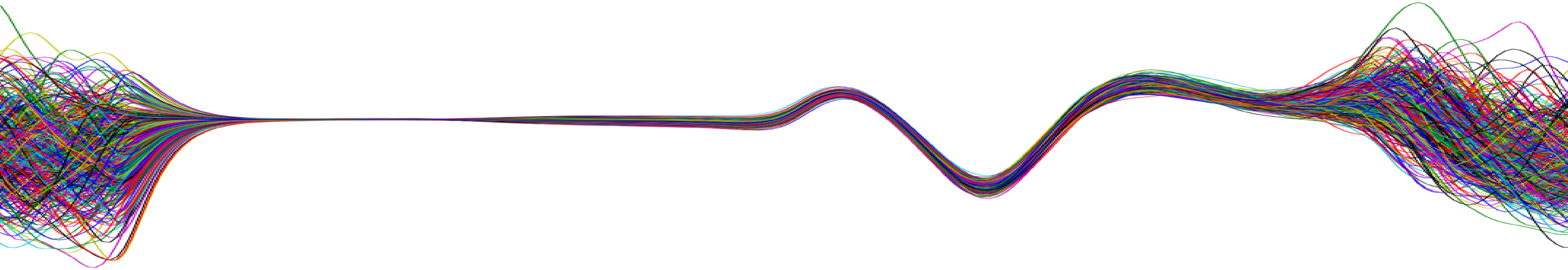
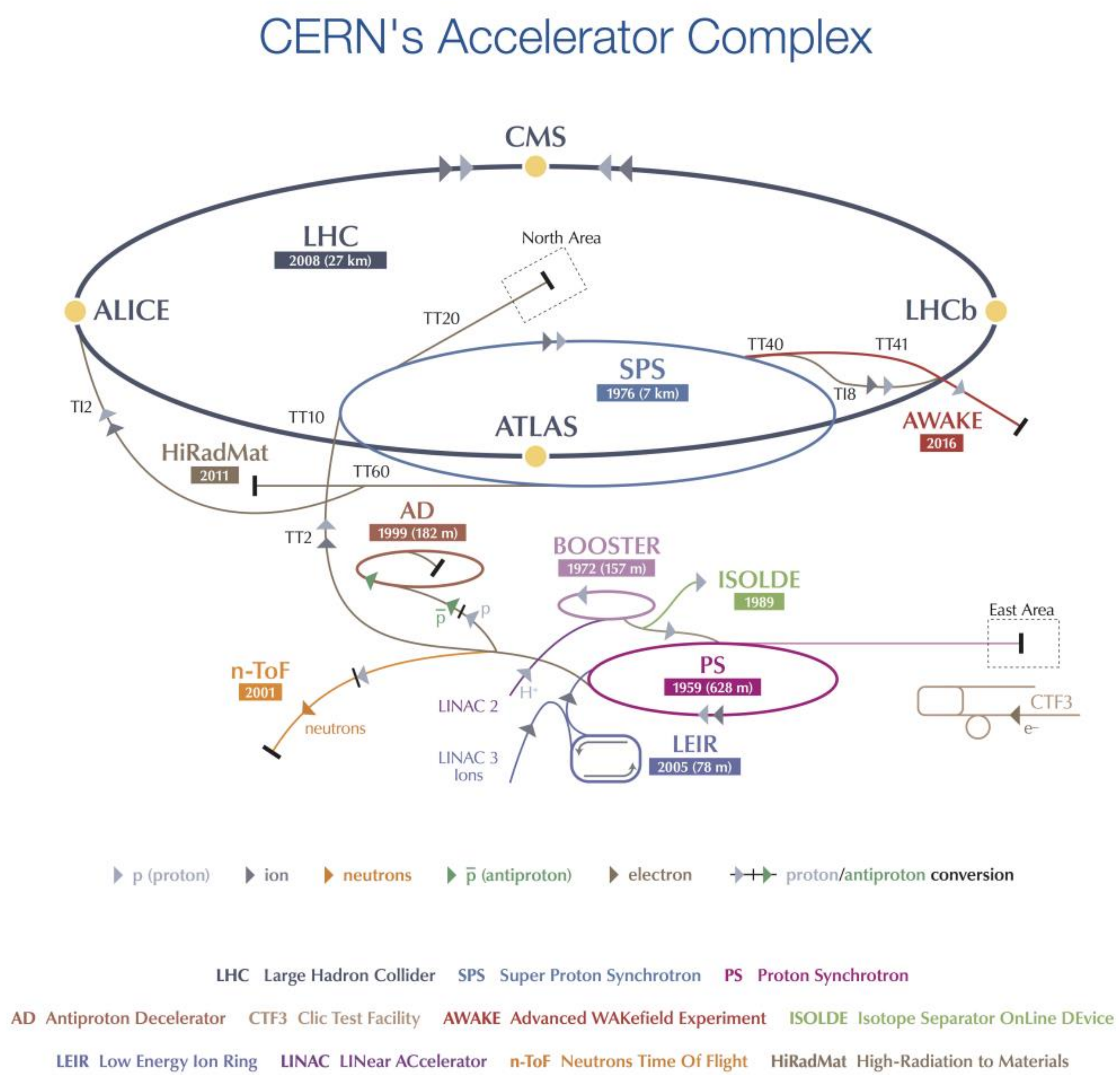
Performance of the new Logarithmic Amplifier based Electronics developed for the SPS at CERN



Outline

- SPS beam specifications
- Beam positions monitors
- SPS infrastructure
- Front end hardware
- Lab results
- Preliminary measures with beam
- Conclusions



SPS Beam Specifications

SPS Beam Type	Bunch spacing	Bunch number	Bunch charge $[10^{10}]$	Bunch length [4σ: ns]
SFTPRO 5nS	5 ns	400-4000	0.1-2	1-4
LHC 25nS	24.96 ns	$N_{batch} \times 72$	1-35	1-4
LHC 50 nS	49.92 ns	$N_{batch} \times 36$	1-35	1-4
LHC 75 nS	74.88 ns	$N_{batch} \times 24$	1-35	1-4
LHC single bunch	524.4-2022.6 ns	1-16	0.2-35	1-4
LHC ion / Pb82+	100 ns	$N_{batch} \times 4$	0.05-2	1-4

N_{batch}: Protons[1-4]; Ions[1-13]   Bunch charge dynamic range: 57dB

- Orbit acquisition: averaged over 40 turns [40x23μs=920 μs] (@1kHz up to 100s) 100k turns total
- Trajectory acquisition: 50 first turns (automatic) & 10k turns total (on request)
- Resolution over ±15mm aperture, for large intensity beams (>2.10^{10} p):
  - Orbit mode: 0.1 mm ↔ BPH [Na=77mm]: 0.1% BPV [Na=41.5mm]: 0.2%
  - Trajectory mode: 0.4 mm ↔ BPH: 0.5% BPV: 1%
- Resolution over ±15mm aperture, for single bunches (LHC pilot [2.10^{9} p]):
  - Orbit mode: 0.4 mm ↔ BPH: 0.5% BPV: 1%
  - Trajectory mode: 1 mm ↔ BPH: 1.3% BPV: 2.4%

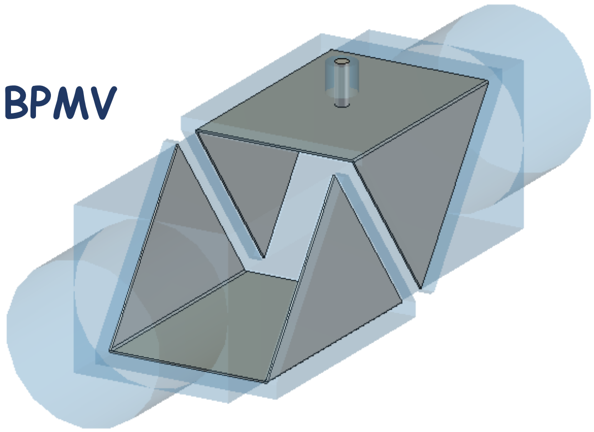
SPS Beam Position Monitors

Monitor Type	Physical Beam Aperture (mm)	Quantity	Mechanical Section	Comments
BPH	154H x 44V	103	rectangular	Electrostatic shoe-box
BPV	83 x 83	94	square	Electrostatic shoe-box
BPCN	76	7	circular	Strip-line directional couplers
BPCE	206	12	circular	

- Electrostatic shoe-box (BPV & BPH) need an electrode impedance matching network
- Strip-line directional couplers (BPCN & BPCE) are 50Ω matched

BPM Pickup Signal Analysis

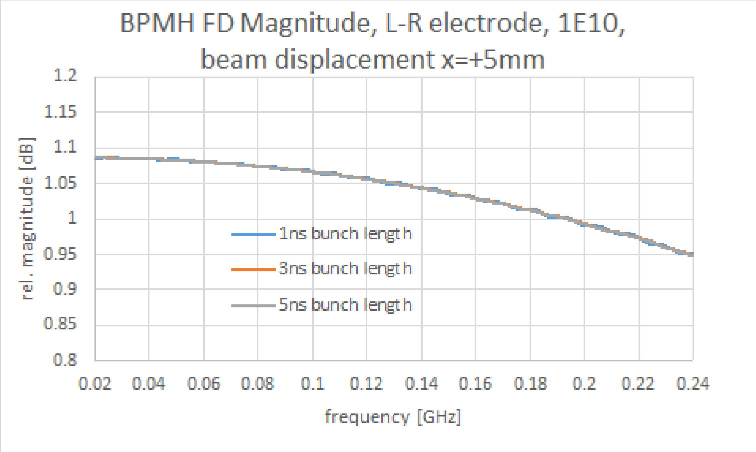
BPMV

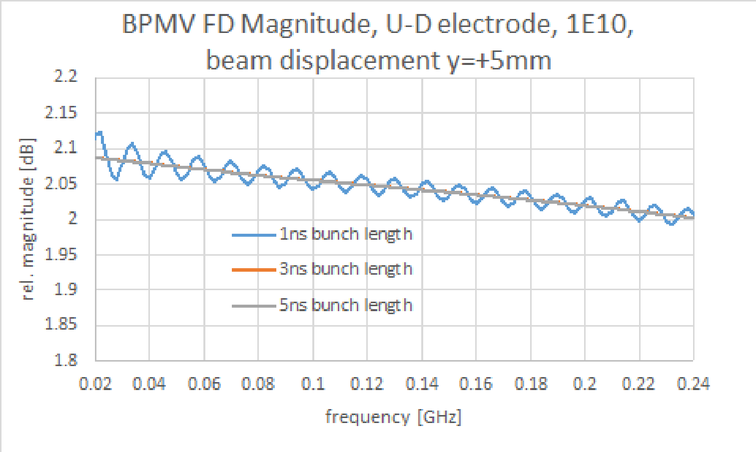


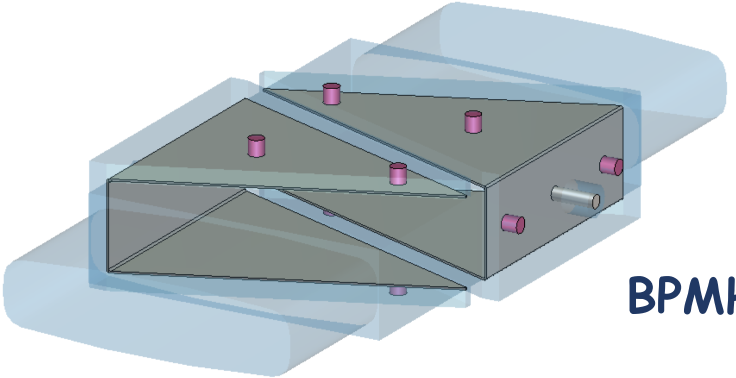
BPM Position Sensitivity

BPMH : 0.1988 dB/mm
BPMV : 0.4040 dB/mm

BPCN : 0.7825 dB/mm
BPCE : 0.3092 dB/mm



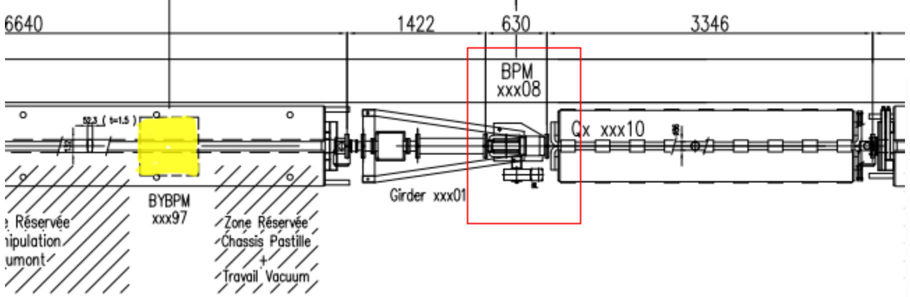


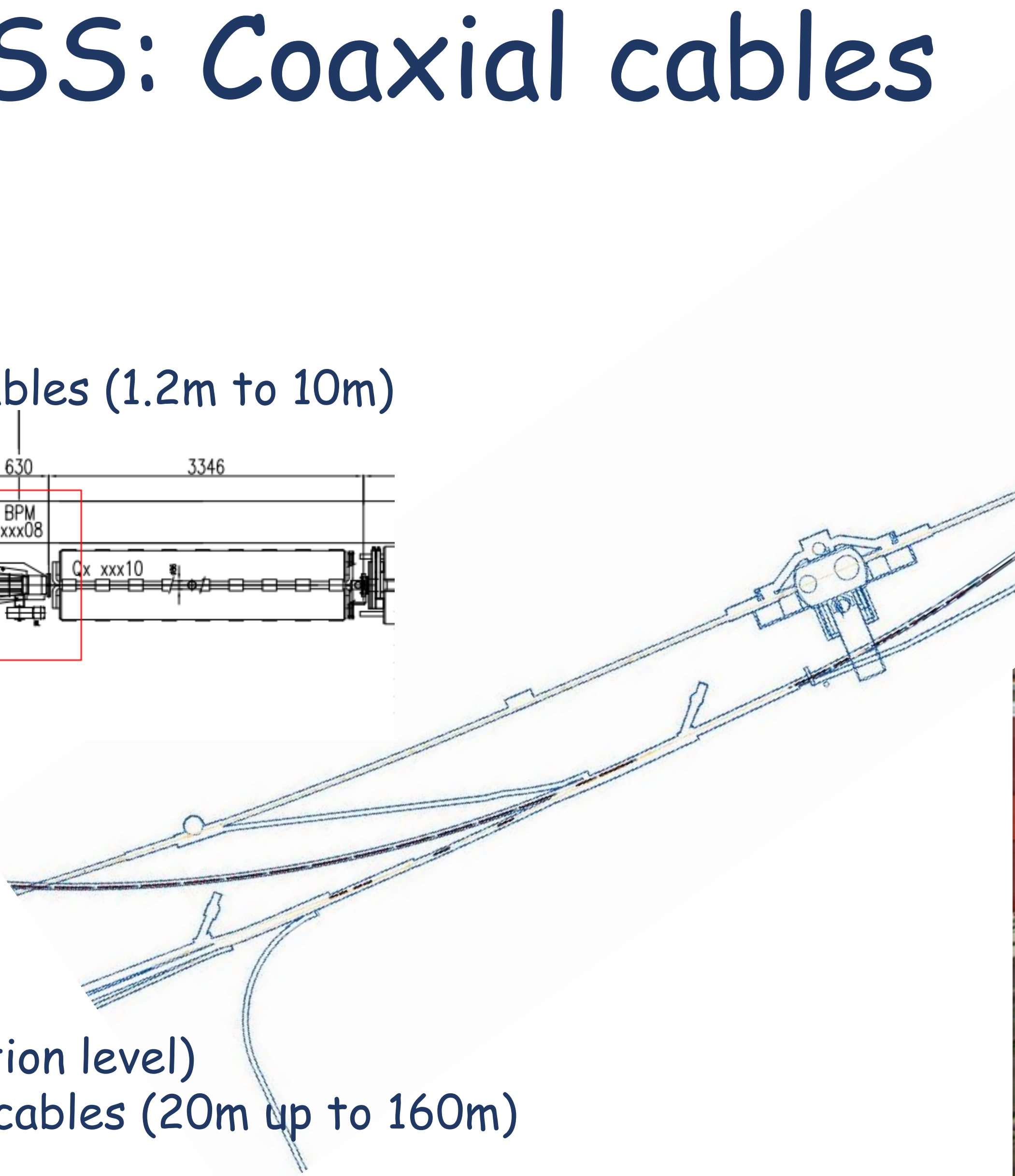


BPMH

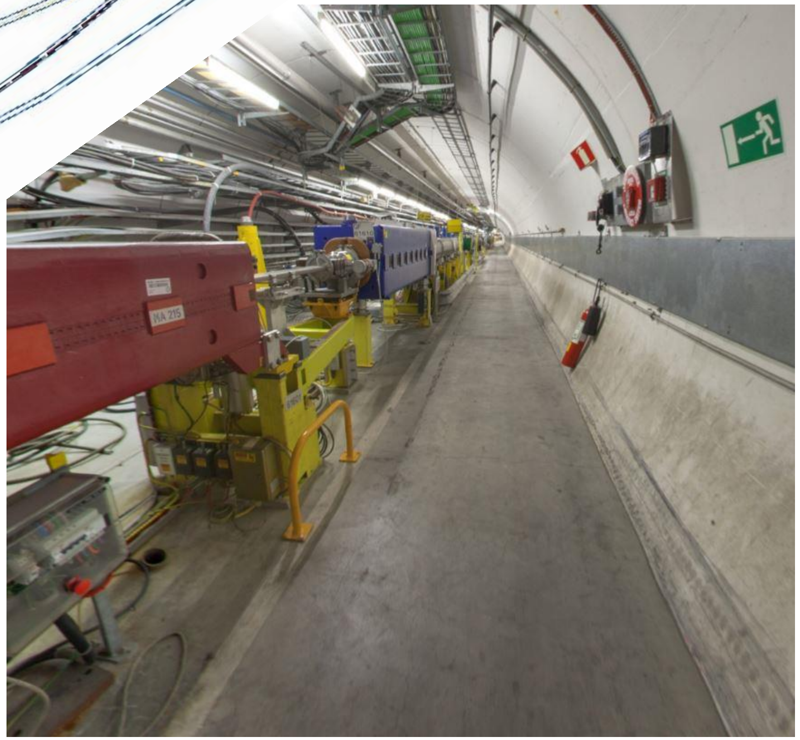
Arcs & LSS: Coaxial cables

- ARC
- RG 58 coaxial cables (1.2m to 10m)

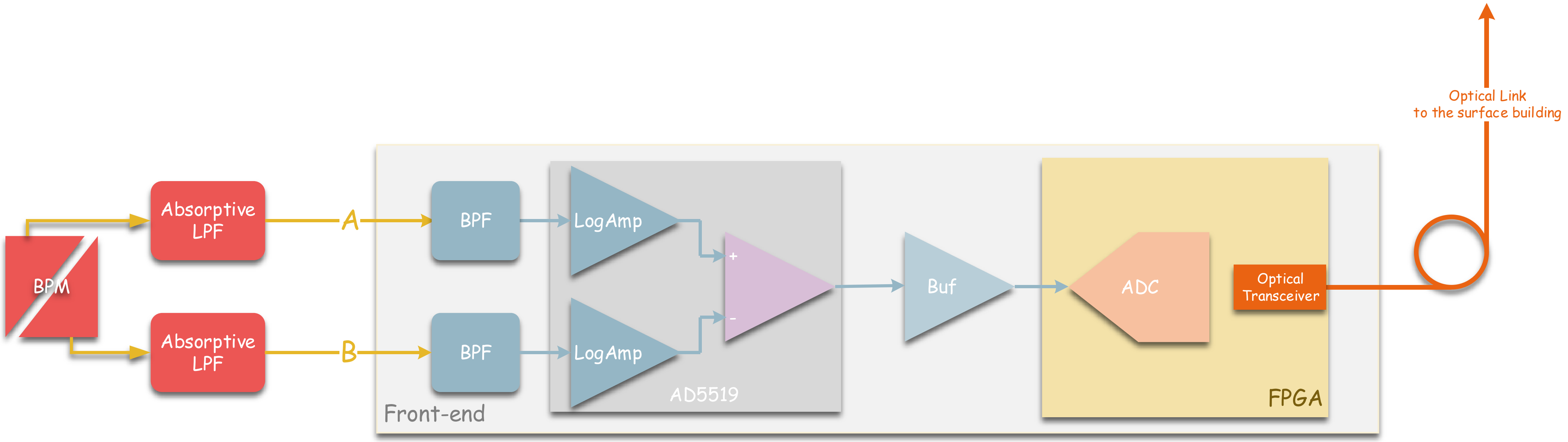




- LSS (high radiation level)
- CMC 50 coaxial cables (20m up to 160m)



ALPS Frond-end Layout

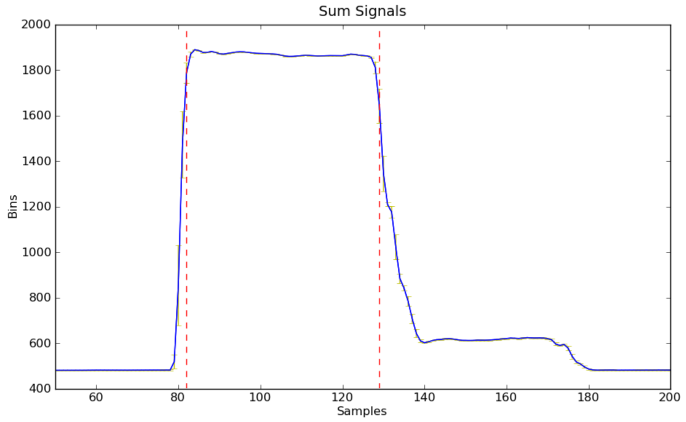


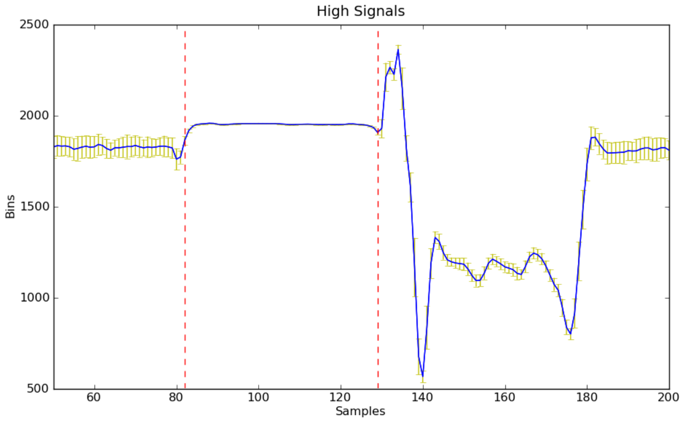
- *Each electrode signal is compressed by a logarithmic amplifier, filtered*
- *The difference is applied to an ADC channel*
- *The position response is* $Pos. \equiv log(A/B) = [log(A)-log(B)] \equiv (V_{out})$

  where V_{out} *is the voltage difference between the log-amplifiers*

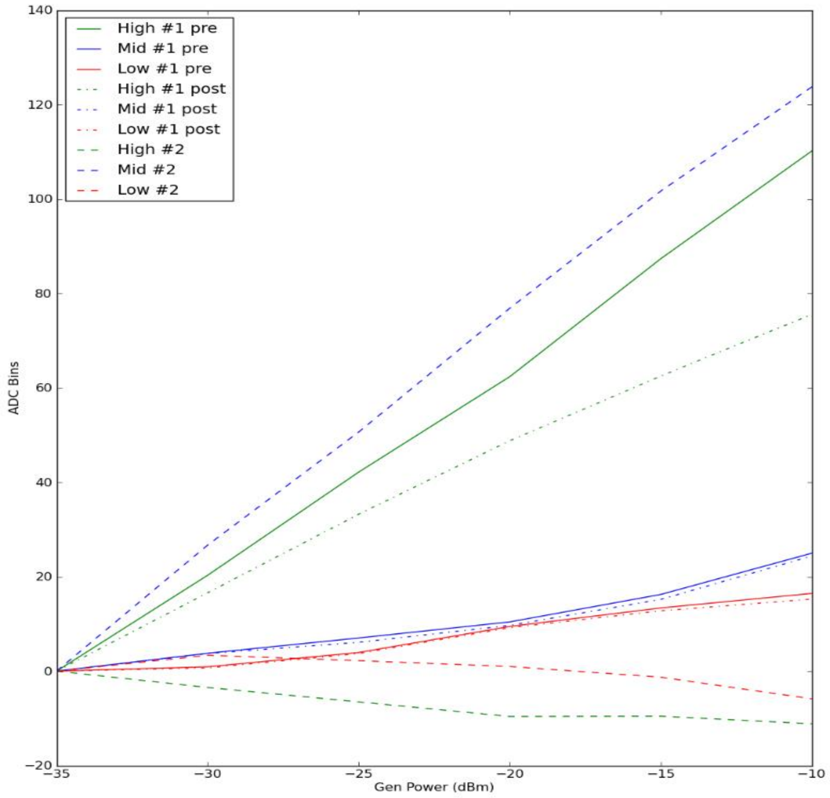
ALPS Frond-end Layout

- *Real beam signal*
- *Characteristics of input signal:*
  - ✓ *50 ns spacing*
  - ✓ *~20 bunches*
- *920 samples/acq., 71 acq.*
- *Averaged signal + standard deviation*



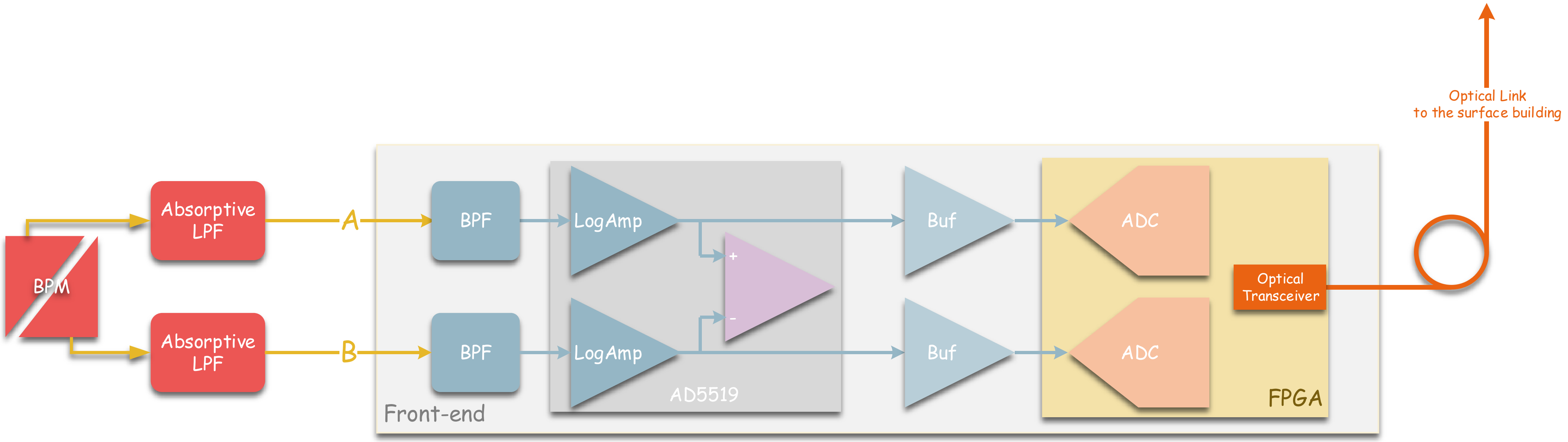


- *Results of power sweep when the difference between inputs is zero (the signal has been split).*



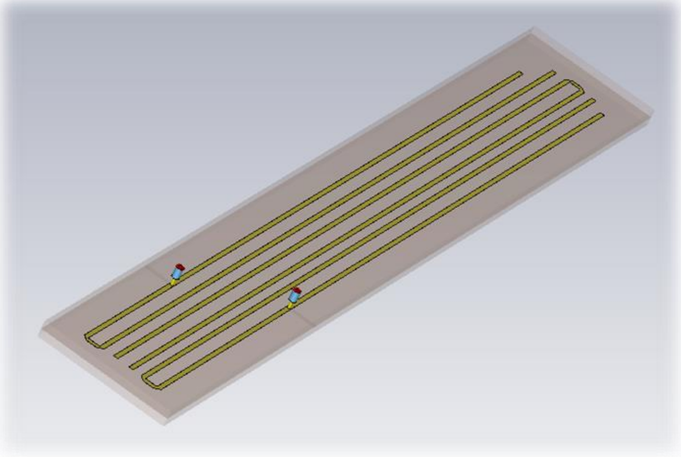
- *A strong dependency of intensity has been found in one channel in each board*

ALPS Frond-end Layout



- *Each electrode signal is compressed by a logarithmic amplifier, filtered and applied to an ADC channel*

Hairpin band-pass filter



F_0 200 MHz

BW = 10 MHz

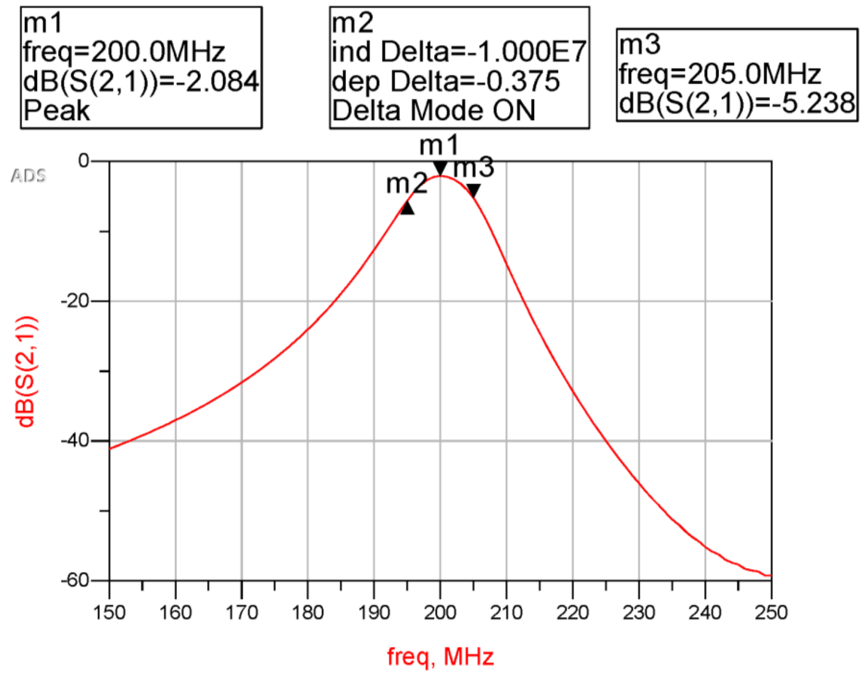
2dB insertion loss

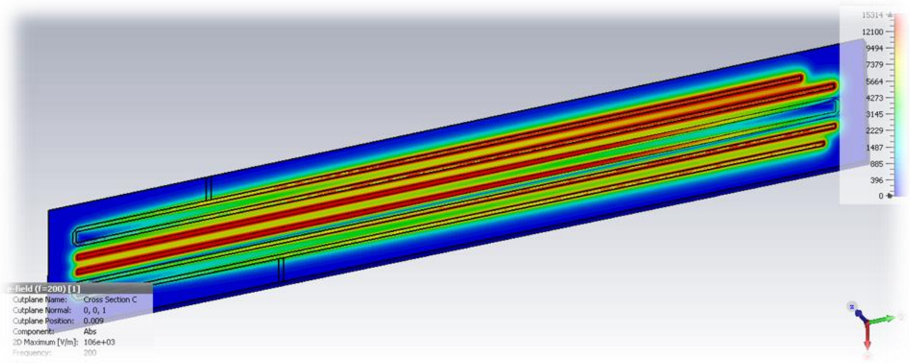
Rogers substrate PCB

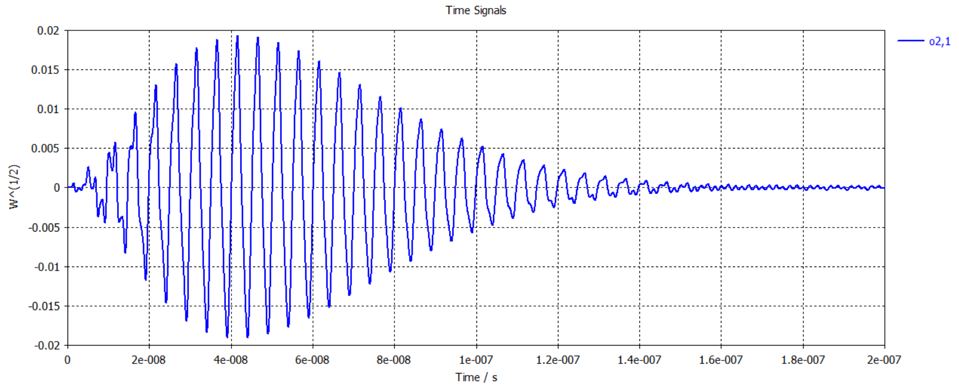
Good reproducibility

Tolerances (paired)

Low cost



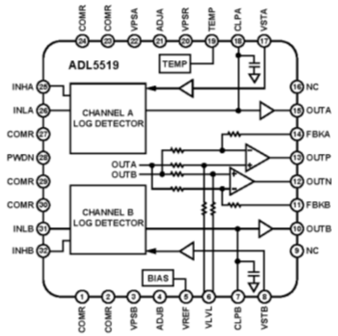




Analog Devices ADL5519

dual-channel logarithmic amplifier

FUNCTIONAL BLOCK DIAGRAM



- 2-ch LogAmp
  - ✓ Rare!
- Broadband
  - ✓ However, not required…
- Dynamic range
  - ✓ 62 dB at 3 dB error
  - ✓ 50 dB at 0.5 dB error
  - ✓ 40 dB at ~0.1 dB error
    -45…-5 dBm intensity range
    (3.56…356 mVpp)
- ~ 50dBm sensitivity
  - ✓ ~2mVpp (0.5 dB error)

TYPICAL PERFORMANCE CHARACTERISTICS

V_P = 5 V; T_A = +25°C, −40°C, +85°C; CLPA, CLPB = 1 µF. Colors: +25°C black, −40°C blue, +85°C red.

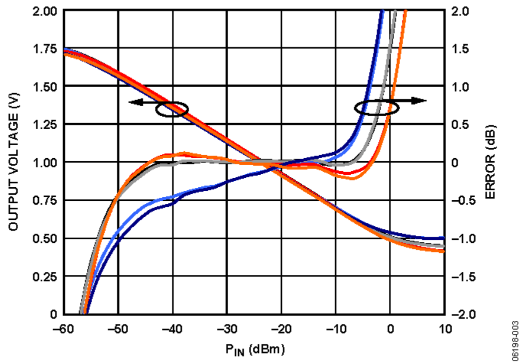


Figure 3. OUTA, OUTB Voltage and Log Conformance vs. Input Amplitude at 100 MHz, Typical Device, ADJA, ADJB = 0.65 V, 0.7 V, Sine Wave, Single-Ended Drive

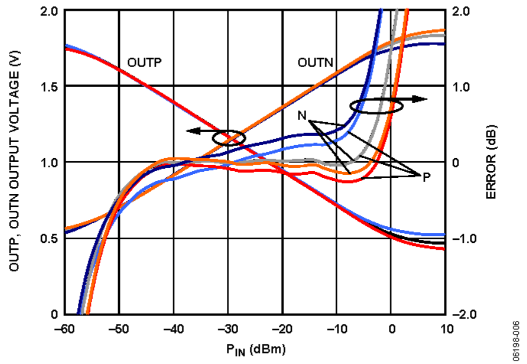


Figure 6. OUTP, OUTN Gain Error and Voltage vs. Input Amplitude at 100 MHz, Typical Device, ADJA, ADJB = 0.65 V, 0.7, Sine Wave, Single-Ended Drive, P_{INHB} = −30 dBm, Channel A Swept

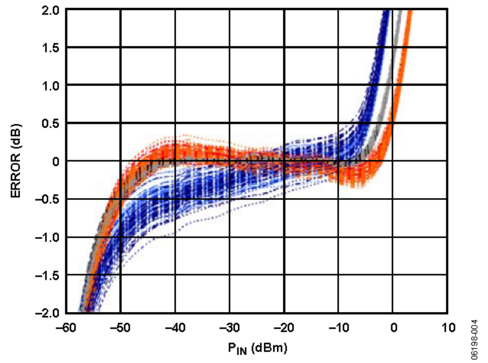


Figure 4. Distribution of OUTA, OUTB Error over Temperature After Ambient Normalization vs. Input Amplitude for 45 Devices, Frequency = 100 MHz, ADJA, ADJB = 0.65 V, 0.7 V, Sine Wave, Single-Ended Drive

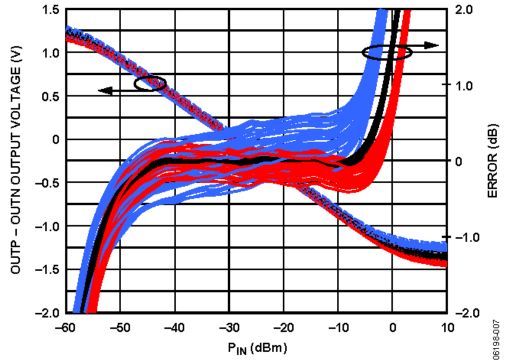
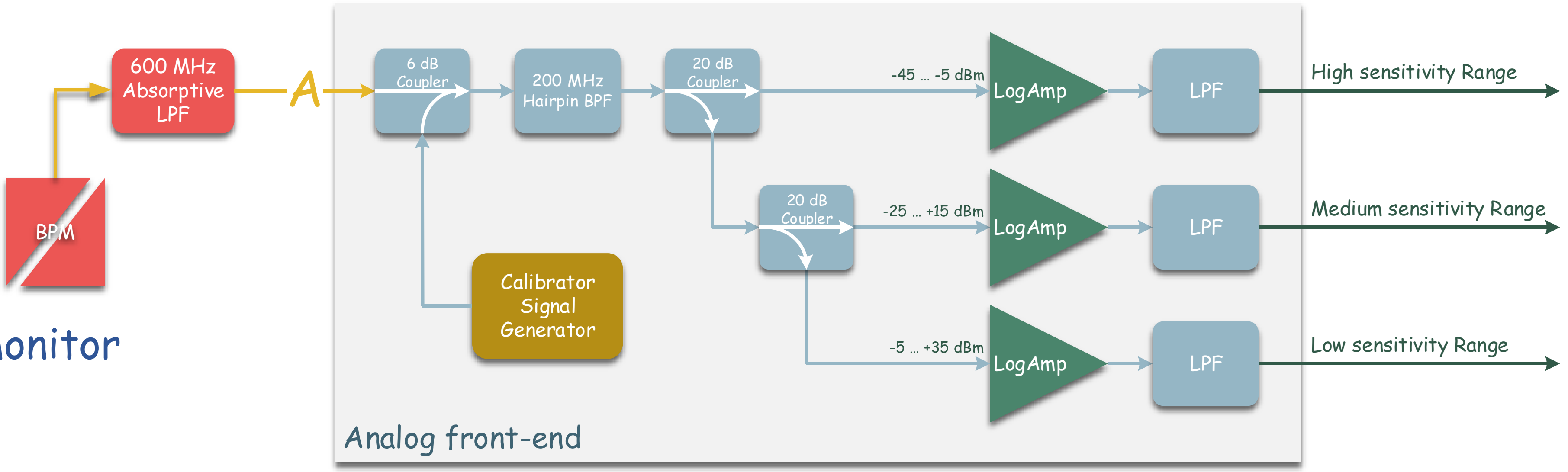


Figure 7. Distribution of [OUTP – OUTN] Gain Error and Voltage vs. Input Amplitude over Temperature, After Ambient Normalization for 45 Devices from a Nominal Lot, Frequency = 100 MHz, ADJA, ADJB = 0.65 V, 0.7 V, Sine Wave, Single-Ended Drive, P_{INHB} = −30 dBm, Channel A Swept

ALPS RF Frond-end Layout (1 Ch.)

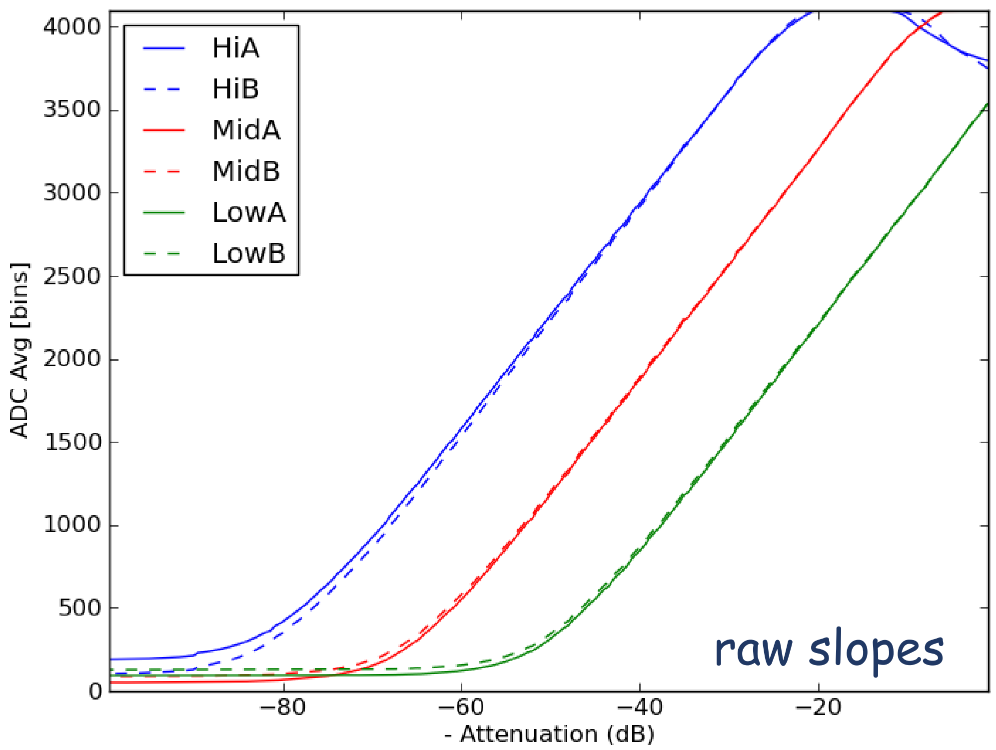
- The typical performance of the LogAmp (~40 dB dynamic range at ~0.1 dB error)
- Do not cover the full dynamic of BPM signal (> 60 dB dynamic range)
- Depending of
  - ✓ bunch charge
  - ✓ beam position
  - ✓ beam position monitor

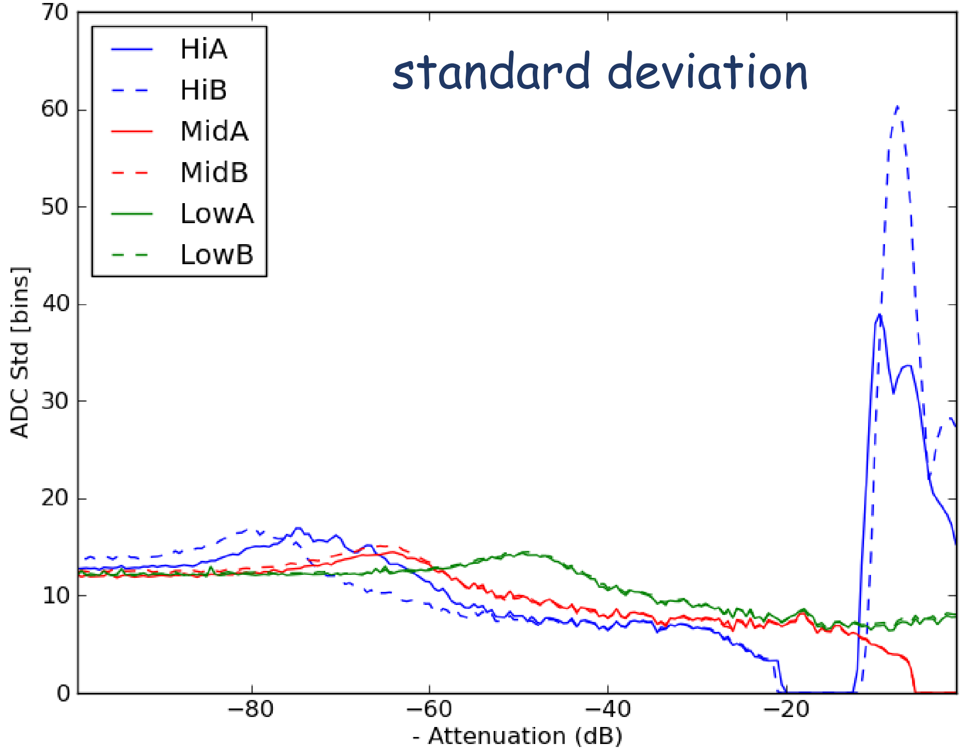


- *To fit with the large dynamic of the input signal 3 sensitivity levels with 20 dB step were implemented*
- *For off-line test a calibrator is also embedded on the analogue board*

Measurements with lab setup

400 bunch's / 5nS bunch spacing / ~ 2nS bunch length

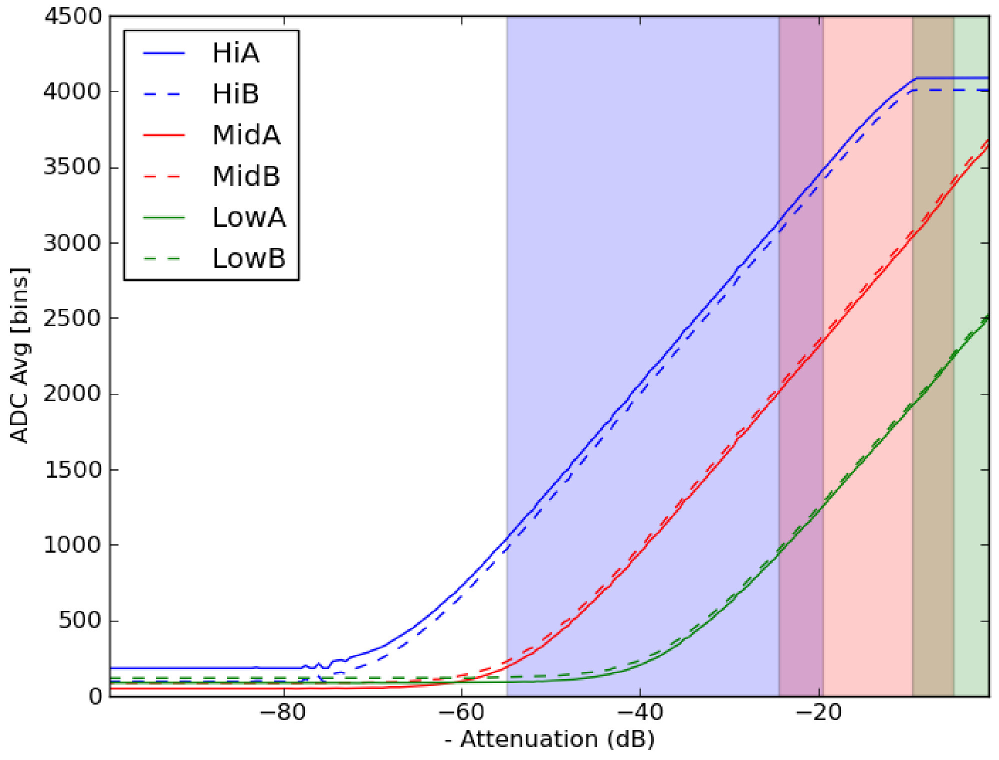




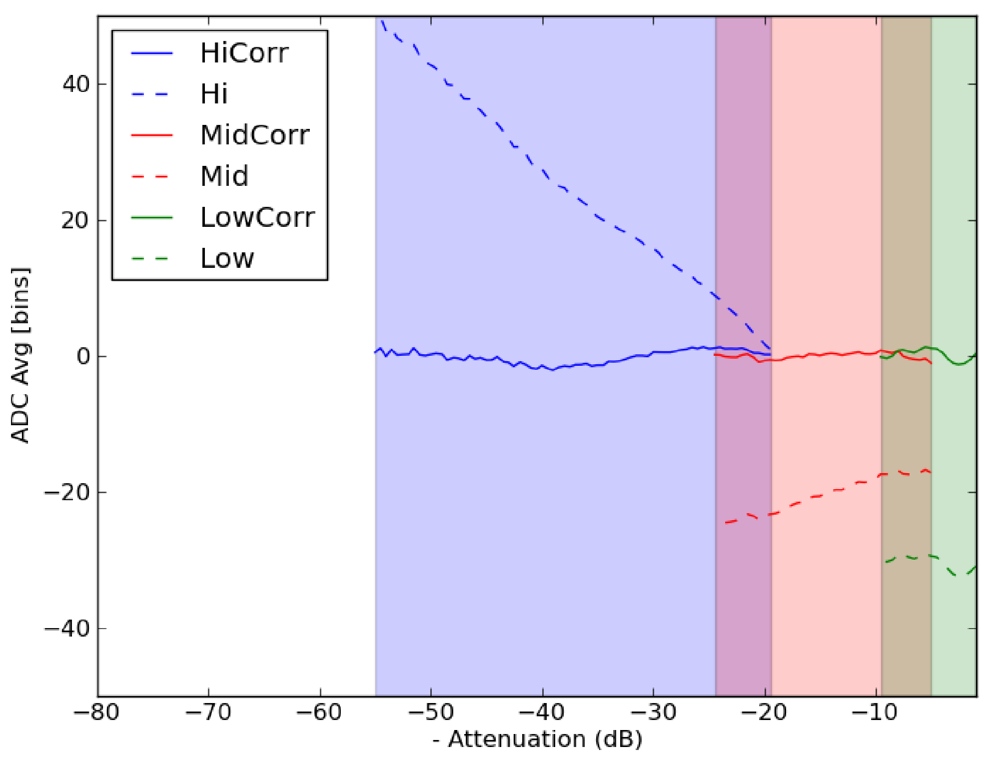
Even though standard deviation looks high (around 10 bins in the range of use of each channel), it's mainly noise due to the setup. When doing the difference of channels (A-B) it drops to 2-5 bins.

Measurements with lab setup

400 bunch's / 5nS bunch spacing / ~2nS bunch length



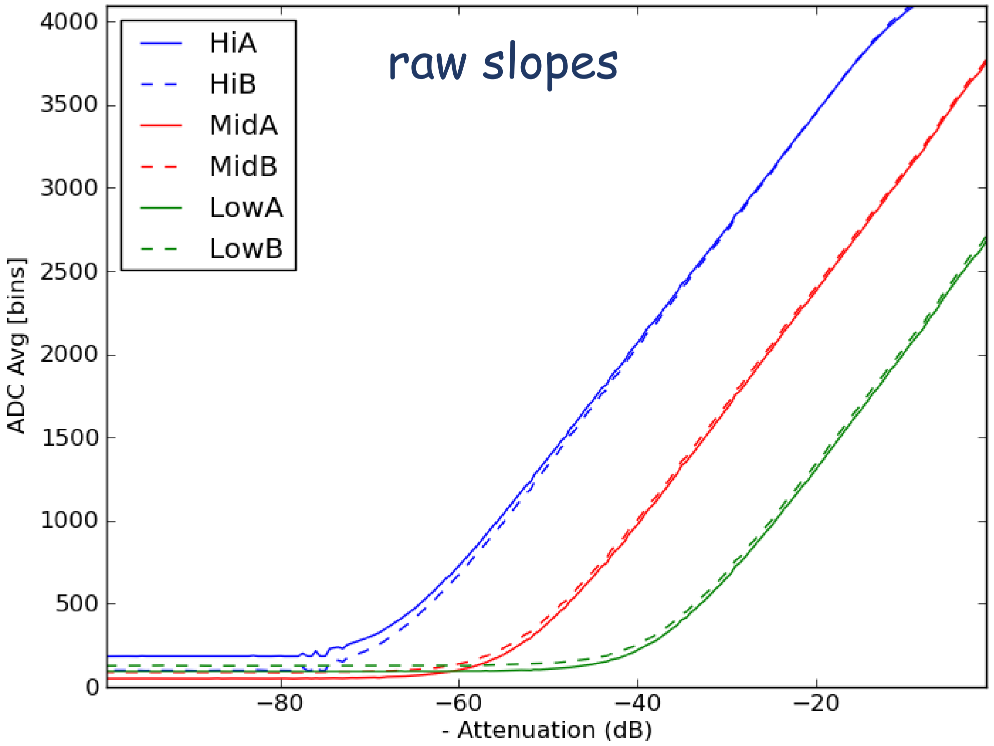
Corrected slope 69 bins/dB
(Original offset)

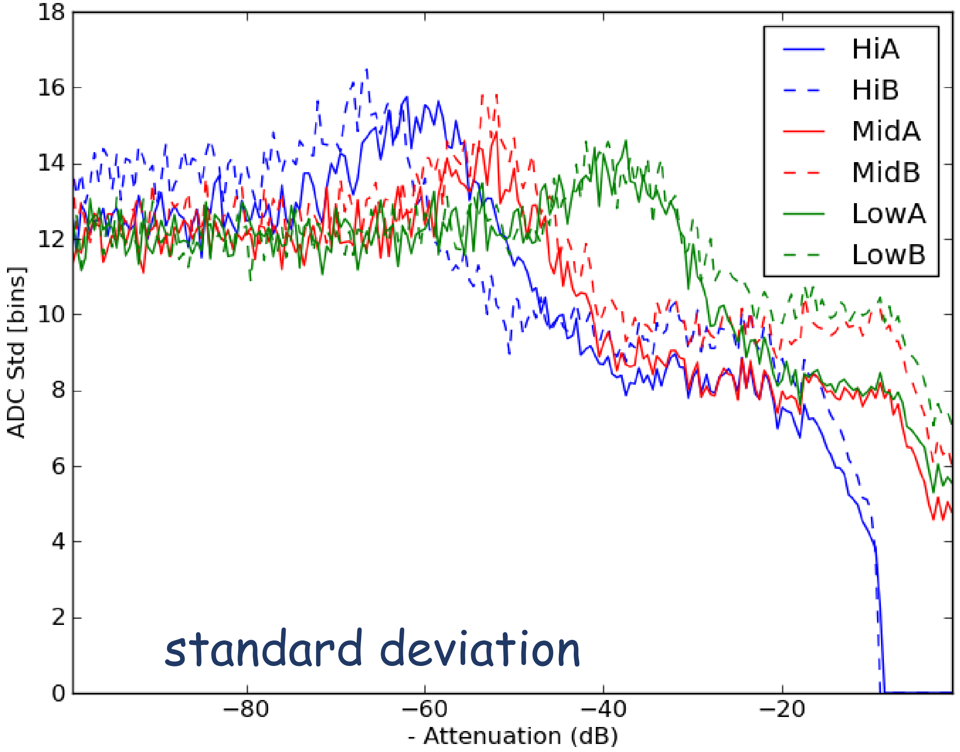


difference between channels (A-B) before (dashed lines) and after correction (slope and offset, continuous lines)

Measurements with lab setup

Single bunch / ~ 2nS bunch length

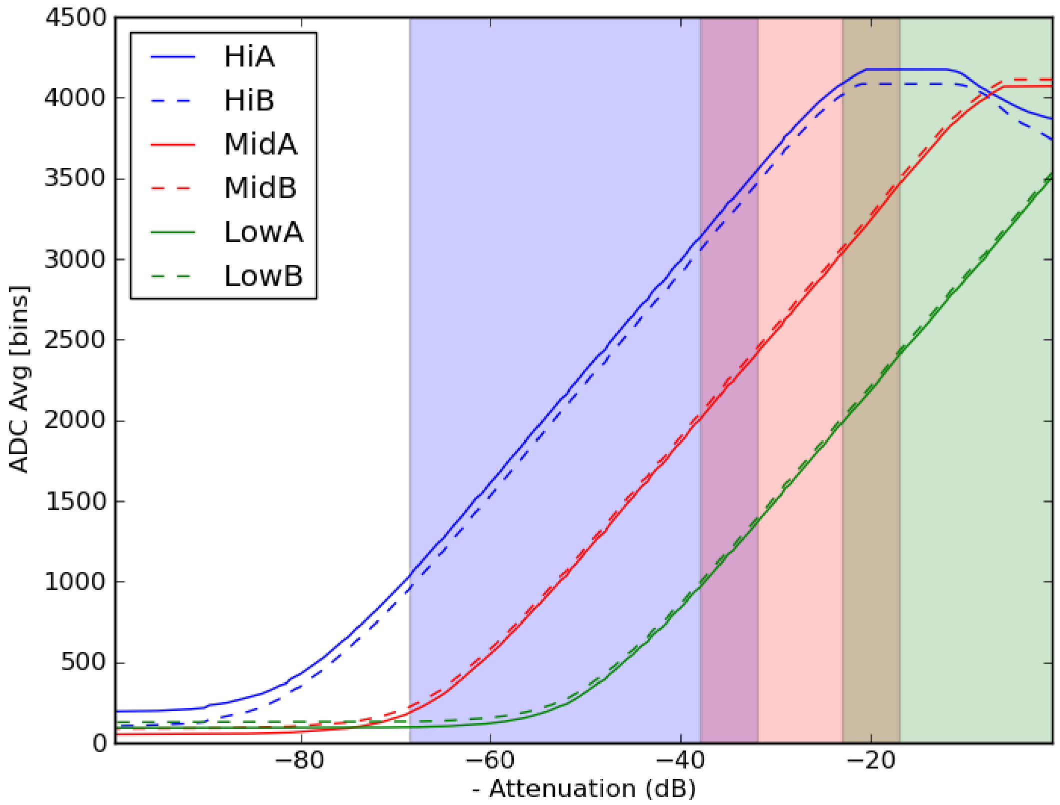




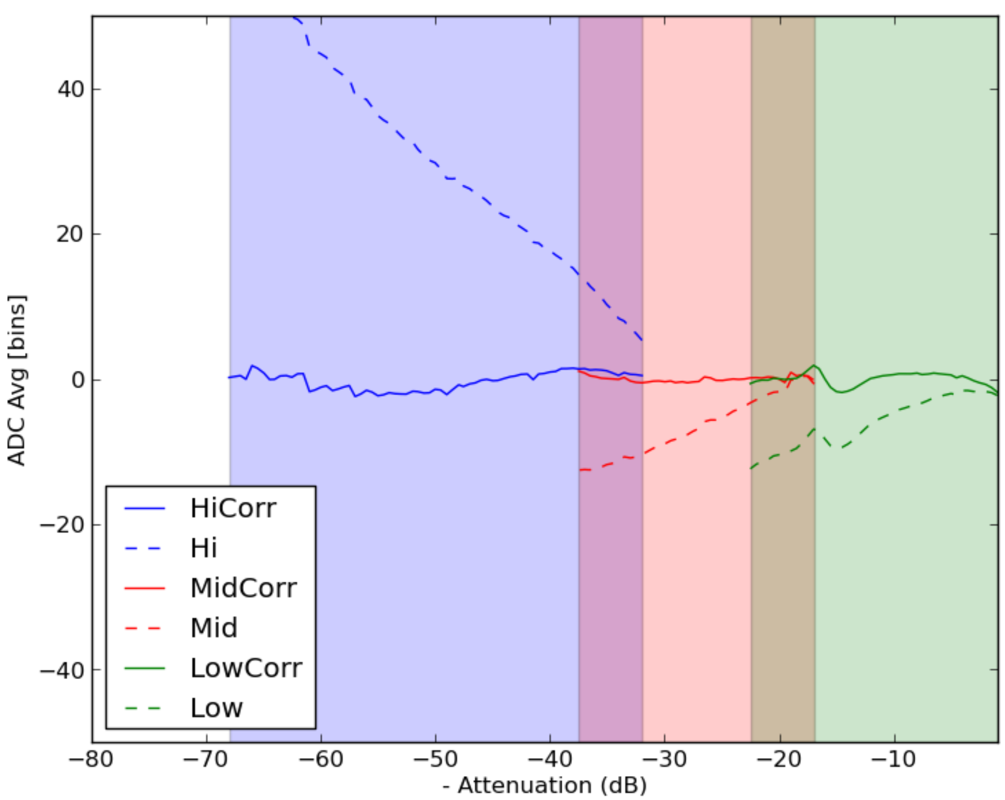
Again standard deviation is mainly influenced by setup noise.
When doing the difference of channels (A-B) it drop.

Measurements with lab setup

Single bunch / ~2nS bunch length



Corrected slope 69 bins/dB
(Original offset)



difference between channels (A-B) before (dashed lines)
and after correction (slope and offset, continuous lines)

The aim of the beam test

- **Verify the electronics with Beam**
  - Scaling factors
  - Possible artefacts
  - Resolution
  - Reliability

- **Verify the system integration on the software side**
  - Orbit
  - Injection oscillations
  - Capture/Trajectory

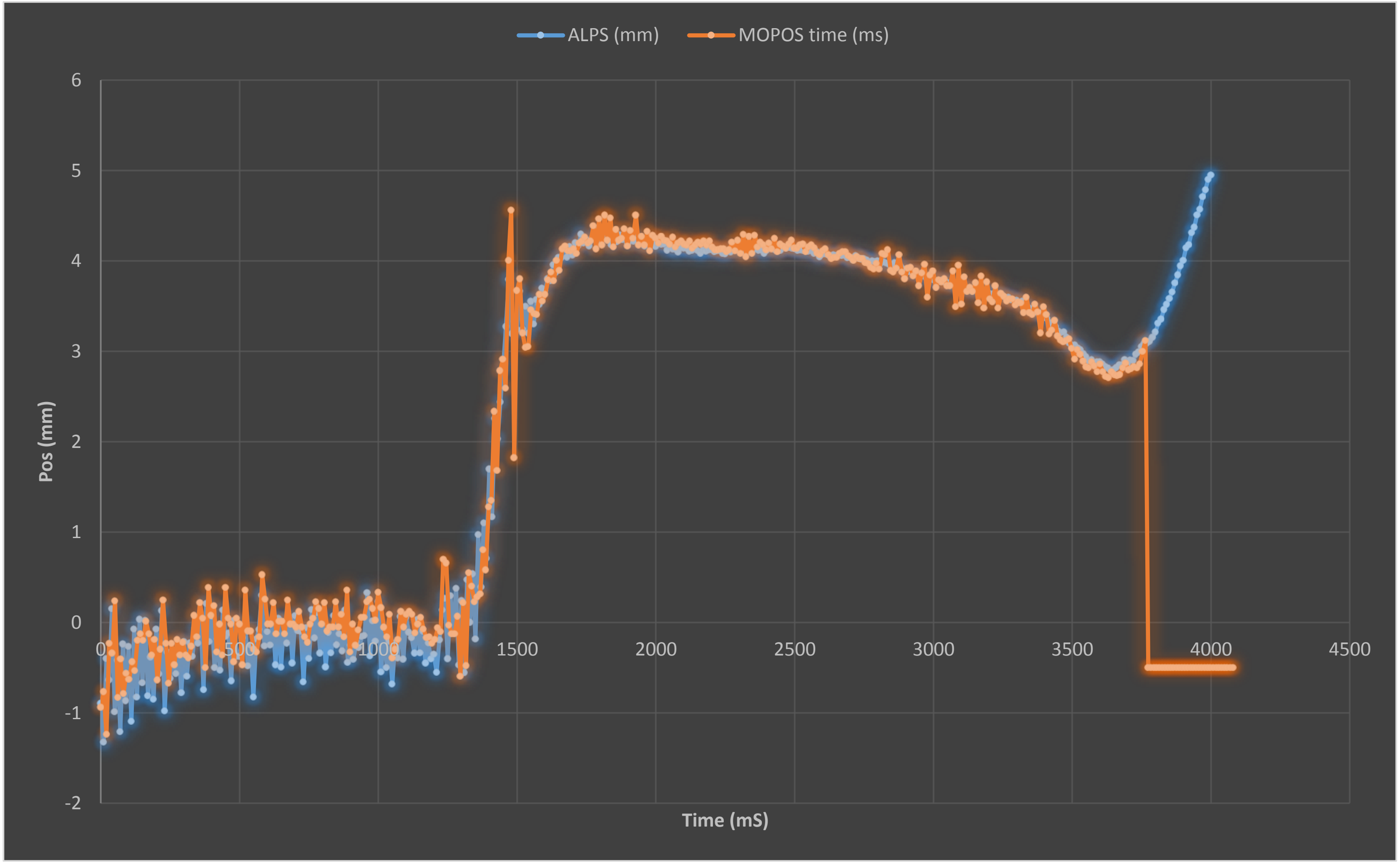
Fall 2018 installation status

- 12 BPMs in point 6 have been split and are now connected in parallel to MOPOS (actual operational system) and ALPS
- The BPM where chosen by OP and are a mix of BPH, BPV, BPCE and BPCN with short or long cables
- 1 system is on the surface in HCA4 (BPV421)
- 1 system is still in the lab for tests and studies

Chanel	BPM		Plan	Cable
1	61008	BPH	H	no
2	61108	BPCN	V	No
3	61208	BPH	H	No
4	61308	BPCN	V	No
5	61408	BPH	H	No
6	61508	BPV	V	No
7	61608	BPH	H	No
8	61705	BPCE	H	Yes
9			V	Yes
10	61805	BPCE	H	Yes
11	61931	BPCE	H	Yes
12	62008	BPH	H	Yes

BPMH data (MOPOS / ALPS)

- SFTPRO2 beam (~4000 bunch's - 5nS bunch spacing)
- Orbits every 10ms
- Manual acquisition via FESA for both systems
- Orbit based on mS for ALPS, on turns for MOPOS



Scaling MOPOS Vs. ALPS

- Offset difference: +- 500um
- MOPOS DON'T use geometrical alignment correction
- Difference in the expected:
  - MOPOS drift (old system with aging issues)
  - Splitter symmetry matching (500um is about 0.05dB)

- Gain difference: <10% (typical ~4%)
- Theoretical corrected by measures (MOPOS) Vs. BPM simulation (ALPS)
- MOPOS cables drift?
- Bumps during commissioning will give us a better idea

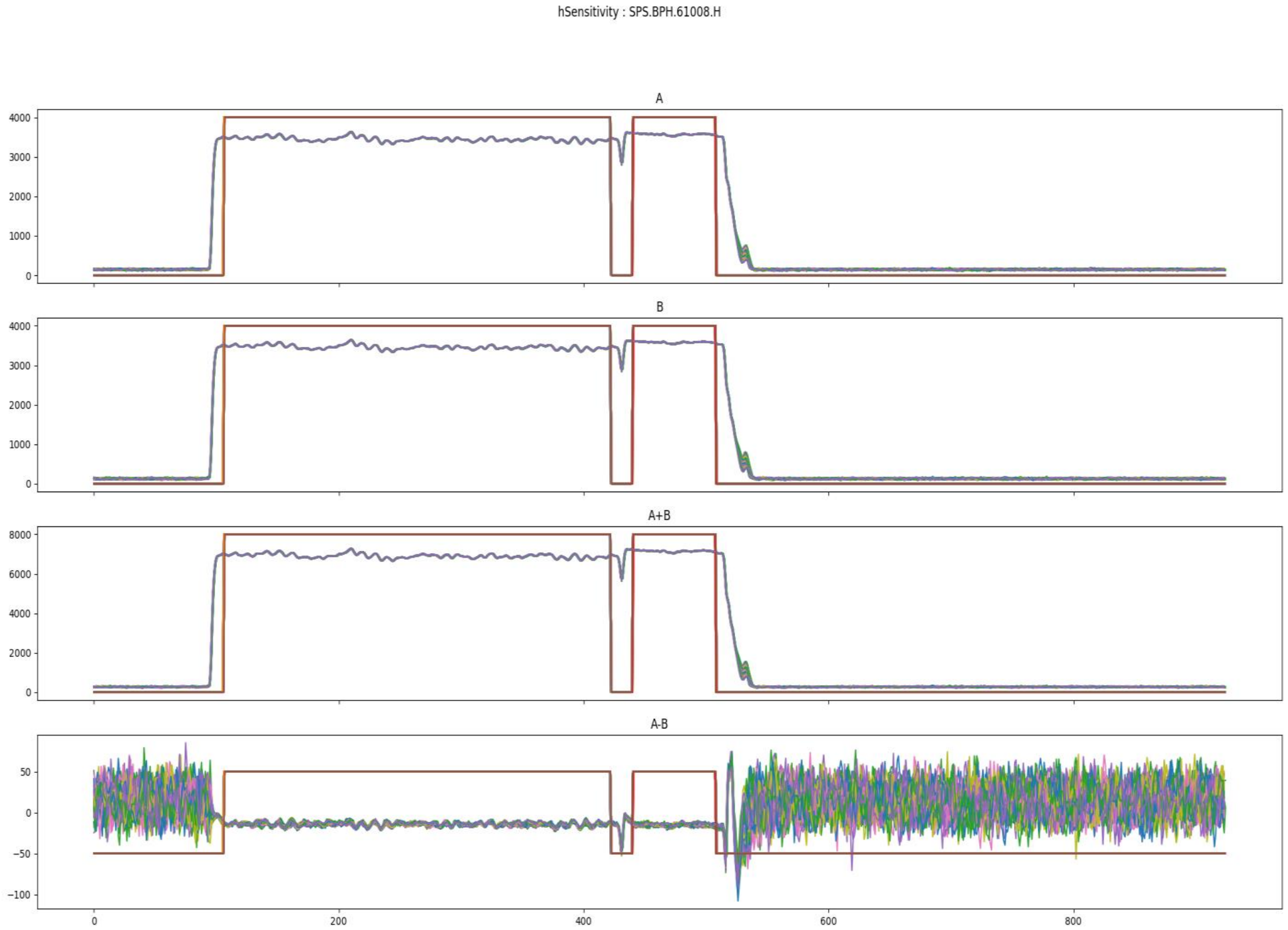
Known artefacts

Transient affects (single bunch / batch)

- 200 MHz filter matching : better matchings for final mass production

- LogAmp burst response

- High intensity effects due to high resolution channel protection : harmonic LPF filter tested with lab setup give good results



Resolution

Reminder

BPH (154mm) : ~ 7.29 µm / bin
BPV (83mm) : ~ 3.59 µm / bin
BPCN (76mm) : ~ 1.85 µm / bin
BPCE (206mm) : ~ 4.69 µm / bin

- Resolution Vs Intensity
  In the measurement range almost insensitive

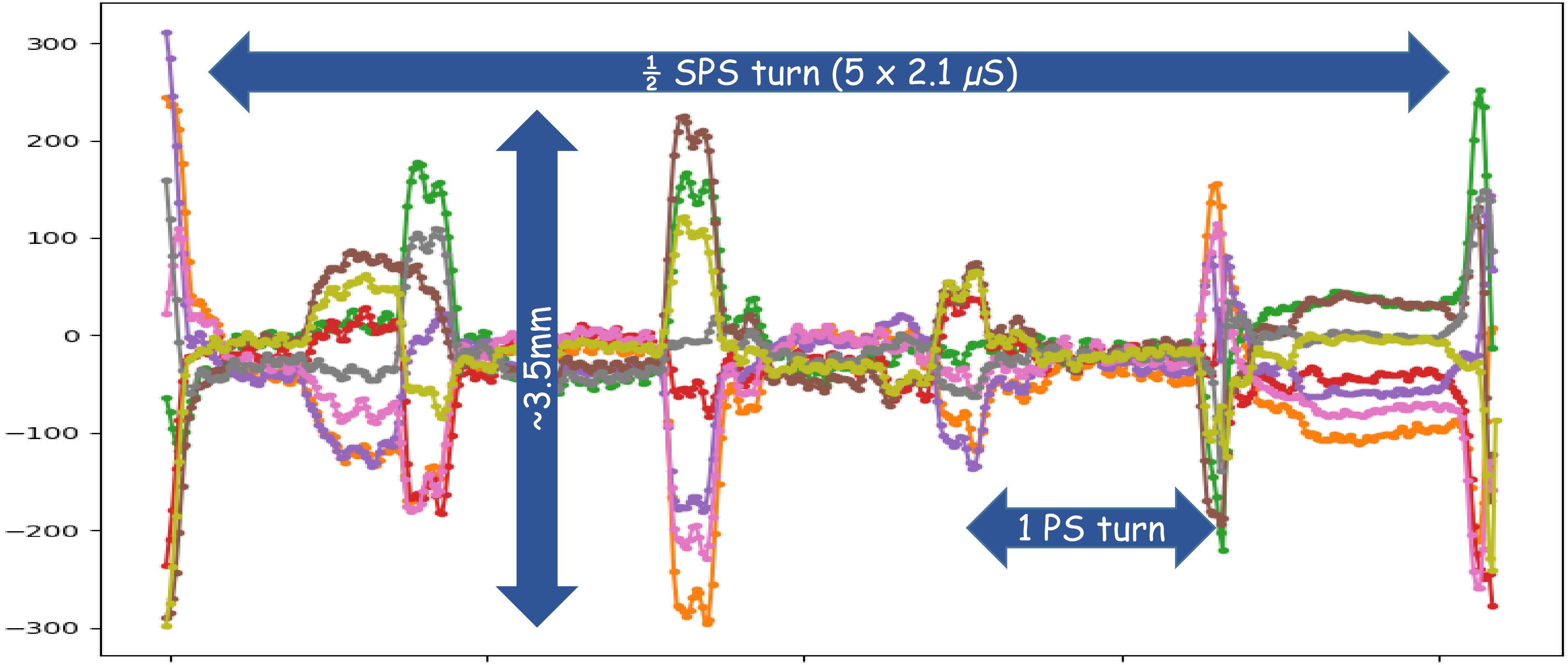
- Single point, single turn resolution (injection trajectory/capture)
  For long batches (>200ns): 0.04 dB => ~200um
  For short batches: up to 0.12dB and an equivalent systematic => ~600um

- Orbit @1kHz
  for long batches : ~33um for single point
  for single bunch: ~100um but the systematic remaining…

- Minimum detection level
  waiting for ions to say

SFTPRO beam at injection

- *BPH 61008*
- *PS MTE extraction*
- *First batch*
- *8 turns*
- *40 MHz sample rate*
- *Injection*

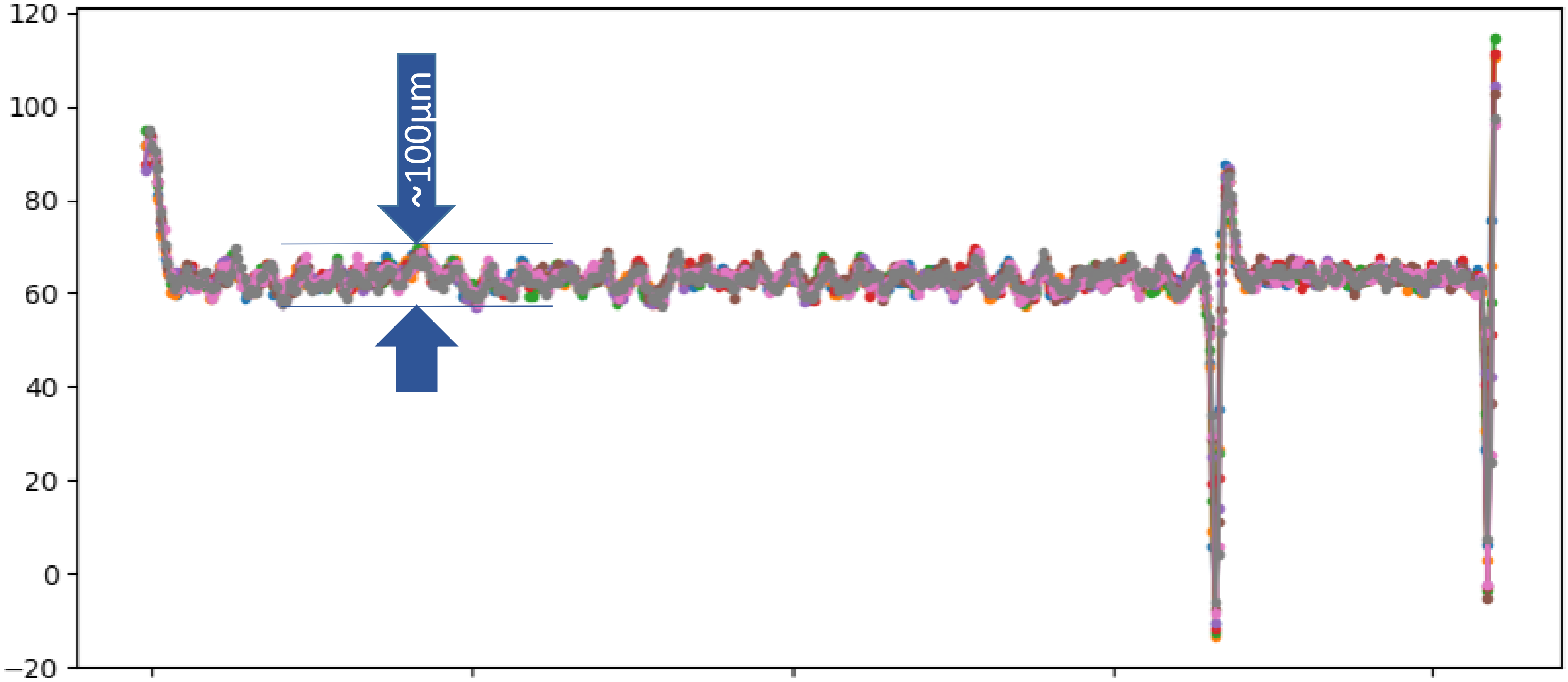


SFTPRO beam at injection

- *BPH 61008*
- *PS MTE extraction*
- *First batch*
- *8 turns*
- *40 MHz sample rate*

- *500 mS later*

(not the same cycle)



Summary

- *Still some known hardware problems to solve*
- *New automatique sensitivity selection algorithm*
- *On line calibration to be added*
- *1 or 2 calibration table (Batch / Bunch)*
- *Position algorithm must be verified*
- *Few additional components to be checked in radiation*
- *Lab test bench for production has to be set up*
- *Full installation and tests during LS2 (2019)*
- *Commissioning with beam after LS2 (summer 2020)*