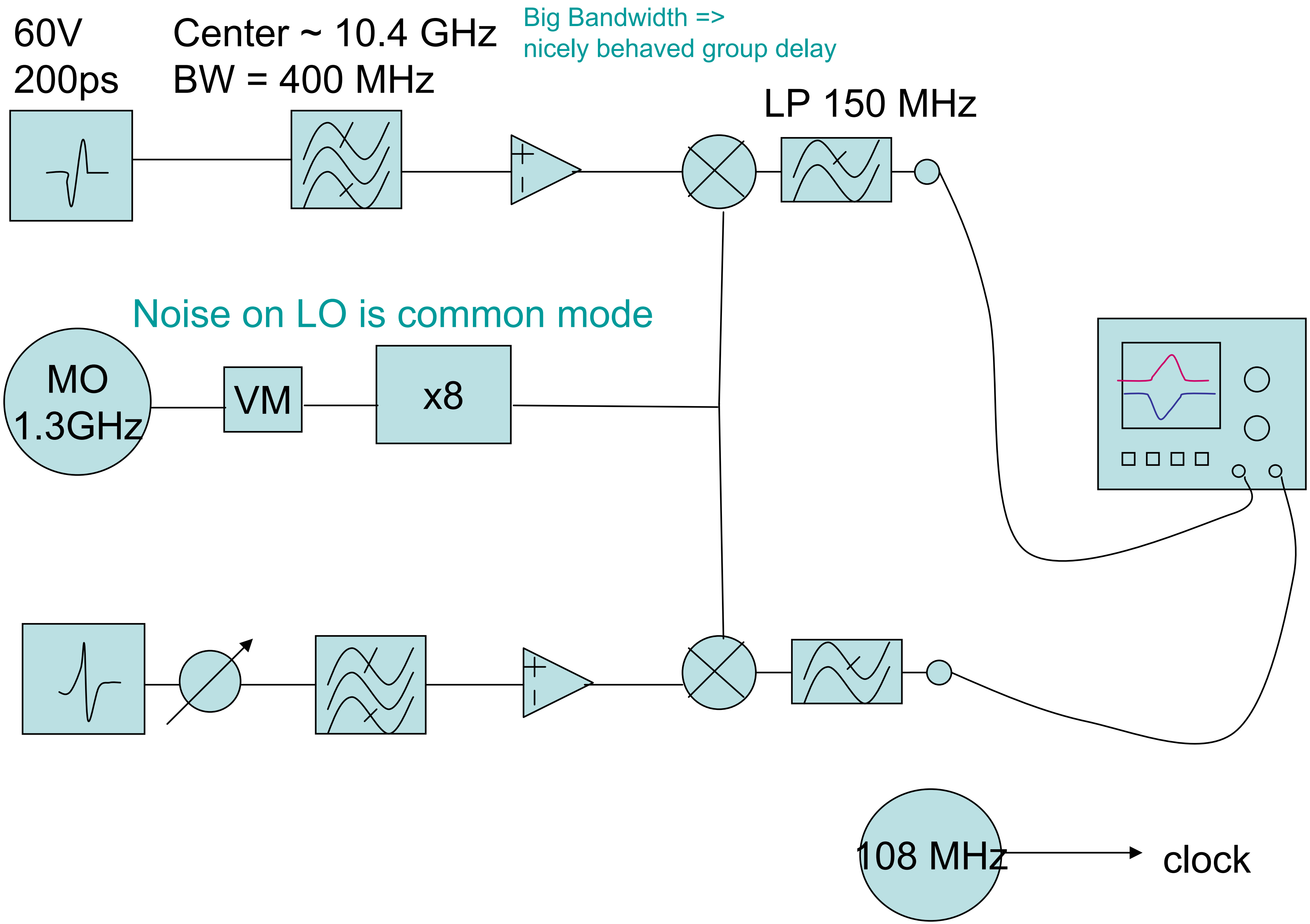
EOM measurements

Out-of-tunnel : 3 µm resolution
In tunnel : 2 µm resolution

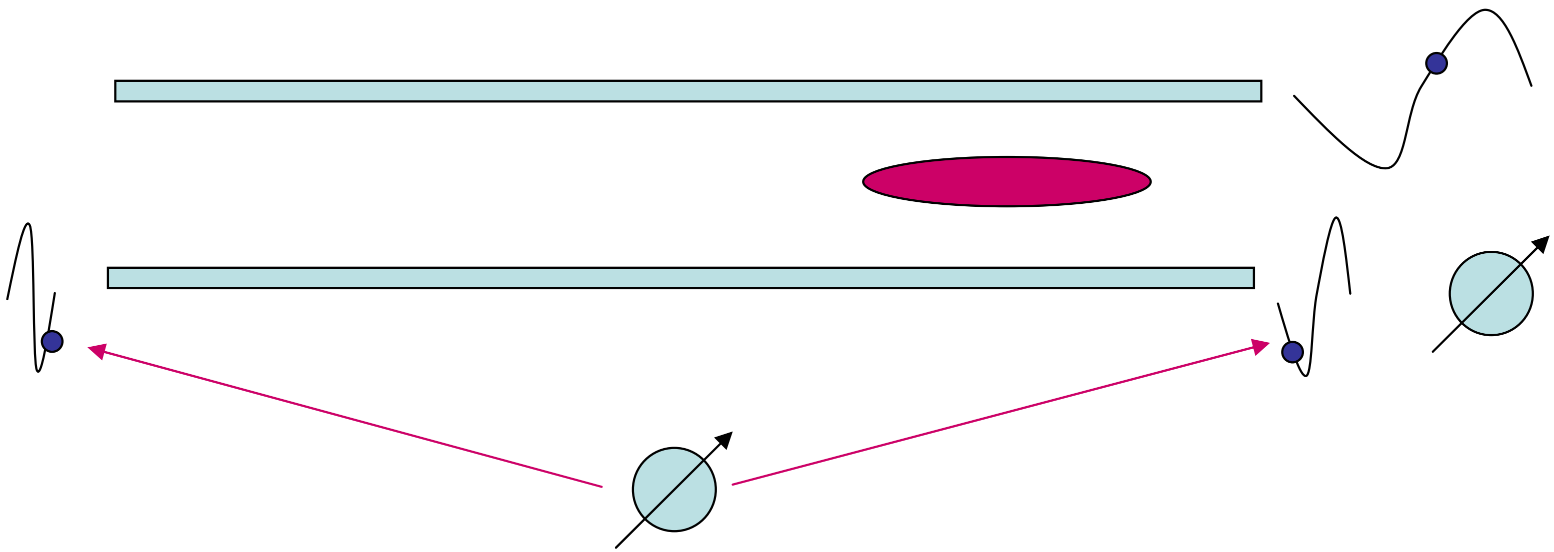


Only in operation for a couple of days
Difficult to keep in operation
ADCs spontaneously malfunction
Problems with buffer numbers

HF Down Mixing Front-end

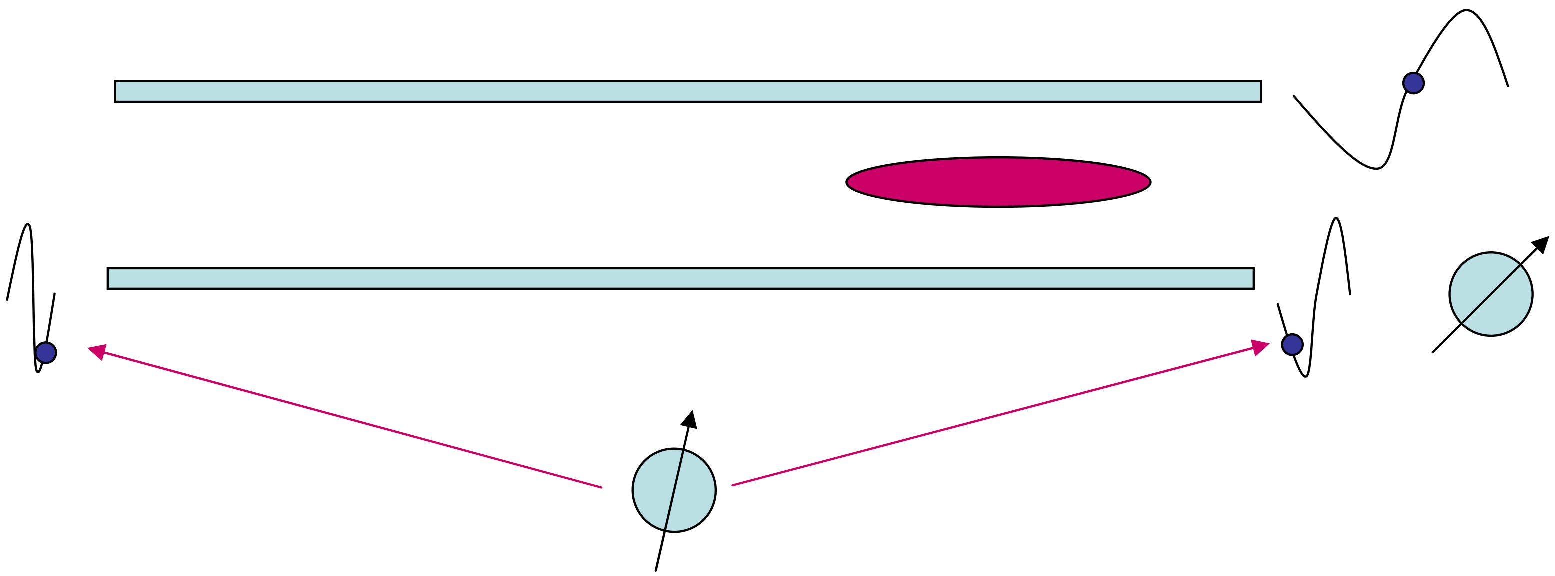


Using a coarse measurement to put fine measurement in range



One phase shifter moves both signals until the left mesurement is in range

Using a coarse measurement to put fine measurement in range



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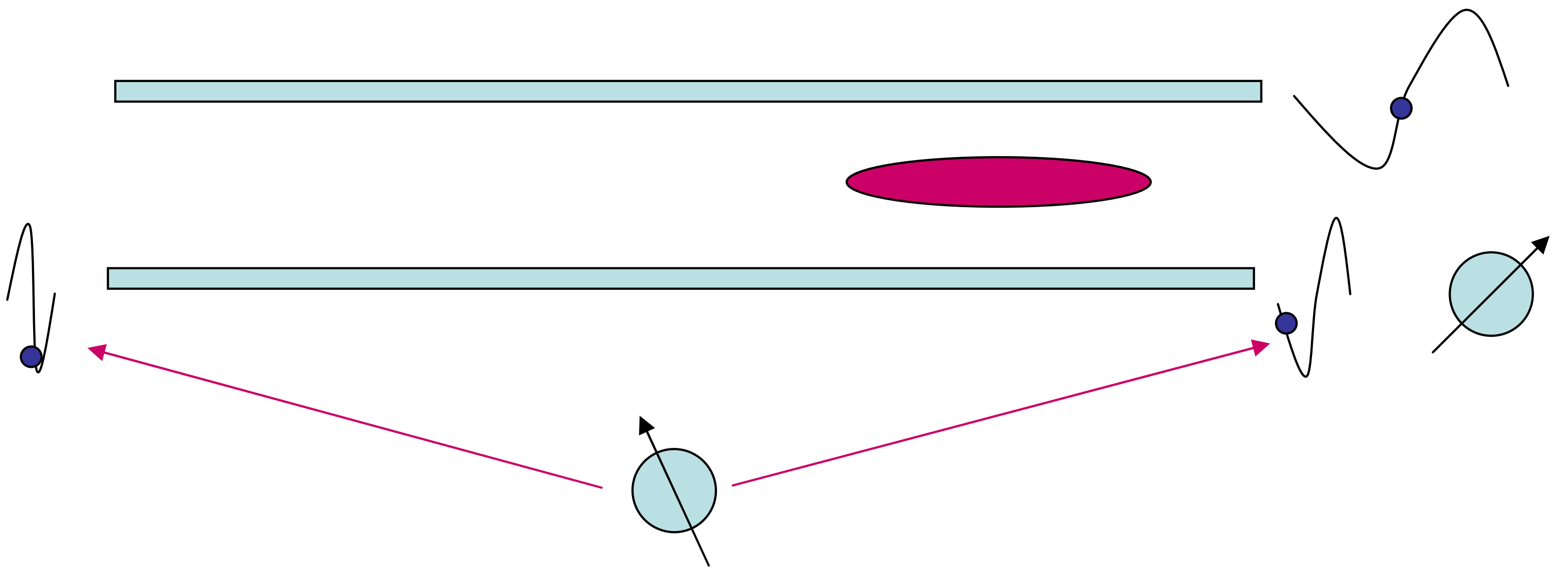

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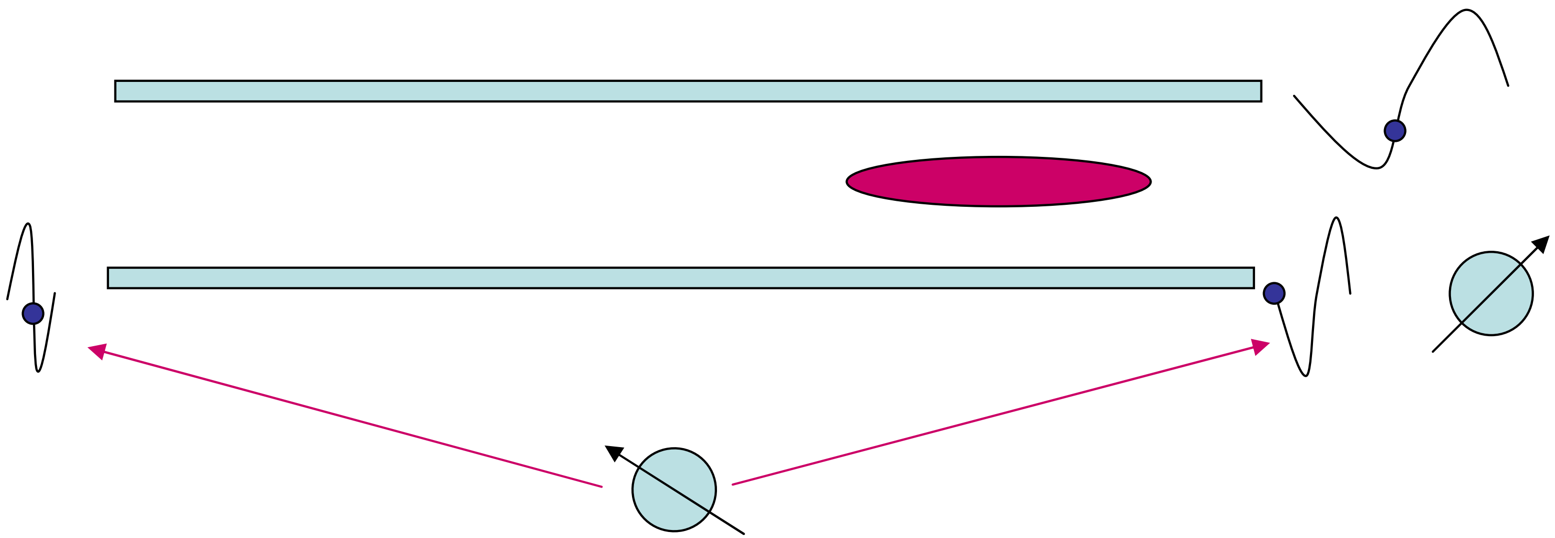

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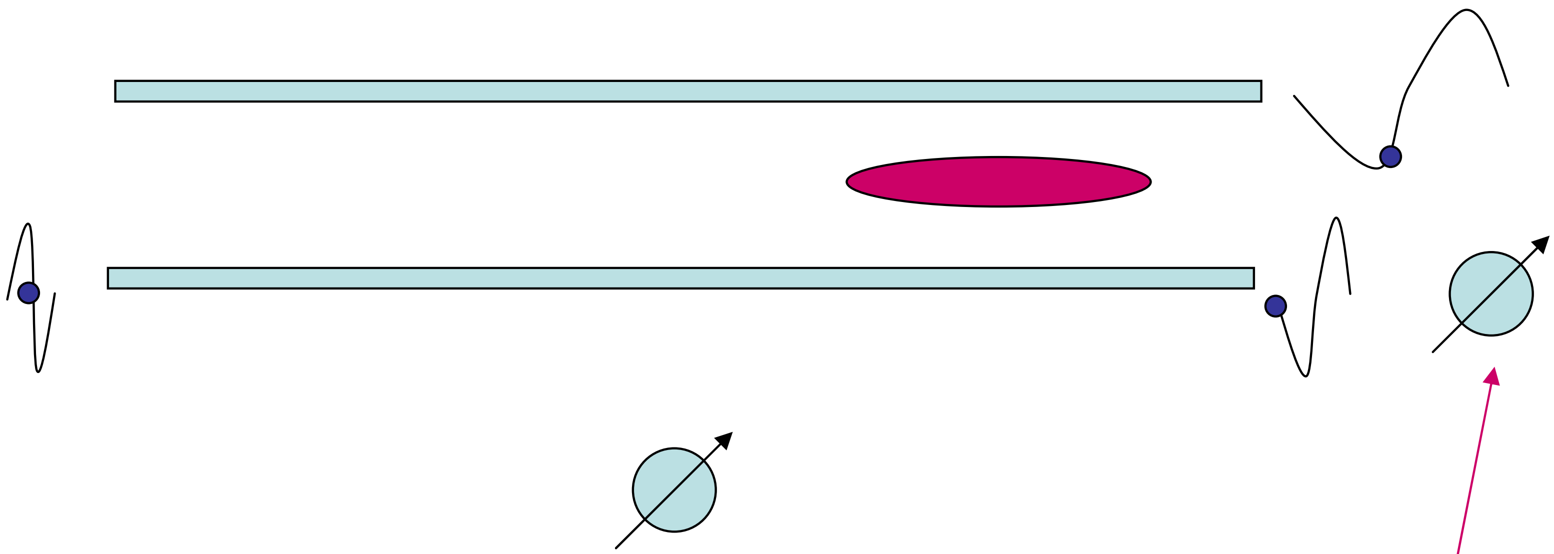
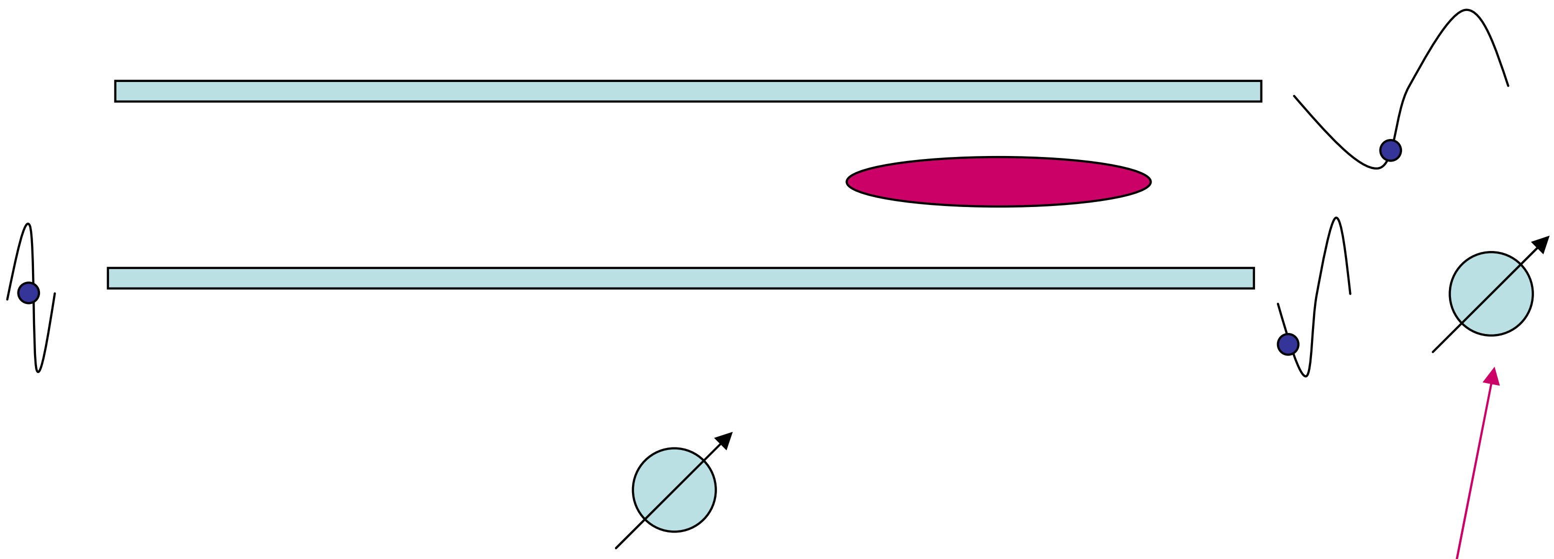


Another phase shifter optimizes just one side, using a lower frequency signal as a guide.

Using a coarse measurement to put fine measurement in range



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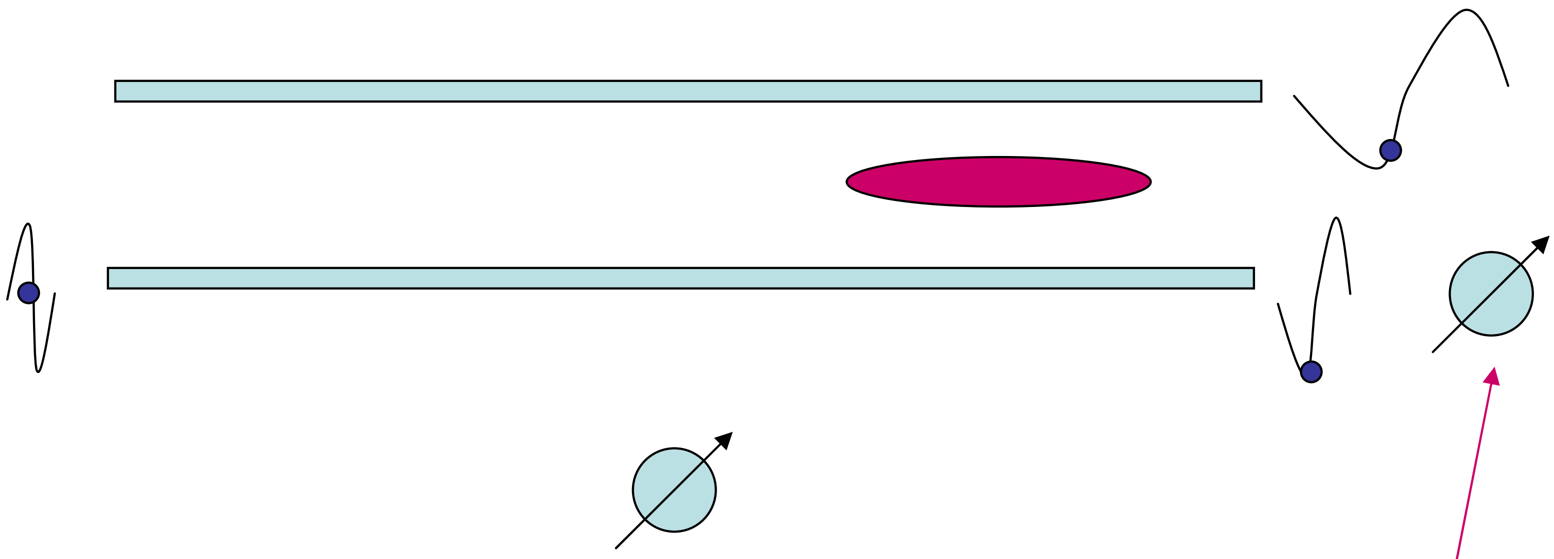

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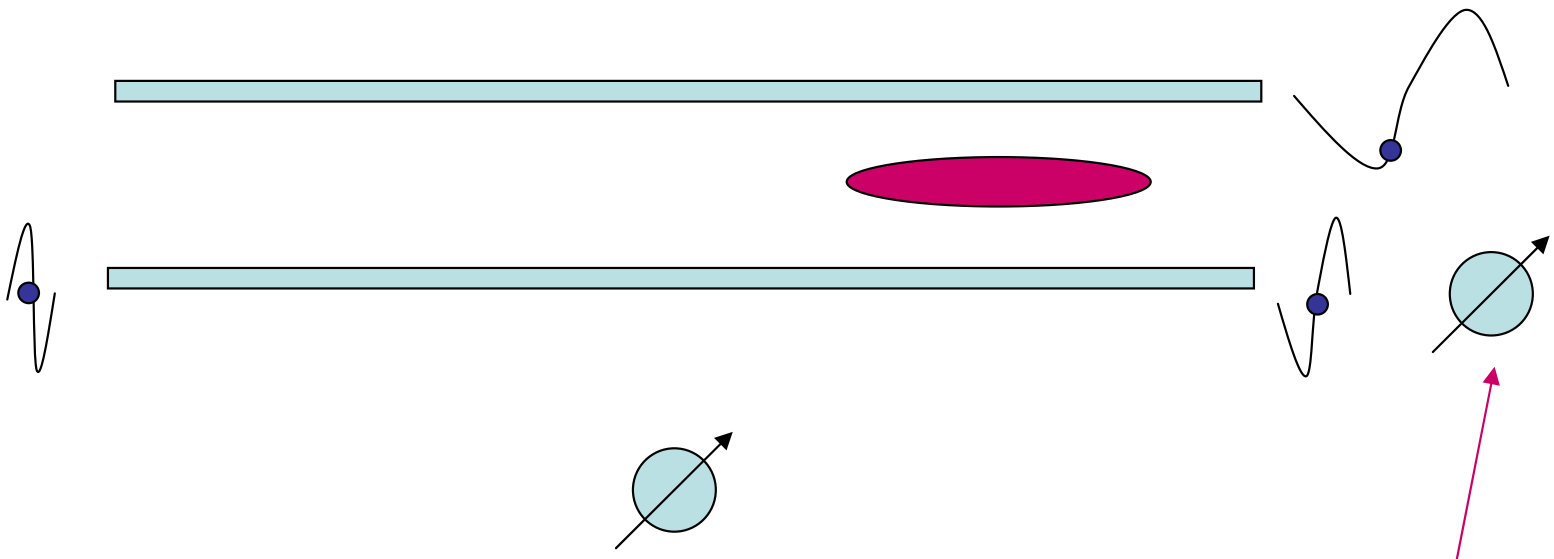

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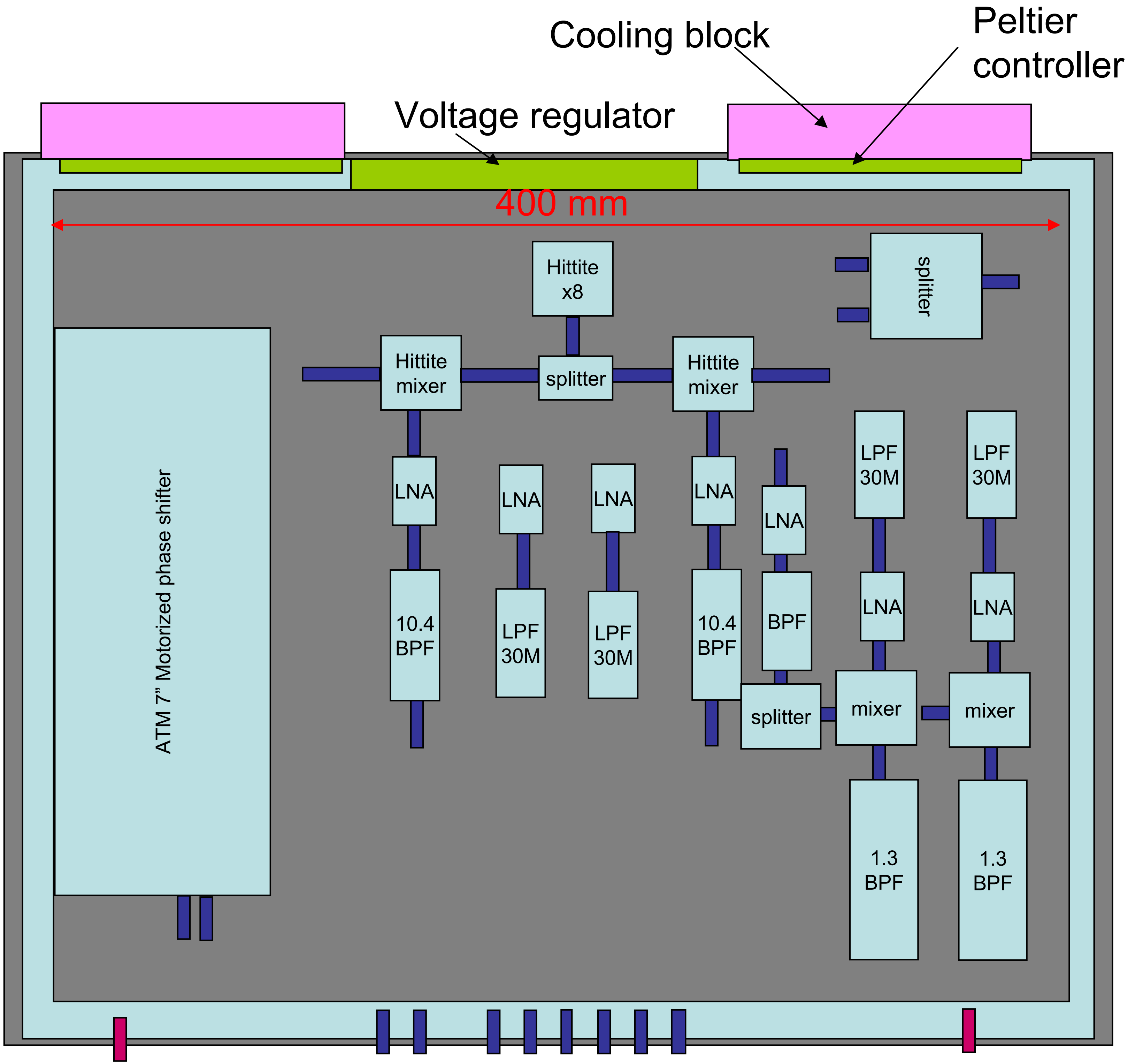
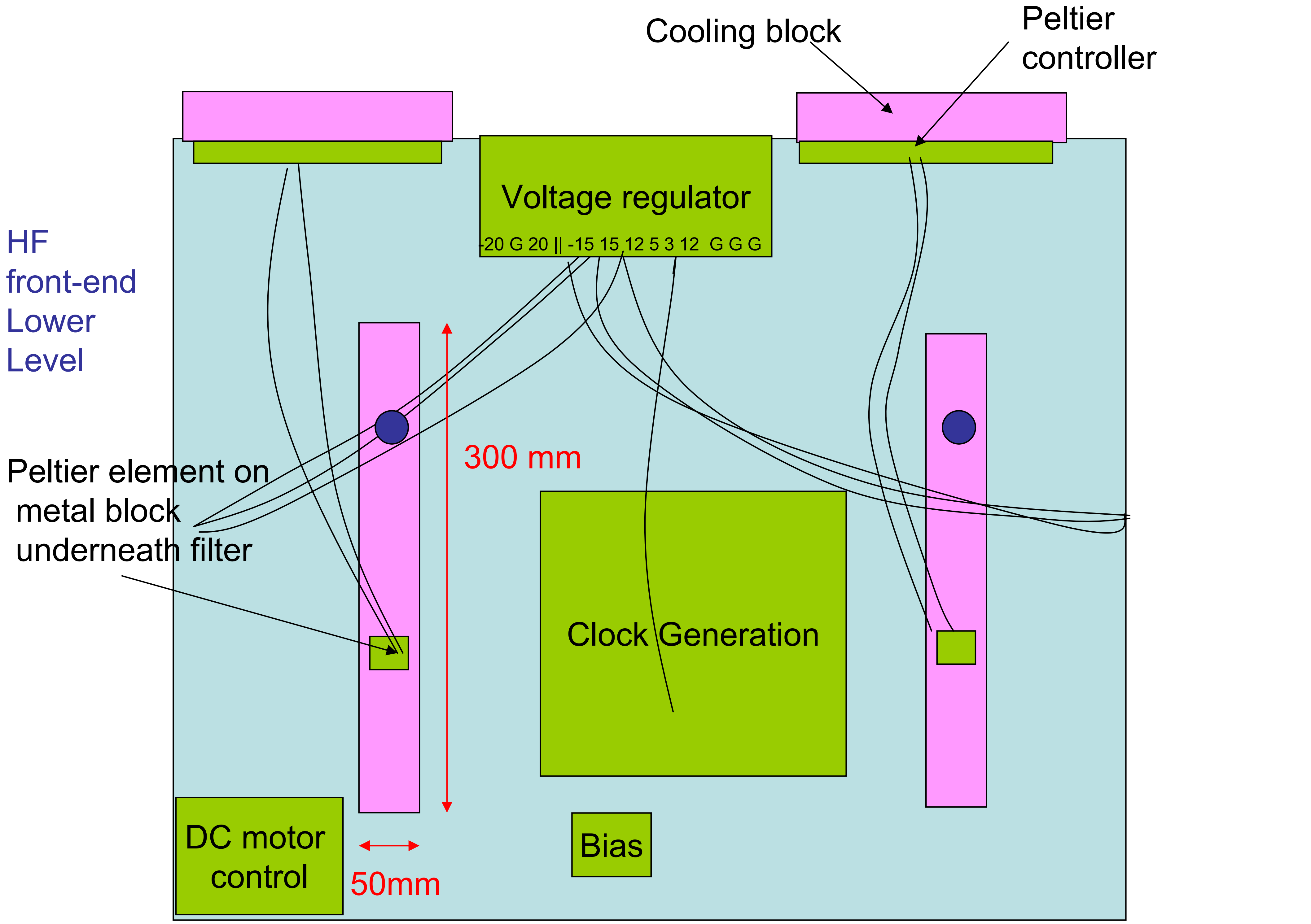
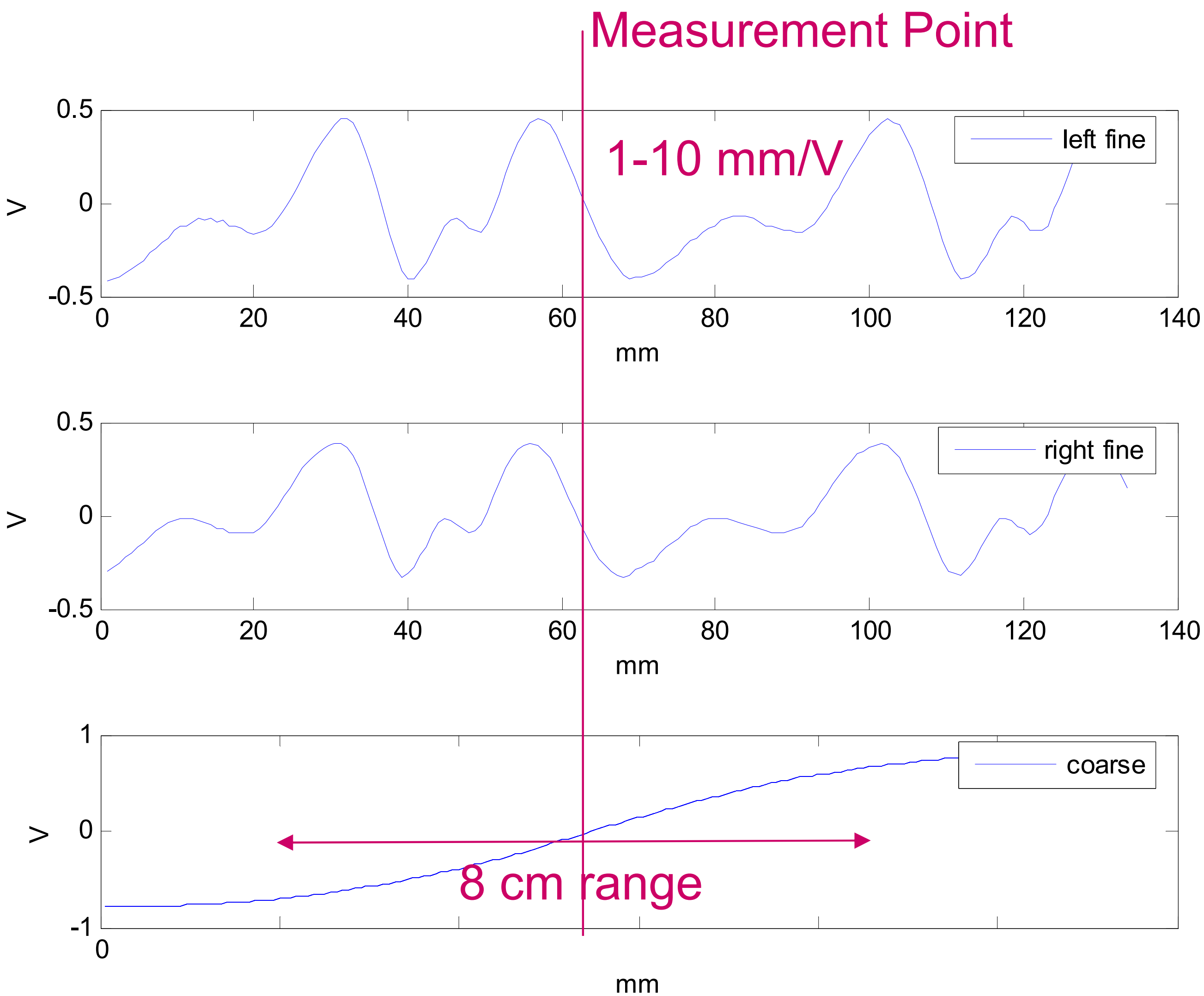
HF front-end Upper Level



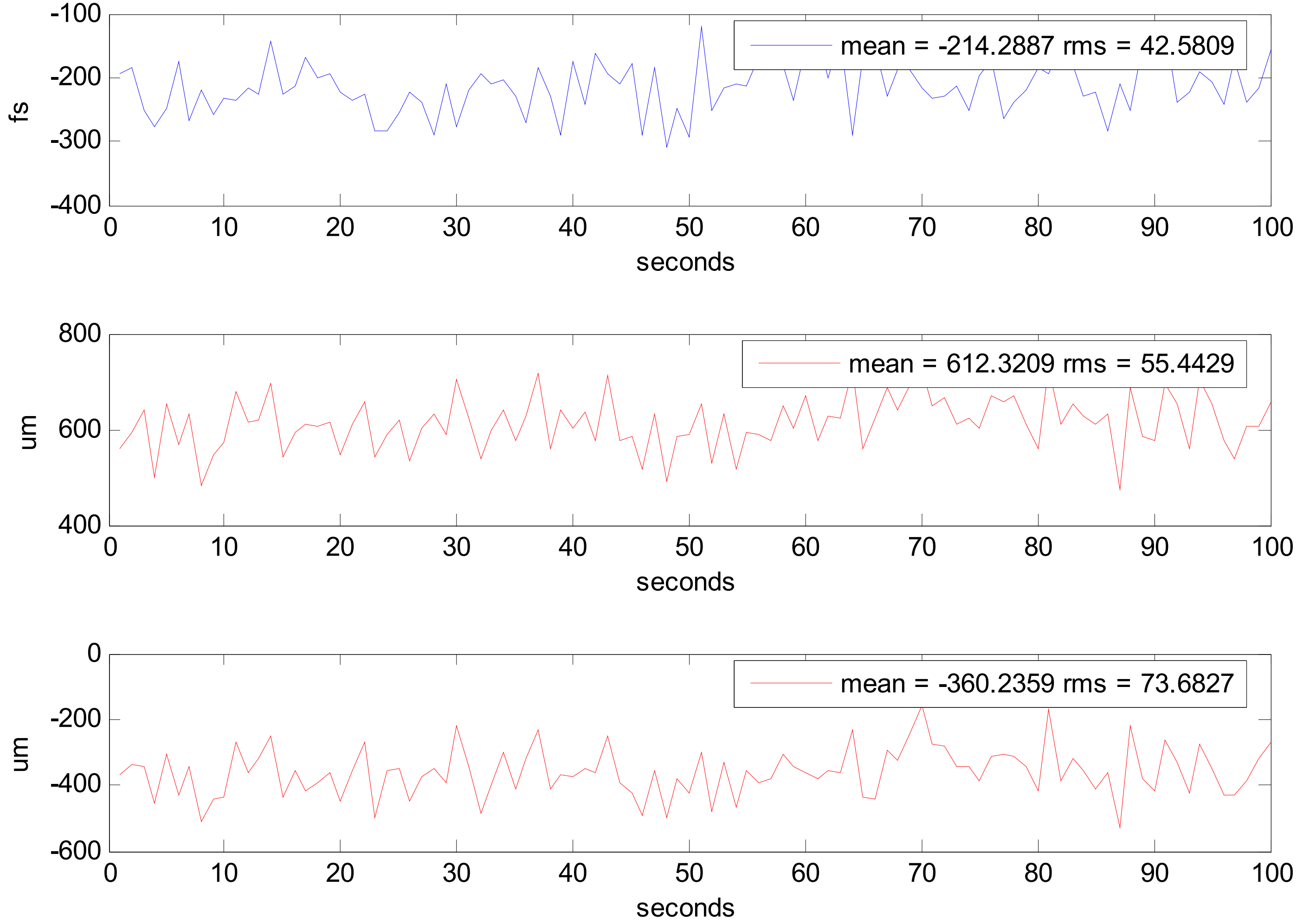

Cooling block
Peltier controller
HF front-end Lower Level
Voltage regulator
-20 G 20 || -15 15 12 5 3 12 G G G
300 mm
Peltier element on metal block underneath filter
Clock Generation
DC motor control
50mm
Bias

Phase Scan with Vector Modulator



BAM: 1V/ps->0.3 mm/V

Correlation with PhotoMultiplier Monitor

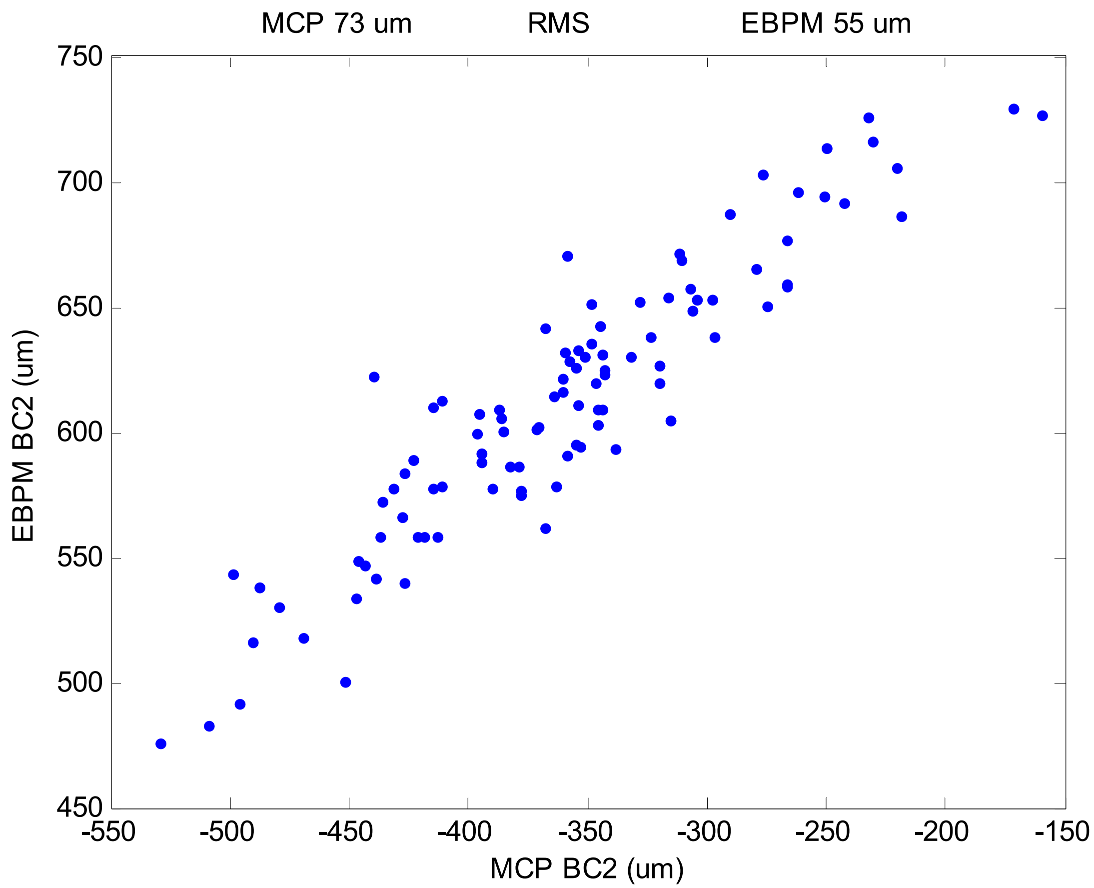


EBPM arrival

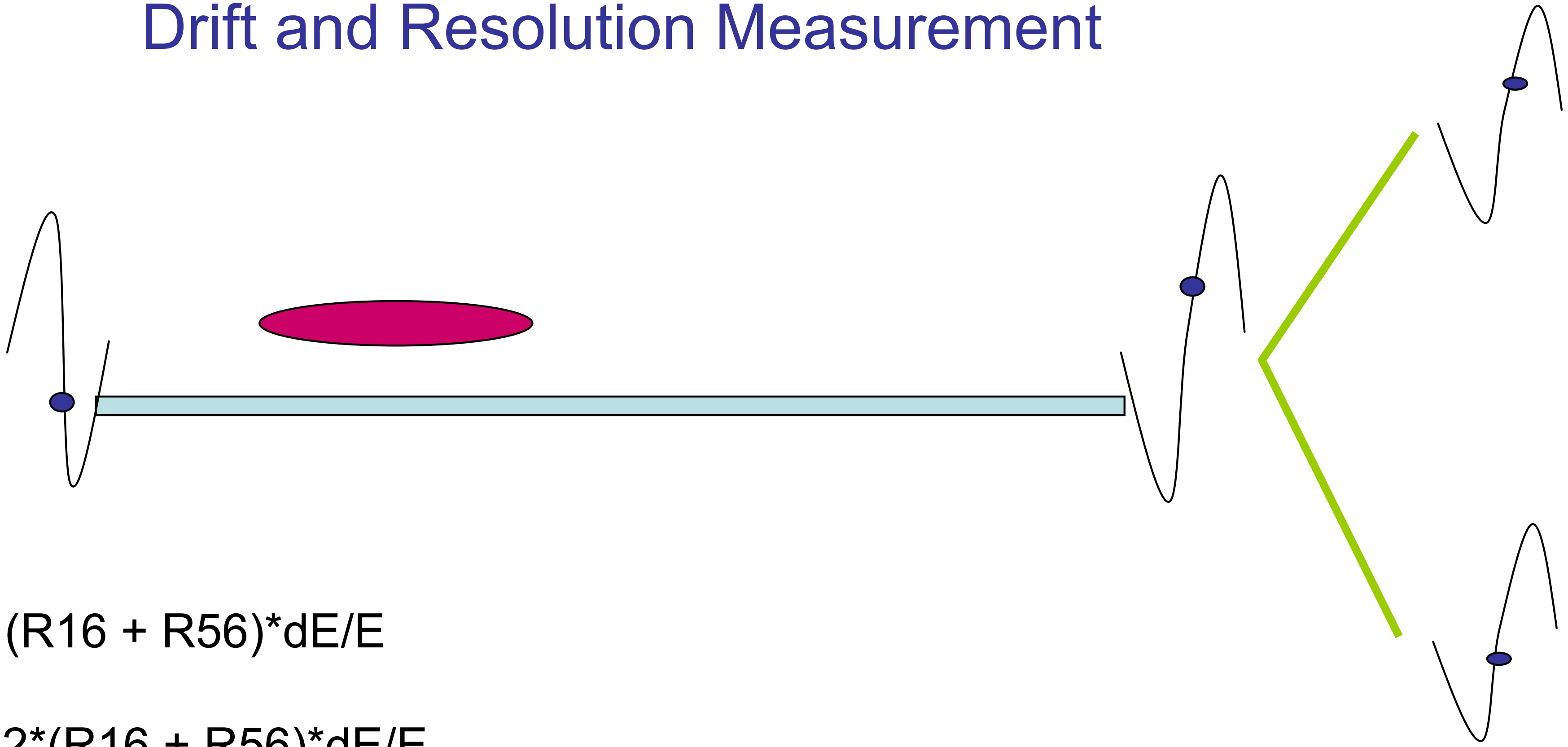
EBPM position

PMT position
(C. Gerth)

Correlation with PM Monitor



Drift and Resolution Measurement

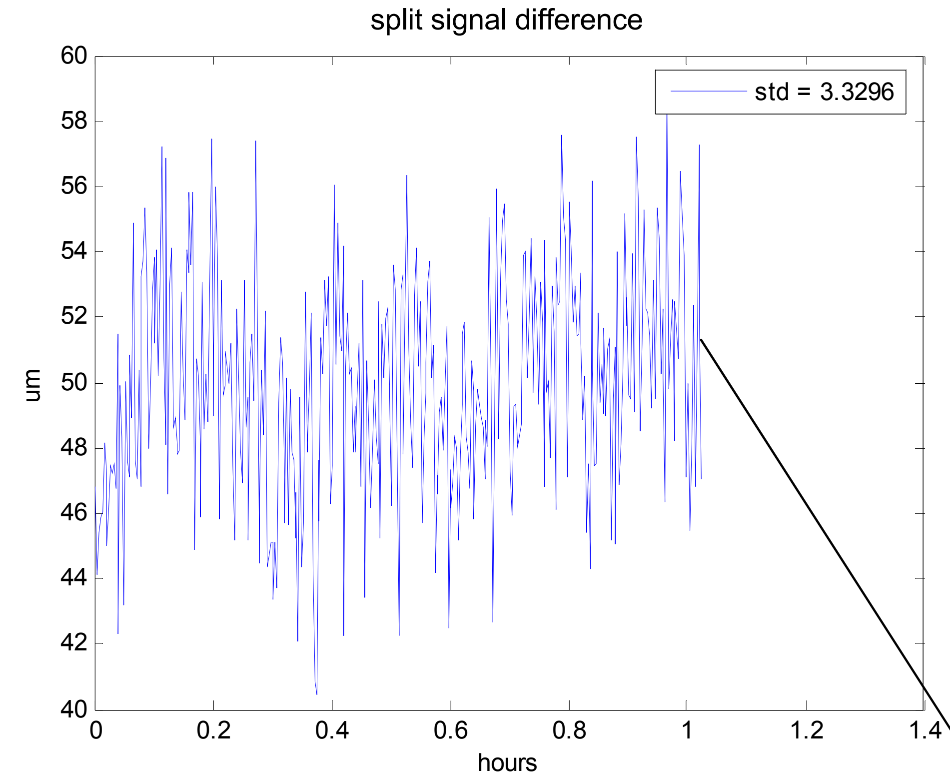


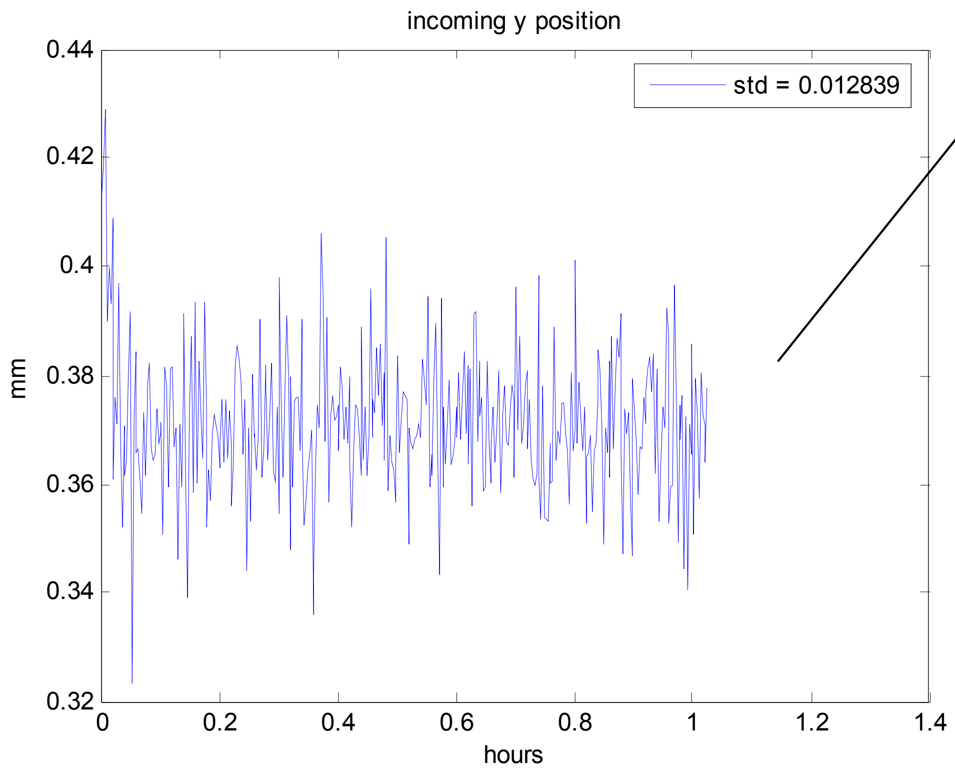
right = (R16 + R56)*dE/E

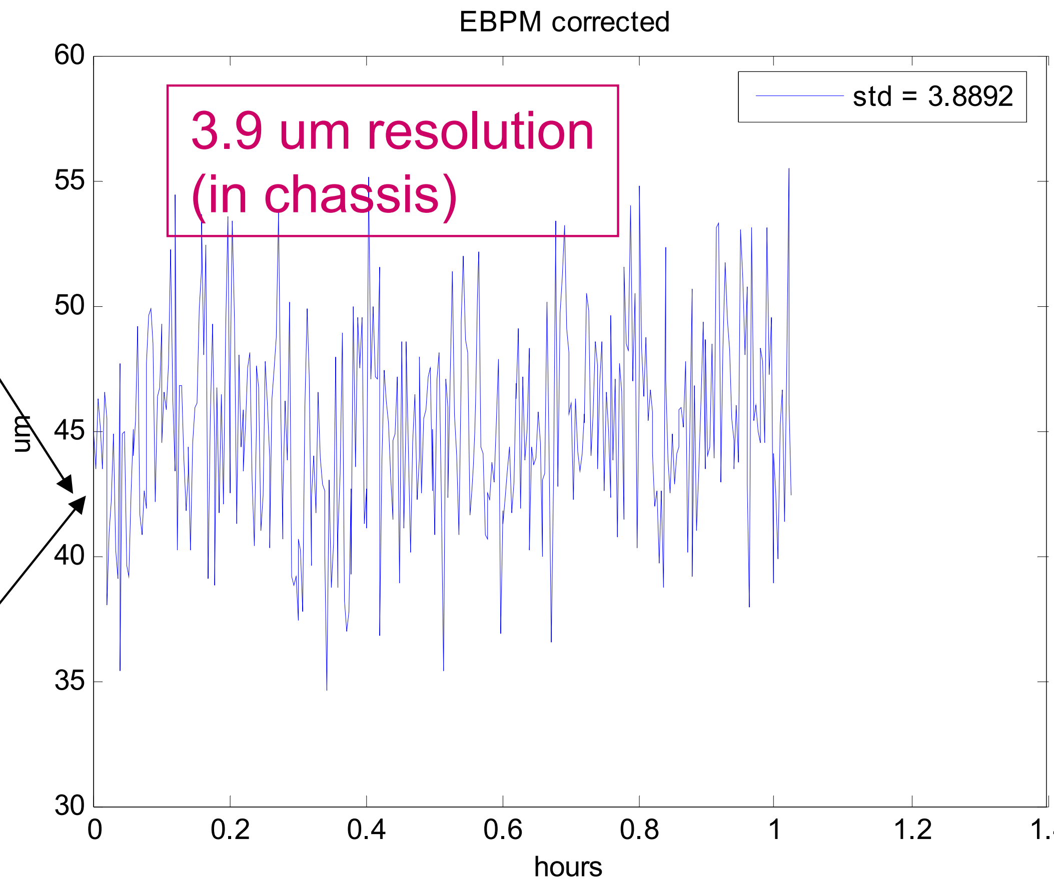
sum = 2*(R16 + R56)*dE/E
diff = 0

Difference of split signals should stay constant
RMS Jitter of split signal gives monitor’s resolution

Dependence on y position
and charge removed





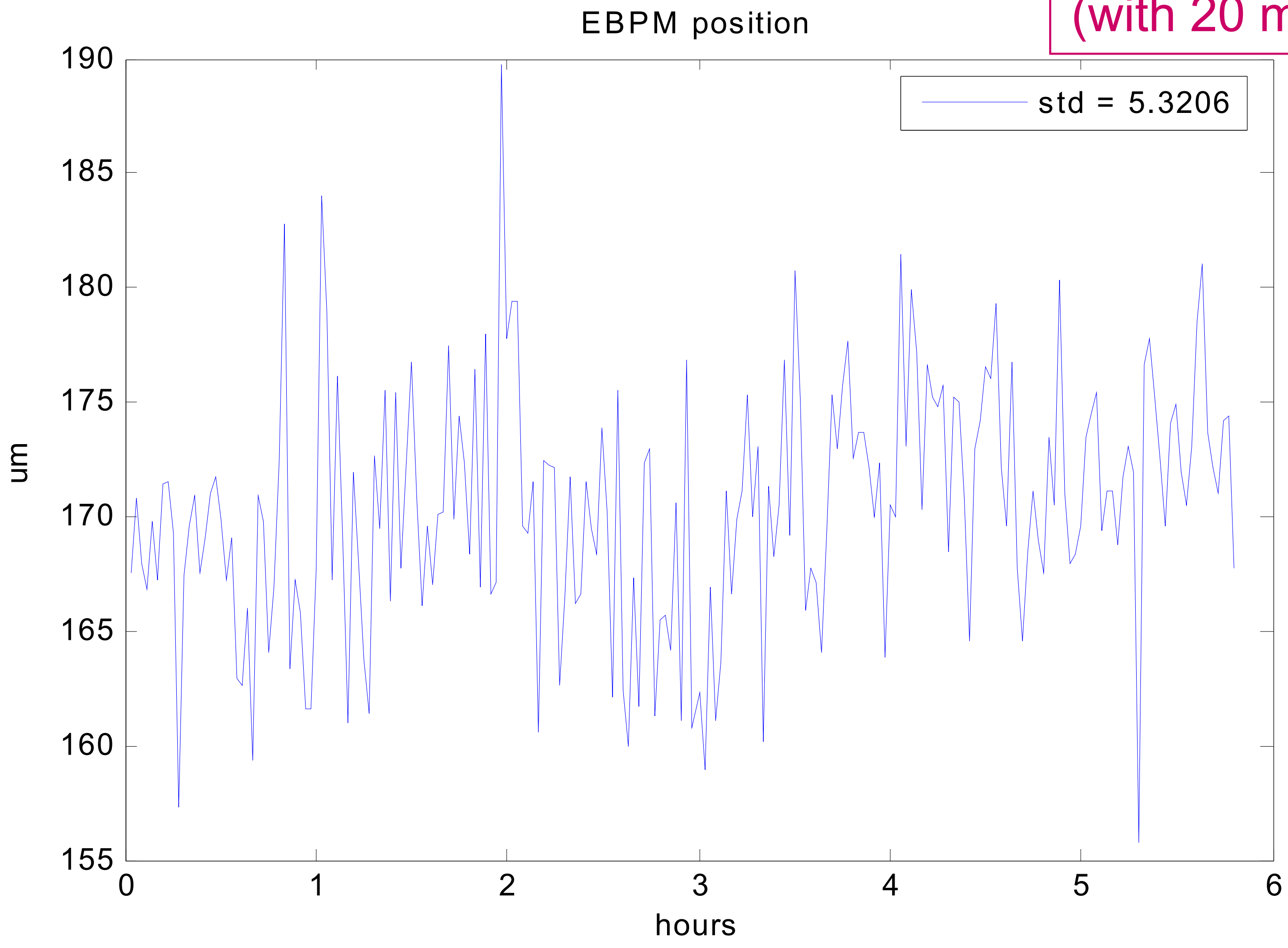


Temperature stabilized chassis
Cable drift not included

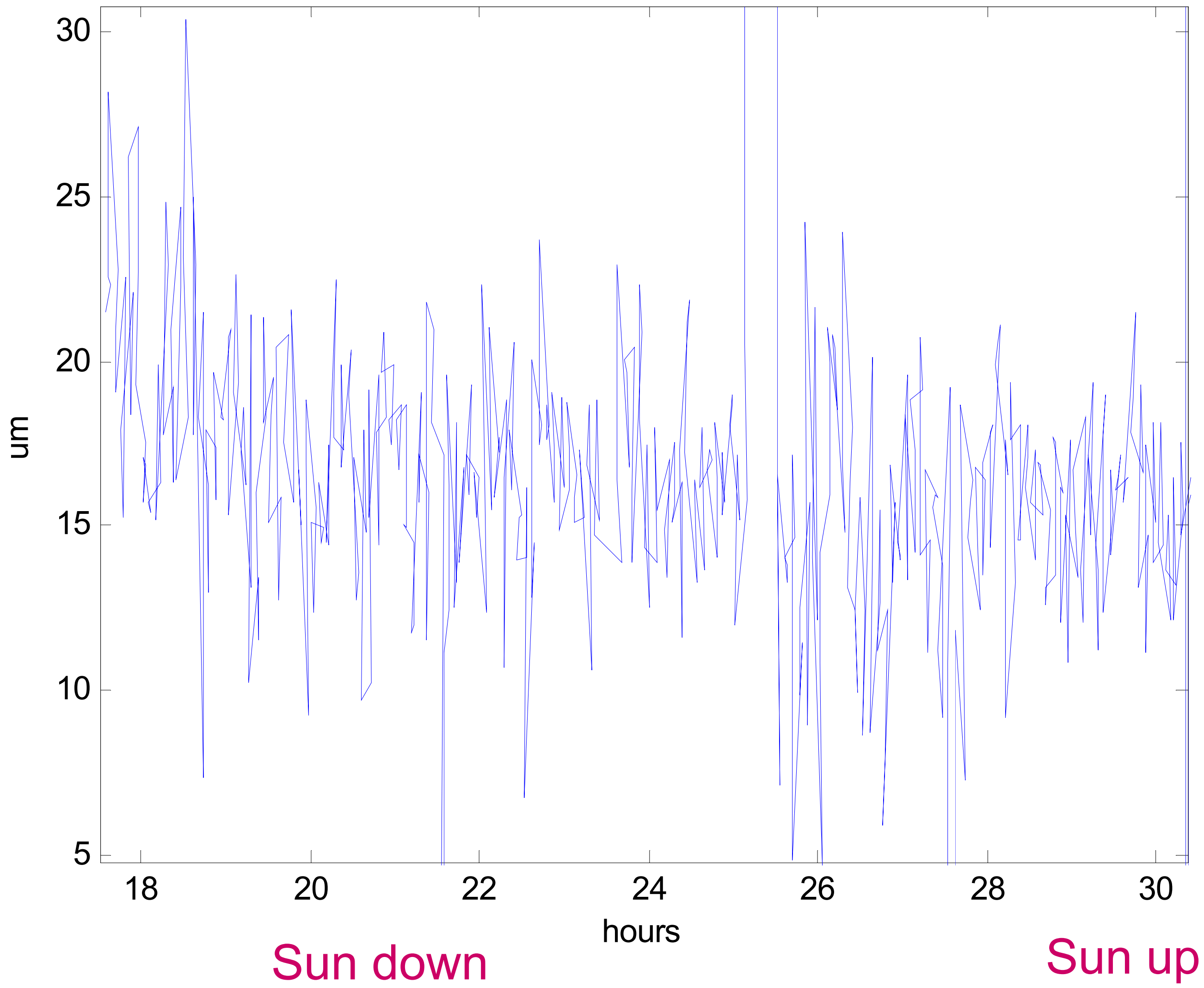
cable phase drift and jitter on a quiet night

VM feedback on

5.3 um resolution (with 20 m cables)

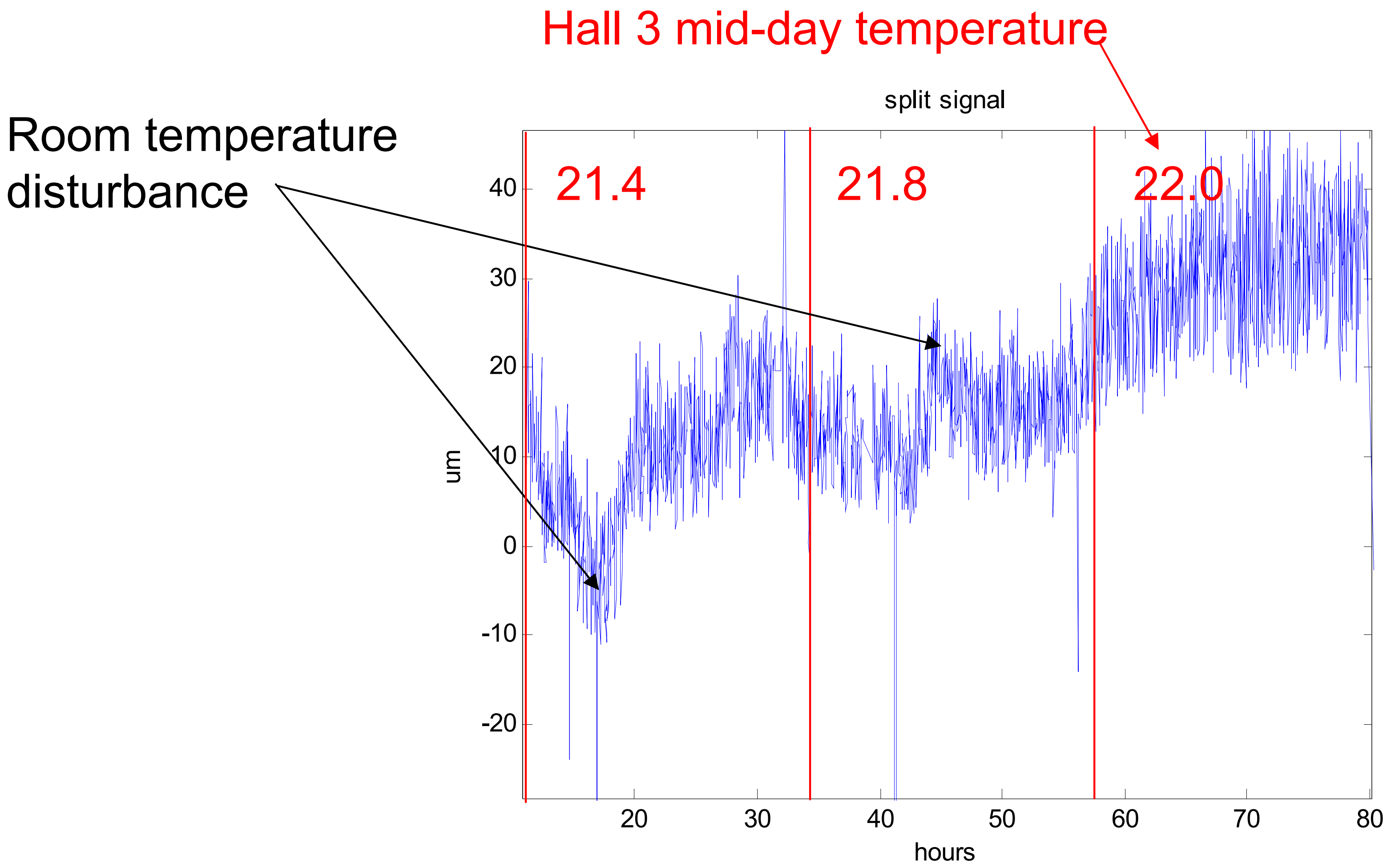


5 um drift and 5 um resolution over a quiet night



<5um rms jitter and <5um evening-morning drift

20 um drift over 3 days

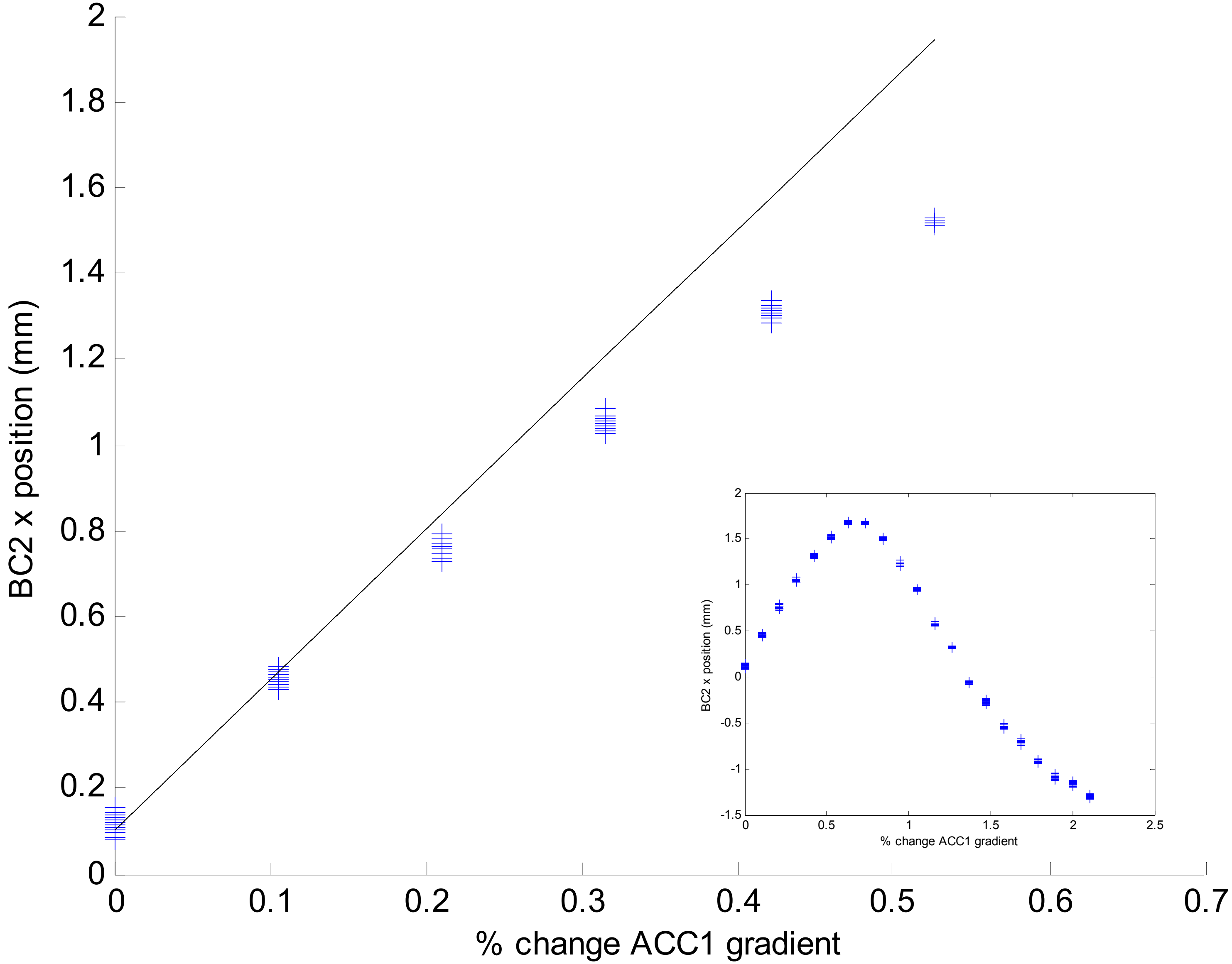


ACC1 gradient scan
Off-crest ACC1

Calibration done once at beginning
VM kept sample point at zero crossing
(of one signal)
No trombone change

For a 1% energy change:

dE/E * R16 = 3.5 mm
Measured = 3.5 ± 0.1 mm
over first 2 pts => 1-2 mm range

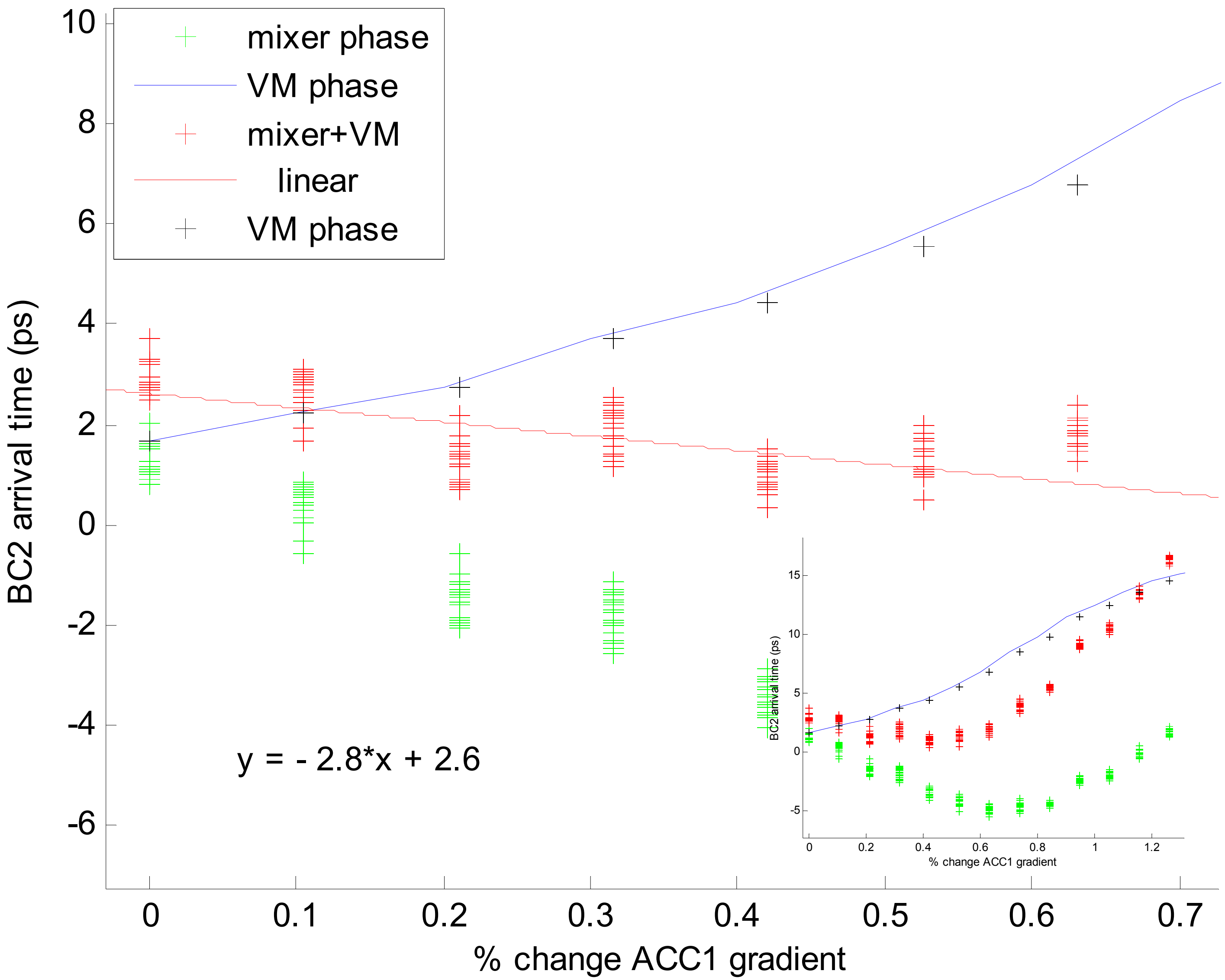


ACC1 gradient scan
Off-crest ACC1

Calibration done once at beginning
VM kept sample point at zero crossing
(of one signal)
No trombone change

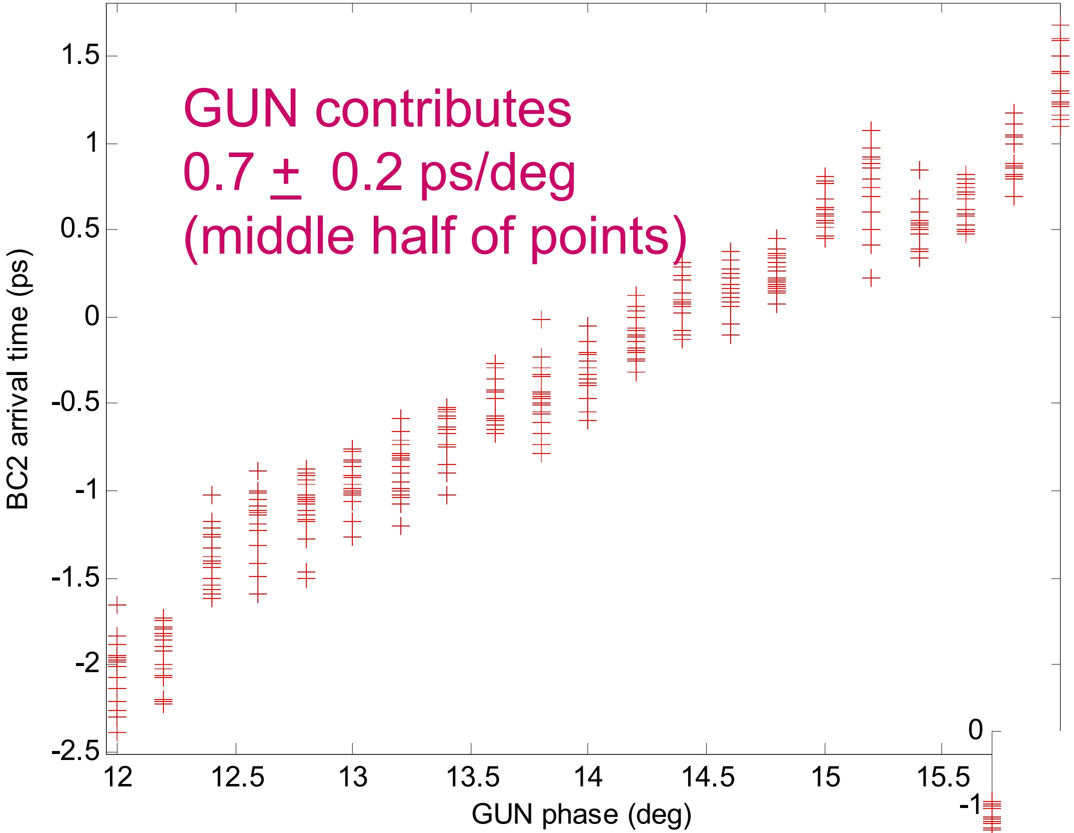
For a 1% energy change:

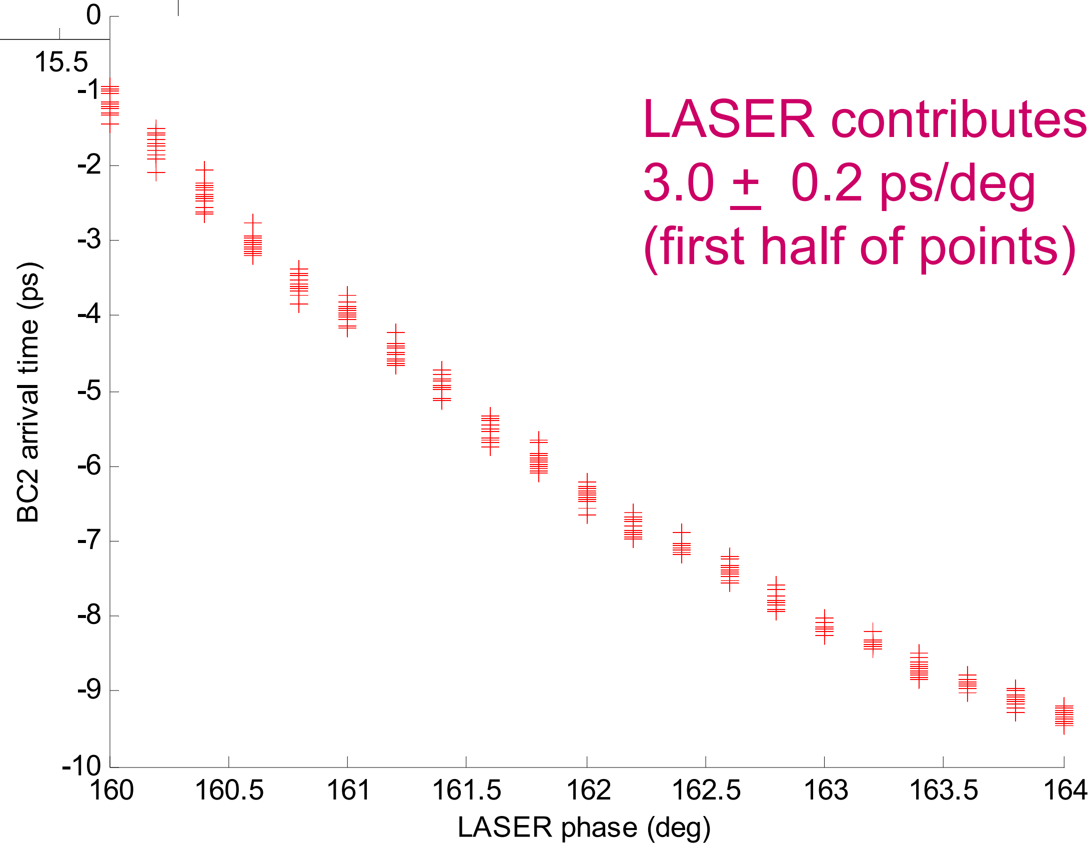
dE/E * R56/2 = 3.1 ps
Measured = 2.8 $\pm$ 0.4 ps
~5 ps range



GUN and LASER phase scans On-crest ACC1

Calibration done once at beginning
No VM change
No trombone change



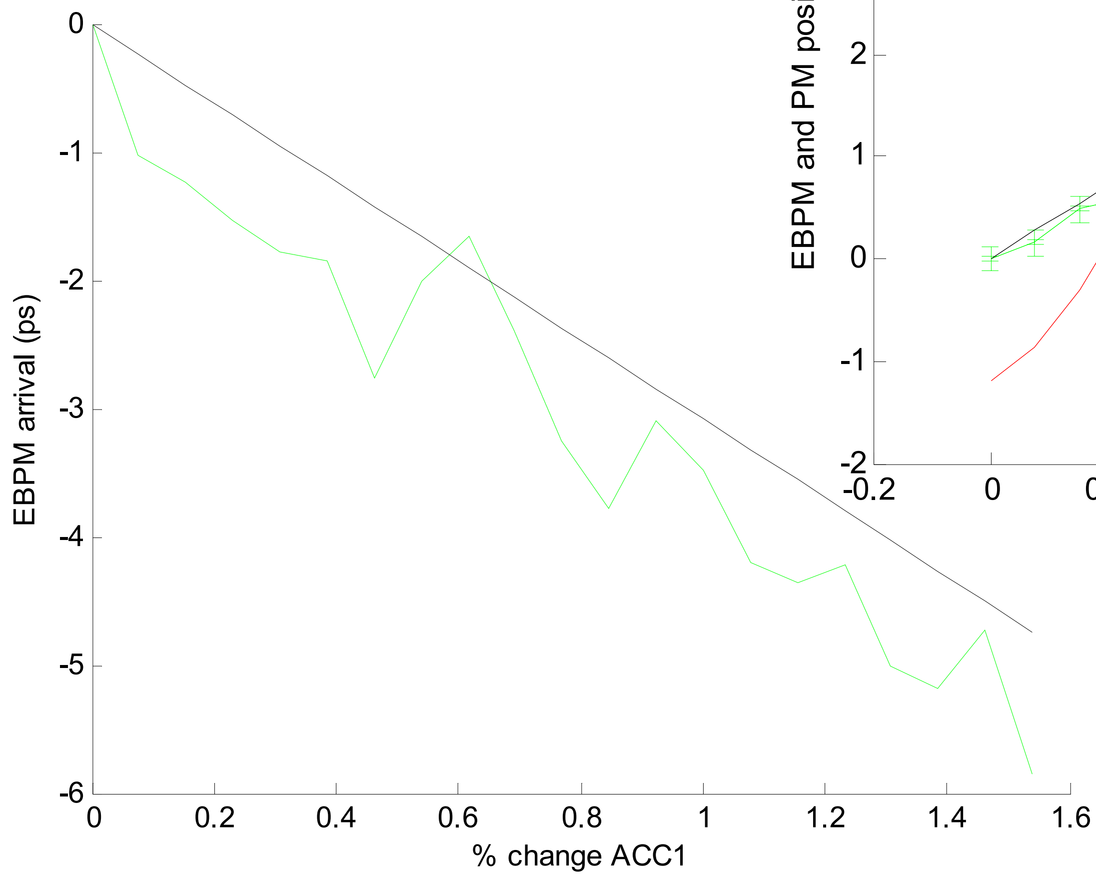


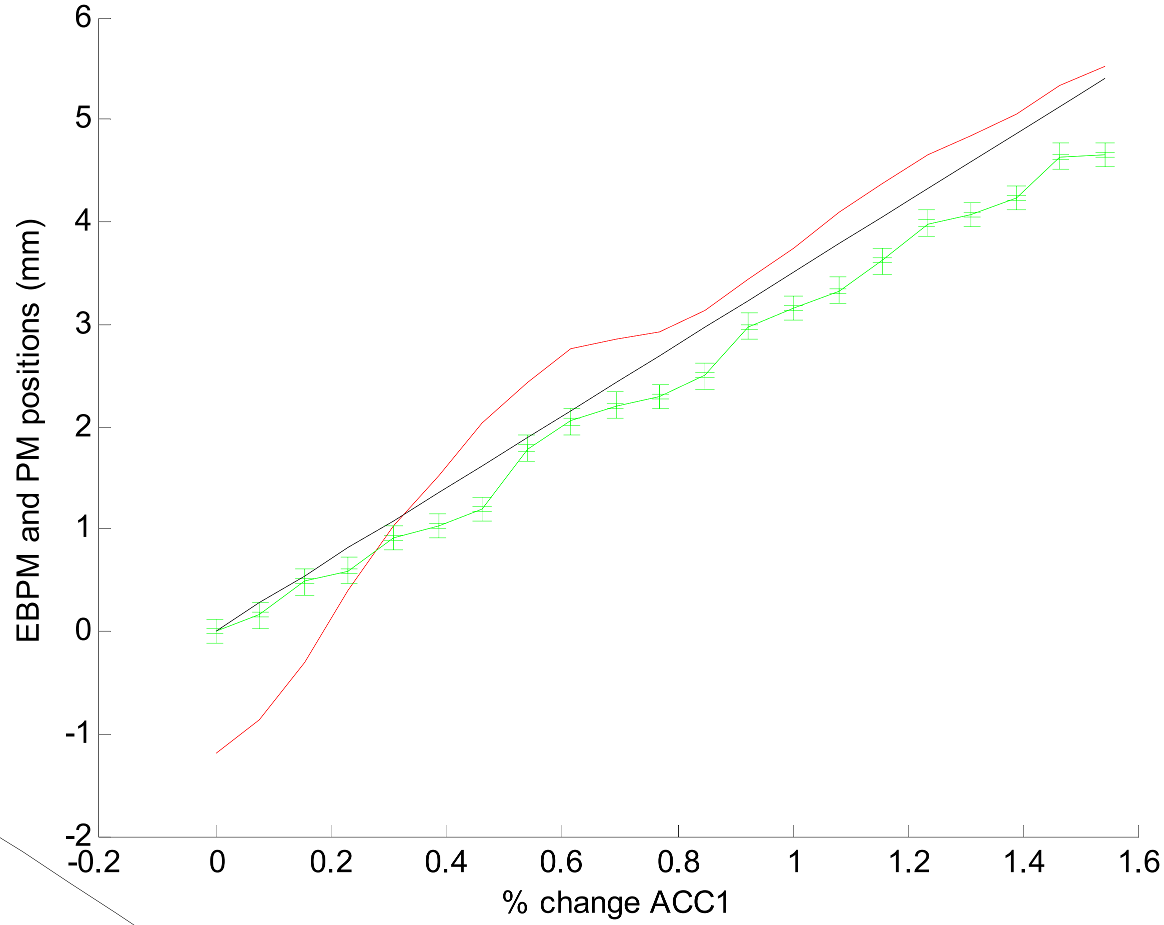
For 1 degree of phase shift,
Sum of arrival-time change from
Gun and Laser should = 2.125 ps

$\boxed{3.0 - 0.7 = 2.3 \pm 0.2 \text{ ps/deg}}$

1.3 GHz (coarse) signal down-mixed

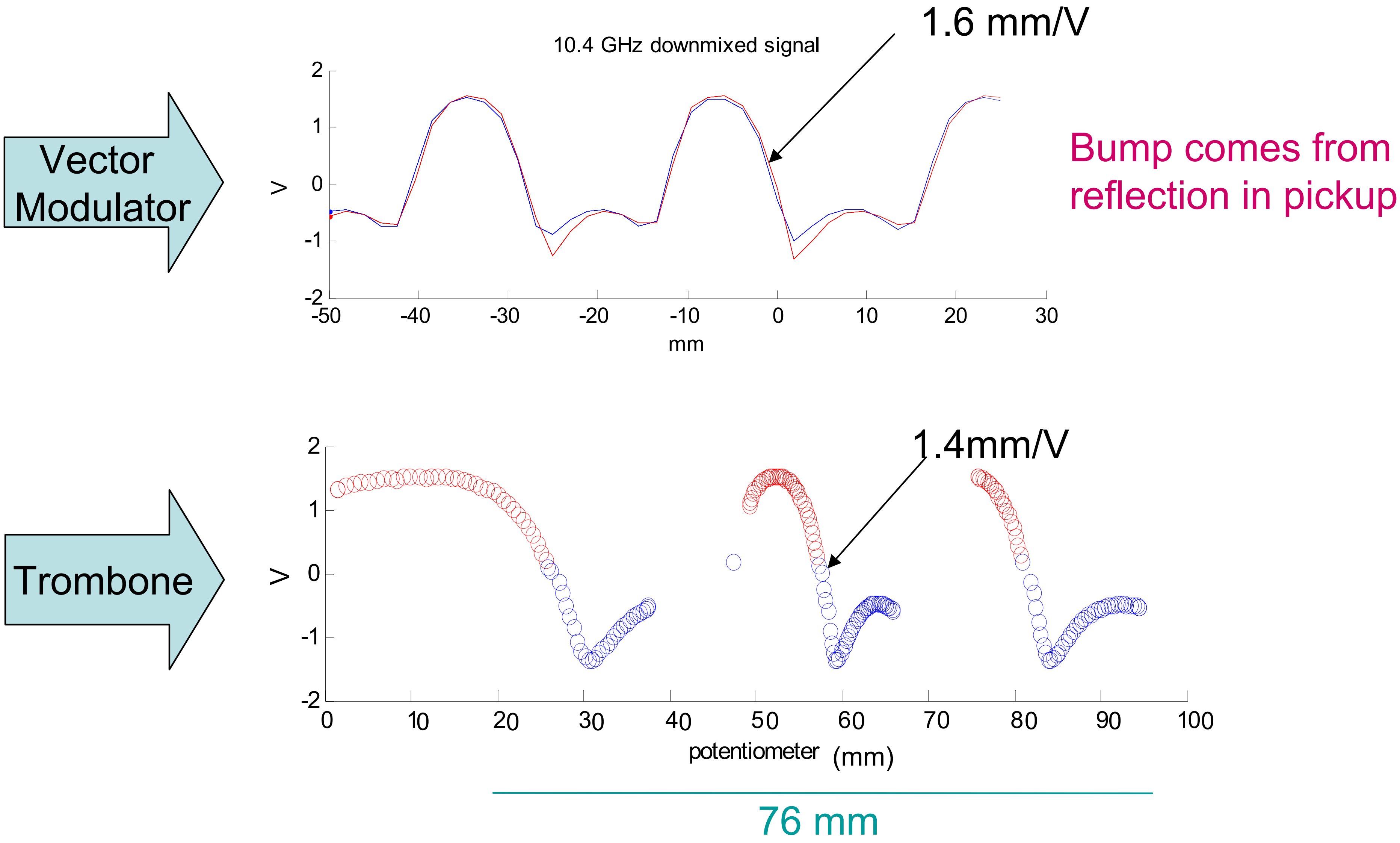
5% (0.5 cm) of monitor's range
25 um resolution (RMS)



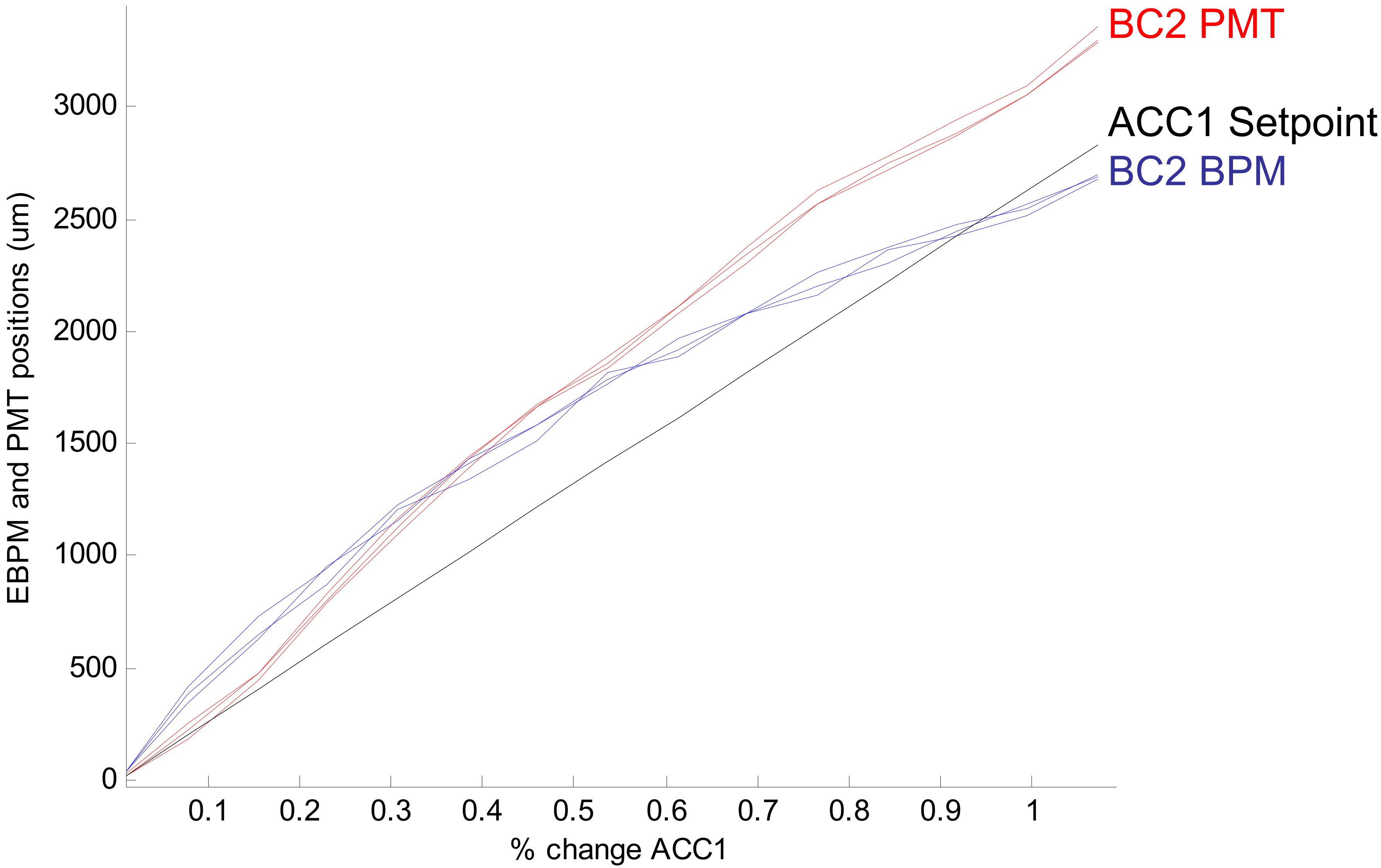


BPM (coarse)
PMT
ACC1 setpoint

Fiducializing the Trombone



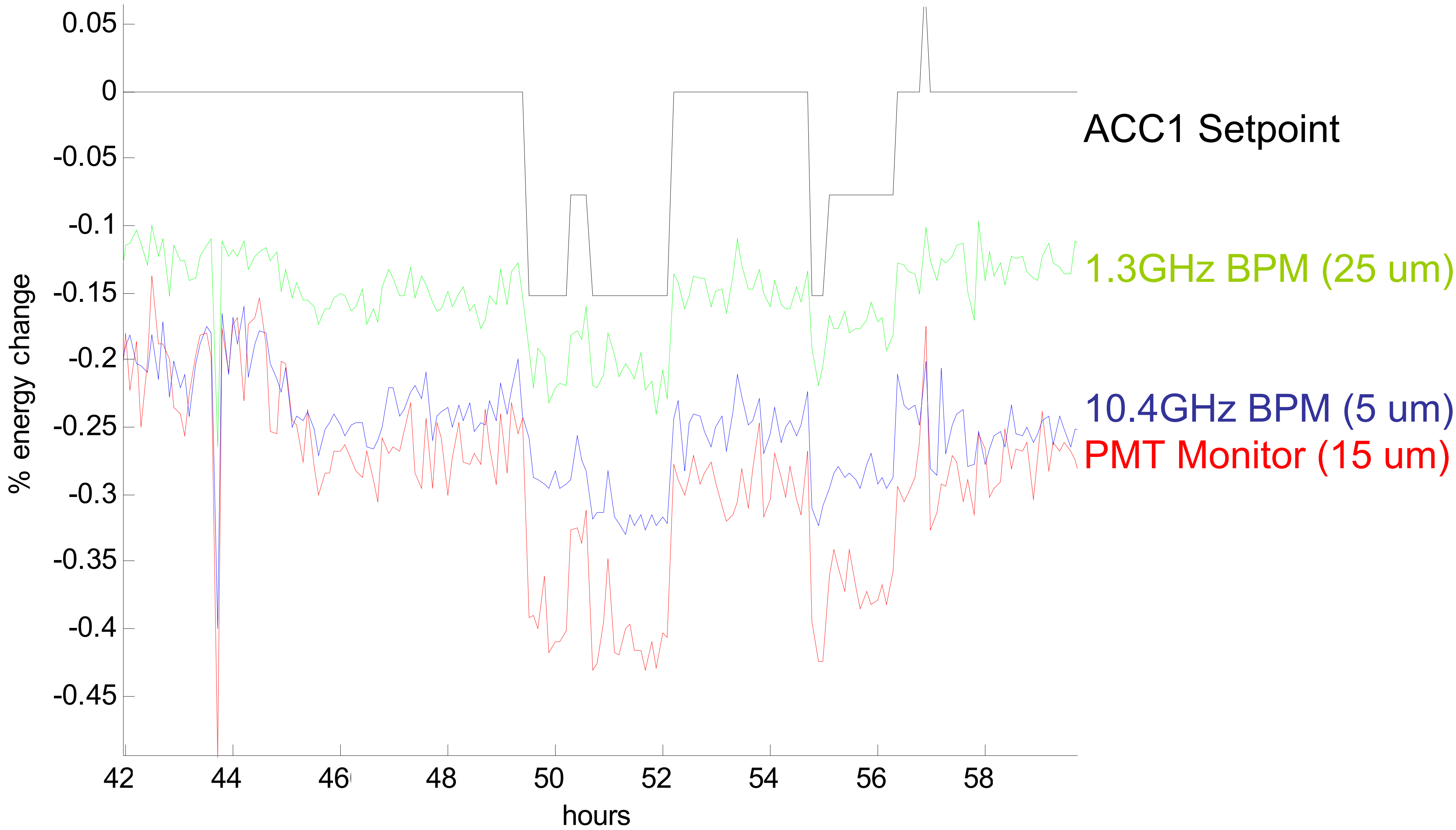
Trombone Feedback On



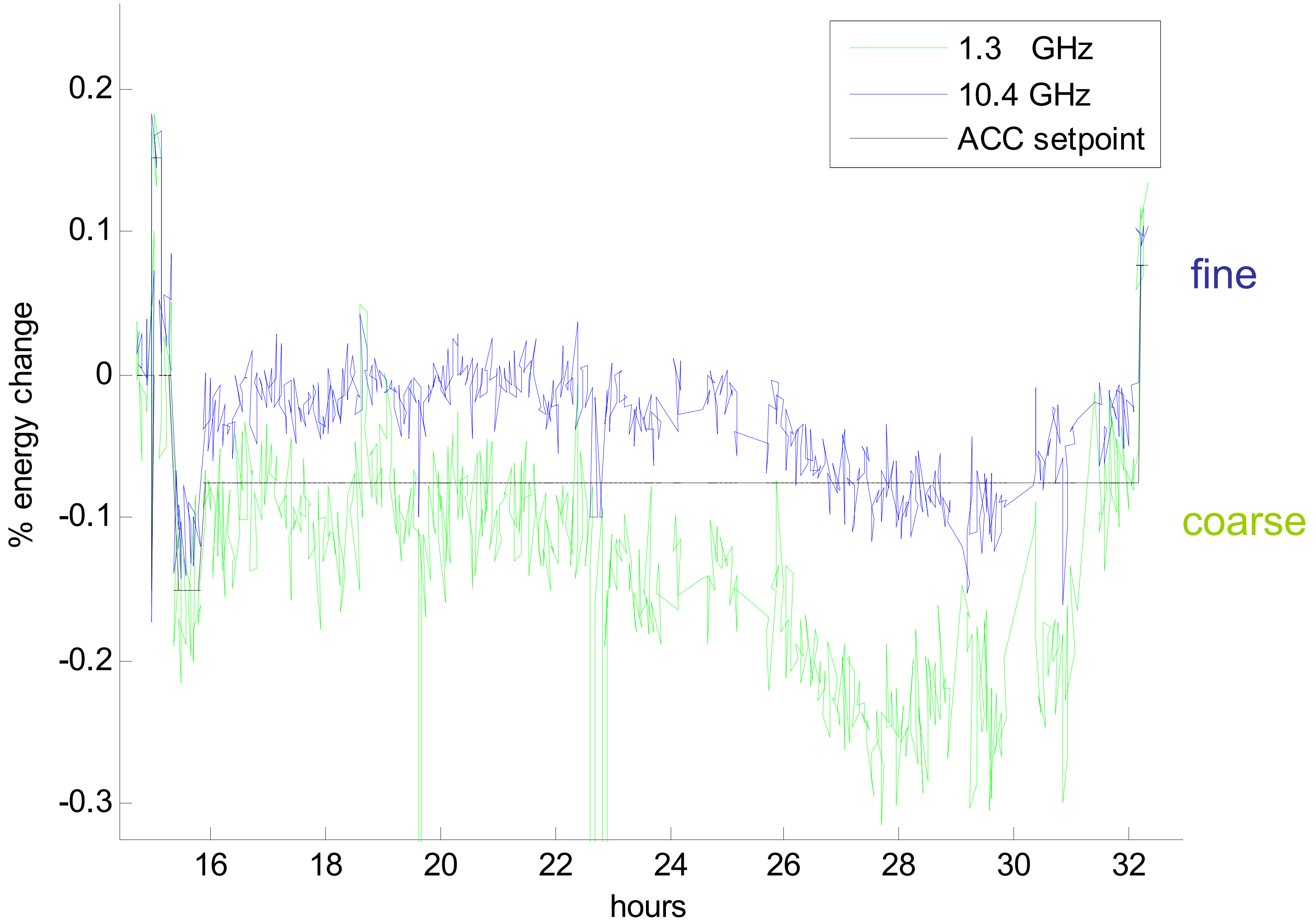
Each measurement point averaged over 20 shots
Scan repeated 3 times

Done with higher power amps
(smaller dynamic range)

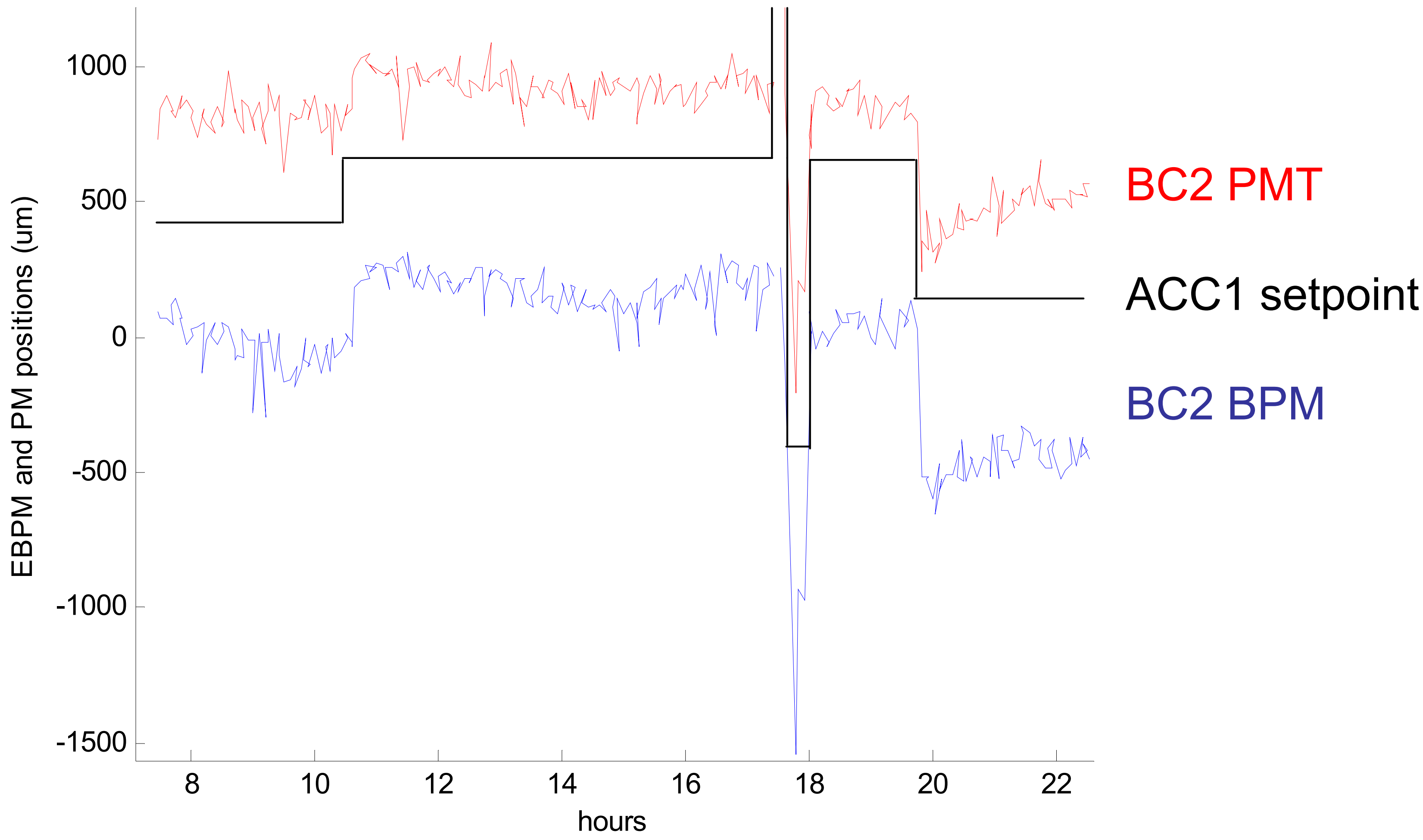
Which one is right?



Coarse and Fine BPM measurements

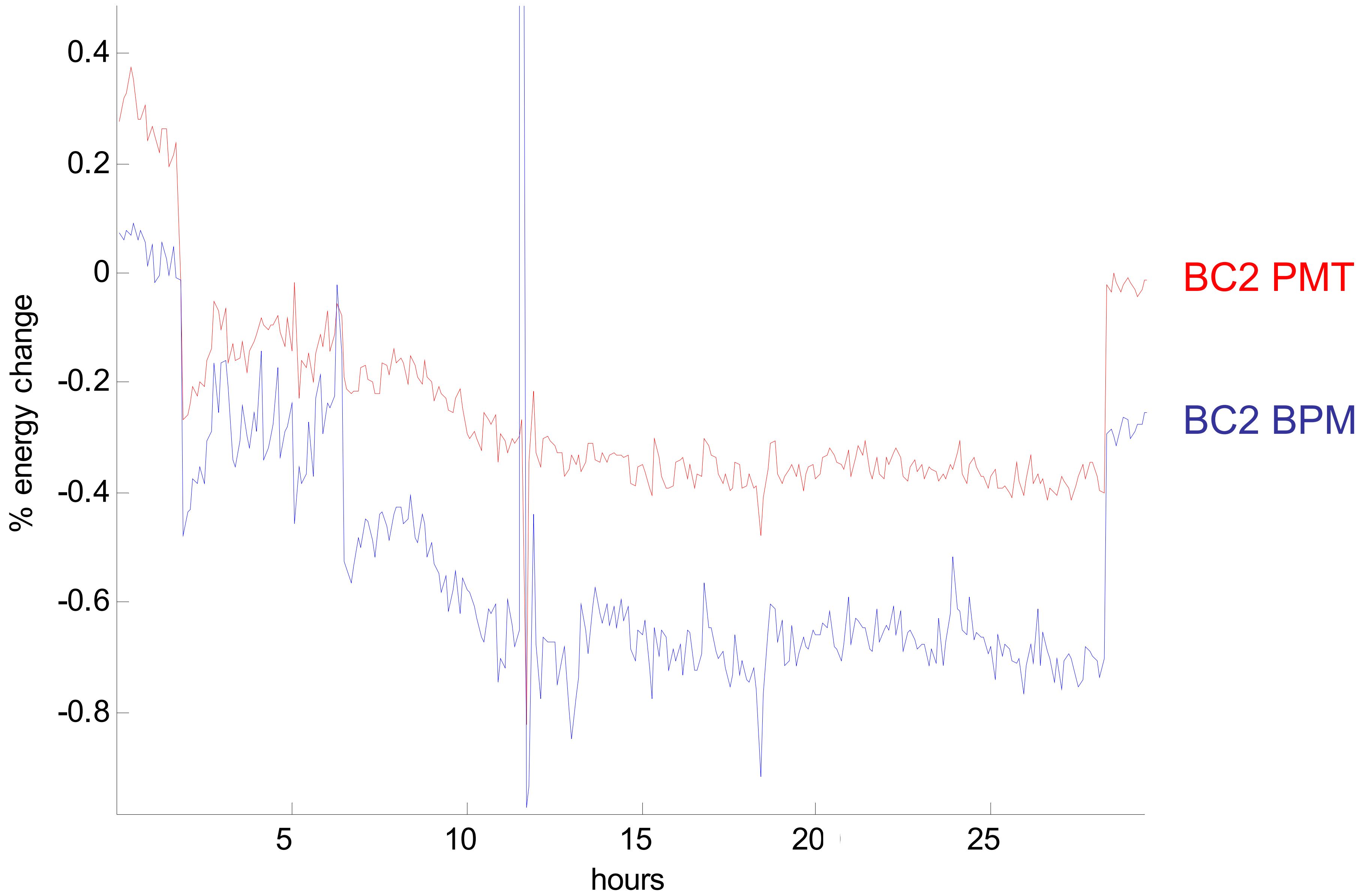


PMT and BPM Sometimes they agree

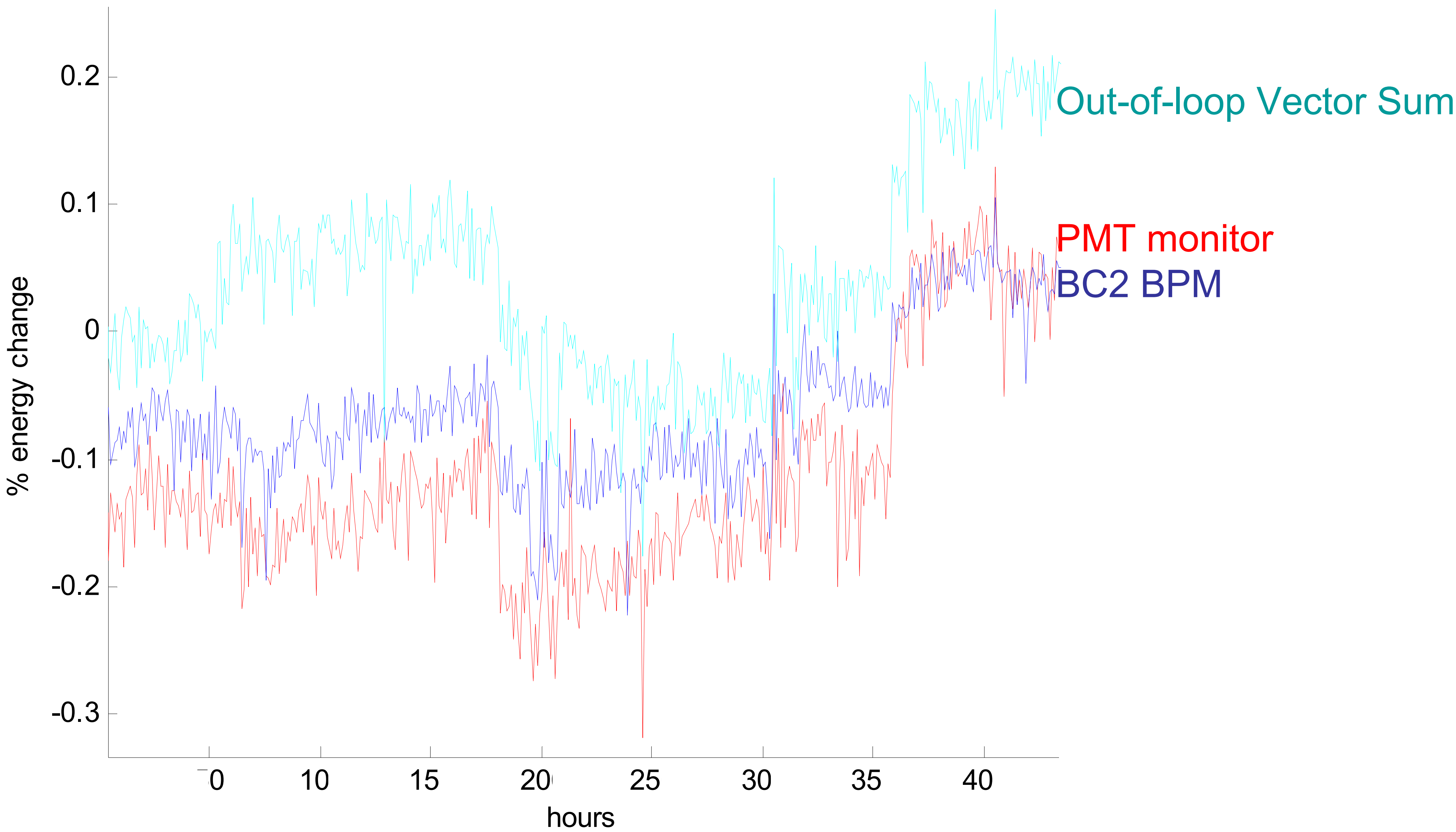


Done with higher power amps
(smaller dynamic range)

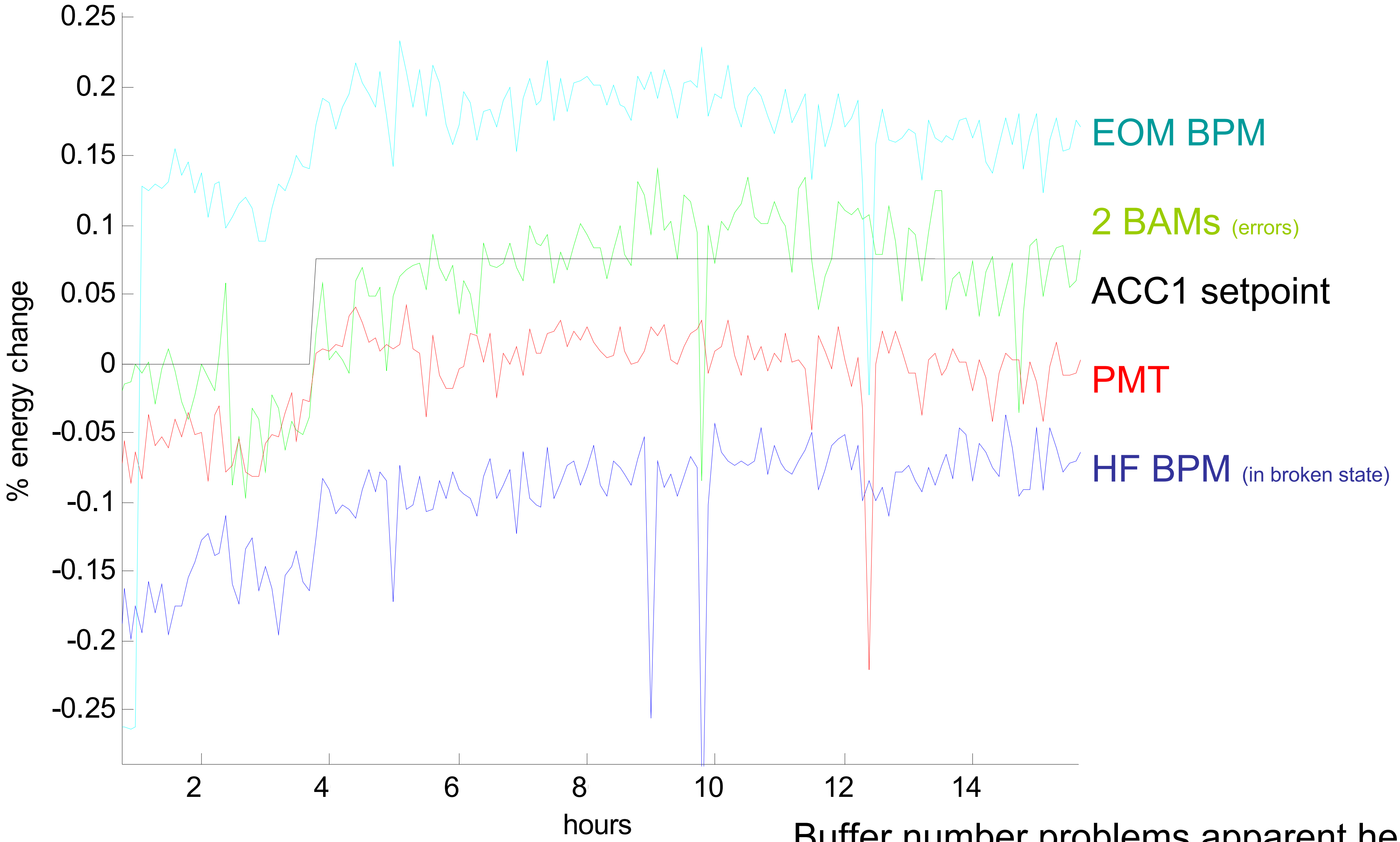
PMT and BPM
Sometimes they don't



3 Independent Energy Monitors

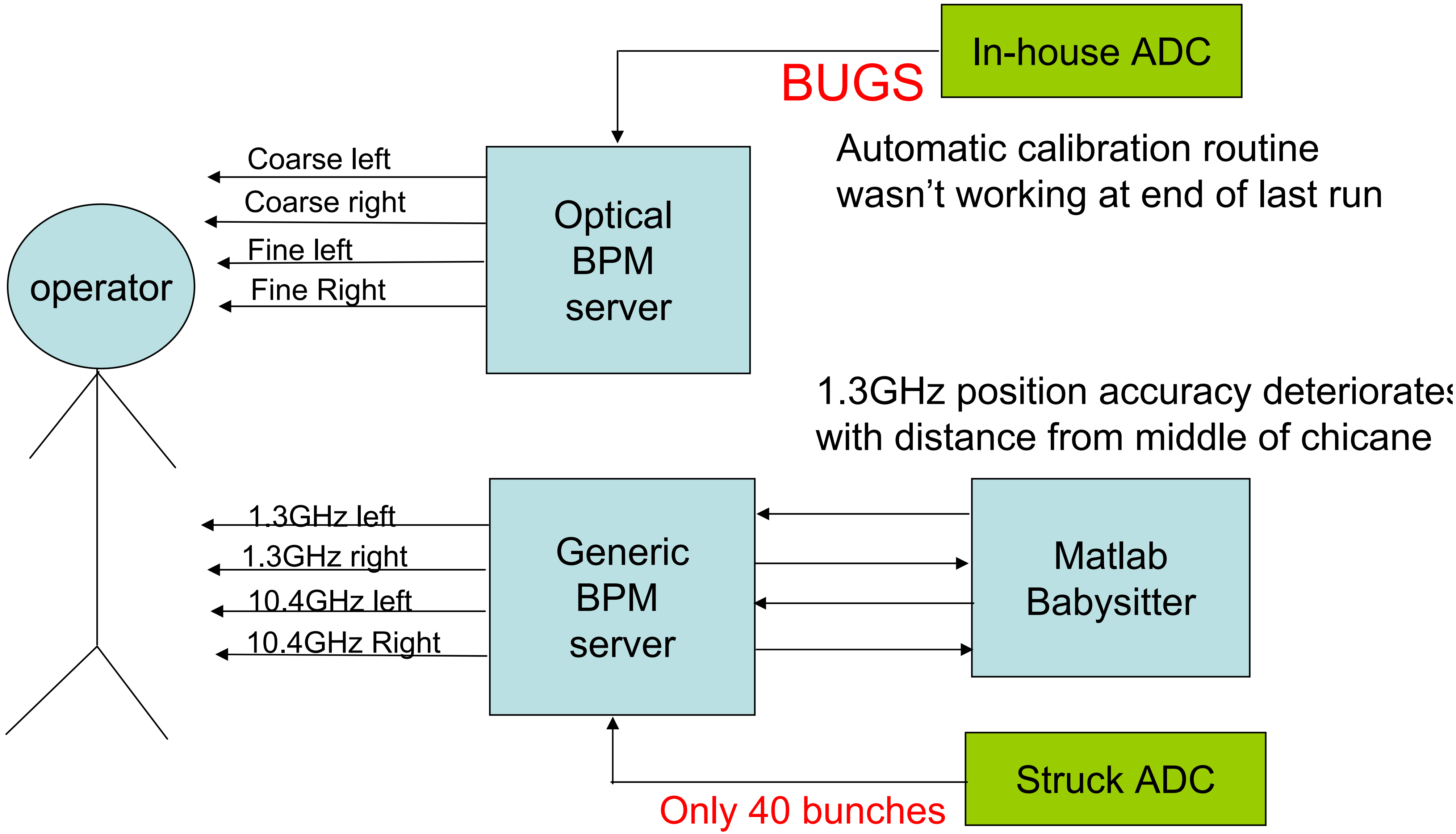


5 Independent BC2 Energy Stability Measurements



Buffer number problems apparent here

Exactly what is available to operators on day one?



Conclusion

- HF can do the job without optical synchronization infrastructure
  - 1.3 GHz measurement in BC2 ready for users
    - DOOCS BPM server
    - Not yet linearized (2ond order polynomial parameters)
    - 25 um resolution
  - 10.4 GHz meas still needs babysitting
    - DOOCS BPM server works in principle (not bulletproof)
    - Takes ~10 seconds to settle in on a new sampling position after dynamic range is exceeded
    - Sampling location is sometimes bad => algorithm needs work
    - Trombone potentiometer adds errors => linear encoder desired

- Optical method works, but infrastructure needs development
  - 2 um resolution demonstrated
  - Motor feedbacks operated for a few hours unattended

Outlook (BC3)

- Quick fix with 1.3 GHz front-end could make (~25 um) low resolution measurement available in BC3 for machine start up

- Components for BC3 optical chassis are ordered, but it is low on priority list for optical synchronization => no stabilized link available