Detector summary

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2nd Open collaboration meeting, March 19, 2009

Contents

General comments

Selected subsystem topics

Details of individual subdetectors → see the talks earlier today

General comments

A lot of progress in all subsystems – congratulations!

Our designs are getting more realistic – we even have some CAD drawings

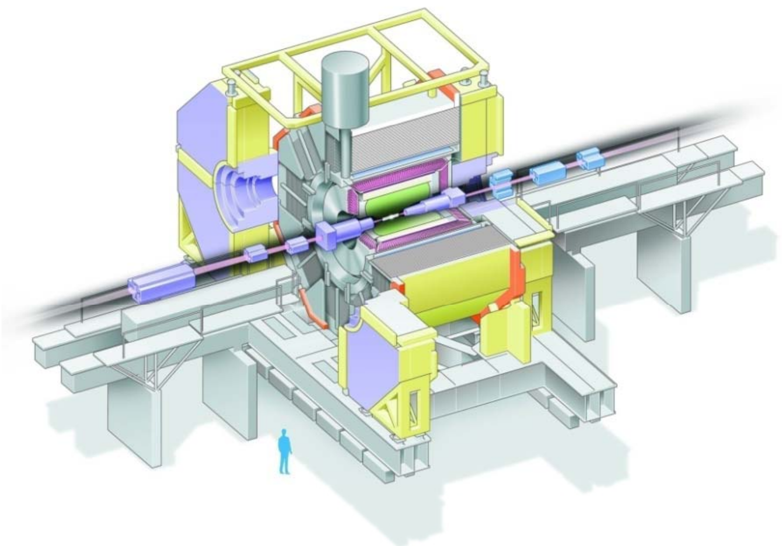
Realistic design and studies → we find problems – and try to solve them

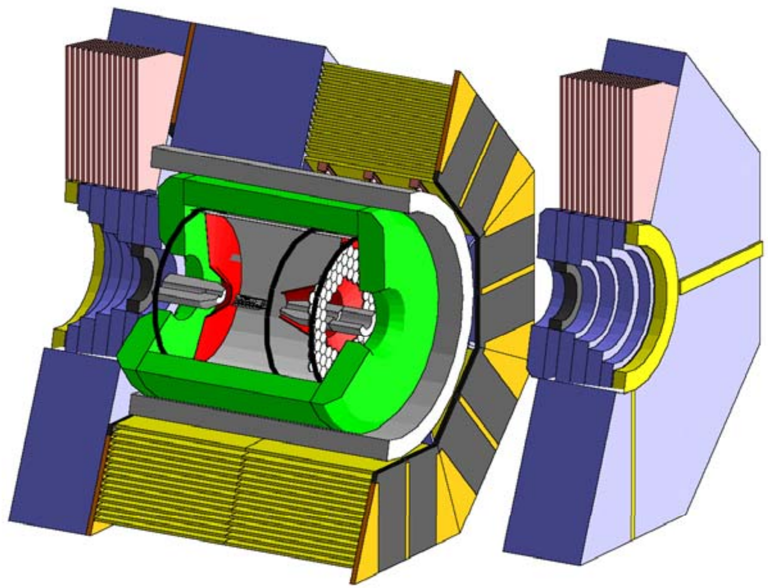
Machine design is changing – have to check the background estimates

We have to keep in mind our general timetable – which might even get accelerated...

Motivation for the detector upgrade

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





Accelerator changes - impact

Stronger final quad closer to the IP:

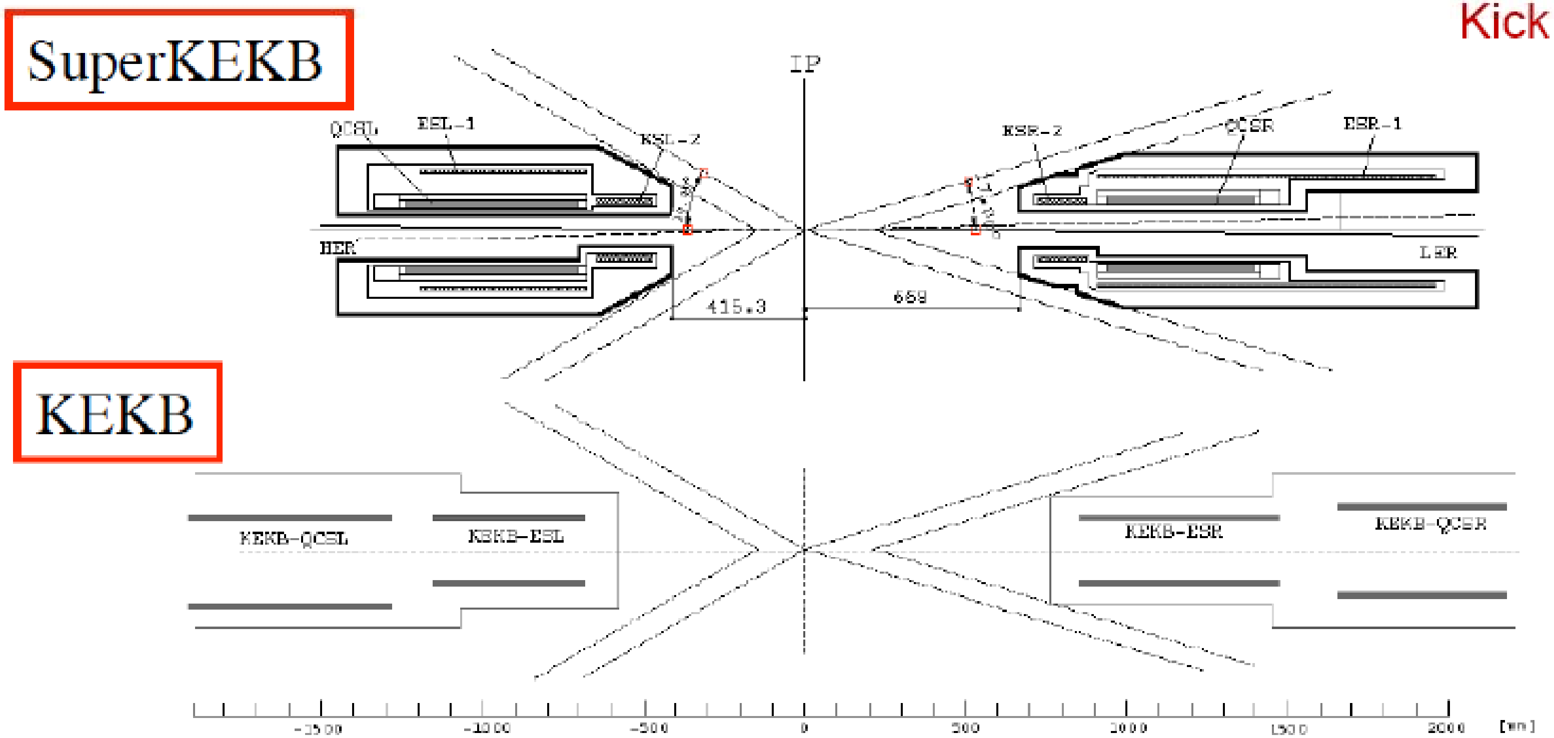
- Less space, installation issues
- Background from radiative Bhabhas?

Low emittance option:

- Possible further move of final quads closer to the detectors
- Magnetic field distortions in the tracking volume: impact on tracking
- Lower currents – less background? Touschek?
- A different beam asymmetry?

From KEKB to Super-KEKB 2
Place QCS magnets closer to IP

Y.Funakoshi
Kick off meeting



The boundary between KEKB and Belle is the same.
ESL and ESR will be divided into two parts (to reduce E.M. force).
QCSL (QCSR) will be overlaid with (the one part of) ESL(ESR).

IP – QCS distance : ~60cm → ~40cm (L side) ~75cm → ~65cm (R side)

There is little space in L-side… We must think about the detector assembly

Interaction region

1. <u>Machine status</u>

- New SuperKEKB optics designed: less SR power
- We have a new 1.9K QCS design
- Designing of the nano-beam option has just started
- Little space on the L-side (high-current) or both (nano-beam)

<u>2. Detector/machine assembly</u>

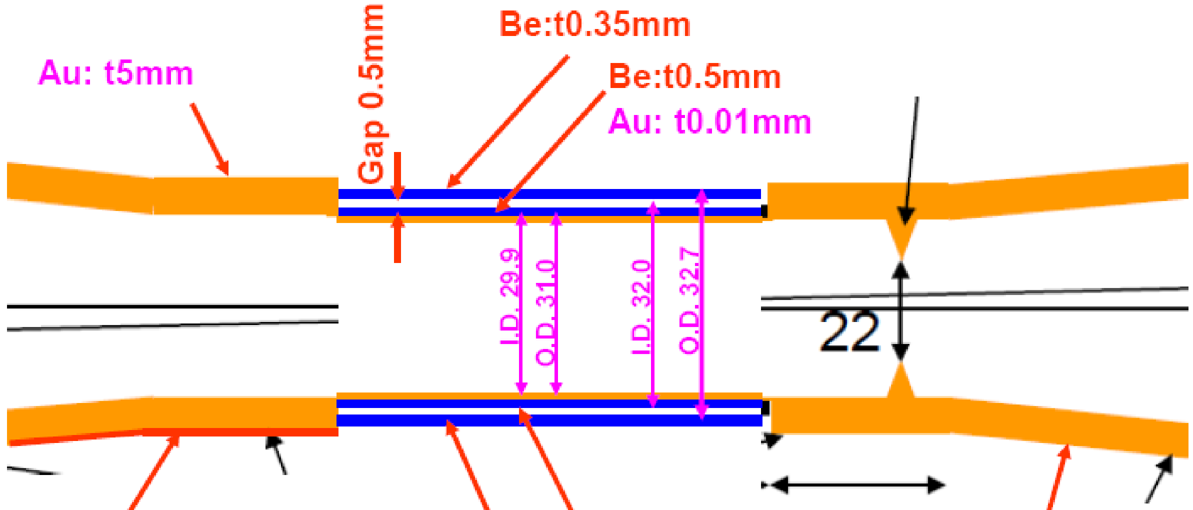
- Installation of QCS cryostat, beam pipe, and the vertex detector will have to be tightly coupled

<u>3. SR simulations / heating calculations</u>

- Design of the cooling system: to be started
- Studies of other sources of backround: to be done

Calculation-B (Double Be-tube)

H.Yamaoka (KEK)



1. **Outer surface of the Au-Beam Pipe.**
→ 3000W/m²·℃、25℃

2. **In the Be-gap.**
→ 3000W/m²·℃、25℃

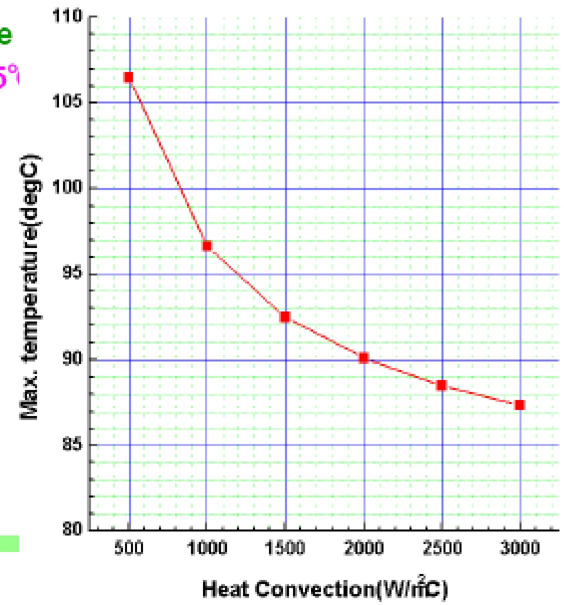
3. **Outer surface of Be-gap.**
→ 5W/m²·℃、25℃

4. **Inside of the B.P.**
→ 0W/m²·℃

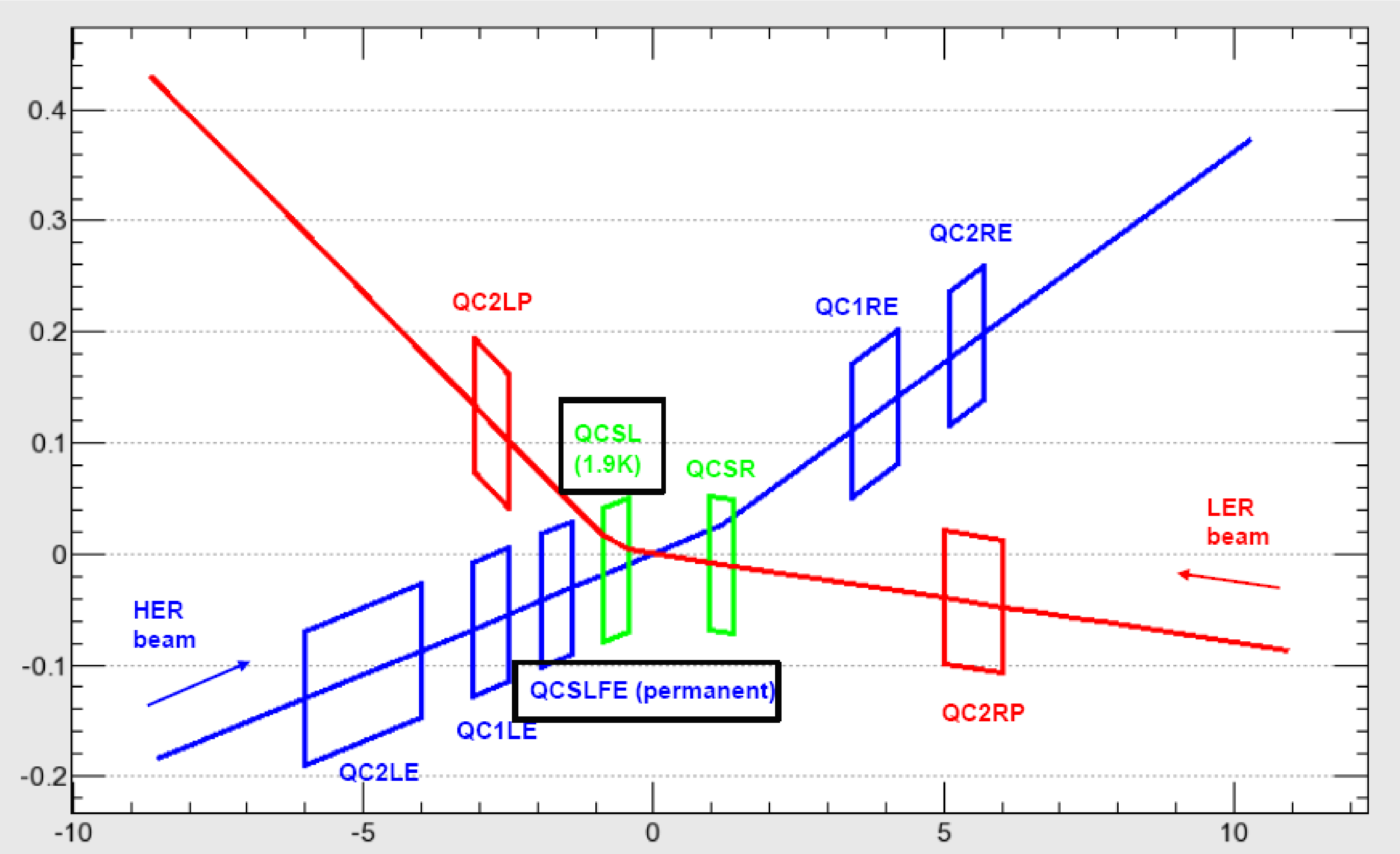
1. **Outer surface of the**
→ 3000W/m²·℃、25℃

Assumption:
Cooling position → (Be-Gap + Outer surface of the Au-pipe)

Max. temp. vs. Cooling ability.



Interaction region – beam elements

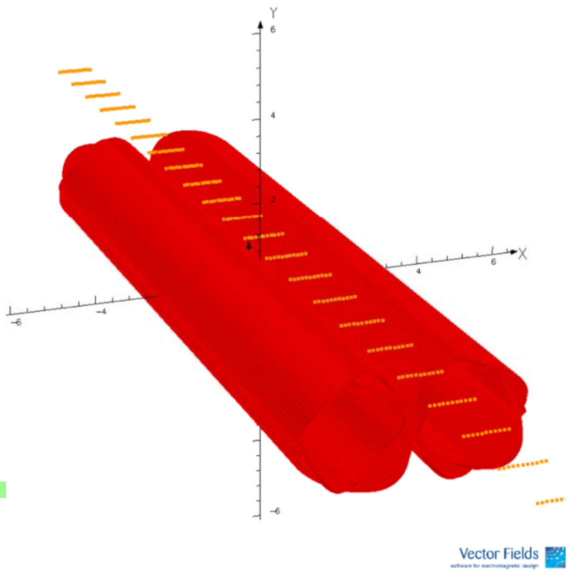


Interaction region

To be studied: impact of closer quads (low emittance option) on detector acceptance

Background sources other than SR have to be studied: particular worry radiative Bhabhas, off-energy particles get deflected in off-axis quads (1 quad for both beams)

Could we have a 2 in 1 quad? Difficult to produce. Frascati is working on a possible design



Pixel detector: becoming hardware

First run PXD6: 2009

-: first DEPFET run on SOI wafers!!

→ 50 μm thin DEPFET arrays

-: 6 SOI and 2 std. Hi-Res Wafer

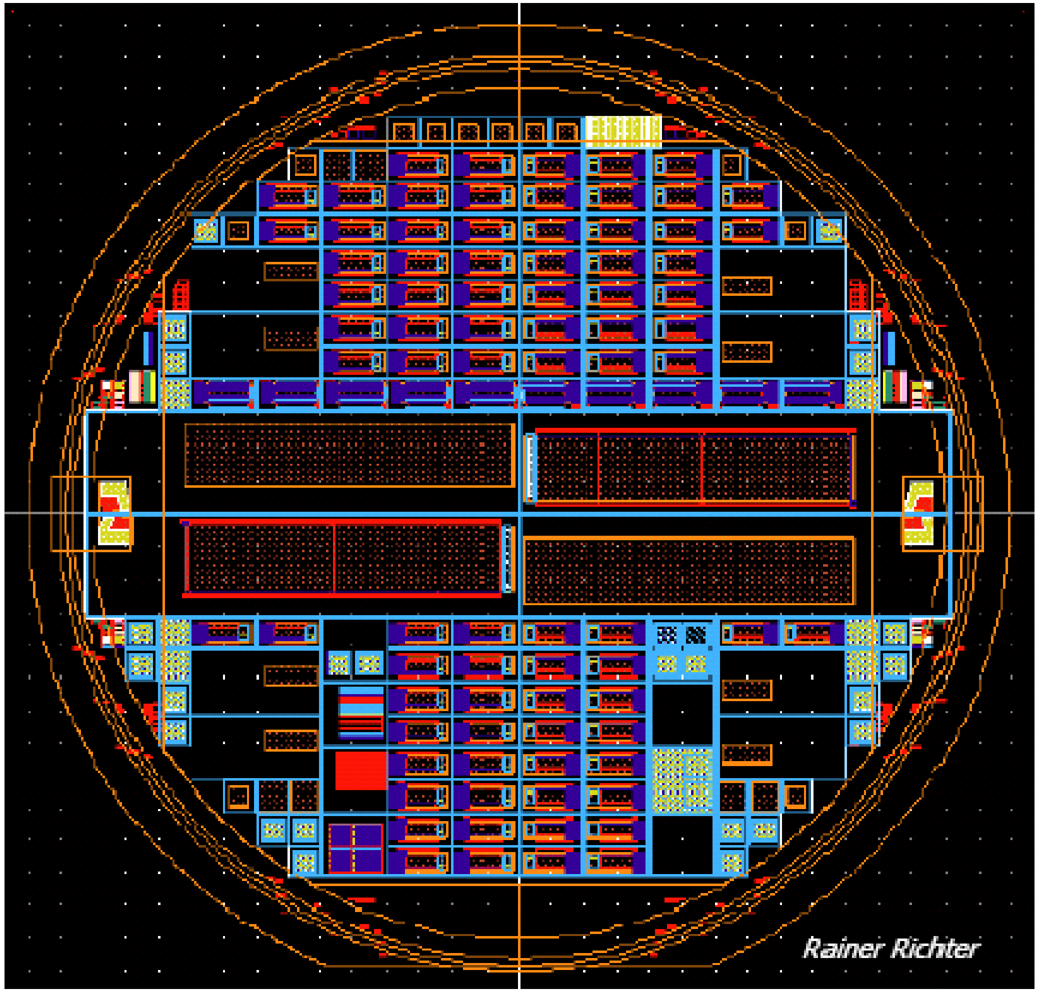
-: top wafer (front side) technology like PXD5

-: new technology: thinning and BS process

-: Aim: - find optimal design

- optimize technology and yield
- provide devices for all-silicon module

End Spring 2010



wafer floor plan for PXD6

SuperBelle Production PXD7: Start 2011

-: With improved technology

-: 20 Wafer? (depends on yield of PXD6)

End Spring 2012

DEPFET Readout and Control ASICs

Switcher - row control chip with high voltage line drivers

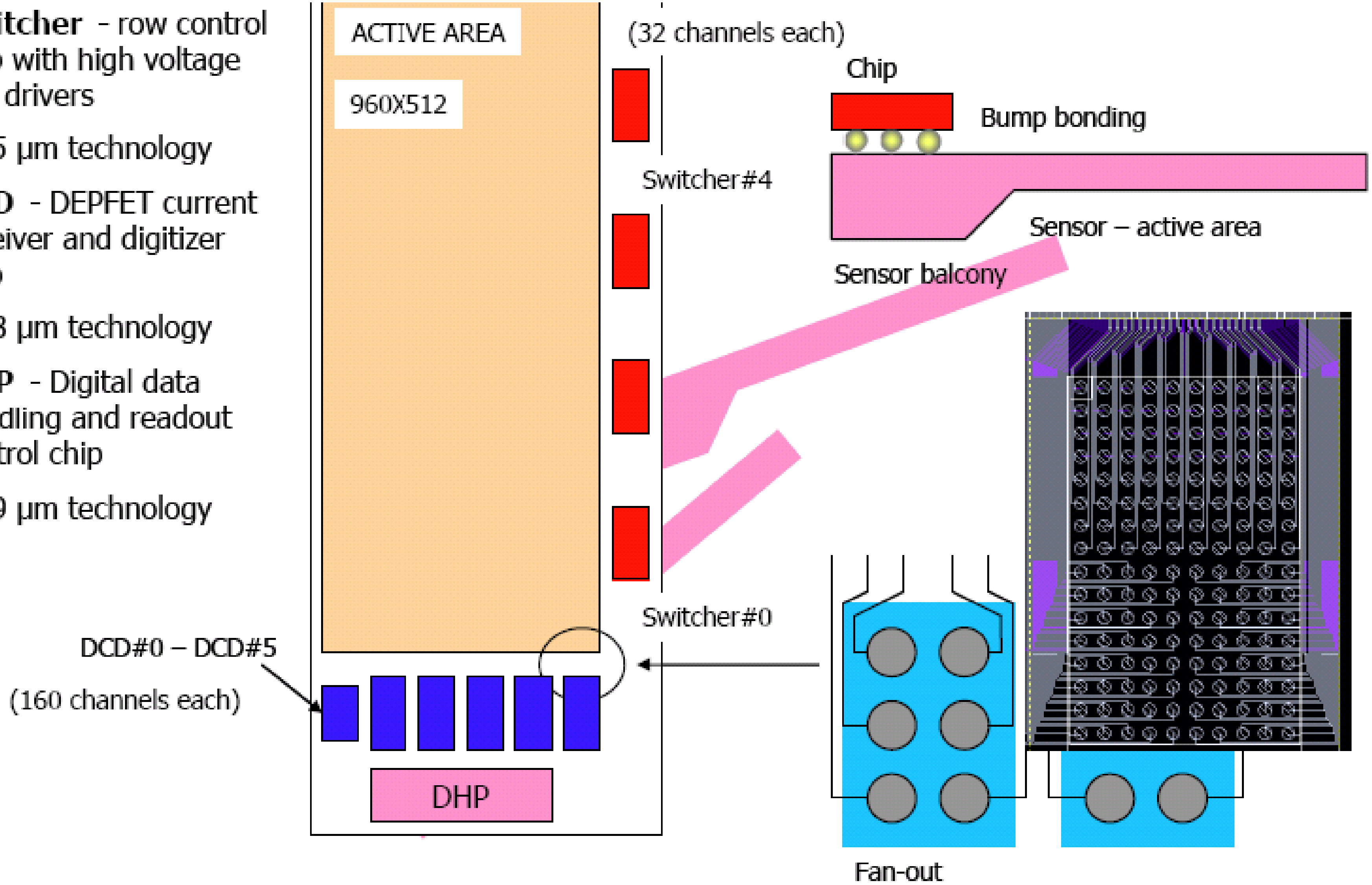
0.35 µm technology

DCD - DEPFET current receiver and digitizer chip

0.18 µm technology

DHP - Digital data handling and readout control chip

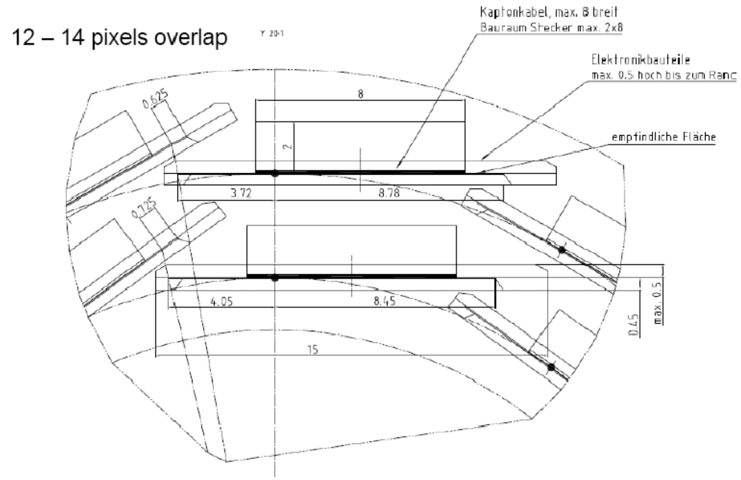
0.09 µm technology



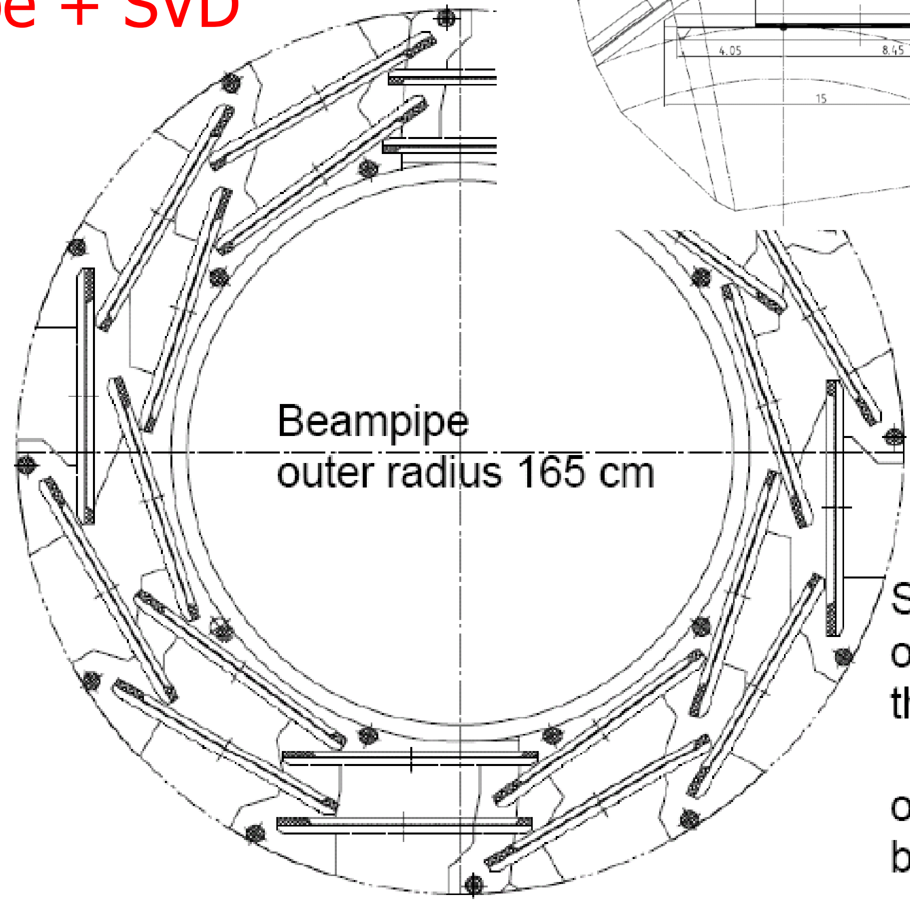
Well under way: prototypes tested, rad hard

Pixel detector: mechanics

Geometrical arrangement
Clearances
Space for connectors…
Overlap for alignment
Related to beam pipe + SVD



Ladders should
be mounted
on the
beampipe
to get as close
as possible
to the vertex



Layer 1 : 1.8 cm
Layer 2: 2,2 cm

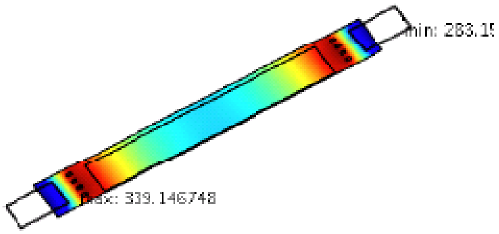
Support:
outside of
the accept.,

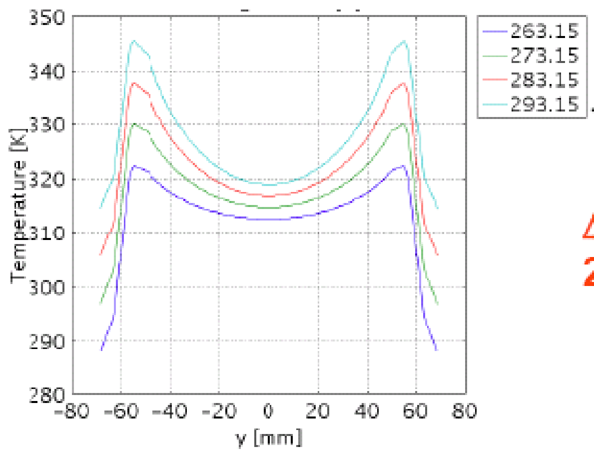
on the ends,
but how ?

Thermal Studies

Simulations started (Karlsruhe, Valencia); remove ~ 150 W

- ➢Active (liquid) cooling at the module ends
- ➢Forced air cooling along the module





-10 °C
0 °C temperature of
10 °C the heat-sink
20 °C

ΔT goes down!
25 °C -> 10 °C

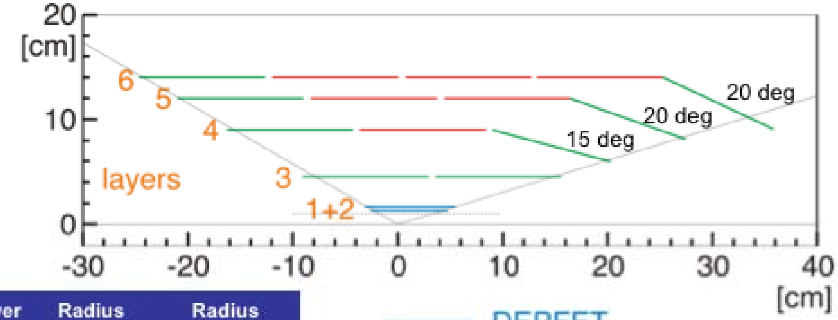
Service routing:

Power, data and control, cooling (air, liquid)
Space restricted and shared with SVD
Common effort needed -> working group?

SVD: proposals for DSSD layout

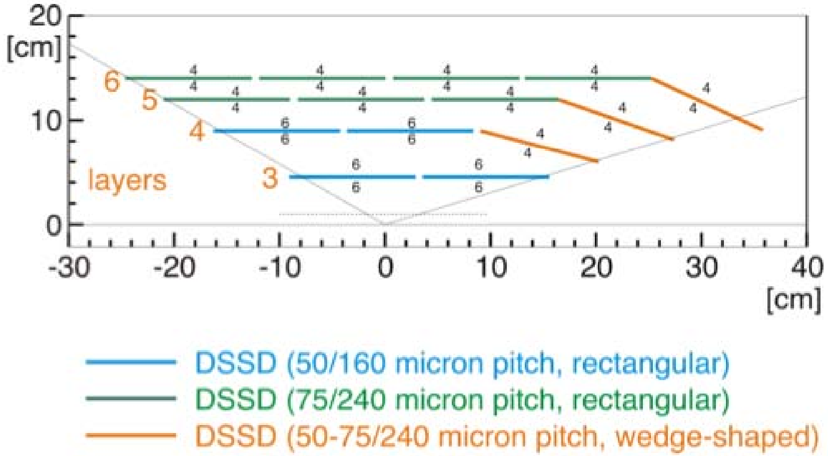
- With sensors from 6” wafers, SVD can be build by using just two type of sensors.
  - horizontal: rectangular
  - slanted: trapezoidal
- Save on number of APV25 chips → wider readout pitch in the outer two layers.

Proposed 6” SVD Layer Arrangement

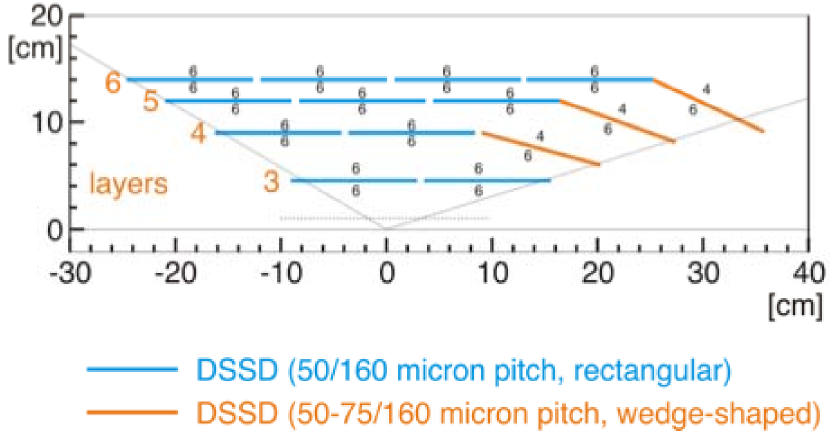


Layer	Radius (barrel)	Radius (slanted)
6	14 cm	10.7 – 14 cm
5	12 cm	8.3 – 12 cm
4	9 cm	6.1 – 9 cm
3	4.5 cm	-

SVD Layout with 3 sensor types



SVD Layout with 2 sensor types only

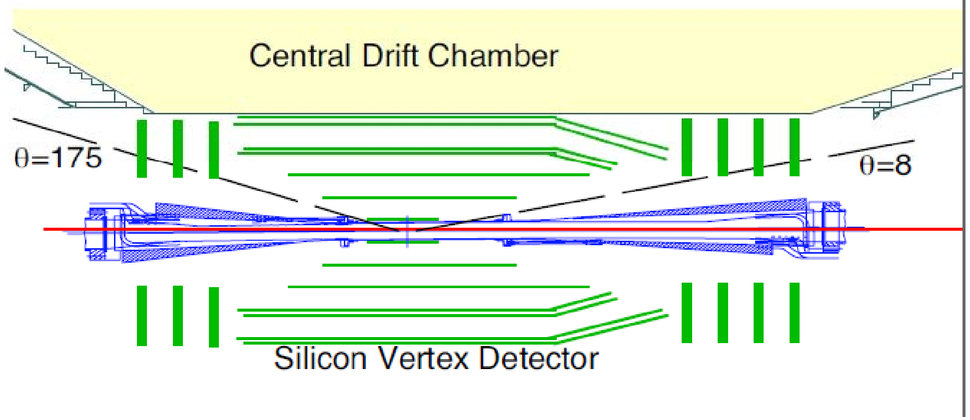


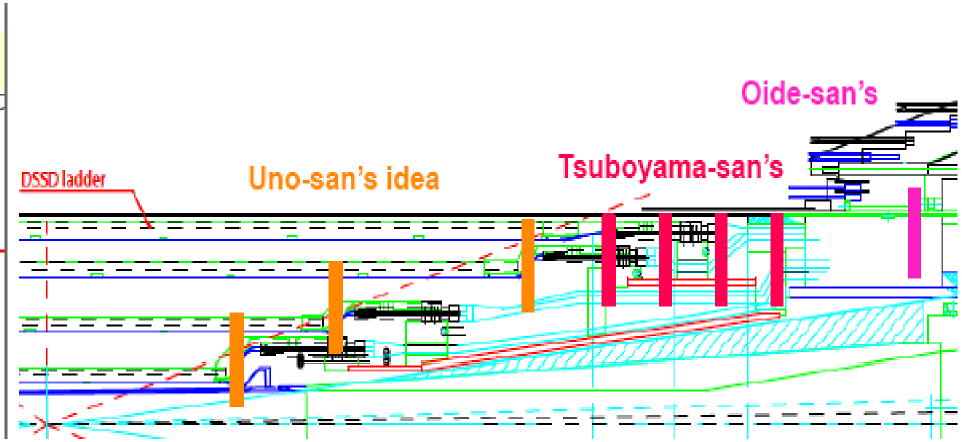
SVD: production

- DSSD production
  - HPK: some intentions to restart DSSD production but no decision.
  - SINTEF and Micron, technology and delivery both OK, Micron cheaper (~1/2)
  - 3 years for sensor production + spares
- APV25 purchase (thinned, good yield)
  - Bought 4000 chips, just enough for SVD production.
- Super BEAST → If SVD/PXD is not installed at T=0, we need a radiation measurement system.

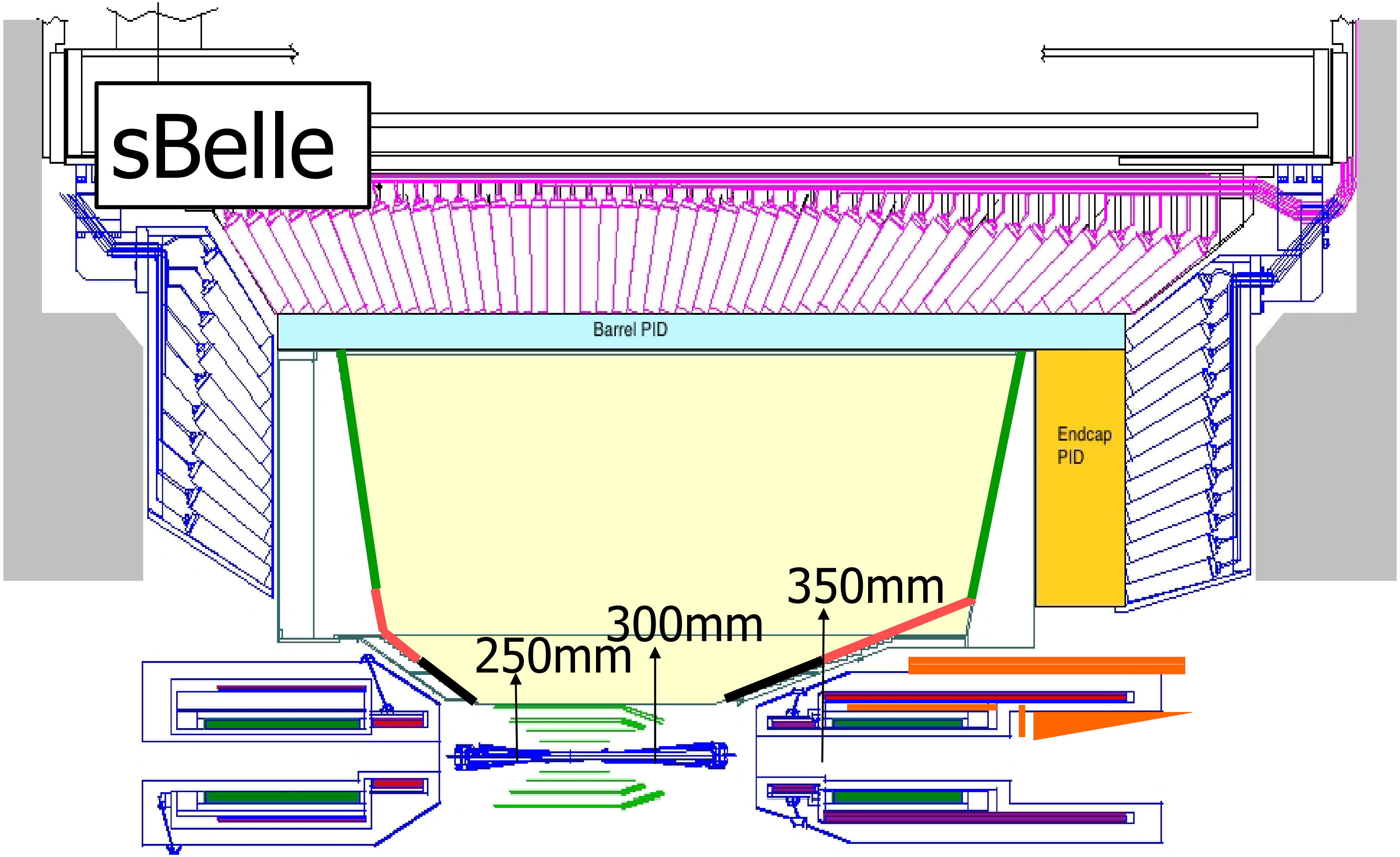
Forward detector: some ideas

- Purpose
  1. Extend the Belle acceptance to improve physics potential.
  2. Measure the e+ or e- which is generated in the e+e- interaction and scattered by beam. Then the beam size measurement becomes possible.
- For 2, random triggered data should be used.
- If enough space is not available, we could consider to extend the angular acceptance of SVD





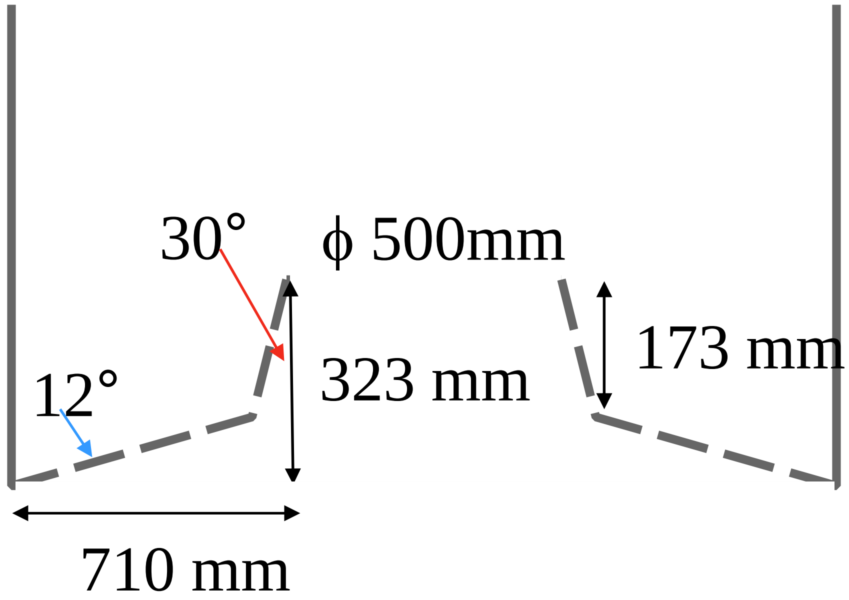
CDC: Endplate Design



CDC: Wire stringing

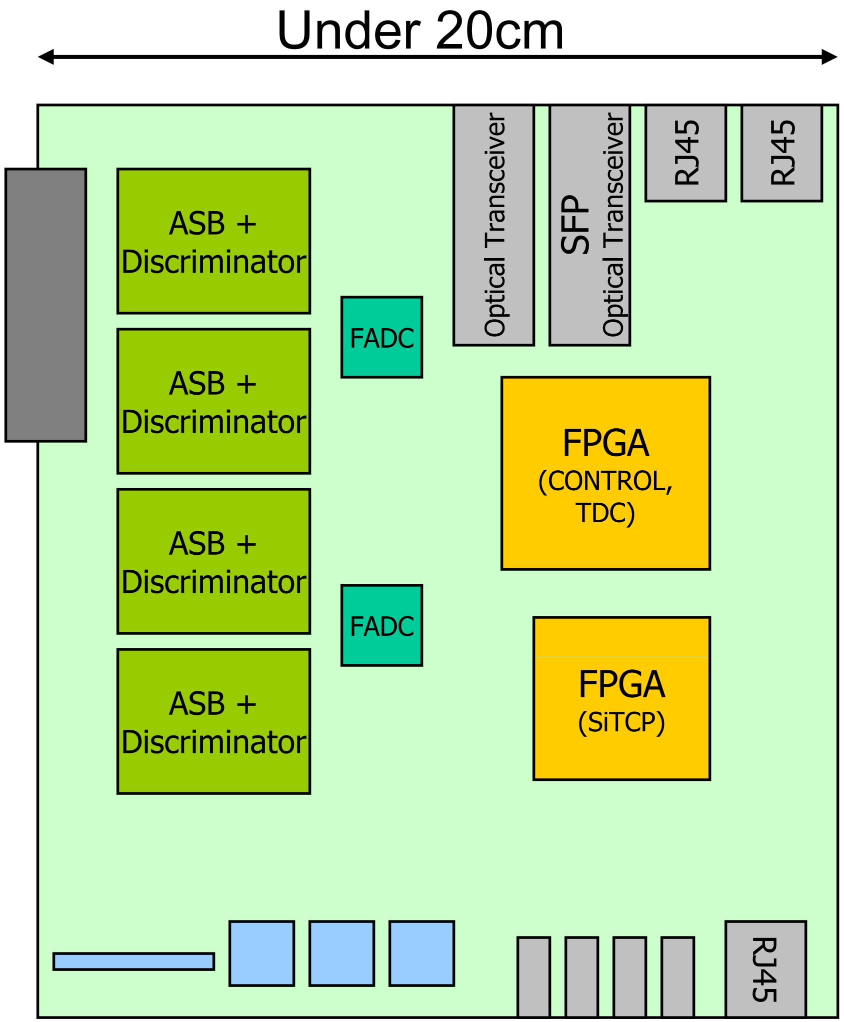
Strategy

- Vertically string wire
- Outer cylinder is assembled before wire stringing.



- We can access wires from inside of chamber.
- Nanae Taniguchi confirmed it with a hand-made mockup.

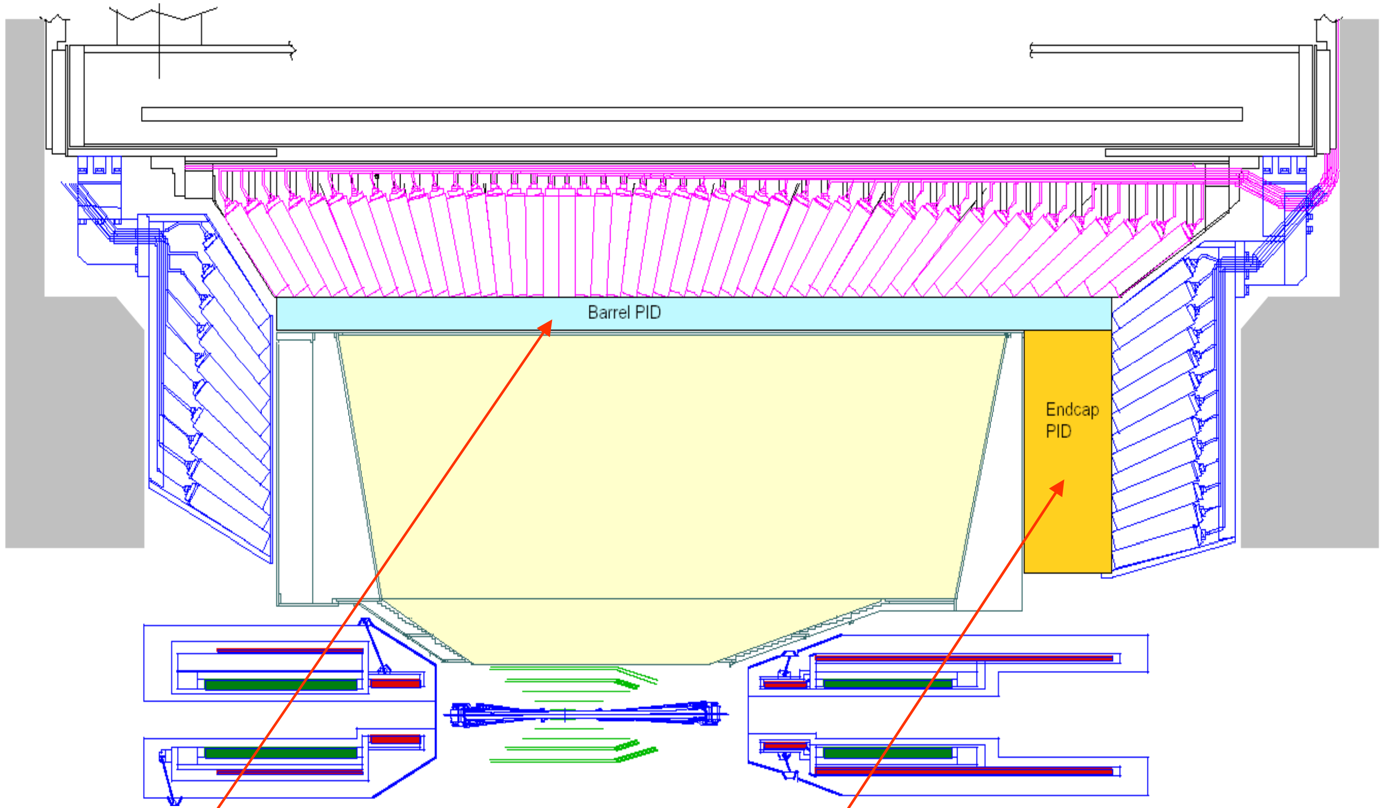
CDC FE Prototype card



- 16ch/board
- BJT-ASB/Discriminator
- FADC: over 20MHz / 10bit
- FPGA : Vertex-5 LXT
  - TDC: 1 nsec counting
  - FADC reading
  - Control
- FPGA: Spartan3A
  - SiTCP for CDC study

Alternative: waveform sampling (G. Varner) – under discussion

PID upgrade

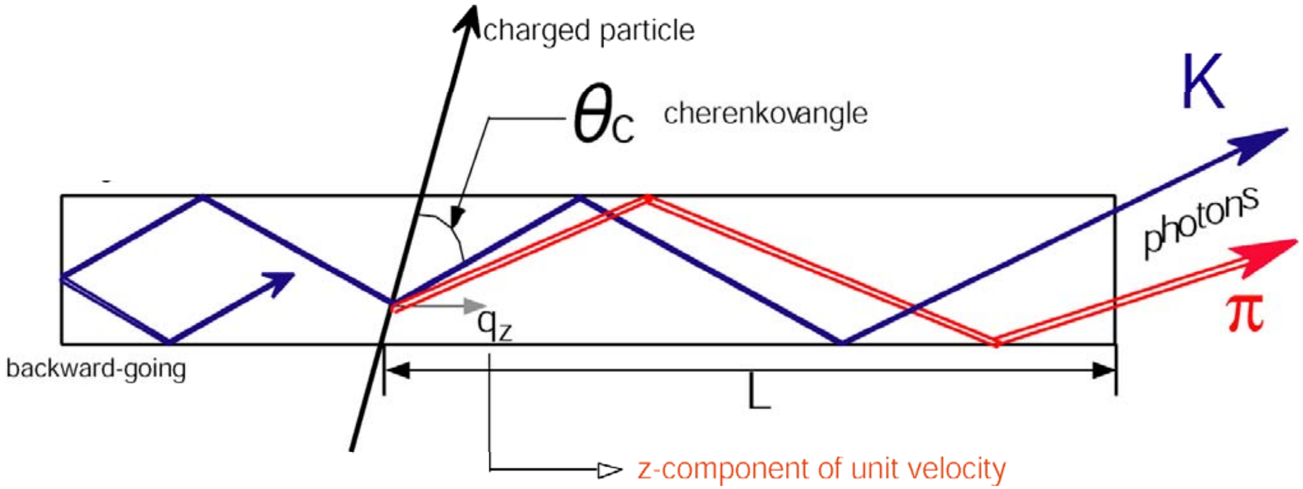


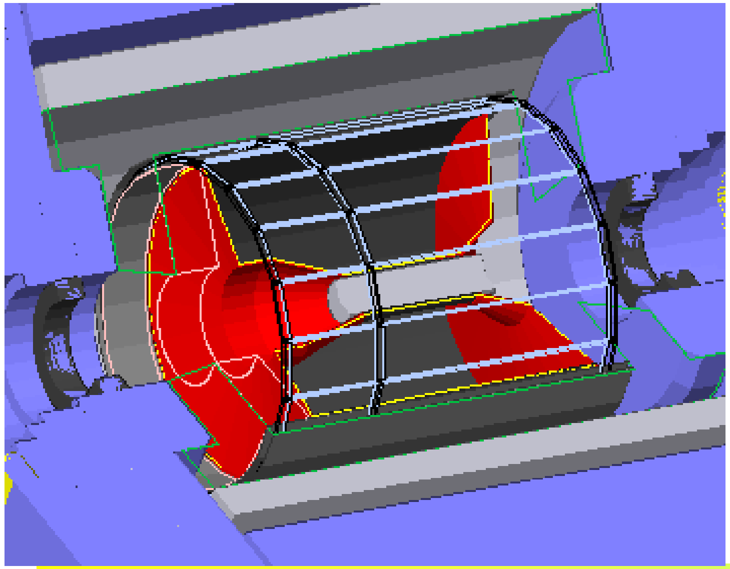
Two new particle ID devices, both RICHes:

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

Endcap: proximity focusing RICH

Barrel PID





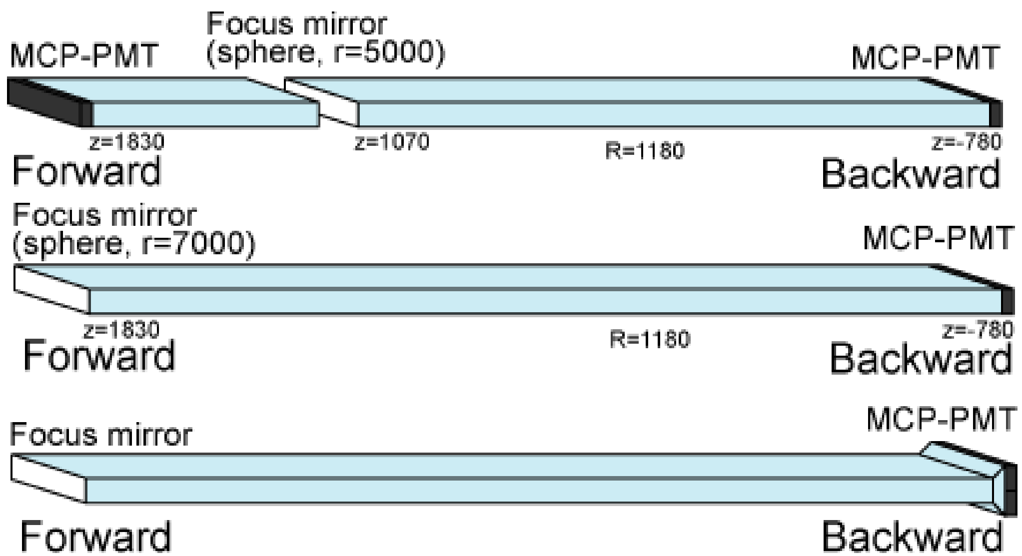
Imaging Cherenkov counter with quartz bars as radiators.

Image read-out:

- Time-Of-Propagation (TOP)
- Focusing DIRC
- Imaging TOP

Design study

- Simulation studies
  - Handmade + Geant3 (K.Inami, Nagoya)
  - Geant4 + ROOT (K.Nishimura-san, Hawaii)
  - Mathematica, Handmade (Cincinnati)
  - Analytical calculation of likelihood f. (M.Starič, Ljubljana)
    - → Reconstruction program for gsim study



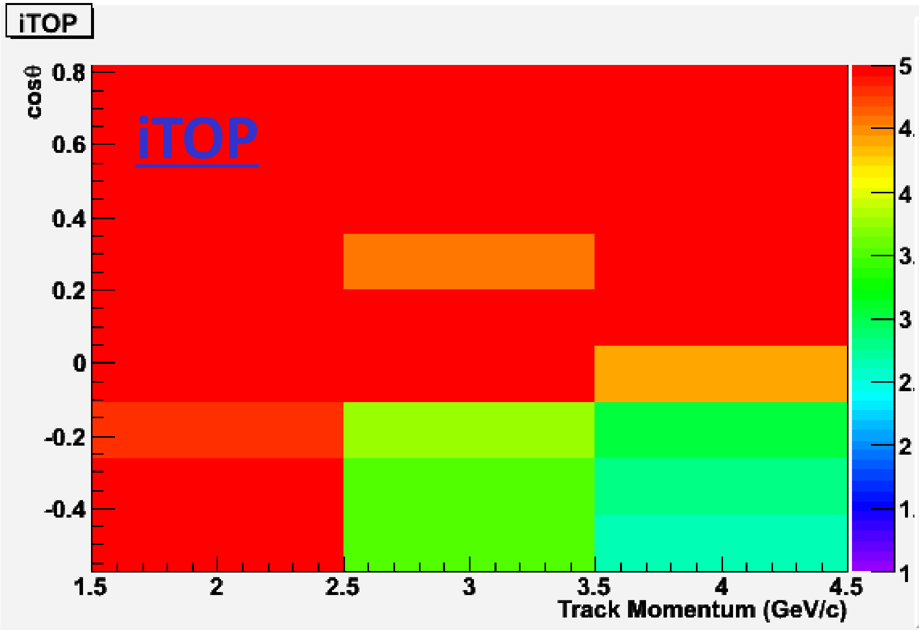
2 readout

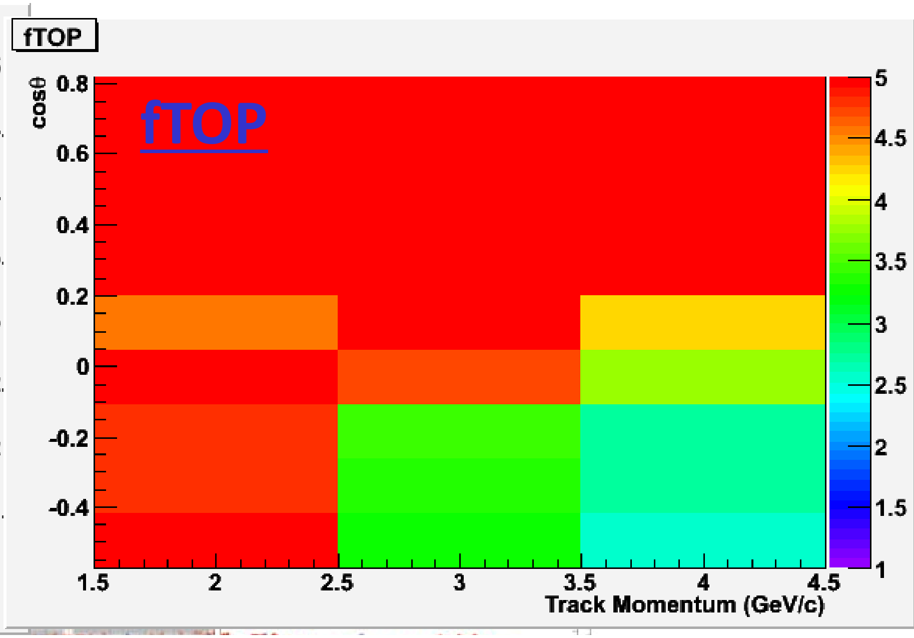
1 readout

Standoff

Barrel PID: Comparison of various options

Separation (in sigmas) vs angle and momentum Hawaii





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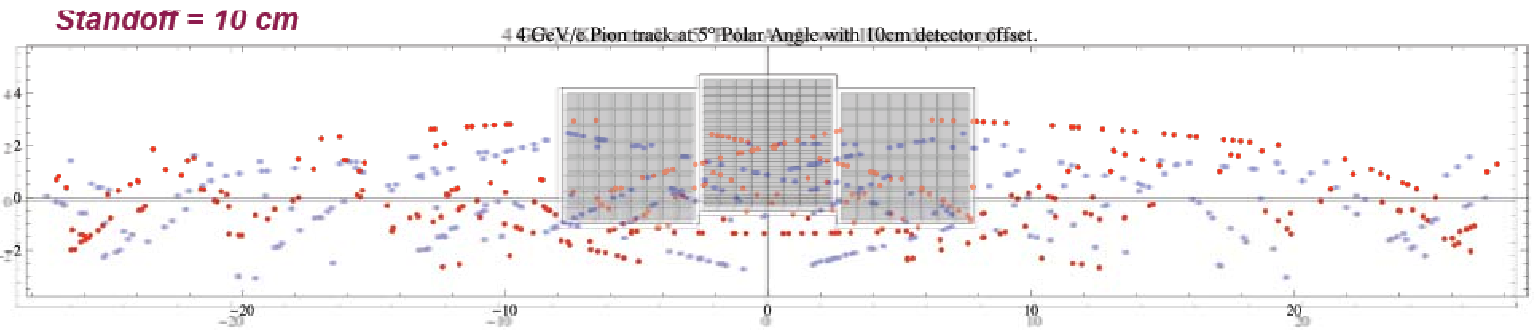
Ray tracing – Cincinnati



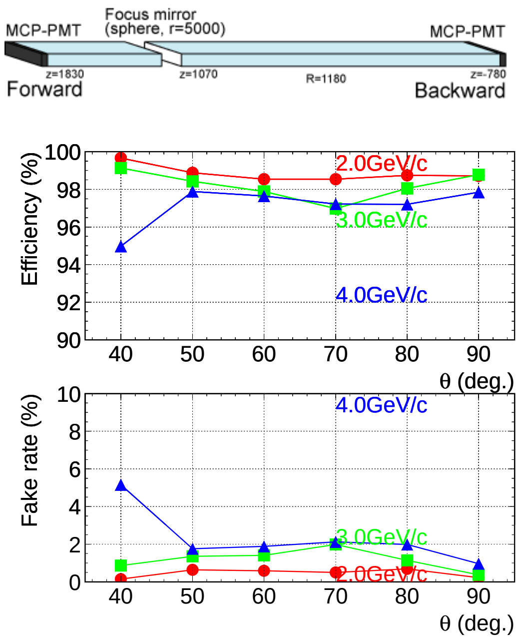
jana

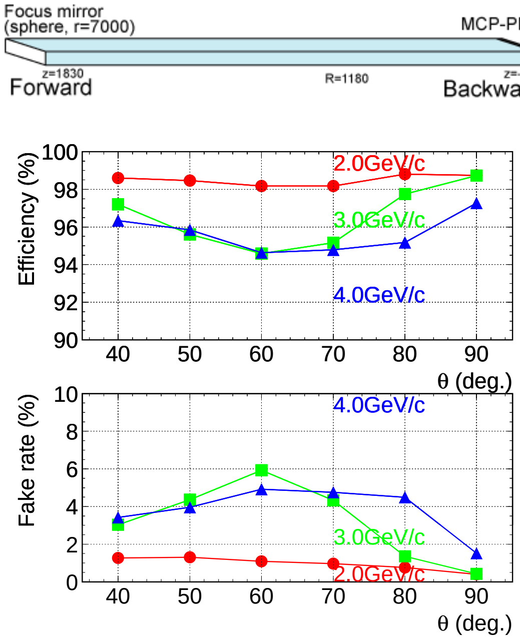
Barrel PID: Comparison of various options

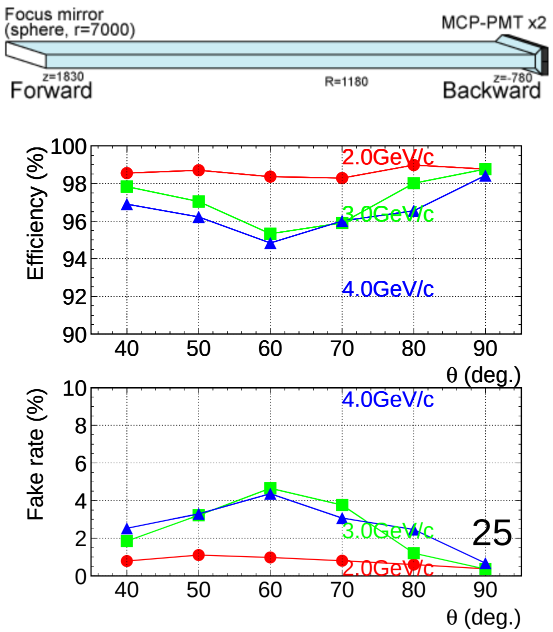
- GaAsP, CE=35%, λ>400nm

10ps T_0 jitter

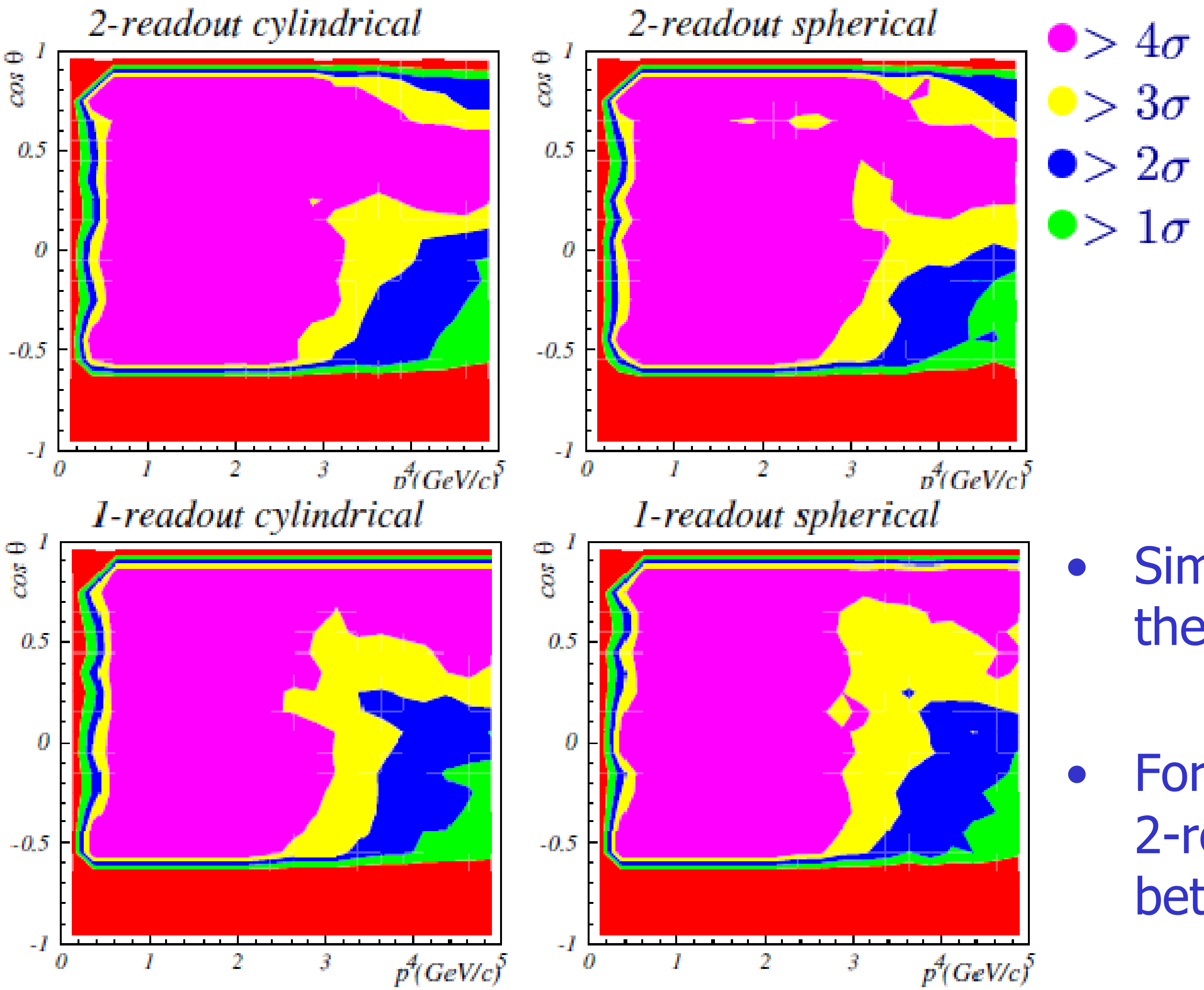
Nagoya







Barrel PID: Comparison of various options



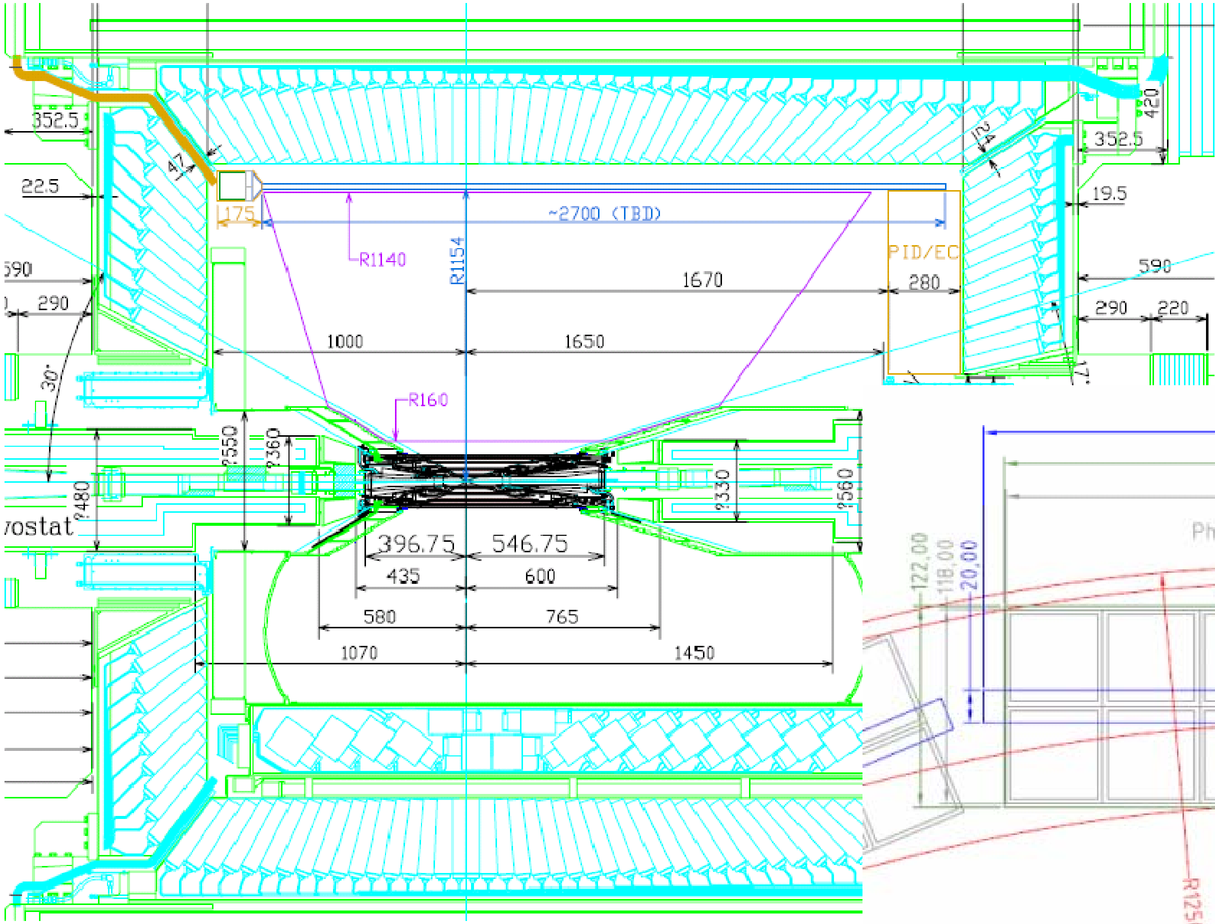
M.Starič

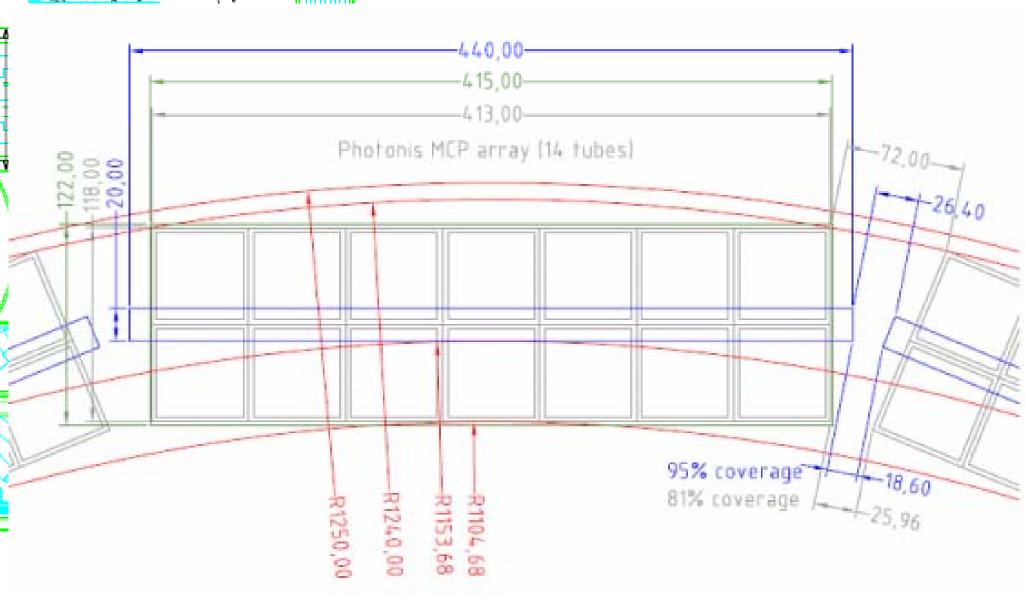
- Similar results as with the Nagoya simulation
- For B→ππ/Kπ case, 2-readout type shows better results.

→ Converging on methods and results

Barrel PID: first CAD drawings

Marc Rosen





First studies of mechanical stress and deformation

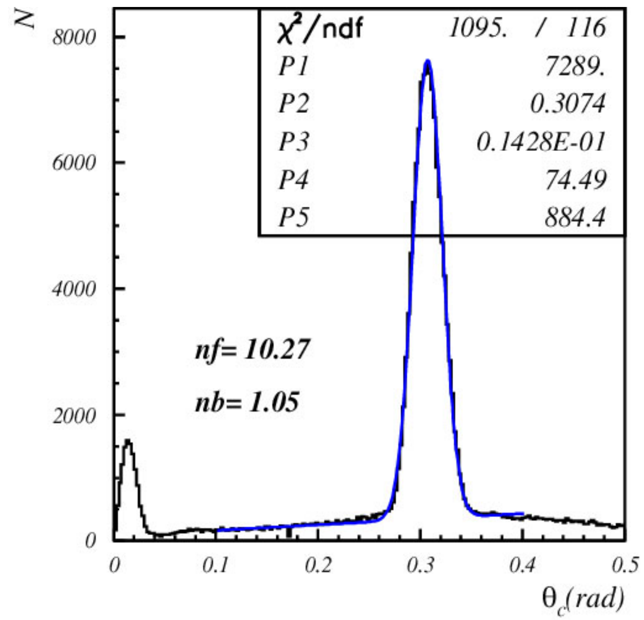
Barrel PID: status

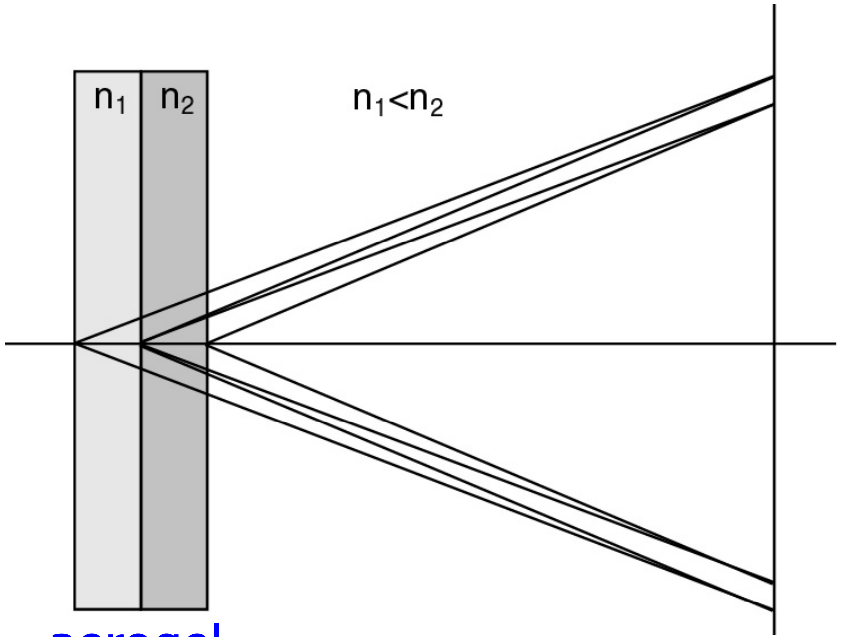
- Barrel PID based on TOP/DIRC
  - Cherenkov ring imaging with position and precise timing (<50ps) using Quartz + MCP-PMT
  - Wide bar (40~50cm^{W} x 2cm^{T}), focus mirror (R=5~7m)
  - Shape of readout plane depends on the choice of photon detector
  - Started structure design
- Prototype study
  - Verified expected TOP performance in beam test
  - Readout electronics with BLAB3 ASIC will be tested soon.
- Photon detector
  - Lifetime test with round shape and square shape MCP-PMTs
  - Check production reliability and lifetime, type of photocathode
- Design study
  - With several simulation programs, converging
  - Decide 1 vs 2 layers, type of counter → impact on CDC design

Endcap PID: Aerogel RICH

Requirements and constraints:

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



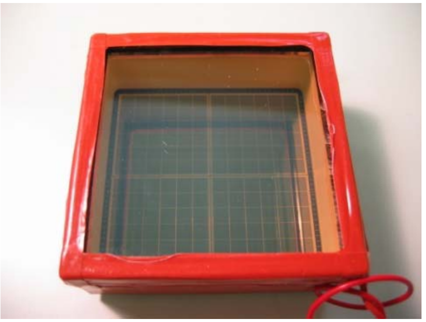


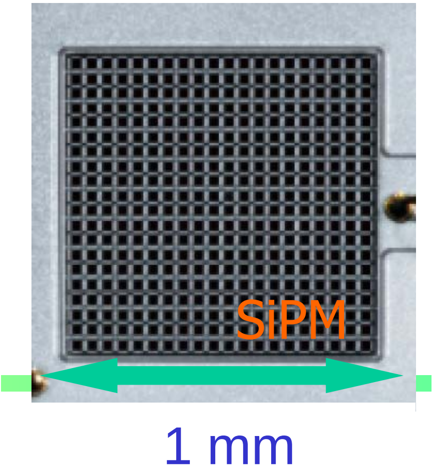
- n = 1.05
- $\theta_c(\pi)$ ~ 308 mrad @ 4 GeV/c
- $\theta_c(\pi) - \theta_c(K)$ ~ 23 mrad
- pion threshold 0.44 GeV/c,
- kaon threshold 1.54 GeV/c

- 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

- HAPD
  - Tested on the bench and in the beam
  - Stability, radiation hardness? Need more production R&D
- MCP-PMT
  - Excellent beam and bench performance
  - Good TTS for TOF information
    - ~35ps TOF resolution (low momentum PID)
  - Need lifetime estimation
- SiPM (GAPD)
  - Large number of photons, good stability, enough gain and reasonable TTS
  - Light guides tested to increase the active area fraction
  - Radiation hardness: most probably a show-stopper





Photon detector: comparison table Dec 08

	HAPD	MCP-PMT	MPPC
N_{ph}	7 (→14)	10 (→15)	30
σ_{ϑ}	14	15	14
B = 1.5T	OK (improved perf.)	OK (improved perf.)	OK
long term stab. (aging)	OK (HV stability?)	OK?	OK
neutron damage	leakage current? → signal / noise	OK(?)	X
production	2.5 y	2 y	?
pieces	< 600	< 1000	< 500000
cost / piece	< 7000 €	< 4000 €	< 20 €
electronics	ASIC	WFS	WFS
channels	~ 75k	~ 60k	~ 120k

Photon detector: comparison table March 09

	HAPD	MCP-PMT	MPPC
N_{ph}	8(+1) (→16)	10 (→15)	30
σ_ϑ	14	15	14
B = 1.5T	OK (improved perf.)	OK (improved perf.)	OK
long term stab. (aging)	OK (HV stability?)	OK?	OK
neutron damage	leakage current? → signal / noise	OK(?)	X
production	2.5 y	2 y	?
pieces	< 600	< 1000	< 500000
cost / piece	< 7000 €	< 4000 €	< 20 €
electronics	ASIC	WFS	WFS
channels	~ 75k	~ 60k	~ 120k

Endcap PID: photon detector, plan

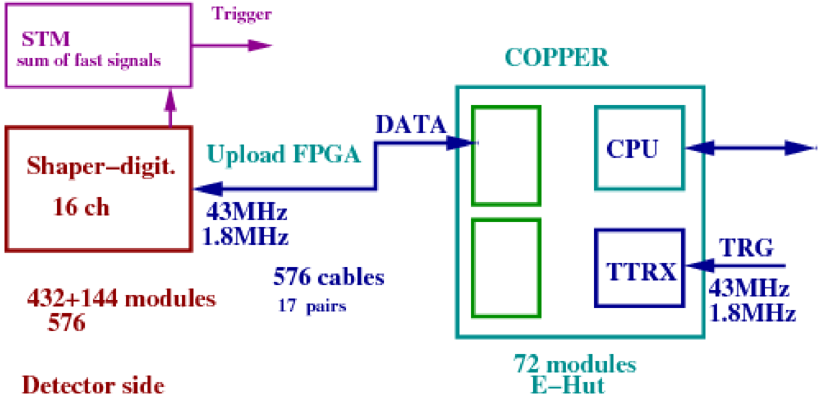
Progress since December:
•HAPD: exposure to neutrons, stability tests started
•MCP PMT: common timing channel read-out studied, wave-form sampling, ageing test set-up prepared

To be done
•HAPD: evaluate neutron irradiation effects, ion feedback effects, production stability, higher quantum efficiency
•MPC PMT: ageing test, production availability
•SiPM: revisit the MC performance at high occupancies, reevalute for low emittance background levels

All: check the input for the comparison table again (including cost)

→Decision postponed to May

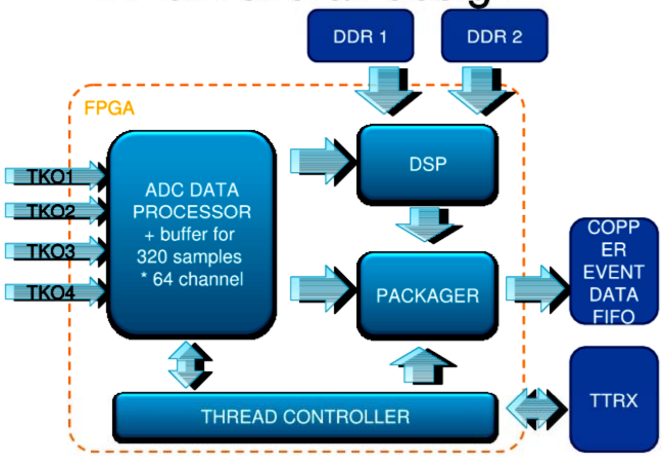
ECL new electronics test



576 cables(x 17 pair)

72 copper modules 2 FINNESSE×4 channels

FPGA overall design



-Shaper-digitizer modules and copper modules have been produced

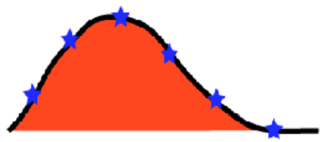
-New electronics allows to fit shape of the signal and determine amplitude and time online

Algorithm details

$$\chi^2(A,p,t_0)=\sum_{i,j}\left(y_i-Af(t_i-t_0)-p\right)S_{ij}^{-1}\left(y_j-Af(t_j-t_0)-p\right)\to \min$$

$$S_{ij}=\overline{(y_i-\bar{y})(y_j-\bar{y})}$$

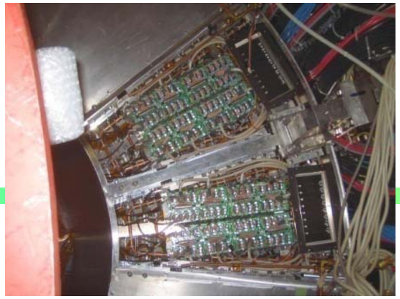
$f(t)$ – counter response



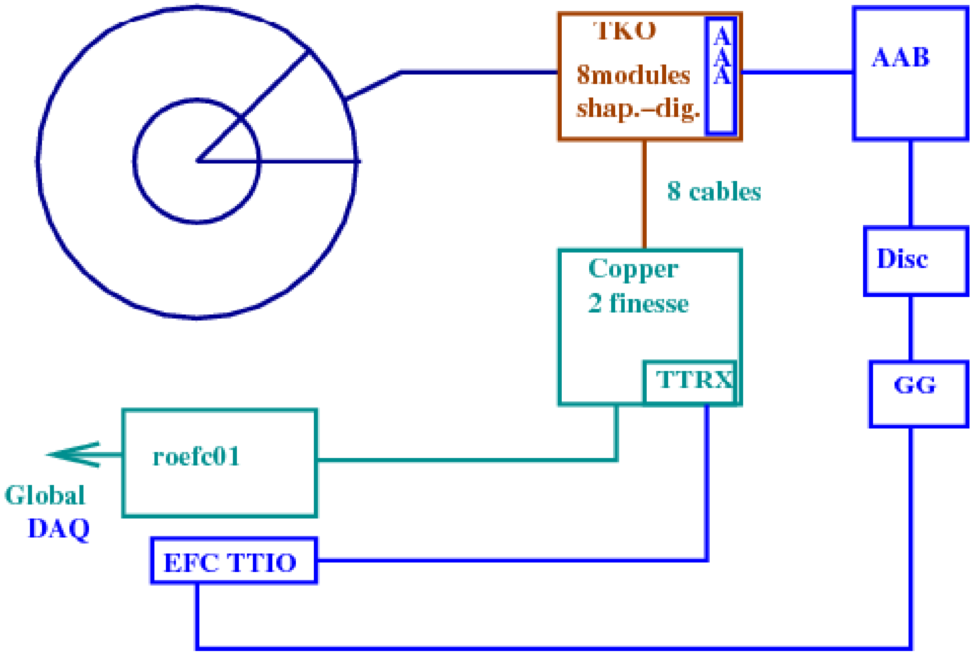
$$Af(t_i-t_1-\Delta t)=Af(t_i-t_1)-A\Delta t f'(t_i-t_1)=Af(t_i-t_1)+Bf'(t_i-t_1)$$

where t_1 – initial time (trigger time)

$$\begin{cases}\sum_{i,j} f_i S_{ij}^{-1}\left(y_j-Af_j-Bf'_j-p\right)=0\\ \sum_{i,j} f'_i S_{ij}^{-1}\left(y_j-Af_j-Bf'_j-p\right)=0\\ \sum_{i,j} S_{ij}^{-1}\left(y_j-Af_j-Bf'_j-p\right)=0\end{cases}\Rightarrow\quad A=\sum_i \alpha_i y_i,\quad B=\sum_i \beta_i y_i \Rightarrow \Delta t=-B/A,\quad p=\sum_i \gamma_i y_i$$



Read-out scheme



In summer 2008 120 channels (1/8 of the BE) were connected to 8 new shaper-digitizer boards with read out by the copper module. Other ECL channels were in the usual status.

Since beginning of this experiment (exp.67) up to Oct.23 ECL was running in this configuration.

About 965 pb-1 were collected

8 Shaper digitizer were connected to ECL B3 sector (120 channels)
Copper module installed in the crate near Fastbus rack in EH
The Copper is readout by EFC PC roefc01
Trigger: Normal cosmic trigger for global run.(or of all trigger cells)

Noise measurement

Without beam

Incoherent noise:

5.7 counts (330keV) (outer layers)

7.1 counts (410keV) (inner layers)

10% higher than expected

Coherent noise:

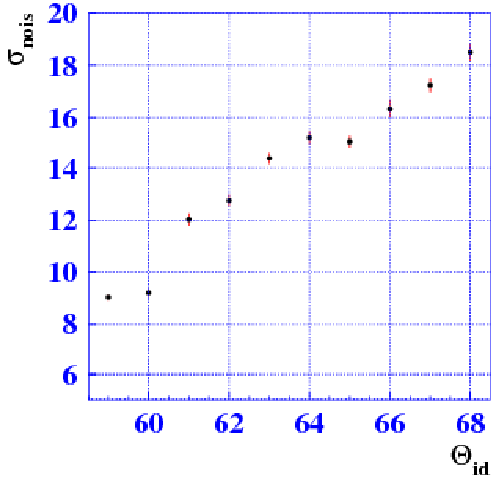
1.2 counts (70 keV) for 1 module

0.6 counts (30keV) for 120 modules

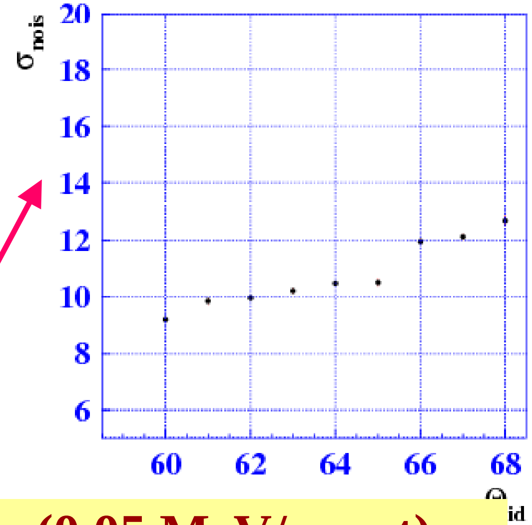
On test bench we got 1.0 channel

With beam

old electronics



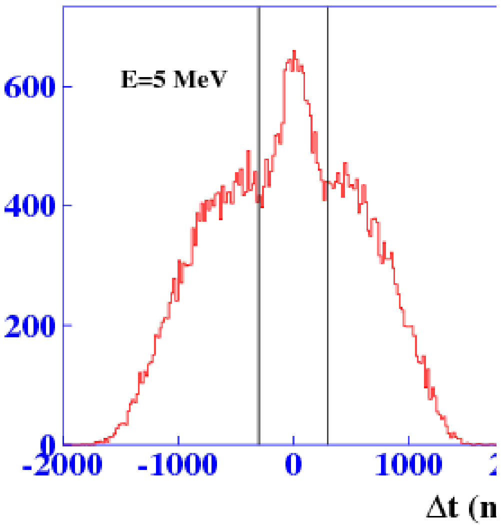
new electronics

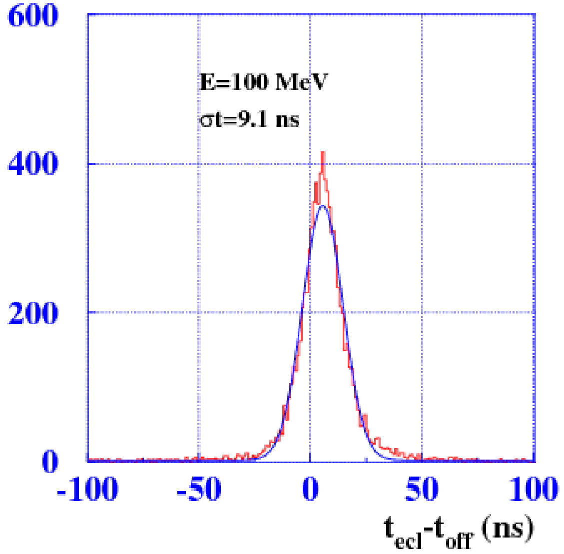


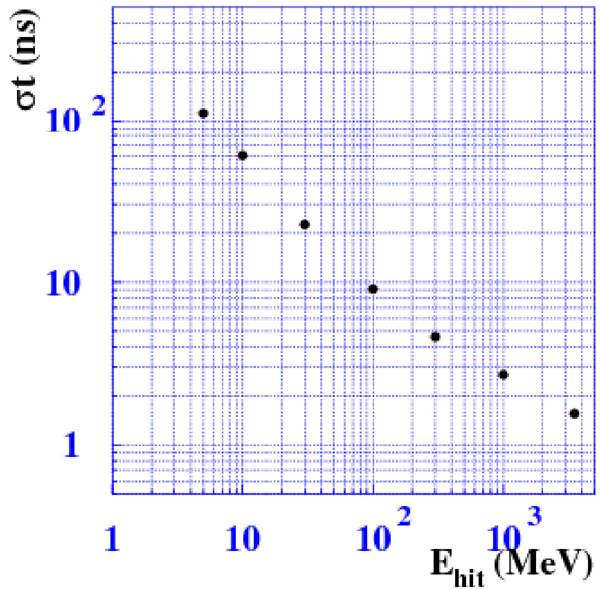
ADC counts (0.05 MeV/count)

- New electronics allows to suppress pile-up noise

Timing and background suppression

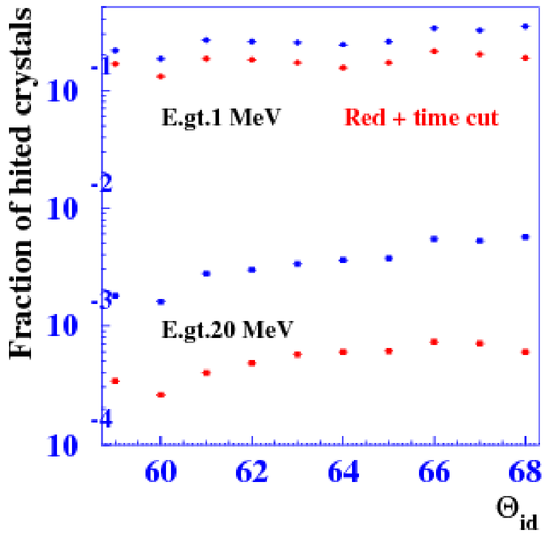






Time resolutions about 100ns for 5 MeV and 3 ns for 1 GeV counters

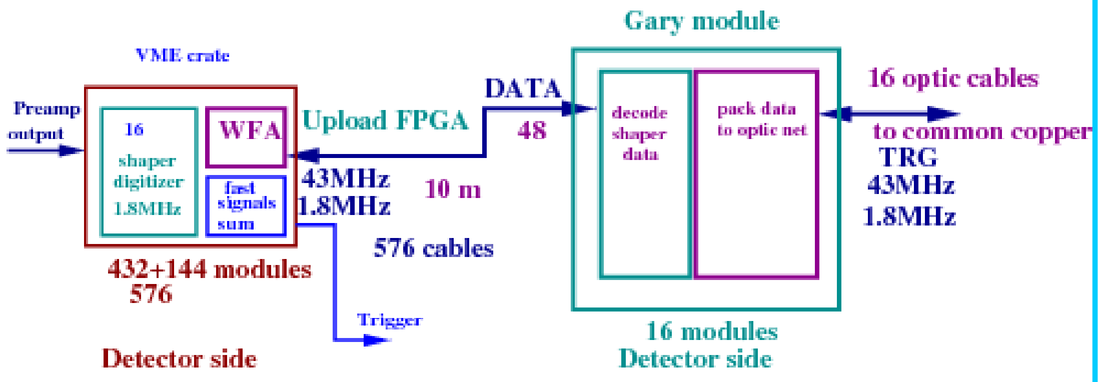
Background is distributed uniformly.
Applying cut for time we got about 7 times fake clusters suppression for E>20 MeV keeping > 97% efficiency.(In agreement with simulation)



↓ ~1/2

↓ ~1/7

Another new version of electronics



16 cables(optical)

16 Gary modules×(48) channels

Trigger, uploading, protocol..? under design

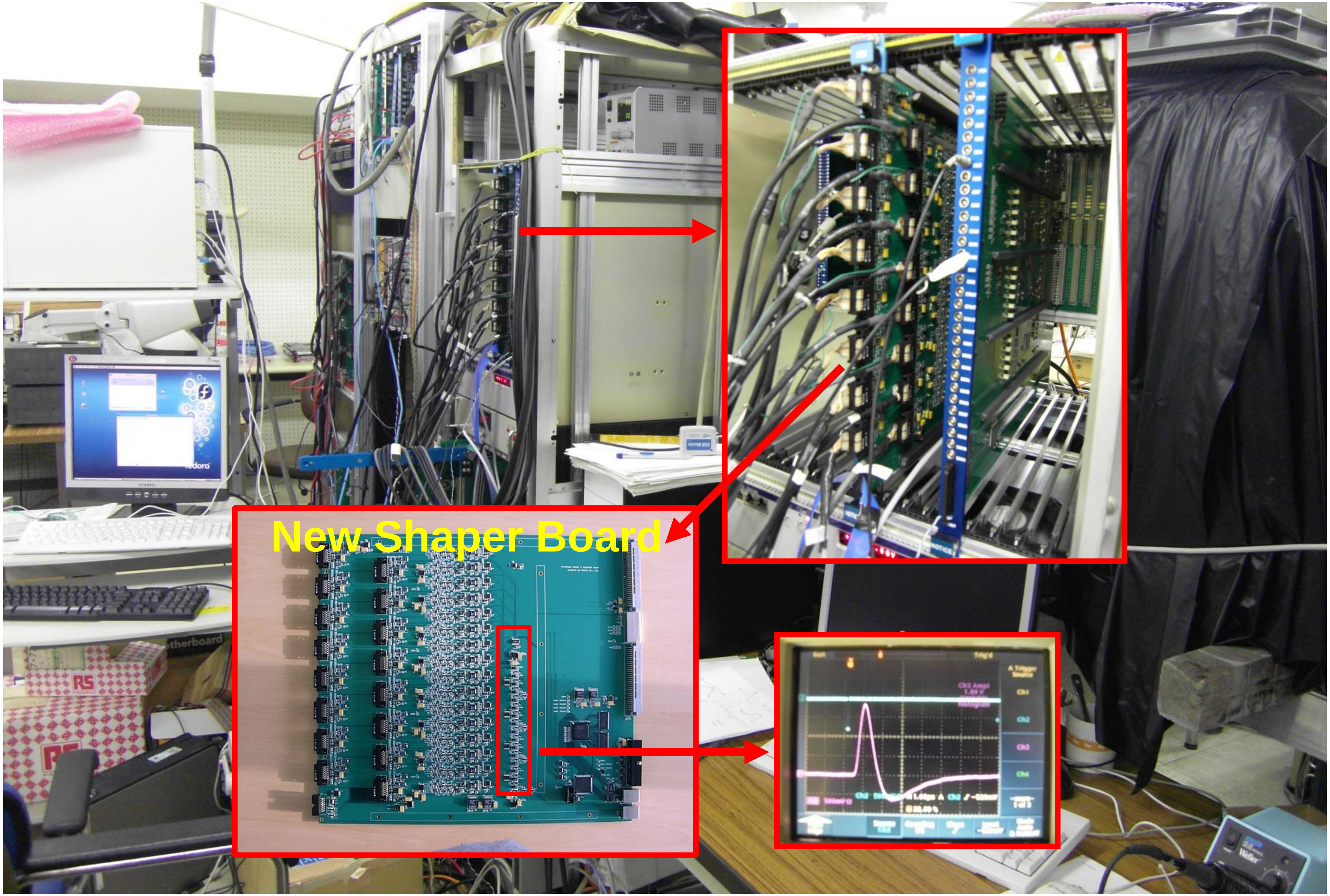
Shaper-digitizer+
WFA FPGA+
Trigger module on
single 9U VME board

Test module was designed, produced and obtained. Now test and adjustment is in progress.

Used also for the new ECL trigger

New version of shaper-DSP:
capacitors: Tantalum → ceramic

Test bench for VME shaper board



A new idea for endcaps

Logic (and probably advantages)

1. Radiation damage only to front ~10 cm of crystals → need to be checked
2. High energy signals → enough signal in CsI(Tl) crystals ->do not lose resolution
3. Fast/Slow → another handle for shower correction by knowing shower shape
4. Fast trigger signal using fast signal → blind to beam background
5. Much cheaper

Endcap ECL upgrade : 11 M USD (8.2M for crystals)
Crystal costs ¼ of full crystal → 2 M → total <5 M should be OK

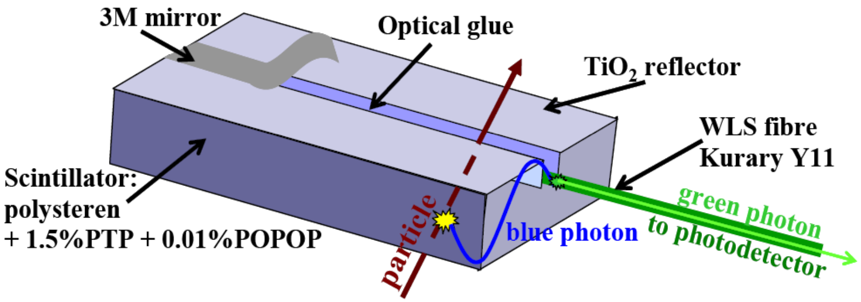
Scintillator KLM end cap detector

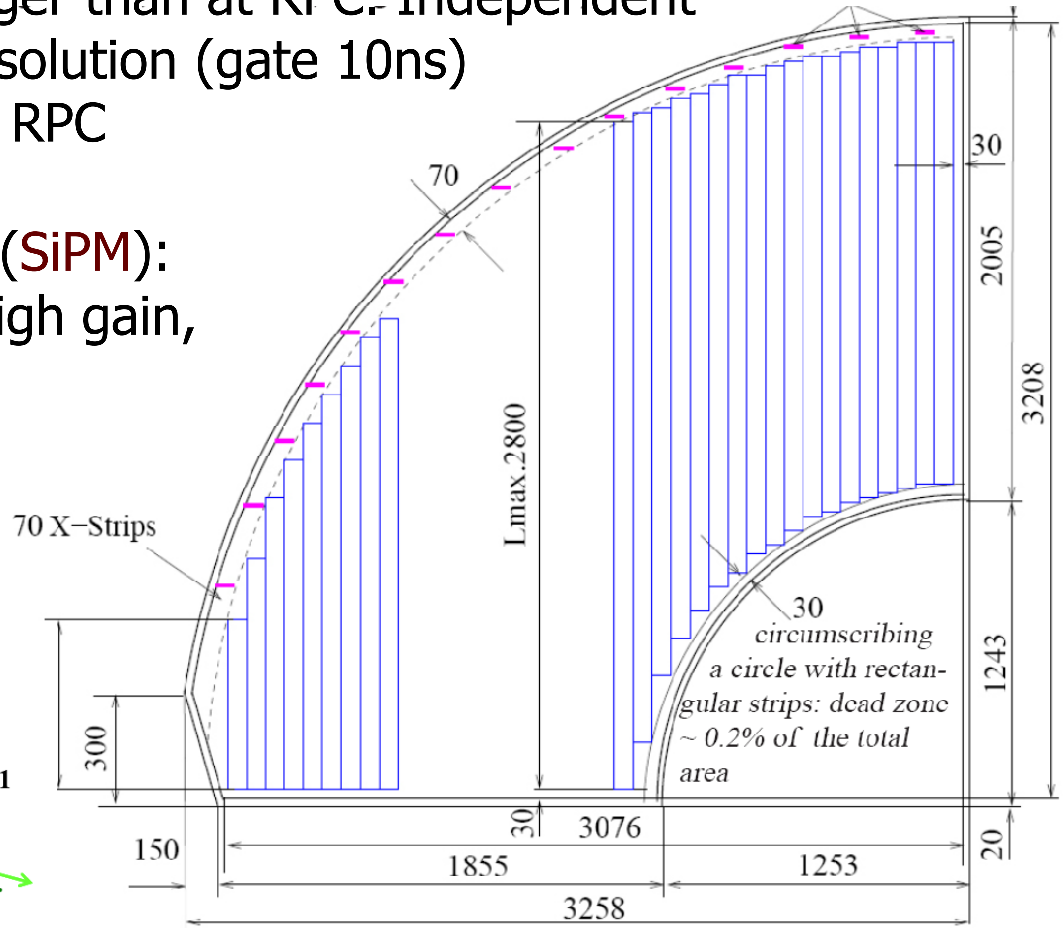
Scintillator detector with WLS fiber readout is a well established technique for particle detection: stable; fast; radiation hard; cheap

Possible drawback: more sensititive to neutrons due to hydrogen. Tests in the KEKB tunnel demonstrated that neutron bg rate at scintilator is 5-7 times larger than at RPC. Independent x-y read-out + good time resolution (gate 10ns)
→ suppress bg better than RPC

Photosensor (one per strip) =
Si photo diode in Geiger mode (SiPM):
fast, efficienct to green light, high gain, compact, operable in B-fields, relatively cheap

Key issues: reliability, radiation hardness





Summary and to do list

- Comparison of designs with two sensor types MRSAPD (CPTA) & MPPC (Hamamatsu)
  - Both are ok, however application of either requires to solve some technical problems.
  - Elaborate details of using for both: mounting, HV supply, control and calibration, maintenance, cost.
  - Compare and find optimal solution.
- Comparison of Kharkov and Fermilab scintillator strips
  - Both are ok.
  - Need to compare scintillator quality first end elaborate the manufacuring (fiber gluing) procedure.
  - Compare resulting quality and cost to find optimal solution.
- Full Geant MC study (standalone MC for KLM endcap is done already) to confirm/study physics performance.
- Electronics:
  - Gary's electronics seems to be optimal for the purpose. The features that seemed to be excessive are very welcomed now.
  - Need to check that it is possible to work without preamplifier
  - Adjustable HV supply has to be elaborated

DAQ summary

- Proposal from DAQ group on trigger rate limit
— 30 kHz at least, but do not limit your design (allow for 60kHz)

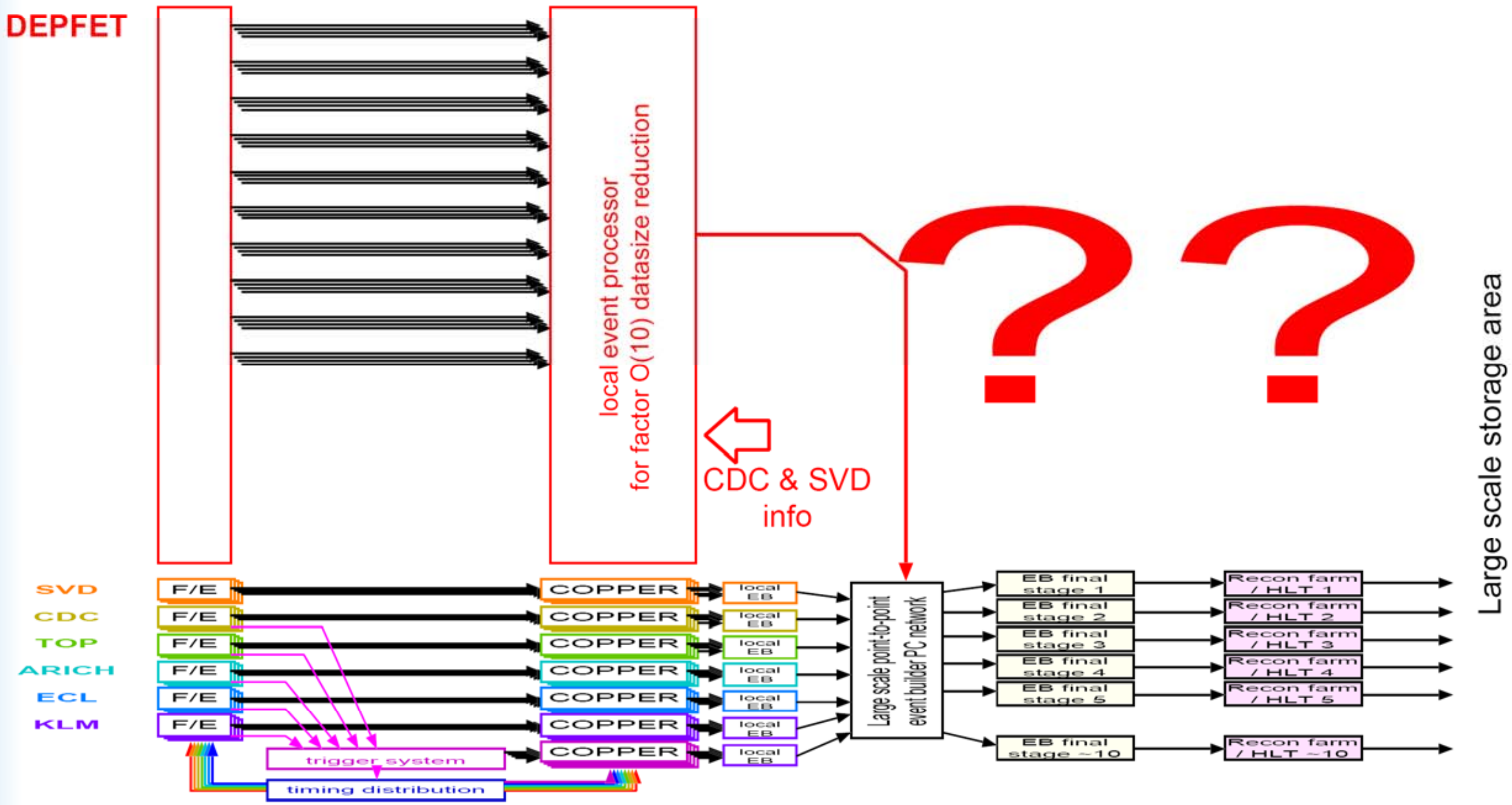
Proposal from DAQ group on deadtime
— 3.5% readout deadtime limit

Hardware development and unification?
— still in prototype stage, we will see if unification is possible

Still COPPER?
— 30 kHz bottleneck to be tested again, no other good alternatives

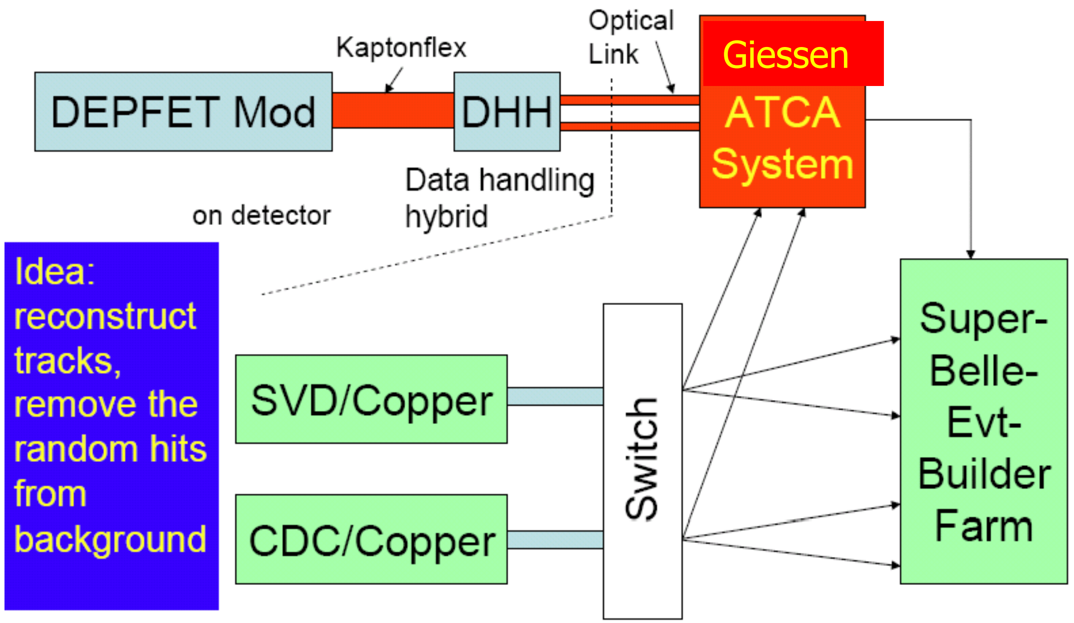
PXD readout and event building?
- *— on-going discussion issue*

DAQ: pixel detector

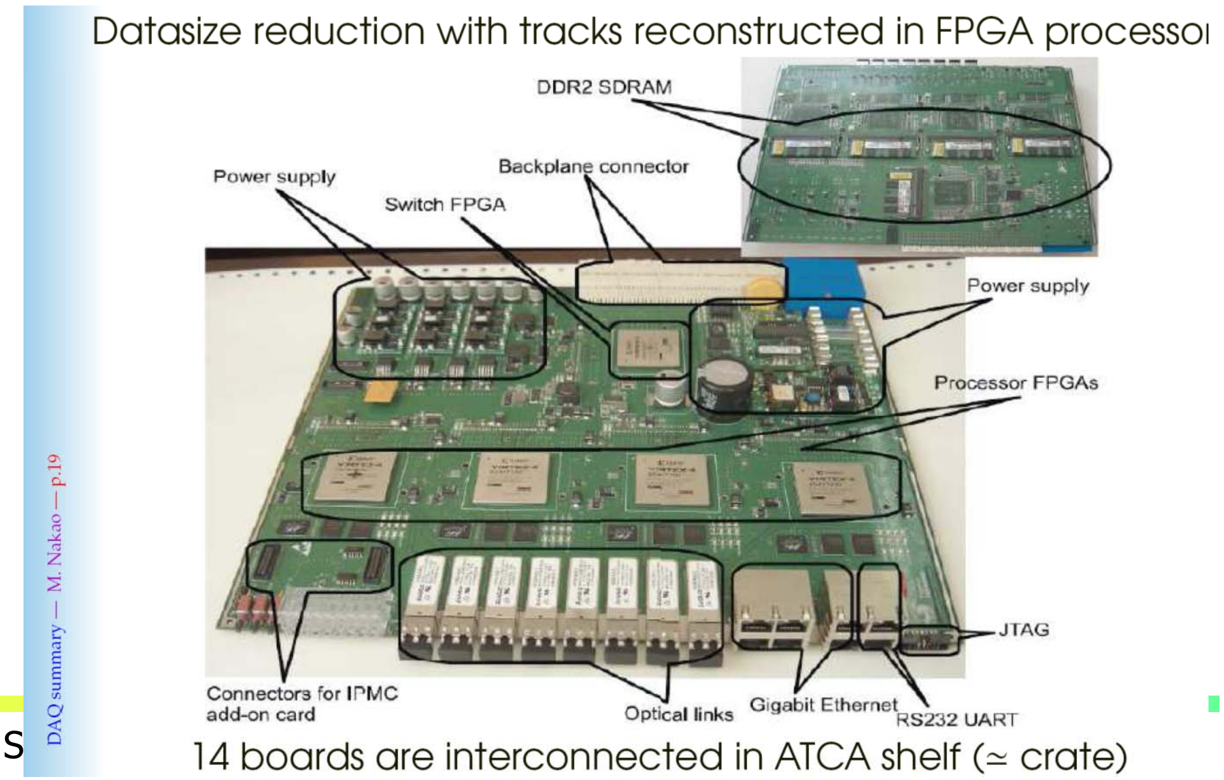


→Need tracking information to reject background hits (x20 rejection factor)

DAQ: pixel detector



One possibility:

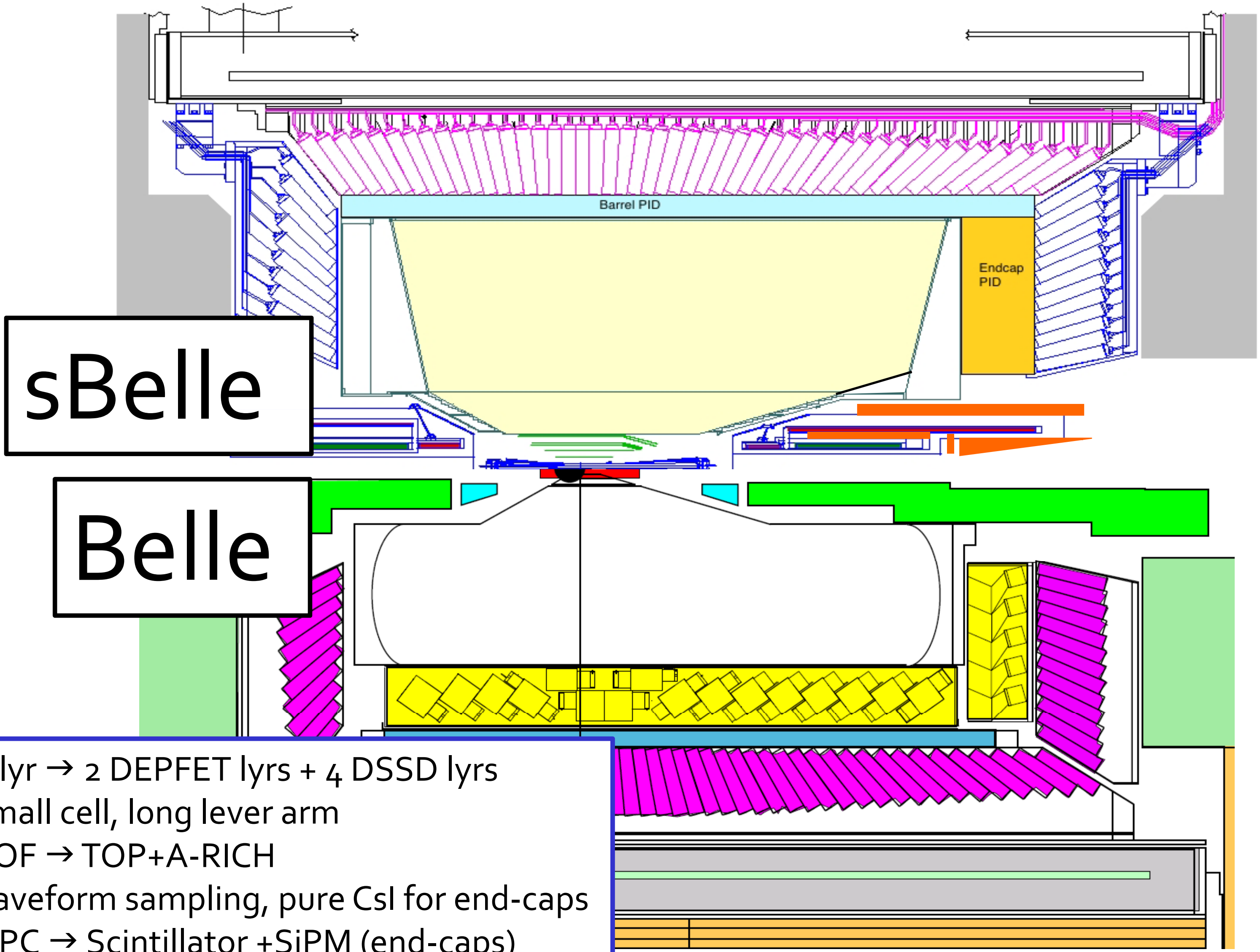


Deadlines: as set a year ago

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	

To be updated!

Baseline Design (updated: Mar.18, 2009)



SVD: 4 lyr → 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling, pure CsI for end-caps
KLM: RPC → Scintillator +SiPM (end-caps)

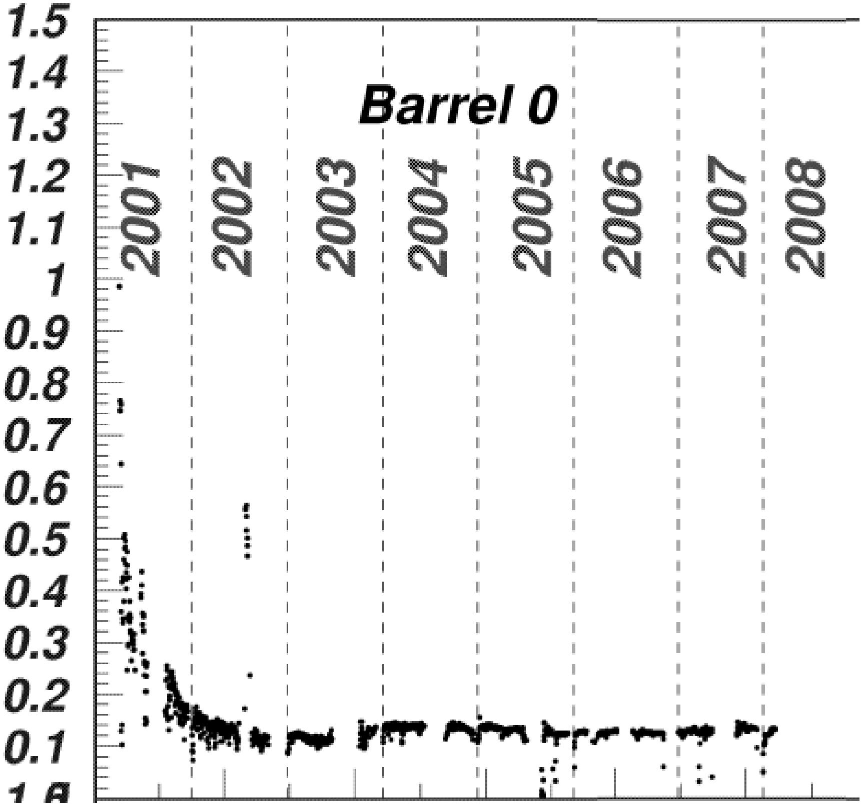
Summary

- A lot of progress in understanding of the detector and technical details
- New open issues, some solutions
- Ongoing detector R+D has to be wrapped up soon...
- Backgrounds: simulate and add to MC events for the analysis of impact

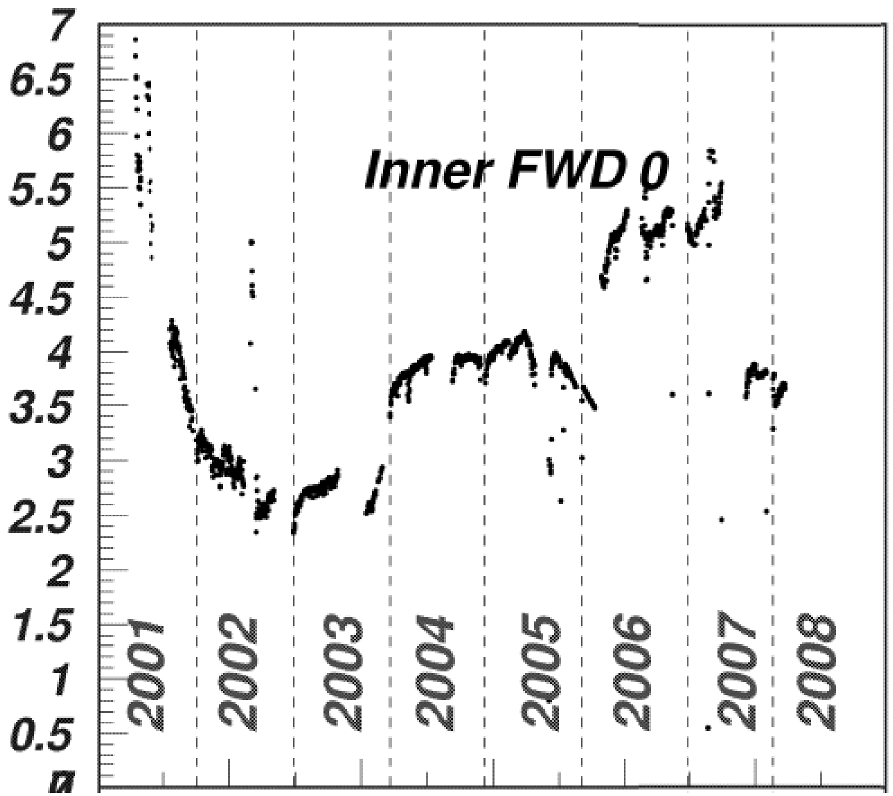
Backup slides

Bias current increase in ECL photodiodes (Denis Epifanov)

ΔI_{bias} / (Integrated beam current)



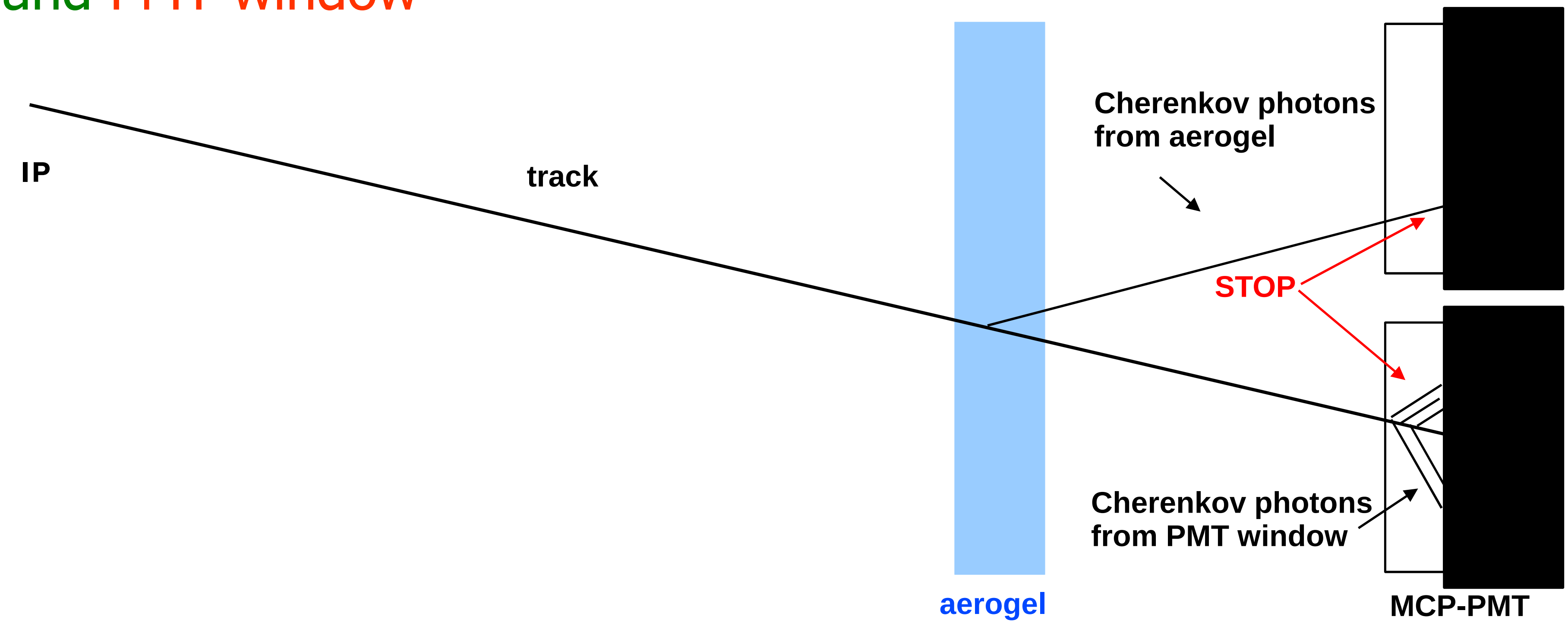
Typical barrel region



Inner forward region

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

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

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.

Radiation Hardness of ECL Components

I. Nakamura

❑ to γ 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)	ΔI(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)	ΔI(nA)	C_j/C_{j0}	G/G_0
1×10^{11}	~ 100	1	1.00
1×10^{12}	~ 1000	1	0.98
1×10^{13}	~ 10000	1	0.93

- Crystals

crystal	dose (/cm^2)	# photons
CsI(Tl)*	1×10^{12}	~0.7
CsI(Pure)	1×10^{12}	1.0–0.95

* small crystal doesn't show degradation

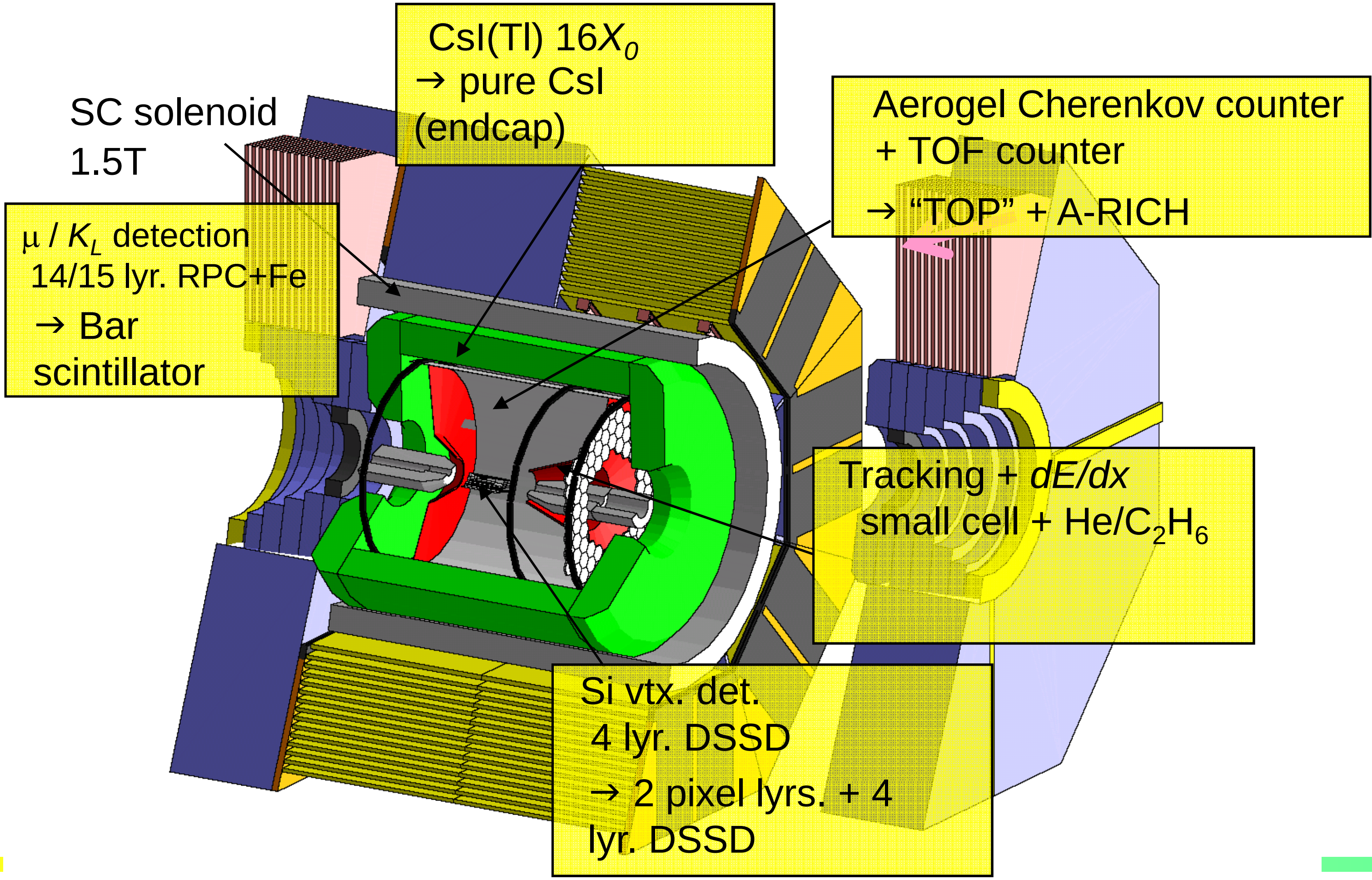
❑ γ rays no problem

❑ some degradation with Neutrons

❑ Rad. hardness of crystals depend on producer

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



Summary: ASICs

- \- **DCD** prototype chip has been tested with test signals that correspond to DEPFET currents and irradiated up to 7 Mrad.
- The chip works fine and has high enough conversion speed.
- Operation with matrices still to be tested – we do not expect problems.
- Only „fine tuning" of the design for the super KEKB operation is necessary.
- \- **Switcher** prototype with **LV** transistors has been tested and irradiated up to 22 MRad.
- The chip works fine and has adequate speed for SBelle operation.
- \- Another prototype with **HV** transistors has been designed and tested.
- \- The irradiation of the chip still has to be done but the basic and most critical part (high-voltage NMOS) has been irradiated up to 600 KRad and no damage has been observed.
- \- **DHP** chip will be designed using digital design tools in intrinsically radiation hard 90 nm technology

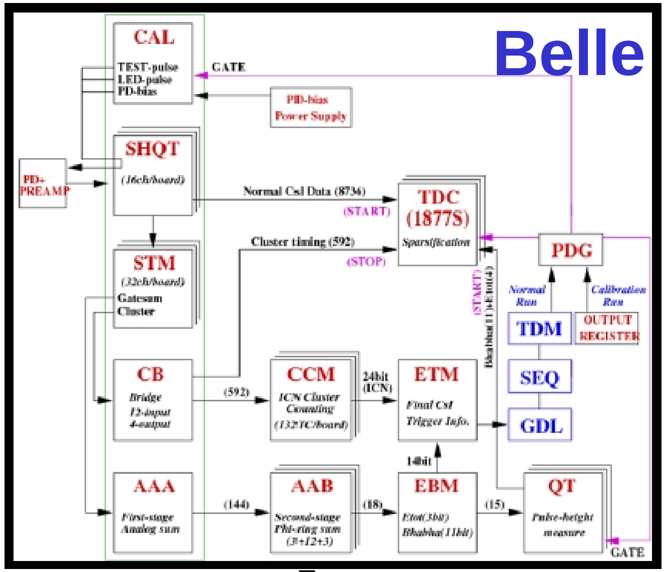
Barrel PID: status and to do

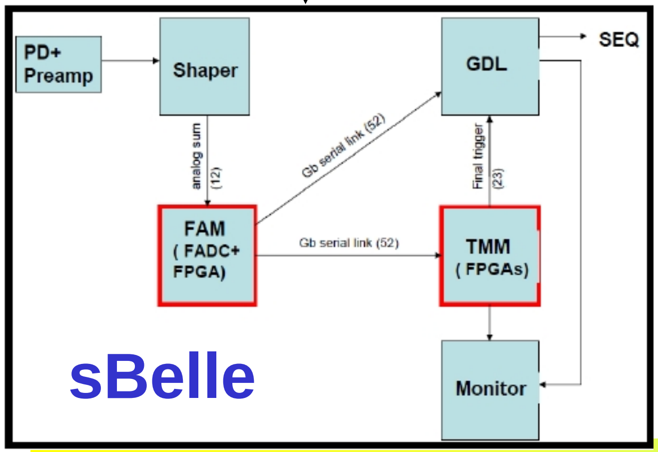
- Prototype study
  - Check ring image with focus mirror, quality of quartz radiators
  - Electronics prototype performance
- Design study
  - Simulation programs are converging
    - Design choice and optimization
    - Robustness against multi-track events, beam BG
  - Effect to outer detector, again
    - Material of standoff, structure
    - Distance btw. radiator and ECL
- Photon detector choice
  - Lifetime for MCP-PMT
    - Test with square-shape MCP-PMT from Hamamatsu and Photonis
  - Performance and production reliability
    - Hamamatsu vs. Photonis → Determine the size
    - Photo-cathode (GaAsP/Multi-alkali)

By this summer

B.G. Chec

sBelle calorimeter trigger





Feature :

- Much simpler electronics chain (2 steps) than Belle
- More flexible trigger algorithm design than Belle
  - 1st step (FAM) : 10MHz/12bit FADC + FPGA
  - 2nd step (TMM) : cascade/partitioning FPGAs
- Bulky copper cables → 52 optical fibers
- Simple monitoring scheme
- Simultaneous handling of CsI(Tl) and pure-CsI signals

Current status :

- We now investigate fast shaping signal from new Shaper.
- FAM core firmware algorithm has been tested.
- TSIM MC study has been performed w/ g4superb.

Plan :

- FAM/TMM prototypes will be ready by June.
- Basic test of Shaper/FAM/TMM readout chain
  - Under real environment before Belle shutdown