First measurements with Libera CavityBPM

Manuel Cargnelutti, Libera Workshop 2017, 01.06.2017

Presentation outline

- Motivation: ELI-NP gamma beam source
- Principle: How does it work?
- The Libera CavityBPM instrument
- First measurement results
- Future applications

The ELI-NP Gamma Beam Source project

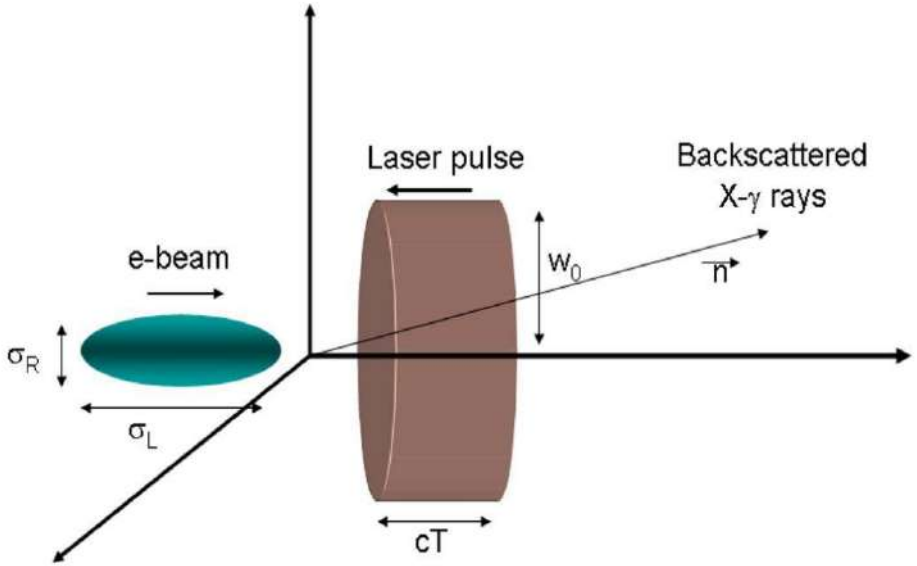
Magurele - Romania

The ELI-NP Gamma Beam Source project

Magurele - Romania

Intense and brilliant γ beam

incoherent Compton back-scattering



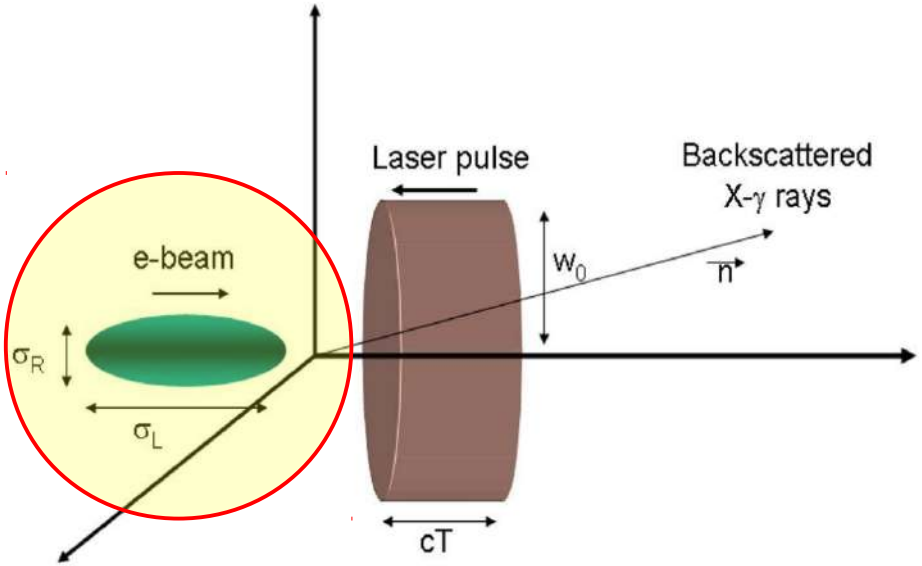
Instrumentation Technologies

The ELI-NP Gamma Beam Source project

Magurele - Romania

Intense and brilliant γ beam

incoherent Compton back-scattering

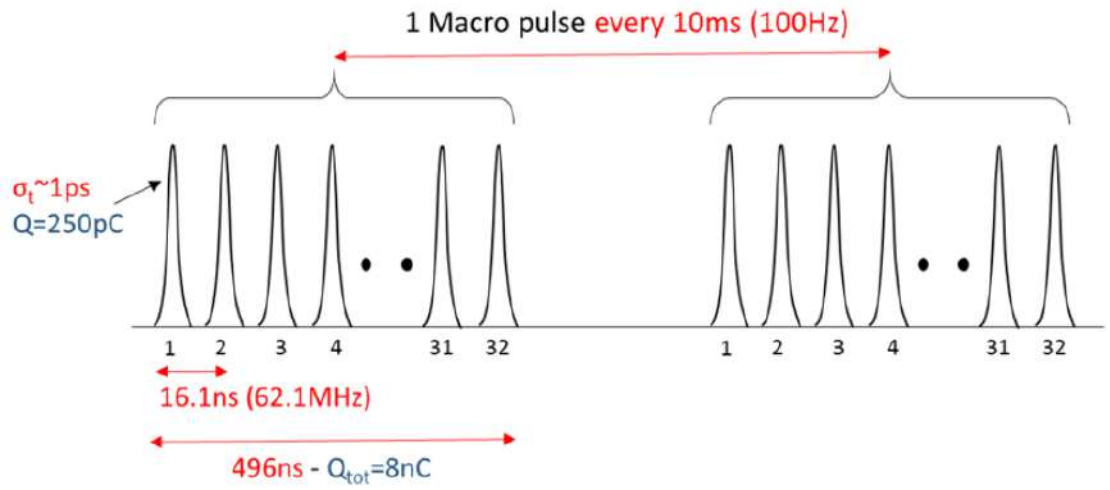


IP: Very good alignment is required → **BPM resolution**!

Instrumentation Technologies

Electron Beam Parameters:

Parameter	Value
Energy (MeV)	720
Bunch charge (pC)	25-250
# bunches in the train	≤ 32
Bunch separation (ns)	**16.1**



Electron Beam Parameters:

Parameter	Value
Energy (MeV)	720
Bunch charge (pC)	25-250
# bunches in the train	≤ 32
Bunch separation (ns)	**16.1**

BPM requirements:

- Sub-μm position resolution in the range of +/- 1mm
- Bunch-by-bunch position measurement

Electron Beam Parameters:

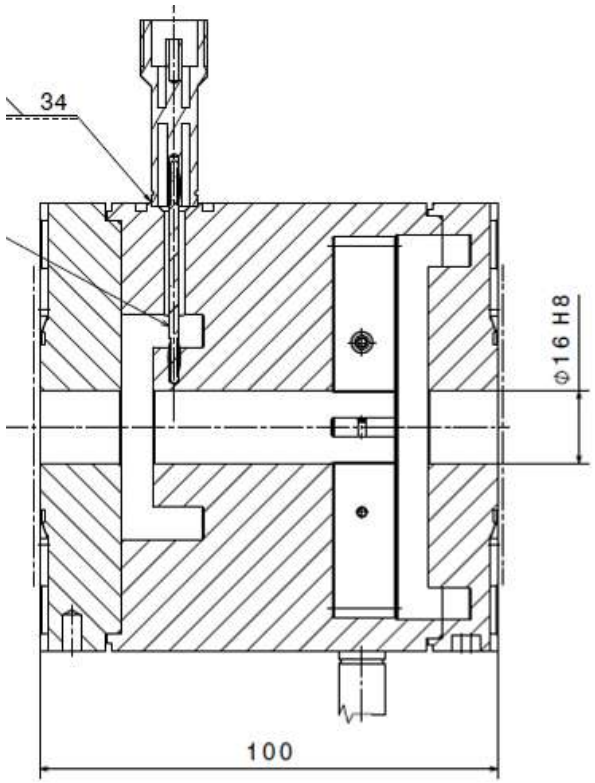
Parameter	Value
Energy (MeV)	80-720
Bunch charge (pC)	25-400
# bunches in the train	≤ 32
Bunch separation (ns)	**16.1**

BPM requirements: → **Cavity BPM**

- Sub-μm position resolution in the range of +/- 1mm
- Bunch-by-bunch position measurement

Libera

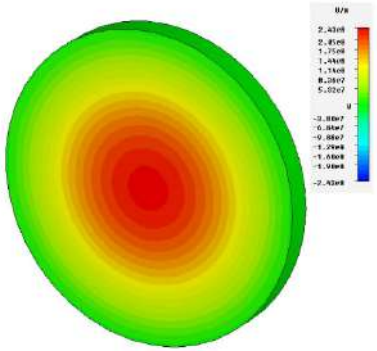
Cavity BPM pickup



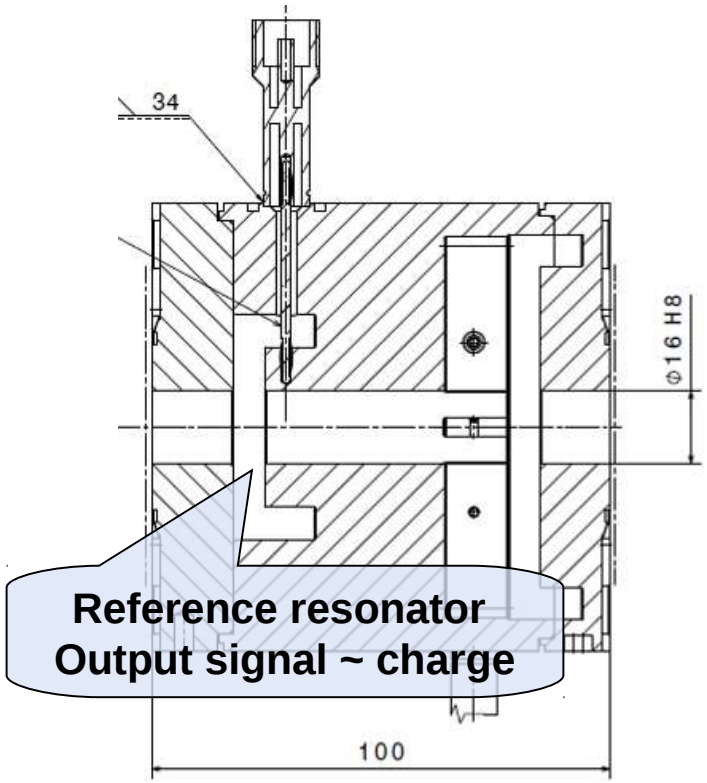
PSI – BPM16 pickup

Instrumentation Technologies

Cavity BPM pickup

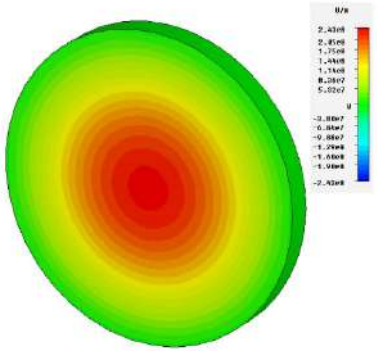


Mode TM_{110}

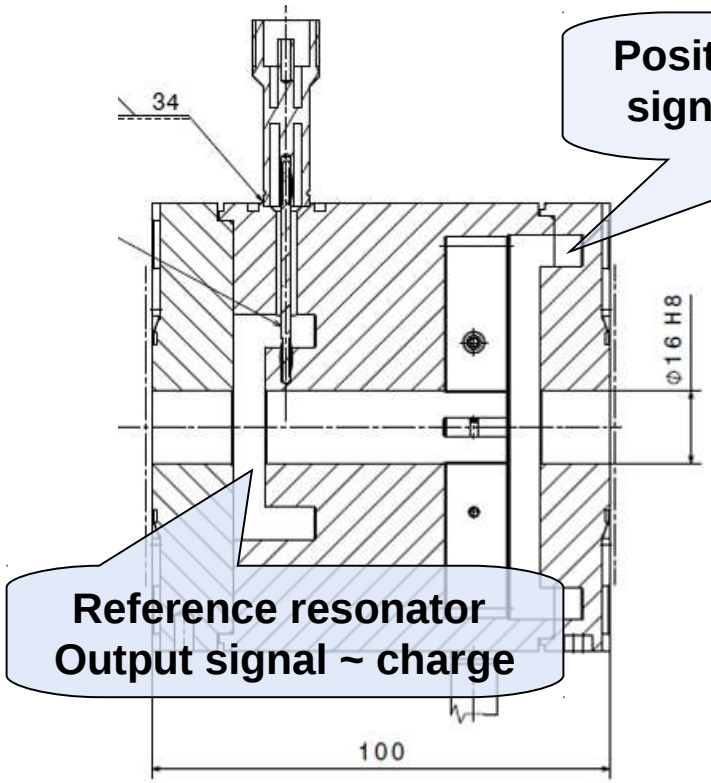


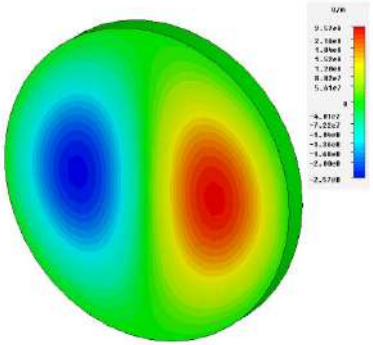
PSI – BPM16 pickup

Cavity BPM pickup



Mode TM_{110}

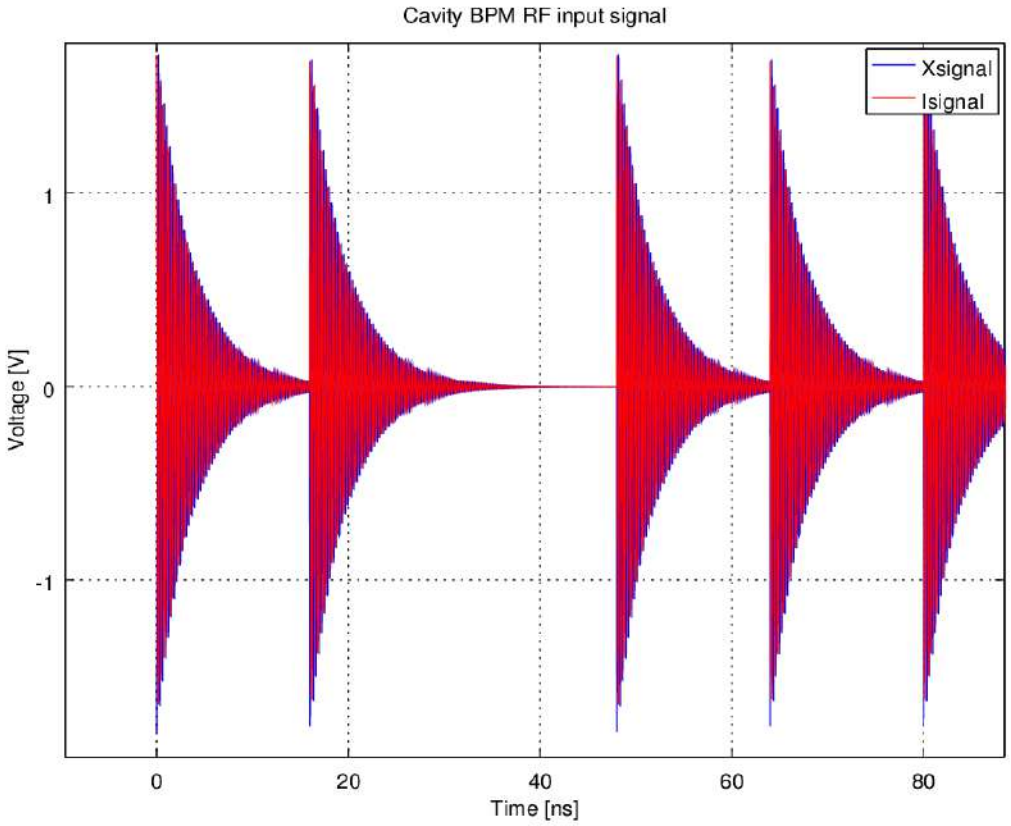




Mode TM_{010}

PSI – BPM16 pickup

Cavity BPM output signal

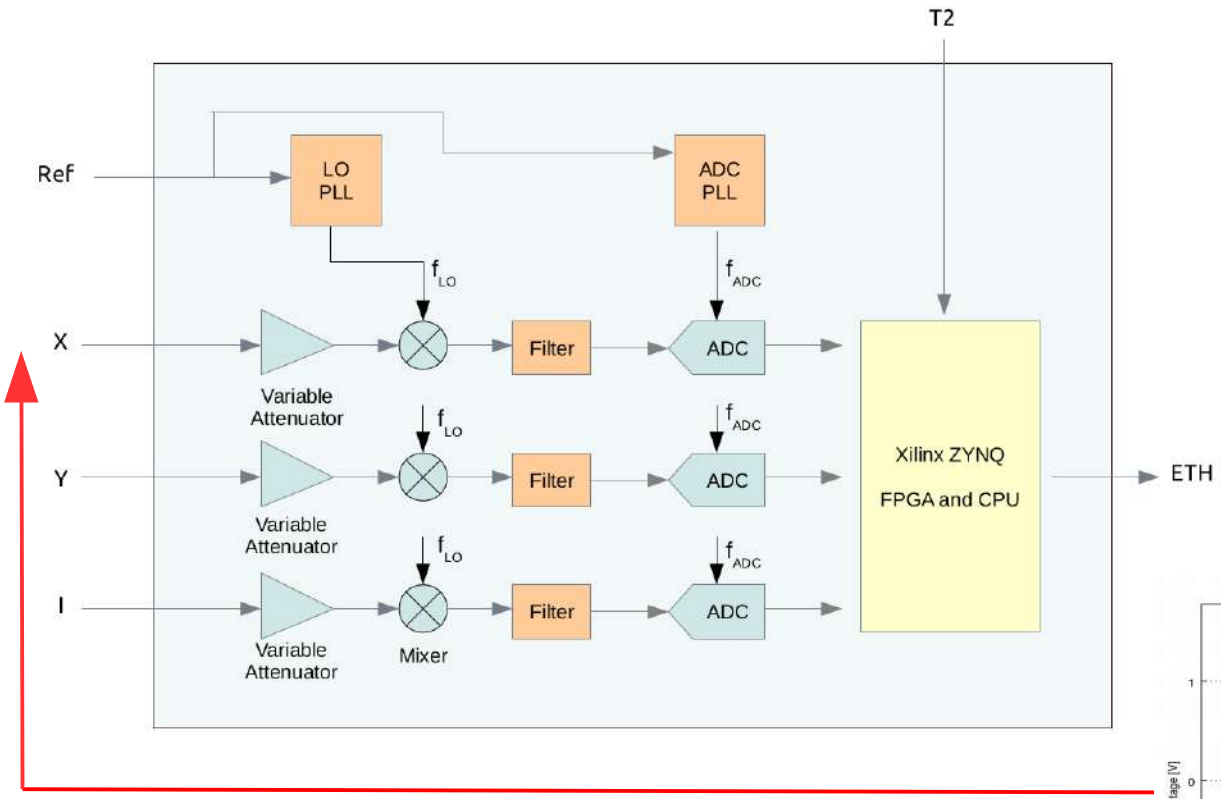


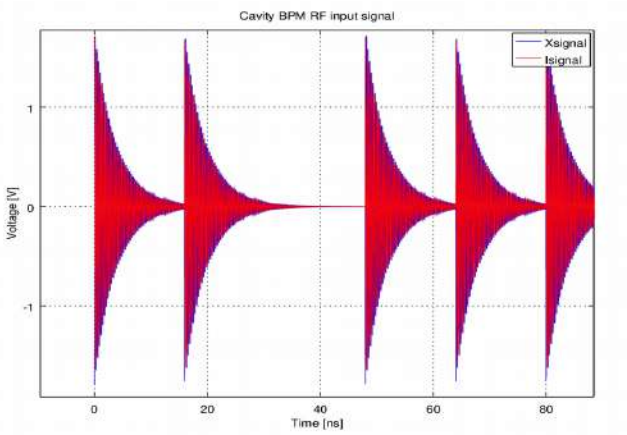
$$f_{res} = 3.284 GHz$$

$$Q = 40$$

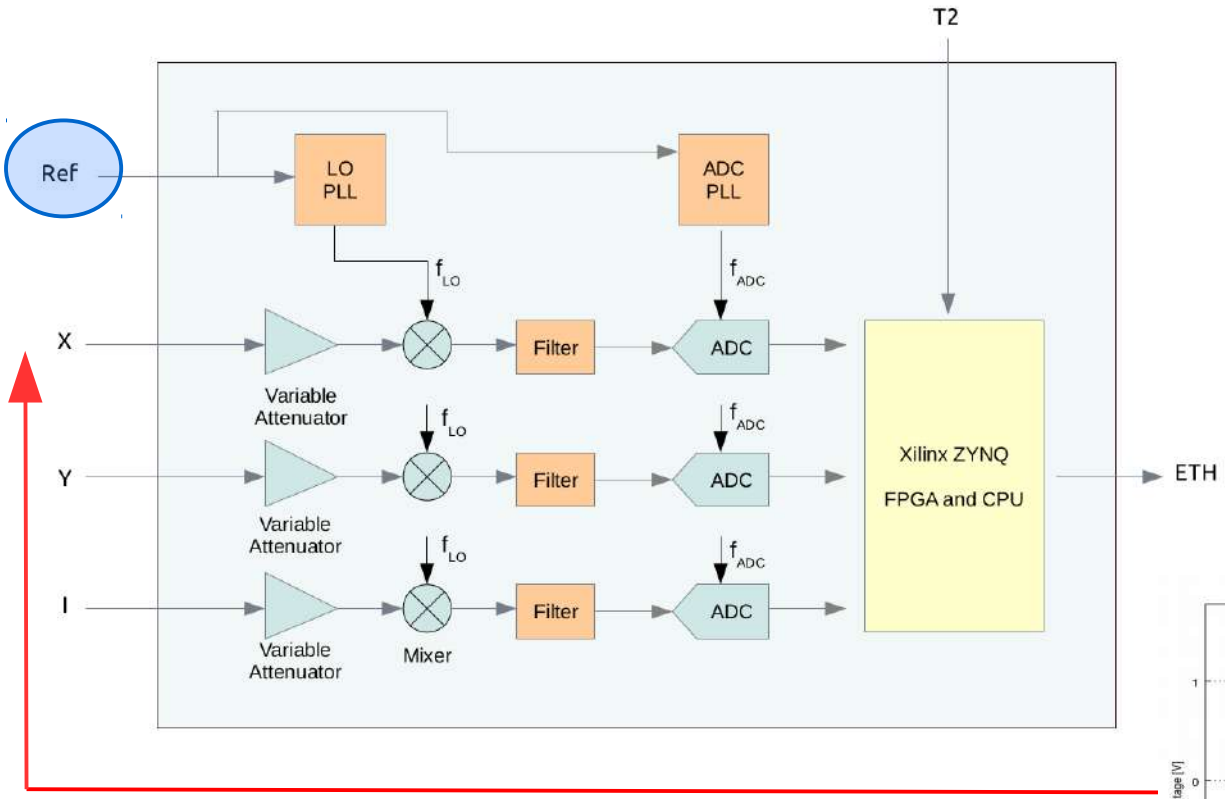
$$T_{decay} \cong Q/f_{res} = 12.1 ns$$

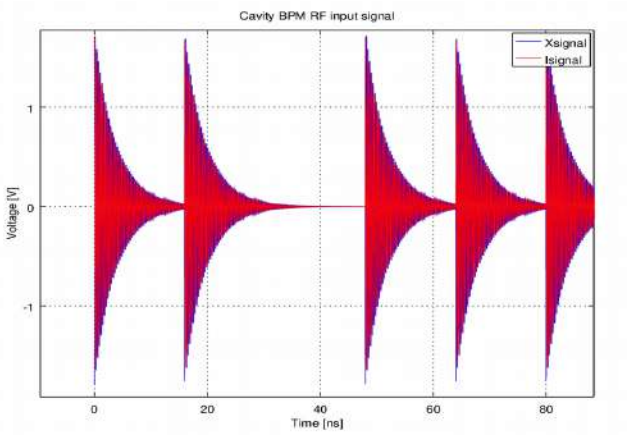
How does it work?



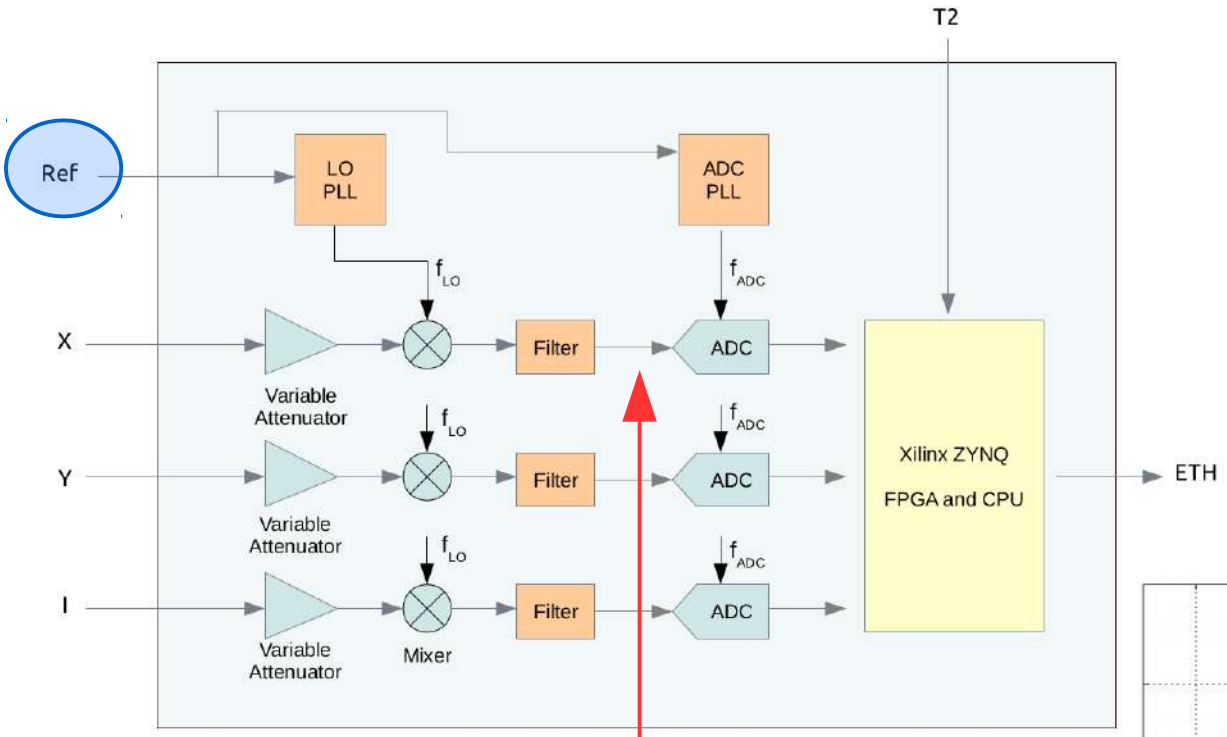


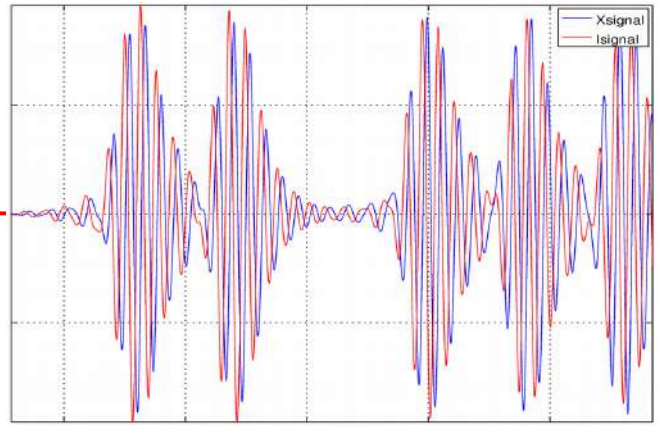
How does it work?



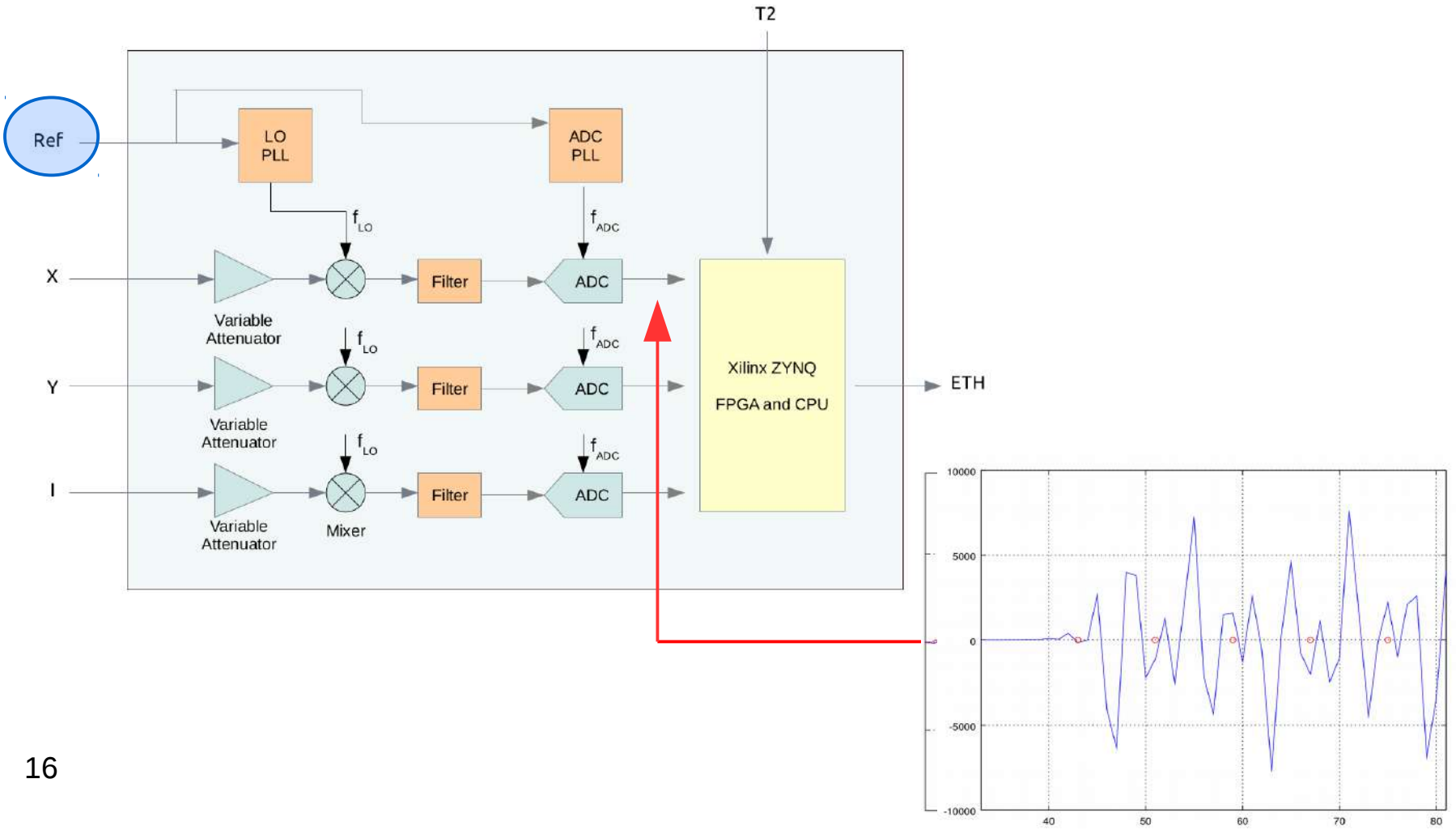


How does it work?

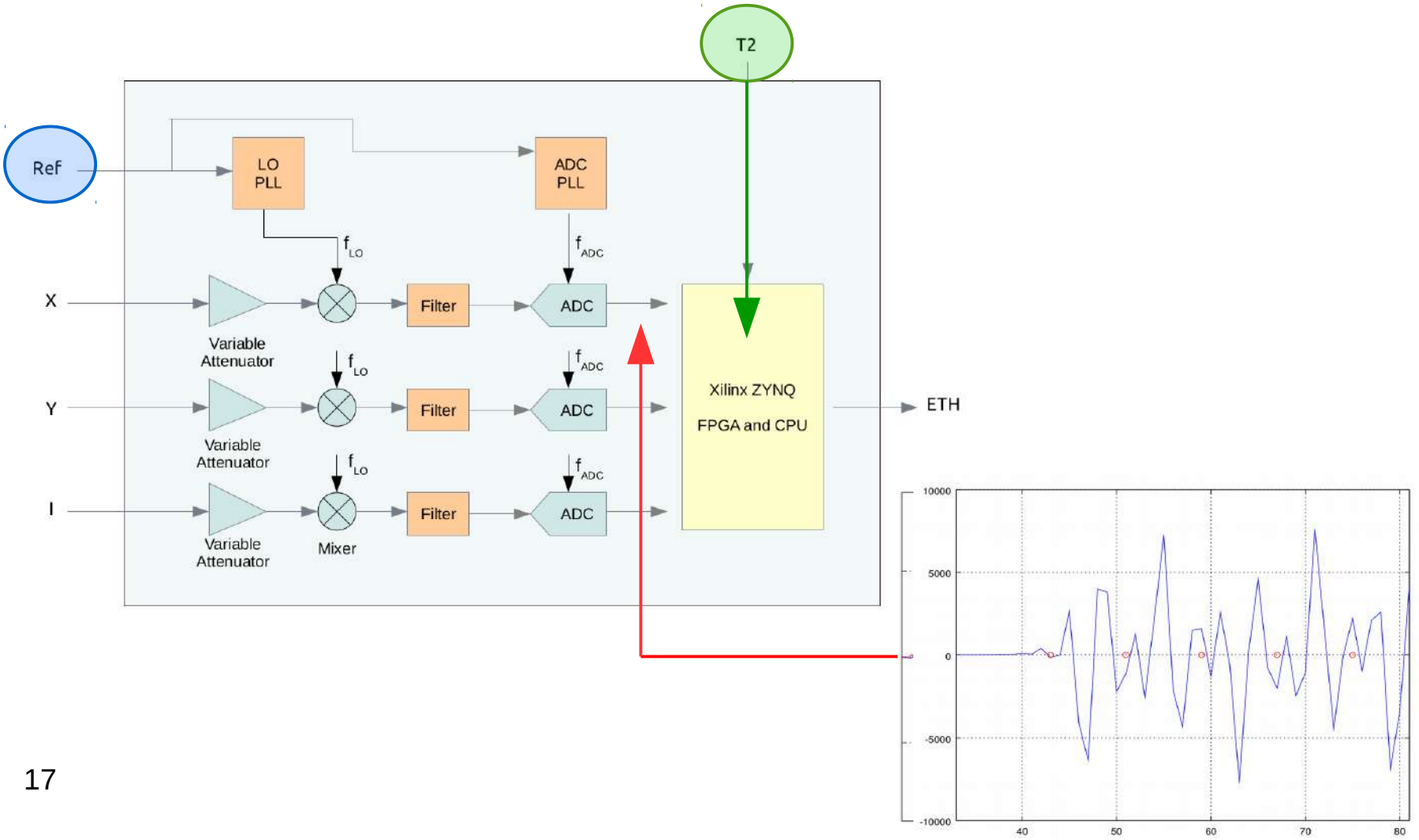




How does it work?



How does it work?



Presentation outline

- Motivation: ELI-NP gamma beam source
- Principle: How does it work?
- The Libera CavityBPM instrument
- First measurement results
- Future applications

Libera CavityBPM

Libera CavityBPM

Technical facts

ADC	4 channels, 500MS/s, 14bit
SoC	ZYNQ 7035 / ARM Cortex A9
ADC buffer	4kS/channel (~8us)
Variable attenuation	31dB, channel-independent
Input signal frequency	C-band, S-band
Reference signal frequency	Up to 250MHz
Cooling	Passive

Presentation outline

- Motivation: ELI-NP gamma beam source
- Principle: How does it work?
- The Libera CavityBPM instrument
- First measurement results
- Future applications

Test setup

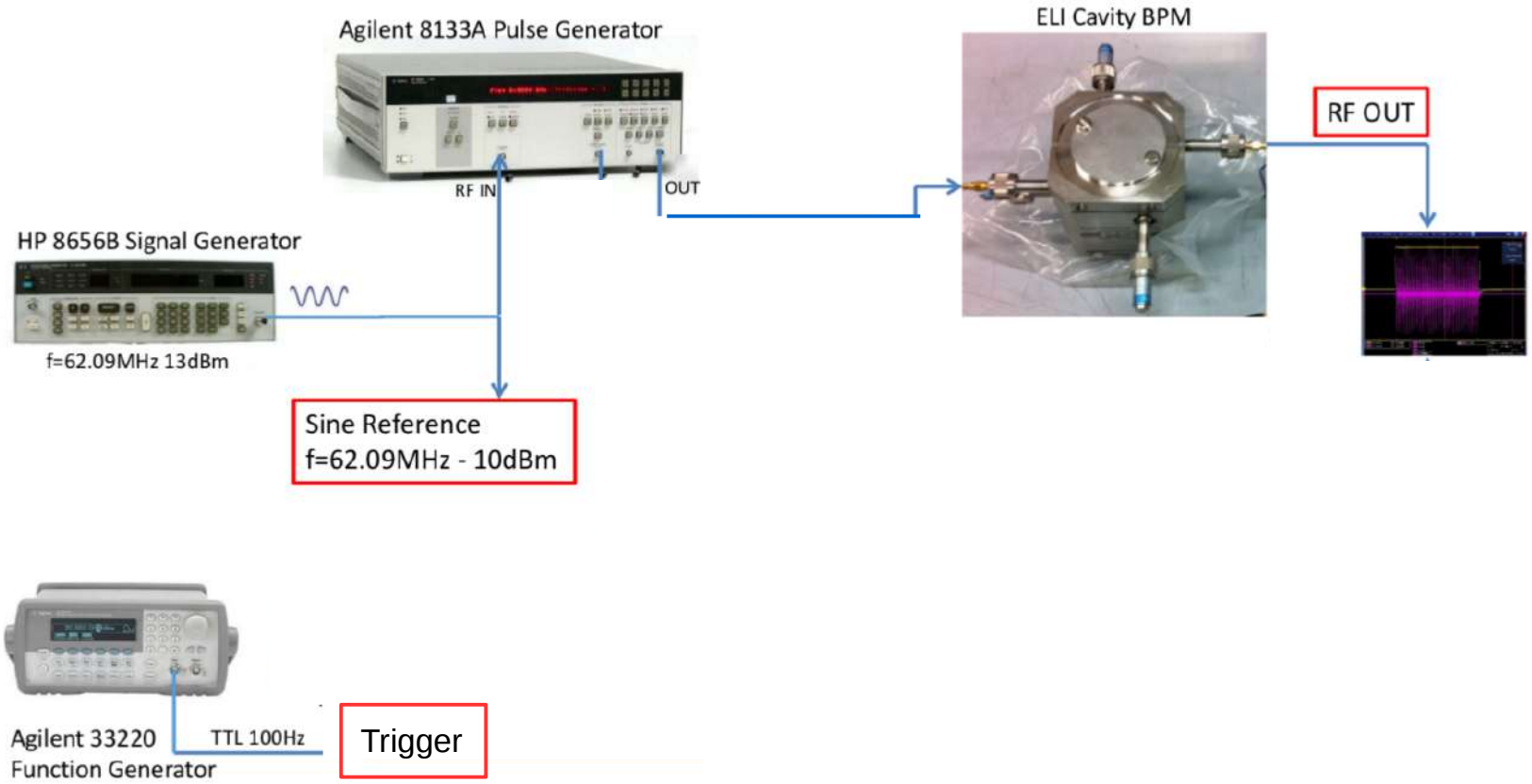
How to reproduce the signal from a Cavity BPM?

Test setup

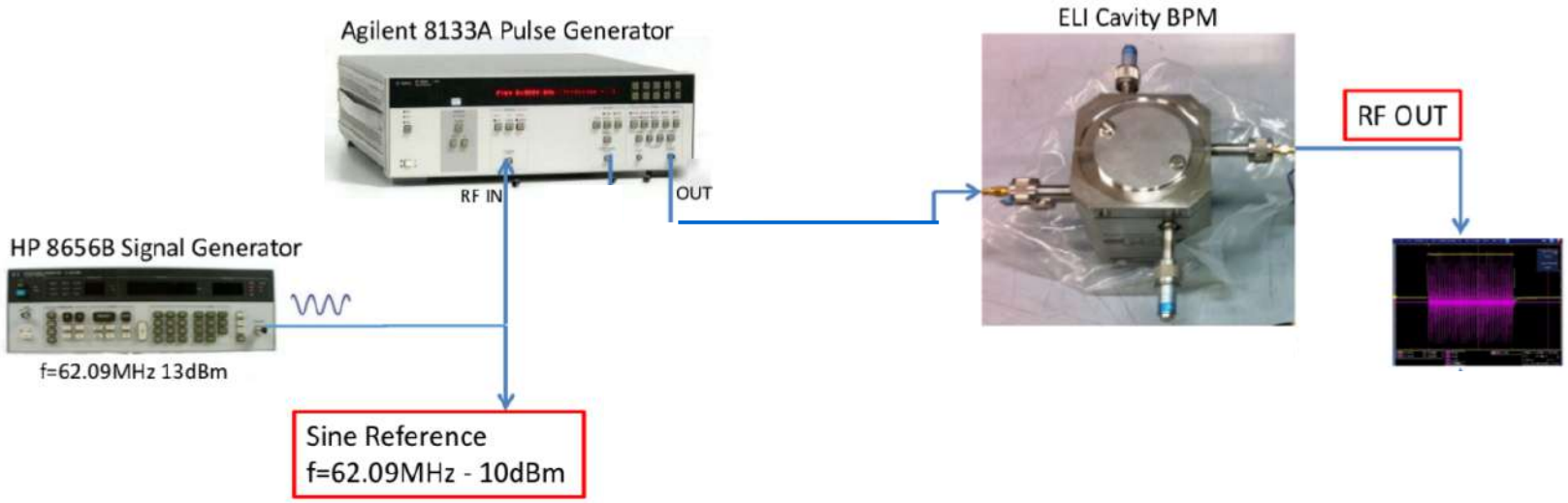
How to reproduce the signal from a Cavity BPM?

...use a cavity!

Test setup

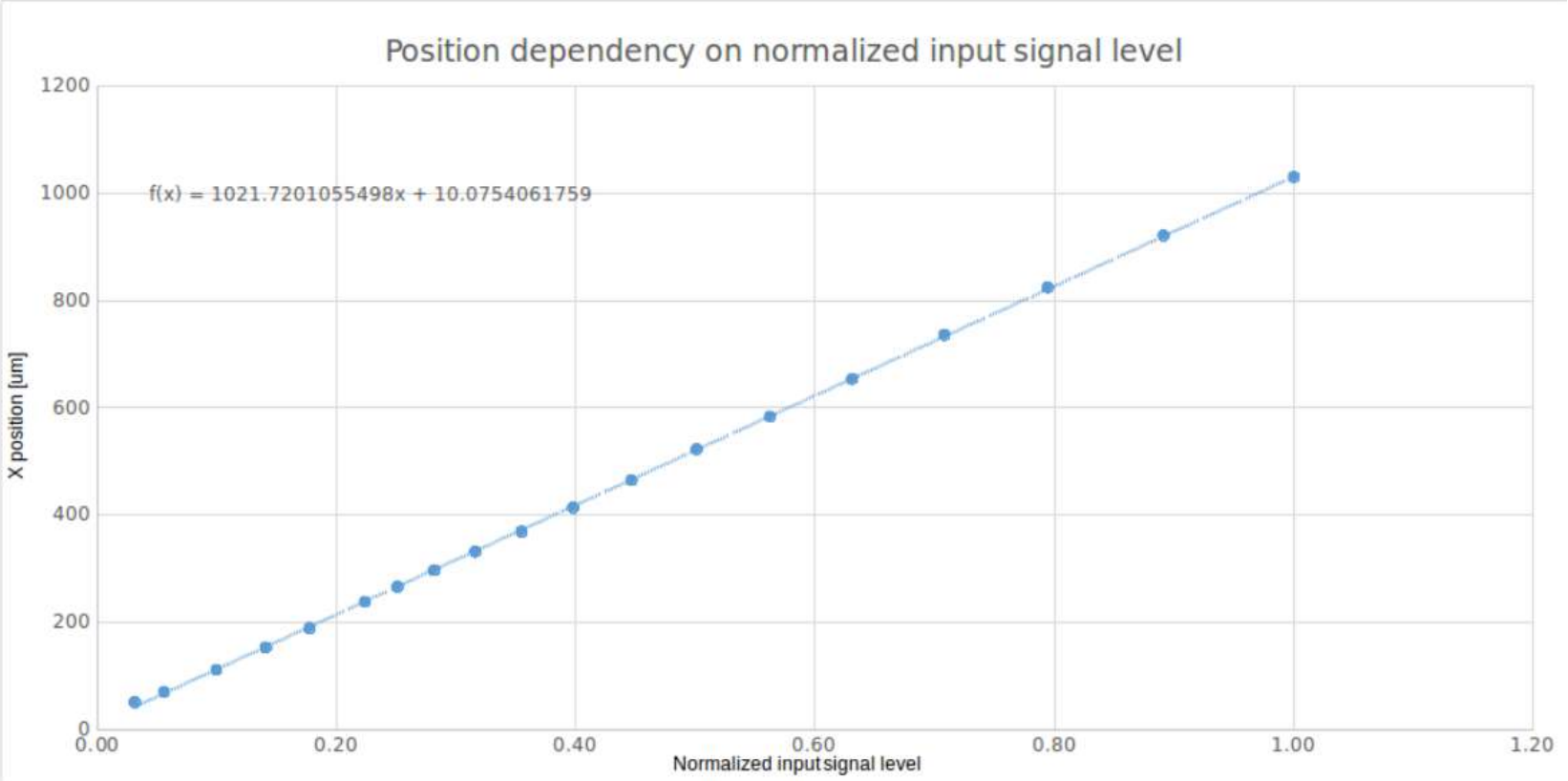

Agilent 8133A Pulse Generator
RF IN
OUT
ELI Cavity BPM
RF OUT
HP 8656B Signal Generator
f=62.09MHz 13dBm
Sine Reference
f=62.09MHz - 10dBm
Agilent 33220
Function Generator
TTL 100Hz
Trigger

Test setup

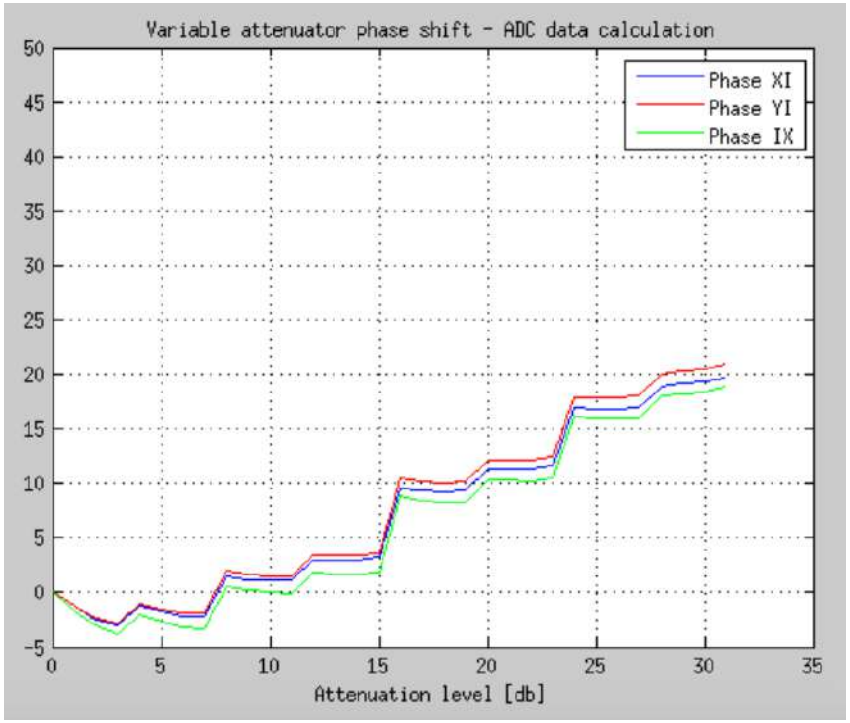


...Single bunches!

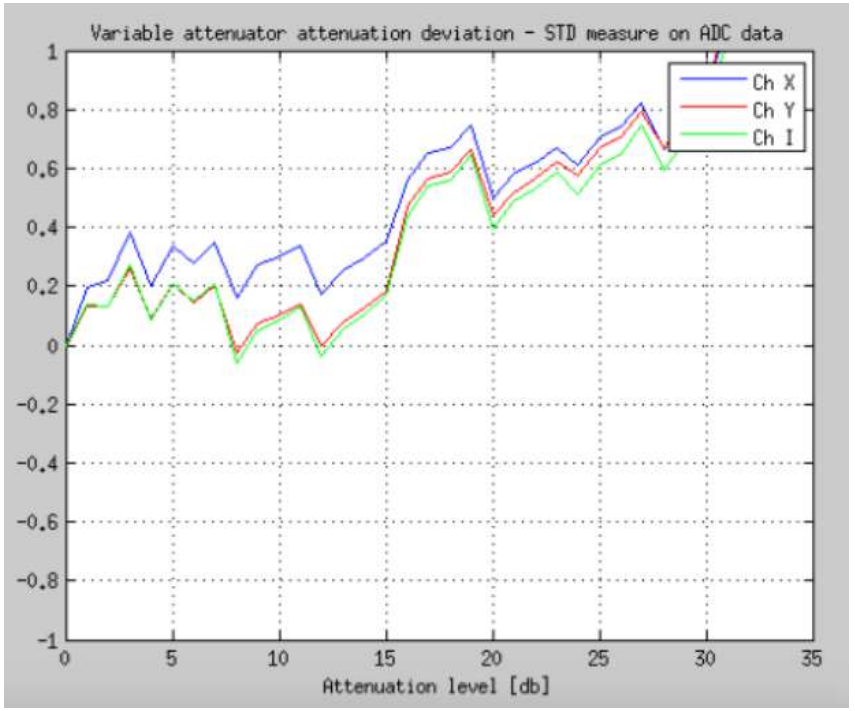
Linearity measurement



Attenuator non-idealities

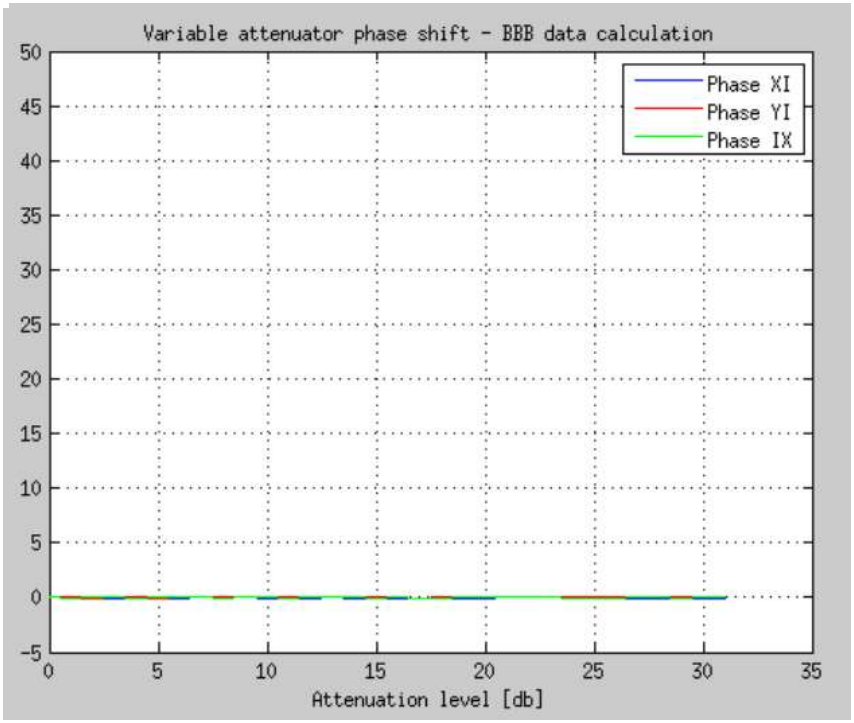


Different phase-shift

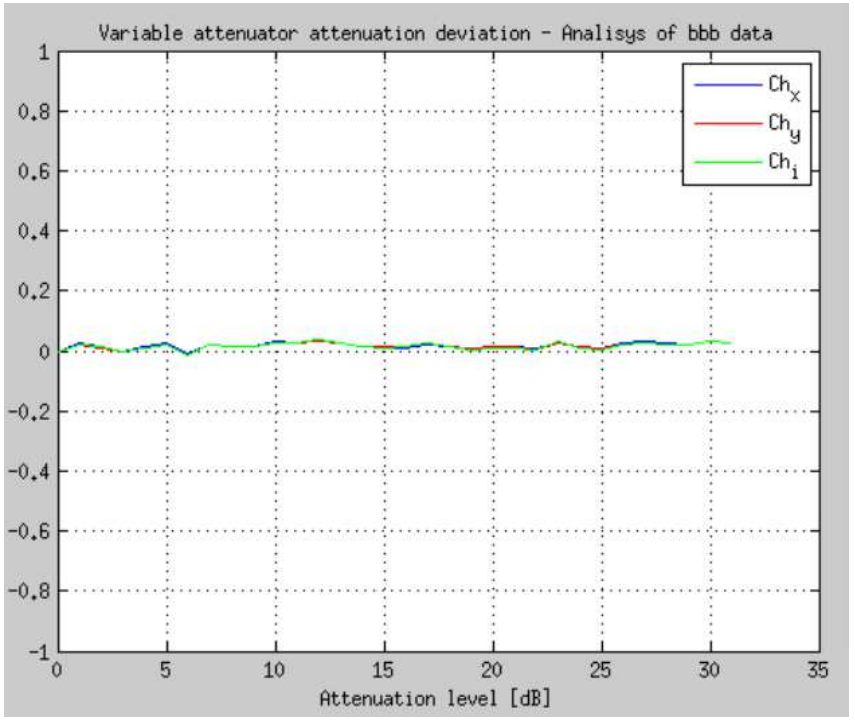


Attenuation deviations

Attenuator non-idealities can be calibrated

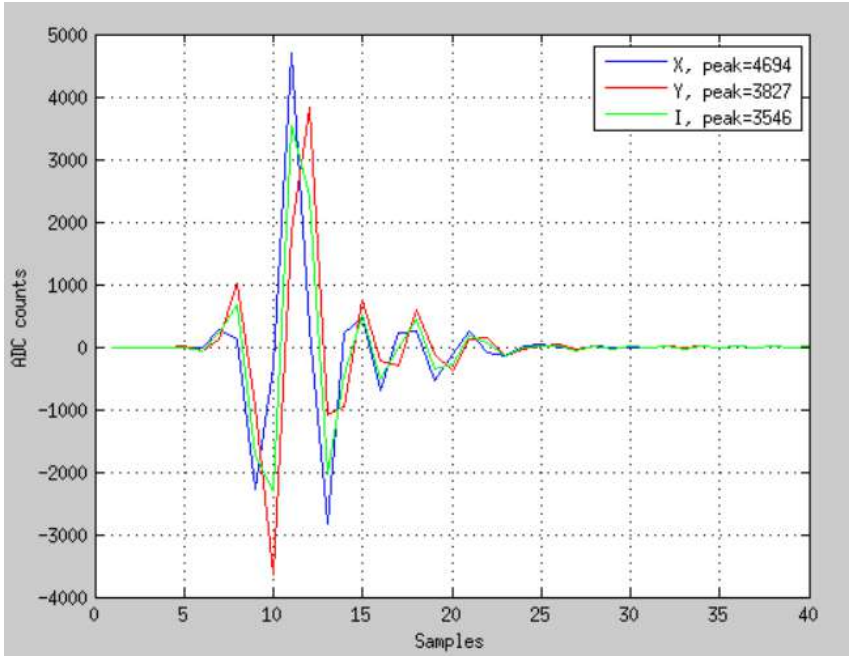


Compensated phase-shift

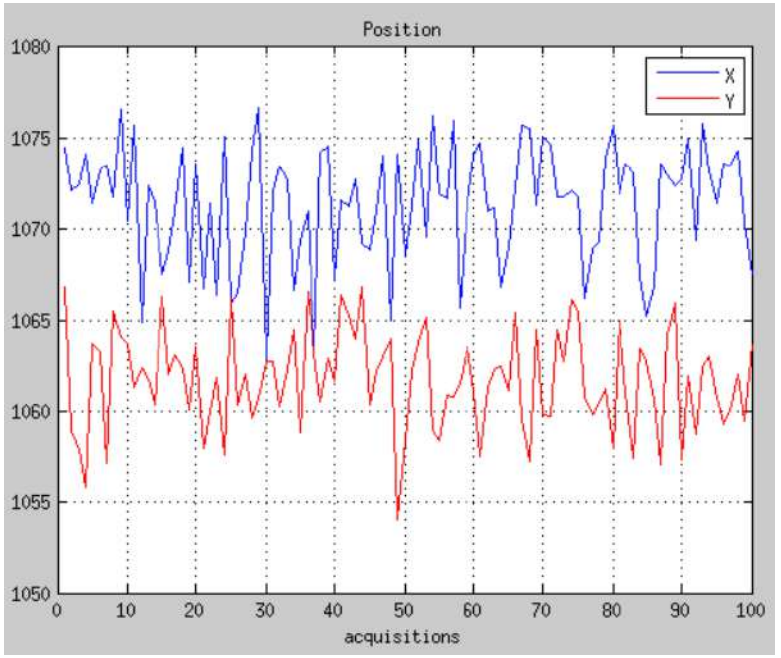


Compensated attenuation deviation

Single-bunch position resolution

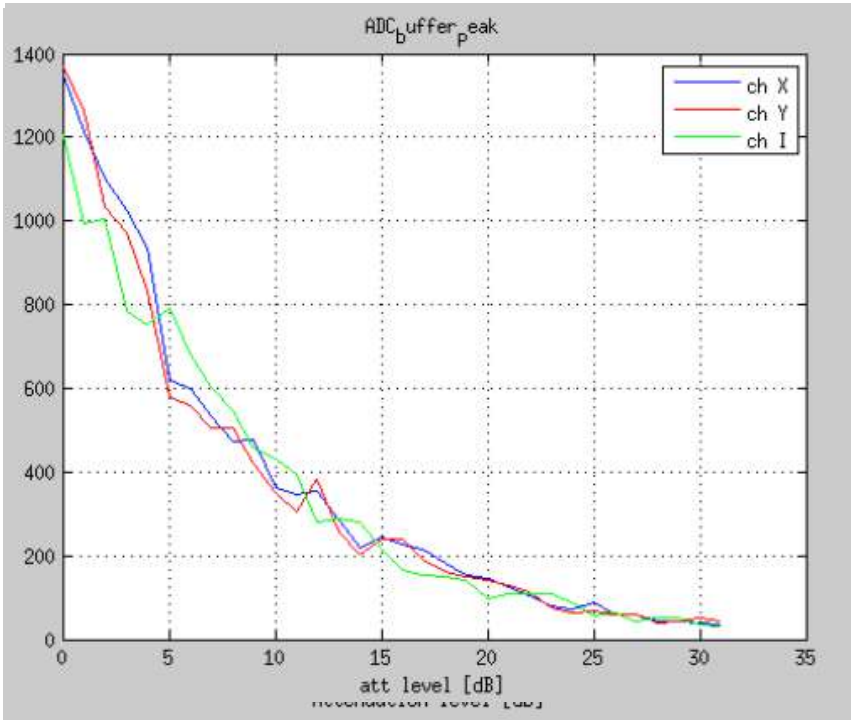


ADC Data

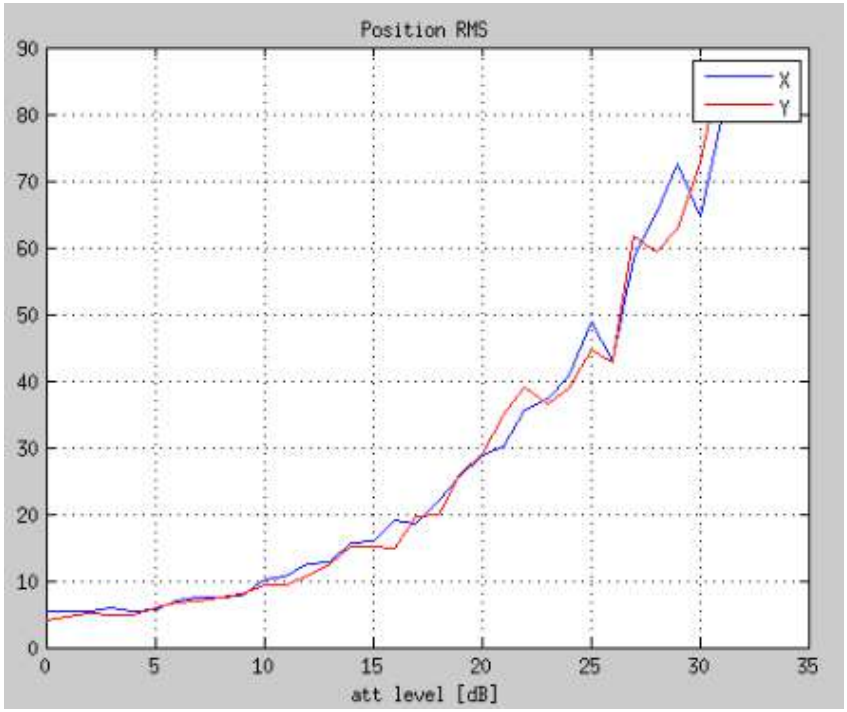


Beam position measurements
X_{RMS}, Y_{RMS} < 3µm

Resolution vs signal level



ADC buffer peak level

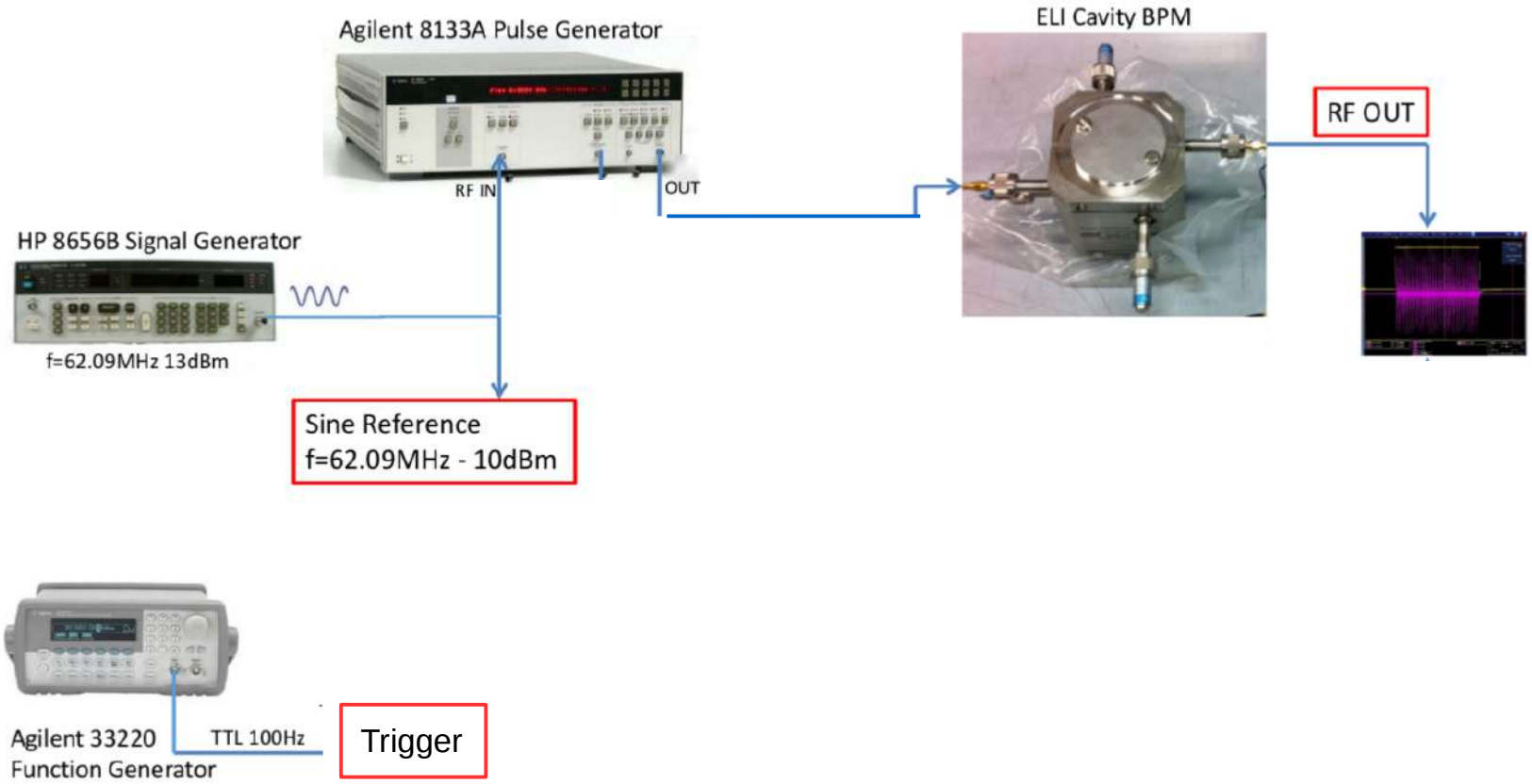


X&Y Position RMS resolution

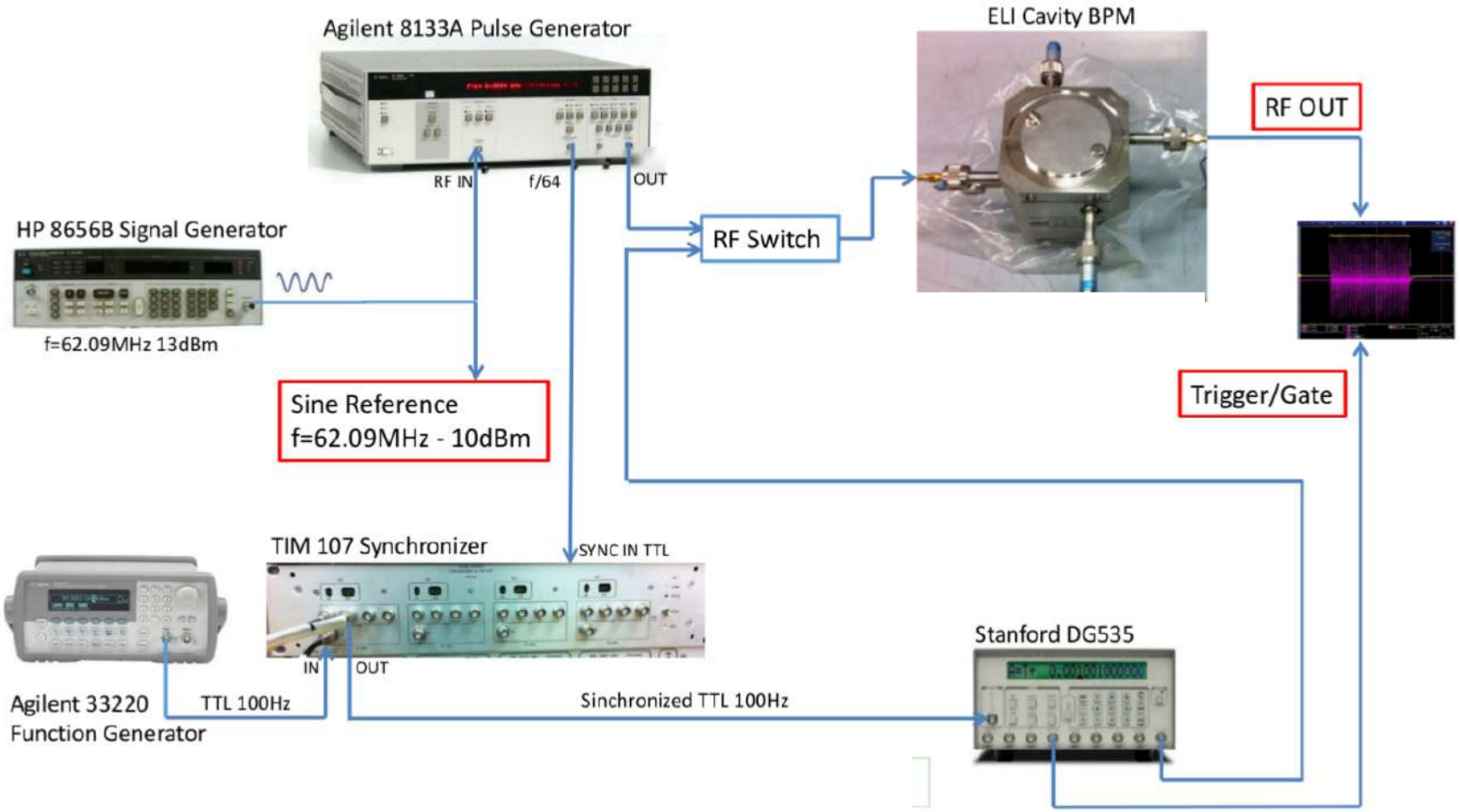
Test setup

What about train of bunches separated by 16ns?

Test setup

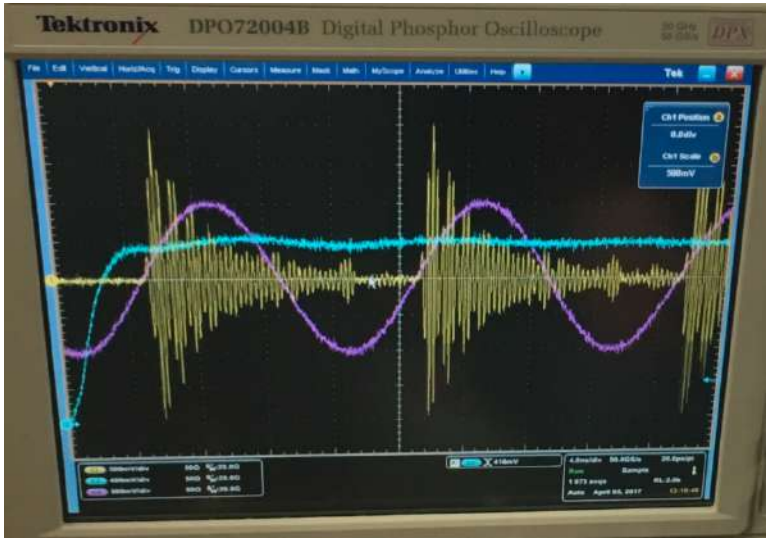

Agilent 8133A Pulse Generator
RF IN
OUT
ELI Cavity BPM
RF OUT
HP 8656B Signal Generator
f=62.09MHz 13dBm
Sine Reference
f=62.09MHz - 10dBm
Agilent 33220
Function Generator
TTL 100Hz
Trigger

Test setup


Agilent 8133A Pulse Generator
RF IN
f/64
OUT
ELI Cavity BPM
RF OUT
HP 8656B Signal Generator
f=62.09MHz 13dBm
RF Switch
Sine Reference
f=62.09MHz - 10dBm
Trigger/Gate
TIM 107 Synchronizer
SYNC IN TTL
IN
OUT
Stanford DG535
Agilent 33220
Function Generator
TTL 100Hz
Sinchronized TTL 100Hz

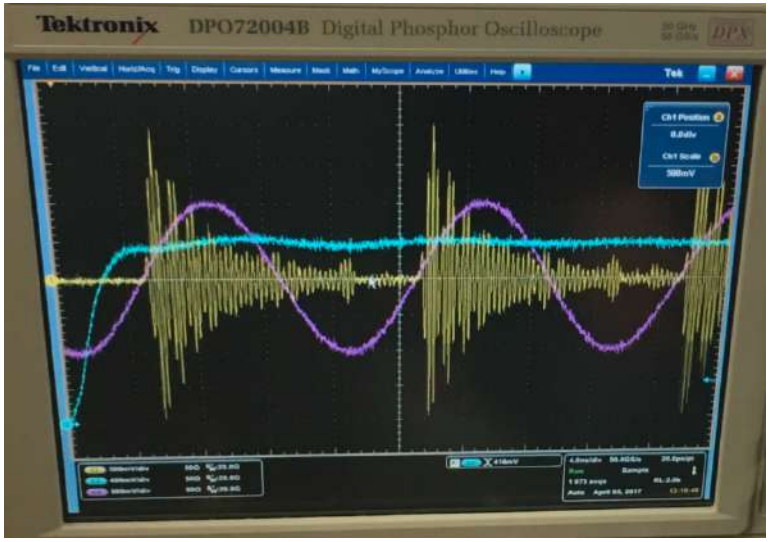
Libera

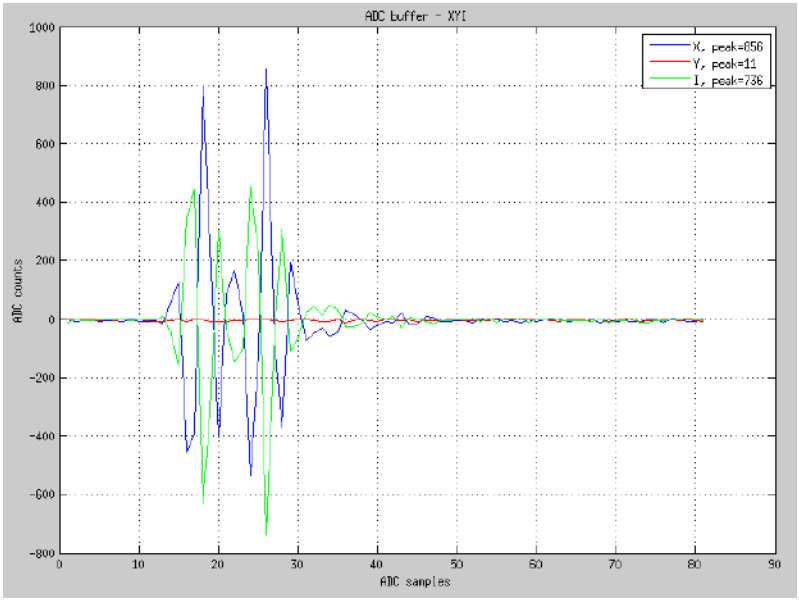
Multiple bunches



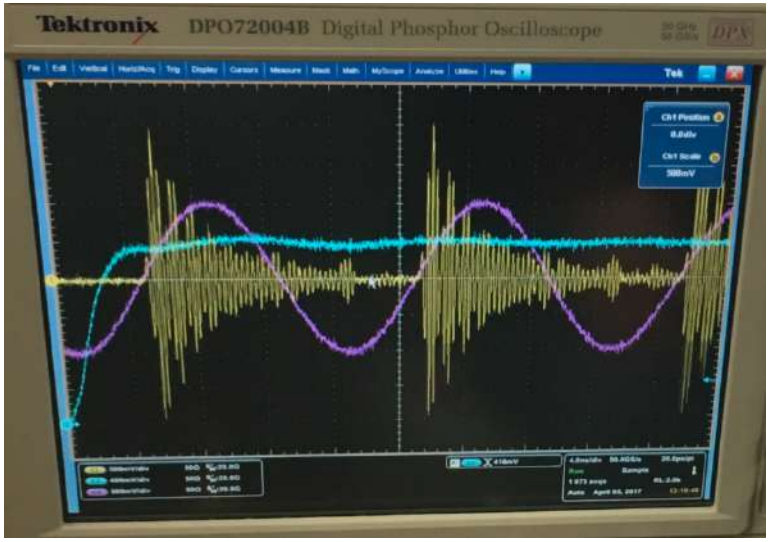
Instrumentation Technologies

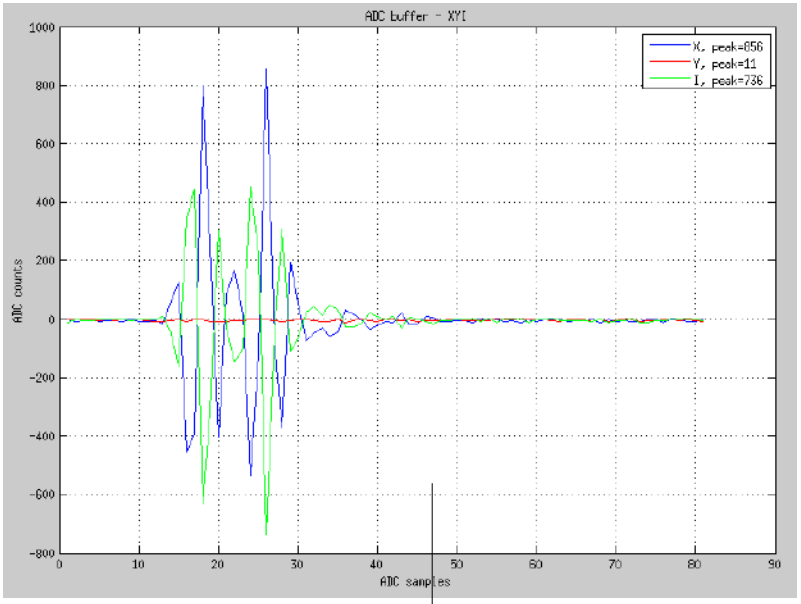
Multiple bunches

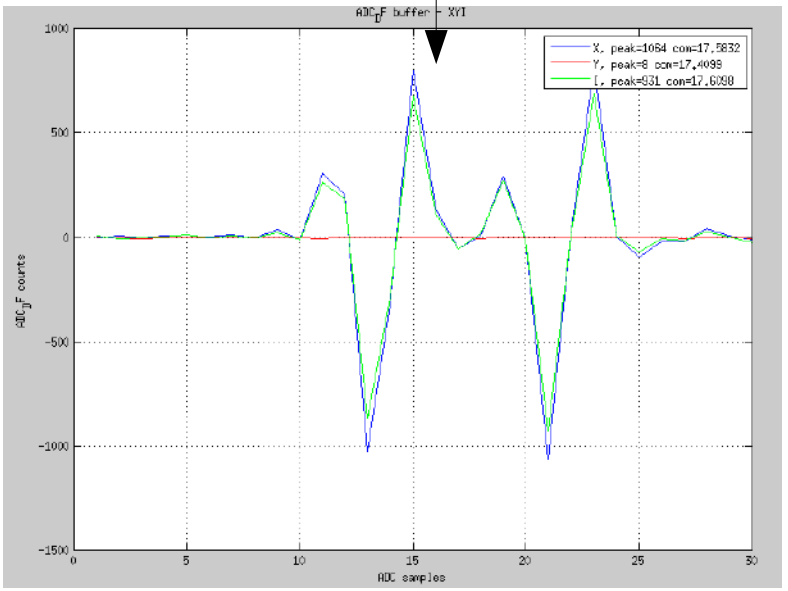




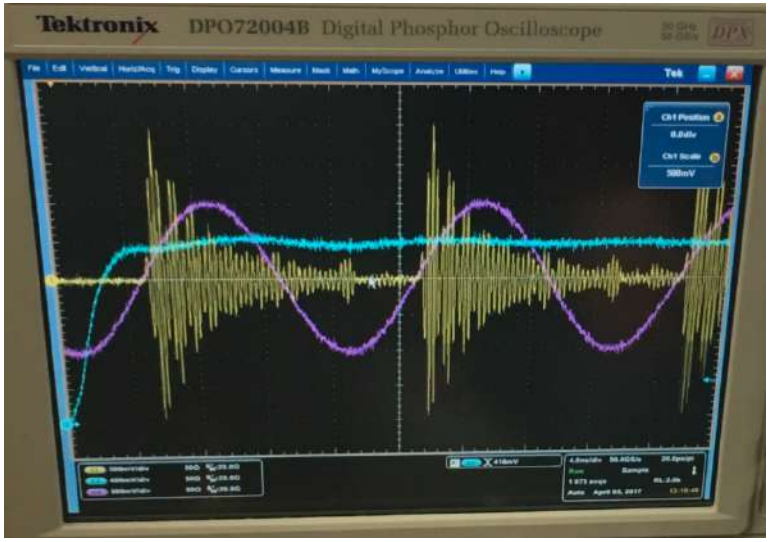
Multiple bunches

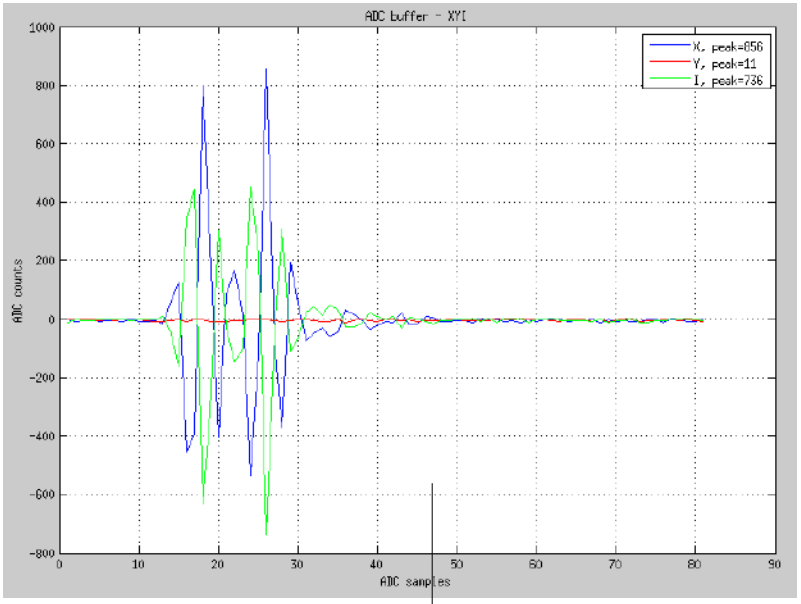


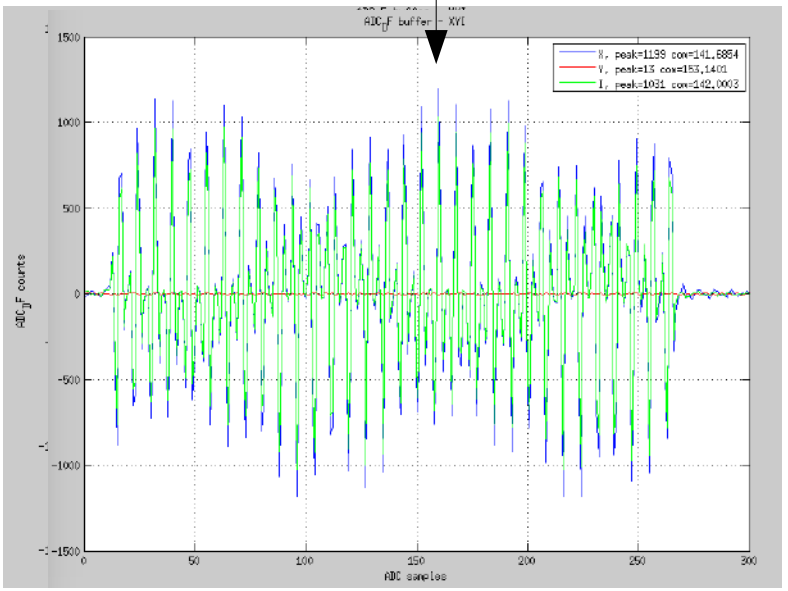




Multiple bunches







Presentation outline

- Motivation: ELI-NP gamma beam source
- Principle: How does it work?
- The Libera CavityBPM instrument
- First measurement results
- Future applications

The core is a 4 channel AC digitizer

ADC	4 channels, 500MS/s, 14bit
SoC	ZYNQ 7035 / ARM Cortex A9
ADC buffer	4kS/channel (~8us)
Variable attenuation	31dB, channel-independent
Cooling	Passive

Possible upgrades

ADC	1GS/s, 1.25GS/s – 14bit – 4ch
SoC	More powerful SoC
Memory	4GB external memory
Fast data transfer	SFP connectors
Power supply	PoE++

Possible upgrades

ADC	1GS/s, 1.25GS/s – 14bit – 4ch
SoC	More powerful SoC
Memory	4GB external memory
Fast data transfer	SFP connectors
Power supply	PoE++

Applications

- Analysis of fast transients / pulses
- Bunch-by-bunch diagnostics
- Fast data transfer / Feedback front-end

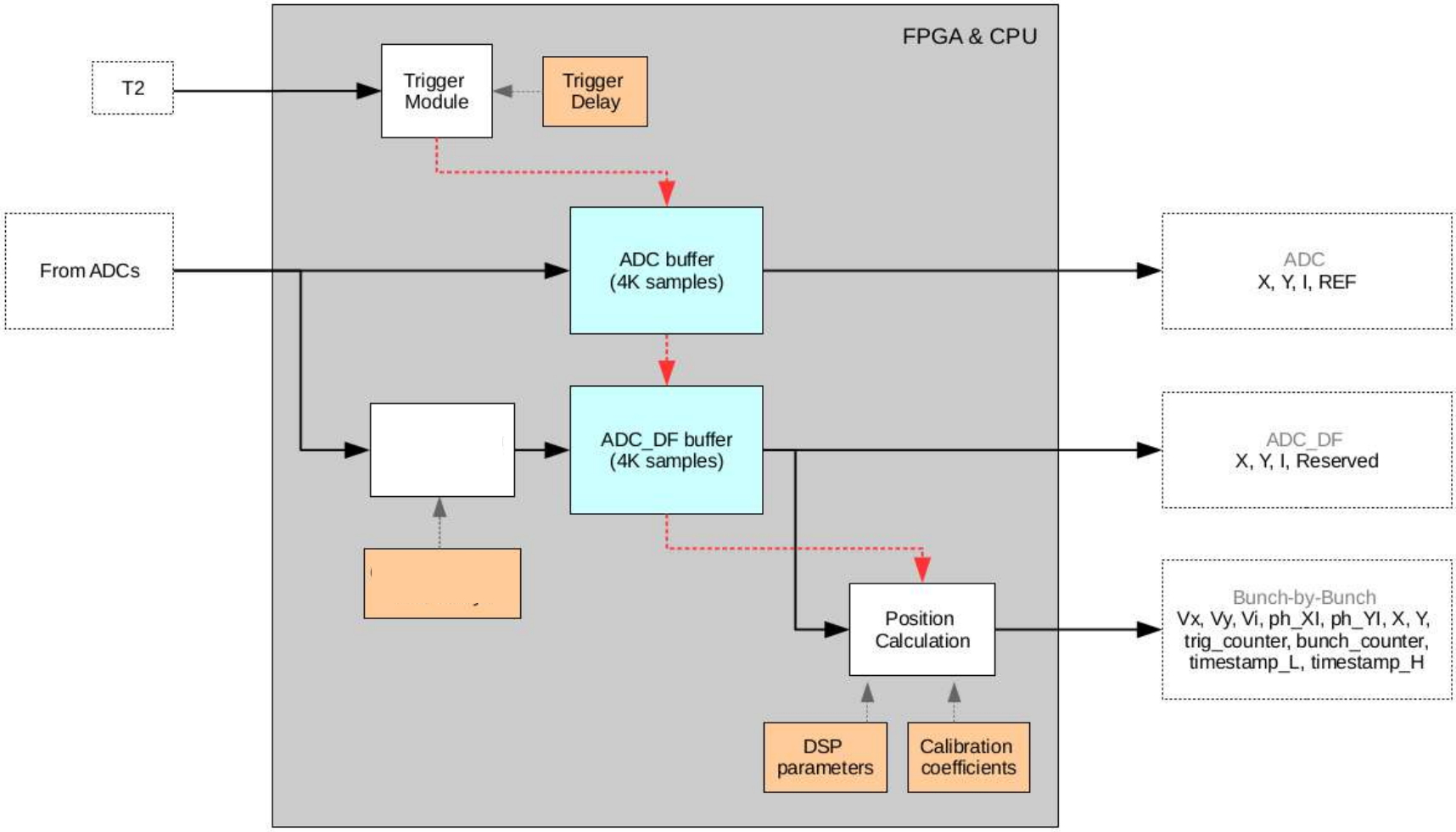
Conclusions

- Libera CavityBPM is now a product
- Can operate at different frequencies, cavities, beam modes
- First test results are promising, more to be performed
- New potential instrument platform based on 500MS/s ADCs

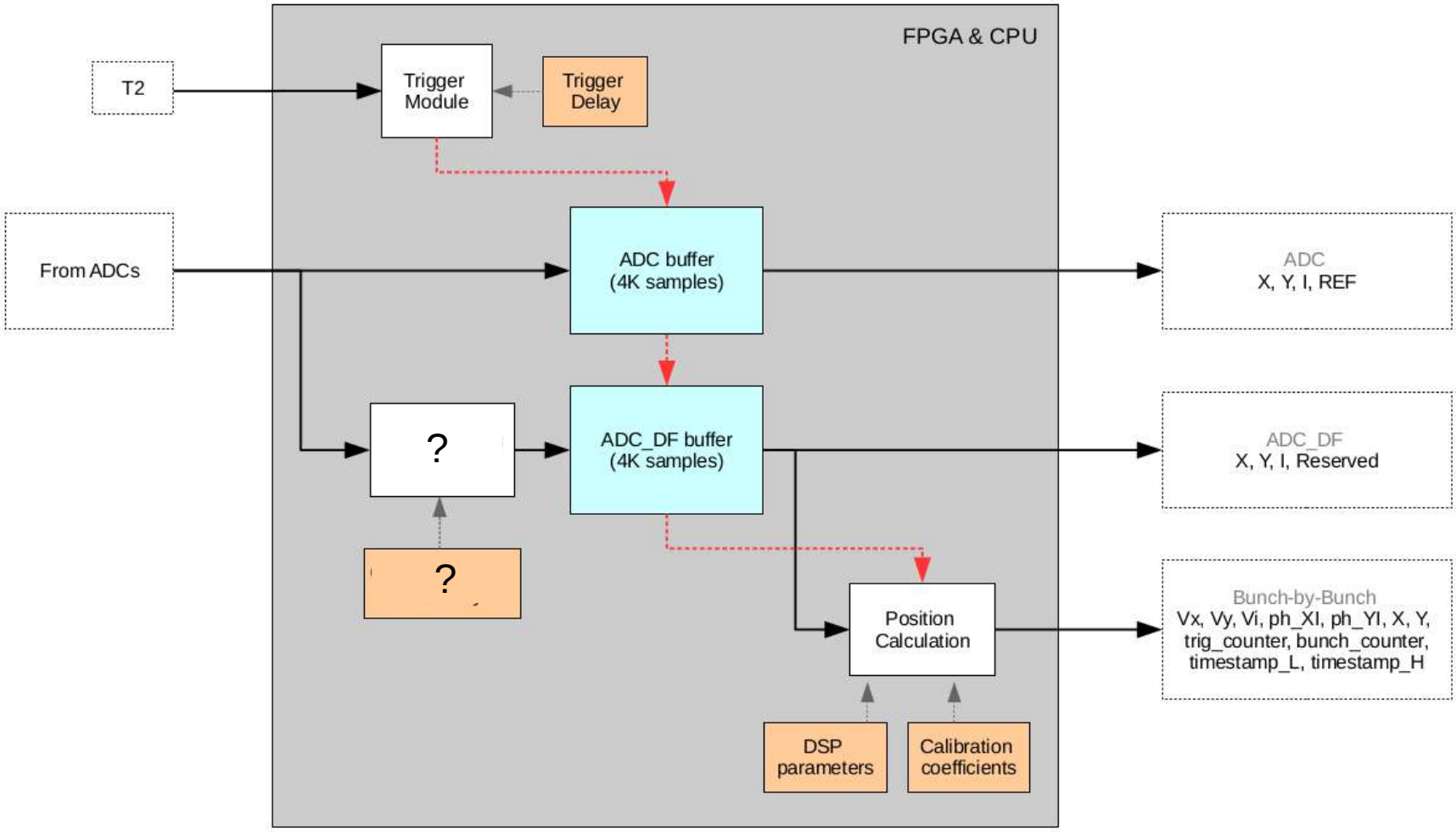
Thanks for your attention!

manuel.cargnelutti@i-tech.com

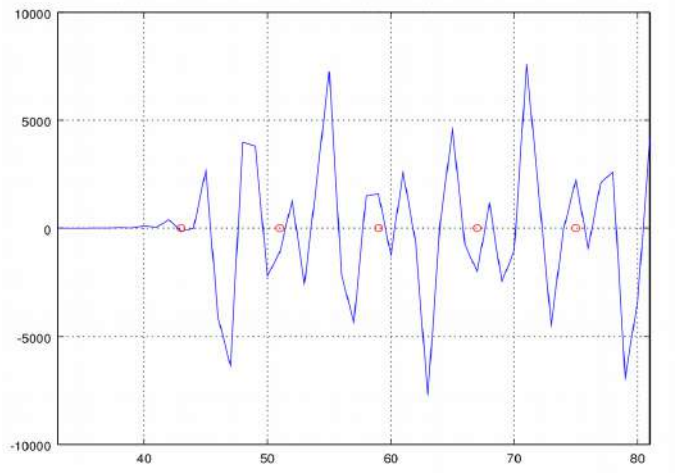
Appendix: Digital Signal Processing



Appendix: Digital Signal Processing



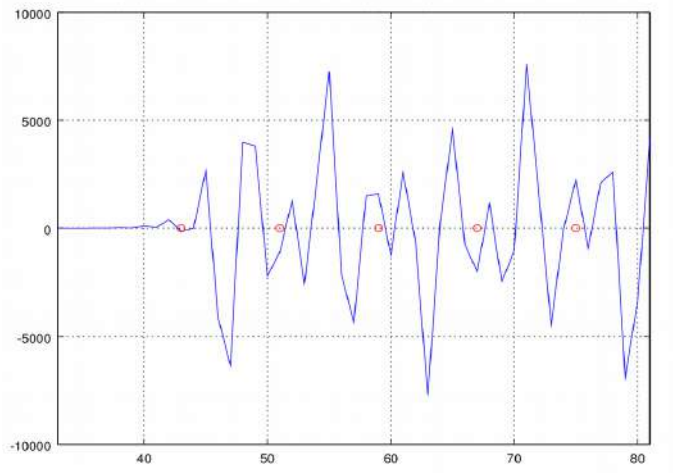
Appendix: Digital Signal Processing



500MHz → 8 samples / bunch

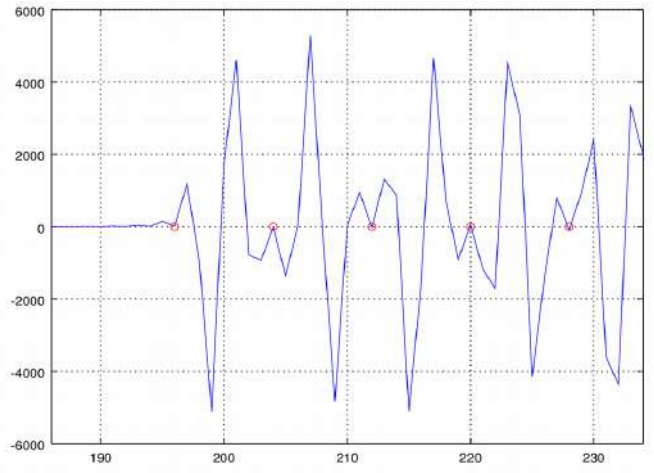
How to decouple each bunch?

Appendix: Digital Signal Processing



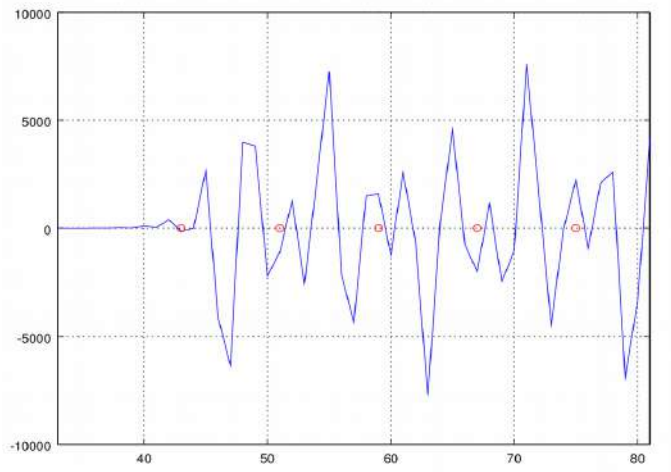
500MHz → 8 samples / bunch

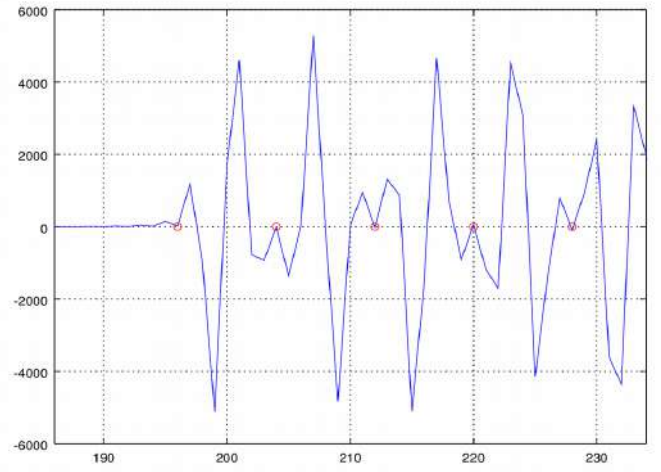
How to decouple each bunch?



Bunches can be separated

Appendix: Digital Signal Processing





500MHz → 8 samples / bunch

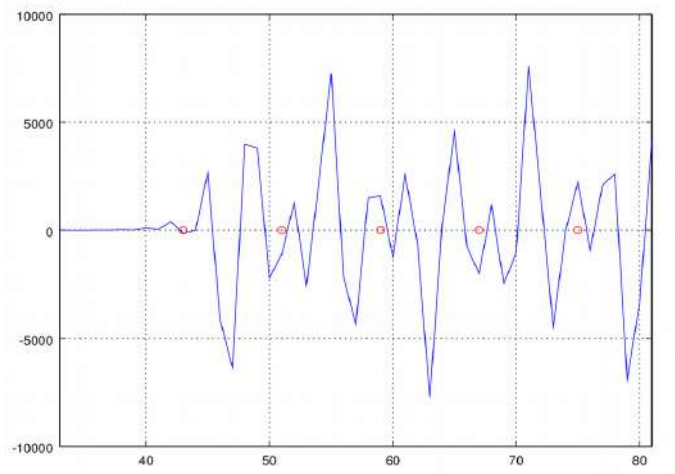
Bunches can be separated

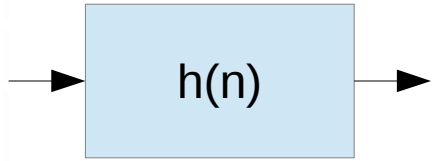
How to decouple each bunch?

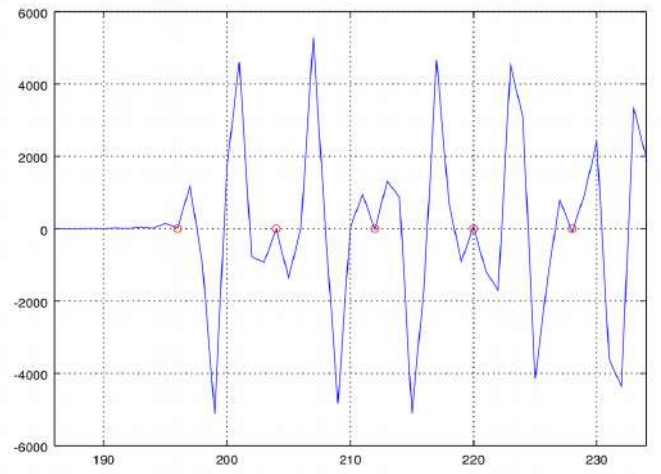
$$V_r, V_x, V_y \rightarrow \begin{cases} X = K_x \dfrac{V_x}{V_r} \\ Y = K_y \dfrac{V_y}{V_r} \end{cases}$$

Instrumentation Technologies

Appendix: Digital Signal Processing







500MHz → 8 samples / bunch

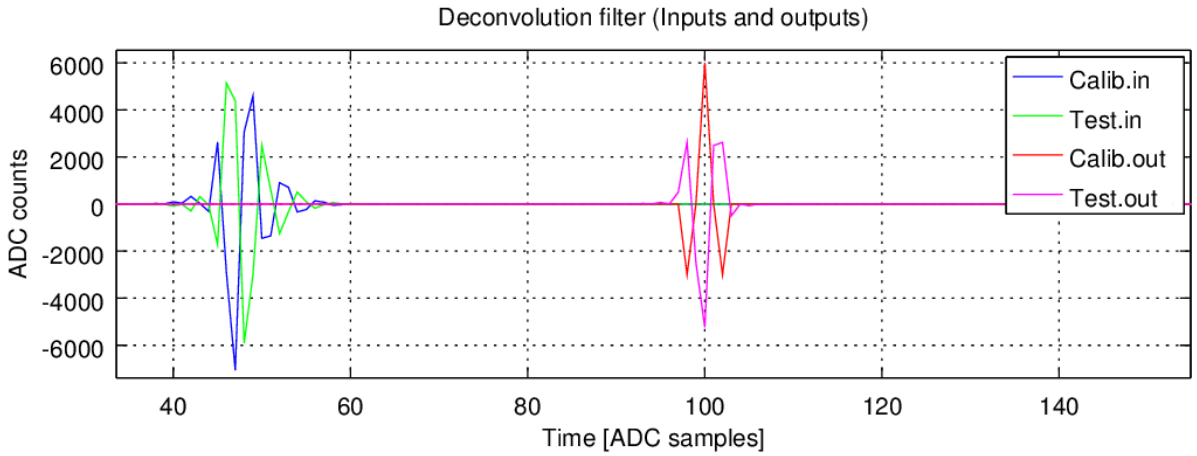
Bunches can be separated

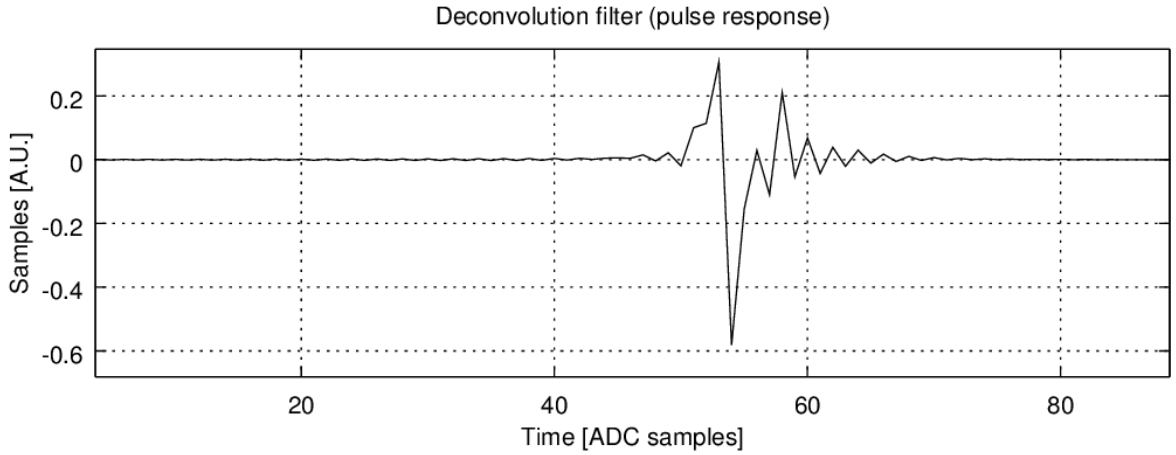
How to decouple each bunch?

$$V_r, V_x, V_y \rightarrow \begin{cases} X = K_x \dfrac{V_x}{V_r} \\ Y = K_y \dfrac{V_y}{V_r} \end{cases}$$

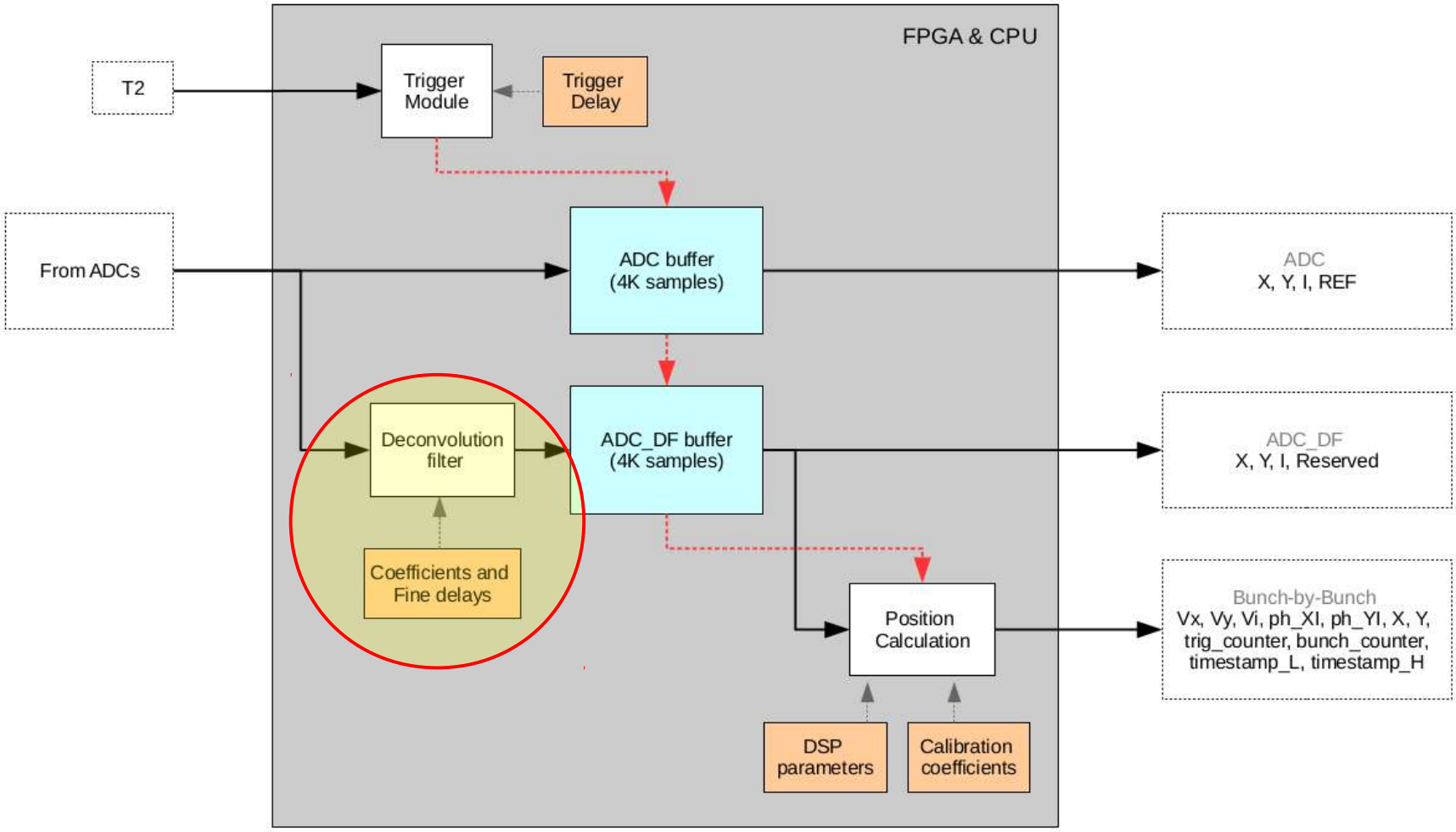
Instrumentation Technologies

Appendix: Deconvolution filter





Appendix: Digital Signal Processing



Appendix 2: Digital Signal Processing