CLAWS Phase II: Beam background monitoring in the commissioning of SuperKEKB

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Outline

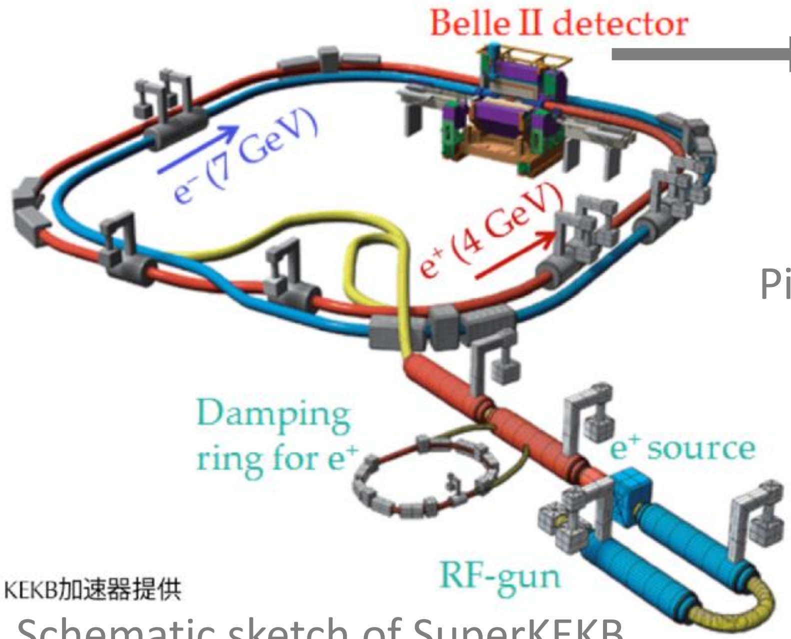
- SuperKEKB and Belle II
- CLAWS as subsystem of BEAST II
- CLAWS Phase II: System, basics, measurements
- Testbeam at DESY
- Summary & Outlook

SuperKEKB and Belle II

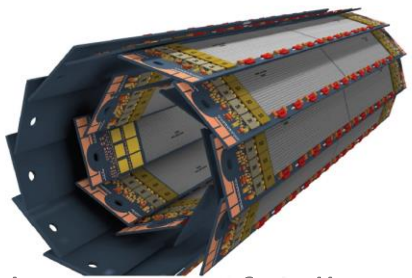
- KEKB: Asymmetric e^-e^+ -collider for the investigation of CP violation:
  - High energy ring for 7 GeV e^-
  - Low energy ring for 4 GeV e^+

- Currently KEKB and Belle detector undergoing extensive commissioning campaign to SuperKEKB and Belle II:
  - Goal: Increase luminosity by factor 40 to $L = 8 \times 10^{35} cm^{-2} s^{-1}$ for high statistics

- BEAST II: Commissioning detector for SuperKEKB (**B**eam **E**xorcism for **A ST**able Belle Experiment II)
  - Phase II (start of 2018): BEAST II instead of inner vertex detectors of Belle II



Schematic sketch of SuperKEKB


Pixel Detector of Belle II

BEAST II logo

CLAWS as subystem of BEAST II

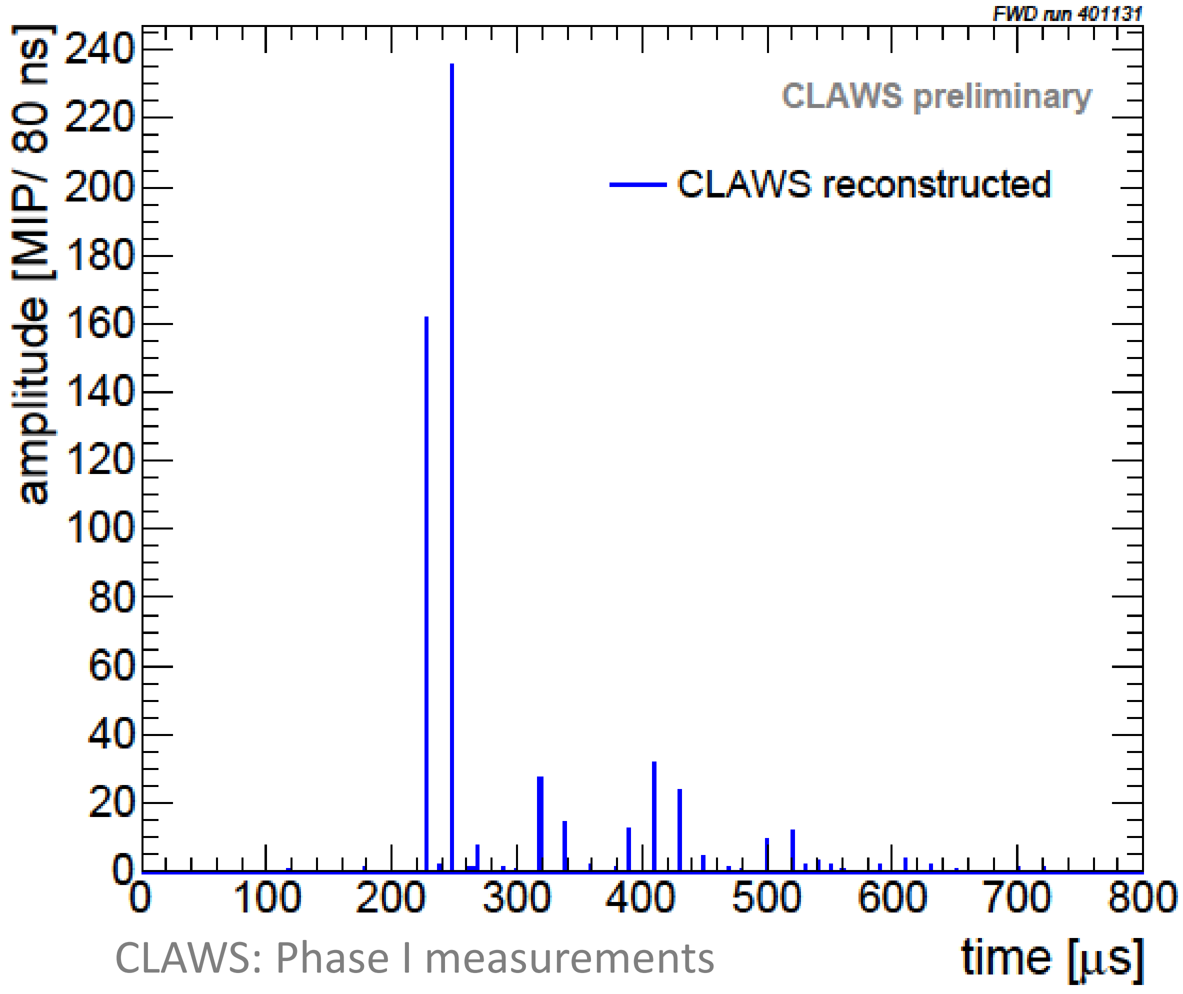
- To achieve high luminosity a continuous top-off injection at full energy is required

→ First rounds after injection: High background noise
→ Saturation of the Belle II Pixel detector (PXD)
  → Timed gating required

→ **Detailed studies of the beam background time evolution inevitable!**

- CLAWS: Measurement of time evolution of injection background and its decay constant with:
  → High time resolution: 0.8ns sampling rate
  → Continuous sampling up to the order of ms

→ Provide timing information for PXD gating



CLAWS: Phase I measurements

SCintillator Light And Waveform Sensors (CLAWS)

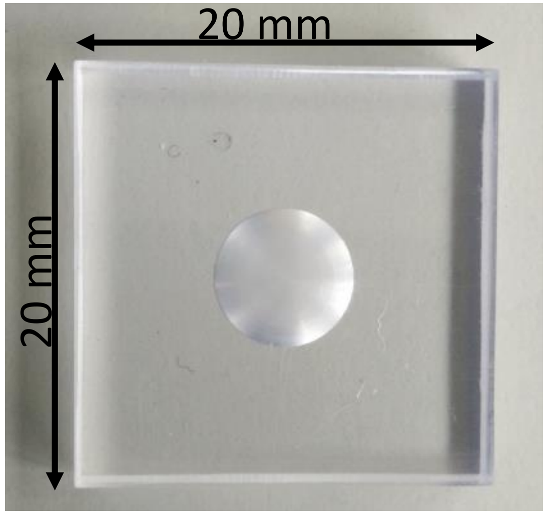
→ Plastic scintillator coupled to SiPM readout

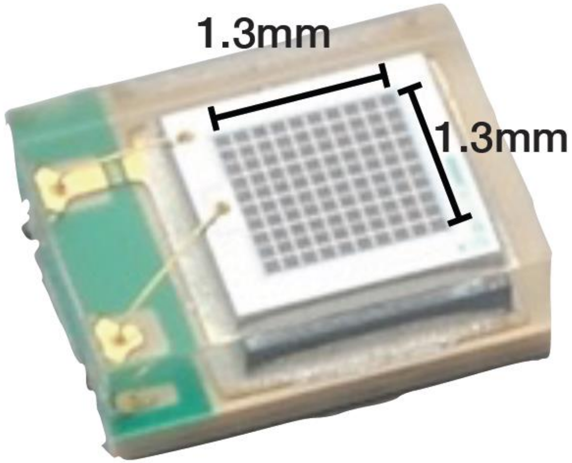
Scintillator tile:

- Design: CALICE hadron calorimeter for ILC
- Sensitive almost entirely to charged particles
- Packaged with self-reflecting foil to avoid photon escape
- Photons collected by Silicon Photo-multiplier located in the centered dimple
  → Dimple preserves uniformity

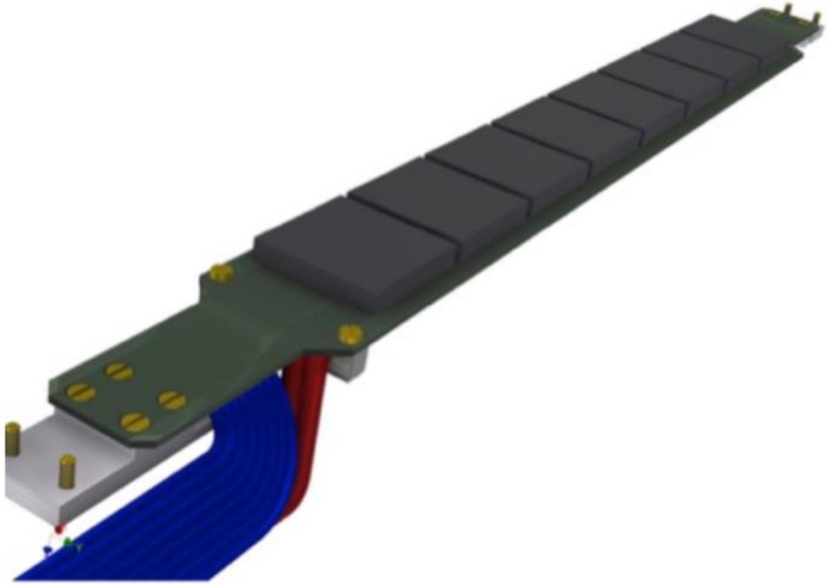
Silicon Photomultiplier (SiPM):

- Mounted on PCB board
- Hamamatsu MPPC-S13360-1325PE



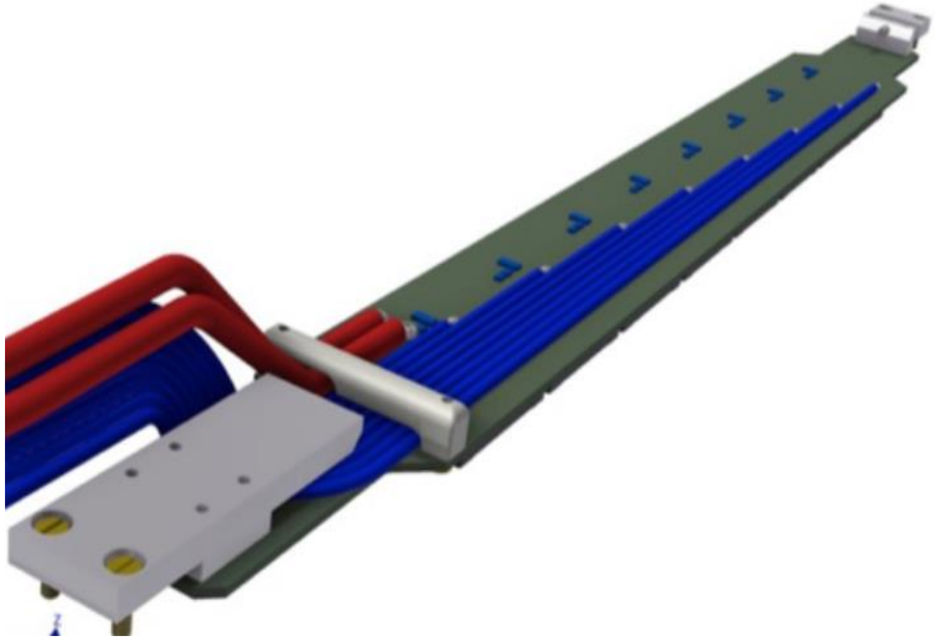


Unpackaged scintillator tile and a SiPM of CLAWS

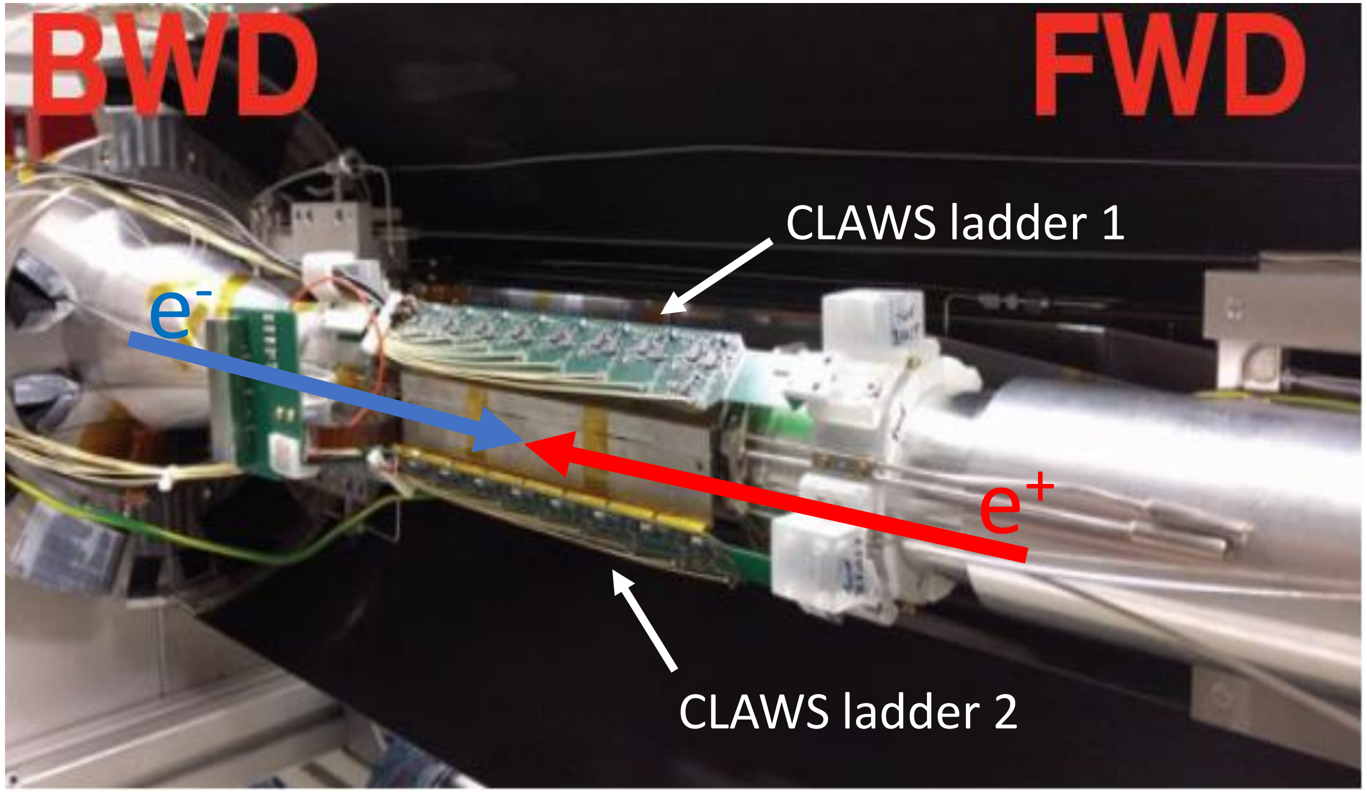


CLAWS ladder with scintillators on top of SiPMs

CLAWS - Setup



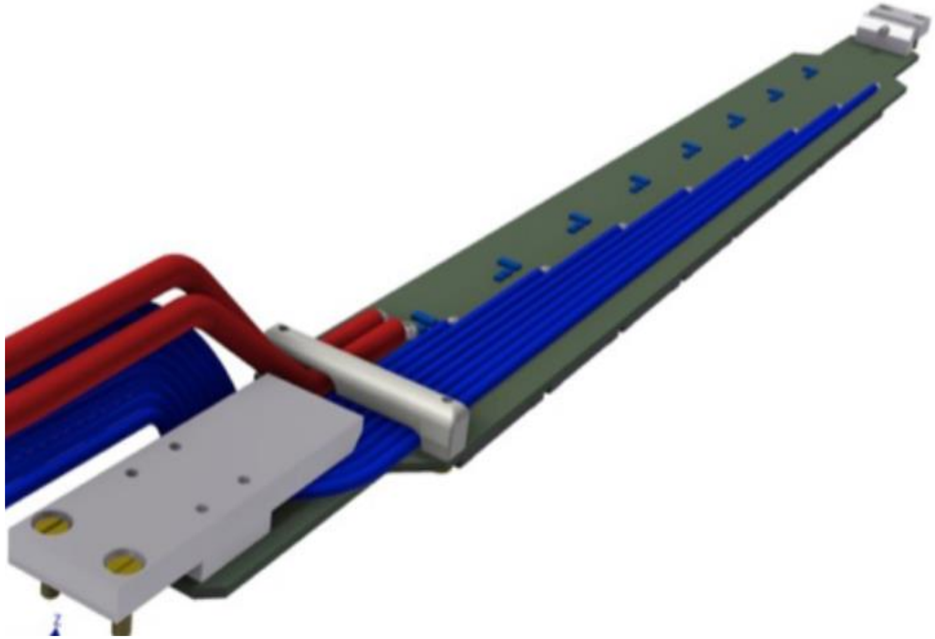
CLAWS Phase II ladder design



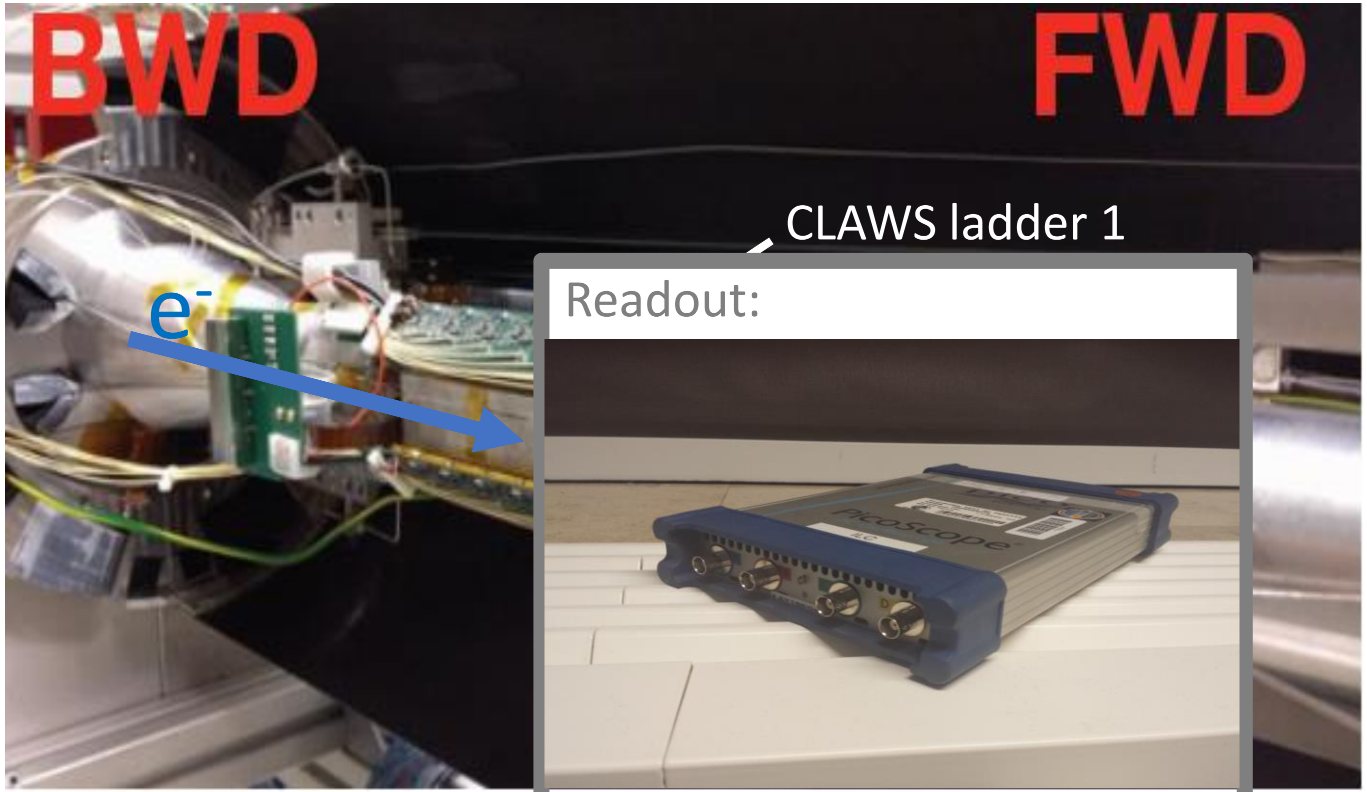
CLAWS and other subsystems mounted on a beampipe mock up

- Two ladders with 8 channels each
- SiPMs and amplifiers on ladder powered commonly (red)
- High gain/low gain setting implemented (amplifier on/off)
- Each channel read out individually with signal cable (blue)
- Signals externally amplified and read out by 4 Picoscopes

CLAWS - Setup



CLAWS Phase II ladder design



CLAWS and other subsyste

Readout:

Picoscope:

- 8 bit resolution
- 4 channels + ext. Trigger
- Sampling rate of 0.8 ns
- Can store up to 400ms/channel

- Two ladders with 8 channels each
- SiPMs and amplifiers on ladder powered commonly (red)
- High gain/low gain setting implemented (amplifier on/off)
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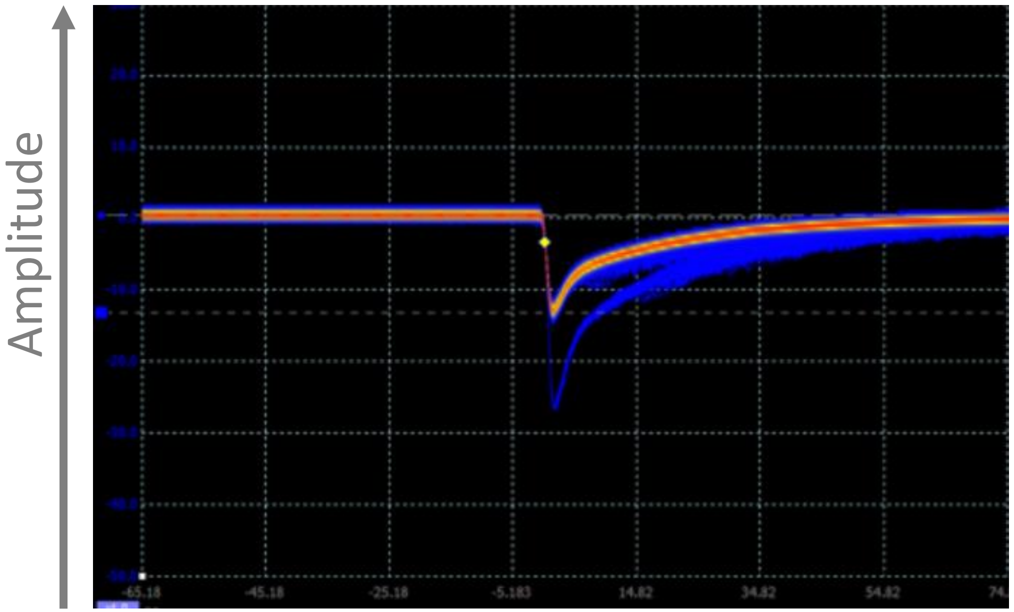
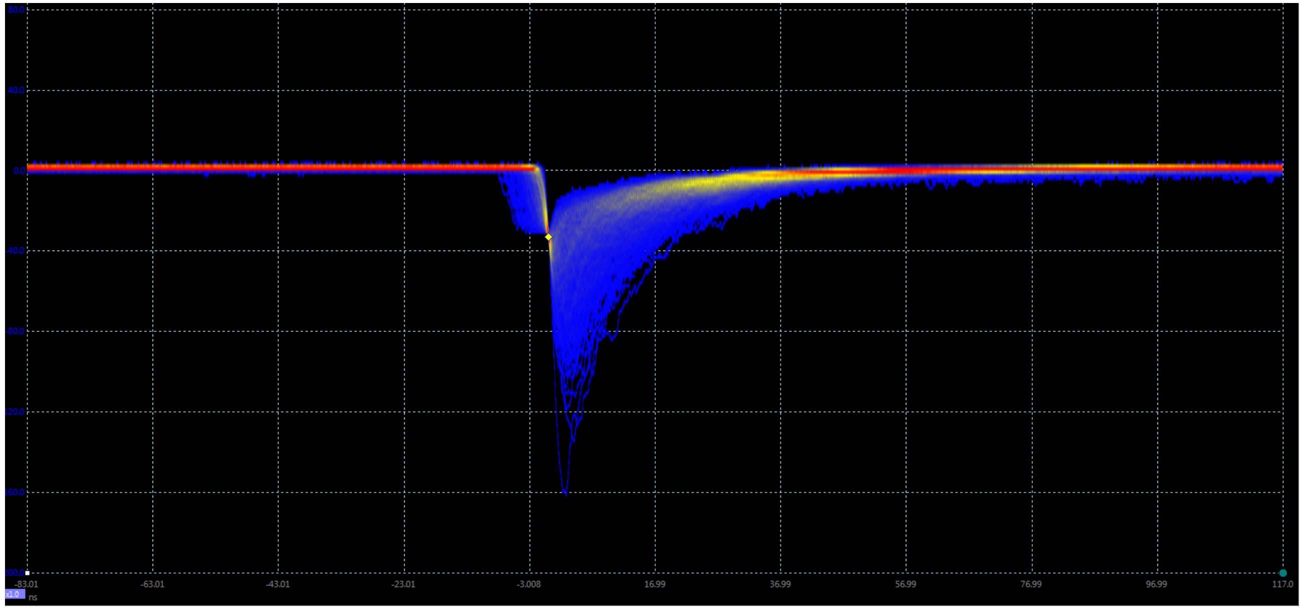
CLAWS - First measurements and signals



<u>Amplified</u> 1pe and 2pe darkrate signal

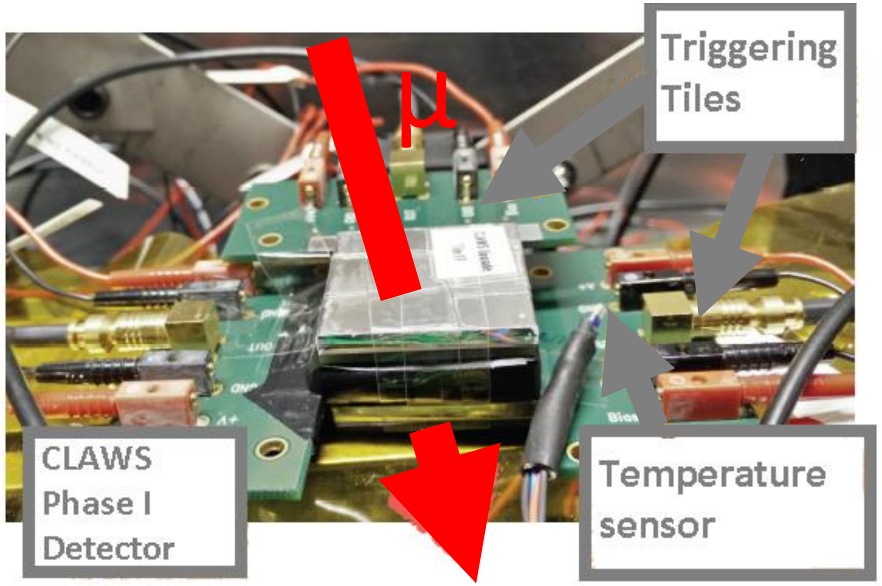


<u>Not amplified</u> multiple pe signal by a Sr90 source on top of one scintillator

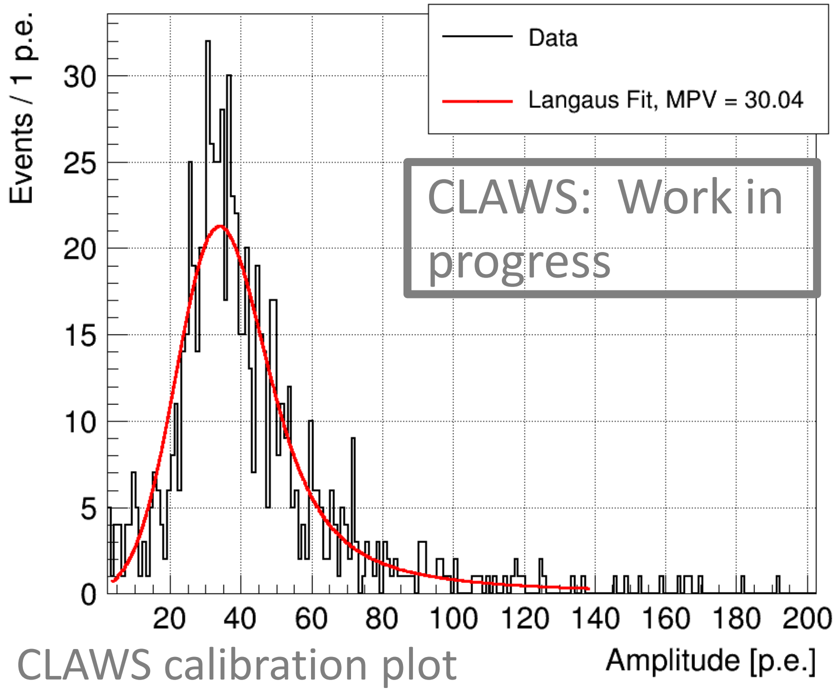
→ Next step: Calibration and characterisation

CLAWS - MIP Calibration

- Calibration with minimum ionizing particles (MIPs)
  → cosmic muons
- Sandwich structure:
  → Trigger if coincident signal on upper and lower sensor
  → Save and analyze the μ-signal in the middle sensor



CLAWS calibration setup

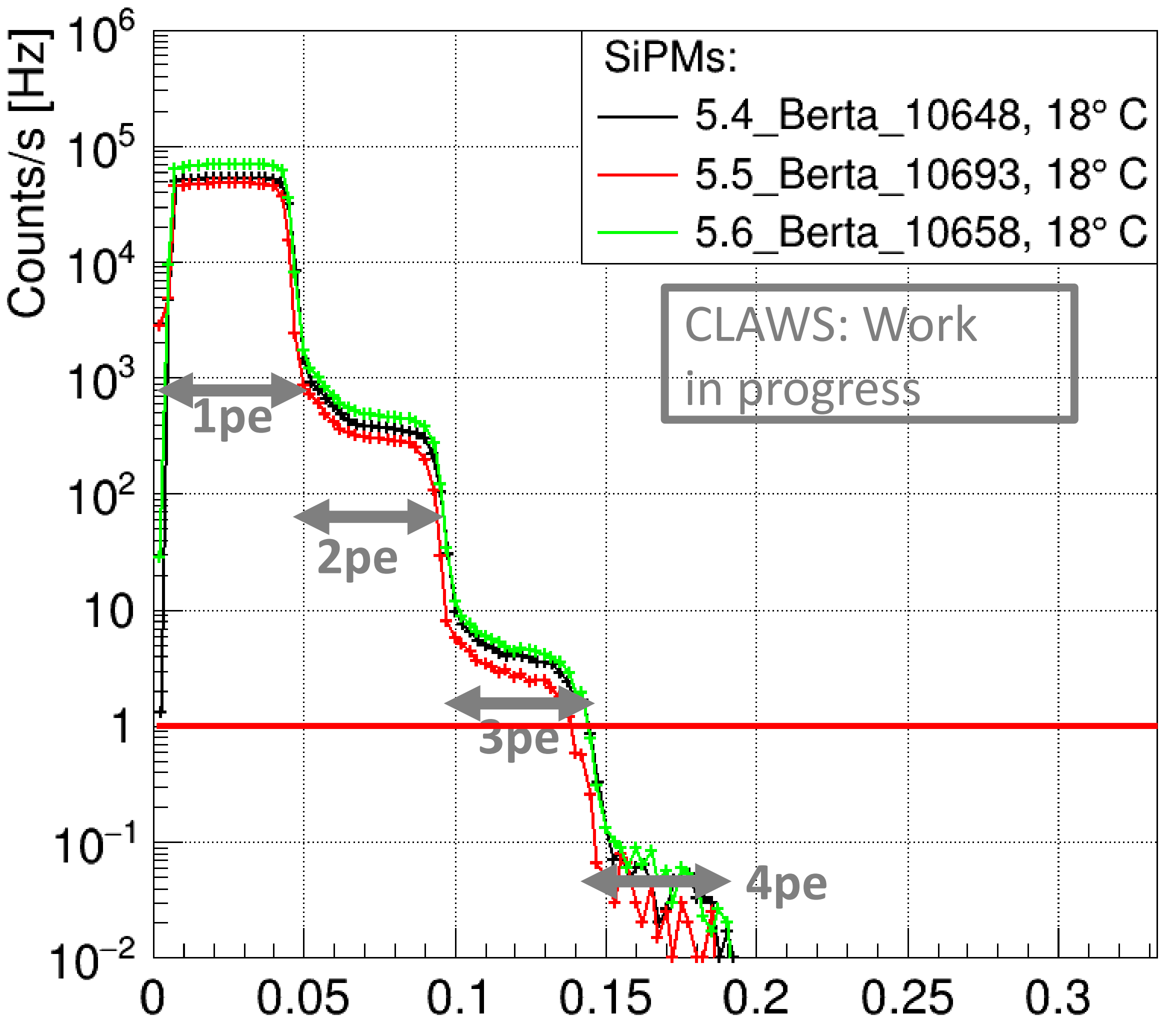


CLAWS calibration plot

- Most probable value = average light yield per MIP

→ First measurements show light yield of around 30pe/MIP

CLAWS - Darkrate characterisation



Darkrate over counter treshold voltage for 3 channels of a CLAWS ladder

- Darkrate of SiPMs measured with a voltage counter
- 4pe darkrate is low (below 1 Hz)

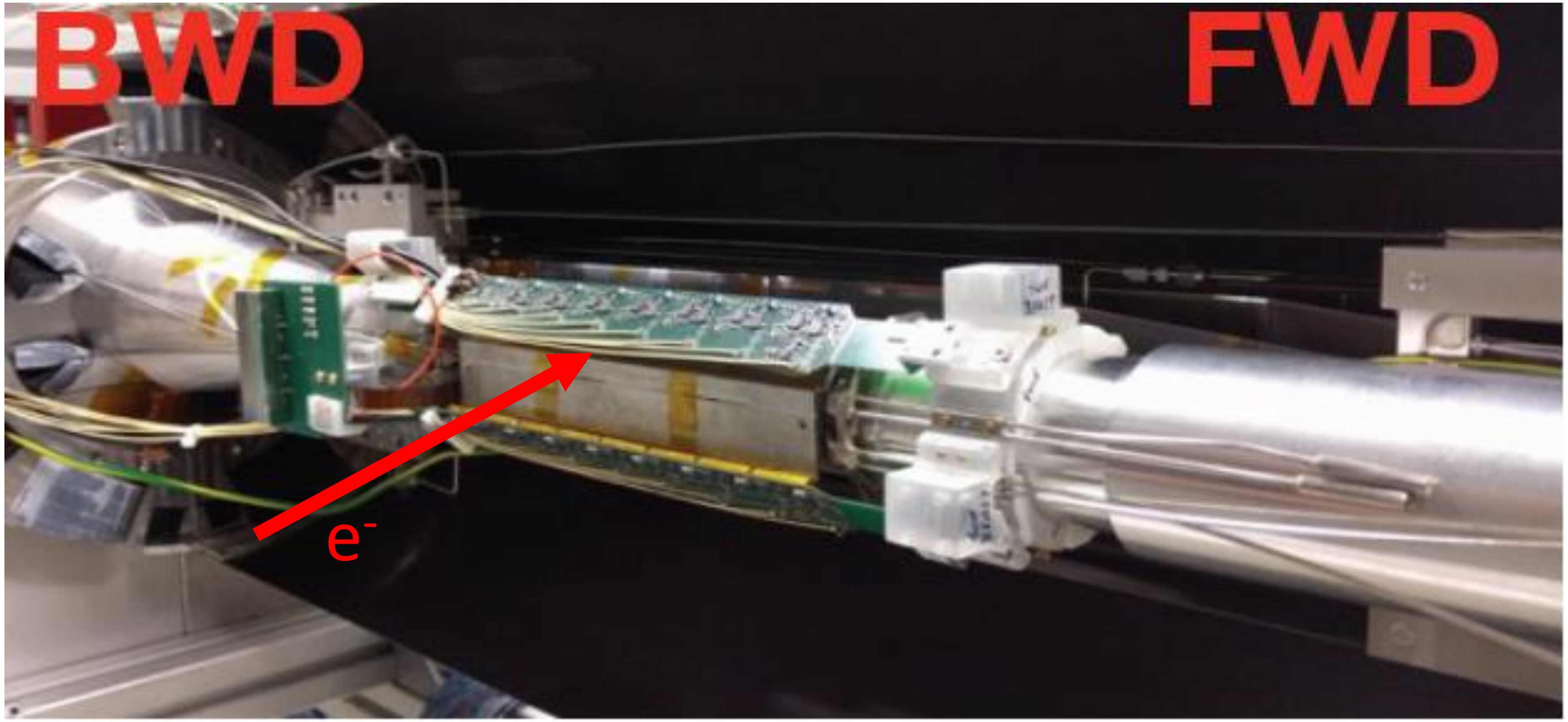
  → Comparison to 30pe MIP signals with GHz rate in accelerator (4ns bunch spacing)

  → Darkrate is negligible

- CLAWS is noise-free

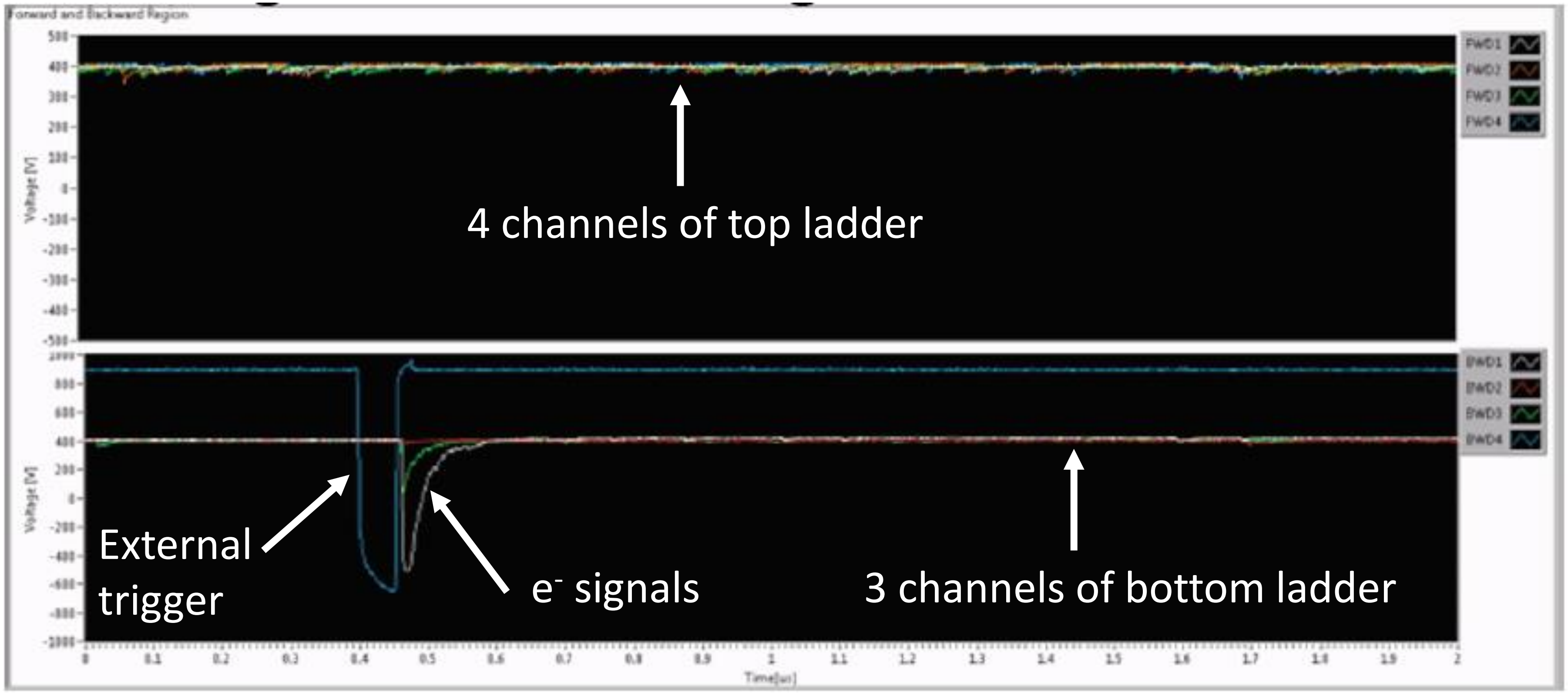
Testbeam at DESY

- Testbeam with e^- at DESY in Hamburg
- Two CLAWS ladders installed
- e^- beam perpendicular to CLAWS ladders
- Operation with and without 1.5 T magnetic field



The two CLAWS ladders mounted on the testbeam mock up with other subsystems

Testbeam at DESY



CLAWS DAQ for Phase II during data taking of single MIP signals with an external trigger (blue): Simultaneous e^- signals in two channels of the bottom ladder

- Measurements with different dynamic ranges and settings
- Measurements of single MIPs
- Constant recording over 20 ms with more than 50 MIPs in one waveform
- Successfully operated in High gain and Low gain mode during data taking
  → Analysis ongoing

Summary & Outlook

- Injection background in the SuperKEKB accelerator, appearing the first rounds after a top-off injection, has to be investigated in detail
  → Avoid saturation of the Belle II PXD by timed gating

- Therefore, CLAWS in Phase II, as part of BEAST, will replace a future Belle II vertex detector and measure timing properties and particle rates of the injection background

- CLAWS: Plastic Scintillator with a SiPM readout for fast timing
- Phase II design: Two CLAWS ladders with 8 channels each
- Characterisation and Calibration measurements on going

- Three successfull testbeam weeks at DESY showing that the CLAWS Phase II design works and the CLAWS system is on track for Phase II
  → Analysis of the measurements on going

- Hardware installation November 2017 and Phase II data taking early 2018

Thank you very much for your attention!

BACKUP

BEAST II - Commissioning Schedule

Beam Exorcism for A STable Belle Experiment II

After the major upgrade of the KEKB accelerator

Phase I (Feb 2016 – June 2016):

- No Belle II detector
- No beam focusing optics
- Injection in HER or LER

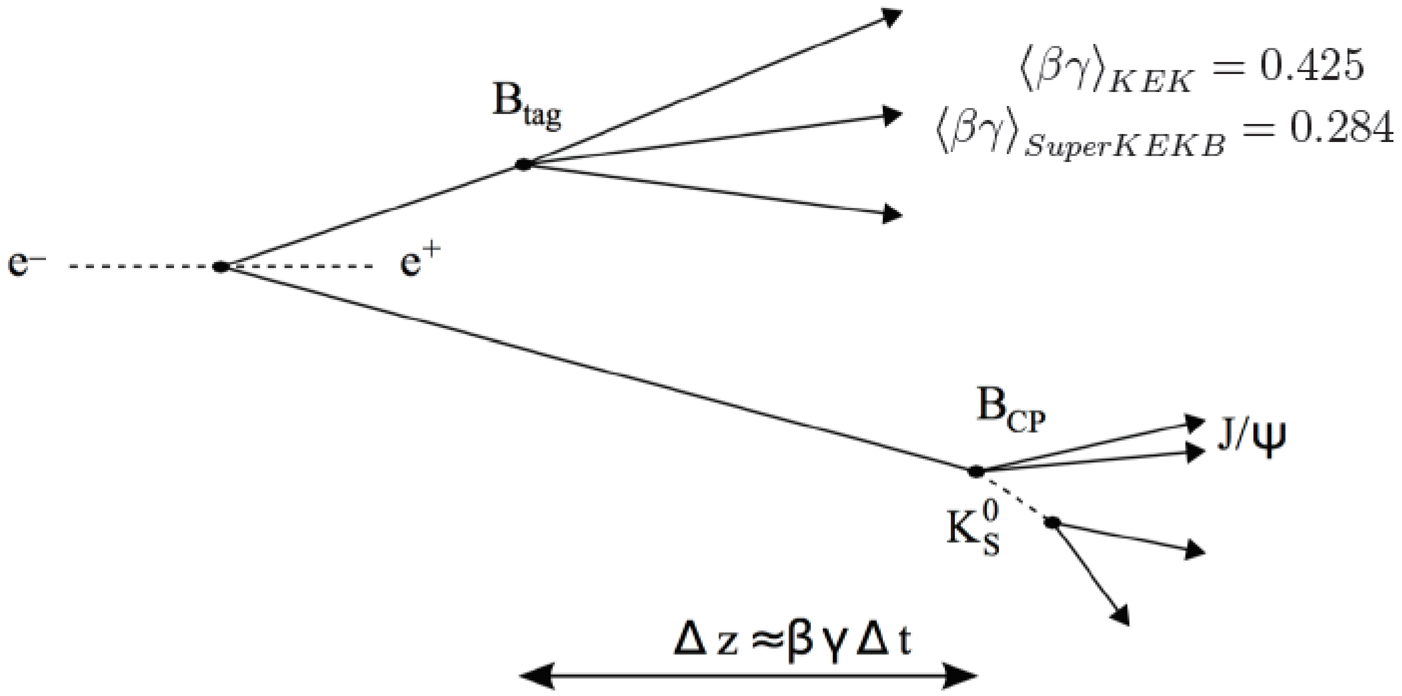
Phase II (autumn 2017 – spring 2018):

- **Belle II (without VXD)**
- **Optics for nano-beam scheme**

Phase II (starting mid 2018):

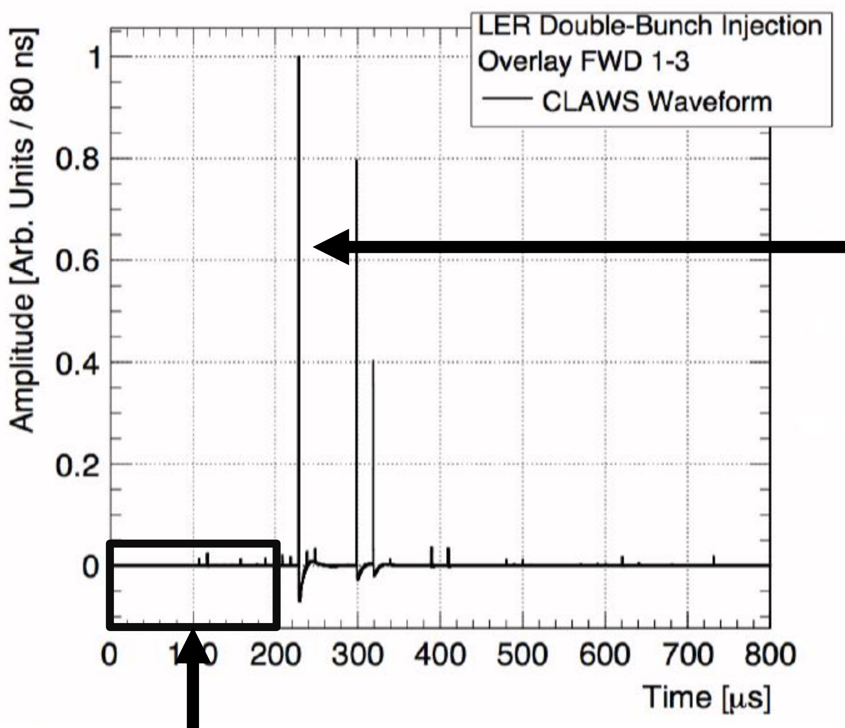
- Full Belle II detector
- Real physics collisions

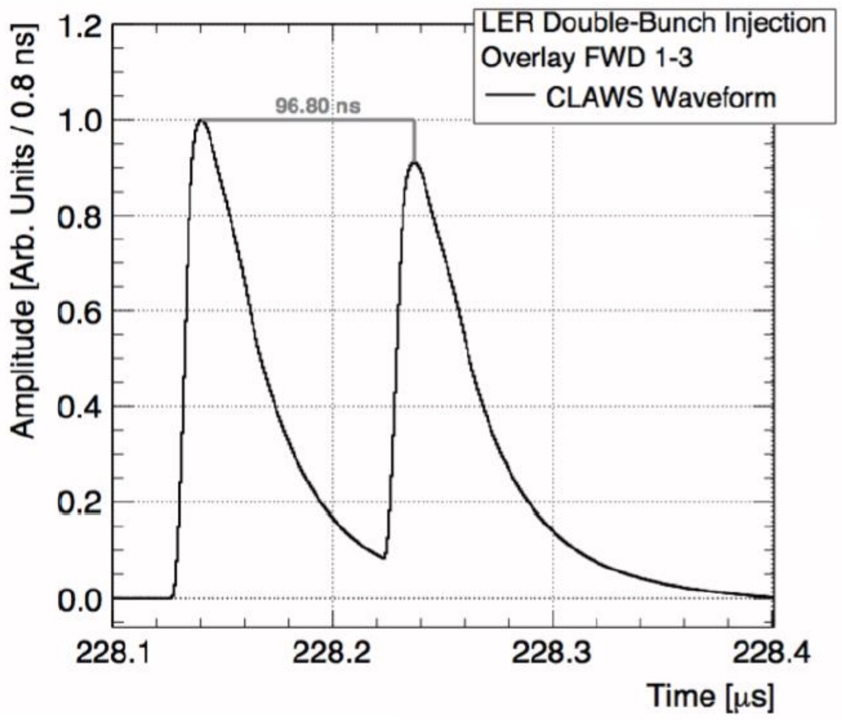
Theory

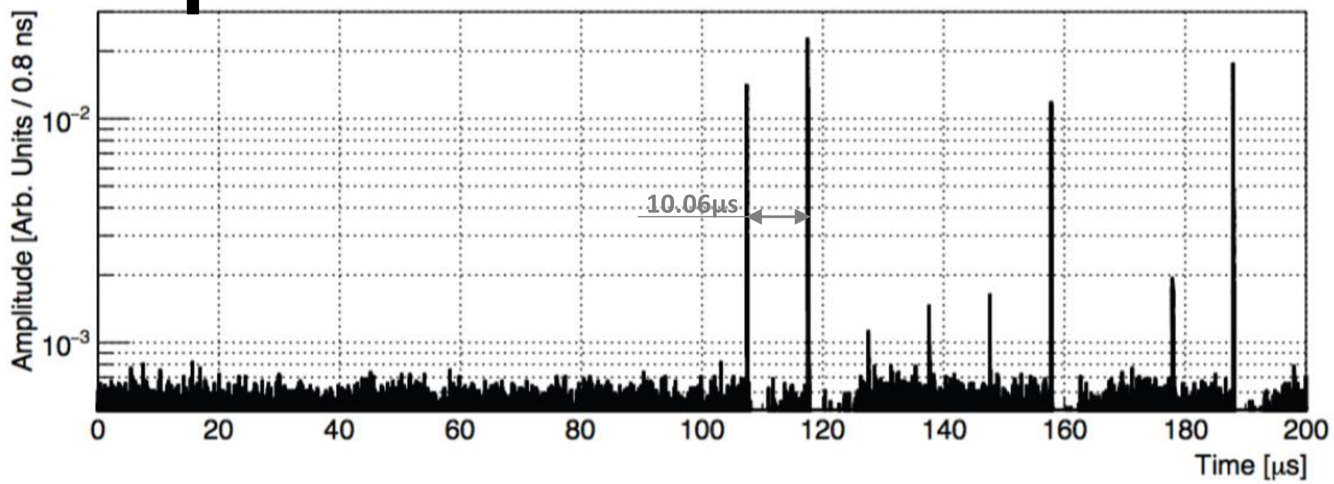


- CME of 10.58 GeV -> Resonance Y(4s) -> Decays mostly into bb -> b-factory
- Investigation of CP violating b decays, bb mixing!
- Different decay times, positions? Vertex and Pixel detectors with high spatial resolution for investigation Belle II

CLAWS – Phase I timing measurements







CLAWS Phase I data

- Compare measurements with design properties:

→ Bunch timing in double bunch injection: 96.285ns

→ Revolution time: 10.061 ns

- Measure decay time of noise coming from injected bunches

- Measure particle rates of noise

CLAWS - Measurements

What does CLAWS measure in detail?

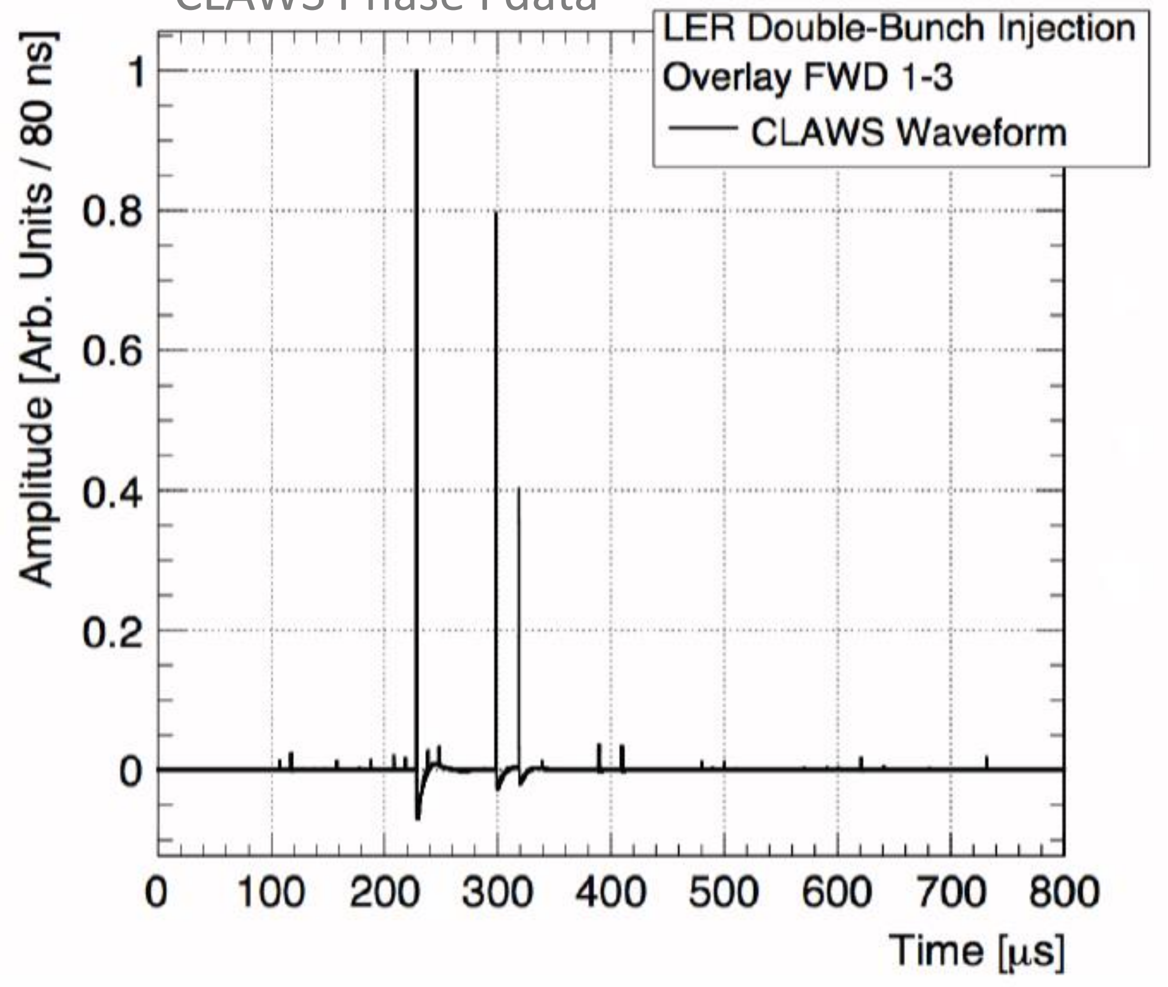
- Time evolution of the beam background
    - → Sensitive to charged particles
    - → High time resolution: 0.8ns sampling rate
    - → Continuous sampling up to the order of ms

- Intra-bunch interactions create different types of background at the interaction point:

    → Regular signals from circulating bunches with small amplitude

    → Signals of top-off injected daughter bunches with high amplitude (Signals decrease turn by turn)

CLAWS Phase I data



CLAWS - System and Basics

sCintillator Light And Waveform Sensors

→ Plastic scintillator coupled to SiPM readout

Readout:

Picoscope 6404D:

- 8 bit resolution
- 4 channels + ext. Trigger
- Sampling rate of 0.8 ns
- Can store up to 400ms/channel

Unpac

WS

Scintillator tile:

- Design taken from CALICE hadron calorimeter for ILC
- Sensitive almost entirely to charged particles
- Tiles are packaged with self-reflecting foil to avoid photon escape
- Photons are collected by the Silicon Photo-multiplier located in the centered dimple
  → Dimple preserves uniformity

Silicon Photomultiplier (SiPM):

- Mounted on PCB board within the centered dimple of the scintillator tile
- SiPM is an array of avalanche photodiodes in limited Geiger mode
- Hamamatsu MPPC-S13360-1325PE:
  → 2668 pixels
  → Typical operation voltage 55-60 V