EuroGammaS

European Consortium for the delivery of a Gamma Beam System to ELI-NP

DEELS Workshop 2017

Status of the R&D on Cavity BPM and its readout electronics

Giovanni Franzini

Contributions:

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ELI-NP Gamma Beam System

Magurele - Romania

ELI-NP GBS is an Advanced Gamma Source for studies in new nuclear spectroscopy and new photonuclear physics.

It is a Compton back-scattering machine with a tunable energy of the gamma photons between 0.2 and 19.5 MeV, a narrow bandwidth (0.5%) and a high spectral density (>10^4 photons/sec/eV).

The EuroGammas consortium, led by INFN, is responsible for its develop and delivery. The machine installation is scheduled by the end of 2017.

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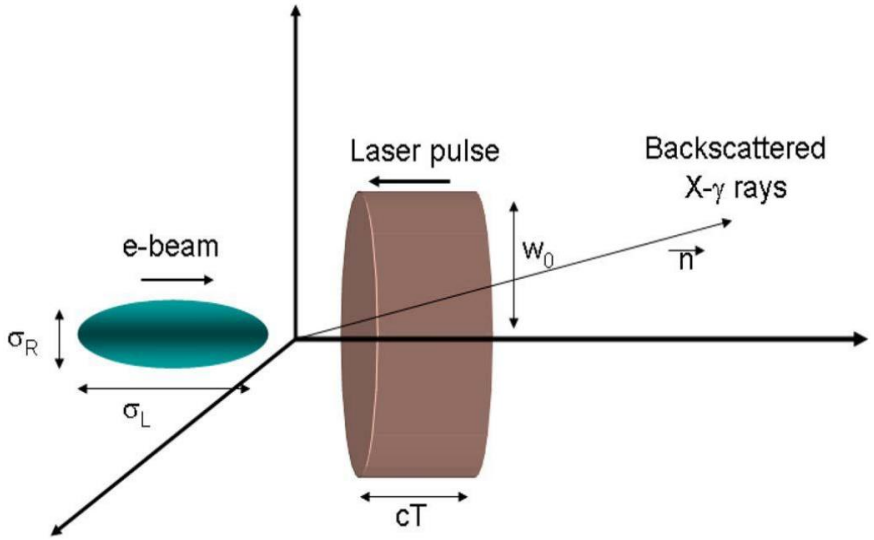
Gamma Beam Specifications



Gamma Beam Specifications	
Energy [MeV]	0.2 – 19.5
Spectral Density [ph/s·eV]	$0.8 – 4 \cdot 10^4$
Bandwidth rms [%]	≤ 0.5
Peak brilliance [N_{ph}/s·mm²·mrad²·0.1%]	$10^{20} – 10^{23}$
Macro repetition rate [Hz]	100
# pulses per macropulse	32
Pulse–to–pulse separation [ns]	16.1

By using an optical re-circulator, a single laser pulse will collide with a multi-bunch (32) electron beam at the interaction point, generating the gamma beam by Compton back-scattering.

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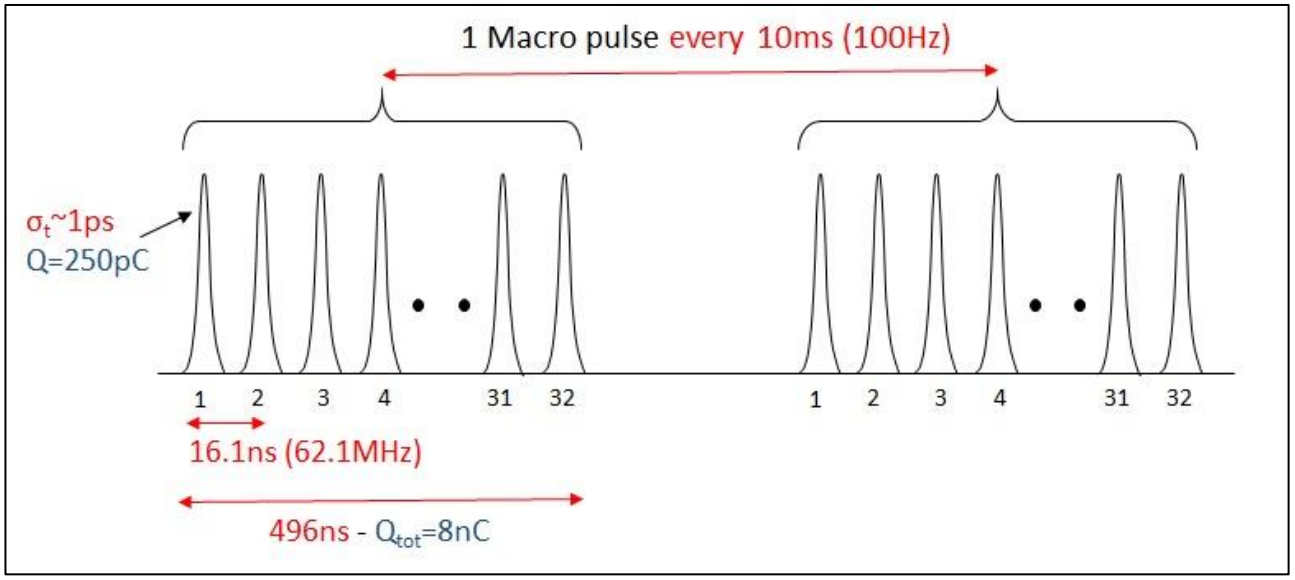
Beam parameters and structure



Electron Beam Specifications	
Max. Energy at IP [MeV]	280 – 720
Macro Pulse rep. Rate [Hz]	100
Number of bunches	up to 32
Bunch spacing [ns]	16.1
Bunch length [ps]	0.91
Bunch charge [pC]	25-250
Bunch Energy Spread	< 0.1%

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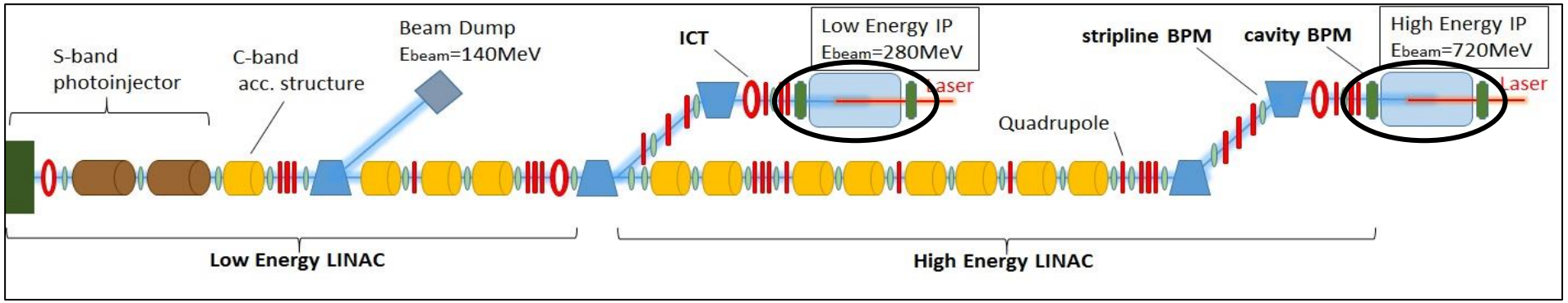
ELI-NP GBS Diagnostics



Non-intercepting diagnostics:

Charge measurements:

- 4 Integrating Current Transformers (bunch by bunch)

Position measurements:

- 29 stripline BPMs (Macro pulse)
- 4 cavity BPMs (bunch by bunch)

- Beam Loss Monitor System

Intercepting diagnostics:

Position and spot size measurements:

- 23 Beam Screens (YAG and OTR)

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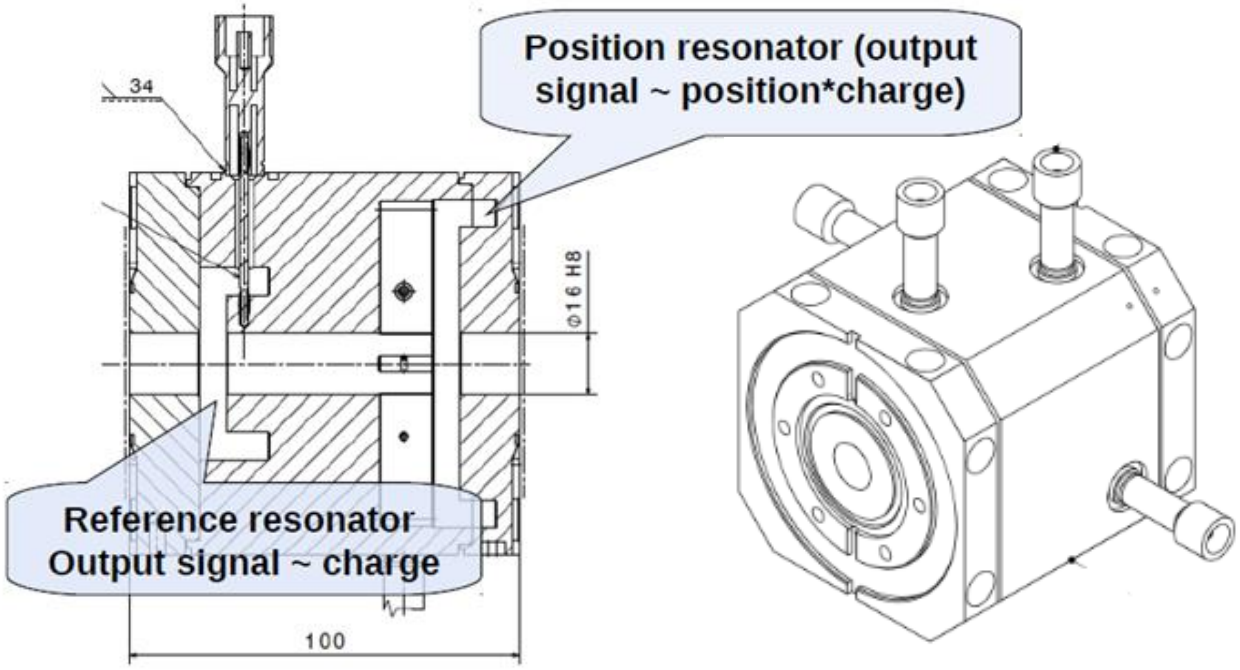
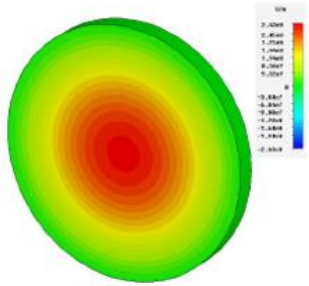
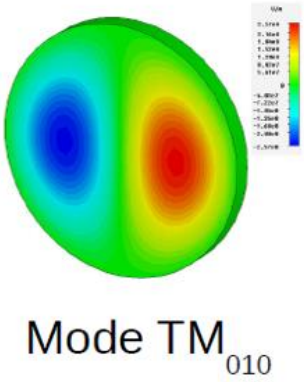
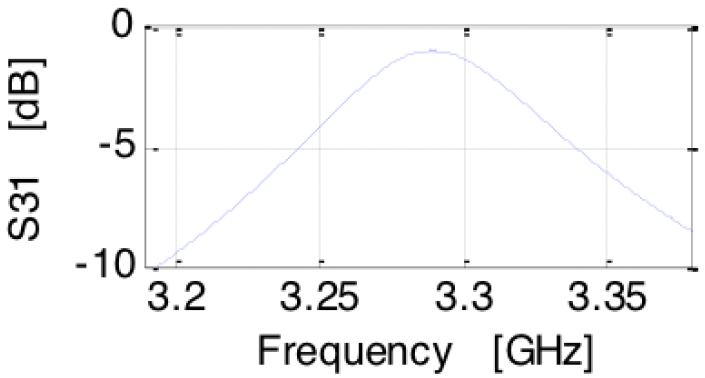
Cavity Beam Position Monitor









f_0=3.2886GHz ¶

Q=42.4 ¶

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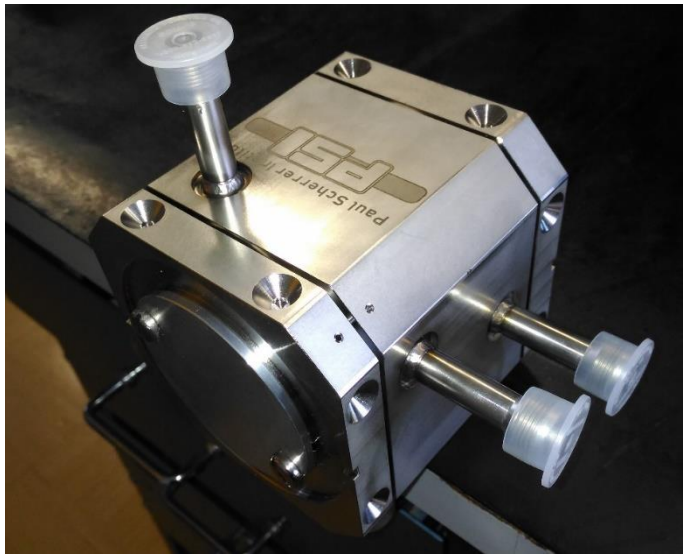
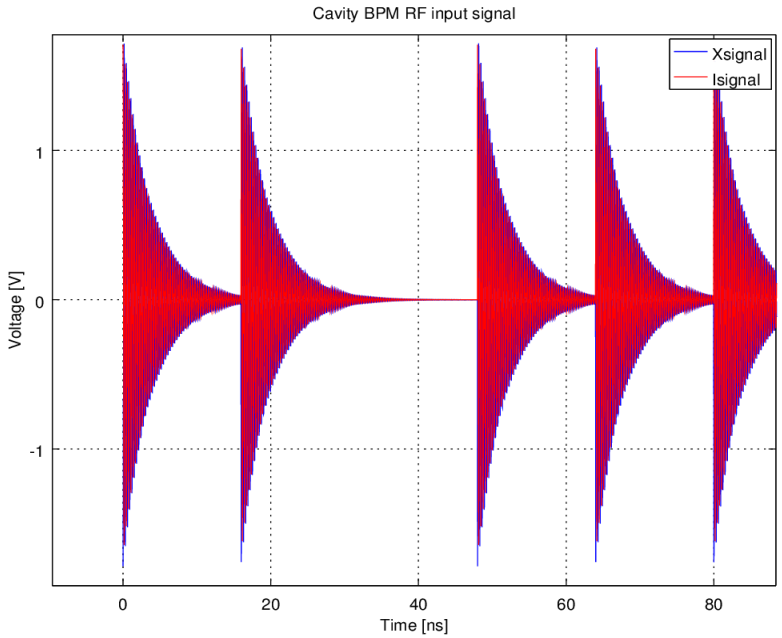
PSI Cavity BPM16



Position Cavity Resonator	
Inner Aperture [mm]	16
Q_L	40
TM_{110} Frequency [GHz]	3,284
TM_{010} Frequency [GHz]	2,252
Position Signal [V/mm/nC]	7,07
Angle Signal [µm/mrad]	4,3



Reference Cavity Resonator	
Q_L	40
TM_{010} Frequency [GHz]	3,284
Charge Signal [V/mm/nC]	135

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Readout Electronics

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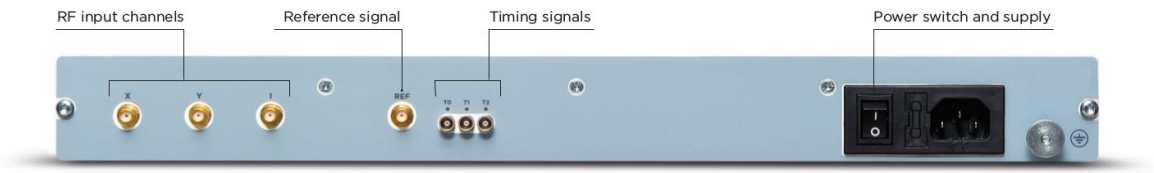
Readout Electronics

Libera CavityBPM



ADC	4 channels, 500MS/s, 14bit
ADC buffer	4kS/channel (~8us)
Variable attenuation	31dB, channel-independent
Input signal frequency	C-band, S-band
Ref. signal frequency	62.08 MHz
Cooling	Passive

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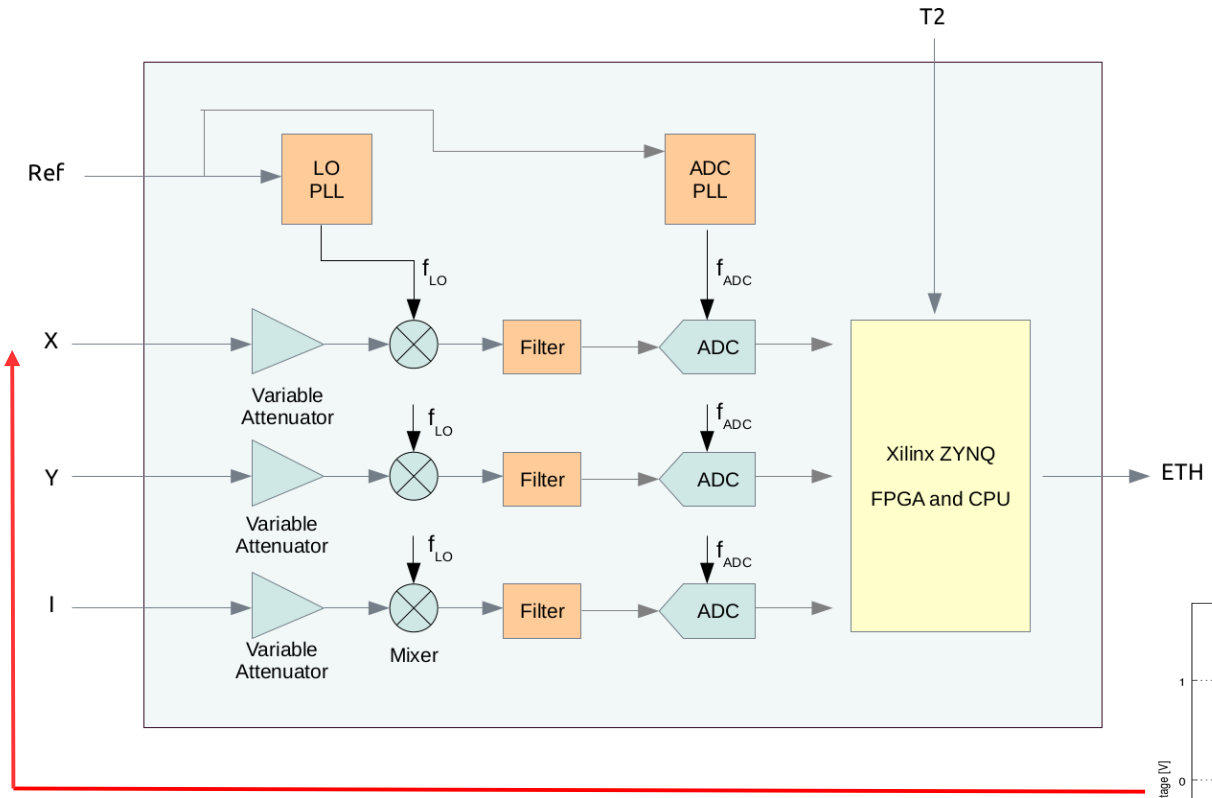
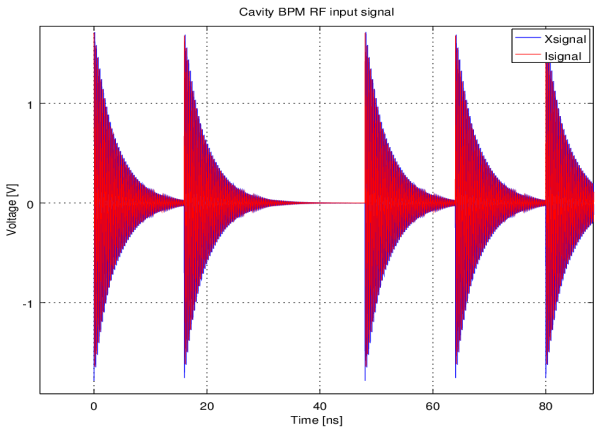
Signal Processing





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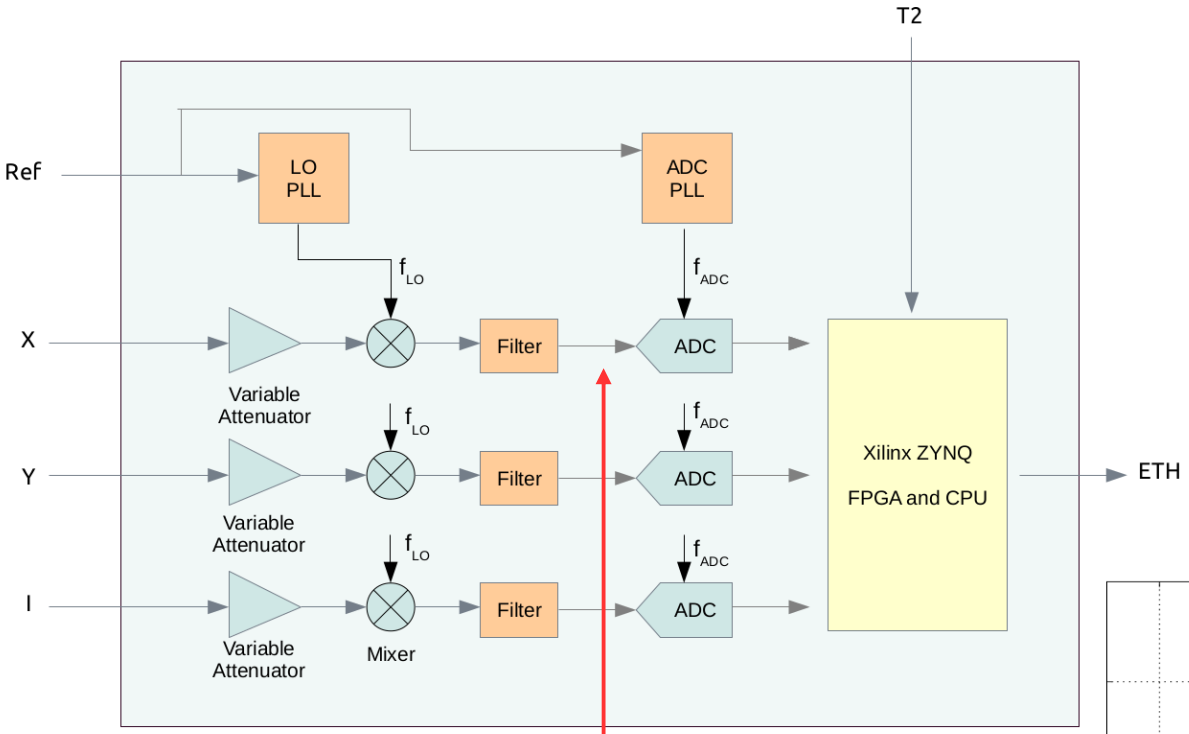
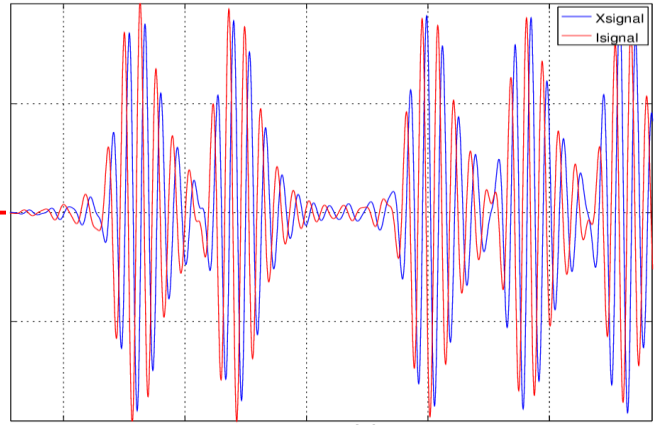
Signal Processing





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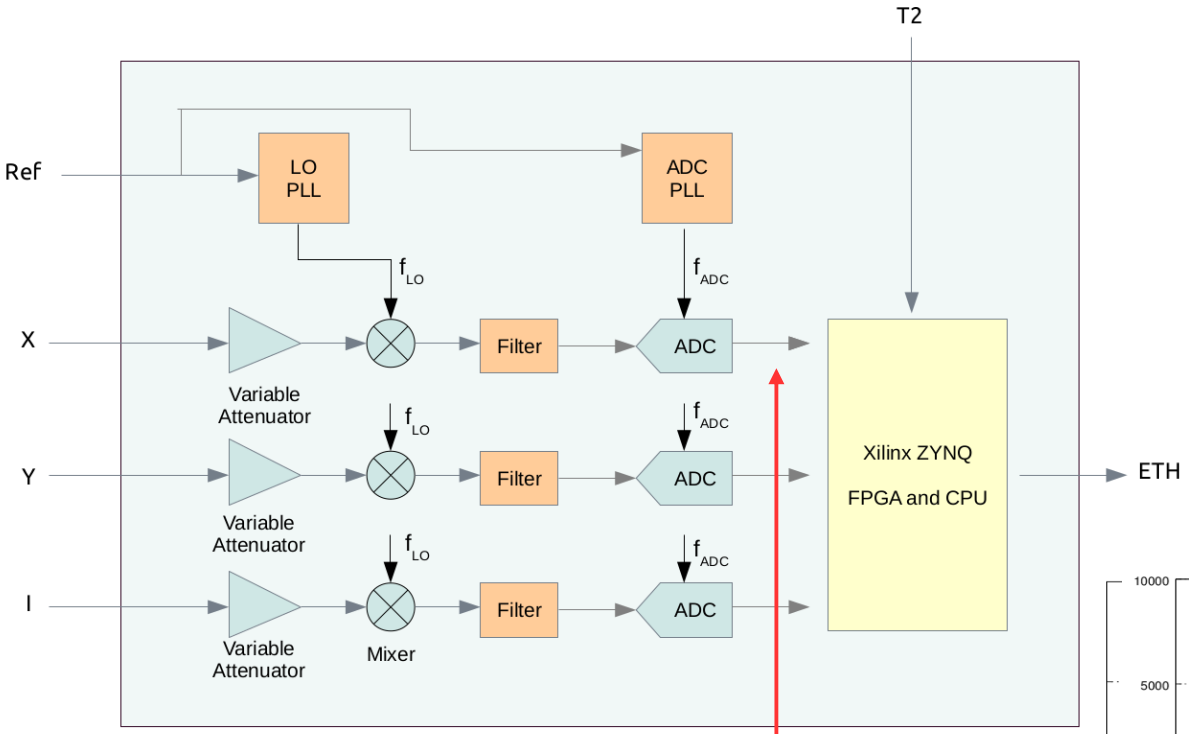
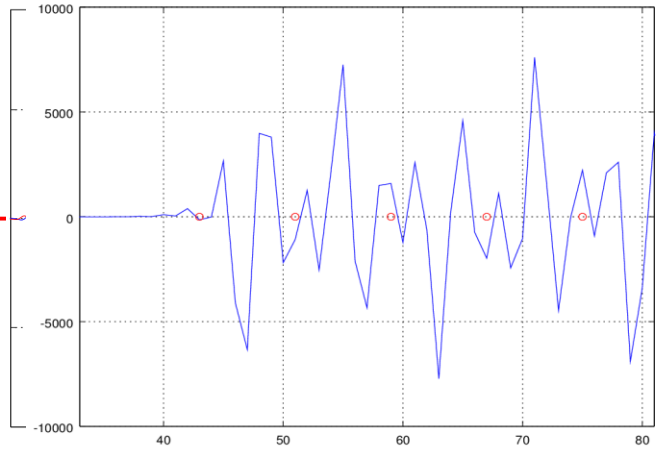
Signal Processing





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Test Setup

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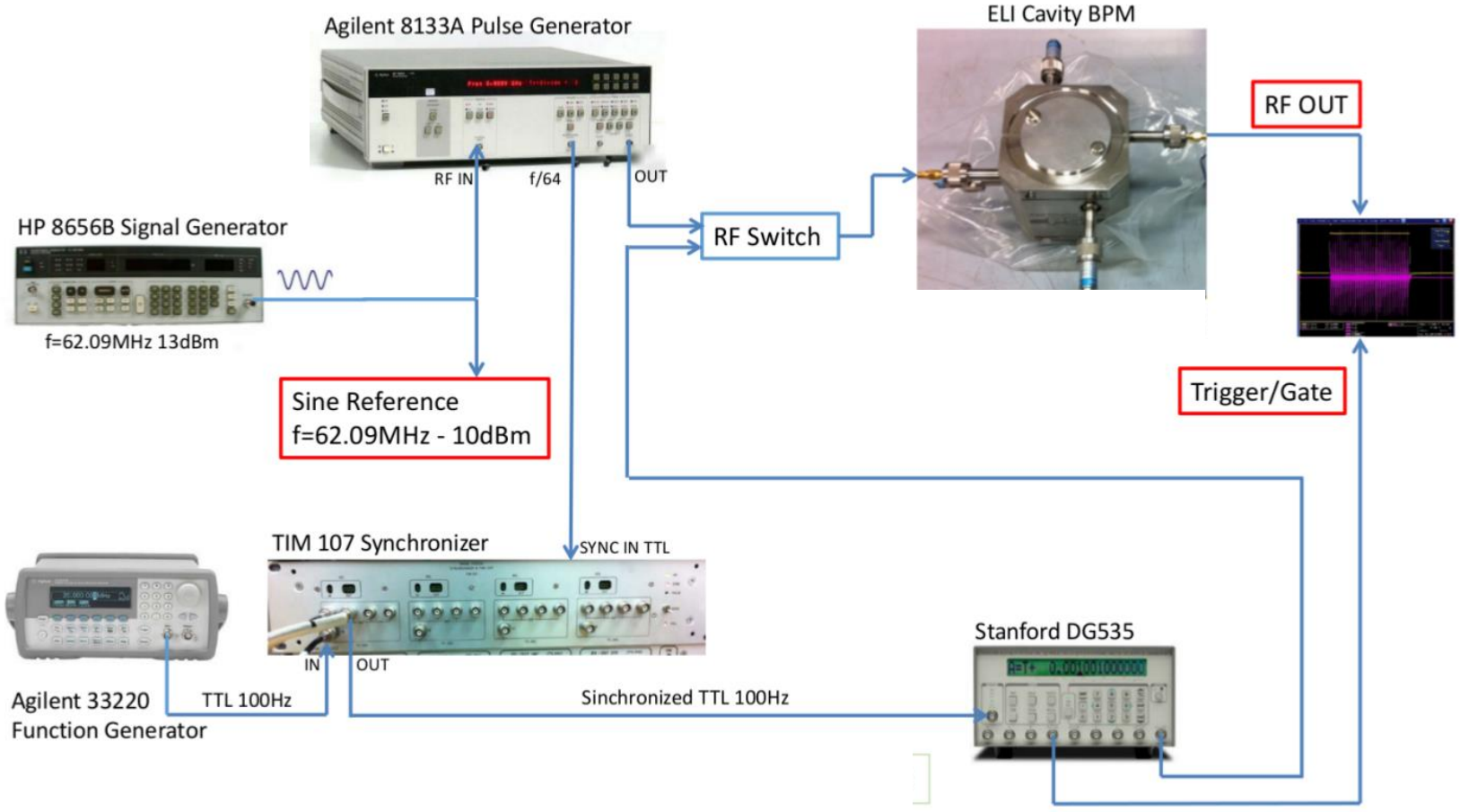
Test Setup



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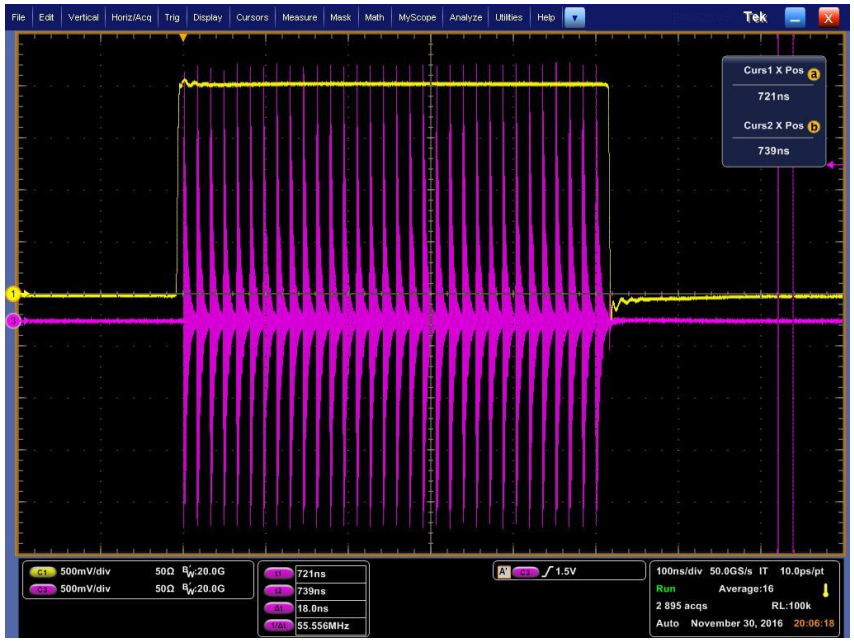
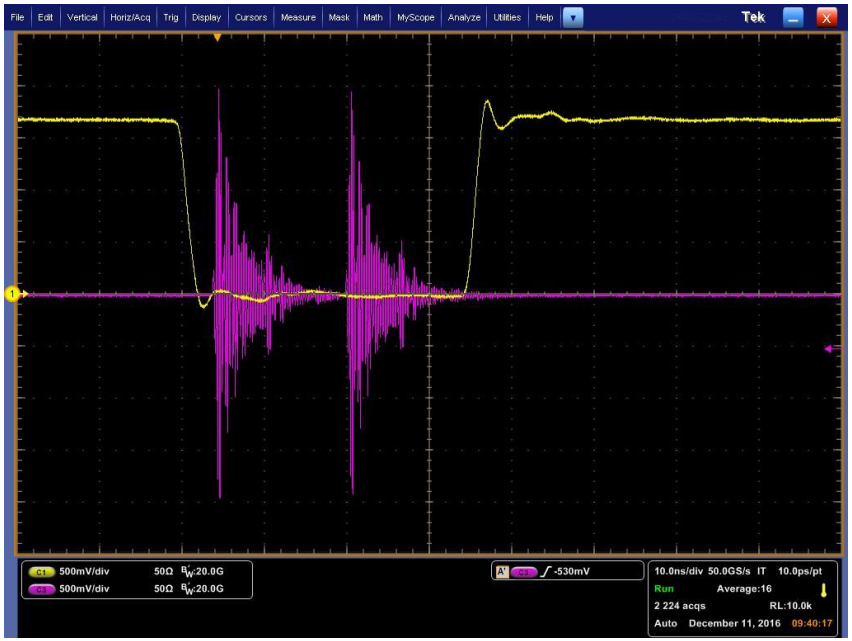
Test Setup

Gate duration defines the number of bunches per train.



32 bunches (515 ns)



Two bunches (32 ns)

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First Measurements

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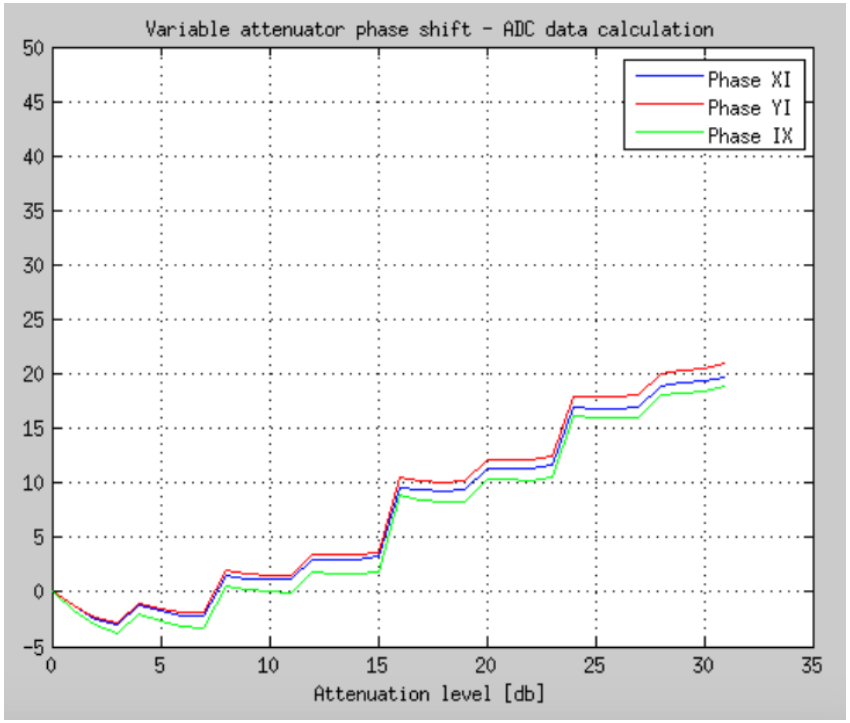
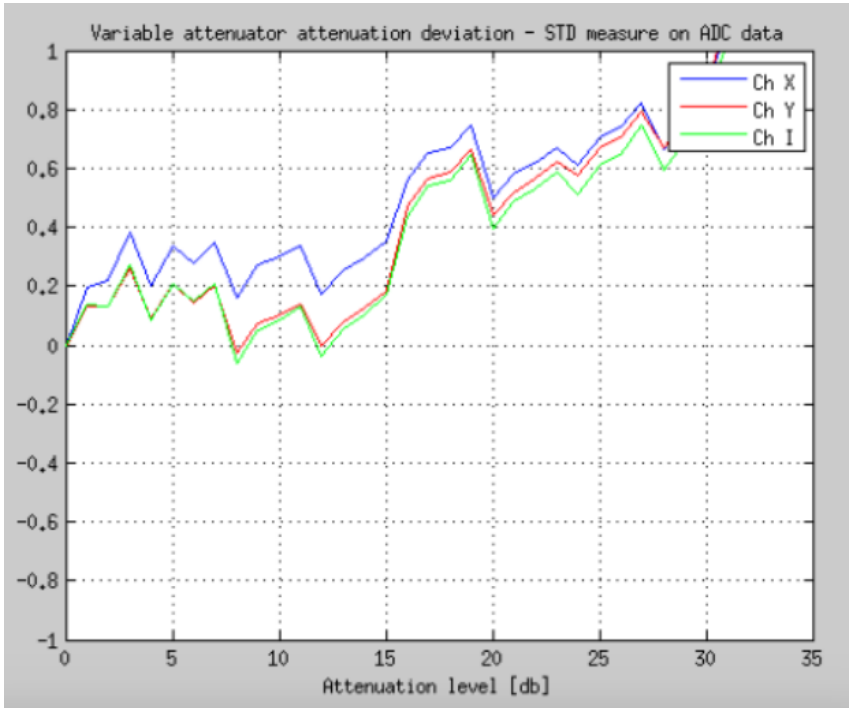
Attenuator non-idealities



Different phase-shift



Attenuation deviations

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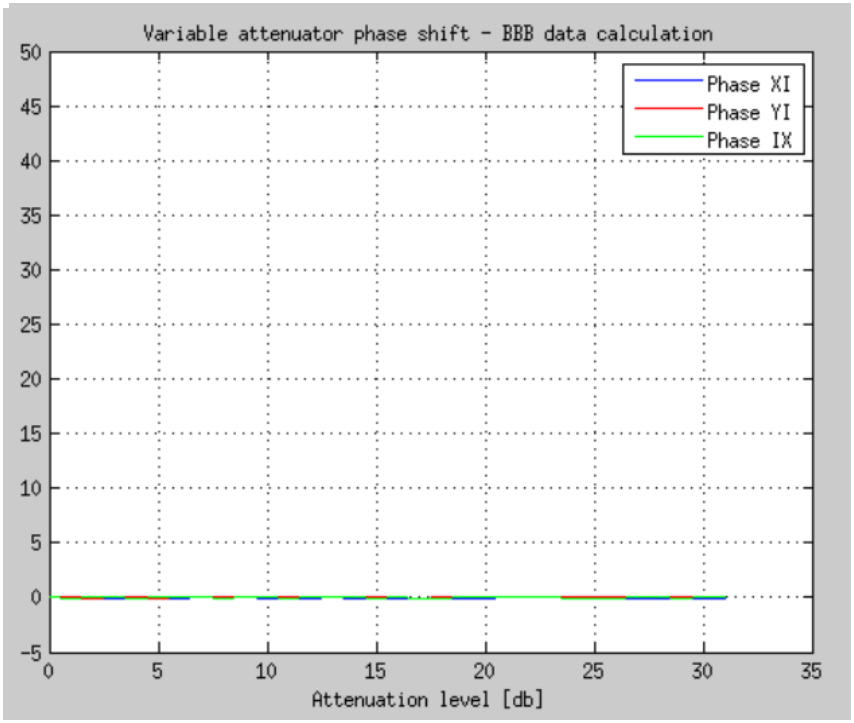
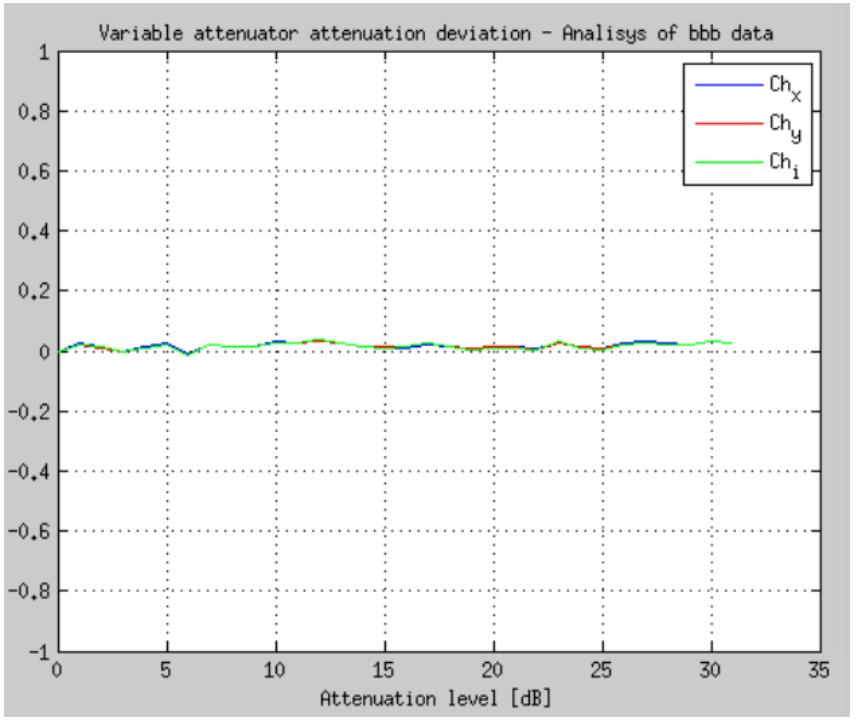
Attenuator non-idealities

Attenuator non-idealities can be calibrated



Compensated phase-shift



Compensated attenuation deviation

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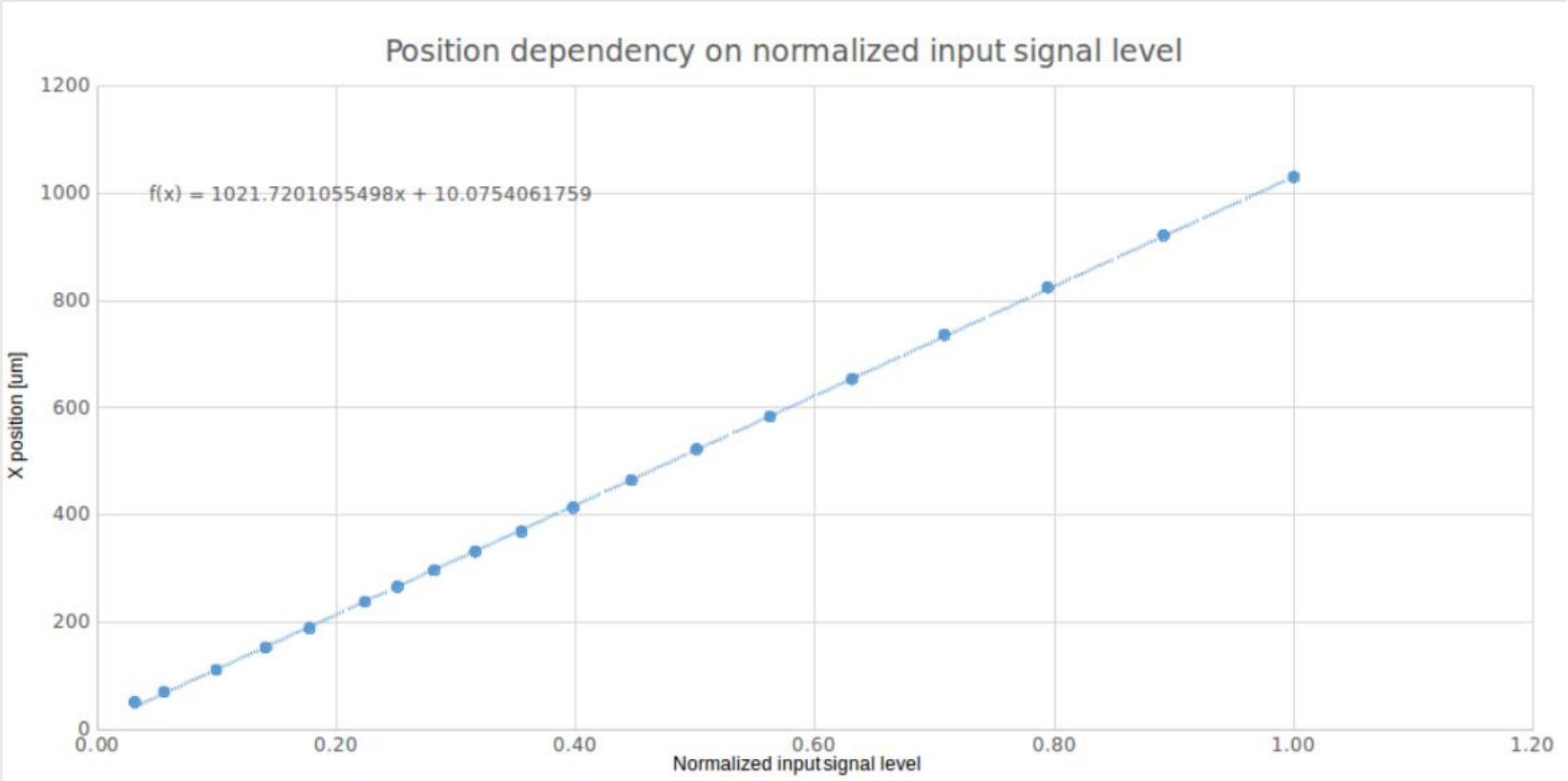
Linearity measurements



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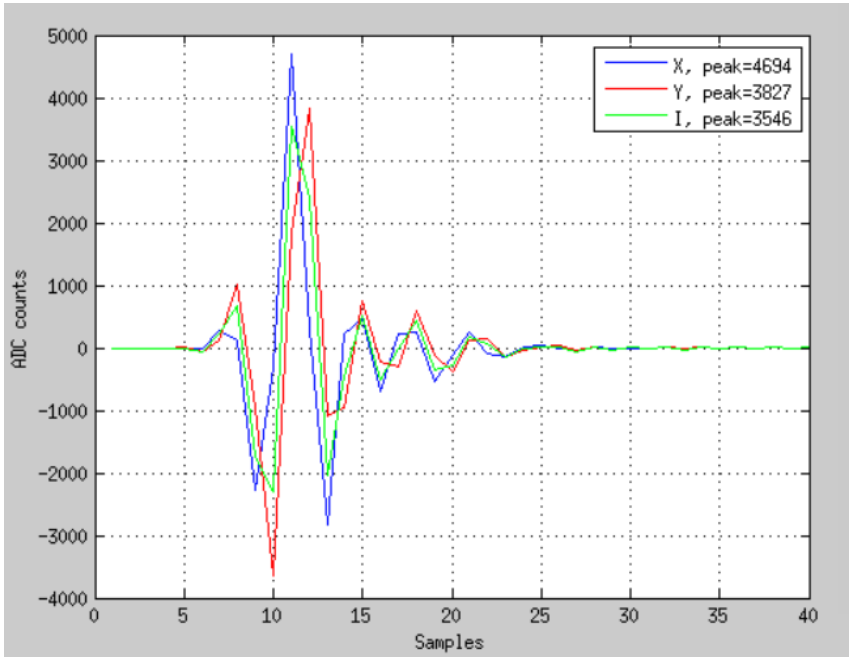
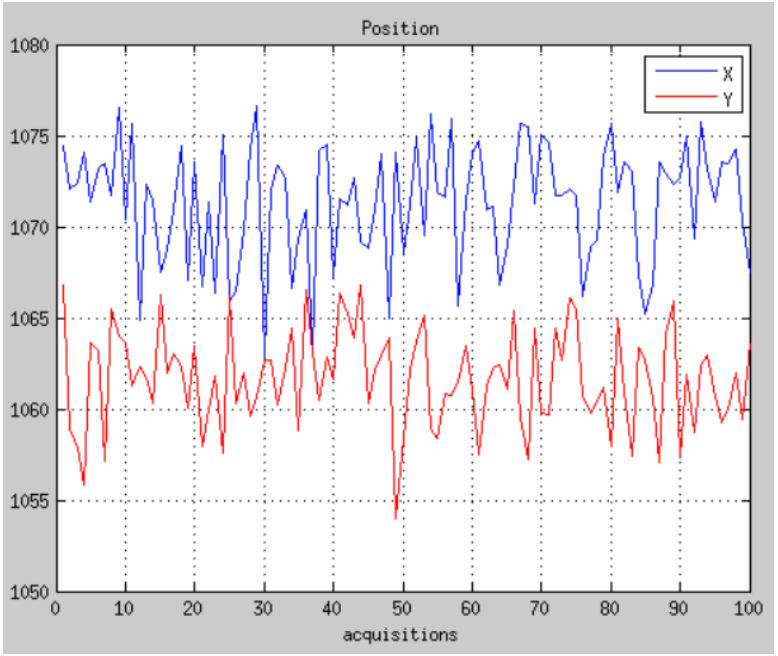
Single bunch position resolution



ADC Data



Beam position measurements

X RMS , Y RMS < 3µm

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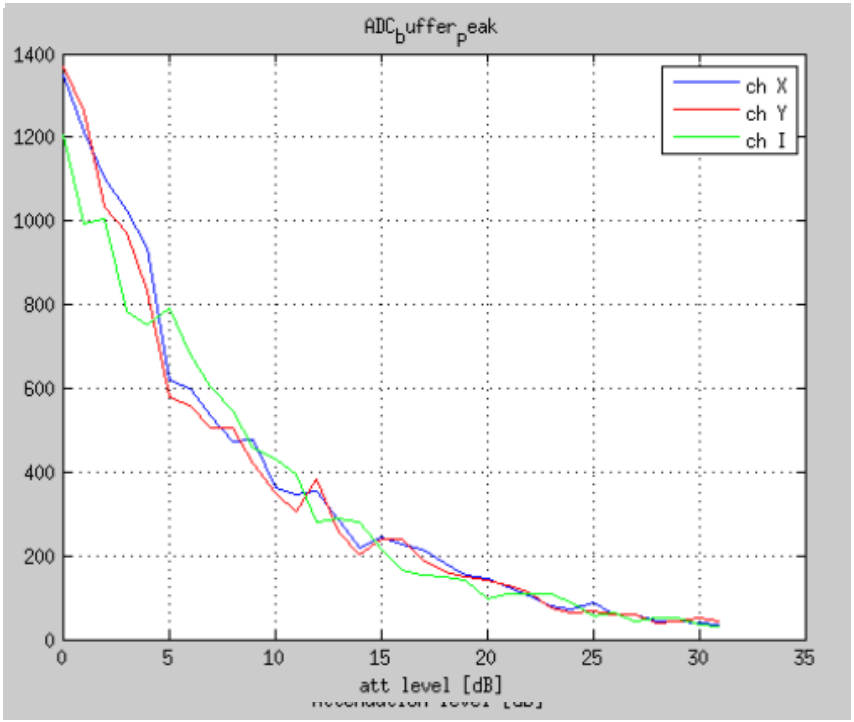
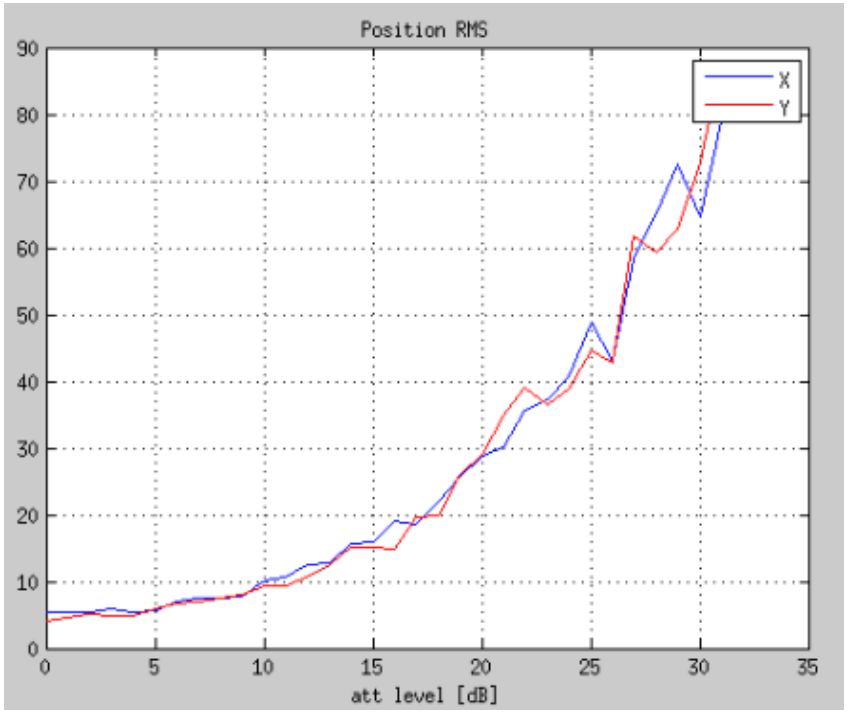
Resolution vs Signal Level



ADC buffer peak level



X&Y Position RMS resolution

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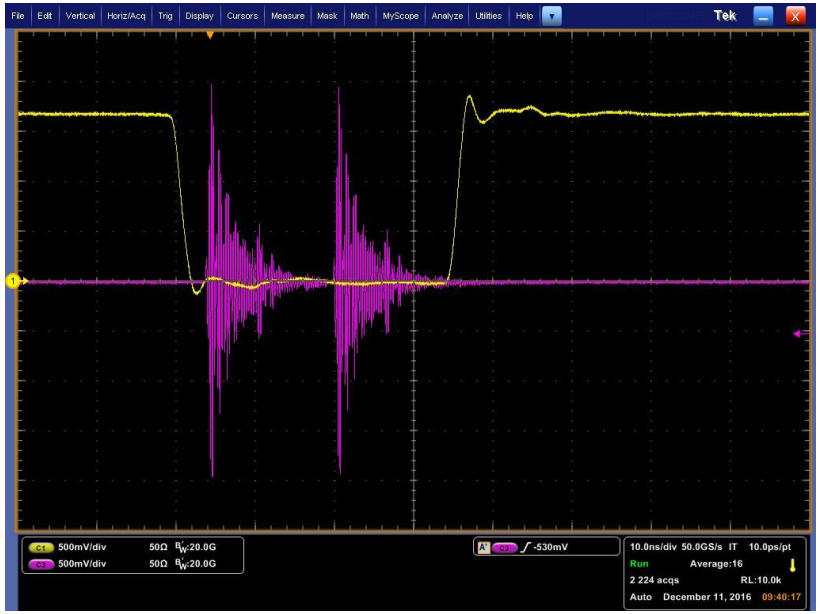
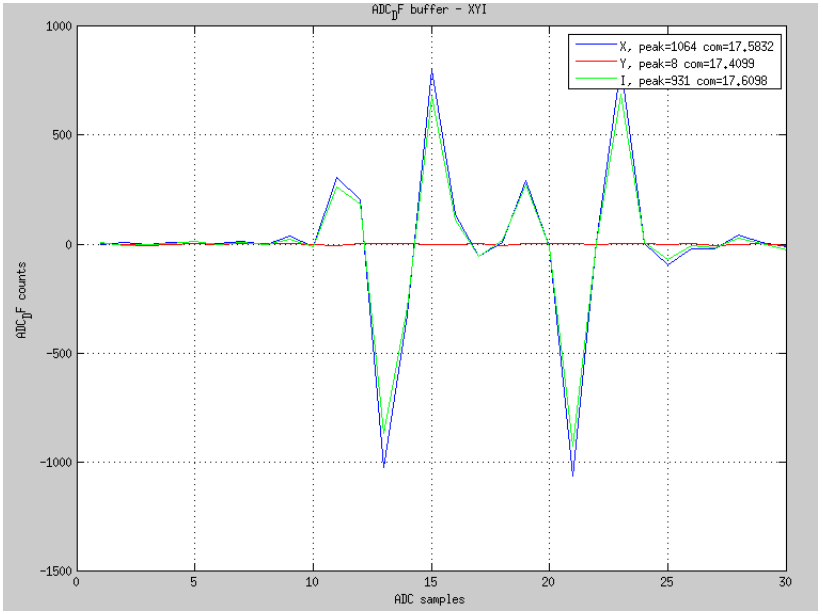
Multiple bunches





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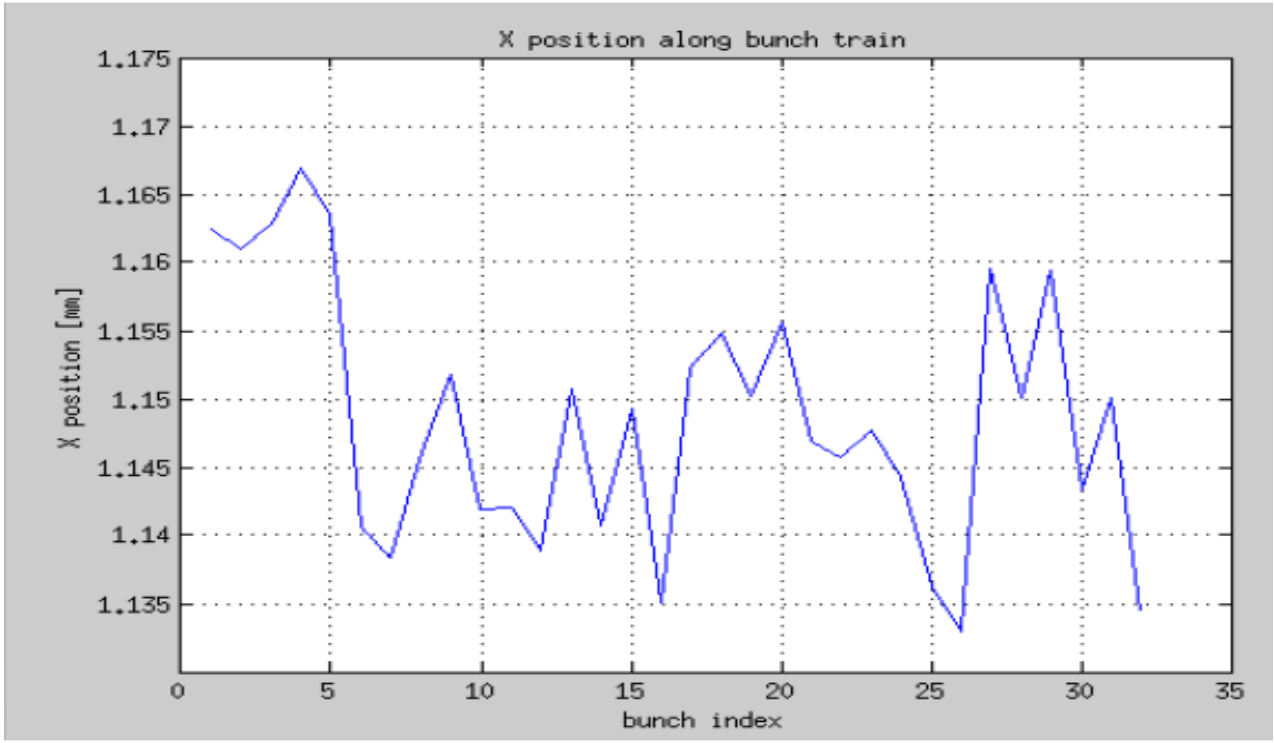
Multiple bunches measurements



The first multiple bunches measurements shows a high variation (bunch to bunch).
This has to be further investigated.

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Future measurements and conclusions

- We are performing tests on cavity BPMs and its readout electronics in order to calibrate the measurement system and perform a fast commissioning.
- Single bunch measurements show a resolution of 3μs over 1000 μm, but…
  - we are dominated by signal generator noise (trying to improve it)

We are continuing our tests in order to measure:

- Resolution with multiple bunches
- Jitter-related loss of resolution
- Phase-recognition
- Drifts over time

Thank you for your attention!

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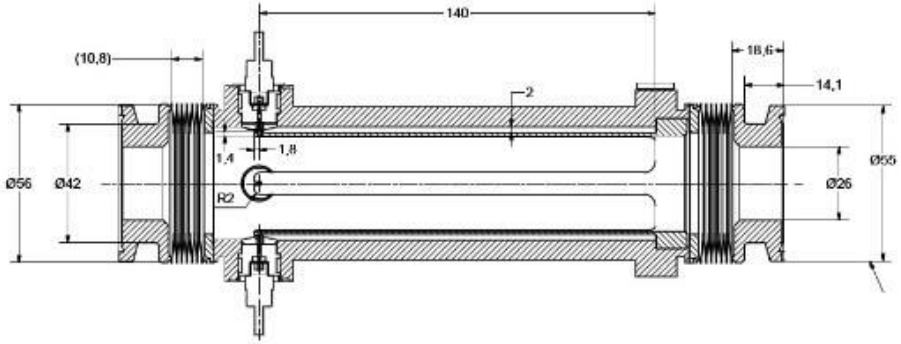
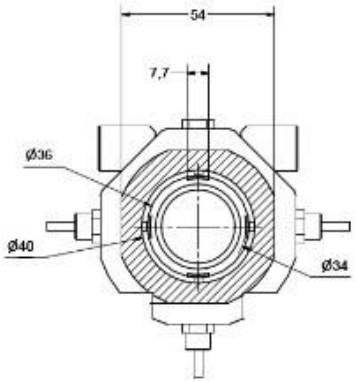
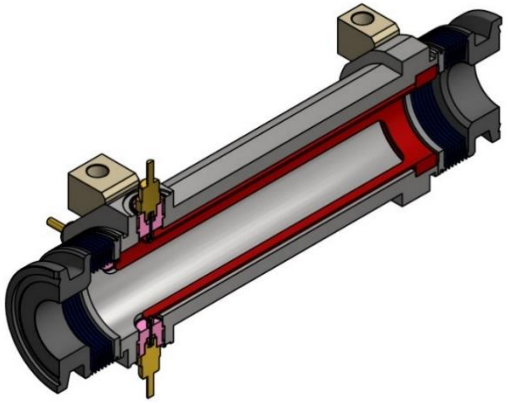
Stripline Beam Position Monitor







Libera Single Pass-E (readout electronics)

Keypoints:

- Resolution: 10 μm
- Only Macro pulses average position
- Will be used also for charge measurements

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GBS - Beam Specifications

Energy [MeV]	0.2 – 19.5
Spectral Density [ph/s·eV]	$0.8 – 4 \cdot 10^4$
Bandwidth rms [%]	≤ 0.5
# photons/pulse within FWHM bdw.	$\leq 2.6 \cdot 10^5$
# photons/s within FWHM bdw.	$\leq 8.3 \cdot 10^8$
Source rms size [μm]	10 – 30
Source rms divergence [μrad]	25 – 200
Peak brilliance [N_{ph}/s·mm^2·mrad^2·0.1%]	$10^{20} – 10^{23}$
Radiation pulse length rms [ps]	0.7 – 1.5
Linear polarization [%]	> 99
Macro repetition rate [Hz]	100
# pulses per macropulse	32
Pulse–to–pulse separation [ns]	16
Polarization axis wiggling [deg]	< 1
Synchronization to an external clock [ps]	≤ 0.5
Source position transverse jitter [μm]	< 5
Energy jitter pulse–to–pulse [%]	< 0.2
# photons jitter pulse–to–pulse [%]	≤ 3

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Table 3. Yb:Yag Collision Laser beam parameters

	Low Energy Interaction	High Energy Interaction
Pulse energy (*J*)	0.2	2x0.2
Wavelength (*eV,nm*)	2.3,515	2.3,515
FWHM pulse length (*ps*)	3.5	3.5
Repetition Rate (*Hz*)	100	100
M^2	≤ 1.2	≤ 1.2
Focal spot size w_0 (μm)	> 28	> 28
Bandwidth (*rms*)	0.1 %	0.1 %
Pointing Stability (μrad)	1	1
Sinchronization to an ext. clock	< 1 *psec*	< 1 *psec*
Pulse energy stability	1 %	1 %

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Table 2. Electron beam parameters at Interaction Points: general characteristics

all values are rms	
Energy (MeV)	80-720
Bunch charge (pC)	25-400
Bunch length (μm)	100-400
$\varepsilon_{n\_x,y}$ (mm-mrad)	0.2-0.6
Bunch Energy spread (%)	0.04-0.1
Focal spot size (μm)	> 15
# bunches in the train	≤ 32
Bunch separation (nsec)	16
energy variation along the train	0.1 %
Energy jitter shot-to-shot	0.1 %
Emittance dilution due to beam breakup	< 10%
Time arrival jitter (psec)	< 0.5
Pointing jitter (μm)	1

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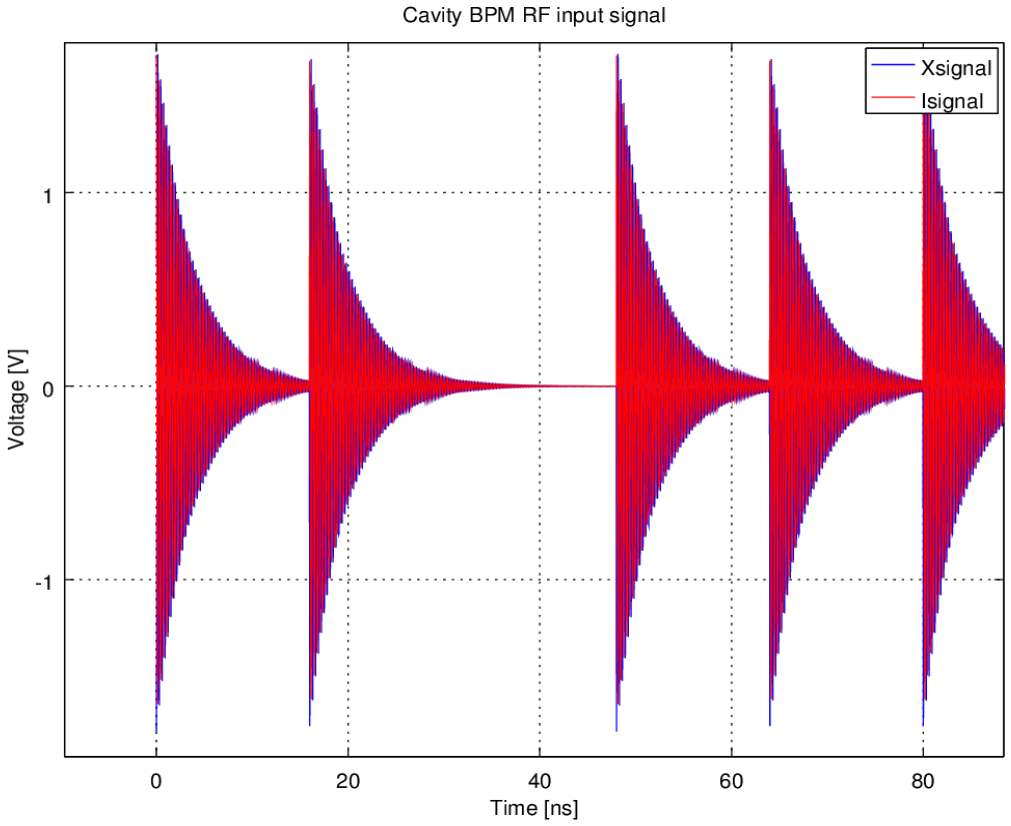

$$f_{res} = 3.284 GHz$$

$$Q = 40$$

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

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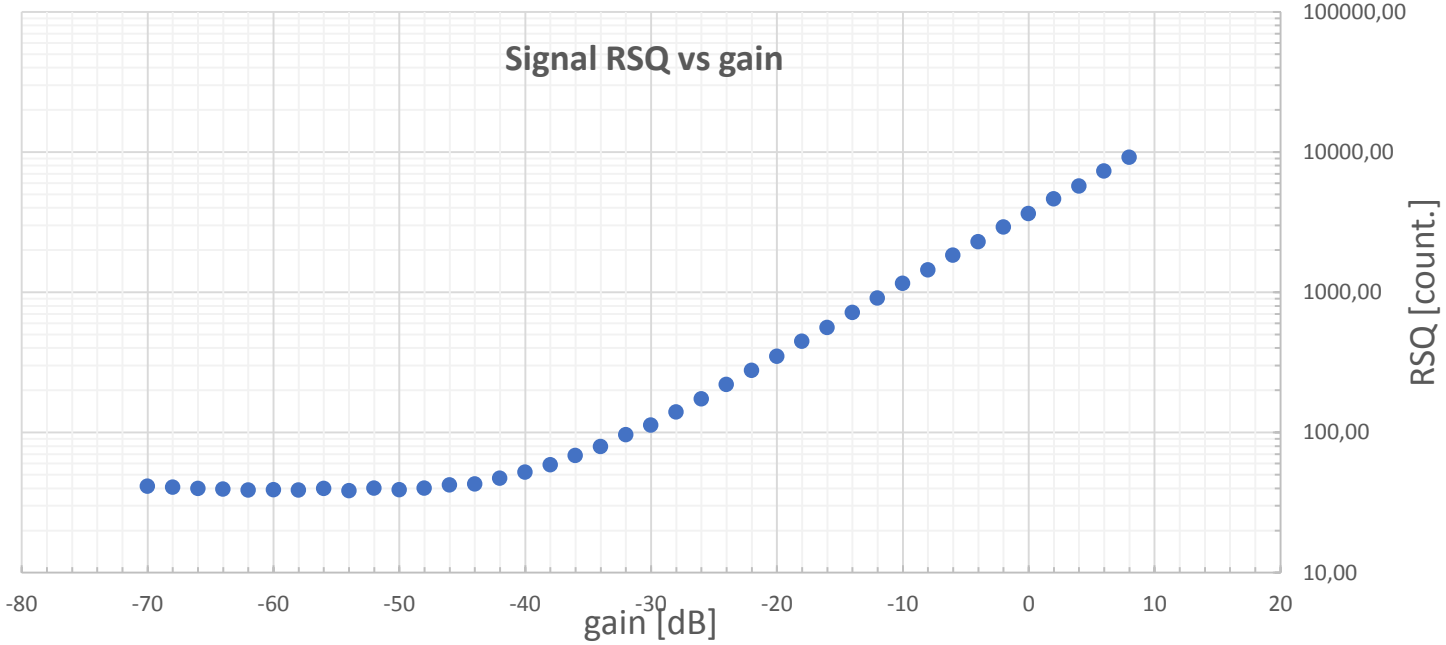
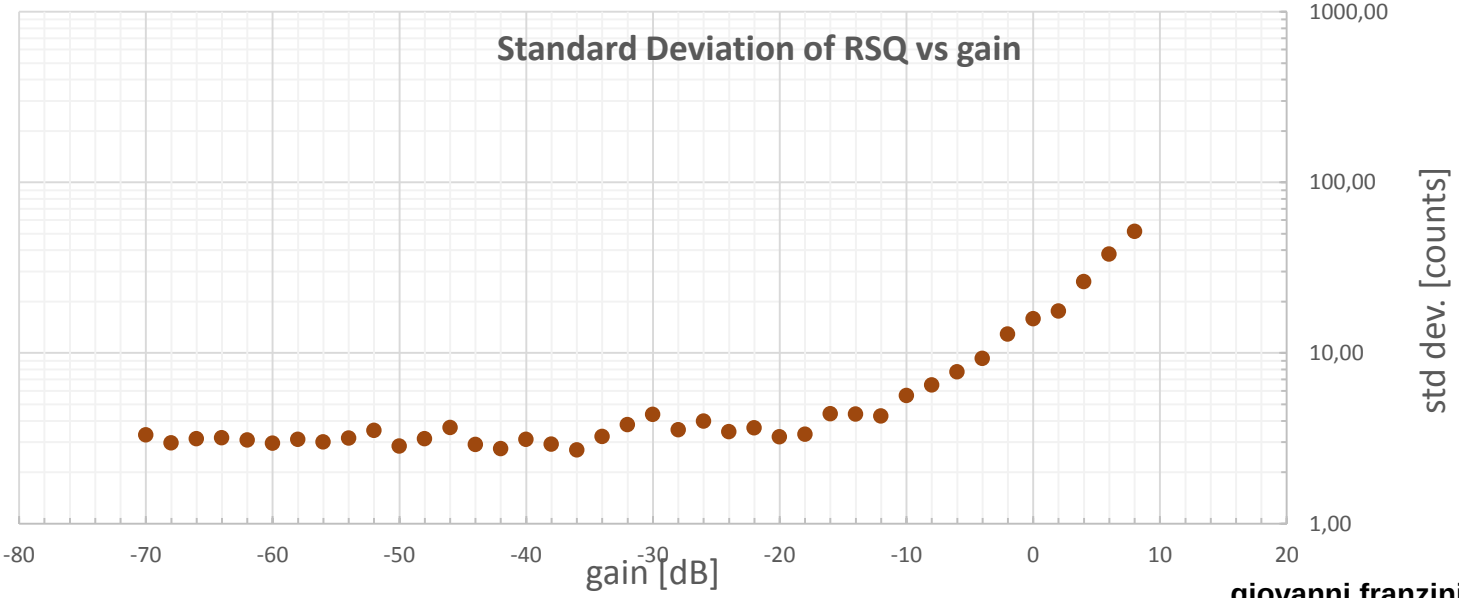
Single bunch position resolution





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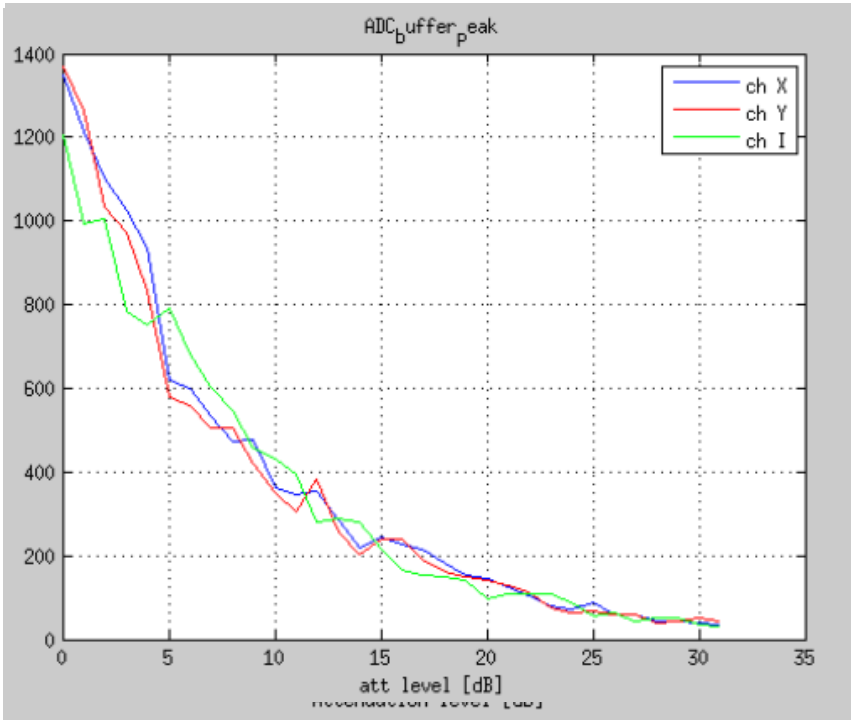
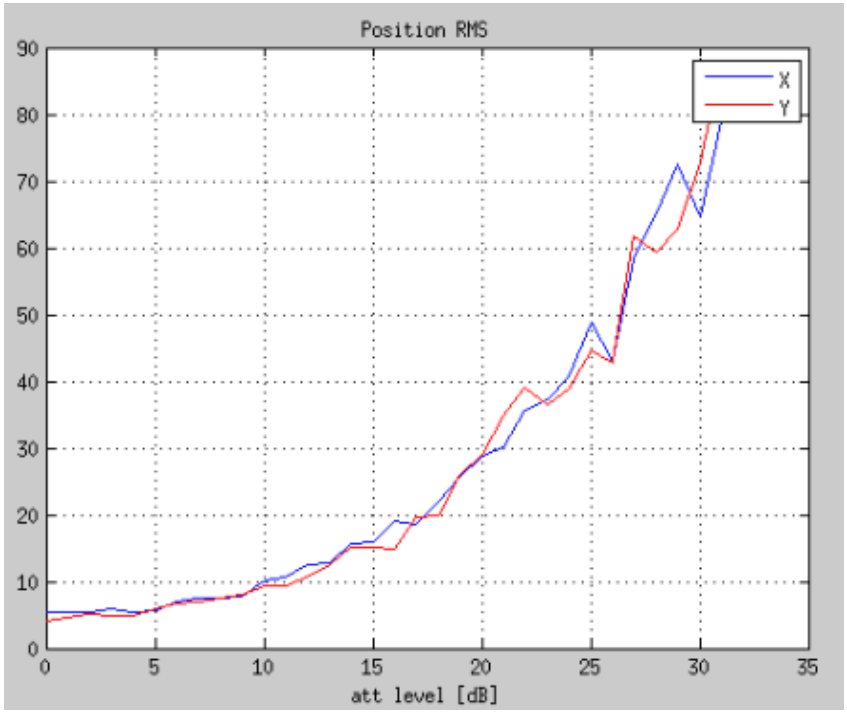
Resolution vs Signal Level



ADC buffer peak level



X&Y Position RMS resolution

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Parameter	Value
Maximum Energy	720 MeV
Macro Pulse rep. rate	100 Hz
Number of bunches per Macro Pulse	up to 32
Bunch Spacing	16.1 ns
Bunch Length (σ_t)	0.91 ps
Bunch Charge	25 pC – 250 pC

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