CLAWS - A Plastic Scintillator / SiPM based Detector measuring Backgrounds during the Commissioning of SuperKEKB

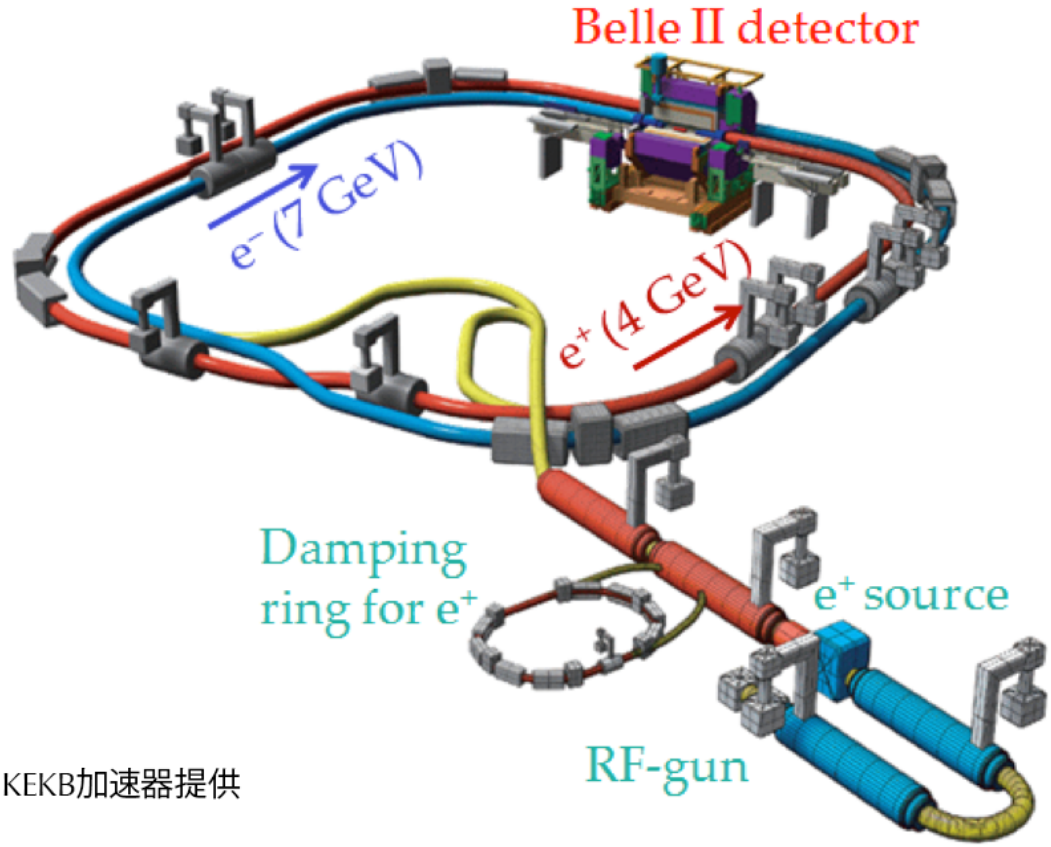
- Introduction SuperKEKB
- What do we measure?
- The CLAWS System
  - Calibration, Results & Radiation Damage
- The CLAWS Upgrade

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

TIPP 2017 - HENDRIK WINDEL - For the BEAST II Collaboration

The SuperKEKB Accelerator

- particle accelerator for the Belle II experiment
- extensive upgrade of KEKB with factor 40 increased luminosity
  - ➡ $8 \times 10^{35} cm^{-2} s^{-1}$
- asymmetric e^+e^- -collider:
  - cms 10.58 GeV
  - low energy ring for 4 GeV e^+
  - high energy ring for 7 GeV e^-



KEKB加速器提供

BEAM EXORCISM FOR A STABLE BELLE EXPERIMENT II

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- Phase 1 (Feb 2016 - June 2016):
  - no Belle II detector
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- Phase III (start early 2019):
  - final Belle II detector composition
  - final physics runs

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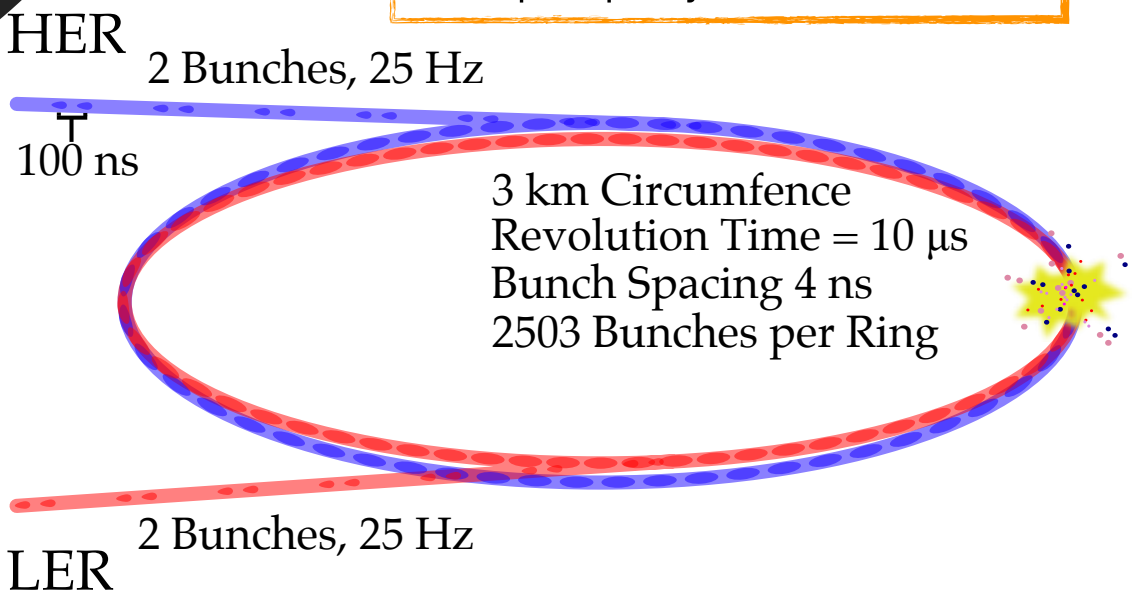
➡ Top-Up injection scheme

- measurement of particle loss of injection bunches



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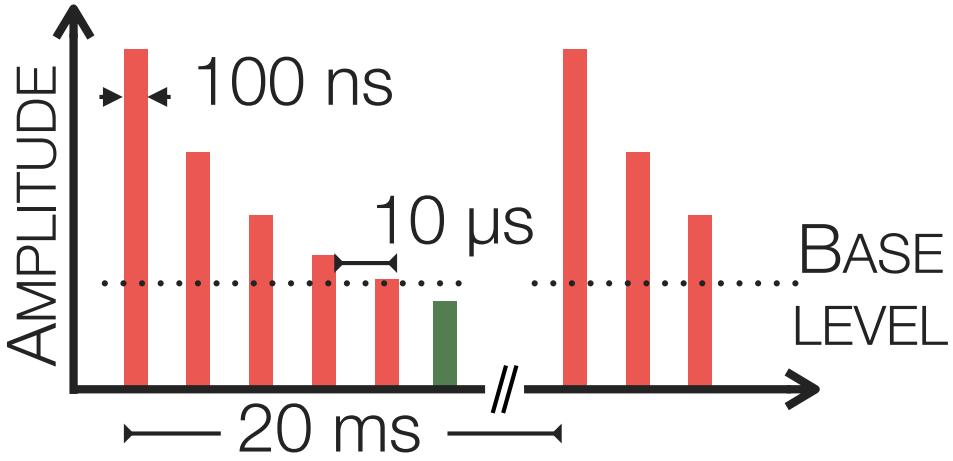

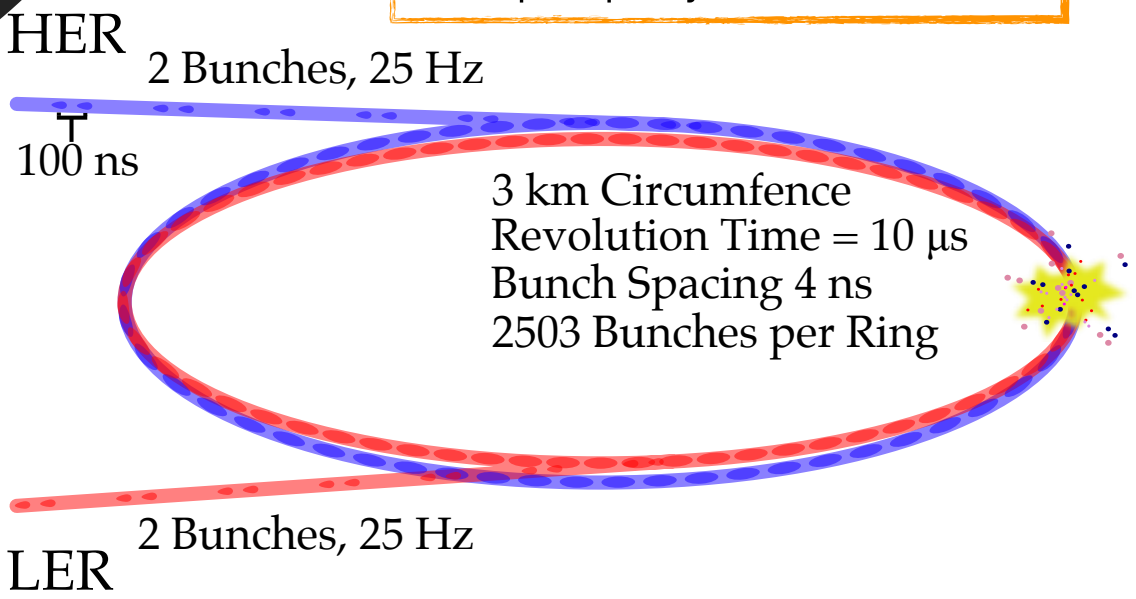

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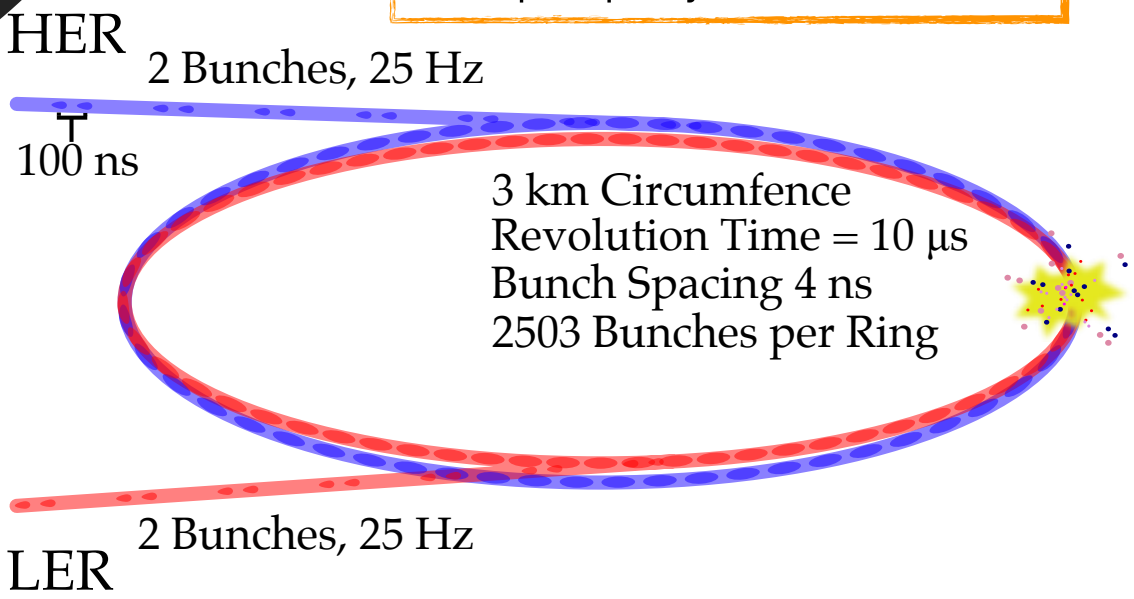

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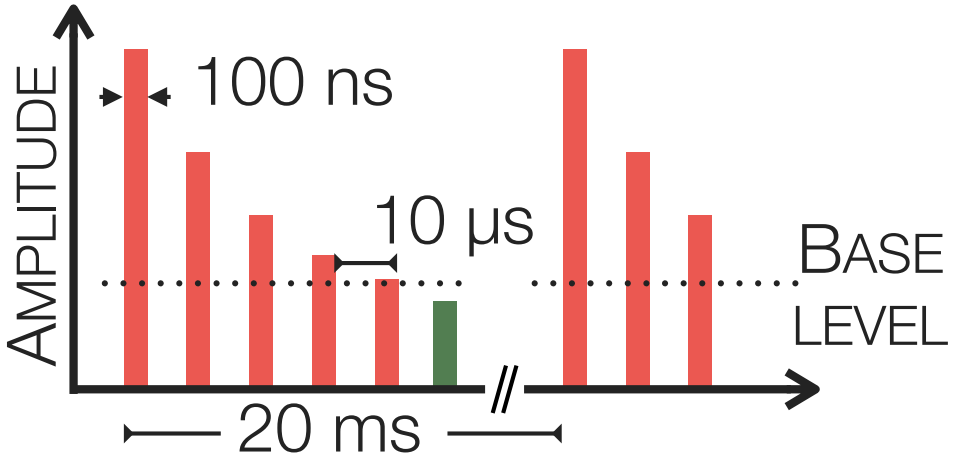

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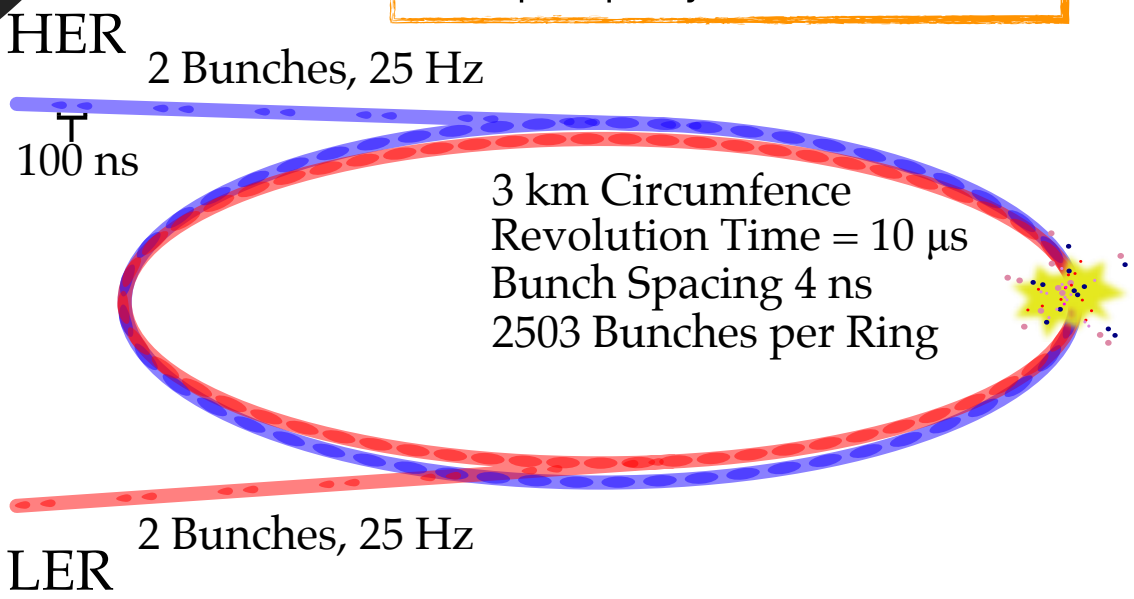

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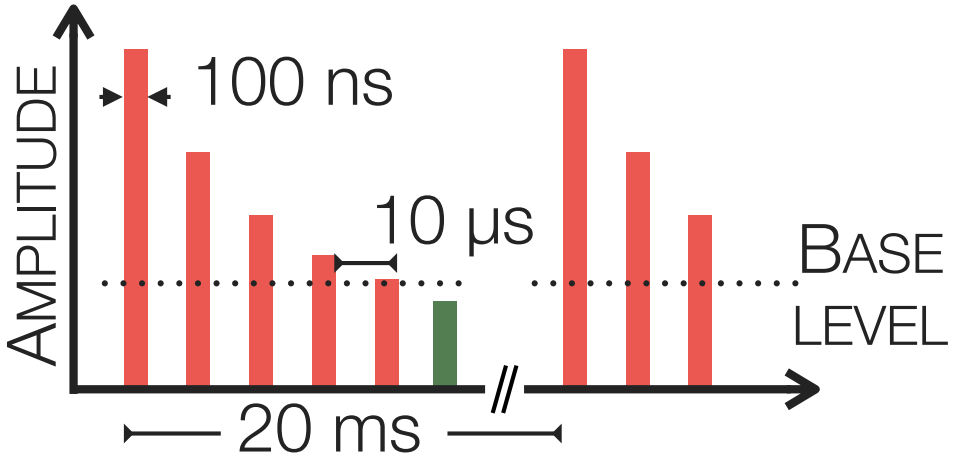

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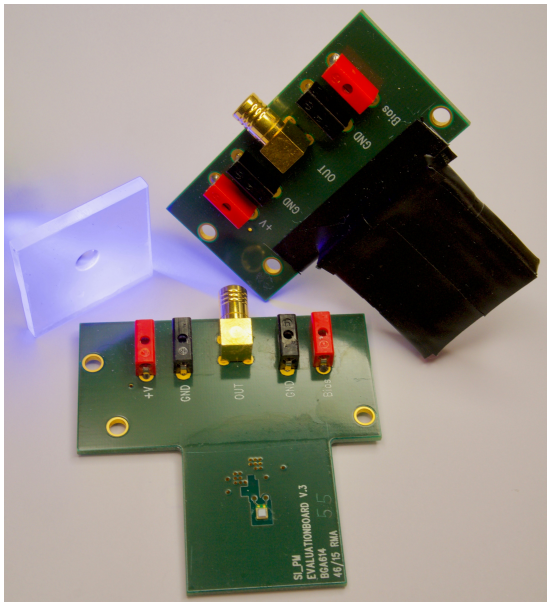
Detector requirements:

- single bunch resolution
  - ➡ sampling time <4 ns
- extended monitoring over multiple particle revolutions
  - ➡ several milliseconds

The Detector
A scintillating tile with SiPM readout



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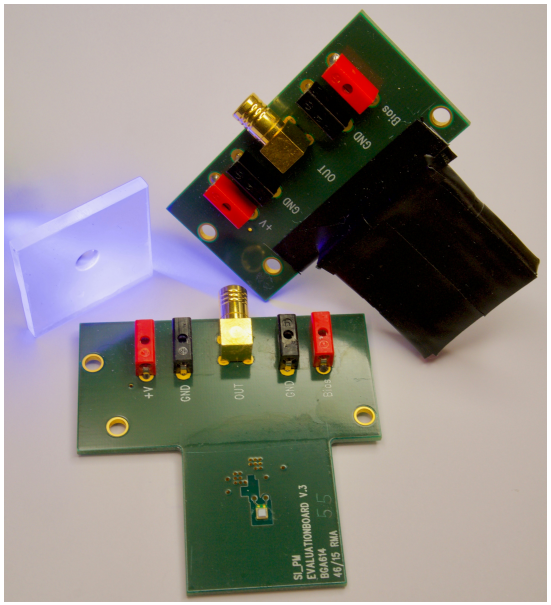

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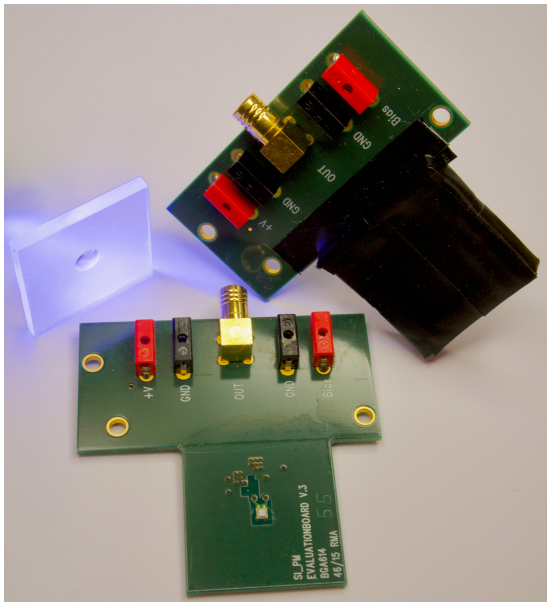

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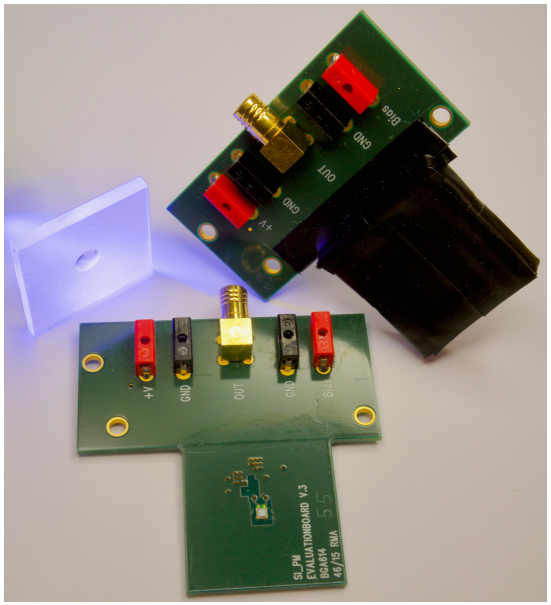

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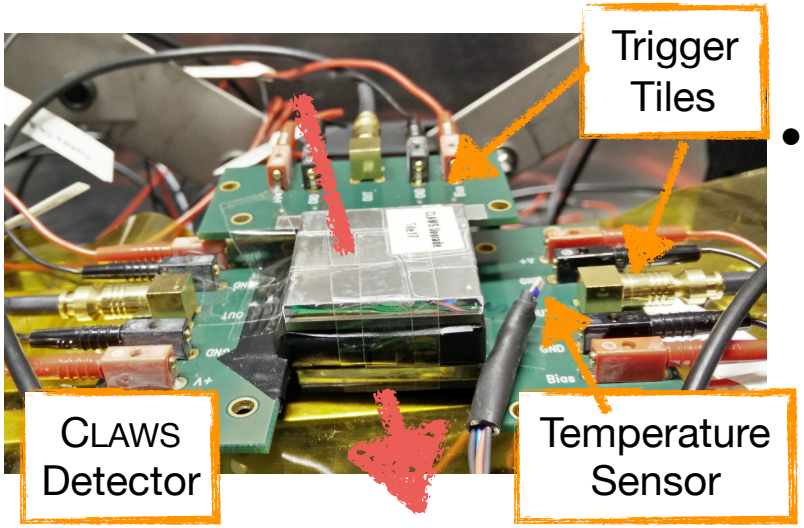
Picoscope 6404D

- 4 channel + ext. trigger channel
- 8 bit vertical resolution
- 800 ps sampling time
- records up to 40 ms per channel

Calibration

PRELIMINARY



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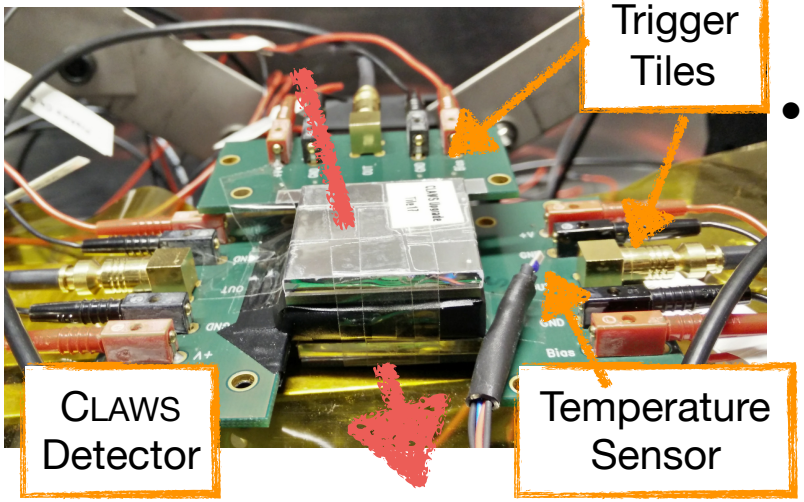

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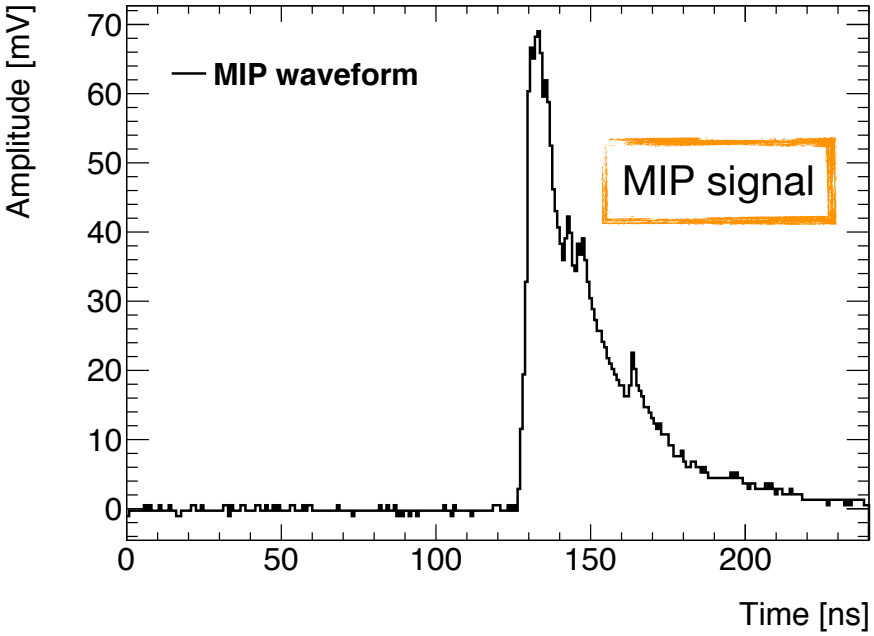

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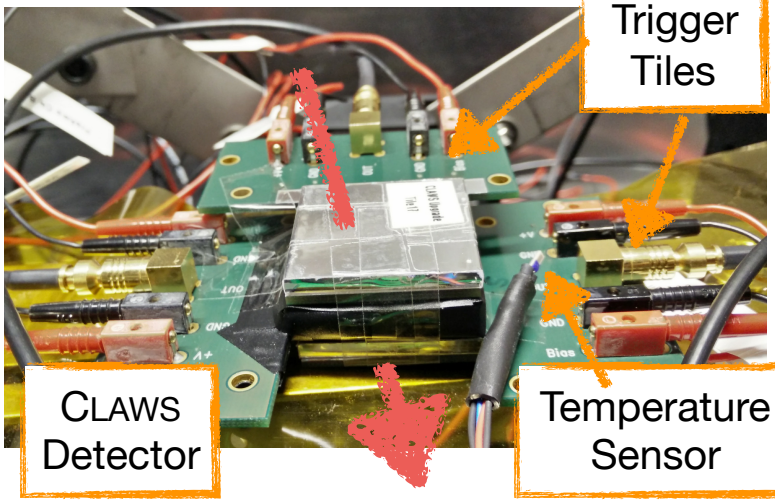

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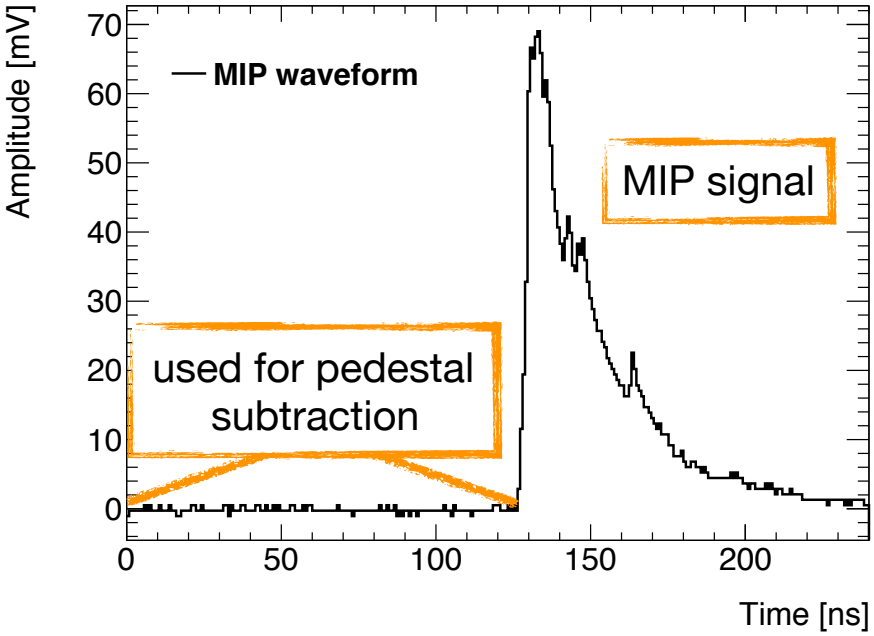

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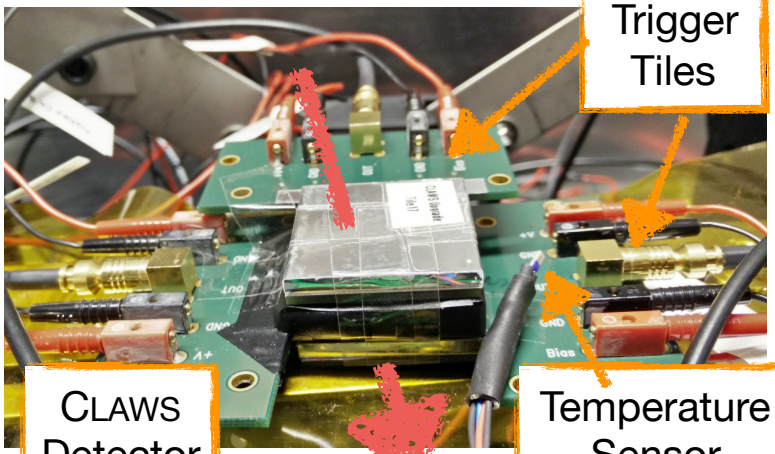

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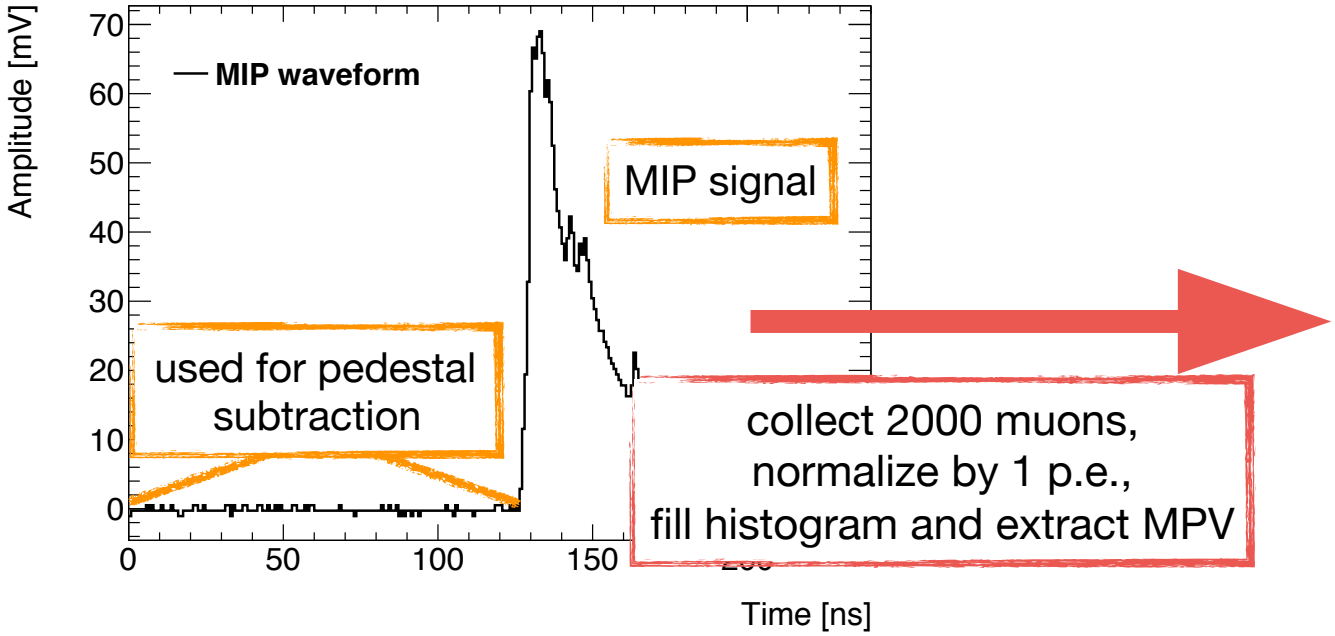

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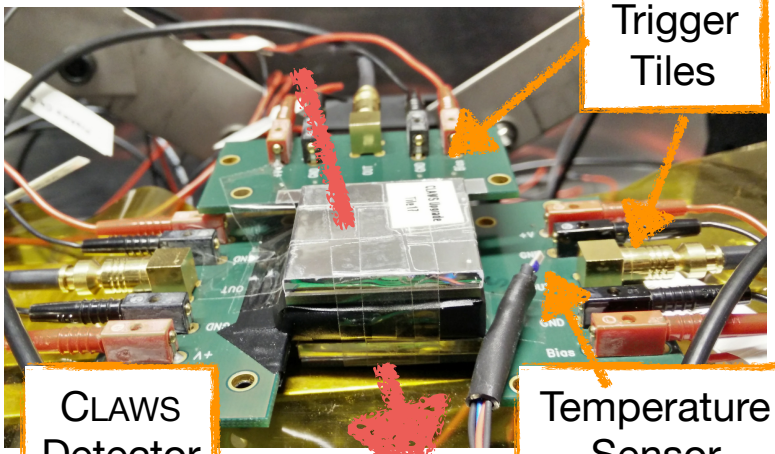
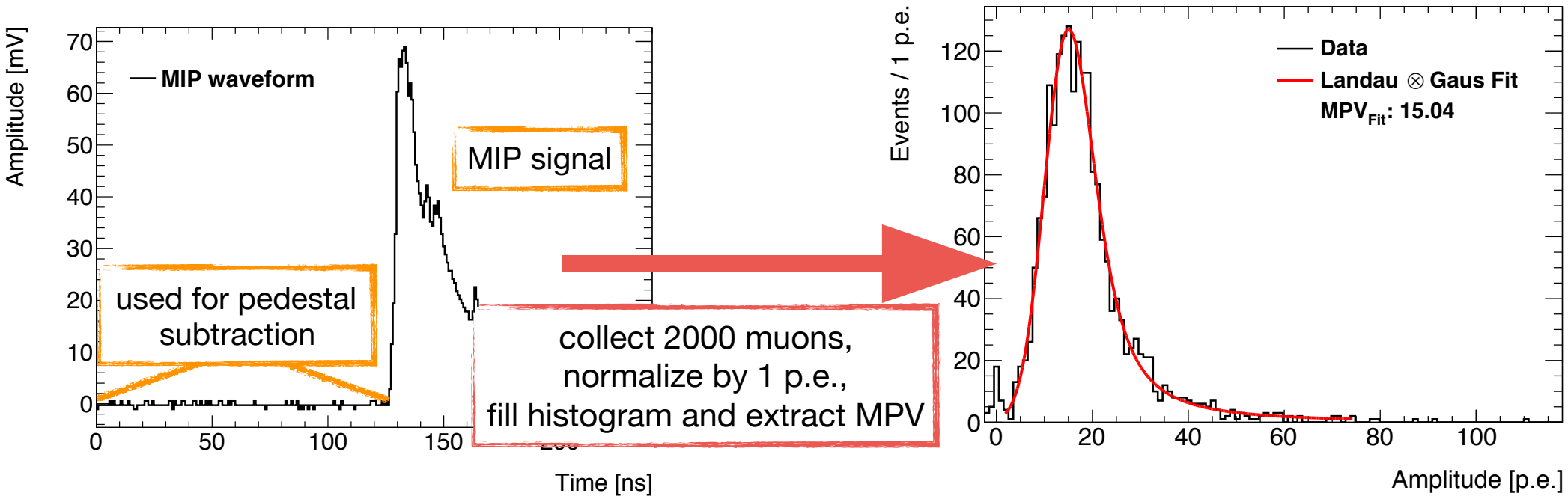


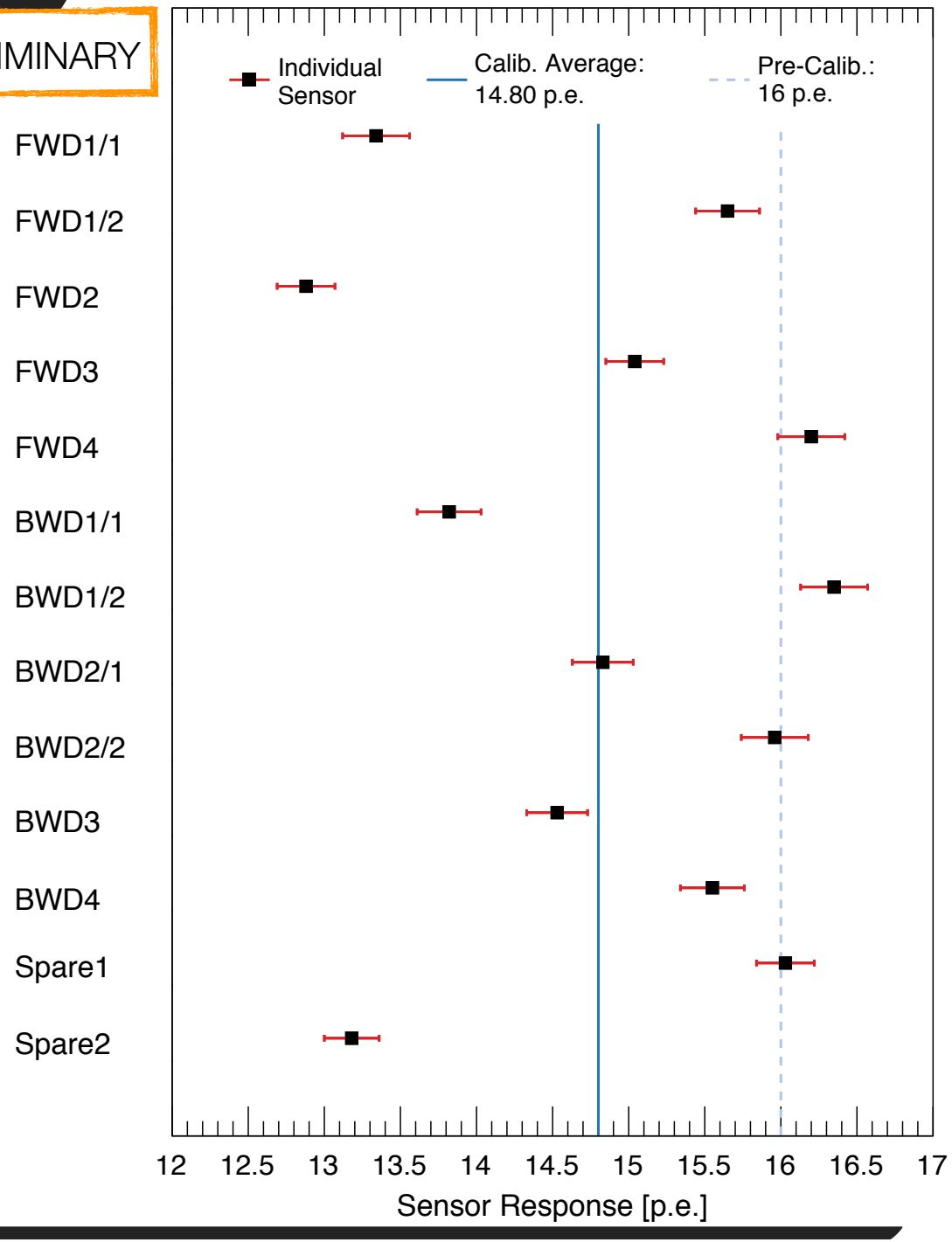
- Minimum Ionizing Particle (MIP) calibration
- follows Landau convoluted Gaussian distribution
  - extraction of the most probable value here: ~15 p.e.



Calibration Results

PRELIMINARY

- final average 14.80 p.e. with ±1.5 p.e. spread
- shown errors are of statistical origin
- systematic error due to packaging much larger



SCINTILLATOR LIGHT AND WAVEFORM SENSORS

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- 4 on outer side of ring
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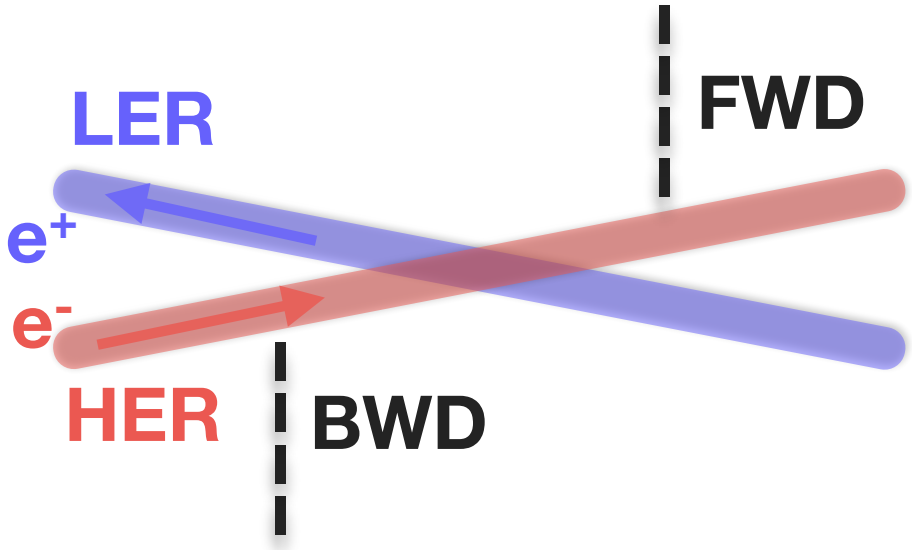

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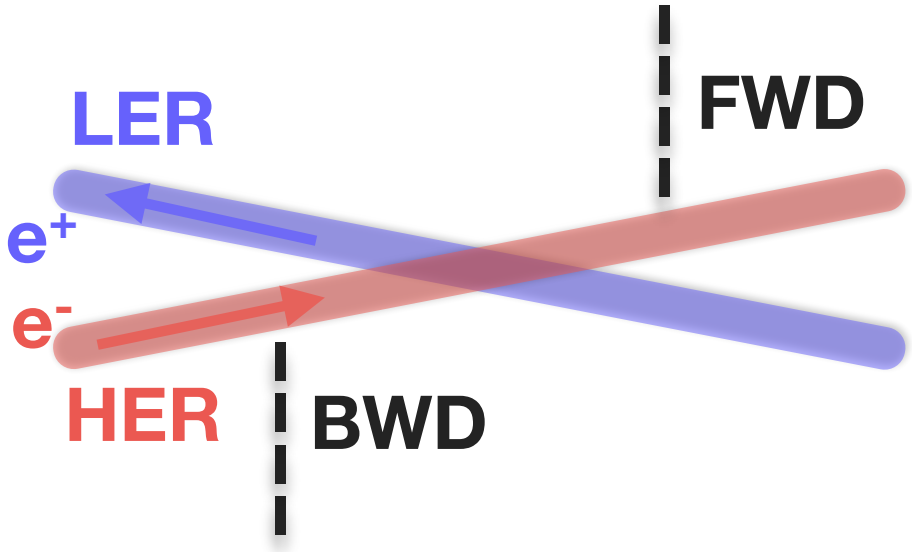

Online Monitor

The Online Monitor

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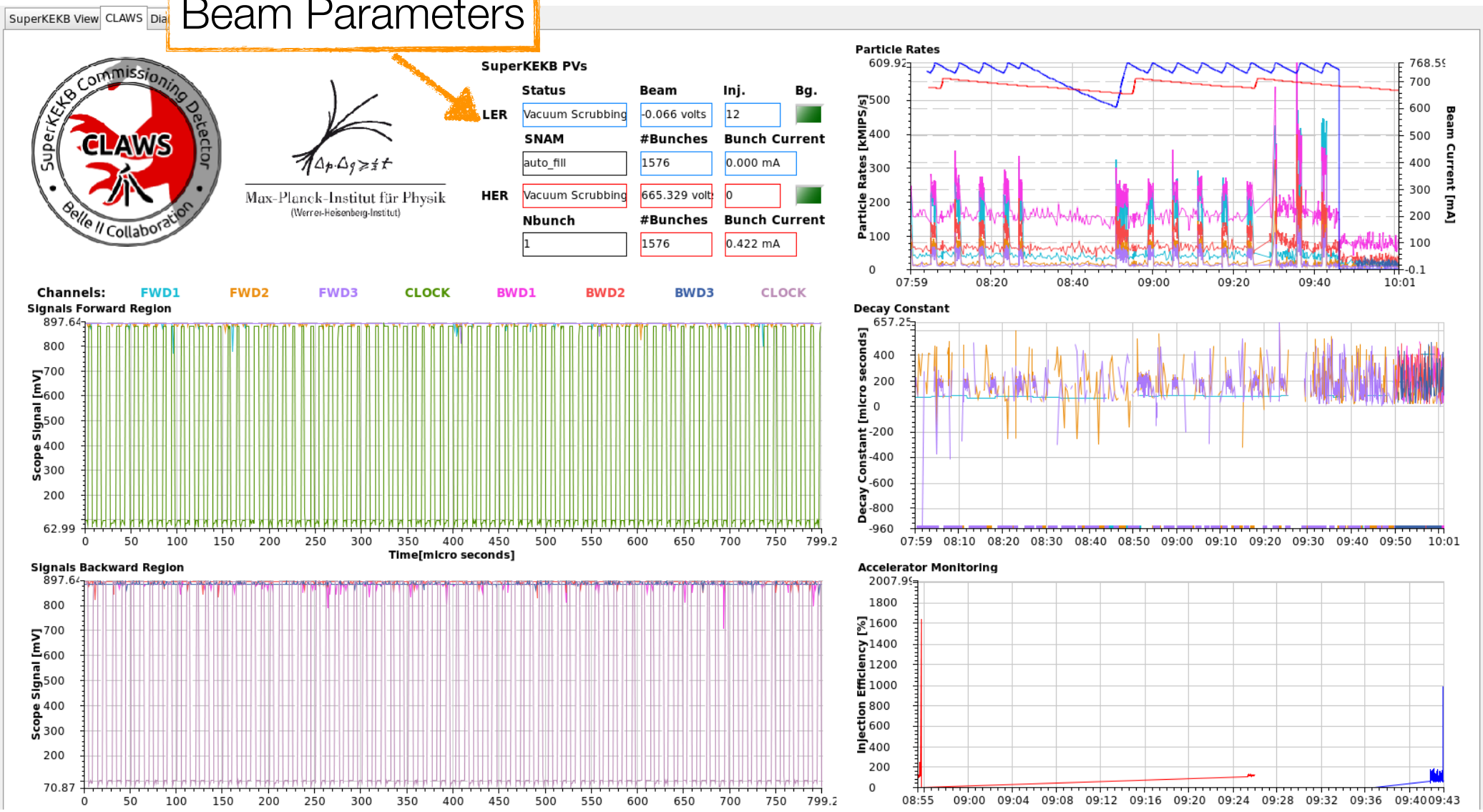
Beam Parameters



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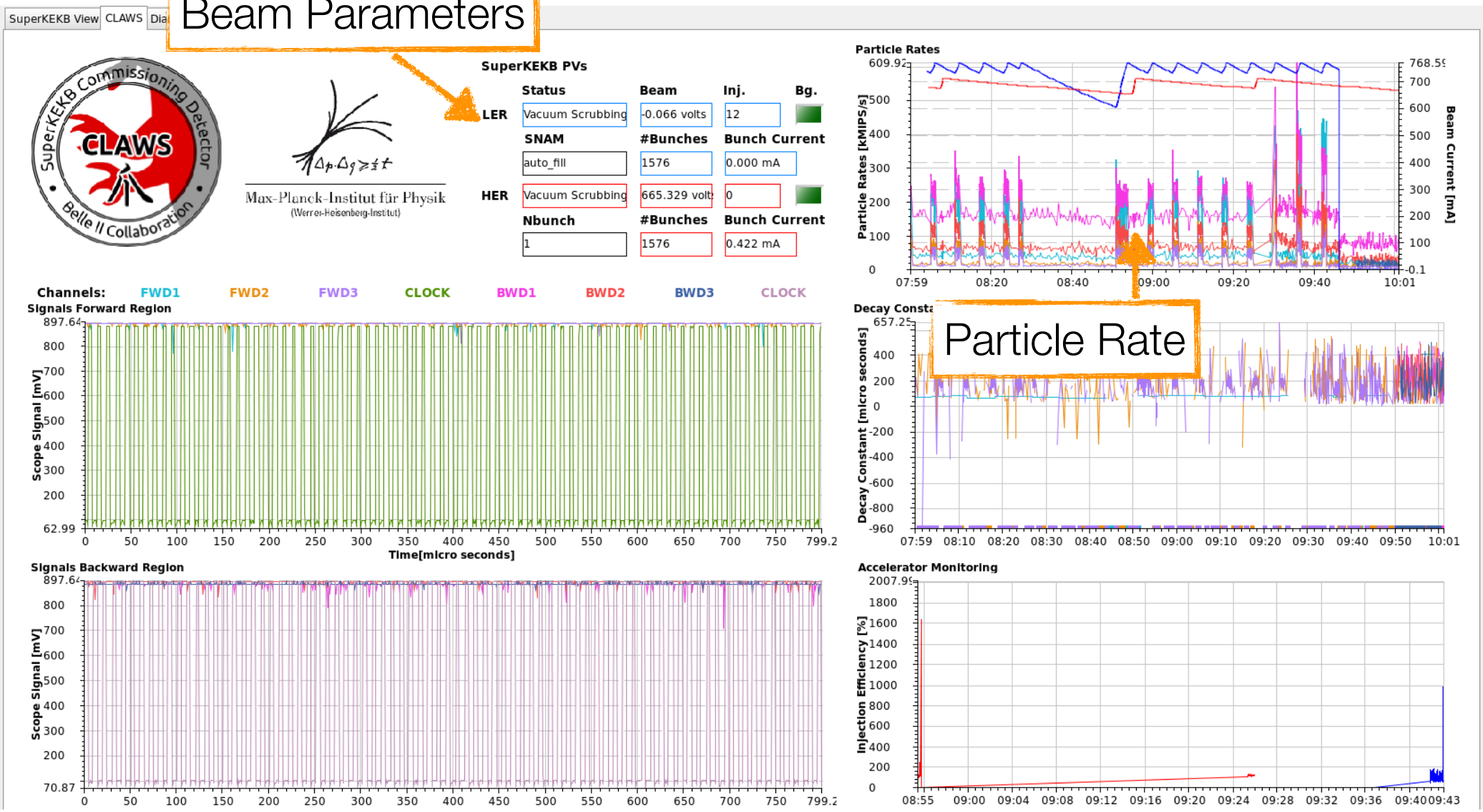

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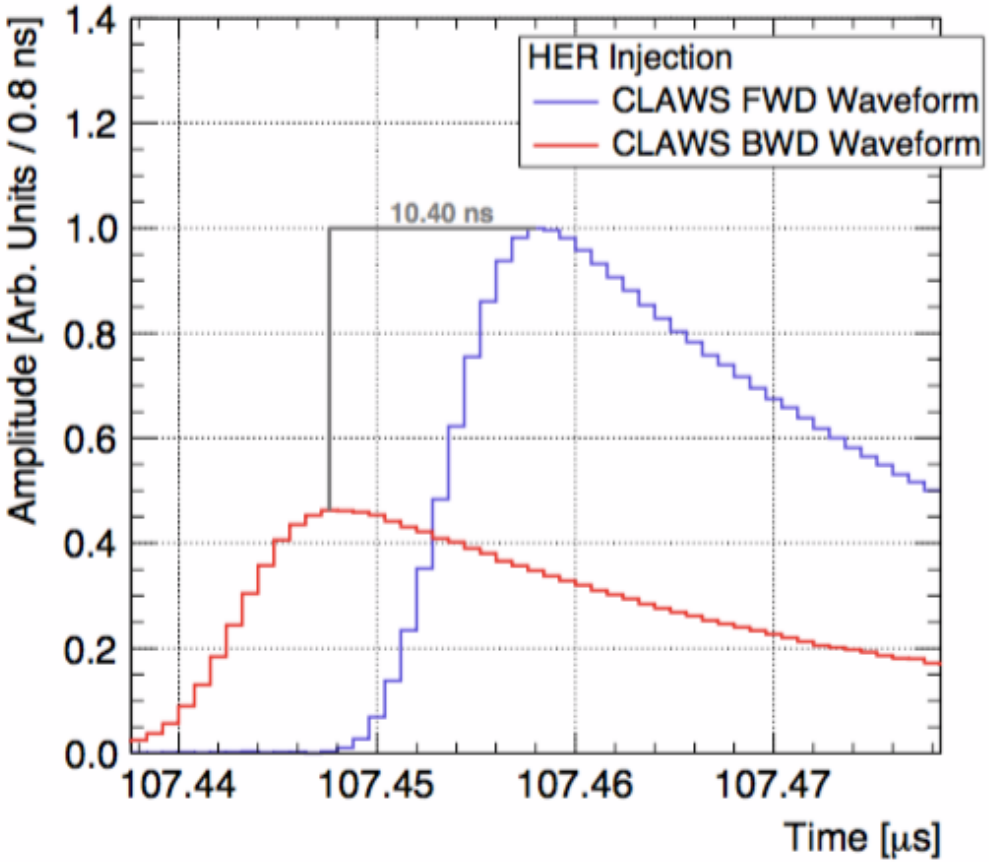
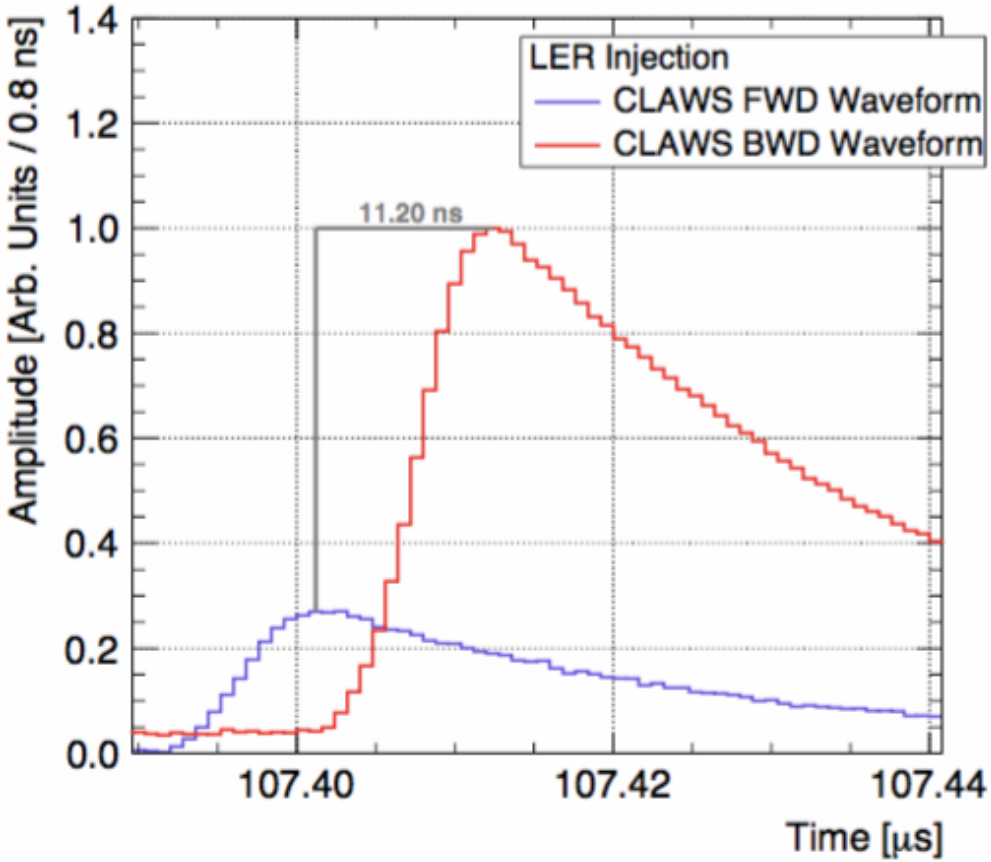
Geometry Check

PRELIMINARY

Sanity Check: Speed of light

- forward and backward region are about 3 m apart
  - bunches clearly distinguishable





Time Properties of the Beam

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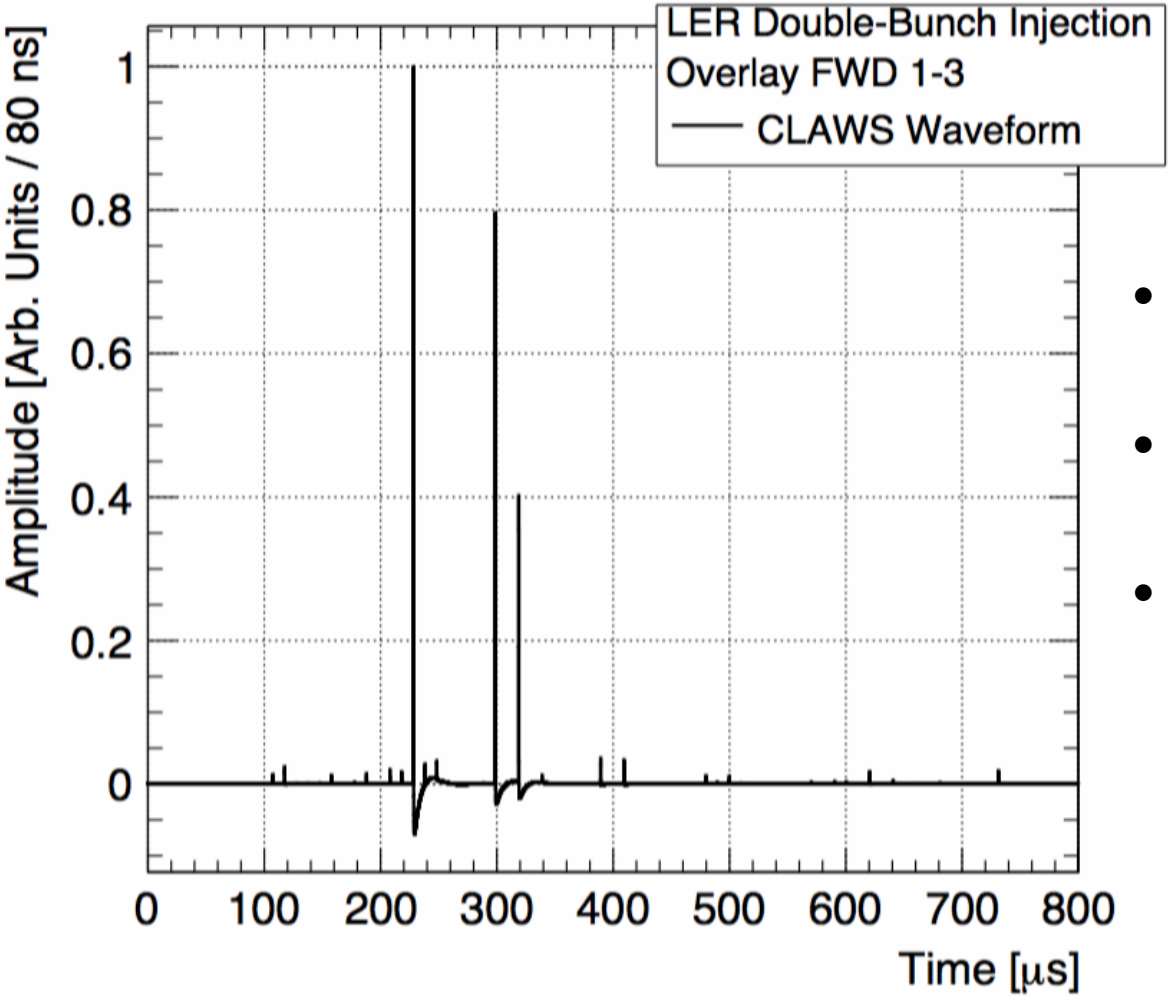
Injection background in LER



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- signals substantially reduced after 100 μs of high activity

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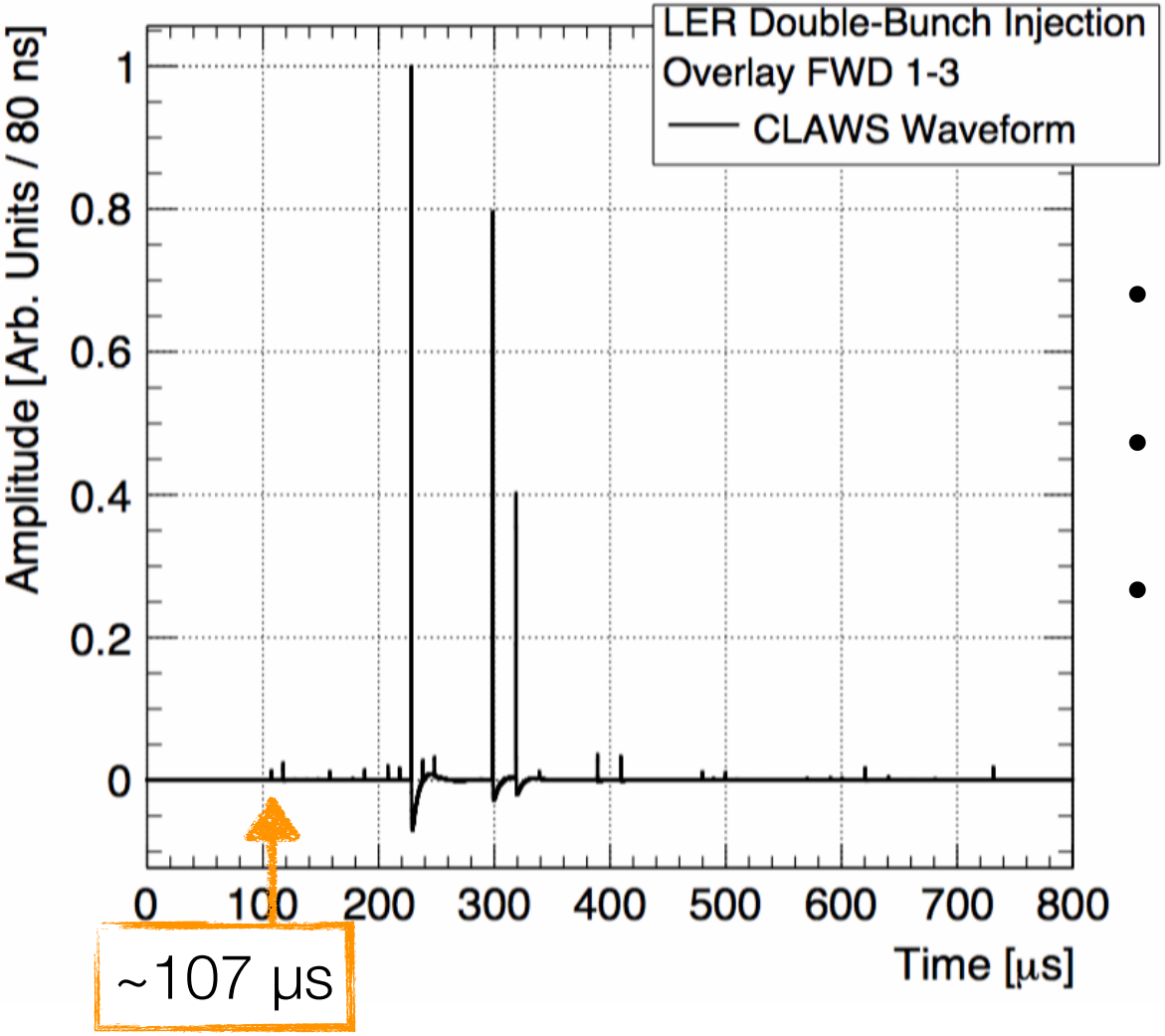

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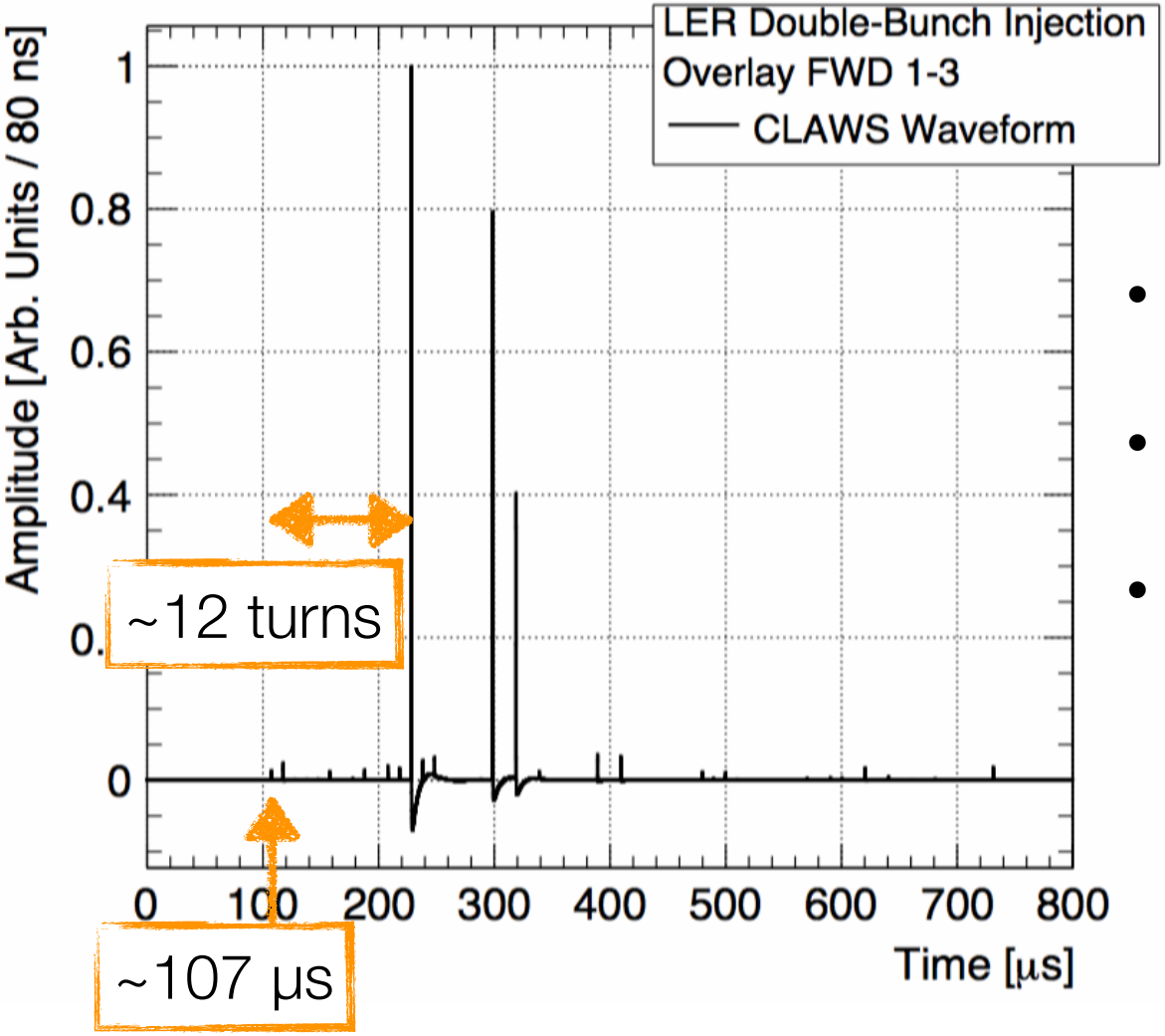

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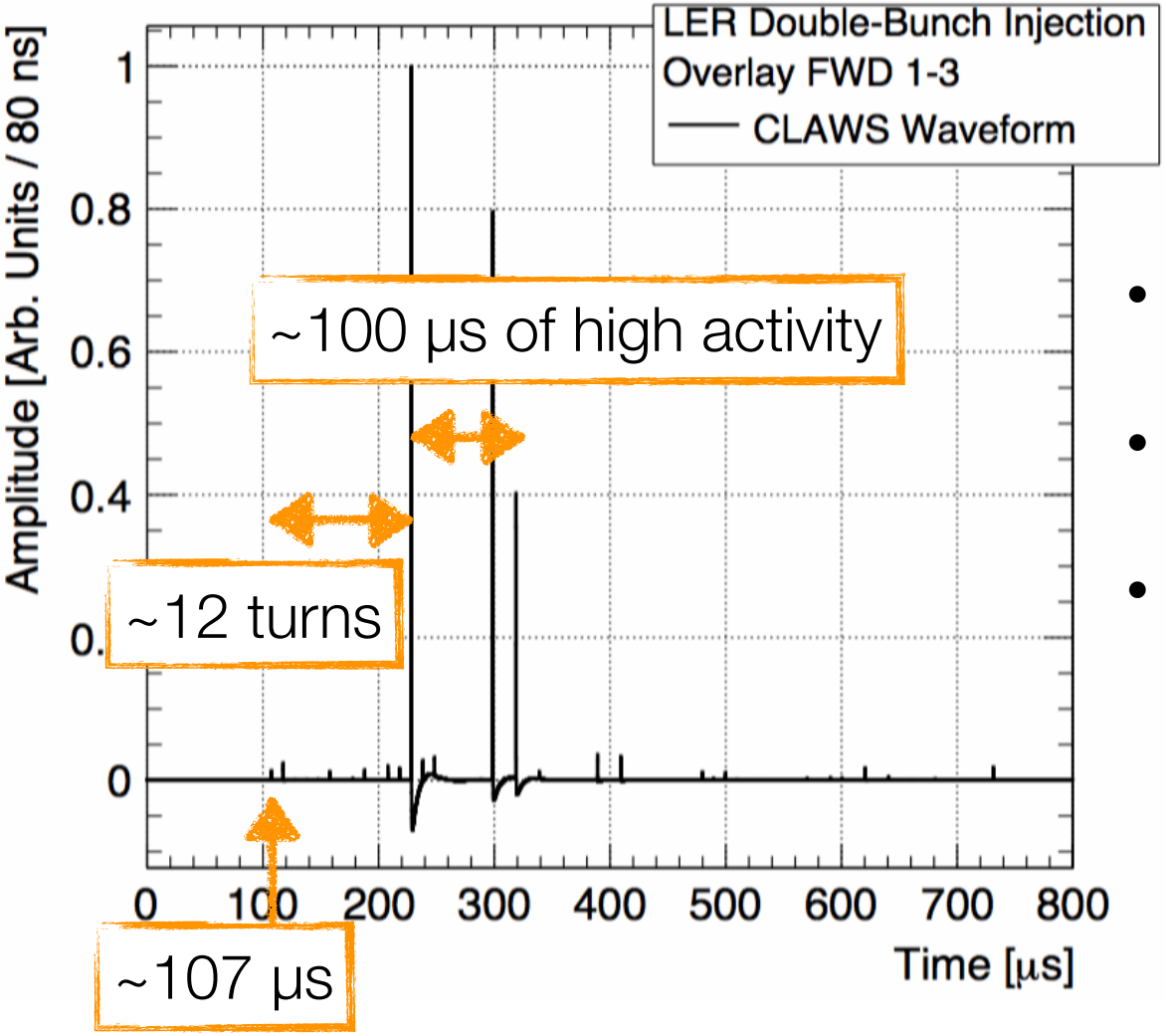

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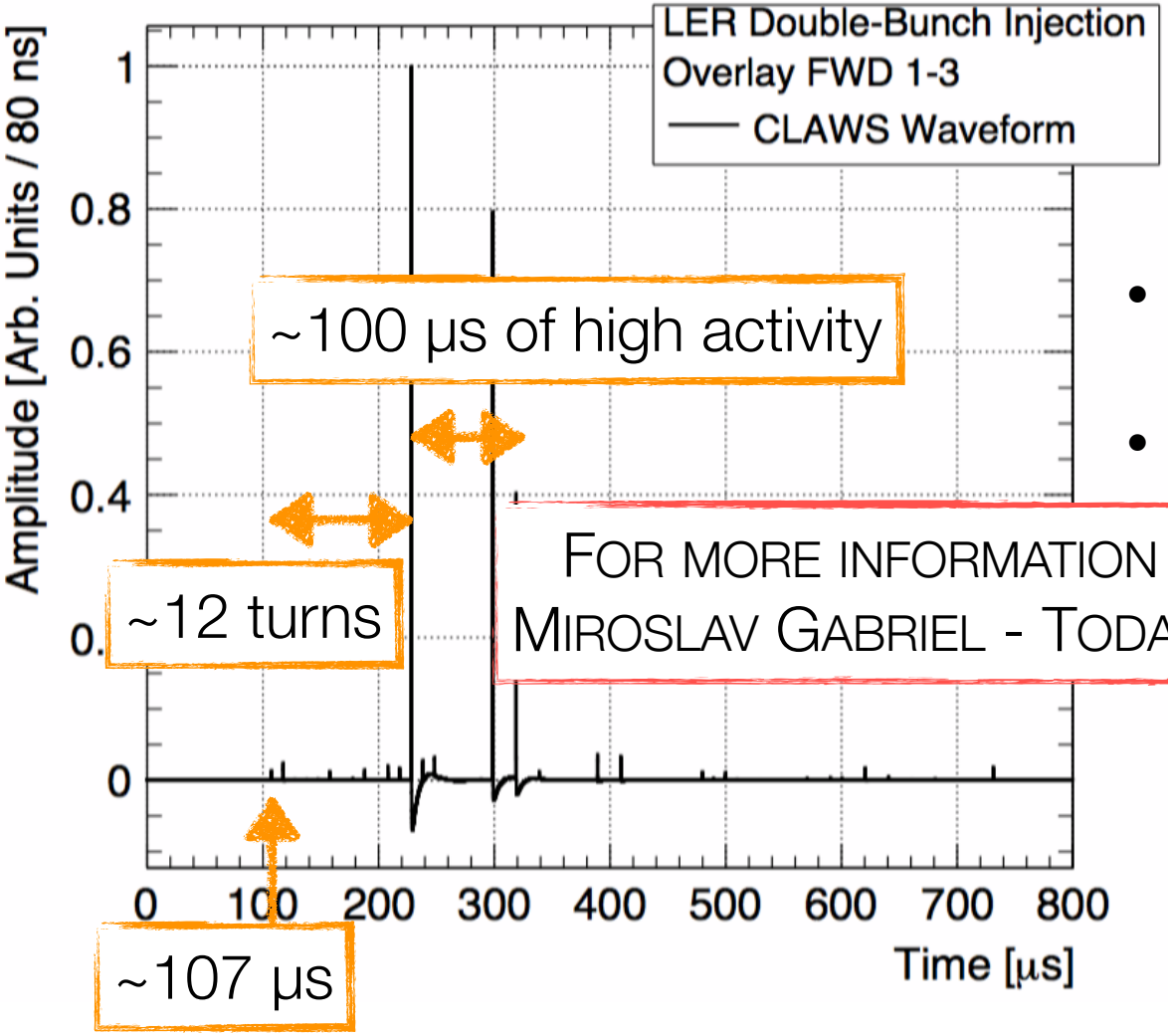

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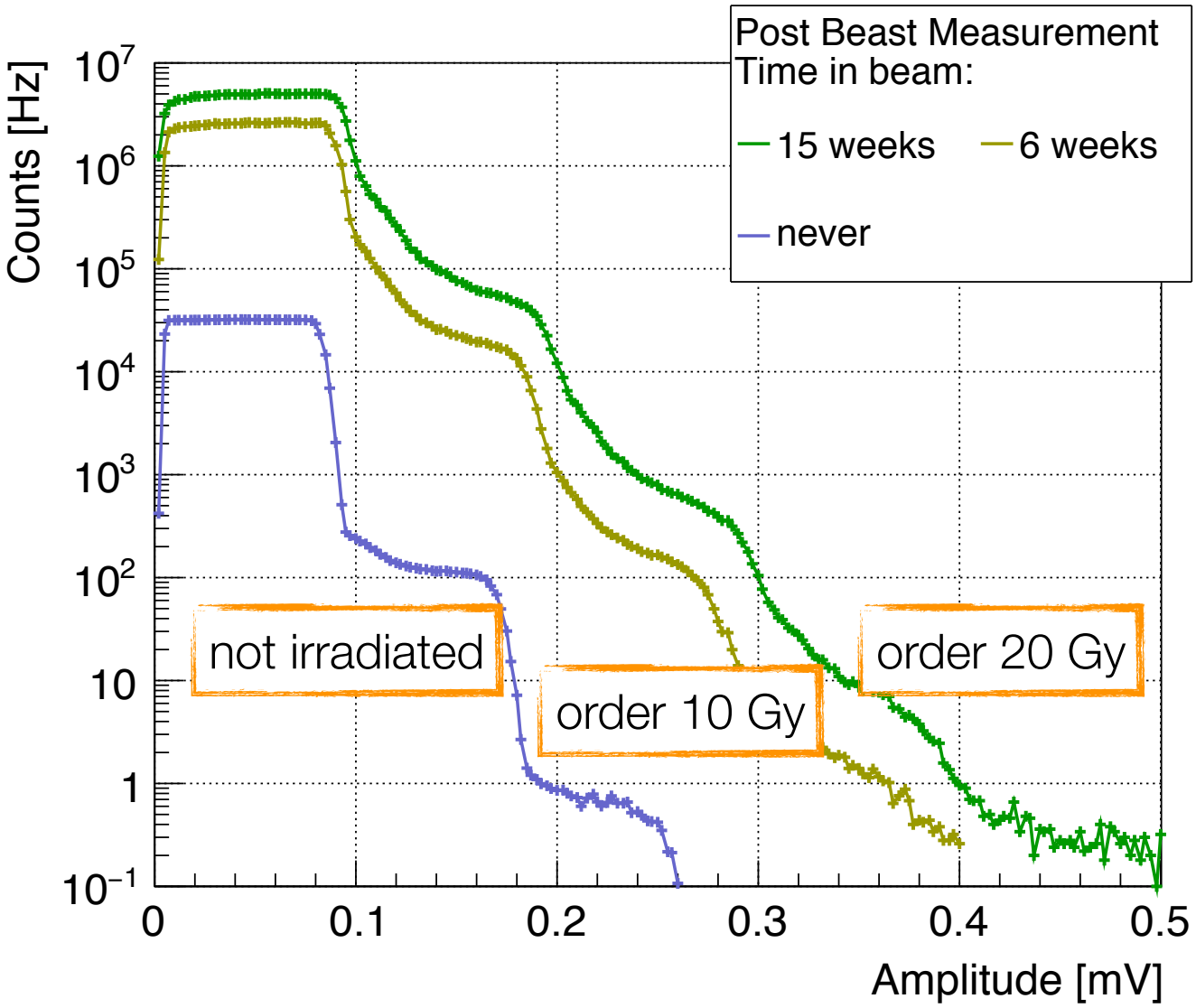
FOR MORE INFORMATION ABOUT PHASE 1 RESULTS:
MIROSLAV GABRIEL - TODAY AT 2:00 PM - ROOM305C

Radiation Effect on CLAWS

PRELIMINARY



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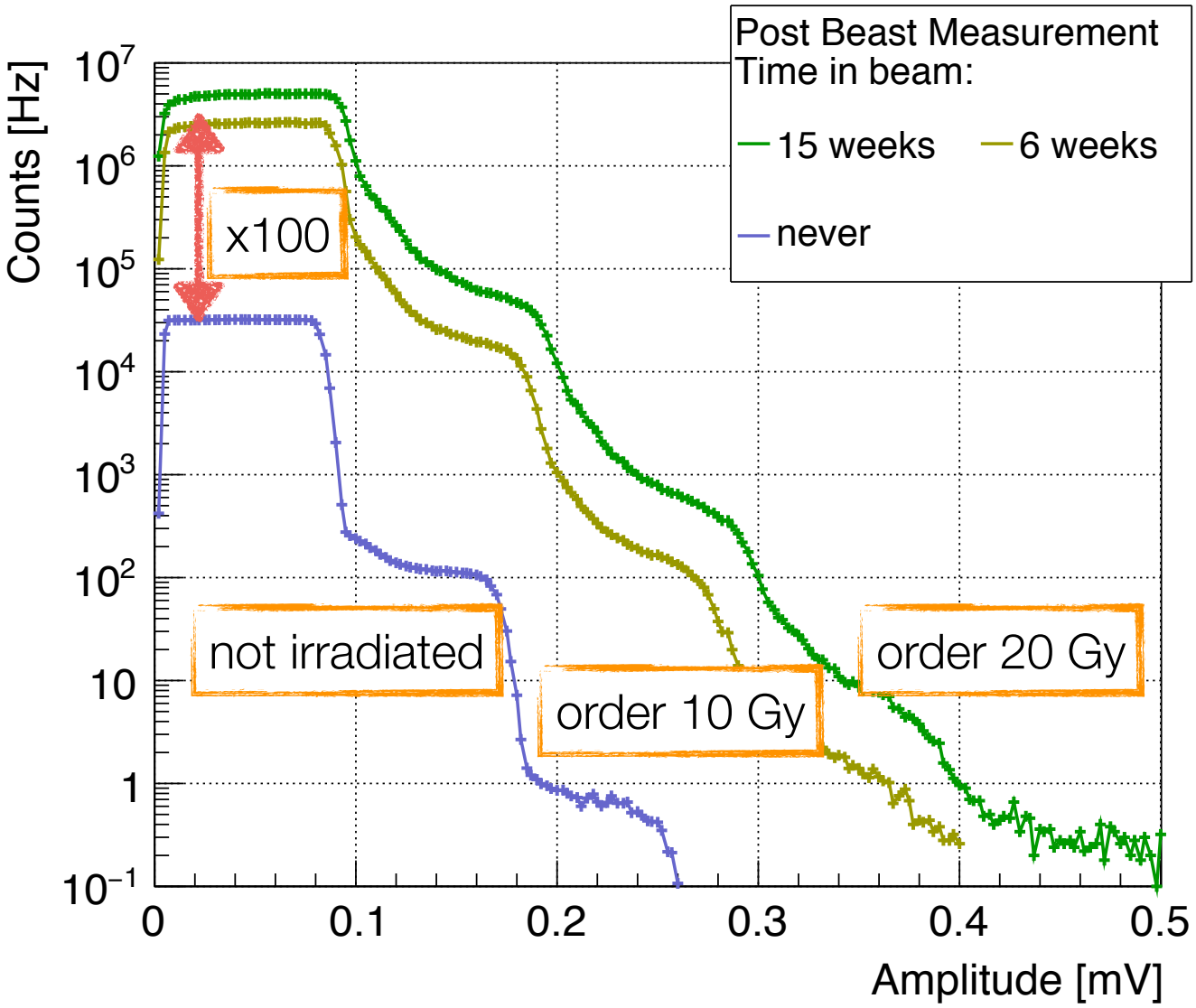

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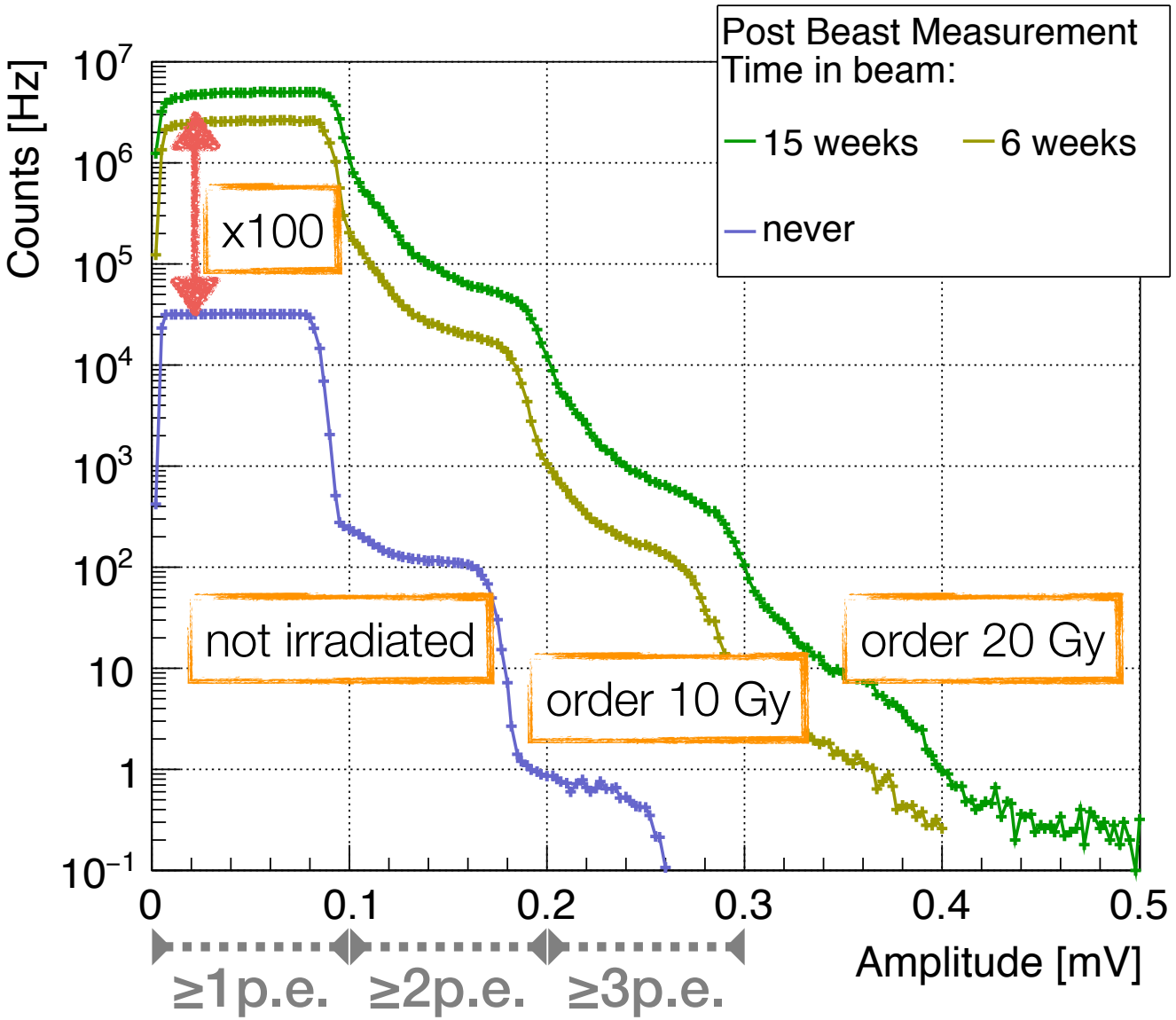

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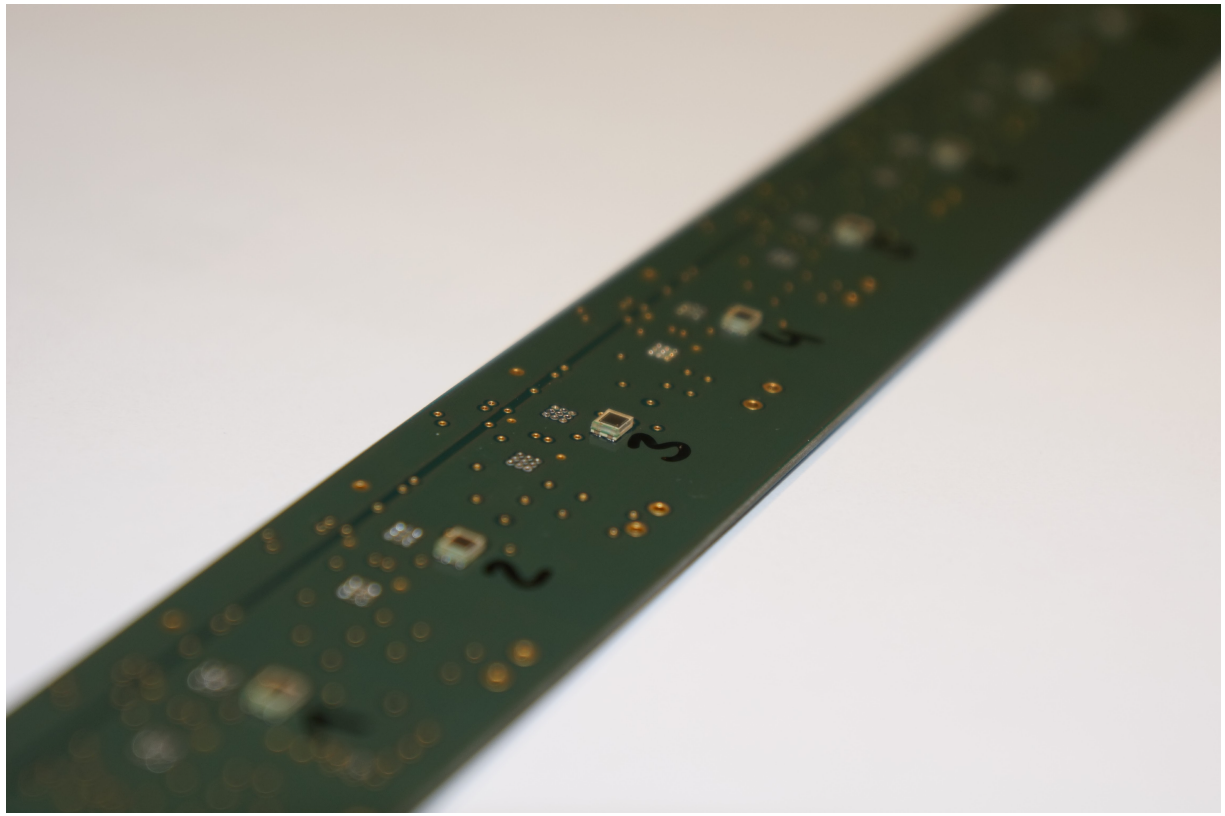

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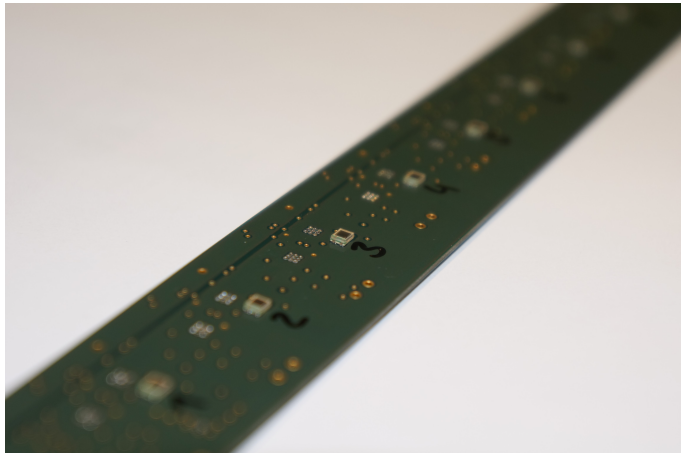

CLAWS for Phase II

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  - equipped with 8 sensors each
  - new low gain mode to increase dynamic range
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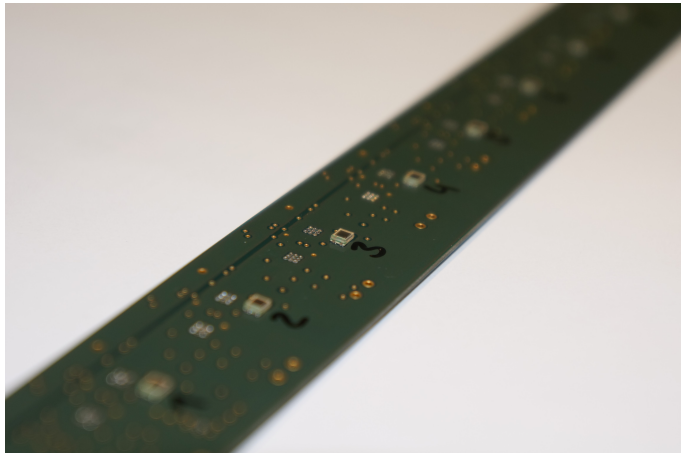

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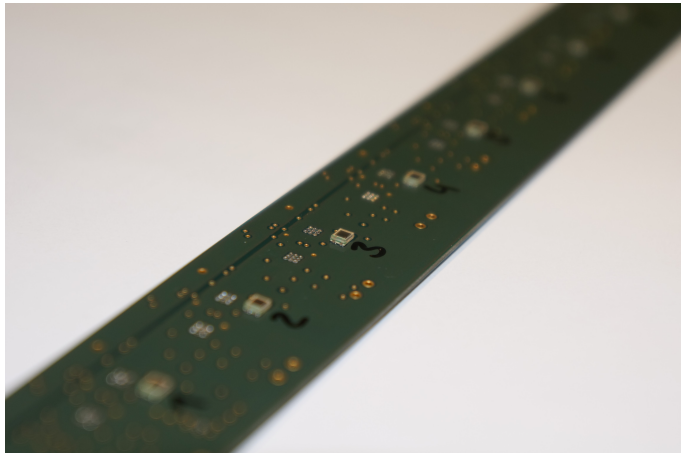
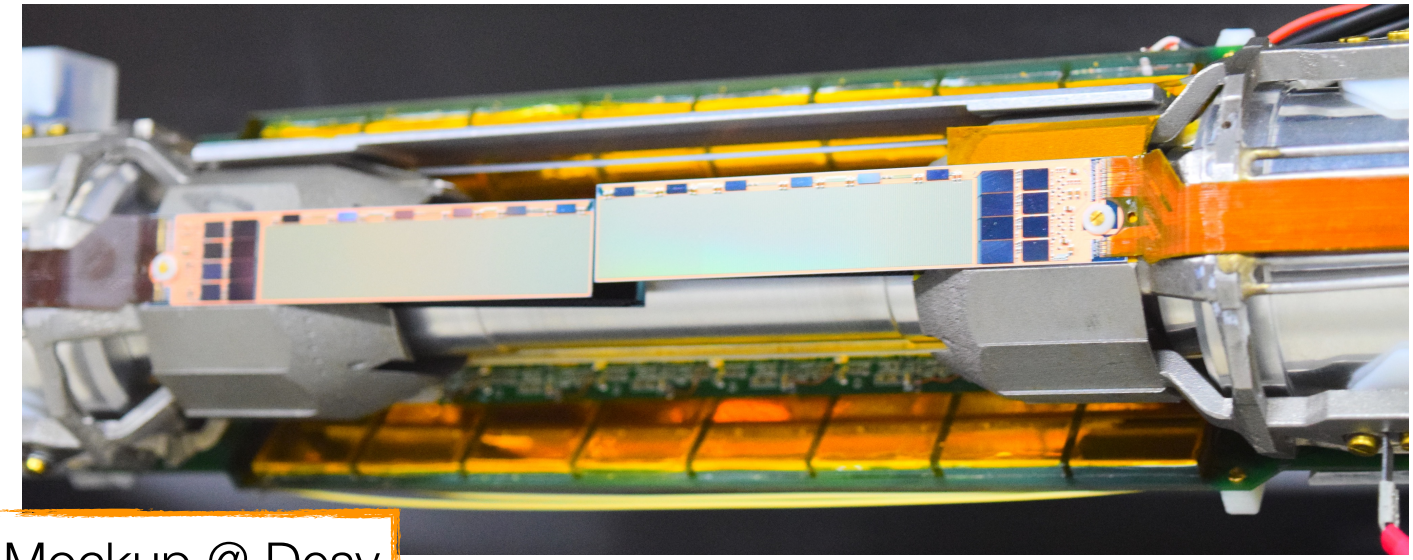




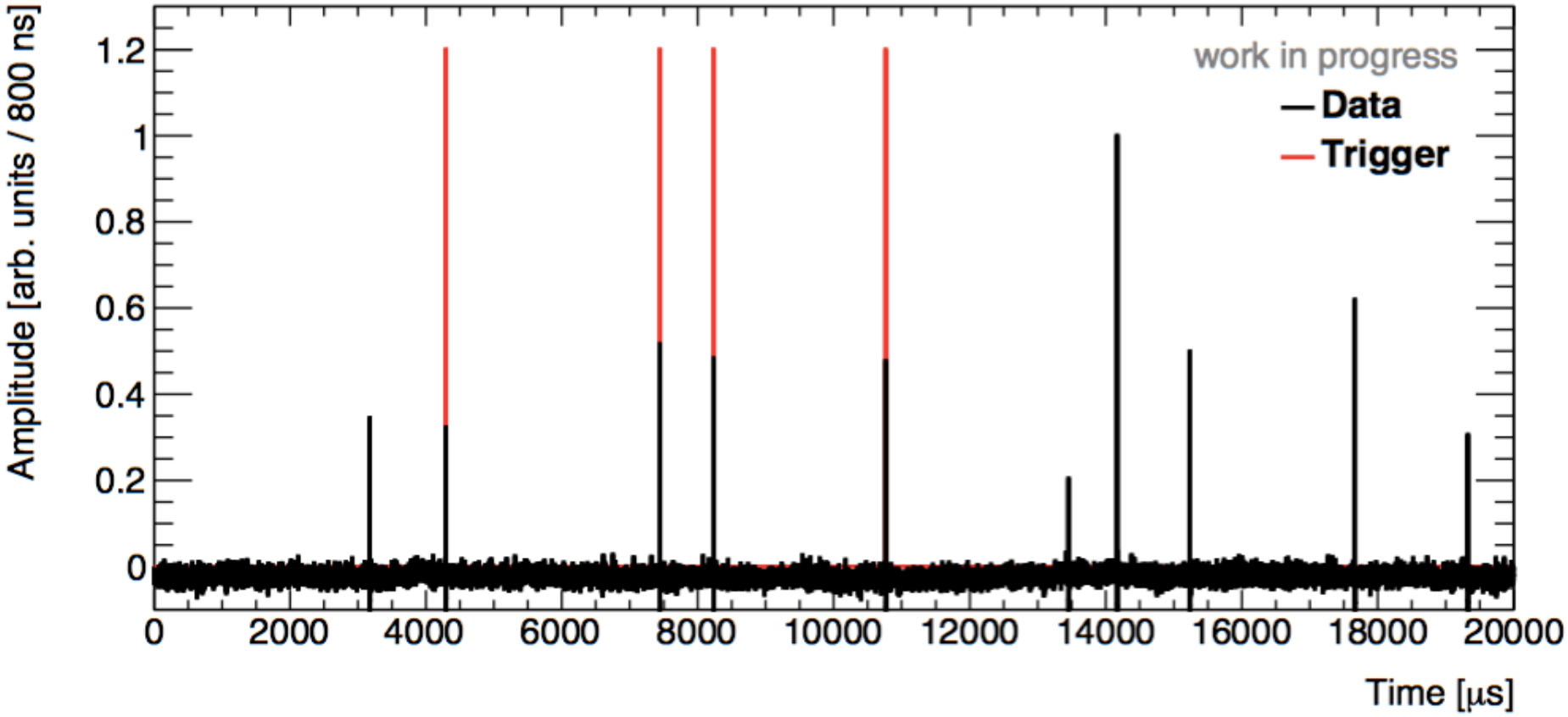
Mockup @ Desy

Testbeam @ Desy

PRELIMINARY

Electrons with up to 4 GeV at ~100 Hz

- 20 000 µs ~ 2000 particle revolutions in SuperKEKB (recorded with 800 ps sampling rate)



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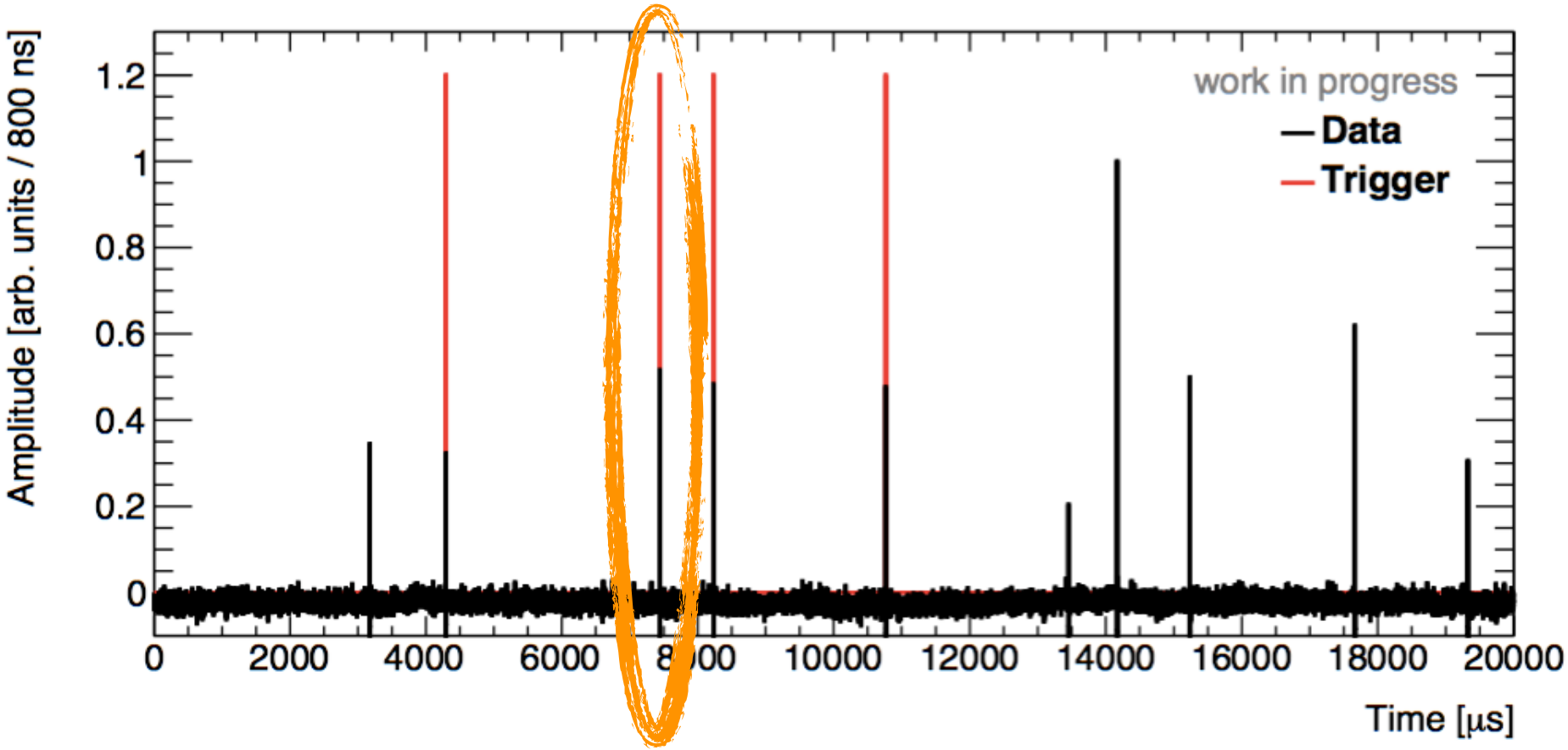

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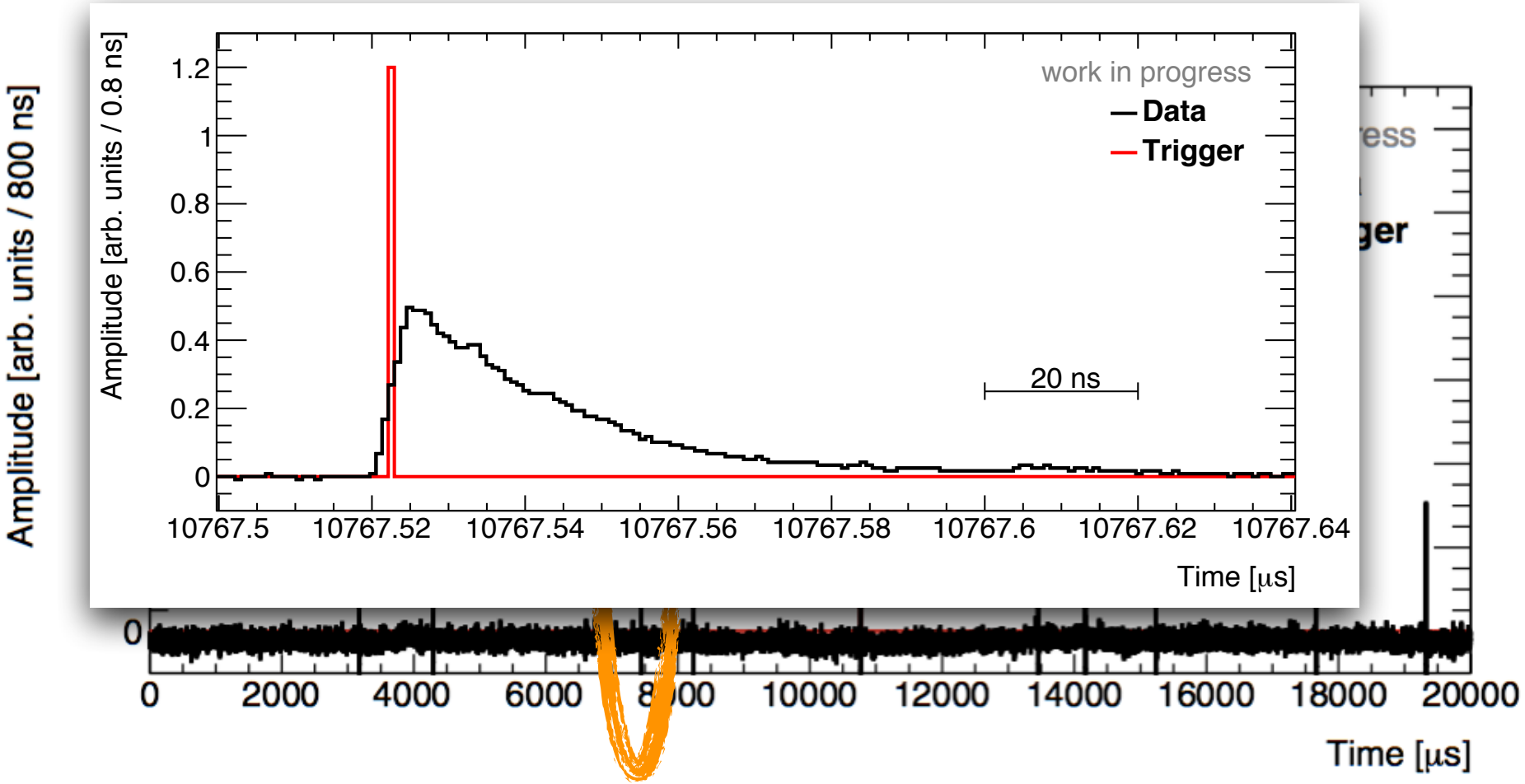
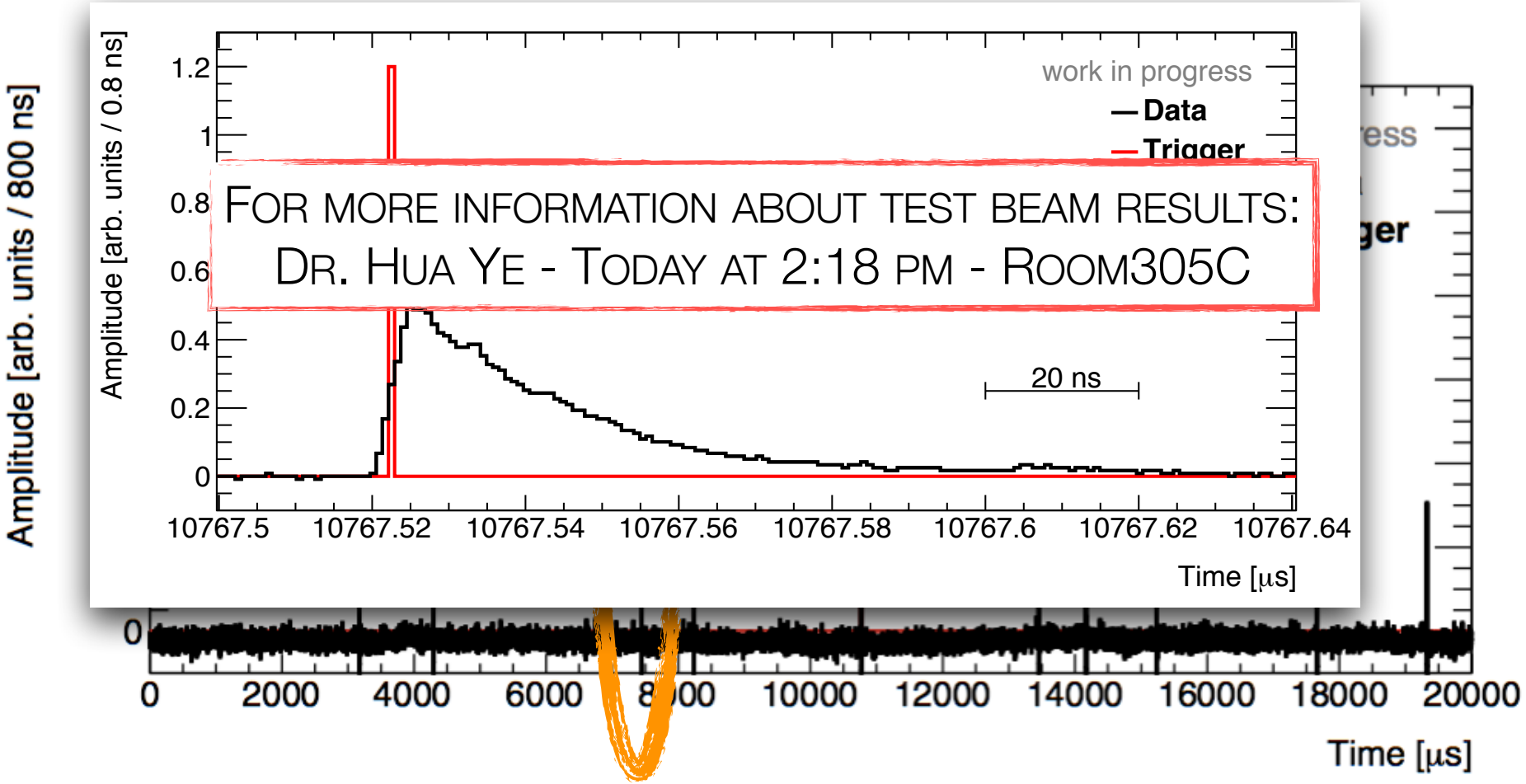


Testbeam @ Desy

PRELIMINARY

Electrons with up to 4 GeV at ~100 Hz

- 20 000 µs ~ 2000 particle revolutions in SuperKEKB (recorded with 800 ps sampling rate)



FOR MORE INFORMATION ABOUT TEST BEAM RESULTS:
DR. HUA YE - TODAY AT 2:18 PM - ROOM305C

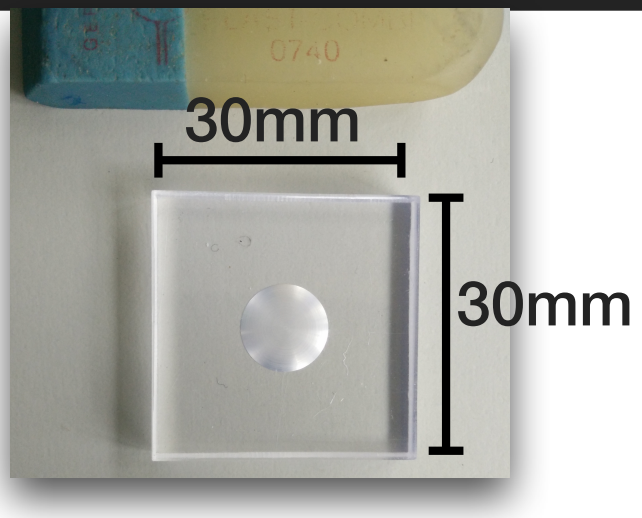
Summary & Outlook

- Commissioning of the SuperKEKB accelerator started in Feb 2016
  - ➡ CLAWS measured timing properties and particle rates (charged particles)
- the sub-nanosecond resolution is capable of detecting single bunches
  - ➡ the radiation damage in the SiPMs is manageable

- Commissioning Phase II starts in Feb 2018
  - Belle II detector on the beam line without final inner detectors
  - CLAWS in a modified version will take part in Phase II
    - ➡ the test beam @ Desy, Hamburg was successful
    - ➡ equivalent of 2000 particle revolutions in SuperKEKB were recorded in one single waveform

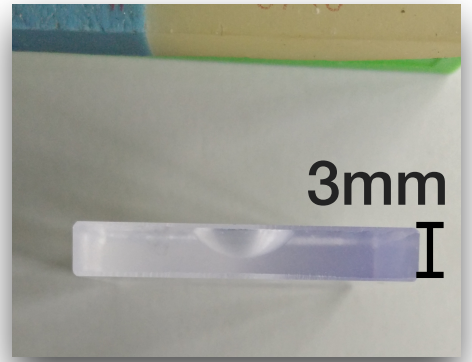
BACKUP!

The CLAWS Detector



- scintillator shape taken from CALICE hadron calorimeter for ILC
  - material: POPOP doped Polystyrene
  - mostly sensitive to charged particles
  - wrapped in reflective foil

The CLAWS Detector



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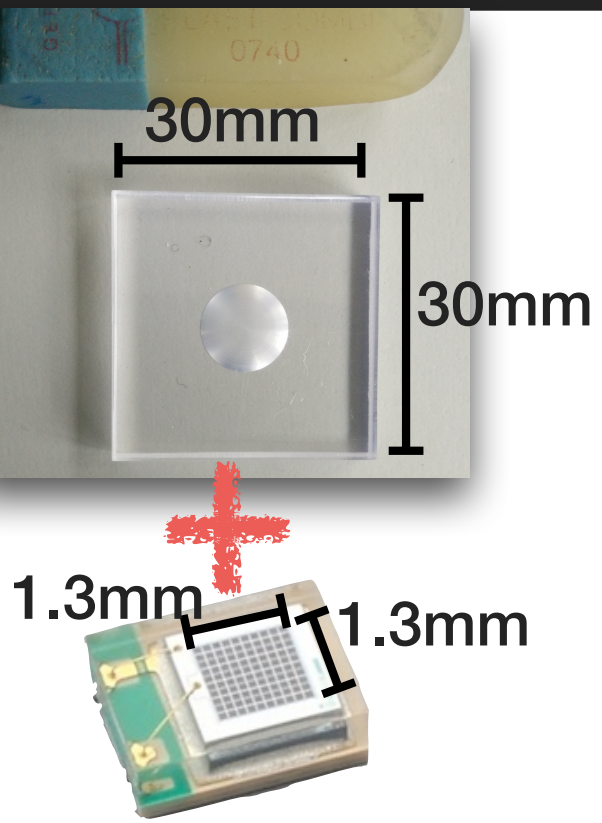

- scintillator shape taken from CALICE hadron calorimeter for ILC
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- Hamamatsu MPPC-1325PE SiPM
  - 2668 pixel
  - low noise: <1 Hz for 3 p.e.
  - operating voltage: 56 V
    - overvoltage: 2.5 to 3.5 V

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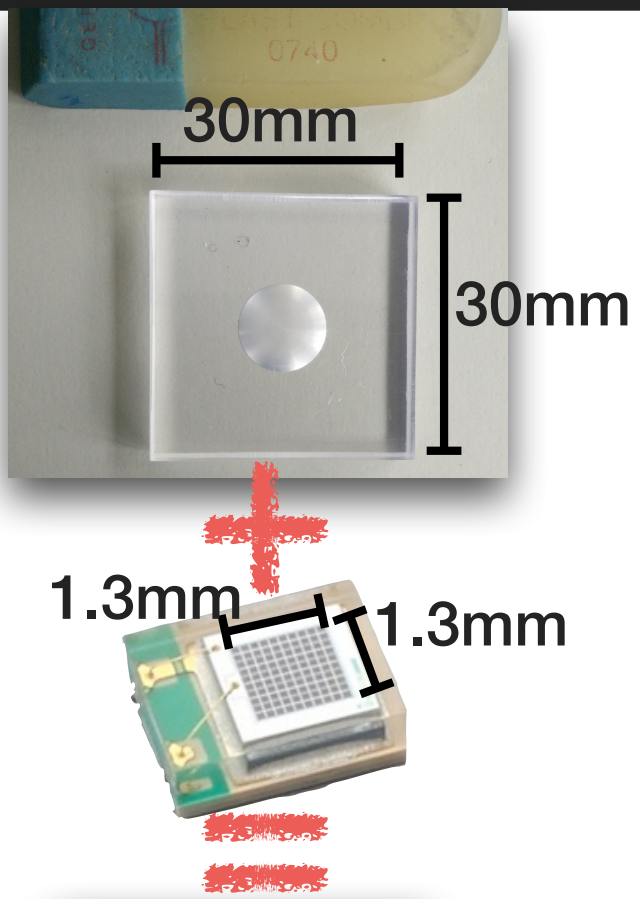

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➡ light tight CLAWS detector
  - scintillator and SiPM attached on PCB with onboard preamplifier

The CLAWS System

Keysight 6700N

- modular power system with 4 slots
  - 2x N6733B with V_{max} = 20 V & I_{max} = 2.5 A
    ➡ powering the preamp & amp
  - 2x N6736B with V_{max} = 100 V & I_{max} = 0.5 A
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Picoscope 6404D

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- 8 bit vertical resolution
- 800 ps sampling time
- 2 GB buffer to record up to 40 ms per channel in continuous waveform

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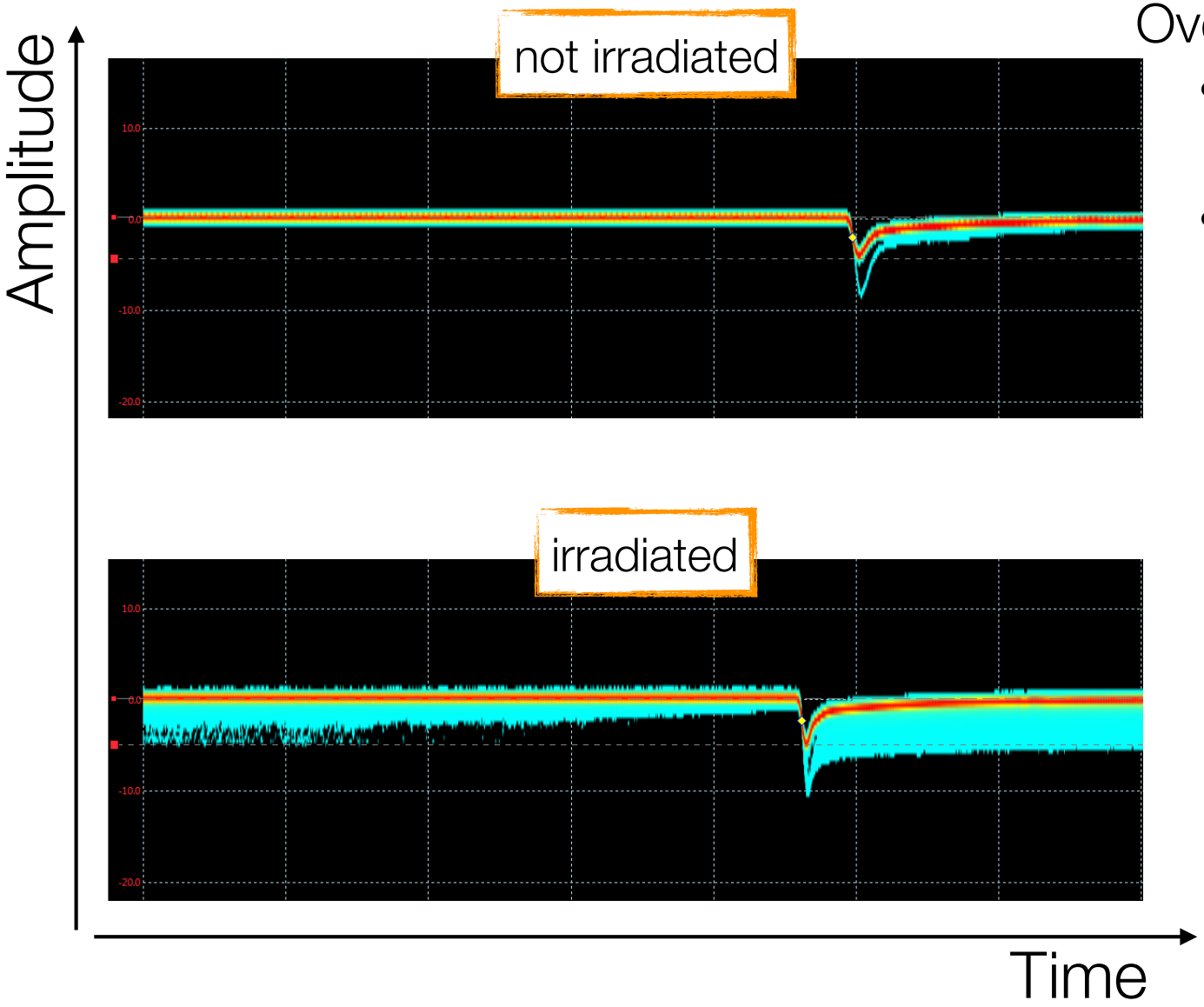
Workstation

- Windows 7
- 12 core workstation with 32 GB ram
- Labview based data acquisition software
  - steering power supply and oscilloscope
  - offers a live monitor with online analyzed data

Radiation Effect on Claws

WORK IN PROGRESS



Overlay of waveforms unveils

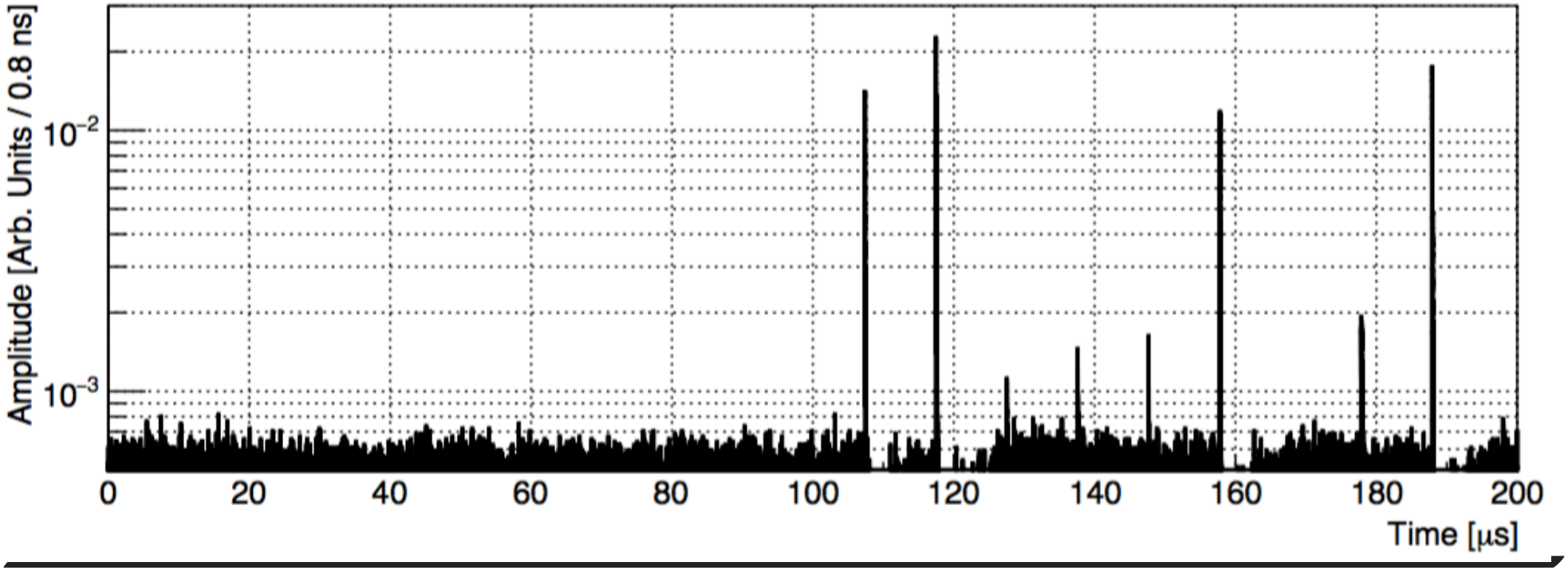
- higher dark rate due to radiation damage
- clearly visible for 1 p.e.

First Arrival of Particles

PRELIMINARY

Injection background in LER with double bunch injection

- zoom into the first 200 μs
  - first signal arrives ~107 μs after trigger
  - mostly after every turn a signal
    - ➡ signal at 167 μs is missing
    - ➡ signal at 197 μs is not clearly visible
    - ➡ Betatron oscillation frequency is 44.59/Turn in LER (horiz.)



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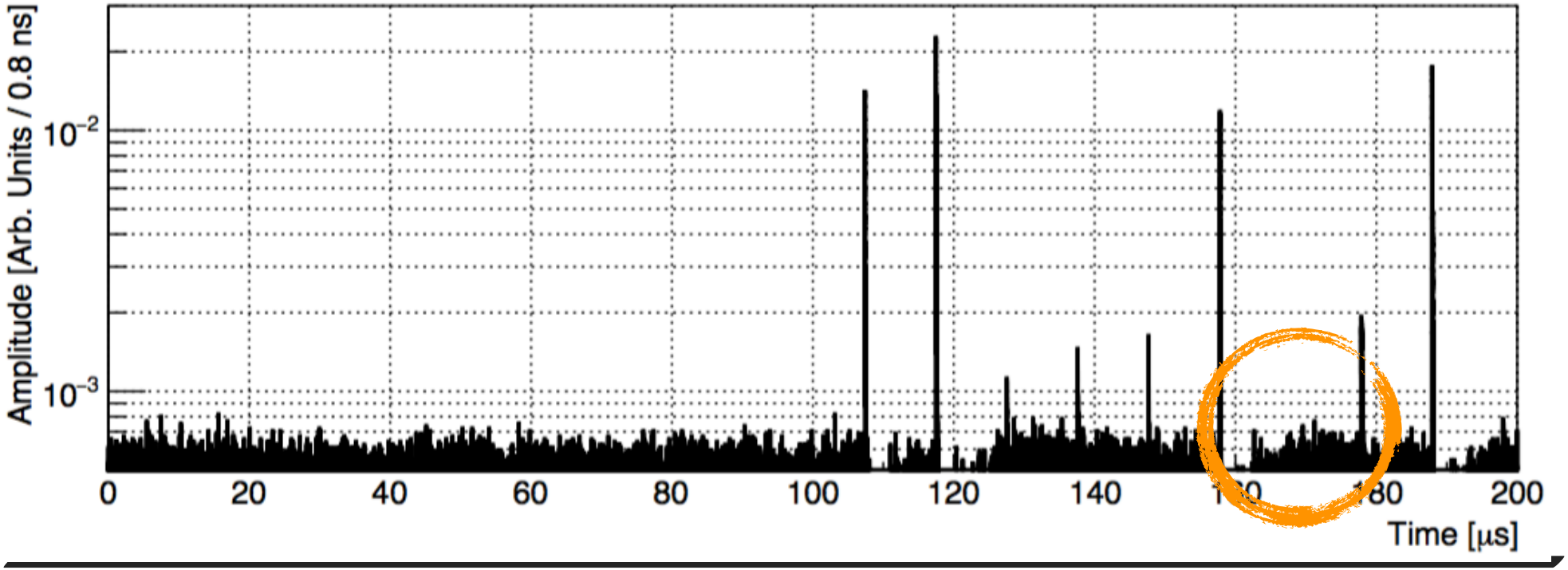

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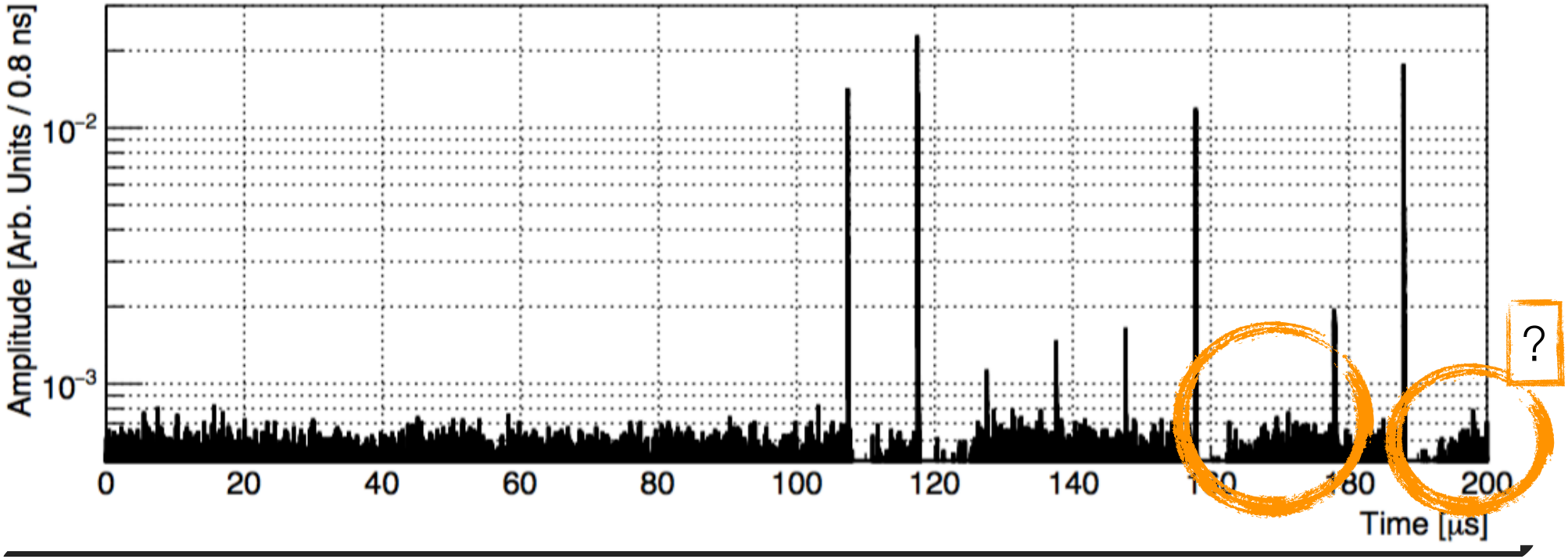

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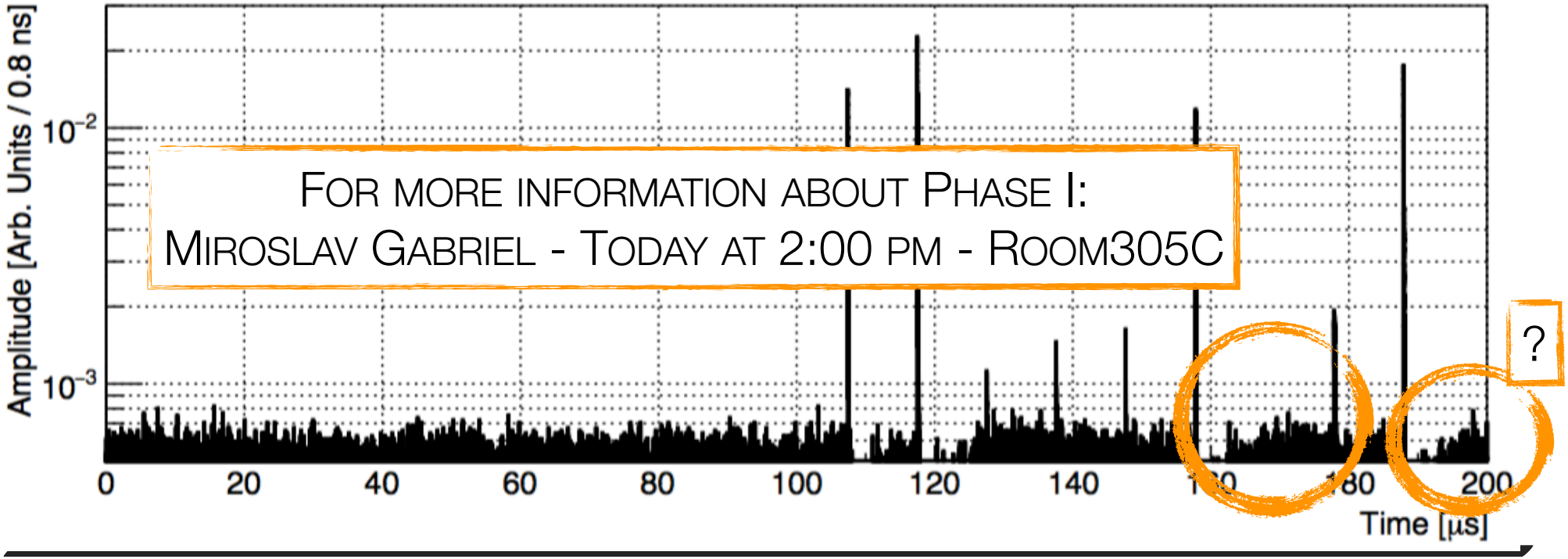
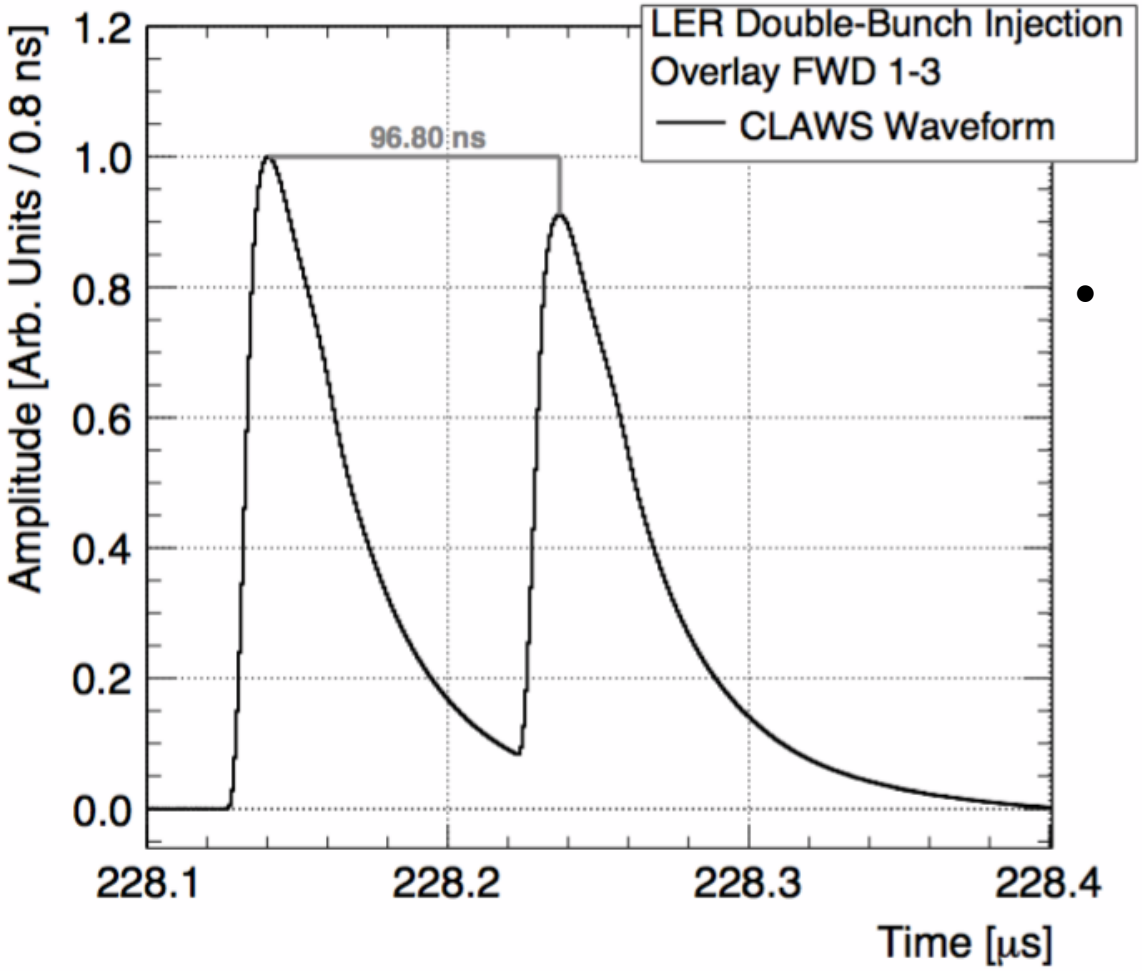


FOR MORE INFORMATION ABOUT PHASE I:
MIROSLAV GABRIEL - TODAY AT 2:00 PM - ROOM305C

Double Bunch Spacing

WORK IN PROGRESS

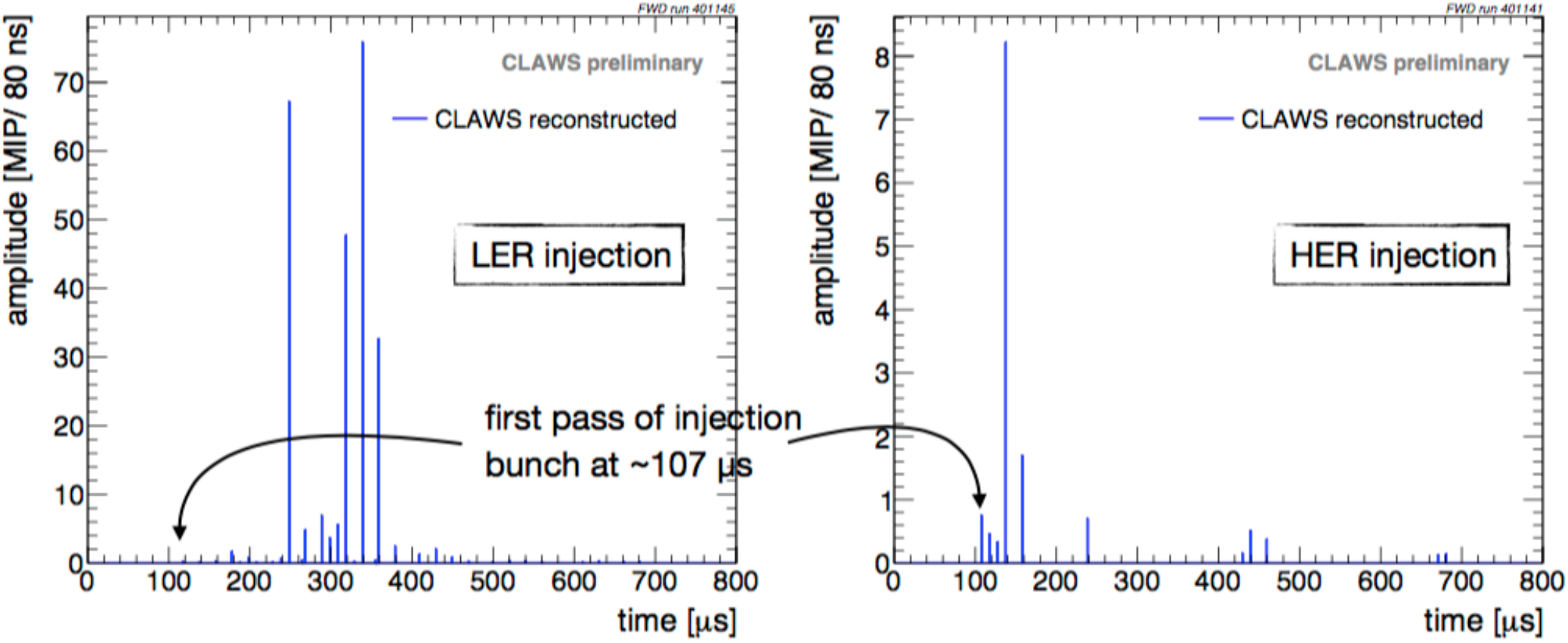
Injection background in LER with double bunch injection



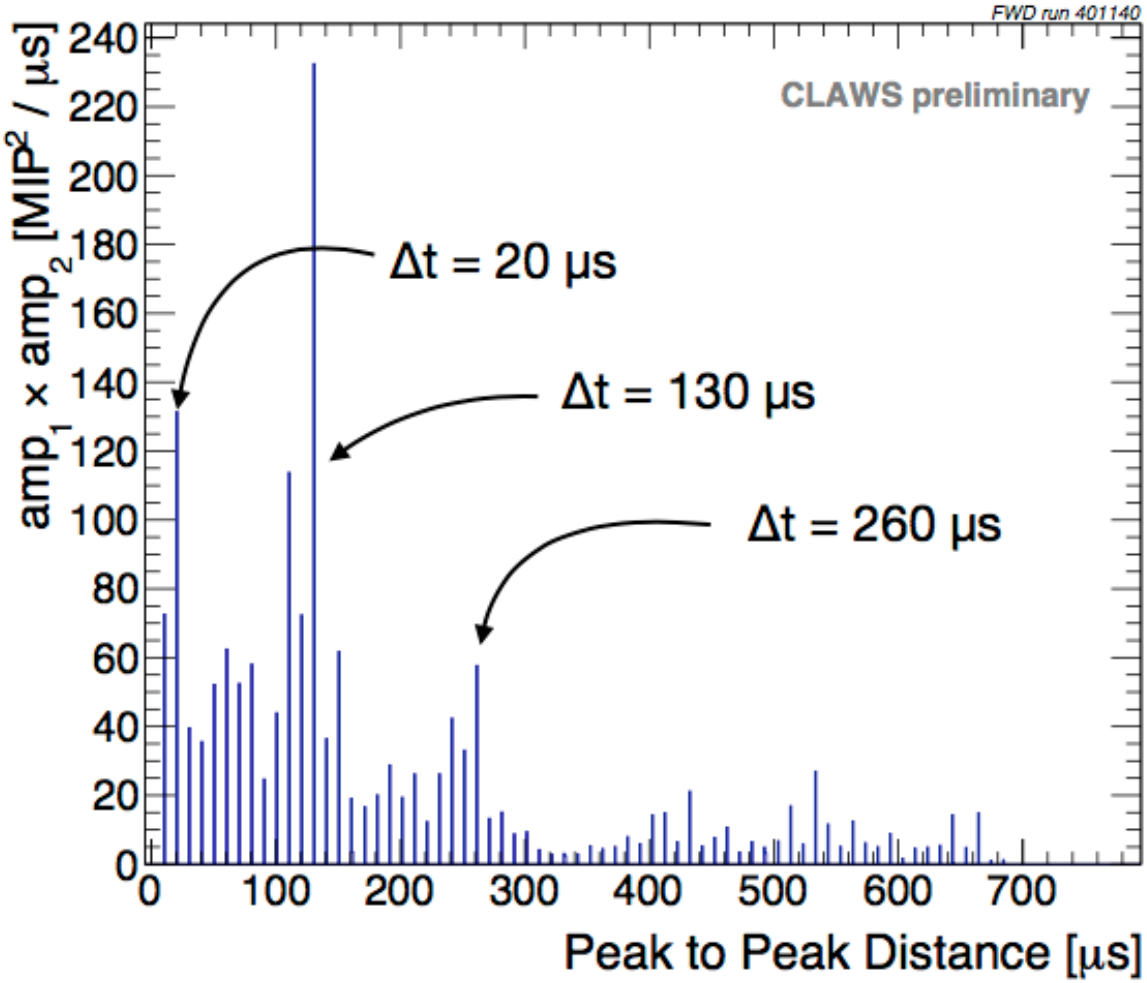
- design distance of two bunches in a double bunch injection is 96.285 ns
  - ➡ measured distance in agreement with the design value

Reference Injection: LER vs. HER

- General observation:
  - ➡ LER injection results in much higher backgrounds than HER injection
  - ➡ very different timing behavior; HER background appears promptly, LER with substantial delay



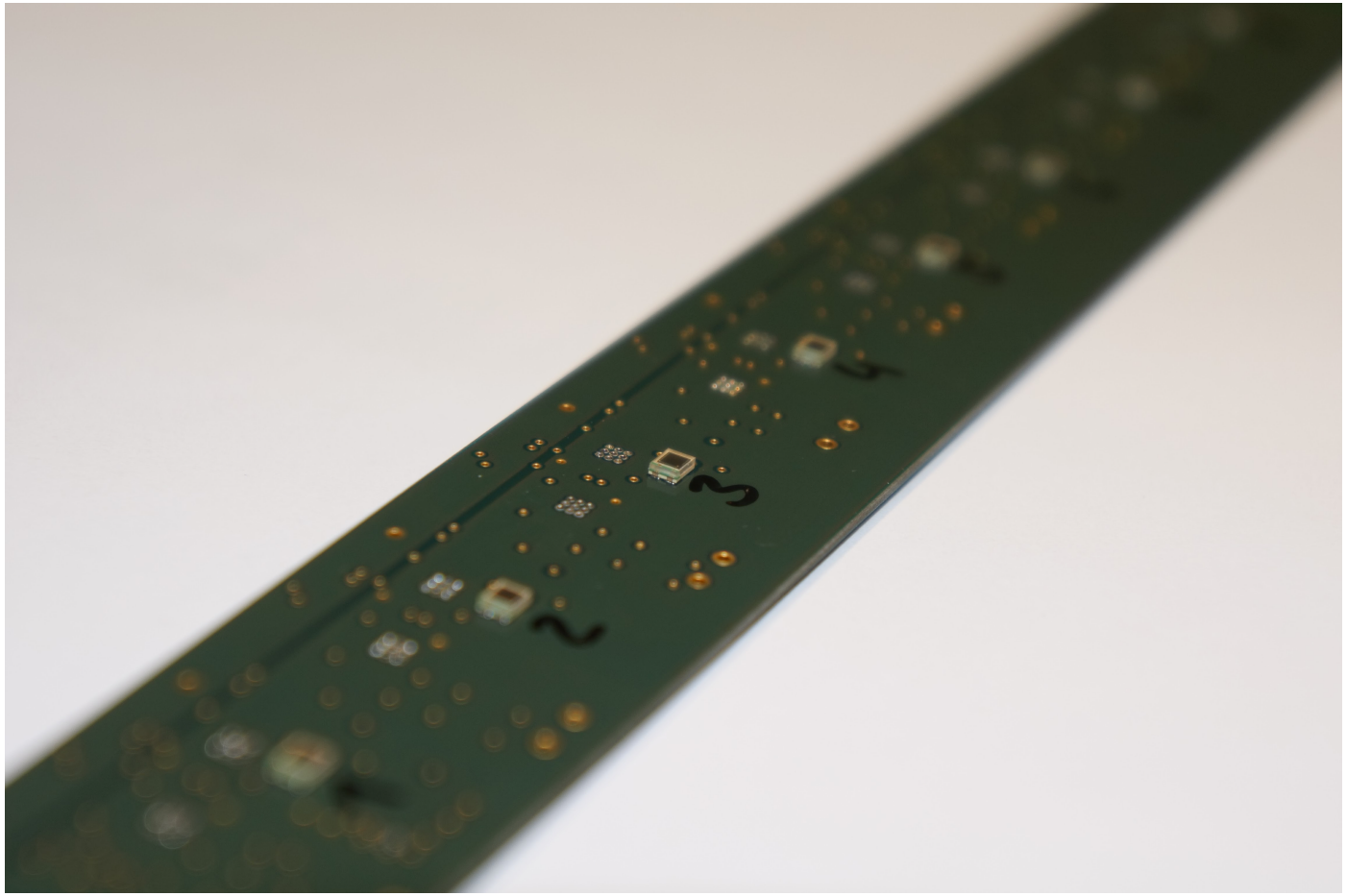
A closer look at HER



Identify patterns in the time structure of injection signals:

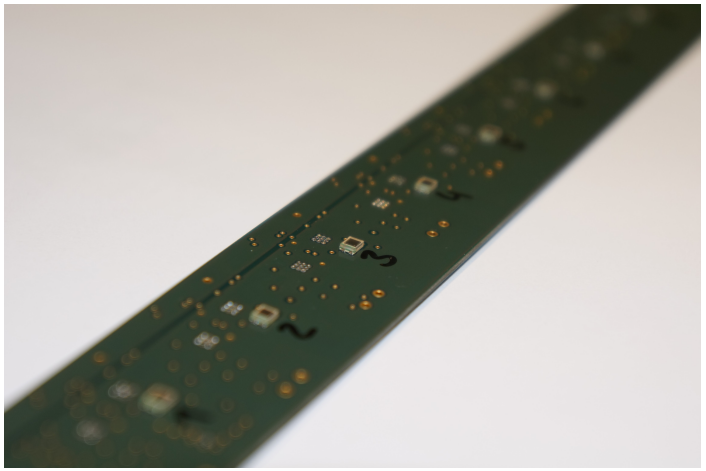
- plot dt for all bin pairs, weighted by the product of amplitudes
- 130 μs super structure
- on-off pattern in background

CLAWS Phase II



CLAWS Phase II

- Phase II (start early 2018)
  - Belle II rolled in without final inner detectors (SVD & PXD)
  - final quadrupole magnets are operating



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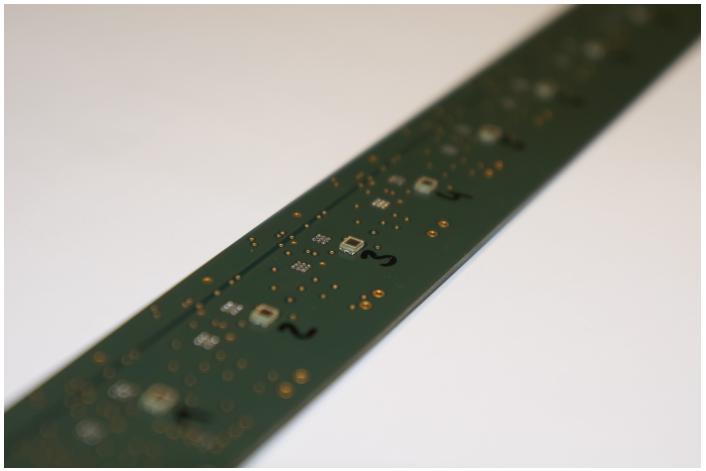

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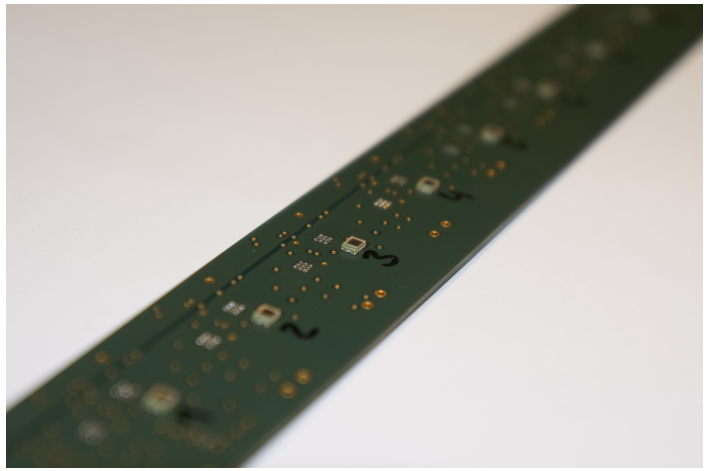
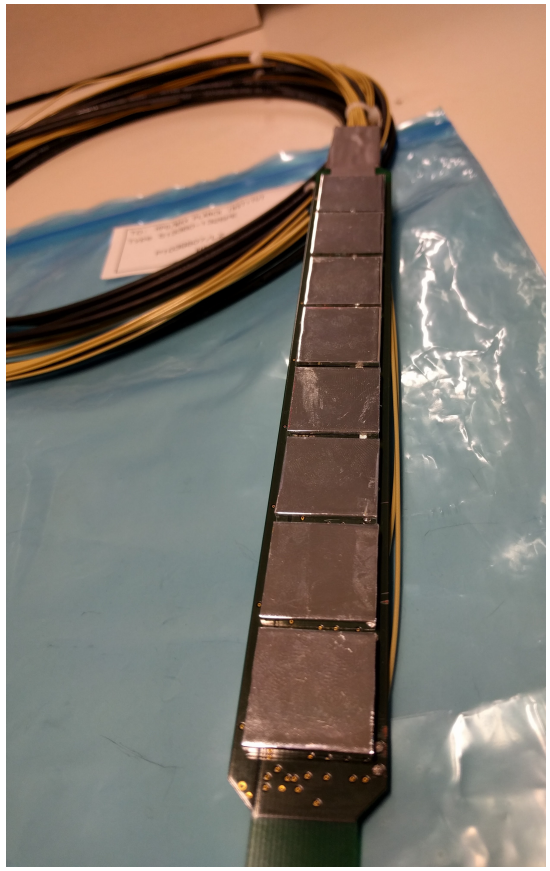
    - equipped with 8 sensors each
    - replaces 2 ladders of the outer pixel detector
    - new low gain mode to increase dynamic range





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