Belle and Belle II

(Schwerpunkt deutsche Gruppen)

Jens Sören Lange (Justus-Liebig-Universität Gießen)

KET Meeting, Bad Honnef, 15.11.2014

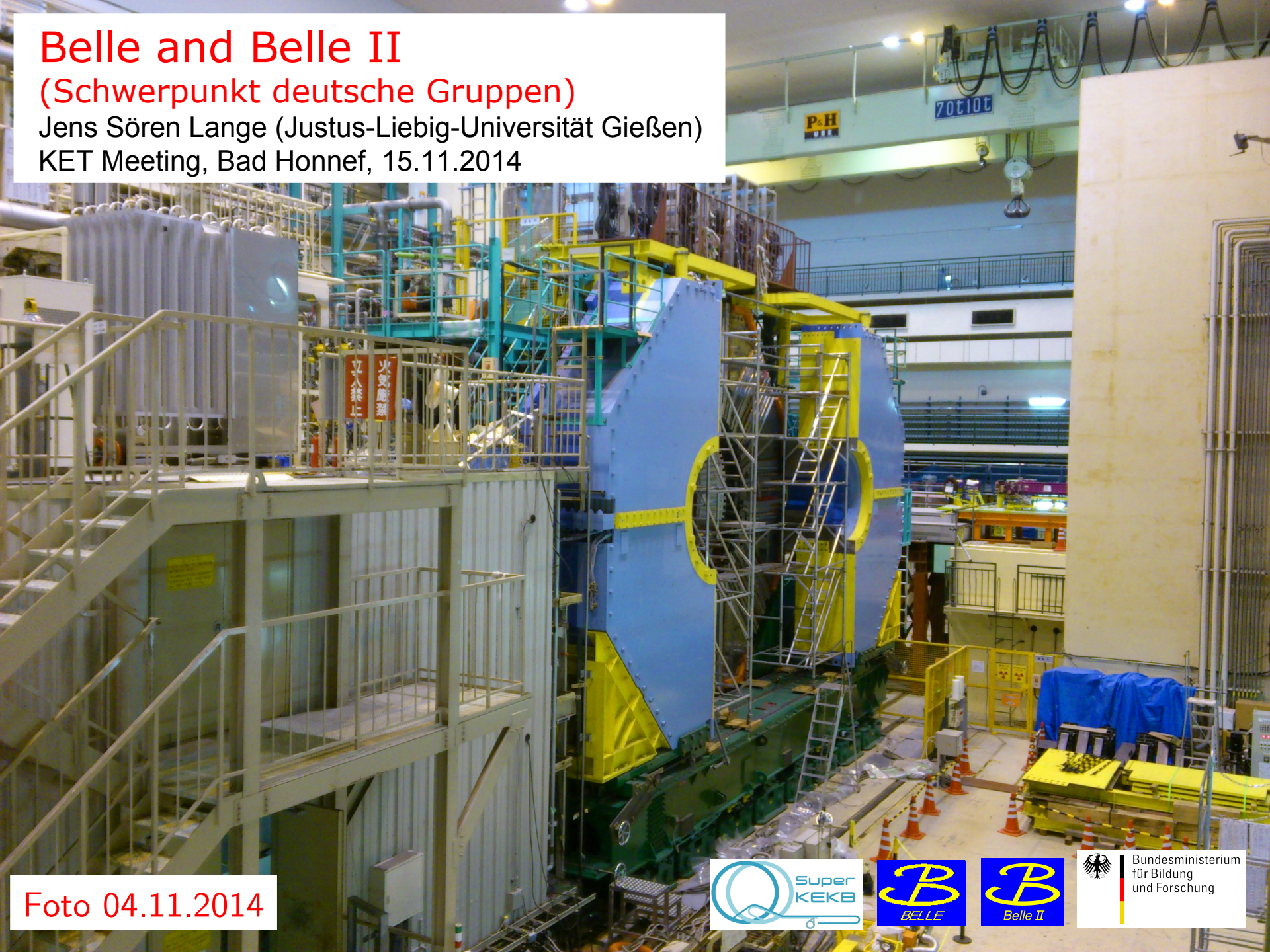


Foto 04.11.2014

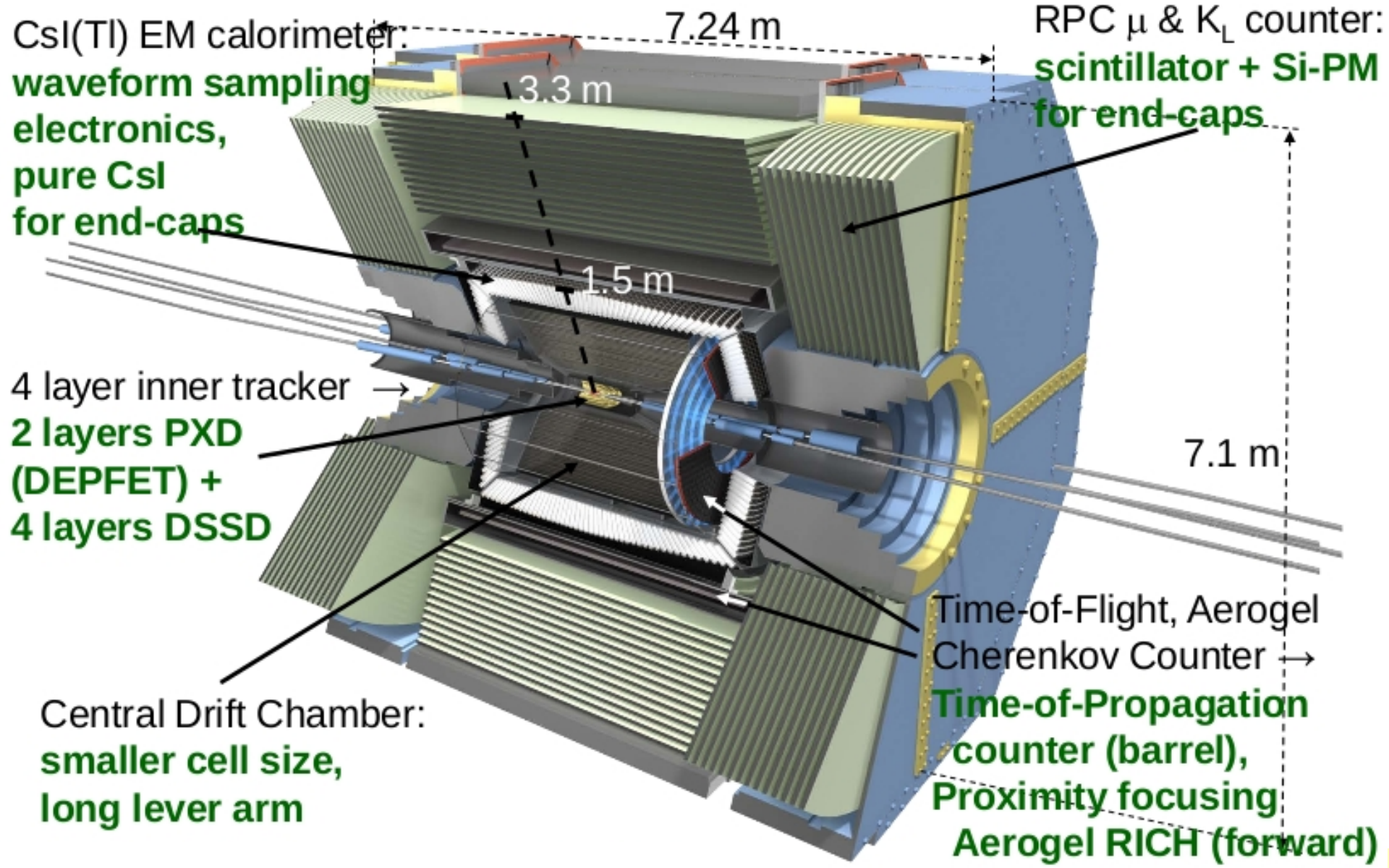
Super KEKB

BELLE

Belle II

Bundesministerium für Bildung und Forschung

The Belle II Detector



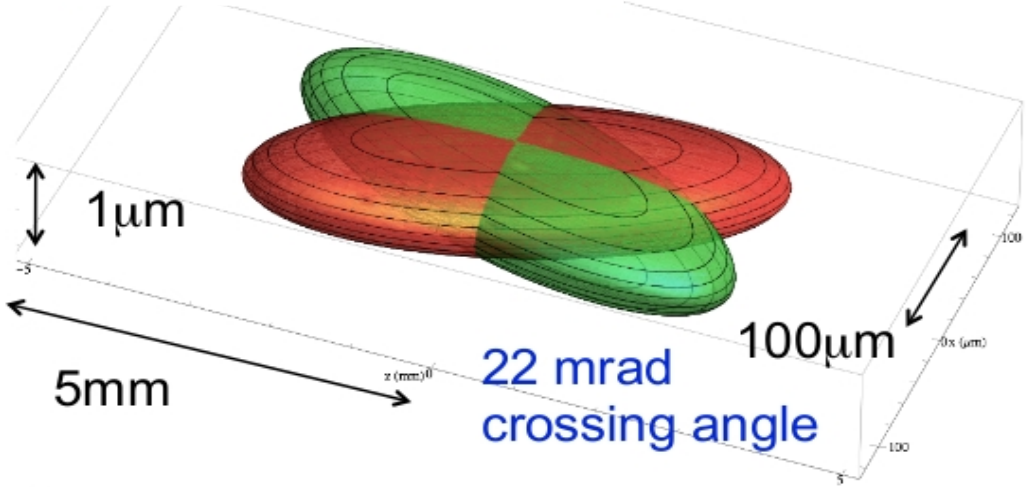
Nano-Beam Scheme

Belle → Belle II

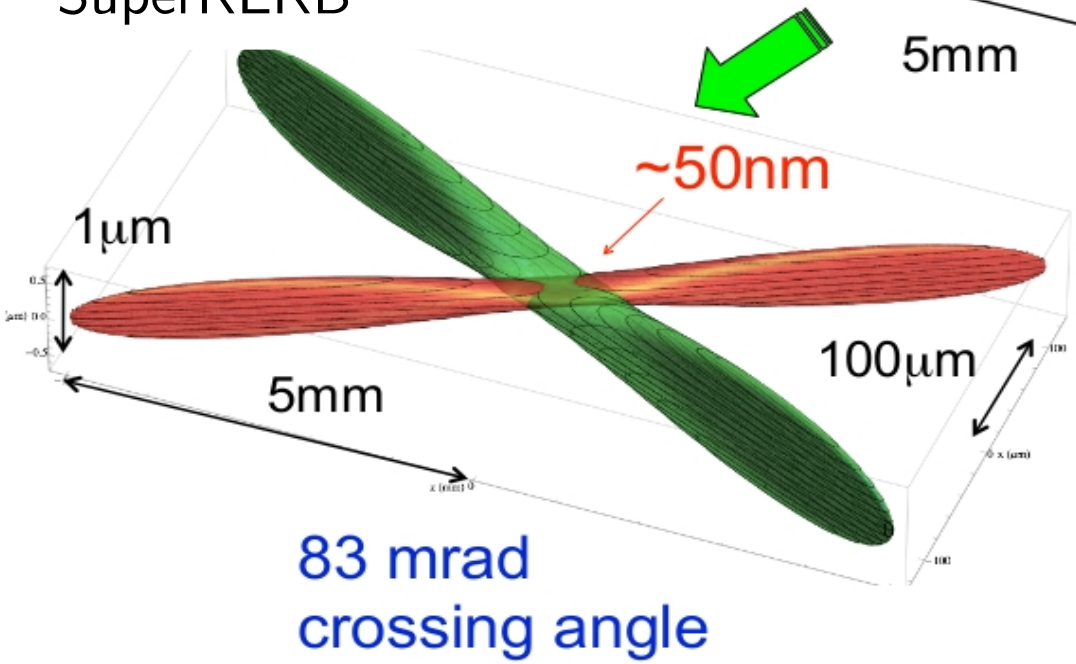
Luminosity x 40

$\mathcal{L} \leq 0.8 \times 10^{36}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$

KEKB *(without crab)*



SuperKEKB

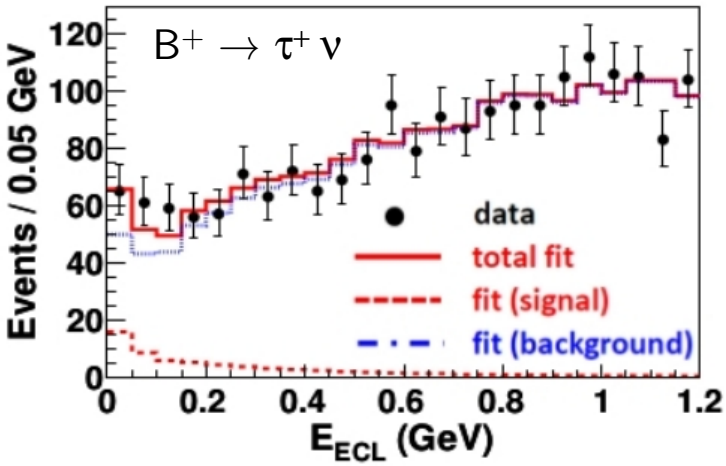


originally proposed for SuperB by P. Raimondi (INFN)

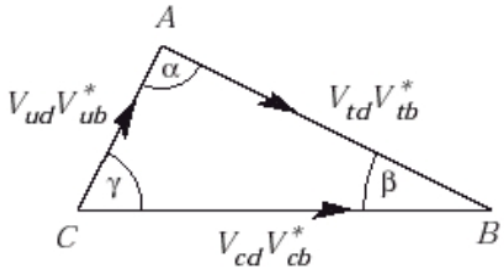
graphics E. Paoloni (Pisa)

Belle II Physik (Beispiele)

Belle, Phys. Rev. Lett. 110(2013)131801



- Präzisionsvermessung des Unitaritätsdreiecks (CKM)



Ziel:
γ (1°)
V_{ub} (5%)
V_{cb} (2%)

- Seltene B Zerfälle
  - $B^+ \to \tau^+ \nu$
  - $b \to s\, \nu \bar{\nu}$

  Vorteil: BB Paar-Rekonstruktion (zweites B Meson, andere Seite)

→ Sensitivität CKM Kopplungen
$\Lambda_{NP} \leq 10^4$ TeV
rechtshändige Kopplungen
$\Lambda_{NP} \leq 10^6$ TeV

- XYZ Zustände (Charmonium, Bottomonium)
- A_{FB} in $e^+e^- \to \mu^+\mu^-$
- Leptonenzahlverletzung in τ Zerfällen
- Suche nach dunklem Photon
- ...

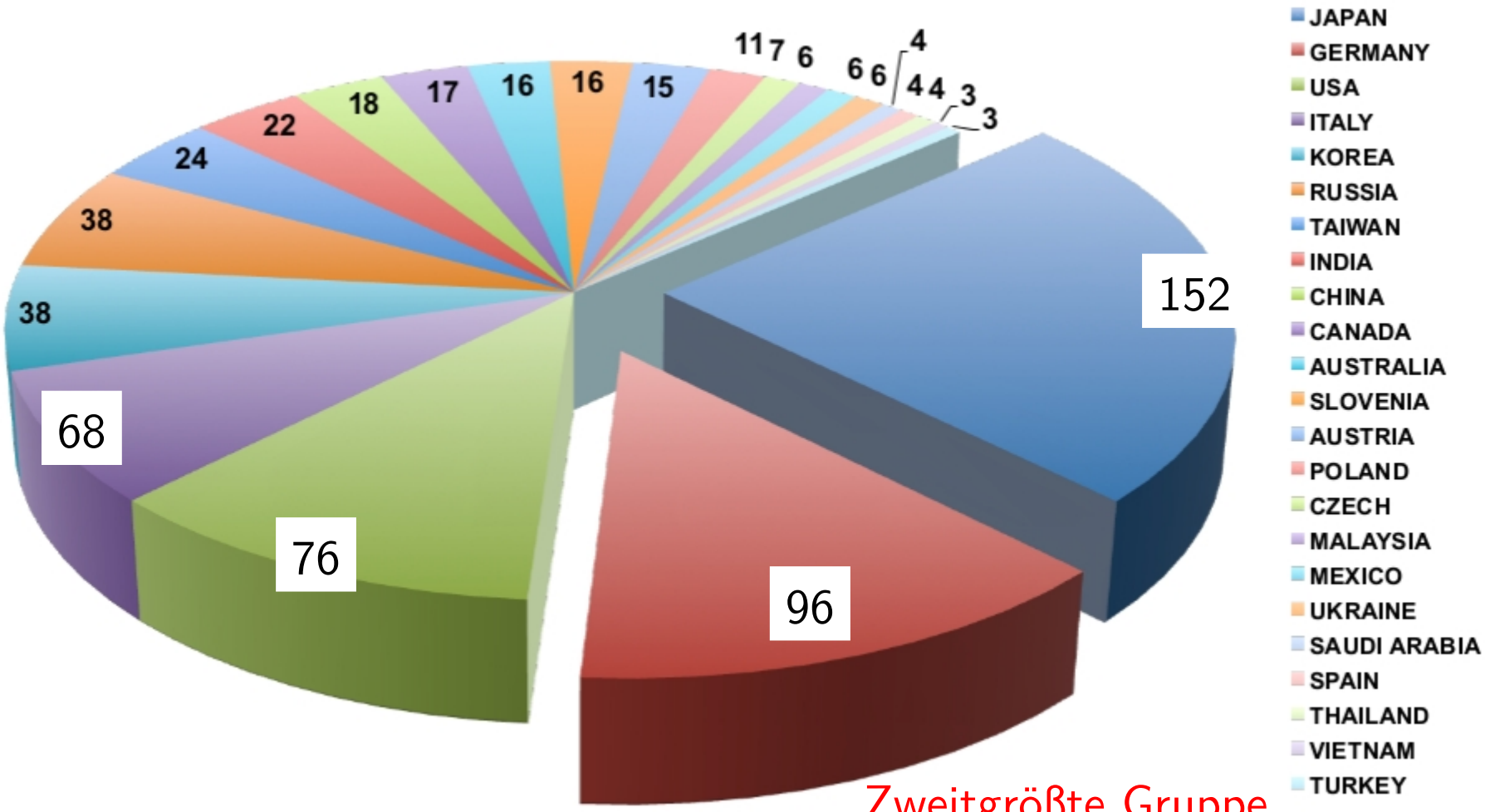
→ Sensitivität Kontaktwechselwirkungen
$\Lambda_{NP} \leq 33$ TeV

Belle II Kollaboration (Status 09.11.2014)

679 Mitglieder, 99 Institute, 23 Länder

Belle II Mitglieder

(inkl Studenten und Techniker)



Zweitgrößte Gruppe in Belle II

Status Belle and Belle II (deutsche Gruppen)

- Belle 62 Mitglieder, 7 Instititute (Status 09.11.2014)
  Belle II 96 Mitglieder, 11 Institute
  mit neuen deutschen Mitgliedern $\rightarrow \geq 100$
- BMBF Anträge
  neue Institute: Univ. Mainz (Sfienti), Univ. Hamburg (Hagner)
  neue Gruppen: KIT Karlsruhe IPE (Peric)
- DPG 2014 Mainz
  29 Beiträge (Belle I und II)
- Vorträge auf Konferenzen/Workshops in 2014
  19 (Belle I und II)
- erfolgreicher EU RISE Antrag – JENNIFER (Belle II und T2K)
  Japan and Europe Network for Neutrino and Intensity Frontier Experimental Research
  5 deutsche Institute
  Reisekosten: 93 Personenmonate am KEK (über 4 Jahre)

Deutsche Beiträge zu Belle II

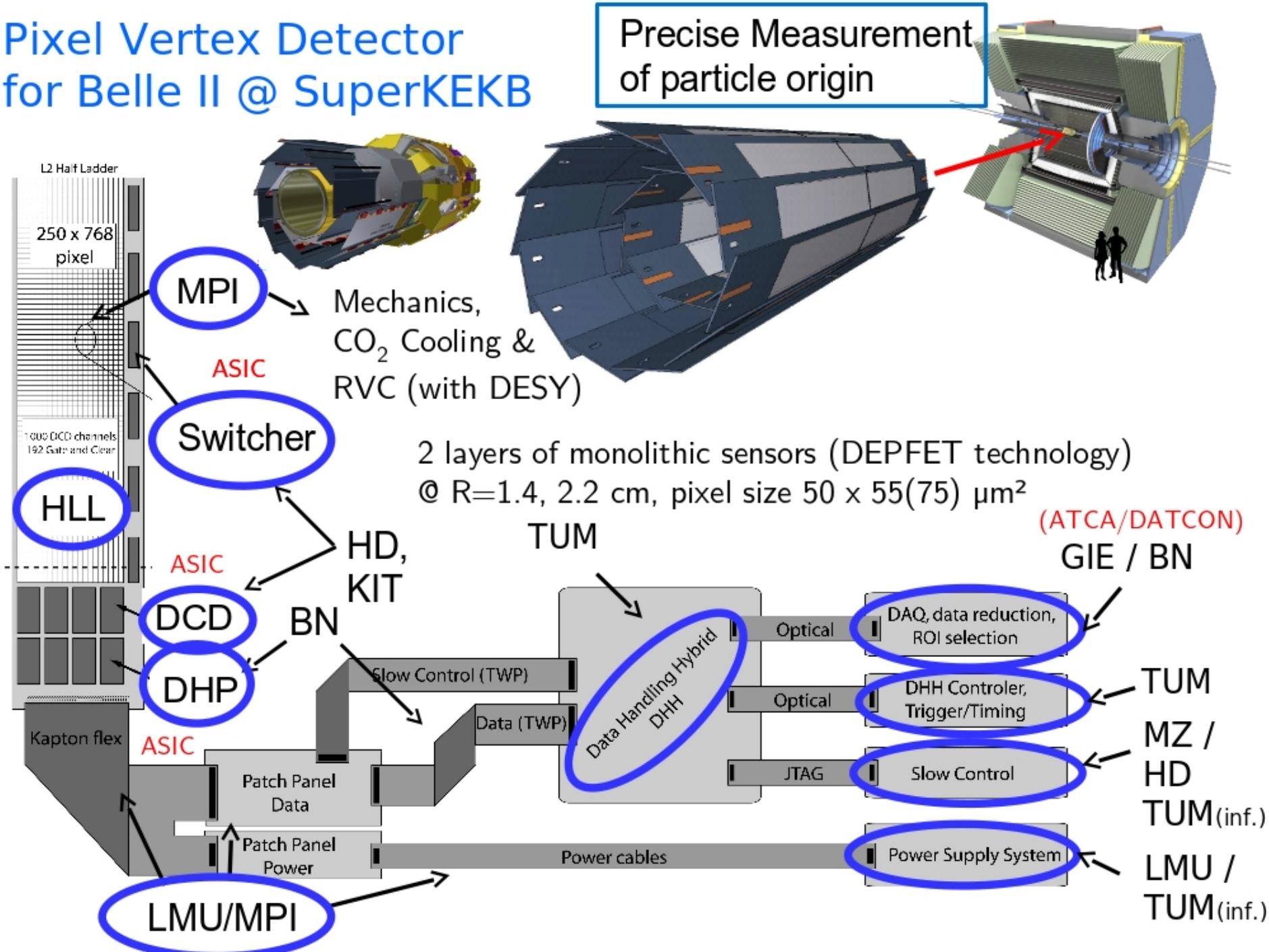
- PXD alle
- spare-PXD

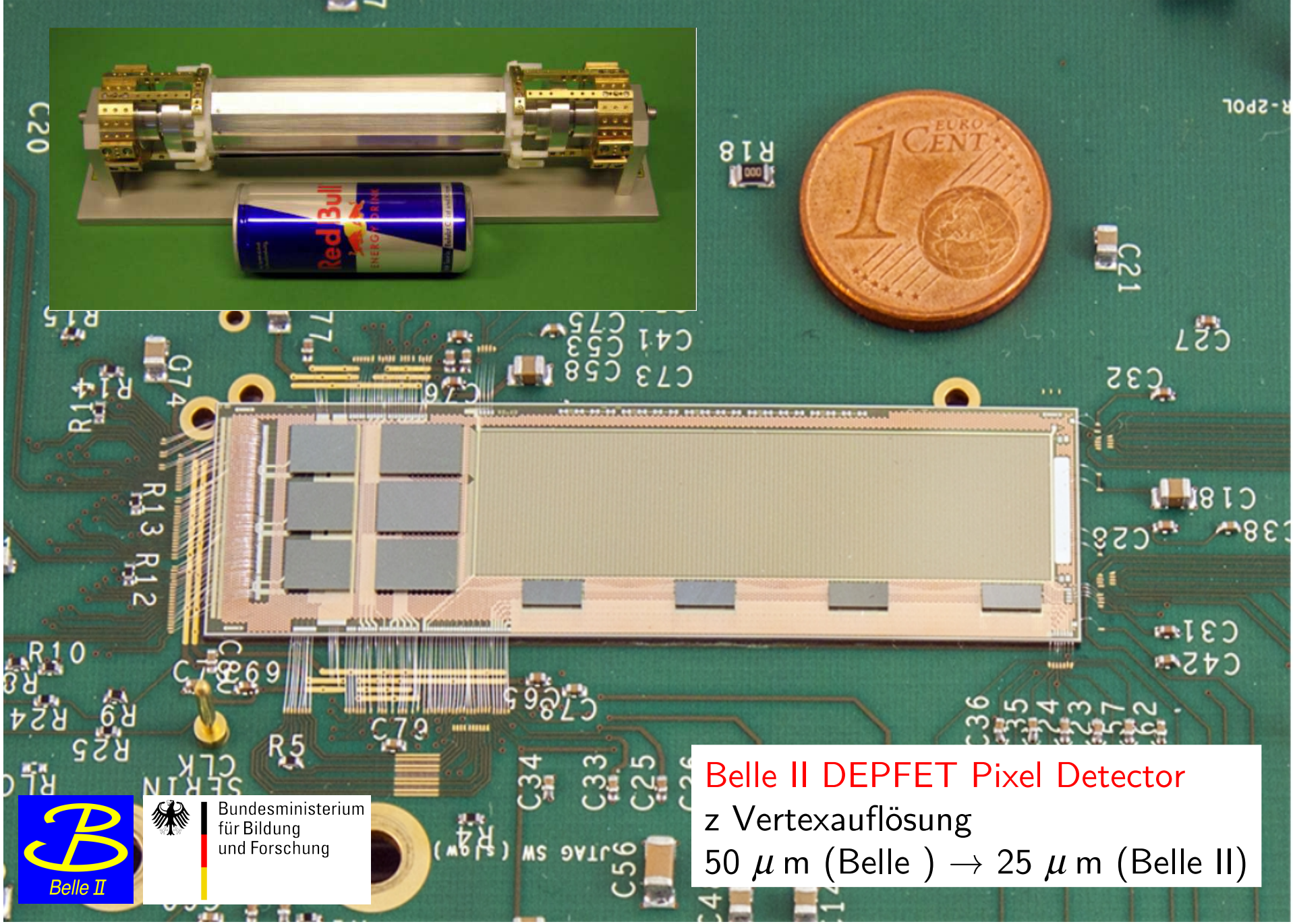
  nächste Förderperiode (2015–18)
- L1 z–Vertex–Neurotrigger TUM, MPI
- Computing
  - Softwareentwicklung
    - PXD alle
    - non-PXD KIT
  - Tracking Algorithmen

    DESY, KIT, LMU, TUM, MPI (Vertexing), Bonn, Giessen (Online)
  - GRID Ressourcen DESY, KIT, MPI
  - Alignment DESY

Pixel Vertex Detector for Belle II @ SuperKEKB

Precise Measurement of particle origin



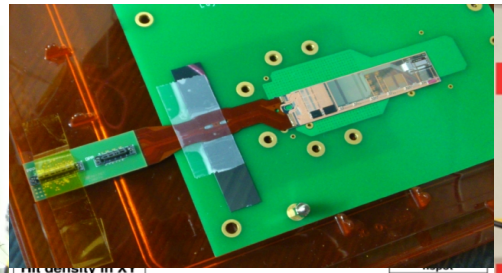


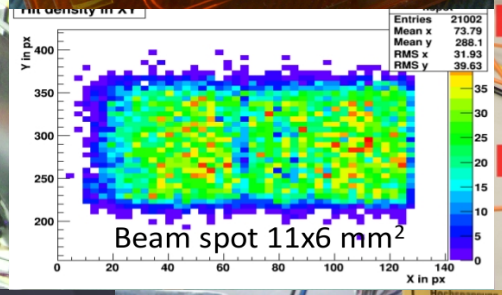
Belle II DEPFET Pixel Detector

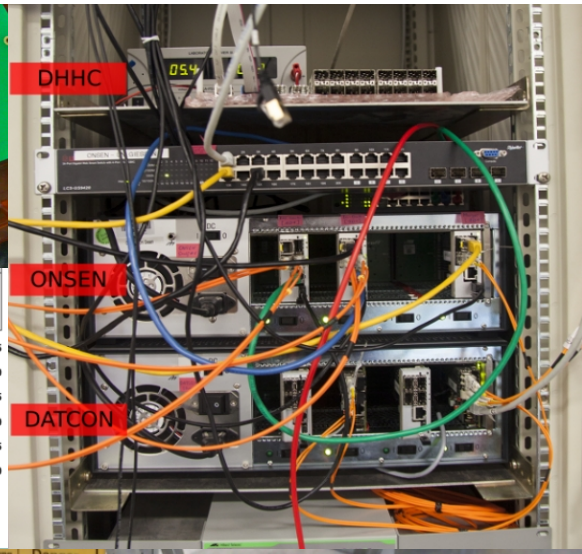
z Vertexauflösung

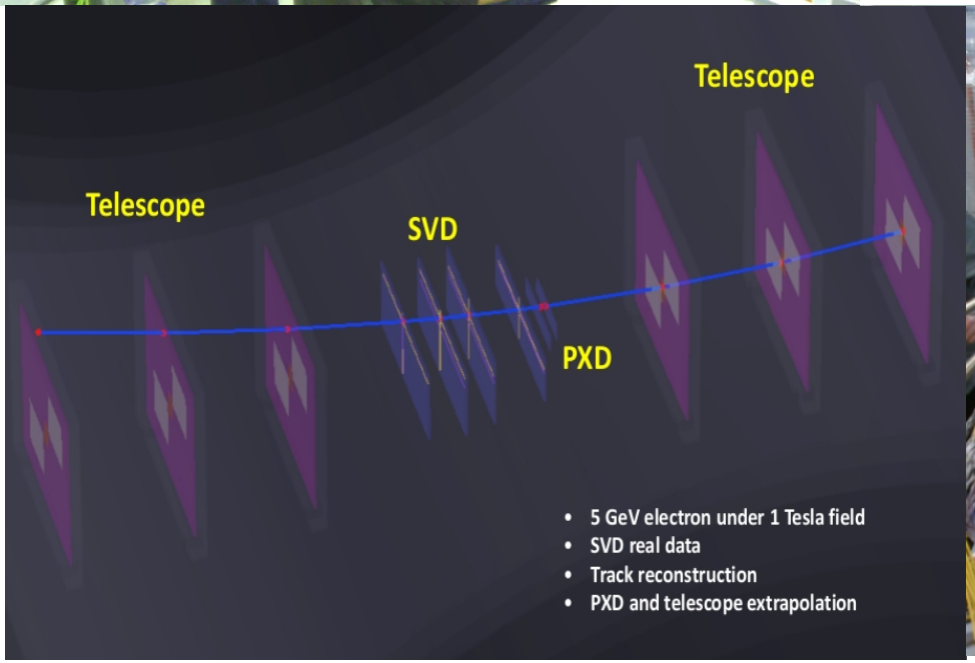
50 μm (Belle) $\rightarrow$ 25 μm (Belle II)

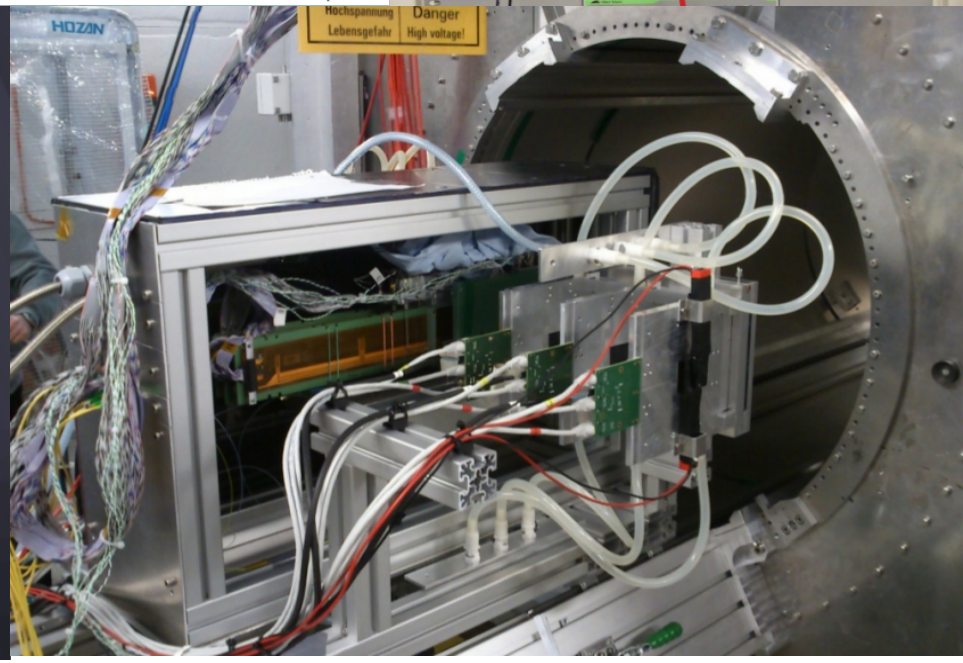
PXD+SVD DESY team test (01/2014)
≥2 x 10^7 events recorded



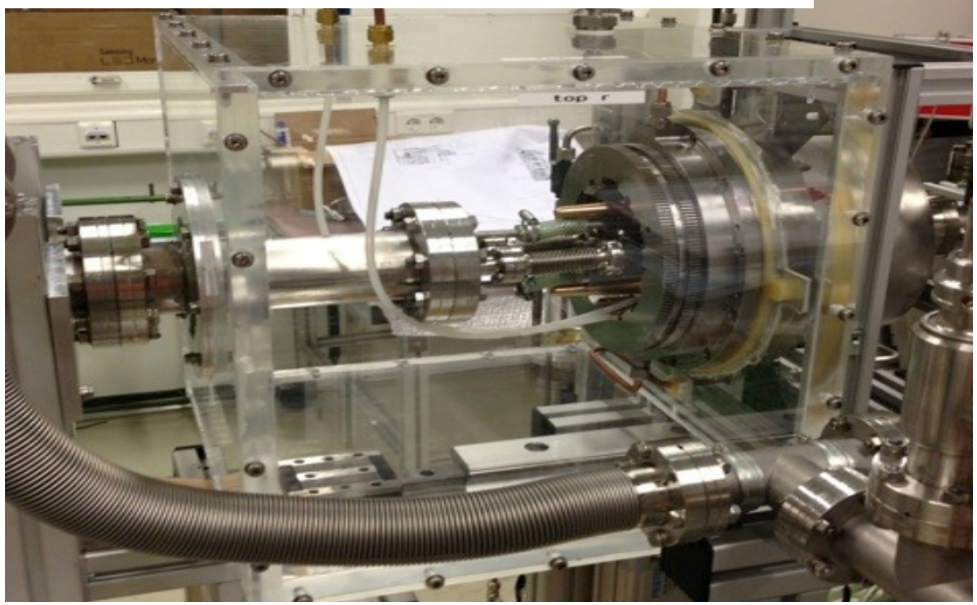






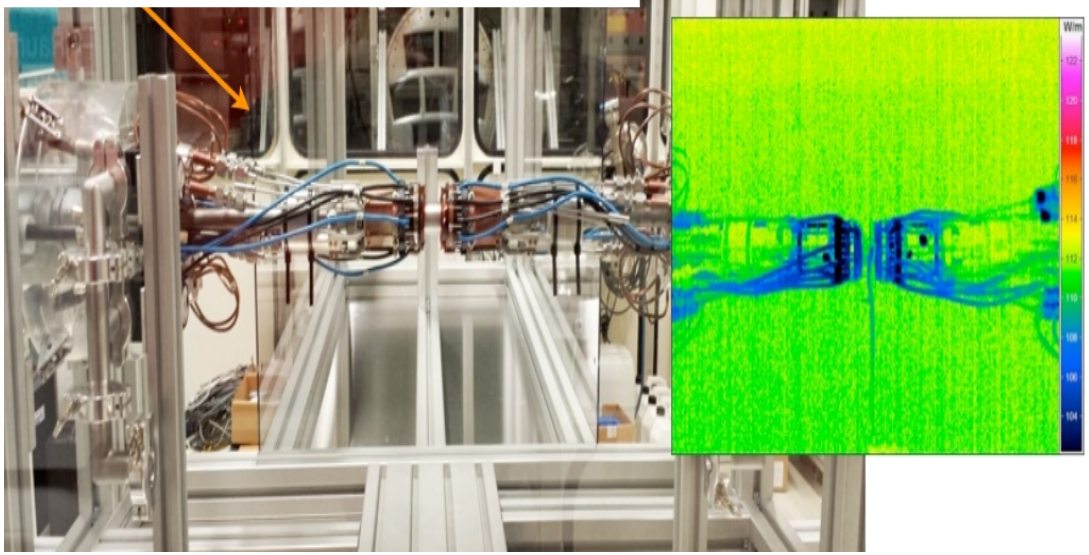


IR Mechanics, Remote Vacuum Connection (DESY,MPI)



CO_2 Cooling PXD+SVD (MPI, DESY)

Thermal Mockup (DESY, Hamburg)

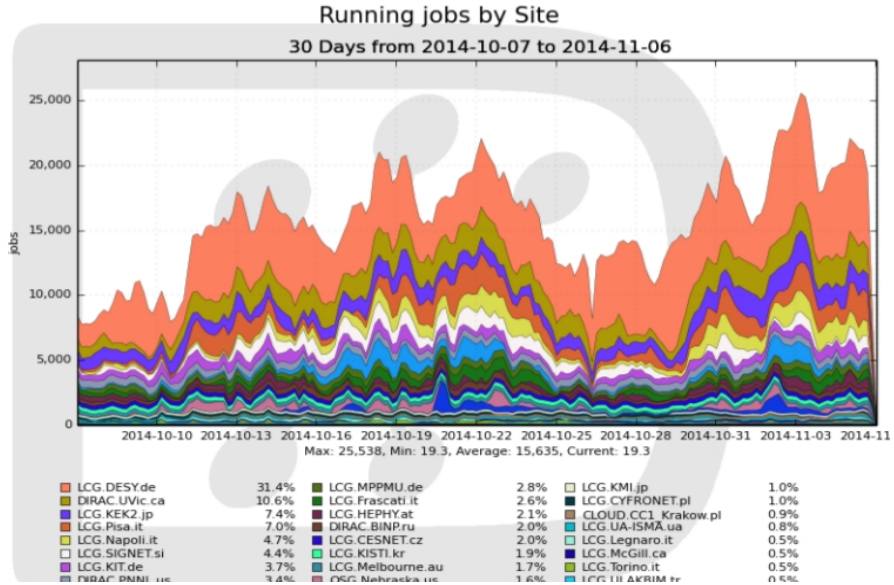


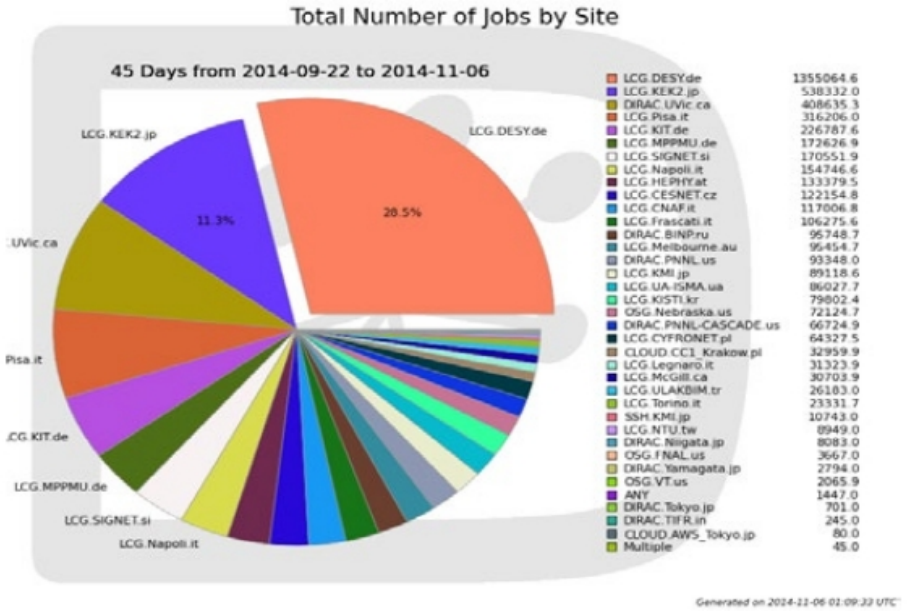
Belle und Belle II Daten in Deutschland

- Alle Belle I Daten
  ($\simeq$1 ab^{-1}, µDST)
  nach DESY kopiert

  Zugang aller Gruppen
  zur DESY National Analysis Facility

- Belle II MC Produktion 10/2014
  - 4.7M Jobs
  - entspricht 2.9 ab^{-1}
  - Peak vergleichbar
    mit LHCb (26k Jobs)
  - DESY 28.5%,
    KIT 3.7%,
    MPI 2.8%





Belle Publikationen mit starker deutscher Beteiligung (Status 09.11.2014) (Belle I Analysen nicht BMBF gefördert)

- *Measurement of branching fractions and CP violation parameters in B -> omega K decays with first evidence of CP violation in B0 -> omega KS0,*
  V. Chobanova, J. Dalseno, C. Kiesling, et al. (Belle Collaboration),
  arXiv:1311.6666[hep-ex], publiziert in Phys. Rev D90(2014)012002,
  Suche nach CP Verletzung in einem Pinguin-dominierten Zerfall, sensitiv auf den Winkel phi1 im Unitaritätsdreieck

  $B \to \omega K$

- *Study of B0 -> rho0 rho0 decays, implications for the CKM angle phi_2 and search for other B0 decay modes with a four-pion final state,*
  P. Vanhoefer, J. Dalseno, C. Kiesling, et al. (Belle Collaboration),
  arXiv:1212.4015[hep-ex], veröffentlicht in Phys. Rev. D89(2013)072008,
  Constraint für den Winkel phi2=84.9+-12.9 grad im Unitaritätsdreieck

  $B \to \rho^0\rho^0$

- *Angular analysis of B0 -> phi K* decays and search for CP violation at Belle*
  M. Prim, et al. (Belle Collaboration)
  arXiv:1308.1830[hep-ex], veröffentlicht in Phys. Rev. D 88(2013)072004
  b-> s sbar s Pinguin Zerfall, in welchem eine überraschend geringe longitudinale Polarisation gemessen wurde (Hinweis auf Verletzung der Faktorisierung).

  $B \to J/\psi K^*$

- *Search for B -> h(*) nu nu-bar with the full Belle data sample,*
  O. Lutz, S. Neubauer, M. Heck, T. Kuhr, et al. (Belle collaboration),
  arXiv:1303.3719[hep-ex], veröffentlicht in Phys. Rev. D87(2013)111103,
  Seltener Zerfall, welcher sensitiv auf rechtshändige Kopplungen jenseits des Standardmodells ist.

  $B \to h^{(*)}\, \nu\bar{\nu}$

- *Measurement of the inclusive semileptonic branching fraction B(Bs0 -> X l nu) at Belle,*
  C. Oswald, P. Urquijo, J. Dingfelder, et al. (Belle collaboration),
  arXiv:1212.6400[hep-ex], veröffentlicht in Phys. Rev. D87(2013)072008,
  Test von SU(3) Symmetrie

  $B_s \to X\, l\, \nu$

- *First observation of CP violation and improved measurement of the branching fraction and polarization of B0 -> D*+ D*- decays,*
  B. Kronenbitter, et al. (Belle collaboration),
  arXiv:1207.5611[hep-ex], veröffentlicht in Phys. Rev. D86(2012)071103(R),
  Messung eines CP-verletzenden Zerfalls mit Charm-Mesonen

  $B \to D^{*+}D^{*-}$

- *Measurements of Branching Fractions and Time-dependent CP Violating Asymmetries in B0 -> D(*)+- D-+ Decays,*
  M. Rohrken, et al. (Belle collaboration),
  arXiv:1203.6647[hep-ex], veröffentlicht in Phys. Rev. D85(2012)091106(R),
  Messung eines CP-verletzenden Zerfalls mit Charm-Mesonen

  $B \to D^{(*)+}D^{-}$

Belle II Organization

Executive Board
Chair : H. Aihara
aihara@phys.s.u-tokyo.ac.jp

D.M.Asner, T.Aziz, A.Bozek, P.Chang, F.Forti, T.Iijima, P.Krizan, S.Lange, P.Podesta, M.Roney, C.Schwanda, M.Sevior, E.Won, C.Z.Yuan, K.Akai

Spokesperson : Thomas E. Browder
teb@phys.hawaii.edu

Project Manager : Yoshihide Sakai
Yoshihide.Sakai@kek.jp

Financial Board
Chair : Y.Sakai
Yoshihide.Sakai@kek.jp

W.Abdullah, H.Aihara, D.Asner, R.Ayad, T.Aziz, A.Bozek, T.Browder, P.Chang, Z.Dolezal, G. Finocchiaro, P.Krizan, C.Lacasta, M.I.Martinez, H-G.Moser, C.Niebuhr, P.Pakhlov, A.Rekalo, M.Roney, C.Schwanda, M.Sevior, C. P. Shen, U.Tippawan, T.Tran, N.Wermes, E.Won, M.Zeyrek

Institutional Board
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dolezal@ipnp.troja.mff.cuni.cz

Speakers Committee
Chair : A.Schwartz
alan.j.schwartz@uc.edu

T.Iijima, I. Peruzzi, Y.Sakai, C.Schwanda

Physics Coordinator : P.Urquijo
purquijo@unimelb.edu.au

Semileptonic & Missing Energy : A. Zupanc, G. De Nardo
Radiative & Electroweak Penguin : A. Ishikawa, J. Yamaoka
T-Dep. CP Violation : T. Higuchi, K. Sumisawa
Hadronic B Decay & DCPV : J. Libby, P. Goldenzweig
Y(nS) : R. Mizuk, T. Pedlar
Charm & Carmonium : R. Briere, G. Casarosa
Tau & Low Multiplicity : T. Ferber, K. Hayasaka, H. Nakazawa

Technical Coordinator : Y.Ushiroda
ushiroda@post.kek.jp

Integration Leaders : I. Adachi (Outer), S. Tanaka (Inner)

PXD : H.G. Moser, C. Kiesling
SVD : K. Hara, C. Irmler
CDC : S. Uno
TOP : J. Fast
ARICH : S. Nishida, S. Korpar
ECL : A. Kuzmin
EKLM : P. Pakhlov
BKLM : L. Piilonen

TRG : Y. Iwasaki
DAQ : R. Itoh
IR : H. Nakayama
STR : J. Haba
BKG : S. Vahsen

Liaisons :
S. Tanaka (PXD)
I. Adachi (BPID)
I. Nakamura (ECL)
K. Sumisawa (BKLM/EKLM)

Software Coordinator : T.Kuhr
Thomas.Kuhr@kit.edu

Simulation : D. Kim
Tracking : M. Heck, E. Paoloni
Alignment : S.Yashchenko
Database : M. Bracko, L. Wood

Computing Coordinator : T.Hara
takanori.hara@kek.jp

Distributed Computing : M. Sevior
Data Transfer / Network : M. Schram
MC prod. manager : H. Miyake
Monitor : K. Hayasaka

Installation of 100 new LER Dipole Magnets

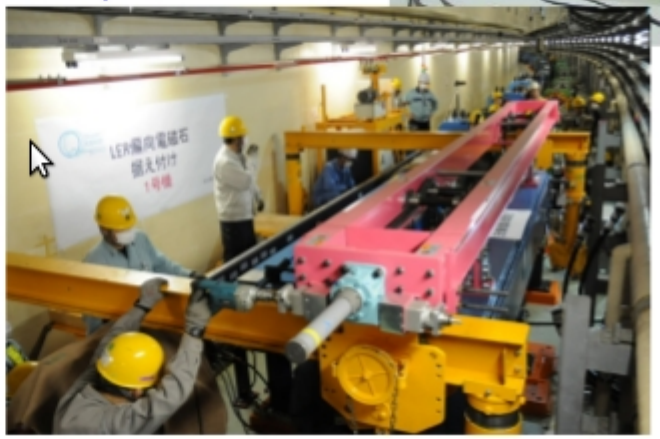
field measurement

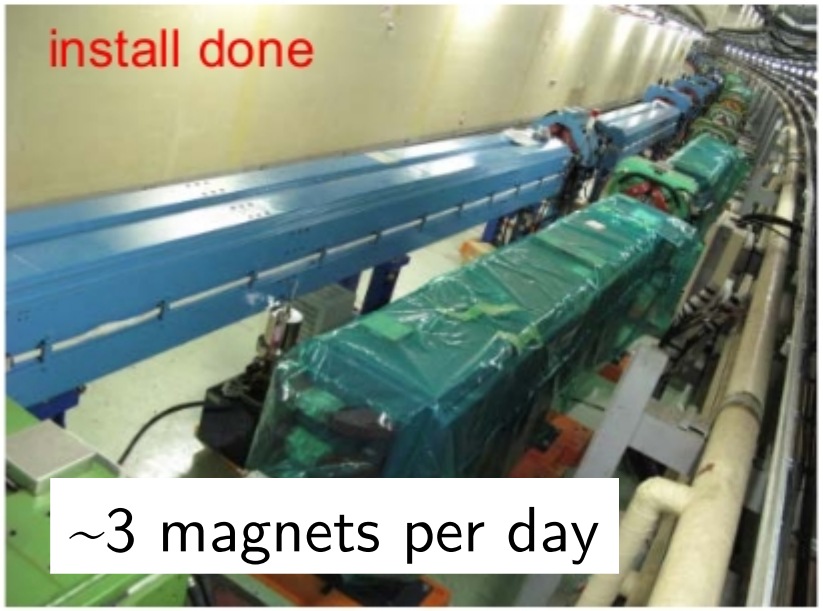
move into tunnel

Installation of 100 new LER bending magnets done

carry on an air-pallet

Install over HER magnets





~3 magnets per day

SuperKEKB Status, 7th BPAC, Mar. 11, 2013, K. Akai

19

B-KLM Installation

2013

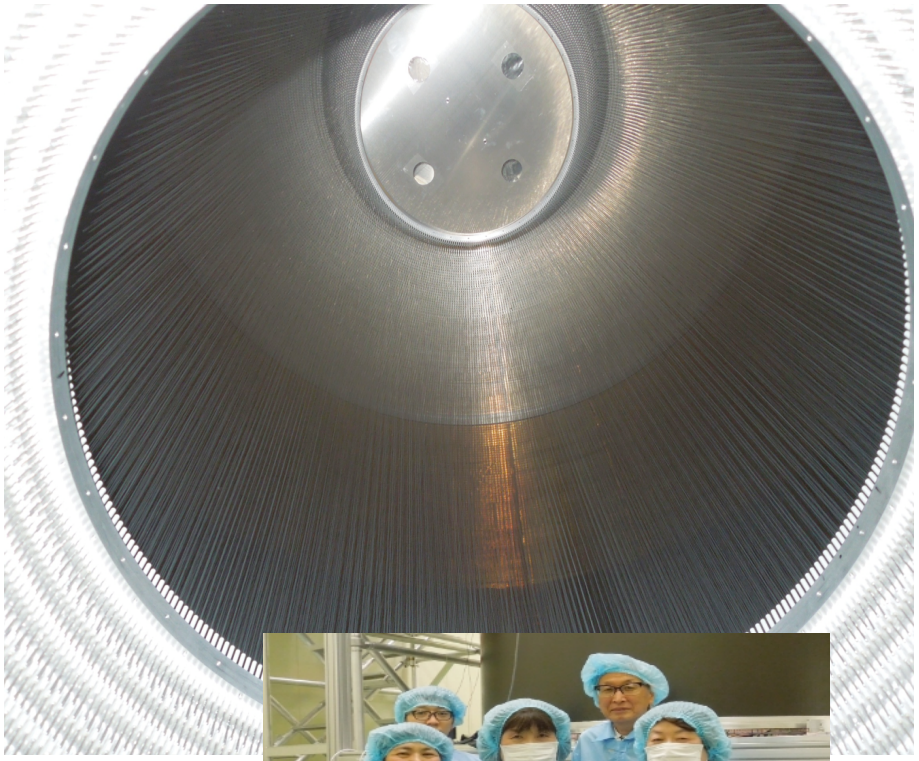
Completed on November 16th

~2 months delay

During installation, modules have been checked, found to be healthy.

The 1st New Detector Installed !!

CDC wire stringing finished (01/2014)
51456 wires



FWD side: ground cabling finished (11/2014)
white: axial super layers
green: stereo super layers

TOP Assembly of 1st Module

Mirror

Glue joint between two bars

Optics done, need to integrate with bar box

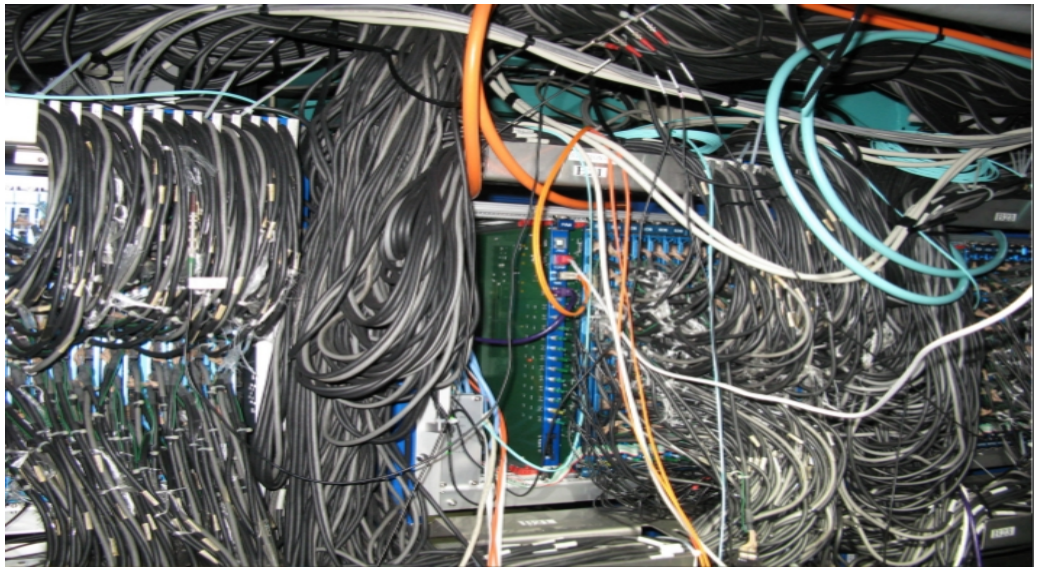
Lifting jig with vacuum chucks

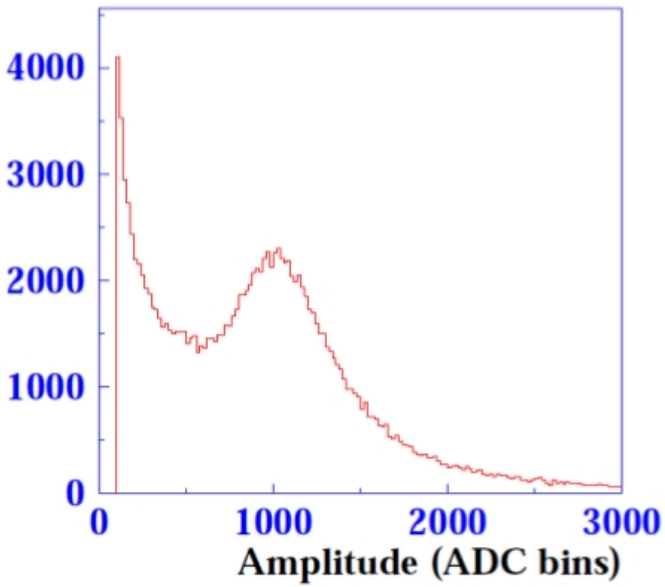
"Expansion block" or prism

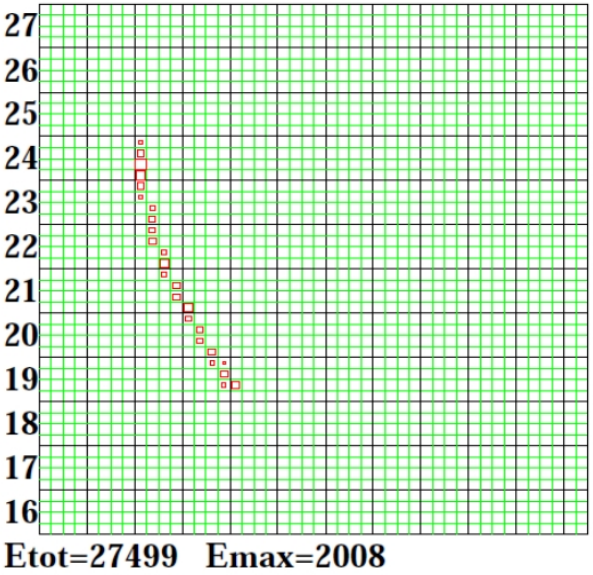
Scene at the Fuji Hall clean room just before Halloween 2014

ECL cosmic data taking w/ ~4000 crystals

31.10.2014, w/ new electronics:
- shaping time 1 us (before) → 0.5 us (Belle II)
- waveform digitization 2 MSamples/s







Kürzungen des KEK Operations-Budget

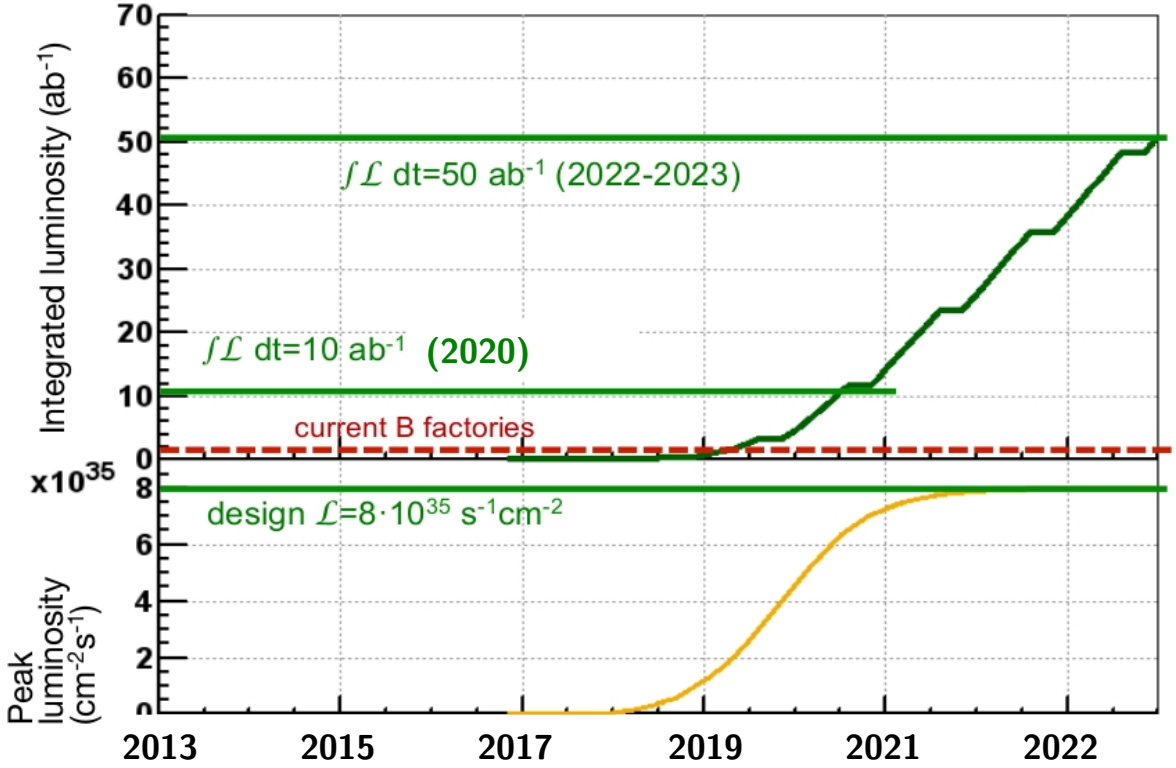
betrifft z.B. Commissioning des Beschleunigers

Jahr	Betrag benötigt und beantragt: 50.4 MEuro
2014	10.9 MEuro
2014	13.7 MEuro (Forderung Rückzahlung von 2013)
2015	16.9 MEuro

$\rightarrow$ Verzögerung des Schedules

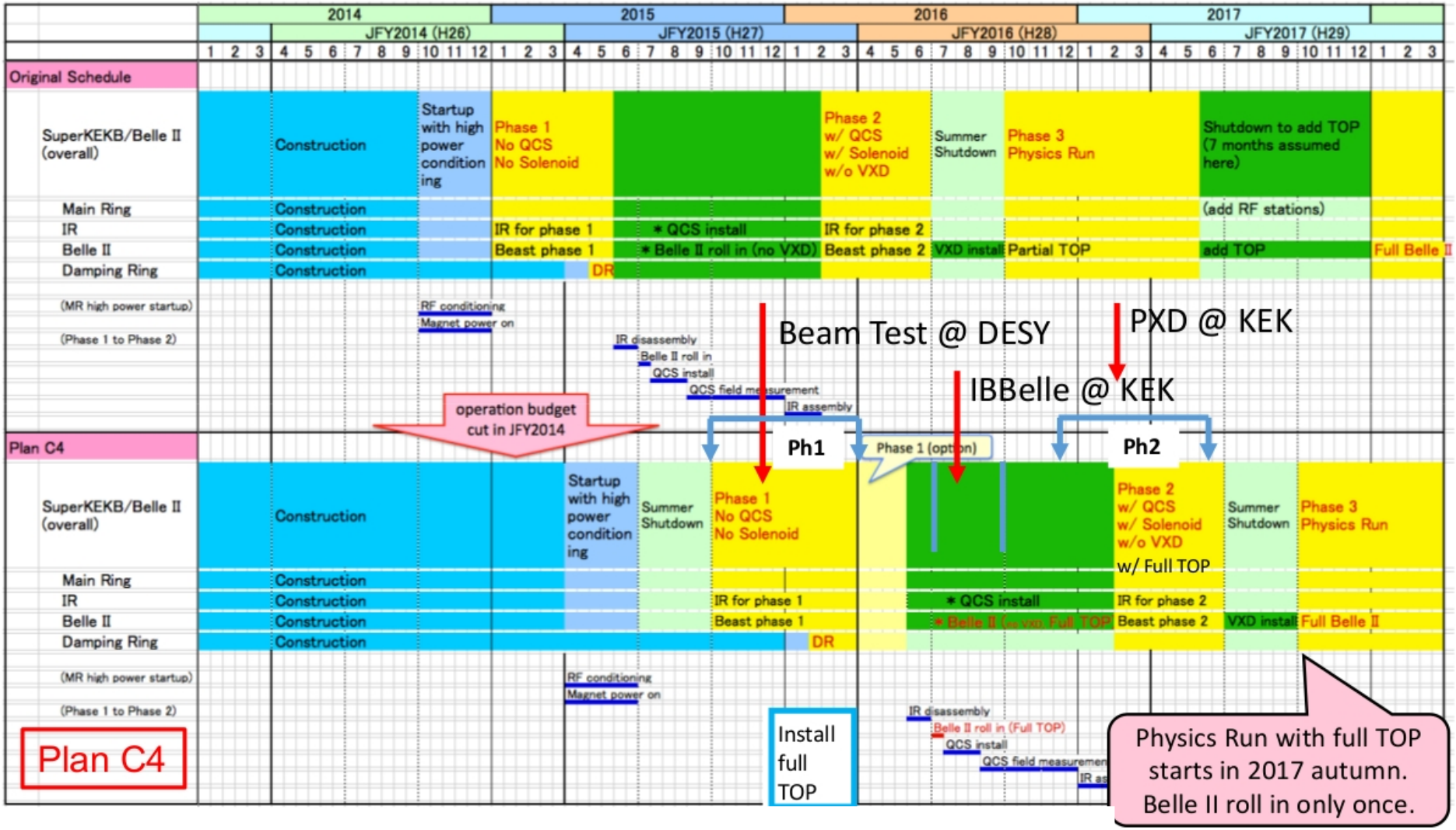
SuperKEKB Luminositätsextrapolation

(post–KEK–Budgetkürzung FY2014)



Start der Physikdatennahme verzögert sich 10/2016 → 10/2017
Impliziert Planänderung: alle TOP Module werden verfügbar sein
Aus– und Wiedereinbau von PXD, SVD, CDC nicht mehr notwendig
(keine Datennahme mehr mit ½ TOP)

Belle II Schedule



Zusammenfassung

- Deutschland ist zweitstärkste Gruppe in Belle II (≥100 Mitglieder)
- signifikante Beiträge (PXD, Computing)
- KEK Budgetkürzungen erfordern Verschiebung des Schedules
  → erste Physikdatennahme geplant für 10/2017

Vielen Dank.

CLICK → [Belle deutsche Sektion WWW Homepage] ← CLICK

Backup

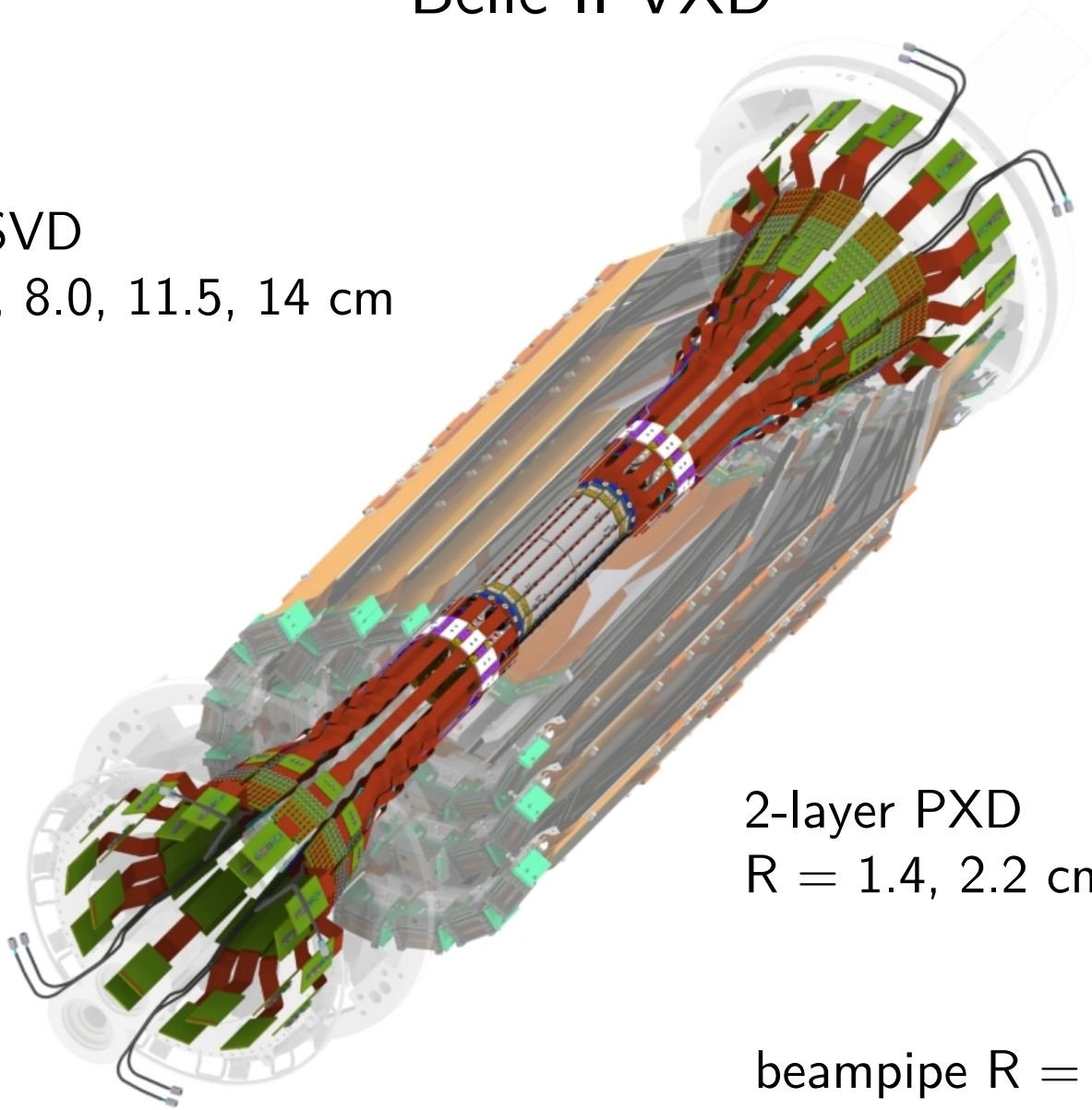
The DEPFET-Collaboration

Spokesman: C. Kiesling (MPI), Technical coordinator: H.-G. Moser (MPI)

Group	Pers.	Responsibilities
IHEP Beijing, China (Z.A. Liu)	10	ATCA Boards
Charles University, Prague, Czech Rep. (Z. Dolezal)	7	Beam test analysis
DESY Hamburg (C. Niebuhr)	14	RVC, CO2, th. mock-up
University of Bonn (N. Wermes, H. Krüger)	15	DHP ASIC, DatCon ROIs
University of Hamburg (C. Hagner)	3	mech. mock-up
University of Heidelberg (P. Fischer)	2	Slow Control
University of Giessen (W. Kühn, S. Lange)	5	DAQ hardware
University of Göttingen (A. Frey)	7	Beam tests, analysis
University of Karlsruhe (T. Müller, M. Feindt, I. Peric)	16	S/W framew., DCD, SW
University of Mainz (C. Sfienti)	4	Slow Control
Ludw.-Max.-University, Munich (Th. Kuhr)	3	P/S, Kapton, tracking
MPI for Physics, Munich (C. Kiesling, H.G.Moser	17	Sensors, mech., CO2
Semiconductor Lab (HLL) (J. Ninkovic)	5	Sensors
Technical University, Munich (S. Paul, A.Knoll)	7	DHH, Slow Control
Struct. Biol.Research Center, KEK (S. Wakatsuki)	4	Sensor testing
IFJ PAN, Krakow, Poland (A. Bozek)	11	FTB for DatCon
University of Barcelona, Spain (A. Dieguez)	3	ASIC design
CNM, Barcelona, Spain (E. Cabruja)	2	(flip chipping)
IFCA Santander, Spain (I. Vila)	3	environm. sensors
IFIC, Valencia, Spain (C. Lacasta)	4	SMD + sensor rework
University of Tabuk (R. Ayad)	3	Comic ray test setup

Belle II VXD

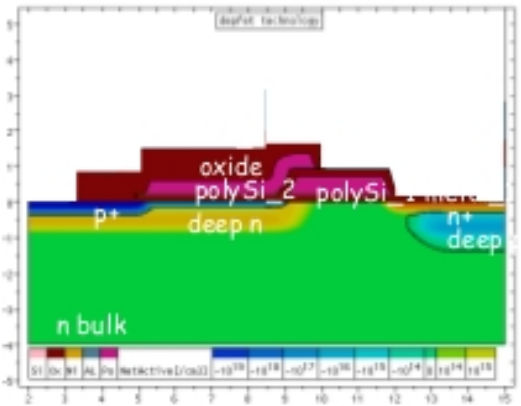
4-layer SVD
R = 3.8, 8.0, 11.5, 14 cm

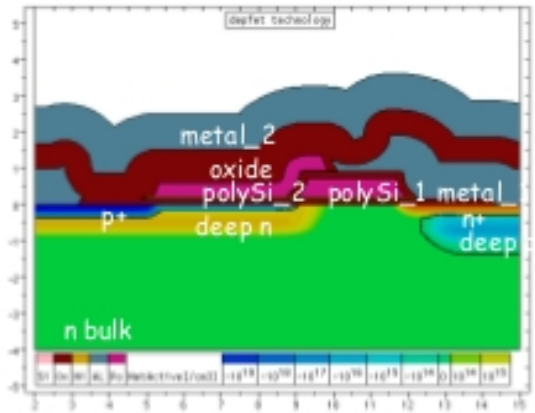


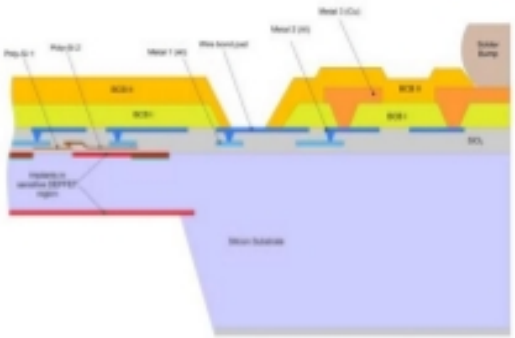
2-layer PXD
R = 1.4, 2.2 cm

beampipe R = 1.0 cm

DEPFET Production







Phase I – before metal

- Implantations
- Polysilicon
- Dielectric depositions

Phase II - Alu

- Metal 1
- isolation
- Metal 2

Phase III – thinning and Cu

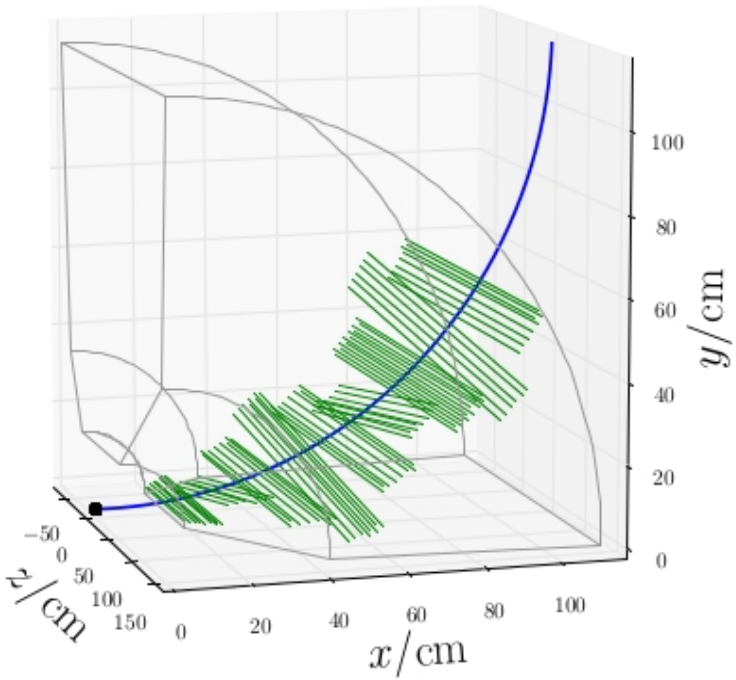
- Handle wafer removal
- Dielectric deposition
- Metal 3
- Passivation

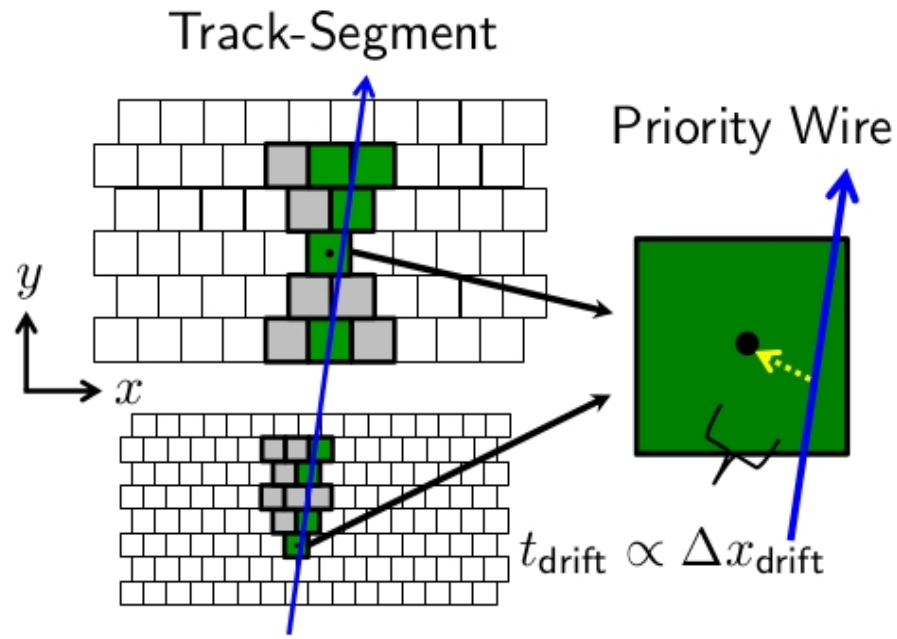
☑ Phase II:EMCM production(s) for Alu/Cu

z–Vertex–Neurotrigger

CDC Tracking:

- 15000 wires ⇒ 2336 track-segments (TS)





Which information is available for triggering?

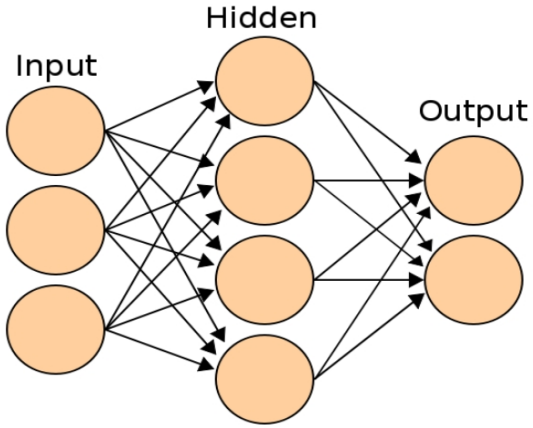
a) Identification numbers of active track-segments (TS-IDs)

⇒ Position of priority wire

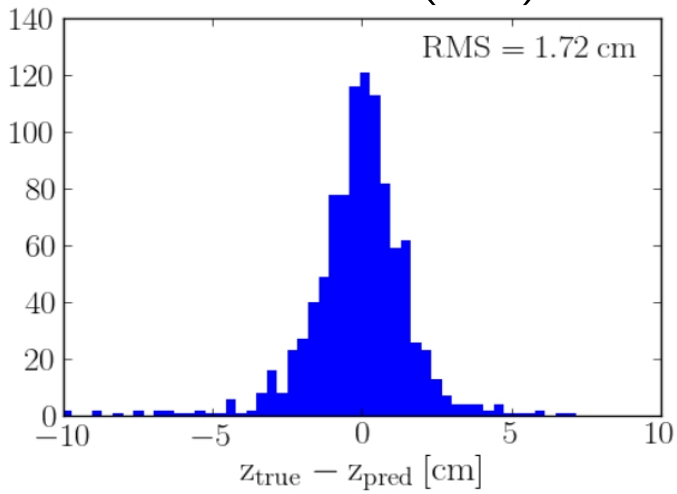
b) Drift times of priority wires

z–Vertex–Neurotrigger

Algorithmus: Multi-Layer Perzeptron



Resolution (MC)

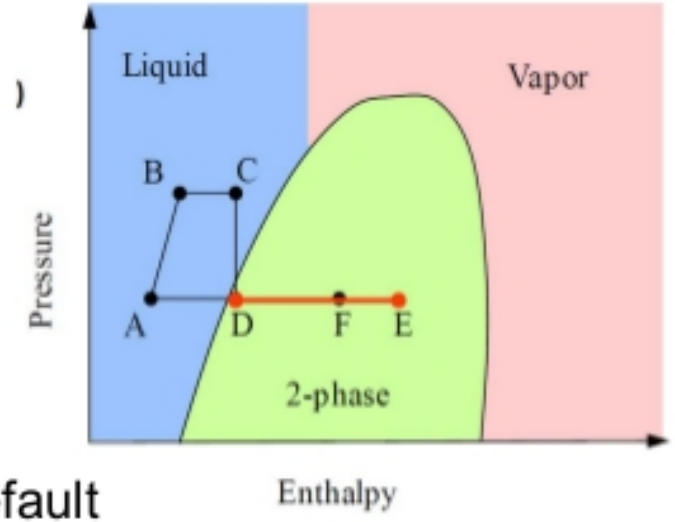


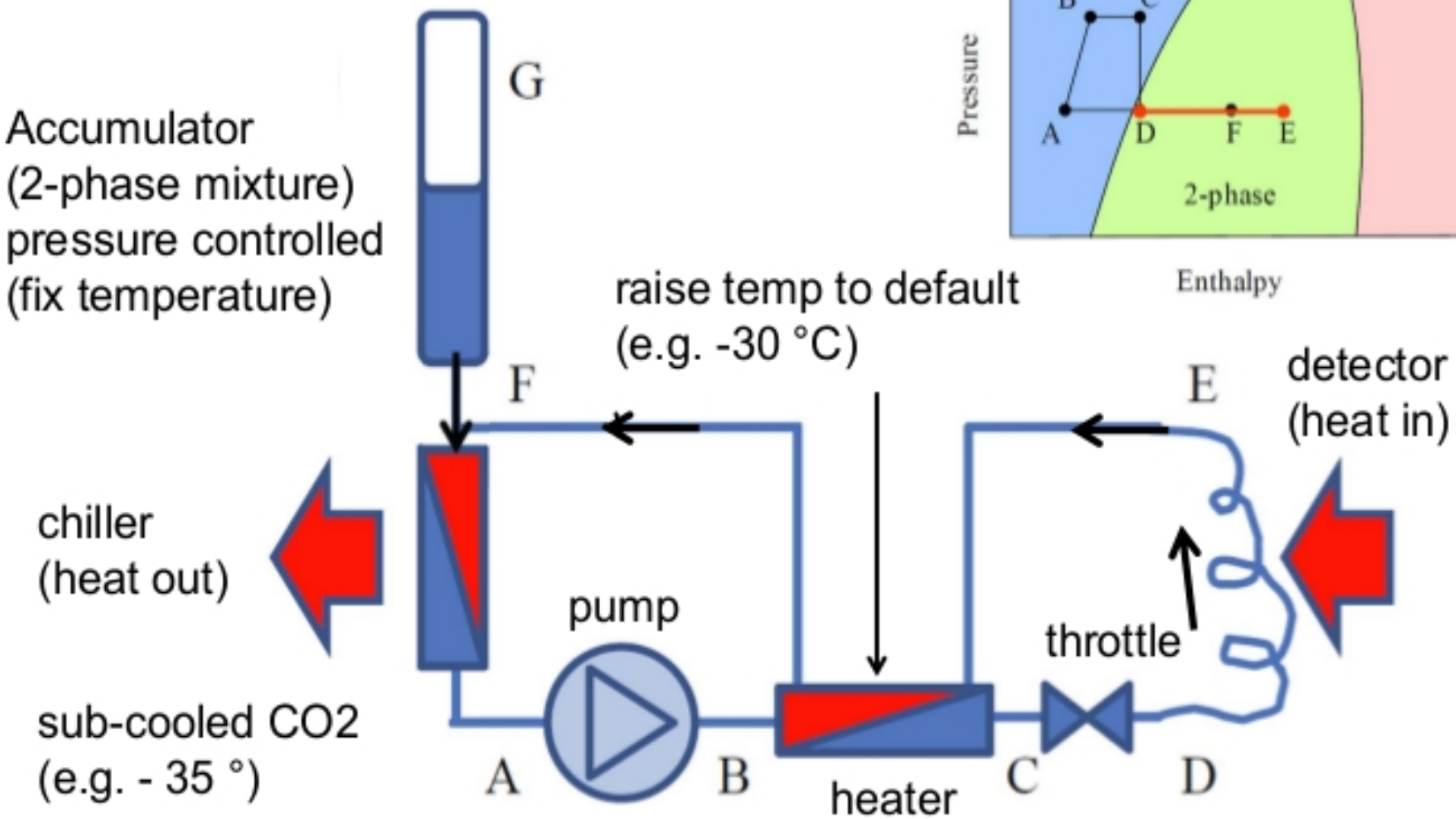
Hardware platform
UT3 board (Xilinx Virtex-6 HXT)

S. Skambraks et al., arXiv:1406.3319[physics.ins-det]
S. Neuhaus et al., arXiv:1410.1395[physics.ins-det]

2 Phase Accumulator Controlled Loop

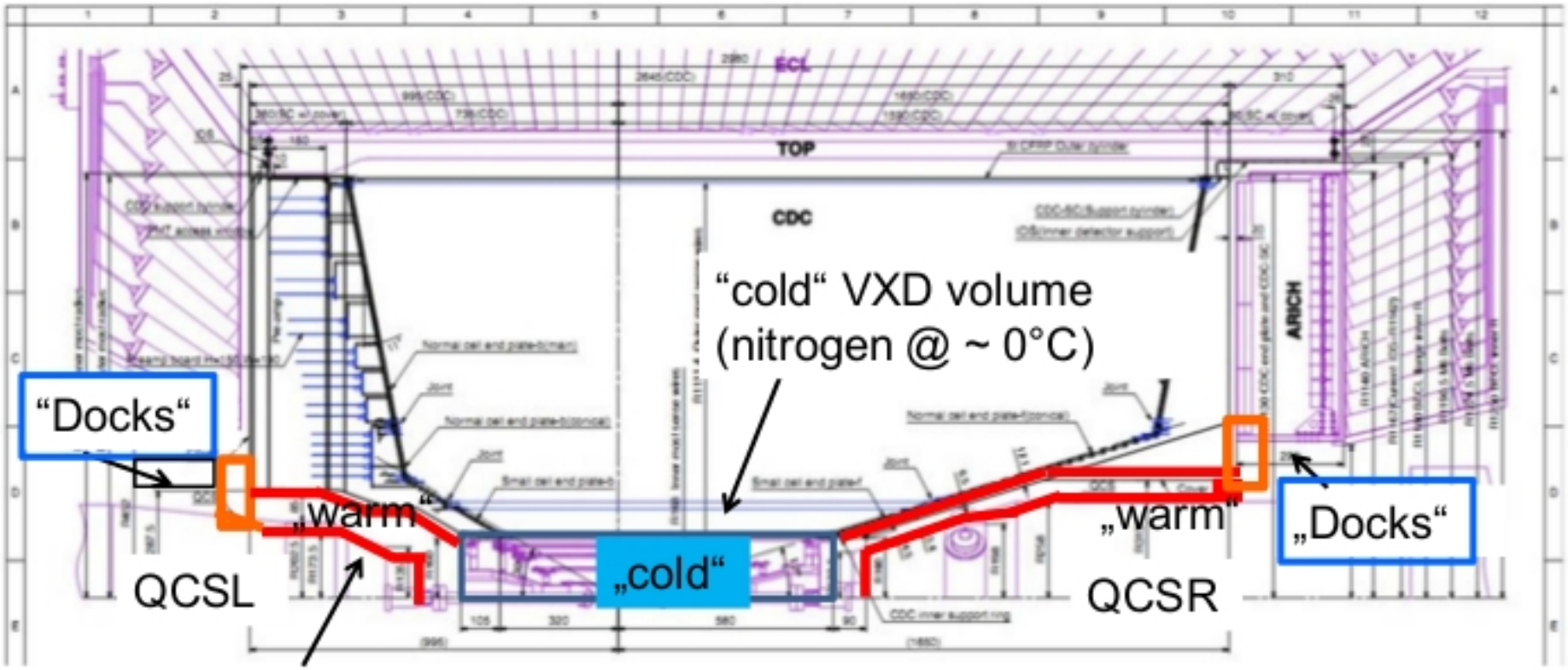
"2PACL", proposed by B. Verlaat (NIKHEF)





(C. Kiesling)

Two Dry Volumes: “cold“ and “warm“



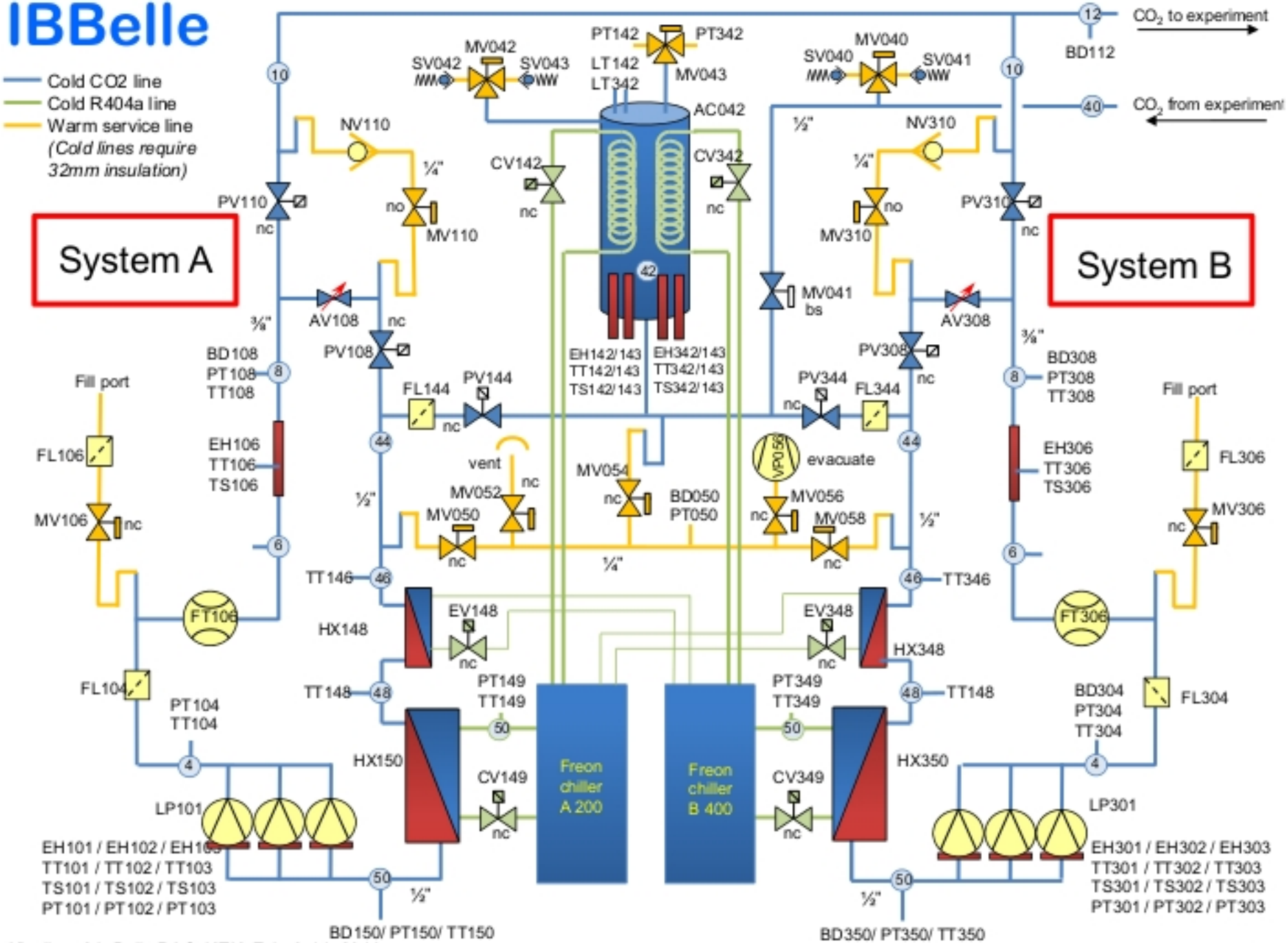
“warm“ volumes between QCS and CDC inner wall, up to CDC end wall, both in FWD and BWD directions.

flushed by nitrogen mandatory (potential hazard by oil from dry air supplier)

VXD Cooling Requirements & Specs

- Minimize material in acceptance region
- SVD requirements:
  coolant temperature for APV25 @ -20°C for SNR improvement
  total dissipated power ~ 700 W
- PXD requirements:
  sensor temp. < 25°C, ASICs < 50°C : cooling block @ <-20°C
  dissipated power ~ 360 W
- Cooling power ~ 1.6 kW at VXD (incl. ~ 540 W parasitic heat influx)
  have to add heat loss through 15 m of transfer lines → ~ 2-3 kW
- Dry Volume (preferably nitrogen):
  dew point inside VXD volume: ~ -30 °C
- Outside of VXD: room temperature (~ 23°C) at the CDC
  may need a thermal enclosure towards CDC, well isolated

IBBelle


Cold CO2 line
Cold R404a line
Warm service line
(Cold lines require 32mm insulation)
System A
System B
CO2 to experiment
CO2 from experiment
BD112
PT142
PT342
LT142
LT342
MV042
MV043
MV040
SV042
SV043
SV040
SV041
AC042
NV110
NV310
CV142
CV342
PV110
PV310
MV110
MV310
MV041
bs
AV108
AV308
PV108
PV308
BD108
PT108
TT108
BD308
PT308
TT308
EH142/143
TT142/143
TS142/143
EH342/143
TT342/143
TS342/143
FL144
PV144
PV344
FL344
Fill port
FL106
MV106
EH106
TT106
TS106
EH306
TT306
TS306
FL306
MV306
vent
MV052
MV050
MV054
BD050
PT050
VP056
evacuate
MV056
MV058
TT146
TT346
FT106
FT306
HX148
EV148
EV348
HX348
FL104
PT104
TT104
TT148
PT149
TT149
PT349
TT349
BD304
PT304
TT304
FL304
HX150
CV149
Freon chiller A 200
Freon chiller B 400
CV349
HX350
LP101
LP301
EH101 / EH102 / EH103
TT101 / TT102 / TT103
TS101 / TS102 / TS103
PT101 / PT102 / PT103
EH301 / EH302 / EH303
TT301 / TT302 / TT303
TS301 / TS302 / TS303
PT301 / PT302 / PT303
BD150/ PT150/ TT150
BD350/ PT350/ TT350

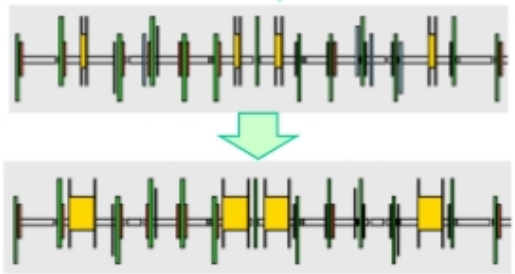
IBBelle: The "Twin" at CERN

Installation at CERN (ATLAS Experiment)

Accum. rack

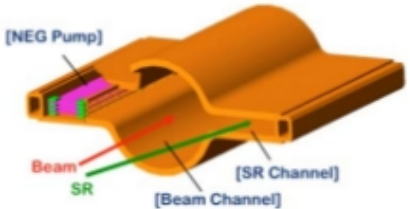

SuperKEKB accelerator Japan
Mt. Tsukuba
SuperKEKB ring (HER+LER)
Belle II detector
Linac
KEK - Tsukuba
merinas@uni-bonn.de

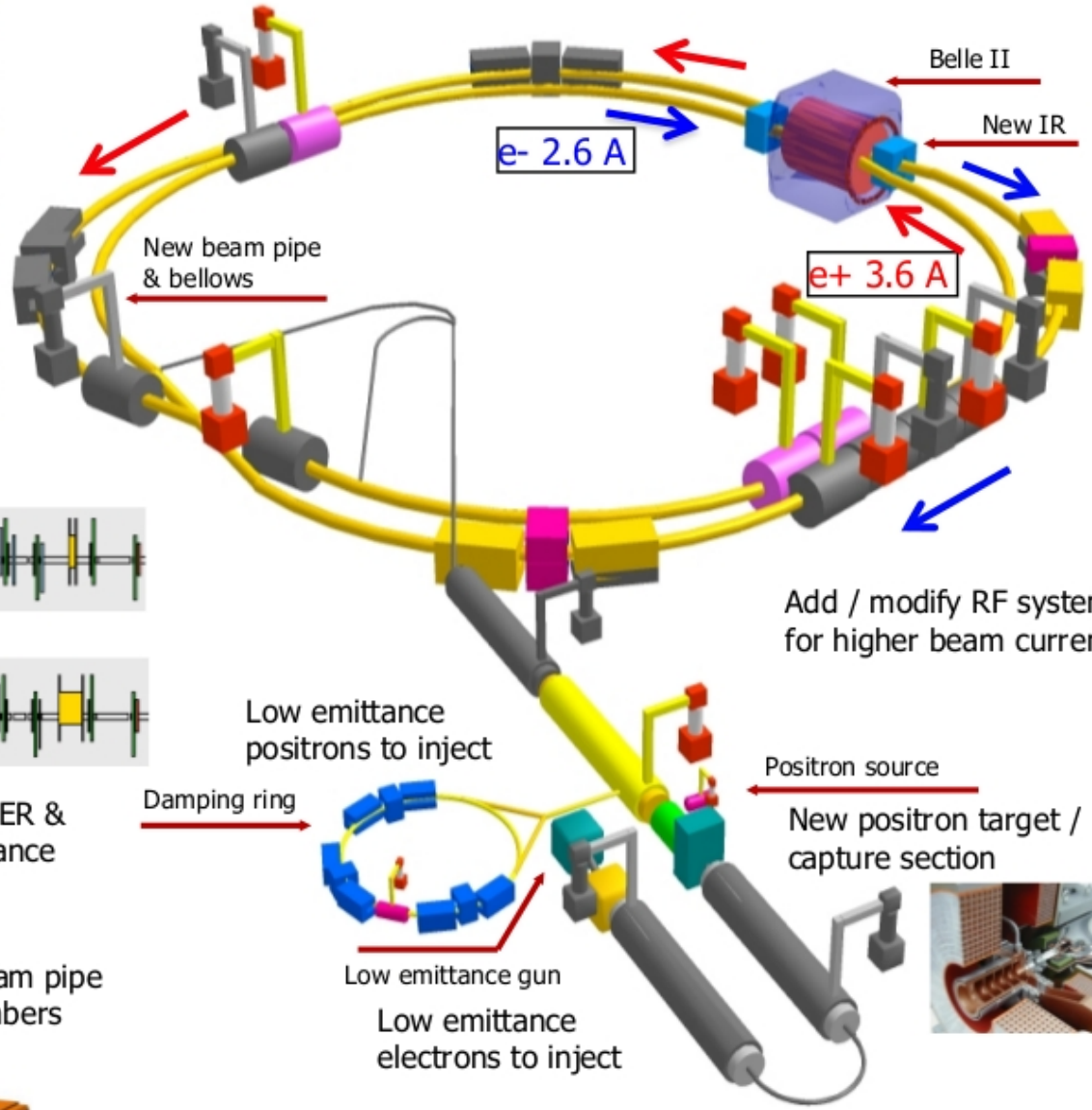
Replace short dipoles with longer ones (LER)



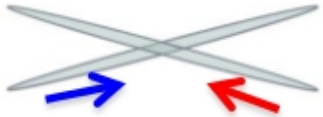
Redesign the lattices of HER & LER to squeeze the emittance

TiN-coated beam pipe with antechambers

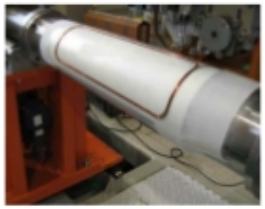




Colliding bunches

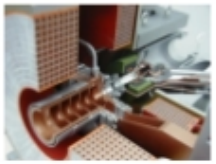


New superconducting /permanent final focusing quads near the IP



Add / modify RF systems for higher beam current

New positron target / capture section



To get x40 higher interaction rate

Luminosity increase

1. beam current

1.64/1.19 A $\rightarrow$ 3.6/2.6 A for e+ (e−) beam

$\rightarrow$ factor 2 increase in luminosity

2. beta function

β_y*

5.9 mm $\rightarrow$ 0.27 mm

$\sigma_y \rightarrow$ 59 nm

''nanobeam''

$\rightarrow$ factor 20 increase in luminosity

$$\sigma_y(z) \propto \sqrt{\varepsilon_{inj} \cdot \beta_y(z)}$$

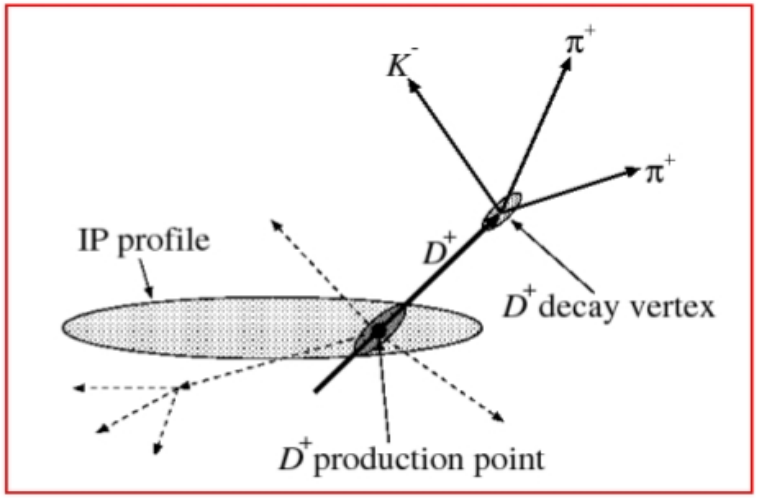
$$\beta_y(z) = \beta_y^*(1 + \frac{(z - Z_0)^2}{\beta_y^{*2}})$$

Z_0 is position of minimum beta function („waiste“)

$\rightarrow$ total factor 40 increase in luminosity

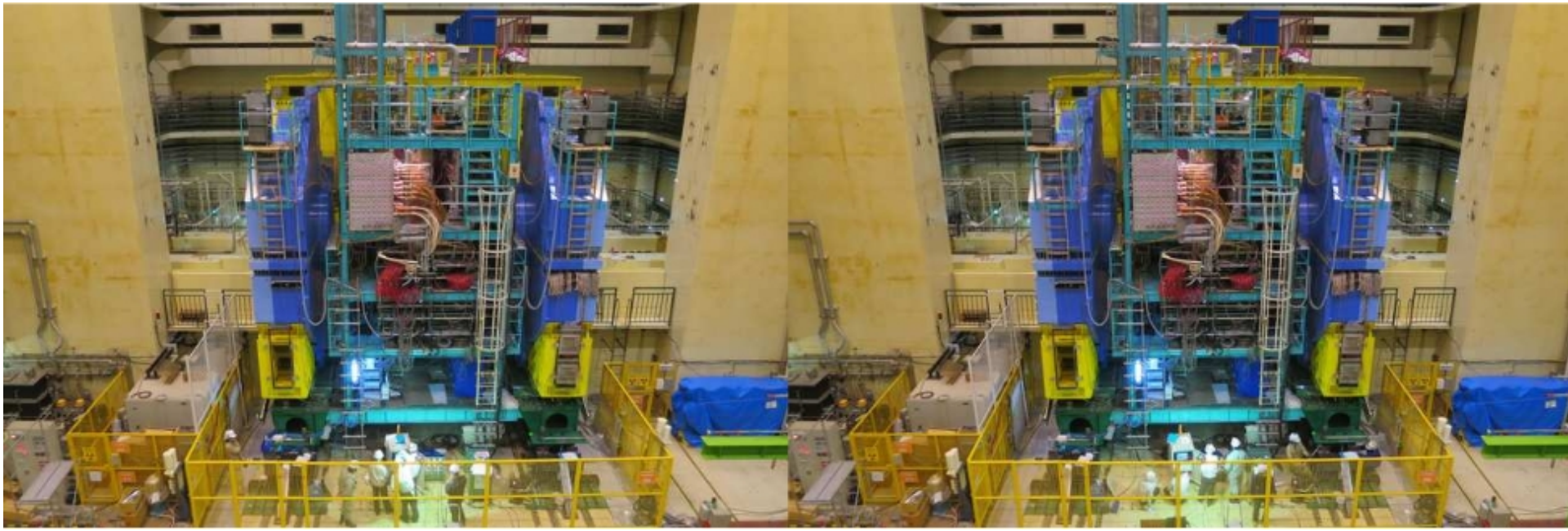
IP Profile for Belle and Belle II („nanobeam“)

100μm(H) x 2μm(V) → 10μm(H) x 59nm(V)



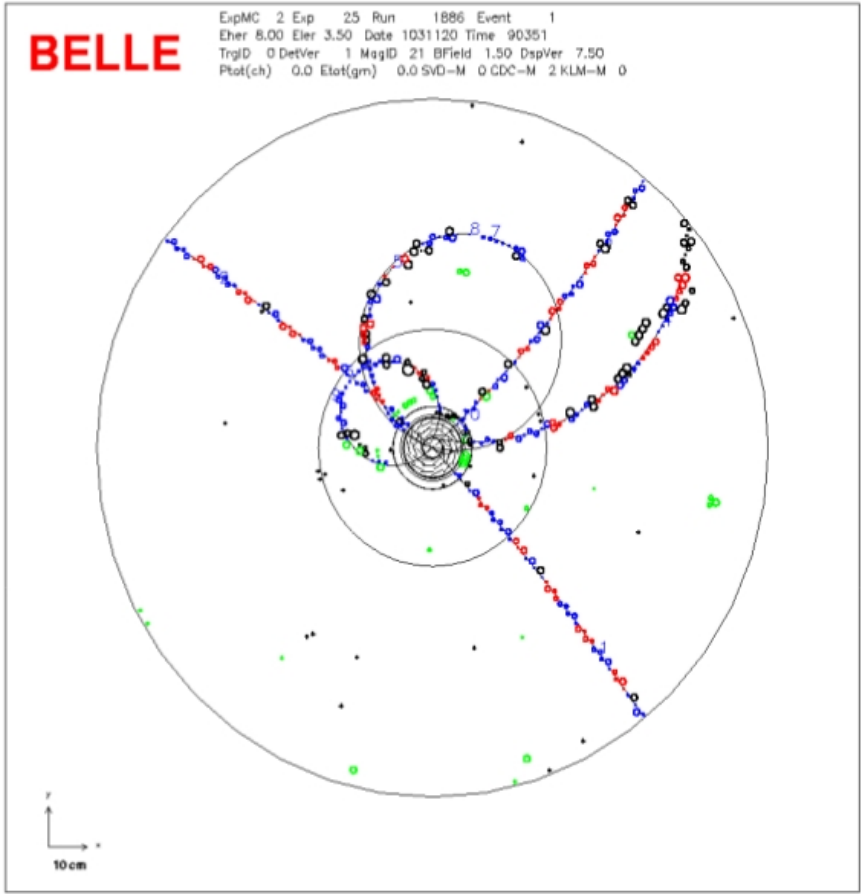
Belle Rotation 03/2013

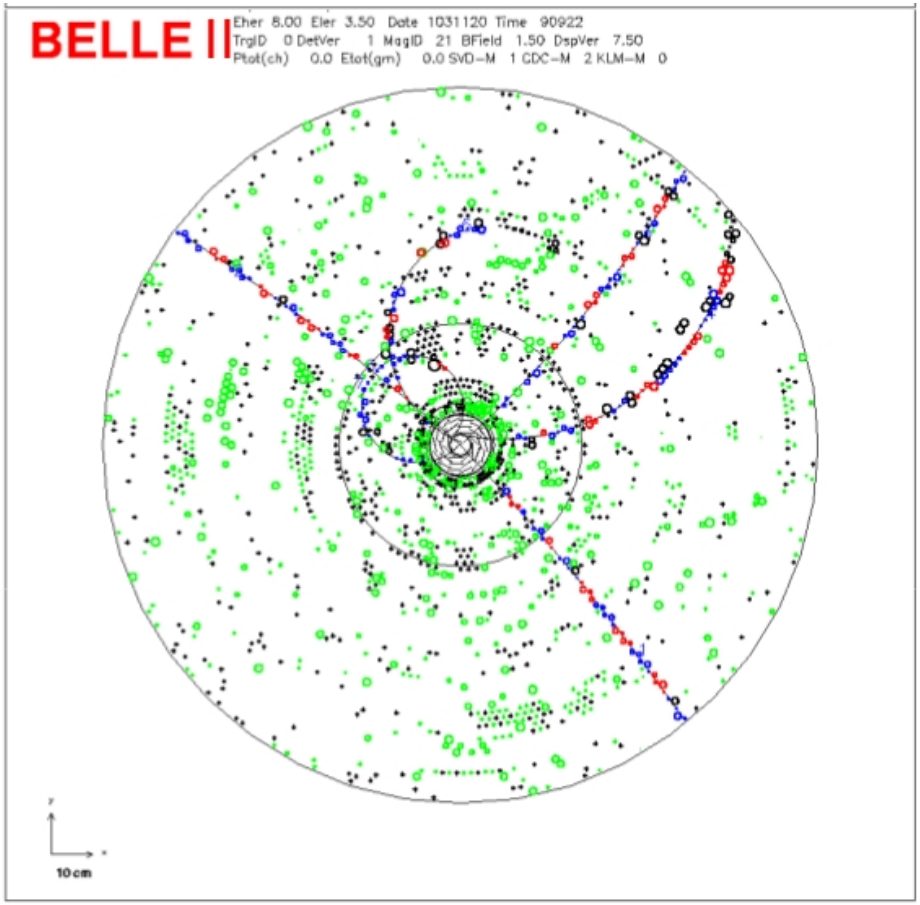
for larger crossing angle 22 mrad $\rightarrow$ 83 mrad (nanobeam)



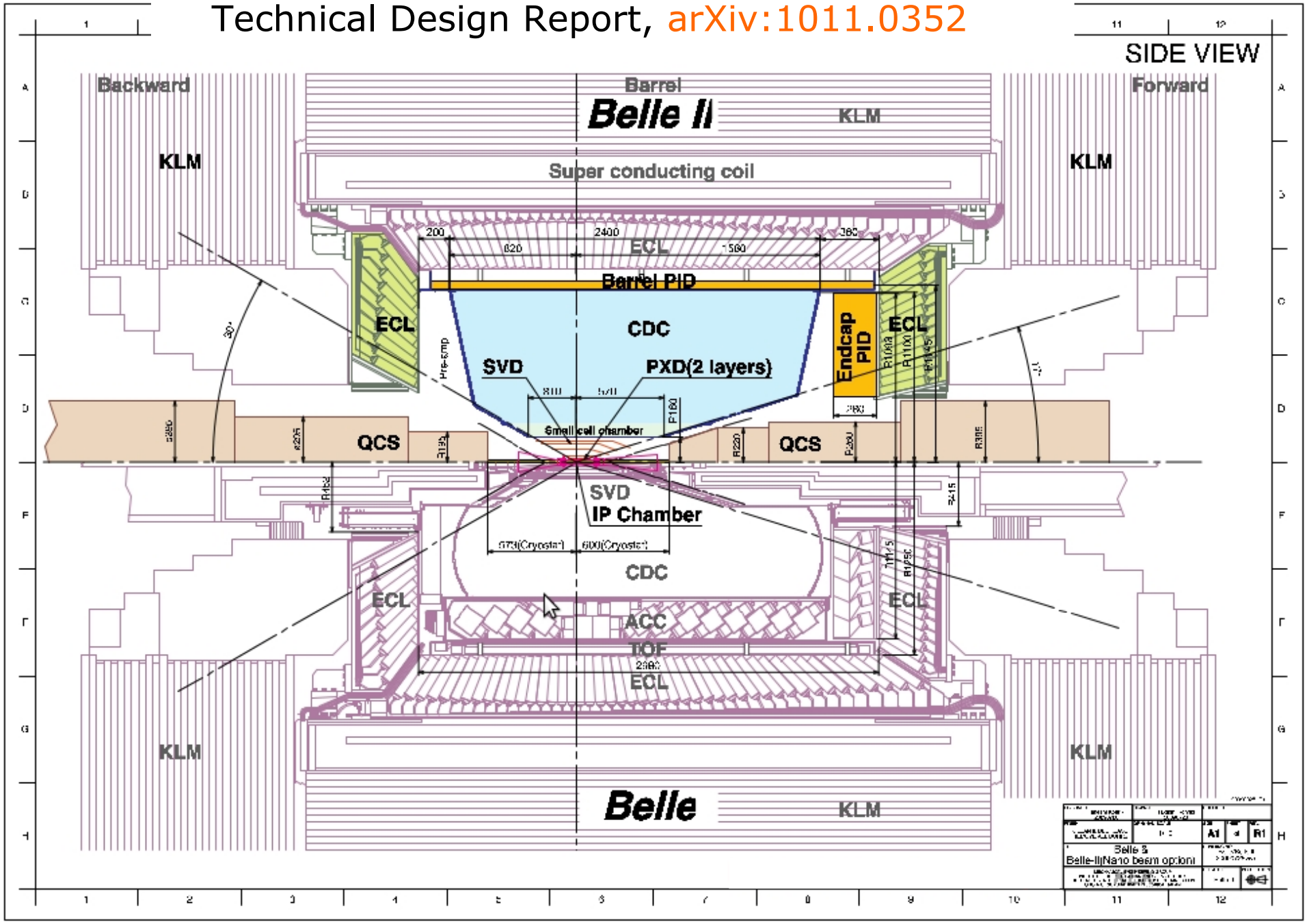
18.6 cm @ end of platform (accuracy 0.5 mm)

Background increase x factor 10–20

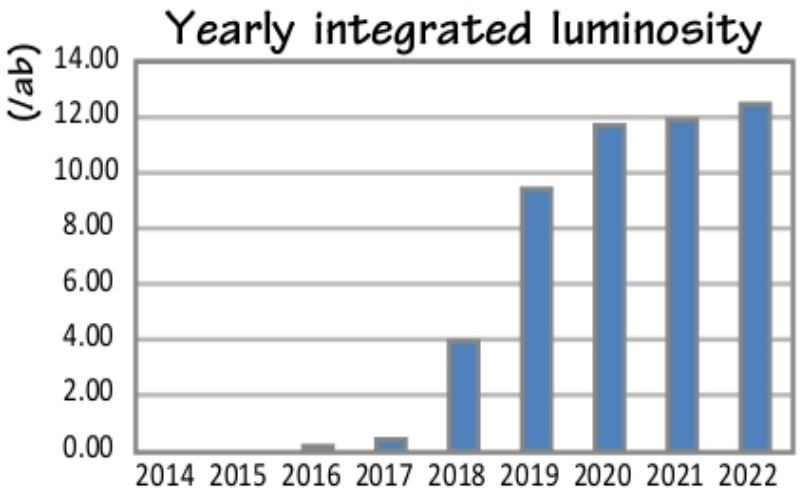


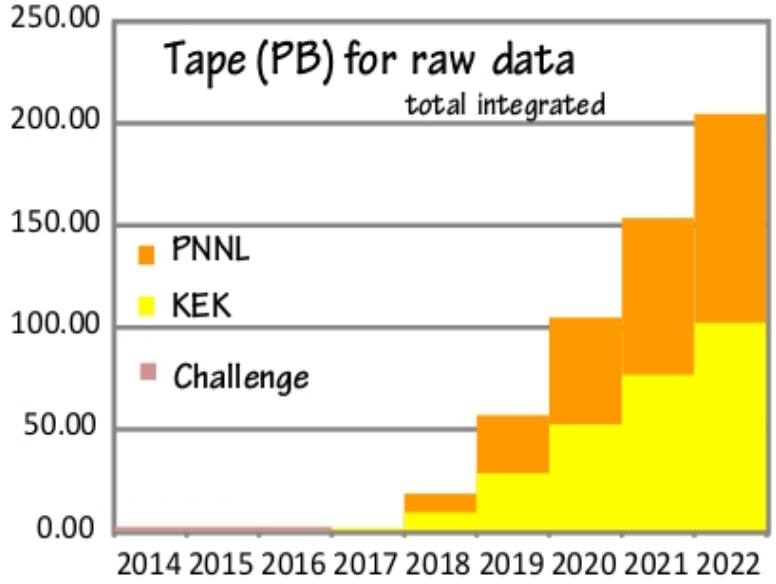


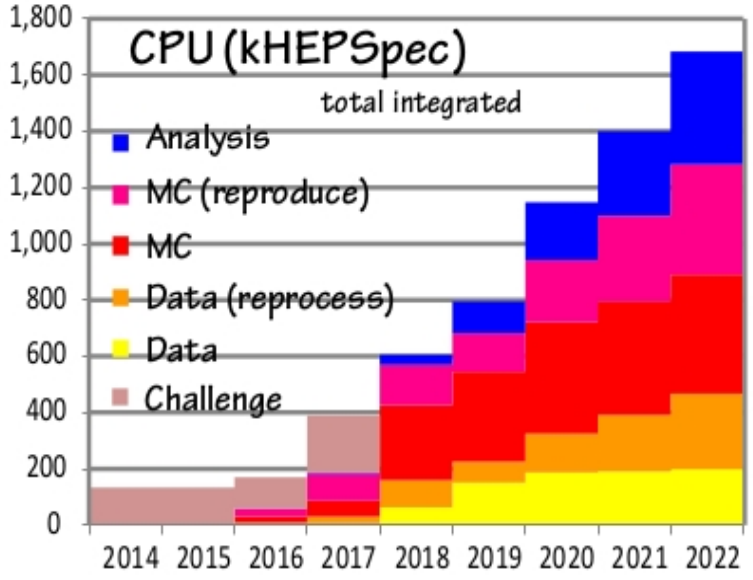
Technical Design Report, arXiv:1011.0352

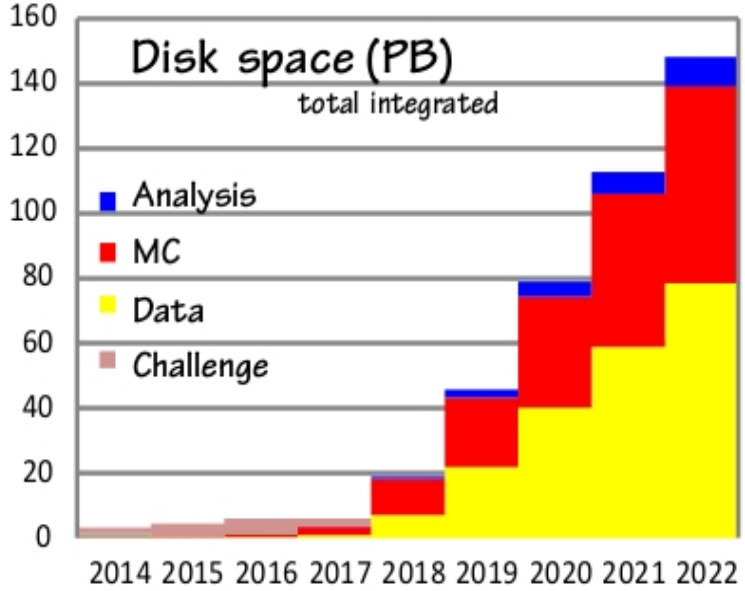


Hardware Resources for Belle II









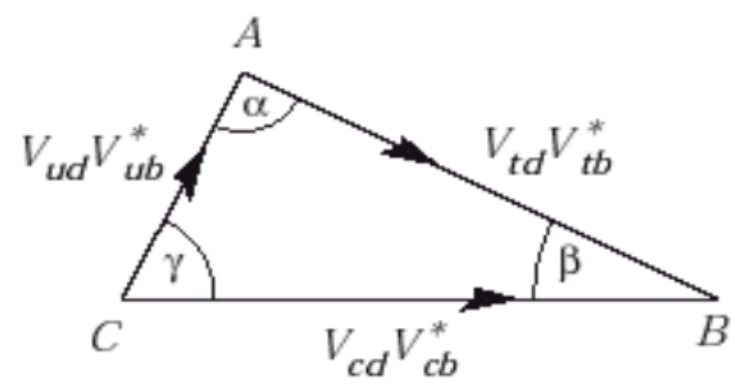
Site or Tier 1 fraction	Germany	This can be a site name as given on the Sites sheet or a number
Data faction		If this is empty the data fraction will be equal to the number given on the Sites sheet or 0 for numberical Tier 1
Used Tier 1 facrion	0.12	*The fraction of MC production and user analysis done at the site*
Used data fraction	0.40	*The fraction of mDST data stored at the site*

Regional Center resources:

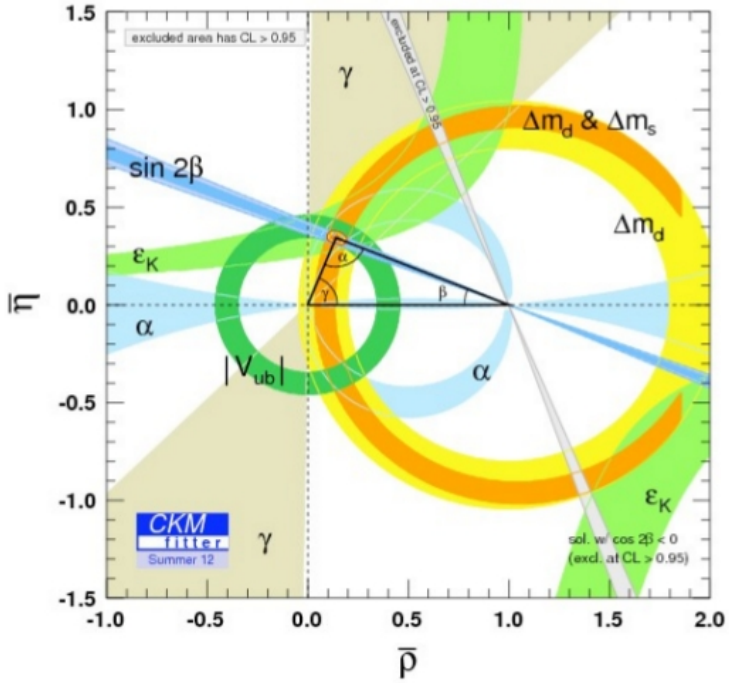
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Disk (data) [PB]	0.00	0.00	0.00	0.00	0.02	0.08	0.66	2.03	3.73	5.46	7.28
Disk (MC) [PB]	0.00	0.00	0.00	0.00	0.04	0.15	0.67	1.28	2.05	2.83	3.64
Disk (analysis) [PB]	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.30	0.56	0.82	1.09
Disk (challenges) [PB]	0.00	0.12	0.24	0.48	0.60	0.30	0.00	0.00	0.00	0.00	0.00
Disk [PB]	**0.00**	**0.12**	**0.24**	**0.48**	**0.67**	**0.54**	**1.42**	**3.61**	**6.34**	**9.11**	**12.01**
CPU (MC) [kHepSPEC]	0.00	0.00	0.00	0.00	4.33	14.36	32.02	38.28	47.55	56.71	68.23
CPU (an.) [kHepSPEC]	0.00	0.00	0.00	0.00	0.15	0.55	4.34	13.42	24.69	36.15	48.16
CPU (ch.) [kHepSPEC]	0.00	7.55	15.99	15.99	13.32	24.27	0.00	0.00	0.00	0.00	0.00
CPU [kHepSPEC]	**0.00**	**7.55**	**15.99**	**15.99**	**17.81**	**39.18**	**36.37**	**51.70**	**72.23**	**92.86**	**116.39**
CPU [# of cores 14.72HS/core]	**0.00**	**512.95**	**1,086.25**	**1,086.25**	**1,210.17**	**2,661.56**	**2,470.63**	**3,512.18**	**4,907.23**	**6,308.22**	**7,906.99**
WAN (data) [Gbit/s] (inward)	0.00	0.00	0.00	0.00	0.03	0.08	0.43	0.61	0.88	1.06	1.27
WAN (MC) [Gbit/s] (outward)	0.00	0.00	0.00	0.00	0.04	0.11	0.34	0.28	0.38	0.44	0.50
WAN (MC) [Gbit/s] (inward)	0.00	0.00	0.00	0.00	0.07	0.23	0.68	0.56	0.76	0.87	1.01
WAN (ch.) [Gbit/s](in/out)	0.00	0.19	0.38	0.77	0.77	0.00	0.00	0.00	0.00	0.00	0.00
WAN [Gbit/s] (outward)	**0.00**	**0.19**	**0.38**	**0.77**	**0.80**	**0.11**	**0.34**	**0.28**	**0.38**	**0.44**	**0.50**
WAN [Gbit/s] (inward)	**0.00**	**0.19**	**0.38**	**0.77**	**0.86**	**0.31**	**1.12**	**1.18**	**1.64**	**1.94**	**2.27**

Belle II Physik

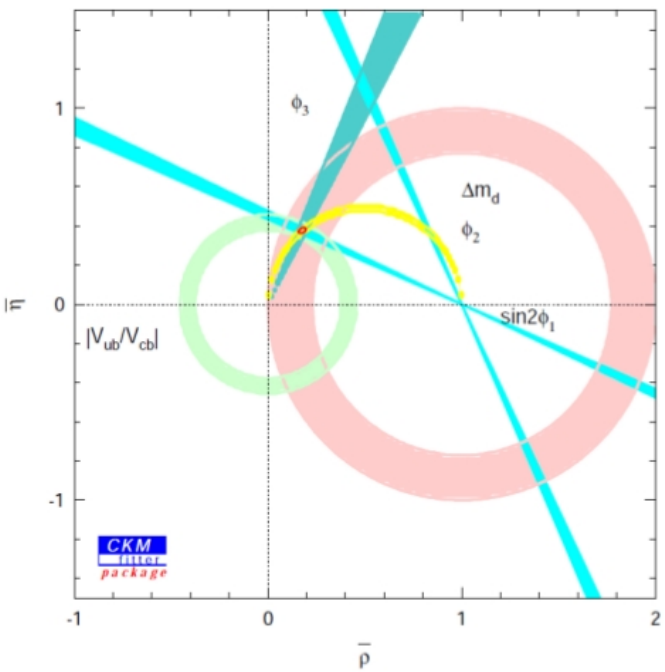
Präzisionsvermessung des Unitaritätsdreiecks (CKM, Cabbibo-Kobayashi-Maskawa)



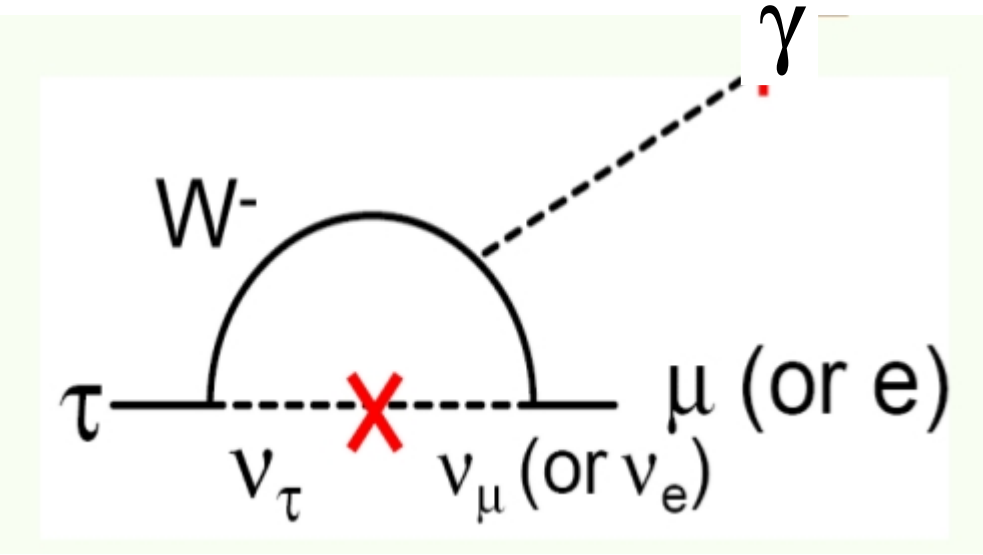
2012 (~1000 fb^{-1} at Belle and BaBar)



Expected constraint at 50 ab^{-1}



Tau lepton flavour violation

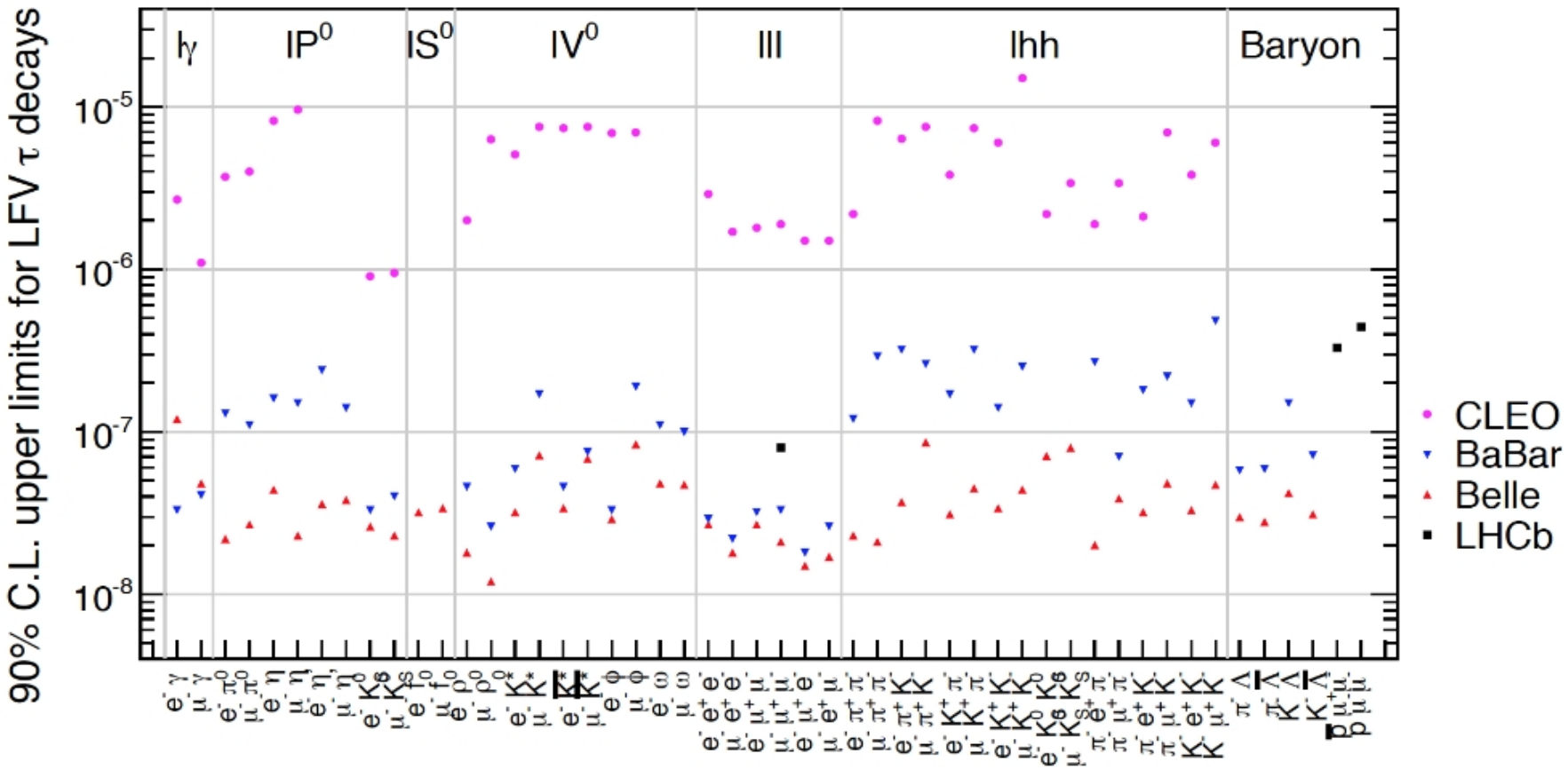


SM predictions are small

Br($\tau \to$ lepton γ) $\sim 10^{-54}$

Br($\tau \to$ 3 leptons) $\sim 10^{-14}$

Lepton Flavour Violating Tau Decays



T. Iijima, TAU2014

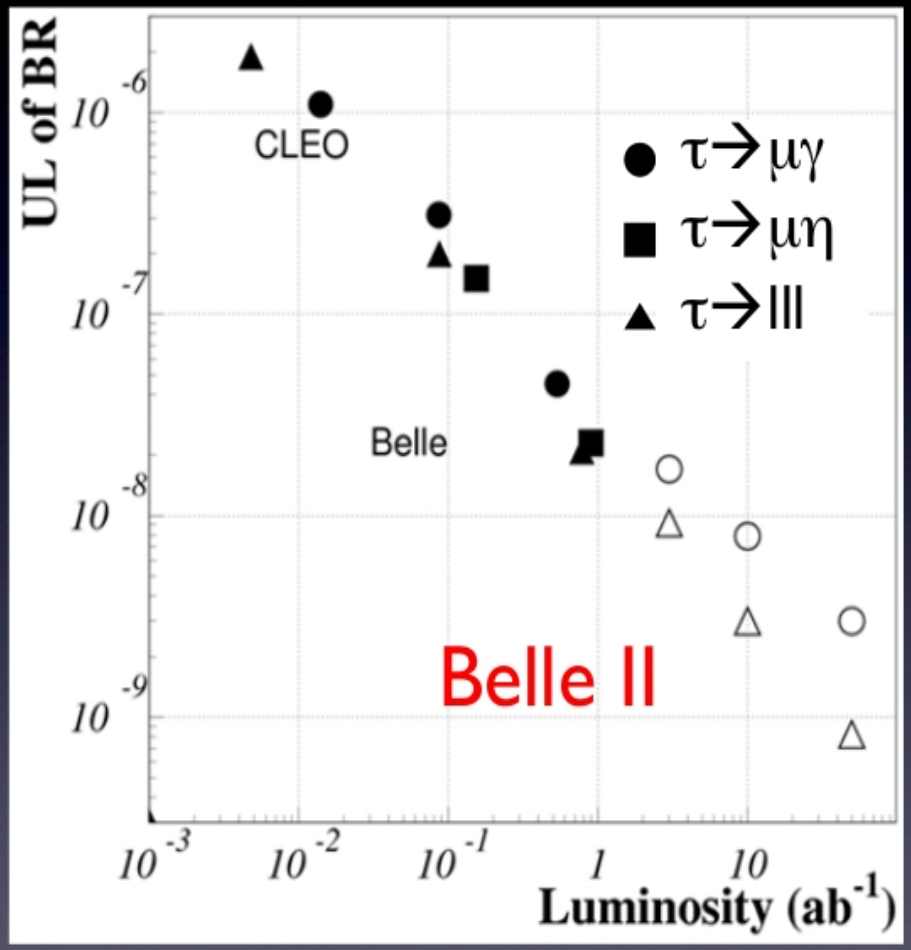
Future Prospect at Belle II

- Sensitivity will be…
  - $\tau \to \mu\gamma$: BG non-free :

$$\propto 1/\sqrt{N_\tau}$$

  - $\tau \to \mu\mu\mu$: BG free

$$\propto 1/N_\tau$$



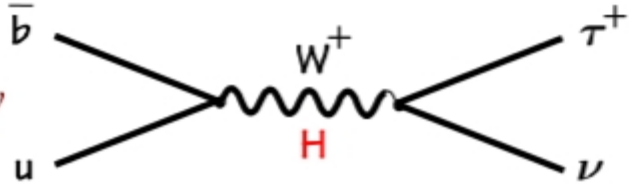
Expected limit:

$B(\mu\gamma) \sim O(10^{-9})$

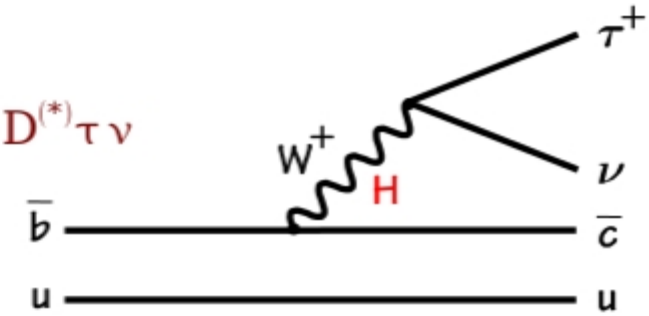
$B(\mu\mu\mu) \sim O(10^{-9}) \to O(10^{-10})$

LHCb can also push down $\tau \to \mu\mu\mu$ to $O(10^{-9})$ with $O(10 fb^{-1})$ data

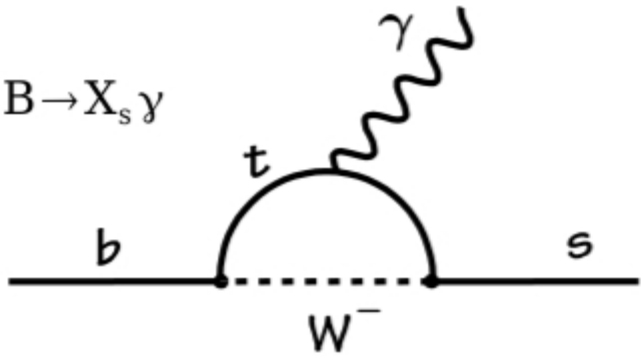
$B \to \tau \nu$

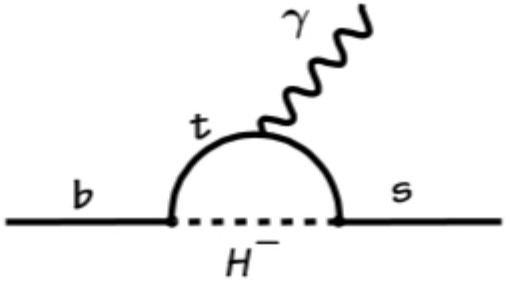


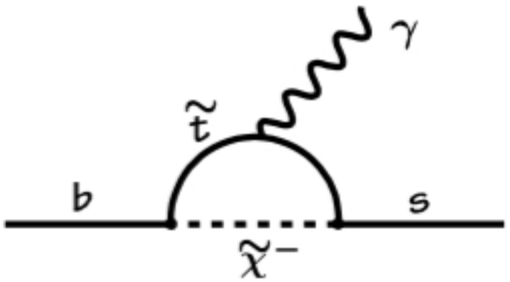
$B \to D^{(*)} \tau \nu$



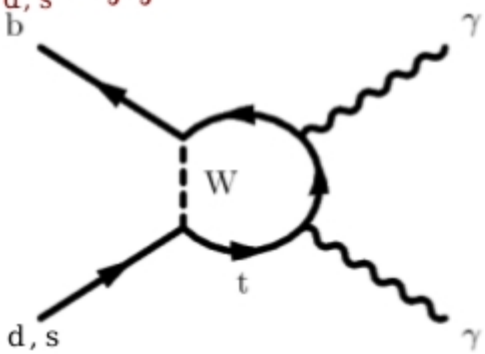
$B \to X_s \gamma$



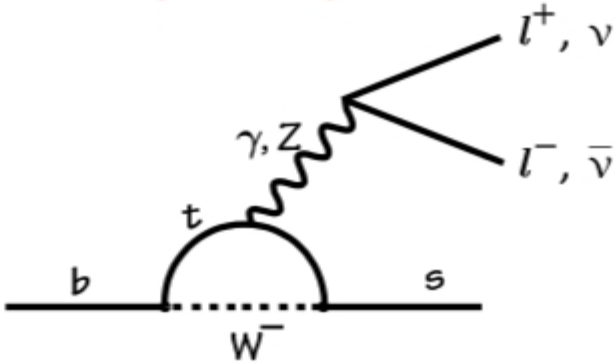


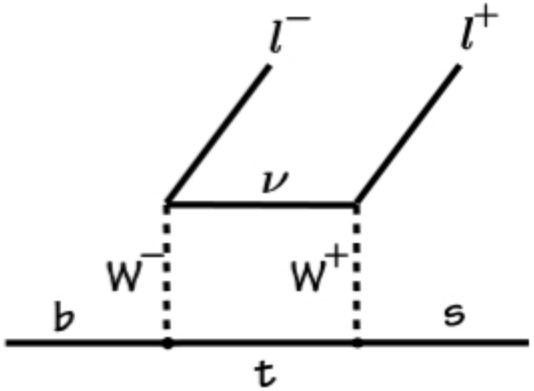


$B_{d,s} \to \gamma\gamma$



$B \to X_s l^+ l^-$, $X_s \nu \bar{\nu}$





More Belle II Physics

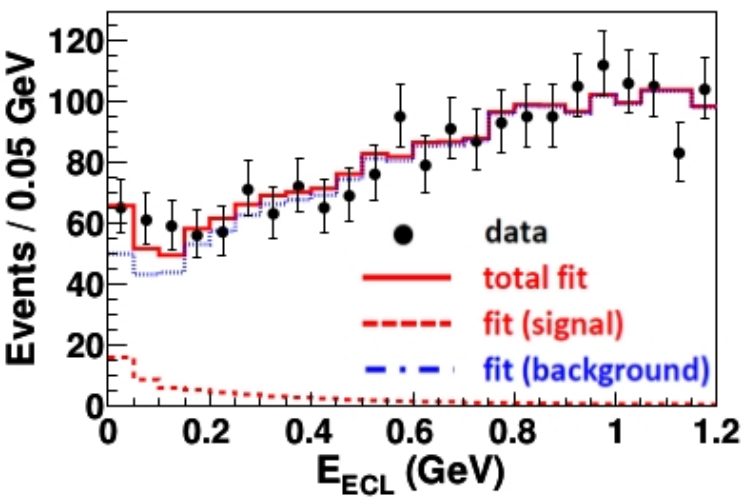
Observable	Belle 2006 ($\sim$0.5 ab^{-1})	SuperKEKB (5 ab^{-1})	SuperKEKB (50 ab^{-1})	†LHCb (2 fb^{-1})	†LHCb (10 fb^{-1})
Hadronic $b \to s$ transitions					
$\Delta\mathcal{S}_{\phi K^0}$	0.22	0.073	0.029		0.14
$\Delta\mathcal{S}_{\eta' K^0}$	0.11	0.038	0.020		
$\Delta\mathcal{S}_{K^0_S K^0_S K^0_S}$	0.33	0.105	0.037	-	-
$\Delta\mathcal{A}_{\pi^0 K^0_S}$	0.15	0.072	0.042	-	-
$\mathcal{A}_{\phi\phi K^+}$	0.17	0.05	0.014		
$\phi_1^{eff}(\phi K_S)$ Dalitz		3.3°	1.5°		
Radiative/electroweak $b \to s$ transitions					
$\mathcal{S}_{K^0_S\pi^0\gamma}$	0.32	0.10	0.03	-	-
$\mathcal{B}(B \to X_s\gamma)$	13%	7%	6%	-	-
$\mathcal{A}_{CP}(B \to X_s\gamma)$	0.058	0.01	0.005	-	-
C_9 from $\overline{\mathcal{A}}_{FB}(B \to K^*\ell^+\ell^-)$	-	11%	4%		
C_{10} from $\overline{\mathcal{A}}_{FB}(B \to K^*\ell^+\ell^-)$	-	13%	4%		
C_7/C_9 from $\overline{\mathcal{A}}_{FB}(B \to K^*\ell^+\ell^-)$	-		5%		7%
R_K		0.07	0.02		0.043
$\mathcal{B}(B^+ \to K^+\nu\bar{\nu})$	†† $< 3\,\mathcal{B}_{SM}$		30%	-	-
$\mathcal{B}(B^0 \to K^{*0}\nu\bar{\nu})$	†† $< 40\,\mathcal{B}_{SM}$		35%	-	-
Radiative/electroweak $b \to d$ transitions					
$\mathcal{S}_{\rho\gamma}$	-	0.3	0.15		
$\mathcal{B}(B \to X_d\gamma)$	-	24% (syst.)		-	-
Leptonic/semileptonic B decays					
$\mathcal{B}(B^+ \to \tau^+\nu)$	3.5σ	10%	3%	-	-
$\mathcal{B}(B^+ \to \mu^+\nu)$	†† $< 2.4\mathcal{B}_{SM}$	4.3 ab^{-1} for 5σ discovery		-	-
$\mathcal{B}(B^+ \to D\tau\nu)$	-	8%	3%	-	-
$\mathcal{B}(B^0 \to D\tau\nu)$	-	30%	10%	-	-
LFV in τ decays (U.L. at 90% C.L.)					
$\mathcal{B}(\tau \to \mu\gamma)$ [10^{-9}]	45	10	5	-	-
$\mathcal{B}(\tau \to \mu\eta)$ [10^{-9}]	65	5	2	-	-
$\mathcal{B}(\tau \to \mu\rho\mu)$ [10^{-9}]	21	3	1	-	-
Unitarity triangle parameters					
$\sin 2\phi_1$	0.026	0.016	0.012	$\sim$0.02	$\sim$0.01
ϕ_2 ($\pi\pi$)	11°	10°	3°	-	-
ϕ_2 ($\rho\pi$)	$68° < \phi_2 < 95°$	3°	1.5°	10°	4.5°
ϕ_2 ($\rho\rho$)	$62° < \phi_2 < 107°$	3°	1.5°	-	-
ϕ_2 (combined)		2°	$\lesssim 1°$	10°	4.5°
ϕ_3 ($D^{(*)}K^{(*)}$) (Dalitz mod. ind.)	20°	7°	2°	8°	
ϕ_3 ($DK^{(*)}$) (ADS+GLW)	-	16°	5°	5-15°	
ϕ_3 ($D^{(*)}\pi$)	-	18°	6°		
ϕ_3 (combined)		6°	1.5°	4.2°	2.4°
$\lvert V_{ub}\rvert$ (inclusive)	6%	5%	3%	-	-
$\lvert V_{ub}\rvert$ (exclusive)	15%	12% (LQCD)	5% (LQCD)	-	-
†††$\bar{\rho}$	20.0%		3.4%		
†††$\bar{\eta}$	15.7%		1.7%		

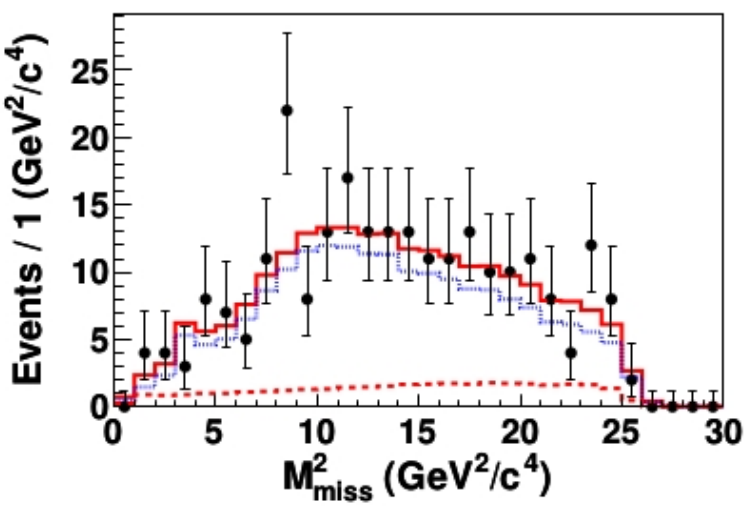
Observable	Belle	Belle/SuperKEKB		LHCb† (2 fb^{-1})	LHCb† (10 fb^{-1})
B_s physics	(25 fb^{-1})	(5 ab^{-1})			
$\mathcal{B}(B_s \to \gamma\gamma)$	$< 8.7 \times 10^{-6}$	0.25×10^{-6}		-	-
$\Delta\Gamma_s^{CP}/\Gamma_s$ ($Br(B_s \to D_s^{(*)}D_s^{(*)})$)	3%	1% (model dependency)		-	-
$\Delta\Gamma_s/\Gamma_s$ ($B_s \to f_{CP}$ t-dependent)	-	1.2%		-	-
ϕ_s (with $B_s \to J/\psi\phi$ etc.)	-	-	-	0.02	0.01
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-			6 fb^{-1} for 5σ discovery	
ϕ_3 ($B_s \to KK$)	-			7-10°	
ϕ_3 ($B_s \to D_sK$)	-			13°	
Υ decays	(3 fb^{-1})	(500 fb^{-1})			
$\mathcal{B}(\Upsilon(1S) \to$ invisible)	$< 2.5 \times 10^{-3}$	$< 2 \times 10^{-4}$			
	($\sim$0.5 ab^{-1})‡	(5 ab^{-1})	(50 ab^{-1})		
Charm physics					
D mixing parameters					
x	0.25%	0.12%	0.09%		0.25%††
y	0.16%	0.10%	0.05%		0.05%††
$\delta_{K\pi}$	10°	6°	4°		
$\lvert q/p\rvert$	0.16	0.1	0.05		
ϕ	0.13 rad	0.08 rad	0.05 rad		
A_D	2.4%	1%	0.3%		
New particles*					
$\gamma\gamma \to Z(3930) \to D\bar{D}^*$		$> 3\sigma$			
$B \to KX(3872)(\to D^0\bar{D}^{*0})$		400 events			
$B \to KX(3872)(\to J/\psi\pi^+\pi^-)$		1250 events			
$B \to KZ^+(4430)(\to \psi'\pi^+)$		1000 events			
$e^+e^- \to \gamma_{ISR}Y(4260)(\to J/\psi\pi^+\pi^-)$		3000 events			
Electroweak parameters		($\sim$10 ab^{-1})			
$\sin^2\Theta_W$	-	3×10^{-4}			

Very broad physics program within Belle II!

See arXiv:1002.5012: "Physics at Super *B* Factory"

$B \to \tau\nu$ [PRL110, 131801 (2013)]

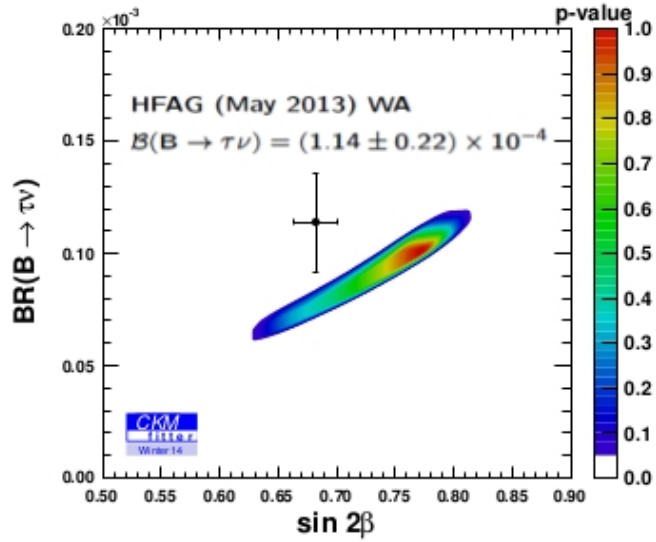




- Data sample 711 fb^{-1}
- Hadronic tagging
- 2D fit in excess calorimeter energy (E_{ECL}) and M^2_{miss}

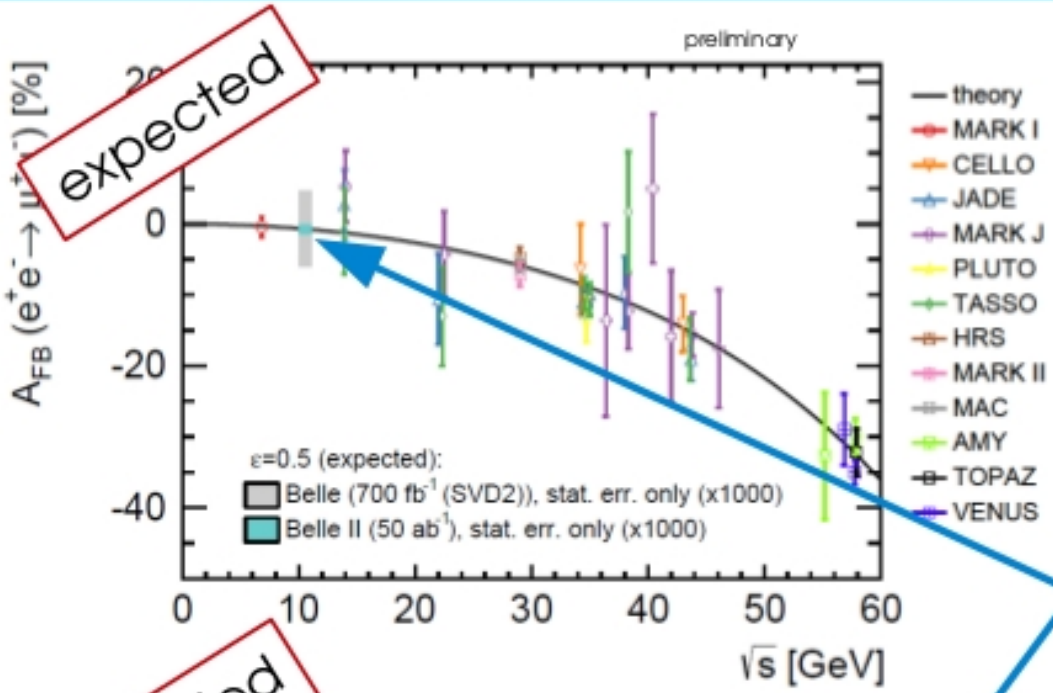
$$\mathcal{B}(B \to \tau\nu) = (0.72^{+0.27}_{-0.25} \pm 0.11) \times 10^{-4}$$

- Significance: 3σ



Tension in CKM fit between $\sin(2\phi_1)$, $\mathcal{B}(B \to \tau\nu) \sim 1.6\sigma$

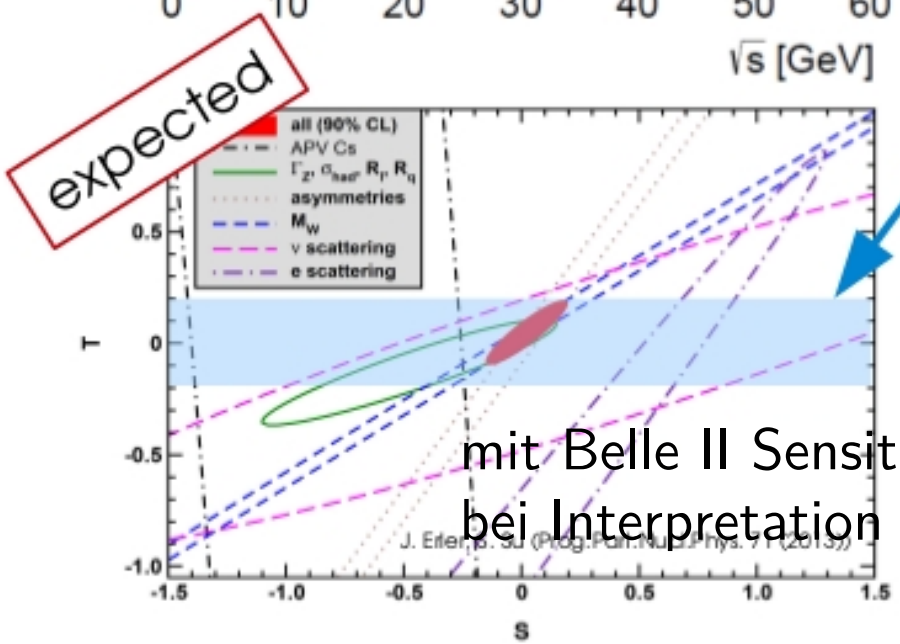
Measurement of A_{FB}



$$\mathcal{A}_{FB}(s) \approx \rho \frac{3G_F}{4\sqrt{2}\pi\alpha} \frac{sM_Z^2}{s - M_z^2} g_A^e g_A^\mu$$

Stat. errors are x1000!
(otherwise not visible)

Belle 2: $\sigma_{stat}(A_{FB})/A_{FB} \approx 0.1\%$



$$\Delta\rho^{\text{new}} = \frac{\hat{\Pi}_{WW}^{\text{new}}(0) - \hat{c}_Z^2 \hat{\Pi}_{ZZ}^{\text{new}}(0)}{M_W^2(1 - \Delta\hat{r}_W)} \equiv \frac{\alpha T}{1 - \Delta\hat{r}_W} \approx \hat{\alpha}_Z T$$

mit Belle II Sensitivität auf Compositeness $\Lambda \leq 33$ TeV
bei Interpretation im Rahmen von Contact Interactions)

Is there $c\bar{c}$ admixture inside the X(3872) ?

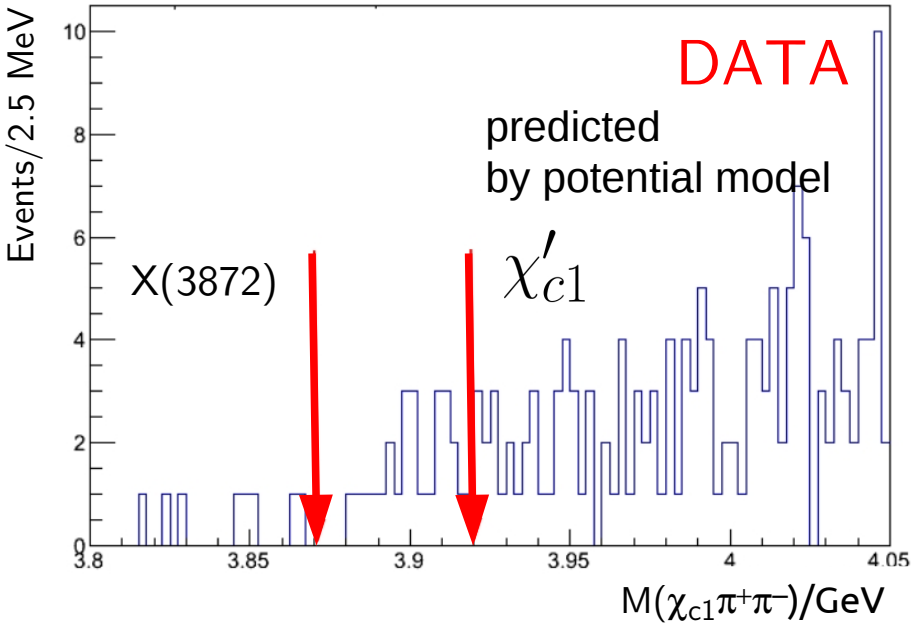
$$|X(3872)>= c_1|c\bar{c}> + c_2|\overline{D}^0 D^{0*}>$$

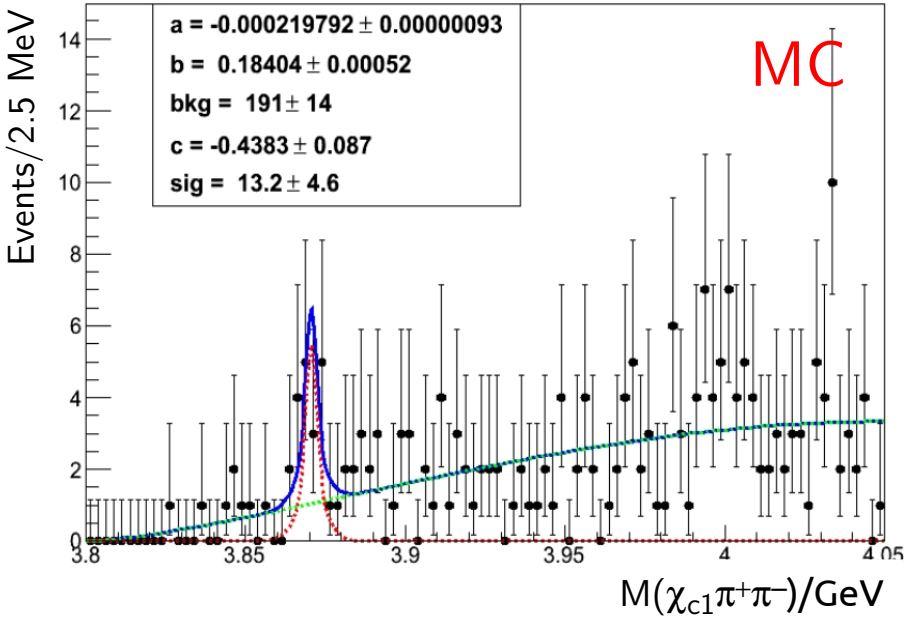
Belle, 711 fb^{-1}
E. Panzenboeck
(Göttingen/Nara COTUTELLE program)
Hadron 2013. LLWI 2014

Search for X(3872) $\rightarrow \chi_{c1}\,\pi^+\pi^-$

No signal observed
(no indication of admixture)

MC simulation, assuming
$\mathcal{B}(\chi_{c1}\,\pi^+\pi^-) = \mathcal{B}(J/\psi\,\pi^+\pi^-)$

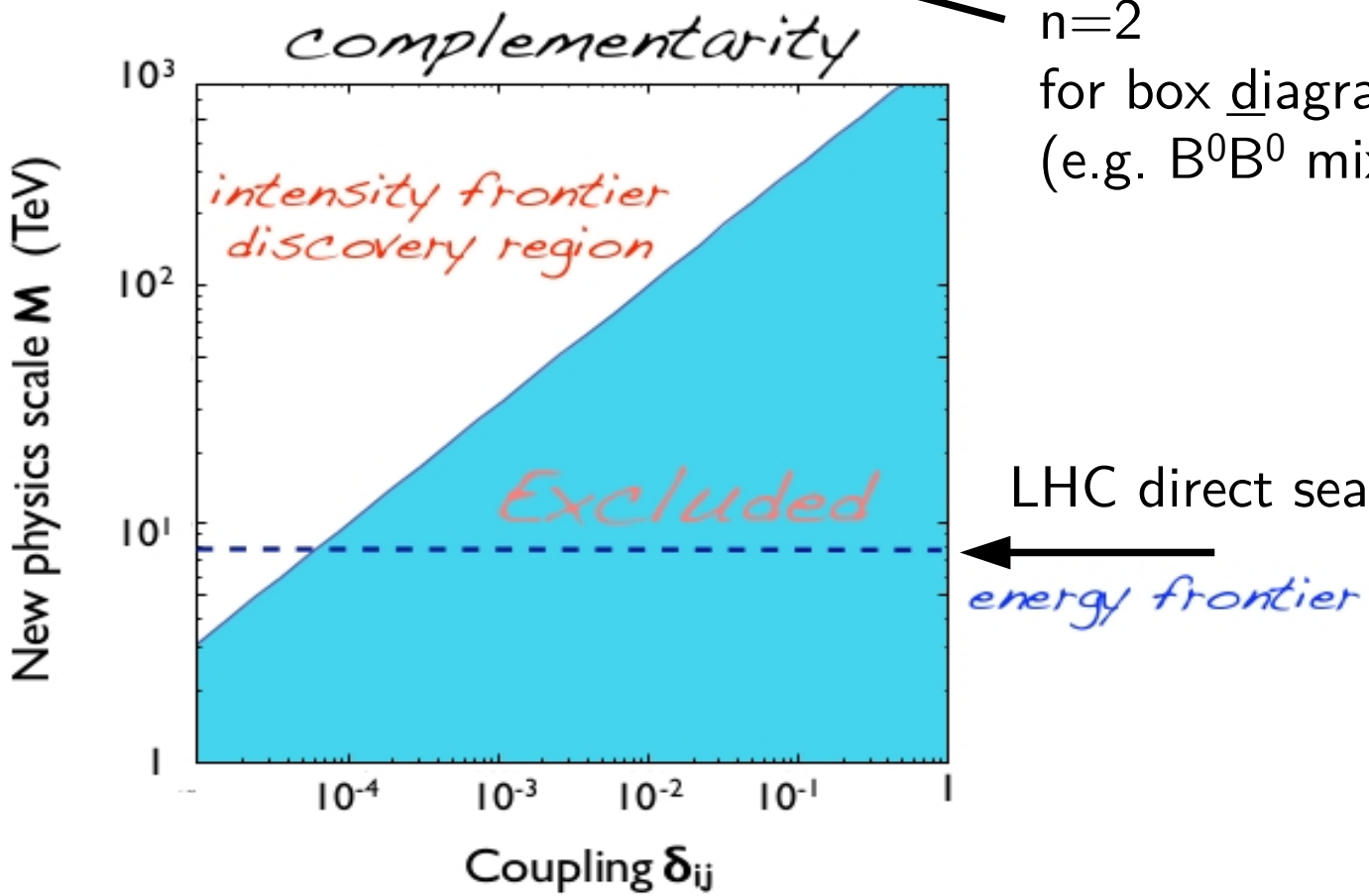




Belle II Search for New Physics

$$\Delta_{NP} = (\text{exp.} - \text{SM}) \pm \sqrt{(\sigma_{exp})^2 + (\sigma_{SM})^2}$$
$$= c/(M_{NP})^{n=2}$$

n=2
for box diagram
(e.g. B^0B^0 mixing)

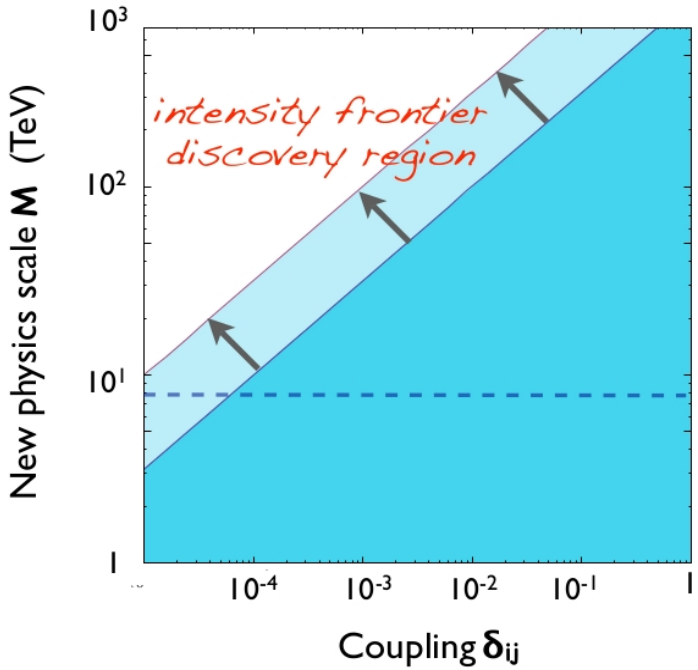


LHC direct search

E. Kou, Belle II Open Meeting 11/2014

$$\Delta_{NP} = (\text{exp.} - \text{SM}) \pm \sqrt{(\sigma_{exp})^2 + (\sigma_{SM})^2}$$

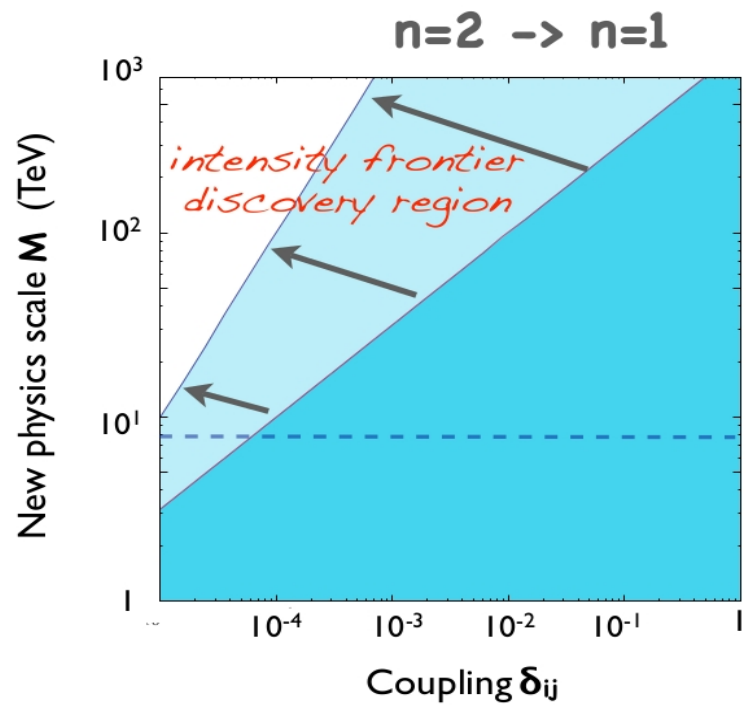
→ improve stat. and syst. errors



new detectors (PXD, TOP), reduce hadronic uncertainties (lattice QCD), ...

$$\Delta_{NP} = c/(M_{NP})^n$$

→ find decays with smaller n



e.g. penguin decays
n=1 for b → sγ
m>~10^6 TeV in reach

E. Kou, Belle II Open Meeting 11/2014

Bounds on M_{NP} (or scale Λ) based upon existing data

Open Symposium on the European Strategy for Particle Physics
Isidori, Teubert, arXiv:1402.2844[hep-ph]

$M_{NP} \geq 140$ TeV (standard left-handed CKM couplings)

Operator	Bounds on Λ in TeV ($c_{NP} = 1$) Re	Im	Bounds on c_{NP} ($\Lambda = 1$ TeV) Re	Im	Observables
$(\bar{s}_L \gamma^\mu d_L)^2$	9.8×10^2	1.6×10^4	9.0×10^{-7}	3.4×10^{-9}	Δm_K; ϵ_K
$(\bar{s}_R d_L)(\bar{s}_L d_R)$	1.8×10^4	3.2×10^5	6.9×10^{-9}	2.6×10^{-11}	
$(\bar{c}_L \gamma^\mu u_L)^2$	1.2×10^3	2.9×10^3	5.6×10^{-7}	1.0×10^{-7}	Δm_D; $\lvert q/p \rvert_D$, ϕ_D
$(\bar{c}_R u_L)(\bar{c}_L u_R)$	6.2×10^3	1.5×10^4	5.7×10^{-8}	1.1×10^{-8}	
$(\bar{b}_L \gamma^\mu d_L)^2$	6.6×10^2	9.3×10^2	2.3×10^{-6}	1.1×10^{-6}	Δm_{B_d}; $\sin(2\beta)$ from $B_d \to \psi K$
$(\bar{b}_R d_L)(\bar{b}_L d_R)$	2.5×10^3	3.6×10^3	3.9×10^{-7}	1.9×10^{-7}	
$(\bar{b}_L \gamma^\mu s_L)^2$	1.4×10^2	2.5×10^2	5.0×10^{-5}	1.7×10^{-5}	Δm_{B_s}; $\sin(\phi_s)$ from $B_s \to \psi\phi$
$(\bar{b}_R s_L)(\bar{b}_L s_R)$	4.8×10^2	8.3×10^2	8.8×10^{-6}	2.9×10^{-6}	

Table 1. Bounds on representative dimension-six $\Delta F = 2$ operators [96,97]. The bounds on Λ are evaluated assuming an effective coupling $1/\Lambda^2$ (i.e. setting $c_{NP} = 1$). Alternatively, the bounds on the respective c_{NP} are obtained assuming $\Lambda = 1$ TeV. In the last column we list the observables used to set such bounds; the observables related to CPV are separated from the CP conserving ones with semicolons.

Isidori, Teubert, arXiv:1402.2844[hep-ph]

$\rightarrow \Lambda_{NP}$ scales with at most $N^{1/4}$,

where N is relative increase of number of events

1 $ab^{-1} \rightarrow$ 50 ab^{-1} ($50^{0.25} = 2.65$)

e.g. Λ_{NP}=100 TeV (Belle) $\rightarrow$ 265 TeV (Belle II)

If physics beyond the SM respects the SM gauge symmetry, as we expect from general arguments, the low-energy amplitudes describing the transition of a fermion ψ_i to a fermion ψ_j (of different flavour) can be decomposed in the following general form

$$\mathcal{A}(\psi_i \rightarrow \psi_j + X) = \mathcal{A}_0 \left[\frac{c_{\rm SM}}{M_W^2} + \frac{c_{\rm NP}}{\Lambda^2} \right] , \tag{16}$$

where Λ is the energy scale of the new degrees of freedom and the SM result is recovered in the limit $c_{\rm NP} \rightarrow 0$. This structure is completely general: the coefficients $c_{\rm SM(NP)}$ may include appropriate CKM coefficient factors and eventually a $\sim 1/(16\pi^2)$ suppression if the amplitude is loop-mediated. Given our ignorance about the $c_{\rm NP}$ coefficients, the values of the scale Λ probed by present experiments vary over a wide range. However, the general result in Eq. (16) allows us to predict how these bounds will improve with future experiments: increasing the statistic on a given observable, the corresponding bound on Λ scales at most as $N^{1/4}$, where N is the relative increase in the number of events used to measure the observable.[2] From Eq. (16) it is also clear that indirect searches can probe NP scales well above the TeV for models where ($c_{\rm SM} \ll c_{\rm NP}$), namely models which do not respect the symmetries and the symmetry-breaking pattern of the SM.