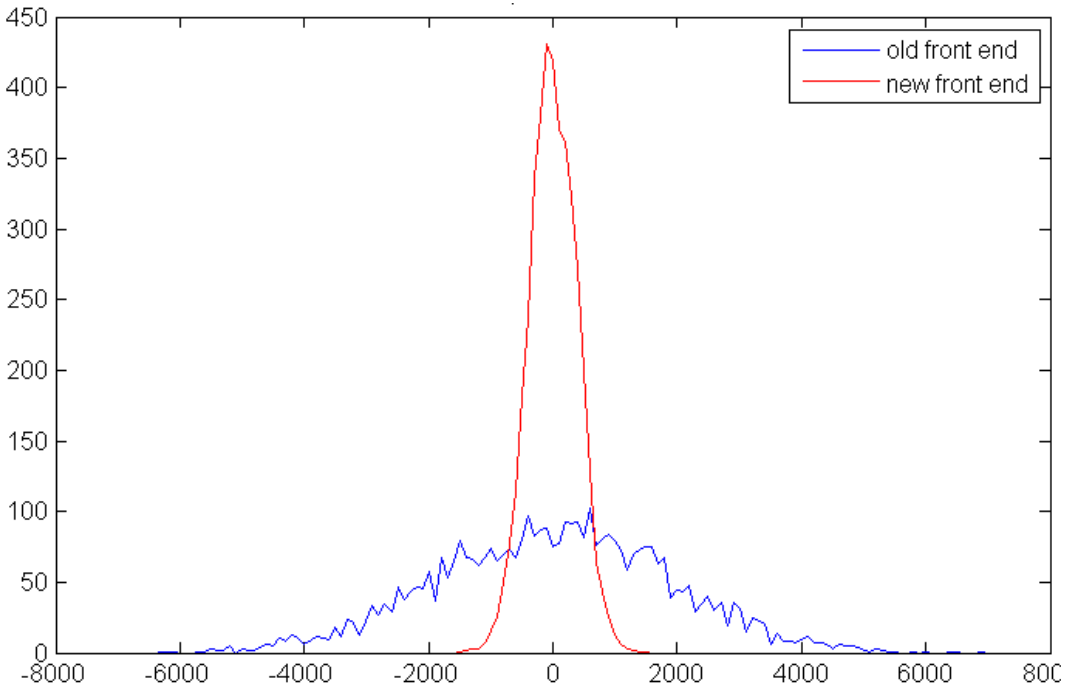
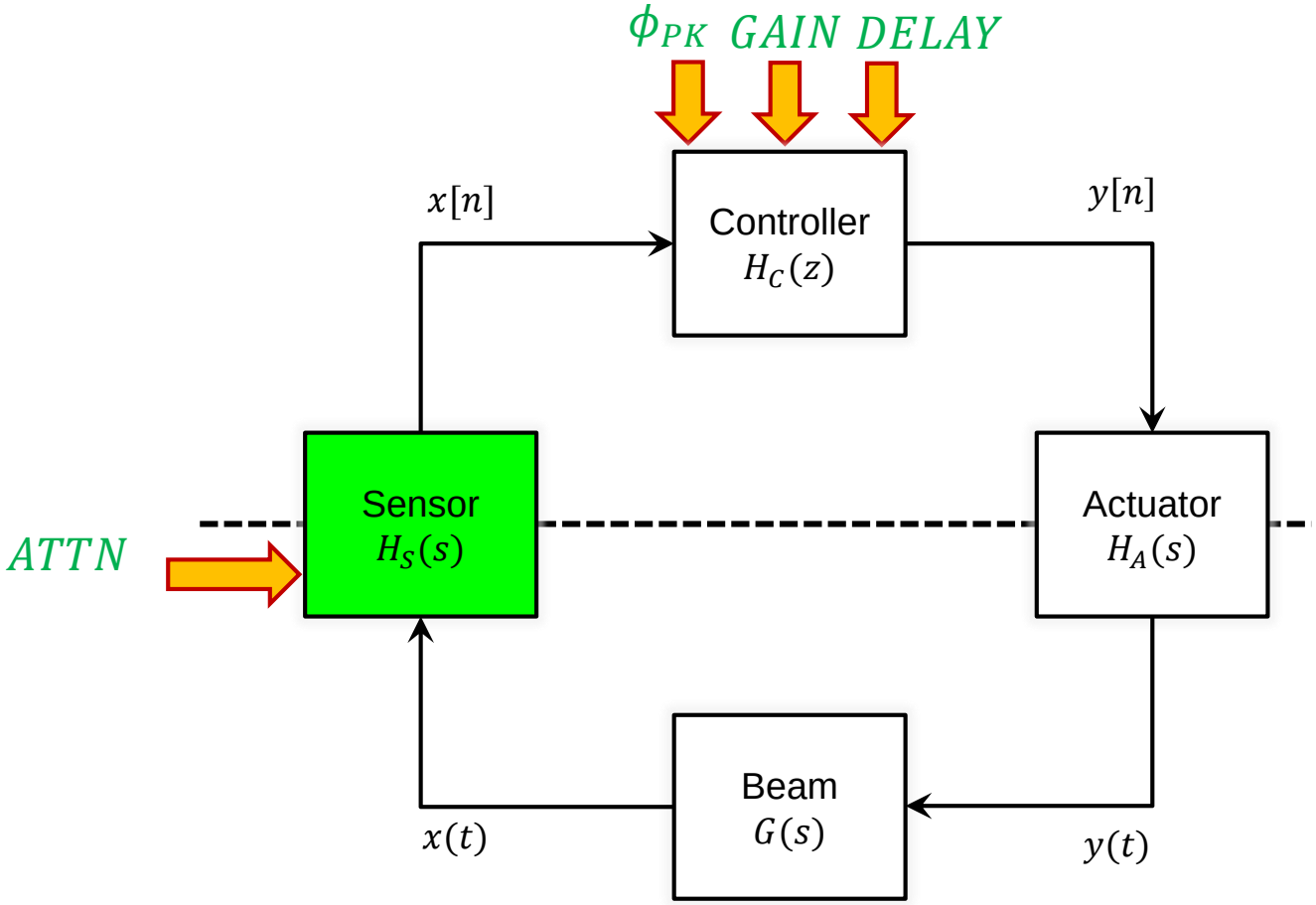
On improving the ADT pick up resolution



Daniel Valuch

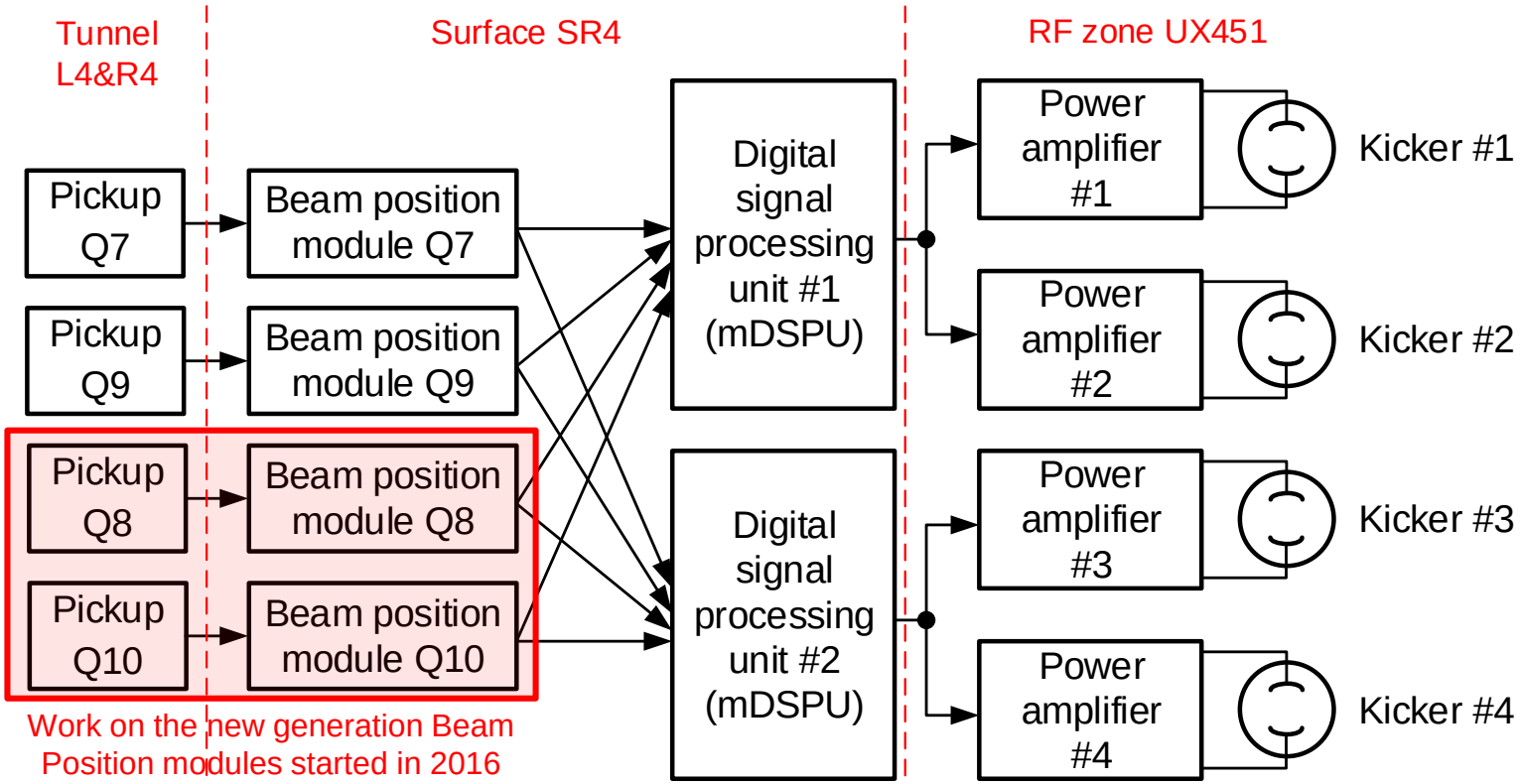
ADT – Overall System Architecture

The “Sensor” converts transverse beam position signals x(t) into a per-bunch sequence of samples x[n]



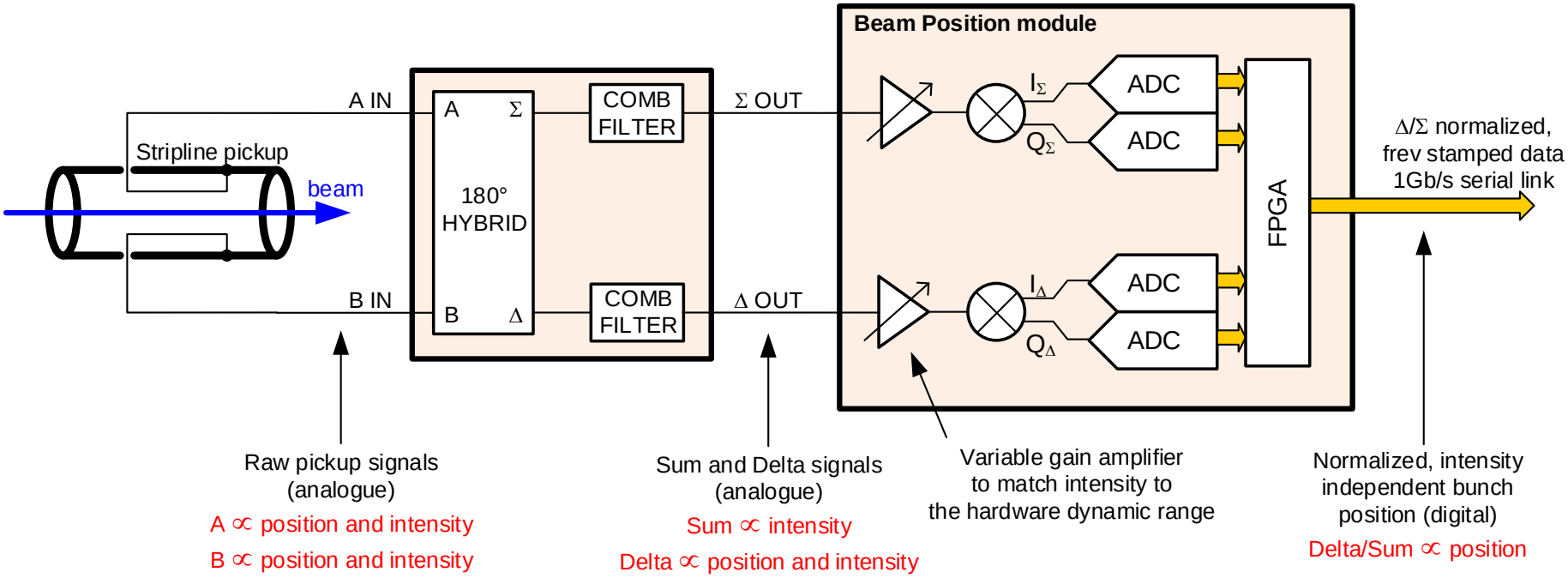
ADT – Overall System Architecture

- Pickups in the tunnel (pt. 4), signal processing on the surface (SR4), driver amplifiers and controls UX45, power amplifiers and kickers in the RF zone (UX451)



Beam Position Module (BeamPos)

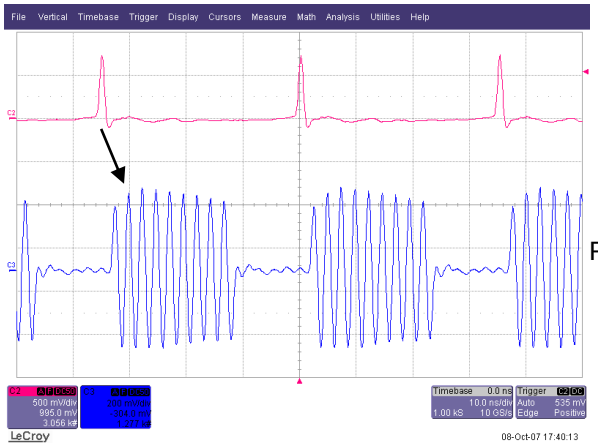
- VME module which receives RF signals from stripline pickups and calculates a normalized, intensity independent bunch by bunch beam position
- Important parameter: **per-bunch intensity (and bunch length)**
- Noise floor is constant in number of bits, optimal signal mapping vital…



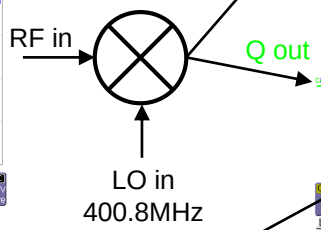
Bunch Position Measurement

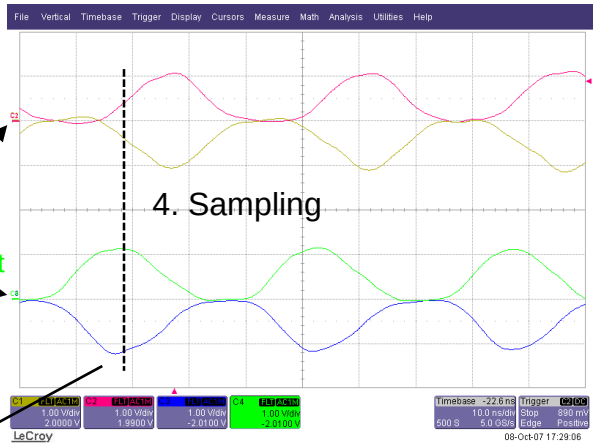
1. Raw pickup signal

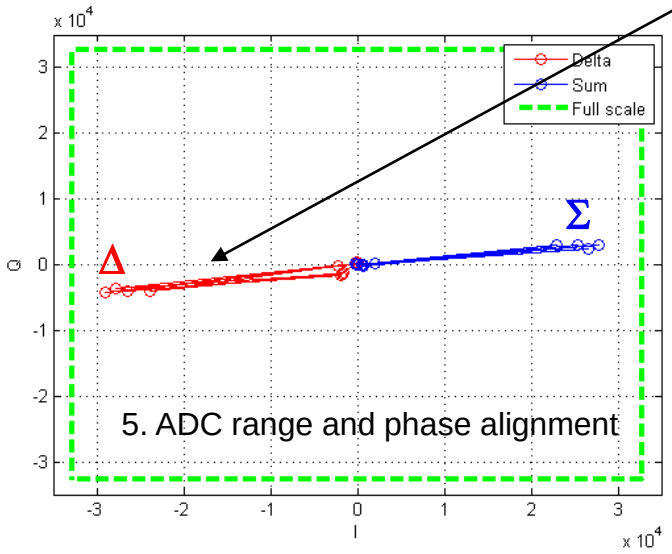
2. Bandpass filtered delta signal



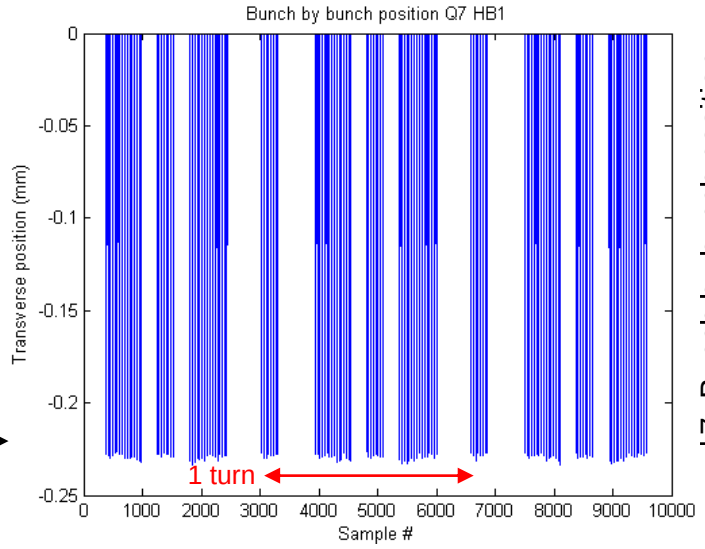
3. Demodulation







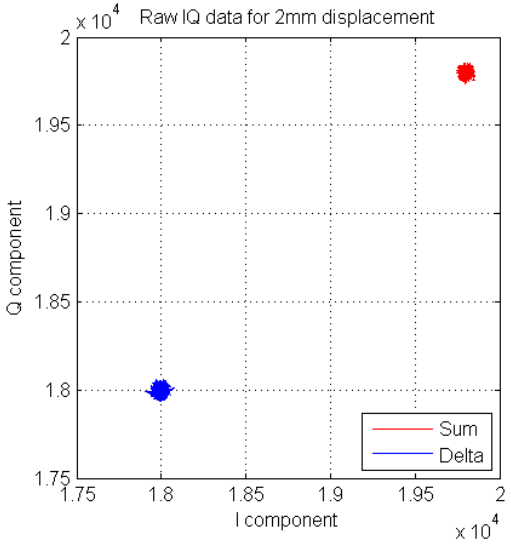
6. Normalization

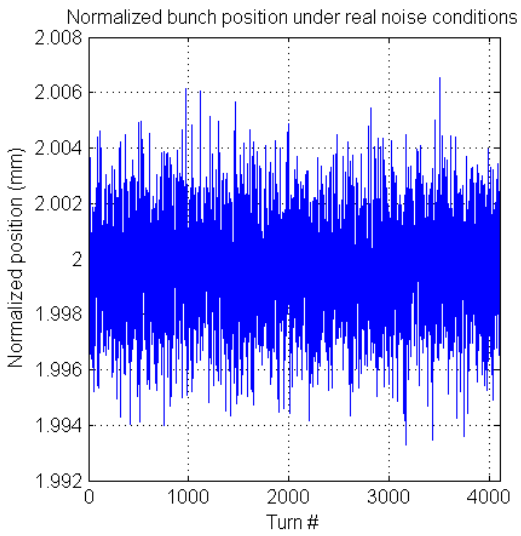


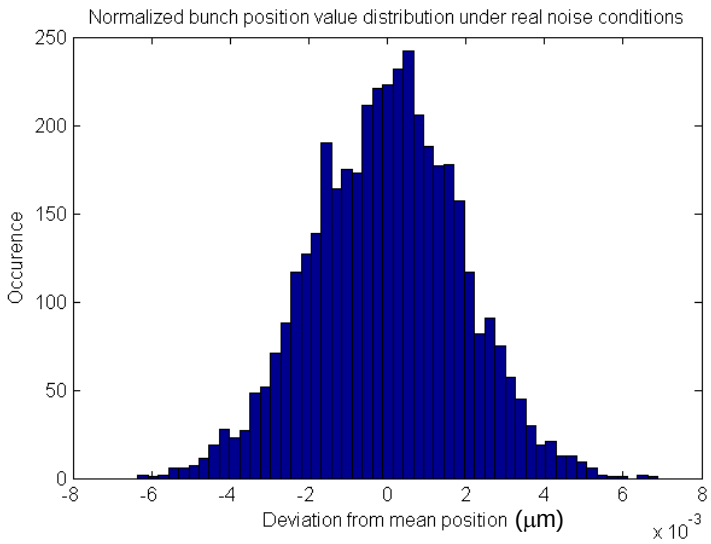
7. Bunch by bunch position data to signal processing and ADTObsBox

Bunch Position Module Performance

- Bunch-by-bunch position information available for all bunches
- **Resolution <0.1 μm/LSB**
- **Typical noise performance* σ=1-2 μm**, 8-14 μm_{pk-pk}

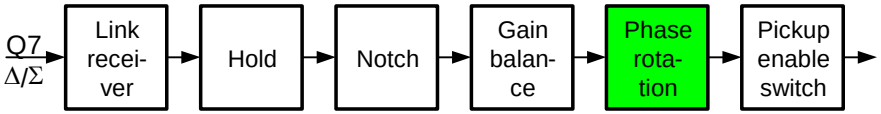




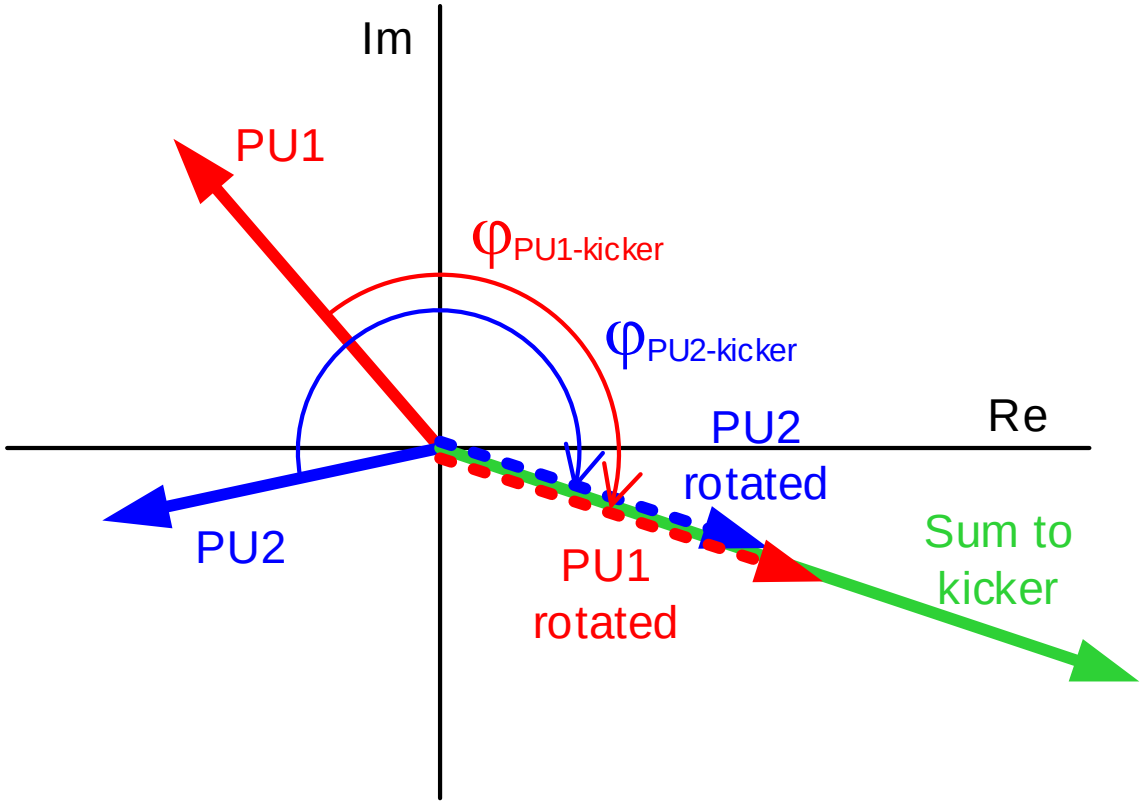


- Simulated Σ/Δ signals for nominal intensity and 2mm displacement, I-Q components at 45°. Real, measured front-end noise superimposed to all four input ADC channels. **Data taken in 2016.**
- Numbers vary with different work points

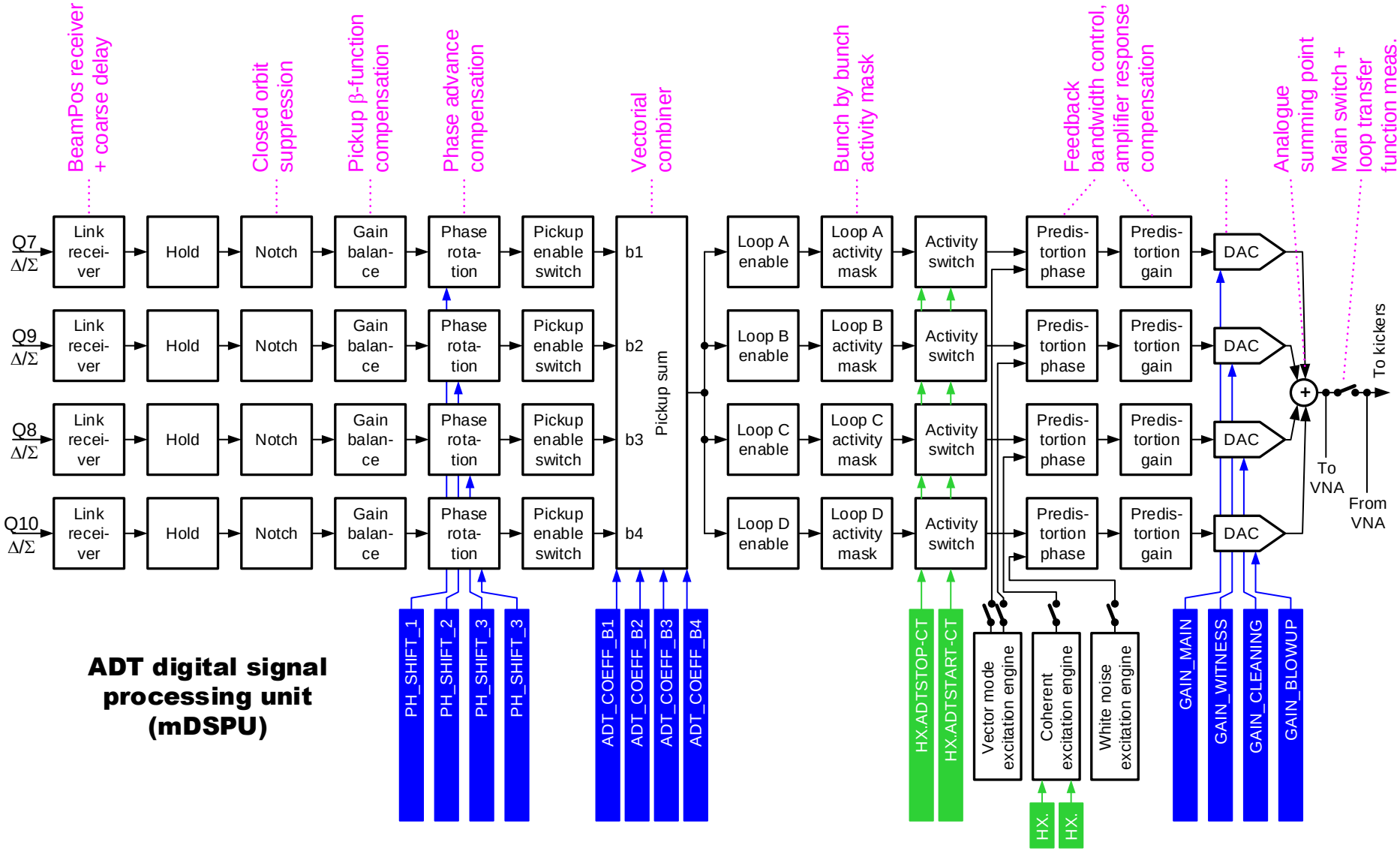
ADT Digital Signal Processing



- Signals from two (currently), or four (in the future) pickups are combined to calculate the correction to the beam

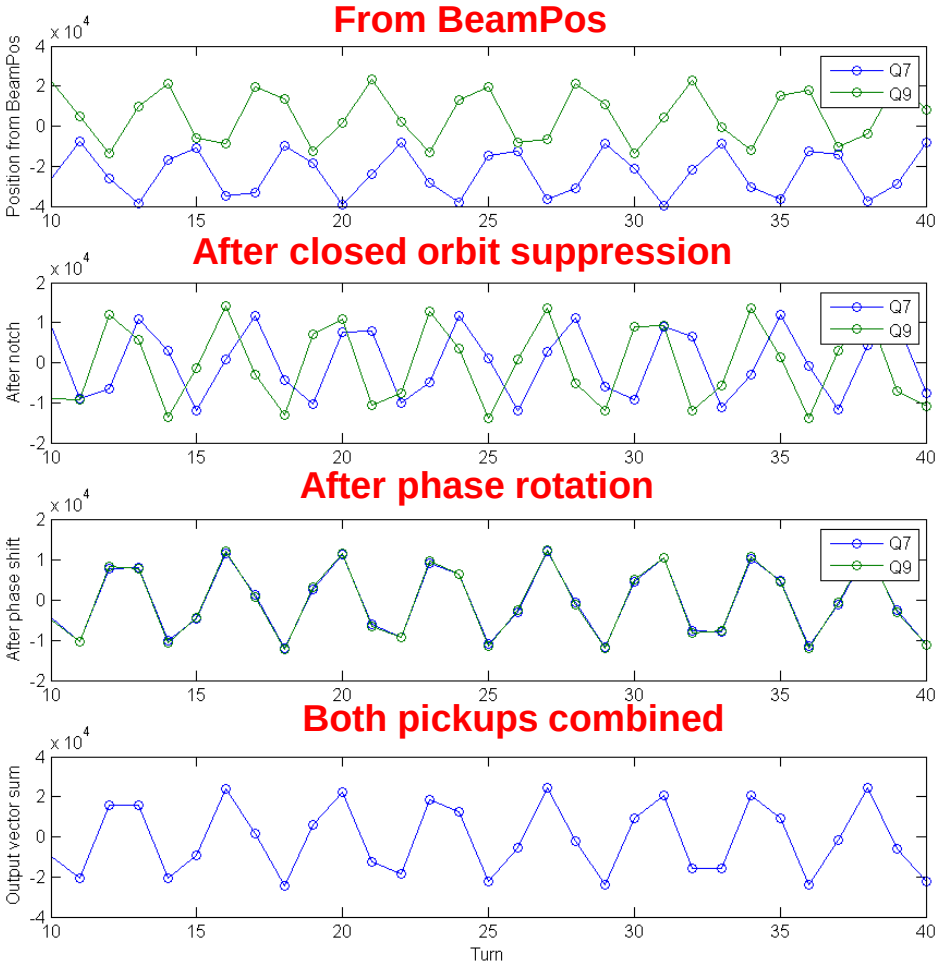


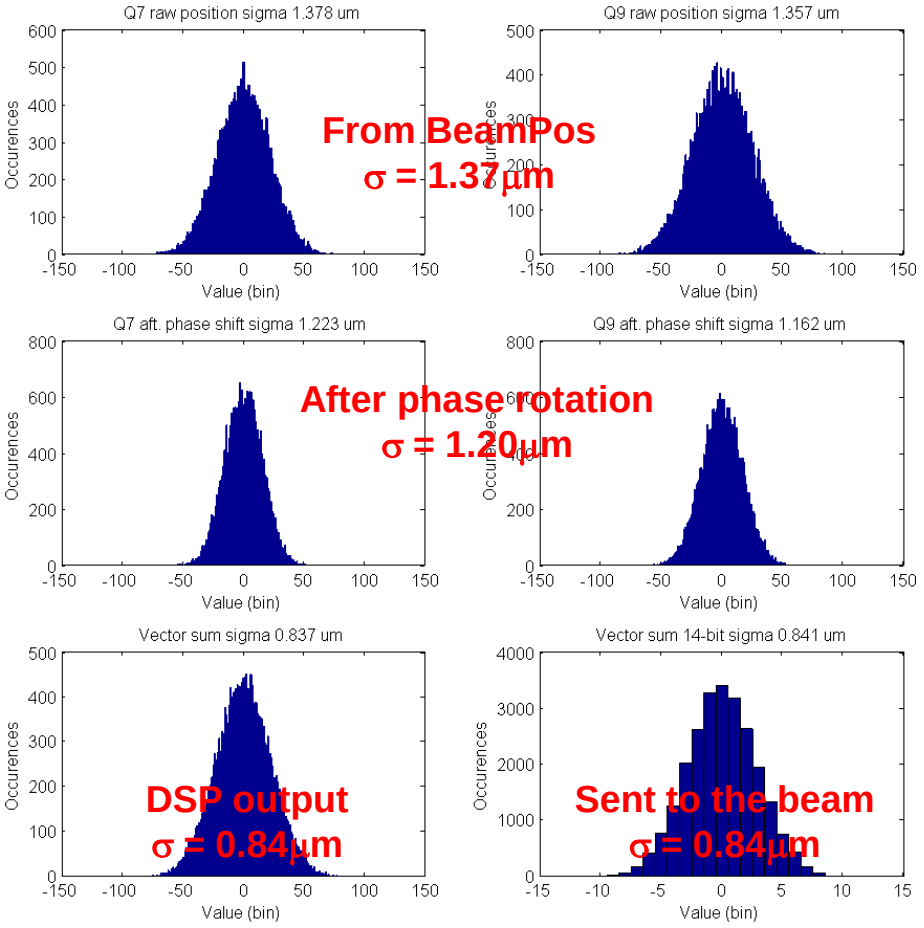
ADT Digital Signal Processing Unit (mDSPU)



ADT digital signal processing unit (mDSPU)

Noise performance of the full ADT signal chain





Simulated signals for nominal intensity and 1mm displacement, phase advance between pickups 90°. Real, measured front-end noise and real digital signal processing algorithm (16bit integer). **Data taken in 2018.**

Typical ADT noise performance

- Data acquired for VB1 on 9.4.2018:

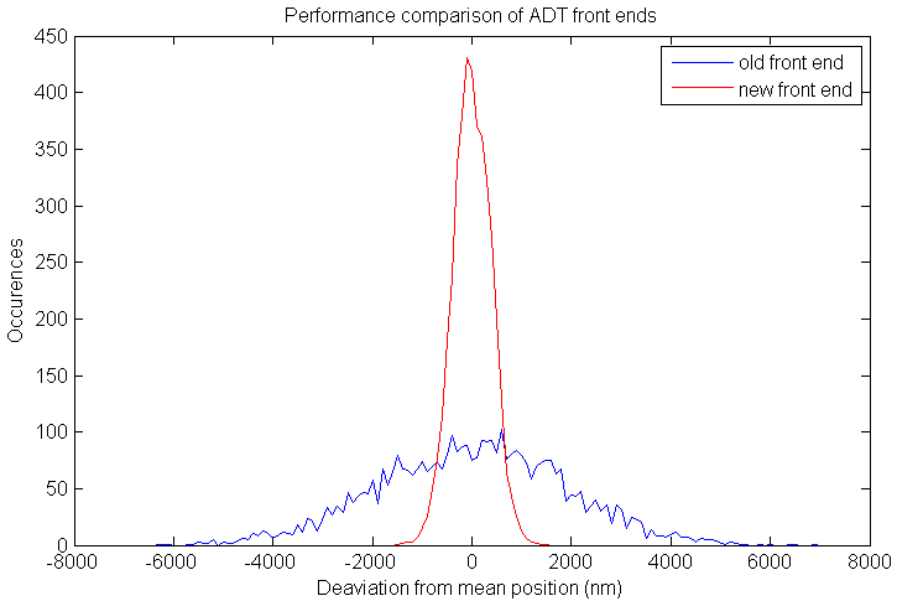
Raw bunch position value Q7 σ = 21.834 bins, **i.e. 1.378 um**
Raw bunch position value Q9 σ = 19.678 bins, **i.e. 1.066 um**
After notch Q7 σ = 15.583 bins, i.e. 1.245 um
After notch Q9 σ = 14.031 bins, i.e. 0.963 um
After phase shift Q7 σ = 15.560 bins, i.e. 1.223 um
After phase shift Q9 σ = 13.352 bins, i.e. 0.916 um
Vector sum σ = 20.440 bins, i.e. 0.743 um
Vector sum 14-bit σ_{ADT} = 2.570 bins, **i.e. 0.748 um**

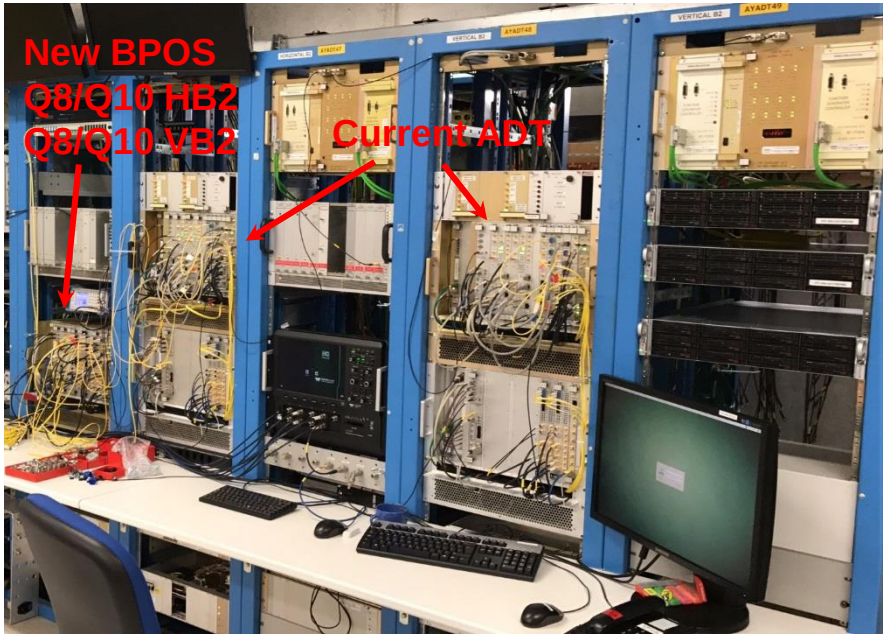
- **Beam σ at ADT pickup** σ = sqrt(ε_{NORM} * β / γ). At flat top beam σ = sqrt(2um*250m*6930) = 270um

- **ADT σ seen by the beam** σ_{ADT} * norm. gain = 0.748 um * 0.04 = 0.0299 um

Upgrade plans

- The new beam position modules are proposed since LS1
- Novel concept eliminating noisy components
- First tests with real hardware in January 2016 showed potential for noise floor improvement by factor 3 to 10.
- Pickups Q8 and Q10 of B2 are equipped by test hardware since 01/2017





Summary

- In the past ~2 years the requirements for ADT had evolved from:
  - “as fast as possible”,
  - “as low as possible”,
  - “as large as possible”
- to something like:
  - “can it be 0.001 sigma?”,
  - “we should try 1MHz bandwidth”.
- **This is an unprecedented progress, thank you very much for all the effort!**
- Having scientific grounds allows us to benchmark the ADT performance against the requested machine parameters/models.

Summary

- The ADT noise contribution is dominated by the beam position measurement noise, rest of the system can be considered noiseless
- Current position measurement sigma is in order 1.2-1.8um.
- It was demonstrated this can be lowered by factor 3 to 10, using the new Beam Position measurement concept+hardware
- Project completion requires about 6 months **of uninterrupted work**.
- Much lower noise floor opens completely new observation/detection possibilities with ADTObsBox…