Particle Identification with the Belle II Aerogel RICH

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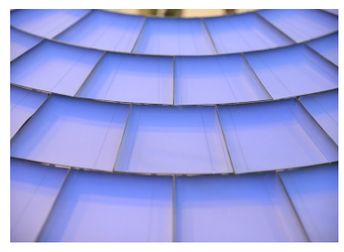
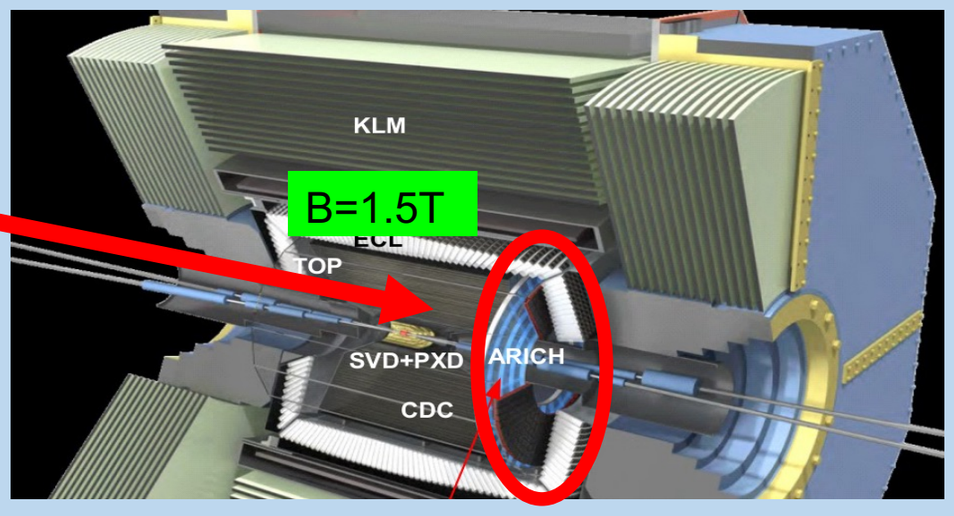
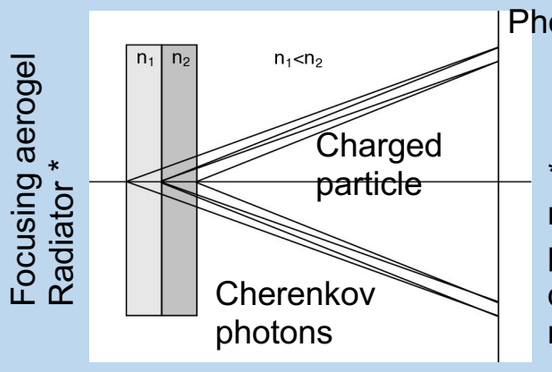


15th Pisa Meeting on Advanced Detectors, 22-28 May 2022

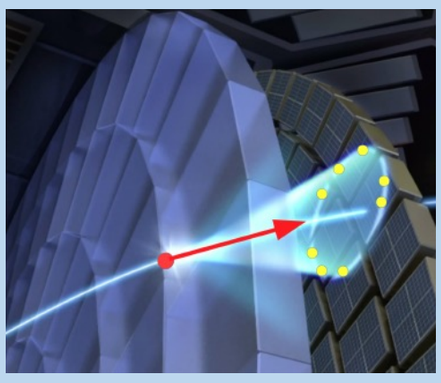
Introduction

- Belle II, KEK, Japan - an experiment to study rare B, D and tau decays;
- Ring Imaging Cherenkov Detector with an aerogel radiator (ARICH) in the forward endcap of Belle II spectrometer inside the 1.5 T magnetic field;
- Cherenkov photons irradiated in two 2cm thick layers of silica aerogel are propagated to the photon detector equiped with single photon sensors;
- Goal: > 4 σ K/π separation @ 1-3.5 GeV/
- Constraints and requirements:
  - designed for luminosity of $8x10^{35}$ cm^{-2} s^{-1}
  - limited available space ~280
  - radiation tolerance (n – 10^{12} n_{eq}/cm^2, γ – 1kGy)





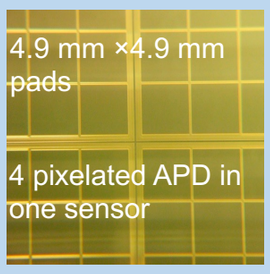
*to increase the number of photons without degrading the resolution

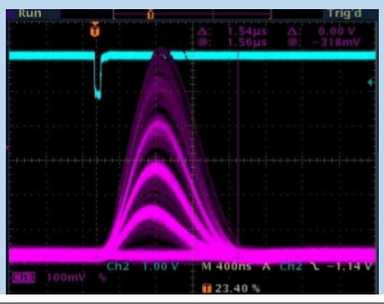


ARICH has shown a very reliable operation in several years of operation. 94% of channels are fully operational; there hasn't been any significant degradation since the beginning. Although each HAPDs requires six different high voltages for the operation, the intelligent slow control and monitoring system supports the ARICH function. The ARICH runs almost without any human intervention, e.g., during the last run period, there has not been any significant downtime due to ARICH.

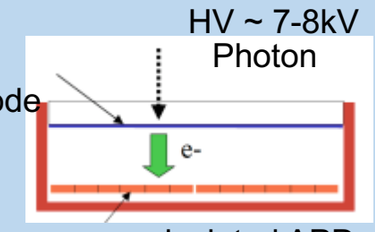
Hybrid Avalanche Photo-Detector - HAPD

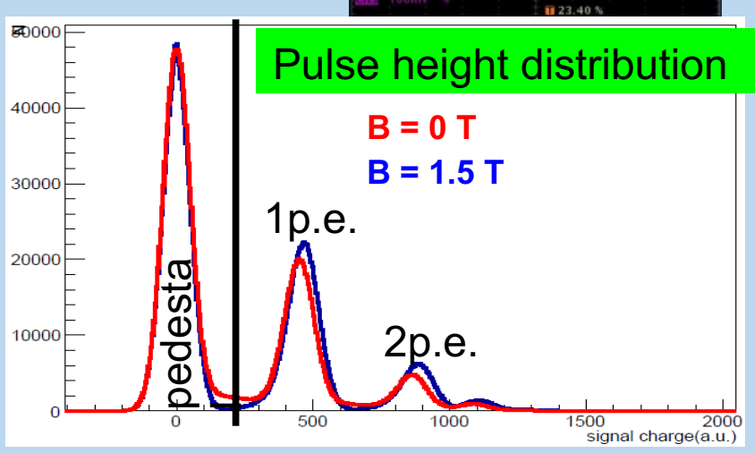
- 144 ch. HAPD developed with the Hamamatsu Photonics
- Excellent separation of single photoelectrons
- Works in a magnetic field of 1.5T





Bi-alkali photocathode

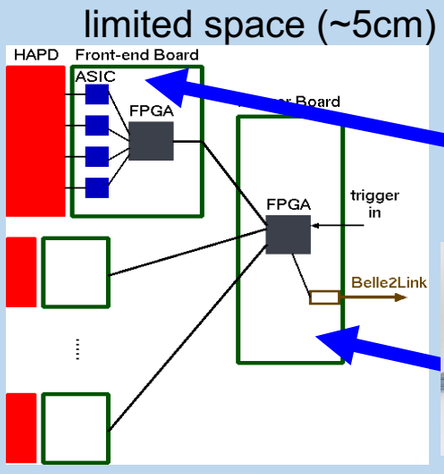


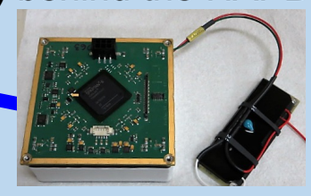


Package	73×73mm2
sensitive area	64%
# of pixels	144(36×4chips)
capacitance	80pF
weight	220g
peak QE	28%
bombardment gain	1500
avalanche gain	~30
total gain	~45000

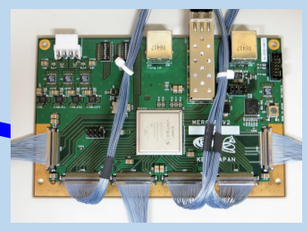
Readout electronics

limited space (~5cm) behind the HAPD

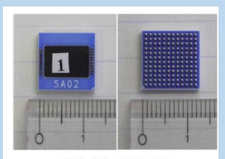


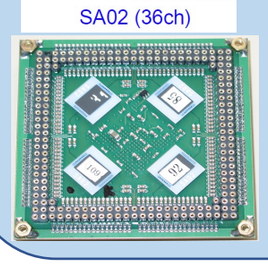


Front-end board with 4 ASICs and Spartan6 FPGA

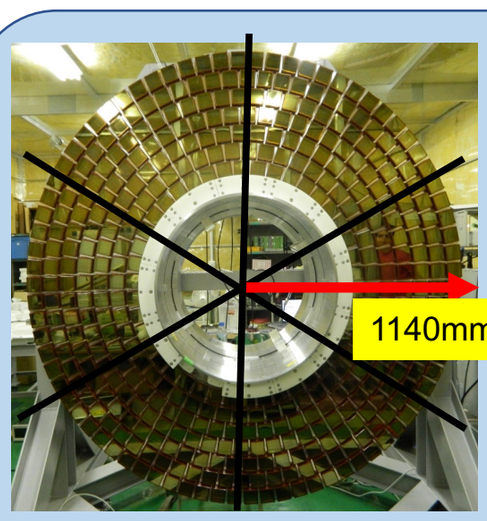


Merger board prototype with Virtex5 FPGA: JTAG, optical link, trigger in, front-end conn.



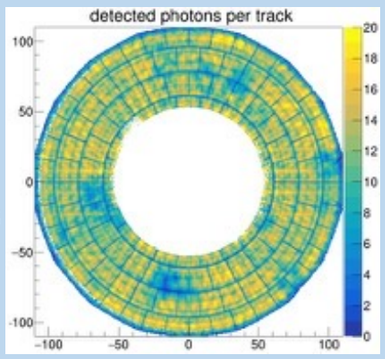


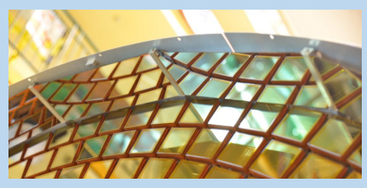
- 36 channel ASIC (preamp., shaper and comparator) provides hit information.
  - settings: 4 step gain, 4 step peaking time, offset level
  - peaking time >100 ns



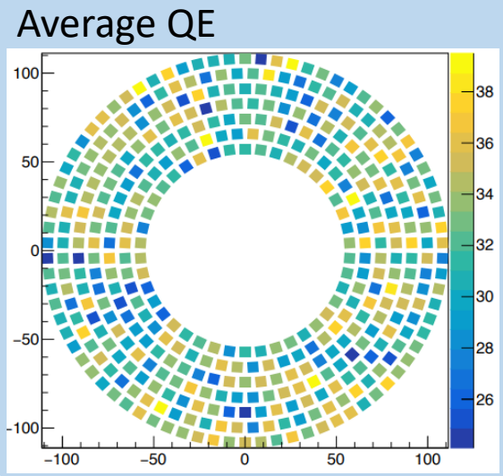
ARICH in operation since 2018

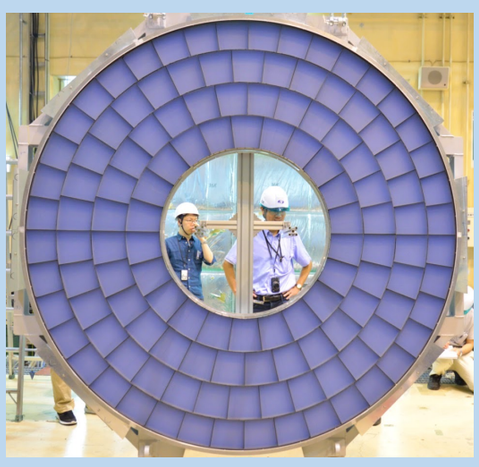
- 2x124 wedge shaped 2 cm thick aerogel tiles of n=1.045 and 1.055 in 4 rings
- Expansion volume 16 cm
- Planar mirrors at the side to reflect photons on the photon detector
- 420 HAPDs in 7 rings
- each HAPDs requires six different high voltages for the operation
- Custom readout electronics at the backside of the photo sensors

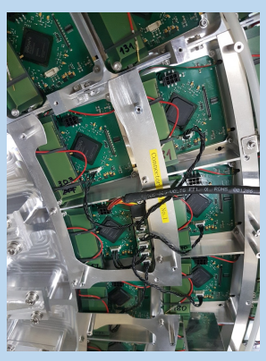


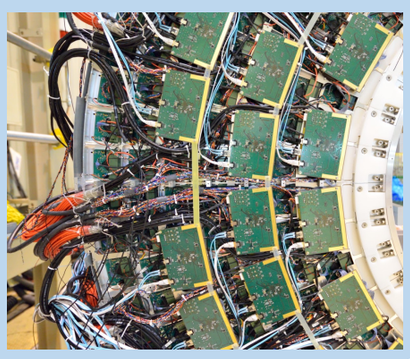


Average QE









Event display

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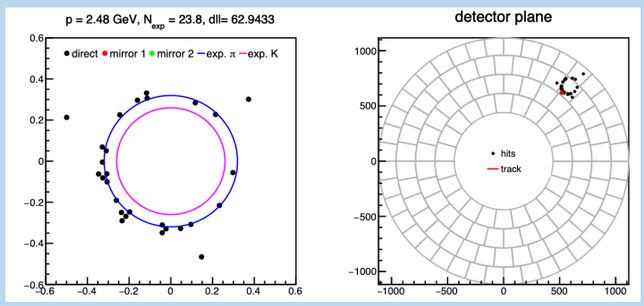
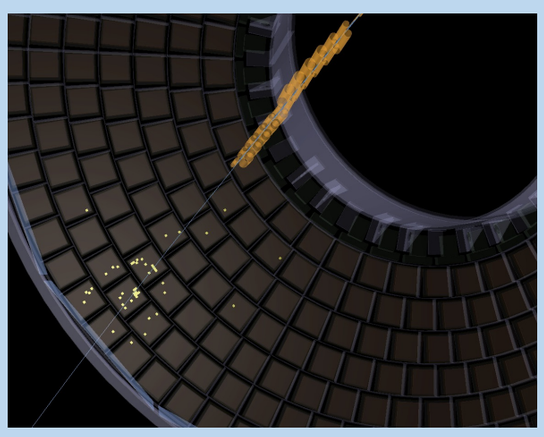
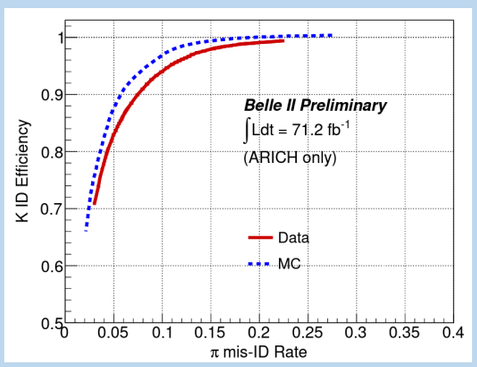
Pions from D*

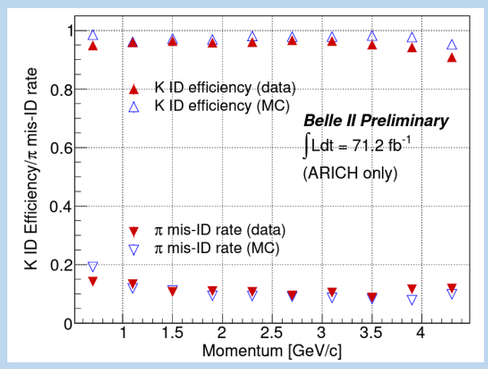


Cosmic ray events



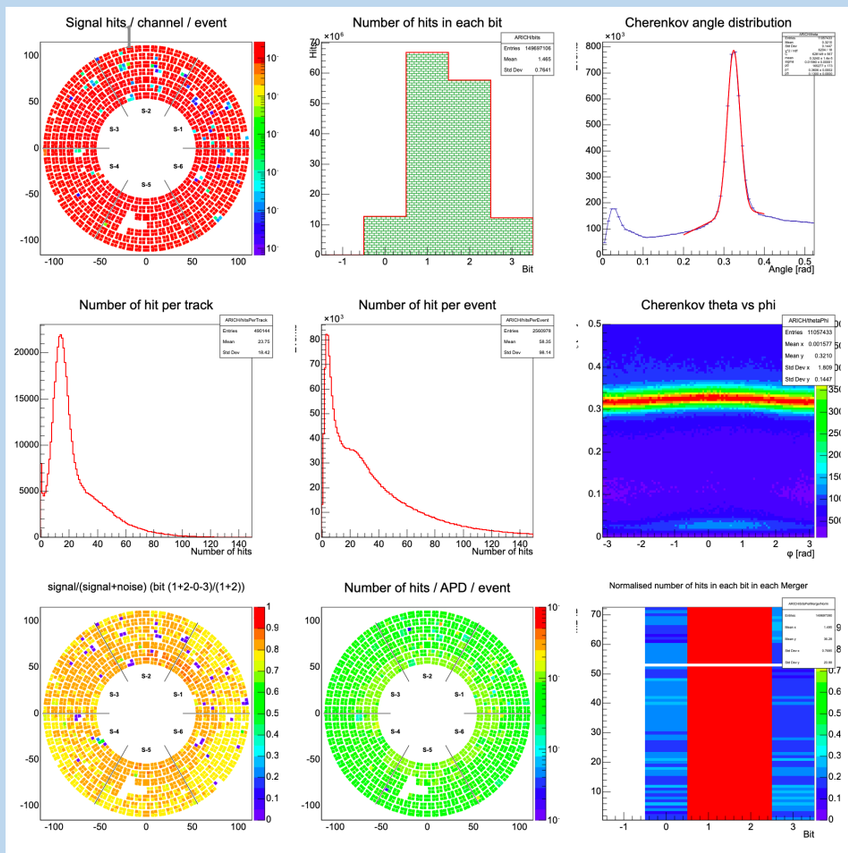
Particle Identification Performances





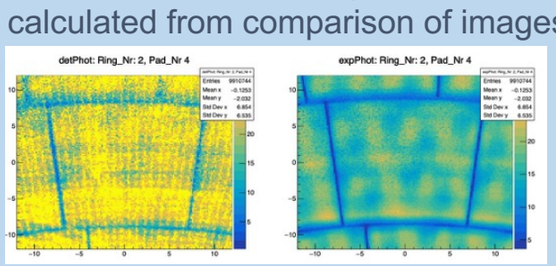
The kaon identification efficiency is above 96% in the wide momentum range from 0.5 to 4 GeV/c at a relatively low pion misidentification probability of 10%.

Data quality monitor



Alignment

Photons per track for one aerogel tile - local rotations and displacements calculated from comparison of images



Single event upset monitoring and correction controller