The Belle II imaging Time-Of-Propagation (iTOP) detector in first collisions

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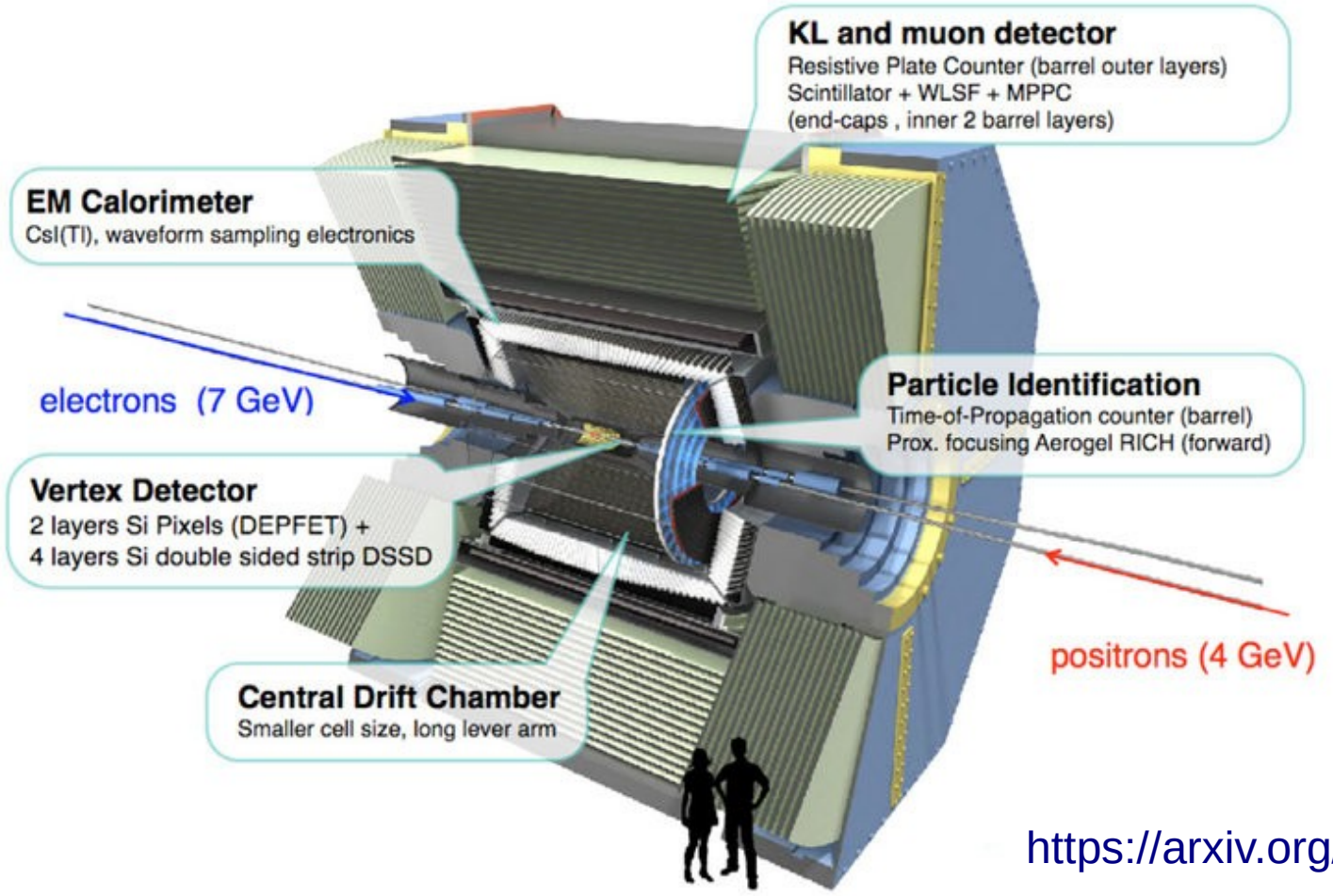
for the iTOP group
Belle II

VCI
Vienna, Feb 22, 2019

Belle II

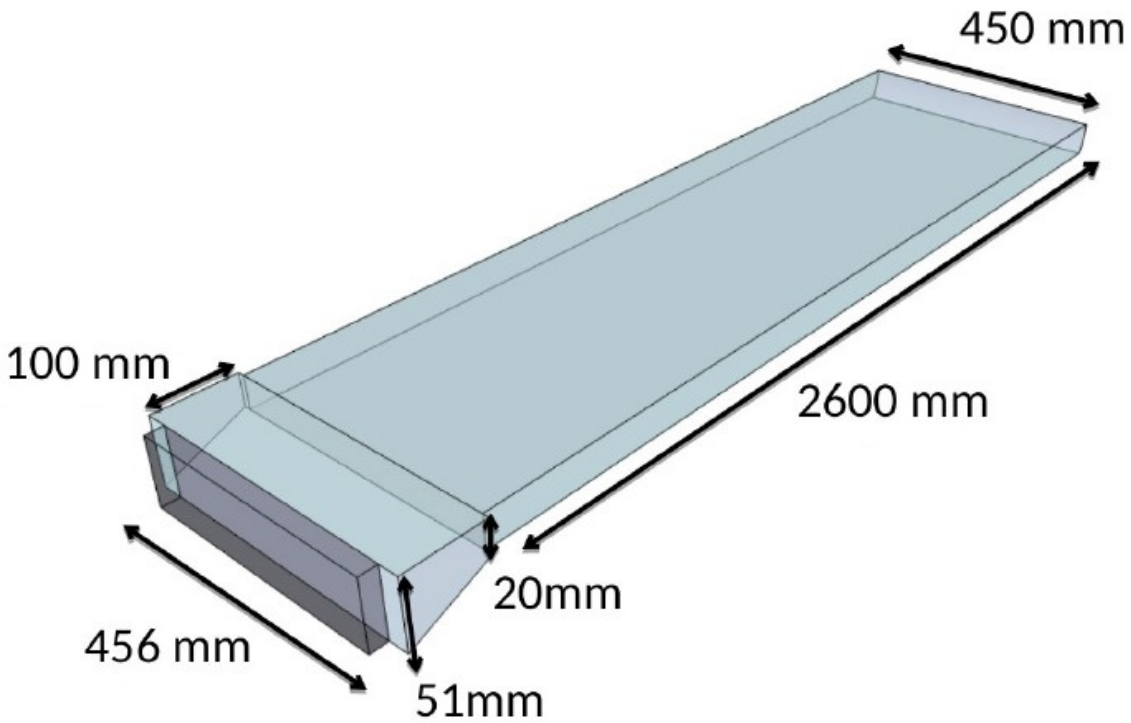
- Detector for SuperKEKB B-factory
- Higher luminosity than KEKB: 8E35/(cm^2 s) and 50/ab
- More precision, 30 kHz trigger rate, larger tracking detector

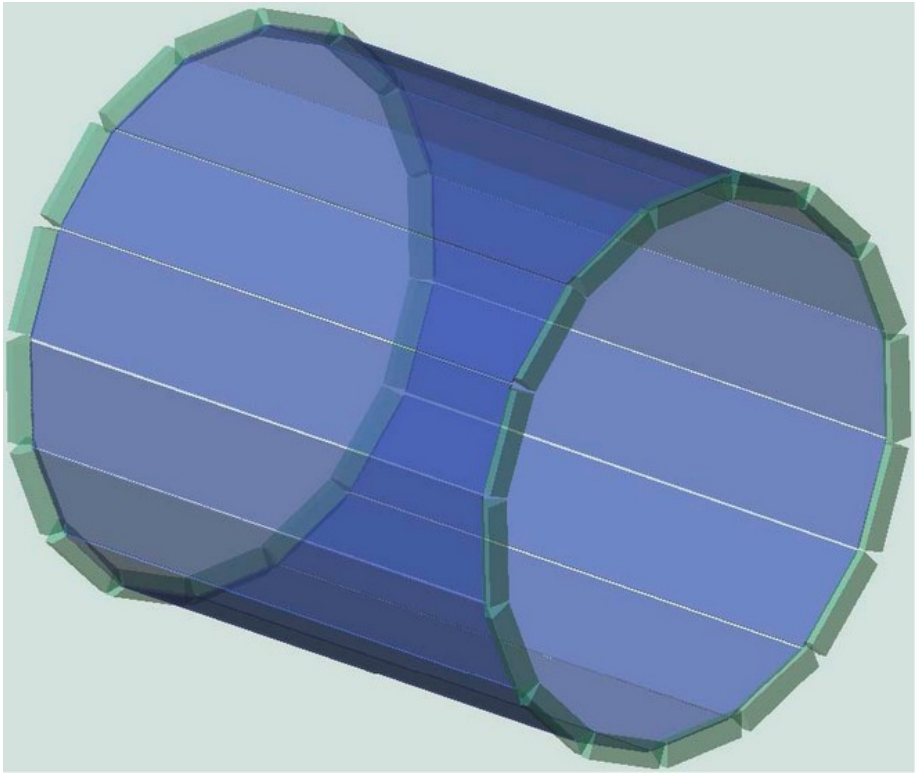


https://arxiv.org/abs/1011.0352

iTOP

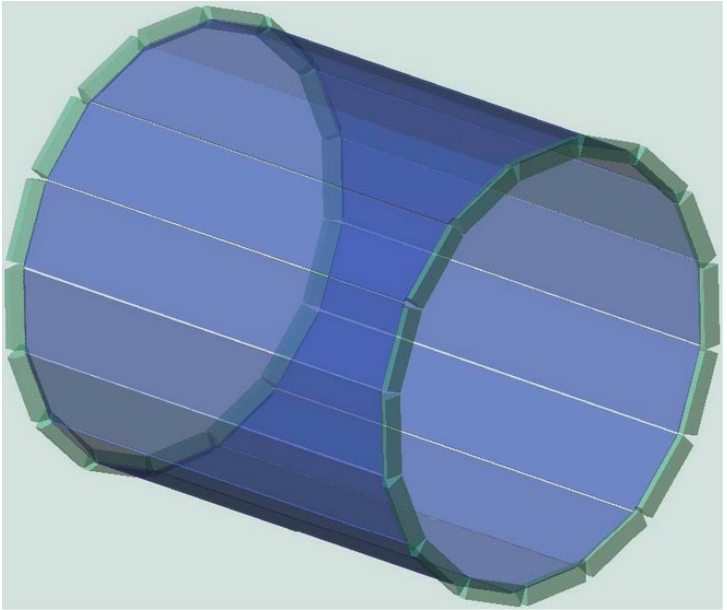
- Particle identification in 2 cm
- Cherenkov detector
- Angle reconstructed from position and time of arrival
- 16 modules around interaction point

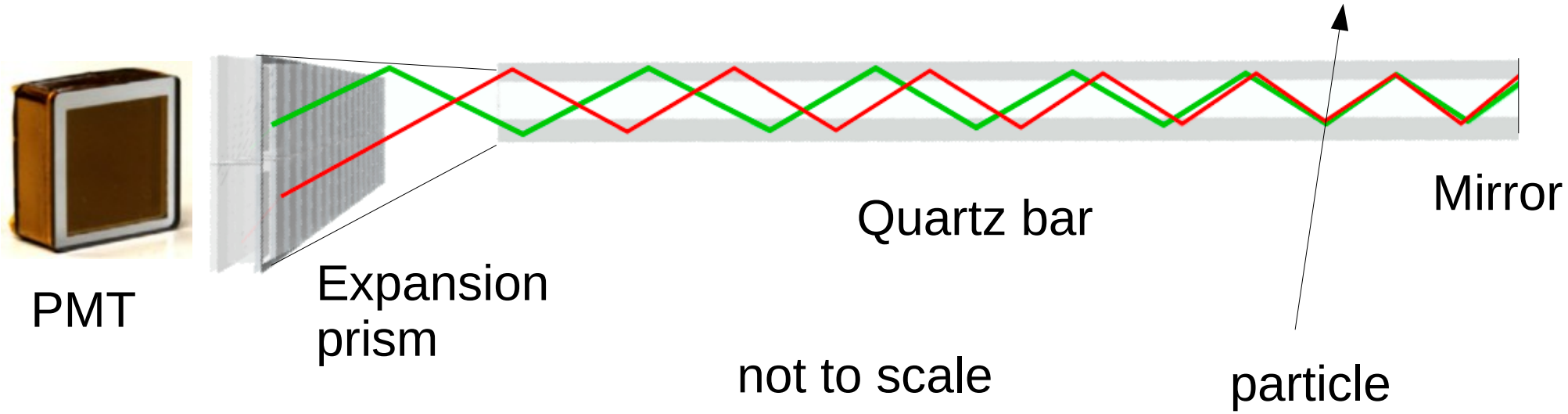




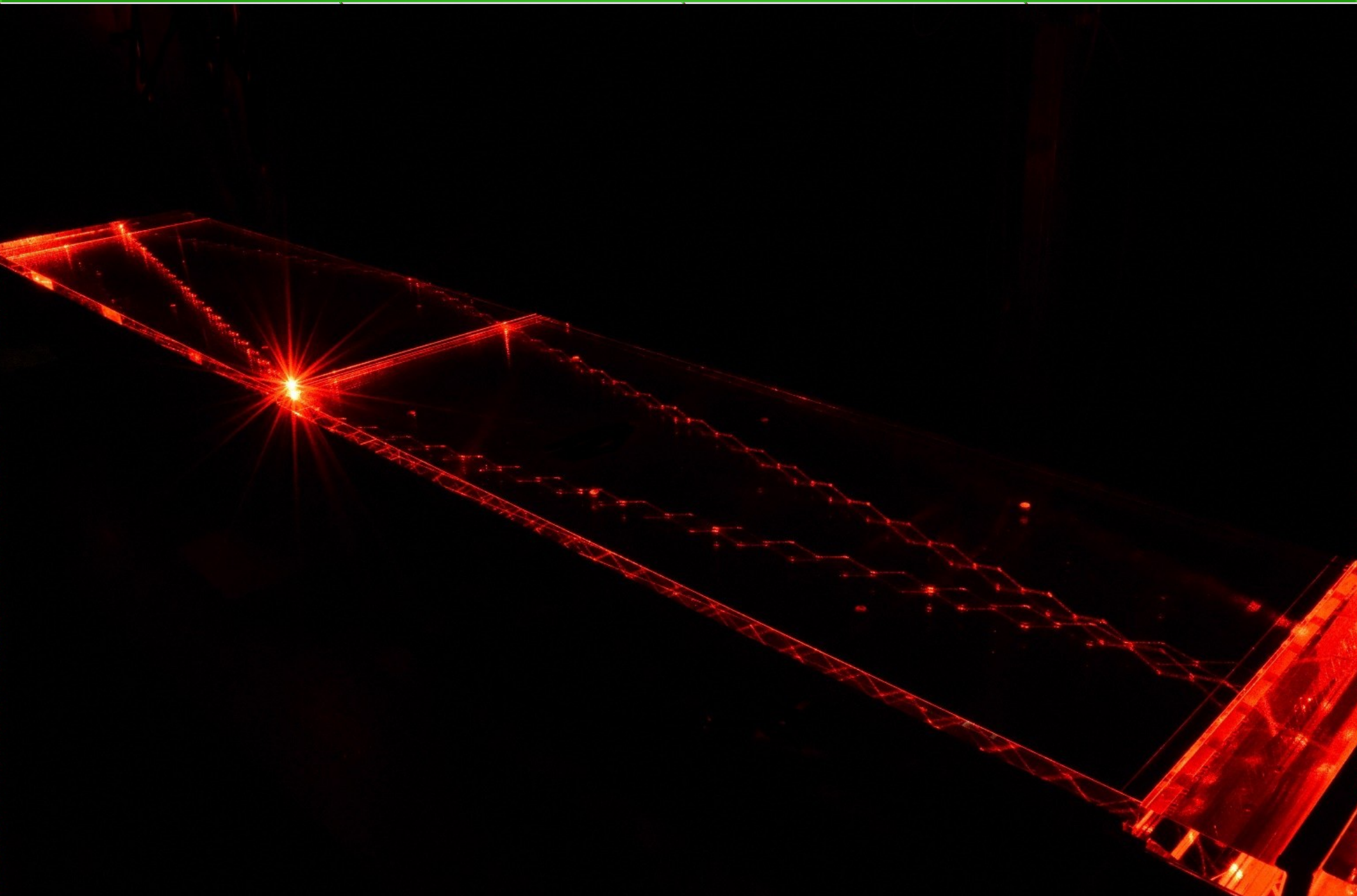
Light path

- Total internal reflection
  (>100 times)
- Expansion prism at backward side
  spatial resolution
- PMTs for detection
- 64x8 pixels per module
- Mirror at forward side



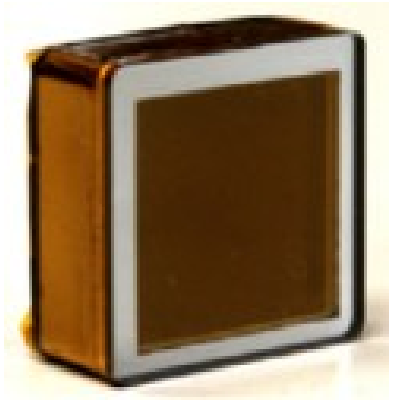


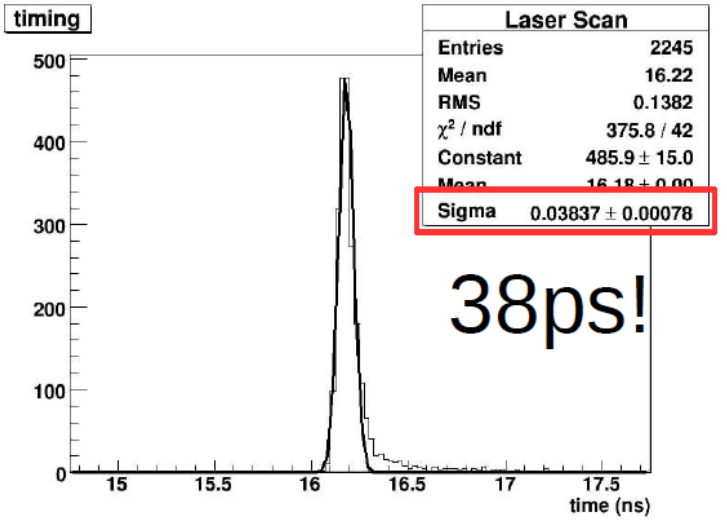
Light path

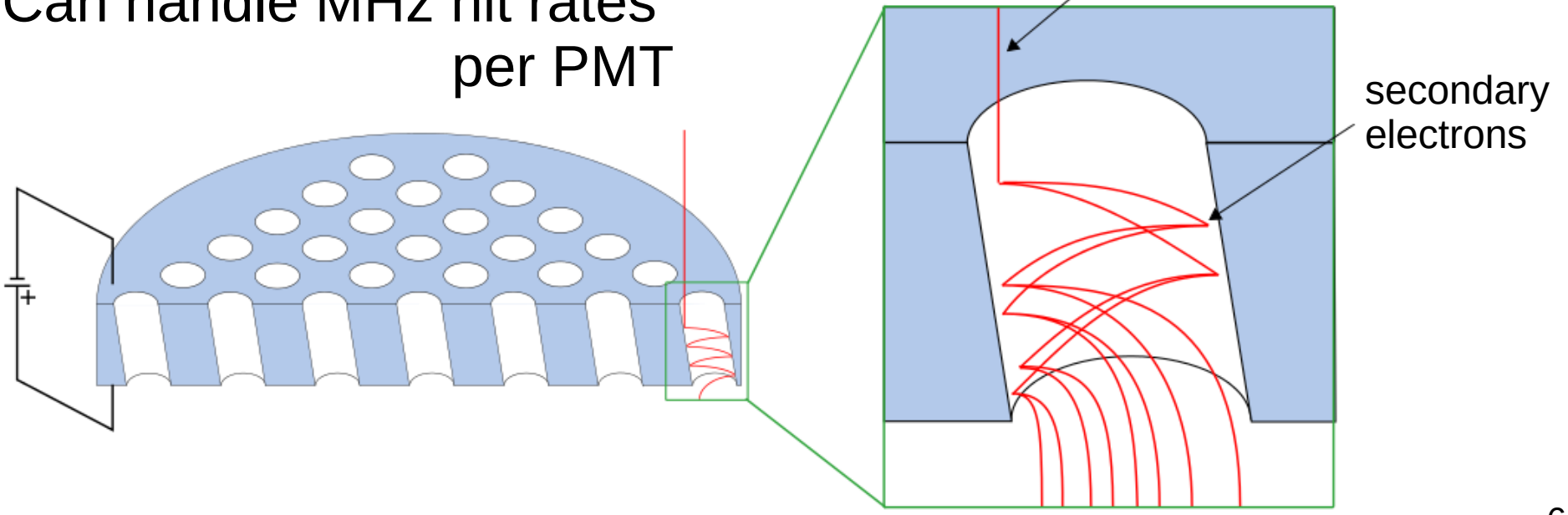


MCP-PMTs

- Microchannel plate PMTs
  25 mm x 25 mm
- Single photon sensitivity
- Excellent time resolution
- 16 channels each
- Large sensitive area
- Works in magnetic field (1.5T)
- Can handle MHz hit rates
  per PMT



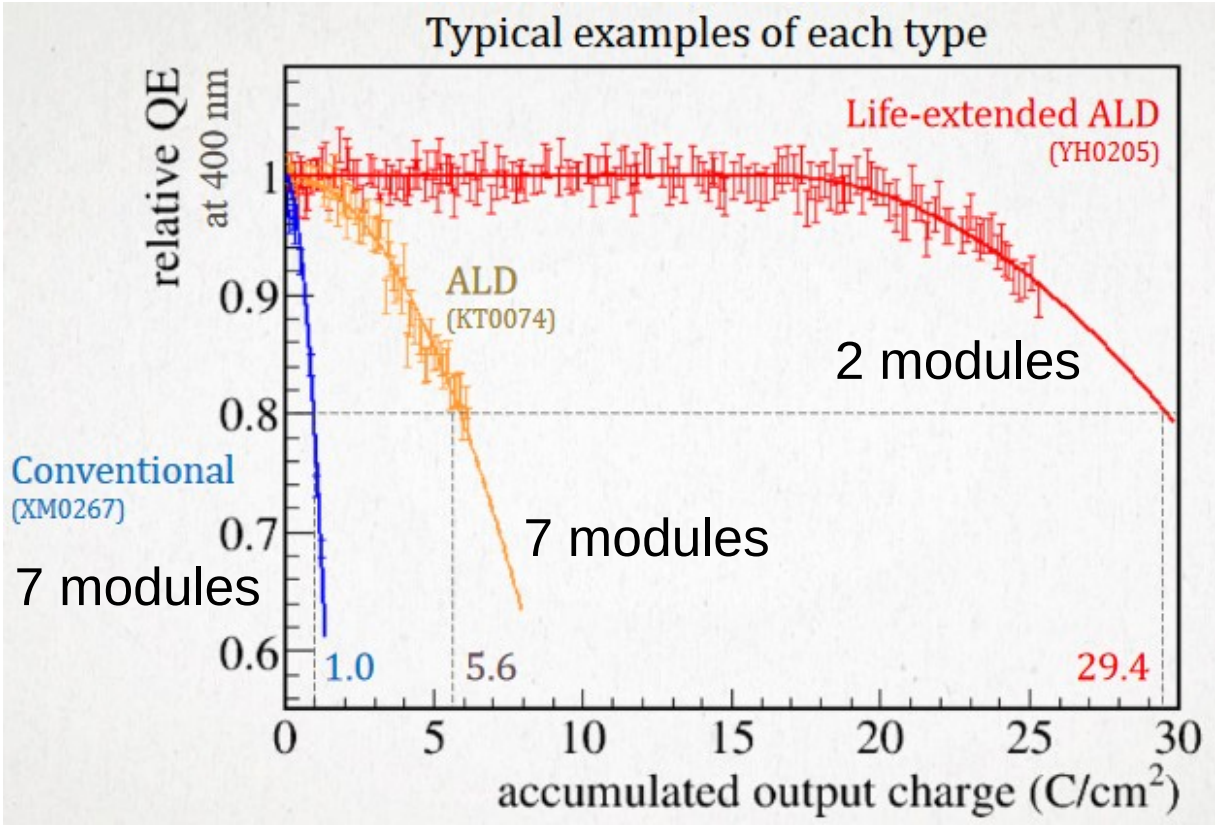




PMT lifetime

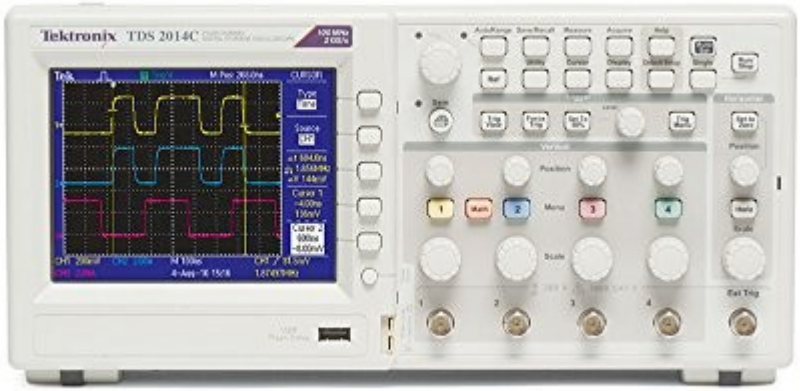
- PMTs accumulate several C/cm^2
- Major challenge for MCP-PMTs:
  Outgassing reduces efficiency
- Hamamatsu: Improvements during mass production

- Three types installed
- Need to replace first type by 2020-2021



Digitization

- Need ~100 ps resolution → 2.7 GSamples/s, 12 bit
- Oscilloscopes?
  4 channels



- Detector: 8192 channels
  multiply: 33 TB/s

- 2000 oscilloscopes?

Digitization

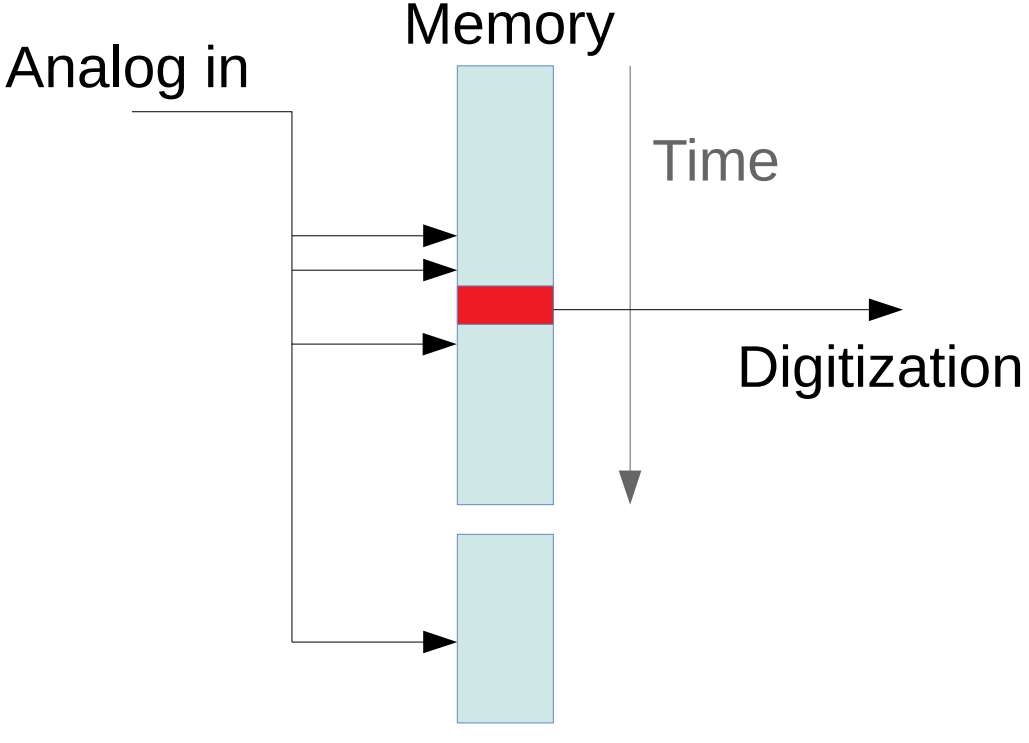
- Need
- Oscil
  4

- Detec
  m
- 2000

Readout system: IRSX

- Custom chips, 8 channels/chip
- Write continuously to analog ring buffer (10 us)
- Internal trigger
  - Flags regions of interest
  - Digitize if there is a global trigger
- Extra memory region to avoid overwriting hits

https://arxiv.org/abs/1804.10782

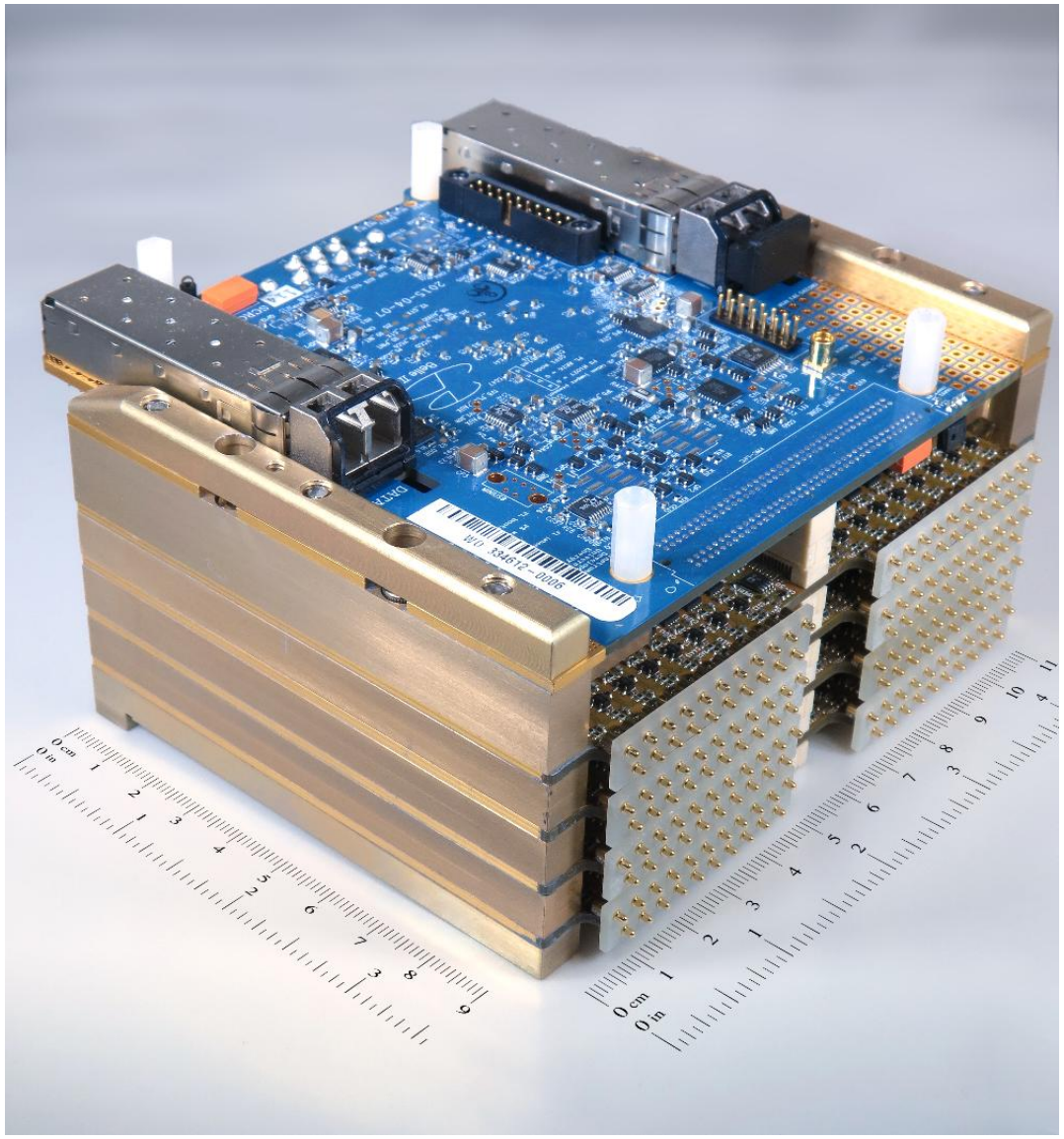


Data processing

- 8 channels per IRSX
- 4 IRSX per carrier PCB
- 4 carriers per boardstack

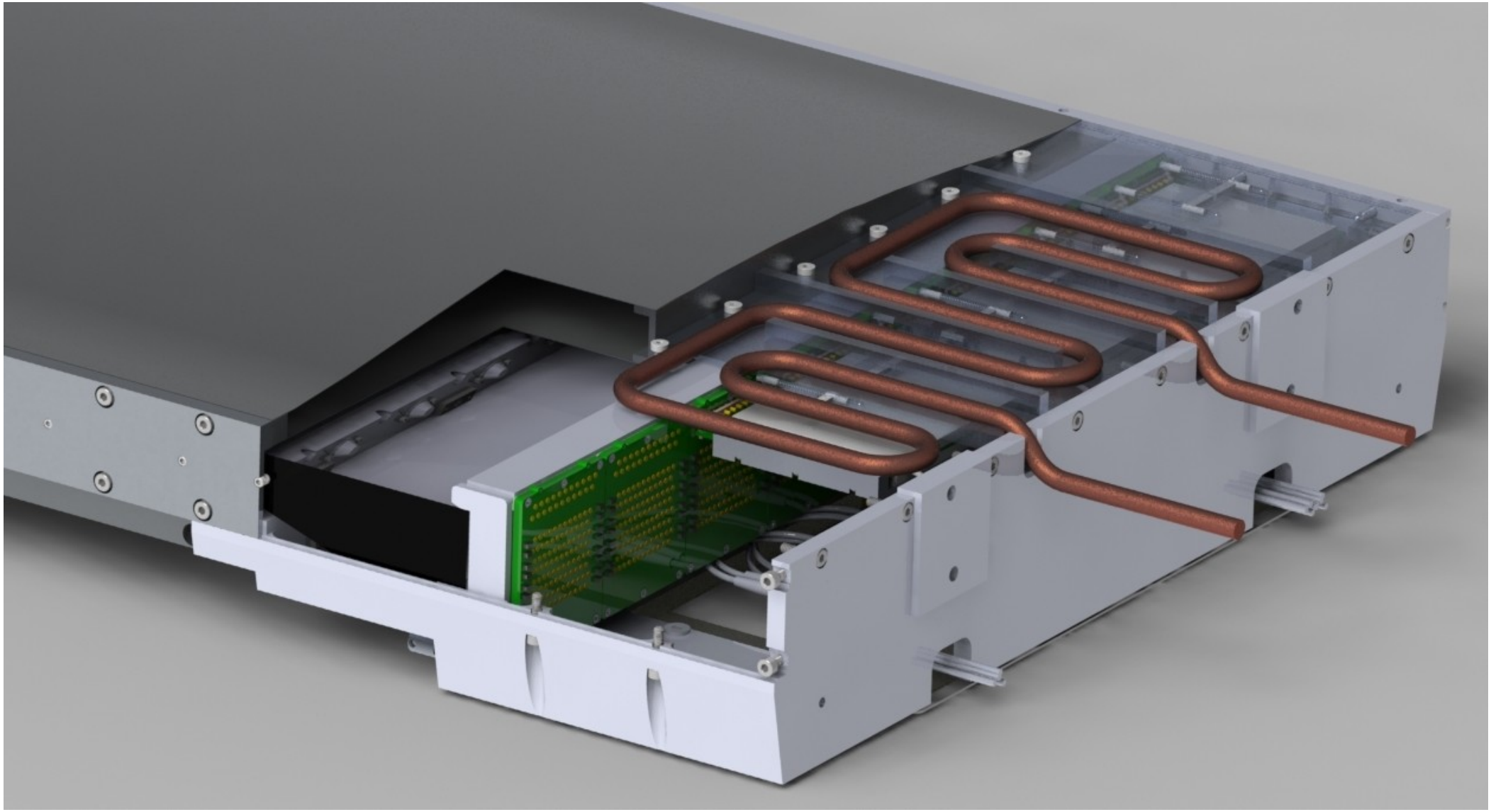
- Each step collects data
  from subsystems
- Feature extraction of
  digitized wave forms
  (50% constant fraction)
- Hits sorted to form events

- Data sent out with optical link



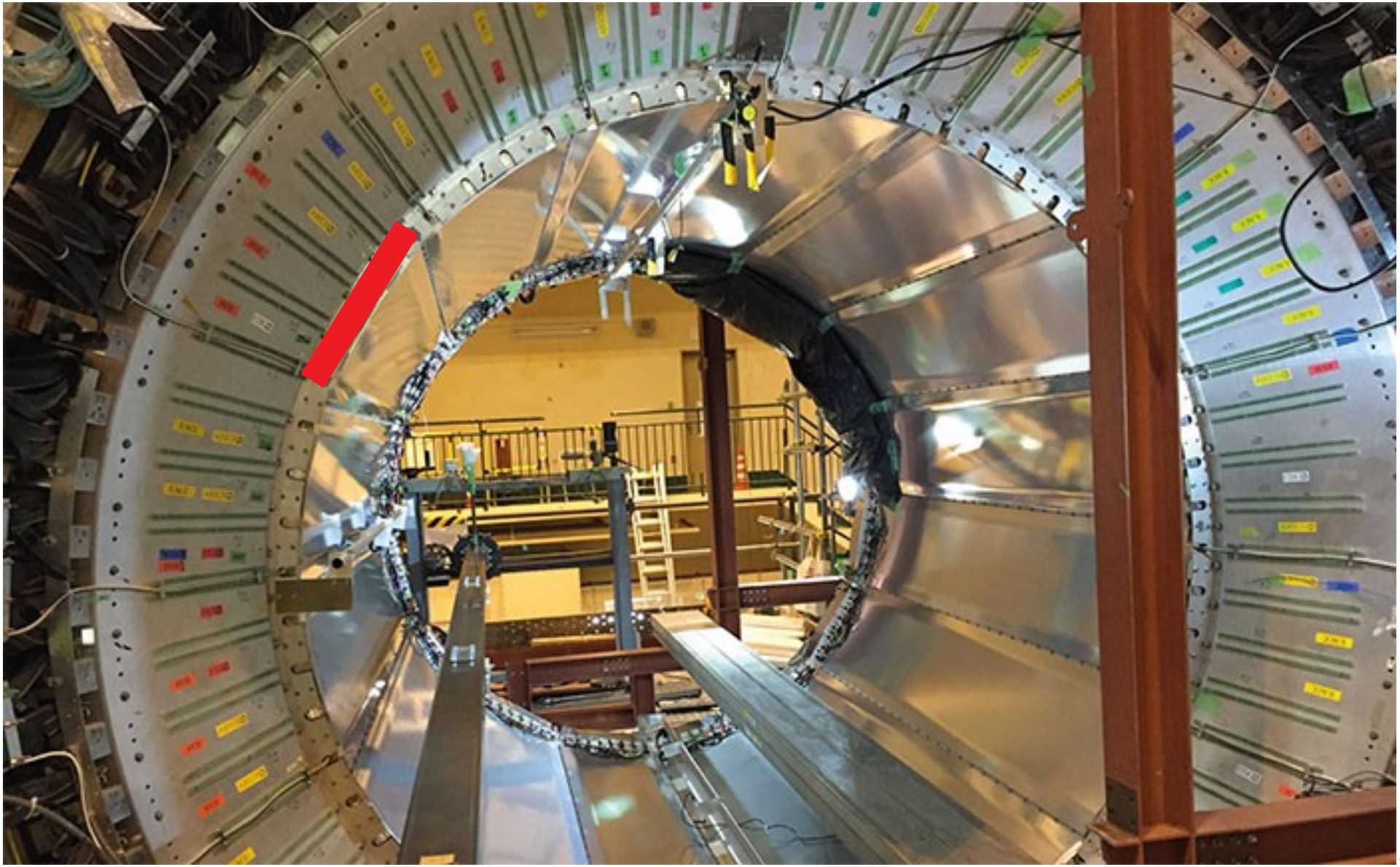
TOP module

4 boardstacks per module



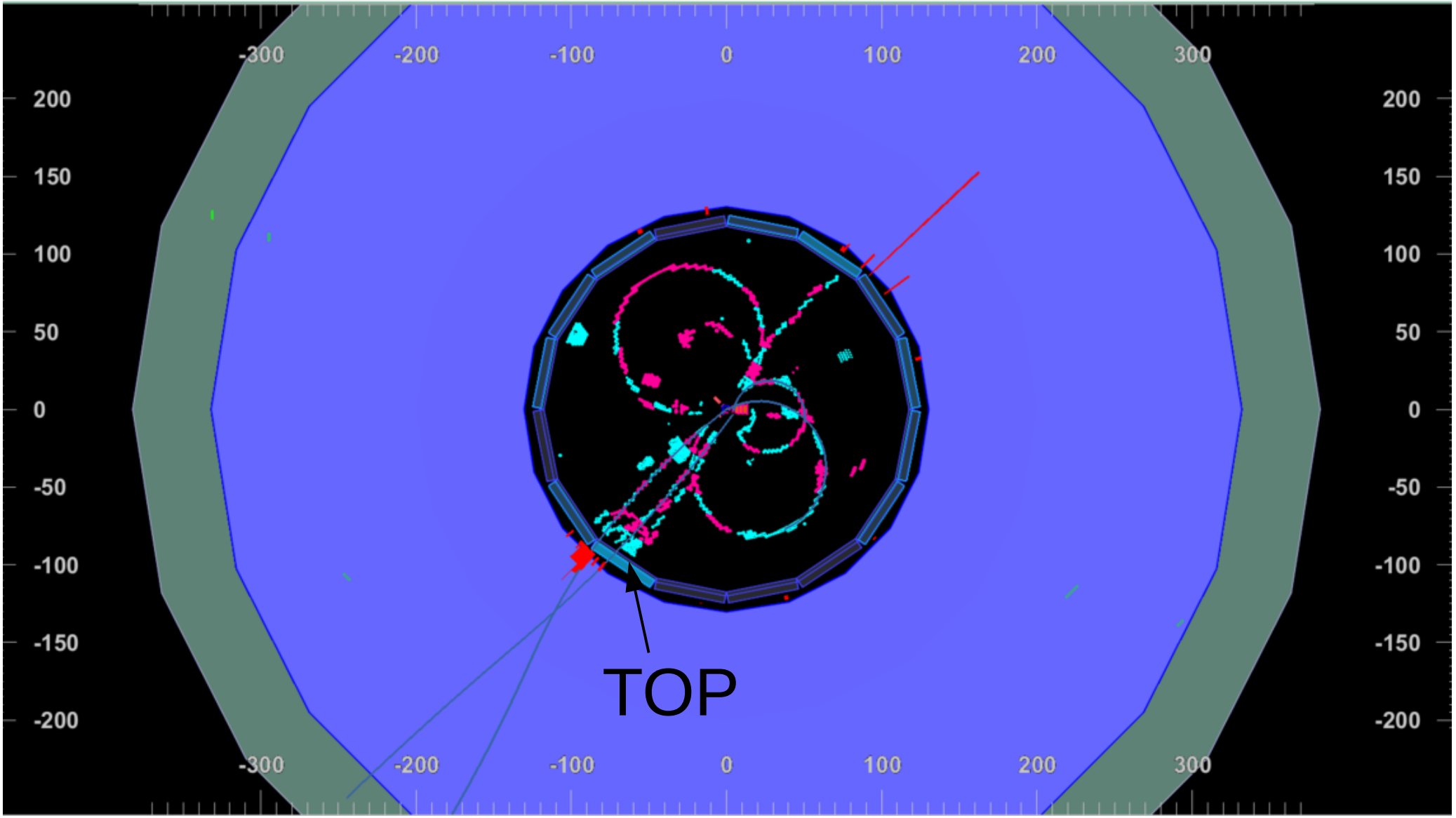
Putting it together...

16 modules



First collisions

April 26, 2018



Control room

Time calibration

Goal: ~100 ps time resolution
Done in 4 steps:

- Within channels
  Inject electronic pulses with known delay
- Between channels
  Inject laser pulses in module
- Between modules
  Cosmic muons, collision data
- Relative to collision time
  Collision data

- Geometrical alignment
  Cosmic muons, collision data

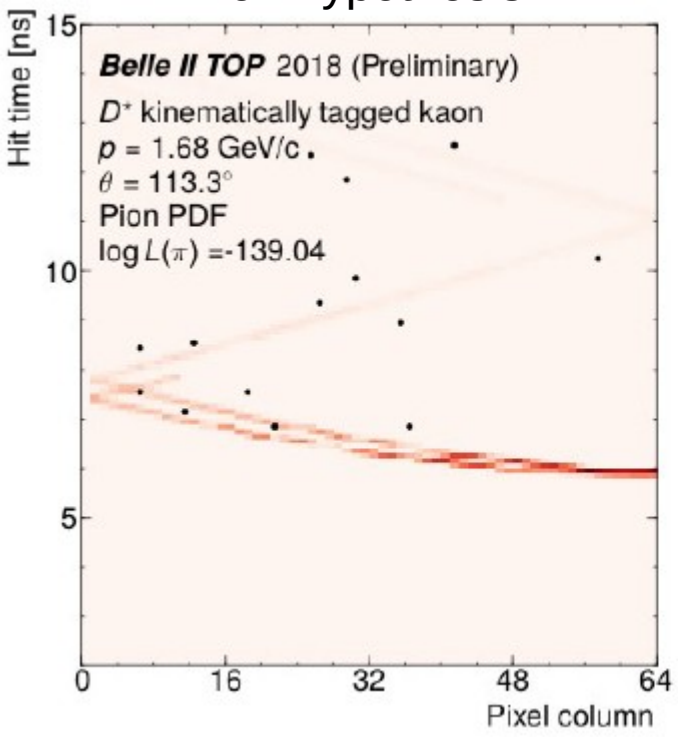
http://inspirehep.net/record/1642909/

Reconstruction

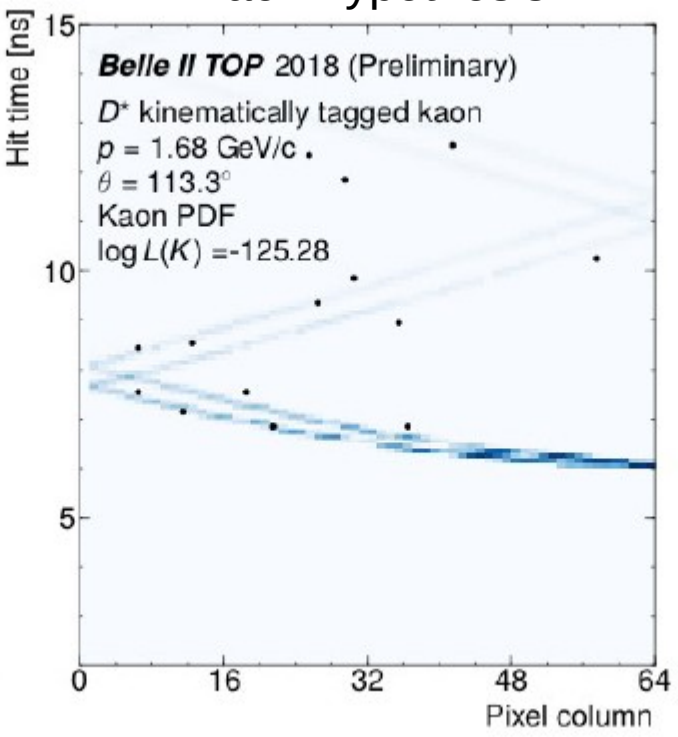
- Channel: $D^{*+} \rightarrow D^0 \pi_s^+$ with $D^0 \rightarrow K^- \pi^+$

  Tagging from π_s^+
- Position vs. time diagram
- Kaon flying towards prism
- PID from time of flight

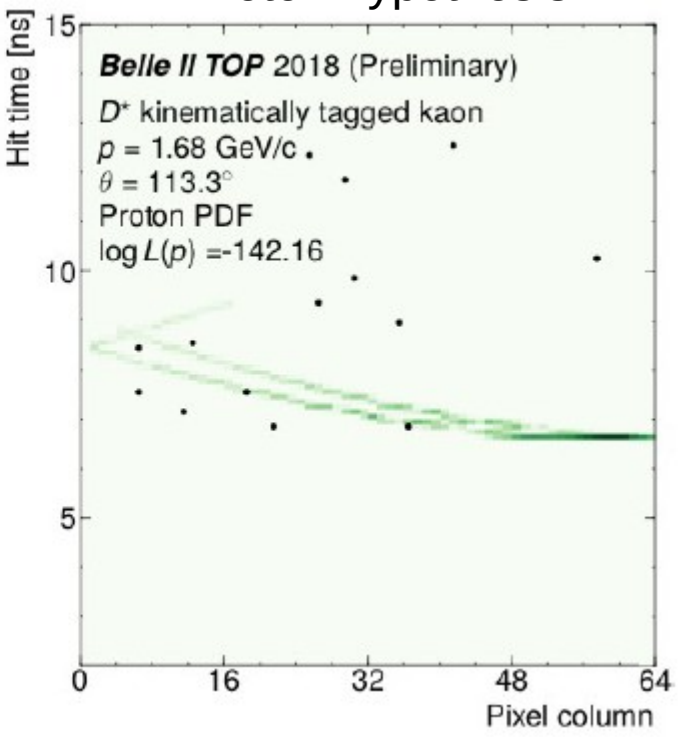
Pion hypothesis



Kaon hypothesis



Proton hypothesis

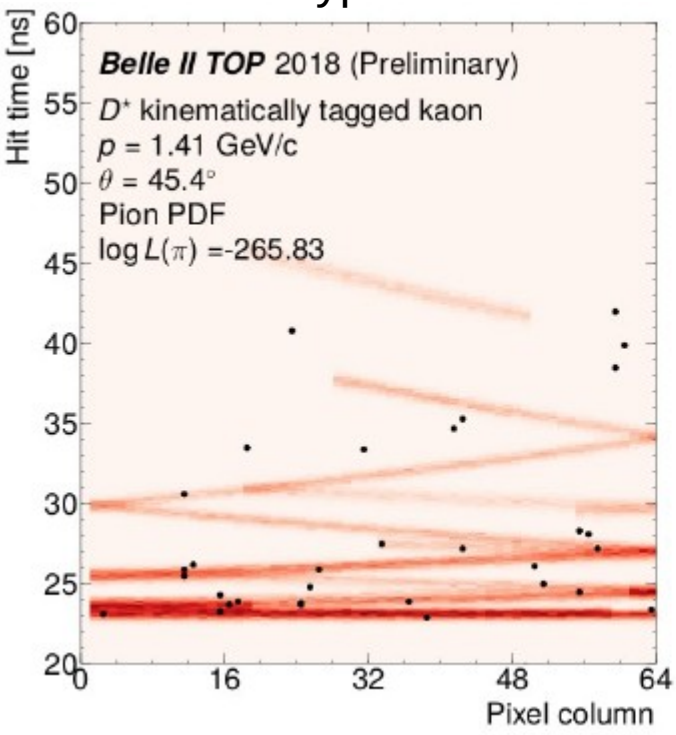


Reconstruction

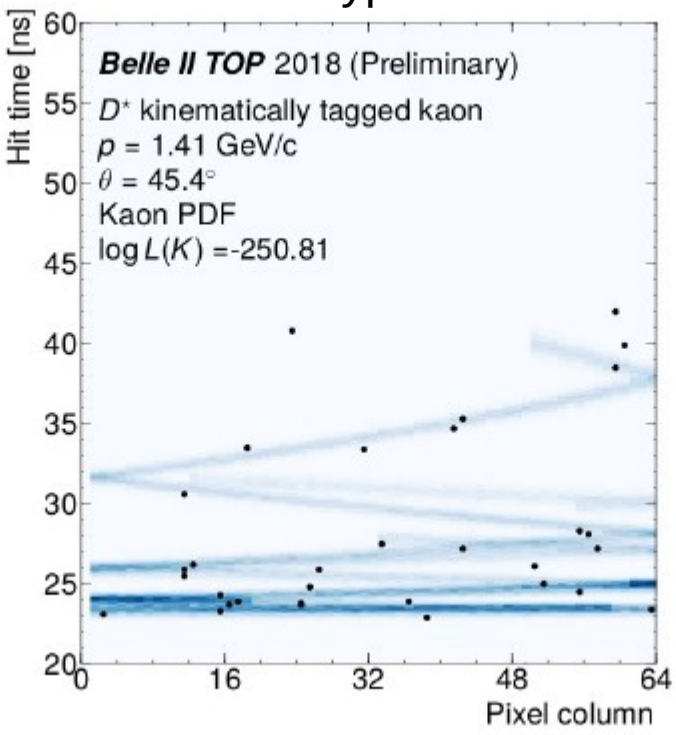
- Channel: $D^{*+} \rightarrow D^0 \pi_s^+$ with $D^0 \rightarrow K^- \pi^+$

  Tagging from π_s^+
- Position vs. time diagram
- Kaon flying away from prism
- PID from pattern of photons

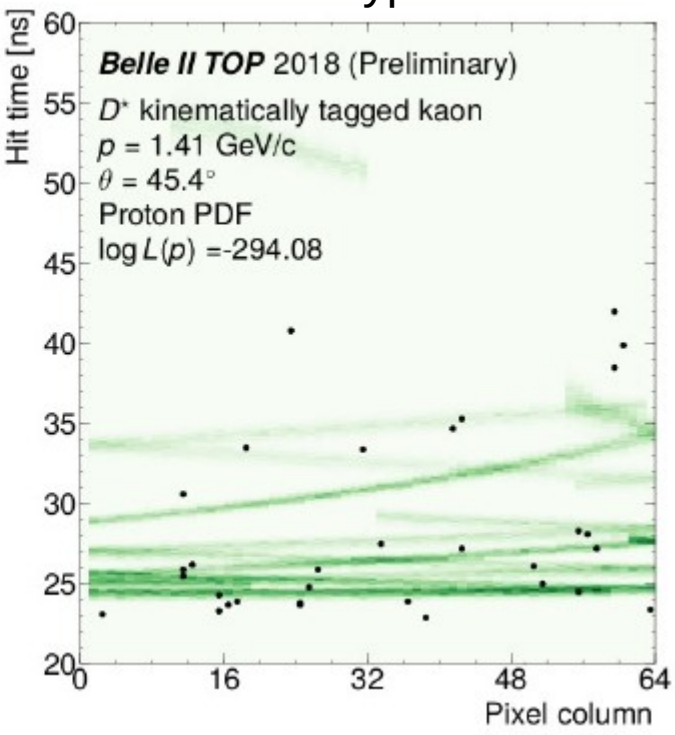
Pion hypothesis



Kaon hypothesis



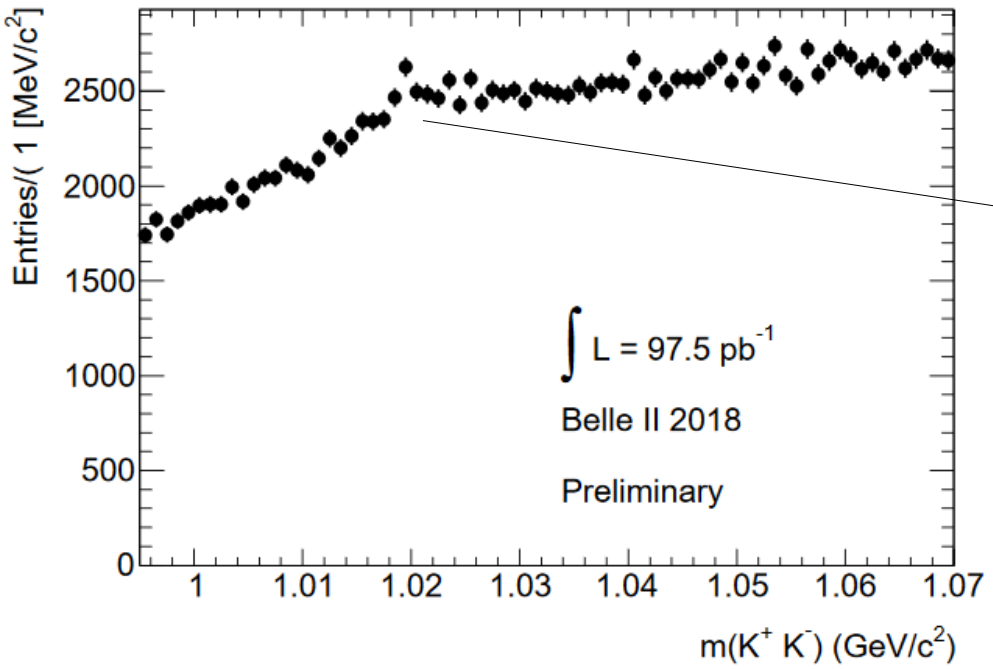
Proton hypothesis



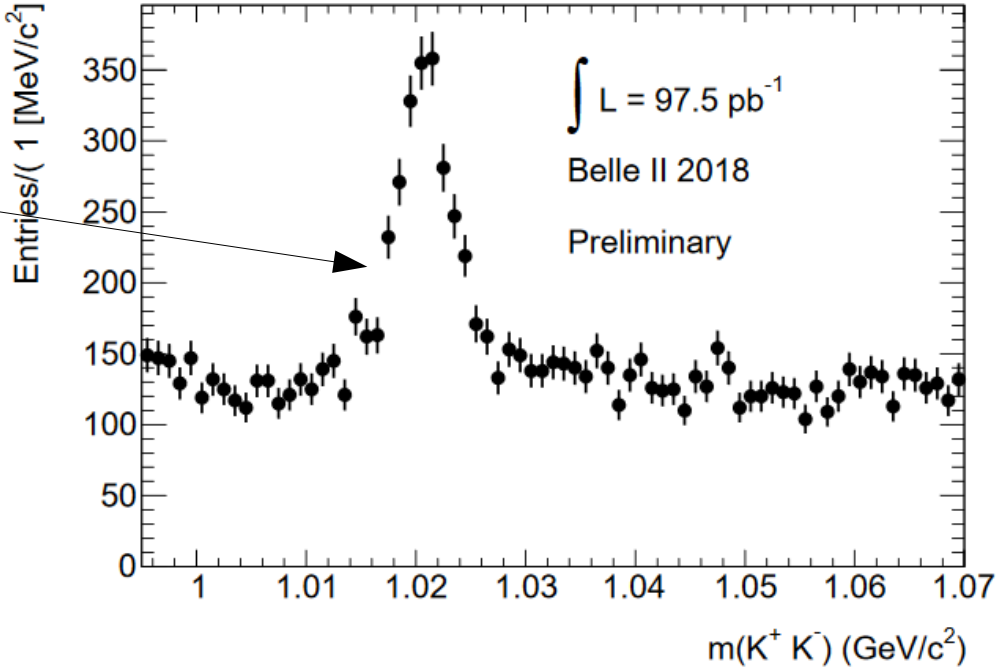
Particle identification

- Applied to 2018 data
- ϕ decaying to kaons
- TOP particle identification only
  (also dE/dx from tracking available)

No PID

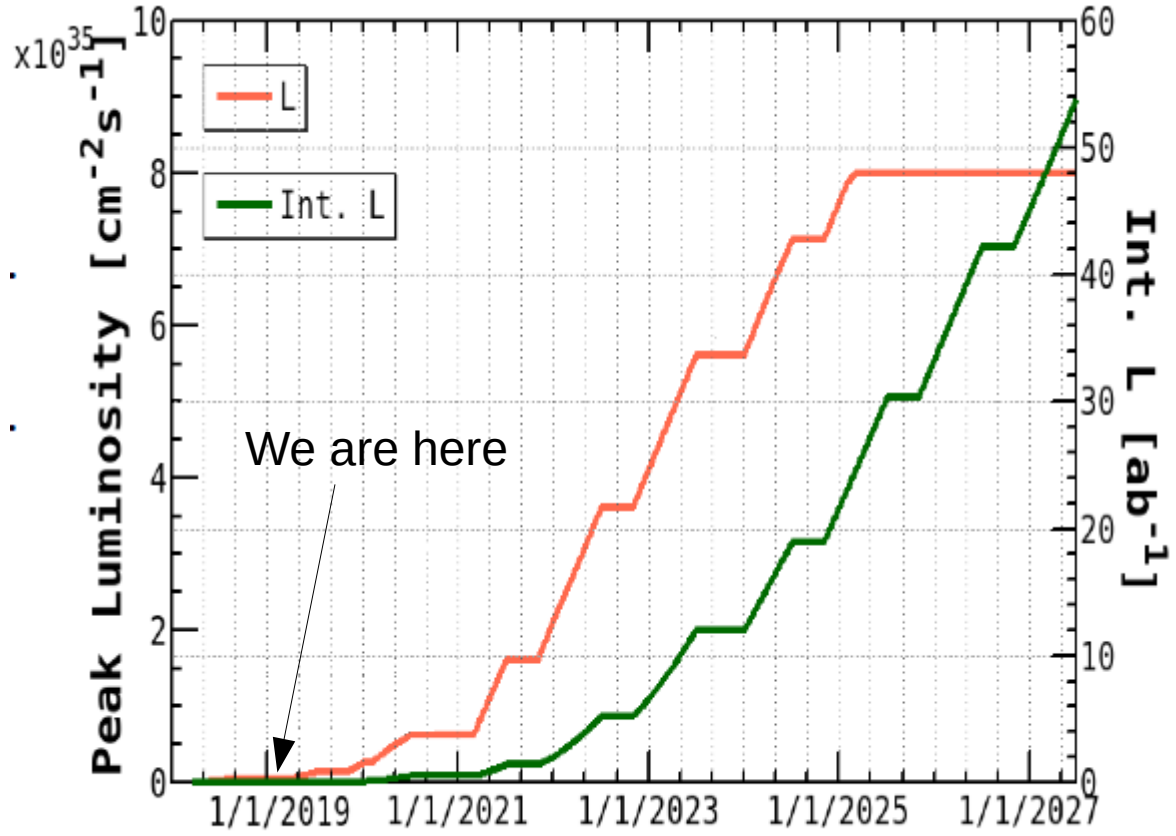


with TOP



Outlook

- Data taking will resume in March
- 7-9 months/year
- Goal: 50/ab
- What will Belle II discover?



Summary

- Belle II: More data, higher precision than Belle
- TOP: New detector type for particle identification

- Time of propagation + imaging
- Excellent time resolution for single photons at high rate

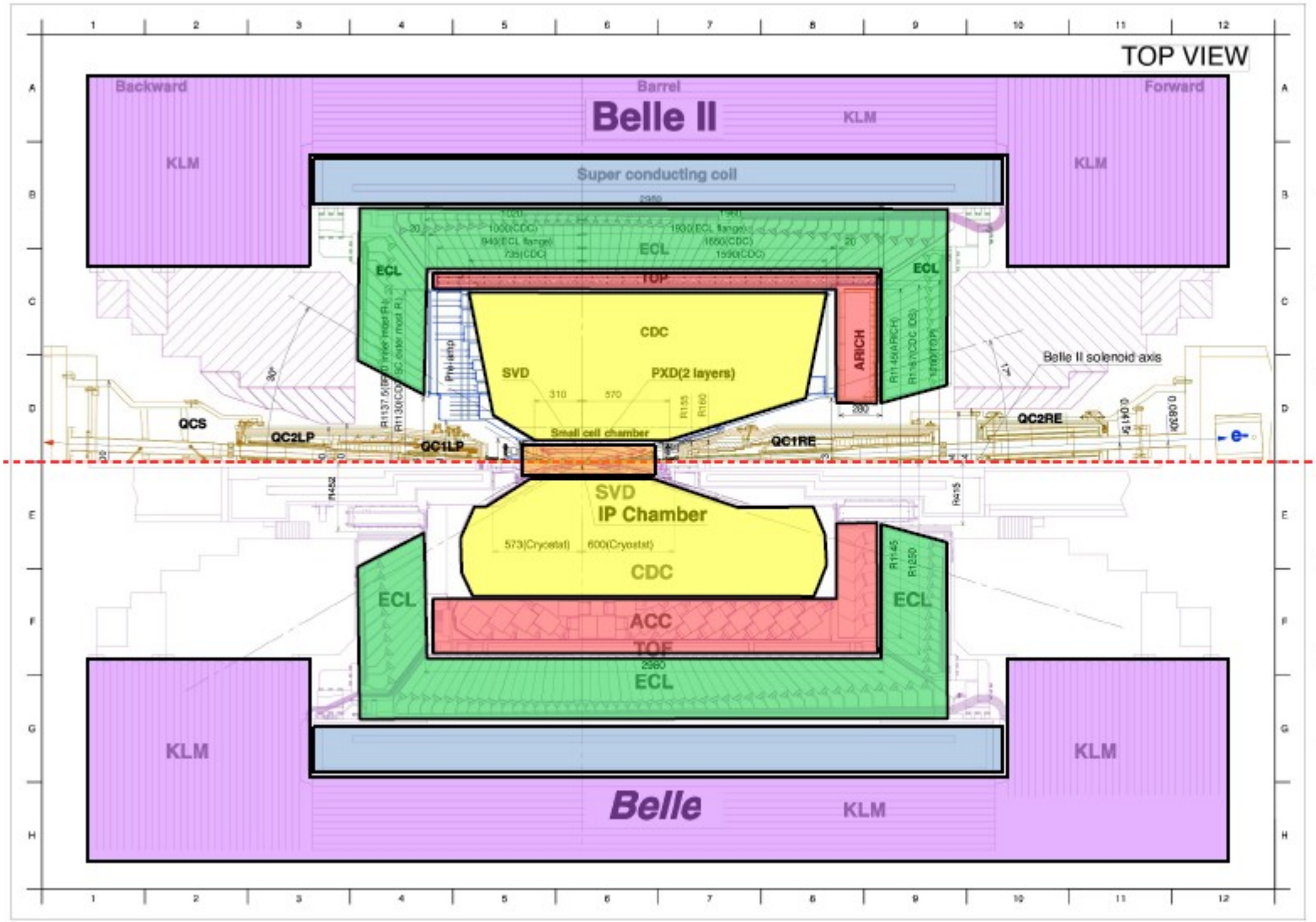
- First run in 2018
- Detector commissioning, initial data-taking
- Demonstrated concept of TOP

- Regular data-taking starting March 2019

  Stay tuned!

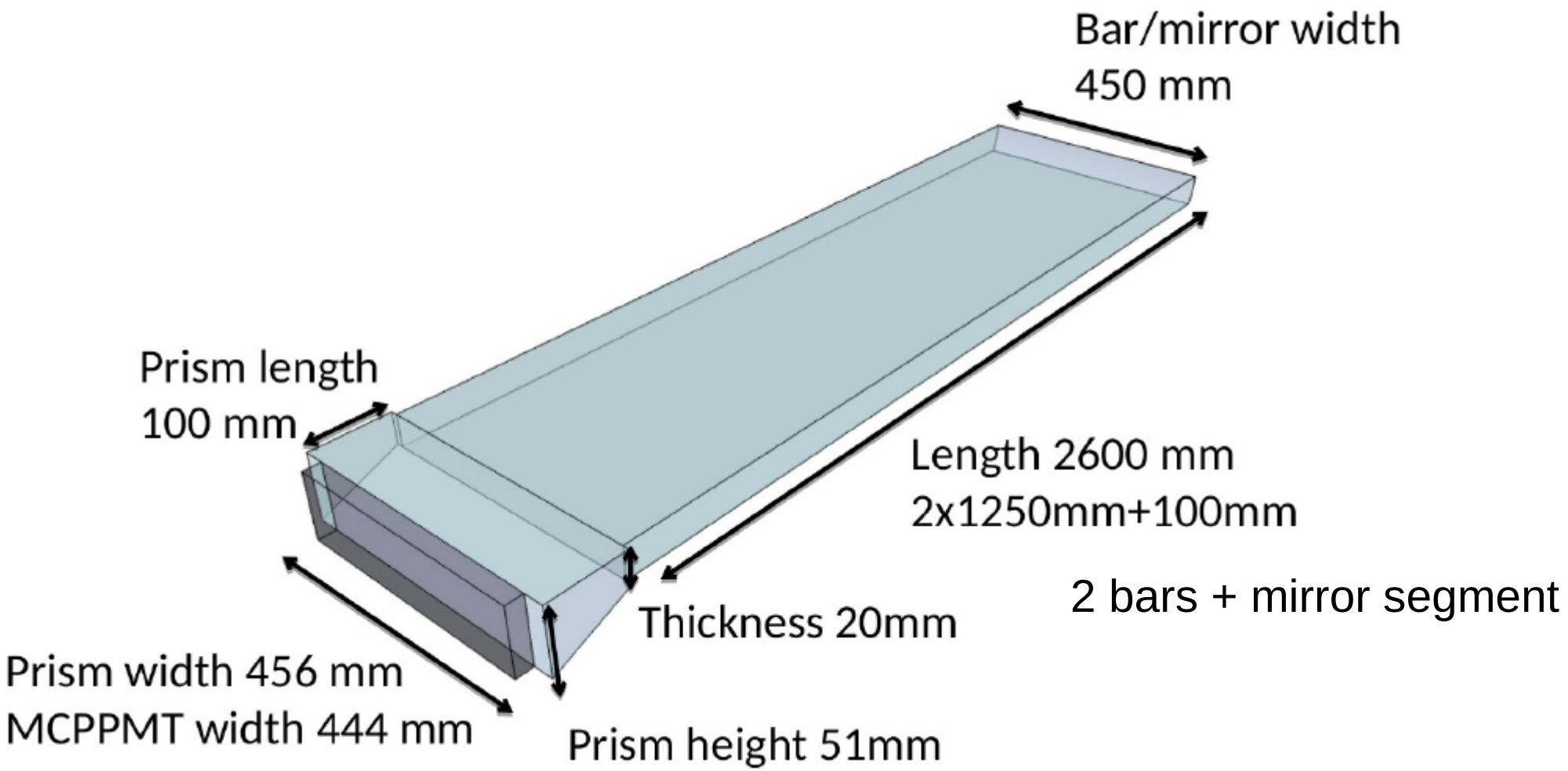
Backup slides

Belle II vs. Belle



- K_L/Muon System
- Magnet Coil
- EM Calorimeter
- π/K Identification
- Drift Chamber
- Silicon Tracking

Quartz bar

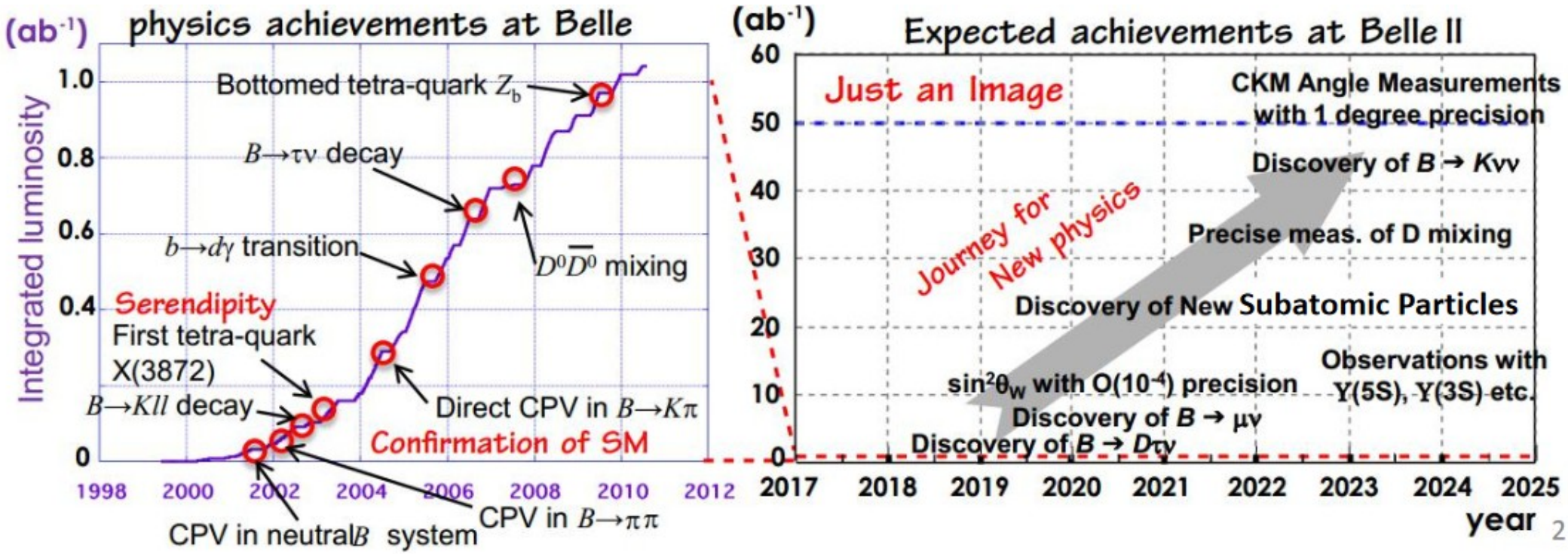


2 bars + mirror segment

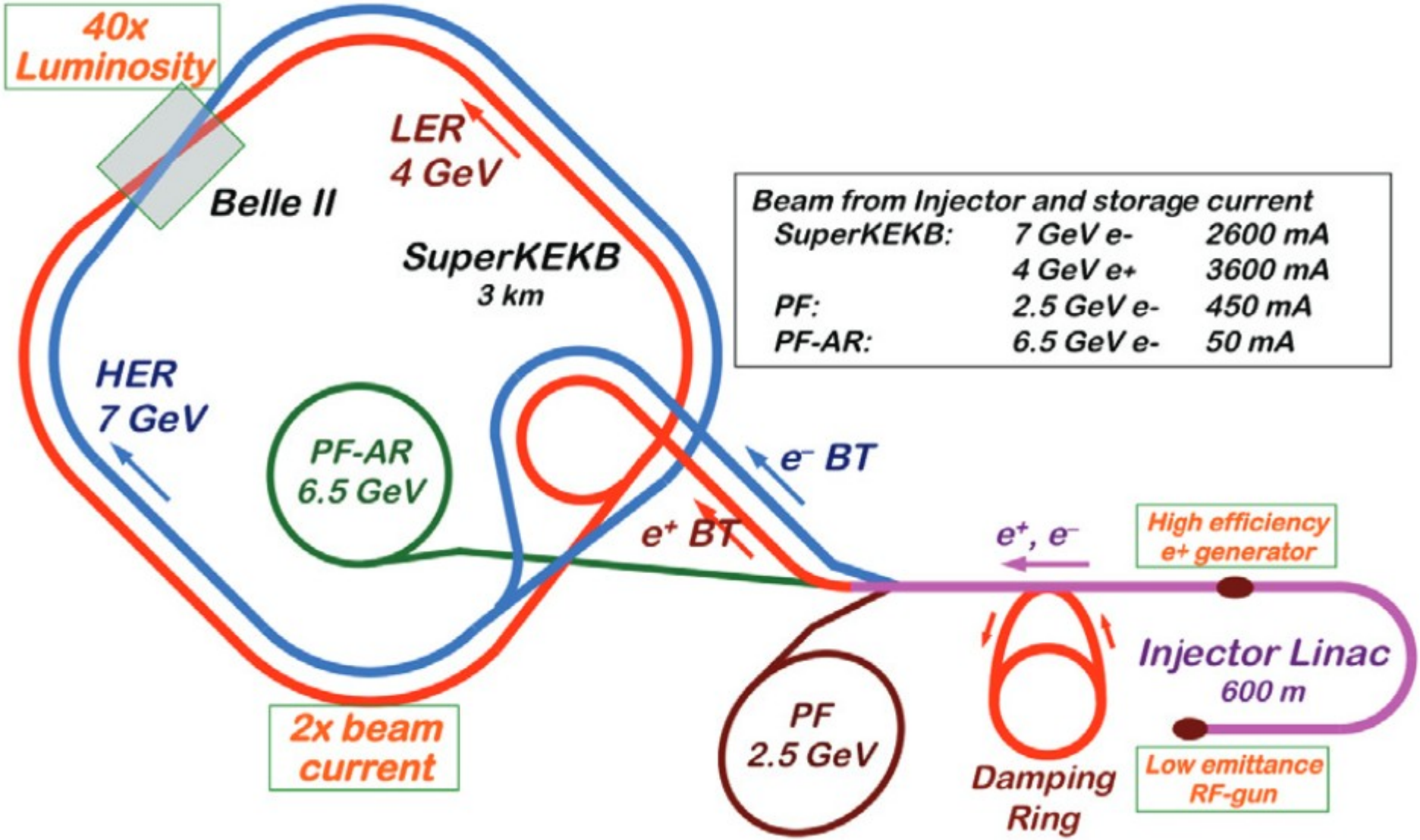
n=1.47

Comparison: Belle timeline

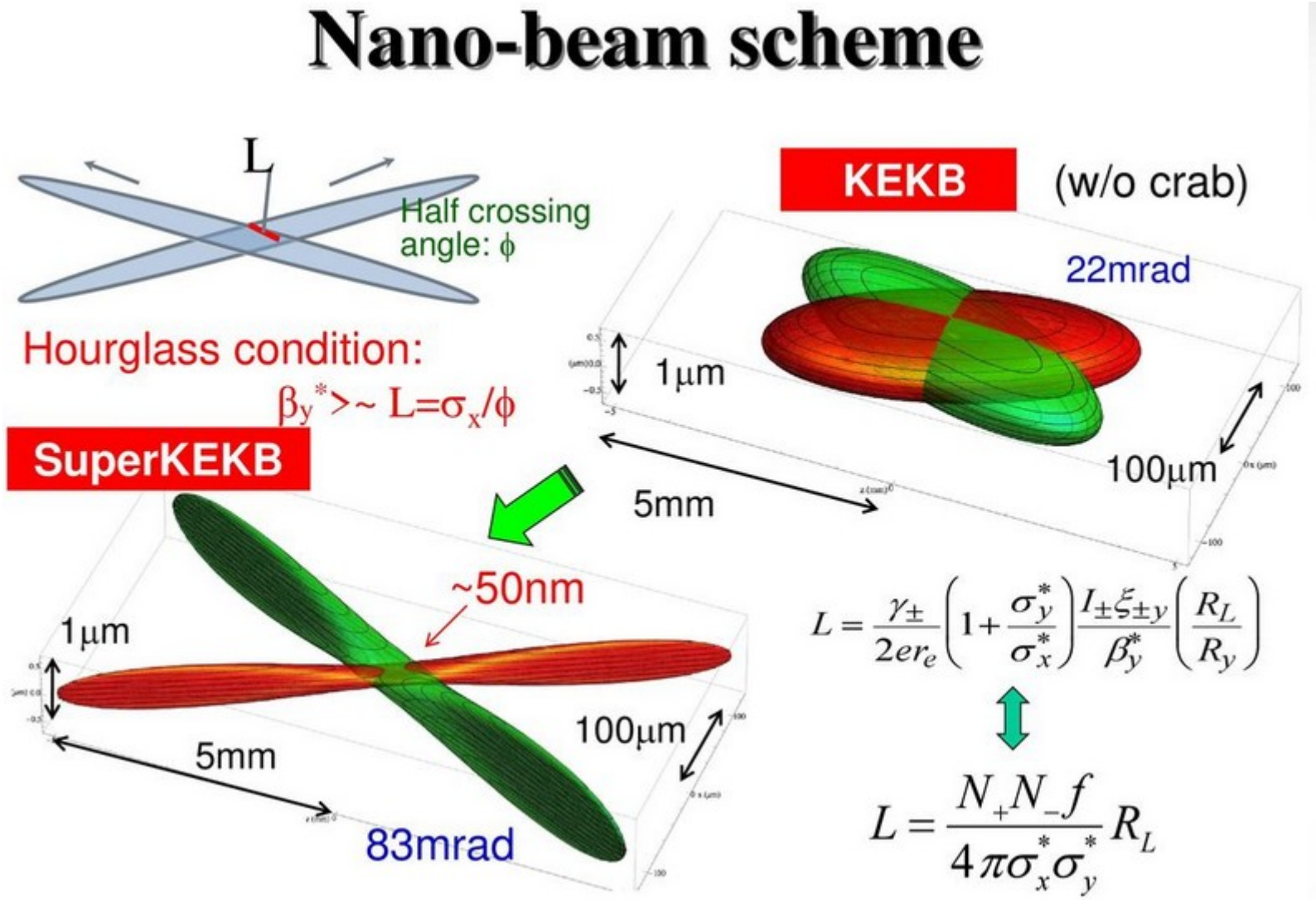
Hua YE, “Belle & Belle II Activities”, 2016



SuperKEKB

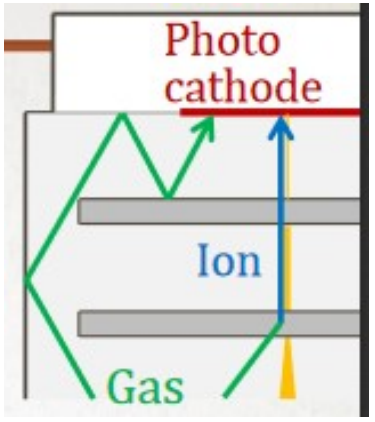

40x
Luminosity
LER
4 GeV
Belle II
SuperKEKB
3 km
HER
7 GeV
PF-AR
6.5 GeV
e⁻ BT
e⁺ BT
e⁺, e⁻
High efficiency
e+ generator
Injector Linac
600 m
Low emittance
RF-gun
Damping
Ring
PF
2.5 GeV
2x beam
current
Beam from Injector and storage current
SuperKEKB: 7 GeV e- 2600 mA
4 GeV e+ 3600 mA
PF: 2.5 GeV e- 450 mA
PF-AR: 6.5 GeV e- 50 mA

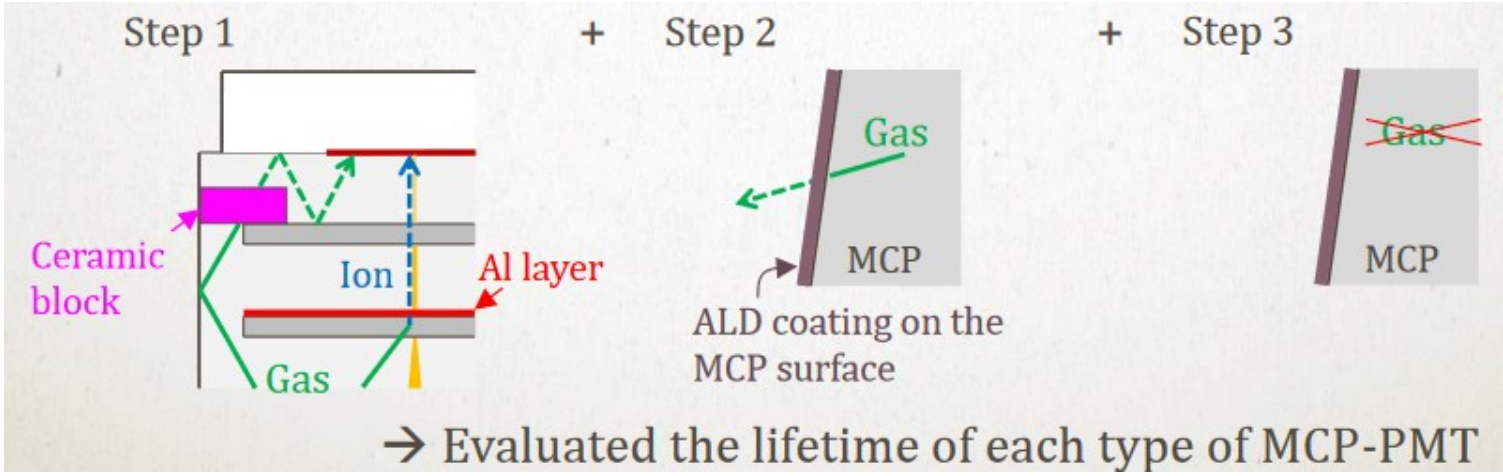
SuperKEKB collisions

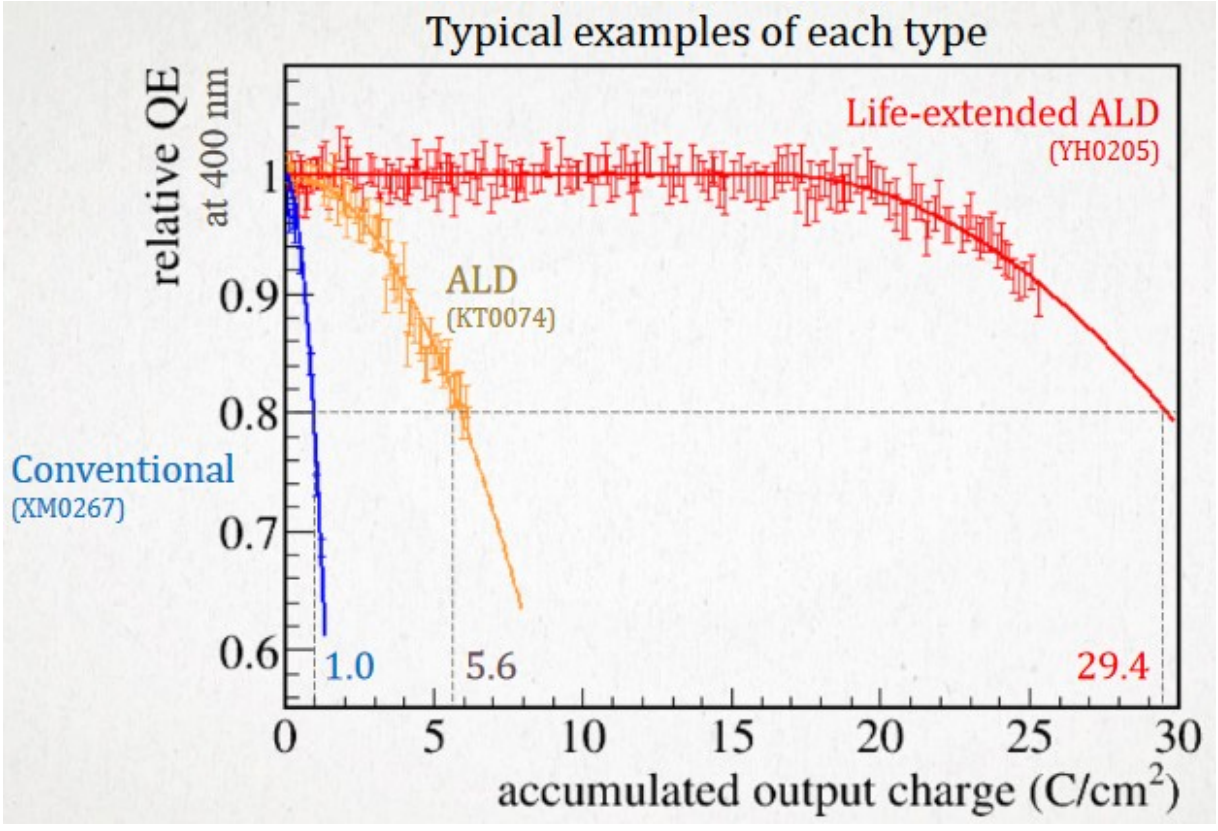


See poster by Luka Šantelj:
“Measurements of Beam Backgrounds at SuperKEKB”

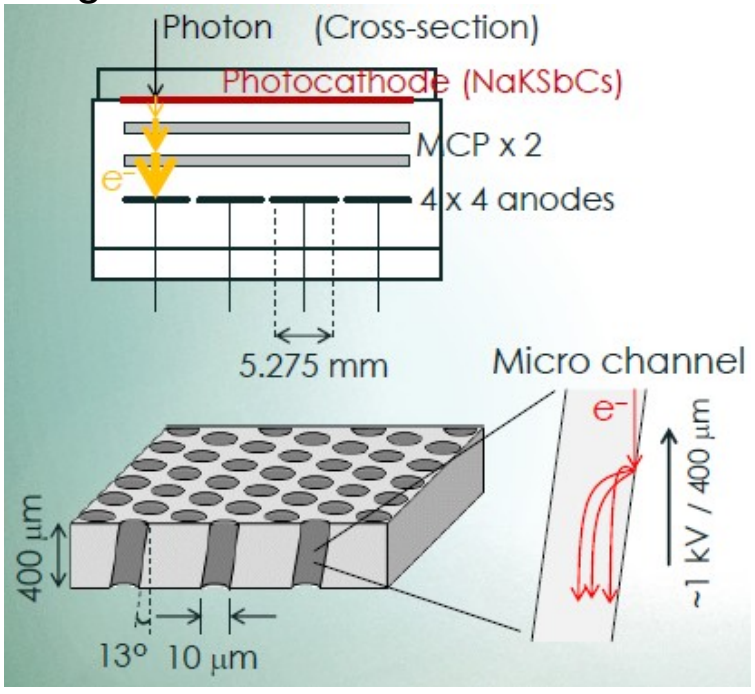
MCP PMT lifetime



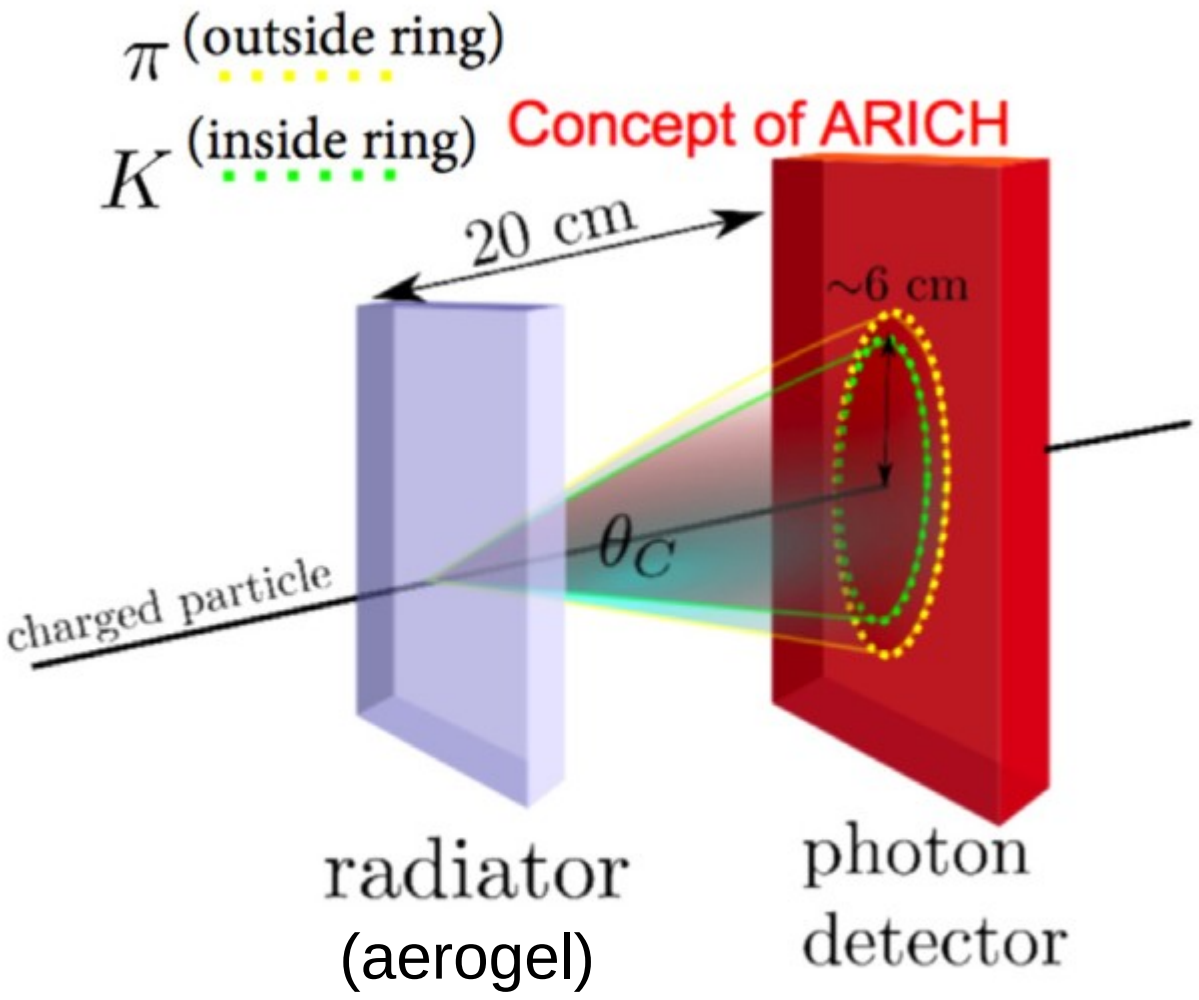




Kodai Matsuoka, “Improvement of the MCP-PMT performance under a high count rate”, TIPP 2017

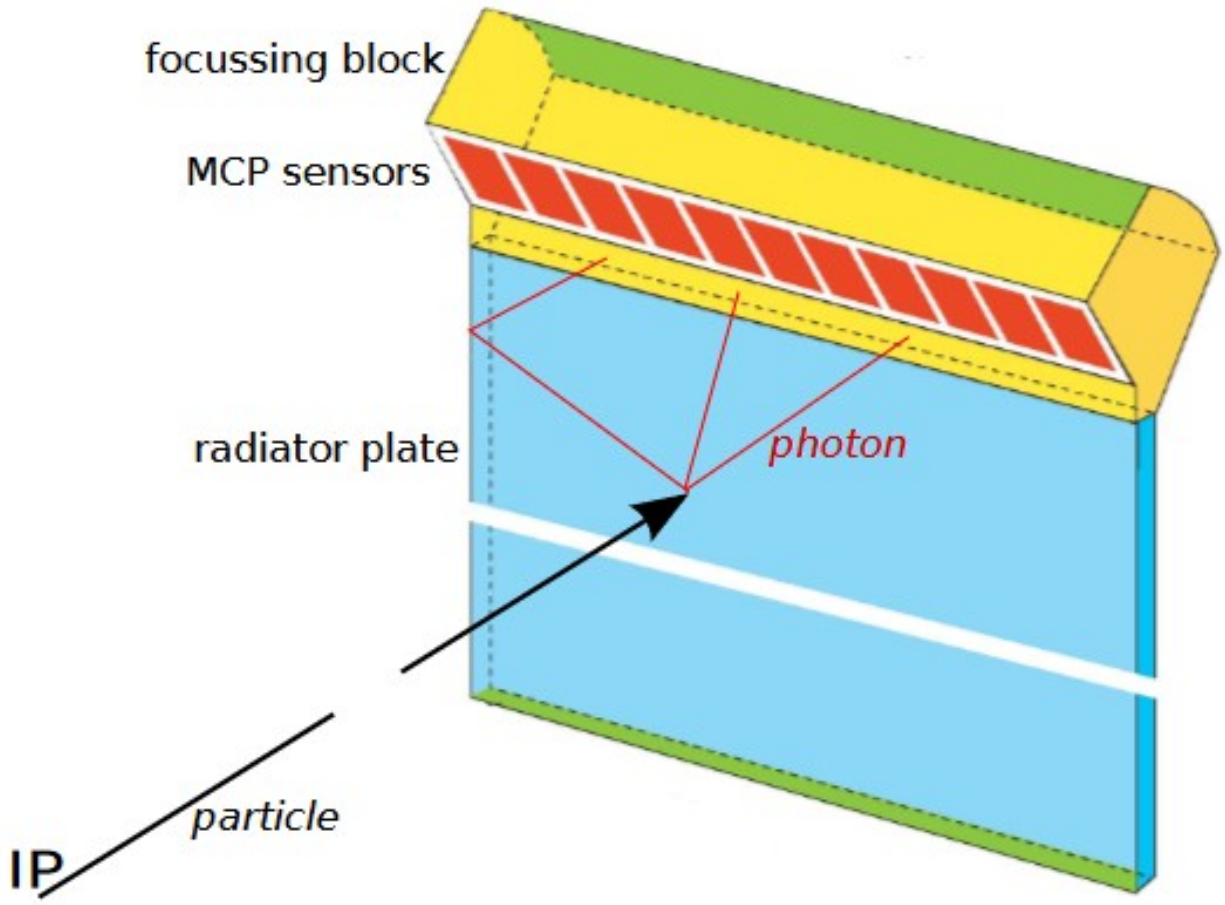


Endcap PID: ARICH



See talk by Leonid Burmistrov:
“Belle II aerogel RICH detector”

Similar: LHCb's TORCH



https://cds.cern.ch/record/1981563

See talk by Thomas Henry Hancock:
"Beam tests of a large-scale TORCH time-of-flight demonstrator"