Techniques for Round Beams

GOAL:
- vertical emittance increase to increase lifetime in 4GSLS
- At ALBA-II, we look round beams!
- Watch out: actual emittance growth, no betatron motion

METHOD: use beam excitation using stripline kickers at specific frequencies

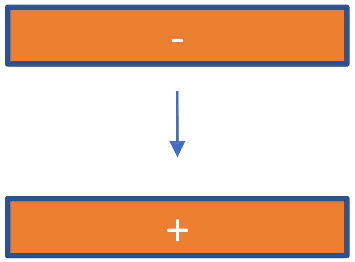
Based Exc. Freq.	Exc. Config	Machine	Emittance
(Qv+Qs)*	Vertical	Diamond	S. Preston, IPAC22, TUPOMS035 S. Preston, IBIC22, WEP37
(Qv-Qh)*	Skew	ALBA	M.Carla, IPAC23, MOPL002
White Noise	Vertical	Soleil / ESRF	iFAST 2024, Karlsruhe https://indico.scc.kit.edu/event/3742/overview

*or its revolution harmonics

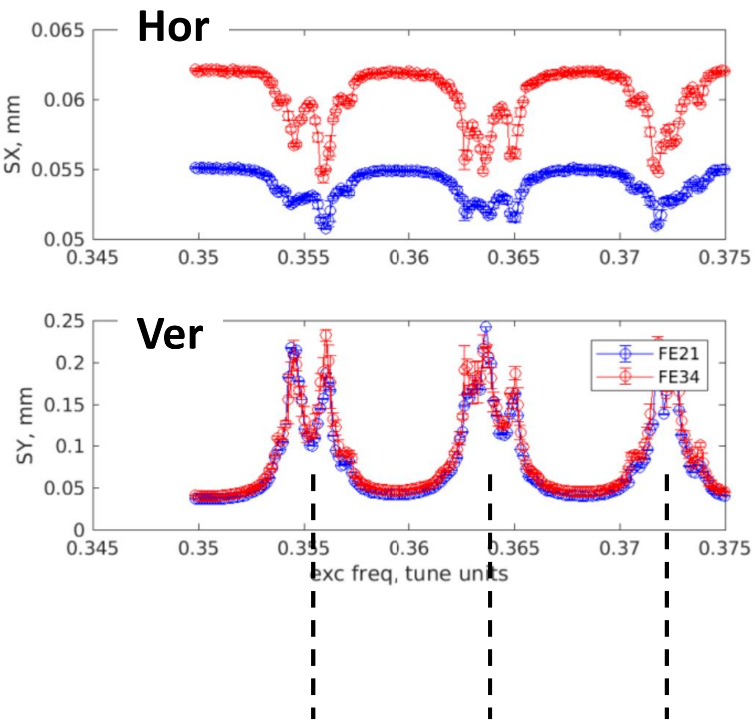
Vertical Exc around [Qv + Qs]

- Scan frequencies to see most effective one
- Excite using a pure sinusoidal signal, with Q=[Qv-Qs, Qv+Qs]

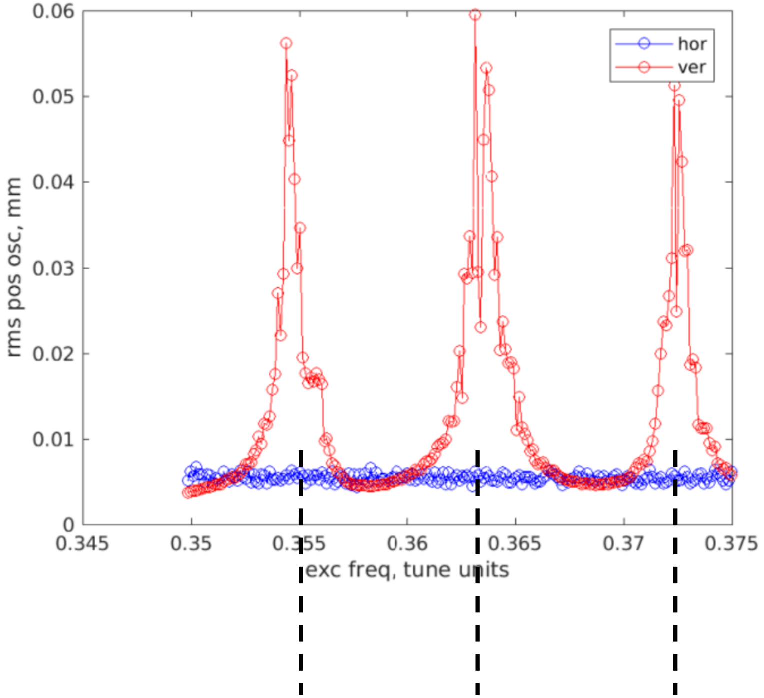
Dipolar Kick



Beam Size at Pinholes



Position Oscillations at BPM



Qv-Qs **Qv** **Qv+Qs**

Qv-Qs **Qv** **Qv+Qs**

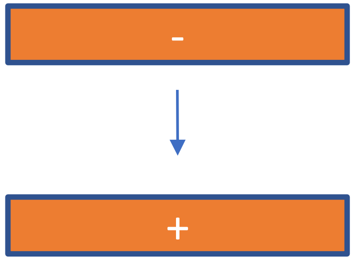
➔ Both emittance and betatron motion are seen at Qv, and Qv+-Qs peaks

➔ See noise around peaks: add certain frequency bandwidth to cope with tune jitter

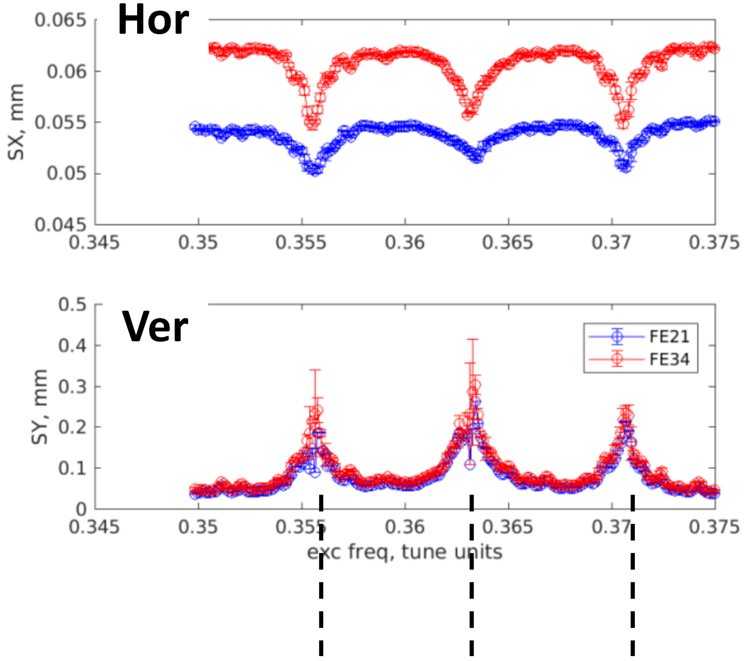
Vertical Exc around [Qv + Qs + ΔQ]

- Scan frequency to see most effective one
- Excite with sinusoidal signal, but with certain bandwidth:
  - with Q= Qexc + ΔQ
  - with ΔQ = 1e-3 (~20*TuneJitter)

Dipolar Kick

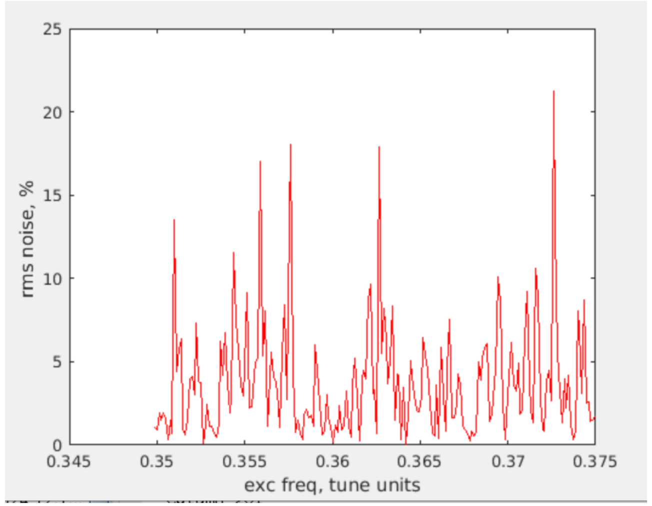


Beam Size at Pinholes

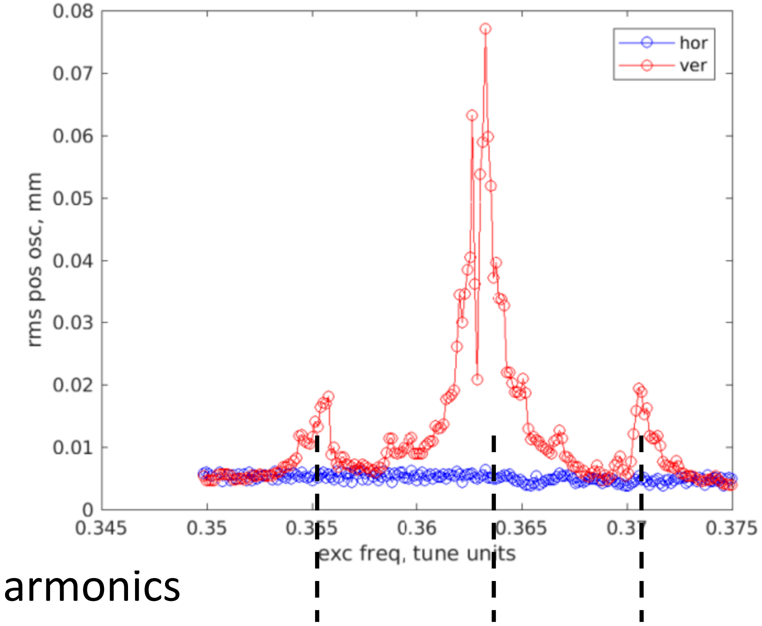


Qv-Qs Qv Qv+Qs

RMS beam size %



Position Oscillations at BPM



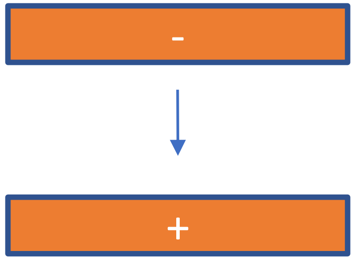
Qv-Qs Qv Qv+Qs

➔ Focus at (Qv+Qs), but higher harmonics

➔ (Qv+-Qs) peaks show much lower betatron motion than Qv

Vertical Exc around [n + Qv + Qs + ΔQ]

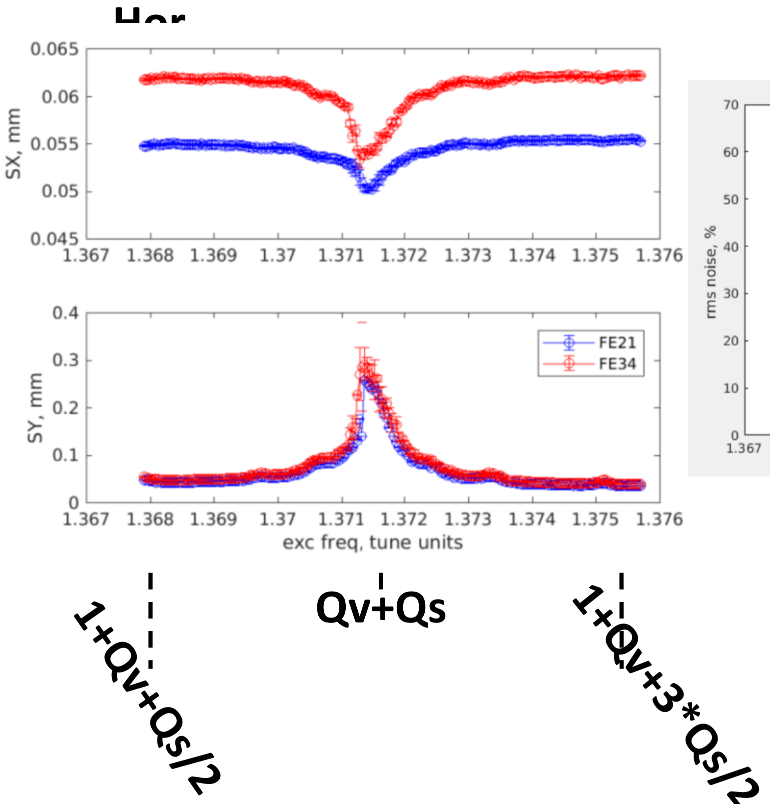
Dipolar Kick



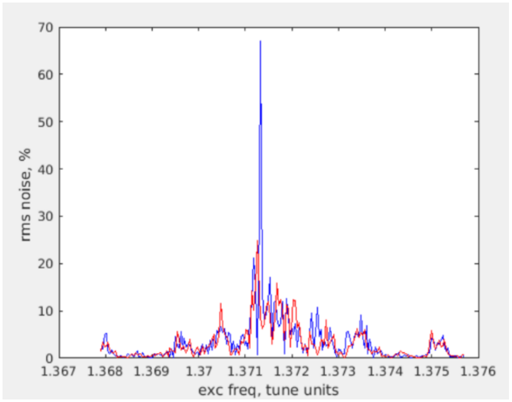
- Scan frequency to see most effective one
- Excite with sinusoidal signal, but with certain bandwidth:
  - with Q= Qexc + ΔQ
  - with ΔQ = 1e-3 (~20*TuneJitter)

➔ Negligible rms oscillation seen at BPMs:
- Is it really negligible or we cannot detect it? High frequencies (higher than one revolution) will be averaged out by BPMs
- Need to carefully look at other observables (lifetime) or use other instruments

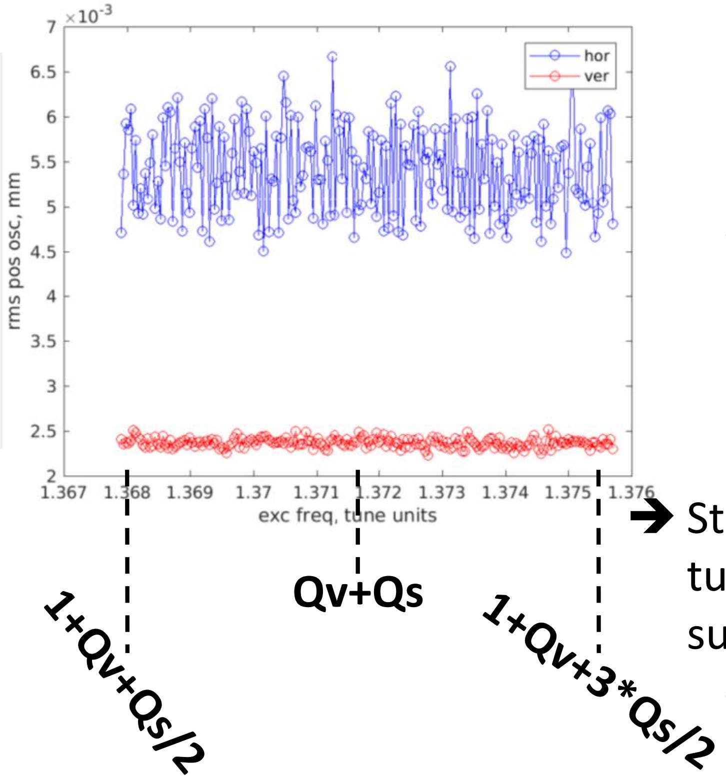
Beam Size at Pinholes Hor



RMS beam size %



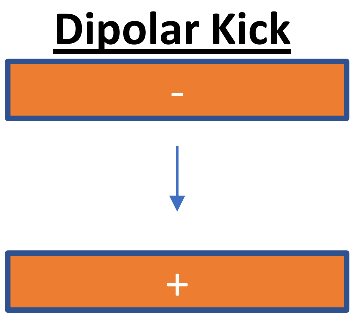
Position Oscillations at BPM



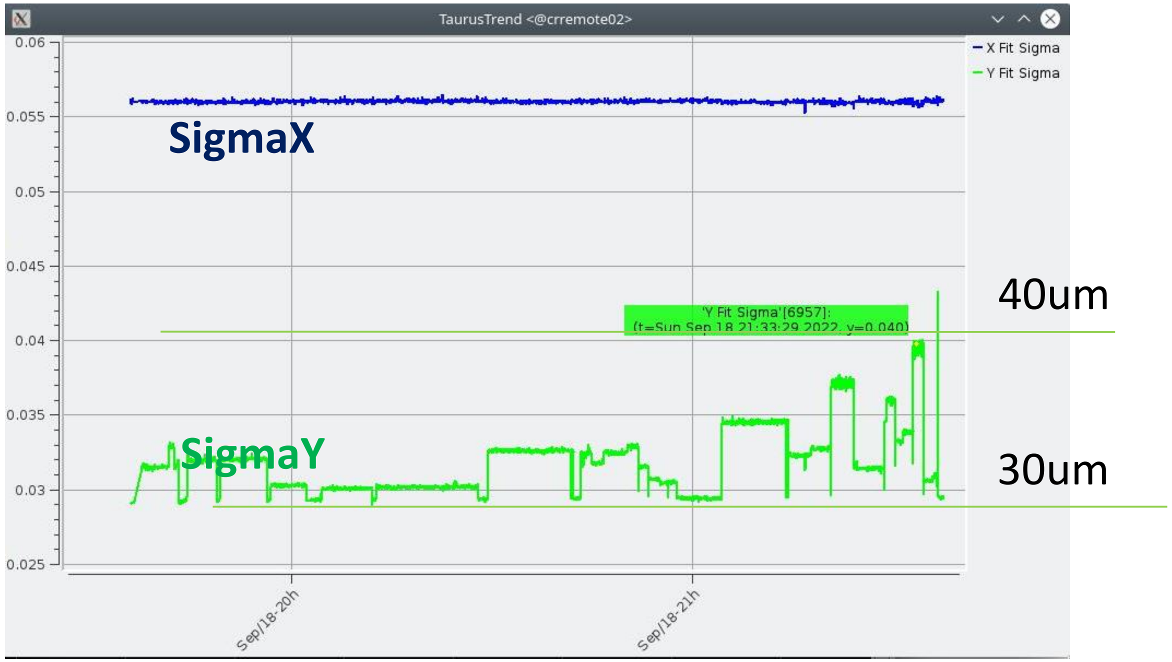
➔ Still not fully stable beam size: tune jitter not fully suppressed.
- Need to use PLL!!

White Noise

- In order to cope with tune jitter, excite at many different frequencies at the same time
- The particles will always be excited by its own frequency
- In principle, excitation with several tune jitter should be enough, but both Soleil and ESRF use large bandwidths



- At ALBA, our attempts with white noise were not fully satisfactory because:
  - we always see beam size oscillations (the larger beam size, the beamsize oscillations)
  - Low rms position oscillations if large bandwidths used



➔ Usually not very large beam size increase
➔ Found always better efficiency for large bandwidths, but in our set-up is currently not very practical:

The WhiteNoise in our AFG needs to be pre-programmed, then loaded using USB… not very practical!

White Noise

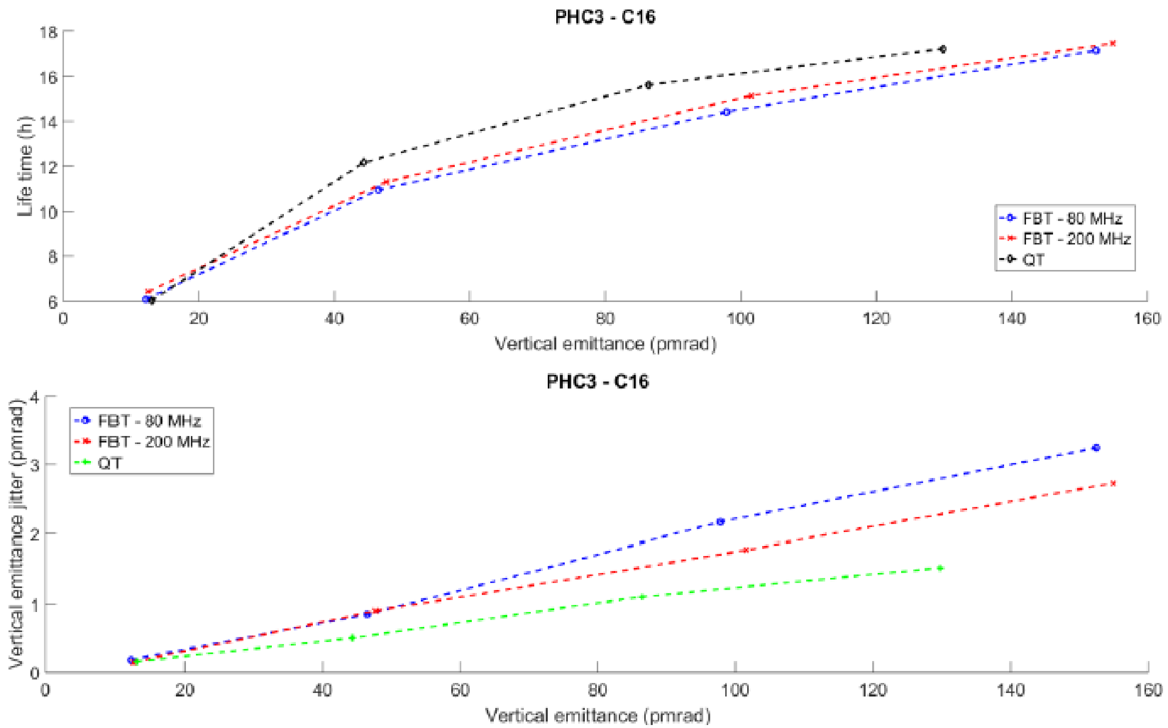
- Example at SOLEIL (from https://indico.scc.kit.edu/event/3742/overview)

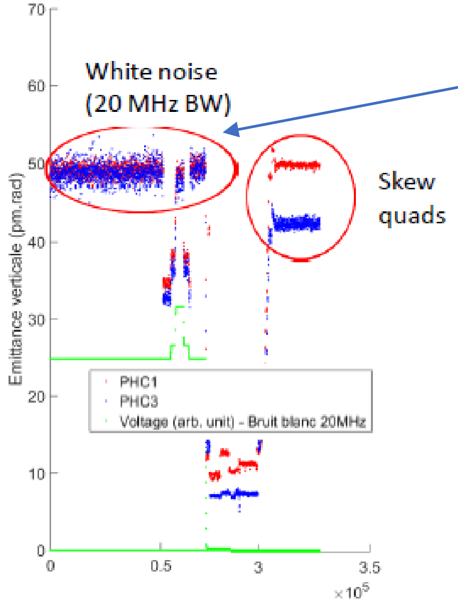
SOLEIL SYNCHROTRON

Beam size feedback

A general issue regarding beam size control with white noise:

- You must make sure that you are **generating emittance** (i.e. lifetime) and **not betatron motion** (i.e. just shaking the beam).
- You cannot always trust your detectors (here pinhole cameras) because some of the high frequency motion will be integrated.
- Our experience shows that using **a high bandwidth (BW) white noise is crucial to generate emittance and reduce jitter.**





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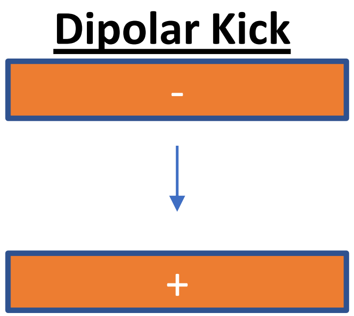


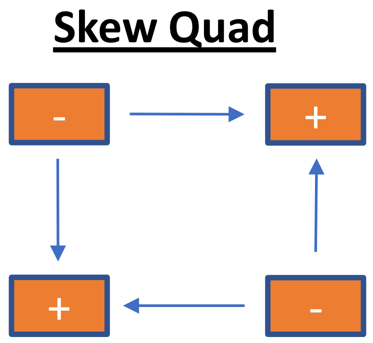
Some noise (~2%) also detected

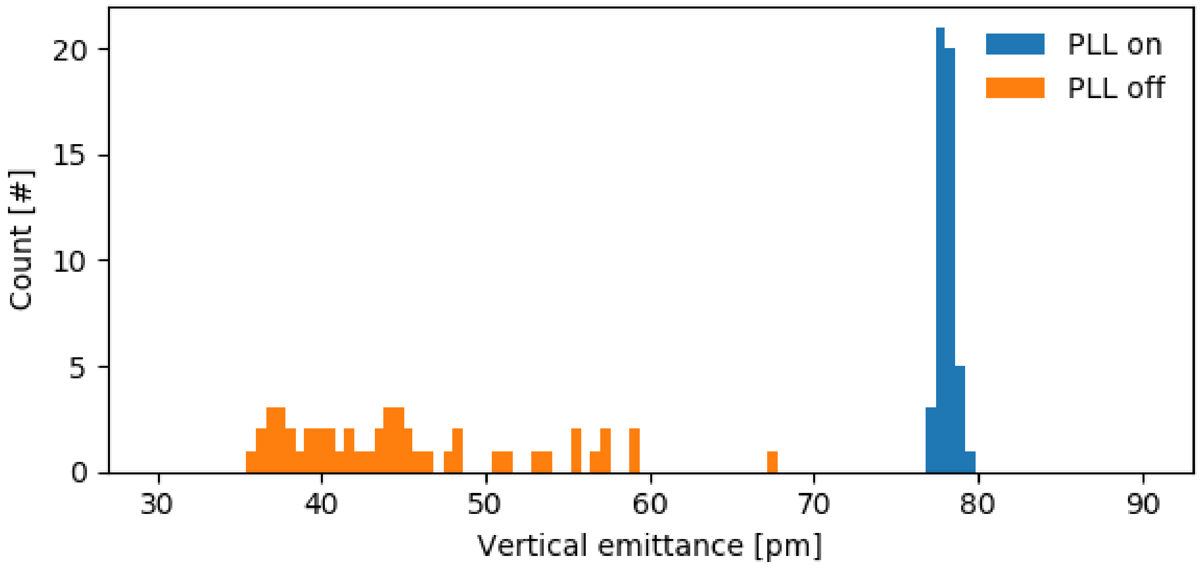
➔ How does it scale if you go to round beam?

➔ Would users complain?

Skew Excitation at Qv-Qh

- Skew Quad Excitation
  - Excite resonantly at coupling resonance Qv-Qh so motion is transferred from Hor <--> Ver
  - No field in the center → no centroid motion (unless misalignments)
  - Need to follow tune jitter – use the PLL from BBB





➔ A specific circuit was done to combine PLL signals from BBBhor and BBBver

➔ Not compatible with normal use of BBB – tests only at 100mA

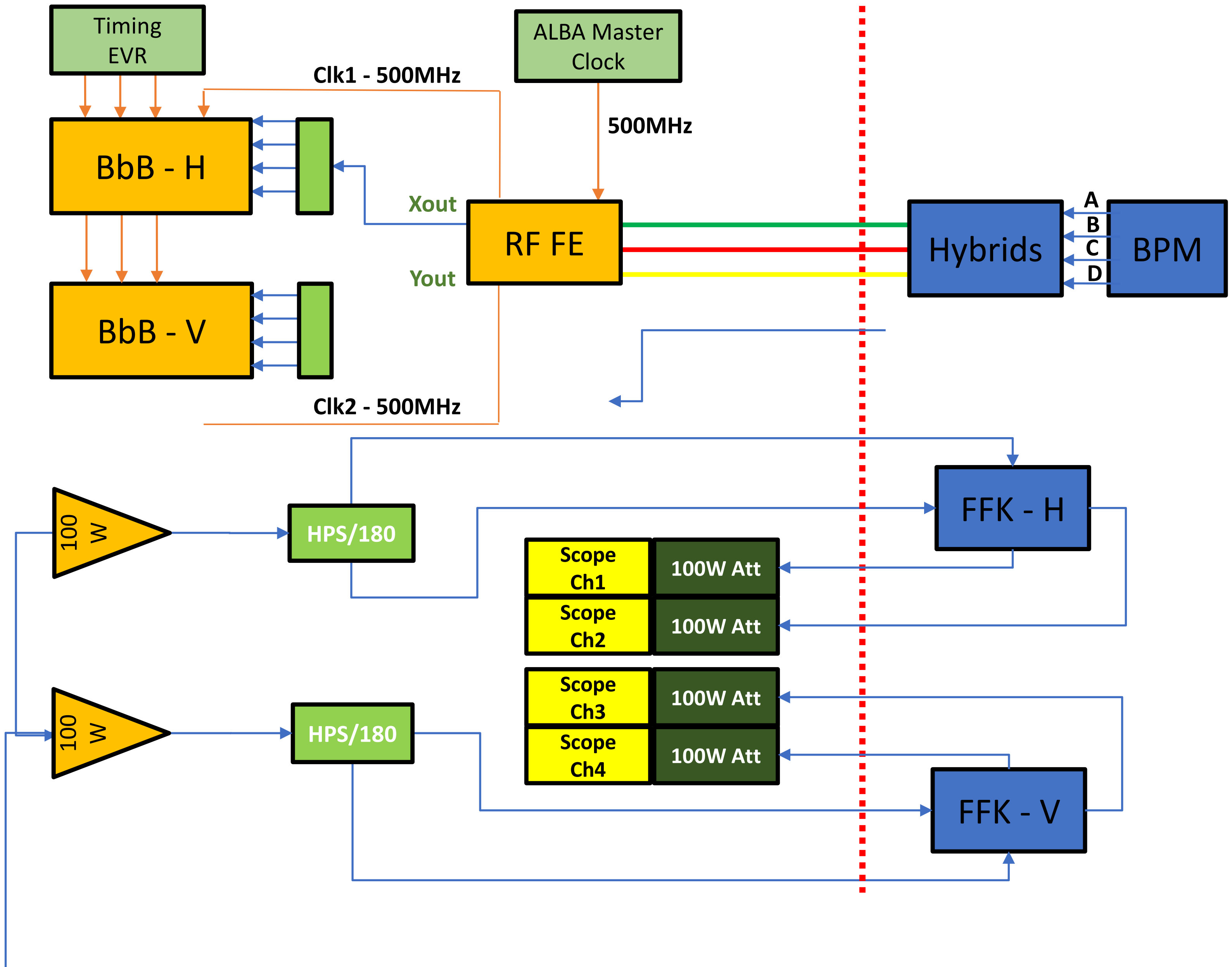
Summary

In your future upgraded machines…

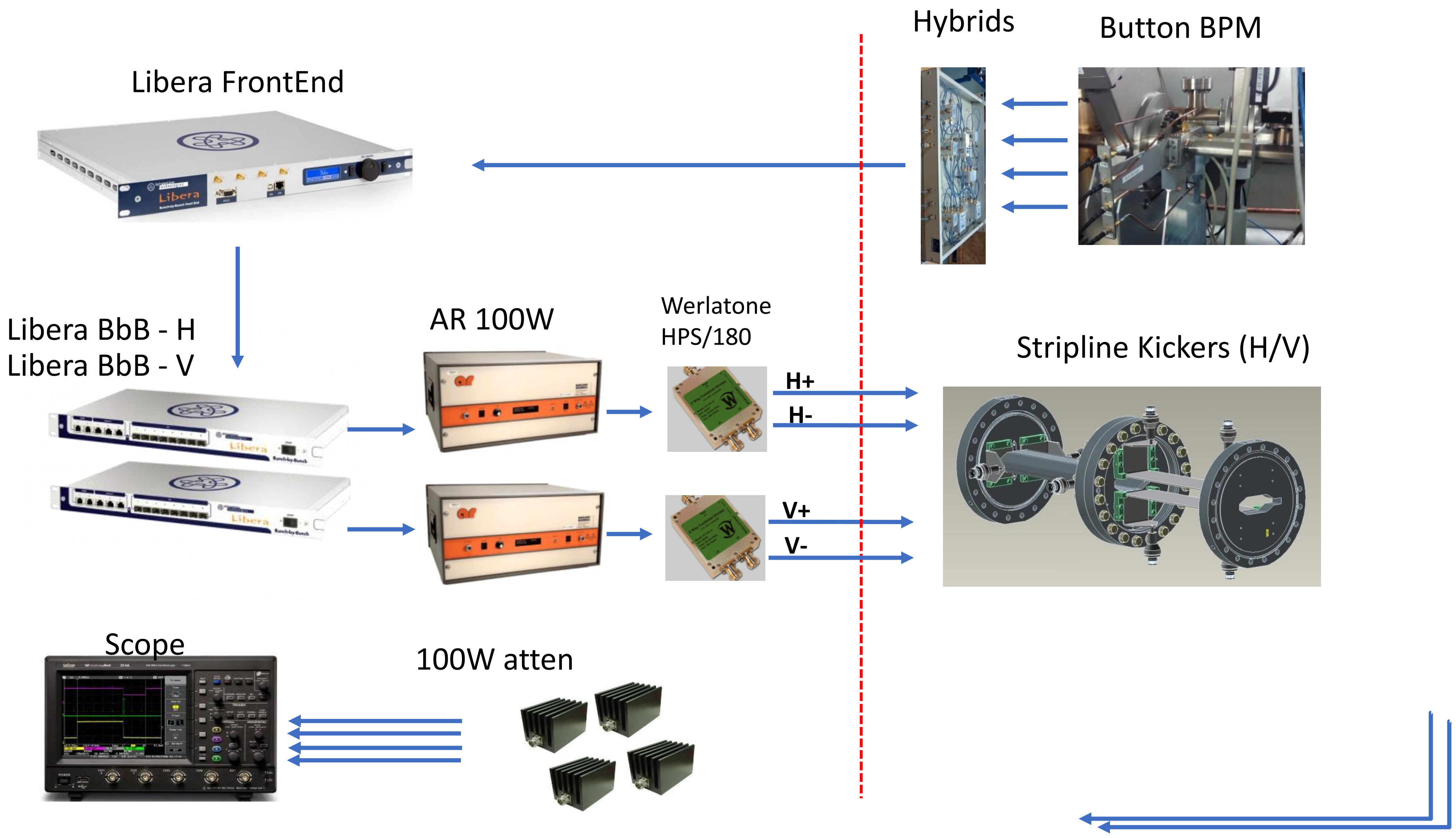
1. Do you also need to increase beam size to reach round beam?
2. Which method would you use?
3. Did you verify that your method works also for higher beam size?
4. Have you tried to measure intra-turn beam oscillations? Would users complain?
5. Anyone doing simulations for this? (i.e. varying chroms, impedance effects, third harmonic…)

extra

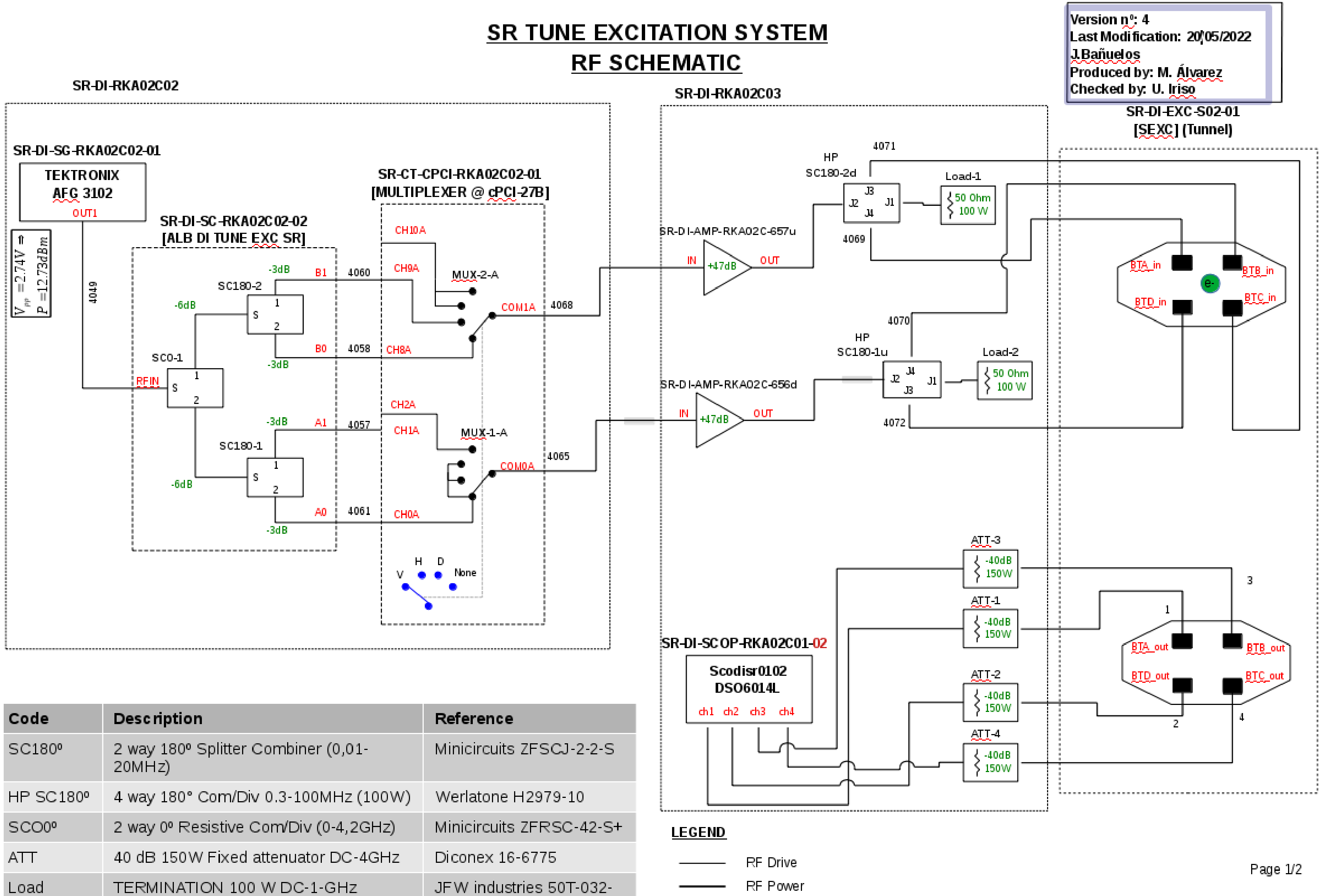
BBB Hardware at a glance



BBB Hardware at a glance

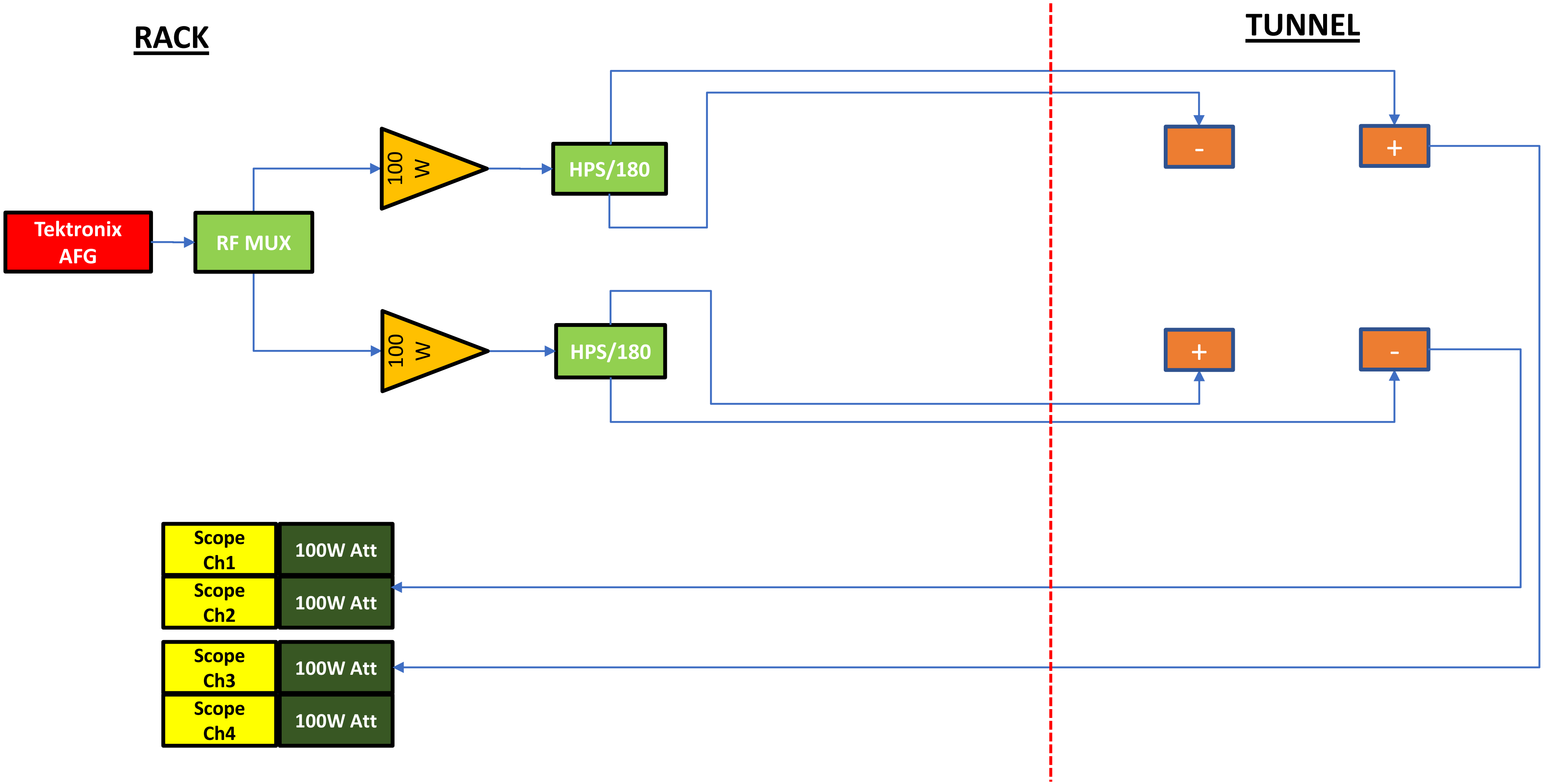


Stripline Hardware for Tune Excitation



Code	Description	Reference
SC180º	2 way 180º Splitter Combiner (0,01-20MHz)	Minicircuits ZFSCJ-2-2-S
HP SC180º	4 way 180° Com/Div 0.3-100MHz (100W)	Werlatone H2979-10
SCO0º	2 way 0º Resistive Com/Div (0-4,2GHz)	Minicircuits ZFRSC-42-S+
ATT	40 dB 150W Fixed attenuator DC-4GHz	Diconex 16-6775
Load	TERMINATION 100 W DC-1-GHz	JFW industries 50T-032-1.0 N

Stripline Hardware (Skew Quad Excitation)



TUNE JITTER MEASUREMENTS

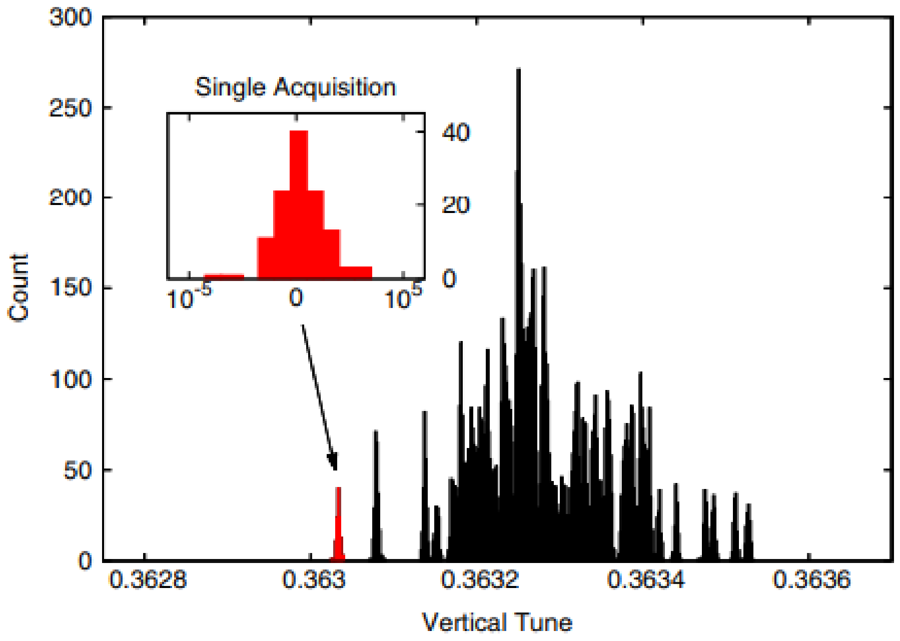


FIG. 3. Histogram of the vertical tune measured by 120 BPMs for 100 acquisitions. The measurement shows an overall standard deviation of 1.1×10^{-4}, on the other hand looking at one single acquisition (in red) the spread is strongly reduced presenting a standard deviation of only 2.1×10^{-6}.

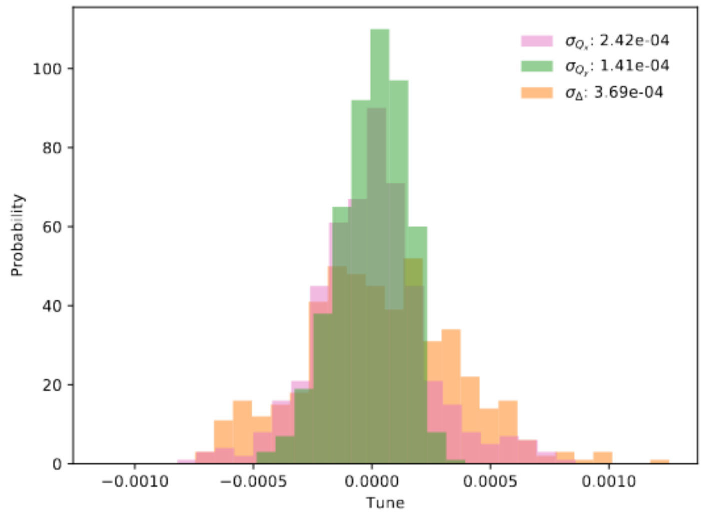
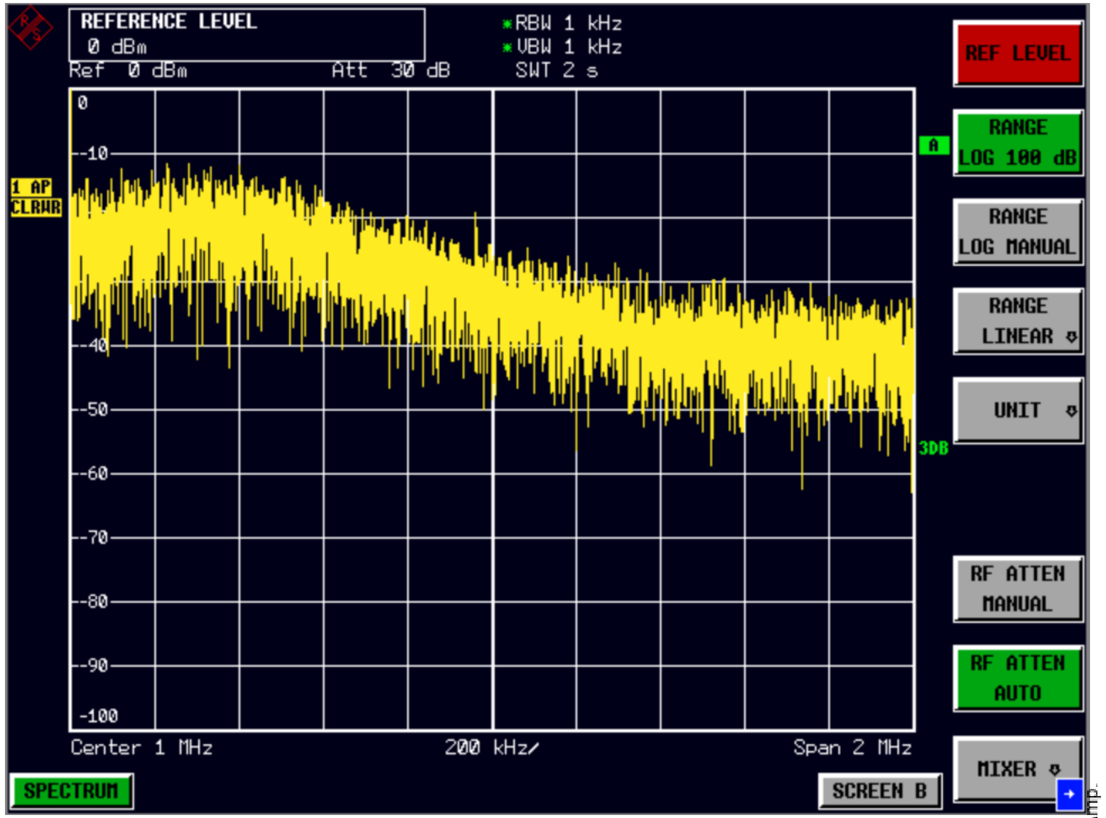


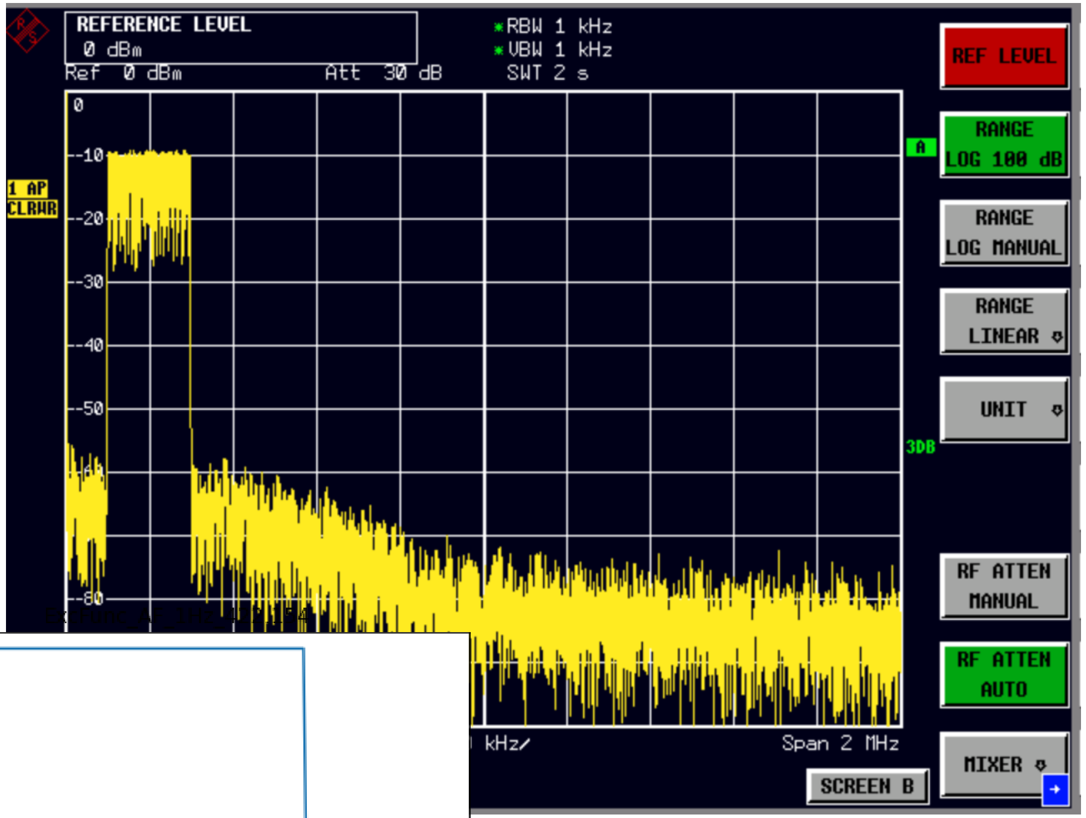
FIG. 2: Distribution of the horizontal (red), vertical (blue) tune and difference of the tunes (black) derived from the spectral analysis of 500 measurements of the horizontal and vertical betatron motion. The average value of the tunes has been removed to align the 3 distributions and make evident the fluctuations. The fluctuation of the difference of the tunes Δ is close to the sum of the fluctuations on Q_x and Q_y pointing to an anti correlation between the horizontal and vertical tunes change. An effect compatible with electrical noise in the quadrupoles circuit.

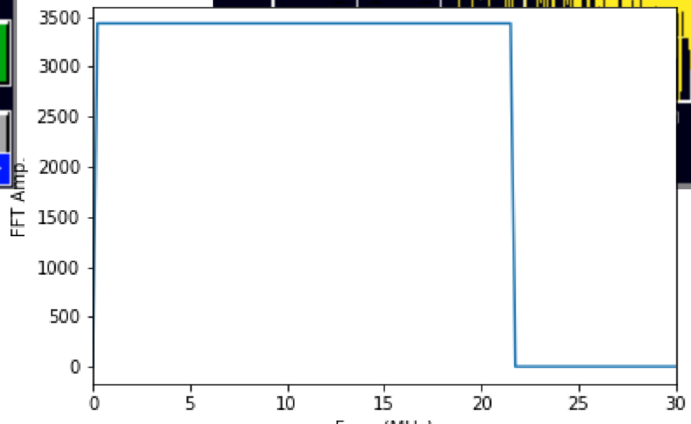
COMPARISON WHITE NOISE 1) AFG AND 2) lt FUNCTIONS

White noise AFG

LT Original: 250 +- 100kHz







Some ALBA numbers

Sigma1 = sqrt(beta*Emit1) ;

Assume usual ALBA : Emit1 has 0.5% coupling. So Emit2 = 200*Emit1

Sigma2 = sqrt(beta*200*Emit1) = sqrt(200)*Sigma1 ~14*Sigma1;

So for ALBA assuming Sigma1=30um and C=0.5% → Sigma2 = 420 um if C=100%

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