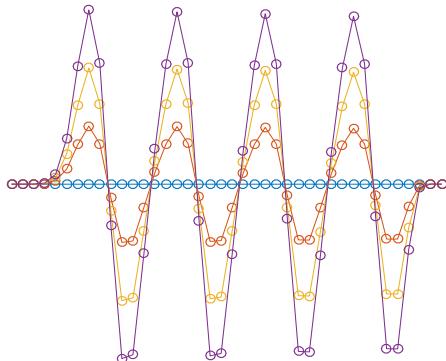


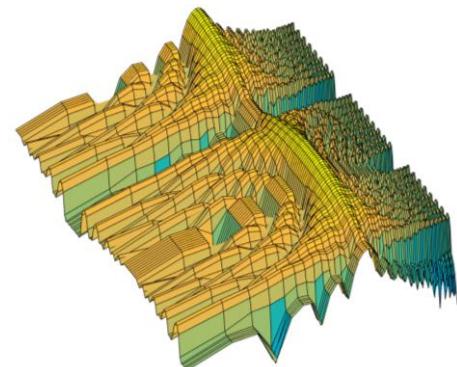
# A New Fast Digitization Acquisition System for the LHC Interlock BPMs



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BE-BI-QP

29. 6. 2017



# Outline

Introduction

Chosen Approach

Simulation Results

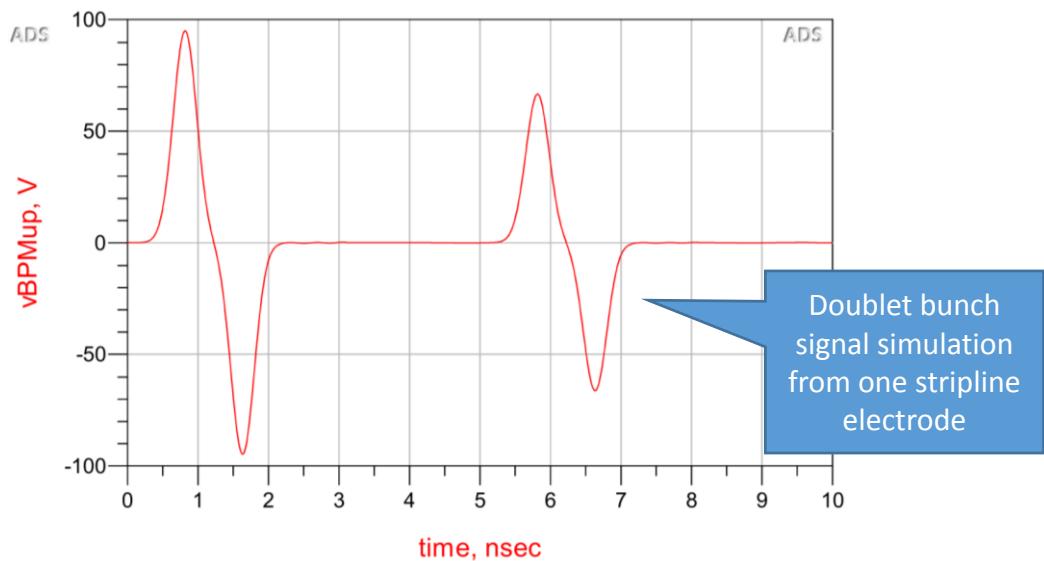
Preliminary Measurement Results



# Main Task

- Develop a new interlock BPM system capable of measuring the position of doublet bunches (with 5 ns spacing)
- Current system cannot cope with spacing < 25 ns

$$d = k \cdot \frac{A - B}{A + B}$$



# System Requirements

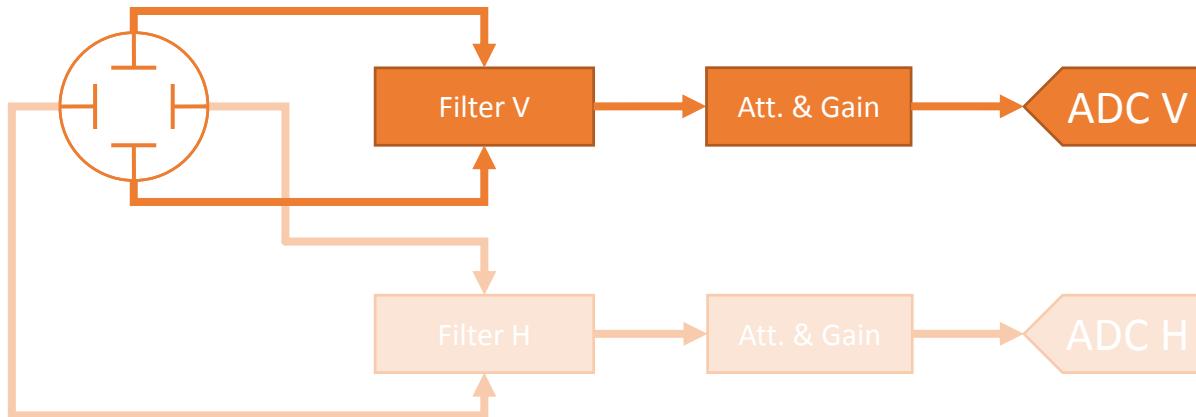
- Single bunch intensity range
  - Machine:  $1.5\text{e}9 - 3\text{e}11$  protons,  $1\text{e}9 - 5\text{e}10$  ions
  - Within one fill: **1e10 – 2e11** (i.e. **26 dB**)
- Position
  - Beam-dump threshold:  $\sim 3$  mm
  - To be covered at least 2x more:  **$\pm 7.5$  mm** (i.e. **6 dB**)
- At least **32 dB** of dynamic range is needed
- Resolution in given range: **< 100  $\mu\text{m}$**

# Chosen Approach

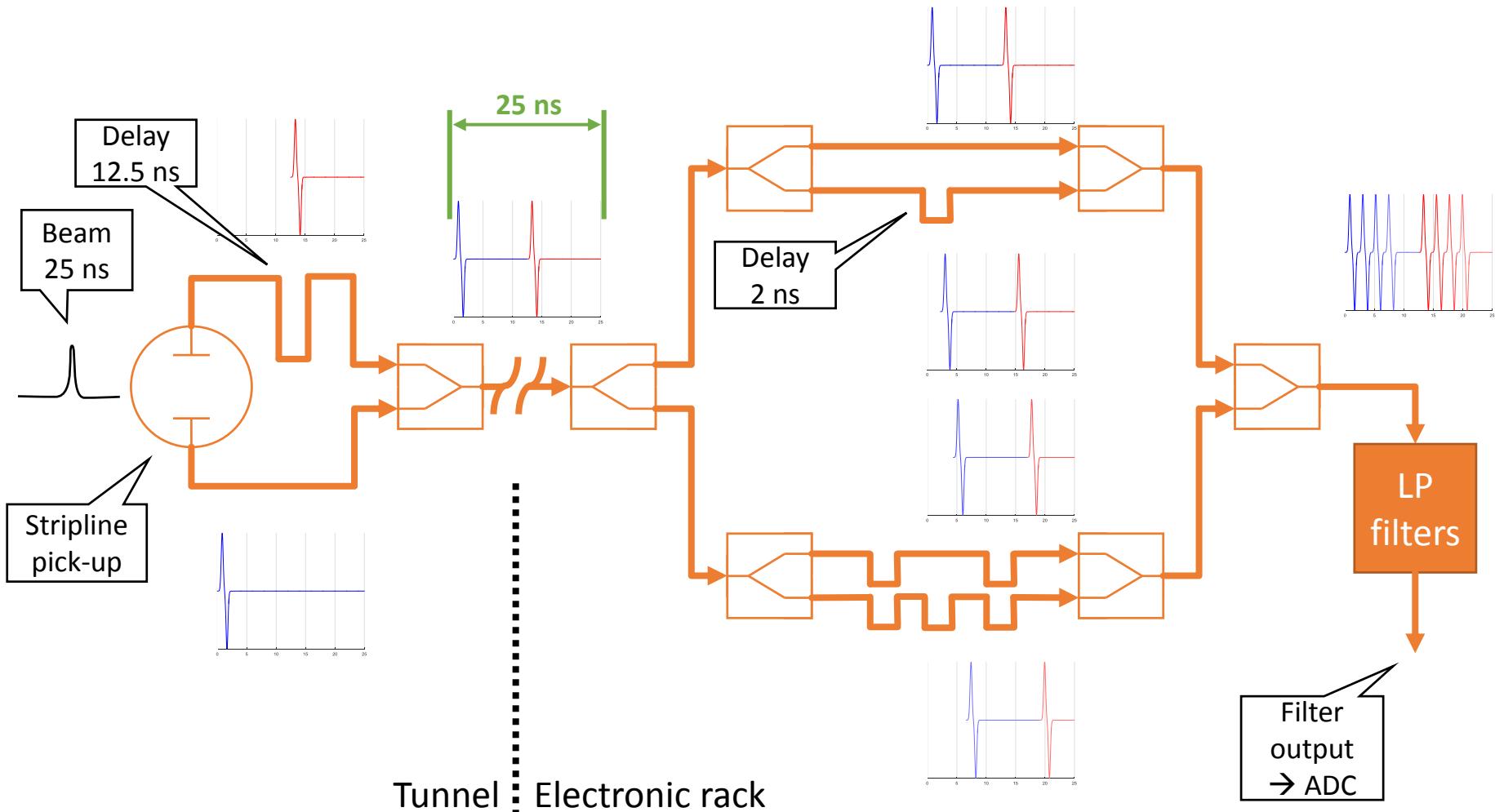


# Chosen Approach – Overview

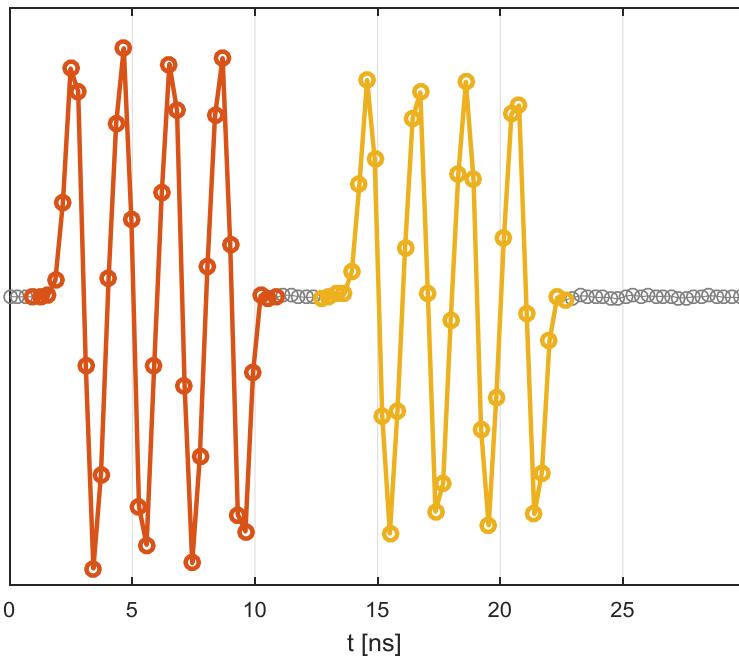
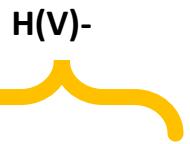
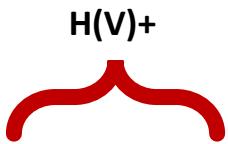
- For each BPM plane:
  - Comb filter + variable attenuation/gain + fast ADC
    - Texas Instruments ADC12J4000 (3.2 GSa/s, 725 mV p-p)
    - SNR (datasheet) ~ -62 dBFs, ENOB ~ 8.7
- One chain for both electrodes
  - No position offset, no scaling/aging problems



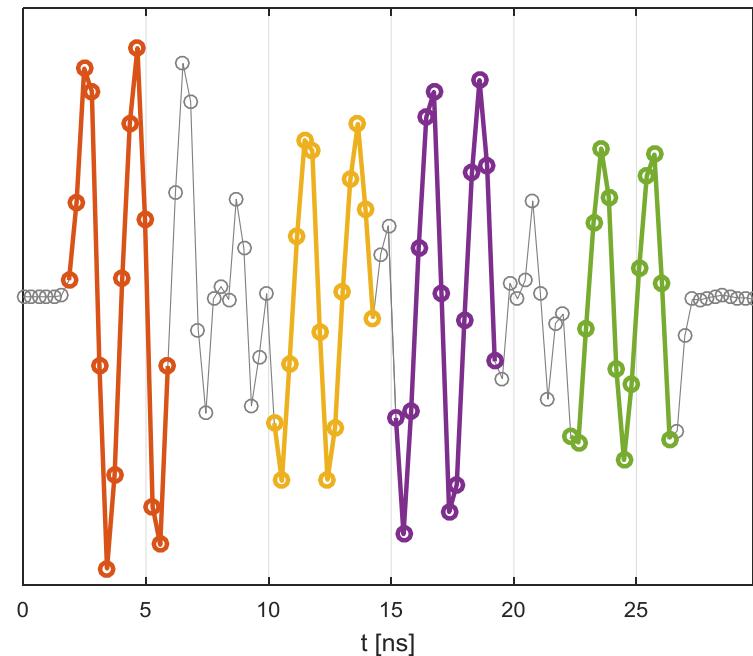
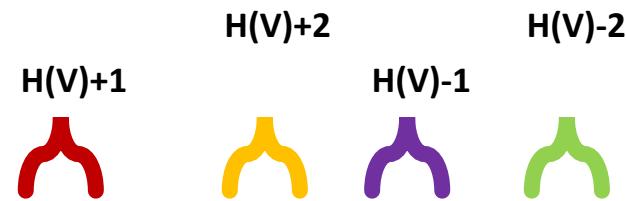
# Analogue Comb Filter



# Expected ADC data



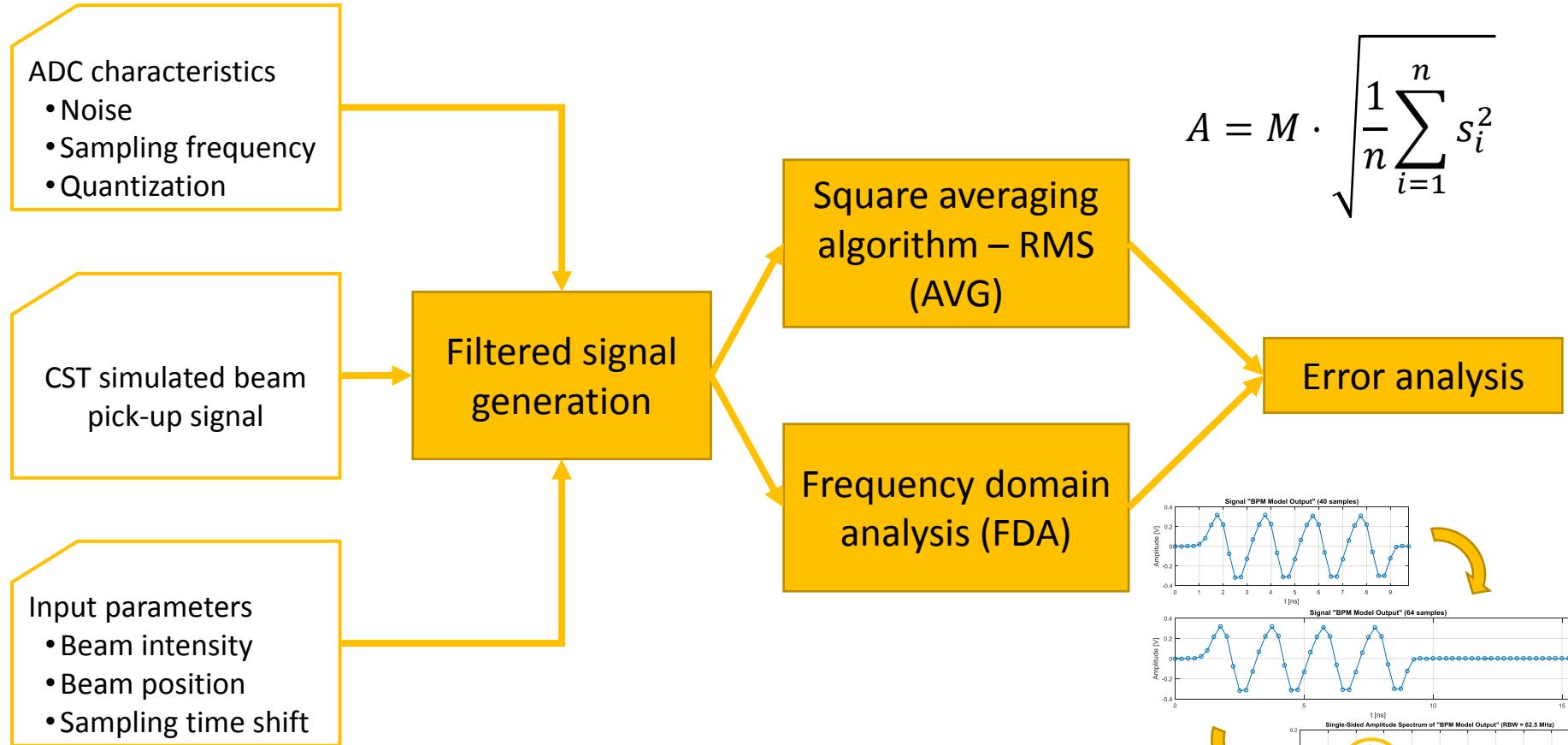
Single bunch



Doublet bunch

# Simulation Results

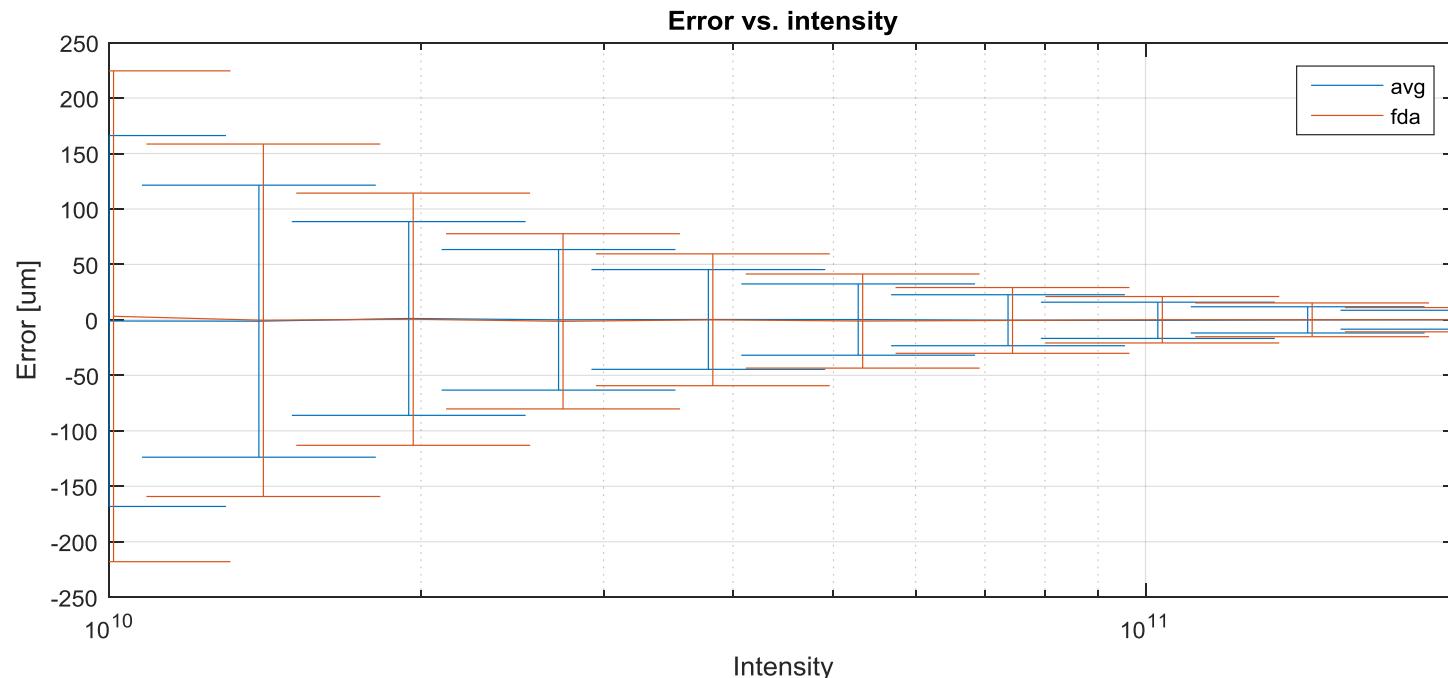
# Simulation Framework (MATLAB)



# Simulation Results (1)

- Sensitivity to intensity
  - Resolution  $< 100 \mu\text{m}$  for  $I > 1.6\text{e}10$  for AVG algorithm

Sim. parameters:  
• 12 bits @ 3.2 GHz  
• Random position  
• Random time shift  
•  $\sigma_{noise} = 380 \mu\text{V}$



# Simulation Results (2)

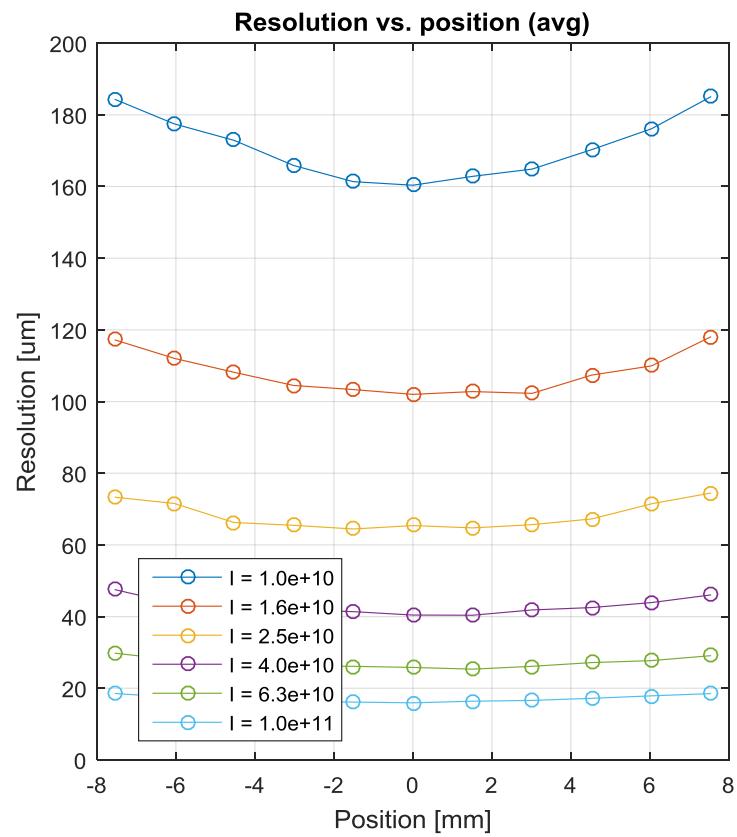
Sim. parameters:

- 12 bits @ 3.2 GHz
- Random time shift
- $\sigma_{noise} = 380 \mu V$

- Sensitivity to position
  - $\sim 25 \mu m$  @ lowest int.
  - $< 2 \mu m$  @ highest int.



- No sensitivity to time shift observed

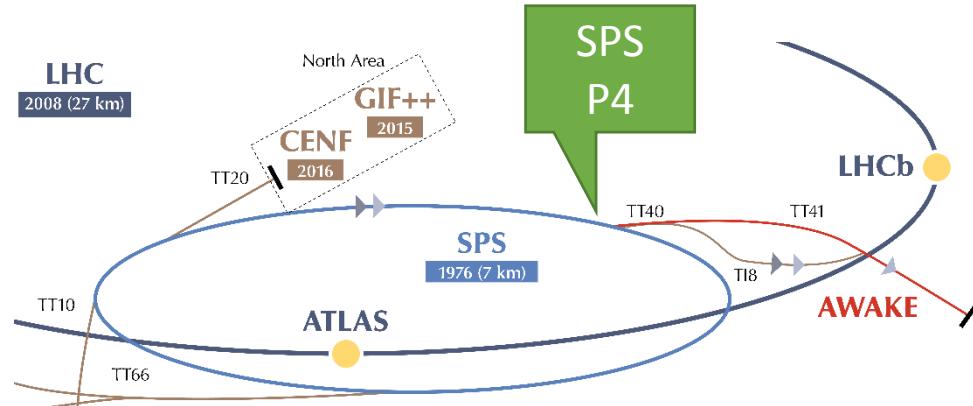


# Preliminary Measurement Results



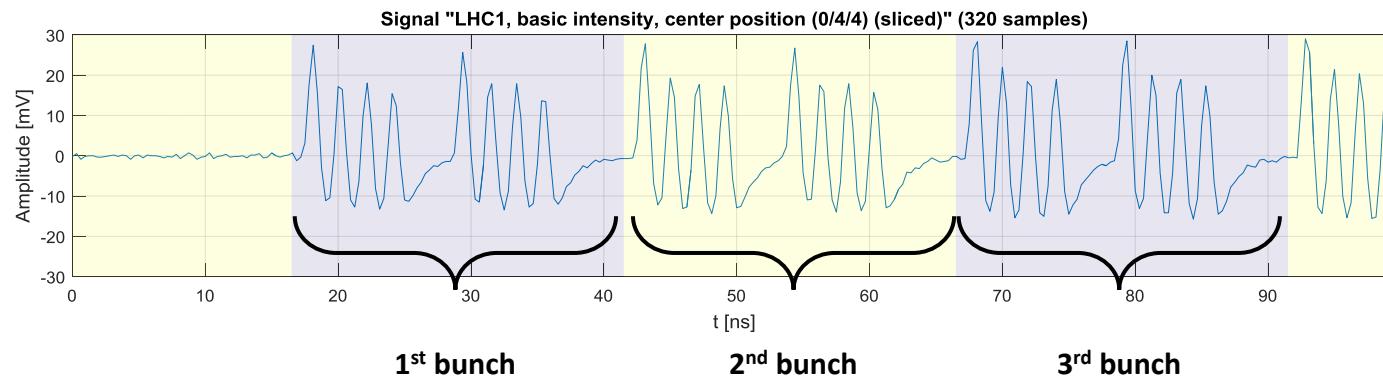
# Test Setup

- Conditions
  - SPS point 4
  - At flat-top (conditions similar to LHC)
    - Cycles: LHC1, LHCINDIV, LHCPILOT
  - One pick-up electrode split + attenuators
    - Fake intensity and position (not influenced by SPS position)
- Hardware & Software
  - SPS button pick-up BPMB42105, electrode UP
  - Prototype comb filter (designed by L. O. Bjorkqvist)
  - Vadatech FMC225 on VFC-HD (only saving raw data)
  - Python script for read-out, MATLAB for processing



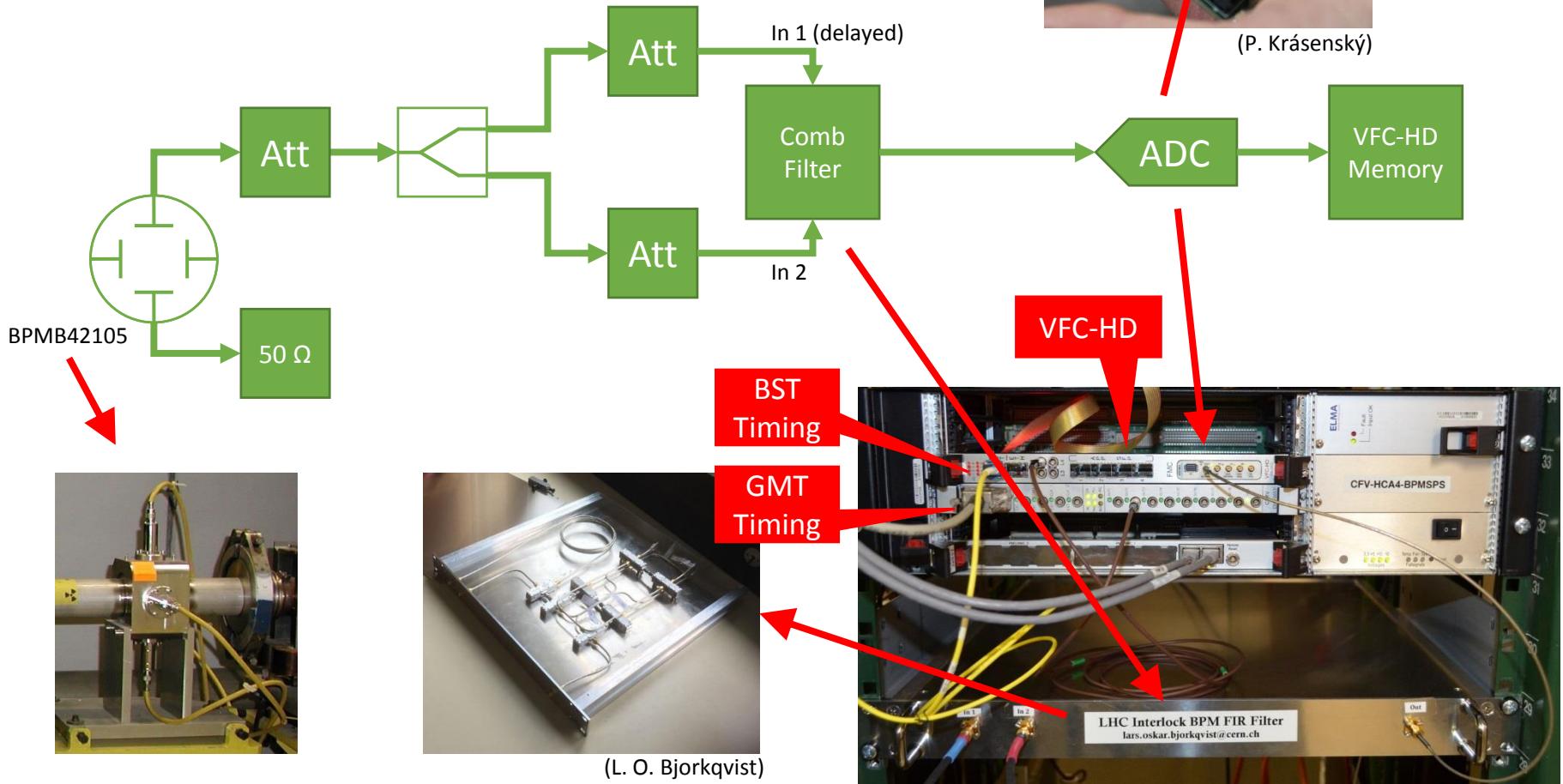
# Measurement Details

- Typical one-turn acquisition (first 100 ns):



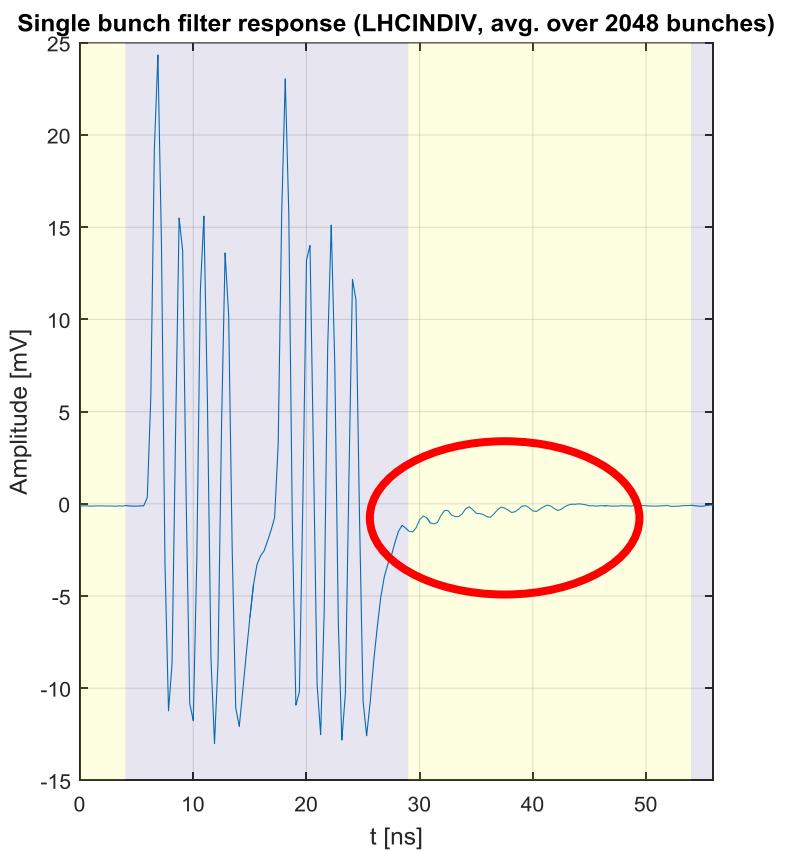
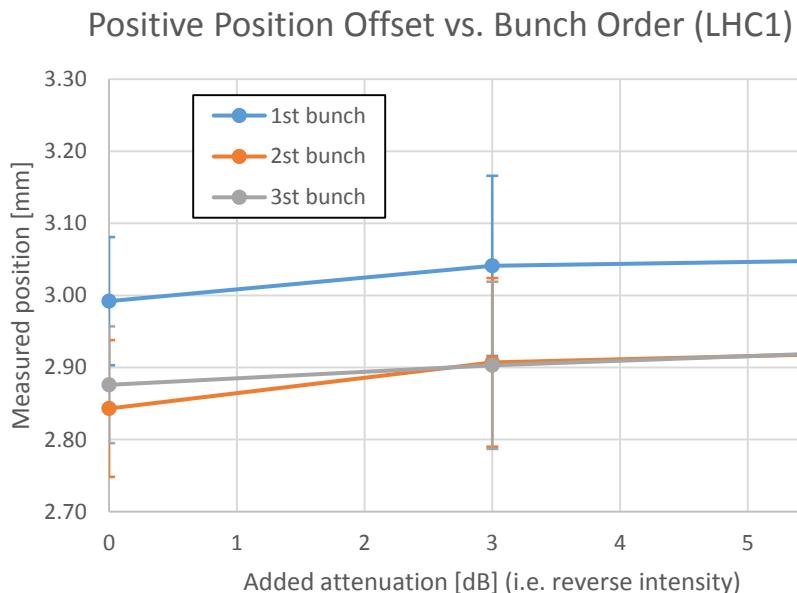
- Position calculated by square averaging algorithm
- Position mean and std. deviation calculated in [mm] according to the sensitivity of the target LHC pick-up (BPMSX) and averaged over 2048 turns.

# Test Setup – Overview

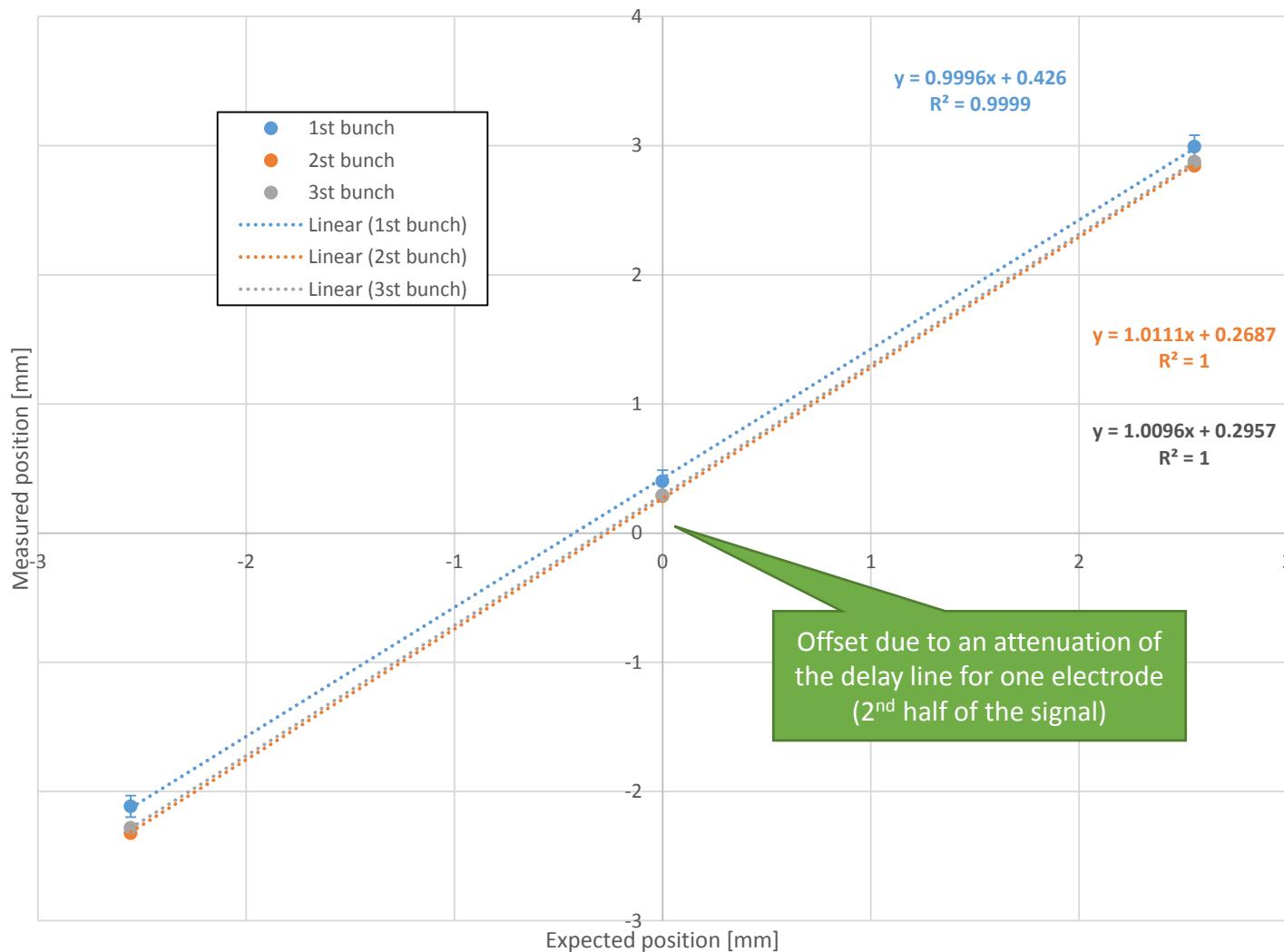


# Bunch Coupling

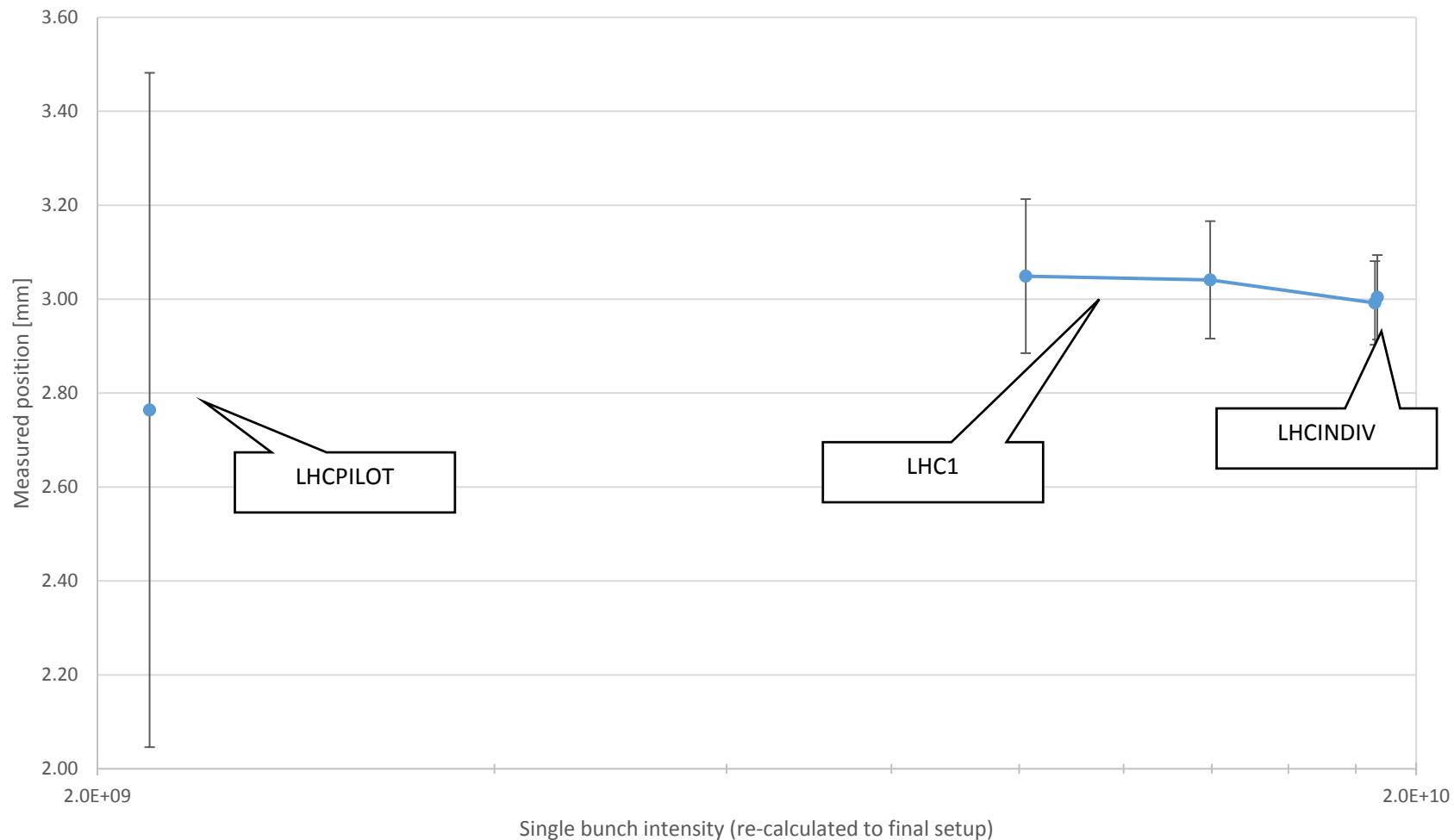
- Filter response > 25 ns
- Residual bunch-to-bunch coupling



## Calculated vs. Expected Position (LHC1, base intensity)

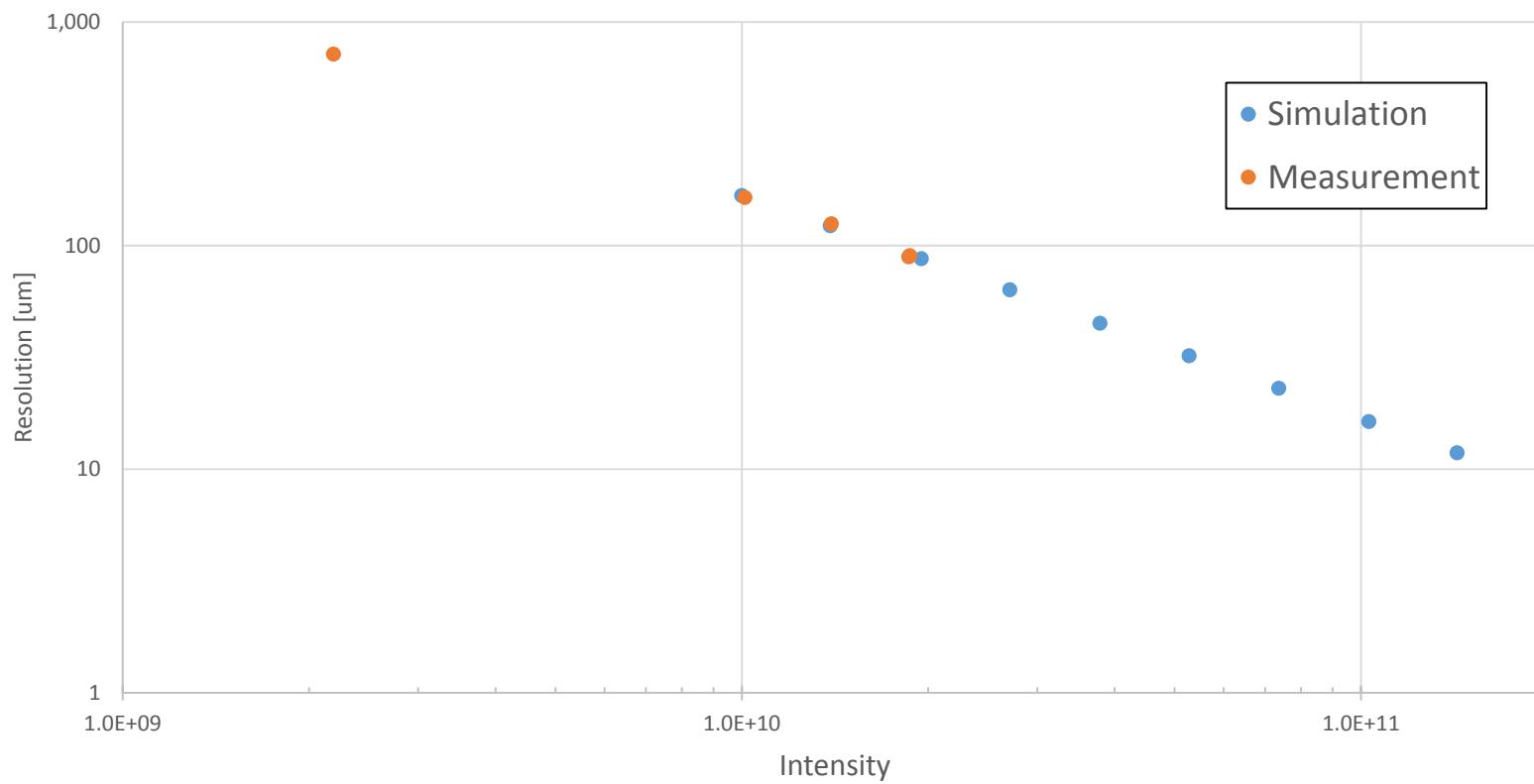


## Calculated Position of 1st Bunch vs. Intensity (positive offset)



# Simulation Crosscheck

Position Resolution vs. Intensity



# Summary

- Done
  - Testing framework + several algorithms crafted
  - Two algorithms (AVG, FDA) selected and tested
    - On simulated and real data, for 25 ns spacing
- Future work
  - Test algorithms with doublets (5 ns spacing)
  - Measure real data with doublets
  - FPGA implementation of algorithms

# References

- Vadatech FMC225:  
<http://www.vadatech.com/product.php?product=379>
- VFC-HD:  
<http://www.ohwr.org/projects/vfc-hd>