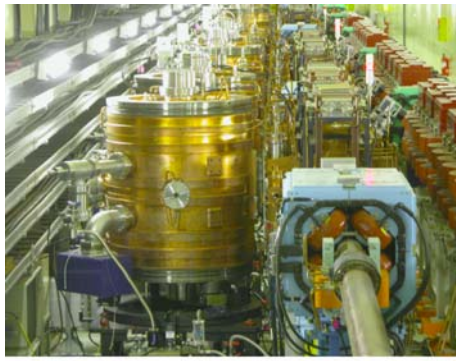
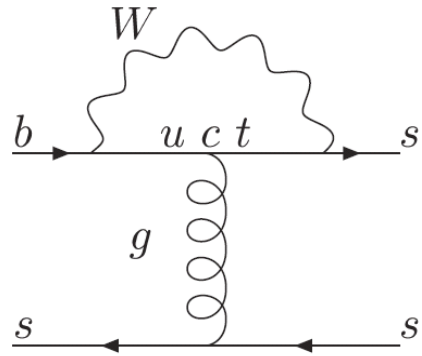
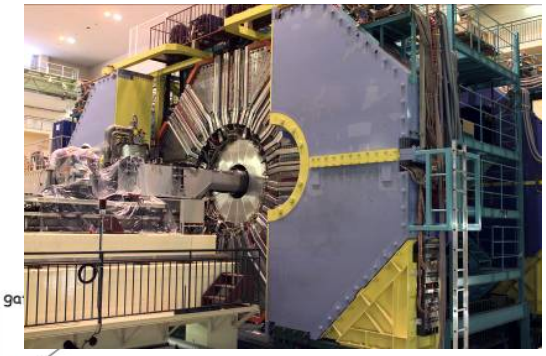
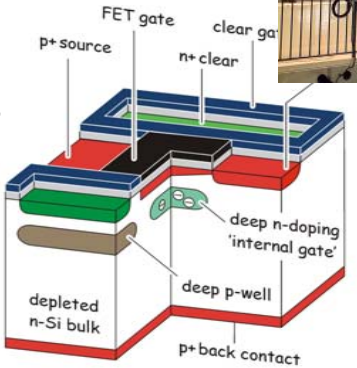
The SuperBelle Experiment at the KEKB Facility in Japan

- Physics Motivation
- Machine & Detector
- DEPFET PXD Planning
- News from Recent Meetings









The way to SuperBelle …

Long term planning of the Institute:

→ Participate at a second accelerator experiment (apart from LHC)

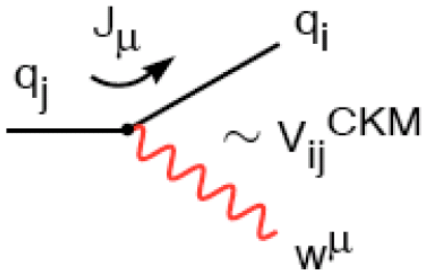
- Strong group at MPI to develop detector concepts for a future e^+e^- Linear Collider (ILC)
- Embedded within larger collaborations („DEPFET“, „CALICE“)
- Schedule for the ILC roughly defined, but very uncertain

→ The Institute has a rich history of participating in e^+e^- experiments:
DASP, CUSB, CELLO, JADE, ALEPH, OPAL

→ Visit by M. Yamauchi / K. Oide (BELLE/KEK-B Factory) in Feb. 2008

- want to upgrade KEKB to SuperKEKB (50-80 x lumi) by 2013
- need a pixel vertex detector for the upgraded (SuperBelle) detector to be ready for installation by the end of 2012

Flavor Physics and CP Violation



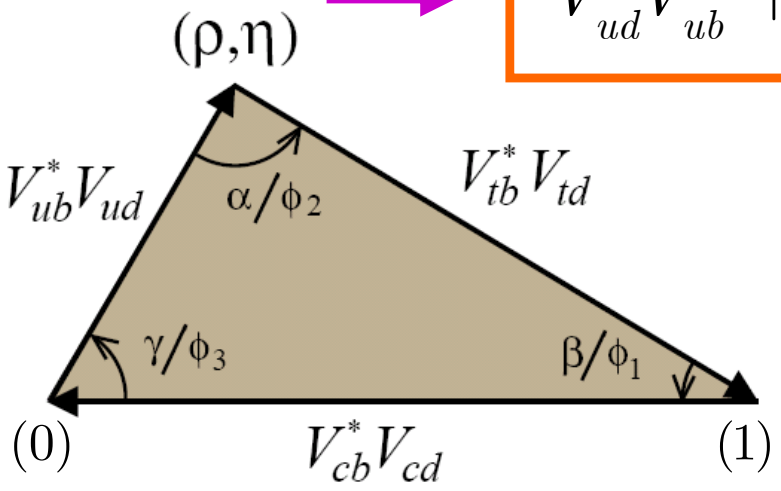
weak decays of hadrons (quarks change flavor) are described in the SM by the CKM matrix

Cabibbo, Kobayashi, Maskawa

$$V^{\mathrm{CKM}} \equiv \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

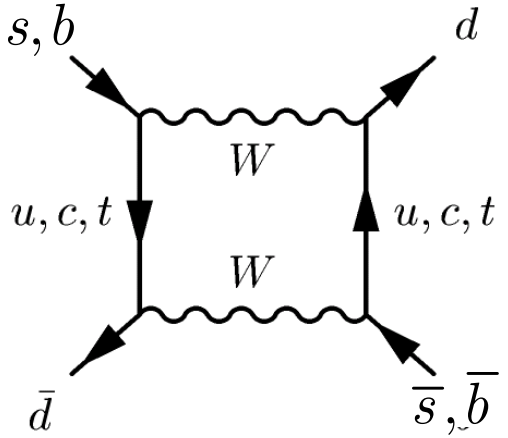
$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

$$\lambda = \sin\theta_C$$



$\eta \neq 0$: CP

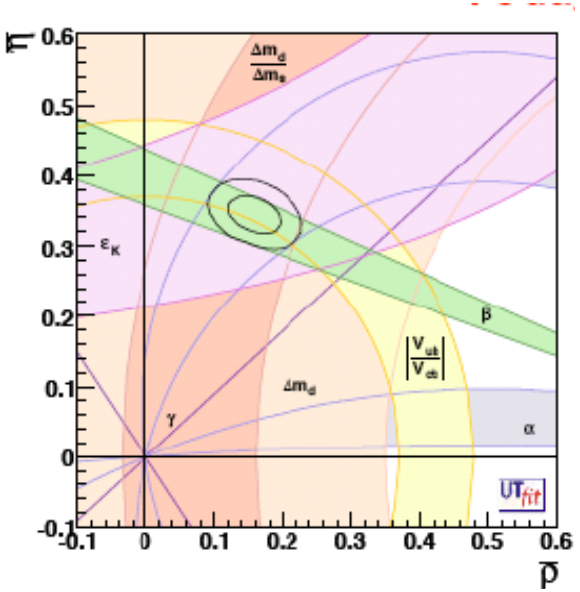
$$\bar{K}^0 \rightarrow K^0$$
$$\bar{B}^0 \rightarrow B^0$$



Why is the Physics @ SuperBelle interesting ?

Nobel Prize 2008: Kobayashi & Maskawa

The Standard Model SU_3 x SU_2 x U_1 (SM) describes all data so far,
yet: cannot be the correct theory, SM only a „low energy“ approximation



need much higher precision

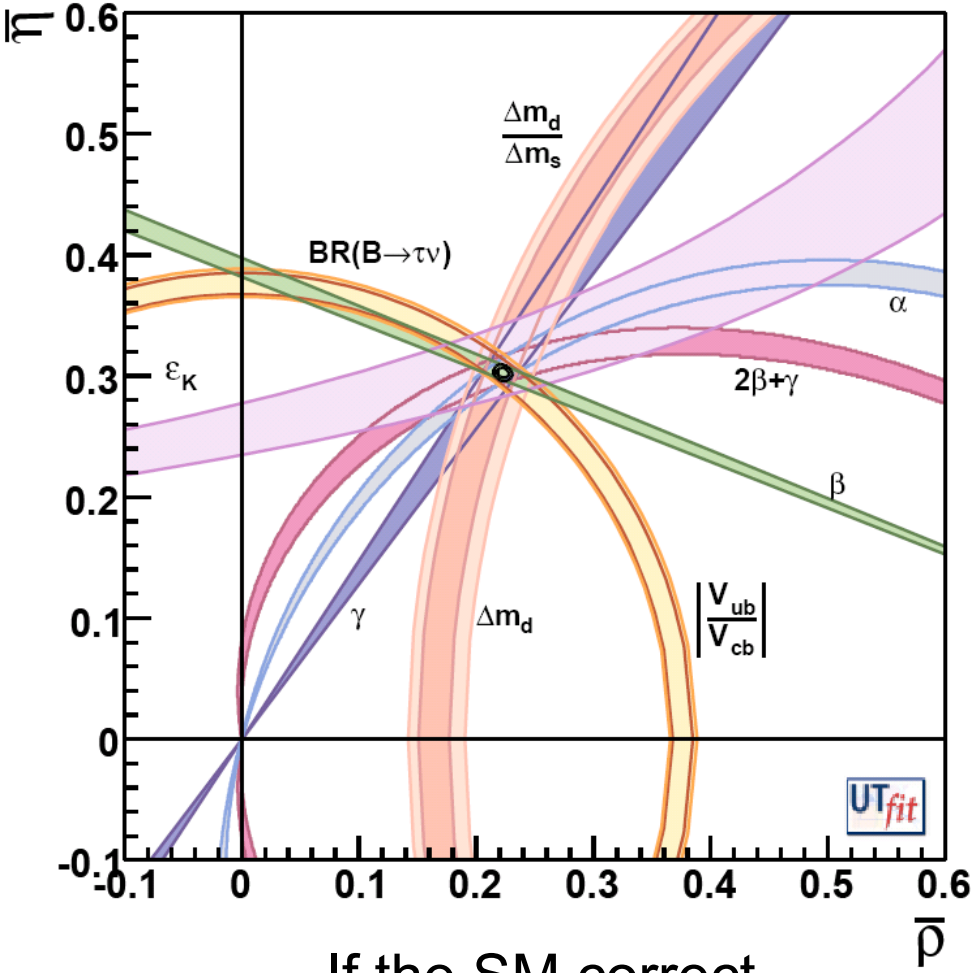
Evidence for Physics beyond the Standard Model:

- Dark Matter exists
  (only 4% of the Universe accounted for by SM)
- Neutrinos have mass (Dirac, Majorana?)
- Baryon Asymmetry is too large
  (new sources of ~~CP~~ needed)

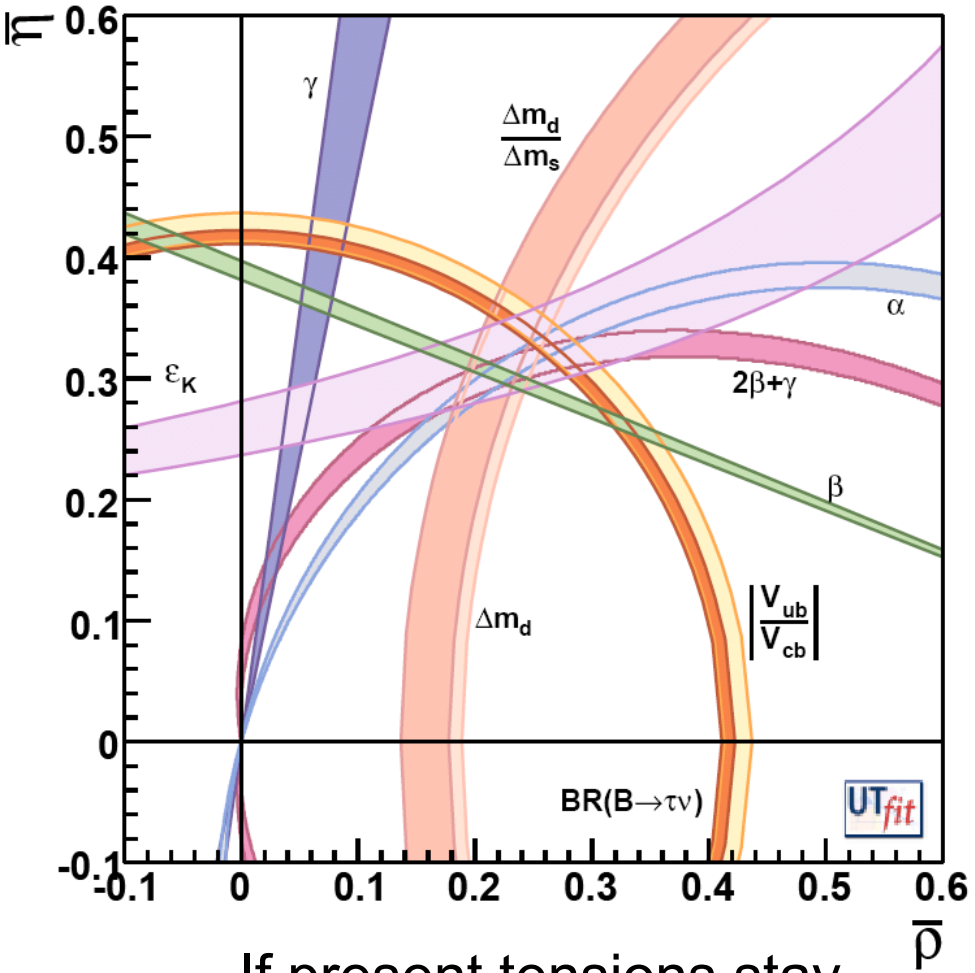
At least two of them have to do with CP Violation

The Unitarity Triangle in the Year 2020

$$\int \mathcal{L}\,dt = 50\ \mathrm{ab}^{-1}$$ (50 times more than now)

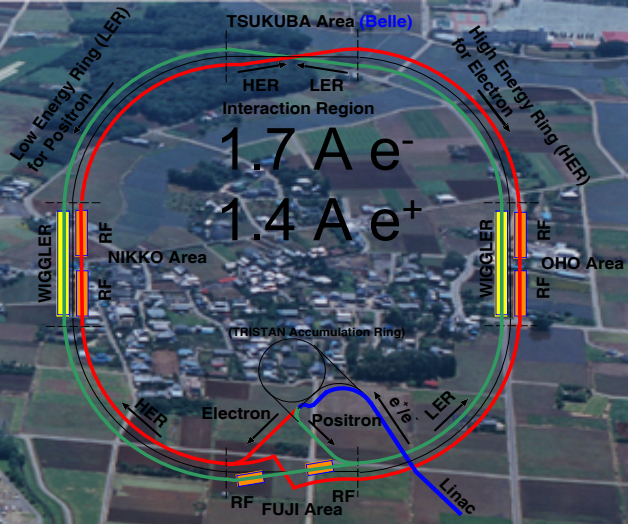


…. If the SM correct
(the nightmare)

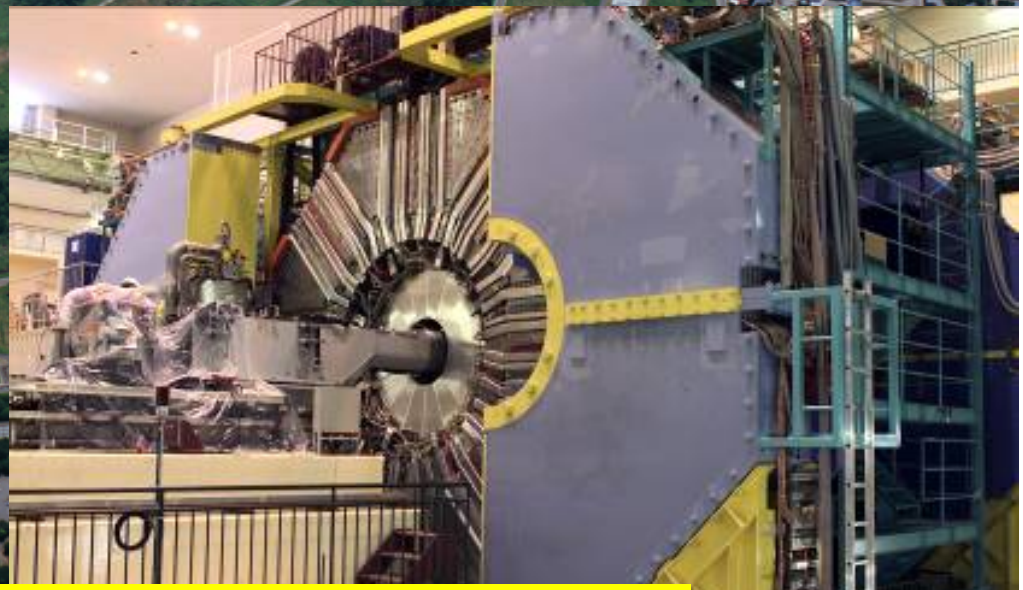


…. If present tensions stay …
(the dream)

KEKB and Belle



1 fb^{-1} per day !



Belle is taking data until the End of 2009

The group will also participate in the Belle physics analysis

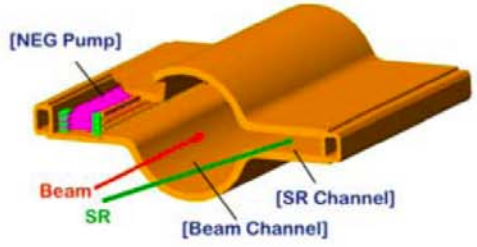
Crab crossing tested successfully, research ongoing

crab cavity

HER e+ 4.1 A

8 GeV

The superconducting cavities will be upgraded to absorb more higher-order mode power up to 50 kW.



The beam pipes and all vacuum components will be replaced with higher-current-proof design.

$\beta^*_y = \sigma_z = 3$ mm

e- 9.4 A LER

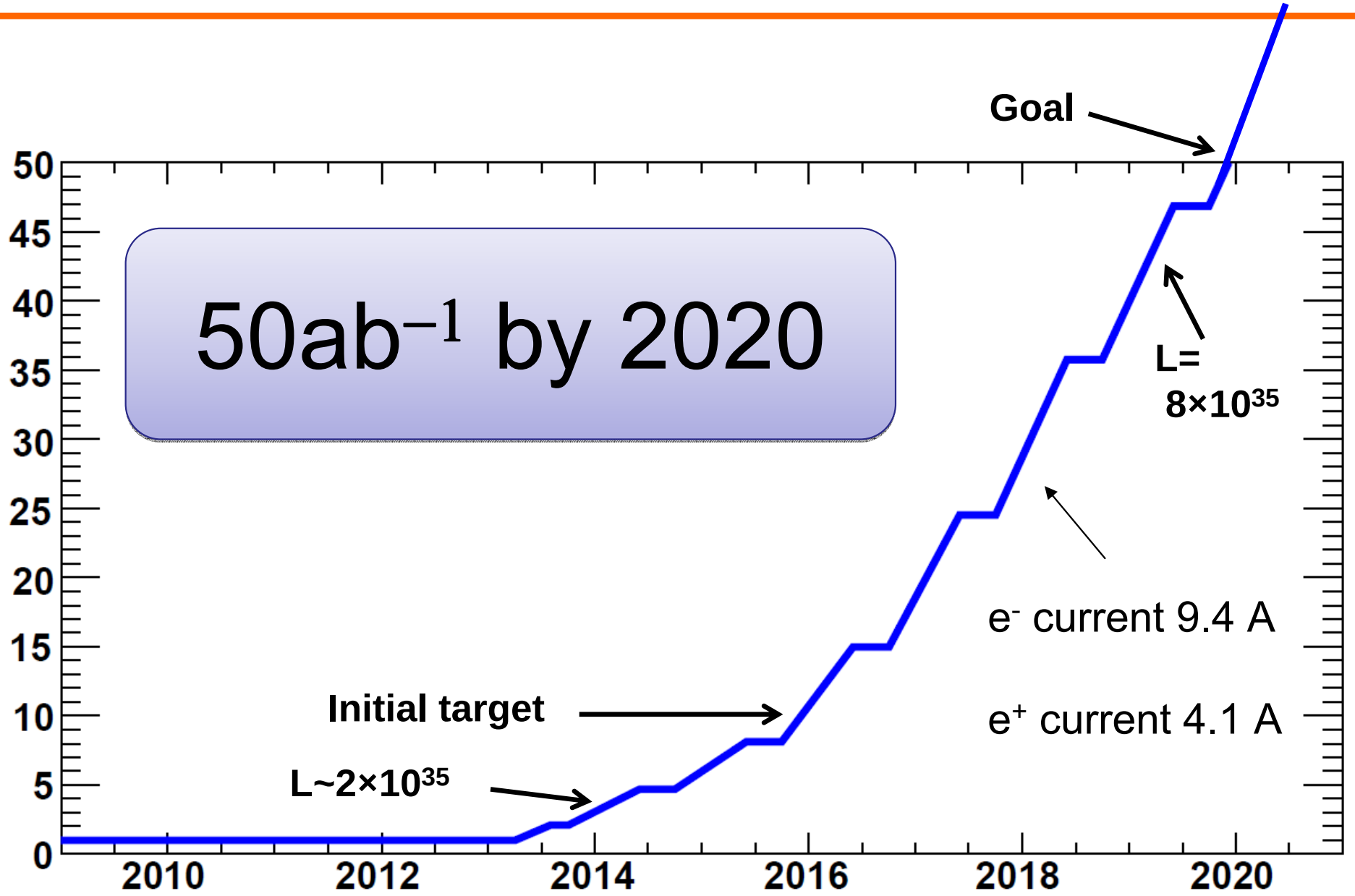
3.5 GeV

The state-of-art ARES copper cavities will be upgraded with higher energy storage ratio to support higher current.

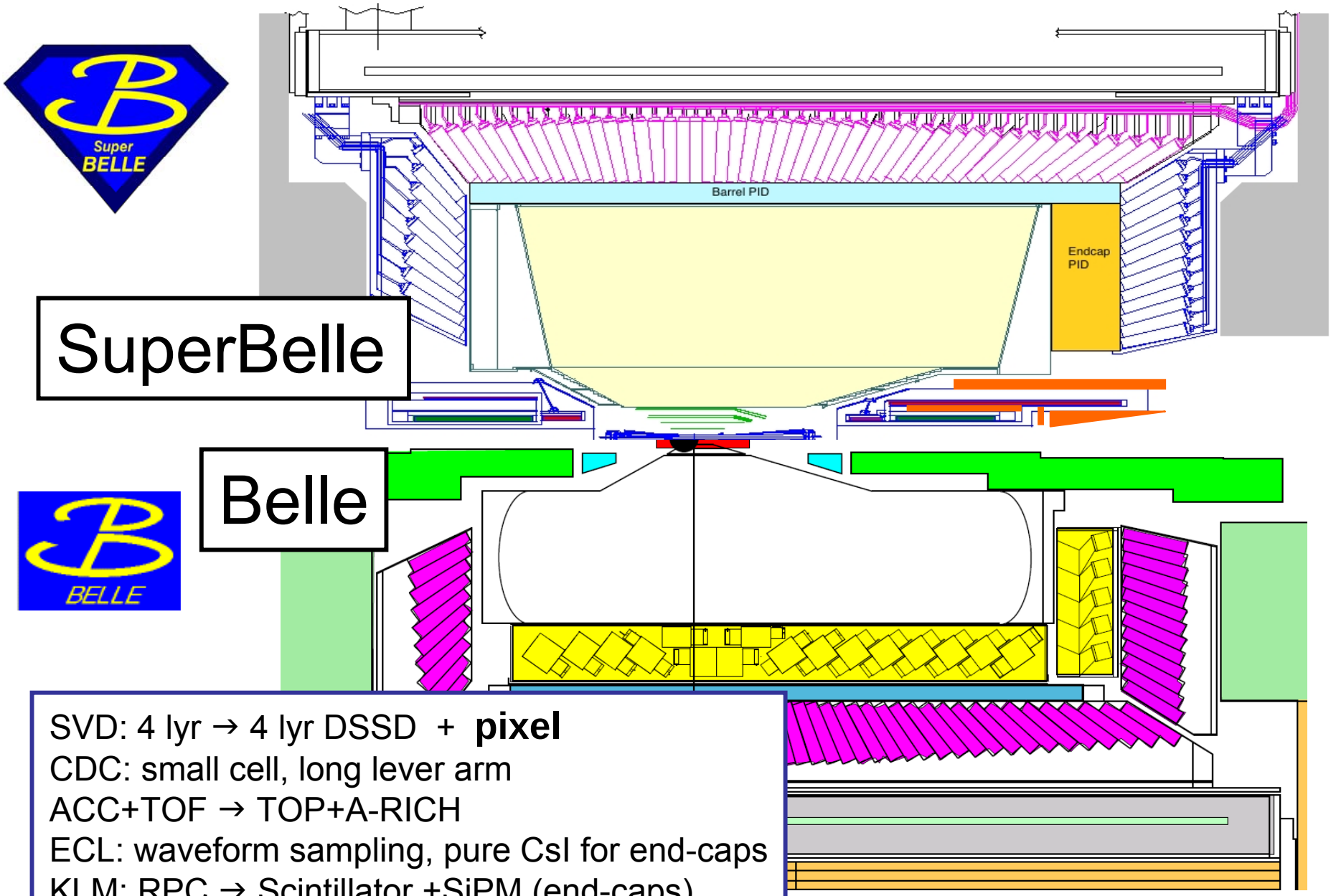
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

will reach 8×10^{35} cm^{-2}s^{-1}.

Luminosity prospect



Baseline Design: LoI (2004) + mod (2008)

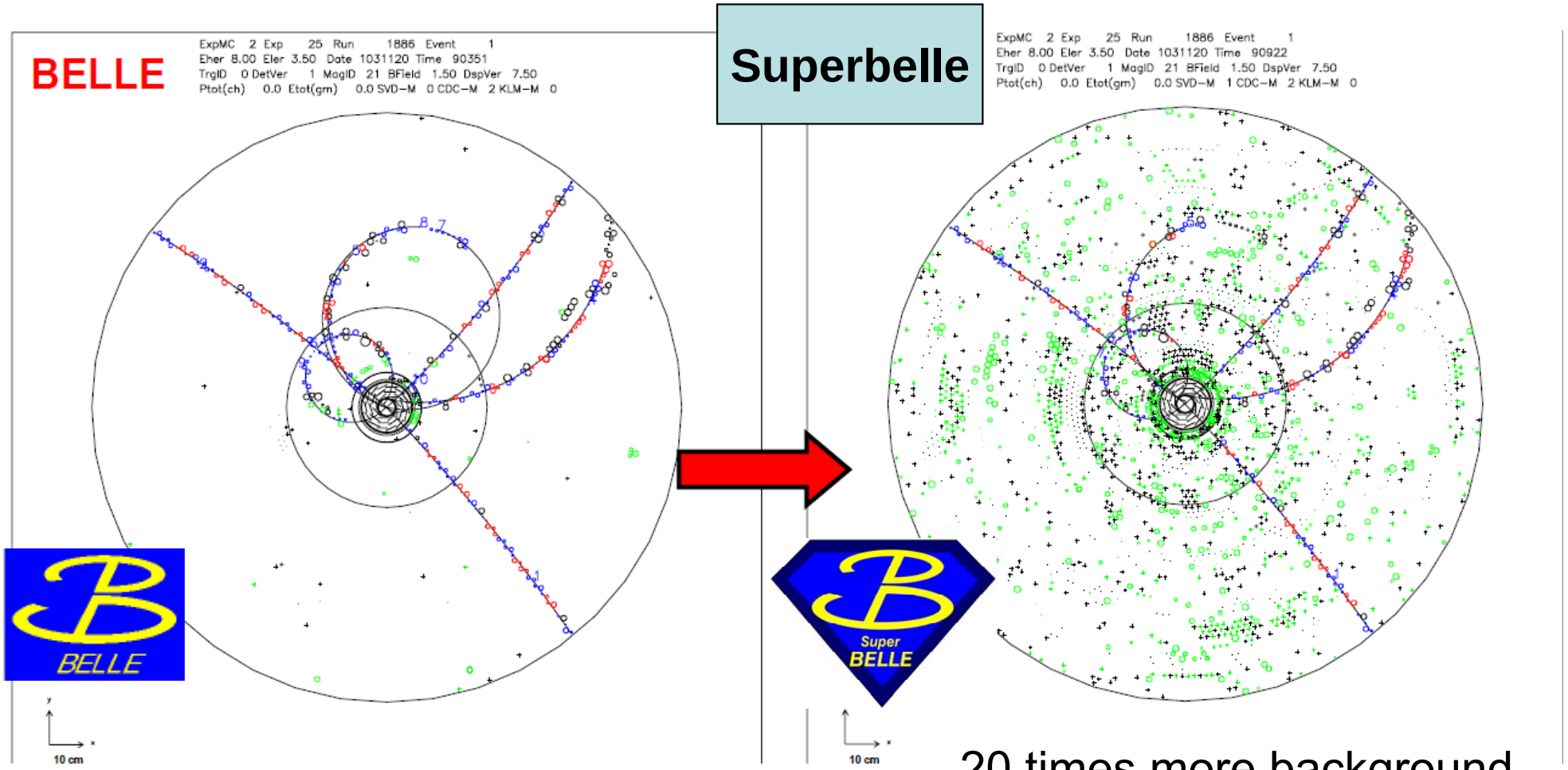


SuperBelle

Belle

SVD: 4 lyr → 4 lyr DSSD + **pixel**
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)

Event in Belle vs SuperBelle



Momenta of particles below 1 GeV : resolution dominated by multiple scattering

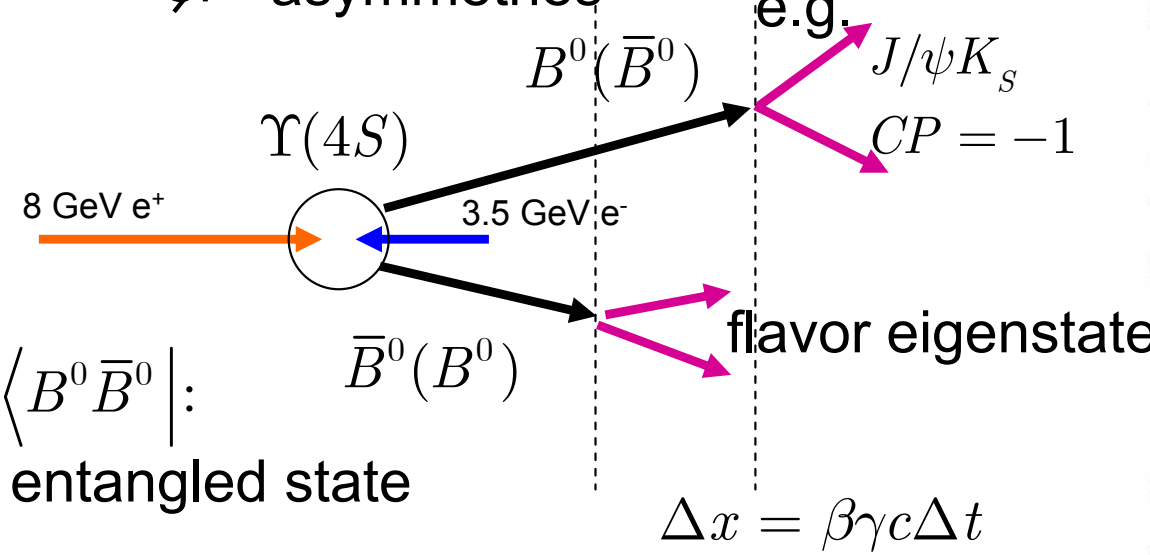
20 times more background (final lumi, upper limit)

Need thin (50 μm) pixel detectors

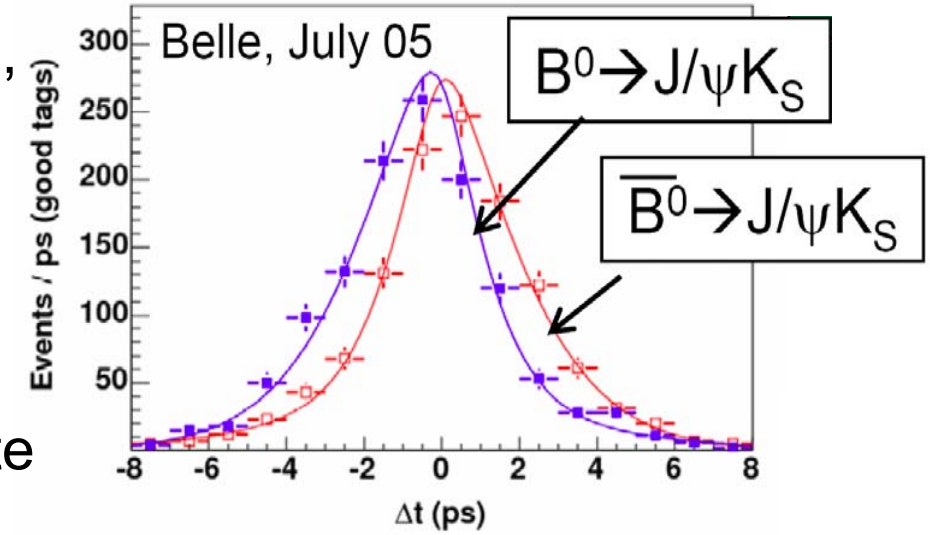
The $\not{CP}$ Observables: What do we measure?

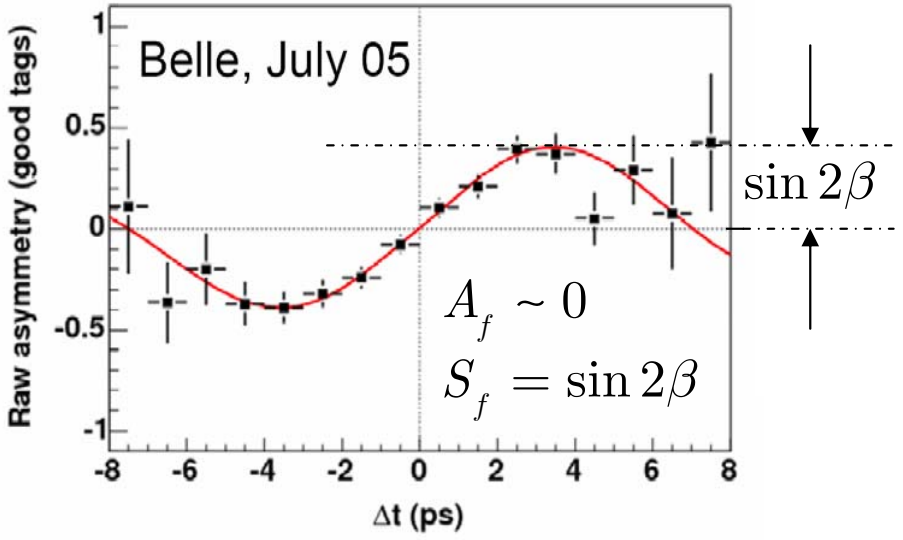
$$\mathcal{A}_{CP}(\Delta t) = \frac{\Gamma(\overline{B}^0 \to f_{CP};\Delta t) - \Gamma(B^0 \to f_{CP};\Delta t)}{\Gamma(\overline{B}^0 \to f_{CP};\Delta t) + \Gamma(B^0 \to f_{CP};\Delta t)} = A_f \cos\Delta m\Delta t + S_f \sin\Delta m\Delta t$$

e.g. time-dependent $\not{CP}$ asymmetries



$\left|B^0\overline{B}^0\right\rangle$: entangled state





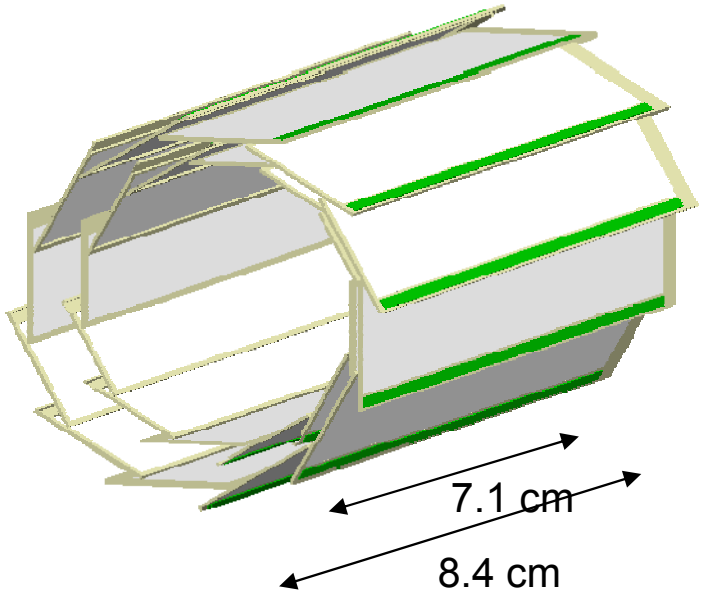
Flavor tagging:

$\overline{b} \to \overline{c}\, l^+\nu$

lepton charge

vertex detector essential

DEPFET Pixel Detector

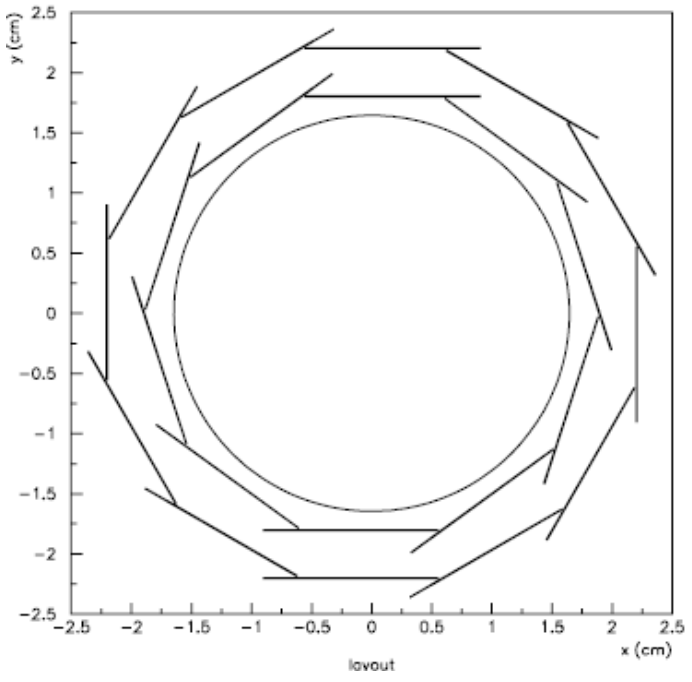


… an MPI invention !!

Small, thin (50µm) detector:
20 – 24 Modules (one sensor each)

Beam pipe radius (presently):
1.5cm initially with upgrade to 1.0 cm later

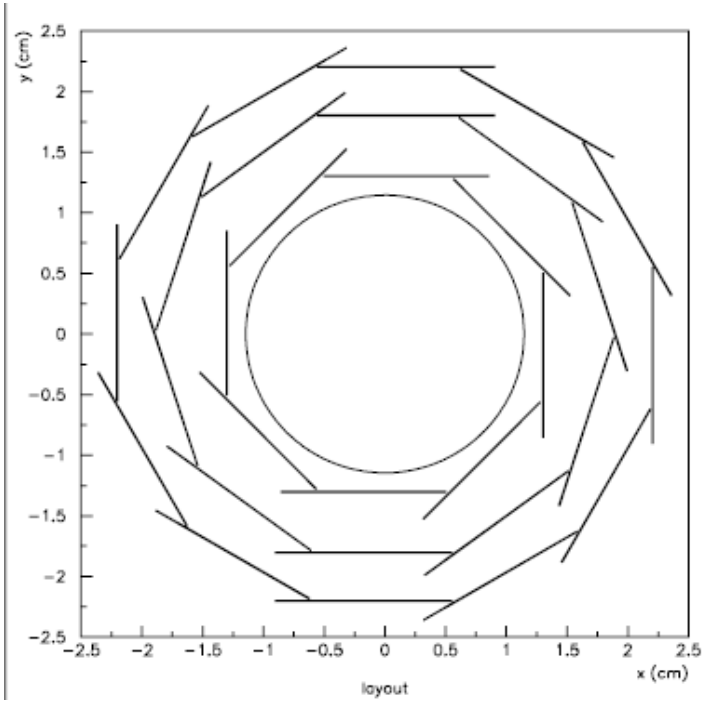
Radii still subject to optimisation:



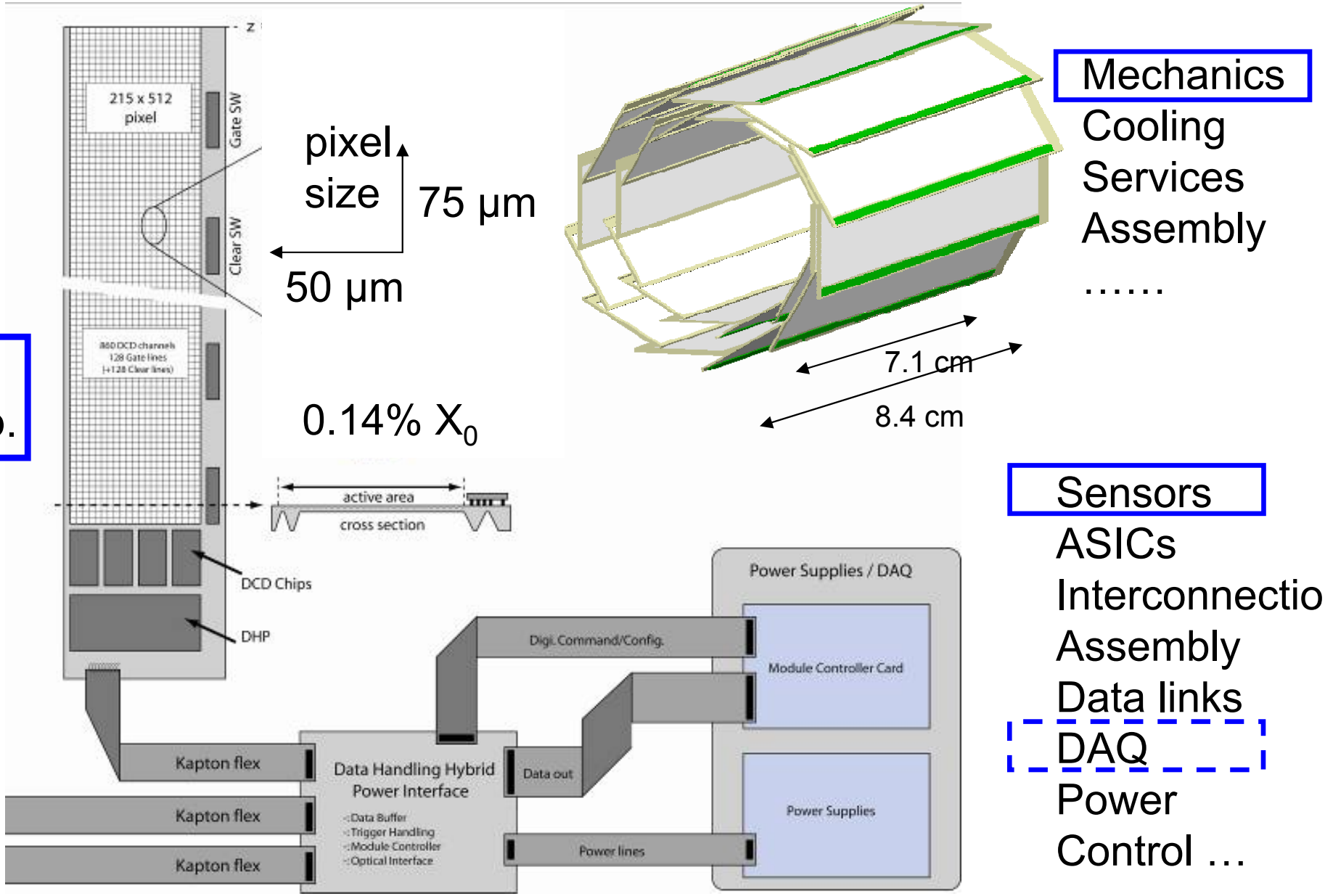
Likely scenario:

Layer 1 at 1.8 cm
Layer 2 at 2.2 cm

Upgrade option:
add Layer 0 at 1.3 cm



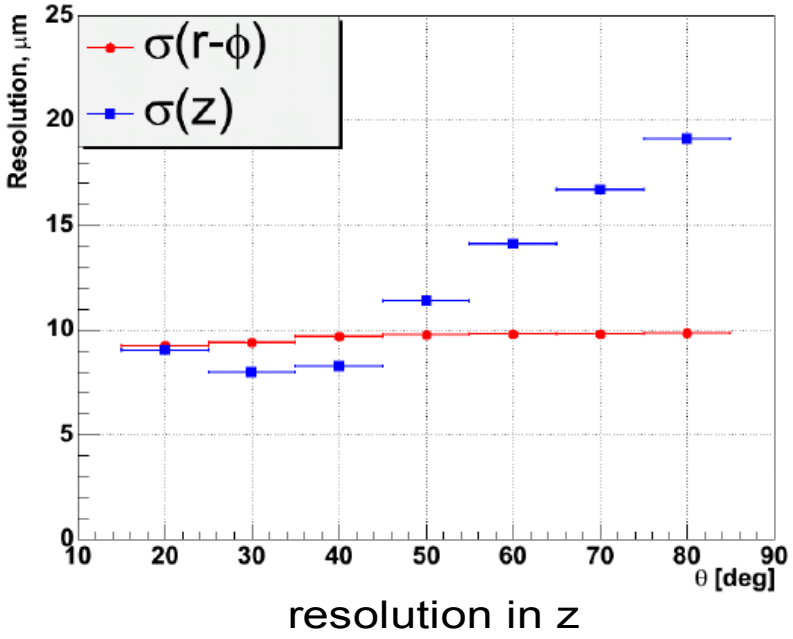
DEPFET Pixel Sensors, some details



MPI resp.

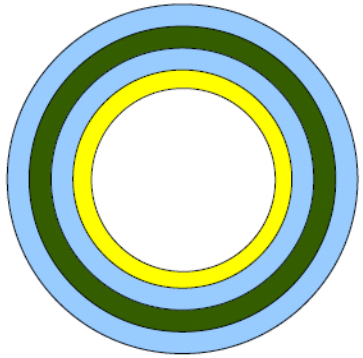
- Mechanics
  - Cooling
  - Services
  - Assembly
  - ……
- Sensors
  - ASICs
  - Interconnection
  - Assembly
  - Data links
  - DAQ
  - Power
  - Control …

Expected Performance of the DEPFET PXD@SuperBelle



resolution in z

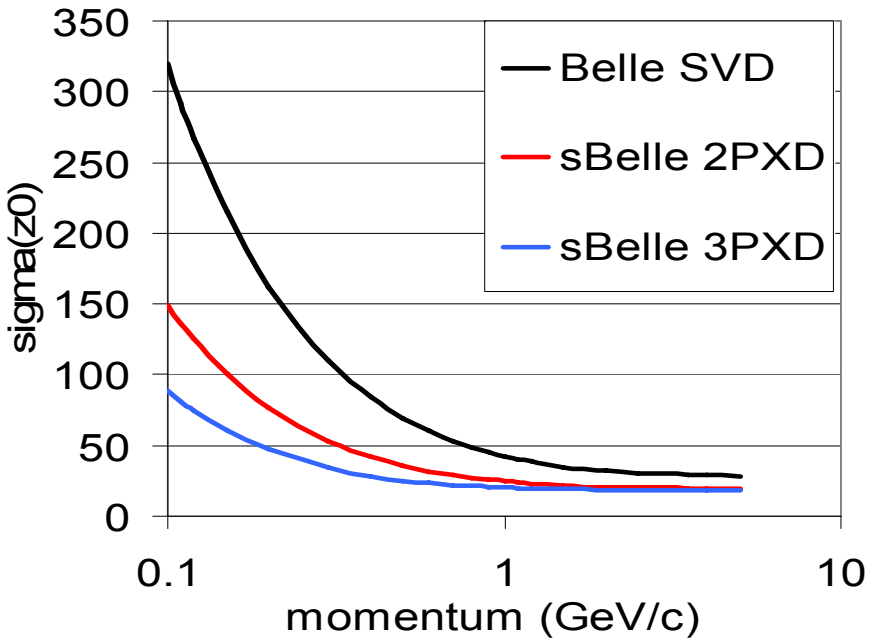
Beampipe



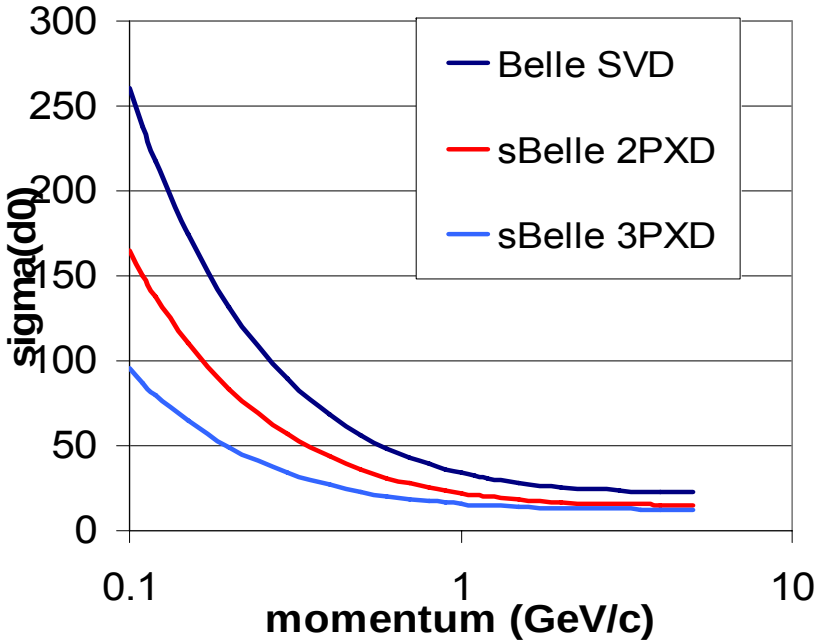
0.66% X_0

pixel size
50μm x 75μm

studies by
A. Raspereza)



Resolution in r=phi



Main R&D Issues

Sensors:	prototyping, radiation hardness (> 10Mrad), thinning, production … pixel geometry -> parameter studies
Read-out ASICs:	Current Digitizer chip (DCD): prototype OK, needs test at full speed (x2) (< O(1%) occupancy) Switcher: rad-hard design, speed OK, redesign for SuperBelle
DHP & Data Link:	Zero-suppr: 400 Gpx/s -> 2 Gpx/s (trigger, occ) -> 1.6 Gb/s per half module
DAQ:	80 Gb/s total -> Gießen R&D for Panda (32 Gb/s)
Test Procedures:	subsystem tests, irradiation, test beams …
Mechanics, Cooling:	Mounting, thermal issues, alignment …,

DEPFET Collaboration

List of Institutions contributing to DEPFET @ SuperBelle

			Contact
Germany			
	MPI	Max-Planck-Institute for Physics, Munich	C. Kiesling, H.-G. Moser
	BON	University of Bonn	N. Wermes
	GIE	University of Giessen	S. Lange
	GOE	University of Göttingen	A. Frey
	HEI	University of Heidelberg	P. Fischer
	KAR	University of Karlsruhe	T. Müller
Austria			
	VIE	Institute for High Energy Physics (HEPHY), Vienna	M. Friedl
Czech Rep.			
	PRA	Charles-University Prague	P. Kodys
Poland			
	KRA	Institute of Nuclear Physics, Krakow	H. Palka
Spain			
	IFV	Instituto de Fisica Corpuscular (IFIC), Valencia	C. Lacasta
	URL	University Ramon Llull, Barcelona	J. Riera Babures
	UBA	University of Barcelona	L. Garrido
	CNM	Centro Nacional de Microelectronica, Barcelona	E. Cabruja
	IFB	Instituto de Fisica d'Altes Energies (IFAE), Barcelona	M. Chmeissani
	USC	University of Santiago de Compostela	P. Vazquez Regueiro
	IFC	Instituto de Fiisica de Cantabria (IFCA), Santander	I. Vila
USA			
	HAW	University of Hawaii	G. Varner
Japan	KEK	KEK	T. Tsuboyama

Work Packages and Assignments

Nr.	Work Package	Lead Institution	Collab. Institutions
1.0	**DEPFET Modules**		
1.1	**Parameter Definitions**	MPI	KRA, PRA
1.2	**Sensor Development**	MPI	
1.3	**ASIC Development**		
1.3.1 1.3.2	Switcher DCD	HEI	
1.3.3 1.3.4	Data Handling Processor (DHP) Data link	BON	MPI, UBA USC, URL
1.4	**Module Design**		
1.4.1	Sensor Ladder	MPI	HEI, BON, IFV, CNM, IFB
1.4.2	Kapton Flex	KEK	VIE, BON
1.4.3	Data Handling Hybrid (DHH)	KEK	VIE, BON

Work Packages and Assignments (cont.)

Nr.	Work Package	Lead Institution	Collab. Institutions
1.5	**Mechanical Design**	MPI	KAR, VIE; KRA, IFV, IFB
1.6	**Thermal Issues**	KAR	MPI, VIE, KRA, IFV, IFB
1.7	**System**		
1.7.1	Data Acqusition board	GOE	KRA, GIE, MPI, KEK, URL, HAW
1.7.2	Power supplies with slow control	KRA	KEK, USC
1.7.3	Cooling plant (refigerator, heat exchanger)	KEK	

Work Packages and Assignments (cont.)

Nr.	Work Package	Lead Institution	Collab. Institutions
2.0	**Test Facilities**		
2.1	Test beams	PRA	KAR, BON, VIE, IFV, IFC URL,CNM, IFB, USC
2.2 2.3	Setups for thermal tests Mechanical mockup	KAR	MPI, VIE, IFV, USC, IFC
3.0	**Integration and running-in scenario**		
4.0	**Operation Issues**		

DEPFET-Collaboration for SuperBelle:

total of 18 Institutes from 7 Countries (now also including Hawaii & KEK)

(WP‘s established in July 2008 in the Munich Meeting)

Schedule

2009: finish checks on radiation hardness up to 10Mrad
demonstrate fast readout with existing components
prepare DEPFET production (SOI wafers)
simulations: detector optimisation

prototype production (processing: ~ 1.5 years)
½ SuperBelle module size (one electrical unit)
some parameter variations

2010: test and evaluation of prototypes
fix geometry & technology
assembly procedure and tooling

2011: final detector production

2012: assembly + tests

2013: spring installation

Very tight schedule, not without risk

Workshop on
Prospects of future Super Flavor Factories

Motivation: German groups should make a decision

→ whether to engage in activities in a Super Flavor Factory, and

→ if yes, in which one: at KEK „SuperKEKB“ or Frascati („SuperB“)

→ Grants from the German government need to be requested for the coming funding period by Dec. 5, 2008

Date: 31. Oct. 2008 and 1. Nov. 2008 (Fri/Sat)
Place: MPI Munich

60 participants from 13 German universities (& outside)

Bochum, Bonn, Dortmund, Göttingen, Gießen, Heidelberg, Karlsruhe, Mainz, Munich (MPI, LMU, TUM), Regensburg, Siegen

Friday 31 October 2008

Introduction - Auditorium (11:00-12:00)

time	[id] title	presenter
11:00	[25] Welcome address	CALDWELL, Allen
11:05	[24] Aim of the Workshop (I)	LENSKE, Horst
11:15	[2] Status and Prospects for B-Physics	UWER, Ulrich

The Physics Case for a Super Flavor Factory (I) - Auditorium (13:00-15:30)

time	[id] title	presenter
13:00	[4] The CKM Parameters	LACKER, Heiko
13:30	[6] Hadronic Two-Body Decays	FLEISCHER, Robert
14:00	[5] CP Violation and Hadronic B-Decays	BUCHALLA, Gerhard
14:30	[7] Physics at the Y(5S) and ISR Perspectives	DENIG, Achim
15:00	[8] Charm and Bottom Spectroscopy	PETERS, Klaus

The Physics Case for a Super Flavor Factory (II) - Auditorium (16:00-19:00)

time	[id] title	presenter
16:00	[1] Aim of the Workshop (II)	MäTTIG, Peter
16:10	[9] FCNC Processes and Rare Decays	NIERSTE, Ulrich
16:40	[10] Lepton Flavor Violation	PAES, Heinrich
17:10	[11] Weak Interactions of Charm	BIGI, Ikarus
17:40	[12] Flavor Theory Perspective	BURAS, Andrzej

Saturday 01 November 2008

The Super Flavor Factory Projects (I) - Auditorium (08:30-10:00)

time	[id] title	presenter
08:30	[13] The SuperKEKB Project	YAMAUCHI, Masa
09:15	[14] Machine Aspects of the SuperKEKB	OIDE, Katsunobu

The Super Flavor Factory Projects (II) - Auditorium (10:30-12:30)

time	[id] title	presenter
10:30	[15] The SuperB Project	HITLIN, David
11:15	[16] Machine Aspects of SuperB	HITLIN, David
12:00	[17] RECFA Recommendations	NAKADA, Tatsuya

German Interests in a Super Flavor Factory - Auditorium (13:30-15:00)

time	[id] title	presenter
13:30	[21] Report of the MPI Group	MOSER, Hans-Günther
13:40	[20] Report of the Karlsruhe Group	FEINDT, Michael
13:50	[22] Report of the Bonn Group	WERMES, Norbert
14:00	[23] Report of the Giessen Group	LANGE, Soeren
14:10	[26] Report of the Göttingen Group	FREY, Ariane

Concluding Discussion - Auditorium (15:00-16:00)

Concluding Discussions of the Munich Meeting

- Theoretical colleagues unanimously supporting SFF
- DEPFET will be baseline for SuperBelle (M. Yamauchi)
  DEPFET can also be installed in SuperB detector (D. Hitlin)
- 6 German groups expressed interest to participate in the SuperKEKB/SuperBelle project
- No group expressed interest to participate in SuperB
- Some German groups are busy with LHCB, but expressed their opinion that a Super-B-Factory (> 50 /ab) opens a new Era of Flavor Physics and must be pushed

→ Very positive outcome of the German Meeting for the DEPFET@SB

after this: Green Light for the SuperBelle Group by Directorate

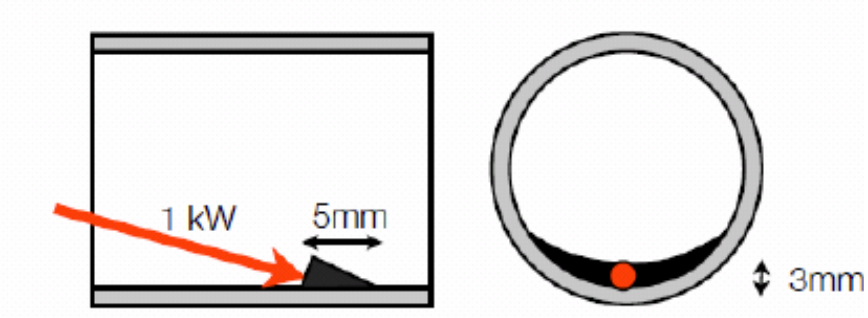
1st Open Meeting of the SuperKEKB Collaboration

Dec. 10-12, 2008 at KEK

Talks on physics prospects, machine and detector issues

- Machine session: Design of the IR:

  Very strong SynRad
  from HER
  (no solution yet)



- Session on PXD (Pixel-Detector), chaired by Hans-Günther Moser

  Talks on DEPFET PXD by
  CK, Laci Andricek and Peter Kodys (Prague)
  (talks were very well received)

Unanimous decision during the first closed session
of the SuperBelle Institutional Board (IB) on Dec. 12, 2008:

DEPFET is baseline for the SuperBelle detector

MPI group members (Belle/SuperBelle):

C. Kiesling, S. Lu, A. Moll, E. Nedelkovska, A. Raspereza,
K. Prothmann, B. Reisert, M. Ritter, F. Simon, V. Shekelian,
P. Vanhoefer, NN (PostDoc), (consulting: S. Kluth, J. Schieck)

L. Andricek, H.-G. Moser, R. Richter, S. Rummel, M. Schnecke,
A. Wassatsch, Q. Wei, NN (PostDoc), NN (Techn.)

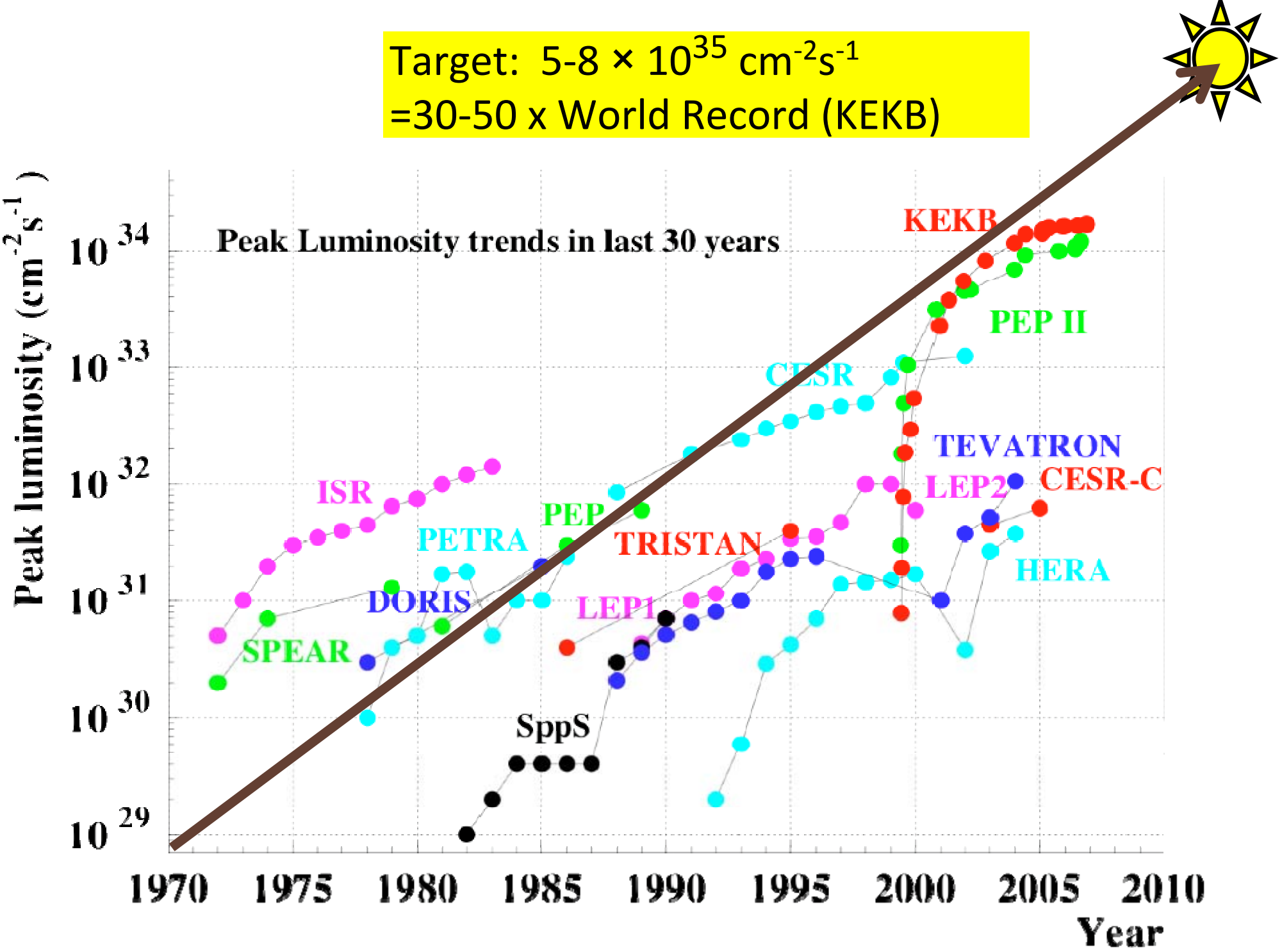
Engineers: K. Ackermann, H. Wetteskind, W. Haberer, M. Fras

Conclusions

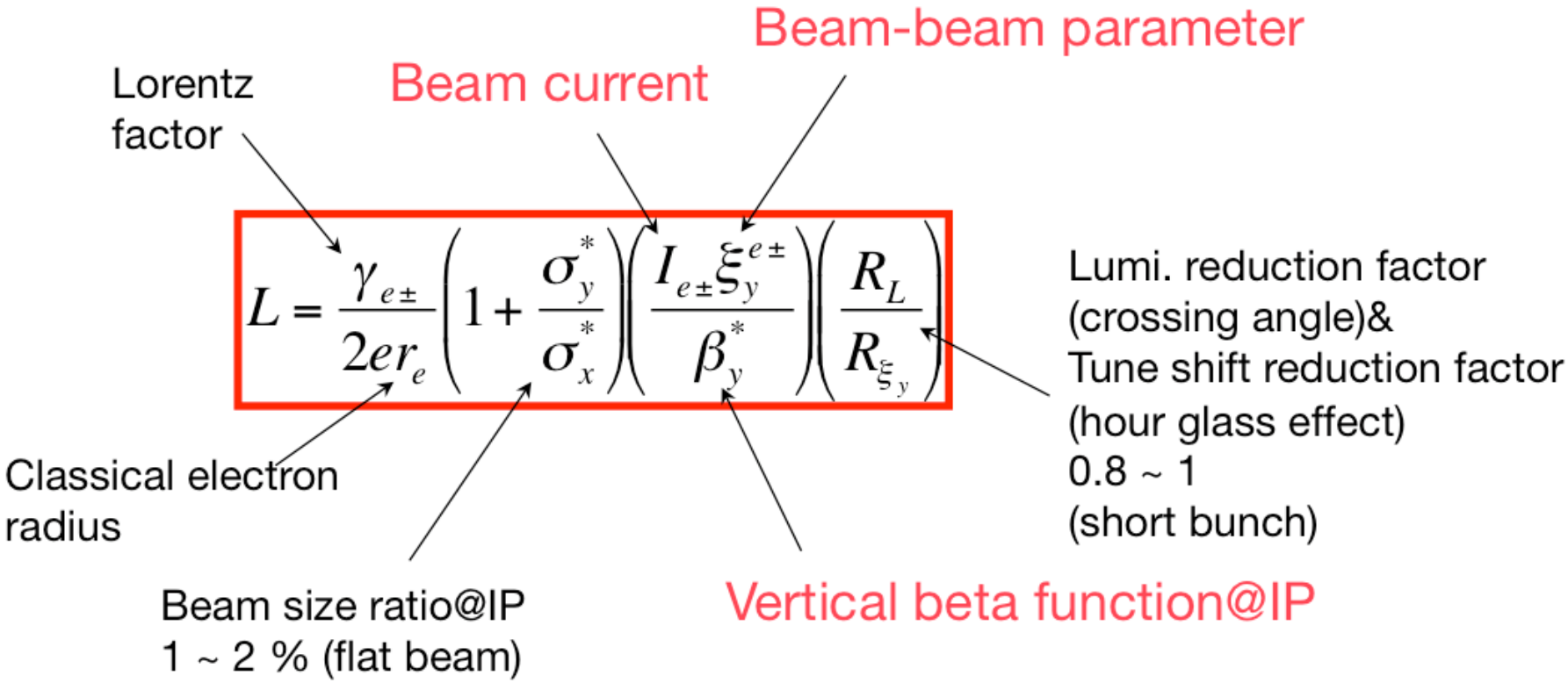
- Flavor physics at SuperKEKB has a high potential in NP searches, and is complementary to the LHC program, with sensitivity up to multi TeV scales
- Signals from KEK concerning realisation of SuperKEKB very positive
- The DEPFET technology is mature and should face physics now
  - → many technological details still to solve, but no showstopper visible
  - → the time scale for SuperBelle is tight: install by spring of 2013
- DEPFET PXD is „baseline“ now at SuperBelle
- The MPI Group is mainly responsible for the sensor development
- The Group will also participate in the analysis of the Belle data, many interesting physics analyses are waiting.
- Many years of hard work, but also world-record luminosity and unique, challenging physics are ahead of us …

BACKUP

Target: 5-8 × 10^{35} $cm^{-2}s^{-1}$
=30-50 x World Record (KEKB)



Strategy



(1) Increase beam currents

- 1.7 A (LER) / 1.4 A (HER) → 9.6 A (LER) / 4.1 A (HER)

(2) Smaller β_y^*

- 6.5(LER)/5.9(HER) mm→3.0/3.0 mm

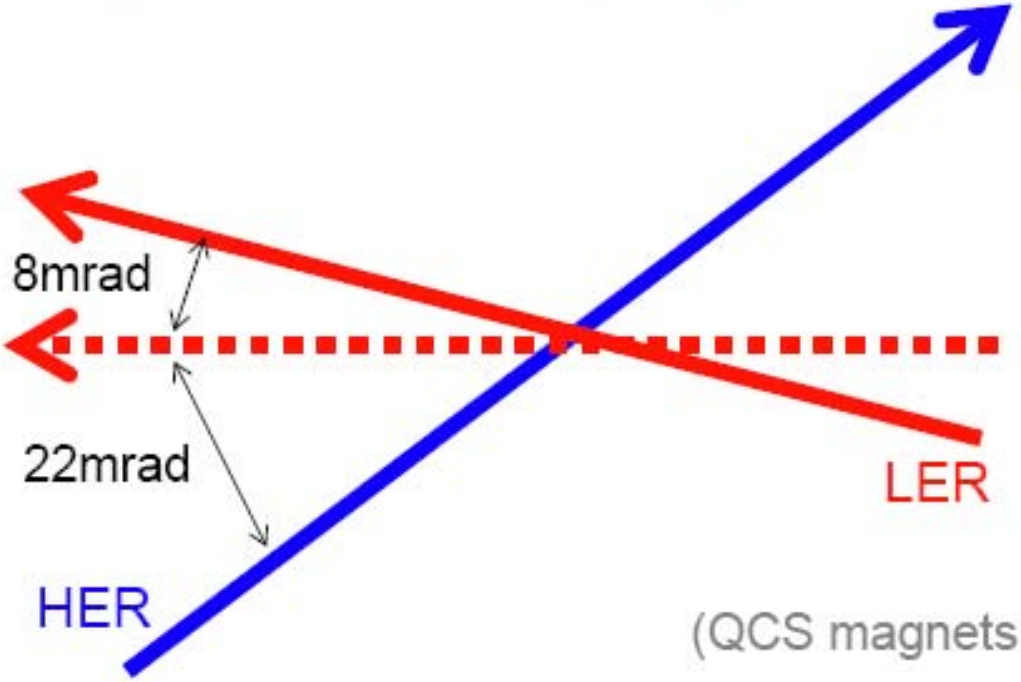
(3) Increase ξ_y

- 0.09 (with Crab) → 0.29

Relationship between s-Belle and Super-KEKB

Talk by
M. Iwasaki

In Super-KEKB, crossing angle will be increased : 22mrad → 30mrad



e^- KEKB / Super-KEKB
HER(e^-) axis will not change

e^+ KEKB, Belle solenoid
Belle solenoid will not change

e^+ Super KEKB
LER(e^+) axis will rotate by 8mrad

(QCS magnets will be set parallel to Belle solenoid)

Belle beam pipe (and SVD??) axis at Super-KEKB

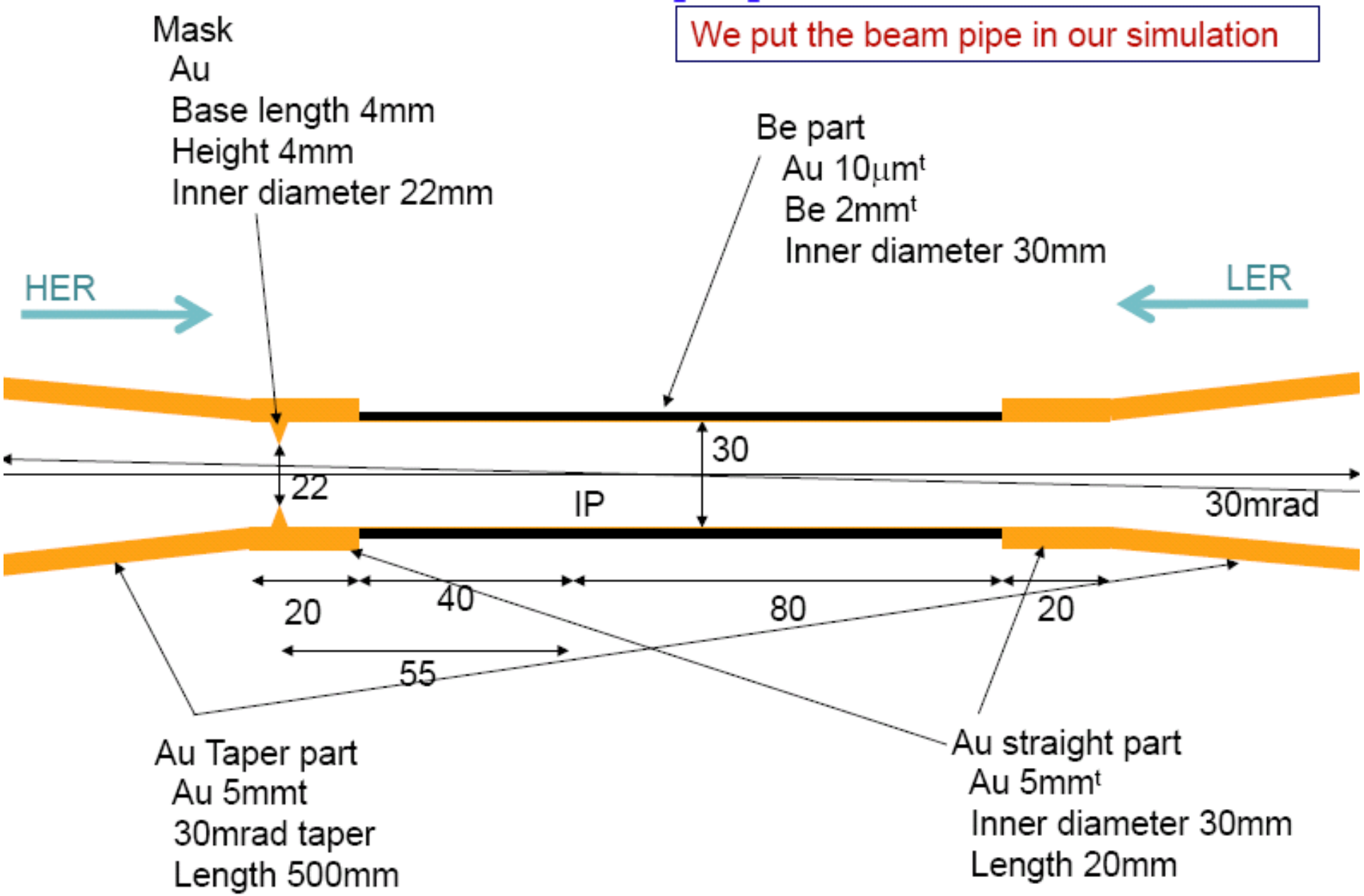
- Belle solenoid
- Center of the LER and HER (7mrad from Belle solenoid)
- HER axis (22mrad from Belle solenoid)

Talk by
M. Iwasaki

Beam pipe v1

S.Uno

We put the beam pipe in our simulation



Talk by
M. Iwasaki

Conclusion

SR BG simulation

- We design the IP beam-pipe to avoid SR from HER

To avoid the SR direct hit, we should

1. Locate the beam pipe parallel to HER direction, and
   (22mrad from Belle solenoid)
2. Put a 4mm height SR mask

- Study of the energy deposit to the IP beam-pipe

1. There is huge energy deposit from HER SR
   ~5kW to SR mask ~20kW to beam-pipe
2. 1kW deposit to 4mm mask makes ~2000°C temperature rise
   → We cannot cool the beam pipe

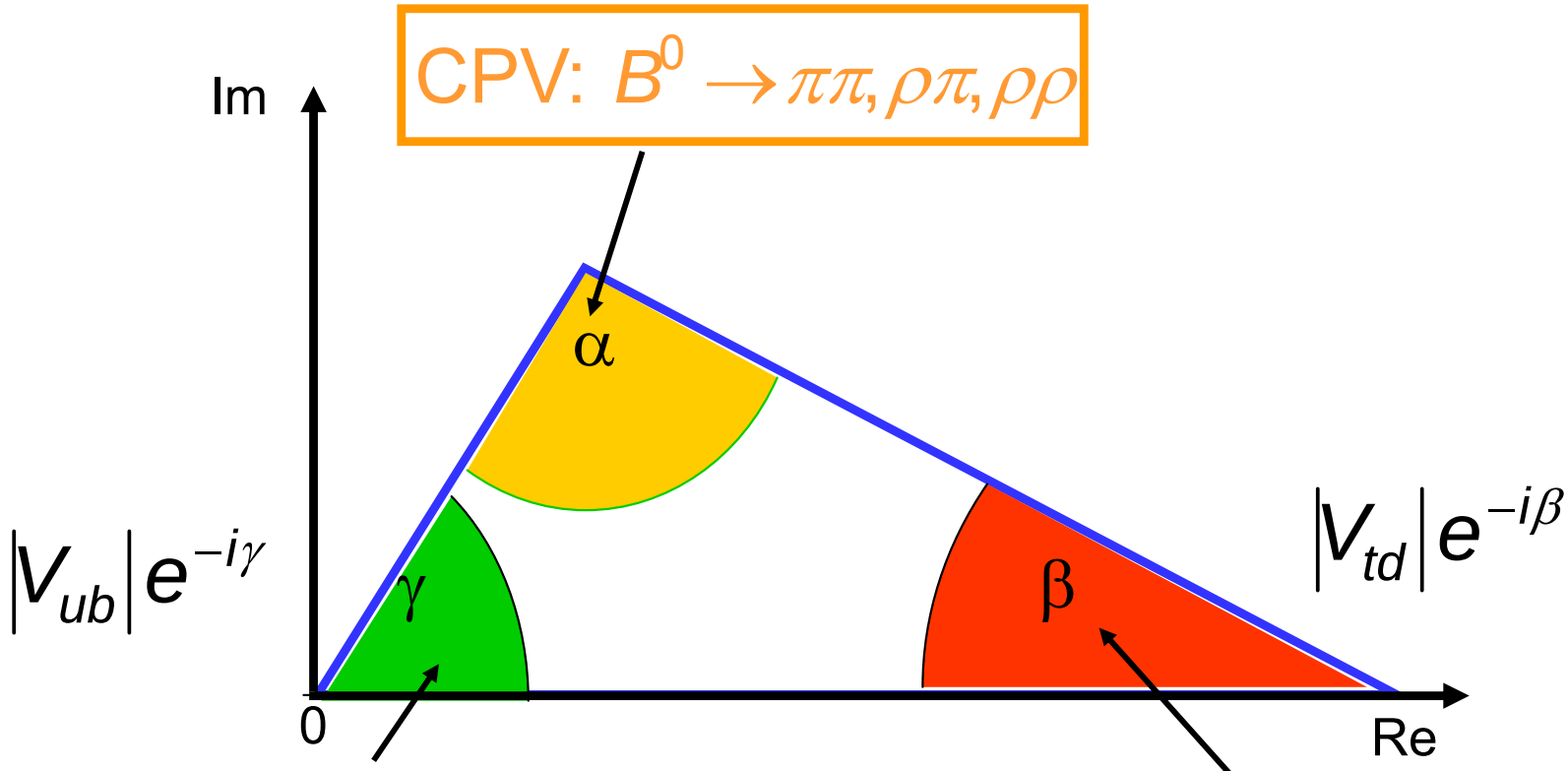
We try to minimize the BG effect in our beam-pipe design, but SR power is so huge that beam-pipe easily melts…

Belle Collaboration

BINP
Chennai
Chiba U.
Hanyang U.
U. of Cincinnati
Fu-Jen U.
Giessen U.
Gyeongsang Nat'l U.
U. of Hawaii
Hiroshima Tech.
HEPHY, Vienna
IHEP, Protvino
IHEP, Beijing
INFN, Torino
ITEP
Kanagawa U.
Karlsruhe
KEK
Korea U.
Krakow Inst. of Nucl. Phys.
Kyoto U.
Kyungpook National U.
U. of Lausanne
Jozef Stefan Inst.
MPI, Munich
U. of Melbourne
Nagoya U.
Nara Women's U.
National Central U.
National United U.
National Taiwan U.
Nihon Dental College
Niigata U.
Nova Gorica U.
Osaka U.
Osaka City U.
Panjab U.
Peking U.
Princeton U.
Illinois U. - Riken
Saga U.
USTC
Seoul National U.
Shinshu U.
Sungkyunkwan U.
U. of Sydney
Tata Institute
Toho U.
Tohoku U.
Tohuku Gakuin U.
U. of Tokyo
Tokyo Inst. of Tech.
Tokyo Metropolitan U.
Tokyo U. of A and T.
Toyama Nat'l College
U. of Tsukuba
VPI
Yonsei U.

Unitarity triangle

$$V_{ud}\boxed{V_{ub}^*} + V_{cd}V_{cb}^* + \boxed{V_{td}}V_{tb}^* = 0$$



CPV: $B^0 \to DK^{(*)}, DK_S^0, K\pi, D^*\pi$

$B_s^0 \to D_s K, KK$

LHCb

CPV: $B^0 \to J/\psi K_S^0$

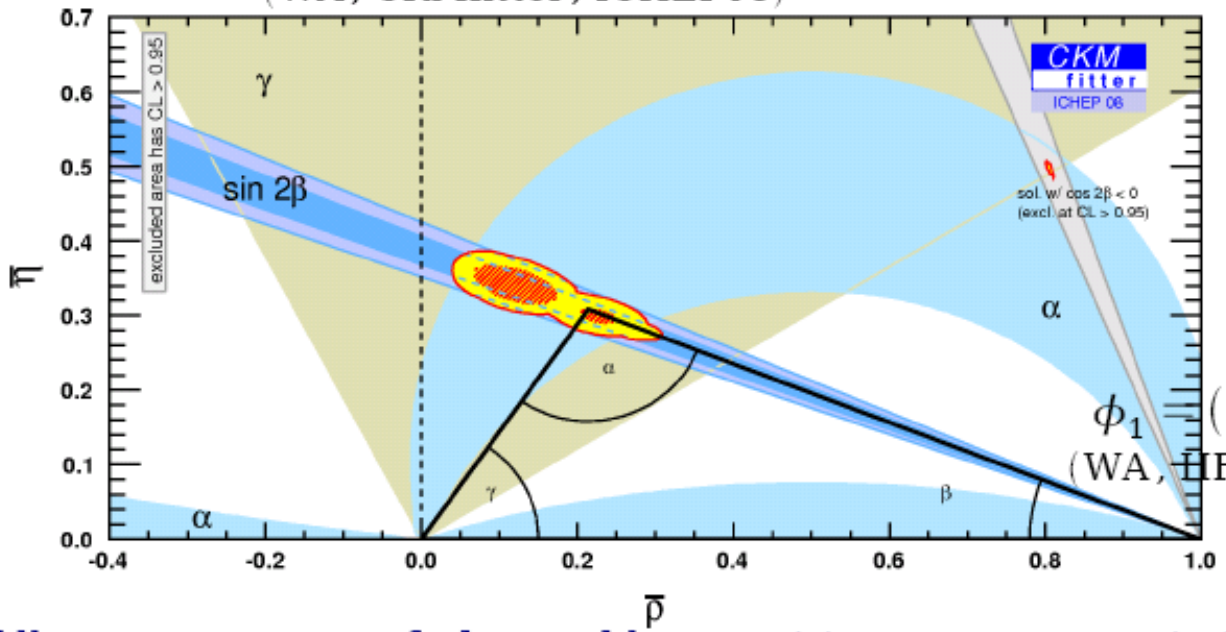
„golden channel“

BELLE

Physics Analysis with Belle

$\phi_2 = (88.4^{+5.6}_{-4.9})^\circ$

(WA, CKMfitter, ICHEP08)



$\phi_1 = (21.1 \pm 0.9)^\circ$

(WA, HFAG, ICHEP08)

All measurements of observables sensitive to ϕ_3 are statistically limited

$\boldsymbol{\phi_3 = (70^{+27}_{-29})^\circ}$ (WA, CKMfitter, CKM08)

Although not all the statistics yet analyzed by Belle

1. Alignment of the SVD using muon pairs (a la BaBar), TCPV with $J/\psi\, K_S$

2. Time-dependent CP Viol with charmless decays (measure $\Phi_2=\alpha$ (e.g. $B \to \pi\pi, \rho\pi, \rho\rho$) , rare decays ($B \to \tau\nu$), LFV ($\tau \to \mu\gamma$)

SuperBelle Collaboration – present list

from the IB meeting (P.Krizan)

- Australia: Melbourne and Sydney
- Austria: Vienna
- Czech Republic: Prague
- China: IHEP Beijing, USTC
- Germany: Giessen, Karlsruhe, MPI Munich
- India: Guwahati, Panjab, Chennai
- Japan: KEK, Nagoya, Nara, Osaka City, Tokyo U.
- Korea: Korea U., Yonsei U., Kyungpook National U., KISTI, Hanyang U., Gyeongsang National U., Seoul National U.
- Poland: Krakow
- Russia: ITEP Moscow, BINP Novosibirsk
- Slovenia: JSI (Ljubljana), Nova Gorica
- US: Cincinnati, Hawaii, Virginia Tech, Wayne State
- Taiwan: Fu Jen, NCU, NTU, NUU

from the IB meeeting (P.Krizan)

Detector choices

Major choices in detector components should reflect a consensus of the collaboration.

Procedure: Executive board ratifies proposals on major choices in detector components. If required, EB nominates referee(s).

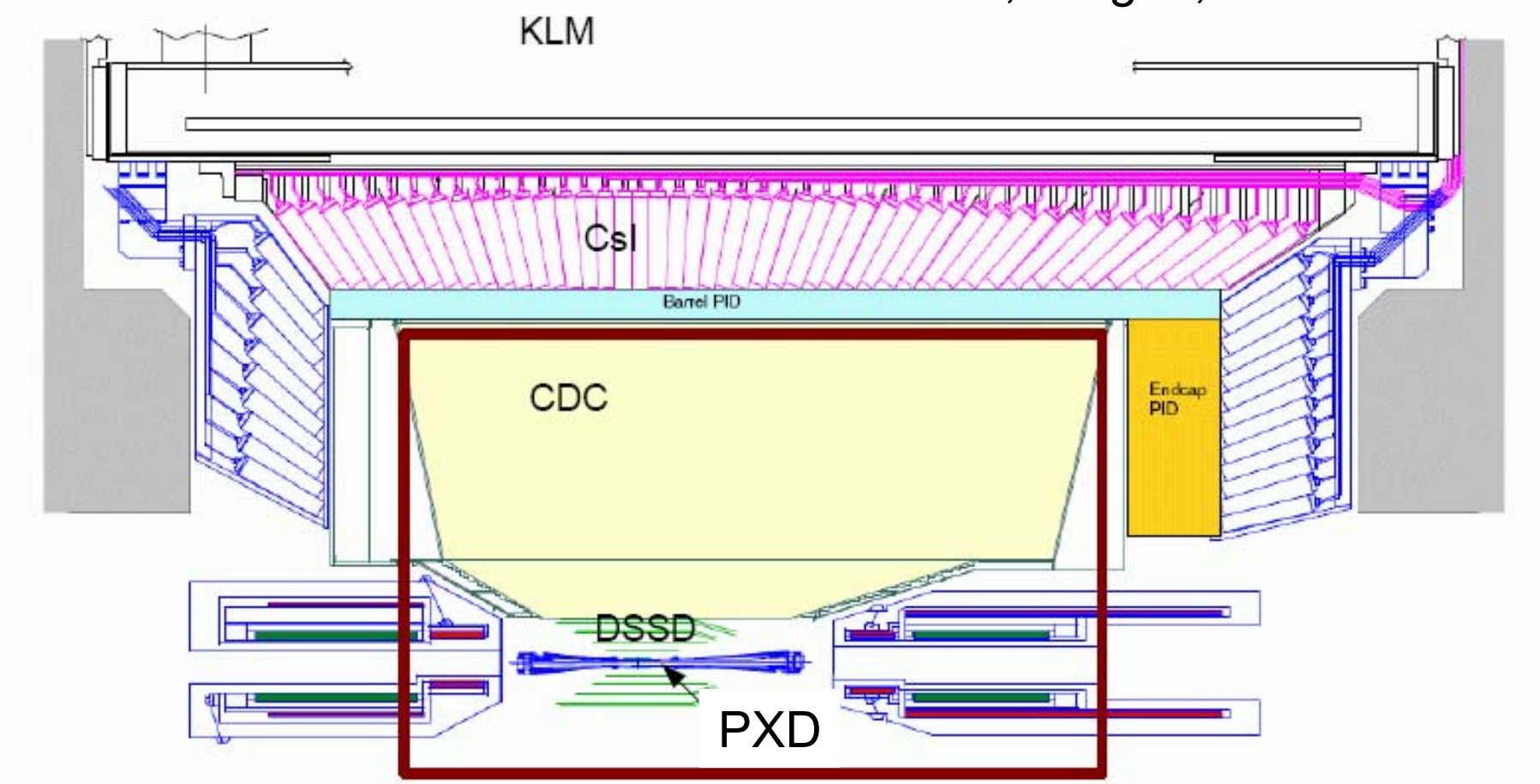
First example: inner vertexing. Innex vertexing group proposes DEPFET as the baseline technology, and they encourage continuing R+D on other options for higher luminosity and higher backgrounds.

Next example: photon detectors for endcap PID; to be decided at the March meeting.

discussion: could be „Institutional Board“

Example of Work Package „Parameter Definitions“

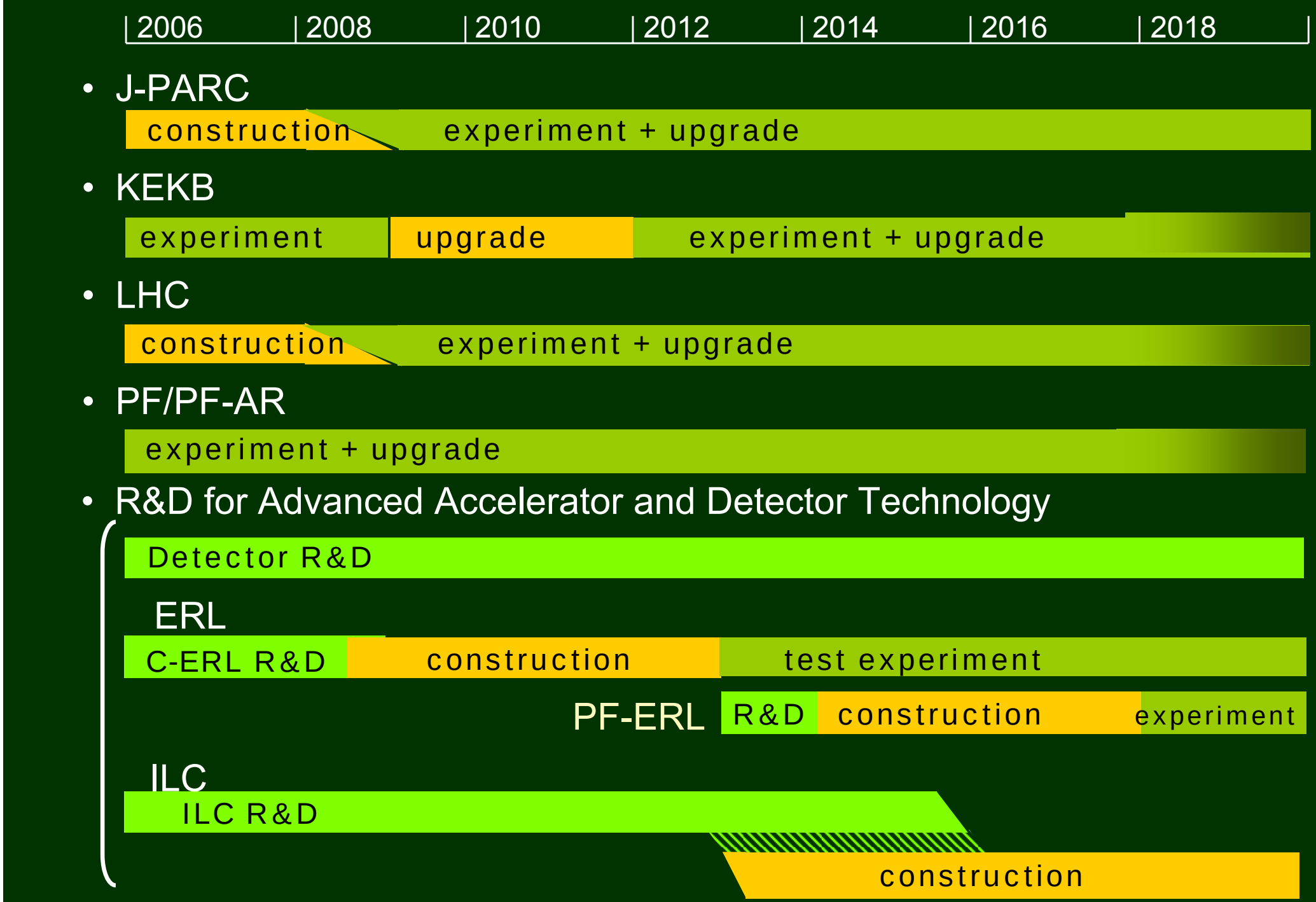
MPI, Prague, Krakow



Components implemented in detector simulation

beampipe, SVD, CDC

KEK Roadmap


2006
2008
2010
2012
2014
2016
2018
J-PARC
construction
experiment + upgrade
KEKB
experiment
upgrade
experiment + upgrade
LHC
construction
experiment + upgrade
PF/PF-AR
experiment + upgrade
R&D for Advanced Accelerator and Detector Technology
Detector R&D
ERL
C-ERL R&D
construction
test experiment
PF-ERL
R&D
construction
experiment
ILC
ILC R&D
construction

from the IB meeeting (P.Krizan)

SuperBelle Collaboration meeting Closed Session

1) Report from KEK (Yamauchi)
2) Forming the new collaboration, collaboration members, name
3) Report on a SC proposal for the internal organisation
4) Discussion on the internal organisation
5) Next meeting