Japan and Europe Network for Neutrino and Intensity Frontier Experimental Research, H2020
Consortium General Meeting, Paris, France, 30.-31. October 2018

Status of Belle II ARICH

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JENNIFER
EU grant n.644294

Outline

Introduction

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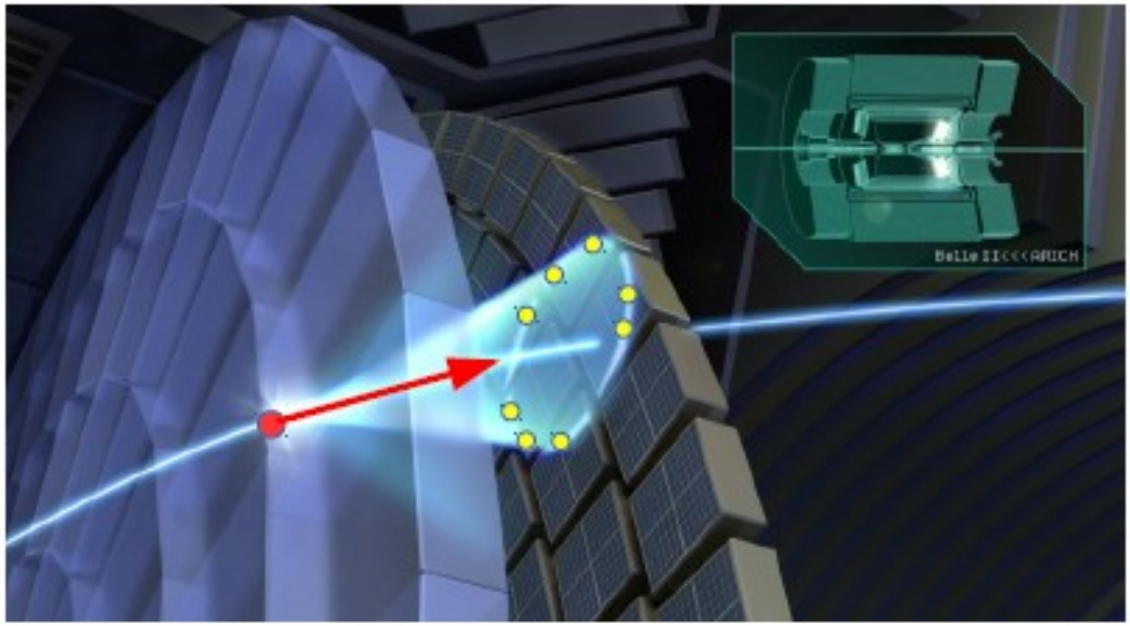
JENNIFER impact

Summary

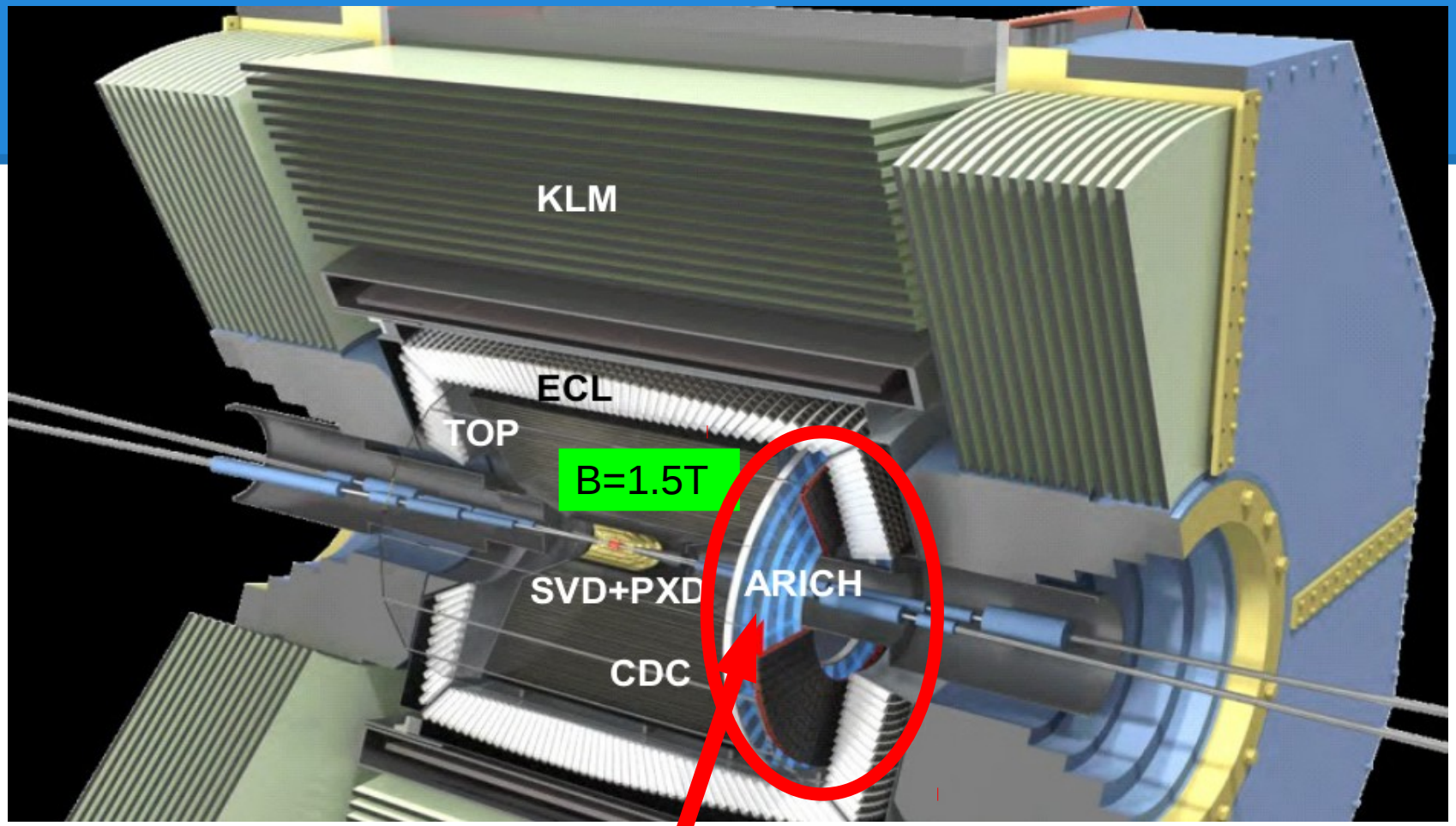


JENNIFER deliverables - ARICH part:

EU grant n.644294

full commissioning and calibration → March 2018
operation in 2018 data taking (Phase 2) → April – July 2018
improvements and preparation for 2019 data taking (Phase 3) → February 2019

Particle identification in Belle II



Two dedicated particle ID devices - both RICHes – designed to fit into available space:

- Barrel: imaging Time-Of-Propagation (TOP)
- End-cap: **Proximity focusing Aerogel RICH (ARICH)**

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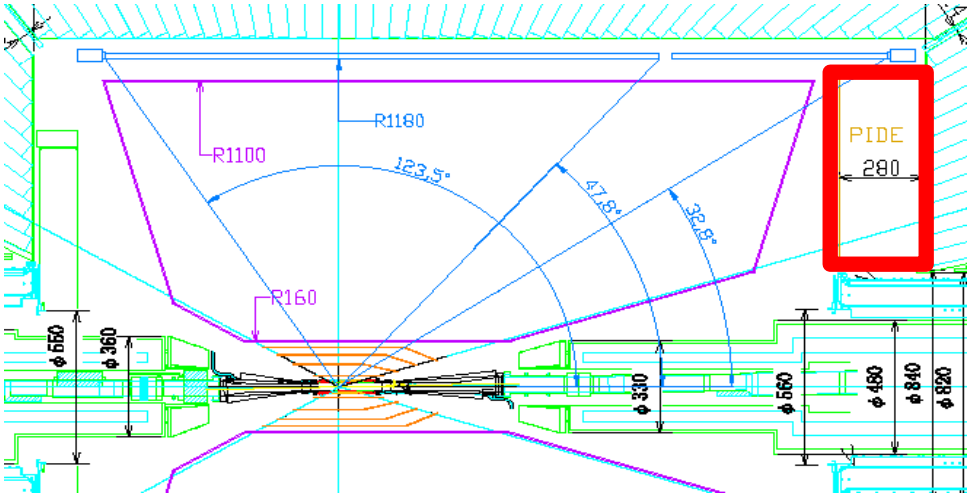
Introduction : Aerogel RICH

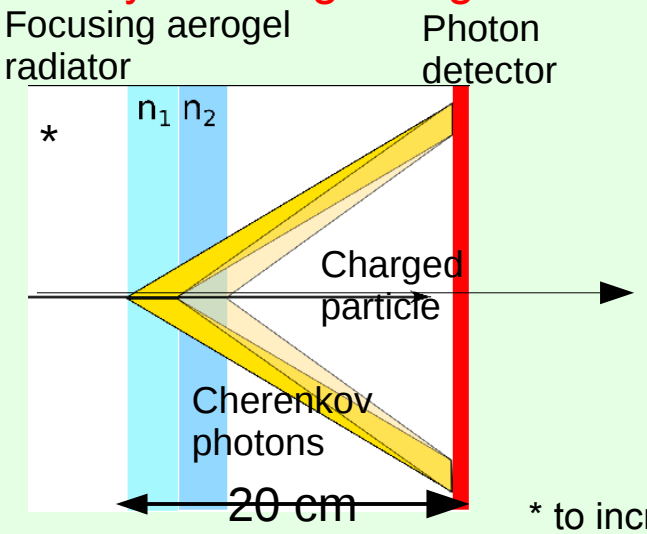
Goals and constraints:

- > 4 σ K/π separation @ 1-3.5 GeV/c
- operation in magnetic field 1.5T
- limited available space ~280 mm
- radiation tolerance (n,γ)



Selected type:

proximity focusing aerogel RICH



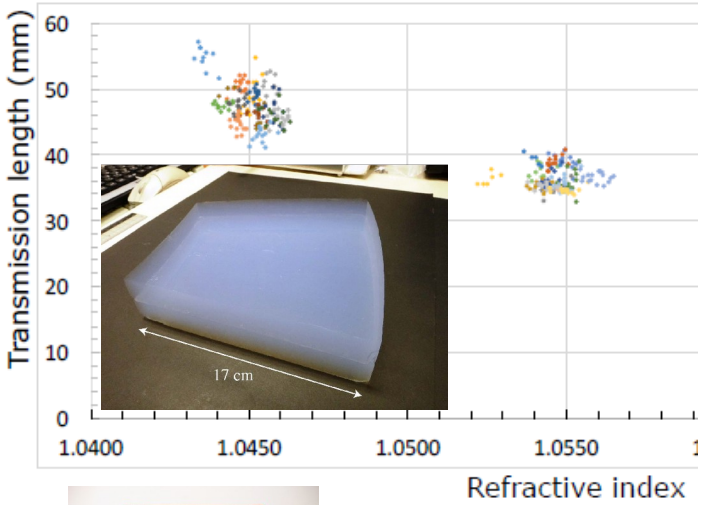
- <n> ~ 1.05
- $\theta_c(\pi) \approx 307$ mrad @ 3.5 GeV/c
- $\theta_c(\pi) - \theta_c(K) = 30$ mrad @ 3.5 GeV/c
  - pion threshold 0.44 GeV/c,
  - kaon threshold 1.54 GeV/c
- neutron fluence: up to ~10^{12} n/cm2
- radiation dose: up to ~1000 Gy

* to increase the number of photons without degrading the resolution

ARICH components

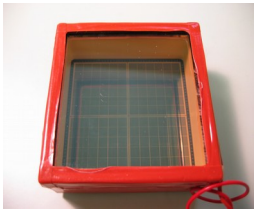
Photon radiator: hydrophobic silica aerogel radiator

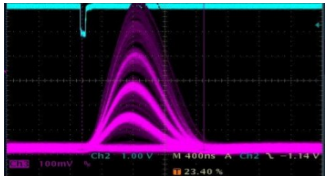
- Two 2cm thick layers n_1= 1.045 n_2= 1.055
- Optical transparency limited due to Rayleigh scattering
- large tiles (18x18x2 cm^3) to minimize photon losses at the edges
- 124×2 tiles compose ARICH radiator



Photon detector: Hybrid Avalanche Photo Detector (HAPD)

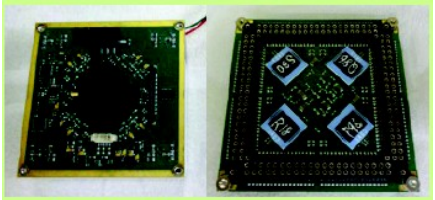
- QE: 30%
- 144 channels, total area 7cm x 7cm
- Excellent separation of single photoelectrons
- Works in a magnetic field of 1.5T
- 420 HAPDs compose ARICH photon detection side.





Readout Electronics: limited space behind the HAPD (5cm)

- Front-end board with 4 ASICs and Spartan6 FPGA
- Merger board with Virtex5 FPGA:
  JTAG, optical link, trigger in, front-end connector

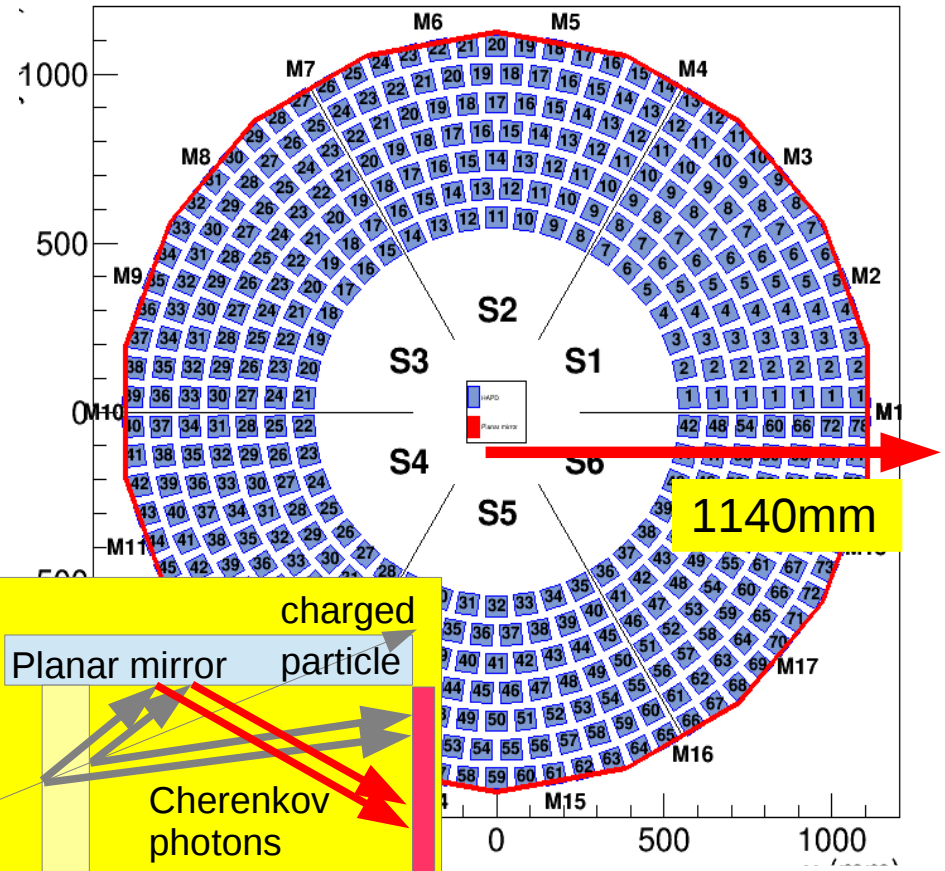


Front-end board
with Xilinx Spartan6 FPGA :
Four 36 channel ASICs

Merger board
with Vertex5 FPGA :
JTAG, optical link, trigger in,
6 front-end board connection.

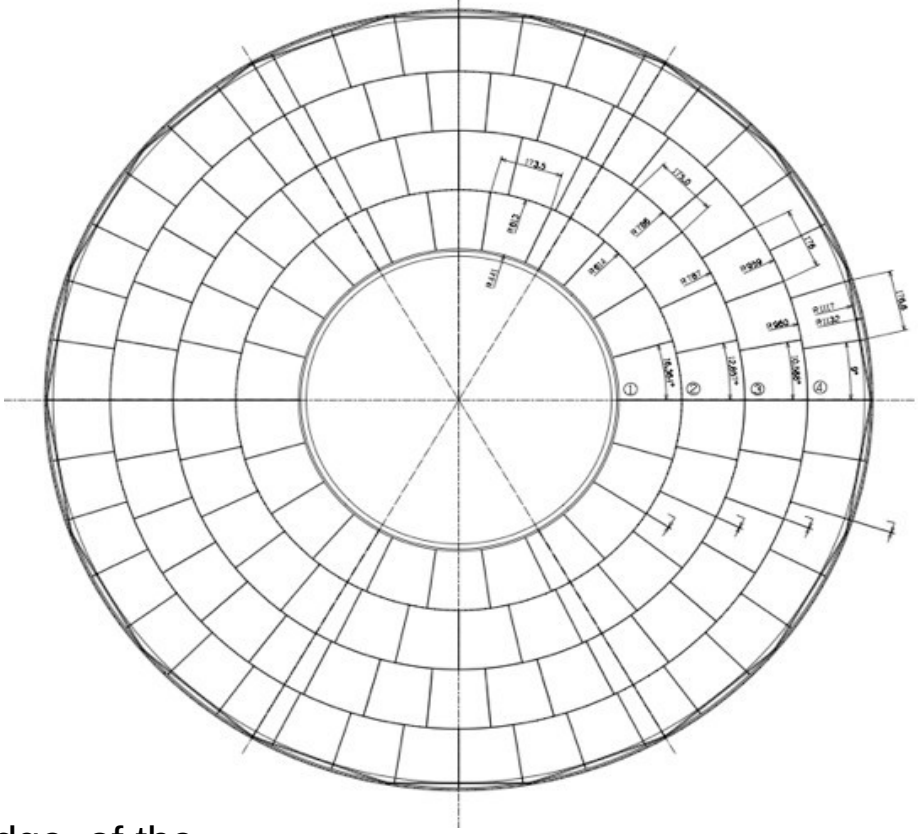
ARICH geometry design

420 HAPD modules in 7 rings



Aerogel : 124x2 layers
wedge-shaped

strict mechanical tolerances to minimize photon loss

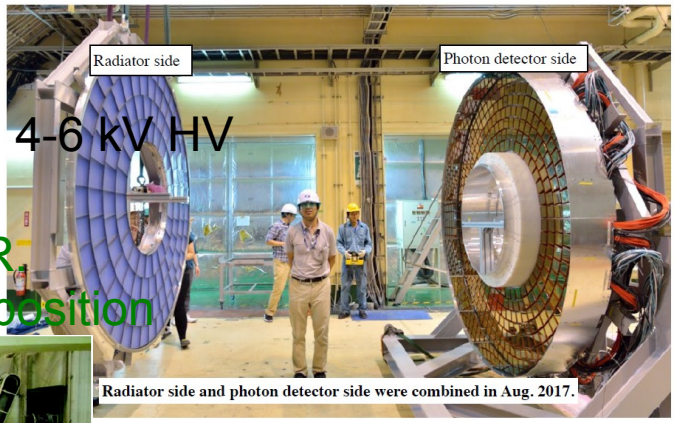


Planar mirrors on the edge of the detector to improve photon detection

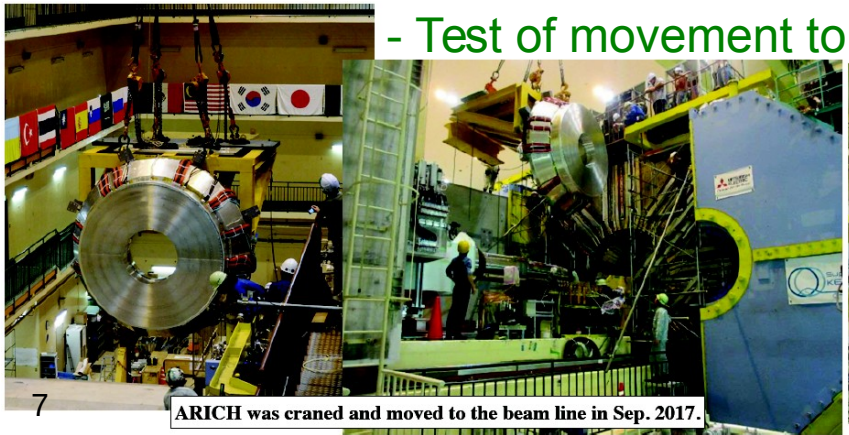
Status of the ARICH installation/commissioning

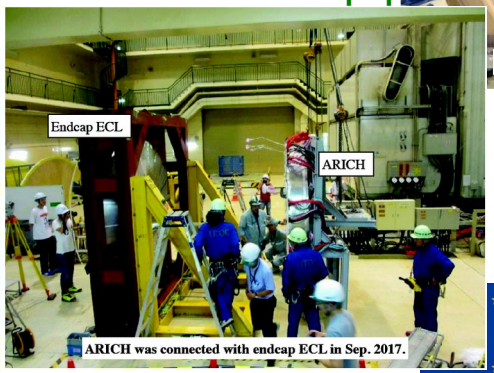
October 2016 – July 2017:
Installation of major components:
- Aerogel tiles installed in the mechanical frame
- 420 HAPDs+FEBs+HV-divider boards, 72 merger boards, supply cables, polyethylene shield, LED monitor system

August 2017:
- Missing detector cables installed
- Planar front surface mirrors and side plates installed.
- Assembly: aerogel side combined with the HAPD side.
- DAQ and HV test with one sector setup: Nominal bias + 4-6 kV HV



September 2017:
- ARICH and forward ECL combined and transferred to IR.
- Test of movement to the final end-cap position





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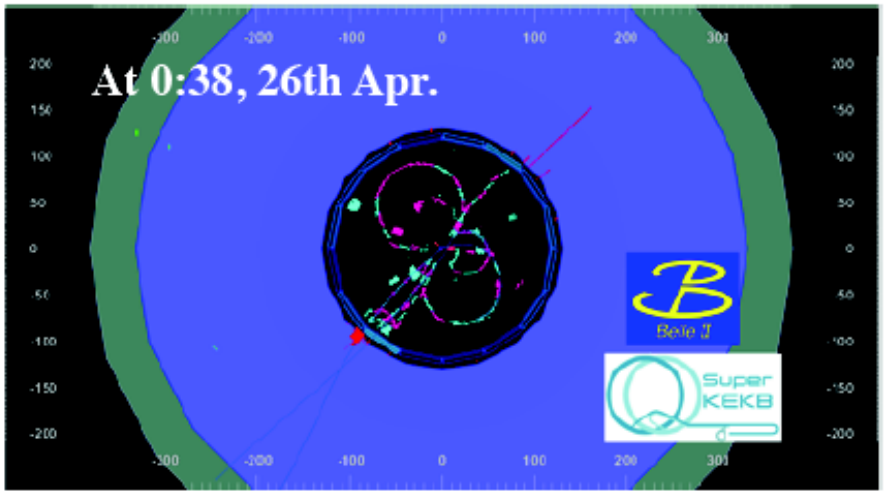
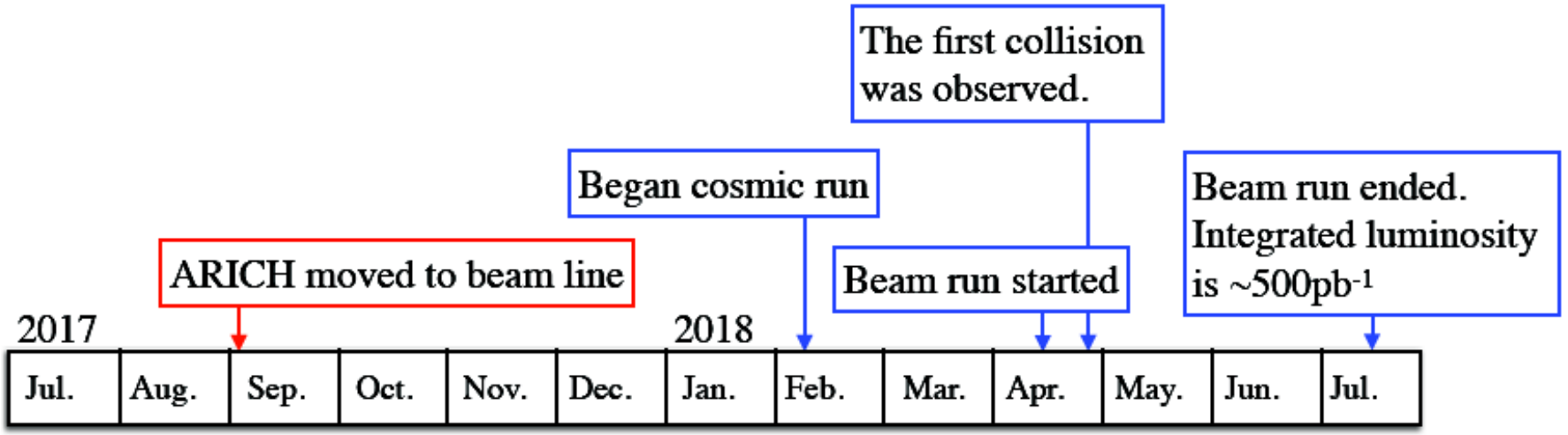
ARICH further progress

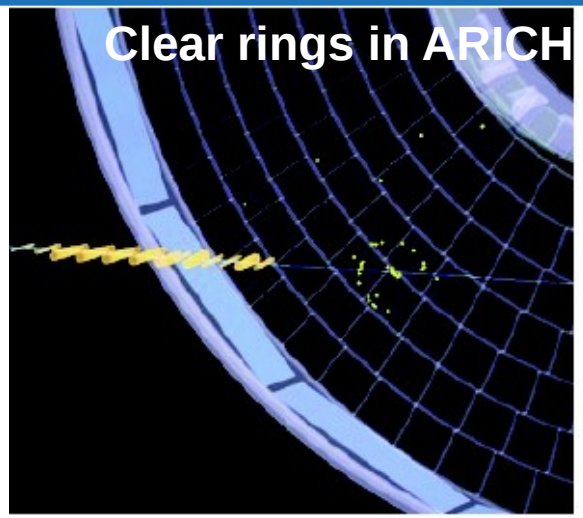
- ARICH moved to the beam line and installed in Belle II spectrometer in Sep. 2017.
- Cosmic run began in Feb. 2018.
- Beam run started in Apr. 2018.
- The first collision was observed in 26th Apr .2018.
- Beam ended in Jul. 2018.



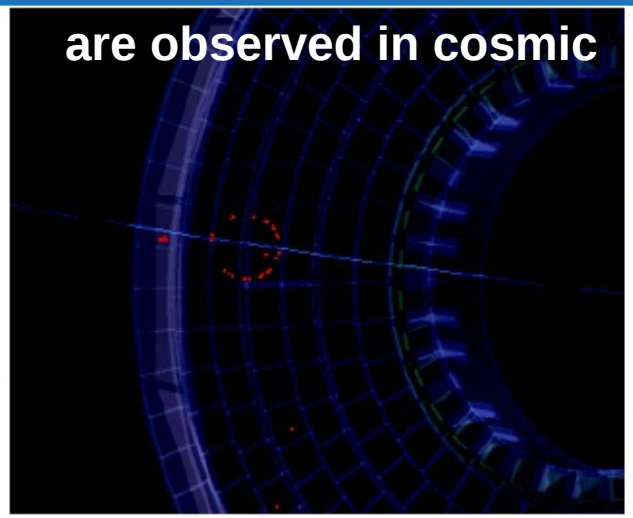


ARICH operation

Clear rings in ARICH are observed in cosmic runs and beam runs.

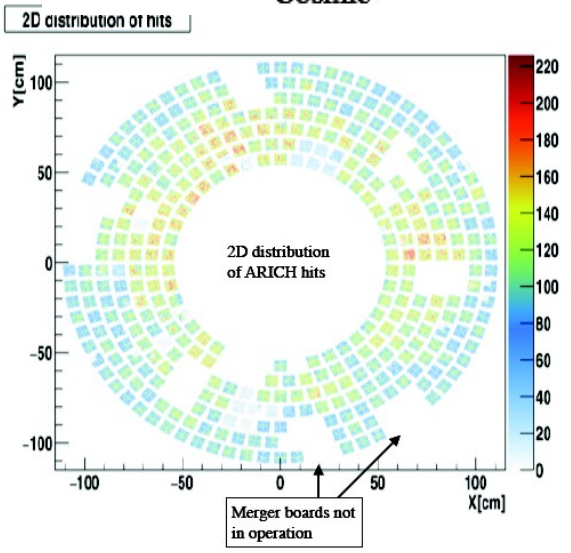


Cosmic



Beam

Beam



- Hit distribution in two runs(run 4339 and 4340) is shown.
- Readout system can read hit information from ~60,000 channels.
- Some merger boards are not in operation.

HV = -6kV
Bias of APD = ~350V

Beam current (e^-) = 285mA
Beam current (e^+) = 353mA
Luminosity = 1.0×10^{30} $cm^{-2}s^{-1}$

Total runtime = 58' 56"

ARICH is operational.

ARICH basic performance in 2018 running

The message about ARICH performance:
Basic parameters agree with expectations and we can expect further improvements by better alignment and calibration.

- For calibration and alignment studies we are using Bhabha events – muon pairs not available in forward direction
- For the estimates only part of the detector was used since calibration and alignment parameters are not fully implemented yet

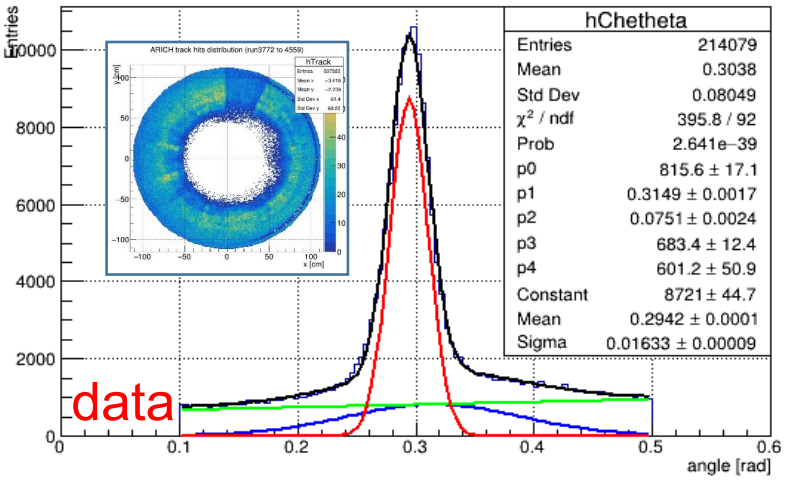
- Cherenkov angle distribution and number of hits per track look reasonable:
  - $N_{p.e.}$ = 9.5 (10.4),
  - σ = 16.3 (14.7) mrad

  corresponding to ~ 4.3 σ K/π separation at 4 GeV

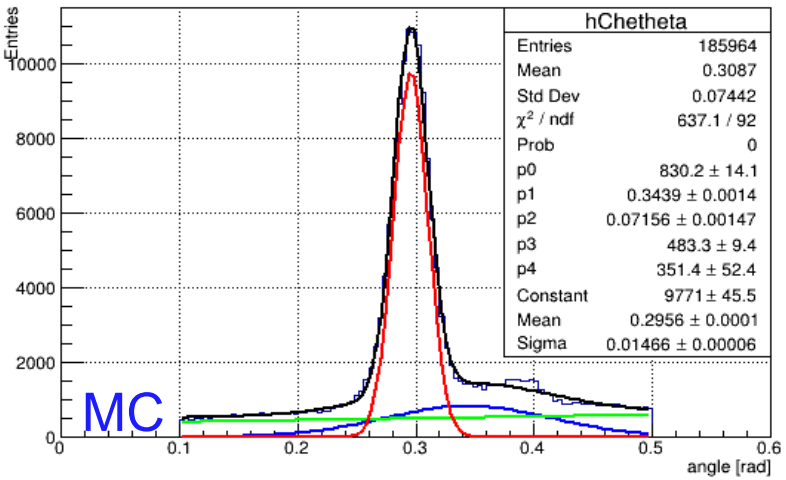
- We can expect improvement by better implementation of alignment and calibration parameters

- Different PID efficiency studies are being prepared but require better detector calibration.

Cherenkov angle distribution (run3772 to 4559)

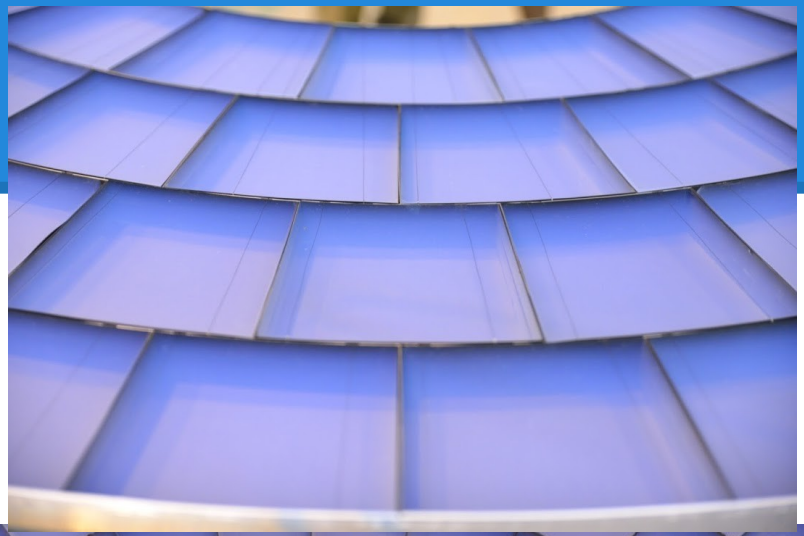


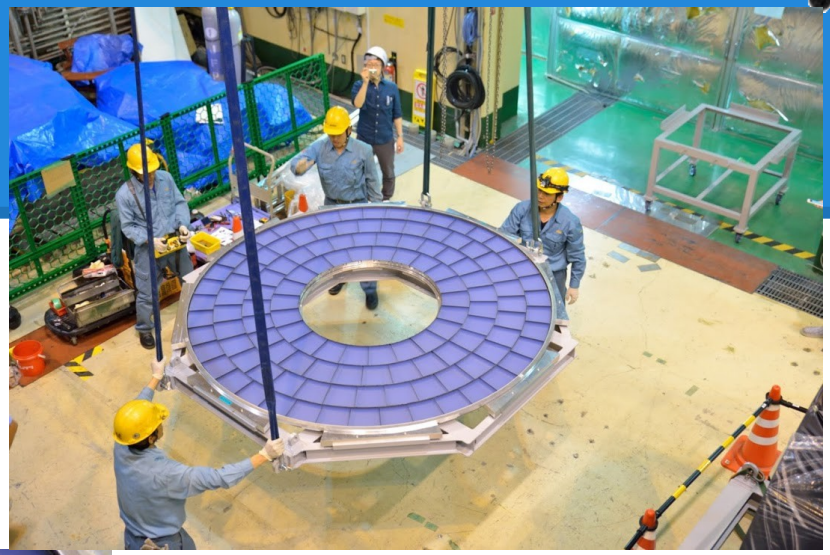
Cherenkov angle distribution (BhabhaMC)



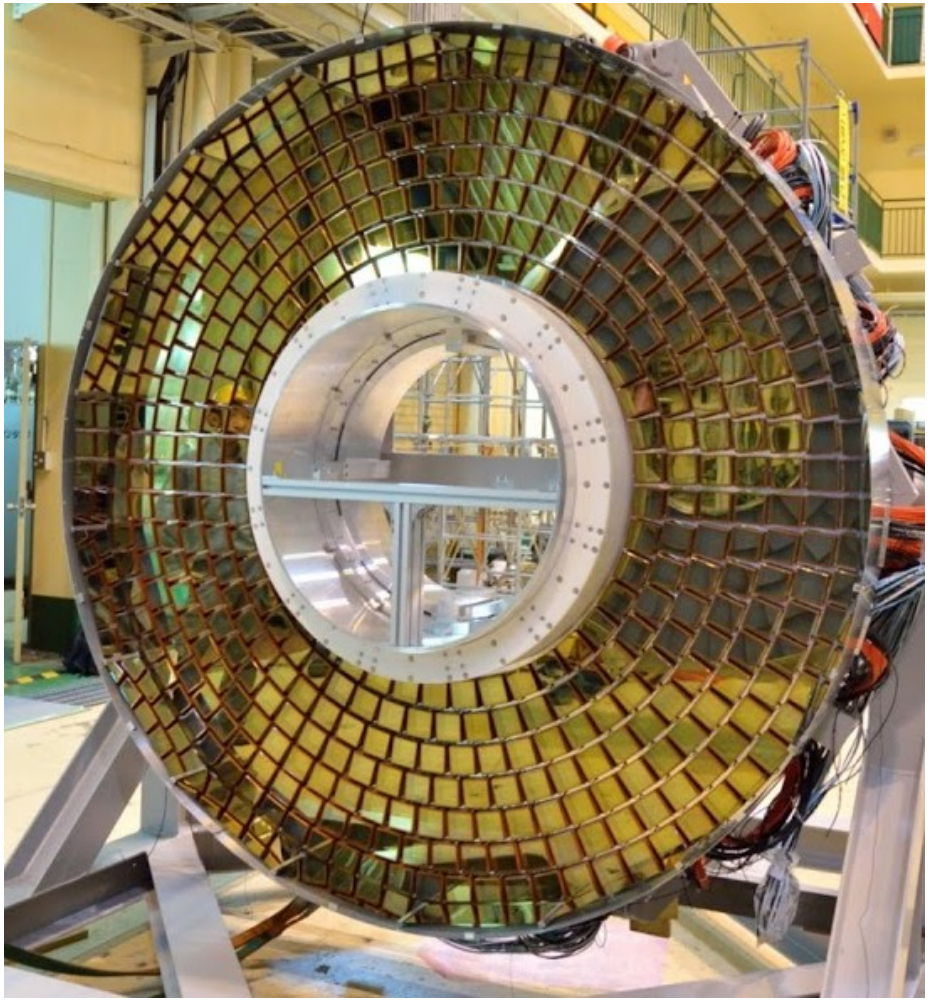
Belle II ARICH installation in pictures ...

Aerogel Plane

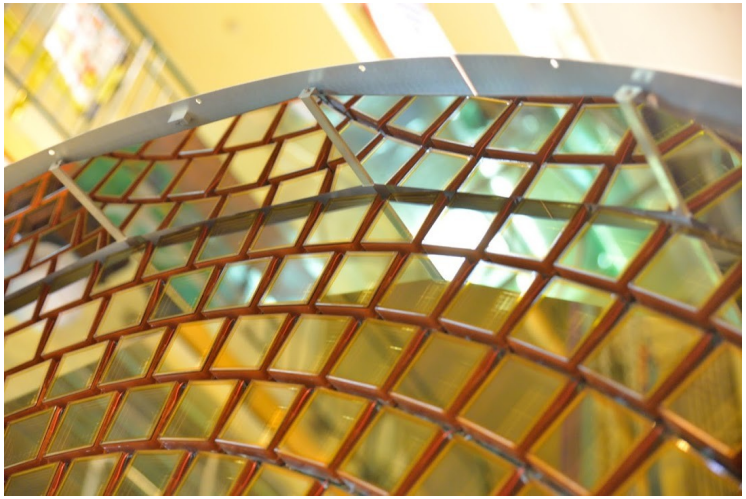




Photon detector



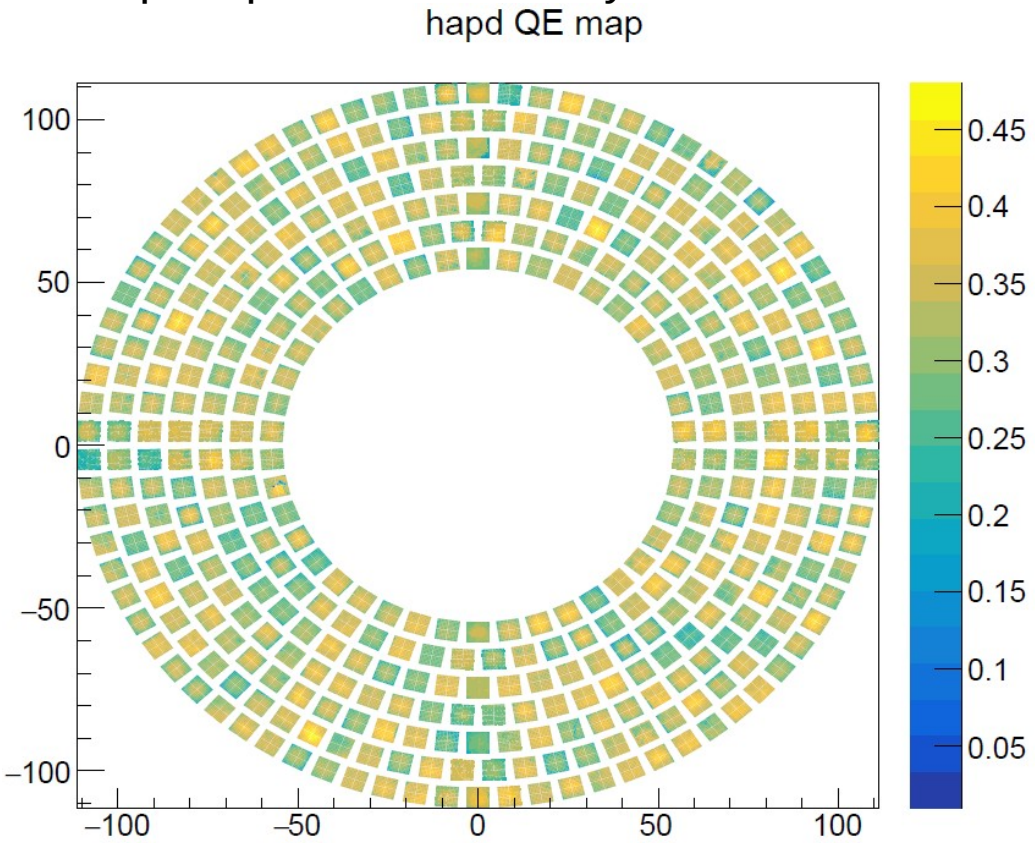
HAPD Modules
Polyethylene shield
Planar Mirrors at the edges

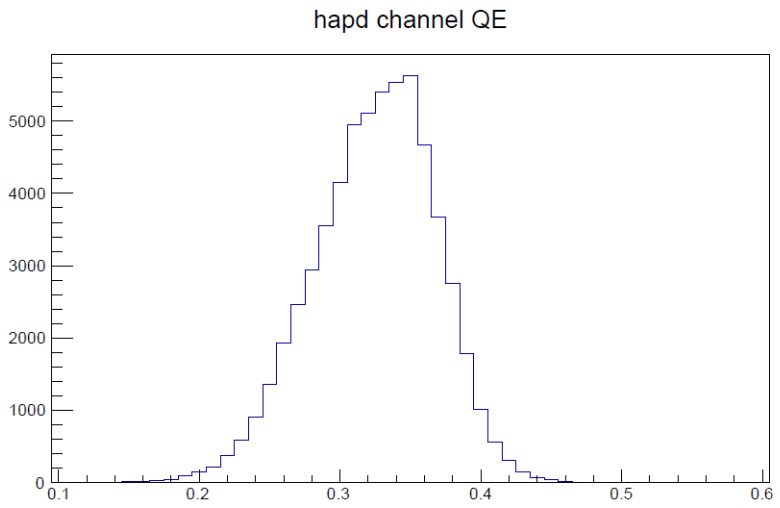


ARICH Database

Operational & geometrical parameters and mappings of the consisting elements are kept in the centralized common Belle II database.

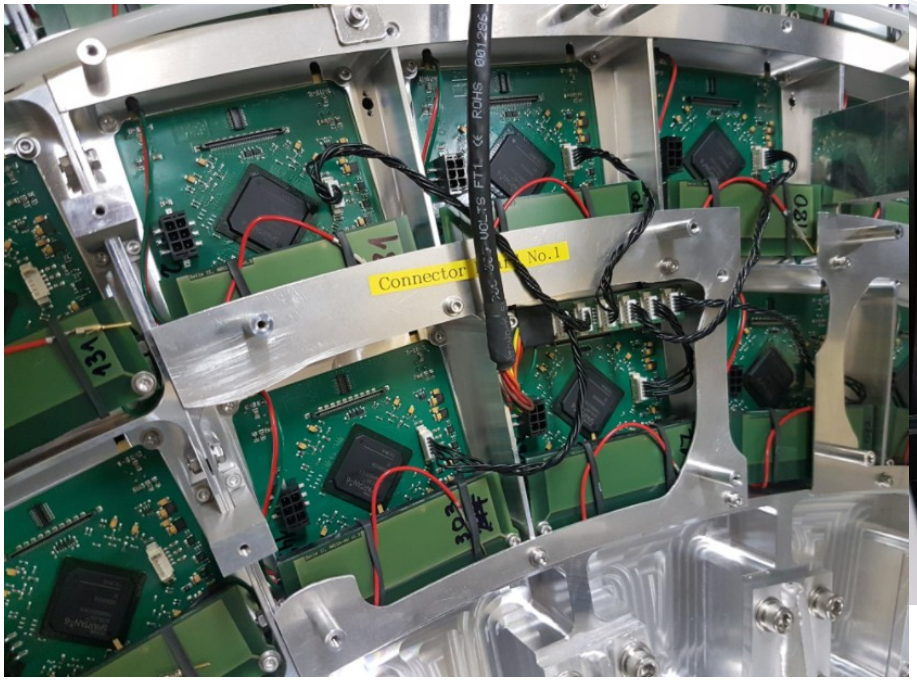
Example: quantum efficiency of the channels



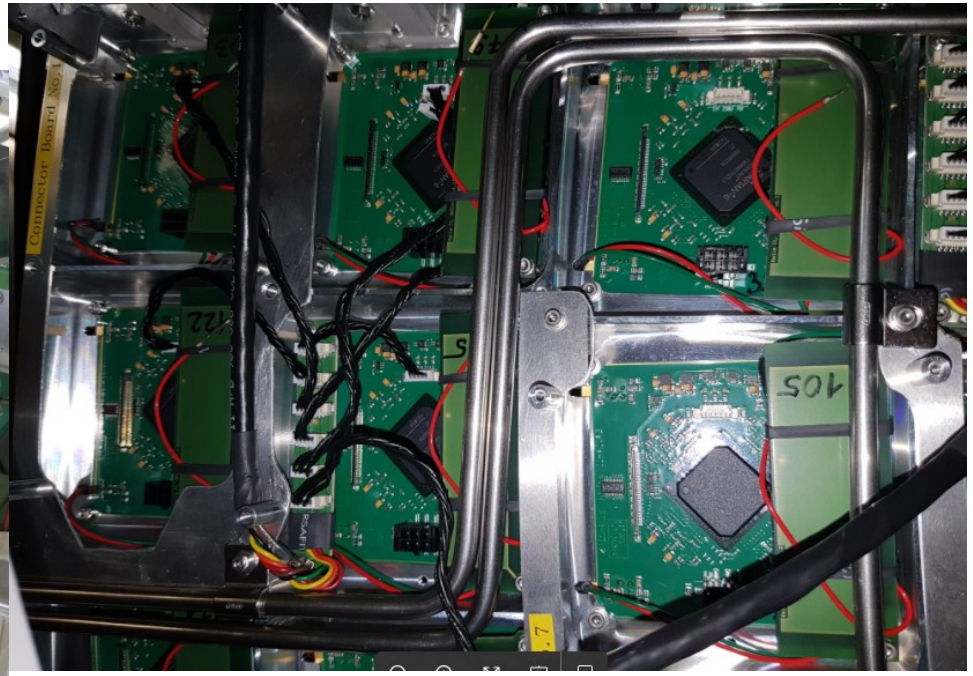


Installation of services

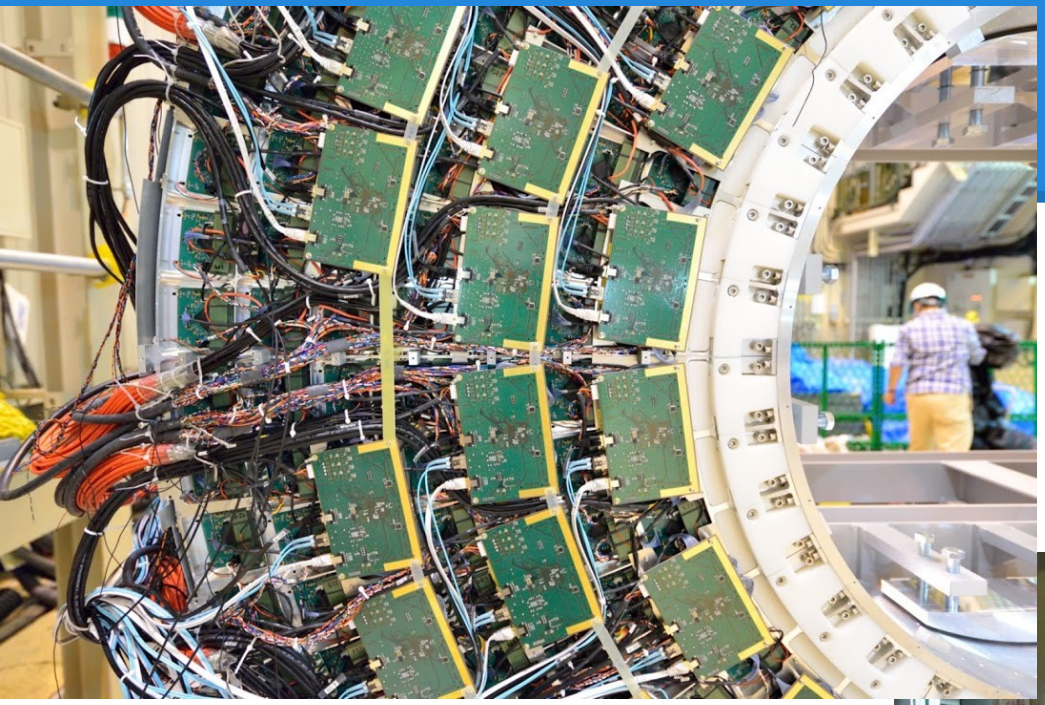
Front end boards
HV divider boards,
FEB Power supply distribution
Merger support

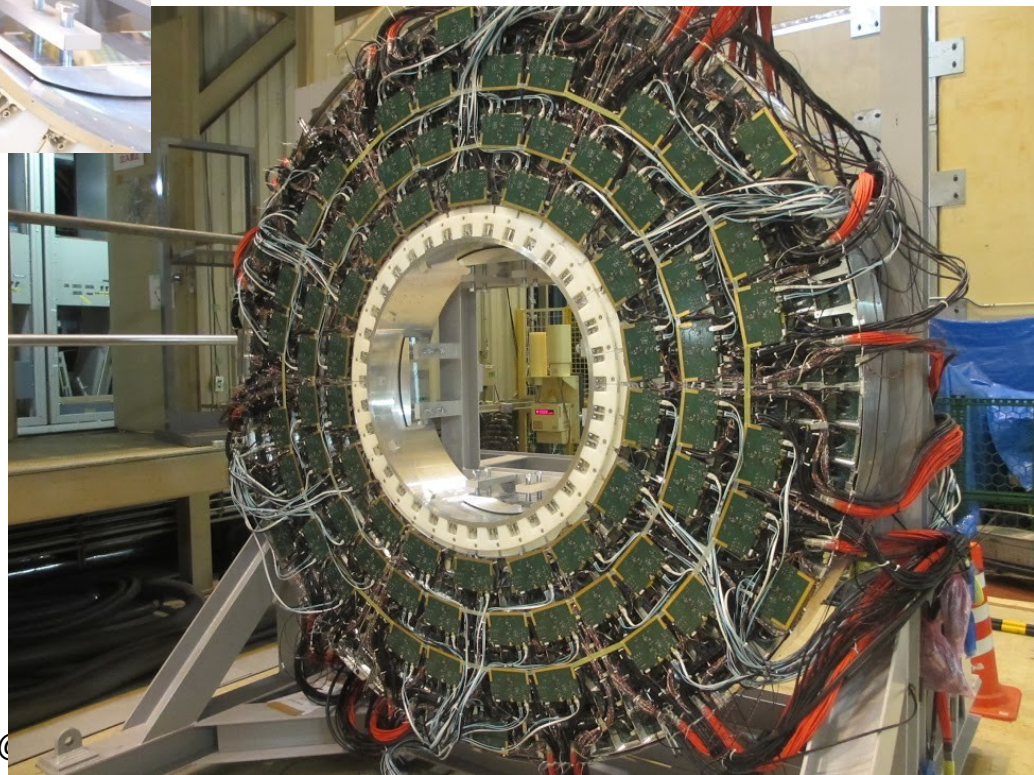


Cooling pipe

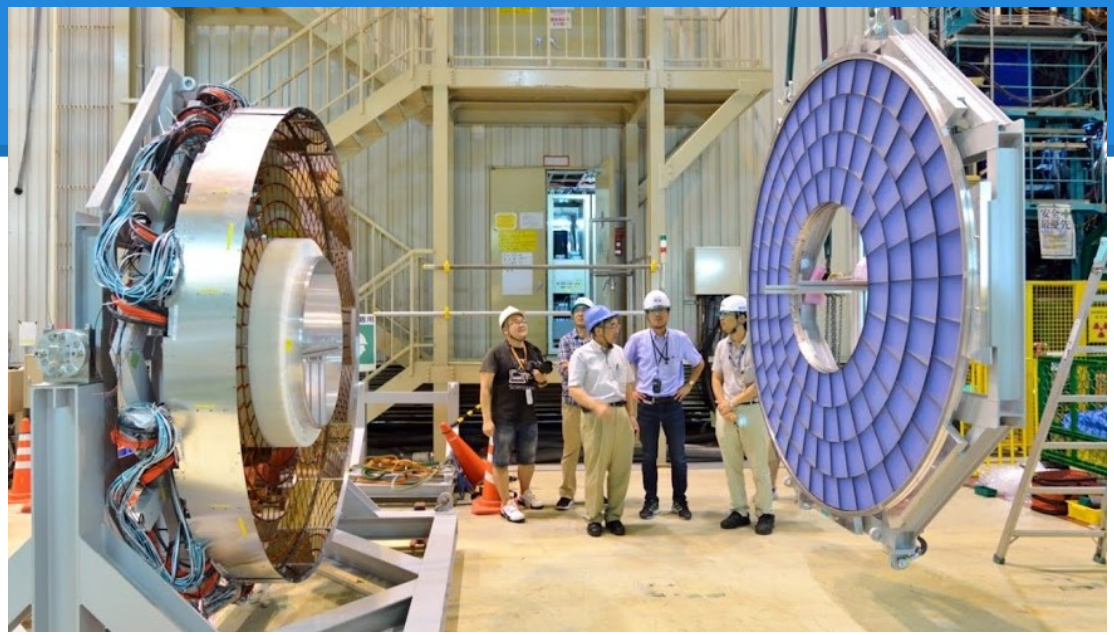


Backside of the photon detector with all the cables

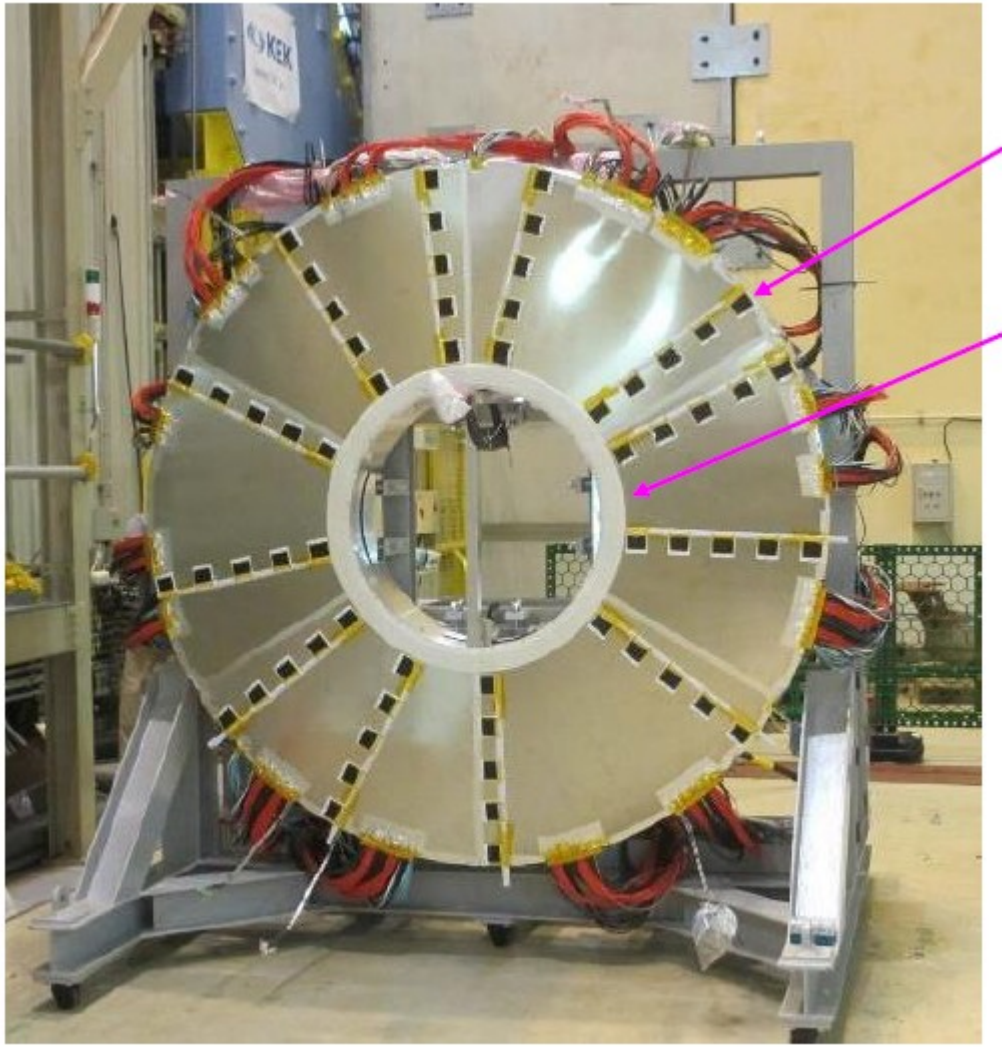




Integration of photon detector and aerogel plane



Integration with forward ECL

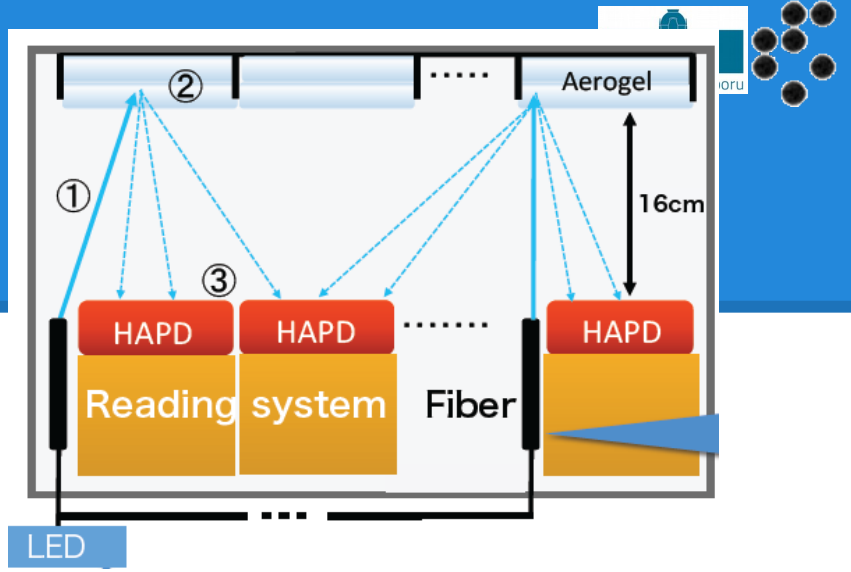


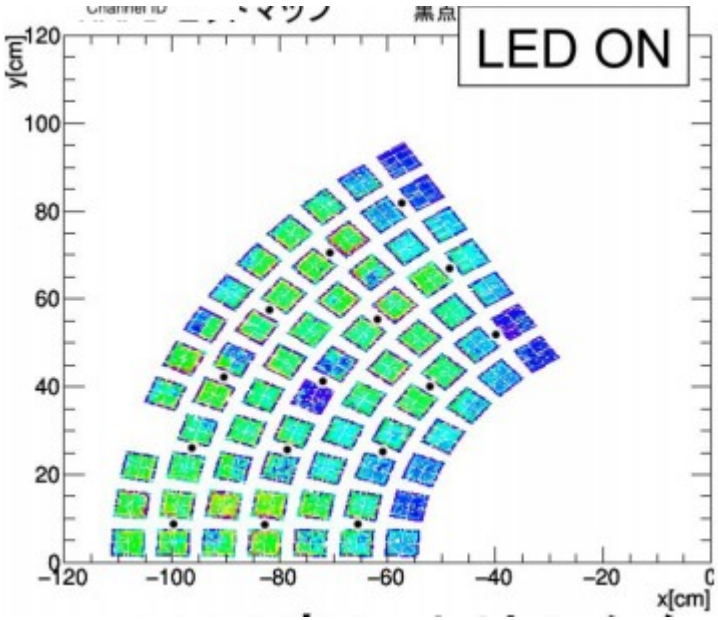
Radiation monitors

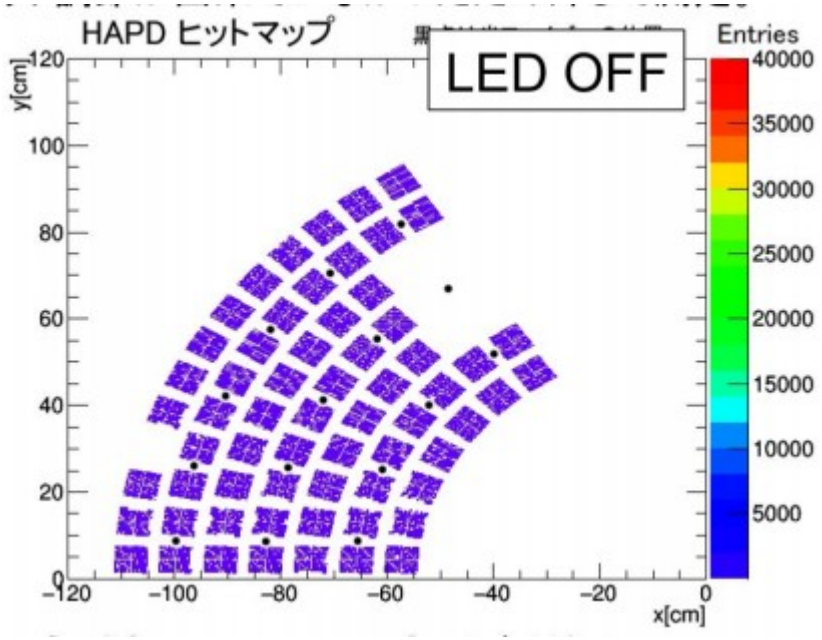
Additional polyethylene shield

Integration in the Belle II spectrometer

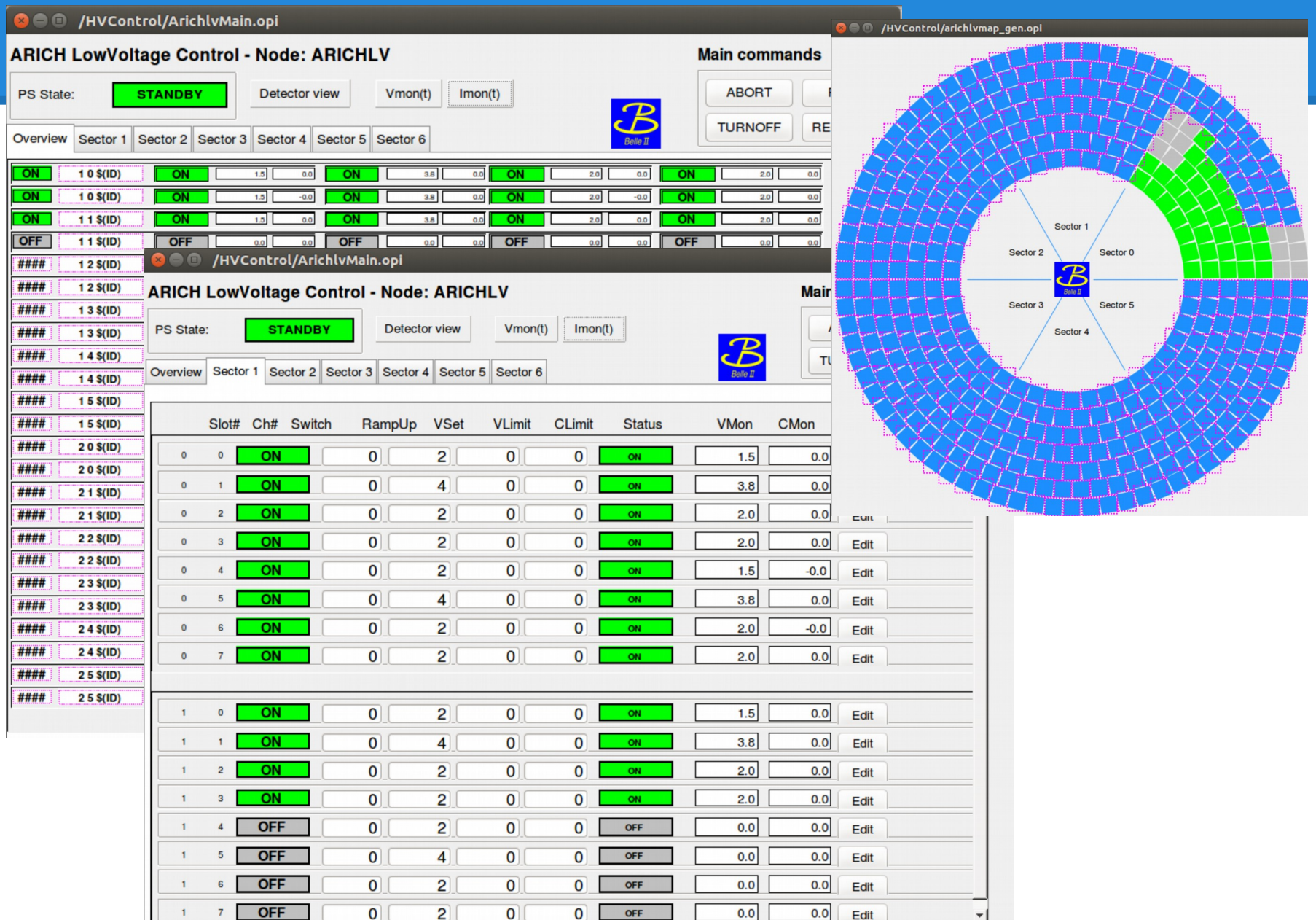
LED monitoring system





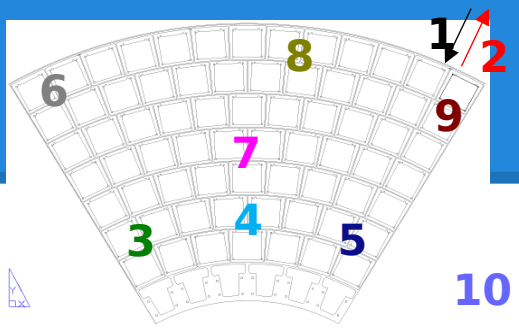


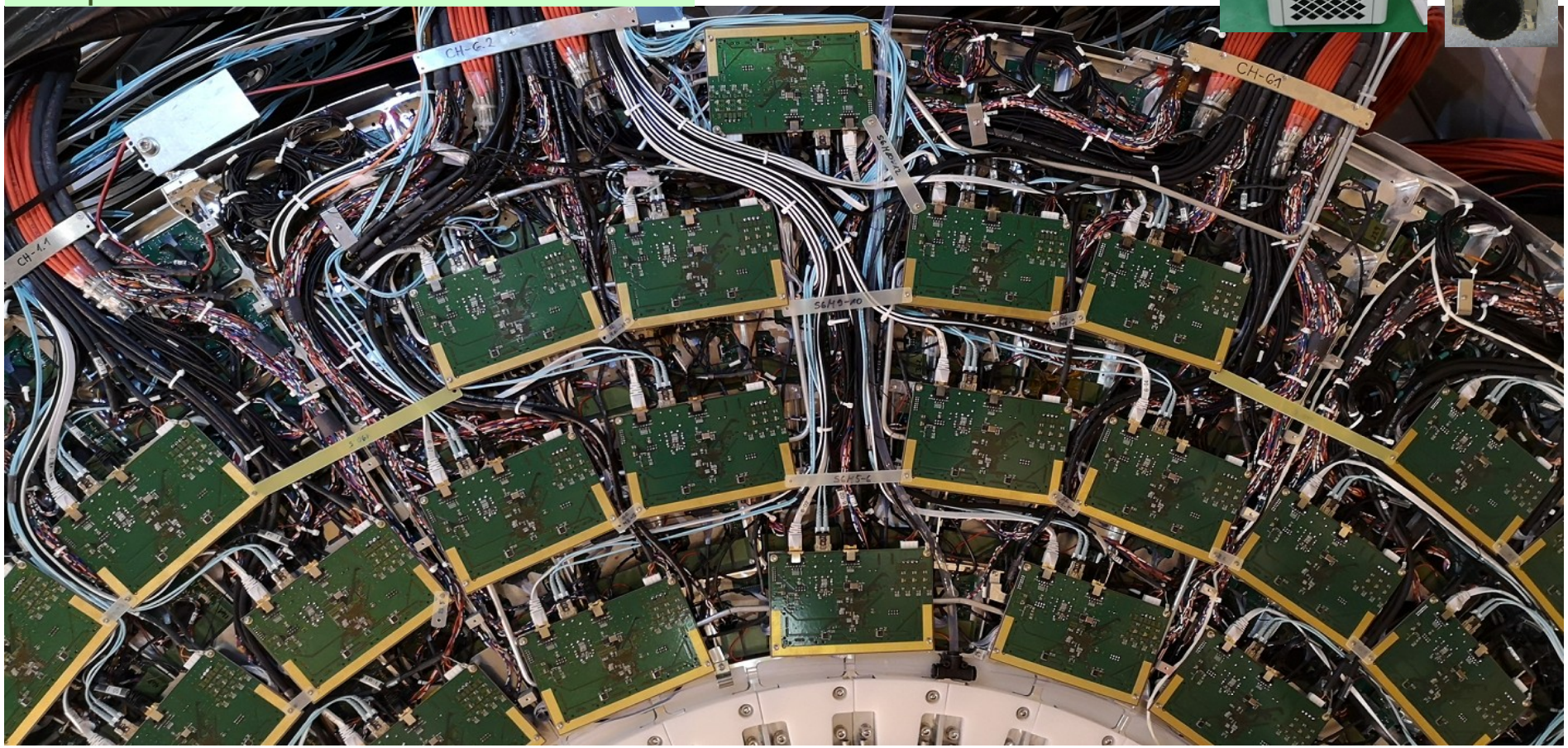
Power Supply Control system



Upgrade of the ARICH cooling system: test with one sector

- Full sector wired back
- Temperature sensors attached to the structure
- Water cooling flow ≈ 1.2 l/min and temperature ≈ 20°C





Schedule

- ARICH installation was successfully completed on time.
  (The detector in position, LV and HV systems connected.)

- All systems and the software were tested well before the data taking in 2018.
  (Data acquisition system, LED monitoring, calibration and alignment tools&procedures.)

- Data taking in 2018: ARICH Operation assured. Performance confirms that basic parameters agree with expectations.

- Before the 2019 data taking (Sept 2018 → February 2019):
  - Improve calibration and alignment procedures and tools.
  - Install improved cooling system.

- Physics data taking from February 2019.

Impact of the JENNIFER secondments

Direct impact:

Jennifer secondments enable

- crucial on-site presence during construction commissioning and operation of the ARICH detector,
- young researchers: extended stays are possible
- face-to-face cooperation with group members from other countries

Indirect impact:

Enable the European institution to be part of the leading groups in the particle identification instrumentation by Cherenkov radiation:

- Jožef Stefan Institute organized the most important conference in the area of Ring Imaging Cherenkov Detectors – RICH 2016, Sep. 4-9, Bled, Slovenia
  (12 contributions from the ARICH group were presented)
- RICH 2018 conference in Moscow, Russia, August 2018
  (8 contributions from the ARICH group were presented)

JENNIFER EU grant n.644294

Summary

- Proximity focusing RICH with an aerogel as a radiator (ARICH) is used for efficient particle identification in the forward end-cap of the Belle II spectrometer.

- ARICH was installed and commissioned on time for the 2018 data taking.
- Performance shows that basic parameters agree with expectations and we can expect further improvements by better alignment and calibration.
- Hardware improvement: Installation of cooling system is planned before the next data taking in February 2019.

- Data taking in 2019 with improved performance.

- Jennifer enables the researchers from European Institute (JSI) to increase their on-site presence and thus participate in R&D, the installation, commissioning and operation of the detector, and to share their expertise with the Japanese collaborators.

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