Recent experimental results with BAMs at FLASH.

Marie Kristin Bock[1] *on behalf of the LbSyn Team*

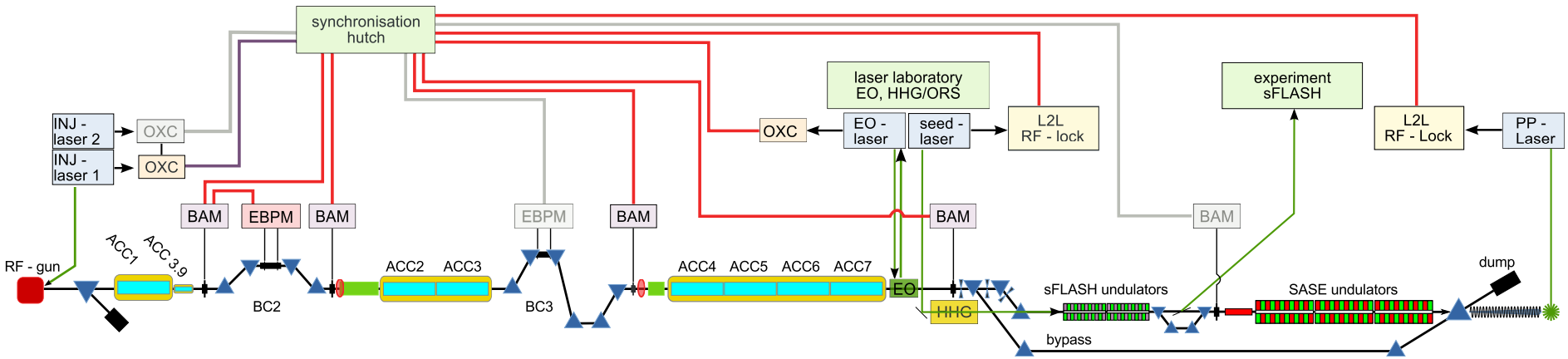
[1] Deutsches Elektronen-Synchrotron (DESY), Hamburg

FLASH Seminar

Outline.

Laser-based Synchronisation Infrastructure at FLASH.

Locations of Bunch Arrival Time Monitors



1. Generation: BAM 4DBC3 and 18ACC7 :first prototypes of engineered design
2. Generation: BAM 1UBC2 - installed in 2009 : general redesign of opto-mechanics
3. Generation: BAM 3DBC2 - installed May 2010 : minor design changes
4. Generation: BAM 1SFELC - scheduled for 2012 : further design improvements
5. Generation: BAMs for FLASH2 mode of operation : extensive redesign necessary

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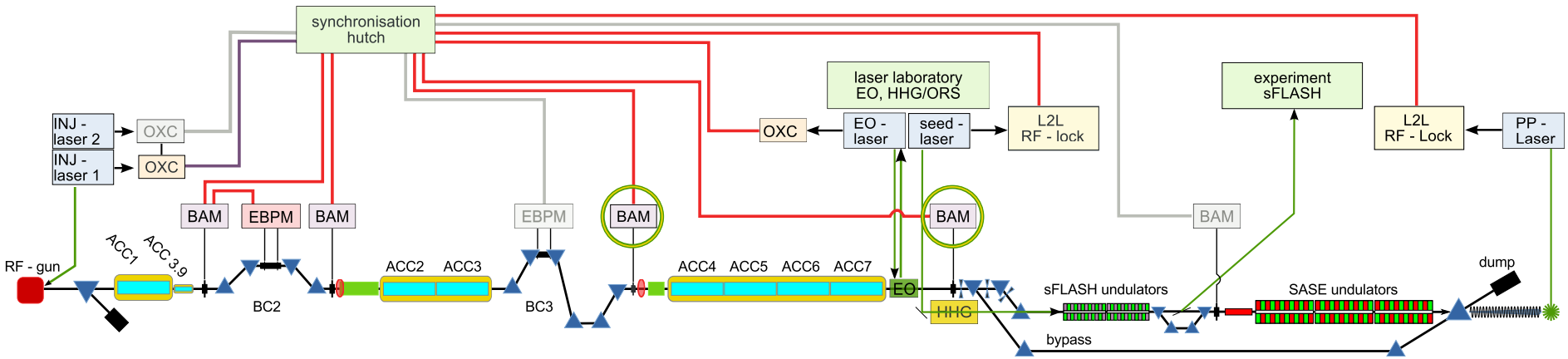

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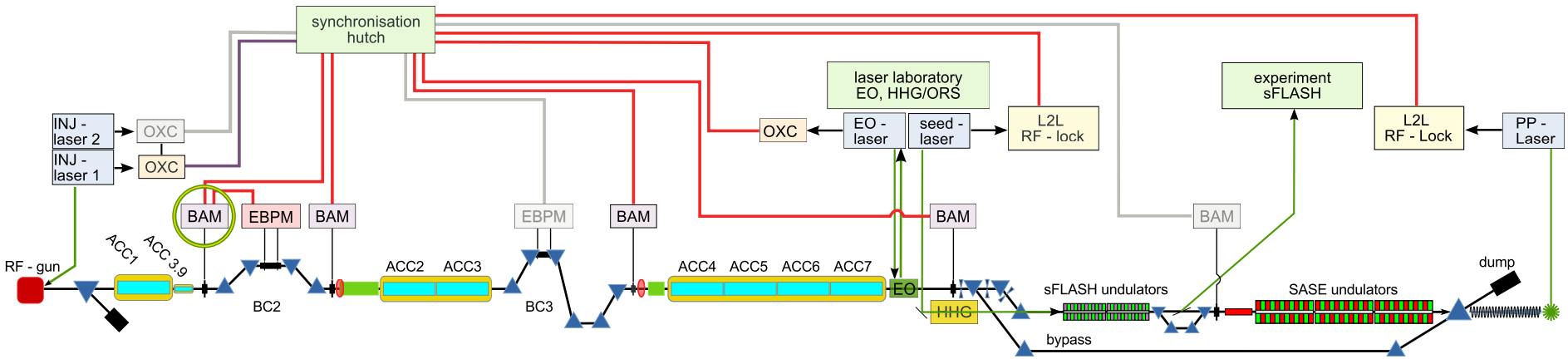

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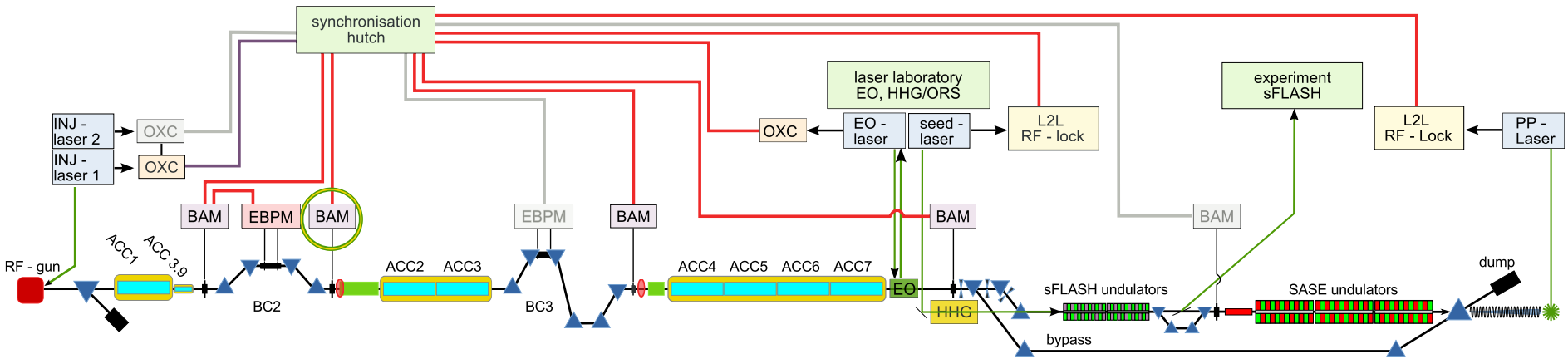

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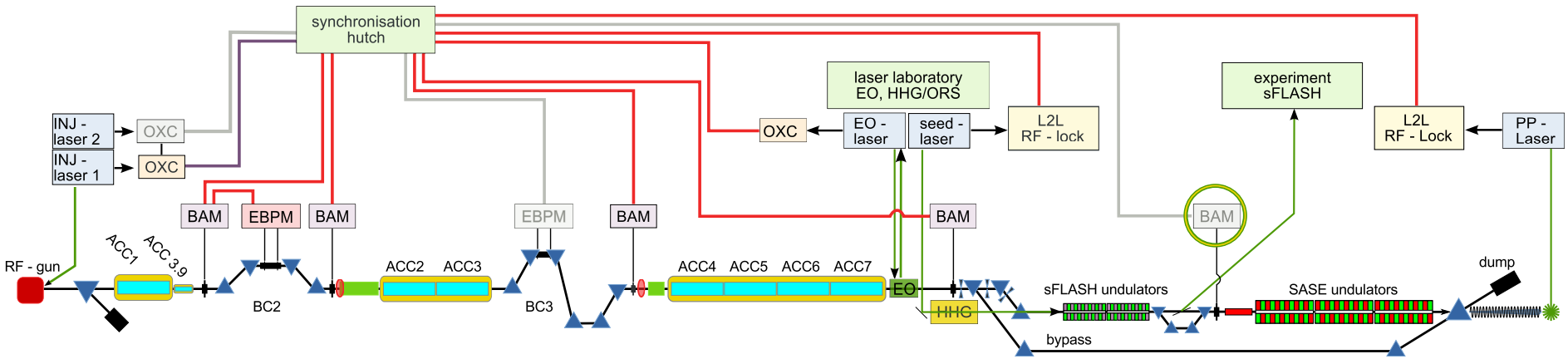

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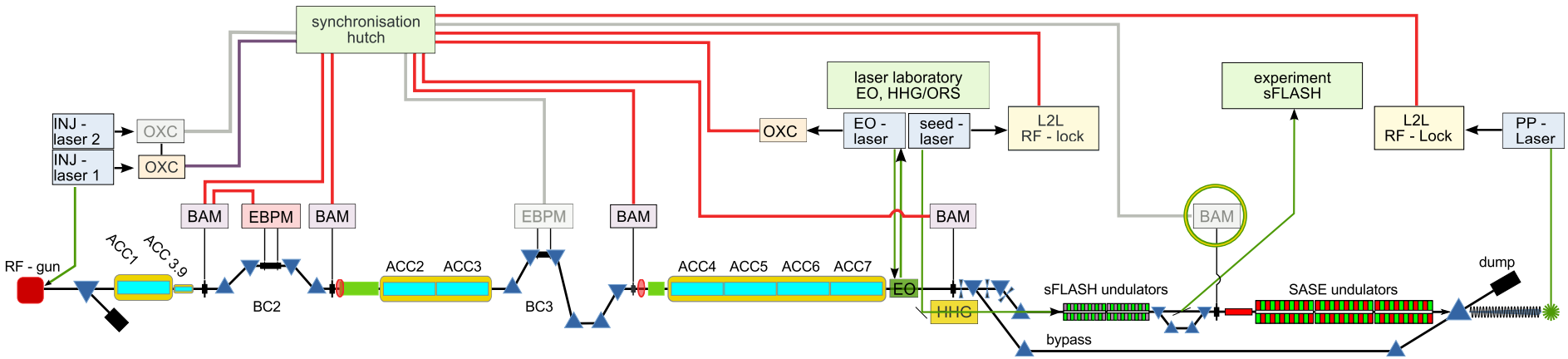

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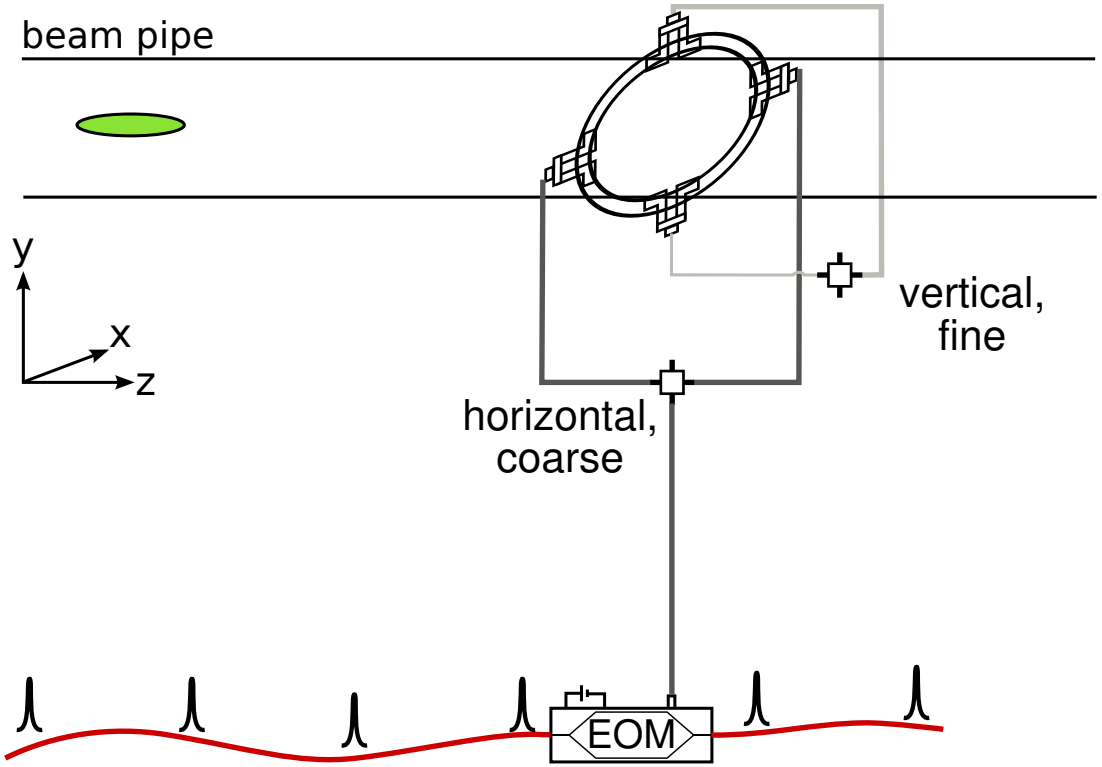
Arrival Time - Detection Principle.

How to sample a RF signal with an optical pulses...



- RF-Signal from Bunch
  $\Delta T \sim 100$ ps
- Bunch Separation
  1 µs@ 1 MHz
- Optical Pulse Trains
  216.67 MHz
  Pulse Separation
  4.65 ns= 1.4 m
- Small Optical Pulse Width
  $\sim$ 330 fs $\simeq$ 100 µm

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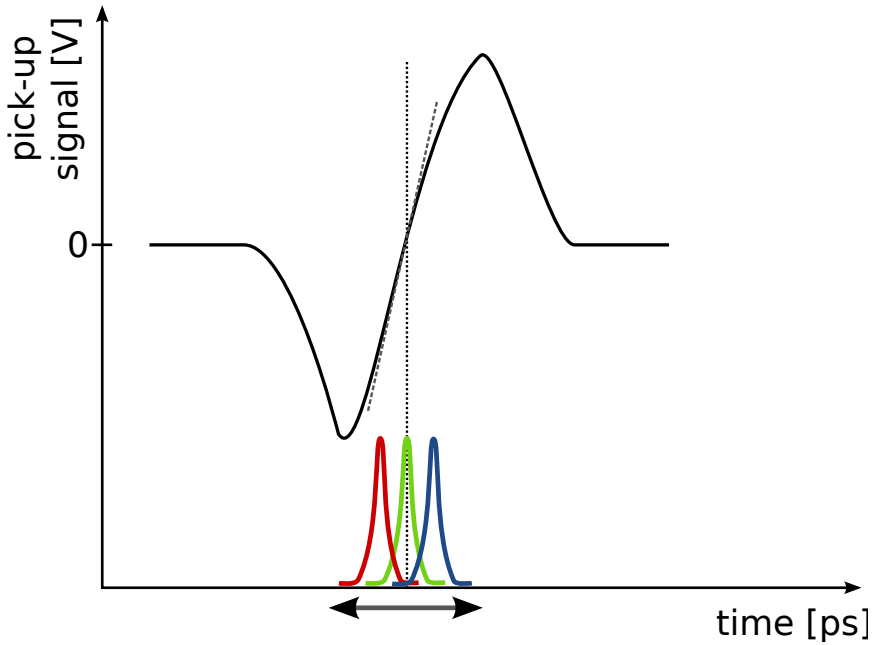
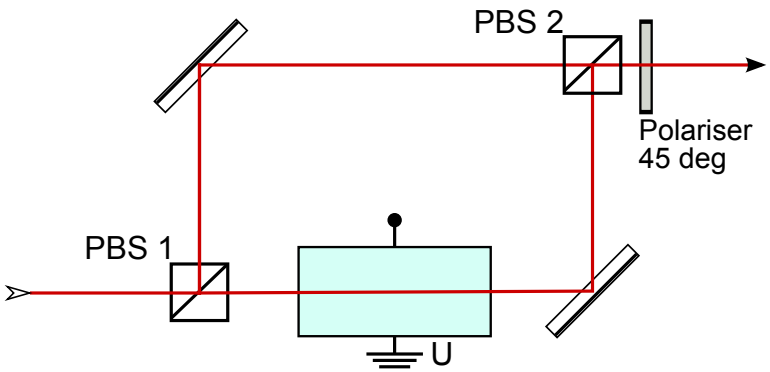


set correct timing of optical pulses relative to pick-up signal:

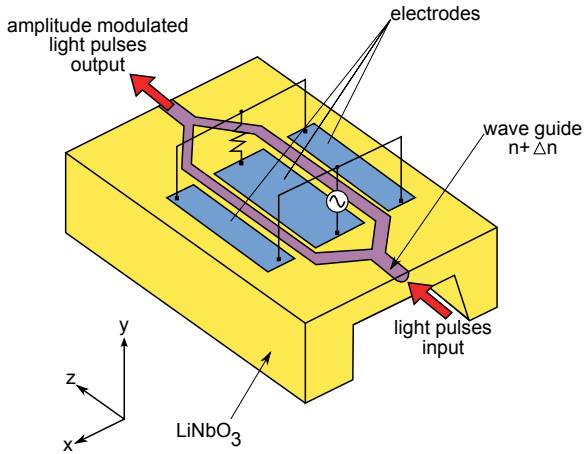
- globally:
  shift the 1.3 GHz phase of MLO using VM
- locally:
  1. change optical path length of input laser pulses with motor stage
  2. change RF cable length (only once when commissioning 1st time)

Arrival Time - Detection Principle.

How to sample a RF signal with an optical pulses...



- interferometric device
- refractive index depends linearly on electrical field strength
- voltage signal induces phase shift between both interferometer arms
- relative phase shift is translated into an intensity modulation of optical pulses



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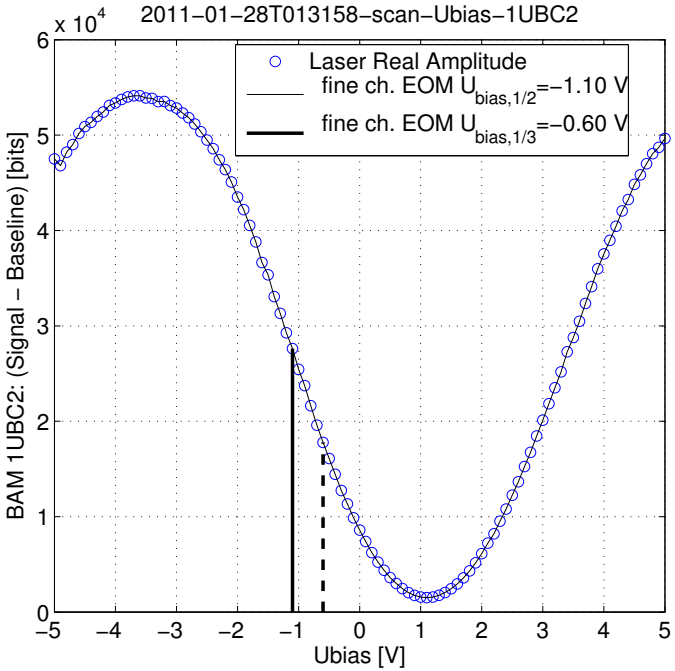
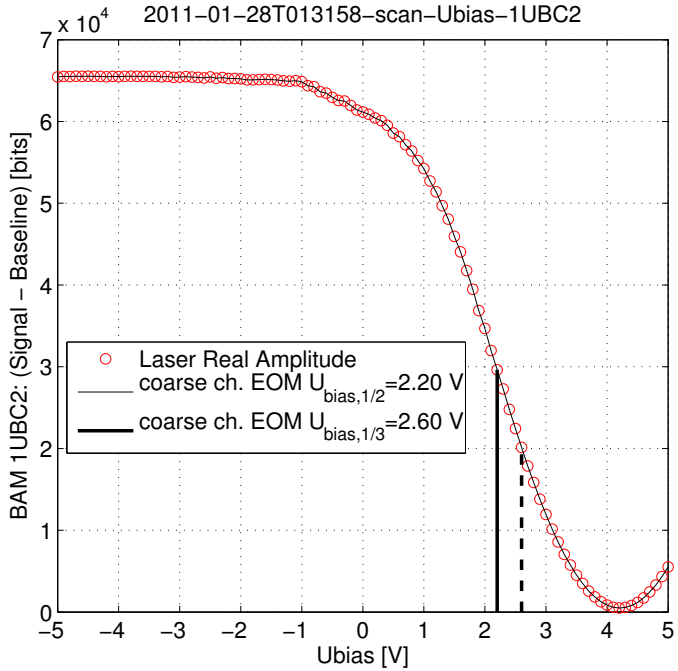




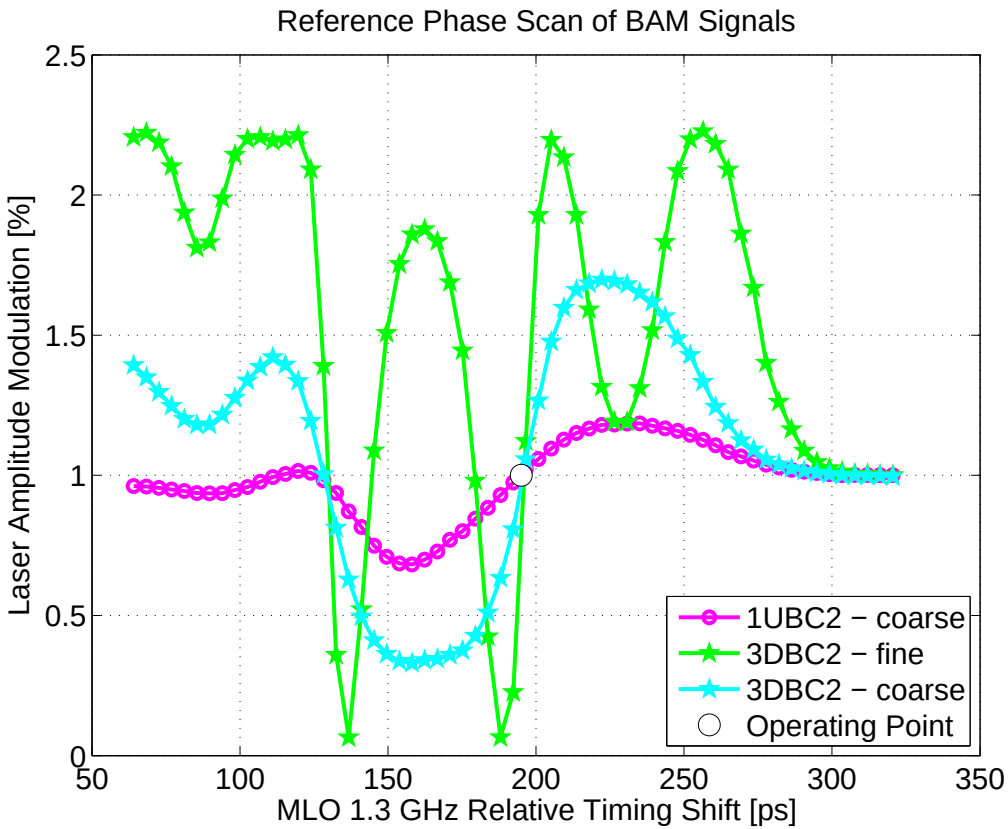
Transmission of EOM: $T(U) = \frac{I(U)}{I_{\max}} = \cos^2(\frac{\Phi}{2} + \frac{\alpha(U)}{2})$

α is related to U_π

$\alpha(U) = -\pi * \frac{U}{U_\pi}$

Arrival Time - Detection Principle.

How to sample a RF signal with an optical pulses...



- two channels, 'Fine' & 'Coarse':
  1. RF-signal + limiter
     large signal
     small dynamic range: 4 ps
  2. RF-signal + attenuator
     small signal
     large dynamic range: 65 ps
- coarse channel used for motor position FB on fine channel

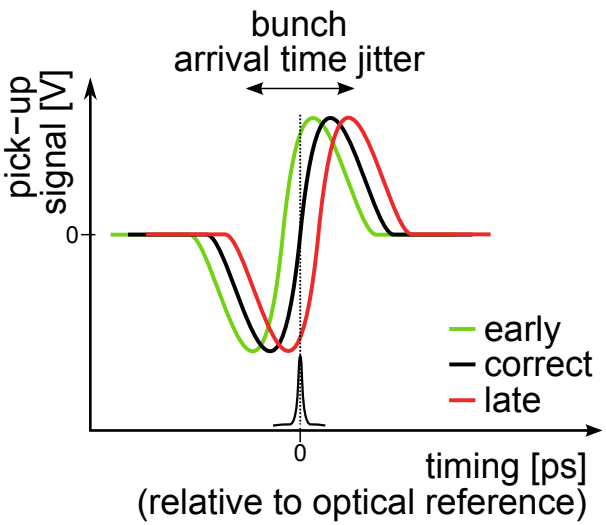
General Operating Principle.

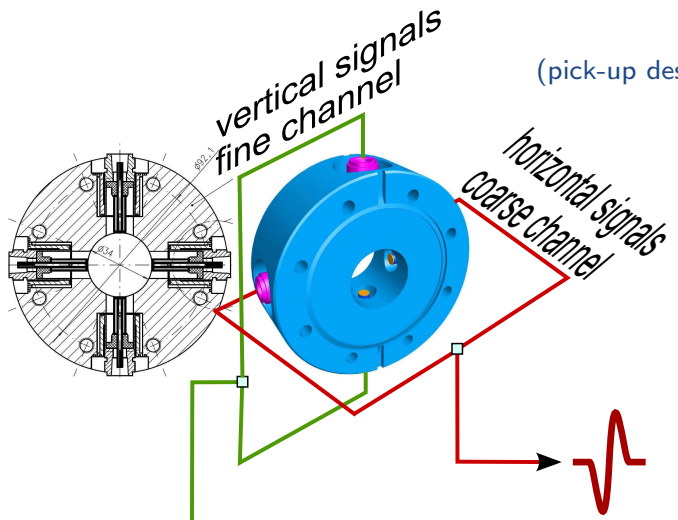
Electro-Optical Detection Scheme

reduced dependency on beam orbit

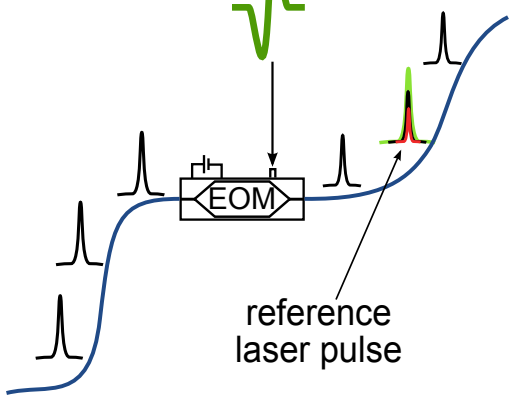
reduced dependency on bunch charge

sensitivity in terms of
% modulation per fstiming change

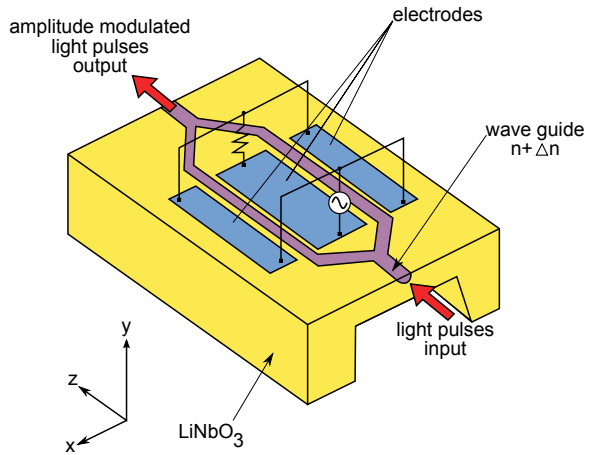




(pick-up design drawing, courtesy: K. Hacker)

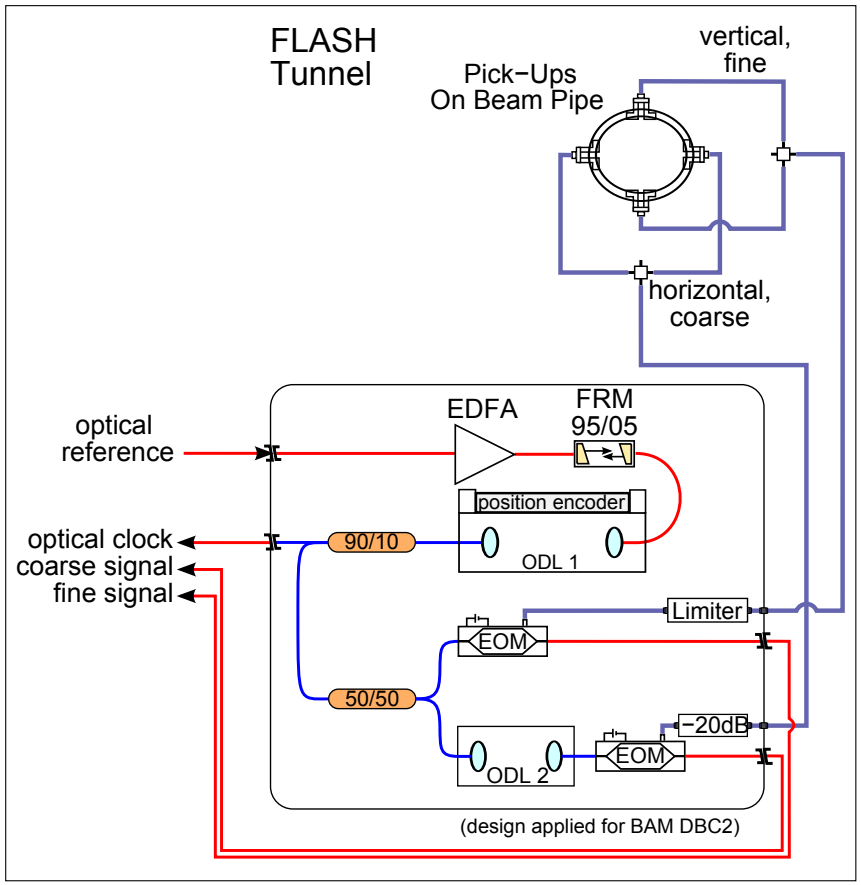


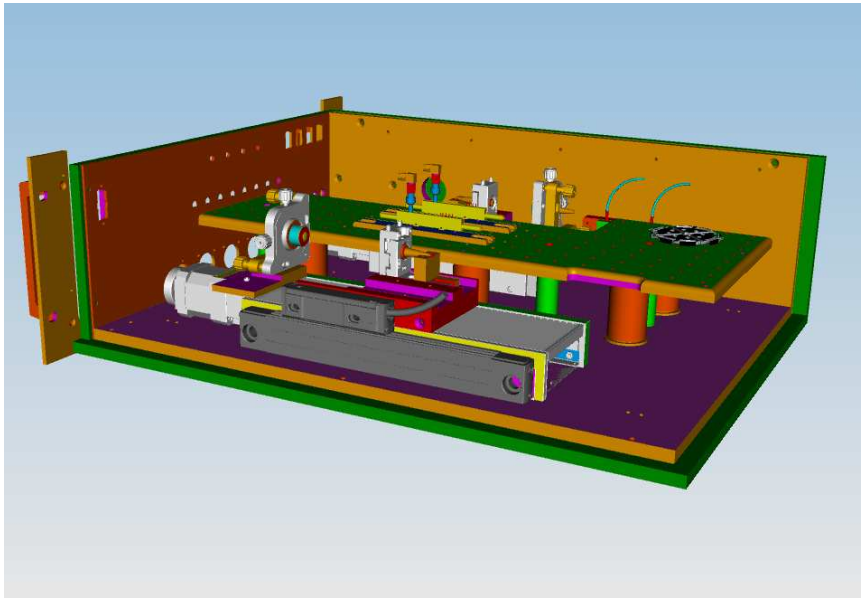
electro-optical modulator



Opto-Mechanical Front-End.

Schematic & Design Drawing.

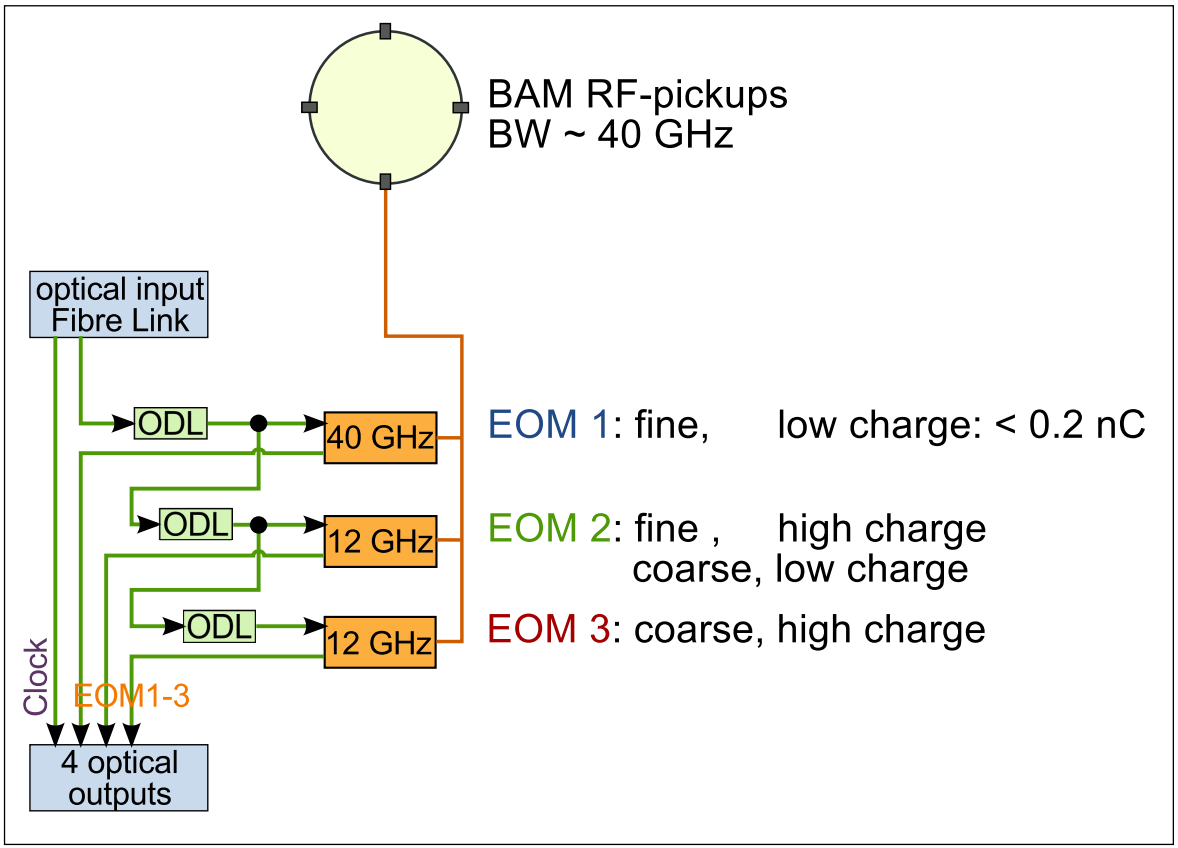




(19" rack slide-in module, 4 HE)

Opto-Mechanical Front-End.

Redesign for 5^{th} Generation BAM

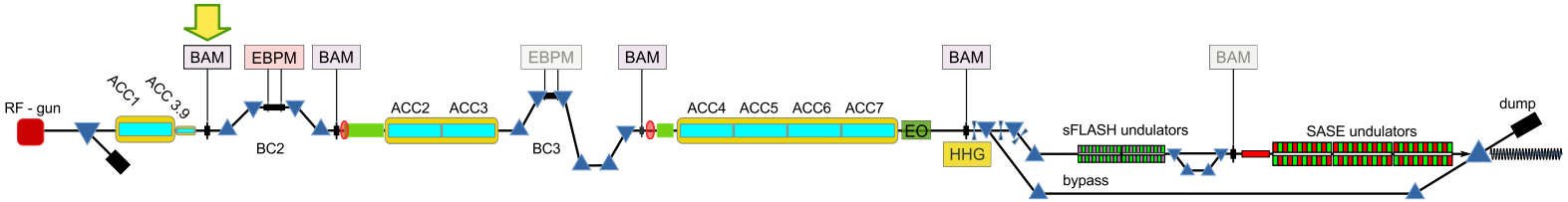


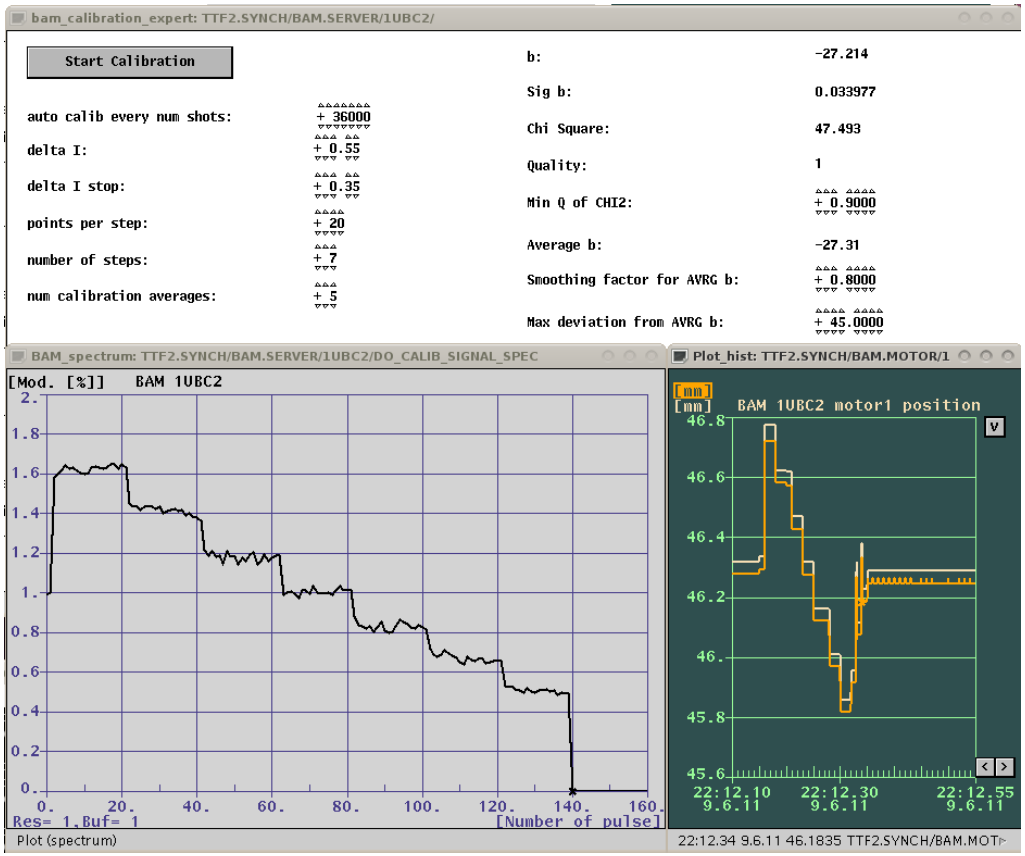
- Bunch charge pattern with 2 different states within 1 bunch train or between bunch trains
- 3^{rd} detection channel needed
- currently: redesign of RF pickups to extend to BW $\sim$ 40 GHz

in collaboration with Uni Darmstadt

Charge Dependence of Calibration.

Resolution for high and low bunch charge.





- absolute position encoder:
  $timing\ change\ [\mathrm{fs}] = 3.33\ \mathrm{fs}/\mu\mathrm{m} * \Delta s[\mu\mathrm{m}]$
- calibration constant C.C. in $[\mathrm{fs}/\%mod.]$

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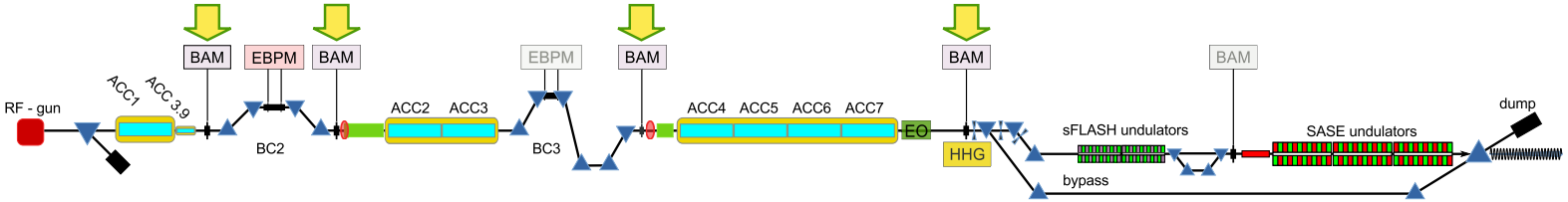

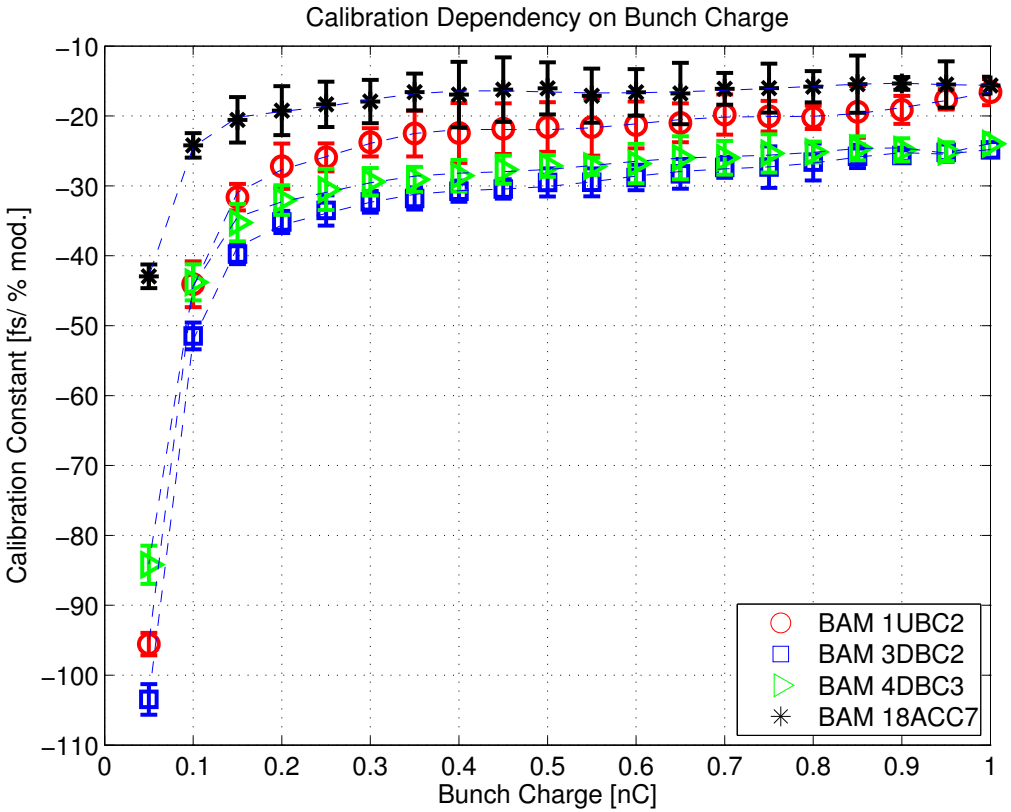

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- strong linear decrease below 0.15 nC
- for high charge only weak dependence
- Resolution:
  $Res.[\mathrm{fs}] = C.C.[\mathrm{fs}/\%mod.] * \cdots$
  $AmplitudeNoise[\%]$

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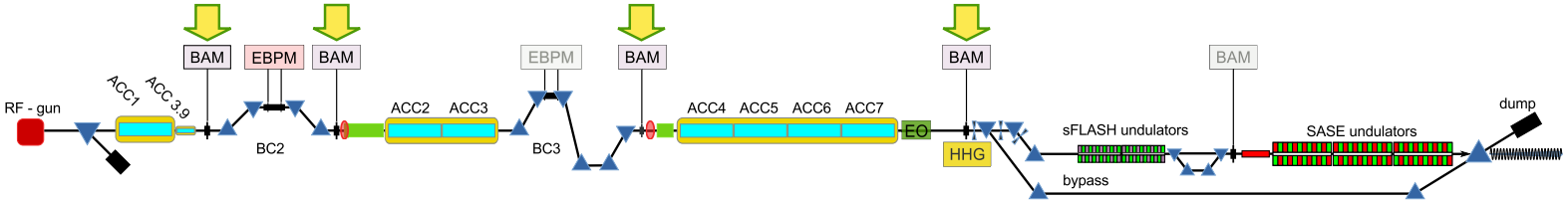

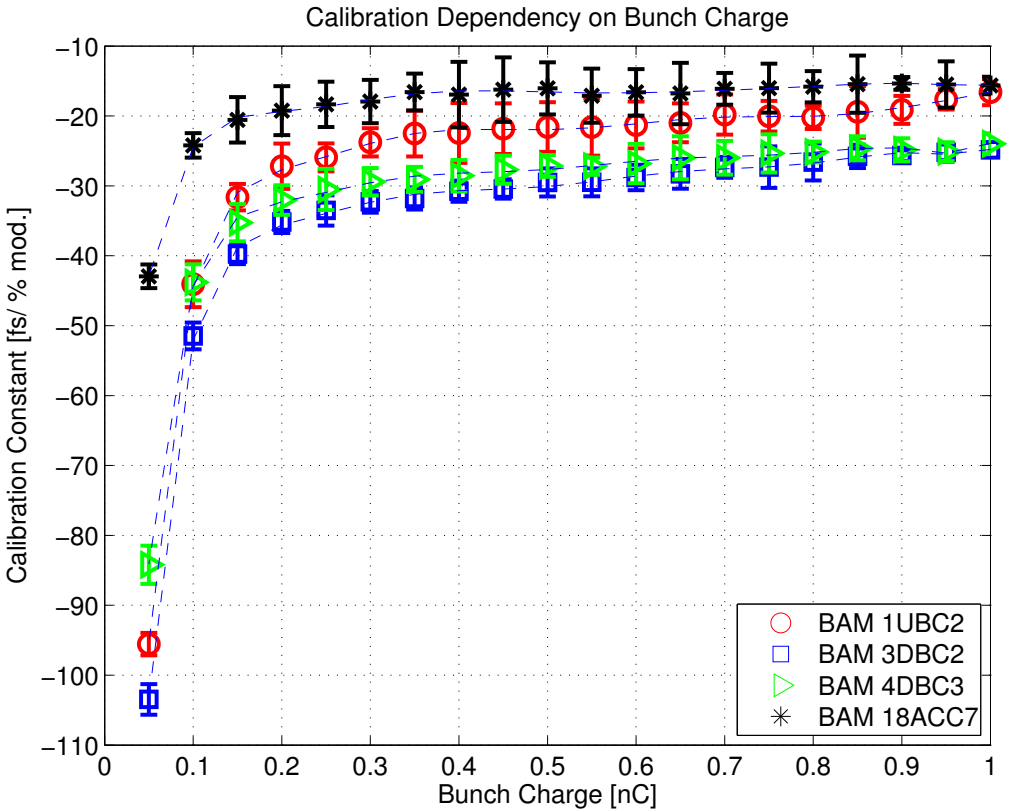

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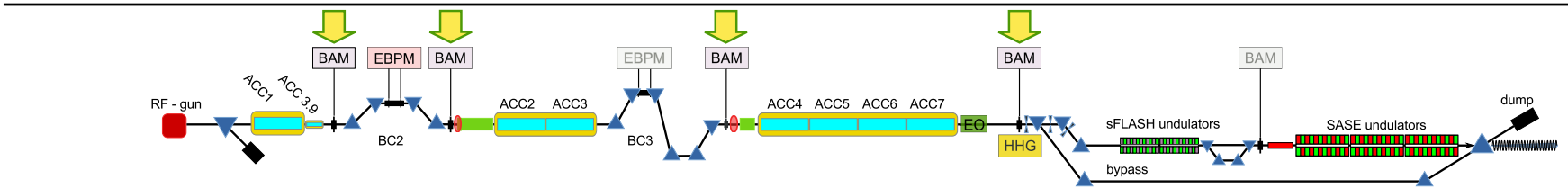
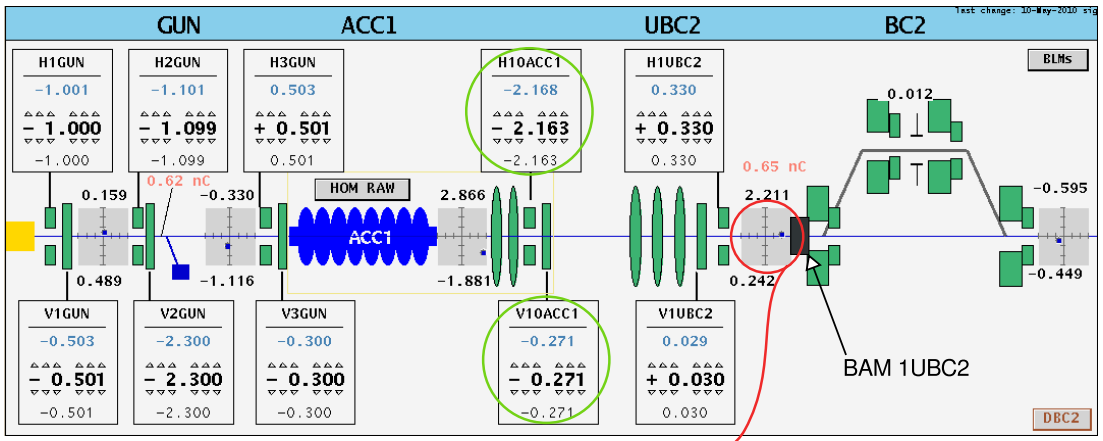
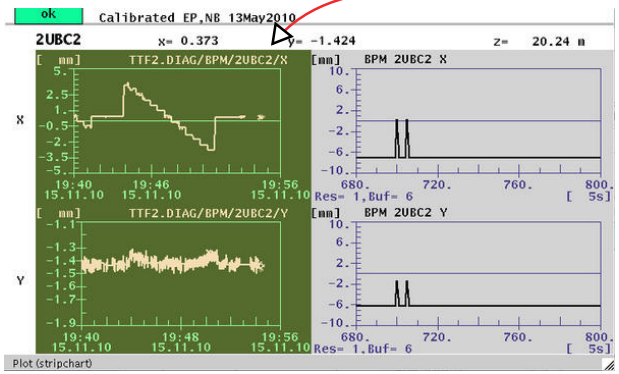
  $Res.[\mathrm{fs}] = C.C.[\mathrm{fs}/\%mod.] * \cdots$
  $AmplitudeNoise[\%]$
- averaged amplitude noise of unmodulated transmitted laser pulses typically 0.20 % - 0.45 %
- at high bunch charges:
  resulting resolution of BAMs $<$ 10 fs (shot-to-shot)

Dependency of Arrival Time Measurement on Bunch Orbit.

Orbit Scans from Nov.2010 & Jan. 2011.







- need 1 BPM right next to a BAM
- changed bunch orbit with steerer magnets upstream of BAMs
- in both planes for all BAMs individually

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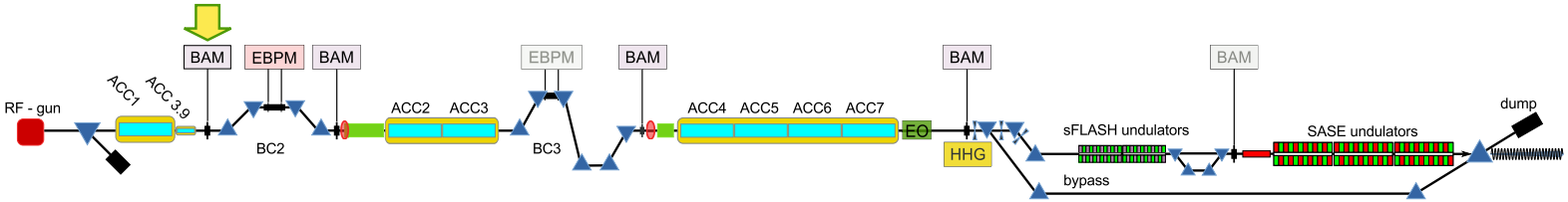

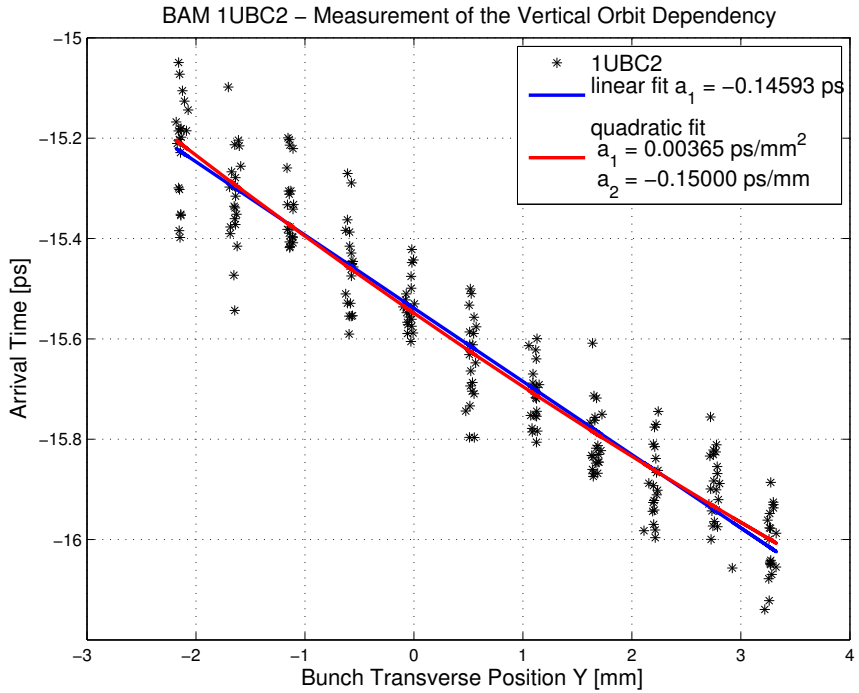

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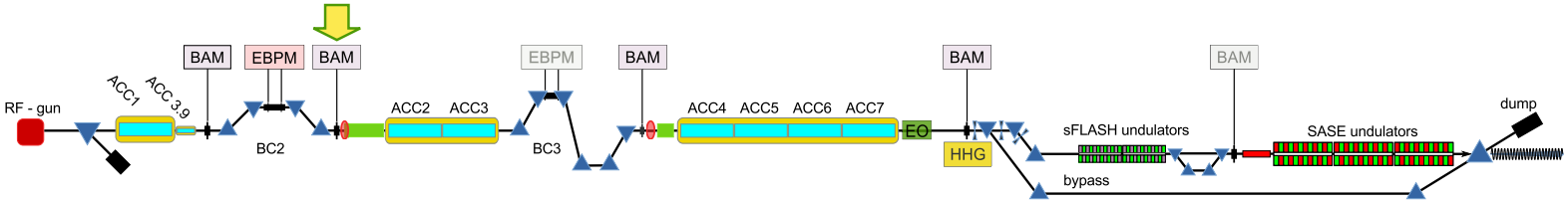

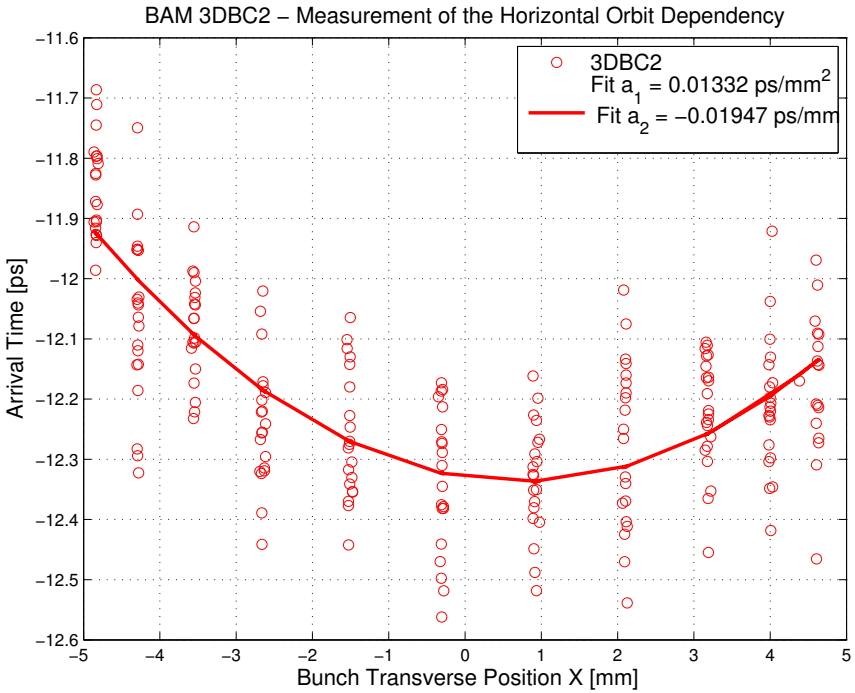

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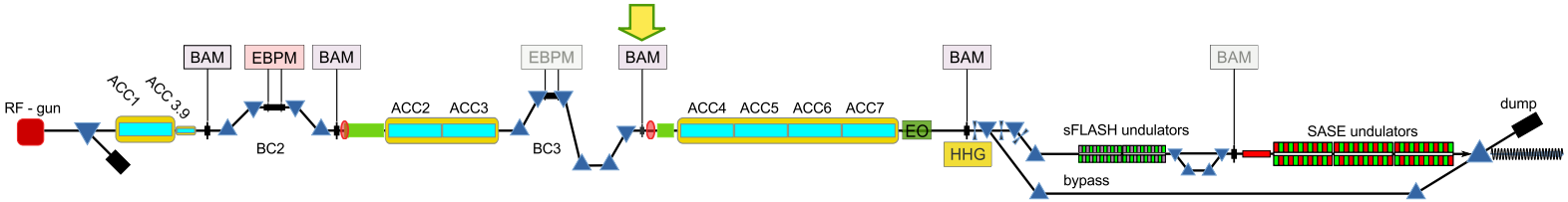

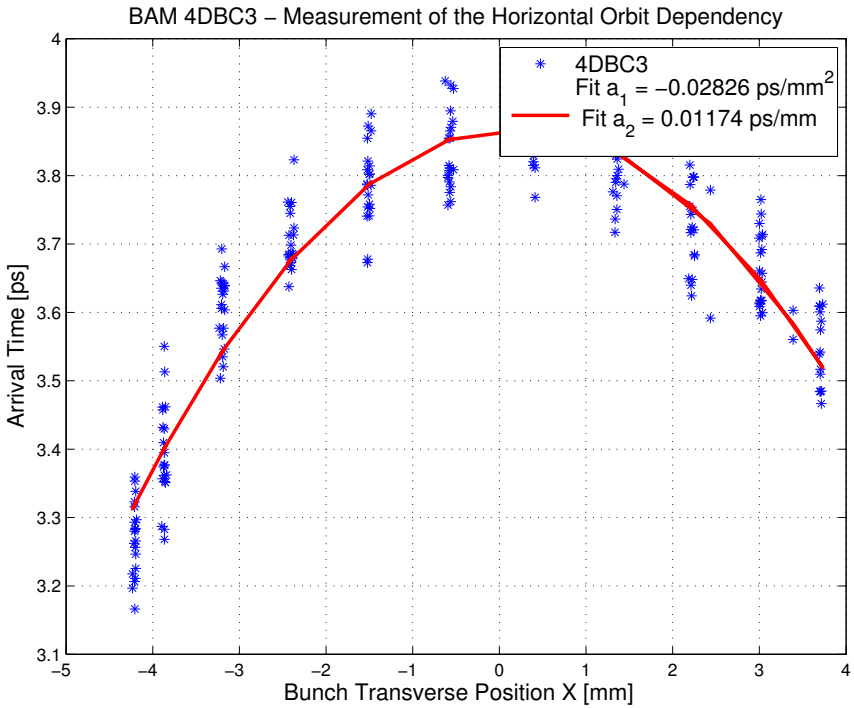

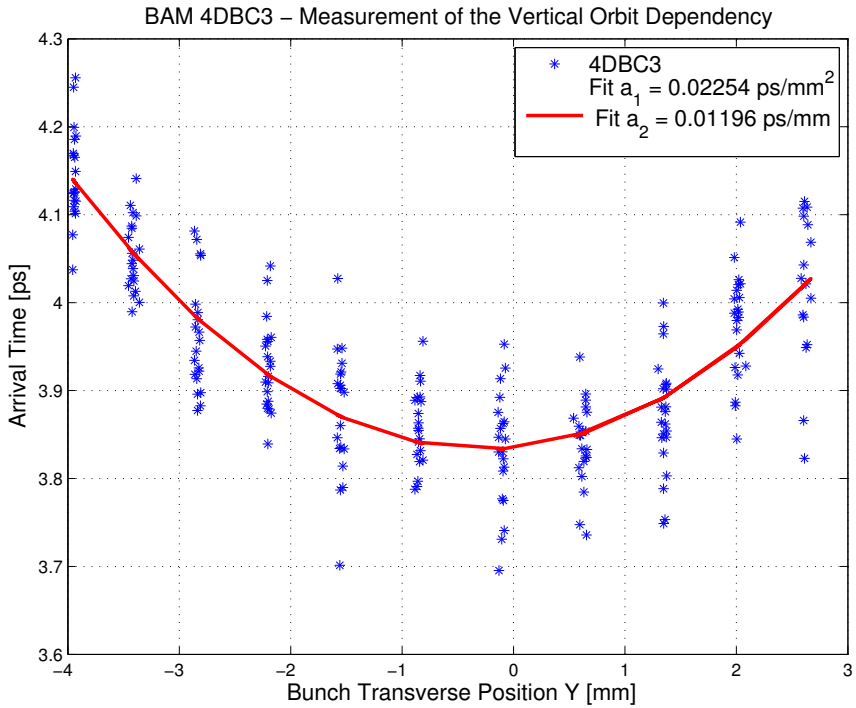

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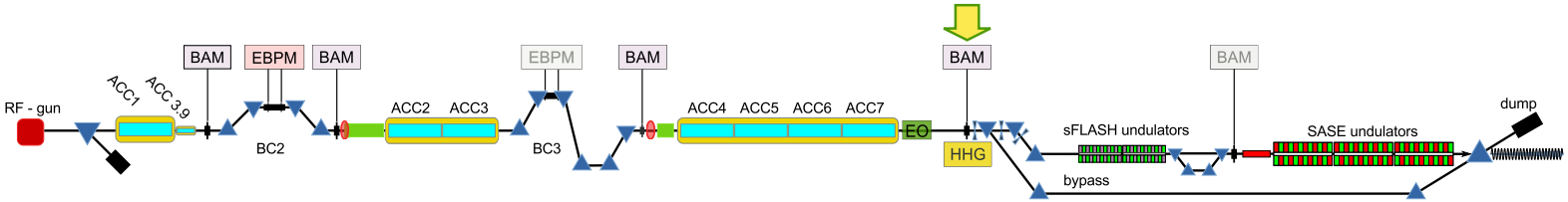

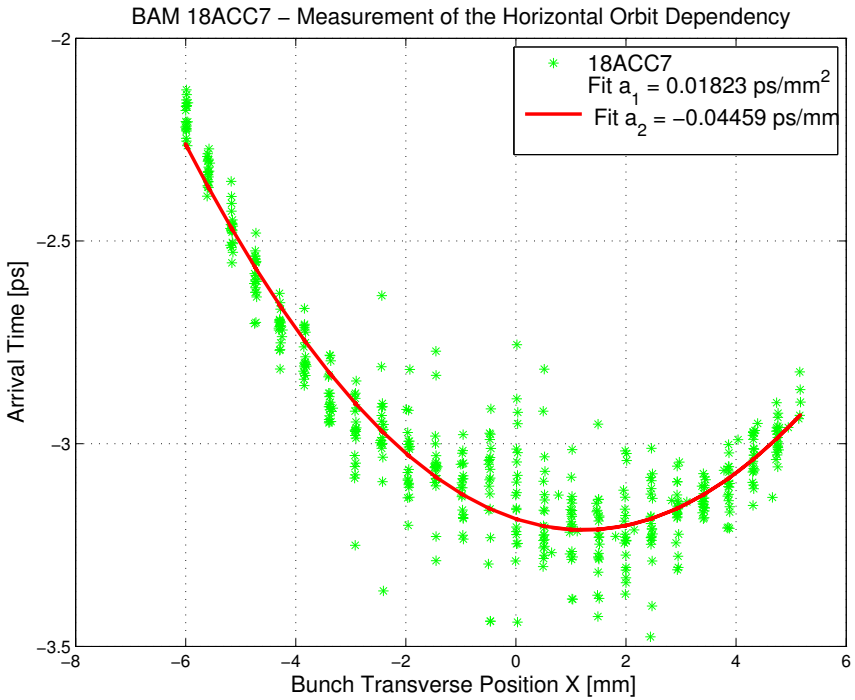

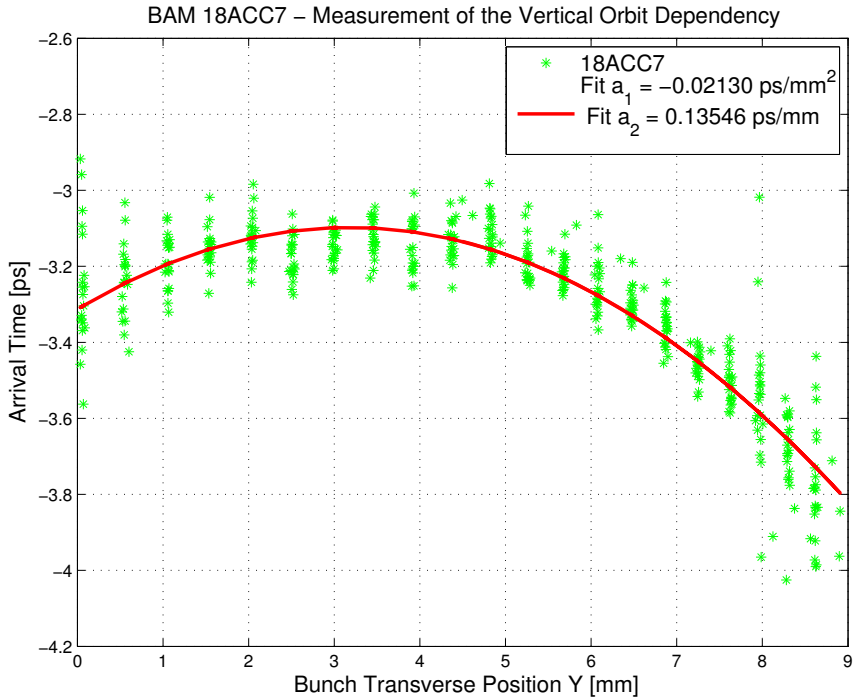

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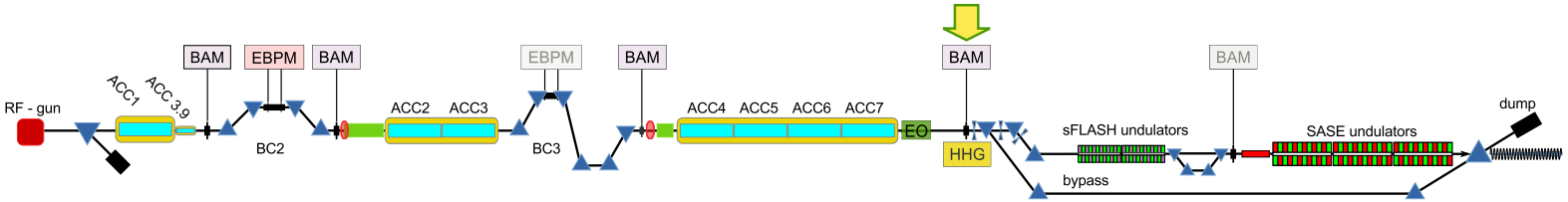
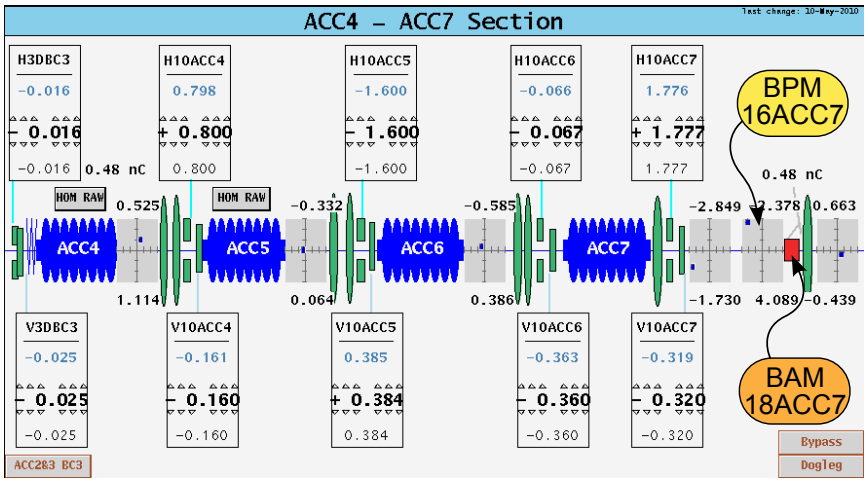
Arrival Time Orbit Correction in BAM-Server.





- need 1 BPM right next to a BAM
- algorithm implemented in BAM-Server
- set some DOOCS properties:
  - ADDRESS_BPM1_X
  - ADDRESS_BPM1_Y
  - ORBIT_COORECTION_X.POLY_PARA
  - ORBIT_CORRECTION_Y.POLY_PARA
  - CORRECT_ORBIT_DEPENDENCE_ON
- currently:
  only useful for Slow Arrival Time FB
- in future:
  for Intra-Train Arrival Time FB need fast BPM read-out

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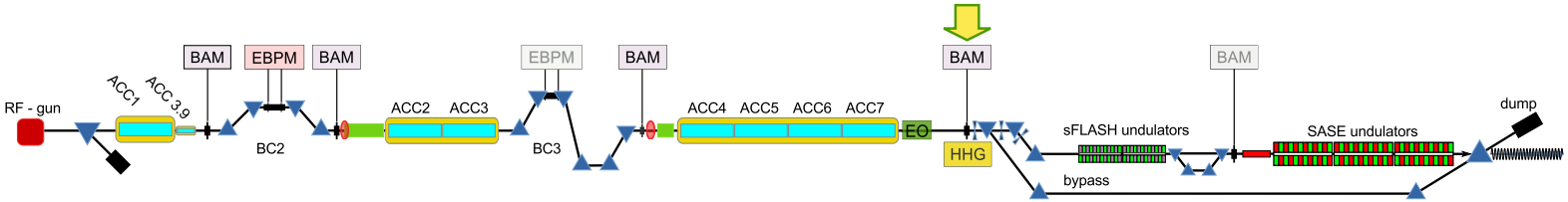

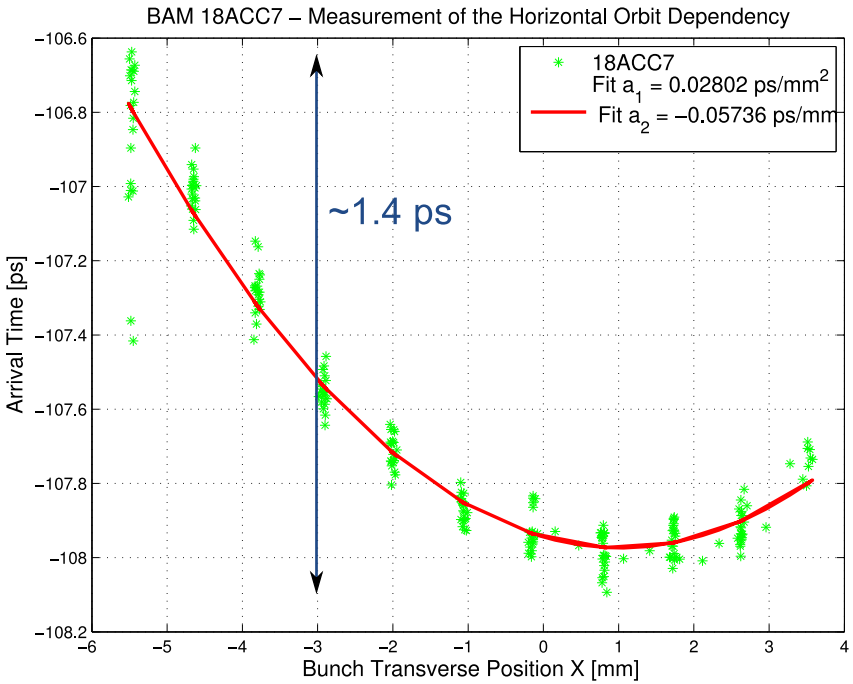

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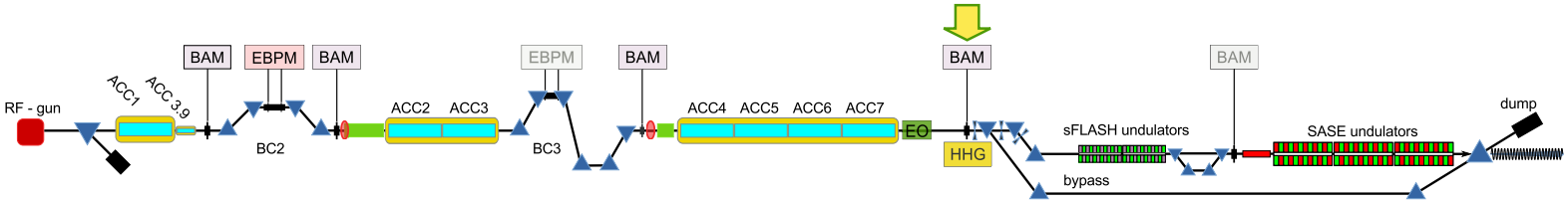
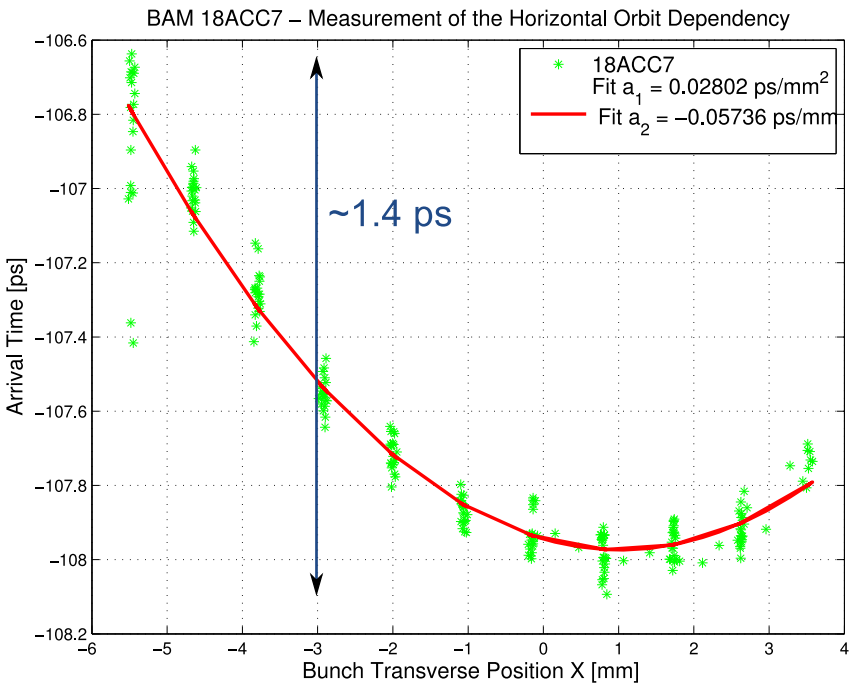
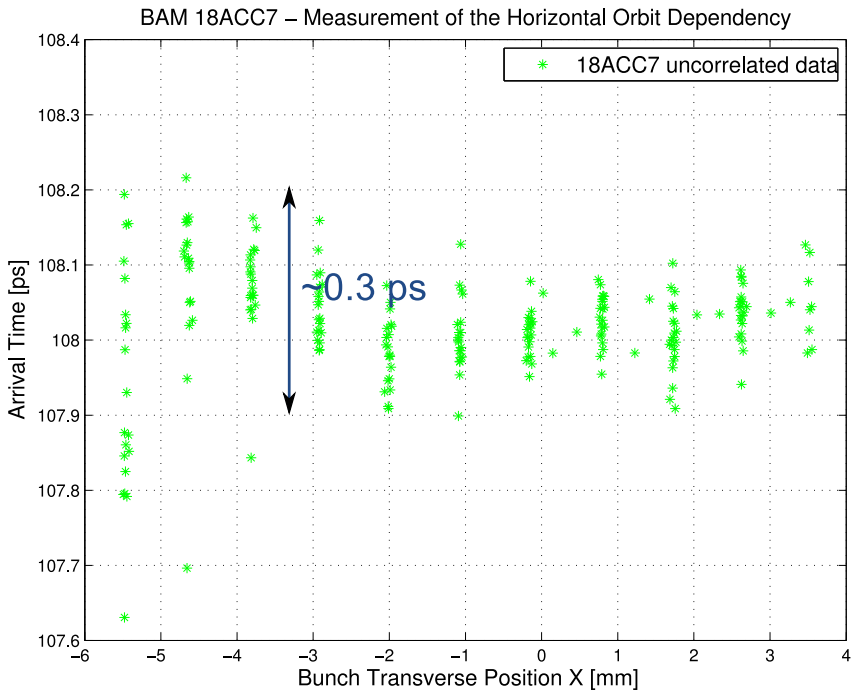
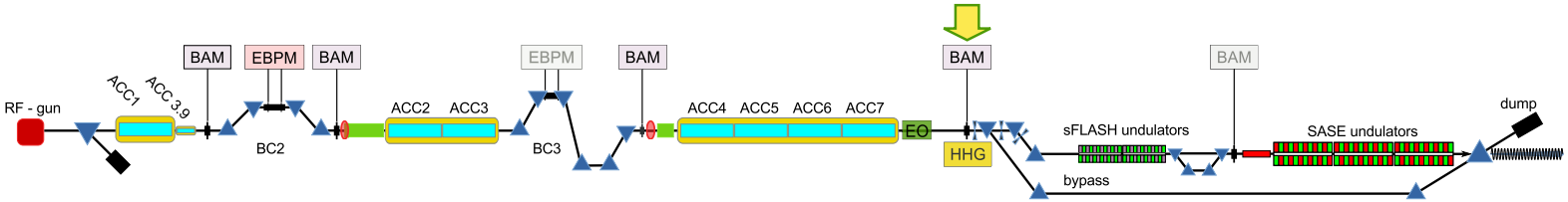


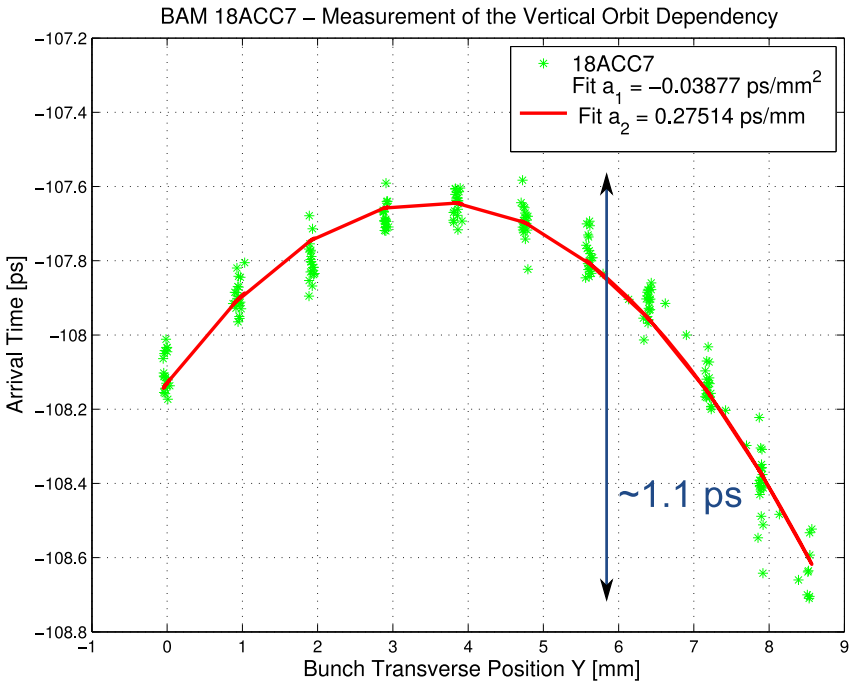




Dependency of Arrival Time Measurement on Bunch Orbit.

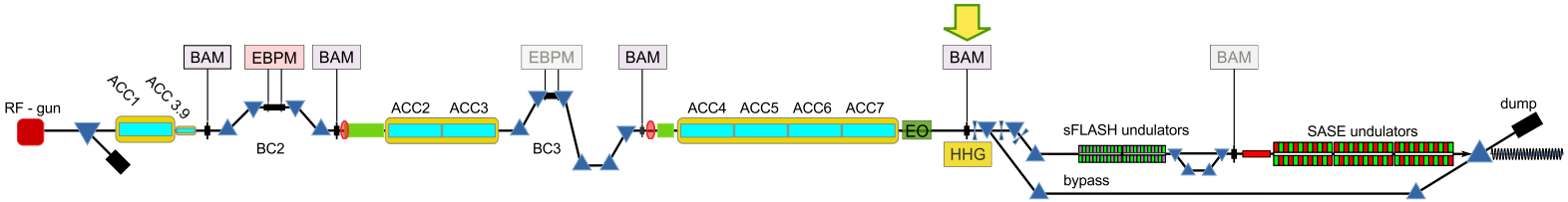
Arrival Time Orbit Correction in BAM-Server.

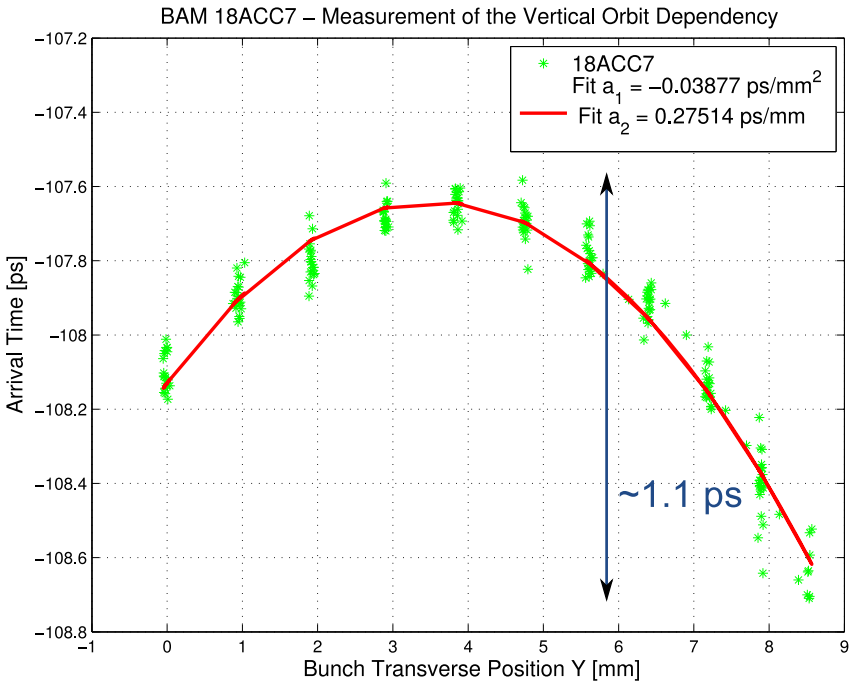


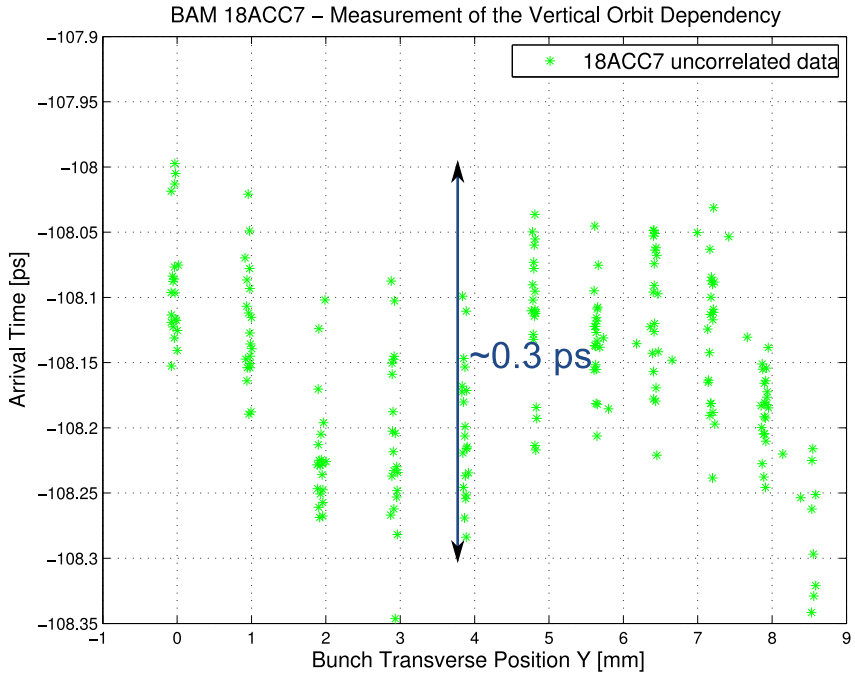


Dependency of Arrival Time Measurement on Bunch Orbit.

Arrival Time Orbit Correction in BAM-Server.

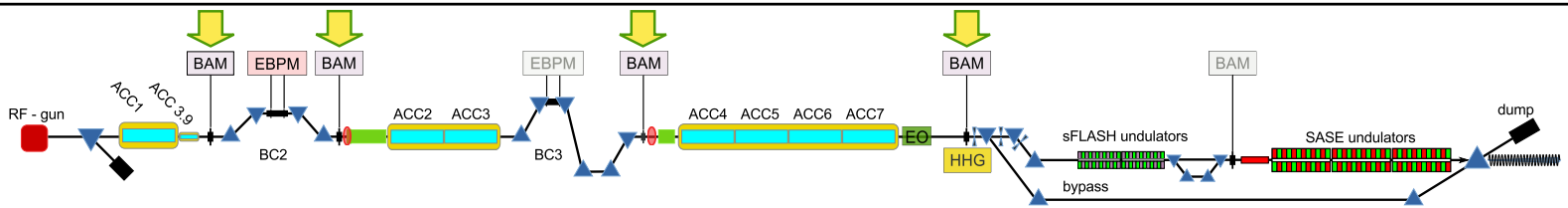


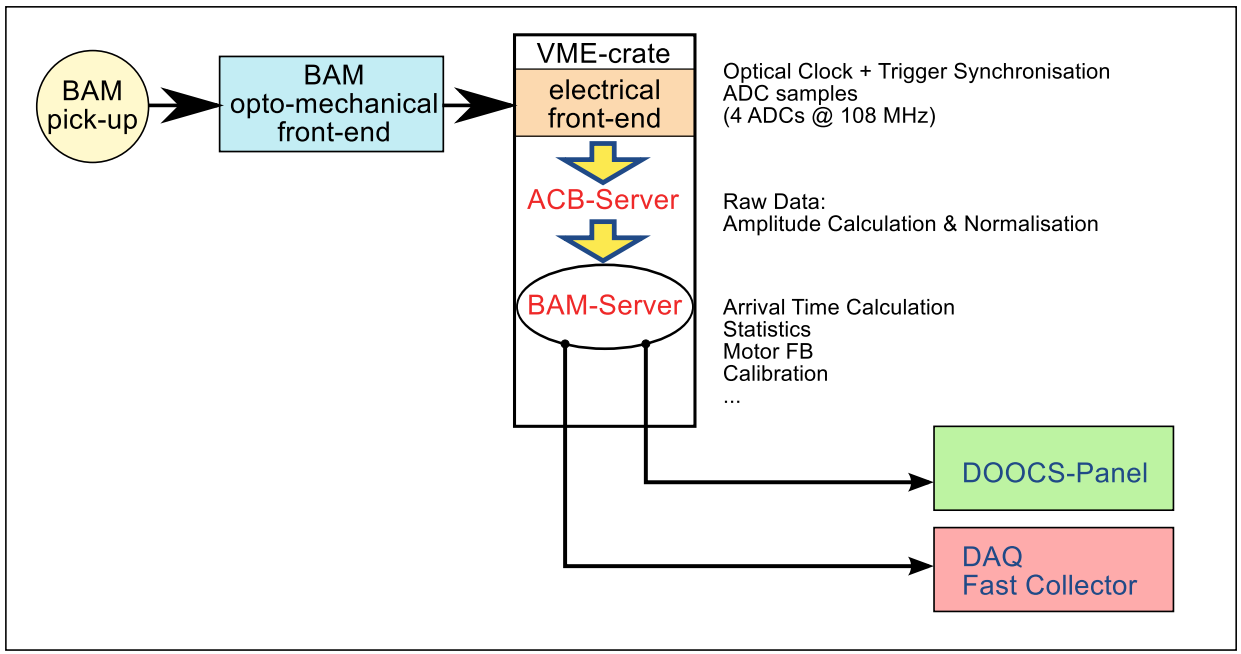




BAM Data in DAQ Linac-Stream.

BAM data spectra & statistics.

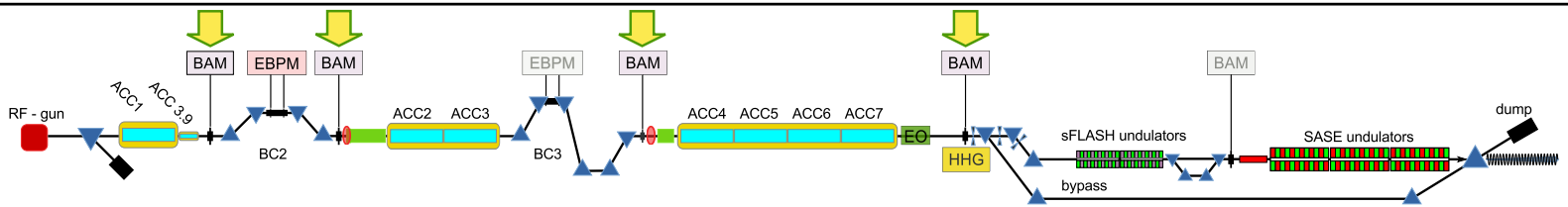




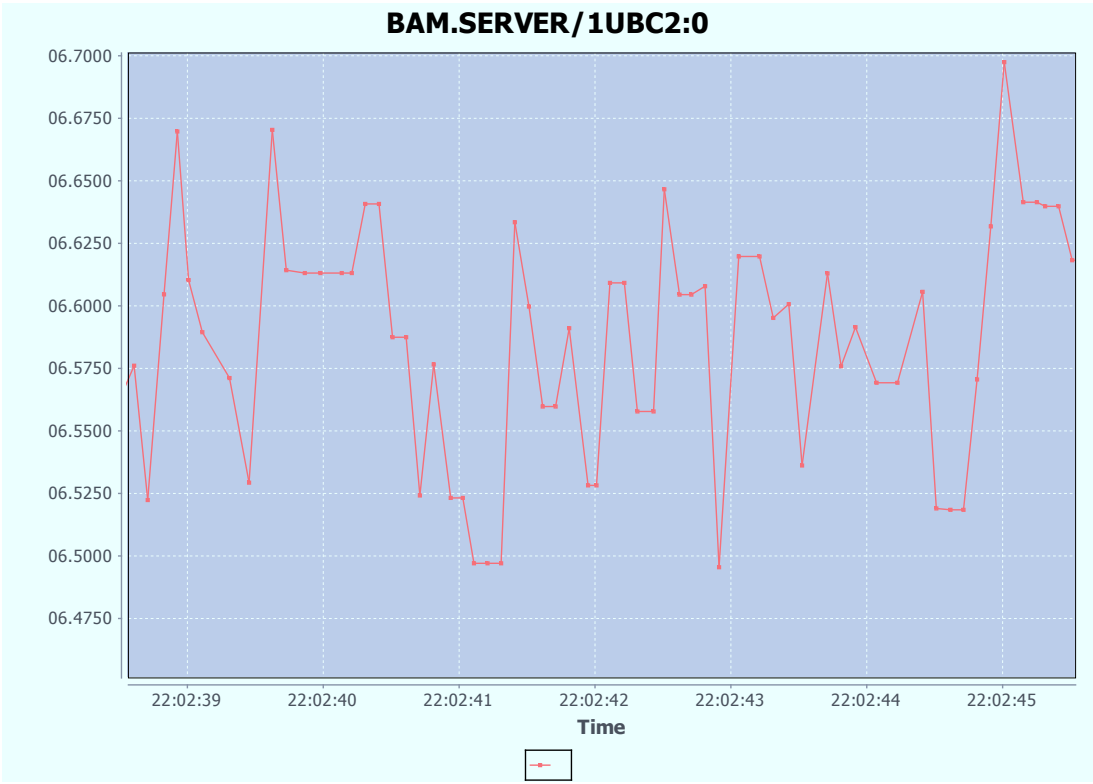
BAM-Server sends data to DAQ

BAM Data in DAQ Linac-Stream.

BAM data spectra & statistics.



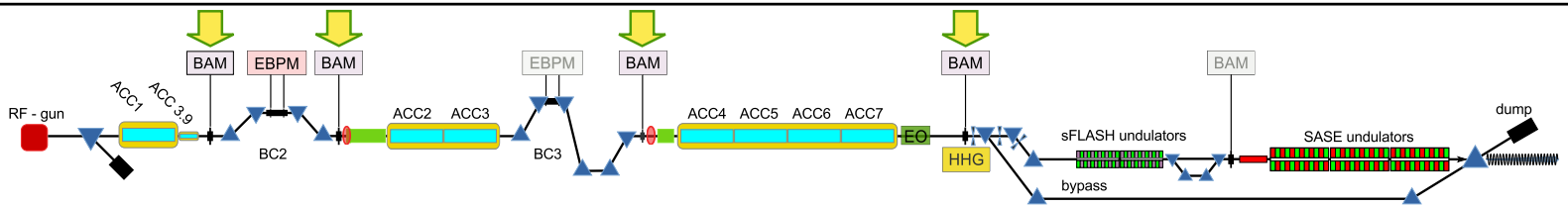
Arrival Time of 1^{st} Bunch, $\sim$ 70 events:



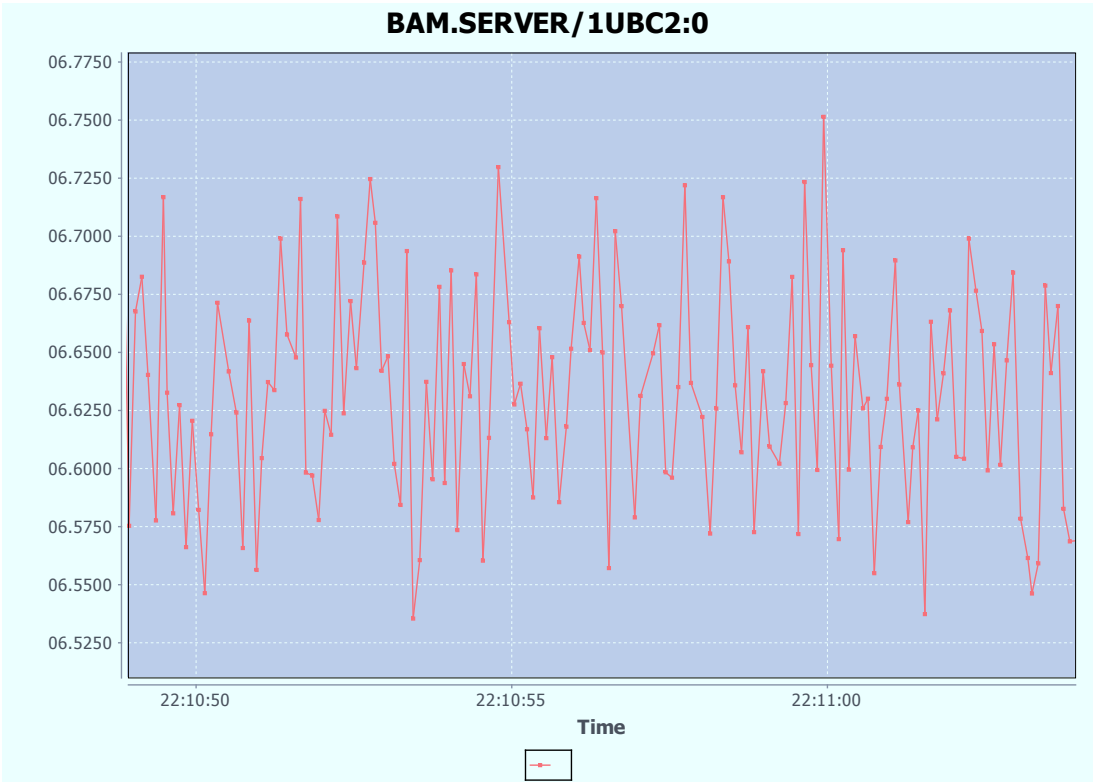
04.06.2011: identified problem of data being sent from BAM-Server to DAQ:
duplicated data in all BAM channels, 50 % of all events corrupted

BAM Data in DAQ Linac-Stream.

BAM data spectra & statistics.



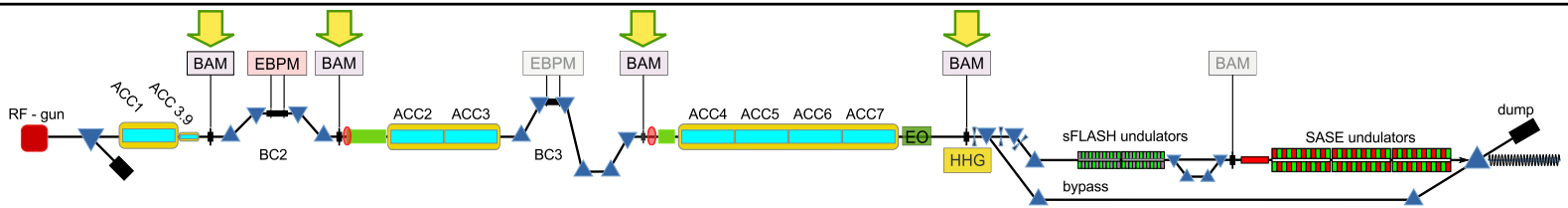
Arrival Time of 1^{st} Bunch, $\sim$ 150 events:



21.06.2011: software error in BAM-Server finally solved

BAM Data in DAQ Linac-Stream.

BAM data spectra & statistics.



BAM-Server/1UBC2

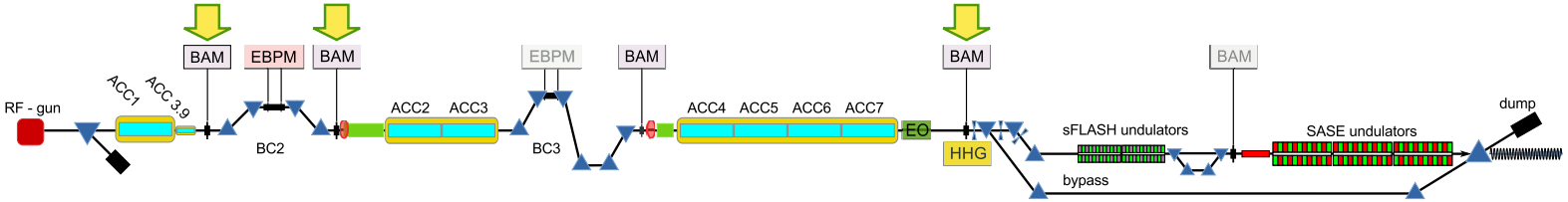
- FLOAT [0]: Arrival Time Spectrum (fine channel)
  - [SPEC_STAT_SPARE0]: Arrival Time Jitter
  - [SPEC_STAT_SPARE1]: Averaged Arrival Time
  - [SPEC_STAT_SPARE2]: Calibration Constant
  - [SPEC_STAT_SPARE3]: Position Encoder Value
  - ⋮
  - [SPEC_STAT_SPARE16]: Resolution (fine channel)
  - ⋮
  - [SPEC_STAT_SPARE19]
- FLOAT [1]: Arrival Time Spectrum (coarse channel)
  - [SPEC_STAT_SPARE0:3]
- FLOAT [2]: Laser Amplitude Spectrum (fine channel)
- FLOAT [3]: Laser Amplitude Spectrum (coarse channel)
- FLOAT [4]: Laser Amplitude Noise Spectrum (fine channel)
  - [SPEC_STAT_SPARE0]
- FLOAT [5]: Laser Amplitude Noise Spectrum (coarse channel)
  - [SPEC_STAT_SPARE0]

BAM DAQ data structure:
in detail:
\FLAelog\doc\Synchronisation\DOOCS\

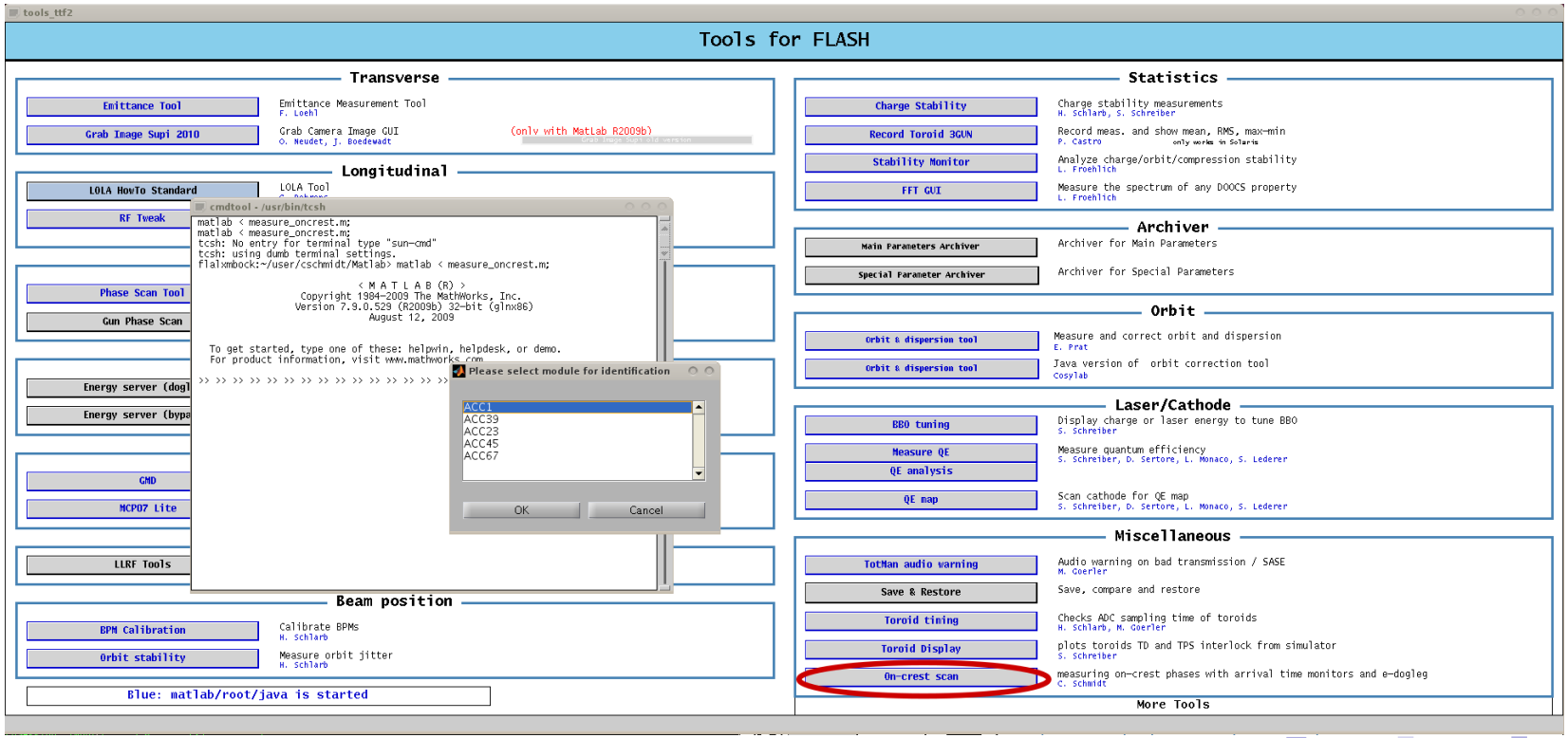
"Channel and Field description of BAM DAQ Data Sets"

Measure On-Crest Phases with BAMs.

Matlab Tool *"measure_oncrest.m"*



- \home\ttflinac\user\cschmidt\Matlab



Measure On-Crest Phases with BAMs.

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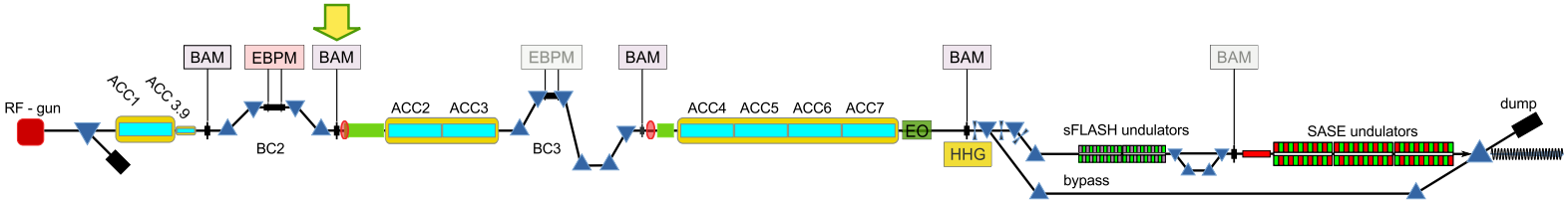
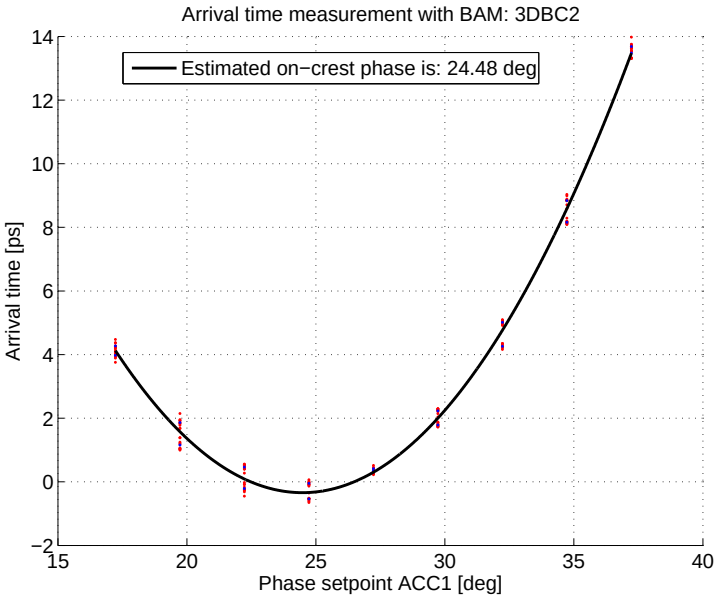
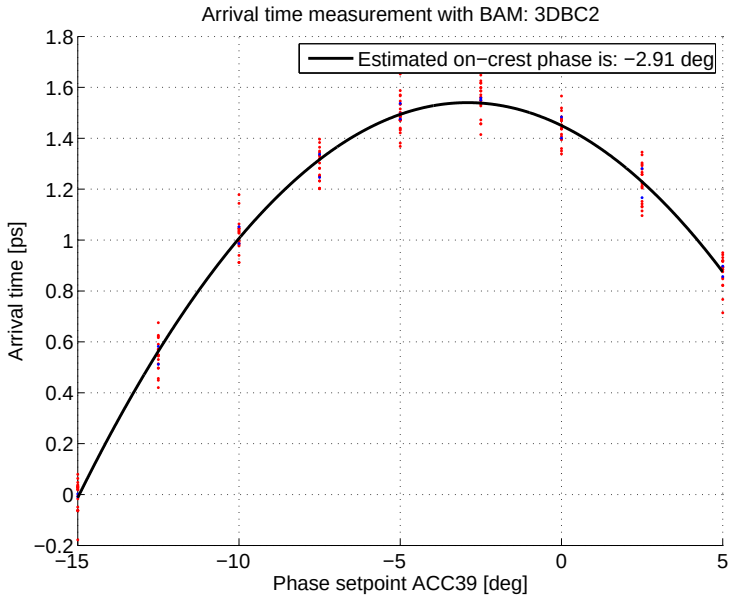
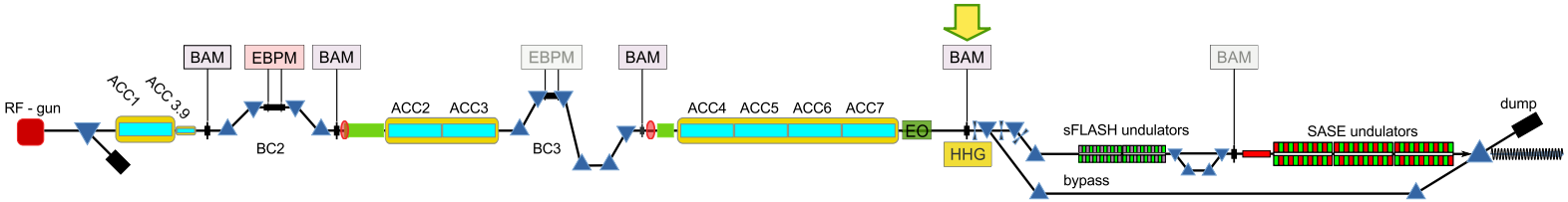


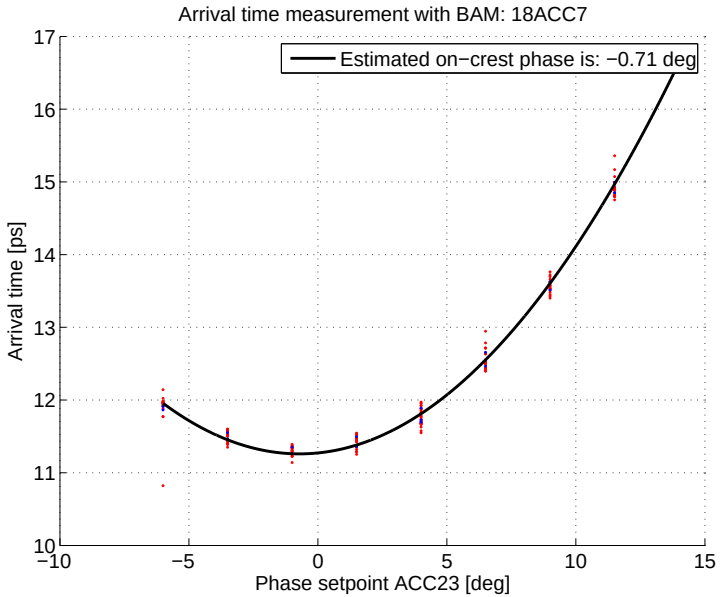




Measure On-Crest Phases with BAMs.

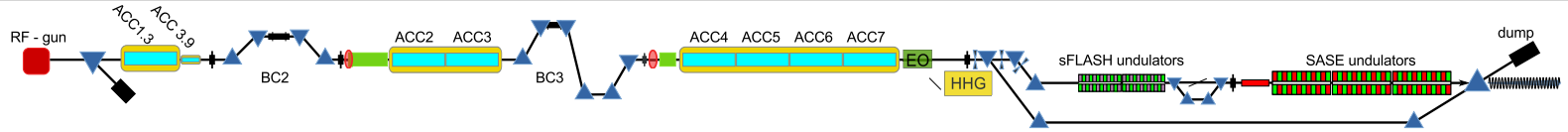
Matlab Tool *"measure_oncrest.m"*



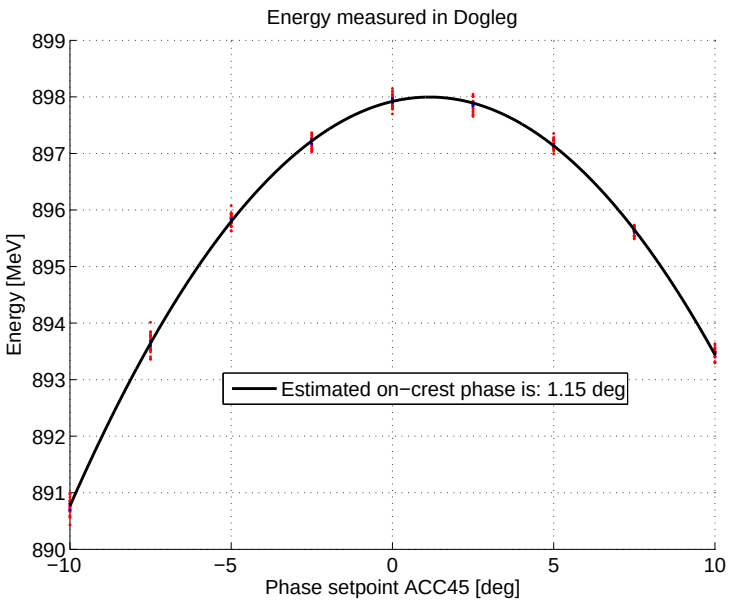


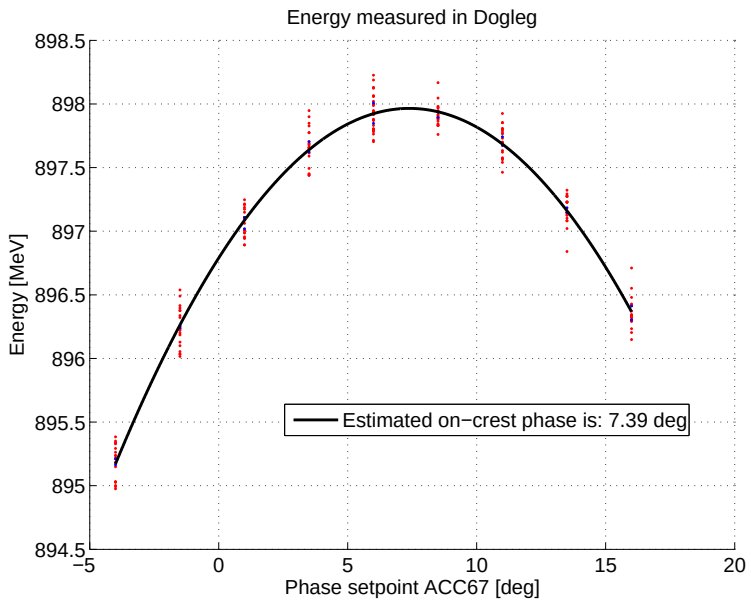
Measure On-Crest Phases with BAMs.

Matlab Tool *"measure_oncrest.m"*



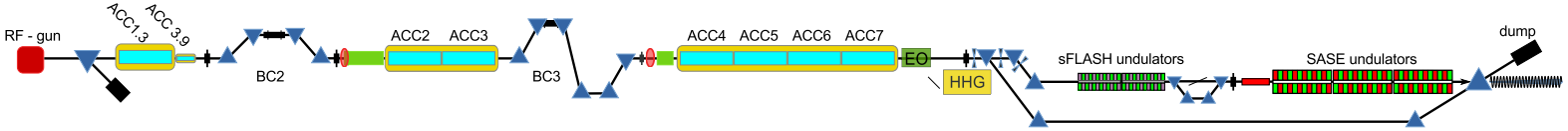
- with correct energy in BC3 (450 MeV)





Summary & Outlook.

Functionality & Reliability of BAMs.



- Identified residual Charge- & Orbit Dependency of current BAM Pick-Up Design
  - > Software correction for orbit dependency possible
  - > Hardware change necessary to remove charge dependency for $< 200\ \mathrm{pC}$
- Availibility of BAM data through DAQ
- Successively Reducing Down-Time of BAM operation
  - > currently, through improvements in BAM-Server
  - > in future: more reliable & stable signal read-outs with µTCA technology (hopefully $\cdots$)
- Expanded Application of BAMs:
  - > Measurement of on-crest phases of modules ACC1, ACC3.9 & ACC23
  - > Slow Arrival Time Feedback on ACC1 & ACC23
  - > Intra Bunch Train Arrival Time Feedback on ACC1/ACC3.9 & ACC23
  - > (yet to prove) Enlarging data accuracy of User Experiments when sorting data with bunch arrival time information