Recent Developments of the Bunch Arrival Time Monitor with Femtosecond Resolution at FLASH.

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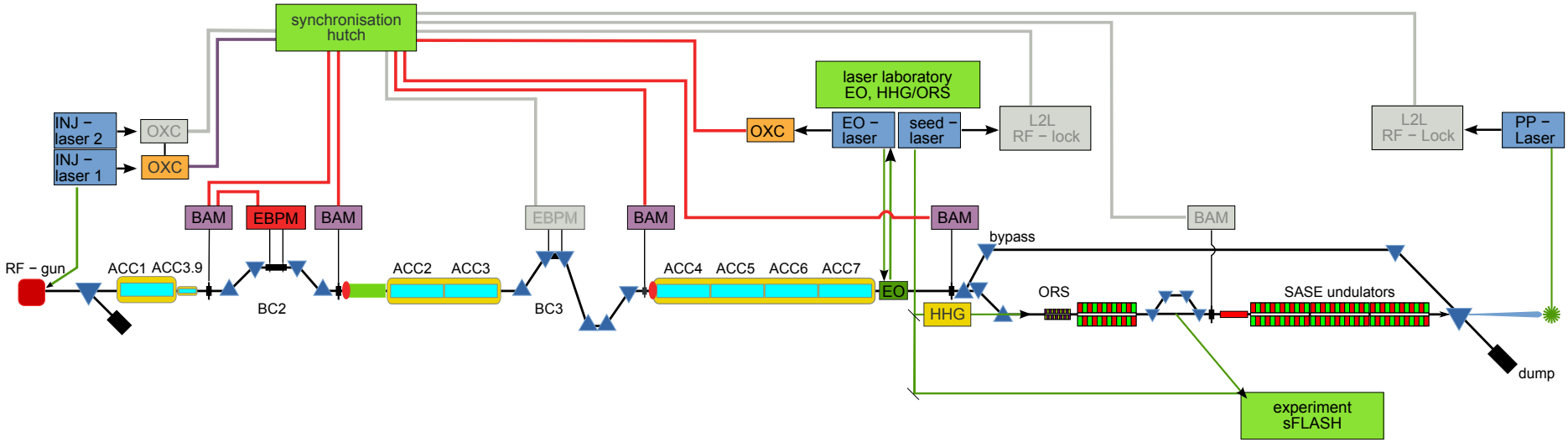
Hamburg University, Germany

IPAC - Beam Instrumentation & Feedback - May 26^{th} 2010

Laser-based Synchronisation Infrastructure at FLASH.

Locations of Bunch Arrival Time Monitors (BAM)



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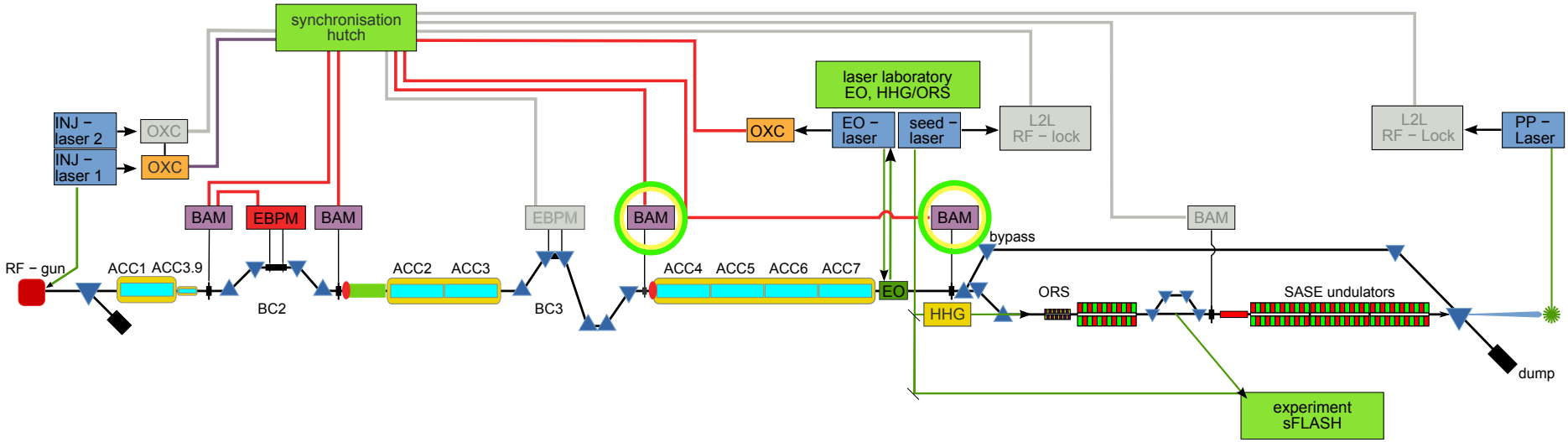

- 1. Generation: BAM 4DBC3 and 18ACC7

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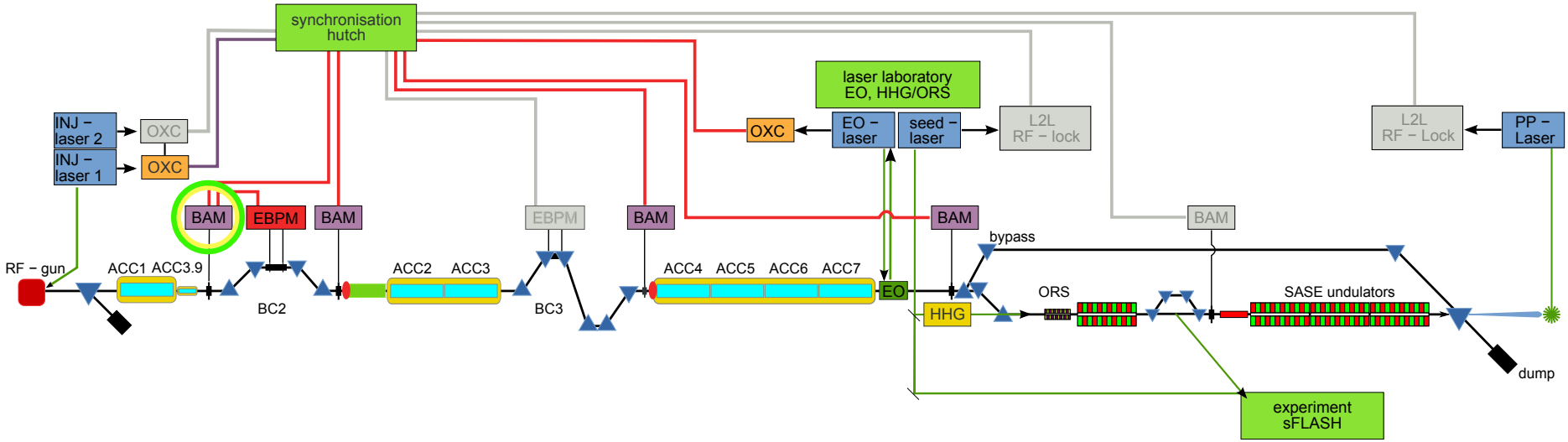

- 1. Generation: BAM 4DBC3 and 18ACC7
- 2. Generation: BAM 1UBC2 - installed in 2009

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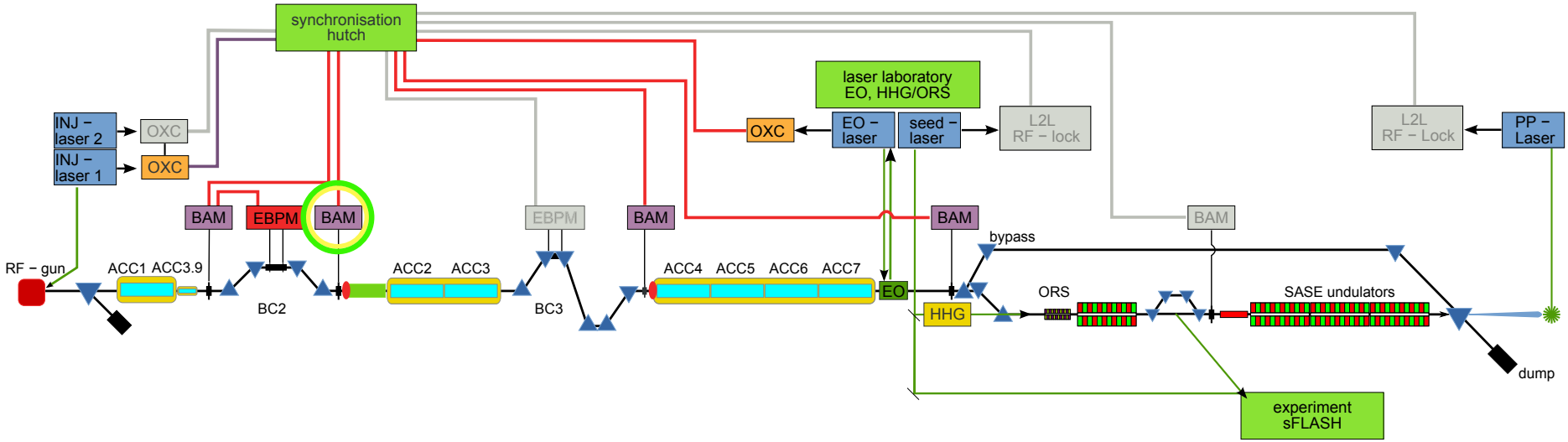

- 1. Generation: BAM 4DBC3 and 18ACC7
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- 3. Generation: BAM 3DBC2 - installed May 2010

Laser-based Synchronisation Infrastructure at FLASH.

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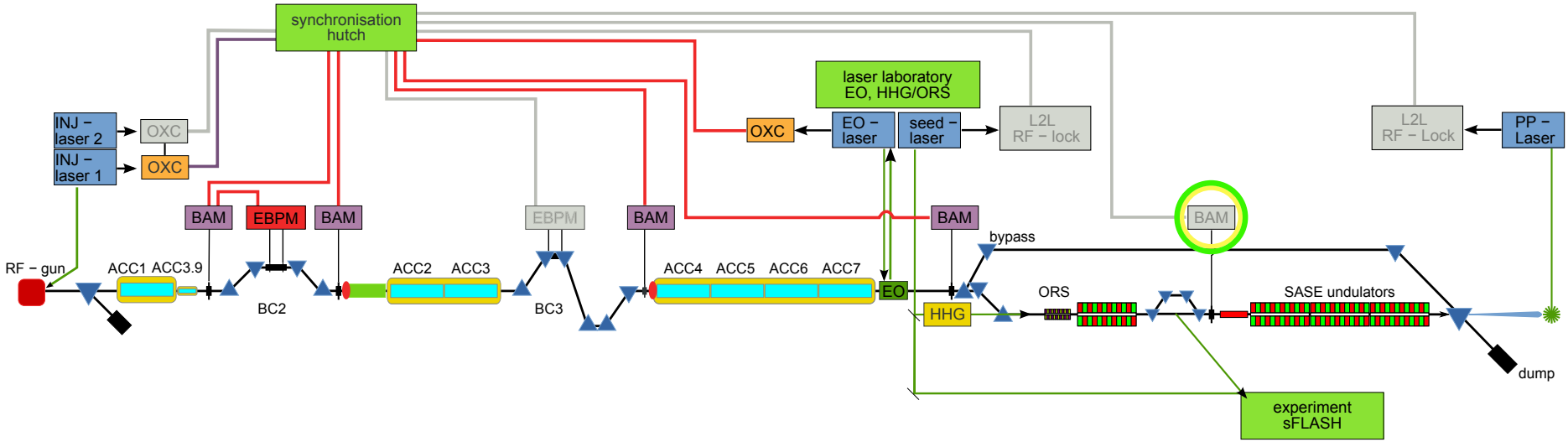
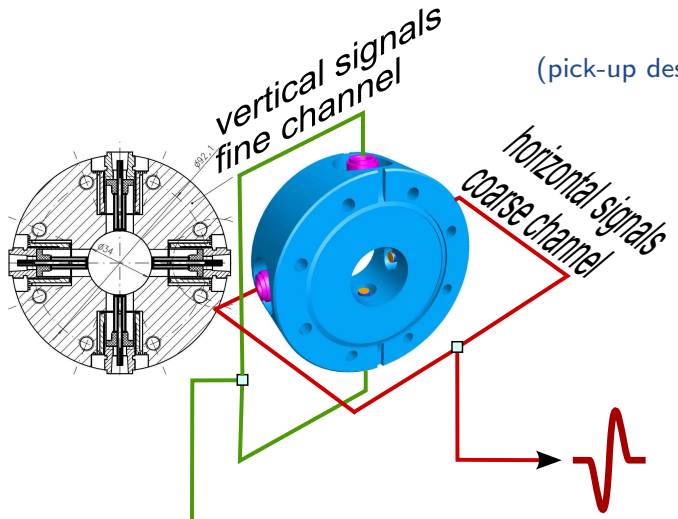


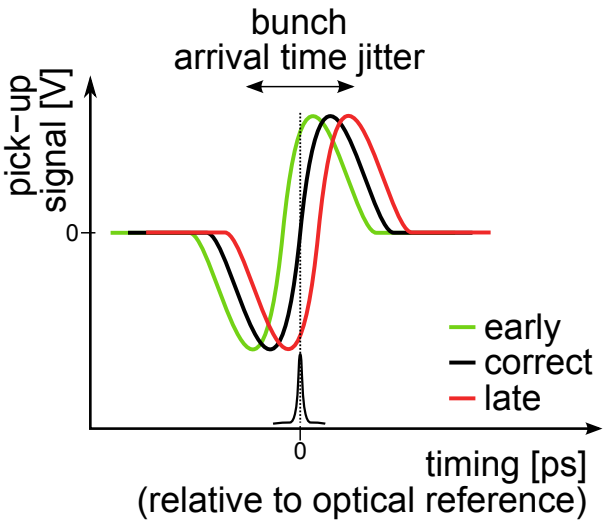
- 1. Generation: BAM 4DBC3 and 18ACC7
- 2. Generation: BAM 1UBC2 - installed in 2009
- 3. Generation: BAM 3DBC2 - installed May 2010
- 4. Generation: BAM 1SFELC - scheduled for 2011

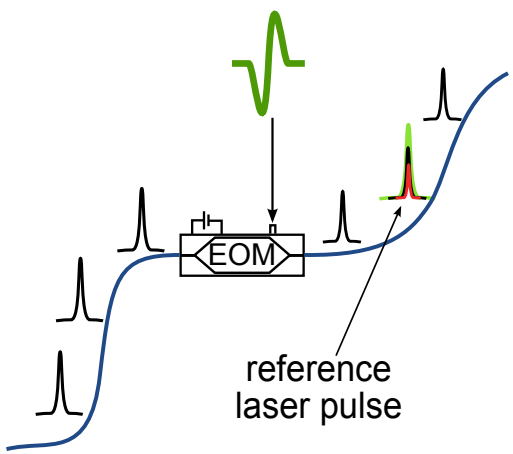
Bunch Arrival Time Measurement.

Electro-Optical Detection Scheme

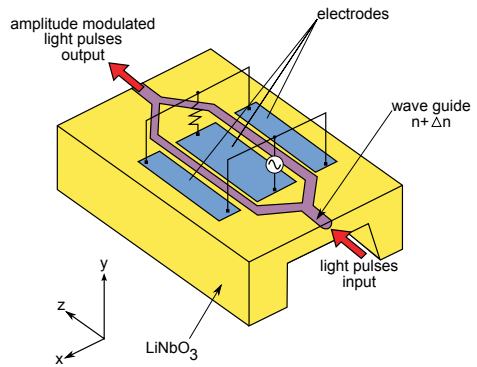


(pick-up design drawing, courtesy: K. Hacker)





electro-optical modulator



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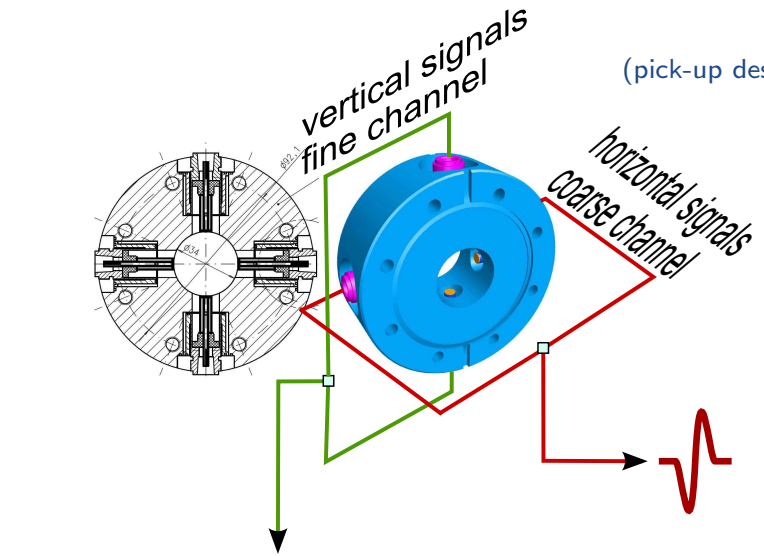
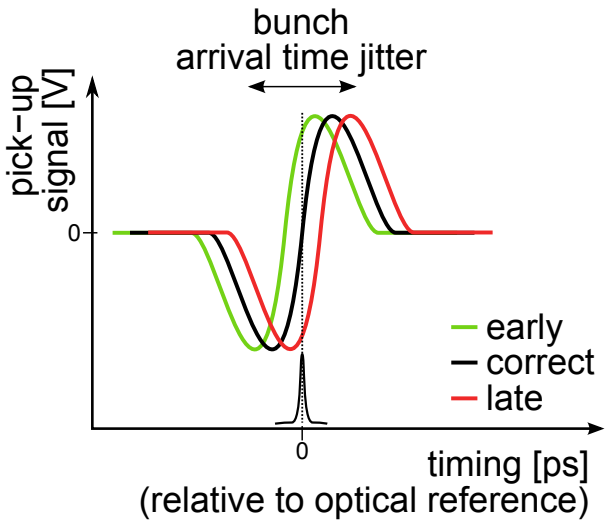
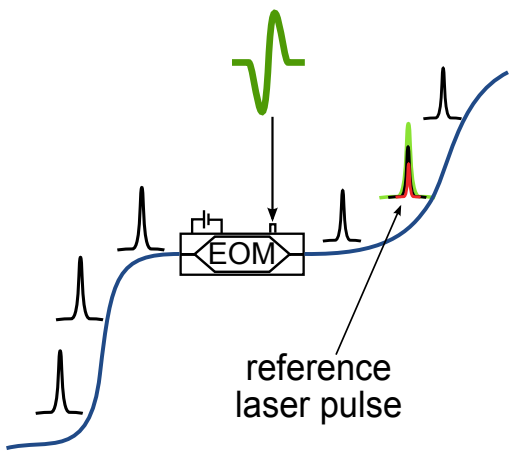
reduced dependency on beam orbit







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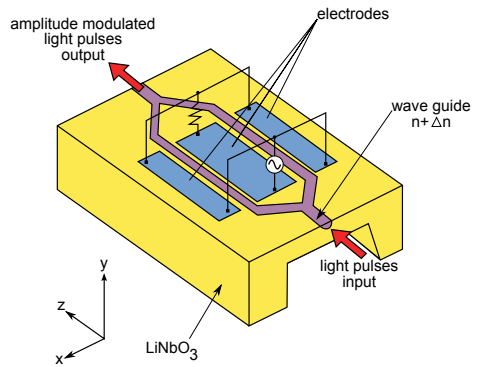

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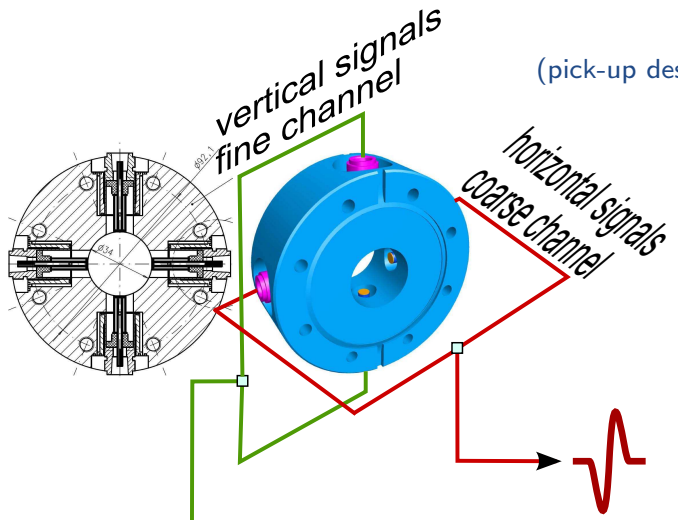
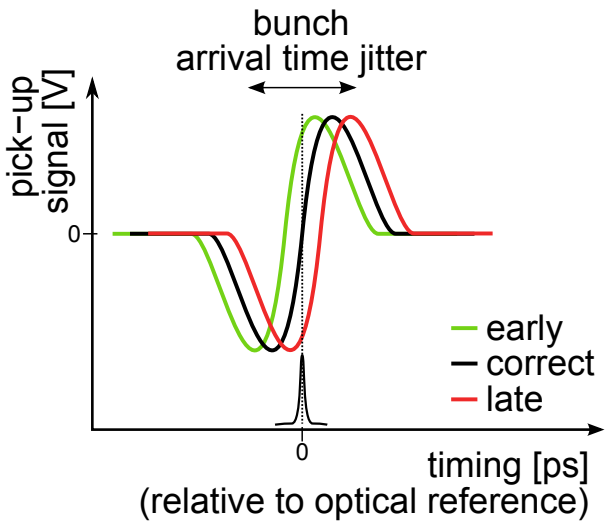
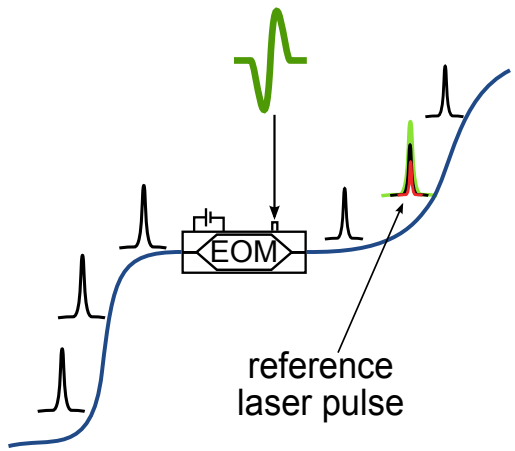


reduced dependency on beam orbit

reduced dependency on bunch charge





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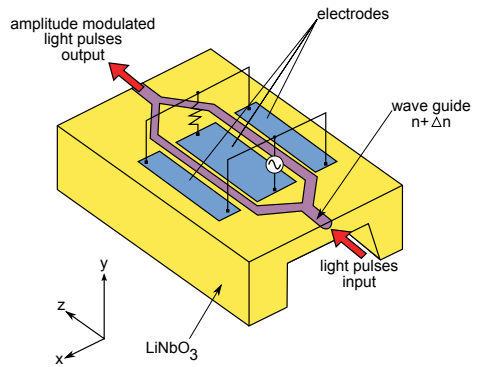


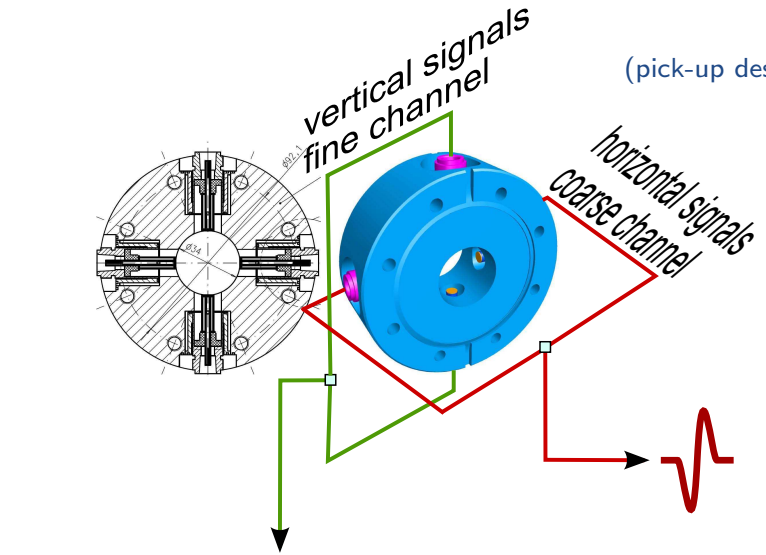
Bunch Arrival Time Measurement.

Electro-Optical Detection Scheme

reduced dependency on beam orbit

reduced dependency on bunch charge

sensitivity in terms of
% modulation per fs timing change



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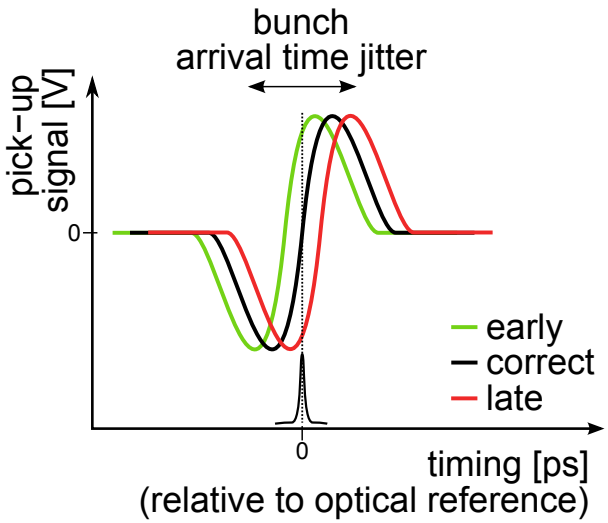

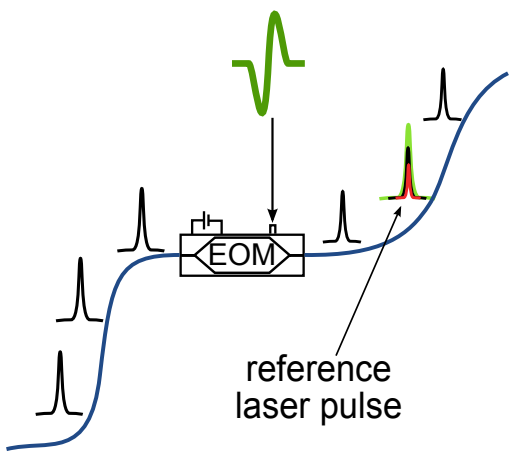

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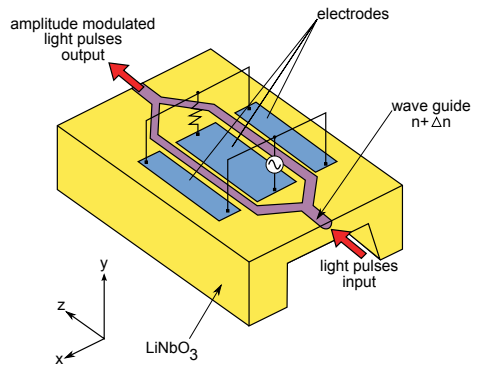
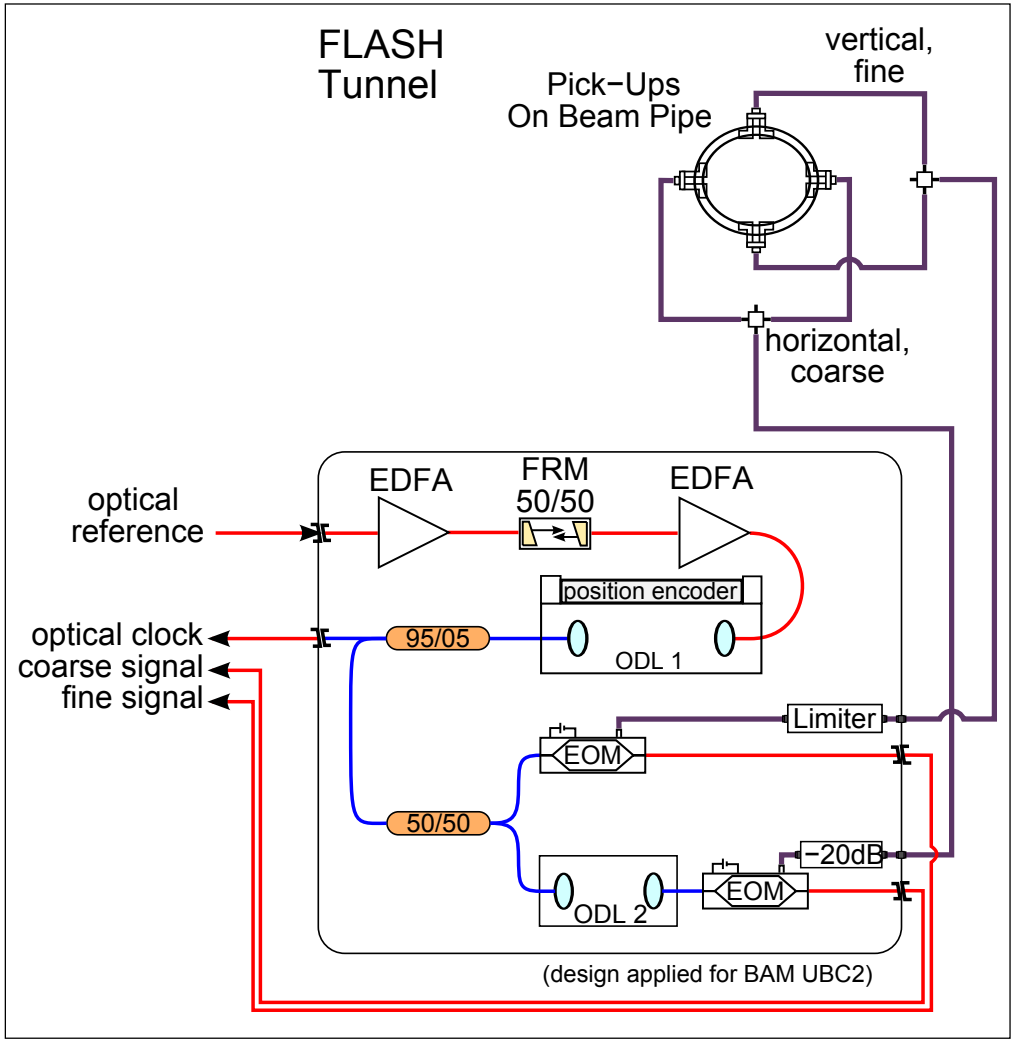


Opto-Mechanical Front-End.

Fibre-Optical Layout - Recent Design Changes



Design 2. Generation

- self-spliced Polarisation Maintaing Fibre Section
- 2 Erbium-doped Fibre Amplifiers (EDFA)
- uncompensated fibre length in total: $\approx 5m$
- distance FRM - EOM 1: $\approx 3.5m$

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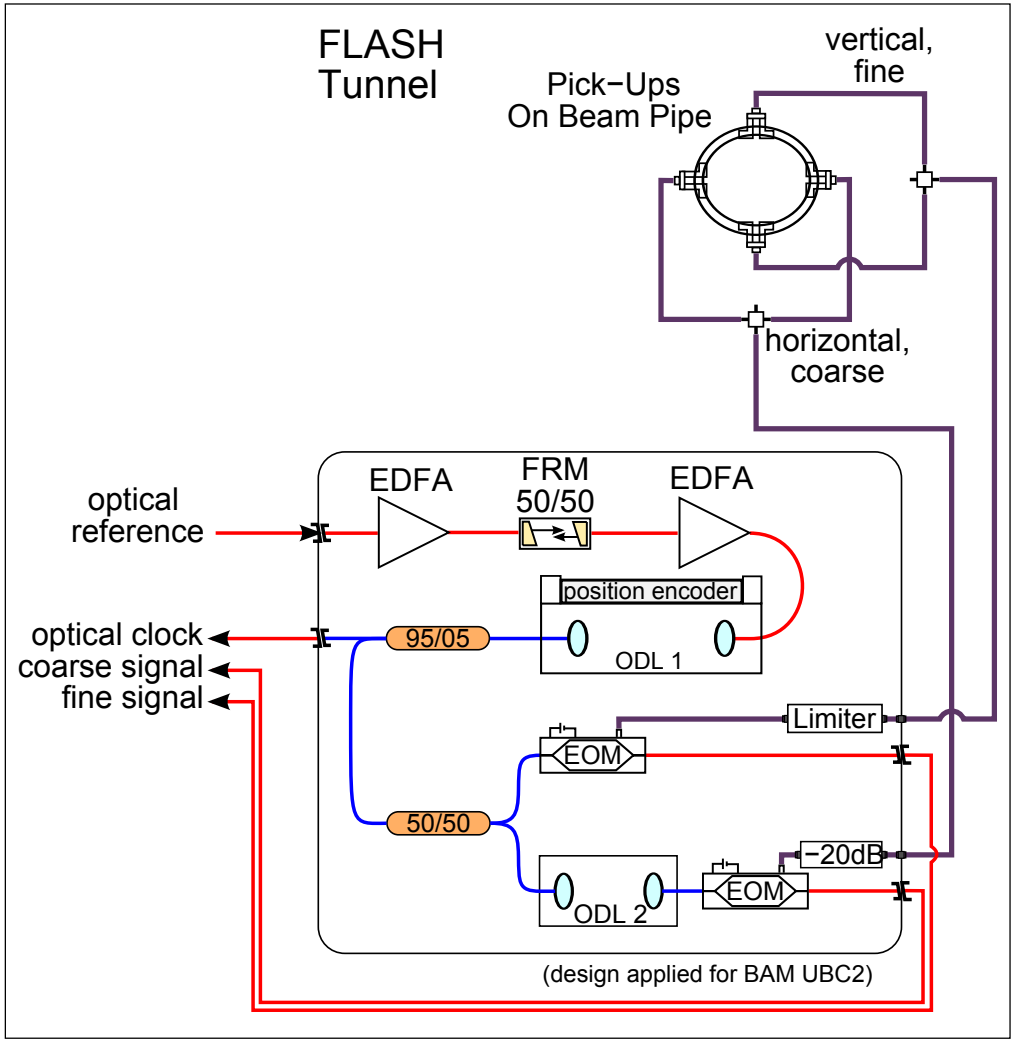

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- uncompensated fibre length in total: $\approx 5m$
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- temperature drift of SMF: 60 fs/K/m

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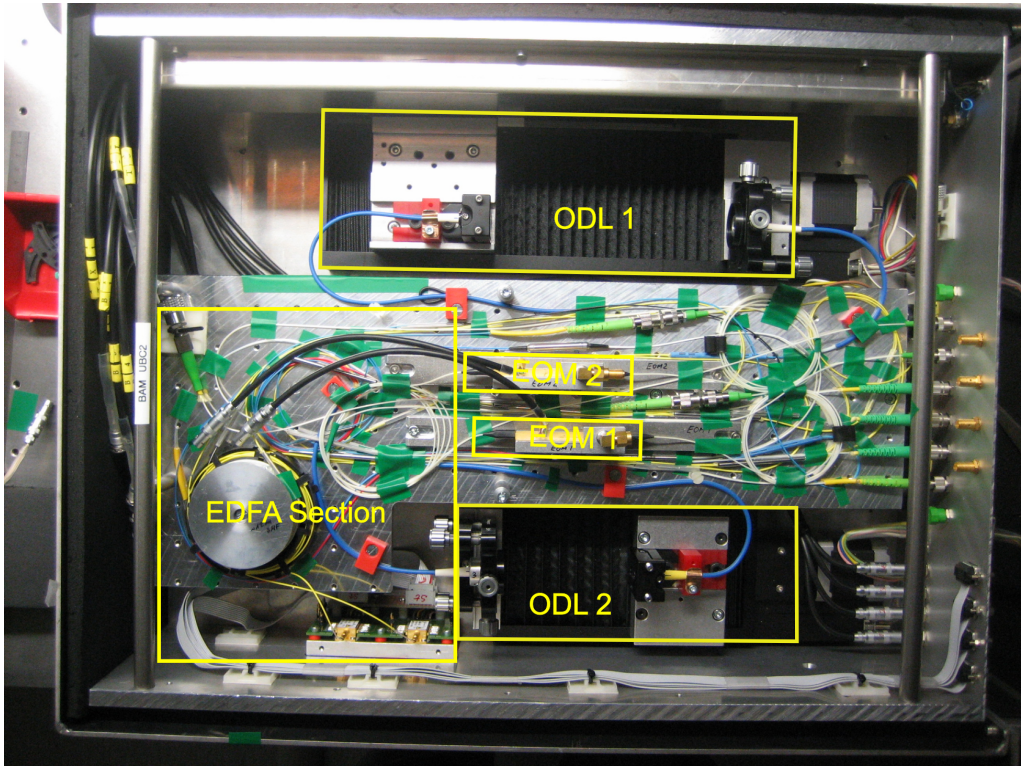

Improvements compared to 1.Generation

- custom motorised stage suited for high-duty cycles
- temperature regulation using peltier elements:

  40 mK peak-to-peak over 8 hours
  100 mK peak-to-peak over a few days

Opto-Mechanical Front-End.

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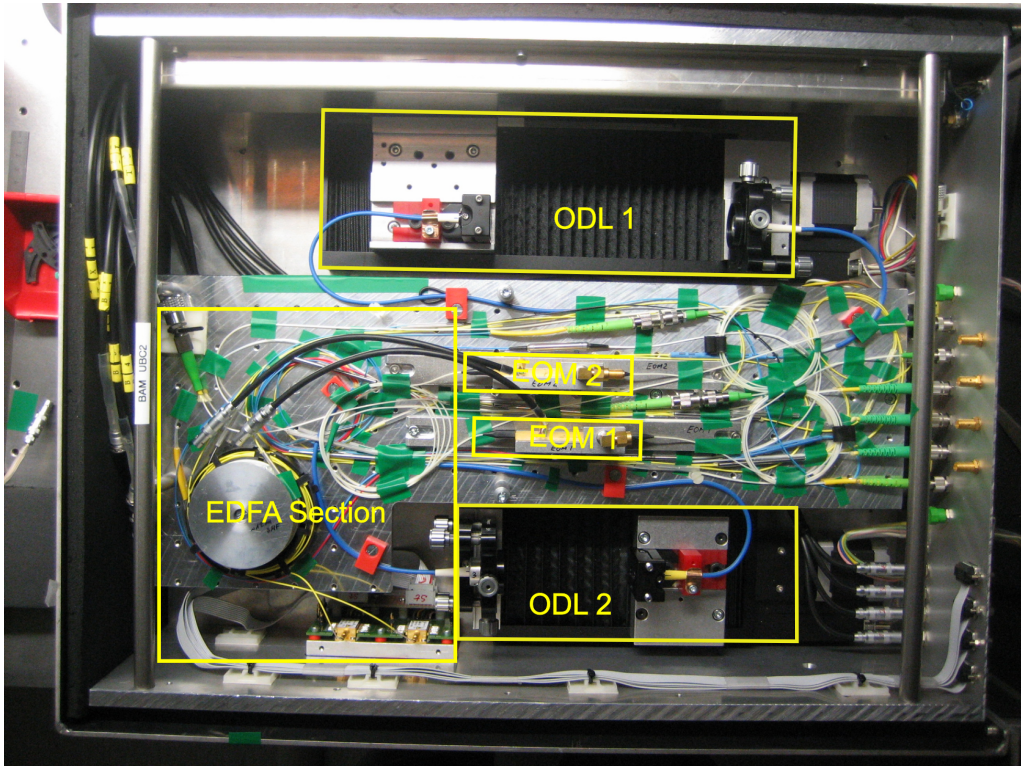

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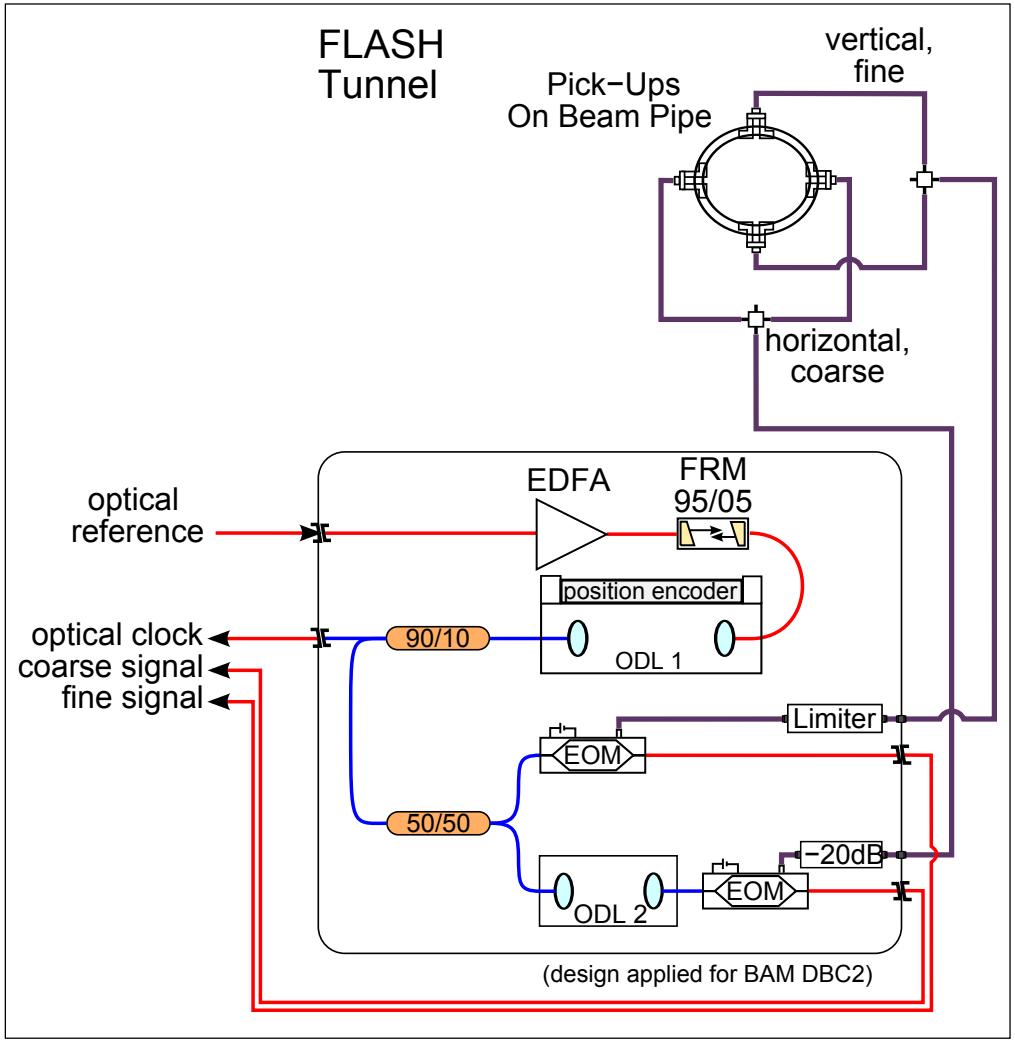
Design Issues

- EDFA in uncompensated fibre section
- uncompensated fibre too long
- long fibre sections complicates assembly

Opto-Mechanical Front-End.

Fibre-Optical Layout - Recent Design Changes



3. Generation BAM - Improvements

Opto-Mechanical Front-End.

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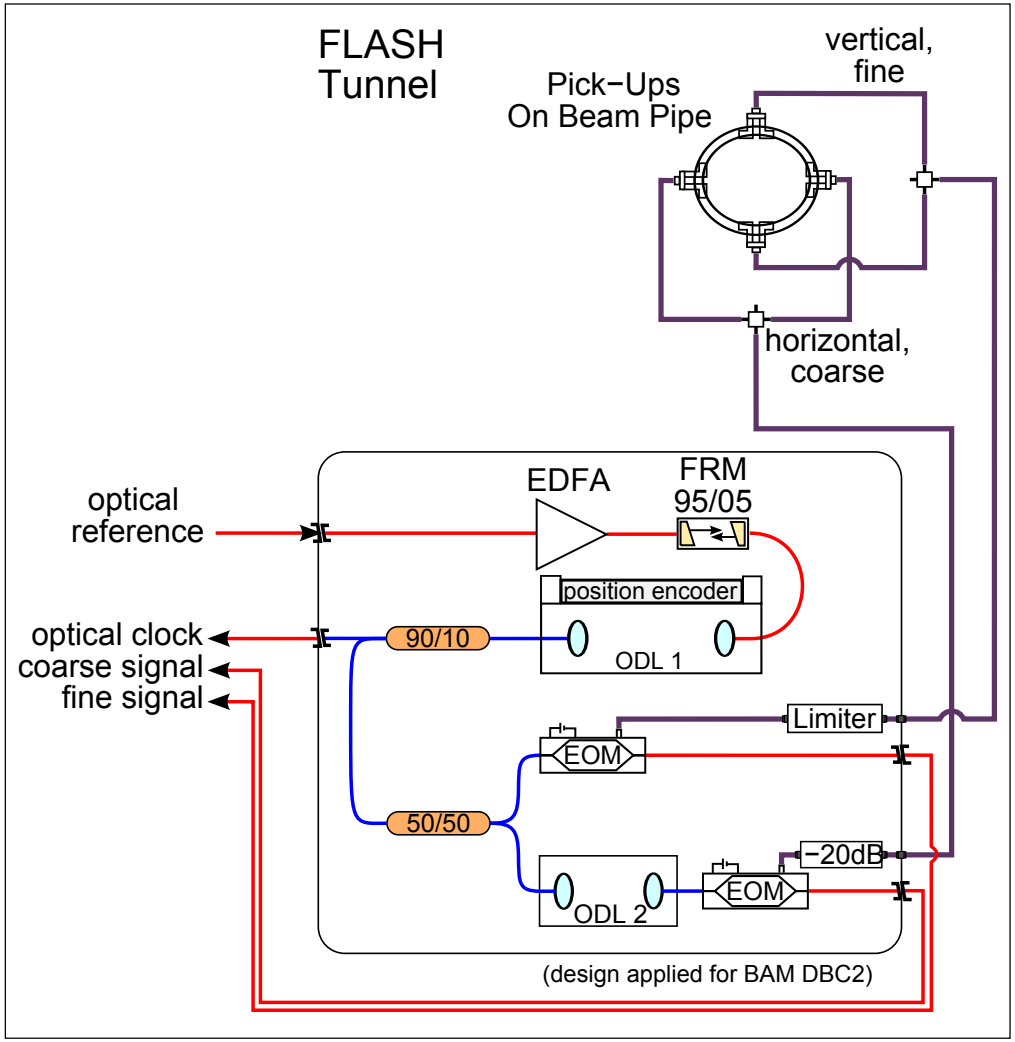
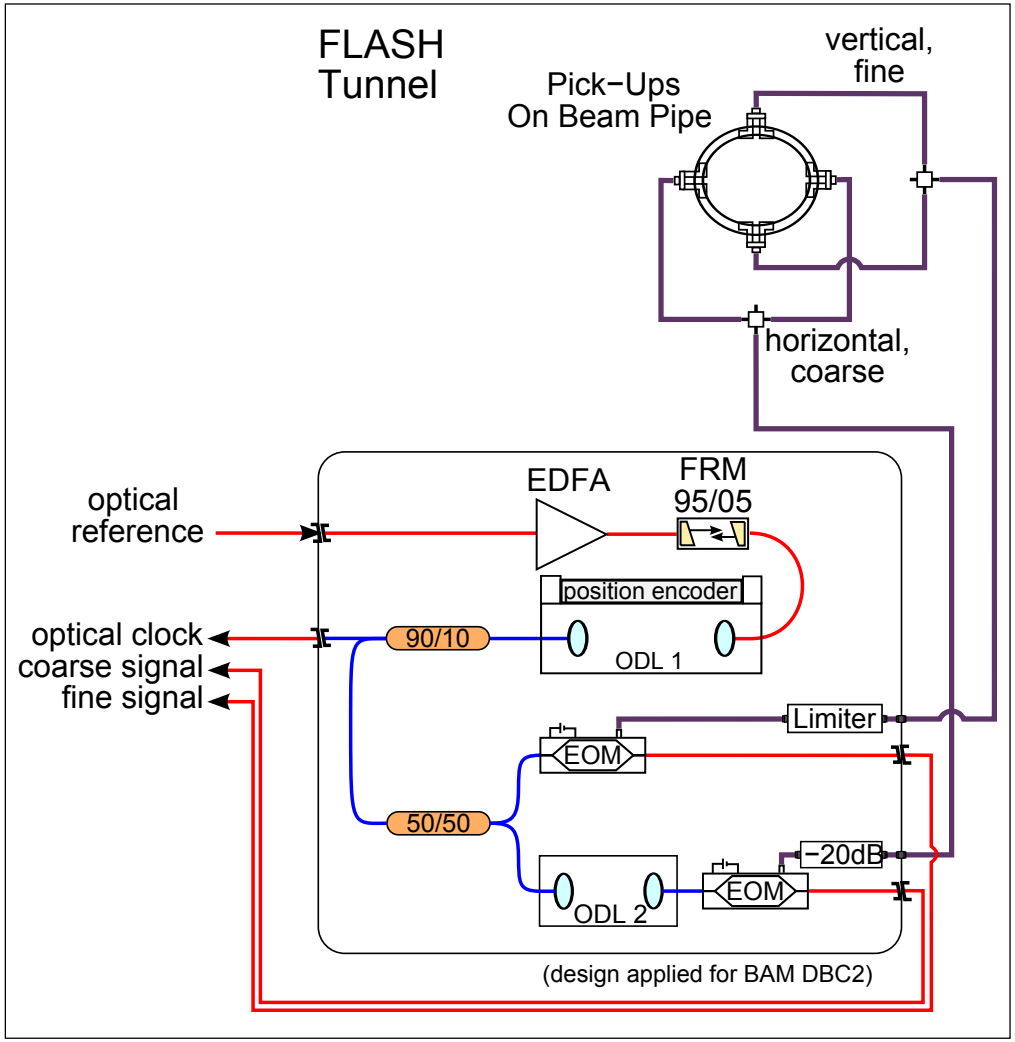


3. Generation BAM - Improvements
   - only one EDFA, compensated for timing drifts

Opto-Mechanical Front-End.

Fibre-Optical Layout - Recent Design Changes

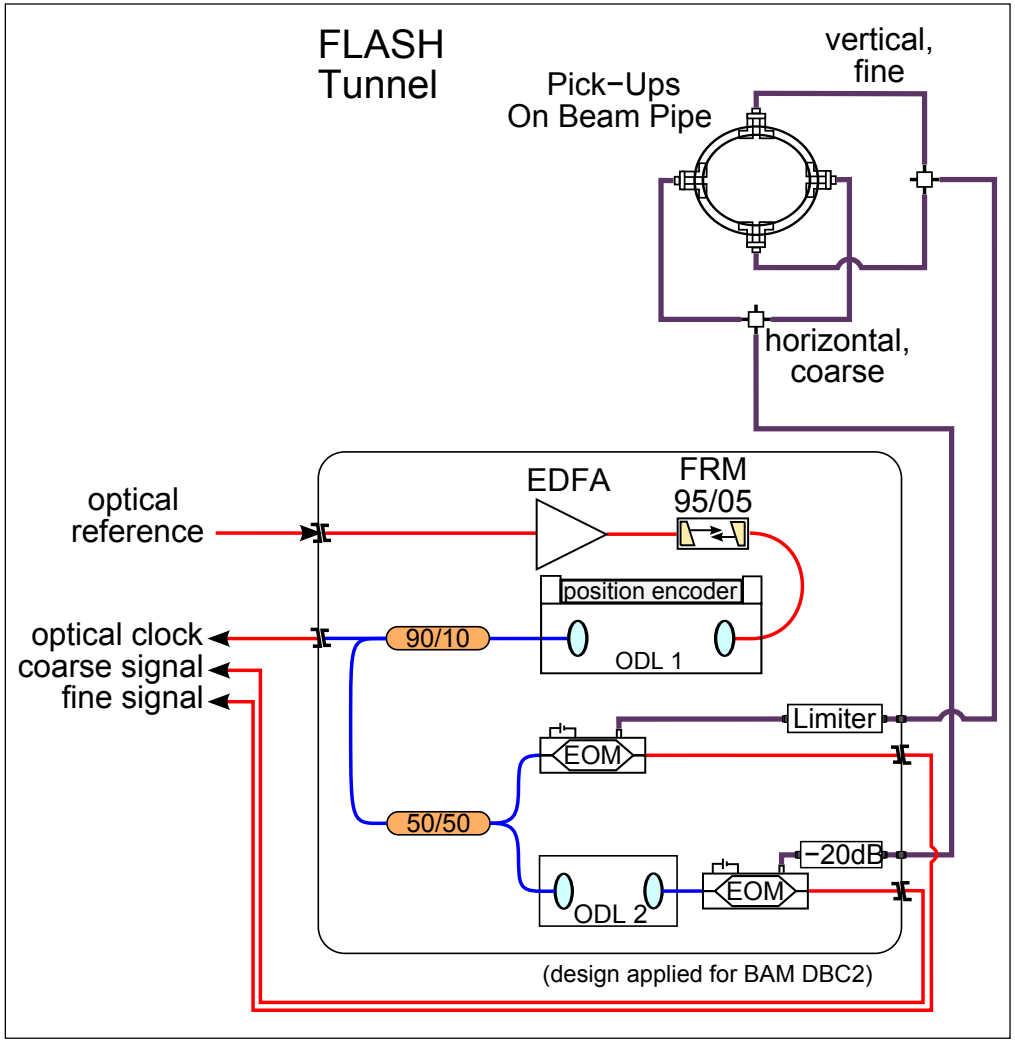


3. Generation BAM - Improvements

- only one EDFA, compensated for timing drifts
- shortened PM fibre section:
  FRM - EOM 1: $\approx 1.5m$

Opto-Mechanical Front-End.

Fibre-Optical Layout - Recent Design Changes

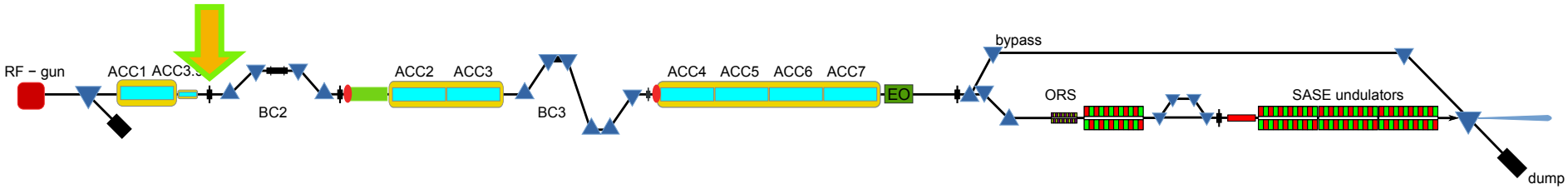


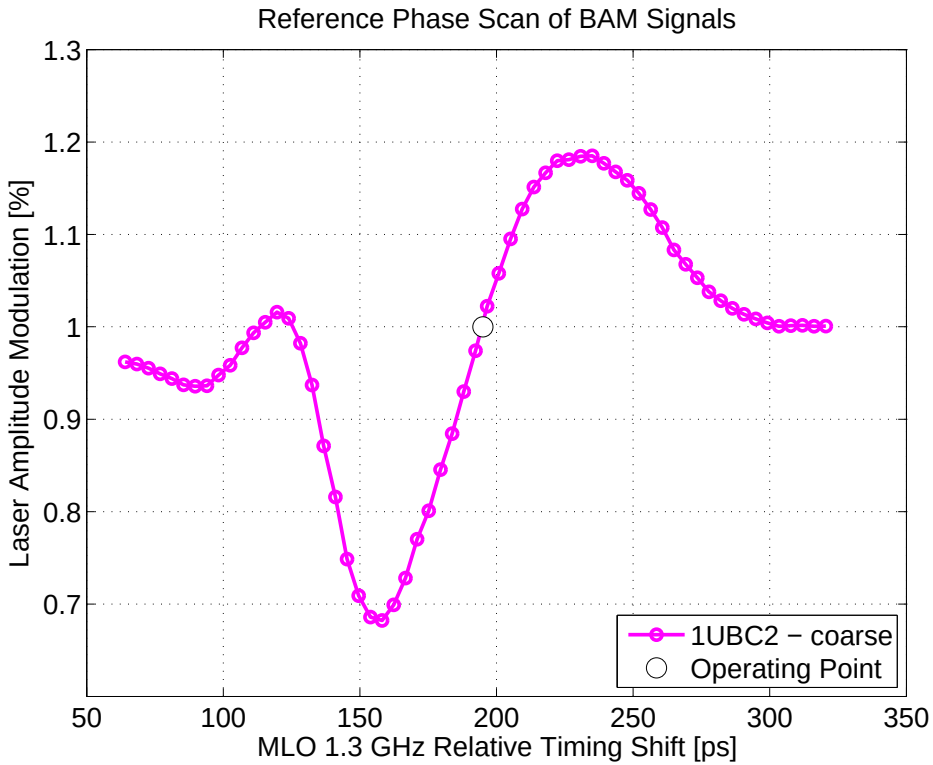
3. Generation BAM - Improvements

- only one EDFA, compensated for timing drifts
- shortened PM fibre section:
  FRM - EOM 1: $\approx 1.5m$
- improved fibre management

Commissioning of the BAMs.

BAM Signal Scans



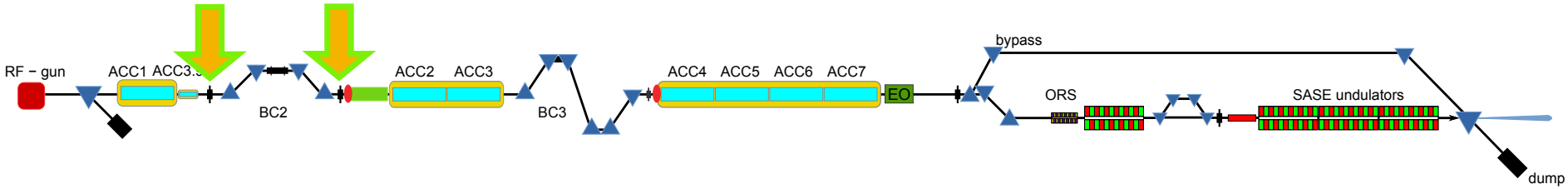


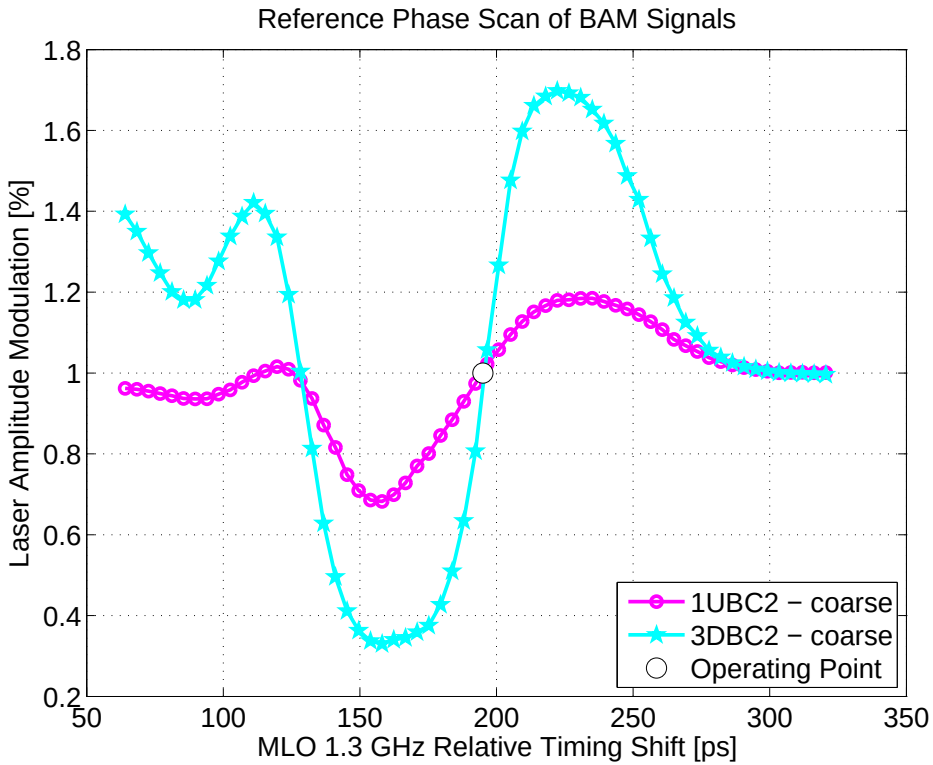
Shift 1.3 GHz phase of reference laser pulse to sample RF pick-up signal

- **coarse channel** BAM 3: attenuated signal by -30 dB

Commissioning of the BAMs.

BAM Signal Scans



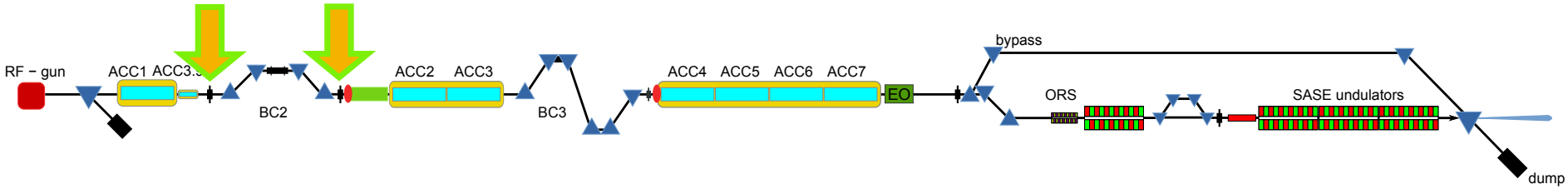


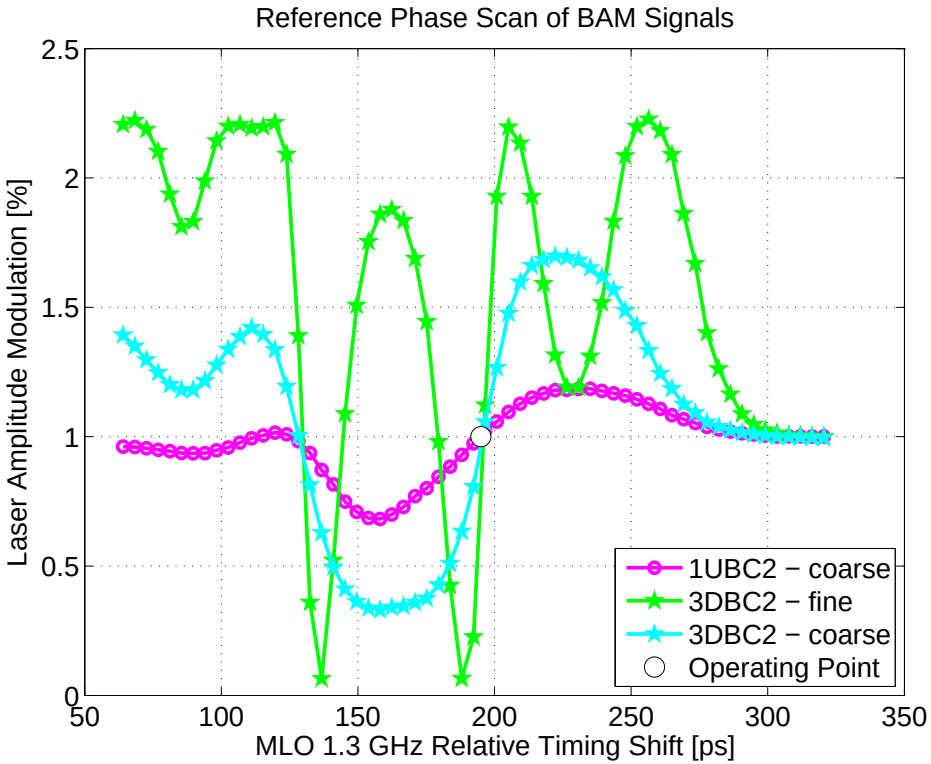
Shift 1.3 GHz phase of reference laser pulse to sample RF pick-up signal

- **coarse channel** BAM 3: attenuated signal by -30 dB
- **coarse channel** BAM 4: attenuated signal by -19 dB

Commissioning of the BAMs.

BAM Signal Scans



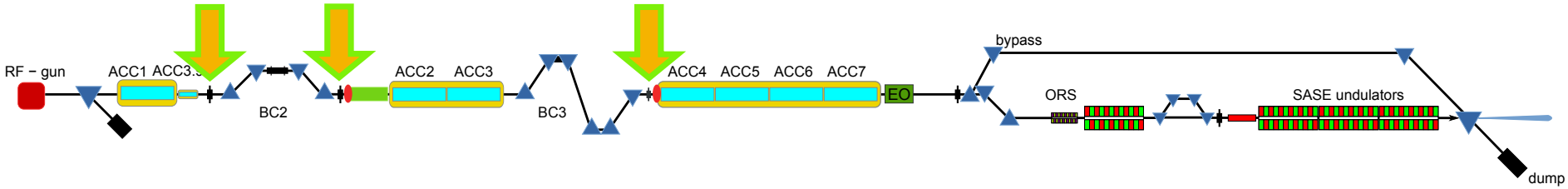


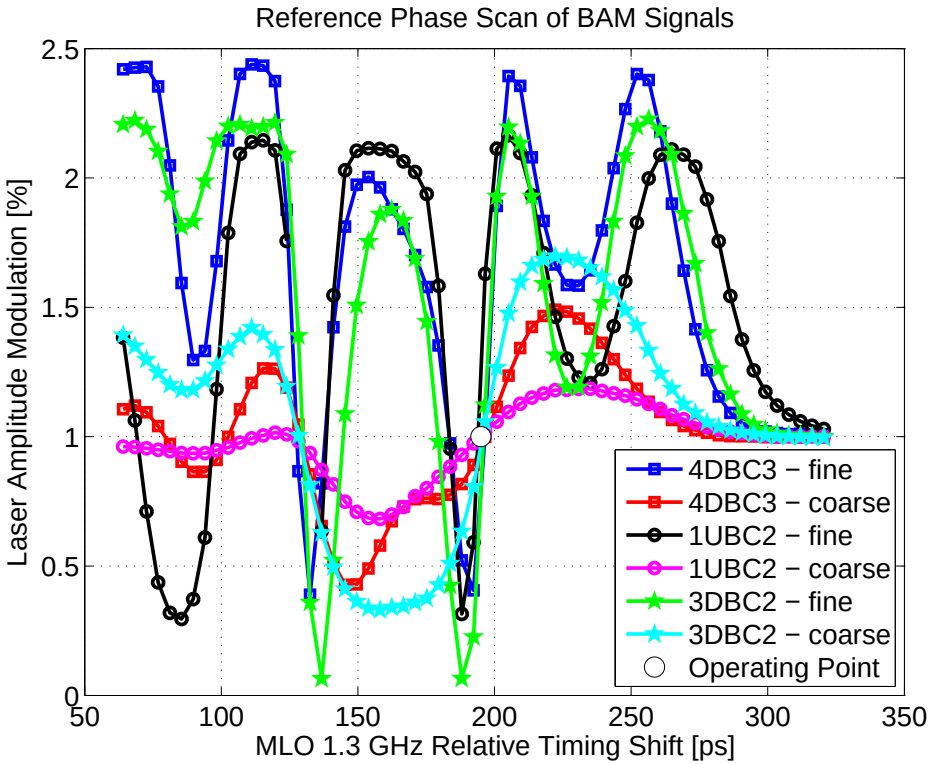
Shift 1.3 GHz phase of reference laser pulse to sample RF pick-up signal

- **coarse channel** BAM 3: attenuated signal by -30 dB
- **coarse channel** BAM 4: attenuated signal by -19 dB
- **fine channel** BAM 3: power limiter, no attenuator

Commissioning of the BAMs.

BAM Signal Scans



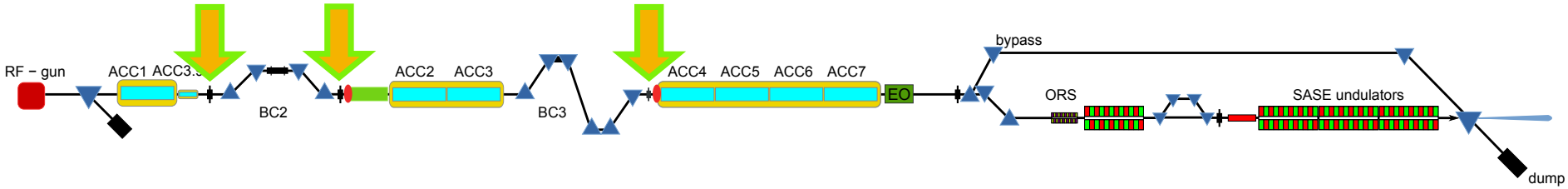


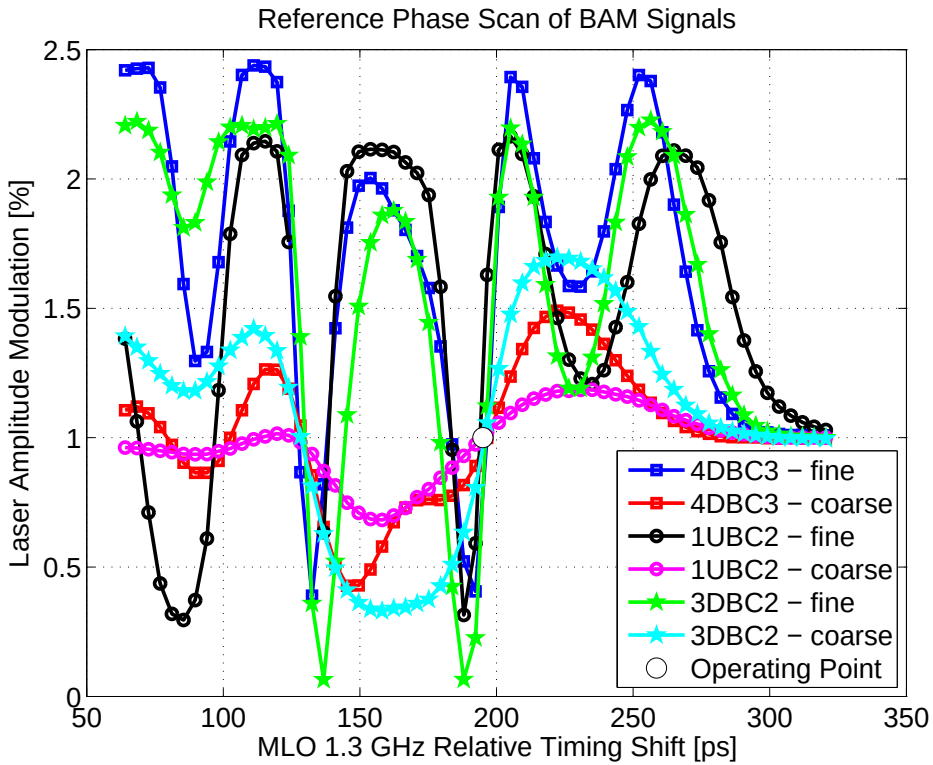
Shift 1.3 GHz phase of reference laser pulse to sample RF pick-up signal

- all signals from 3 BAMs

Commissioning of the BAMs.

BAM Signal Scans





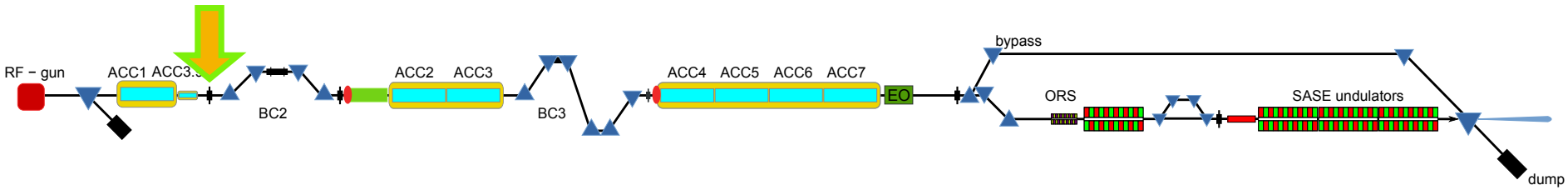
Shift 1.3 GHz phase of reference laser pulse to sample RF pick-up signal

- all signals from 3 BAMs
- all signals aligned at same reference phase of 197 ps = 92 deg (1.3GHz):

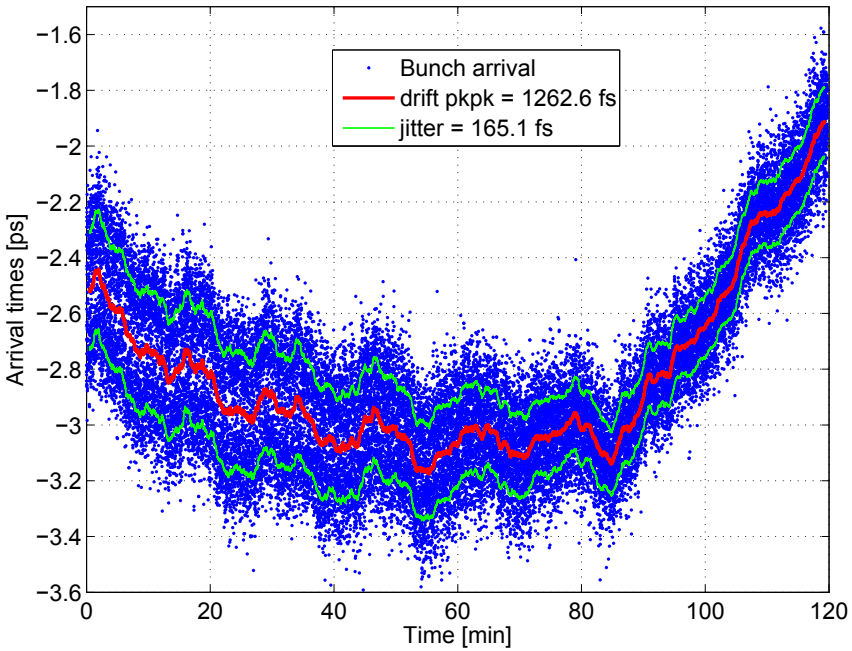
  adjust RF cable lengths
  adjust motorised stages

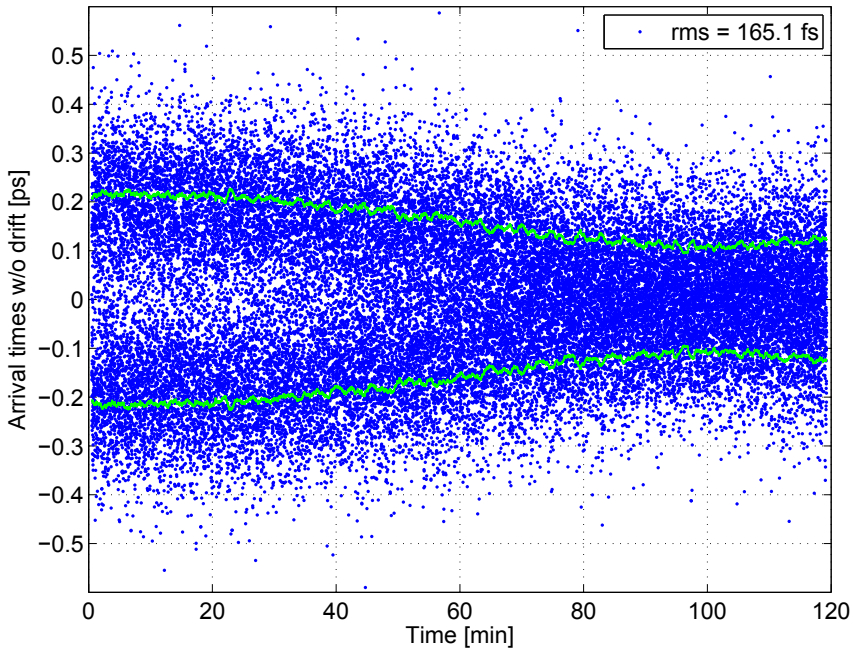
Arrival Time Measurement in Injector Section of FLASH.

Bunch Arrival Time at Entrance of 1st Bunch Compressor



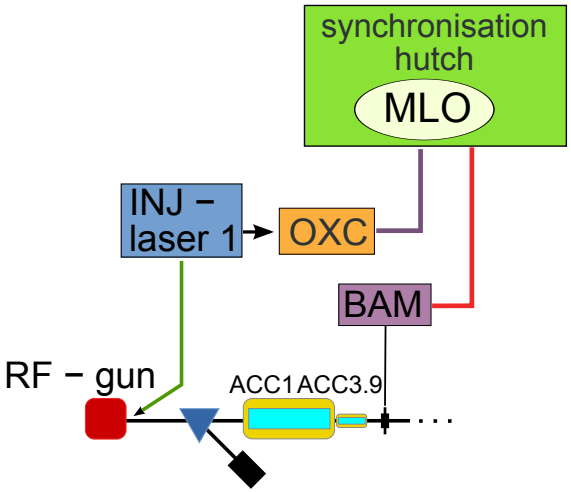
PRELIMINARY





Injector Timing Measurement.

Optical Cross-Correlator & Bunch Arrival Time

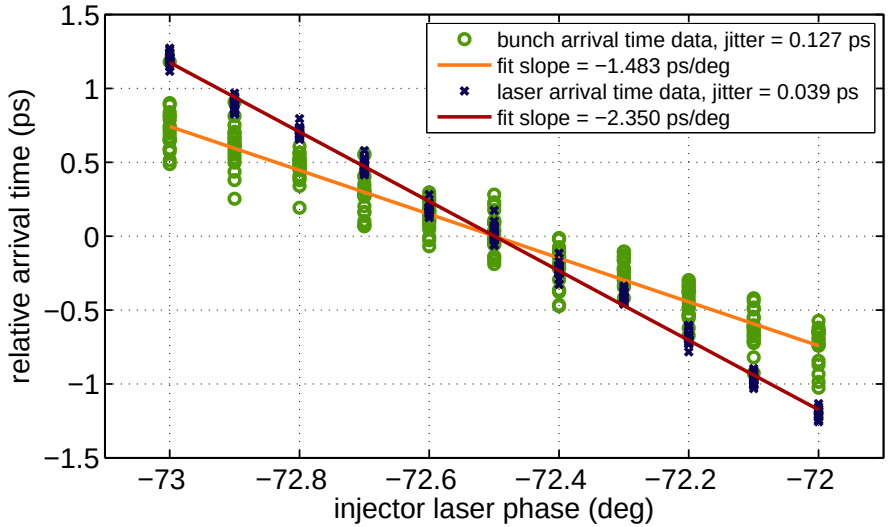


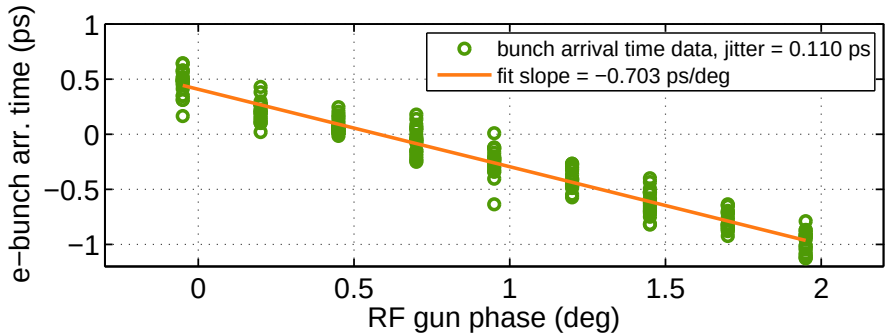
$$\begin{aligned} \delta t_{\text{bunch}} &= G_{\text{gun}}\delta t_{\text{gun}} + G_{\text{laser}}\delta t_{\text{laser}} \\ 1 &= G_{\text{gun}} + G_{\text{laser}} \\ \delta t_{\text{bunch}} &= 2.14\,\frac{\text{ps}}{\text{deg}} \end{aligned}$$

poster WEPEB076

today, 16:00 - 18:00, Event Hall,

Poster Area B





Summary & Outlook.

Electro-Optical Bunch Arrival Time Monitors at FLASH

Current Status

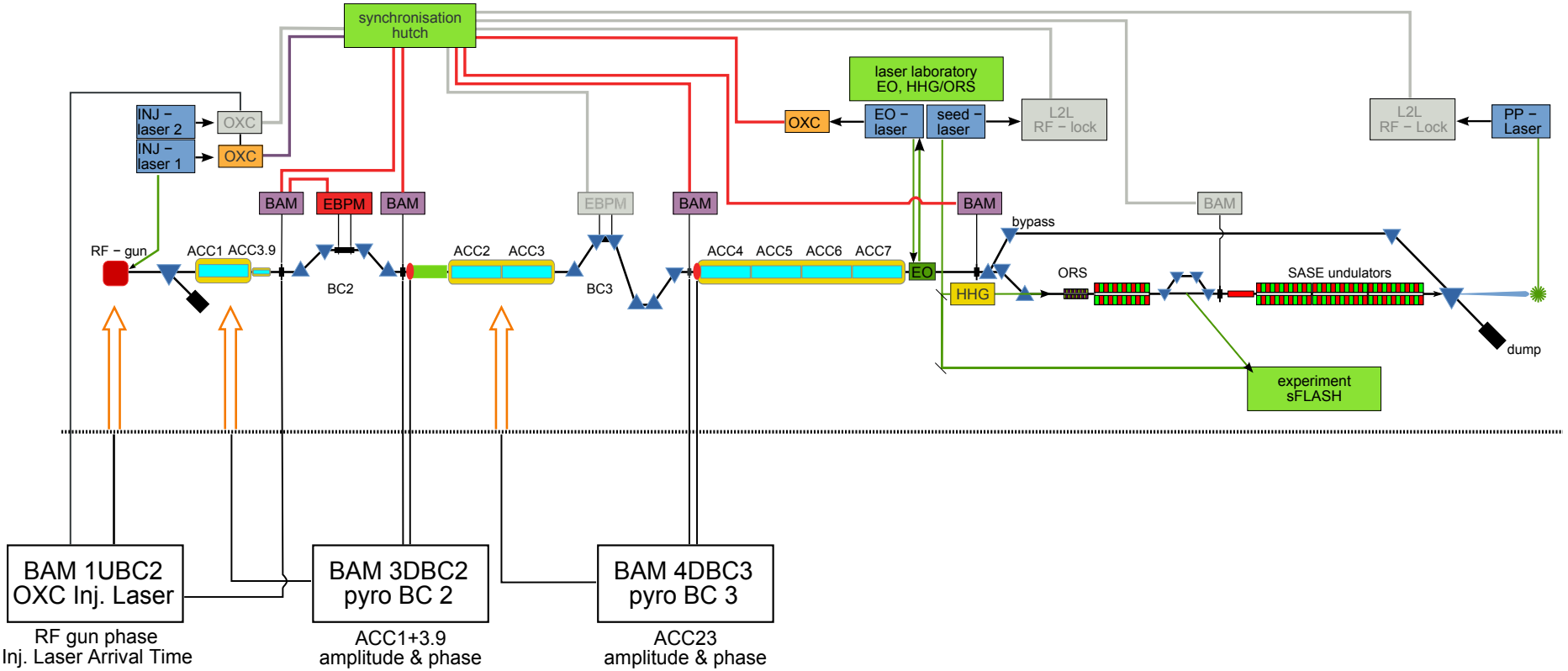
- 4 BAMs are currently installed & commissioned at FLASH
- successive improvements in design and performance

Outlook

- 5th BAM scheduled for 2011
- major change in upcoming design review:
  reduce total fibre length
  eliminate mechanical stress on movable fibres
- further improve read-out electronics
- continue preparation for switching from VME crates to new crate standard: μTCA

Outlook.

Beam Based Feedback Implementation



system focusses on reliability & robustness,
compared to previously demonstrated experiments [1]

[1] F. Löhl, et al. Phys. Rev. Lett.,Volume 104, Issue 14, 144801