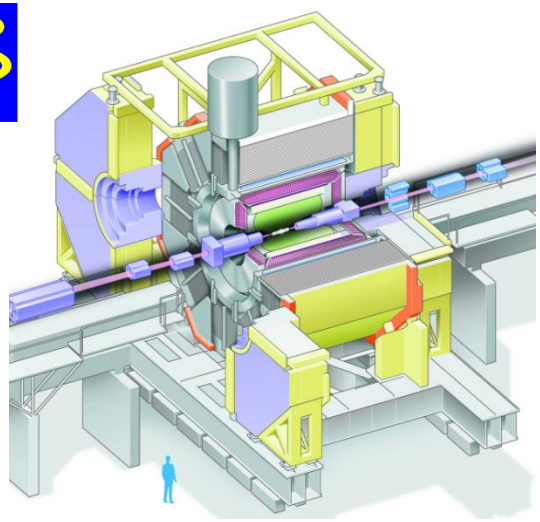
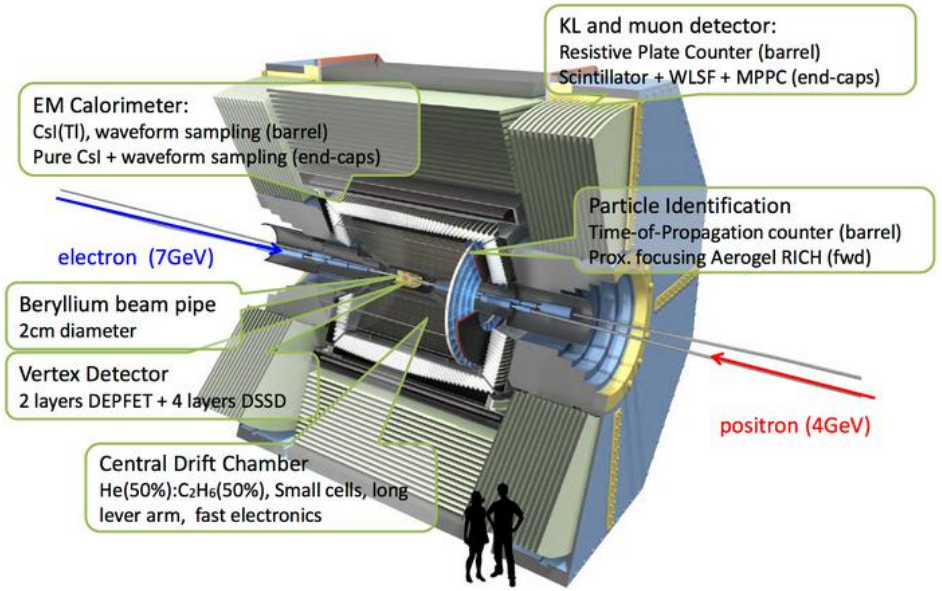
Belle & Belle II Activities

Hua YE
on behalf of DESY Belle II Group

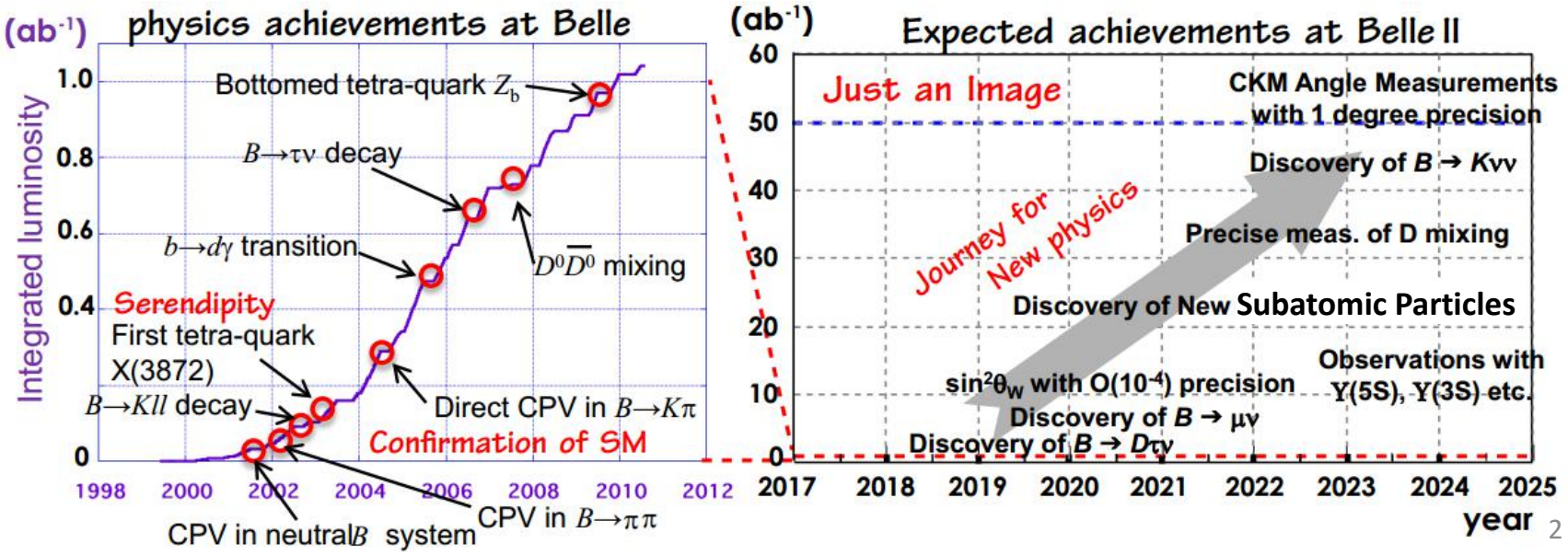
82nd PRC Open Session
20/10/2016, DESY Zeuthen

From Belle to Belle II

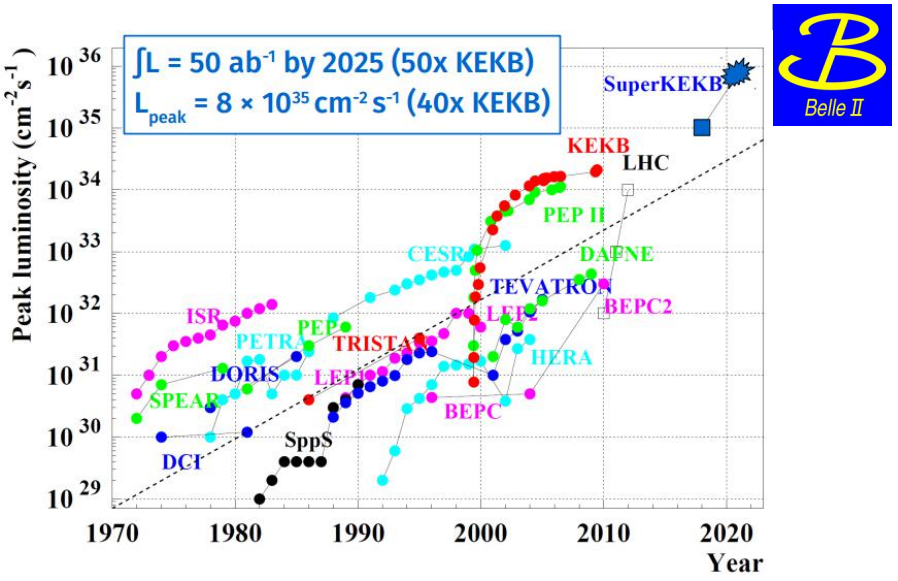


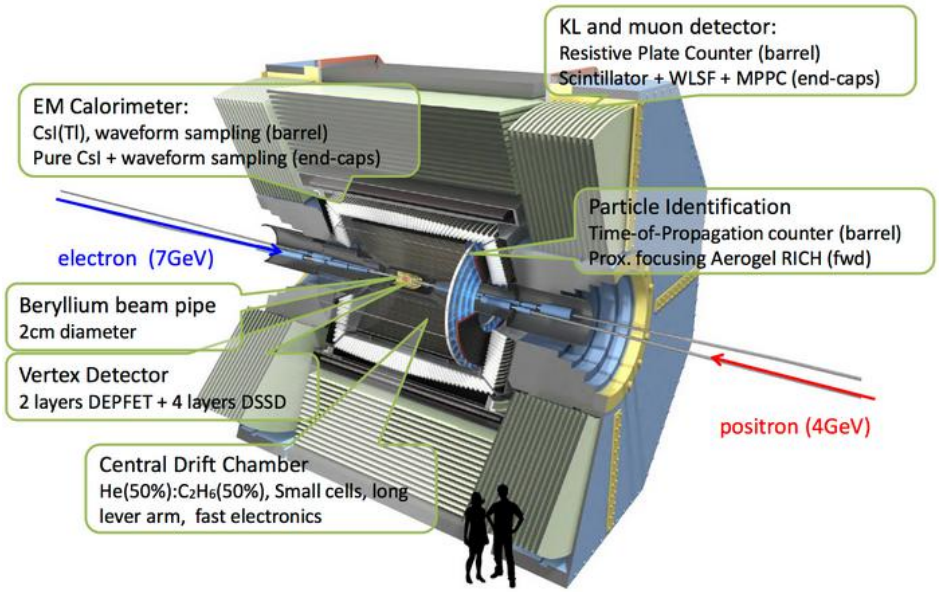


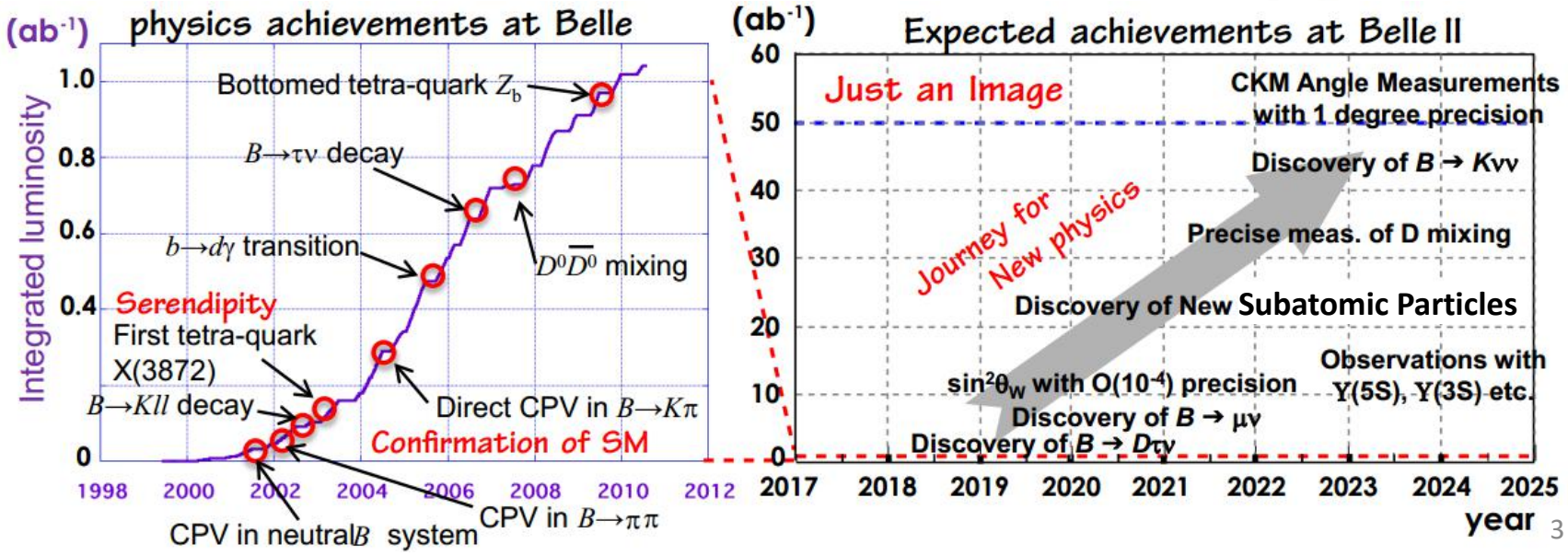
Belle achieves >450 Physics Journal Publications



From Belle to Belle II



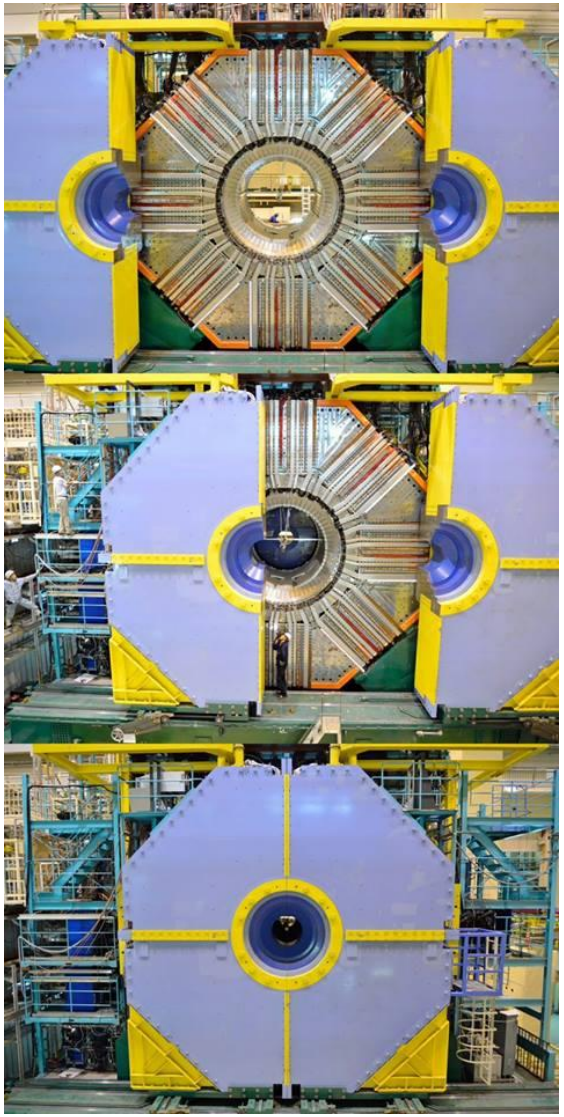




Outline

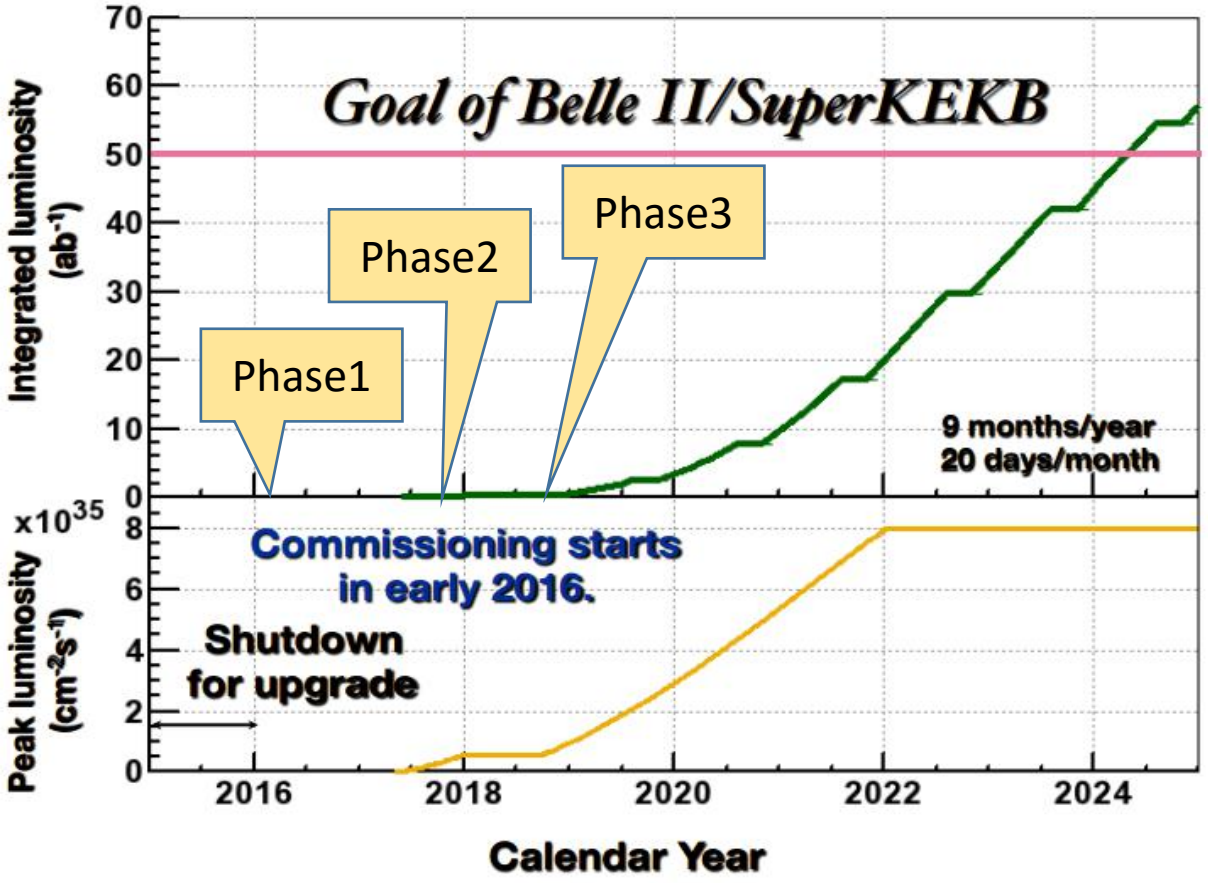
DESY Belle II group contributes in

- Hardware
  - B-field measurements
  - Belle II vertex detector
    - Integration
    - Mechanics and Cooling performance
    - Beam Tests
    - ...
- Analysis and Software
  - Belle analyses
    - $B \rightarrow K^{*}ll$
    - Dark Photon searches
    - ...
  - Belle II analyses
    - in preparation
  - PYTHIA8 Generator tuning
  - Track reconstruction, alignment and calibration
  - Background simulation
  - K_L^0 identification
- Computing
  - GRID and MC Campaigns
  - Collaborative services
  - ...

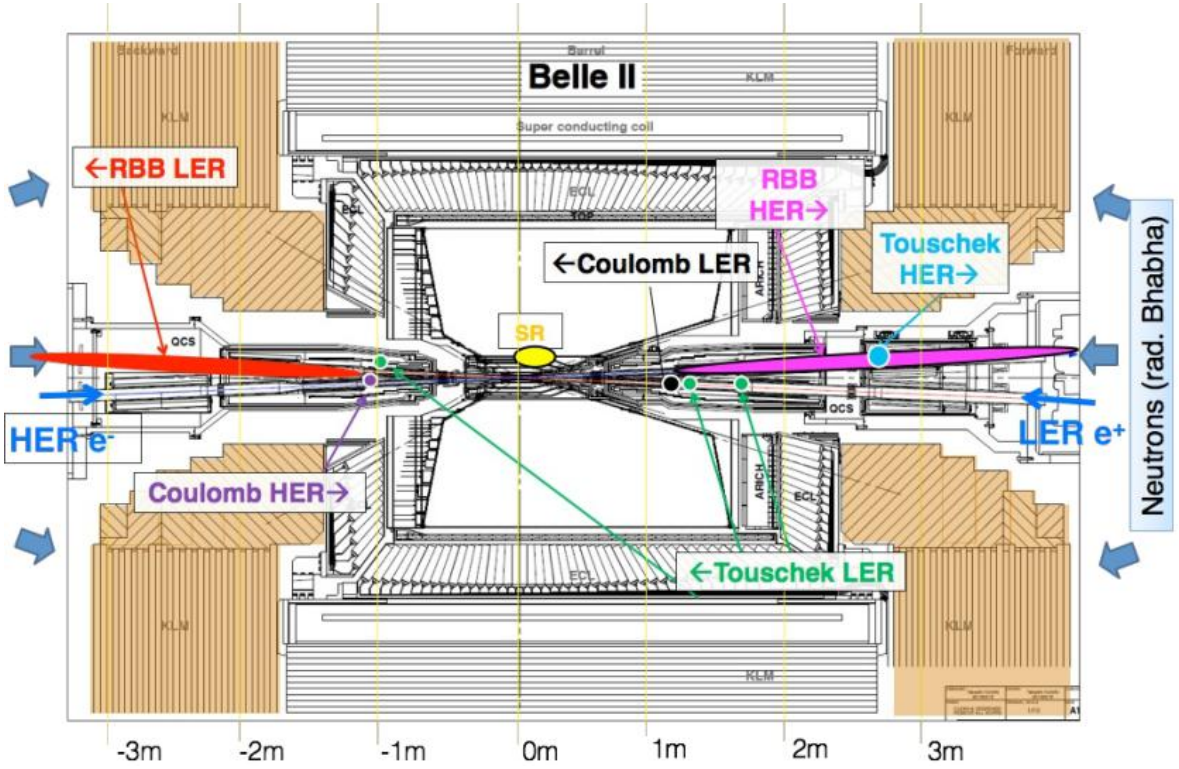


SuperKEKB Commissioning Schedule

- Phase 1: Beam commissioning, without collisions & Belle II (Successfully done)
- Phase 2: partial Belle II is rolled in (without full VXD), collision tuning starts.
- Phase 3 – Physics Run: Full Belle II with VXD



Beam Induced Background & synchrotron radiation (SR) simulation



DESY group is working on the simulation of SR to predict levels of background in each subdetector for each commissioning phase and compare them with measured rates.

- ☐ Phase 1 : No simulated hits found in all systems : upper limits of hit rates - 500Hz. Primary online measurements didn't show the presence of SR.
- ☐ Phase 2 :

Simulation is performed for all subdetectors. The prediction of hit rates for VXD is done.

Hardware

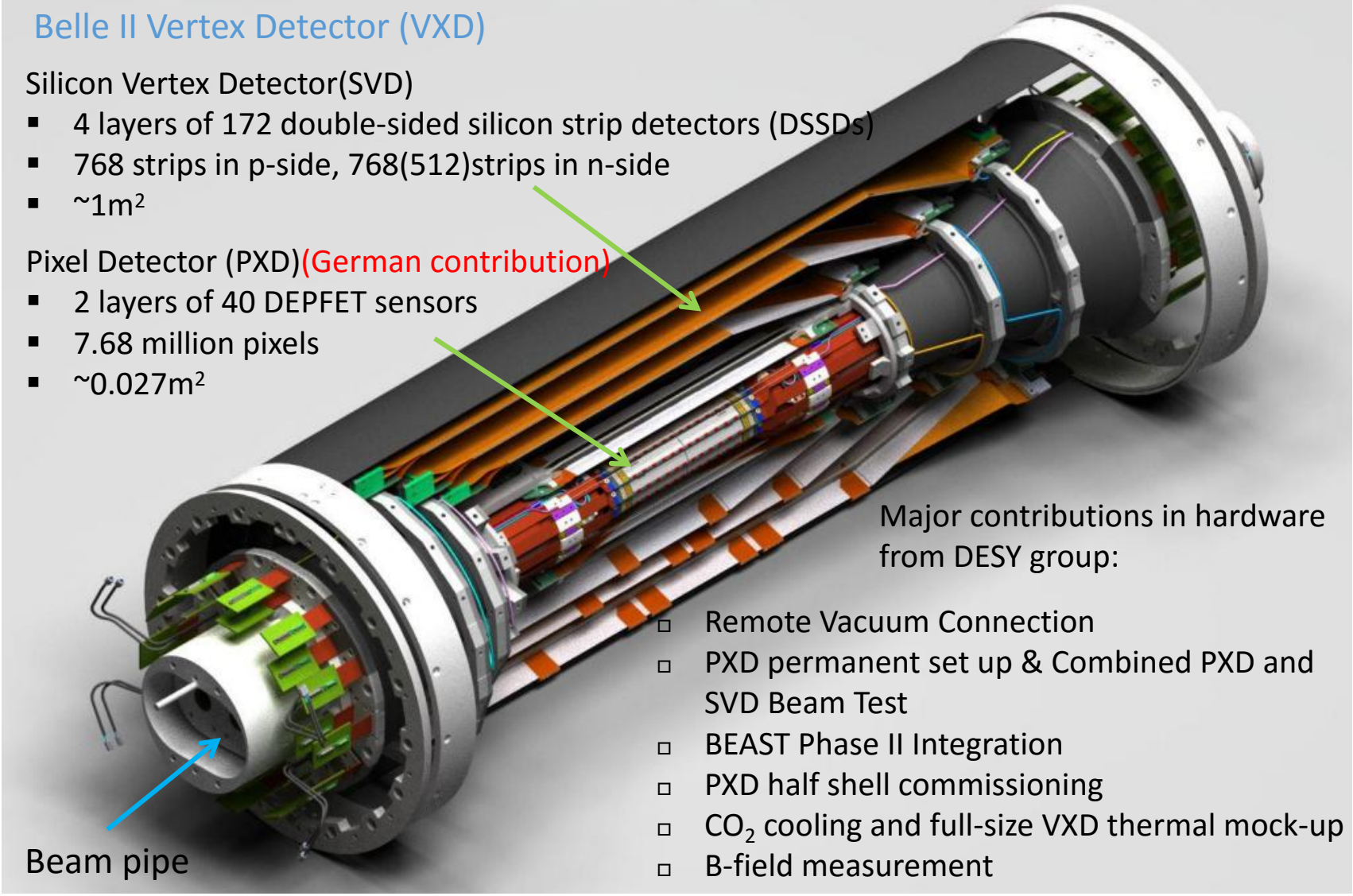
Belle II Vertex Detector (VXD)

Silicon Vertex Detector(SVD)

- 4 layers of 172 double-sided silicon strip detectors (DSSDs)
- 768 strips in p-side, 768(512)strips in n-side
- ~1m^2

Pixel Detector (PXD)(German contribution)

- 2 layers of 40 DEPFET sensors
- 7.68 million pixels
- ~0.027m^2



Major contributions in hardware from DESY group:

- Remote Vacuum Connection
- PXD permanent set up & Combined PXD and SVD Beam Test
- BEAST Phase II Integration
- PXD half shell commissioning
- CO_2 cooling and full-size VXD thermal mock-up
- B-field measurement

SuperKEKB Commissioning Phase II

Beam Exorcism for A STable experiment (BEAST II) :

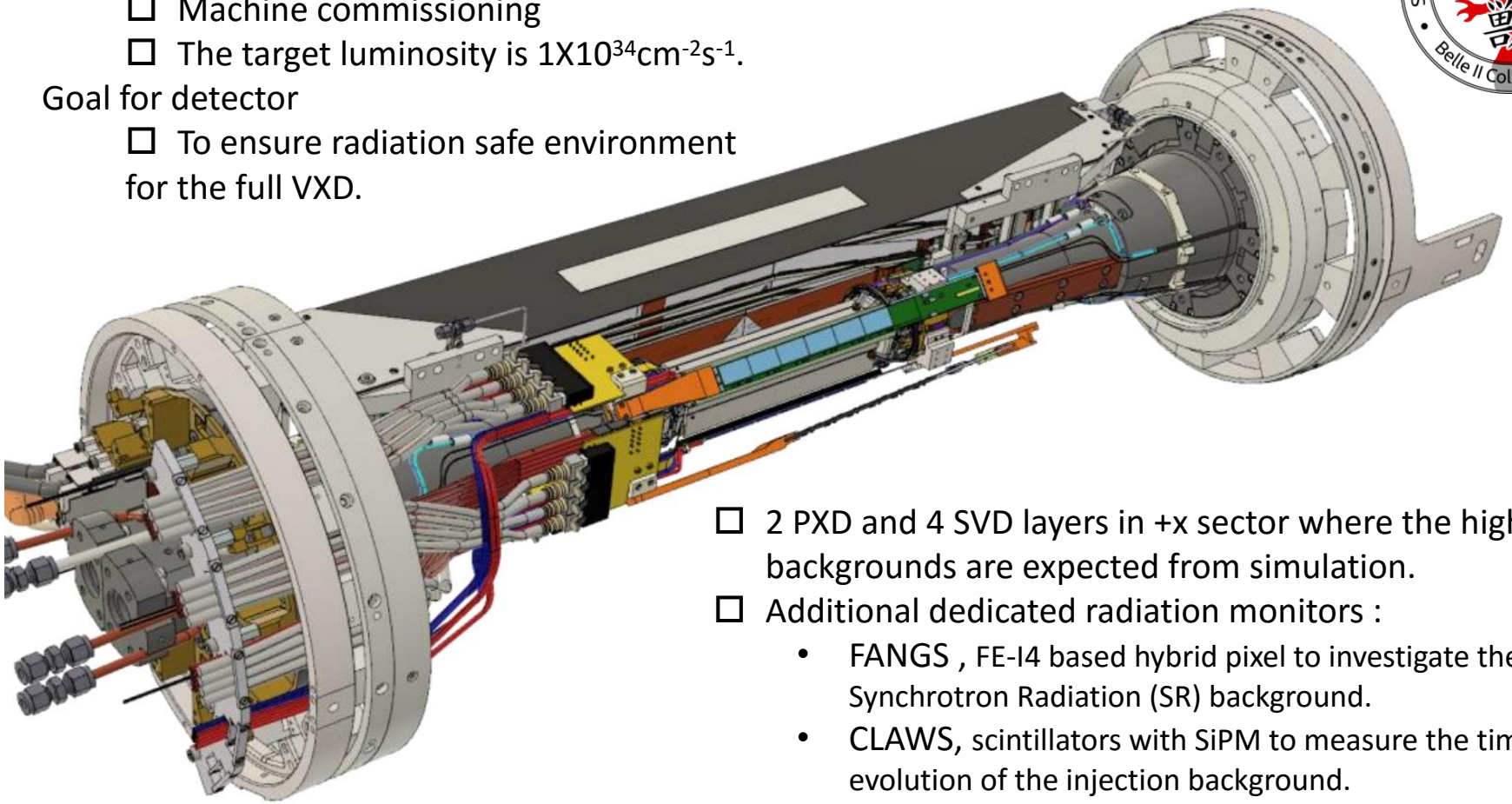
To characterize beam-induced backgrounds near the interaction point (IP)

Goal for accelerator

- ☐ Machine commissioning
- ☐ The target luminosity is $1X10^{34}cm^{-2}s^{-1}$.

Goal for detector

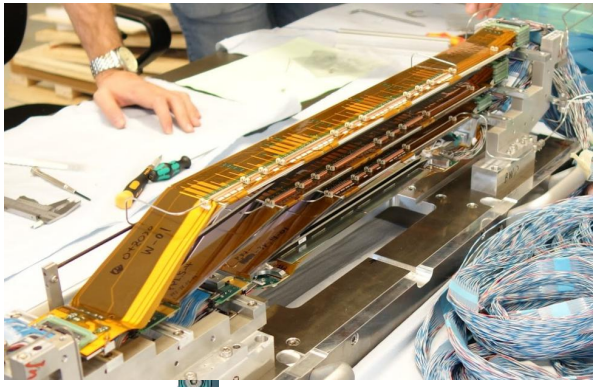
- ☐ To ensure radiation safe environment for the full VXD.

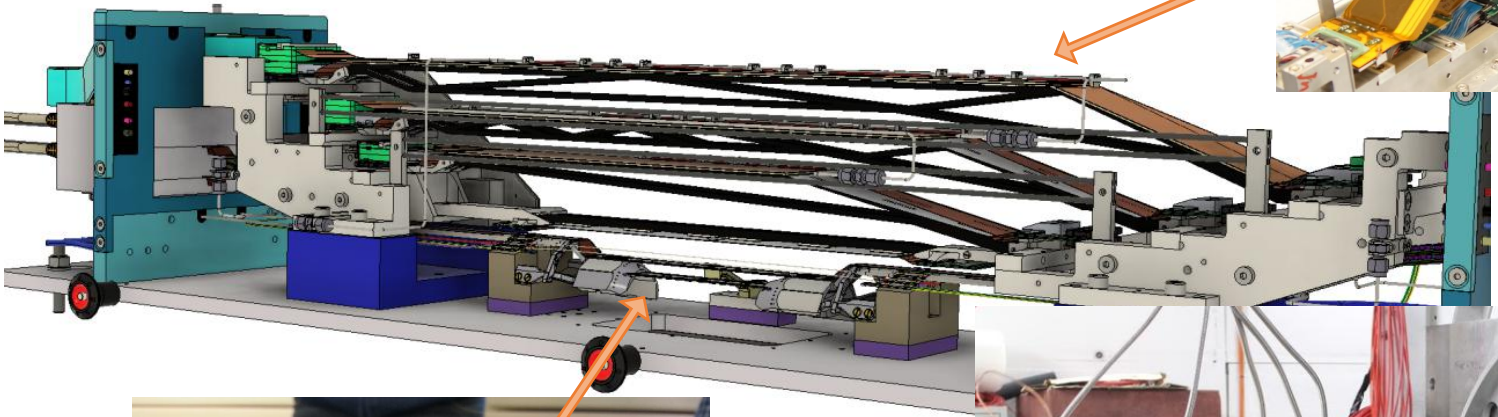


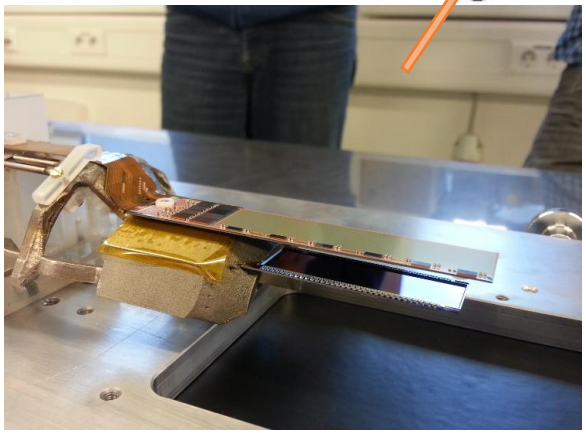
- ☐ 2 PXD and 4 SVD layers in +x sector where the highest backgrounds are expected from simulation.
- ☐ Additional dedicated radiation monitors :
  - FANGS , FE-I4 based hybrid pixel to investigate the Synchrotron Radiation (SR) background.
  - CLAWS, scintillators with SiPM to measure the time evolution of the injection background.
  - PLUME, double-sided high granularity MIMOSA pixels

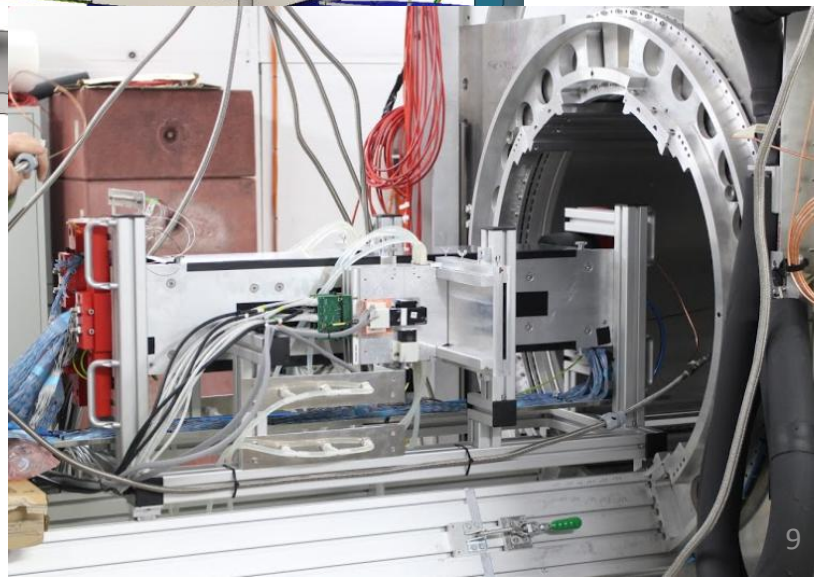
VXD Combined Beam Test @DESY in April

- 2 PXD + 4 SVD layers of the final sensors and ASICs were tested during the 4-week beam time
- Complete VXD readout chain: HLT, ROI, monitoring, event building, pocketDAQ, CO2 cooling, slow control, environmental sensors.
- Illumination with (up to) 6 GeV e^- under solenoid magnetic field (PCMAG)

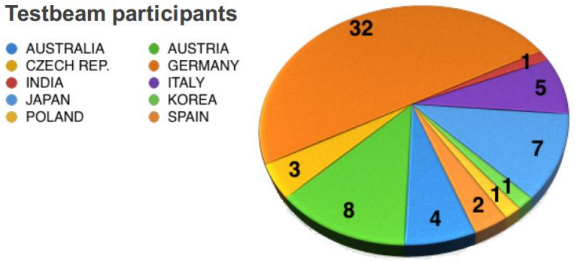






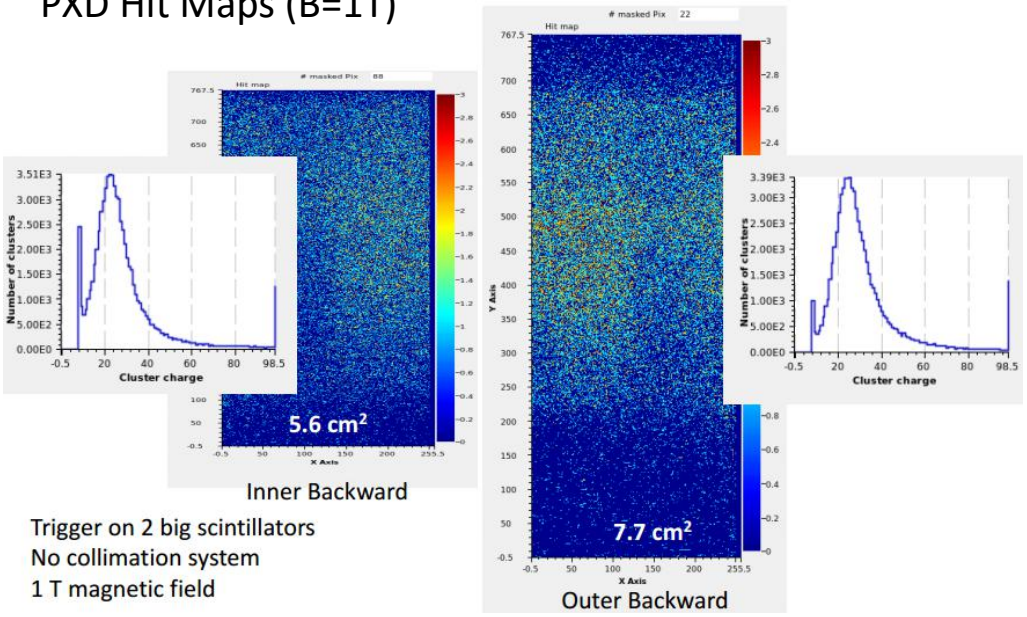


VXD Combined Beam Test @DESY in April

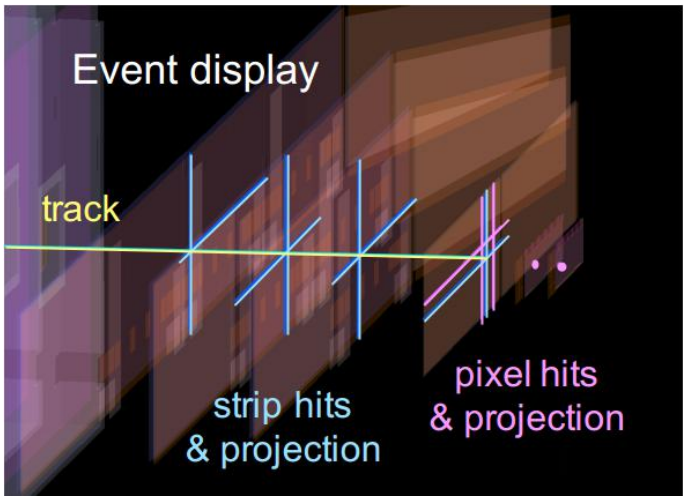


- SVD shows very high efficiency (>99%) for all strips.
- SVD L.3 : σ of 9.6(23.9)μm in rϕ(z) direction.
- PXD efficiency is high and close to expectation for both half-ladders (~95%).
- PXD resolution of 14.3(18.3) μm in rϕ(z) direction.

PXD Hit Maps (B=1T)



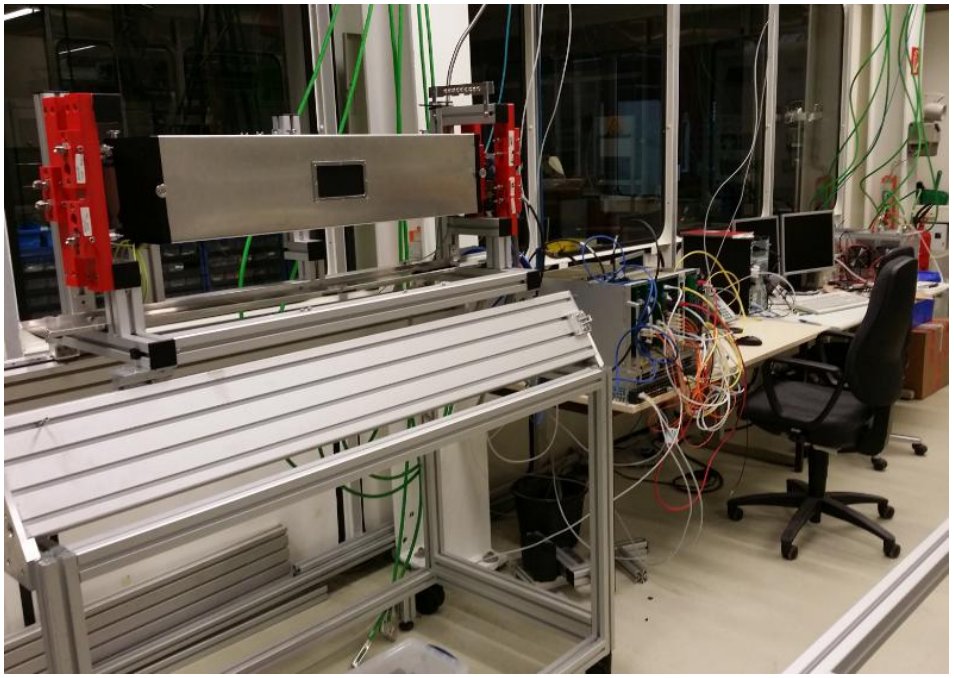
Trigger on 2 big scintillators
No collimation system
1 T magnetic field



BEAST Phase II preparations @DESY

- Detailed characterization of the April PXD modules is planed at DESY permanent setup, to have a complete and well understood set up running 24/7 in a lab accessible by the entire collaboration.
- Another combined VXD Beam Test at DESY is scheduled in 2017.
- PXD half shell commission at DESY. Integration and commissioning Phase 2 detector system before shipping to KEK.

Schedule	
2016 Oct.	• Integration the PXD permanent setup at DESY • PXD/VXD laser/radioactive source tests.
Nov.	• Dry box assembly • VXD modules, FANGS, CLAWS and PLUME installation and tests
2017 Feb./Mar.	• Test beam in TB24/1 @DESY2
May	• Sensors sent to KEK • Phase 2 VXD integration and commissioning

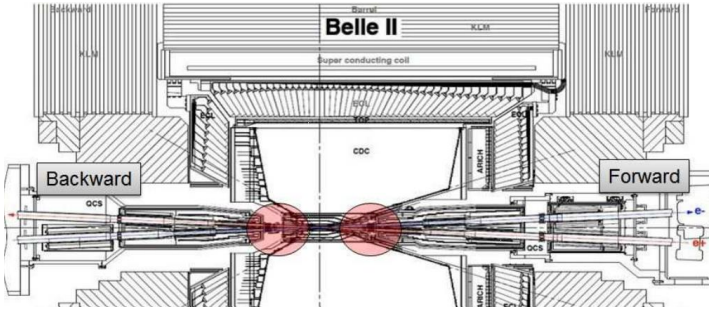


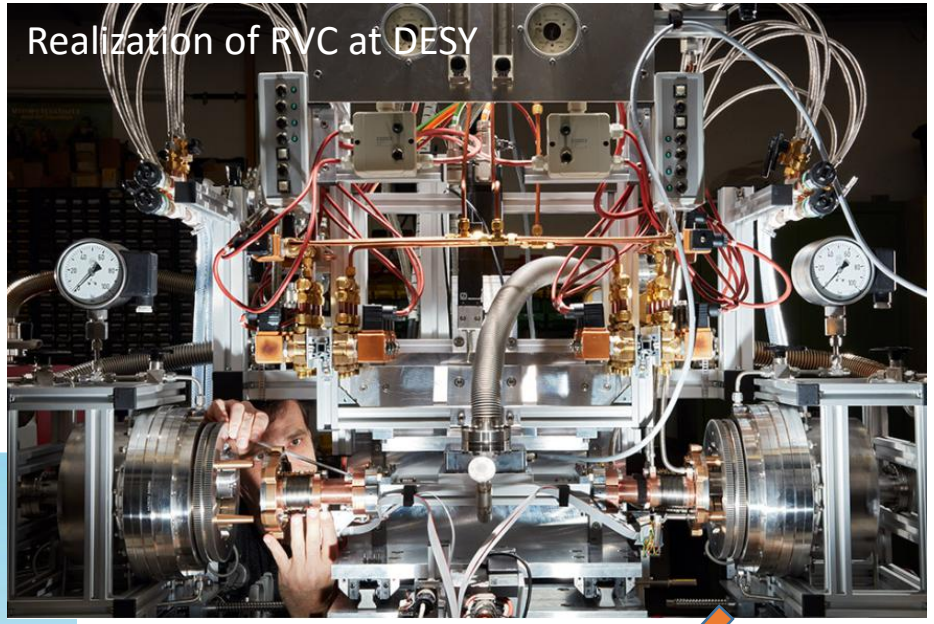
Cooperation with experts from MPP, HLL, Bonn, Göttingen, Gießen, Mainz, Heidelberg, KEK...

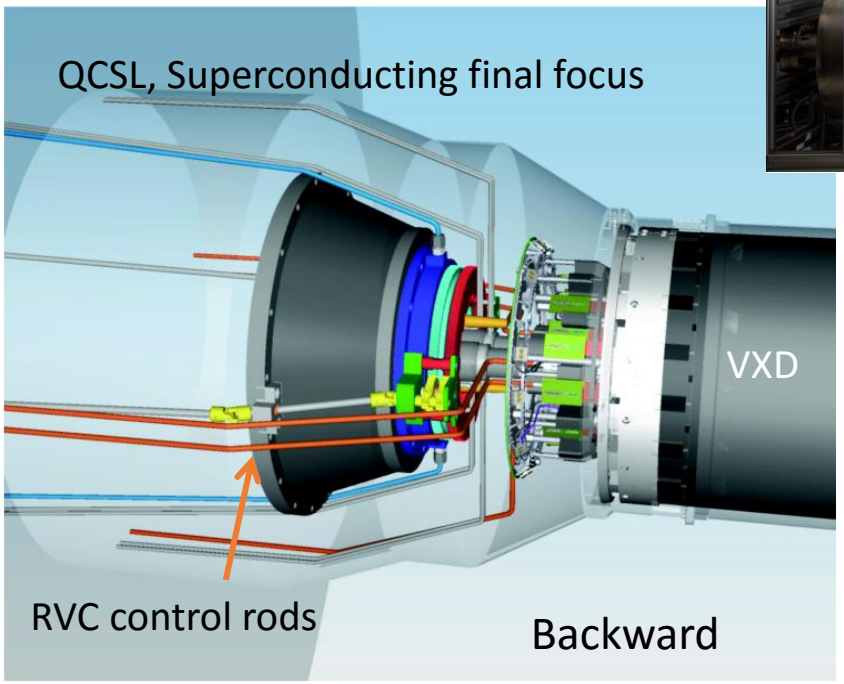
Vertex Detector Integration

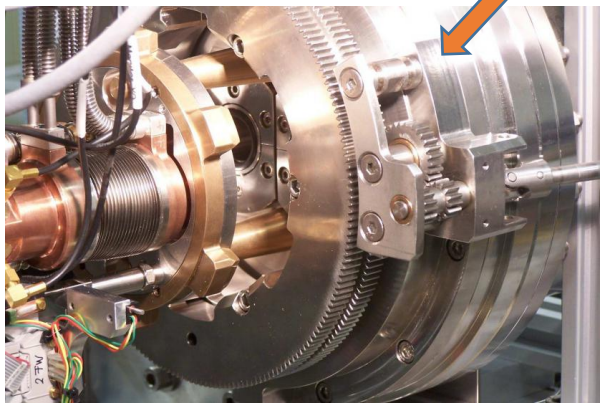
Remote Vacuum Connection (RVC)

Crucial interface between SuperKEKB and Belle II





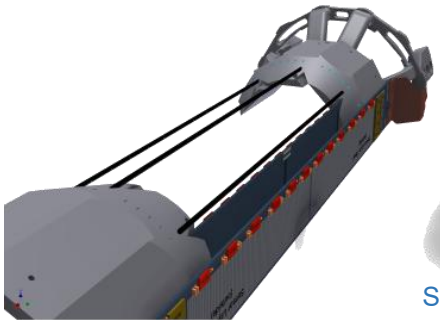


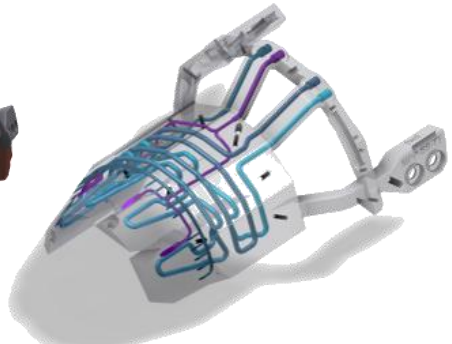


Installation at KEK spring 2017 for BeastII

CO_2 Cooling & VXD Thermal Mockup

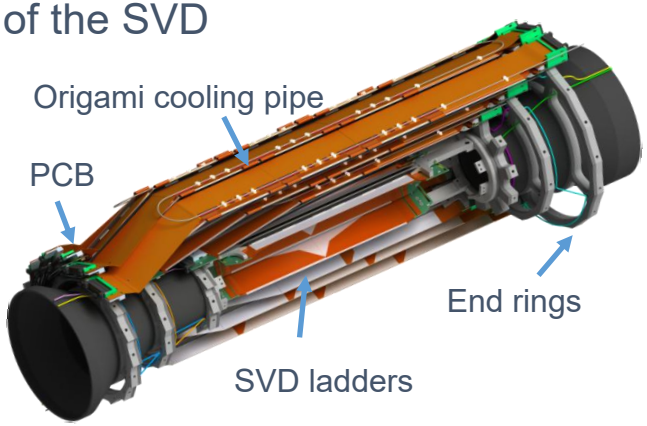
Cooling of the PXD



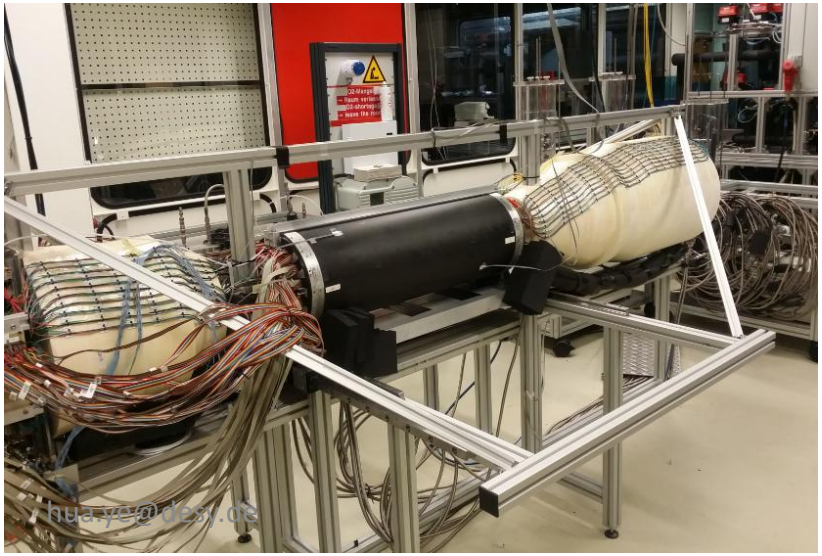


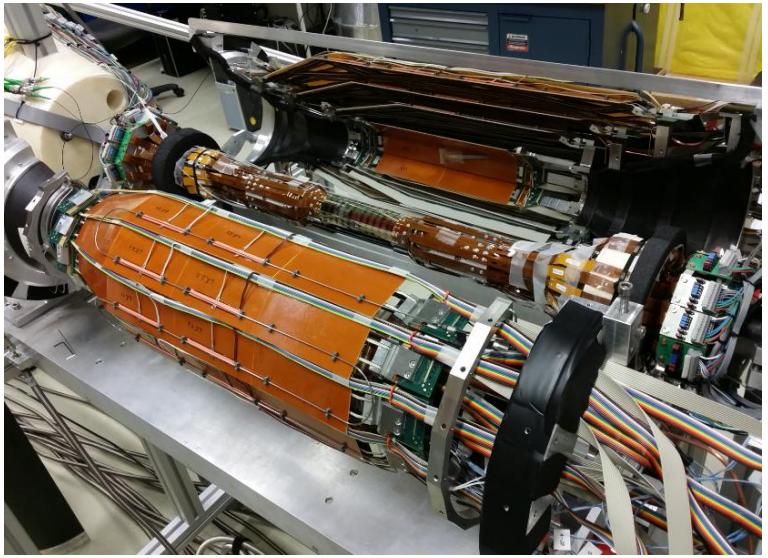
Support Cooling Block (SCB),
with CO_2 and N_2 channels inside.

Cooling of the SVD



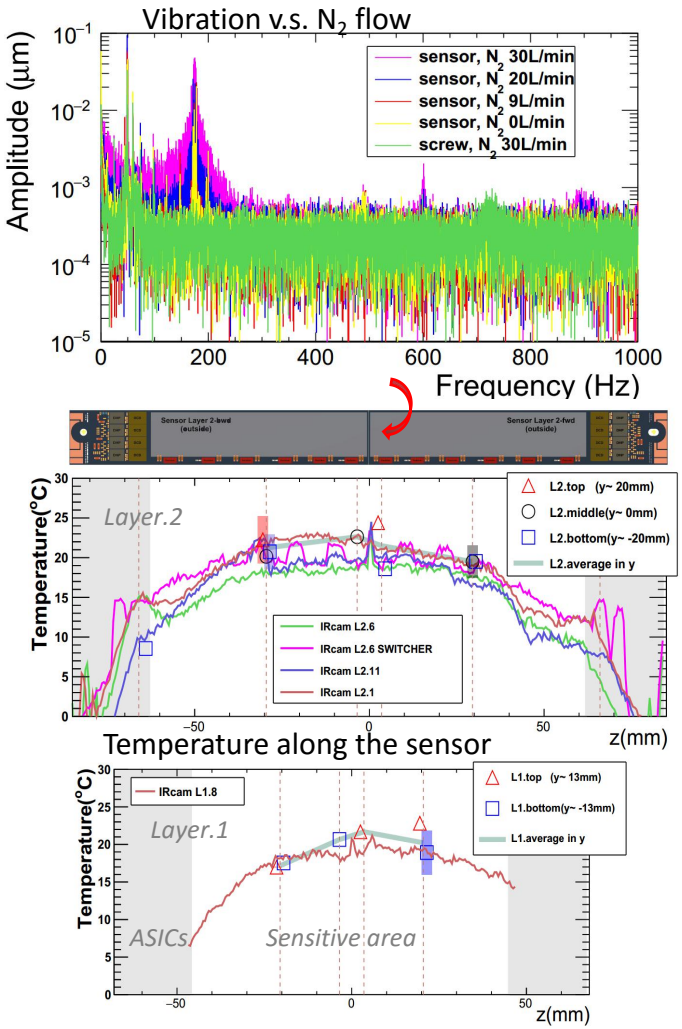
- Power consumption: PXD 360W; SVD 700W, together with the heat load through 9m of vacuum isolated flex lines; required cooling capacity of 2-3kW.
- VXD needs to be thermally isolated against CDC and beam pipe. A full-size thermal mock-up is built at DESY, to verify and optimize the cooling concept of Belle II VXD.





CO_2 Cooling & VXD Thermal Mockup

PXD : CO_2@-30°C; N_2 23L/min

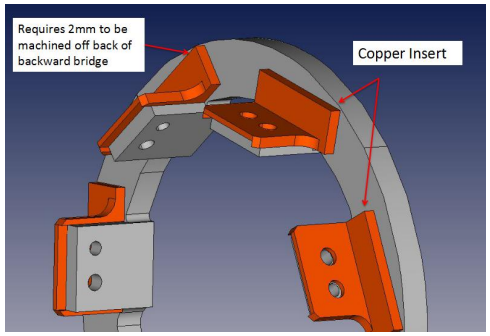


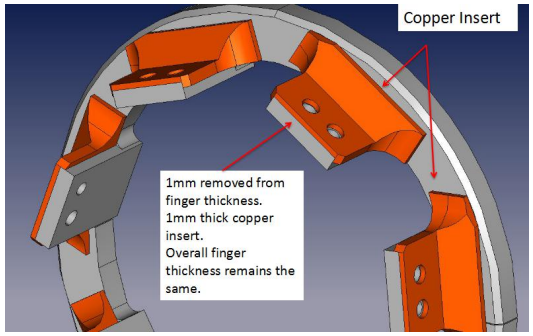
arXiv:1607.00663, submitted to Nucl. Instrum. Meth. A

SVD : CO_2@-30°C

Local temperature at
SVD L.3 FW ASICs will reach ~70°C.

Modification in BW endring/FW figure proposed by DESY.



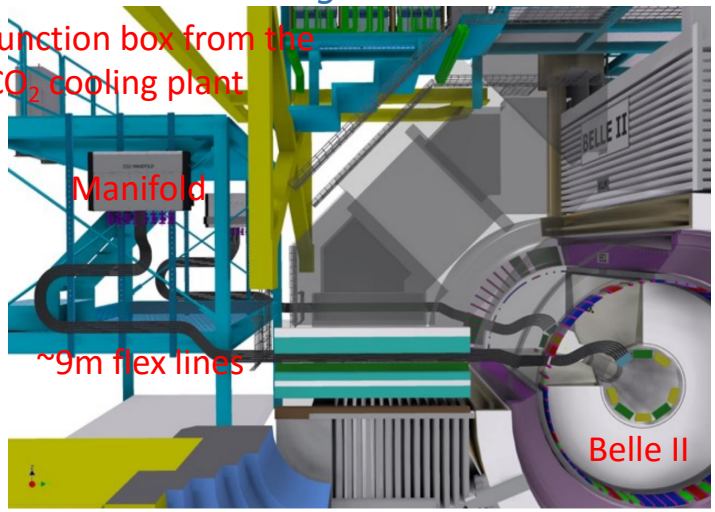


- ☐ F-L3/4 will be newly produced.
- ☐ For SVD L.4/5/6, with nominal load, the temperature on the ASICs is well controled.
- ☐ Dew point inside the VXD dry volume is ~-35°C.
- ☐ Temperature gradient on top/bottom of VXD volume is ~5°C.

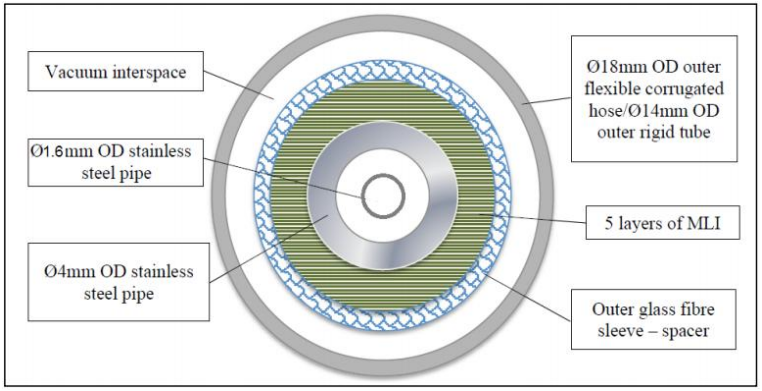
CO_2 vacuum isolated flex lines production

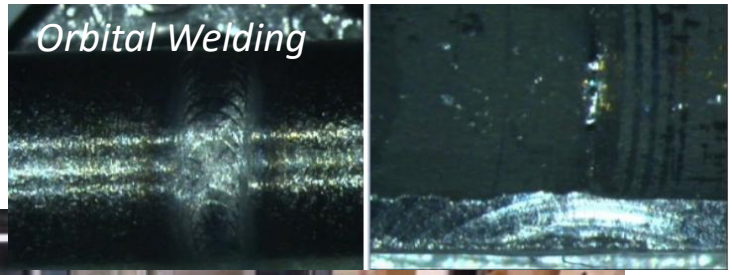
DESY has to produce 26 flex lines, in December 12 lines will be installed at KEK.

Flex Line Routing



Flex Line Design (adopted from ATLAS IBL)

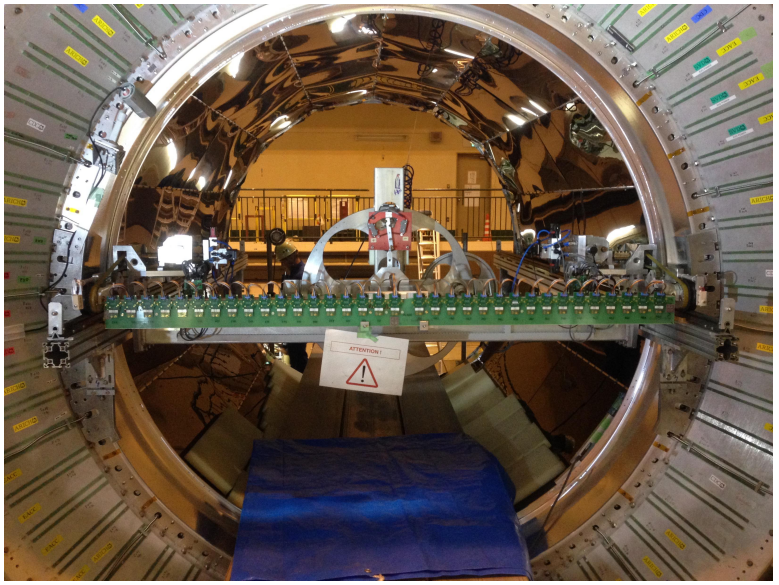


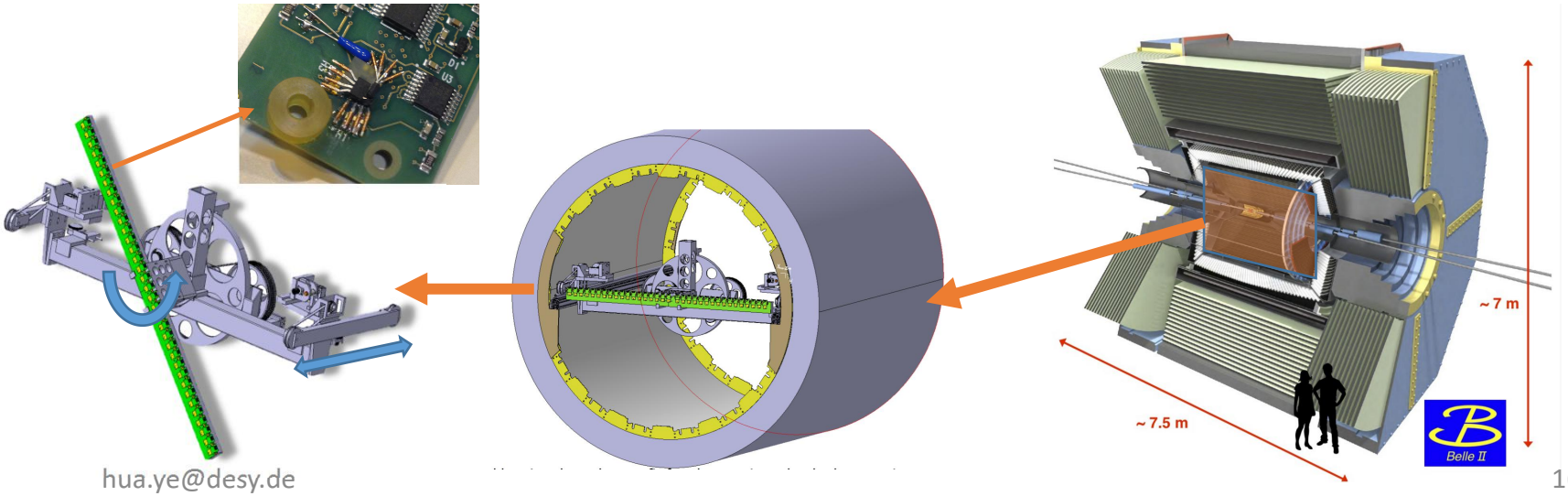


Rotatable Connector

Measurement of B field for BelleII solenoid

- Goal of the measurement: achieve accuracy of final B-field map better than 0.1%
- First step: measure B-field in full tracking volume before installation of final focus magnets
- Constraint: only very short time window available
- Measurement possible thanks to fruitful collaboration with CERN
- Mapper made of non-magnetic materials and driven by pneumatic engines
- $B_z B_r B_\phi$ measured simultaneously by 34 fully calibrated 3-D Hall probes
- Scan with 1.4M 3-D measurements in ~1 week



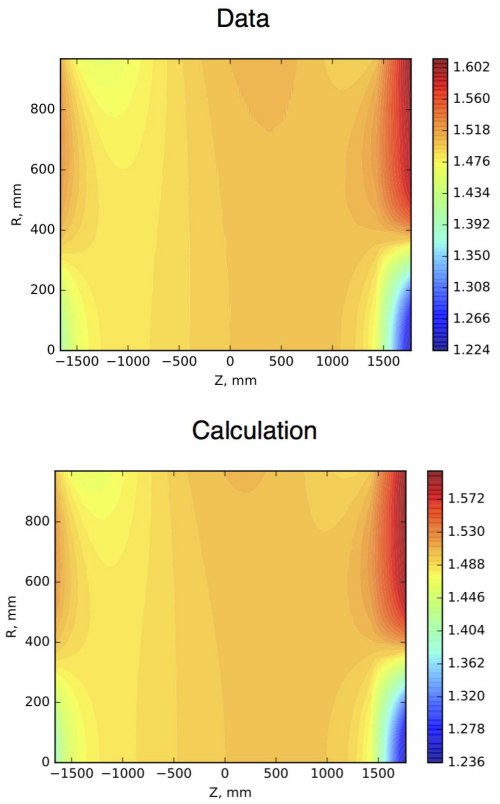


B_{tot} Comparison: Data and Calculation

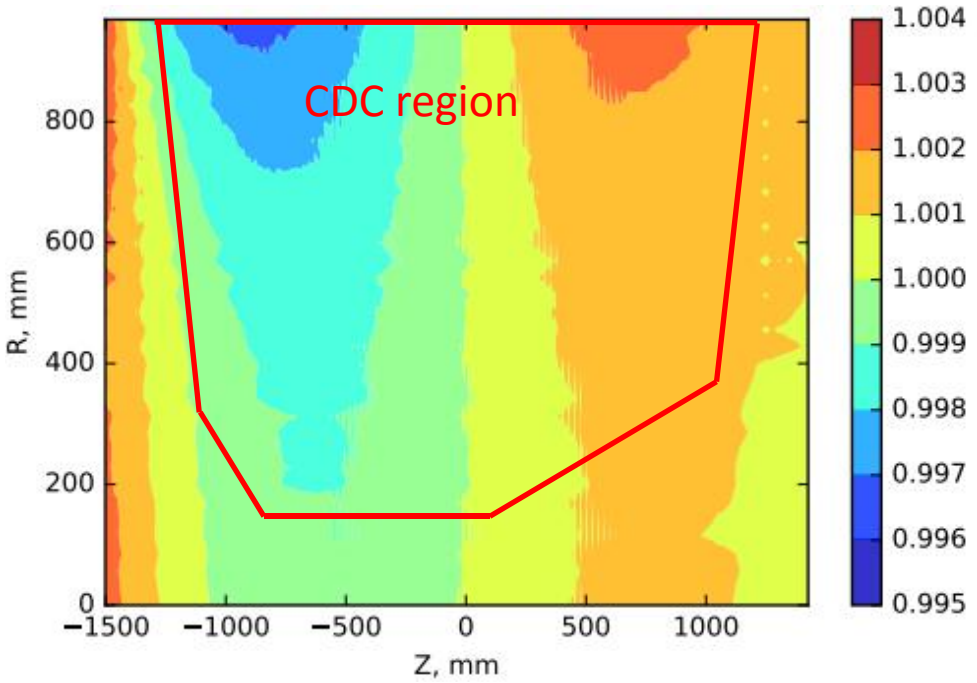
Mis-alignment Corrections are done:

- **Global mis-alignment** is due to imperfect movement of mapper
- **Local mis-alignment** is due to imperfect positioning of sensors on the arm

After corrections:



Ratio Data over Calculation

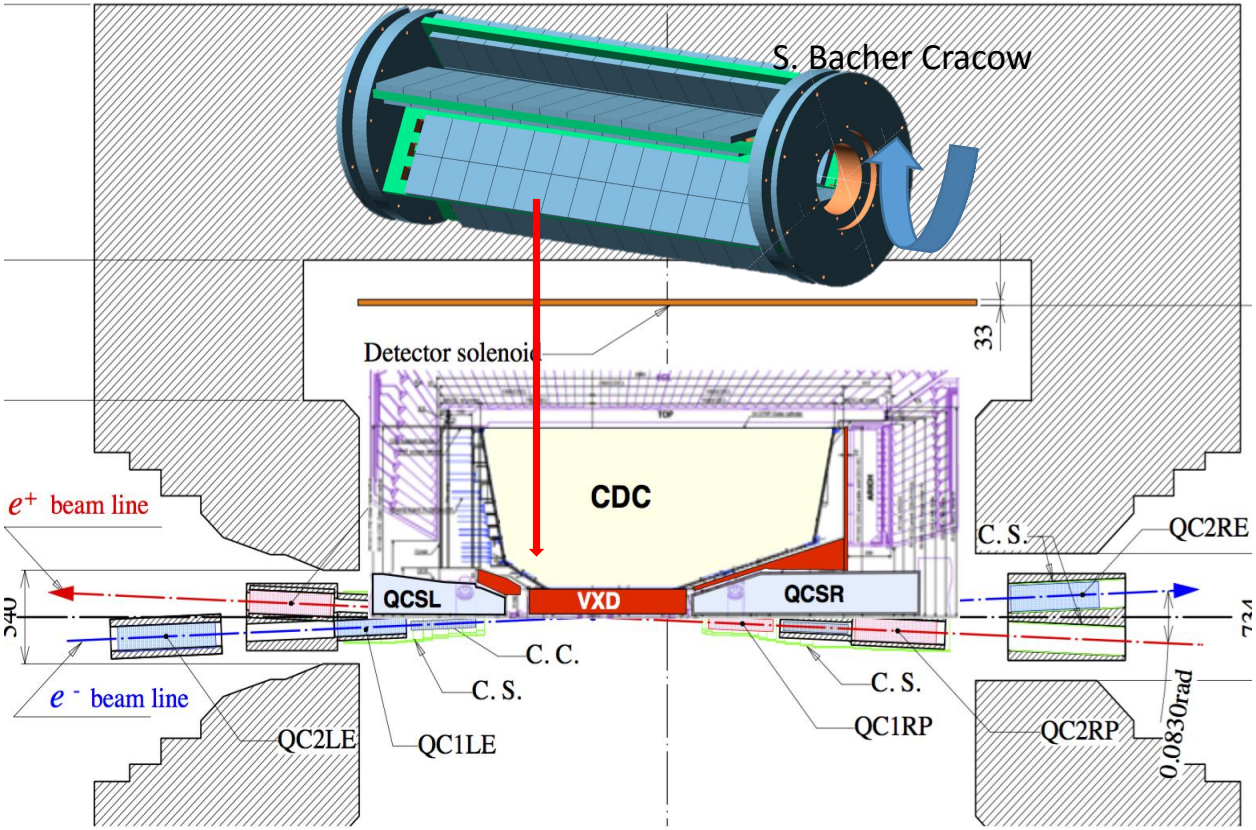


- $|\Delta B/B| > 0.1\%$ in most of the tracking volume
- Tuning of input parameters for calculation ongoing (KEK)

B field measurements: Outlook

Another B field measurement campaign is scheduled after the installation of QCS in 2017 to measure the effect of their stray fields

- Can only be done after CDC and QCS installation
- Measure the B field in the region where VXD will be located => need new robot design
- The gap between QCS and CDC will also be measured
- The final B field map will be modeled based on all the measurements



Physics Analyses and Software

Belle Analyses:

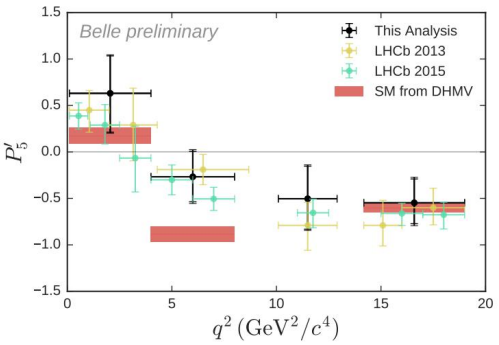
Flavour Changing Neutral Currents

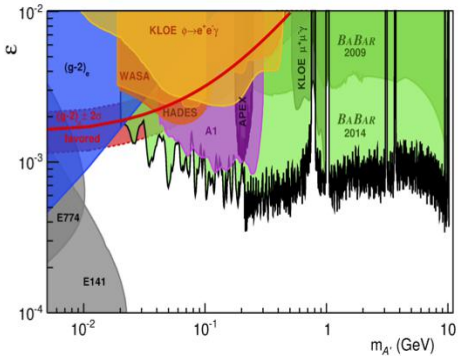
- Angular analysis in $B \rightarrow K^* ll$ (l=μ,e)
- Search for $B^+ \rightarrow K^+\tau^+\tau^-$

Dark Photon

- Search for the long lived dark photon
  - $A' \rightarrow l^+l^-$ (l=μ,e)

Fragmentation function studies

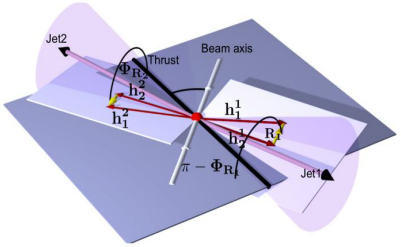




Belle II Analyses (in preparation)

FCNC, LFV, Dark Sector

- Search for $\tau \rightarrow lhh$ (l=μ,e; h=π,K)
- Search for long lived A',
- Search for B and Υ disappearance
- Search for $B \rightarrow K^{(*)}\nu\nu$

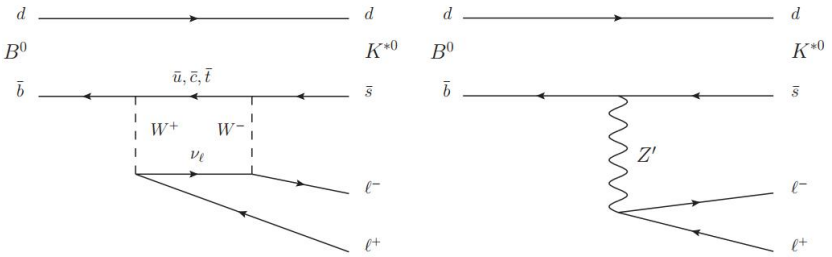


Software:

- PYTHIA8 Generator tuning
- Track reconstruction, alignment and calibration
- Background simulation
- K_L^0 identification studies for Belle II (master thesis)

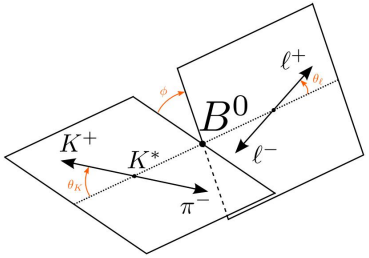
FCNC: B $\rightarrow K^{*}ll$ (l=μ,e)

- b→s flavor changing neutral current (FCNC) is suppressed within the SM, new physics can interfere with the SM amplitude can lead to the modified branching fraction or angular distribution.
- LHCb: evidence (3.4σ) for a discrepancy from the SM prediction in $B^0 \rightarrow K^{*0}\mu^+\mu^-$ angular distribution.

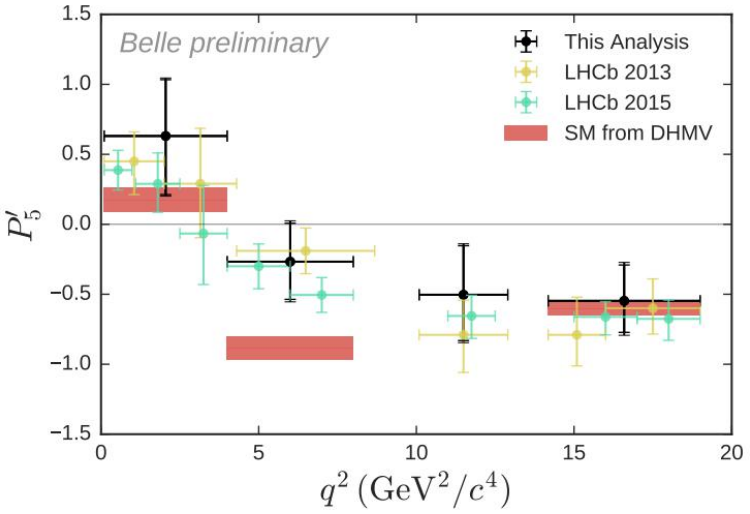


SM example NP example

$$\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi\,\mathrm{d}q^2} = \frac{9}{8\pi}\left[\frac{3}{4}(1-F_L)\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1}{4}(1-F_L)\sin^2\theta_K\cos 2\theta_\ell - F_L\cos^2\theta_K\cos 2\theta_\ell + \frac{1}{2}(1-F_L)A_T^{(2)}\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + \sqrt{F_L(1-F_L)}P_5'\sin 2\theta_K\sin\theta_\ell\cos\phi\right].$$



3 free parameters: F_L, $A_T^{(2)}$, P'_5



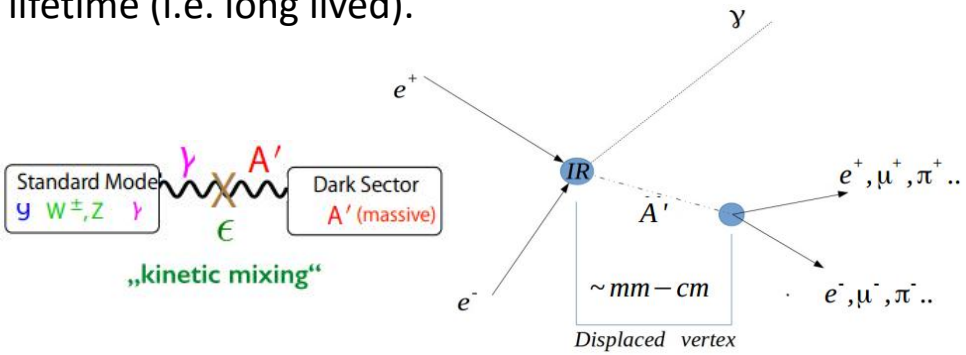
Deviate by 2.1σ from the prediction in the same q^2 region where LHCb reported the anomaly.

Preliminary results were shown at LHCSKI 2016, Austria in April.
Conference paper: *arxiv.1604.04042*
Ph.D thesis : *DESY-THESIS-2016-025*

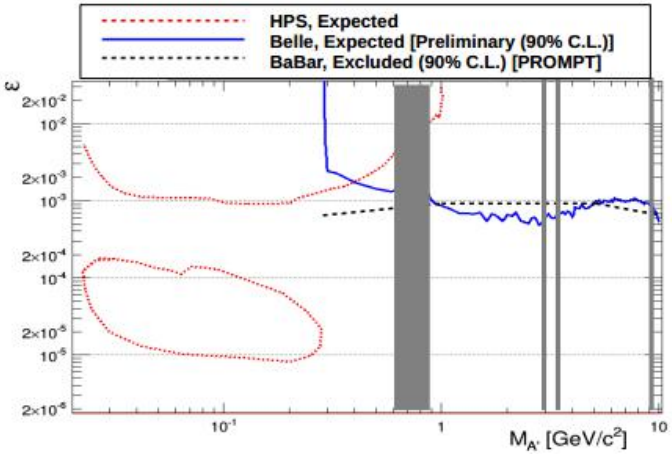
Dark Photon search

- (Holdom, 1986) A new boson (dark photon, A') belonging to an additional U(1)' symmetry would mix kinetically with the photon.

The strength of the kinetic mixing is supposed to be small, 10^{-5}-10^{-2}, the smaller the value the longer A' lifetime (i.e. long lived).



Sensitivity estimated with 5% of the Belle data.



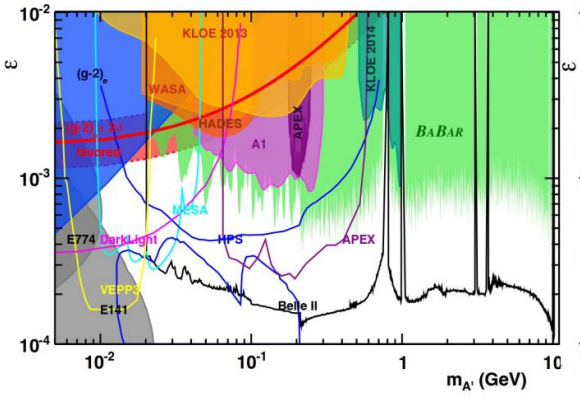
Belle II

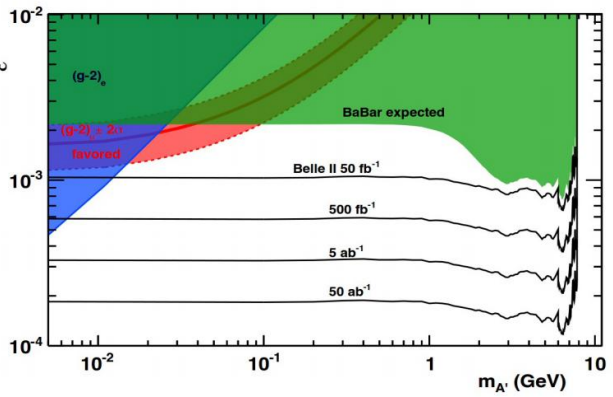
$e^+e^- \to \gamma A' \to \gamma e^+e^-, \gamma \mu^+\mu^-$, *prompt*

$e^+e^- \to \gamma A' \to \gamma \chi \bar{\chi}$

Expected limits at Belle II compared to other experiments

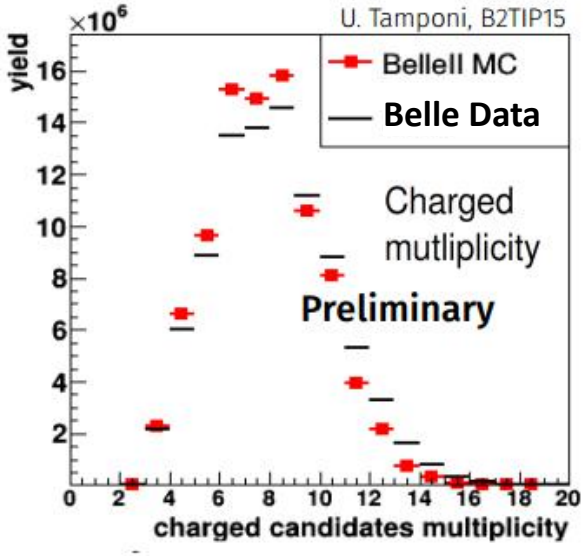
- Projection from BABAR results to Belle 2 luminosity assuming same trigger/detection/reconstruction efficiency





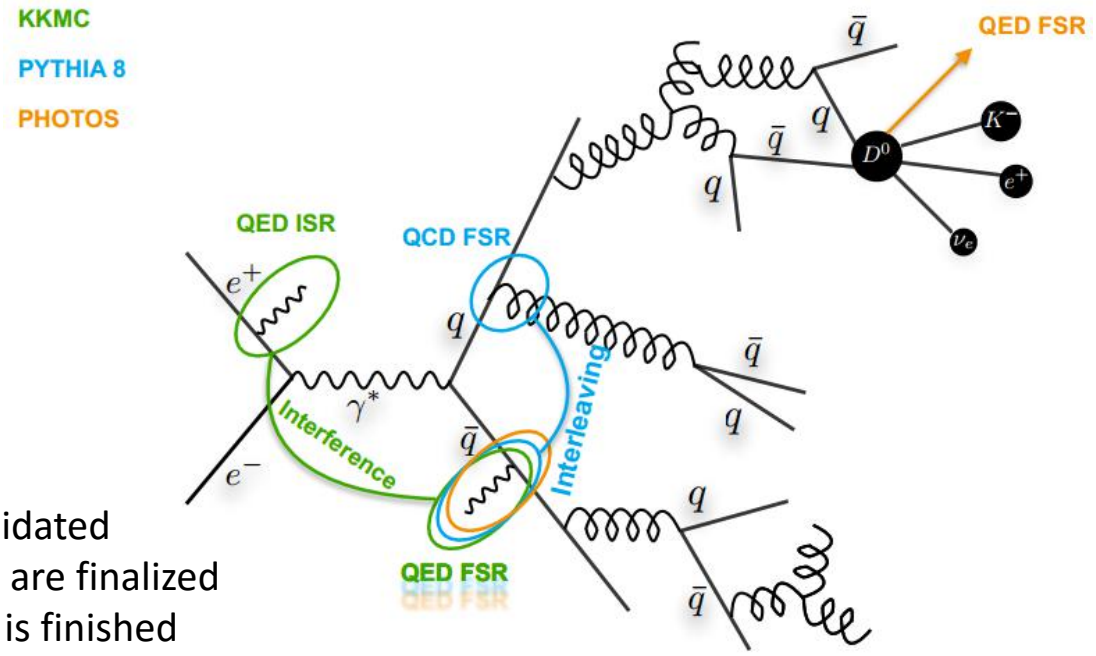
Presentation 'Studies of dark sector at Belle & Becays involving tau' in ICHEP 2016@Chicago.

Belle to Belle II: PYTHIA8 Tuning



Goal: Improve the understanding of the continuum spectrum

- Not satisfactory description of data
- Important task for itself
- Background in, e.g., rare B decays



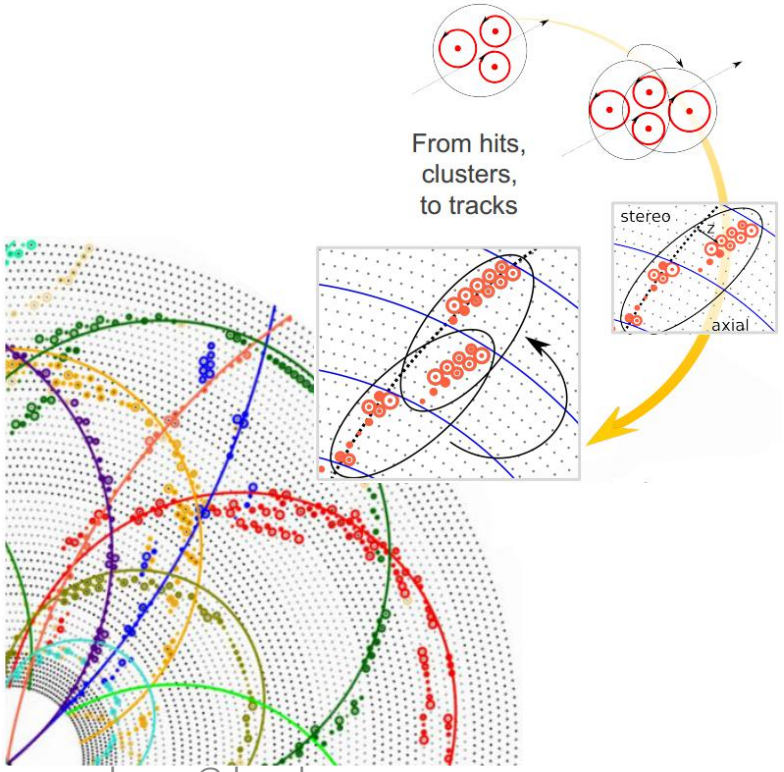
DESY contribution:

- New framework: developed and validated
- PYTHIA8 parameter sensitivity tests are finalized
- Mass production of generated data is finished
- Belle II MC tuning is ongoing, which requires large amount of CPU time

Track Reconstruction, Alignment & Calibration

Tracking in the drift chamber (CDC)

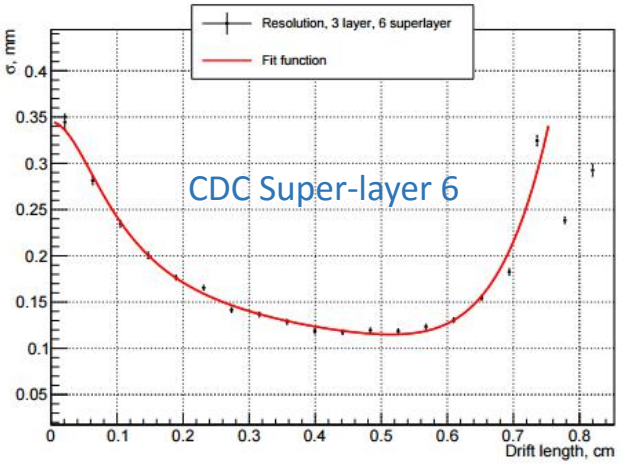
- Two stage Cellular Automaton on
  Hit triplets & Segment pairs
- Integrated for Belle II with
  Global hough searches & Kalman filter
  for DAF final fit
- Cosmic ray tests without B-field.



Track-based Alignment and Calibration:

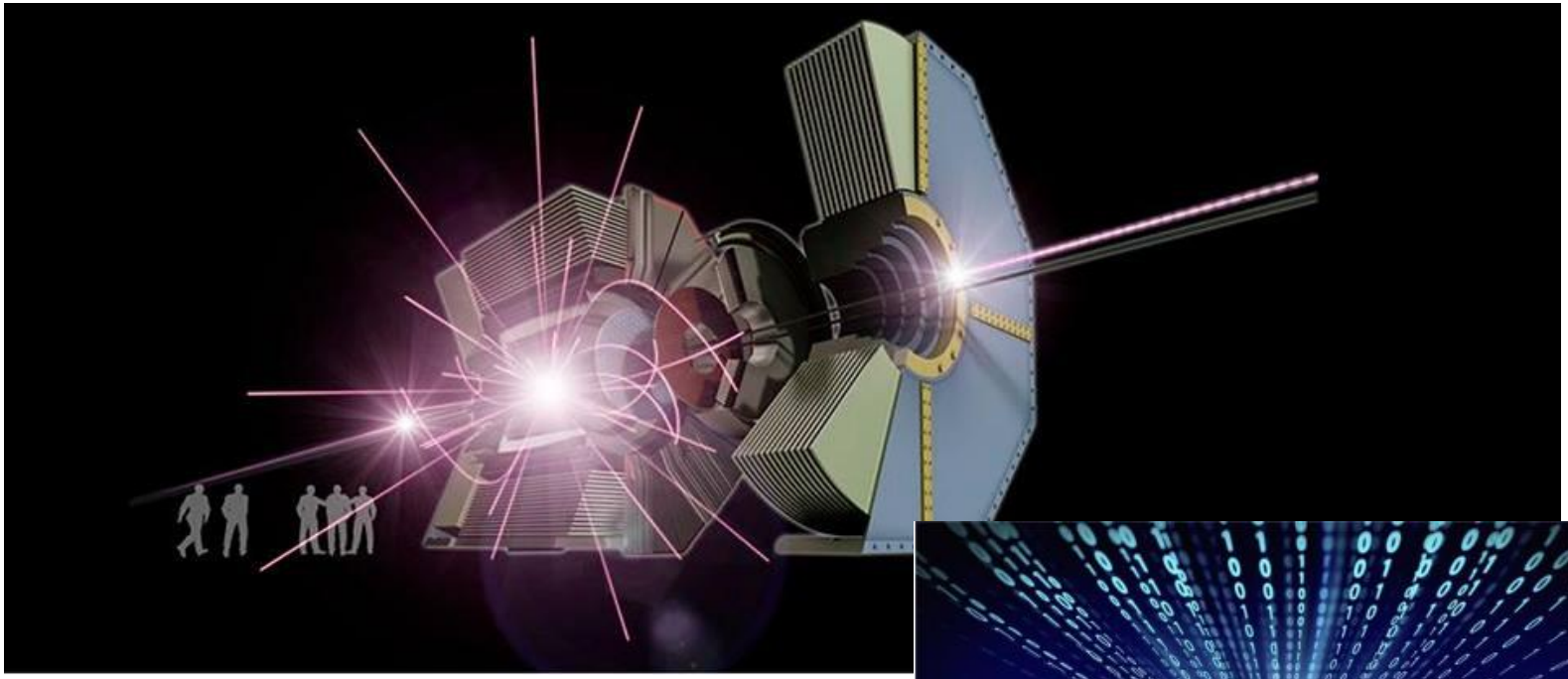
based on the MillePede algorithm and the General Broken Line (GBL) concept as track model

- Millepede-II calculates corrections to initial values of parameters.
- Track fitting with GeneralBrokenLines.
- Exercising the data-driven CDC (wire) alignment and calibration ('x-t relation') with the first cosmics taken (partial readout, no B-field) .



- Single hit resolution after alignment and calibration reaches 120 -140μm

Computing



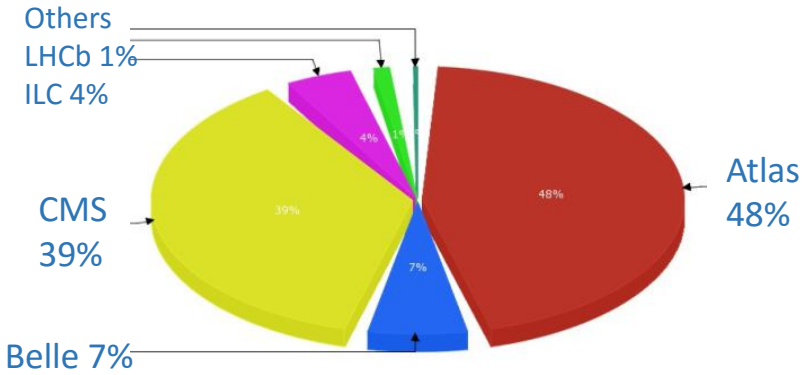
Major contributions of DESY:

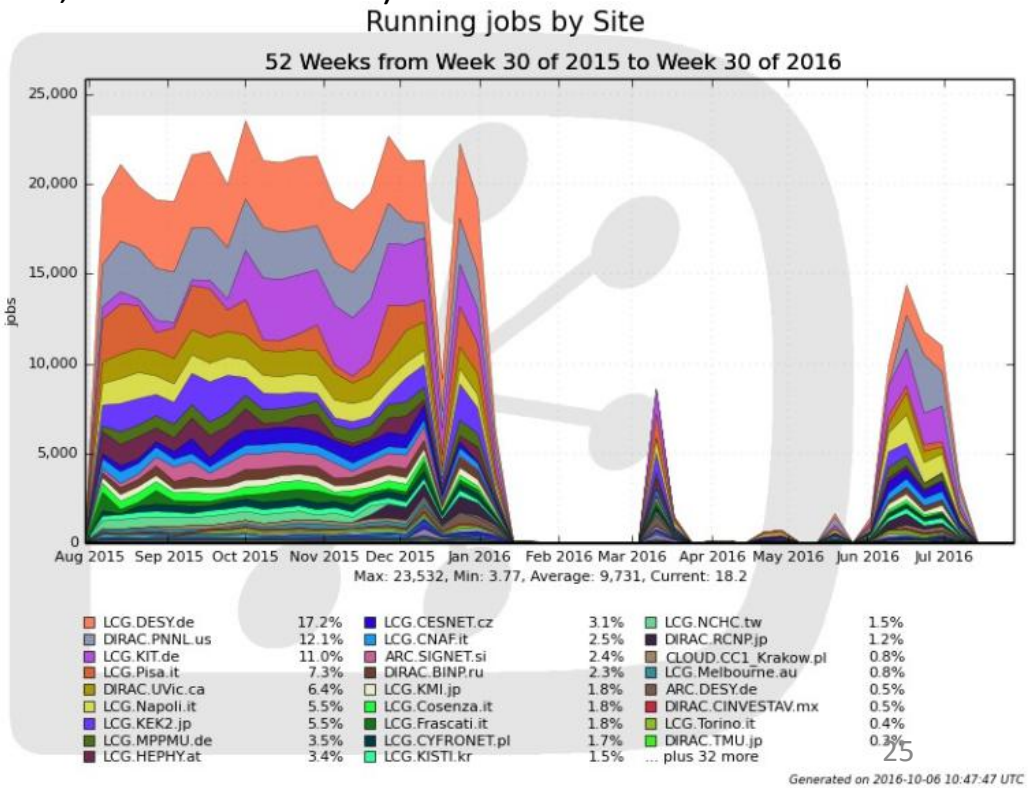
- Belle II Grid and Collaborative services & tools
- Belle II Monte Carlo Campaigns

Belle II Computing @DESY

- Grid Computing:
  Tier-2 site for ATLAS, CMS, LHCB, and Belle II w/ ~15000 cores (150kHS06)
- Belle II Monte Carlo Campaigns:
  Main contributor (MC5+6: 17.7%) (MC6: 12.6%)
- Belle II Data Challenges:
  KEK ⟶ DESY (3.0 Gpbs) and PNNL ↔ DESY (6.6 Gbps) (meets requirements of 2024)
- Grid Services:
  Replicating some KEK Grid services (VOMS, CVMFS stratum-1)

DESY-HH Normalised Elapsed time (HEPSPEC06) per VO



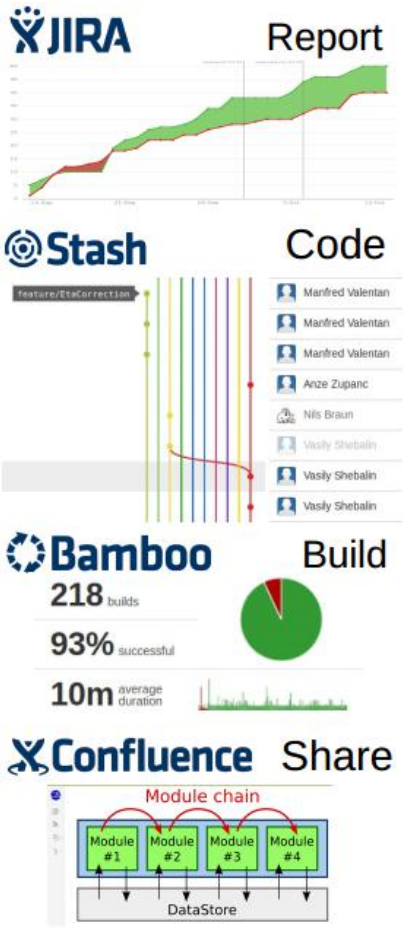


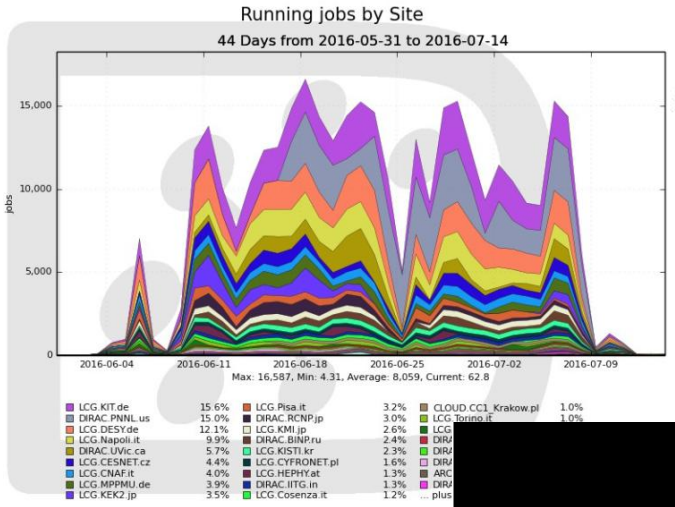
Belle II Collaborative Services & Tools (B2CS)

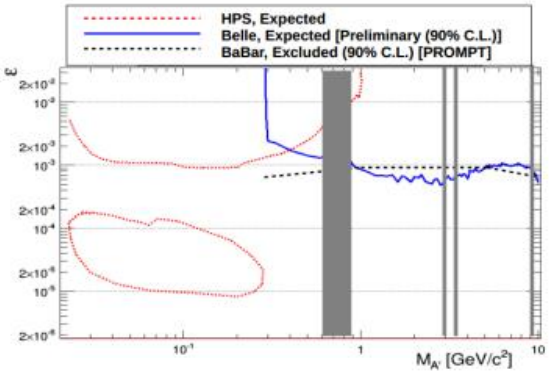
- Collaborative services and tools are essential for (HEP) experiments
- Migration to DESY are finished before the KEKCC summer shutdown
- The DESY IT infrastructure includes fail-over mechanisms, back-up and archiving options for all services as well keeping the security level high
- Additional manpower of 1 FTE for 2 years was negotiated with Belle II

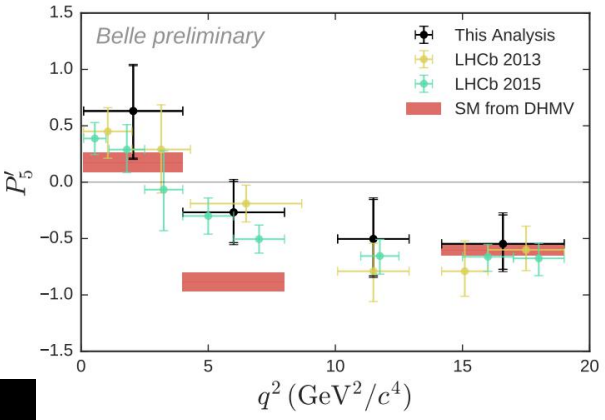
The DESY IT infrastructure services and tools for B2CS

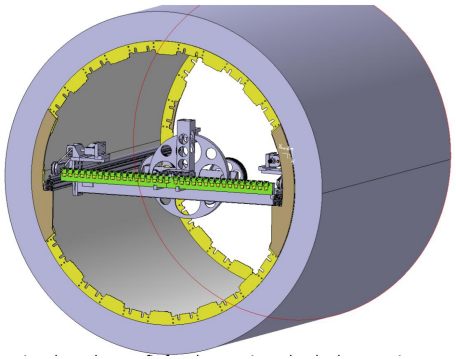
> *Content Mgmt System*:	Belle II Website (*www.belle2.org*)
> *Confluence*:	Wiki (*confluence.desy.de*)
> *JIRA*:	Issue tracking (*agira.desy.de*)
> *Stash:*	Code repositories and browsing (*stash.desy.de*)
> *Sympa*:	Mailing list services (*lists.belle2.org*)
> *Indico*:	Meeting organization (indico.belle2.org)
> Invenio:	Document management (*docs.belle2.org*)
> Virtual machines:	Build services

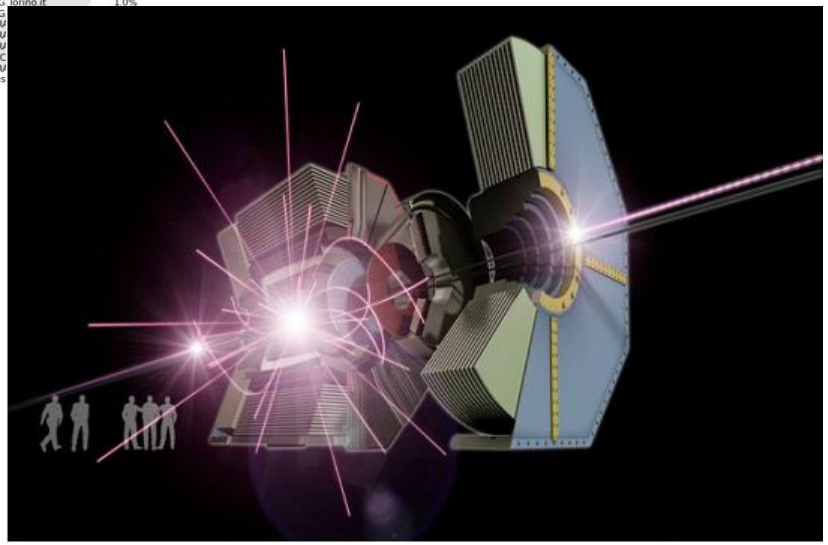


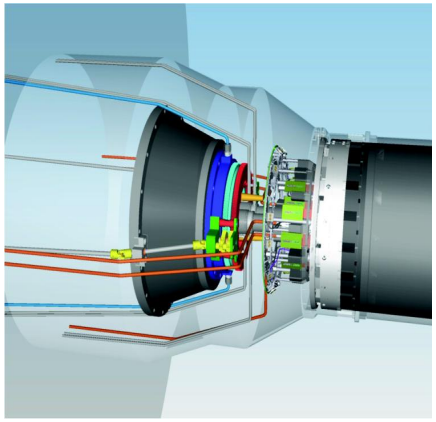

Running jobs by Site
44 Days from 2016-05-31 to 2016-07-14
jobs
15,000
10,000
5,000
0
2016-06-04
2016-06-11
2016-06-18
2016-06-25
2016-07-02
2016-07-09
Max: 16,587, Min: 4.31, Average: 8,059, Current: 62.8
LCG.KIT.de 15.6%
DIRAC.PNNL.us 15.0%
LCG.DESY.de 12.1%
LCG.Napoli.it 9.9%
DIRAC.UVic.ca 5.7%
LCG.CESNET.cz 4.4%
LCG.CNAF.it 4.0%
LCG.MPPMU.de 3.9%
LCG.KEK2.jp 3.5%
LCG.Pisa.it 3.2%
DIRAC.RCNP.jp 3.0%
LCG.KMI.jp 2.6%
DIRAC.BINP.ru 2.4%
LCG.KISTI.kr 2.3%
LCG.CYFRONET.pl 1.6%
LCG.HEPHY.at 1.3%
DIRAC.IITG.in 1.3%
LCG.Cosenza.it 1.2%
CLOUD.CC1_Krakow.pl 1.0%
LCG.Torino.it 1.0%

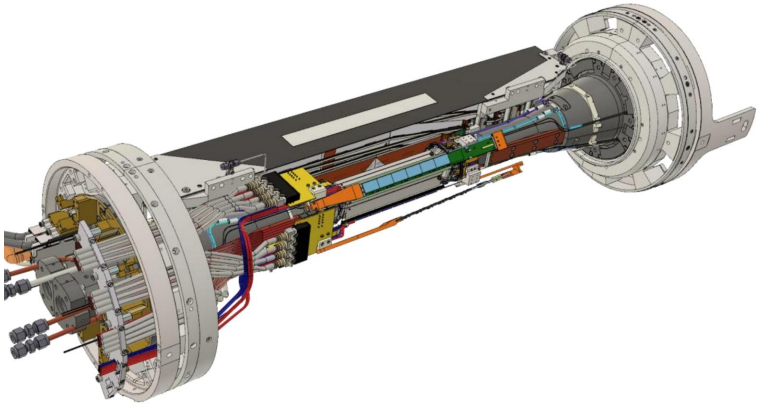

HPS, Expected
Belle, Expected [Preliminary (90% C.L.)]
BaBar, Excluded (90% C.L.) [PROMPT]
ε
$M_{A'}$ [GeV/c²]

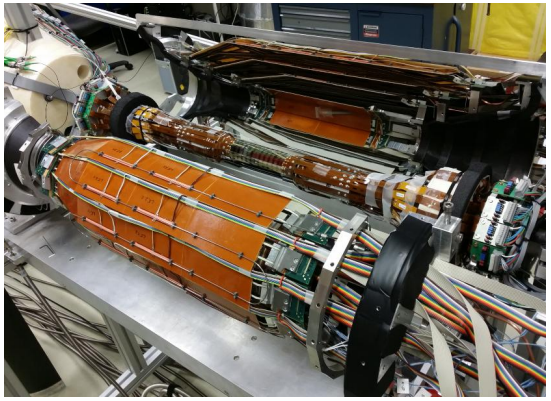

Belle preliminary
This Analysis
LHCb 2013
LHCb 2015
SM from DHMV
P_5'
q^2 (GeV^2/c^4)





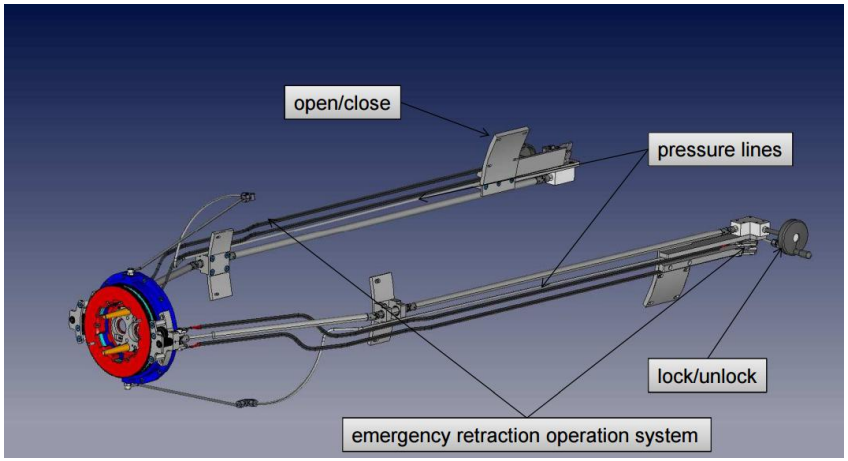




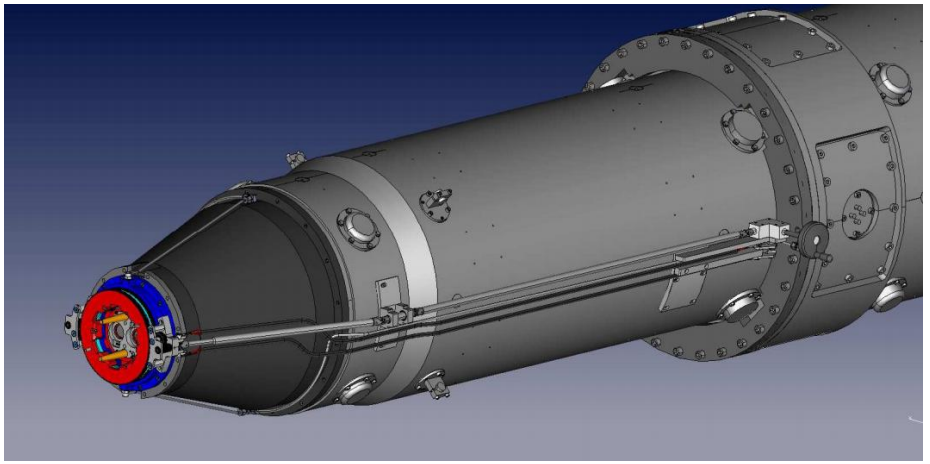


backup

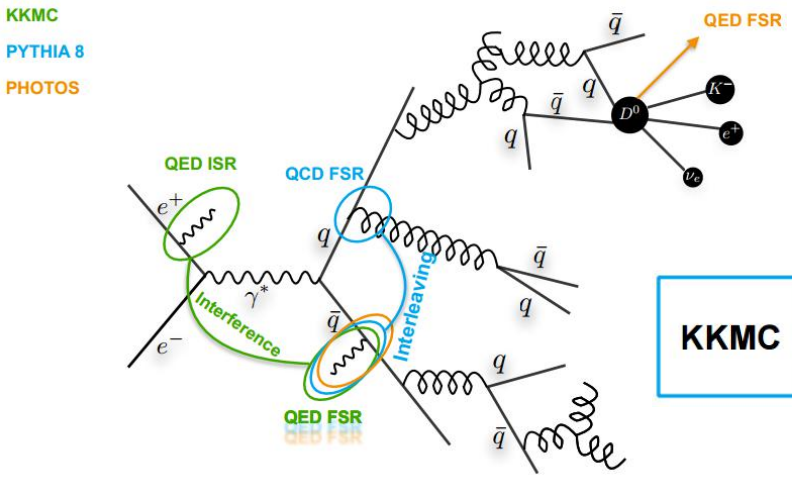
RVC forward



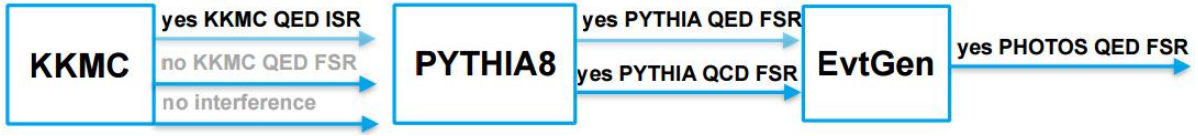
RVC forward with QCSR



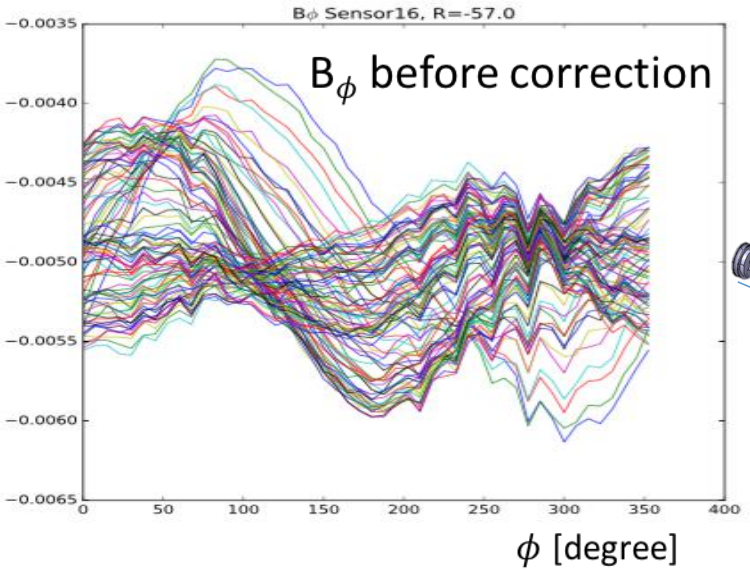
PYTHIA8 tuning

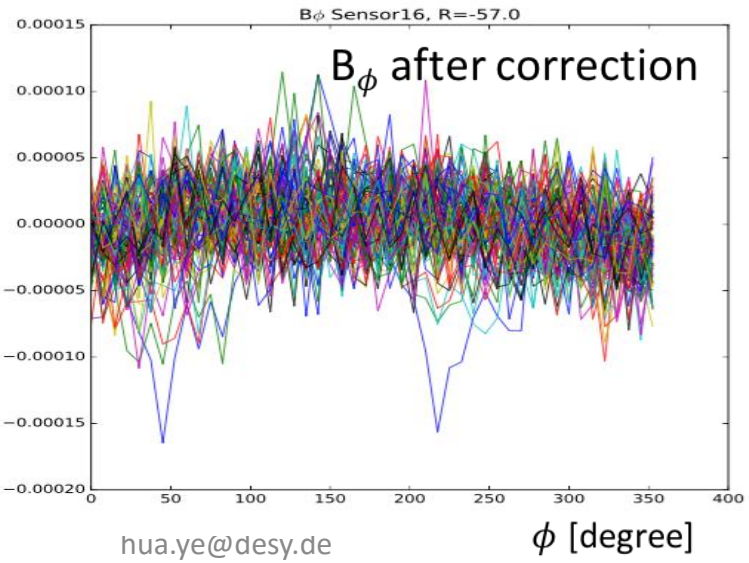


➞ large effect of ISR
➞ three options to generate the FSR
➞ maximum 10-20% effect of FSR on radiated photon spectrum at low momenta
  ➞ source of systematic uncertainty
➞ tiny effect of ISR/FSR interference

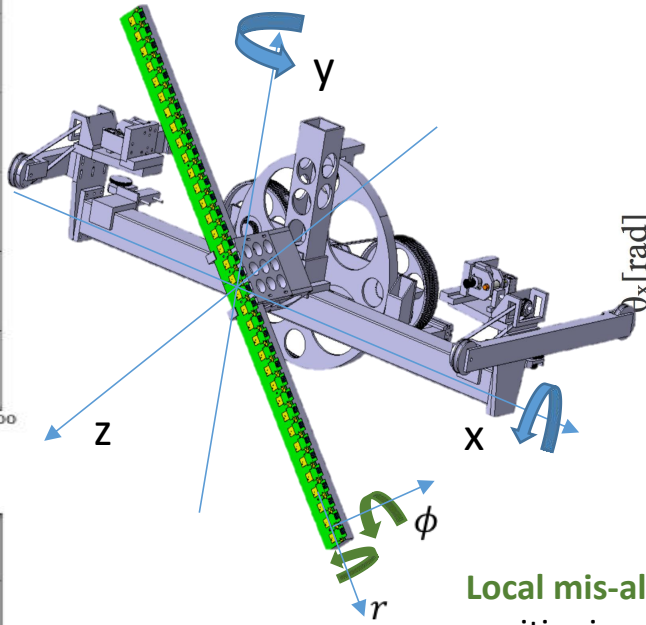


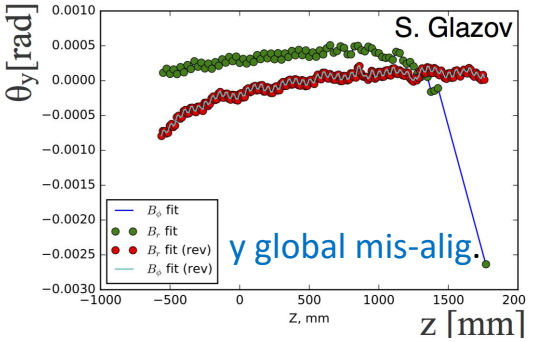
Mis-alignment Corrections

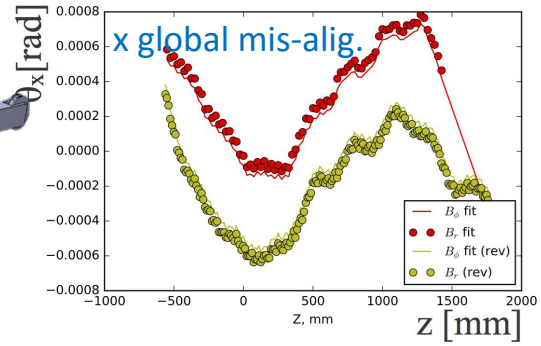




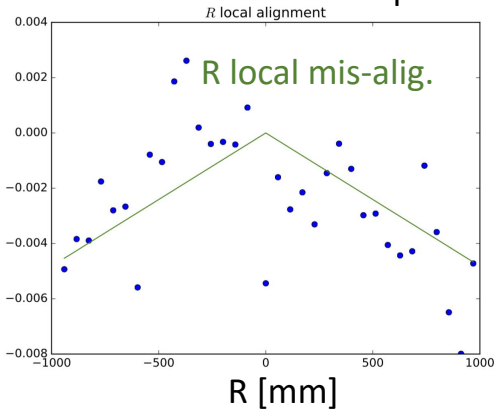
Global mis-alignment is due to imperfect movement of mapper

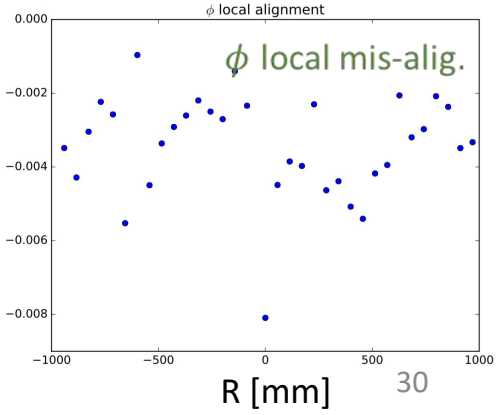






Local mis-alignment is due to imperfect positioning of sensors on the arm





Dark photon searches @ LHCb

Preliminary studies for run 3: from ~2021

During run 3 LHCb will run in a "triggerless" Mode. Plan to search for

- low mass dark photon in the reaction:

$$D^{*0} \to D^0 \gamma$$

$$\frac{\Gamma(D^{*0} \to D^0 A')}{\Gamma(D^{*0} \to D^0 \gamma)} = \epsilon^2 \left(1 - \frac{M_{A'}^2}{\Delta m_D^2}\right)^{3/2}$$

- Prompt and displaced vertex decays of the dark photon in the mass region $[2 m_\mu, 50\, GeV/c^2]$ in the reaction:

$$pp \to X A', \quad A' \to \mu^+ \mu^-$$

$$\Gamma_{A'} \approx \Gamma(A' \to l^+ l^-) = \frac{1}{3} \alpha \epsilon^2 m_{A'} \sqrt{1 - \frac{4 m_l^2}{m_{A'}^2}} \left(1 + \frac{2 m_l^2}{m_{A'}^2}\right)$$

Expected sensitivity during run 3: