TIPP'14

Aerogel RICH Counter for the Belle II forward endcap PID

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On behalf of the Belle II
ARICH group

Content:

- Belle II / SuperKEKB
- Aerogel RICH
- Simulation studies
- Performance in test beam
- Schedule

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4 June 2014

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Belle II & SuperKEKB

New facility on the **intensity frontier:** **Virtual production of new particles** to probe energies beyond the energy frontier (prime examples: GIM, M_c, 3 gen., M_t)

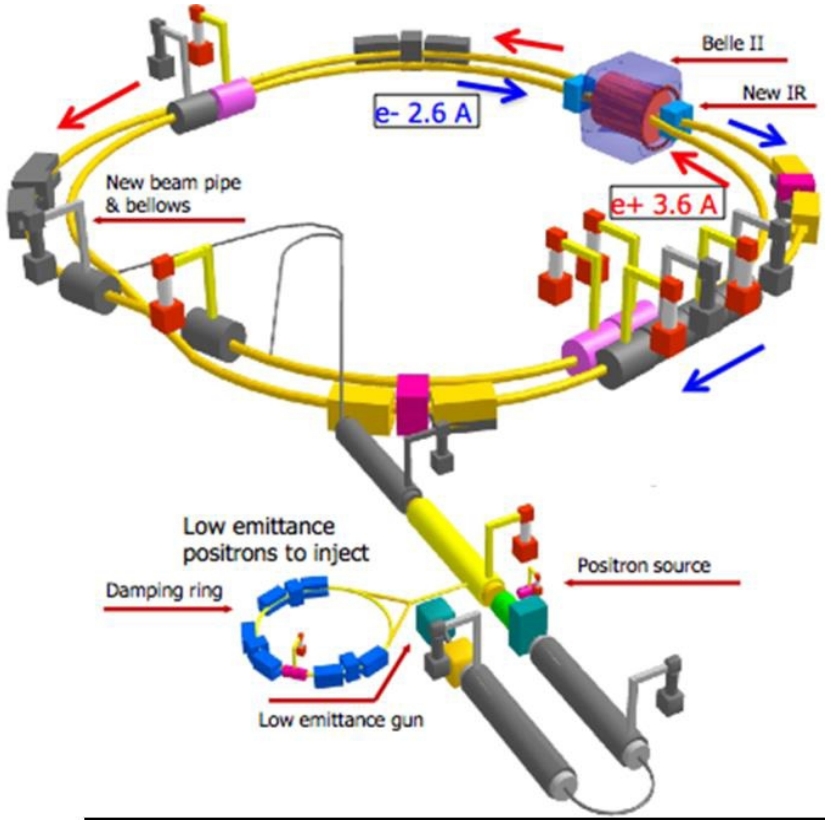
Successor of the very successful KEKB/Belle @ KEK, Tsukuba, Japan.

KEK / Belle
In operation: 1999-2010
Accumulated data: **1 ab^{-1}**
Peak luminosity: **2 x 10^{34} cm^{-2} s^{-1}**

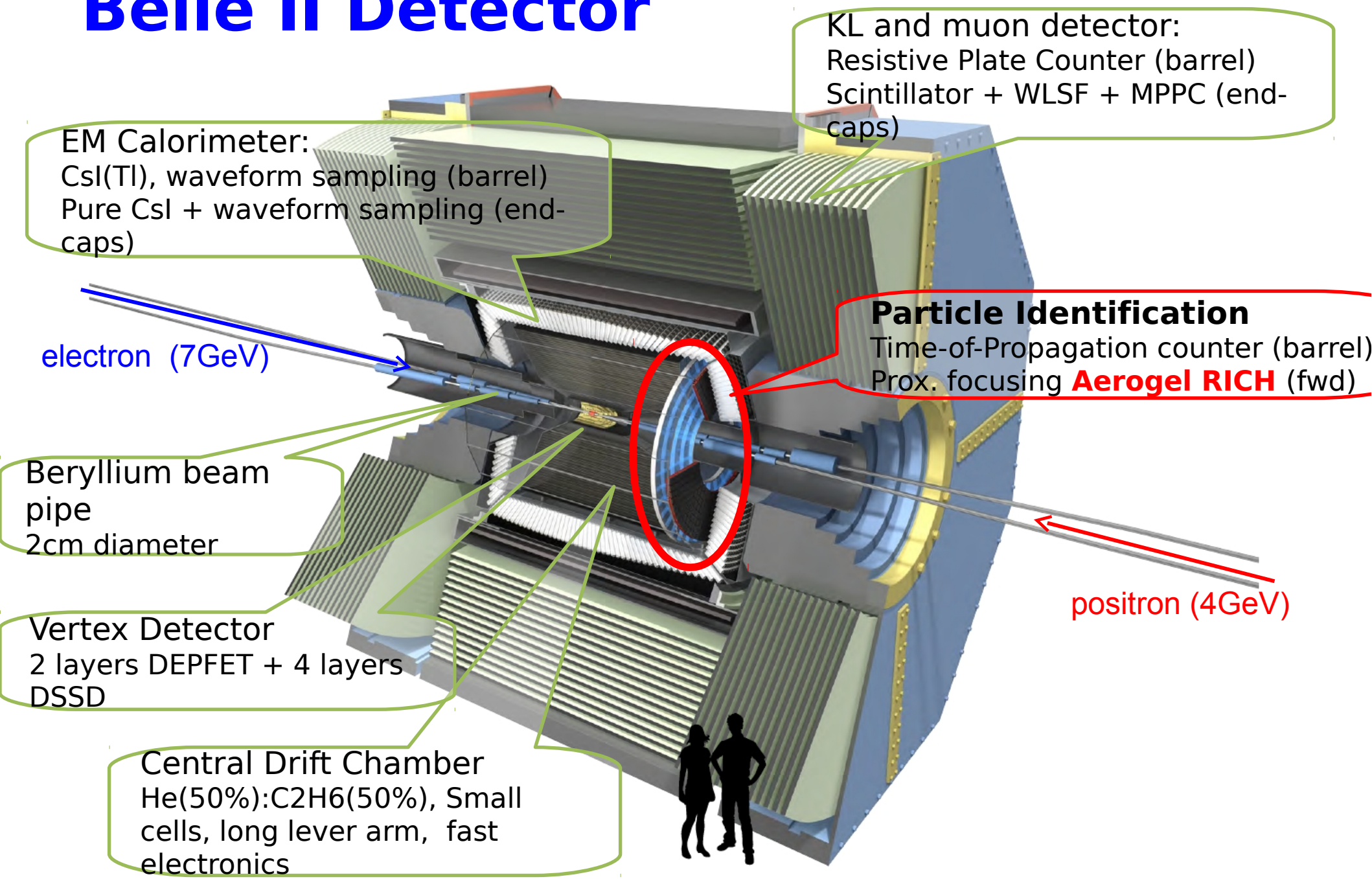
High precision confirmation of the SM flavor structure (KM mechanism is the main source of CPV,...).

KEKSuperB / Belle II
Planned: 2015-2022
Accumulated data: **50 ab^{-1}**
Luminosity: **8 x 10^{35} cm^{-2} s^{-1}** **(Belle x 40)**

Are there new CPV phases?
Are there right handed currents from NP?
Does nature have multiple Higgs bosons? …



Belle II Detector



Aerogel RICH

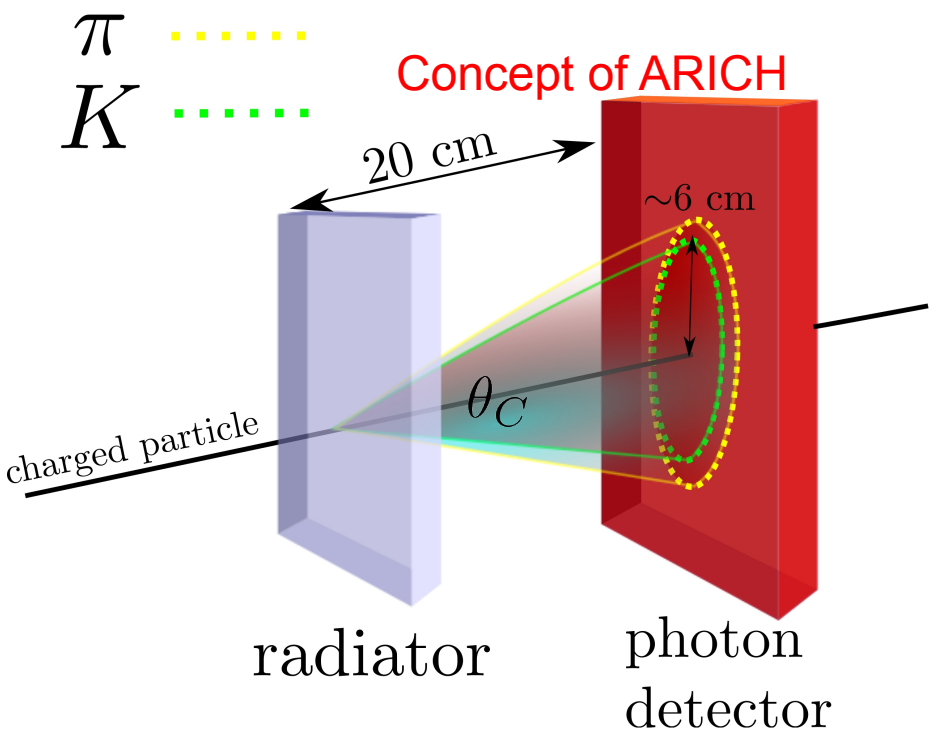
Good particle identification (mainly π /K separation) is a key issue for Belle II:

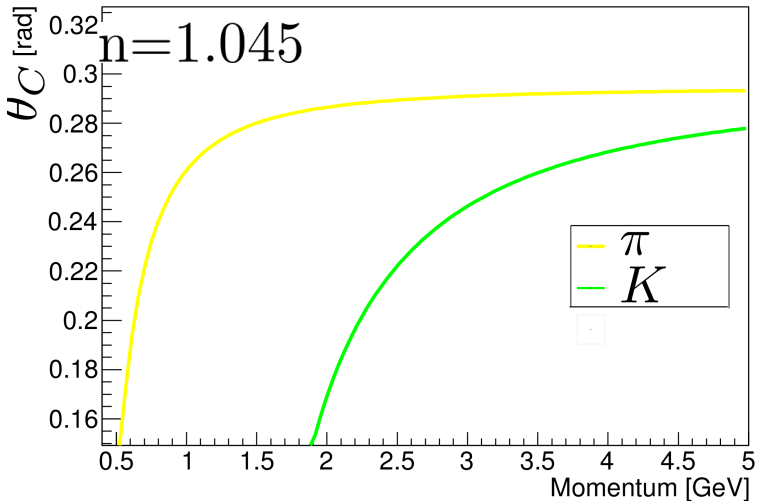
- background reduction (e.g. $B \to \rho\,\gamma$ vs. $B \to K^*\gamma$)
- efficient flavor tagging (determination of B meson flavor)

Goal:
4σ π /K separation, at 1.0 - 3.5 GeV

In the forward endcap → **Aerogel RICH.**

Constraints:
- in 1.5 T magnetic field.
- limited available space ~28 cm.
- radiation hardness (n, γ).

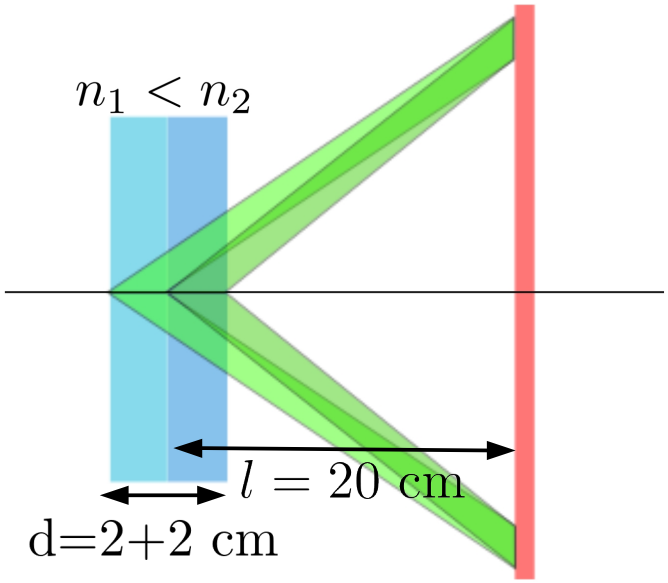




$\theta_C(\pi) - \theta_C(K) \sim 30$ mrad @ 3.5 GeV

Radiator – Silica Aerogel

See poster by M. Tabata (#151)



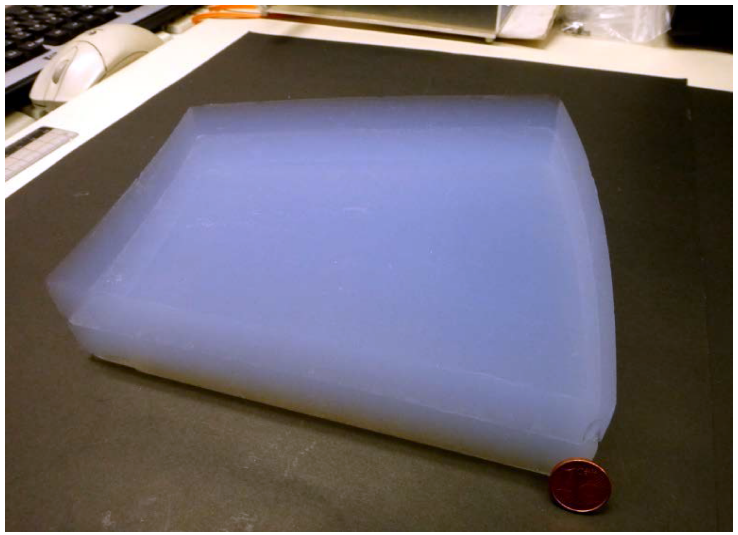
Two aerogel layers in focusing configuration:
$n_1 = 1.045,\ n_2 = 1.055$
Overlapping rings from 1st and 2nd layer!

Doubling the number of photons with no resolution degradation (due to unknown photon emission point).

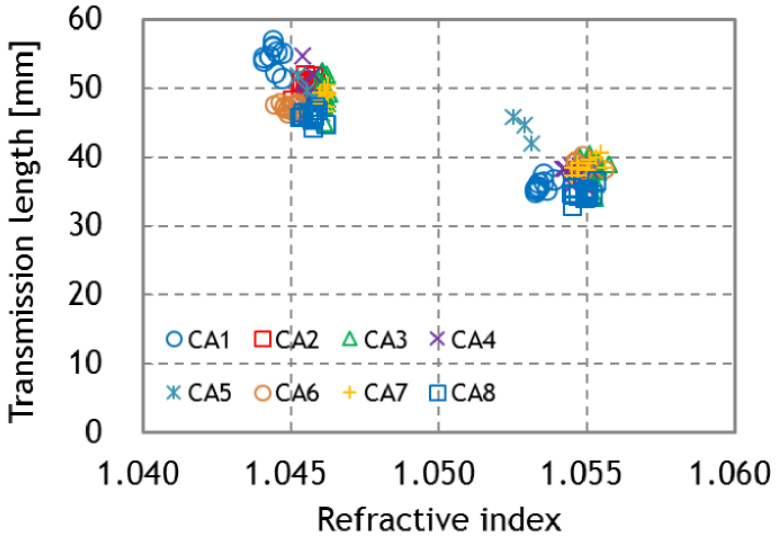
$$\sigma_{gel} = \frac{d \sin\theta_C \cos\theta_C}{l\sqrt{12}} \frac{1}{\sqrt{N_{p.e.}}} \qquad N_{p.e.} \propto d$$

High transmission length is required (>30 mm).

Minimize photon loss on tile edges
→ large tiles (~ 18 x 18 cm)



Mass production already finished, with relatively stable tr. length and ref. index

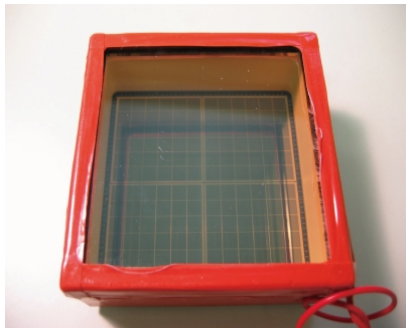


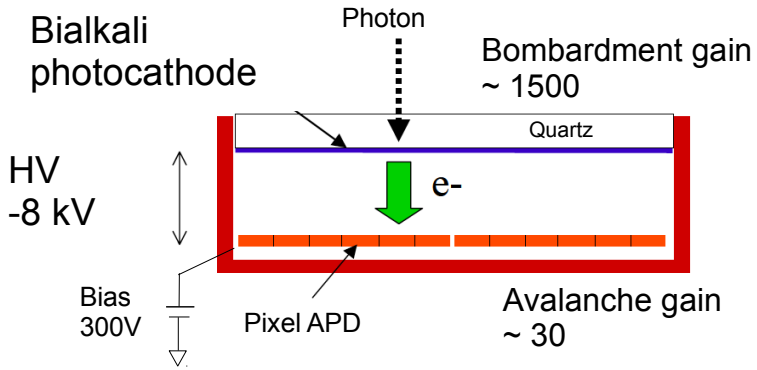
Photon detector - HAPD

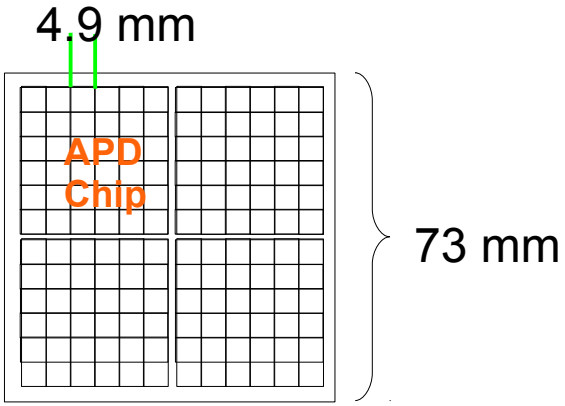
Talk by S. Iwata
(Friday @ Photon)

HAPD – Hybrid Avalanche Photo-Detector

Satisfies basic requirements: - 1.5 T - n,γ tolerance - large coverage

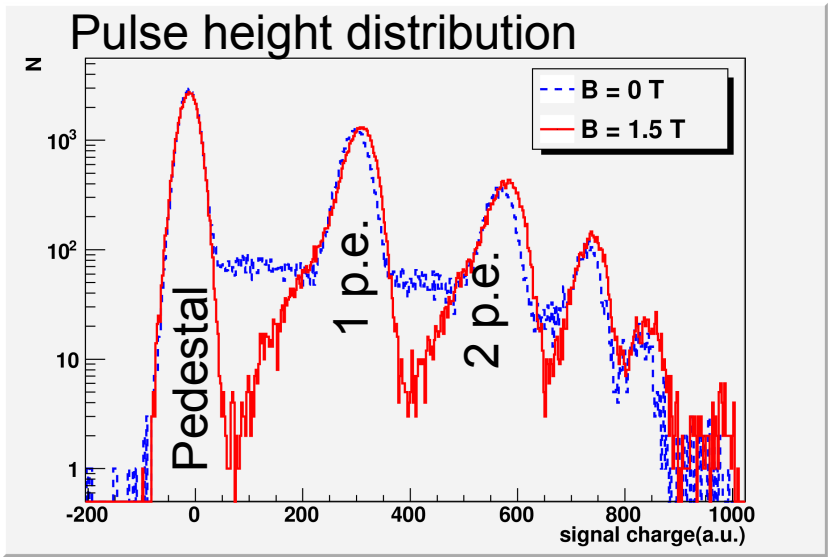






- Developed with Hamamatsu photonics

Size	73x73 mm
# of channels	144 (36-ch APD x 4)
Total gain	>45000
Peak QE	~30%
Active area	64%
Weight	220g

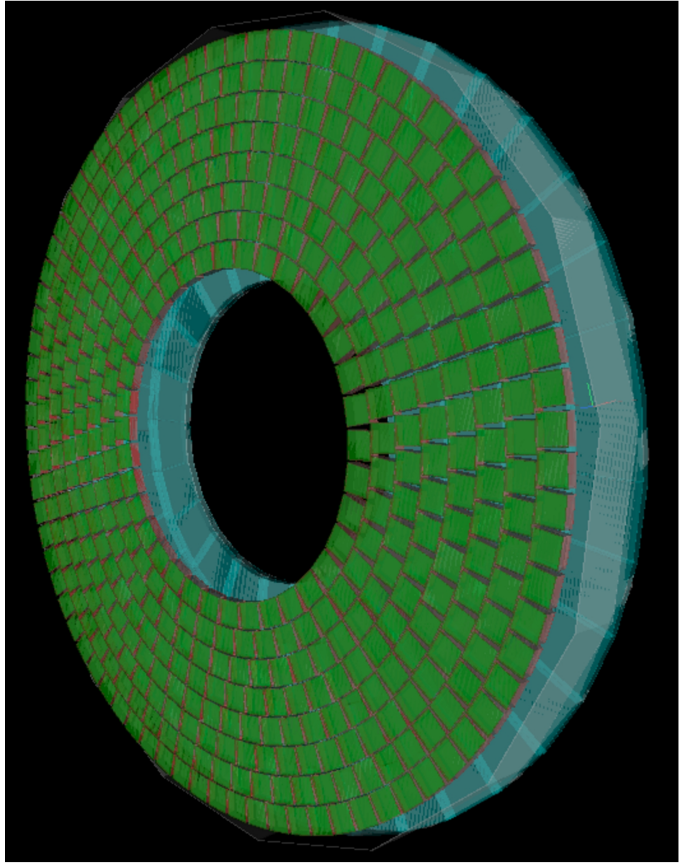


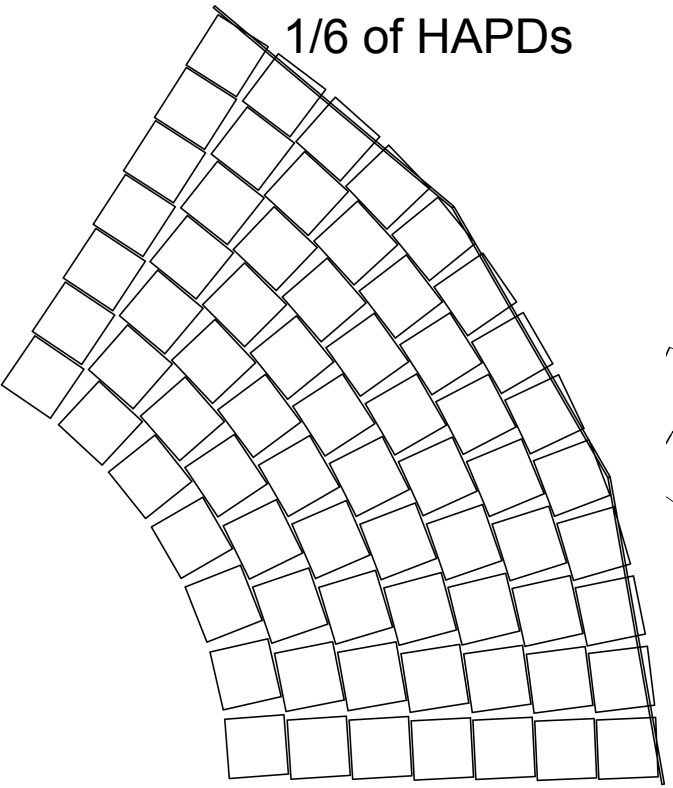
Design of ARICH

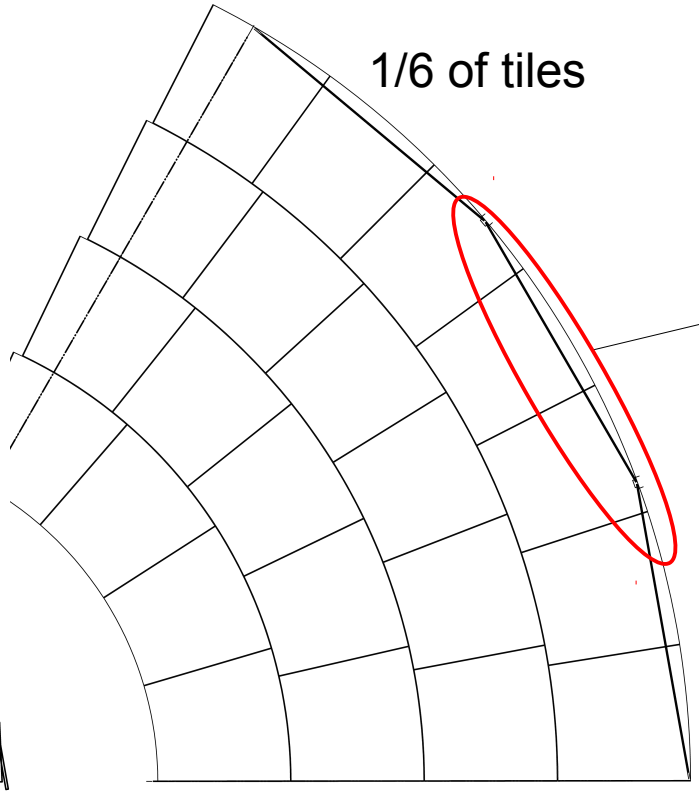
420 HAPD modules arranged in 7 rings.
(inner radius 56 cm, outer radius 114 cm)

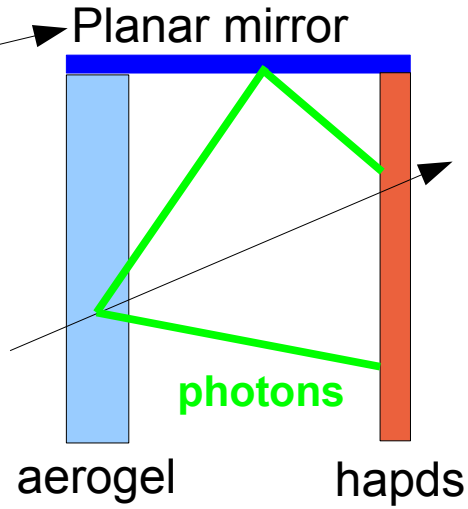
2 x 124 aerogel tiles, wedge shape,
4 types (radius dependent)

Planar mirrors on the outer edge, to prevent photon loss.





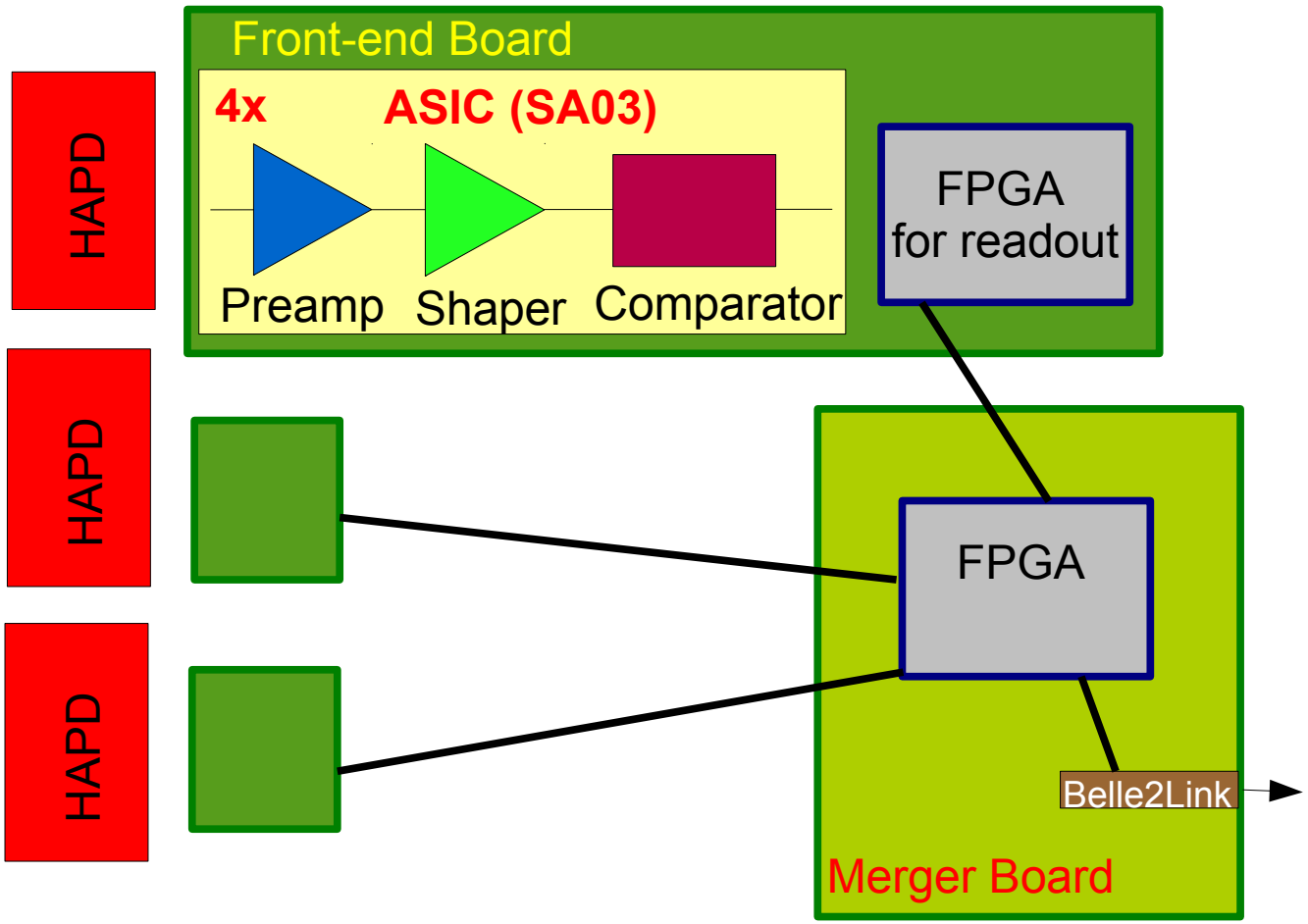




Electronics

Talk by S. Iwata
(Friday @ Photon)

- 60000 channels (1 bit ON/OFF).
- limited space of 5 cm behind HAPDs.
- ASIC SA03 (36ch/chip → 4 ASICS / HAPD).
- Variable gain (3.1-12.5 V/pC) and shaping time (100-200 ns).



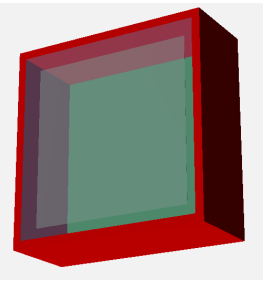
Front-end Board

Xilinx FPGA (Spartan6):
- Hit detection.
- ASIC settings.

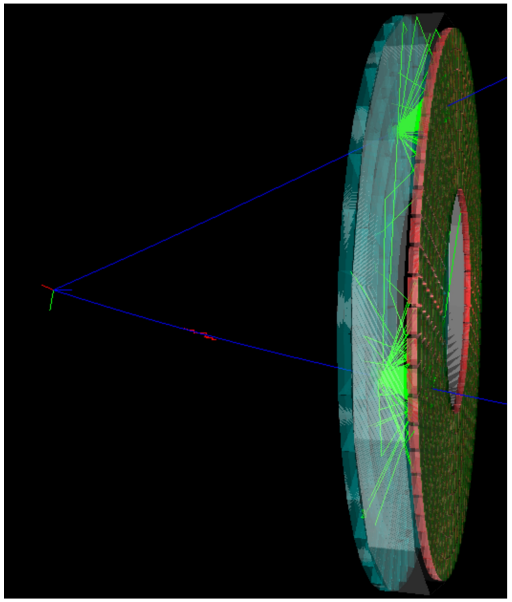
Merger Board

- Collect hit data from 5-6 F.E. Boards.
- Send to DAQ system.

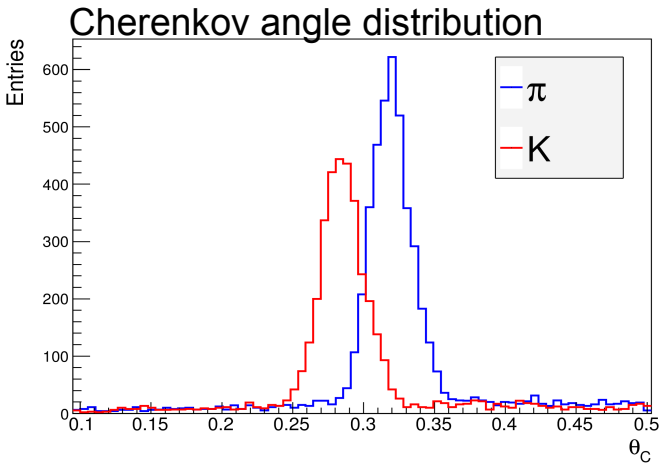
Simulation Studies

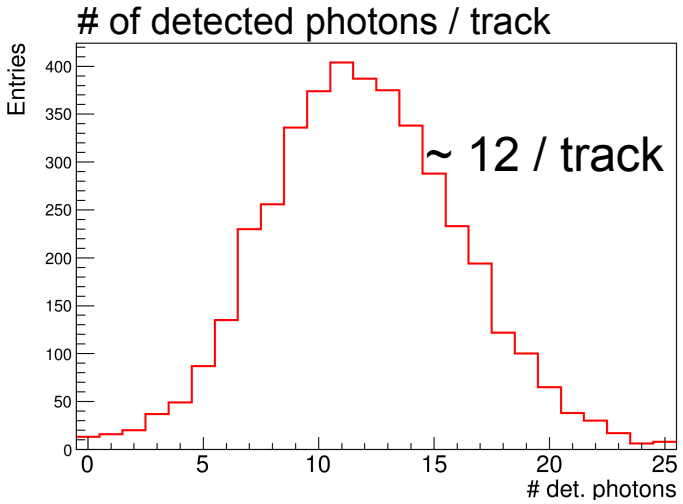


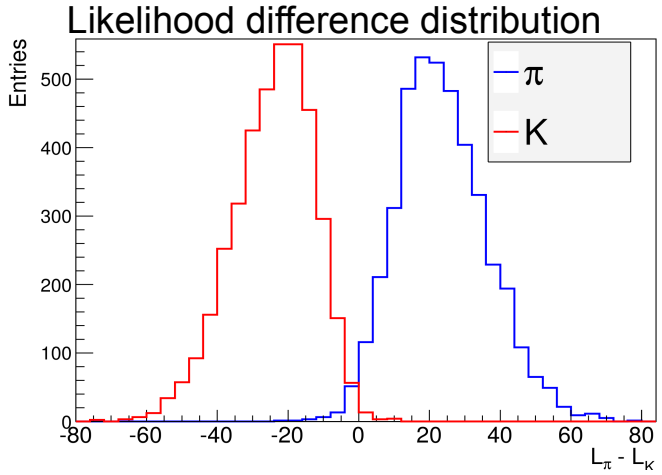
Detailed Geant4 simulation of ARICH was developed. Used for:
- performance studies (design optimization).
- integrated into the full Belle II detector simulation (for MC production).
- simulation studies of beam induced backgrounds.



Shooting π, K from the Interaction Point @ 3.0 – 3.5 GeV







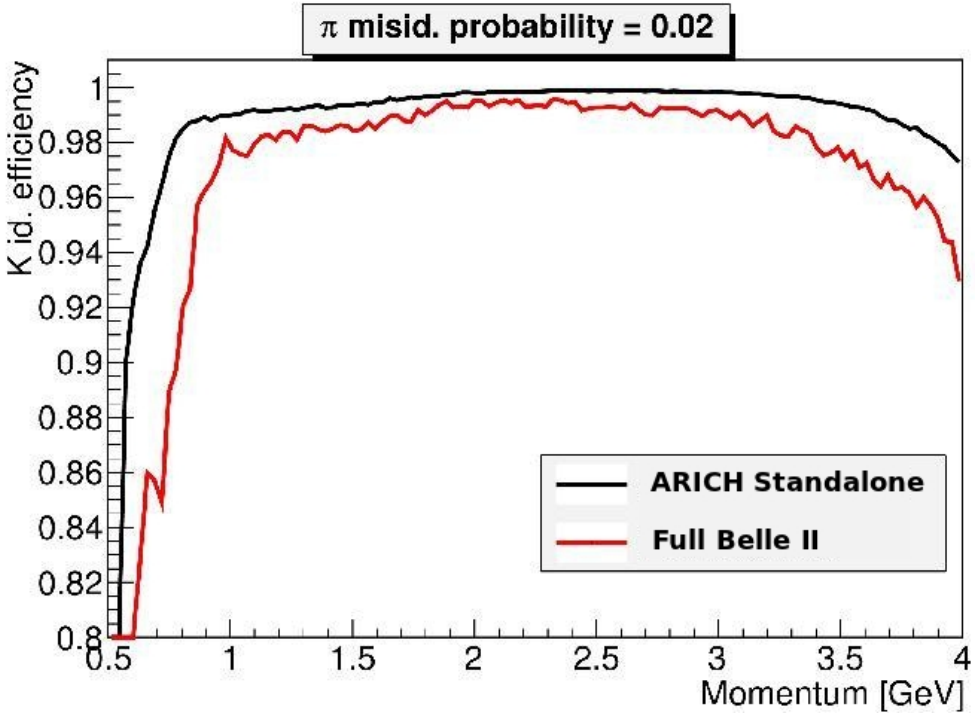
For each track we evaluate the likelihood function for different particle hypotheses $(\mathrm{e}, \mu, \pi, K, p)$

$$\ln \mathcal{L} = -N + \sum_{hits} [n_i + \ln(1 - e^{-n_i})]$$

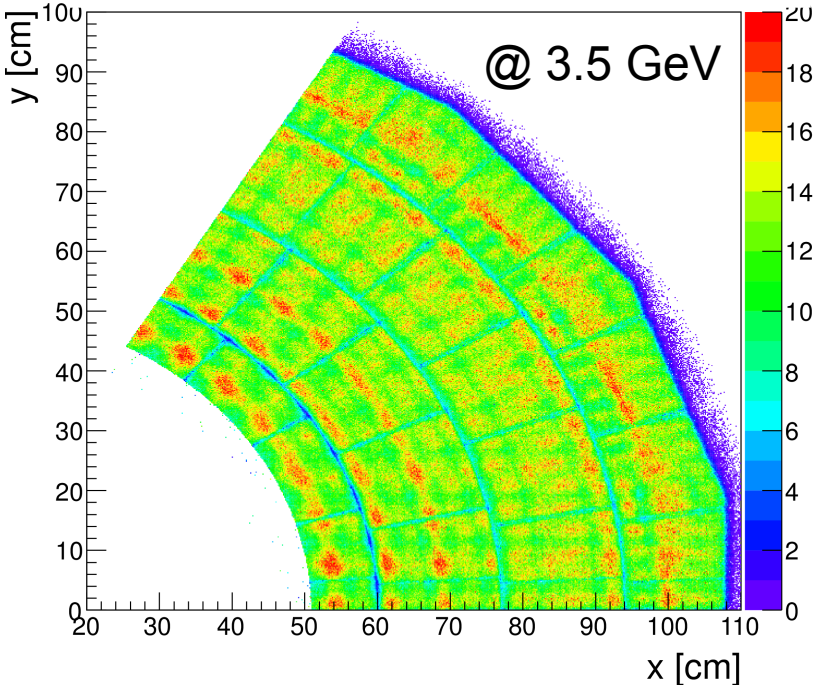
Expected # of hits

Expected # of hits on i-th pixel with a hit

Performance in the full momentum range



# of detected photons vs. track position on the detector plane



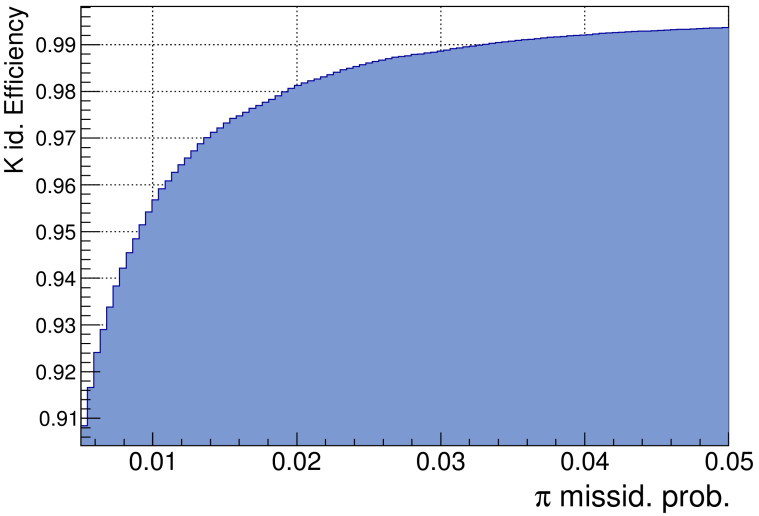
ARICH Standalone - Track information from MC (smeared for **1 mm** and **1 mrad)**.
Full Belle II - Track information from Belle II tracking system.

Excellent performance!

Belle II simulation of physical events

$$e^+e^- \to \Upsilon(4S) \to B^0\bar{B}^0 \to (K^+\pi^-)(\text{generic})$$

98% K identification efficiency, and
2% pion misidentification probability



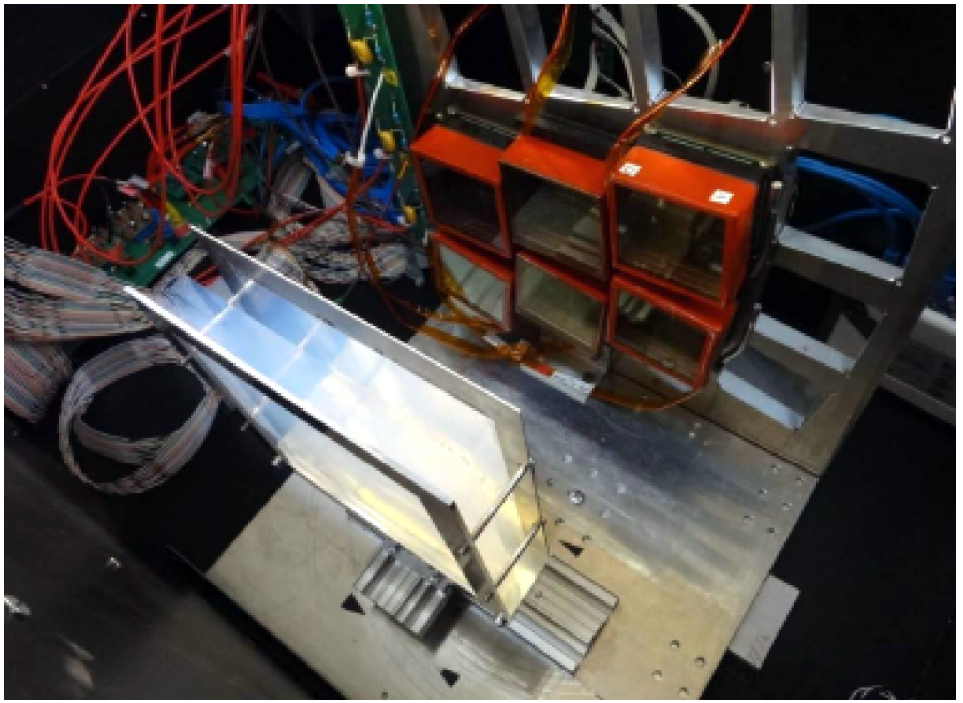
Performance in the test beam

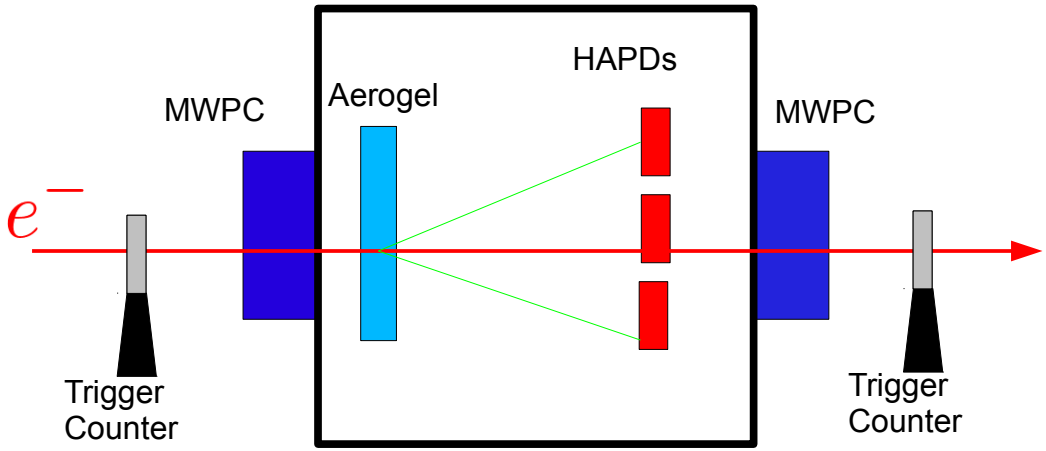
Prototype ARICH in electron test beam
@ DESY (2013)

- Part of the actual ARICH layout:
  - 6 HAPD modules
  - 2 aerogel layers

- Front-end board with ASIC (close to final)

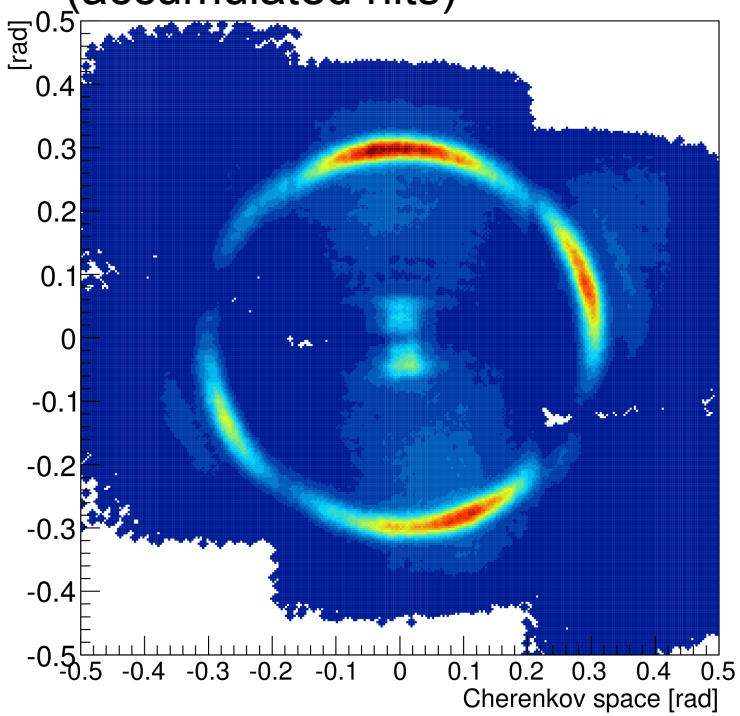
- studied performance with close to final electronics, different aerogels, performance with irradiated HAPDs.



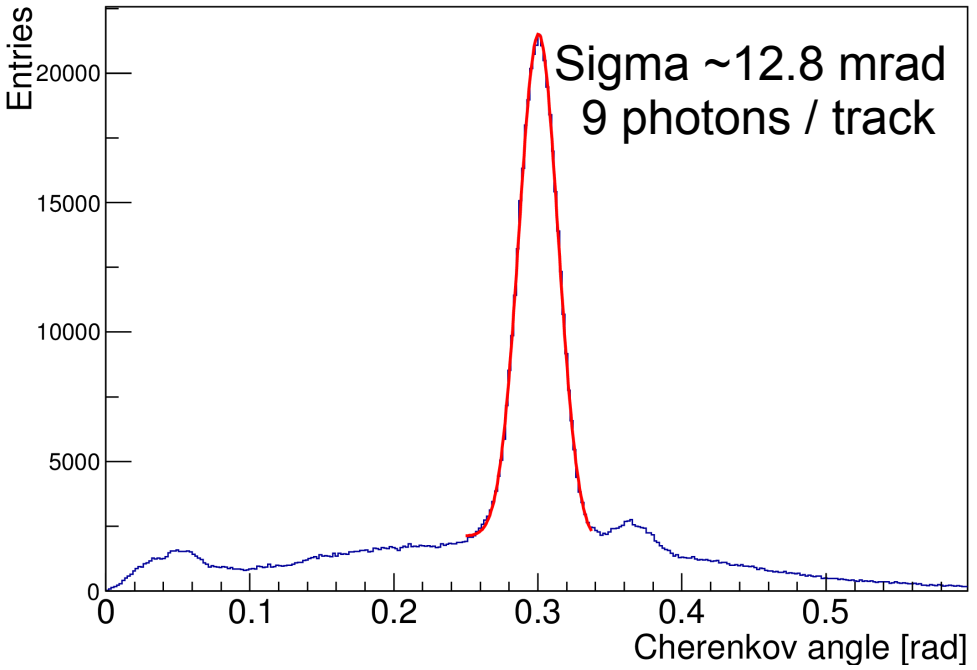


Perpendicular track incidence

Reconstructed Cherenkov ring (accumulated hits)



Cherenkov angle distribution



Naive estimate of π, K separation:

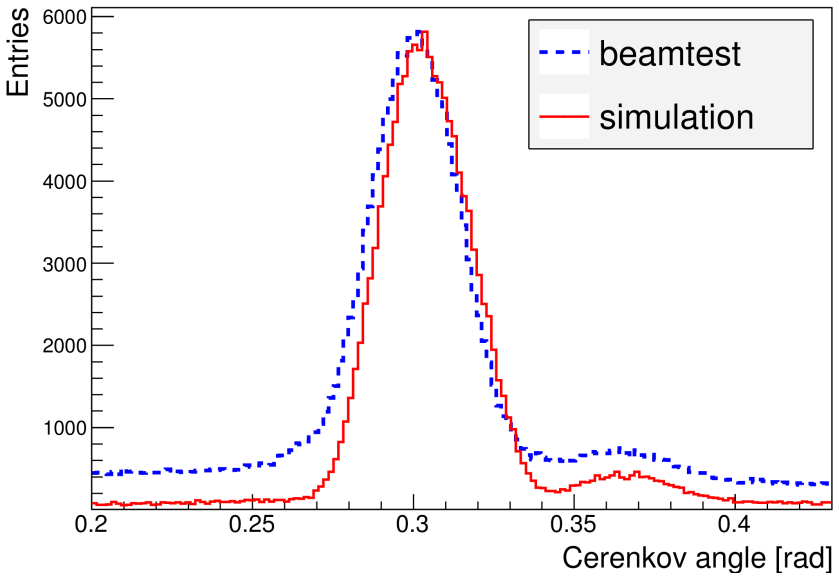
$$\frac{\Delta\theta_C}{\sigma_C}\sqrt{N_{\mathrm{phot}}} \simeq 5\,\sigma$$

Comparison with the simulation
(Geant4 simulation of beamtest setup)

- excellent agreement in the width of Cherenkov peak.

- and also in the # of detected photons.

- less background in the simulation (electronics, double tracks,...)

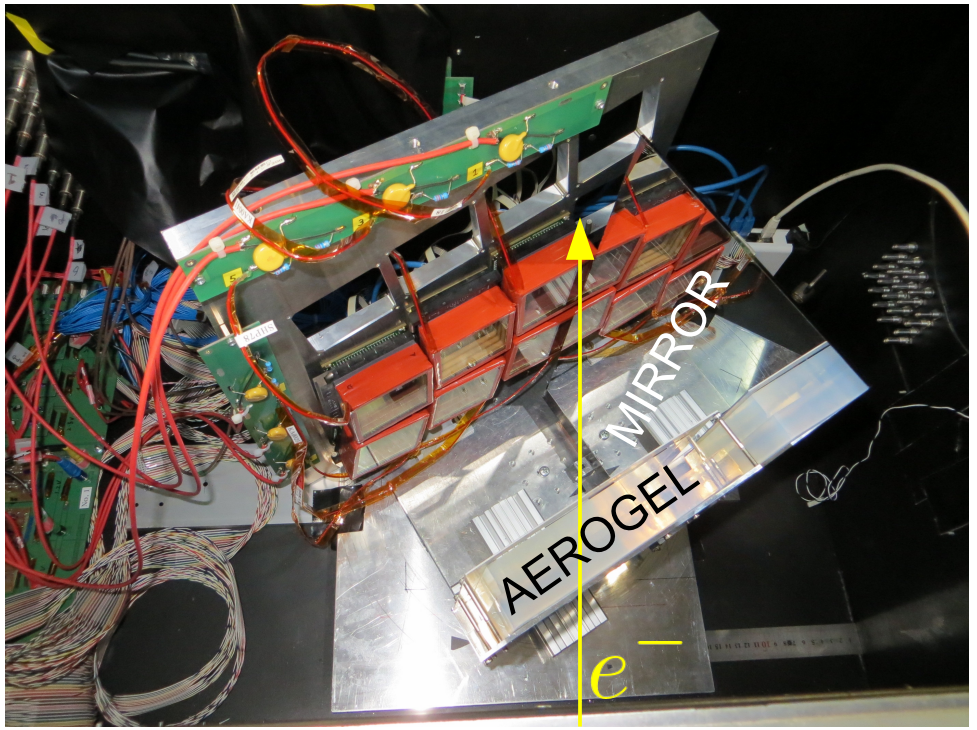


Non-perpendicular track incidence

Run with track incidence angle of 30°, and installed planar mirror.

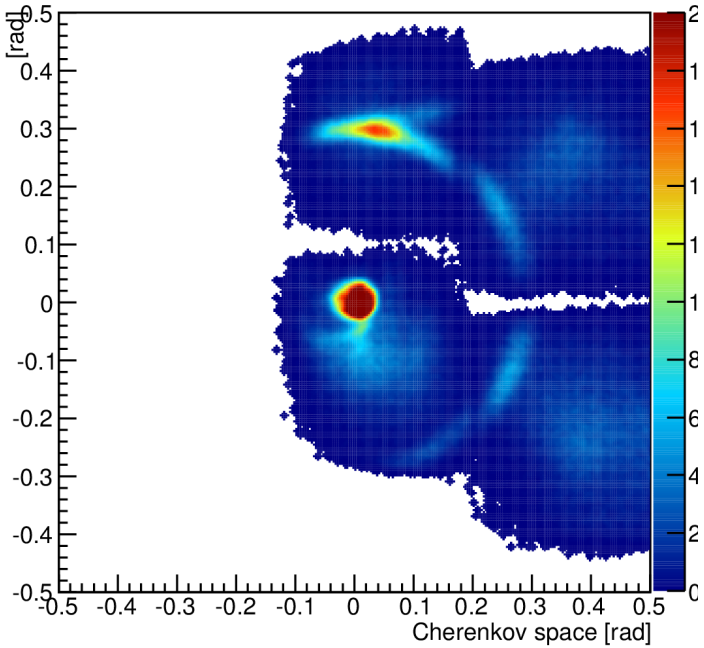
Reconstructing Cherenkov angle with and without assuming photon reflection from the mirror.

Width of the reflected part of the ring ~ 12 mrad



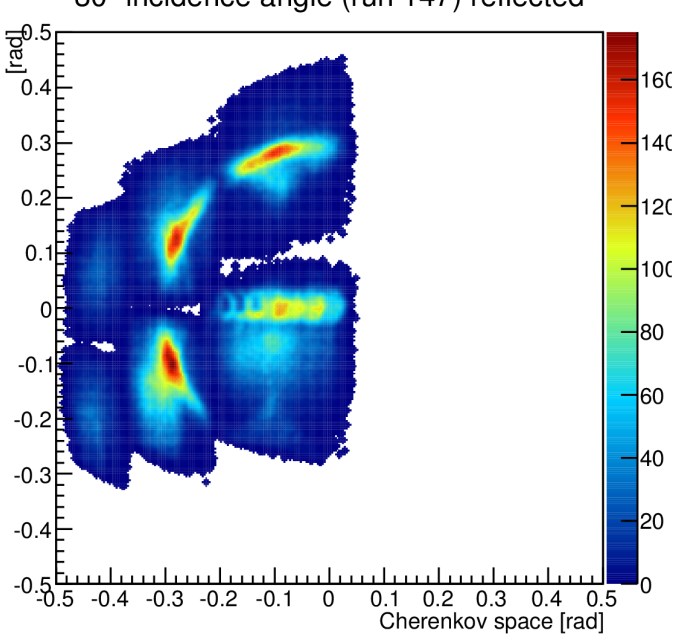
Non-reflected

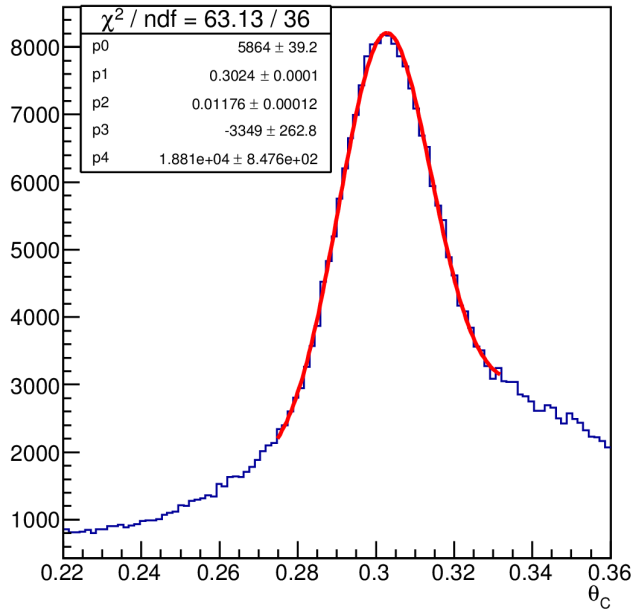
30° incidence angle (run 147), non reflected



Reflected

30° incidence angle (run 147) reflected





Schedule

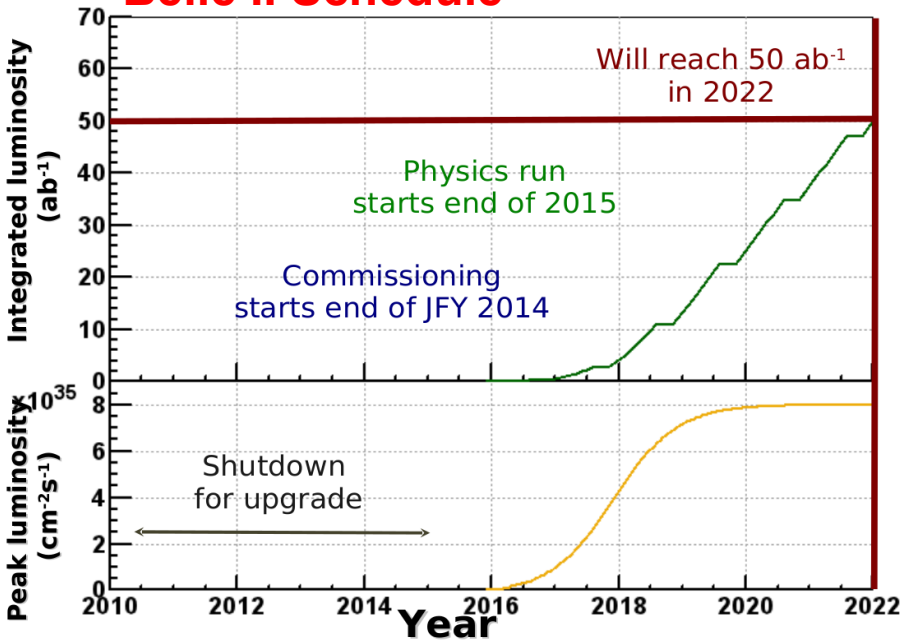
- HAPD production is to be finished in September 2014 (420 + spare modules).

- Aerogel production already finished (248 + spare tiles).

- Counter assembly in the end of 2014.

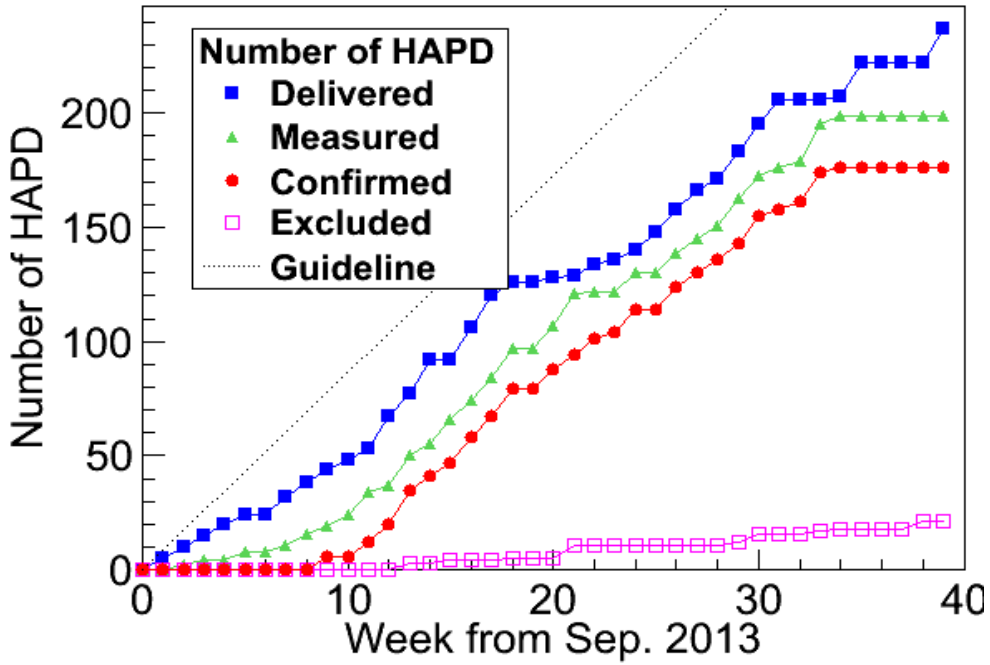
- Installation in early 2015.

Belle II Schedule



HAPD Production Last update: 2014/05/23

Delivered = 237 (out of 450 + 1). Confirmed = 176.



Summary

- At the **Belle II** experiment the **Aerogel RICH** will be used for particle identification in the forward endcap region:

  - 2 aerogel layers in focusing configuration.
  - 240 hybrid avalanche photo-detectors.

- ARICH simulation was developed (based on Geant4) and integrated into full Belle II detector simulation:

  - excellent performance in the full kinematic region of experiment.

- Prototype of ARICH was tested in the beamtests:

  - performance was confirmed (consistent with expectations from simulation)
  - no significant degradation of performance with irradiated HAPDs.

- Components are in mass production. Assembly in 2014, installation in 2015.

- Stay tuned for a lot of interesting physics from the Belle II experiment!