

Commissioning of the new BPM Electronics in the ESRF Booster

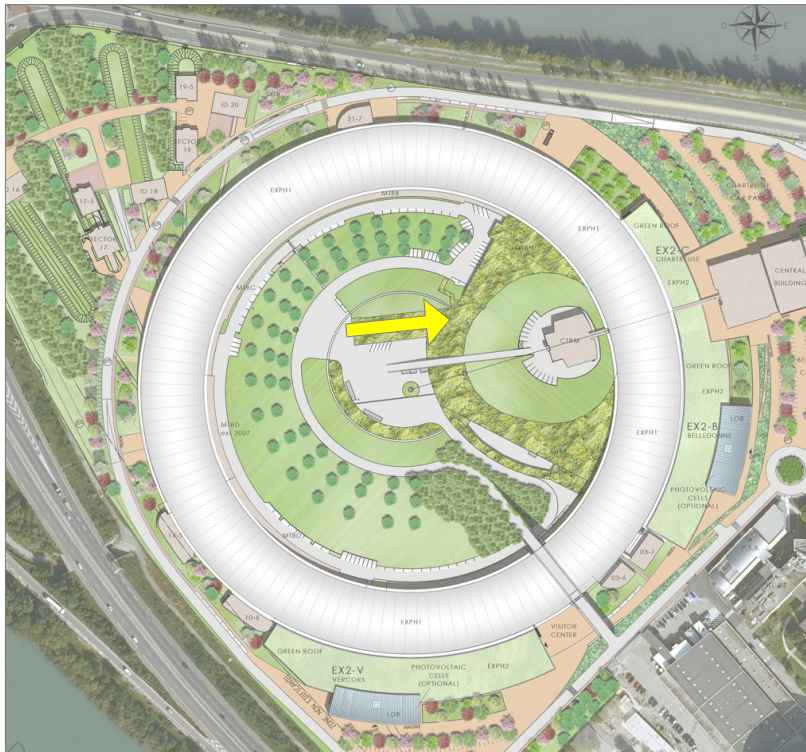
Manuel Cargnelutti, Instrumentation Technologies, 15.06.2015



Presentation outline

- The ESRF Booster Ring
- Libera Spark electronics
- Commissioning results
- Applications of the BPM electronics
- Conclusions

The ESRF Booster Ring



Pre-Injector LINAC
from **0 to 200 MeV**

This aerial photograph shows a large, circular building complex with a central courtyard. A red circle and a yellow arrow highlight the central area, which is labeled 'EXH1' and 'M105'. The building has a white, curved facade and is surrounded by green roofs and landscaped areas. Various labels are visible around the perimeter, including 'EXH1', 'EXH2', 'EXH3', 'EXH4', 'EXH5', 'EXH6', 'EXH7', 'EXH8', 'EXH9', 'EXH10', 'EXH11', 'EXH12', 'EXH13', 'EXH14', 'EXH15', 'EXH16', 'EXH17', 'EXH18', 'EXH19', 'EXH20', 'EXH21', 'EXH22', 'EXH23', 'EXH24', 'EXH25', 'EXH26', 'EXH27', 'EXH28', 'EXH29', 'EXH30', 'EXH31', 'EXH32', 'EXH33', 'EXH34', 'EXH35', 'EXH36', 'EXH37', 'EXH38', 'EXH39', 'EXH40', 'EXH41', 'EXH42', 'EXH43', 'EXH44', 'EXH45', 'EXH46', 'EXH47', 'EXH48', 'EXH49', 'EXH50', 'EXH51', 'EXH52', 'EXH53', 'EXH54', 'EXH55', 'EXH56', 'EXH57', 'EXH58', 'EXH59', 'EXH60', 'EXH61', 'EXH62', 'EXH63', 'EXH64', 'EXH65', 'EXH66', 'EXH67', 'EXH68', 'EXH69', 'EXH70', 'EXH71', 'EXH72', 'EXH73', 'EXH74', 'EXH75', 'EXH76', 'EXH77', 'EXH78', 'EXH79', 'EXH80', 'EXH81', 'EXH82', 'EXH83', 'EXH84', 'EXH85', 'EXH86', 'EXH87', 'EXH88', 'EXH89', 'EXH90', 'EXH91', 'EXH92', 'EXH93', 'EXH94', 'EXH95', 'EXH96', 'EXH97', 'EXH98', 'EXH99', 'EXH100'. The surrounding area includes a highway, a river, and other buildings.

from 0 to 200 MeV

200 MeV $\rightarrow$ 6 GeV

1 μ s orbit time

current from **2.5 mA** down to **50 μ A**

This aerial view of the circular building complex features a prominent blue circle around the main structure and a red circle highlighting a specific section. A yellow arrow points to the red circle. The diagram includes labels for various areas such as EX2-V, EX2-B, EX2-C, and EX2-D, as well as green roofs and photovoltaic cells. The building is surrounded by landscaped grounds with trees and walkways. A compass rose is visible in the top right corner.

from 0 to 200 MeV

200 MeV $\rightarrow$ 6 GeV

1 μ s orbit time

current from **2.5 mA** down to **50 μ A**

Storage Ring (200 mA)

This aerial view of the stadium design shows a large, circular stadium bowl with a white, ribbed roof. The bowl is surrounded by green spaces and various facilities. A red circle highlights a specific area within the stadium bowl, which appears to be a small, rectangular structure or a specific seating area. The surrounding area includes various facilities such as the EX2-V VerCors, EX2-B Bellefonte, and EX2-C Charlotte. The design also shows the stadium's proximity to a highway and a river.

Need new BPM electronics

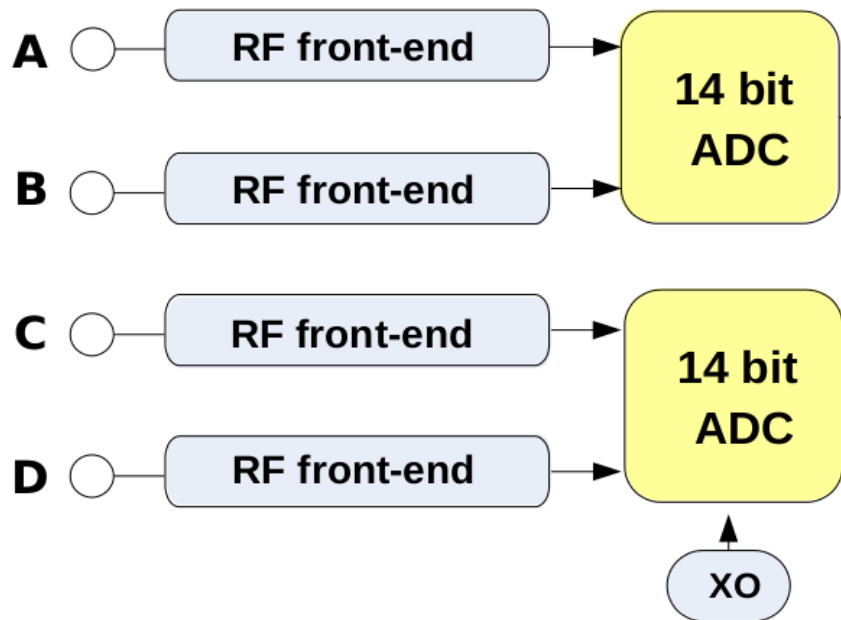
What kind of electronics?



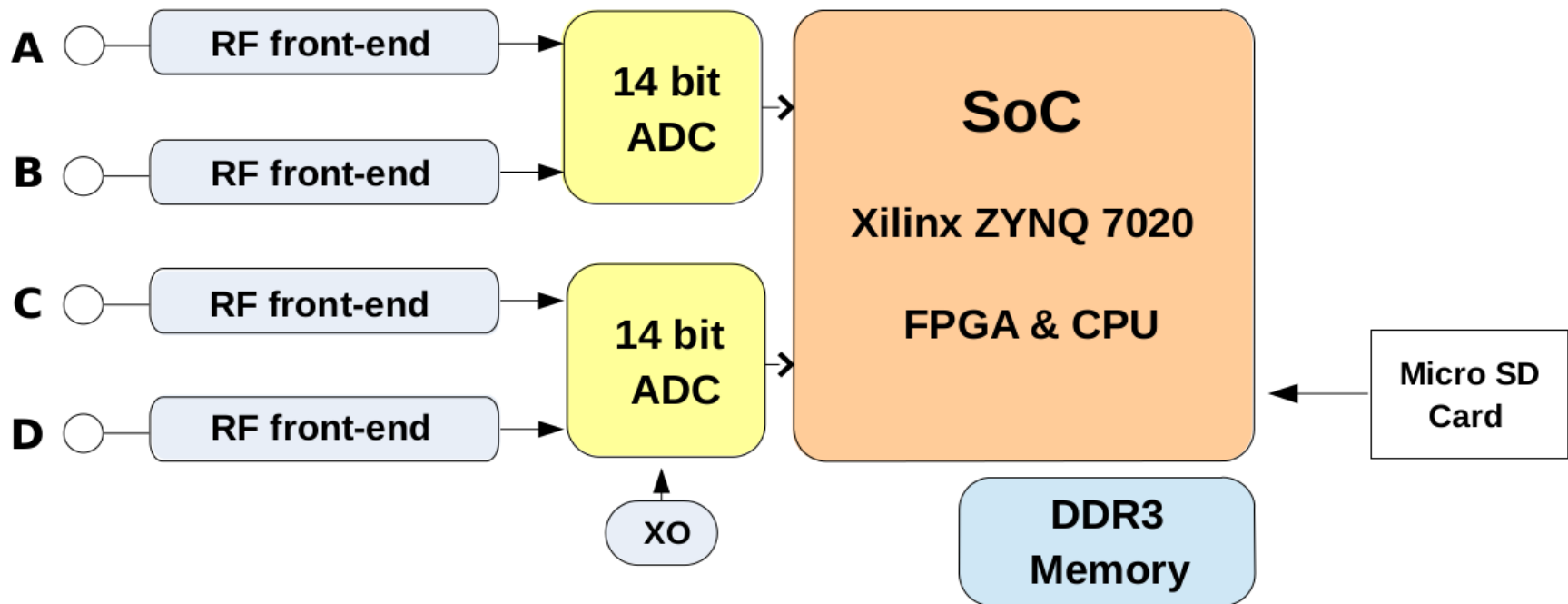
Libera Spark

- + Good Price/Performance
- + Turn-By-Turn data
- + Easy to use
- + No maintenance required

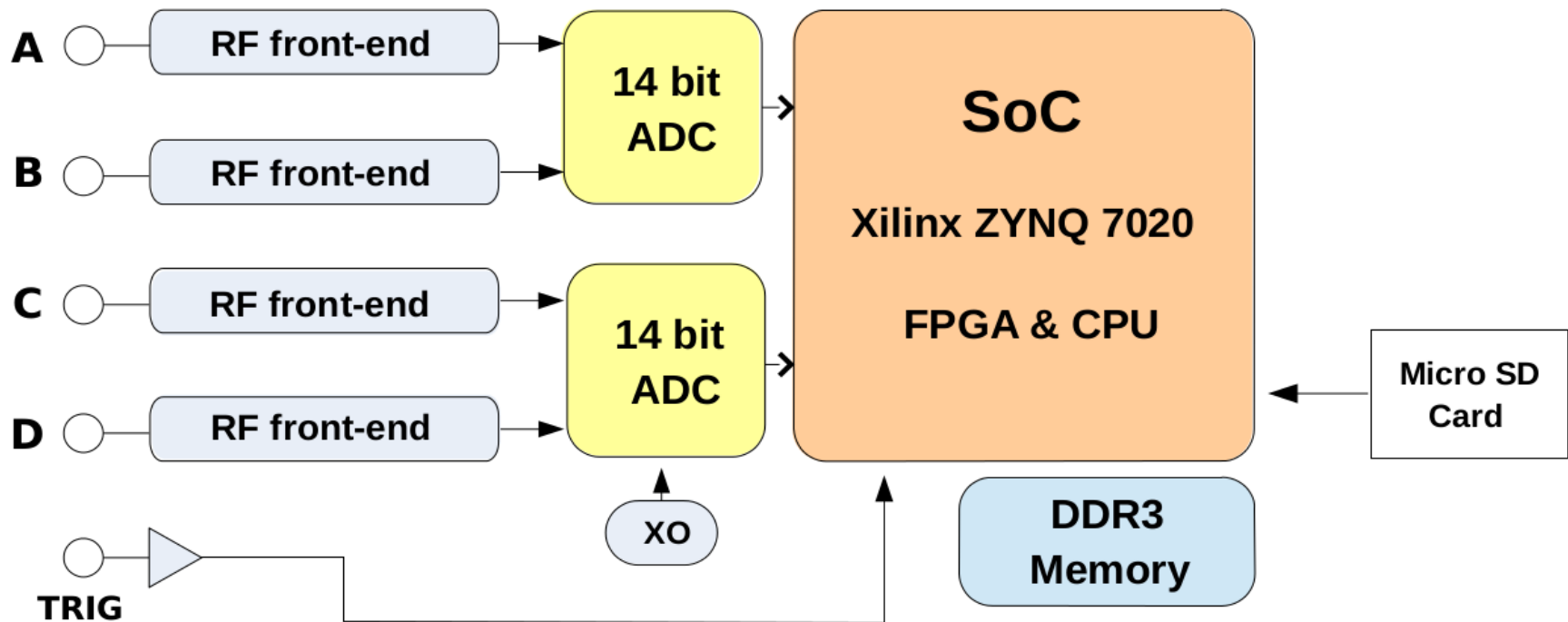
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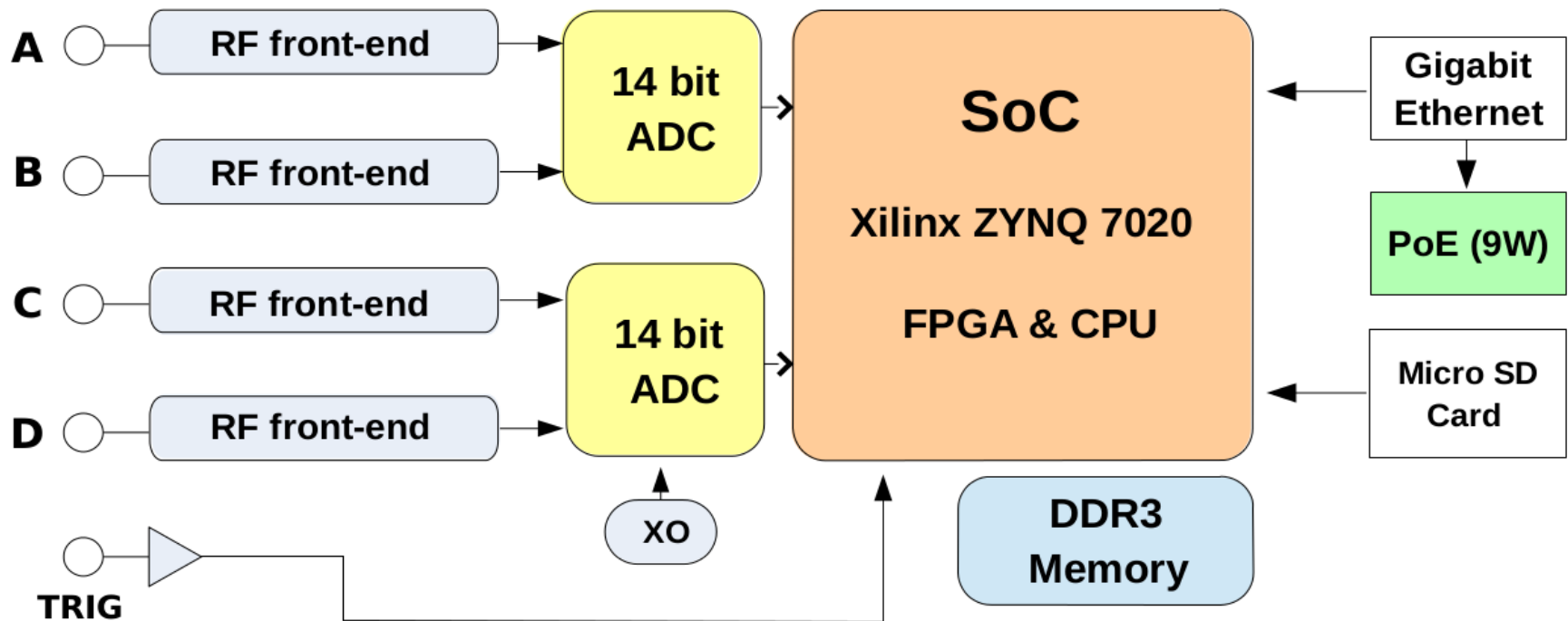
What kind of electronics?



What kind of electronics?



What kind of electronics?



Installation in the tunnel

- Radiation dosimetry tests (>6 months) shown very low radiation dose
- 3 m long RF cables
- Powered with Ethernet cable



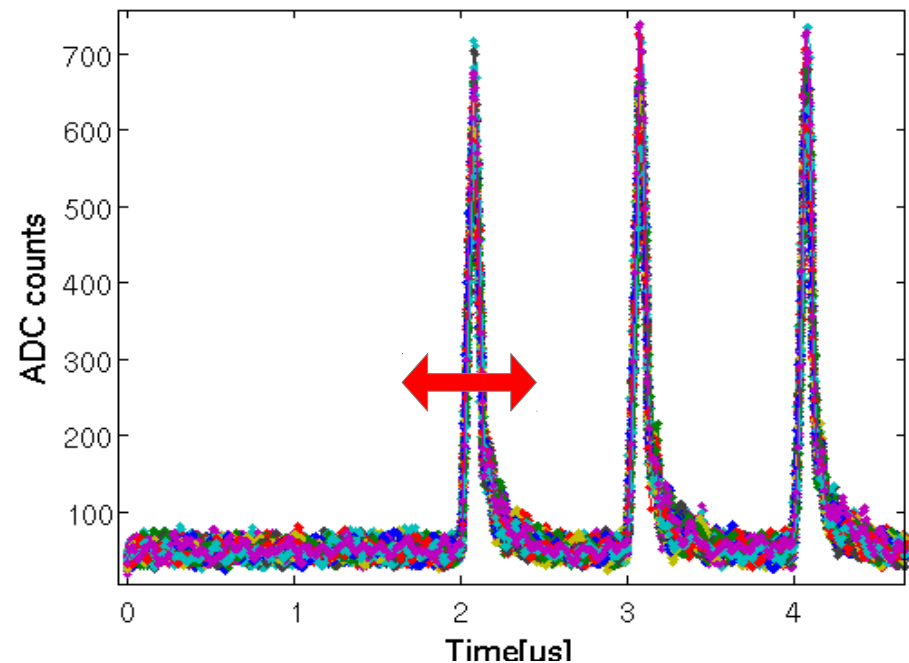


Commissioning Results

0) Synchronization with the beam arrival

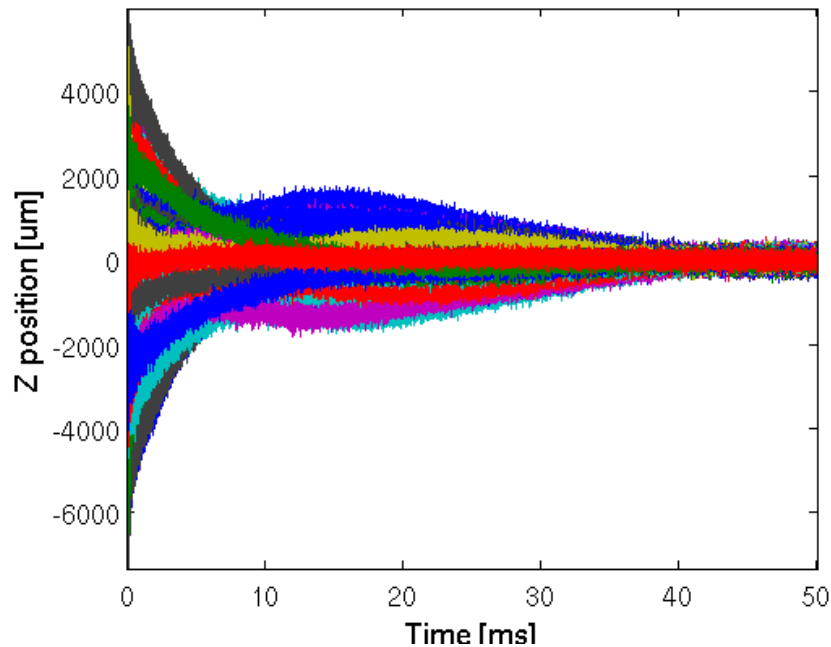
- Data in the ADC buffer synchronized for all the units using the **Trigger Delay** parameter.

Single Bunch Beam mode



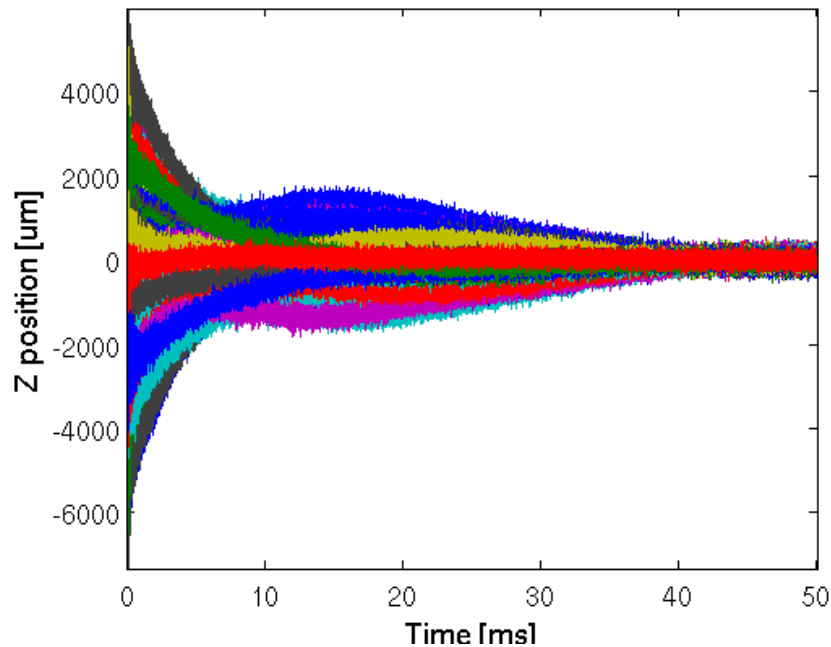
1) Tune monitor with Turn-by-Turn data

Turn-by-Turn position (1 μ s)



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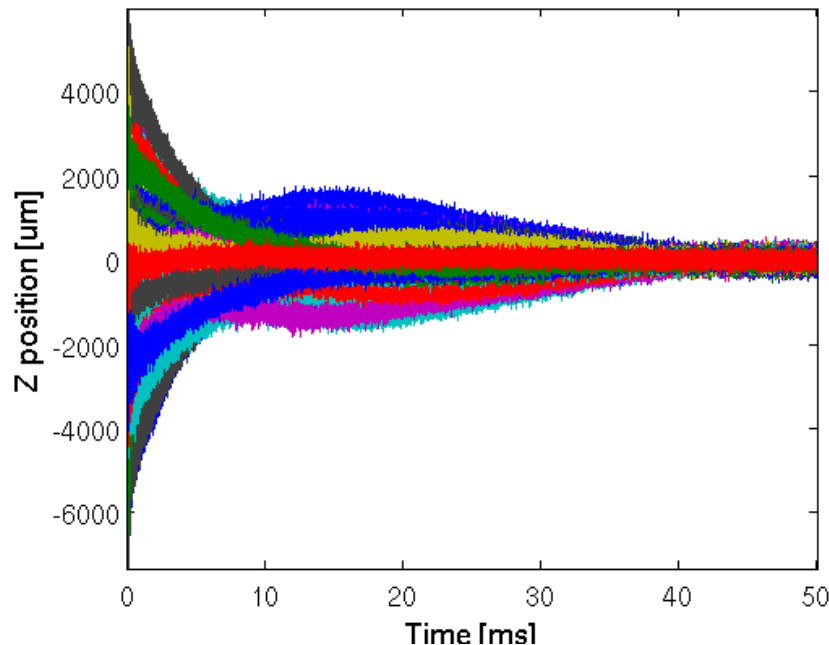
Turn-by-Turn position (1 μ s)



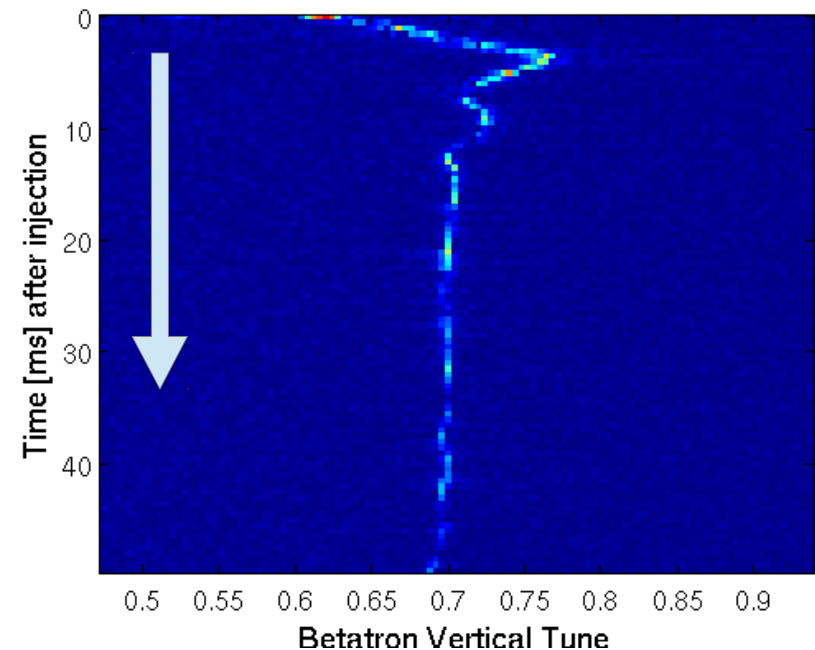
FFT in 0.5 ms data slices

1) Tune monitor with Turn-by-Turn data

Turn-by-Turn position (1 μ s)



Vertical Tune monitor



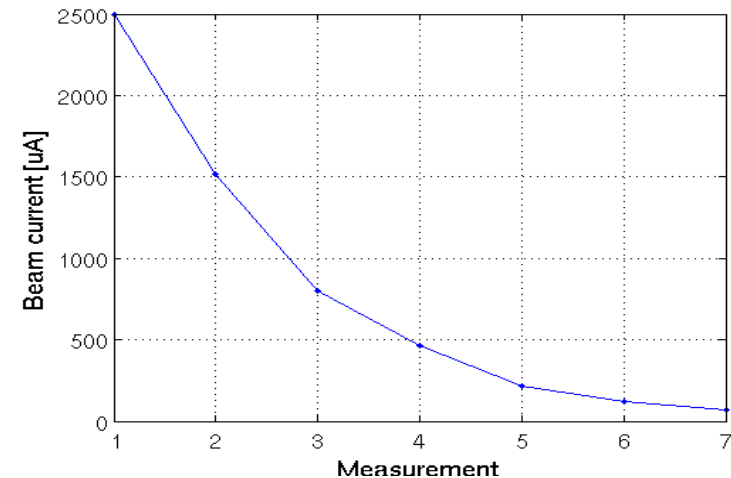
FFT in 0.5 ms data slices

2) Position resolution vs Beam current

- Booster operating with long-pulse mode (80% fill pattern)
- Current was reduced in steps from **2.5 mA** to **50 μ A**

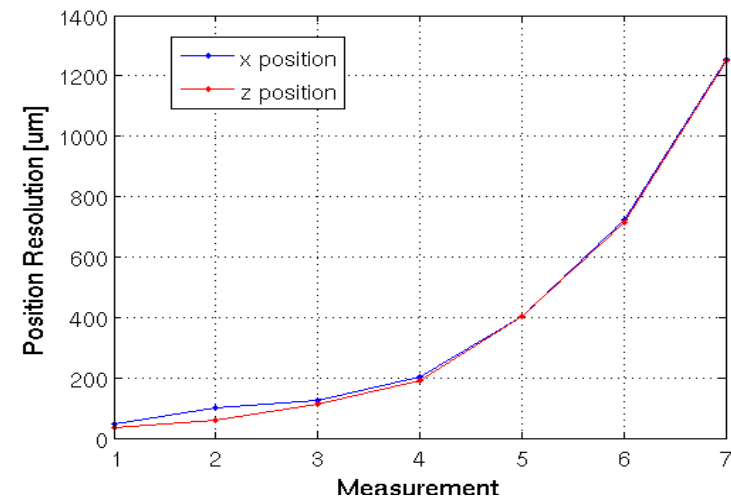
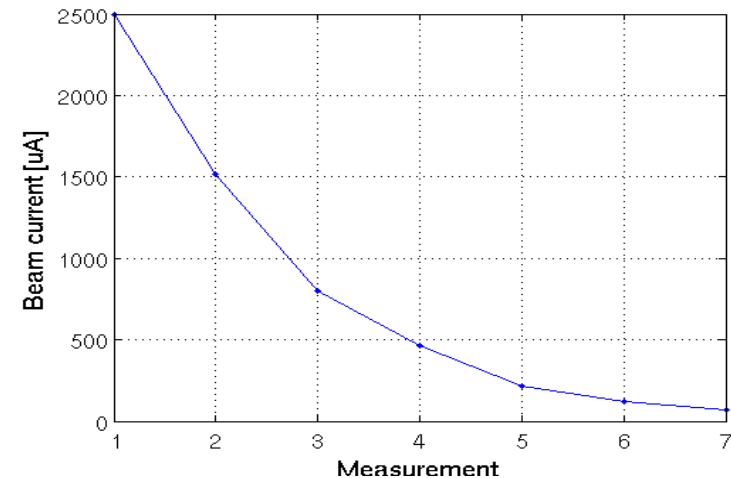
2) Position resolution vs Beam current

- Booster operating with long-pulse mode (80% fill pattern)
- Current was reduced in steps from **2.5 mA** to **50 μ A**
- **Sum signal**: estimate real current intensity

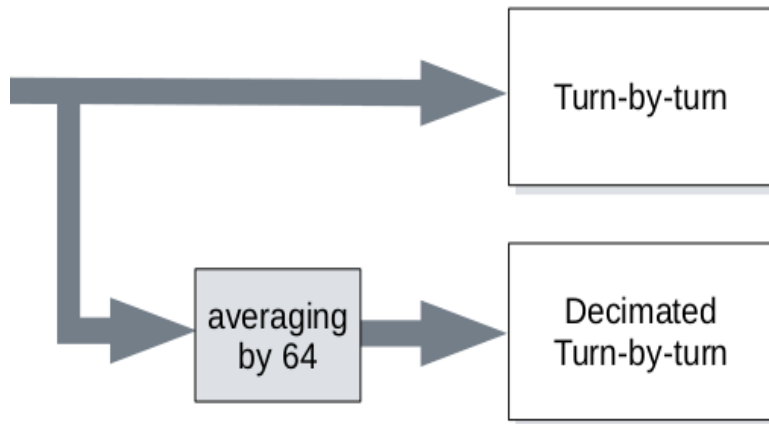


2) Position resolution vs Beam current

- Booster operating with long-pulse mode (80% fill pattern)
- Current was reduced in steps from **2.5 mA** to **50 μ A**
- **Sum signal**: estimate real current intensity
- **X Z position**: estimate resolution with RMS



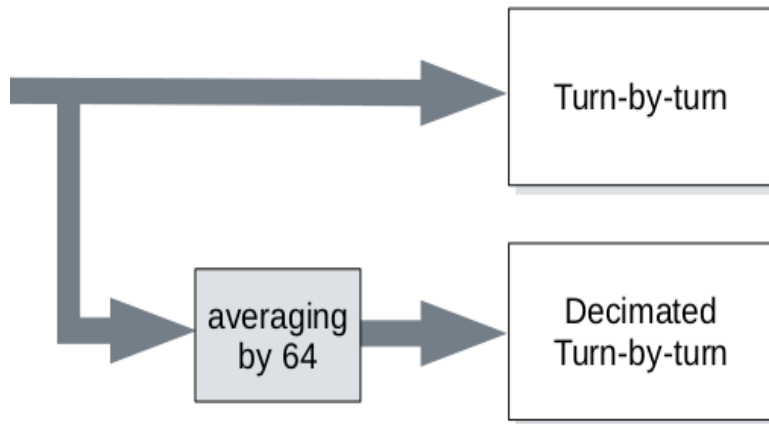
Decimated T-b-T data



1 sample = 1 turn = 1 μ s

1 sample = 64 turns = 64 μ s

Decimated T-b-T data

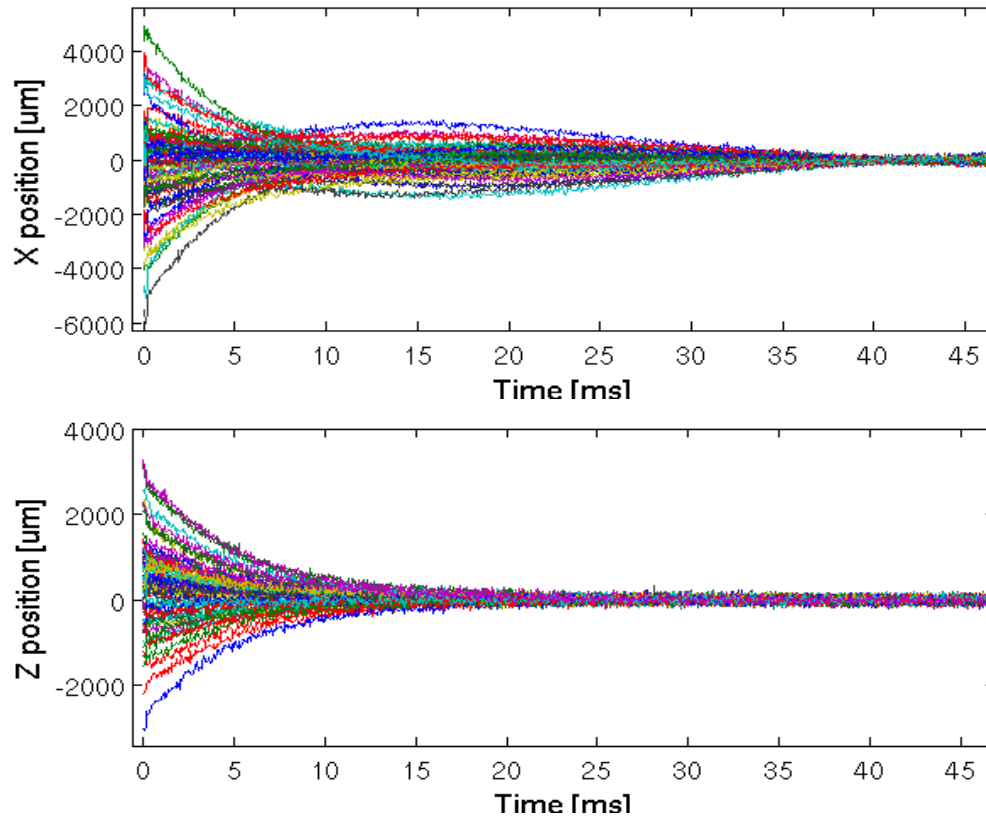


1 sample = 1 turn = 1 μ s

1 sample = 64 turns = 64 μ s

Motivation?

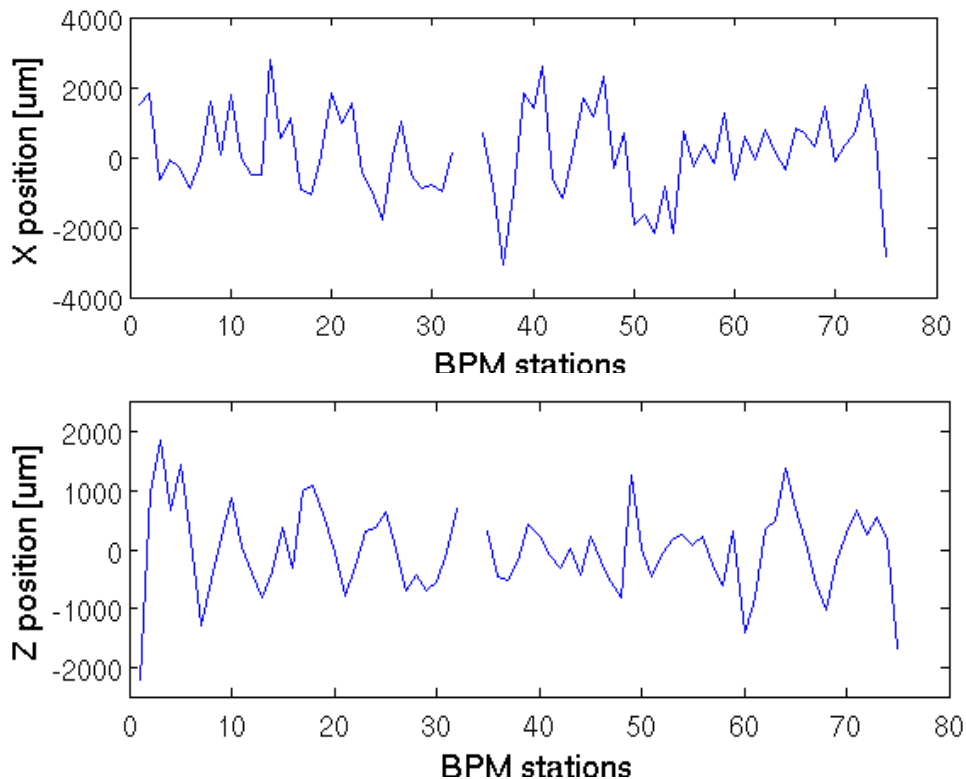
3) Position measurements



Motivation?

Reduced bandwidth
means reduced
noise contribution

4) Orbit measurements



Motivation?

Reduced amount of
data to be transferred
over the network



Applications

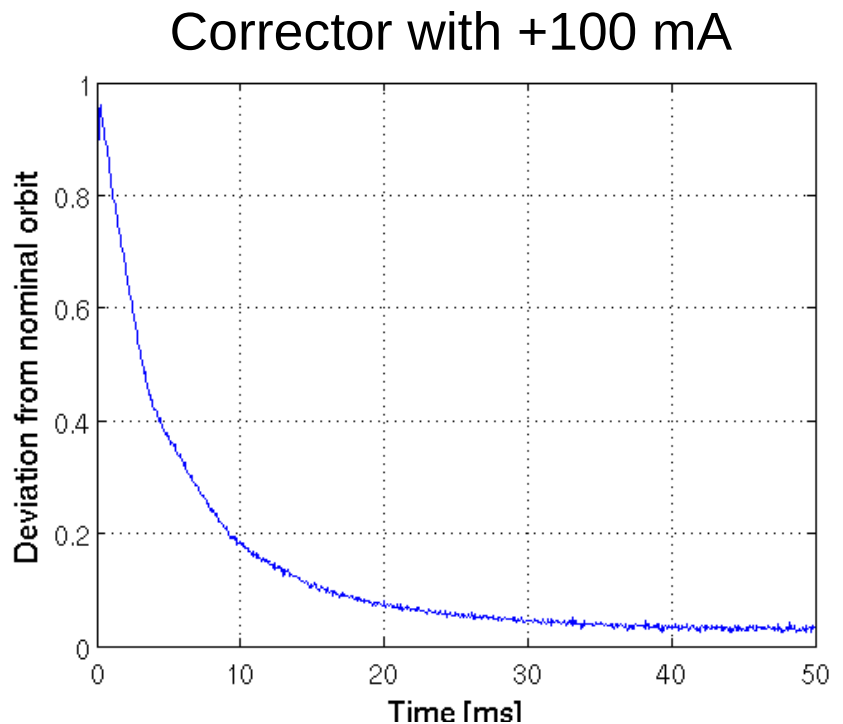


5) Quadrupole orbit correction

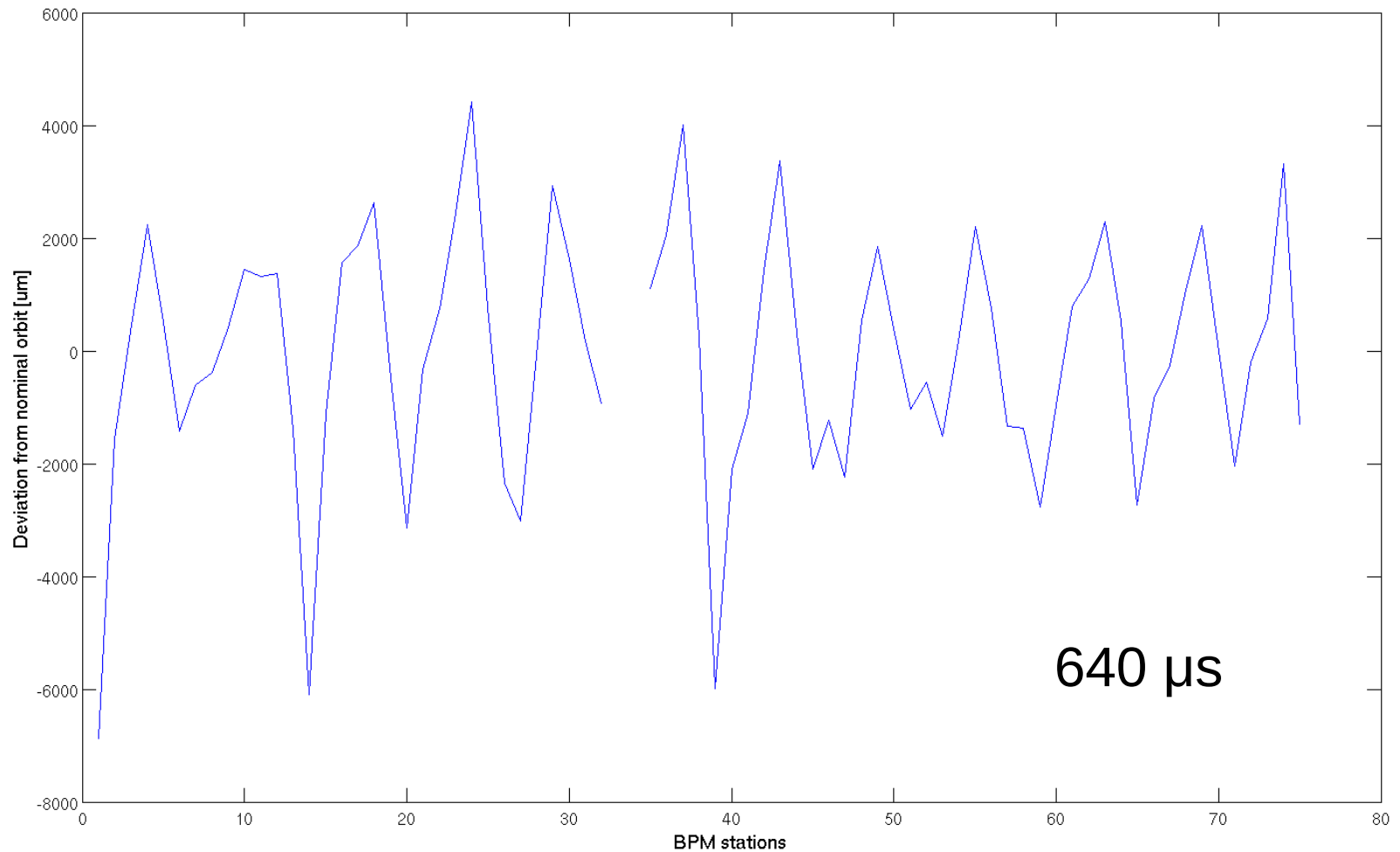
- Corrector magnets are not ramped like dipoles and quadrupoles during the booster acceleration

5) Quadrupole orbit correction

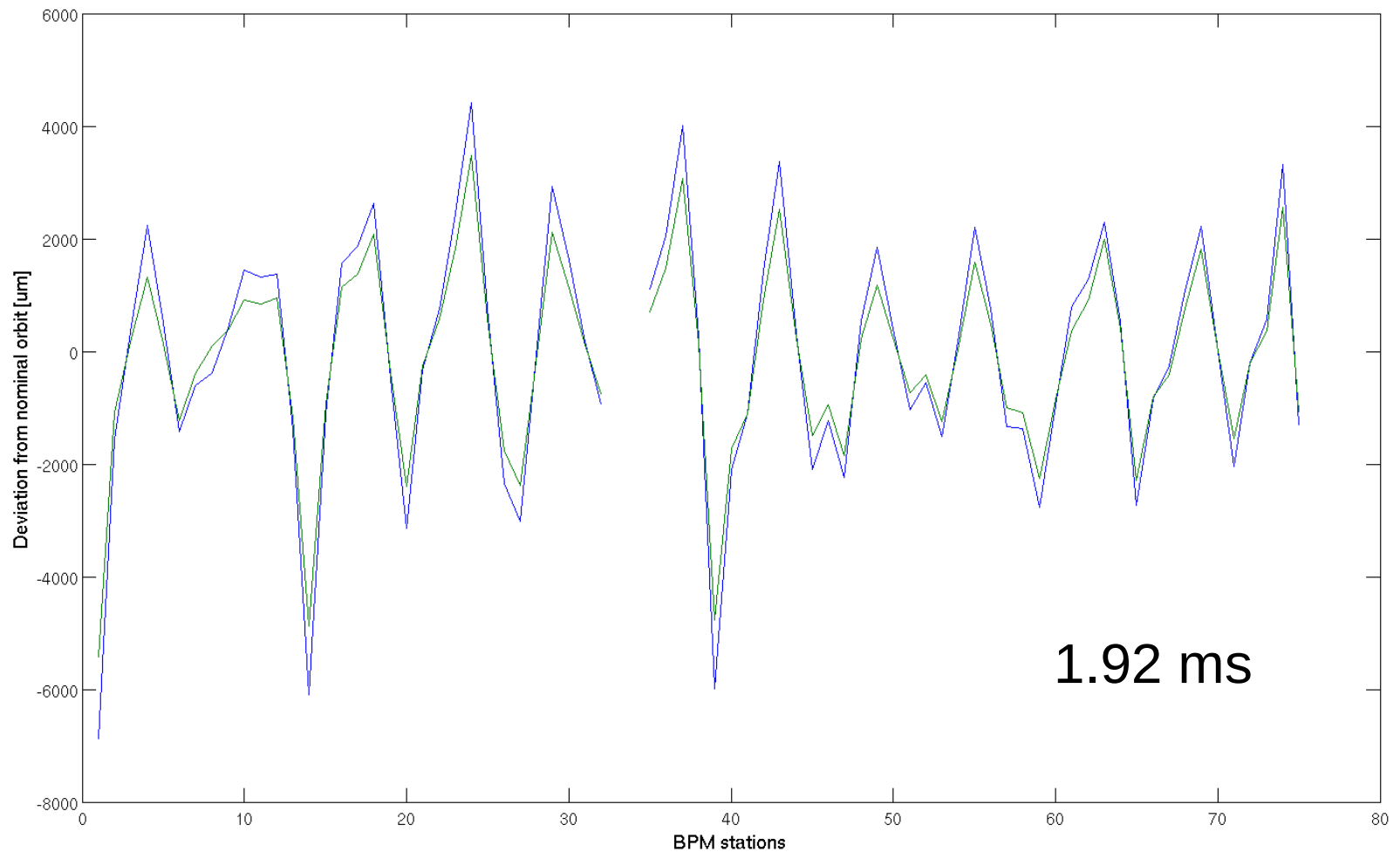
- Corrector magnets are not ramped like dipoles and quadrupoles during the booster acceleration
- Possible to correct the orbit **only at low energy** while at high energy the correction is dumped



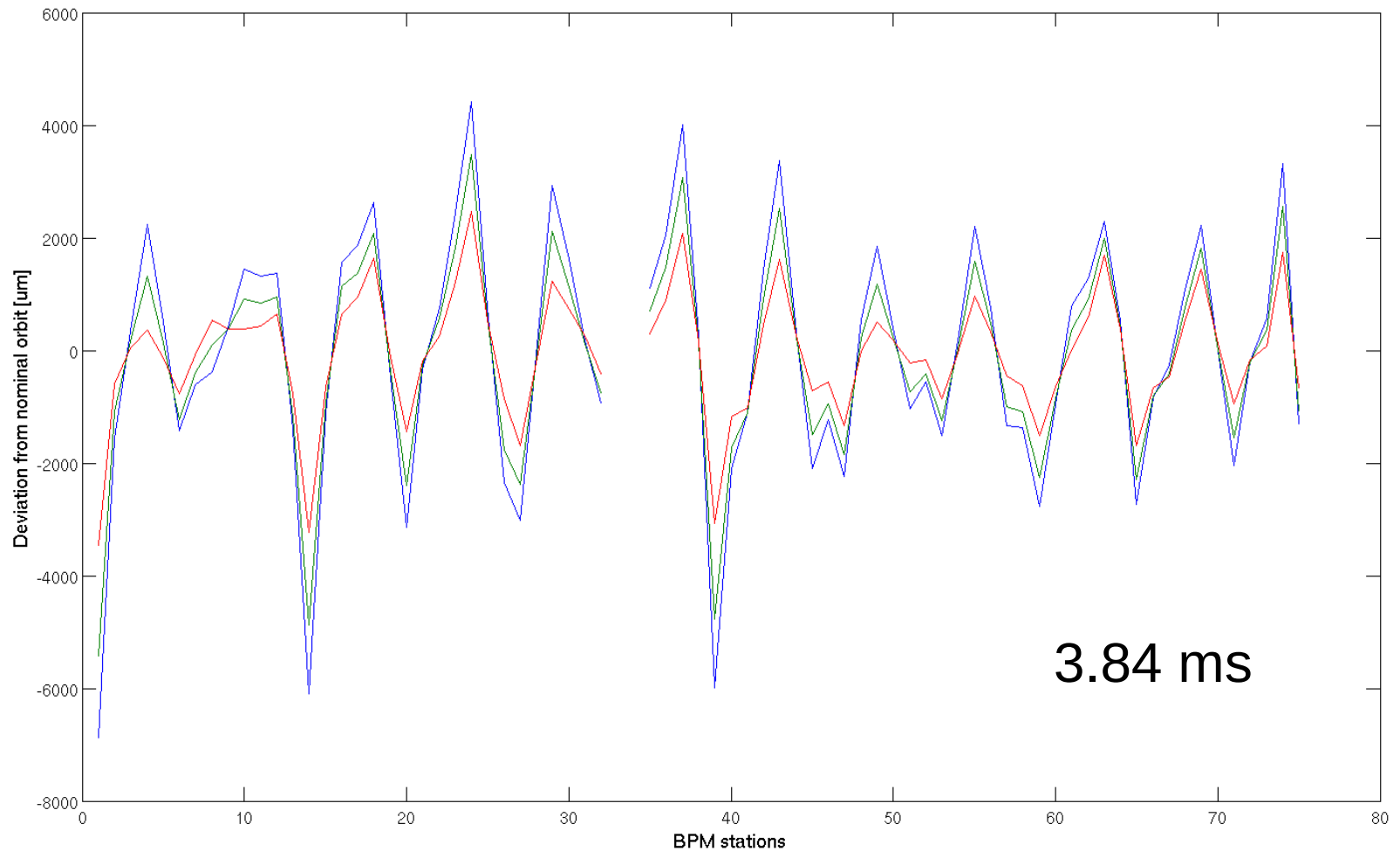
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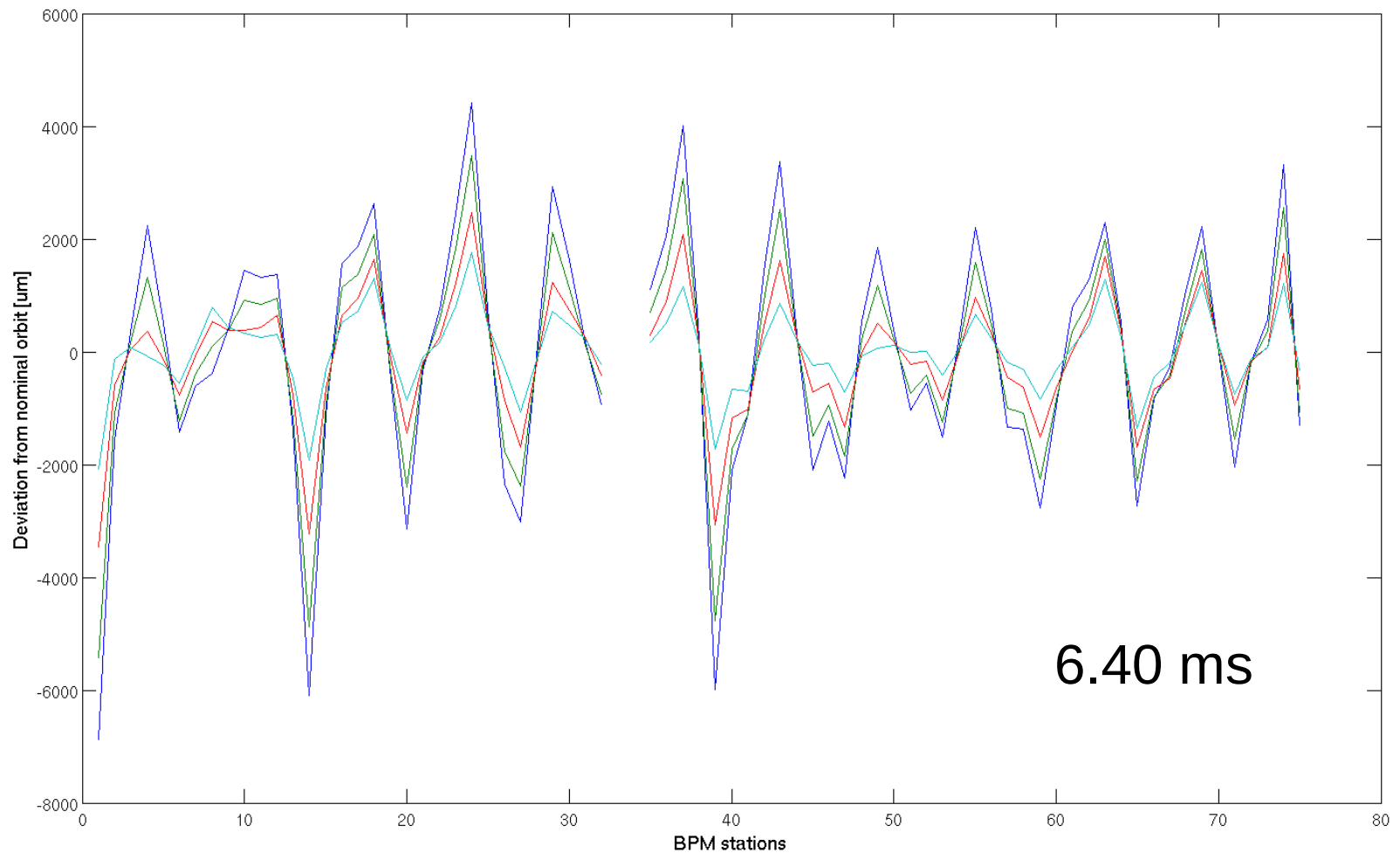
5) Quadrupole orbit correction



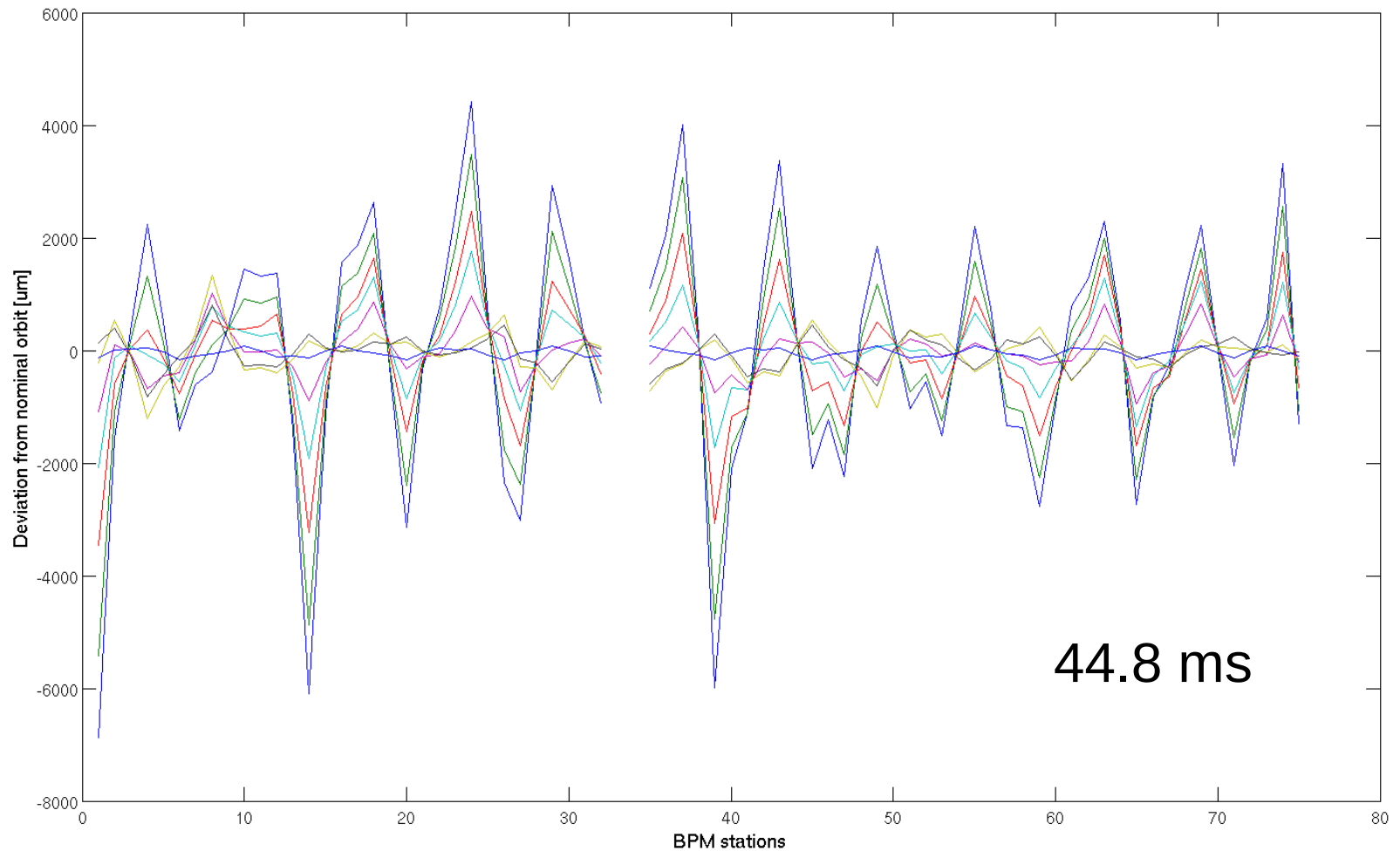
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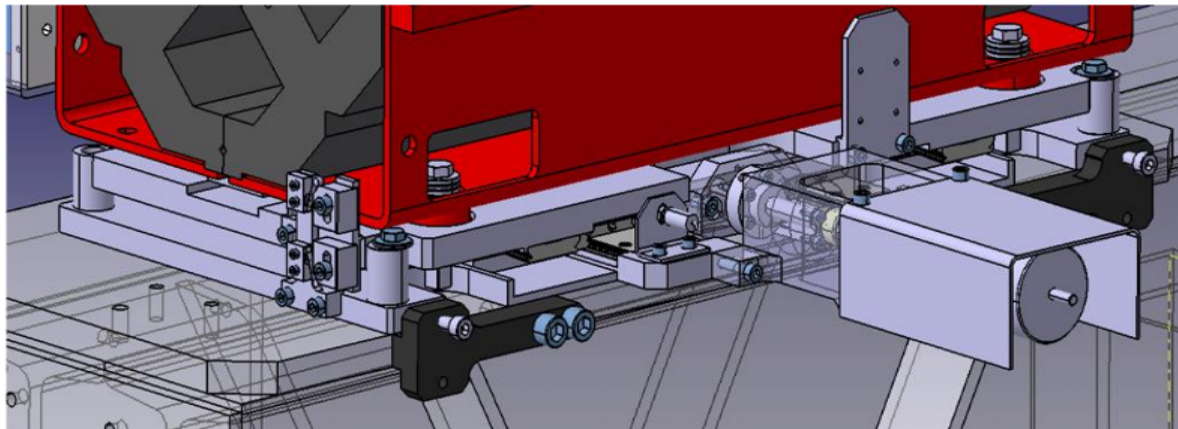


5) Quadrupole orbit correction

- a) Buy and install more expensive correctors,
ramped during the acceleration

5) Quadrupole orbit correction

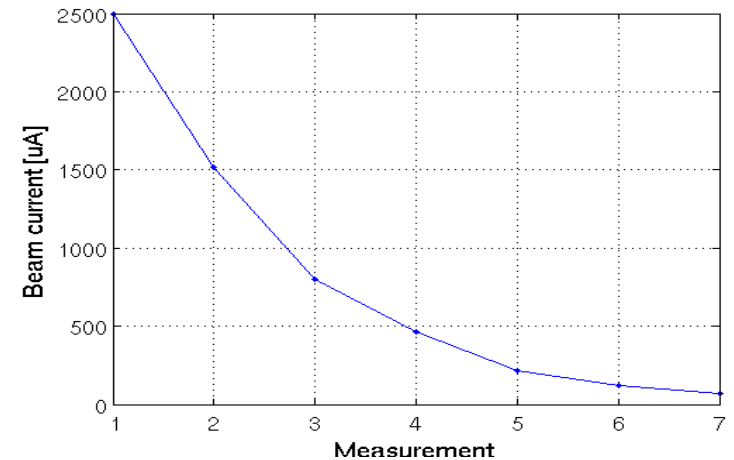
- a) Buy and install more expensive correctors, ramped during the acceleration
- b) Install translation stages under the quadrupoles: efficient and low-cost



*Courtesy of
Kees Scheidt*

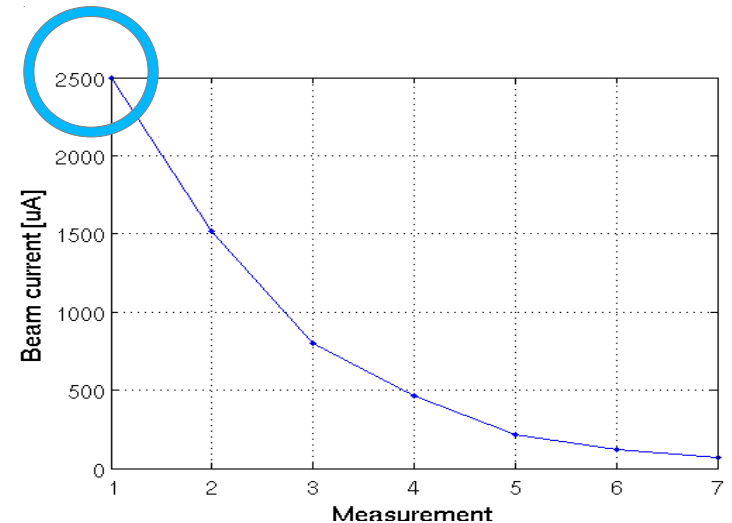
6) Transmission efficiency

- The SUM signal can be used for relative current measurements



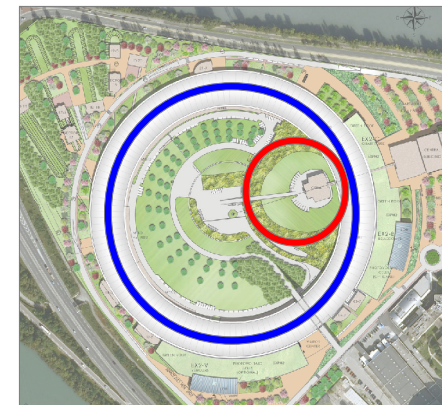
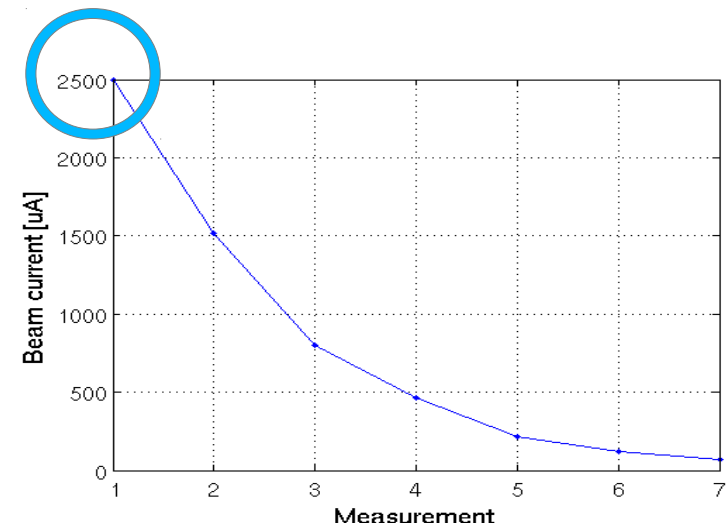
6) Transmission efficiency

- The SUM signal can be used for relative current measurements
- Once calibrated, all the 75 BPMs act as current monitors



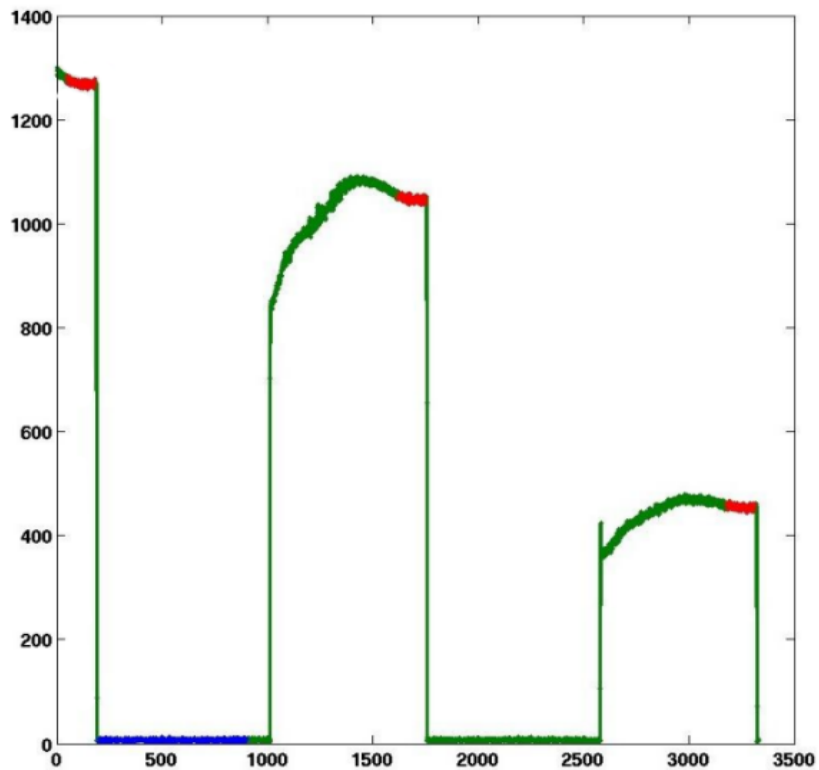
6) Transmission efficiency

- The SUM signal can be used for relative current measurements
- Once calibrated, all the 75 BPMs act as current monitors
- Together with the storage ring BPMs, they can measure the transmission efficiency



6) Transmission efficiency

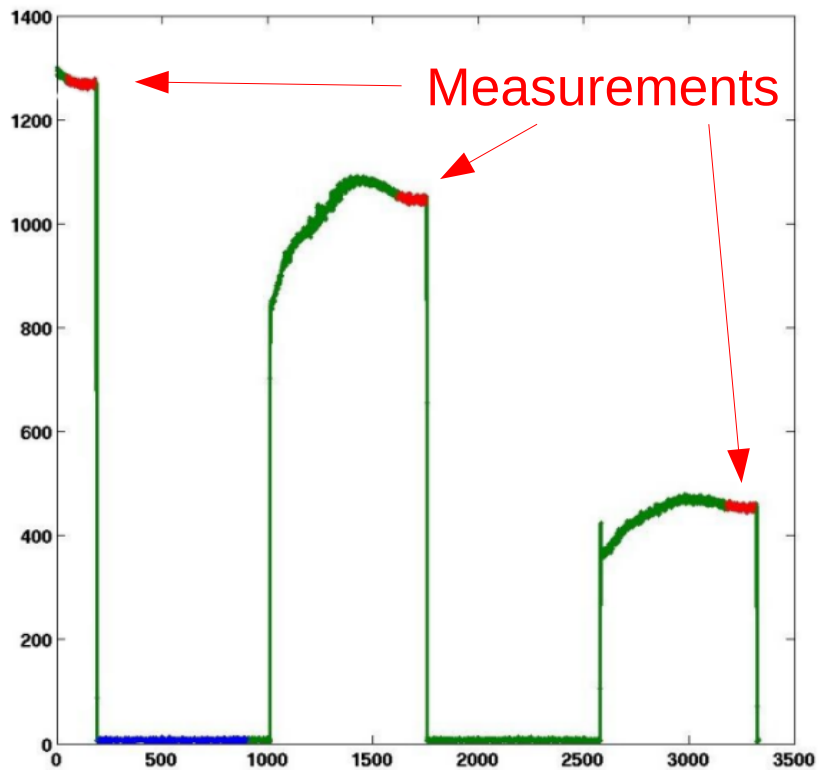
AU



Booster ring (Spark)

6) Transmission efficiency

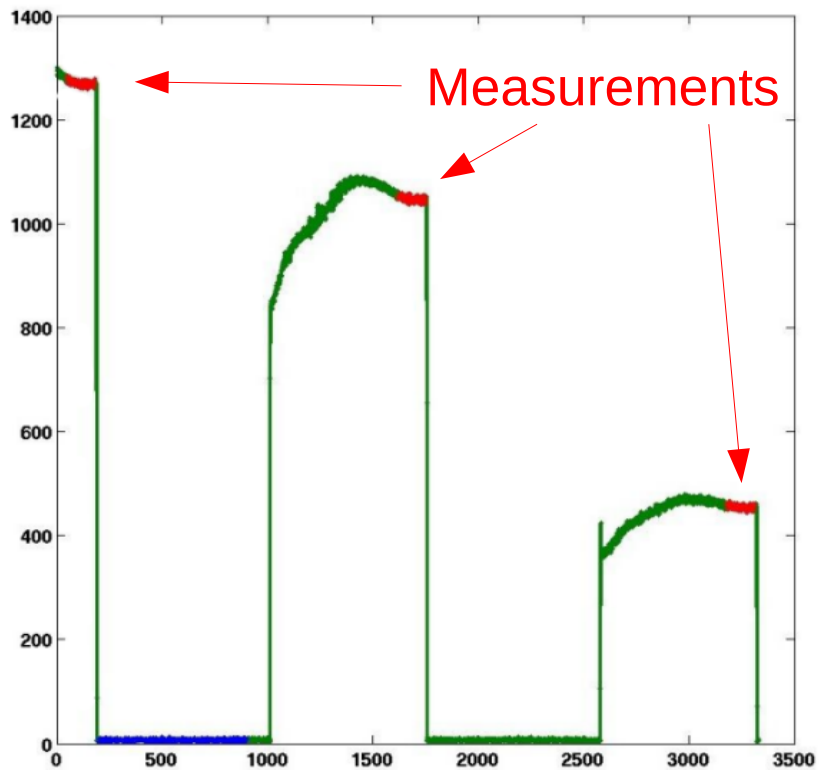
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Booster ring (Spark)

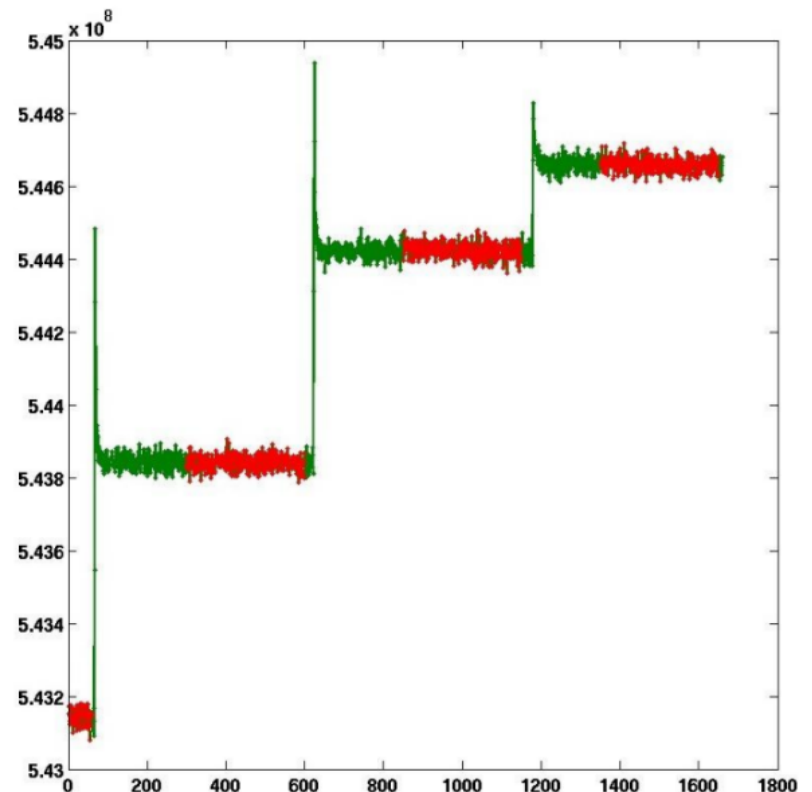
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AU



Booster ring (Spark)

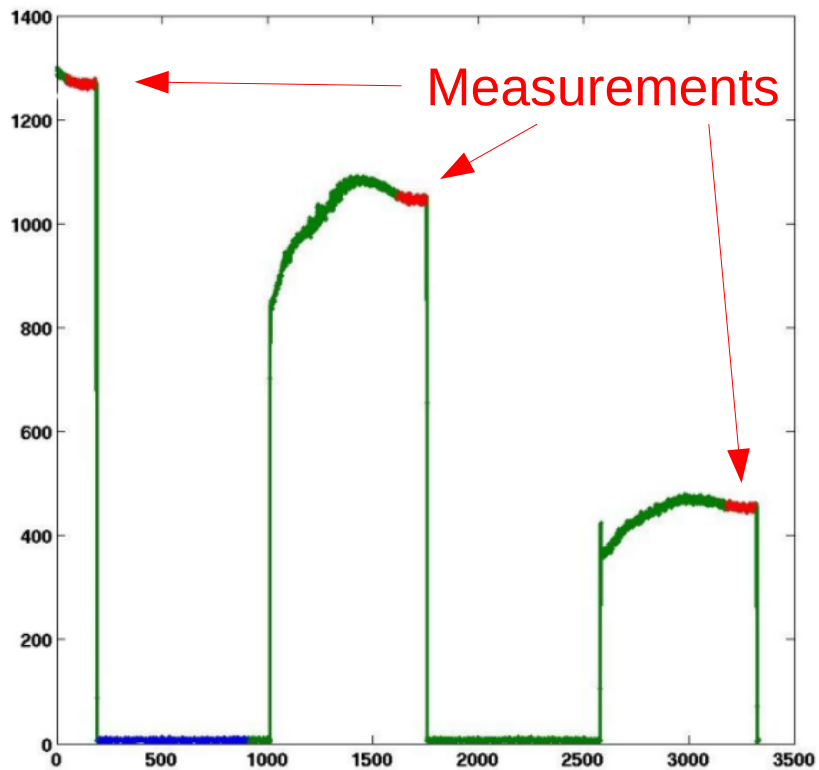
AU



Storage ring (LB)

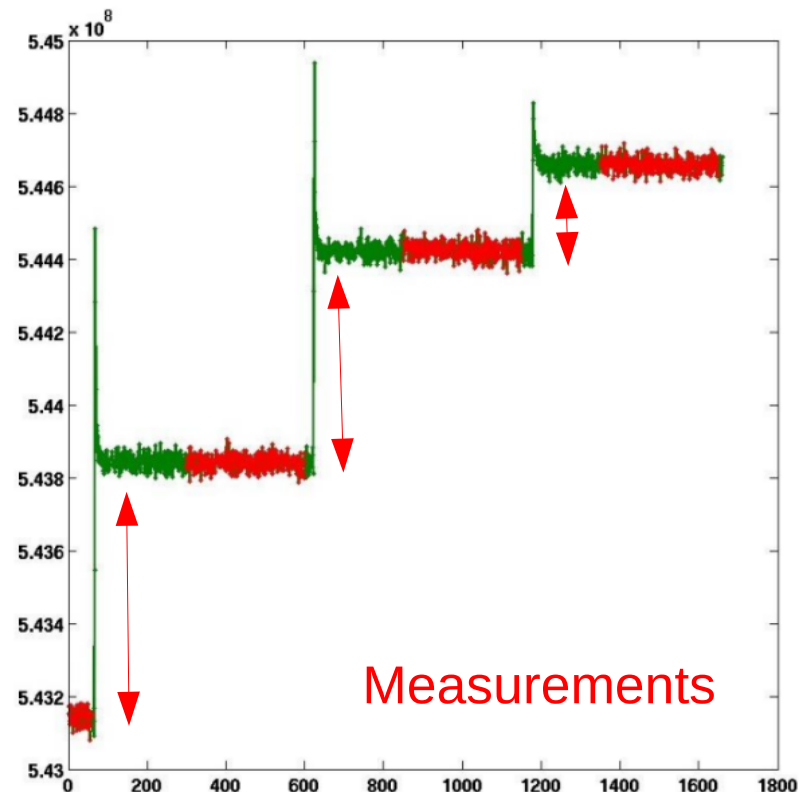
6) Transmission efficiency

AU



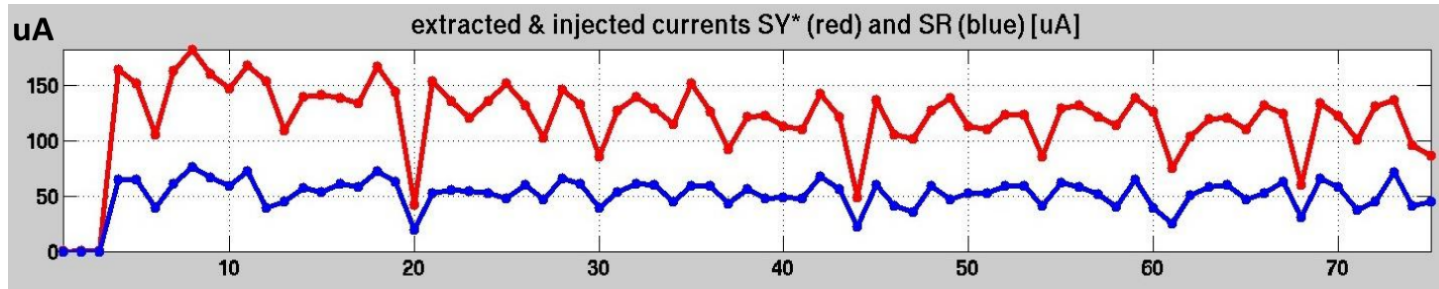
Booster ring (Spark)

AU

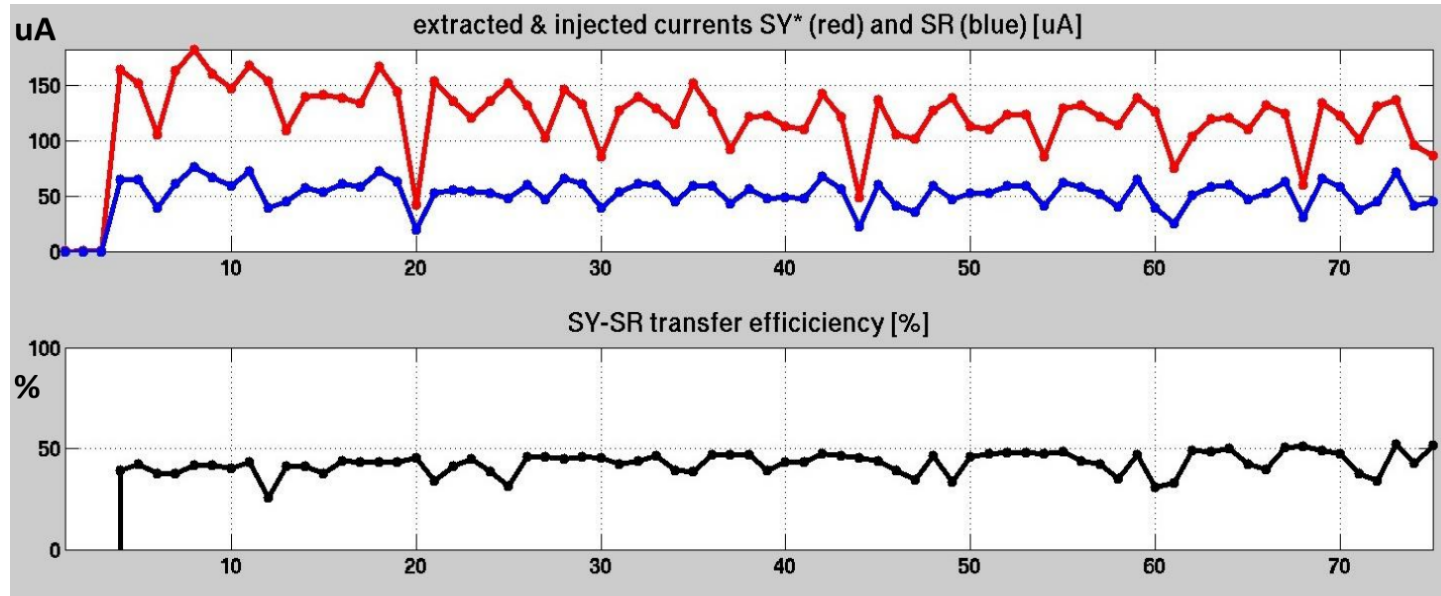


Storage ring (LB)

6) Transmission efficiency



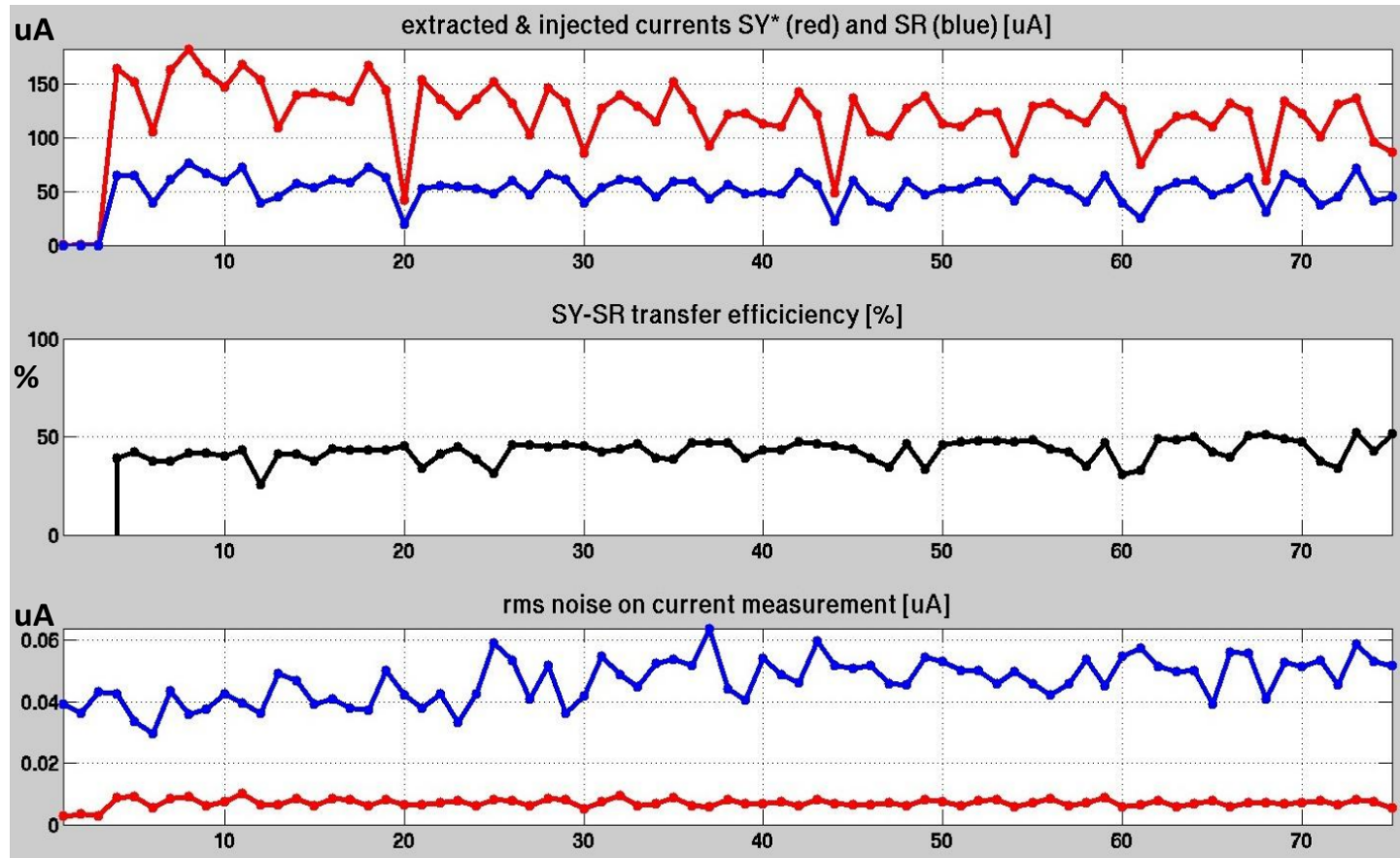
6) Transmission efficiency



Booster

SR

6) Transmission efficiency



Booster

SR

Conclusions

- Commissioning of **75** new BPM electronics
- Installation, Integration and Measurements: **2 weeks**
- ADC, T-b-T and Decimated data proven to be very useful
- Libera Spark is a cost-effective and valuable solution



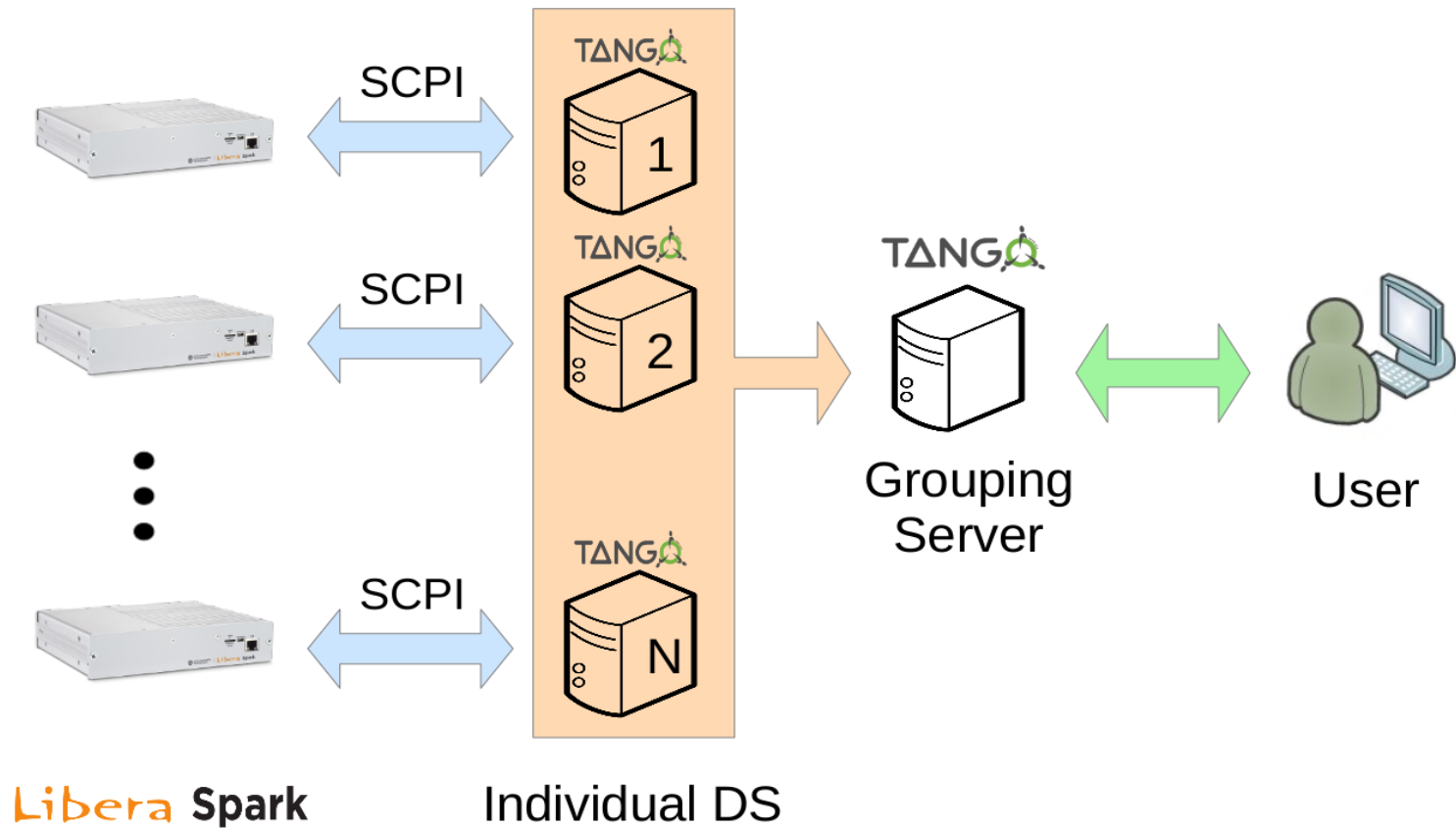
Libera Spark

Thanks for your attention!

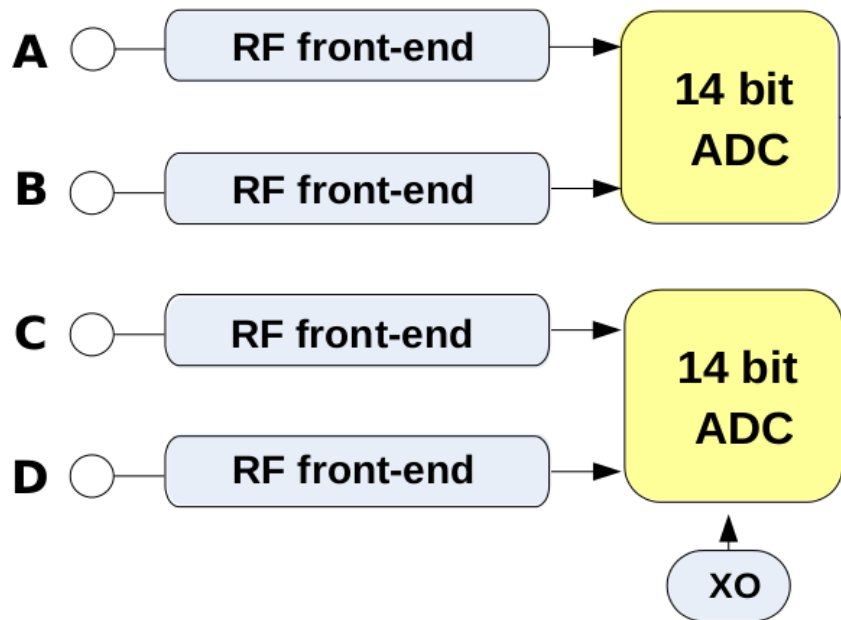
manuel.cargnelutti@i-tech.com



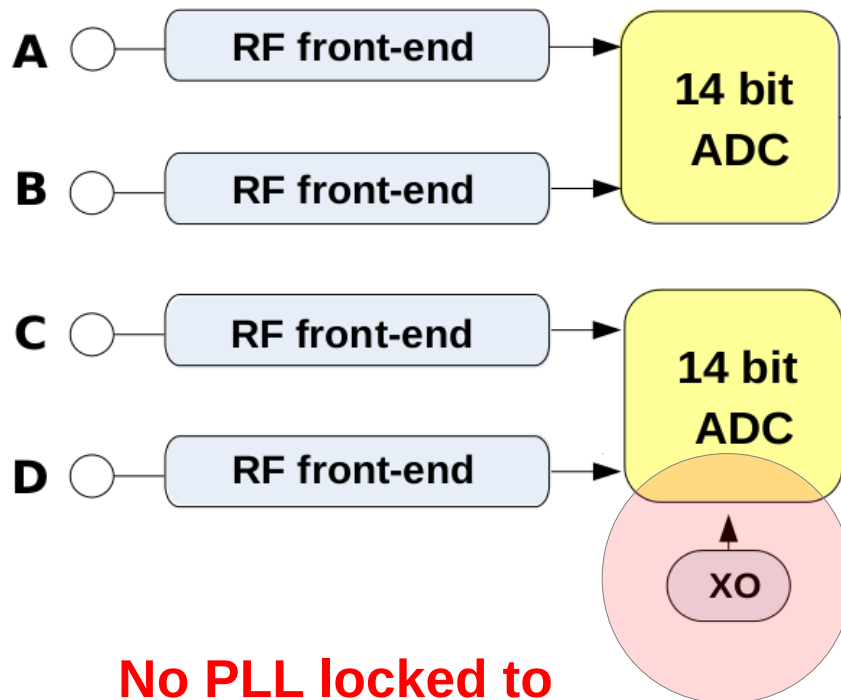
a) Integration in the Control System



2) Tuning of the XOs

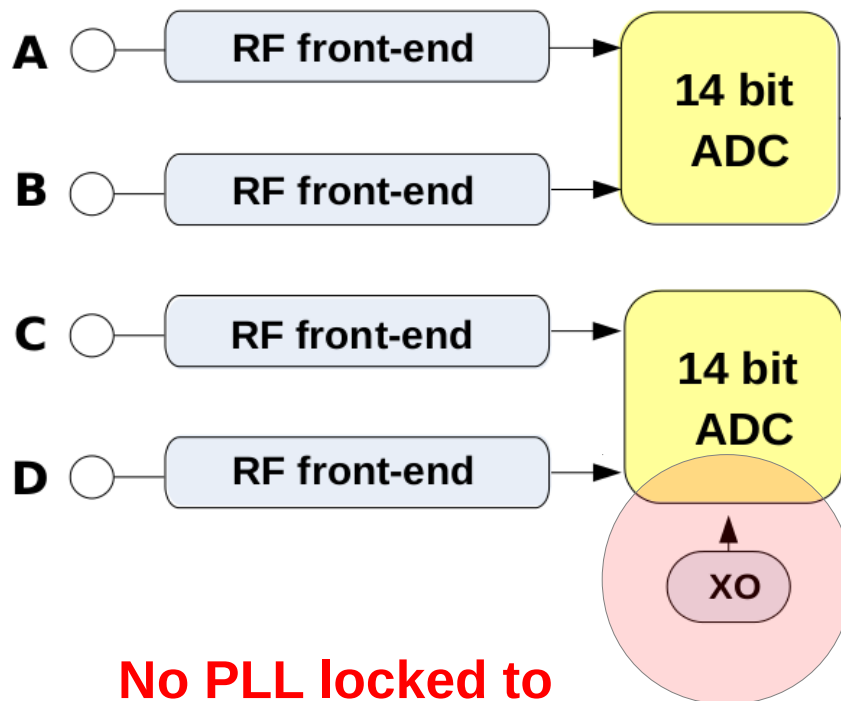


2) Tuning of the XOs



**No PLL locked to
any machine reference!**

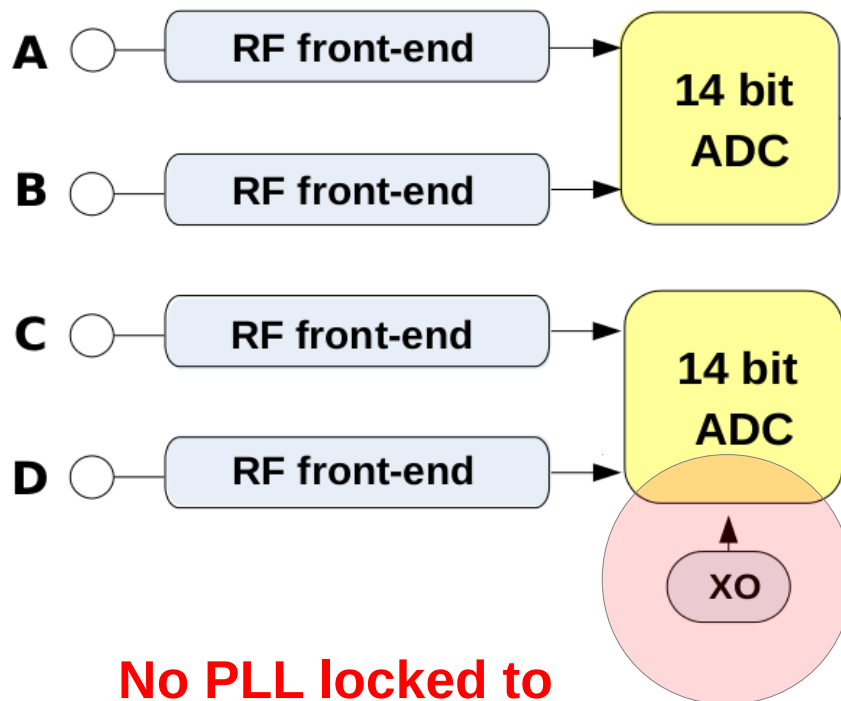
2) Tuning of the XOs



**No PLL locked to
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- Every device have a different sampling rate

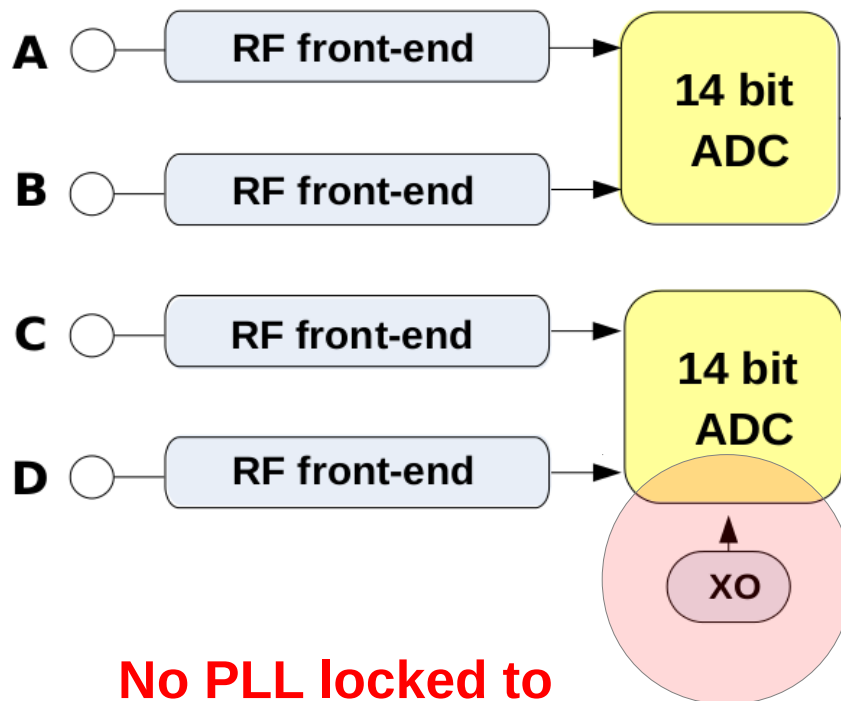
2) Tuning of the XOs



**No PLL locked to
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- Every device have a different sampling rate
- If rates are to different
→ misalignment in time
→ MAF filtering issues

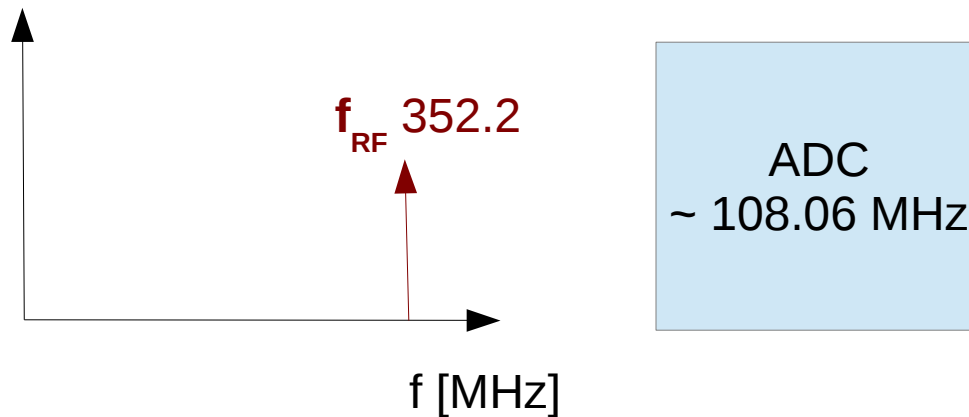
2) Tuning of the XOs



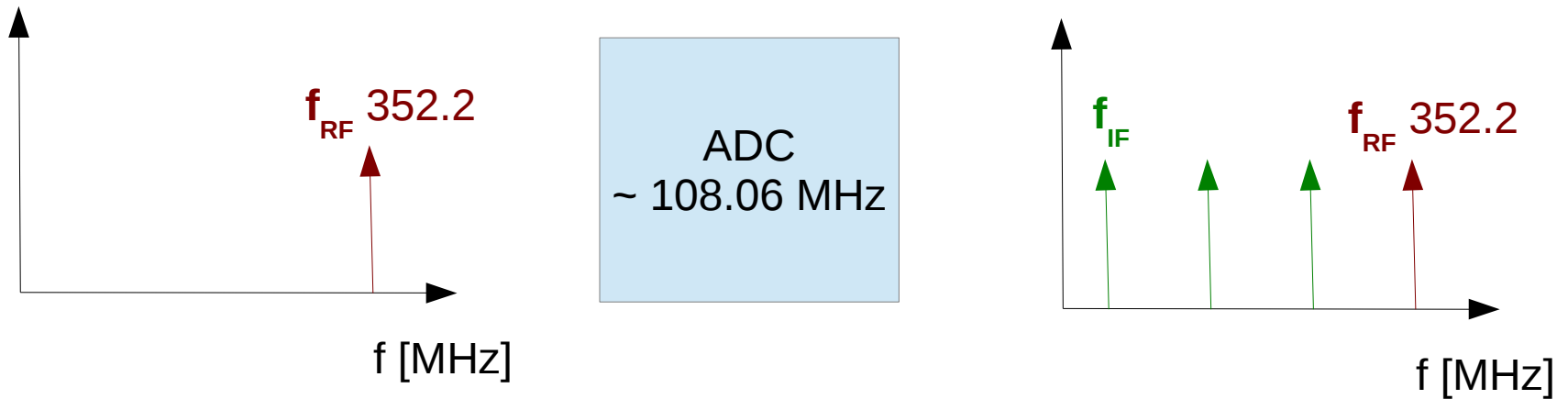
**No PLL locked to
any machine reference!**

- Every device have a different sampling rate
- If rates are to different
→ misalignment in time
→ MAF filtering issues
- Sampling frequency is a parameter and can be corrected

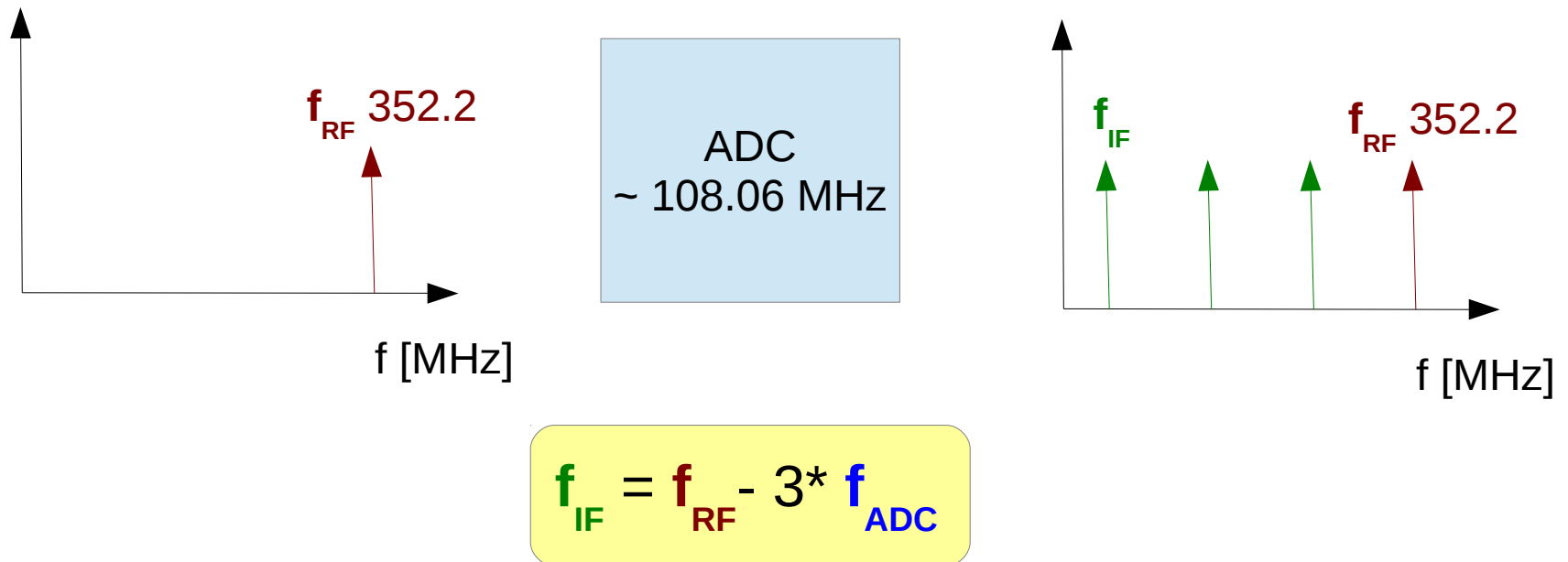
Estimate the difference



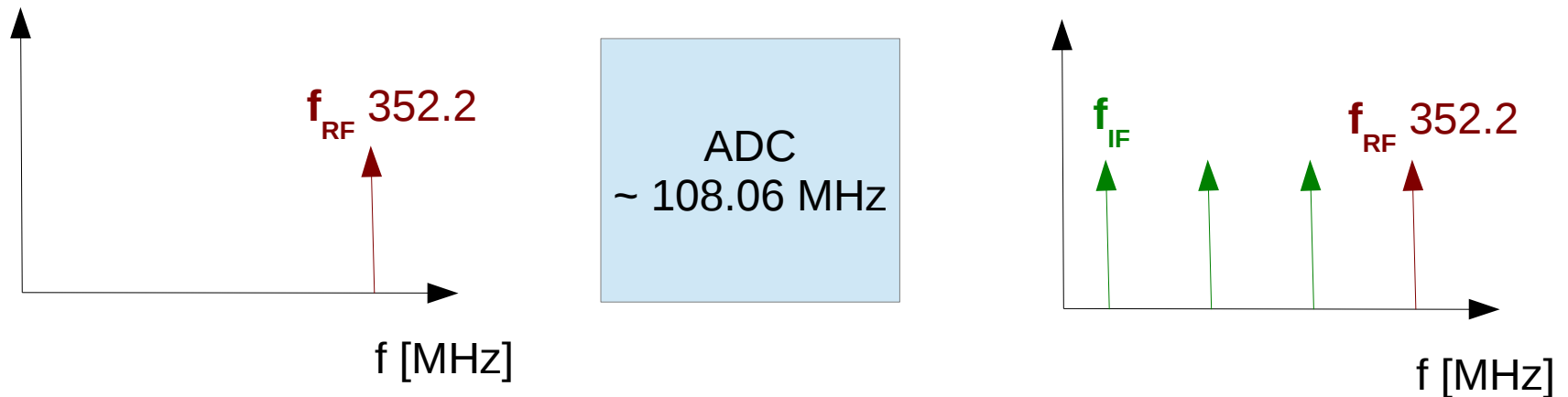
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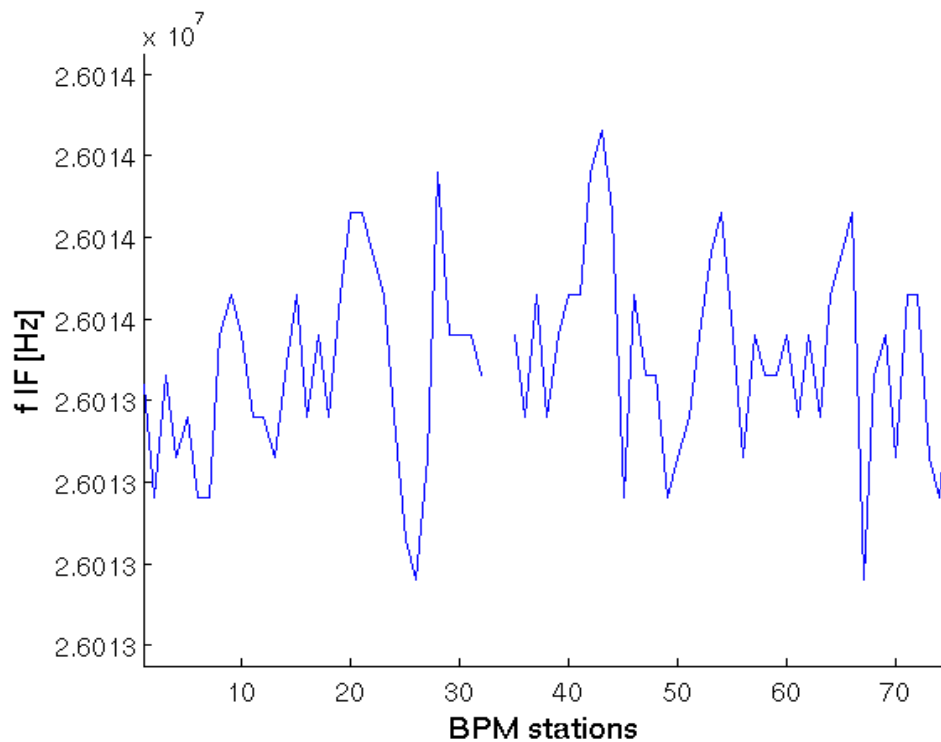


ADC
~ 108.06 MHz

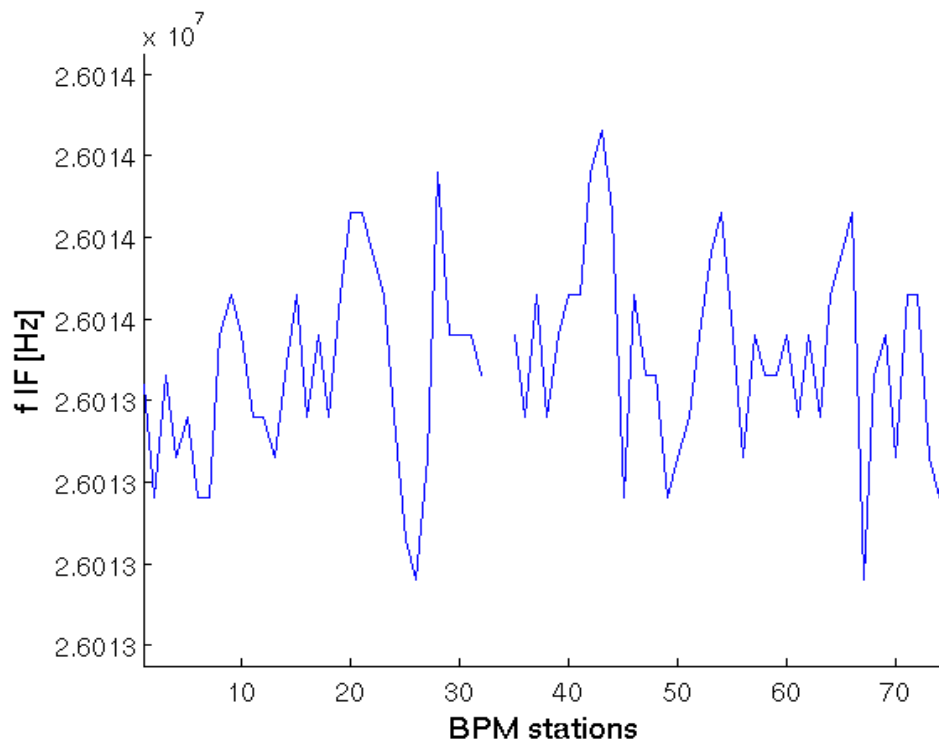
$$f_{IF} = f_{RF} - 3 * f_{ADC}$$

$$\Delta f_{IF} = 3 * \Delta f_{ADC}$$

Estimate the difference

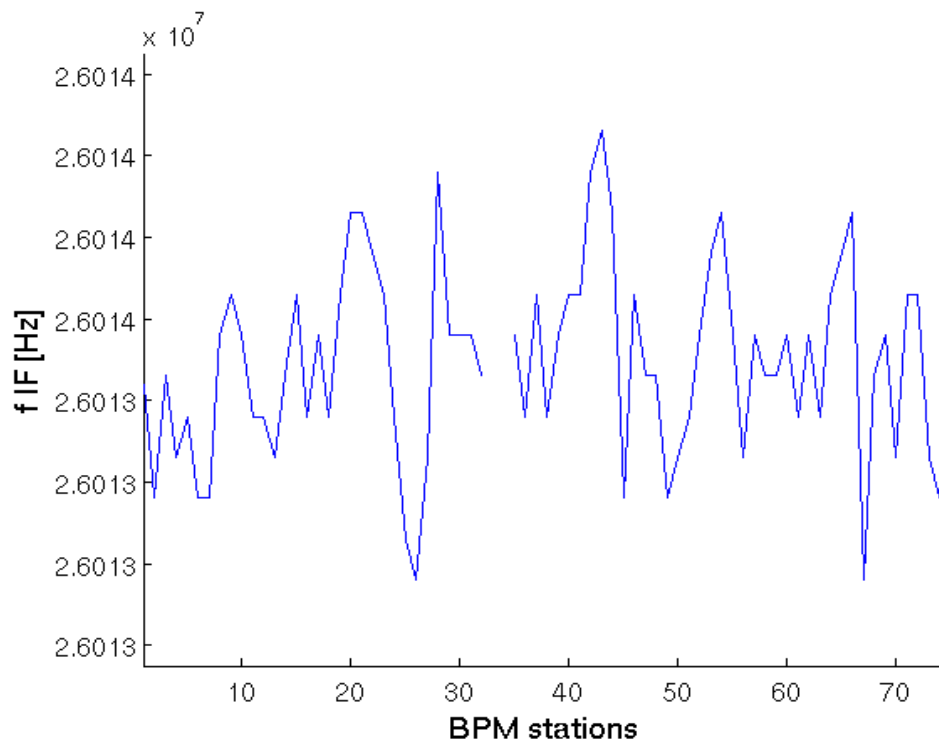


Estimate the difference



$$\Delta f_{IF} = 1100 \text{ Hz p2p}$$

Estimate the difference

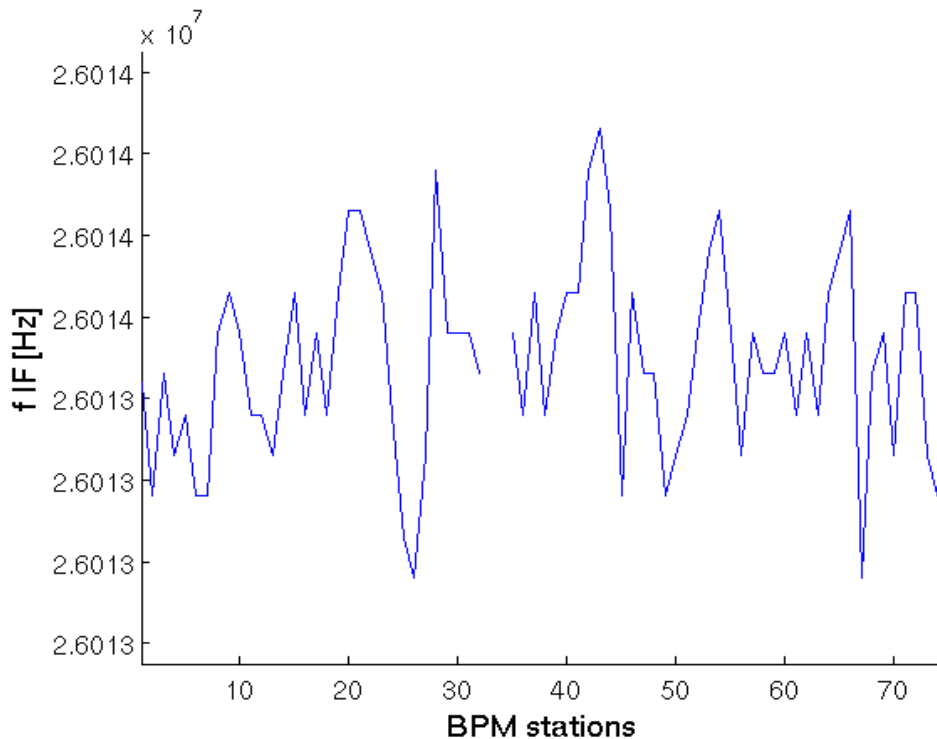


$$\Delta f_{IF} = 1100 \text{ Hz p2p}$$

:3

$$\Delta f_{ADC} \sim 367 \text{ Hz}$$

Estimate the difference



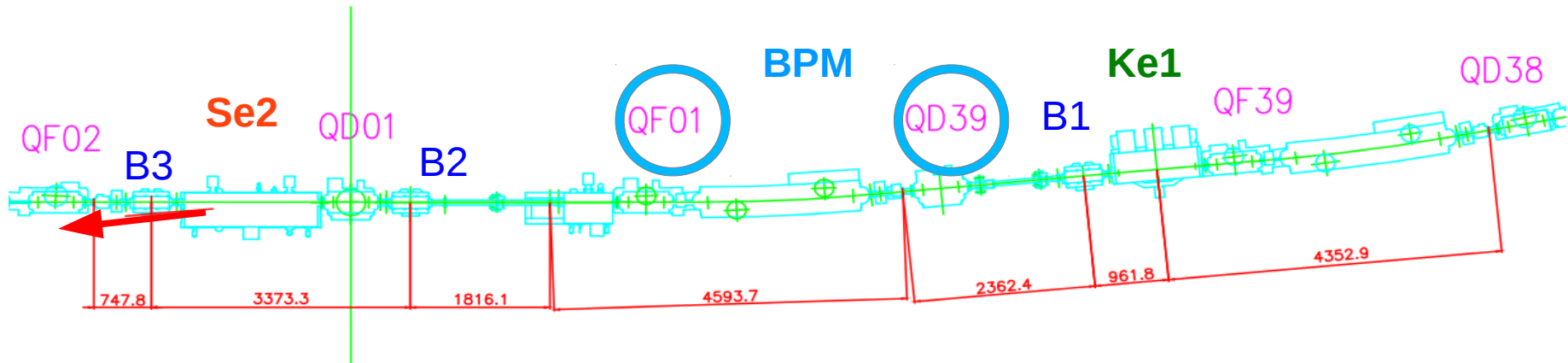
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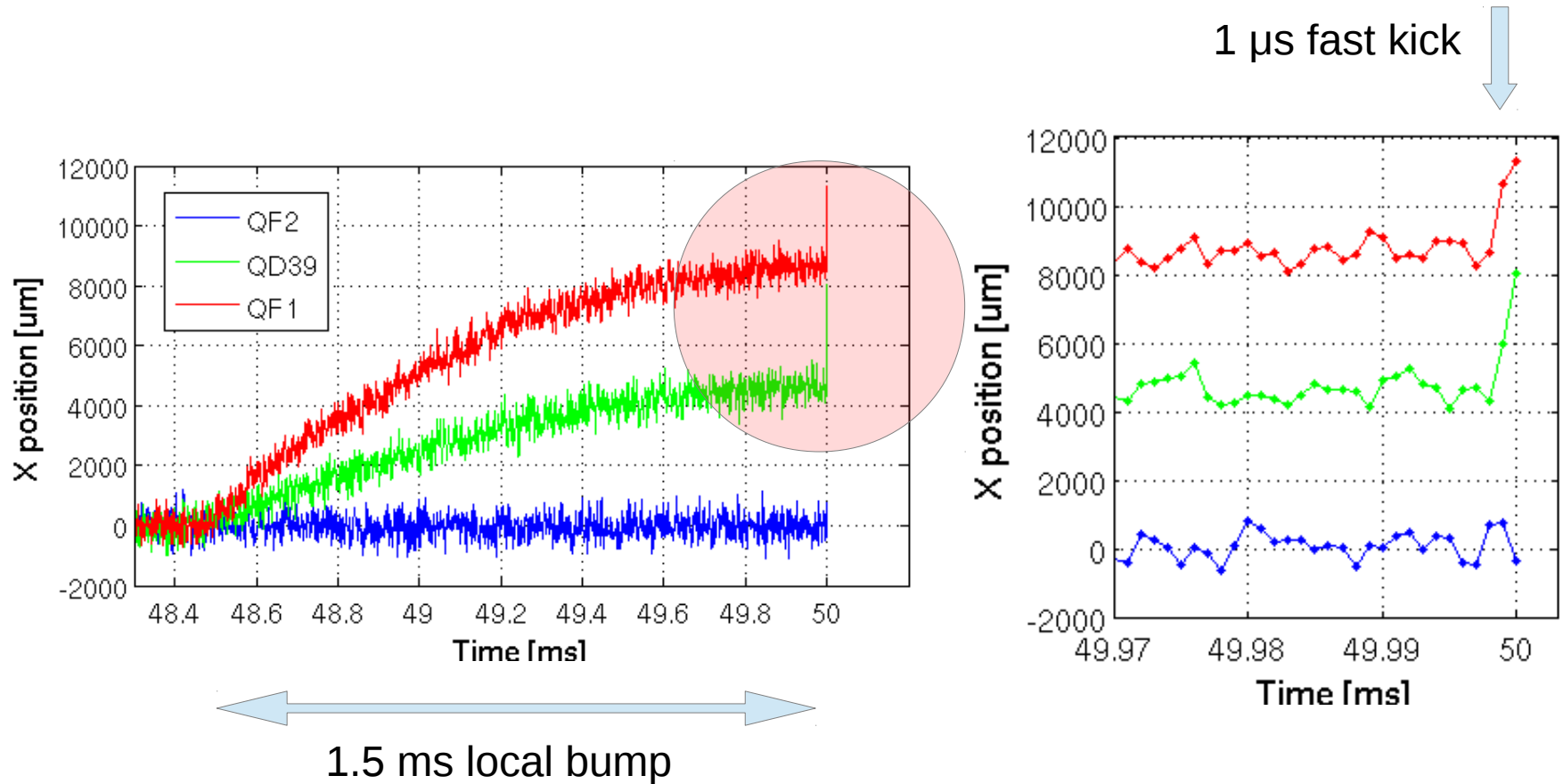
18 samples in 50ms

c) Extraction process



- Three bumpers (**B1**, **B2** and **B3**) create an horizontal bump 1.5 ms before extraction
- This moves the beam closer to the extraction septum magnet **Se2**
- The fast kicker **Ke1** extracts the beam in one turn

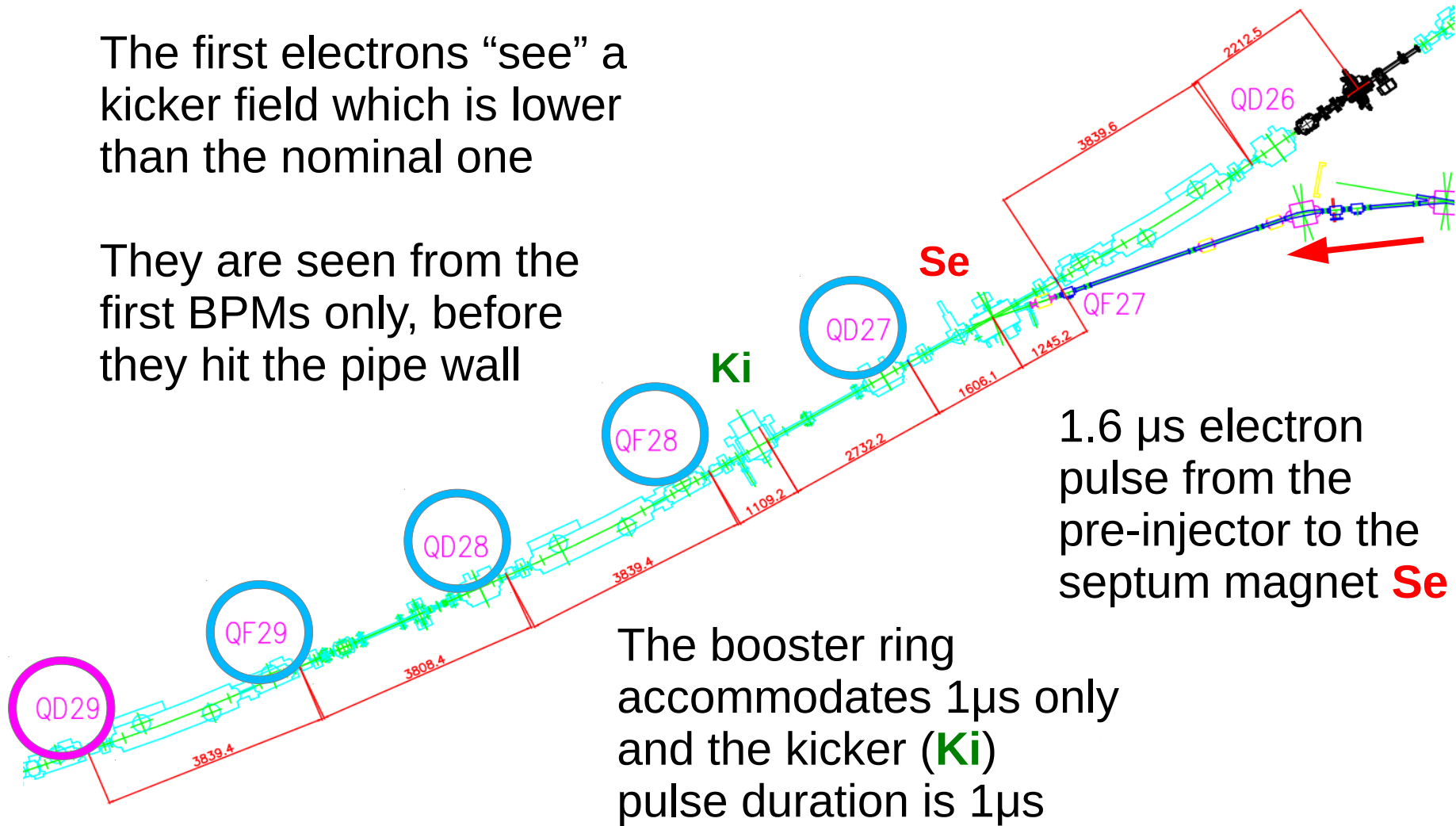
c) Extraction process



d) Injection process

The first electrons “see” a kicker field which is lower than the nominal one

They are seen from the first BPMs only, before they hit the pipe wall



d) Injection process

