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PhD28: Post-processing of ATF resolution measurements3

Laura Karina Pedraza, Nuria Fuster, Daniel Esperante, Benito Gimeno

PhD Journal, 24/03/2026

PhD28:
Post-processing
of ATF resolution
measurements 3

LabRF meeting, 24/03/26

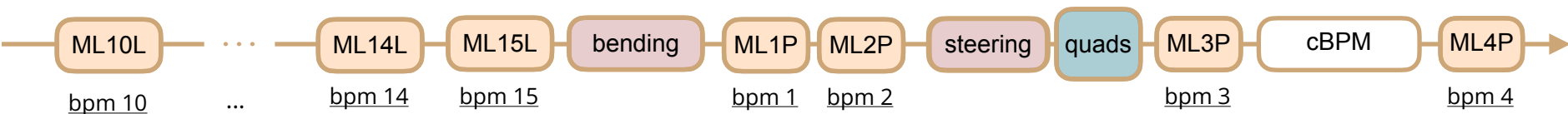
Introduction

- I. Corrections on time acquisition
 - A) Visualisation of the acquisition times
 - B) Time window selection for synchronisation
 - C) Comparison of EPICS acquisition by different computers
- II. Estimation of the resolution error
 - A) Estimation of the stripline resolution and impact on the cBPM resolution
 - B) Thought experiments

Conclusion

I. Corrections on time acquisition

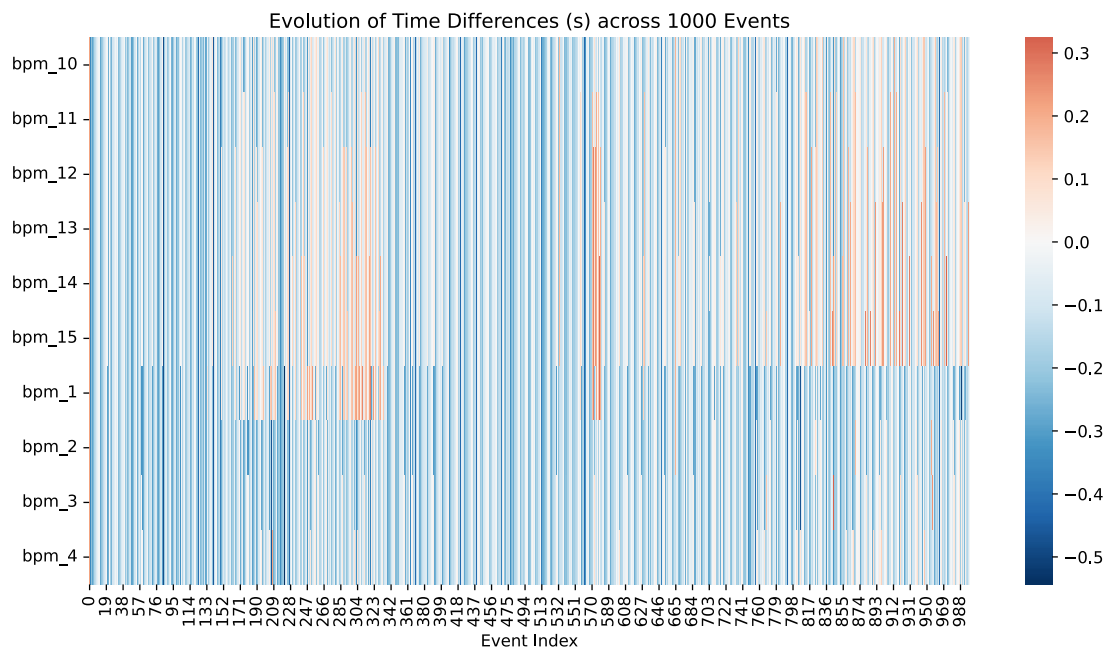
A) Visualisation of acquisition times



Observing all BPMs time-stamps differences with the oscilloscope acquisition.

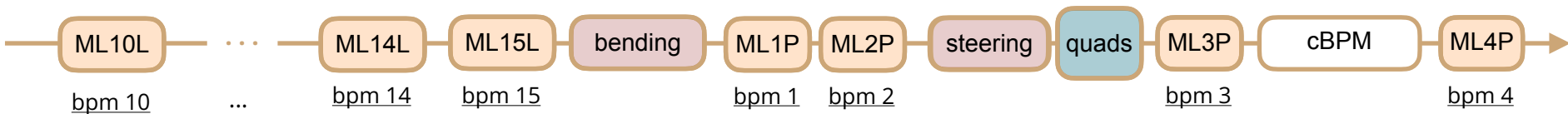
$$t_{diff, BPMx} = t_{s_{cBPM}} - t_{s_{BPMx}}$$

This time difference is observed for all BPMs and all bunches in the Heat-map:



I. Corrections on time acquisition

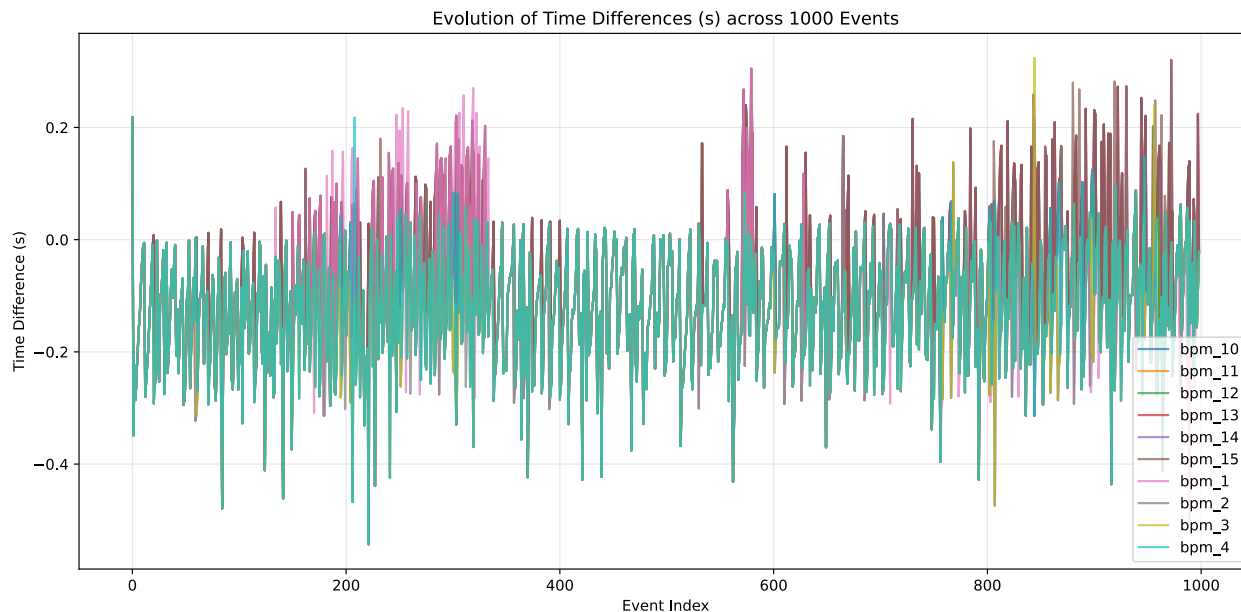
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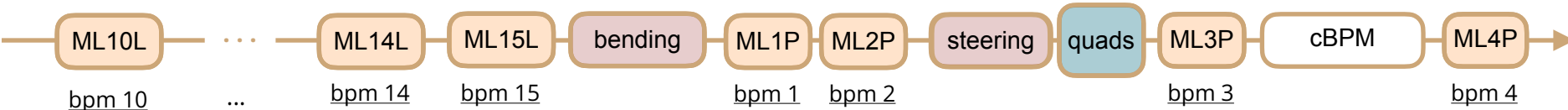
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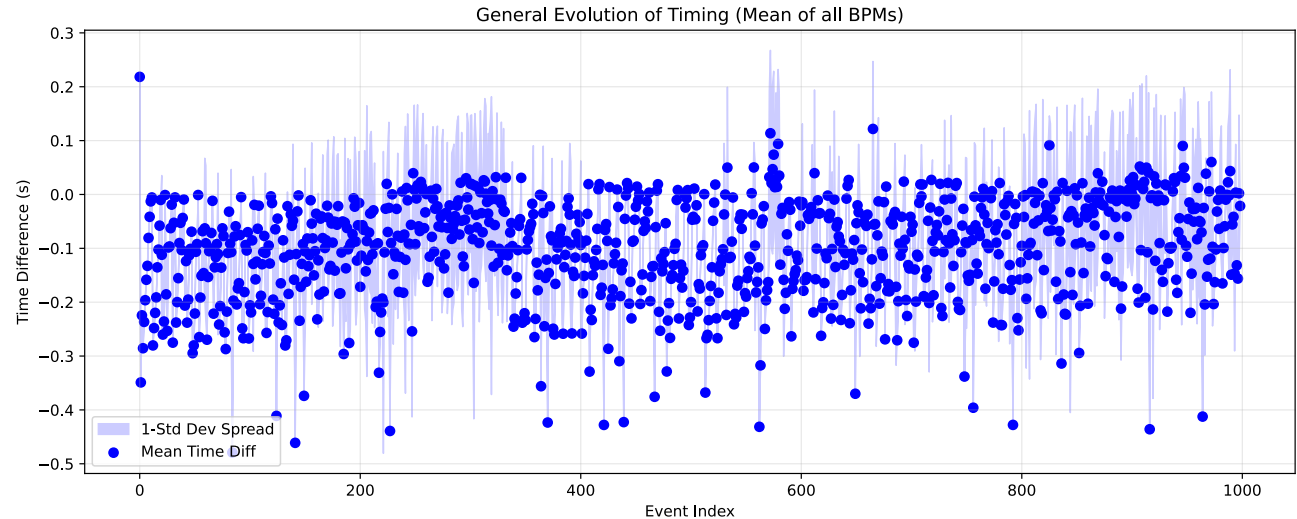
I. Corrections on time acquisition

A) Visualisation of acquisition times



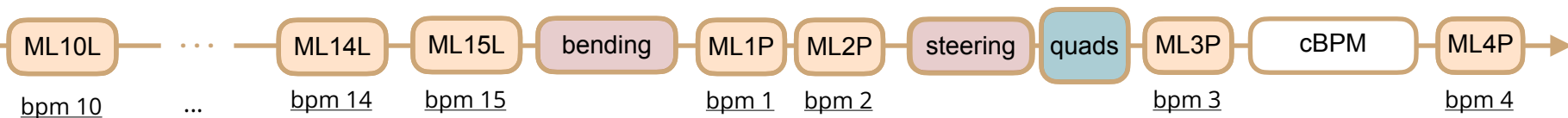
Averaging for each bunch all the stripline BPMs time-differences and calculating the standard deviation:

$$\overline{t_S} = \frac{\sum t_{diff, BPMx}}{\#BPMs}$$

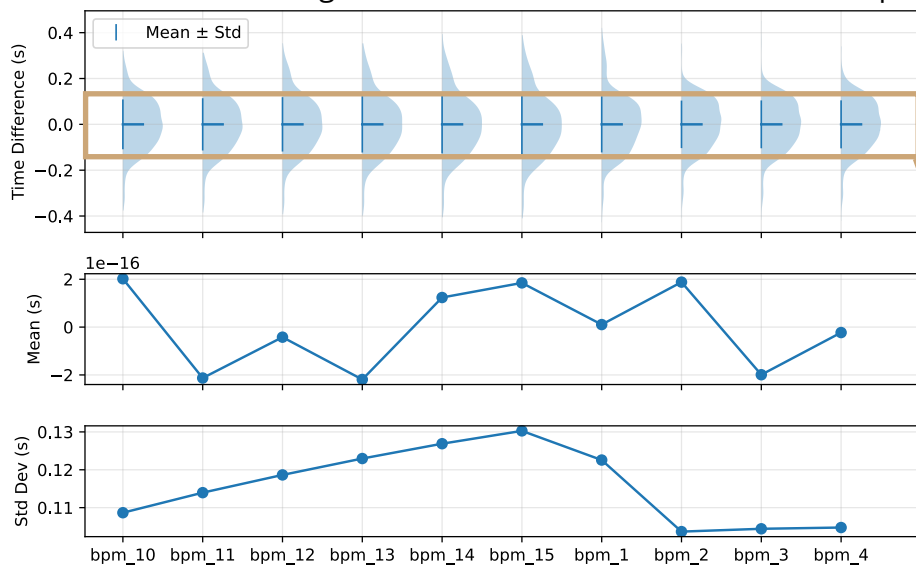


I. Corrections on time acquisition

B) Time window selection for synchronisation



After removing the mean value to each BPM time-stamp



Distribution of time differences for each BPM:

$$t_{diff,BPM_x} = t_{s_{cBPM}} - t_{s_{BPM_x}} - \bar{t}_{s_{BPM_x}}$$

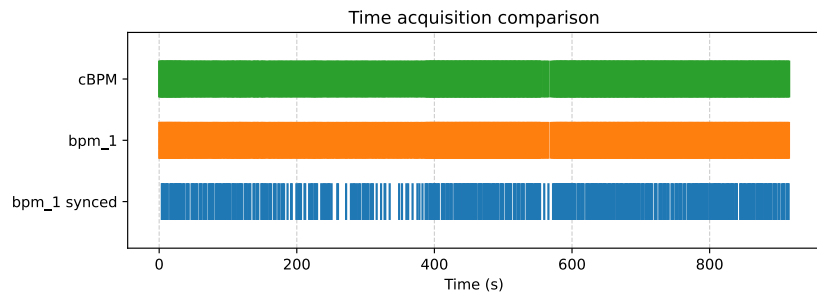
Mean value of the time difference for each BPM
(should be close to 0)

Stdv of the time difference for each BPM

I select only the values present in a **time window**

I. Corrections on time acquisition

B) Time window selection for synchronisation



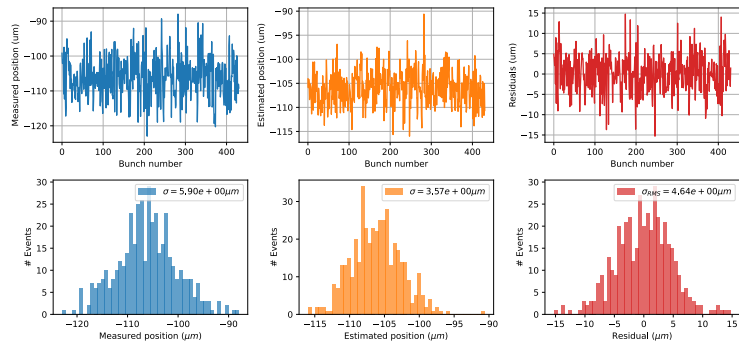
For time_window = 0.25 s

Subtracting the mean time difference per BPM to the time-stamps comparison:

```
No synchronization found for 511 bunches at BPM bpm_1
No synchronization found for 515 bunches at BPM bpm_2
No synchronization found for 494 bunches at BPM bpm_3
No synchronization found for 475 bunches at BPM bpm_4
No synchronization found for 433 bunches at BPM bpm_10
No synchronization found for 424 bunches at BPM bpm_11
No synchronization found for 421 bunches at BPM bpm_12
No synchronization found for 422 bunches at BPM bpm_13
No synchronization found for 419 bunches at BPM bpm_14
No synchronization found for 422 bunches at BPM bpm_15
```

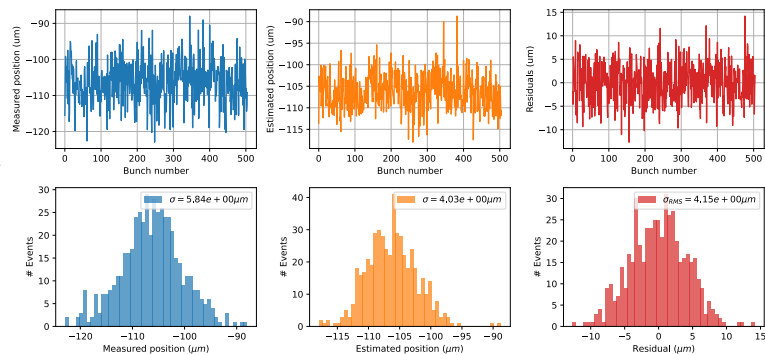
```
No synchronization found for 272 bunches at BPM bpm_1
No synchronization found for 240 bunches at BPM bpm_2
No synchronization found for 233 bunches at BPM bpm_3
No synchronization found for 228 bunches at BPM bpm_4
No synchronization found for 247 bunches at BPM bpm_10
No synchronization found for 267 bunches at BPM bpm_11
No synchronization found for 279 bunches at BPM bpm_12
No synchronization found for 289 bunches at BPM bpm_13
No synchronization found for 302 bunches at BPM bpm_14
No synchronization found for 321 bunches at BPM bpm_15
```

BPM Resolution on the Y axis for $L_{ZV2P}=2.2$, $L_{ZH2P}=-0.2$ and $L_{beam}=0.896$



4.64 µm

BPM Resolution on the Y axis for $L_{ZV2P}=2.2$, $L_{ZH2P}=-0.2$ and $L_{beam}=0.896$



4.15 µm

I. Corrections on time acquisition

C) Comparison of EPICS acquisition

Adquisición de datos:

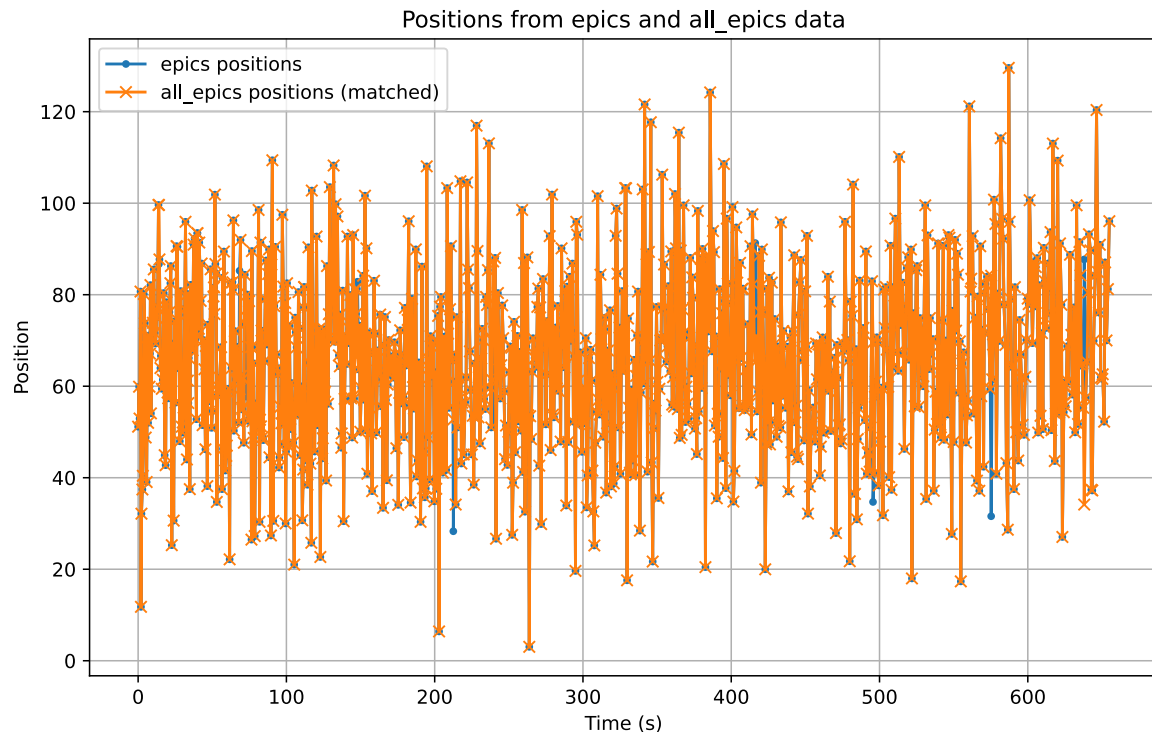
"epics_all_data" fue adquirido por el código escrito por Eduardo en la última campaña en ATF.

El código le pide los datos a EPICS cada `sampling_time=0.1 s` for a certain number of `cycles=3000`

El código corría en paralelo en el ordenador de Eduardo mientras mi ordenador realizaba la adquisición de datos del BPM (y también de EPICS) con el trigger del osciloscopio.

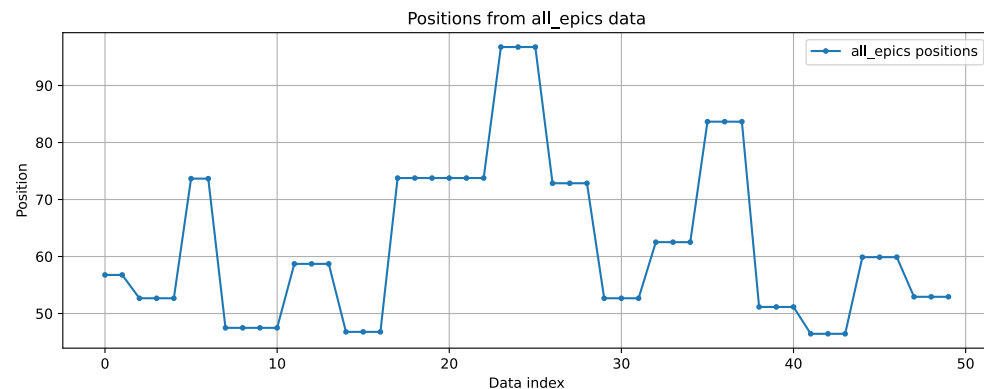
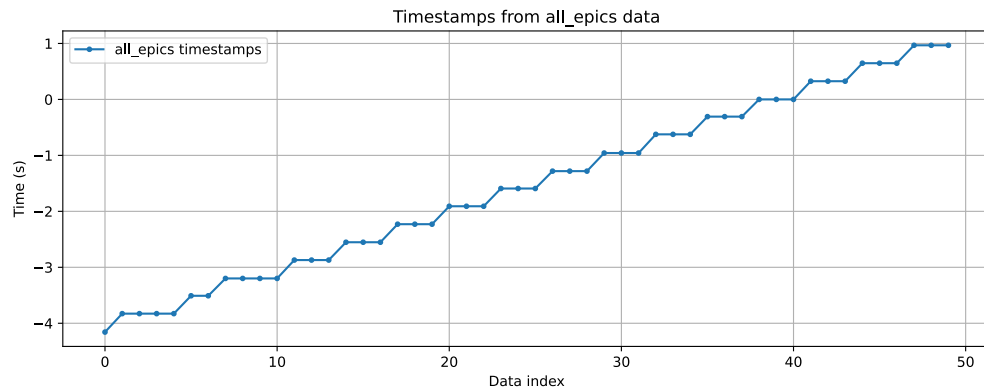
Comparación:

Se compararon las dos adquisiciones de EPICS para los mismos time-stamps:



I. Corrections on time acquisition

C) Comparison of EPICS acquisition



A closer look into the all_epics acquisition:

El time-stamp se renueva cada 3 adquisiciones (cada 0.3 segundos aproximadamente) indicando que se recopilan 3 medidas para cada bunch.

Si embargo, parece que en algunos casos, la medida de posición no se refresca a la misma rapidez que el tiempo de adquisición.

Al sincronizar los datos del cBPM con los de EPICS:

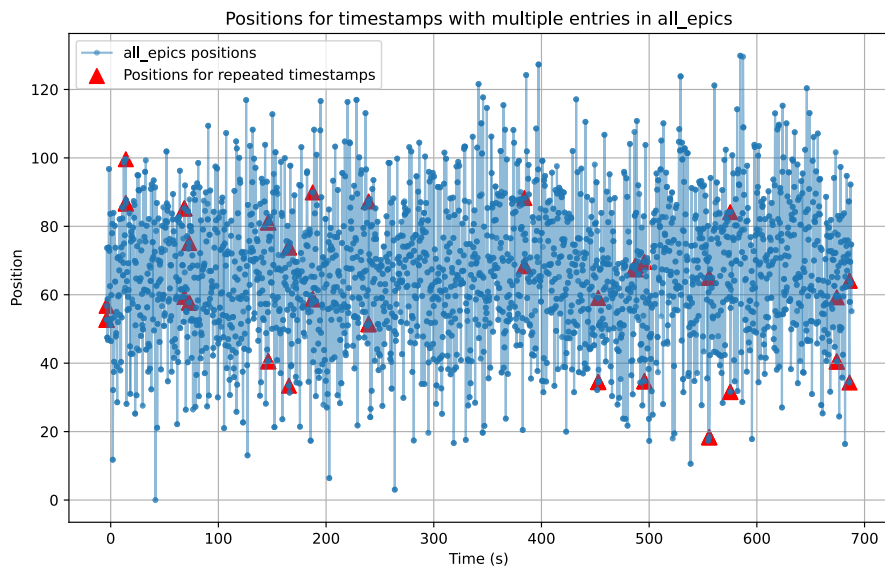
Se selecciona la primera medida con el time-stamp mas cercano al de la adquisición del osciloscopio (que a veces puede no estar actualizada)

I. Corrections on time acquisition

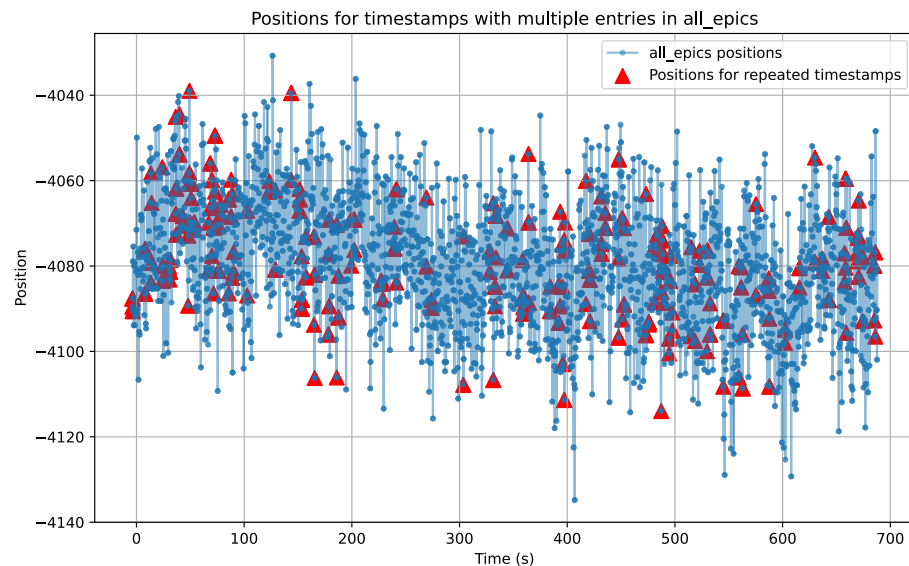
C) Comparison of EPICS acquisition

Si observamos sobre todas las medidas de `all_epics`, las que tienen varias posiciones para un solo time-stamp:

Para el bpm 4:



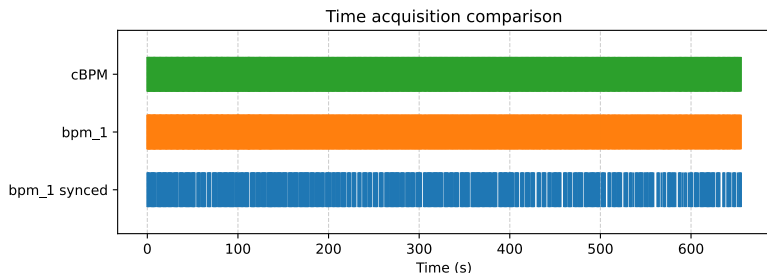
Para el bpm 1:



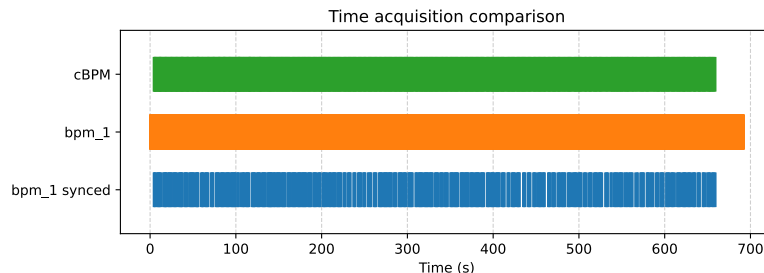
I. Corrections on time acquisition

C) Comparison of EPICS acquisition

With my EPICS acquisition:

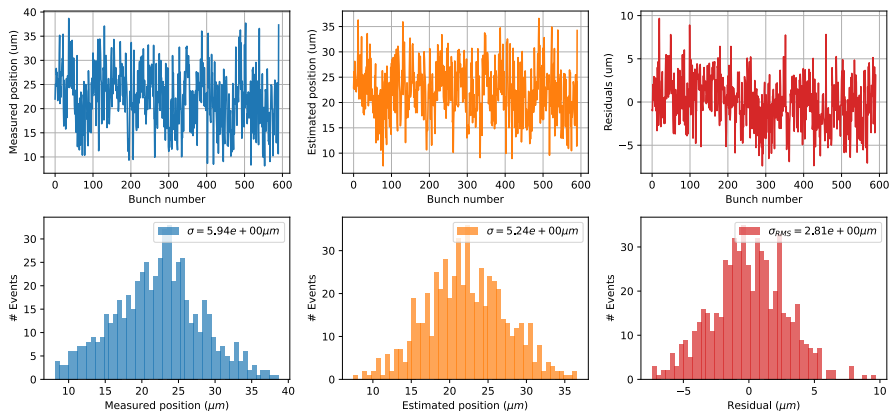


With Eduardo EPICS acquisition:



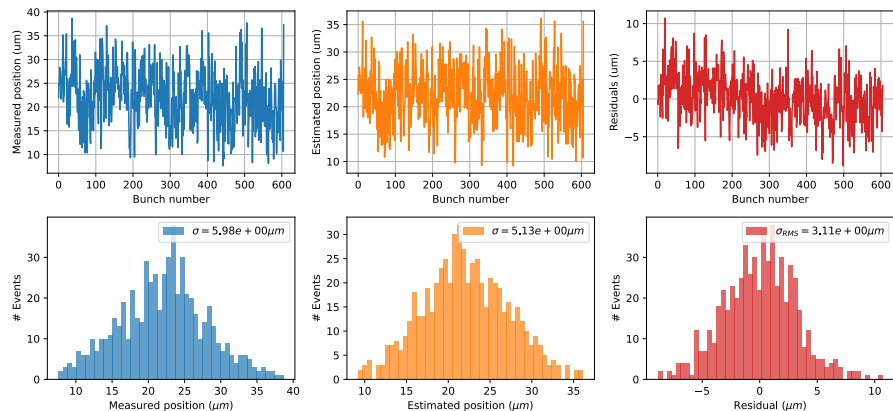
No sync found for ~304 bunches

BPM Resolution on the Y axis for $I_{ZV2P}=1.3$, $I_{ZH2P}=-0.05$ and $I_{beam}=0.88$



No sync found for ~300 bunches

BPM Resolution on the Y axis for $I_{ZV2P}=1.3$, $I_{ZH2P}=-0.05$ and $I_{beam}=0.88$



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Conclusion

II. Estimation of the resolution error

A) Estimation of the stripline resolutions

Conclusion

Next: - SVD analysis
- DDC alternative: mean value on amplitude and phase over the whole waveform



Thank you for your attention

We gratefully acknowledge the ATF staff for their assistance during the installation and BPM measurements. Special thanks to Toshiyuki Okugi, Alex Aryshev, and Konstantin Popov for their support. We also thank Toshihiro Matsumoto and Hiroshi Kaji for providing the necessary equipment for the measurements.

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This work was partially supported by the European Union's Horizon Europe Marie Skłodowska-Curie Staff Exchanges programme under grant agreement no. 101086276.

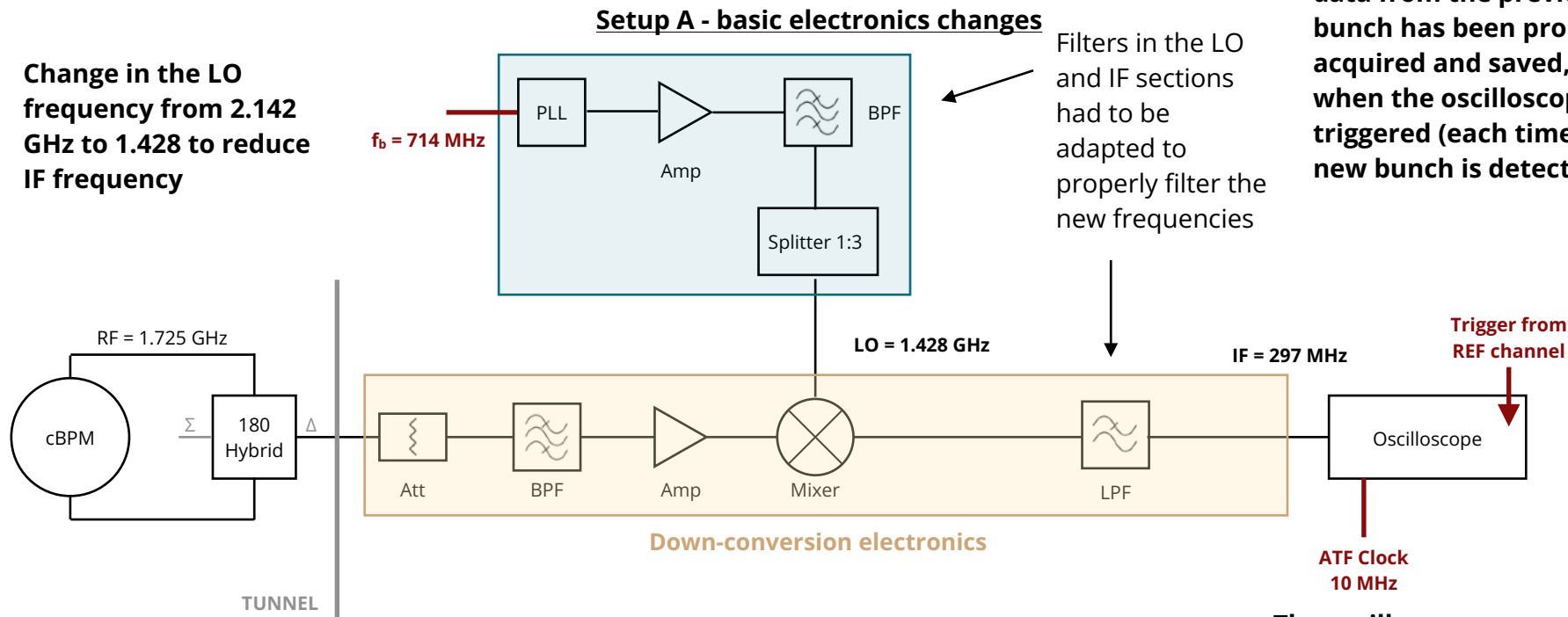
laura.pedraza@ific.uv.es

Back-up slides

I. Resolution measurement and calculation

A) Setups employed for measurements

Change in the LO frequency from 2.142 GHz to 1.428 to reduce IF frequency



The bunch data (from cBPM and from striplines) is taken every time the data from the previous bunch has been properly acquired and saved, and when the oscilloscope is triggered (each time a new bunch is detected)

The LO frequency has to be adapted to match a harmonic of the bunch repetition signal from ATF: 714 MHz

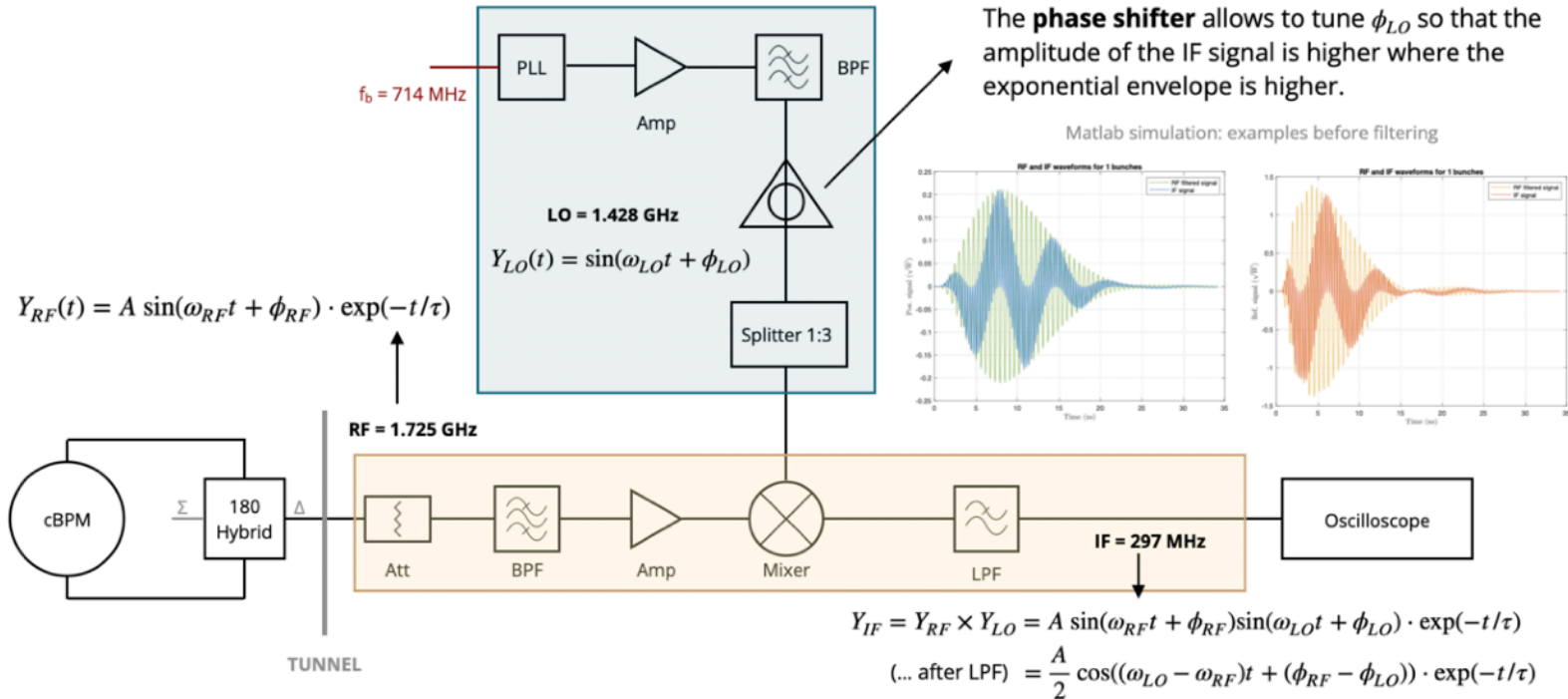
The oscilloscope was self-triggered using the reference channel

I. Resolution measurement and calculation

A) Setups employed for measurements

Setup B - Phase shifter

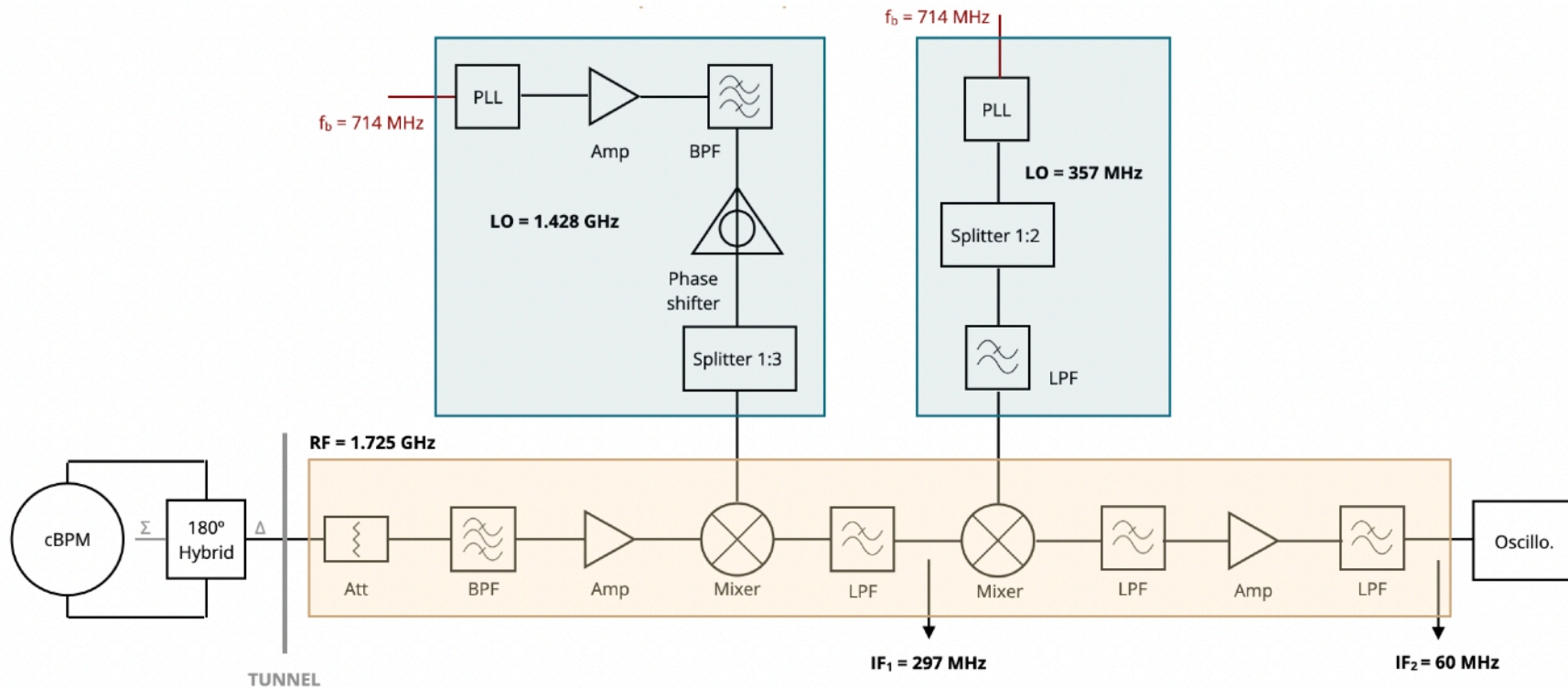
Phase shifter for LO to maximise sensitivity



I. Resolution measurement and calculation

A) Setups employed for measurements

Setup C - double down conversion



I. Resolution measurement and calculation

B) Resolution calculation

Resolution measurements: Model Independent Analysis

Taking a long set of data in a unique beam position:

$M = 1000$ is the number of measured waveforms

$N = 10$ is the number of BPMs used

$$\begin{array}{c} \text{cBPM measured values} \end{array} \rightarrow \begin{pmatrix} d_{k0} \\ d_{k1} \\ d_{k2} \\ \vdots \\ d_{kM} \end{pmatrix} = \begin{pmatrix} d_{00} & d_{10} & d_{20} & \cdots & d_{i \neq k, 0} & \cdots & d_{N0} \\ d_{01} & d_{11} & d_{21} & \cdots & d_{i \neq k, 1} & \cdots & d_{N1} \\ d_{02} & d_{12} & d_{22} & \cdots & d_{i \neq k, 2} & \cdots & d_{N2} \\ \vdots & \vdots & \vdots & & \vdots & & \vdots \\ d_{0M} & d_{1M} & d_{2M} & \cdots & d_{i \neq k, M} & \cdots & d_{NM} \end{pmatrix} \cdot \begin{pmatrix} v_0 \\ v_1 \\ v_2 \\ \vdots \\ v_N \end{pmatrix} \leftarrow \text{correlation coefficients}$$

↑
stripline BPM measured values

To find the correlation coefficients: $\mathbf{v} = \mathbf{D}_k^{-1} \mathbf{d}_k$. where the inverse of D_k is calculated using the SVD method: $SVD(\mathbf{D}_k) = \mathbf{U} \mathbf{S} \mathbf{V}^T$,

The residuals between measured position and estimated position are calculated as $\mathbf{R}_k = \mathbf{d}_k - \mathbf{D}_k \cdot \mathbf{v}$.

And the resolution is estimated do be the rms of the residuals:

$$\sigma_k = \sqrt{\frac{\sum_i^M R_{ki}^2}{M}}$$

BPMs taken: up-stream: ML10L, ML11L, ML12L, ML13L, ML14L, ML15L, ML1P, ML2P, ML3P ; down-stream: ML4P