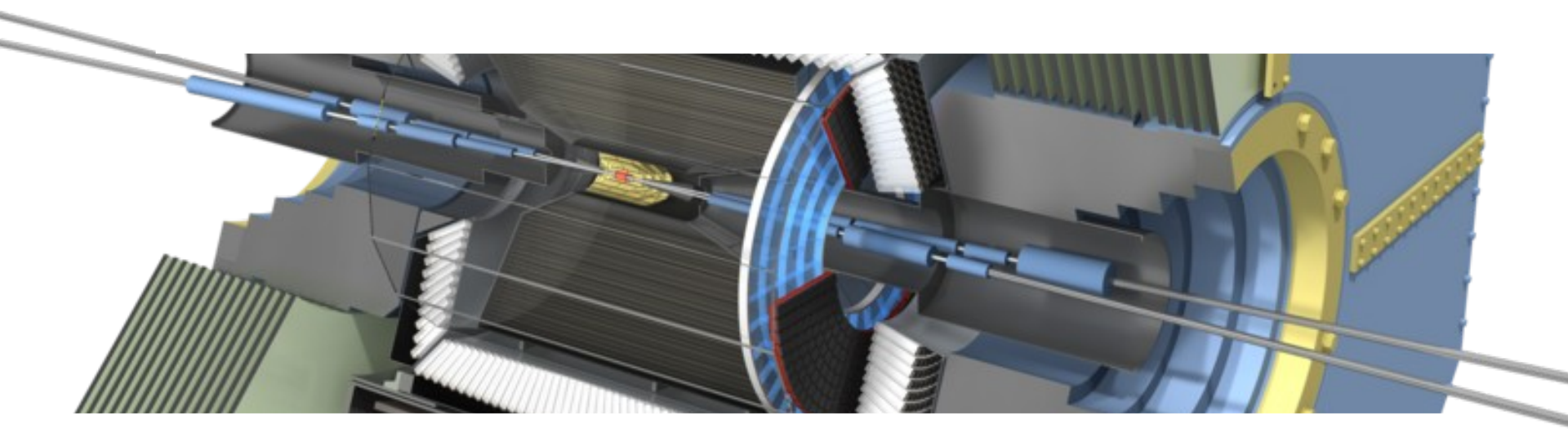
Belle and Belle II



- Belle at KEKB
- Belle II at SuperKEKB

76. DESY PRC October 2013
Torben Ferber
24.10.2013

HELMHOLTZ ASSOCIATION

Belle

Belle II

DESY

Belle at KEKB

PARTICLE PHYSICS

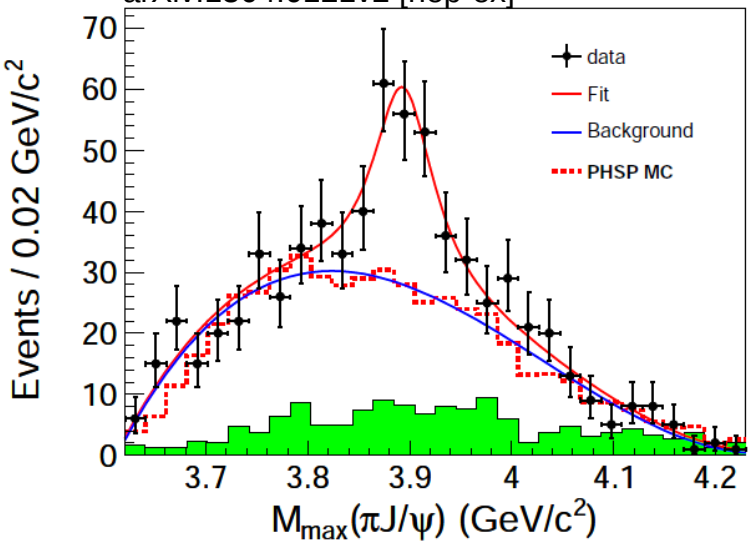
Quark quartet opens fresh vista on matter

First particle containing four quarks is confirmed.

Tetraquark!?

Zwei Experimente finden Hinweise auf ein neues Teilchen aus vier Quarks

arXiv:1304.0121v2 [hep-ex]



Mögliche neue Materieform: Physiker entdecken mysteriöses Teilchen

Von Holger Dambeck

Tetraquark

Mächtiger Neuzugang im Teilchenzoo

20.06.2013 · Ein geladenes Teilchen, das bei Beschleuniger-Experimenten in China und Japan aufgespürt wurde, ist viermal so schwer wie ein Proton. Womöglich besteht der Exot aus vier Quarks. Das wäre für die Physiker eine kleine Sensation.

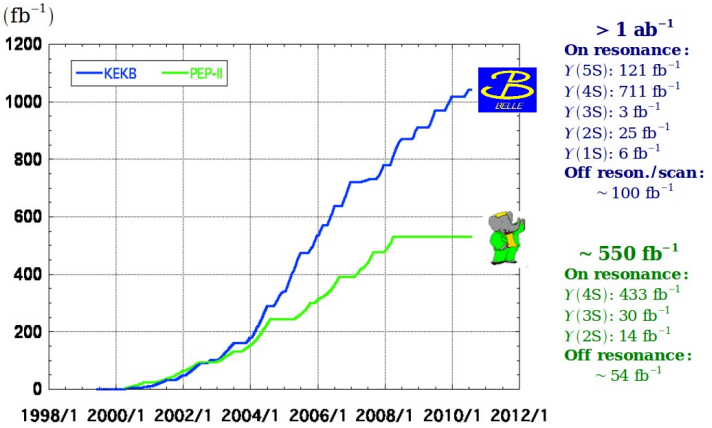
Von MANFRED LINDINGER

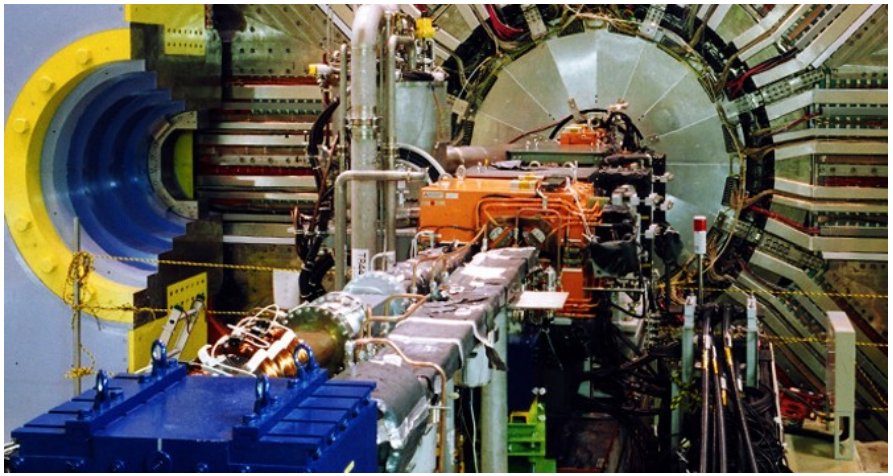
DESY

Belle at KEKB

> Data taking: 1999-2010

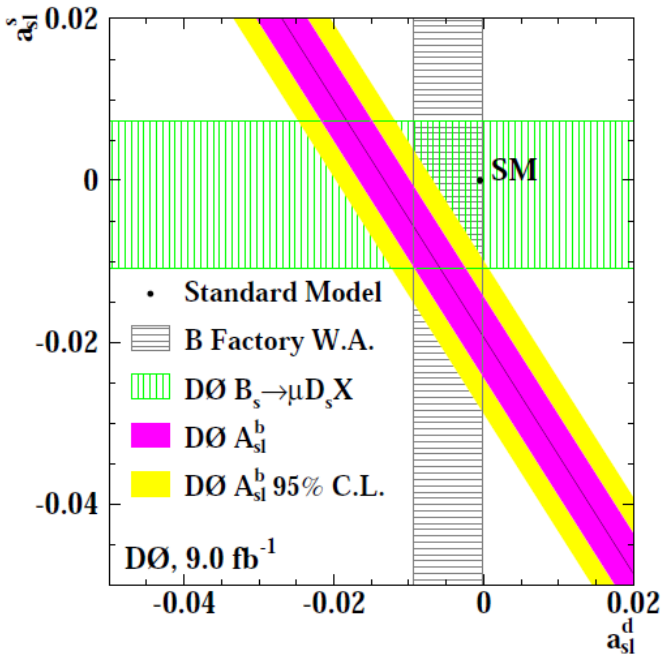
- 3.5 GeV e^+ on 8 GeV e^-
- World record: $L=2.1 \times 10^{34}\ cm^{-2}s^{-1}$
- Total integrated luminosity $\sim 1 ab^{-1}$:
  - > $\sim 800 \times 10^6\ B\bar{B}$ pairs at Y(1/2/3/4/5S)
  - > $\sim 10^9\ \mu\bar{\mu}/\tau\bar{\tau}/c\bar{c}$ pairs each
- >400 physics publications





Belle analysis: Idea to measure BF B → K τ τ

- Anomalous large CPV in semileptonic B-decays (D0: 3.9σ from SM)
- Possible explanation: Large BF B → X τ τ
- In contact with A. Lenz
- Experimentally almost unconstraint (UL~10^{-3}), SM prediction ~10^{-7} (K τ τ)
- Full reconstruction with hadronic tag (ε_{Btag}~0.3%)

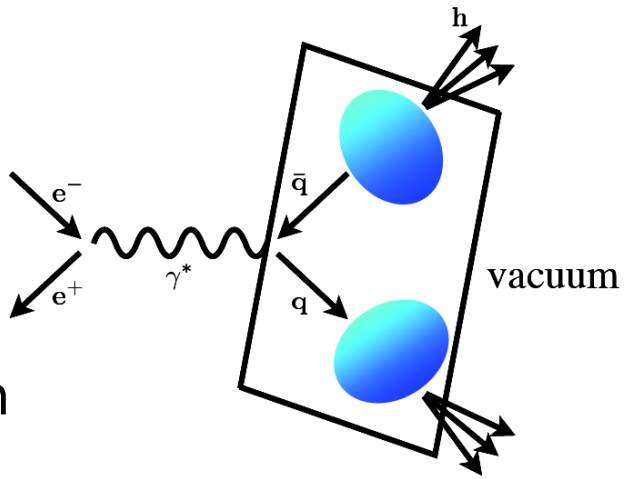


Belle analysis: Studies of QCD vacuum structure in e^+e^- annihilation

> Measure 2-hadron final states

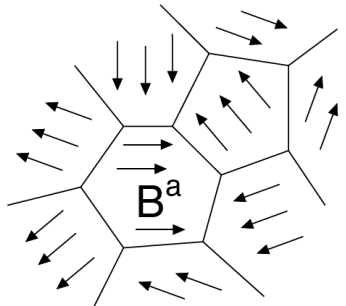
- Longitudinal jet handedness

$$H = \frac{N_R - N_L}{N_L + N_R}$$



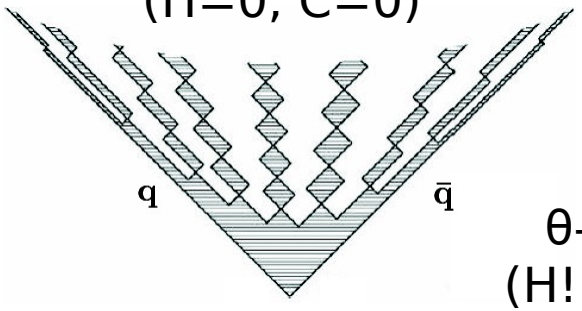
- Longitudinal jet handedness correlation

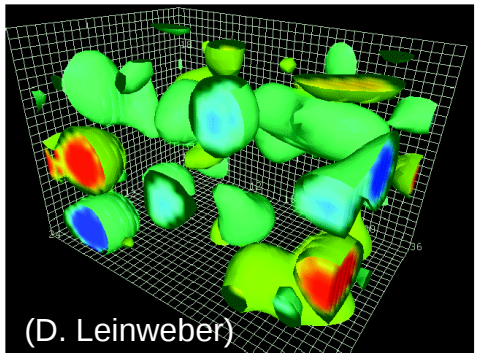
$$C = \frac{N_{LR} + N_{RL} - N_{RR} - N_{LL}}{N_{LR} + N_{RL} + N_{RR} + N_{LL}}$$



non-pQCD
(H=0, C!=0)

pQCD
(H=0, C=0)



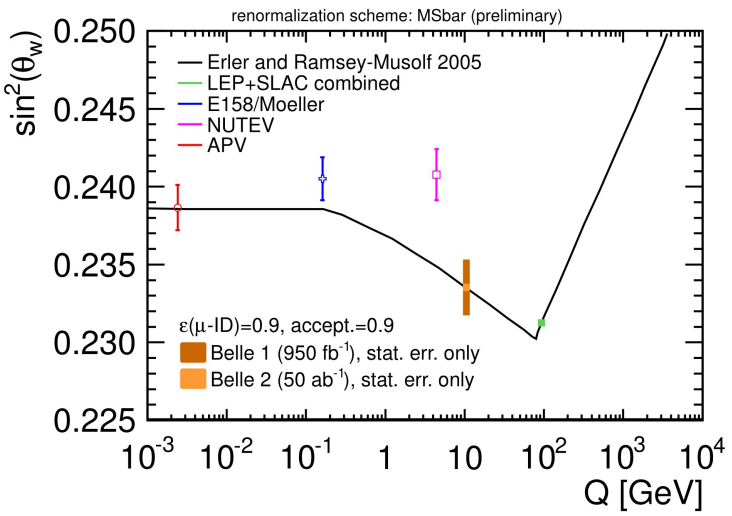


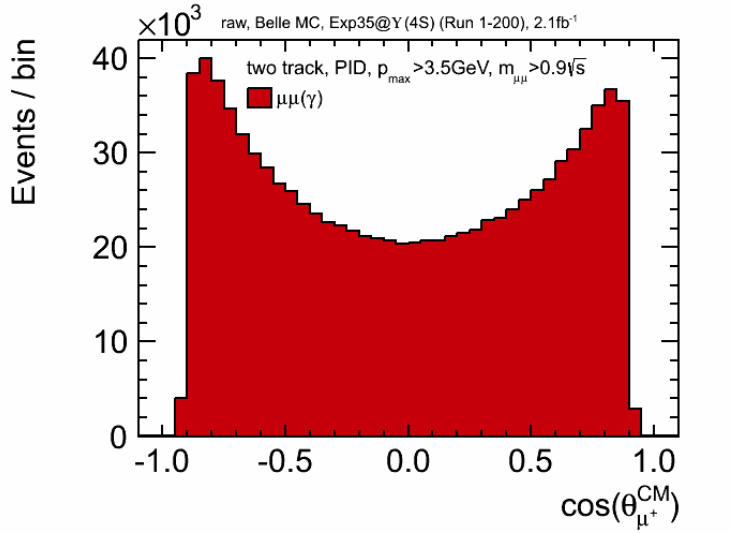
θ-vacuum
(H!=0, C!=0)

→ Applied for DFG grant

Belle analysis: A_{FB}

- γ-Z interference: $A_{FB}(\sin^2\theta_w)$=-0.6% at Belle
- Reach ΔA_{FB}~10^{-4} at Belle (10^{-5} at Belle II)
- In contact with J.Erler and PRISMA (Mainz)
- Need unskimmed data
- Biggest remaining issue:
  - Track trigger systematics → Input for Belle II

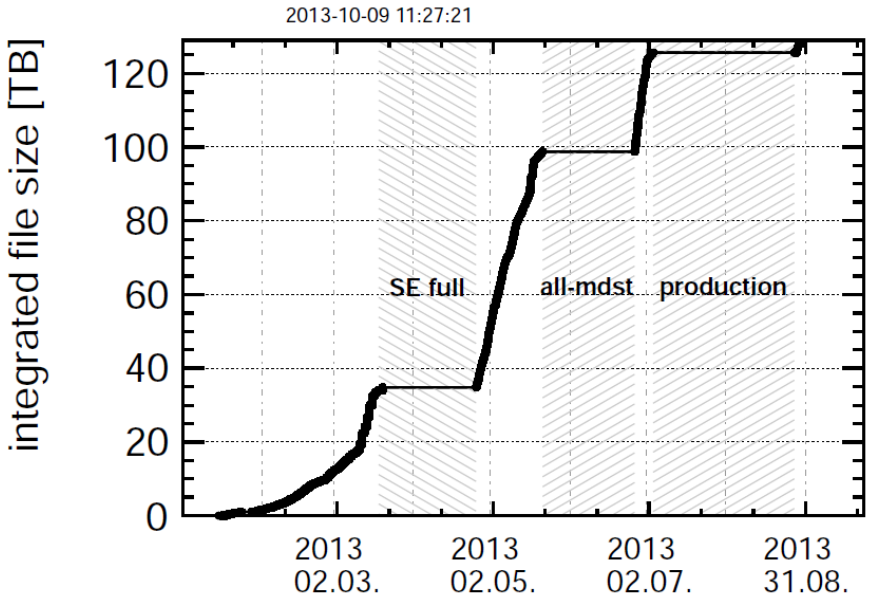


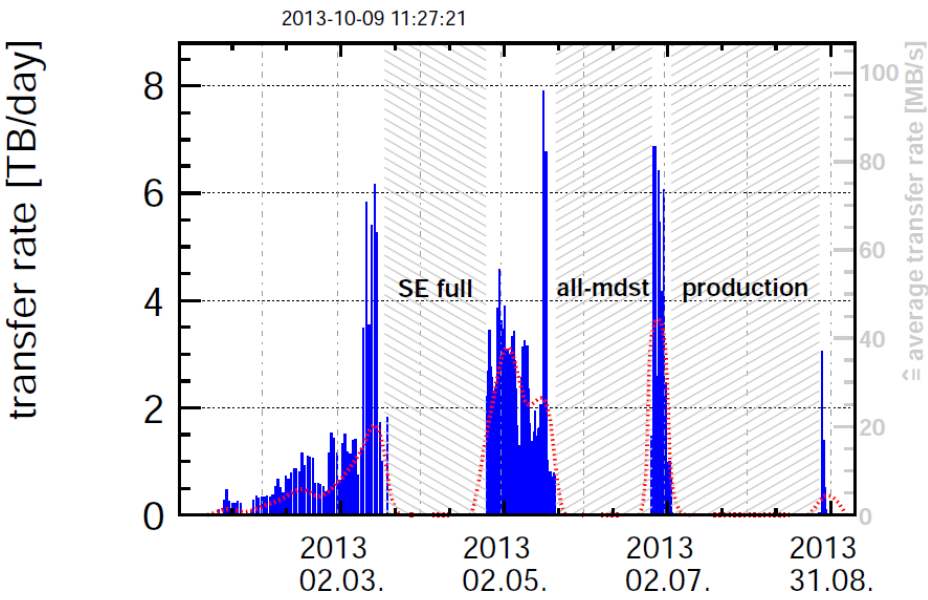


Belle: Computing

>Done

- Copying all available and reproduced mDST from KEK to DESY completed (12k physic runs, 205k files, 127TB)
- Tested NFS 4.1 mount of dCache storage on Belle WGSs





Belle: Computing

> Doing now:

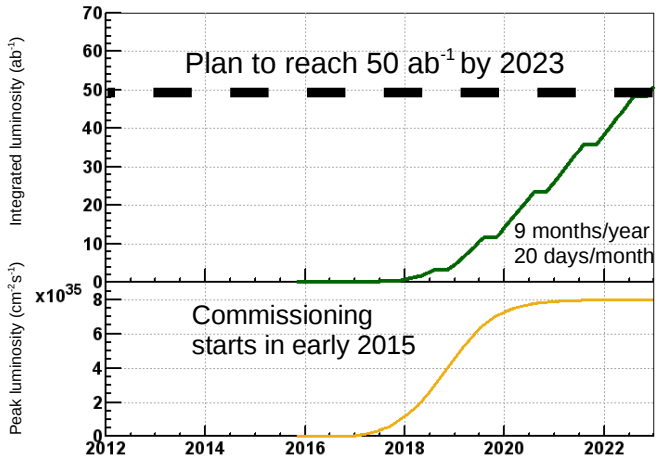
- Copying MC to DESY (muon pair (all), tau pair (all), off-resonance u/d/s/c) (~50TB)
- Copying selected skims to DESY (for fragmentation studies)

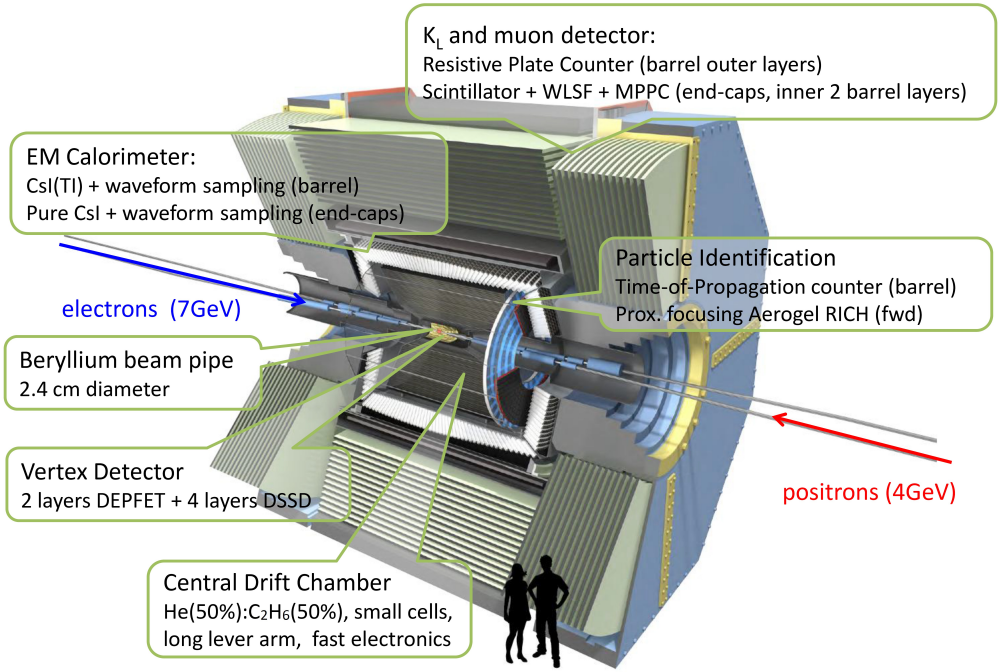
> Next steps:

- NFS 4.1 mount of dCache storage on NAF 2.0 batch queue nodes
- Open NAF2.0 for national Belle and Belle II communities

Belle II at SuperKEKB

Belle II at SuperKEKB





SuperKEKB

+ Luminosity 50xKEKB
  (using nano beam scheme)
- Less asymmetric energies
- Larger crossing angle
- Higher backgrounds

Belle II

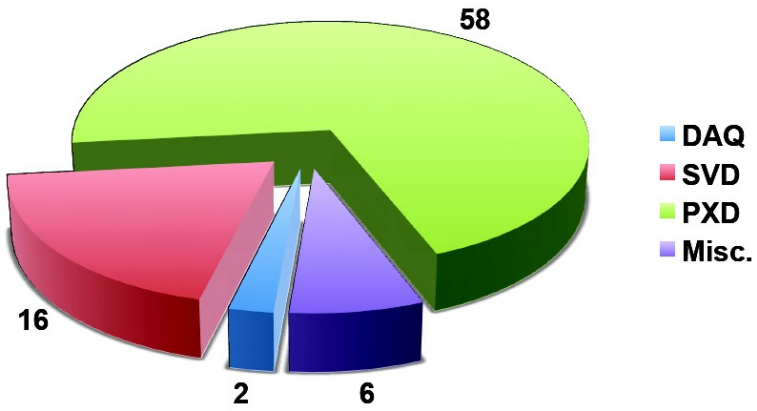
+ DEPFET pixel vertex detector
+ New PID
+ New ECL+WFD
+ Scintillator KLM

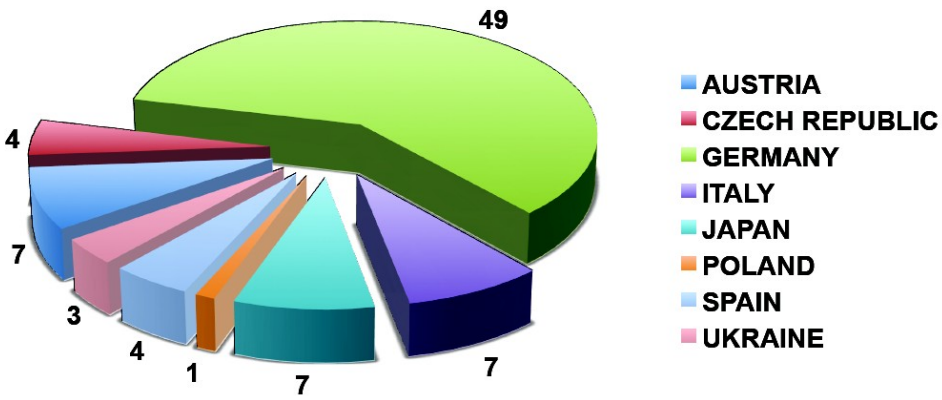
~~Possible~~ new collaborators:
Italian groups from SuperB ~~will~~ decided this summer. Some Canadian groups already joined.

Belle II: Collaboration

Belle II: PXD/SVD workshop at DESY

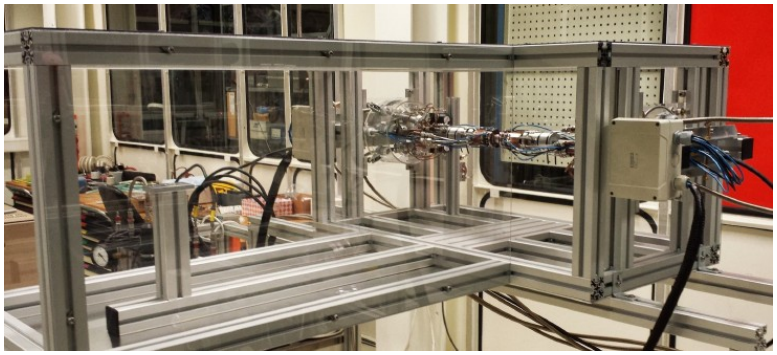
> 80+ participants

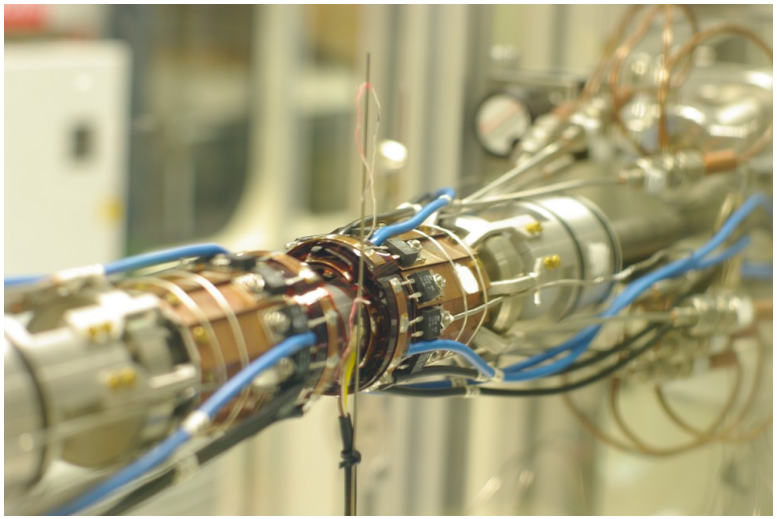




Belle II: Thermal Mock Up

- Beampipe
  - Water-heated, paraffin cooling
- PXD support
  - Electrically-heated
- Cold volume w. N_2 flow
- Vac.-isolated CO_2 lines
- Manifold
- Foam-isolated CO_2 pipes
- CO_2 cooling unit
- SVD mock up in warm volume

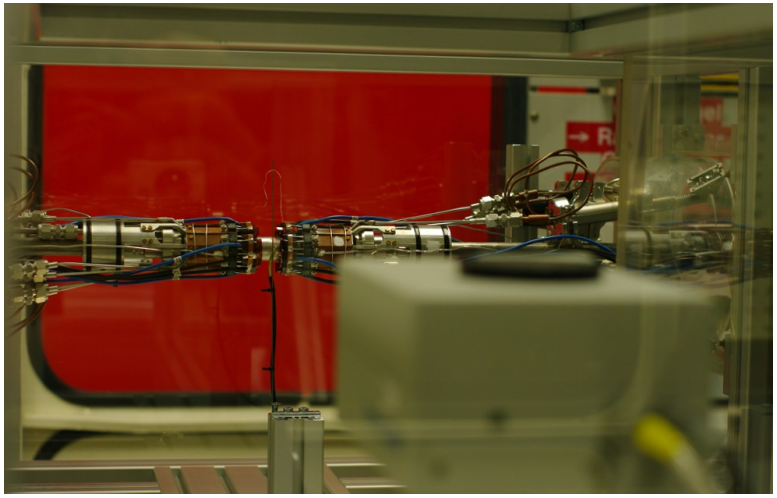


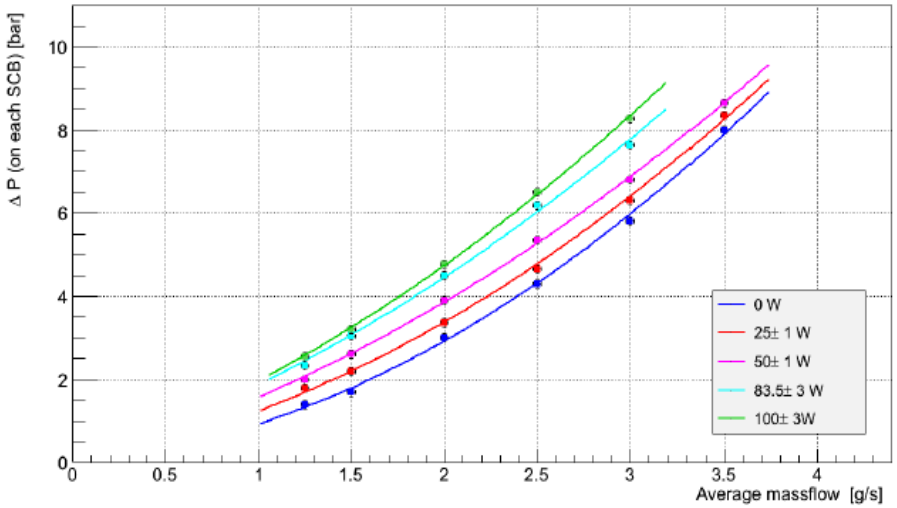


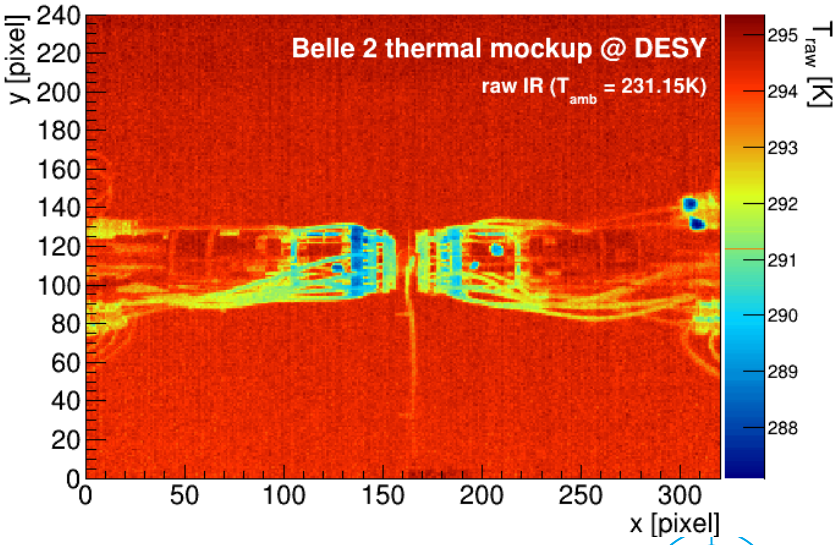
Belle II: Thermal Mock Up

> Validate VXD cooling

- Transfer pipe design from manifold → detector
- Dry air/N_2 flow in cold volume
- Overall cooling concept
- Semi-analytical calculations

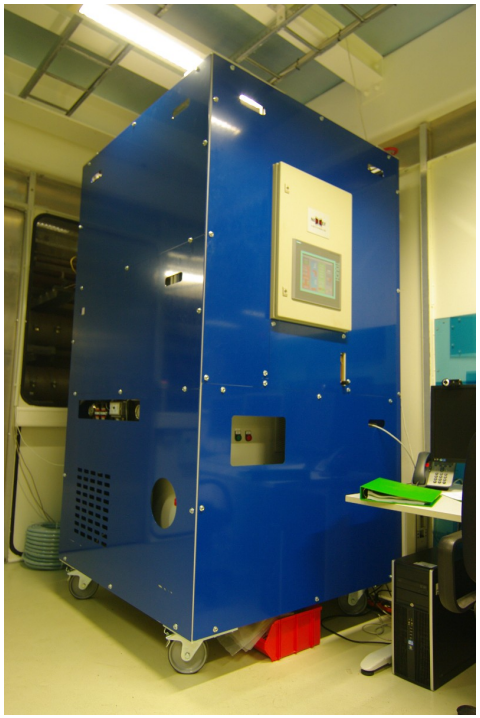






Belle II: VXD CO2 cooling

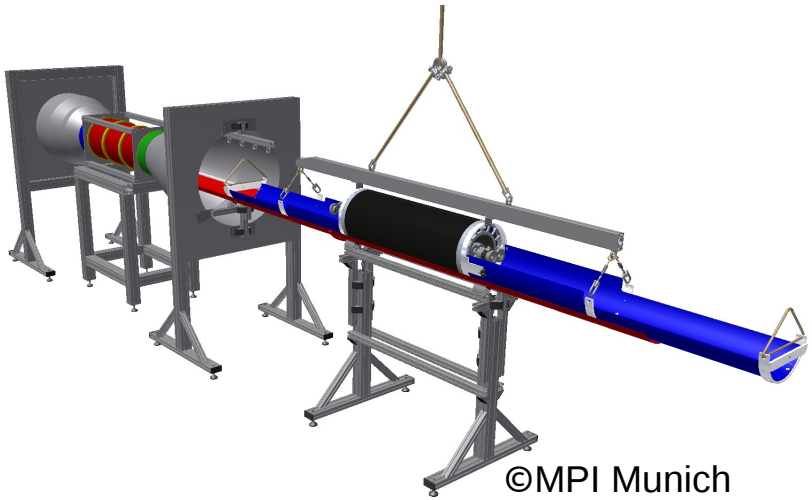
- MARCO commissioned at CERN, now in detector lab at DESY
  - MARCO moves to testbeam area TB24 in November



- XFEL-Cooler (1.2kW) now in detector lab at DESY
  - Continue thermal studies during TB

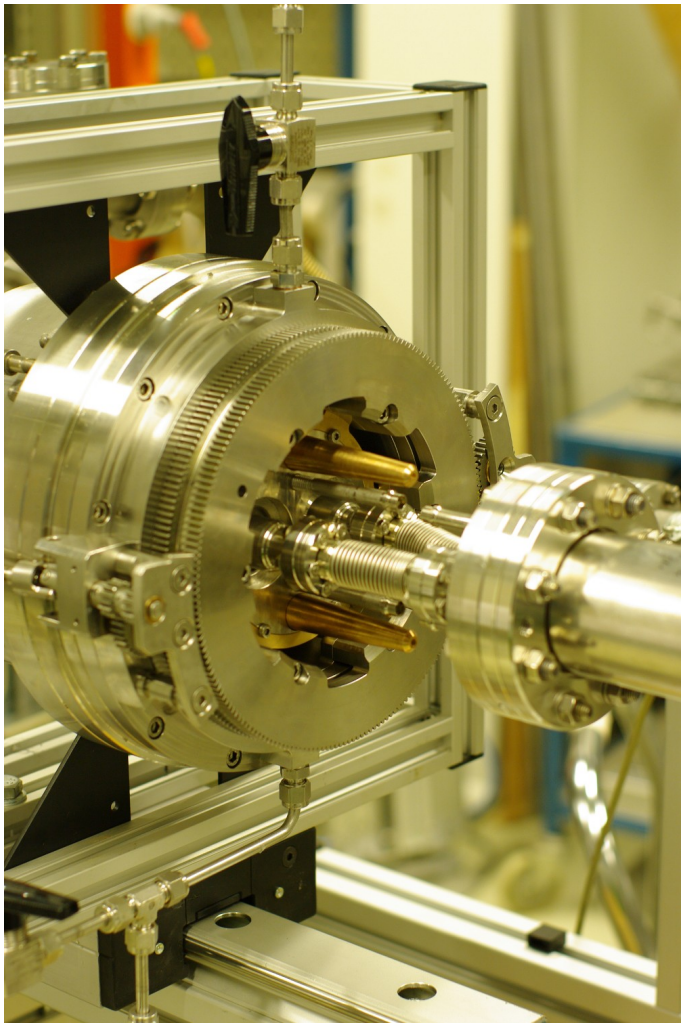
Belle II: Installation Mock Up

- VXD groups prefer “alternative installation method” independently from QCS magnets
  - No VXD removal needed if bellows or QCS fail
  - Lower stress and higher sensibility during installation
- University of Hamburg joined DEPFET collaboration



©MPI Munich

Belle II: Remote Vacuum Connection (RVC)



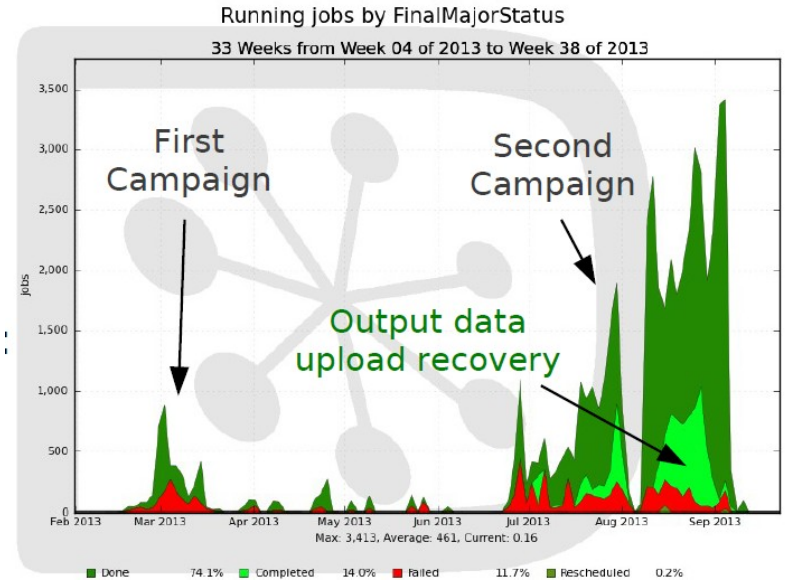
- Both VXD installation procedures count on RVC at least on backward side
- DESY proposal/design
- Tests requested by KEK:
  - Mechanical repeatability test passed
  - Vacuum test passed (helicoflex seals)
  - Rubber seals radiation test ongoing
- Risk analysis until mid of November

Belle II: Computing

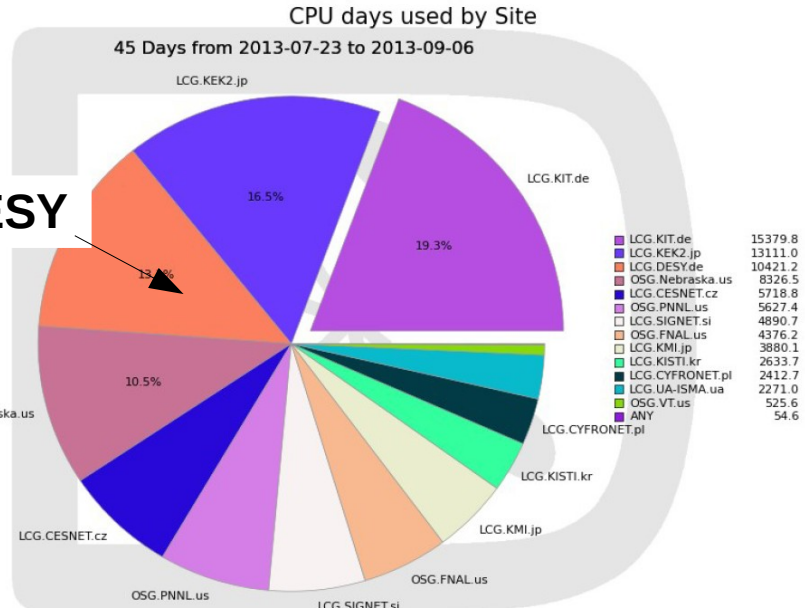
> Two large MC campaigns (GRID)

- March 2013: event generation, detector simulation
  240k jobs, 60M events, 160TB (raw+mDST)
- August 2013: background simulation, reconstruction
  700k jobs, 560M events, 8.5TB (mDST)

> Regular software shifts



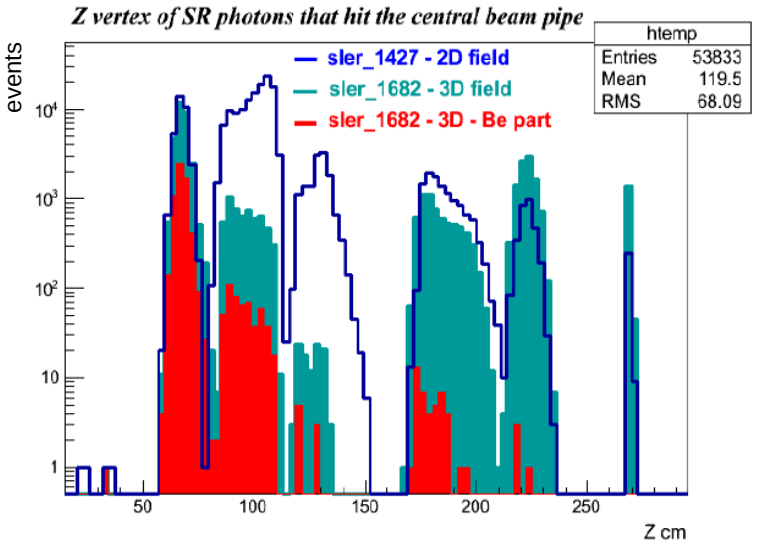
DESY

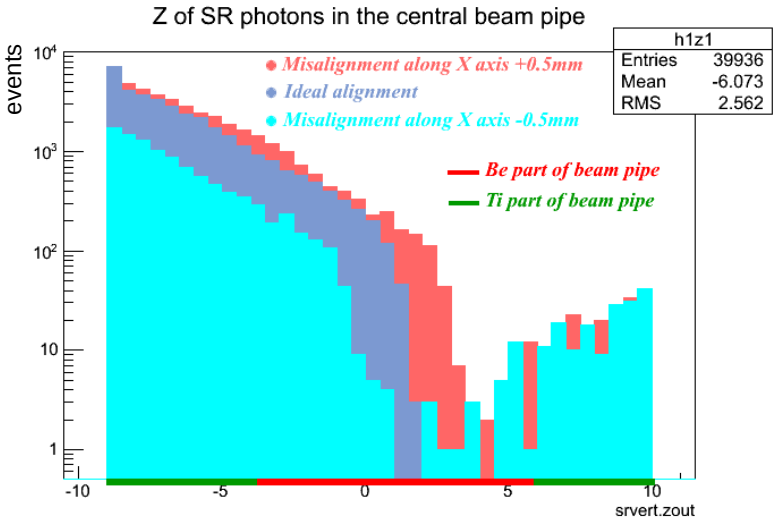


[CHEP 2013]

Belle II: Background studies

- Synchrotron radiation (SR) background simulation at DESY using:
  - 3D magnetic field
  - Beam misalignment (± 0.5mm)
  - 10σ beam halo (using Belle values)
- PXD occupancy:
  - 0.9% (non SR)
  - 0.5% (SR HER)
  - 0.2% (SR LER)
- Direct impact on IR design

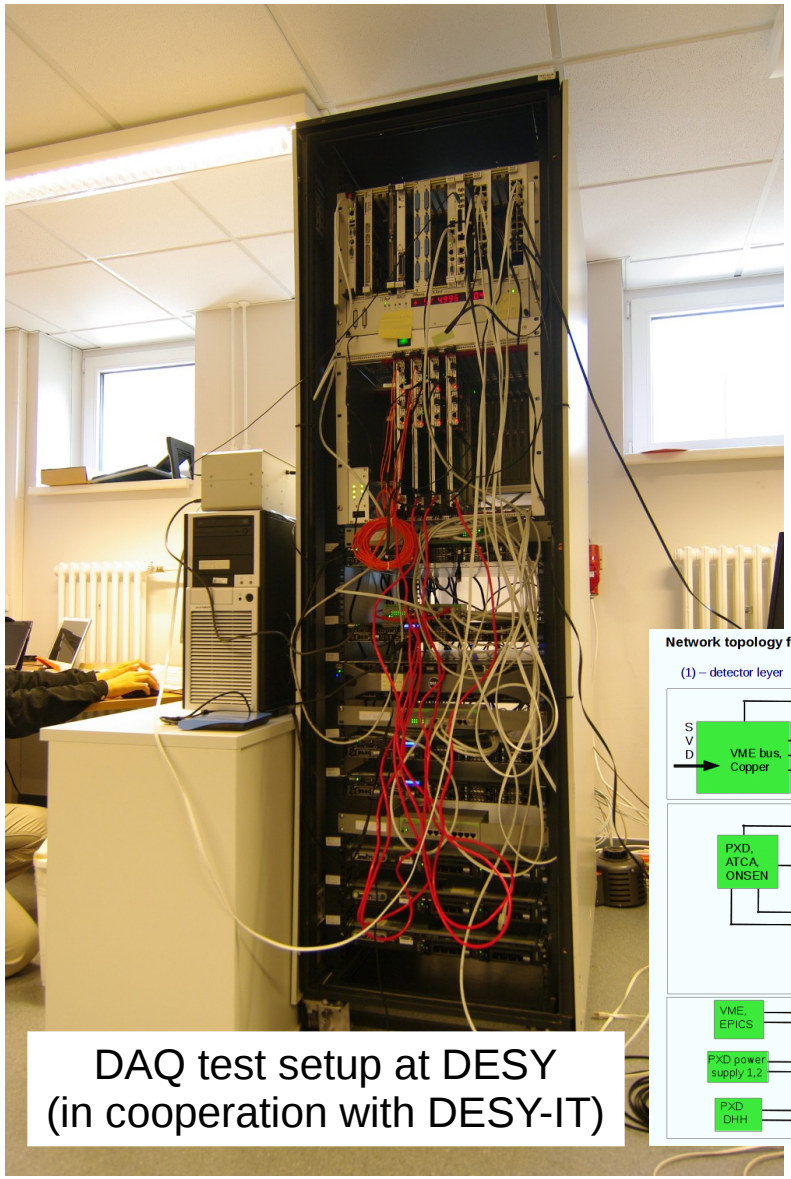




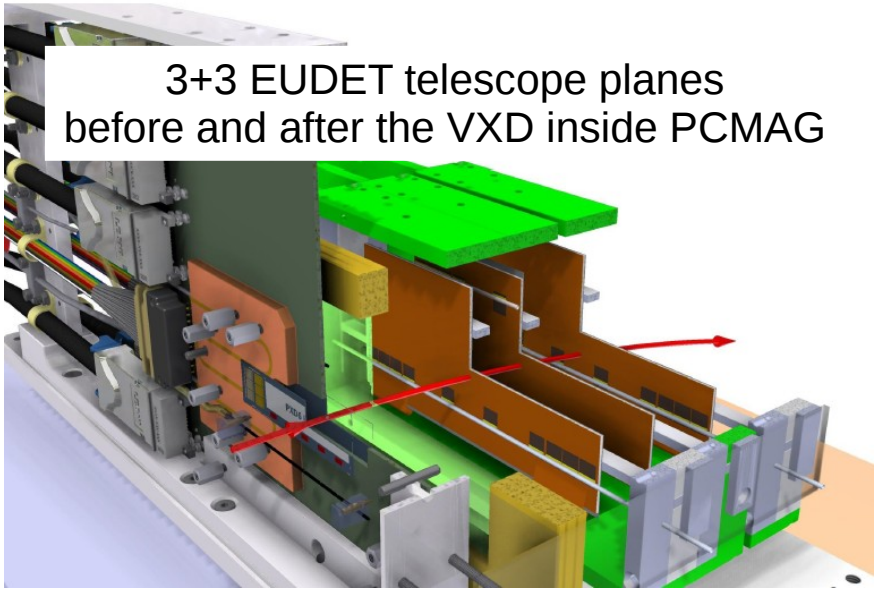
Belle II: Combined testbeam

- Full system test of PXD and SVD detectors 07.01.-31.01.2014 at DESY TB 24/1
  - Latest hardware in magnetic field
  - Full readout chain and DAQ
  - High level triggers and ROI finding for PXD
  - MARCO CO_2 cooling
  - Tracking and alignment using Belle II software (basf2)
  - Common slow control for PXD and SVD (EPICS)
- System setup since last week at DESY
- More testbeam runs needed 2014 (with PXD9)

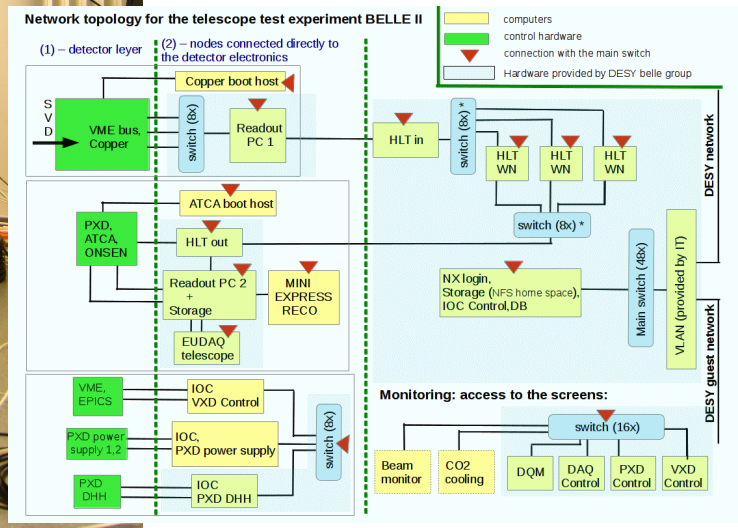
Belle II: Combined testbeam



DAQ test setup at DESY
(in cooperation with DESY-IT)



3+3 EUDET telescope planes
before and after the VXD inside PCMAG



Belle II: Alignment, calibration and tracking

- Alignment and calibration task force lead by DESY group
- Milestones:
  - CDC cosmics alignment: May 2015
  - VXD cosmics alignment: October 2015
- Supporting GBL and Millipede II
- Two new PhDs in DESY group: calibration monitoring and track finding
- Alignment software prepared for testbeam

→ Alignment and slow control will be tested in DESY testbeam 2014

Belle and Belle II: Summary

> Belle:

- Three analyses started
- Full Belle data set copied from KEK to DESY
- Testing NFS 4.1 mount for dCache storage,
  Belle data available on NAF2.0 soon

> Belle II:

- Multiple mock ups: thermal, remote vacuum, installation
- Key role in alignment, calibration and slow control
- Very visible computing contribution to MC campaigns
- **Belle II milestone**: Testbeam in January 2014 at DESY
- First physics run of Belle 2 in 2016

more information:

https://belle2.desy.de

additional information

Belle II physics reach compared to LHCb

Observable/mode	Current now	LHCb (2017) $5\,\text{fb}^{-1}$	SuperB (2021) $75\,\text{ab}^{-1}$	Belle II (2021) $50\,\text{ab}^{-1}$	LHCb upgrade (10 years of running) $50\,\text{fb}^{-1}$	theory now
			τ Decays			
$\tau \to \mu\gamma$ $(\times 10^{-9})$	< 44		< 2.4	< 5.0		
$\tau \to e\gamma$ $(\times 10^{-9})$	< 33		< 3.0	< 3.7 (est.)		
$\tau \to \ell\ell\ell$ $(\times 10^{-10})$	$< 150 - 270$	< 244 [a]	$< 2.3 - 8.2$	< 10	< 24 [b]	
			$B_{u,d}$ Decays			
BR$(B \to \tau\nu)$ $(\times 10^{-4})$	1.64 ± 0.34		0.05	0.04		1.1 ± 0.2
BR$(B \to \mu\nu)$ $(\times 10^{-6})$	< 1.0		0.02	0.03		0.47 ± 0.08
BR$(B \to K^{*+}\nu\overline{\nu})$ $(\times 10^{-6})$	< 80		1.1	2.0		6.8 ± 1.1
BR$(B \to K^{+}\nu\overline{\nu})$ $(\times 10^{-6})$	< 160		0.7	1.6		3.6 ± 0.5
BR$(B \to X_s\gamma)$ $(\times 10^{-4})$	3.55 ± 0.26		[illegible]	0.13	0.23	3.15 ± 0.23
$A_{CP}(B \to X_{(s+d)}\gamma)$	0.060 ± 0.060		[illegible]	0.02		$\sim 10^{-6}$
$B \to K^*\mu^+\mu^-$ (events)	250 [c]	8000	12-14k [d]	7-10k	100,000	-
BR$(B \to K^*\mu^+\mu^-)$ $(\times 10^{-6})$	1.15 ± 0.16		[illegible]	0.07		1.19 ± 0.39
$B \to K^*e^+e^-$ (events)	165	400	10-15k	7-10k	5,000	-
BR$(B \to K^*e^+e^-)$ $(\times 10^{-6})$	1.09 ± 0.17		[illegible]	0.07		1.19 ± 0.39
$A_{FB}(B \to K^*\ell^+\ell^-)$	0.27 ± 0.14 [e]	[f]	[illegible]	0.03		-0.089 ± 0.020
$B \to X_s\ell^+\ell^-$ (events)	280		800	7,000		-
BR$(B \to X_s\ell^+\ell^-)$ $(\times 10^{-6})$ [g]	3.66 ± 0.77 [h]		0.08	0.10		1.59 ± 0.11
S in $B \to K^0_S\pi^0\gamma$	-0.15 ± 0.20		0.03	0.03		-0.1 to 0.1
S in $B \to \eta' K^0$	0.59 ± 0.07		0.01	0.02		± 0.015
S in $B \to \phi K^0$	0.56 ± 0.17	0.15	0.02	0.03	0.03	± 0.02
			B^0_s Decays			
BR$(B^0_s \to \gamma\gamma)$ $(\times 10^{-6})$	< 8.7		0.3	$0.2 - 0.3$		0.4 - 1.0
A^s_{SL} $(\times 10^{-3})$	-7.87 ± 1.96 [i]	[j]	4.	5. (est.)		0.02 ± 0.01
			D Decays			
x	$(0.63 \pm 0.20)\%$	0.06%	0.02%	0.04%	0.02%	$\sim 10^{-2}$ [k]
y	$(0.75 \pm 0.12)\%$	0.03%	0.01%	0.03%	0.01%	$\sim 10^{-2}$ (see above).
y_{CP}	$(1.11 \pm 0.22)\%$	0.02%	0.03%	0.05%	0.01%	$\sim 10^{-2}$ (see above).
$\lvert q/p \rvert$	$(0.91 \pm 0.17)\%$	8.5%	2.7%	3.0%	3%	$\sim 10^{-3}$ (see above).
arg$\{q/p\}$ (°)	-10.2 ± 9.2	4.4	1.4	1.4	2.0	$\sim 10^{-3}$ (see above).

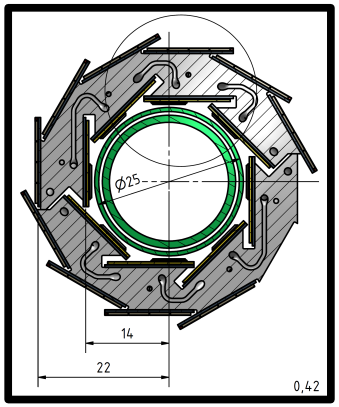
cancelled

arXiv:1109.5028v2

DESY

Belle II Vertex Detectors

- 2 layers of DEPFET pixel detectors (PXD)
- 4 layers of double-sided silicon strip detectors (SVD)



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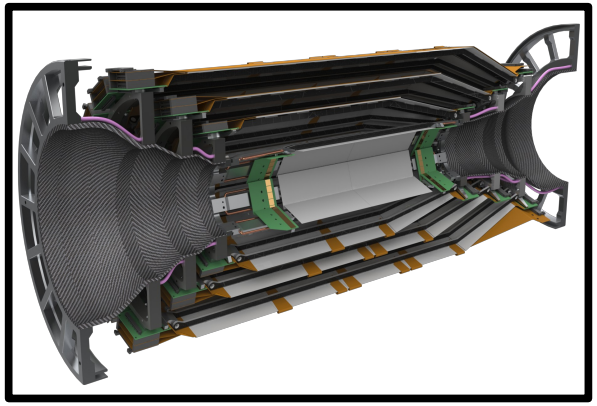

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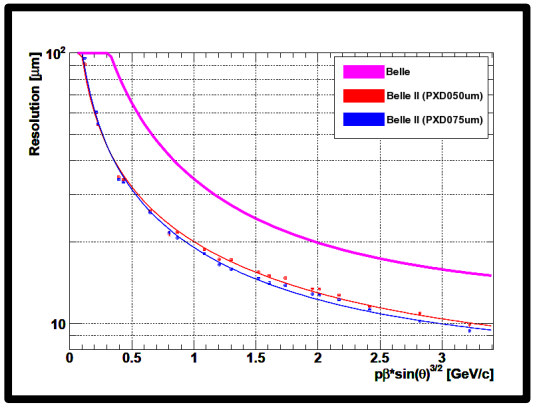

PXD
0.21% X_0/layer

pixel: 50x55/85µm
thickness: 75µm

hit time resolution: 20µs

SVD
0.55% X_0/layer

shaping time: 20ns
hit time resolution: 3ns

PXD + SVD = VXD

Z vertex resolution two times better than Belle

Improved K_s efficiency (e.g. $B \rightarrow K_s K_s K_s$, ...)

DESY

Belle detector performance

Detector	Type	Configuration	Readout	Performance
Beam pipe	Beryllium double wall	Cylindrical, $r = 20$ mm 0.5/2.5/0.5 (mm) = Be/He/Be		He gas cooled
EFC	BGO	Photodiode readout segmentation: 32 in ϕ; 5 in θ	160×2	RMS energy resolution: 7.3 % at 8 GeV 5.8% at 3.5 GeV
SVD	Double-sided Si strip	Chip size: 57.5×33.5 mm^2 Strip pitch: 25 (p)/50 (n) μm 3 layers: 8/10/14 ladders	ϕ: 40.96k z: 40.96k	$\sigma_{\Delta z} \sim 80$ μm
CDC	Small cell drift chamber	Anode: 50 layers Cathode: 3 layers $r = 8.3$–86.3 cm $-77 \leqslant z \leqslant 160$ cm	A: 8.4k C: 1.8k	$\sigma_{r\phi} = 130$ μm $\sigma_z = 200$–1400 μm $\sigma_{p_t}/p_t = 0.3\%\sqrt{p_t^2 + 1}$ $\sigma_{dE/dx} = 6\%$
ACC	Silica aerogel	960 barrel/228 end-cap FM-PMT readout		$N_{\text{p.e.}} \geqslant 6$ K/π separation: $1.2 < p < 3.5$ GeV/c
TOF	Scintillator	128 ϕ segmentation $r = 120$ cm, 3-m long	128×2	$\sigma_t = 100$ ps K/π separation: up to 1.2 GeV/c
TSC		64 ϕ segmentation	64	
ECL	CsI (towered structure)	Barrel: $r = 125$–162 cm End-cap: $z = -102$ cm and $+196$ cm	6624 1152 (F) 960 (B)	$\sigma_E/E = 1.3\%/\sqrt{E}$ $\sigma_{\text{pos}} = 0.5$ cm$/\sqrt{E}$ (E in GeV)
KLM	Resistive plate counters	14 layers (5 cm Fe + 4 cm gap) 2 RPCs in each gap	θ: 16k ϕ: 16k	$\Delta\phi = \Delta\theta = 30$ mr for K_L $\sim 1\%$ hadron fake
Magnet	Supercon.	Inner radius = 170 cm		$B = 1.5$ T

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