BAM implementation challenges

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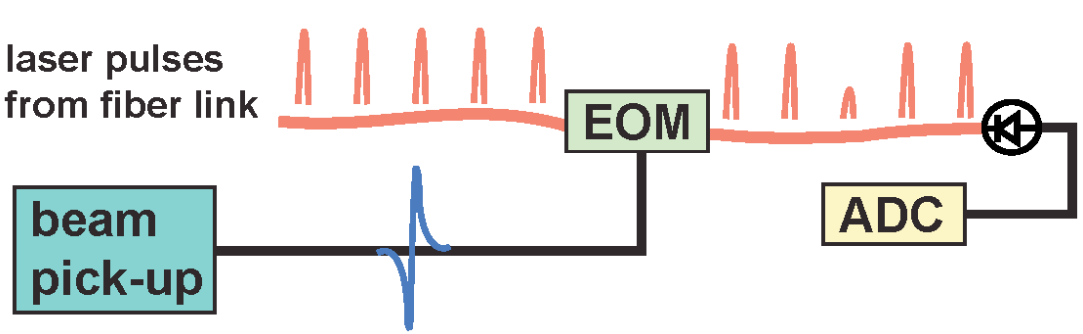
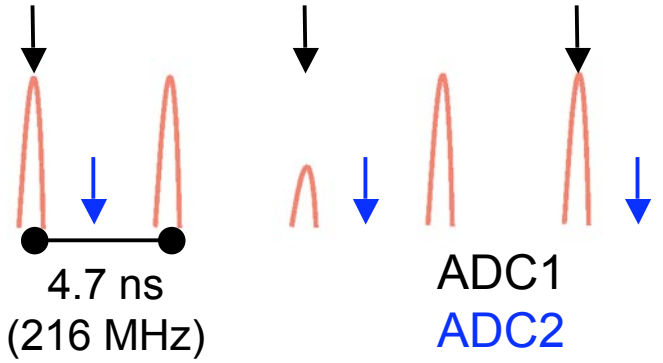
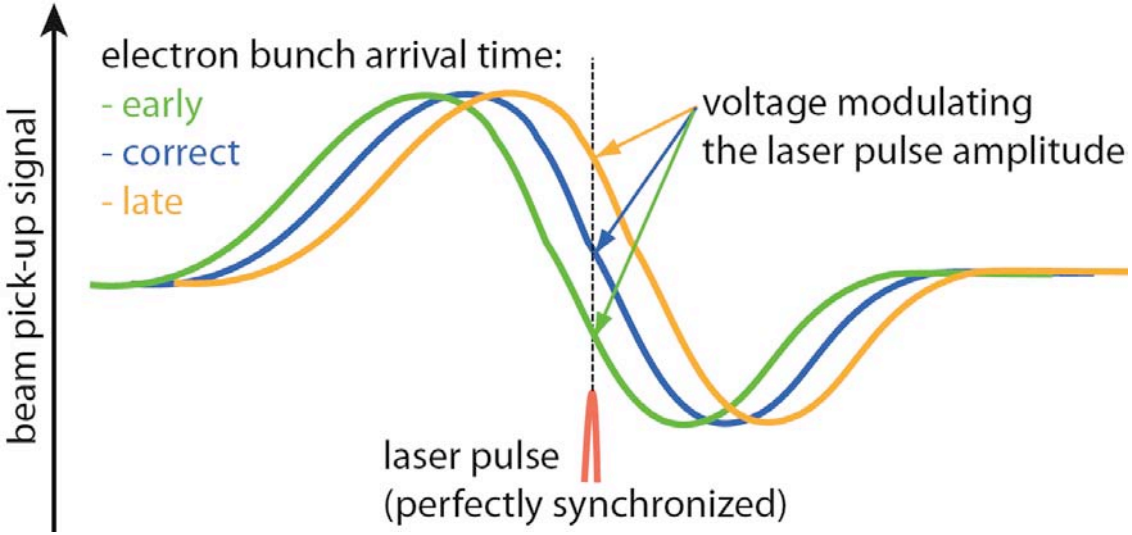
BAM principle



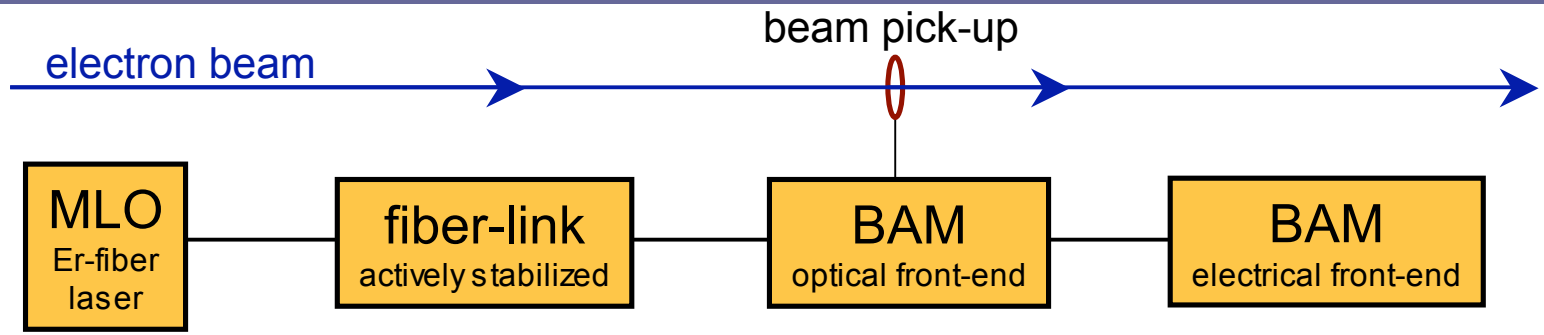


The timing information of the electron bunch is transferred into a laser amplitude modulation. This modulation is measured with a photo detector and sampled by a fast ADC.

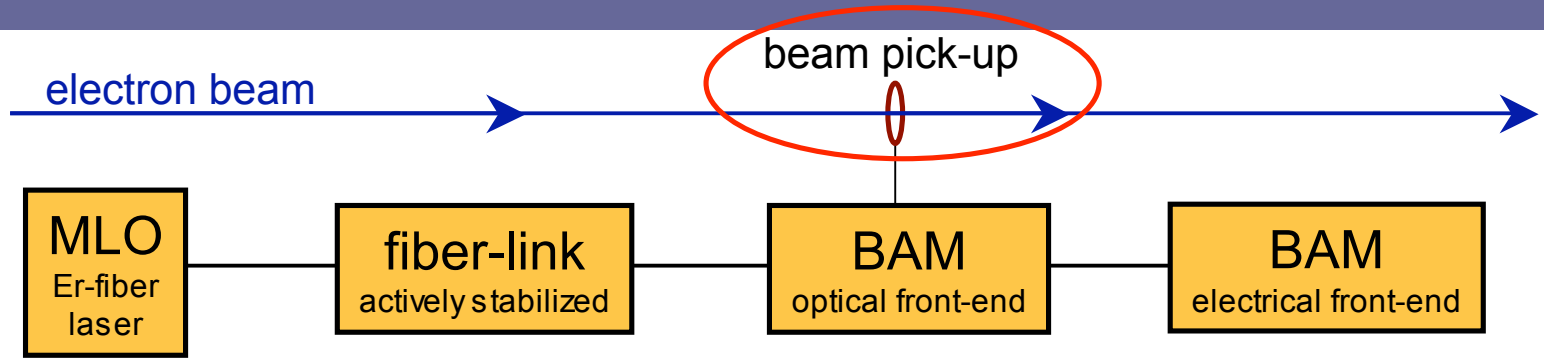


Patented in 2006 by DESY

General layout

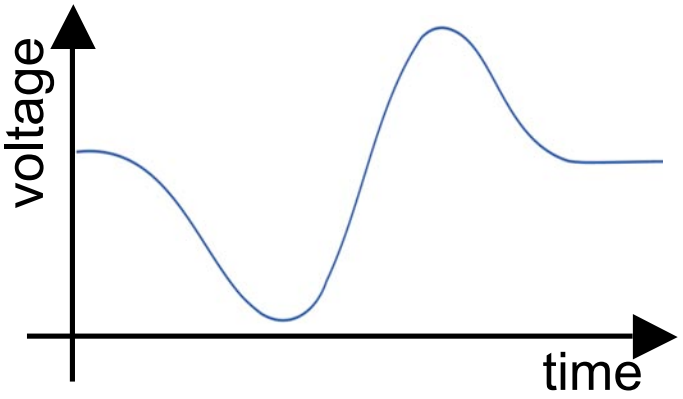


Beam pick-up



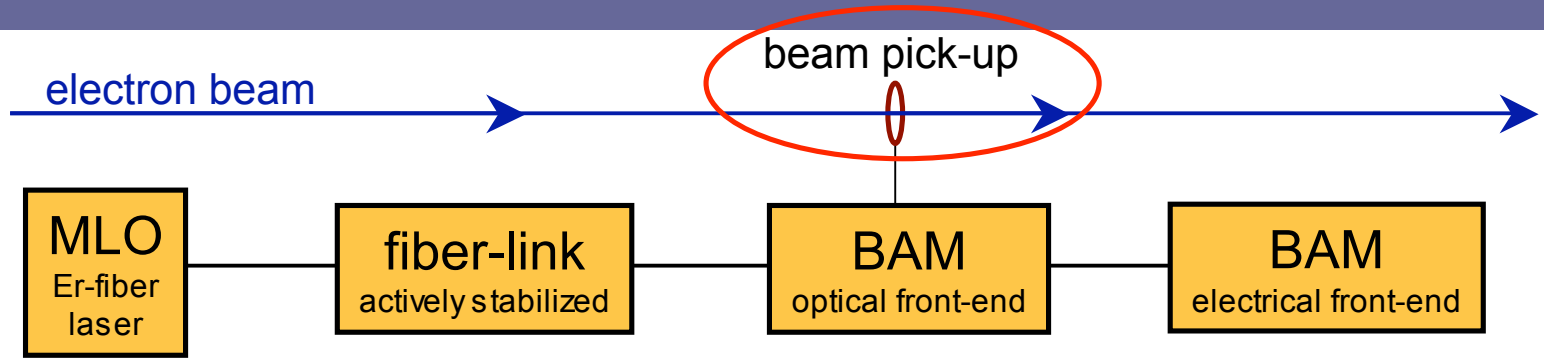
Wish-list for beam induced pick-up signal:

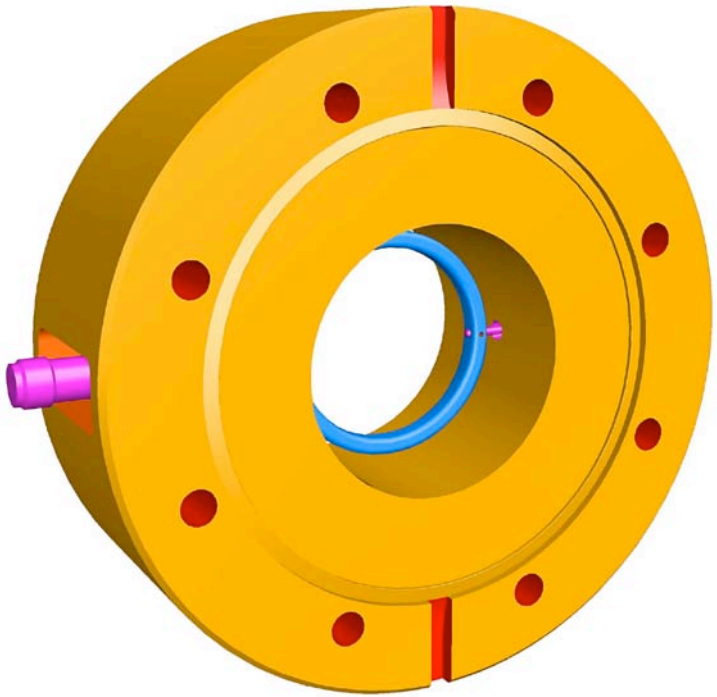
- steep slope at zero-crossing
- low peak-peak voltage
  - → EOMs stand ± 5 V
  - → limiters are non-linear
- low bandwidth
  - → reduces dependence of zero-crossing position on bunch shape



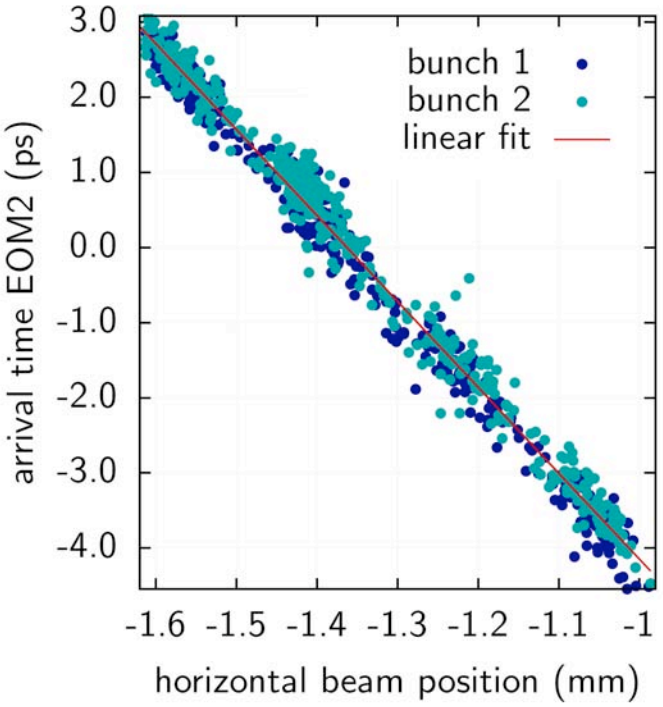
Not all conditions can be fulfilled at the same time!

Beam pick-up experience: ring-type

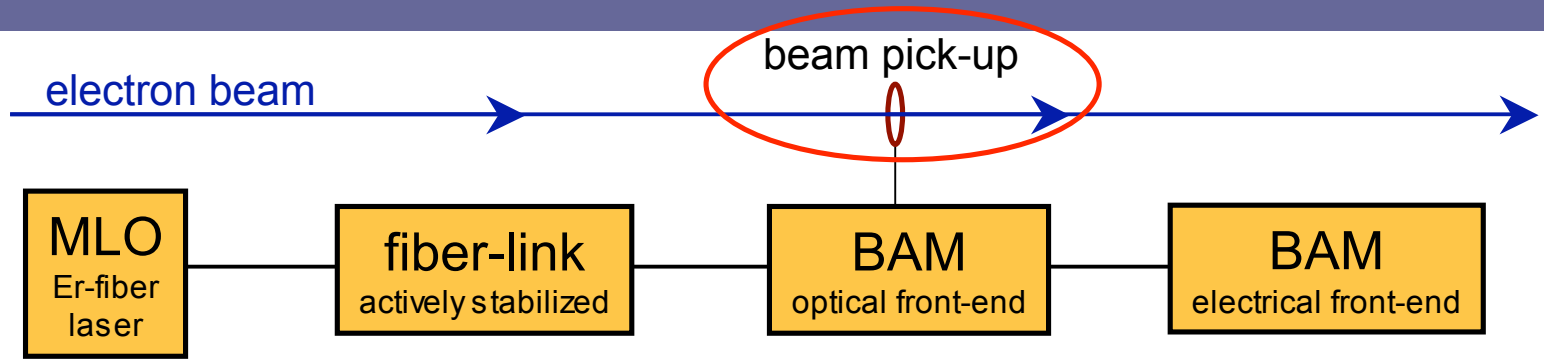




very strong orbit dependence!



Beam pick-up experience: ring-type



Enables high precision beam position measurements:

$$t_{\text{arrival}} = t_{\text{meas},1} + a_{x,1}x + a_{y,1}y$$

$$t_{\text{arrival}} = t_{\text{meas},2} + a_{x,2}x + a_{y,2}y$$

$$a_{x,1} = (-6.94 \pm 0.05)\frac{\text{fs}}{\mu\text{m}} \qquad a_{x,2} = (10.7 \pm 0.02)\frac{\text{fs}}{\mu\text{m}}$$

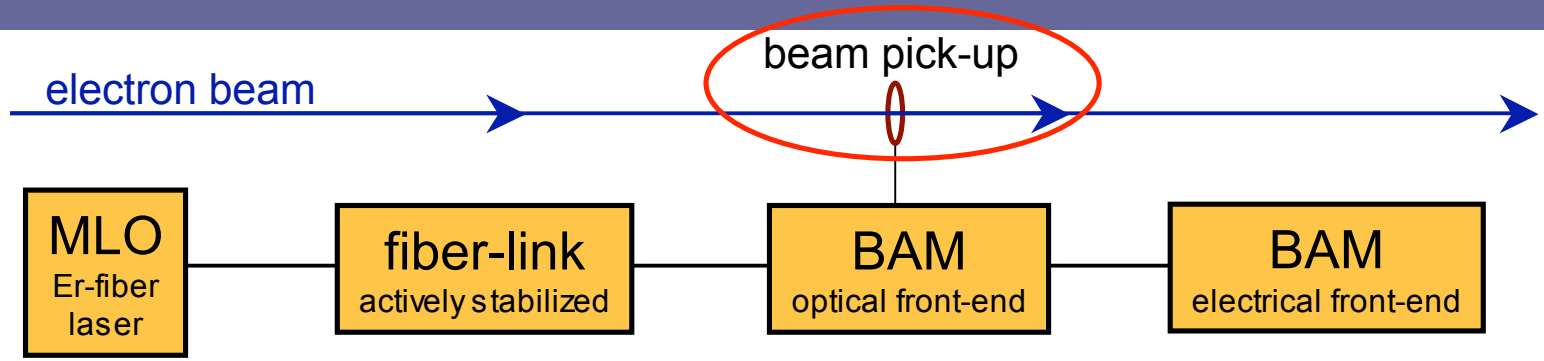
$$a_{y,1} = (-0.16 \pm 0.07)\frac{\text{fs}}{\mu\text{m}} \qquad a_{y,2} = (0.29 \pm 0.02)\frac{\text{fs}}{\mu\text{m}}$$

The setup had 30 fs resolution

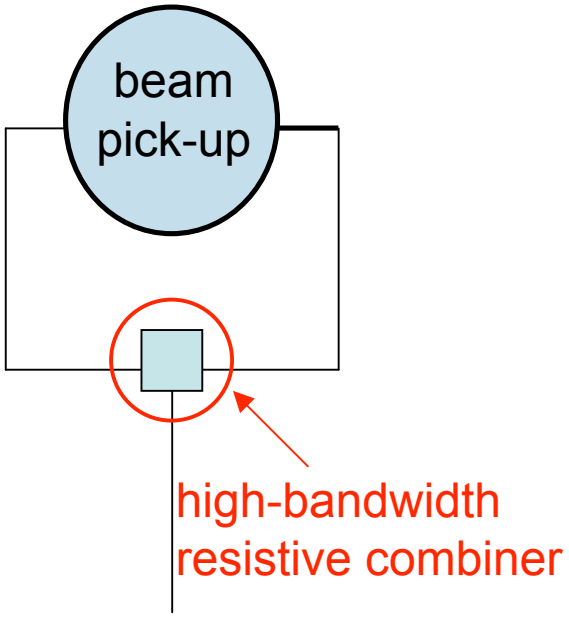
→ 3 µm resolution

But: arrival-time measurement is sensitive to calibration constant errors.
→ reduce orbit dependence

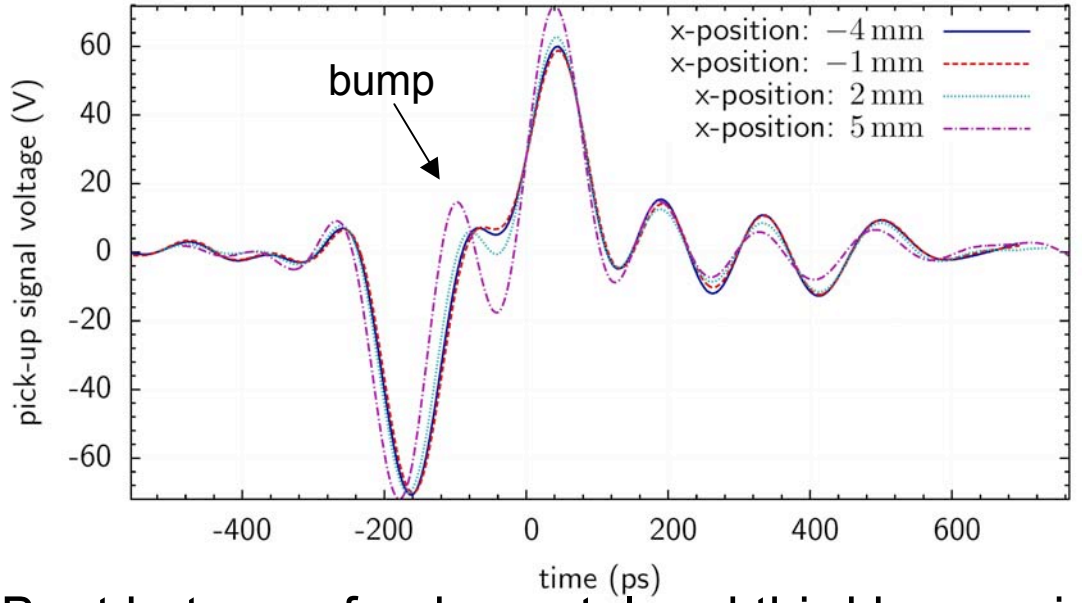
Beam pick-up experience: ring-type



Combining both outputs reduces orbit dependence by a factor of 30-50

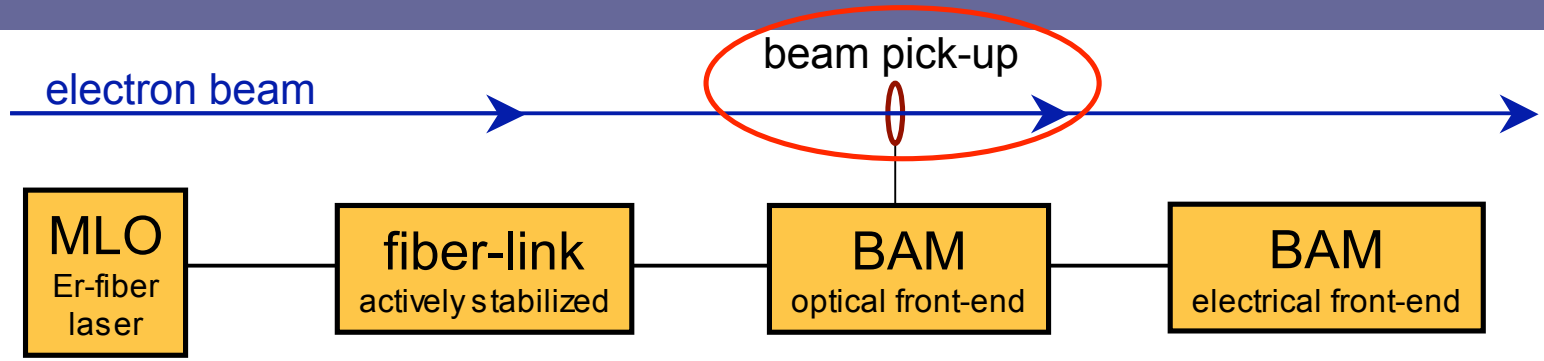


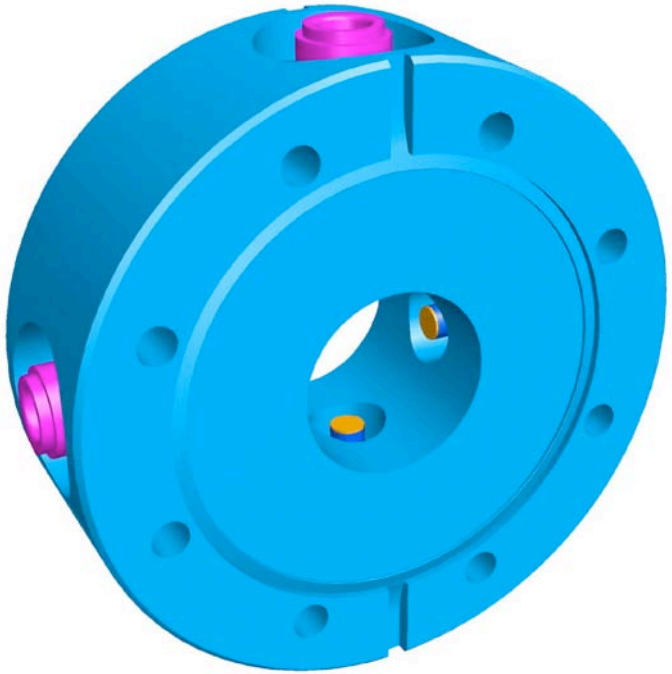
But…



Beat between fundamental and third harmonic of ring-circumference causes notch at 5 GHz
→ “bump”

Beam pick-up experience: button-type

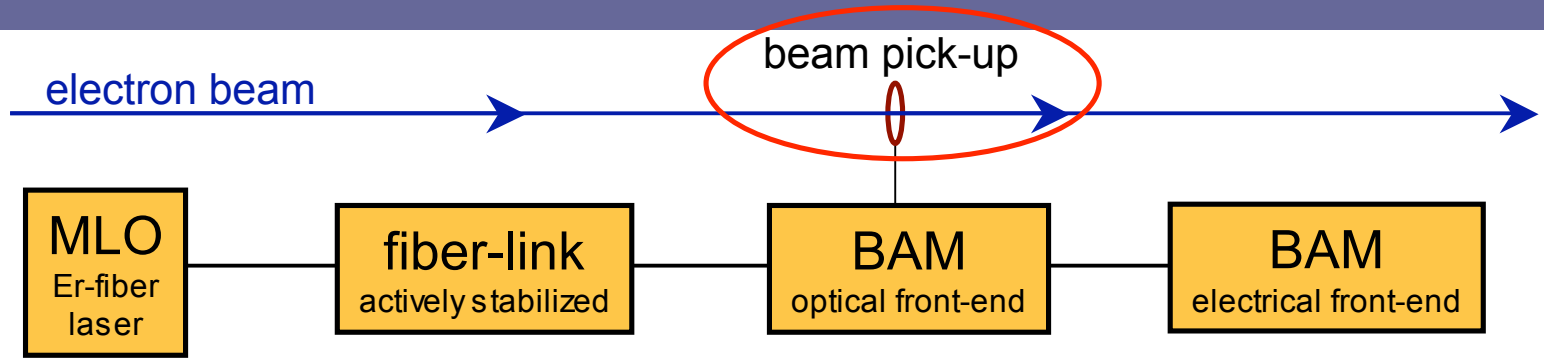




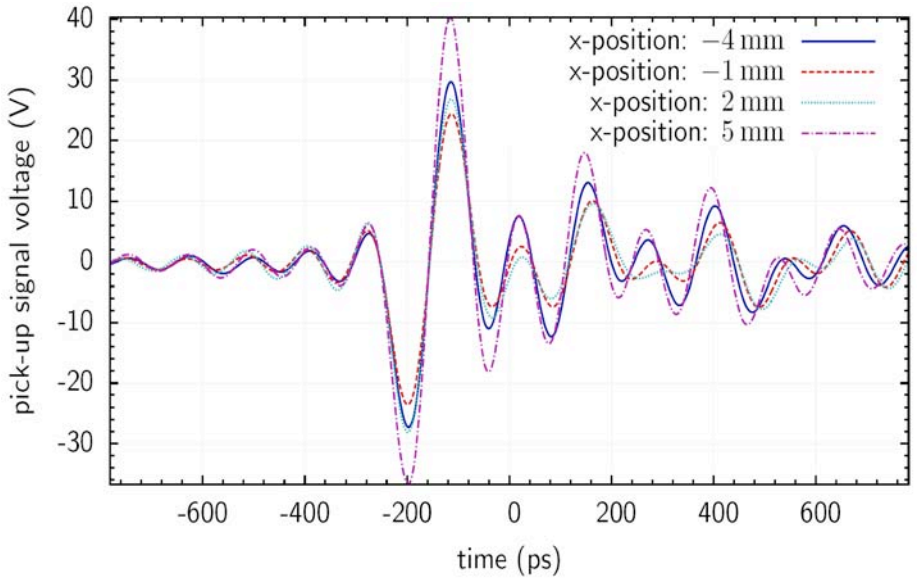
- opposite outputs are combined
- optimized for steep zero-crossing slope and low peak voltage

Design: K. Hacker

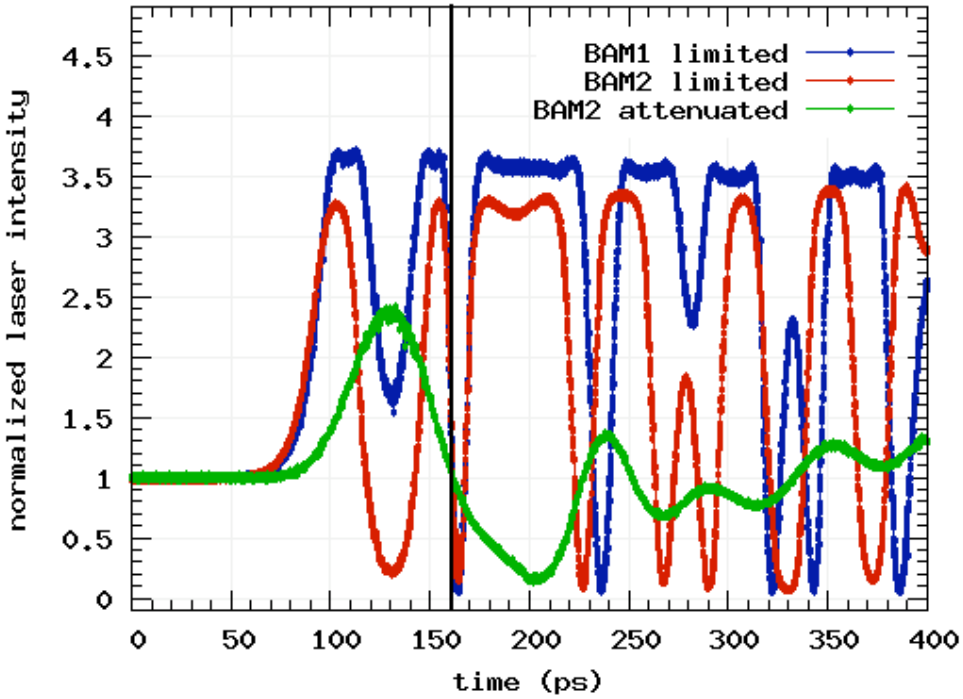
Beam pick-up experience: button-type



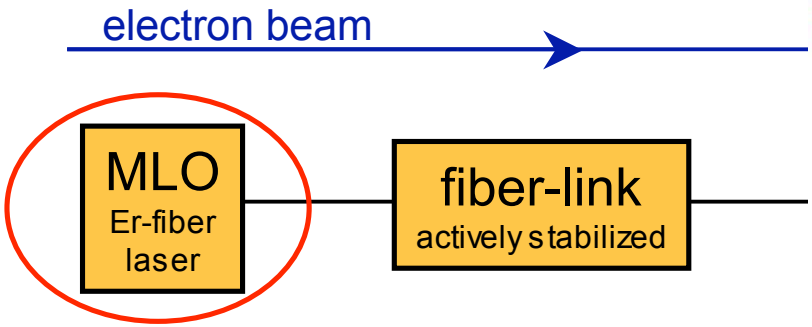
8 GHz oscilloscope measurement



BAM measurement



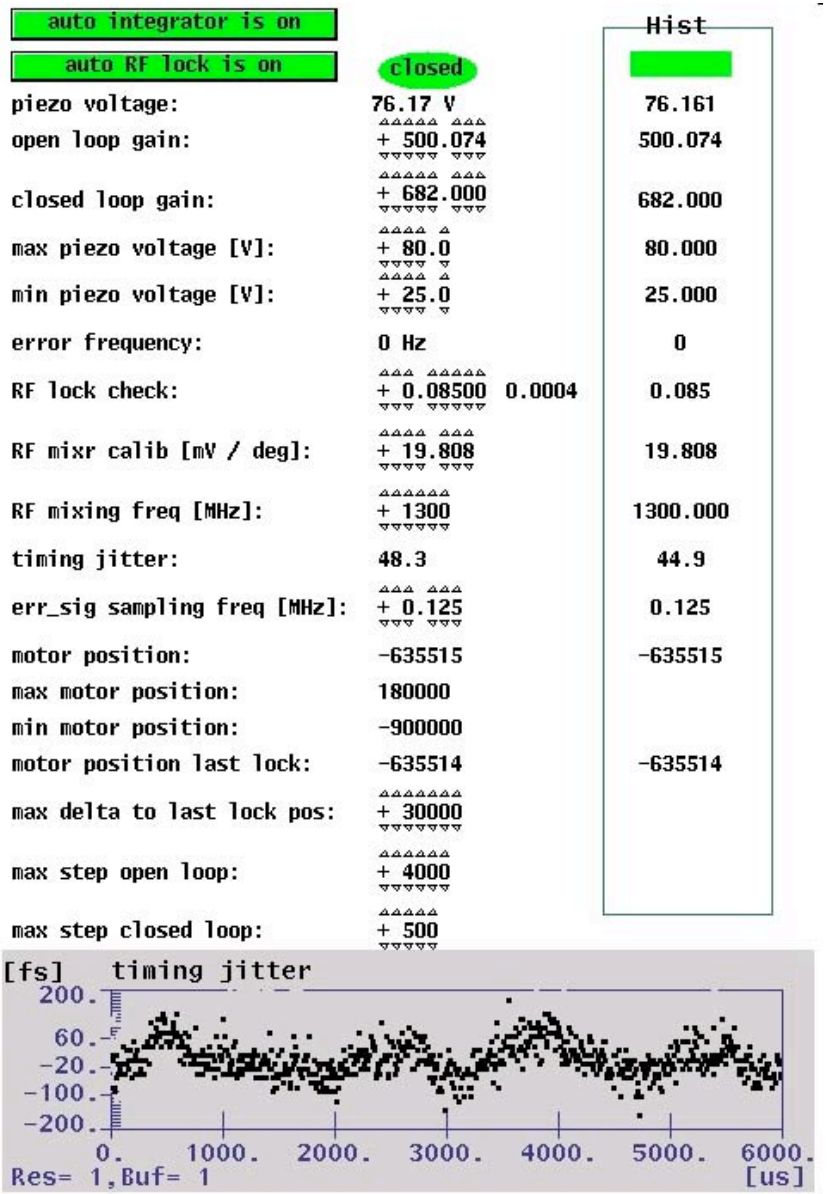
MLO automation



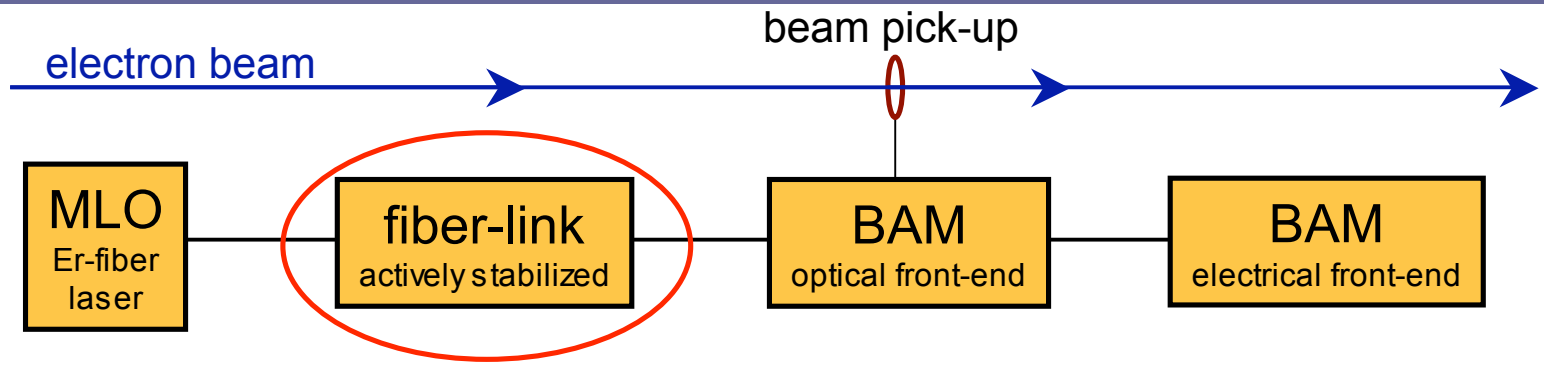
Automated locking to RF reference required!

→ DOOCS server

- controls movement of MLO piezo mirror delay stage
  - locks RF feedback loop
  - keeps piezo voltage in acceptable range
- control of digital regulation parameters
- …



Fiber-link automation

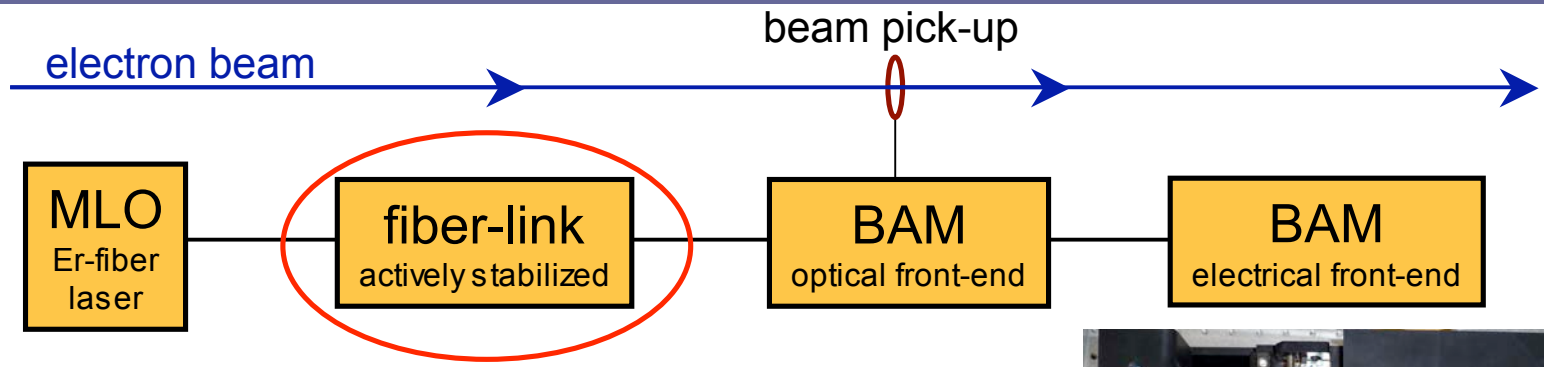


Automated cross-correlator feedback required!

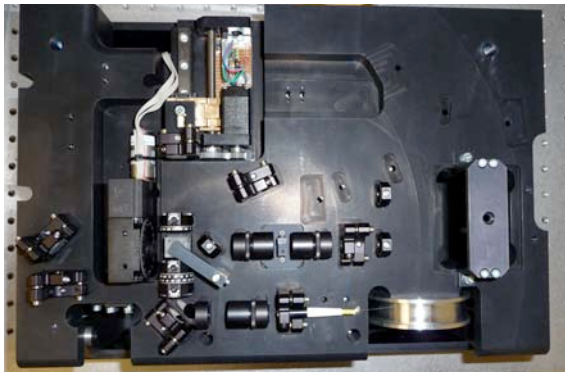
→ DOOCS server

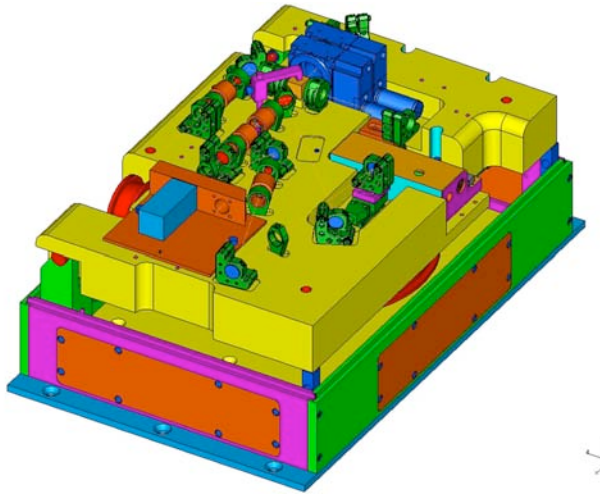
- controls movement of optical delay stage
  - locks feedback loop
  - keeps piezo voltage in acceptable range
- communicates with MLO server
- …

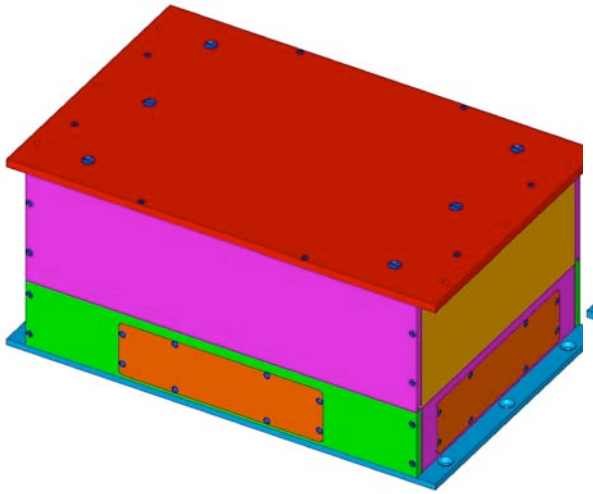
Fiber-link

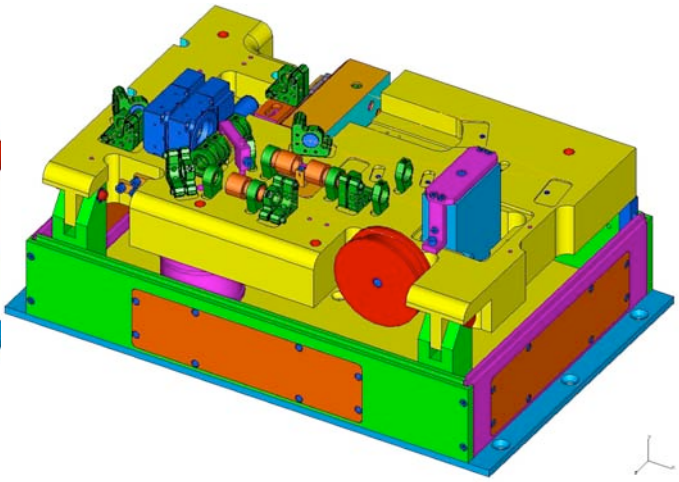


Installation of new front-ends ongoing

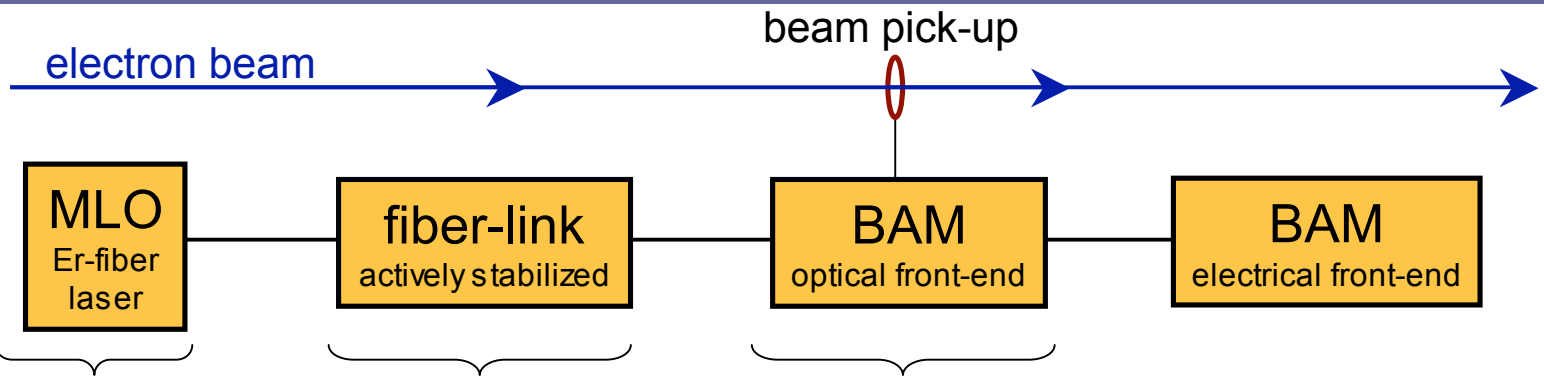








Timing…



Timing can be adjusted for only one end-station! (e.g. by vector modulator)

length cannot be changed! (adjusted to achieve overlap in the cross-correlator)

sampling at zero-crossing

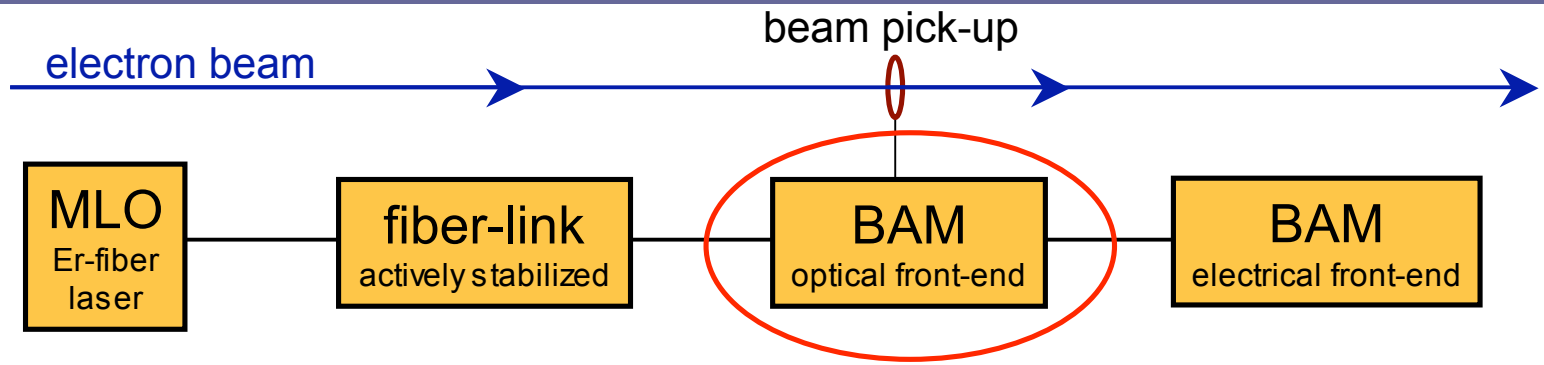
Fiber delay after link or cable delay required!
→ High laser repetition rate! (dispersive length ~8 cm)

The timing reference of the optical synchronization system is fixed!

→ All timings have to be adjusted for by delays outside the fiber-link
(vector modulator for MLO needed to measure delays!)

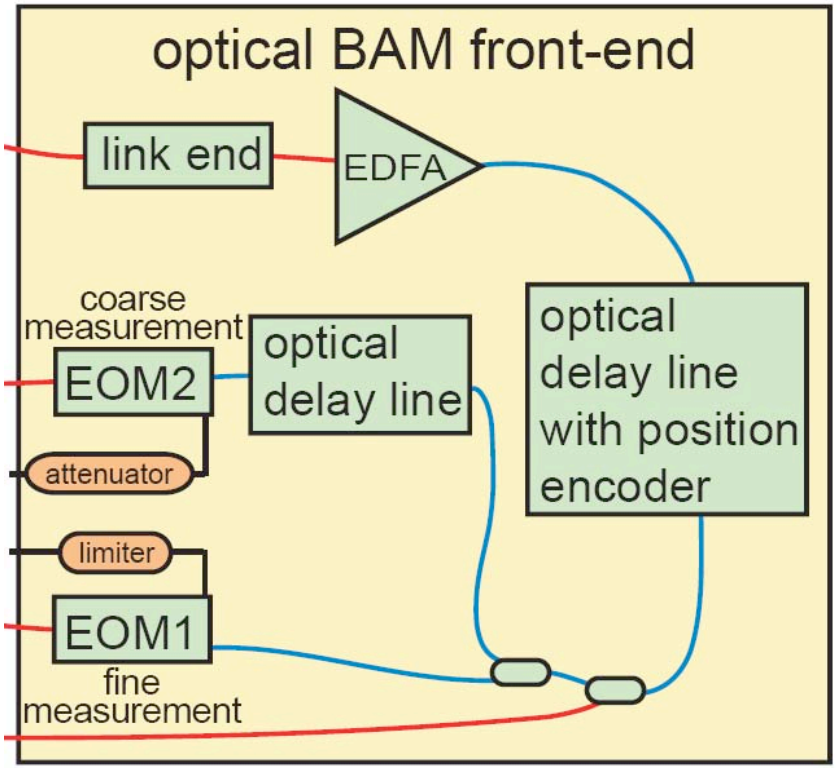
→ Delay stages needed for timing changes (bunch compressors!)

BAM optical front-end



Polarization maintaining setup
→ Special splice equipment needed

Installed in accelerator tunnel
→ Radiation shielded
→ Everything remote controlled



BAM optical front-end

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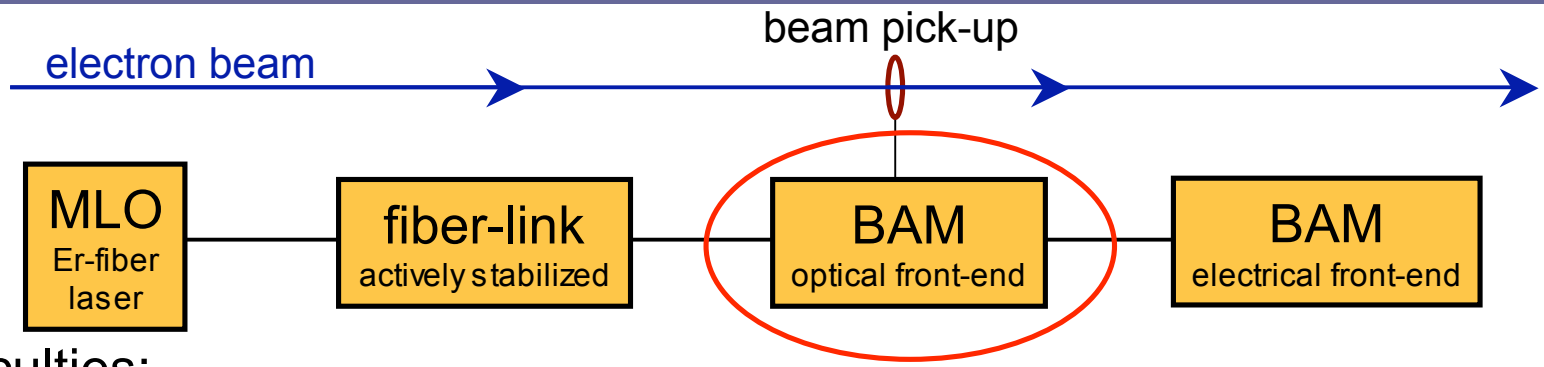


Difficulties:

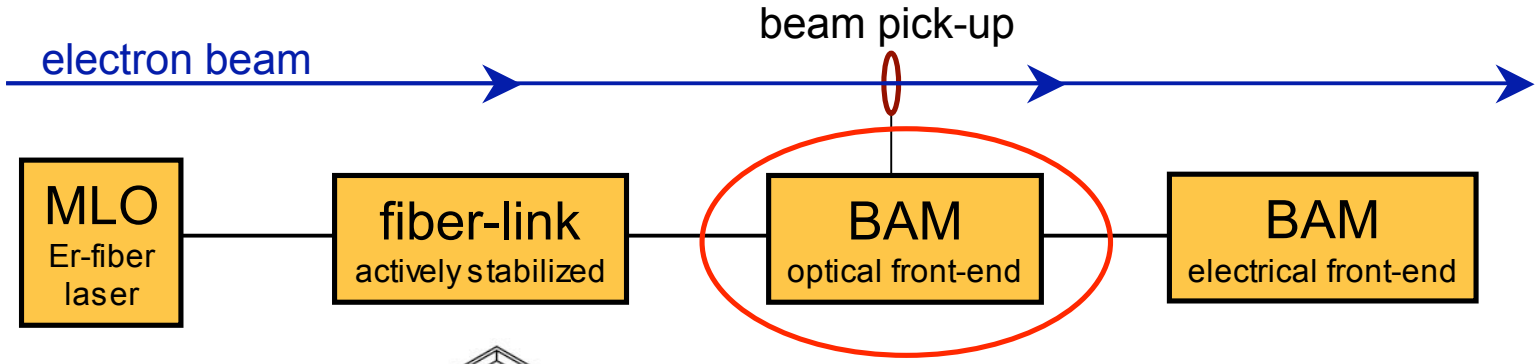
- Position encoders / readout fail from time to time
  → radiation? EMI? ground currents? …

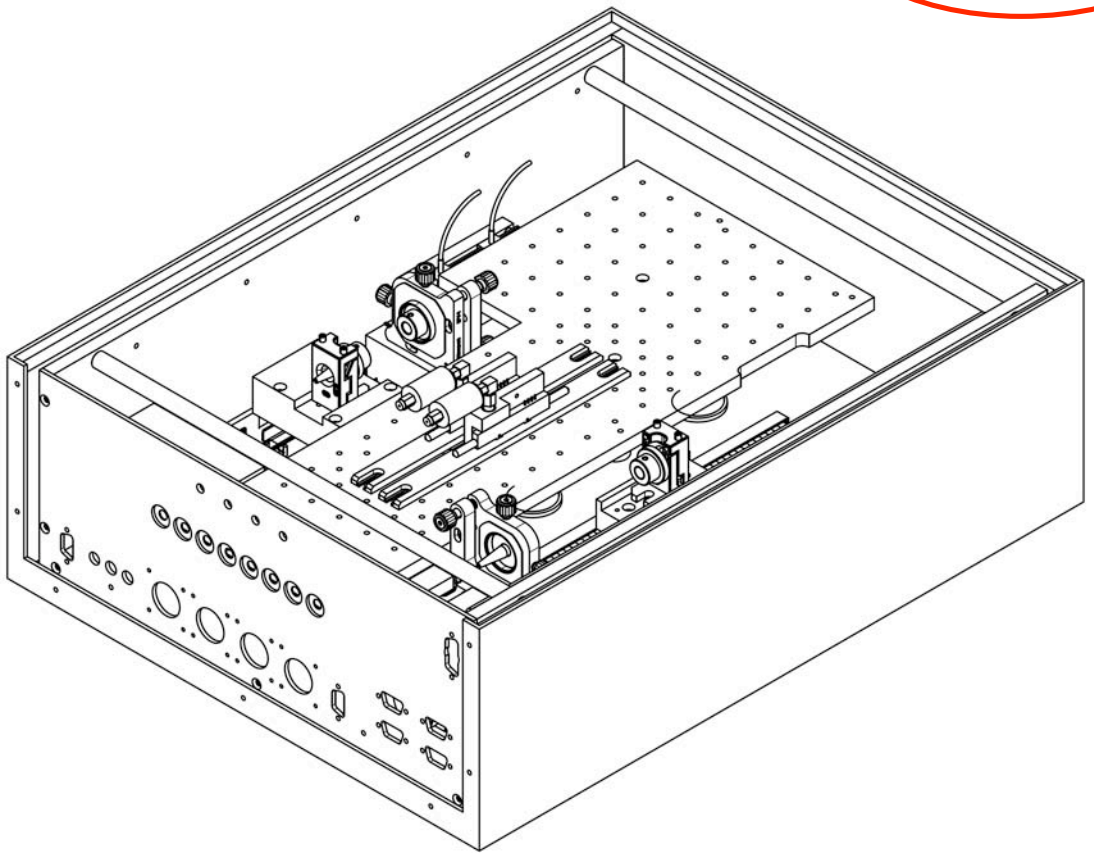
- VME crates for laser diode drives crash from time to time
  → radiation? EMI? ground currents? …

- Installation problems with EDFA pump diodes:
  - Tested in laboratory → ☺
  - Tested with drivers in the tunnel → ☺
  - EOMs connected to pick-up → ☹
    different ground potentials of beam pipe and VME crate

- Optical delay stages are not robust enough

BAM optical front-end

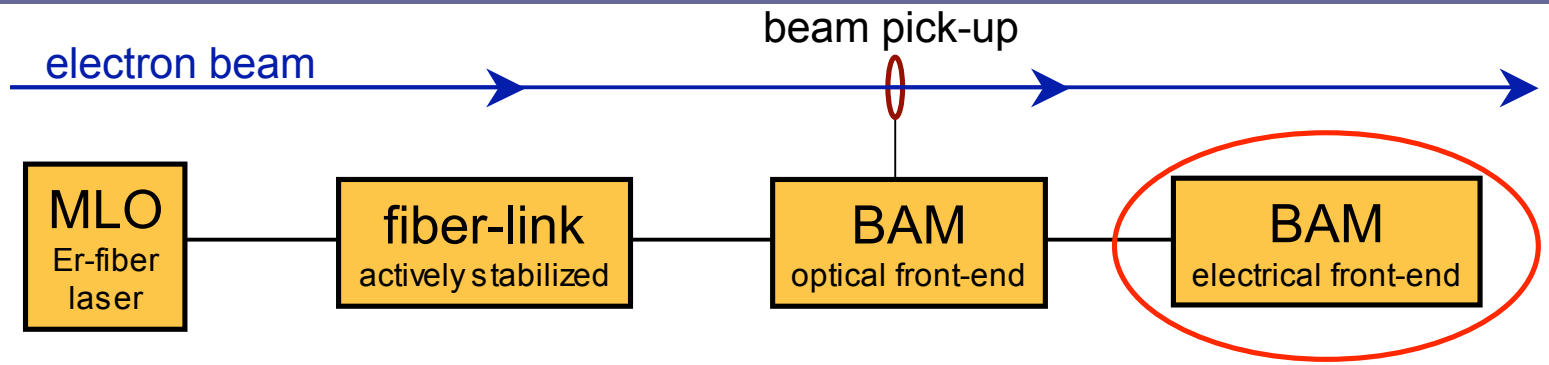


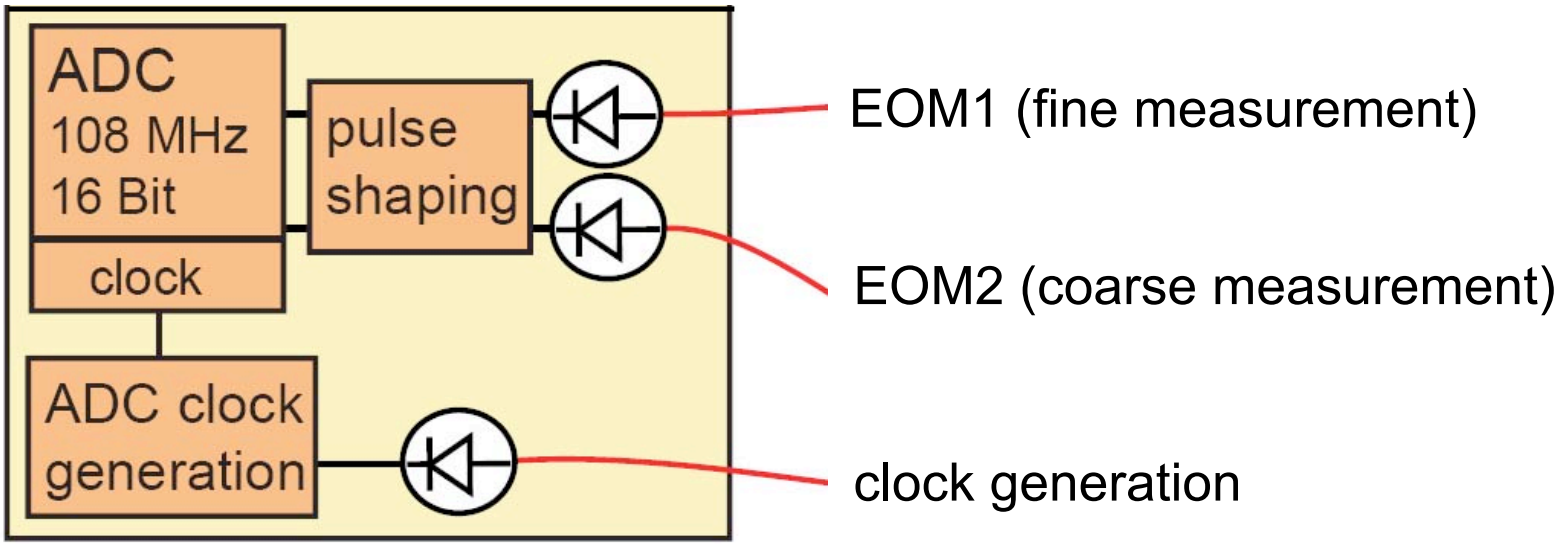


New design:

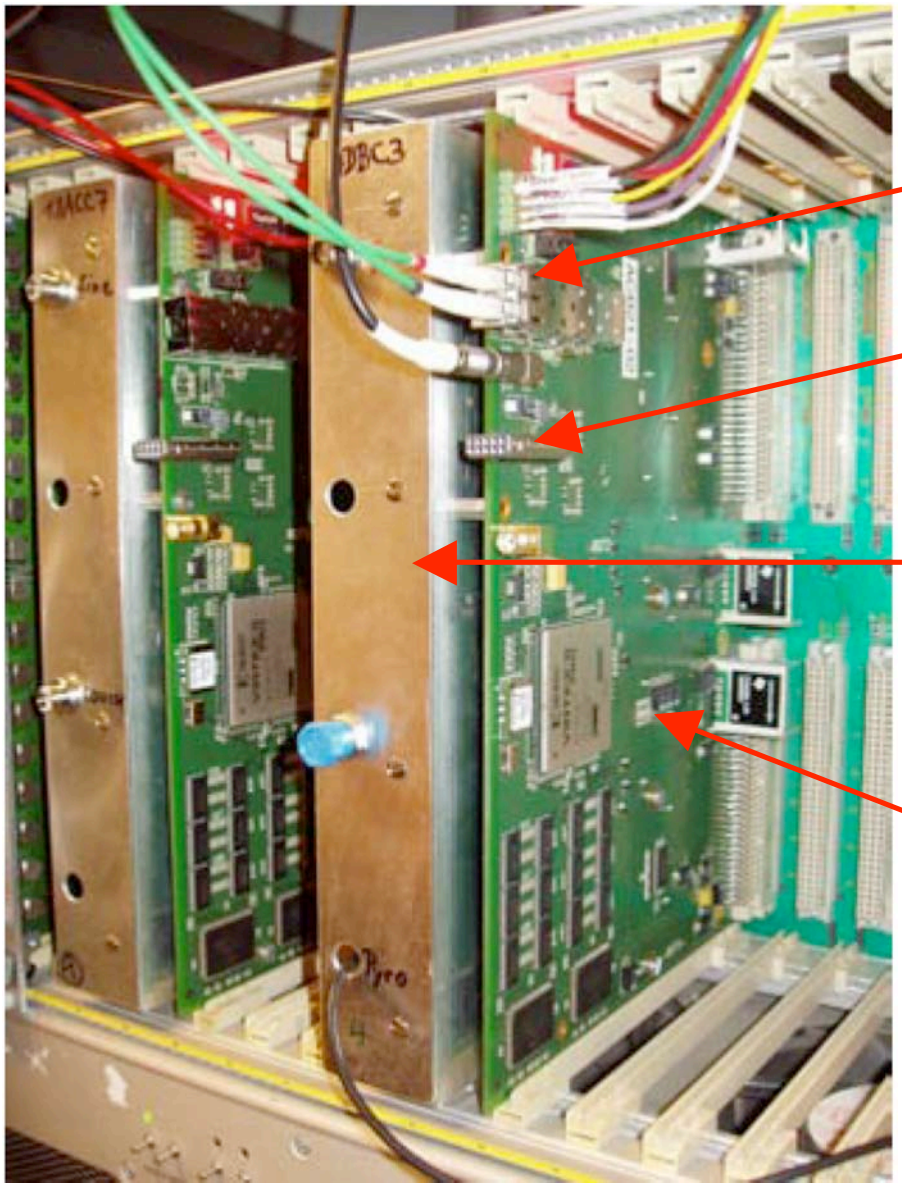
- new optical delay stages allowing > 10^6 movements
- Improved temperature stabilization

BAM electrical front-end





BAM electrical front-end



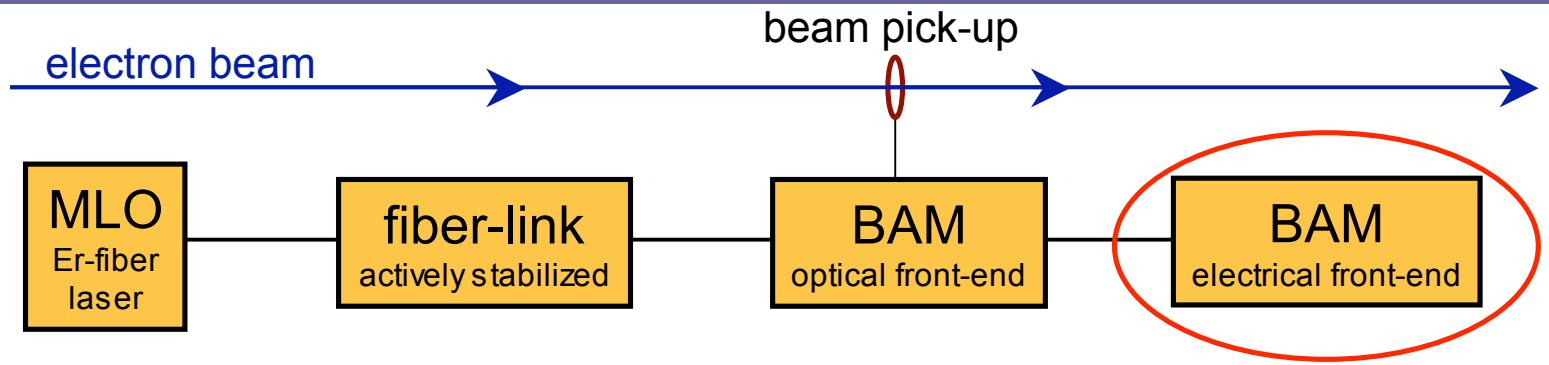
RocketIO ports for fast feedbacks

ADC clock input
(integrated clock generation on the way)

Analog front-end with
- 4 ADCs (16 bit, 130 MSPS)
- 2 photo detectors

VME carrier board with
- FPGA: Xilinx Virtex II Pro (xc2vp30)
- 3x AD9510 clock managers

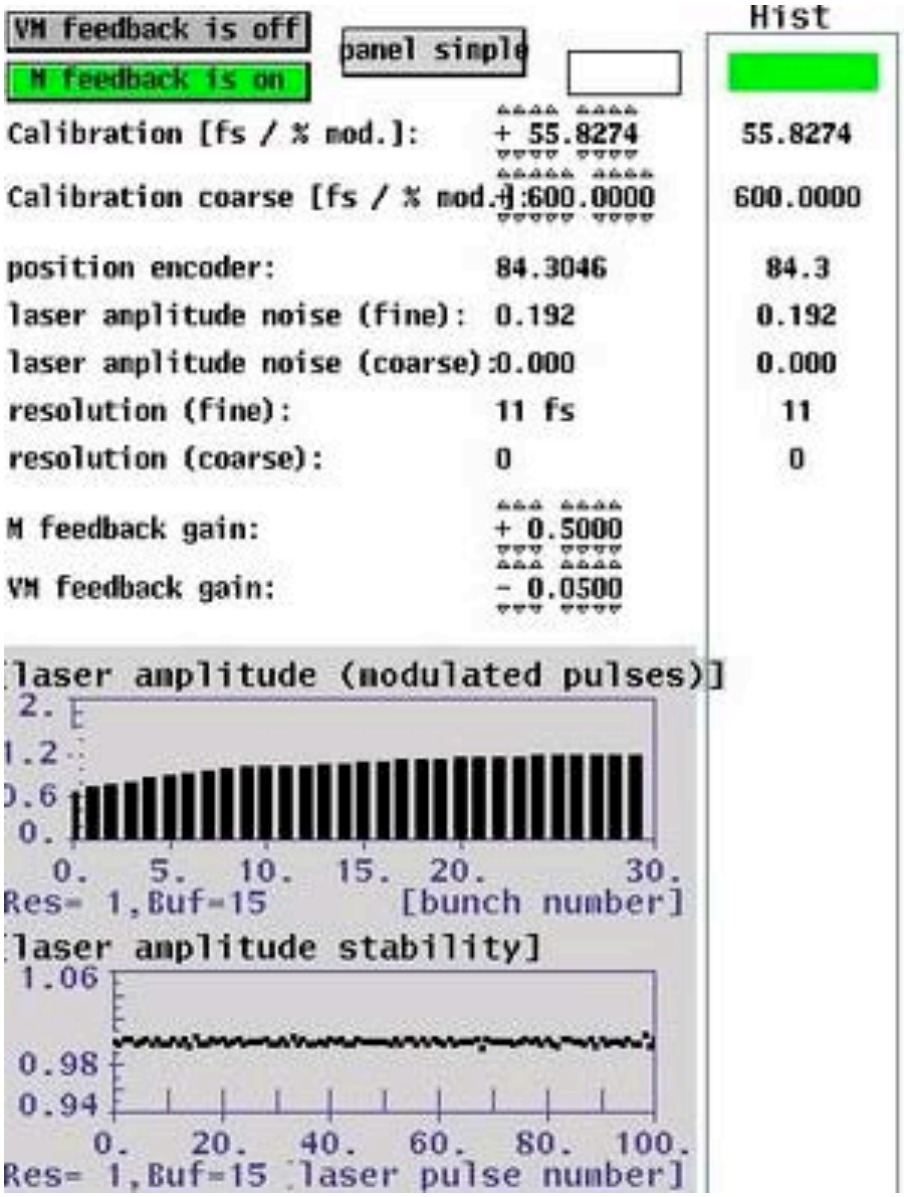
BAM server

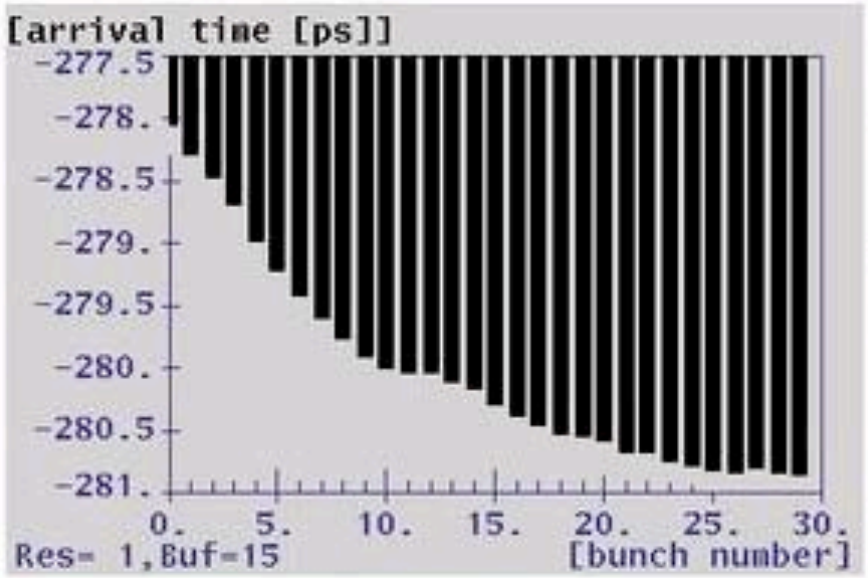


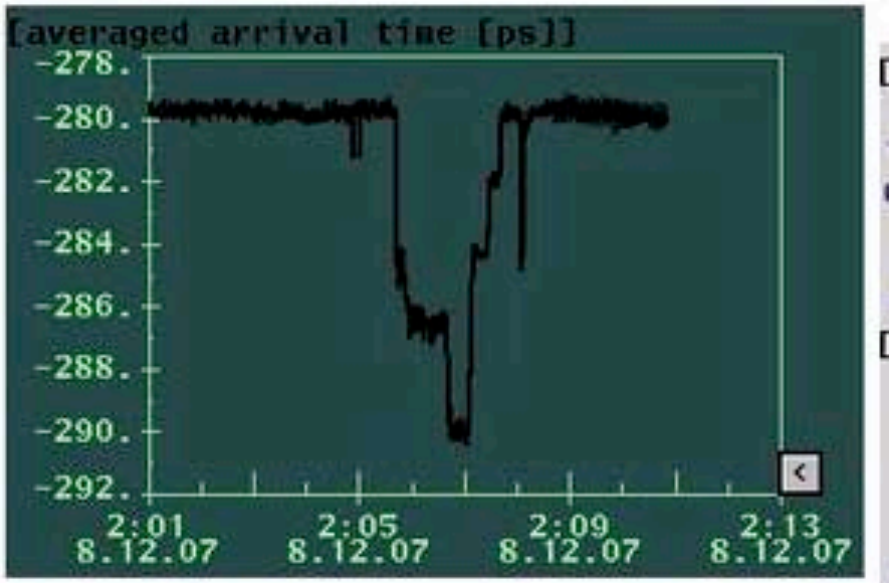
BAM DOOCS server:

- Online arrival-time calculations
- provides time-stamps for correlations with other machine data
- Slow feedback to maintain sampling at the zero-crossing
- Automated, online calibration
- communication with MLO and fiber-link server
- …

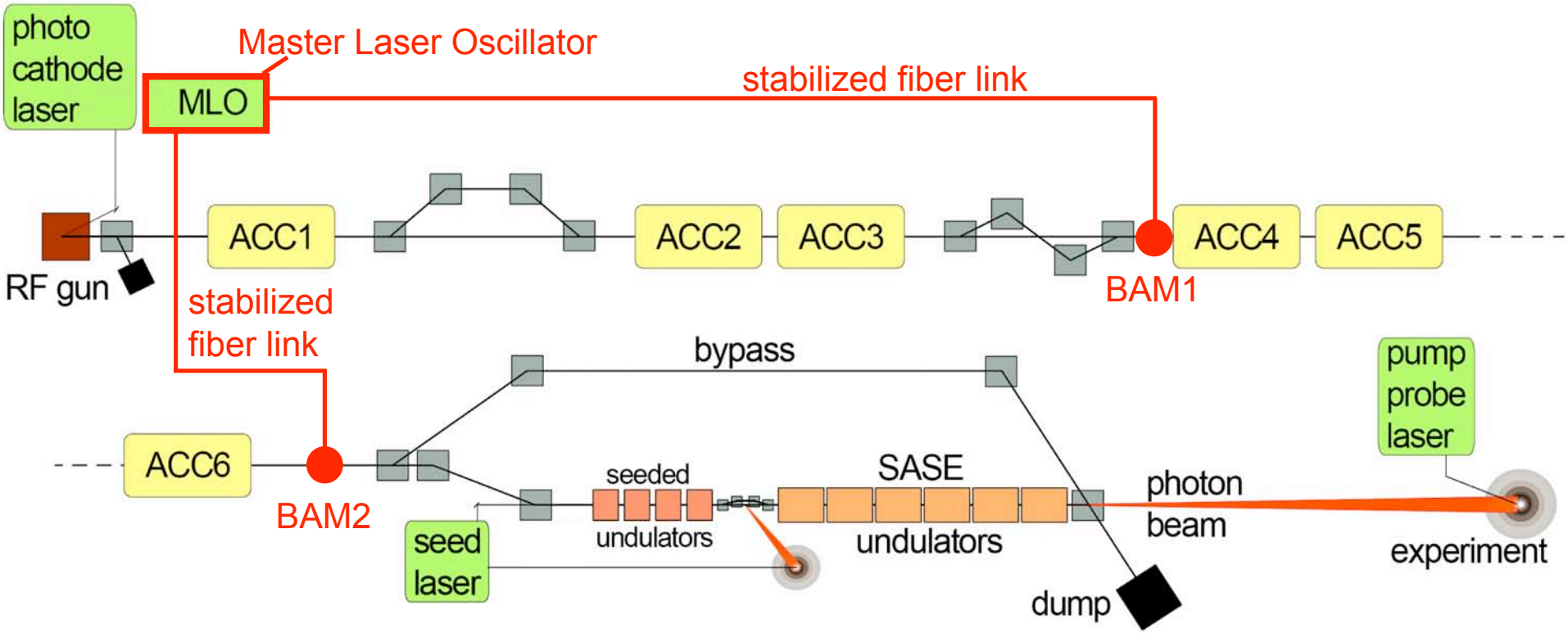
BAM server


VM feedback is off
M feedback is on
panel simple
Hist
Calibration [fs / % mod.]: + 55.8274 55.8274
Calibration coarse [fs / % mod.]: 600.0000 600.0000
position encoder: 84.3046 84.3
laser amplitude noise (fine): 0.192 0.192
laser amplitude noise (coarse): 0.000 0.000
resolution (fine): 11 fs 11
resolution (coarse): 0 0
M feedback gain: + 0.5000
VM feedback gain: - 0.0500
[laser amplitude (modulated pulses)]
2.
1.2
0.6
0.
0. 5. 10. 15. 20. 30.
Res= 1,Buf=15 [bunch number]
[laser amplitude stability]
1.06
0.98
0.94
0. 20. 40. 60. 80. 100.
Res= 1,Buf=15 [laser pulse number]


[arrival time [ps]]
-277.5
-278.
-278.5
-279.
-279.5
-280.
-280.5
-281.
0. 5. 10. 15. 20. 25. 30.
Res= 1,Buf=15 [bunch number]


[averaged arrival time [ps]]
-278.
-280.
-282.
-284.
-286.
-288.
-290.
-292.
2:01 8.12.07
2:05 8.12.07
2:09 8.12.07
2:13 8.12.07

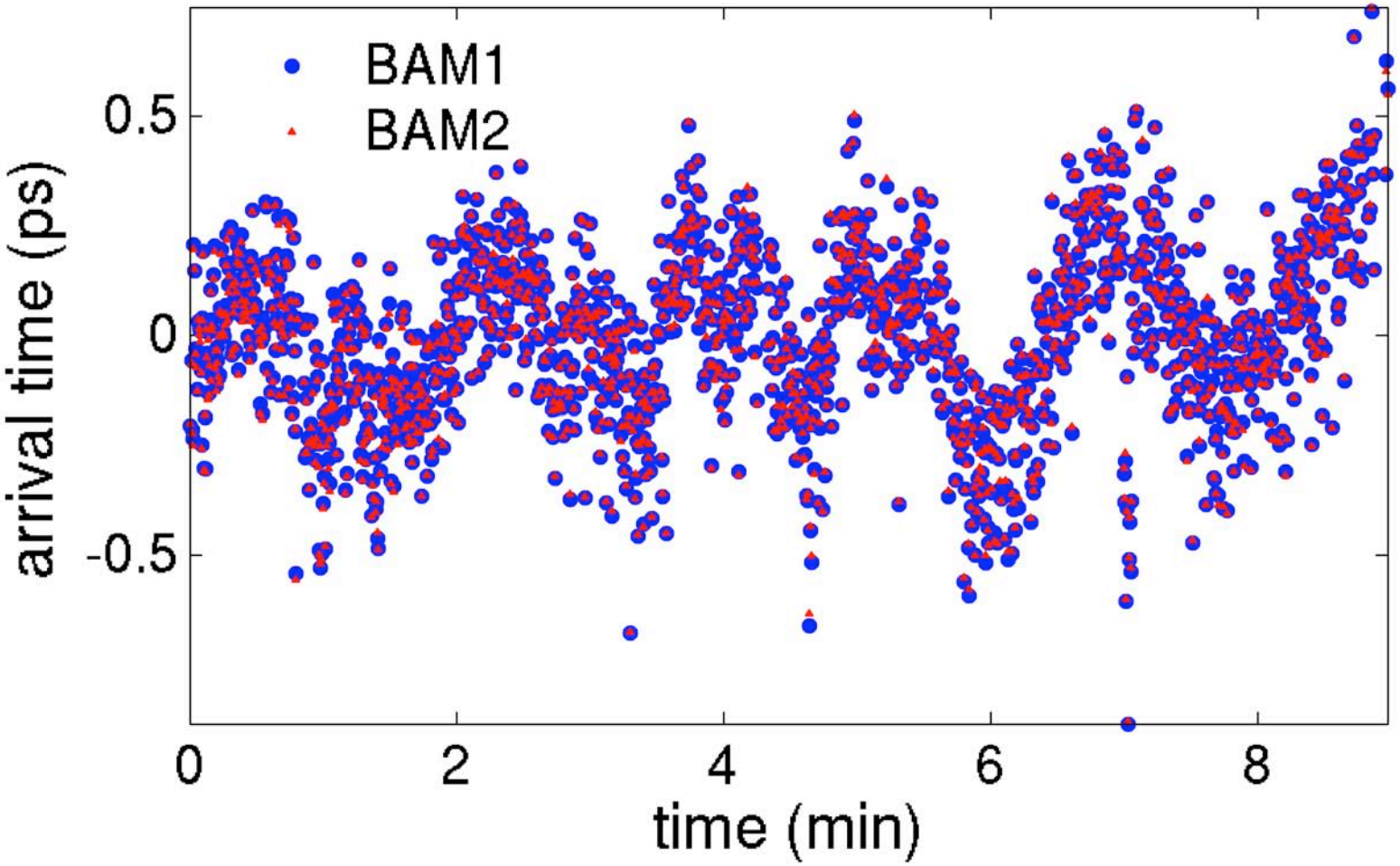
BAM resolution measurement



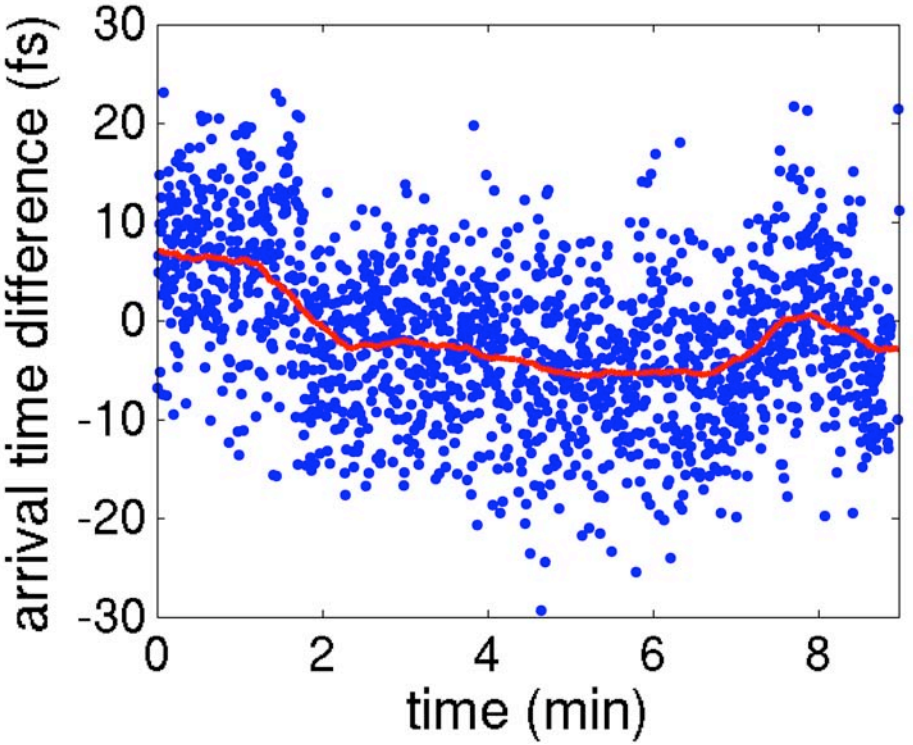
Two BAMs in a straight section are used to measure the arrival times of the same bunches

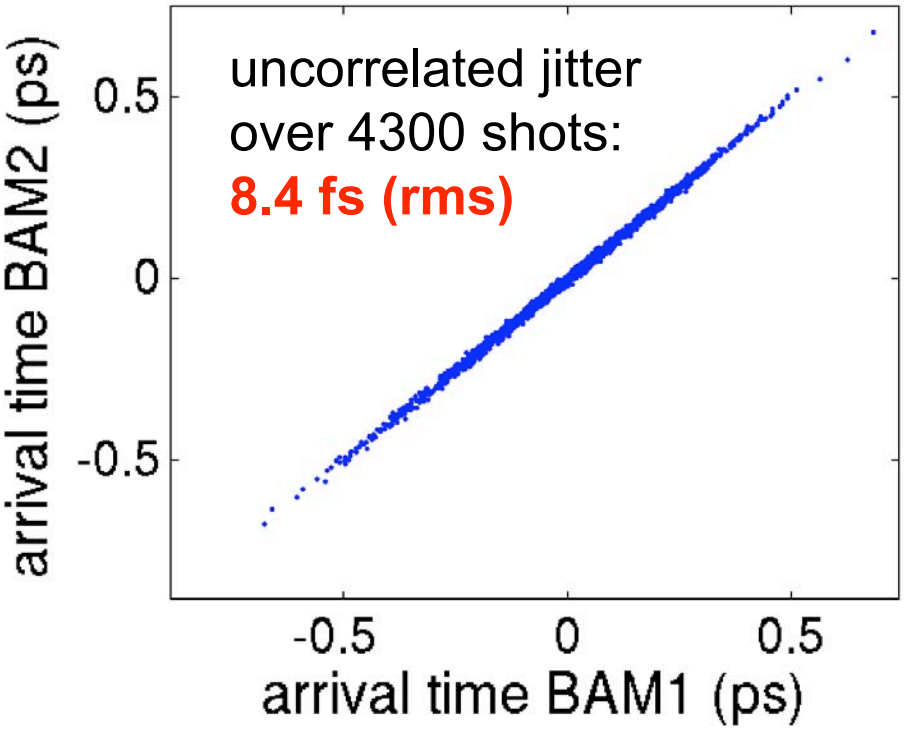
The BAMs are separated by 60 m.

Arrival time correlation between two BAMs



Arrival time correlation between two BAMs





Arrival time difference contains:

- high frequency laser noise (~3 MHz – 108 MHz)
- stability of two fiber links
- two BAMs

Single bunch resolution of entire measurement chain: **< 6 fs (rms)**