Belle II iTOP Optics: Design, Construction and Performance

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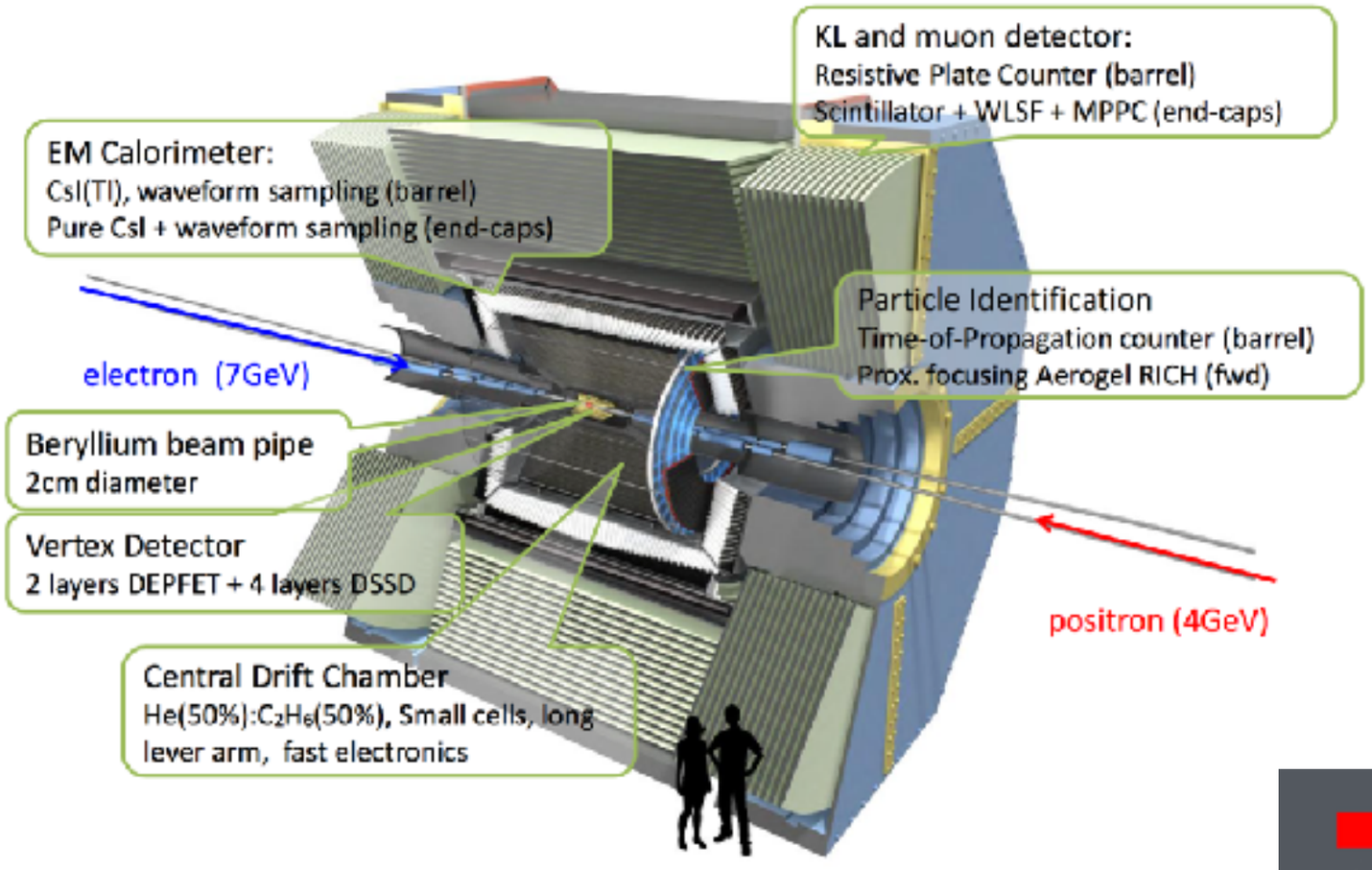
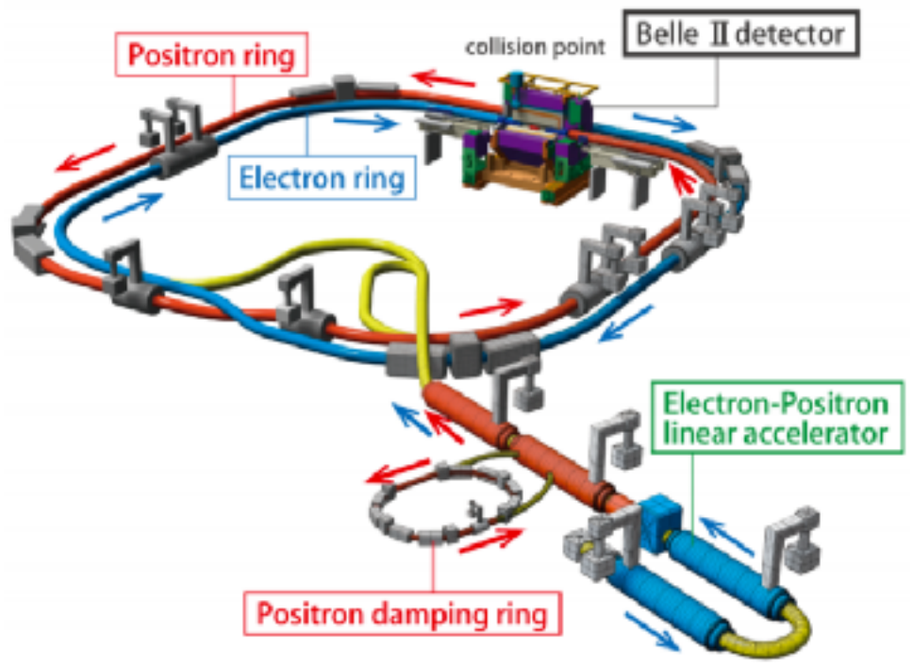
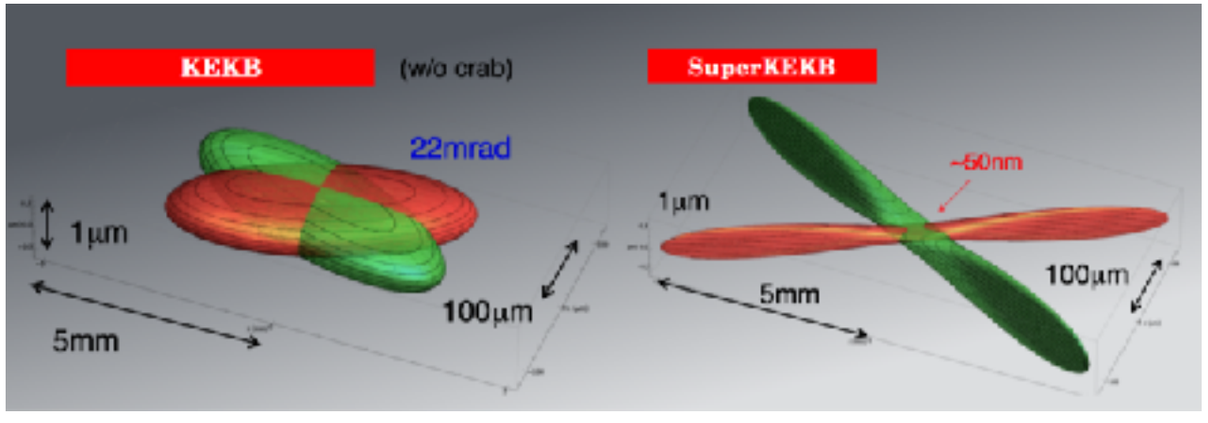
Overview of Super-KEKB and Belle II



Super-KEKB

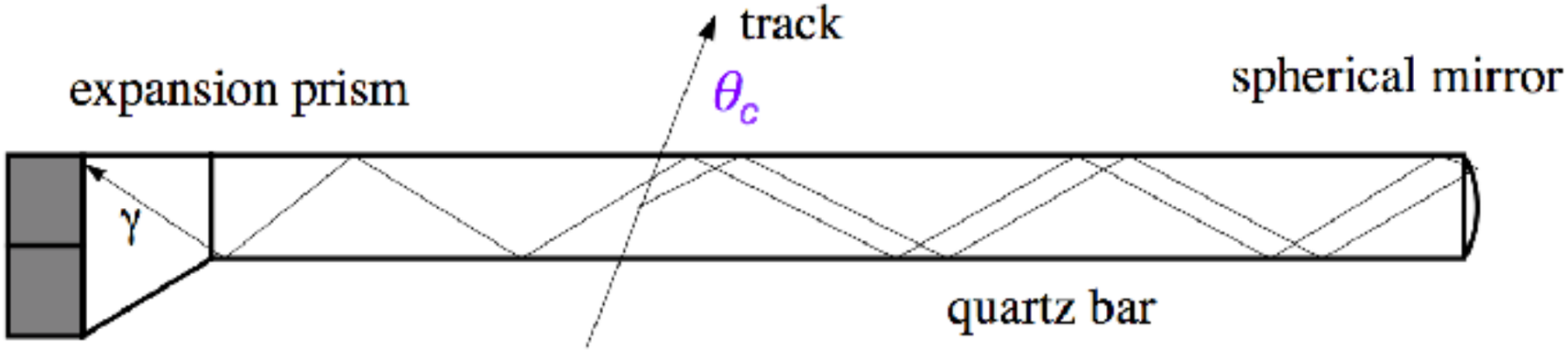


Target integrated luminosity: ~50 ab^{-1}
Peak luminosity: 8 x 10^{35} $cm^{-2}s^{-1}$ (by using nano-beam technology)
Physics run: ~ 2018

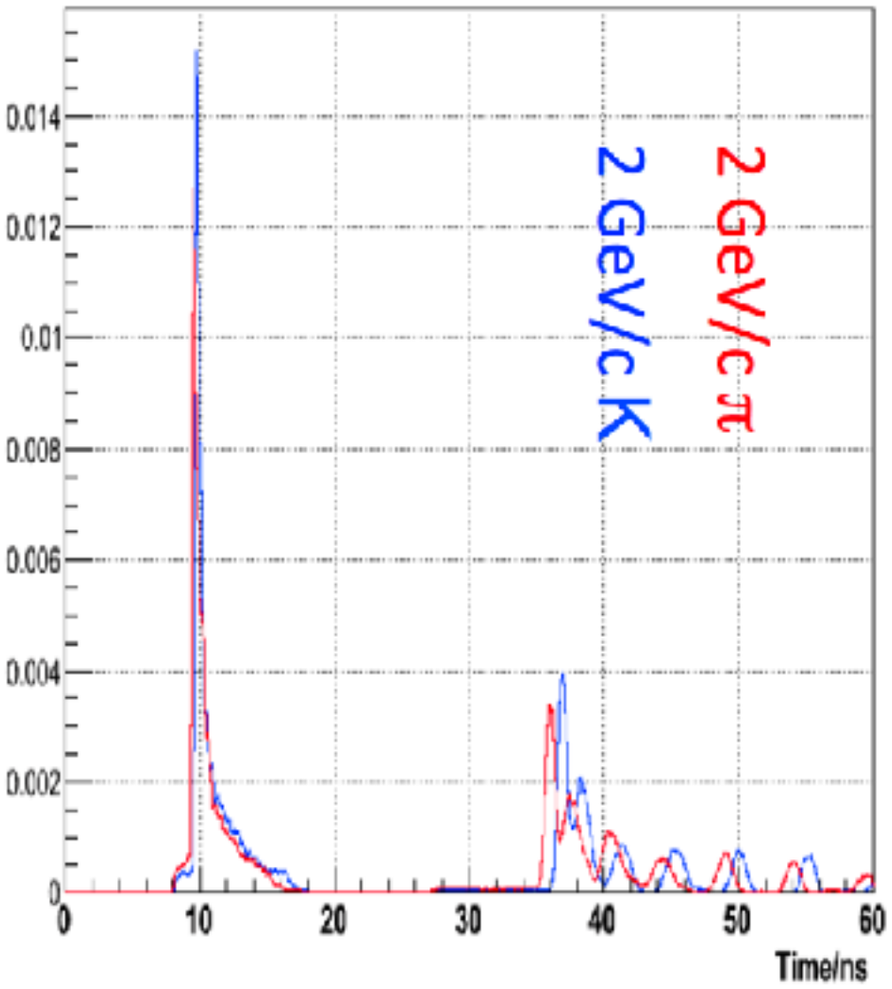


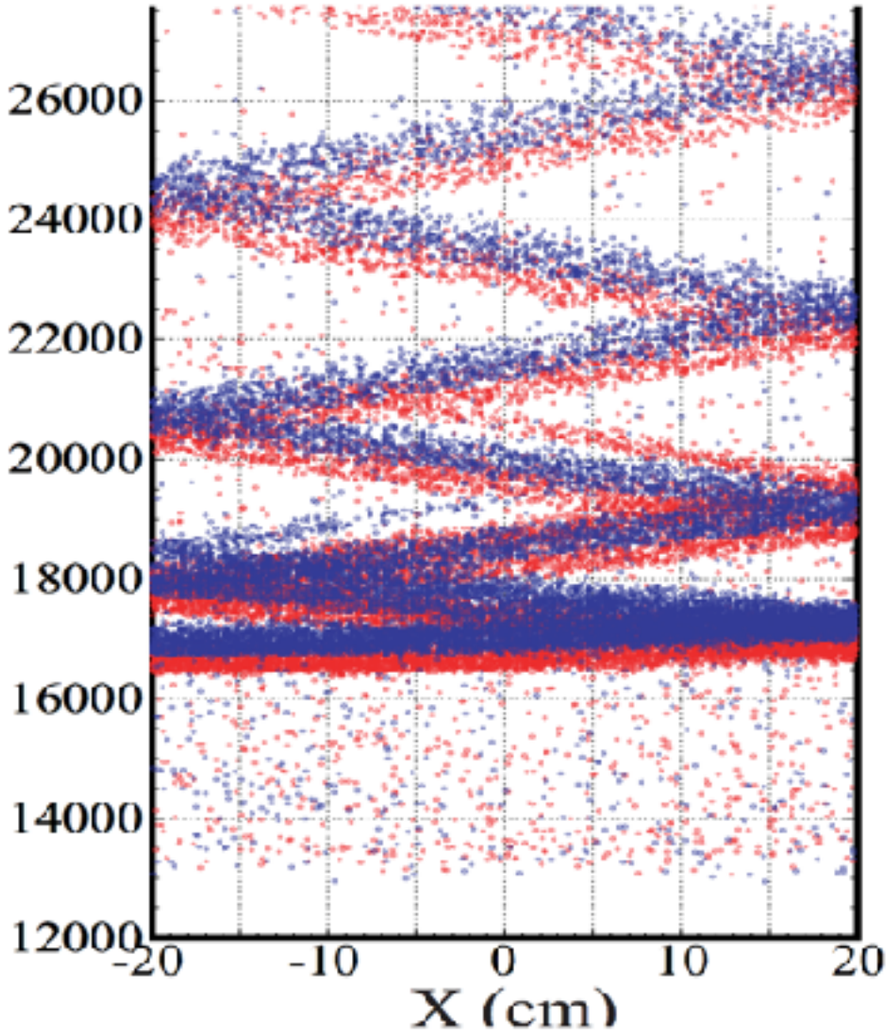
Nano-beam

Principles of iTOP Detector



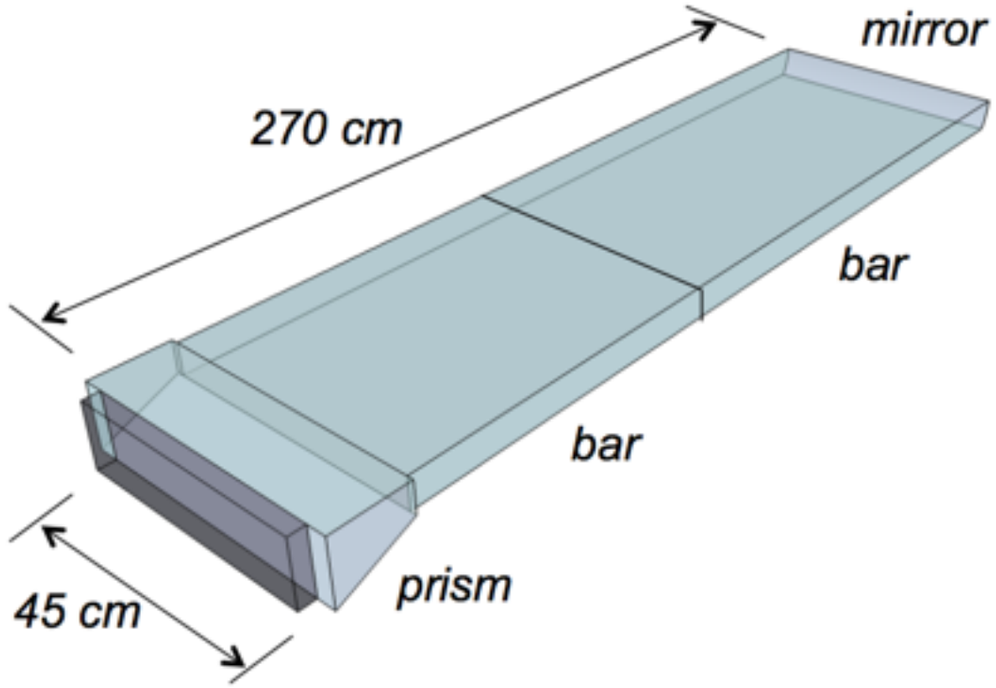
$\cos\theta_C = 1/n\beta$
π and K have different θ_C
Different hit positions and arrival times of photons

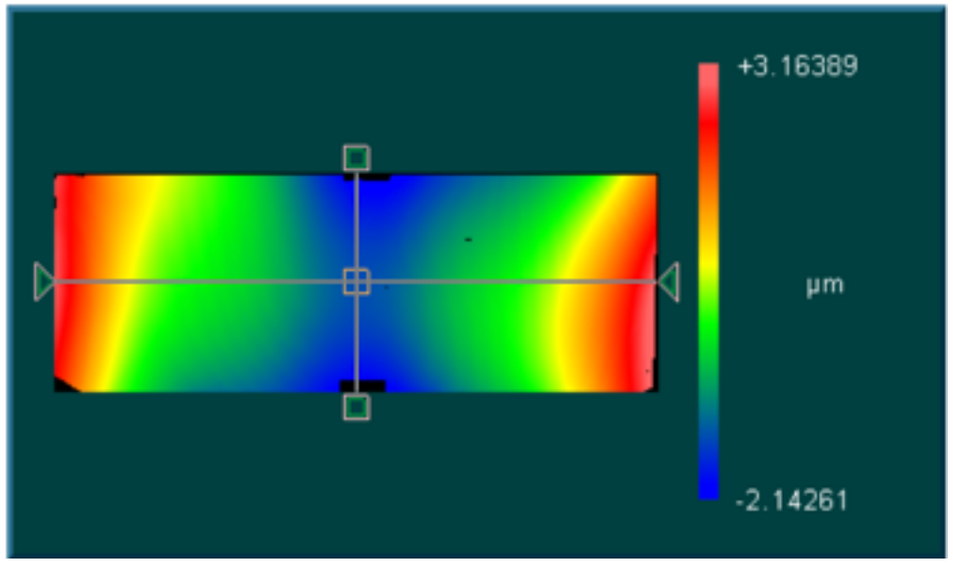




Procurement of Synthetic Fused Silica (Quartz)

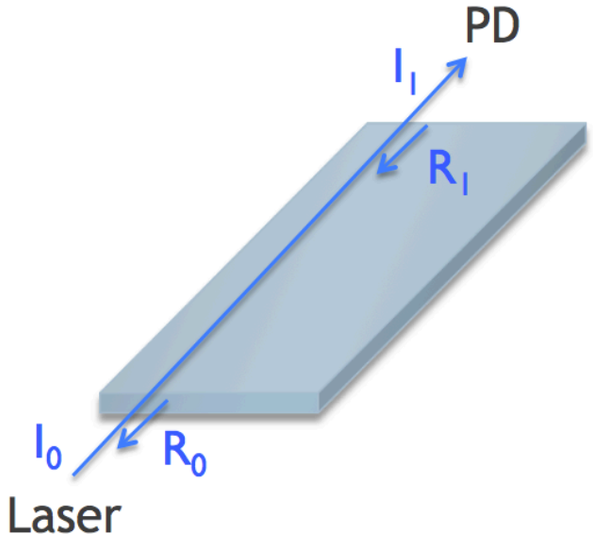
- Two bars, one mirror and one prism per module.
- Totally 16 modules and 1 spare module.
- Acceptance test:
  - For 32+ bars: chip inspection, bulk transmittance, internal surface reflectance.
  - For 16+ mirrors: chip inspection, reflectivity, position of optical axis, focal point and focal length, spherical aberration, astigmatism
  - For 16+ prisms: chip inspection, transmission, angle of tilted surface.
- Surface flatness, surface roughness, parallelism, perpendicularity and chamfer specs were qualified by vender.





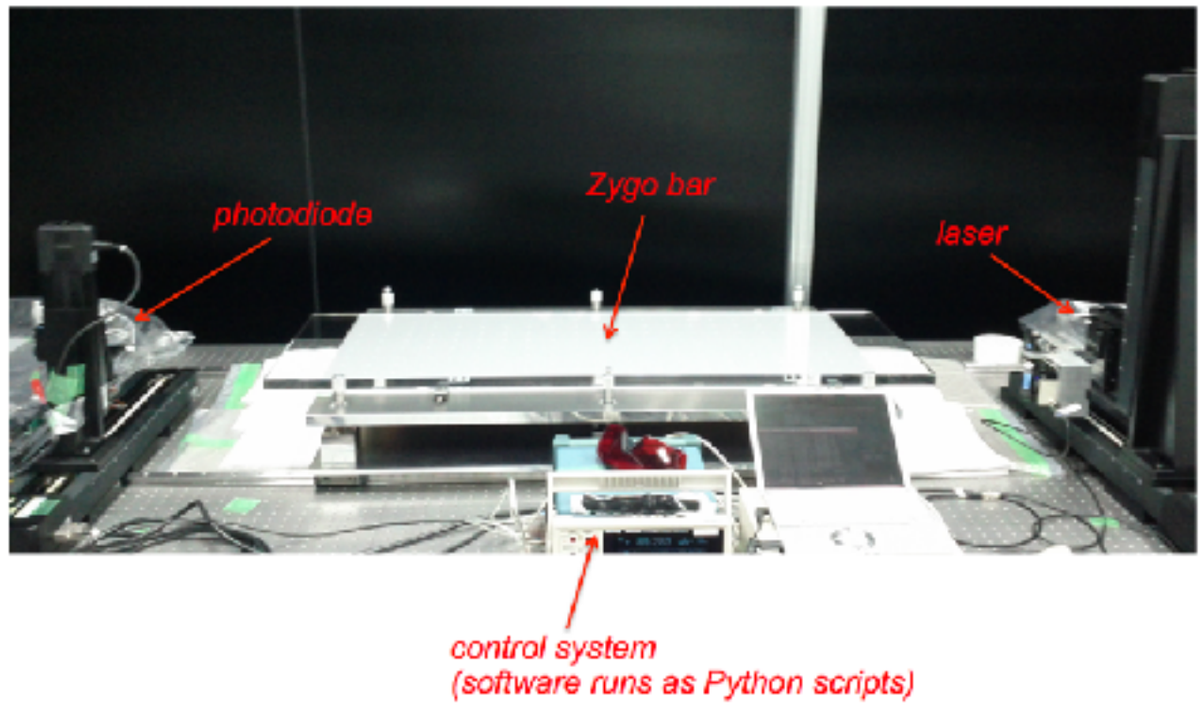
Interferograms from metrology report

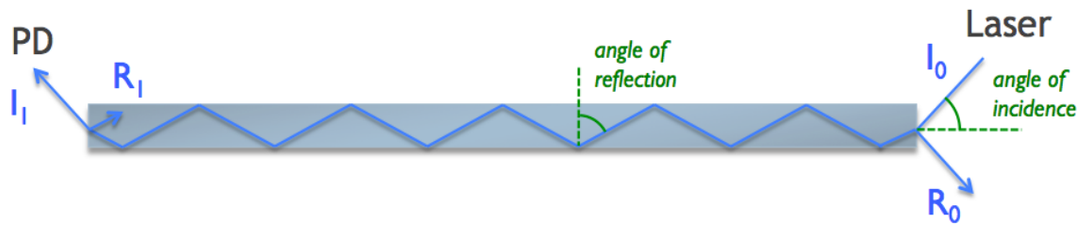
QA: Quartz Bar



Bulk Transmission

$$I_0 (1 - R_0)\, \tau\, (1 - R_1) = I_1$$

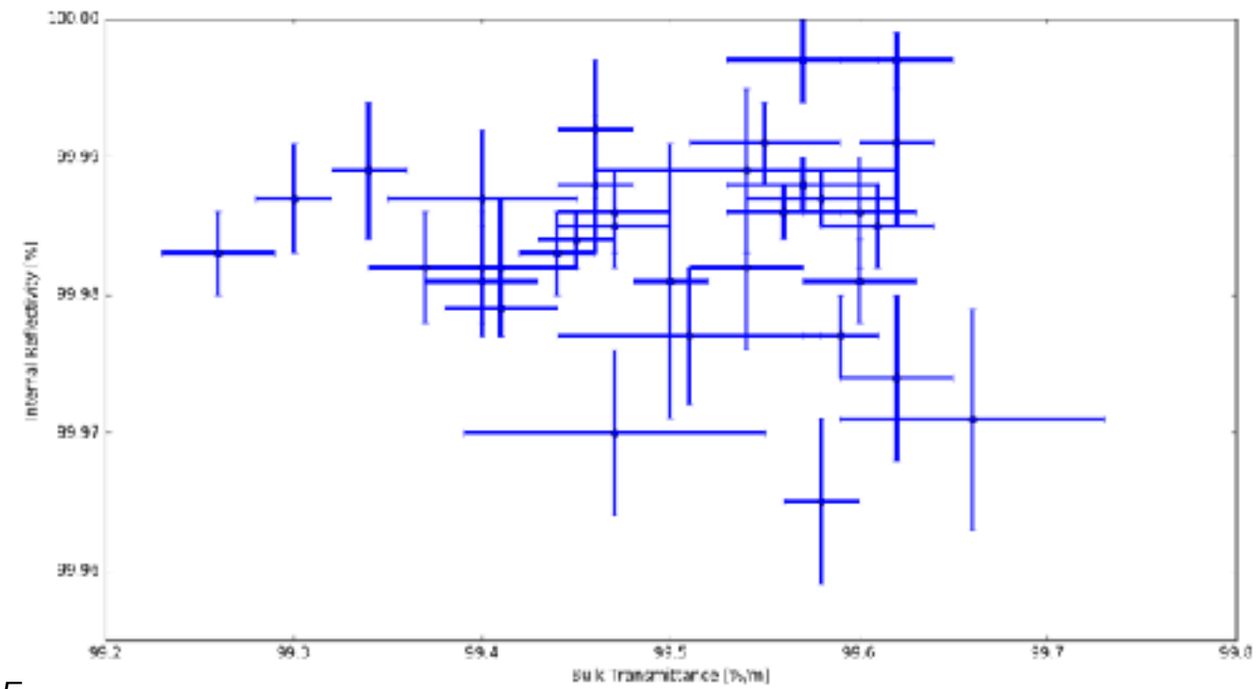




Internal Reflectivity

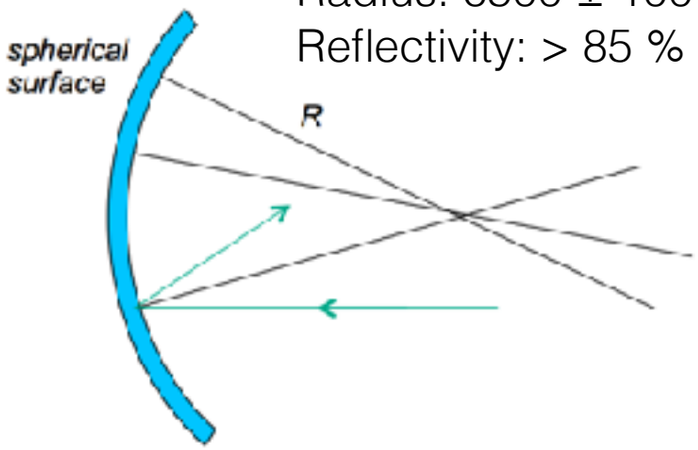
$$(I_1 - R_1) \;=\; (I_0 - R_0) \cdot \alpha^N \cdot \exp\left(-\frac{L}{\Lambda} \cdot \sqrt{1 + (Nh/L)^2}\right)$$

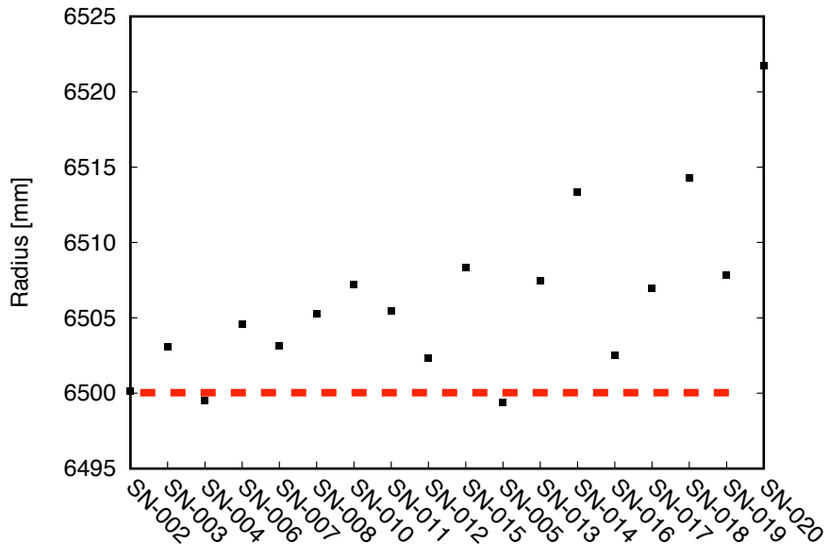
Requirement:
Bulk Transmittance: > 98.5 %/m
Internal Reflectivity: > 99.9 %

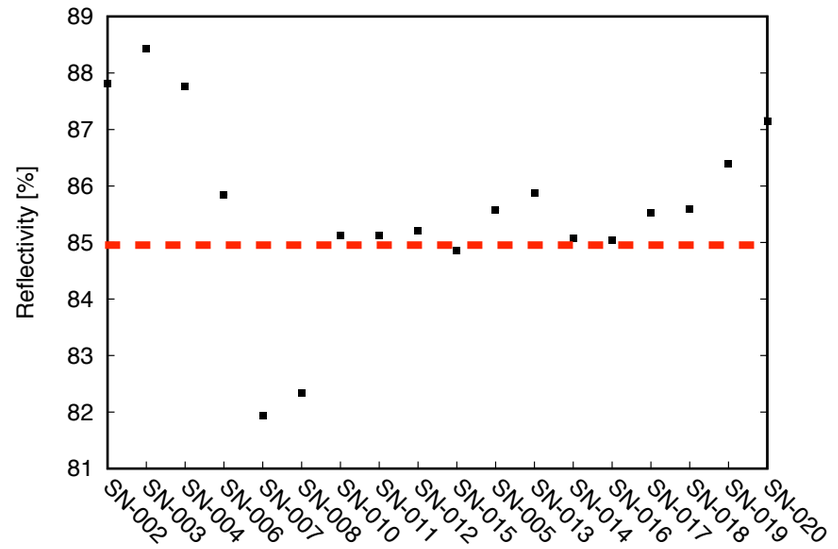


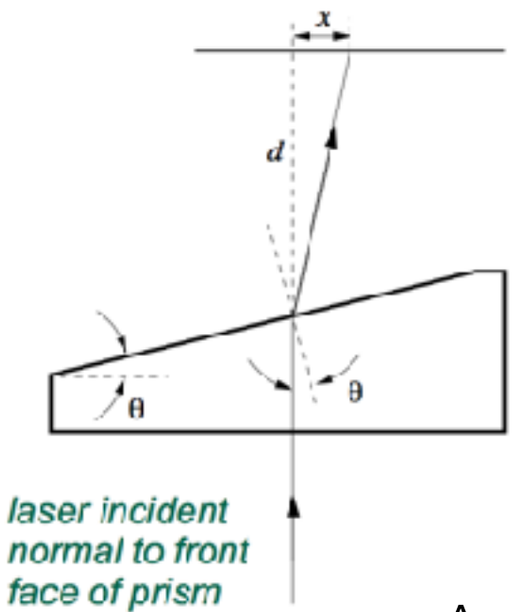
QA: Mirror & Prism

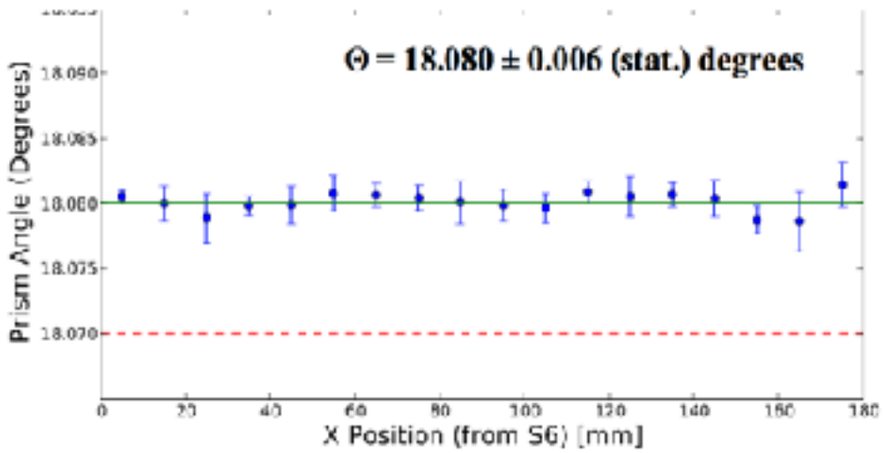
Specification
Radius: 6500 ± 100 mm
Reflectivity: > 85 %

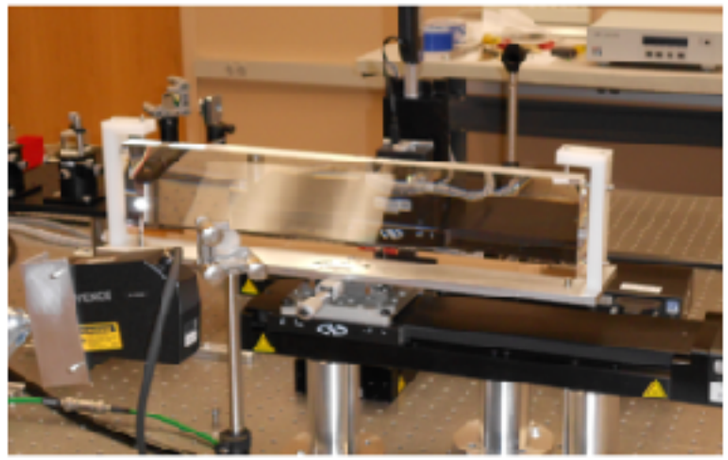










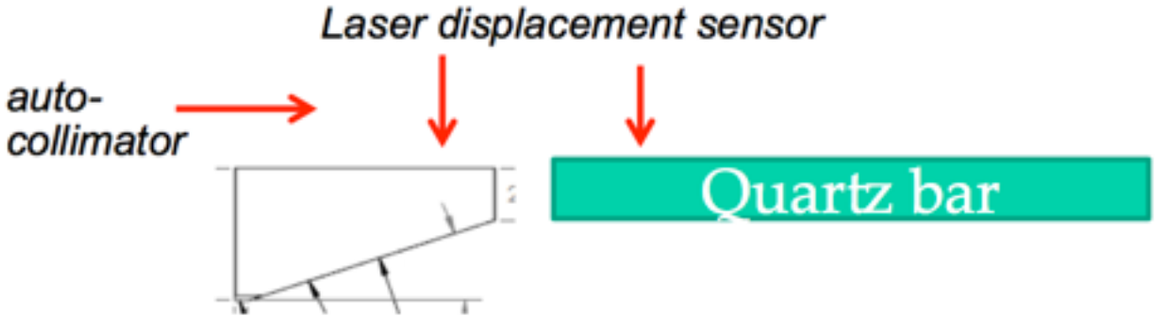


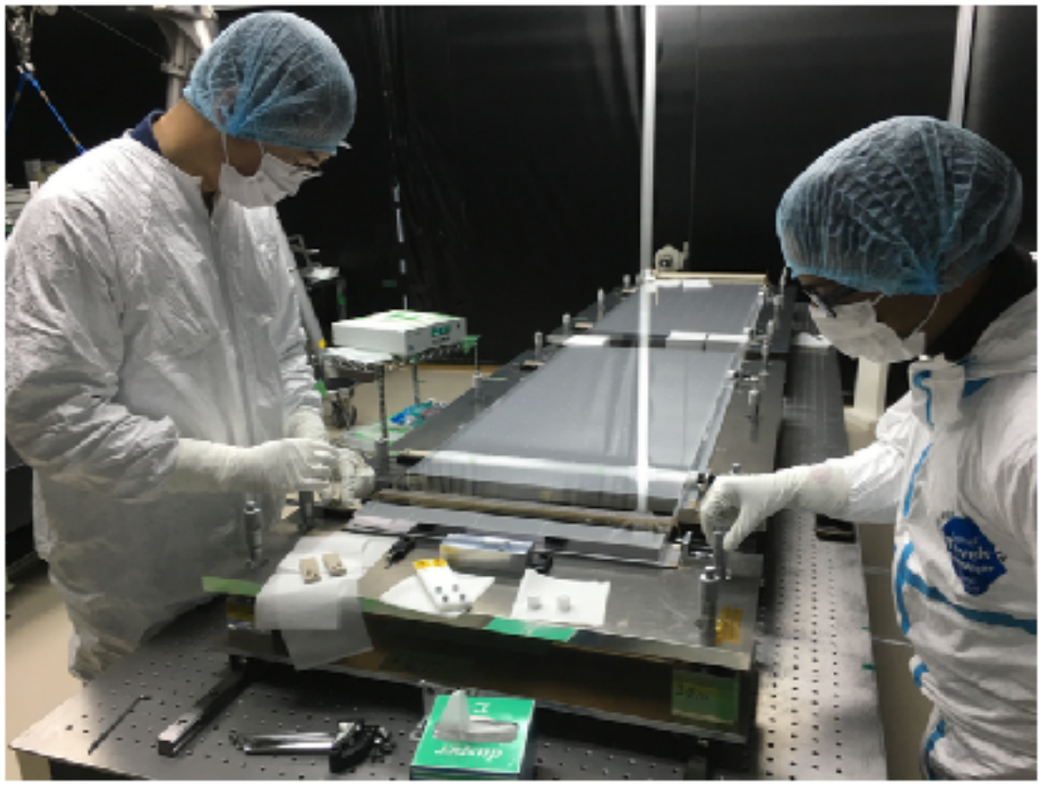
Angle of tilted face: 18.07 ± 0.04 deg (± 144 arcsec)

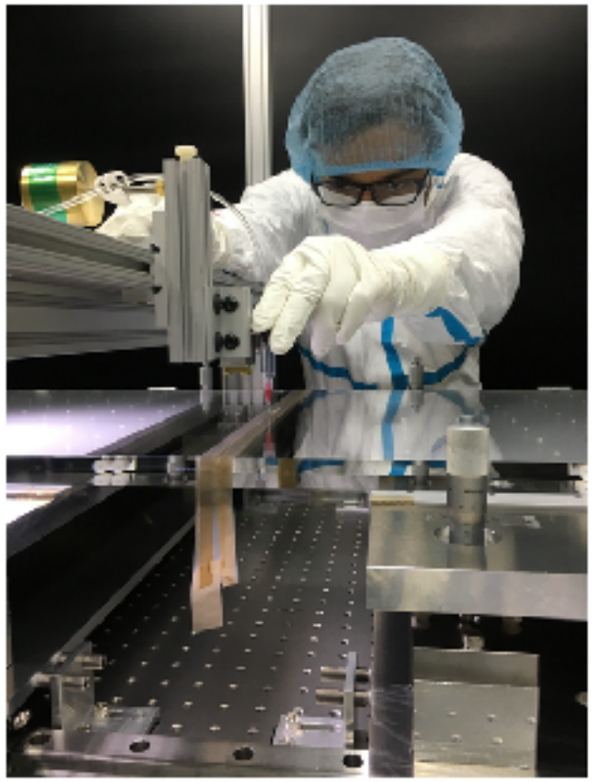
Alignment & Gluing

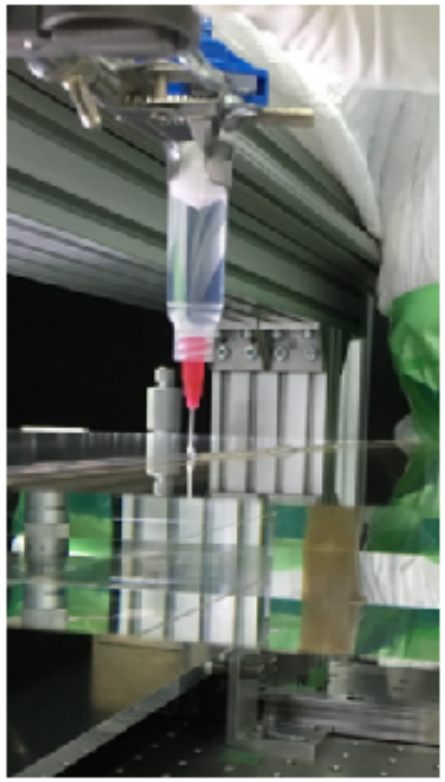
Procedure:

- adjust surfaces positions using laser displacement sensor and micrometers
- adjust surfaces angles using autocollimator and micrometers
- insert shims, tape joint and repeat steps 1, 2
- apply epoxy (EPOTEK 301-2) to joint

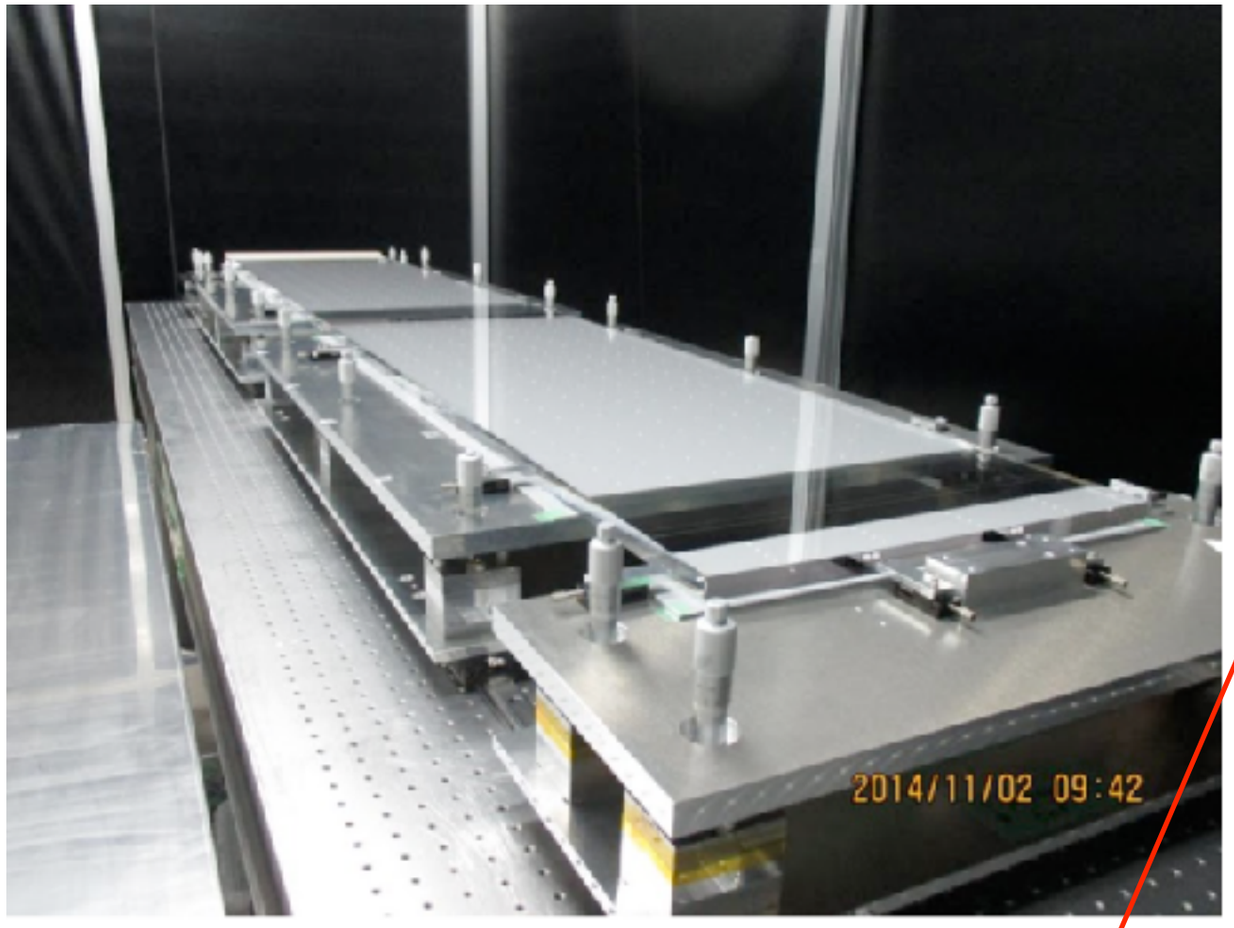


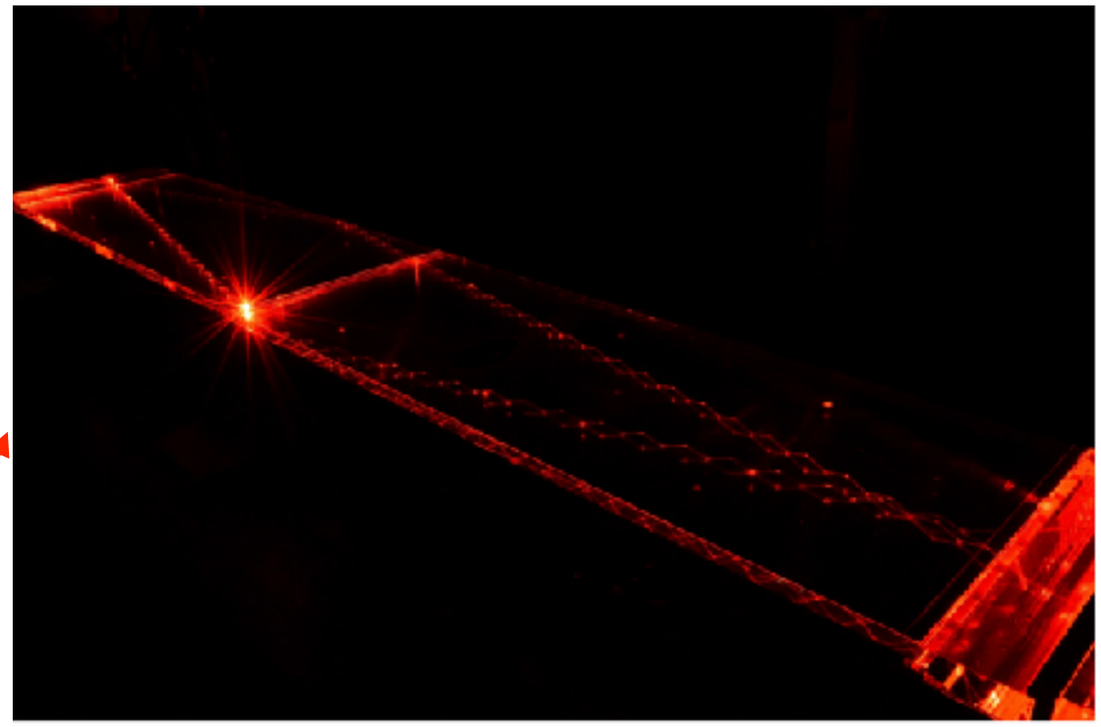






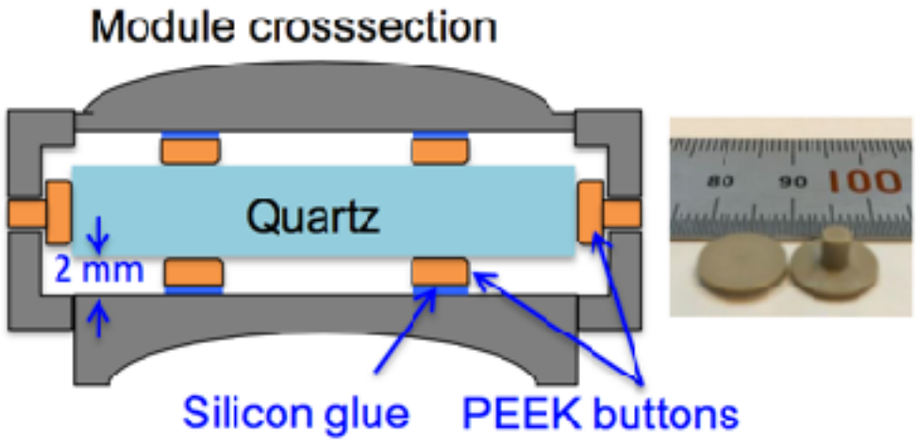
After Gluing



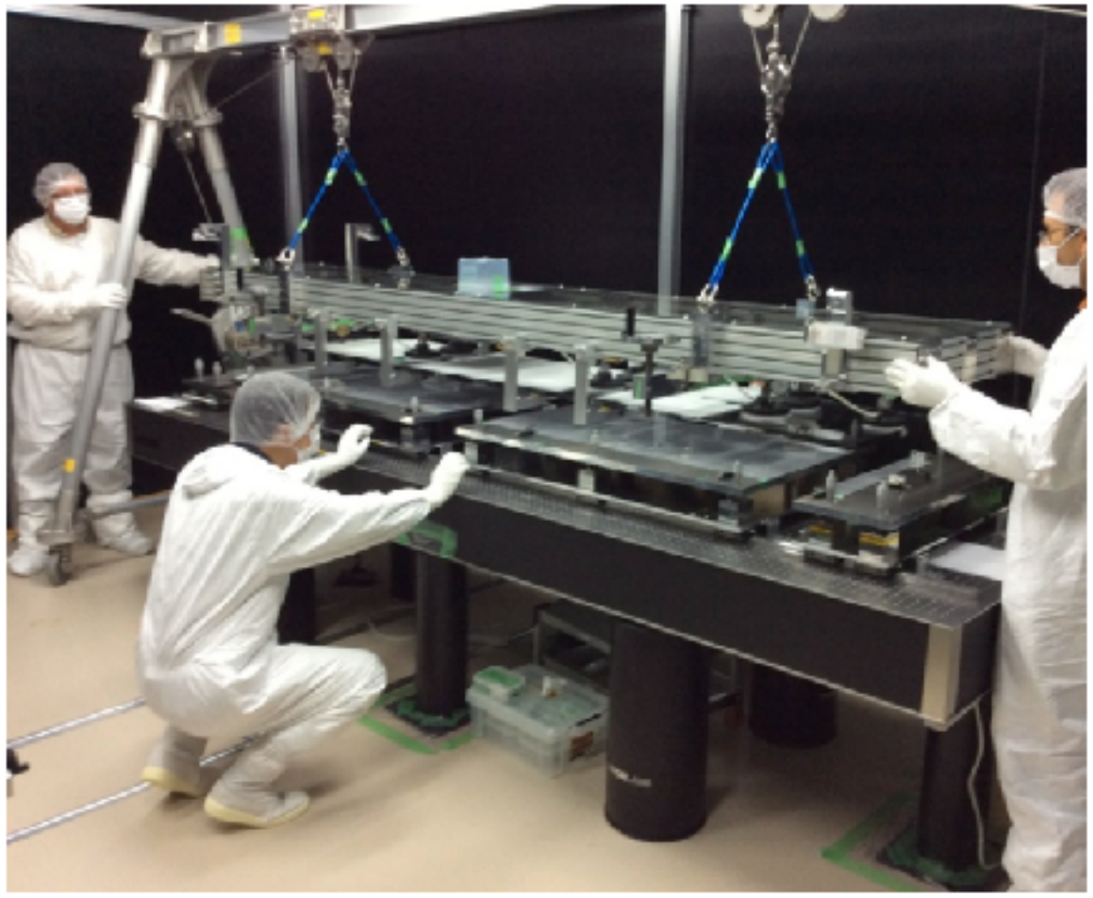


Long time exposure with laser input from prism end
Laser scattering on the surface and inside the bar

QBB Assembly



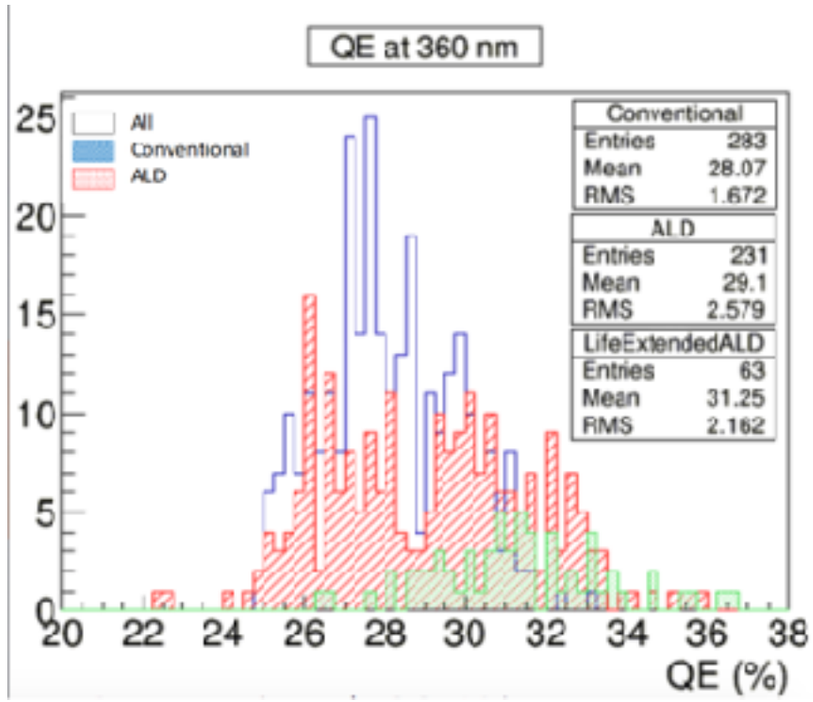
Use vacuum based lifting jig to move glued optics to QBB assembly table

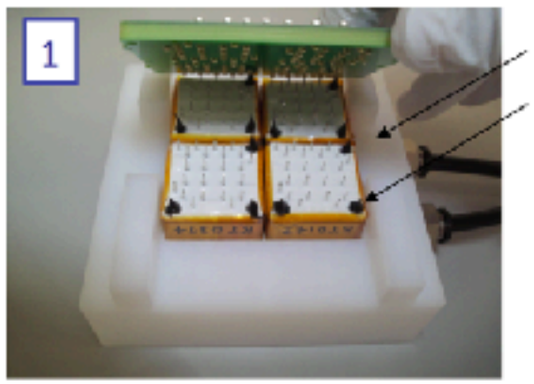


MCP-PMT

4 x 4 anodes
27.6 x 27.6 mm2
23.0 x 23.0 mm2 active

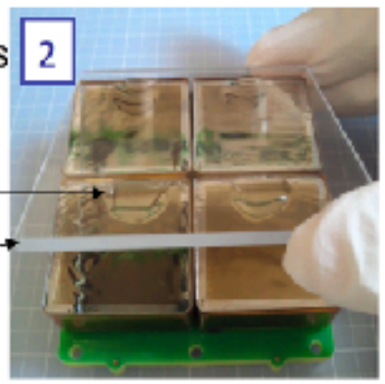
QE requirement:
> 24% at peak λ
> 28% average

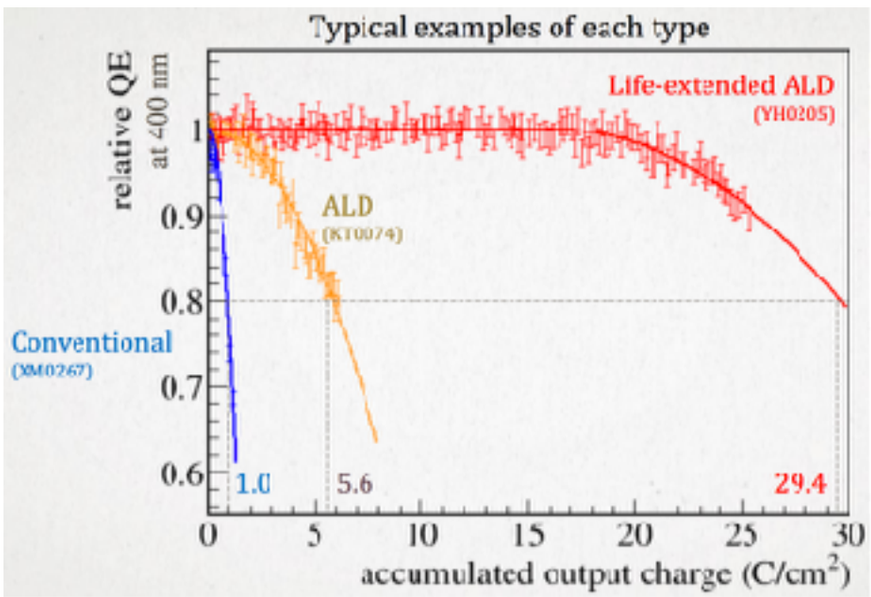


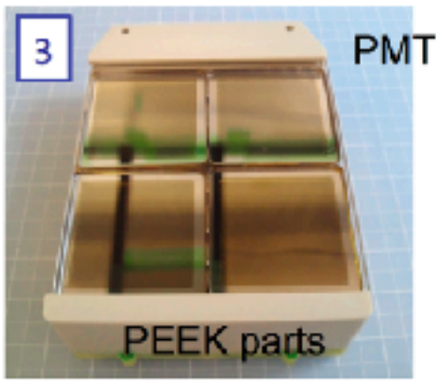


Vacuum chuck to align the PMT faces
RTV silicon rubber to hold the PMTs

Silicon rubber TSE3032 (before curing) to be filled between the PMTs and the wavelength cut filter

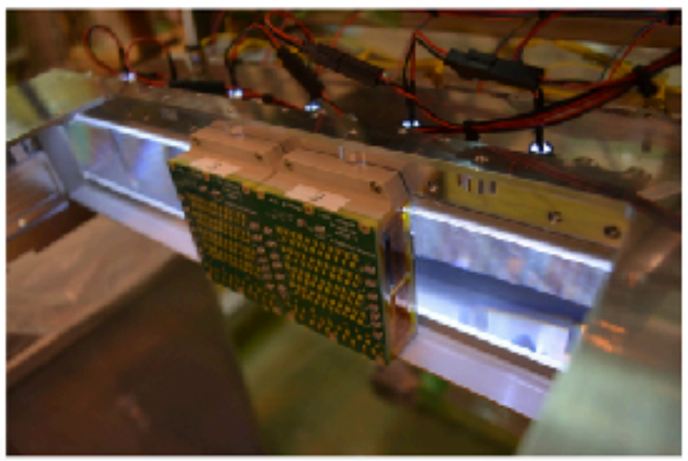






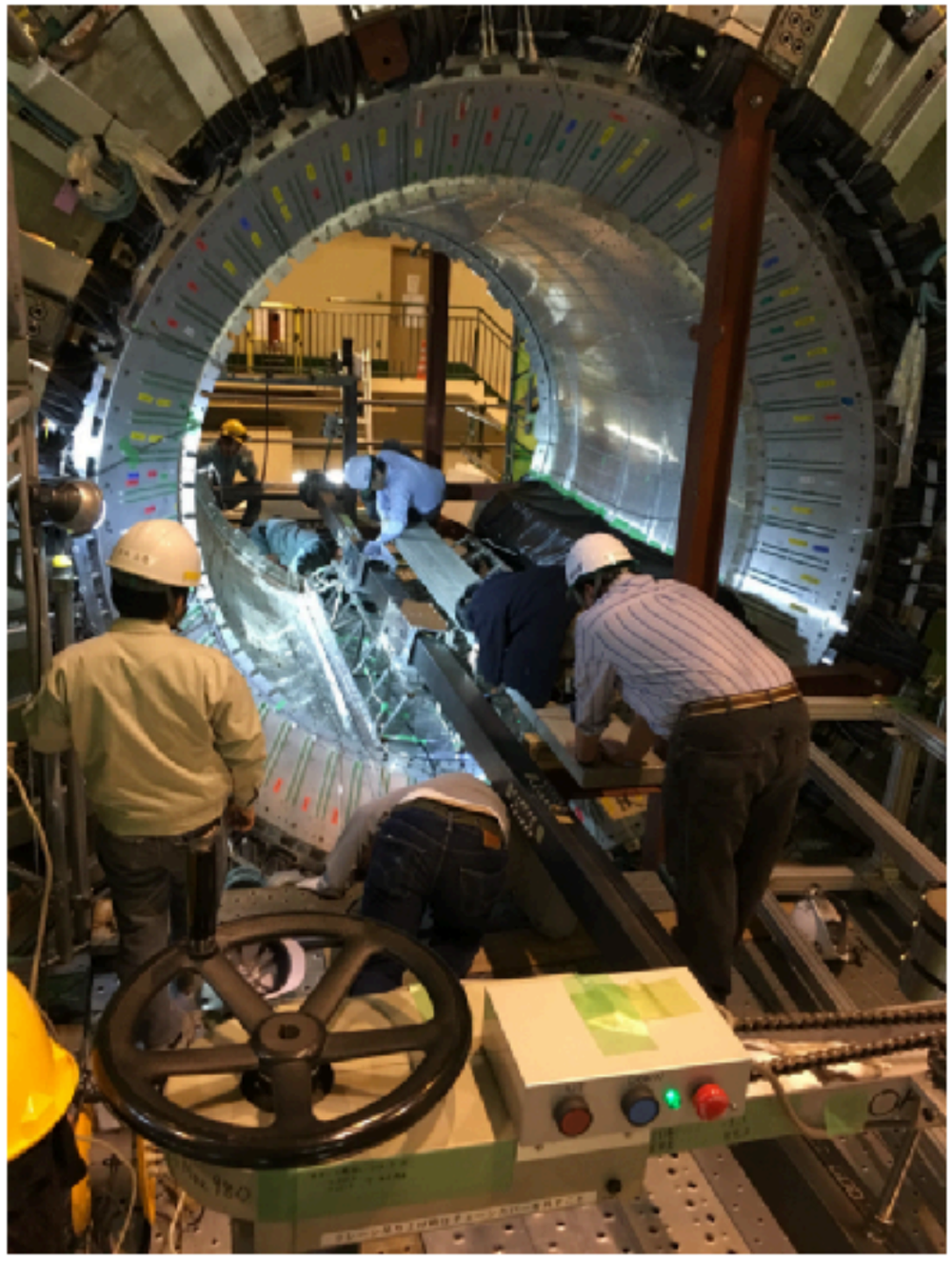
PMT module completed

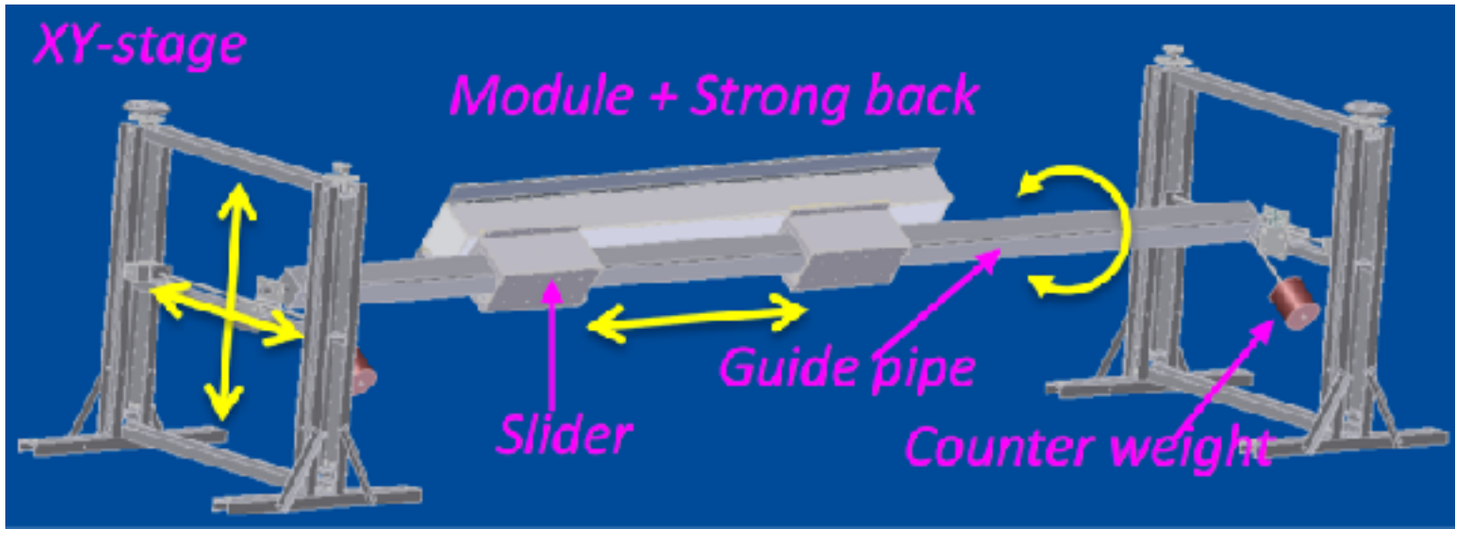
2 PMT modules mounted to prism with a "cookie" (+oil):

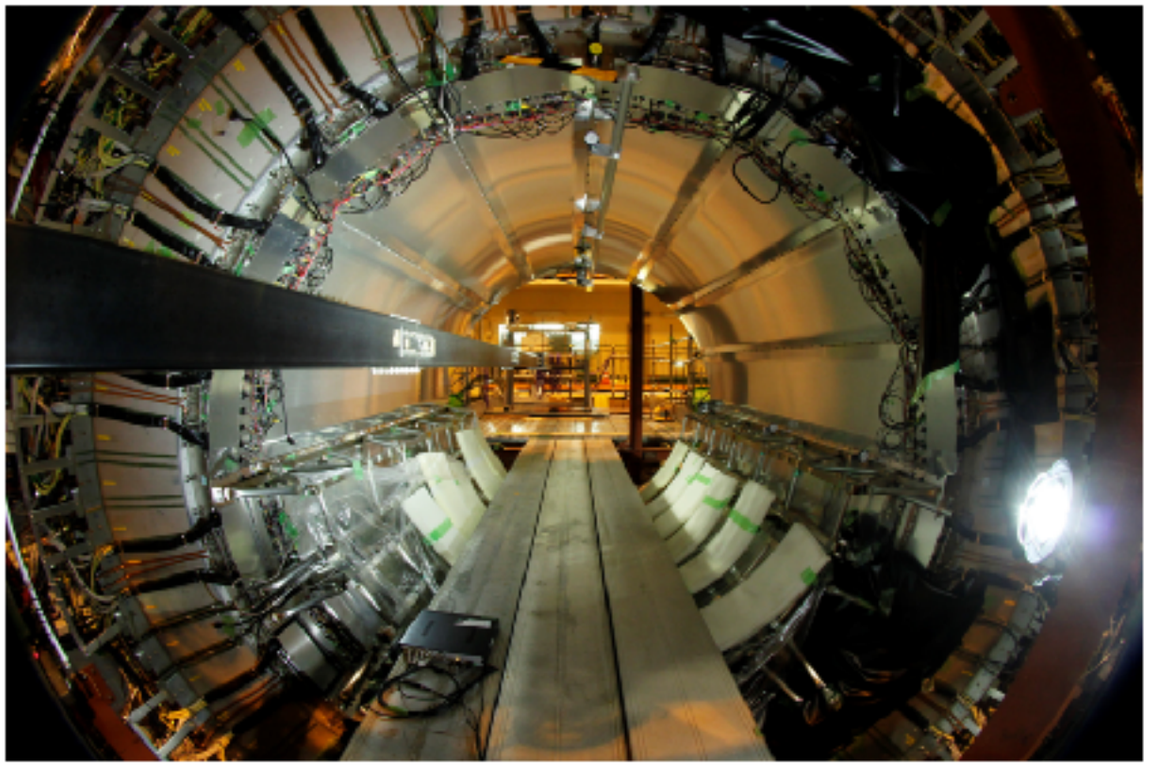


Life time extension
See Kodai Matsuoka's talk

Installation

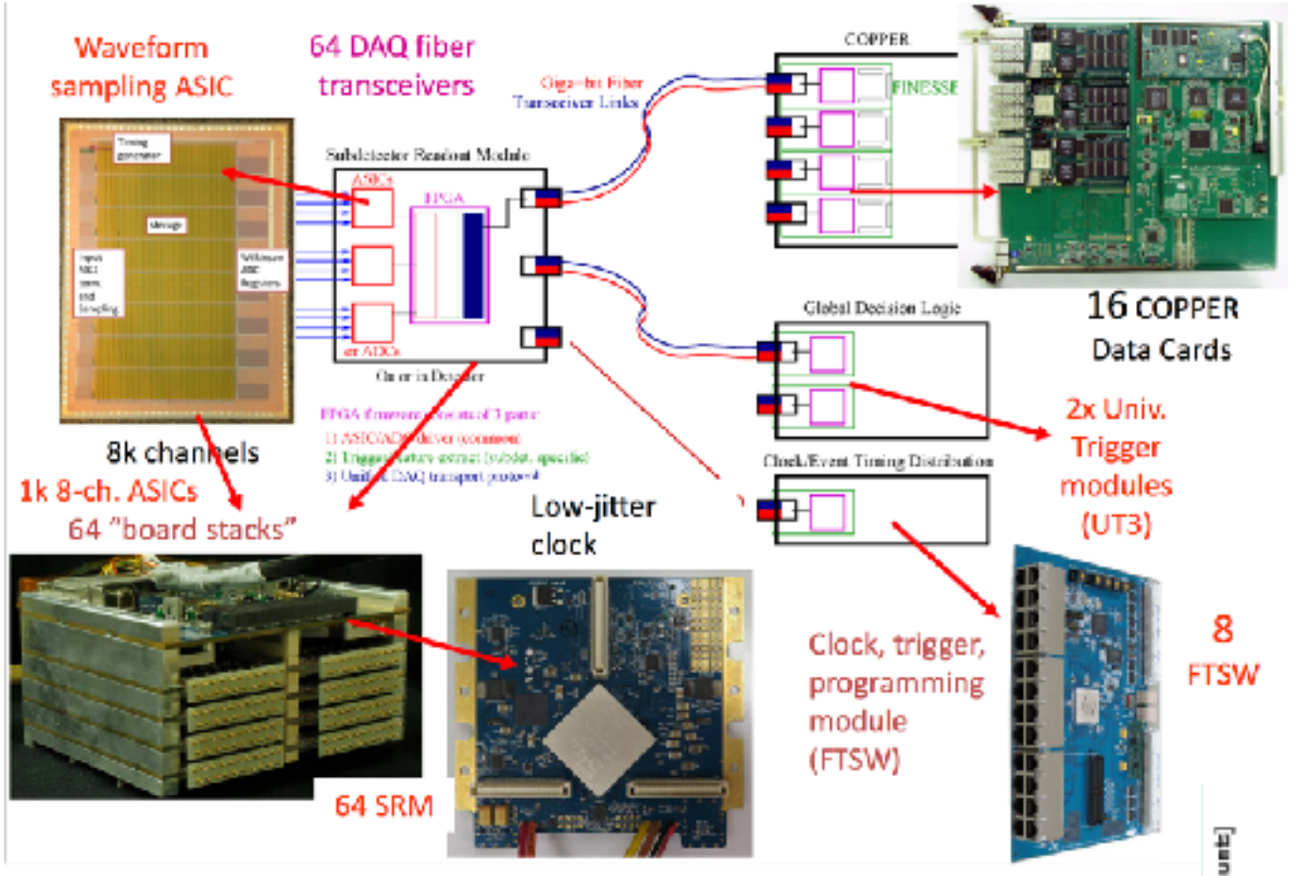


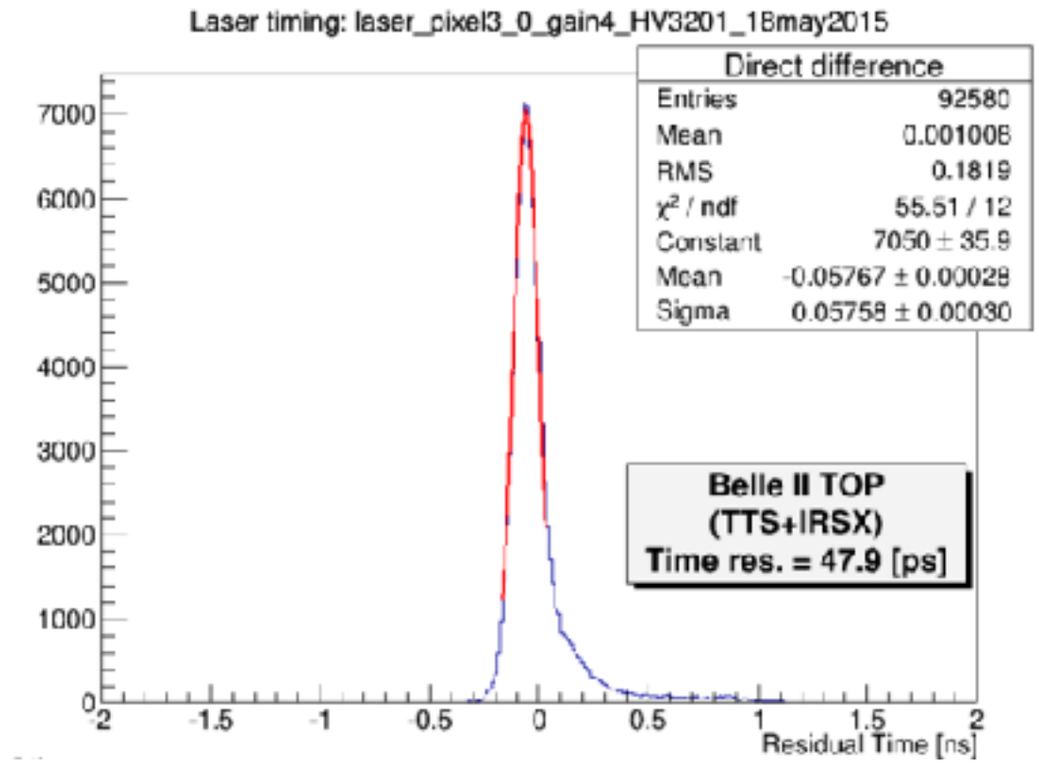




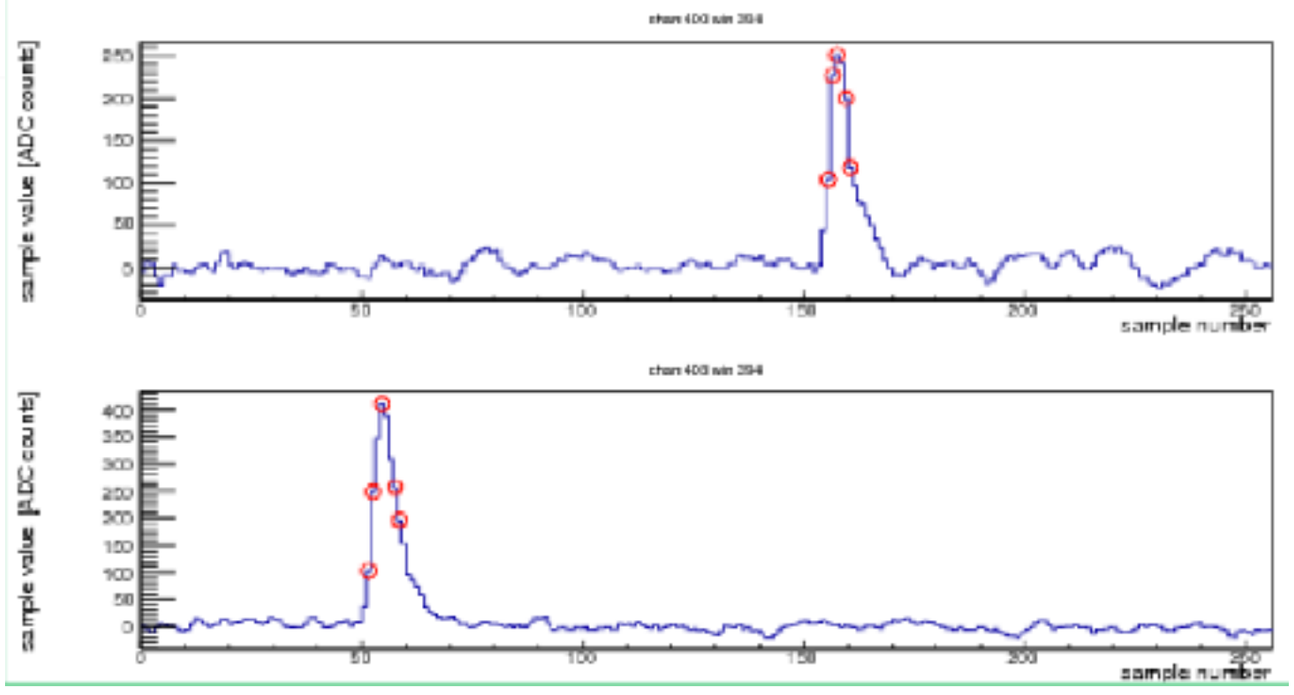
All module installed by May 2016

Readout System

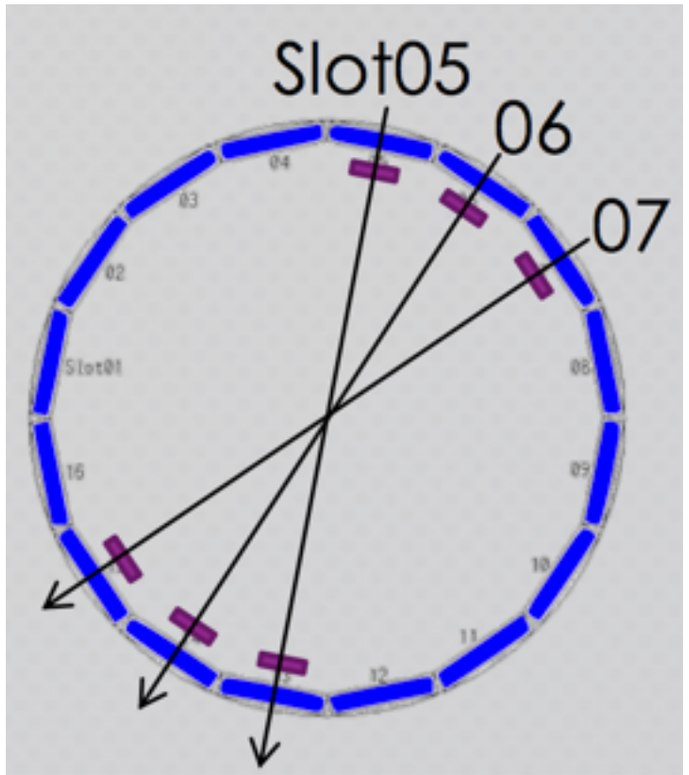




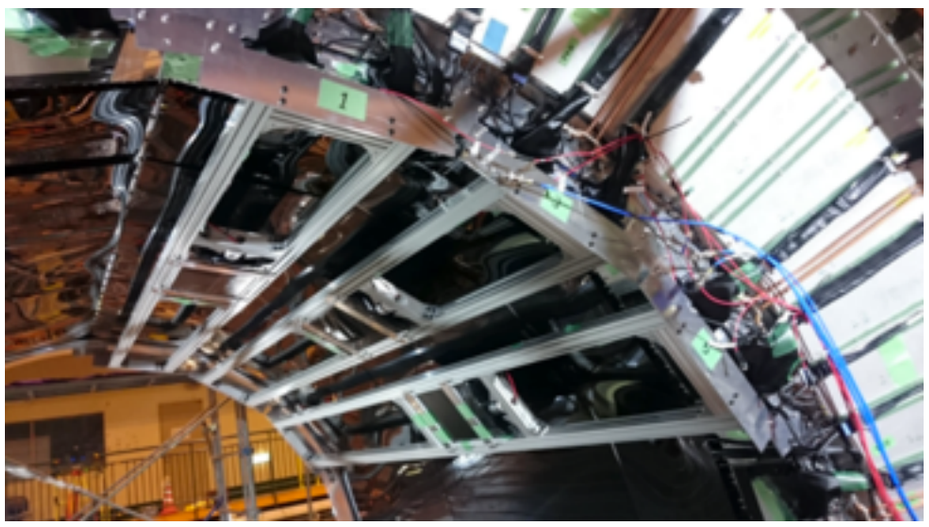
Full Waveform
vs
Region of Interest & Feature Extraction



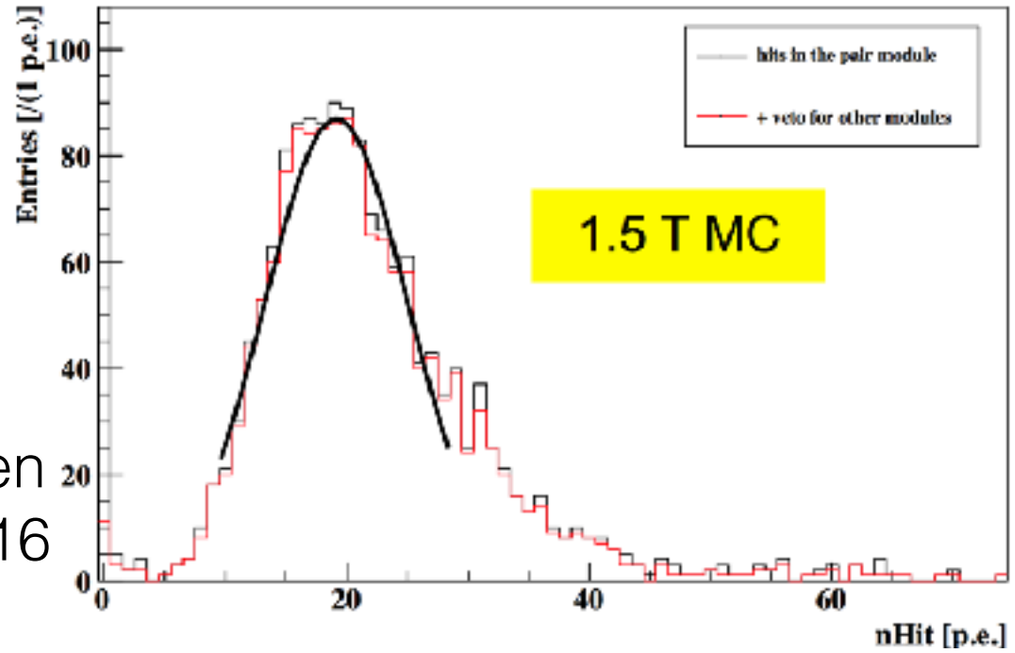
Cosmic Ray Test



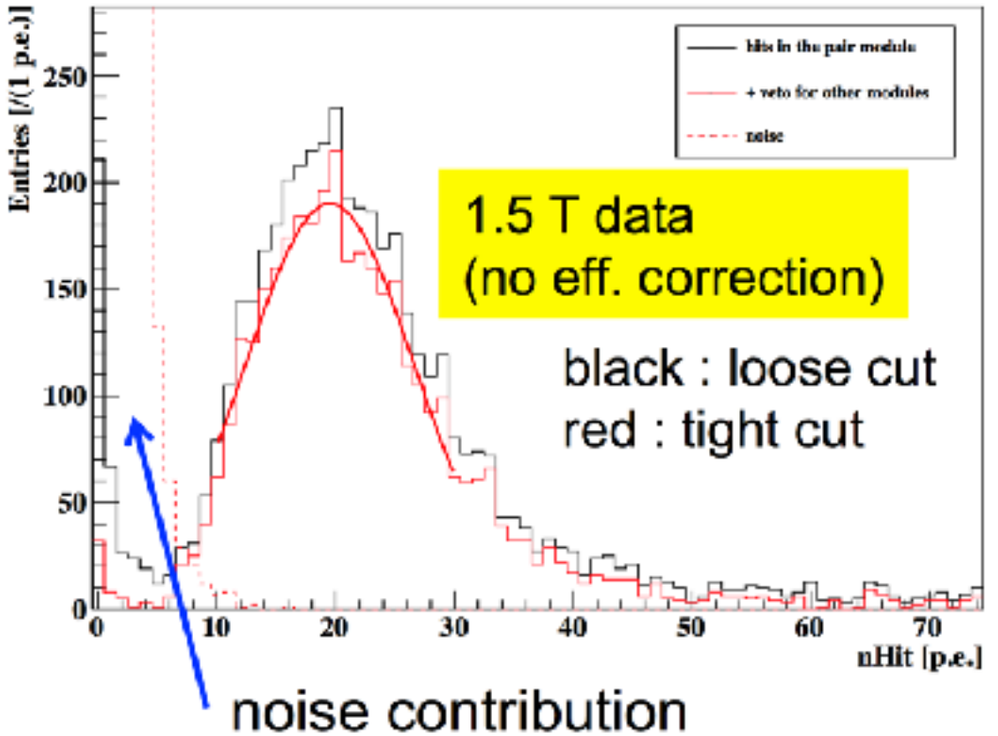
Scintillator paddles as trigger



Cosmic ray data taken during Sep - Oct, 2016

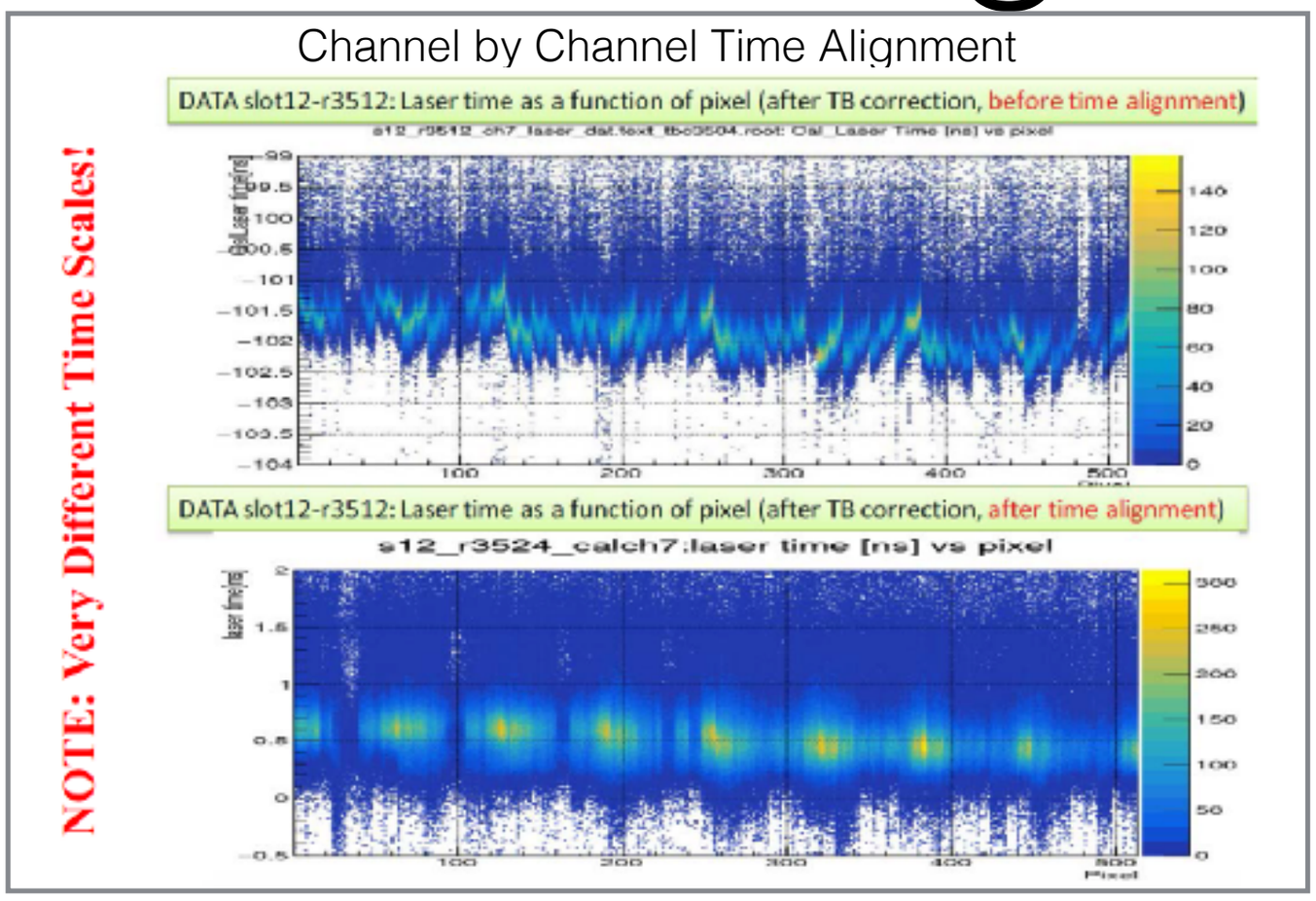


nHit distribution for slot05 (slot05 - slot13)

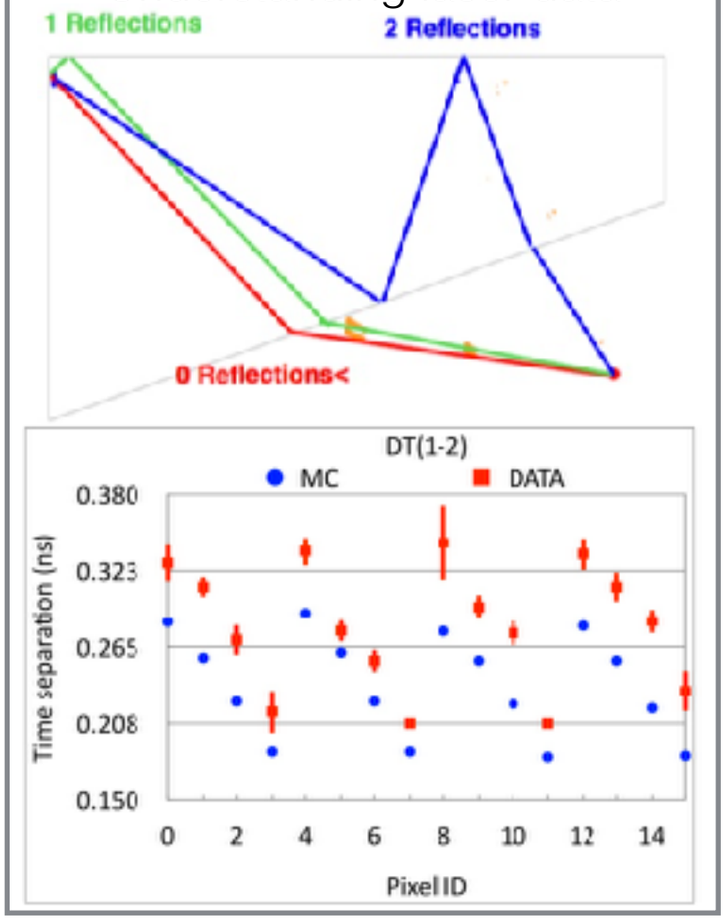


More Ongoing Work

Channel by Channel Time Alignment

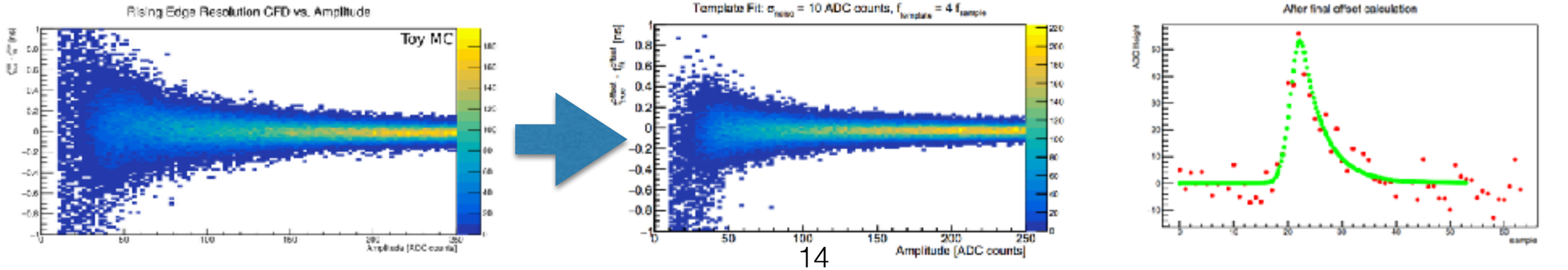


Understanding laser data



More from Prof. Gary Varner's talk

Improve low PMT gain: use template fit to waveform data



Summary

- iTOP is a new type of ring-image Cherenkov detector for Belle II. It provides particle identification ability in the barrel region.
- The construction of all modules took ~18 months. They're all installed to Belle II and cabled, ready for testing.
- The cosmic ray data and laser data have been taken and the analysis of these data is ongoing.
- Belle II will take physics data with all sub-detectors installed in late 2018.