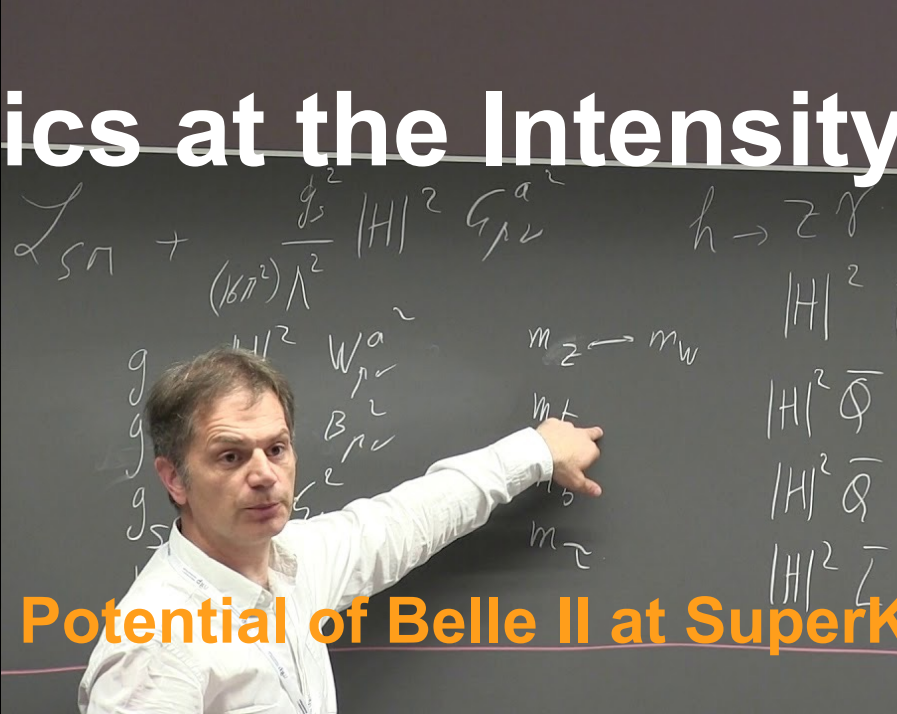
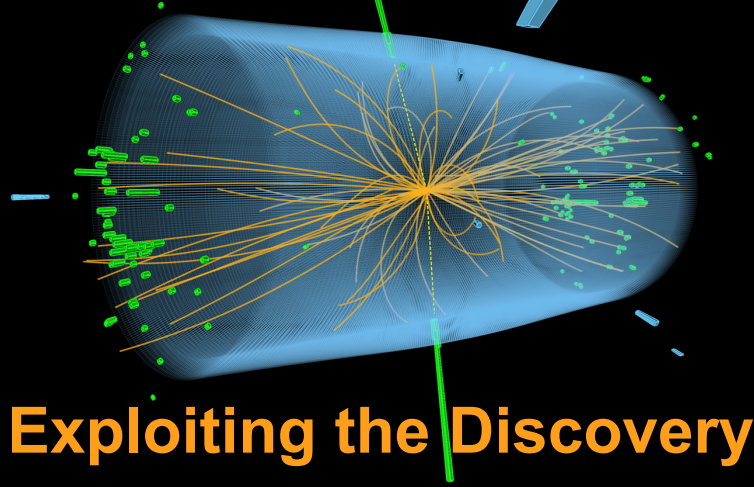


Precision Physics at the Intensity Frontier



Exploiting the Discovery Potential of Belle II at SuperKEKB

Helmholtz Program: Matter and the Universe (MU)

PoF III Topic: Fundamental Particles and Forces

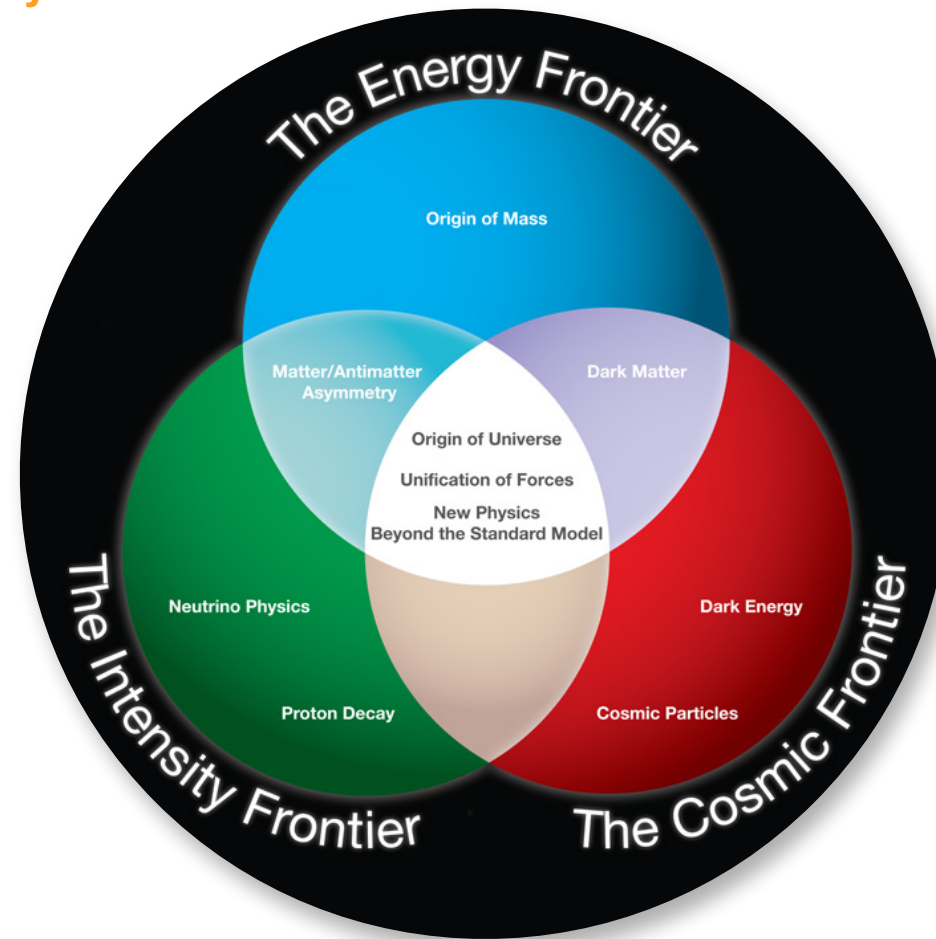
DESY Research Unit: Experimental Particle Physics

Carsten Niebuhr

Center Evaluation DESY, 5 – 9 February 2018

Looking Beyond the Standard Model

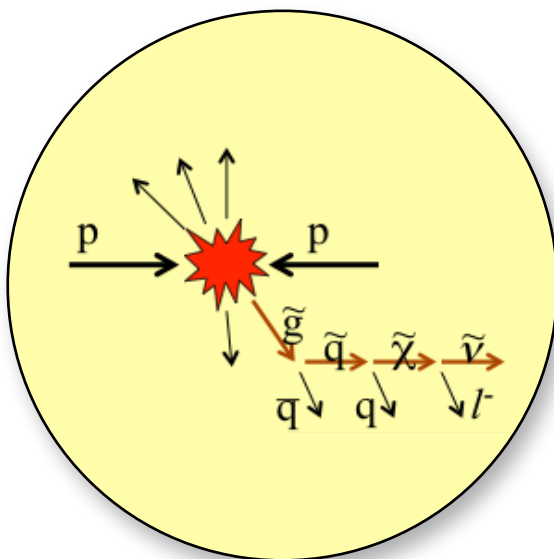
Complementary Pathways to New Physics



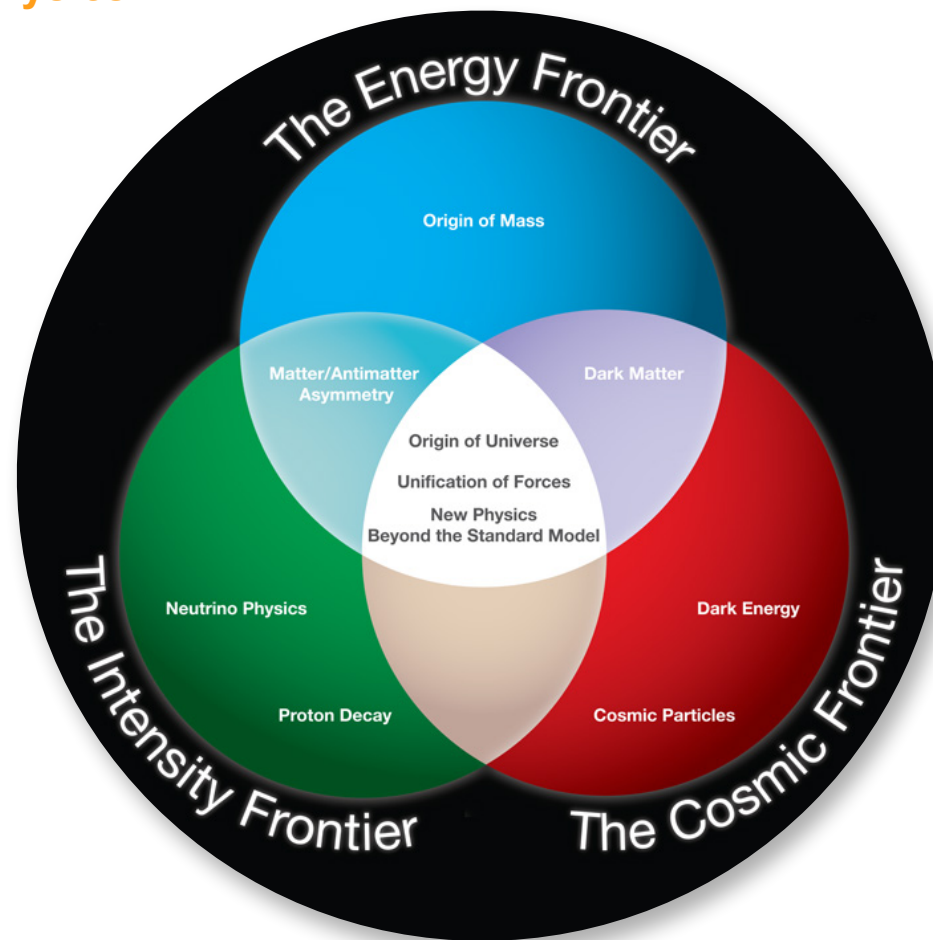
Looking Beyond the Standard Model

Complementary Pathways to New Physics

Energy frontier



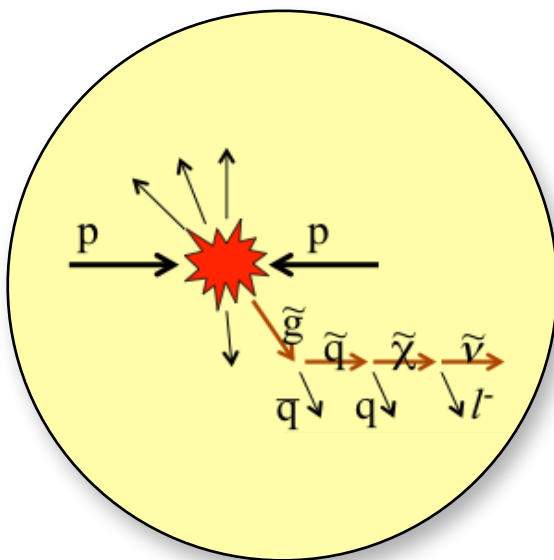
Direct production of new particles



Looking Beyond the Standard Model

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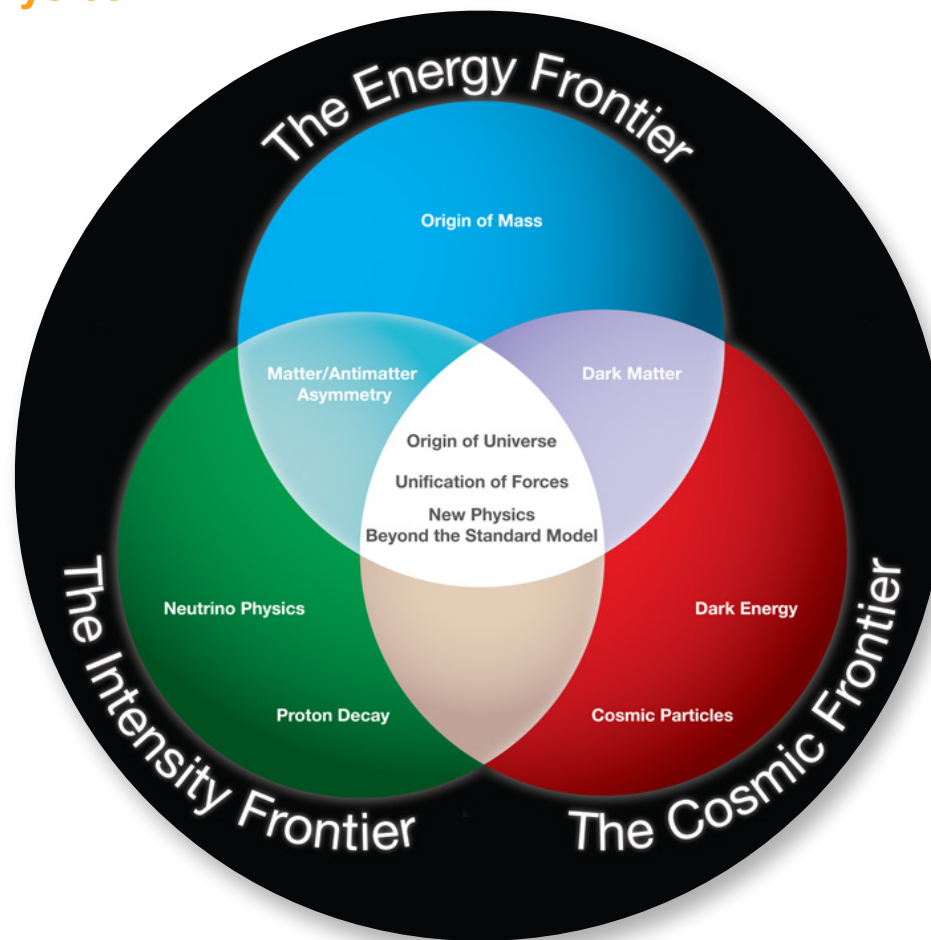
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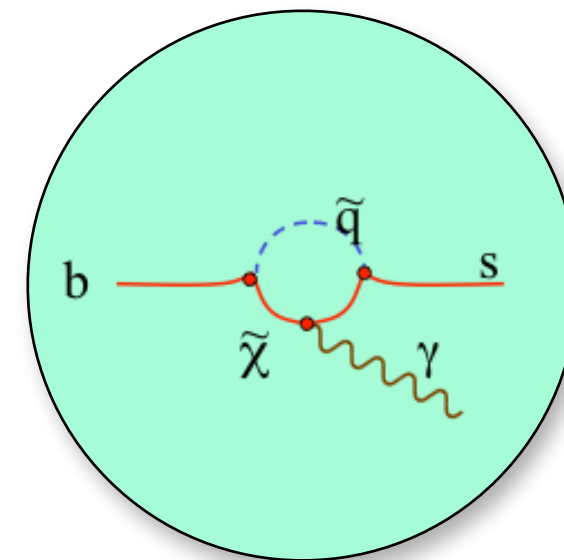
Direct production of new particles

Current experimental situation

- No clear evidence for Beyond Standard Model (BSM) physics at the high energy frontier
- Intensity frontier offers **indirect** sensitivity to **very high** scales



Intensity frontier



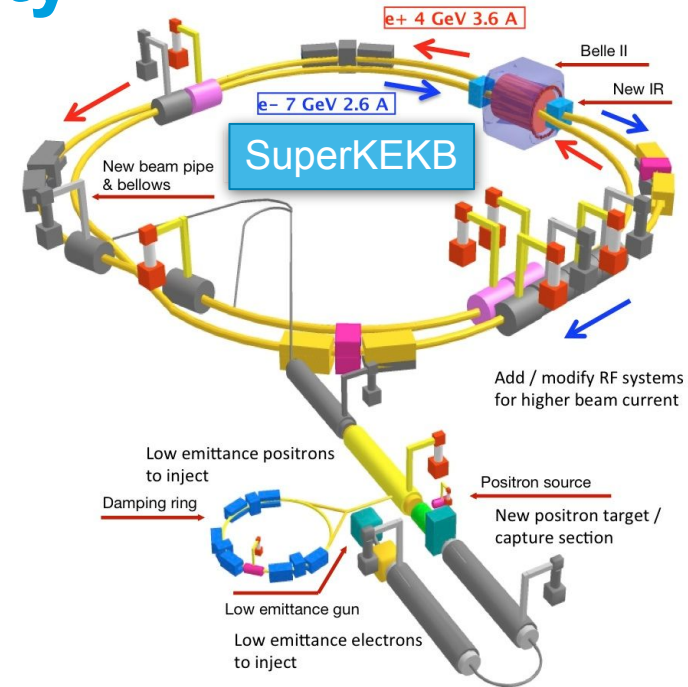
Indirect sensitivity through loops

The Next Big Step in Luminosity

Striving for unprecedented data samples: $\int \mathcal{L} dt = 50 \text{ ab}^{-1}$

Collider upgrade KEKB \Rightarrow SuperKEKB

- Increasing peak luminosity by a factor of 40:
 $\mathcal{L}_{\text{inst}} = 8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
- Nano beam scheme* requires very sophisticated final focus system QCSL and QCSR:
 - beam spot at IP: $\sigma_x \times \sigma_y \sim 10 \mu\text{m} \times 50 \text{ nm}$
- Machine commissioning proceeds in 3 phases

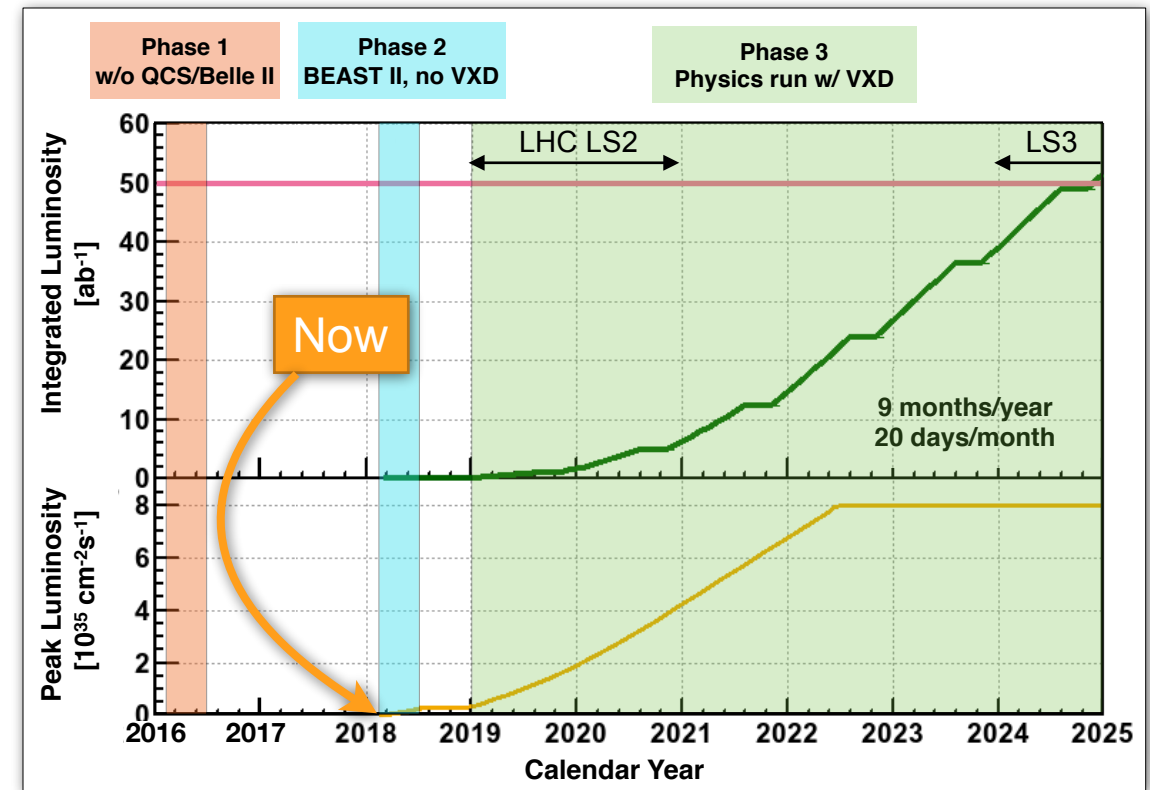


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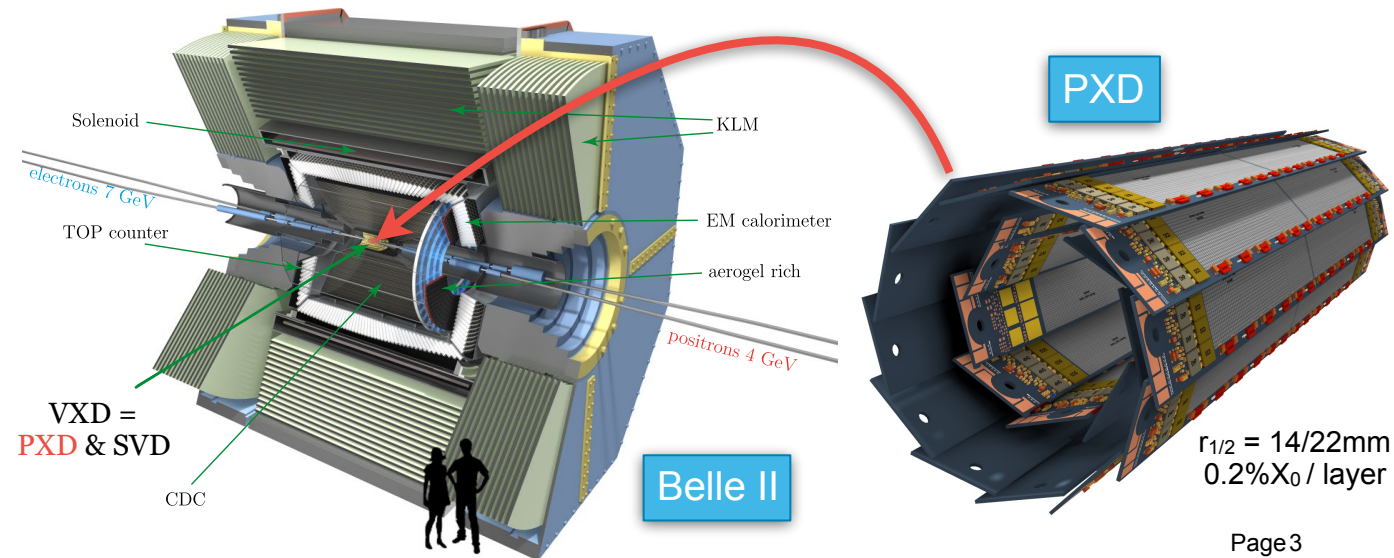
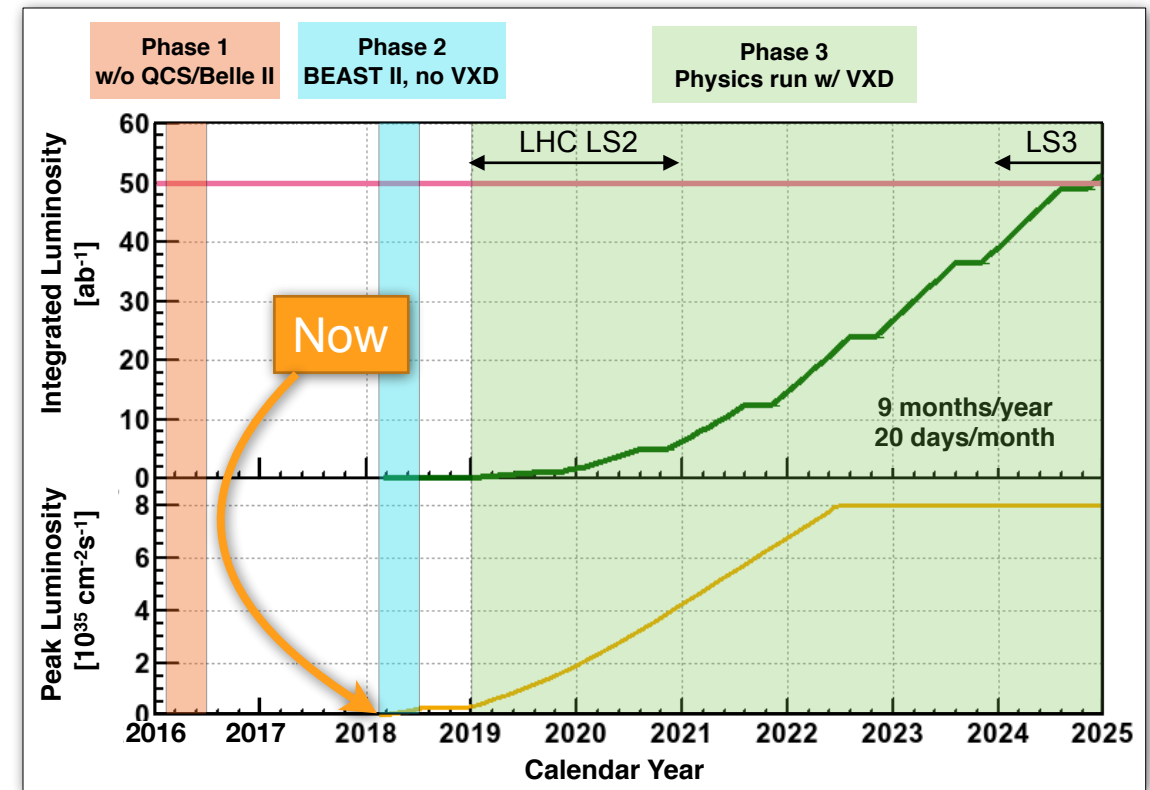
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Detector upgrade Belle \Rightarrow Belle II

- Replacement of most sub-detectors to cope with increased background rates and to improve performance
- Main German deliverable
 - novel **pixel vertex detector PXD** (DEPFET) as part of the new vertex detector VXD
 - PXD leadership MPP \Rightarrow DESY in July 2017

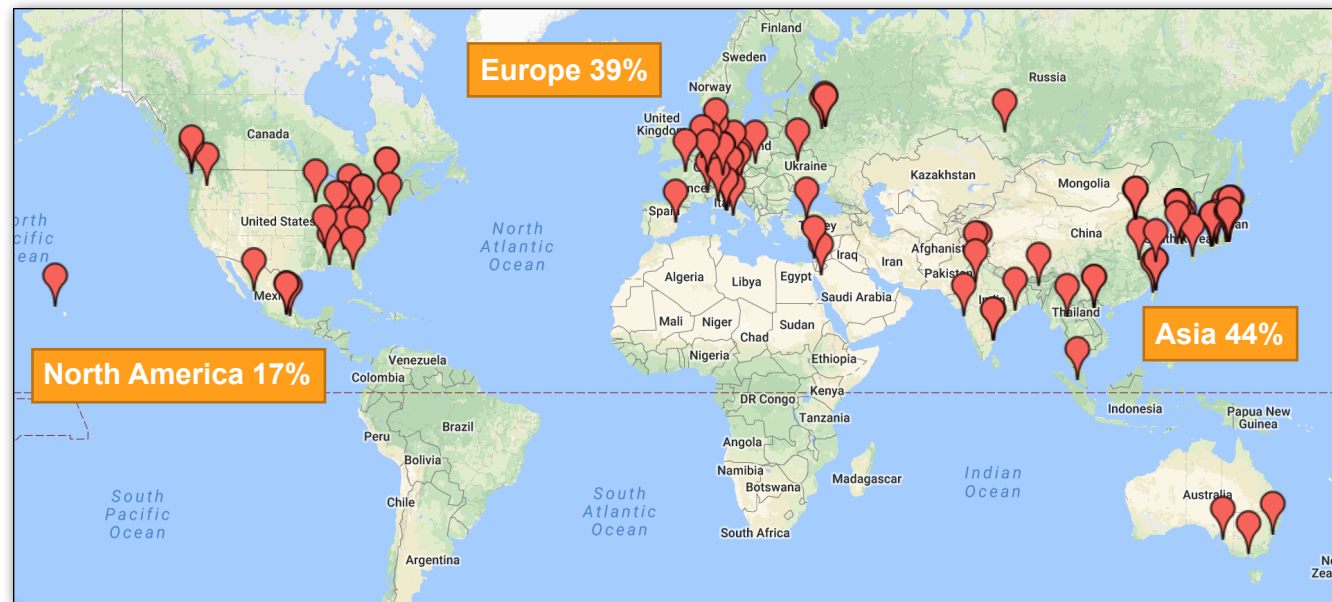


Belle II Collaboration

780 members from 106 institutions in 25 countries

Four largest countries by members / institutes

- Japan (149 / 13)
- **Germany** (111 / 12)
- US (92 / 15)
- Italy (77 / 9)



Belle II Collaboration

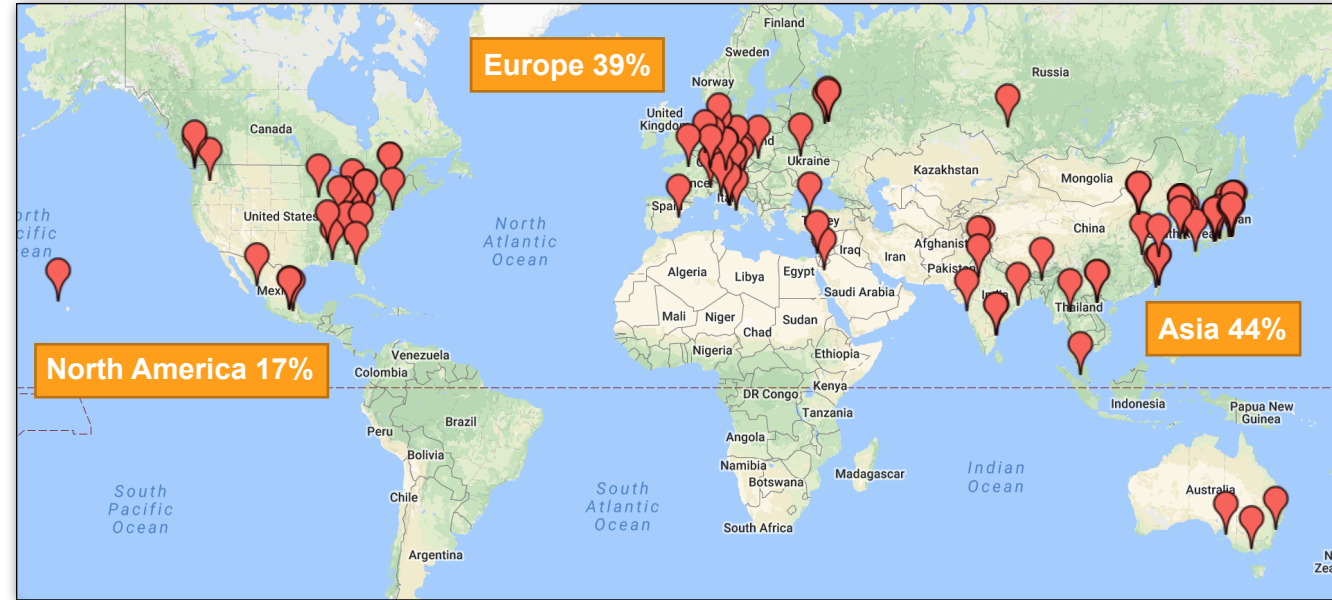
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Key role of DESY within Germany and beyond

- Enabling VXD commissioning and integration
 - Test beam facility
 - Helmholtz detector lab (dedicated PERSY set-up)
- Acting as computing hub
 - Grid & NAF at DESY
 - host complete copy of Belle mDSTs
 - 50% of German share as *Raw & Regional Data Center*
- Migration of Belle II collaborative tools to DESY in 2016/17



German Belle II institutions

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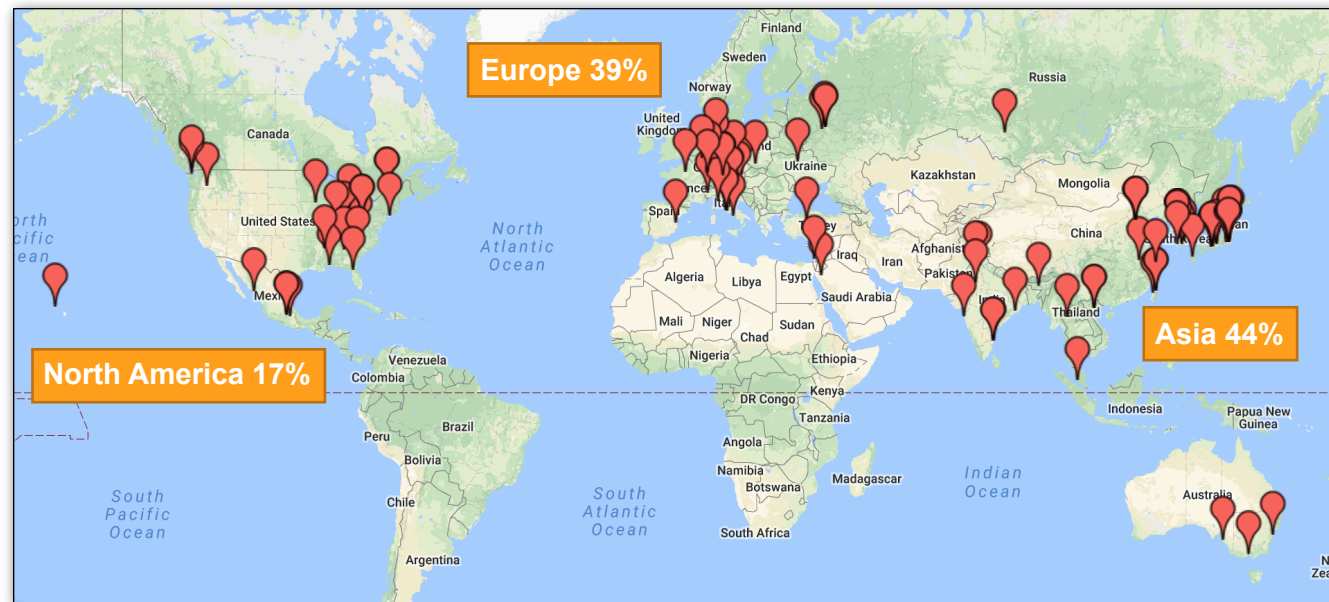
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⇒ TIER-2 talk by
Birgit Lewendel

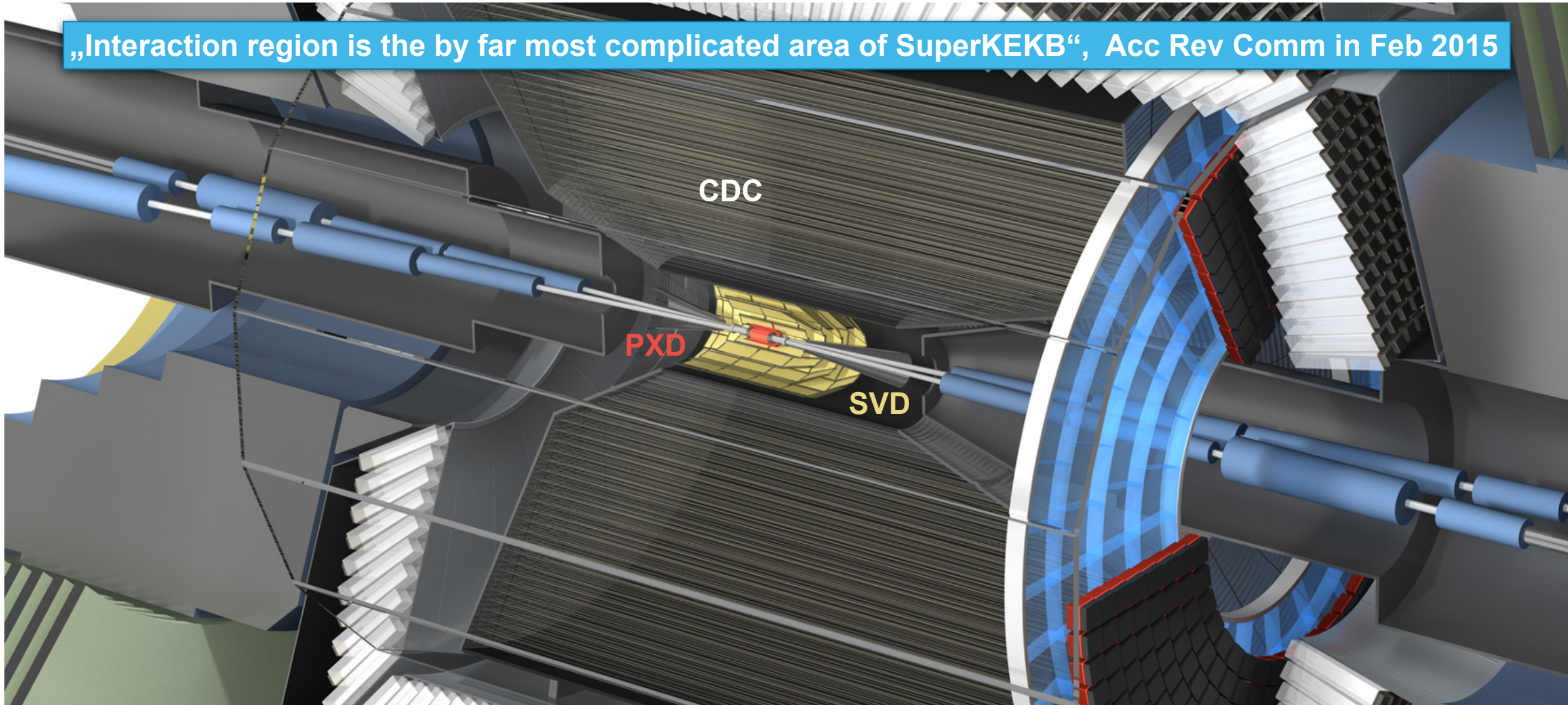


German Belle II institutions

DESY Contributions to VXD Integration

Fulfilling our facilitating role as national lab for particle physics

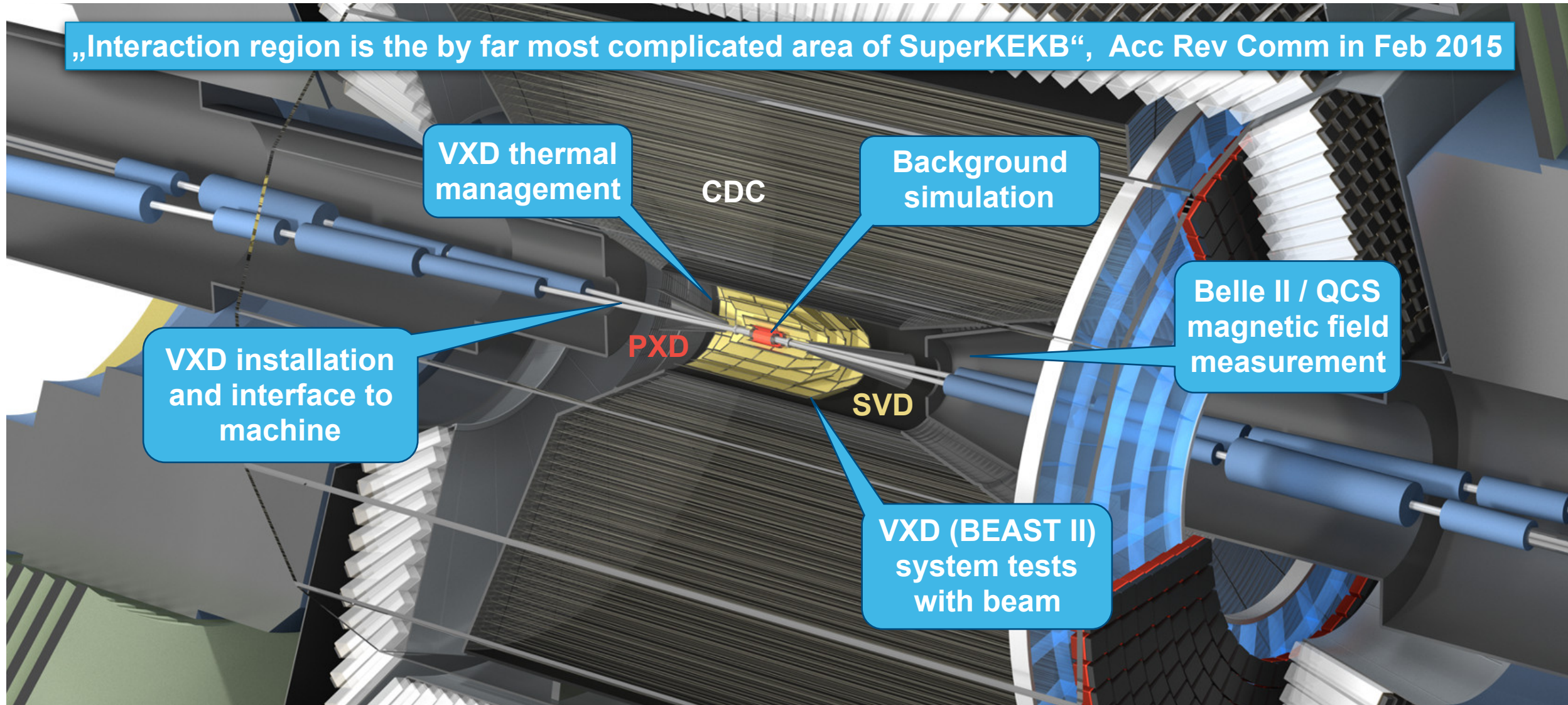
„Interaction region is the by far most complicated area of SuperKEKB“, Acc Rev Comm in Feb 2015



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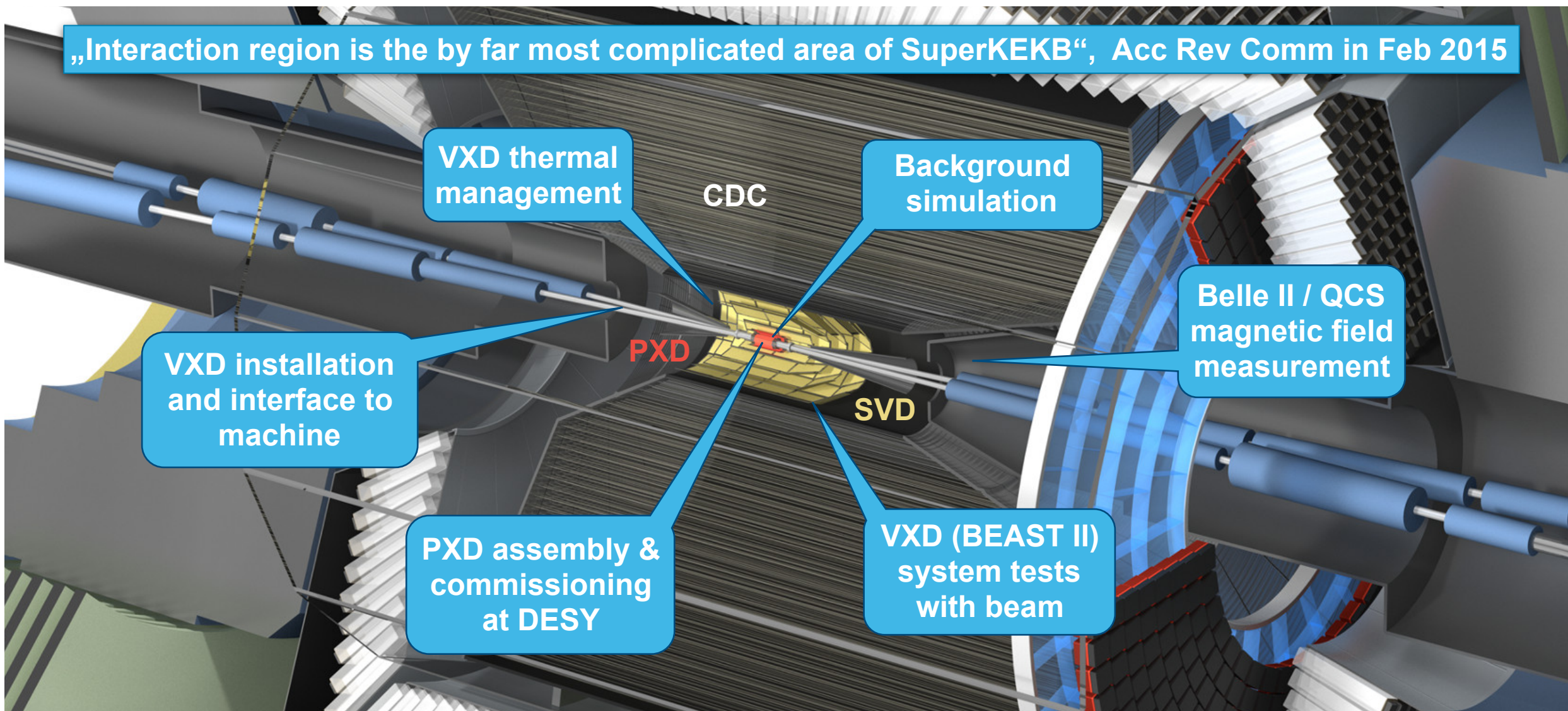
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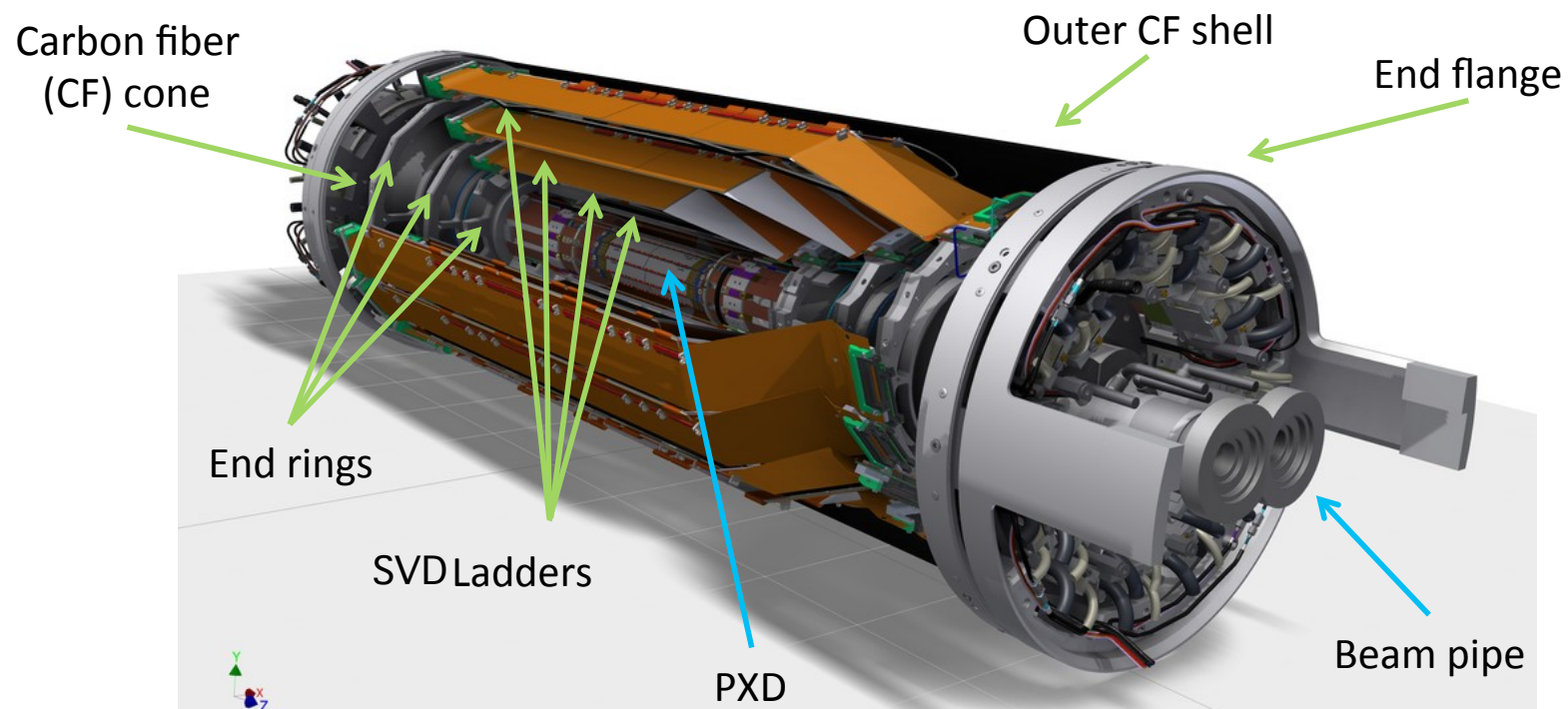


Machine-Detector Interface

DESY development: Remote Vacuum Connection RVC

Challenge

- VXD has to be assembled on the central beam pipe outside Belle II
- Standard methods to connect central beam pipe with machine **not viable**



Belle II vertex detector VXD

Machine-Detector Interface

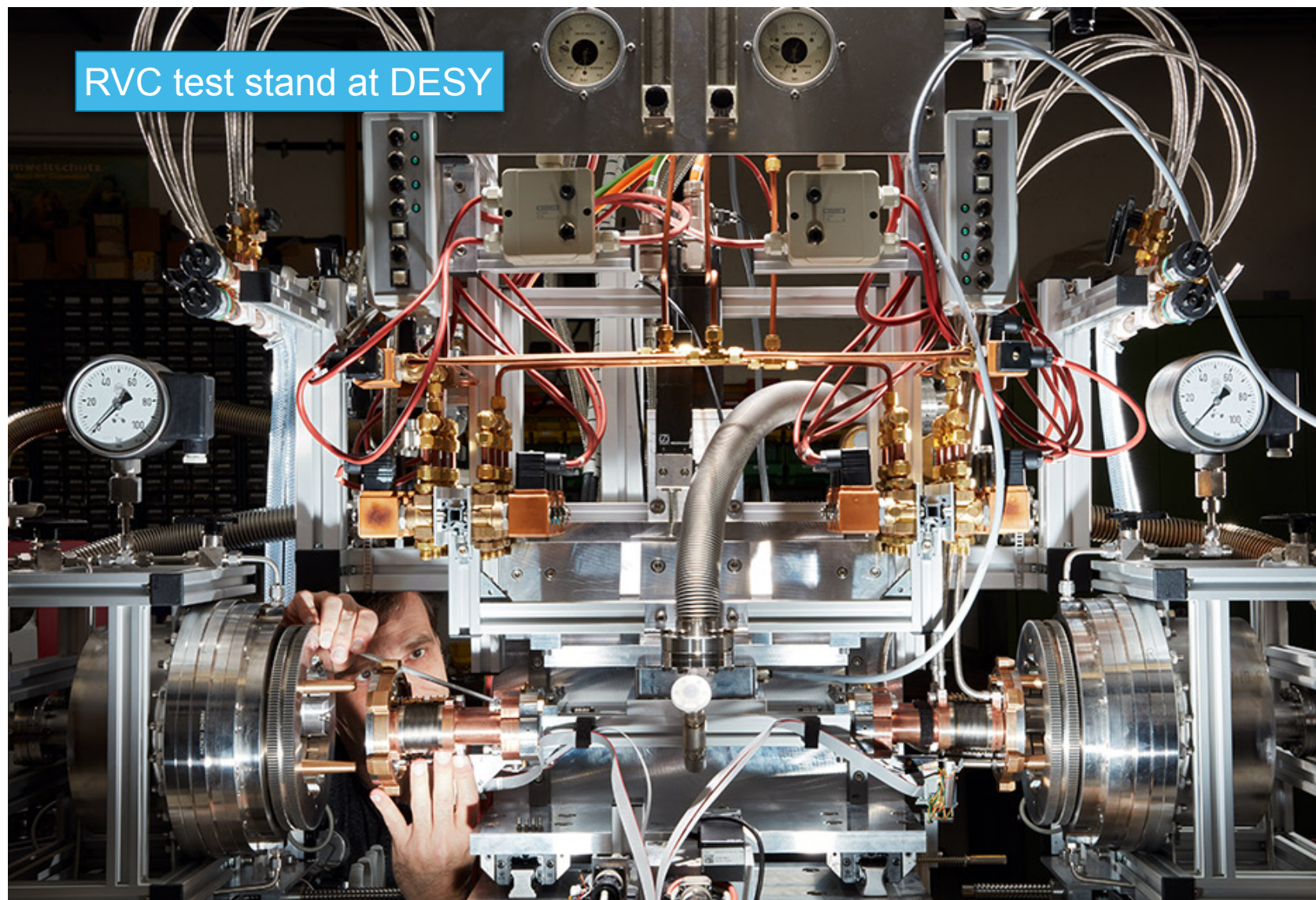
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- Development of a novel, remotely actuated hydraulic system
- Very close collaboration with vacuum & magnet groups of SuperKEKB
- Functionality of **RVC absolutely crucial** for VXD installation
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- First in-situ operation during QCS insertion for phase 2 in Jan 10-15



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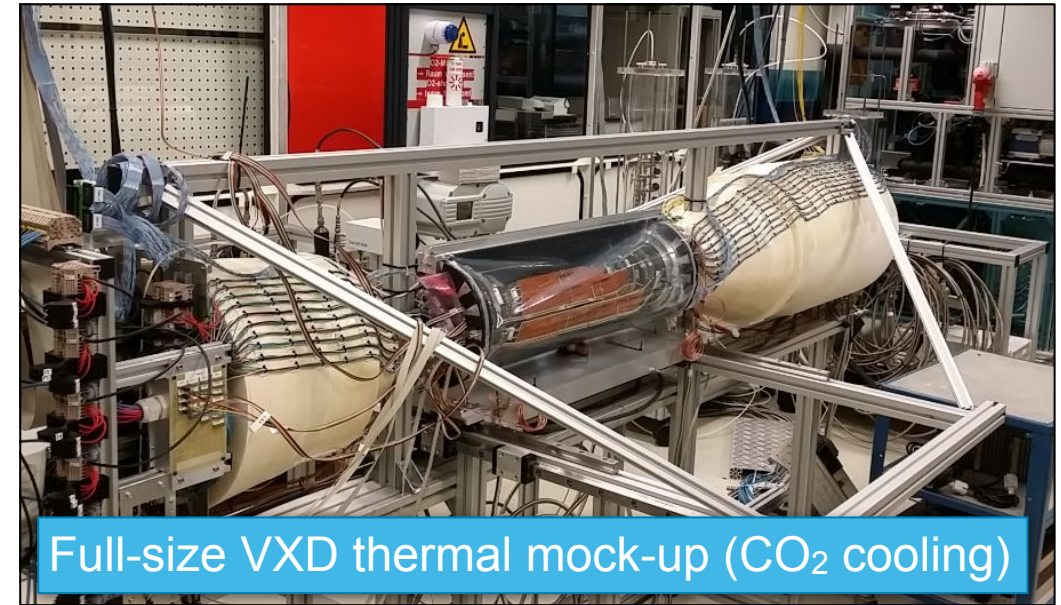
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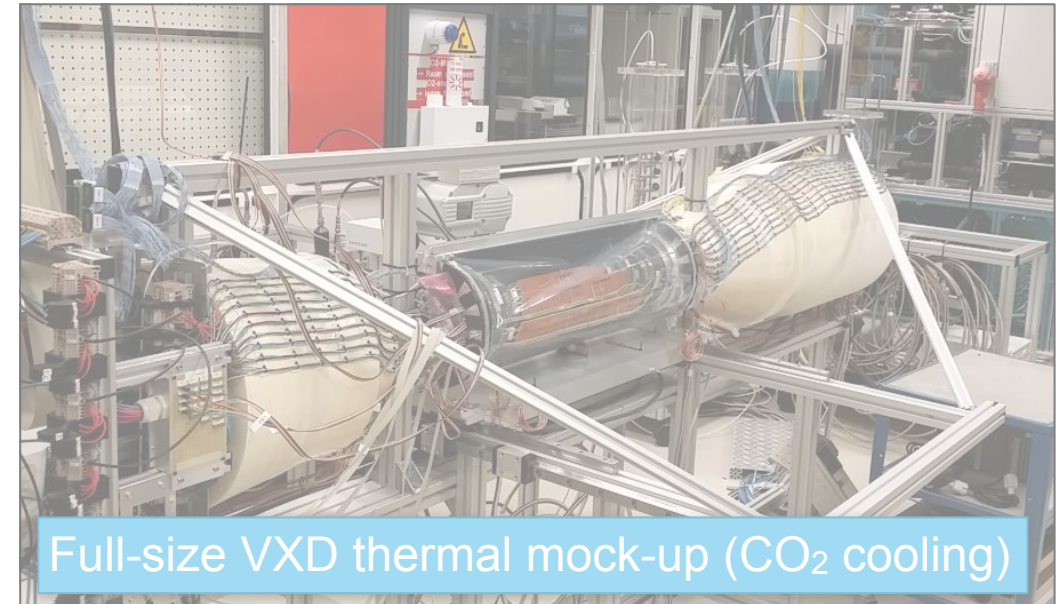
Other DESY Involvements

Optimal exploitation of DESY expertise & infrastructure

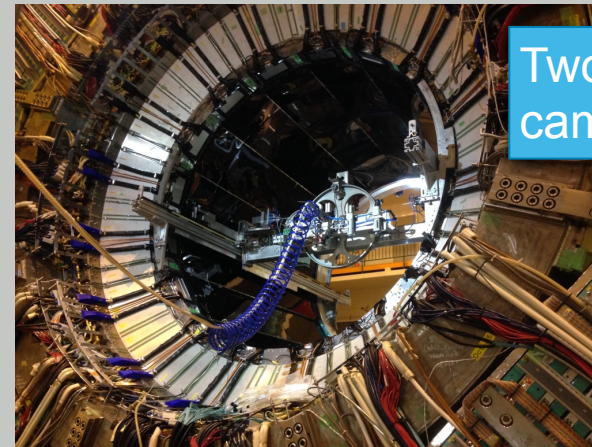


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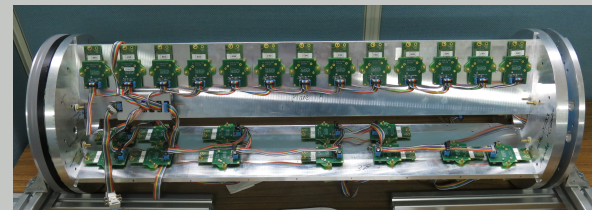
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Full-size VXD thermal mock-up (CO₂ cooling)

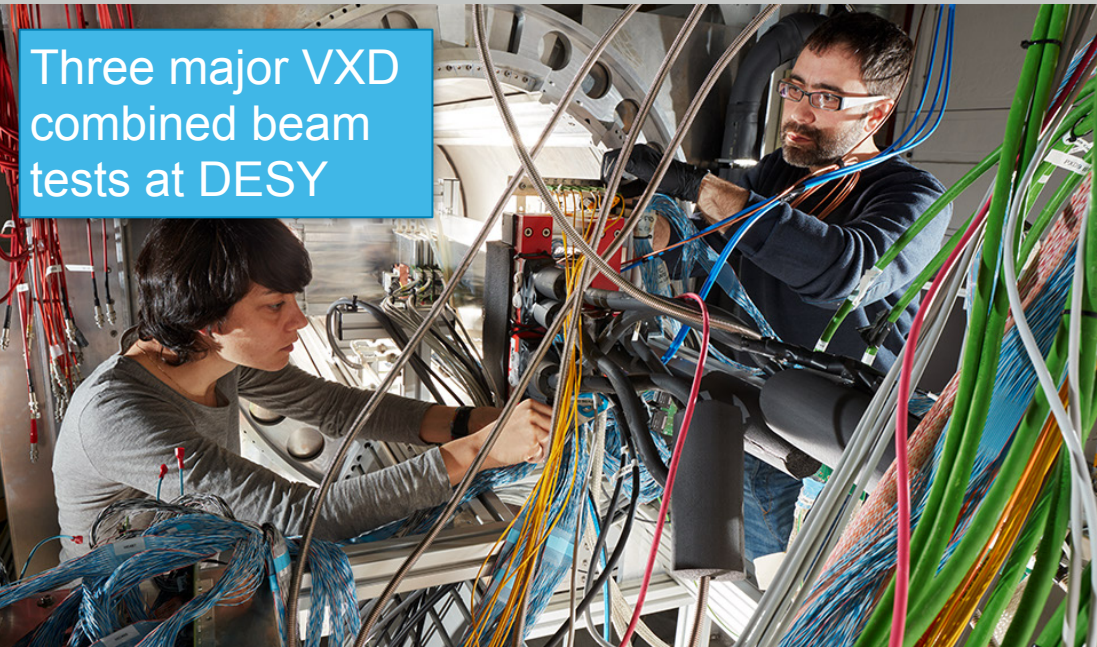


Two B-field measurement campaigns at KEK

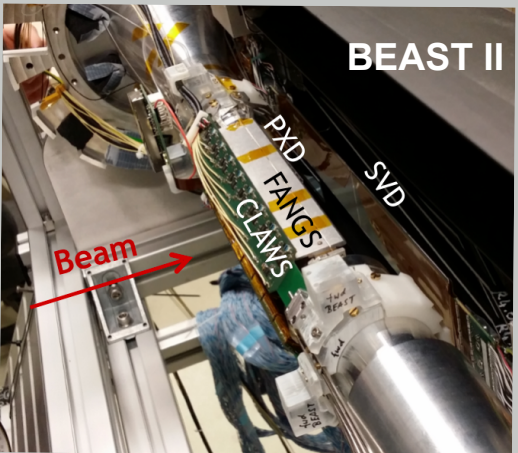
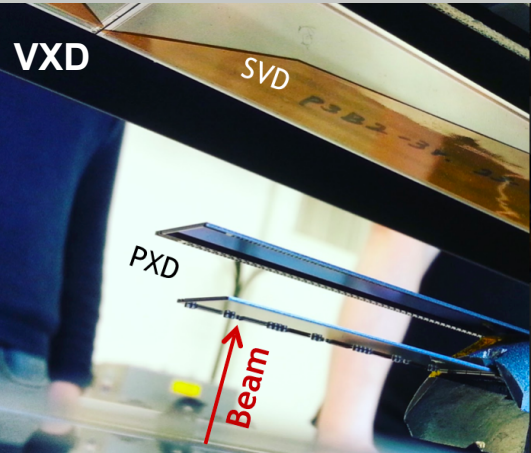


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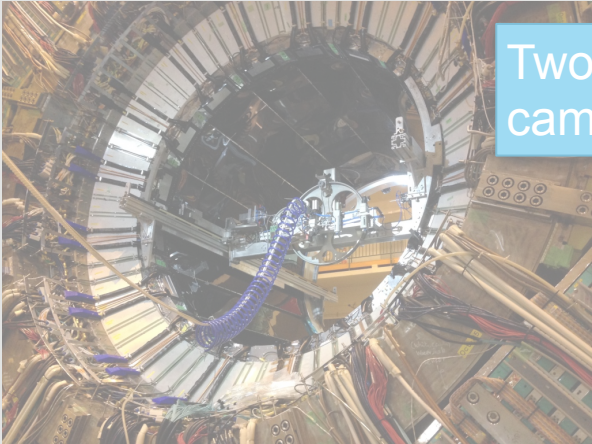
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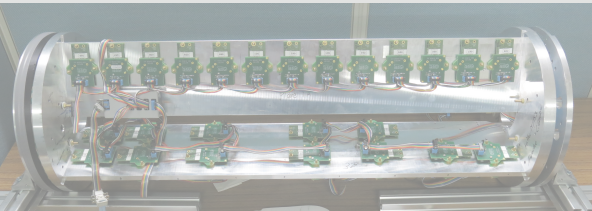
Three major VXD combined beam tests at DESY



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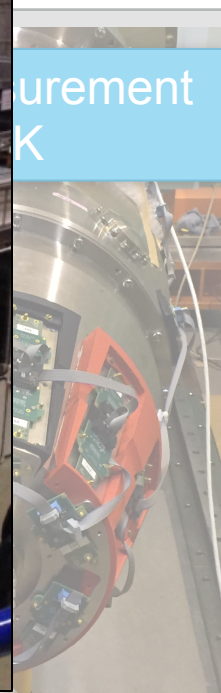
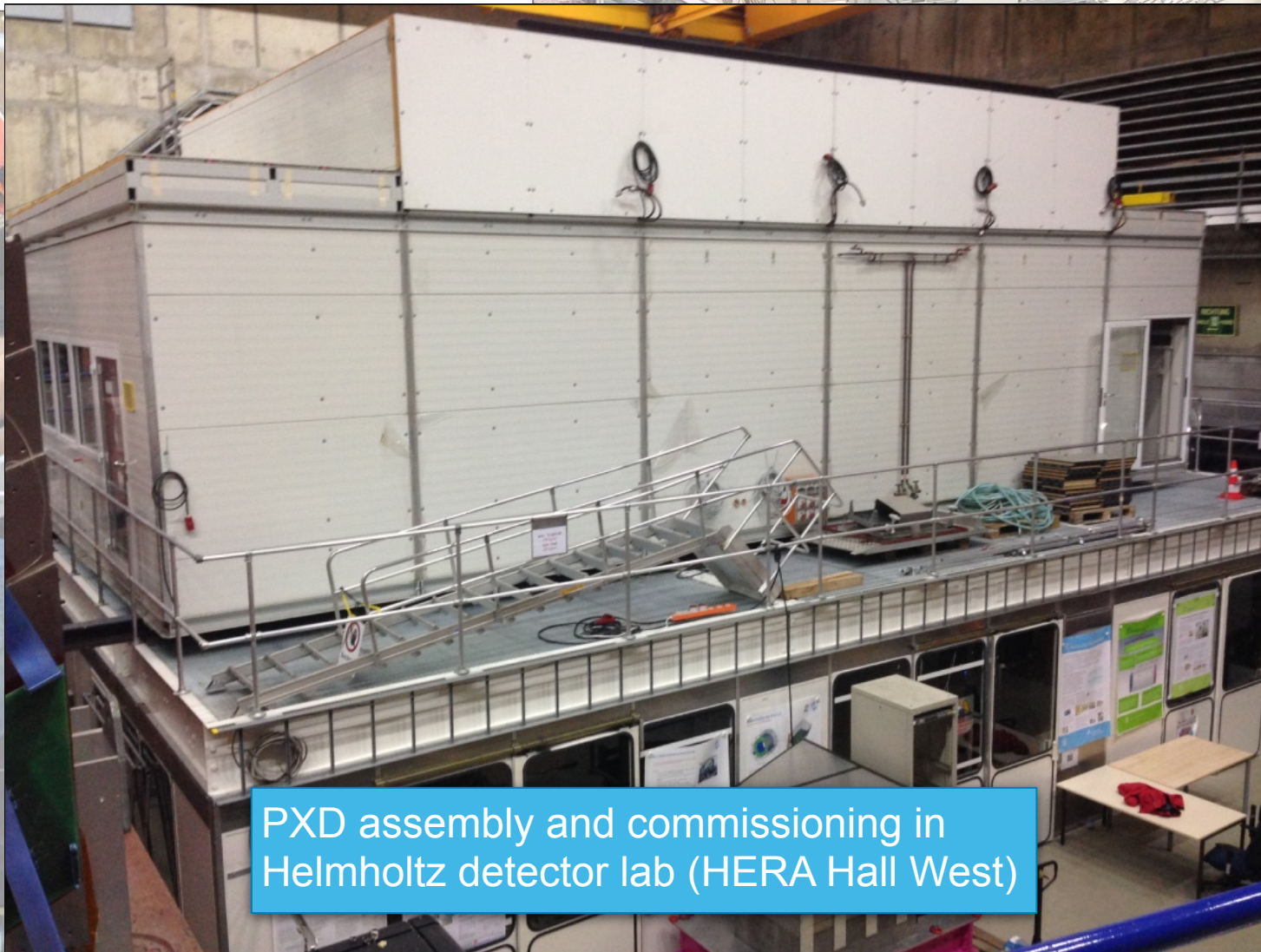
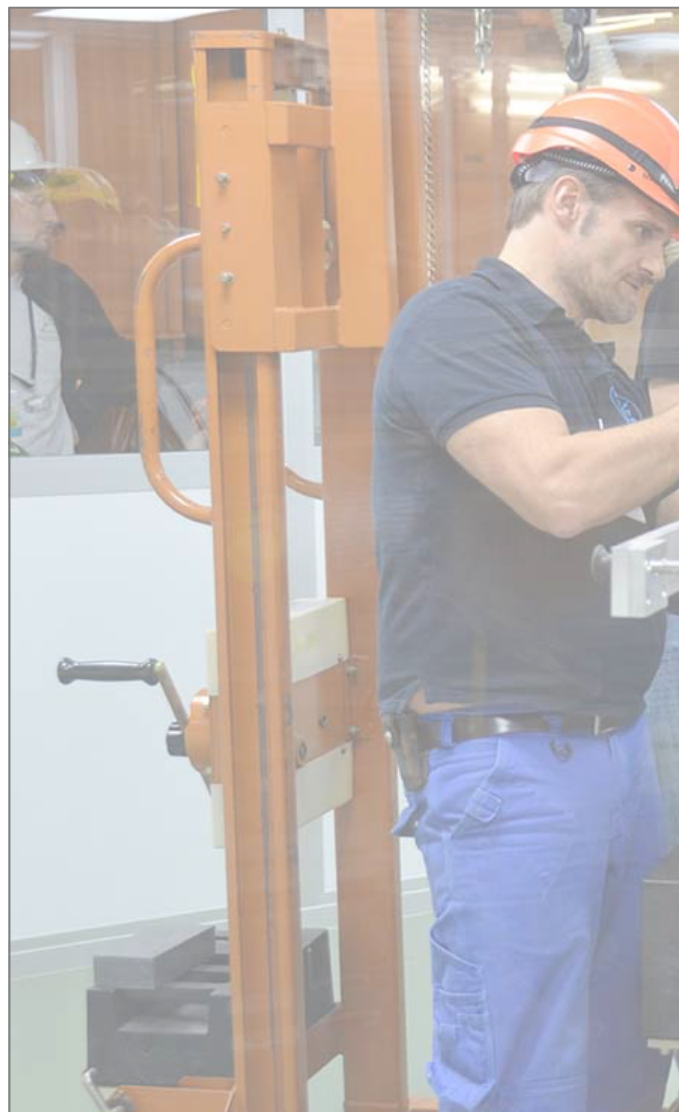
BEAST II Installation at KEK

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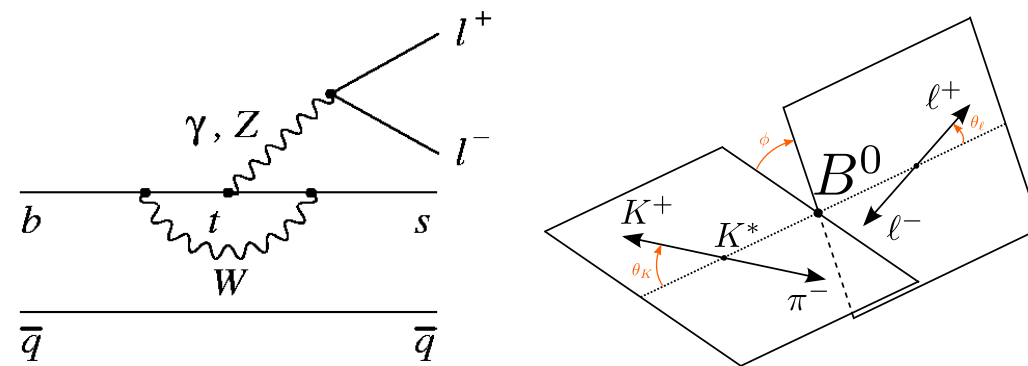
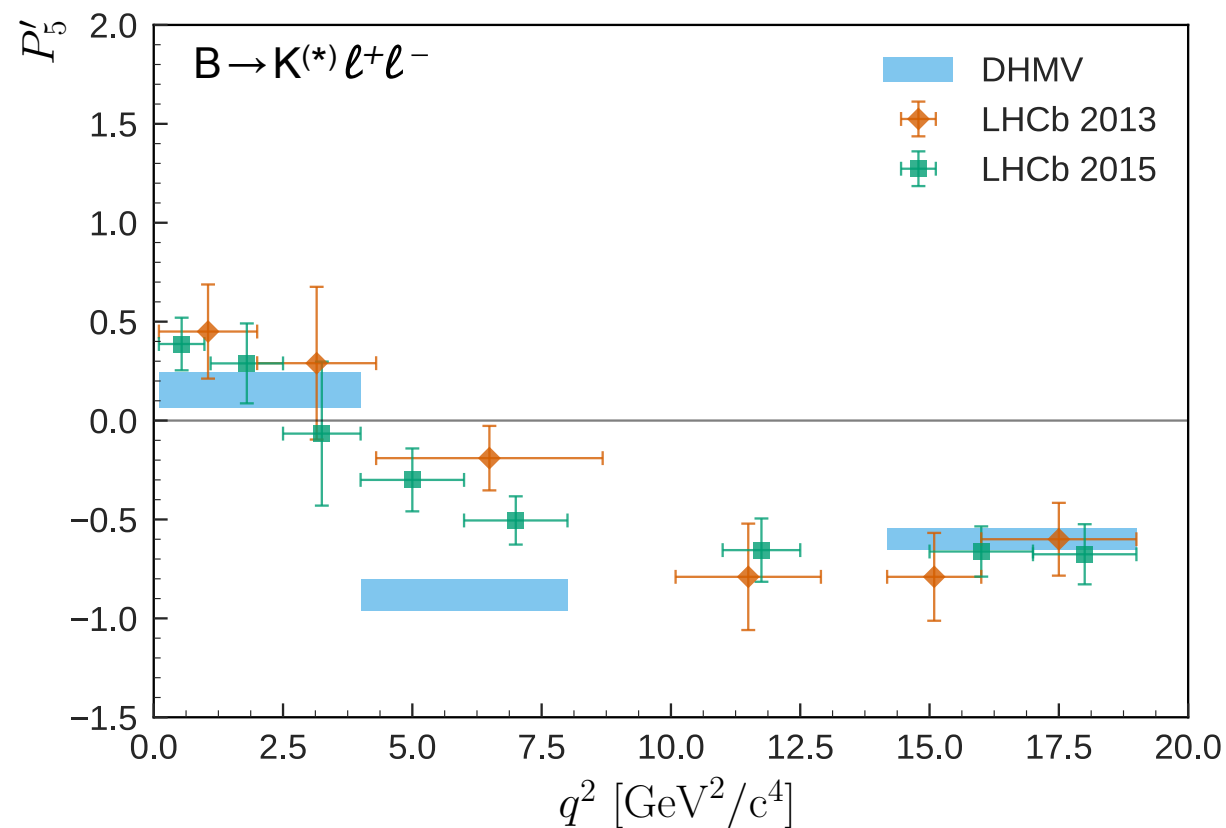
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Analysis of Belle Data

Shedding light on the puzzle of flavour anomalies

Recent observation of several **anomalies** in flavour physics
(1st generation B-factories, LHCb, ...)

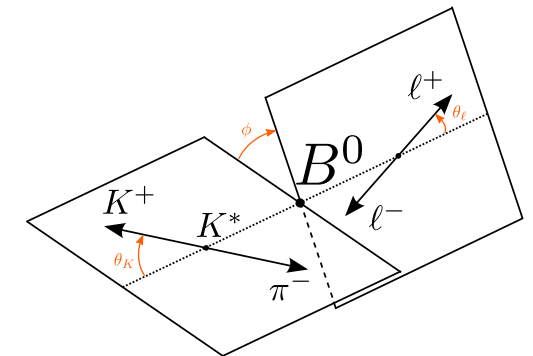
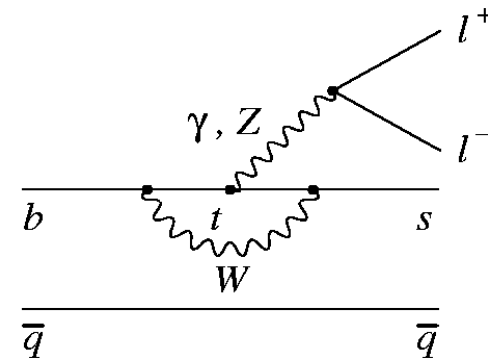
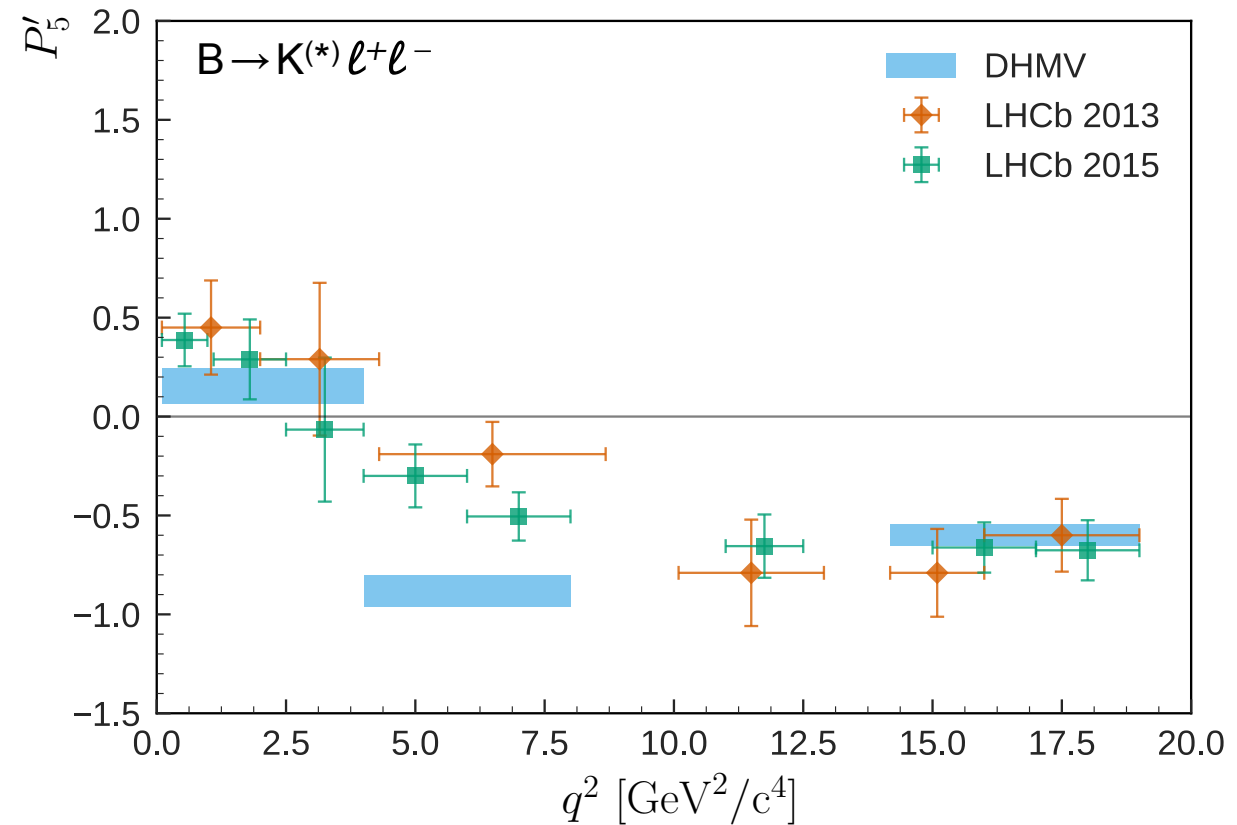


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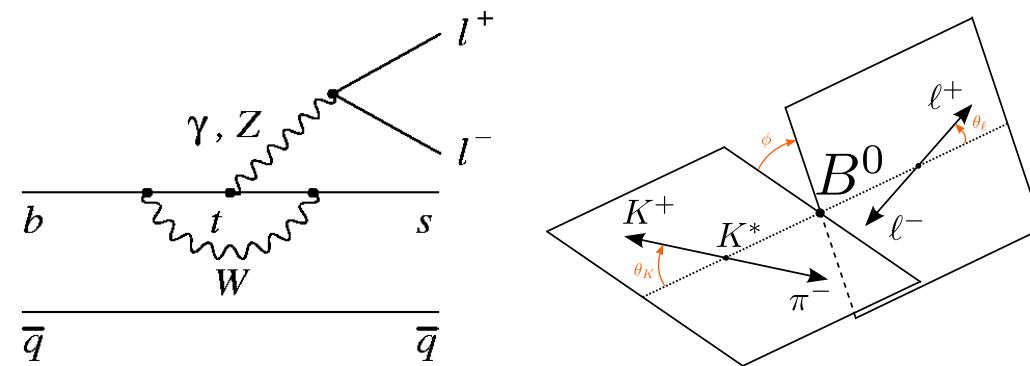
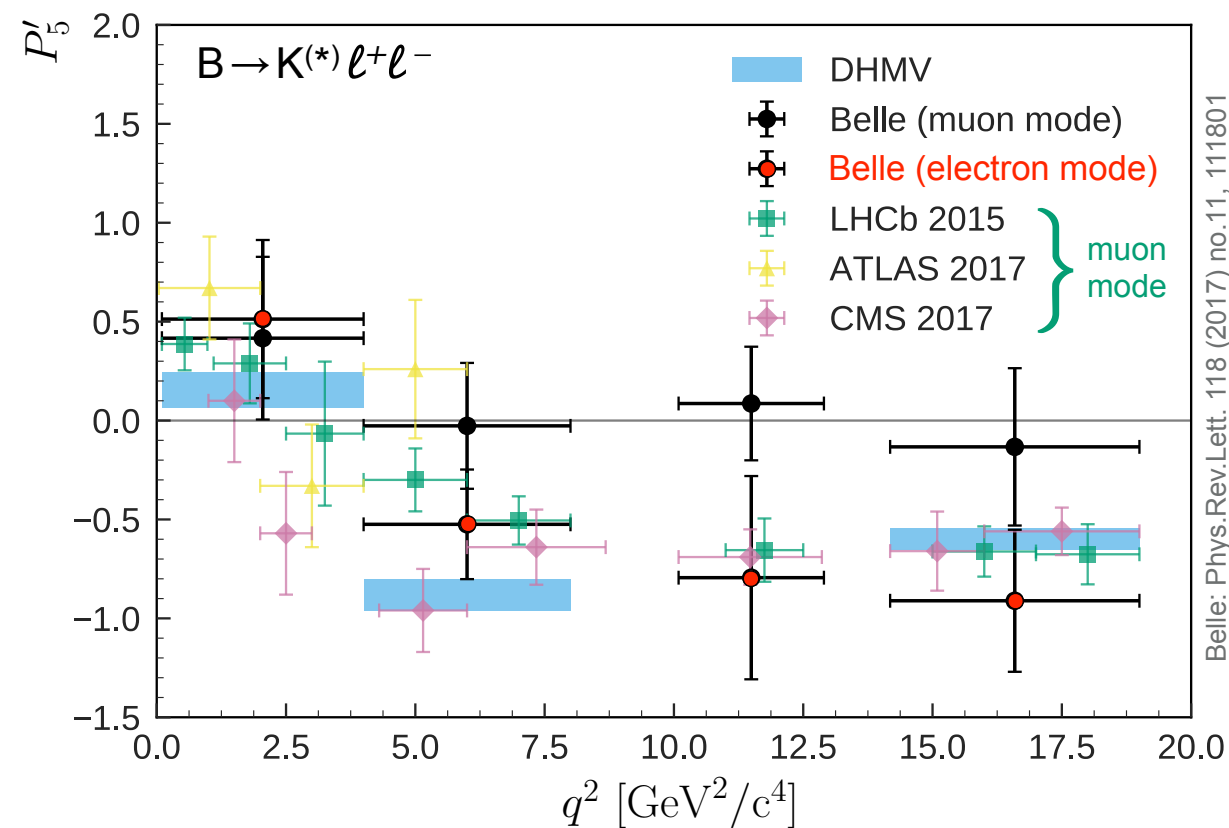
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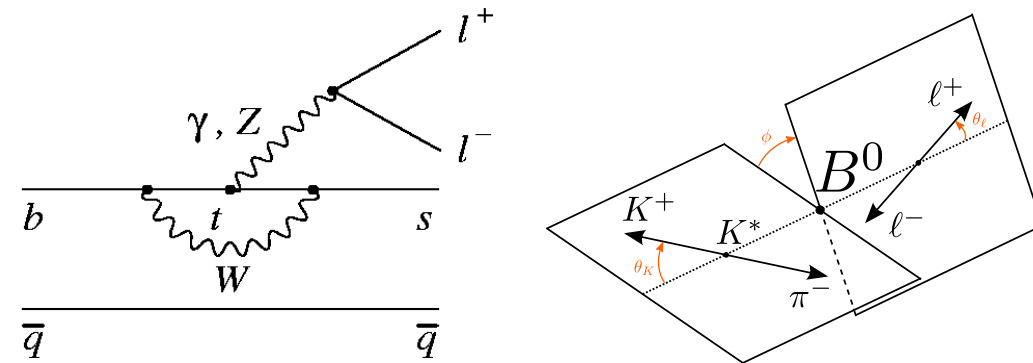
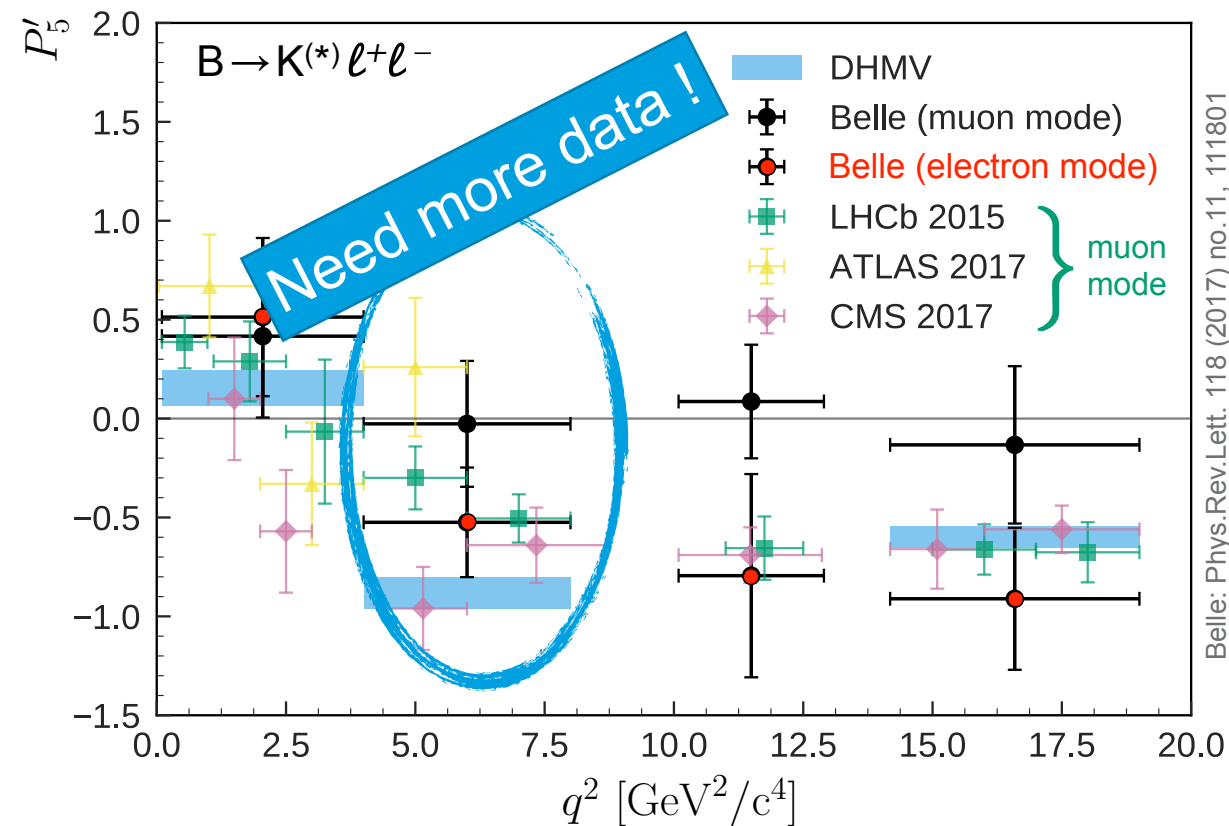
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Future Analysis Plans

Search for BSM Physics in several directions

*Computing
Infrastructure
Grid & NAF*

Future Analysis Plans

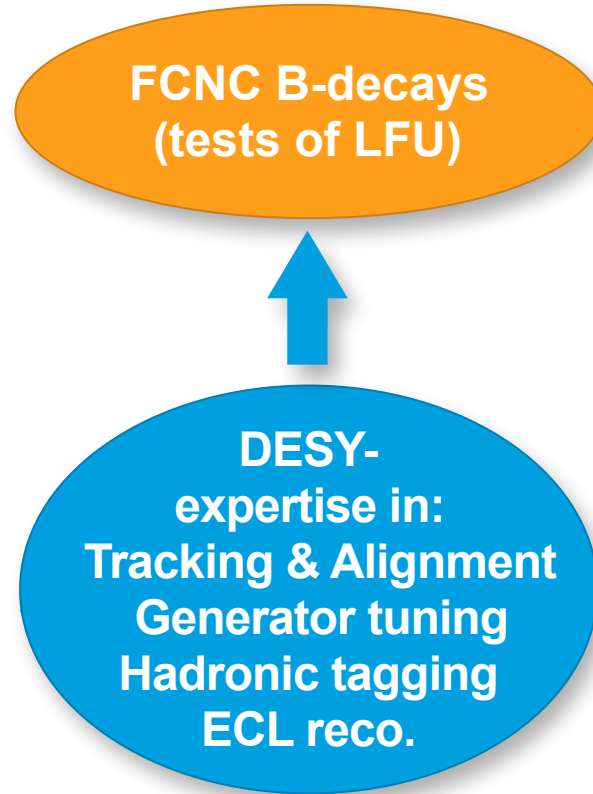
Search for BSM Physics in several directions



DESY-
expertise in:
Tracking & Alignment
Generator tuning
Hadronic tagging
ECL reco.

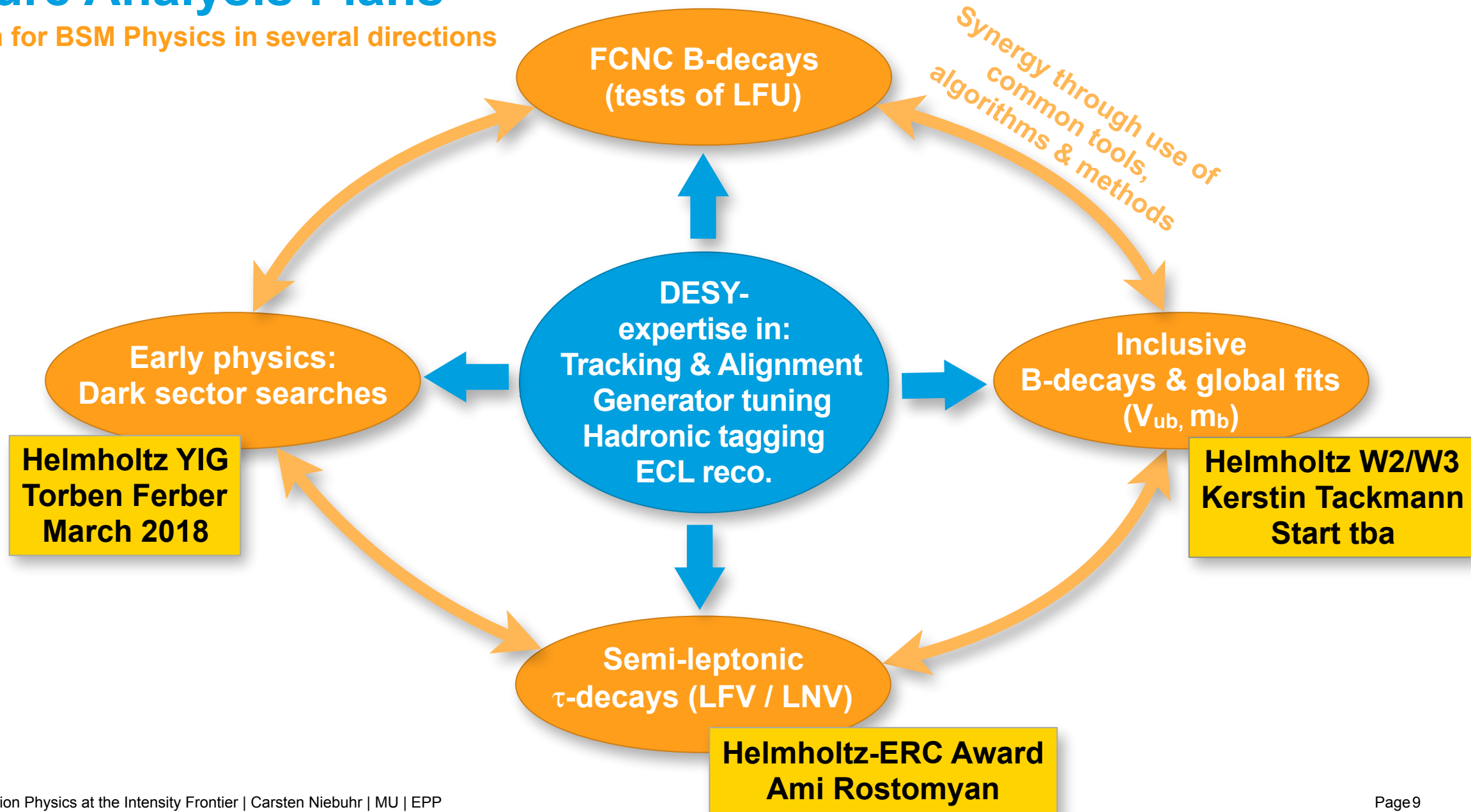
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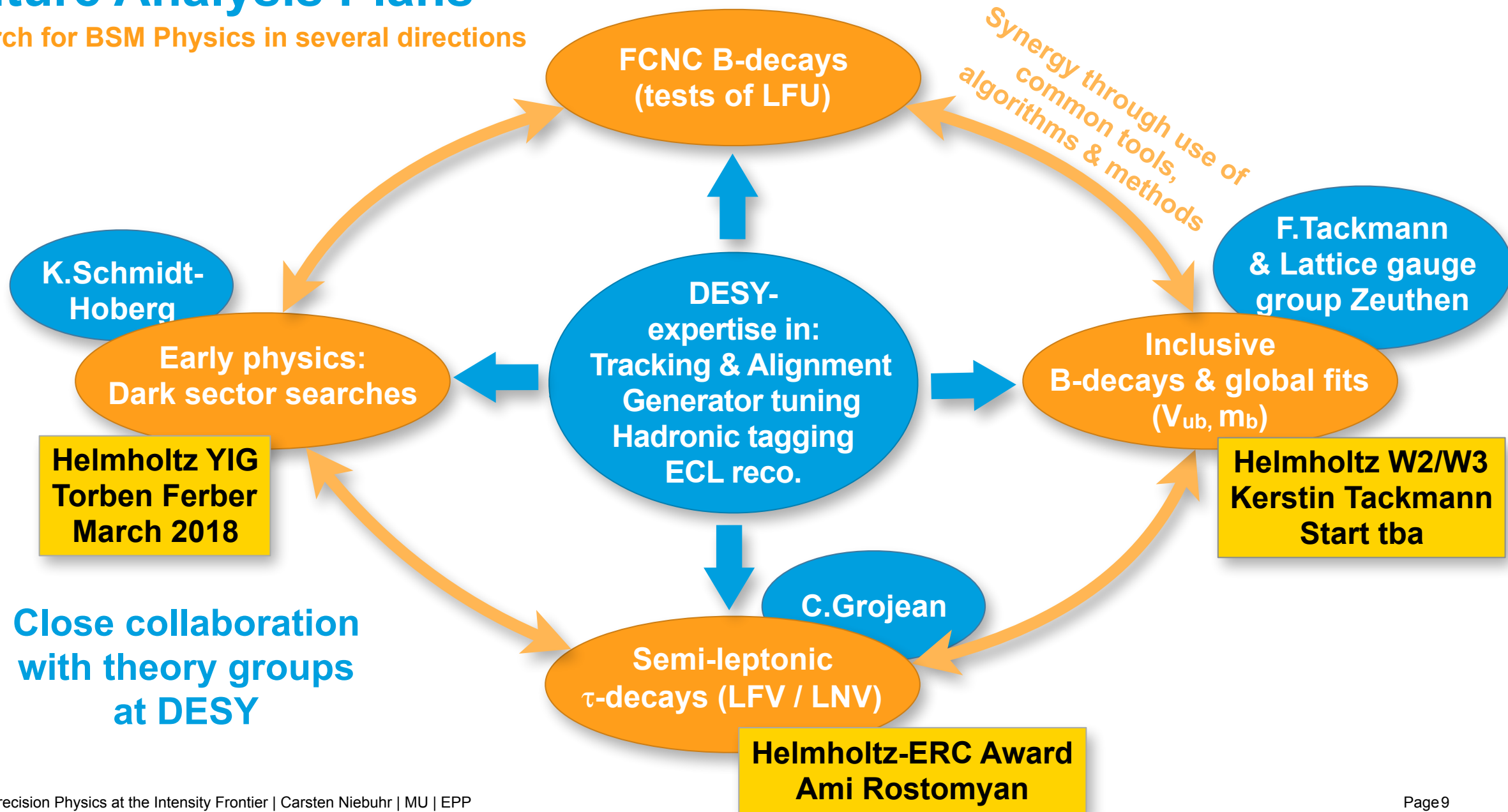
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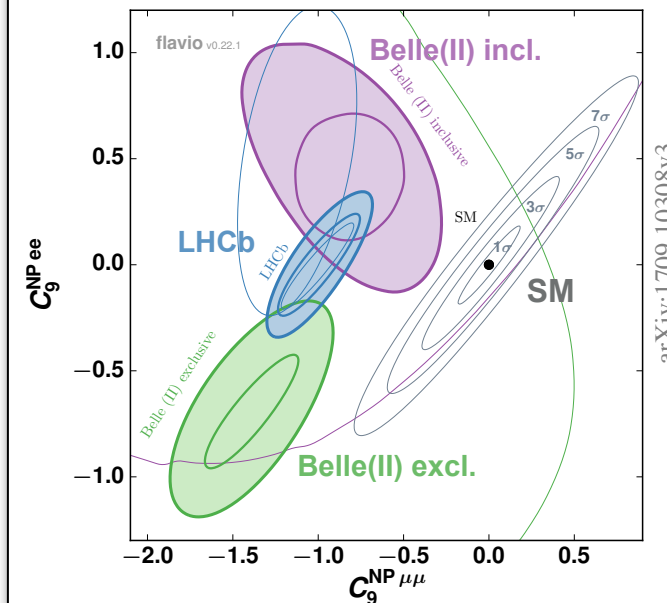
Summary and Outlook

Precision physics as a tool for discovery

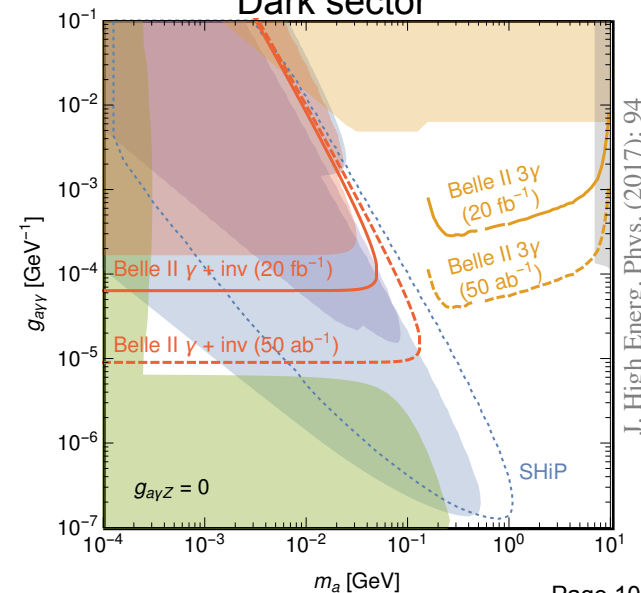
- Challenging upgrade projects SuperKEKB and Belle II are nearing completion
 - Excellent prospects for BSM searches in flavour physics
- DESY is playing a key role in
 - VXD commissioning and integration
 - Machine-detector interface
 - Computing
 - Software development and physics analysis
- Activities are an ideal preparation for potential participation at a future high energy e^+e^- collider

Prospects for BSM Searches

LFU tests in $b \rightarrow s\ell\ell$



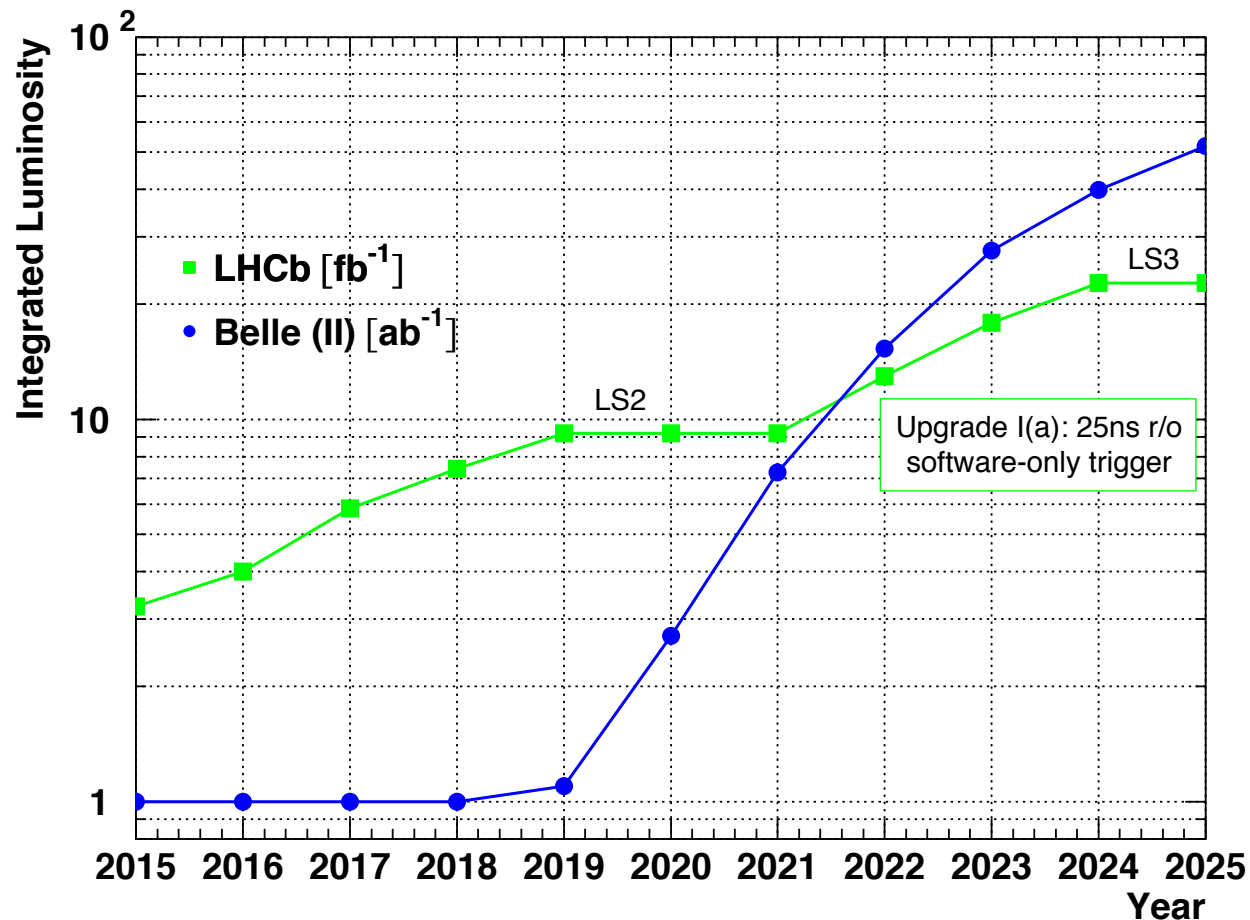
Dark sector



Backup

LHCb vs Belle II

Competition & Complementarity



<ul style="list-style-type: none"> • B_s System • CPV in $J/\psi\phi$, $\phi\phi$, CPV in Mixing • $B \rightarrow \mu\mu$ 	LHCb	B_s & charged tracks
<ul style="list-style-type: none"> • CKM phase γ in $B \rightarrow DK$ • CPV in B_d • $B \rightarrow X_s \ell\ell$ (exclusive) • $B \rightarrow X\gamma$ (exclusive) • Charm physics • Semi-leptonic B decays 		Important cross checks
<ul style="list-style-type: none"> • τ - physics: LFV • $B \rightarrow D, D^* \tau \nu$ • $B \rightarrow X_s \ell\ell$ (inclusive) • $B \rightarrow X\gamma$ (inclusive) • $B \rightarrow \tau \nu, \mu \nu$ • $B \rightarrow K^* \nu \nu, B \rightarrow \nu \nu$ 	Belle II	inclusive & neutrals

Table adapted from J.Albrecht, DESY Seminar 25.10.16

- Very healthy competition between LHCb and Belle II
- Complementary approaches but physics programs have also significant overlap for cross checks in important areas

SuperKEKB & Belle II

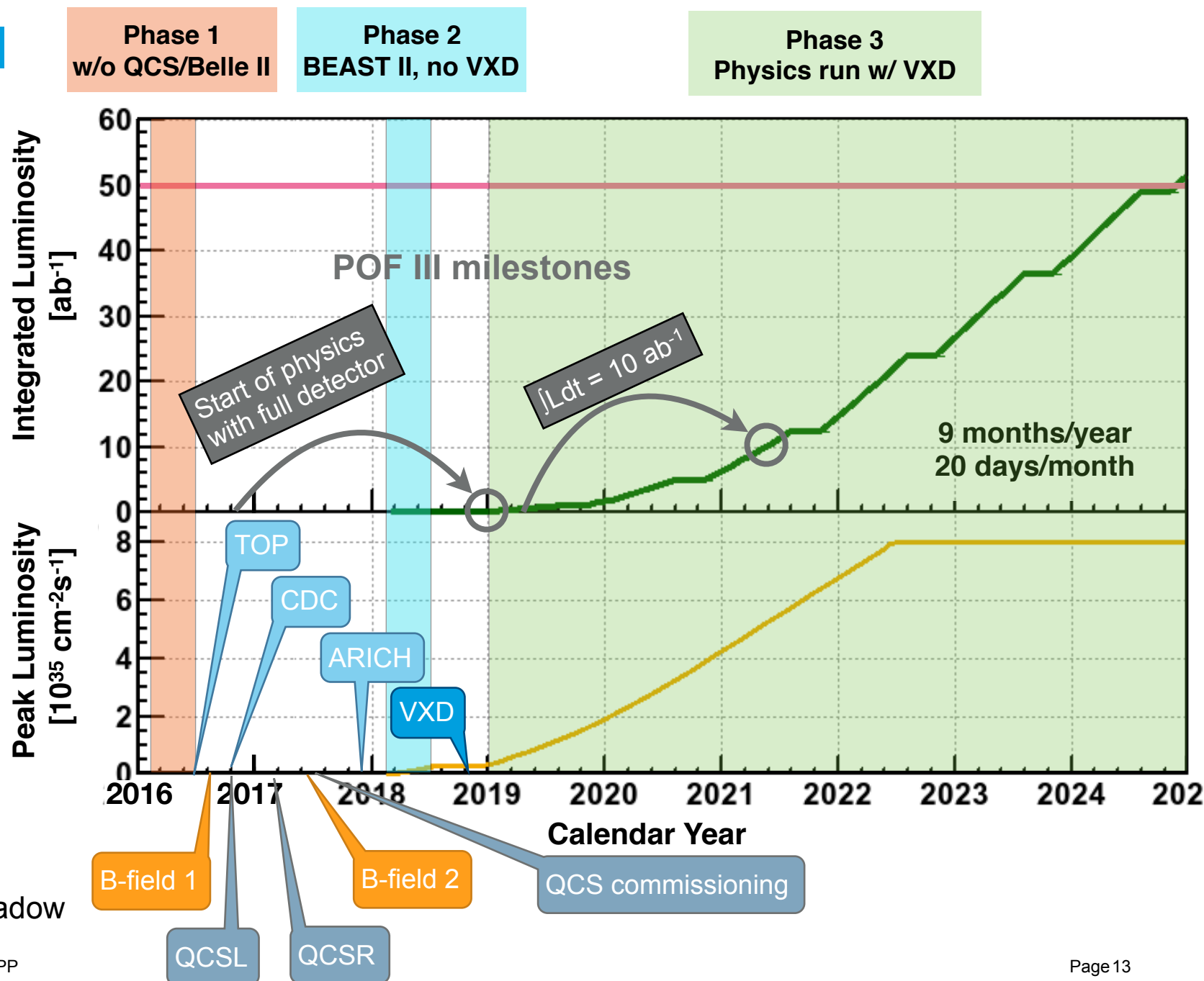
Luminosity projection and milestones

Commissioning in 3 phases

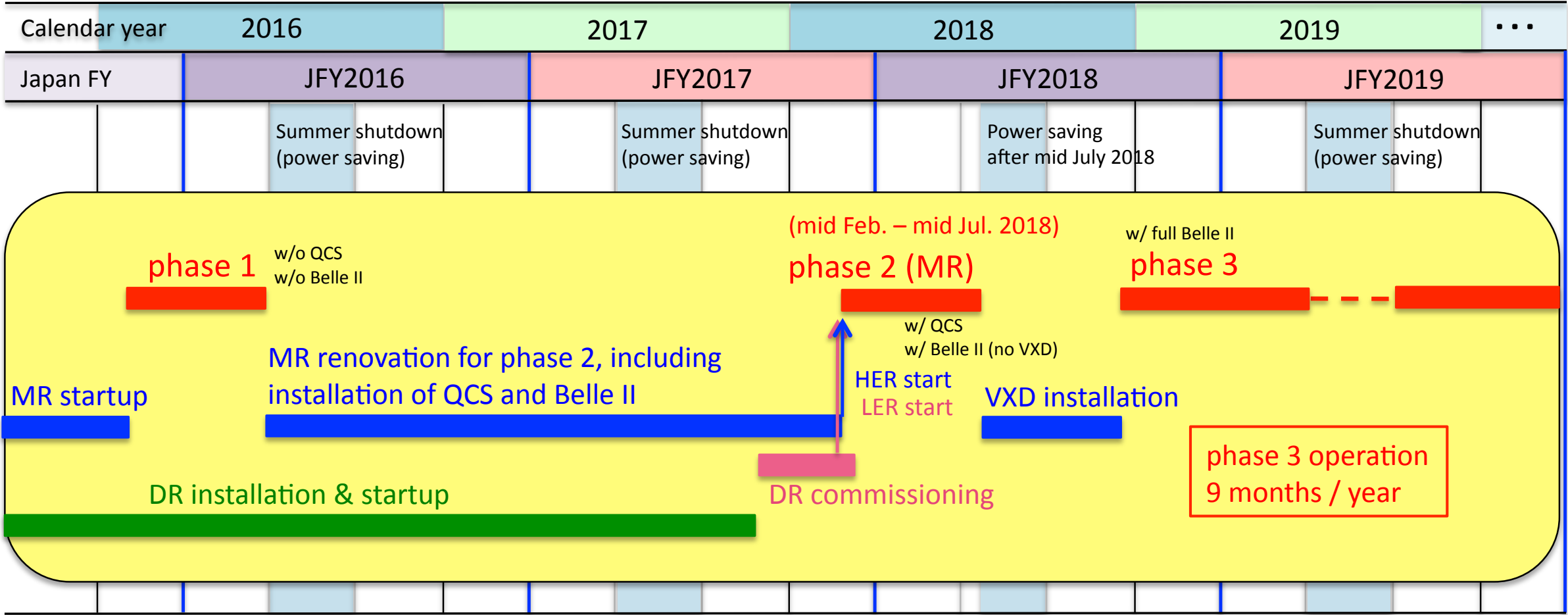
- Phase 1 [*accomplished in 2016*]
 - w/o Belle II, no collisions
 - operate MR, vacuum scrubbing
 - first background studies
- Phase 2 [*imminent Feb-Jul 2018*]
 - nano-beam scheme operation
 - reach $10^{34}\text{cm}^{-2}\text{s}^{-1}$ (KEK design)
 - verify background models and ensure safe conditions for VXD: BEAST II
 - hope for $\sim 20\text{fb}^{-1}$ of physics data
- Phase 3 [*start beginning 2019*]
 - physics run with full detector

Schedule driven by the machine

- Detector installations proceed in the shadow



SuperKEKB Schedule Details



Belle II Computing at DESY

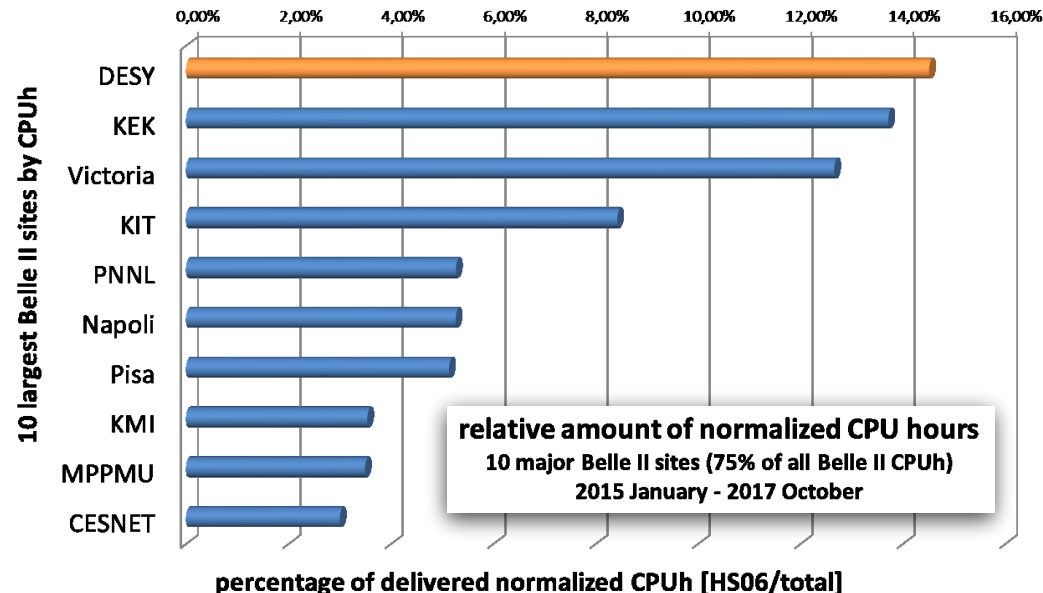
Providing 50% of the German contribution to Belle II Grid resources

Belle II @ DESY Grid Site

- DESY provides **half** of the requested German resources
 - for 2018+9: (70 kHS06, 2.2 PB) x 0.5
 - MoU in preparation for Raw & Regional Data Center
- The **National Analysis Facility (NAF)** complements the Grid for **interactive data analysis** and supports Belle II members

Full suite of collaborative services and tools was migrated from KEK to DESY in 2016/17:

- Content Mgmt: ZMS
- Wiki: Confluence
- Issue tracking: JIRA
- Version control: Stash / GIT
- Mailing lists: Sympa
- Document service: Invenio
- Electronic logbook: eLog
- Build System: Bamboo / Buildbot
- Membership Mgmt: B2MMS / IAM
- Knowledge database: AskBot
- Analysis framework: Jupyter

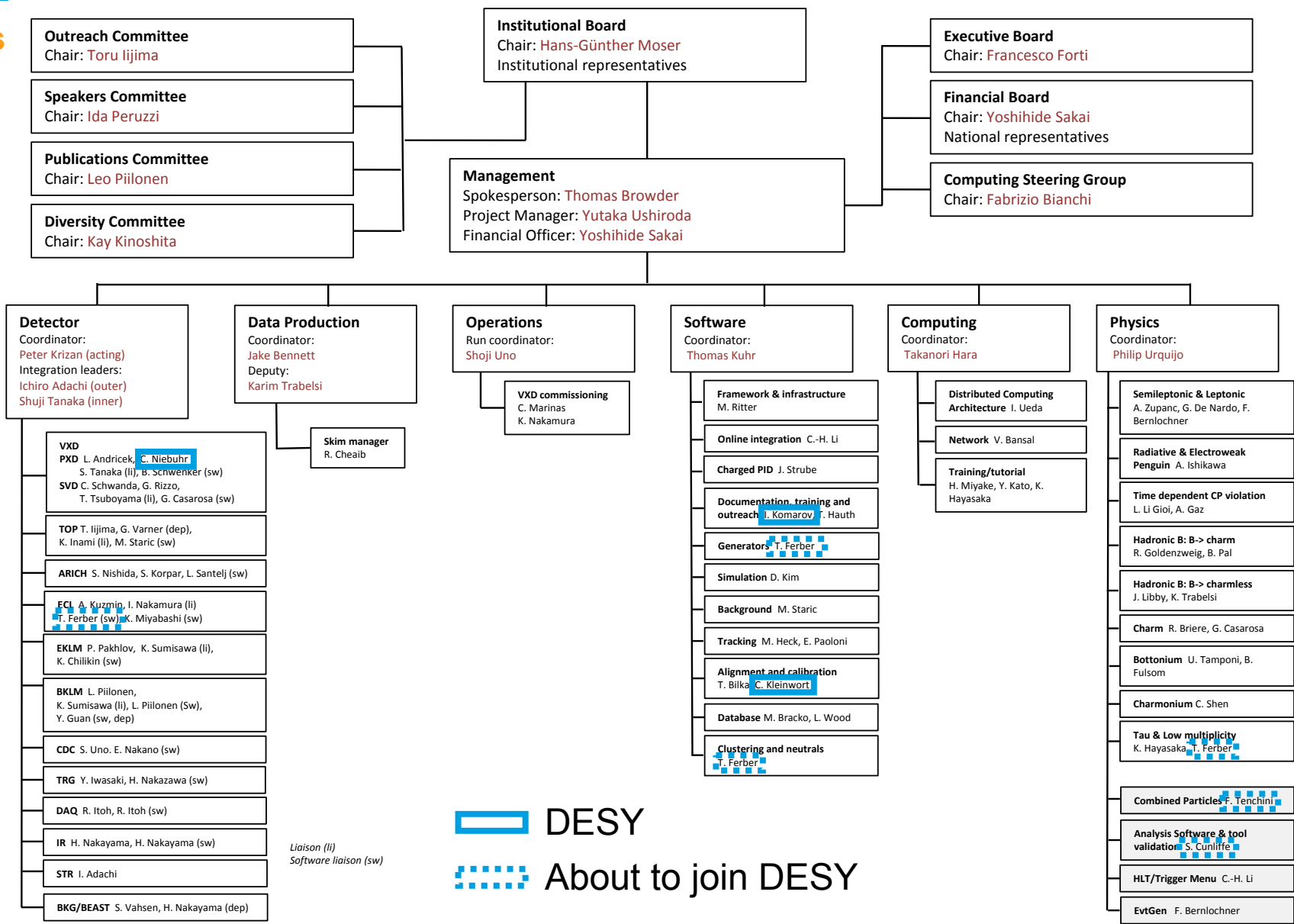


Belle II Organization

Coordinating roles of DESY members

Key responsibilities in many areas

- Detector
 - PXD project
 - ECL reconstruction
- Software
 - Documentation, training & outreach
 - Generators
 - PYTHIA8 tuning
 - Alignment & calibration
 - Clustering & neutrals
- Physics
 - Tau & low multiplicity
 - Combined particles
 - Analysis software & tool validation



 DESY
 About to join DESY