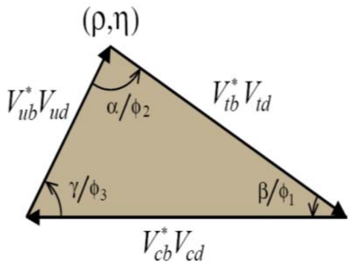
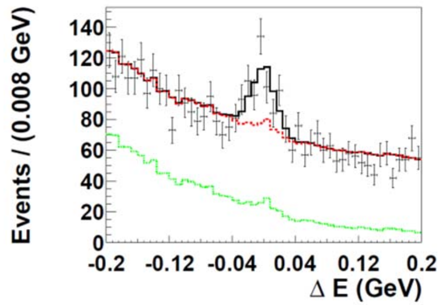
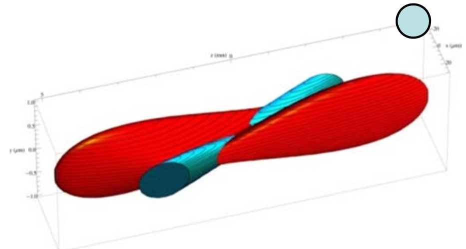
B-Physics with Belle and a Pixel Vertex Detector for Belle II

C. Kiesling, MPI Munich

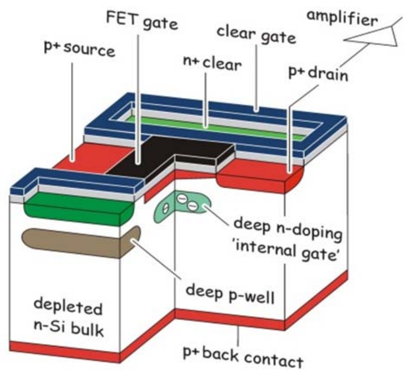


- Physics Motivation
- Analysis of the Full Belle Data Sample at MPI

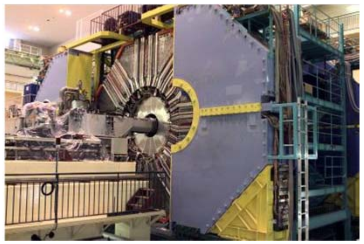




- New Physics at High Luminosity
  The SuperKEKB Collider and Belle II



- Status of the PXD Project



- Schedule and Take-off

The Belle (II) Group at MPI

Director: Allen Caldwell

Staff

Laci Andricek, Christian Kiesling, Hans-Günther Moser,
Rainer Richter, Vladimir Shekelyan

Post Doctoral Scientists

Jeremy Dalseno, Susanne Koblitz, Jelena Ninkovic, (Burkard Reisert),
Frank Simon

PhD Students

Christian Koffmane, Andreas Moll, Elena Nedelkovska,
Kolja Prothmann, Andreas Ritter, Martin Ritter

Diploma Students

Veronika Chobanova, (Claudio Heller, Peter Müller), Pit Vanhoefer

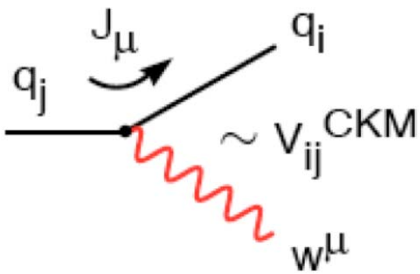
Technical Support

Karl-Heinz Ackermann, Walter Kosmale, Marlene Schaber,
Günter Tratzl, Andreas Wassatsch, Holger Wetteskind,

Technology@HLL

Anastasia Plis, Martina Schnecke, Gerhard Schaller (MPE),
Florian Schopper (MPE), Klaus Heinzinger (PNS), Rouven Eckardt (PNS)

The CKM Matrix and Unitarity



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

Cabibbo, Kobayashi, Maskawa

$$\lambda = \sin\theta_C$$

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

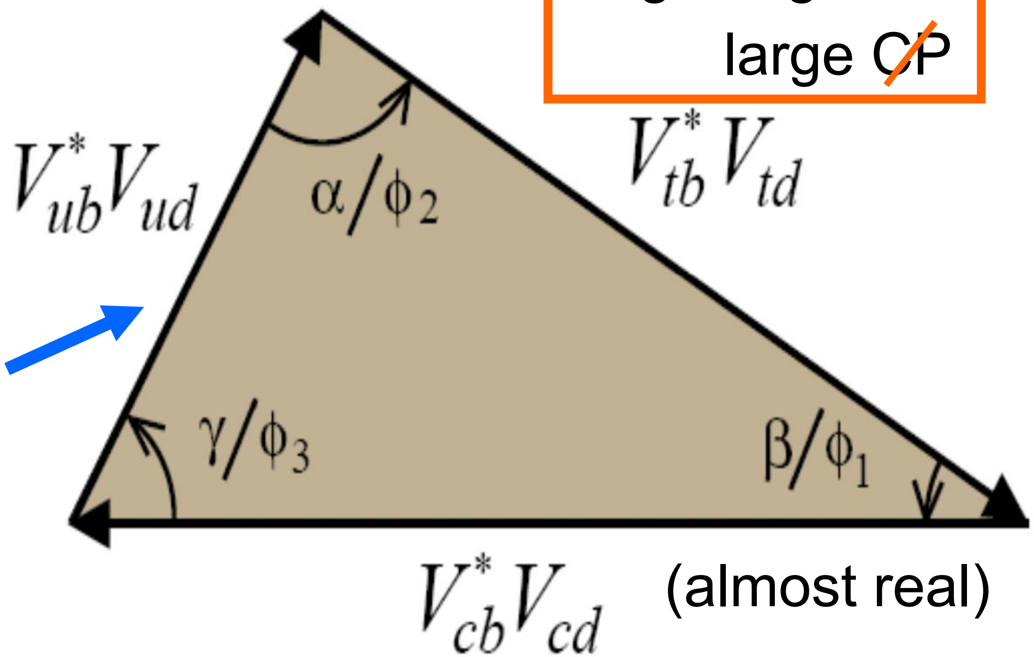
$$V_{ud}V_{us}^* + V_{cd}V_{cs}^* + V_{td}V_{ts}^* = 0$$

Triangle for K mesons

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

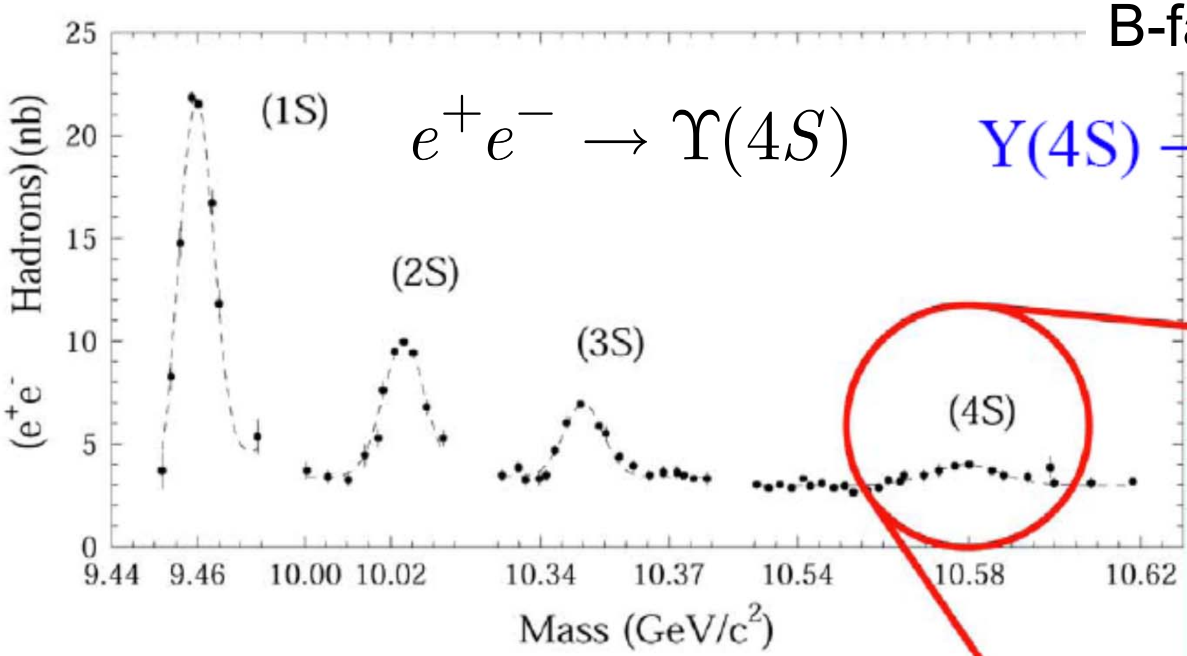
Triangle for B mesons

large angles = large ~~CP~~



(almost real)

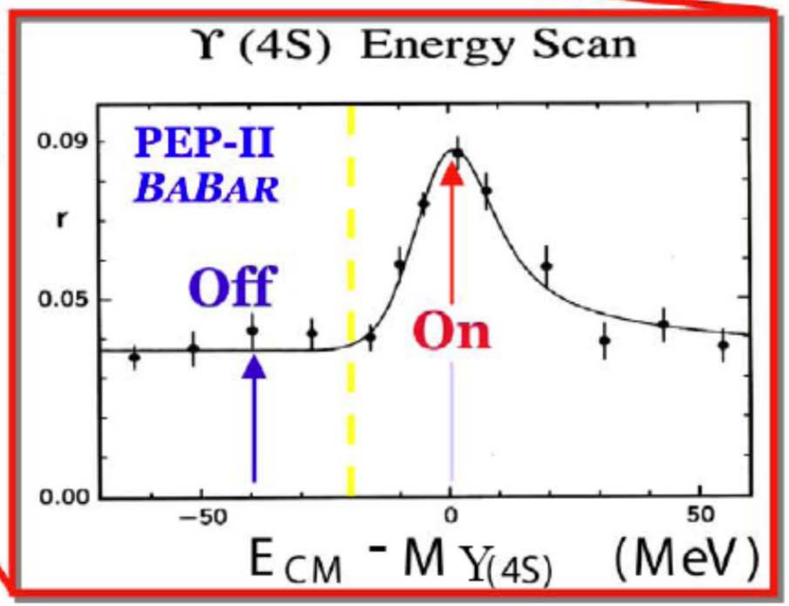
Where do we Measure?

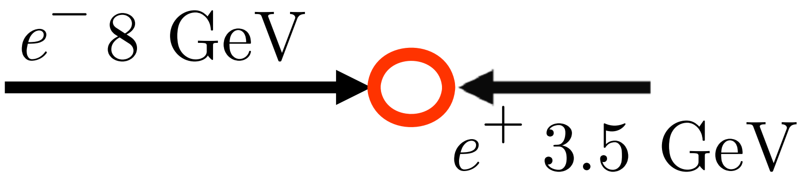


B-factories at KEK and SLAC

$\Upsilon(4S) \to B^0 \bar{B}^0$ (50%), B^+B^- (50%)

quantum entangled

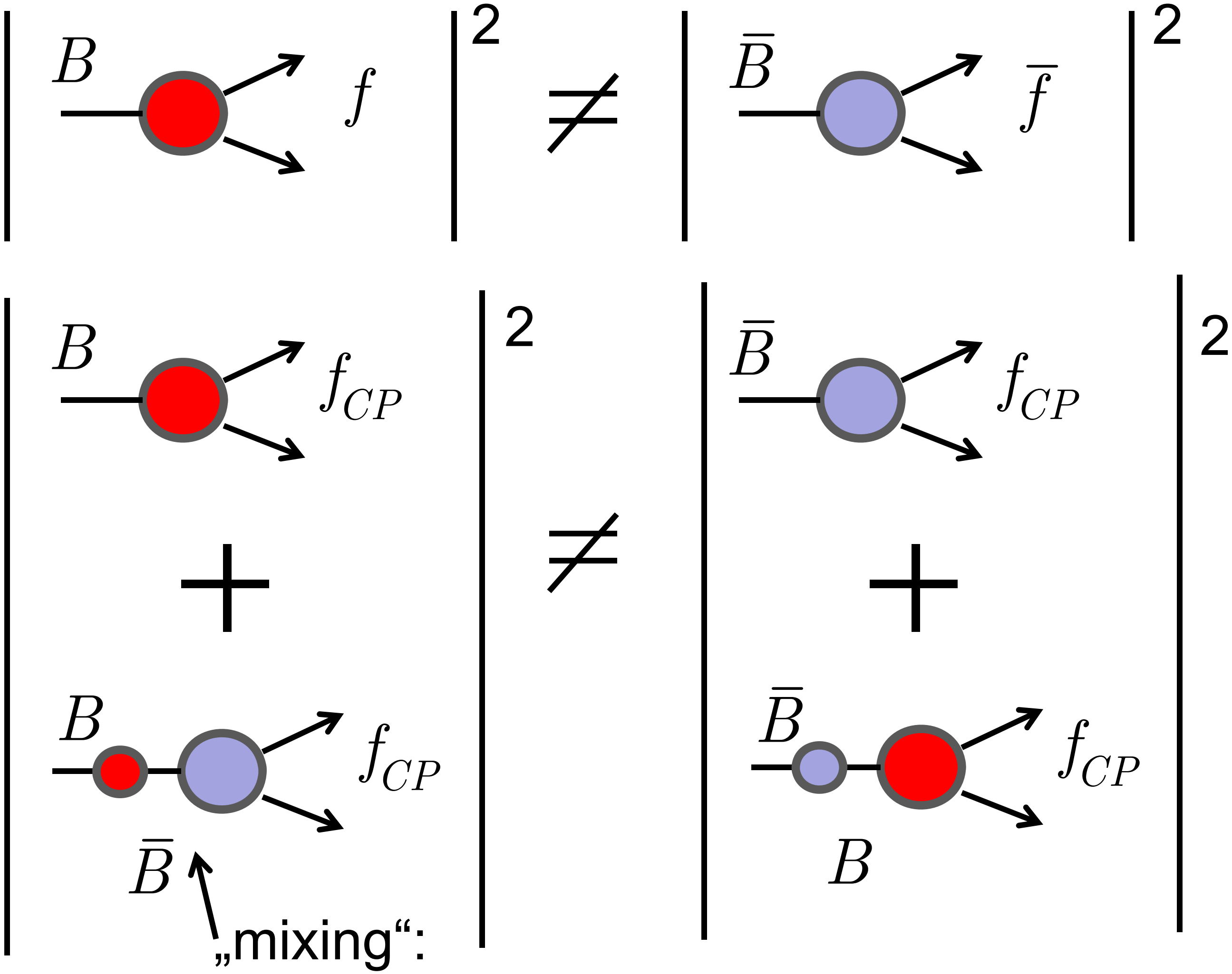




Beam energies are asymmetric:
B's have the same Lorentz boost, translate time to distance of average decay length ~200 µm ($t \to z$) , flavor of the CP decay of one B determined by the other B

Large background from continuum of light quarks (udsc)

Types of CP Violation in the B-System



direct
CP violation

(charged and
neutral B mesons)

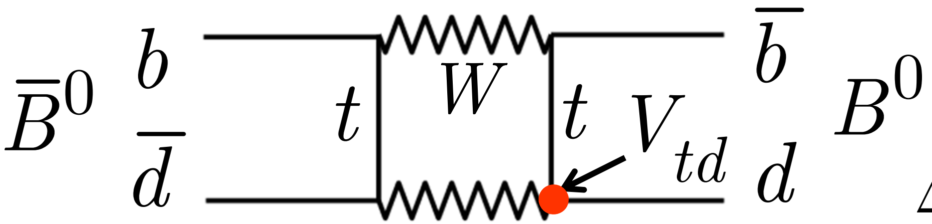
mixing-induced
CP violation

(only
neutral B mesons)

$$B_L = pB^0 + q\bar{B}^0$$

$$B_H = pB^0 - q\bar{B}^0$$

$$\frac{q}{p} = e^{-i2\phi_1}$$



$$\Delta m = M(B_H) - M(B_L)$$

Mixing-Induced CP Asymmetry

Def: $A(B^0 \to \psi) \equiv A \qquad A(\bar{B}^0 \to \psi) \equiv \bar{A}$

$$\lambda_\psi \equiv \frac{q}{p}\frac{\bar{A}_\psi}{A_\psi} \equiv e^{-2i\phi_1}$$

↖ CP eigenstate

$$\mathcal{A}_{CP}(\psi, \Delta t) = \frac{N(\bar{B}^0 \to \psi; t) - N(B^0 \to \psi; t')}{N(\bar{B}^0 \to \psi; t) + N(B^0 \to \psi; t')}$$

$$= \left[\underbrace{\frac{1 - |\lambda_\psi|^2}{1 + |\lambda_\psi|^2}}_{A_f} \cos \Delta m \Delta t + \underbrace{\frac{2\,\mathrm{Im}(\lambda_\psi)}{1 + |\lambda_\psi|^2}}_{S_f} \sin \Delta m \Delta t \right]$$

$$\Delta t = t - t'$$

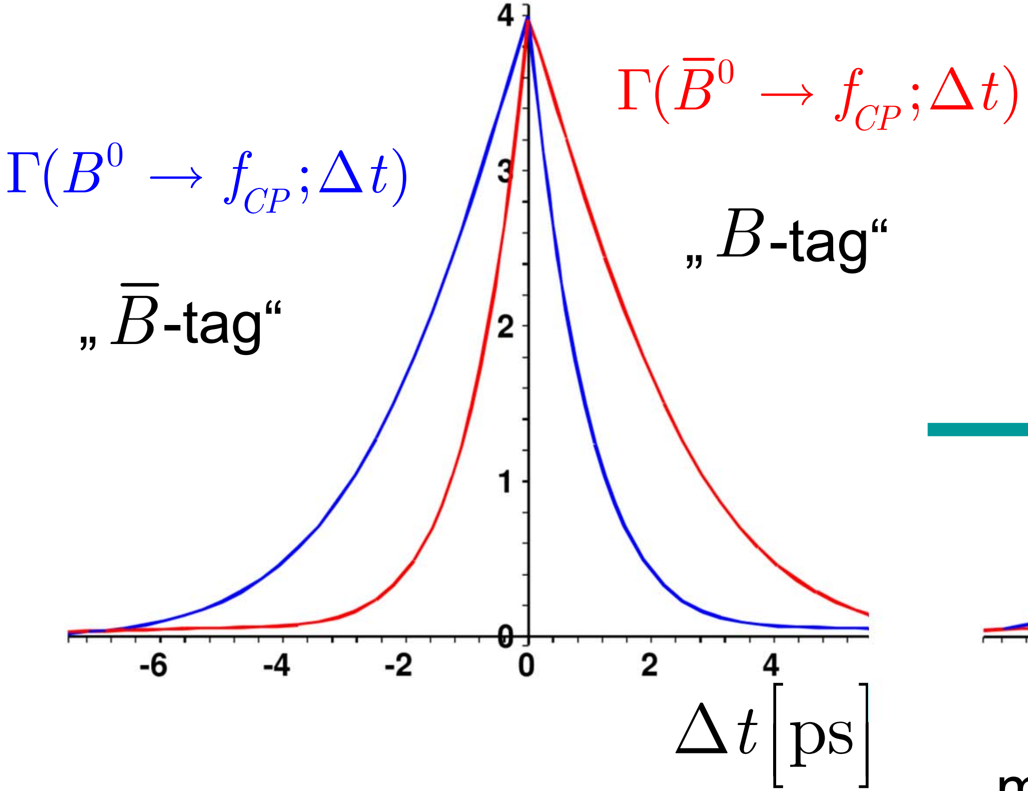
A_f Direct CP-Violation

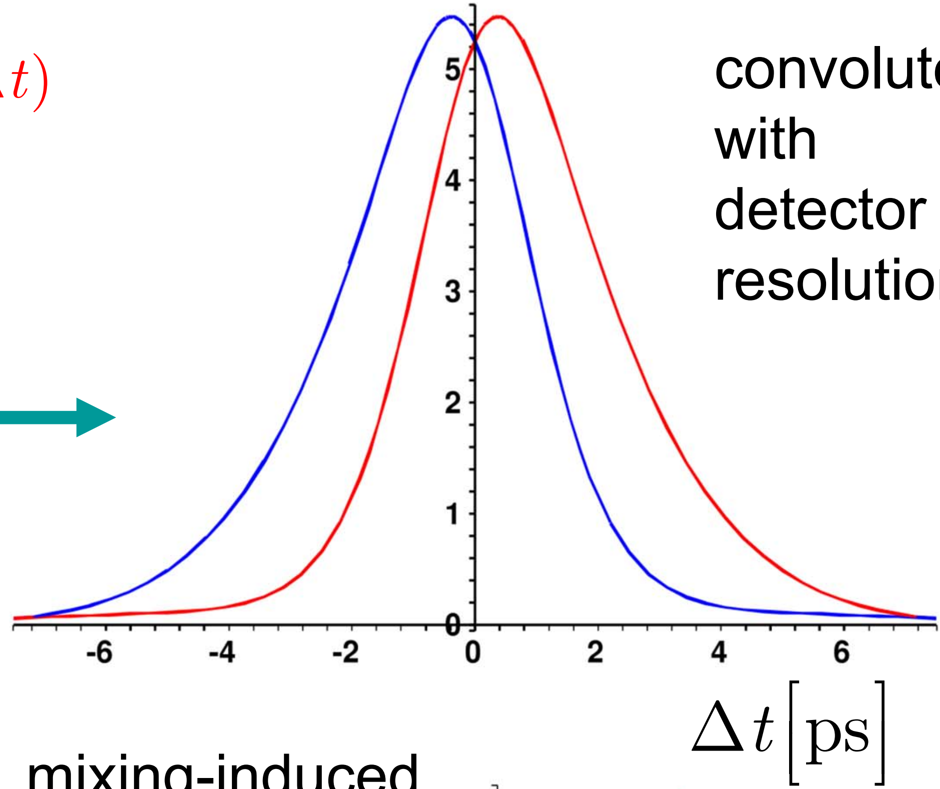
S_f CP-Violation via Mixing and Decay („mixing-induced“ CP violation)

$J/\psi K_S$:

$$\lambda_{CP} = e^{-i2\phi_1}$$

Time-Dependent CP-Asymmetries

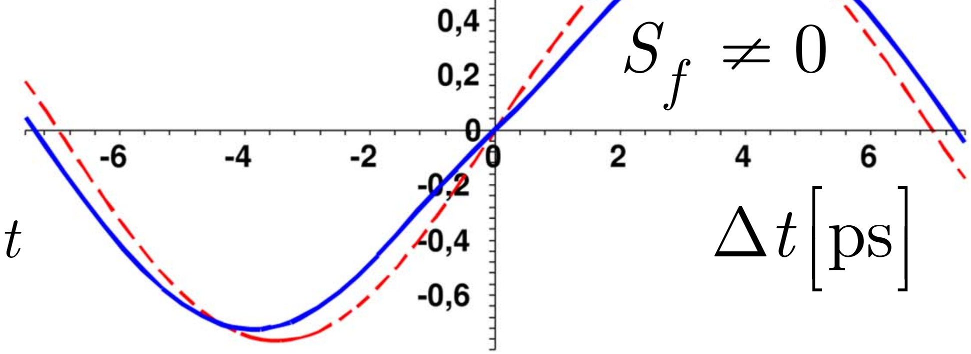




convoluted
with
detector
resolution

Direct CP violation: $A_f \neq 0$

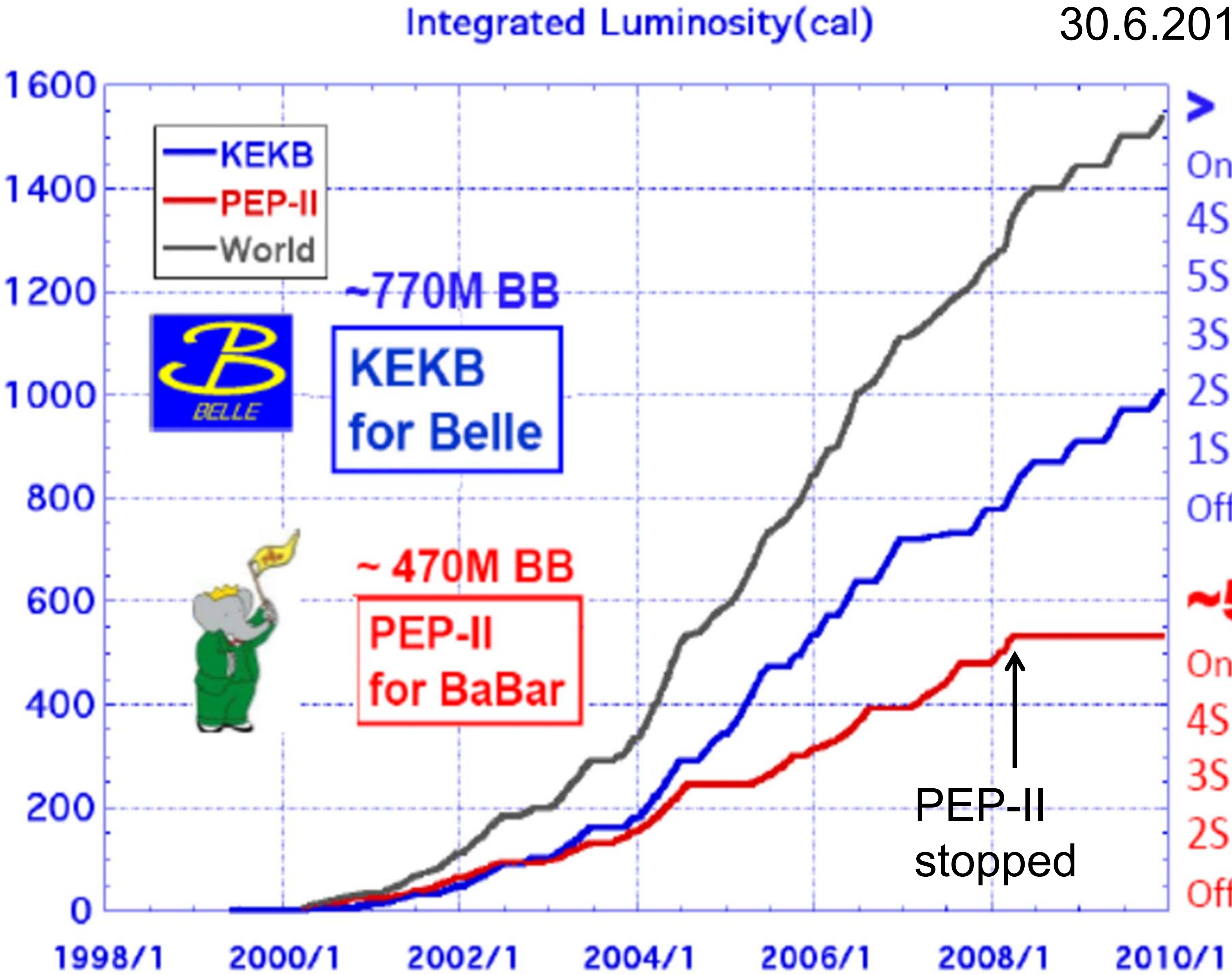
mixing-induced
CP violation



$$\mathcal{A}_{CP}(\Delta t) = \frac{N(\overline{B}^0,t) - N(B^0,t')}{N(\overline{B}^0,t) + N(B^0,t')}$$
$$= A_f \cos\Delta m\Delta t + S_f \sin\Delta m\Delta t$$

Luminosity accumulated at Present B-Factories

30.6.2010: KEKB stopped



> 1.0 ab^{-1}

On-resonance samples:

4S: 711 fb^{-1}

5S: 121 fb^{-1}

3S: 3.0 fb^{-1}

2S: 24 fb^{-1}

1S: 5.7 fb^{-1}

Off-resonance: 87 fb^{-1}

~553 fb^{-1}

On-resonance samples:

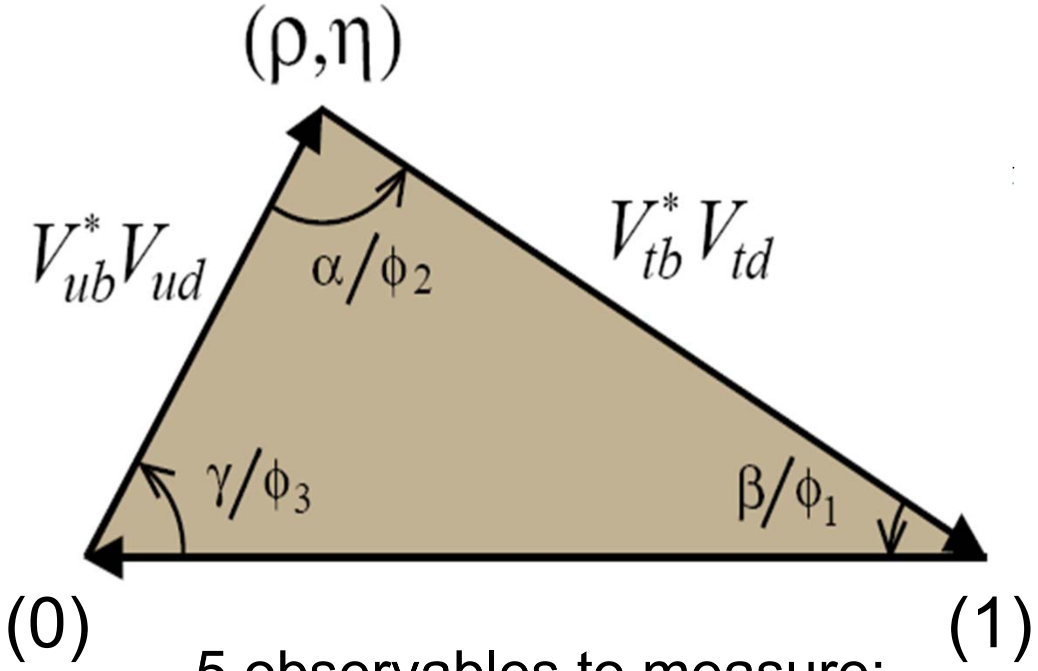
4S: 433 fb^{-1}

3S: 30 fb^{-1}

2S: 14 fb^{-1}

Off-resonance: 54 fb^{-1}

How do we see the New Physics ?



5 observables to measure:
2 sides, 3 angles:
heavily over-determined

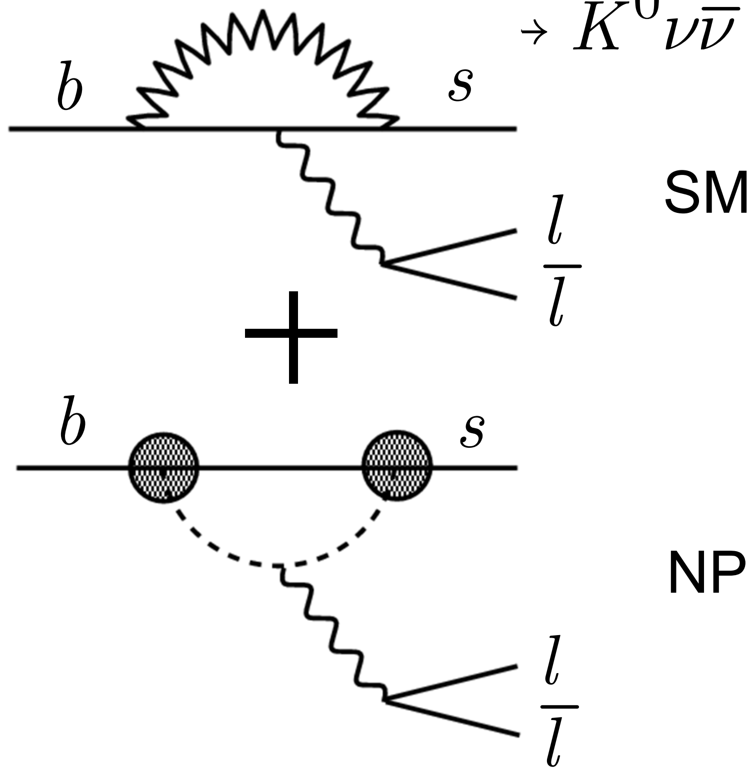
Standard Model: all 5 measurements must give consistency with the triangle

Rare decays, e.g.

$$\overline{B}^0 \rightarrow \overline{K}^0 l^+ l^-$$

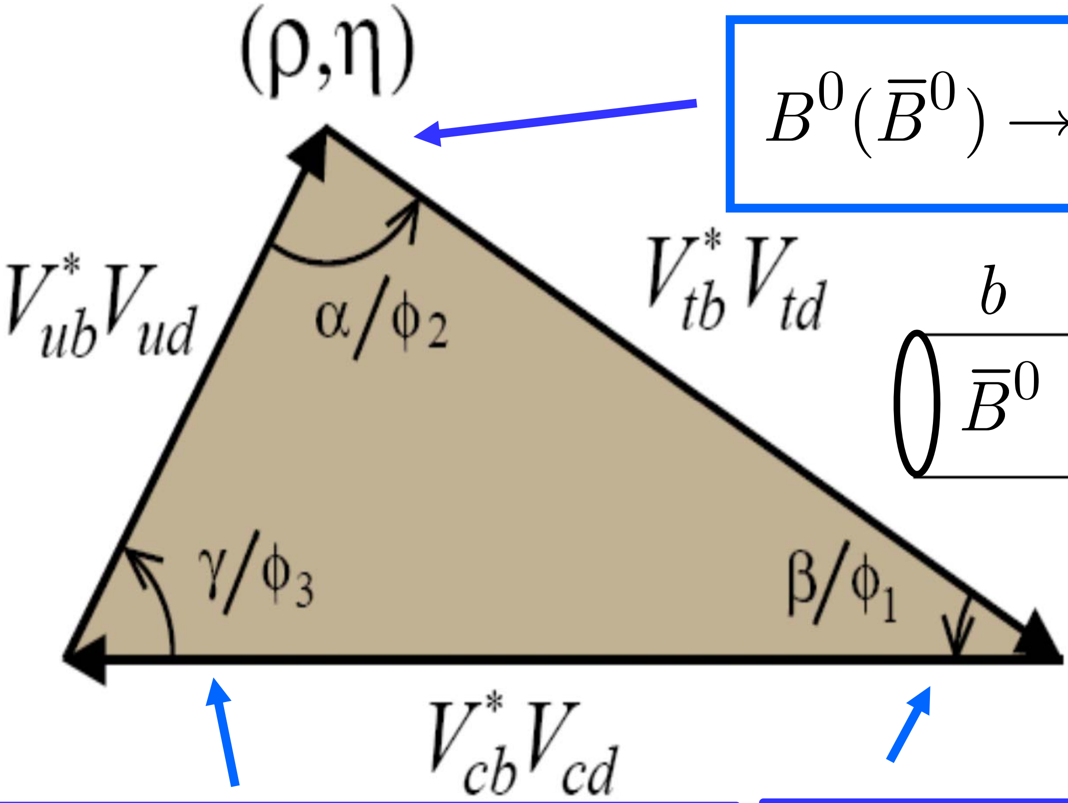
$$\rightarrow \overline{K}^0 \nu \overline{\nu}$$

„Penguin“

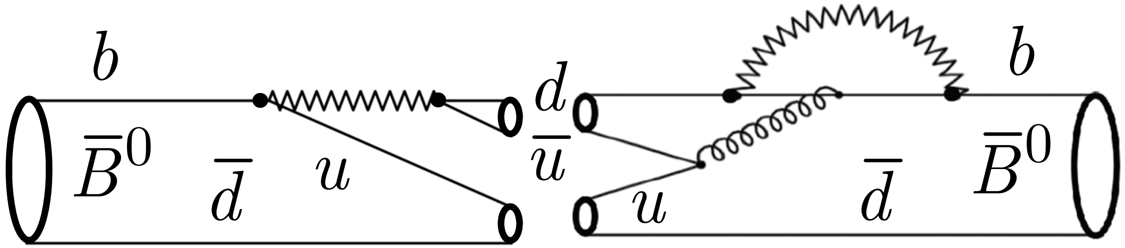


If triangle „does not close“ → **New Physics** ← unexpectedly „large“ branching fractions

Measuring the Angles (Φ_1,Φ_2,Φ_3)



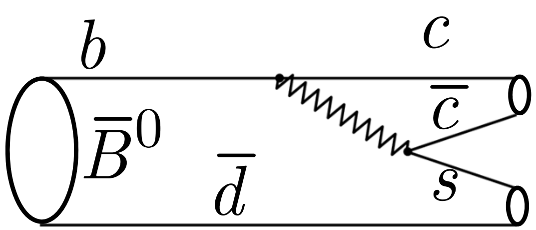
$$B^0(\overline{B}^0) \to \pi\pi, \rho\rho, \rho\pi, a_1\pi \qquad Br \sim 10^{-6}$$



T ~ P

$Br \sim 10^{-4}$

T or P dominates

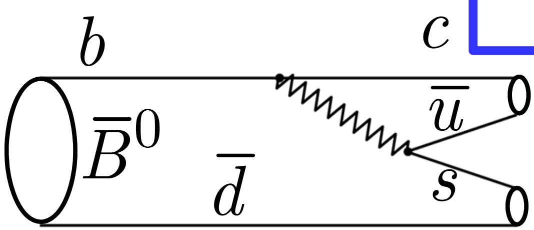


T

$$B^0(\overline{B}^0) \to D\,K_{S,L}, D^*\pi$$
$$\to K\pi$$

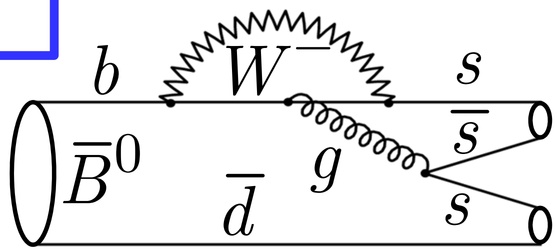
$$B^0(\overline{B}^0) \to J/\psi\,K_{S,L}$$
$$\to \phi\,K_{S,L}$$

$Br \sim 10^{-5}$



....

T (only)



P

Comparison Tree and Penguins for ϕ_1 (β)

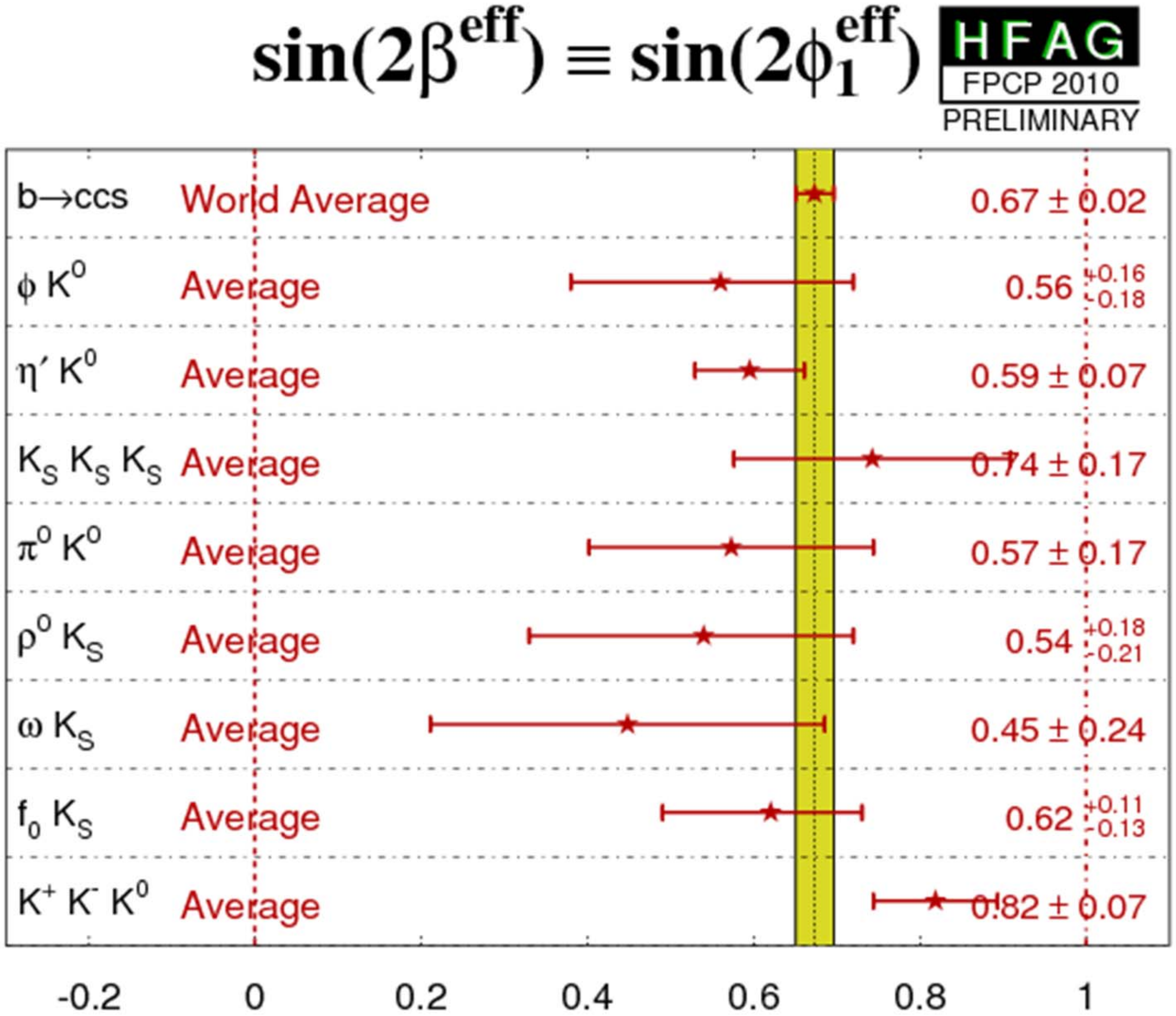
$b \longrightarrow c\bar{c}s$ tree

$b \longrightarrow sq\bar{q}$ penguins

penguins from 2-body decays

penguins from Dalitz plot analysis

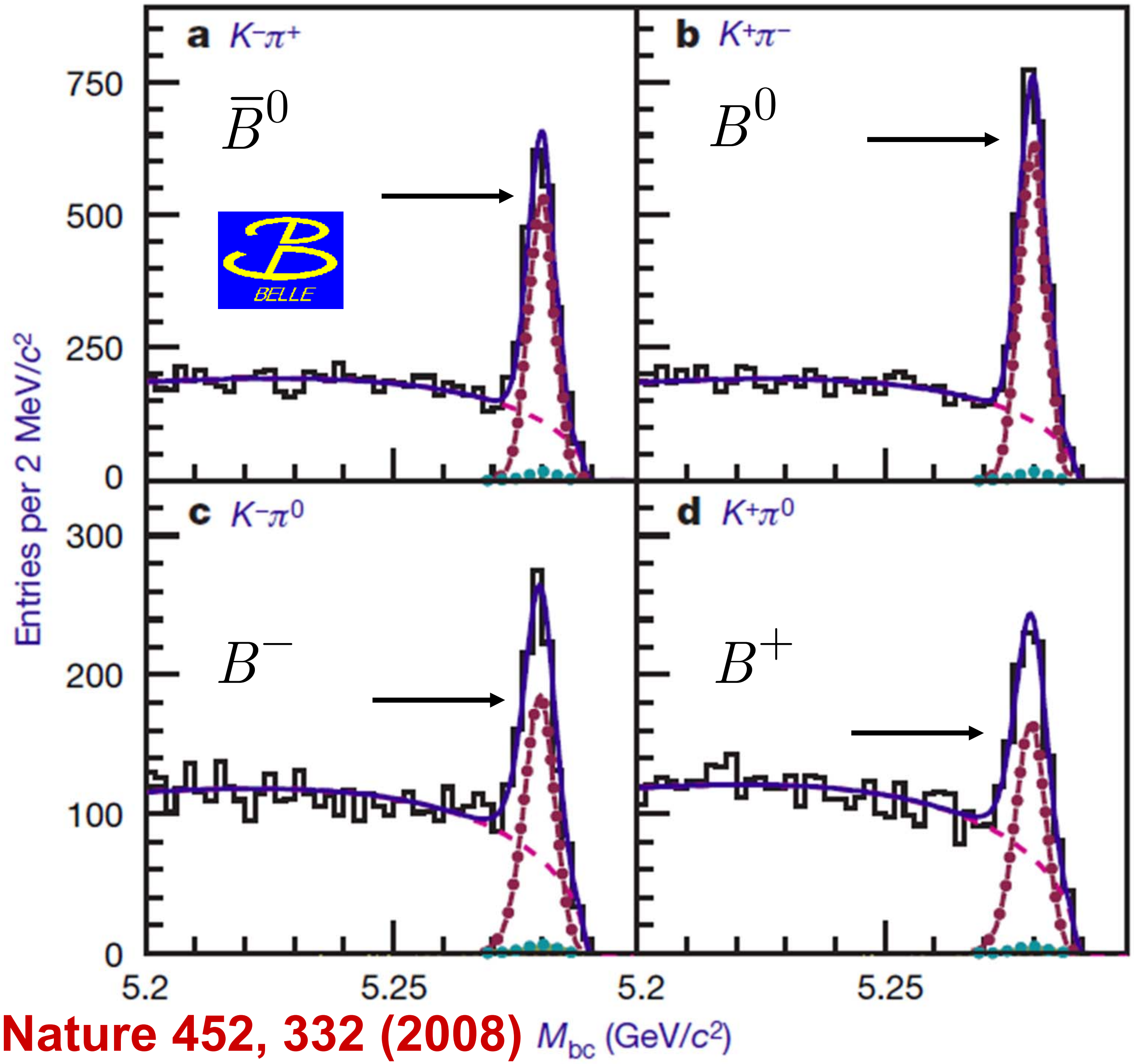
only small contr. from T -> „eff.“



ϕ_1 from tree and penguins consistent, but …

Theory (SM) predicts $\phi_1^{eff} > \phi_1$

Another Puzzle: Direct CP Violation in $B \to K\pi$



Nature 452, 332 (2008)

$A_{CP}(K^+\pi^-) < 0$

WA: -0.098 ± 0.012

$A_{CP}(K^+\pi^0) > 0$

WA: $+0.050 \pm 0.025$

should be equal !

- Large color-suppressed tree amplitude?
- Enhanced EW penguin?
- New Physics?

Adding to the Kπ Puzzle

Isospin relation provides test for New Physics:

$$\mathcal{A}_{CP}(K^+\pi^-) + \mathcal{A}_{CP}(K^0\pi^+)\frac{Br(K^0\pi^+)}{Br(K^+\pi^-)}\frac{\tau_0}{\tau_+}$$

$$= \mathcal{A}_{CP}(K^+\pi^0)\frac{2Br(K^+\pi^0)}{Br(K^+\pi^-)}\frac{\tau_0}{\tau_+} + \mathcal{A}_{CP}(K^0\pi^0)\frac{2Br(K^0\pi^0)}{Br(K^+\pi^-)}$$

Need to measure $B^0 \rightarrow K_S\pi^0$

first Belle paper by MPI group
PRD 81 (2010) 011101

Isospin sum rule predicts: $\mathcal{A}_{CP}(K^0\pi^0) = -0.153 \pm 0.045$

We measure: $\mathcal{A}_{CP}(K^0\pi^0) = +0.14 \pm 0.14$

(1.9 σ deviation)

Ongoing and Planned Analyses @ MPI

Mode	Physics parameter(s) of interest	
$B^0 \to D^{*+}D^{*-}K^0_S$	$\sin 2\phi_1, \cos 2\phi_1$	
$B^0 \to \psi(2S)\pi^0$	$\sin 2\phi_1$	tree / penguin consistency in Φ_1
$B^0 \to K^0_S\pi^+\pi^-$		
$B^0 \to K^{*+}\pi^-, K^{*+}(1430)\pi^-$	$\mathcal{A}_{CP}$	
$B^0 \to \rho^0 K^0_S, f_0K^0_S, f_2K^0_S, f_X K^0_S, \chi_{c1}K^0_S$	ϕ_1	
$B^0 \to K^0_S\pi^0$	$\mathcal{A}_{CP}, \sin 2\phi_1$	
$B^0 \to \omega K^0_S$	$\sin 2\phi_1$	
$B^0 \to \pi^+\pi^-, K^+\pi^-, K^+K^-$	$\mathcal{A}_{CP}, \sin 2\phi_2$	„complete“ Φ_2 analysis
$B^0 \to \rho^0\rho^0$, $\rho^+\rho^-$	$\sin 2\phi_2$	
$B^0 \to a_1^\pm\pi^\mp$	$\sin 2\phi_2$	

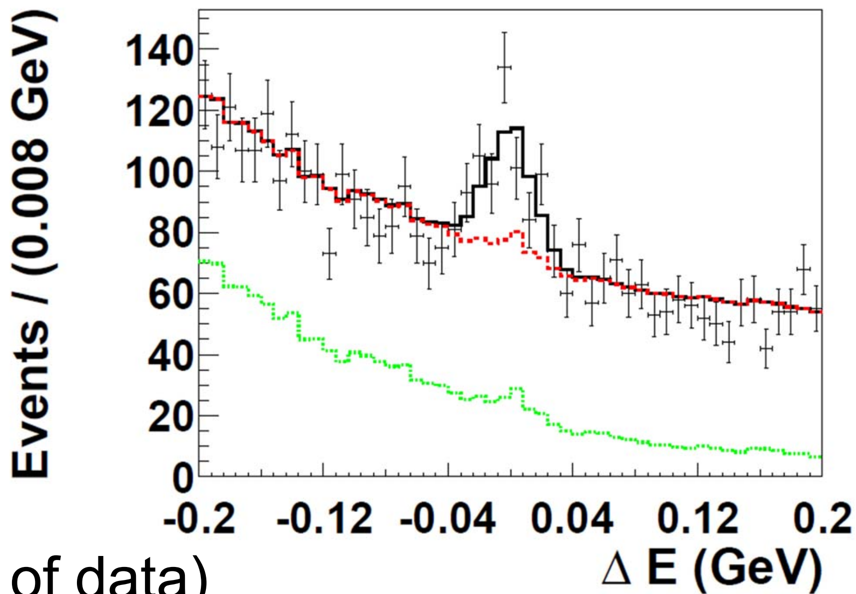
Members involved: V. Chobanova, J. Dalseno, C.K., S. Koblitz, A. Moll, E. Nedelkovska, K. Prothmann, P. Vanhoefer

New Analysis Strategy of MPI group

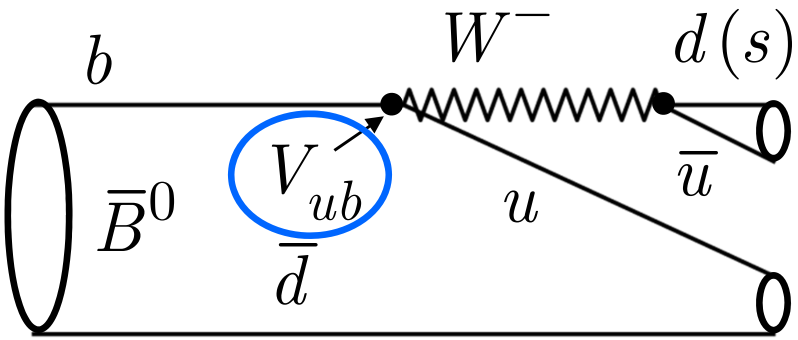
- $b \rightarrow u\bar{u}d$ strongly suppressed by CKM matrix elements (T & P)
  - → high background levels (other *B* decays, continuum)
  - → construct variables to discriminate signal from continuum
- Standard Belle procedure: cuts on variables to optimize $S\,/\,\sqrt{S+B}$
- J. Dalseno et al.: minimize # of cuts, instead use multi-variate fitting approach to get best signal sensitivity

Example $B^0 \rightarrow a_1(1260)^+\pi^-$

	previously	now (@MPI)	
eff	8.6 %	19.1 %	
BR	13.2 ± 3.0	13.2 ± 1.6	(x 10^{-6})
similarly:			
eff ($\rho^0\rho^0$)	9 %	23 %	(Pit V.)
Nsig	25 ± 29	57 ± 23	(only 1/3 of data)



Ongoing Analyses of MPI group: measure Φ_2

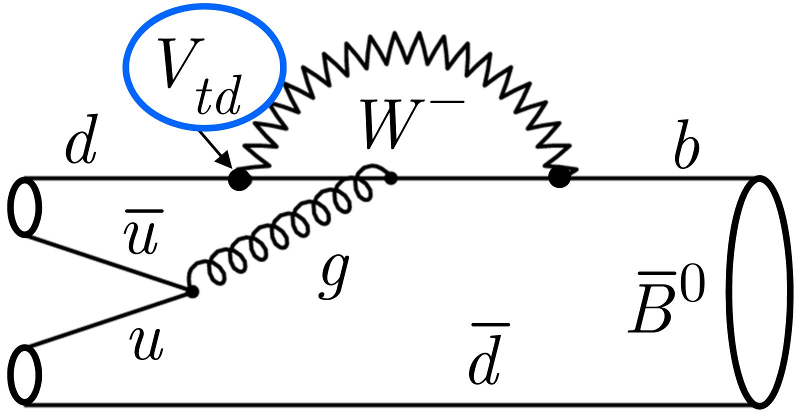


T

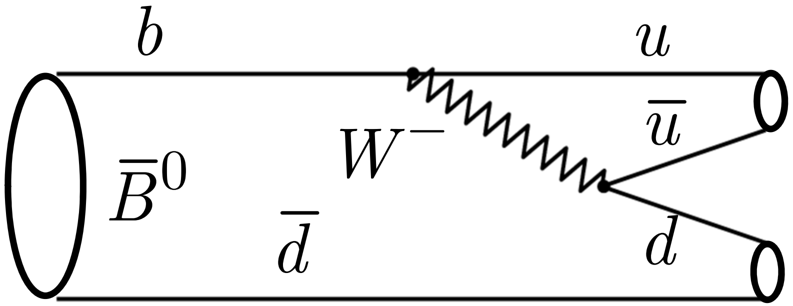
$b \to u\bar{u}d$

π^-, ρ^-, π^-

π^+, ρ^+, a_1^+



P



π^0, ρ^0

π^0, ρ^0

color-suppressed (~1/9)

Present value of α: 92 ± 7 °

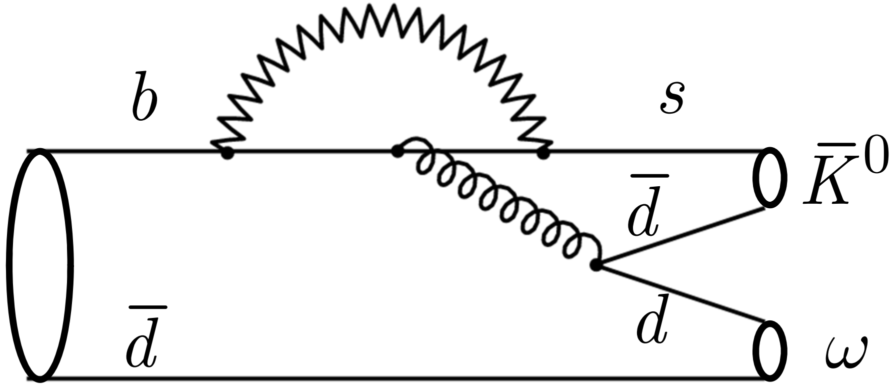
$B^0 \to \pi^+\pi^-$	Kolja Prothmann
$\to \rho^+\rho^-$	Pit Vanhoefer
$\to \rho^0\rho^0$	Pit Vanhoefer
$\to a_1\pi$	Jeremy Dalseno

- hope to improve with full Belle data sample + new analysis methods
- isospin analyis to lift the ambiguities (GL method)

Analyses just Started: Tree vs. Penguin

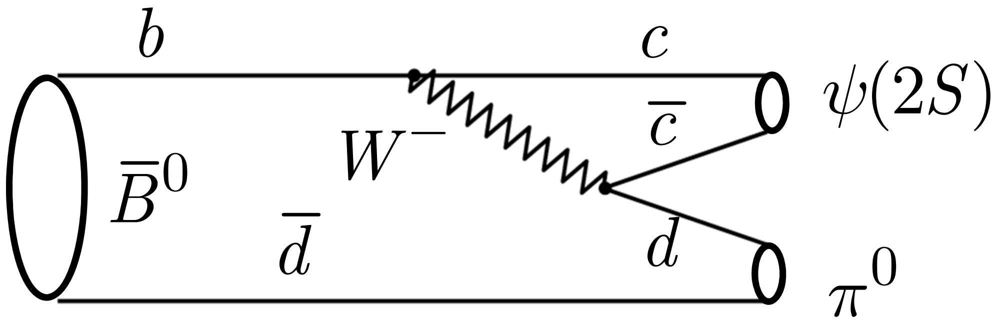
$B^0 \to \omega K_S$ (V.C.)

penguin-dominated,
significant improvement
with full data set



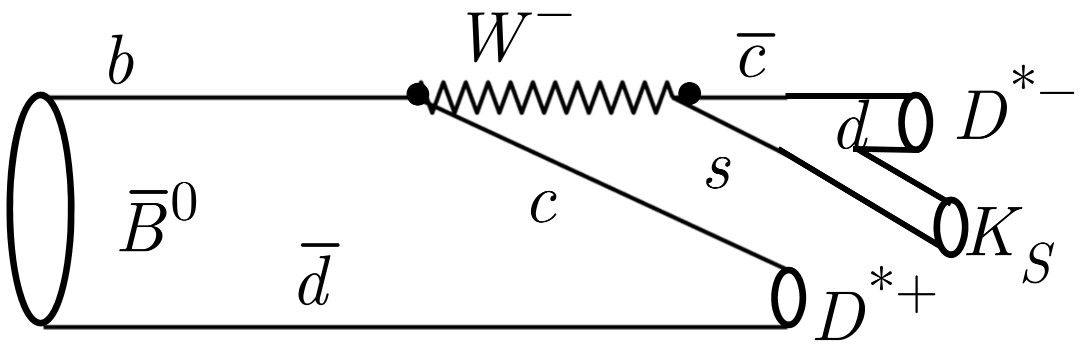
$B^0 \to \psi(2S)\pi^0$ (E.N.)

Color-suppressed tree,
check penguin contamination
in $B^0 \to J/\psi\, K^0$
hope for first measurment in Belle



$B^0 \to D^{*+} D^{*-} K_S$ (M.R.)

lift sign ambiguity for Φ_1,
Ideal to test slow pion finder



SuperKEKB and Belle II

Belle-II Collaboration founded in Dec. 2008

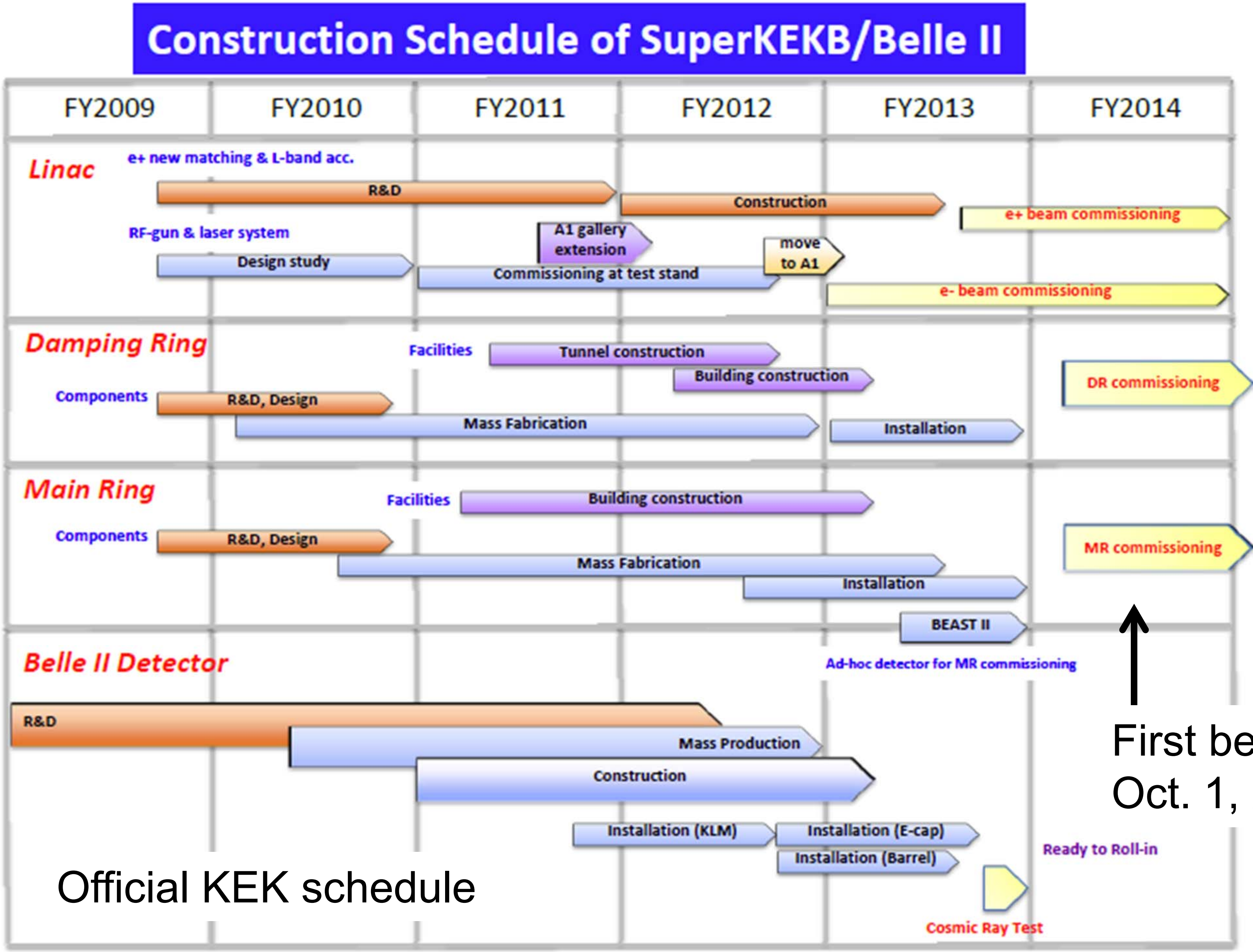
now over 350 members from
47 institutions and 13 countries
strong European participation:
Austria, Germany, Czech Republic,
Poland, Spain, Slovenia,
(mainly in Pixel Vertex Detector,
Si Strip Detector)

PXD project led by MPI

SuperKEKB: increase luminosity by
a factor of 50

Project given “Green Light” (110 M$ granted)
Two more steps: MoF and parliament (2011.3)

Schedule for SuperKEKB and Belle II

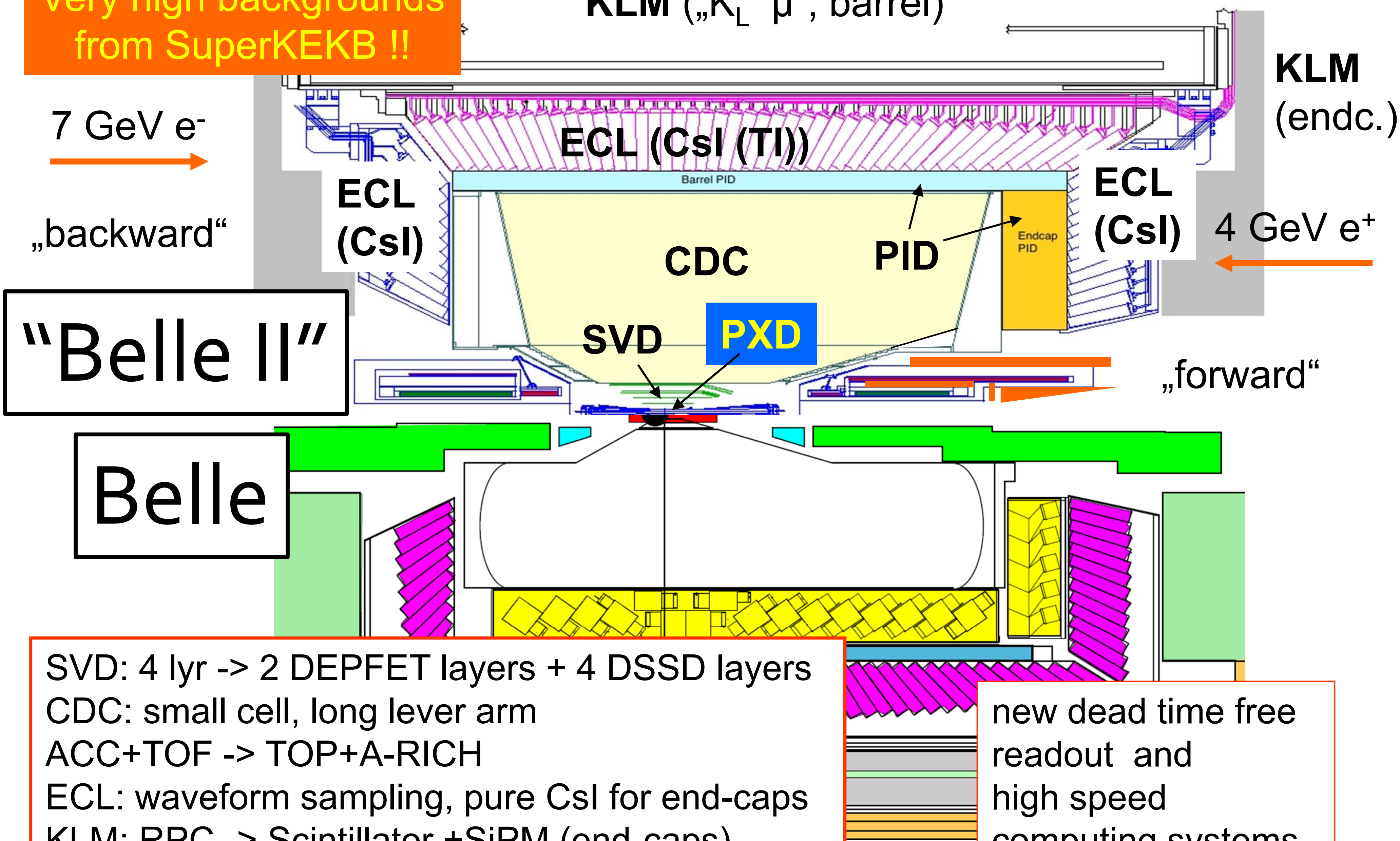


First beams Oct. 1, 2014

Official KEK schedule

Detector: Baseline Design

Very high backgrounds from SuperKEKB !!



SVD: 4 lyr -> 2 DEPFET layers + 4 DSSD layers
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)

new dead time free readout and high speed computing systems

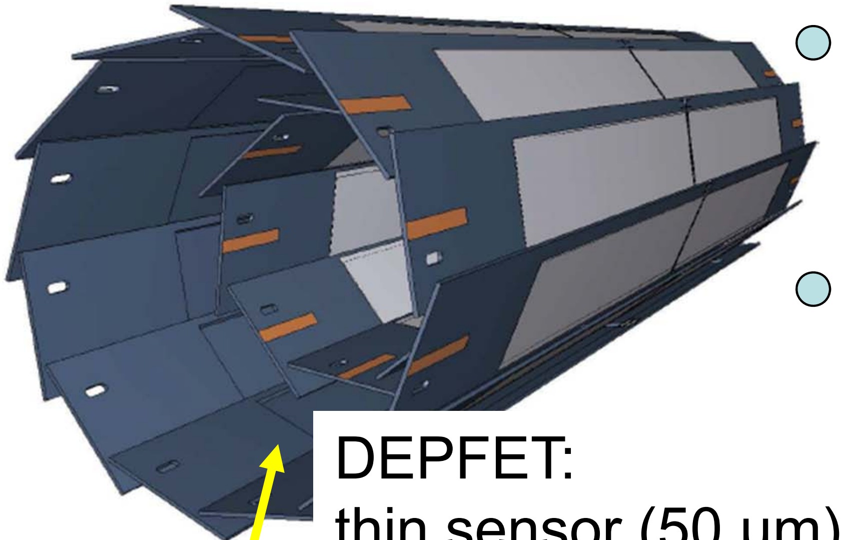
Silicon Tracking System @ Belle II

SuperKEKB: Nano beam option, 1 cm radius of beam pipe

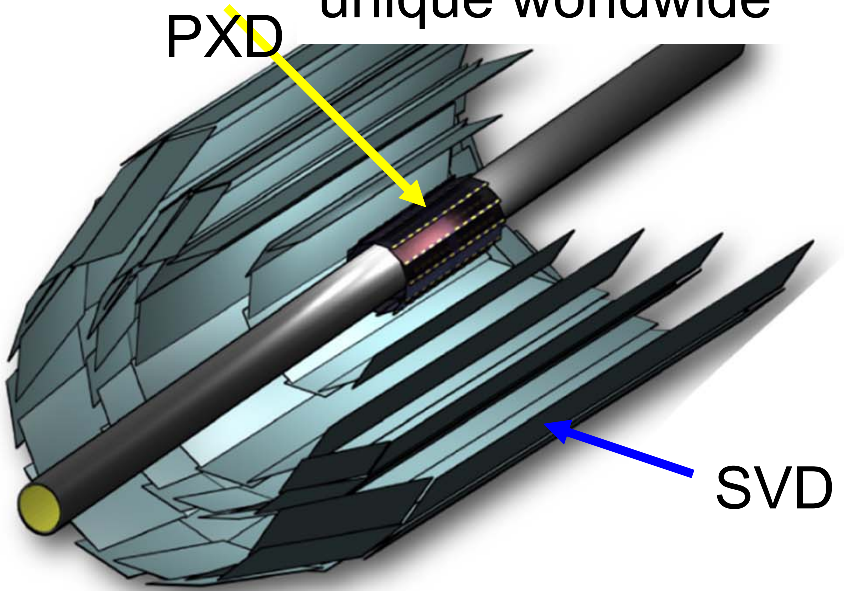
„PXD“

- 2 layer Si pixel detector (DEPFET technology)
  (R = 1.4, 2.2 cm) monolithic sensor
  thickness 75 µm (!), pixel size ~50 x 50 µm²

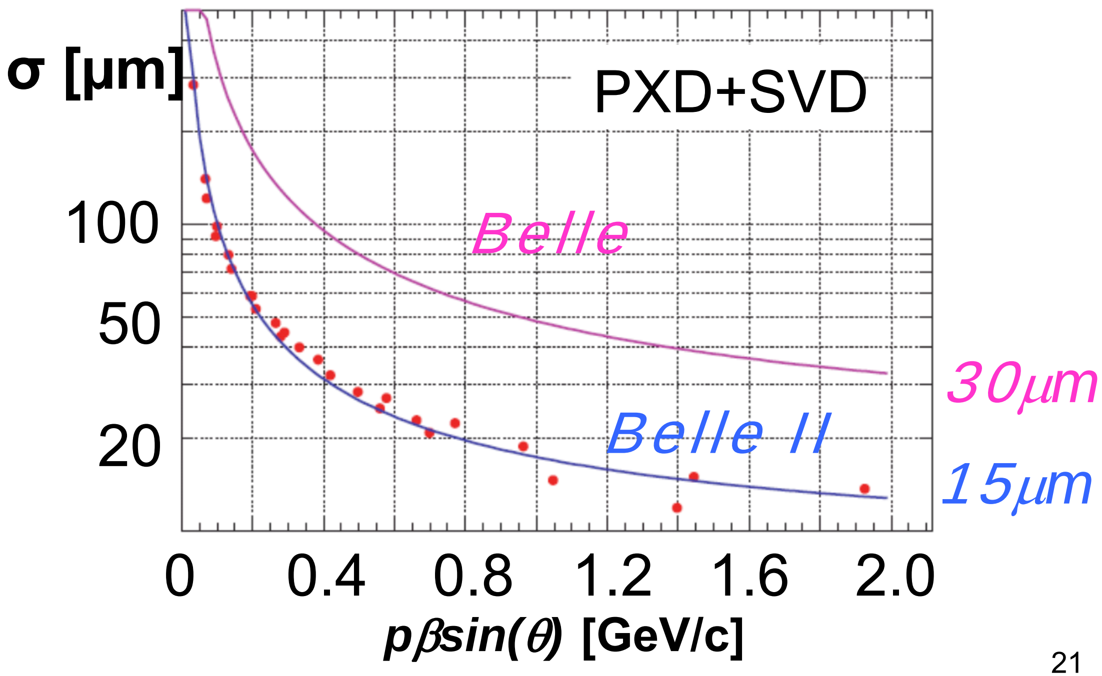
- 4 layer Si strip detector (DSSD) ← „SVD“
  (R = 3.8, 8.0, 11.5, 14.0 cm)



DEPFET:
thin sensor (50 µm)
unique worldwide



Significant improvement in z-vertex resolution



DEPFET-Collab. @ Belle II

Mission: DEPFET pixel detector @ Belle II by end of 2013

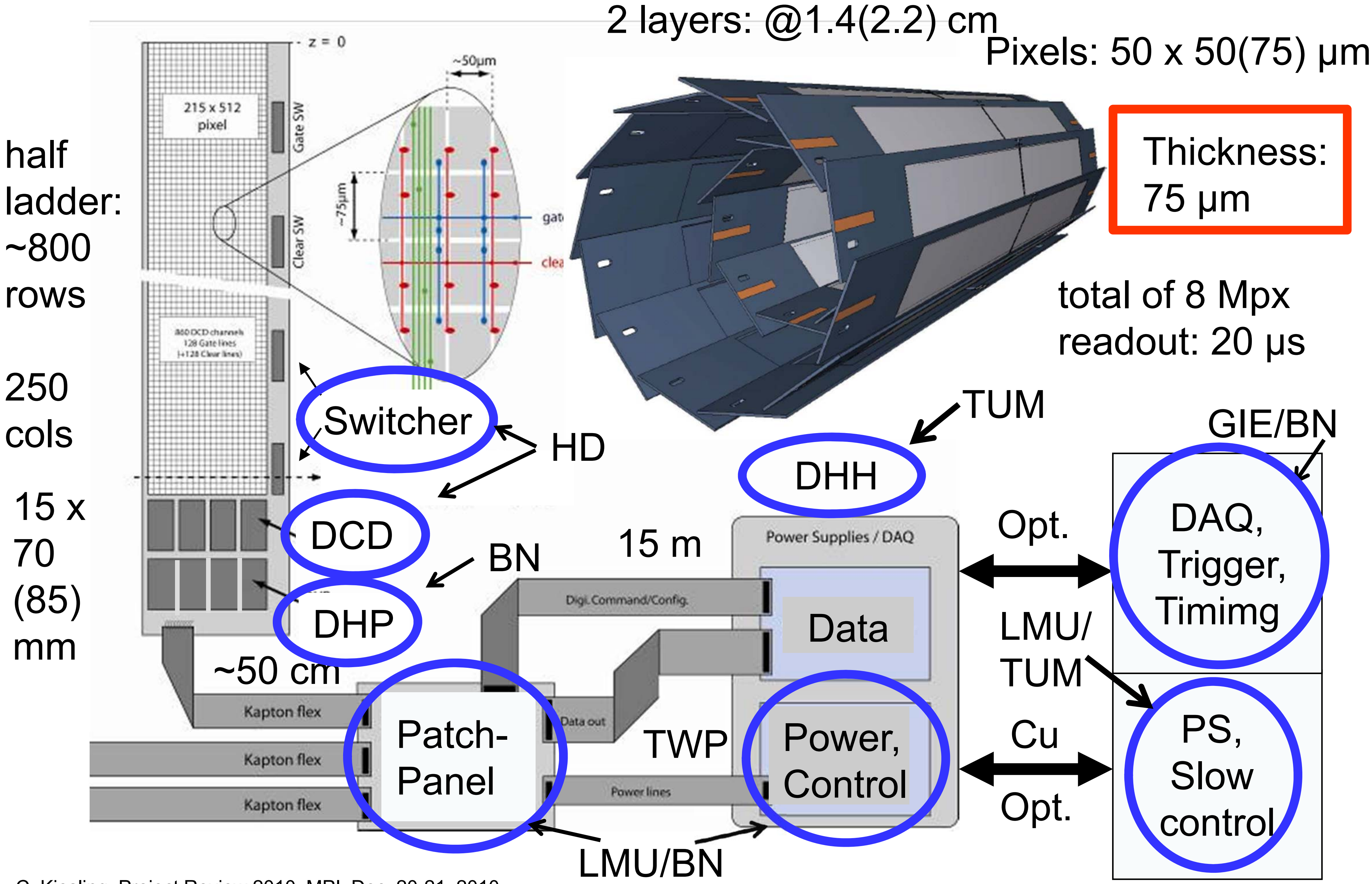
University of Barcelona, Spain
CNM, Barcelona, Spain
IHEP Beijing, China
University of Bonn (N. Wermes, H. Krüger)
University of Heidelberg (P. Fischer, I. Peric)
University of Giessen (W. Kühn, S. Lange)
University of Göttingen (A. Frey)
University of Karlsruhe (T. Müller, M. Feindt)
IFJ PAN, Krakow, Poland
Ludw.-Max.-University, Munich (J. Schieck)
Max-Planck-Institute for Physics, Munich
Technical University, Munich (S. Paul)
Charles University, Prague, Czech Republic
IFCA Santander, Spain
IFIC, Valencia, Spain

DEPFET@Belle II

Management:

- Project Leader
  C. Kiesling (MPI)
- Technical Coord.
  H.-G. Moser (MPI)
- IB- Board
  Chair: Z. Dolezal (Prag)
- Integration Coordinator
  Shuji Tanaka (KEK)

PXD Project - Layout



Main Tasks for our Group in Belle II

Hardware

- Design and production of radiation-hard DEPFET sensors
- Development of test procedures for QC
- Design and construction of the sensor support and the cooling system
- Design and construction of the PXD support on the beam pipe

C. Koffmane
A. Ritter
M. Ritter
(P. Müller)

Software

- Optimization of the DEPFET sensors for Belle-II
- Design of algorithms for the PXD data reduction
- Development of simulation/reconstruction framework
- Development of tracking algorithms and PXD alignment

A. Moll
K. Prothmann
M. Ritter
(C. Heller)

Mechanics and Cooling

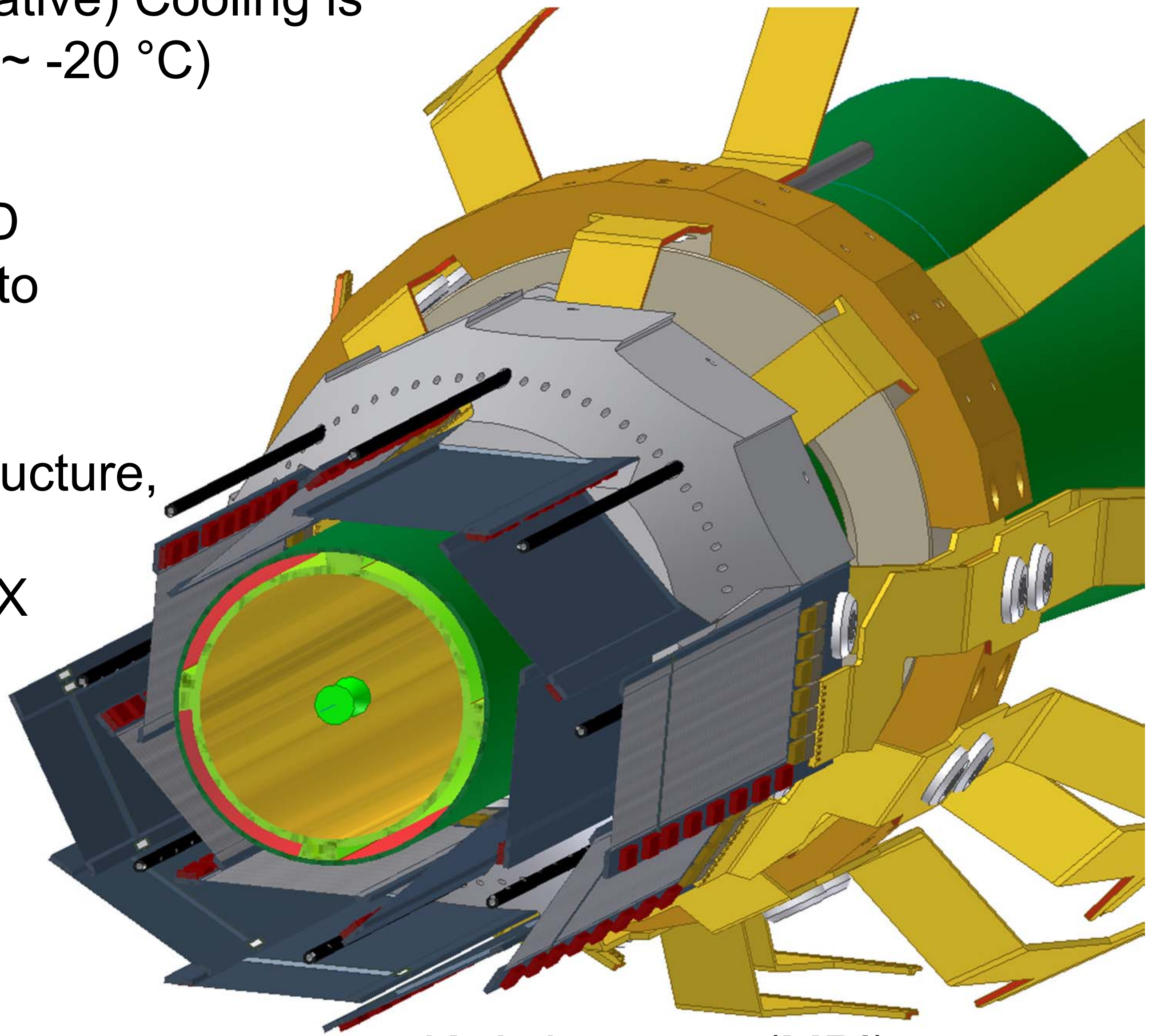
CO2 (2-phase evaporative) Cooling is baseline for the PXD (~ -20 °C)

CO2 pipes within the PXD support structure (needs to stand 120 Bar)

→ new design of support structure, based on novel 3D manufacturing using INOX („rapid prototyping“)

New idea for air flow:

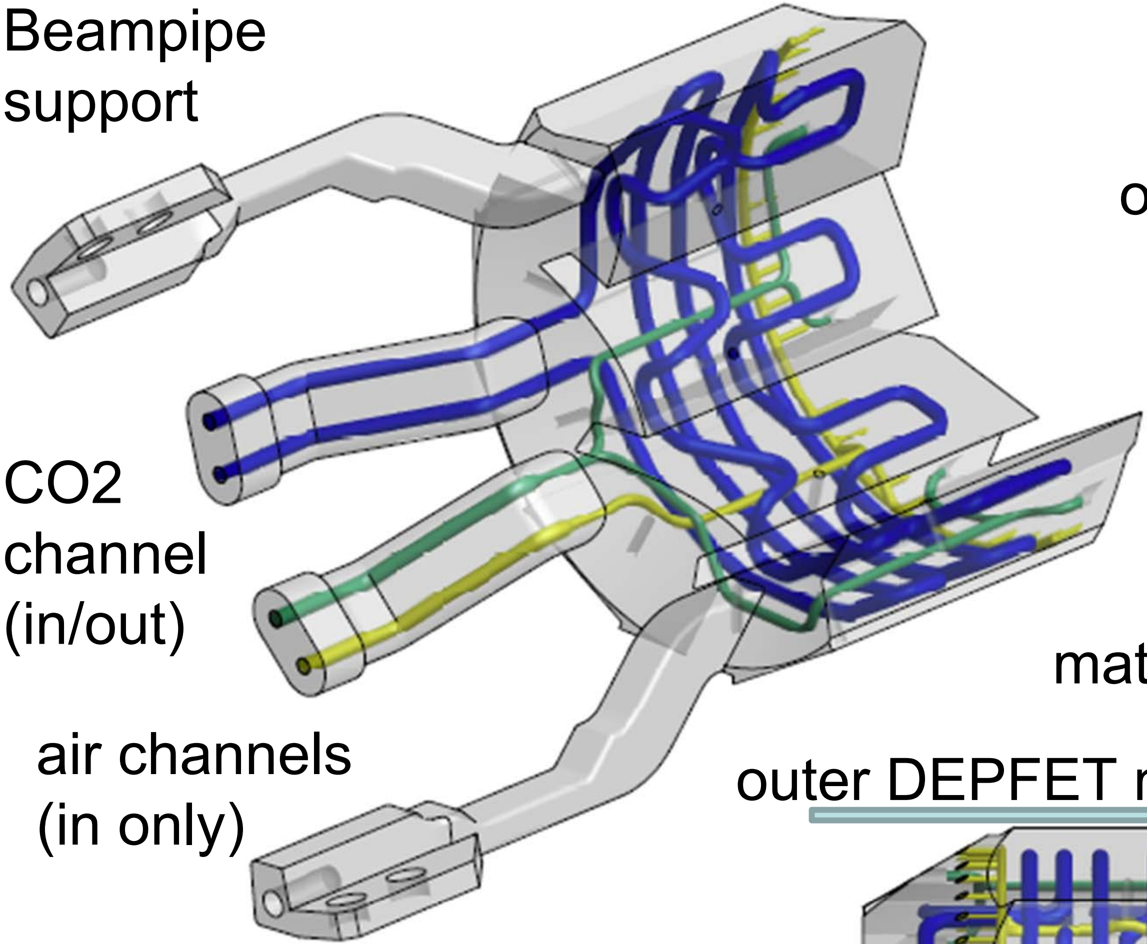
additional carbon pipes for direct air cooling of the switcher chips



K. Ackermann (MPI)

Mechanics and Cooling (cont.)

Beampipe support



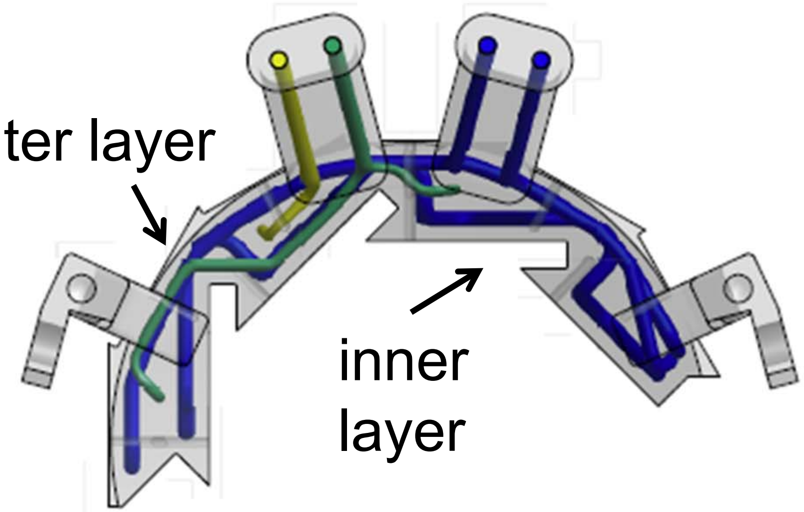
CO2 channel (in/out)

air channels (in only)

air

CO2

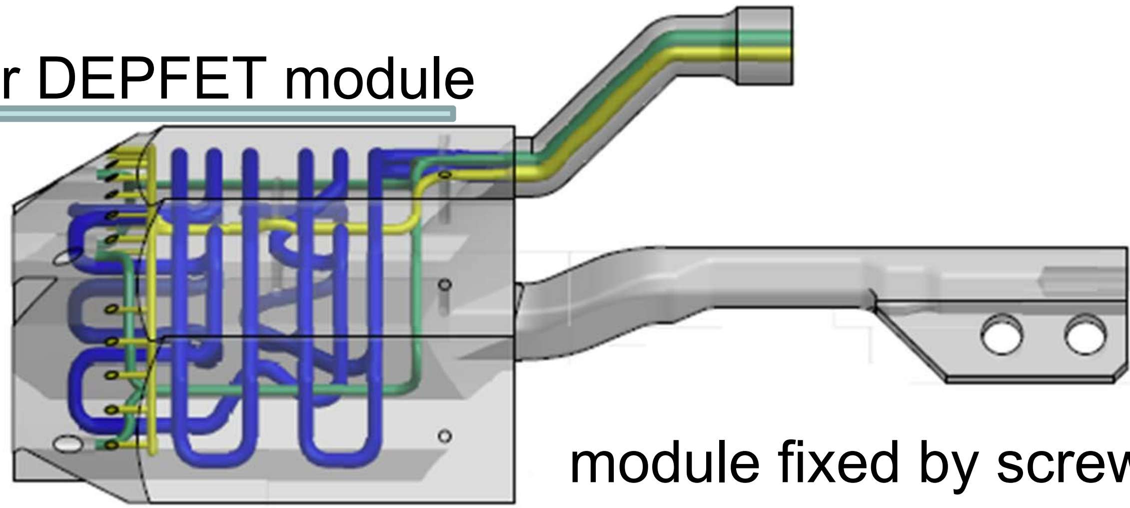
outer layer



inner layer

material INOX

outer DEPFET module



module fixed by screw

design: K.A. (MPI)
manufactured by Fruth Innovative Technology (FIT)

Mechanics and Cooling (cont.)

- 6 cooling blocks in stainless steel ordered

tested to withstand 120 bars:

all OK

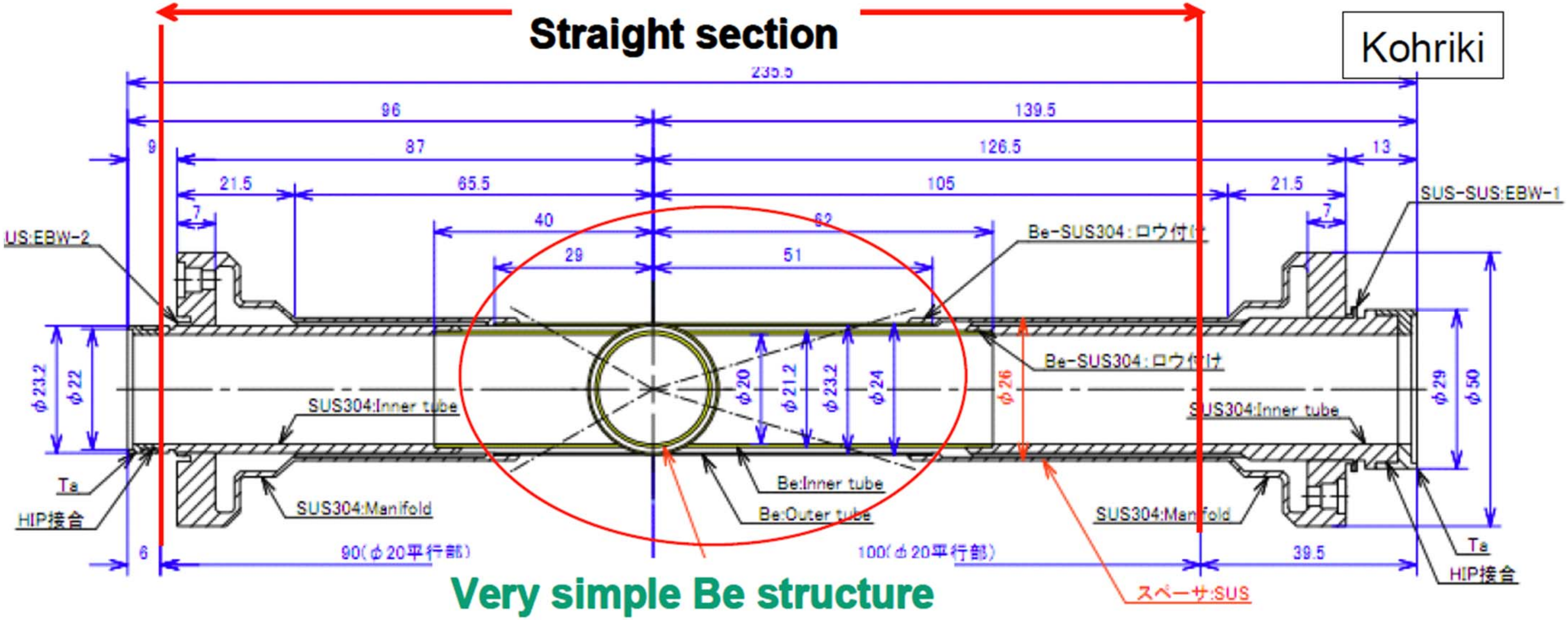
tested for tightness:

2 of 6 OK

- 2 tight blocks now at Karlsruhe for CO_2 cooling tests

Full-Size Mockup of the PXD

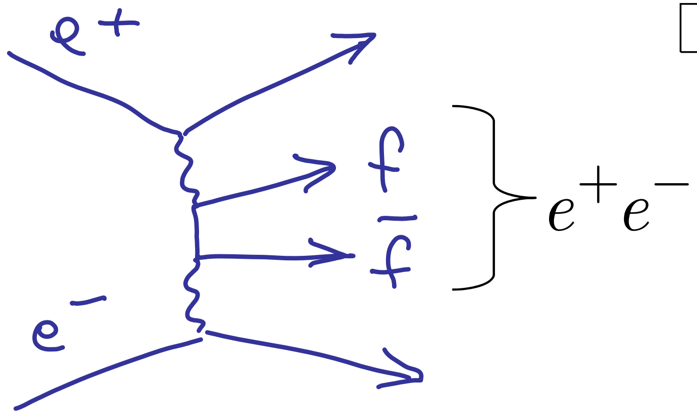
Problem: New Beam Pipe Design



Short Be part, additional SS part -> outer radius increased!!
new radius: 12.7 mm +0 -0.1 (was 12.0 mm !!)

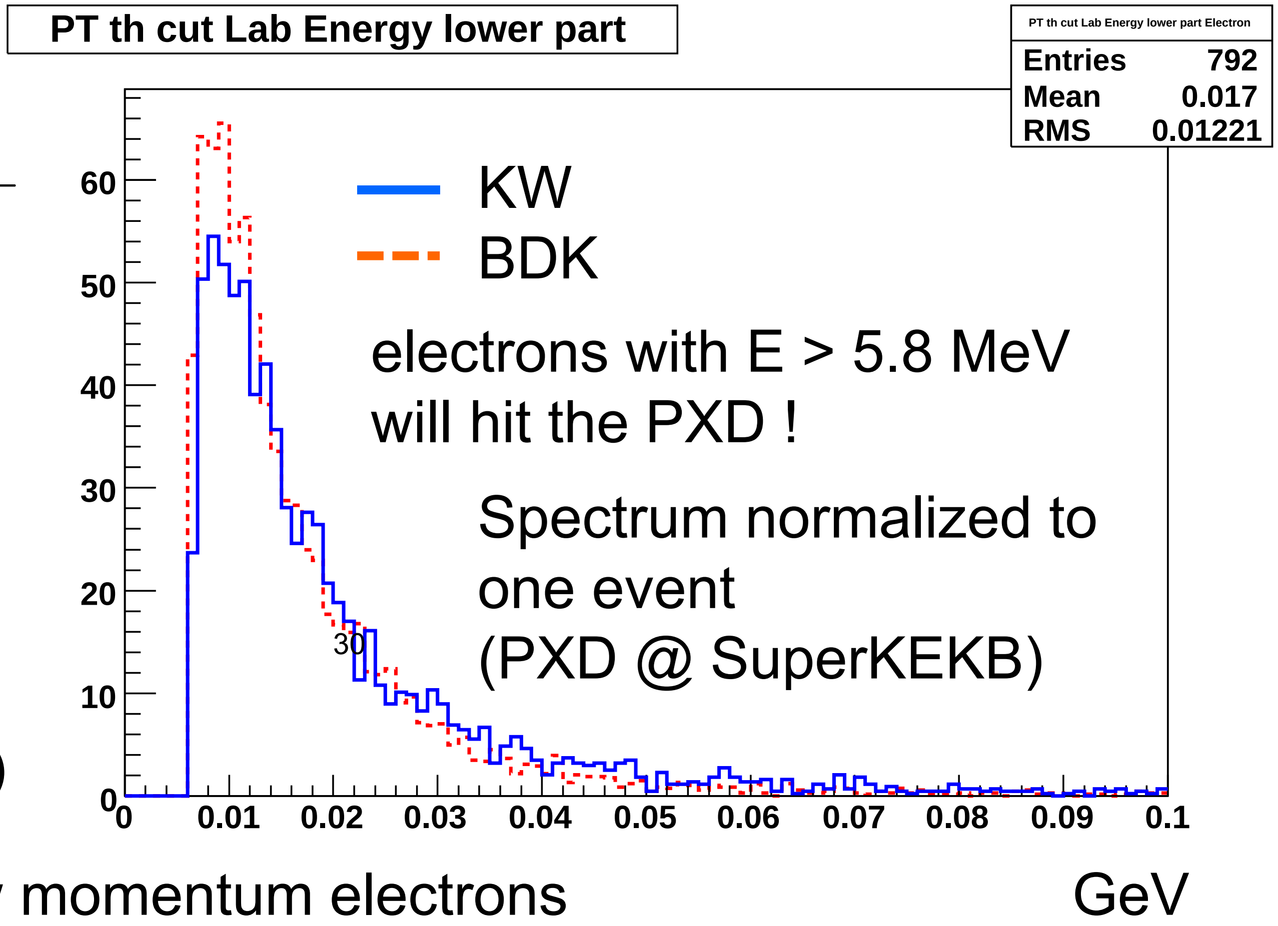
Consequence: too little (?) clearance between SS and PXD ladder
attention: ASIC + caps + wire bonds
(PXD ladder @14 mm)

QED Background @ SuperKEKB



$$e^+e^- : \sigma \sim O(10^7 \mathrm{nb})$$

SuperB MC :
expect many additional hits
(> 1.5 % occupancy in PXD)

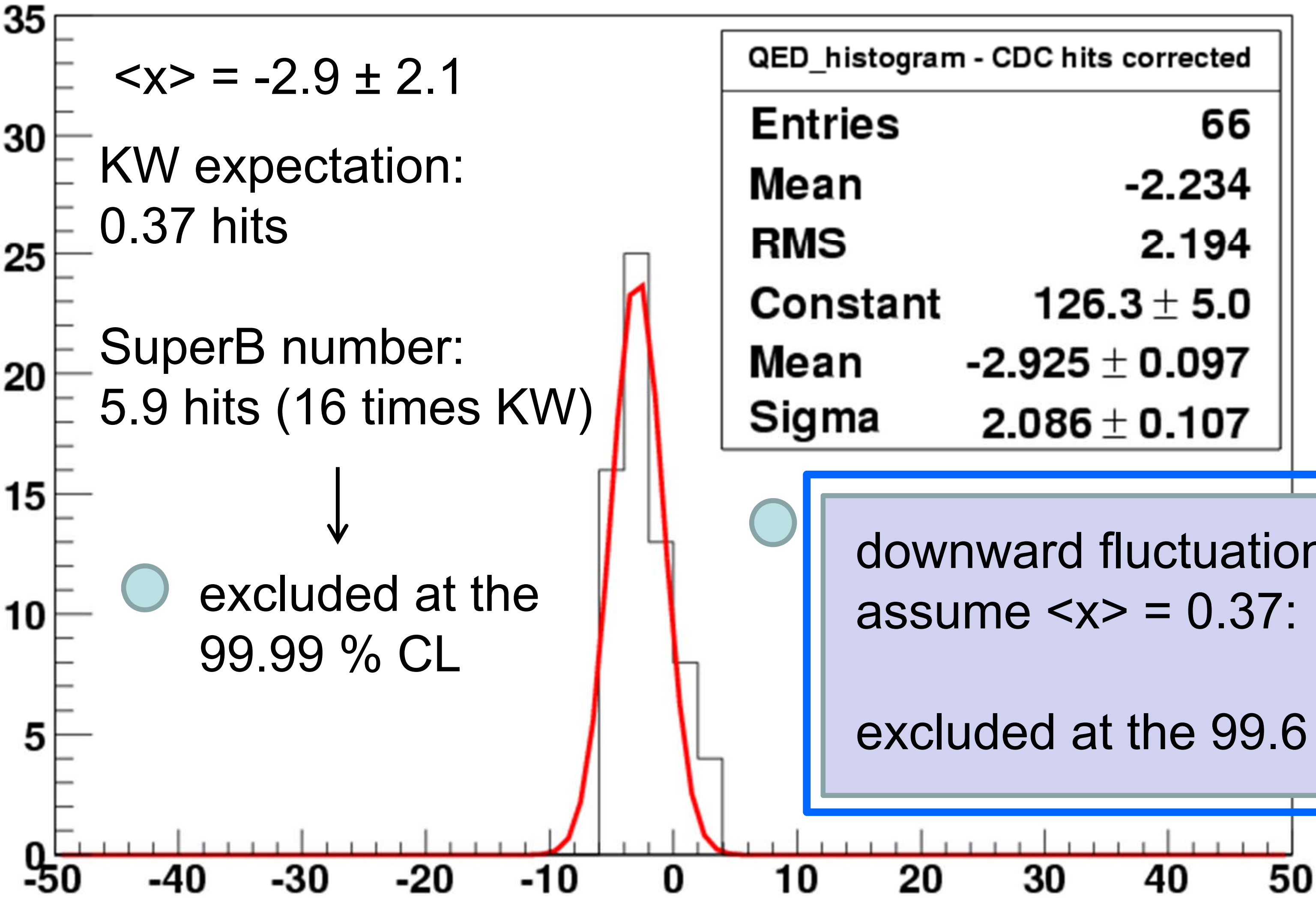


Have only MC for these low momentum electrons

Experiment @ KEKB with random triggers (E. Nedelkovska, A. Moll) in May:
Idea: - vary luminosity to study machine background extrapolated to L= 0
- subtract this background, excess rate due to QED processes
- no tracks -> look only at hits in the Si detector

Result from CDC Hit Correction

2nd - 4th SVD layer, hits corrected - all exp. (layer 1 excluded)



<x> = -2.9 ± 2.1

KW expectation:
0.37 hits

SuperB number:
5.9 hits (16 times KW)

↓

- excluded at the 99.99 % CL

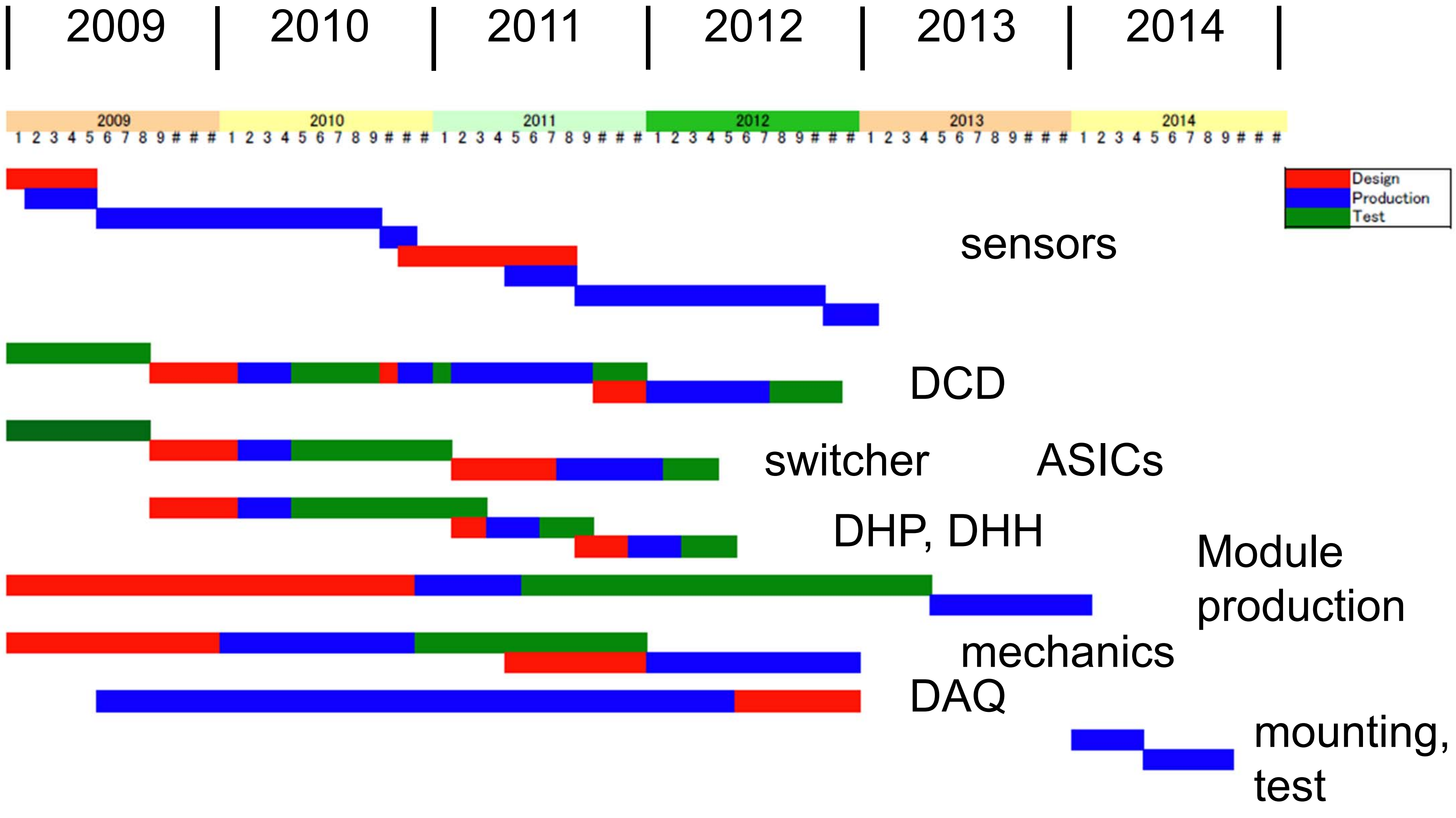
- downward fluctuation seen:
  assume <x> = 0.37:

  excluded at the 99.6 % C.L.

av. # of SVD hits

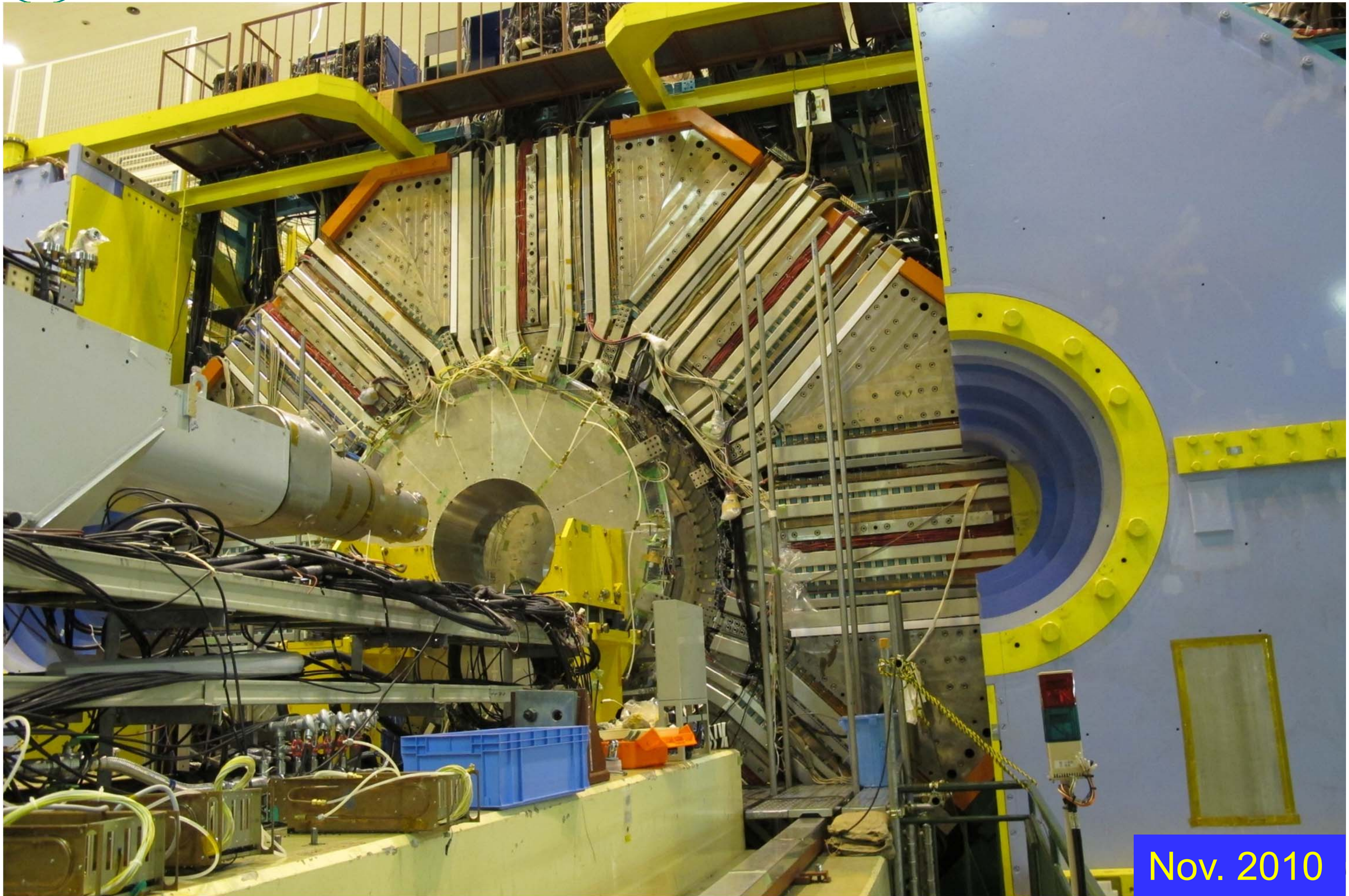
expectation: MPI↑ ↑SuperB

Schedule for the PXD-Project



Schedule still tight, but somewhat more relaxed now …

Prepare for Belle II: Belle Detector (Forward Side)



SVD2 being extracted after 7 Years of Op.

SVD2 Extracted ...

Belle in Roll-out Position: Start of Belle II

Conclusions

- „New Physics“ needed to explain the observed matter-antimatter asymmetry → new sources of CP violation must exist !
- A new generation of B factories planned to search for $\not{C}\!P$ via NP:
  → the precision frontier (complementary to the LHC program)
- At KEK (Japan), the SuperKEKB project is well under way:
  Initial funding by Japanese Gorvernment (110 M$ for 2011) granted

  → **„Green Light“ for SuperKEKB**

- Machine and detector ready for data taking by end of 2014 (tight!)
- Essential contribution from MPI: PXD (sensor production, mechanics) with own and unique(!) technology: DEPFET
- **Very high visibility and impact of the MPI group within the DEPFET and Belle / Belle II collaborations.**

Backup

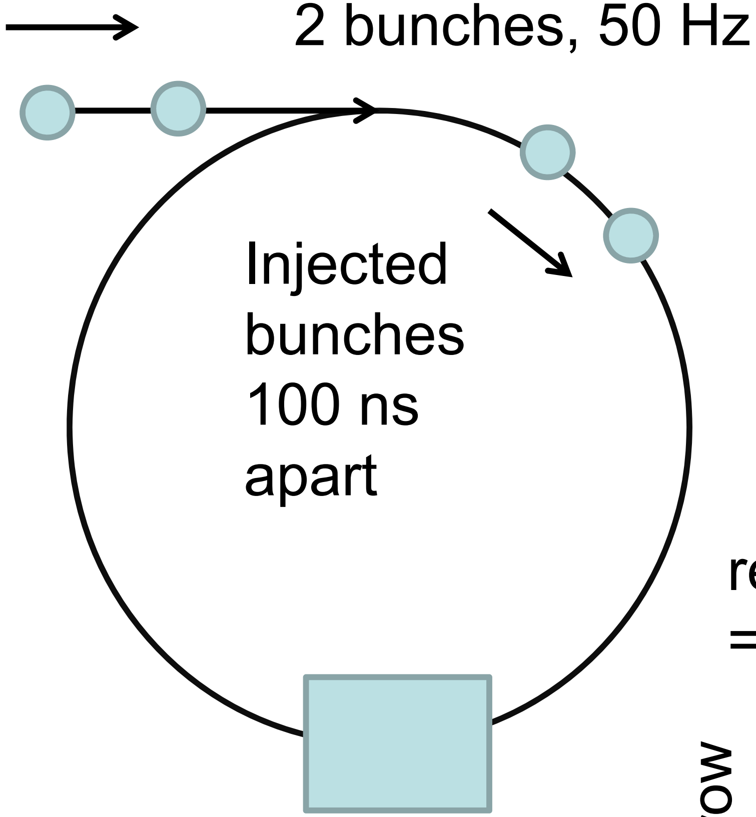
Comparison of Options

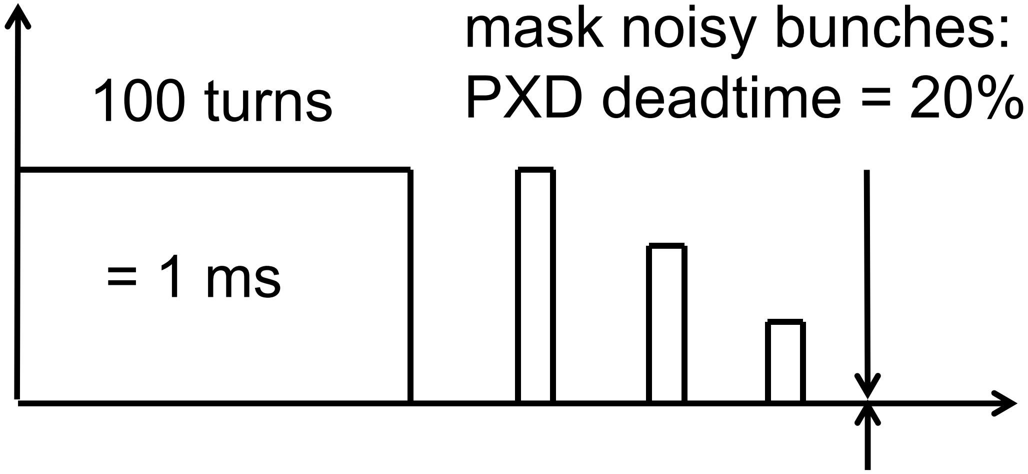
	KEKB Design	KEKB Achieved (): with crab	SuperKEKB High-Current Option	SuperKEKB Nano-Beam Option
β_y^* (mm)(LER/HER)	10/10	6.5/5.9 (5.9/5.9)	3/6	0.21/0.37
ε_x (nm)	18/18	18/24	24/18	2.8/1.6
σ_y(μm)	1.9	1.1 (0.84)	0.85/0.73	0.070/0.052
ξ_y	0.052	0.108/0.056 **(0.120/0.089)**	0.3/0.51	0.07/0.07
σ_z (mm)	4	~ 7	5(LER)/3(HER)	6
I_{beam} (A)	2.6/1.1	1.8/1.45 (1.60/1.13)	9.4/4.1	3.70/2.13
$N_{bunches}$	5000	1387 (1585)	5000	2778
Luminosity (10^{34} cm^{-2} s^{-1})	1	1.76 **(2.11)**	53	80

High Current Option includes crab crossing and travelling focus.
Nano-Beam Option does not include crab waist yet

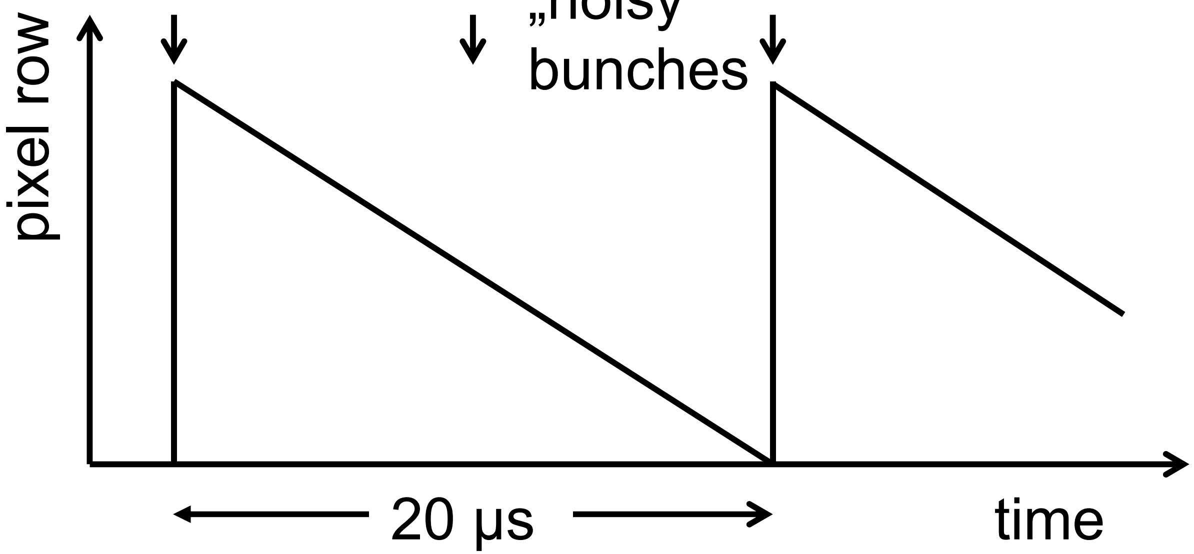
Nano beam was chosen

Injection Scheme of SuperKEKB





revolution time
= 10 µs

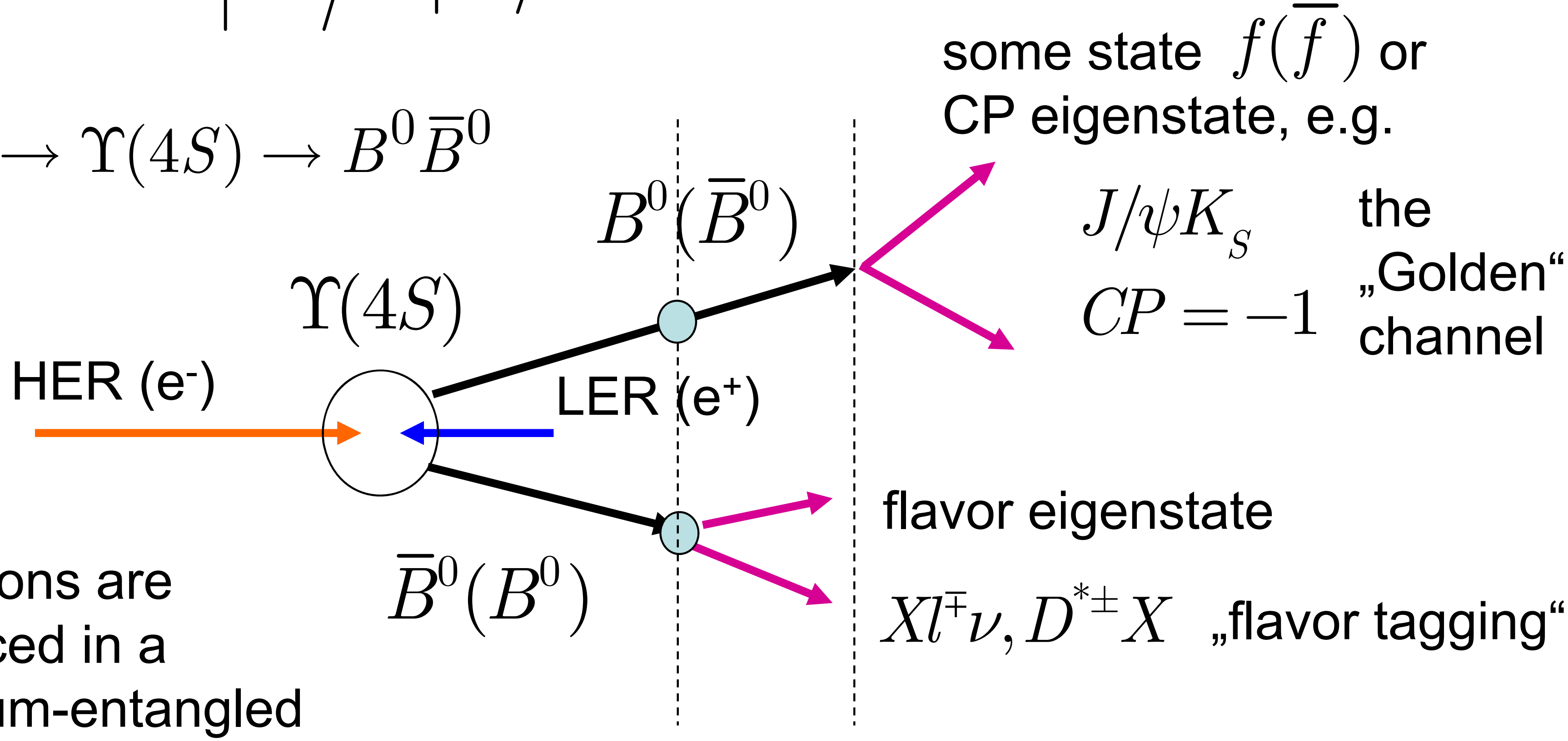


Problem for DEPFET:
noisy bunches cannot be
gated away

The ~~CP~~ Observables: What do we measure?

B-Mesons: $\left|B^0\right\rangle = \left|\overline{b}d\right\rangle$

$$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B^0\overline{B}^0$$



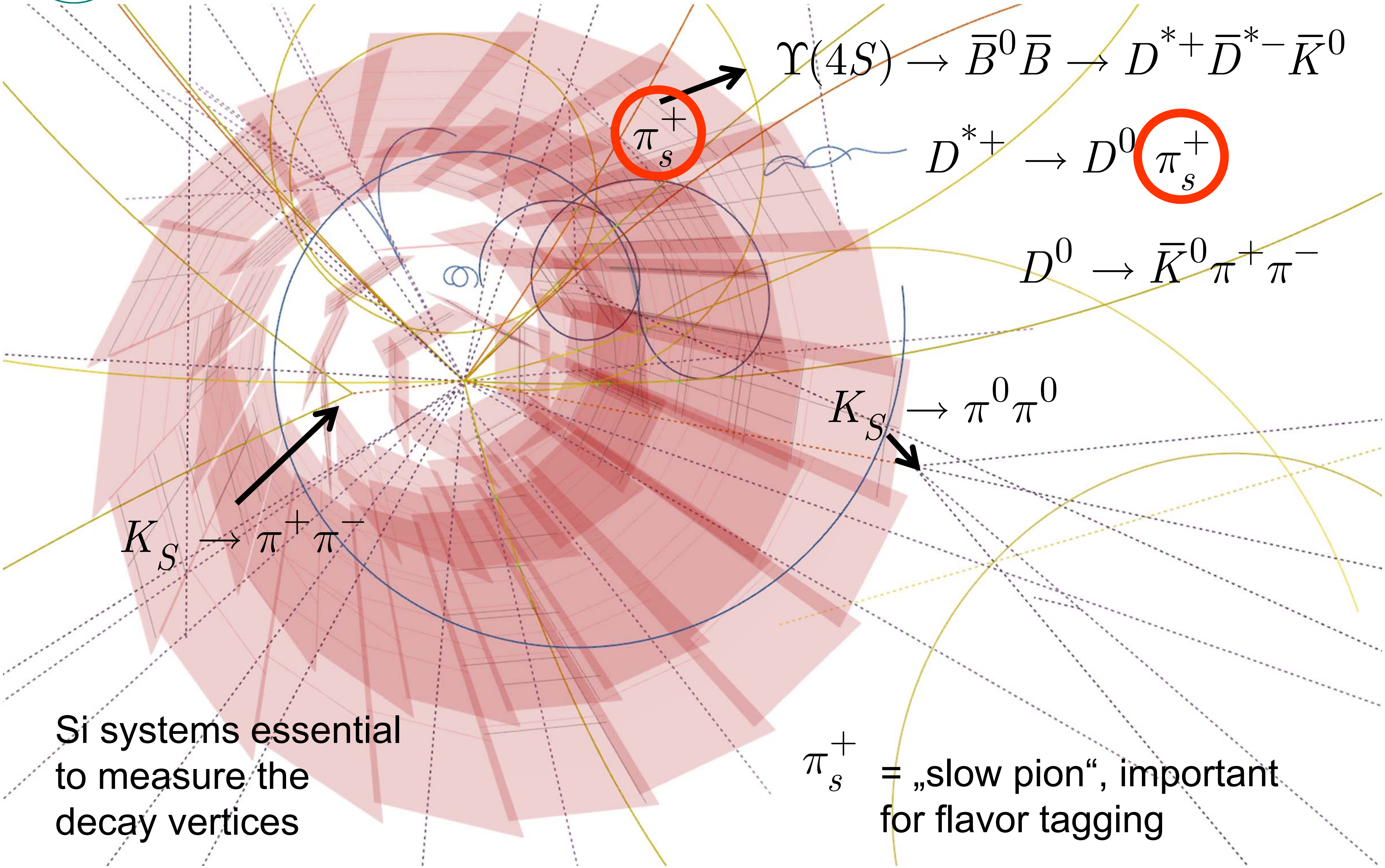
B mesons are produced in a quantum-entangled state

$$\Delta z = \beta\gamma c\Delta t$$

„B-Factory"

Asymmetric beam energies: translate decay time to decay length

An Event in the Silicon Tracking System (Belle)



Si systems essential to measure the decay vertices

π_s^+ = „slow pion“, important for flavor tagging

Work Package Distribution

Nr.	Work Package	Lead Institution	Collaborators
1.0	**DEPFET Modules**		
1.1	Parameter Definitions	**MPI**	PRA
1.2	Sensor Development	**MPI**	
1.3	ASIC Development		
1.3.1	Switcher	**HEI**	
1.3.2	Current Digitizer (DCD)		
1.3.3	Data Handling Processor (DHP)	**BON**	**MPI**, UBA
1.3.4	Interconnection technology	**BON**	**HEI**, USC, URL
1.4	Module Design		
1.4.1	Sensor Ladder	**MPI**	**BON**, CNM, **HEI**, IFV, IFB
1.4.2	Gbit-Link, Kapton Flex, Patch Panel	**BON**	**LMU**. URL
1.4.3	Data Handling Hybrid (DHH)	**TUM**	**BON**, **GOE**, URL

Work Package Distribution (cont.)

Nr.	Work Package	Lead Institution	Collaborators
1.5	Mechanical Design	**MPI**	IFV, **KAR**, KEK, VIE
1.6	Thermal Issues	**KAR**	IFB, IFV, KRA, **MPI**, VIE
1.7	System		
1.7.1	Data Acquistion (+pre-event builder)	**GIE**	**BON, GOE**, KEK, KRA, **MPI**, **TUM**, URL
1.7.2	Power supplies with slow control	**LMU**	KEK, KRA, USC
1.7.3	Cooling plant (refigerator, heat exchanger)	KEK	IFV, **KAR**

Work Package Distribution (cont.)

Nr.	Work Package	Lead Institution	Collaborators
2.0	**Test Facilities**		
2.1.1	Test beam setup	IFV	**BON**, CNM, **HEI**, IFB, IFC, **KAR**, URL, VIE,
2.1.2	Test beam analysis	PRA	**BON**, **GOE**, IFV, **MPI**, USC
2.1.3	Lab test procedures	**MPI**	(all)
2.2	Setups for thermal tests	**KAR**	IFC, IFV, **MPI**, VIE
2.3	Mechanical mockup	**KAR**	IFV, **MPI**
2.4	Irradiation Tests	**MPI**	**BON**, **KAR**
2.5	Full System Test	**MPI**	all

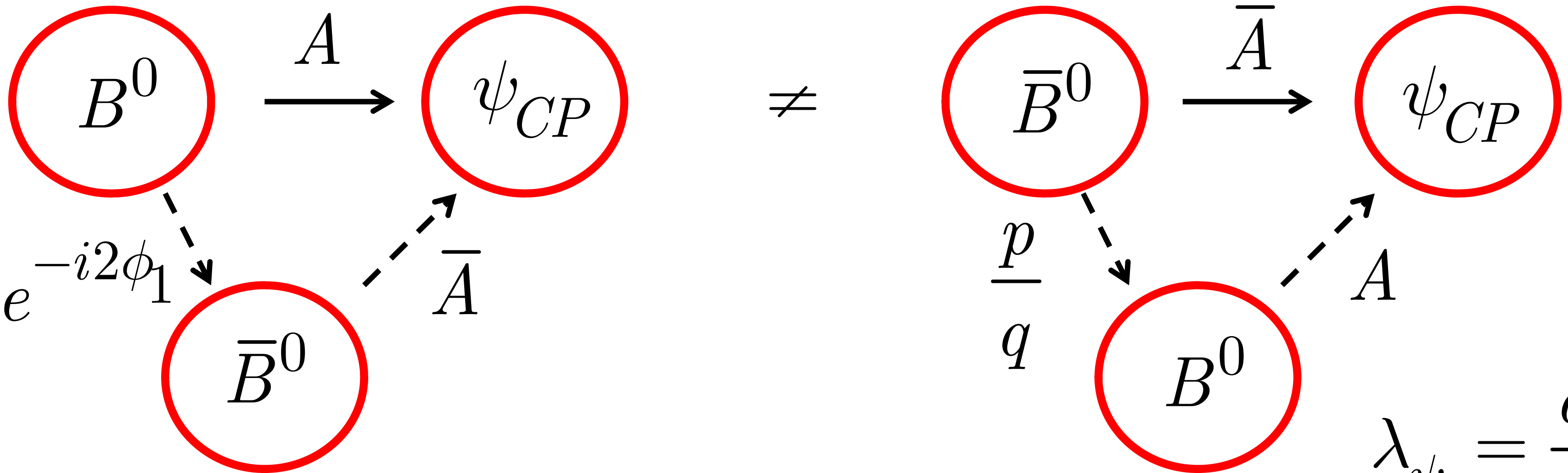
Work Packages Mostly Uncovered

Nr.	Work Package	Lead Institution	Collaborators
3.0	**Integration and running-in**		
3.1	Installation in Tsukuba Hall		
3.2	Slow controls, calibration		
3.3	Radiation monitor (also during machine commissioning and run-in)	**MPI**	
3.4	Roll into beamline		

Example: Mixing-Induced CP Violation

$$A = \left\langle \psi_{CP} \mid B^0 \right\rangle; \quad \bar{A} = \left\langle \psi_{CP} \mid \bar{B}^0 \right\rangle$$

ψ_{CP} : CP eigenstate



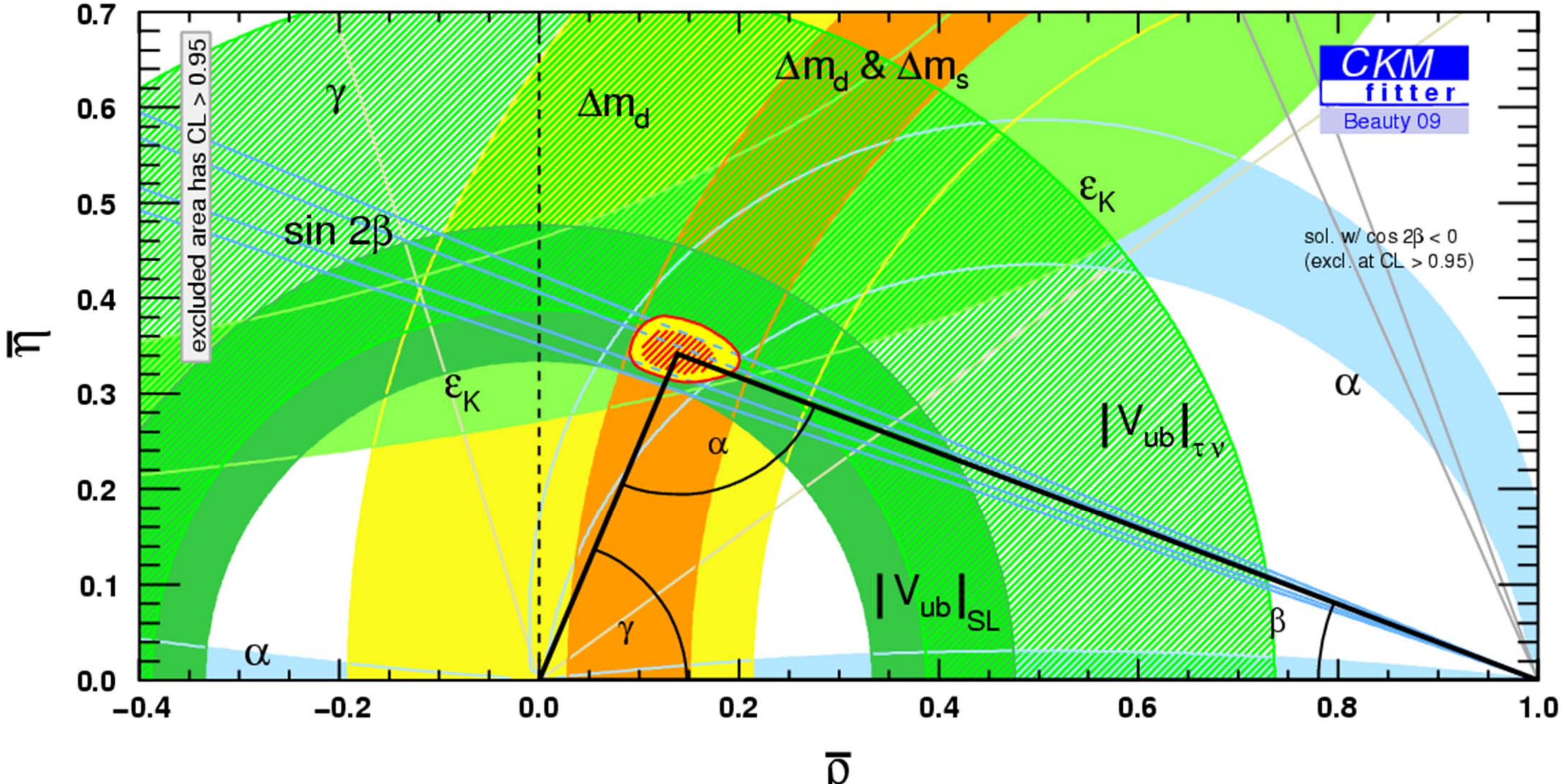
$$\frac{q}{p} = e^{-i2\phi_1}$$

$$\lambda_\psi = \frac{q}{p}\frac{\bar{A}}{A}$$

$$\mathcal{A}_{CP}(\psi, \Delta t) = \frac{\Gamma(B^0 \to \psi; \Delta t) - \Gamma(\bar{B}^0 \to \psi; \Delta t)}{\Gamma(B^0 \to \psi; \Delta t) + \Gamma(\bar{B}^0 \to \psi; \Delta t)}$$

$$= \frac{1 - \left|\lambda_\psi\right|^2}{1 + \left|\lambda_\psi\right|^2} \cos \Delta m \Delta t + \frac{2\,\mathrm{Im}(\lambda_\psi)}{1 + \left|\lambda_\psi\right|^2} \sin \Delta m \Delta t$$

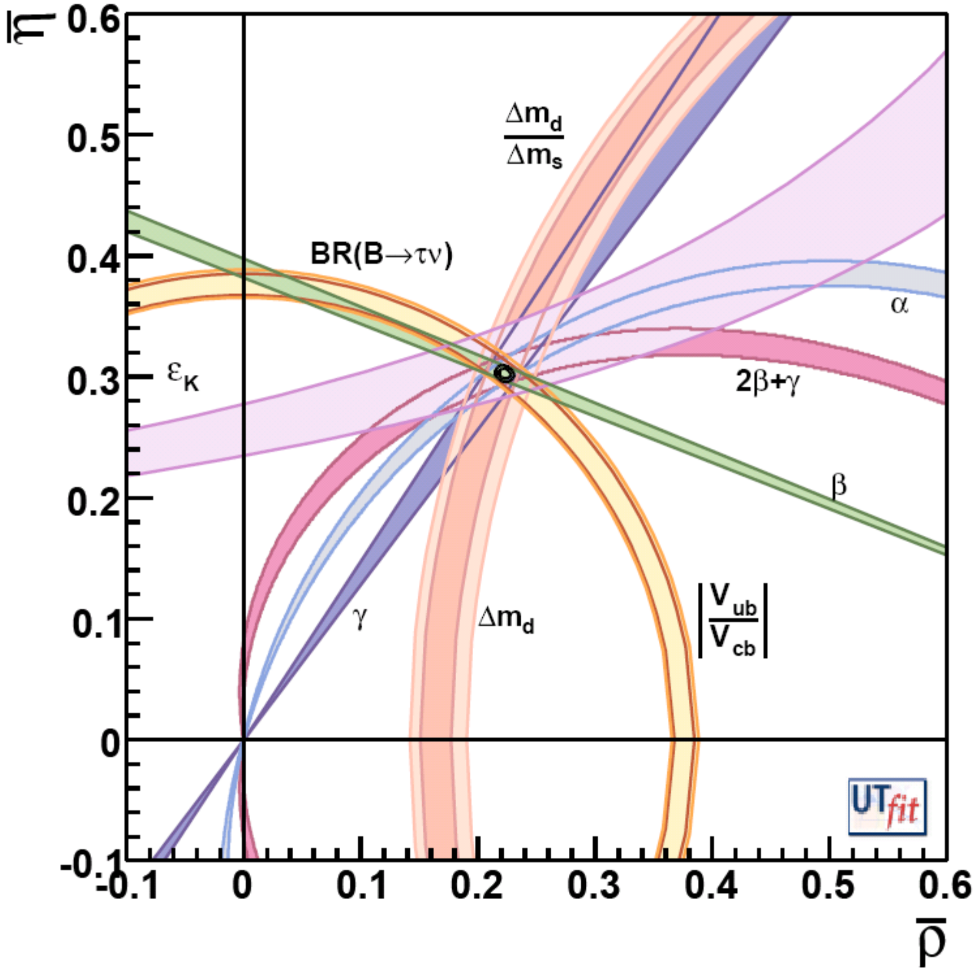
The Unitarity Triangle in the year 2009



CKM Fitter Group, Beauty 2009 Conference, Heidelberg

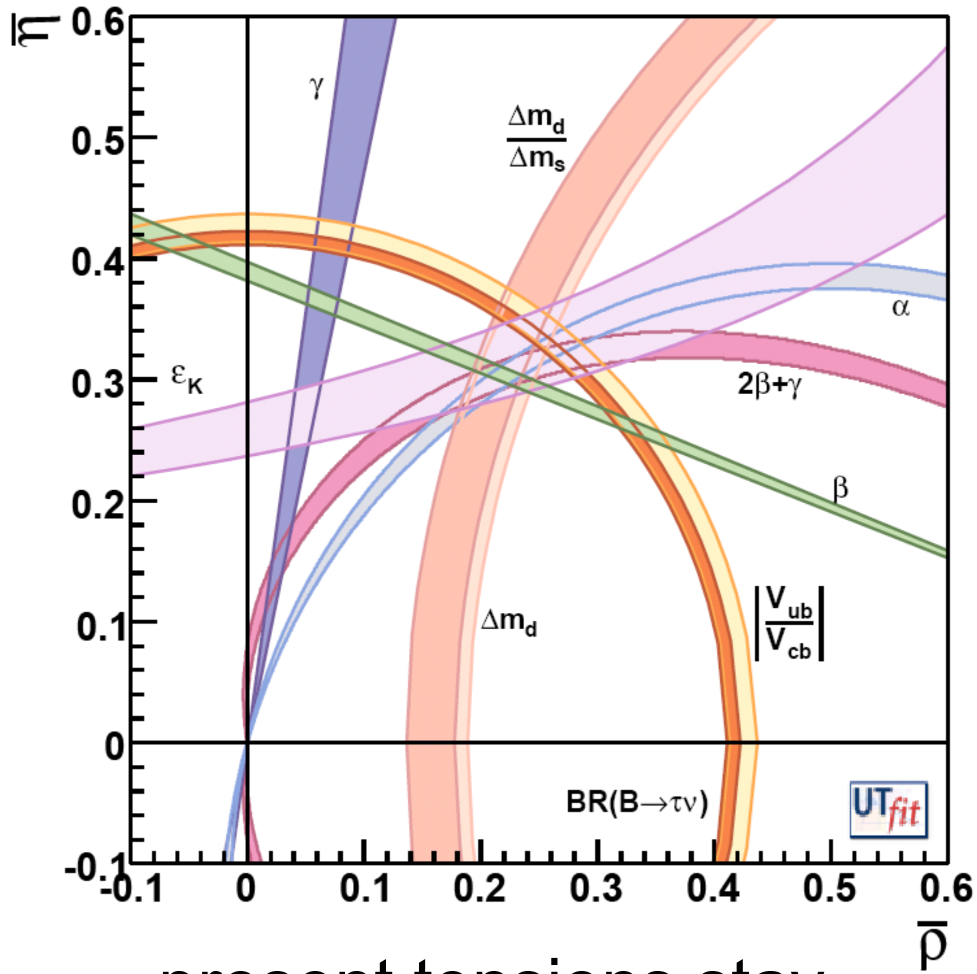
The Unitarity Triangle in the year 2020

$$\int \mathcal{L} dt = 50 \ \text{ab}^{-1}$$



SM correct

a nightmare …

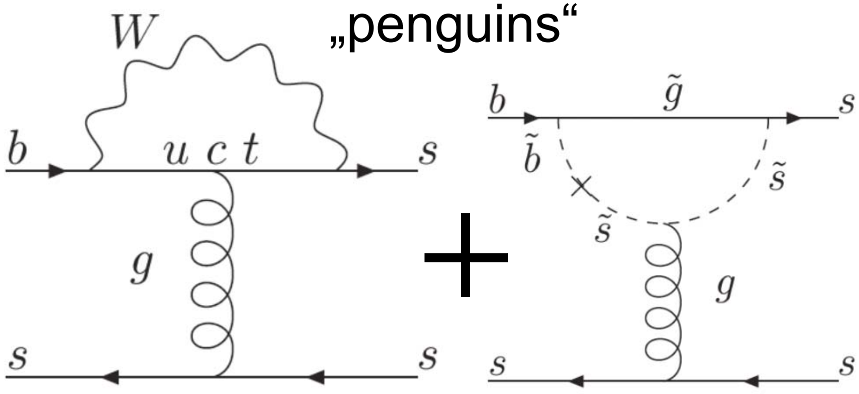


present tensions stay …

… the dream !

New Physics at the Loop Level ....

„penguins“



SM NP

NP in CPV asymmetries:

$$B \to J/\psi K_S \leftrightarrow B \to \phi K_S$$

Principle:

Deviation of observable from the SM prediction signals NP

virtual particles in the loop reveal their existence → Λ_{NP}

Rare Decays of *B* mesons:

	SM pred.
$B \to X_{s,d}\gamma$	$\mathcal{O}(10^{-4})$
$B \to X_{s,d}l^+l^-$	$\mathcal{O}(10^{-6})$
$B \to X_d\nu\overline{\nu}$	$\mathcal{O}(10^{-6})$
$B_s \to l^+l^-$	$\mathcal{O}(10^{-9})$

leptons:

$\tau \to \mu\gamma$
$\tau \to \mu\mu\mu$
$\tau \to \mu\eta$

} NP could make these decays possible

need precision (statistics) to challenge the SM

Energy reach of the SuperKEKB Factory

No flavor structure for NP: $\Lambda_{NP} \geq 100 - 1000\ \mathrm{TeV}$ „NP flavor problem“

Look for FCNC processes (highly suppressed in SM):

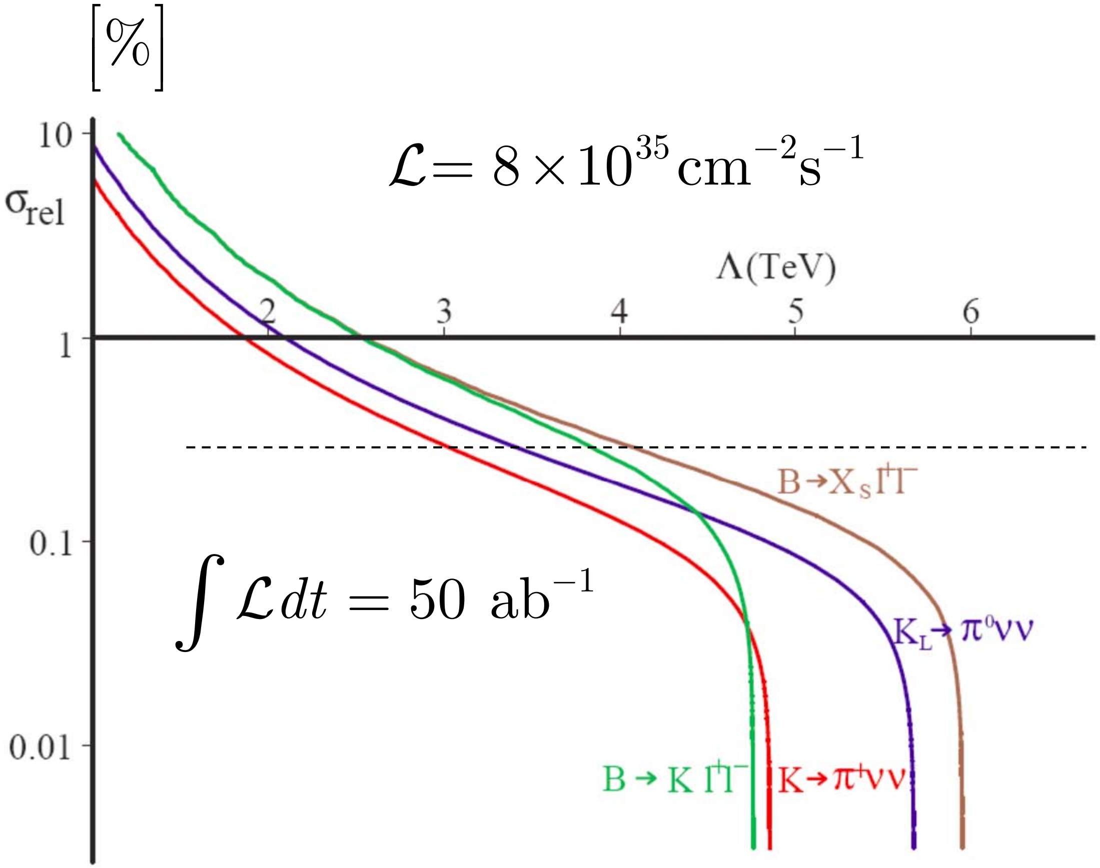
Assumption on NP flavor sector:
Minimal Flavor Violation (MFV)

Measure, e.g., the decay rates:

$B^0 \rightarrow X_s^0 l^+ l^-$ (inclusive)

$B^0 \rightarrow K^0 l^+ l^-$ (exclusive)

.
.
.
.



Belle-II Collaboration

2004.06: LoI for SuperKEKB
2008.01: KEK Roadmap → identified as high priority project at KEK
2008.12: New collaboration (Belle-II) officially formed

❖ 13 countries/region, 43 institutes, ~300 members

Organization:

Executive Board (Chair: H. Aihara)

Spokesperson: P. Križan
Project manager: M. Yamauchi

Institutional Board (Chair: L. Piilonen)

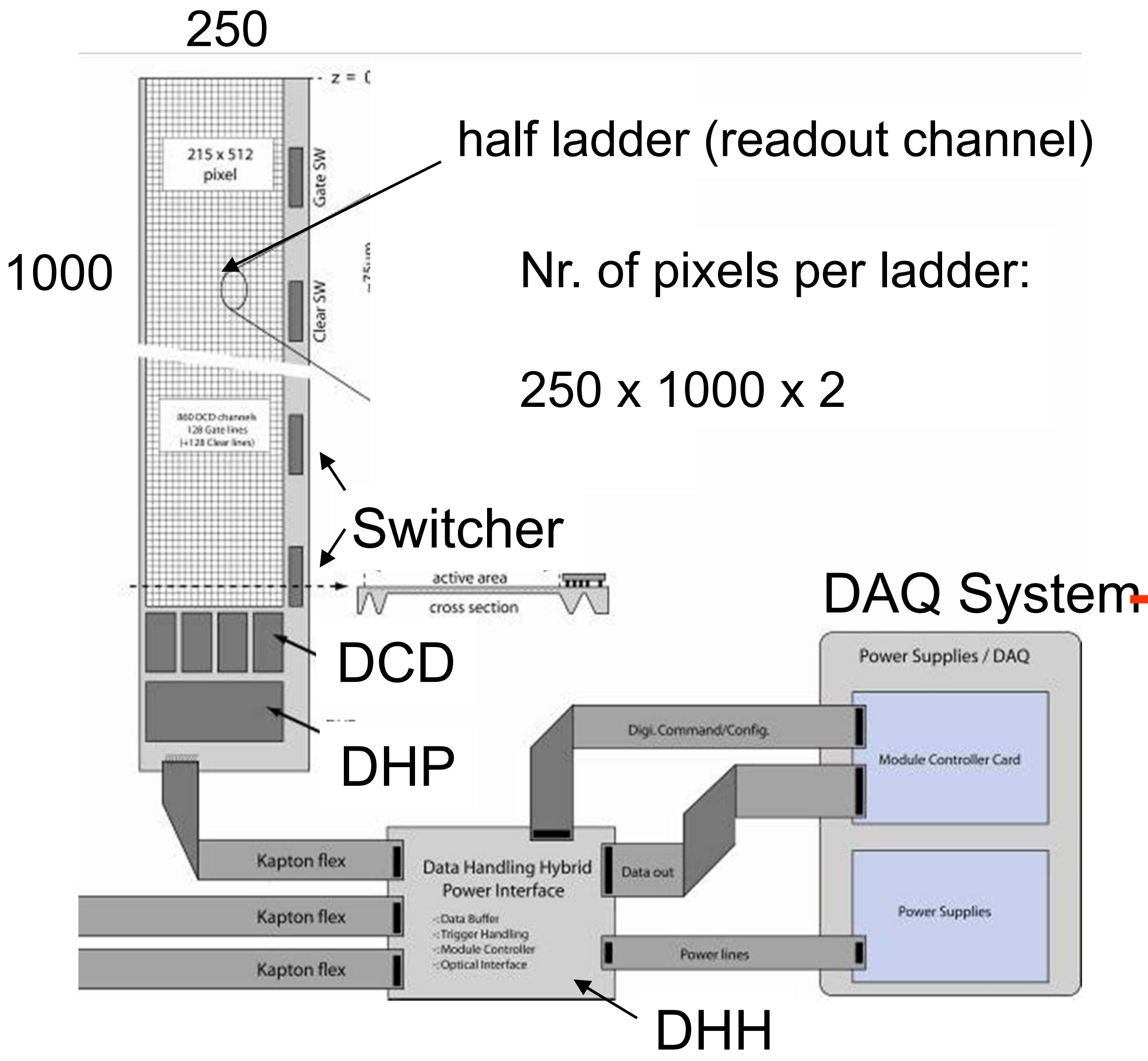
Physics coordinator: B. Golob

Technical coordinator: Y. Ushiroda

Software /computing coordinators: T. Hara / T. Kuhr

2009.11: 4th Open Collaboration Meeting

PXD Data Acquisition

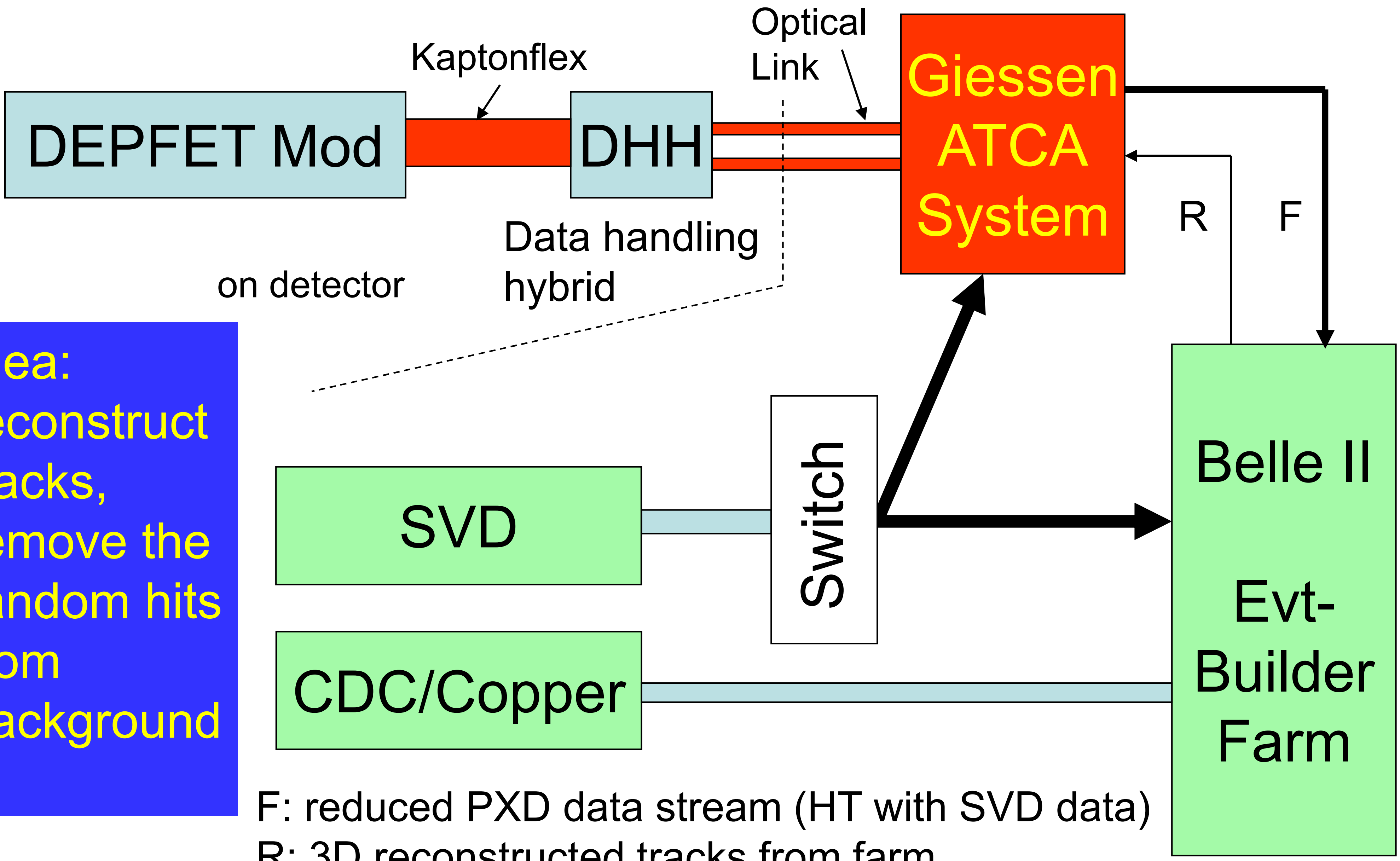


- 40 half ladders:
  10 Million pixels (px)
- 1-2% occupancy (?)
- 200 kpx on at any time
- 2×10^5 px in each event
- 4 bytes per px (pos + ADC)
- 800 kB/event

Total evt size: ~ 1 MByte

Total rate:
200 Gb / sec

Data Acquisition



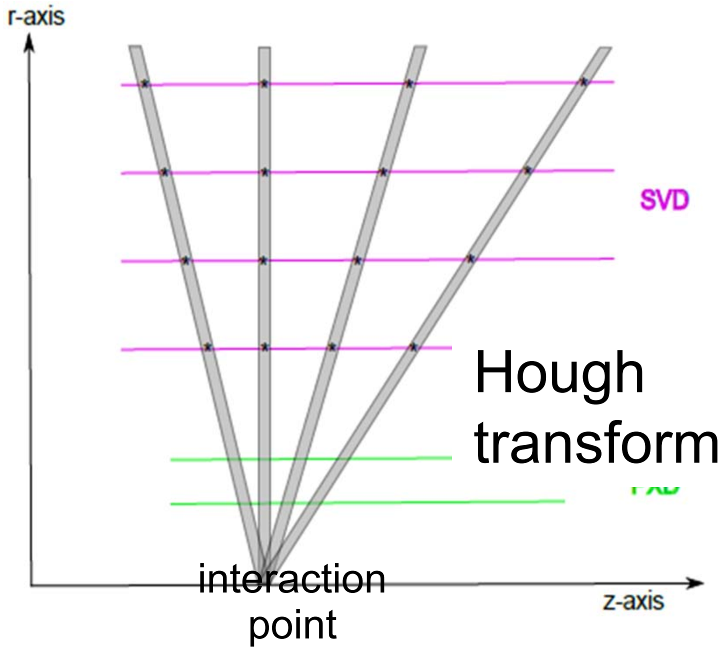
Idea: reconstruct tracks, remove the random hits from background

F: reduced PXD data stream (HT with SVD data)
R: 3D reconstructed tracks from farm

Online PXD Data Reduction

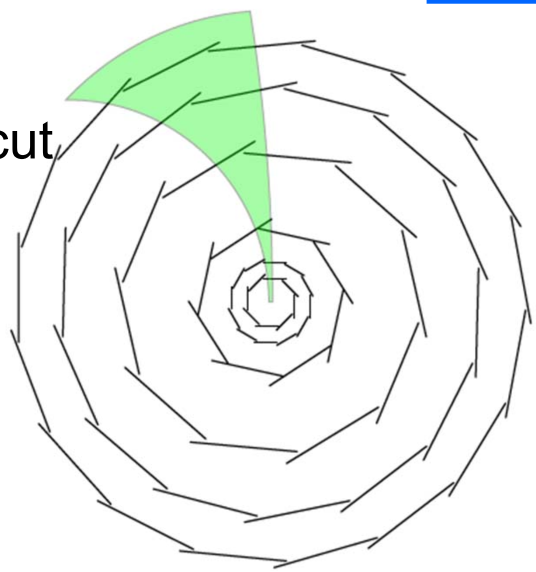
Claudio Heller (MPI)

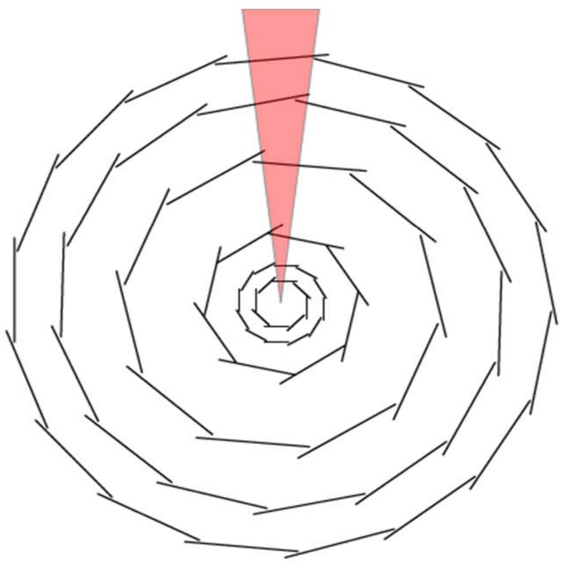
- 2D pattern recognition in z-r-plane using SVD data: Hough-transform with fast peak finding algorithm
- SVD hits are divided into 3 x 40 overlapping sectors in r-phi rotated with $\Delta\Phi=9^\circ$
- different shaped sectors for low momentum particles and nearly straight tracks in r-phi-plane

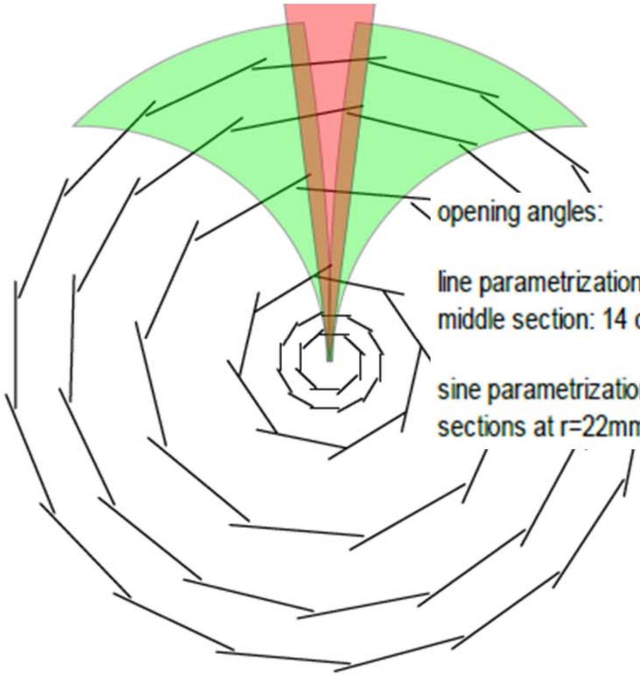


factor 10 seems possible

p_T cut

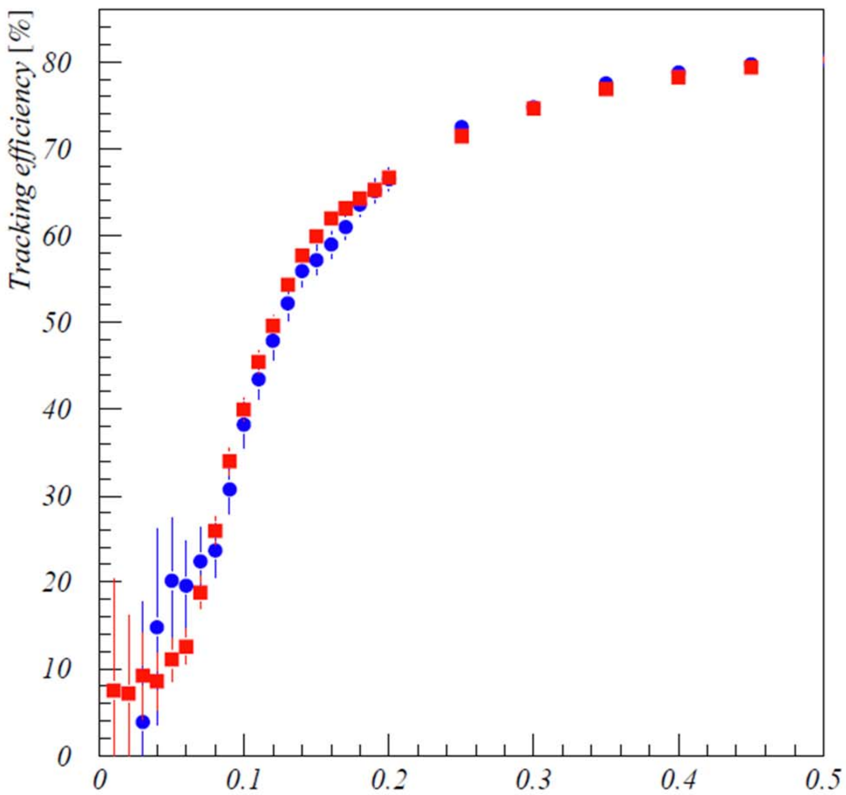






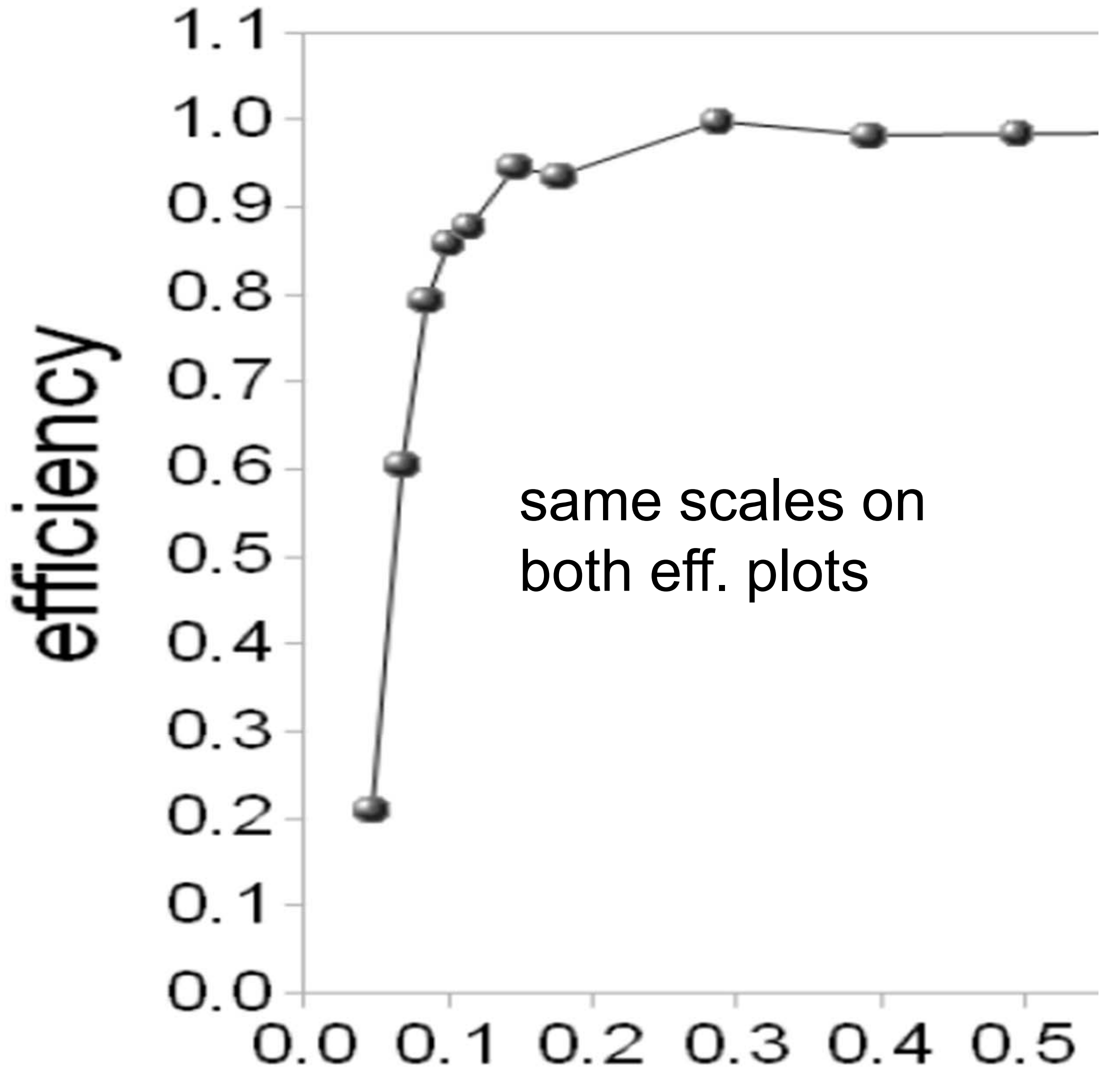
Track Efficiencies

Full reconstruction, Belle
SVD + CDC



P (GeV)

Hough with SVD, Belle-II



P (GeV)