TOP counter
Intro. and status

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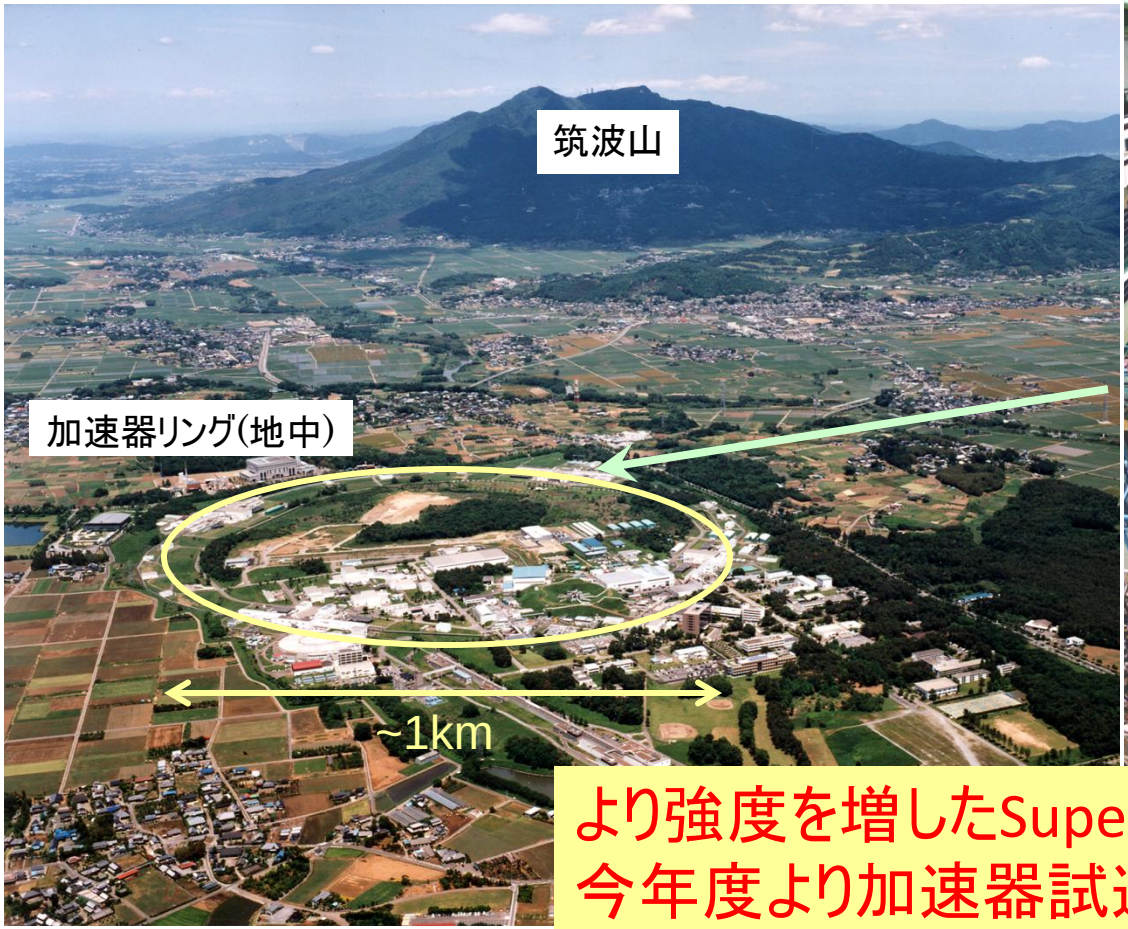
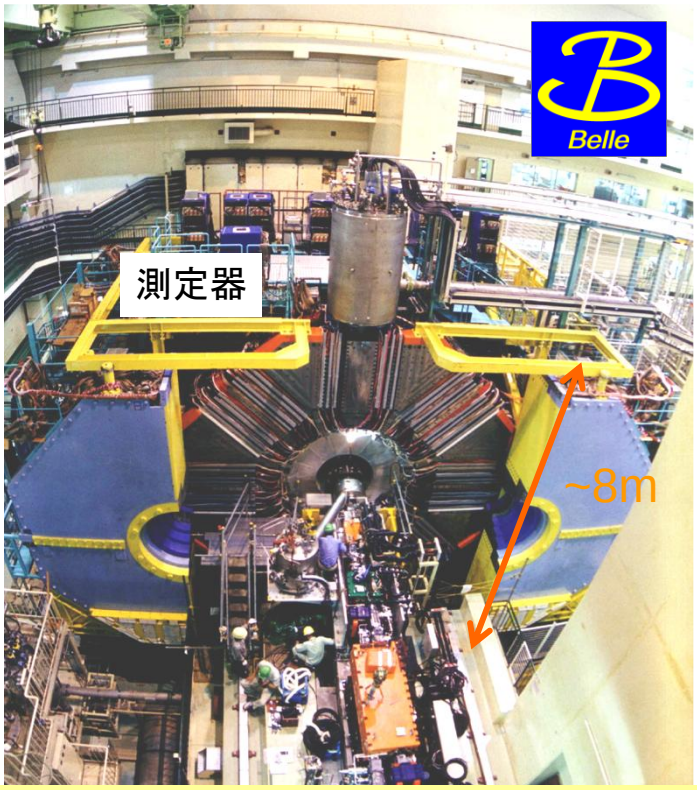
2015/5

KEKB/Belle実験

- つくば市高エネルギー加速器研究機構にて行なわれている電子・陽電子衝突型加速器実験
- B中間子やタウレプトンの性質を調査

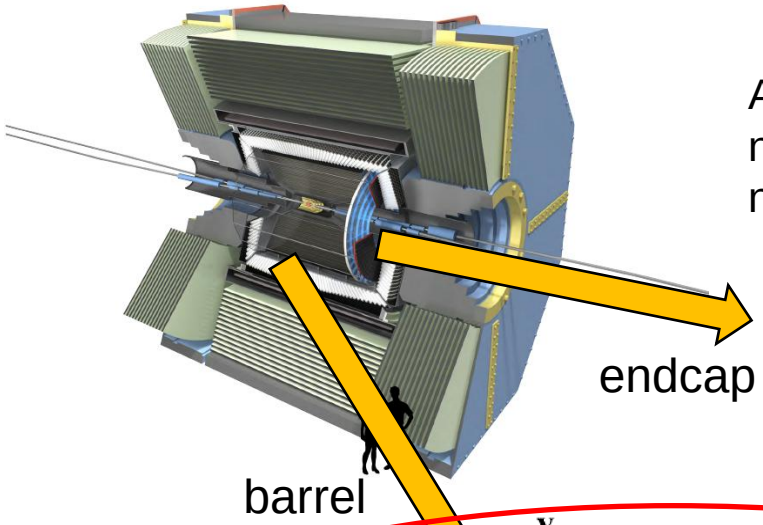


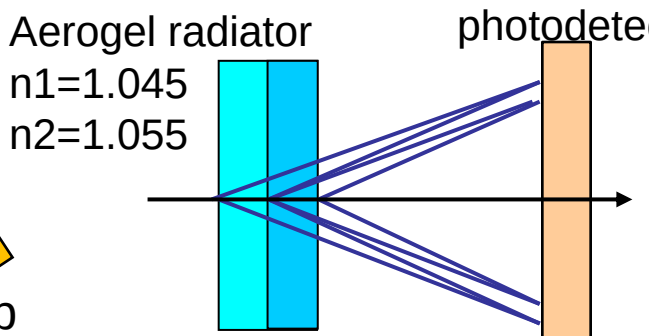


より強度を増したSuperKEKB/BelleII実験を建設中
今年度より加速器試運転開始

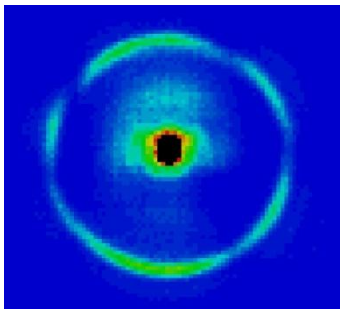
Belle II実験でのPID

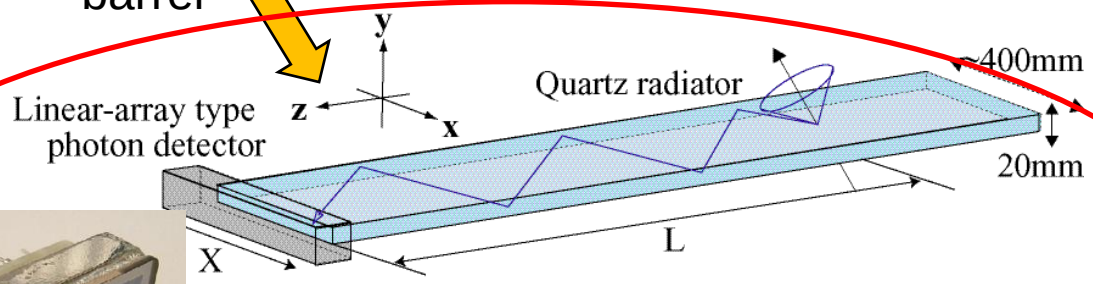
- リングイメージ型チェレンコフ検出器
  - K/π誤識別率：2～5倍少ない

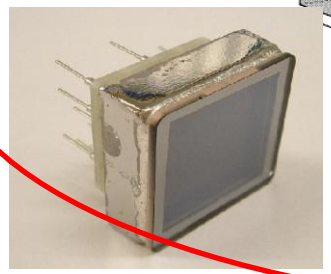




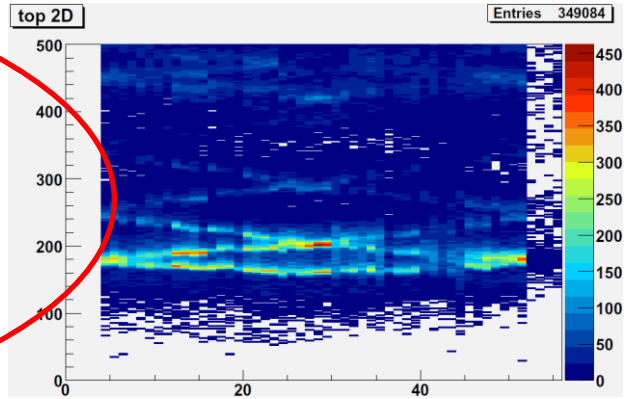
Aerogel RICH







TOP（Time-Of-Propagation）Counter

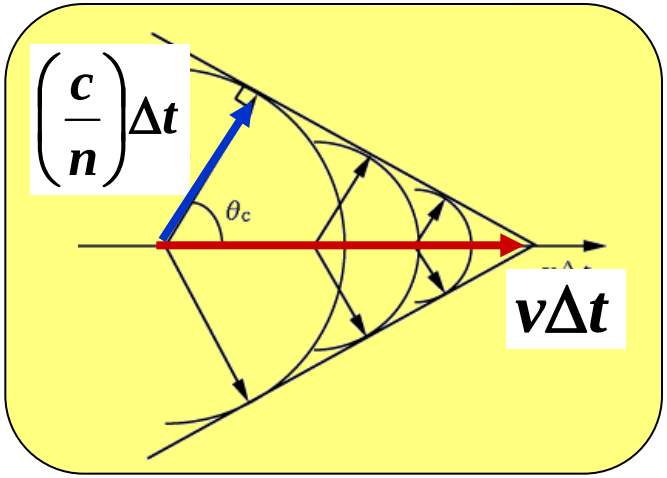


チェレンコフ光を用いた粒子識別

- 粒子識別 ＝ 質量同定
- 運動量と速度→質量 $(p = \beta\gamma mc \sim mv)$
  - 運動量は磁場中の飛跡から正確に測定できる
  - 速度の測定が困難
    - 特に、質量が比較的近く、性質の似ている $\pi^{\pm}$と$K^{\pm}$

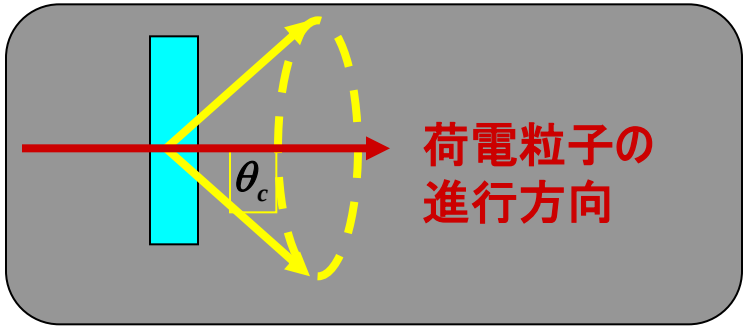
- ***チェレンコフ光***

  荷電粒子が透明な物質中を、
  その物質中での光の速さ:
  c/n（屈折率）より速く進むとき、
  衝撃波としてチェレンコフ光を放射

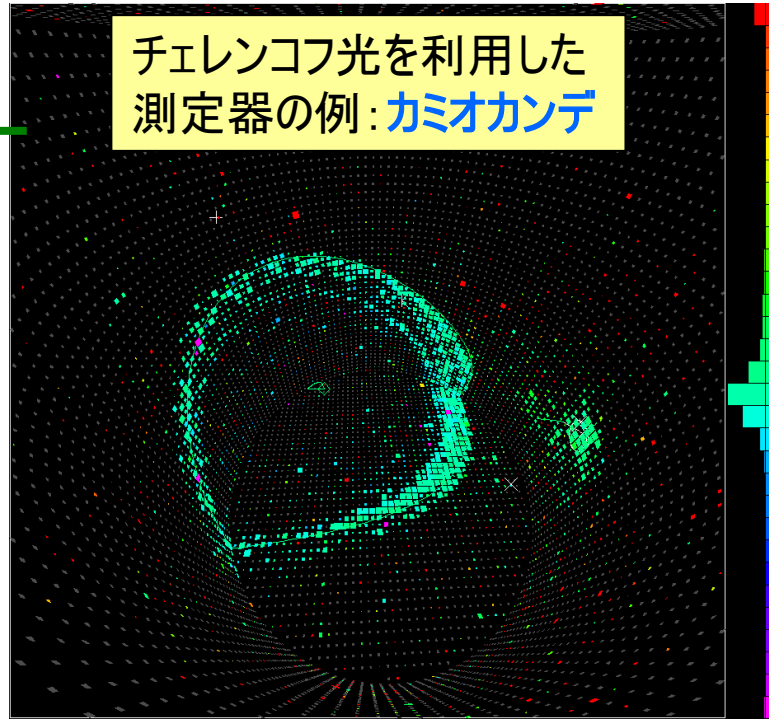


チェレンコフ光を用いた粒子識別(2)

- チェレンコフ放射
  - 荷電粒子の進行方向に円錐状に放射
  - 放射角度: θ_c



$$\cos\theta_c = \frac{\text{真空中の光の速さ(c)}}{\text{屈折率(n)・粒子速度(v)}}$$

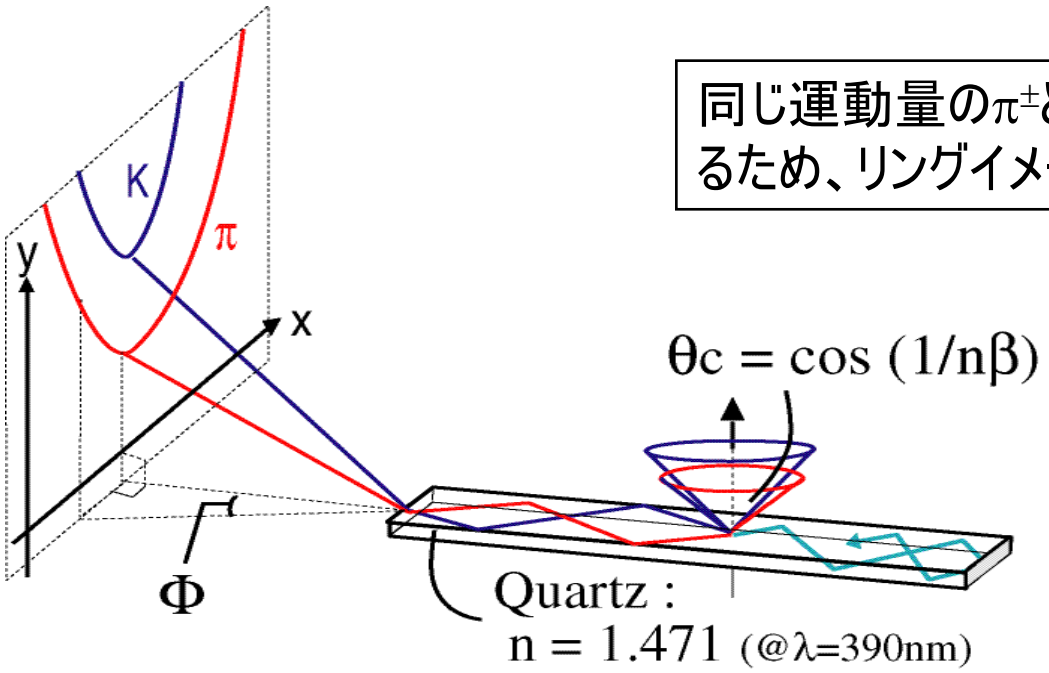


  - リングイメージ(θ_c)から速度が測定できる

→ いかに精確にイメージを撮るか?

TOPカウンター

- 石英を用いたイメージング
  - 石英輻射体で発生したチェレンコフ光を端面まで内部反射(全反射)させ、スクリーン上の20個程度の光の到達点からリングイメージを再構成
  - 光の到達点は光電子増倍管で測定



同じ運動量の$\pi^{\pm}$と$K^{\pm}$では速度が異なるため、リングイメージがずれる。

大きいスクリーンが必要

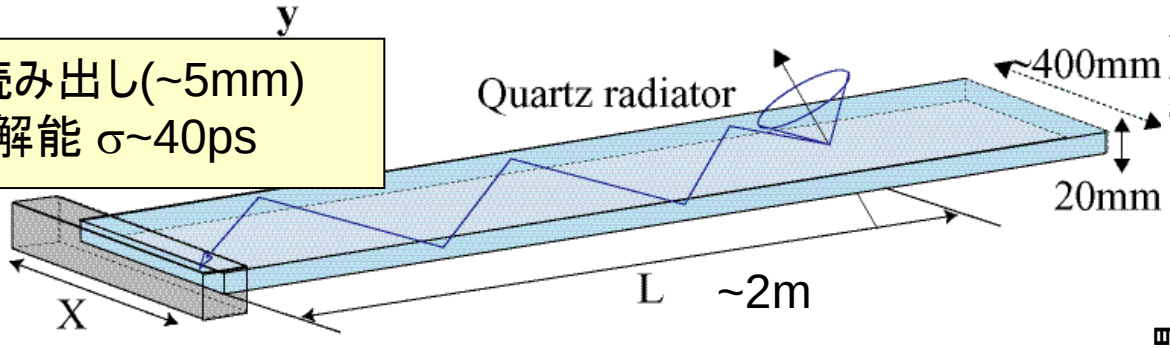
TOPカウンター

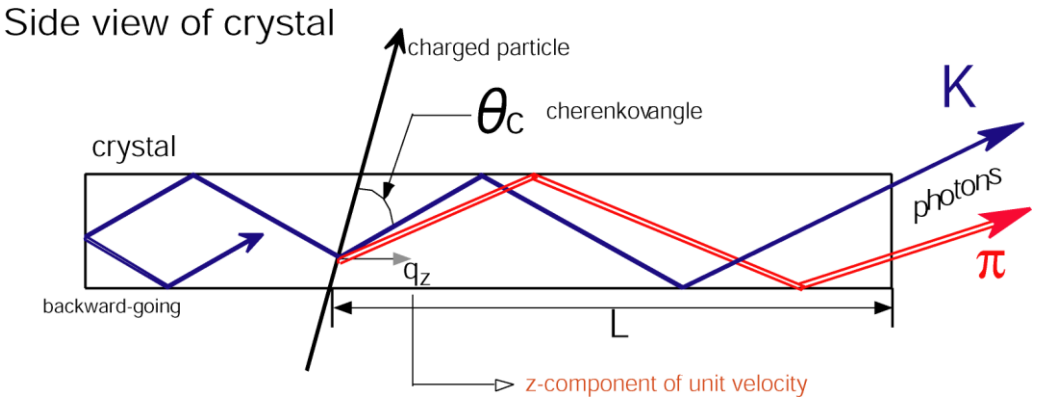
- 2次元位置情報 → 位置+時間
  - コンパクト化に成功

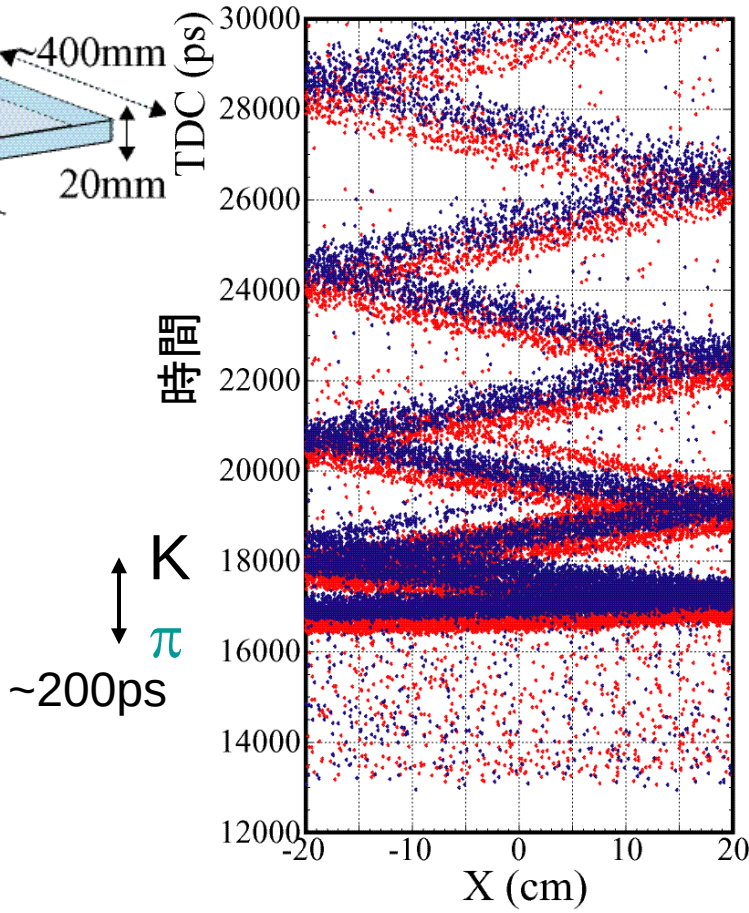
1ps：光の速度で0.3mm

シミュレーション
2GeV/c, θ=90 deg.

1次元読み出し(~5mm)
時間分解能 σ~40ps



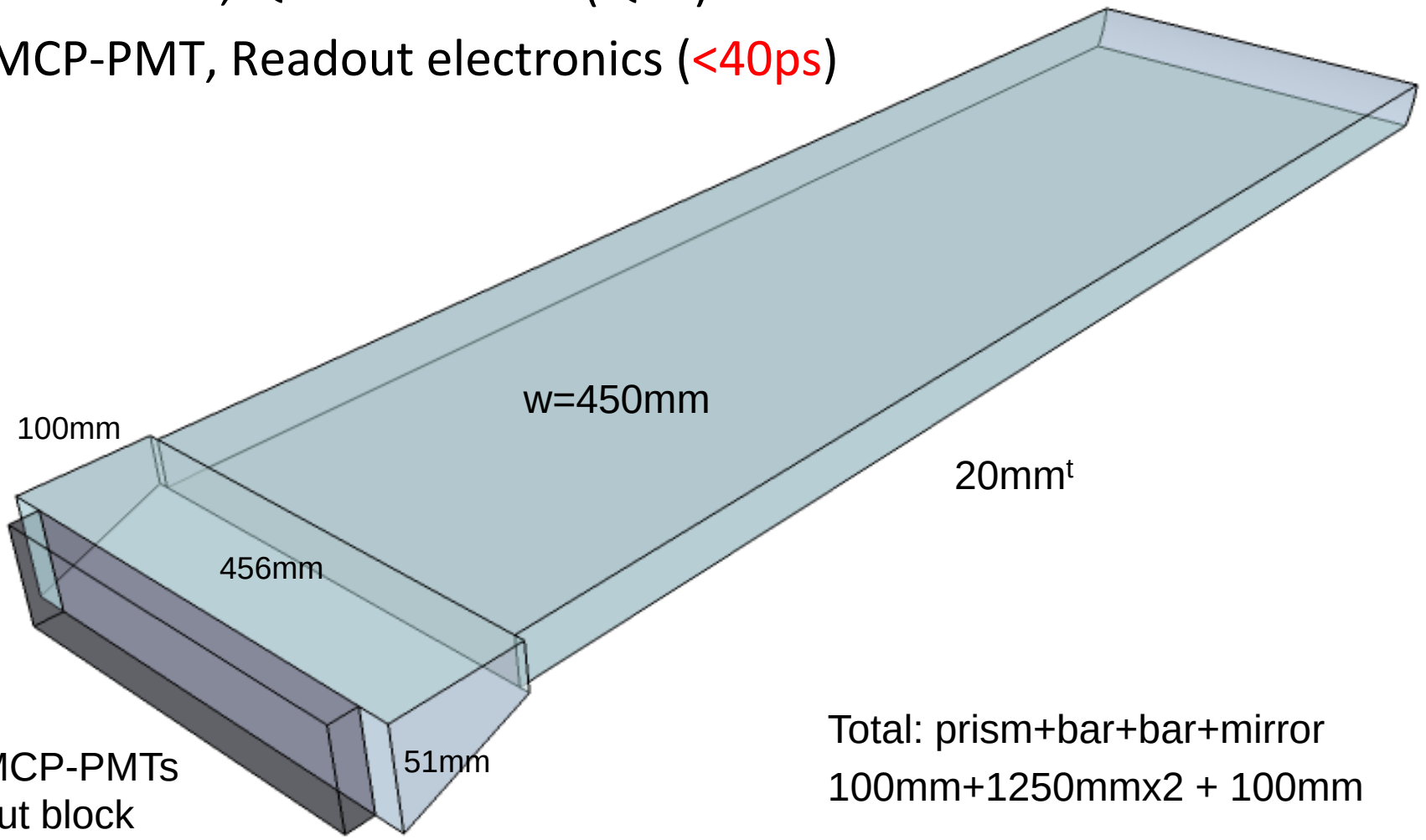




同じ運動量ではリングの開きが異なる
→ 伝播距離(=伝播時間が異なる)

TOP components

- Quartz (flatness:10λ, roughness:5A)
- Mechanics, Quartz Bar Box (QBB)
- MCP-PMT, Readout electronics (<40ps)



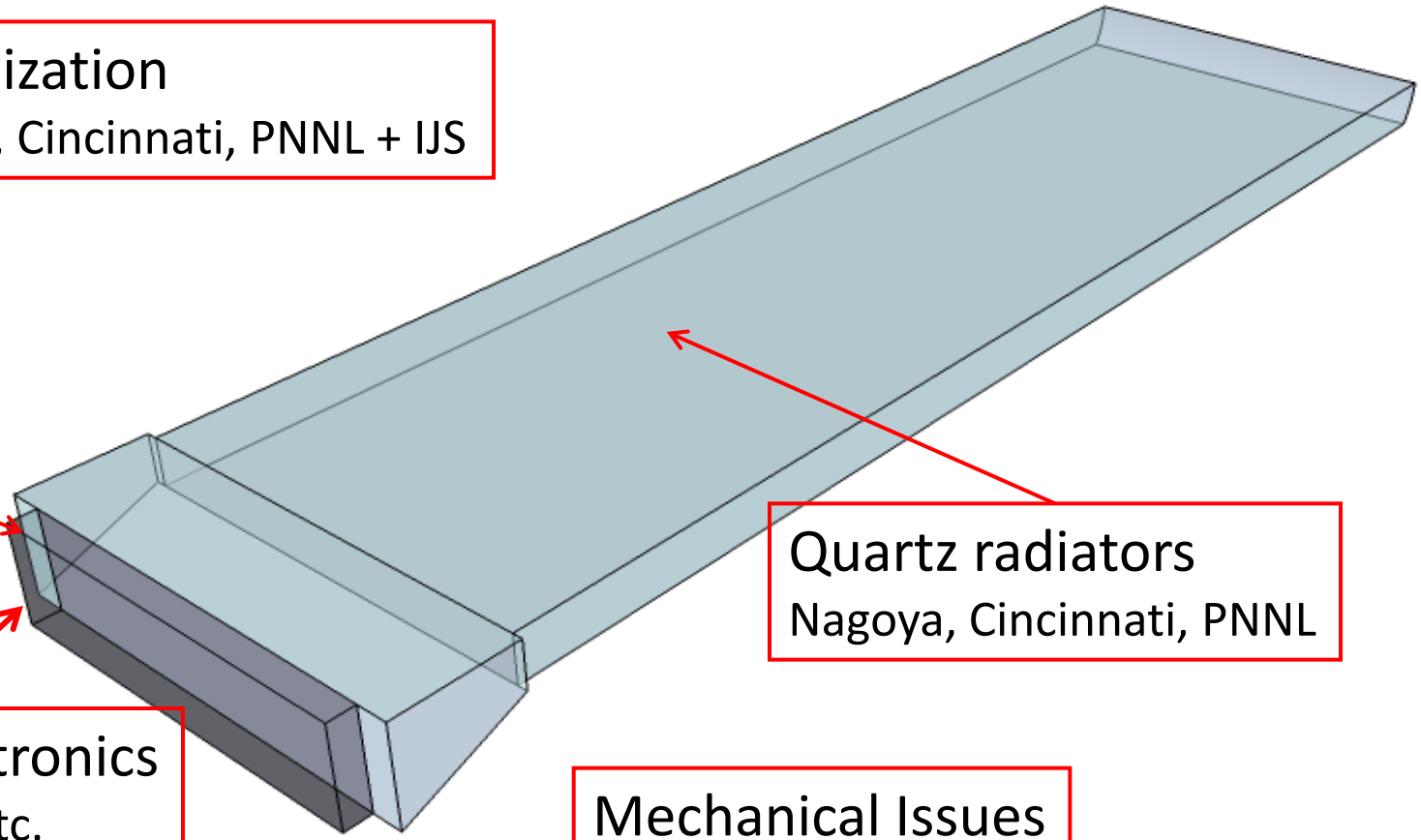
16x2 MCP-PMTs
Readout block

Total: prism+bar+bar+mirror
100mm+1250mmx2 + 100mm

Belle II TOP collaboration

Design optimization
Nagoya, Hawaii, Cincinnati, PNNL + IJS

MCP-PMT
Nagoya



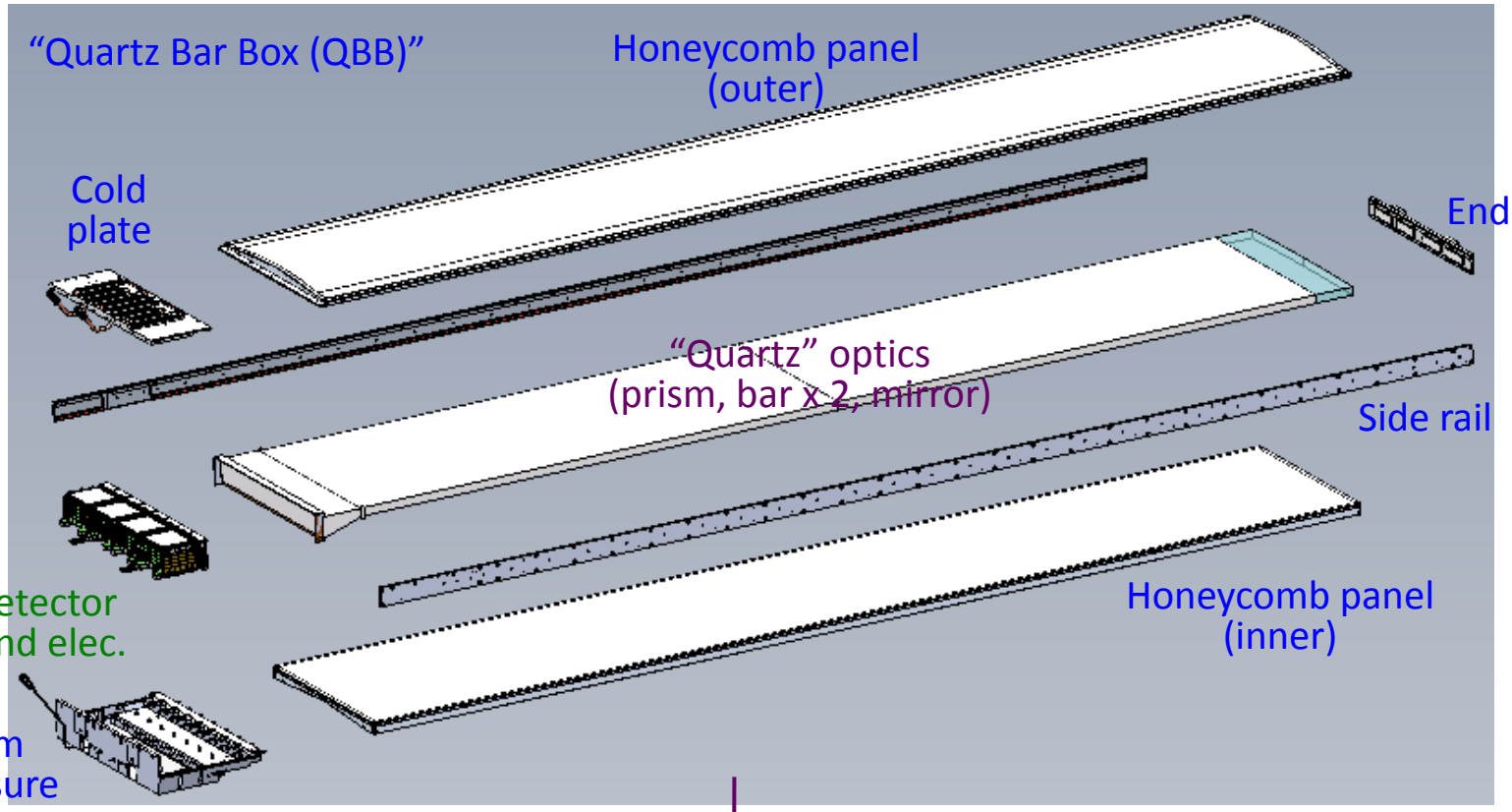
Quartz radiators
Nagoya, Cincinnati, PNNL

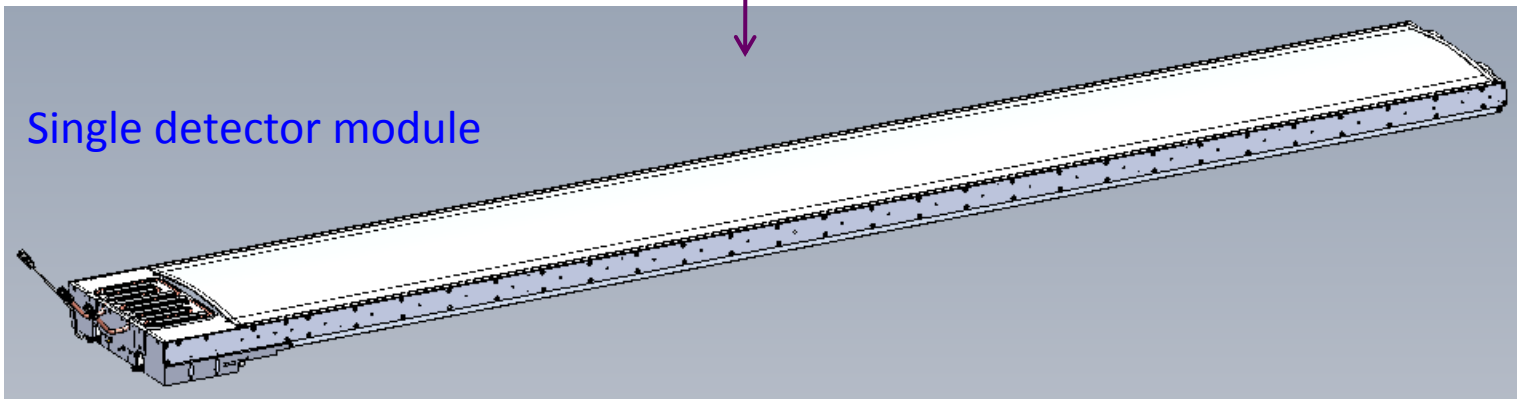
Readout Electronics
Hawaii, PNNL, etc.

Mechanical Issues
Nagoya, KEK, Hawaii

Software
IJS, Nagoya, Hawaii

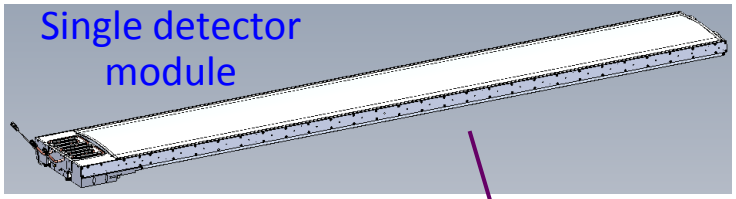
Single detector module

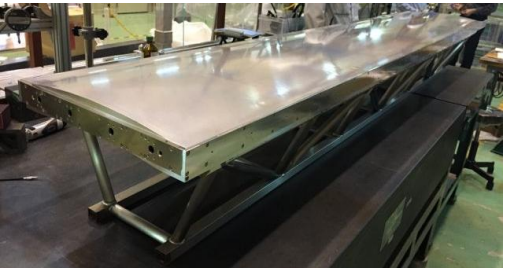




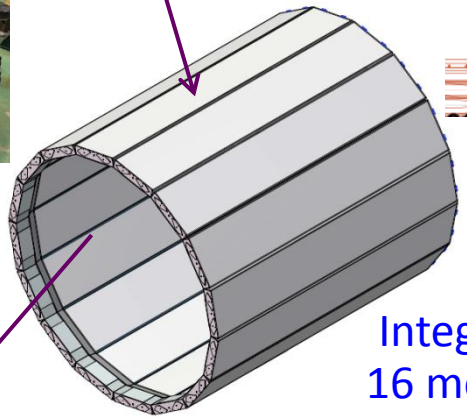
Module integration

Single detector module

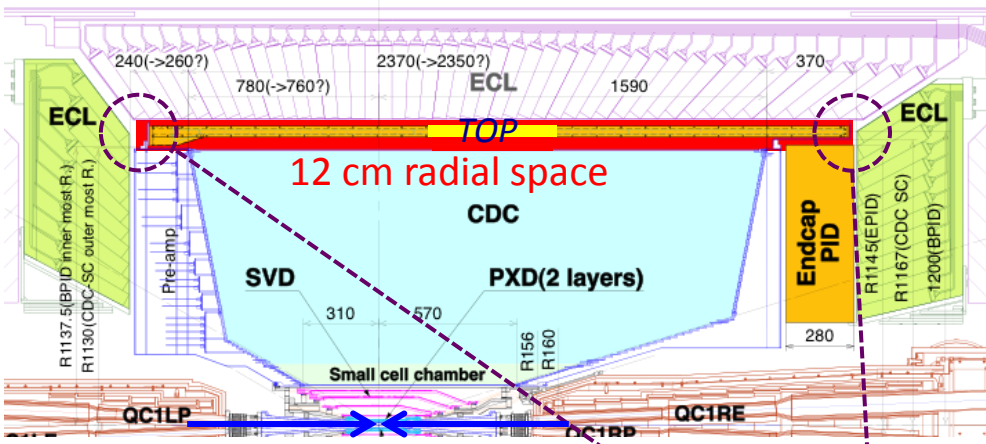


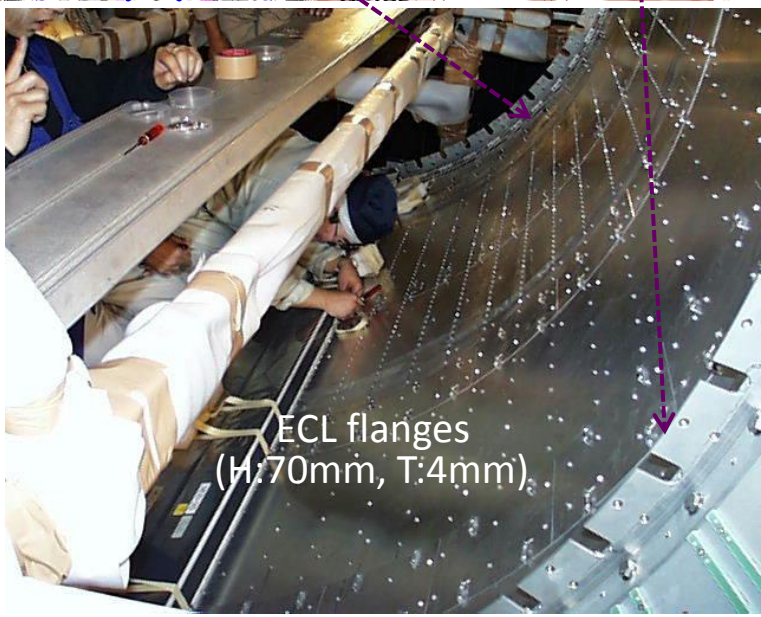


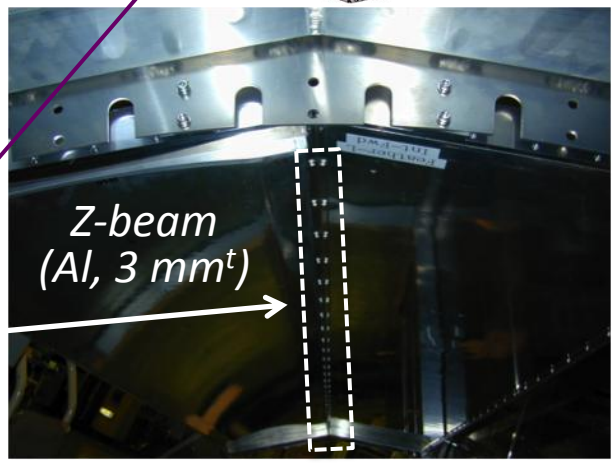
QBB with "Strong Back"



Integrated 16 modules

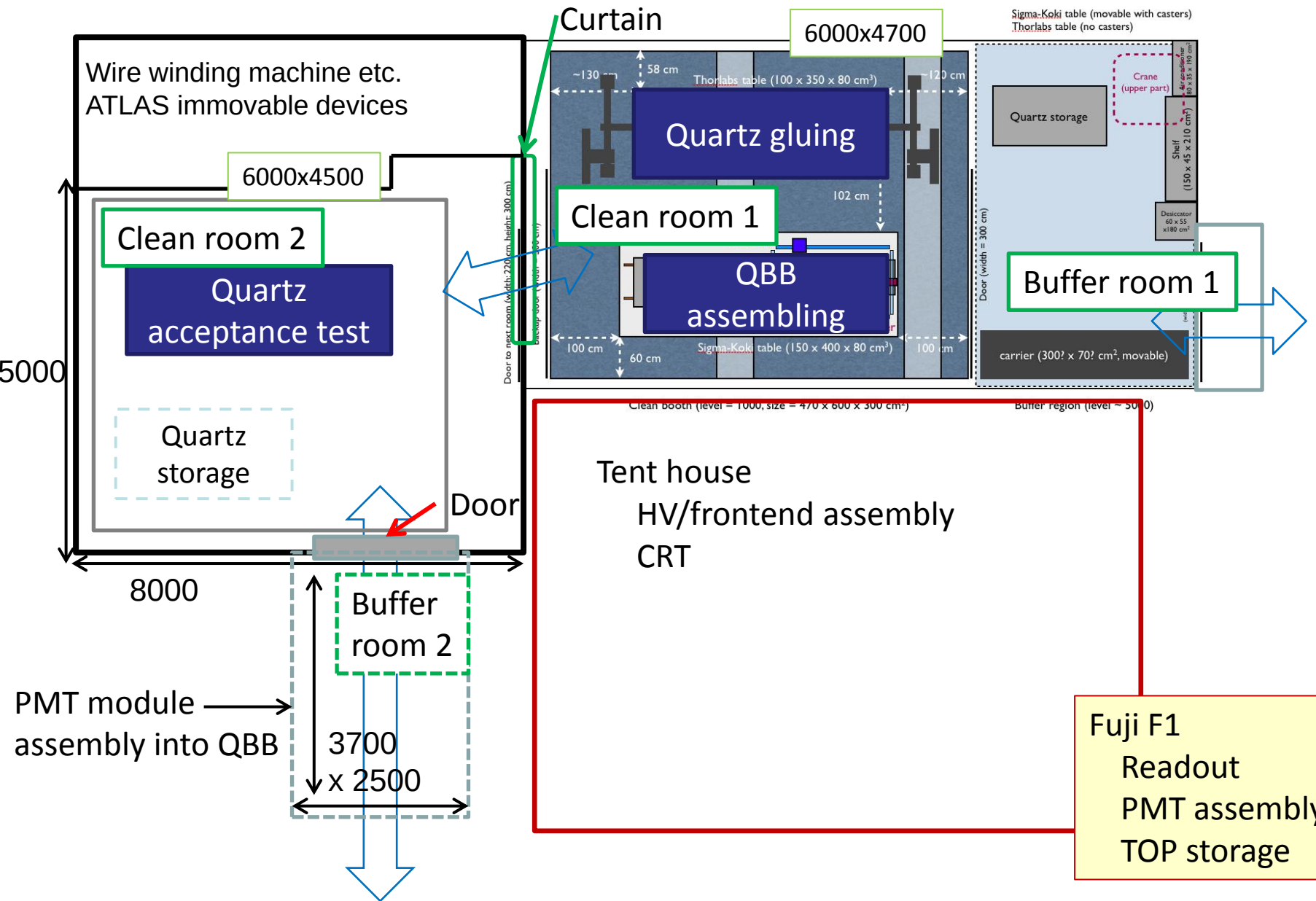






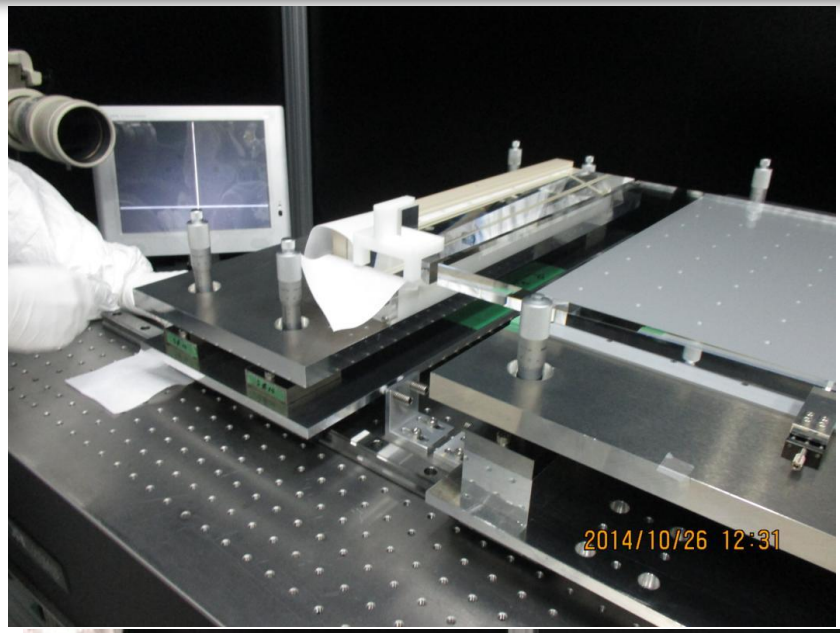
QBB design requirement:
- rigid support with low material budget
  (max. sag ≤ 0.5 mm based on MC)

Module production at KEK Fuji



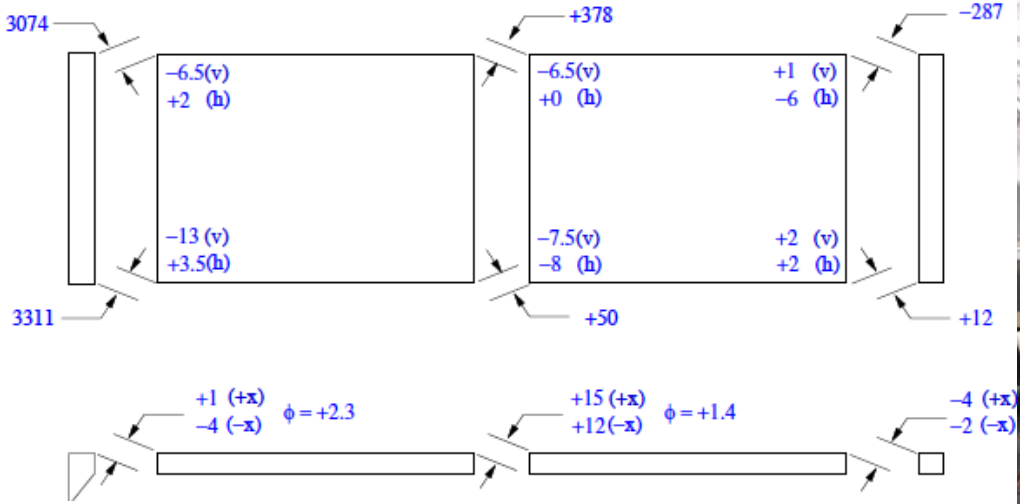
Quartz Alignment

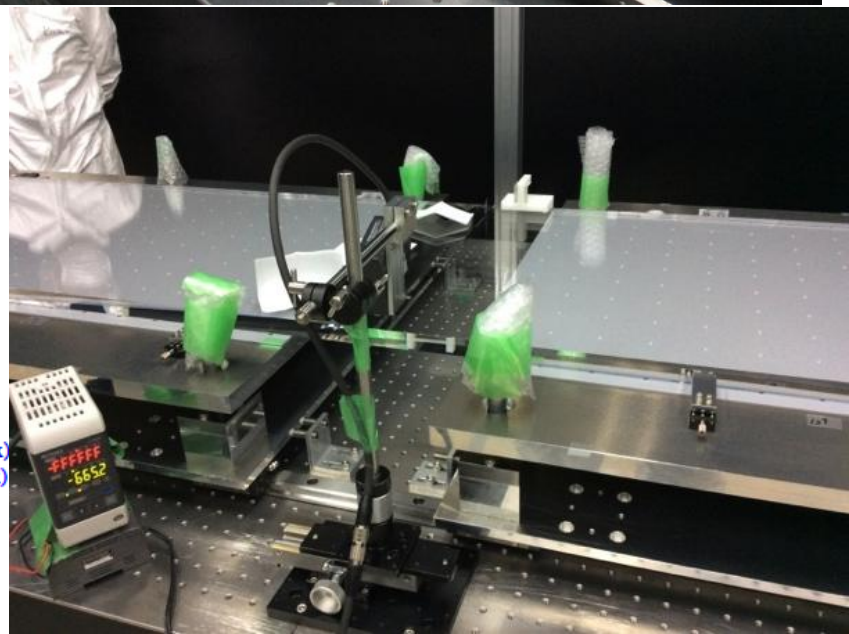
- Quartz alignment with Nagoya gluing stage, autocollimator, and laser sensors, with procedures based on dry runs.



Module: 01 Units: microns/arcseconds Angle sign convention: AC at prism (+z) side

prism: 449006 base bar: OOW 3 front bar: OOW 1 mirror: SN002

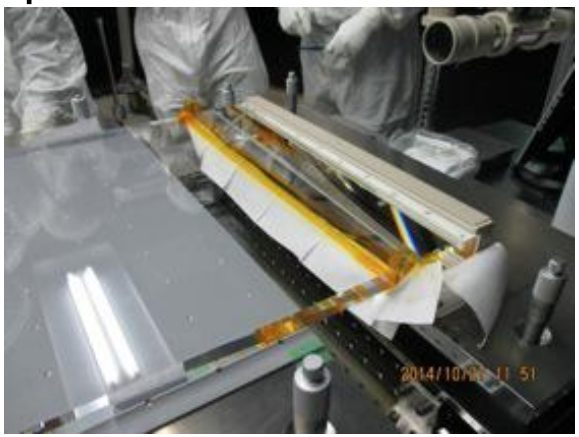




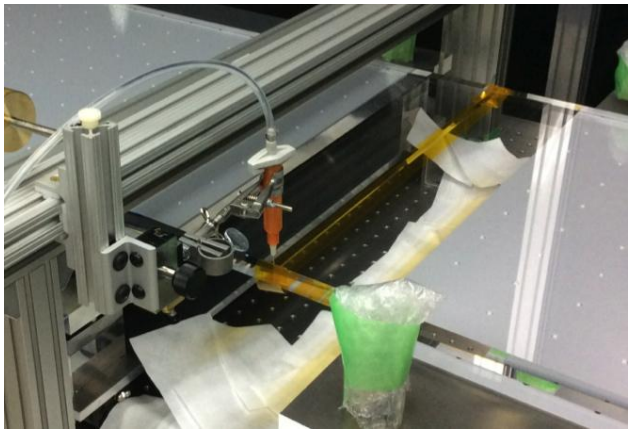
Quartz Gluing

- Gluing procedure is based on dry runs + some R&D for details
  - Taping (+ curtain for prism-bar joint)
  - Centrifuge for eliminating bubbles
  - Glue injection with a trolley
  - Cleaning, curing, …

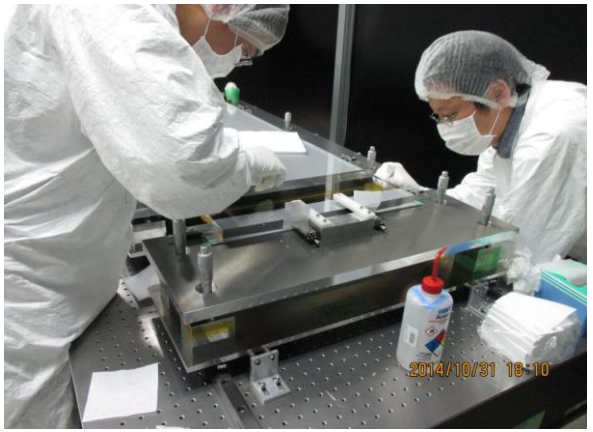
prism-bar



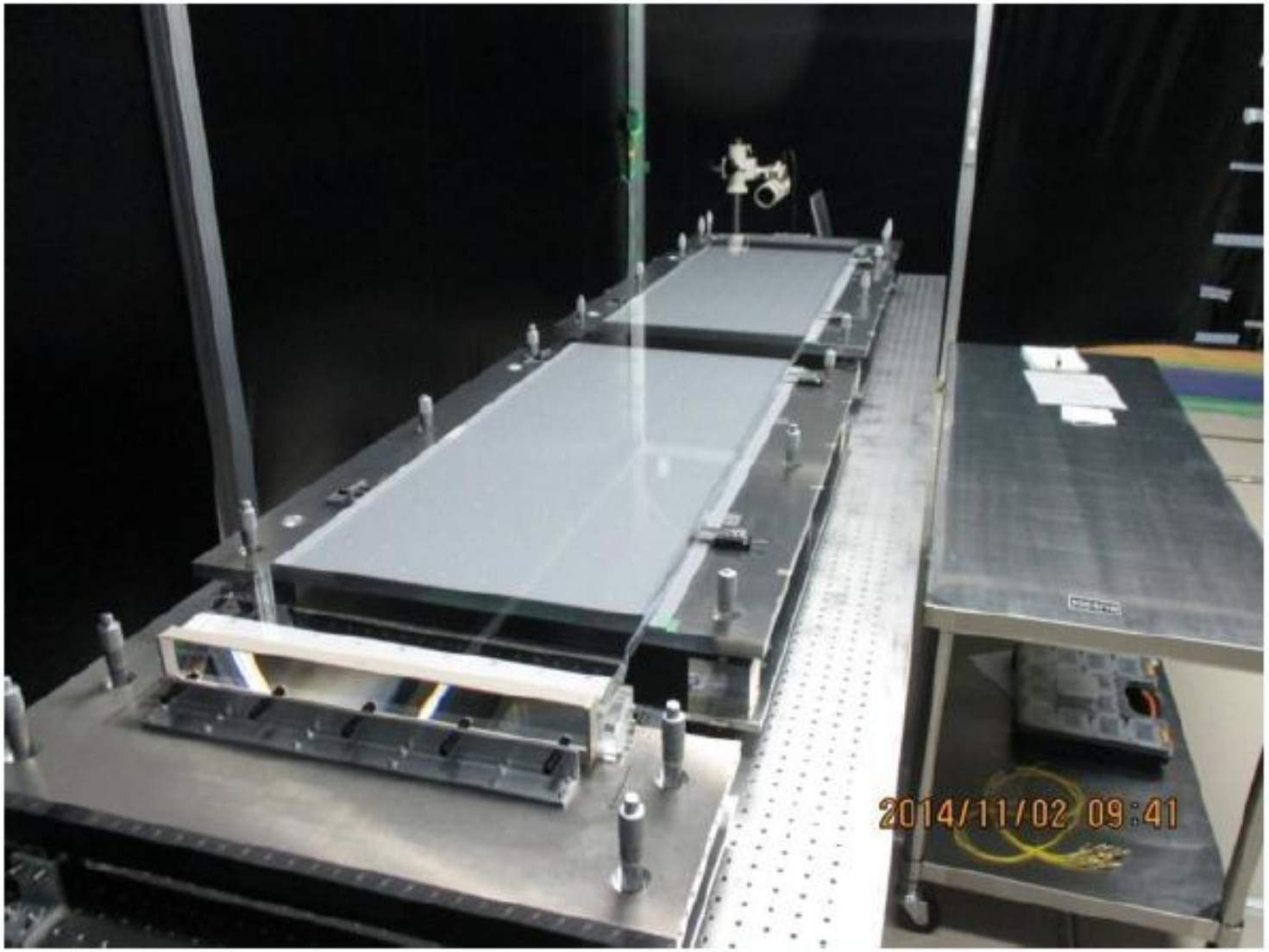
bar-bar



Bar-mirror

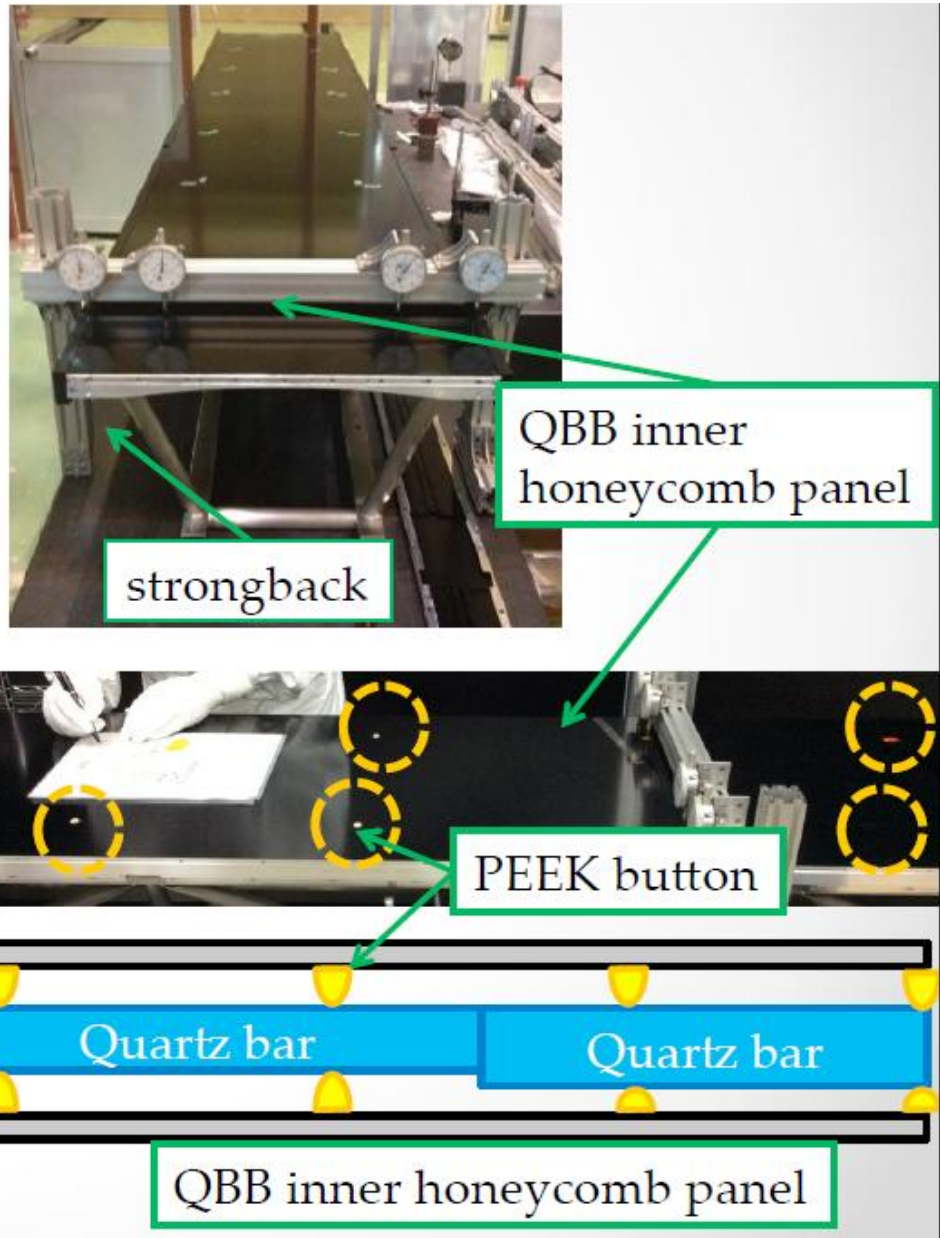


Module 01 Glued Optics !



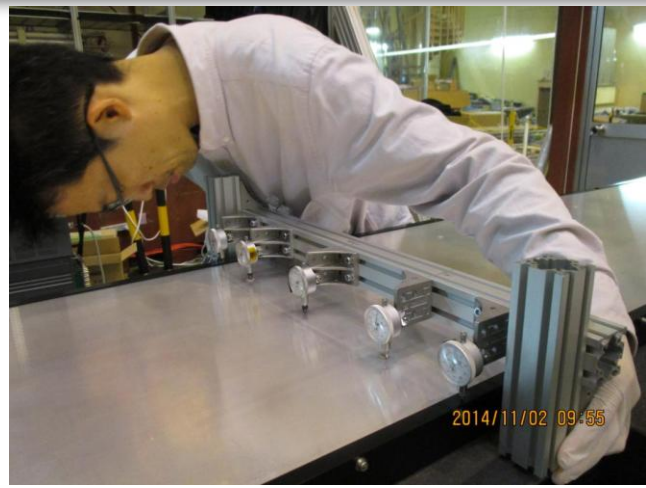
QBB preparation

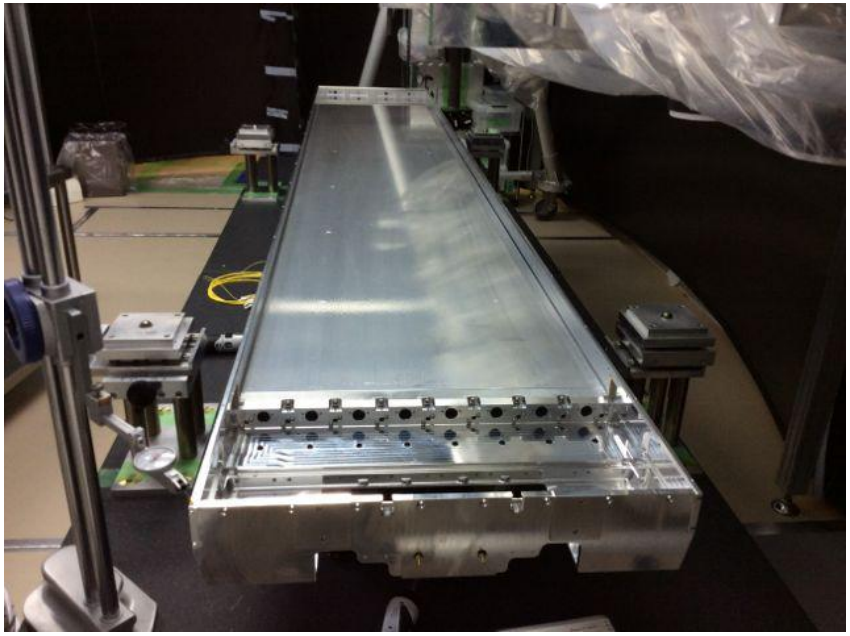
- Honeycomb panel attached to Strong back.
  - Put on stone table
  - Flatness is ~50micron.
- PEEK buttons are glued.
  - 14 buttons/panel
  - Considering height difference of dummy glass
  - ~30micron precision

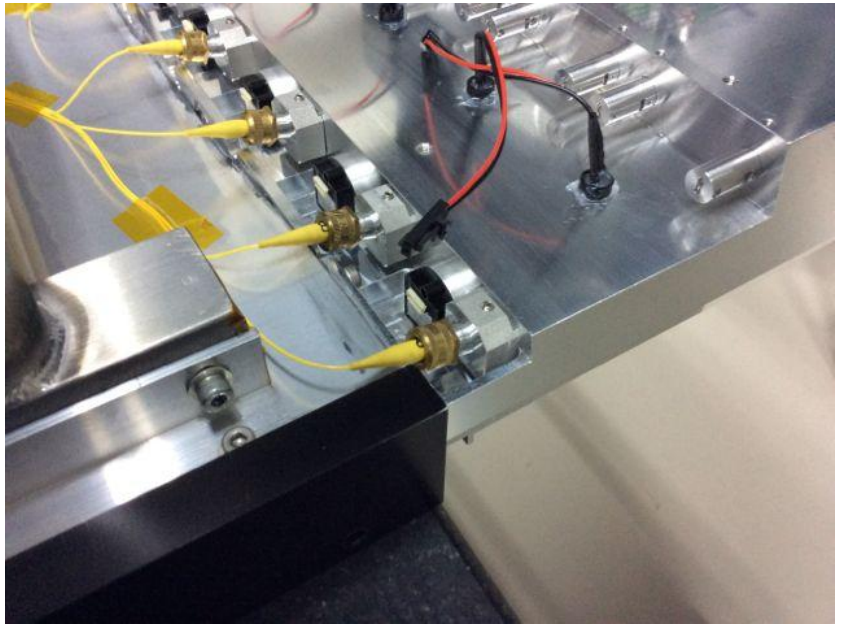


QBB preparation

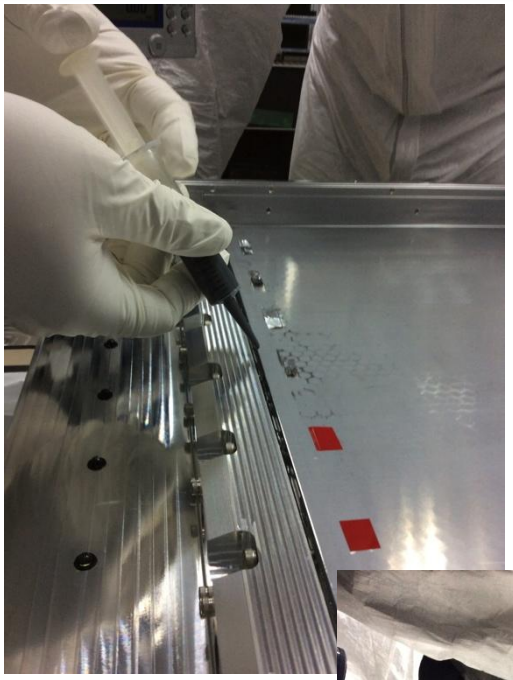
- Measure flatness of the honeycomb panels.
- Attach strong-back, tune and test stability.
- Assemble enclosure
  - Align inner-panel and enclosure < 0.06mm.
- Install LEDs, cameras, spring holders, fiber holders

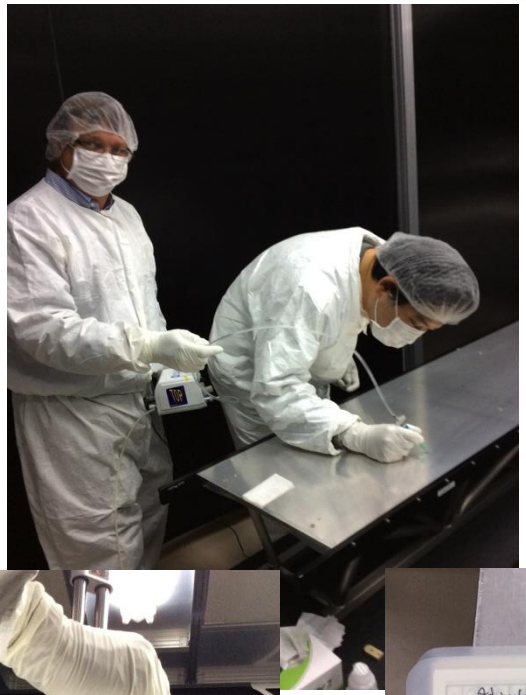


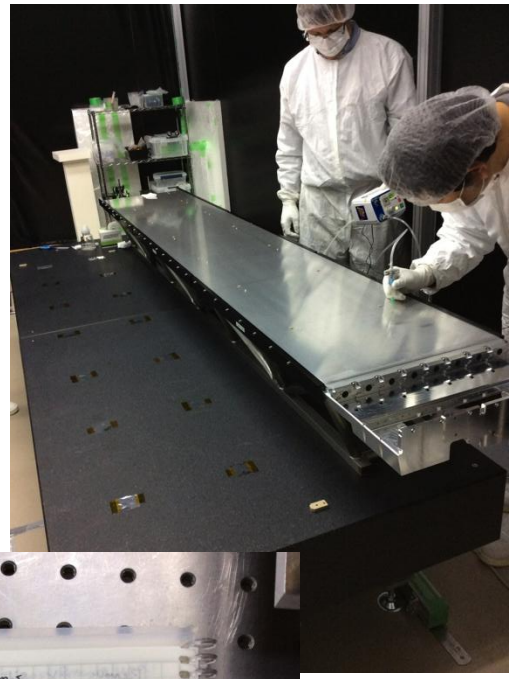


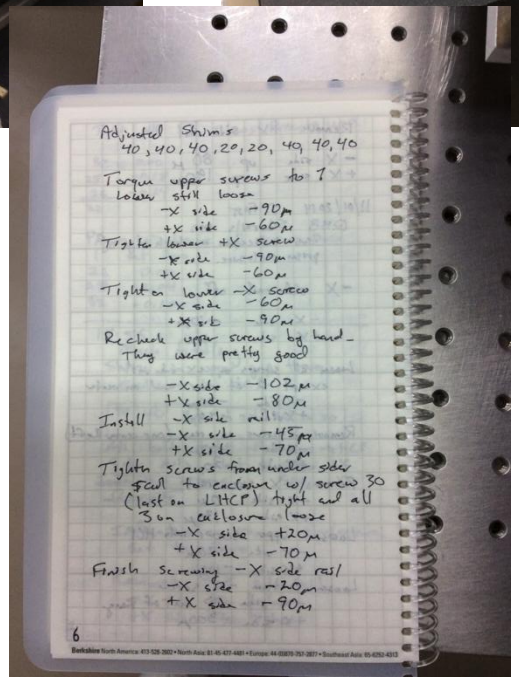


More Pictures from QBB Preparation



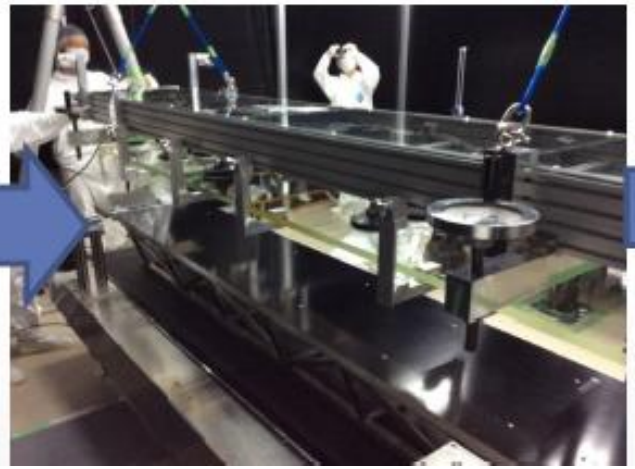


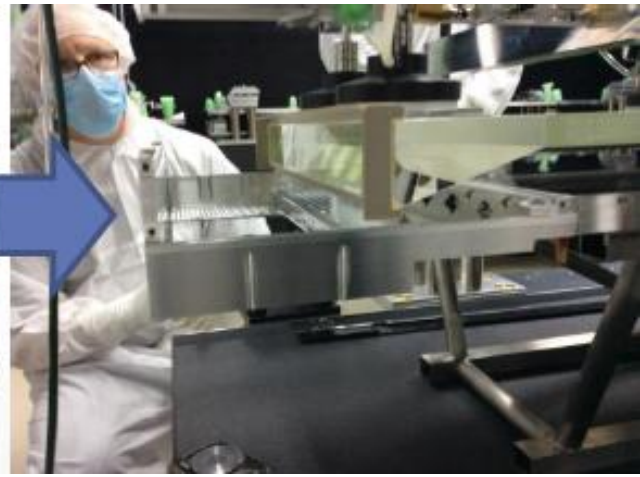




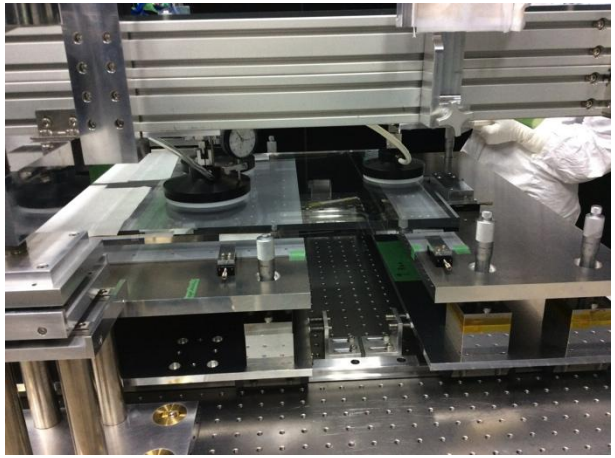
Lifting jig operation

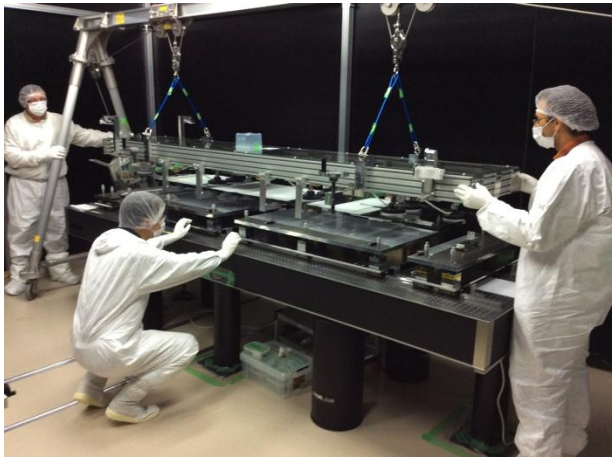
- Successfully lift up dummy glass from gluing stage to QBB stage
  - Need to refine crane path, flooring
  - Small improvement to make easier operation
- Touch down to QBB
  - Need to check clearance
  - Need many jigs to guide quartz
  - Check assembling procedure after cups off

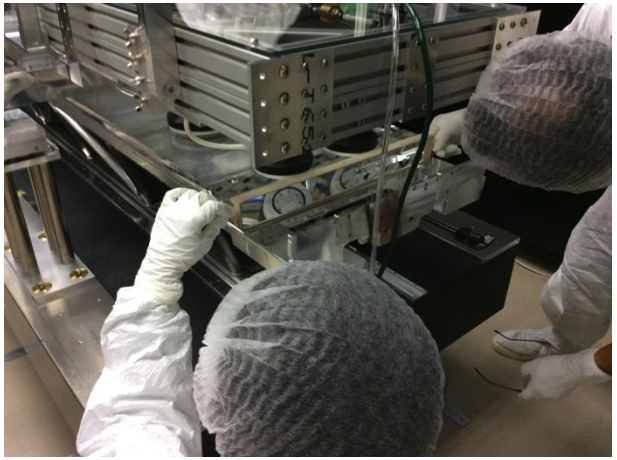


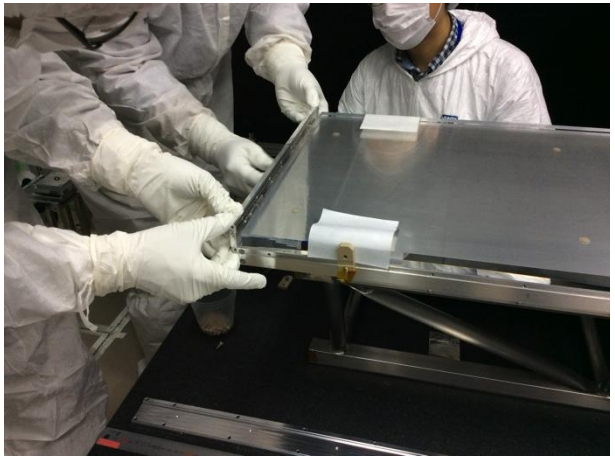


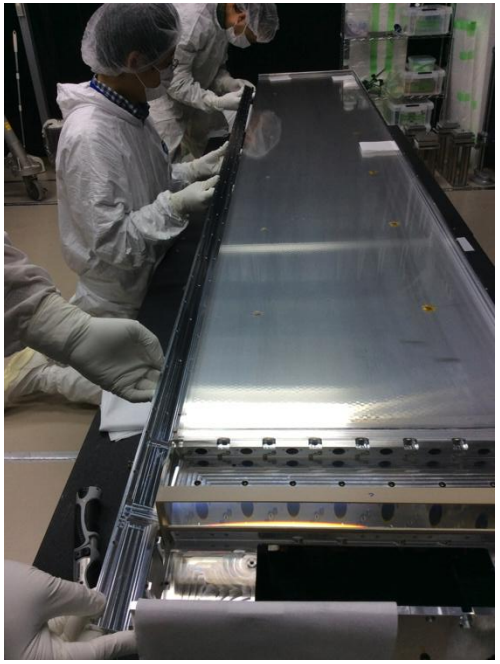
Installation of Optics to QBB



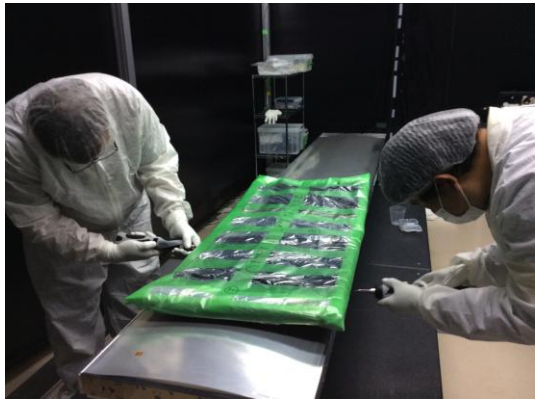


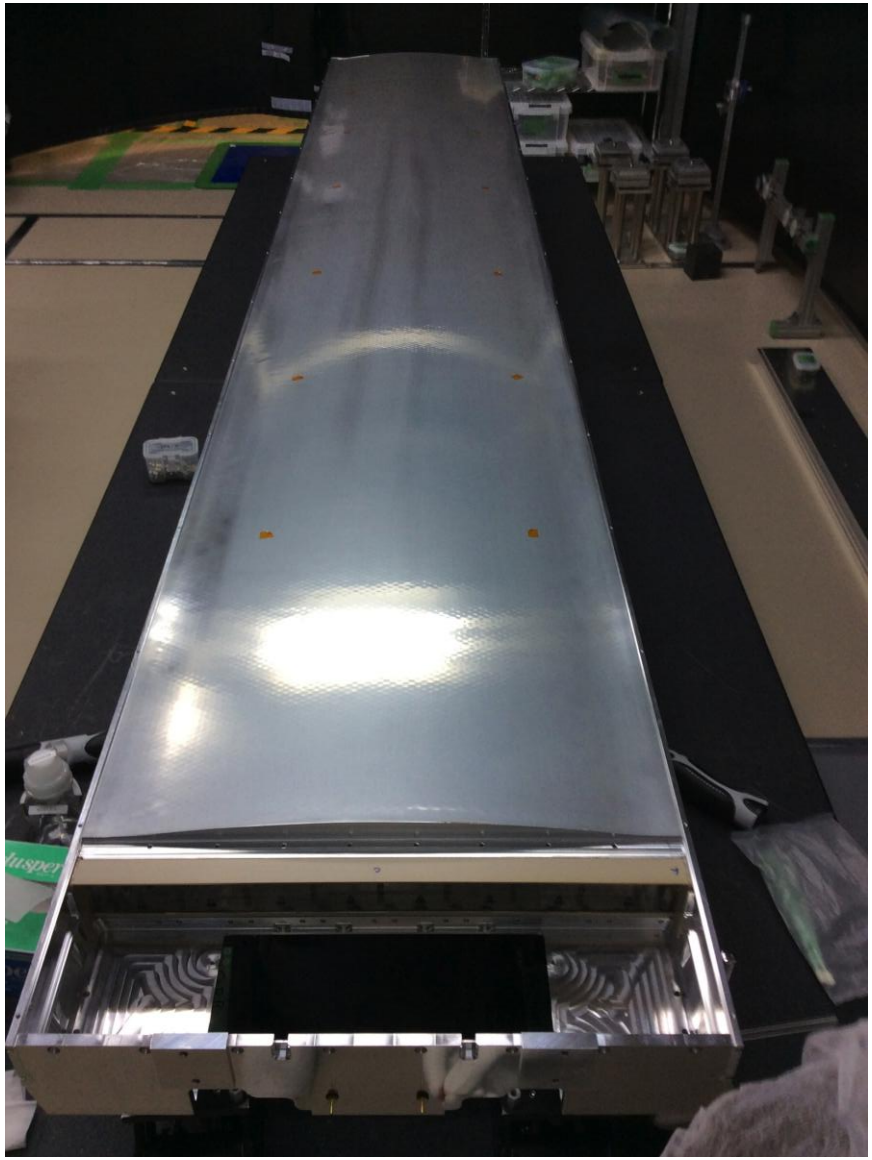






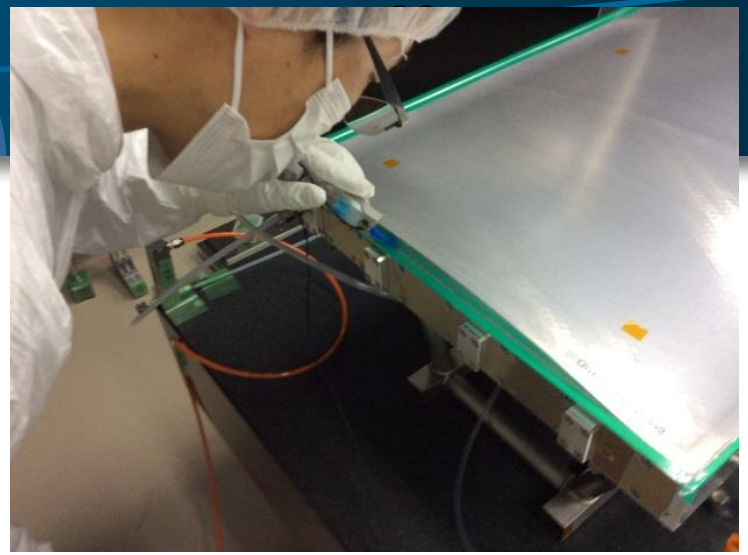
Completion of Optics + QBB (Nov.10)

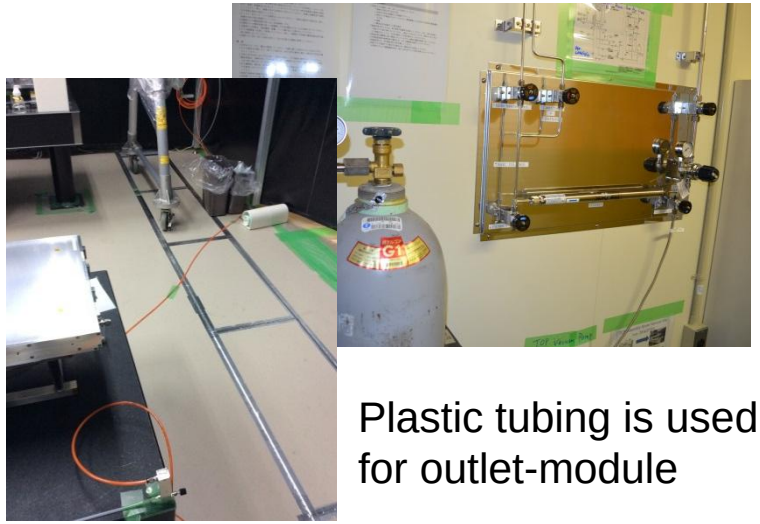




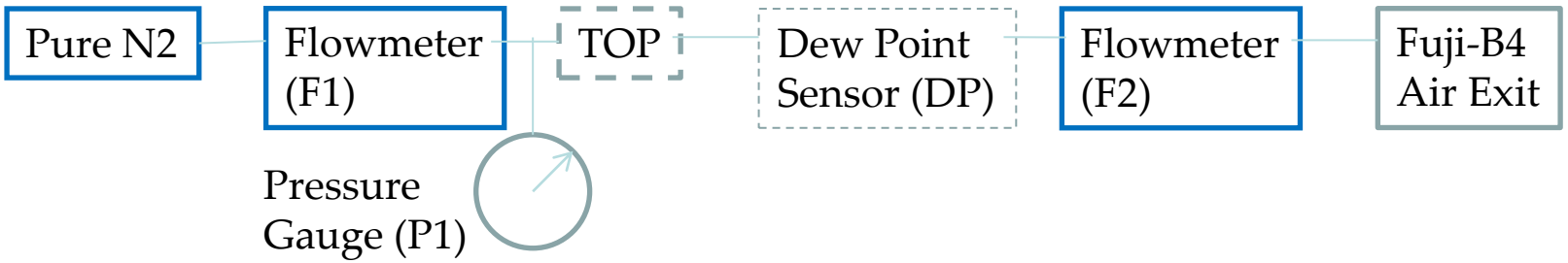
Gas sealing

- QBB panels, side Rails, FWD endplate, prism enclosure were sealed with Si glue.
- Tested with Restek Electronic Leak Detector + Pure N2 (& G1 Ar)
  - Significant leaks were found in the prism enclosure through the mounts for CCD cameras, LED, fibers and others (fixed now).
- Started to flow pure N2, and measure dew point.
  - < -51 degC. (34.31ppm) achieved
  - Target is - 60 deg (11 vol.ppm) with the inlet flow rate of 0.5L/min. and pressure < 1kPa.

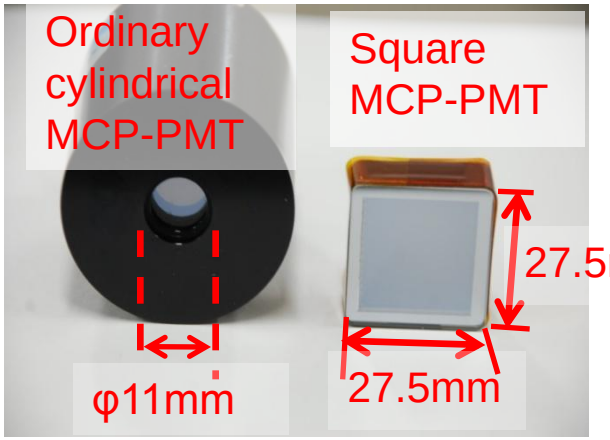




Plastic tubing is used for outlet-module

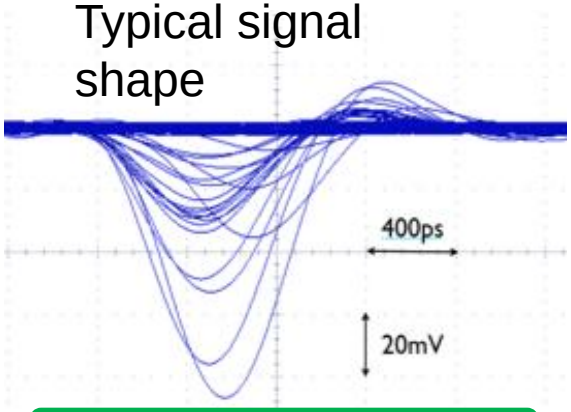


MCP-PMT

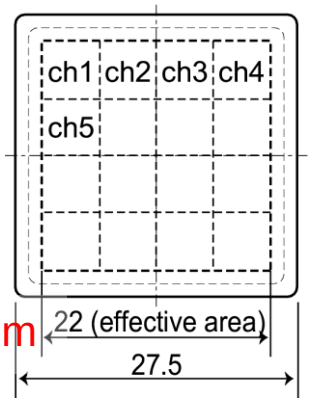


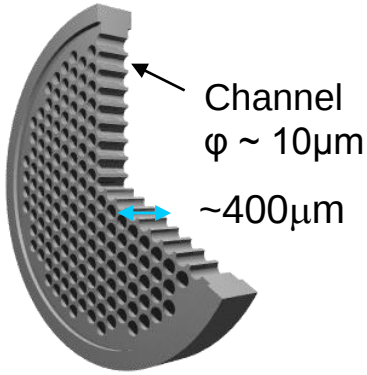
Co-development with
Hamamatsu Photonics K.K.

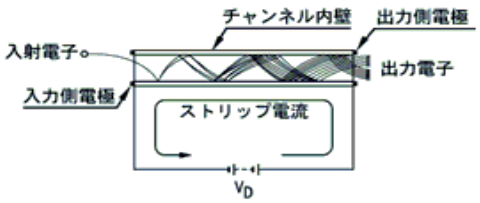
Typical signal shape



Single photon irradiation





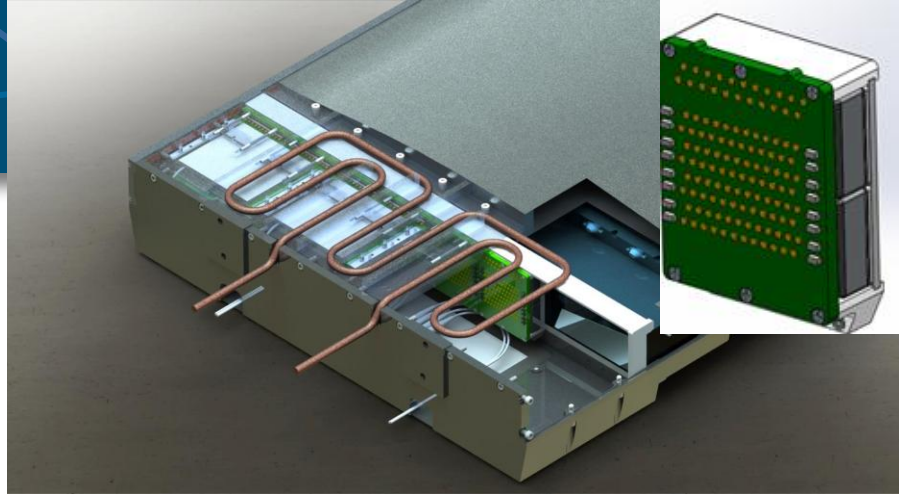


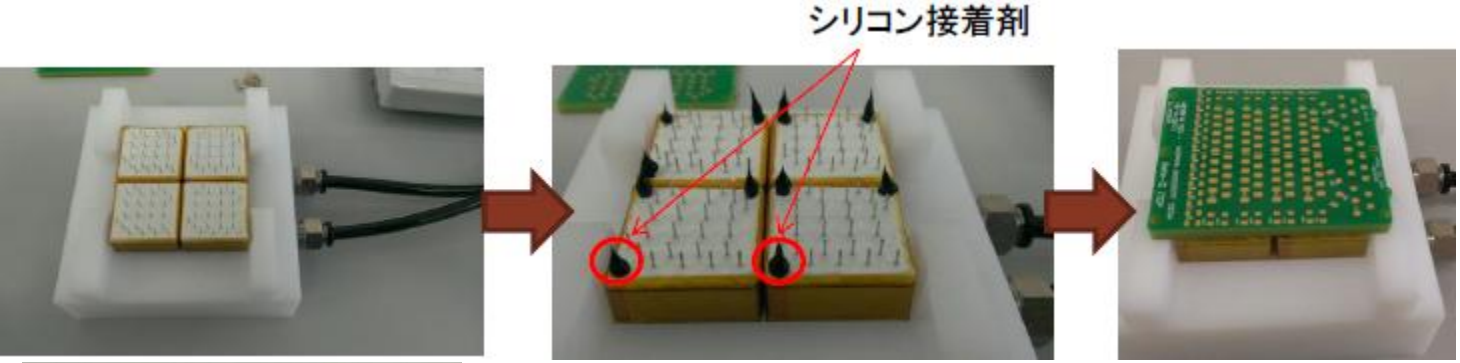
MCP(Micro channel plate)

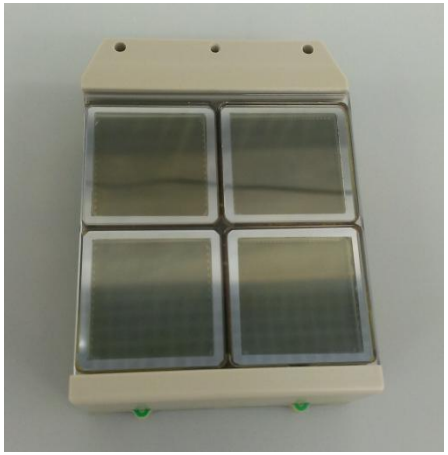
Catalog spec	
Photo-cathode	Enhanced multi-alkali (>28% QE at peak)
MCP Channel ϕ	10μm
MCP bias angle	13°
MCP thickness	400μm
MCP layers	2
Al protection layer	On 2nd MCP
Anode channels	4 × 4
Sensitive region	64%
HV	~ 2500 – 3500 V

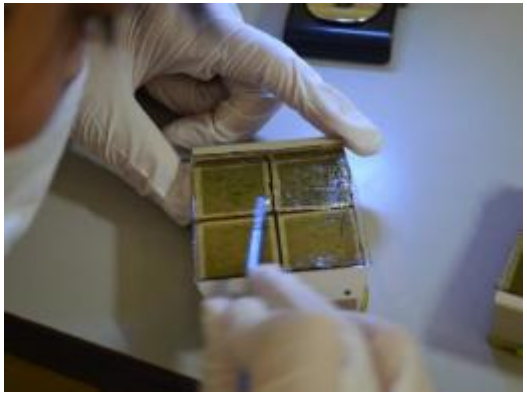
PMT module

- 4 MCP-PMTs assembled into one module
  - Fixed by silicone glue on optical filter using vacuum chuck

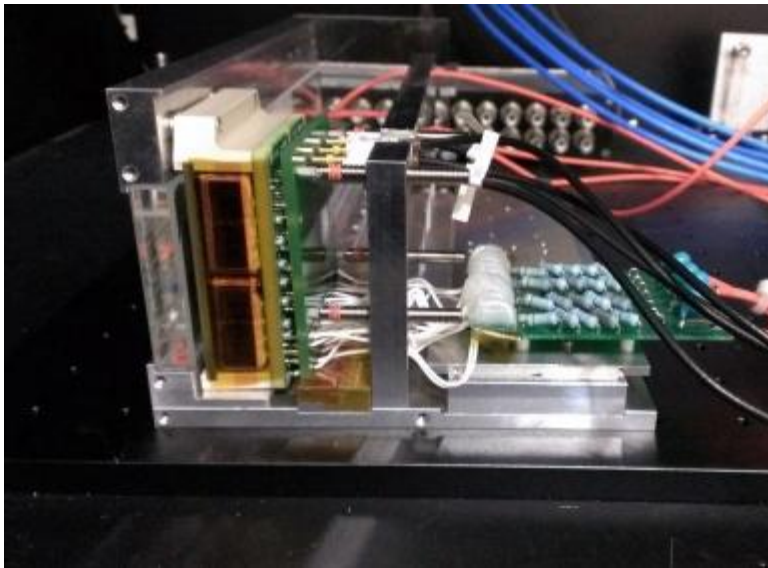






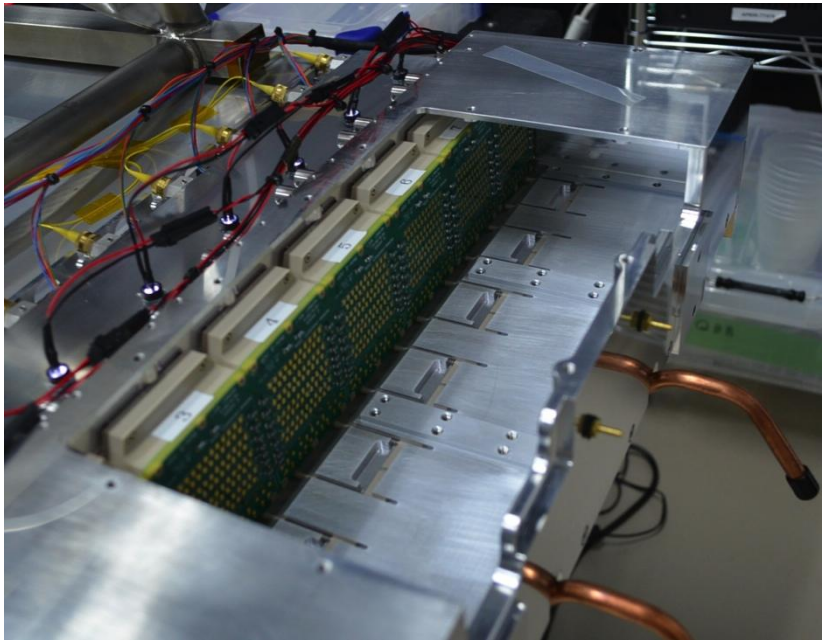


HV test



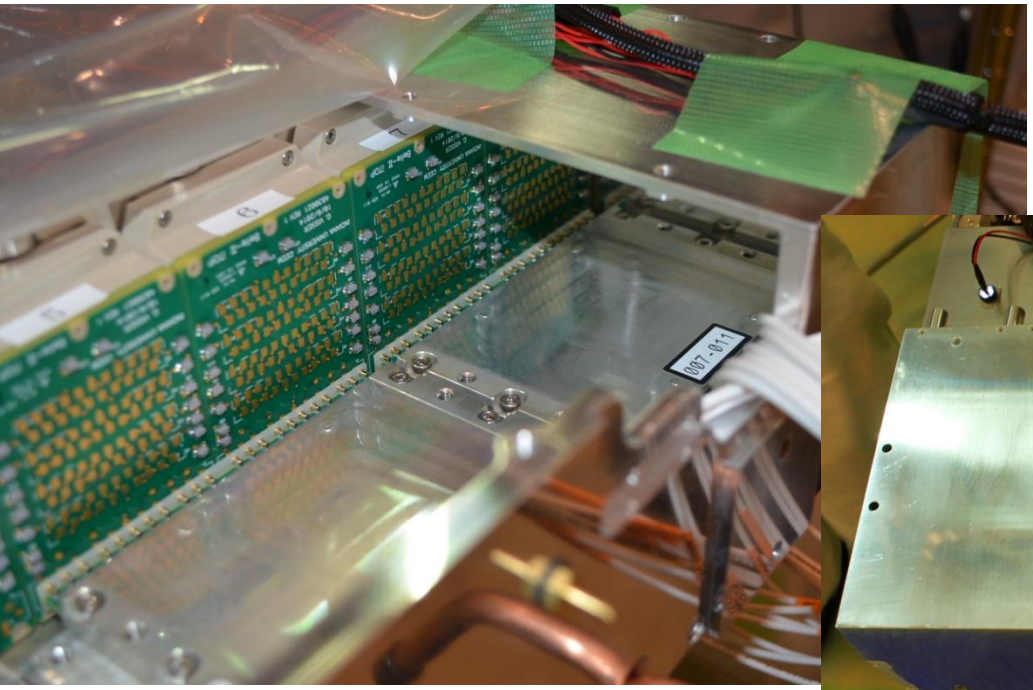
PMT module mounting

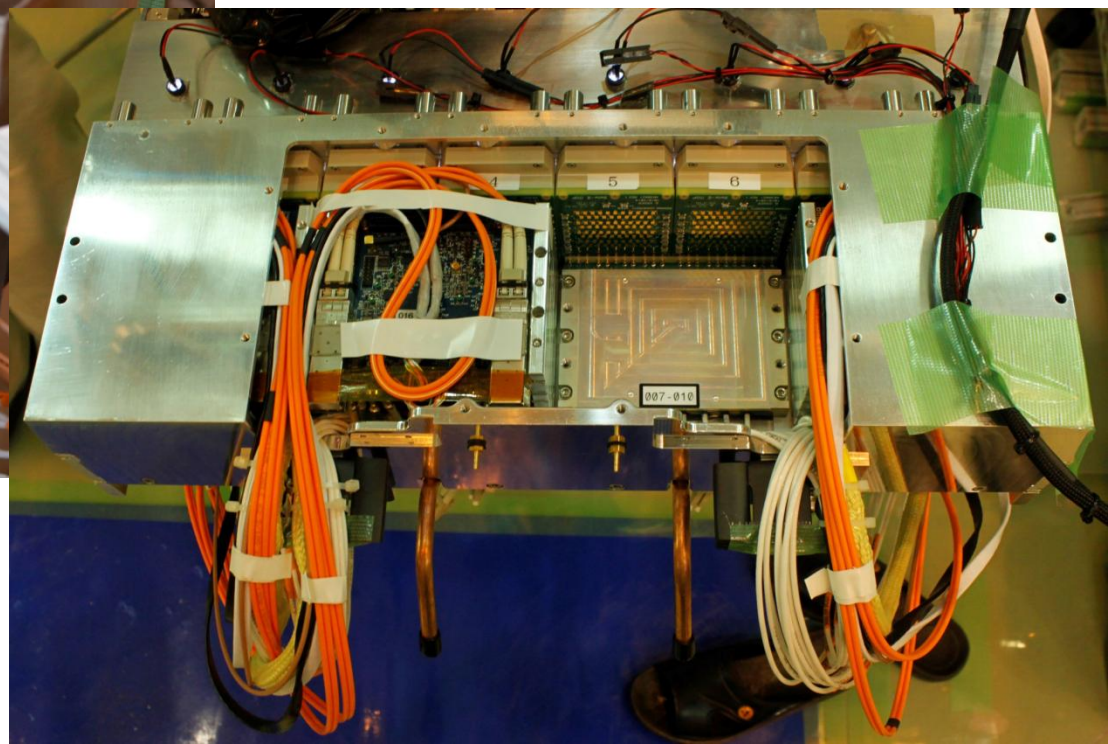
- After PMT module assembling and Silicone cookie preparation, PMT modules are mounted into the TOP module.
- Goodness of optical contact is checked by CCD camera image.
- Successfully done all modules after small modification.



HV board/front end mounting

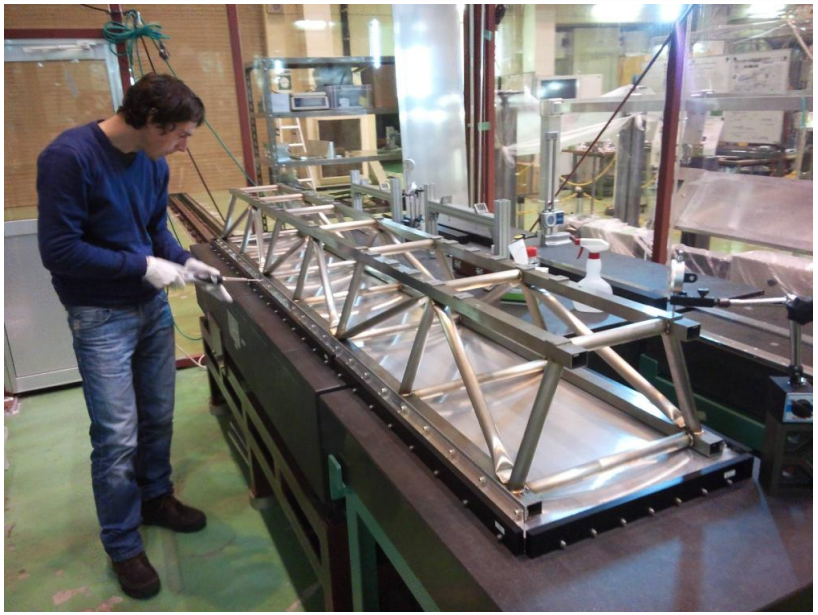
- HV boards and front end elecs are mounted at buffer2, successfully
  - Using temporal shims between HV board and backend of prism enclosure
  - Will improve cable fixture during the installation





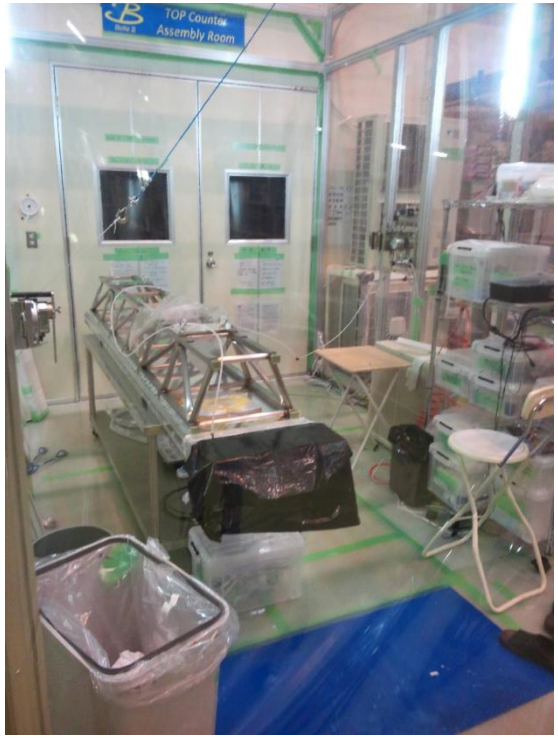
Module02

- Glue/assemble from March.19
  - With updated procedure
- Quartz alignment/glue went rather smoothly.
  - Made new technique for glue joint taping
  - Still weak index fluctuation appeared, but much improved from module01
- QBB flatness and button glue was done within the targeted tolerance (20~30μm).
- Need to update the procedure further



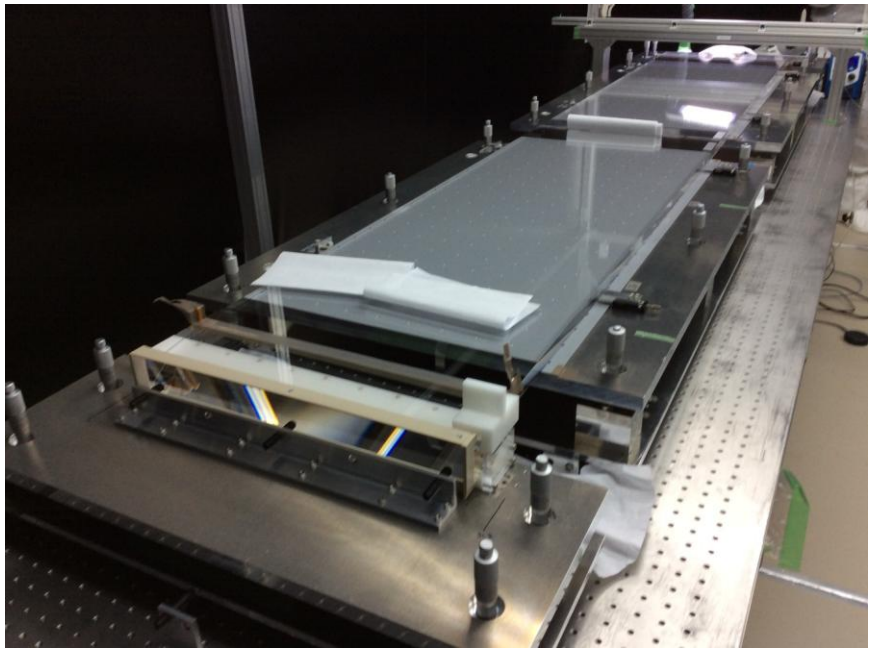
Module02

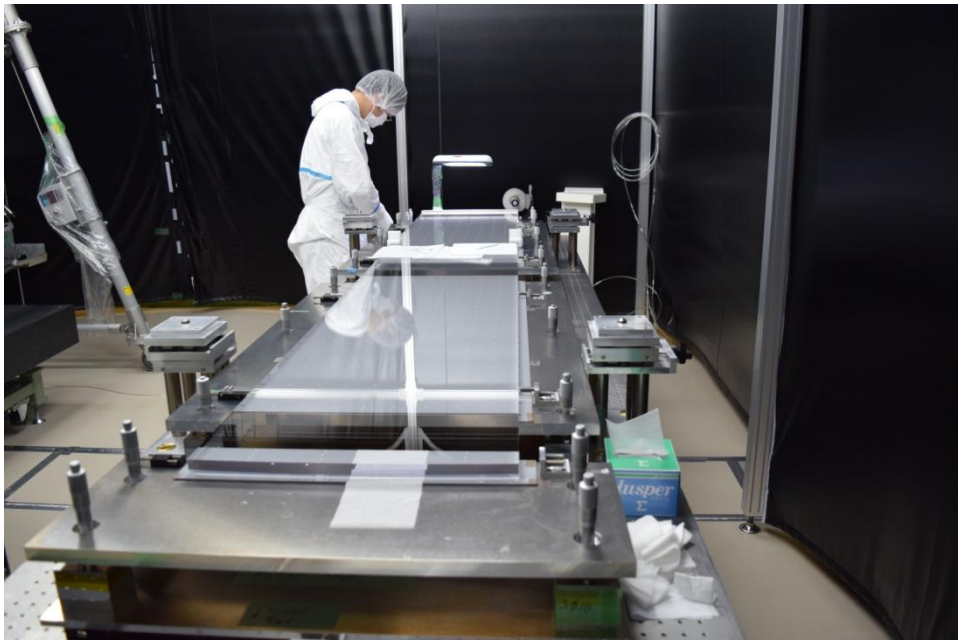
- Finish up to initial gas sealing within 2.5 weeks
  - Quartz cleaning, lift up quartz, QBB assembly, gas sealing was done.
  - Moved to Buffer2
  - Gas leak test is underway.
    - Put silicone on screw holes, keyway between side rail and enclosure
    - Improved to 80% of return gas, but still large leakage inside enclosure
    - Continue to fix



Module03

- Quartz alignment started in parallel with the module02 gas sealing.
- All optics were glued
  - Following new recommendation from company, expecting to suppress further the index fluctuation, but no change (or worse) in result
  - Alignment was fine, but a bit large tilt angle of bar-mirror joint (~10arcsec)
  - Cleaned up



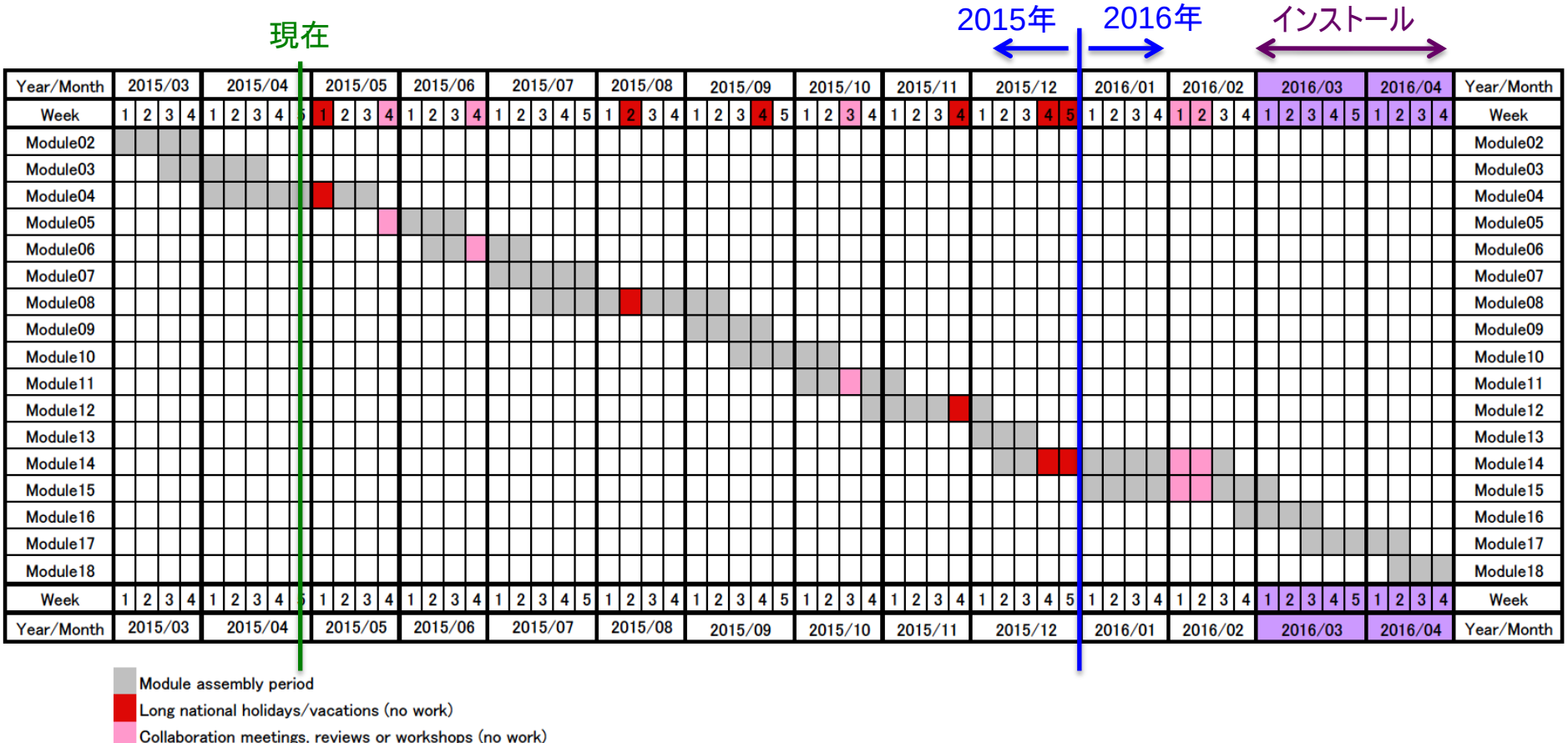


Module03

- QBB prepared
  - Careful dry fitting and tuning of inner honeycomb panel, strong back and enclosure. Still need some improvement to make the procedure easy
  - Tried new button gluing method. Works well and easy. Button flatness is +-10micron level.
- Quartz-QBB assembling
  - Almost done. Gas sealing check continuing.

Schedule

- 2016/4末までに16台インストール
  - 製作ペースの向上が必要
  - 2015/10頃から順次インストール開始
- ガス、水冷パイプ：2015/8までに設置



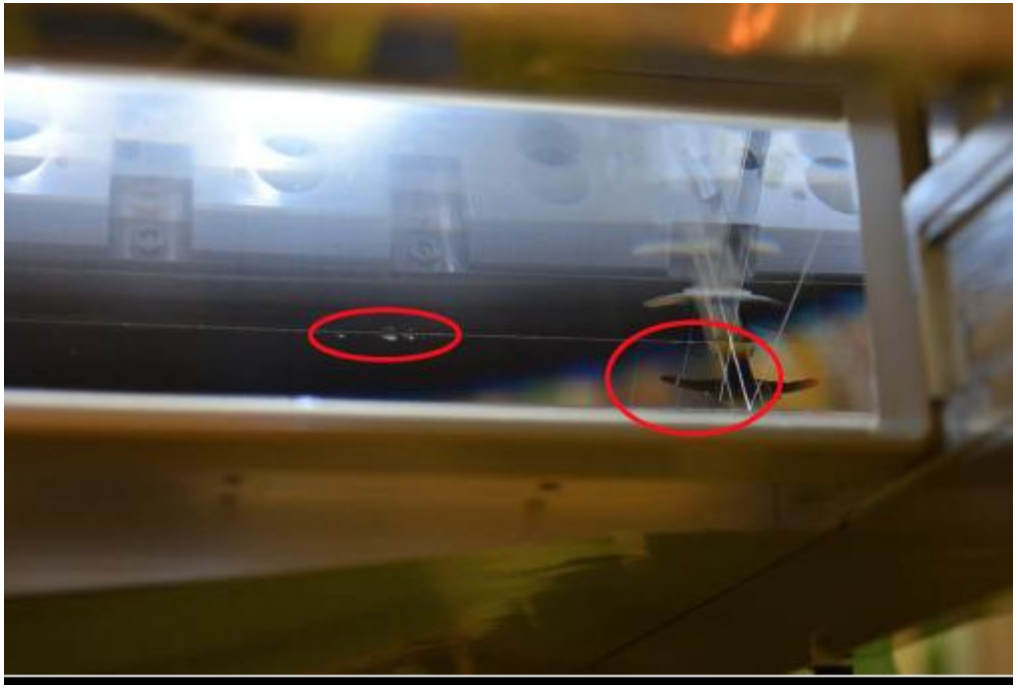
予定（議論）

- TOPモジュール製作
- ストロングバック改良
- インストレーション

Start Date		End Date	Days	Module(s)	Optics lead	QBB lead	Technician
	2015/3/16	2015/3/30	15	02/03	Schwartz	Suzuki	Erzen
	2015/3/30	2015/4/1	3	03	Inami	Suzuki	Brunasso
New JFY 4/1/2015		2015/4/12					
	2015/4/2	2015/4/14	13	03/04	Fast	Inami	Brunasso
	2015/4/15	2015/4/24	10	04	Inami	Suzuki	Benettoni
Golden Week 4/29/15		2015/5/5					
	2015/5/11	2015/5/22	12	04	Inami	Suzuki	Brunasso, Ketter
FPCP @ Nagoya 5/25/2015		2015/5/29					Ketter
	2015/5/28	2015/6/6	10	05	Fast	Suzuki	Ketter
	2015/6/8	2015/6/22	15	05/06	Schwartz	Inami	Erzen
B2GM 6/22/15		2015/6/26					
	2015/6/27	2015/7/12	16	06/07	Inami	Suzuki	Ramina, Rebeschini
	2015/7/13	2015/7/27	15	07/08	Schwartz	Suzuki	Glasgow
	2015/7/28	2015/8/7	11	07/08	Inami	Suzuki	Glasgow
Obon 8/8/2015		2015/8/16					
	2015/8/17	2015/8/31	15	08	Fast	Inami	Brunasso
	2015/8/31	2015/9/12	13	08/09	Schwartz	Suzuki	Erzen
	2015/9/14	2015/9/28	15	09/10	Inami	Suzuki	
	2015/9/28	2015/10/7	10	10			Erzen
	2015/10/8	2015/10/16	9	10/11			Glasgow
B2GM 10/19/15		2015/10/23					
	2015/10/26	2015/11/9	15	11/12	Inami	Suzuki	Ramina, Rebeschini
	2015/11/10	2015/11/24	15	12	Fast	Inami	
Thanksgiving 11/24/15		2015/11/29					
	2015/11/30	2015/12/4	5	12/13	Inami		
	2015/12/7	2015/12/18	12	13/14	Fast		
Christmas/New Years 12/21/15		2015/1/5					
	2016/1/6	2016/1/24	19	14/15	Schwartz		
	2016/1/27	2016/1/31	5	14	Inami		

Issue in gluing

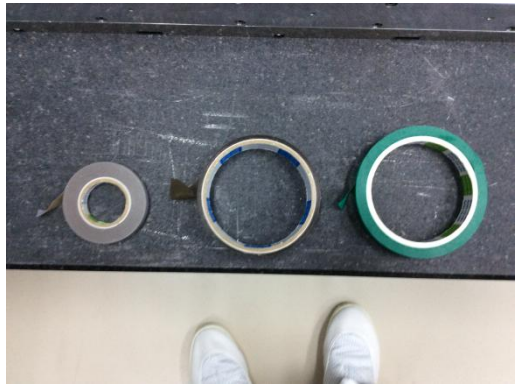
- We found small regions of adhesion failure in the prism - bar glue joint.
- The peeled part is the side of bar, which is the side the glue was leaked and striae like structure seen at the corner.
- Unusual steps were taken to remove the excess glue leakage.
- The gluing process for module 02 has been stopped to investigate the issue.

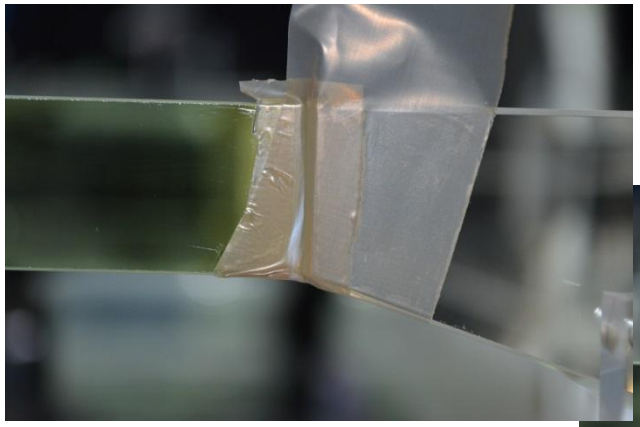


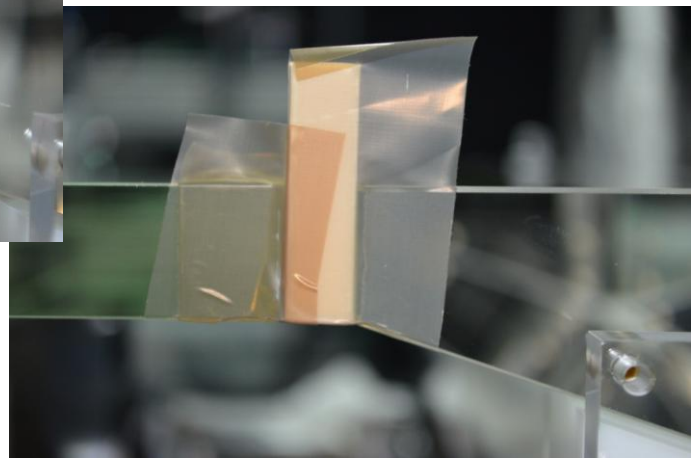
Check whether the crack develop or not, by normal operation (moving, rotation for several times etc.).
⇒ No change was found.

Taping method development for EPOTEK

- Striae like structure was appeared in the case of glue leakage. We need to improve the taping method for the stable glue curing (better strength).
- Teflon tape (softer than Kapton tape) for mirror part
- Test Teflon block and tape for prism part with glue
  - Difficult joint due to the difference of width
    - Prism (456mm), bar (450mm)
  - Trials look OK. No leakage happened for 4 trials.



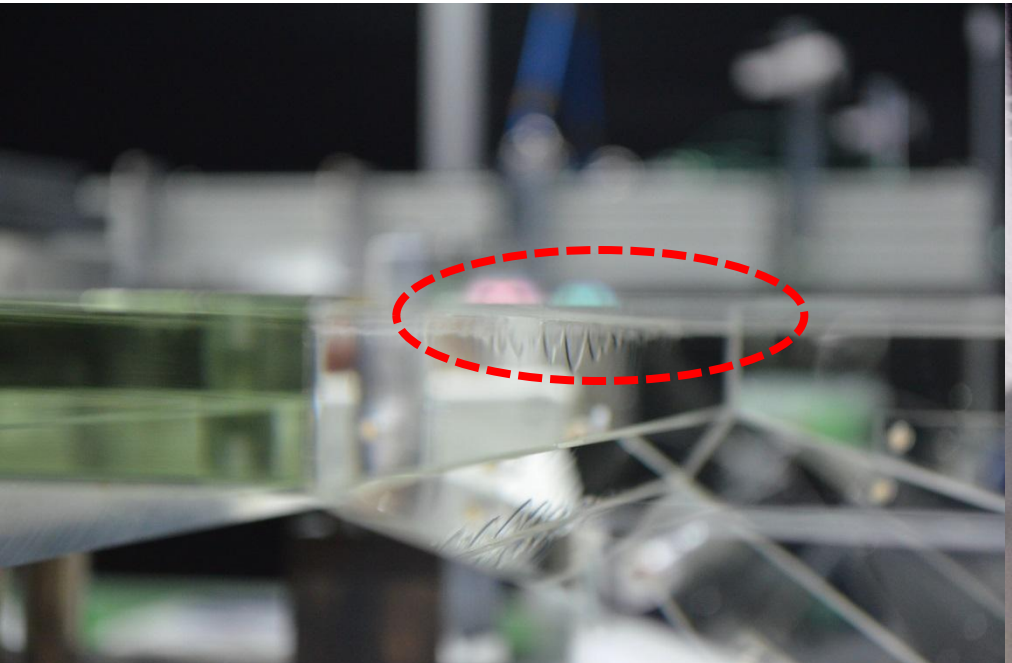


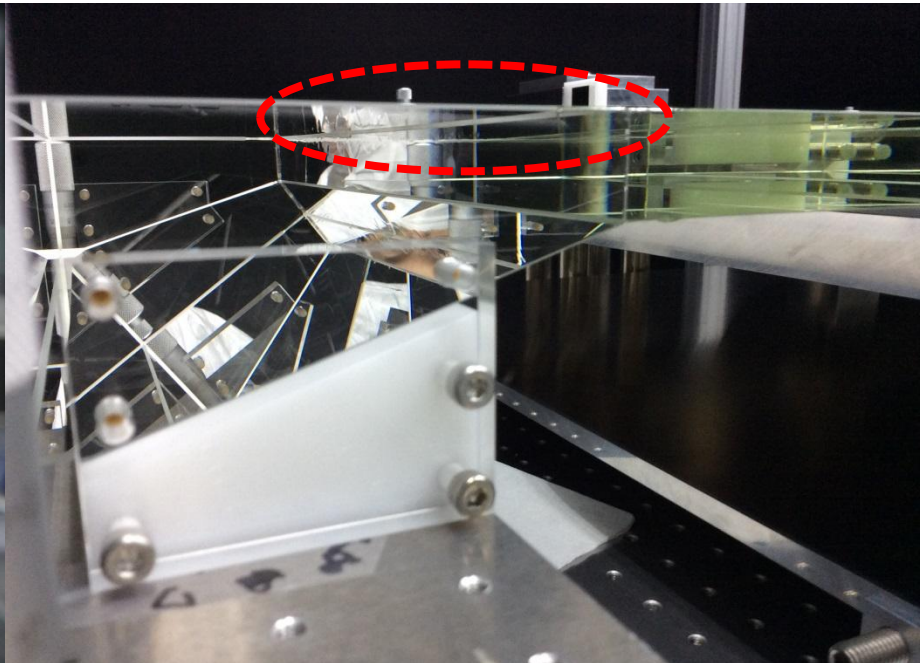


Index fluctuation

- Typical striae-like structures seen in the 3rd trial of prim-bar gluing R&D too
  - Tiny index change ➔ Difficult to find this structure on small pieces.
    (Large (wide, long) optics, large angle of view, angle of incidence, … needed)
  - The observed “drop”-like striae corresponds to
    - Extra glue on upper surface.
    - Glue applied in the latter half of gluing (~30mins)
    - The “drop”-like glue was cured (more sticky) than glue @ start point.

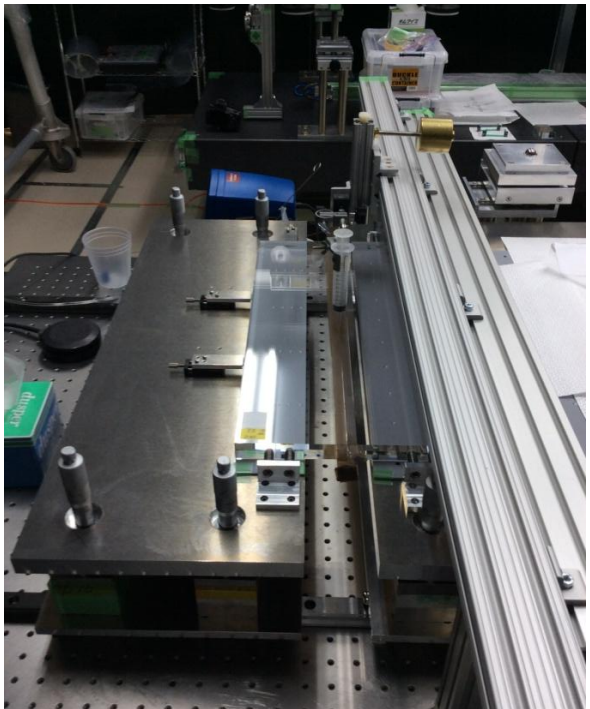
  ➔ It seems that difference of the curing status of glue makes this structure.
    - Curing time, glue/glass temperature, mixing ratios to be checked.

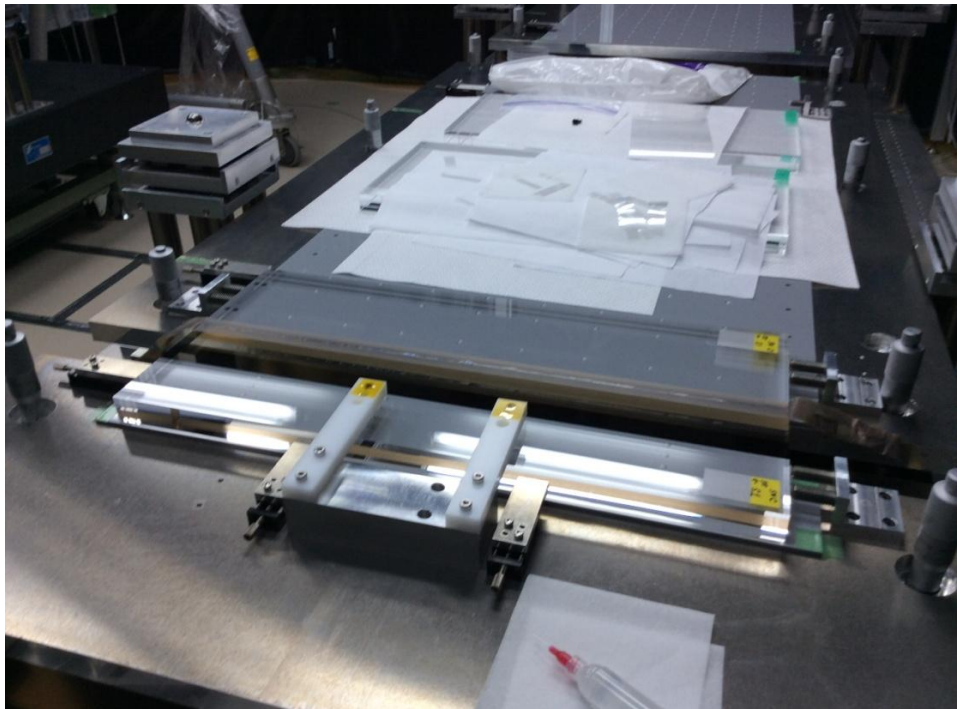




Glue test with dummy quartz sample

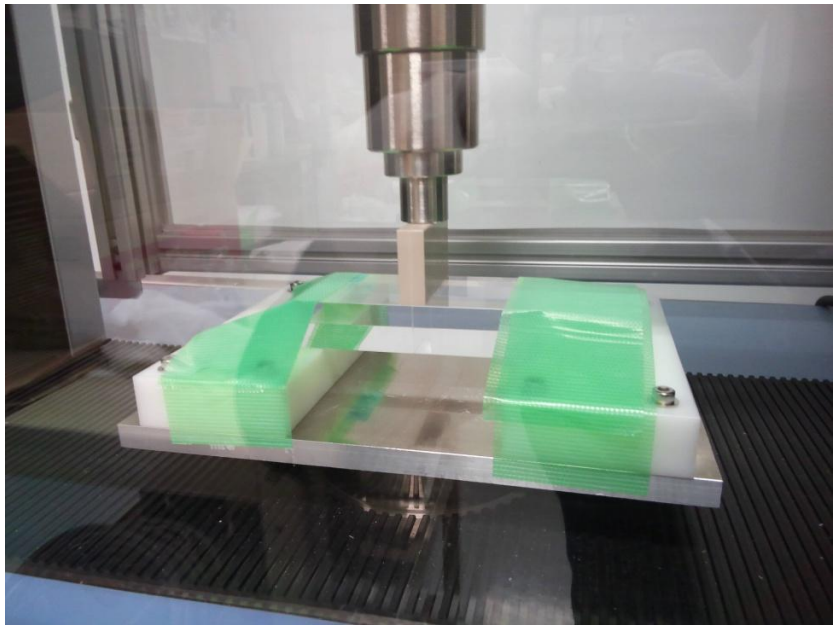
- Done two trials
  - Applied glue with normal procedure with the gap of 30~50micron
  - Index fluctuation found in the first trial → Removed joint
  - Again, index fluctuation happened in the second trial.
  - Proceed to full cure, to check the delamination
  - After full cure the index fluctuation has been weak.





Bending test with small polished quartz

- Test additional 3 samples
  - 841N; corresponds to the maximum stress by the self weight of 2.5m quartz bar supported at the end point without QBB. (extreme case)
- Glue applied by the current procedure shows good strength.
  - No strange delamination was seen during the test.



	Break at (N)
EPOTEK-1 (“normal” procedure)	6000
EPOTEK-2 (“normal” procedure)	6600
EPOTEK-3 (“normal” procedure)	6200
NOA63-1	3000
NOA63-2	2000
EPOTEK with weak striae 1	6500
EPOTEK with weak striae 2	6000
EPOTEK with acetone residue 1	5000
EPOTEK with acetone residue 2	5000
EPOTEK with AP100	4300