Works and Plans

(what I have done and what I will do)

Takanori Hara (Osaka U)

What is B-Factory ?

To explain the dominance of matter in the universe

the Sakharov conditions

. Withdrawal from thermal equilibrium.

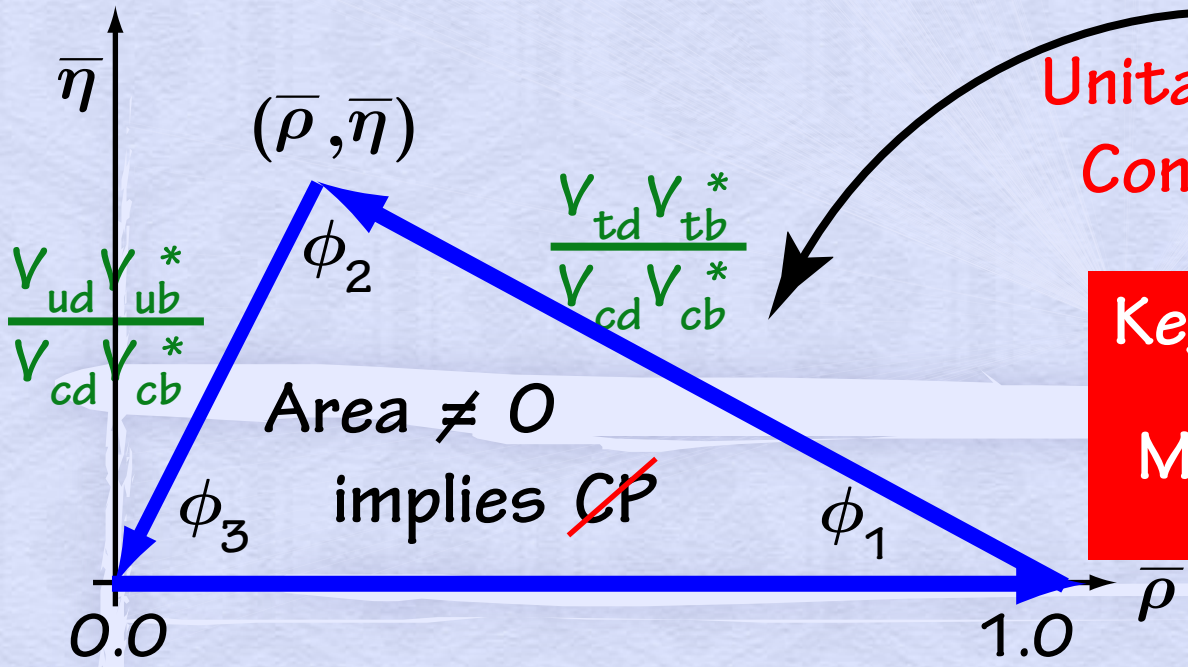
. Baryon number violation.

. CP-symmetry violation.

In the SM of particle phys,
Kobayashi-Maskawa matrix
(= quark mixing matrix)

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Unitarity Constraints

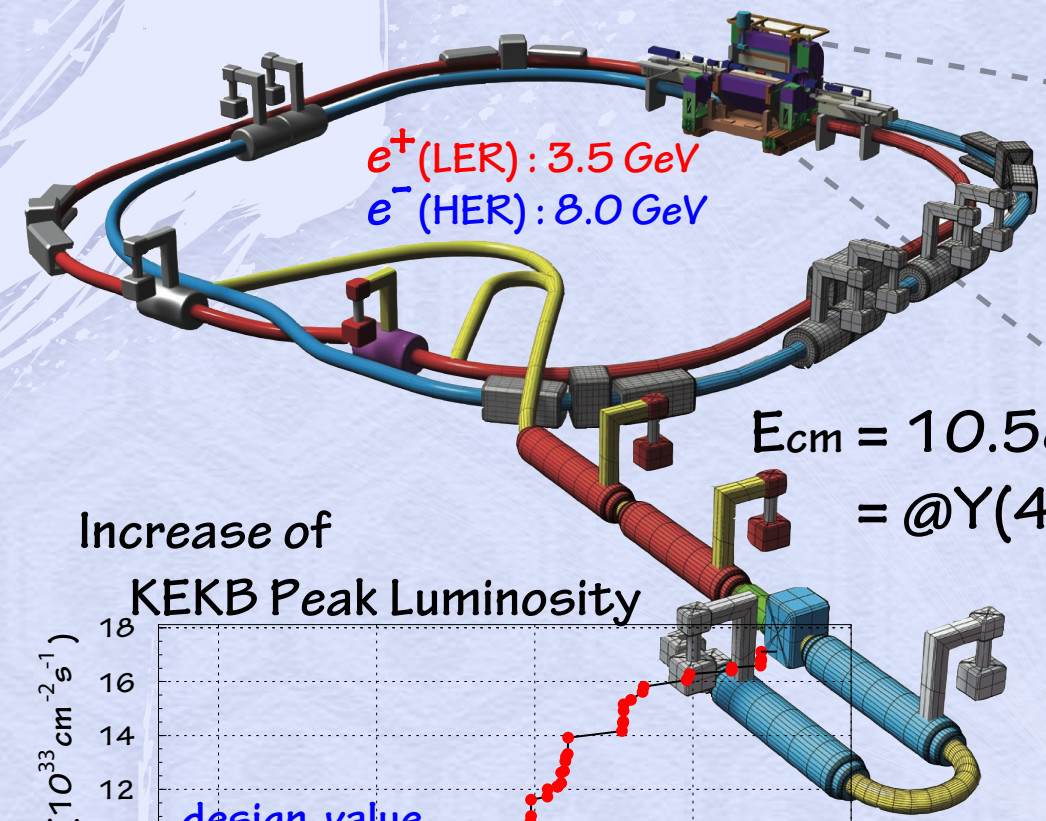


Key objective of B-factories :

Measurements of the { 3 sides / 3 angles }

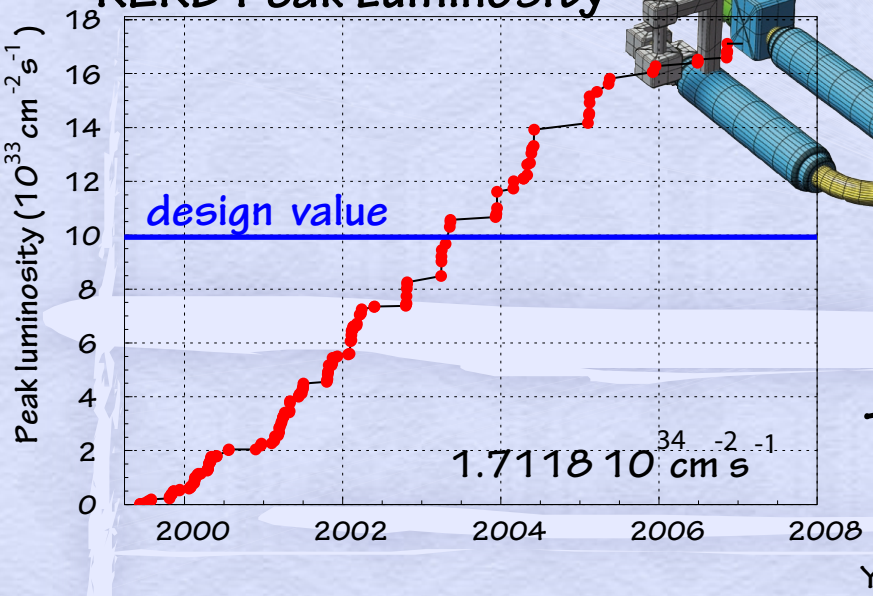
Vast numbers of B-mesons !!

KEKB Accelerator + Belle Detector



Ecm = 10.58 GeV
= @Y(4S)

Increase of
KEKB Peak Luminosity



Total ~0.85 ab^{-1}
(as of 2008/June/30)

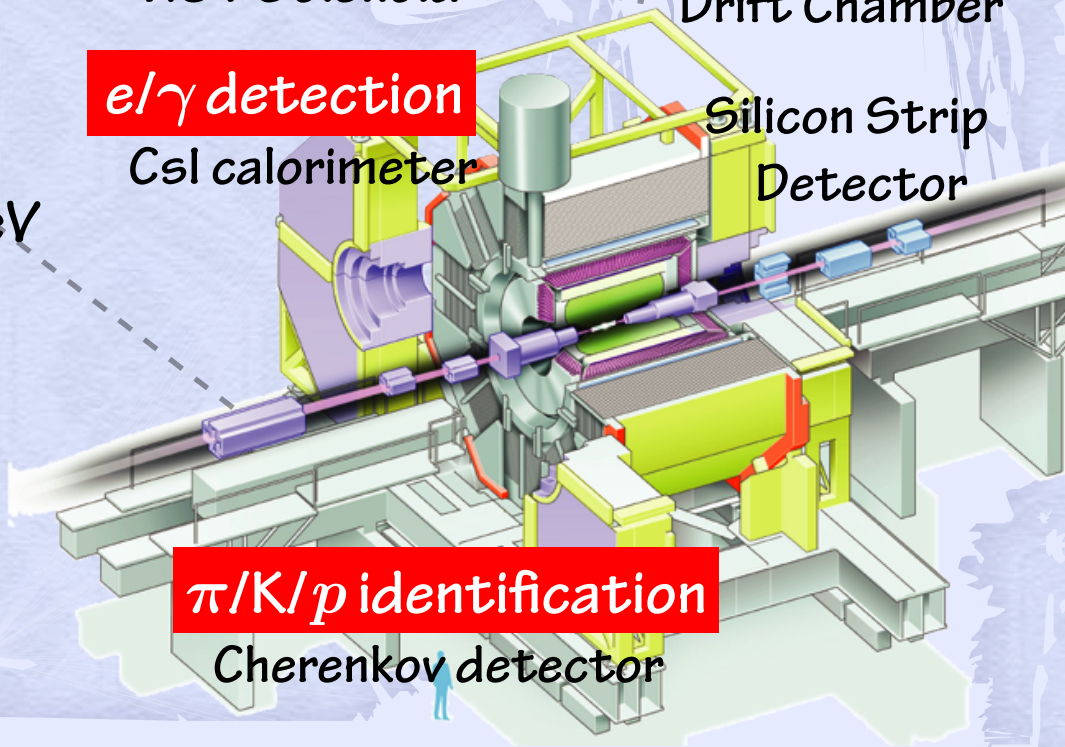
~13 nations
~400 persons

1.5T Solenoid

tracking/vertexing
Drift Chamber

e/γ detection
CsI calorimeter

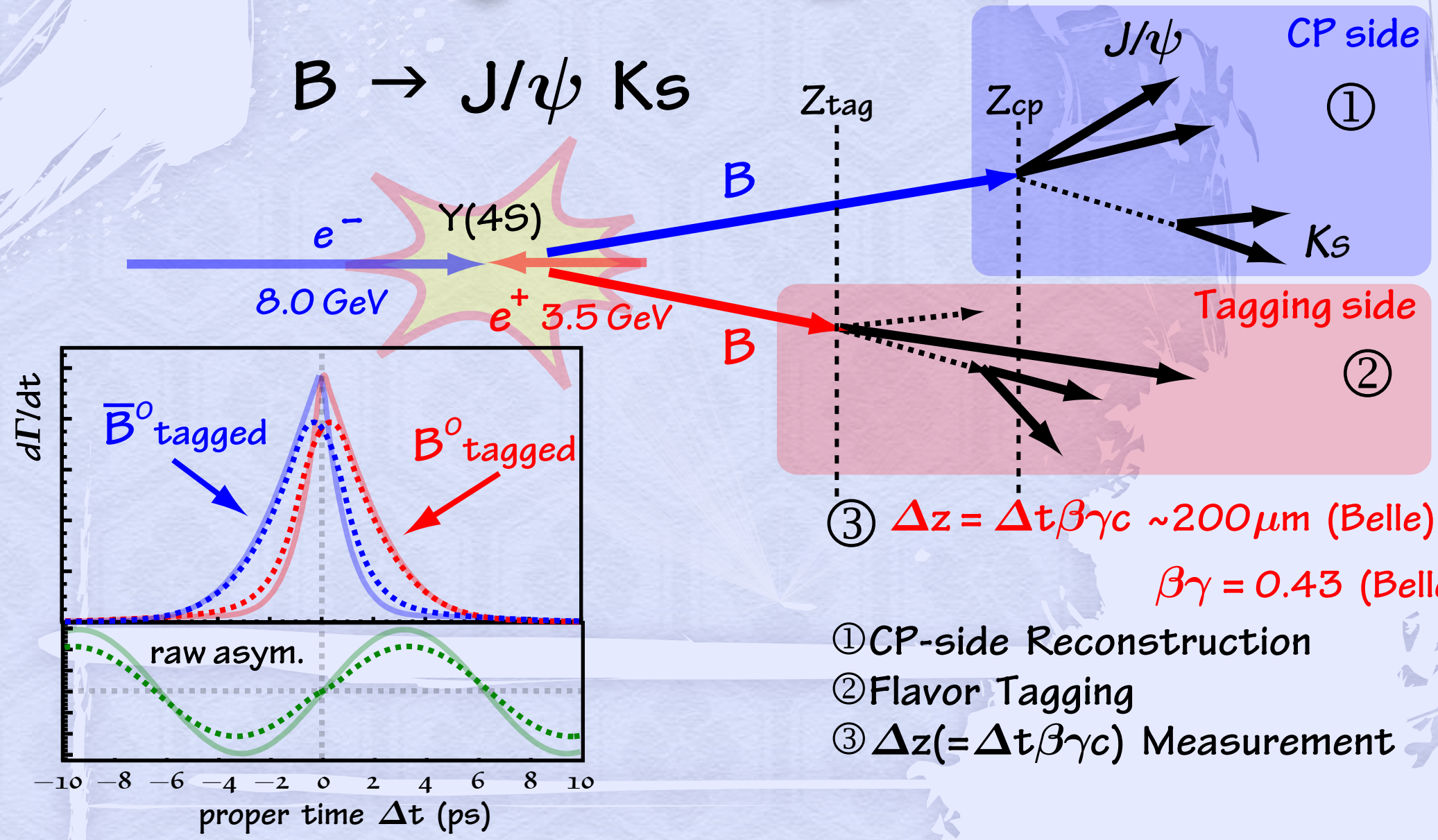
Silicon Strip
Detector



π/K/p identification
Cherenkov detector

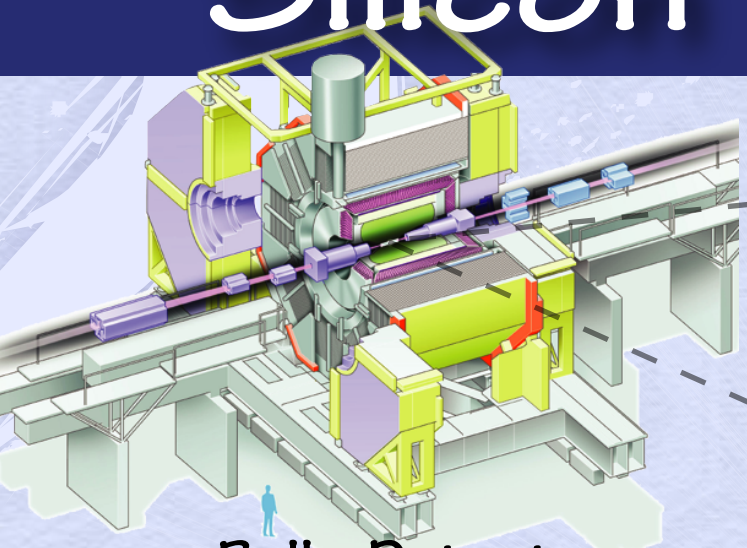
μ/K$_L$ identification
Resistive Plate Chamber

Physics @ Belle



①CP-side Reconstruction
②Flavor Tagging
③Δz(=Δtβγc) Measurement

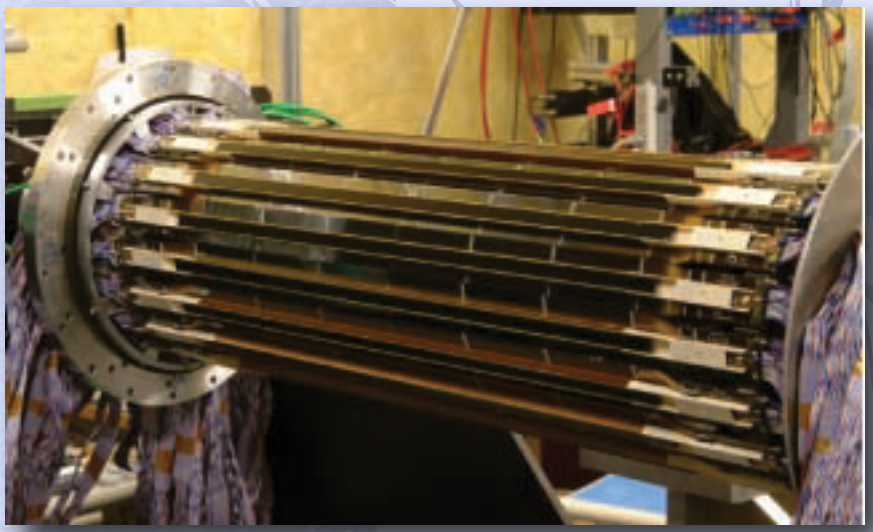
Silicon Vertex Detector



Belle Detector

over 20 institutes
~ 100 members

SVD2



SVD1 (upto 2003 summer)	SVD2 (upto now)	
3-layer (R_{3rd} = 6.0cm)	4-layer (R_{4th} = 8.8cm)	better low P tracking
2.0 (3.0) cm radius of beam pipe (1st lyr)	1.5 (2.0) cm radius of beam pipe (1st lyr)	better vertex resolution
23°< θ < 139°	17°< θ < 150°	larger acceptance
VA1 (0.8 μm) : < 1MRad	VA1TA (0.35 μm) : < 20MRad	rad. hard

Activities in SVD

1996 ~

for Belle (esp. software)

- . SVD Simulation (SVD1.0, 1.2, 1.4, 1.6, 2.0)
- . Offline data format (SVD1 → SVD2)
- . Clustering (w/ T.Hojo@Osaka)
- . Tracking (w/ K.Trabelsi@KEK)
- . trigger simulation
- . SVD2.0 design
- . Alignment
- . Data quality monitor
- . SVD3 simulation / reconstruction / physics test / design ...

SVD3 was not installed finally.

for Super-Belle

- . New readout chip test (w/ T.Tsuboyama+T.Kawasaki)
- . modification of Geant3-base simulation
- . beam background study (simulation / single-beam run data)

Configuration Design

Beam Pipe Design

Beam background components

. Particle (Beam-gas, Touschek, ...)

. SR (direct / backscattering)

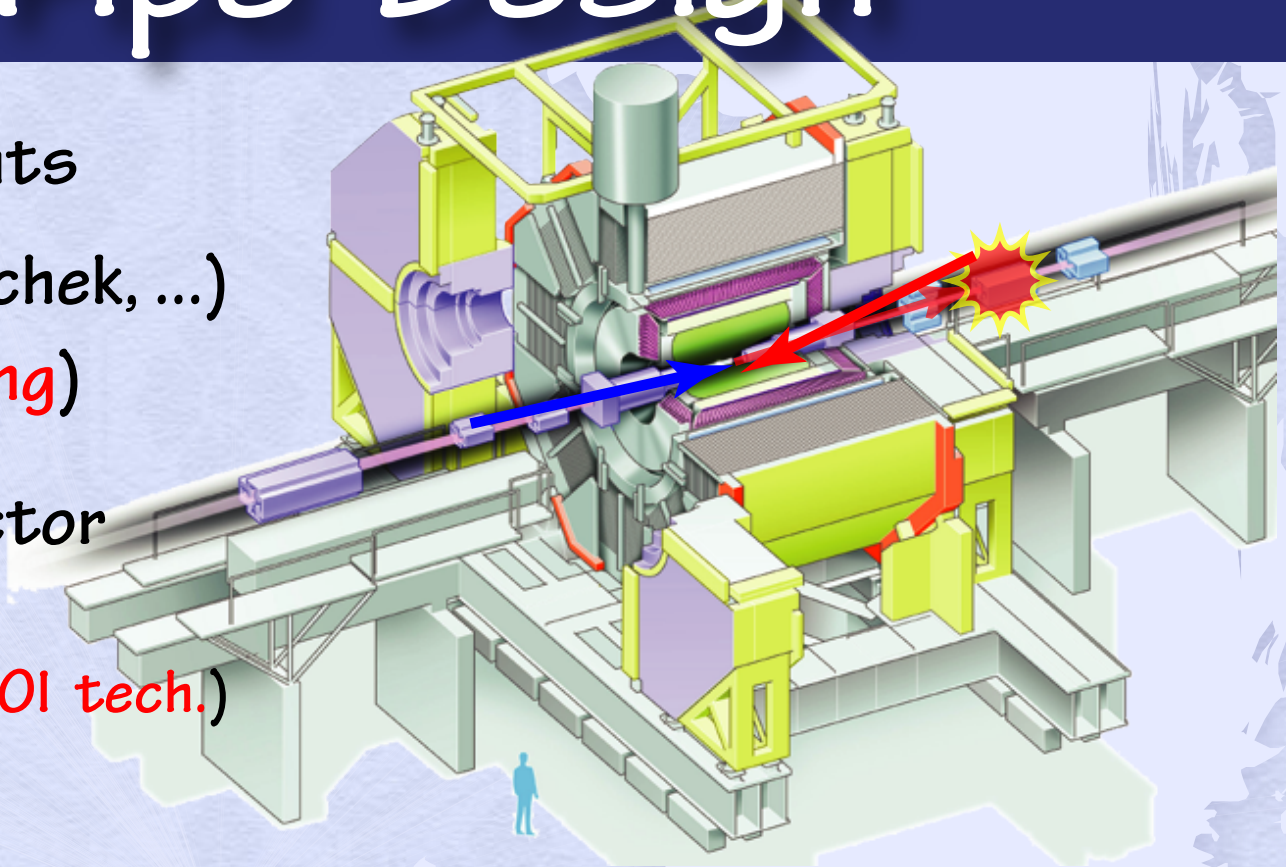
Hurdles faced by VTX detector

. High radiation
(several MRad/yr : CMOS/SOI tech.)

. High occupancy

increases fake clusters
degrades tracking performance
deteriorates vertex resolution

→ have to reduce BG hits as much as possible



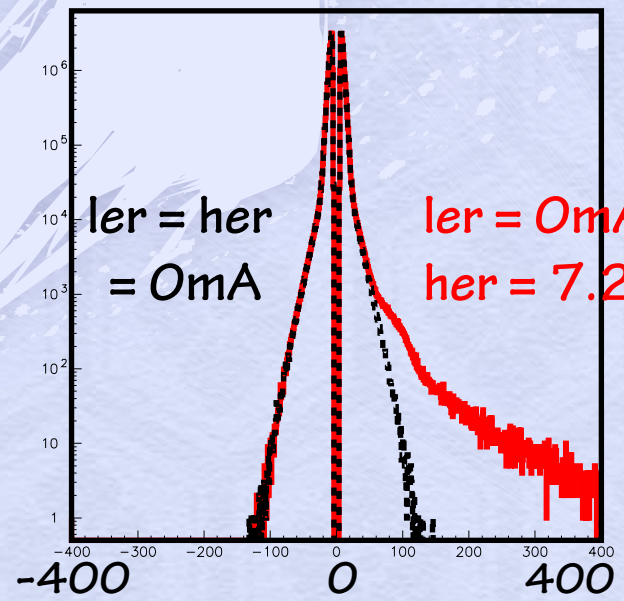
Behavior of low-E γ (<100keV) is very important !!

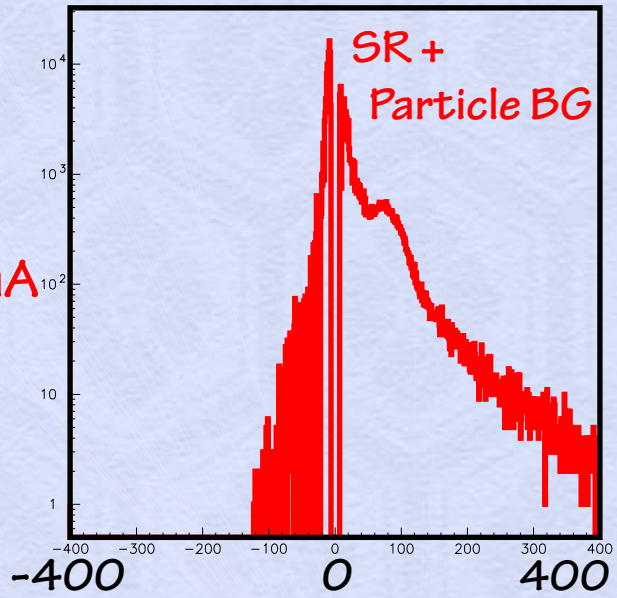
↓

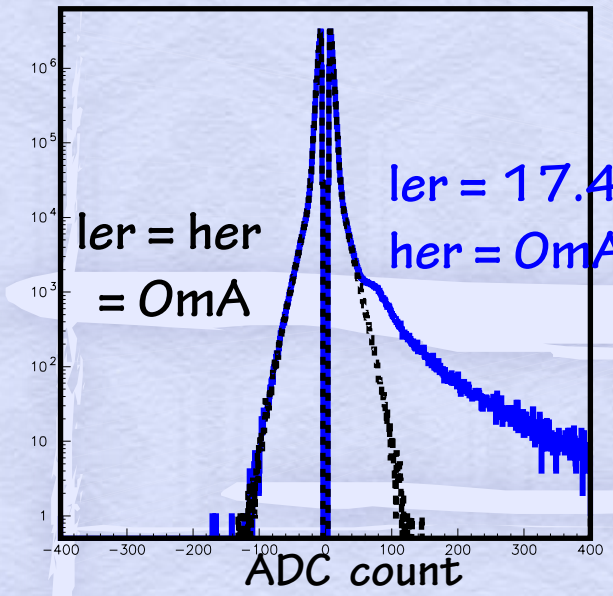
PXD Occupancy

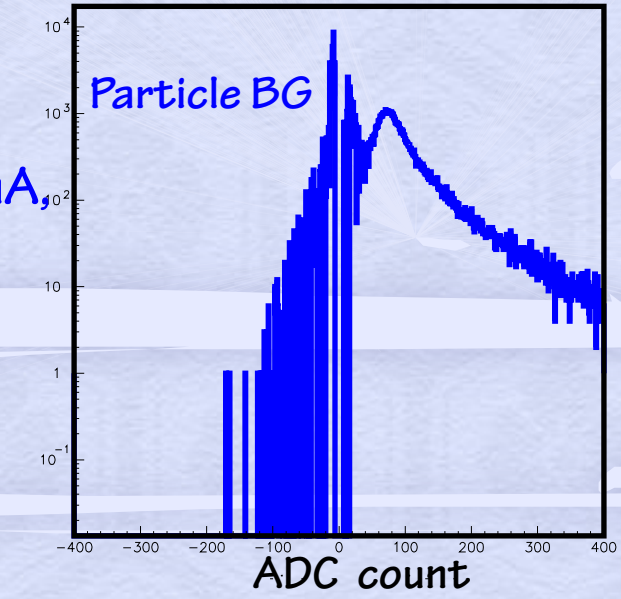
Single beam run

4,June,2008
(beam-BG study)

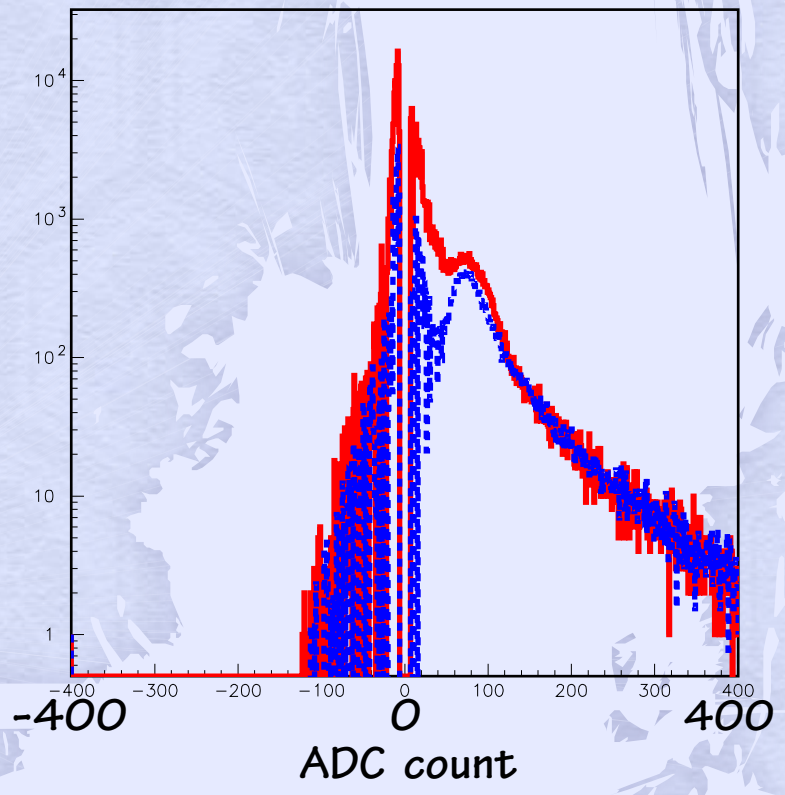








1st layer
: even Hybrid # = z-side
: face to beam pipe



low-E SR is important for occupancy in the 1st layer.

Activities in Belle

1996 ~

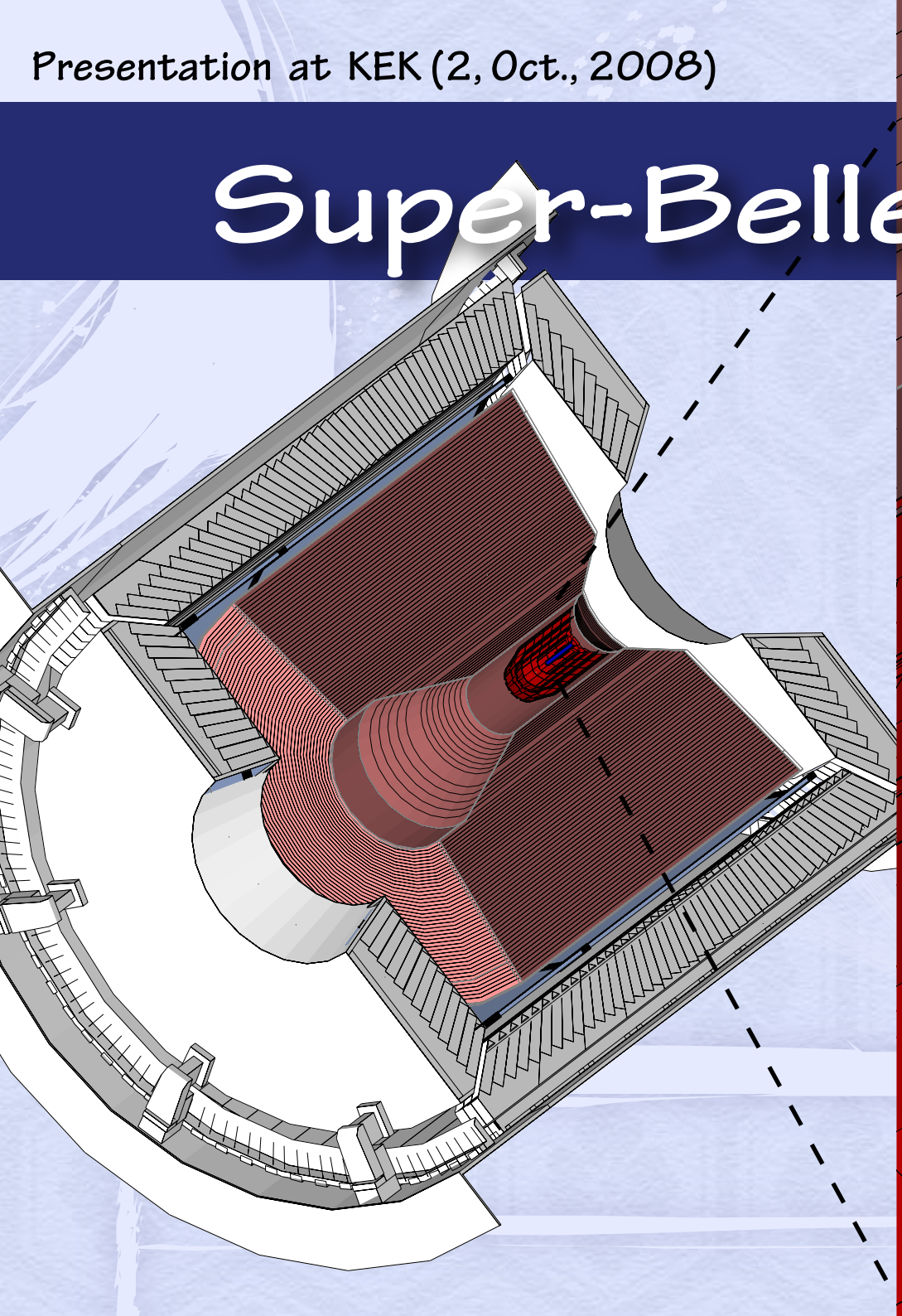
for Belle (esp. software)

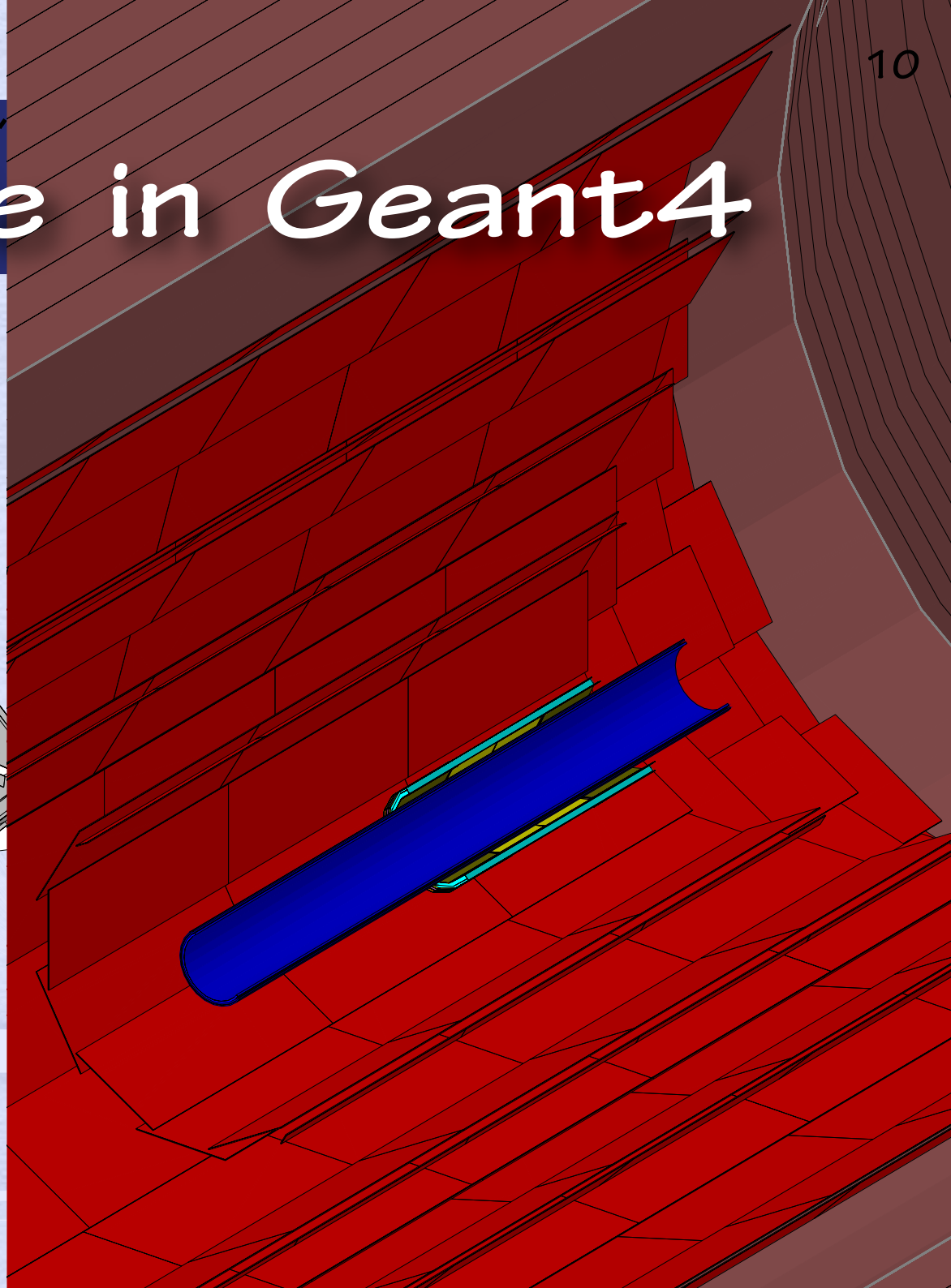
- management of Geant3-based Simulation (not only for SVD)
  - implementaion of run-dependence
- beam background overlay scheme
  - W/o this, nobody can make realistic MC data
  - effect of higher beam background
  - estimation of the tracking eff. in Hadron event (CDC, KLM)
- MC mass production

for Super-Belle

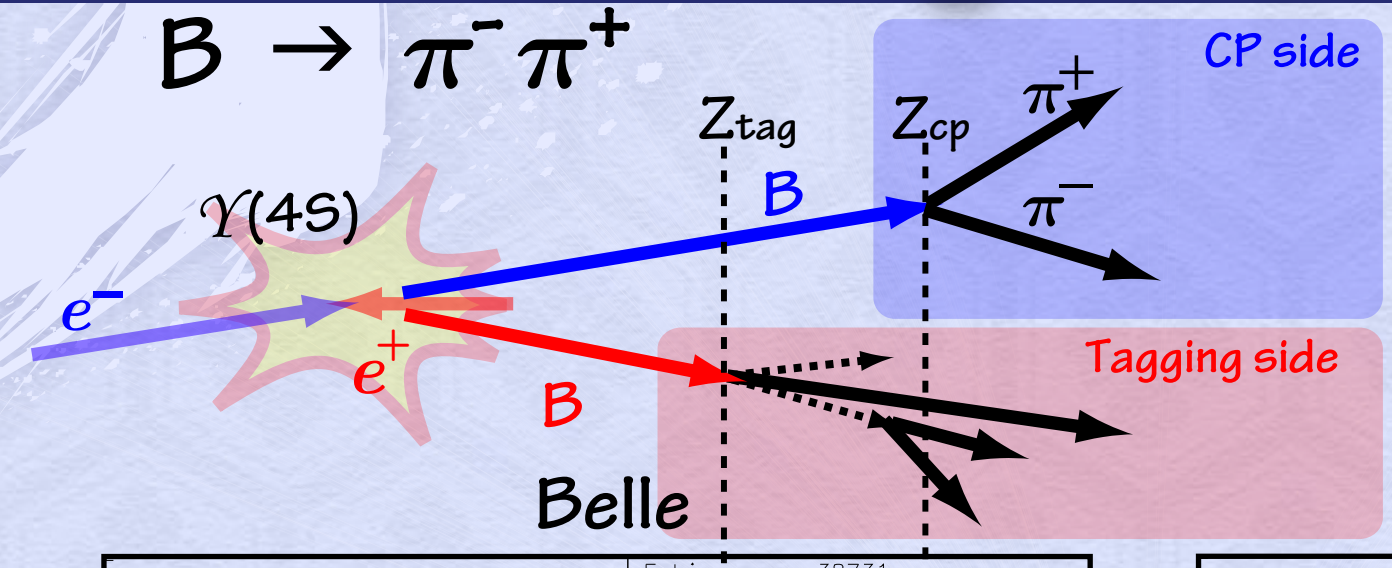
- Geant3-base simulation for Study Report (ECL, ACC, CDC, SVD,...)
  - geometrical design, BG effect, material budget ...
- tracking part of the fast simulator for physics studies
- manage and develop Geant4-base simulation for TDR

Super-Belle in Geant4



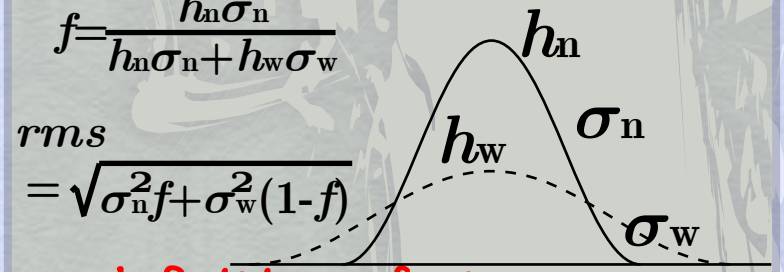


Tracking + Vertexing



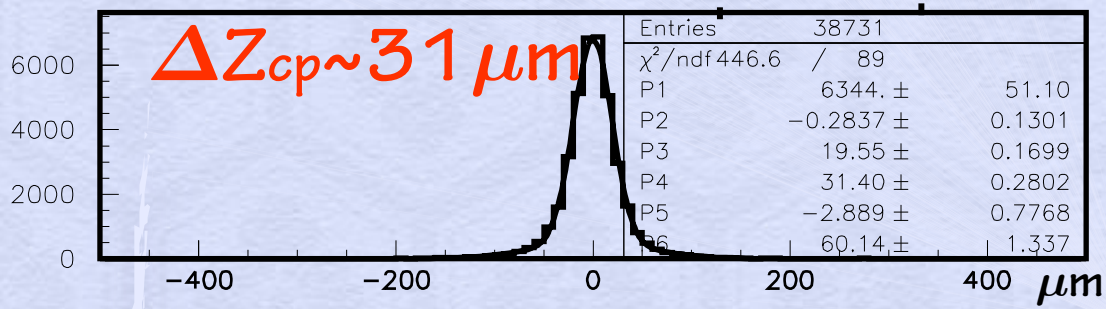
$$f=\frac{h_n\sigma_n}{h_n\sigma_n+h_w\sigma_w}$$

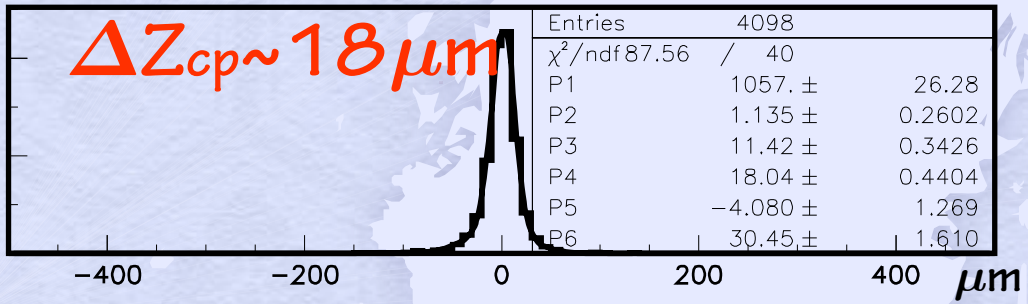
$$rms=\sqrt{\sigma_n^2 f+\sigma_w^2(1-f)}$$

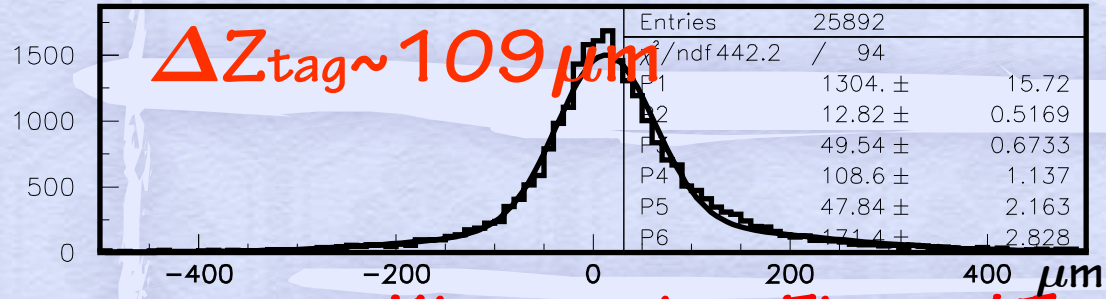


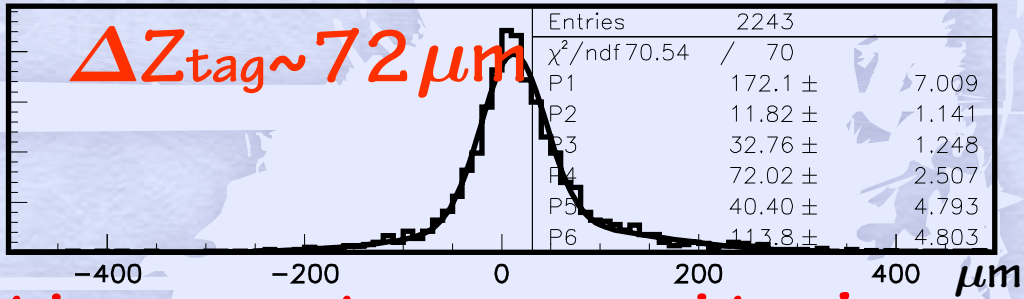
definition of vtx reso.

sBelle









Kinematics Fitter / Tag-side vertexing are working !

Activities in Belle

1996 ~

Physics analyses

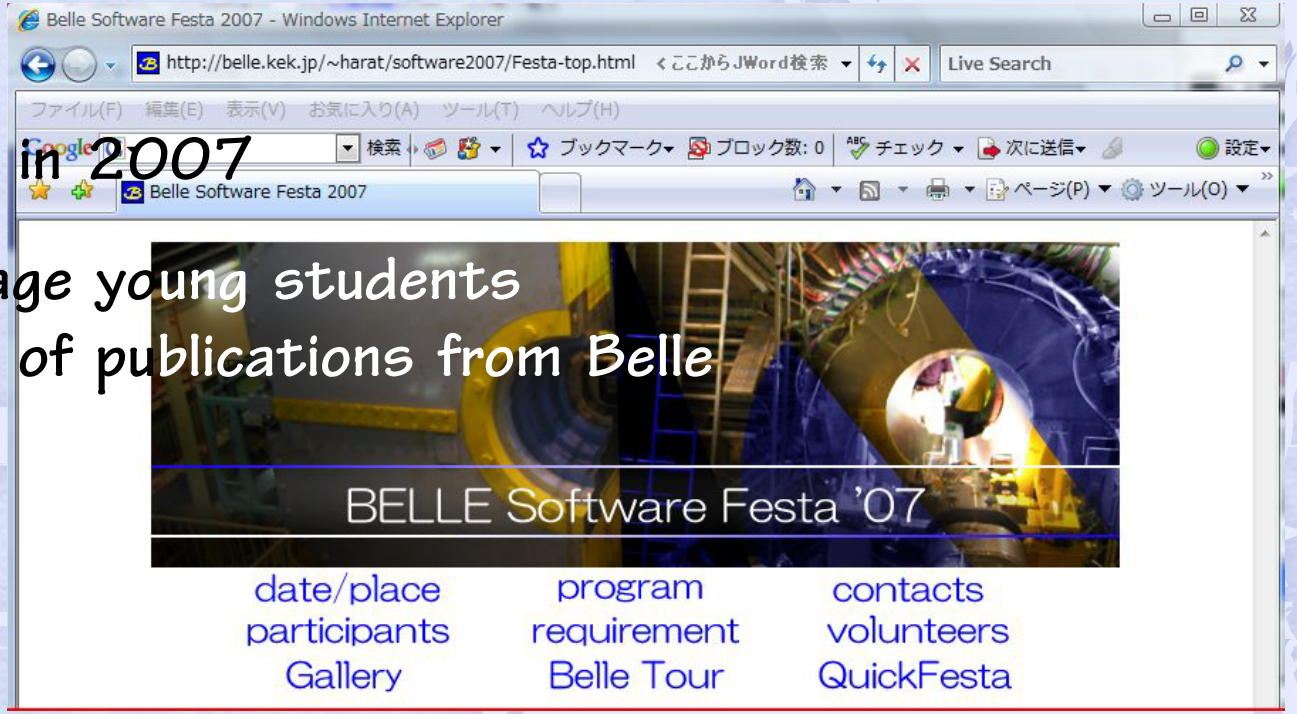
. CPV with $B \to \chi_{c1} Ks$ (w/ D.Heffernan)

. $B \to \tau \nu$ (2002 → Ikado@Nagoya in 2006)

. $B \to \phi \pi$ (2006 → a Korean student)

Education

. Software Festa in 2007



It is important to encourage young students to increase the number of publications from Belle

My works are like ...

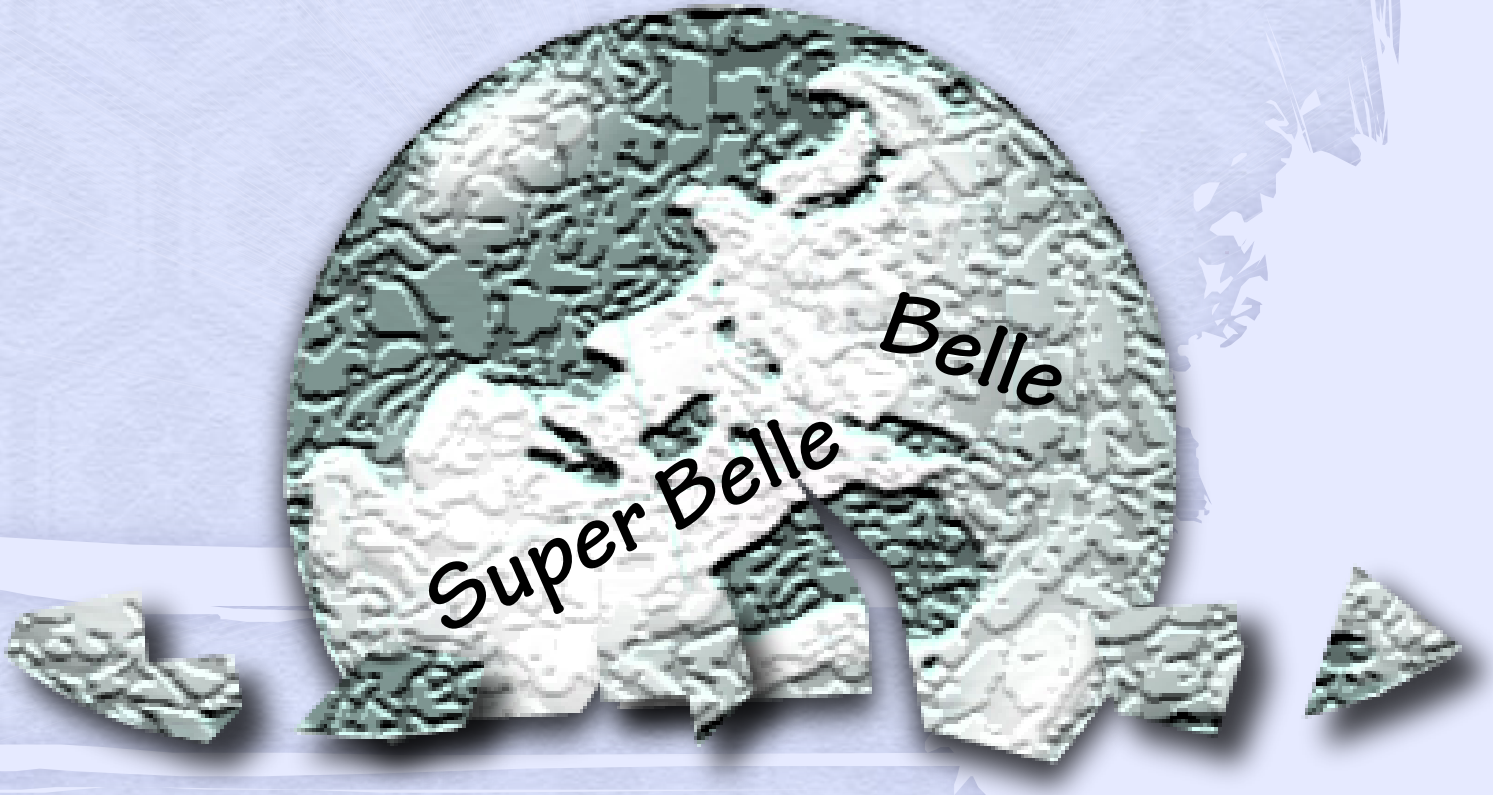
top-view

My works are like ...

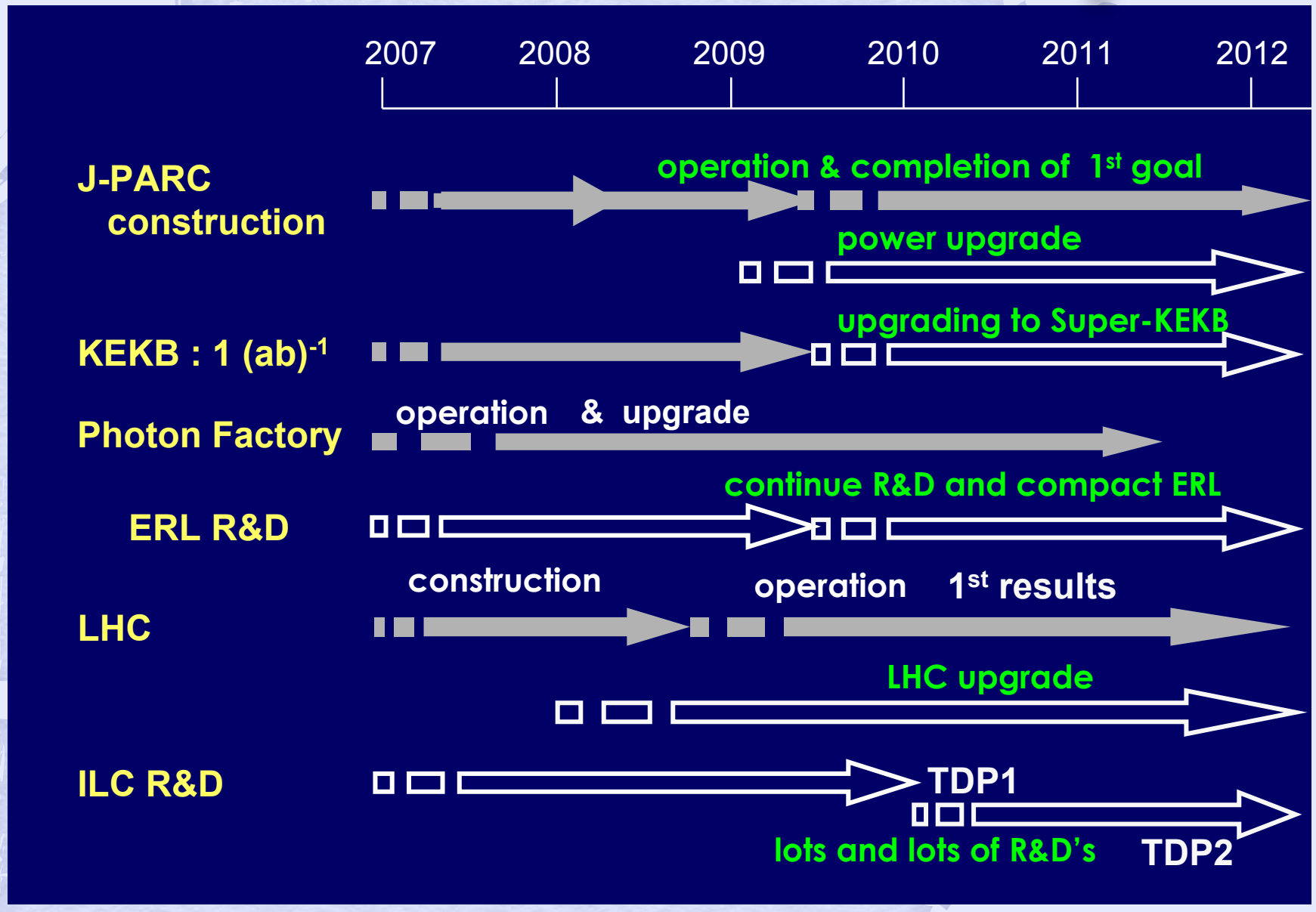
side-view

My works are like ...

Without Atlas ...



KEK Roadmap



A.Suzuki
July,4,2008

Super Belle Detector

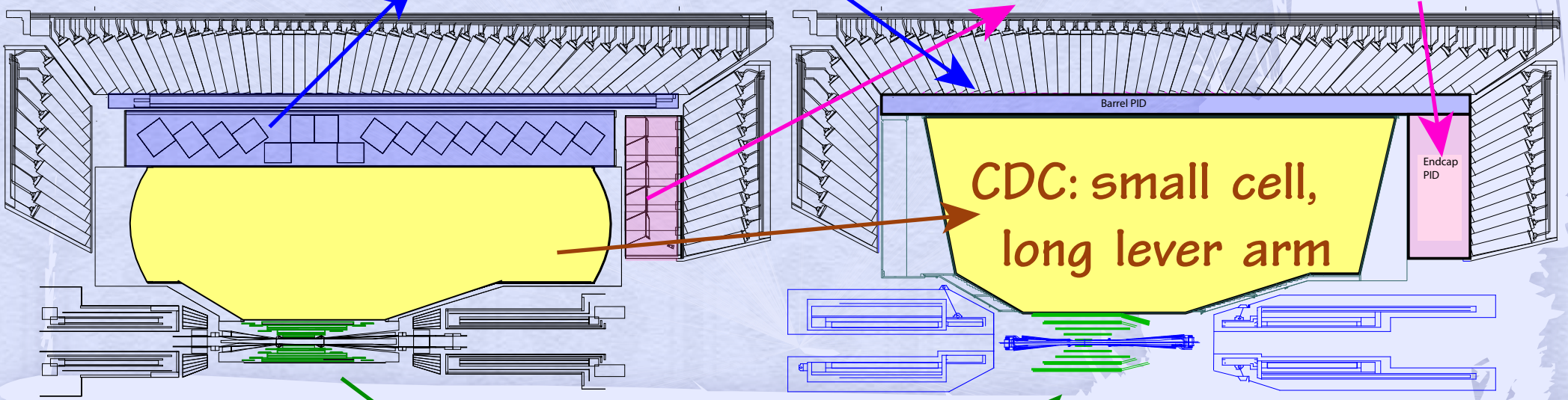
Beam BG tolerant

Belle — low material budget — Super Belle

better performance

Barrel : TOF+ACC → TOP

EndCAP : EACC → A-RICH



SVD: 4 lyr → 6 lyr DSSD (option: pixel, striplet)

ECL: waveform sampling, pure CsI for end-caps

KLM: RPC → Scintillator +SiPM (end-caps)

Plans for Super-Belle

We have only a couple of years !!

SVD+PXD

- management of Geant4-based Simulation (not only for SVD)
- reconstruction software (clustering, tracking)
  - esp. PXD+SVD self-tracking is very important for physics
    - low-P tracking cannot be done in CDC
    - impact on CPV in D*D*, etc...
    - impact on full-reconstruction event
- feedback on hardware design from physics requirement
  - check the hardware-oriented design
    - chip-on-sensor
    - detector configuration
    - systematic error caused by mis-alignment
- decision of the readout chip and pixel technology
    - full demonstration of APV25 front-end, repeater, FADC
    - DEPFET / CMOS / SOI

Chip-on-Sensor

High trigger rate (~10kHz) : Pipeline readout → APV25

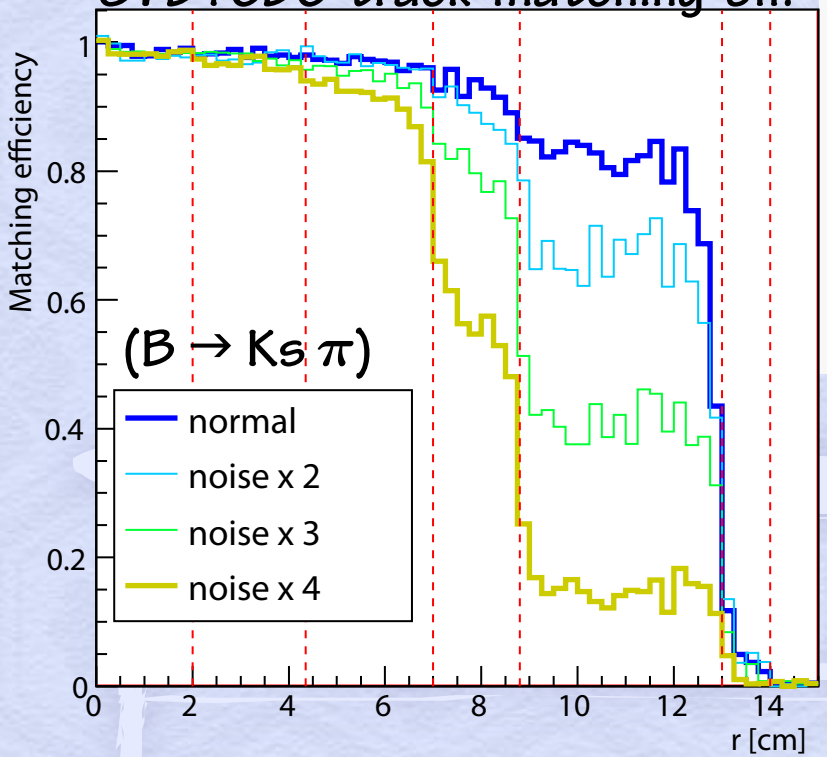
beam BG tolerant : Shorter shaping time (800nsec → 50nsec)

longer sensor + APV25 → worse S/N (VA1TA ~16 for outer layer)

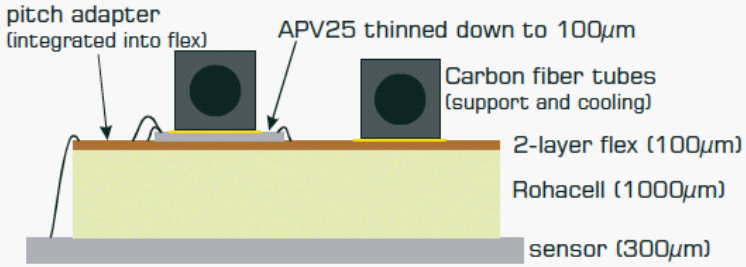
R=16cm

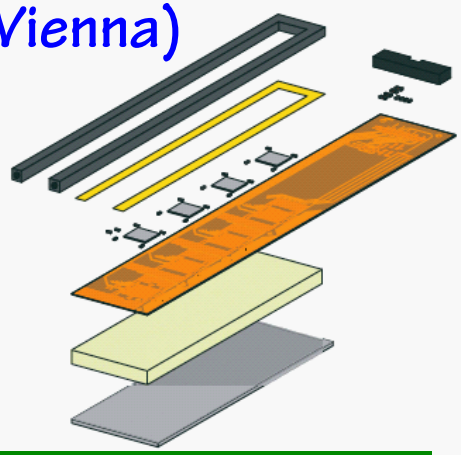
$17° < \theta < 150°$

SVD+CDC track matching eff.



Chip-on-Sensor (proposed by Vienna)





CP side	$\pi^+\pi^-$	$J/\psi Ks$	D^+D^-
$\sigma_{2\times\rho}/\sigma_{\rm def}$ all SVD+CDC lyrs	−6 % $\sigma\cong 31 \rightarrow 33\mu$m	−11 % $\sigma\cong 36 \rightarrow 40\mu$m	−19 % $\sigma\cong 43 \rightarrow 51\mu$m
$\sigma_{2\times\rho}/\sigma_{\rm def}$ all SVD lyrs	−6 % $\rightarrow 33\mu$m	−11 % $\rightarrow 40\mu$m	−21 % $\rightarrow 52\mu$m
$\sigma_{2\times\rho}/\sigma_{\rm def}$ 1+2 SVD lyrs only	−6 % $\rightarrow 34\mu$m	−11 % $\rightarrow 40\mu$m	−19 % $\rightarrow 51\mu$m

Technology options

	DEPFET	CMOS (CAPS/MAPS)	SOI
Material budget	20 ~ 100 μm (adjustable)	<~50 μm (sensitive area 5~10 μm)	50~100 μm (could be <~50 μm)
Size	limited by wafer (50×75 mm^2)	limited by reticle (21×21 mm^2)	limited by reticle (21×21 mm^2)
Power consumption	small (0.5w) (reset switcher chip : Voltage swing > 8V)	small	small
Rad.-hardness (3MRad/yr ?)	tested < 1MRad (up to 8MRad? : irradiation test)	intrinsic rad. hard (must be > 30MRad)	tested > 30MRad
10kHz trig. rate	estimated ~1% ineff.	? (CAP3 too slow)	not proved
Availability	MPI only (already used in other exp.)	R&D in progress	R&D in progress

Plans for Super-Belle

We have only a couple of years !!

Super-Belle

- management of software
  - reconstruction tools
    - vertexing (PXD, SVD)
    - tracking (PXD, SVD, CDC)
    - PID (CDC, A-RICH, TOP, ECL, KLM)
  - GEANT4-base simulation (required for TDR)
  - analysis tools
    - tag-side vertexing, etc...
  - software framework (BASF, Marlin, etc...)
- Improvement of hermeticity
  - important for $B \to \tau\nu$, $K\nu\nu$
- beam background study
  - feedback on the IR design
  - check the occupancy of the PXD / SVD

Current Problems

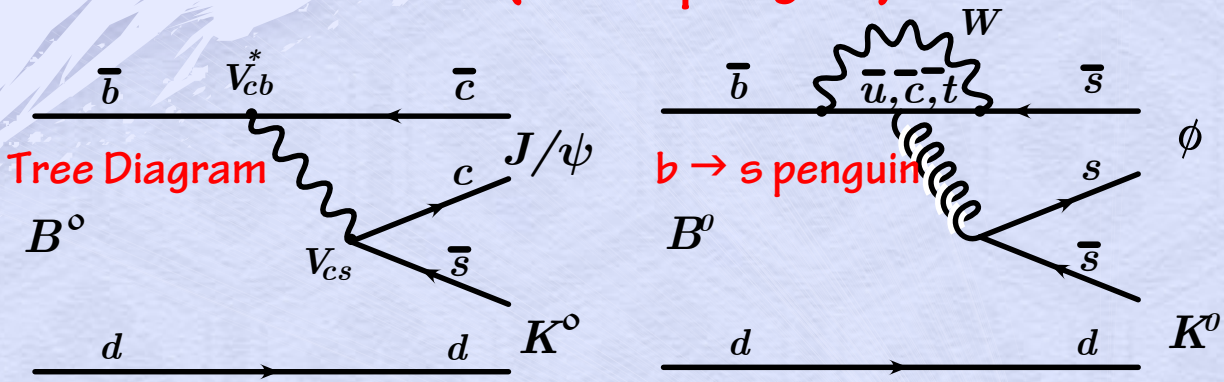
- less communication
- unplanned update
- human resource

need a "head"

Plans for Super-Belle

Super-Belle Physics

. CP Violation (b → s penguin)



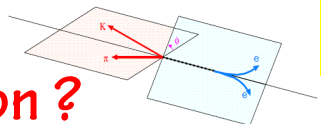
. CP Violation
(B → K*^{0}γ polarization)

γ internal conversion ?

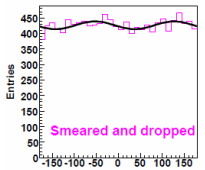
H.Ishino @BNM2008

γの偏光の直接測定

$B^0 \to K^* \gamma$、$K^* \to K\pi$

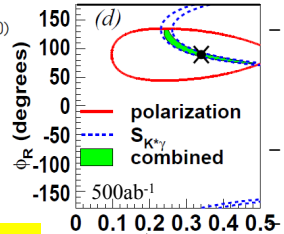


Grossman-Pirjol JHEP 0006,029(2000)



右巻きγが混じるとモジュレーションが現れる

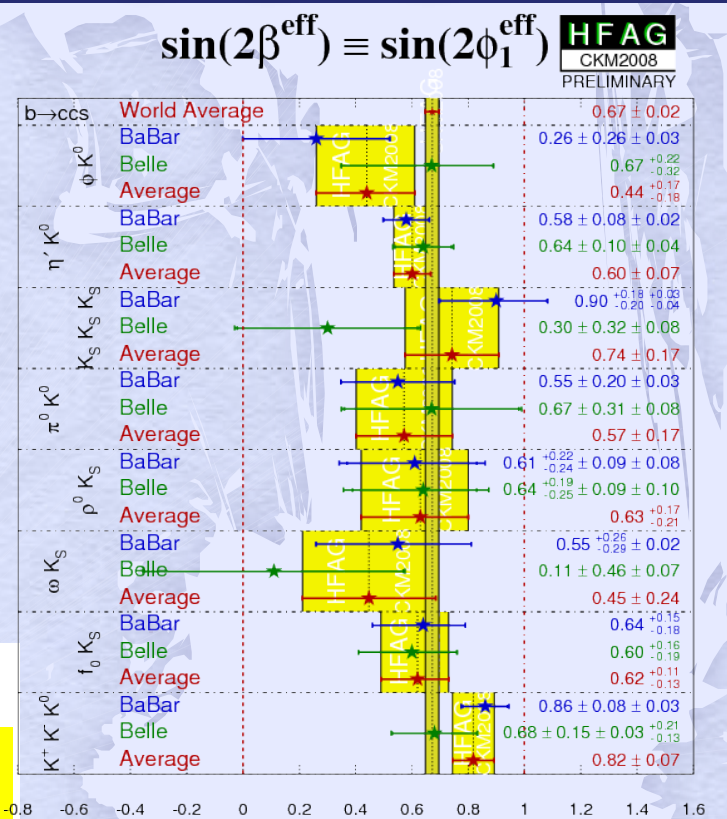
- γ→e^+e^-電子対生成を利用
  - ビームパイプまたはシリコン検出器
  - 現Belle実験検出器では3%の確率で発生
  - SBFでのみ可能な測定



- タングステン箔を挿入、またはCdTeストリップ検出器を使えば5倍の検出効率
- 事象再構成アルゴリズムの改善も必要

挑戦者を求む！

$R = \frac{|F_L||F_R|}{|F_L|^2 + |F_R|^2}$ hep-ex/0703039



. B → τν, Kνν
Full-recon. tagging

Backup

Activities in Kamioka

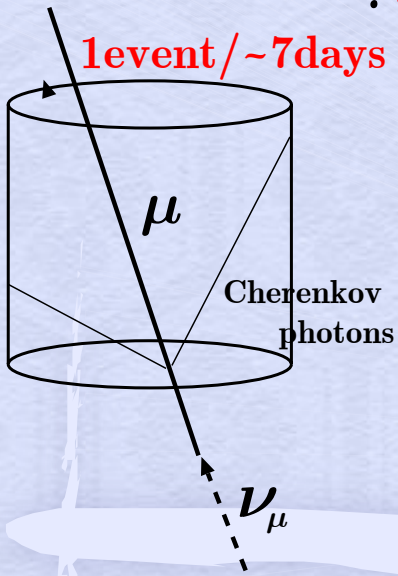
1991 ~ 1996

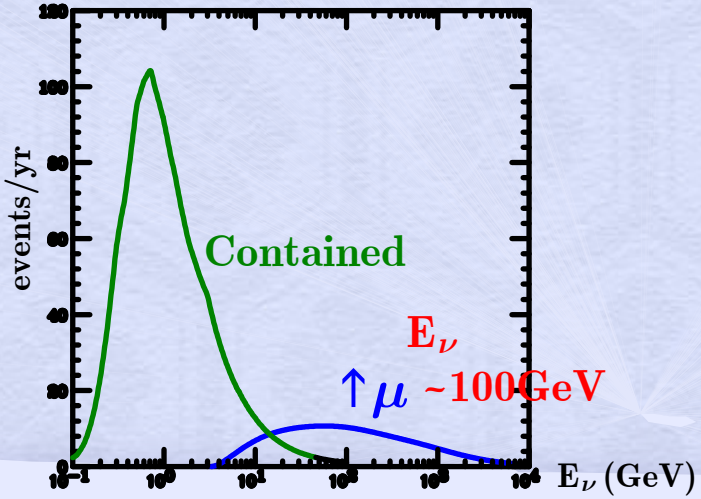
Kamiokande-III

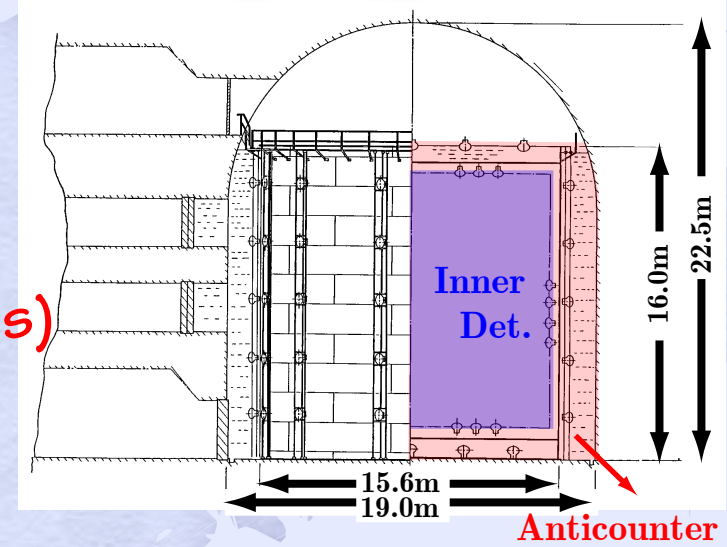
. High-Volatage monitor

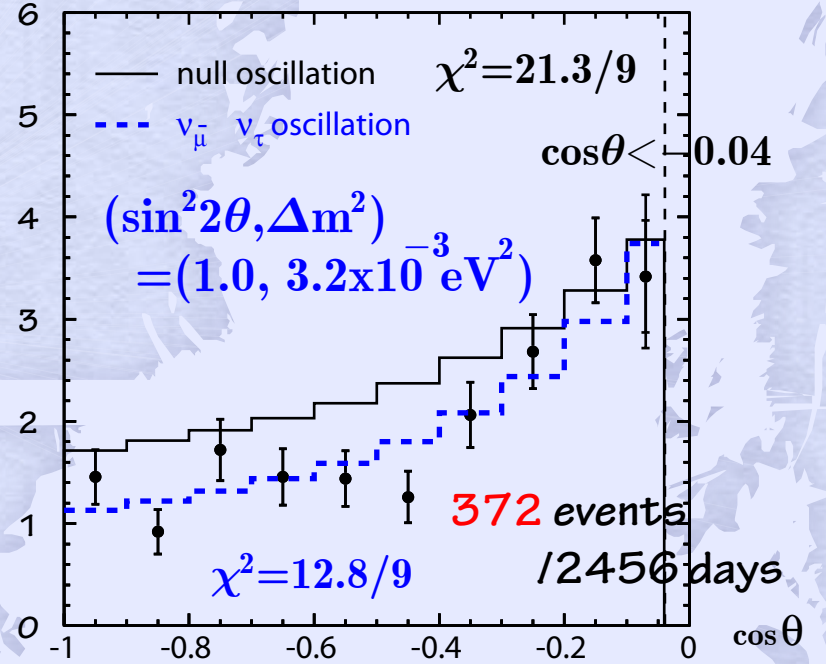
. Upward-stopping muon (master thesis)

. Upward-through going muon (PhD)







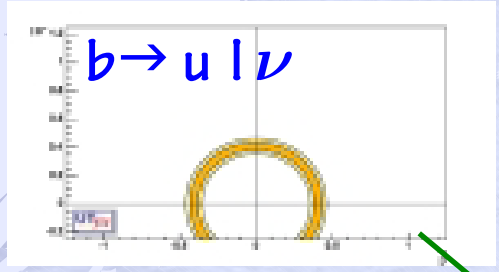


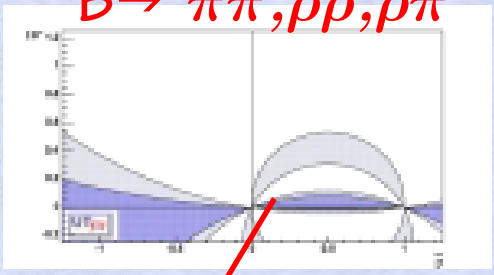
$\Phi_{obs} = 1.94 \pm 0.10(stat.) \pm^{0.07}_{0.06}(syst.) \times 10^{-13}$ cm^{-2}s^{-1}sr^{-1}

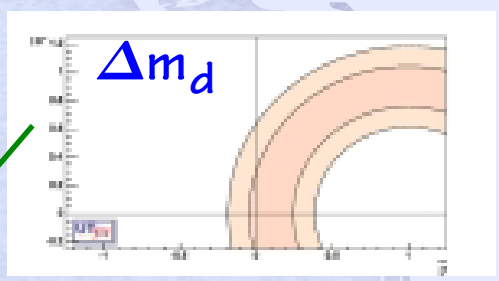
$\Phi_{theo} = 2.46 \pm 0.54(theo.) \times 10^{-13}$ cm^{-2}s^{-1}sr^{-1}

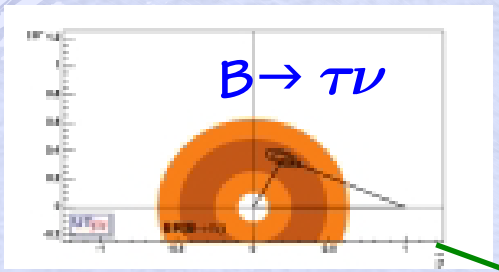
$\nu_\mu \leftrightarrow \nu_\tau$ osc. (PRL 81,2016(1998)) confirmed by SK

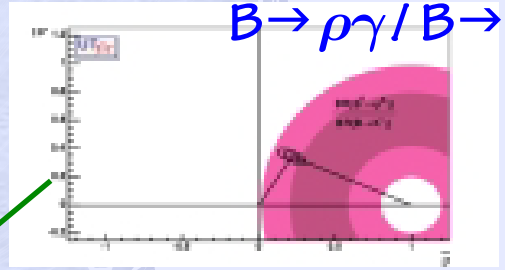
Physics Results





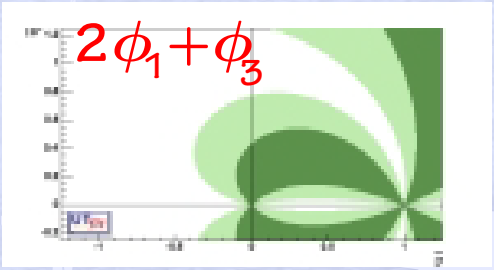


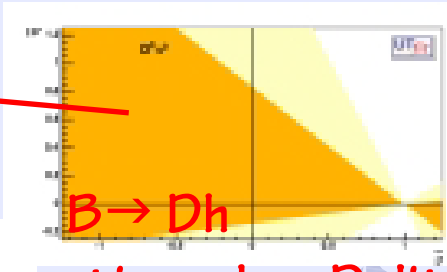




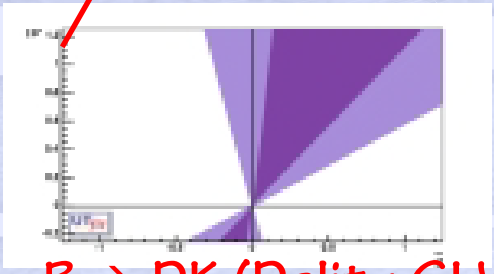
$\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}$ ϕ_2 $\frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*}$

ϕ_3 ϕ_1





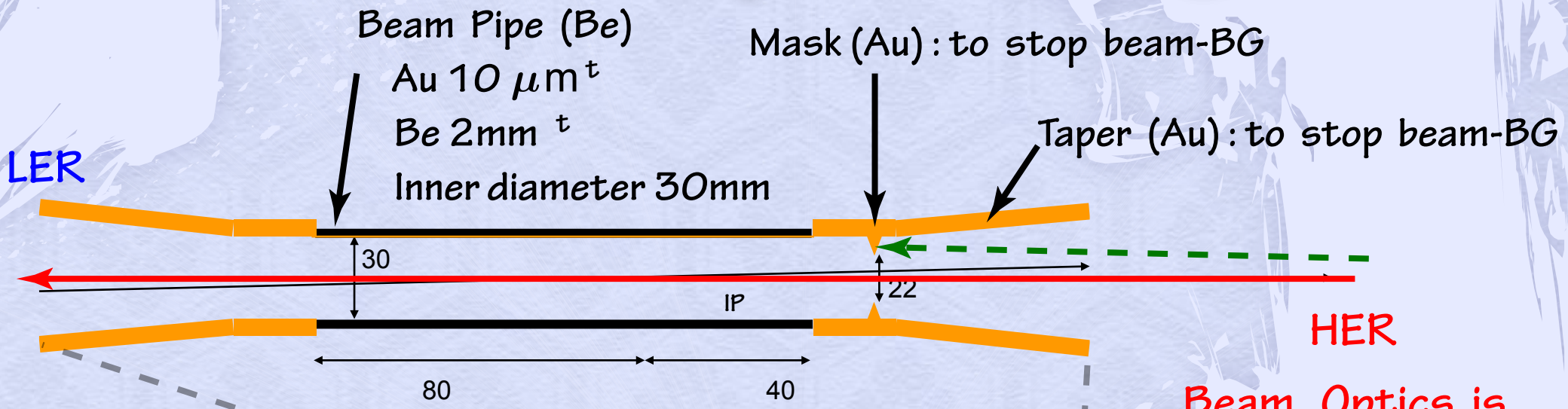
time-dep. Dalitz



B→ DK (Dalitz,GLW)

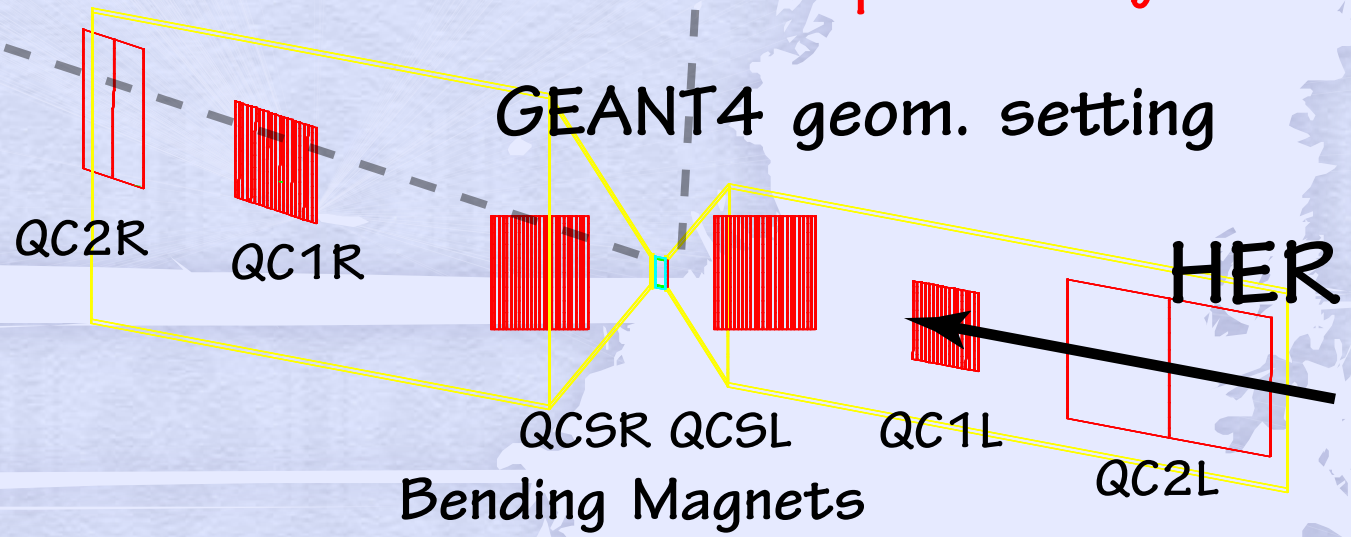
B→ J/ψKs

Beam Pipe Design



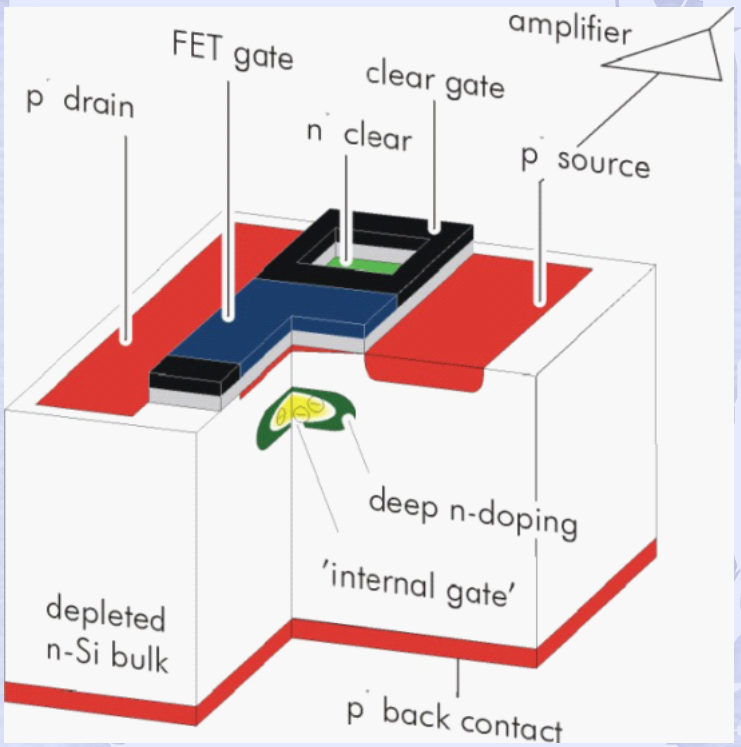
Beam Optics is provided by KEKB

Mask : Shape
: Height
: Position
: Material, ...

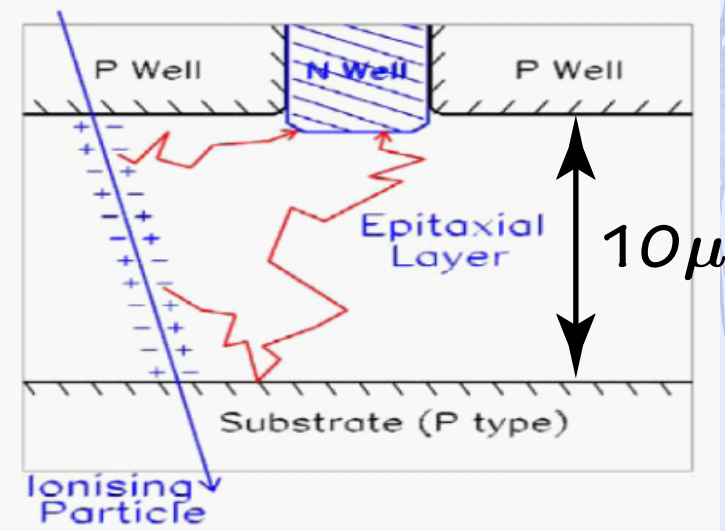


DEPFET

. Intense R&D has been done for ILC pixel sensors
has been used in several experiments already!
. Technology is available in MPI only
. Sensor size is limited by wafer size
50 μm x 75 μm : 215 x 512 pixel (adjustable)
almost no gap in the acceptance
. Not very rad-hard (tested up to 1Mrad)
OK up to 8Mrad ??
. Small power consumption
. Reset switcher chip: Voltage swing > 8V
. Thickness 20μm ~ 100μm (adjustable for experiments)
. Doubly-correlated sampling can be done → low noise
. 10kHz trigger rate, 0-suppression, ~4pixels/hit, 32 bits/pixel includiing address
Disadvantage: ~1% inefficiency
. Data processing is done in subsequent chips
on repeater system or in backend system



CMOS pixel (CAPS/MAPS)



. The same technology as commercial CMOS cameras
  5-10M -pixel chips are in production
. Sensor size is limited by reticle size (21 x 21 mm^2)
  22.5 μm x 22.5 μm
  gap in the acceptance
. Intrinsic rad-hard (deep sub-micron technology)
  > 30 MRad
. Sensor is a thin epitaxial layer (5~10μm thick)
  signal si small → No problem as the detector capacitance is also small
  <= 50μm
. N-well is used to collect charge from the epitaxial layer
. 100kHz frame rate is achieved (132 x 48 pixel)
  Full-size detector (928 x 128 pixel)
  10kHz trigger rate ???

SOI

. Activity started as
one of KEK detector R&D project in 2005

. Sensor size is limited by reticle size (21 x 21 mm^2)
20 μm x 20 μm : 128 x 128
gap in the acceptance

. rad-hard (deep 0.2 μm technology)
tested > 30 MRad

. Depletion depth of 50-100 μm has been achieved
thinning after silicon process
<= 50 μm

. Signal induced in the sensor can be processed by the CMOS circuit
Complex/rad-hard circuit can be made
DEPFET/CAP type readoout is also possible
10kHz trigger rate ???

. R&D in progress
Evaluation of Belle PIXEL chip will start soon
(pixel-shaper-discrimination-digital pipeline)