# Requirements to the detectors

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Why upgrade the Belle detector?

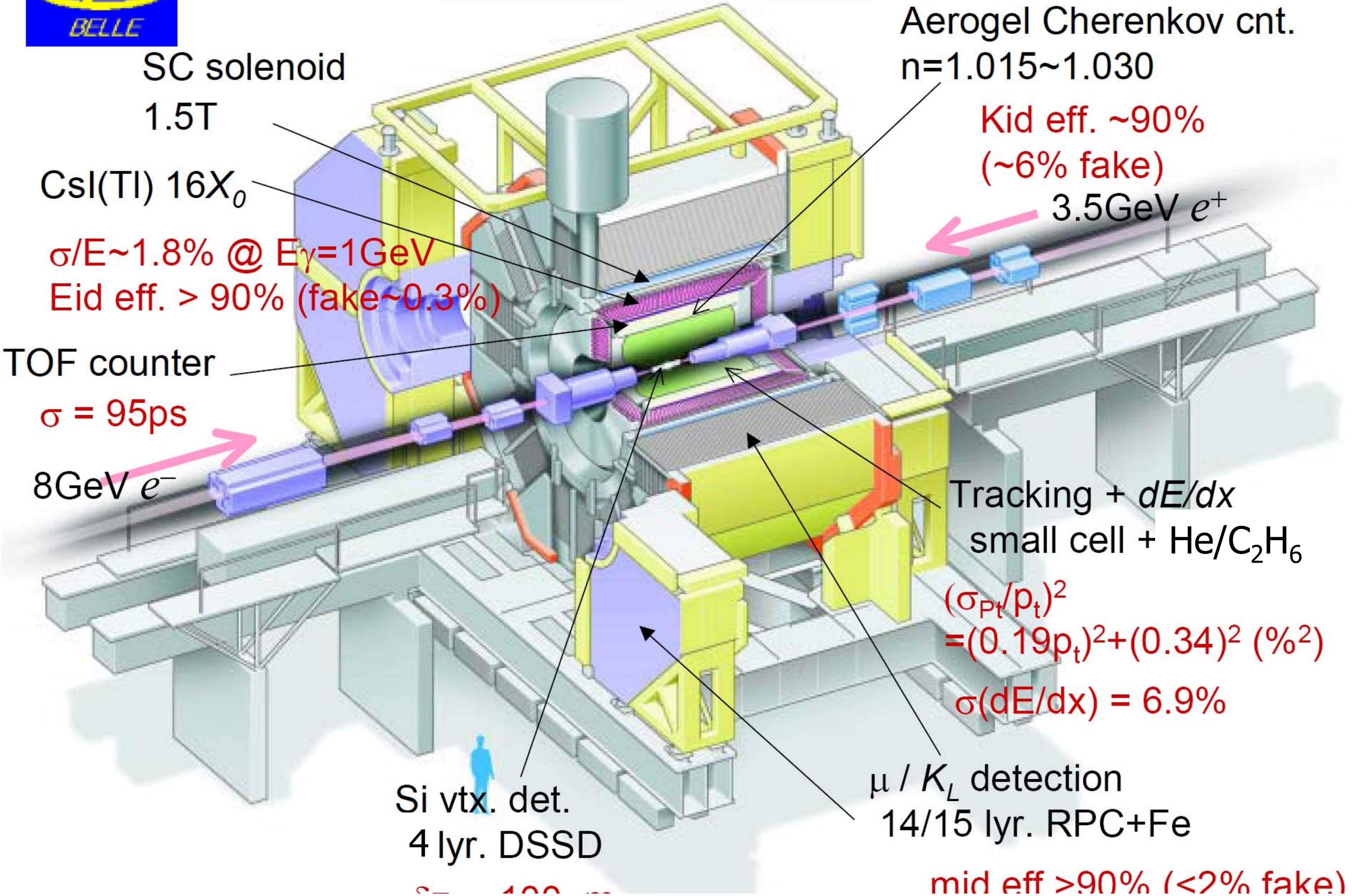
How to upgrade?

Subsystems, options

How to proceed

- Based on slides shown by Y. Ushiroda at BNM2008 and Belle PAC
- Details of individual subdetectors → see the talks later today and tomorrow

# Belle Detector



SC solenoid
1.5T

CsI(Tl) 16$X_0$

$\sigma/E \sim 1.8\%$ @ $E\gamma$=1GeV
Eid eff. > 90% (fake~0.3%)

TOF counter
$\sigma$ = 95ps

8GeV $e^-$

Aerogel Cherenkov cnt.
n=1.015~1.030

Kid eff. ~90%
(~6% fake)

3.5GeV $e^+$

Tracking + *dE/dx*
small cell + He/$C_2H_6$

$(\sigma_{Pt}/p_t)^2$
$=(0.19p_t)^2+(0.34)^2$ ($\%^2$)

$\sigma$(dE/dx) = 6.9%

Si vtx. det.
4 lyr. DSSD

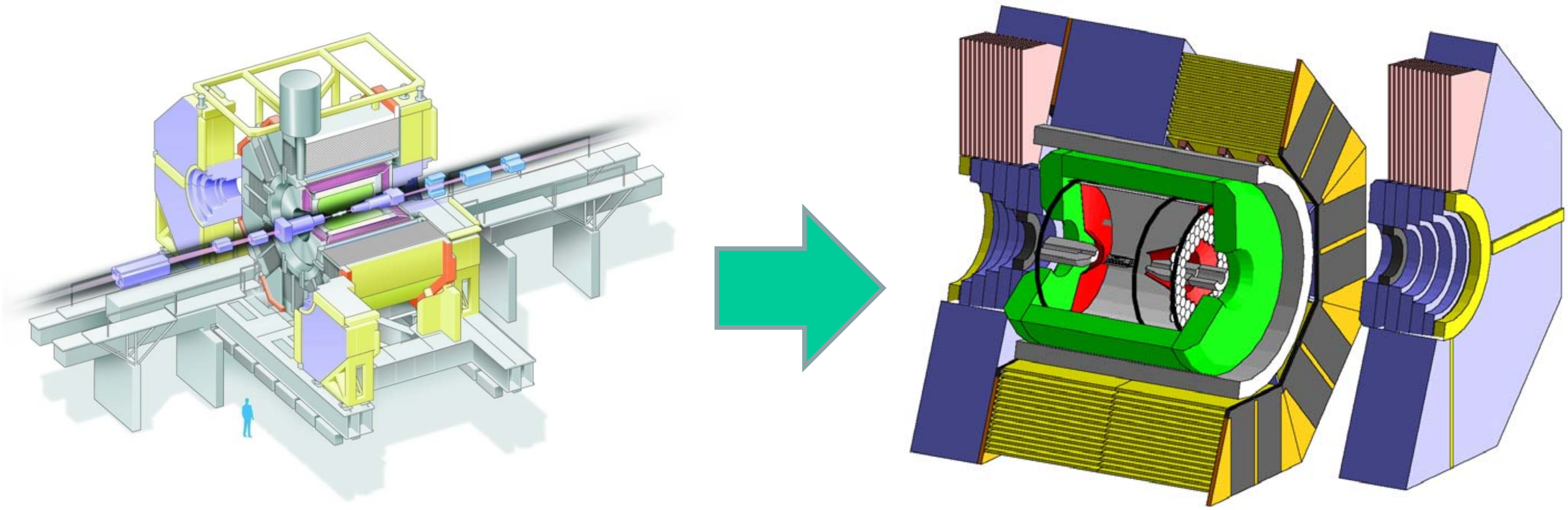
$\delta z \sim 100\mu m$

$\mu$ / $K_L$ detection
14/15 lyr. RPC+Fe

$\mu$id eff >90% (<2% fake)

# Motivation for the detector upgrade

1. Need a better performance, better physics sensitivities and operation at higher rates
2. Operation under higher background rates

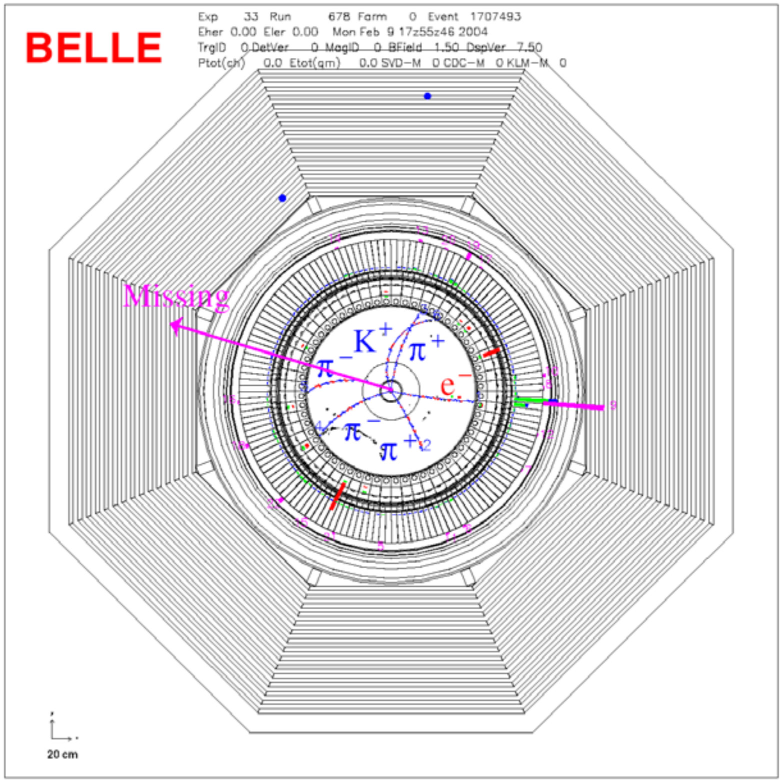


# Motivation for the detector upgrade

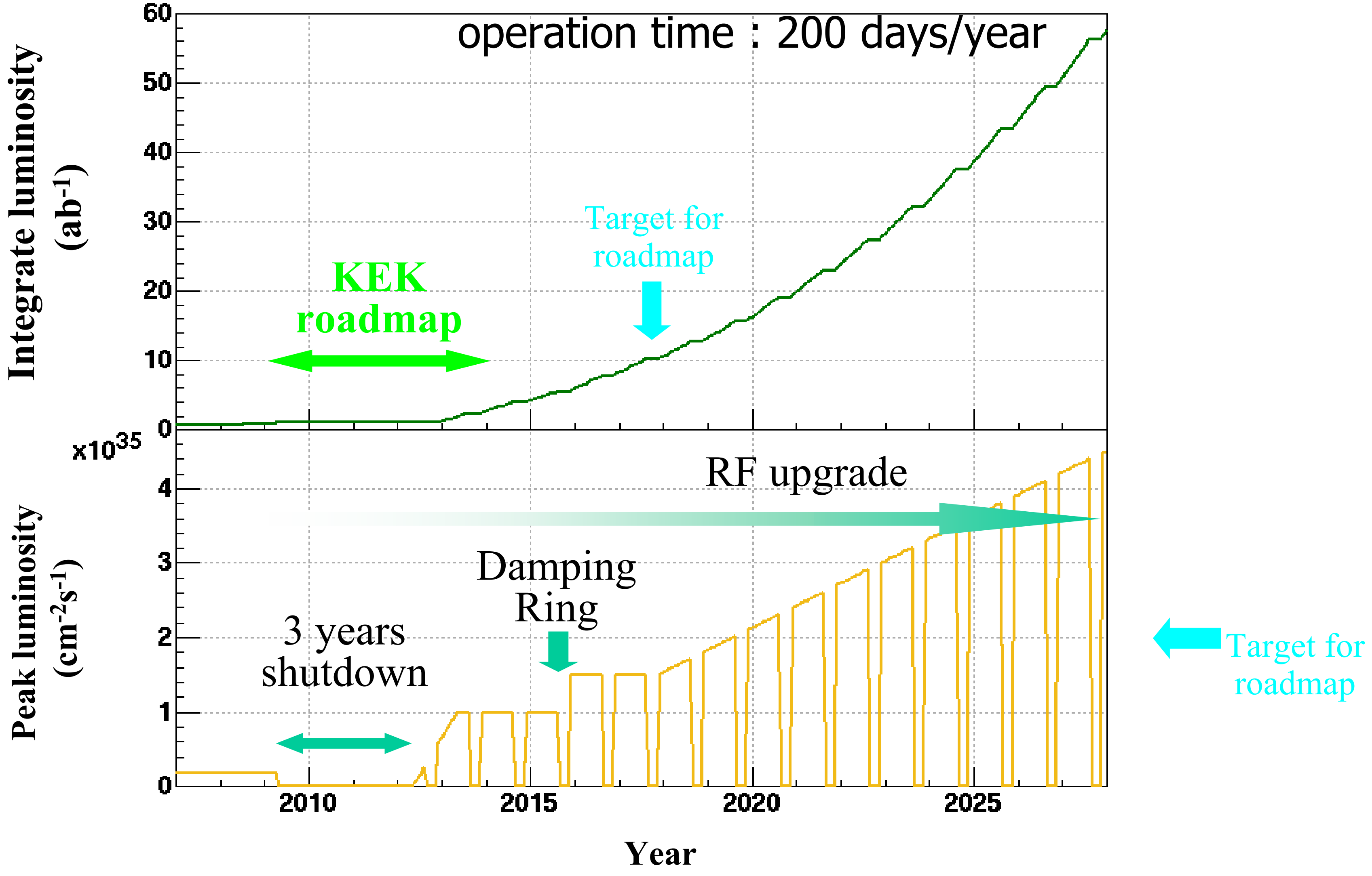
Need a better performance, better physics sensitivities and operation at higher rates

- better π/K separation for B→ργ decays
- low momentum μ identification → sμμ recon. eff.
- hermeticity → ν “reconstruction”

$$\begin{aligned} B^+ &\rightarrow D^0\pi^+ \\ &\quad (\rightarrow K\pi^-\pi^+\pi^-) \\ B^- &\rightarrow \tau(\rightarrow e\nu\bar{\nu})\nu \end{aligned}$$



# Projected luminosity (preliminary)



operation time : 200 days/year

**KEK roadmap**

Target for roadmap

RF upgrade

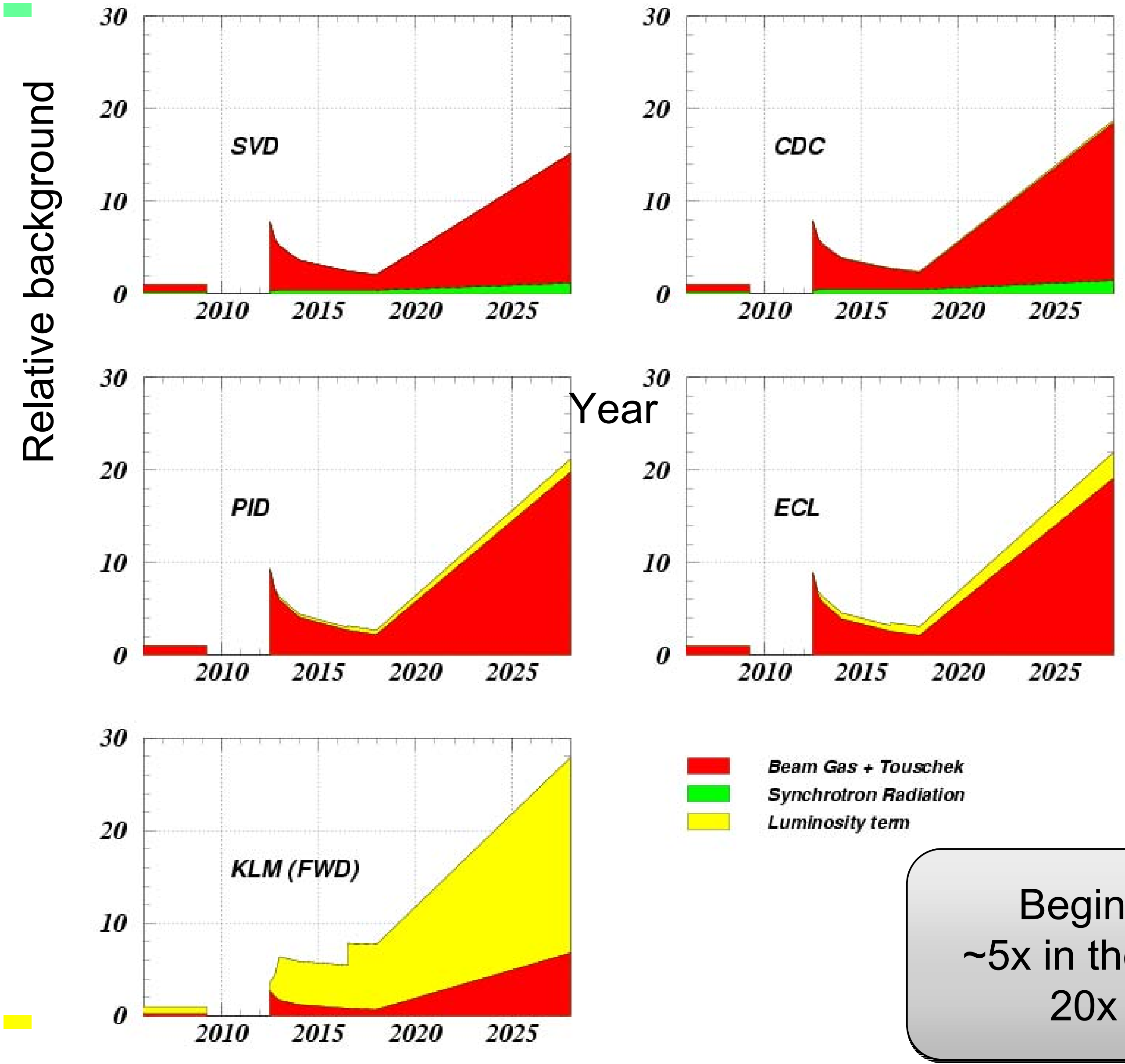
Damping Ring

3 years shutdown

Target for roadmap

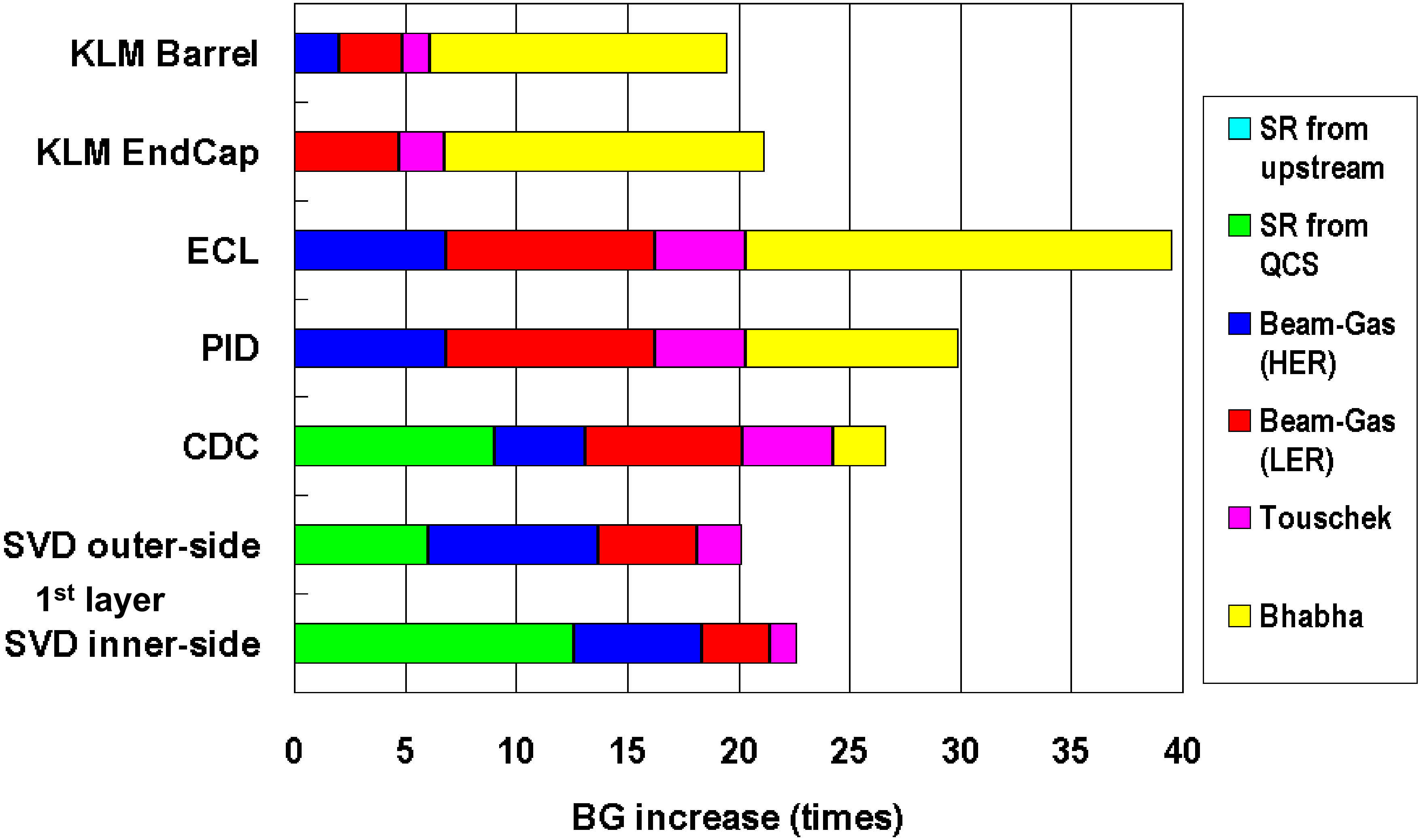
Conservative scenario – quicker with more money!

# Background projection (preliminary)



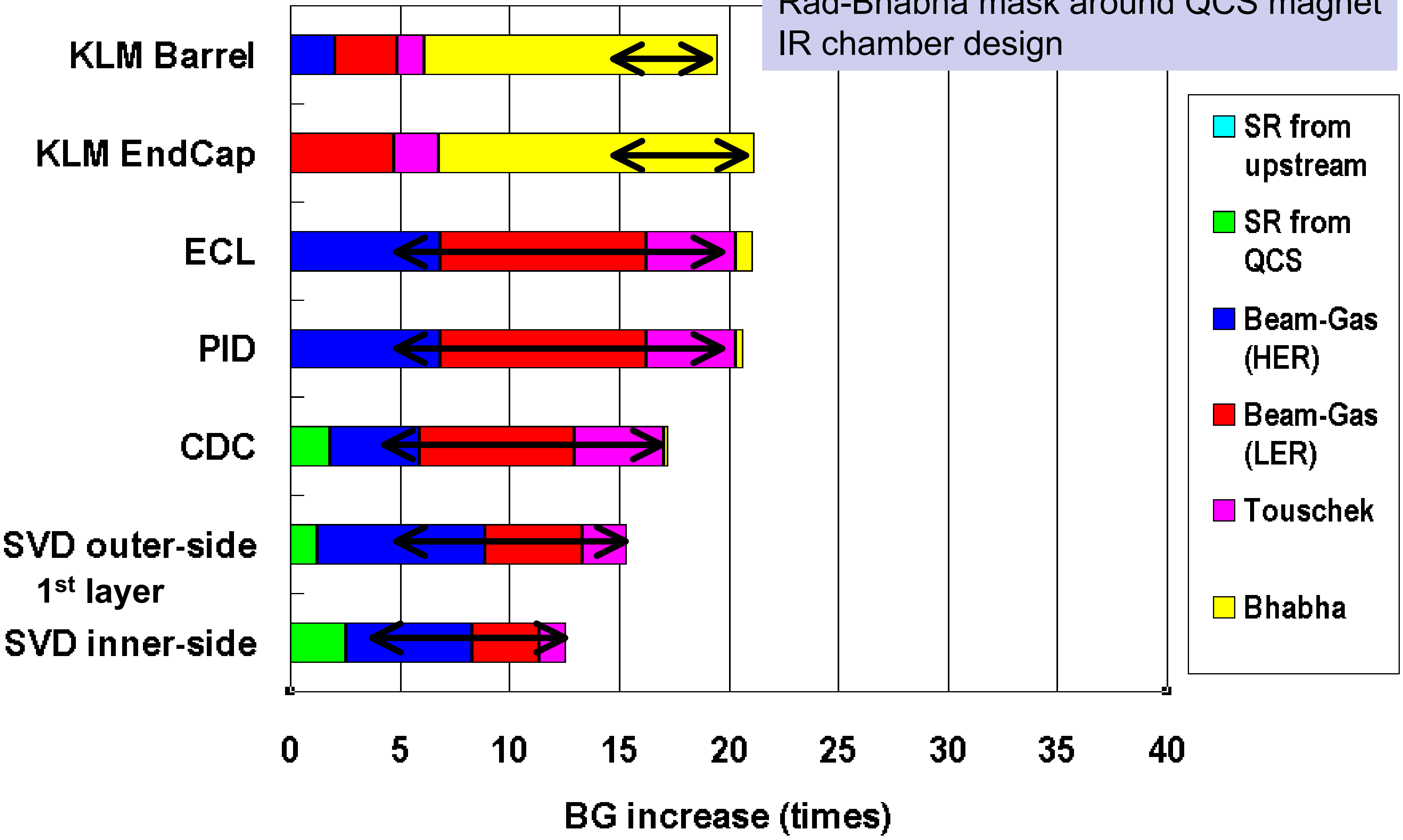
Begins with 7~10x
~5x in the first few years
20x at full spec

# Beam Background (LoI)



# Beam Background (present)

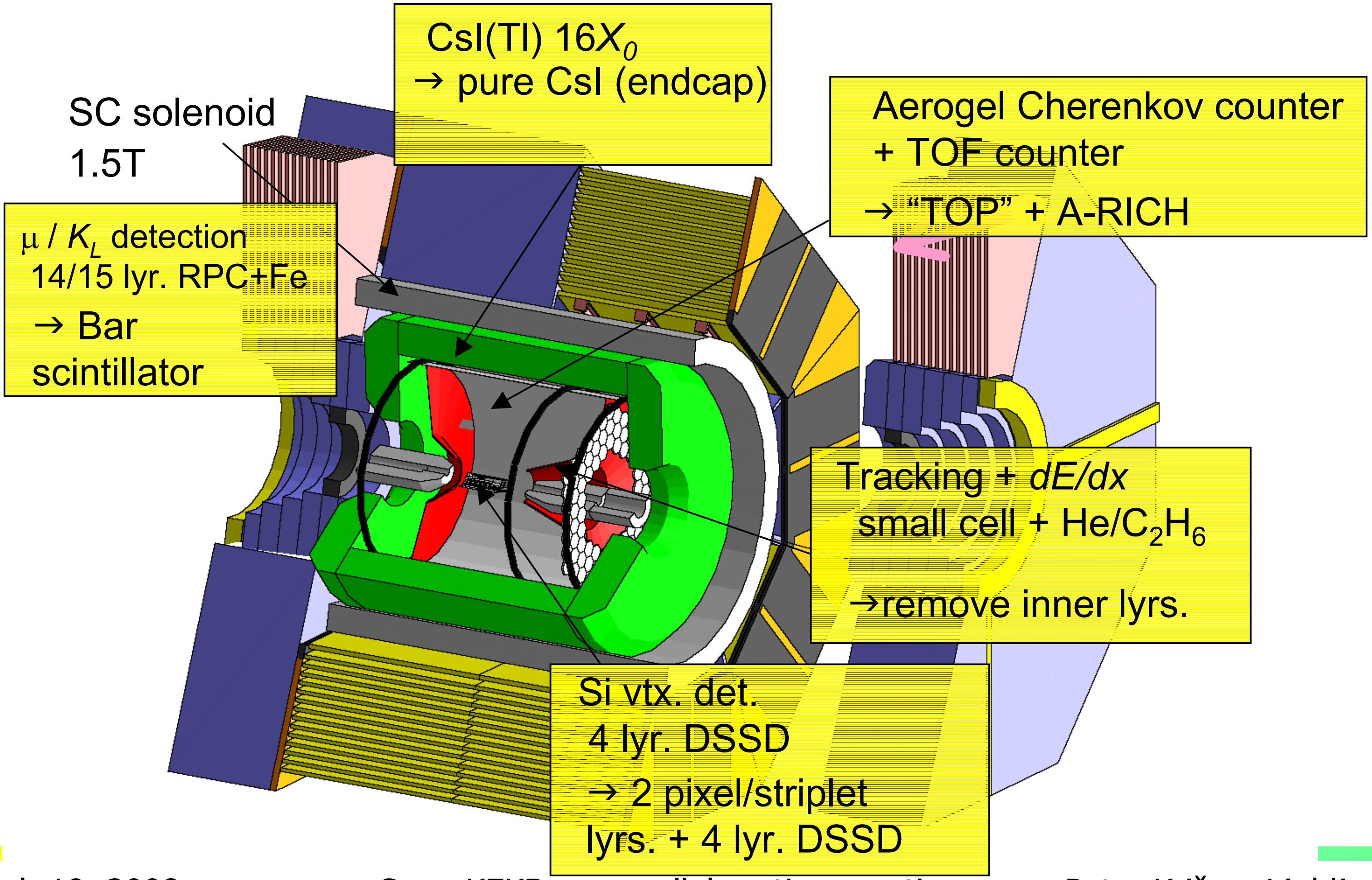
Rad-Bhabha mask around QCS magnet
IR chamber design



Several to 20 times more background (depending on $I_{beam}$)

# Baseline design for the upgrade

One of the possible designs; minimum modification to the Belle structure
Comparable or better performance under 20 times more background



CsI(Tl) $16X_0$
→ pure CsI (endcap)

SC solenoid
1.5T

Aerogel Cherenkov counter
+ TOF counter
→ "TOP" + A-RICH

$\mu$ / $K_L$ detection
14/15 lyr. RPC+Fe
→ Bar scintillator

Tracking + *dE/dx*
small cell + He/$C_2H_6$
→remove inner lyrs.

Si vtx. det.
4 lyr. DSSD
→ 2 pixel/striplet lyrs. + 4 lyr. DSSD

# Motivation of simulation studies

- Detector design is flexible. A few limitations:
  - Should work under 20 times more background
  - Try to keep the same mechanical structure for the outer detectors (ECL,KLM)
  - Technologically feasible (within a few years)
  - Financially possible
- With these limitations, we wish to have the best detector for future physics analyses
  - When the limitation is tight, we look for a compromise rather than the optimum point.

Use fast and full MC, both tuned with present Belle data

# Key points of SVD upgrade

## Vertex Resolution

•1st layer closer to the IP (BP r=15mm → 10mm) *later* with pixel

## Vertex efficiency for $K_S$

- Enlarge radial volume ($r_{N-1}$=70mm → 120mm or more)
  - 20% more $K_S$ for TCPV studies w/ 120mm
- Detector capacitance is an issue

↓

Chip-on-sensor

↓

Material effect is an issue

## Background tolerance

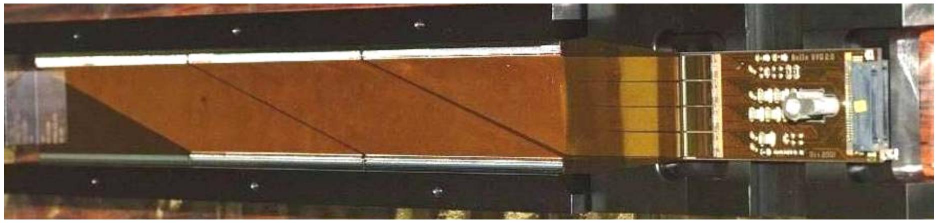
- Current readout chip (VA1TA) dies 3μs/hold, 27μs/readout → analog pipelined chip (APV25)
- Shaping time 0.8μs (VA1TA) → 50ns (APV25)
- Monolithic Pixel detector in the end

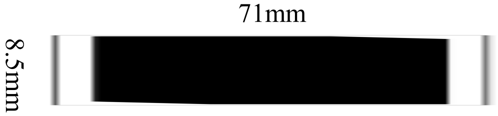
## Other

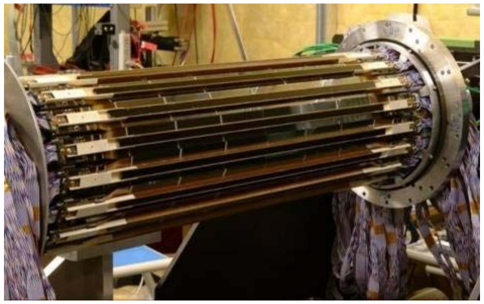
- Standalone tracking to increase slow track efficiency
- dE/dx measurement in SVD
- Better alignment

# Options we have

- Sensor
  - Pixels (SOI, DEPFET)
  - DSSD (striplet/normal)
- Readout chip
  - APV25
    - $t_p$ = 50ns, pipelined, weak at high $C_d$
  - VA1TA (currently used)
    - $t_p$ = 800ns, hold & readout
  - Own ASIC





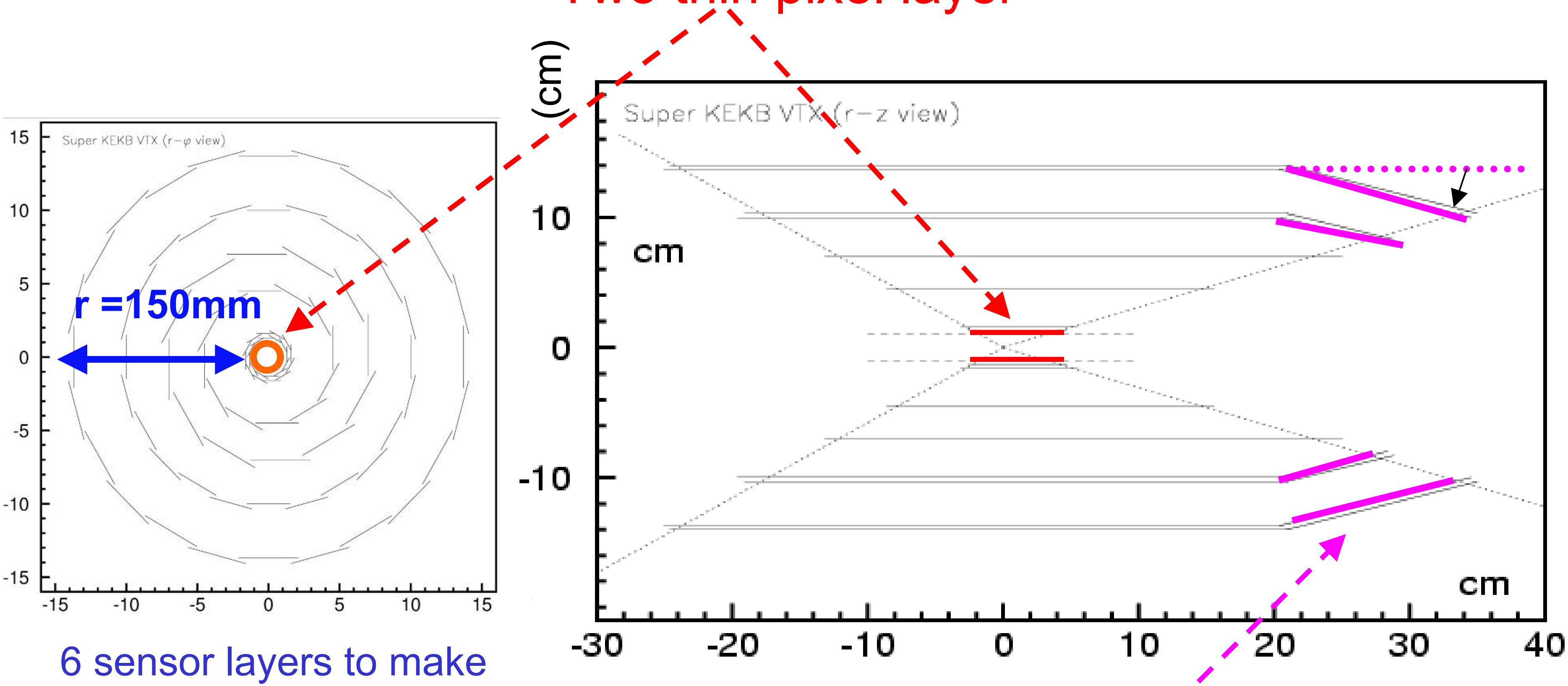


Open questions:

1. Inner radius
2. Outer radius
3. Material budget
4. Readout pitch of outer layers
5. Slant angle

# Baseline Design (LoI ‘04)

Two thin pixel layer



6 sensor layers to make low momentum tracking

Slanted layer to keep acceptance, optimize incident angle and save detector size

# SVT upgrade Strategy

T. Kawasaki
H. Hoedlmoser
H.G. Moser

- T=0 option (2012) for $\mathcal{L}$ = ~$10^{35}$
  - – Keep beampipe radius 1.5cm same as current
  - – Current SVD configuration + 2 outer layers
    - Improve Ks efficiency. Replace CDC inner layers
    - Similar design DSSD can be used
  - – Fast shaping(~50ns) + time slice

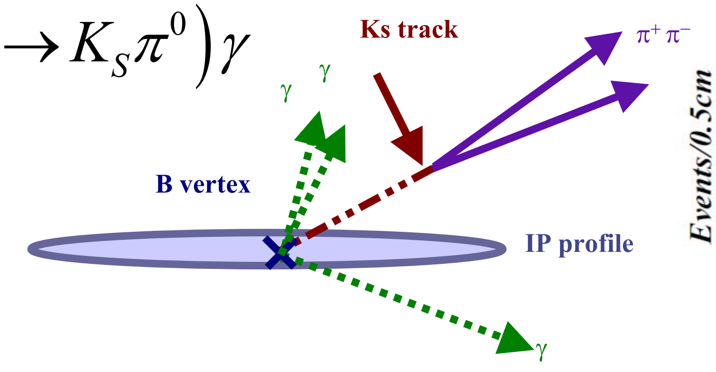
- Further upgrade for $\mathcal{L}$ $>10^{35}$
  - – Smaller beampipe radius (r =1cm or less)
  - – Innermost (thin) pixel layers
    - Improve impact parameter resolution

Pixels could also come on day 1 if ready!

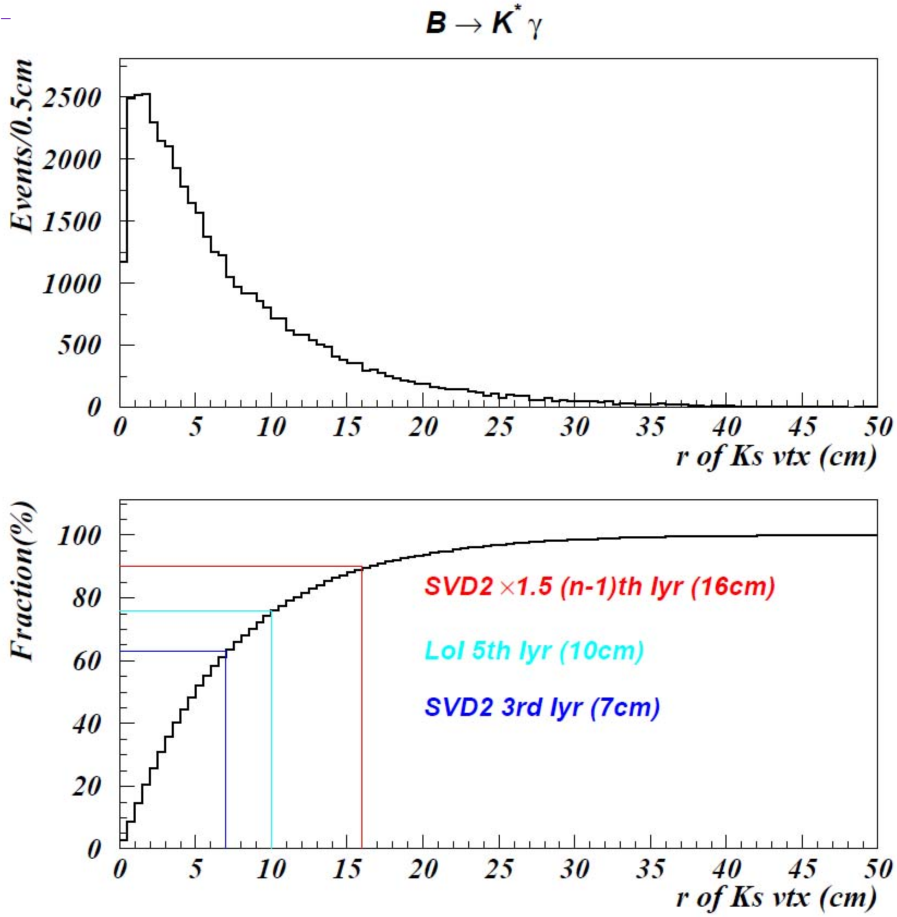
T. Kawasaki

# Outer layers and outer radius

$$B^0 \to K^{*0}\left(\to K_S\pi^0\right)\gamma$$

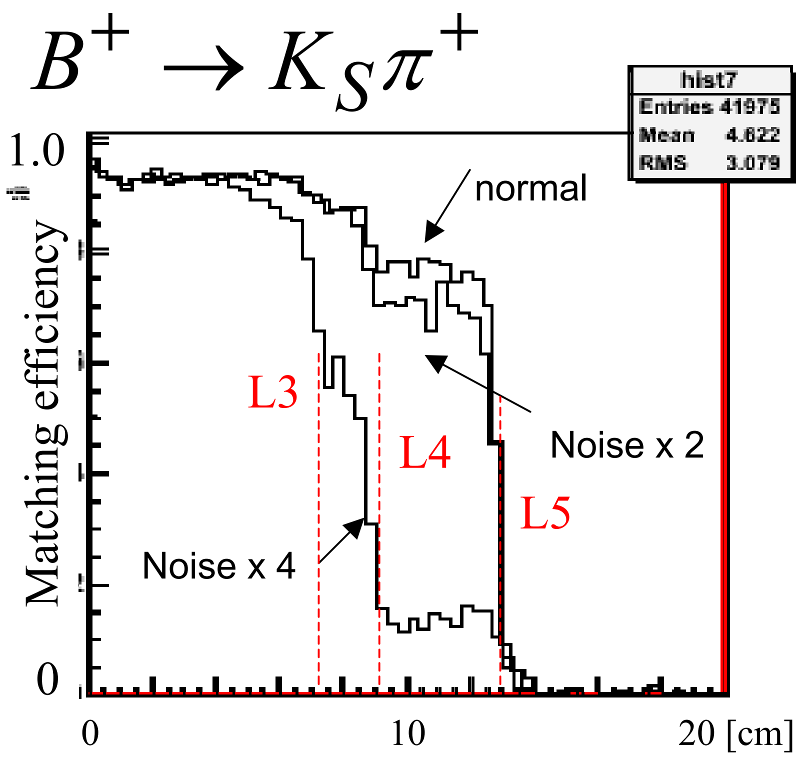


B vertex recon by a $K_S$



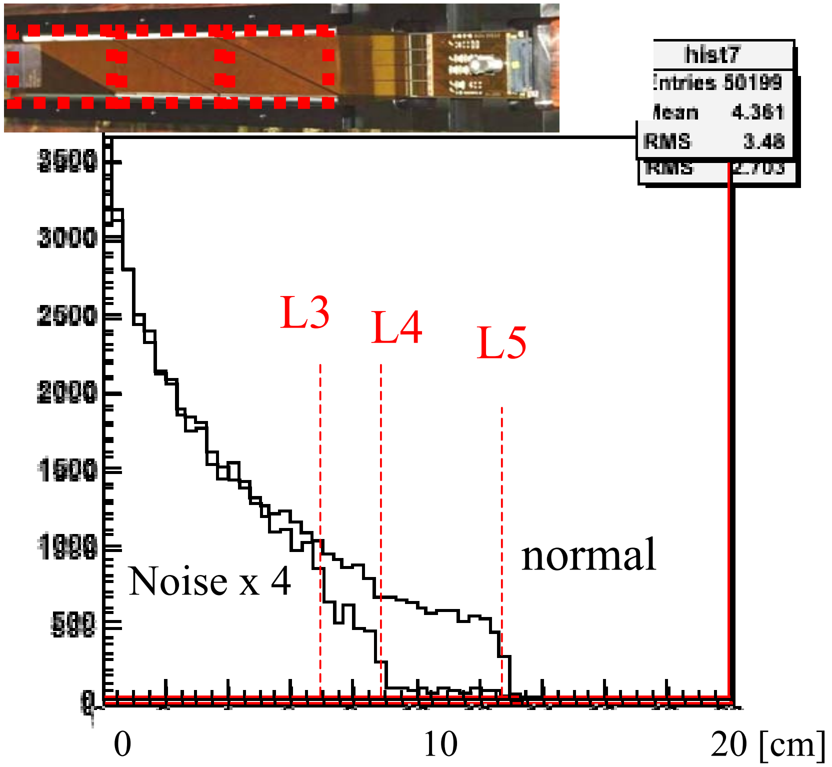
- The larger the better for $K_S$
- Long sensor → large capacitance → big noise

# Matching efficiency for Ks



$B^+ \rightarrow K_S \pi^+$

*r* of Ks decay vertex



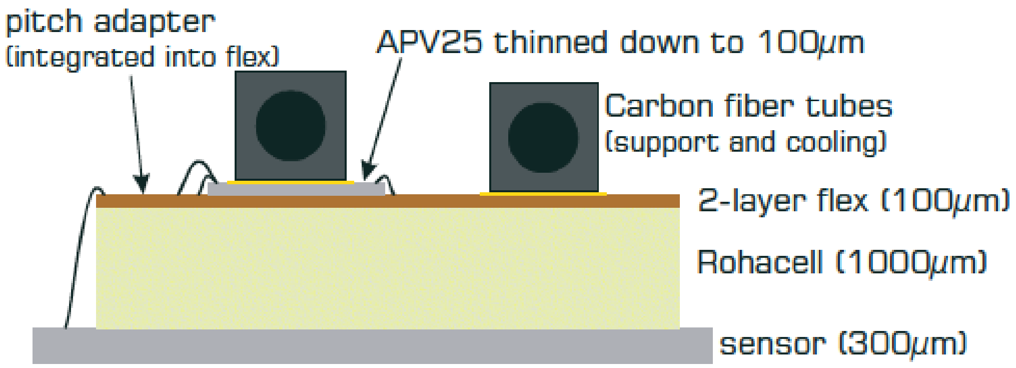
*r* of Ks decay vertex

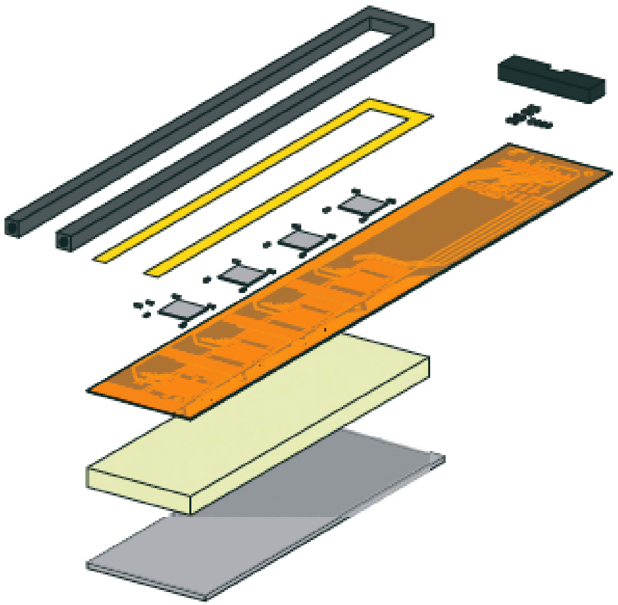
$K_S$ daughter tracks affected by S/N degradation

Loose 20% events with 4 times worse S/N

T. Kawasaki

# Chip on sensor?





(Drawings not to scale)

To use APV25 chips for the outer layers, they have to be put on top of the sensors

1. Material okay?
2. Cooling possible?
3. Stable?

# Material impact on vertex resolution

| | $\pi^+\pi^-$ (31μm) | $J/\psi K_S$ (36μm) | $D^+D^-$ (43μm) | $K^*(K_S\pi^0)\gamma$ (128μm) |
|---|---|---|---|---|
| 2×ρ for SVD,CDC | 6% | 11% | 19% | |
| 2×ρ for SVD | 6% | 11% | 21% | |
| 2×ρ for SVD lyr1,2 | 6% | 11% | 19% | |
| 2×ρ for SVD lyr3,4 | 0% | 0% | 0% | |
| 2×ρ for SVD lyr3,4 + cooling tube | 0% | 0% | 0% | 7% |

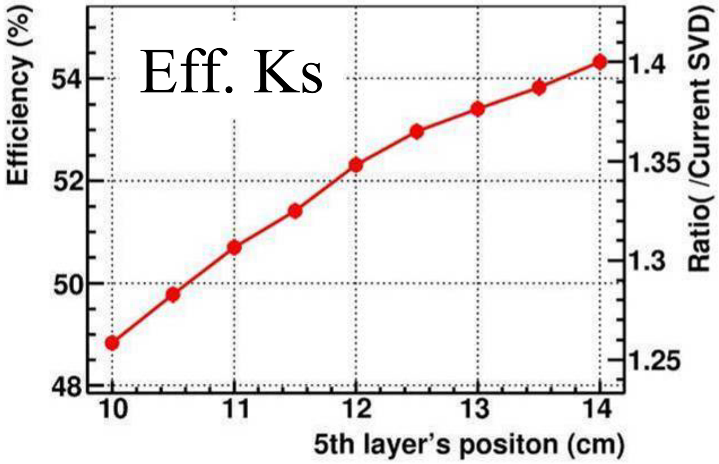
No degradation

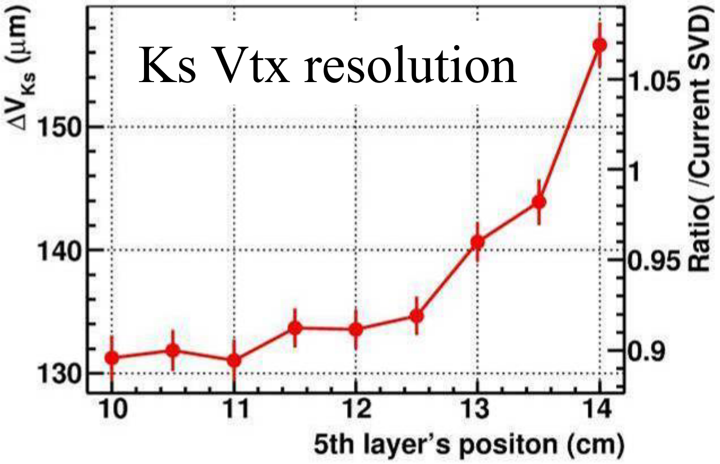
- No problem to increase the material in outer layers for 'normal' vertex reconstruction.
- Dilutes the merit of having a larger volume for $K_S$

T. Kawasaki

# Other MC results

- $K_S$ reconstruction





Fix the 6th lyr at 14cm
Tune the position of 5th lyr

→

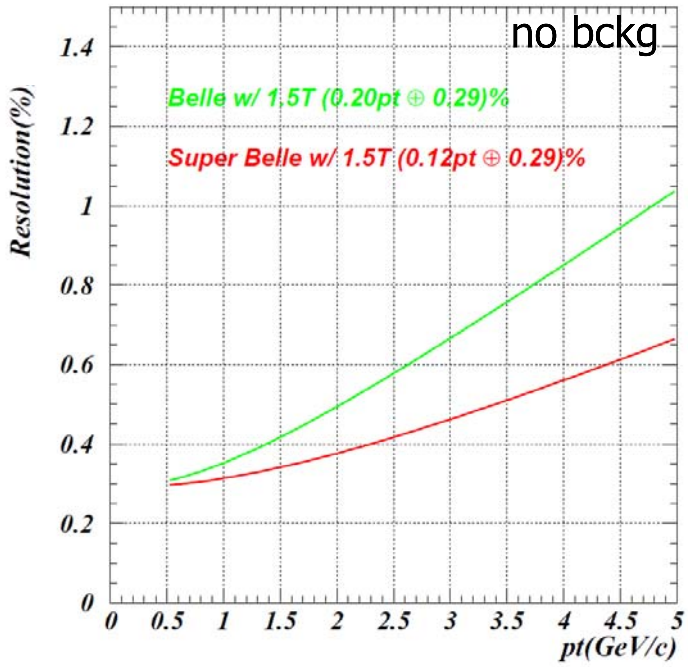
5th lyr at 12 cm is optimal

- Momentum resolution: is not affected by material in SVD

# Key points of CDC upgrade

### pt resolution

- Longer lever arm to improve momentum resolution



### dE/dx

- Larger radial volume for better dE/dx measurement (752mm → 978mm)

### Background tolerance

- Smaller cell size
  - innermost 12mm, 64cells → 8mm, 160cells
- Gas (current one is the best)

# CDC main parameters

| | Present | Upgrade |
|---|---|---|
| Radius of inner boundary (mm) | 77 | 160 |
| Radius of outer boundary (mm) | 880 | 1140 |
| Radius of inner most sense wire (mm) | 88 | 172 |
| Radius of outer most sense wire (mm) | 863 | 1120 |
| Number of layers | 50 | 58 |
| Number of sense wires | 8400 | 15104 |
| Effective length of dE/dx measurement (mm) | 752 | 978 |
| Gas | He-$C_2H_6$ | He-$C_2H_6$ |
| Diameter of sense wire ($\mu$m) | 30 | 30 |

# Background effect on tracking

H. Ozaki
BNM2008

$$D^* D^* (D^* \to D\pi_s, D \to K\mathbf{3}\pi)$$

Many low momentum tracks, the hardest case for tracking

Gain in reconstruction efficiency of B→$D^*D^*$

| Tracker<br>BKG | Belle | Software update | +SVD tracker |
|---|---|---|---|
| Belle | ε=4.3%<br>0% (definition) | ε=7.1%<br>+65% | ε=11.9%<br>+177% |
| × 5 BG | | ε=6.3%<br>+47% | ε=11.2%<br>+160% |
| × 20 BG | | ε=3.8%<br>–12% | ε=8.8%<br>+105% |

Excellent with help of SVD

# Key points of PID upgrade

**$K/\pi$ separation**

- Smaller K contamination in $\pi$ candidate helps a lot in e.g. $B \to \rho\gamma$ analysis

**Forward end-cap**

- No dedicated PID in end caps for high momentum tracks → (A-RICH)

**Material**

- Less material, and material closer to ECL is preferred

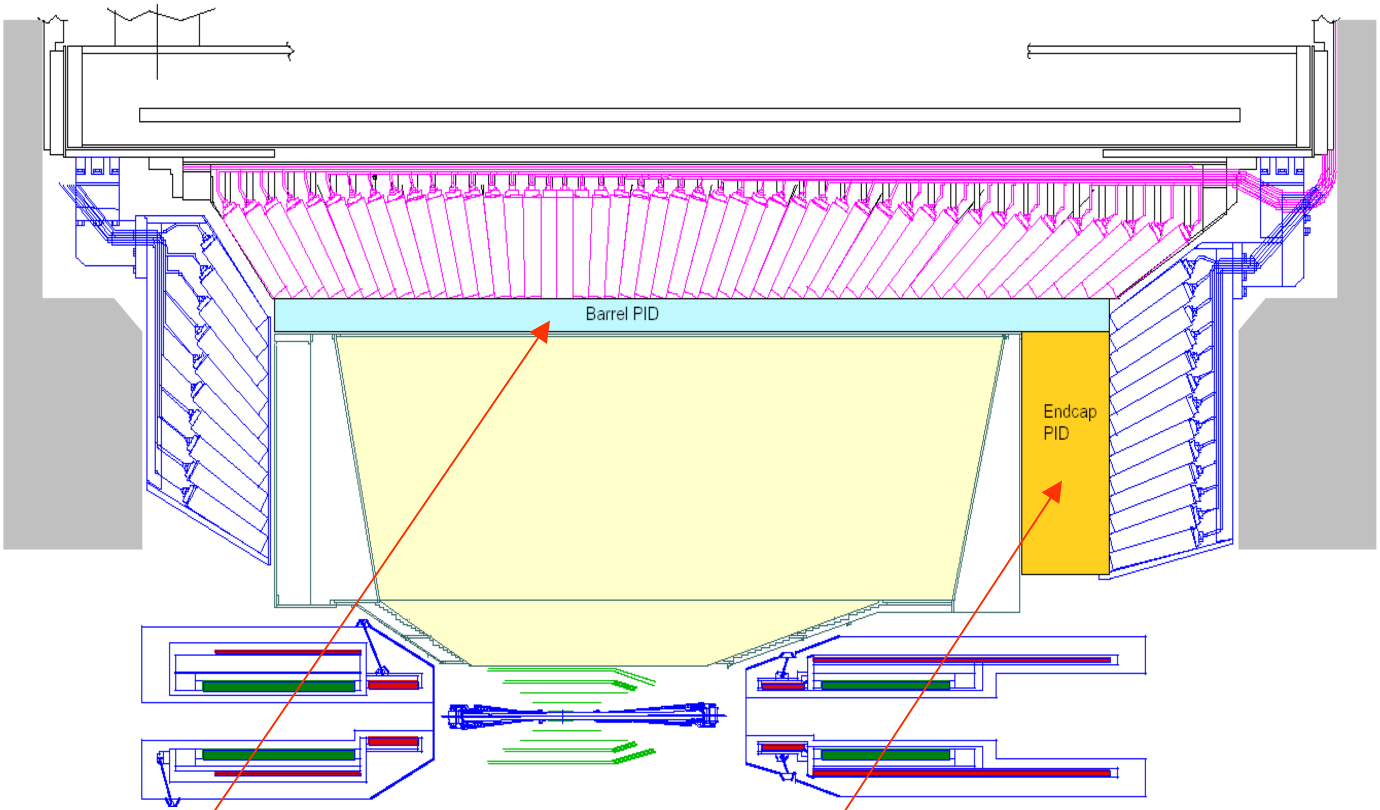
**Charge asymmetry**

- PID efficiency depends on particle charge (a source of systematic error) → quartz bar?!

**Background tolerance**

- TOF will not work under high background → Cherenkov detector (TOP)

# PID upgrade

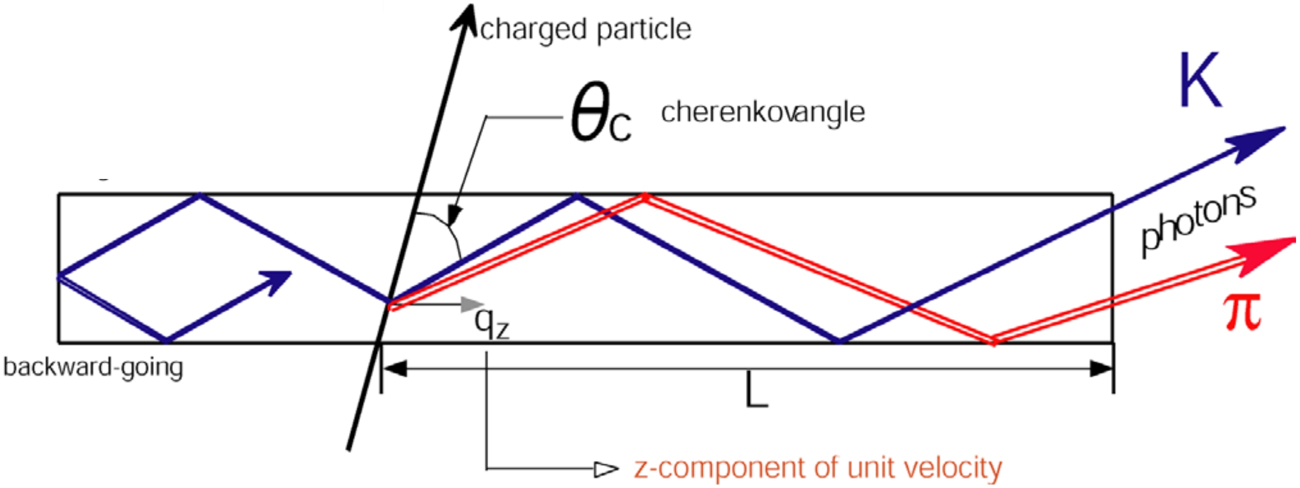


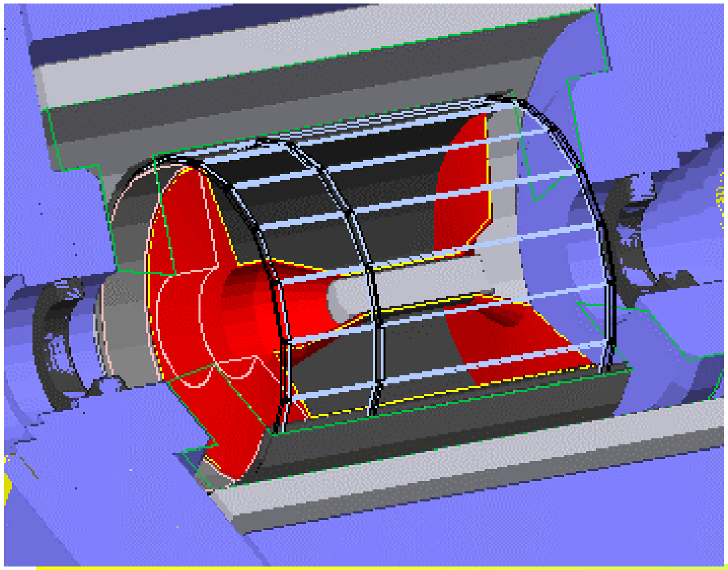
Two new particle ID devices, both RICHes:

Barrel: Time-Of-Propagation (TOP) or fDIRC or iTOP

Endcap: proximity focusing RICH

# Barrel PID

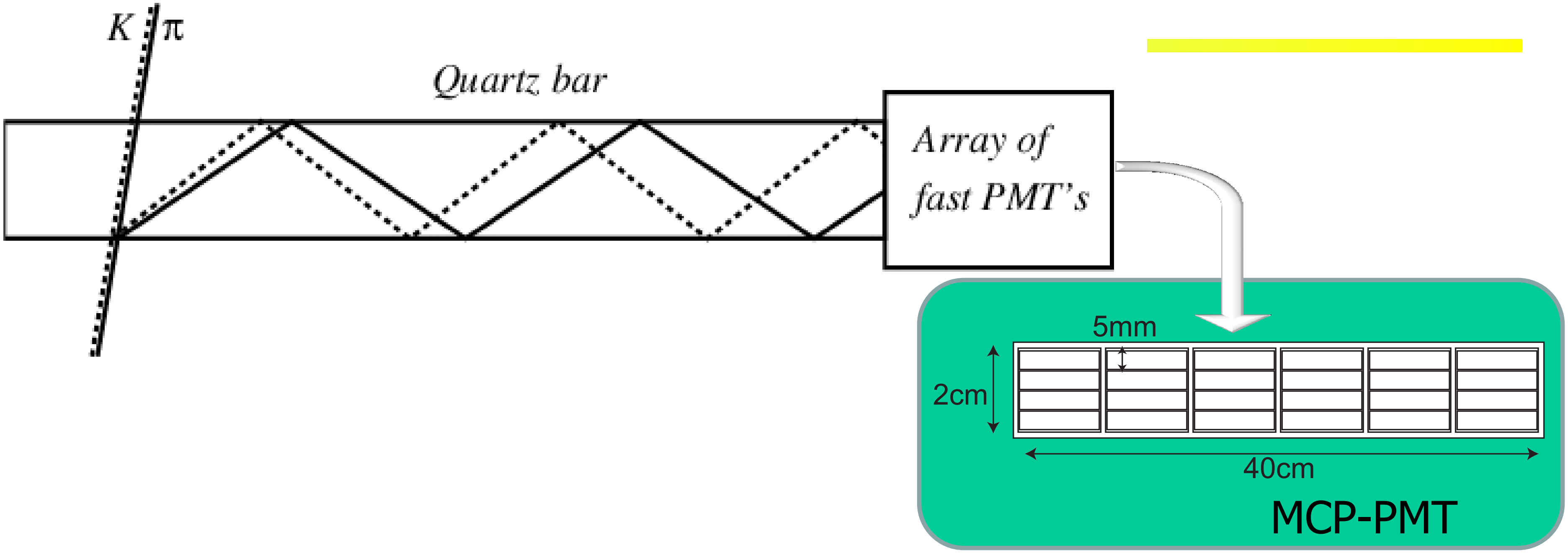




Imaging Cherenkov counter with quartz bars as radiators.

Image read-out:
- Time-Of-Propagation (TOP)
- Focusing DIRC
- Imaging TOP

# Baseline: Time-Of-Propagation (TOP) counter

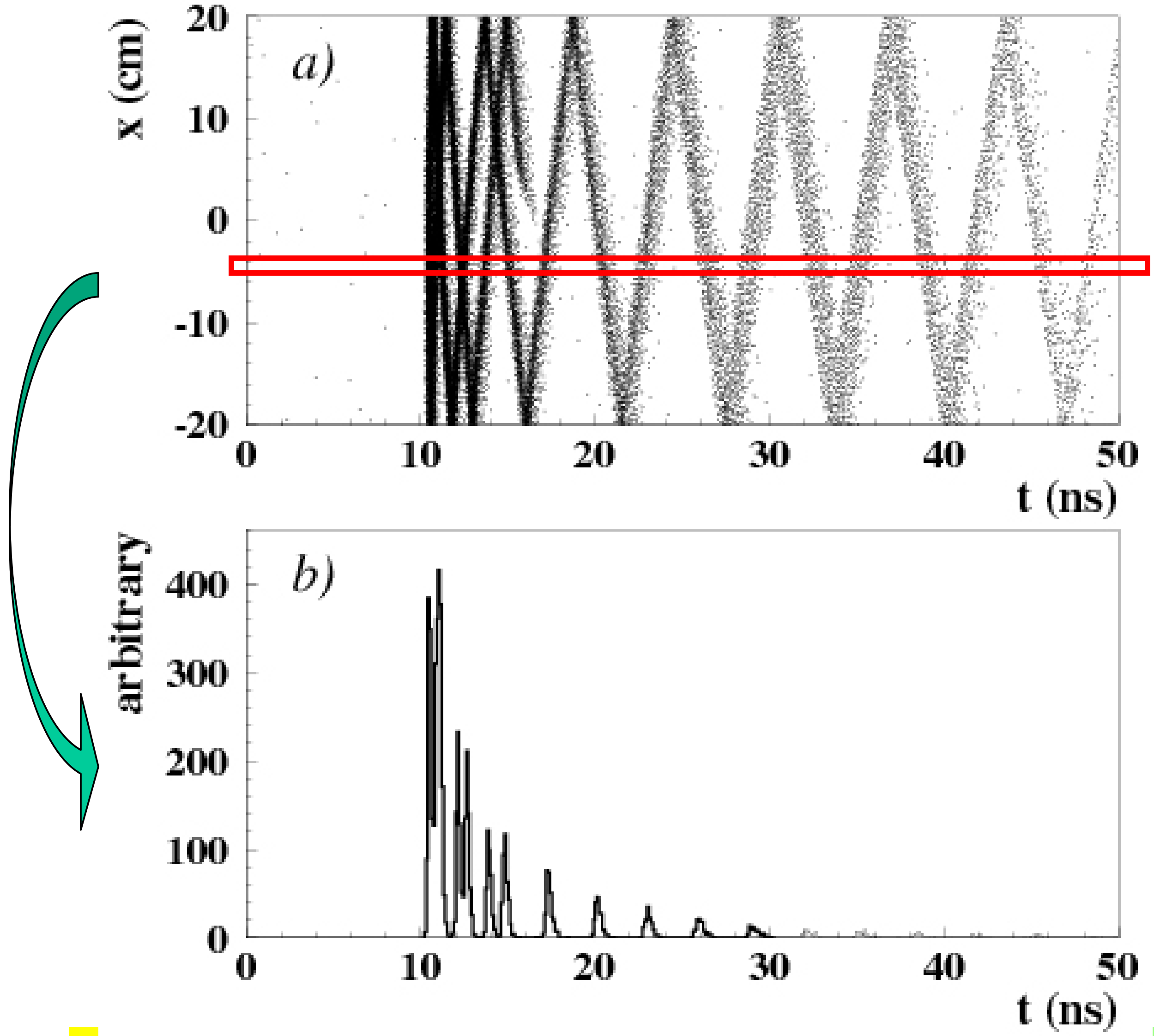


Similar to DIRC, but instead of two coordinates after a stand-off box measure at the bar end:

- One (or two coordinates) with a few mm precision
- Time-of-arrival

→ Excellent time resolution < ~40ps required for single photons in 1.5T B field

# TOP image



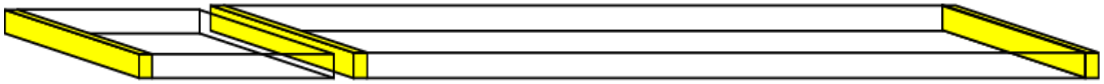
Pattern in the coordinate-time space ('ring') of a pion hitting a quartz bar with ~80 MAPMT channels

Time distribution of signals recorded by one of the PMT channels: different for $\pi$ and K

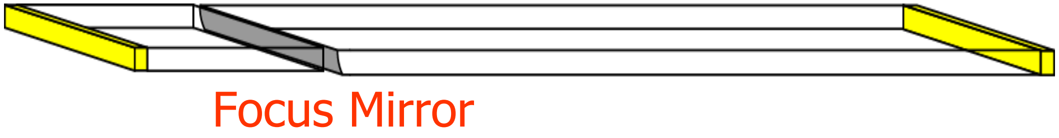
# Possible configuration

K. Inami

- Detector type



  - **3-readout type**
    - Optimized propagation length
    - Simple configuration
    - Simple ring image

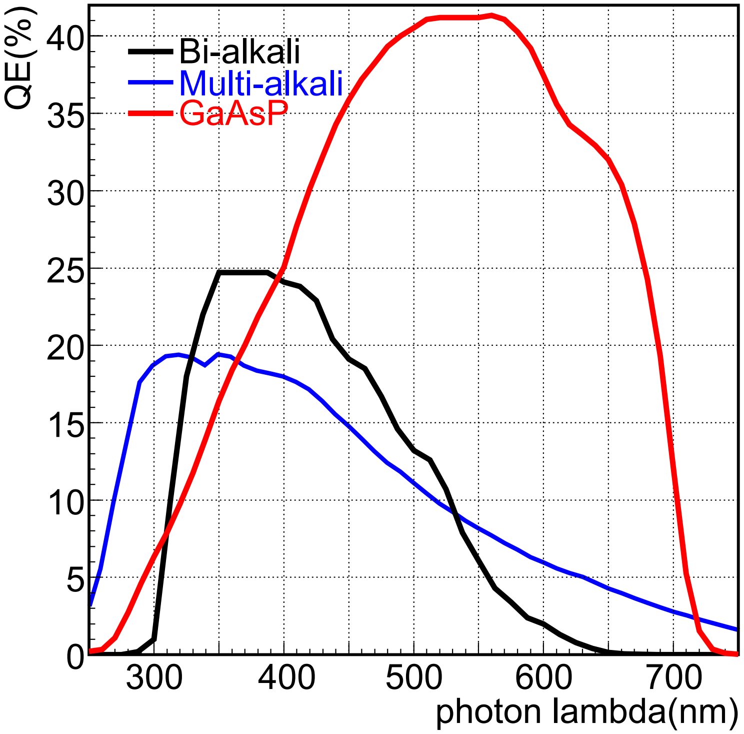


  - **Focusing type**
    - Correct chromaticity
    - 2/3 of PMTs
      - Cost
      - Easy to replace PMTs because of no middle PMT
    - Complicated ring image
      - Need a new reconstruction method
      - May need more sim. study

K. Inami

# Possible configuration

- Photo-cathode of MCP-PMT
  - Multi-alkali
    - Almost established production
    - Enough lifetime (with Al layer)
  - GaAsP
    - Better efficiency at longer wavelength→less dispersion
    - Need more production R&D and lifetime test
  - Multi-alkali without protection layer on MCP
    - Better efficiency (x1.6)
    - Almost established production, but need some modification to improve lifetime (3-layer MCP, lower gain etc.)

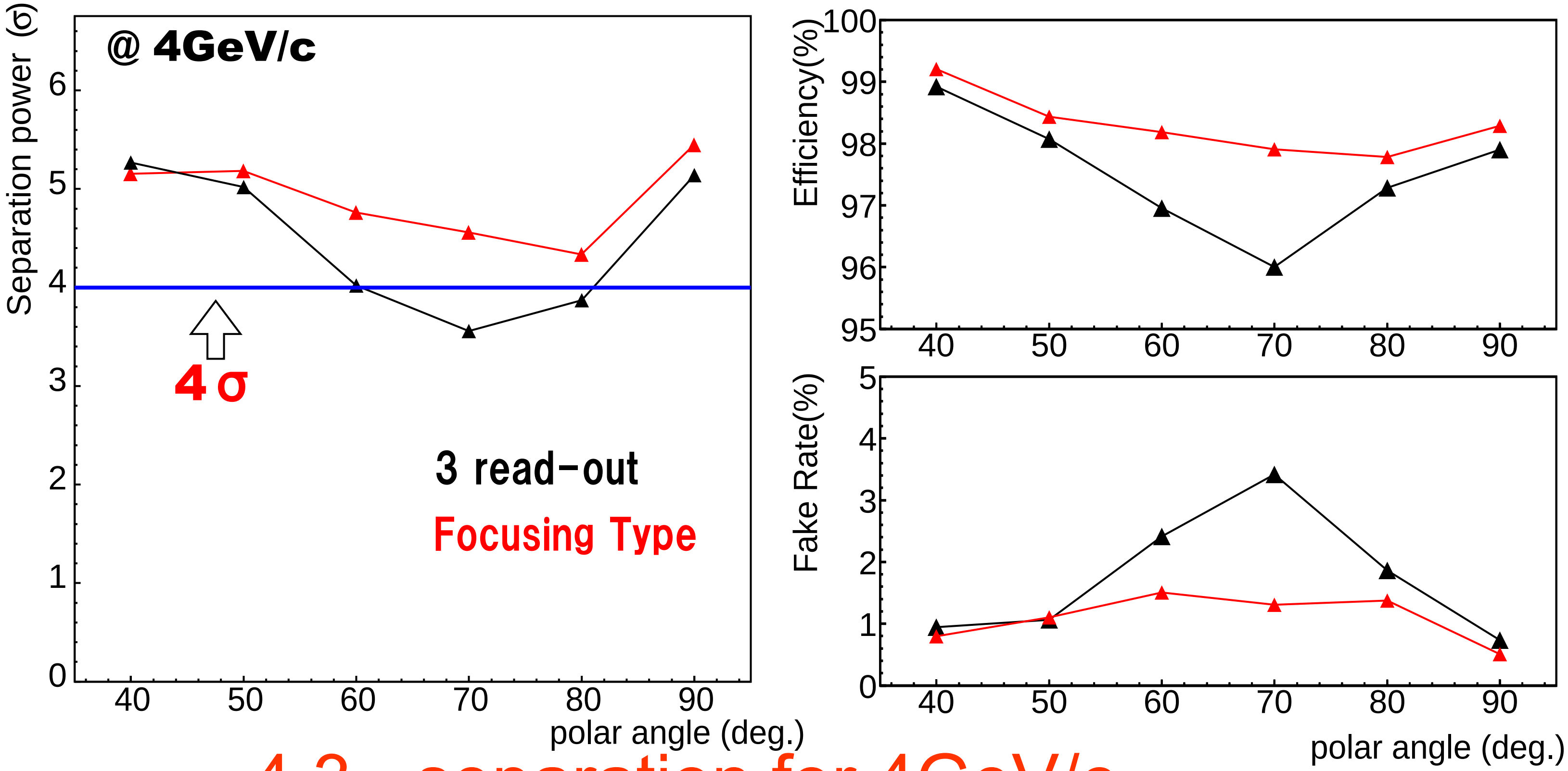


K. Inami

# Performance of focusing TOP

- K/π separation power
  - GaAsP photo-cathode(+>400μm filter), CE=36%

**Separation power** **Efficiency,Fake rate**

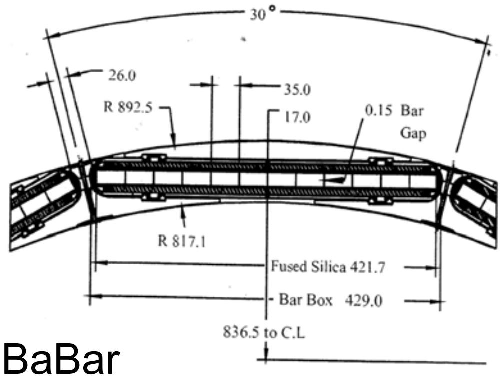


4.3σ separation for 4GeV/c

Talk by K. Inami

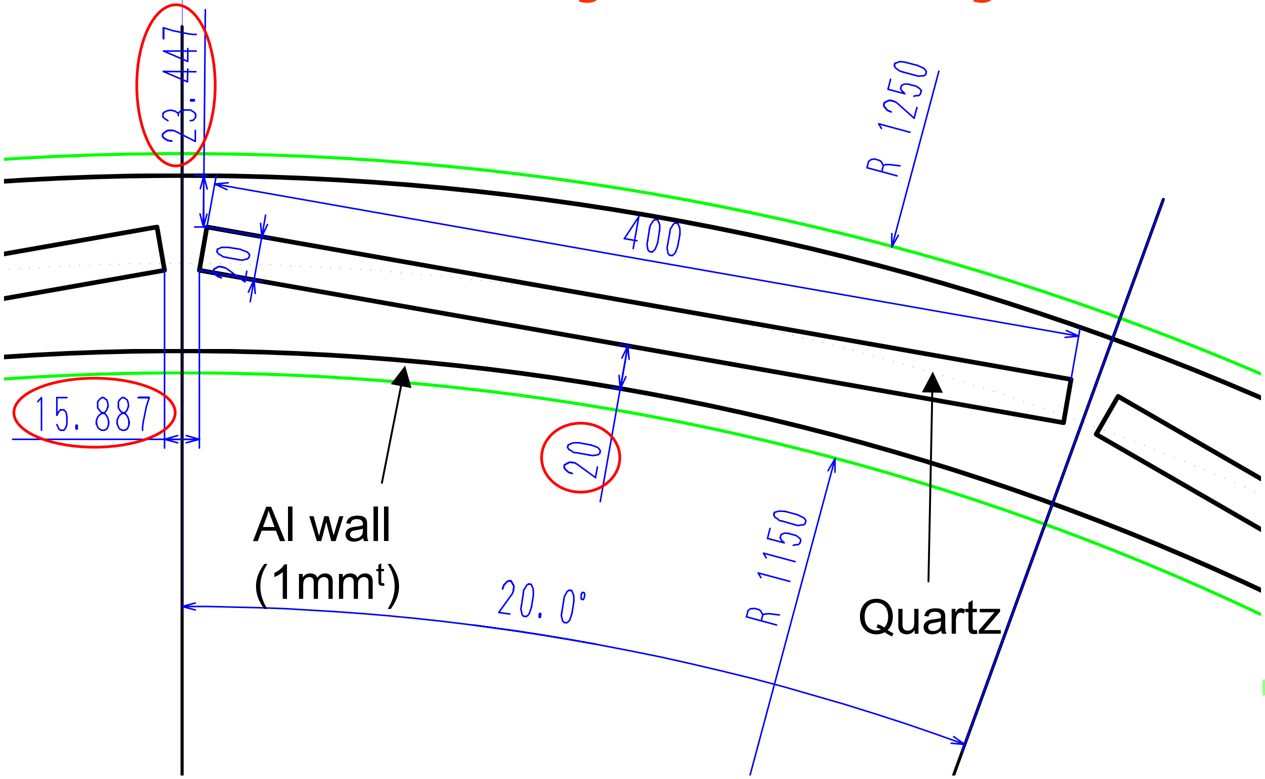
# Geometry

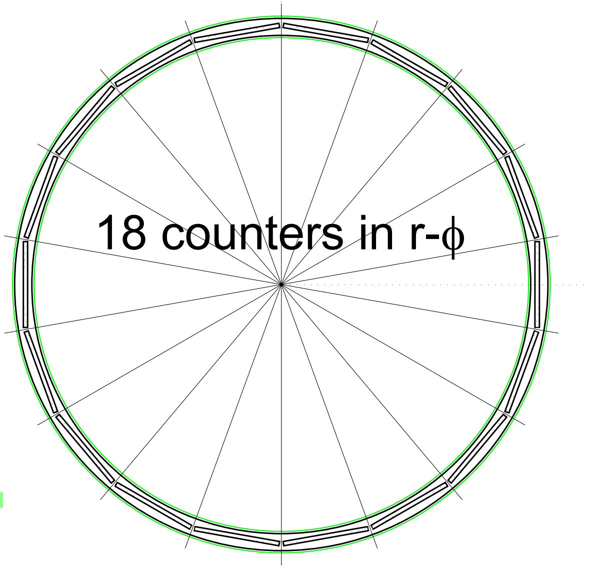
- Similar to BaBar DIRC
  - Need more realistic design study by simulation
- Narrow space for support structure
  - Quartz, Al wall, (Al honeycomb holder)
- Gaps in $\phi$ → ~10% dead space
  - ~1cm weak region from bar edge



BaBar DIRC

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.



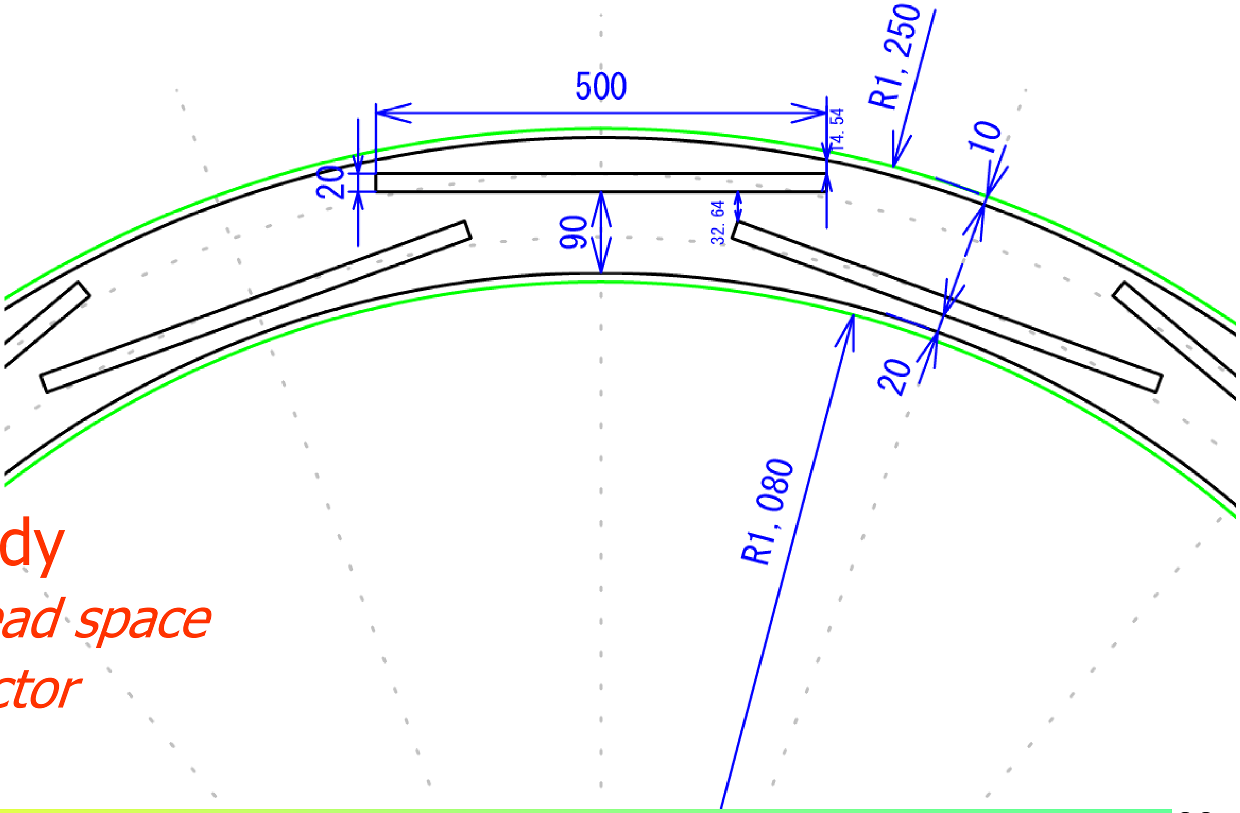


18 counters in r-$\phi$

Talk by K. Inami

# Geometry (2)

- Possible overlapped layout
  - Need 50cm wide quartz bars (← 40cm-width)
  - R1080 of internal radius (← R1150 for no overlap)
- Difficulty for support structure
  - Narrow space
- Need simulation study
  - *Performance and dead space*
  - *Effect to outer detector*



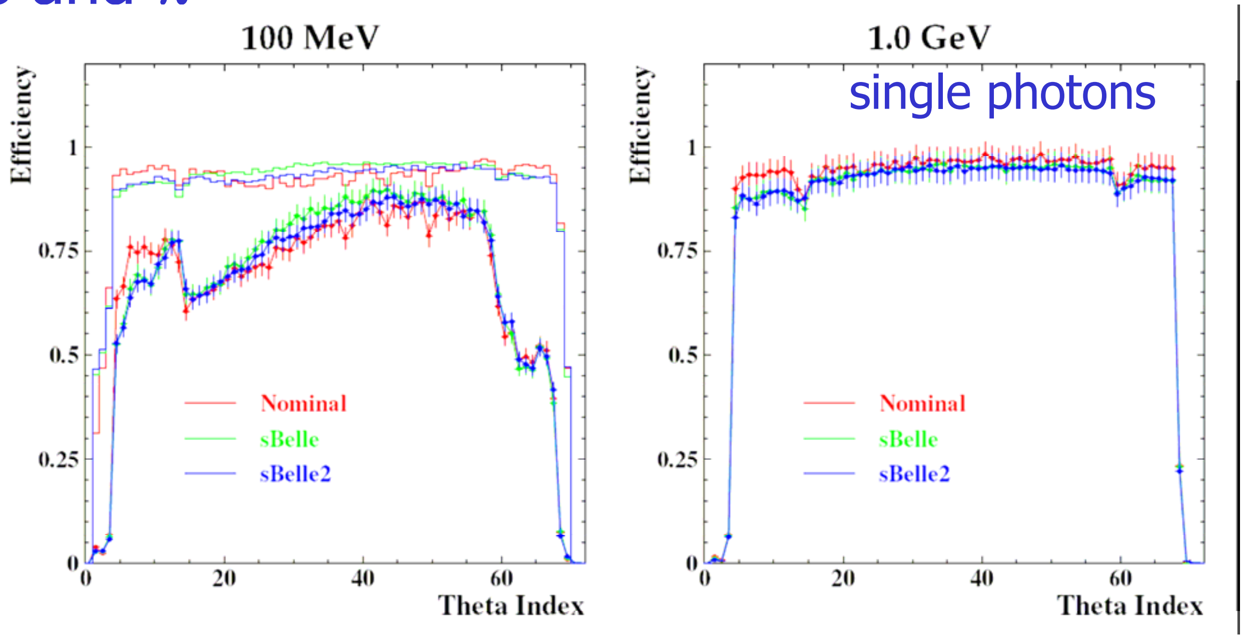
# Geometry (3)

Interference with calorimeter:

- influence on three photons from B→$K^*(K_S\pi^0)\gamma$ → MC check → no difference between the two TOP configurations

- single photons and $\pi^0$

→no difference between the two configurations



single photons

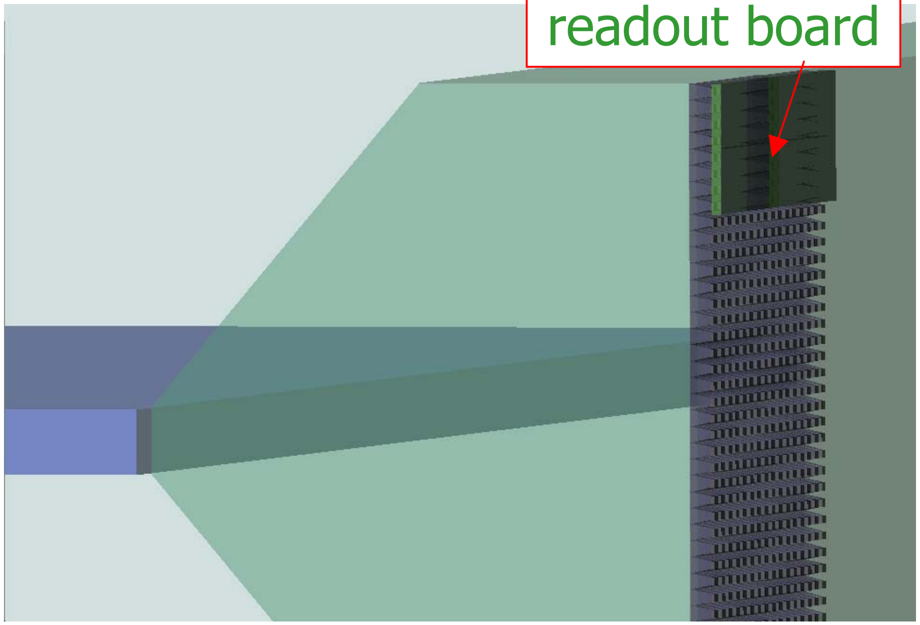
# Alternatives: focusing DIRC and imaging TOP

G. Varner

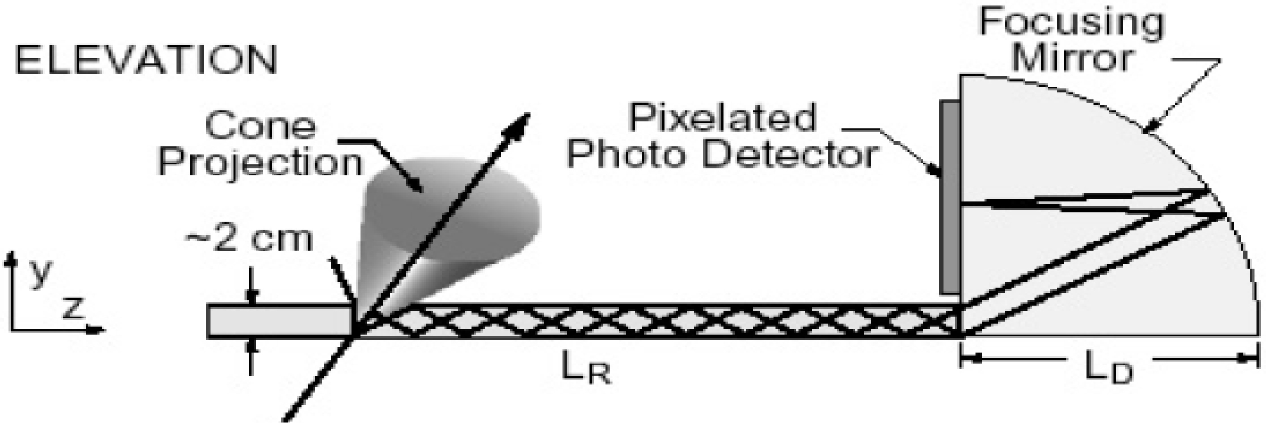
Quartz bars as radiators (same as for TOP)

•Small expansion volume + SiPMs → iTOP

•Mirror + pixelated detector
→ fDIRC



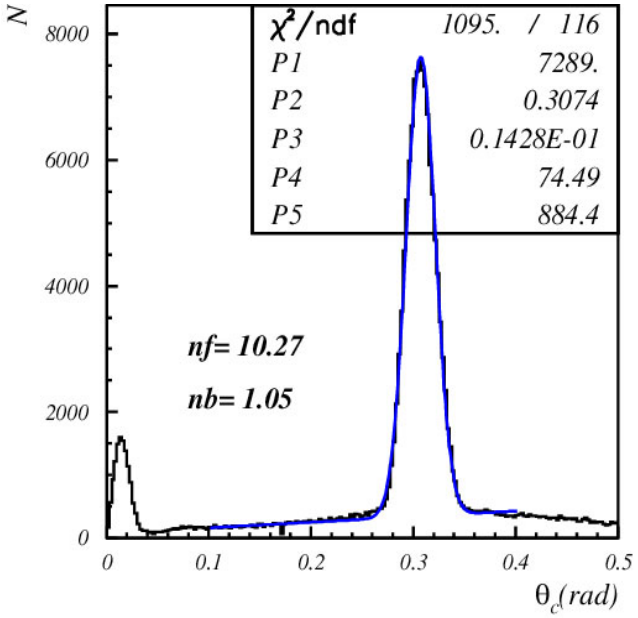
SiPMs + readout board

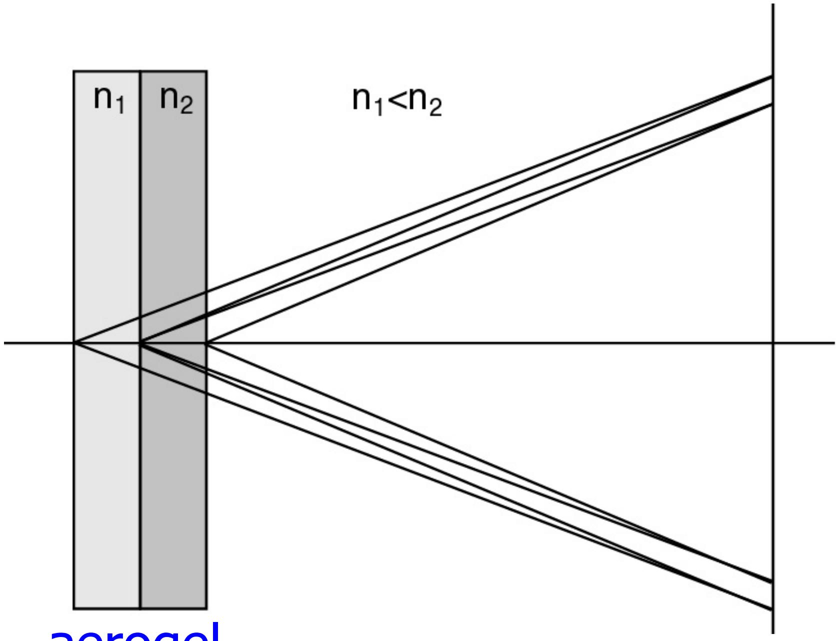


# Proximity focusing RICH in the forward region

Requirements and constraints:

- ~ 5 σ K/π separation @ 1-4 GeV/c
- operation in magnetic field 1.5T
- limited available space ~250 mm





aerogel

photon detector with read-out electronics

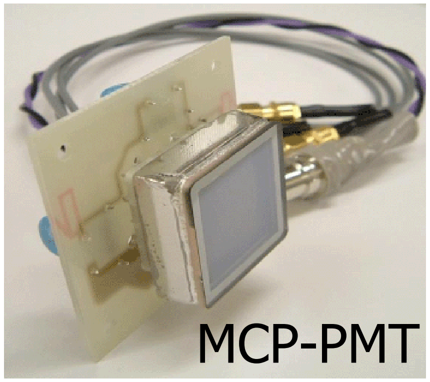
- n = 1.05
- $\theta_c(\pi)$ ~ 308 mrad @ 4 GeV/c
- $\theta_c(\pi)$– $\theta_c(K)$ ~ 23 mrad
- pion threshold 0.44 GeV/c,
- kaon threshold 1.54 GeV/c

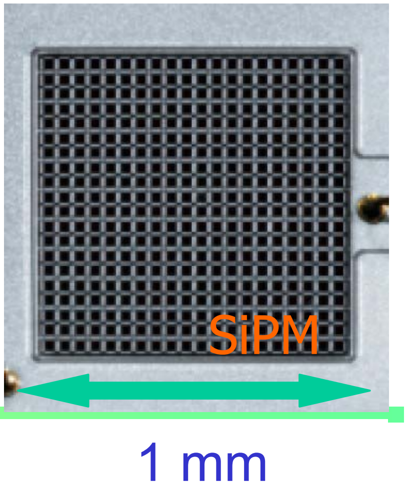
- time-of-flight difference (2m):
  t(K) - t(π)
  = 180 ps @ 2 GeV/c
  = 45 ps @ 4 GeV/c

# Photon detector options for 1.5T

I. Adachi

- HAPD
  - Working samples, being tested on the bench and in the beam
  - Stability, ageing? Need more production R&D
- MCP-PMT
  - Excellent beam and bench performance
  - Good TTS for TOF information
    - <20ps TOF resolution (low momentum PID)
  - Need lifetime estimation
- SiPM (GAPD)
  - Good stability, enough gain and TTS
  - Need large effective area or light guide to make ~5x5mm$^2$ pads
  - Need gated readout because of high dark count (<~MHz)
  - Radiation hardness?





# Barrel – endcap transition region

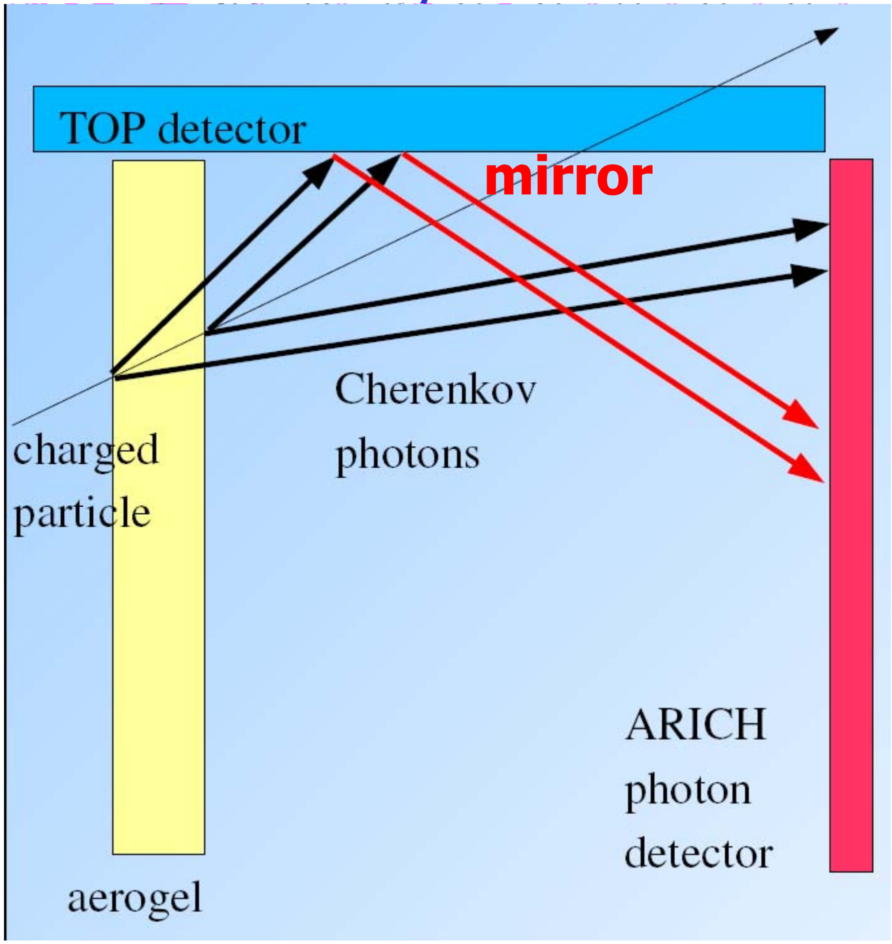
Need to minimize dead space at the transition region

TOP needs PMT region at bar end.

→ can be covered with the aerogel RICH

To detect Cherenkov light emitted to the outside, use planar *mirrors*

MC study: efficiency recovered



# Key points of ECL upgrade

**End caps**

Background is the biggest issue

Faster crystal
CsI(Tl) $\tau$~1$\mu$s → pure CsI $\tau$~30ns

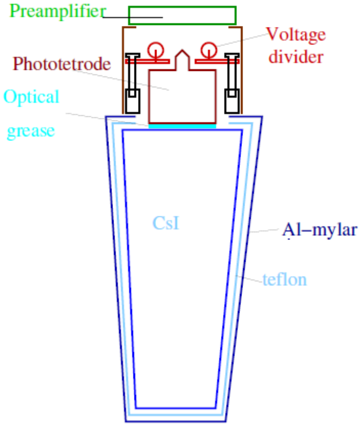
Small light yield
UV

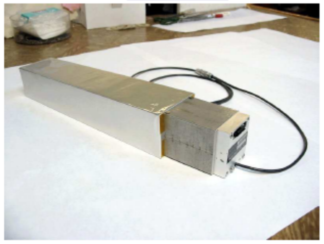
PMT

**Barrel**

Background is the biggest issue, but not as bad as end caps

Waveform sampling & fitting

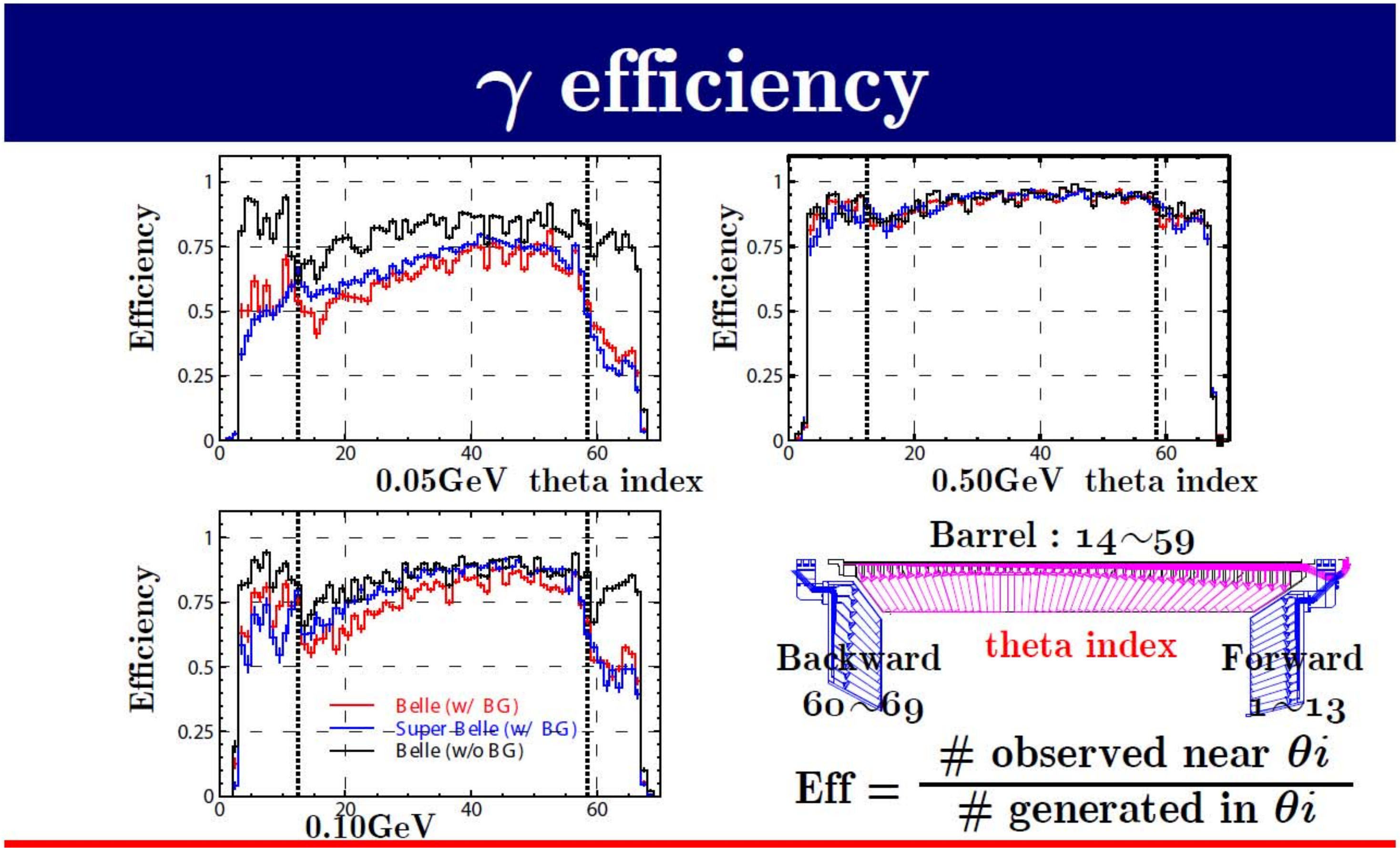




Free bonus: Reduced material in front of ECL due to PID upgrade

# Effect of material in front

T. Hara
BNM2008



## $\gamma$ efficiency

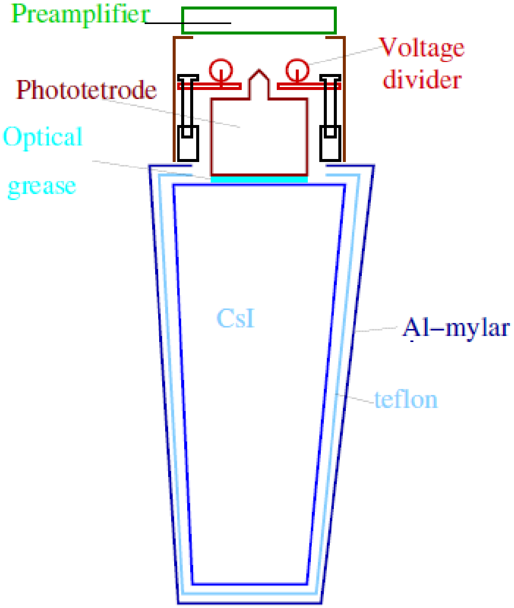
$$\mathrm{Eff} = \frac{\#\ \text{observed near}\ \theta i}{\#\ \text{generated in}\ \theta i}$$

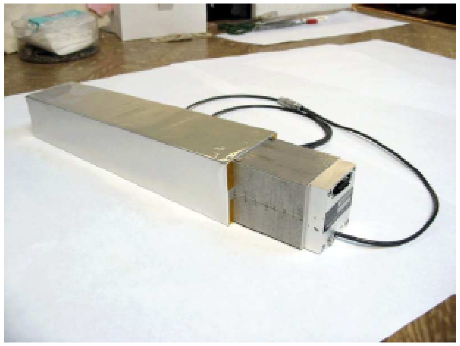
Removal of ACC helps. No big worry

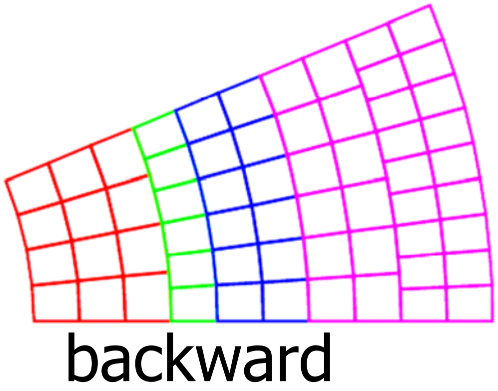
A. Kuzmin

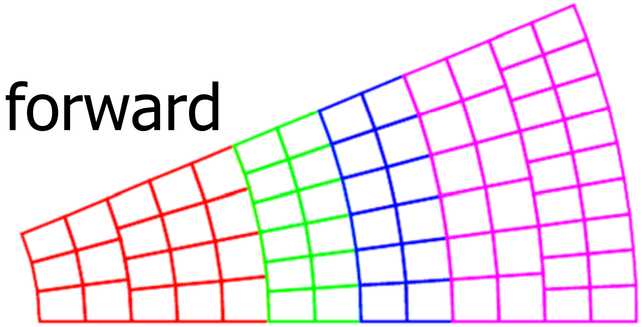
# Baseline

- Waveform sampling & fitting
- CsI(Tl) → pure CsI for end caps









Partial replacement with pure CsI:

- 480 (red only)
- 768 (+green)
- 1152 (+blue)
- 2112 (+pink)

# Pure CsI crystals

| | **Price of crystal** | **Light yield** | **Uniformity** | **Radiation hardness** |
|---|---|---|---|---|
| Kharkov | 6k$ (2004) | 80 p.e./MeV | <10% | Good |
| SICCAS | 4k$ (2006) | 30 p.e./MeV | 10-20% | Good |
| Saint Gobain | 8k$ (2006) | 130 p.e/MeV | <10% | Good |

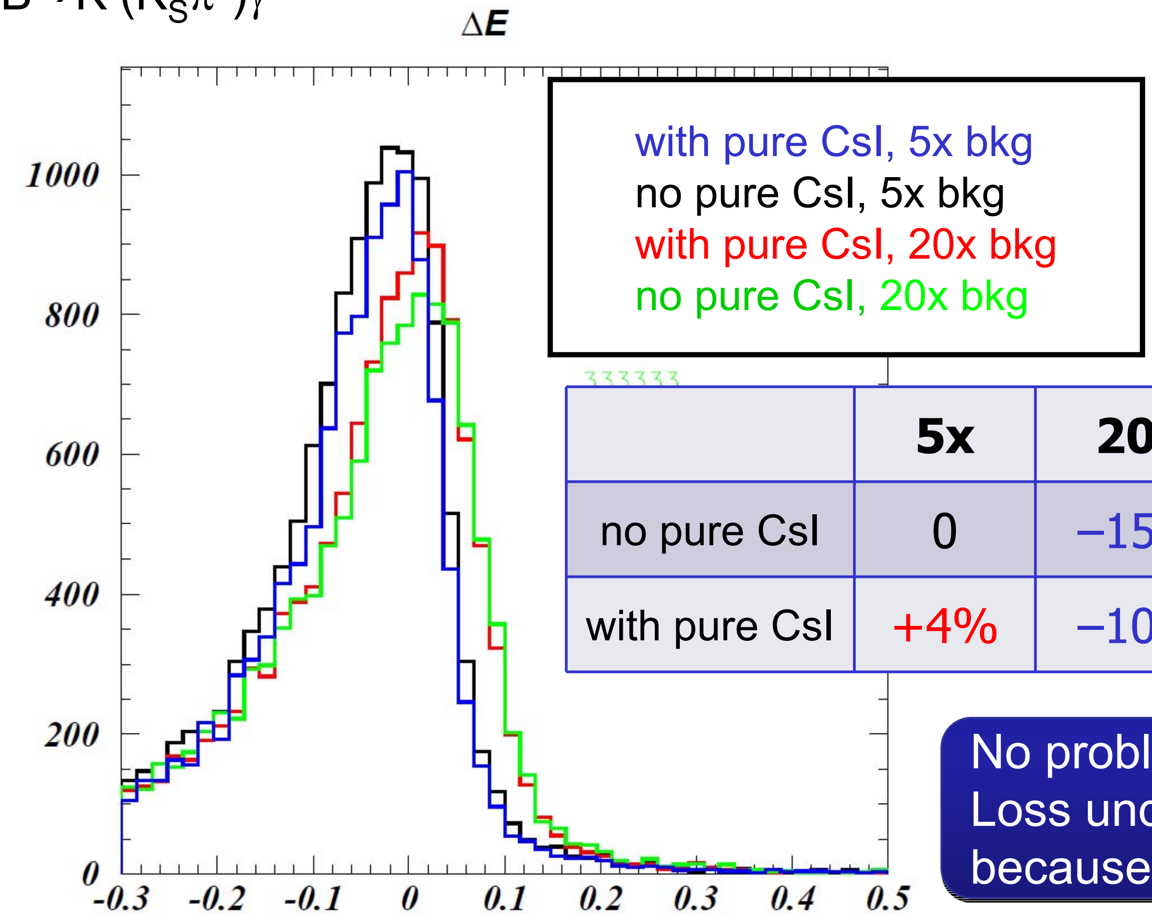
MC study of the impact of using pure CsI on the sample of fully reconstructed B mesons:

- Full backward and forward endcap (2112 crystals): eff +5%, background –7%
- Visible effect if >1000 replaced crystals

Need MC studies of the effect also on other channels.

# Pure CsI – impact 2

B→K$^{*}$(K$_{S}\pi^{0}$)$\gamma$



| | 5x | 20x |
|---|---|---|
| no pure CsI | 0 | −15% |
| with pure CsI | +4% | −10% |

No problem with 5x background
Loss under 20x background
because of CsI(Tl) in barrel

(*) Reduce material not taken into account for this study

# Key points of KLM upgrade

E. Nakano
P. Pakhlov

**End caps**

Background is the biggest issue → Scintillatior + GAPD(SiPM) $t_{recover}$ = 1s → 500ns → Radiation hardness (ok for >5yrs) temperature dependence of gain

**Barrel**

Background will be okay → RPC in avalanche mode if not

| Layer | Barrel(F) | E-cap(F) | E-cap(B) |
|---|---|---|---|
| 0 | 3.6 | 2.4 | 3.4 |
| 1 | 2.3 | 2.4 | 2.9 |
| 2 | 1.6 | 2.4 | 2.8 |
| 3 | 1.1 | 2.0 | 2.8 |
| 4 | 0.7 | 2.2 | 2.8 |
| 5 | 0.6 | 2.7 | 2.9 |
| 6 | 0.6 | 2.7 | 1.5 |
| 7 | 0.4 | 3.3 | 2.6 |
| 8 | 0.7 | 3.1 | 3.0 |
| 9 | 0.5 | 3.9 | 2.8 |
| 10 | 0.3 | 4.7 | 3.5 |
| 11 | 0.4 | 5.3 | 3.0 |
| 12 | 0.4 | | |
| 13 | 0.4 | | |
| 14 | 0.5 | | |

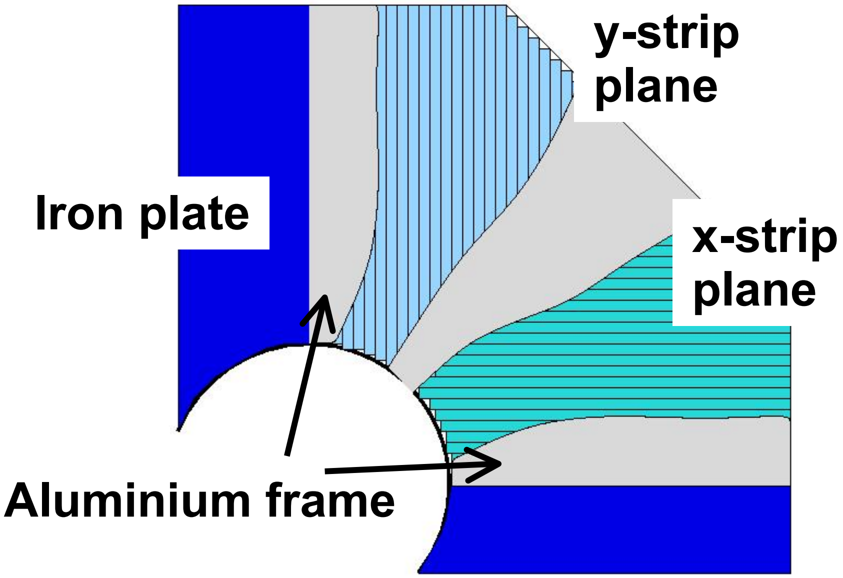
$L=5\times10^{35}/cm^2/s$

Present detector: RPC (Resistive Plate Chamber) in streamer mode needs 1 sec to recover

P. Pakhlov

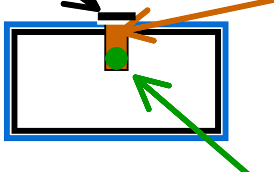
# Scintillator KLM set up

- Two independent (x and y) layers in one superlayer made of orthogonal strips with WLS read out
- Photodetector = avalanche photodiode in Geiger mode (GAPD, SiPM)
- ~120 strips in one 90º sector (max L=280cm, w=25mm)
- ~30000 read out channels
- Geometrical acceptance > 99%



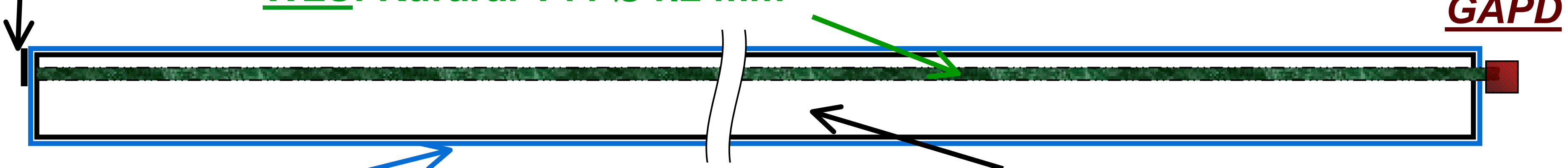
**Mirror 3M (above groove & at fiber end)**

**Optical glue increase the light yield ~ 1.2-1.4)**



**WLS: Kurarai Y11 ∅1.2 mm**

***GAPD***



**Diffusion reflector ($TiO_2$)**

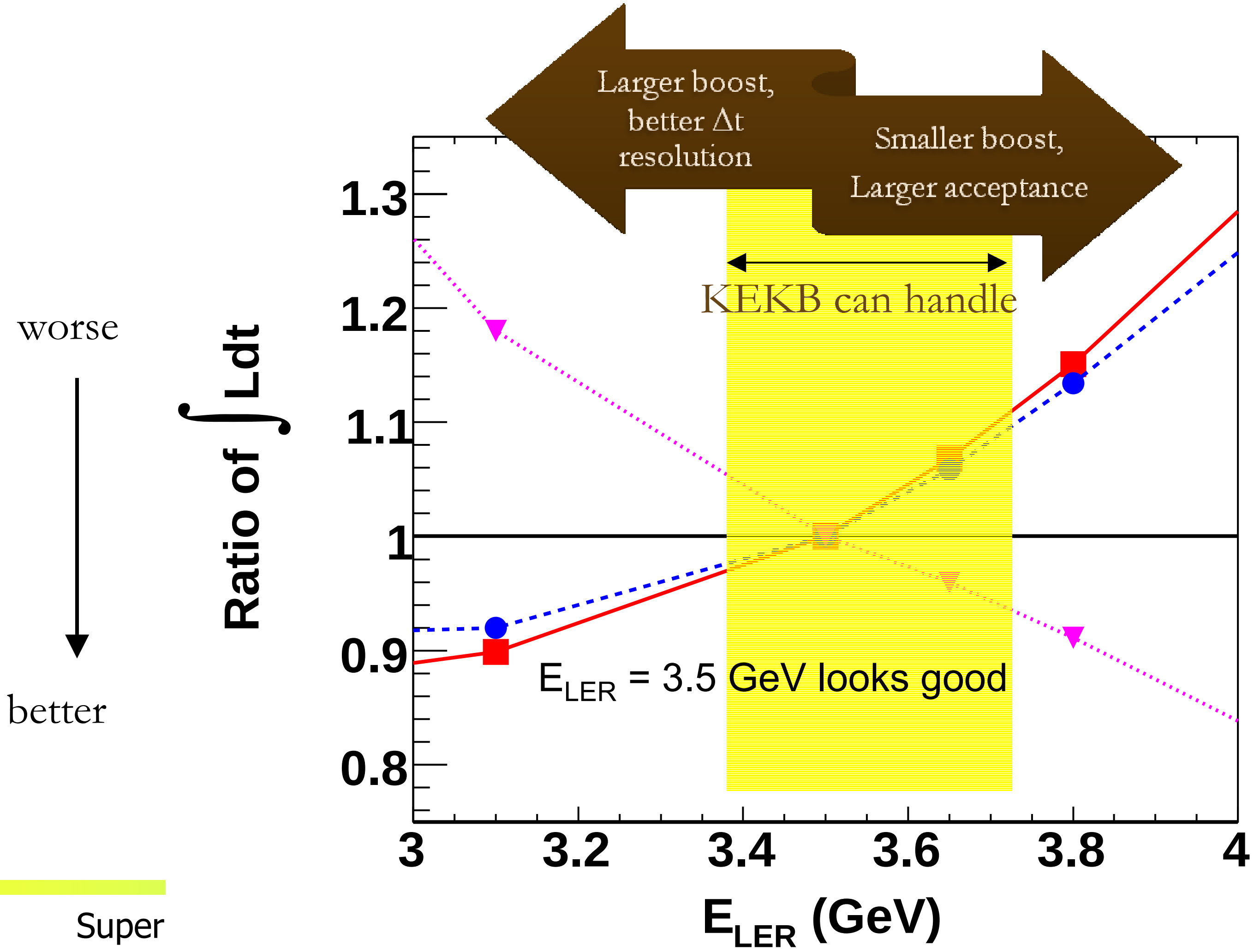
**Strips: polystyrene with 1.5% PTP & 0.01% POPOP**

# Other issues

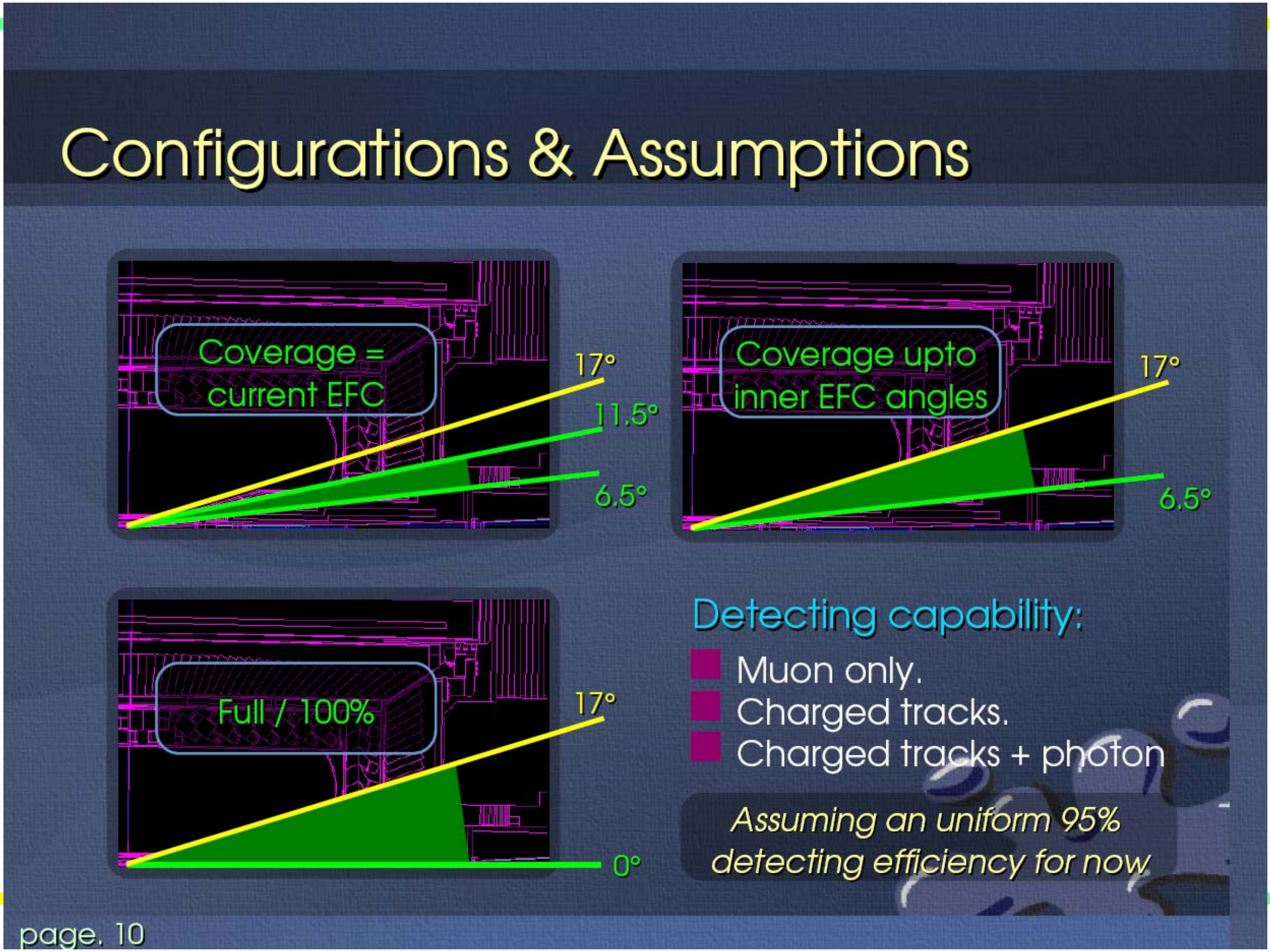
# Boost factor dependence

K. Hara at
BNM2008

- Toy MC results considering Δt resolution and geometrical acceptance.
- Geometrical acceptance is assumed to be same as in the current Belle detector.



# Hermeticity



## Configurations & Assumptions

Coverage = current EFC

Coverage upto inner EFC angles

Full / 100%

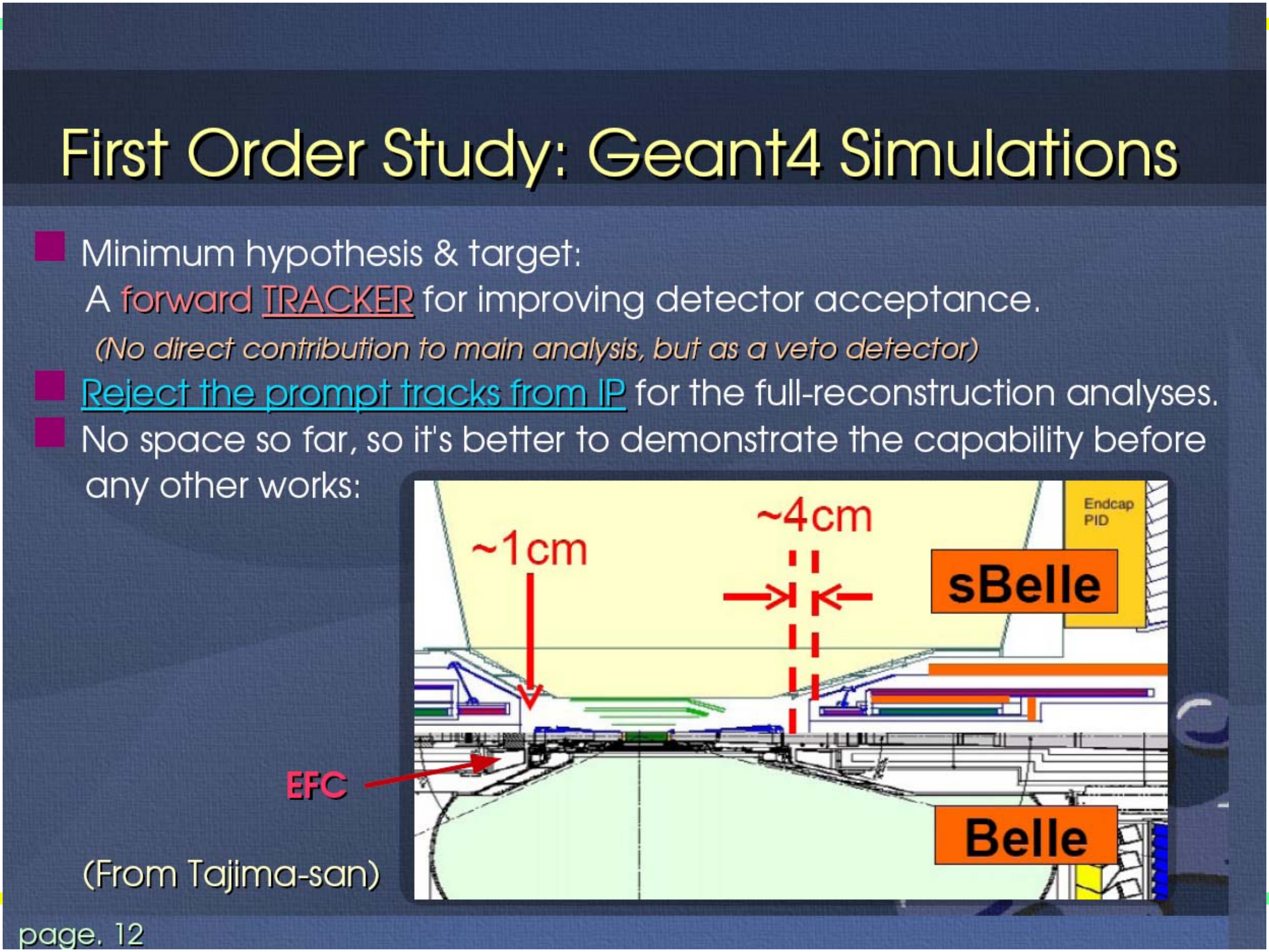
Detecting capability:

- Muon only.
- Charged tracks.
- Charged tracks + photon

*Assuming an uniform 95% detecting efficiency for now*

page. 10

# No space found around IP yet



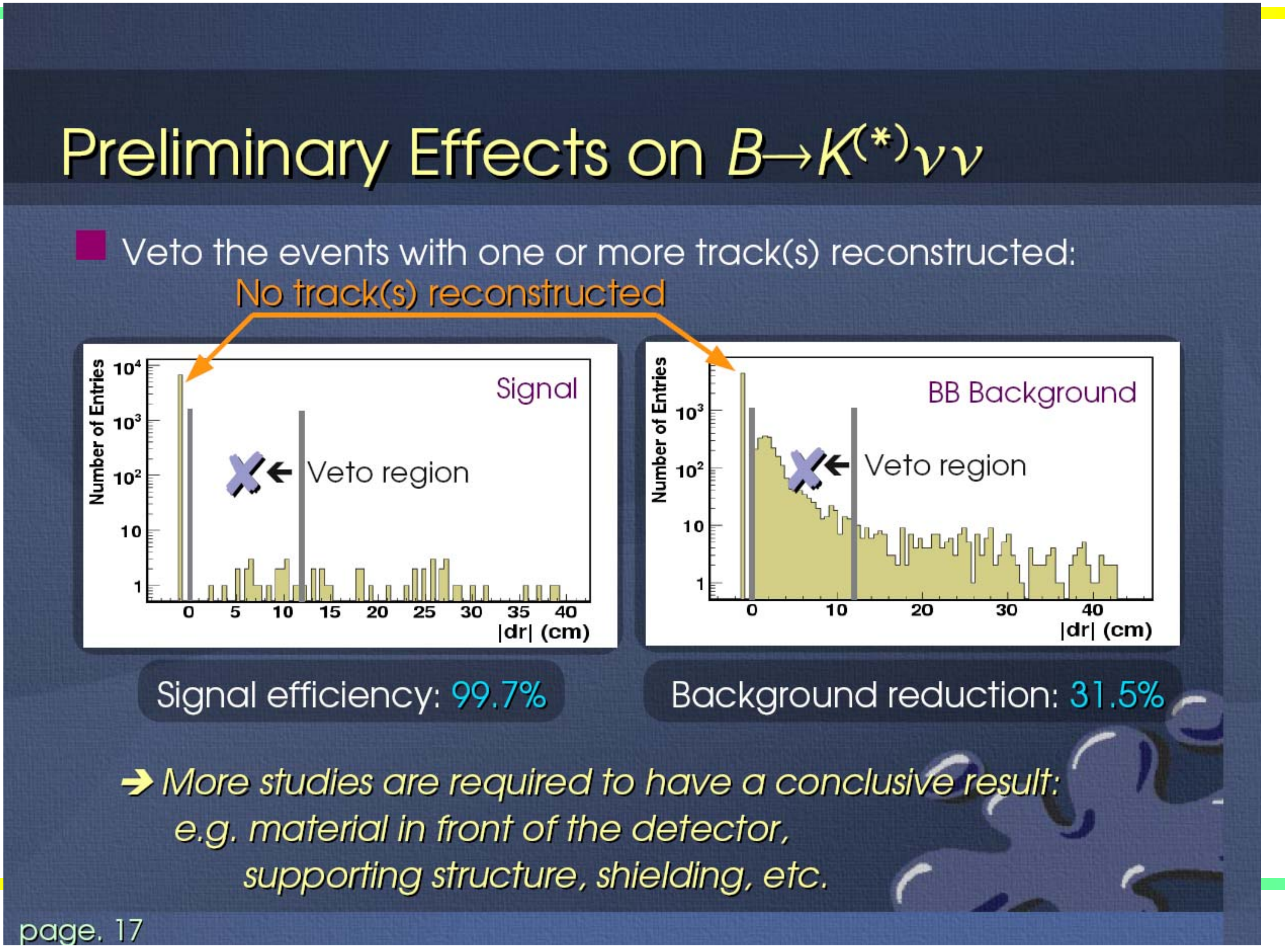
## First Order Study: Geant4 Simulations

- Minimum hypothesis & target:
  A forward TRACKER for improving detector acceptance.
  *(No direct contribution to main analysis, but as a veto detector)*
- Reject the prompt tracks from IP for the full-reconstruction analyses.
- No space so far, so it's better to demonstrate the capability before any other works:

(From Tajima-san)

page. 12

# Powerful if it works



## Preliminary Effects on $B\to K^{(*)}\nu\nu$

- Veto the events with one or more track(s) reconstructed:

No track(s) reconstructed

Signal efficiency: 99.7%

Background reduction: 31.5%

*➔ More studies are required to have a conclusive result:*
*e.g. material in front of the detector,*
*supporting structure, shielding, etc.*

page. 17

# Still to be studied…

- Readout pitch of SVD outer layers
- If 10% hole in TOP is acceptable or not
- Impact of partial upgrade with pure CsI – more modes
- Very forward detector with realistic configuration, realistic background conditions
- Tau decays – more modes
- $K_L$ reconstruction efficiency (with single layer)

# Summaries

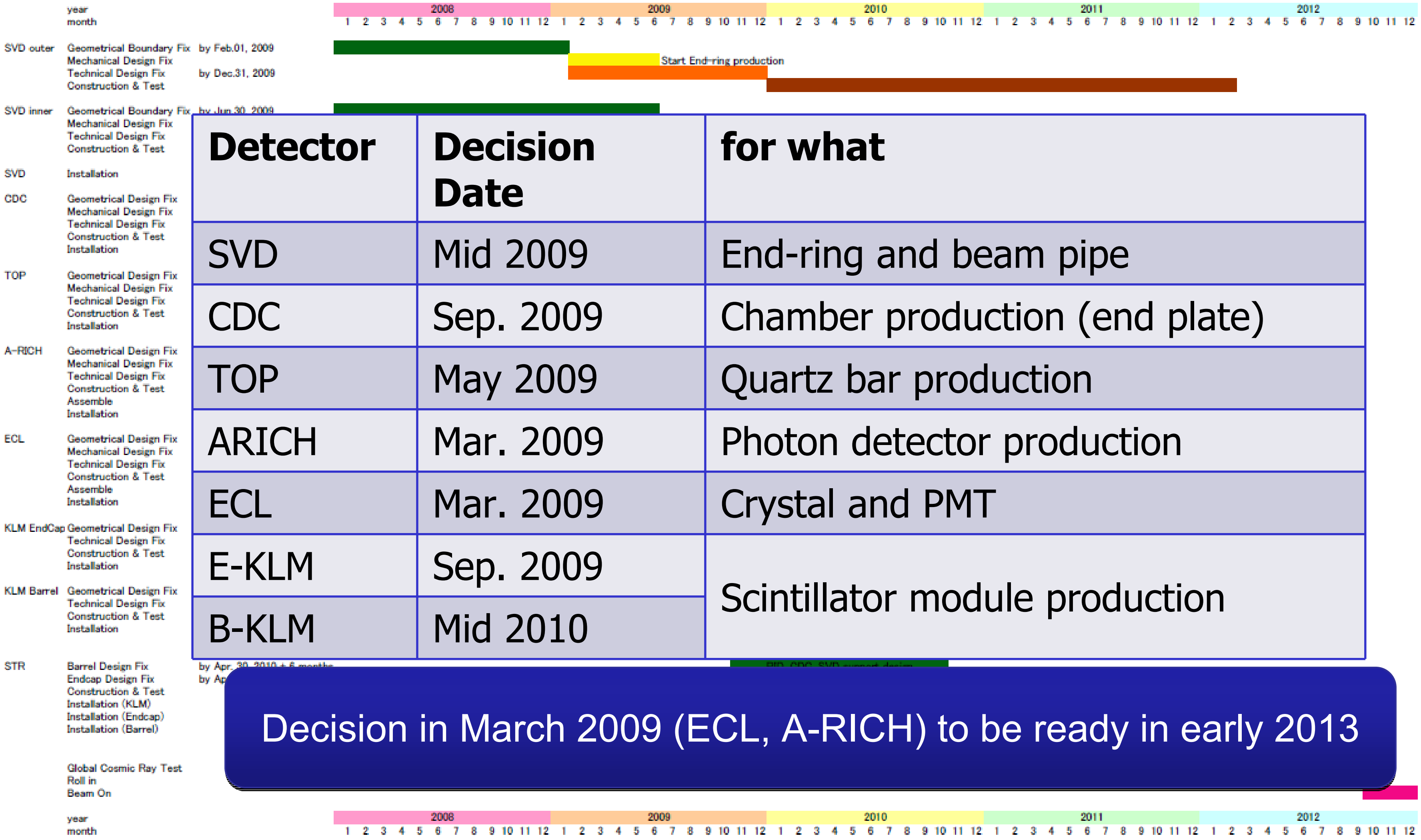
# “effective” background with new hardware

| | Method | Reduction factor | bkg |
|---|---|---|---|
| SVD | Shorter $t_p$ | 50/800 = 1/16 | 0 ~ 1 |
| CDC | Smaller cell | <2/3 | 4 ~ 13 (*) |
| PID | Brand new device | Good enough | 0 ~ 1 |
| B-ECL | Waveform fitting | 1/7 | 1 ~ 2 |
| E-ECL | Pure CsI (shorter $\tau$) | 1/200 | 0 ~ 1 |
| KLM | Faster detector, finer segment | Under control | 0 ~ 1 |

(*) Covered by software for CDC

→We know how to handle high backgrounds

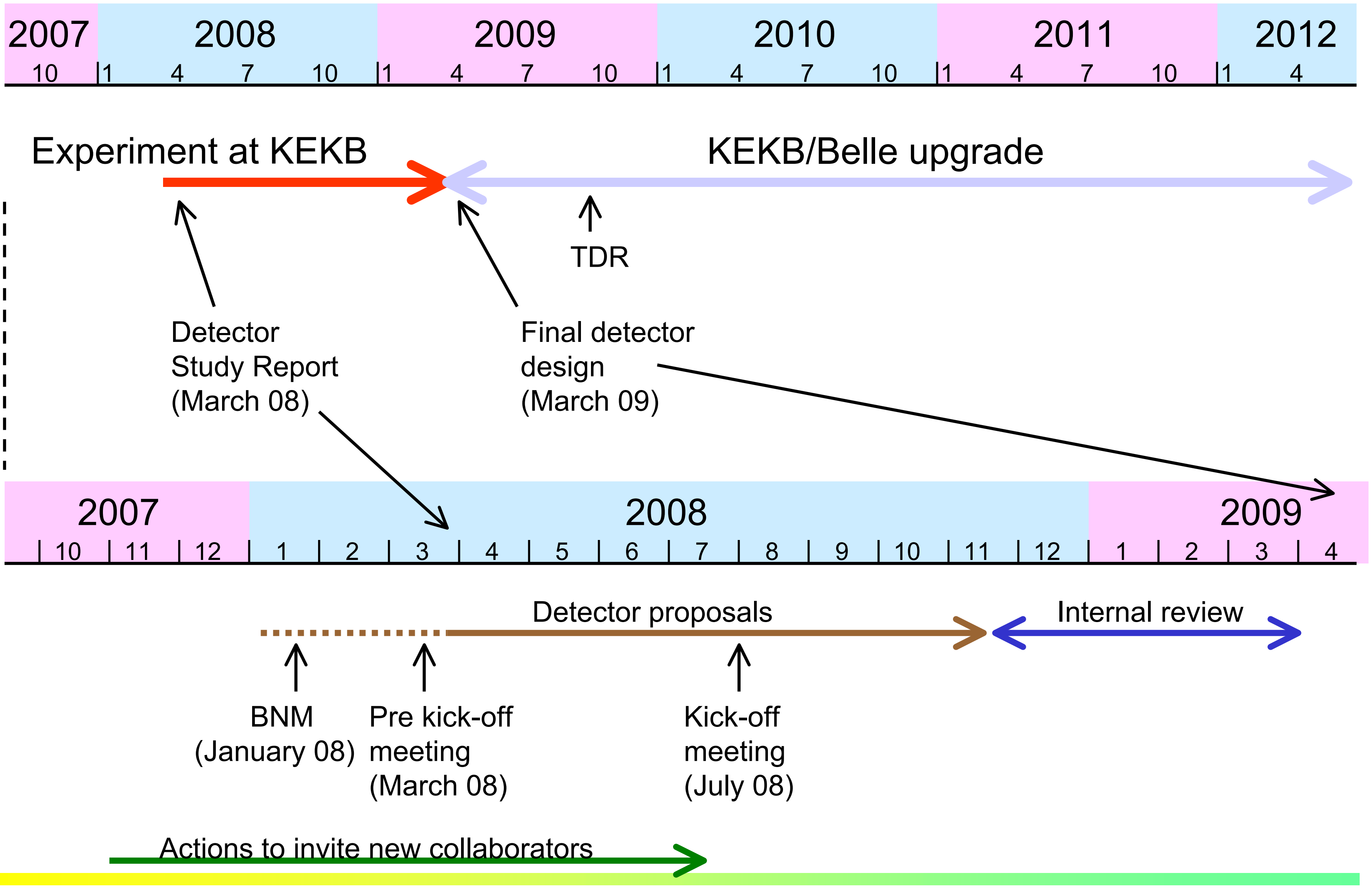
# Overall schedule (back calculation)



| Detector | Decision Date | for what |
|---|---|---|
| SVD | Mid 2009 | End-ring and beam pipe |
| CDC | Sep. 2009 | Chamber production (end plate) |
| TOP | May 2009 | Quartz bar production |
| ARICH | Mar. 2009 | Photon detector production |
| ECL | Mar. 2009 | Crystal and PMT |
| E-KLM | Sep. 2009 | Scintillator module production |
| B-KLM | Mid 2010 | |

Decision in March 2009 (ECL, A-RICH) to be ready in early 2013

# Overall schedule



Experiment at KEKB

KEKB/Belle upgrade

TDR

Detector
Study Report
(March 08)

Final detector
design
(March 09)

Detector proposals

Internal review

BNM
(January 08)

Pre kick-off
meeting
(March 08)

Kick-off
meeting
(July 08)

Actions to invite new collaborators

# Summary

- Belle+KEKB have proven to be an excellent tool for flavour physics; reliable long term operation, constant improvements of the performance.
- Major upgrade in 2009-12 → Super B factory
- More details on components and current options later today and tomorrow.
- Essentially a new project, all components have to be replaced, plans exist, nothing is frozen...
- If you have a bright idea what to add/change, do not miss the chance to propose it!
- Ongoing detector R+D has to be wrapped up soon...

# Backup slides

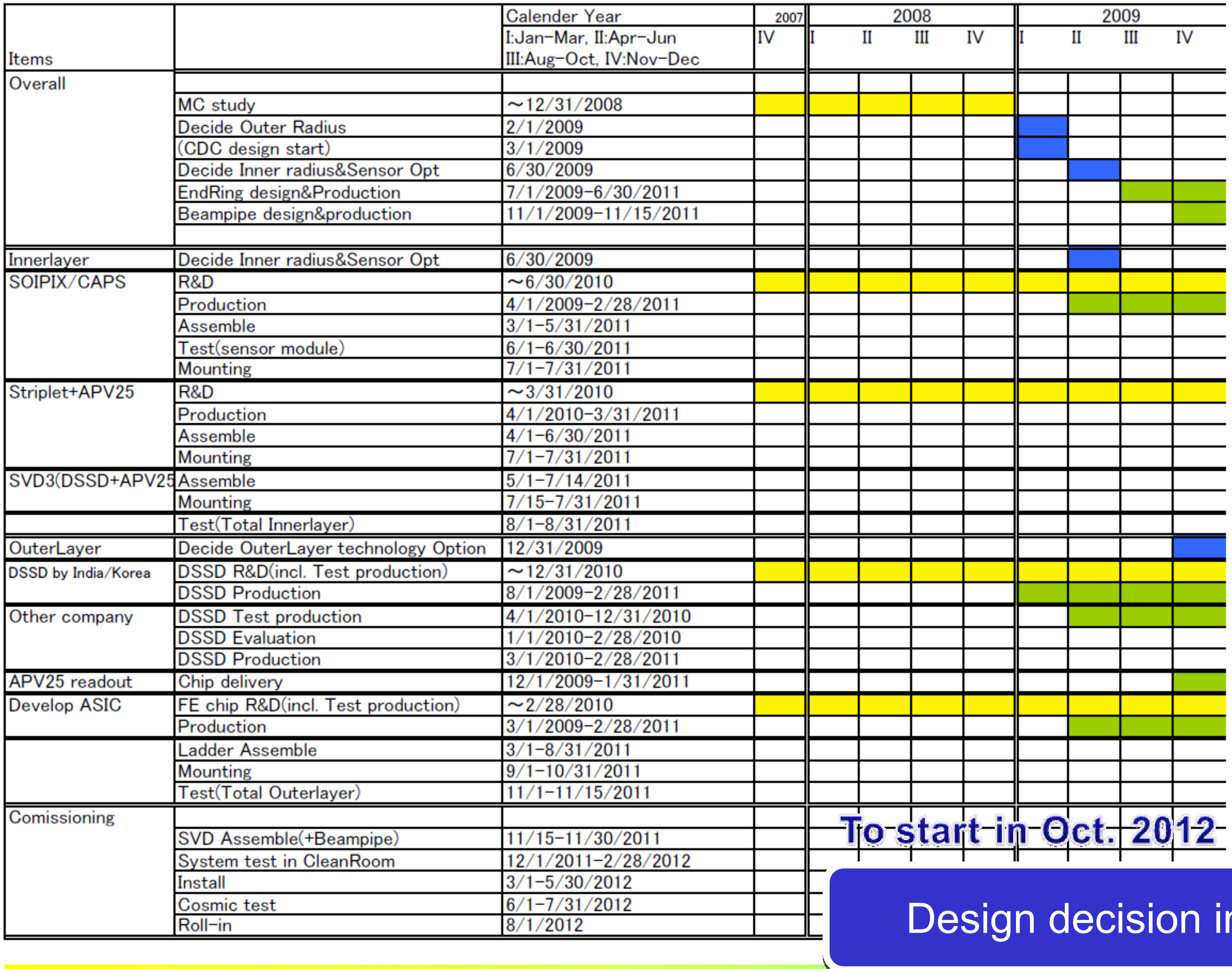
T. Kawasaki

# SVD possible options

| Option 0 | Option 1 | Option 2 |
|---|---|---|
| ‘Cheap and Nasty’ | ‘Baseline’ | ‘Super’ |
| 1.5cm BP | 1.5cm BP | 1cm BP |
| 2lyr APV + 2lyr VA | 6lyr APV | Pixel + 4lyr APV |
| Readout dead time = (27→)15%@10kHz L1<br>Hold dead time = 10%@33kHz L0<br>Otherwise fine in performance<br>No gain in $K_S$ vtx | Pipelined; dead time free, no peak hold<br>$K_S$ vtx +20~30%, slow tracking +20%<br>Good performance in the first few years | 30% better IP resolution<br>Not in time |
| 0.3M$ | 4M$ | Option 1 +1.5M$<br>or 5M$ |

T. Kawasaki

# SVD Schedule (first half)



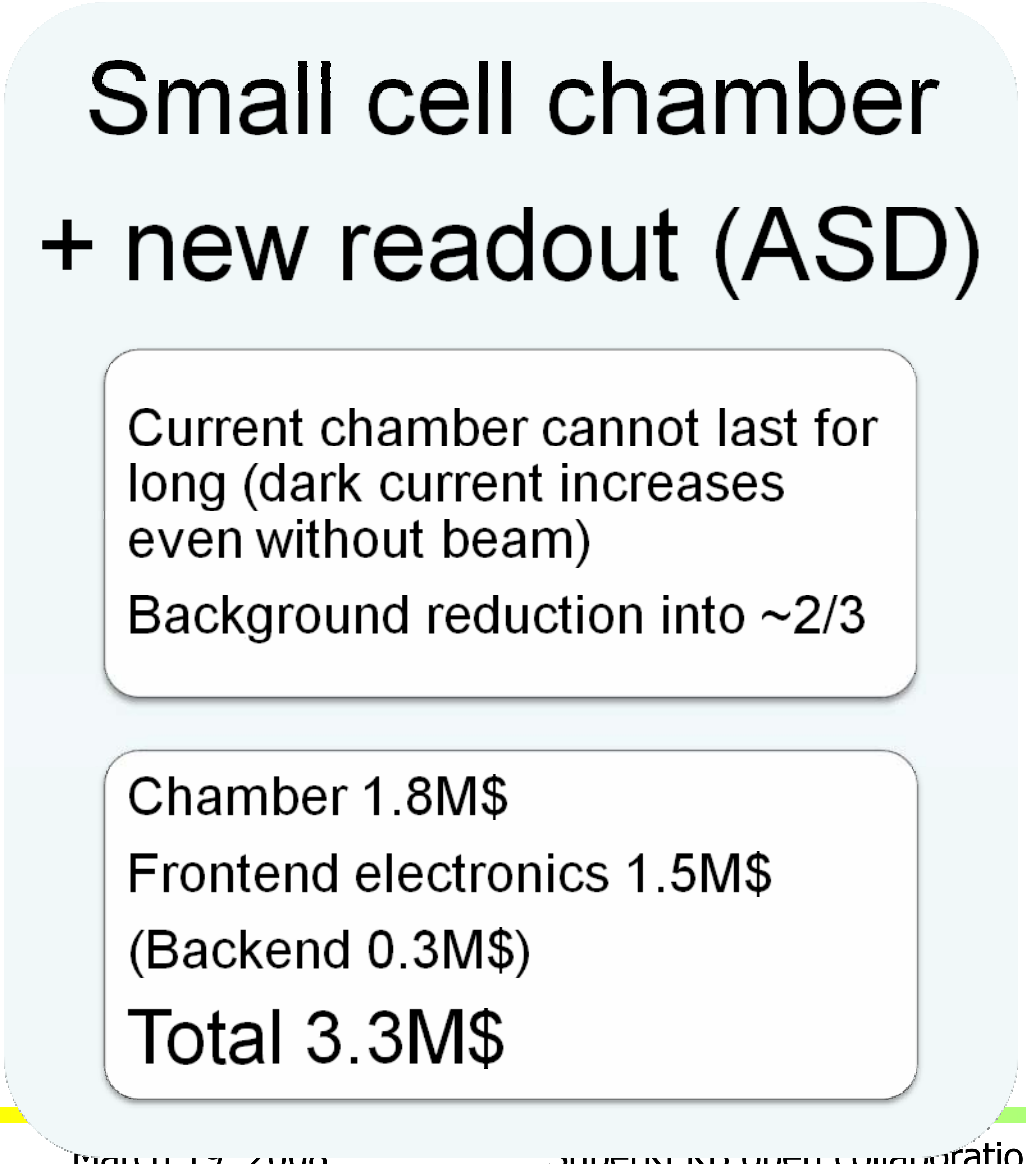
| Items | | Calender Year<br>I:Jan–Mar, II:Apr–Jun<br>III:Aug–Oct, IV:Nov–Dec | 2007 | 2008 | | | | 2009 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | IV | I | II | III | IV | I | II | III | IV |
| Overall | | | | | | | | | | | |
| | MC study | ～12/31/2008 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | | | | |
| | Decide Outer Radius | 2/1/2009 | | | | | | 🟦 | | | |
| | (CDC design start) | 3/1/2009 | | | | | | 🟦 | | | |
| | Decide Inner radius&Sensor Opt | 6/30/2009 | | | | | | | 🟦 | | |
| | EndRing design&Production | 7/1/2009–6/30/2011 | | | | | | | | 🟩 | 🟩 |
| | Beampipe design&production | 11/1/2009–11/15/2011 | | | | | | | | | 🟩 |
| | | | | | | | | | | | |
| Innerlayer | Decide Inner radius&Sensor Opt | 6/30/2009 | | | | | | | 🟦 | | |
| SOIPIX/CAPS | R&D | ～6/30/2010 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 |
| | Production | 4/1/2009–2/28/2011 | | | | | | | 🟩 | 🟩 | 🟩 |
| | Assemble | 3/1–5/31/2011 | | | | | | | | | |
| | Test(sensor module) | 6/1–6/30/2011 | | | | | | | | | |
| | Mounting | 7/1–7/31/2011 | | | | | | | | | |
| Striplet+APV25 | R&D | ～3/31/2010 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 |
| | Production | 4/1/2010–3/31/2011 | | | | | | | | | |
| | Assemble | 4/1–6/30/2011 | | | | | | | | | |
| | Mounting | 7/1–7/31/2011 | | | | | | | | | |
| SVD3(DSSD+APV25 | Assemble | 5/1–7/14/2011 | | | | | | | | | |
| | Mounting | 7/15–7/31/2011 | | | | | | | | | |
| | Test(Total Innerlayer) | 8/1–8/31/2011 | | | | | | | | | |
| OuterLayer | Decide OuterLayer technology Option | 12/31/2009 | | | | | | | | | 🟦 |
| DSSD by India/Korea | DSSD R&D(incl. Test production) | ～12/31/2010 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 |
| | DSSD Production | 8/1/2009–2/28/2011 | | | | | | 🟩 | 🟩 | 🟩 | 🟩 |
| Other company | DSSD Test production | 4/1/2010–12/31/2010 | | | | | | | 🟩 | 🟩 | 🟩 |
| | DSSD Evaluation | 1/1/2010–2/28/2010 | | | | | | | | | |
| | DSSD Production | 3/1/2010–2/28/2011 | | | | | | | | | |
| APV25 readout | Chip delivery | 12/1/2009–1/31/2011 | | | | | | | | | 🟩 |
| Develop ASIC | FE chip R&D(incl. Test production) | ～2/28/2010 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 |
| | Production | 3/1/2009–2/28/2011 | | | | | | | 🟩 | 🟩 | 🟩 |
| | Ladder Assemble | 3/1–8/31/2011 | | | | | | | | | |
| | Mounting | 9/1–10/31/2011 | | | | | | | | | |
| | Test(Total Outerlayer) | 11/1–11/15/2011 | | | | | | | | | |
| Comissioning | | | | | | | | | | | |
| | SVD Assemble(+Beampipe) | 11/15–11/30/2011 | | | | | | | | | |
| | System test in CleanRoom | 12/1/2011–2/28/2012 | | | | | | | | | |
| | Install | 3/1–5/30/2012 | | | | | | | | | |
| | Cosmic test | 6/1–7/31/2012 | | | | | | | | | |
| | Roll–in | 8/1/2012 | | | | | | | | | |

To start in Oct. 2012

Design decision in early 2009

S. Uno

# CDC possible option



Small cell chamber

+ new readout (ASD)

Current chamber cannot last for long (dark current increases even without beam)

Background reduction into ~2/3

Chamber 1.8M$

Frontend electronics 1.5M$

(Backend 0.3M$)

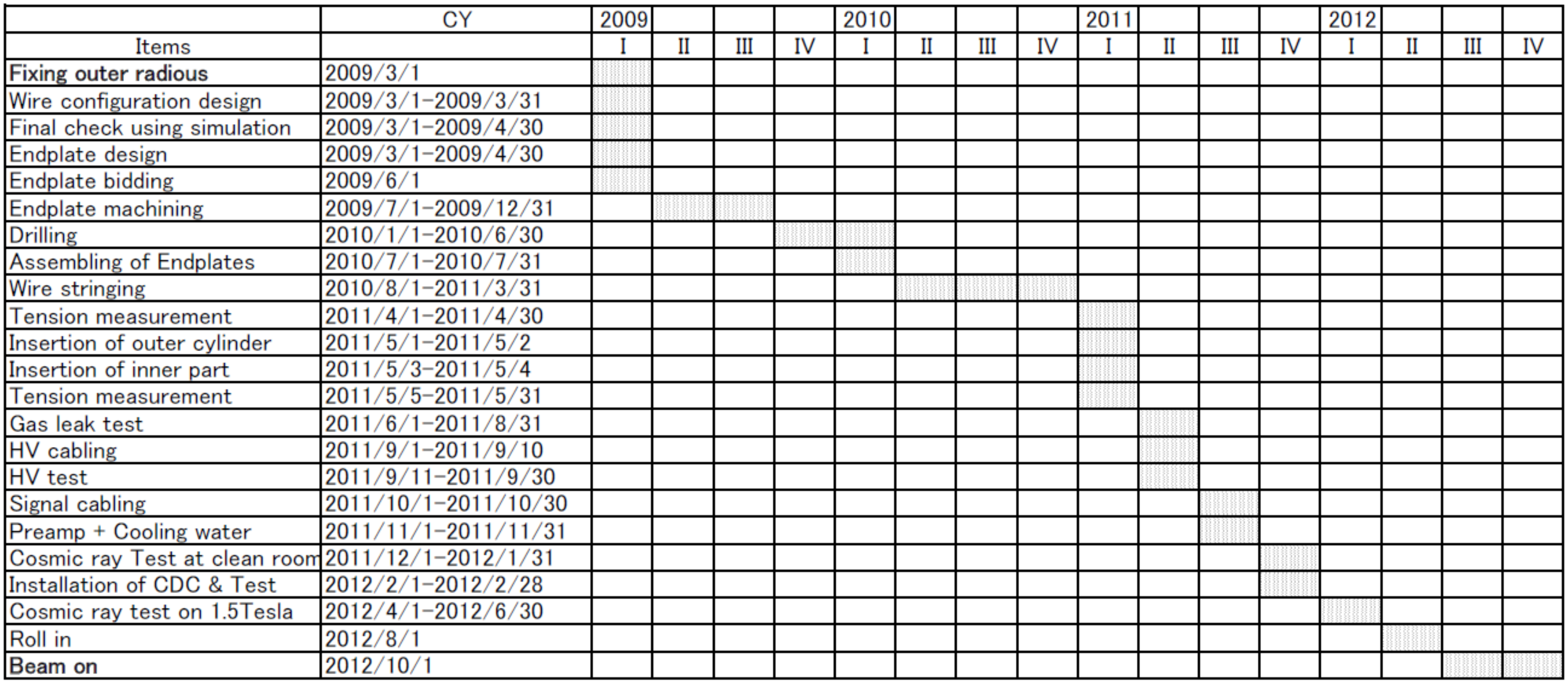
Total 3.3M$

No other option

Inner/outer radii can be adjusted to other detectors (SVD/PID)

S. Uno

# CDC Schedule



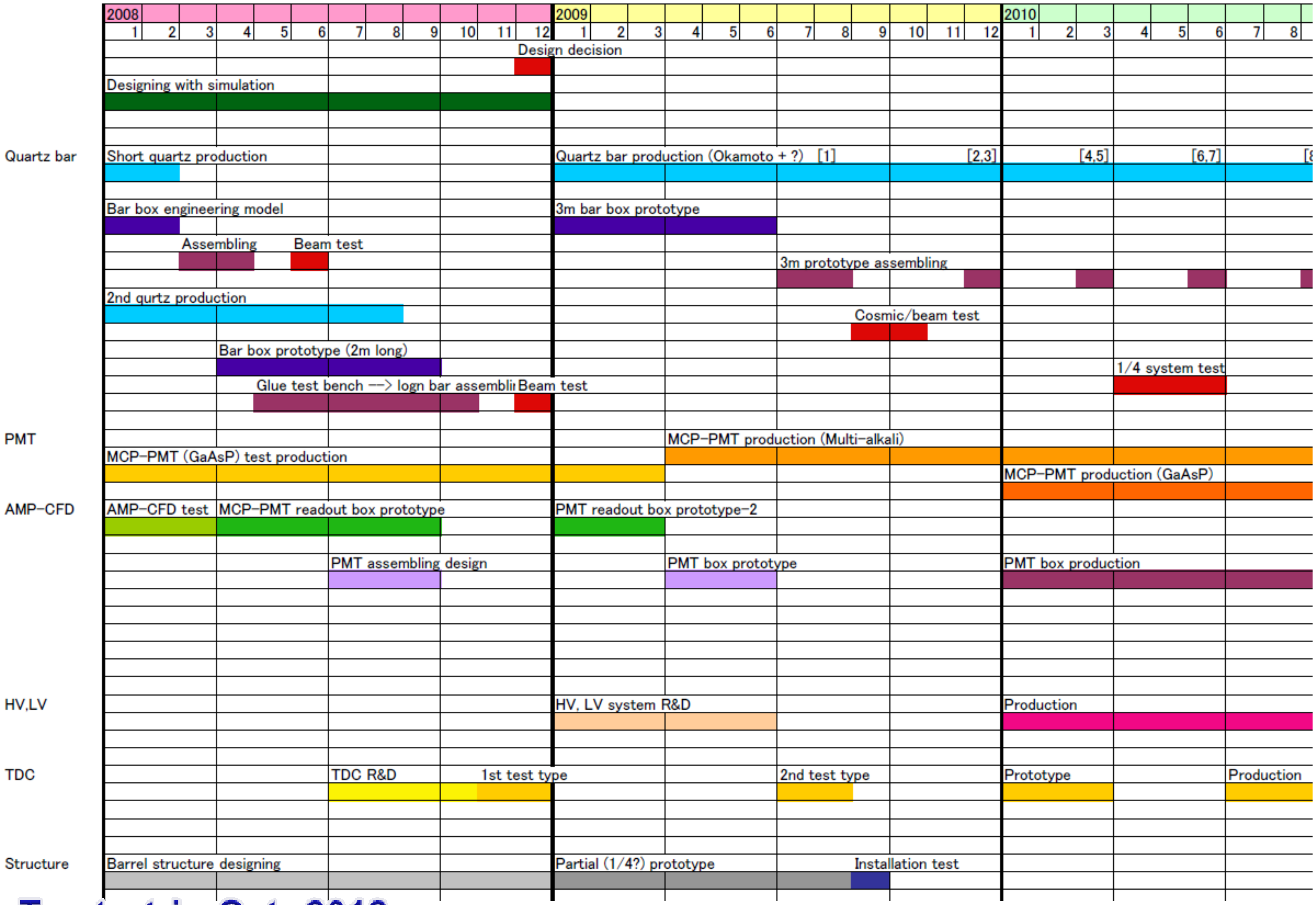
|  | CY | 2009 |  |  |  | 2010 |  |  |  | 2011 |  |  |  | 2012 |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Items |  | I | II | III | IV | I | II | III | IV | I | II | III | IV | I | II | III | IV |
| **Fixing outer radious** | 2009/3/1 | ▨ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Wire configuration design | 2009/3/1–2009/3/31 | ▨ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Final check using simulation | 2009/3/1–2009/4/30 | ▨ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Endplate design | 2009/3/1–2009/4/30 | ▨ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Endplate bidding | 2009/6/1 | ▨ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Endplate machining | 2009/7/1–2009/12/31 |  | ▨ | ▨ |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Drilling | 2010/1/1–2010/6/30 |  |  |  | ▨ | ▨ |  |  |  |  |  |  |  |  |  |  |  |
| Assembling of Endplates | 2010/7/1–2010/7/31 |  |  |  |  | ▨ |  |  |  |  |  |  |  |  |  |  |  |
| Wire stringing | 2010/8/1–2011/3/31 |  |  |  |  |  | ▨ | ▨ | ▨ |  |  |  |  |  |  |  |  |
| Tension measurement | 2011/4/1–2011/4/30 |  |  |  |  |  |  |  |  | ▨ |  |  |  |  |  |  |  |
| Insertion of outer cylinder | 2011/5/1–2011/5/2 |  |  |  |  |  |  |  |  | ▨ |  |  |  |  |  |  |  |
| Insertion of inner part | 2011/5/3–2011/5/4 |  |  |  |  |  |  |  |  | ▨ |  |  |  |  |  |  |  |
| Tension measurement | 2011/5/5–2011/5/31 |  |  |  |  |  |  |  |  | ▨ |  |  |  |  |  |  |  |
| Gas leak test | 2011/6/1–2011/8/31 |  |  |  |  |  |  |  |  |  | ▨ |  |  |  |  |  |  |
| HV cabling | 2011/9/1–2011/9/10 |  |  |  |  |  |  |  |  |  | ▨ |  |  |  |  |  |  |
| HV test | 2011/9/11–2011/9/30 |  |  |  |  |  |  |  |  |  | ▨ |  |  |  |  |  |  |
| Signal cabling | 2011/10/1–2011/10/30 |  |  |  |  |  |  |  |  |  |  | ▨ |  |  |  |  |  |
| Preamp + Cooling water | 2011/11/1–2011/11/31 |  |  |  |  |  |  |  |  |  |  | ▨ |  |  |  |  |  |
| Cosmic ray Test at clean room | 2011/12/1–2012/1/31 |  |  |  |  |  |  |  |  |  |  |  | ▨ |  |  |  |  |
| Installation of CDC & Test | 2012/2/1–2012/2/28 |  |  |  |  |  |  |  |  |  |  |  | ▨ |  |  |  |  |
| Cosmic ray test on 1.5Tesla | 2012/4/1–2012/6/30 |  |  |  |  |  |  |  |  |  |  |  |  | ▨ |  |  |  |
| Roll in | 2012/8/1 |  |  |  |  |  |  |  |  |  |  |  |  |  | ▨ |  |  |
| **Beam on** | 2012/10/1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | ▨ | ▨ |

**To start in Oct. 2012**

Inner and outer radii should be determined by March 2009

K. Inami

# TOP Schedule (first half)



2008 | 2009 | 2010
1 2 3 4 5 6 7 8 9 10 11 12 | 1 2 3 4 5 6 7 8 9 10 11 12 | 1 2 3 4 5 6 7 8

Design decision

Designing with simulation

**Quartz bar**

Short quartz production

Quartz bar production (Okamoto + ?) [1] [2,3] [4,5] [6,7] [

Bar box engineering model

3m bar box prototype

Assembling

Beam test

3m prototype assembling

2nd qurtz production

Cosmic/beam test

Bar box prototype (2m long)

1/4 system test

Glue test bench --> logn bar assembli Beam test

**PMT**

MCP-PMT production (Multi-alkali)

MCP-PMT (GaAsP) test production

MCP-PMT production (GaAsP)

**AMP-CFD**

AMP-CFD test

MCP-PMT readout box prototype

PMT readout box prototype-2

PMT assembling design

PMT box prototype

PMT box production

**HV,LV**

HV, LV system R&D

Production

**TDC**

TDC R&D

1st test type

2nd test type

Prototype

Production

**Structure**

Barrel structure designing

Partial (1/4?) prototype

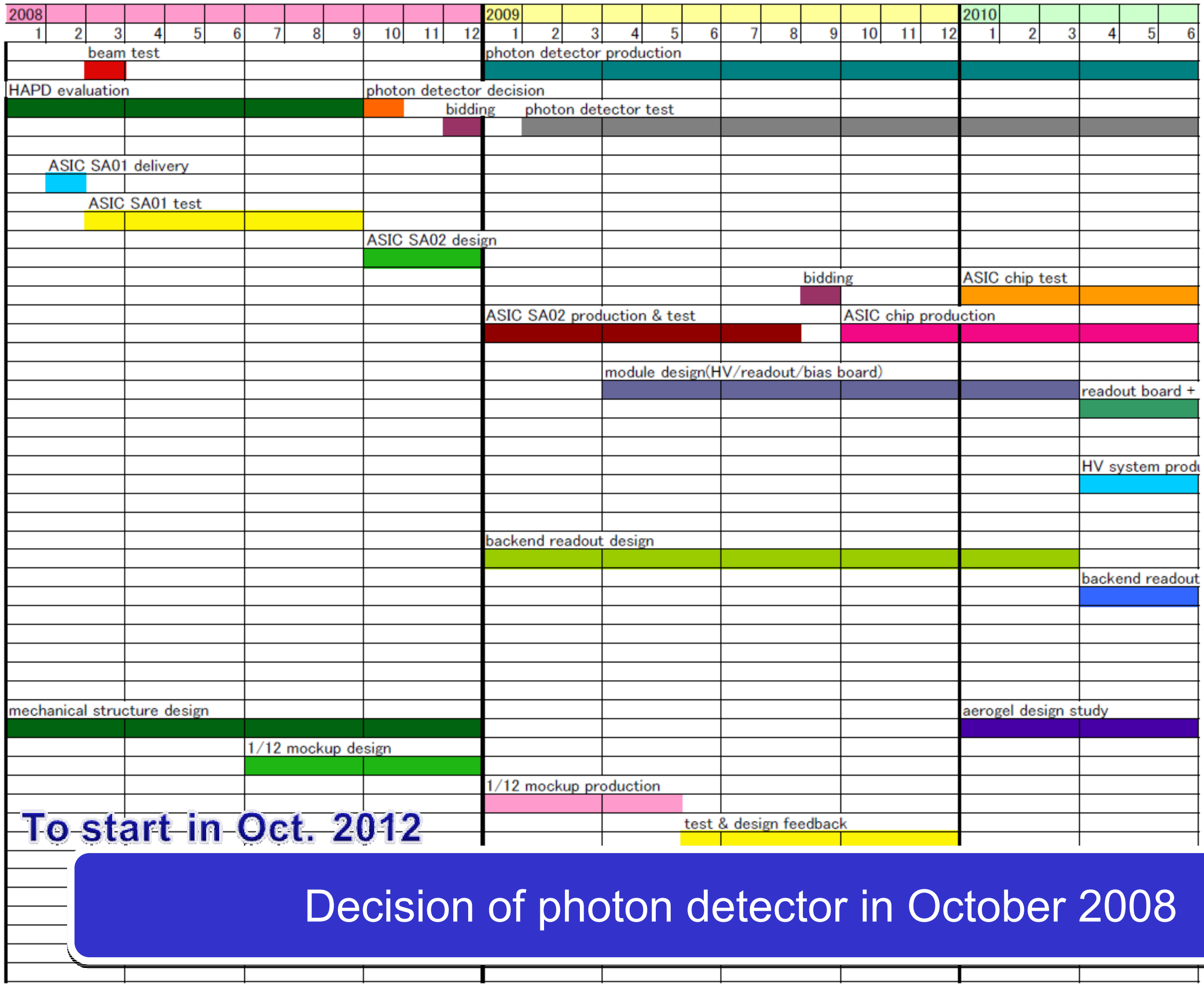
Installation test

**To start in Oct. 2012**

Design decision in December 2008 for quartz bar production

I. Adachi

# A-RICH Schedule (first half)



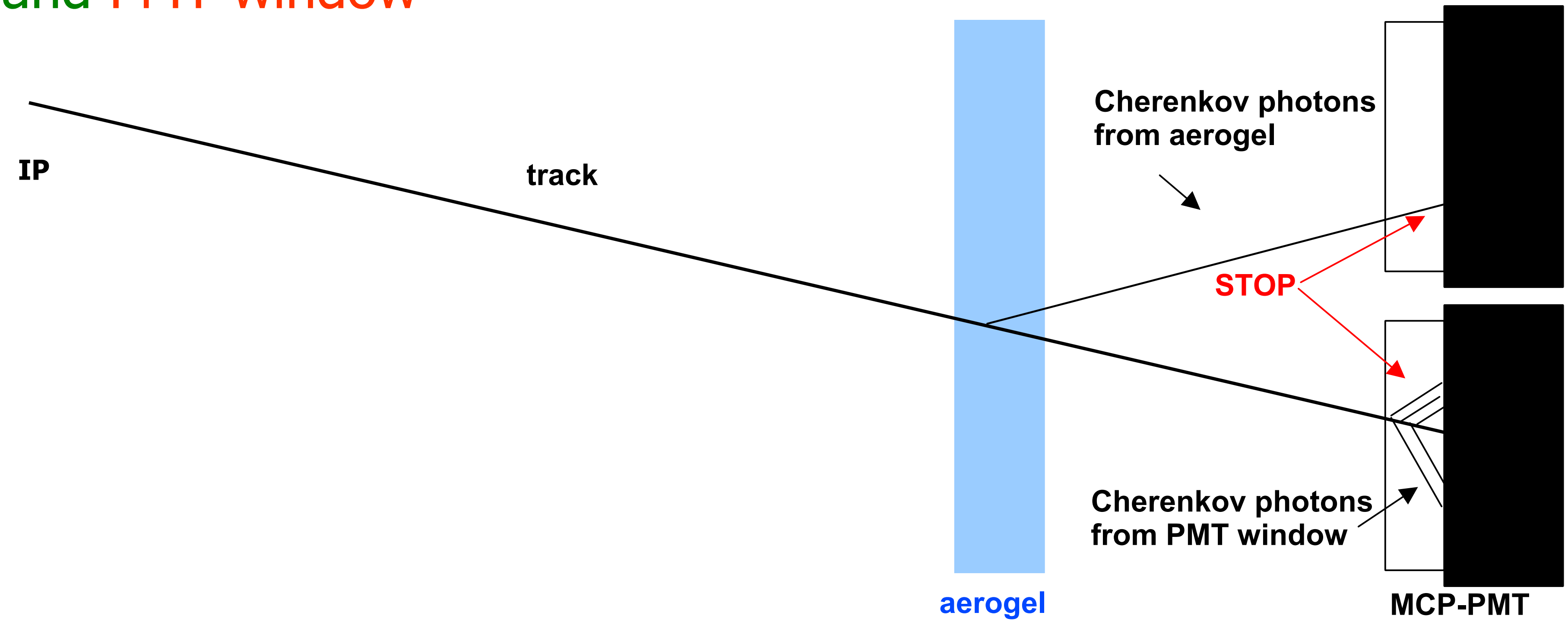
**To start in Oct. 2012**

Decision of photon detector in October 2008

**More details by I. Adachi**

# Time-of-flight measurement

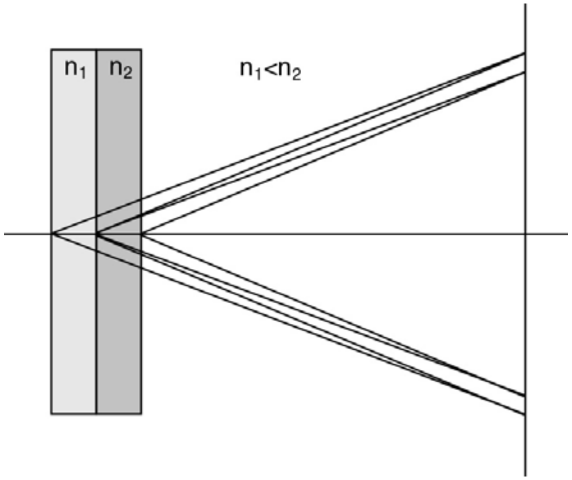
Time-of-flight with Cherenkov photons from aerogel radiator and PMT window



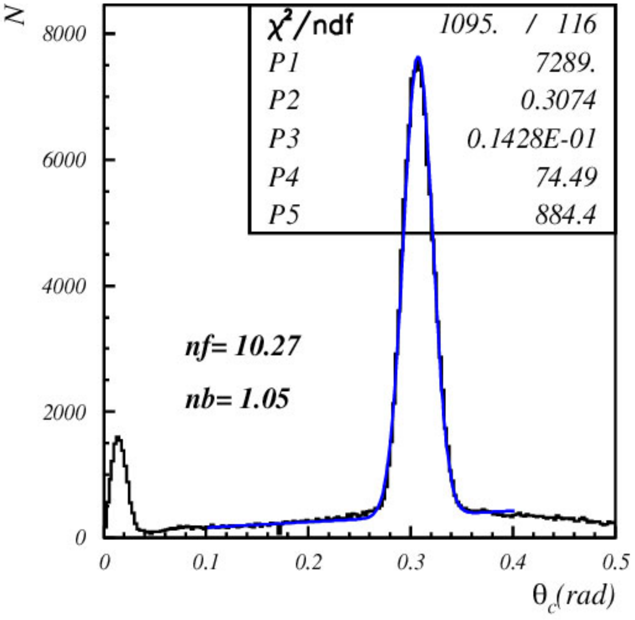
→can positively identify kaons bellow Cherenkov threshold in aerogel (1.5 GeV)

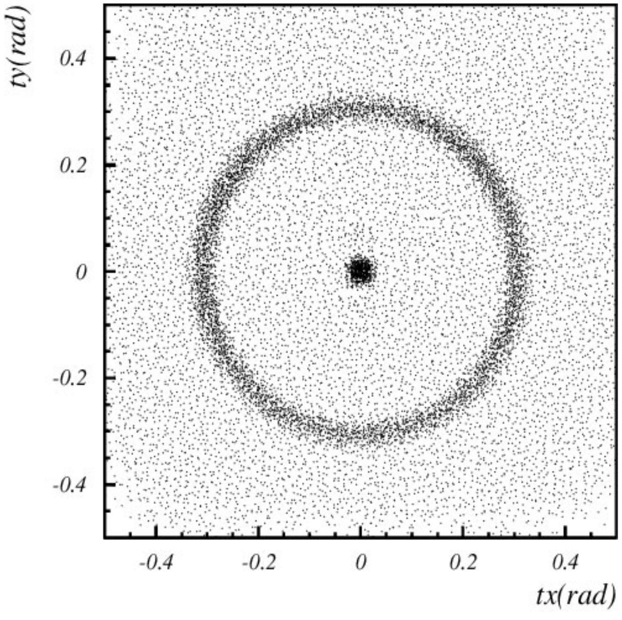
→a fast photon detector is an advantage

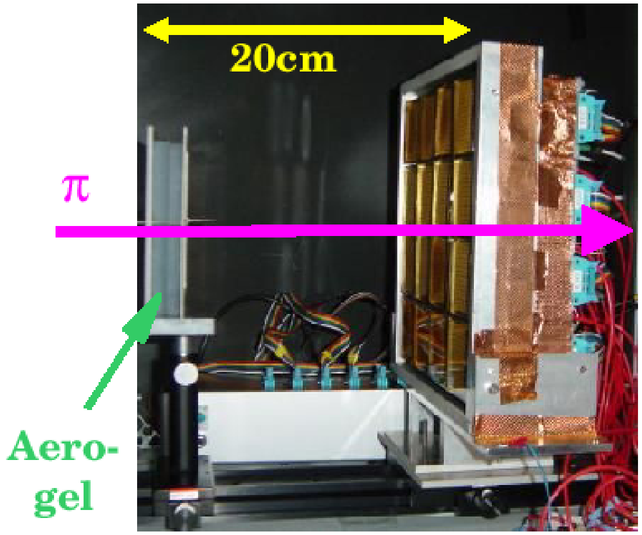
# Beam tests



2cm+2cm focusing aerogel

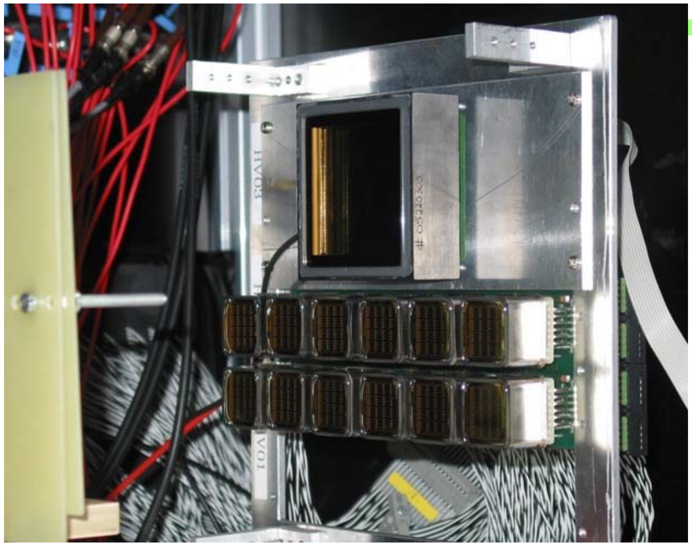






→ This photon detector does not work in magnetic field...

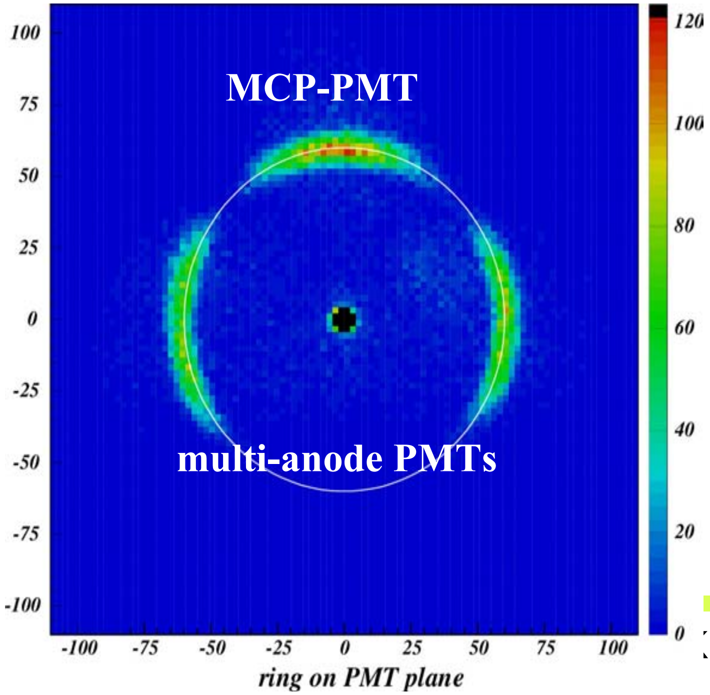
# Beam tests of Burle MCP PMT



Tested in pion beam combination with multi-anode PMTs.
→Stable operation, very good performance

Results:

- $\sigma_\vartheta$~13 mrad (single cluster)
- number of clusters per track N~ 4.5
- $\sigma_\vartheta$~ 6 mrad (per track)
- → ~ **4 σ π/K separation at 4 GeV/c**



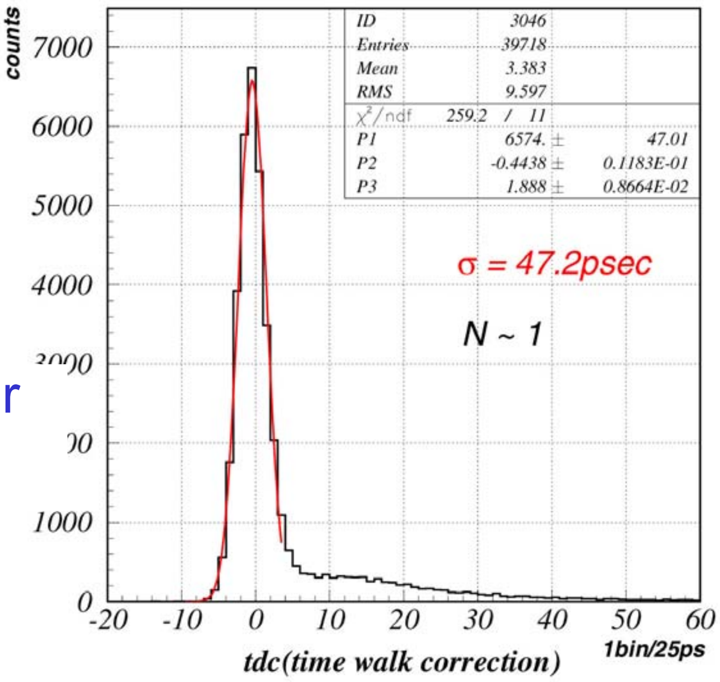
To do list:

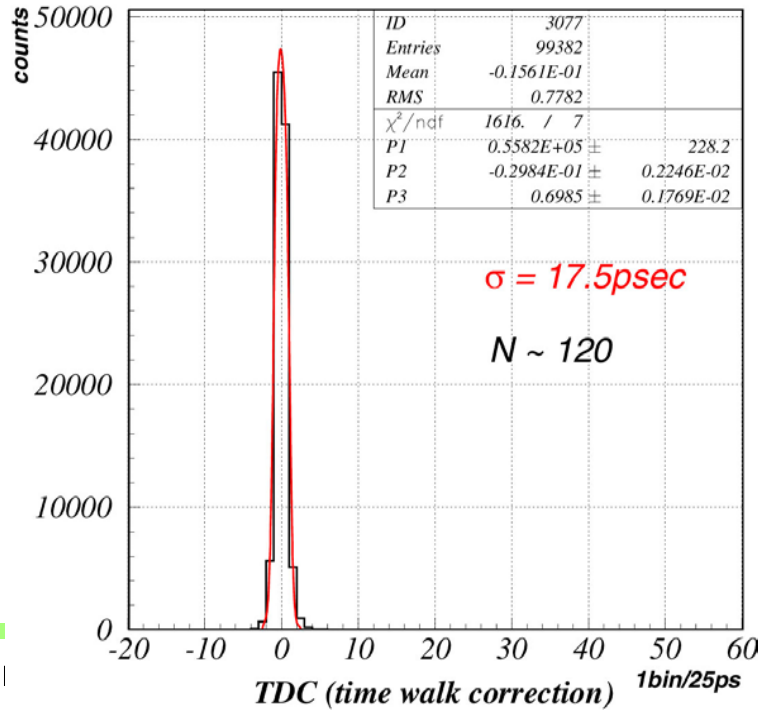
- improve collection efficiency and active area fraction →higher number of det. photons → done
- aging study

# MCP-PMT timing properties

Bench tests with pico-second laser

Time resolution as a function of the number of detected photons →



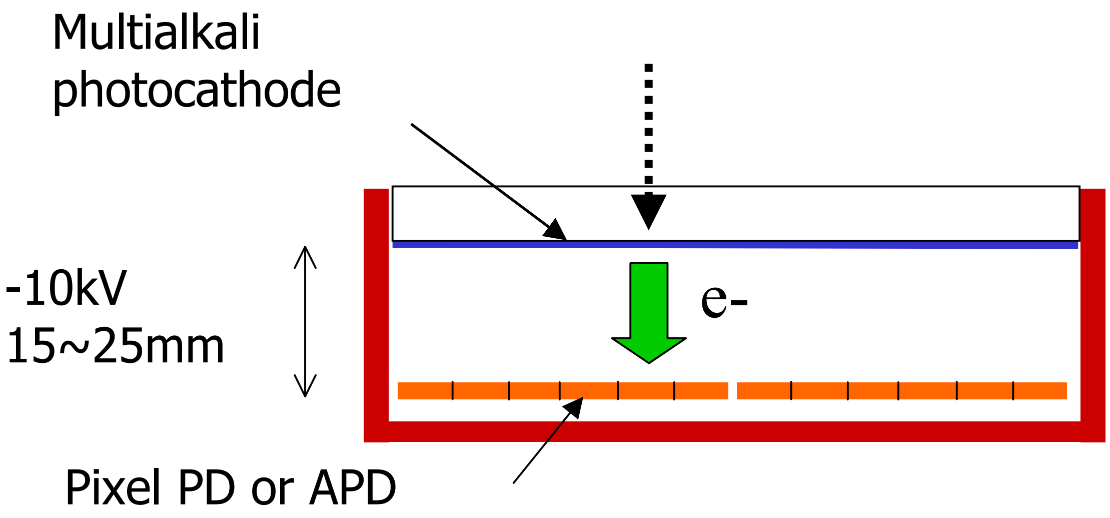


Additional bench tests needed: study detailed timing properties and cross-talk.

Determine their influence on the

- position resolution and
- time resolution

# Photon detector candidate: H(A)PD



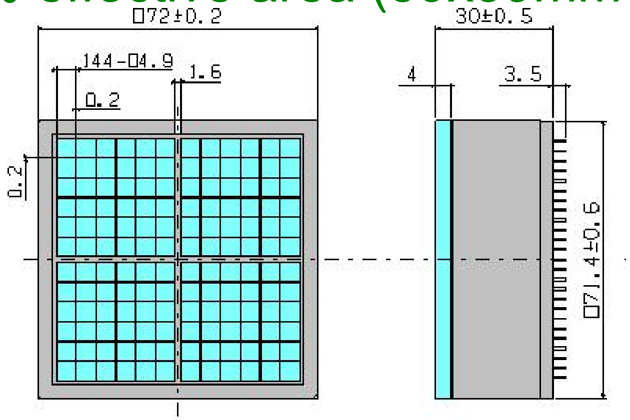
Multialkali photocathode

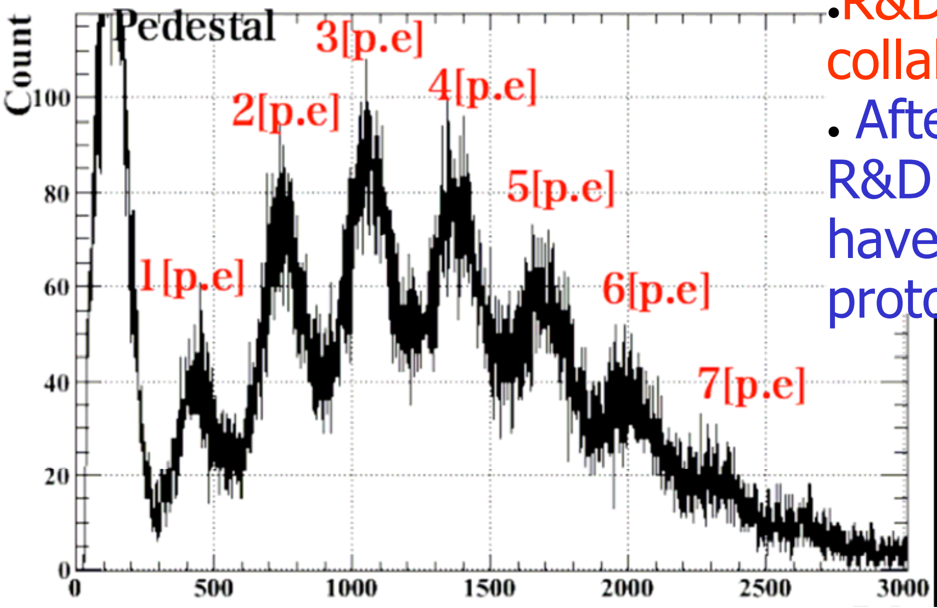
-10kV
15~25mm

e-

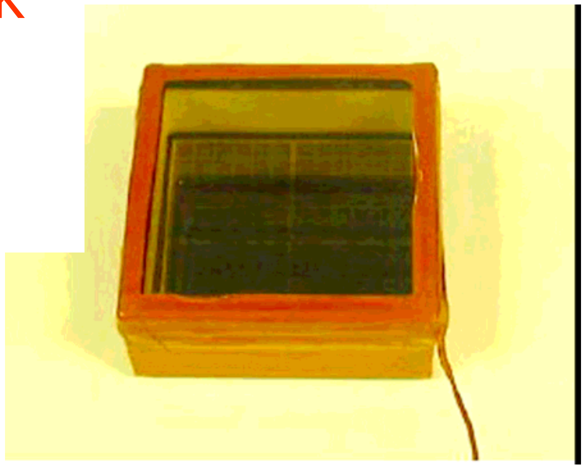
Pixel PD or APD

- 12 x 12 channels
- 65% effective area (59x59mm$^2$)





- R&D project in collaboration with HPK
- After a considerable R&D effort we finally have a full size prototype to study

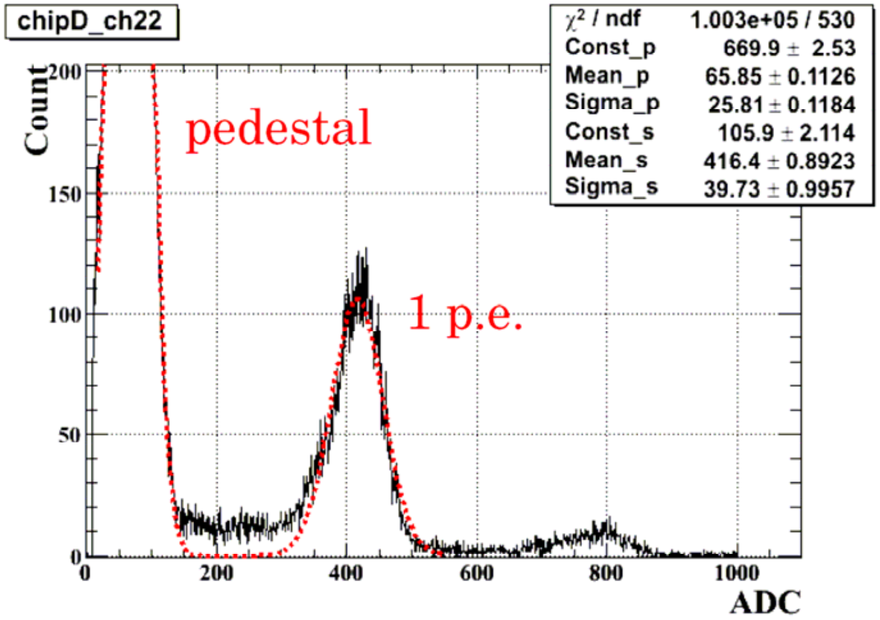


# HAPD bench tests

## ADC distribution of HAPD

- With Maximum bias voltage
- −8.5 kV high voltage
- 1 p.e. level light from LED

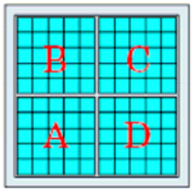
Clear separation between pedestal and 1 p.e. peak!!



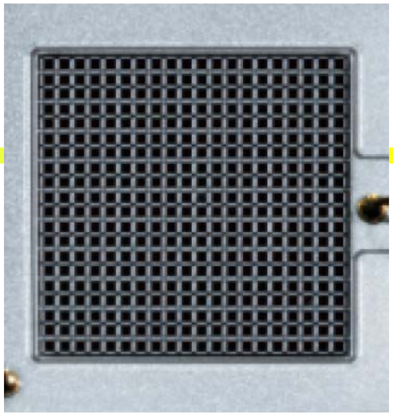
| channel | bias [V] | bombard-ment gain* | total gain | avalanche gain | S/N |
|---|---|---|---|---|---|
| chipA-22 | 331 | 1600 | 32000 | 20 | 8.8 |
| chipB-29 | 331 | 1750 | 26000 | 15 | 8.4 |
| chipC-22 | 337 | 1600 | 60000 | 37 | 15.1 |
| chipD-22 | 343 | 1650 | 67000 | 42 | 13.4 |

*=measured by Hamamatsu

- All the four chips show good performance.
- avalanche gain depends on (max.) bias voltage.



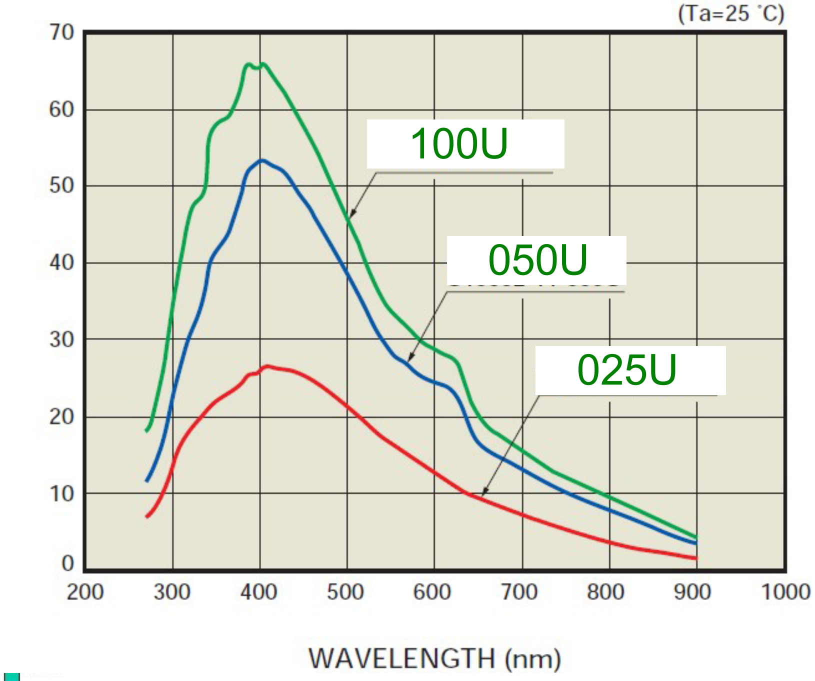
# SiPMs as photon detectors?



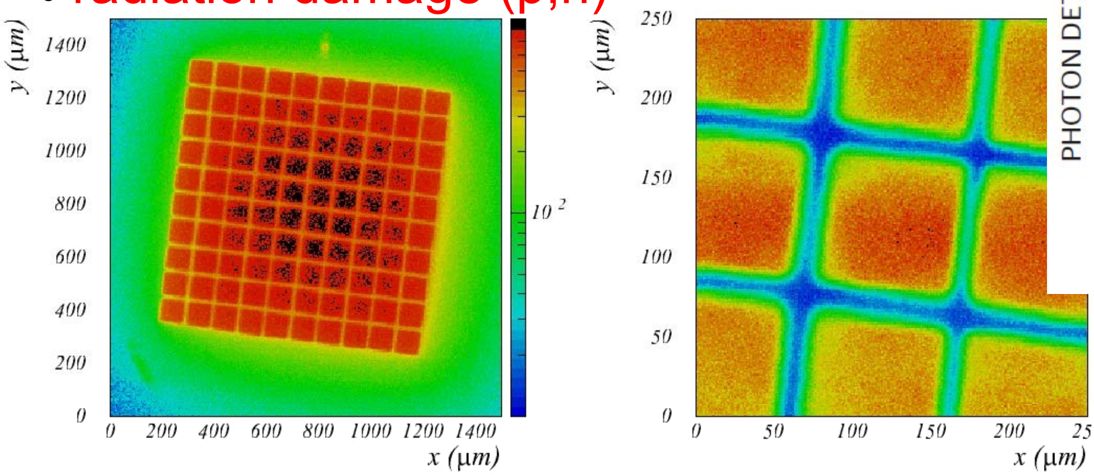
SiPM is an array of APDs operating in Geiger mode. Characteristics:

- low operation voltage ~ 10-100 V
- gain ~ $10^6$
- peak PDE up to 65%(@400nm)

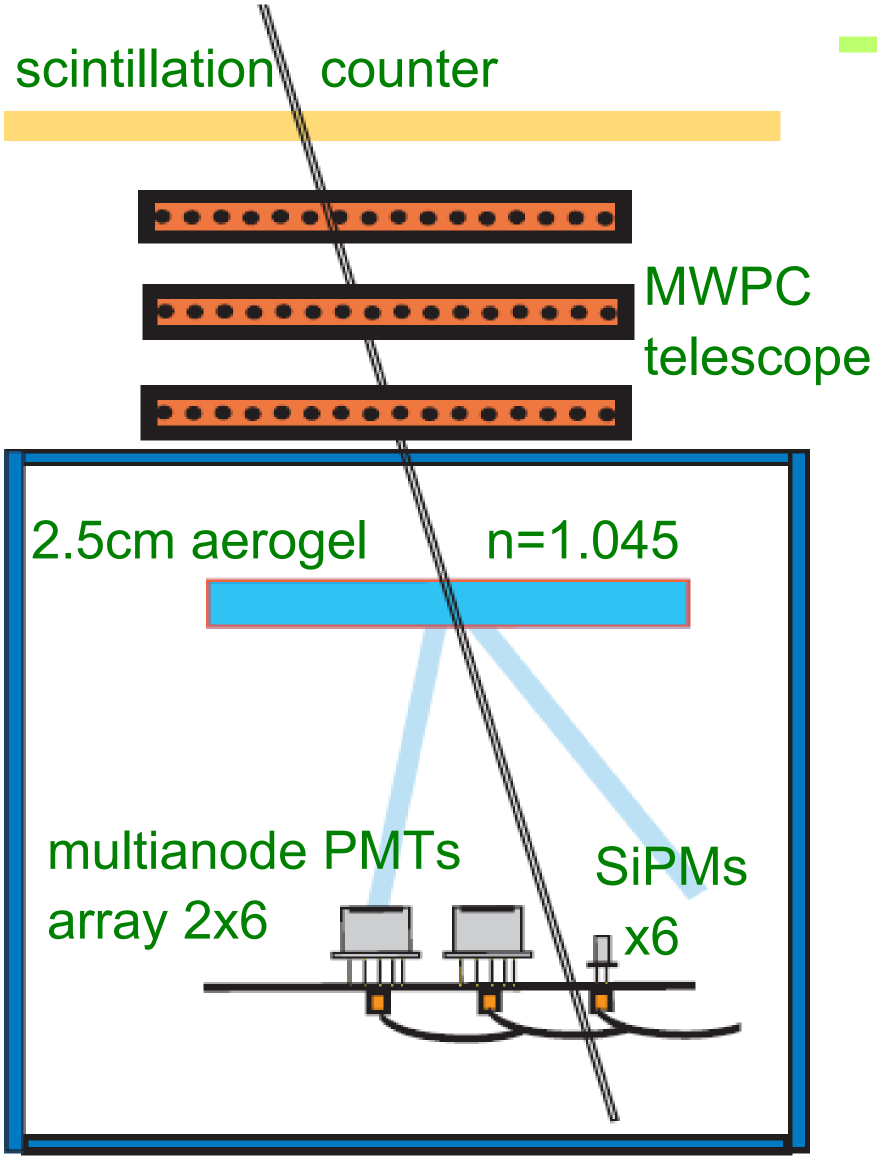
  PDE = QE x $\varepsilon_{geiger}$ x $\varepsilon_{geo}$
- $\varepsilon_{geo}$ – dead space between the cells
- time resolution ~ 100 ps
- works in high magnetic field
- dark counts ~ few 100 kHz/mm$^2$
- radiation damage (p,n)

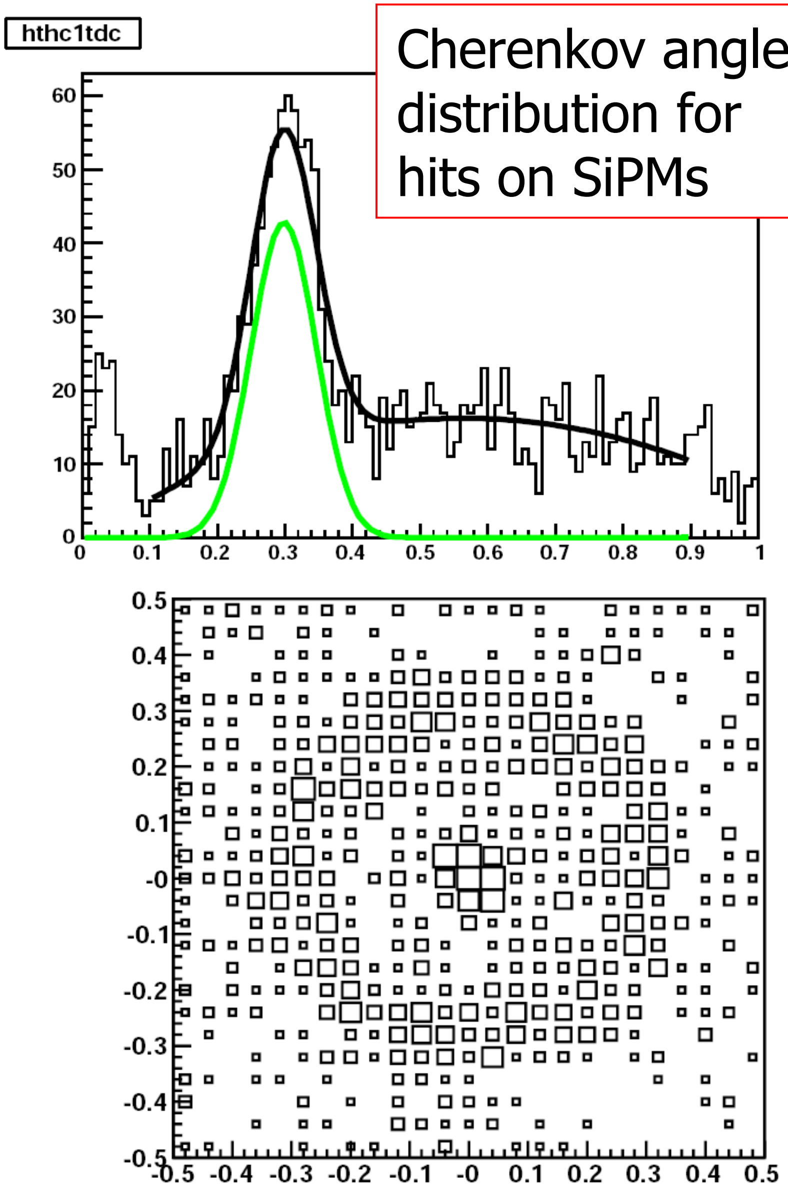


Hamamatsu MPPC: S10362-11



# Cosmic ray test



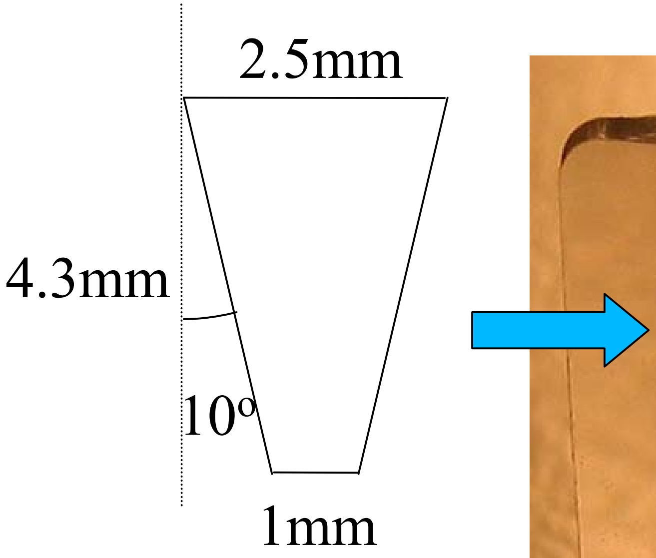


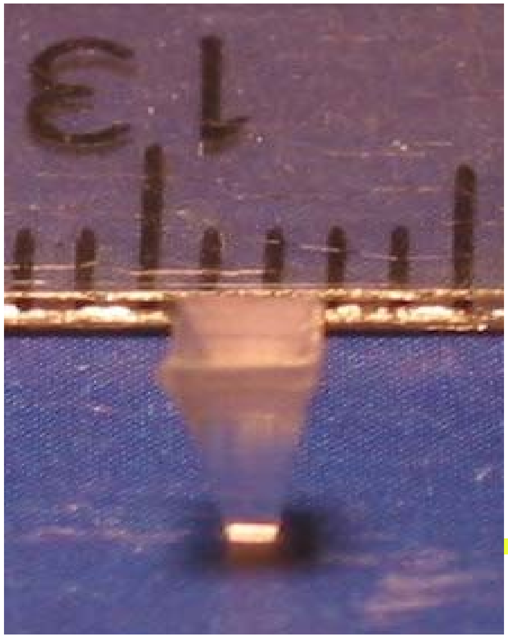
Cherenkov angle distribution for hits on SiPMs

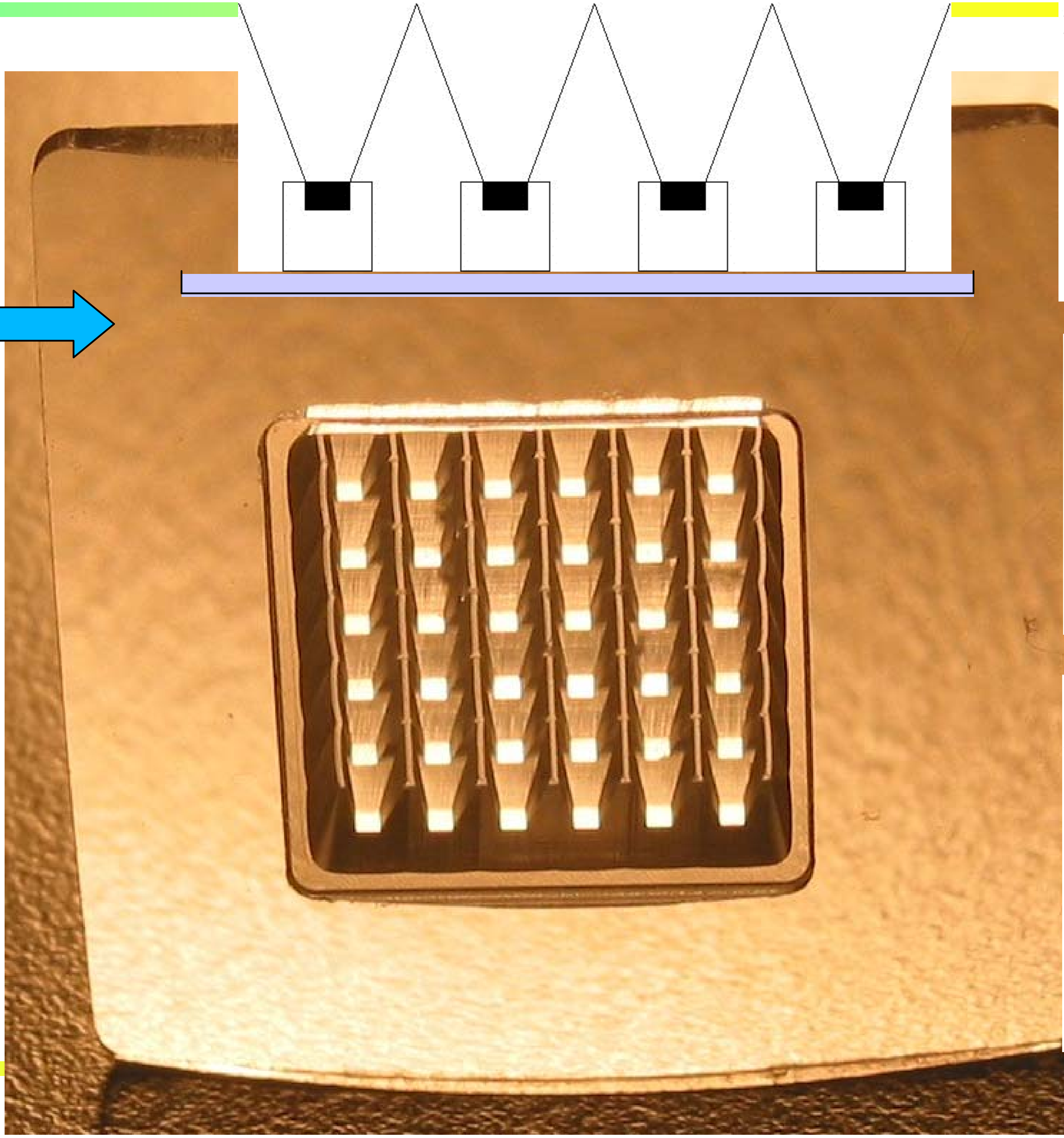
- Results are very promising.

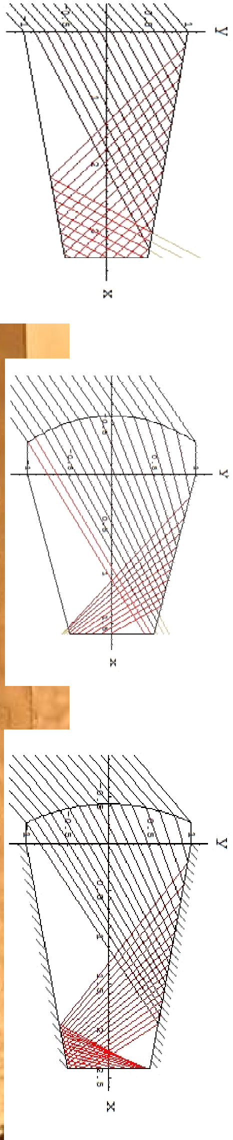
# Detector module design

## SiPM array with light guides









# Photon detectors for the aerogel RICH, summary

BURLE 85011 MPC PMT

- Best understood, beam and bench tested, excellent timing
- Open issues: ageing, read-out for fast timing

Multichannel H(A)PD – R+D with Hamamatsu

- Finally working samples, good progress in read-out electronics
- Open issues: more tests needed, performance in the beam, ageing

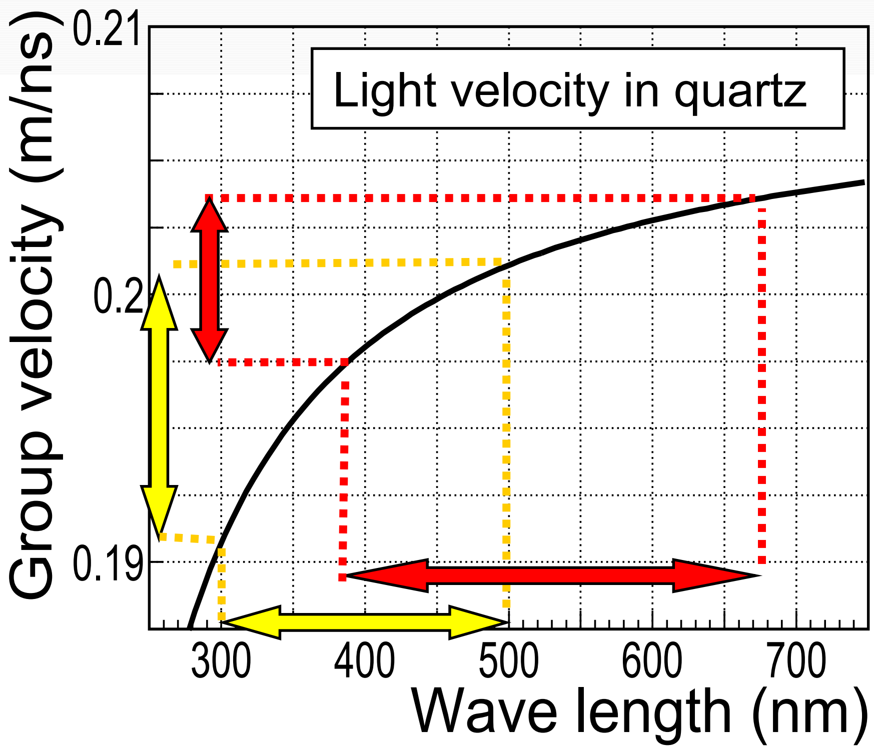
SiPM (G-APD)

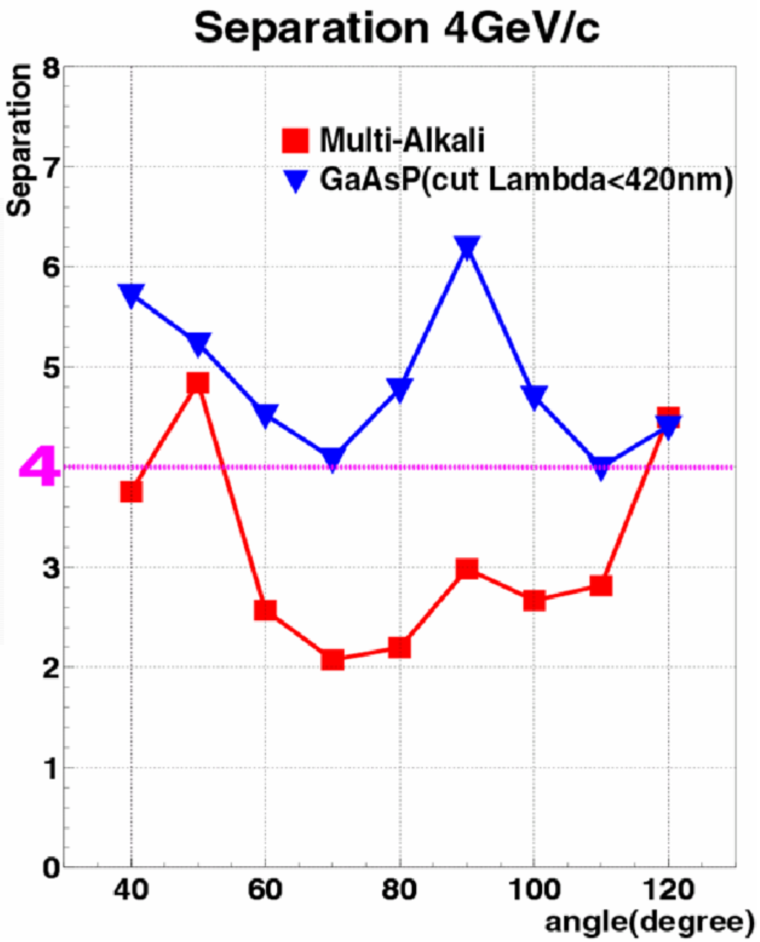
- Very good first results
- Open issues: radiation hardness

# TOP - dispersion

Expected performance with:

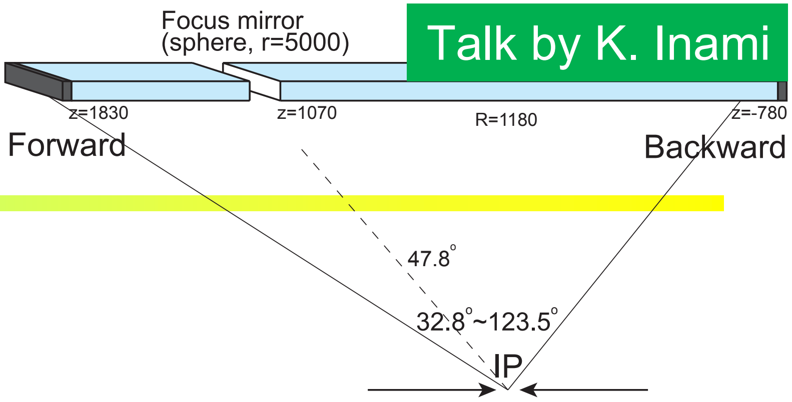
bi-alkali photocathode: <4σ π/K separation at 4GeV/c (← chromatic dispersion)





with GaAsP photocathode: >4σ π/K separation at 4GeV/c

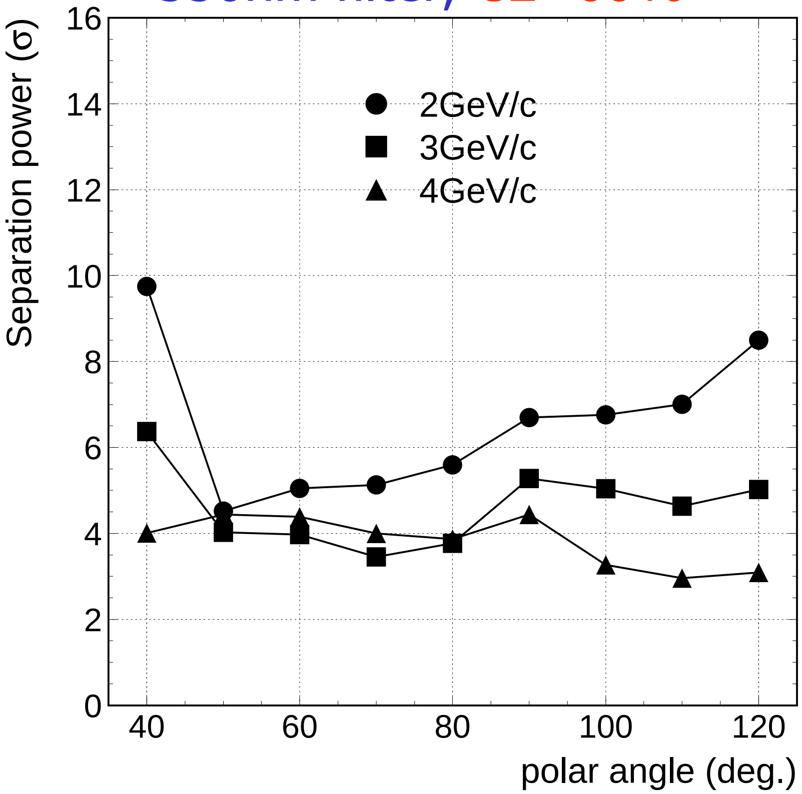
# Multi-alkali option

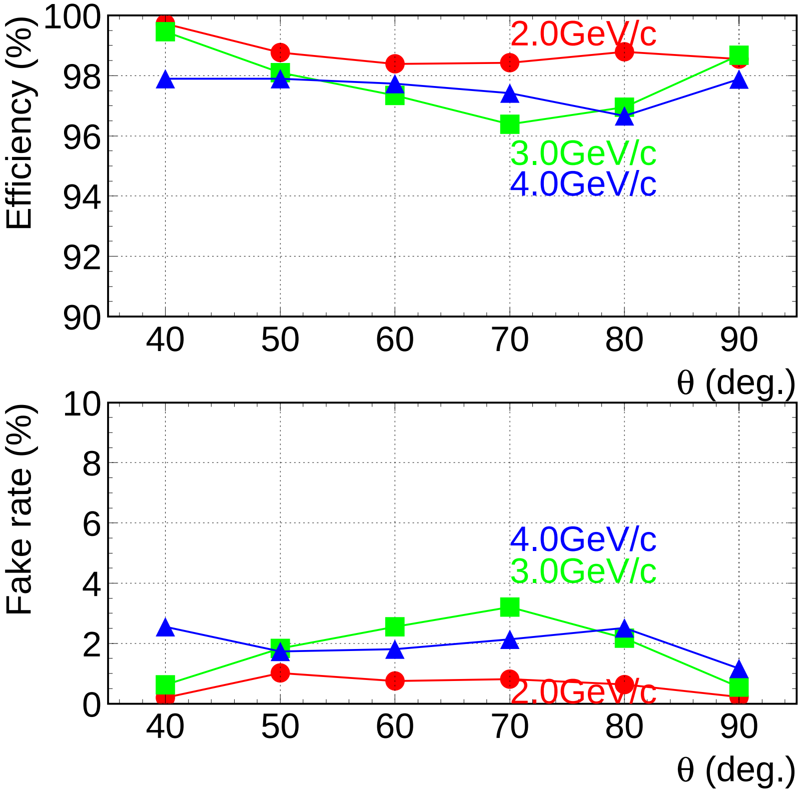


Talk by K. Inami

- Focusing type
  - Multi-alkali photo-cathode

    + >350nm filter, CE=60%





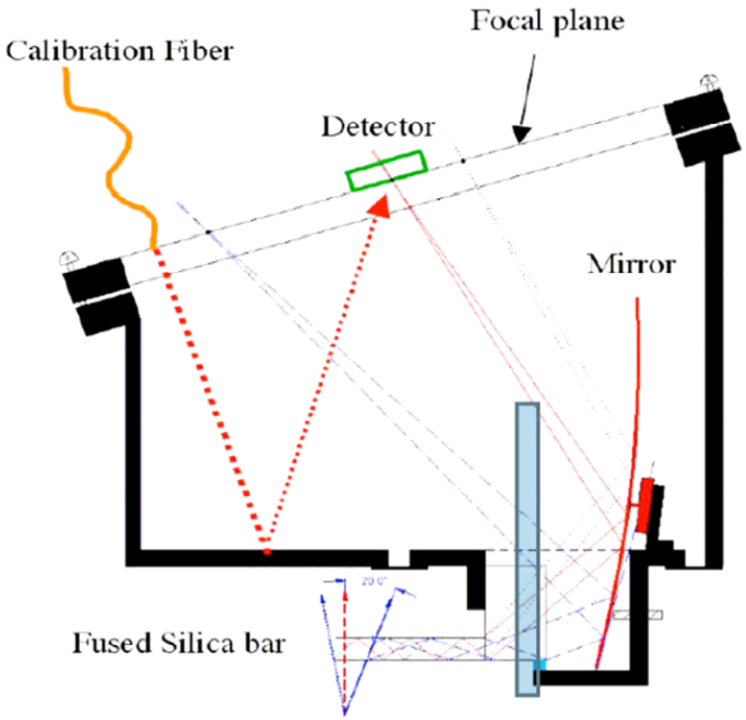
3.5σ K/π for 3 GeV/c, θ=70°

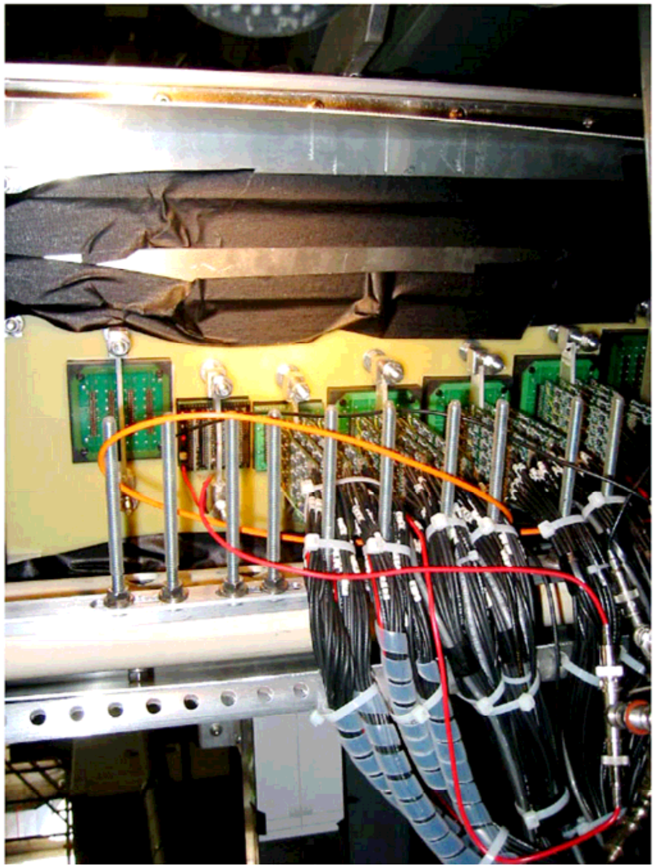
Talk by K. Inami

# TOP configuration summary

| option | K/pi separation performance at 70 deg, 4GeV/c | critical issues |
|---|---|---|
| 3 readout + multi-alkali | 2.8 sigma | (Make prototype) |
| 3 readout + GaAsP | 3.5 sigma | MCP production<br>MCP lifetime |
| Focusing + multi-alkali | 2.5 sigma →<br>4.0 sigma if CE=60% | MCP lifetime |
| Focusing + GaAsP | 4.2 sigma | MCP production<br>MCP lifetime |

# Focusing DIRC tests at SLAC

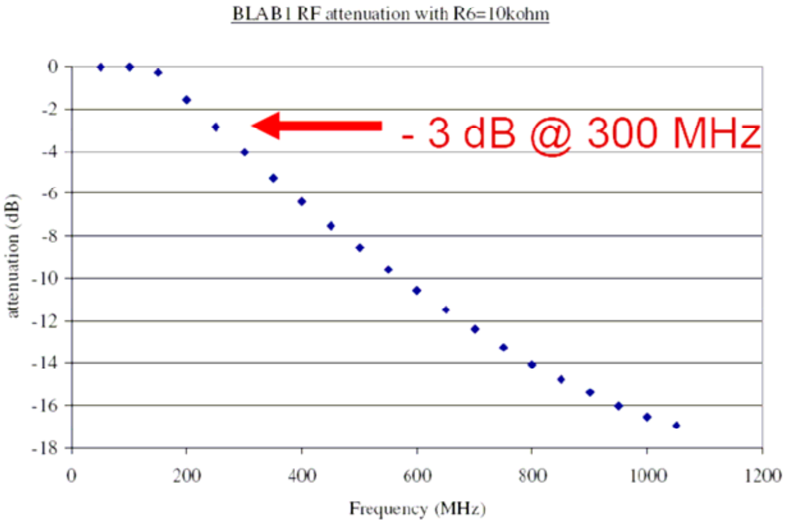




Photon detectors: flat pannel PMTs and Burle MCP PMTs, part of it read-out by Gary Varner's wave sampling read-out

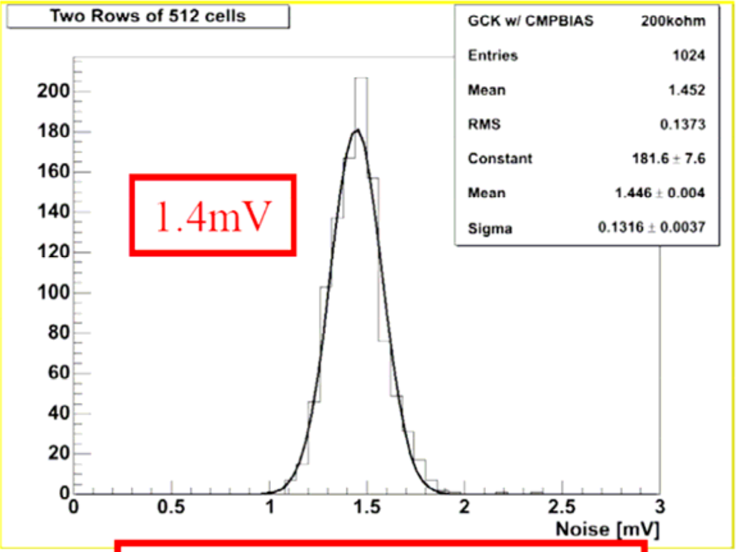
# Buffered Large Analog Bandwidth (BLAB1)

- Custom Analog-to-Digital (ADC)
- 65 k deep sampling
- High speed sampling
- Low power consumption
- 10 real bits of dynamic range



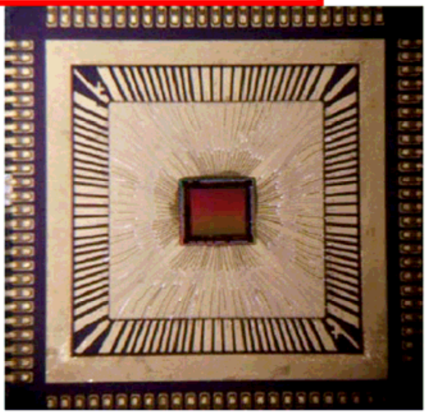
- 3 dB @ 300 MHz

Measured Noise



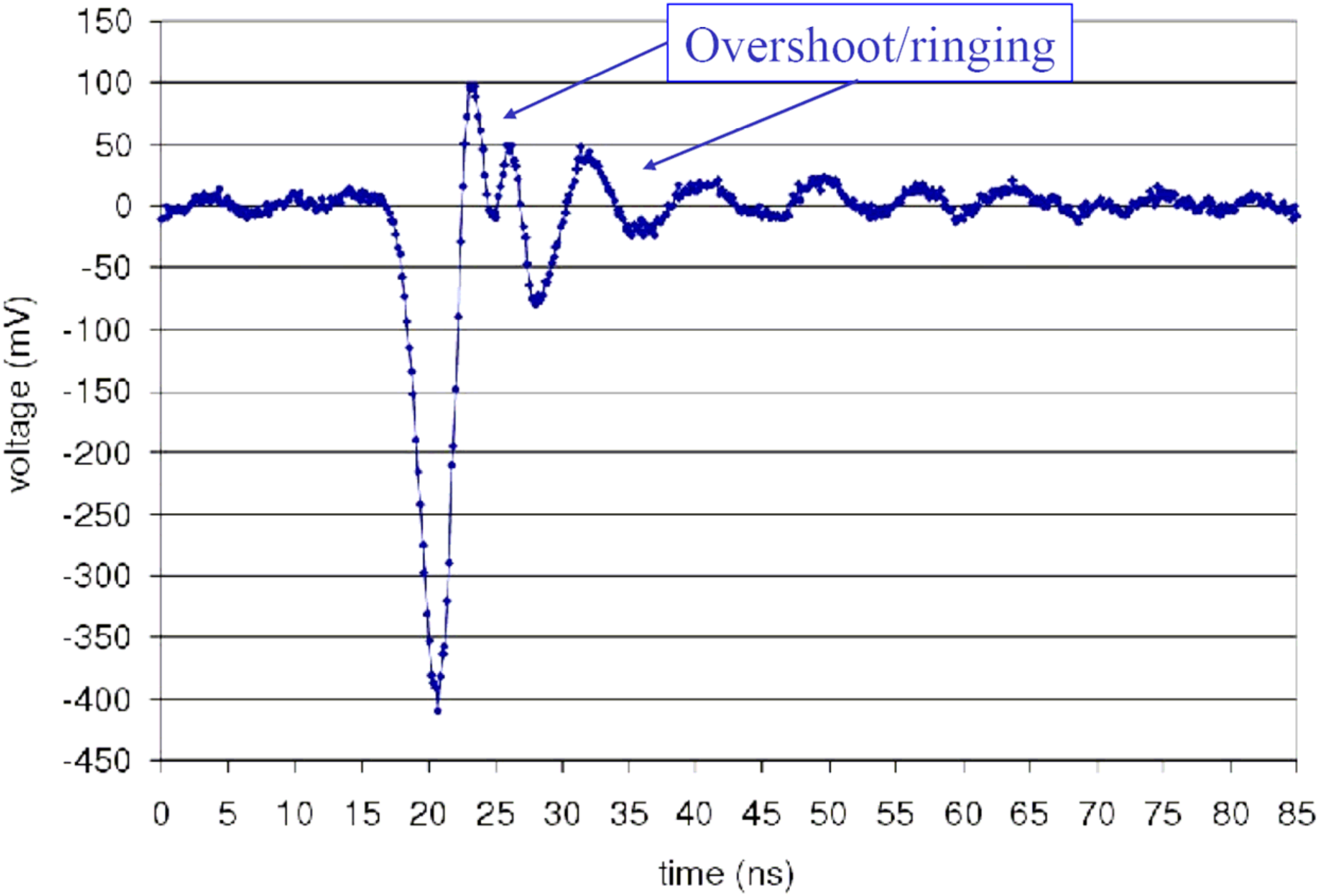
1.4mV

1.8V dynamic range



BLAB1

# Typical single p.e. signal [Burle]



# Focusing DIRC tests at SLAC

Beam test data looks good, being analyzed

Plan for the next beam test: equip 7 MCP PMTs with BLAB read-out

# PID summary

Aerogel RICH:

- A lot of progress in understanding the photon detectors; more beam/bench tests in spring → decision
- Read-out: still a lot to be done, final choice depends on photon detector (timing or not)

TOP:

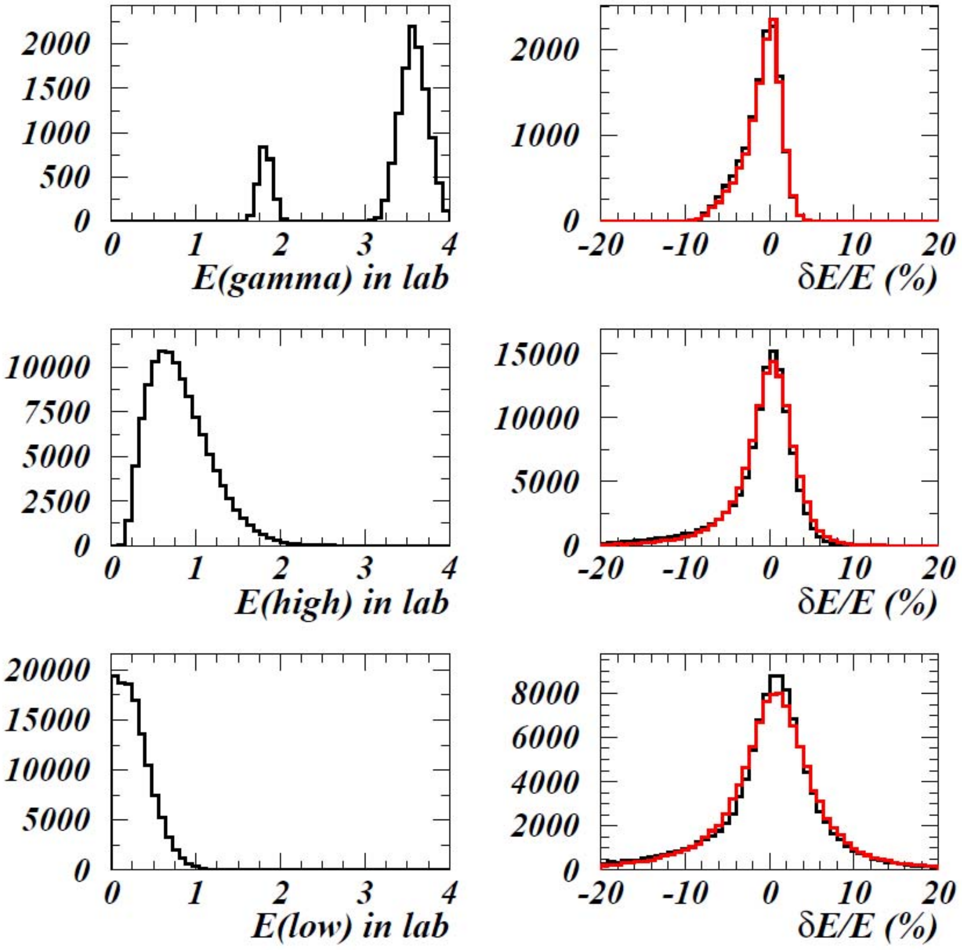
- Photon detector with GaAsP photocathode: excellent Q.E. and timing, dark count rate high.
- Plan: study ageing.

Focusing DIRC:

- Promissing beam tests at SLAC, progress in read-out electronics interesting for other devices as well.

# Photons to the end caps ($K_S\pi^0\gamma$)

More detailed study is going on



| **Energy (GeV)** | **δE/E(%) (r.m.s for +5%)** | |
|---|---|---|
| | Option A | Option B |
| 3.3 | 1.8 | 1.8 |
| 0.8 | 2.1 | 2.2 |
| 0.3 | 2.4 | 2.5 |

Option A:
0x background, 2x material
(pure CsI in the end cap)
Option B:
2x background, 3x material
(CsI(Tl) with waveform fit)

# Radiation Hardness of ECL Components

I. Nakamura

- **to $\gamma$ rays**
  - dose as of Now ~ 100–400 rad
  - Crystals checked @ BINP

| crystal | dose (rad) | # photons |
|---|---|---|
| CsI(Tl) | 100 | ~0.95 |
| | 1000 | ~0.90 |
| CsI(Pure) | 100 | 1.0 |
| | 10000 | 0.9–0.8 |

  - PD checked @ TIT

| dose (rad) | $\Delta I$(nA) | $C_j/C_{j0}$ | $G/G_0$ |
|---|---|---|---|
| 190 | ~ 0 | 1.0 | 1.00 |
| 610 | ~ 0.2 | 1.0 | 1.00 |
| 6.8k | ~ 1 | 1.0 | 1.00 |
| 70k | ~ 6 | 1.0 | 0.99 |

- **to Neutrons**
  - dose as of Now ~$10^{10}$–$10^{11}$ /cm$^2$
  - Test performed @ reactor YAYOI
  - PD

| dose (/cm$^2$) | $\Delta I$(nA) | $C_j/C_{j0}$ | $G/G_0$ |
|---|---|---|---|
| $1\times10^{11}$ | ~ 100 | 1 | 1.00 |
| $1\times10^{12}$ | ~ 1000 | 1 | 0.98 |
| $1\times10^{13}$ | ~ 10000 | 1 | 0.93 |

  - Crystals

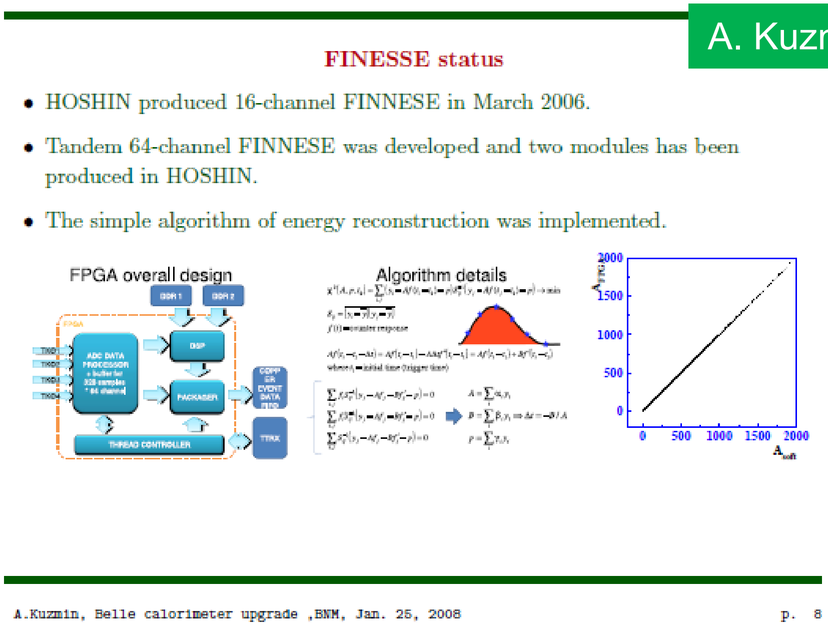
| crystal | dose (/cm$^2$) | # photons |
|---|---|---|
| CsI(Tl)* | $1\times10^{12}$ | ~0.7 |
| CsI(Pure) | $1\times10^{12}$ | 1.0–0.95 |

* small crystal doesn't show degradation

- $\gamma$ rays no problem
- some degradation with Neutrons
- Rad. hardness of crystals depend on producer

# CsI read-out status

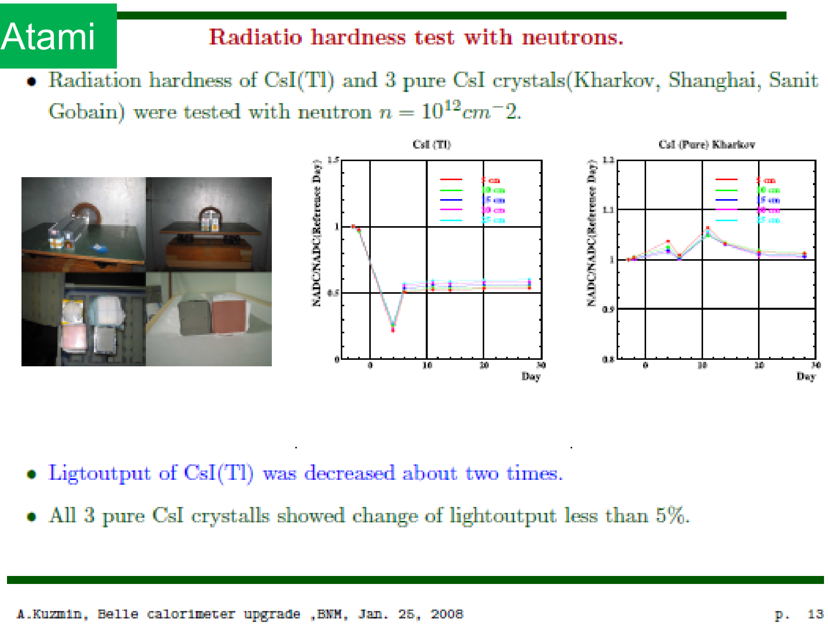
A. Kuzmin @ Atami



**FINESSE status**

- HOSHIN produced 16-channel FINNESE in March 2006.
- Tandem 64-channel FINNESE was developed and two modules has been produced in HOSHIN.
- The simple algorithm of energy reconstruction was implemented.

A.Kuzmin, Belle calorimeter upgrade ,BNM, Jan. 25, 2008 p. 8



**Radiatio hardness test with neutrons.**

- Radiation hardness of CsI(Tl) and 3 pure CsI crystals(Kharkov, Shanghai, Sanit Gobain) were tested with neutron $n = 10^{12}cm^{-}2$.

- Ligtoutput of CsI(Tl) was decreased about two times.
- All 3 pure CsI crystalls showed change of lightoutput less than 5%.

A.Kuzmin, Belle calorimeter upgrade ,BNM, Jan. 25, 2008 p. 13

Development of on-chip waveform fitting algorithm going on

Examining Kharkov, SICCAS and Saint Gobain crystals

| | Price of sample | Light yield | Uniformity | Radiation hardness |
|---|---|---|---|---|
| Kharkov | 6k$ (2004) | 80 p.e./MeV | <10% | Good |
| SICCAS | 4k$ (2006) | 30 p.e./MeV | 10-20% | Good |
| Saint Gobain | 8k$ (2006) | 130 p.e/MeV | <10% | Good |

I. Nakamura

# Possible options for ECL

## Fastbus TDC to Copper AMT3

Free from Fastbus malfunctions

Dead time reduction by factor 3

No background reduction

Copper 5k$*100

AMT3 Finesse 200*0.7k$

Crate 6*5k$

(Total 0.7 M$)

## Option 1

## New readout system

Dead time free

BKG reduction by factor 7

Shaper FADC 5k$*550

(Copper 5k$*80)

(DSP board 1k$*150)

(Crate 5k$*5)

Total 2.8 M$

## Option 2

## Pure CsI in end caps

BKG reduction by factor 200

Option 1 +

Crystal ~5k$/ch

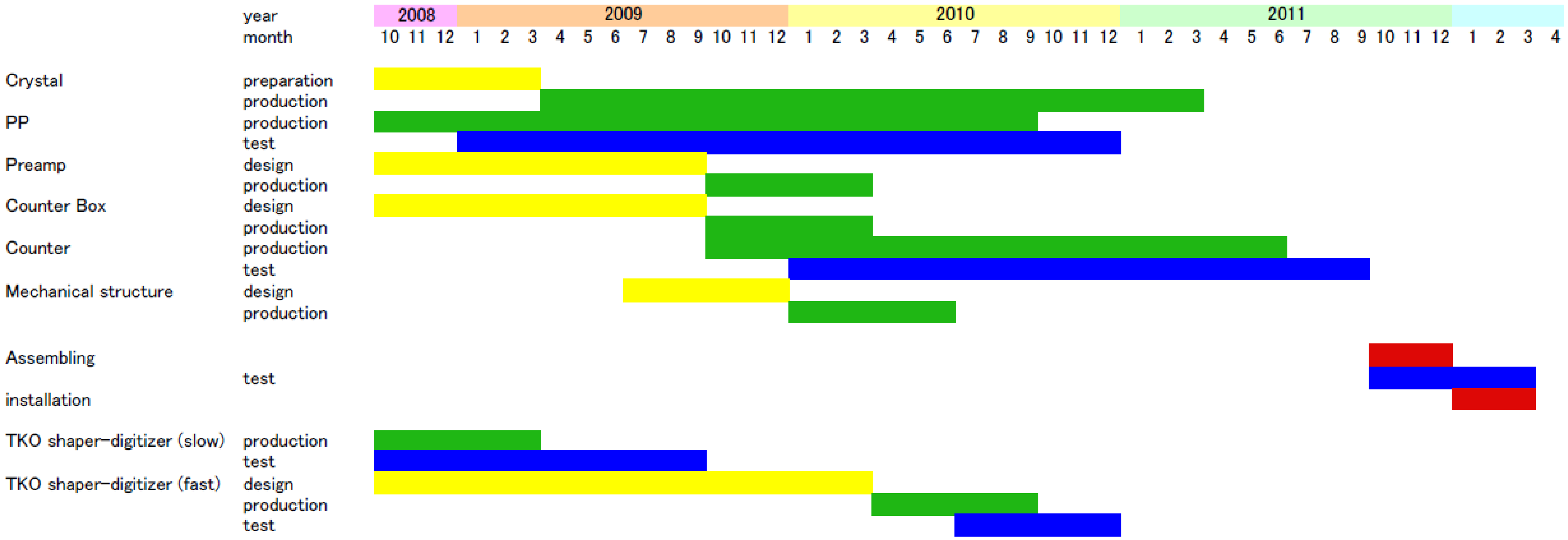
PMT 1k$/ch

Frontend 1k$/ch

Total 6.2M$/480ch to 17.6M$/2112ch

A. Kuzmin

# ECL Schedule

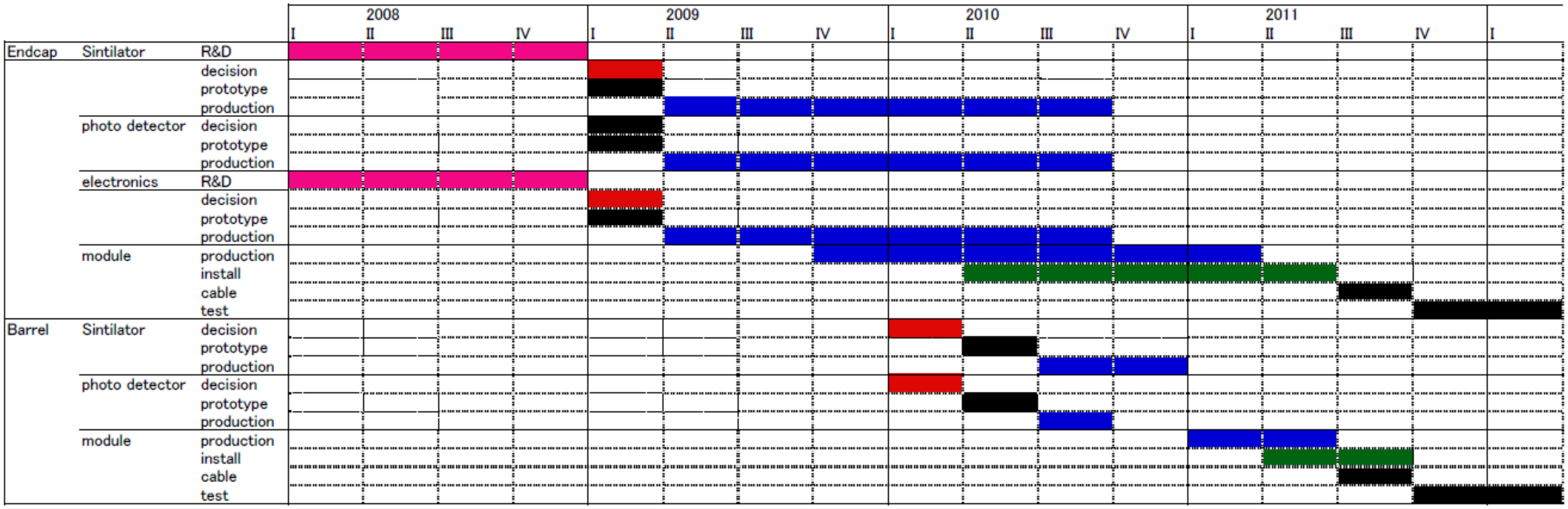


**To start in Oct. 2012**

Design decision in October 2008 for crystal and PMT production

K. Sumisawa

# KLM Schedule



| | | | 2008 | | | | 2009 | | | | 2010 | | | | 2011 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | I | II | III | IV | I | II | III | IV | I | II | III | IV | I | II | III | IV | I |
| Endcap | Sintilator | R&D | 🟪 | 🟪 | 🟪 | 🟪 | | | | | | | | | | | | | |
| | | decision | | | | | 🟥 | | | | | | | | | | | | |
| | | prototype | | | | | ⬛ | | | | | | | | | | | | |
| | | production | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | | | | | | |
| | photo detector | decision | | | | | ⬛ | | | | | | | | | | | | |
| | | prototype | | | | | ⬛ | | | | | | | | | | | | |
| | | production | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | | | | | | |
| | electronics | R&D | 🟪 | 🟪 | 🟪 | 🟪 | | | | | | | | | | | | | |
| | | decision | | | | | 🟥 | | | | | | | | | | | | |
| | | prototype | | | | | ⬛ | | | | | | | | | | | | |
| | | production | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | | | | | | |
| | module | production | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | | | | |
| | | install | | | | | | | | | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | | |
| | | cable | | | | | | | | | | | | | | | ⬛ | | |
| | | test | | | | | | | | | | | | | | | | ⬛ | ⬛ |
| Barrel | Sintilator | decision | | | | | | | | | 🟥 | | | | | | | | |
| | | prototype | | | | | | | | | | ⬛ | | | | | | | |
| | | production | | | | | | | | | | | 🟦 | 🟦 | | | | | |
| | photo detector | decision | | | | | | | | | 🟥 | | | | | | | | |
| | | prototype | | | | | | | | | | ⬛ | | | | | | | |
| | | production | | | | | | | | | | | 🟦 | | | | | | |
| | module | production | | | | | | | | | | | | | 🟦 | 🟦 | | | |
| | | install | | | | | | | | | | | | | | 🟩 | 🟩 | | |
| | | cable | | | | | | | | | | | | | | | ⬛ | | |
| | | test | | | | | | | | | | | | | | | | ⬛ | ⬛ |

**To start in Oct. 2012**

Design decision by March 2009 for end caps, by early 2010 for barrel

# KLM Possible options

K. Sumisawa
P. Pakhalov

## Option 1

Scintillator in the end caps

28k bars + frontend1.34M$

(Backend 0.24M$)

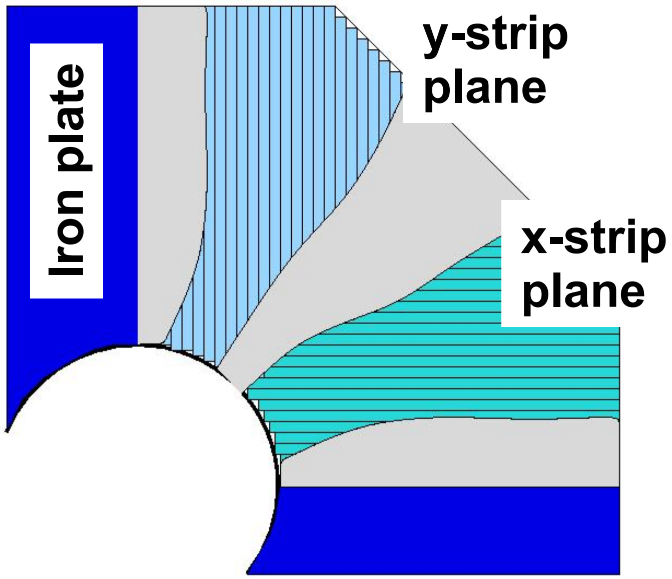
Total 1.4M$

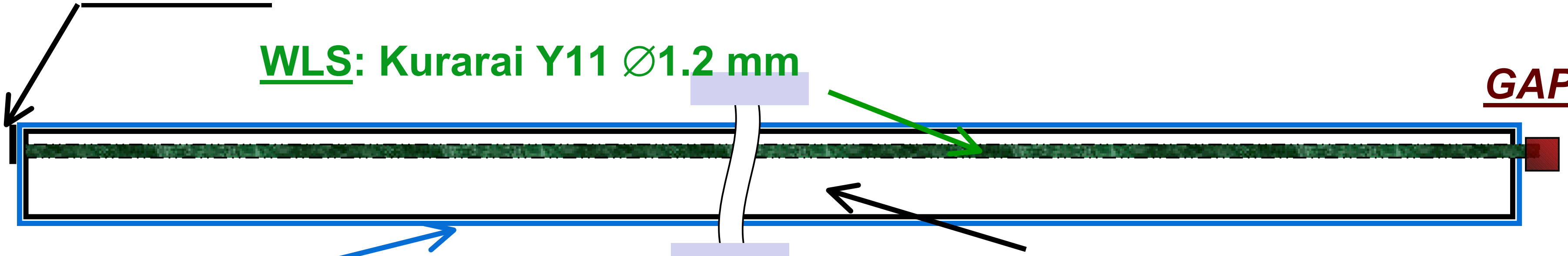
## Option 1’

Opt.1 + avalanche RPC in barrel

1.4M$

+0.03M$/lyr





**Mirror 3M**

**WLS: Kurarai Y11 ∅1.2 mm**

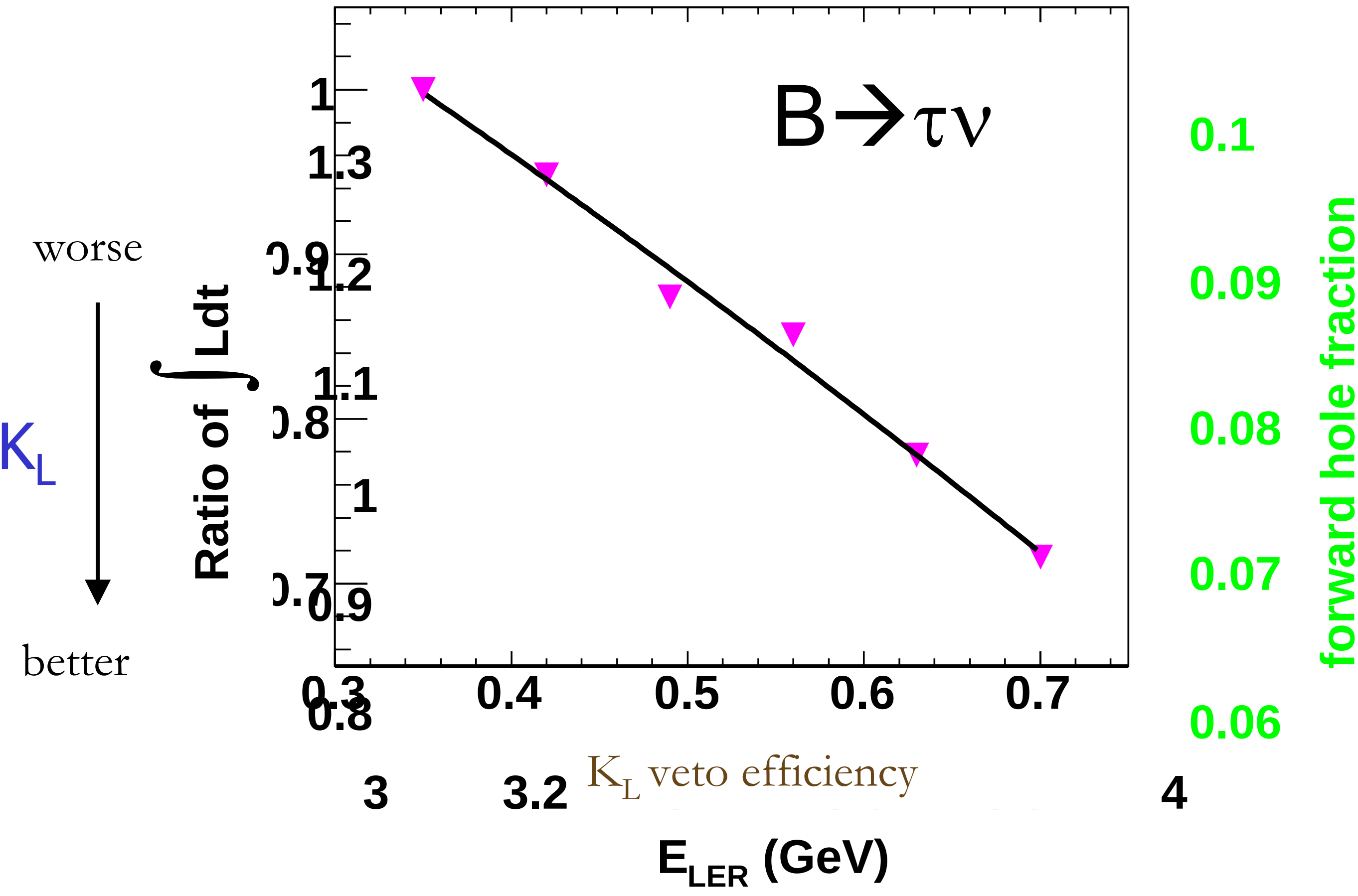
***GAPD***

**Diffusion reflector ($TiO_2$)**

**Strips: polystyrene with 1.5% PTP & 0.01% POPOP**

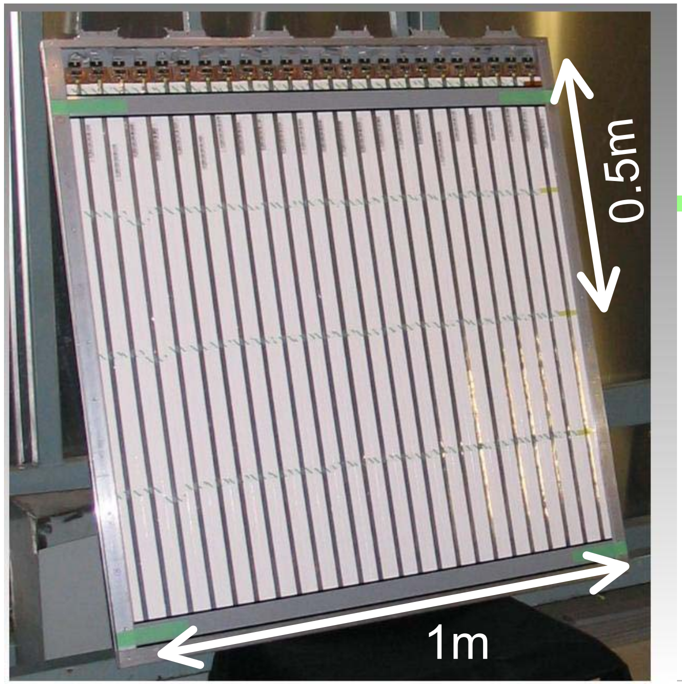
# $K_L$ Veto Efficiency Dependence

- Toy MC results for several $K_L$ veto efficiencies.
- Current is set to 35%
  - guessed by geant simulation + $J/\psi K_L$ data
- How can we improve $K_L$ detection efficiency of super KLM?

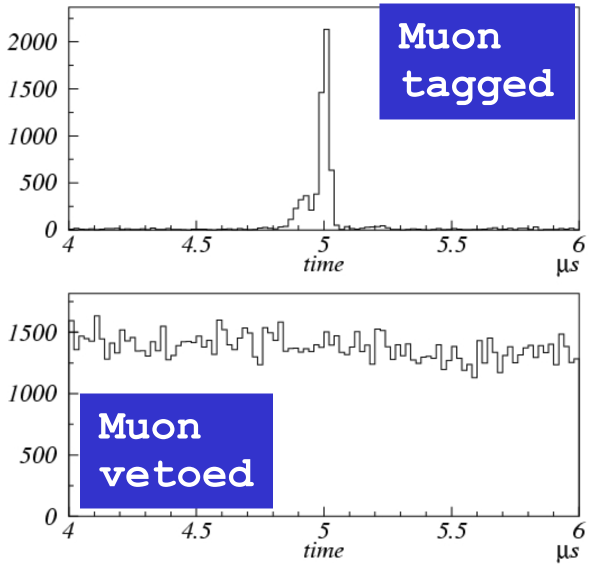


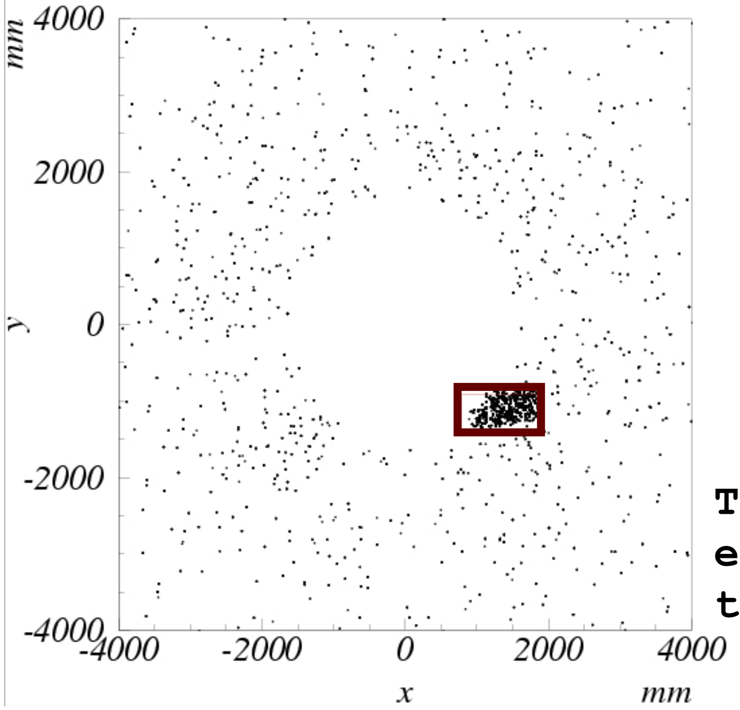
# Test Mod Belle

P. Pakhalov @ Atami



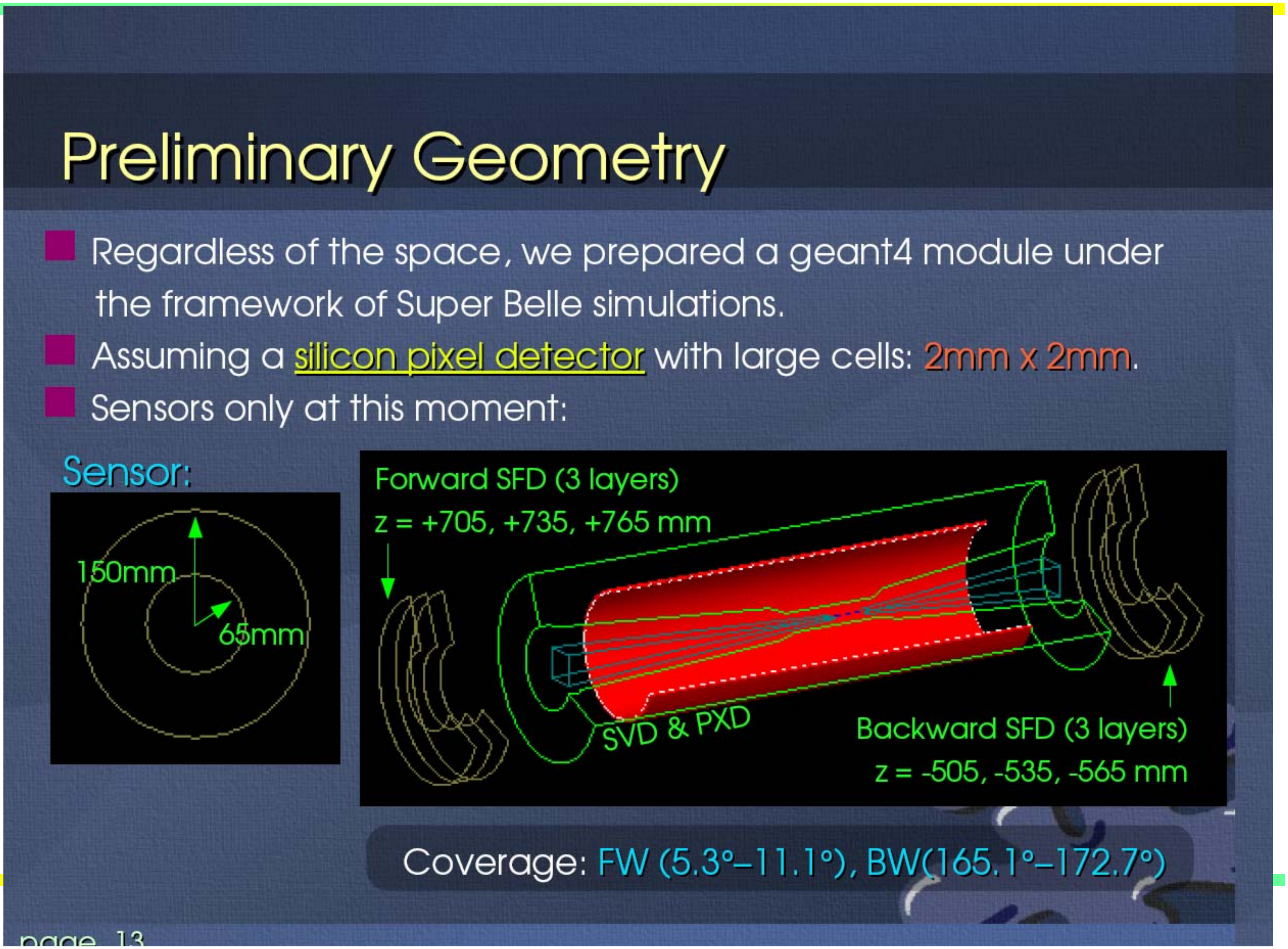
Muons from ee →μμ are seen with proper time, proper position





**The distribution of the muons hits (x%y) extrapolated from CDC to z = $z_{\text{test module}}$ with the proper time sc-KLM module hits**

# Simulation study



## Preliminary Geometry

- Regardless of the space, we prepared a geant4 module under the framework of Super Belle simulations.
- Assuming a silicon pixel detector with large cells: 2mm x 2mm.
- Sensors only at this moment:

Coverage: FW (5.3°–11.1°), BW(165.1°–172.7°)

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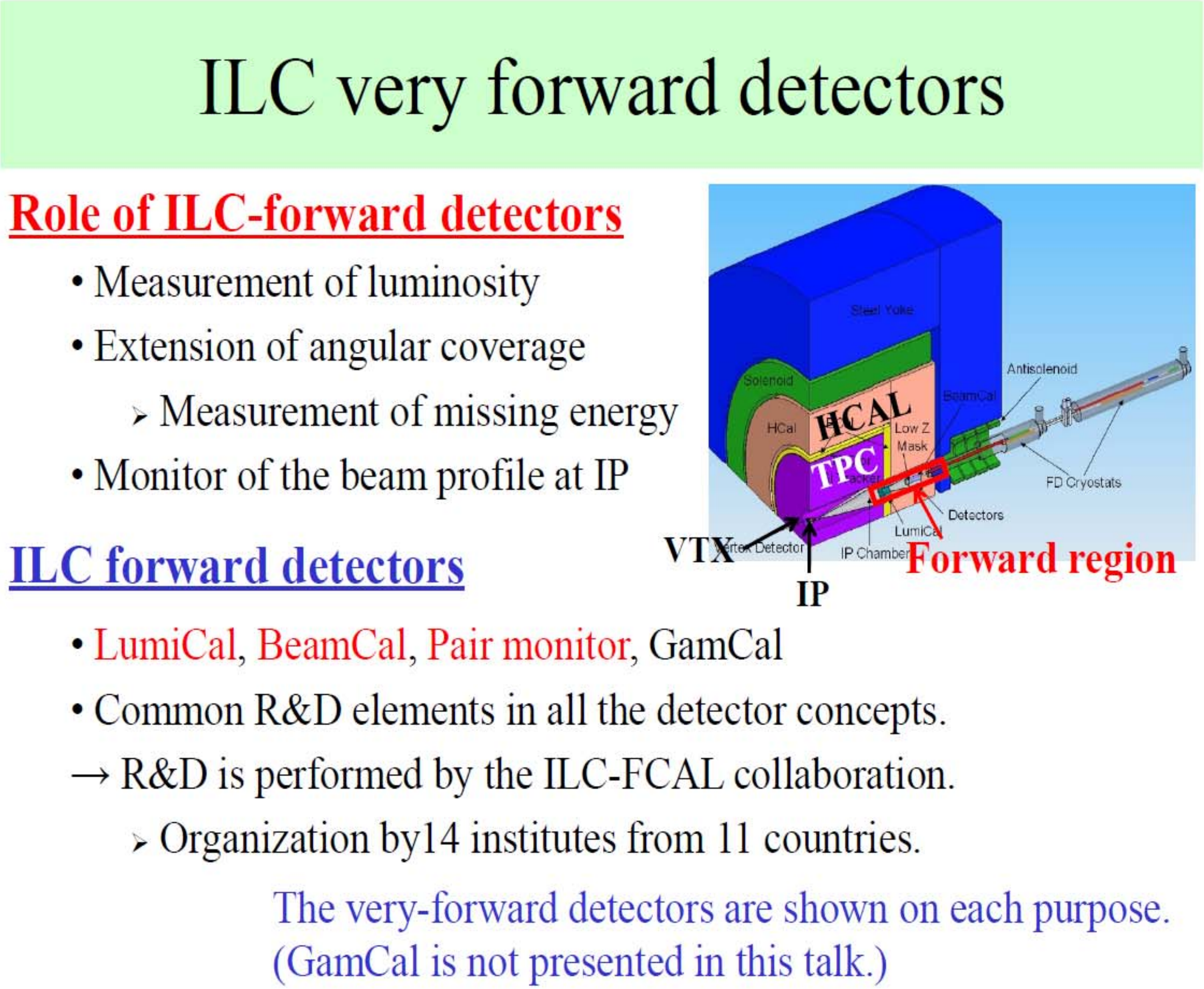
# ILC forward detectors?

Y. Takubo
BNM2008



## ILC very forward detectors

### Role of ILC-forward detectors

- Measurement of luminosity
- Extension of angular coverage
  - Measurement of missing energy
- Monitor of the beam profile at IP

### ILC forward detectors

- LumiCal, BeamCal, Pair monitor, GamCal
- Common R&D elements in all the detector concepts.

→ R&D is performed by the ILC-FCAL collaboration.

- Organization by14 institutes from 11 countries.

The very-forward detectors are shown on each purpose.
(GamCal is not presented in this talk.)