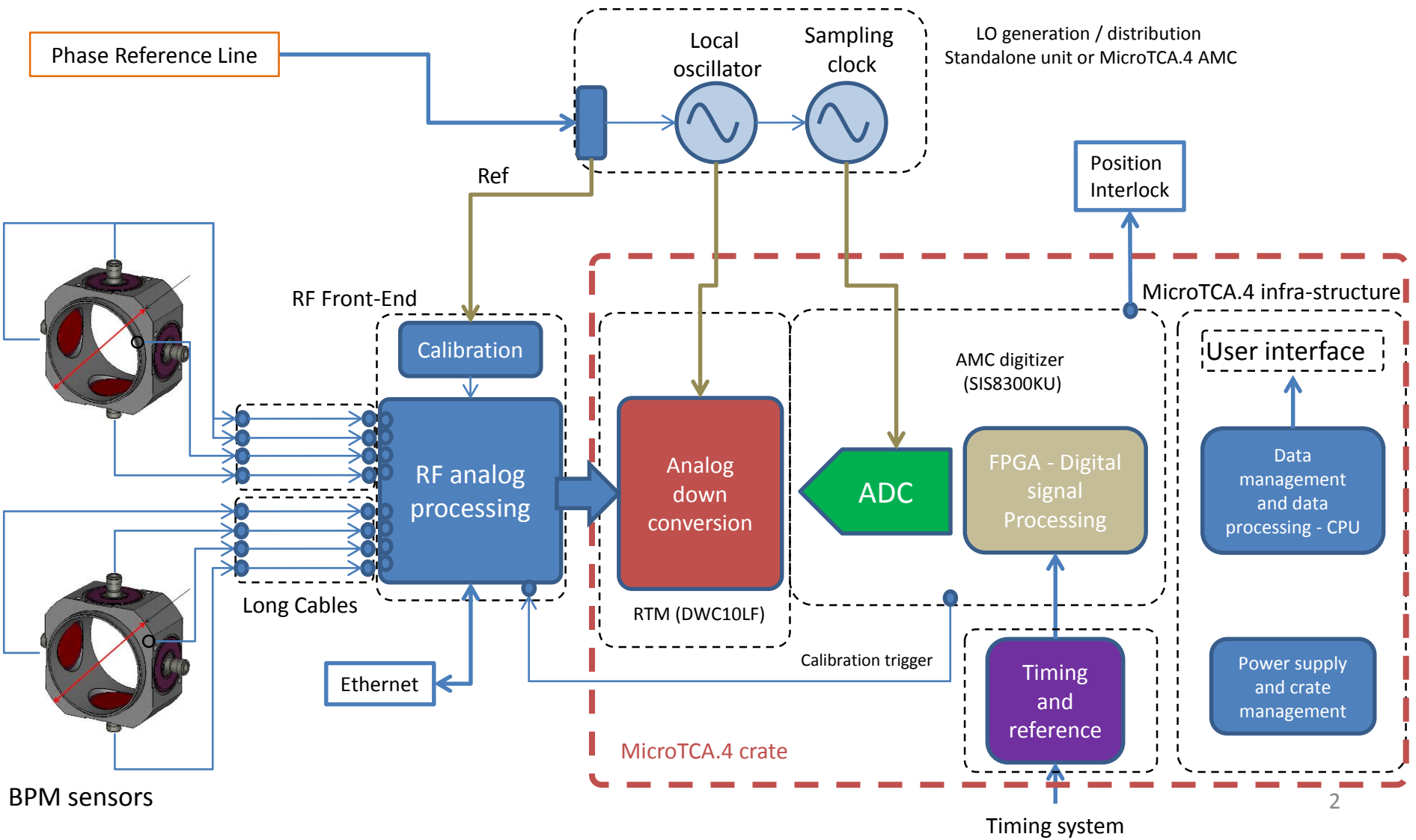
EUROPEAN SPALLATION SOURCE

BPM Electronics

Meeting BI forum

Rafael Baron
Lund - Sweden
2018 - Nov

BPM system


Phase Reference Line
Local oscillator
Sampling clock
LO generation / distribution
Standalone unit or MicroTCA.4 AMC
Ref
Position Interlock
RF Front-End
MicroTCA.4 infra-structure
Calibration
AMC digitizer (SIS8300KU)
User interface
RF analog processing
Analog down conversion
ADC
FPGA - Digital signal Processing
Data management and data processing - CPU
Long Cables
RTM (DWC10LF)
Calibration trigger
Ethernet
Timing and reference
Power supply and crate management
MicroTCA.4 crate
BPM sensors
Timing system

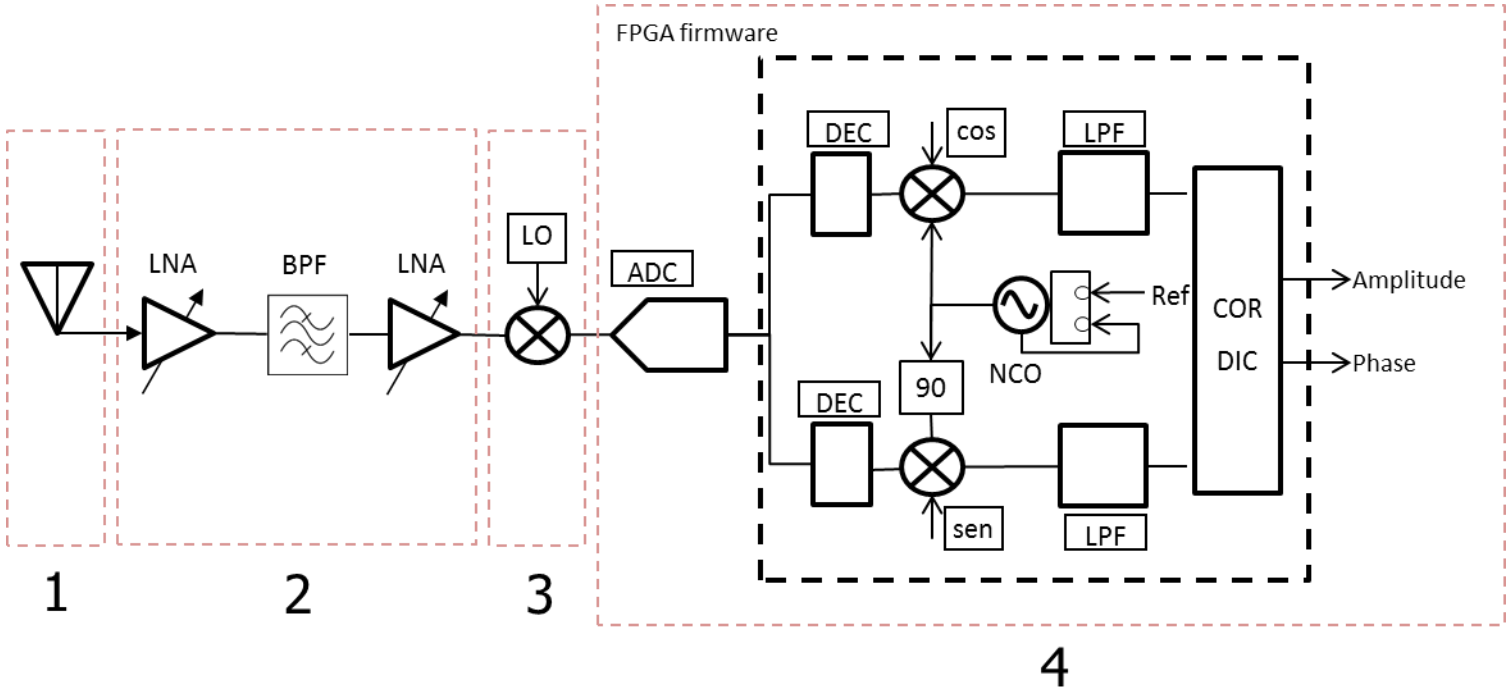
BPM System specifications

- Specifications

Parameter	Value	Comments
Beam phase accuracy for nominal beam	+/- 1 °	
Beam phase precision for nominal beam	0.2 °	1 MHz bandwidth
Beam phase accuracy for 6.3 mA beam and 5 us pulse length	+/- 2 °	
Beam phase precision for 6.3 mA beam and 5 us pulse length	2 °	1 MHz bandwidth
Beam phase accuracy stability over 8 hours for nominal beam	+/- 1°	
Beam position accuracy for nominal beam	+/- 200 um	
Beam position precision for nominal beam	20 um	1 MHz bandwidth
Beam position accuracy for 6.3 mA beam with pulse length of 5 us	+/- 400 um	
Beam position precision for 6.3 mA beam with pulse length of 5 us	200 um	1 MHz bandwidth
Beam position accuracy stability over 8 hours	1 mm	
Beam position dependence for 15 mm off-centered beam	+/- 200 um	
Beam position accuracy for 6.3 mA, 5 us pulse and de-bunched beam.	+/- 10 mm	
Beam position precision for 6.3 mA, 5 us pulse and de-bunched beam.	1 mm	
Phase and Position bandwidth	1 MHz	
Readout latency	2 us	
Current measurement resolution	0.5 mA	
Beam position interlock for horizontal and vertical position	-	Configurable circular threshold

BPM Electronics

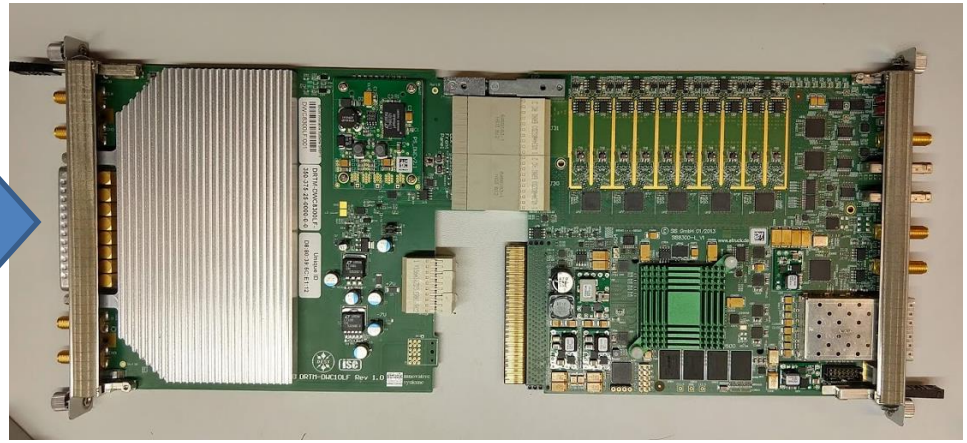
- FPGA-based radio receiver:
  - MicroTCA.4 based electronics.
  - RF Front-End unit for analog and RF processing (filtering, amplification, calibration).
  - Analog down-conversion for better phase resolution.
  - FPGA based for fast signal acquisition from high speed ADCs.



BPM Electronics

- Struck AMC and RTM
- In-house RF Front-End electronics
- External LO and CLK generation unit
- Custom FPGA firmware sharing as much as possible with LLRF as a design and long-term strategy.

RFFE unit for calibration, filtering and gain

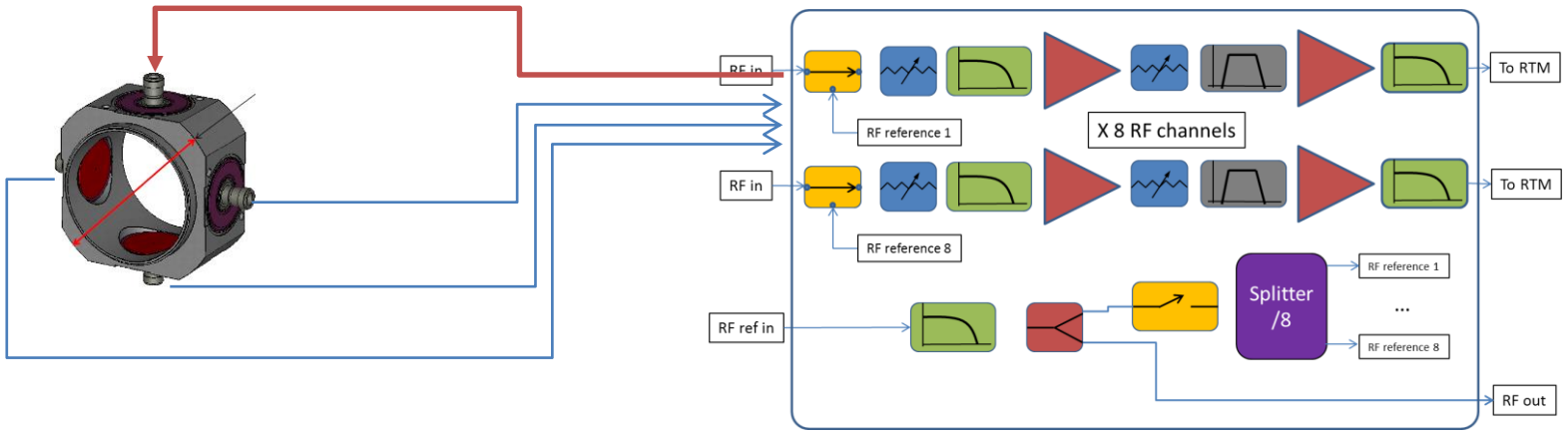


DWC8300-LF (352 MHz)
DWC8300 (704 MHz)

SIS8300-KU

BPM electronics RF Front-End

- BPM – RF Front-End unit:
  - Signal filtering
  - RF amplification for dynamic range
  - Long term drifts calibration



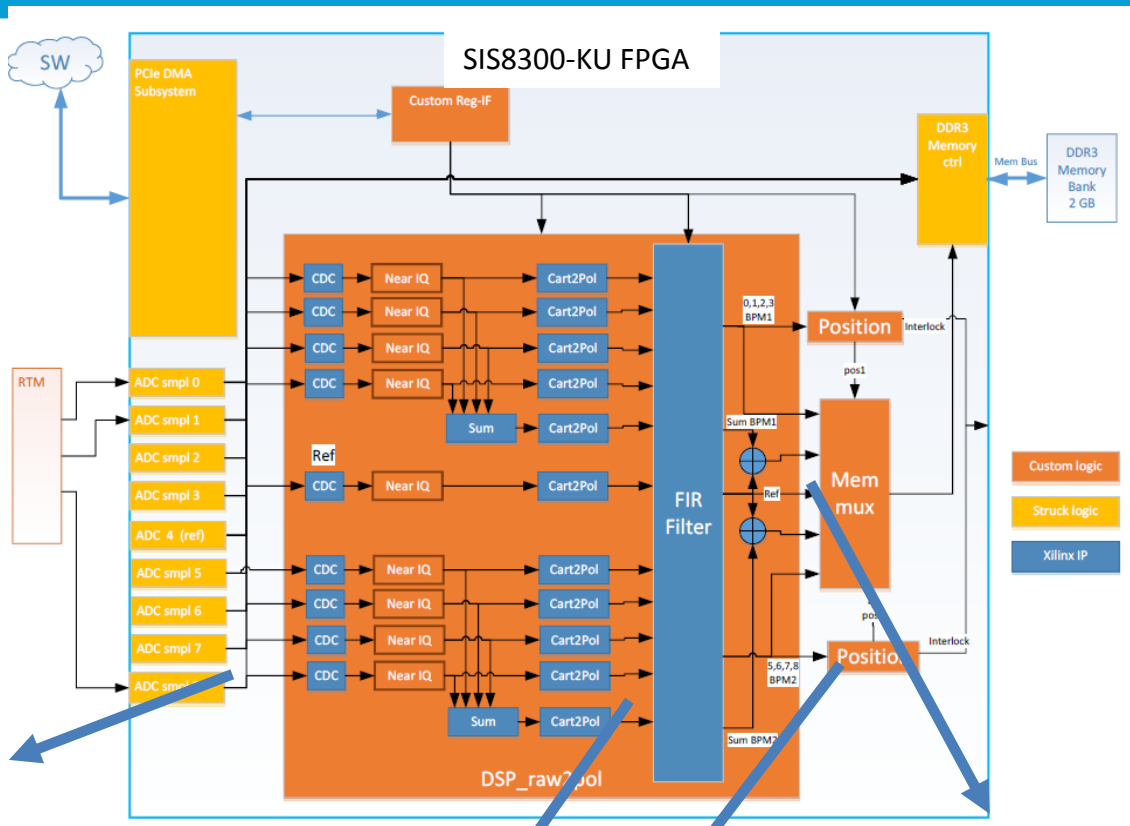
RFFE

New version will be send for production:

- Integrated LO and CLK (PLL-based)

BPM firmware

- Near-IQ
- FIR filtering
- Phase and position calculation
- Position interlock
- 2 BPMs per RTM/AMC



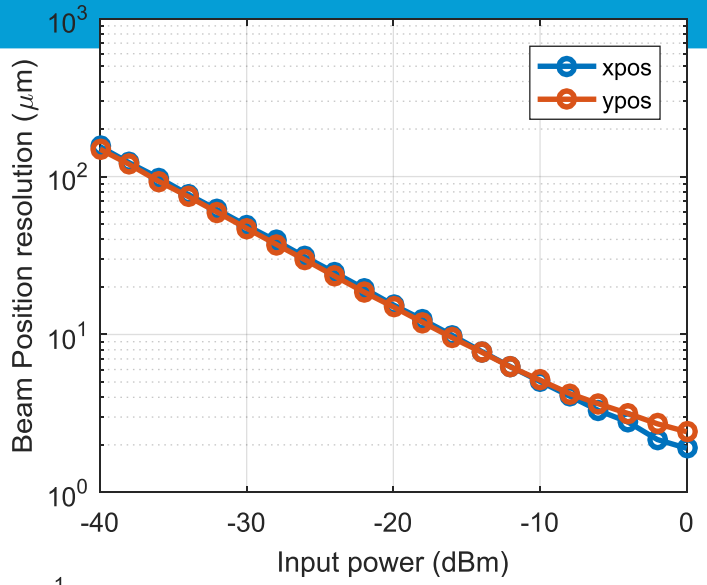
ADC RAW data (full pulse @ 88 MSPs)

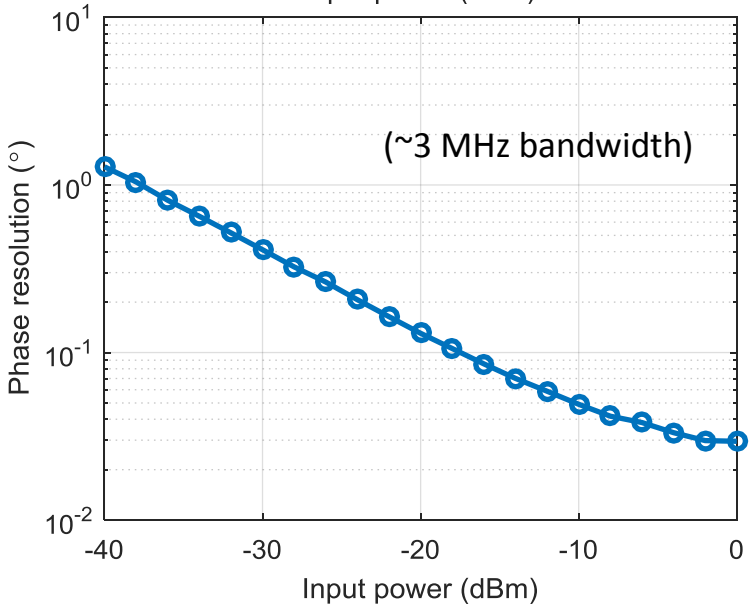
Amplitudes and phases (@ 5.8 MHz)

Individual BPM and differential phases

Position X and Y

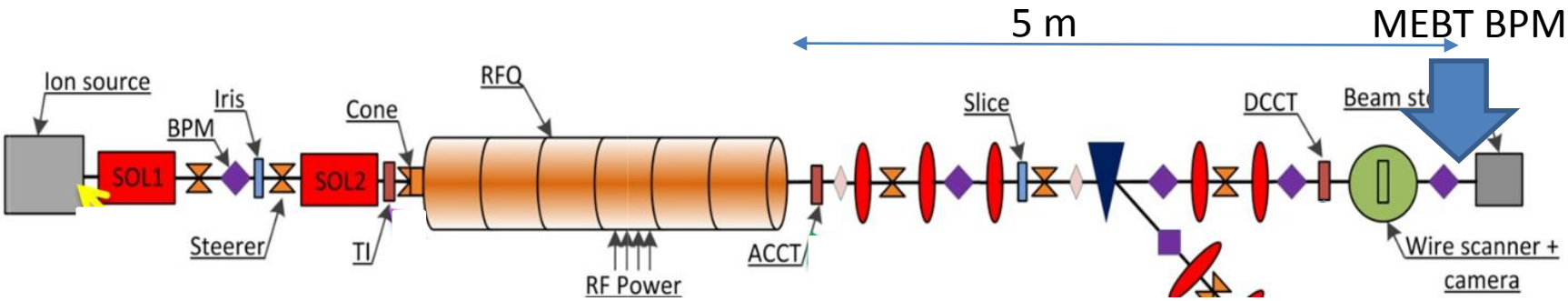
BPM Electronics performance

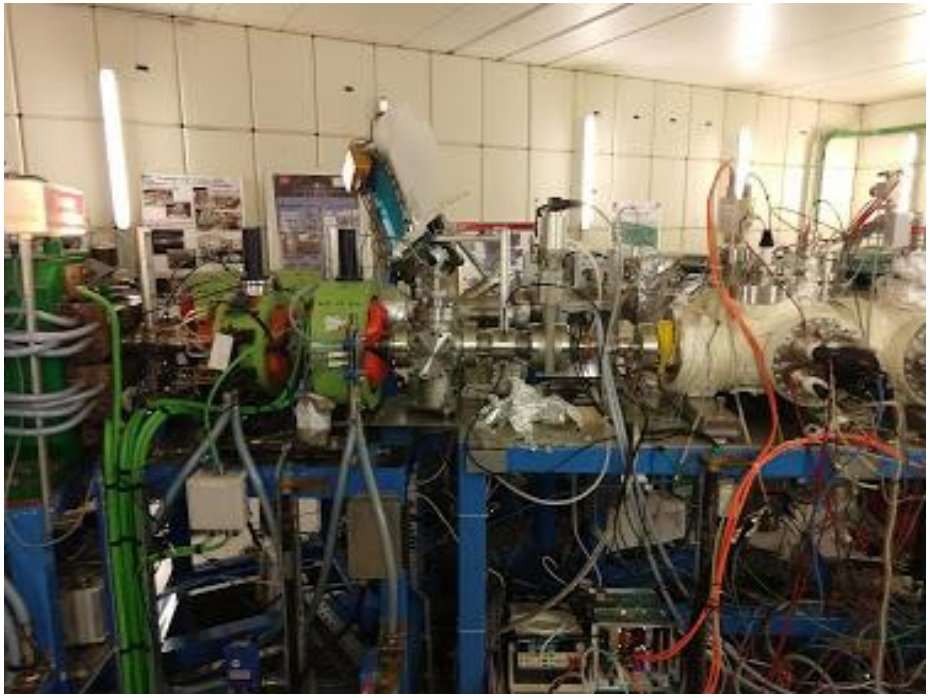




CEA Saclay IPHI tests

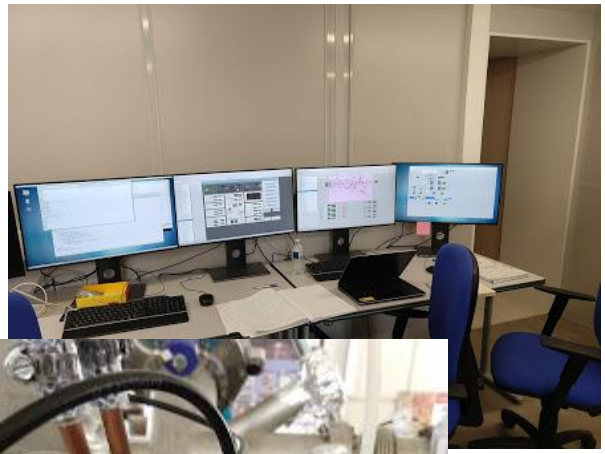
3 MeV, 0.4 mA to 50 mA, proton beam, 352.2 MHz RF

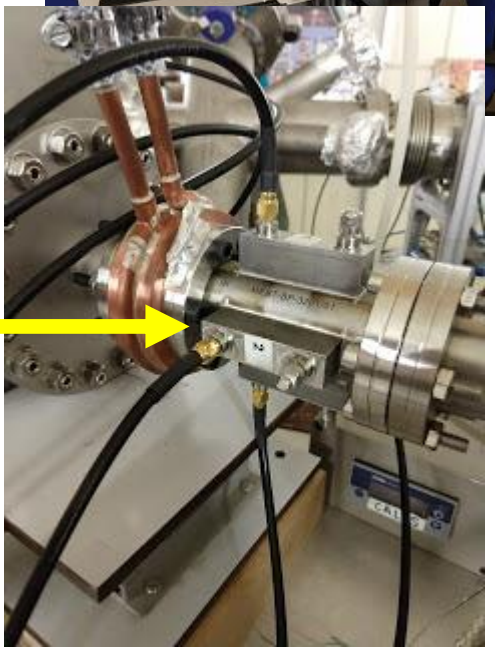




CEA Saclay IPHI tests

3 MeV, 0.4 mA to 50 mA, proton beam, 352.2 MHz RF





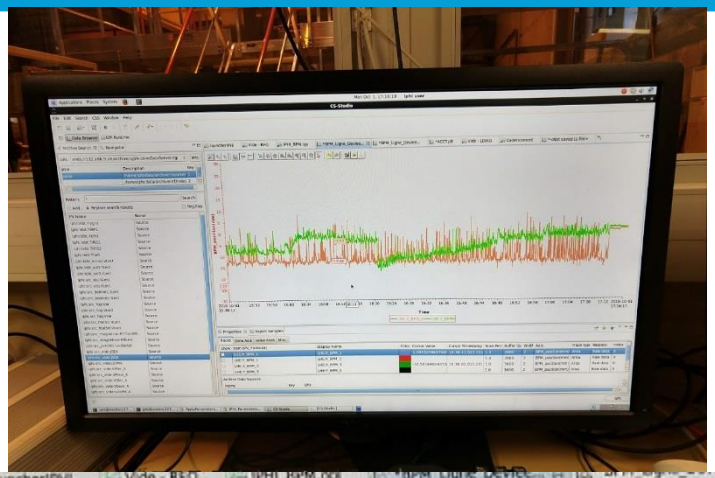
ESS Bilbao MEBT
BPM sensor

CEA Saclay IPHI tests

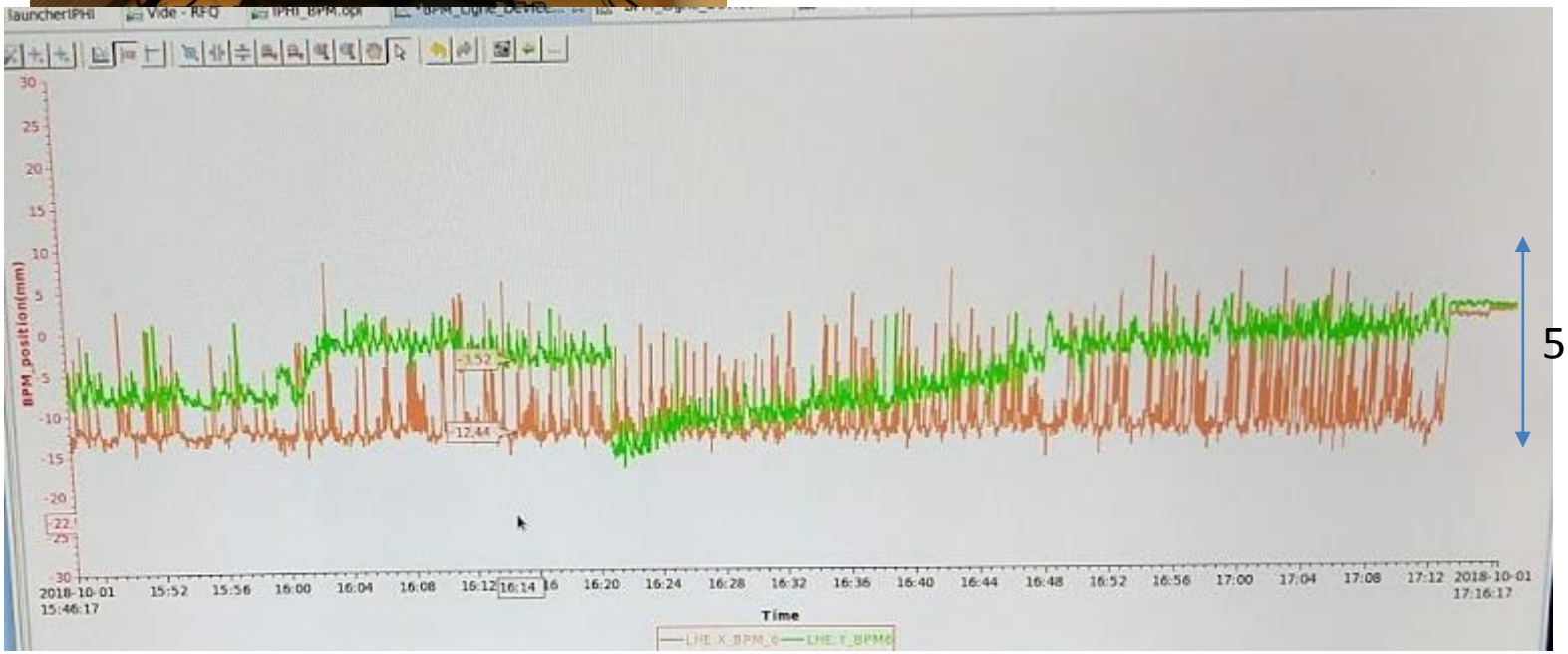
EUROPEAN SPALLATION SOURCE

Test/task	Test description	Priority	Check
High frequency response to short beam	Investigate possible errors introduced on the measurement due to high frequency components of the beam signal.	Day1	ok
Phase and position resolution	Phase and position resolution as function of the beam current.	Day1	ok
BPM self trigger for low current beam	Test the feature for low current and real beam. Test for ESS commissioning beam. Find the correct values.	Day1	ok
Set the correct BPM sensitivity factor for position measurements.	Check the correct values from Seadat simulations	Day1	ok
Beam current dependence	Change beam current and measure the position and phase dependence introduced by the measurement system.	Day2	ok
Beam energy dependence	Verify how the BPM system responds as function of the energy.	Day2	not possible
Measurements at different frequencies	After checking the signal amplitude at 352 and 704 MHz harmonics, check the response to both harmonics.	Day3	ok
Measurements at 352 MHz	Repeat measurements for the 352 MHz harmonics.	Day3	ok
Check the response to different matching schemes	Short, 50 Ohms and open configuration. Measure position and phase resolution. Analyze the raw data spectrum and the oscilloscope time domain measurements to the three different schemes.	Day4	not possible
Long term measurements	Acquire several measurements	Day5	ok
Current sweep for short pulse	150 us pulse length and current from 3 mA to max	Day 2	ok
Beam energy measurements	Time of Flight measurements	Day 3	ok
Bunch length measurements	Compare the bunch length at 352 and 704 MHz by measuring the 2nd and 3rd harmonics	Day 5	ok
Correlate NMP and BPM measurements	Steering experiment by changing the vertical beam position and comparing BPM data to NPM data.	Day 4	ok

CEA Saclay IPHI tests

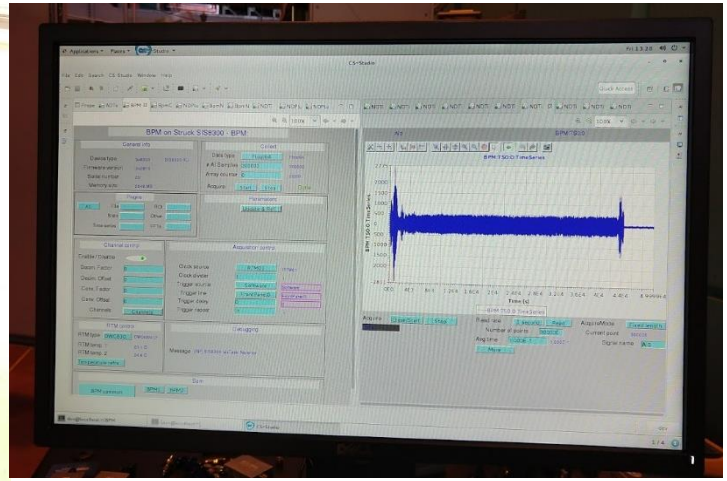


- CEA Saclay BPM electronics can measure 4 points per pulse (low sampling rate).
- Pulse-to-pulse beam position variations in the order of mm.
- Not possible to measure intra pulse for diagnostics and beam improvement.

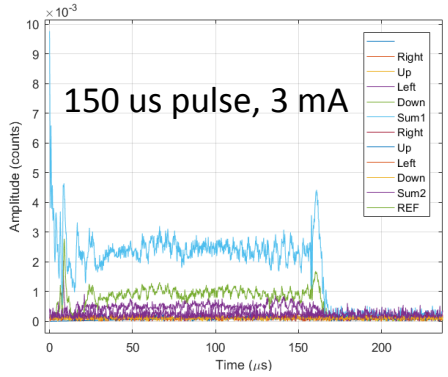


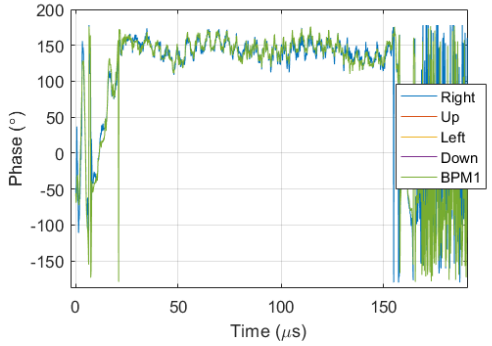
CEA Saclay IPHI tests

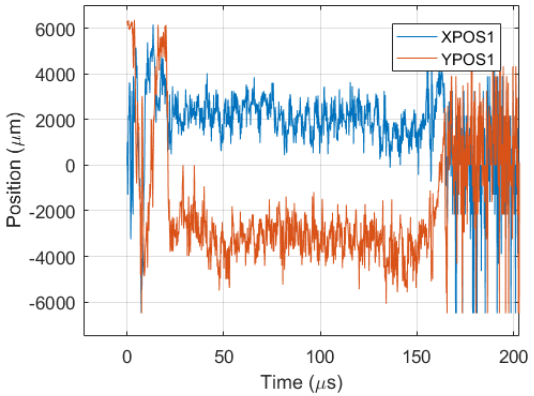
- Complete BPM rack with MicroTCA.4 electronics
- Standalone unit
- Self-trigger
- Cables + RFFE + MicroTCA.4
- Local IOC



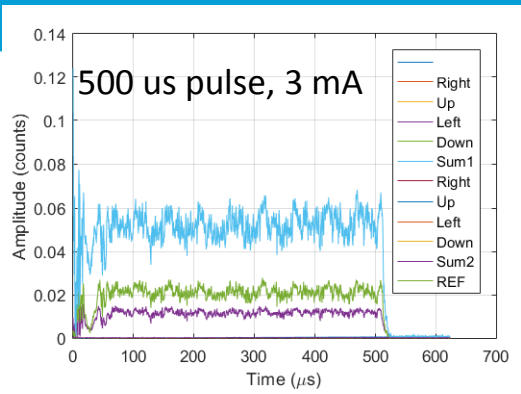
CEA Saclay IPHI tests

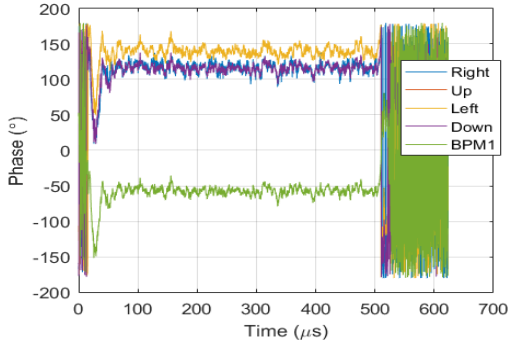


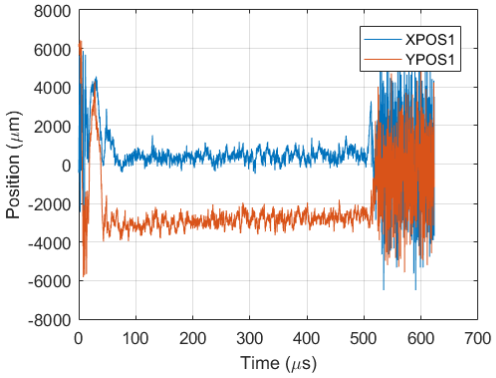




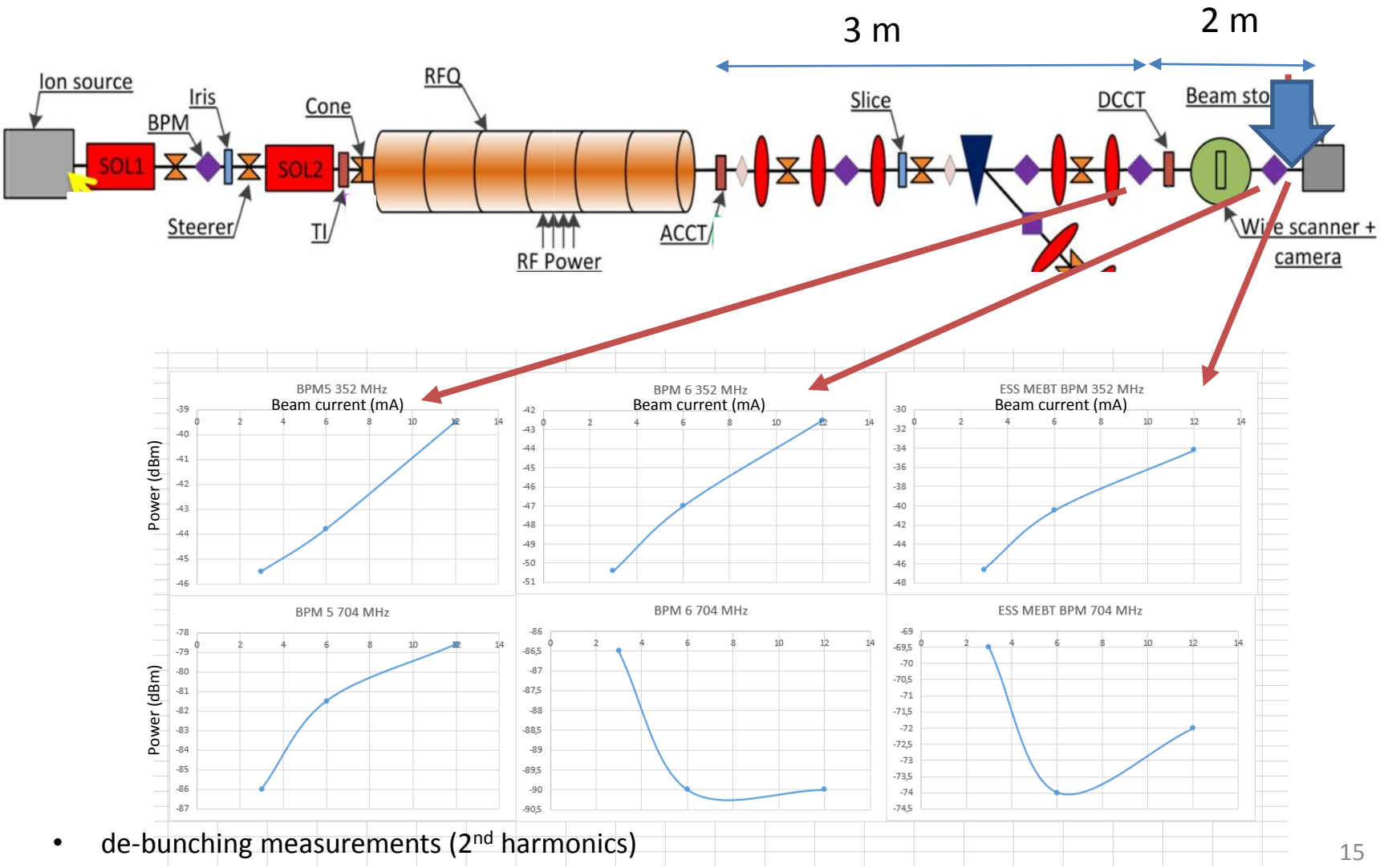
After 2 days of debugging and increasing the amount of H+ gas at the source:







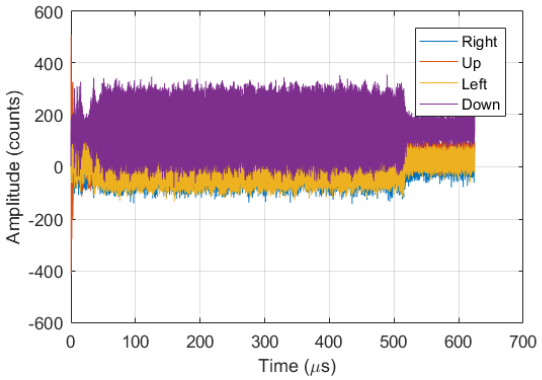
BPM electronics beam tests

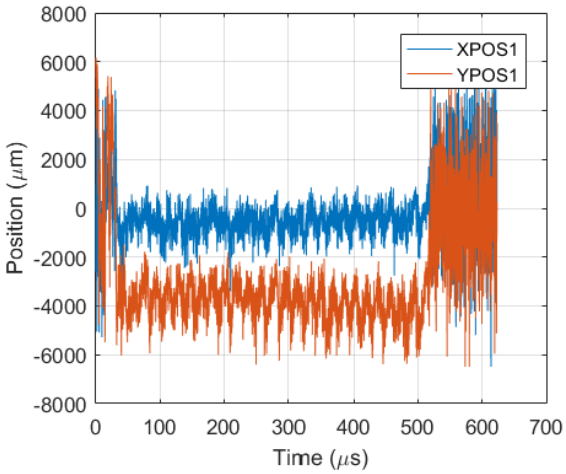


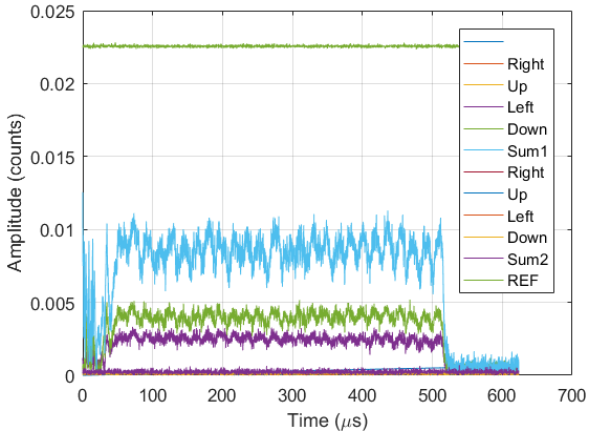
- de-bunching measurements (2nd harmonics)
- Bunch length measurements

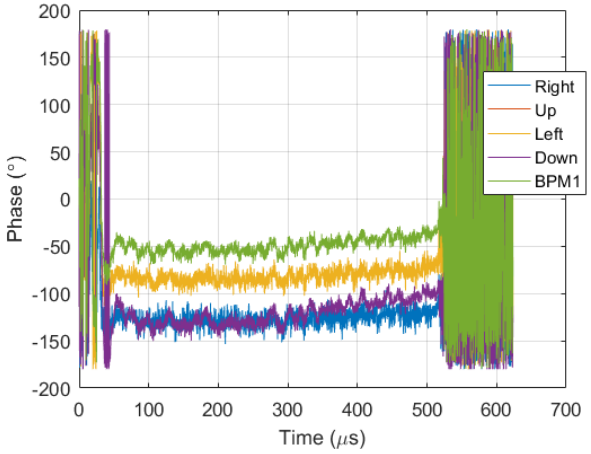
CEA Saclay IPHI tests

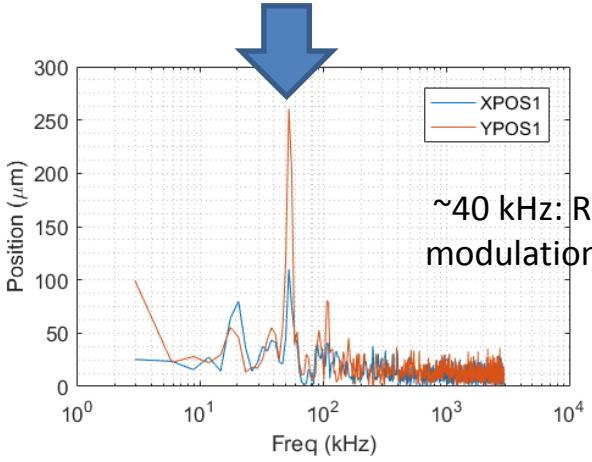
500 us pulse, 0.4 mA. Iris on the limit.







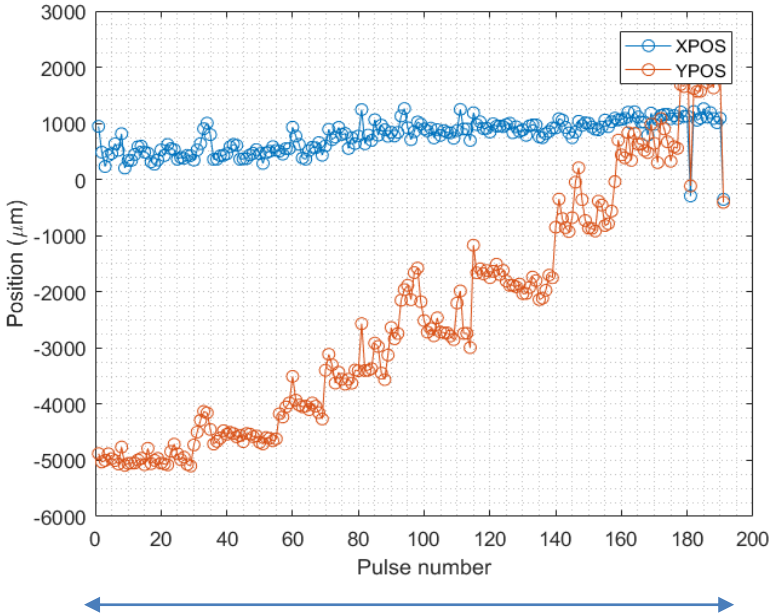




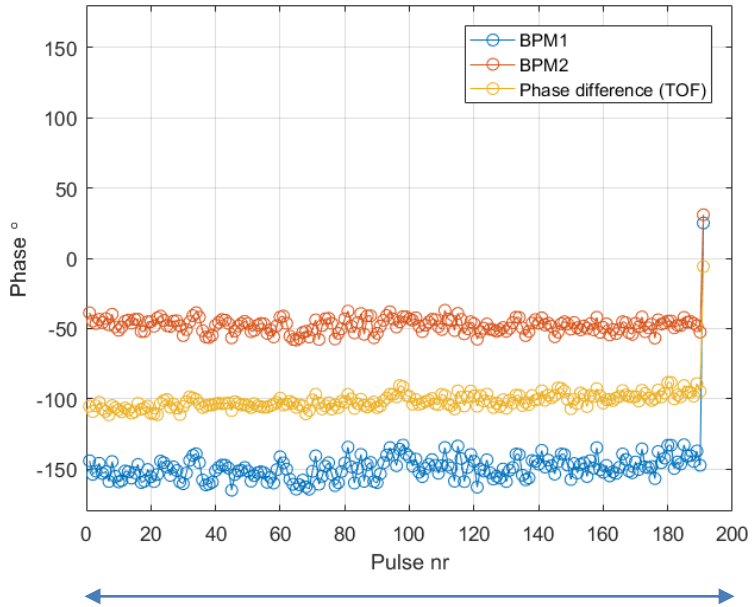
~40 kHz: RF modulation or Magnetron modulation (Power supply)

BPM electronics beam tests

→ Beam steering tests:
- → Vertical dipole to move the beam.
- → Phase monitoring using 2 BPM (TOF measurements)
- → Monitoring beam energy stability (TOF)



~5 minutes

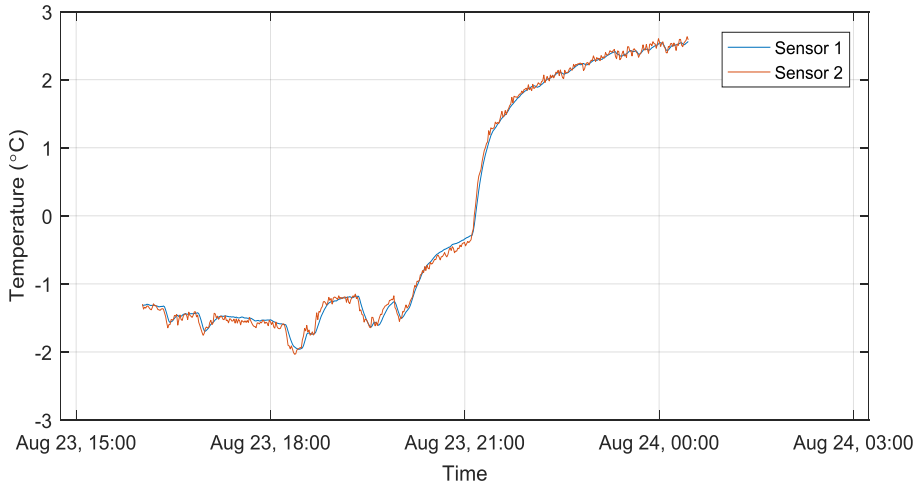


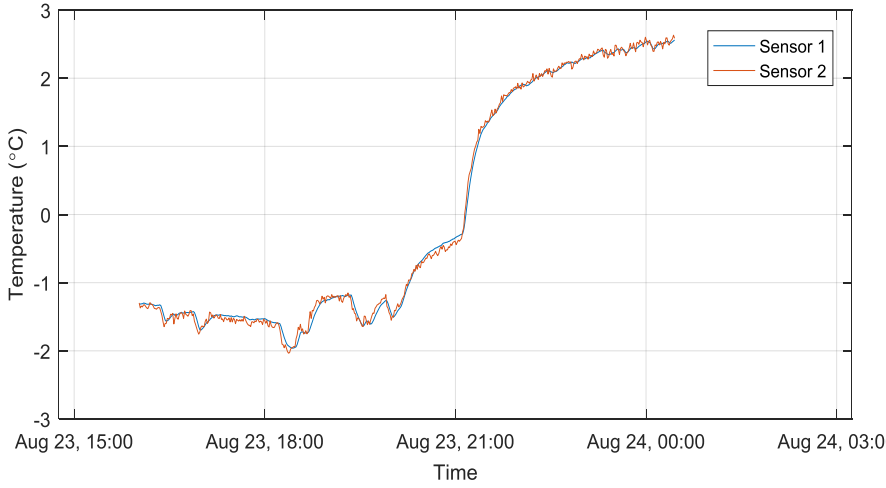
~5 minutes

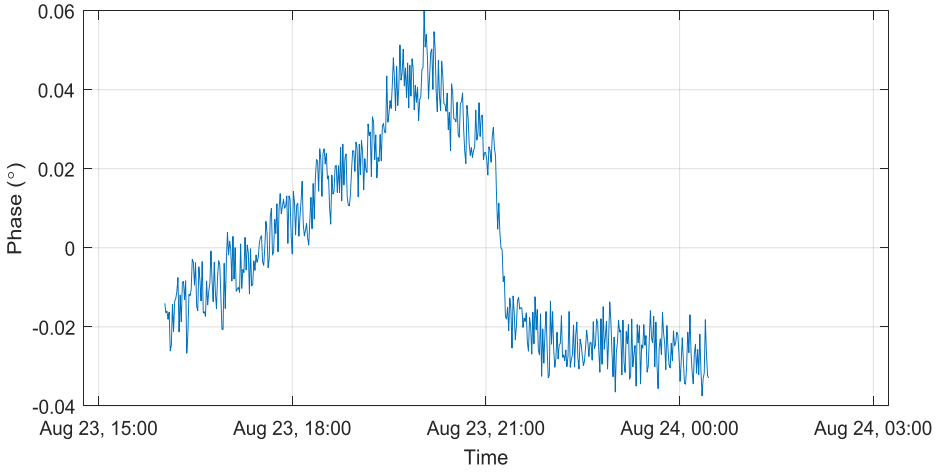
BPM System

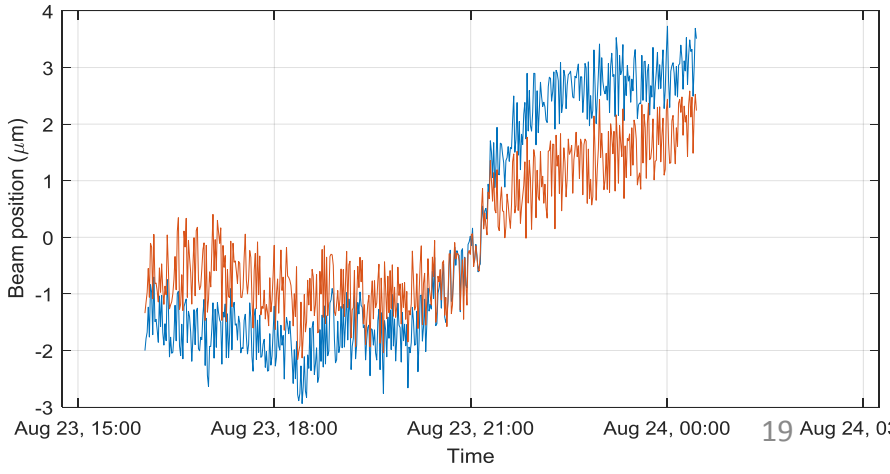
- Thanks!
- Questions?

Backup slides

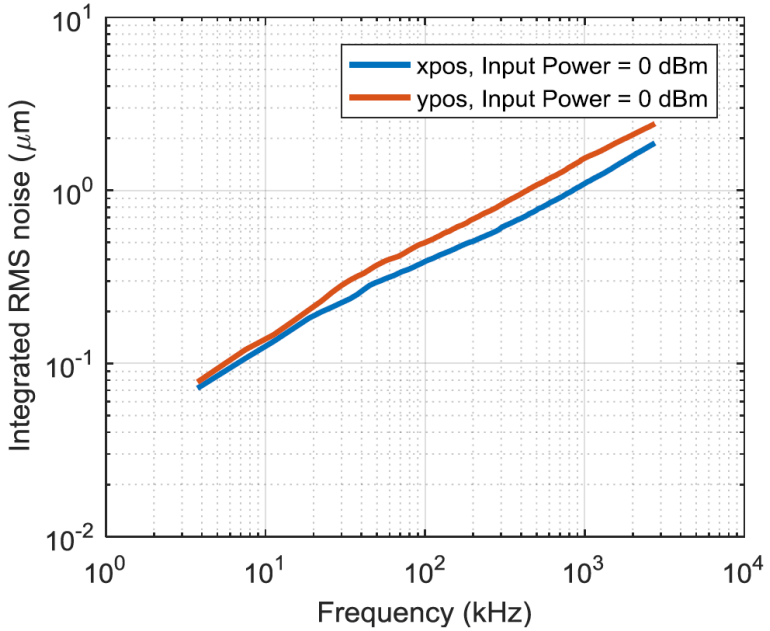




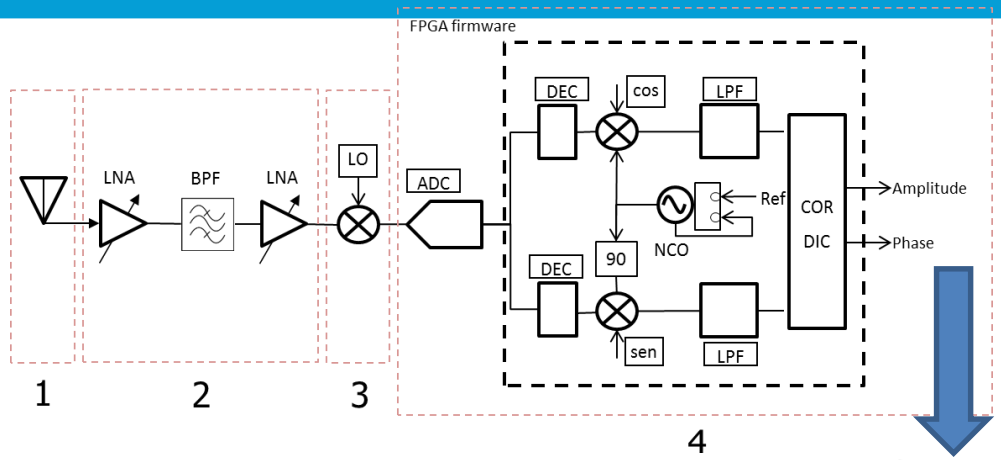


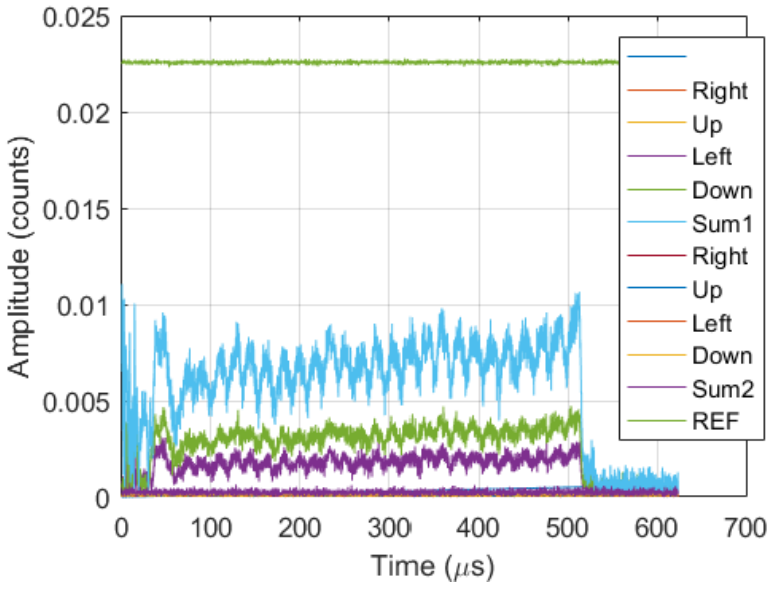


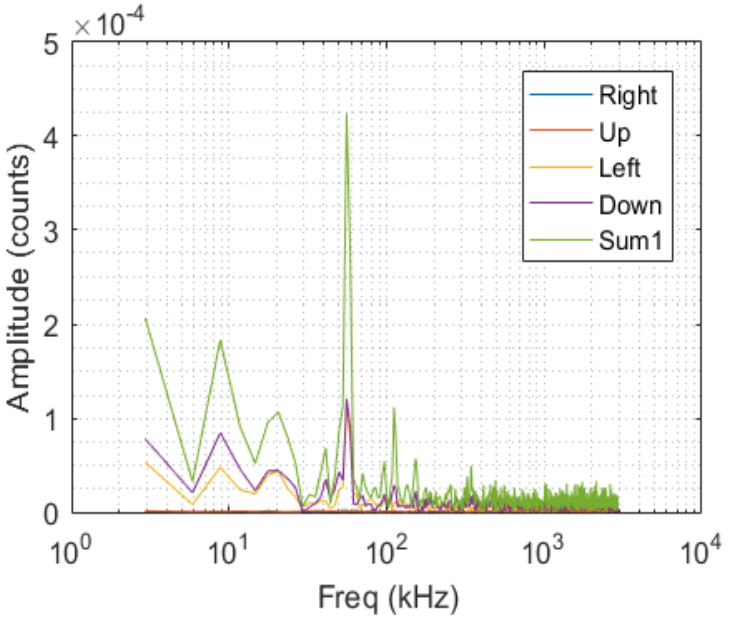
Backup slides



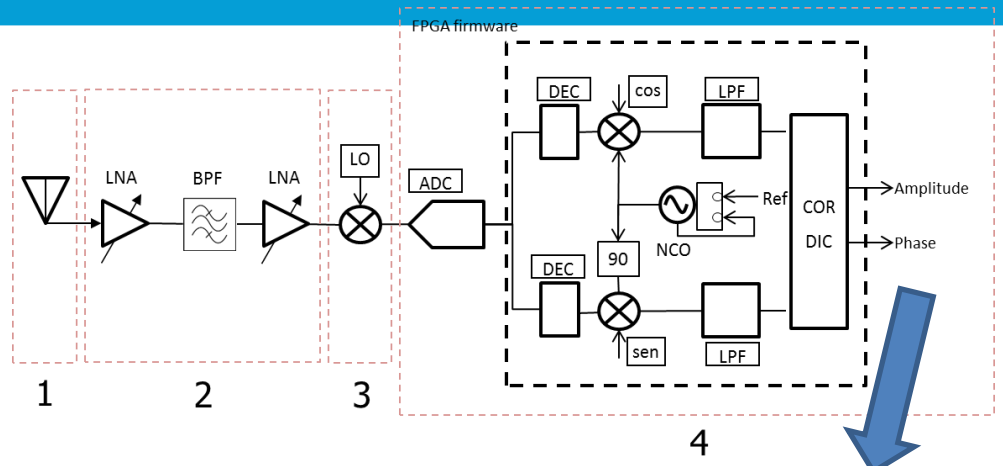
Backup slides

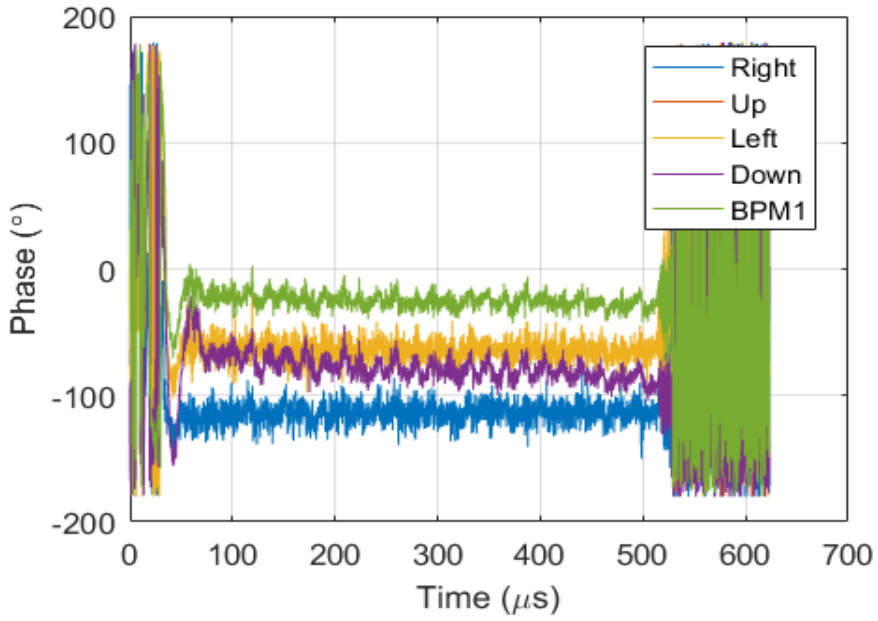


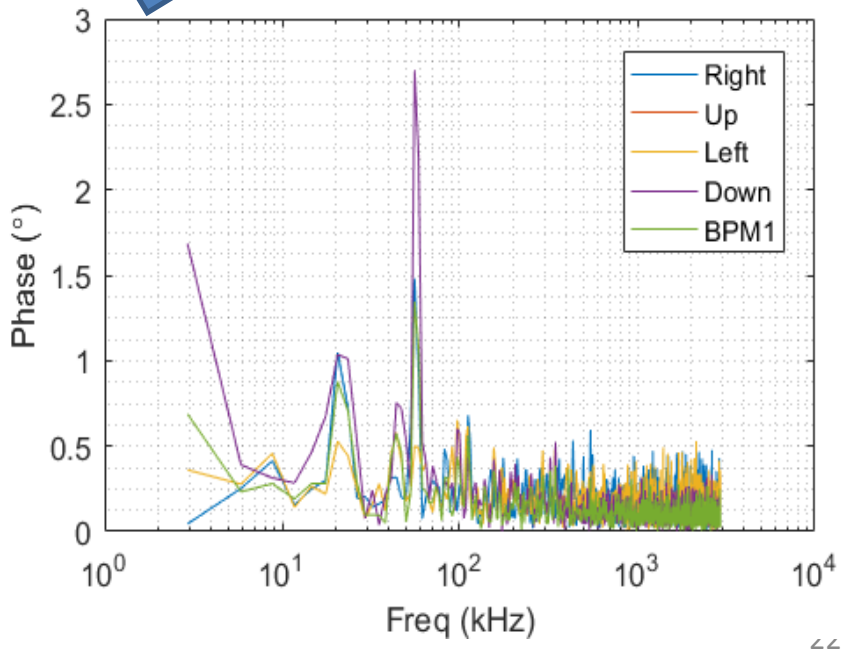




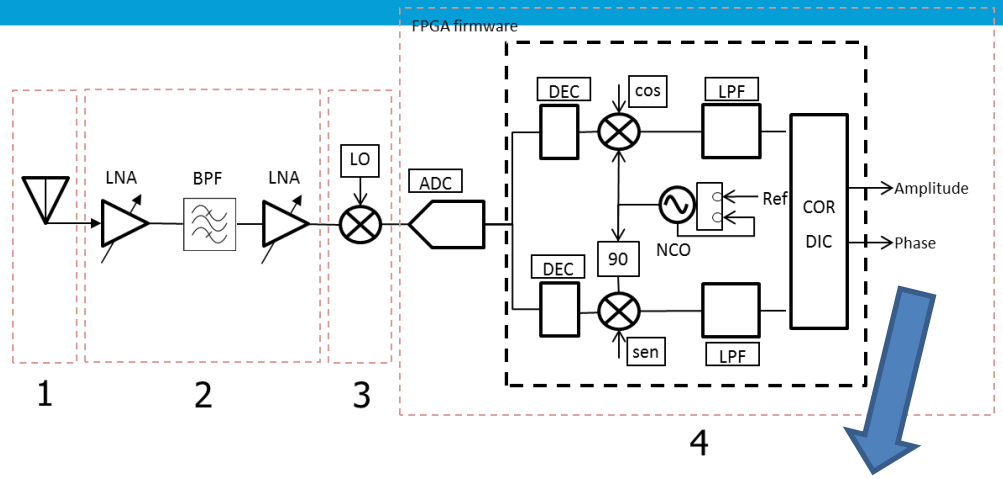
Backup slides

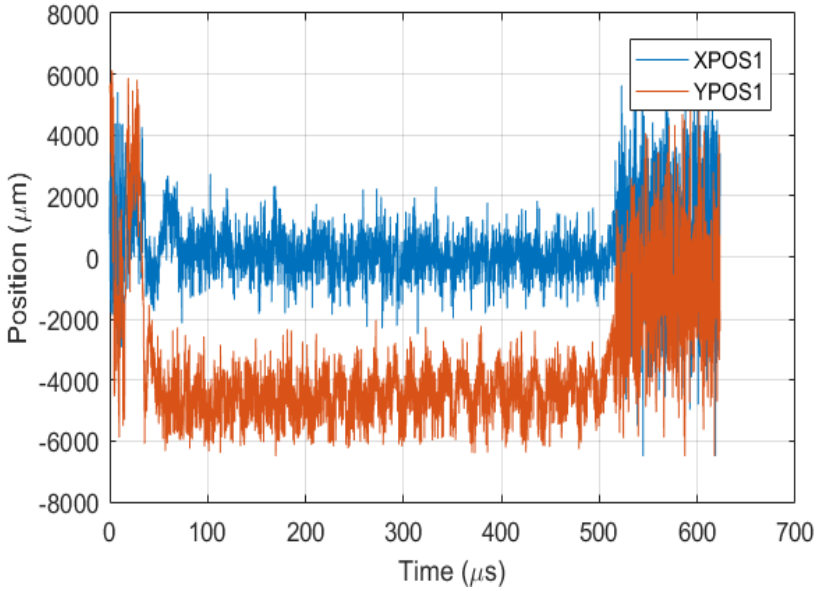


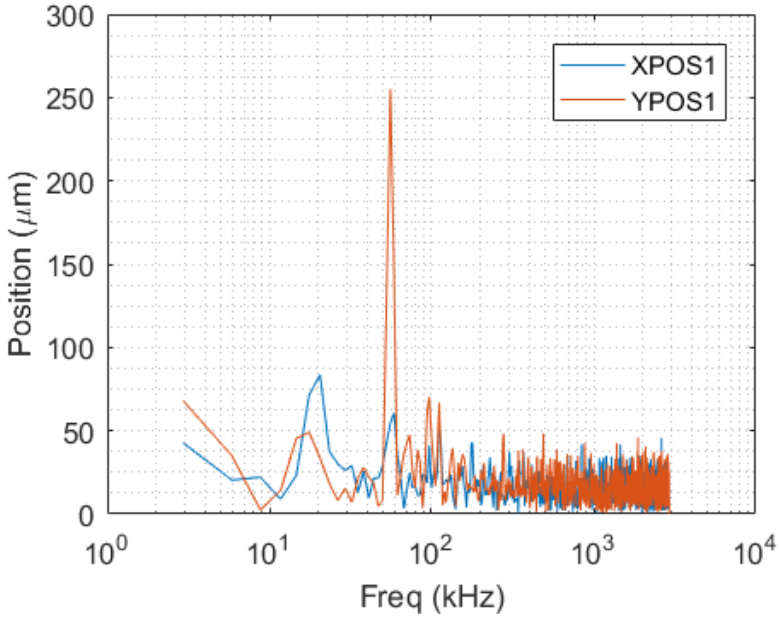




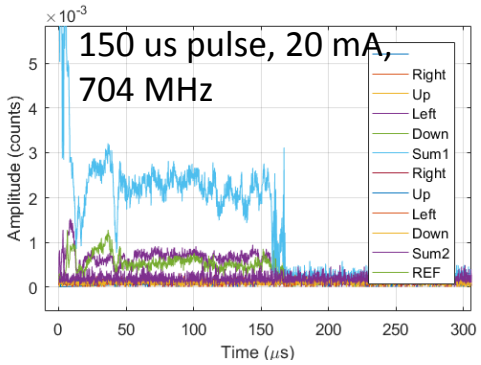
Backup slides

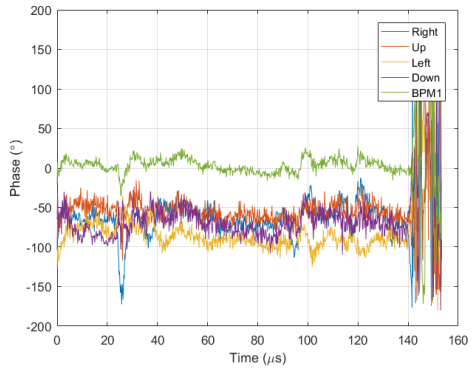


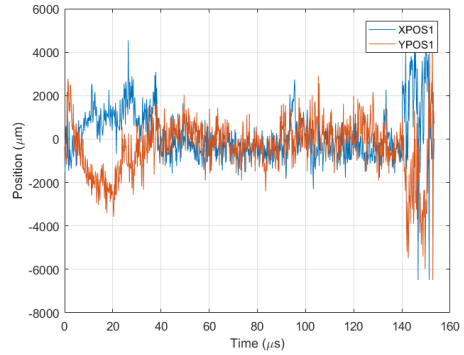




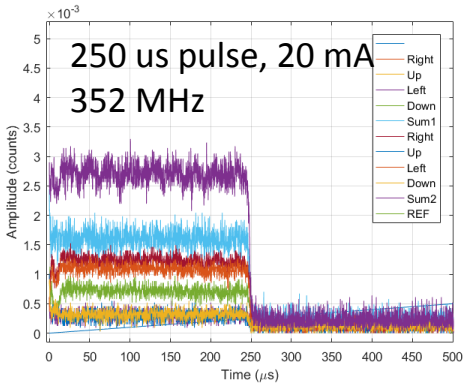
CEA Saclay IPHI tests

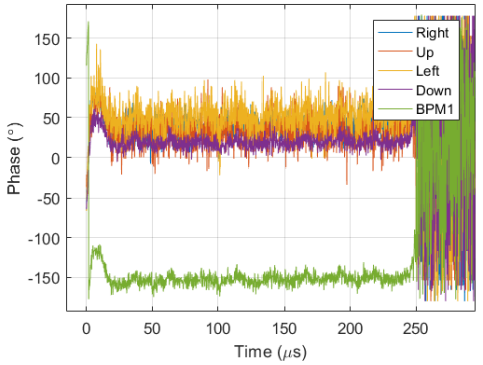


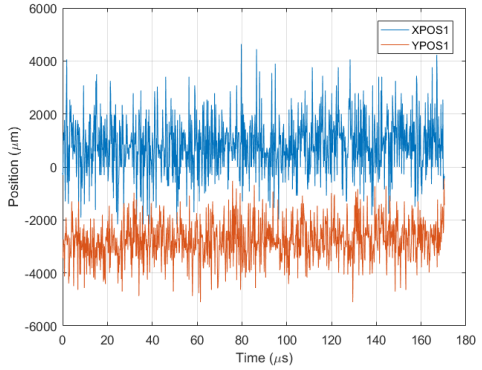




After increasing the amount of H+ gas at the source:







BPM Electronics