Particle identification with the iTOP detector at Belle-II

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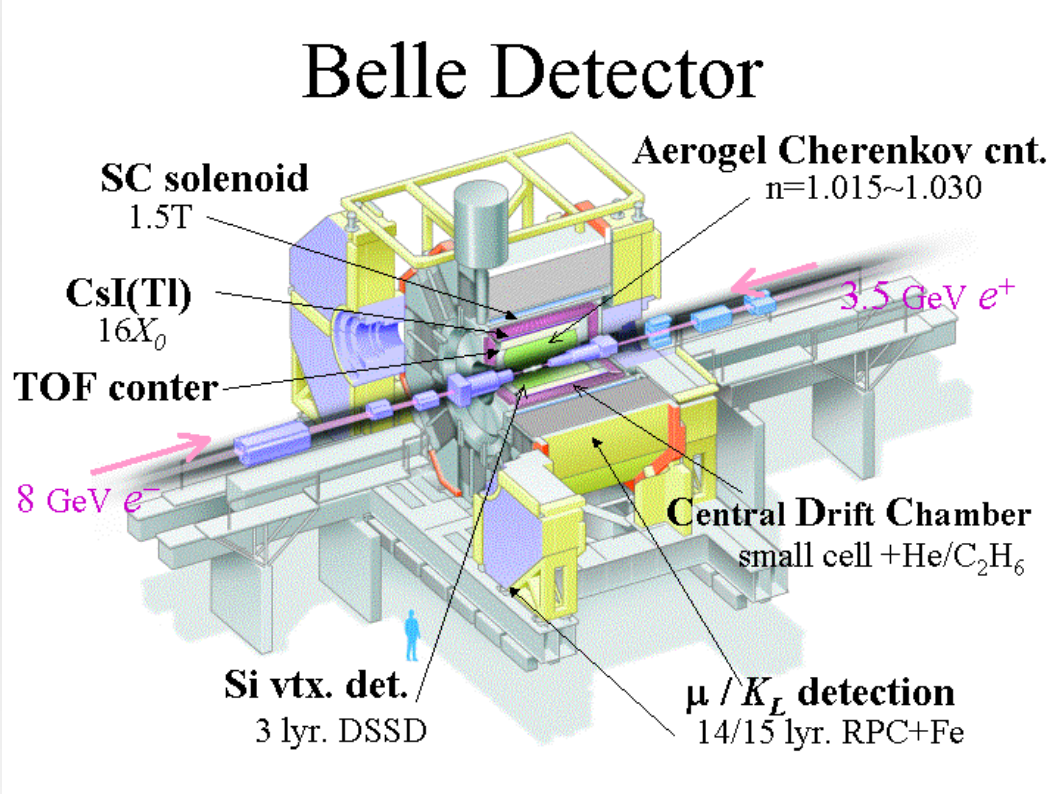
Outline

- From Belle to Belle-II PID.
- The iTOP detector:
  - Quartz;
  - Photodetectors;
  - Electronics.
- Beam test at SPring-8.

From Belle to Belle-II PID

- Belle Detector will be upgraded to Belle-II which will take data with a Luminosity ~50 times higher.
- Belle detector used a time of flight (TOF) counter, and Aerogel Cherenkov counter for PID.
- For Belle-II these will be replaced by a time-of-propagation counter (barrel) and an Aerogel RICH (endcaps).



- This presentation focuses on the (imaging) time-of-propagation (iTOP) system.
- Belle-II will be covered by S. Vahsen – 15:30 16 Aug in Quark and Lepton Flavor Physics session.

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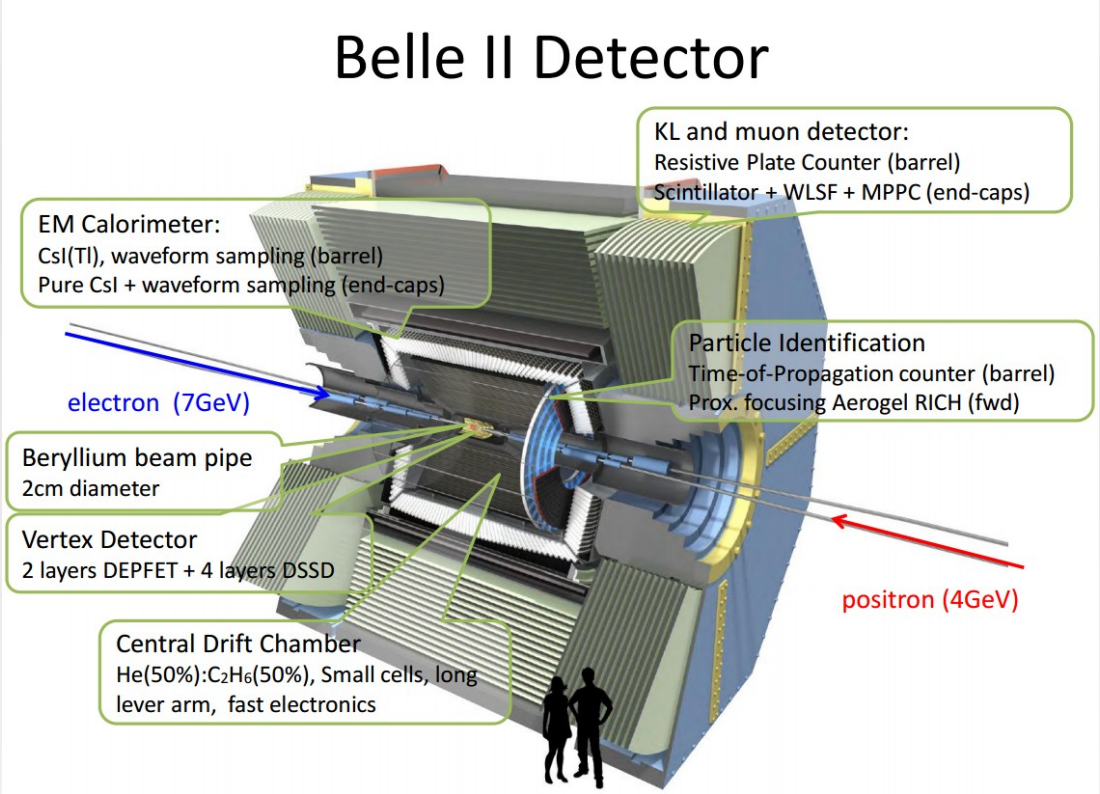

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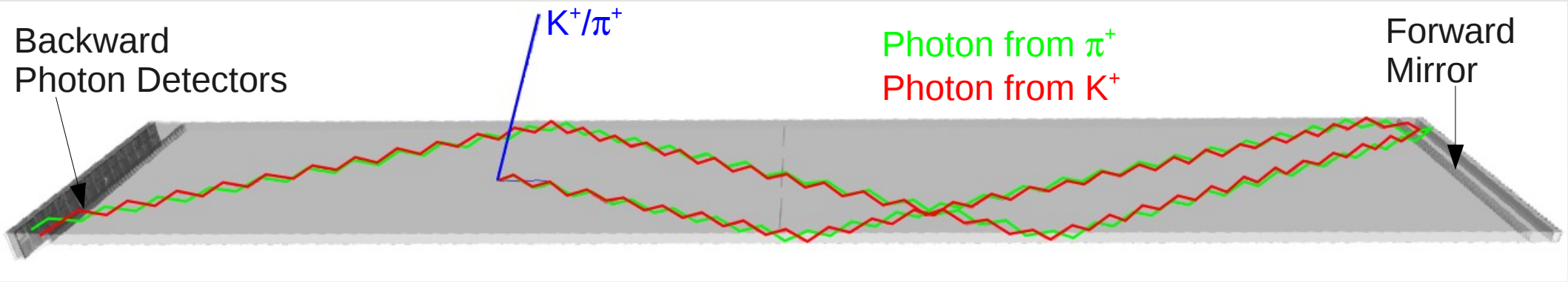
The iTOP detector

- 16 modules will form the barrel PID system for Belle-II.
- Each module consists of quartz bars (~2.5m in length), a mirror, expansion volume, and photon detectors.

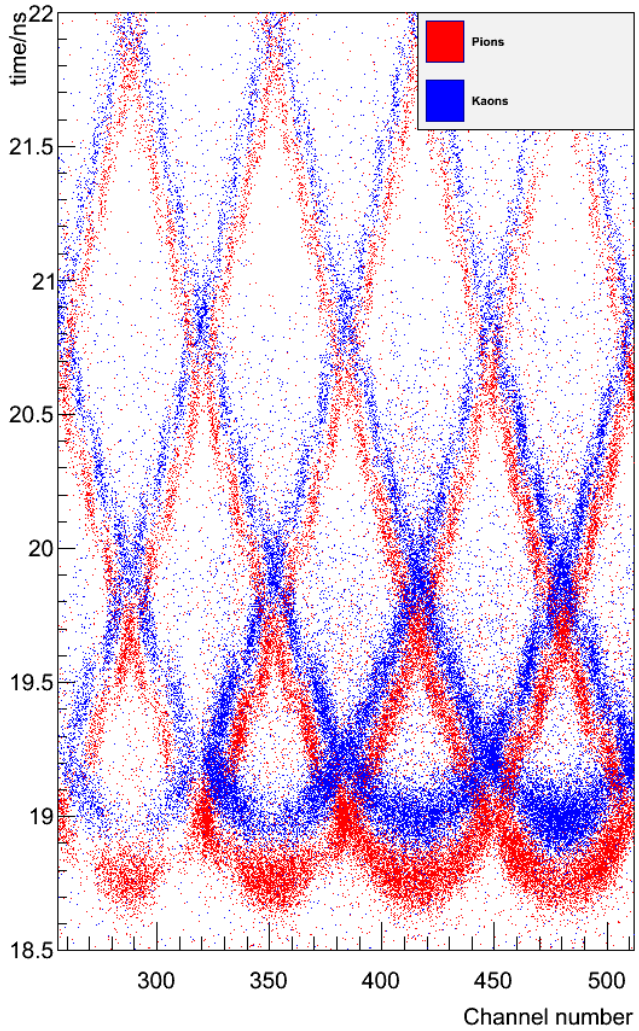


- When a charged particle passes through the quartz, it emits Cherenkov photons:
  - The Cherenkov angle, and hence detection time/position depends on the mass of particle (for given track parameters).

Kaon/Pion separation

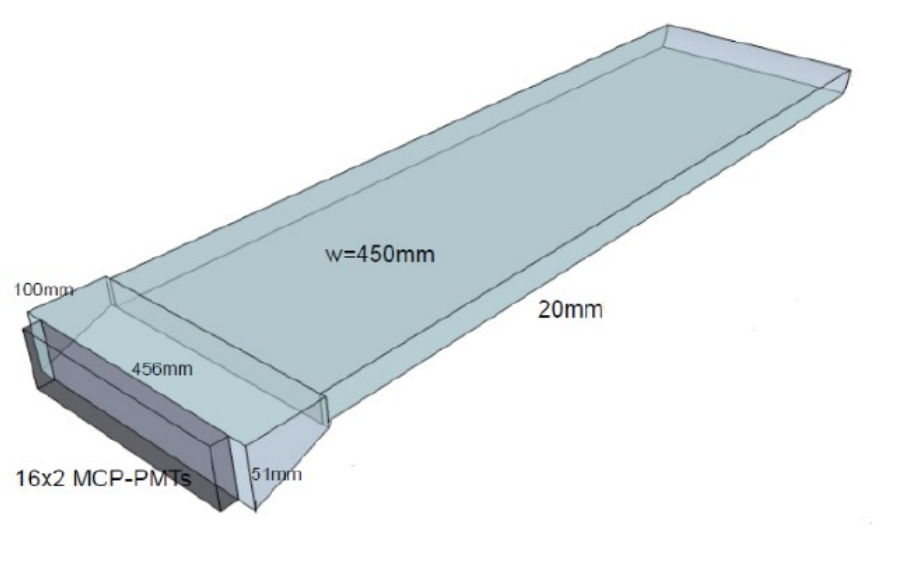
- The primary use for the iTOP will be to discriminate between kaons and pions.
- A 2-dimensional PDF can be constructed based on detection time and detection position of Cherenkov photons.
- The different Cherenkov angle for photons from kaons leads to a later arrival time than for photons from pions.
- The iTOP readout needs to have excellent time resolution to distinguish between particle types, with better than 50ps desirable.
- Final PID performance will also include information from other subdetectors, e.g. dE/dx.

Photon detection time vs channel number (zoom)



Quartz

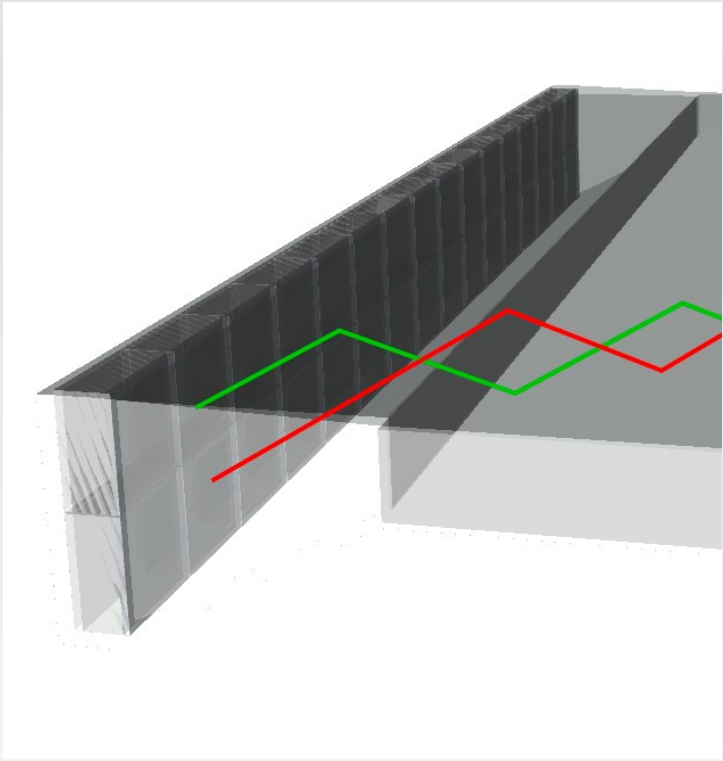
- 32 quartz bars are needed for the full Belle-II detector, each 20×450 ×1250mm^3, with two per module.
- The quartz needs to be of high quality to ensure that photon losses are minimised, and that the Cherenkov photon reflection angles are maintained.



Quartz Property	Requirement
Flatness	<6.3μm
Perpendicularity	<20 arcsec
Parallelism	<4 arcsec
Roughness	< 0.5nm (RMS)
Bulk transmittance	> 98%/m
Surface reflectance	>99.9%/reflection

Photon Detection

- Photons are detected by an array of 32 Micro Channel Plate Photomultipler Tubes (MCP-PMT) in each module.
- Each MCP-PMT has an active area of ~23×23mm^2.
  - NaKSbCs photocathode.
  - Readout via 4×4 channels – 512 total channels per iTOP module.
- PMTs required to have a peak quantum efficiency of >24%, and a collection efficiency of ~55%.
  - PMTs have a gain of ~2×10^6 at operating HV, and an intrinsic transit time spread of ~40ps.



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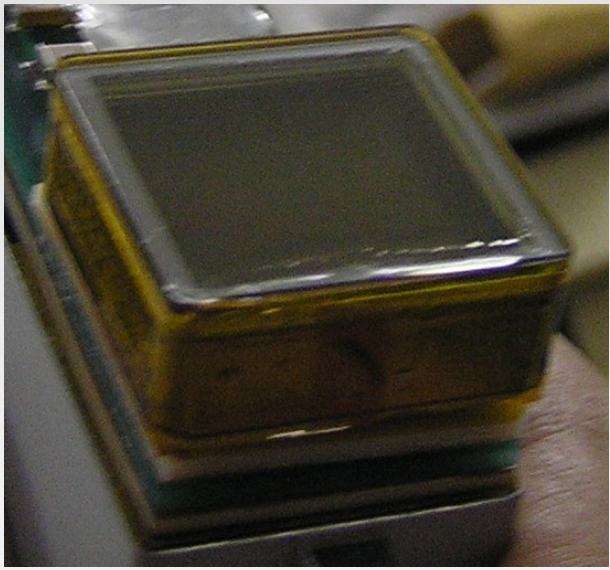
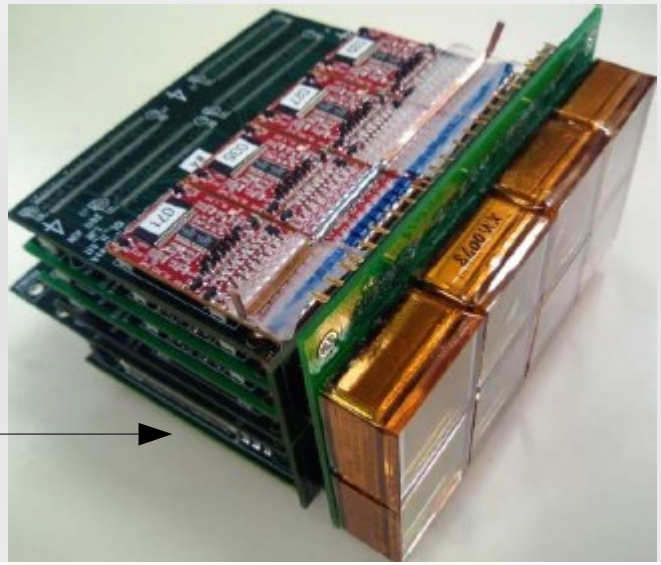
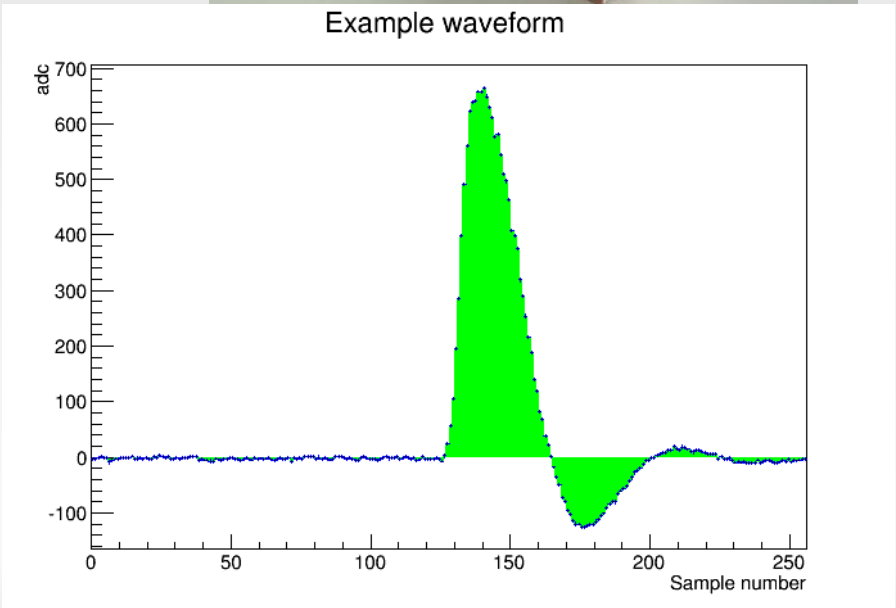


Electronics

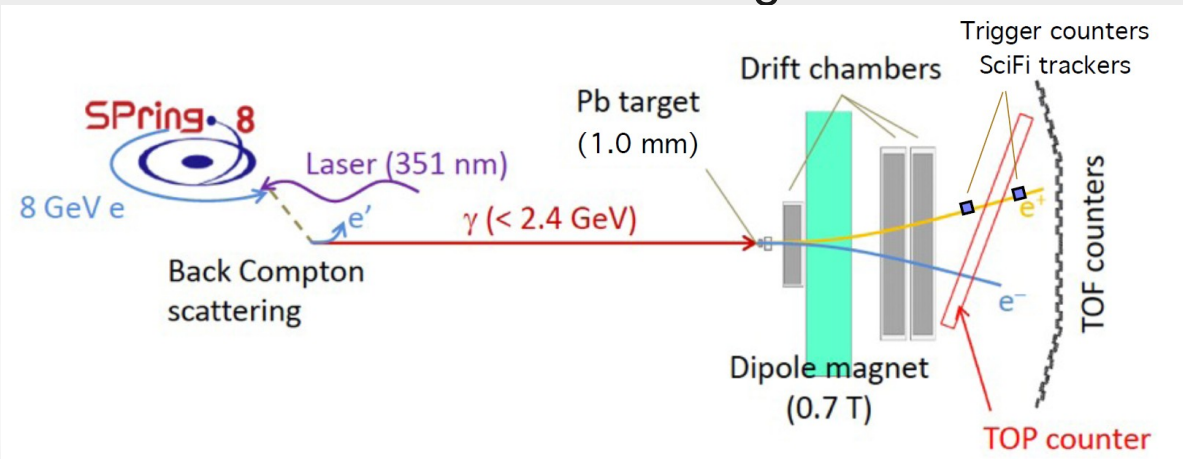
- The PMTs are readout by electronics including waveform sampling ASICs (IRS3B).
  - Two ASICs are used to readout each PMT.
  - These are assembled into readout modules, each with 8 PMTs/16ASICS.
  - 4 readout modules per iTOP module.
- Deposited charge on the PMT anode is converted into a waveform.
  - Used to determine photon detection time.
  - Will have a resolution better than 50ps.
- System needs to be calibrated for optimum performance.





Beam test at SPring-8

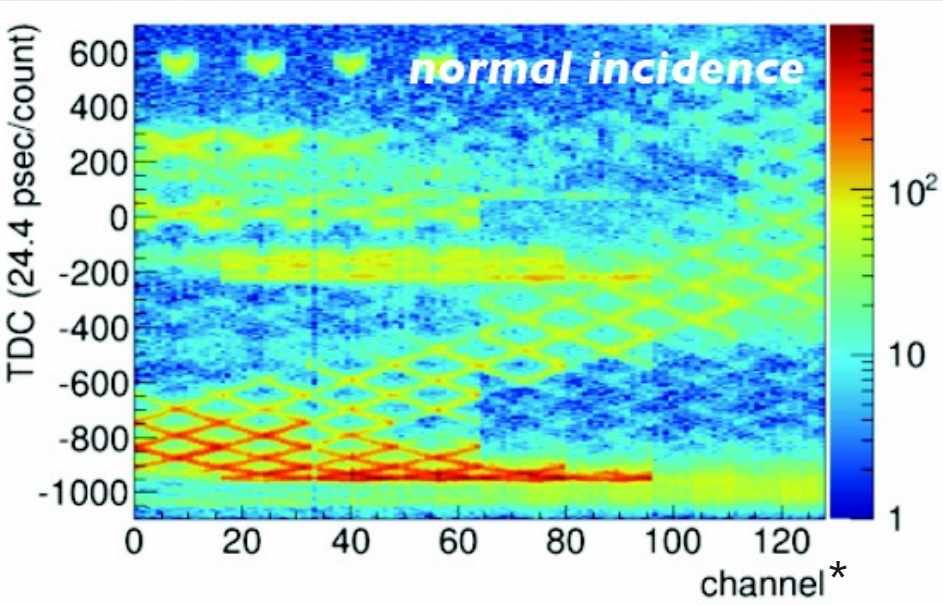
- Beam test in June 2013 at the LEPS beamline at SPring-8 in Japan.
- Used a positron beam with energy ~2.1GeV.
- Prototype iTOP module was placed in LEPS experiment – LEPS subdetectors used to provide tracking and momentum information.
- Data taken with beam hitting module at normal incidence and at forward angles.



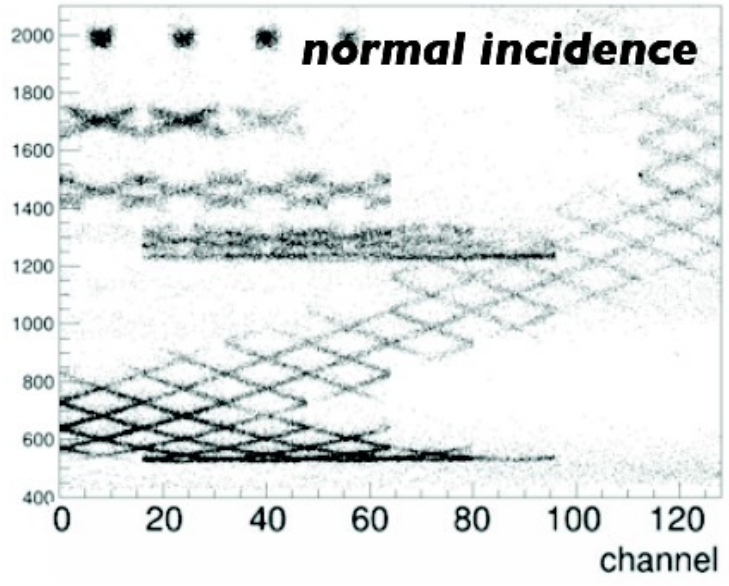
Beam test at SPring-8

- Data was taken with both IRS3B electronics and with alternative CFD (constant fraction discriminator) electronics.
  - IRS3B data requires extensive calibration.
  - Ring image for CFD data taking at normal incidence shown:

Data



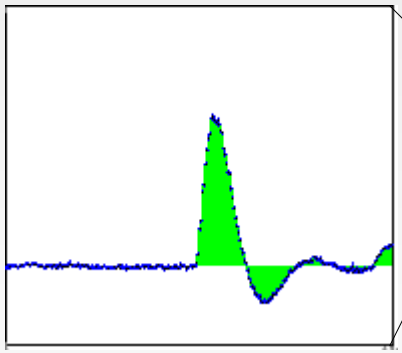
Simulation

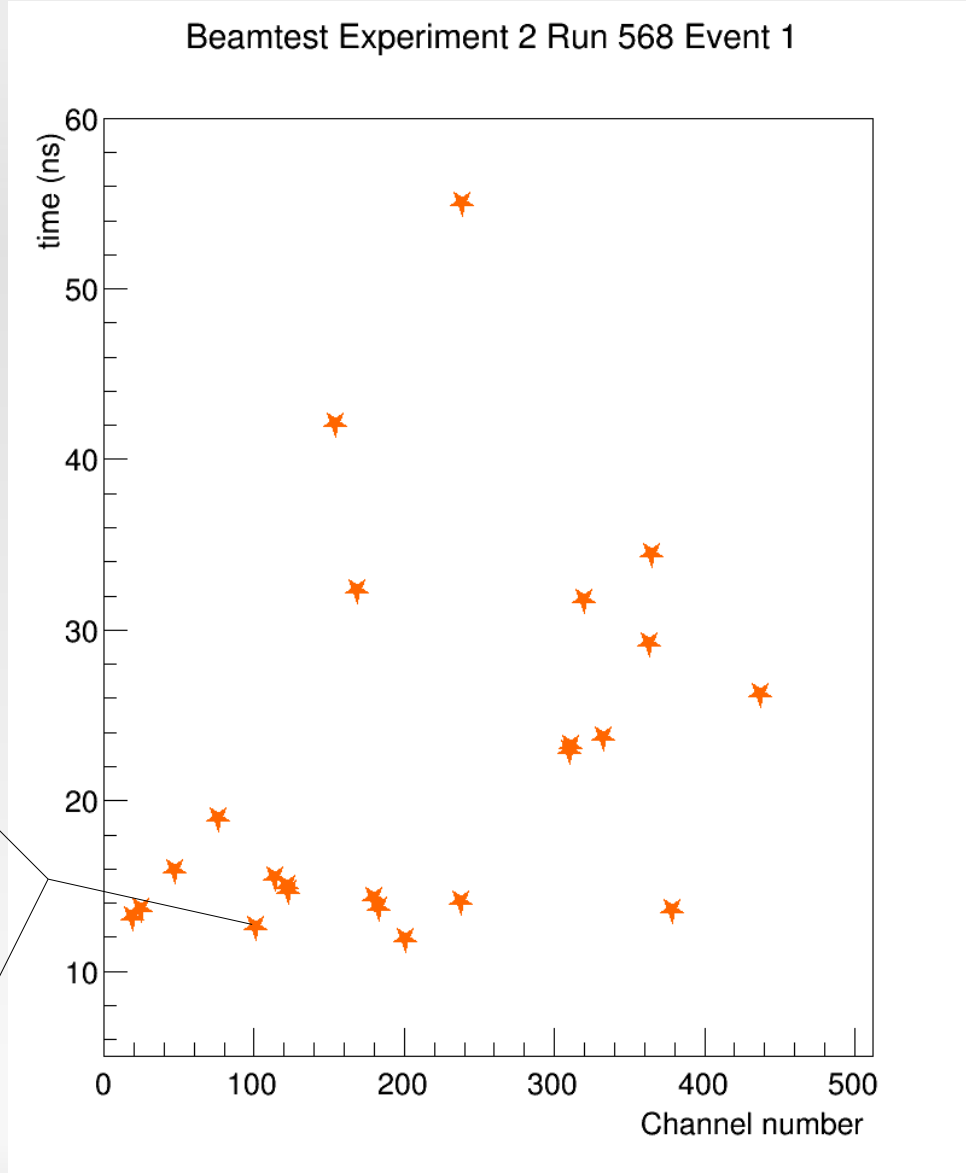


*4 PMT channels read out together, to give a total of 512/4 = 128 channels .

Beam Test Event

- Single events have a mean of ~30 Cherenkov photons detected.
  - Each waveform yields a hit time.
  - Multiple events are required in order to see a ring image.





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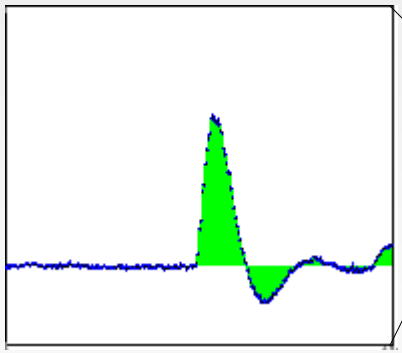
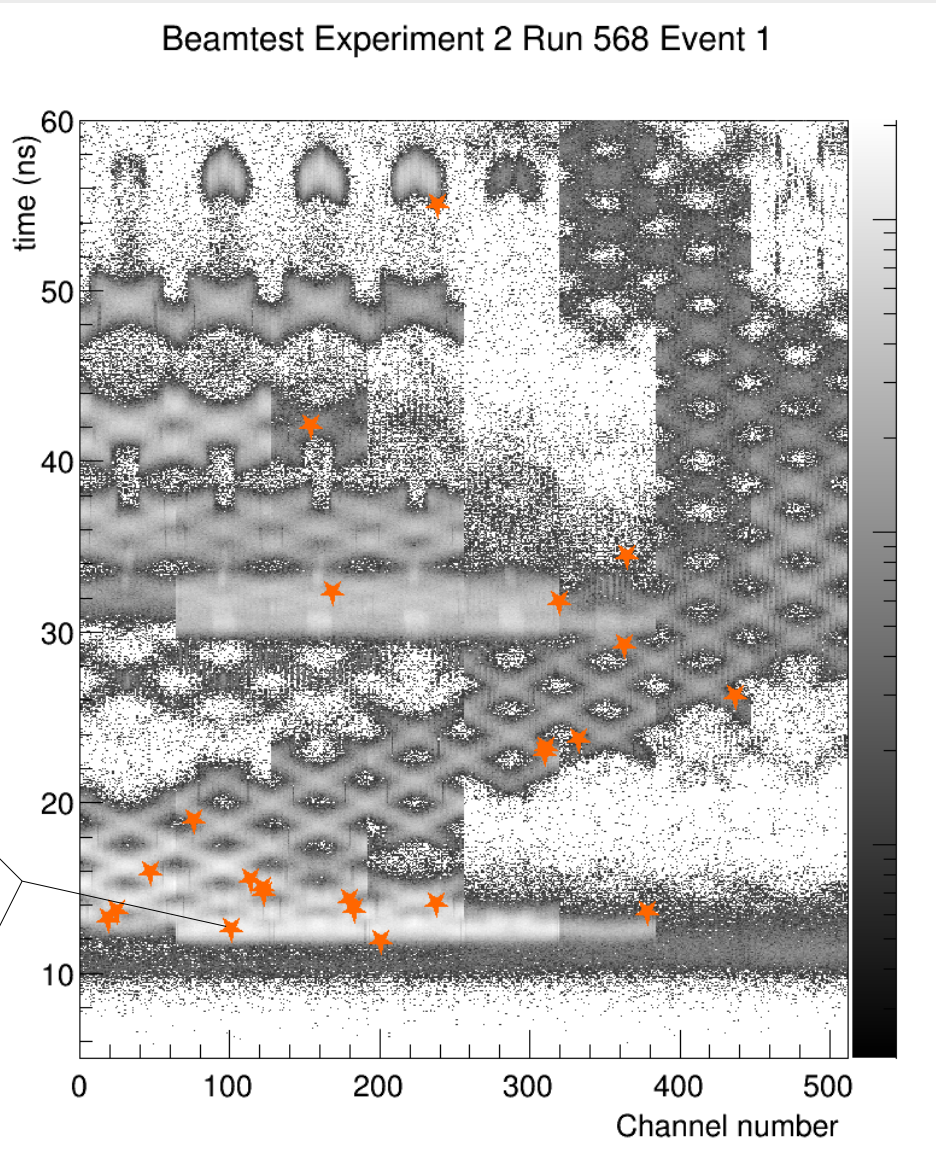
- Greyscale image shows expected distribution from simulation.





Summary

- The iTOP detector will perform particle identification in the barrel region of Belle-II.
- The main task will be to distinguish between kaons and pions.
  - This will require excellent resolution on the detection time of Cherenkov photons.
- A prototype of the final design has recently been tested at a beam test.
- Initial analysis shows good agreement between data and simulation.