RESULTS OF BEAM-CHARGE AND BEAM-POSITION MEASUREMENTS WITH LIBERA SPARK UNITS IN THE ESRF TRANSFER-LINE 2

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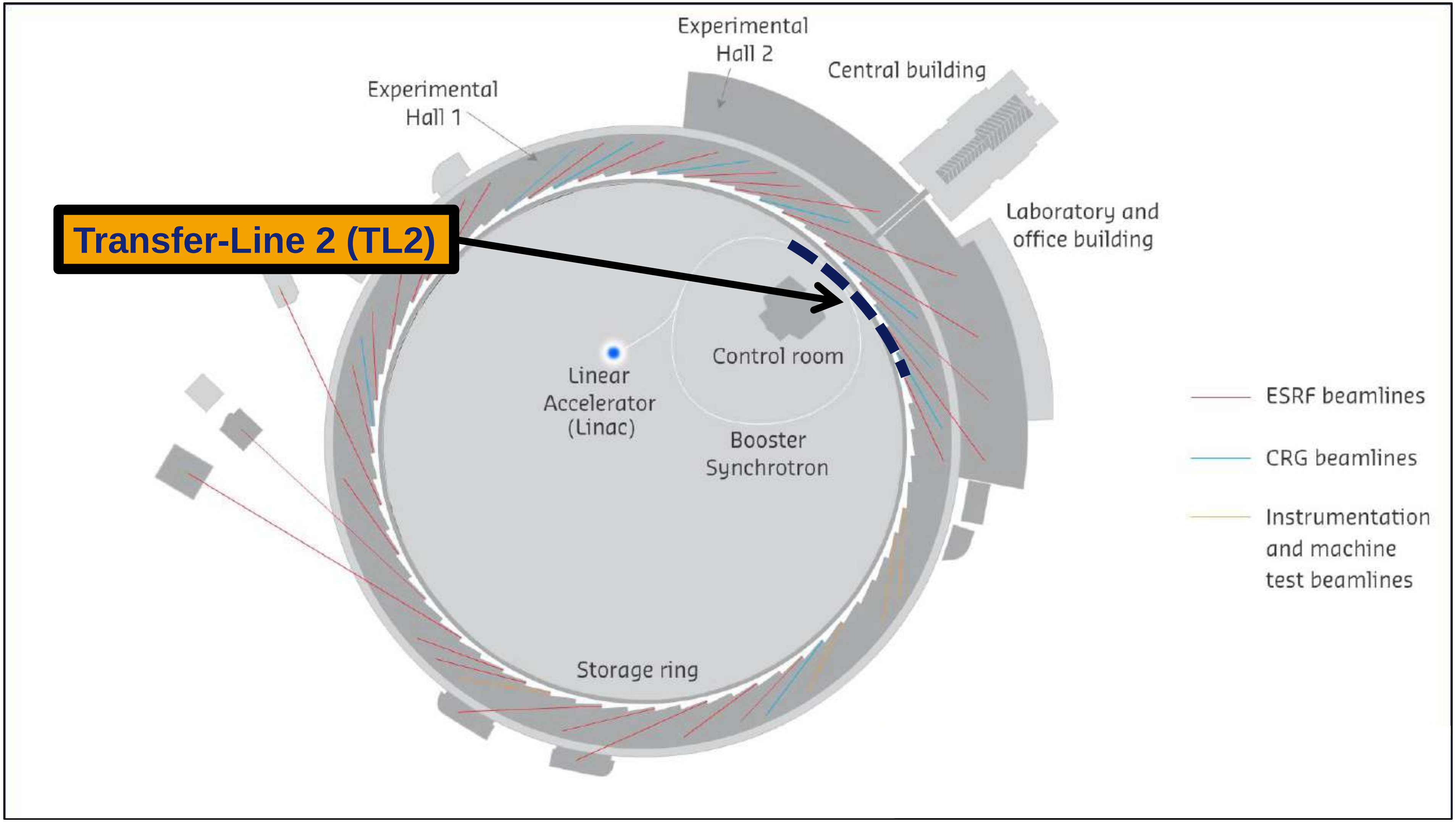
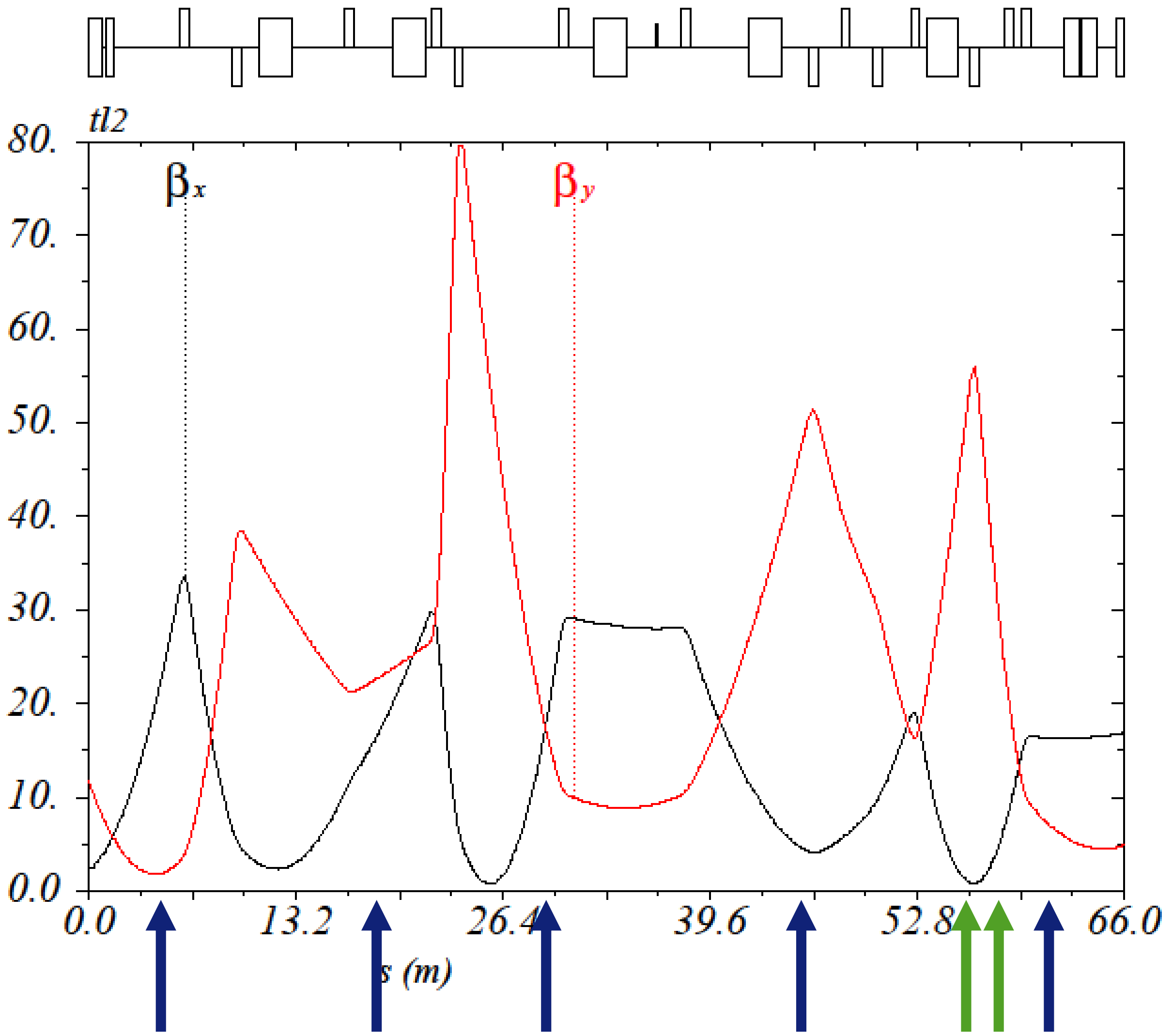
ESRF TRANSFER-LINE 2



MOTIVATIONS

- **Spark ERXR is a good candidate for future ESRF-EBS Storage Ring (2020)**
  - We can take advantages of the 3 remaining years to get use to the Spark ERXR in real conditions
- **Trajectory in TL2 was (until recently) adjusted with fluorescent screens**
  - performed by hand by a beam dynamics expert
  - tedious task
- **Need for an automatic procedure to center the beam in quadrupoles (and the sextupole) to perform fine optics optimization**
- **Measure beam charge along the full injector chain to improve injection efficiency**

TL2 PICKUPS POSITION

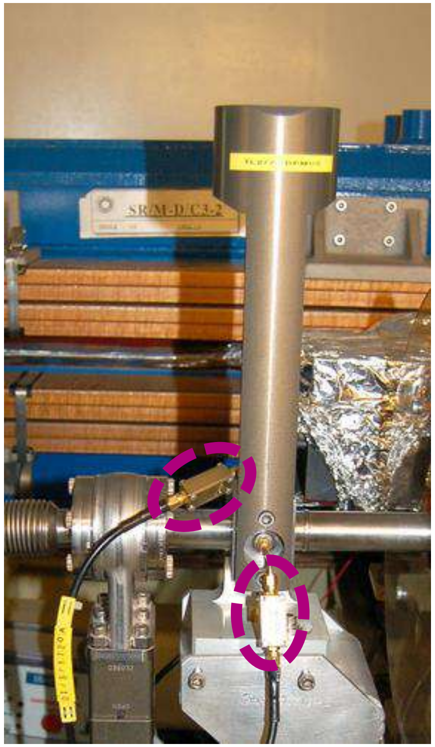


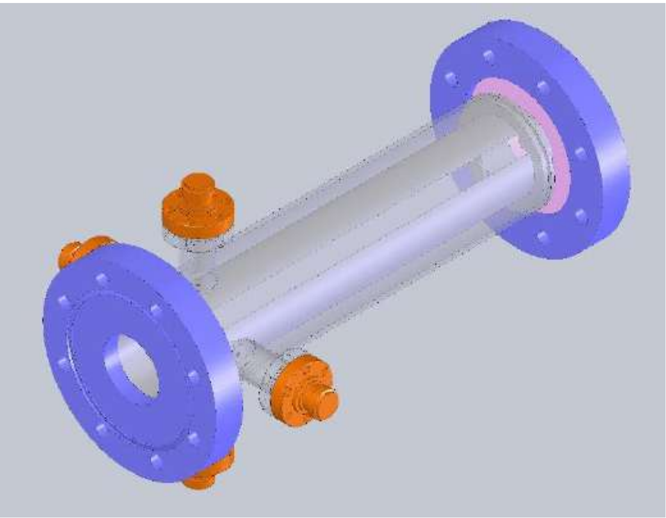
Stripline

BPM block + transformer

+ 2 striplines in the booster synchrotron to measure charge

HIGH SENSITIVITY PICKUPS



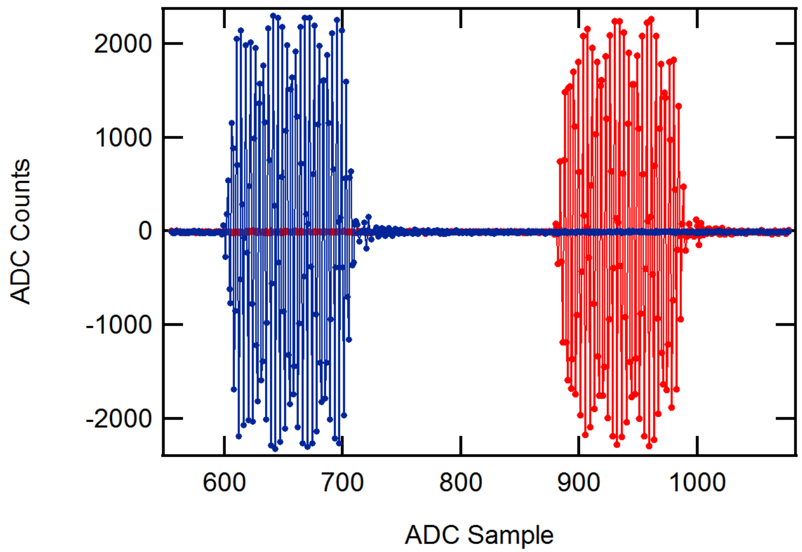


Transformer: increase signal strength by matching buttons' impedance with a resonant transformer
→ 10 times more signal as compared to regular BPM blocks

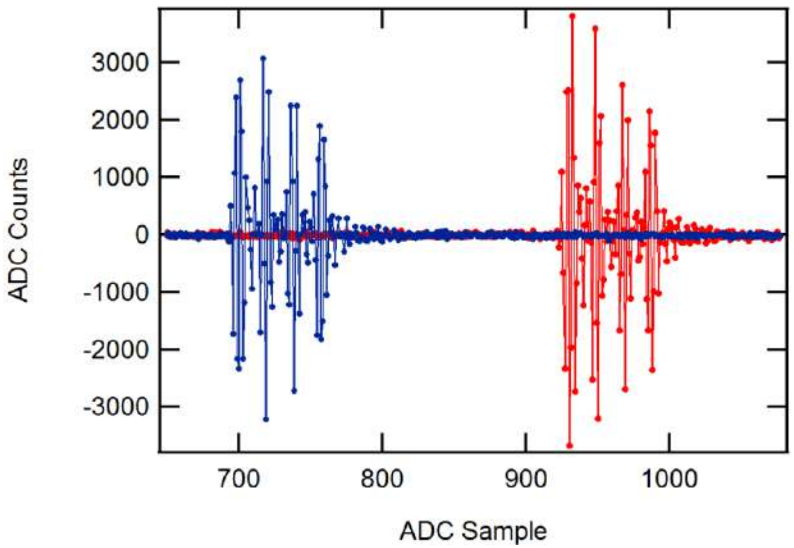
Stripline: 50 Ohm transmission line
→ 100 times more signal as compared to regular BPM blocks

A SINGLE-SHOT MEASUREMENT

RAW ADC data for 2 different shots (blue and red) on one stripline outpout port:



Long pulse mode (~ 350 bunches in a row)



Short pulses mode (4 bunches): The signal has the periodicity of the input bandpass filters

SIGNAL PROCESSING

Spark ERXR features Time Domain Processing (TDP) and Turn By Turn (TBT)

It should also work for a transfer-line (specially the TDP)

But require a precise trigger timing

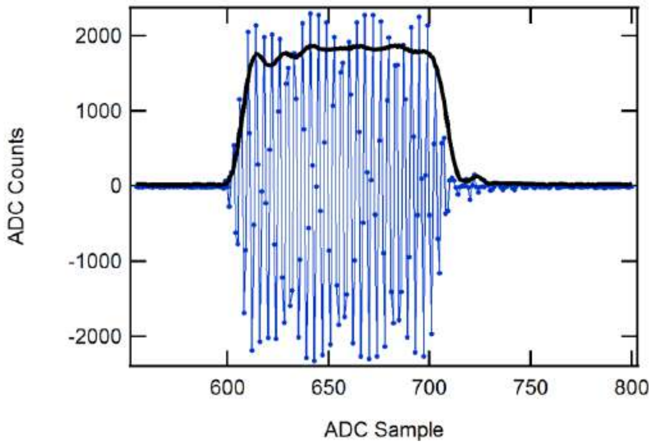
And doesn't allow for more than one position for each shot in the transfer-line (no possible to get the charge per bunch).

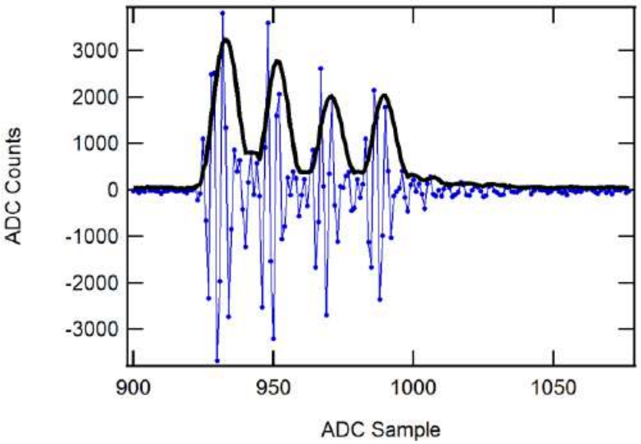
We get raw ADC data and use our own signal processing to get position and charge.

SIGNAL PROCESSING

For visualization purposes only, we calculate a smoothed sum signal with:

$$\tilde{a} = \sqrt{(a - \langle a \rangle)^2 \times \frac{1}{8}[1,2,2,2,1]}$$
$$\tilde{b} = \cdots$$
$$\mathrm{sum} = \tilde{a} + \tilde{b} + \tilde{c} + \tilde{d}$$





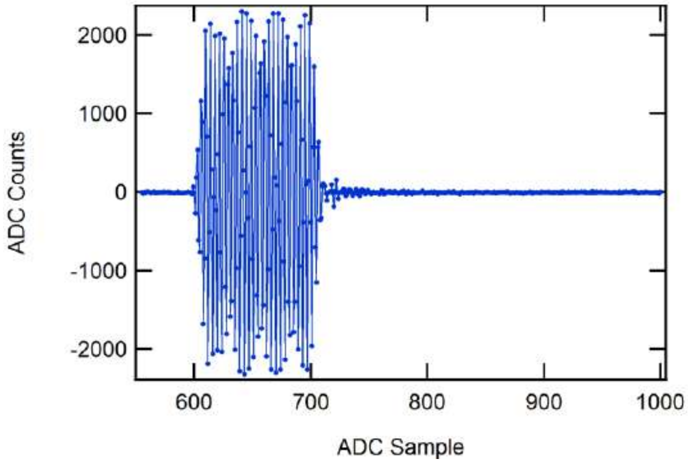
This signal is displayed in control room
It give many information with just a glance of the eye

SIGNAL PROCESSING

For each electrode we compute the amplitude of the signal and of the noise (in ADC units):

$$U_a = \sqrt{(a - \langle a \rangle)^2 \times \frac{1}{108}[1,1,\cdots,1,1]}$$

$$U_b = \cdots$$



108 samples

108 samples

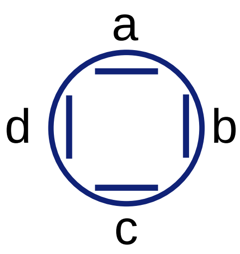
And then find the amplitude at the stripline ports (in Volts):

$$V_a = \text{ADC2V}\ 10^{att/20} \sqrt{{U_a^{signal}}^2 - {U_a^{noise}}^2}$$

$$V_b = \cdots$$

calibration coefficient

Finally we get positions and incoherency:



$$X = K_X . \frac{(V_d - V_b)}{(V_a + V_b + V_c + V_d)}$$

$$Z = K_Z . \frac{(V_a - V_c)}{(V_a + V_b + V_c + V_d)}$$

$$Q = K_Q . \frac{(V_a + V_c - V_b - V_d)}{(V_a + V_b + V_c + V_d)}$$

And charge:

Charge= $K_C . (V_a + V_b + V_c + V_d)$

THE NEED FOR CALIBRATION

The conversion factor from ADC unit to Volt at the output of stripline exhibit large fluctuation because:

- Length difference of the cable between stripline output and Sparks

Cable lengths from stripline to Spark ranges from 10 m to 45 m

Current cable attenuation is 0.27 dB/m (@ 352 MHz)

Attenuation ranges from 2.7 dB et 12.15 dB

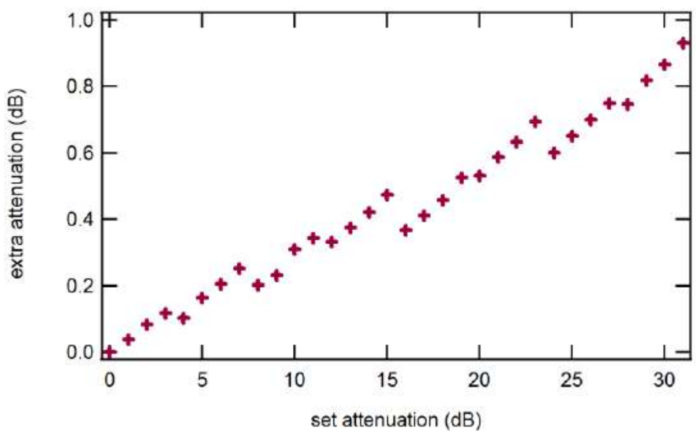
If this attenuation is not taken into account the error on charge measurement would be a factor of 3!

THE NEED FOR CALIBRATION

The conversion factor from ADC unit to Volt at the output of stripline exhibit large fluctuation because:

- Length difference of the cable between stripline output and Sparks

- Spark’s variable attenuator actual attenuation



variable attenuators in Sparks have to be measured to avoid an 1 dB error (max), <u>i.e. 12 %</u>

THE NEED FOR CALIBRATION

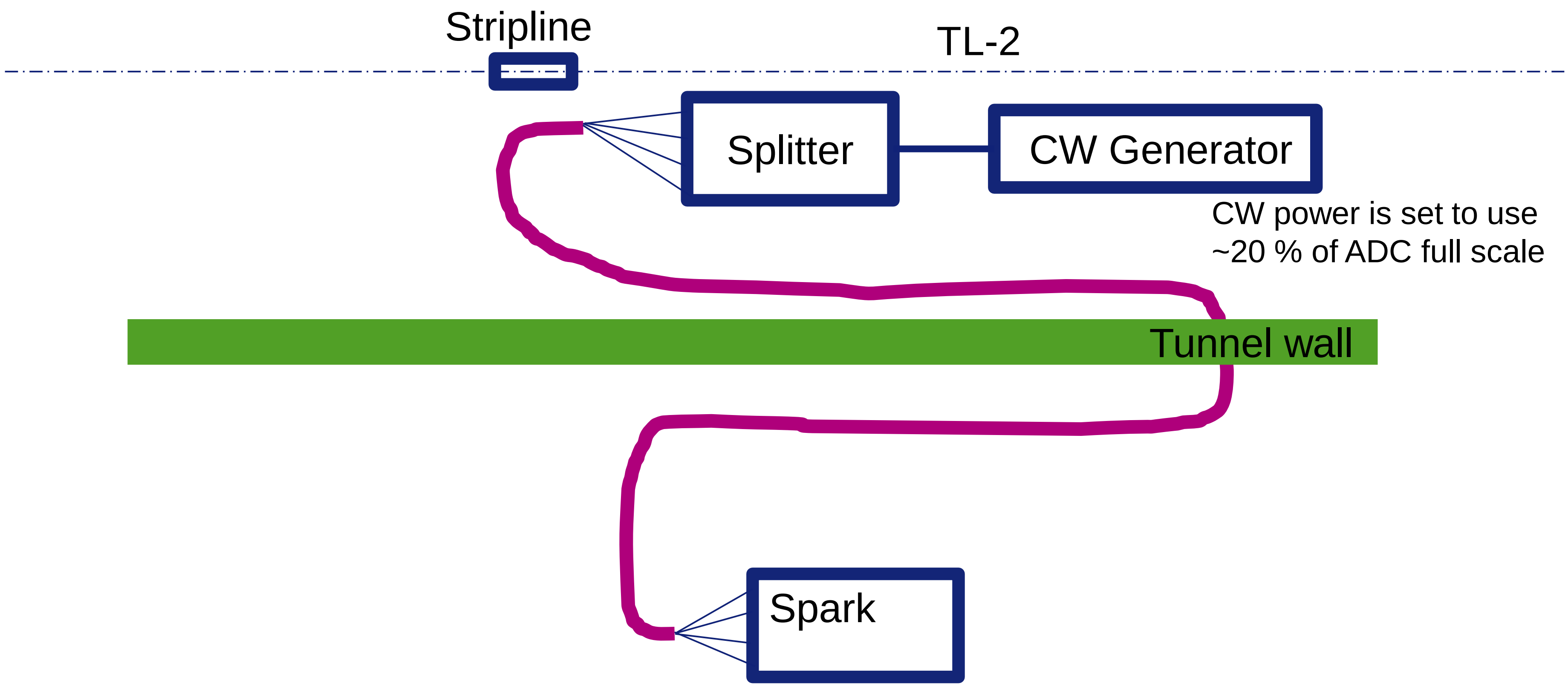
The conversion factor from ADC unit to Volt at the output of stripline exhibit large fluctuation because:

- Length difference of the cable between stripline output and Sparks
- Spark’s variable attenuator actual attenuation
- Different gain of Spark channels

Spark channels doesn’t have exactly the same gain, and no switching is available to compensate for this (unlike Libera Brillance for instance)

A maximum deviation between 4 channels of 2 dB is guaranteed by iTech, which corresponds to <u>an error of 26 %</u> on charge measurement

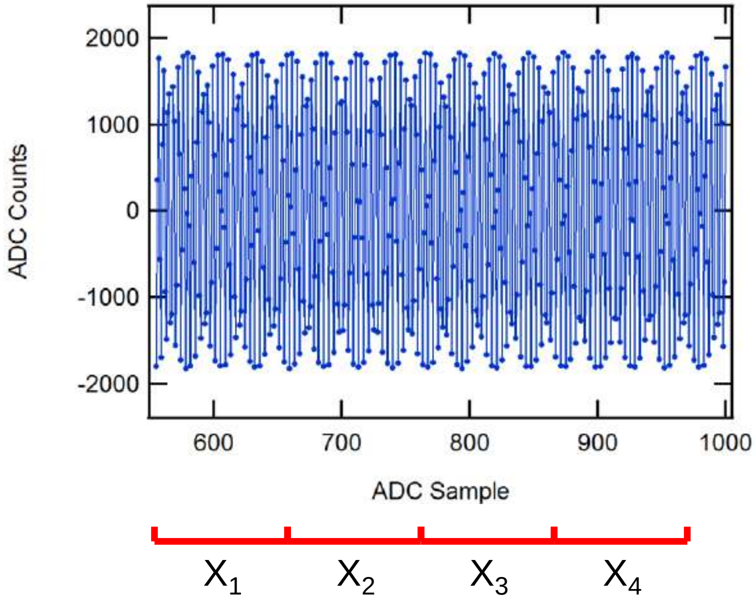
This also impact absolute precision for position measurement (up to 350 µm offset). **We want to take this offset into account for the commissioning of our future ring.**



we measure signal level seen on Sparks for the 32 possible attenuation values
→ we get the relation between RAW ADC data and voltage at the output of striplines:

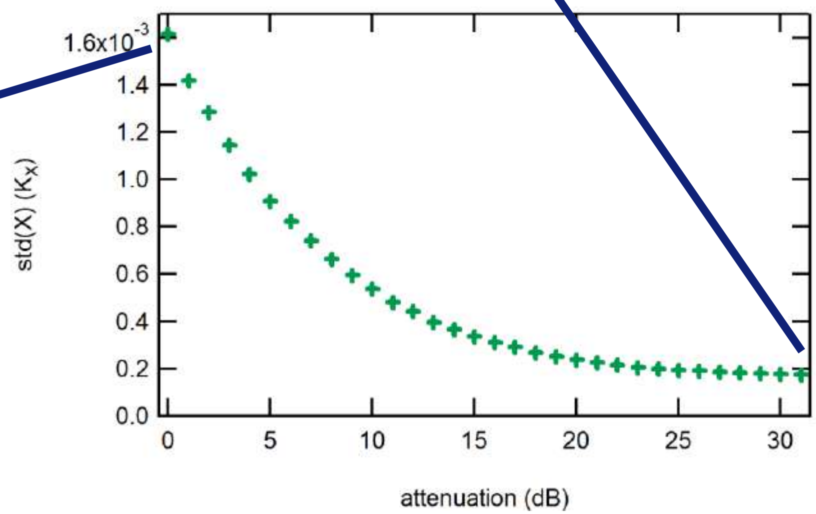
$$V_a = \mathrm{ADC2V}\, 10^{att/20} \sqrt{{U_a^{signal}}^2 - {U_a^{noise}}^2}$$
$$V_b = \cdots$$

We can evaluate error on position measurements:



Nominal conditions for striplines in TL2:
~ 4 mA in booster
$\sigma(X) \approx 4$ µm (K_X = 22 mm)

→ Seems better than beam position fluctuations

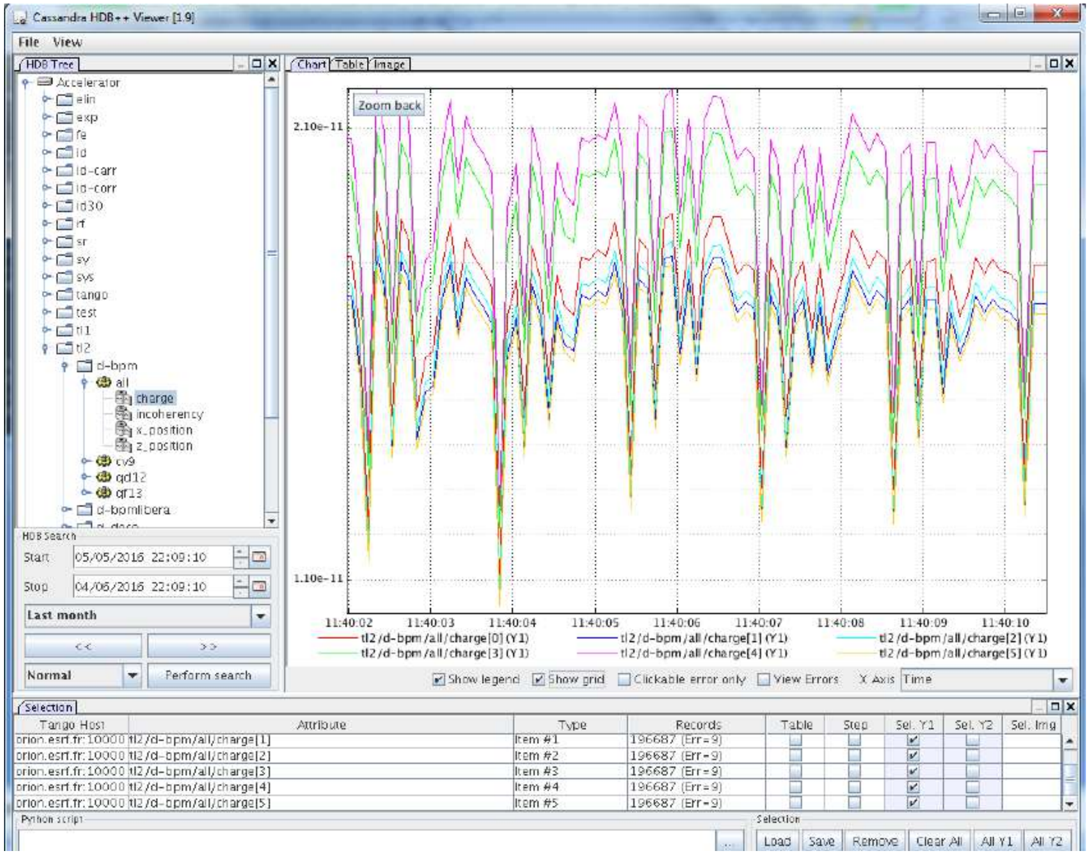


Extreme conditions:
~ 20 µA in booster
$\sigma(X) \approx 35$ µm (K_X = 22 mm)

→ Consistent with measurements

EVERY SHOT SAVE IN A DATABASE

For every shot in TL2 we store beam parameters in a database (HDB++)



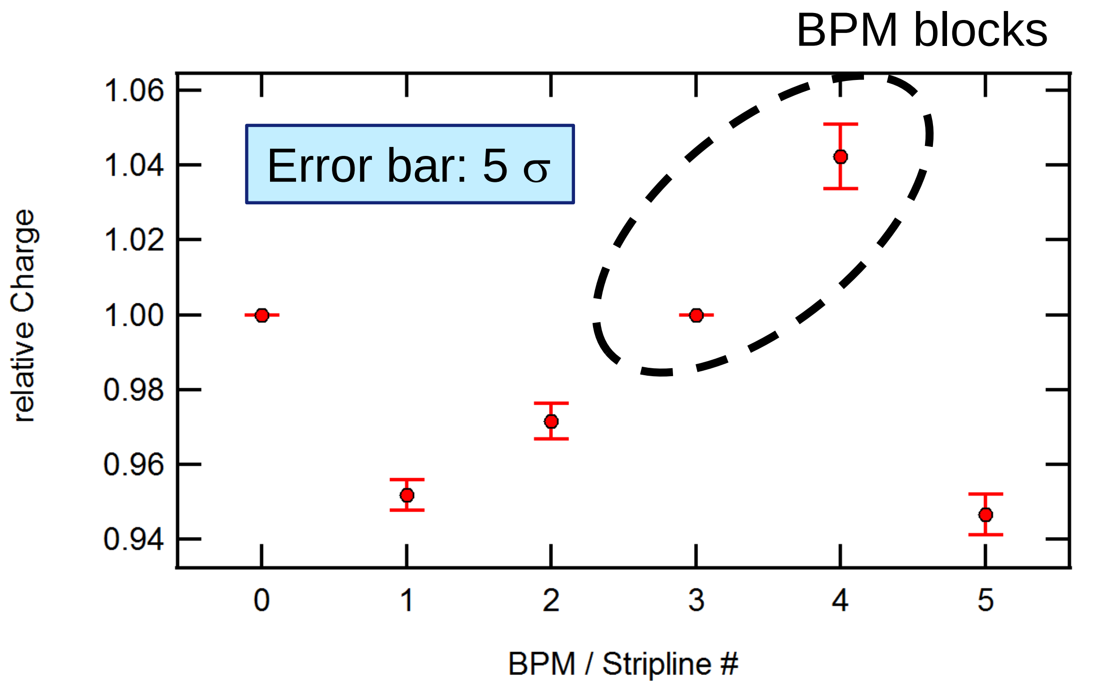
⇨ charge measured @ 10 Hz (injector frequency)

Fluctuations is not noise! It is the fluctuating charge of the beam

CHARGE MEASUREMENT

How good is the charge measurement?

The first stripline and the first BPM block are use as references:



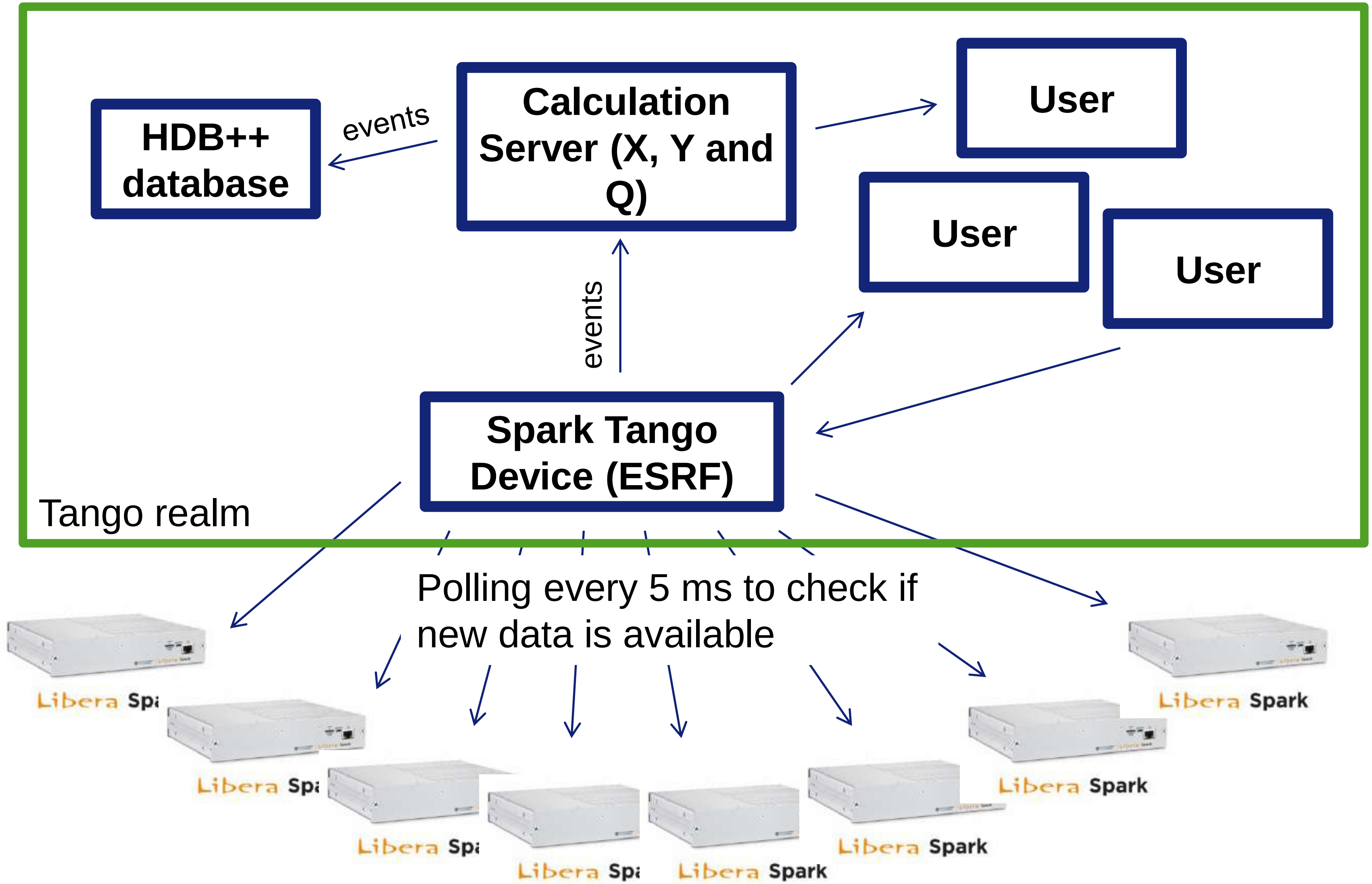
With ~5.10^{-10} C each shot

CHARGE MEASUREMENT

How good is the charge measurement?

With calibrations we only get a few % error in the charge measurement, it could come from:

- small physical discrepancies between striplines
- effect of the beam shape at the stripline location
- a non-centered beam


HDB++ database
events
Calculation Server (X, Y and Q)
User
User
User
events
Spark Tango Device (ESRF)
Tango realm
Polling every 5 ms to check if new data is available
Libera Spark
Libera Spark
Libera Spark
Libera Spark
Libera Spark
Libera Spark
Libera Spark
Libera Spark

ACQUISITION

→ t_1

→ t_2

...

→ t_n

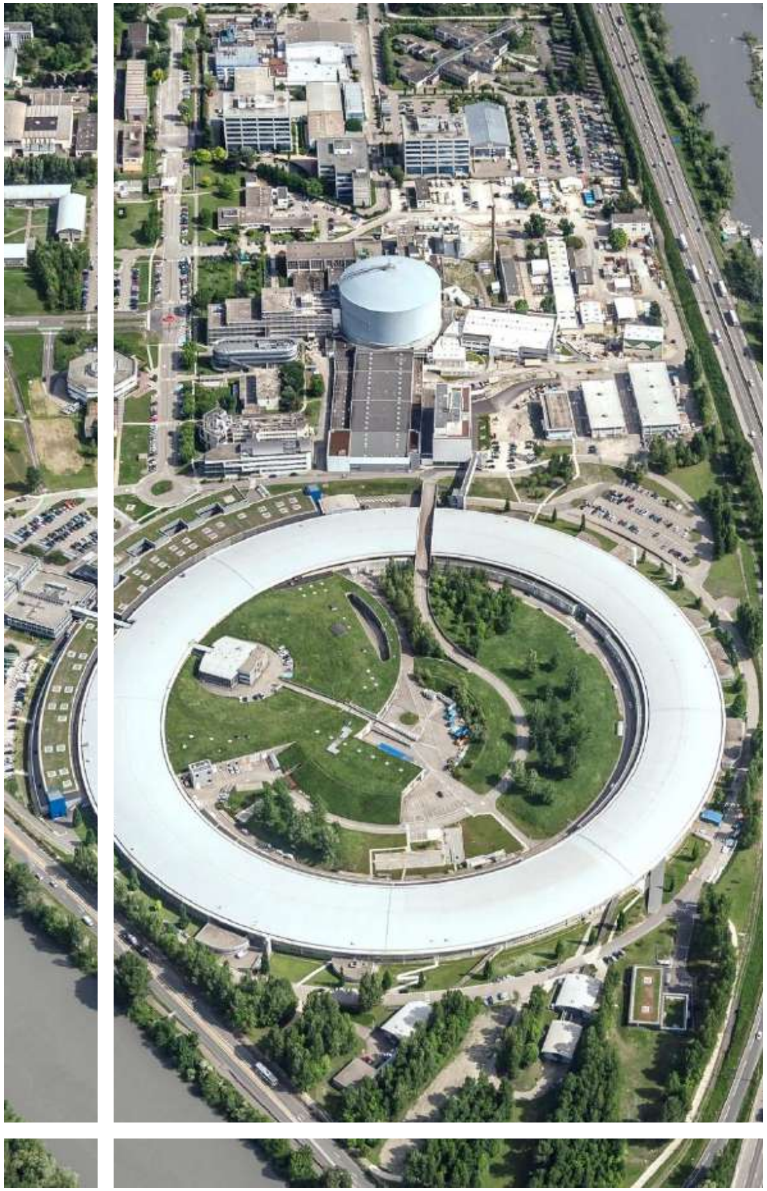
If $\Delta t = \max(t_i) - \min(t_i) < 30$ ms

We consider that data corresponds to the same shot

→ Works pretty well, even though we had some trouble we still don't understand (and can't reproduce)

Future Spark: Tango device embedded in Spark, no more polling required!

CONCLUSION



Spark + stripline is a efficient way of performing single shot measures in a transfer-line

→ precise position
→ bunch charge measurement

If one needs further precision, it is possible with calibrations