CLAWS: Beam background monitoring in the commissioning of SuperKEKb

Dpa-Frühjahrstagung 2016
Hamburg

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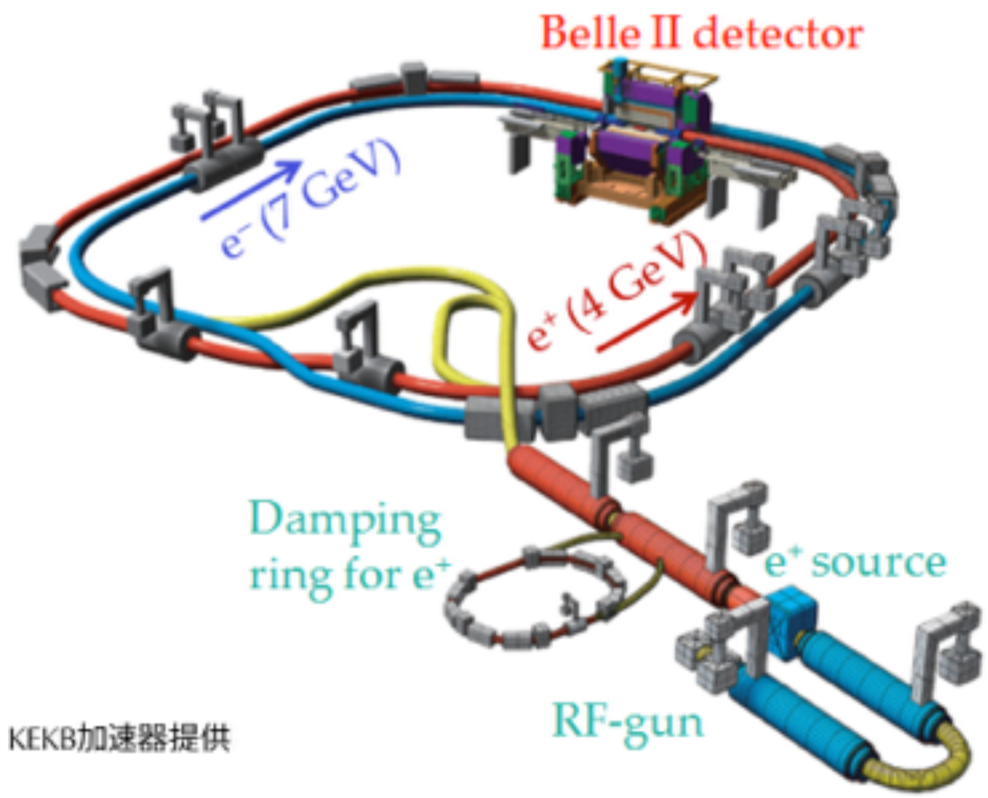
Outline

1. SuperKEKb & Belle 2
2. Beast II
3. CLAWS
    - Motivation
    - Setup
4. First CLAWS/SuperKEKb Signals
5. Summary & Outlook

SuperKEKb & Belle II



Taken from: http://www.kmi.nagoya-u.ac.jp/jpn/spotlight/kekb_belle2.png

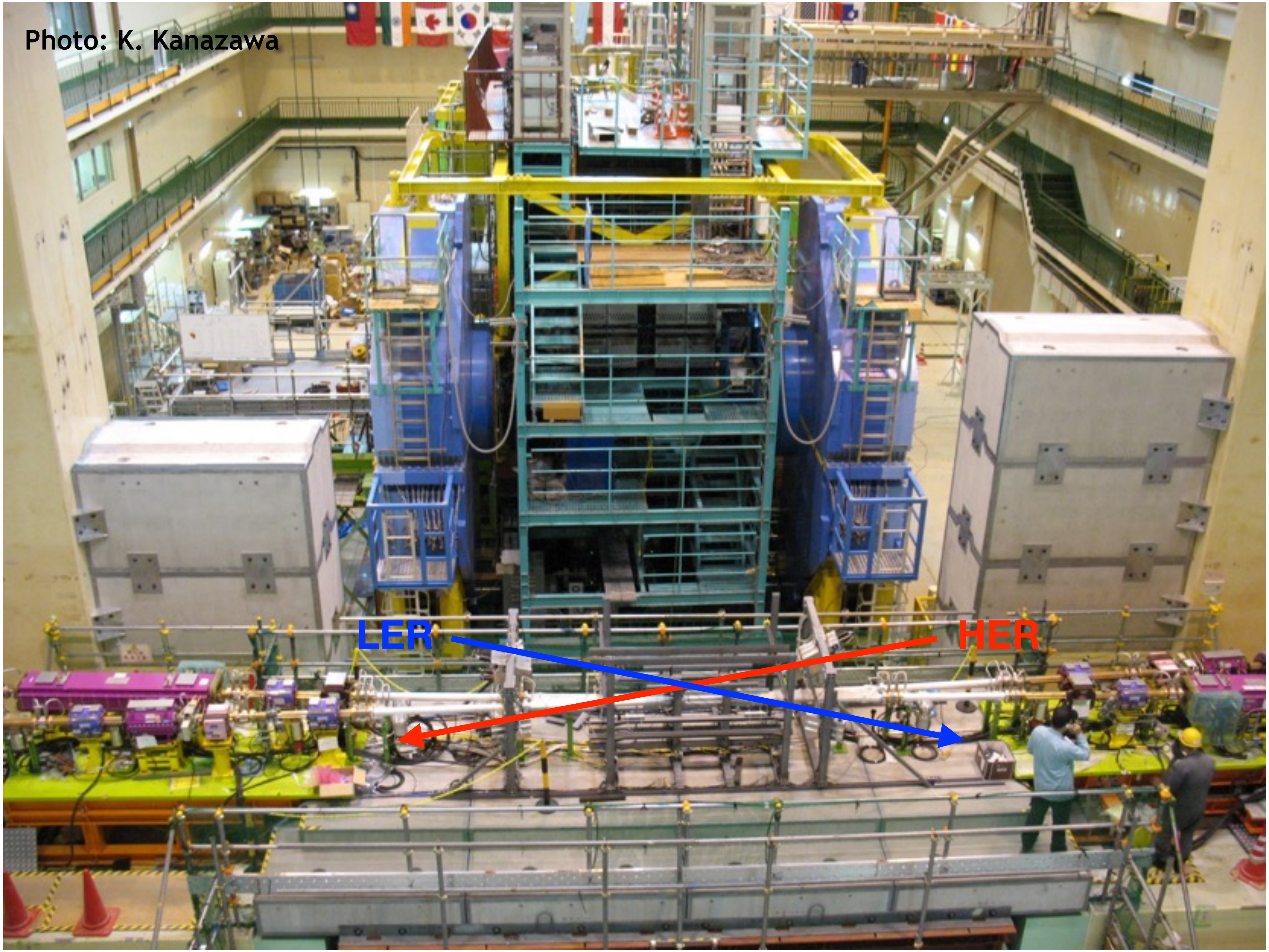
SuperKEKb Accelerator:

- B-Factory: Investigation of CP violation
- Asymmetric e^+e^--collider (10.58 GeV Y(4s))
  - Low Energy Ring (**LER**) for 4 GeV e^+ completely new
  - High Energy Ring (**HER**) for 7 GeV e^-
- Increased luminosity ($8 \times 10^{35} cm^{-2}s^{-1}$)

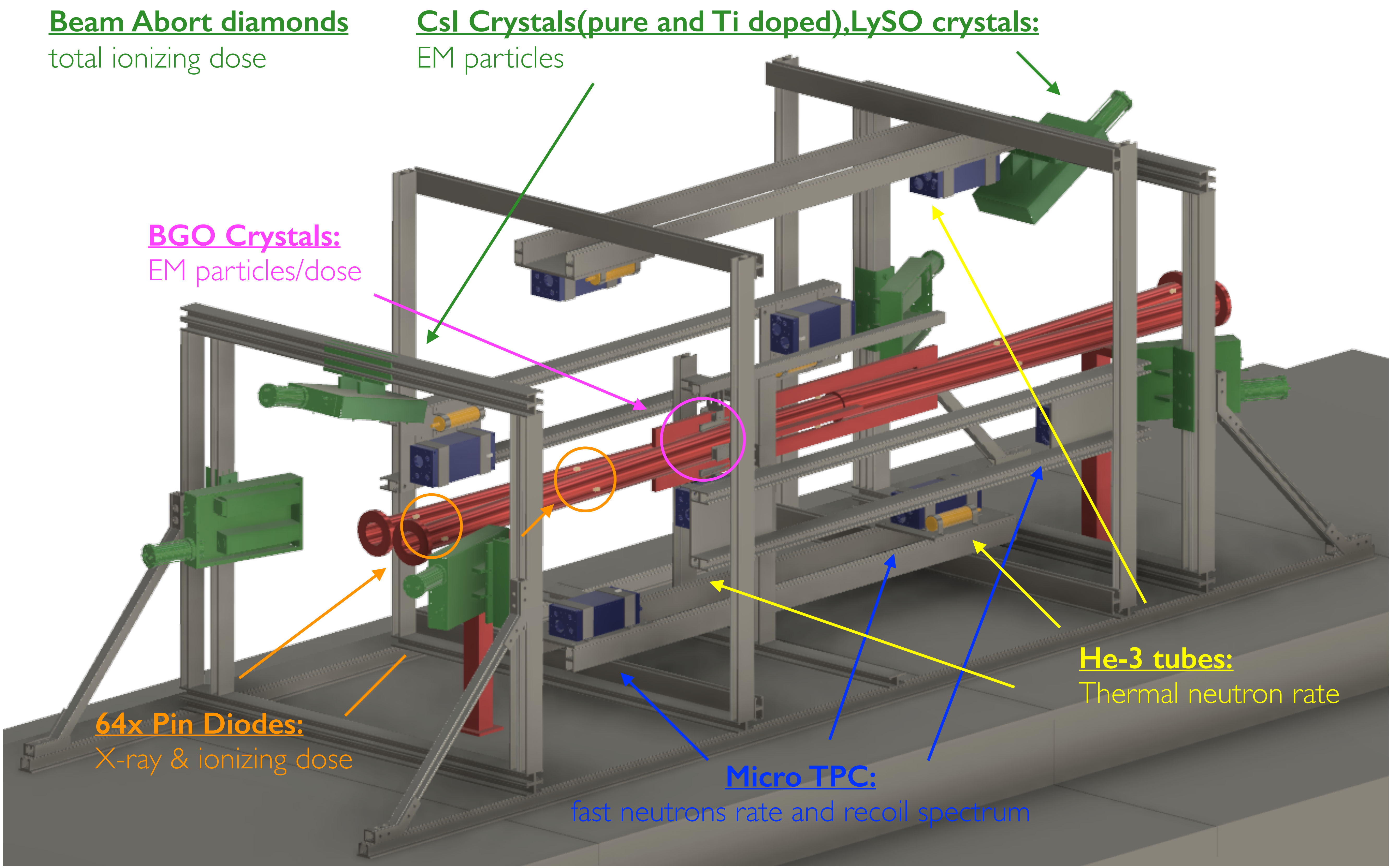
Beam **E**xorcism for **A ST**able BELLE Experiment **(BEAST):**

- Extend commissioning campaign over several years
- Split in three phases
- Phase I:
  - Without Belle II detector
  - Feb 01-07: Beam transport tuning
  - Feb 08-21: LER commissioning and beam storage
  - Feb 22- Mar 06: HER commissioning and beam storage
  - May: proposed BEAST “machine study” dates

Beast II

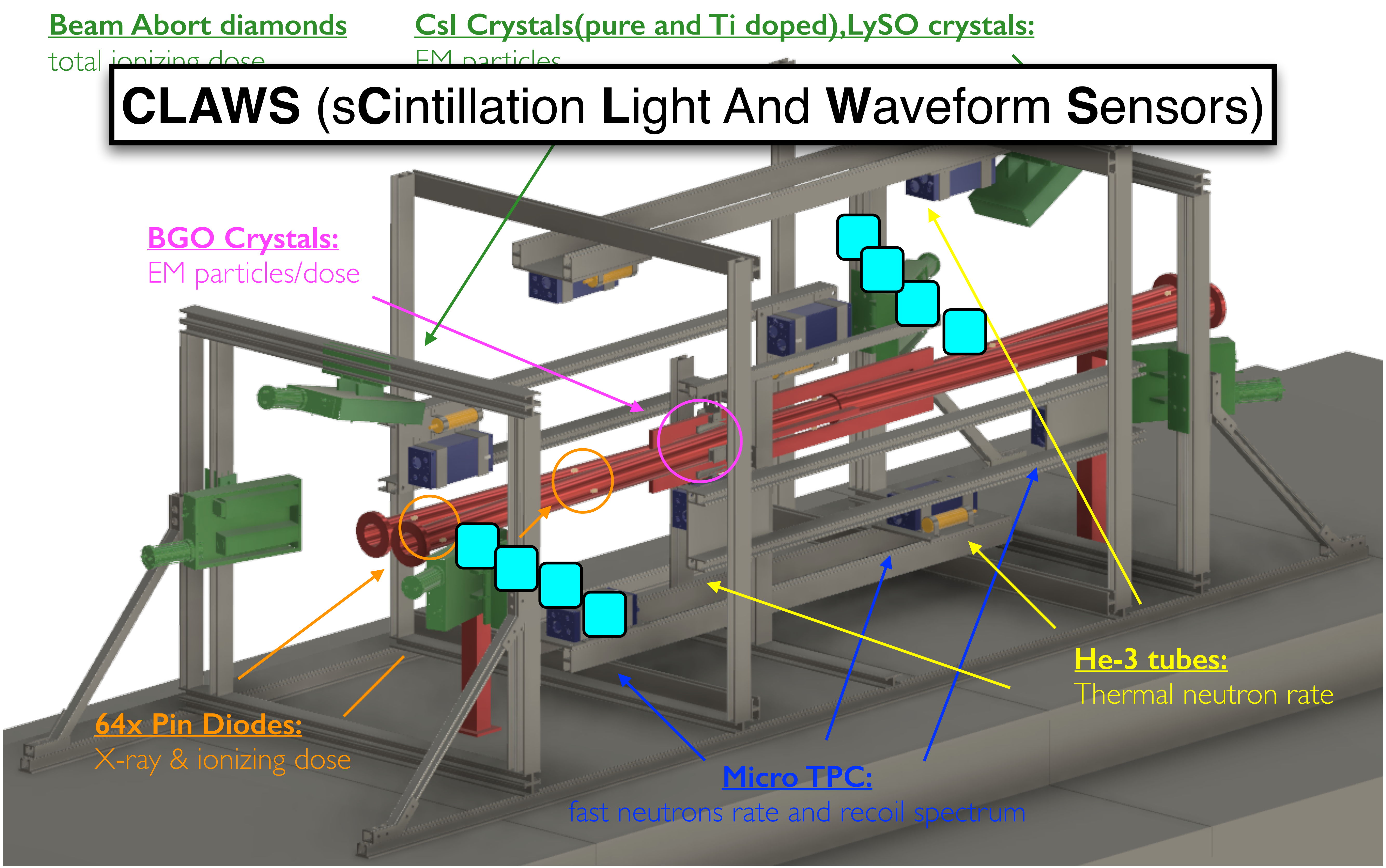


Beast II



Beam Abort diamonds
total ionizing dose
CsI Crystals(pure and Ti doped),LySO crystals:
EM particles
BGO Crystals:
EM particles/dose
64x Pin Diodes:
X-ray & ionizing dose
Micro TPC:
fast neutrons rate and recoil spectrum
He-3 tubes:
Thermal neutron rate

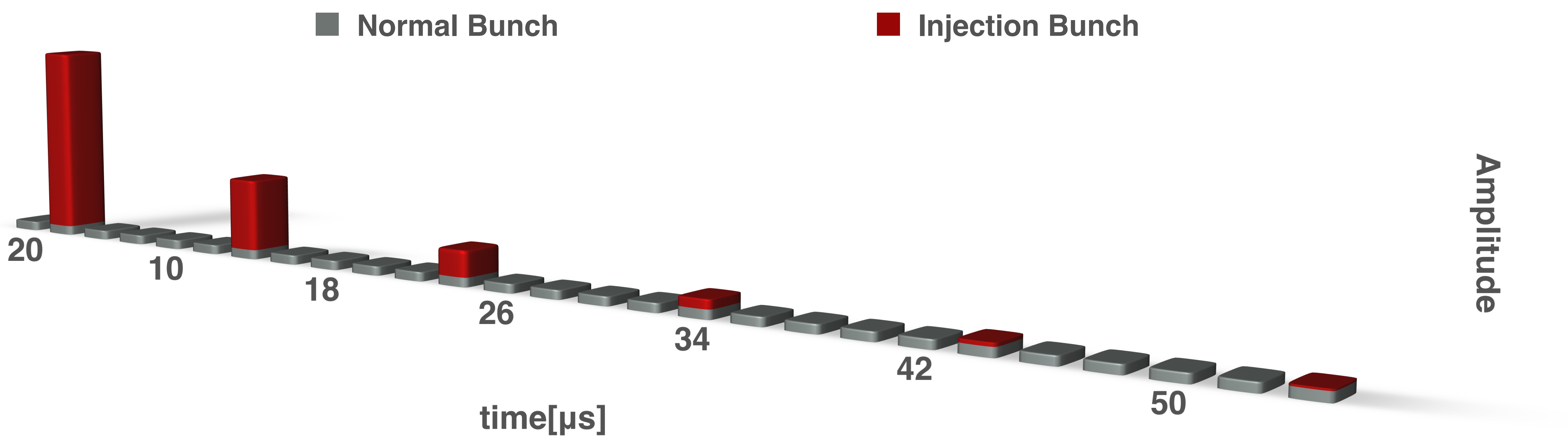
Beast II


Beam Abort diamonds
total ionizing dose
CsI Crystals(pure and Ti doped),LySO crystals:
EM particles
CLAWS (sCintillation Light And Waveform Sensors)
BGO Crystals:
EM particles/dose
64x Pin Diodes:
X-ray & ionizing dose
Micro TPC:
fast neutrons rate and recoil spectrum
He-3 tubes:
Thermal neutron rate

CLAWS: Motivation

SuperKEKB bunching and injection scheme:

- Bunch spacing of 4 ns
- Circulation time of 10 µs
- Two injection bunches per 2500 bunches
- Two injection bunches 100 ns apart

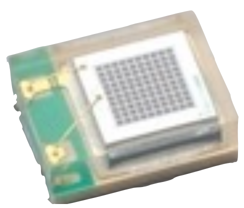


CLAWS goals for phase I:

- Measure exact delay between trigger and particles at IP = Fast timing ~ ns
- Verify timing structure in SuperKEKB = Fast timing ~ ns
- Determine decay time of noise from injection bunches = Sample of extend times ~ 10 of ms
  - Vital for **Belle II PXD**

Readout Chain

Sensors



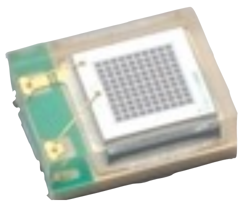
Utility

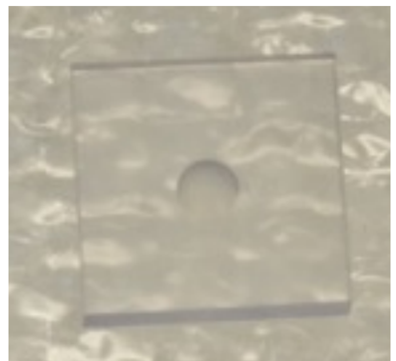
Scope

DAQ

Silicon Photomultipliers & Scintillating Tiles

Sensors





Unpackaged Scintillator

Pre-Amplifier Board

Packaging Material

Fully Packaged

Hamamatsu MPPC-S13360-1325PE SiPMs:

- Active area 1.3x1.3 mm^2, 2668 pixel
- Ultra low noise rate (1 photon rate < 100 kHz, 4 photon rate < 1 Hz)

Polystyrene Scintillator Tiles:

- 30x30x3 mm^3 + half sphere
- Radiation hardness > 1MRad
- ~18 photons/MIP (^{90}Sr & cosmic tests)

Pre-Amplifier

- Closest possible mounting to SiPM (improved S/N)

Cables, Power Supply & Amplifiers

Utility

The Wiring Issue:

- Claws only more than 1km of cables

Modular PSU:

- 2 Low Volt. modules (V_{Amps}+$V_{Pre\ Amps}$)
- 2 High Volt. modules (FWD+BWD V_{bias})

Minicircuit ZF-I 500 Amplifier:

- Located at IP near sensors

Oscilloscopes

Scope

2x Picoscope 6404D:

- 8 bit resolution
- 4 channels + ext. trigger
- 5 Gs/s (1.25 Gs/s per channel) = fast timing
- 2 GS Ultra deep memory
- Up to 400 ms of one continuous waveform = extended sampling

DAQ Workstation

CLAWS Workstation:

- Win 7 machine with LabVIEW DAQ
- Integration in BEAST DAQ and SuperKEKB accelerator slow control via Experimental Physics and Industrial Control System (EPICS)

SuperKEKb LER Commissioning: First Signals

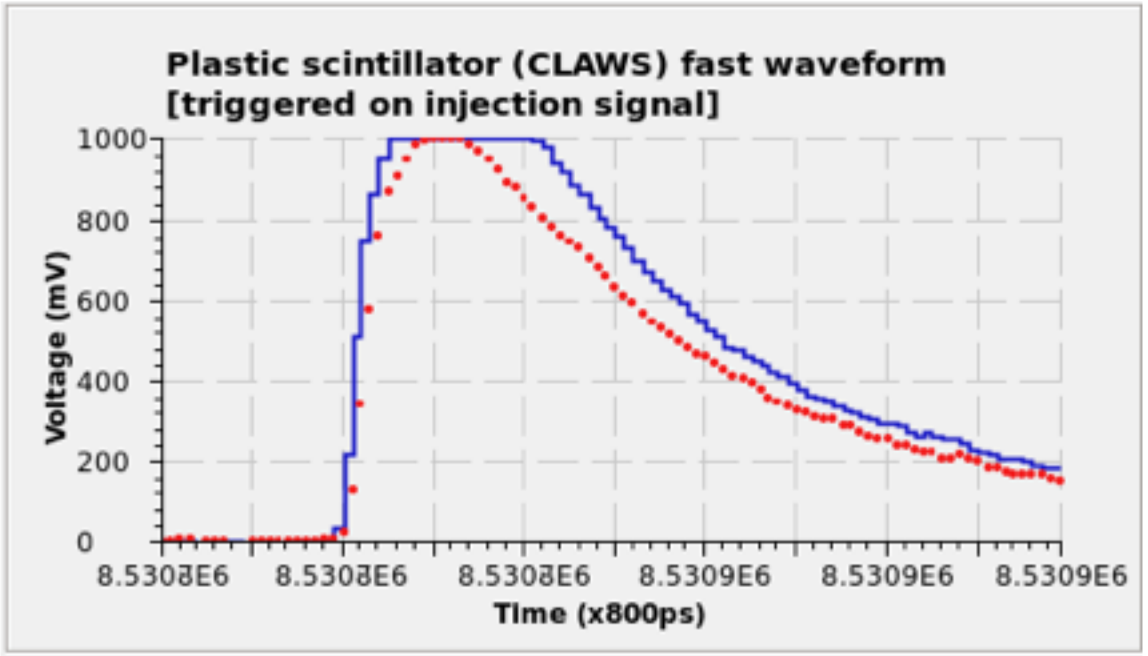
Feb 1st:

- Begin of LER commissioning with linac tests

Feb 8th:

- 08:00 AM first positron injections into LER

SuperKEKb LER Commissioning: First Signals



Feb 1st:

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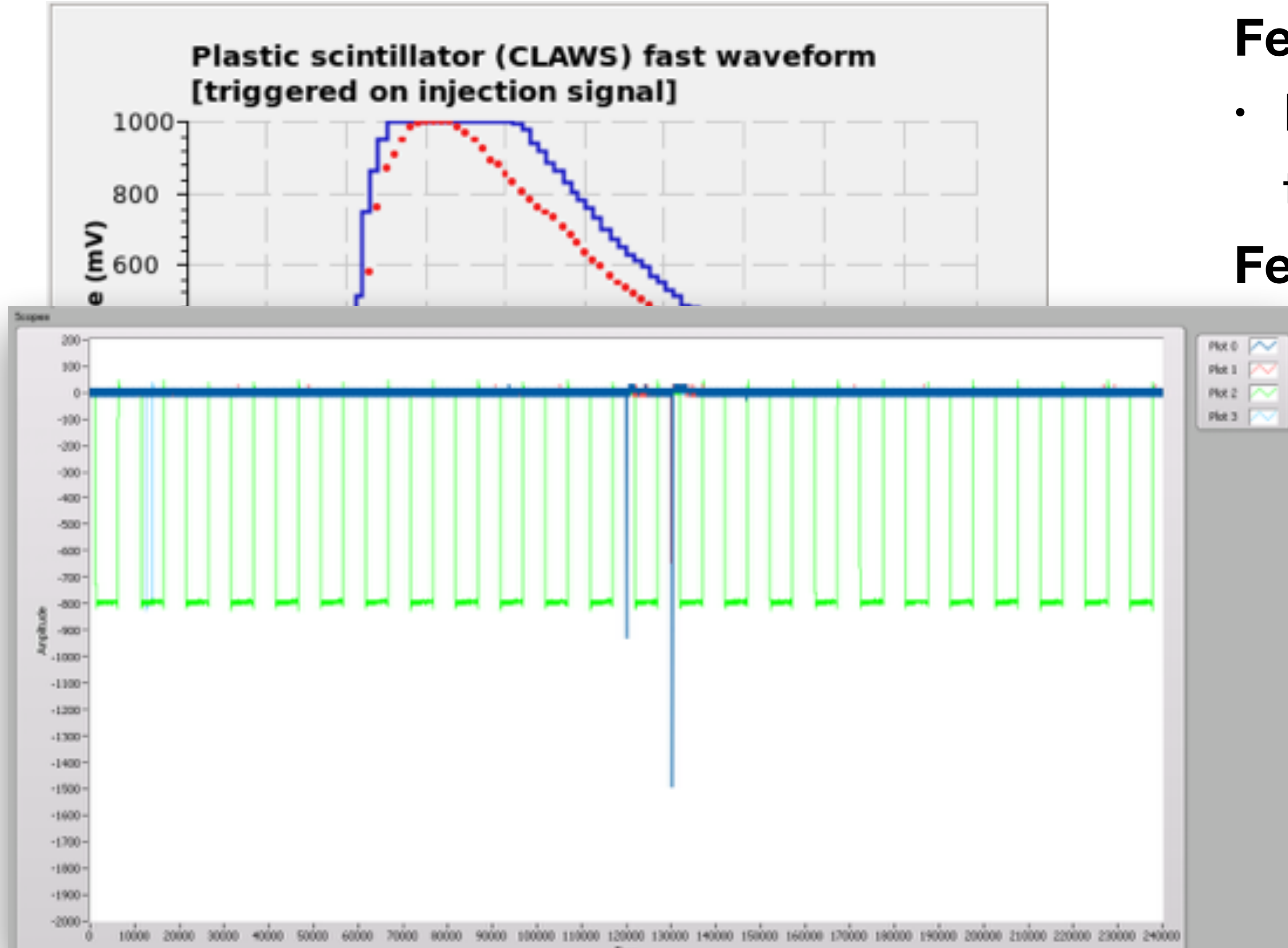
Feb 8th:

- 08:00 AM first positron injections into LER
- 03:30 PM first coincidental signals in two CLAWS sensors

First Particles at the IP of SuperKEKb!

SuperKEKb LER Commissioning: First Turns



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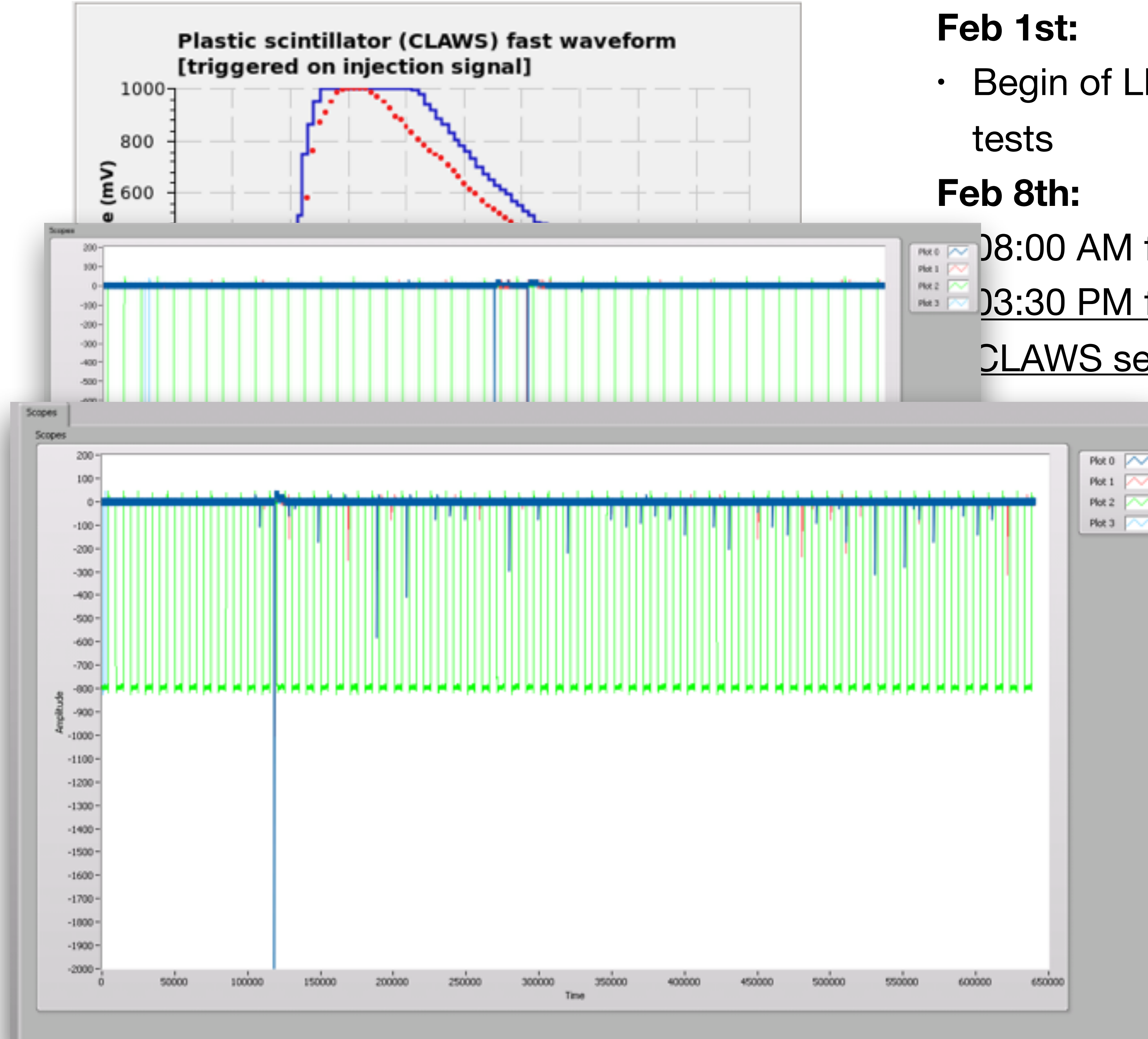
Feb 9th:

- <u>05:20 PM First turns can be seen in SuperKEKb</u>

SuperKEKb LER Commissioning: First Turns



Feb 1st:

- Begin of LER commissioning with linac tests

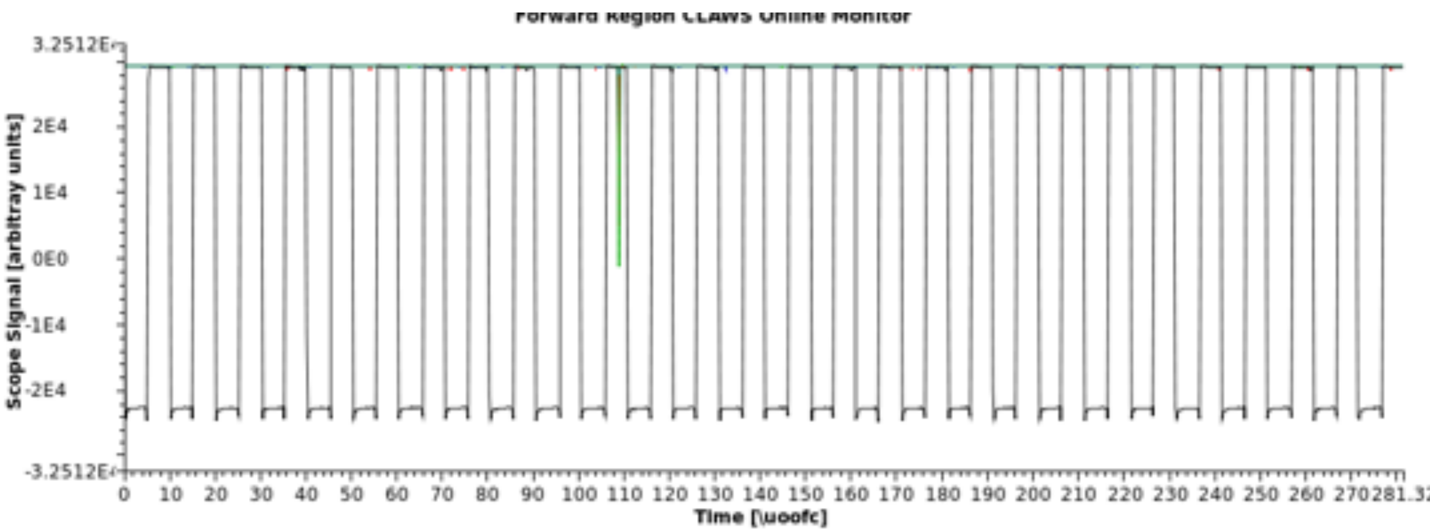
Feb 8th:

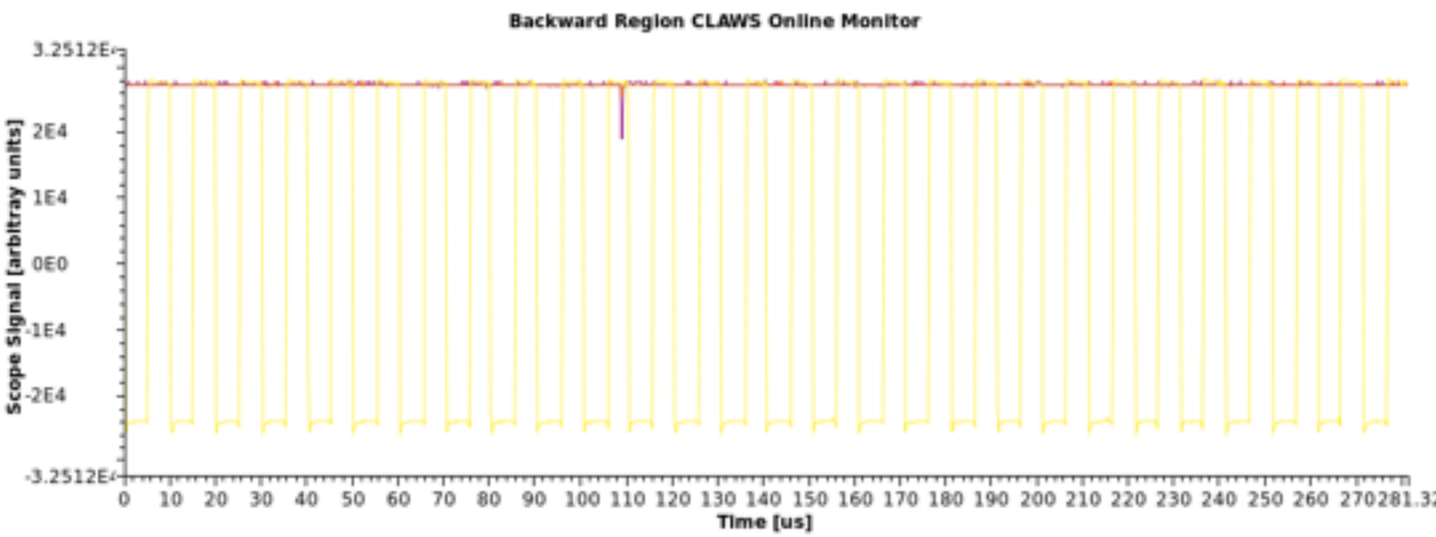
- 08:00 AM first positron injections into LER
- <u>03:30 PM first coincidental signals in two CLAWS sensors</u>

Feb 9th:

- <u>05:20 PM First turns can be seen in SuperKEKb</u>
- <u>05:30 4 Turns</u>
- <u>End of the day more than 50 have been reached</u>

SuperKEKb HER Commissioning: First Signals

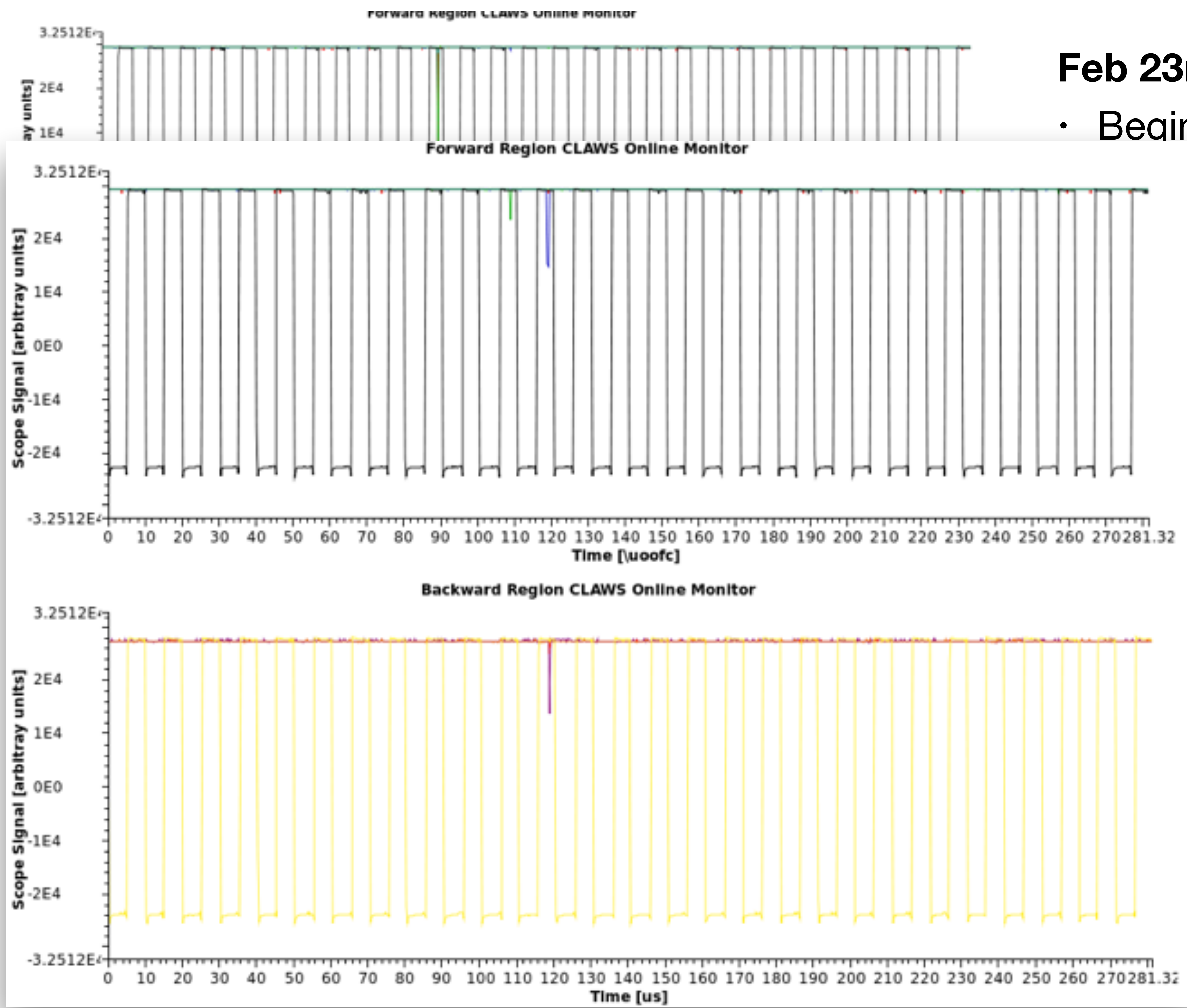




Feb 23rd:

- Begin of HER commissioning
- <u>11:08 AM first coincidental signals in multiple CLAWS sensors</u>

SuperKEKb HER Commissioning: First Signals



Feb 23rd:

- Begin of HER commissioning
- AM first coincidental signals in ple CLAWS sensors

Feb 24th:

- 03:20 PM First turns in the HER as well

Summary & Outlook

CLAWS in the Commissioning of SuperKEKB:

- Beast II: Extended commissioning phase of SuperKEKB with multiple detector systems
- CLAWS part of BEAST: Specifically for investigation of timing characteristics
- Background from injection timing vital to PXD operation

First data from SuperKEKB:

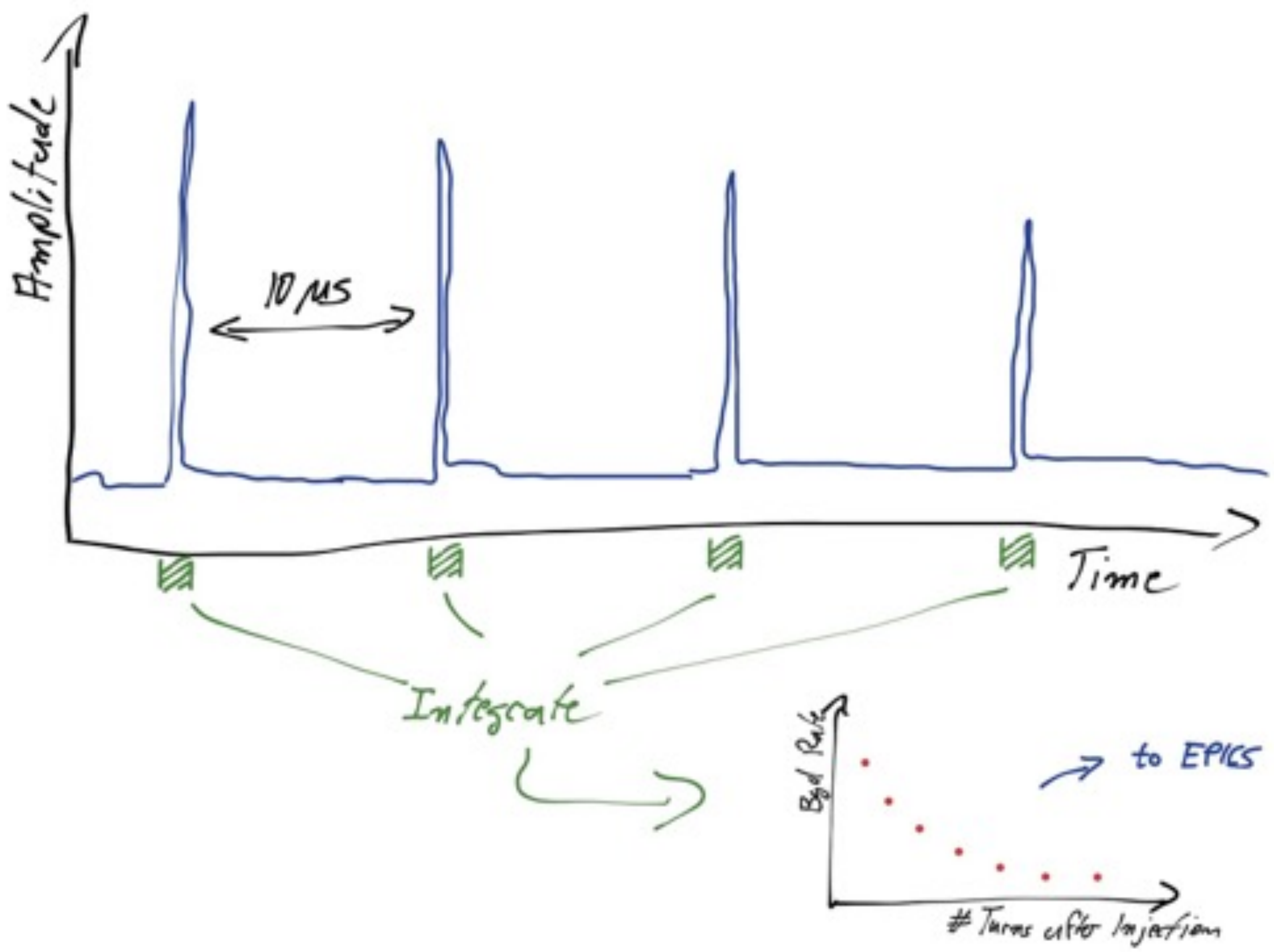
- LER shows first particles at IP, by now multiple turns reached
- HER shows first particles at IP + first turns

To come:

- Offline analysis of data taken
- Preparations for background runs in May
- Phase II: Finish R&D and start production

Backup

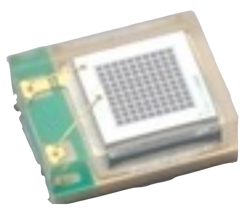
Goals & Motivation



- Independent DAQ system
- Set up to provide fast analysis of injection bunches and other machine backgrounds
- PVs transmitted via EPICS
- Permanent online display in machine control room
- Direct feedback to machine with (maybe) sub-second delay

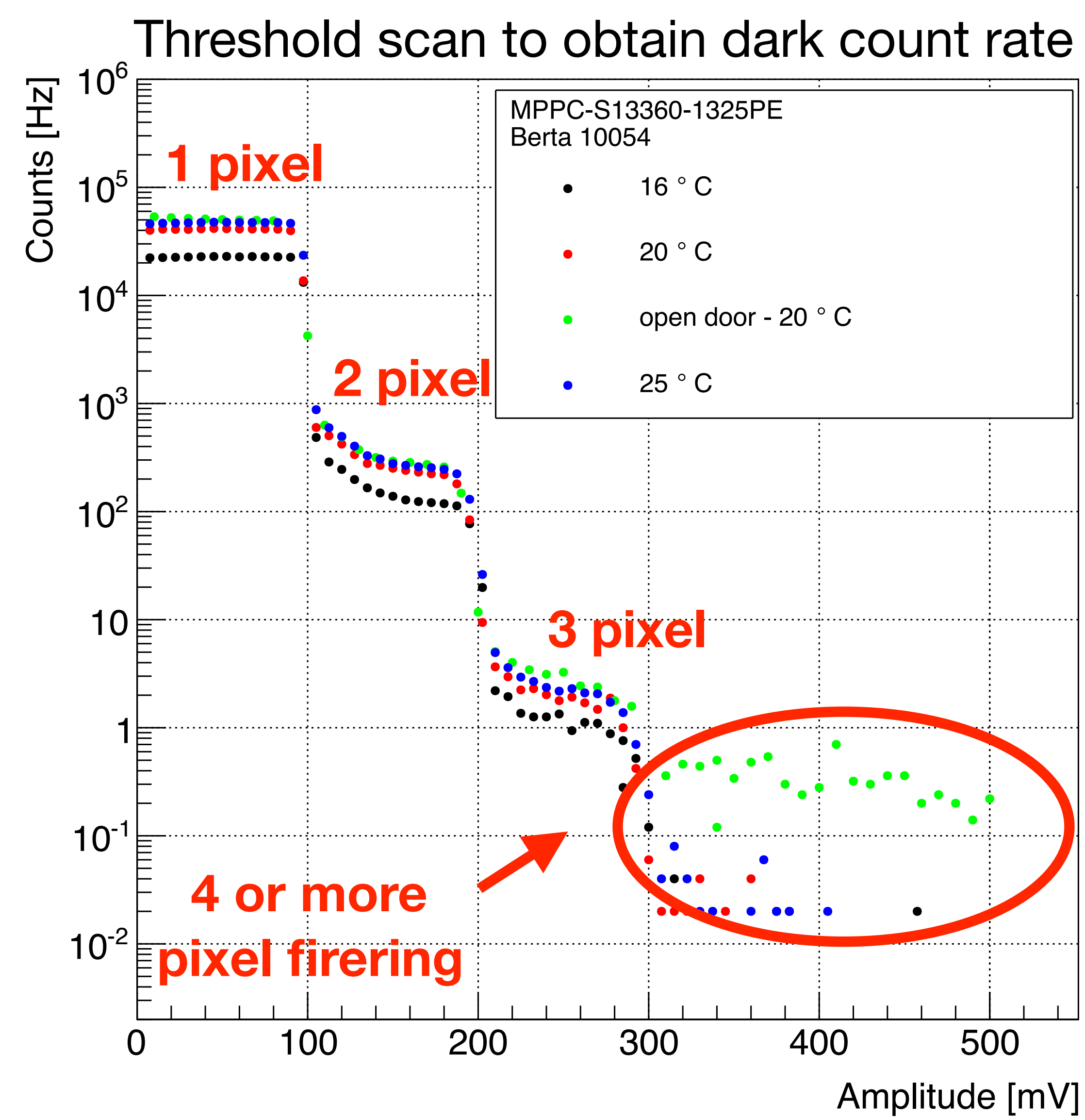
Silicon Photomultipliers & Scintillating Tiles

Sensors



Hamamatsu MPPC-S13360-1325PE SiPMs:

- Active area 1.3x1.3 mm^2
- Dramatically reduced noise :
  - 1 photon event < 100 kHz
  - 4 photon event at the same time < 1 Hz
- Substantially larger dynamic range (2668 Pixel)
- Old sensors still as backup
- Overall very good uniformity of gain of detectors when operated with same bias voltage

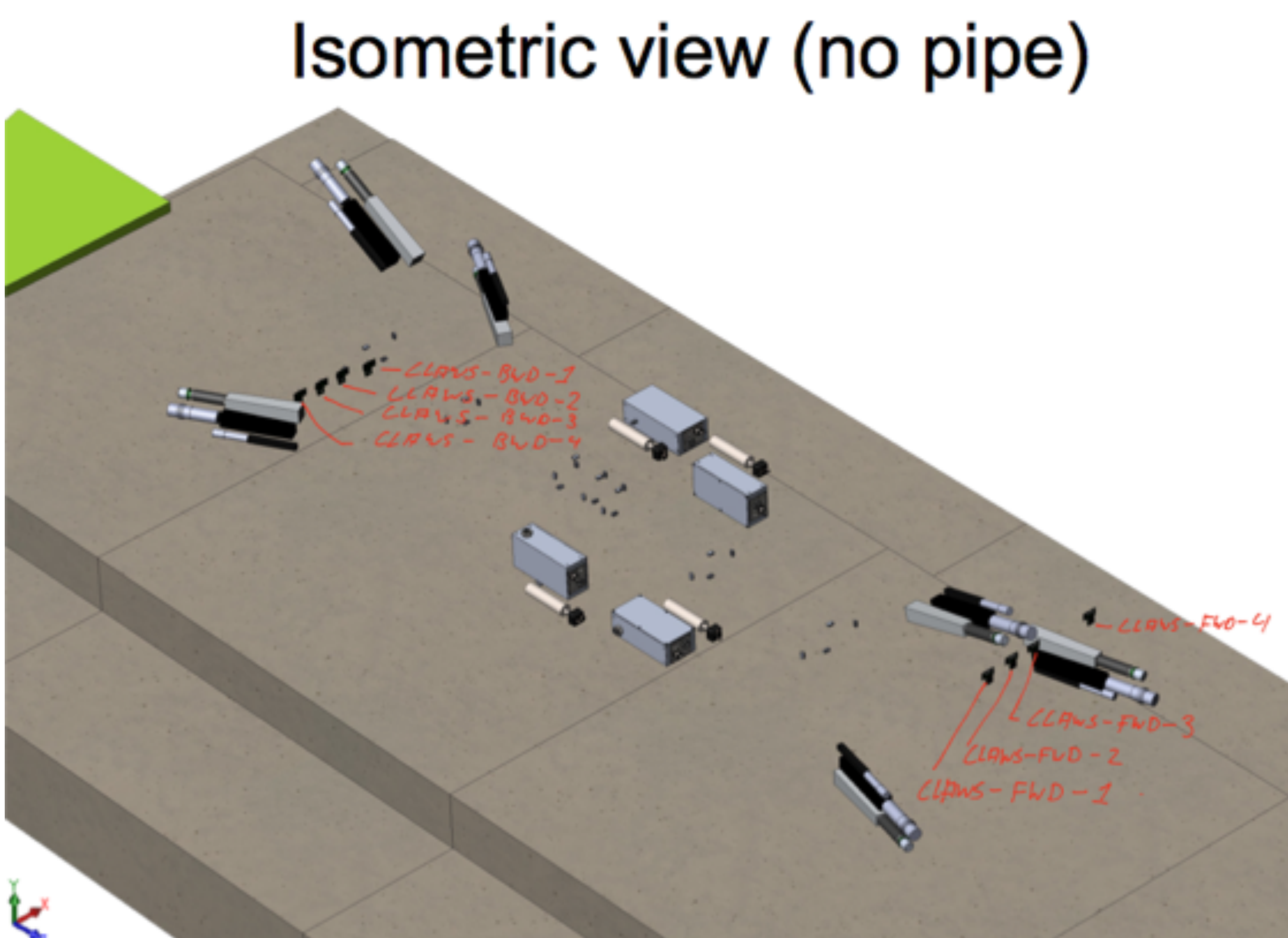


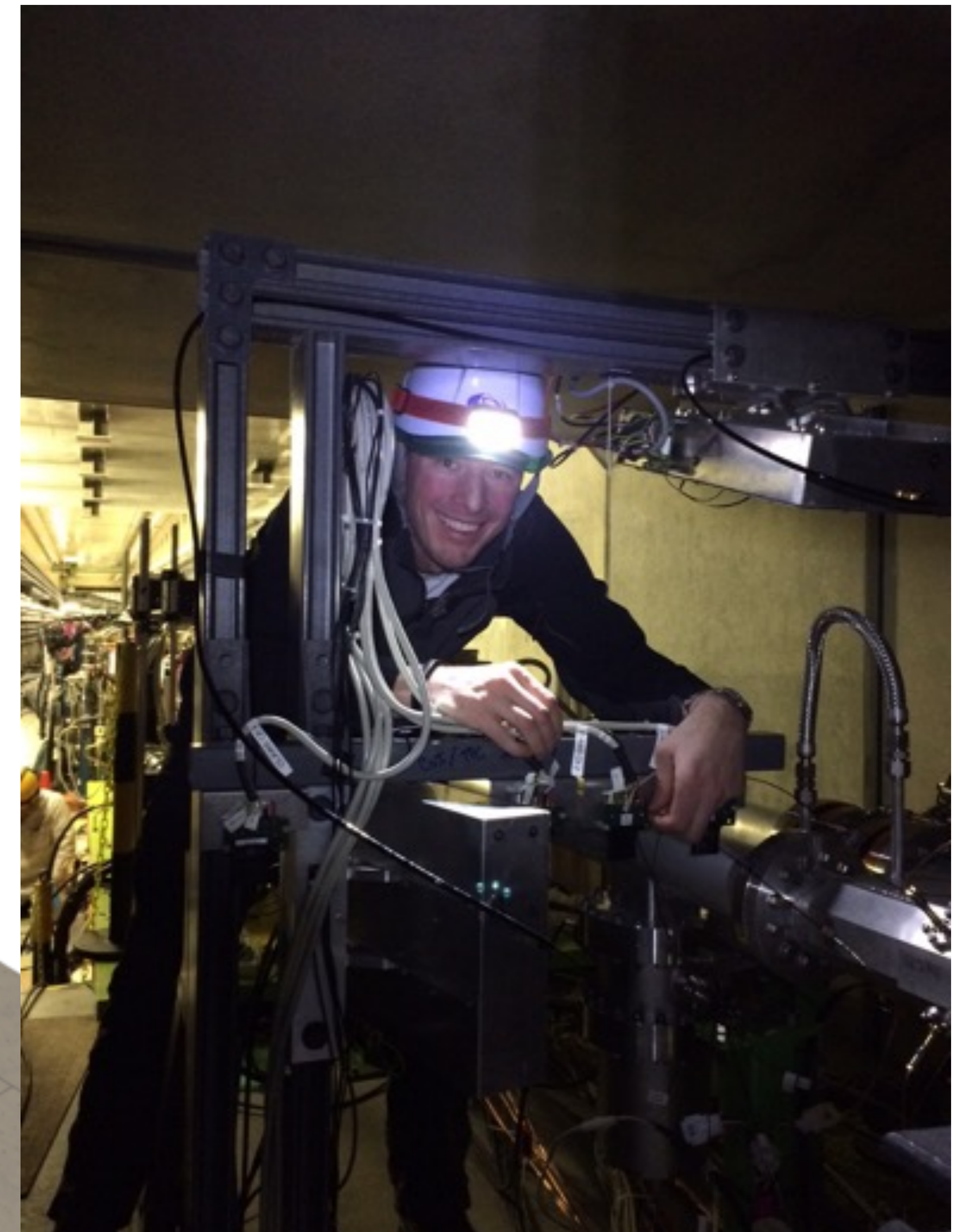
Setup Installation

Total of 8 Sensors:

- All sensors in beam plain with increasing distance form beam pipe
- 4 sensors looking out (“FWD”)
- 4sensors looking inside (“BWD”)

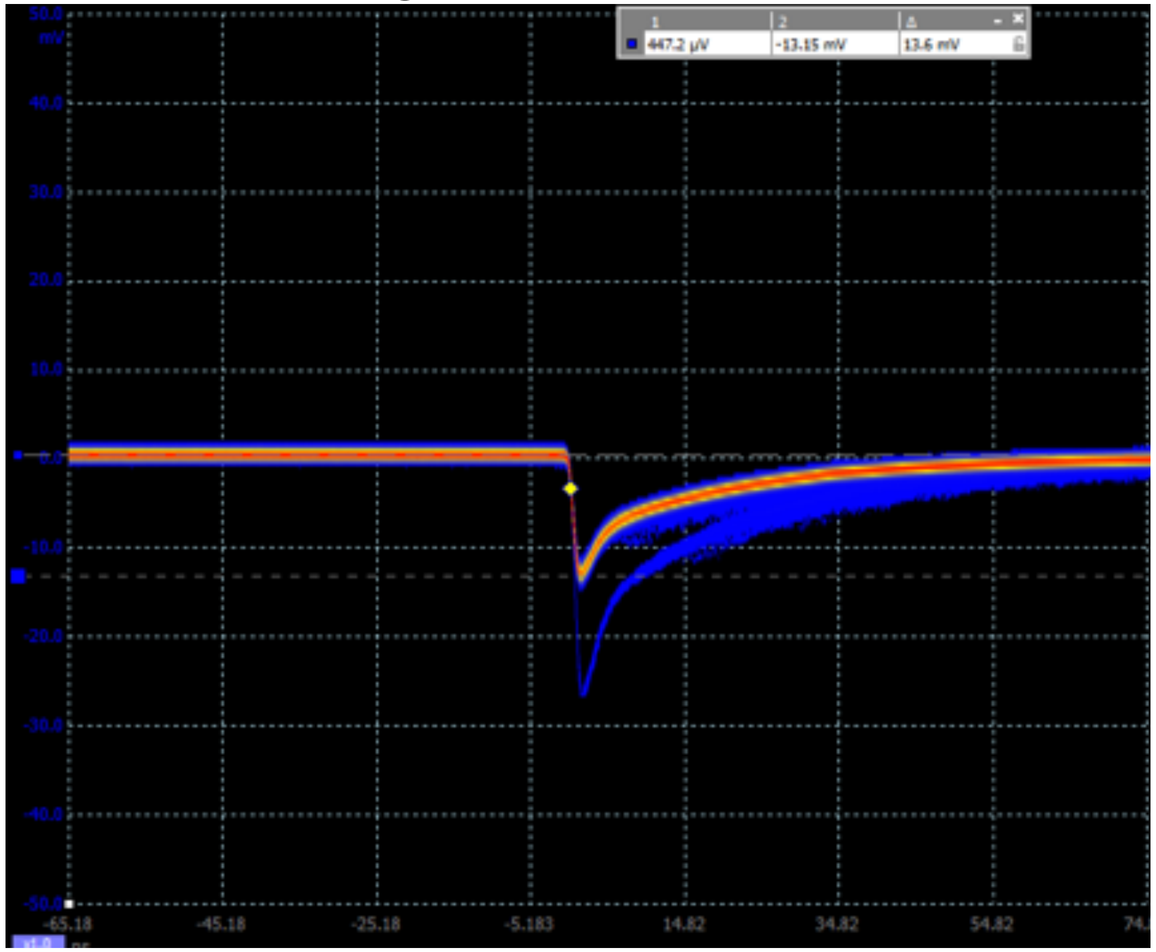
Hardware ready to go!



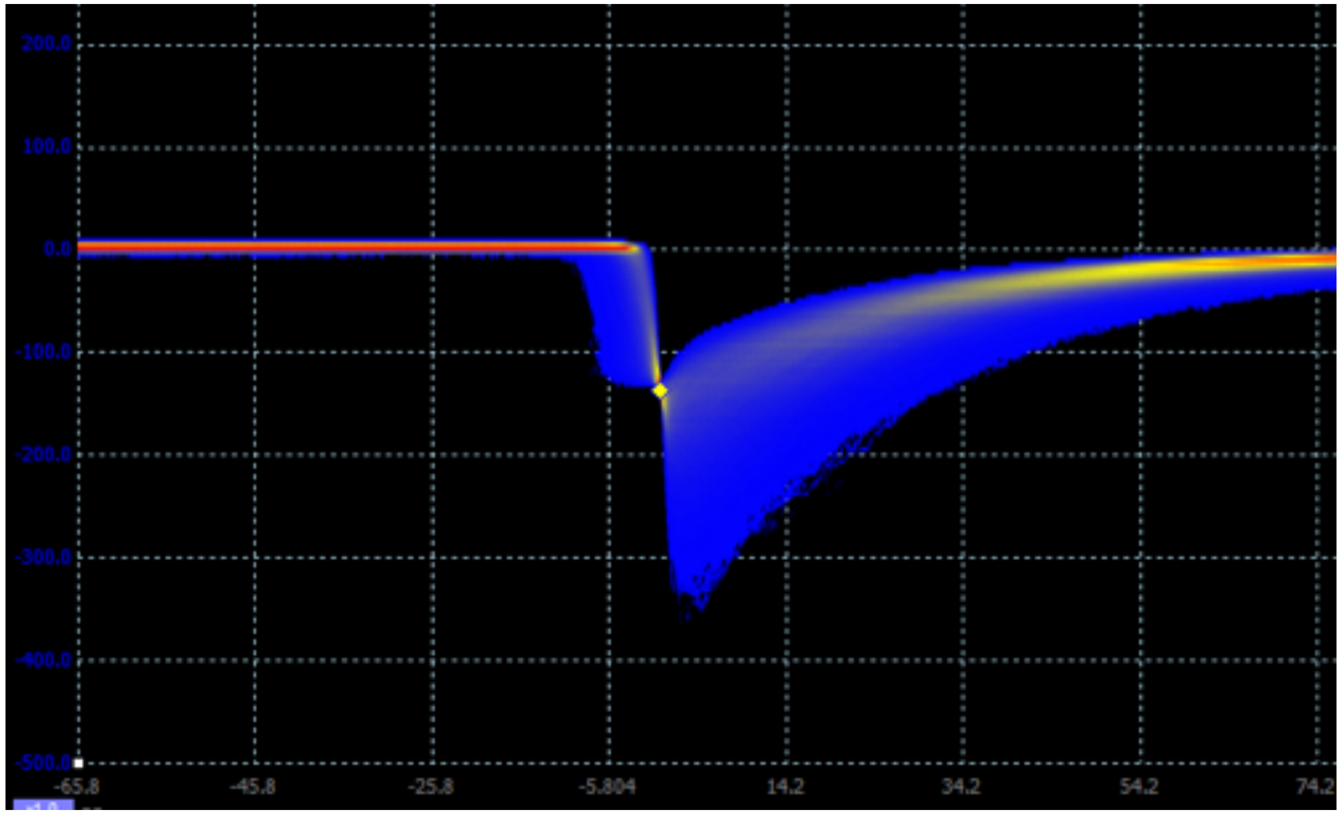


First Signals

One photon signal due to noise



Multi photon signal from ^{90}Sr ("MIP")



- Successful test with ^{90}Sr source: good signals with trigger at 10 p.e.
- From cosmic ray test expect ~ 18 p.e. for MIP

Status & Overview of the Software and EPICS

DAQ PC:

- Running windows 7 as OS due to driver constraints
- Sync to timeserver
- DAQ implemented in LabVIEW due to time constraints:
  - Readout steering of scopes & PSU
  - Multithread online data analysis

DAQ:

- Basic structure - implemented (more testing needed)
- PSU control and readout - implemented
- Began integrating scopes (VIs from different projects doing the same readout at hand)
- EPICS communication - implemented (full testing needed)
- Run modes and online analysis - missing
- Writing data to disk - missing, first step save data locally

EPICS communication:

- LabVIEW running EPICS Client I/O Server module (pure EPICS client)
- EPICS server implemented in pcaspy (python) running on same machine
- Server is publishing PVs with prefix “**BEAST:CLAWSMASTER**” (due to LabVIEW suffix “.VAL”)
- LabVIEW writing to these PVs as client
- Integration of BEAST Run Control almost done

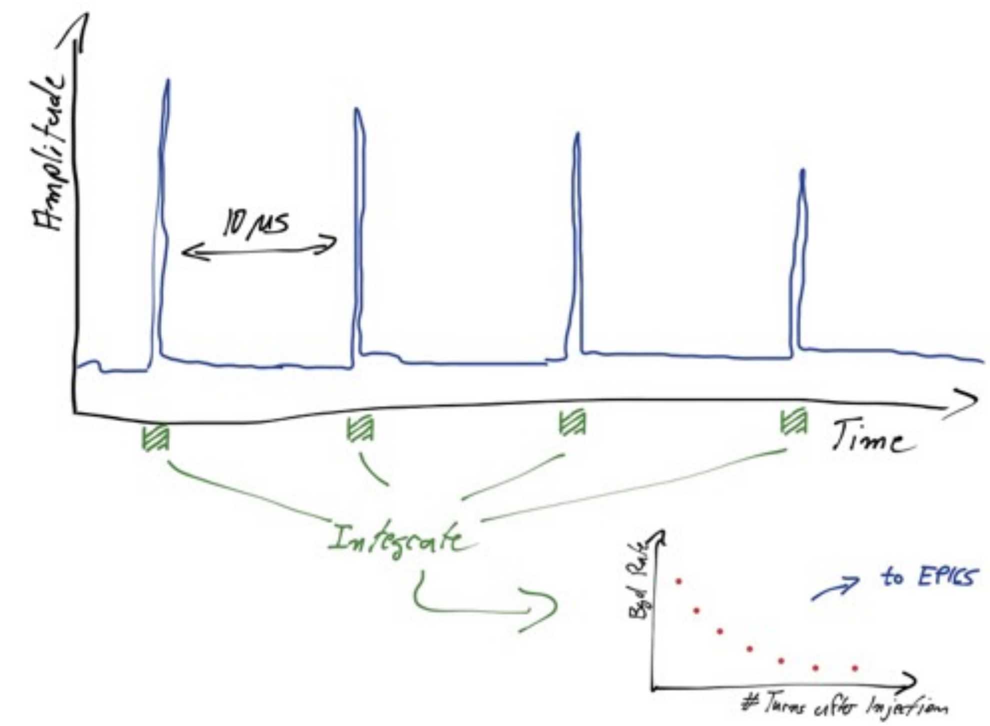
Run-Mode 1: “First Beam Mode”

Purpose:

- Obtain timing delay between trigger signal of “revolution clock” and arrival of bunch
  - Needed for all other Run-Modes
- Verify “revolution clock” and “injection trigger” signals
- First development step for Run-Mode 4

Execution:

- Connect trigger signal to full channel of scope
- Trigger on either signal in sensor or revolution clock
- Extract delay and fill in histogram



Run-Mode 2

Purpose:

- Online monitor for accelerator people
- Publish full waveform of signal via epics with 200 ms refresh time

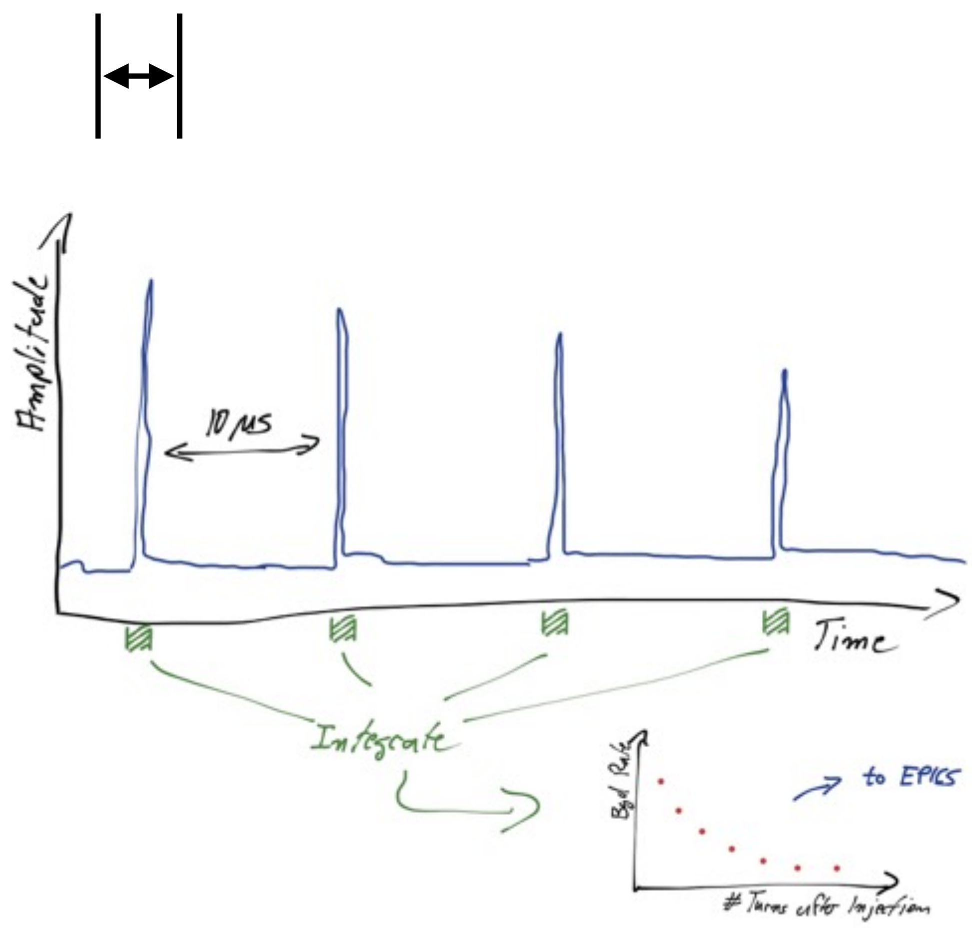
Execution:

- Trigger on injection signal
- Extract first or every 1000th waveform of 200 ns
- Publish them via epics

Problem:

- Inherent design flaw, EPICS clients can only read PVs of datatype waveform (a.k.a. arrays of ints)
- Need to save waveform in file on disk in LabVIEW
- Open file in EPICS server, extract information and published it

Publish full waveform via EPICS with rate > 2Hz



Run-Mode 3

Purpose:

- Extract exact timing between bunches
- Extract background in between bunches
- Measure all signals over extend time span
- Measure decay timing of background from injection bunches
- Verify other run modes

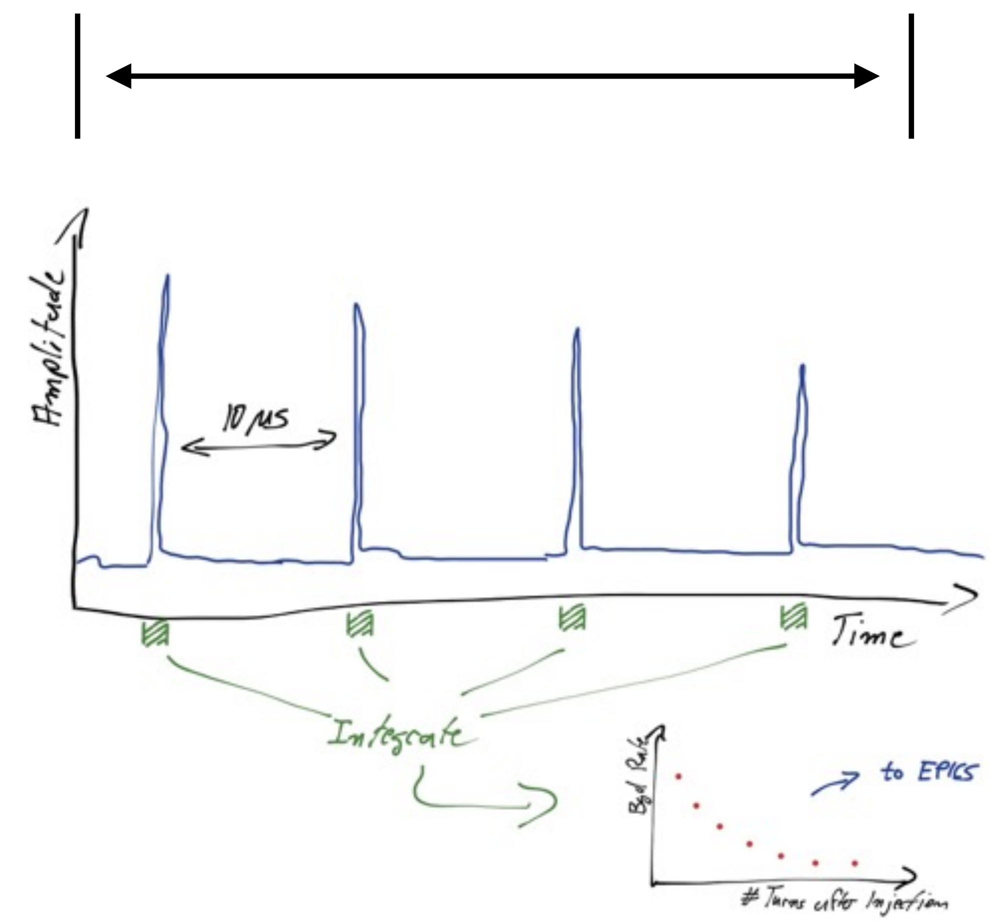
Execution:

- Trigger on signal from injection trigger
- Apply corresponding delay
- Continuously collect data for up to 50 ms, even up to 400 ms possible

Drawbacks:

- Hardware intensive, needs to handle one long waveform >= 50 mb per channels
- Long dead time, probably in the order of minutes
- Low statistics

collect data 50 ms long
(up to 400 ms possible)



Run-Mode 4

Purpose:

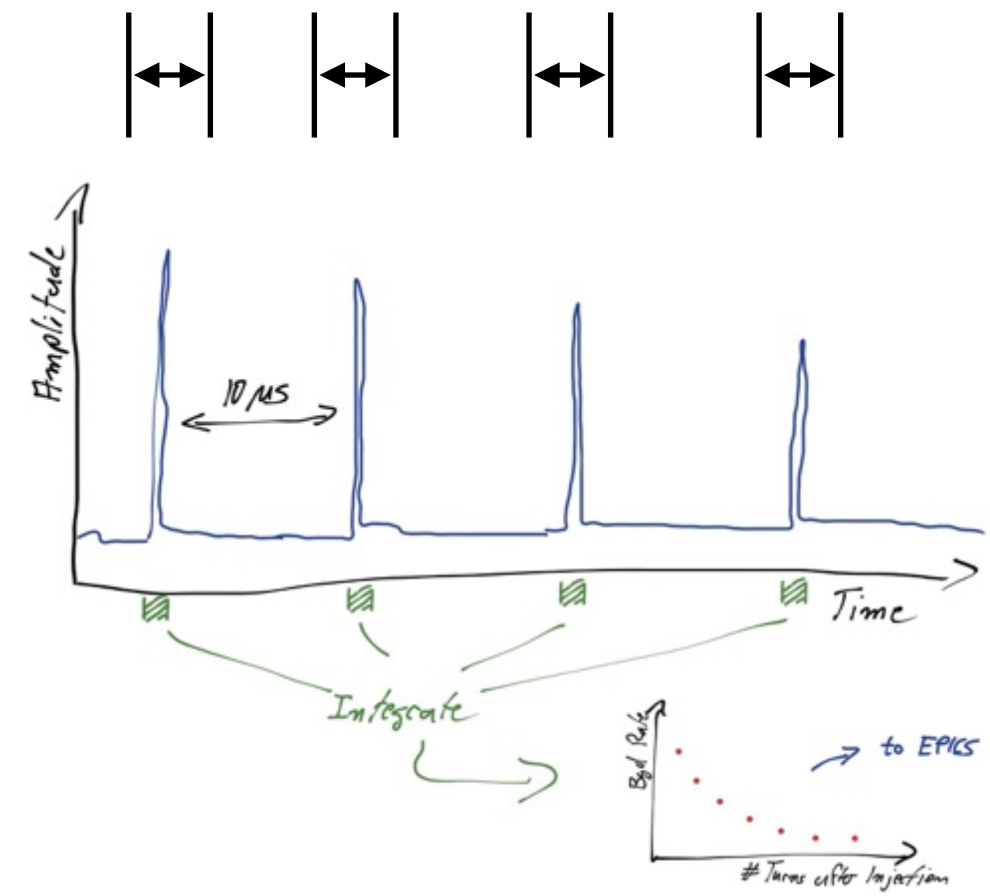
- Get decay timing of noise from injection bunches
- Get precision knowledge of timing between bunches
- Get background
- Most likely the working horse of the run modes

Execution:

- Trigger on revolution clock and collect several 100 ns of data (will depend on signal strength)
- Continuously trigger until memory of scope is full

Pros:

- Almost same information like 3 but without unimportant information between bunches
- Fast
- Online possible



Conclusion & Outlook

Hardware:

- Upgraded sensors installed (previous sensors as backup available)
- PSU, Amplifiers & Attenuators, DAQ PC installed
- Hardware tested & fully working, ready to go

Software:

- Some work left - but making progress

Outlook:

- Finalize definition of Run-Modes
- Implement Run-Modes

CLAWS


CLAWS
CLAWS Ch 8
CLAWS Ch 7
CLAWS Ch
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11

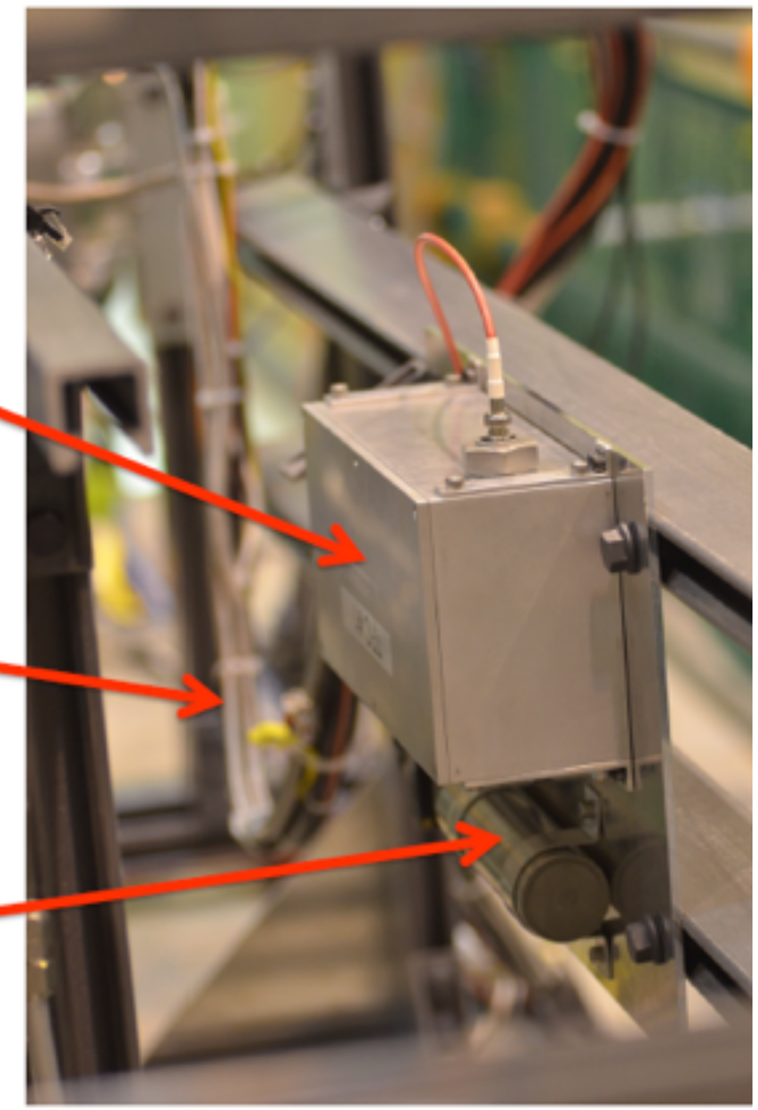
TPC

TPC plate

TPC

Cable
"festoon" for
sliding along z

He3 Tube



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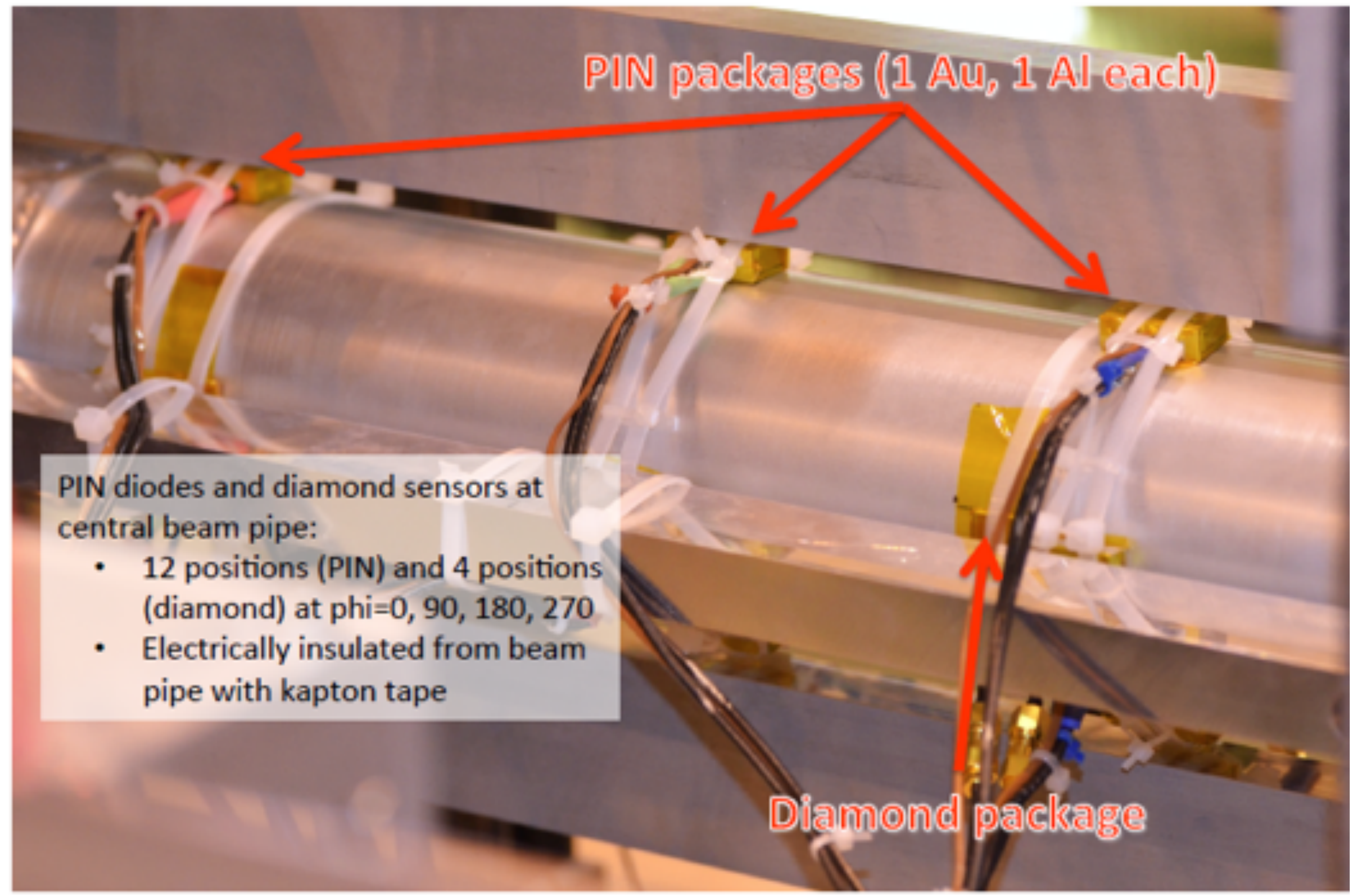
10

PINs

Central beam pipe region



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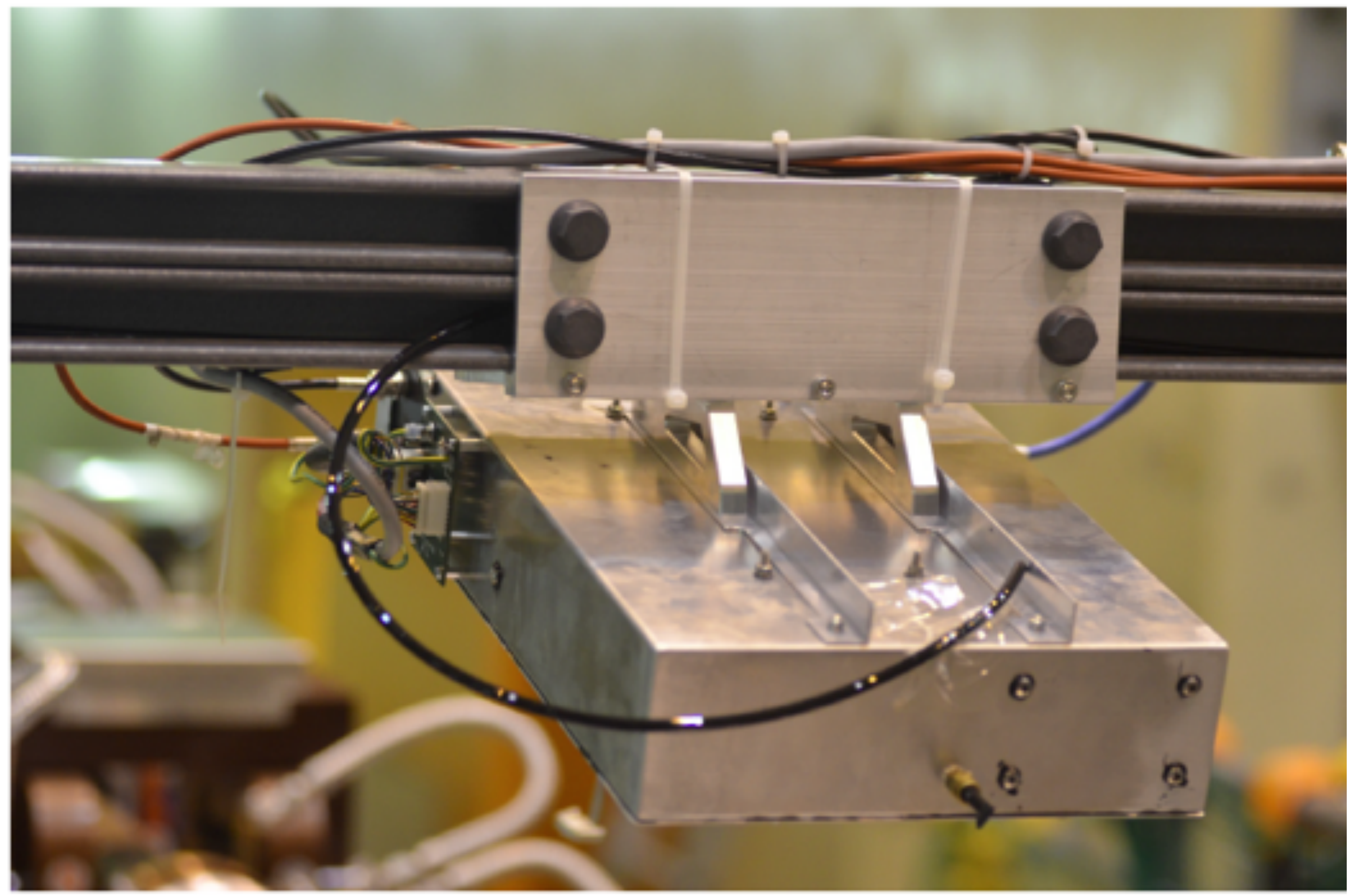
CSI

CsI box



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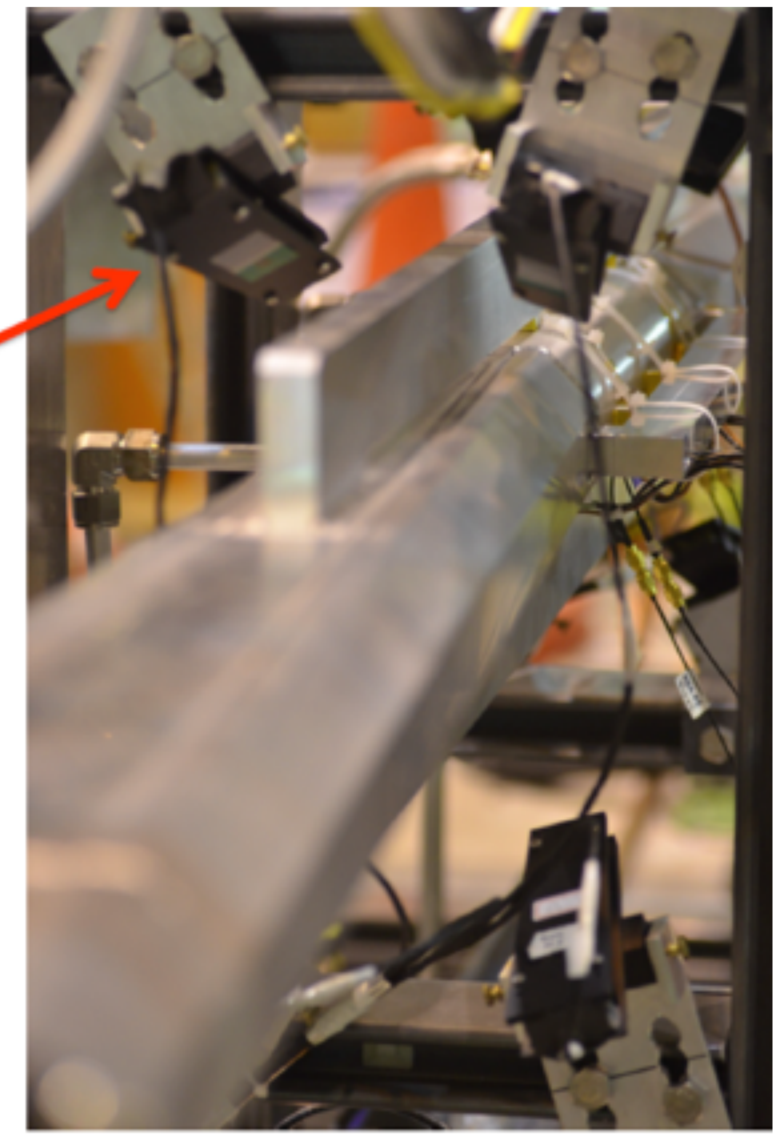
BGOs

BGOs

Orientation:

- No longer mounted on vertical and horizontal planes
- Back-to-back pointing now only approximate



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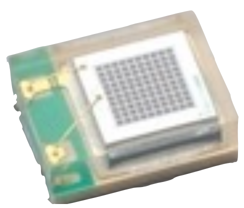
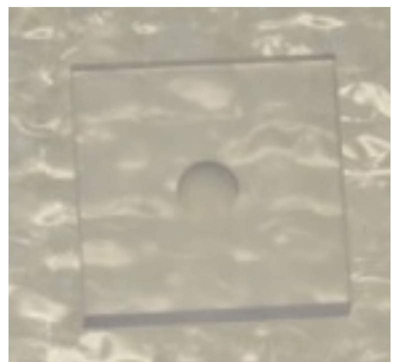
Silicon Photomultipliers & Scintillating Tiles

Sensors





Unpackaged Scintillator

Pre-Amplifier Board

Pre-Amplifier Board

Packaging Material

Tile & Board

Fully Packaged