Aerogel RICH at the Belle II experiment

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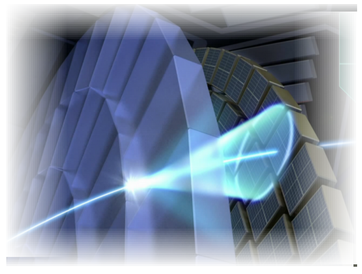


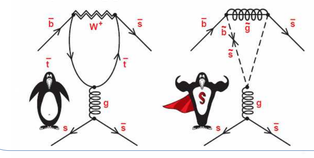
The Belle II Experiment @ SuperKEKB

- New experiment on the **intensity frontier**

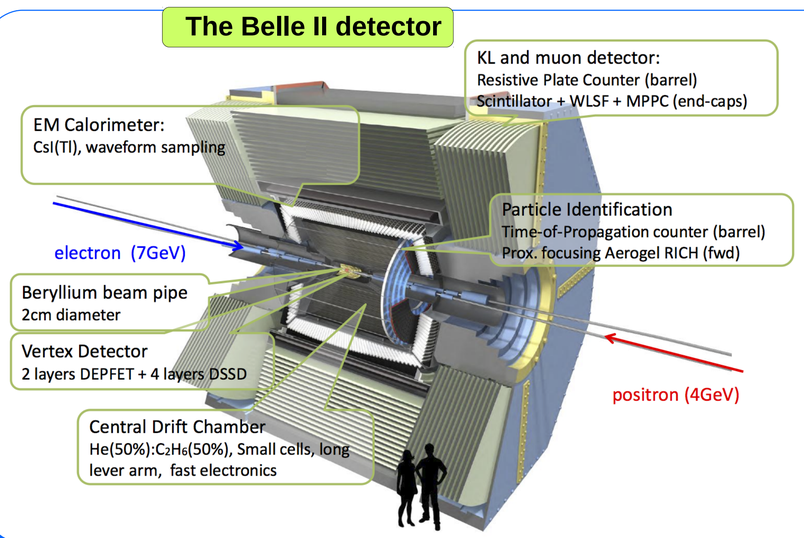
  → search for New Physics via precise measurements of rare decays of B, D mesons and τ leptons
- Successor of the very successful Belle@KEKB, in Tsukuba, Japan.
- Large number of B, D, τ in e^+e^- collisions at $\Upsilon(4S)$
- Instantaneous luminosity **40 x Belle** $\mathcal{L}_{peak} = 8 \times 10^{35}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Plan to collect **50 x Belle** data sample until 2027
- **First physics run with full detector between March-June 2019** → collected $6.5\ \mathrm{fb}^{-1}$

Flavour physics

- New CP violation phases?
- Is Lepton Flavour Violated? (+universality)
- Right-handed currents from NP?
- Multiple Higgs bosons?



The Belle II detector



- General purpose spectrometer (B=1.5 T)
- Excellent decay vertex resolution ($\sigma \sim 60\ \mu\mathrm{m}$ for B,D)
- Clean e^+e^- environment
- **Particle identification is a key issue**

  →background reduction
  e.g. $B \to \rho\gamma, B \to K^\star\gamma$

  → efficient flavor tagging (B^0 or $\bar{B}^0$)
- **two novel PID detectors**

  → Time-of-propagation counter

  → Aerogel RICH

Aerogel RICH detector

Goal

4σ π/K separation @ 0.5 - 4.0 GeV

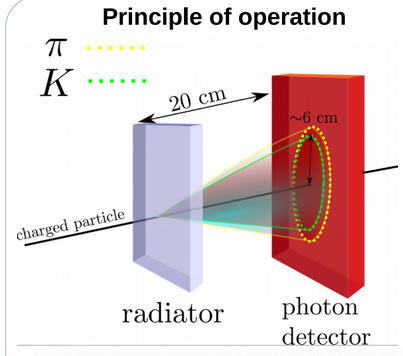
+ low momentum lepton ID

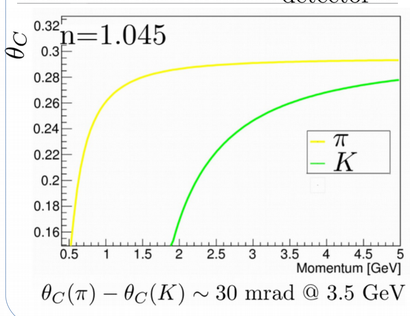
Constraints

- 1.5 T magnetic field
- limited space (~28 cm)
- radiation hardness ($> 10^{12}$ 1 MeV n eq/cm^2)
- covers a large area (~3 m^2)

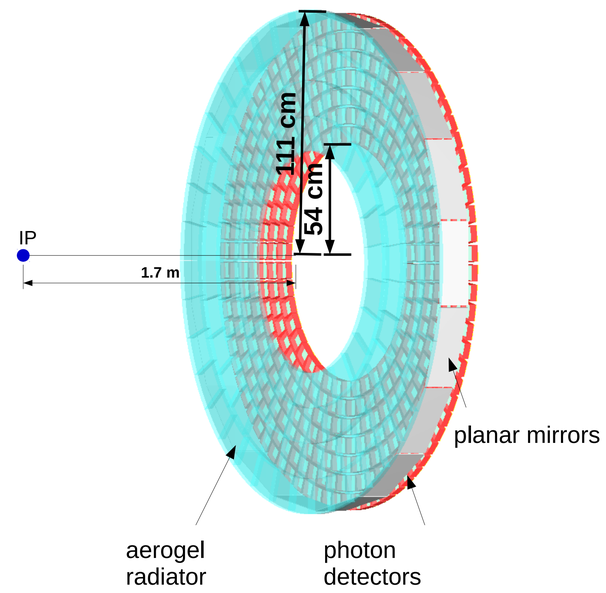
→ **Proximity focusing RICH with aerogel radiator**

Principle of operation





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



Detector design & components

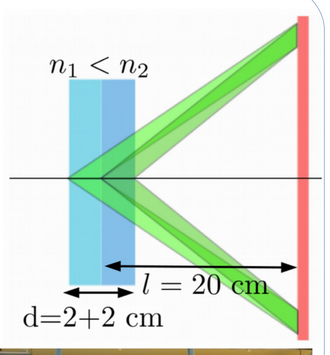
Radiator – Silica Aerogel

- Two aerogel layers in a **focusing configuration** [1]:

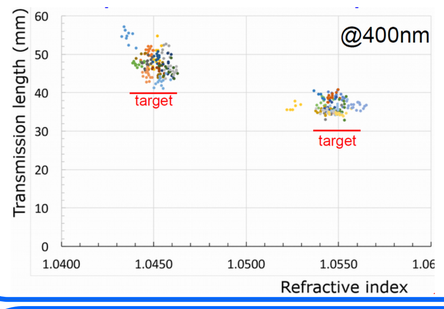
  $\mathrm{n}_1 = 1.045,\ n_2 = 1.055$

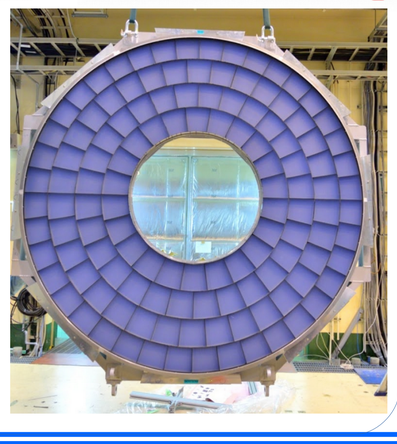
  → increase number of photons w/o degrading Cherenkov angle resolution
  (due to uncertainty in the photon emission position)

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



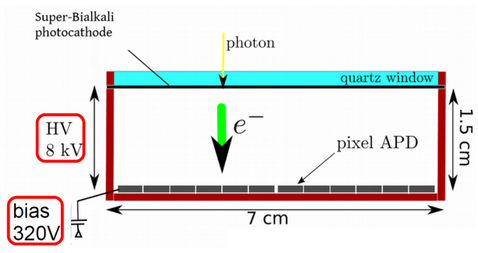
- Requires aerogel with high transparency [2]
- Detector plane covered with 2 x 124 tiles water-jet cut tiles (~ 17x17cm)





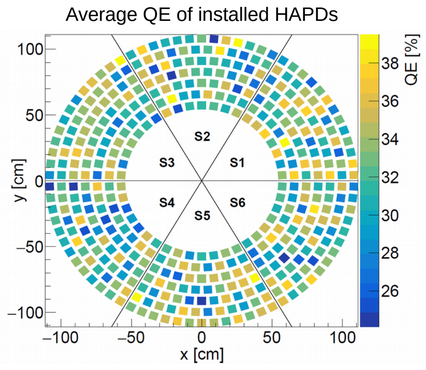
Photon detector – HAPD

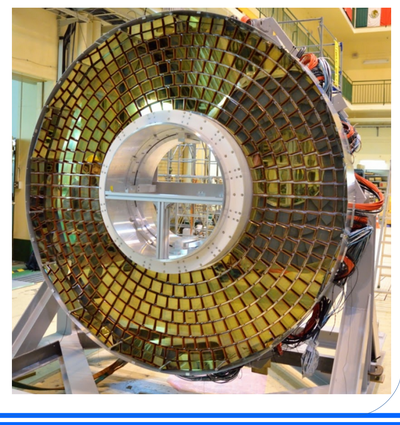
- HAPD – Hybrid Avalanche Photo-Detector [3]



Size	73x73 mm
# of channels	144 (36-ch APDx4)
Total gain	>60000 (1500 x 40)
Peak QE	~30%
Active area	64%
Weight	220g

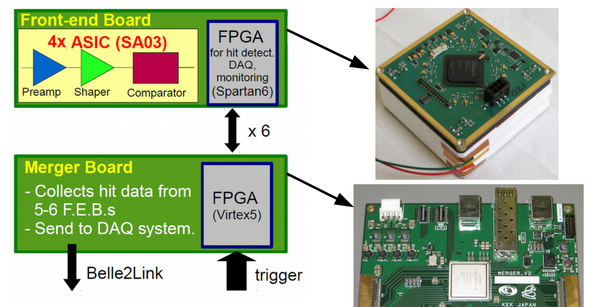
- 420 modules to cover the detector plane



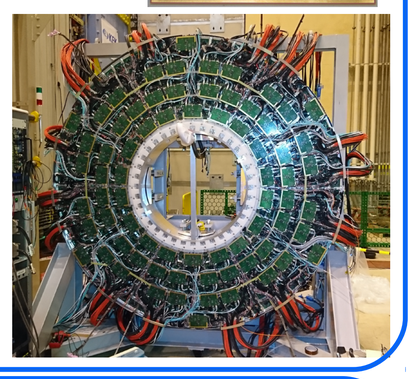


Readout electronics [4]

- In total ~60k channels
- Limited space of 5cm behind HAPDs

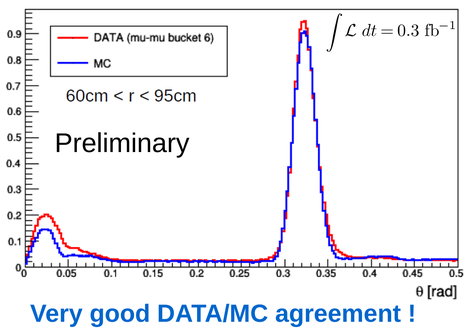


- Variable gain, (3.1-12.5 V/pC) shaping time (100-200 ns)
  → optimization for increased noise levels



Performance in the early Belle II data

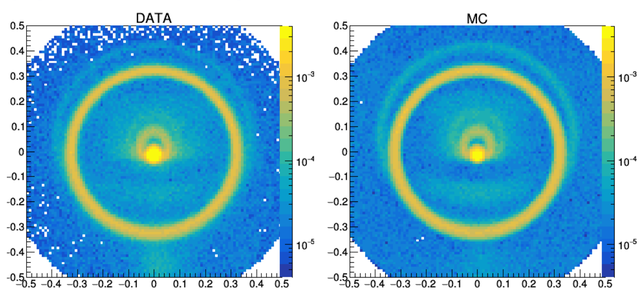
Cherenkov angle distribution in $\mathrm{e^+e^-} \to \mu^+\mu^-$



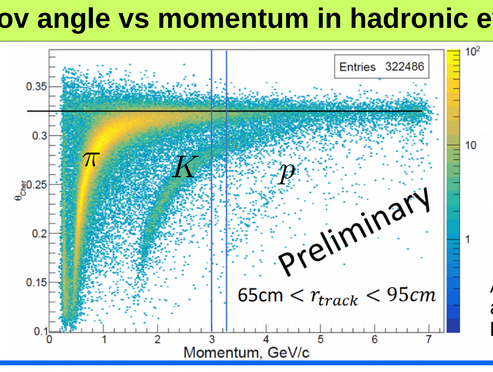
DATA
$N_{\mathrm{sig}} = 11.4/\mathrm{track}$
$\sigma_c = 12.7$ mrad

MC
$N_{\mathrm{sig}} = 11.3/\mathrm{track}$
$\sigma_c = 12.8$ mrad

Very good DATA/MC agreement !



Cherenkov angle vs momentum in hadronic events



Average Cherenkov angle for tracks from hadronic events

Estimation of π/K separation power using $D^{*\pm}$ decays

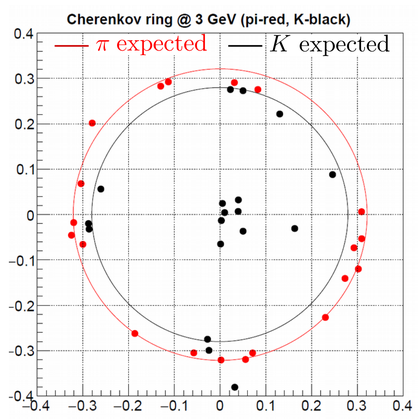
- Identify K, π based on track charge in association with the charge of π_{slow}

$D^{*+} \to D^0\ \pi^+_{\mathrm{slow}}$, $D^0 \to K^-\ \pi^+$

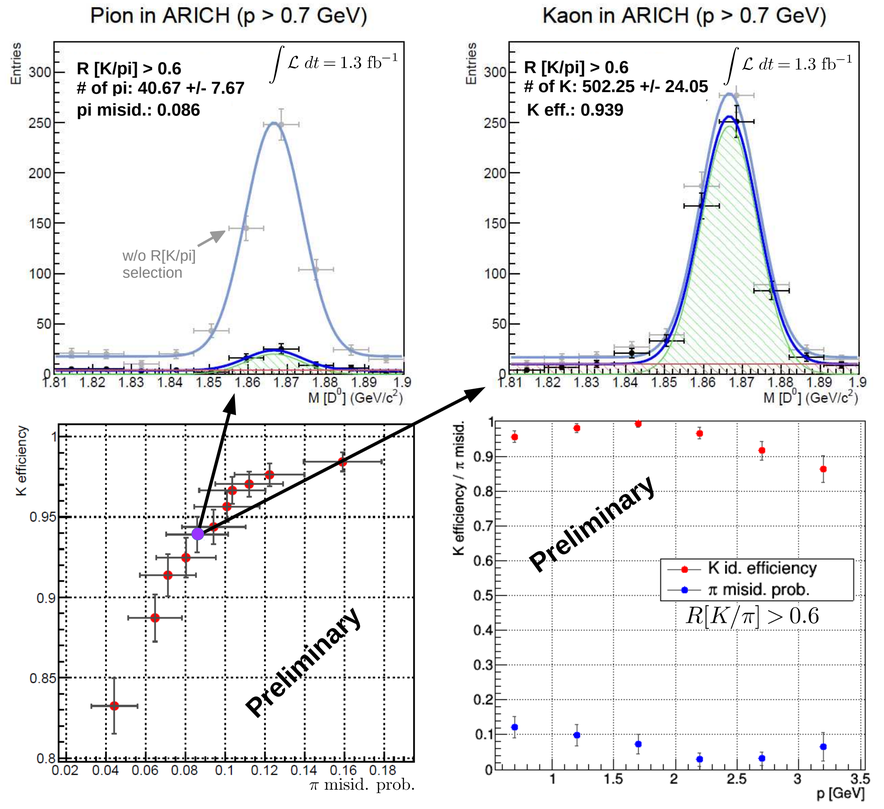
$D^{*-} \to \bar{D}^0\ \pi^-_{\mathrm{slow}}$, $\bar{D}^0 \to K^+\ \pi^-$

- Apply selection criteria on $R[K/\pi] = \frac{\mathcal{L}_K}{\mathcal{L}_K + \mathcal{L}_\pi}$

  $\mathcal{L}$ - likelihood for given id. hypothesis



- Only coarse/preliminary calibrations included
- Performance already close to expected from MC



References: [1] T.Iijima, S.Korpar et al. Nucl. Instrum. Meth. A548 (2005) 383
[2] M.Tabata et al.,The Journal of Supercritical Fluids 110 (2016) 183-192
[3] S. Nishida et al. Nucl. Instrum. Meth. A787 (2015) 59-63
[4] S Nishida et al. Nucl. Instrum. Meth. A623 (2010) 504–506