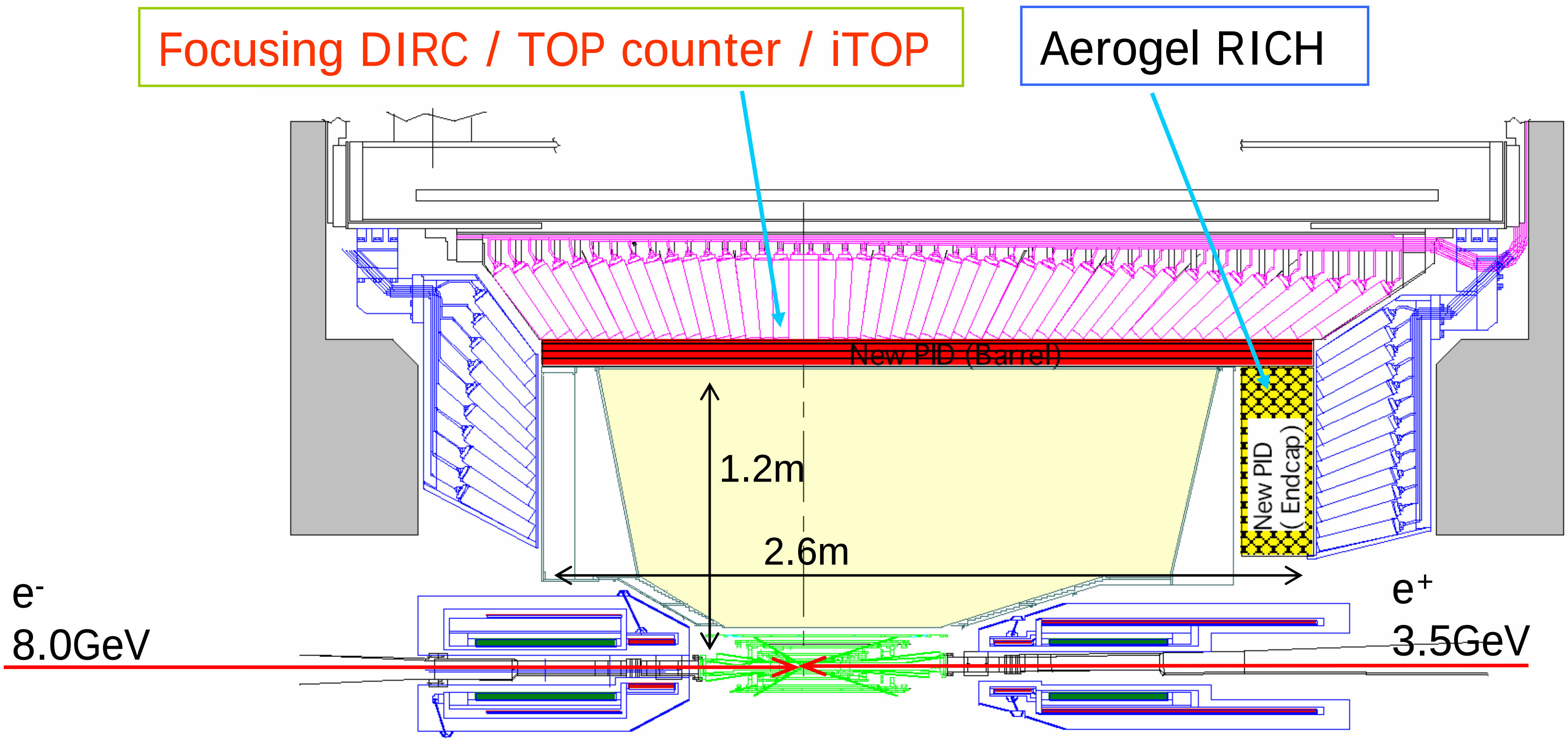
Barrel PID upgrade

- R&D status
  - TOP counter
  - iTOP
  - Focusing DIRC
- To do, cost estimation

K. Inami (Nagoya-u)
Ljubljana, Hawaii, Cincinnati
and PID group

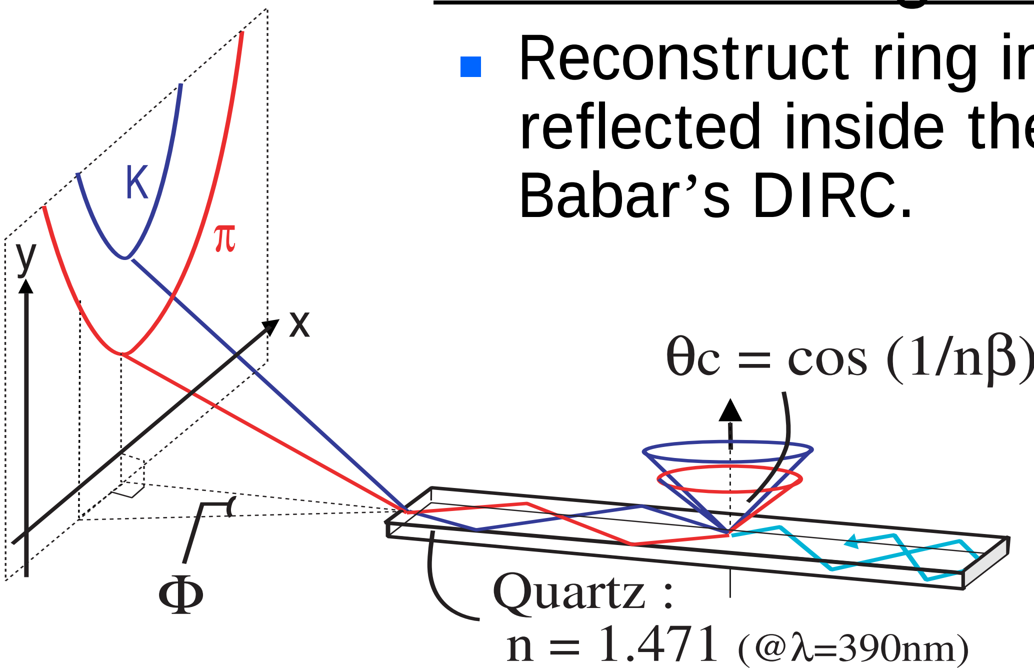
Barrel PID upgrade

- PID (K/π) detectors; Focusing DIRC, TOP, iTOP
  - Cherenkov ring imaging detectors
  - Locate in the current TOF region

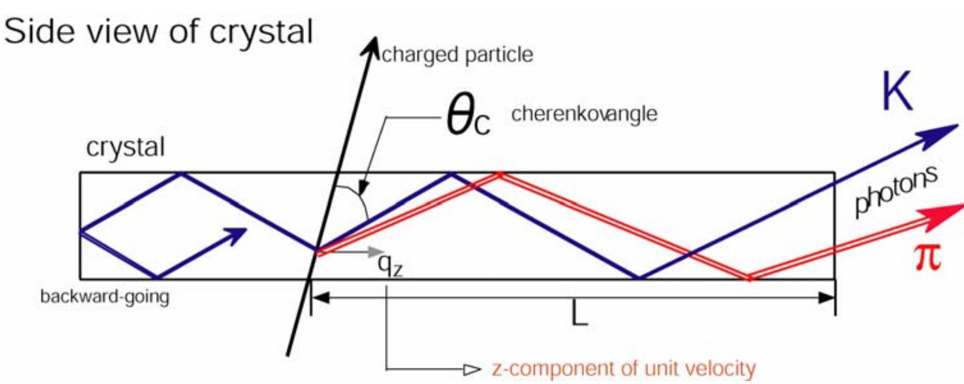


Barrel PID detector

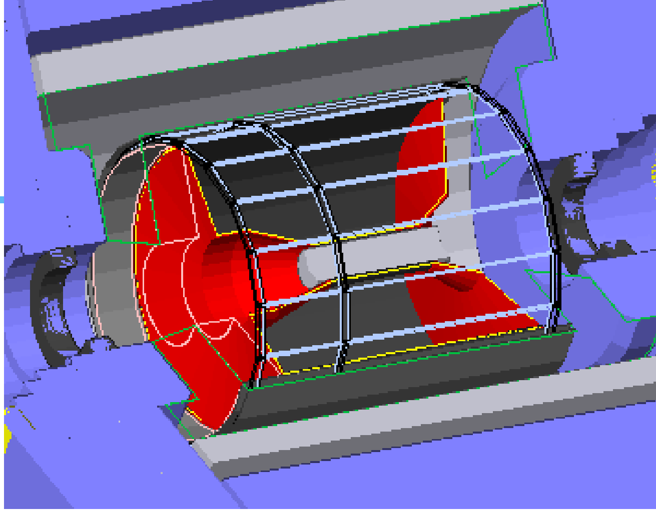
- Cherenkov ring in quartz bar
  - Reconstruct ring image using ~20 photons reflected inside the quartz radiator as a Babar's DIRC.



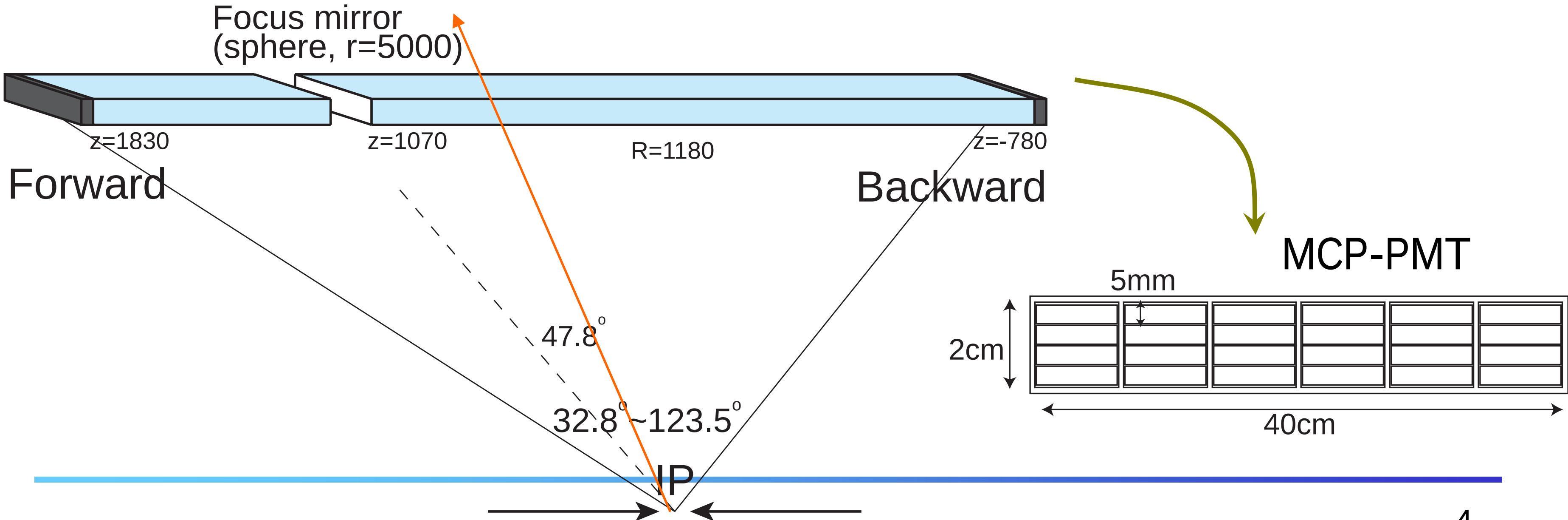
- Utilize 3D information
  - Arrival position (x,y)
  - Arrival timing (t)
  - Difference of propagation time for K/π is ~100ps



TOP counter (Nagoya)



- Quartz: $255cm^L$ x $40cm^W$ x $2cm^T$
  - Focus mirror at 47.8deg.
    to reduce chromatic dispersion
- Multi-anode (GaAsP) MCP-PMT
  - Linear array (5mm pitch), Good time resolution (<~40ps)
  - → Measure Cherenkov ring image with timing info.



Geometry

- Quartz, Al wall, (Al honeycomb holder)
  - Narrow space for support structure
  - Gaps in ϕ
    - To be checked with physics shape

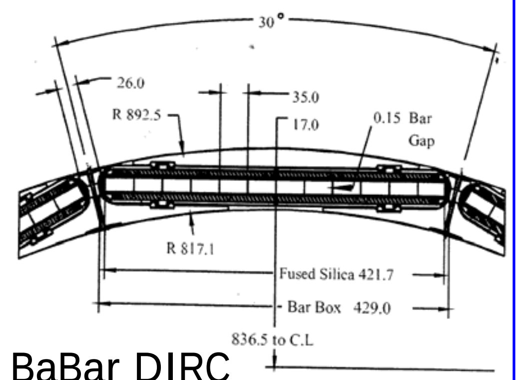
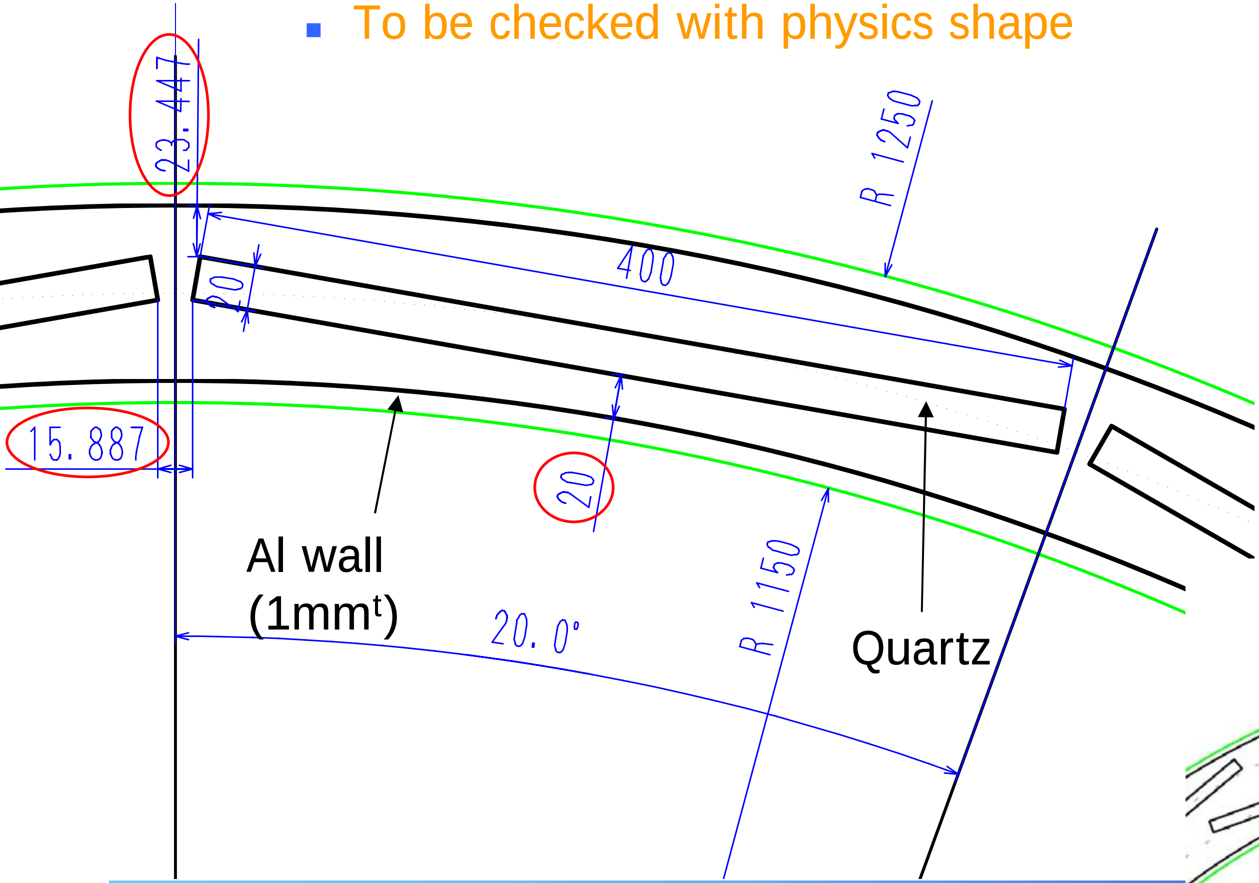
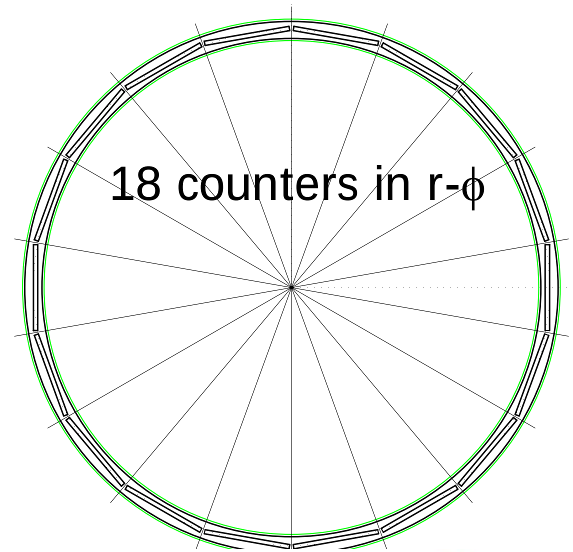
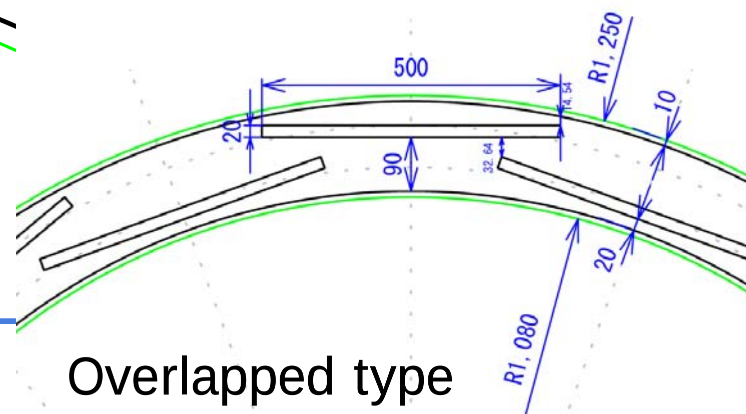


Fig. 11. Cross section through the Central Support Tube showing a bulkhead, the slot liner and a bar box. The inner and outer skins are not shown. All dimensions are in millimeters.

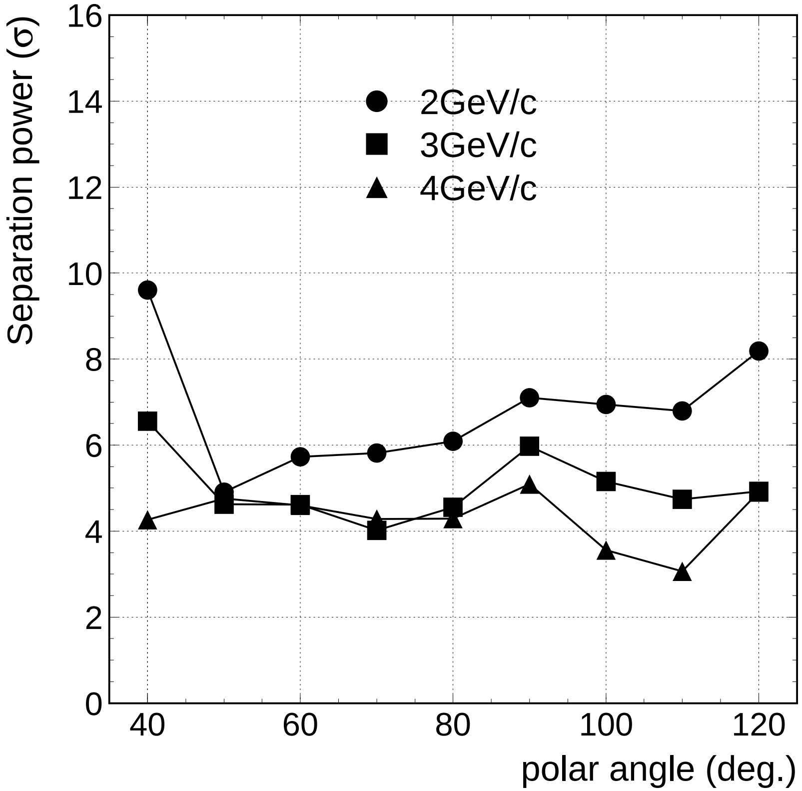


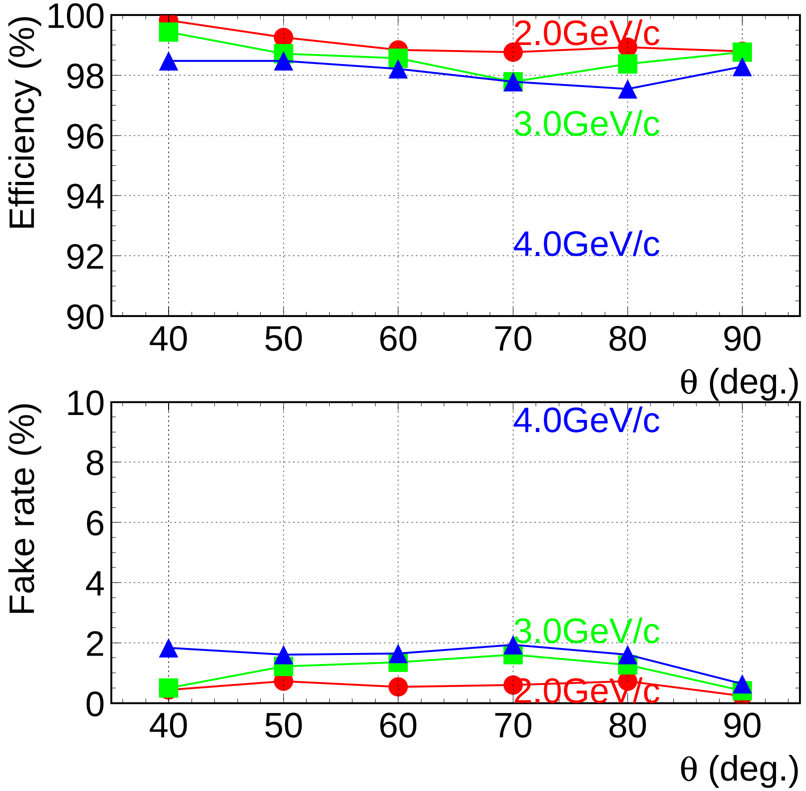




Expected performance

- K/π separation power
  - GaAsP photo-cathode + Focusing mirror



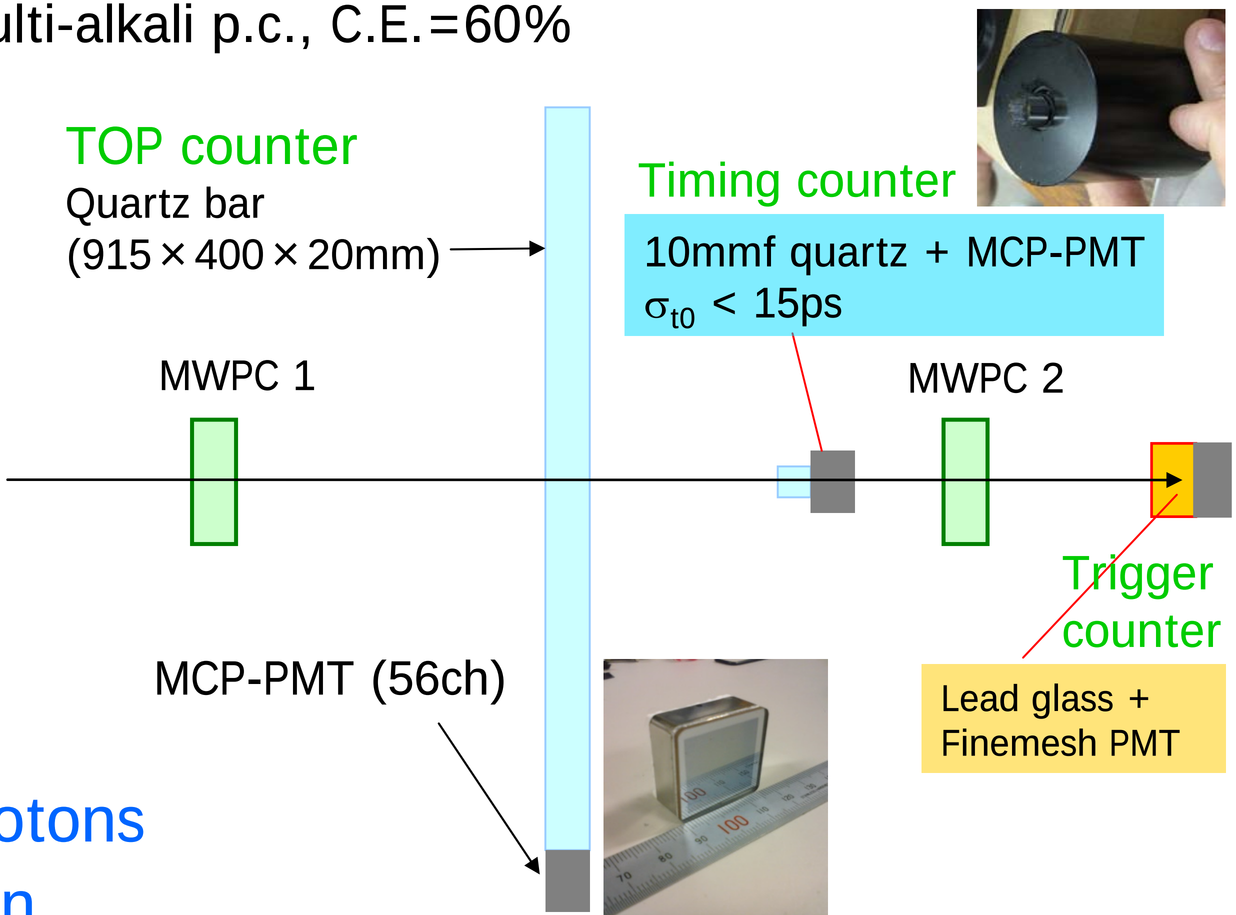


>4σ K/π upto 4 GeV/c, θ<90°

Beam test

- At Fuji beam line in June (e^- 2GeV)
- Using real size quartz and MCP-PMT
  - MCP-PMT: Multi-alkali p.c., C.E.=60%

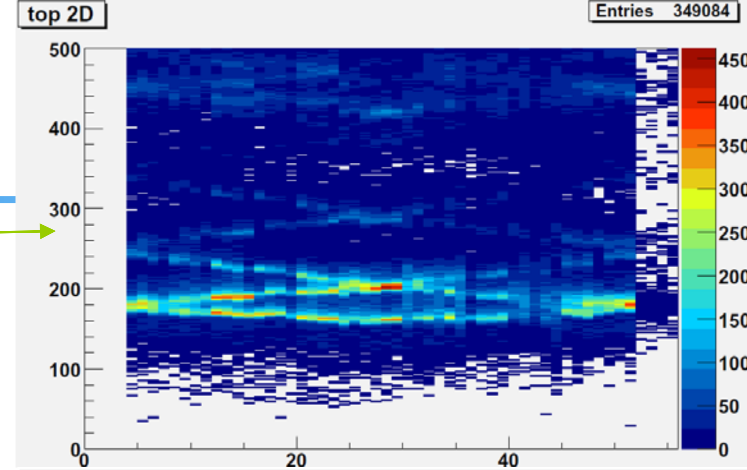
Quartz + support jig

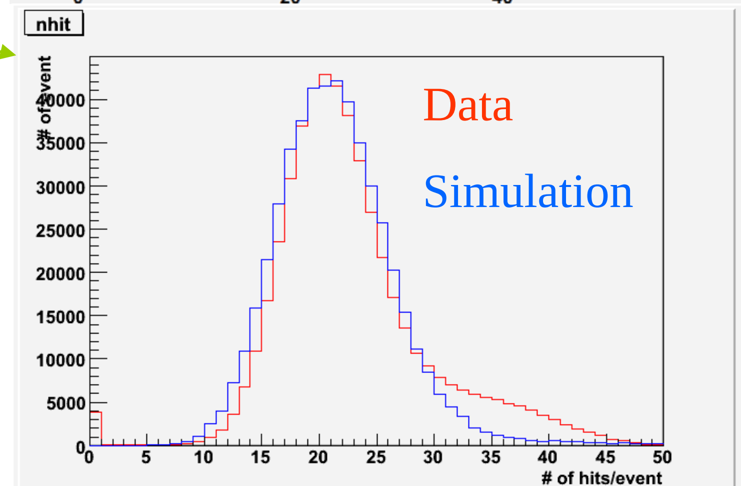


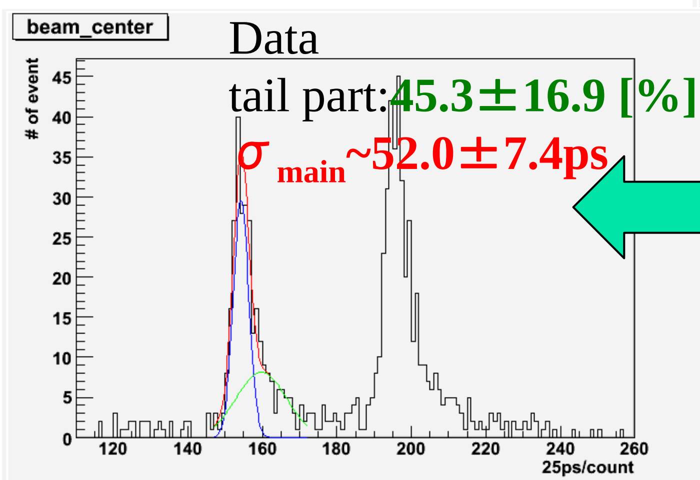
- Check
  - Ring image
  - Number of photons
  - Time resolution

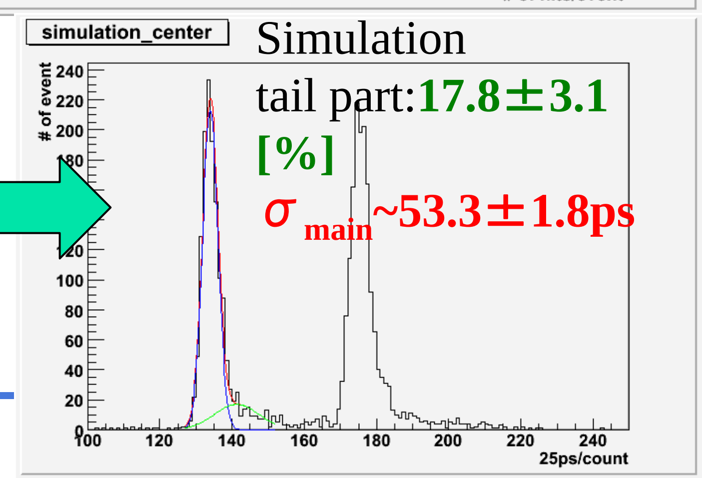
Beam test results

- Ring Image
  - Similar with Simulation
- Number of photons
  - N~20; as expected
    - Tail due to EM shower in triggers
- Time resolution
  - Main part; expected time resolution
  - Rate of tail seems large.
    - Not in MCP-PMT and readout



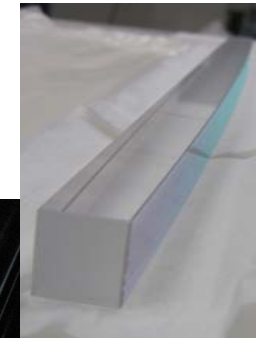


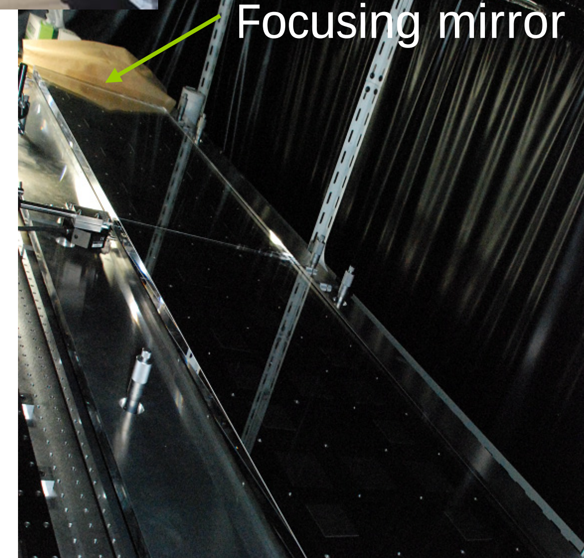


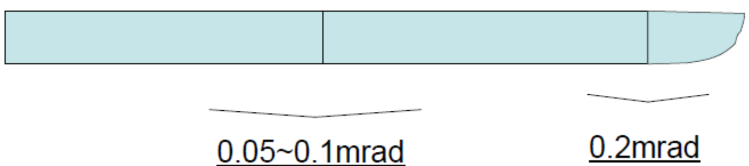


Focusing TOP development

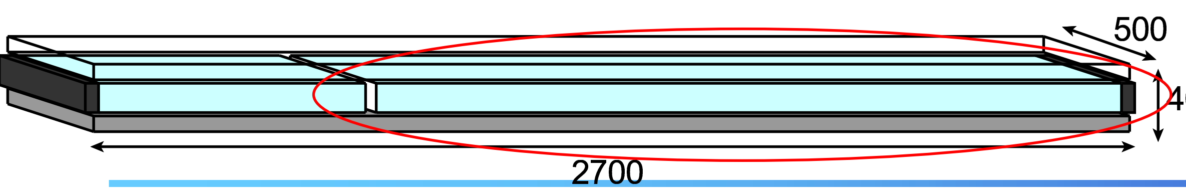
- Beam test now
  - at Fuji beam line
- Quartz radiator
  - Size; 91.5 x 40 x 2 cm^3 x2
  - Focusing mirror
  - Glued; Flatness ~0.2mrad
    - Laser depth meter
    - Laser reflection at mirror

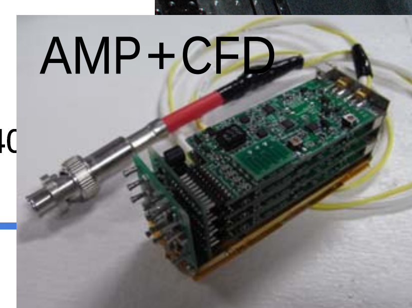






- MCP-PMT
  - 11 PMT with multi-alkali p.c.
  - AMP + CFD board

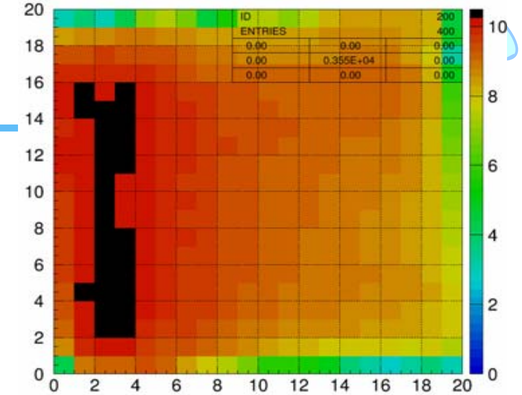




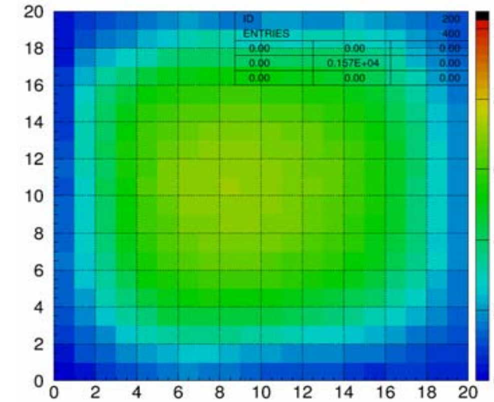
MCP-PMT R&D

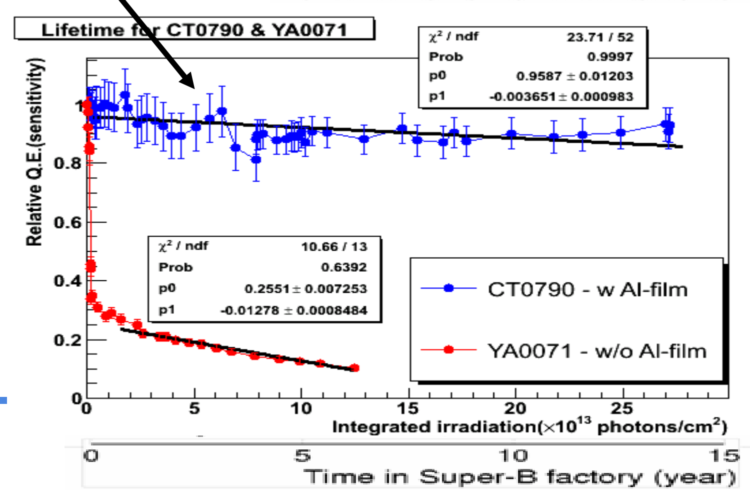
- Lifetime test
  - Multi-alkali p.c. with Al protection
  - With square-shape MCP-PMT
  - → Short lifetime, position dependence
- Difference with round-shape PMT
  - Enough lifetime (>10 super-B year)
  - Need to confirm the difference
    - Internal structure
    - Material difference?
  - Need to check the lifetime of round-shape MCP-PMT again
- GaAsP p.c. MCP-PMT
  - Will start lifetime test with new sample

QE before againg



QE after againg

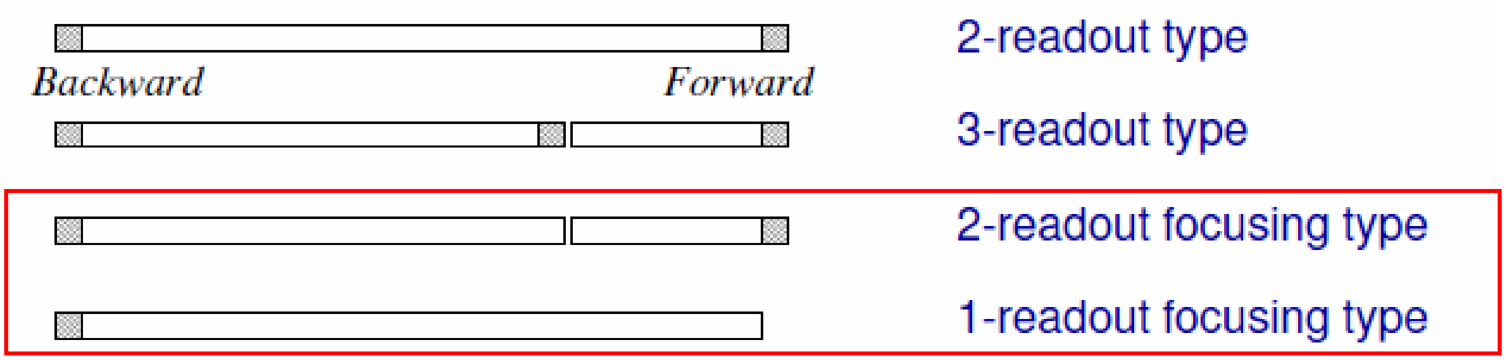




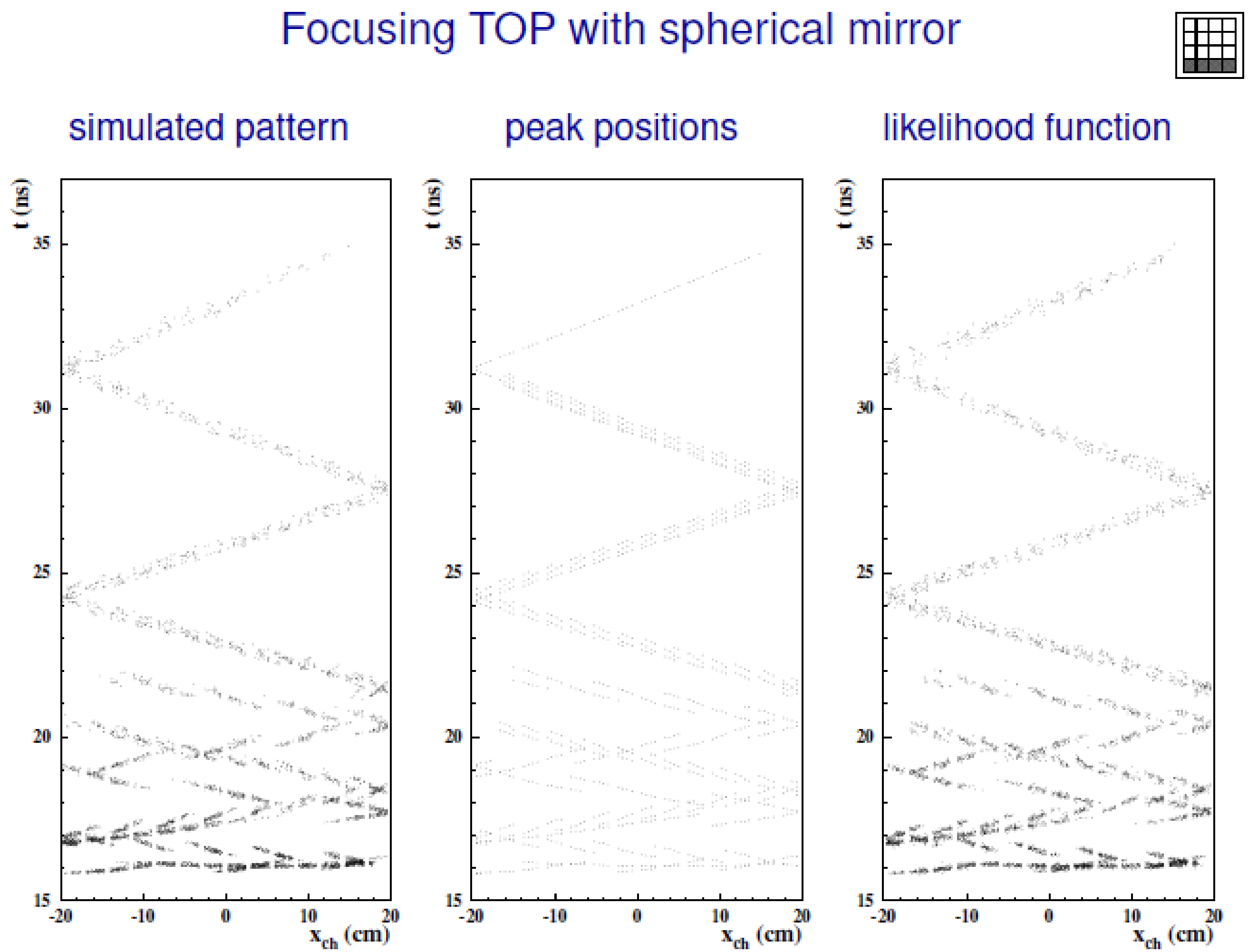
Simulation study for TOP

M. Staric-san
(Ljubljana)

- Different geometry configurations studied; parameters according to *sBelle Design Study Report*
- Quartz bars (18 segments in ϕ at R = 118 cm)
  - dimensions: 261 cm $\times$ 40 cm $\times$ 2 cm
  - non-splitted or splitted at 47.8^0
  - with cylindrical or spherical mirror
- MCP-PMT's:
  - GaAsP, >400 nm filter, 35% collection efficiency
  - 4 $\times$ 4 pads; pad size 0.55 mm
  - PMT size 27.5 mm $\times$ 27.5 mm
  - 14 pieces fitted to Q-bar exit window



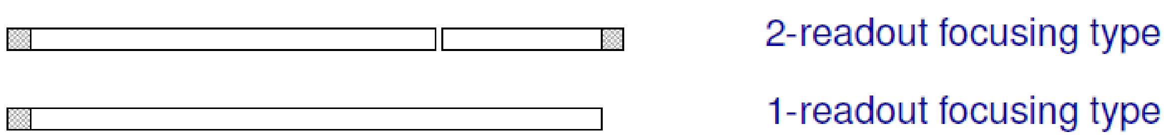
Focusing TOP ring image

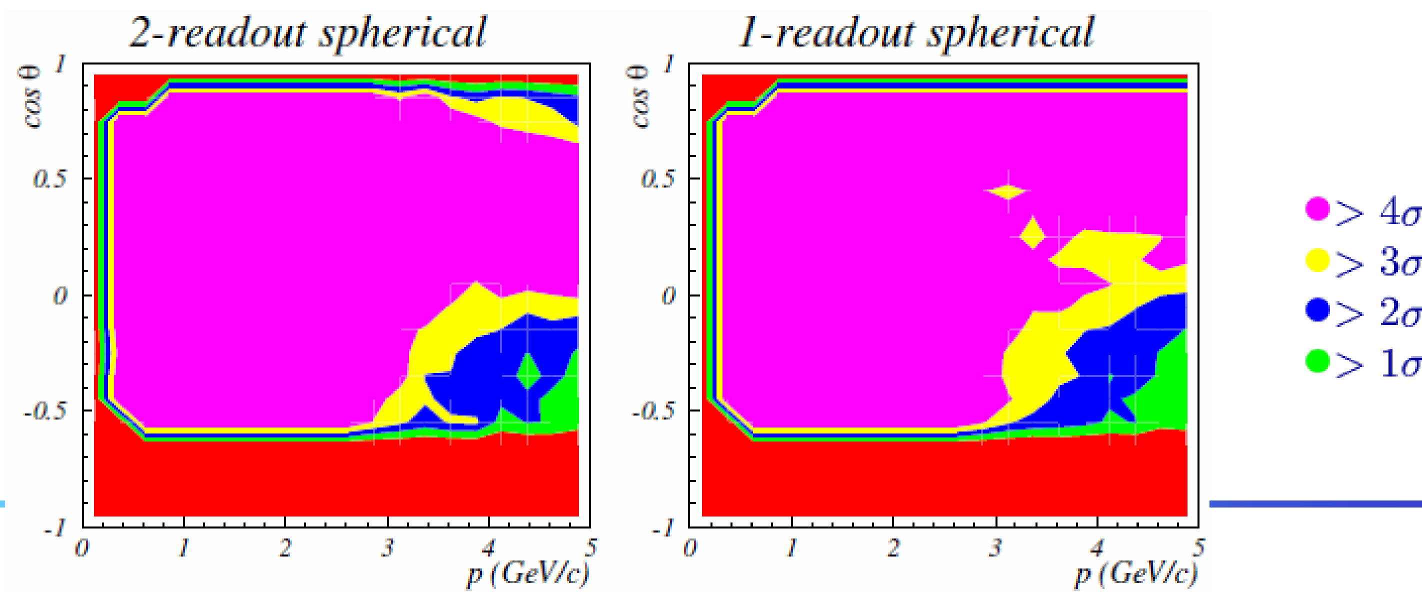


- Successfully reconstruct ring image analytically

Performance

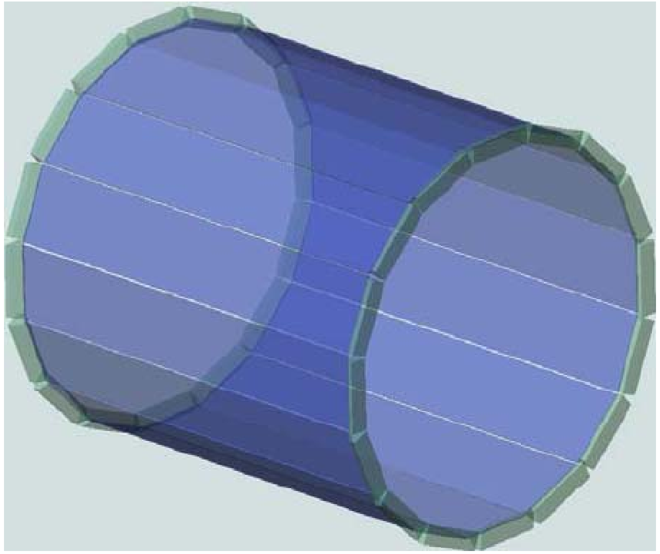
- Compare 2 configurations
  - Good separation in forward part for 1-readout, while good separation in center part for 2-readout
    - Fluctuation of event timing (10ps) seems to make the difference with Nagoya's study.



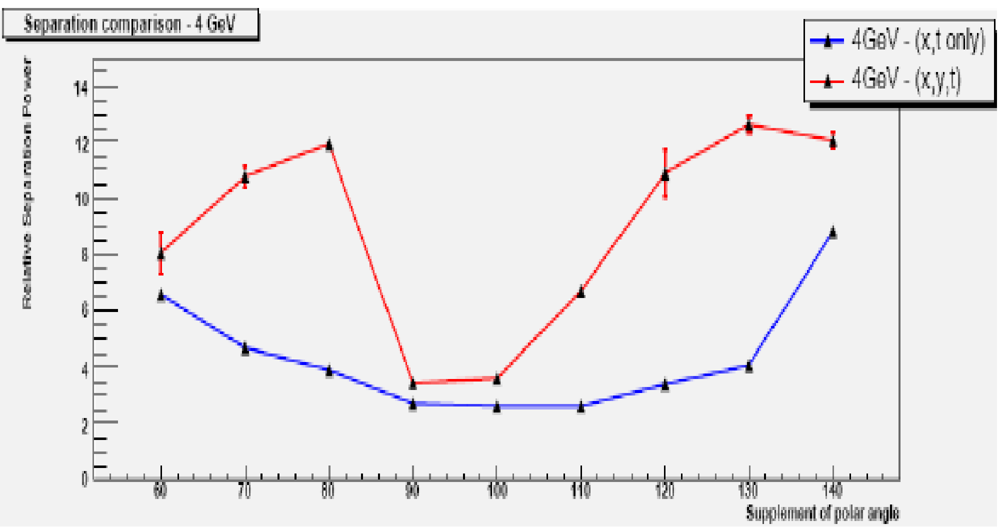


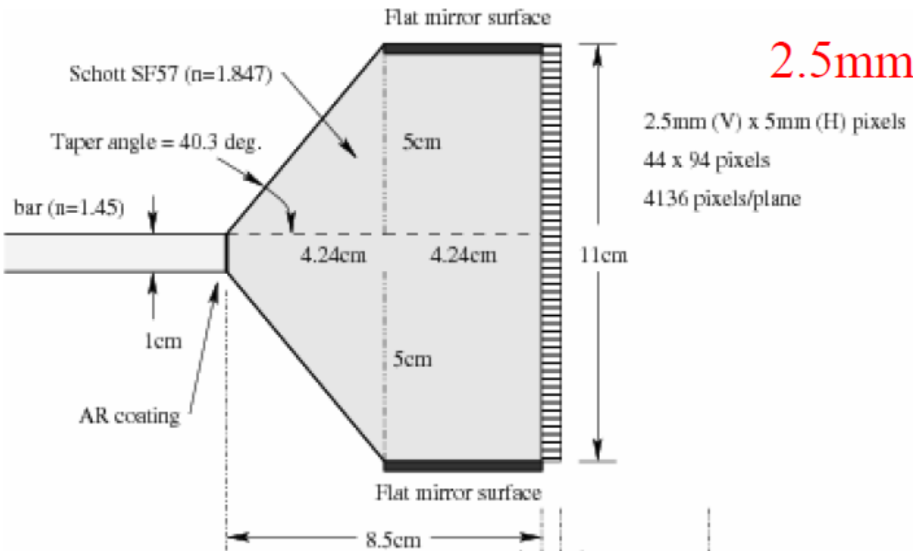
iTOP counter

K.Nishimura-san (Hawaii)



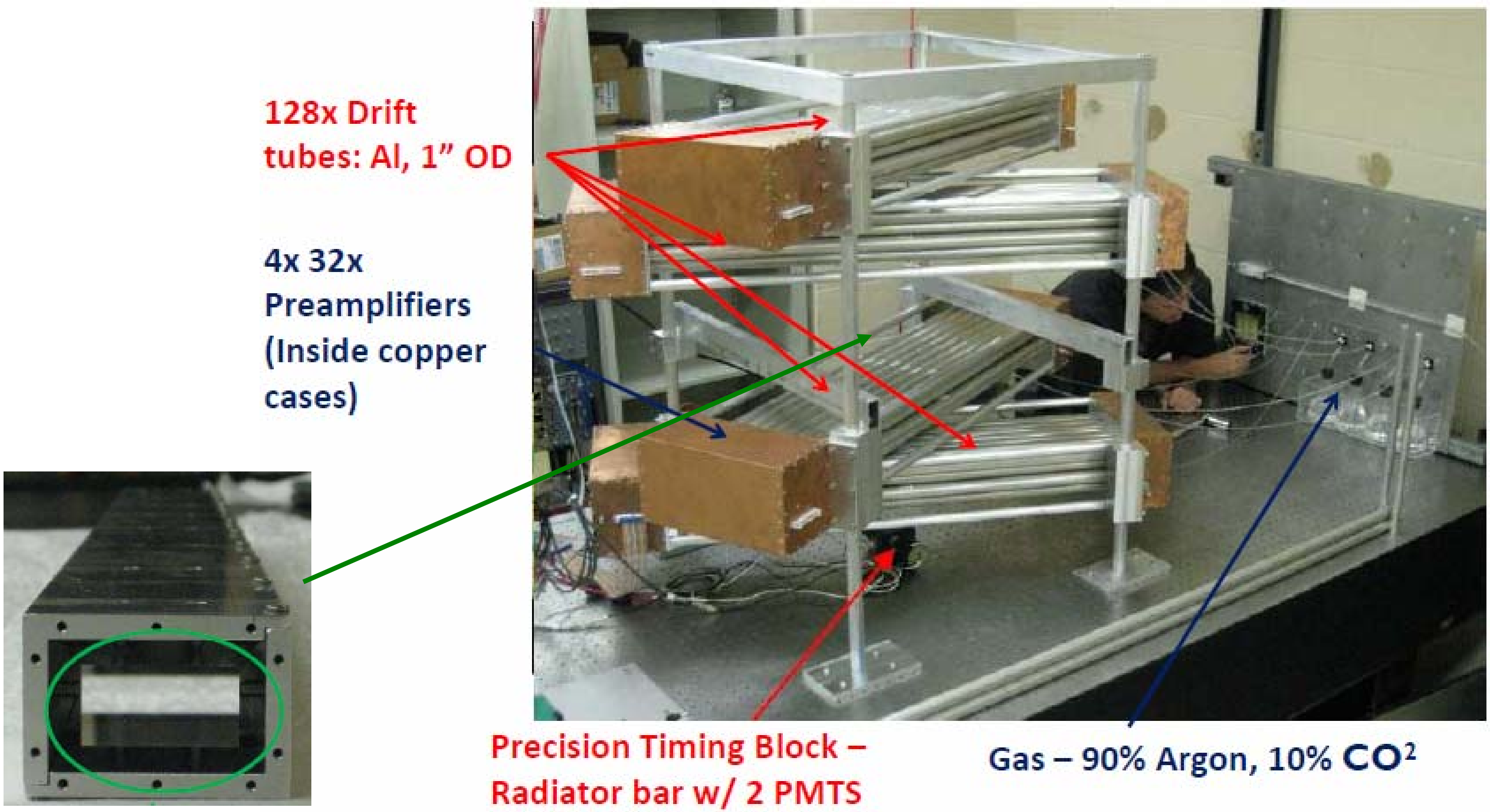
- Ring image reconstruction
  - Fine segmented anodes and precise timing information
    - $2.5 \times 5\text{mm}^2$, ~20ps
    - Solid state photo detector?
      - By Chicago, Argonne and industry
  - Stand-off block ($8.5 \times 11\text{cm}^2$)





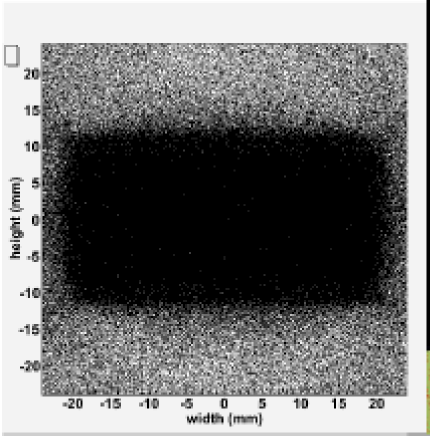
Cosmic-ray test bench

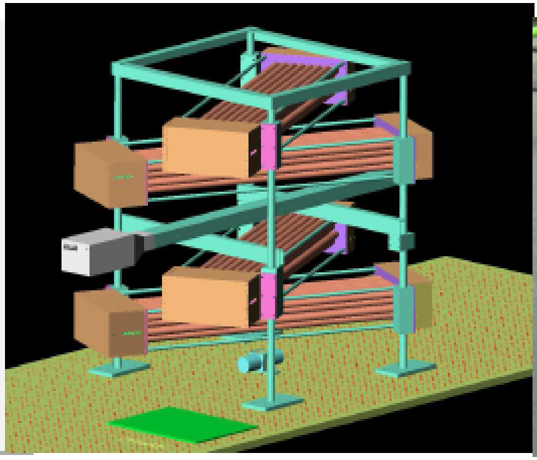
- Drift tubes (σ_r=25μm)
- Timing detector

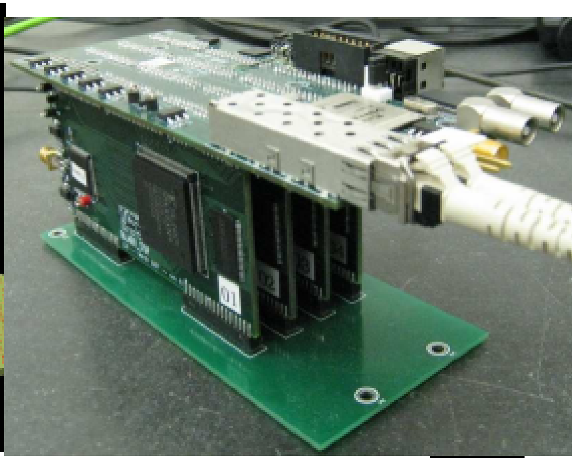


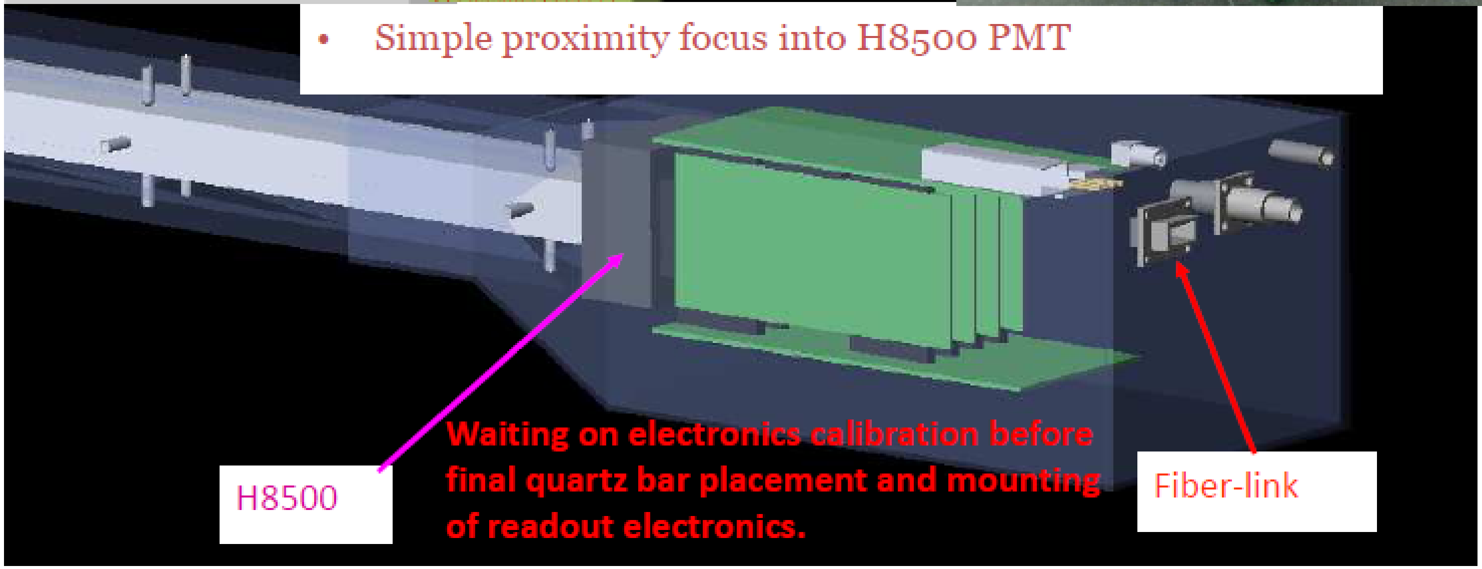
Initial quartz bar test

- With narrow quartz bar (2x4x120cm^3)
- Simple readout on bar end by MA-PMT









Readout elec. R&D

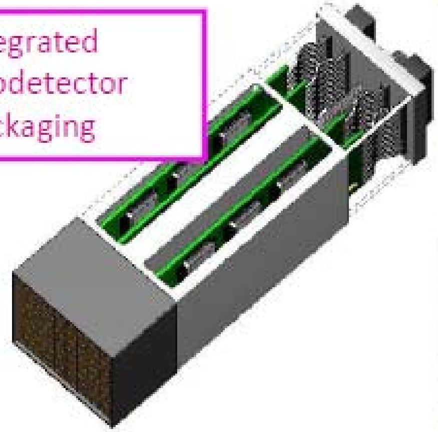
- Highly integrated readout
- High-speed waveform sampling

- **Buffered LABRADOR**

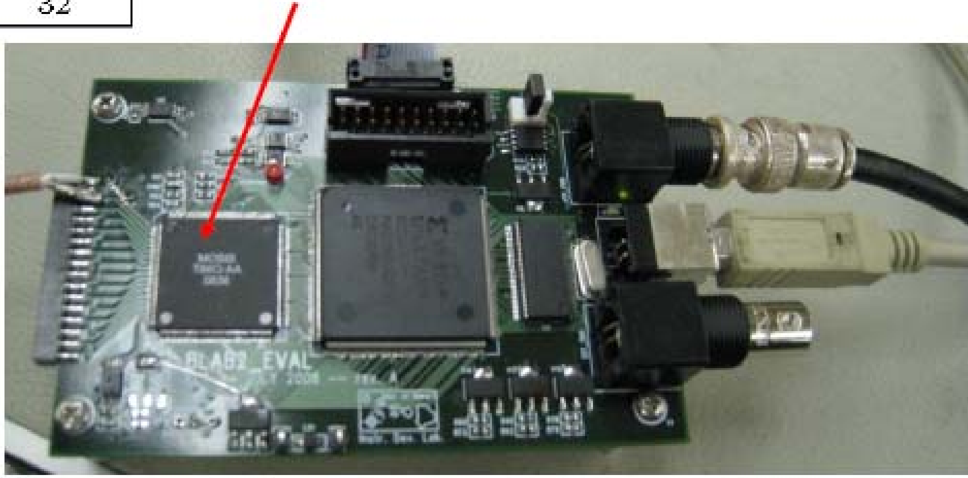
TABLE II: *BLAB2 ASIC Specifications.*

Item	*Value*
Photodetector Input Channels	16
Linear sampling arrays/channel	~~2~~ → 6
Storage cells/linear array	~~512~~ → 1024
Sampling speed (Giga-samples/s)	2.0 - 10.0
Outputs (Wilkinson)	32

Integrated Photodetector packaging



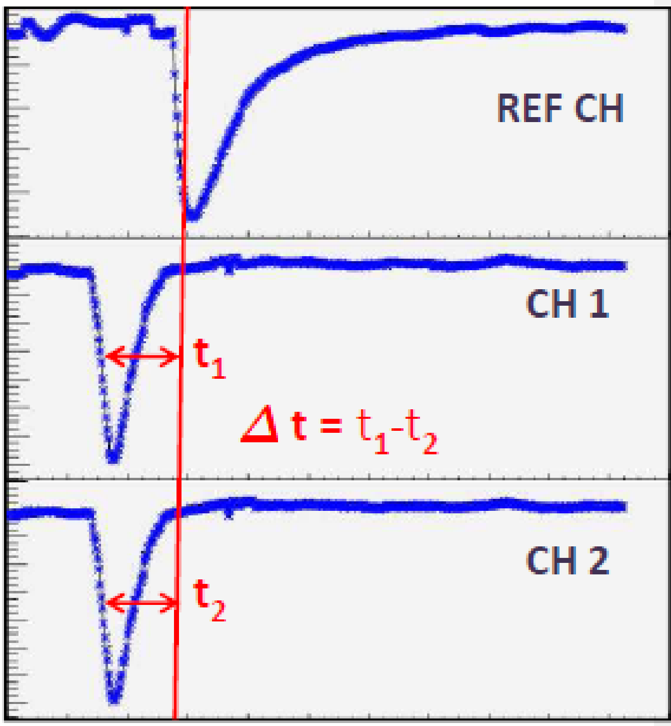
BLAB2 ASIC

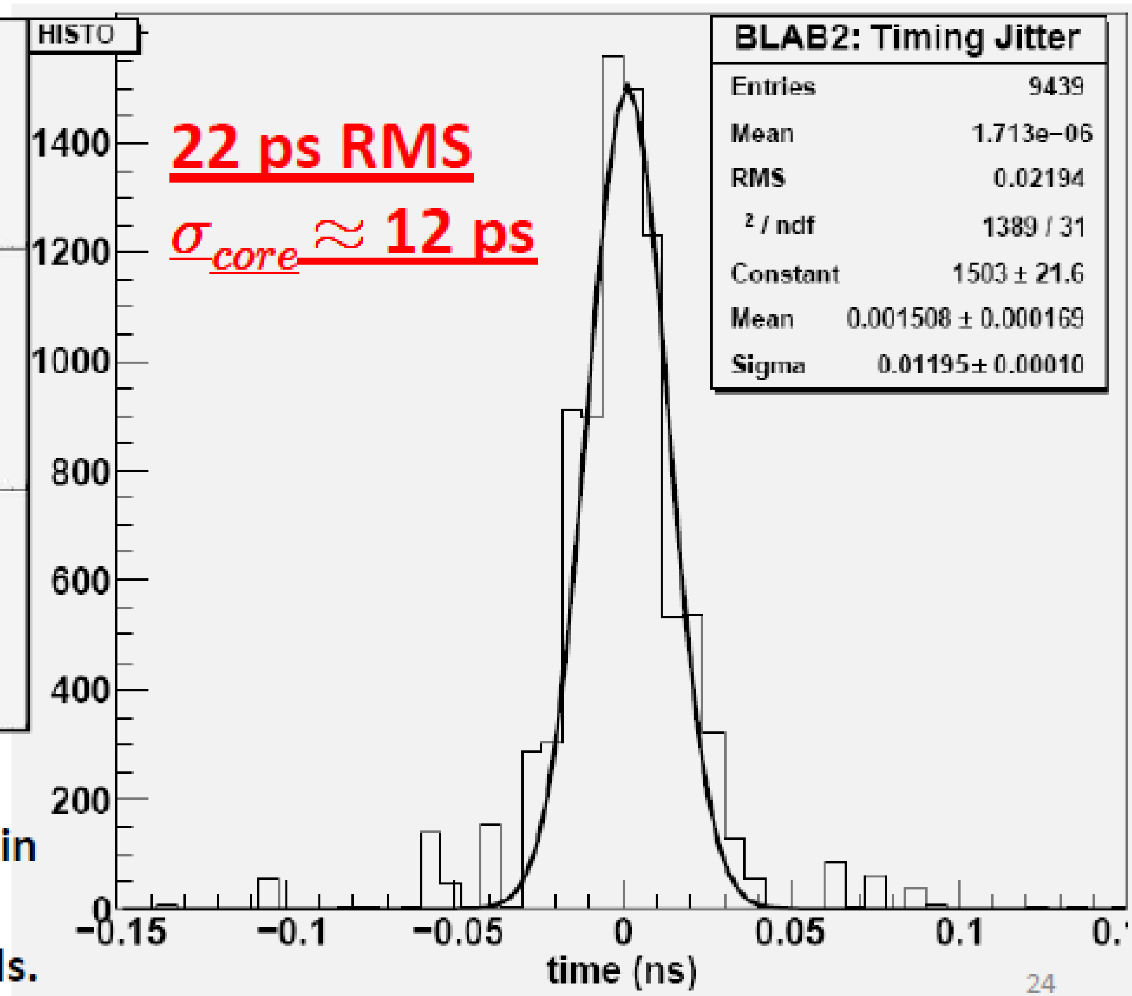


BLAB2 ASICs recently received: now being tested & calibrated!

BLAB2 performance

Measured timing jitter between two channels (same BLAB2).





➔ Good timing calibration is vital! Ongoing improvements in calibration procedures may improve this result, reduce tails.

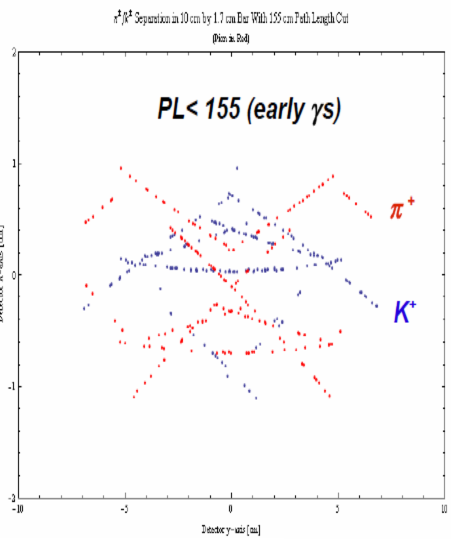
Focusing DIRC

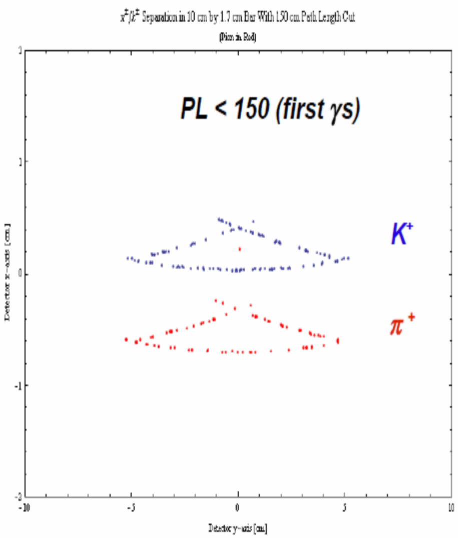
A.Schwartz-san (Cincinnati)

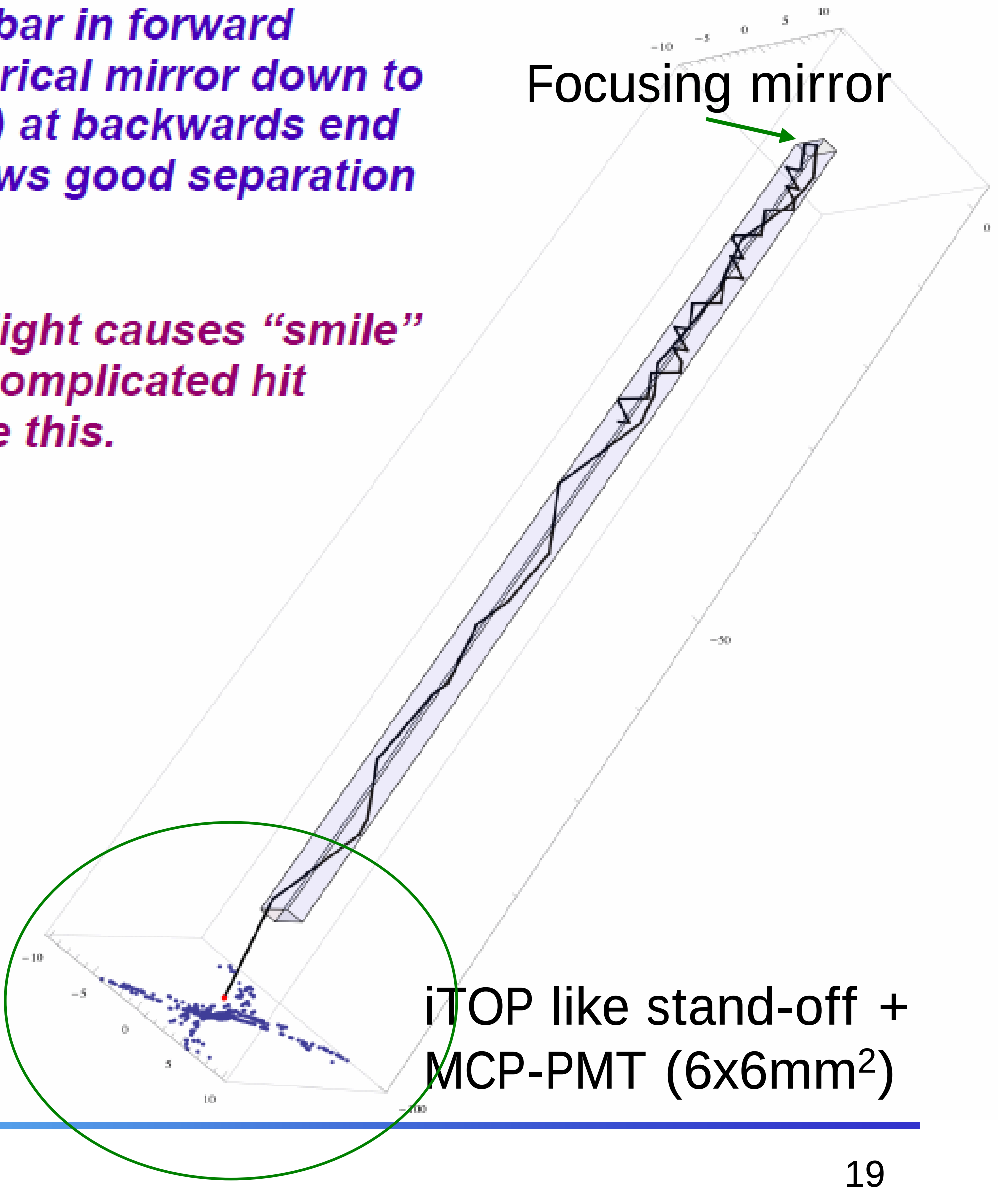
Radiated light reflects down bar in forward direction, is focused by spherical mirror down to detector surface (focal plane) at backwards end of bar. Long focal length allows good separation of π and K hits.

BUT: reflections in focused light causes "smile" to fold-back on itself; gives complicated hit pattern. Use timing to resolve this.

Correlation between path length (= timing) and hit positions (4 GeV track):

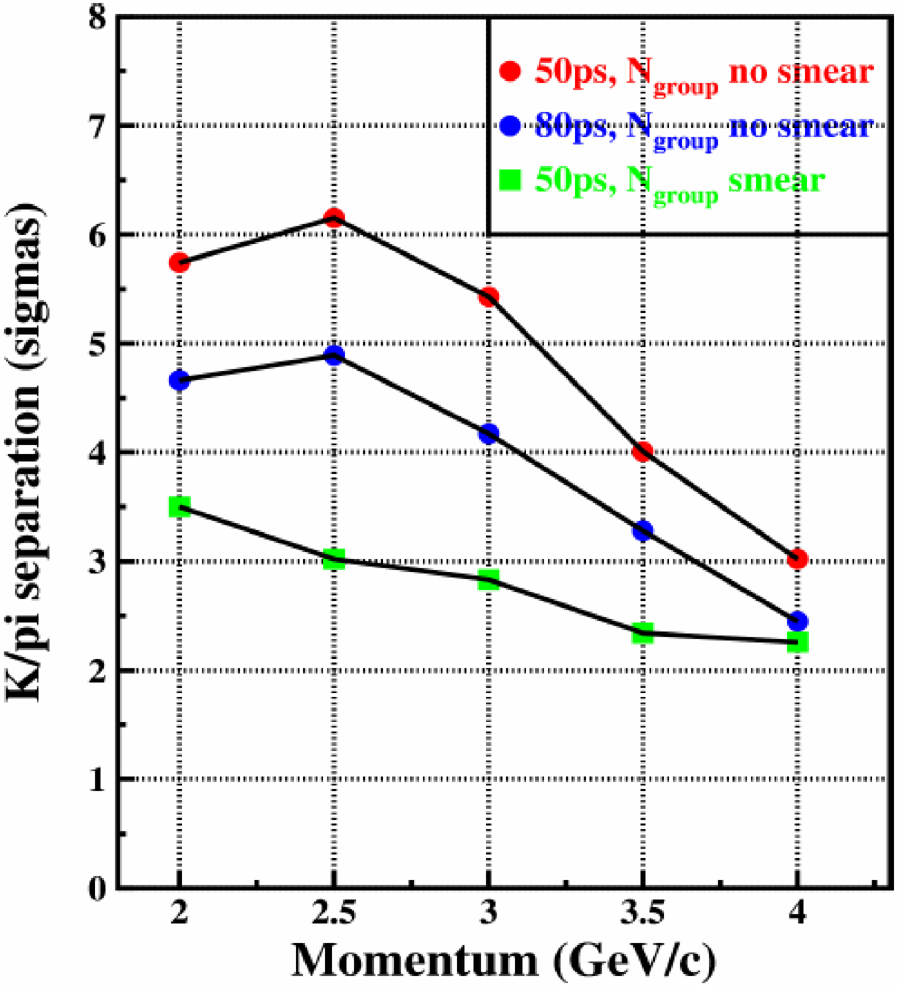






Performance

Narrow (3.5 cm) bar:



π/K separation in 2-6σ range for momentum of 2-4 GeV/c

Timing resolution difference Δ= 30 ps lowers separation by 0.5-1σ (20% of absolute separation)

Chromatic dispersion (N_{group}) lowers resolution by 1-3σ (30-50% of absolute separation -ouch)

Separation sensitive to track DIP angle and also azimuthal angle – Alexey studying this now

These results are for a narrow (Babar-like) bar: not optimal. With Mathematica we saw a notable improvement for wider bars – will study this to find optimal width.

R&D status

	TOP	iTOP	fDIRC
Point for readout	Precise timing	Fine segmented anodes	Many anodes
Detector design	Done (Some choice for focusing mirror)	Done	To be finalized to fit to Belle structure
Photo detector	MCP-PMT Basic performance is OK. Need to establish production and lifetime	Solid-state P.D.? (Chicago, Argonne and company) To be checked	MCP-PMT (Burle 85010) To be checked
Prototype	Partly done with real size quartz and MCP-PMT	Cosmic ray test with narrow bar	To be checked (Some test results with narrow bar)

What to do

- Detector performance
  - Simulation studies
    - Separation power
    - Robustness against multi-track events, beam BG
  - Prototype
    - Need to check the ring image, number of photons and time resolution

- Photo-detector + elec. performance
  - Lifetime for MCP-PMT
    - Test with round-shape and square-shape
  - Production reliability
    - GaAsP MCP-PMT
    - Solid state photon detector

By next summer

(Rough) Cost estimate

- Quartz bars
  - 18 TOP modules ($2x40x91.5cm^3$ x 3)
  - Okamoto optics (by Nagoya)
    - 1800x18+2700万円 ~ 3.6M$
  - Zygo (by A.Schwartz-san); for relaxed specification
    - $88k x 32 + $84k x 18 +alpha ~ 4.9M$
  - Need other company
- Photo detector
  - MCP-PMT for TOP; ~2.2M$
- Electronics
  - LABRADOR; <$10/ch
- Structure

Summary

- TOP / iTOP/ focusing DIRC
  - Cherenkov ring imaging with position and precise timing (<50ps) using Quartz + Photon detector
  - TOP prototype shows the expected performance.
    - Expected ring image, N_{photon}~20, time resol.~50ps
    - Test with focusing TOP proto-type now!
  - iTOP R&D with cosmic-ray test bench
    - Test with narrow quartz bar
  - Focusing DIRC
    - Under design consideration with simulation
- Photon detector
  - MCP-PMT R&D for TOP (TTS<40ps for single photo-electron)
    - Need to establish production reliability and lifetime
- Readout electronics
  - BLAB2 ASIC developed. Time jitter~12ps
- Performance test by next summer and decide detector