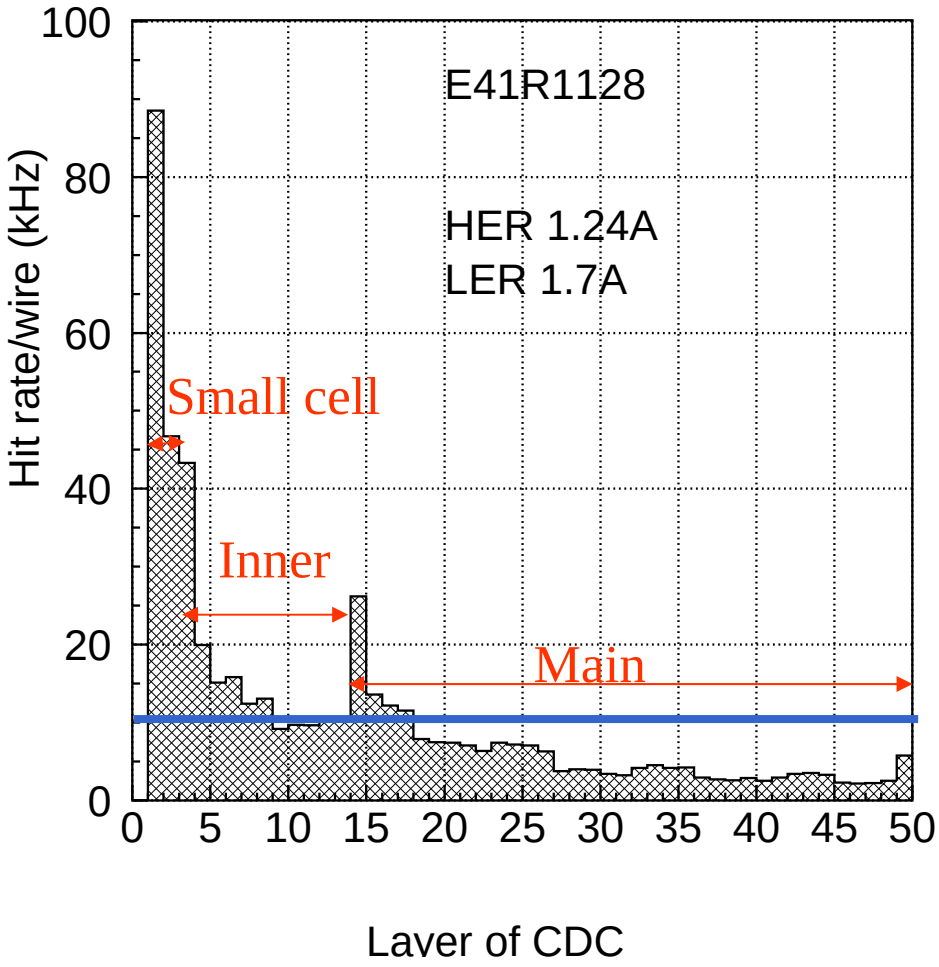
CDC Upgrade

Shoji Uno (KEK)

Mar-20th, 2008

- Beam background
- Simulation study
- Idea for upgrade
- Upgrade plan
- Summary

Hit rate



Apr.-5th ,2005

I_{HER} = 1.24A

I_{LER} = 1.7A

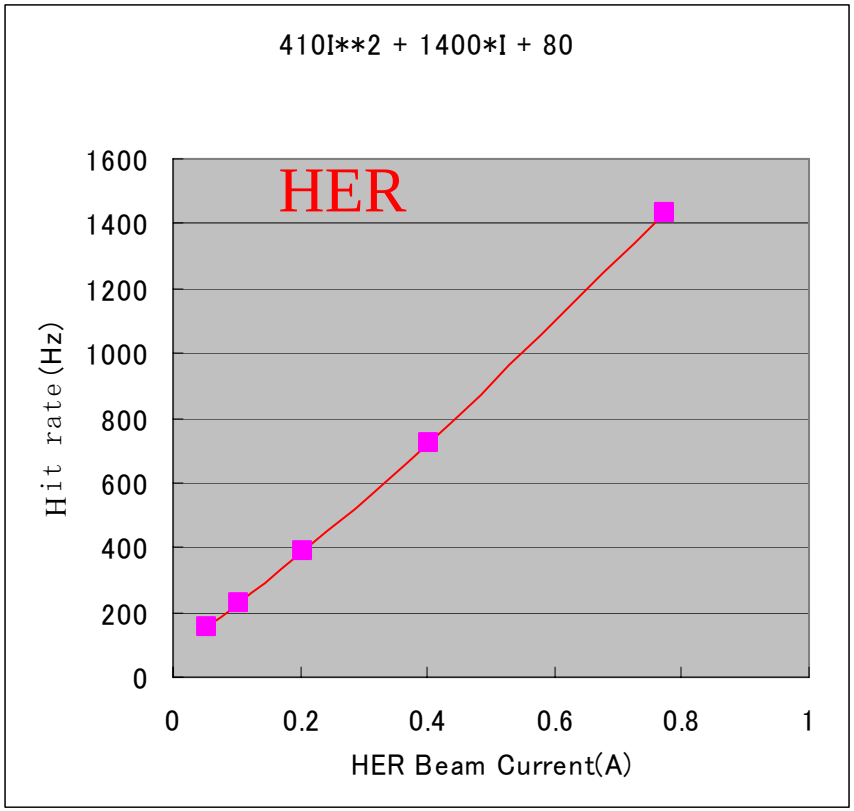
$L_{peak} = 1.5 \times 10^{34} cm^{-2} sec^{-1}$

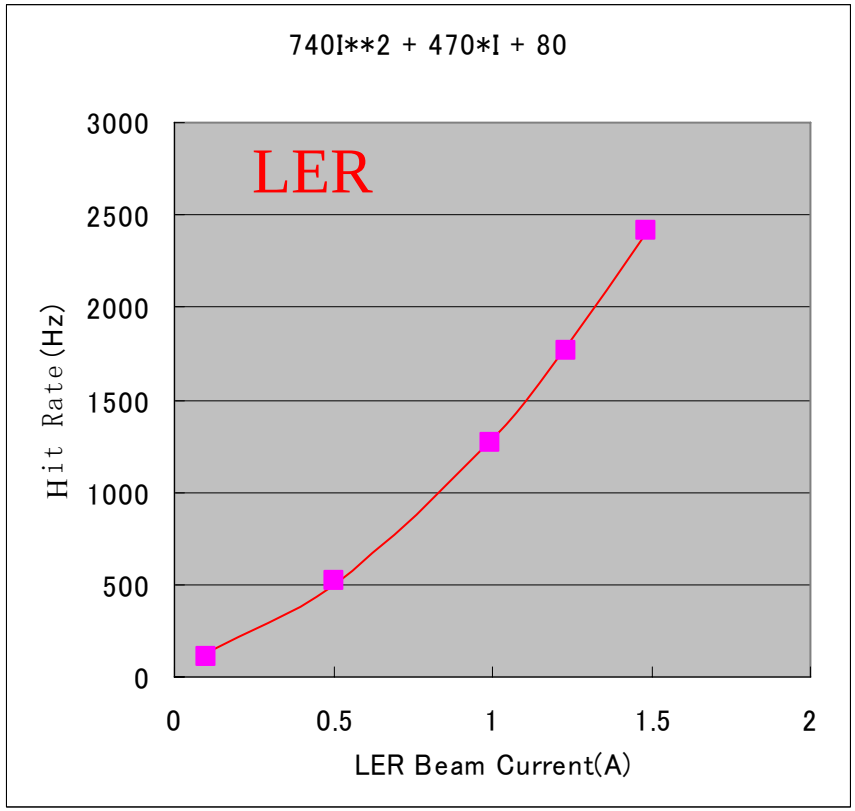
I_{CDC} = 1mA

10KHz

Hit rate at layer 35

Dec.,2003





I_{HER} = 4.1A Hit rate = 13kHz

I_{LER} = 9.4A Hit rate = 70kHz

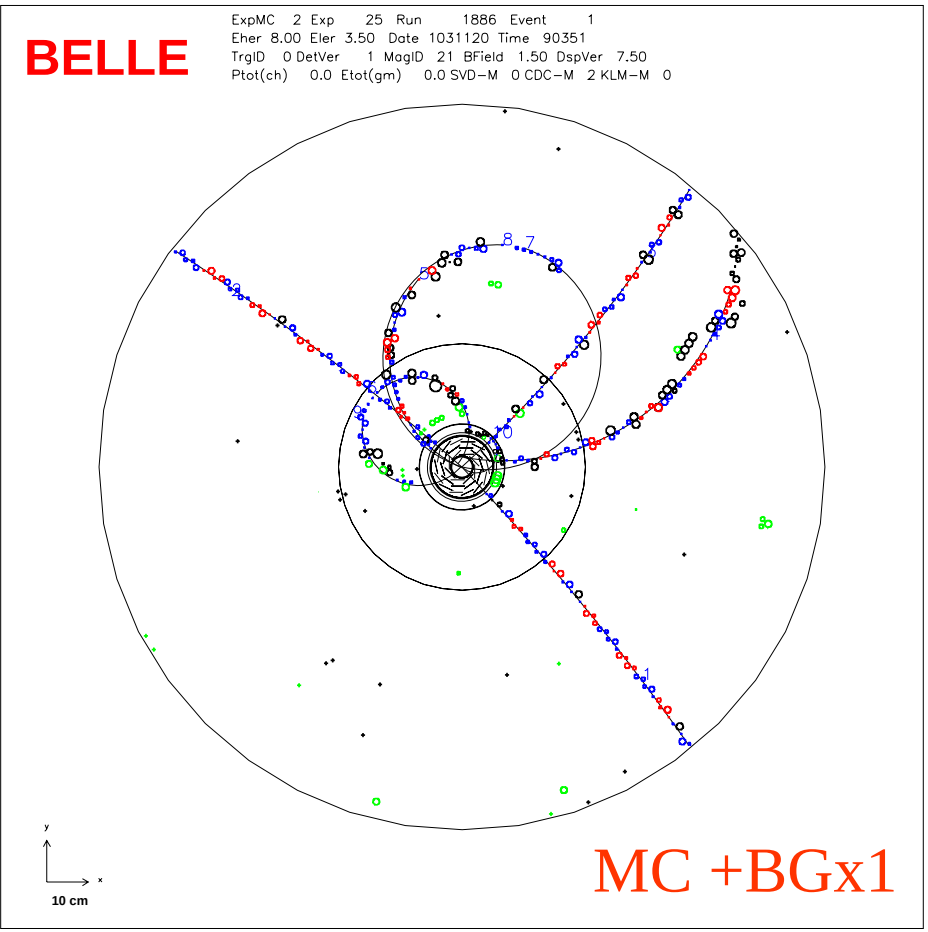
In total 83kHz

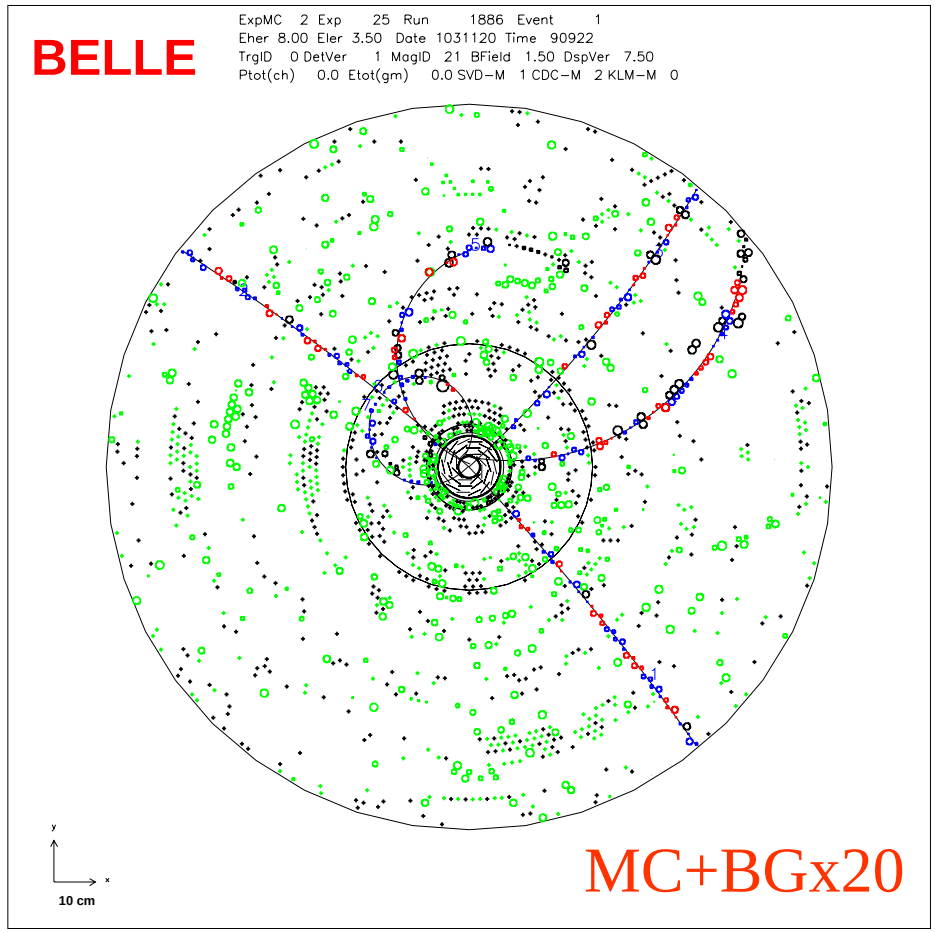
Dec., 2003 : ~5kHz

Now : ~4kHz

Simulation Study for Higher Beam Background

by K.Senyo.





BG effect on analysis

$J/\psi(\rightarrow \mu\mu)K_S(\rightarrow \pi^+\pi^-)$

	B Eff	Ratio-1
Nominal	56.8 %	0.0 %
×5 BG	56.0 %	-1.5 %
×20 BG	49.0 %	-13.8 %
With 40% shorter shaping		
×20 BG	51.4 %	-9.5 %

$D^*D^*(D^* \rightarrow D\pi_s, D \rightarrow K3\pi)$

	B Eff	Ratio-1
Nominal	6.48	0.0 %
×5 BG	5.69	-12.2 %
×20 BG	2.28	-64.9 %
With 40% shorter shaping		
×20 BG	3.86	-40.5 %

Preliminary

By H.Ozaki

- Major loss come from low tracking efficiency on slow particles
- Efficiency loss on high multiplicity event is serious
- Pulse shape information by FADC readout can save efficiency
- SVT standalone tracker will be a great help (not included in this study)

Background effect on tracking

H. Ozaki
BNM2008

$$D^{*}D^{*}(D^{*} \to D\pi_{S}, D \to K3\pi)$$

Many low momentum tracks, the hardest case for tracking

Gain in reconstruction efficiency of $B \to D^{*}D^{*}$

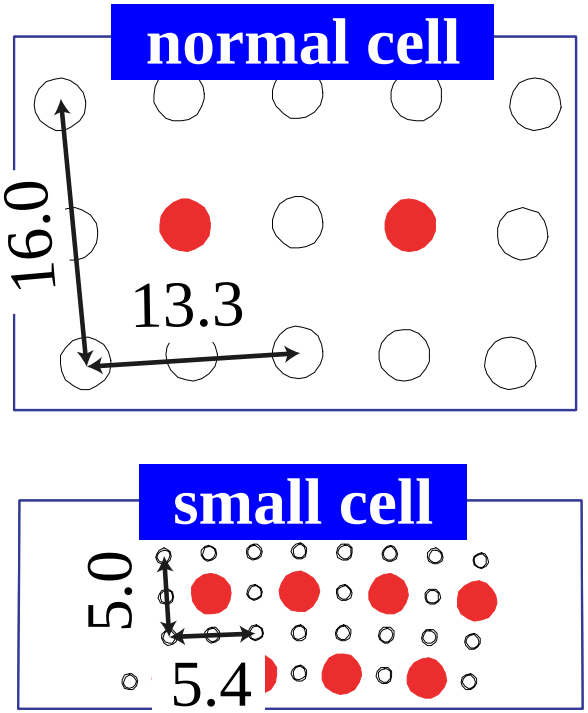
Tracker / BKG	Belle	Software update	+SVD tracker
Belle	ε=4.3% 0% (definition)	ε=7.1% +65%	ε=11.9% +177%
×5 BG		ε=6.3% +47%	ε=11.2% +160%
×20 BG		ε=3.8% –12%	ε=8.8% +105%

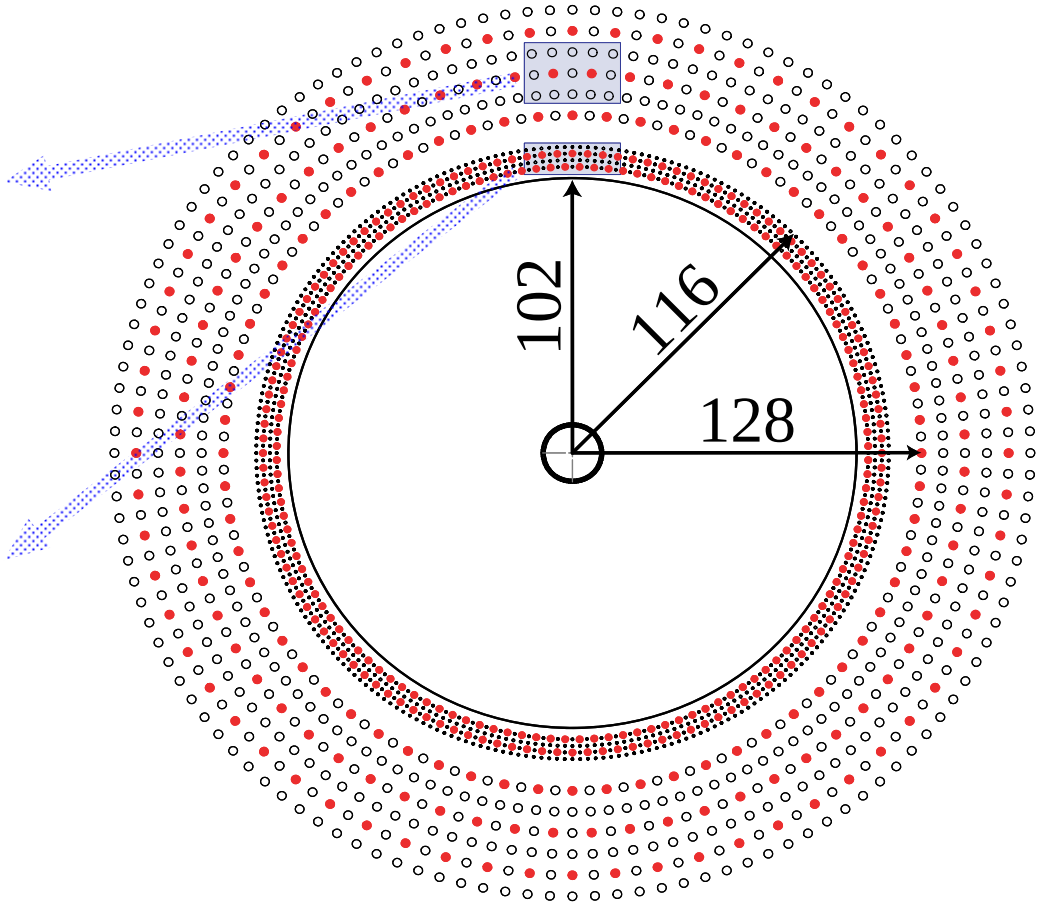
Excellent with help of SVD

Idea for upgrade

- In order to reduce occupancy,
  - →Smaller cell size
    - A new small cell drift chamber was constructed and installed.
    - It has been working, well.
  - →Faster drift velocity
    - One candidate : 100% CH_4
      - → Results show worse spatial resolution due to a large Lorentz angle.
      - → A beam test was carried out under 1.5T magnetic field.
    - So far, no other good candidate.

Small Cell Drift Chamber



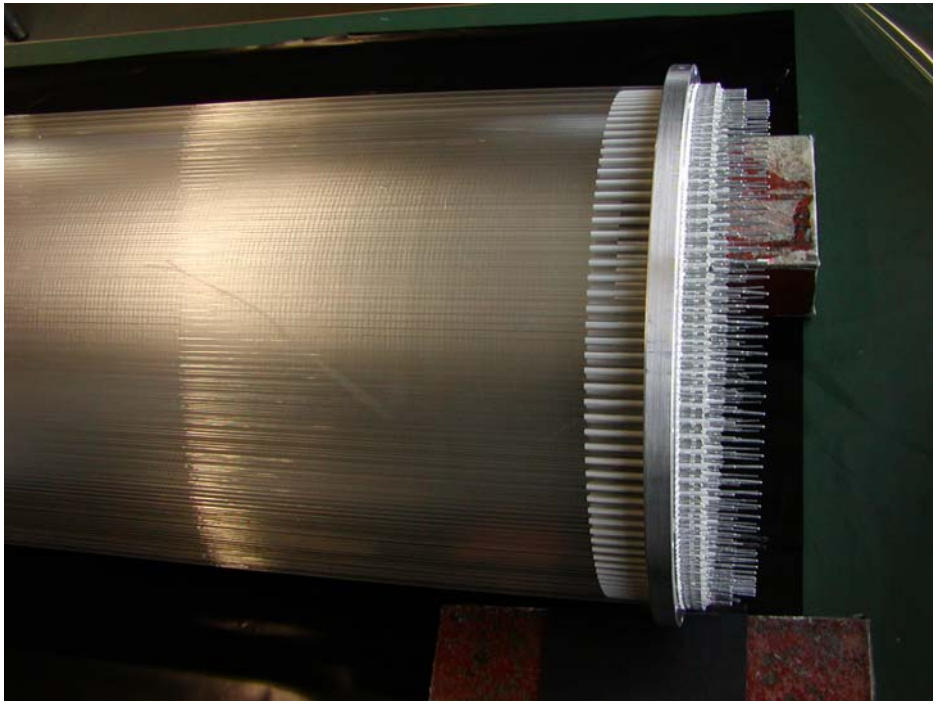


● sense wire

○ field wire

unit : [mm]

Photo of small cell chamber

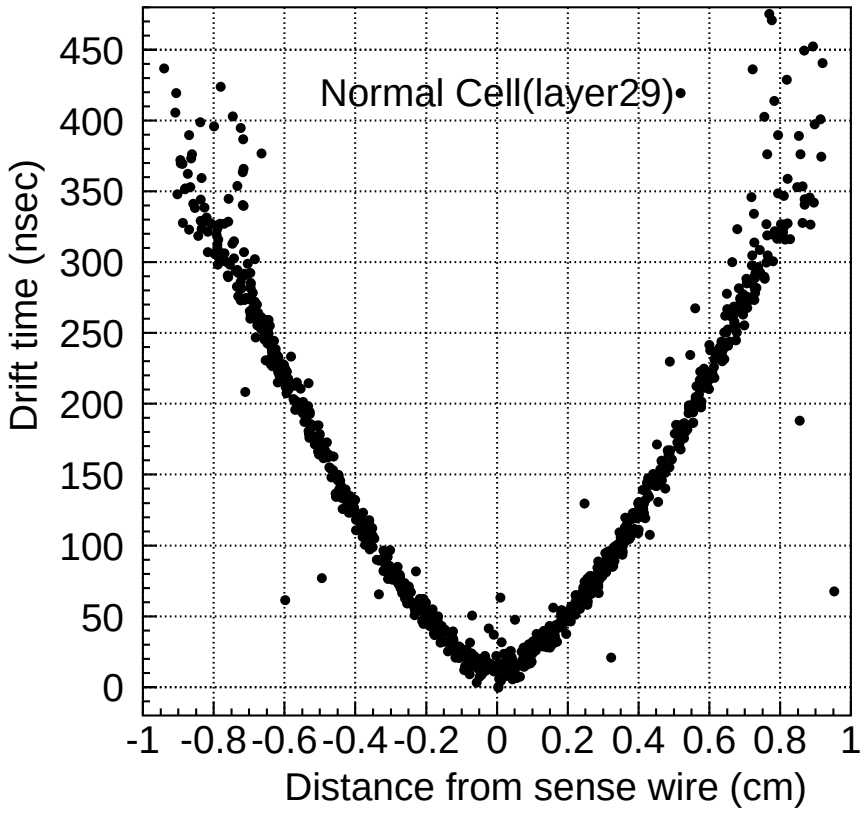


Just after wire stringing

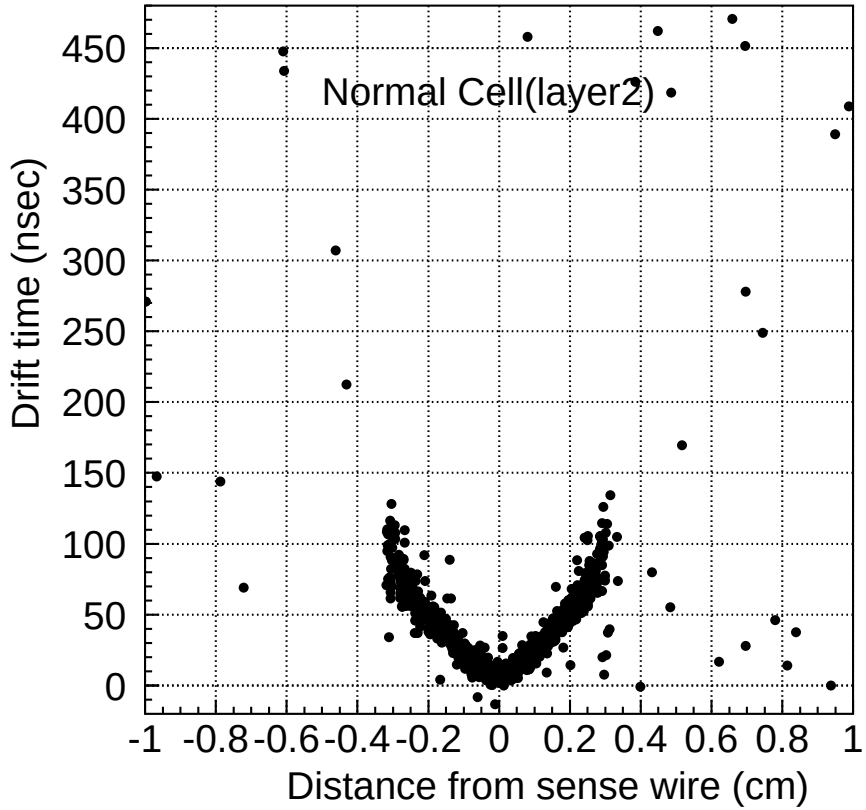
Installation in 2003 summer

XT Curve & Max. Drift Time

Normal cell(17.3mm)



Small cell(5.4mm)



Chamber Radius

- Inner radius
  - → Physics : Vertexing efficiency using Ks
  - → SVD determines the boundary.
  - → At present, the boundary is 15cm in radius.
- Outer radius
  - → New barrel PID device determines the outer radius.
  - → At present, 115cm is selected, tentatively.
- The boundary condition is important to start construction.
  - →Basically, CDC can manage any radius.

Wire configuration 1

- Super-layer structure
- 6 layers for each super-layer
  - → at least 5 layers are required for track reconstruction.
  - → Even number is preferred for preamp arrangement on support board to shorten signal cable between feed-through and preamp.
- Additional two layers in inner most super-layer and outer super-most layer.
  - → Higher hit rate in a few layers near wall.
  - → Inner most layer and outer most layer are consider as active guard wire.

Wire configuration 2

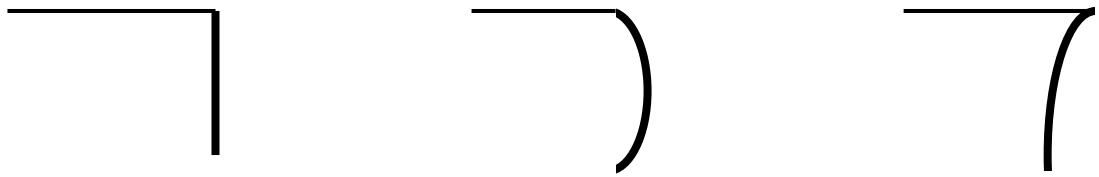
- 9 super-layers : 5 axial + 4 stereo(2U+2V)
  - →A 160*8, U 160*6, A 192*6, V 224*6,
  - →A 256*6, U 288*6, A 320*6, V 352*6, A 388*8
- Number of layers : 58
- Number of total sense wires : 15104
- Number of total wires : ~60000

Deformation of endplate

- Number of wires increase by factor 2.
  - → Larger deformation of endplate is expected.
  - → It may cause troubles in a wire stringing process and other occasions.
- Number of holes increases, but a chamber radius also enlarges. Cell size is changing as a function of radius to reduce number of wires.
  - → The fraction of holes respect to total area is not so different, as comparing with the present CDC.
    - 11.7% for present CDC
    - 12.6% for Super-Belle CDC
- In order to reduce deformation of endplates,
  - → The endplate with a different shape is considered.
  - → Wire tension of field wires will be reduced.
- Anyway, we can arrange the wire configuration and can make a thin aluminum endplate.

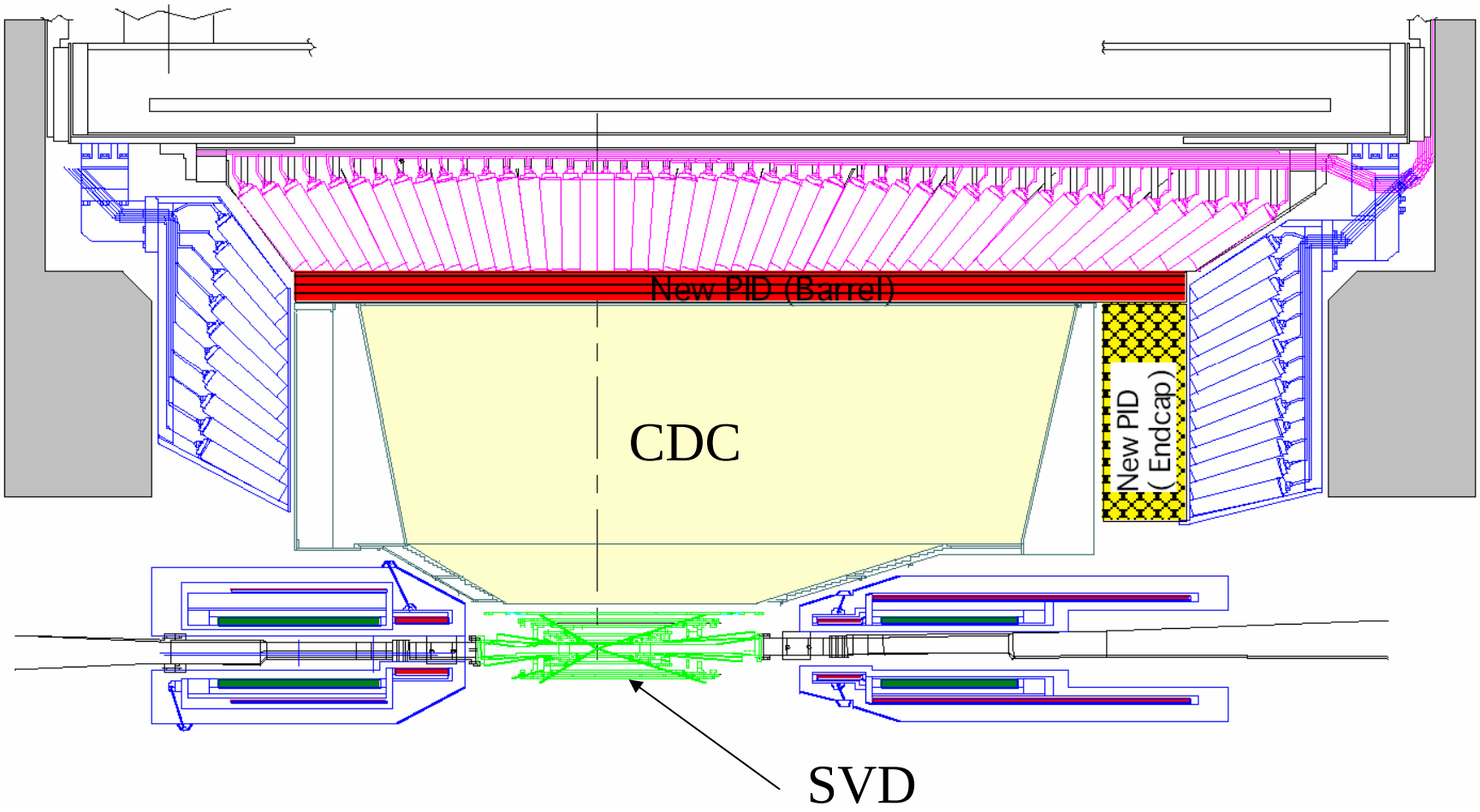
Curved Endplate

- Deformation of endplate due to wire tension was calculated at design stage of present Belle CDC.



Deformation(mm)	35.2	2.03	1.31
		Present	New

Baseline design



Main parameters

	Present	Future
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 total sense wires	8400	15104
Effective radius of dE/dx measurement (mm)	752	978
Gas	He-C_2H_6	He-C_2H_6
Diameter of sense wire (μm)	30	30

Expected performance

- Occupancy
  - →Hit rate : ~100kHz ← ~5Hz X 20
  - →Maximum drift time : 80-300nsec
  - →Occupancy : 1-3% ← 100kHz X 80-300nsec = 0.01-0.03
- Momemtum resolution(SVD+CDC)
  - $\sigma_{Pt}/Pt = 0.19Pt \oplus 0.30/\beta[\%]$: Conservative
  - $\sigma_{Pt}/Pt = 0.11Pt \oplus 0.30/\beta[\%]$: Possible ← $0.19*(863/1118)^2$
- Energy loss measurement
  - →6.9% : Conservative
  - →6.4% : Possible ← $6.9*(752/869)^{1/2}$

About readout electronics

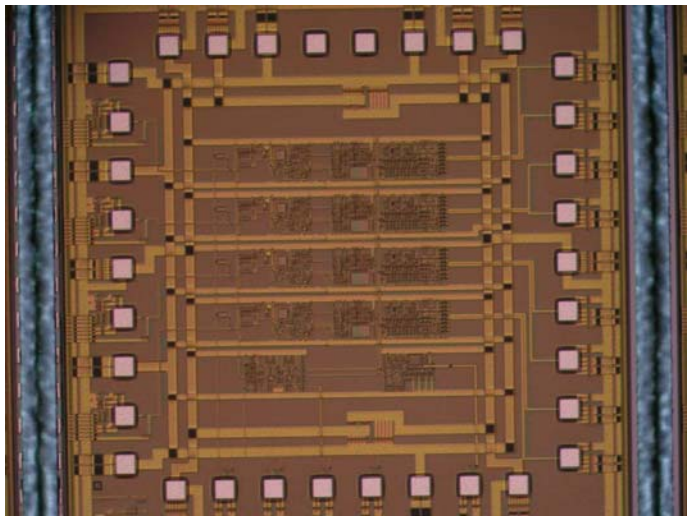
- At present,
  - → S/QT + multi-hit TDC
  - → S/QT : Q to Time conversion
  - → FASTBUS TDC was replaced with pipeline COPPER TDC.
- Three options,
  - → High speed FADC(>200MHz)
  - → Pipeline TDC + Slow FADC(~20MHz)
  - → ASD chip + TMC(or new TDC using FPGA) + slow FADC near detector.
    - ASIC group of KEK Detector Technology Project is developing new ASD chip.
    - New TDC using FPGA is one candidate for TDC near detector.

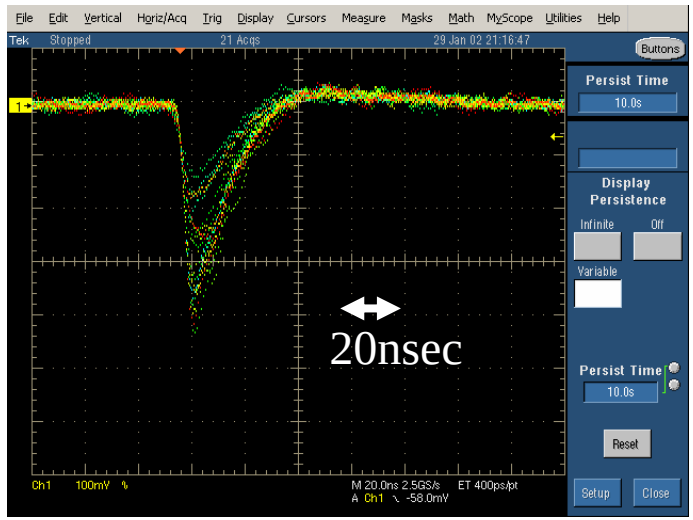
ASD chip

Gain : ～7V/pC

Integration time : 1nsec

1/t tail cancel. PZC

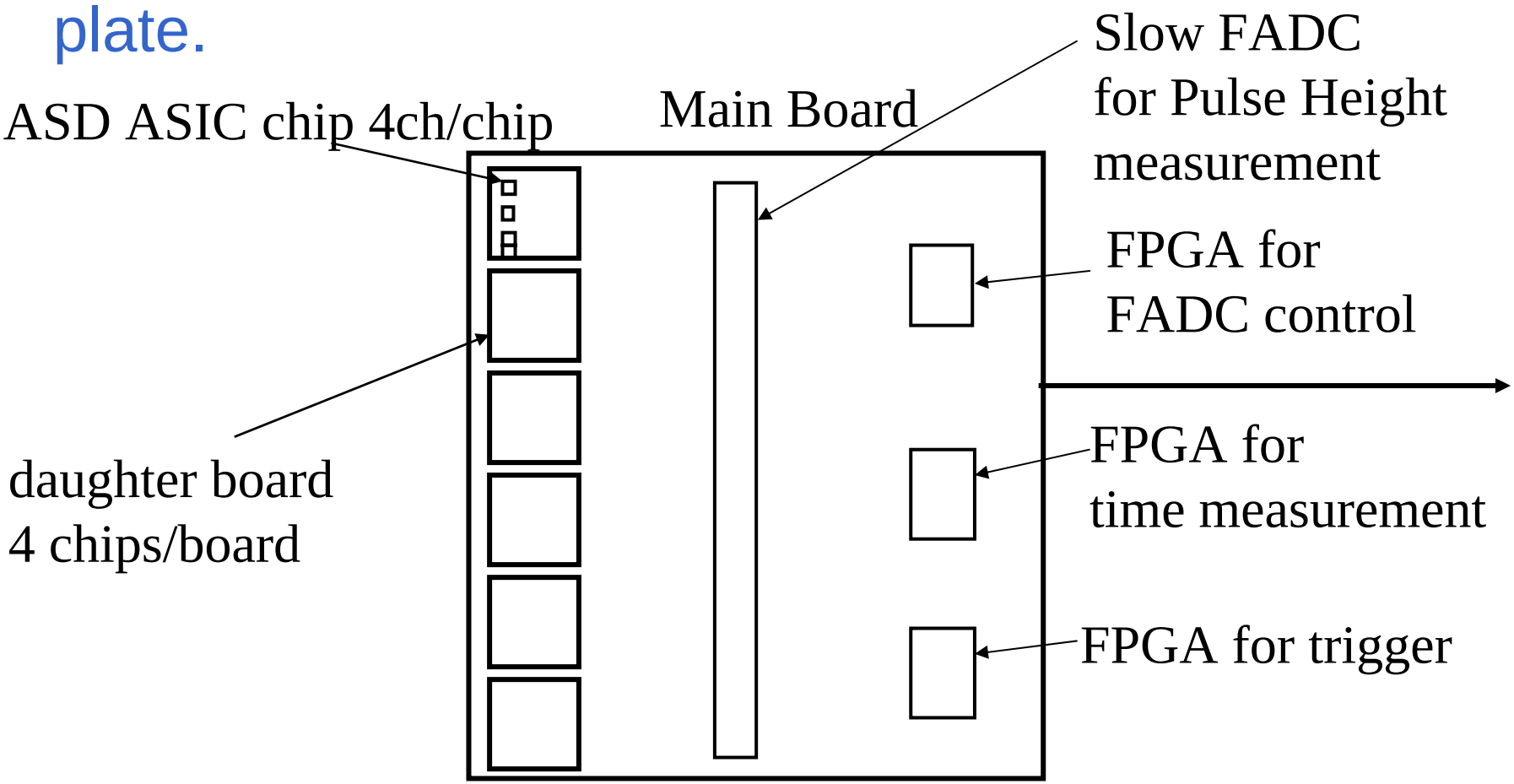




Fe-55 5.9keV X-ray

New electronics (just my idea)

- All electronics should be located near the end plate.



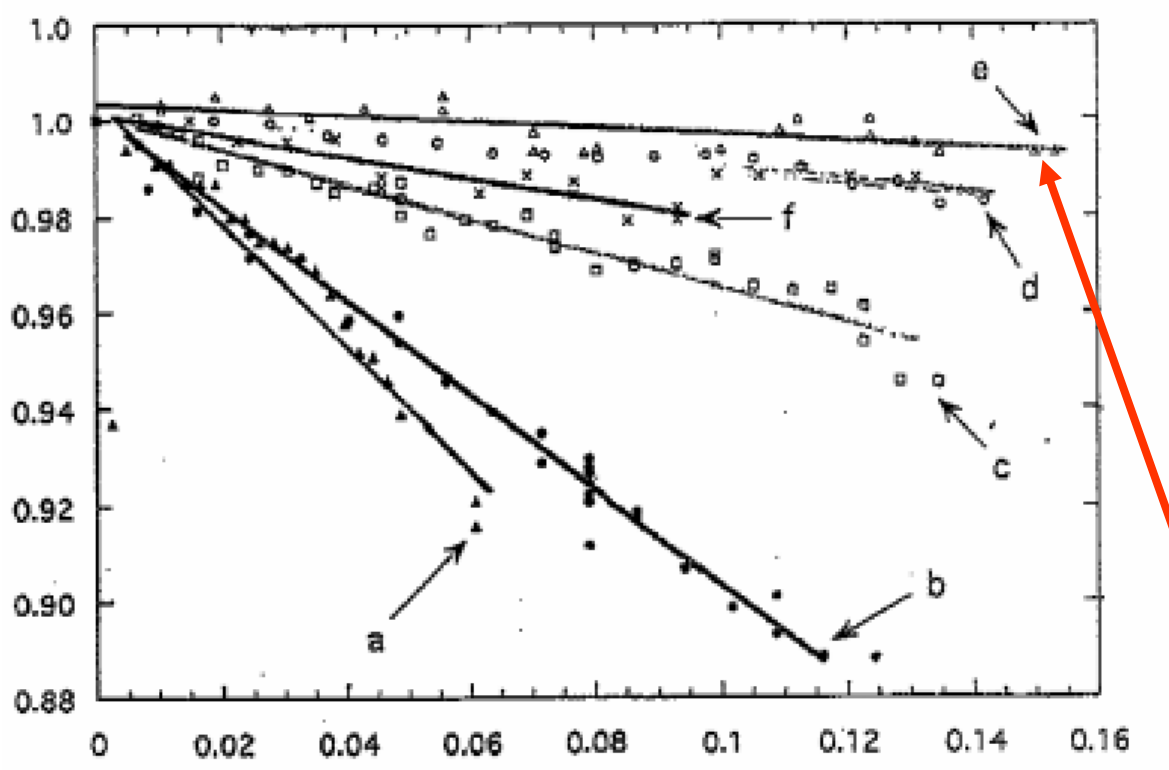
Summary

- When Belle group decides the upgrade plan, we can start construction of the new chamber soon.
  - → It takes three years to construct the chamber.
- Outer radius(and inner radius) should be fixed as soon as possible.
  - → Barrel PID determines the schedule.
  - → Inner radius should be determined by SVD.
  - → Supporting structure should be discussed.
- One big worry is man power.
  - → I hope many people join us when the upgrade plan starts.

My Personal Plan for Construction

	JFY	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																

Radiation Damage Test



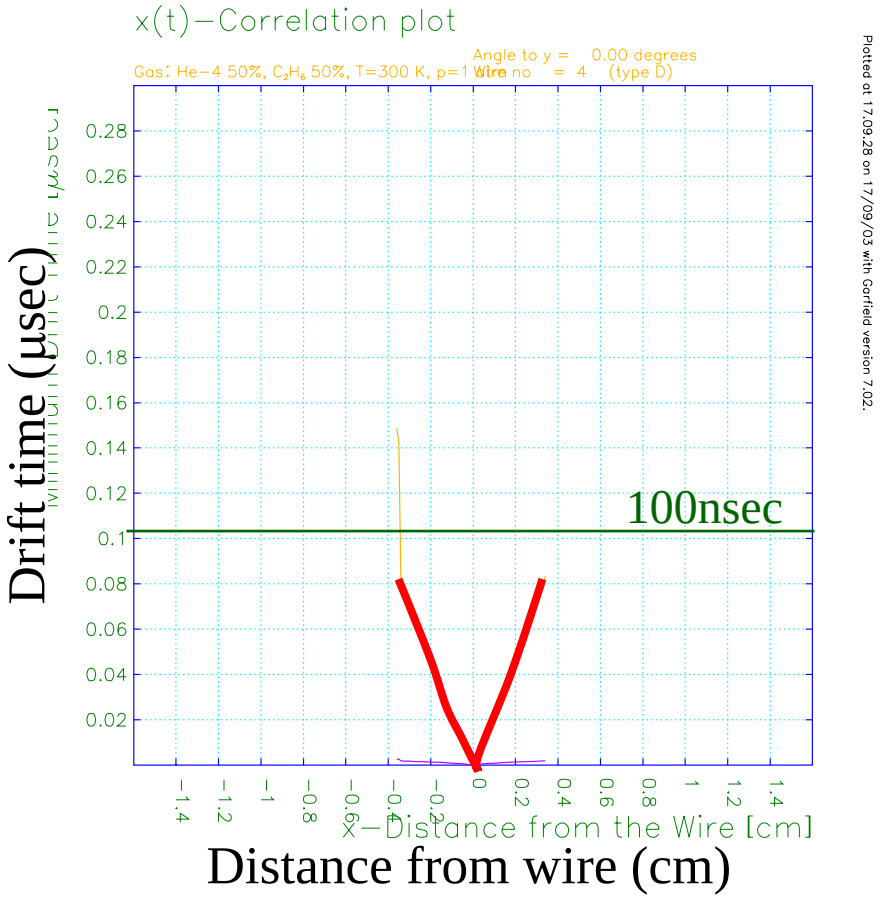
a: ’93 Plastic tube
b: ’93 Plastic tube + O2 filter
c: ’94 Plastic tube
d: ’94 SUS tube
e: ’94 SUS tube + O_2 filter
f: ’94 Plastic tube

Test chamber and beam test

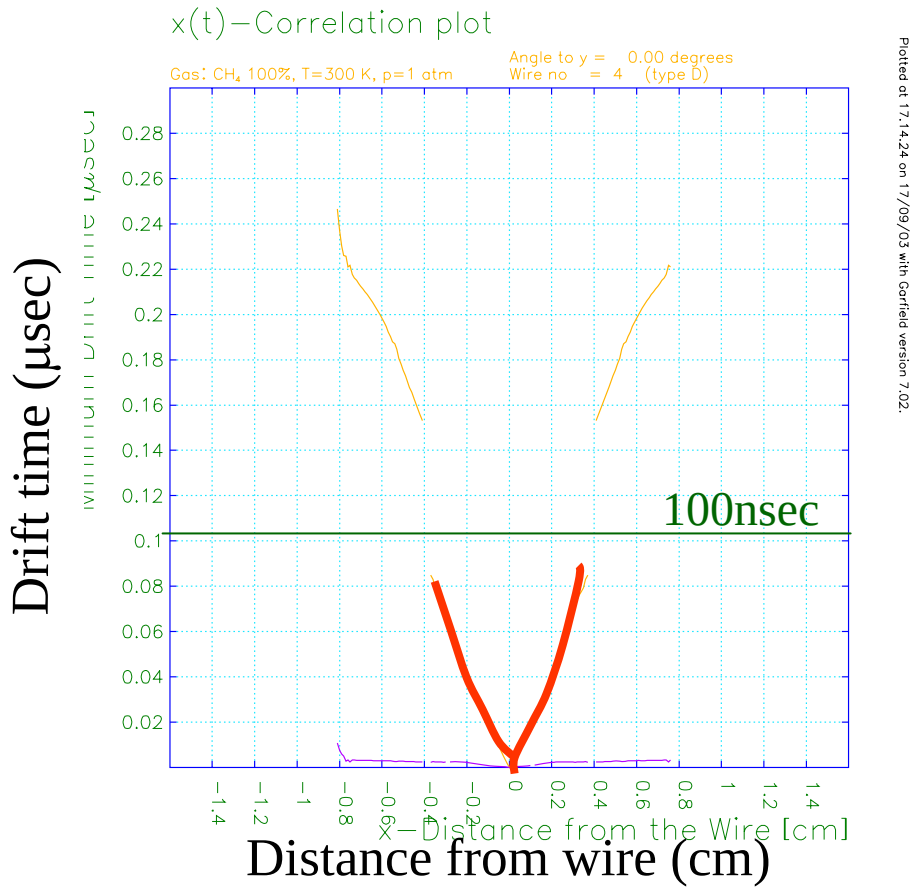
- A test chamber with new cell structure was constructed.
  - → Part of inner most 20 layer(8 layers with small cell + 12 layers with normal cell)
- A beam test was carried out in the beginning of June at $\pi 2$ beam line of 12GeV PS.
  - → We confirmed the simulation for pure CH_4 is correct. Velocity under 1.5T is not faster than the present gas and the drift line is largely distorted due to larger Lorentz angle.
  - → Similar performance could be obtained using new S/QT module with less dead time.
  - → Many data were taken using 500MHz FADC, which was developed by KEK electronics group. Now, a student is analyzing data. We hope to get information about minimum necessary sampling speed for timing and dE/dx measurement.

xt curve for new gas(7mm cell)

$He/C_2H_6 = 50/50$



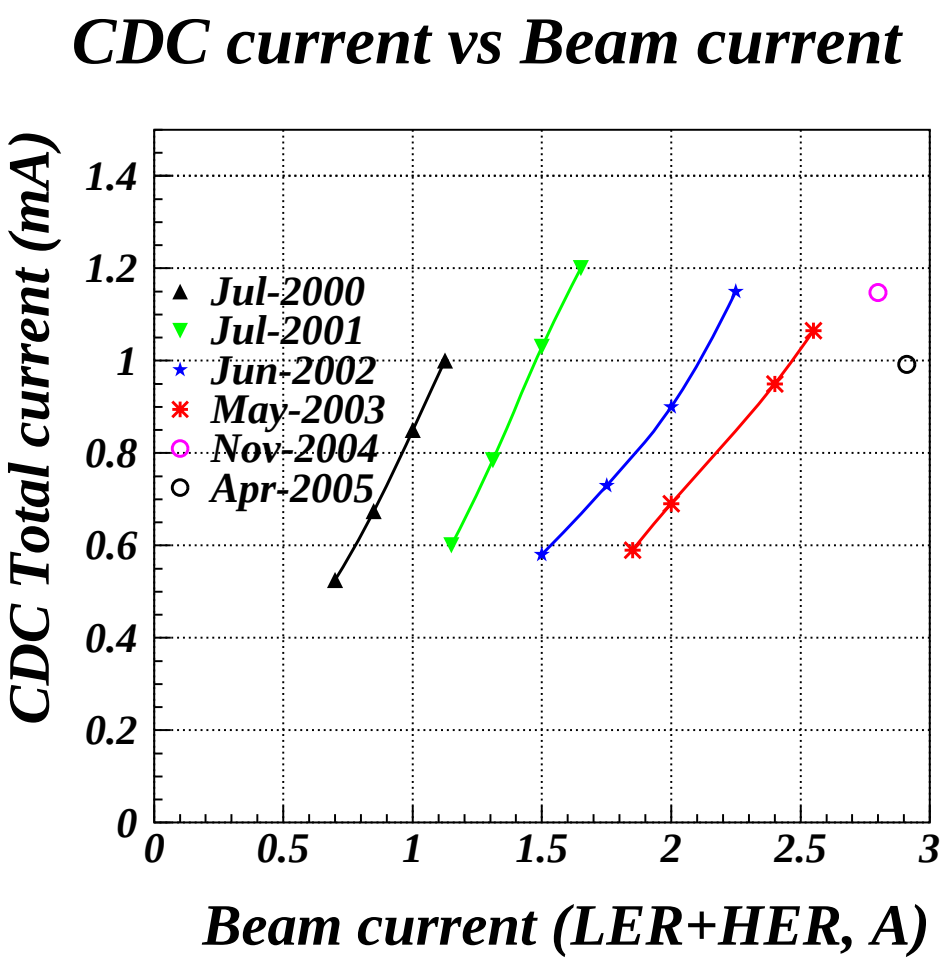
Pure CH_4



Wire chamber

- Wire chamber is a good device for the central tracker.
  - → Less material → Good momentum resolution.
  - → Cheap → It is easy to cover a large region.
  - → Established technology → Relatively easier construction.
  - → Many layers → Provide trigger signals and particle ID information.
- Wire chamber can survive at Super-KEKB.
- Our answer does not change after the last WS in 2004.
  - → The beam background became smaller even for higher beam current and higher luminosity.
  - → We recognize the luminosity term is small, clearly.

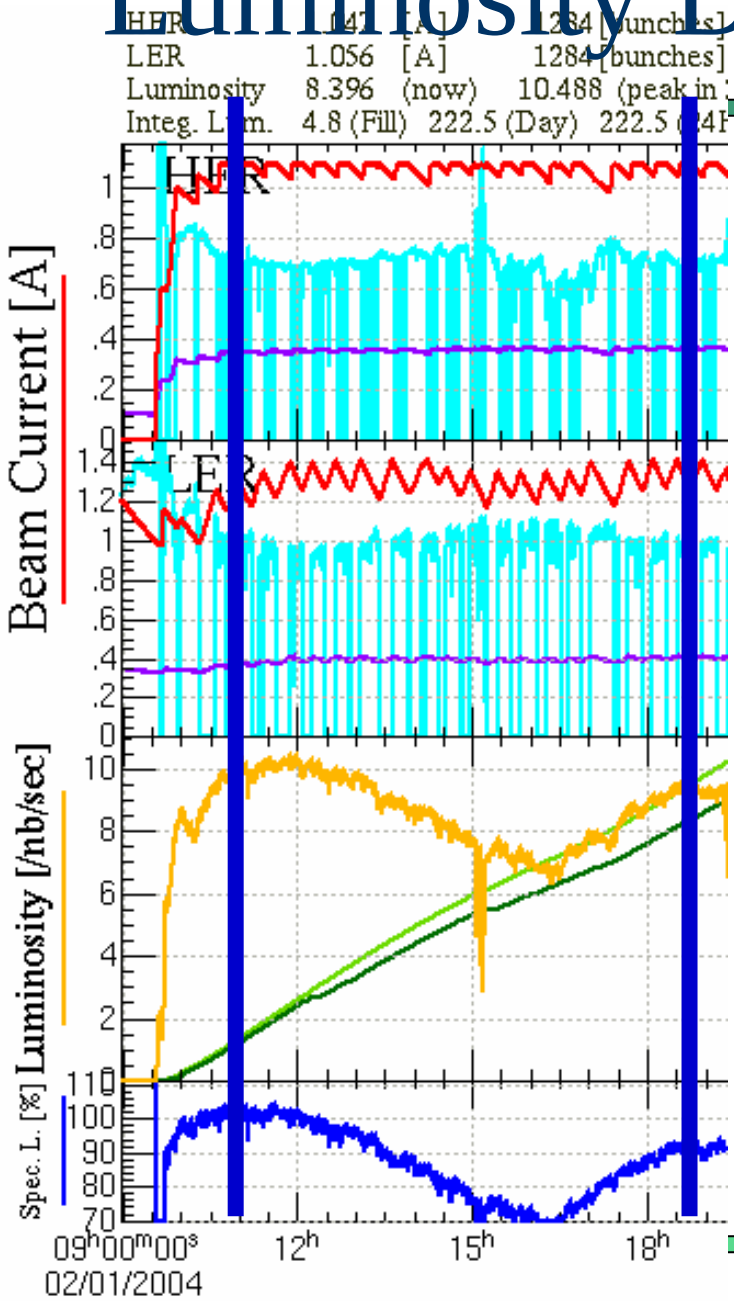
CDC Total Current



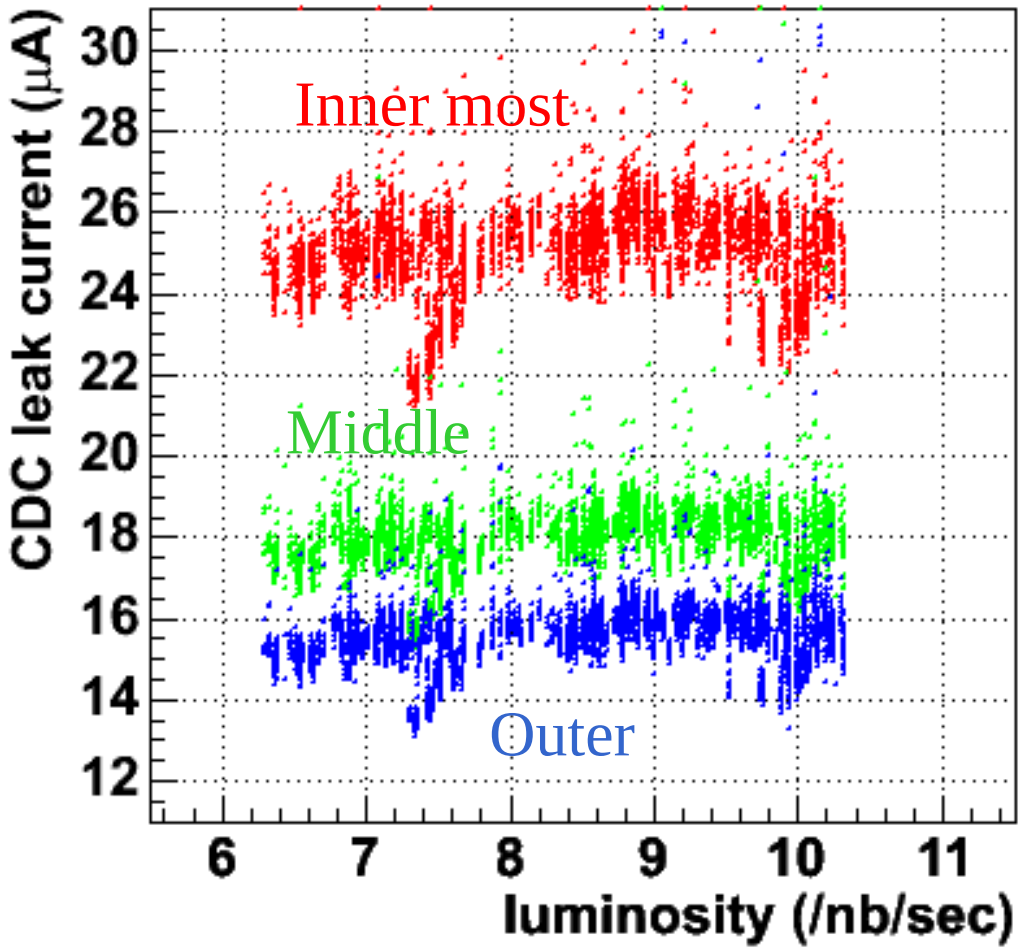
- Maximum current is still below 1.2mA, even for higher stored current and higher luminosity.
- Vacuum condition is still improving.
  - → Thanks KEKB people for hard work.
  - → I hope there is still room to improve vacuum condition further.

Luminosity Dependences

Feb, 2004



CDC BG did not change!



Occupancy

Random trigger

	Luminosity $10^{34}cm^{-2}sec^{-1}$	No. of channel N_{Total}	Readout time (μsec)	Q>0	Q>50 N_{Hit}
Belle	1.5	8464	6	-	300
Babar	0.8	7104	2	~700	~350

	Occ. = N_{Hit}/N_{Total} (%)	Occ./Time (%/μsec)	Max. drift time (μsec)	**Occ./Time x Max. Drift time (%)**	Normalized by Lum.(%)
Belle	3.5	0.58	0.4	0.23	0.15
Babar	4.9	2.45	~0.6	1.47	1.84

x20 Bkgd in Belle CDC ~ x3 Bkgd in Babar DCH

DCH Tracking Performance

For the DCH the interesting quantities are tracking efficiency and momentum resolution
We did not look at impact to particle identification (dE/dx)

Invariant mass and efficiency results:

	1xBkgd	3xBkgd	5xBkdg
Rel. tracking efficiency (%)	100.0	98.6	97.4
Rel. $D0 \rightarrow K^+\pi^-$ efficiency (%)	100.0	96.0	95.5
D^0 mass resolution (MeV/c^2)	6.5	6.5	6.4
$J/\psi \rightarrow \mu^+\mu^-$ efficiency (%)	72.8	72.5	71.5
J/ψ mass resolution (MeV/c^2)	12.7	12.9	13.0

- Tracking efficiency drops by about 2.5% at 5xBkgd (the J/ψ tracks seem somewhat better)
- Mass resolution is about 2% worse for J/ψ events
  - Matches a 1% degradation in momentum resolution seen in generic tracks

The changes are so small that we are not particularly worried