Commissioning of the bunch arrival time monitor (BAM) system at FLASH

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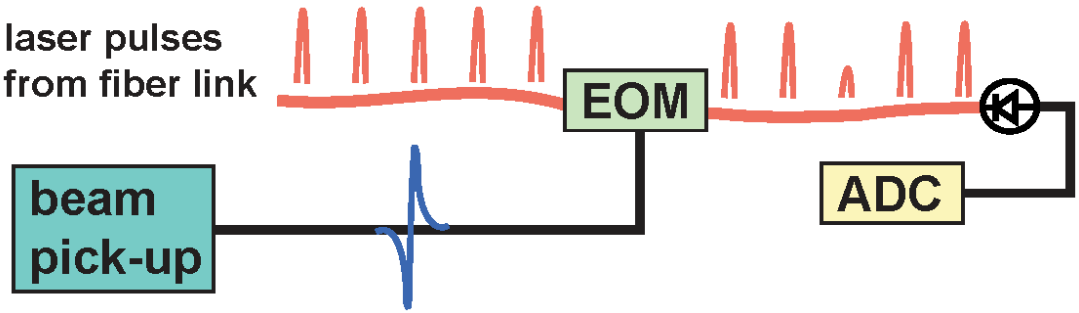
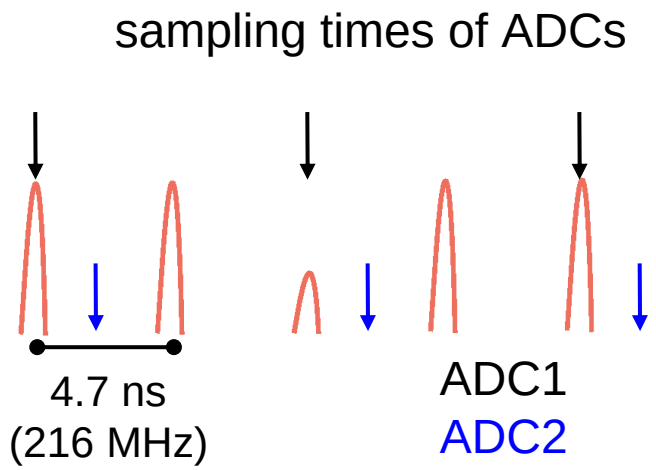
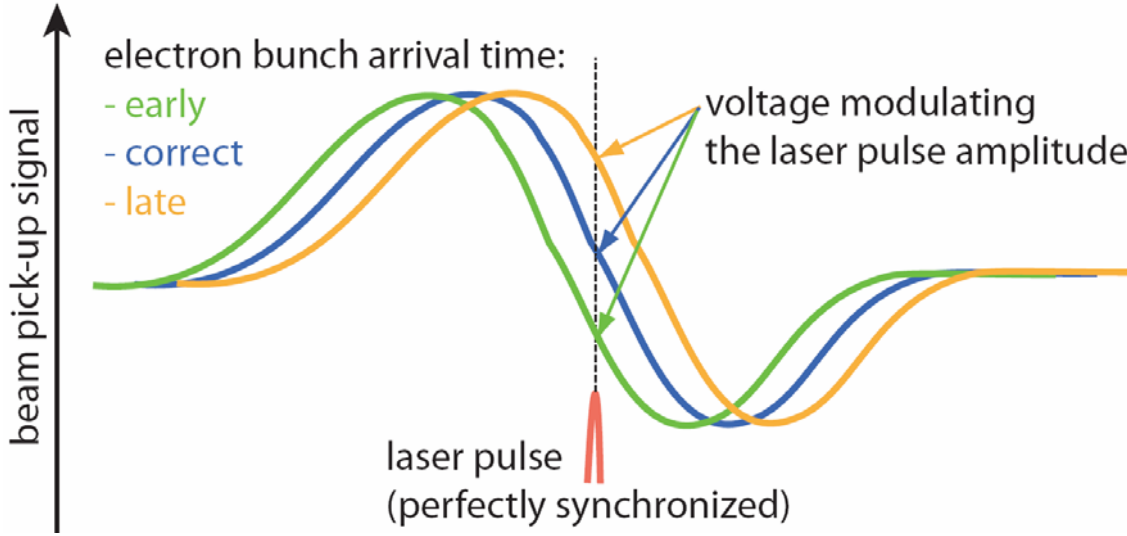
February 26, 2008

Prinziple of the bunch arrival time monitor (BAM)

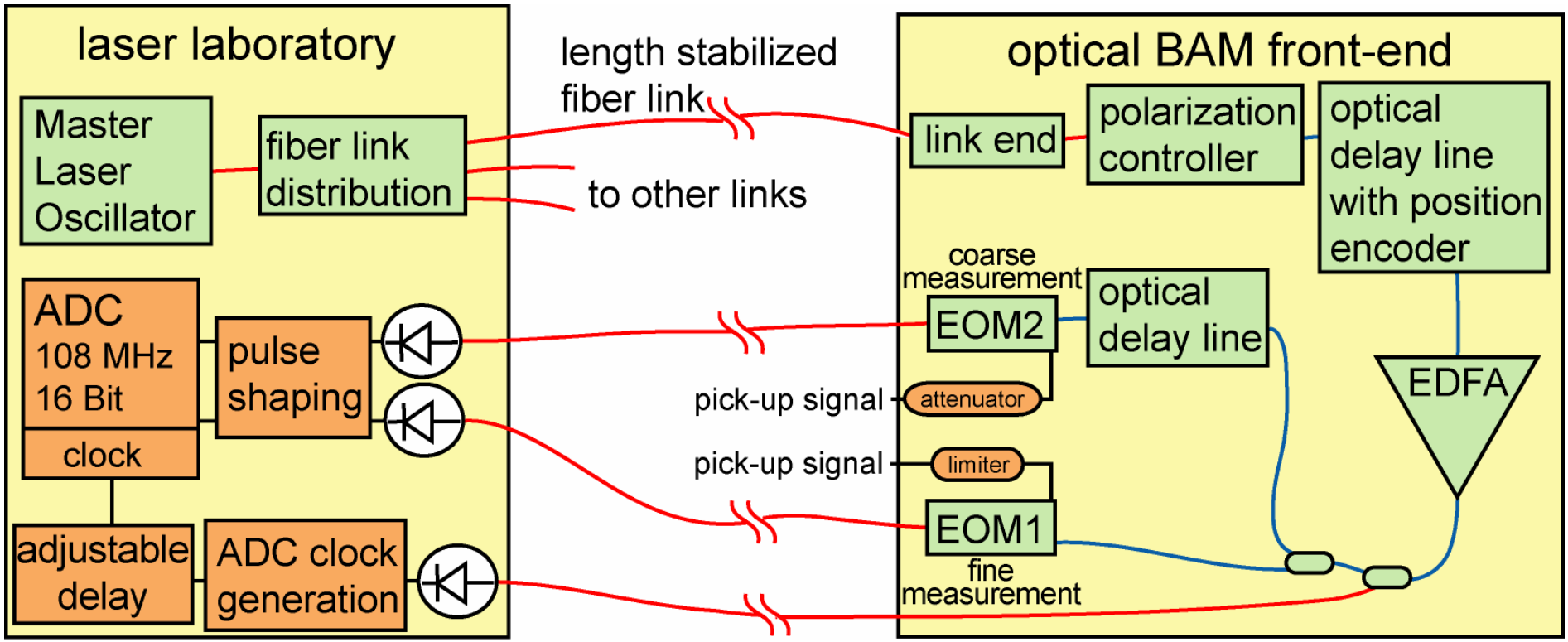




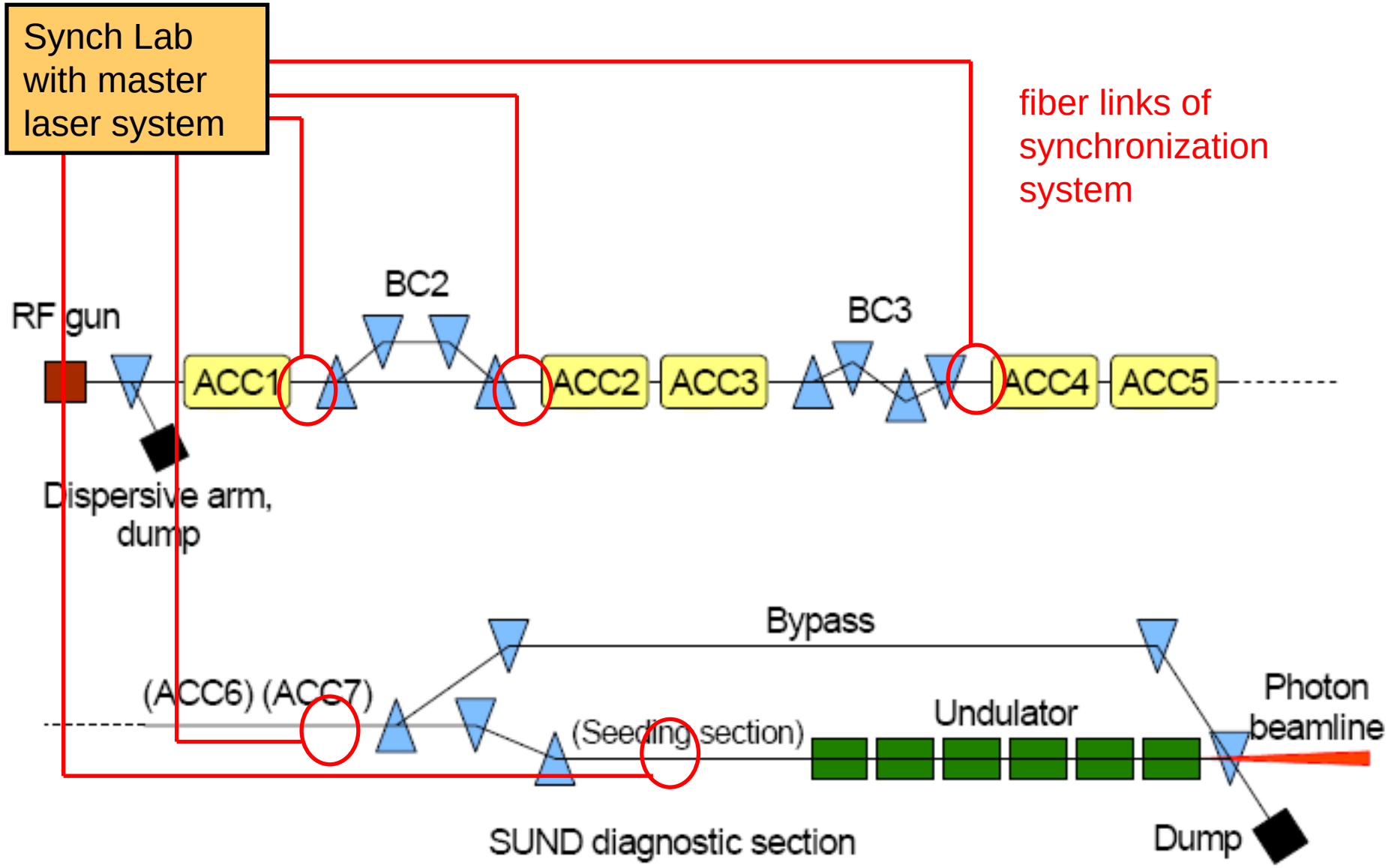
The timing information of the electron bunch is transferred into a laser amplitude modulation. This modulation is measured with a photo detector and sampled by a fast ADC.



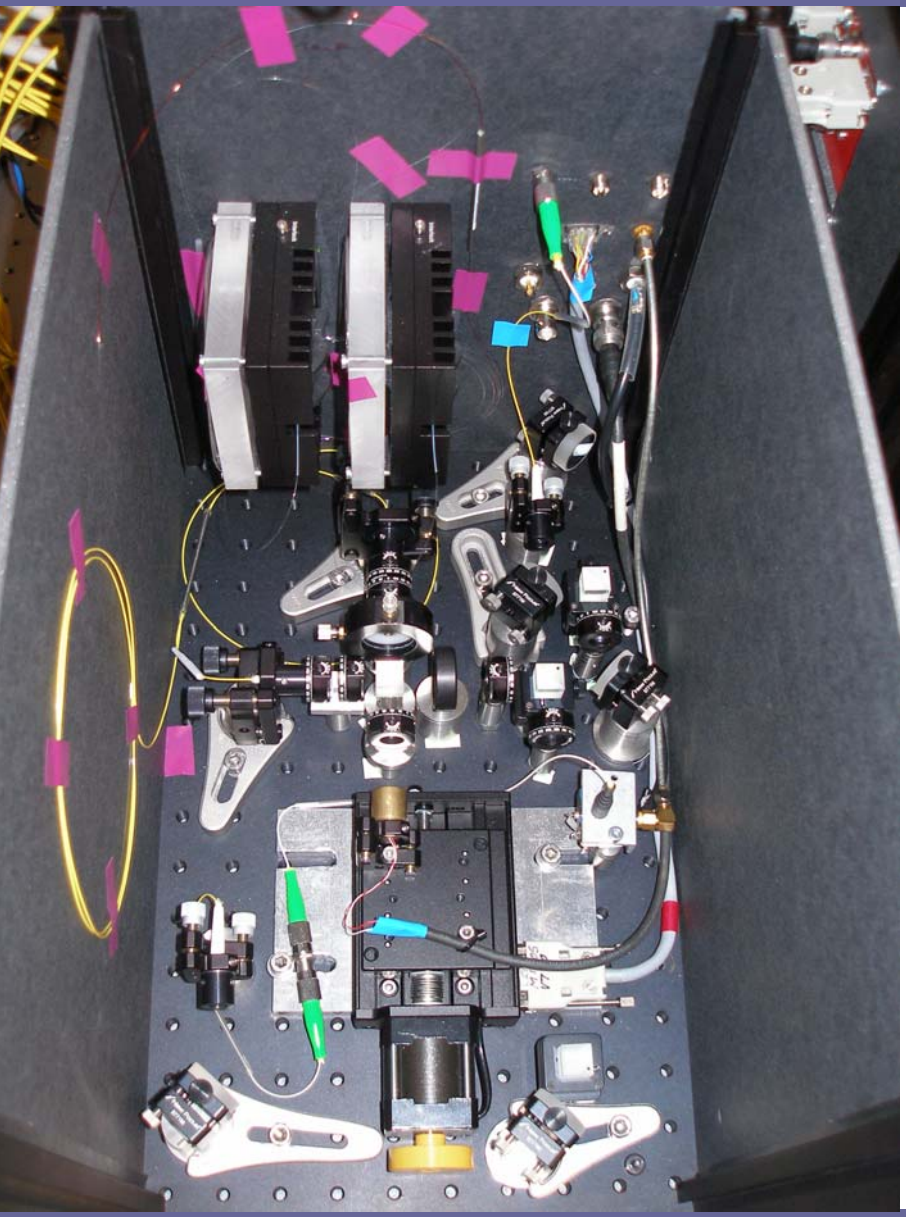
Setup of the bunch arrival time monitors

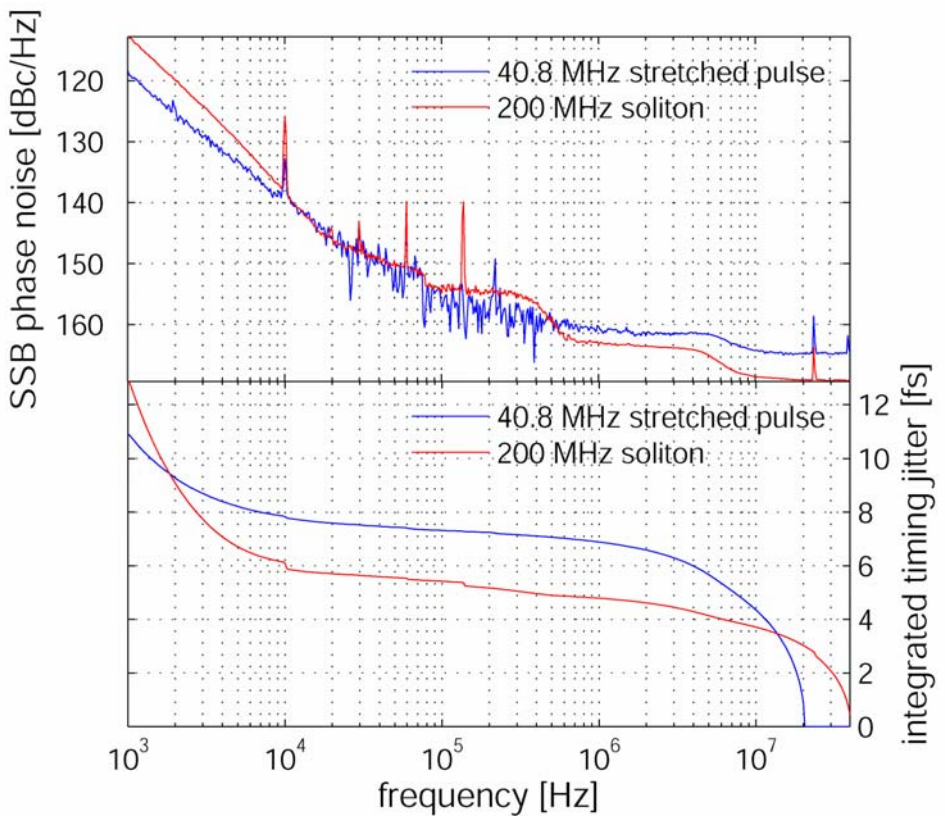


Positions of the BAMs in the FLASH linac



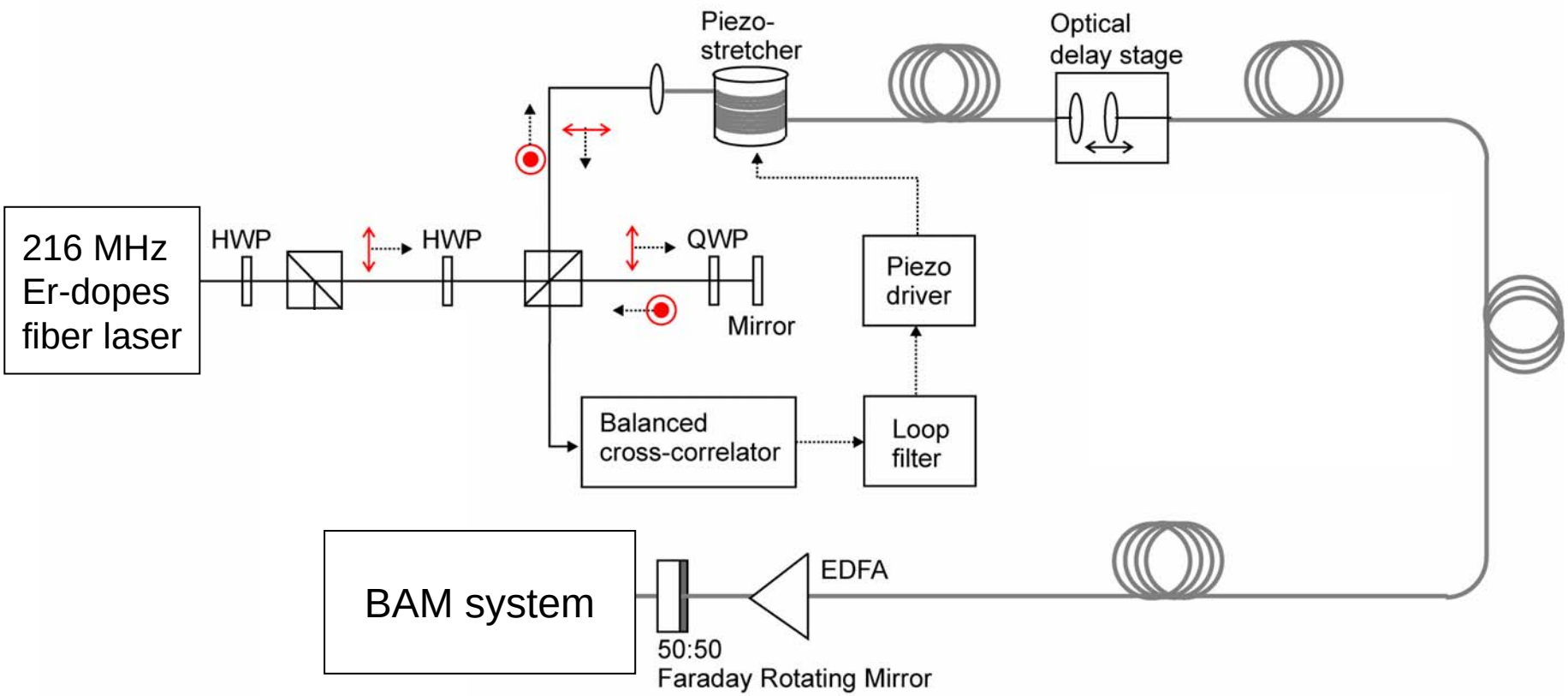
The new fiber laser system





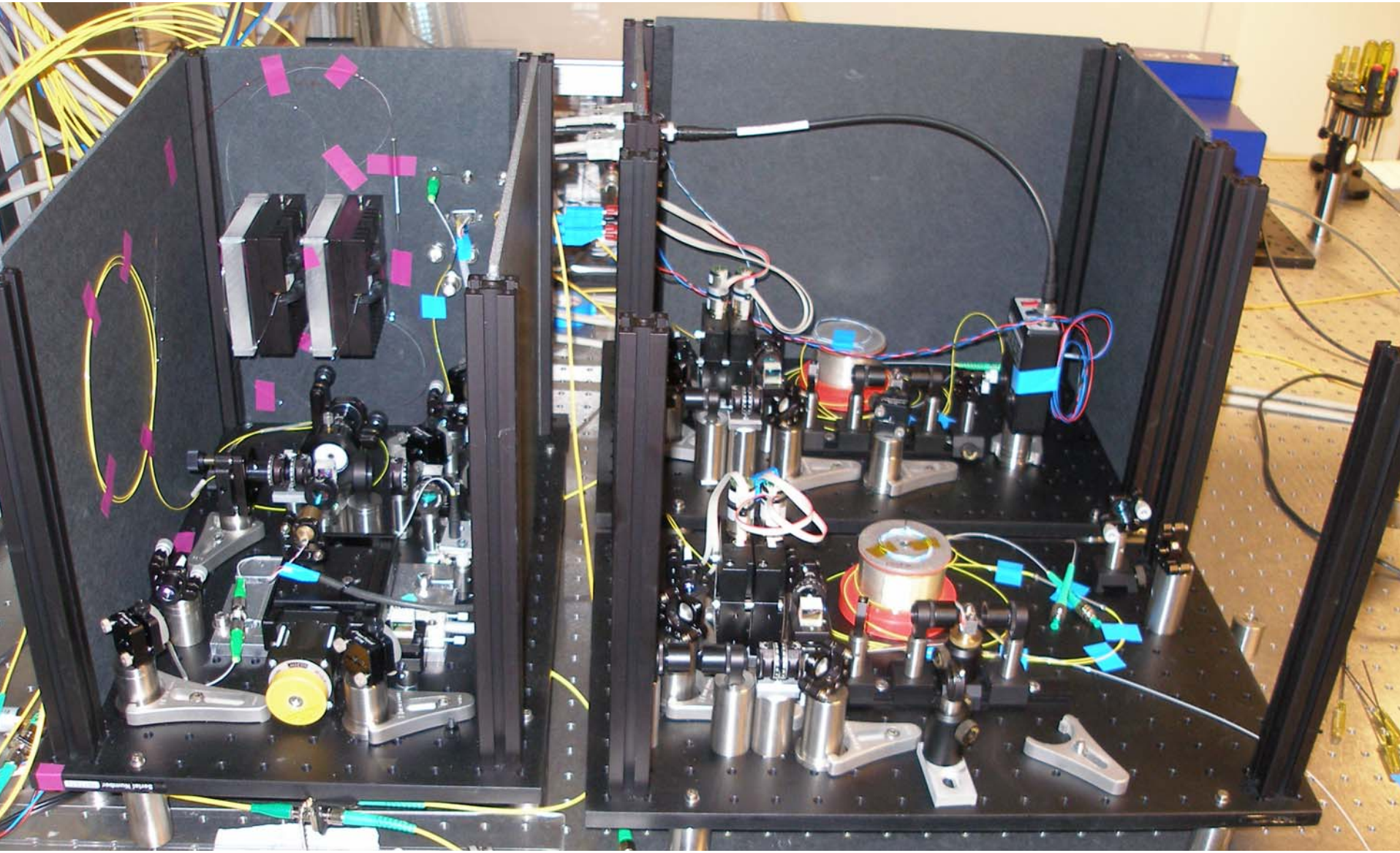
We switched from a 54 MHz stretched pulse laser to a 216 Mhz soliton laser, since the higher repetition rate has several advantages for the subsystems.

The fiber link stabilization



The optical length of the fiber is stabilized to better than 10 fs.

Master laser and fiber link stabilization

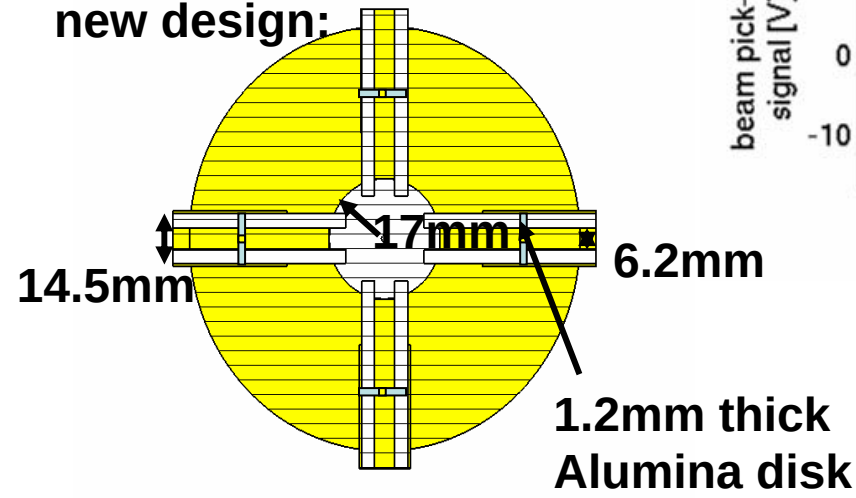


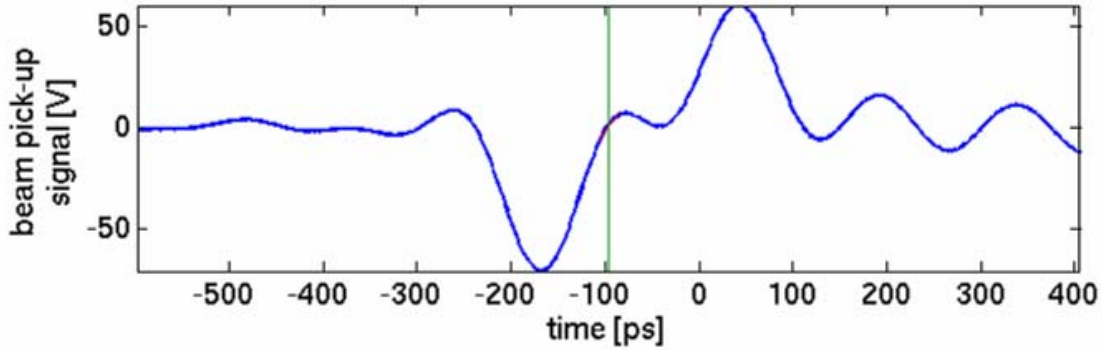
The beam pick-up

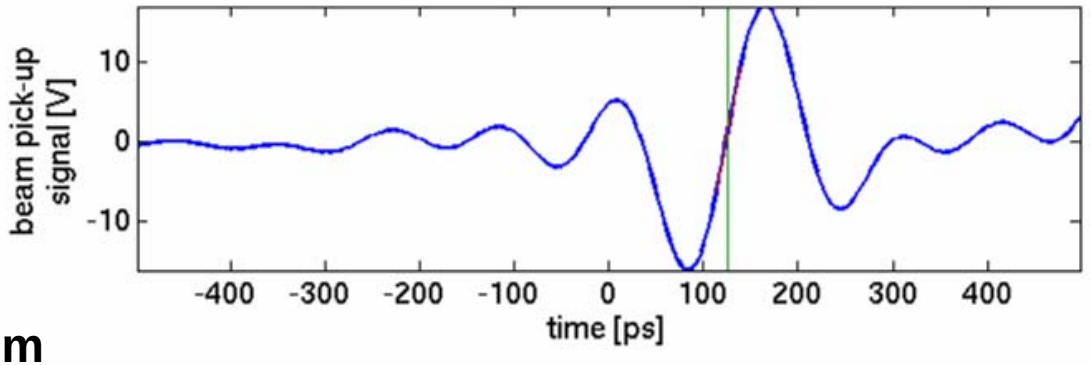
During the summer shutdown, a new beam pick-up (design: K. Hacker) was installed instead of the ring electrodes to improve the pick-up performance.

old ring electrode:

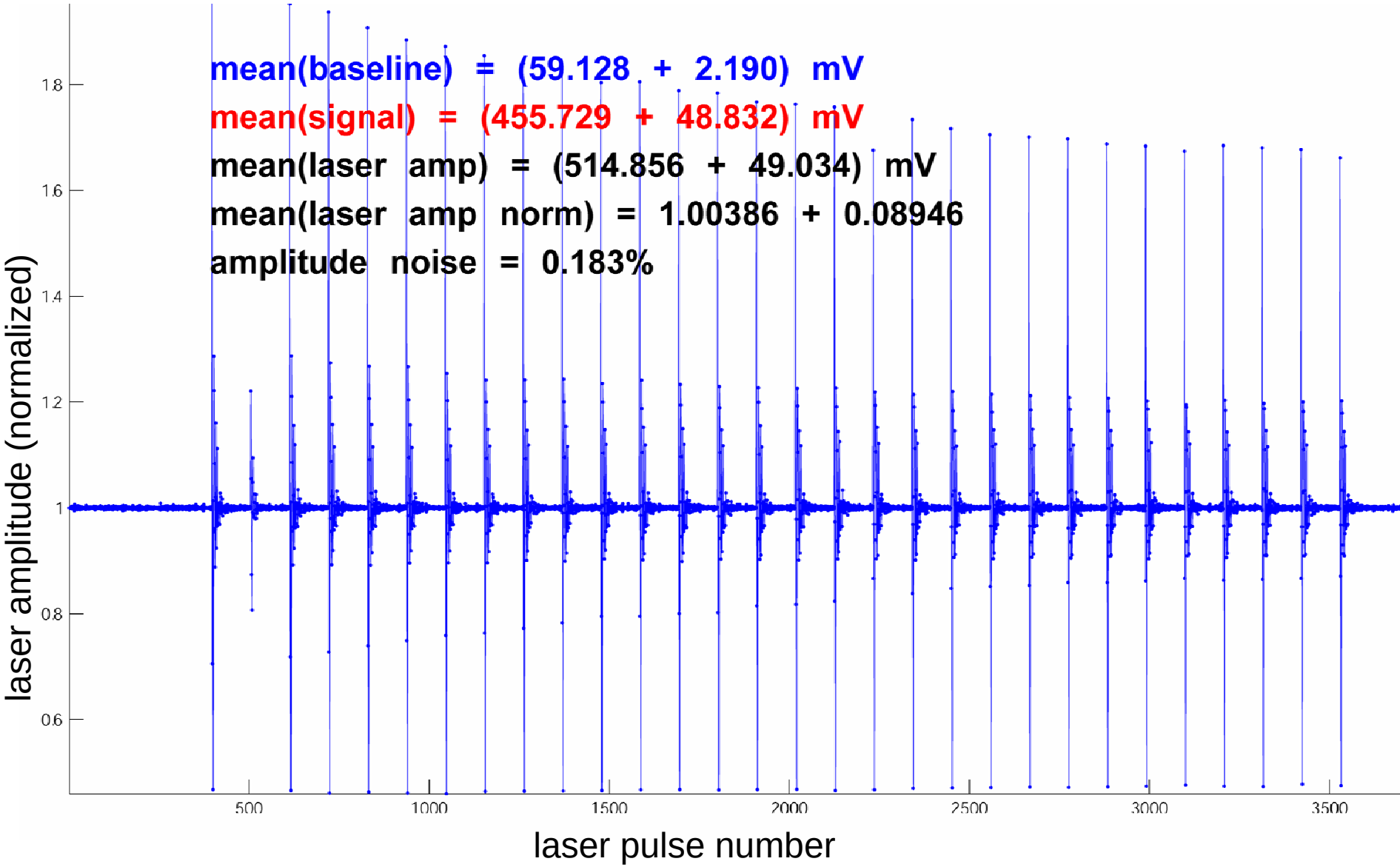
new design:





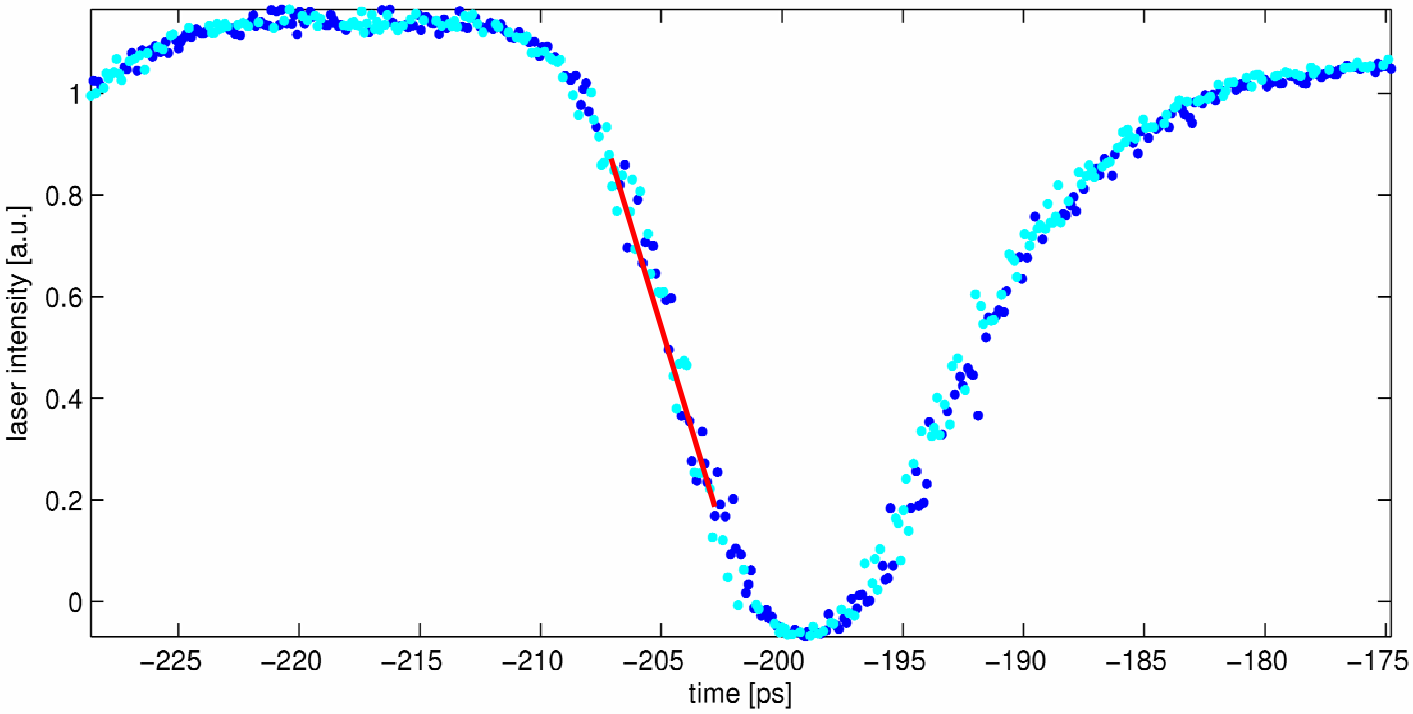


First BAM signals



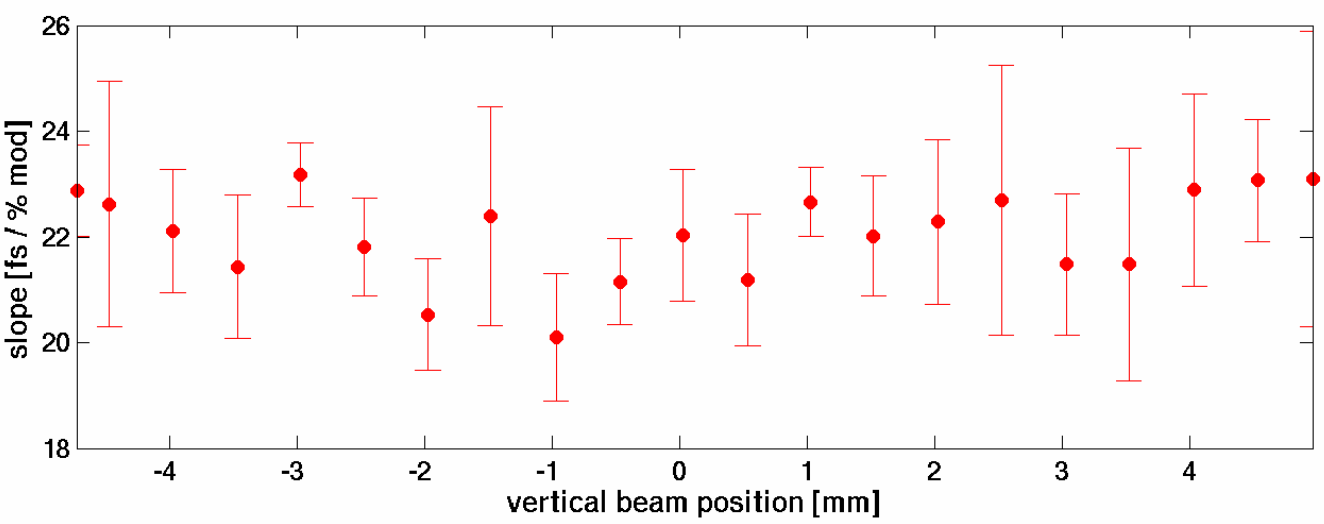
Calibration of the BAM system

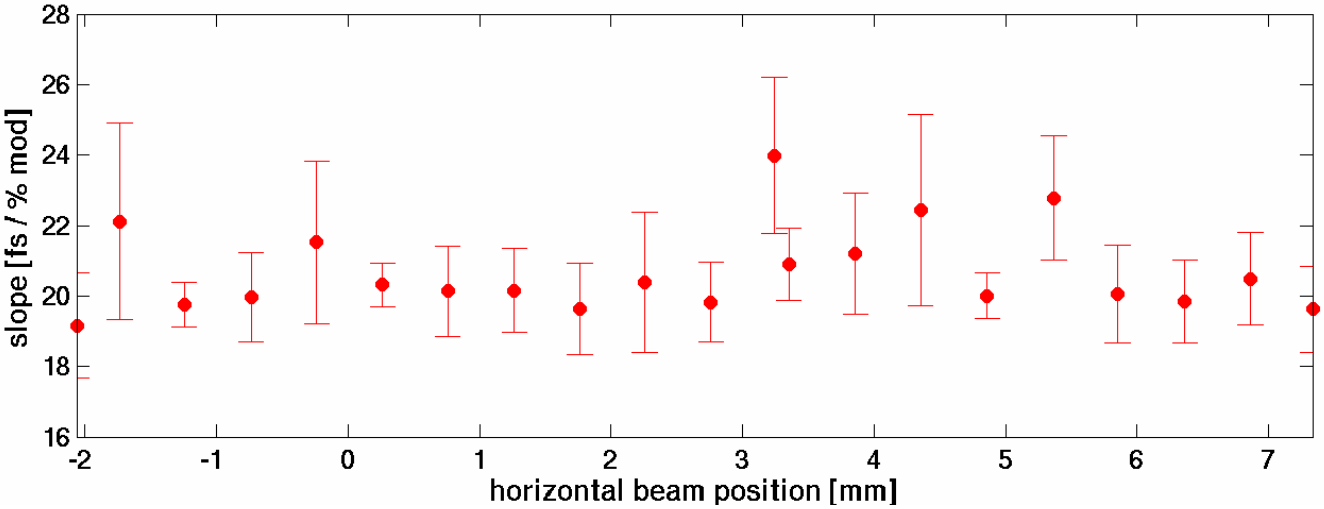
The laser pulses are scanned over the beam pick-up signal to map it onto the laser amplitude. The slope at the zero-crossing is used for the measurement. A calibration run can be made “online” and a continuous calibration update is foreseen in case operation conditions are changed (already implemented in DOOCS server).



(slope measured with old beam pick-up)

Dependence of the pick-up signal slope on the beam position

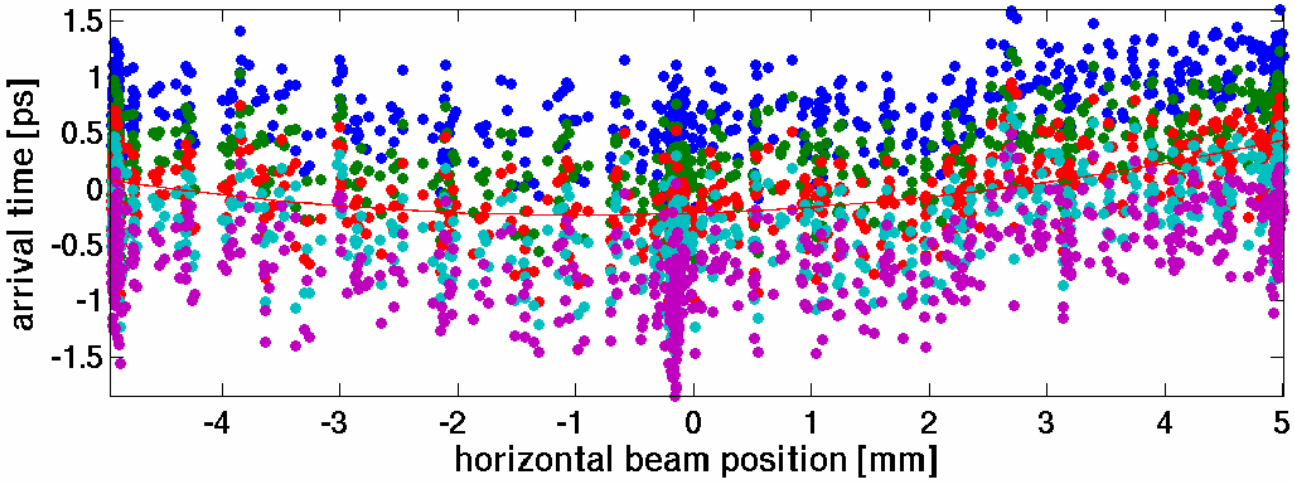


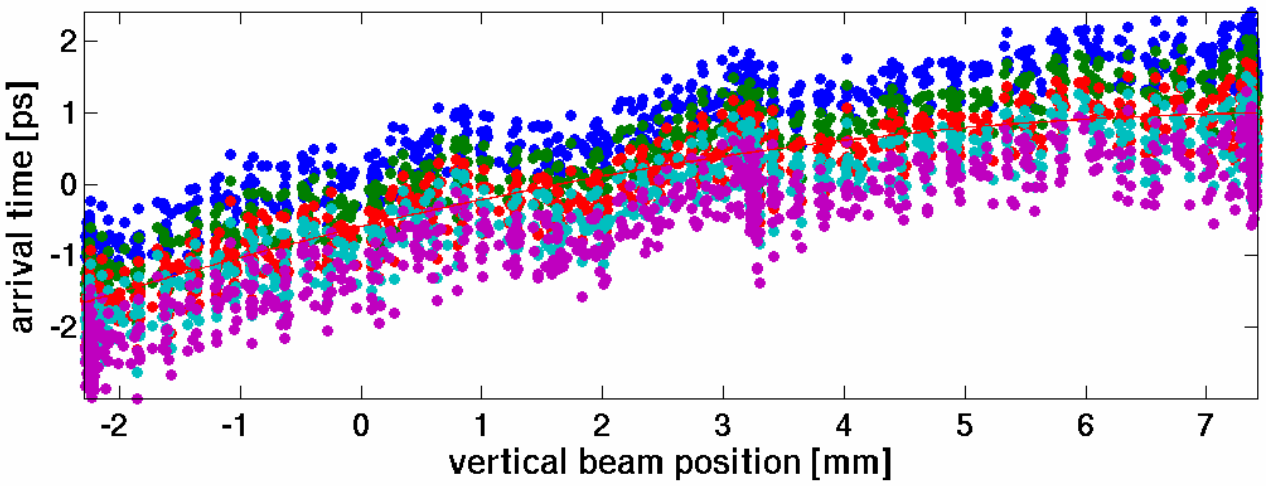


There is basically no dependence!

Dependence of the pick-up zero-crossing on the beam position

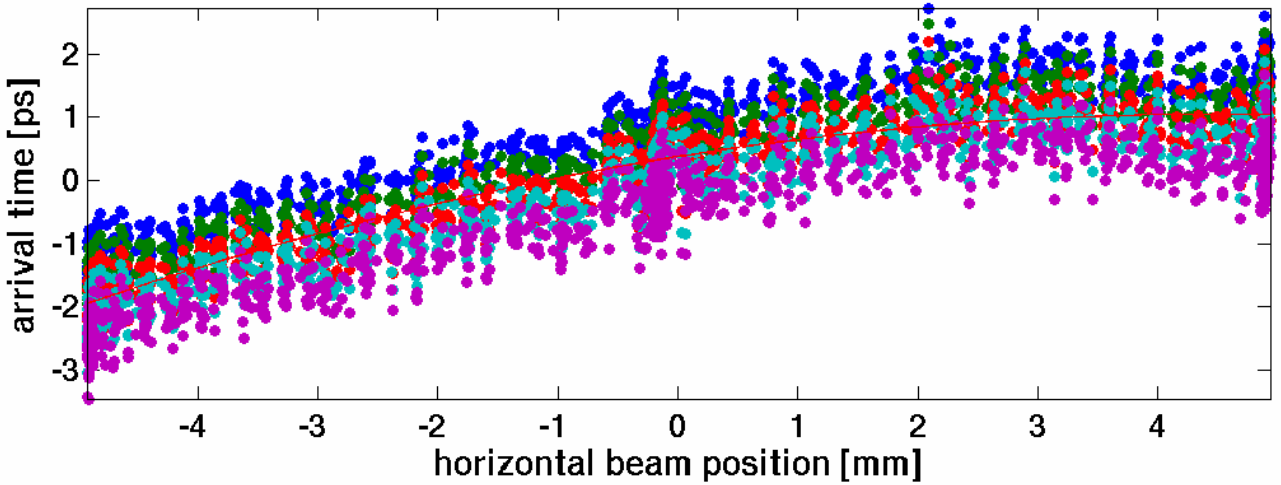
vertical channels combined:

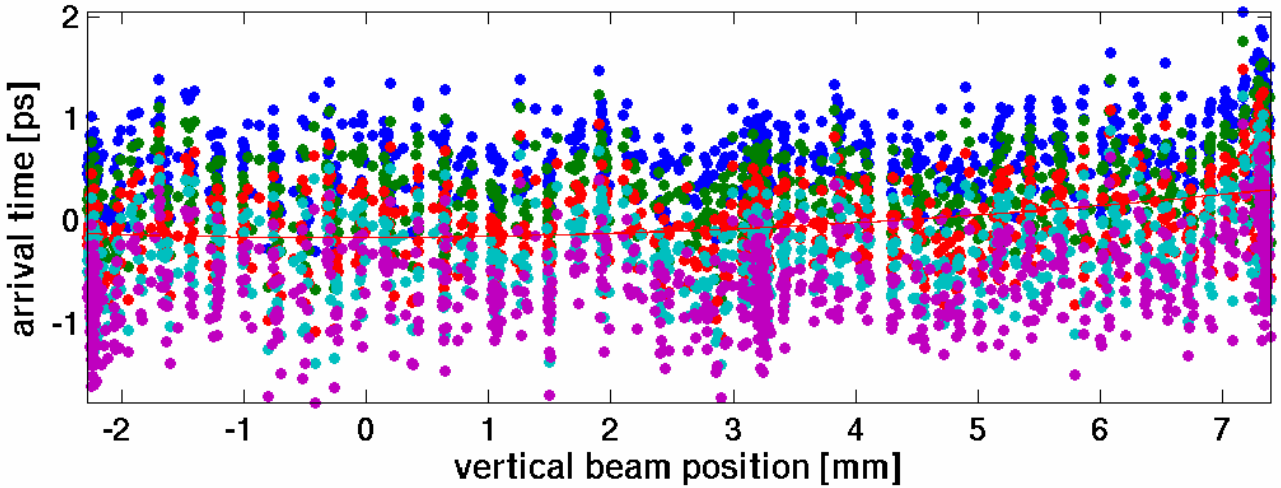




Symmetric curve with zero slope at y = 0 expected!

horizontal channels combined:





Symmetric curve with zero slope at y = 0 expected!

possible reasons:

misalignment of BPM 16ACC7

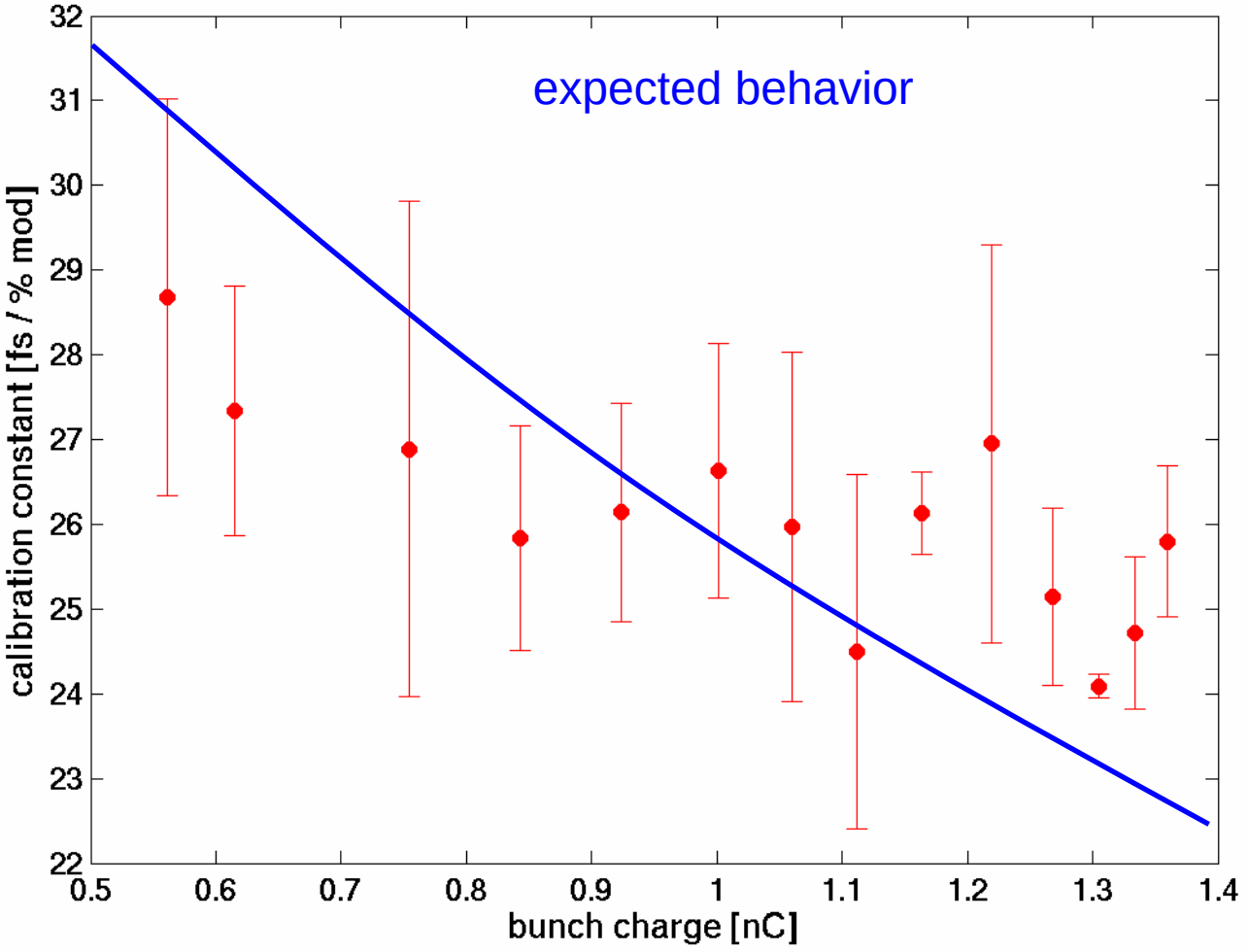
or

misalignment of BAM 18ACC7 and OTR chamber

or

different coupling efficiency of different pick-up electrodes

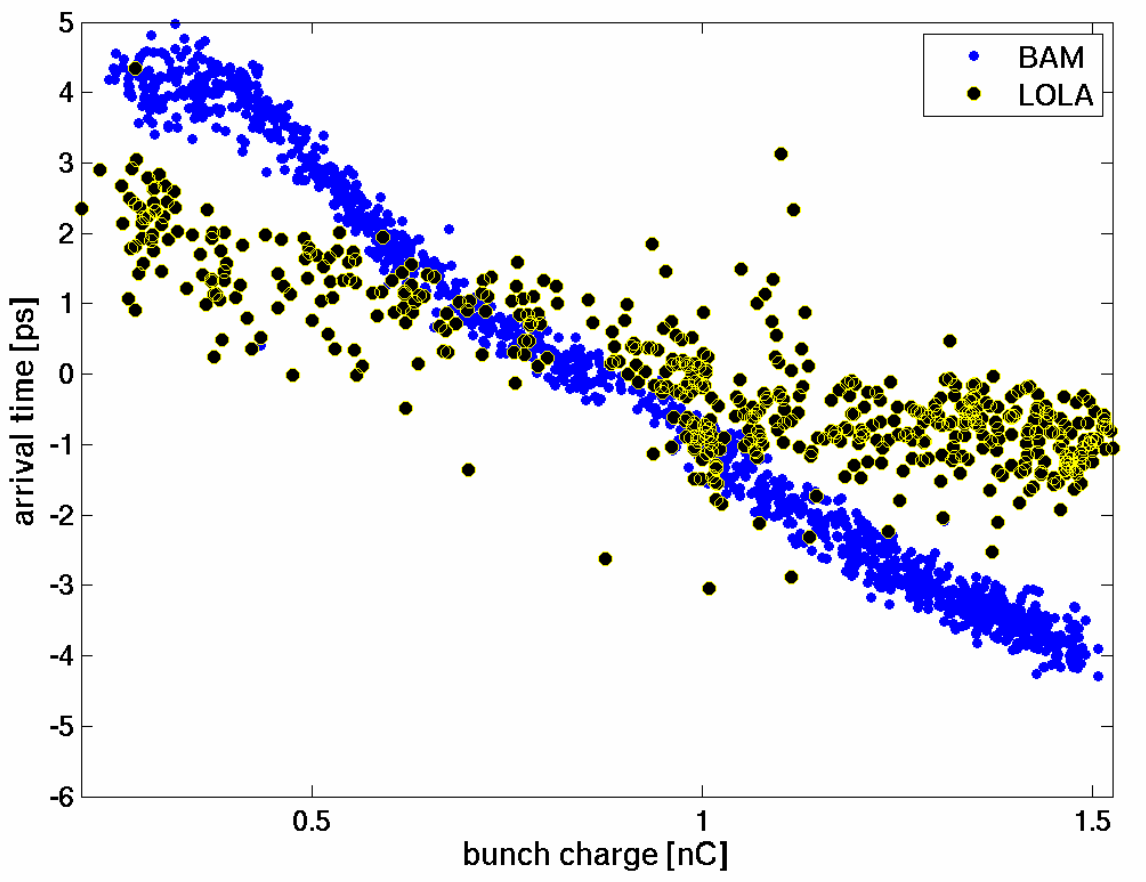
Dependence of the pick-up signal slope on the bunch charge



Slope does not get steeper with increasing charge!

Dependence of the measured bunch arrival time on the charge

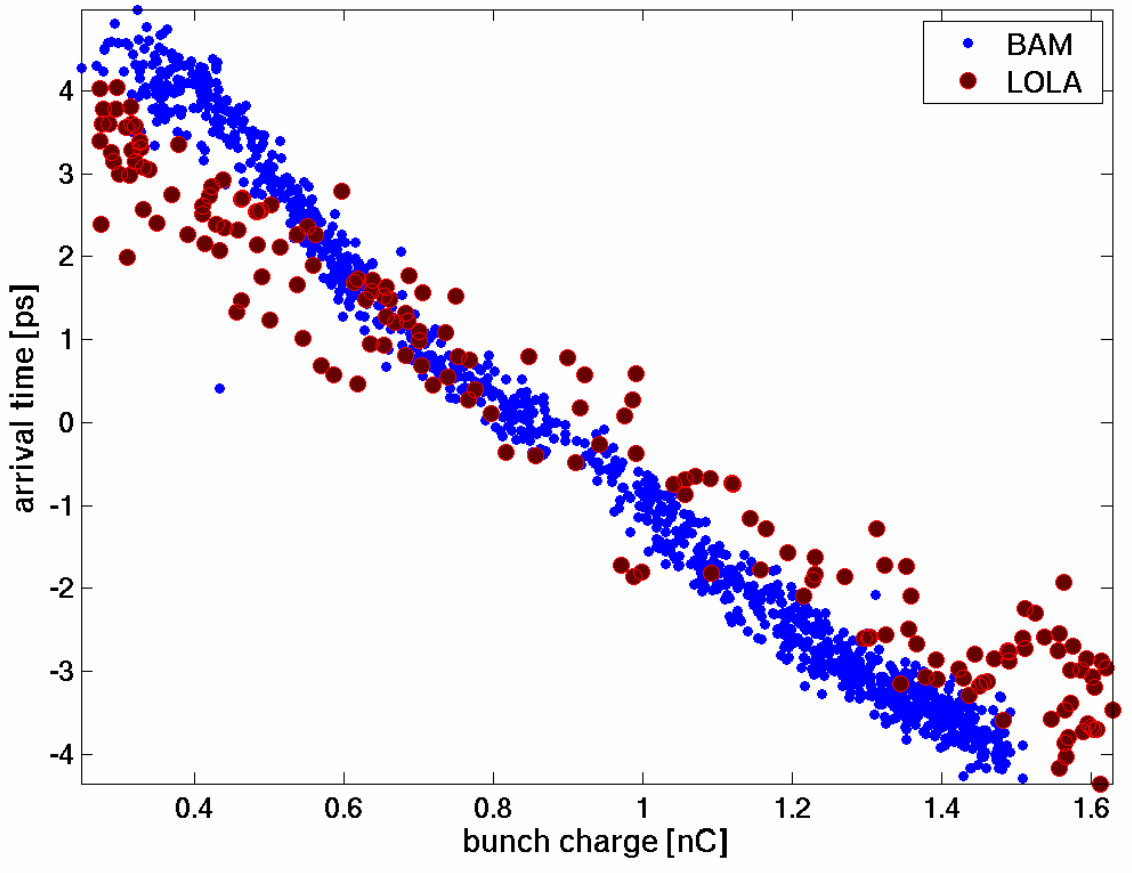
orbit feedback switched on



Arrival time dependence on the bunch charge is much higher for the BAM than for LOLA!

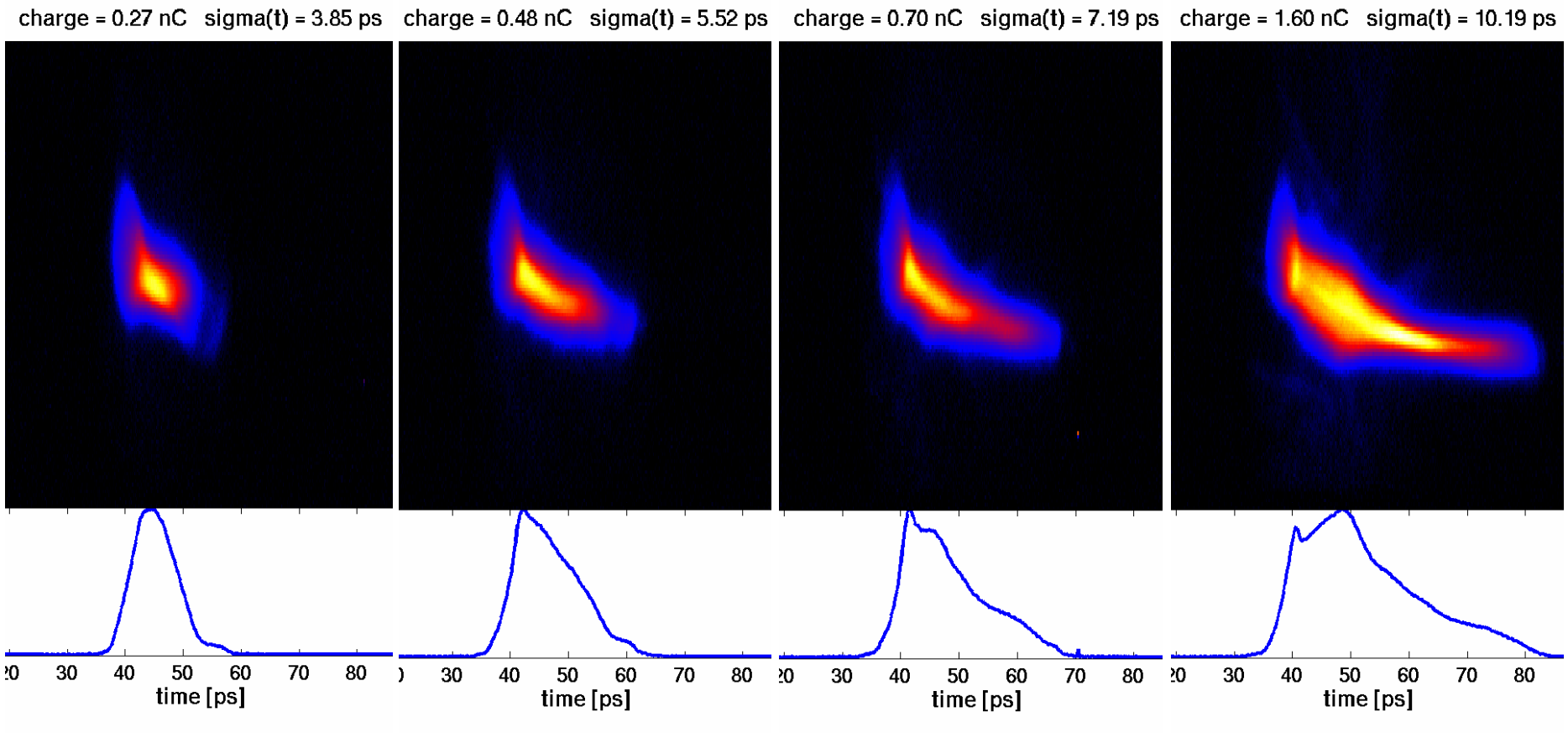
Dependence of the measured bunch arrival time on the charge

orbit feedback switched off



Do the BPMs have a charge dependence?

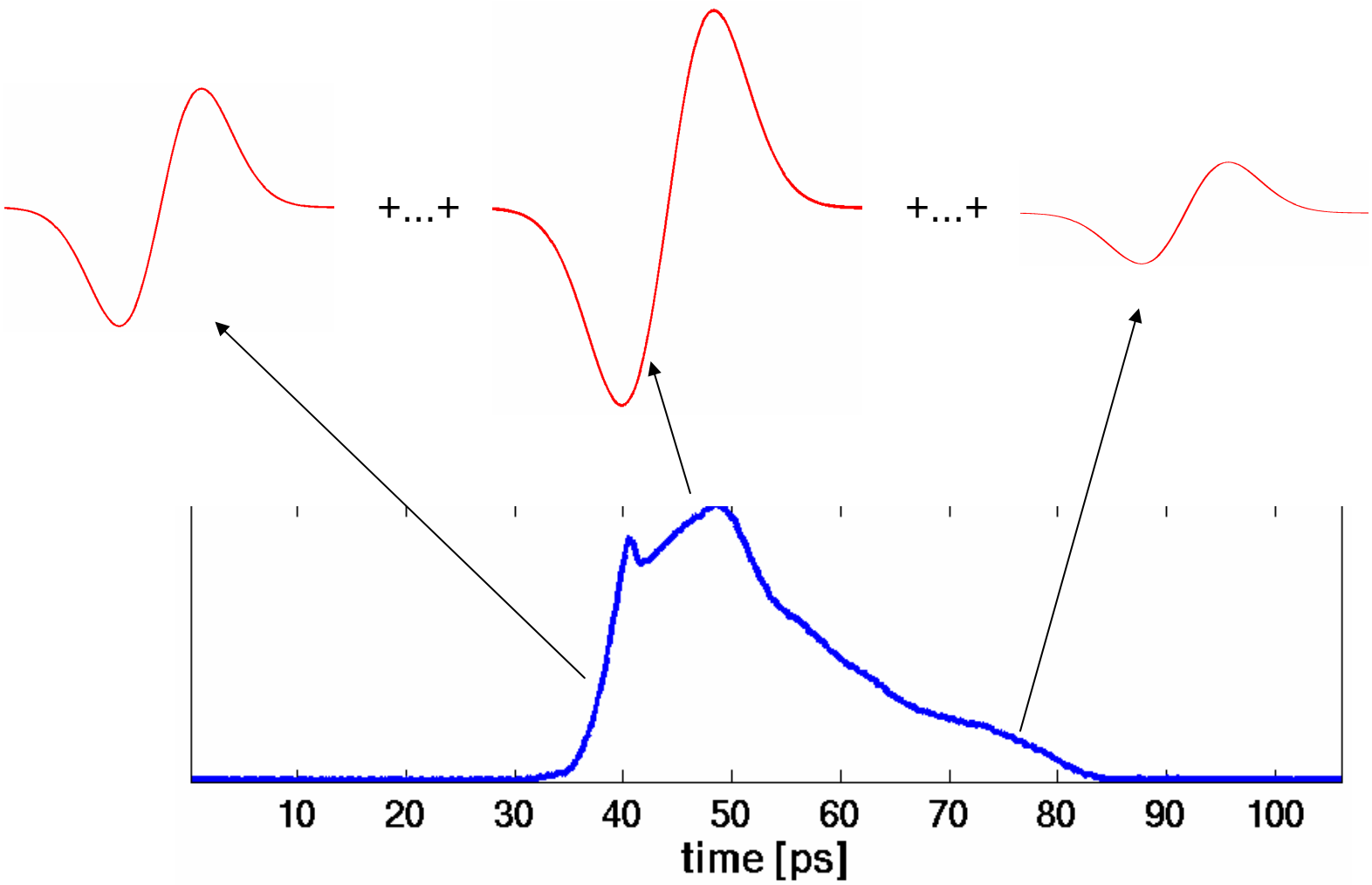
Change of the bunch length with charge (on-crest)



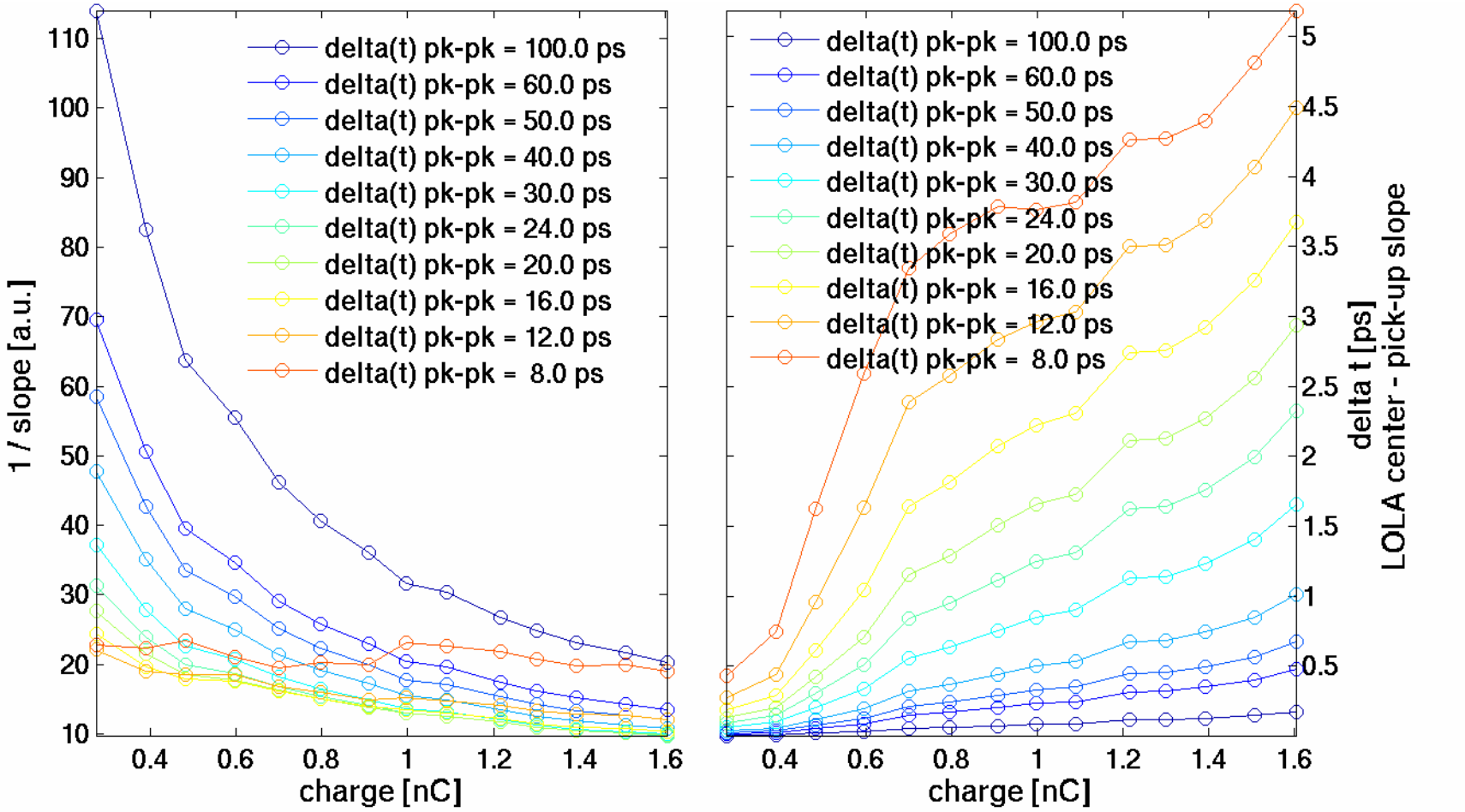
The bunch length is changed almost by a factor of three!
The longitudinal pulse shape is changed significantly!
→ Intra bunch train charge feedback needed.

Simple model to understand the BAM charge dependence

Superposition of “wavelets” for each longitudinal slice.
Free parameter: wavelet duration.



Simple model to understand the BAM charge dependence

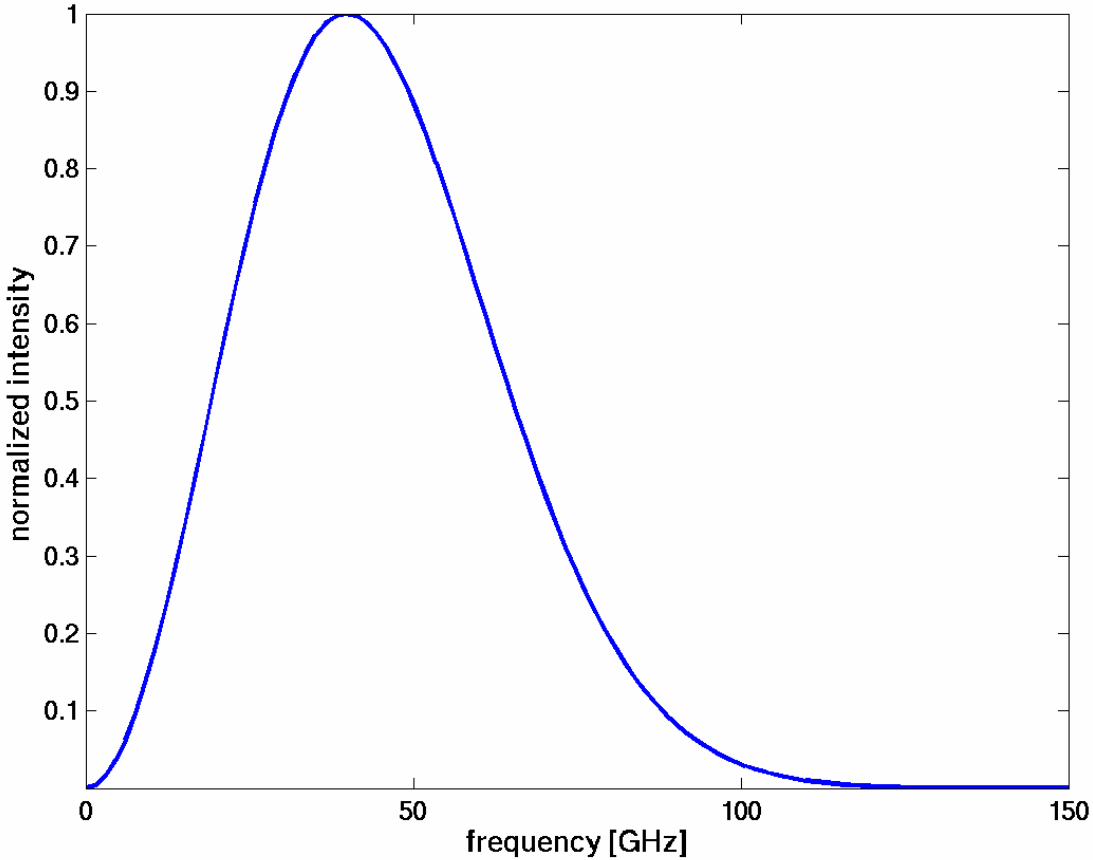


For a compressed bunch, the dependency is strongly suppressed.

Bandwidth of pick-up and EOM?

The previous considerations seem to explain the charge dependence…

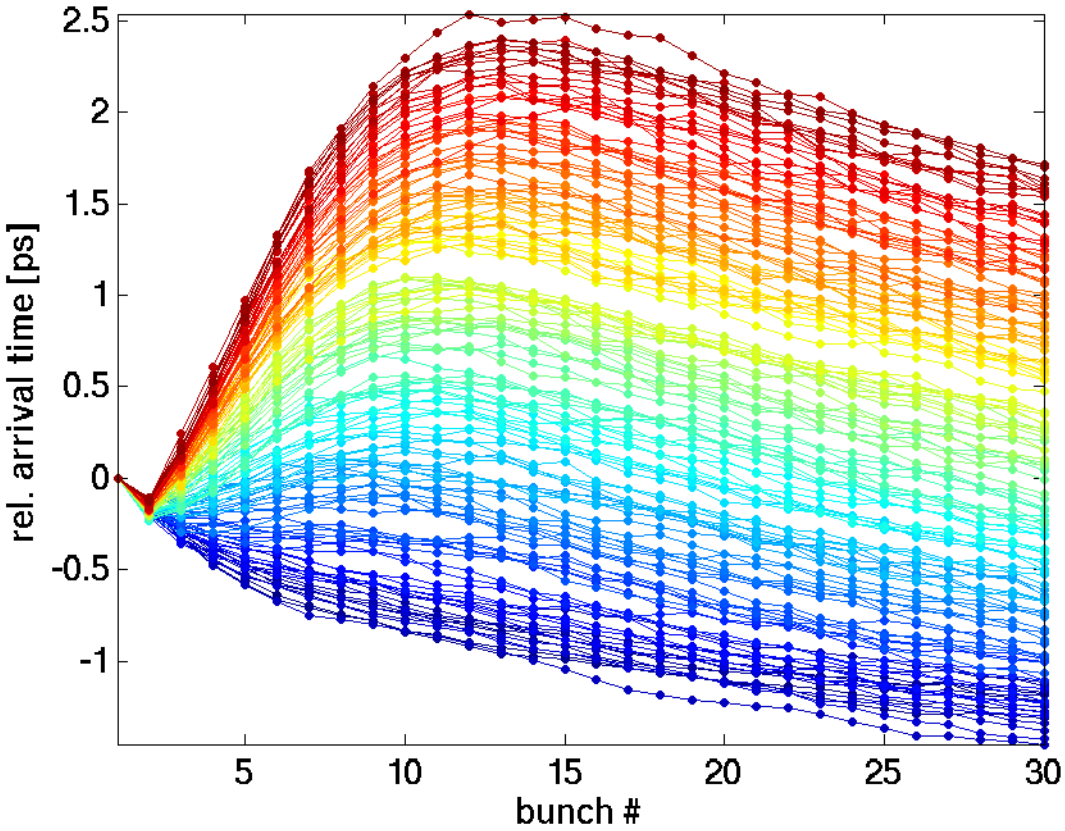
BUT: This is the frequency spectrum of the shortest wavelet:
Has the pick-up a bandwidth of ~ 50 GHz?



Arrival time manipulation over the bunch train

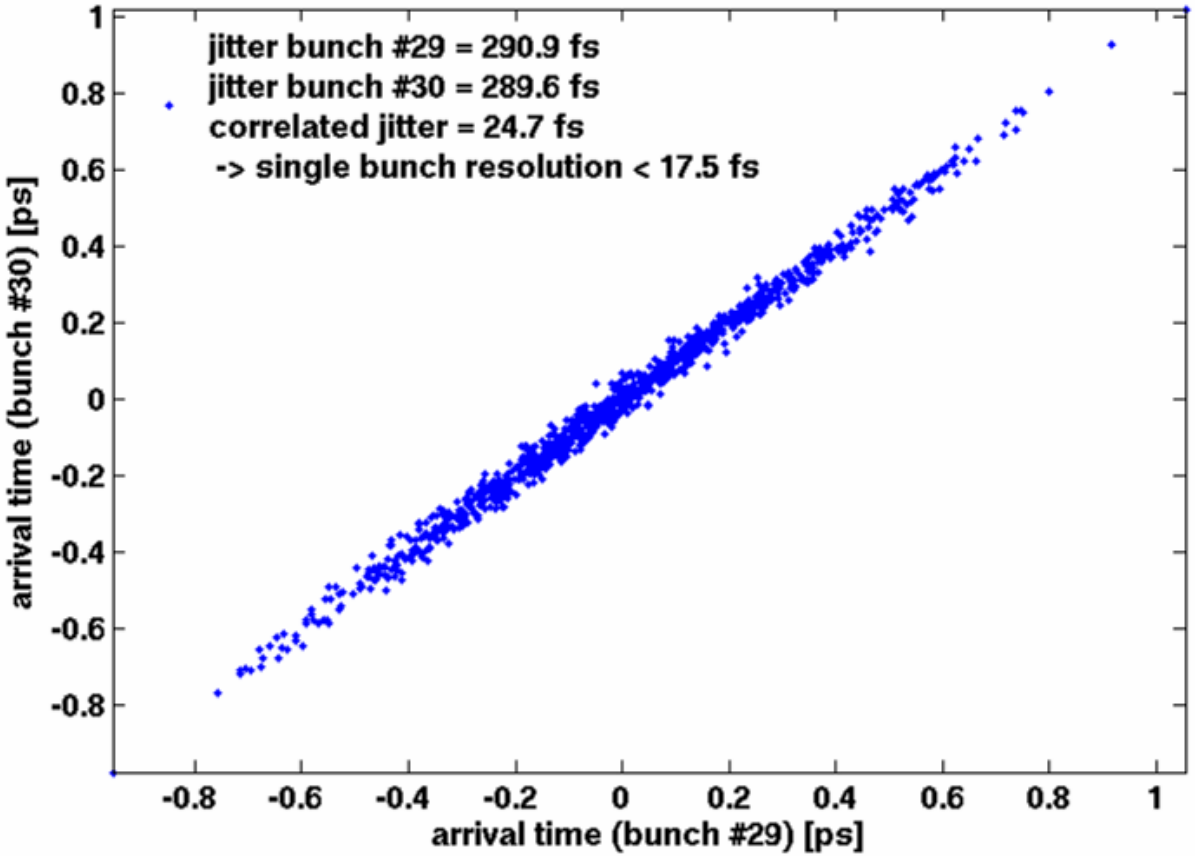
Goal: generate and compensate arrival time slopes with the beam loading amplitude of ACC1

The different colors represent different settings of the beam loading compensation.



BAM resolution

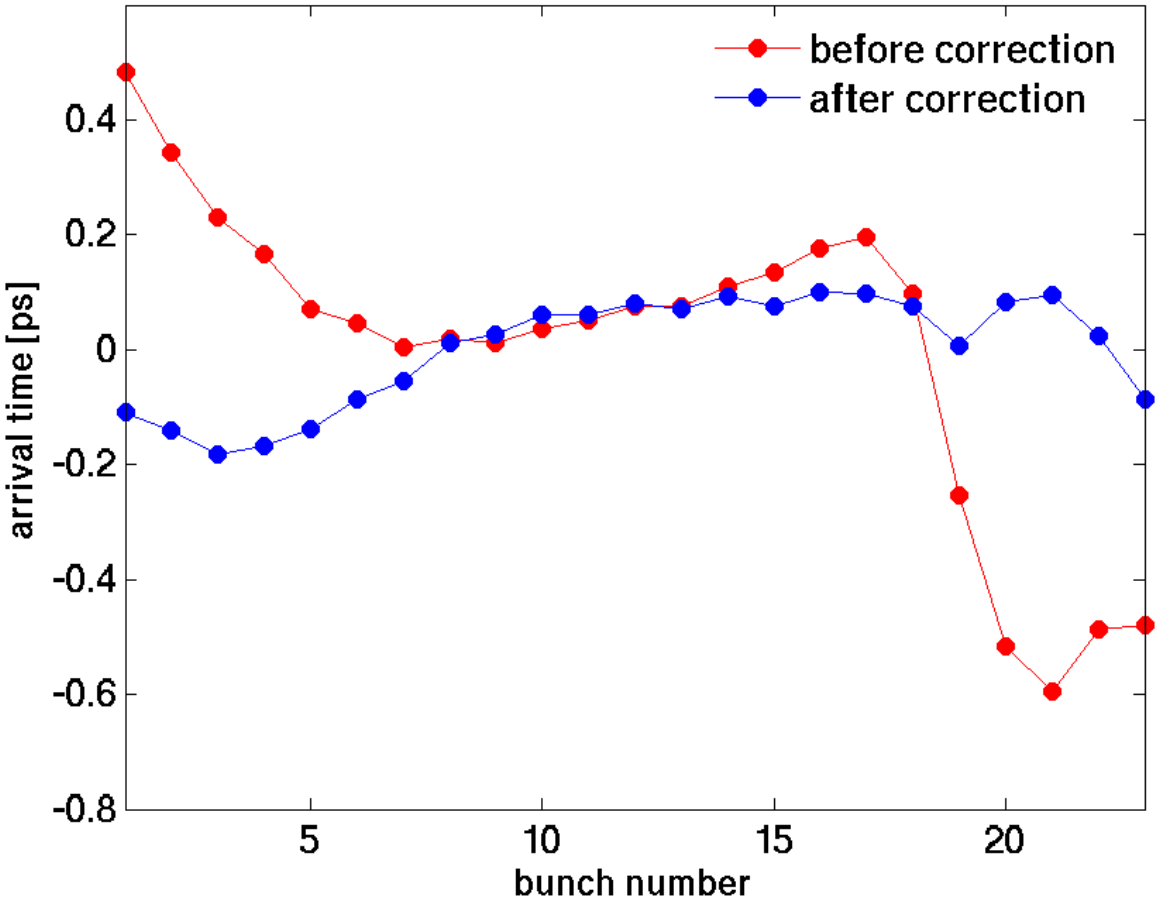
An upper limit for the BAM resolution can be estimated by correlating the arrival time of two adjacent bunches in the bunch train:



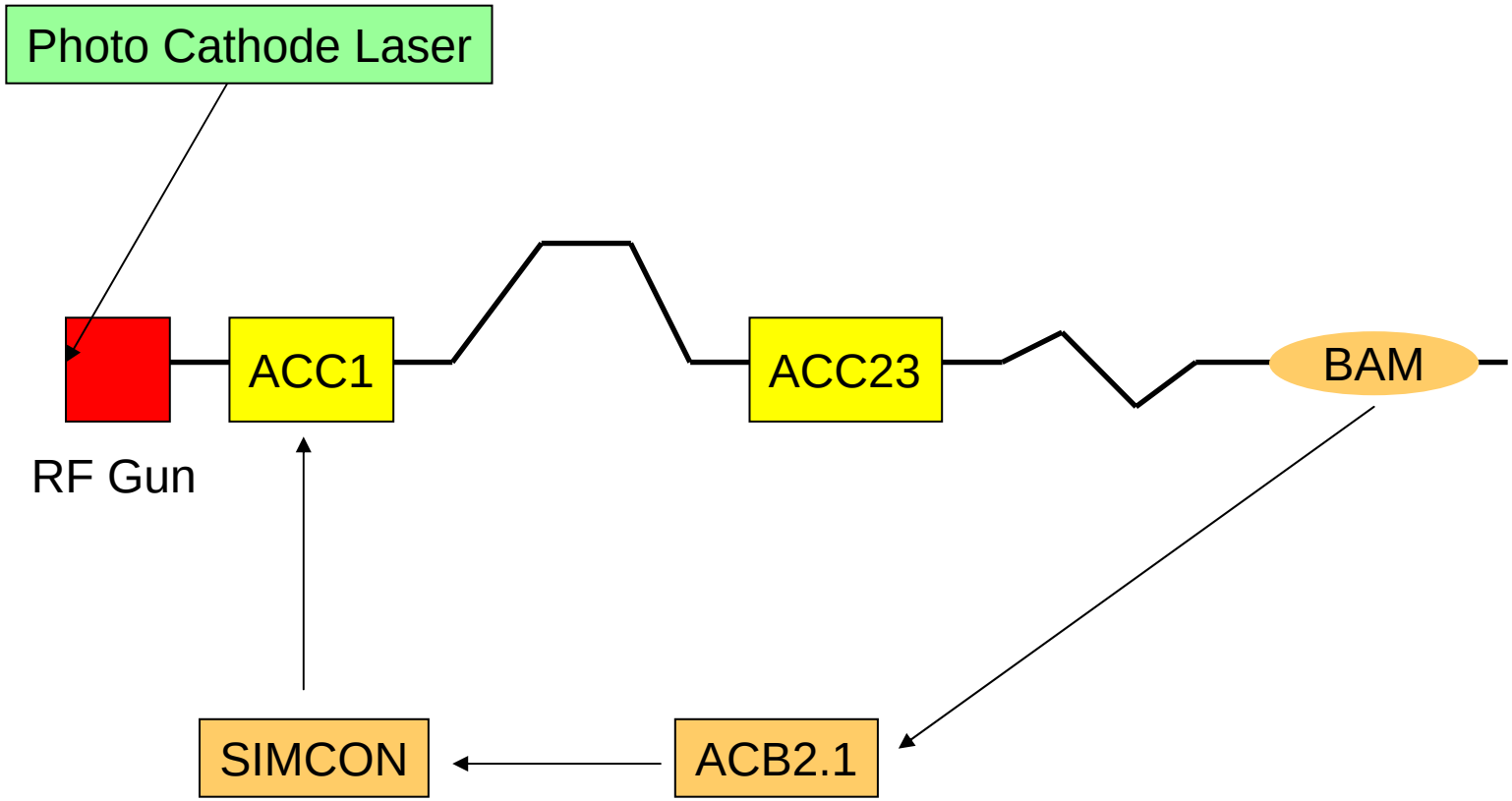
The resolution estimated from the laser amplitude noise and the slope steepness is well beyond 10 fs.

Arrival time manipulation over the bunch train

Arrival time flattened by applying arrival time readings to ACC1 amplitude set point tables.



Next step: intra bunch-train arrival time feedback

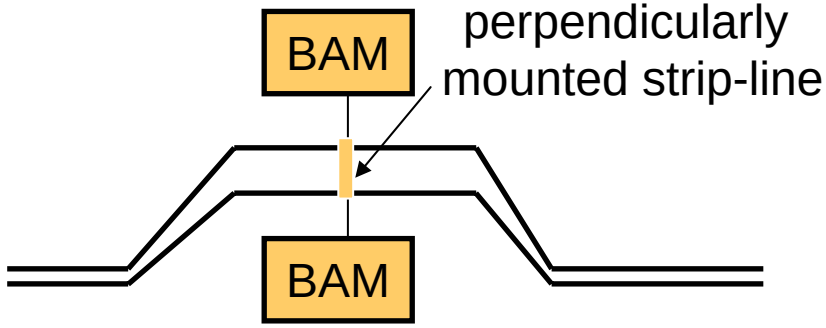


Implementation of feedback in ACB2.1 and SIMCON DSP
by J. Szewinski and W. Jalmuzna

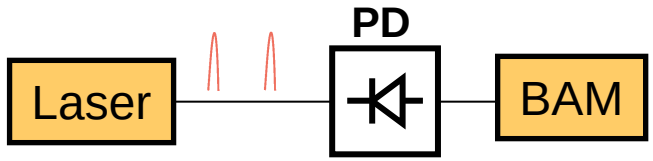
Other applications of the BAM

The bunch arrival time monitors can be used for many different kinds of diagnostics, e.g.:

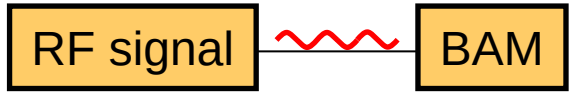
- Beam position measurement as difference of two arrival time measurements



- Laser timing measurement by sampling of photo detector signals

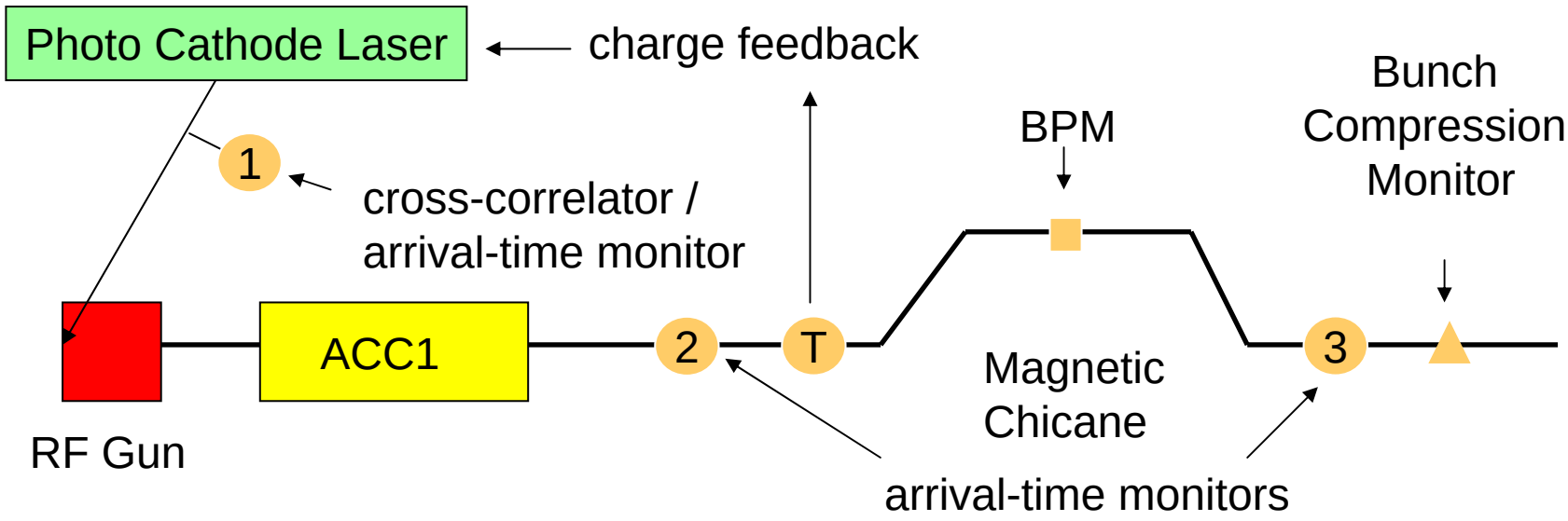


- Phase and Amplitude measurements of RF signals



- …

Outlook: complete longitudinal feedback

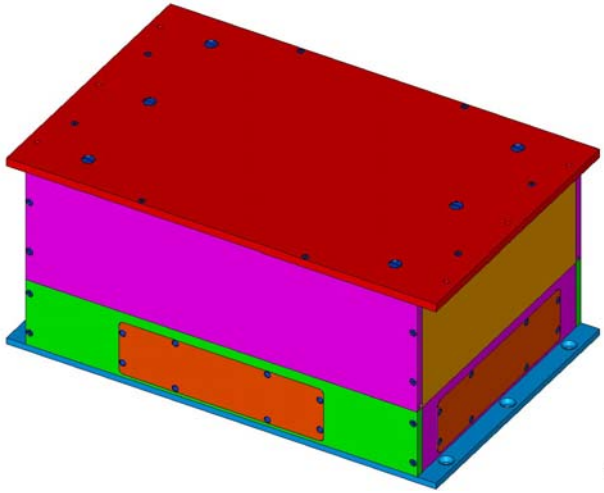


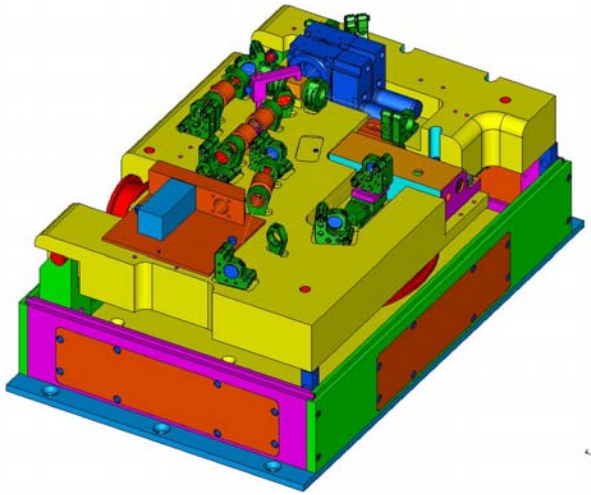
Detection of main arrival-time jitter sources

- Arrival time of photo cathode laser pulses **(CC / 1st arrival time monitor)**
- Phase of RF gun **(difference between 1st and 2nd arrival time monitor)**
- Amplitude of ACC1 **(BPM in magnetic chicane)**
- Phase of ACC1 **(Bunch Compression Monitor)**
- Arrival time of pump-probe laser **(cross-correlation with timing system)**

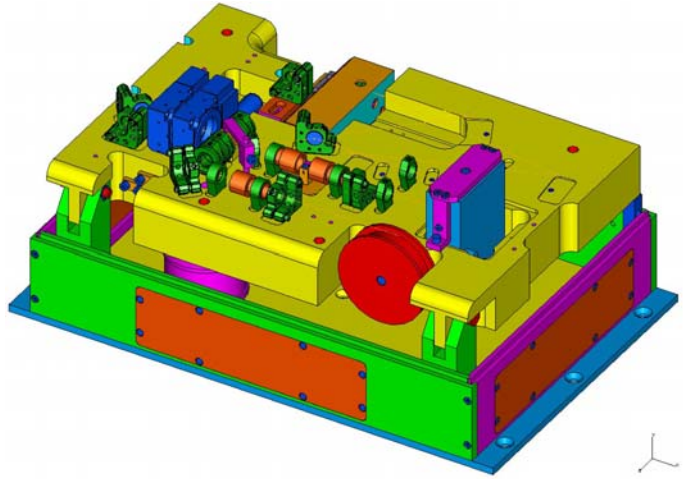
→ next step: fast control of different parameters

Upgrade of the optical synchronization system

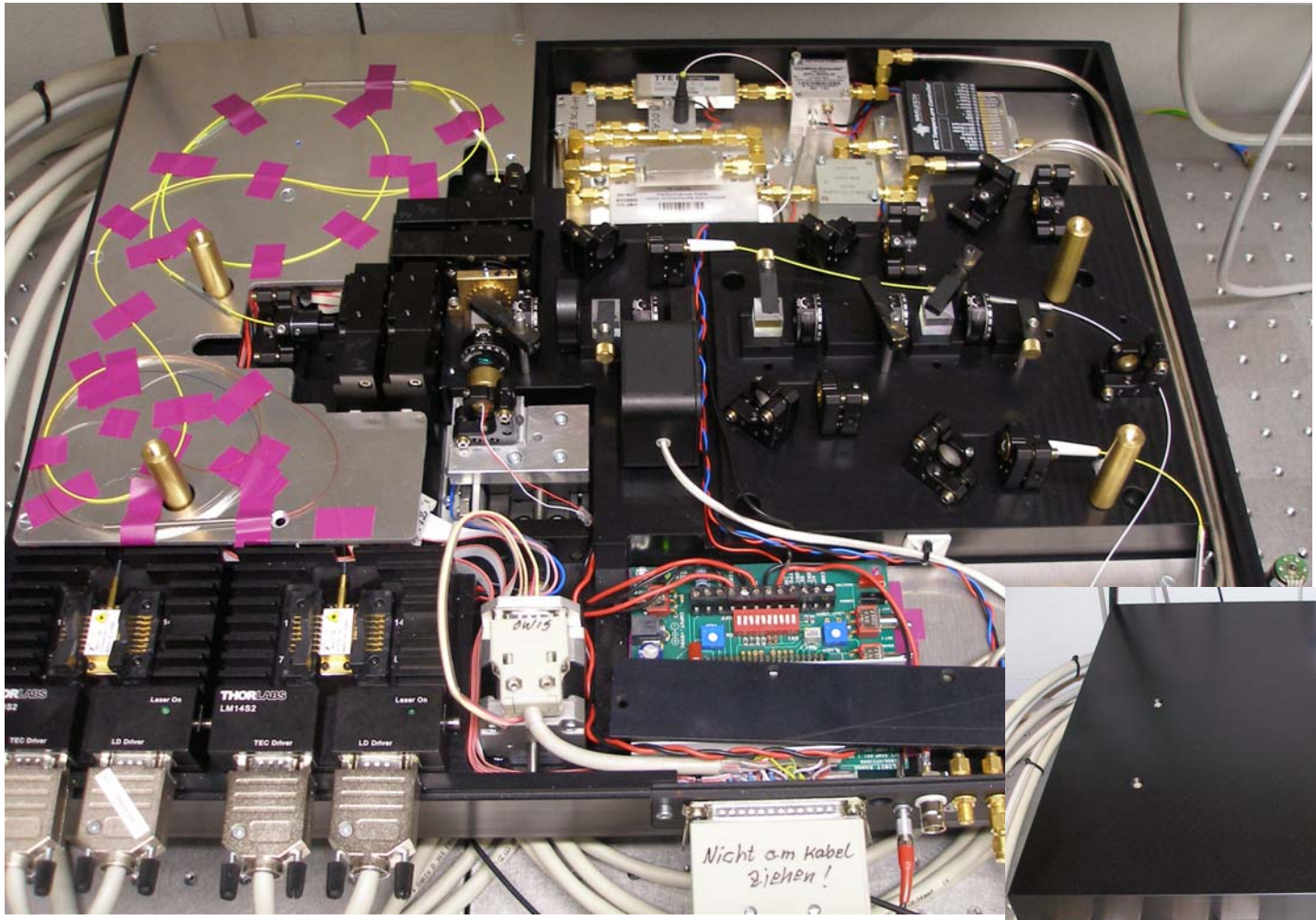




Construction of fiber link mechanics together with K. Jaehnke (ZM1).
Installation: summer 2008.



Upgrade of the optical synchronization system



First prototype of 216 MHz laser and distribution.
Second iteration on its way.

Comments

- A first version of the optical synchronization system is installed and BAM 18ACC7 is commissioned.
- Further studies on charge dependence have to be carried out.
- A resolution below 20 fs could already be reached.

Next steps:

- Implementation and test of the fast bunch arrival time feedback.
- Consistency study: comparison measurement of two BAMs
- Upgrade of synchronization system to reach more end station.

We would like to thank J. Szewinski for his support of ACB2.1, MCS4 for their help with all kinds of controls, and the technicians of the group FLA for their great work.