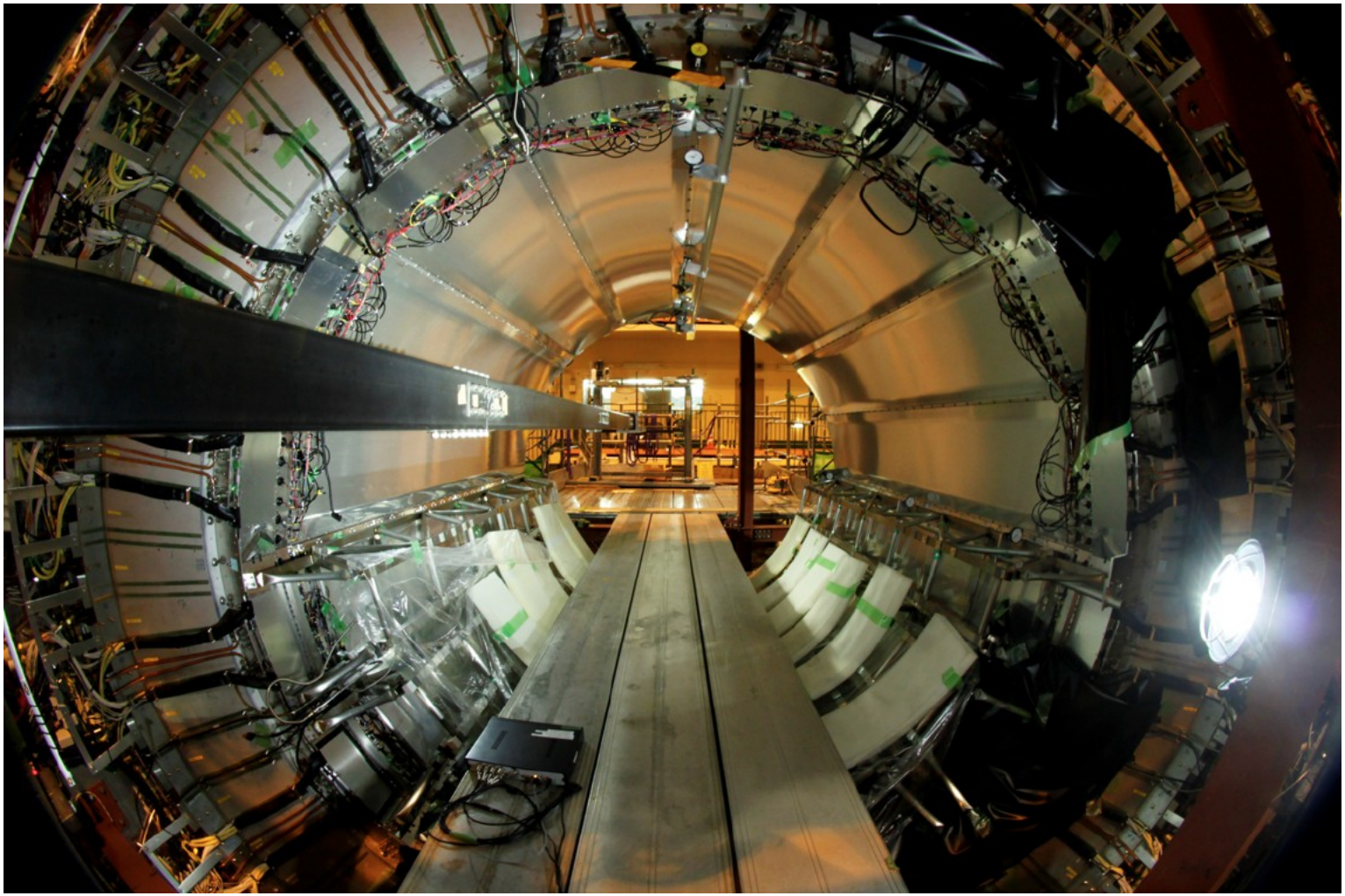
TOP commissioning Status Report

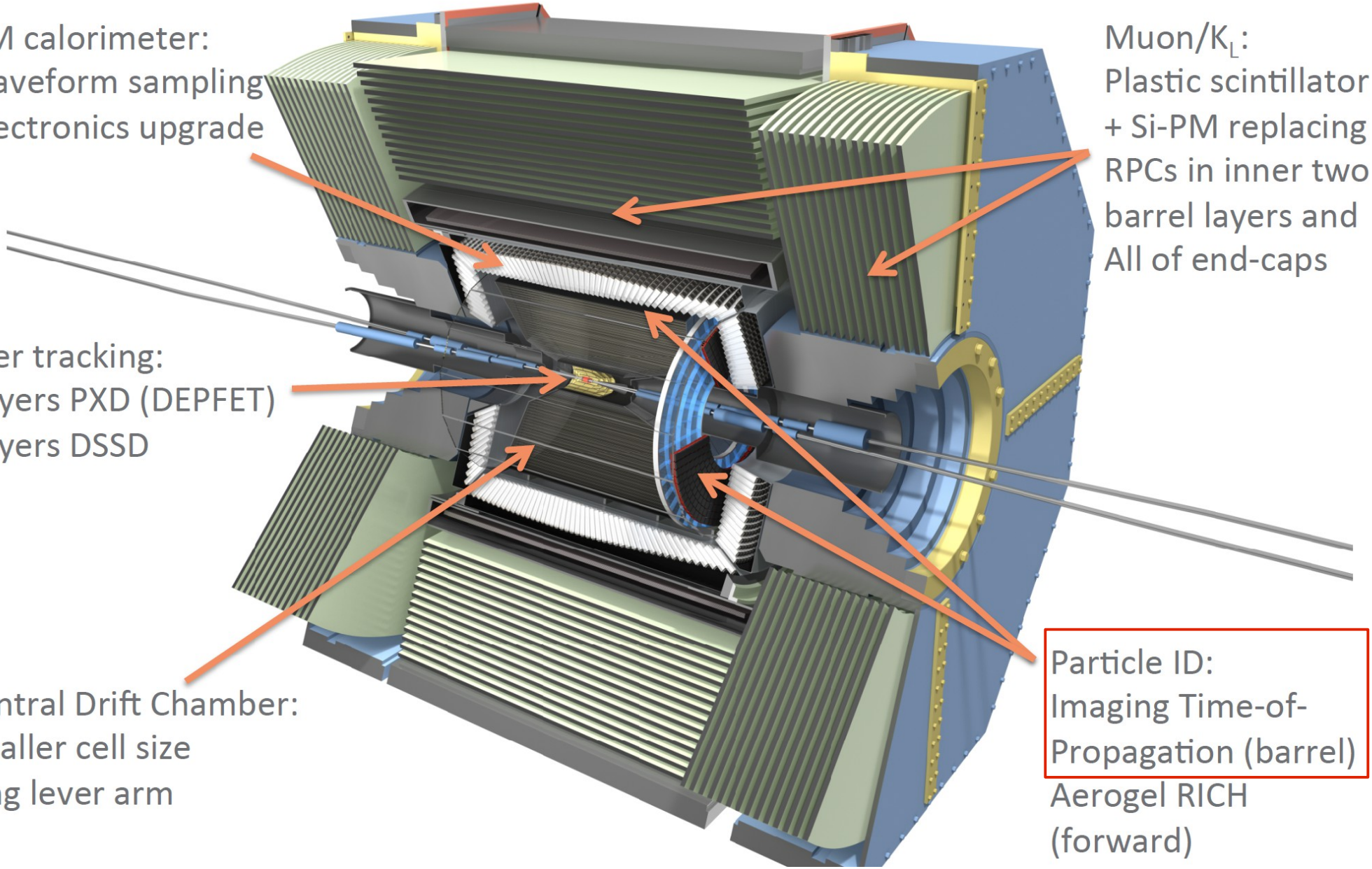
R.Mussa (INFN Torino)



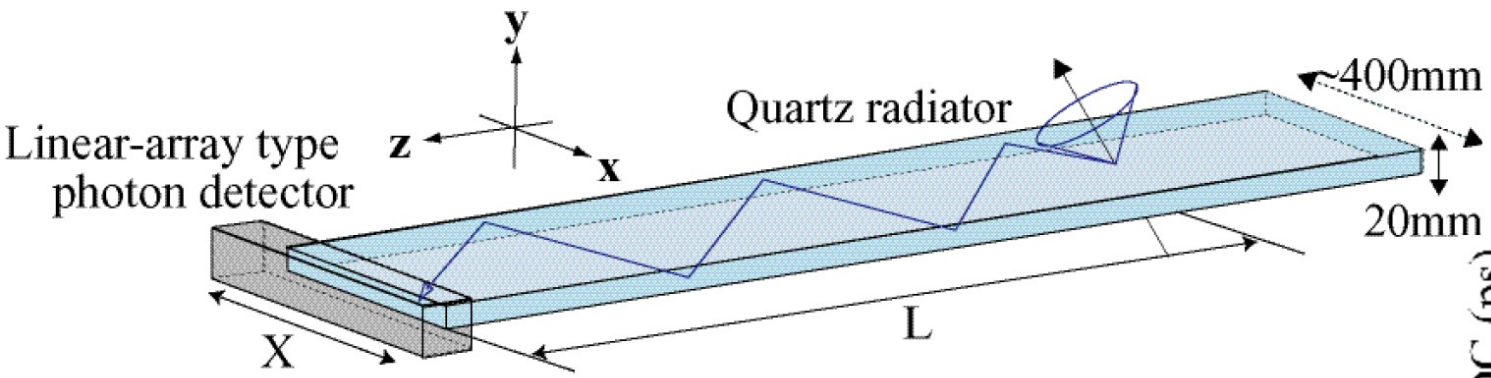
Jennifer Meeting

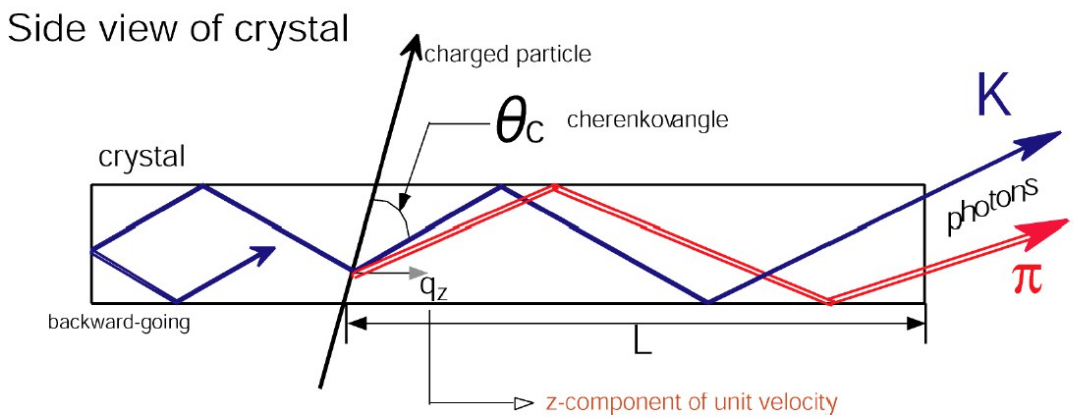
KEK , October 6 2017

Belle-II Detector

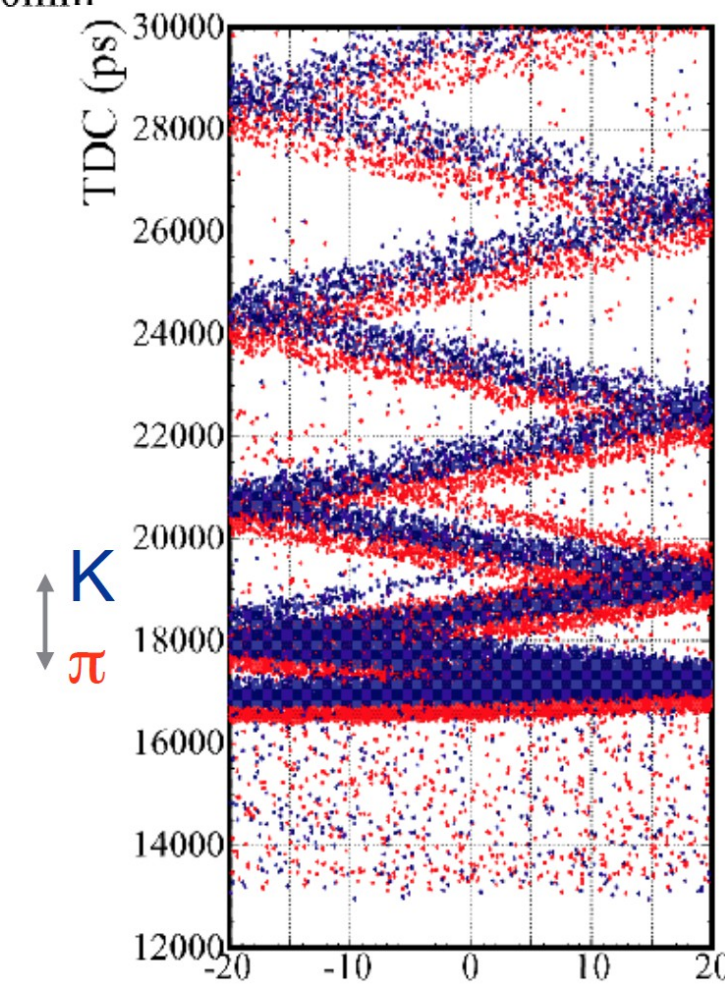


TOP counter: operating principle





Simulation
2GeV/c, θ=90 deg.



Different opening angles for the same momentum

- Measure x-y position (5 mm) of photons (imaging)
- Measure precise (40 ps) time of arrival of photons (time-of-propagation); TOF from IP works additively

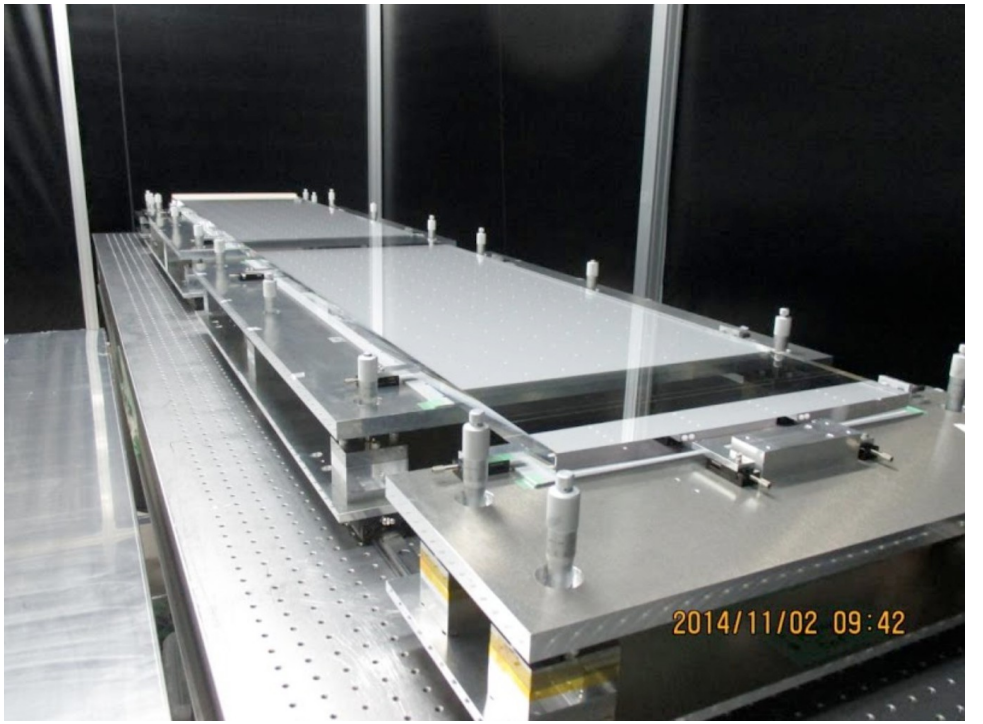
TOP optics

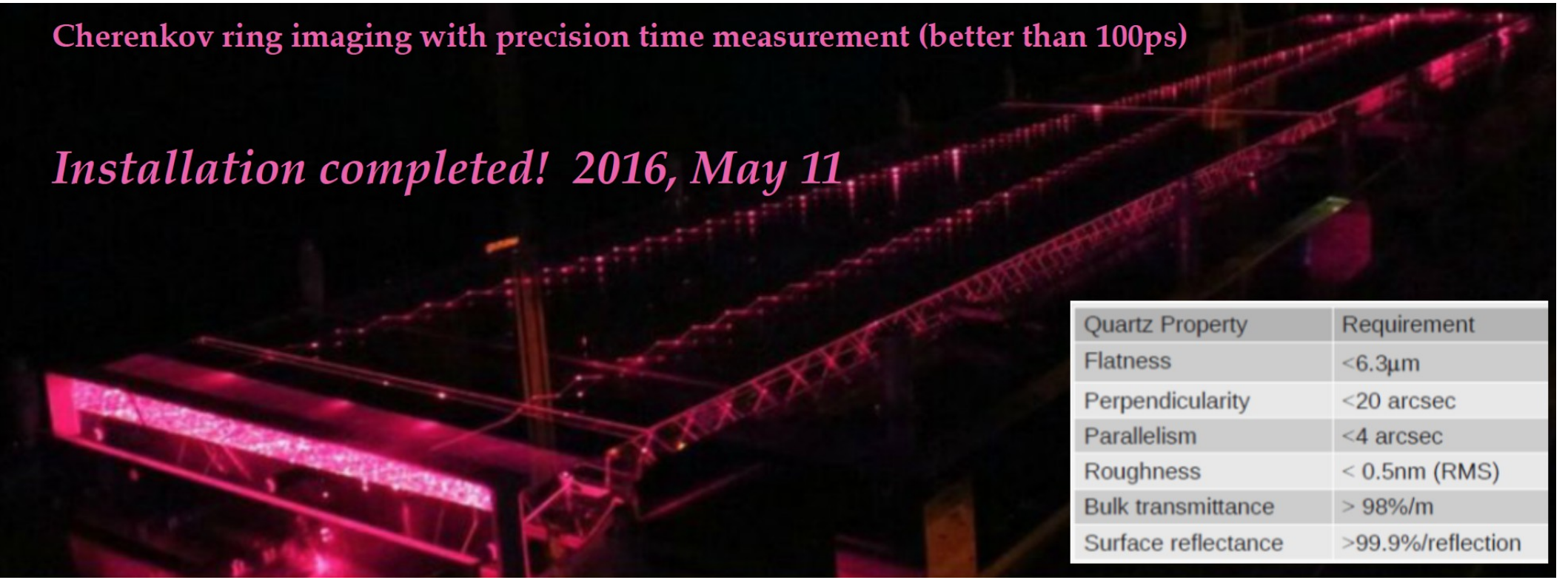
Quartz bars: 1250x450x20 mm^3

Mirrors: 100x450x20 mm^3

Prisms: 100x456x20 mm^3 at bar face, expanding to 456x50 mm^2 at PMT

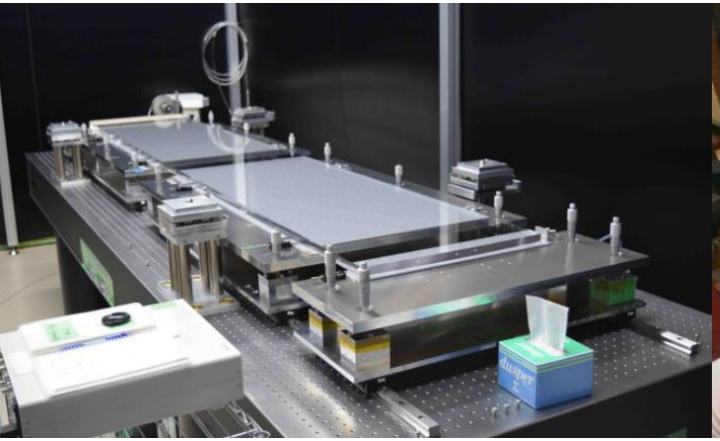
Material: Corning 7980





Quartz Property	Requirement
Flatness	<6.3μm
Perpendicularity	<20 arcsec
Parallelism	<4 arcsec
Roughness	< 0.5nm (RMS)
Bulk transmittance	> 98%/m
Surface reflectance	>99.9%/reflection

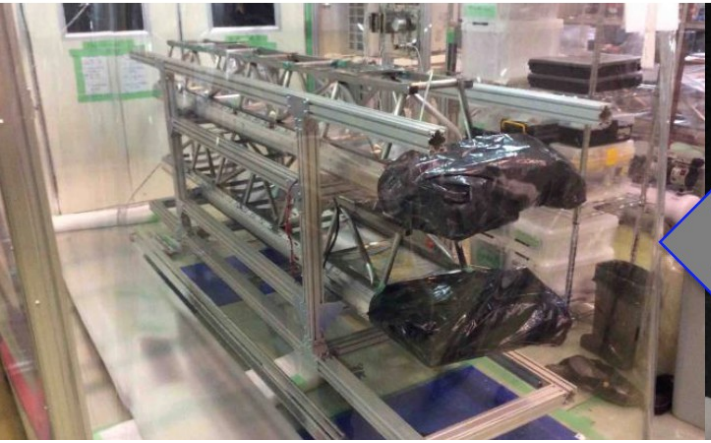
Assembly procedure



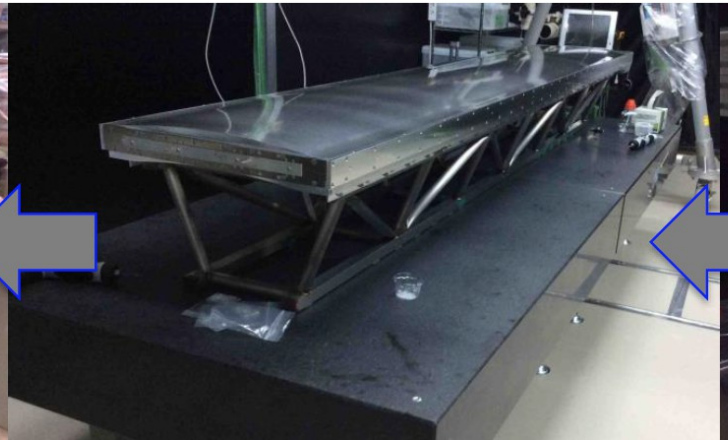
Optics: alignment, gluing, curing and aging (~2 weeks).

Enclosure: gluing CCDs and LEDs, integrating fiber mounts.

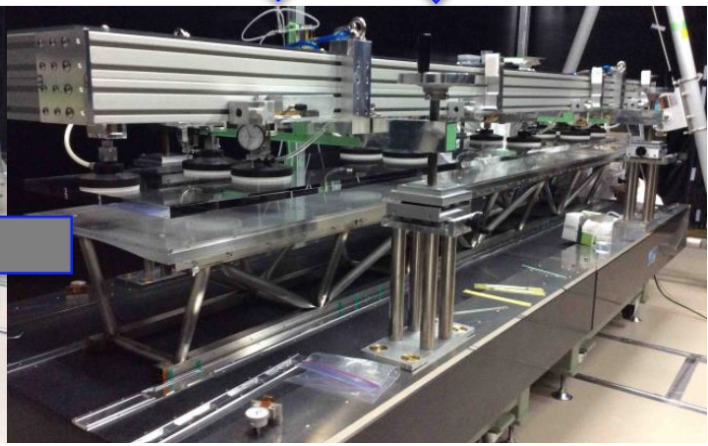
QBB: strong back flattening, button & enclosure gluing.



Put on a cart. PMT and front-end integration, performance check.

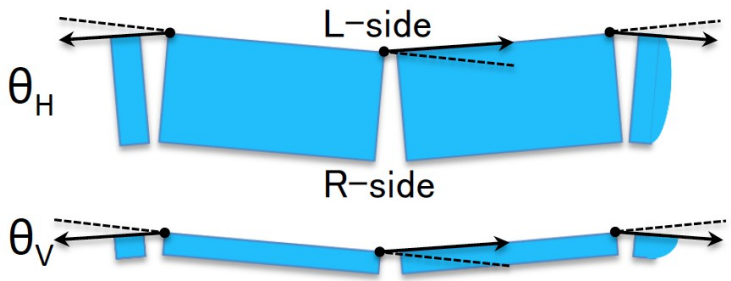


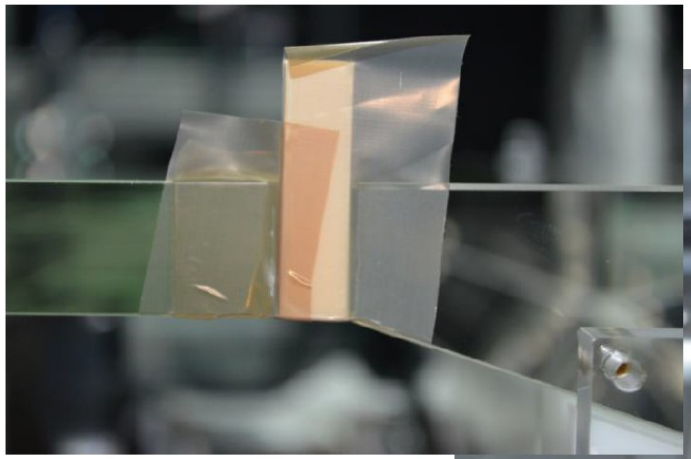
QBB assembly and gas sealing.

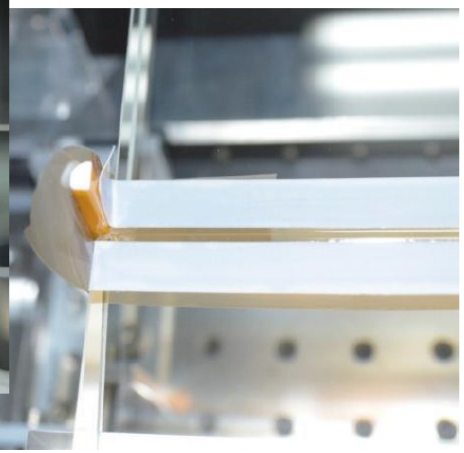


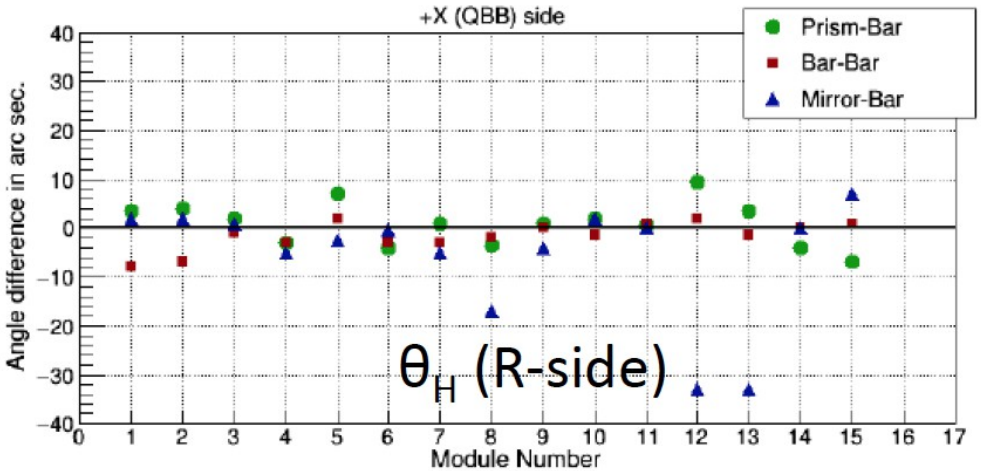
Move optics to QBB using the "lifting jig".

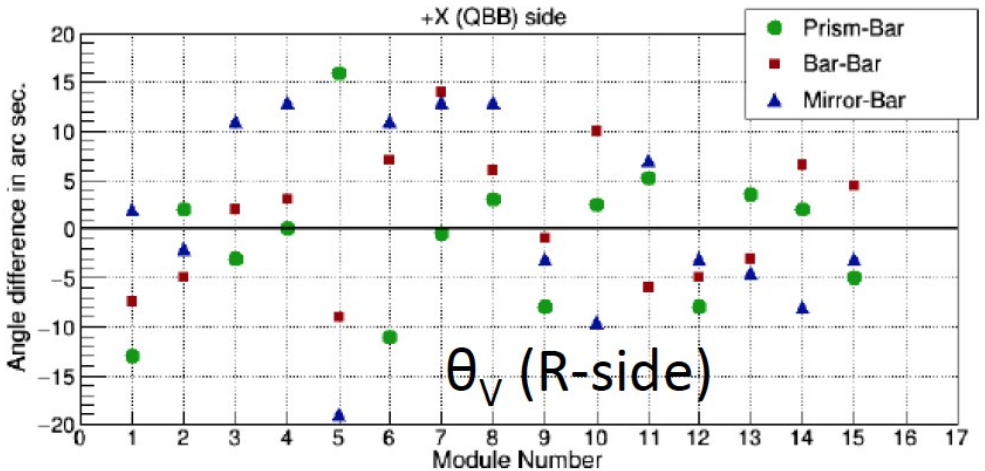
Optics alignment and gluing

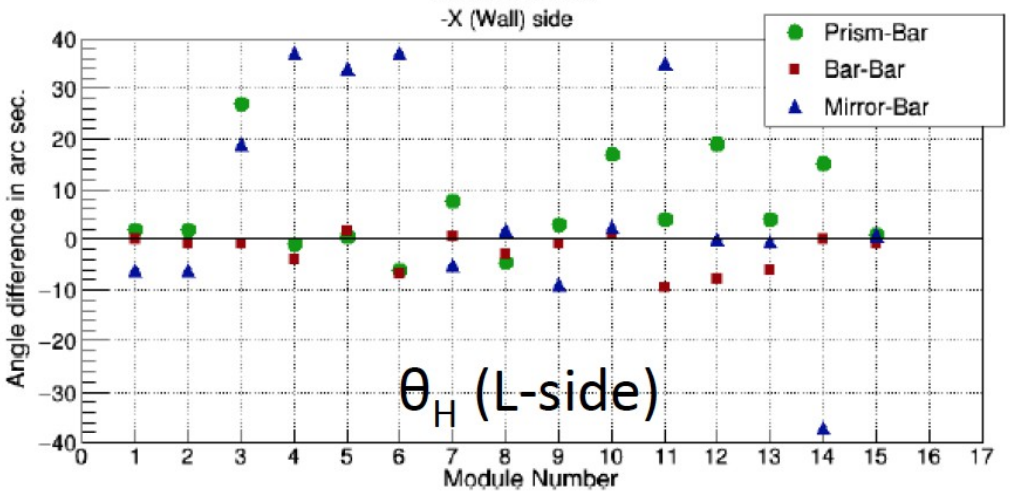


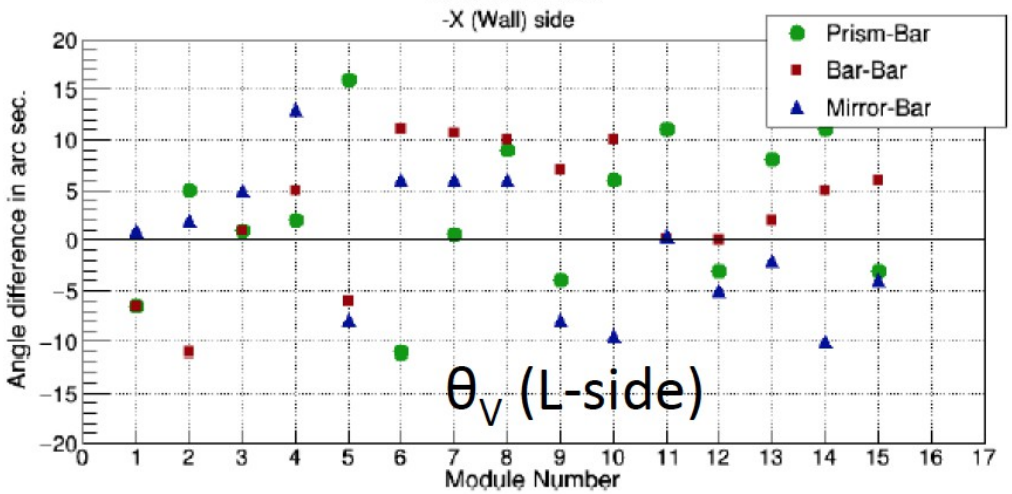








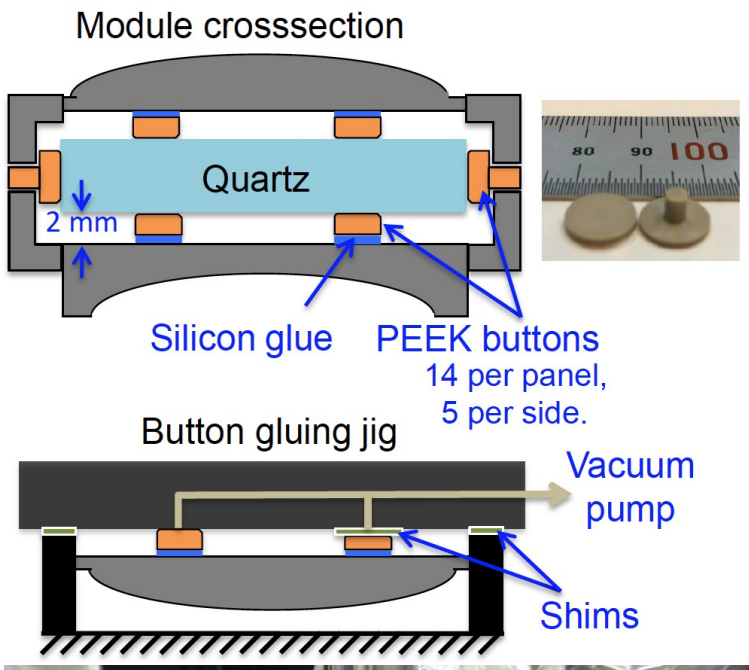


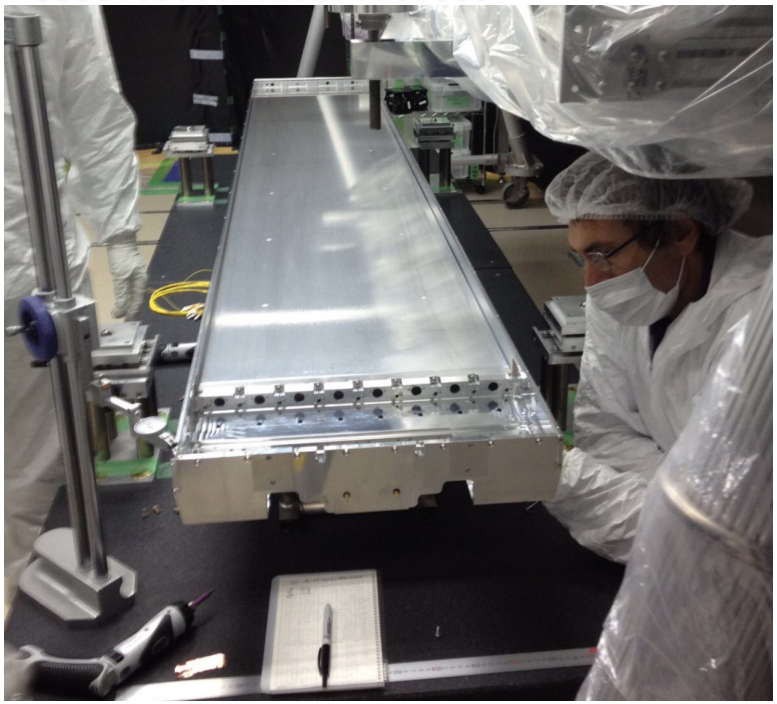


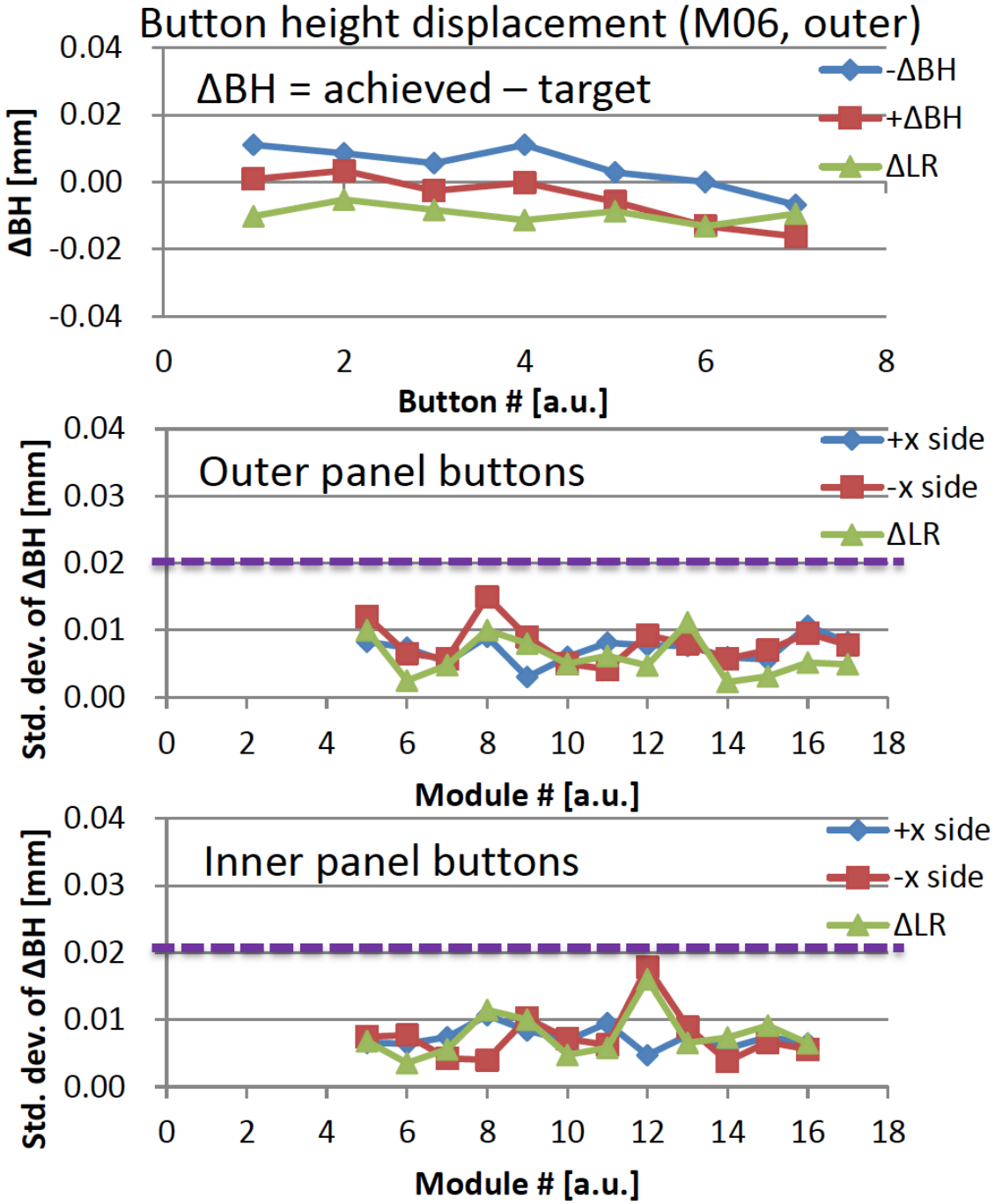
$|\theta_H| < 40$ arcsec.

$|\theta_V| < 20$ arcsec.

Support button alignment

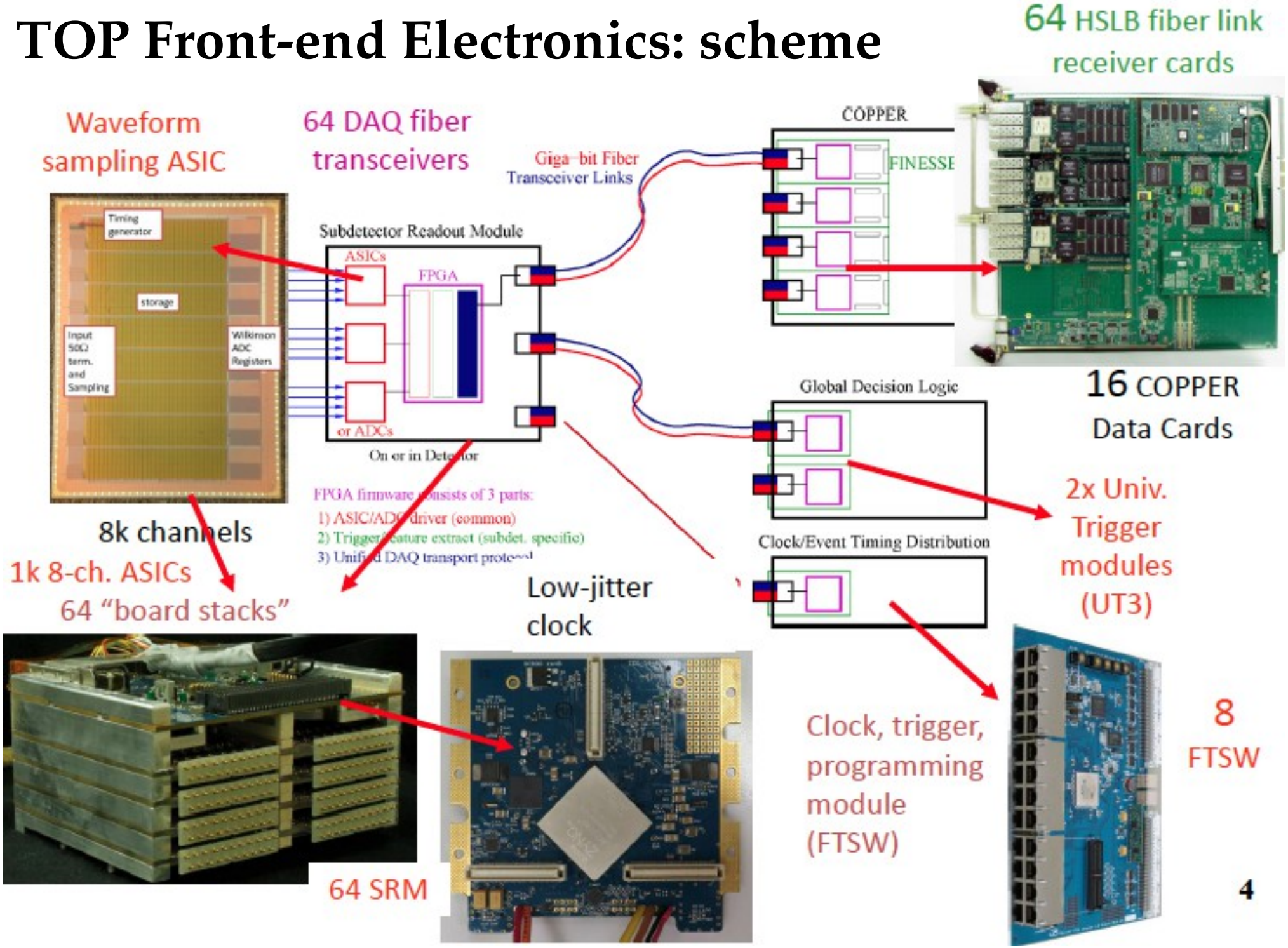






$\sigma(\Delta BH) < 0.02$ mm

TOP Front-end Electronics: scheme

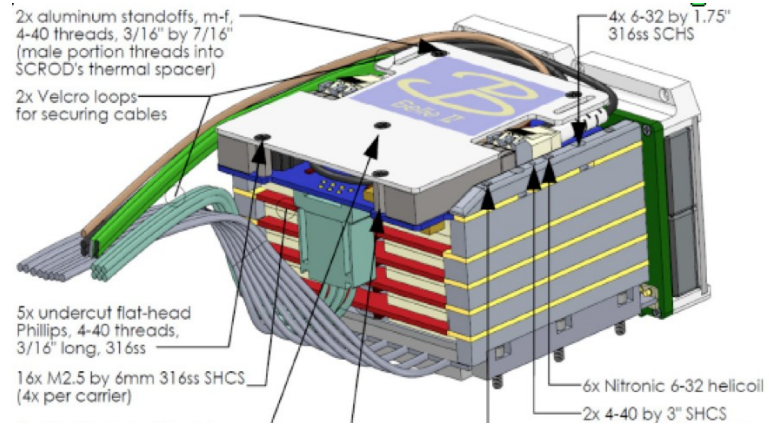


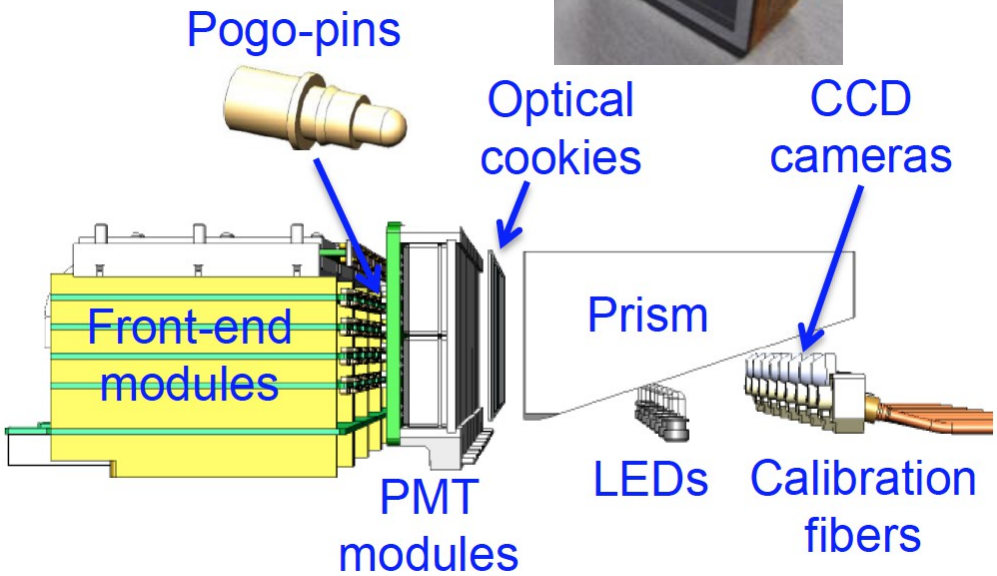
PMTs and Front-end Electronics: Optical and electrical contacting

Hamamatsu MCPPMT

R-10754: 4 x 4 anodes
27.6 x 27.6 mm^2
23.0 x 23.0 mm^2 active

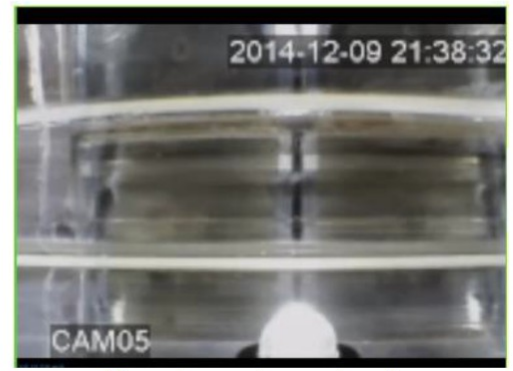
Front-End module: **Boardstack**
128 pixels, 8 MCPPMTs



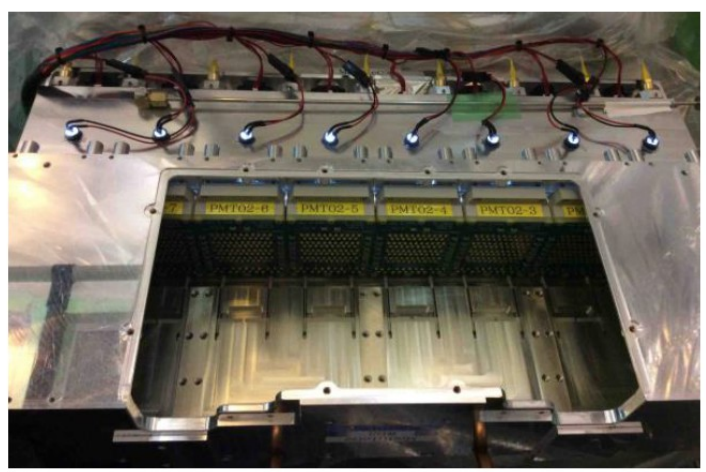


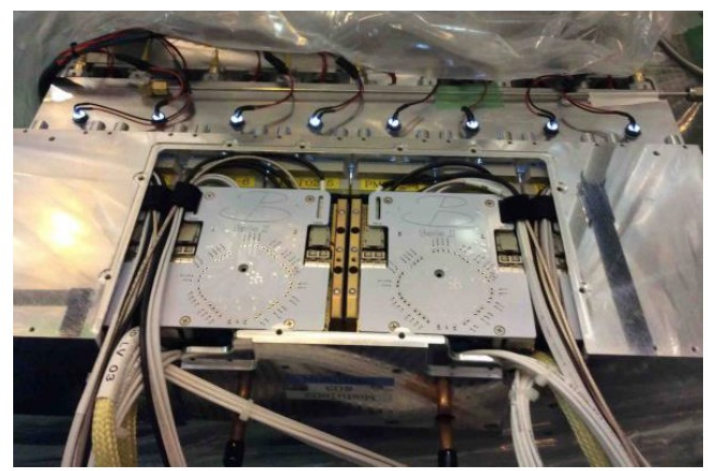
A CCD camera view of the contacts

Unloaded

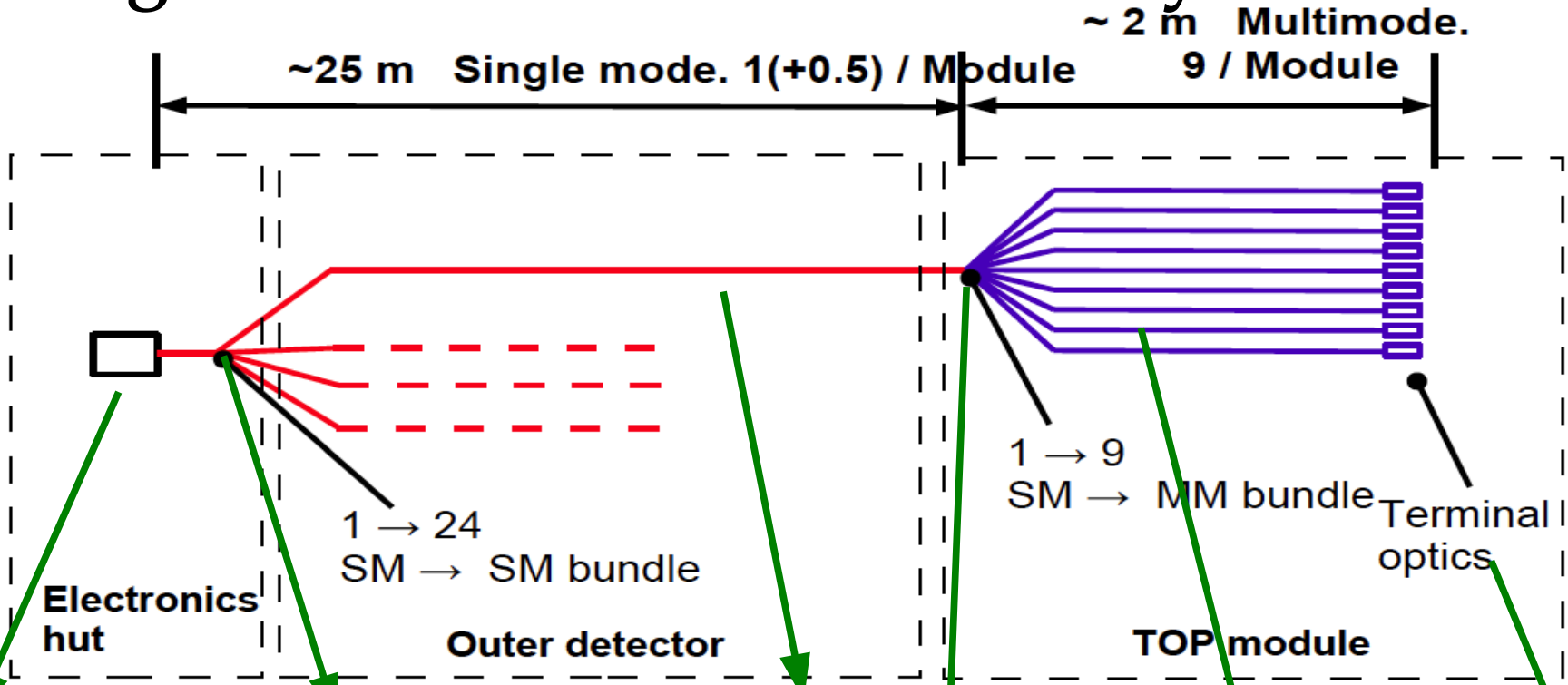


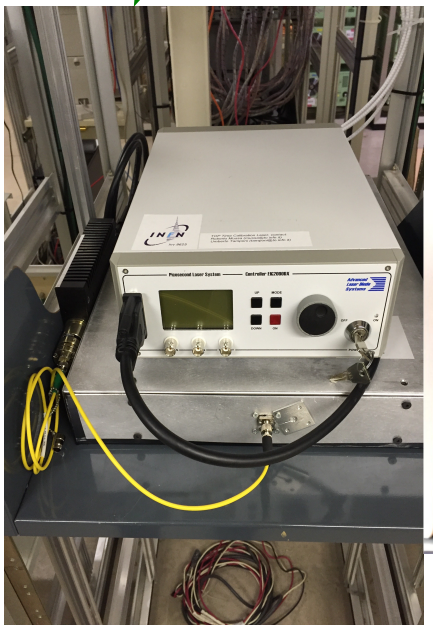
Spring-loaded





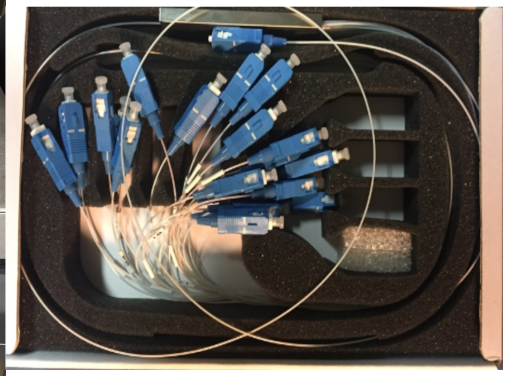
TOP light calibration: distribution system



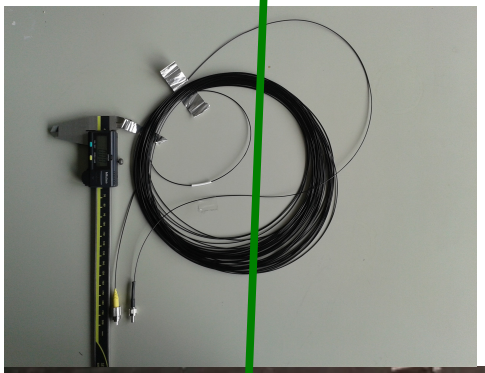


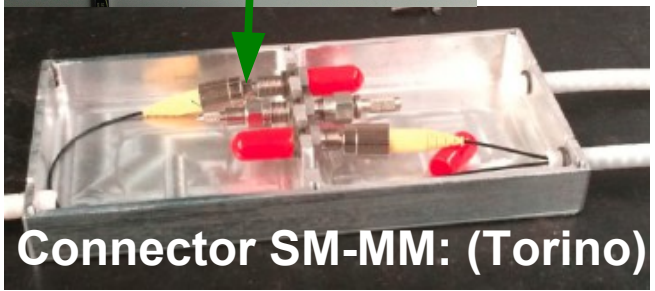
PiLas laser (Torino)

Splitter 1-24 via Planar Light Circuit (Padova)



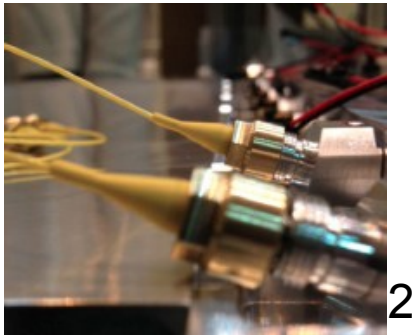
SM fiber (Torino)





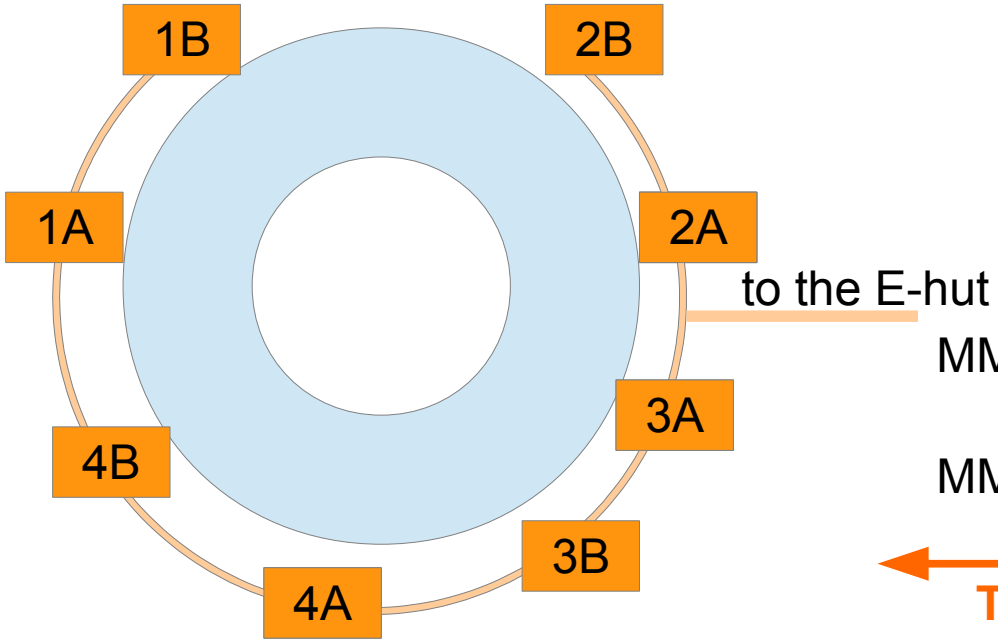
Connector SM-MM: (Torino)

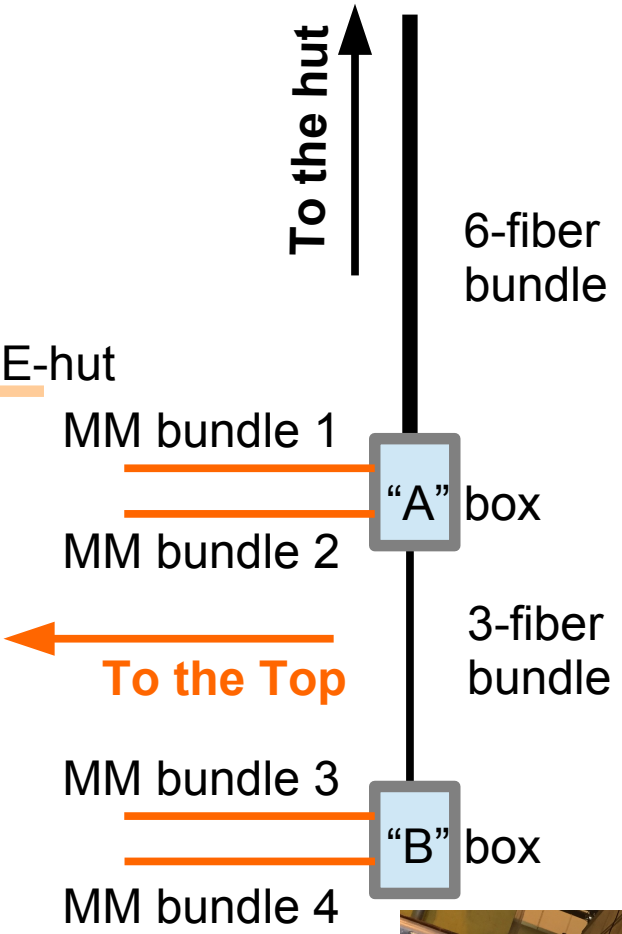
GRIN Lenses (Padova)



Single Mode Fiber routing and preparation

24 fibers are divided into 4 bundles, each one serving 4 modules (+2 spare fibers) Each bundle reaches 2 connector boxes, each one serving 2 modules





Fiber Production/testing procedure:

^ Cut, connect, quality control (Torino)

Tests at KEK Fuji Hall:

- ^ Polishing test w/diffractive method
- ^ Coating integrity test
- ^ Timing measurements

Installation at KEK Tsukuba Hall:

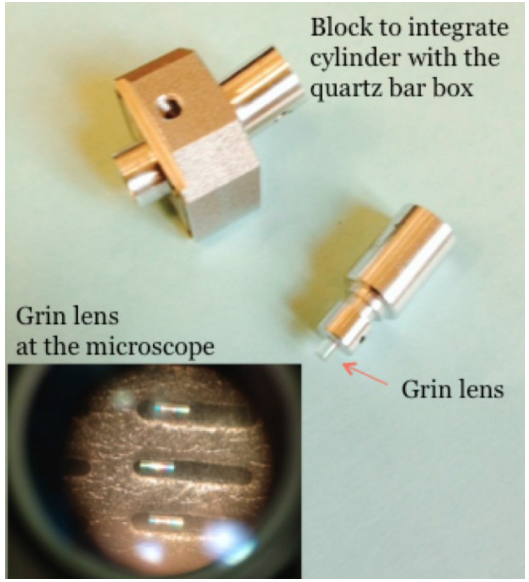
^ Preparation of the 4 bundles

^ Connector box installation

^ Post-installation checks

MultiMode Fiber Bundles assembly and tests

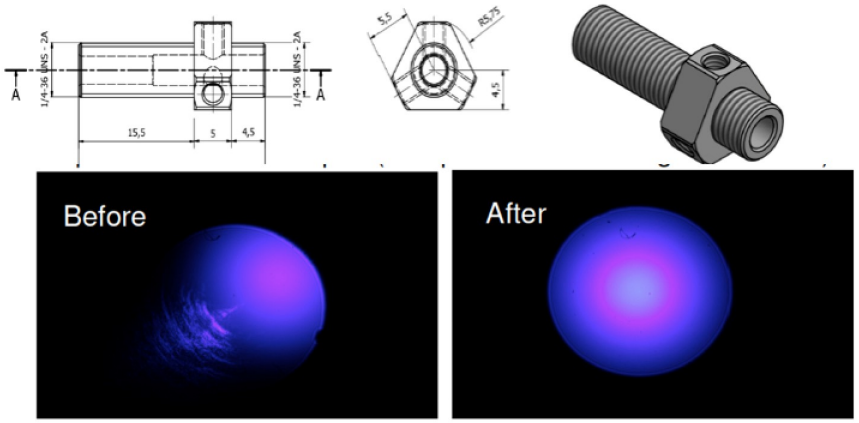
Design, mass production and QC of connectors to insert MM fibers in the Quartz Box (Padova)



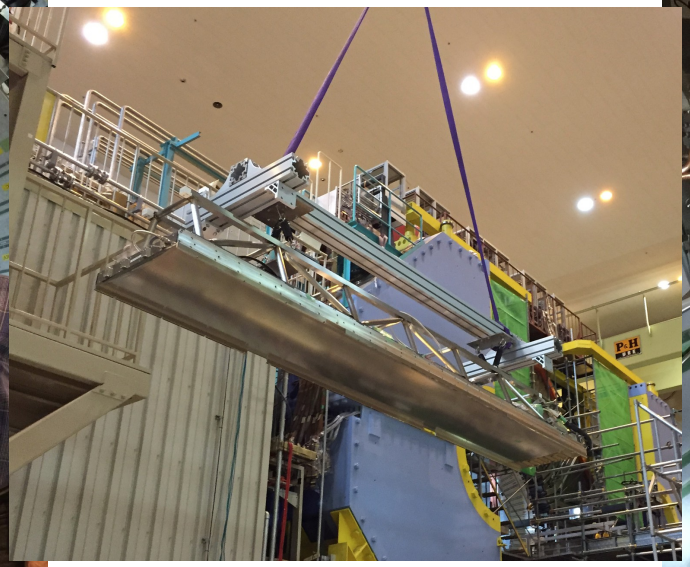
Irradiation tests on GRIN lenses and MM fibers

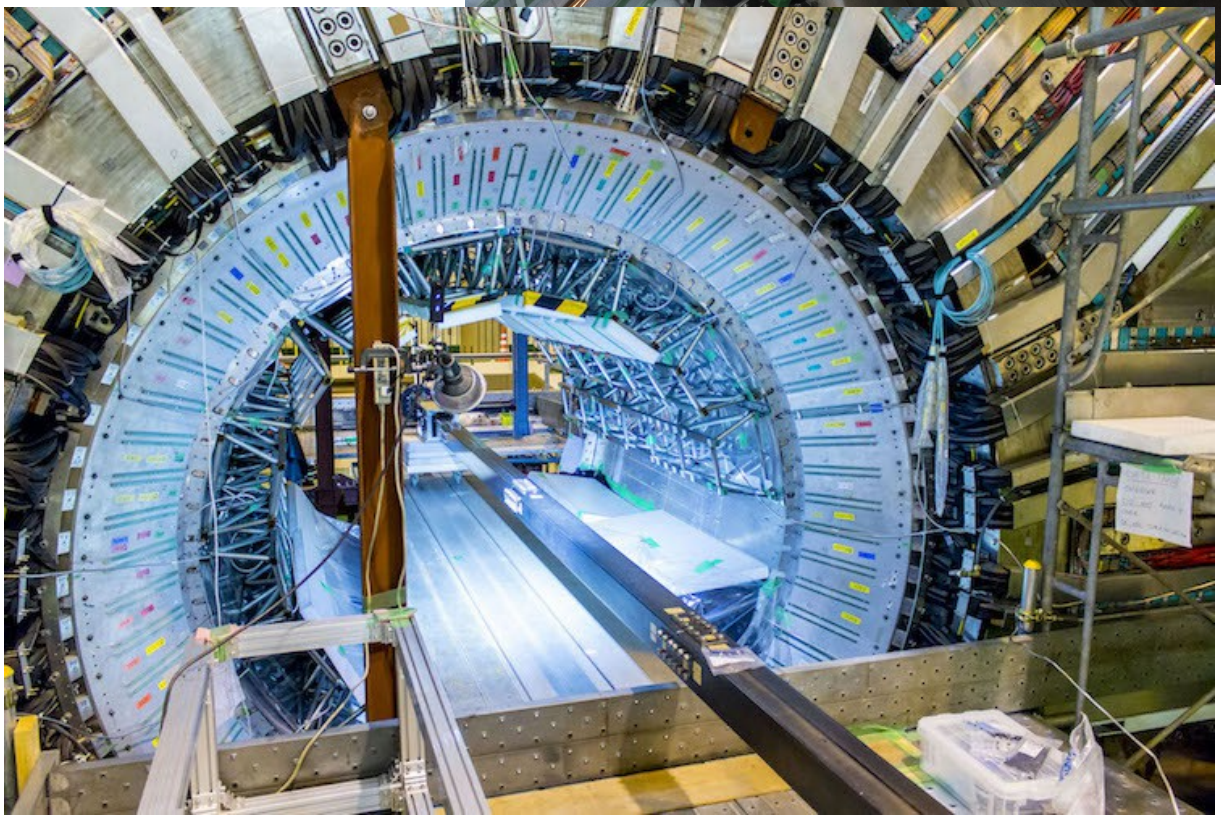
MM fiber QC and characterization (Padova)

Production of SM-MM fiber adaptors for flat-fielding (Padova)



TOP: Quartz Bar Installation





Laser calibration data

The challenge:

- 512 pixels per module
- 9 light sources per module

- Each pixel sees a different laser peak

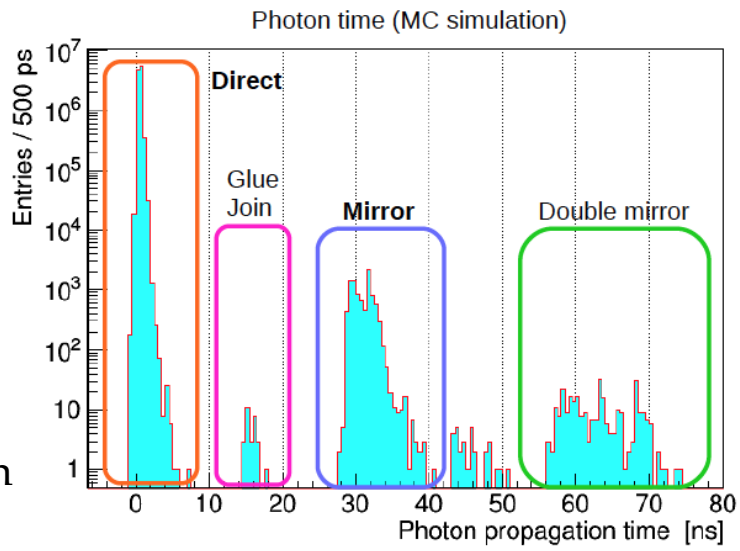
- Laser peak is a combination of 2 or 3 gaussians with the same width: 0,1,2 reflections.

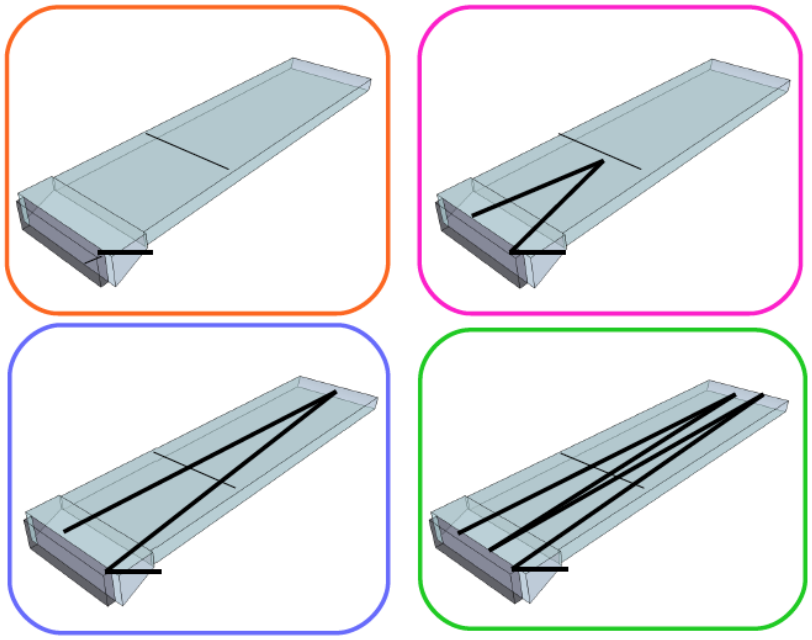
- A fraction of pixels see light from two sources

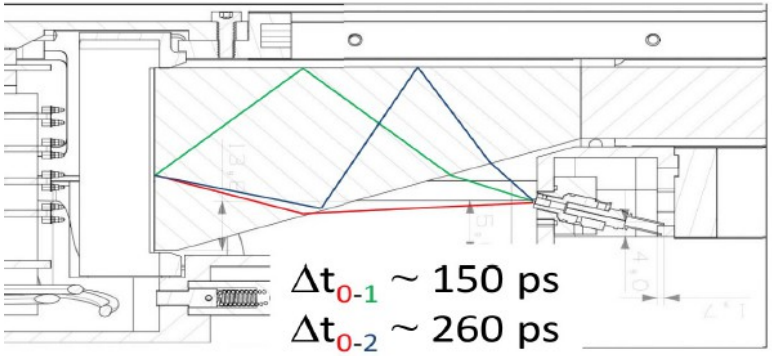
- Light intensity per pixel depend on MM fiber angular distribution.

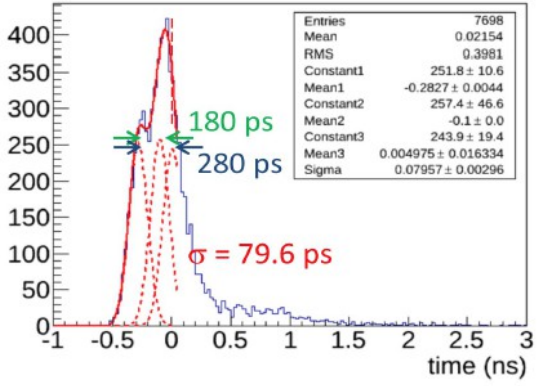
- SM-MM fiber piping efficiency is not constant

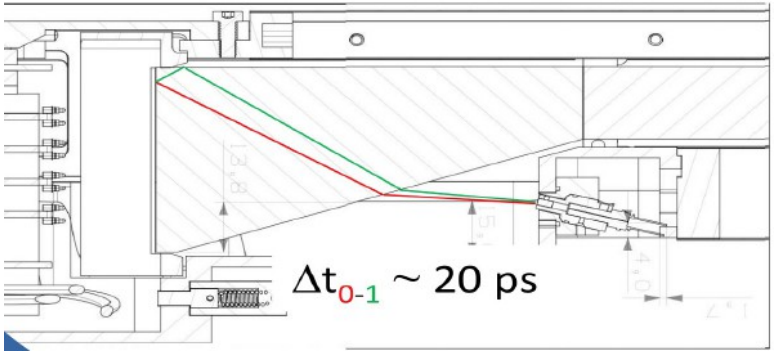
- Each pixel will have its own PDF for fiber calibration.

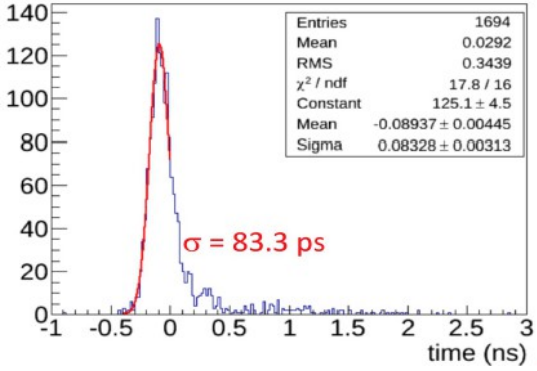






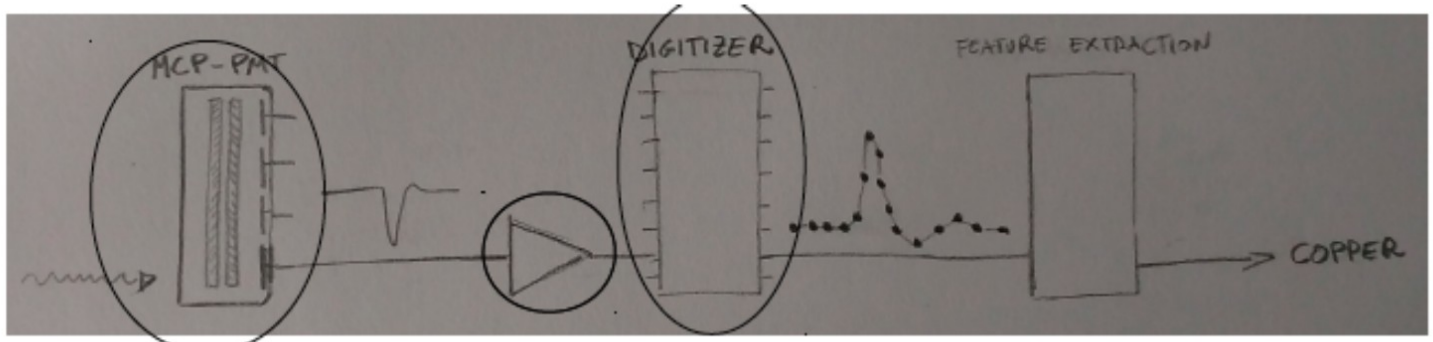






TOP : time calibration (coordinator: U.Tamponi)

What we have to calibrate



Photon detection
→ PMT Transient time

Fast amplifier
→ Transient time

Digitization of the waveform
→ sampling bin size

$$T_{photon} = t_{digit} + T^0_{channel} + T^0_{module}$$

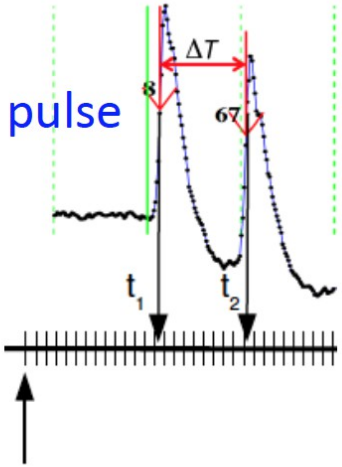
+ PMT channel gain

Time base calibration (TBC)
Calibration of the bin size of the digitizer

Local T0
Synchronization of the channels within a single quartz bar

Module T0
Synchronization of the modules one with the others

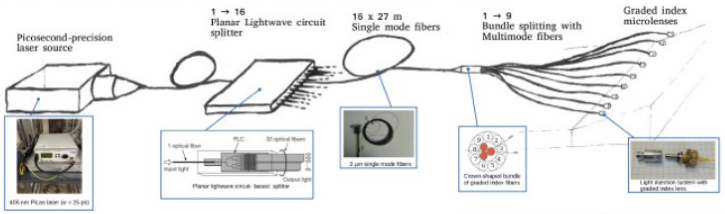
Double cal pulse



SST clock (KEKB clock-based)
Sample 0

Laser pulse calibration

To synchronize the channels within a single module we flash them with a laser pulse



Alignment

$$\chi^2 \equiv -2\sum^{n} \log \mathcal{L}^{(i)}_{\mu}(\hat{p}) = \min,$$

$$\hat{p} \equiv (\Delta x, \Delta y, \Delta z, \alpha, \beta, \gamma, t_0)$$

TOP : time calibration (coordinator: U.Tamponi)

Calibration steps

Time base calibration (TBC)
What is it? Calibration of the sampling rate of each asic.
How many? 256 constants / channel (131072 / module)
Run type? Local pulser runs , O(500k evts / channel)
How frequently? Phase II: ~ 1 per day. PhaseIII: TBD

Local T0
What is it? Inter-calibration of the delays of the channels within a single module
How many? 1 constant / channel (512/module)
Run type? Local lasers run, O(1 hr)
How frequently? Phase II: ~ 1 per day. PhaseIII: TBD

Alignment
What is it? Geometrical and time alignment of the 16 modules
How many? 7 constants / module (3 shifts + 3 angles + 1 time offset)
Run type? Muons, O(10 k evt/module)
How frequently? PhaseII: 1 per run . PhaseIII: 1 per run

Two methods
- Matrix inversion
- Iterative

Xialong Wang

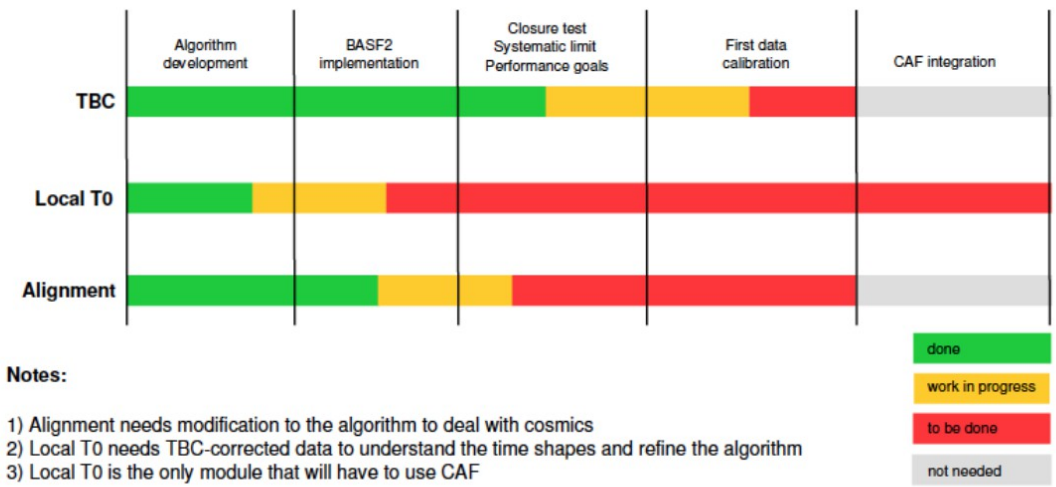
Wenlong Yuan

Studies at Padova to understand distribution of the laser signals

Alessandro Gaz

On top of this we have the **PMT gain**, **threshold efficiency** and **channel masking** monitoring, that go in the condition DB

Readiness and roadmap



Notes:

1) Alignment needs modification to the algorithm to deal with cosmics
2) Local T0 needs TBC-corrected data to understand the time shapes and refine the algorithm
3) Local T0 is the only module that will have to use CAF

The calibration software is evolving steadily.

Issues in Epic

BII-2018	Matrix inversion-based time base correction	DONE	Marko Staric
BII-2019	Iterative based time base correction	DONE	Xiaolong Wang
BII-2020	TOP T0 correction	IN PROGRESS	Stefano Lacaprara
BII-2021	PMT gain monitoring tool	IN PROGRESS	Yosuke Maeda
BII-2022	TOP Calibration monitoring tools	IN PROGRESS	Elisa Guido
BII-2023	TOP Channel masking	DONE	Samuel Thomas Cunliffe
BII-2024	TOP Alignment module	IN PROGRESS	Alessandro Gaz
BII-2026	TOP inter-module time alignment without B field	WON'T FIX	Umberto Tamponi
BII-2045	Realistic digitizer module	IN PROGRESS	Marko Staric
BII-2046	Simulation of the laser events with double calpulse	OPEN	Marko Staric
BII-2061	Missing DB classes for TOP calibration constants	DONE	Umberto Tamponi
BII-2351	TOP Calibration benchmark tools	OPEN	Umberto Tamponi

Also, slow control, DQM

Saurabh Sandyila, Boqun Wang

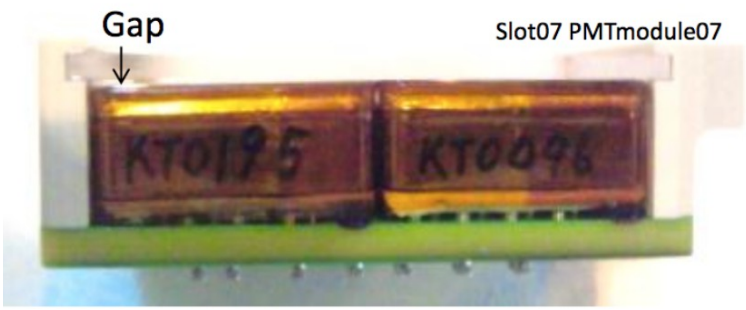
MCPPMT rotation problem

The PMT tube contains Kovar (nickel–cobalt ferrous alloy)

The force on the PMT was measured to be: ~1 kgf/PMT in B=1.5 T

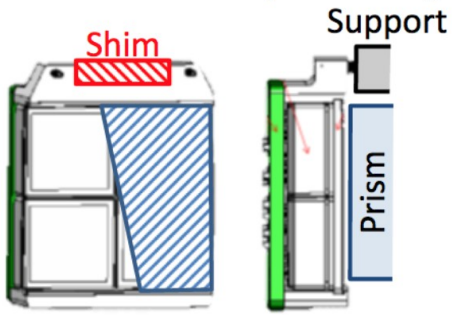
PMT rotation inside PMT module

- Effect only for photons of incident angles large than ~43°
- Will be fixed if necessary after phase 2

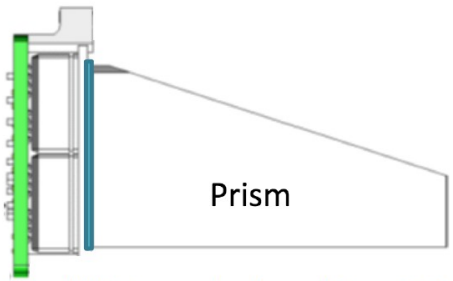


Rotation of PMT module

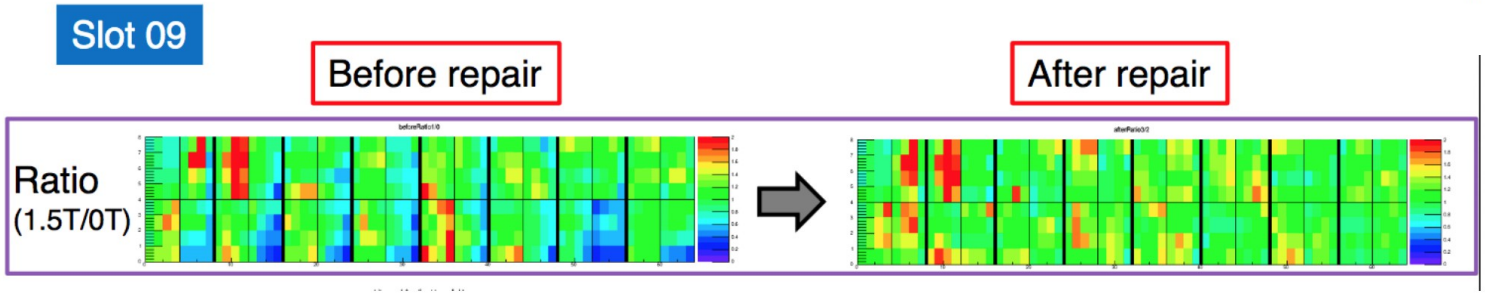
- Large effect on photon transmittance due to bubbles under the optical cookie
- Has been fixed in situ by shimming

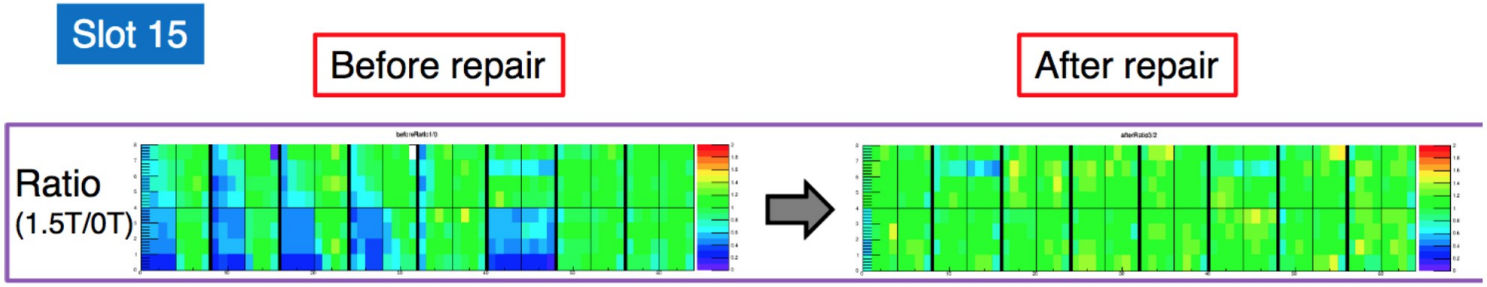


1 PMT module = 4 PMT

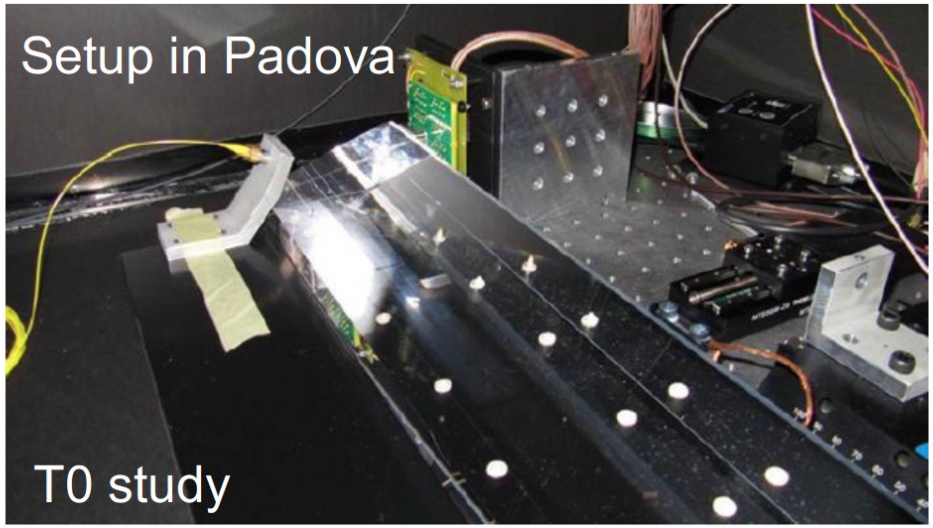


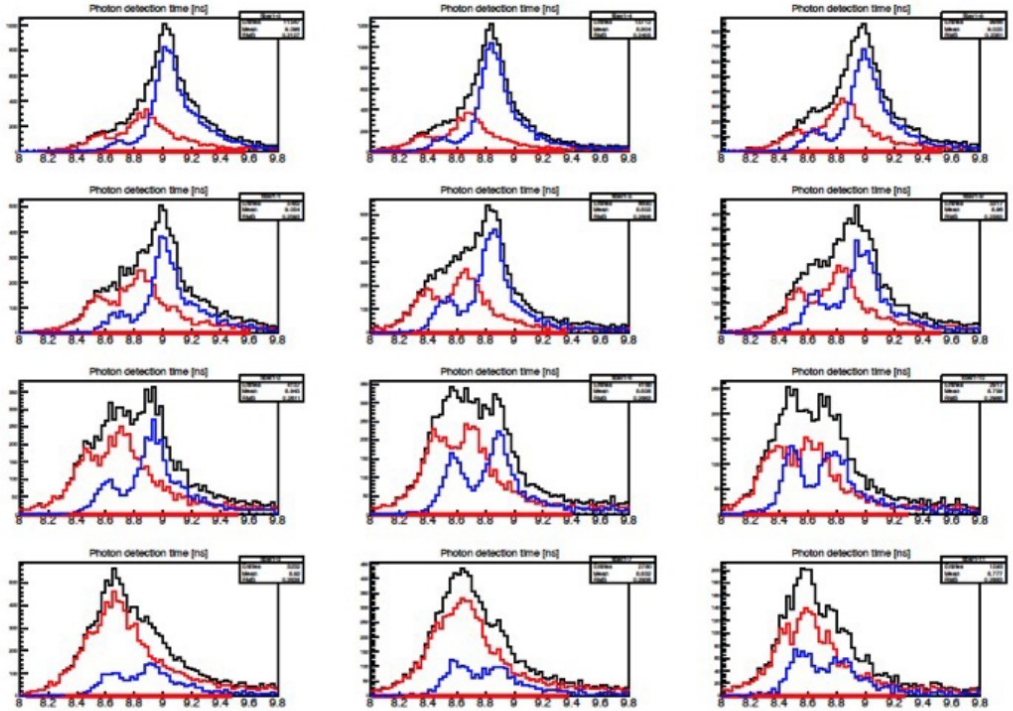
PMT – WLS – optical cookie – Prism (optical oil between them)



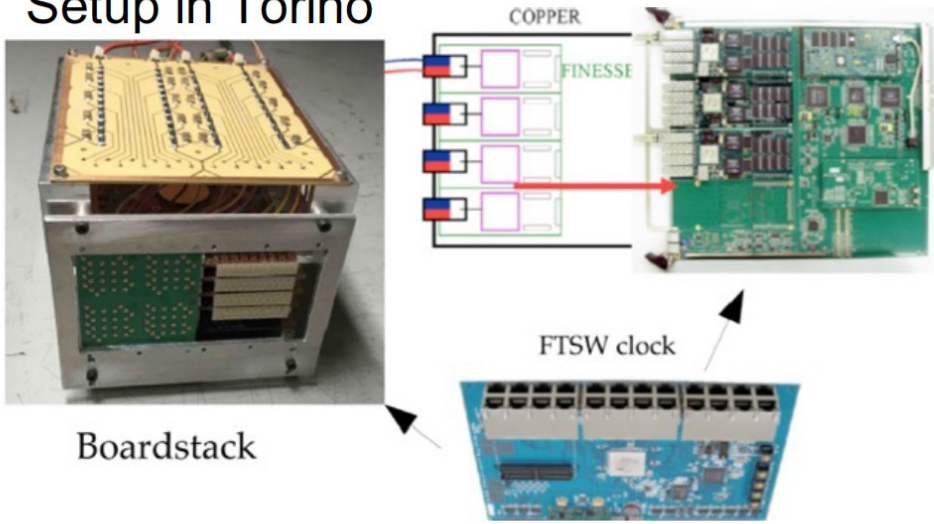


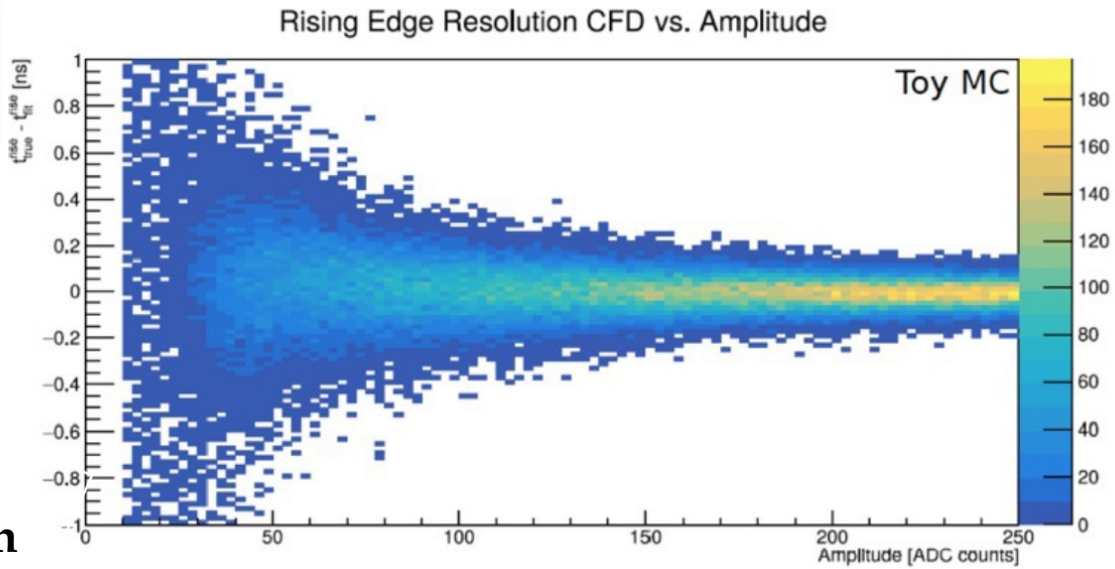
Test stands in Italy





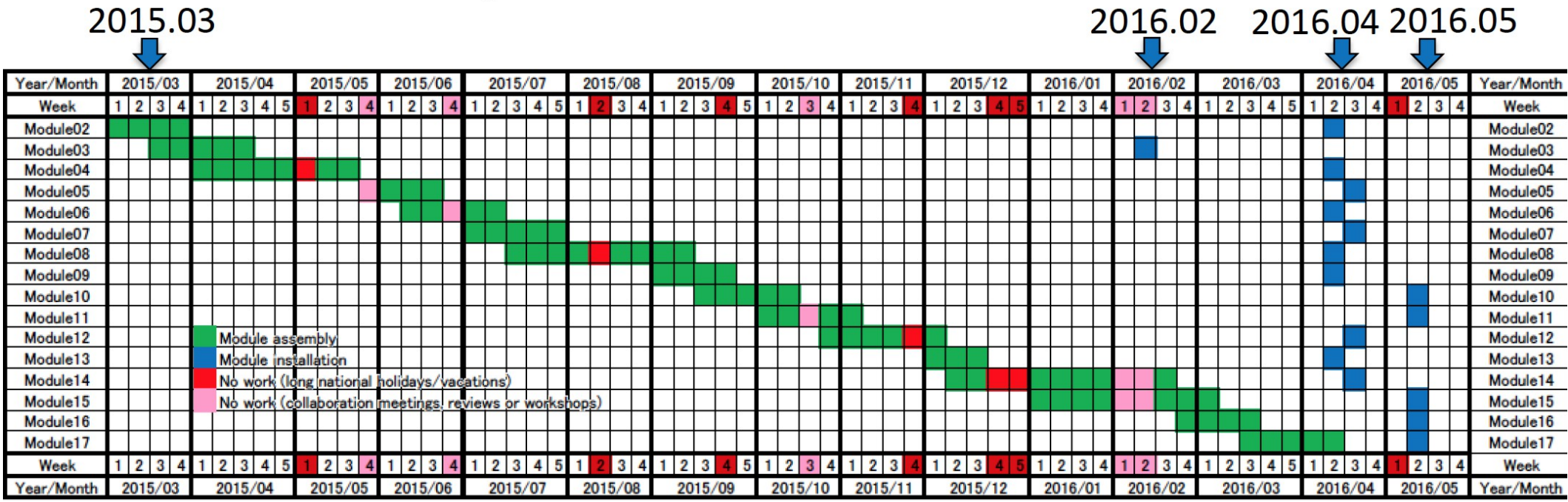
Setup in Torino





Improvements of the constant fraction discriminator (CFD) with templates. Important for time resolution with low gain

TOP: assembly and installation schedule



Secondments Torino

Umberto Tamponi from 1 June to 8 July 2015 (38d construction)
Oscar Brunasso Cattarello from 16 to 31 August 2015 (16d construction)
Roberto Mussa from 3 to 26 October 2015 (24d construction)

Roberto Mussa from 12 to 28 May 2016 (17d construction)
Simonetta Marcello from 20 to 25 June 2016 (6d commissioning)
Fabrizio Bianchi from 16 to 24 October 2016 (9d computing)
Roberto Mussa from 12 to 25 October 2016 (14d commissioning)
Simonetta Marcello from 14 to 22 October 2016 (9d commissioning)

Roberto Mussa from 31 Jan to 15 February 2017 (16d commissioning)
Fabrizio Bianchi from 4 to 15 February 2017 (12d computing)
Roberto Mussa from 13 to 24 June 2017 (12d commissioning)
Fabrizio Bianchi from 17 to 26 June 2017 (10d computing)
Oscar Brunasso Cattarello from 16 July to 2 August 2017 (18d construction)
Roberto Mussa from 3 to 14 October June 2017 (12d commissioning)
Simonetta Marcello from 3 to 12 October June 2017 (10d commissioning)

Totals WP2 : 224 d= 7.5 months

Construction (UT,RM,OBC,SM):
TOP assembly and installation: 113d

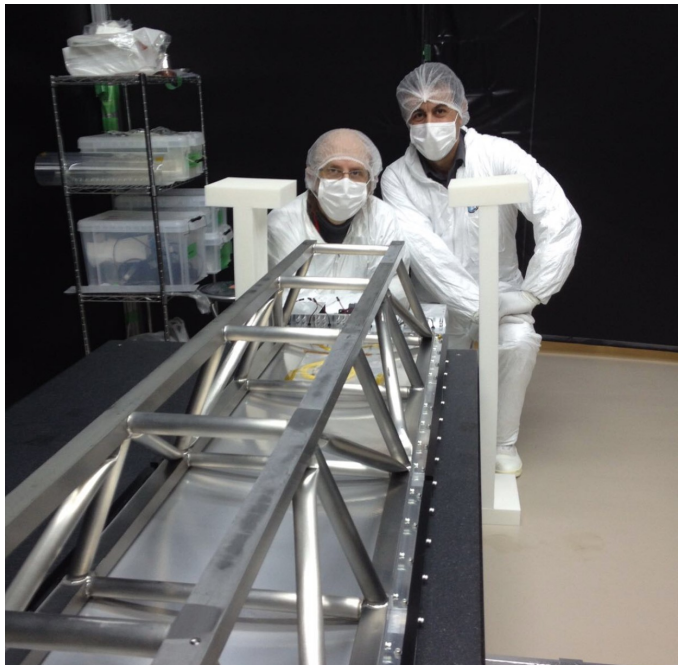
Commissioning (RM+SM):
TOP laser calibration
and cosmic ray test: 79d

Computing (FB): 31d

Remaining on WP2 (UT+RM) : 2.5 months

Secondments details

Massimo Benettoni from 13 to 27 April 2015 (15d construction)
Ezio Torassa from 19 June to 4 July 2015 (15d construction)
Massimo Rebeschini from 27 June to 13 July 2015 (15d construction)
Loris Ramina from 27 June to 13 July 2015 (15d construction)
Alessandro Gaz from 3 October to 1 November 2015 (30d test moduli)
Ezio Torassa from 16 October to 30 October 2015 (15d construction)
Loris Ramina from 24 October to 9 November 2015 (15d construction)
Massimo Rebeschini from 24 October to 9 November 2015 (15d construction)
Massimo Benettoni from 7 November to 22 November 2015 (15d construction)
Ezio Torassa from 4 April to 16 April 2016 (15d installation)
Ezio Torassa from 14 June to 25 June 2016 (15d commissioning)
Wenlong Yuan from 15 May to 19 June 2017 (36d commissioning)
Ezio Torassa from 12 June to 29 June 2017 (18d commissioning)



Summary

1) Construction and assembling of the TOP modules
Massimo Benettoni 1 month (30 d)
Massimo Rebeschini 1 month (30 d)
Loris Ramina 1 month (30 d)
Ezio Torassa 1 month (30 d)

2) Test of the TOP modules before installation :
Alessandro Gaz (30 d)

3) Installation of the TOP detector : Ezio Torassa (15d)
4) Commissioning of the TOP detector :
- Wenlong Yuan 1 month (36 d)
- Ezio Torassa 1 month (33 d)

TOT 7.5 months
To be done (ET+WY+AM): 2.5 months

Work in progress

Cosmic Ray Run with CDC,KLM,ECL,....

Merging in global DAQ

Laser Calibration and comparison with MC simulations

TimeBase Calibration

Firmware: Feature Extraction, Template Fitter

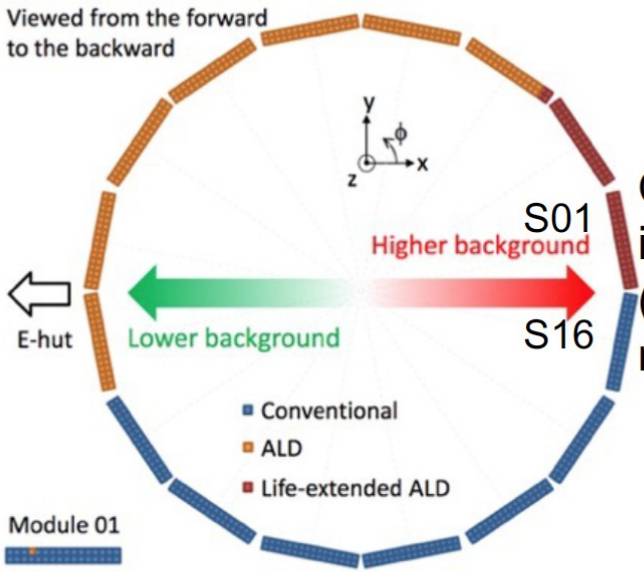
Detector alignment

Pixel by pixel T0 calibration

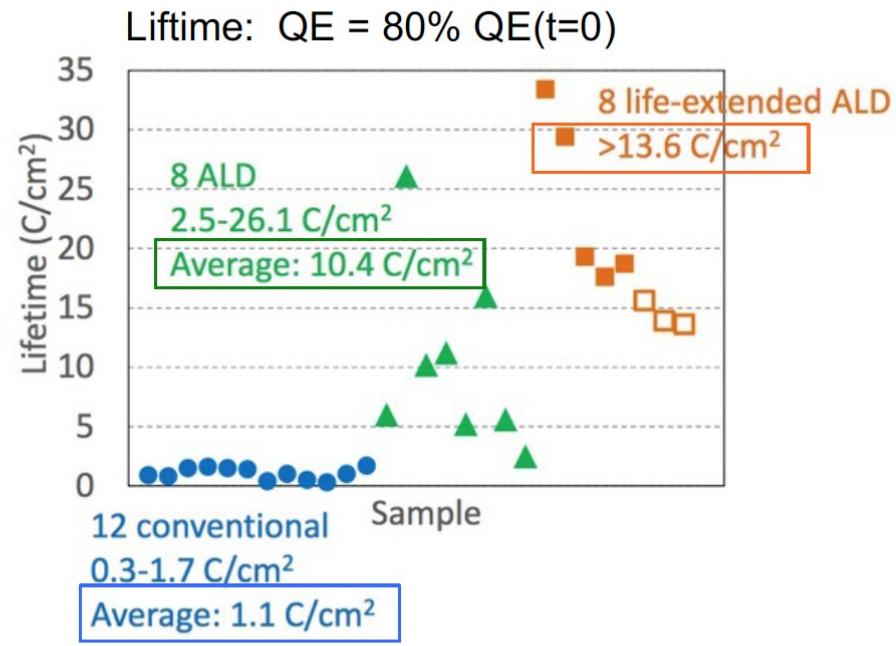
TOP Trigger

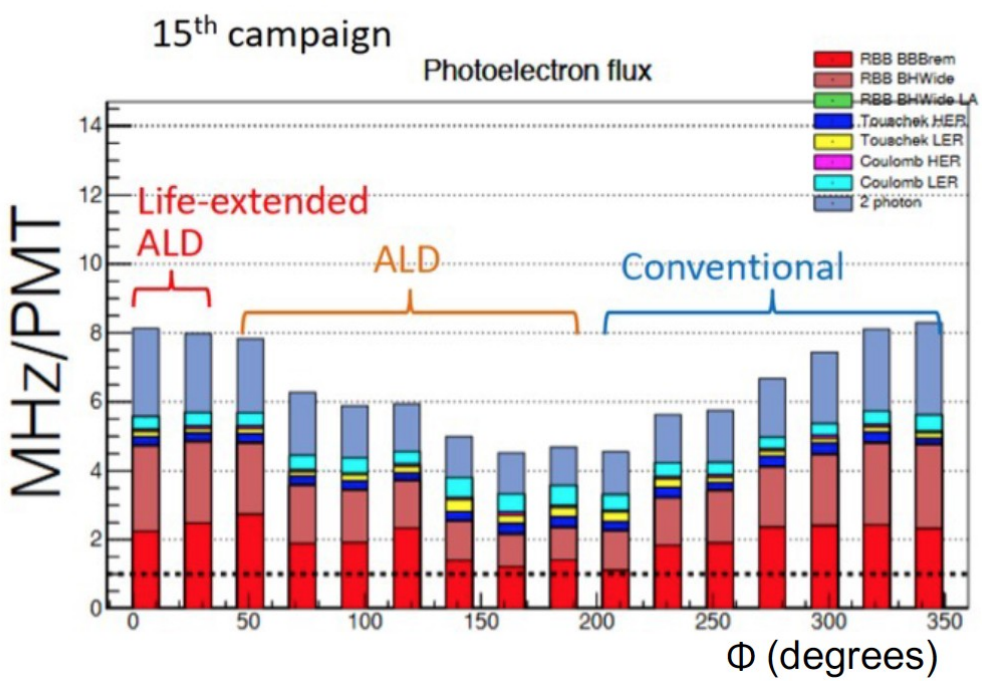
... still plenty of work to do before first collisions

MCPPMT aging



Conventional MCP-PMT inside 7 modules (tot 224 PMT) must be replaced in 2020





1 MHz/PMT at 5 10^5 gain ➔ 1 C/cm² @ 50 ab^{-1}

4÷8 MHz/PMT ➔ 1 C/cm² @ 12÷6 ab^{-1}

Integrated luminosity at the summer shutdown

2019: 0.18-0.33 C/cm² (2 ab^{-1})
2020: 0.72-1.33 C/cm² (8 ab^{-1})
2021: 1.52-2.82 C/cm² (17 ab^{-1})
2022: 2.69-4.98 C/cm² (30 ab–1)
2023: 3.76-6.97 C/cm² (42 ab–1)

Replace conventional MCP-PMT.

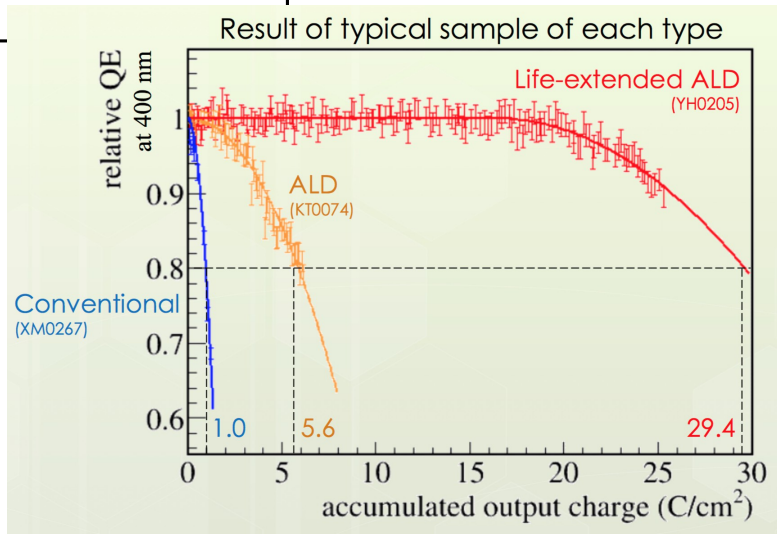
TOP upgrade: life extended ALD-MCPPMT

Test plan (draft)

Year	2017				2018				2019				2020		
Month	1	4	7	10	1	4	7	10	1	4	7	10	1	4	7
Global schedule					Phase 2				Physics run			Physics run			
PMT production	Current production														
			Another small production												
							Mass production if necessary								
New PMTs (prospect)	28	26		5 /month			10 PMTs/month								
PMT test at Nagoya		10 /month		5 /month			10 PMTs/month								
PMT test at KEK								~100 PMTs				~100 PMTs			
PMT installation													Assy	Install	
Available PMTs	37	63	Unclear (depends on budget situation)												

Maximum rate:

- QE measurement: 2 PMTs/day = 40 PMTs/month
- HV test: 8 PMTs/day = 160 PMTs/month
- Laser test in 0 T: 5 PMTs/day = 100 PMTs/month



TOP management

- Leader: Toru Iijima
- Deputy: Gary Varner
- Gemba leader: Kenji Inami
  - Supervision to all Gemba works
  - Liaison to KEK