Belle & Belle II activities at DESY

Gevorg Karyan
on behalf of DESY Belle II group

HELMHOLTZ ASSOCIATION

DESY

Outline

- ✔ **Belle at KEKB**
  - ➢ Belle analysis

- ✔ **Belle/KEKB upgrade to Belle II/SuperKEKB**
  - **Belle II hardware**
    - ➢ VXD-Test Beam, B-field measurement
  - **Belle II software**
    - ➢ Tracking, PYTHIA8 tuning
  - **Belle II computing**
    - ➢ collaborative tools, GRID resources

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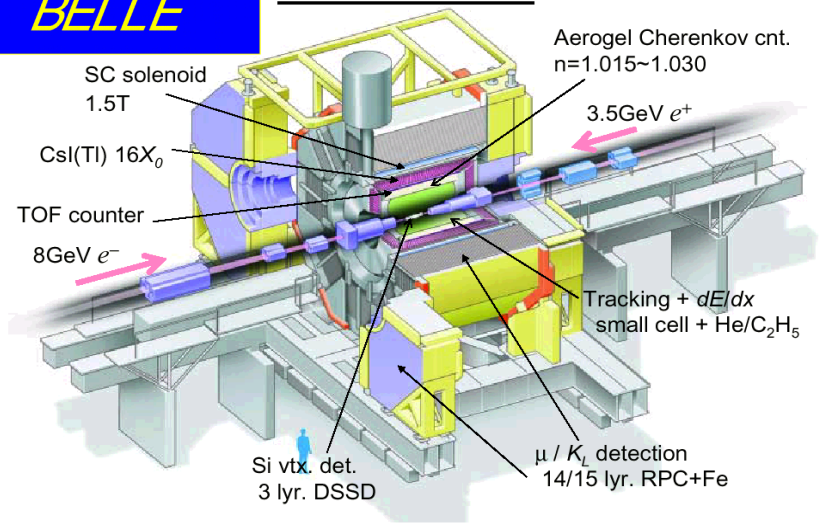
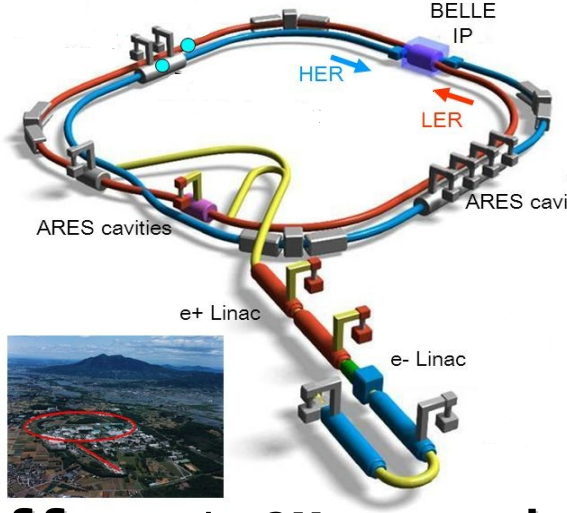
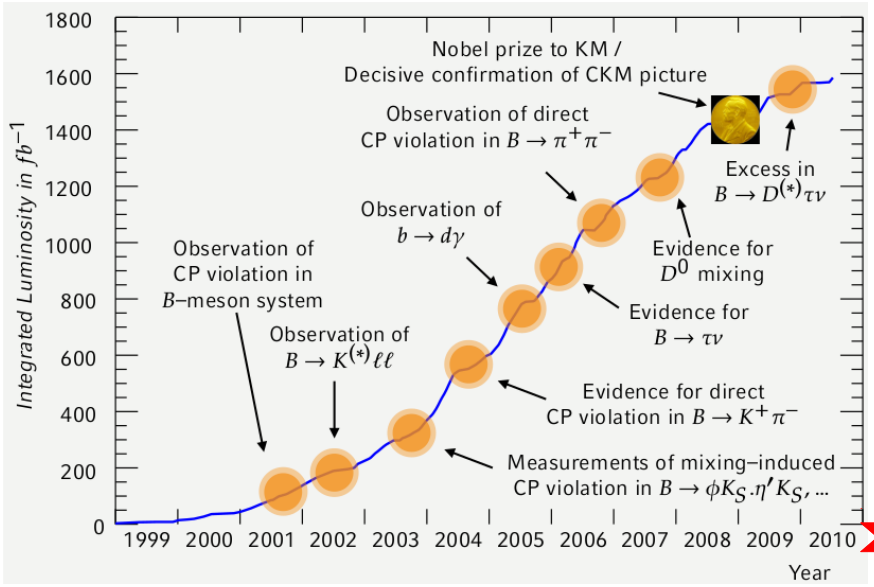
Belle Detector



KEKB

LER: e+ 3.5 GeV 1.7A
HER: e- 8.0 GeV 1.4A
RF freq.: 509 MHz
Cross. Angle: 22 mrad





✔ **different CM energies**

Resonance	On-peak luminosity (fb^{-1})	Off-peak luminosity (fb^{-1})	Number of resonances
$\Upsilon(1S)$	5.7	1.8	102×10^6
$\Upsilon(2S)$	24.9	1.7	158×10^6
$\Upsilon(3S)$	2.9	0.25	11×10^6
$\Upsilon(4S)$ SVD1	140.0	15.6	152×10^6 $B\bar{B}$
$\Upsilon(4S)$ SVD2	571.0	73.8	620×10^6 $B\bar{B}$
$\Upsilon(5S)$	121.4	1.7	7.1×10^6 $B_s\bar{B}_s$
Scan		27.6	

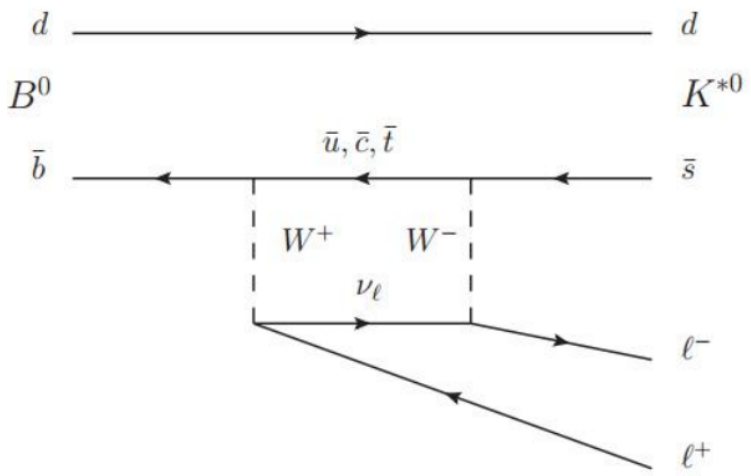
✔ **integrated luminosity** ~ 1 ab^{-1}

✔ **journal publications** ~ 500

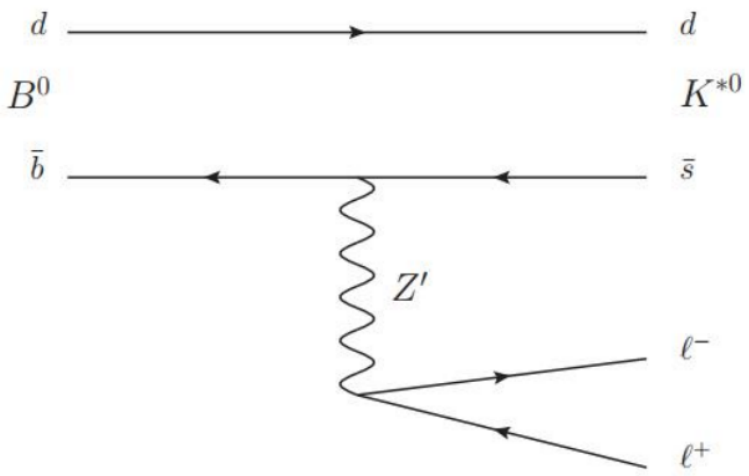
(since last PRC : 6)

$B \to K^* ll\ (l = e, \mu)$

- ✔ Flavor-Changing Neutral Current (FCNC) process $b \to s l^+ l^-$ forbidden at lowest order in the Standard Model (SM)
- ✔ highly suppressed at higher orders (GIM mechanism)
- ✔ sensitive probe in the search of New Physics (NP)



SM example

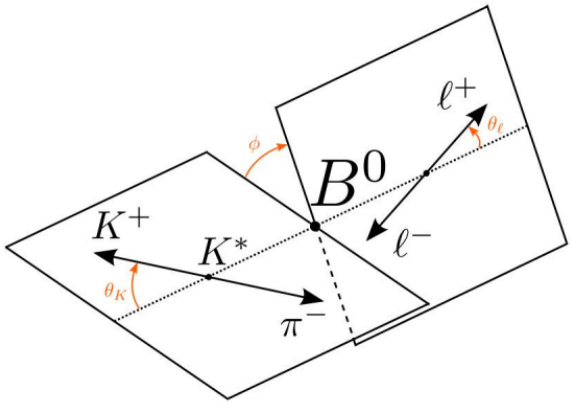


NP example

$B \to K^* ll$ ($l = e, \mu$)

✔ **full angular decay distribution :**

$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{d\cos\theta_\ell\, d\cos\theta_K\, d\phi\, dq^2} = \frac{9}{32\pi}\Big[\frac{3}{4}(1-F_L)\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1}{4}(1-F_L)\sin^2\theta_K\cos 2\theta_\ell$$
$$- F_L\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi$$
$$+ S_5\sin 2\theta_K\sin\theta_\ell\cos\phi + S_6\sin^2\theta_K\cos\theta_\ell + S_7\sin 2\theta_K\sin\theta_\ell\sin\phi$$
$$+ S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big],$$

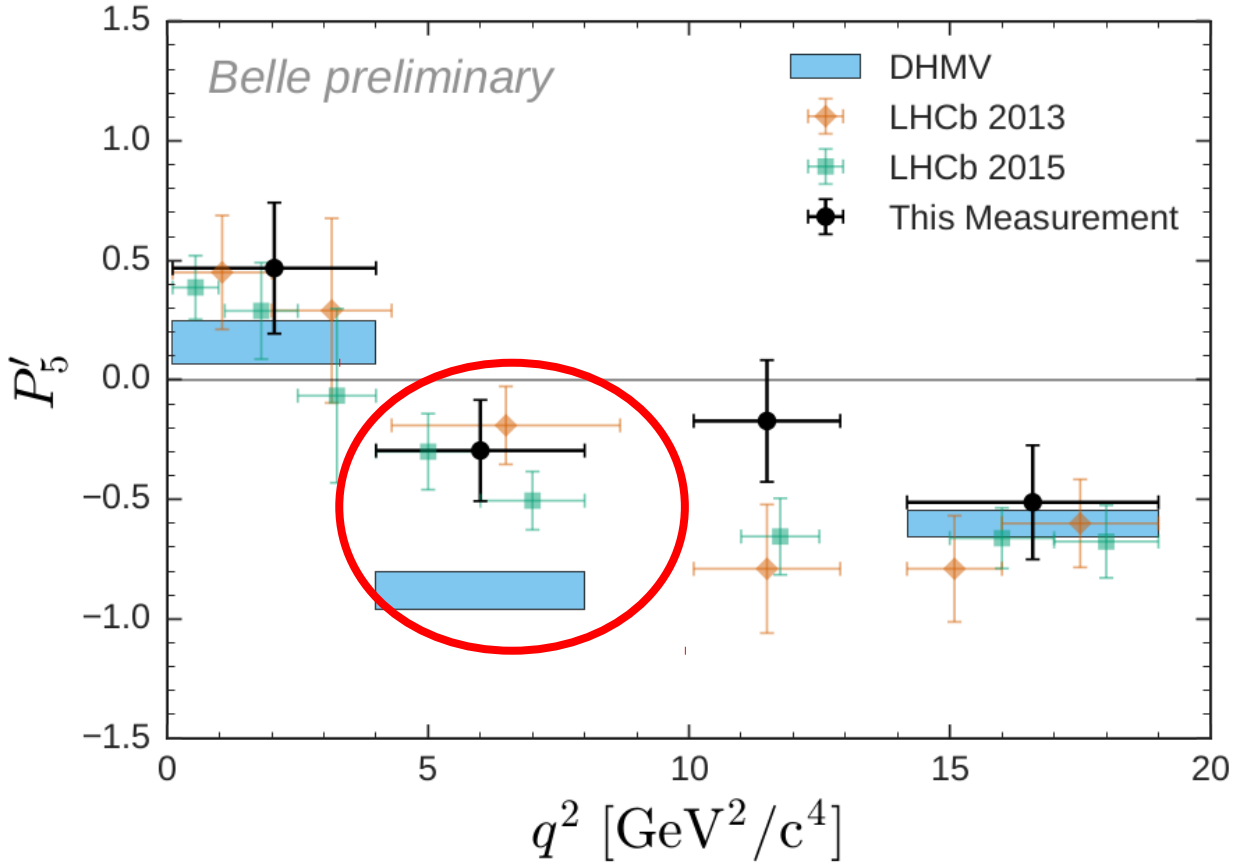


✔ **suppress form-factor uncertainities :**

$$P'_{i=4,5,6,8} = \frac{S_{j=4,5,7,8}}{\sqrt{F_L(1-F_L)}}$$

✔ **extract P_i' via ML fit**

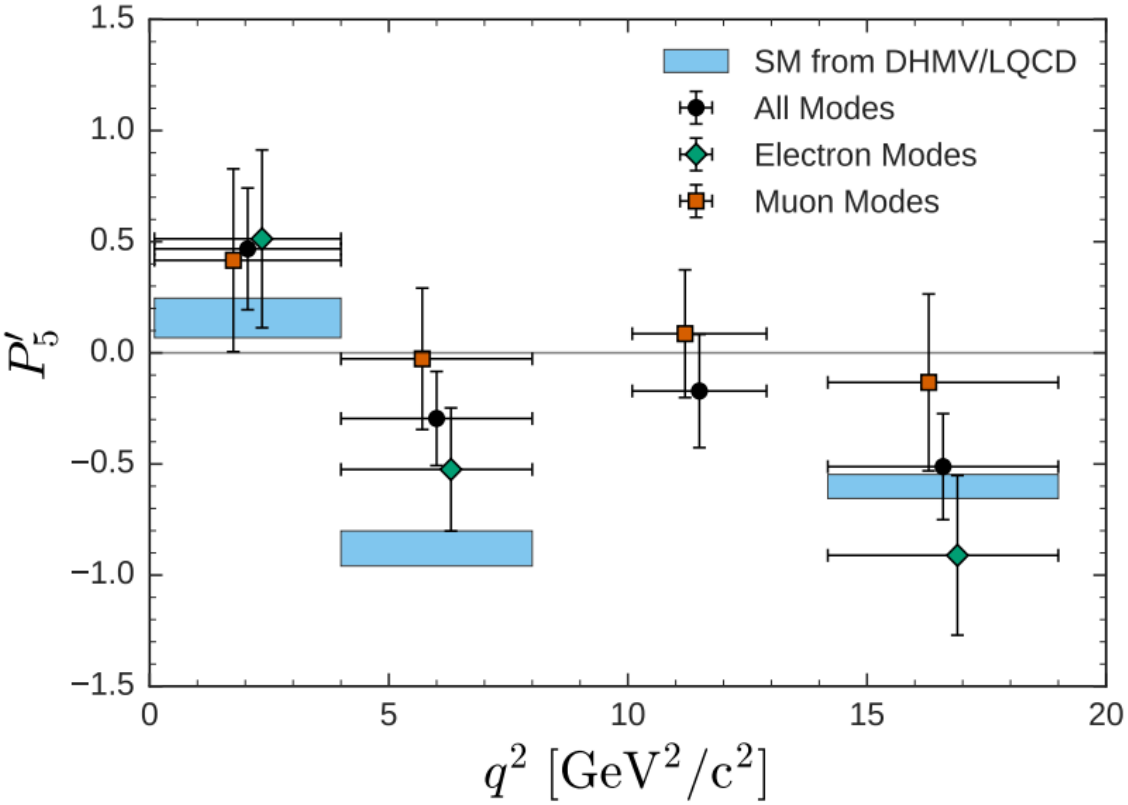
$B \to K^* ll$ ($l = e, \mu$)



✔ only muon mode

✔ P_5' : local deviation with respect to the SM ~ 3.7σ

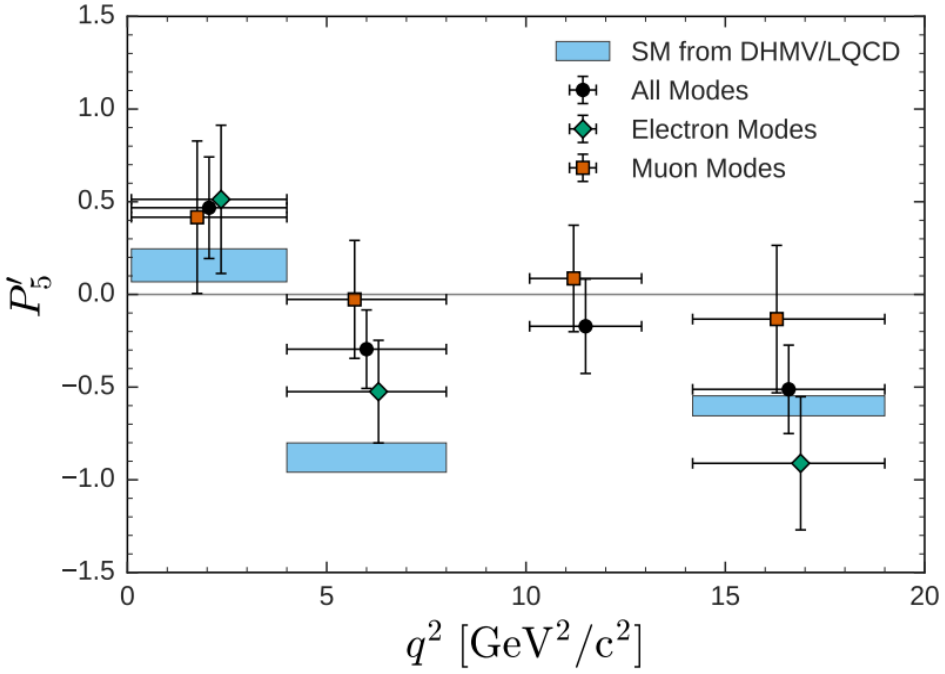
$B \to K^* ll$ ($l = e, \mu$)

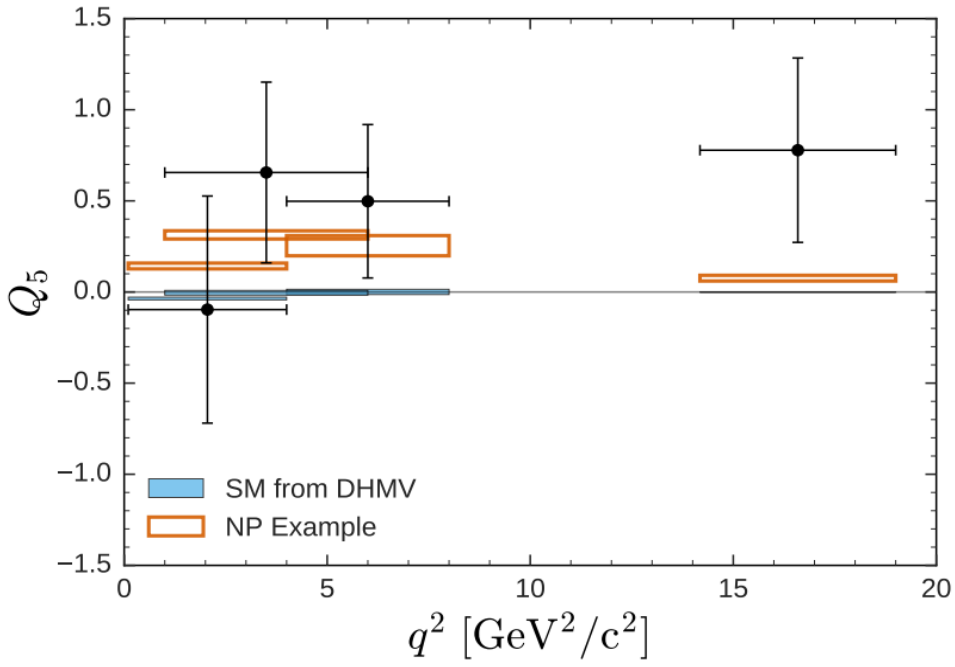


✔ **first lepton flavor dependent angular analysis**

✔ P_5' **(**$4\ \mathrm{GeV}^2/c^2 < q^2 < 8\ \mathrm{GeV}^2/c^2$**): muon mode** $\sim 2.6\sigma$ **discrapancy with SM**

$B \to K^* ll$ ($l = e, \mu$)





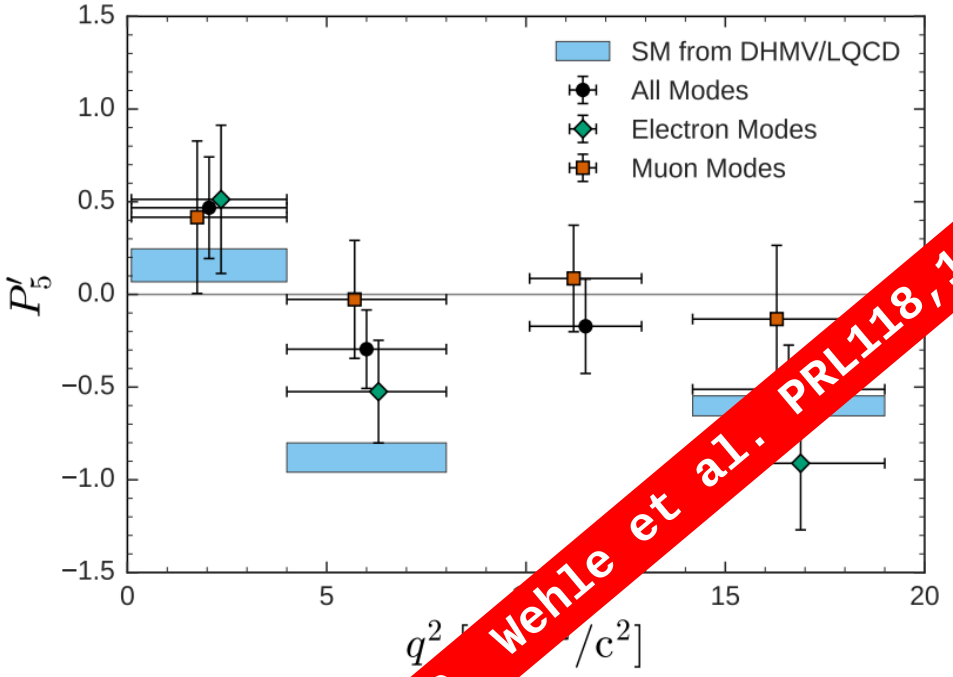
✔ probe for lepton flavour universality (NP) :

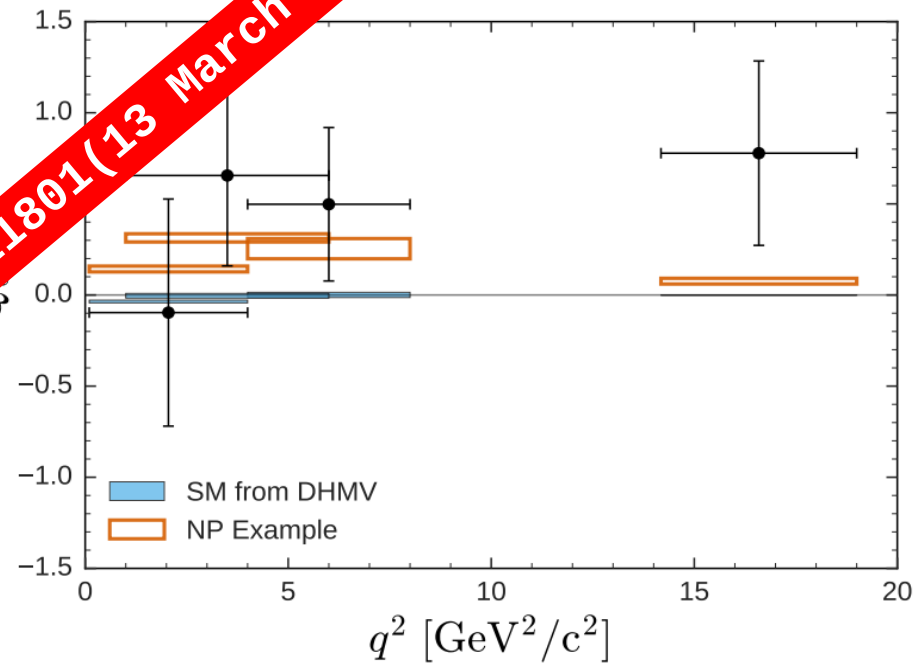
$$Q_i = P_i^{\mu} - P_i^{e}$$

✔ some hint towards lepton flavour universality violation?

✔ need more data for conclusive answer

$B \to K^* ll$ ($l = e, \mu$)

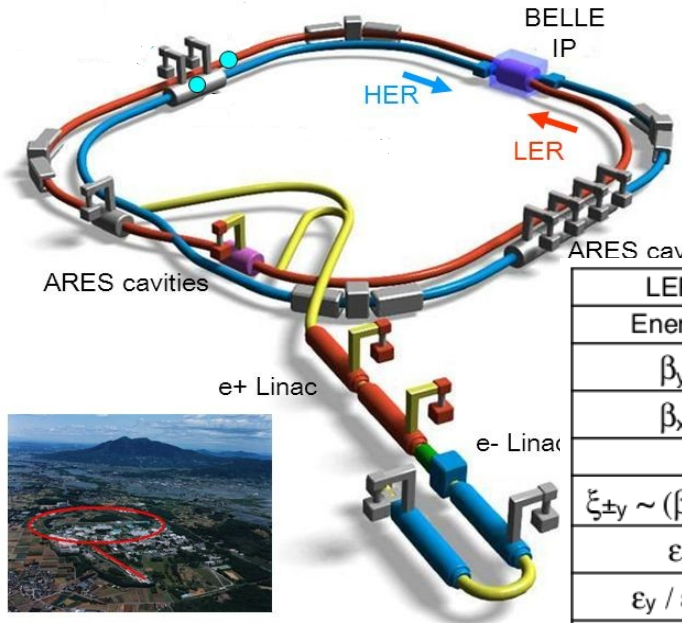




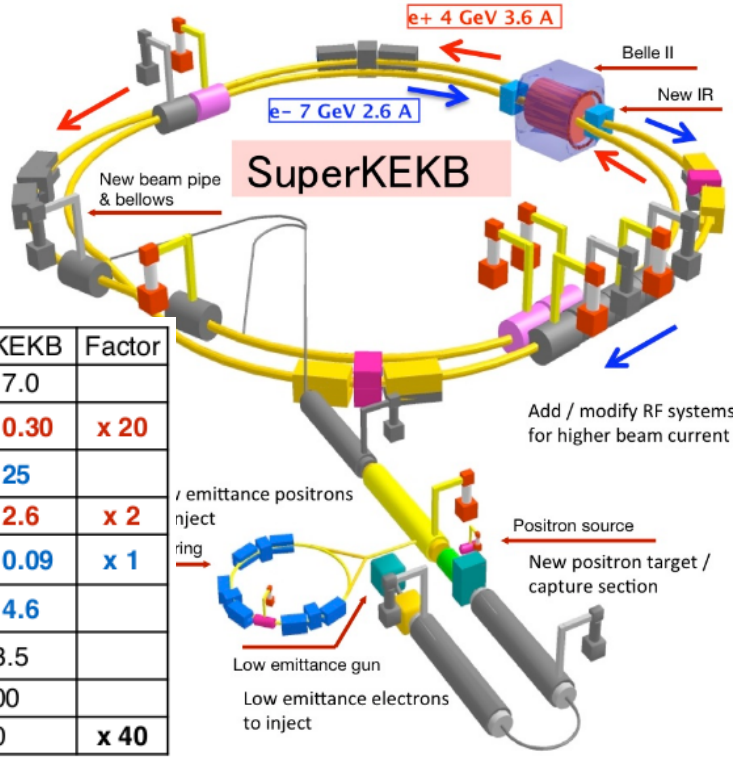
S. Wehle et al. PRL118,111801(13 March 2017)

- ✔ first lepton flavor dependent angular analysis
- ✔ P_5' ($4\ \mathrm{GeV}^2/c^2 < q^2 < 8\ \mathrm{GeV}^2/c^2$): muon mode $\sim 2.6\sigma$ from SM
- ✔ some hint towards lepton flavour universality violation?
- ✔ need more data for conclusive answer

From KEKB to SuperKEKB



LER / HER	KEKB	SuperKEKB	Factor
Energy [GeV]	3.5 / 8	4.0 / 7.0	
β_y^* [mm]	5.9 / 5.9	0.27 / 0.30	x 20
β_x^* [mm]	1200	32 / 25	
$I_\pm$ [A]	1.64 / 1.19	3.6 / 2.6	x 2
$\xi_{\pm y} \sim (\beta_y^*/\varepsilon_y)^{1/2} / \sigma^*_x$	0.129 / 0.09	0.09 / 0.09	x 1
ε_x [nm]	18 / 24	3.2 / 4.6	
$\varepsilon_y / \varepsilon_x$ [10^{-3}]	8 / 6	4 / 3.5	
# of bunches	1584	2500	
Luminosity [10^{34} cm^{-2}]	2.1	80	x 40



Lorentz factor

Beam current

Beam-Beam parameter

$$L = \frac{\gamma}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_{beam}\xi_y}{\beta_y^*}\frac{R_L}{R_{\xi_y}}$$

Geometrical reduction factors (crossing angle, hourglass effect)

Beam aspect ratio at IP

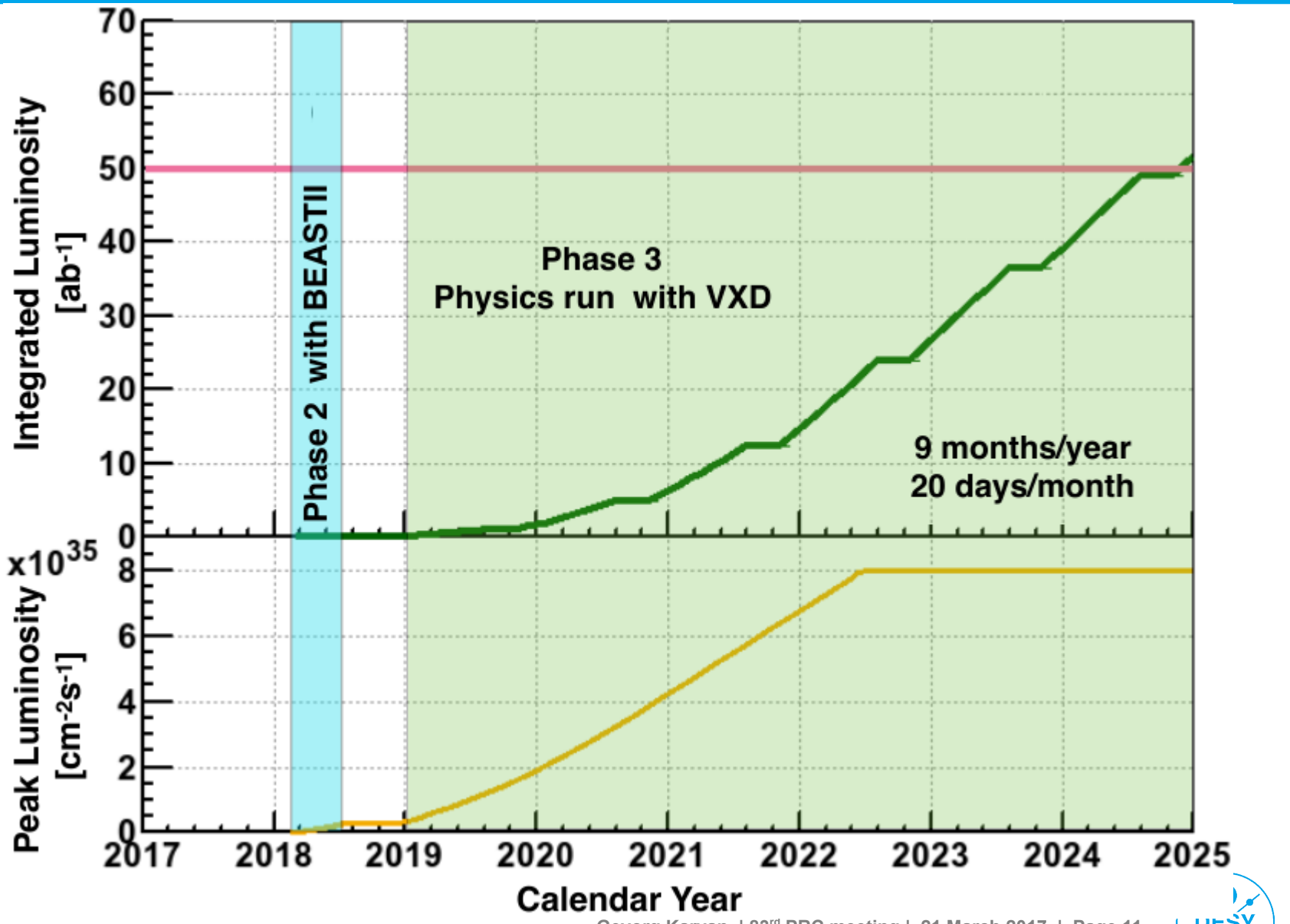
Vertical beta function at IP

$$\beta_y^* \geq \sigma_s$$

- ✔ world record for peak luminosity ×40
- ✔ world's smallest vertical beta function

DESY

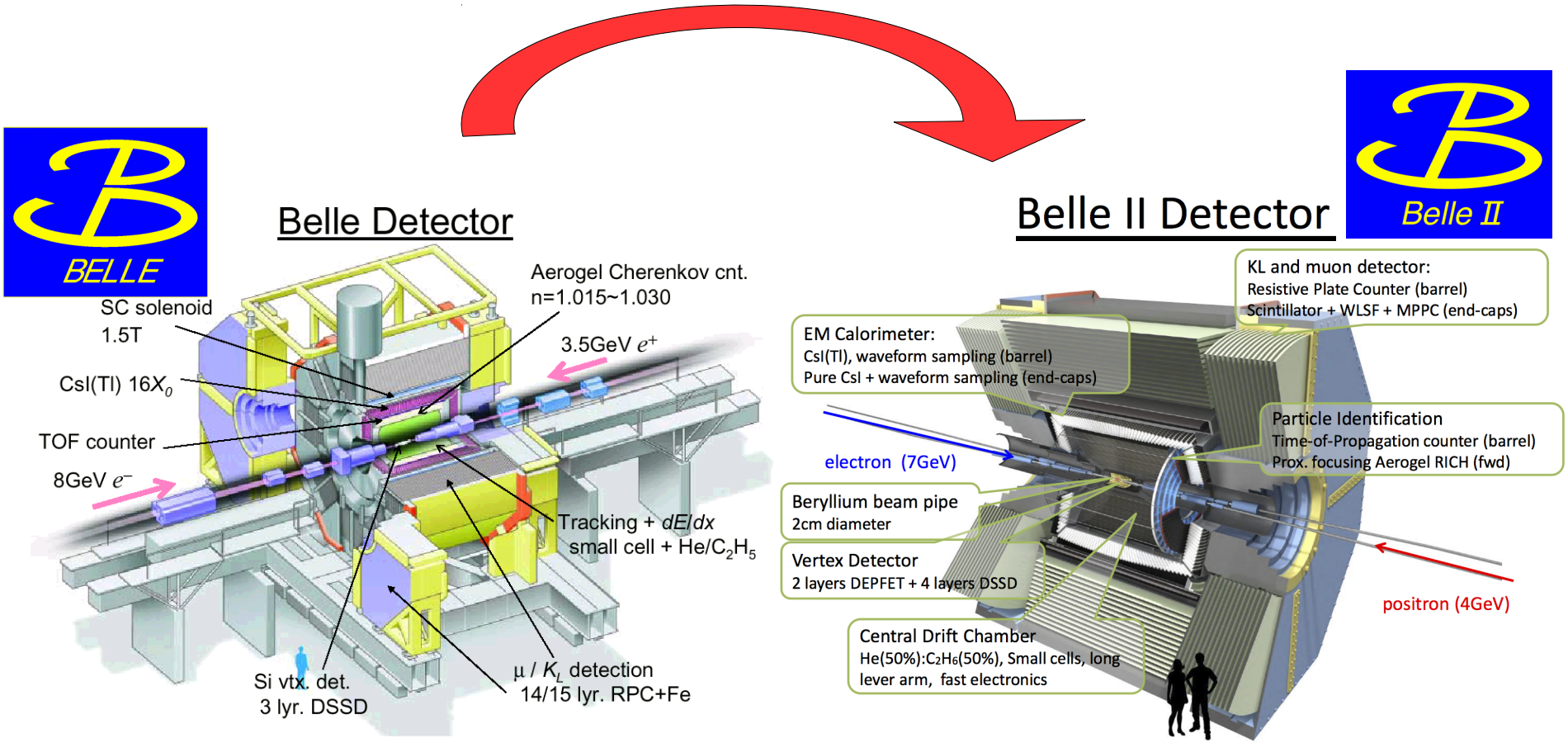
Goal of Belle II/SuperKEKB



QCSR delivery on February 13th

QCSR delivery on February 13th

From Belle to Belle II



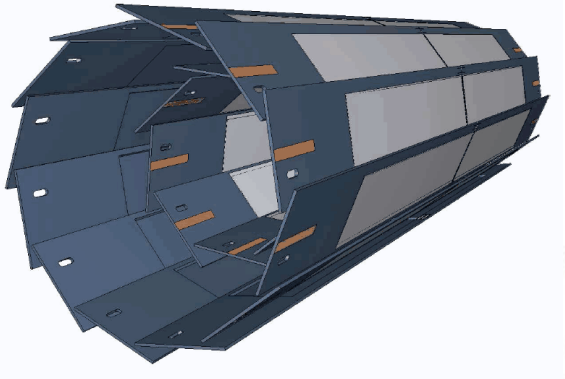
- ✔ **50 times more integrated luminosity**
- ✔ **improved particle ID, tracking, vertex resolution**

DESY

VerteX Detector (VXD)

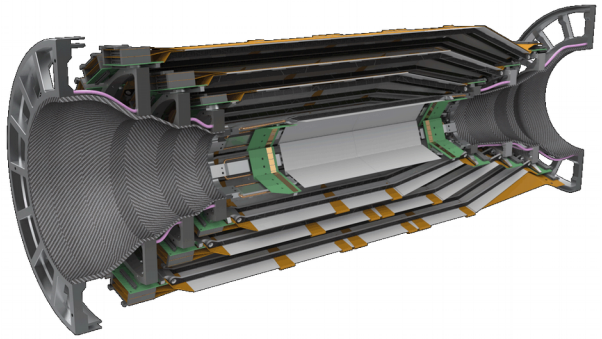
VXD = PiXel Detector (PXD) + Silicon Vertex Detector (SVD)

PXD
(German contribution)

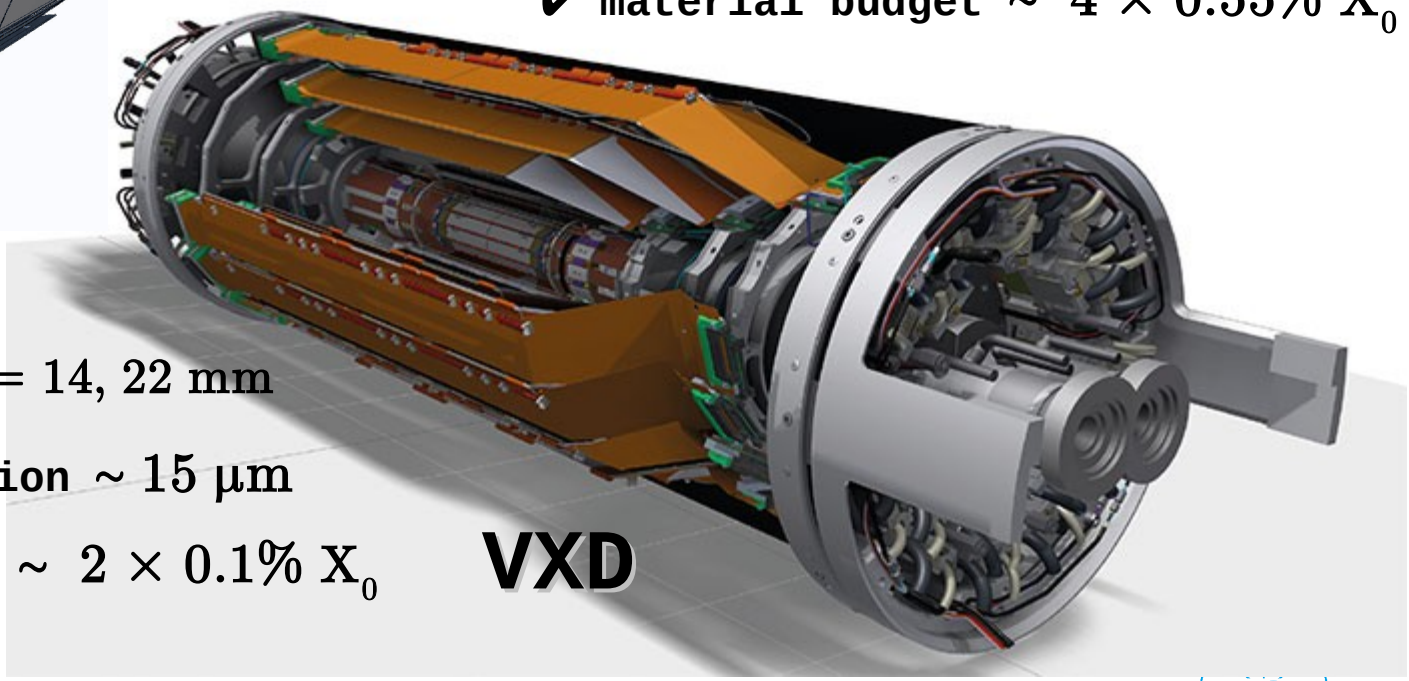


- ✔ 8M pixels
- ✔ two layers at r= 14, 22 mm
- ✔ spatial resolution ~ 15 μm
- ✔ material budget ~ $2 \times 0.1\%\ X_0$

SVD



- ✔ four layers DSSD at r= 38, 80, 104, 124 mm
- ✔ material budget ~ $4 \times 0.55\%\ X_0$



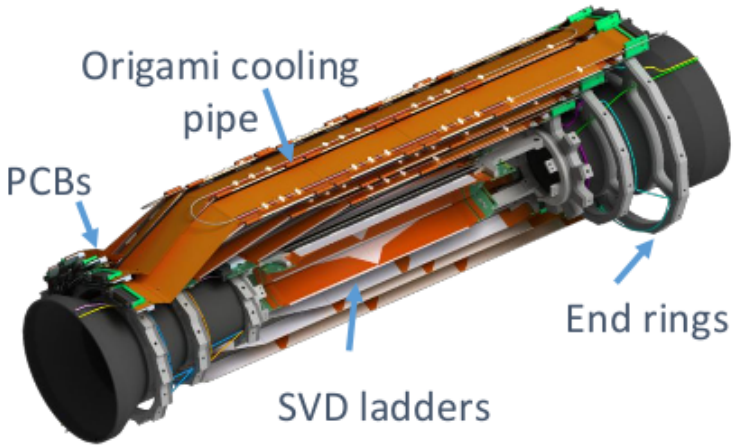
VXD

Thermal Mockup

Cooling of the PXD

Combined Support Cooling Block (SCB), with CO_2 and *N2* channels integrated.

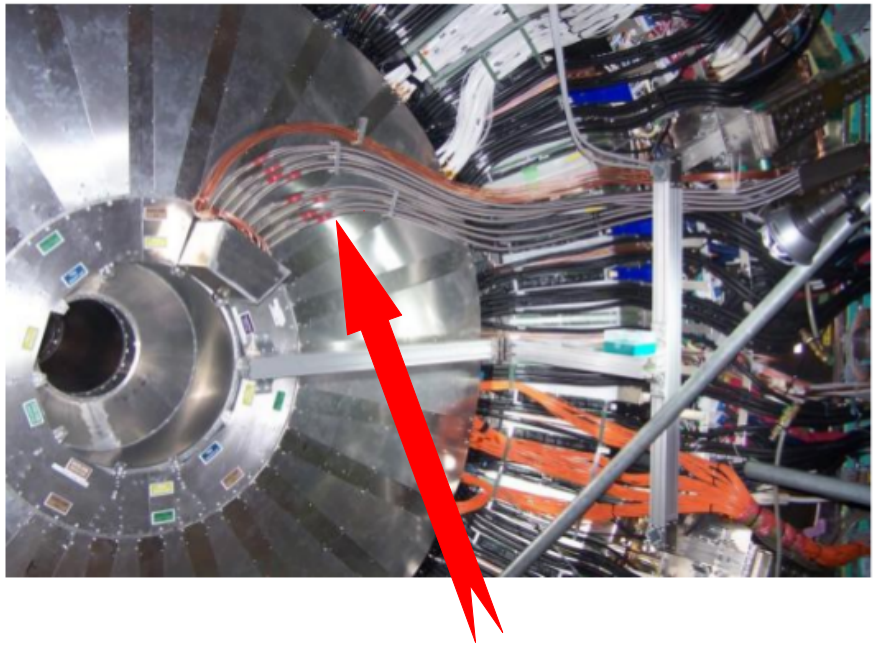
Cooling of the SVD



- ✔ **VXD power consumption** $\sim 1\,\mathrm{kW}$, **PXD(**$360\ \mathrm{W}$**),SVD(**$700\mathrm{W}$**)**
- ✔ **VXD needs to be thermally isolated againts CDC and beam pipe**
- ✔ **in total** 12 **cooling circuits :** 4 **PXD,** 4 **endrings,** 4 **origami cooling pipes**

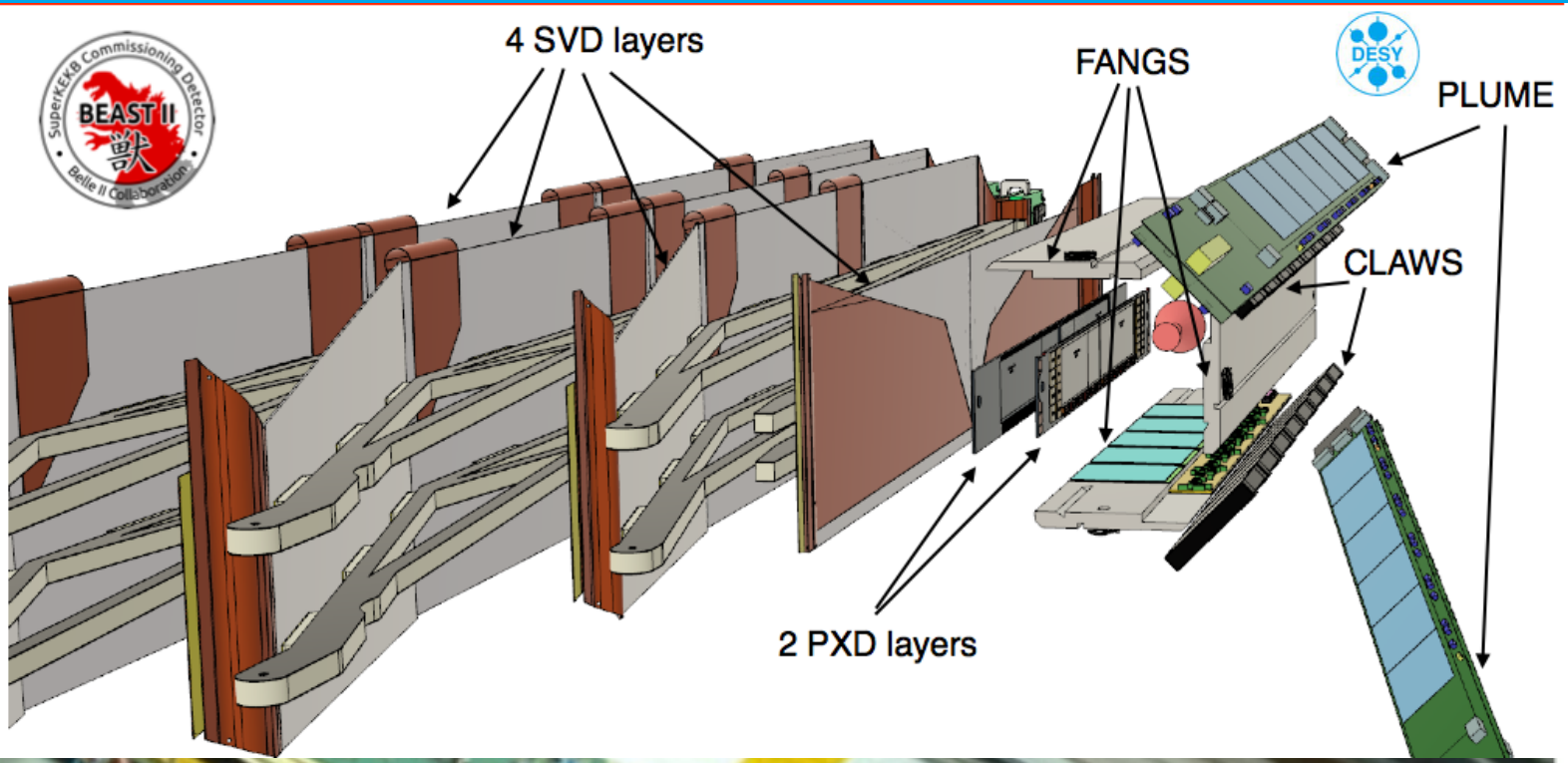
Vacuum isolated flex lines

✔ 12 CO_2 vacuum isolated flex lines were produced at DESY



✔ installed at KEK on December 2016

Test Beam Set Up



VXD-Test Beam (DESY Feb. 2017)

Test Beam Set Up

PXD, SVD, FANGS, CLAWS

PCMAG (1T)

✔ plastic scintilator with Si photomultiplier readout

✔ radiation hard Si pixel detectors

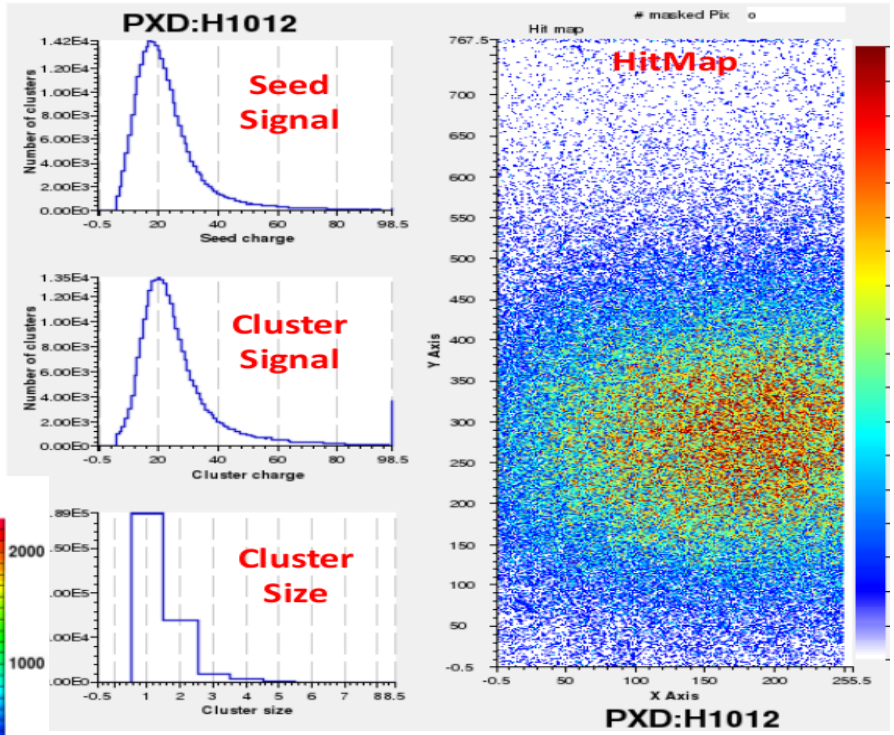
✔ performance test of detector configuration

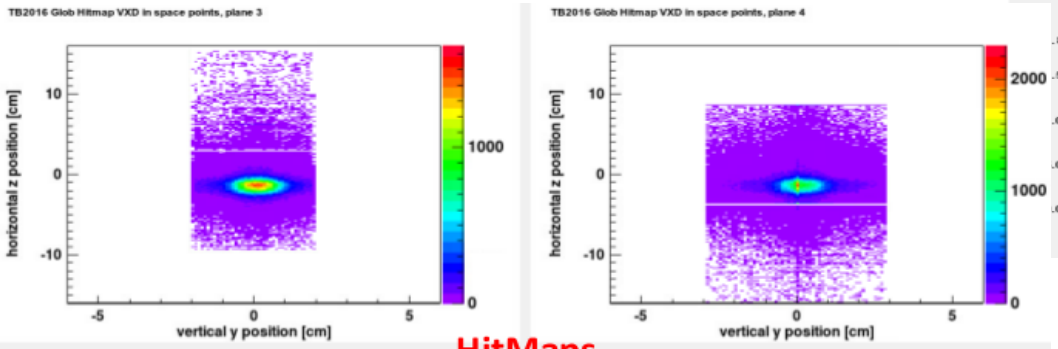
✔ to characterize beam-induced background near the IP

VXD-Test Beam (DESY Feb. 2017)

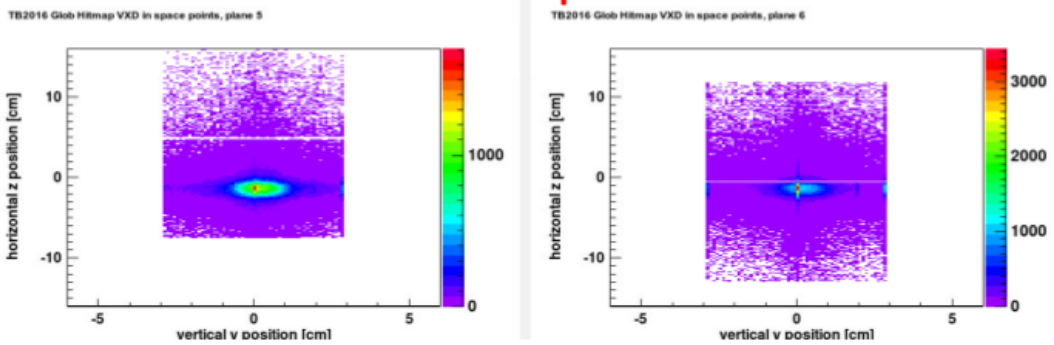
PXD status

- ✔ homogeneous response
- ✔ low noise
- ✔ signal-to-noise ratio ~ 30





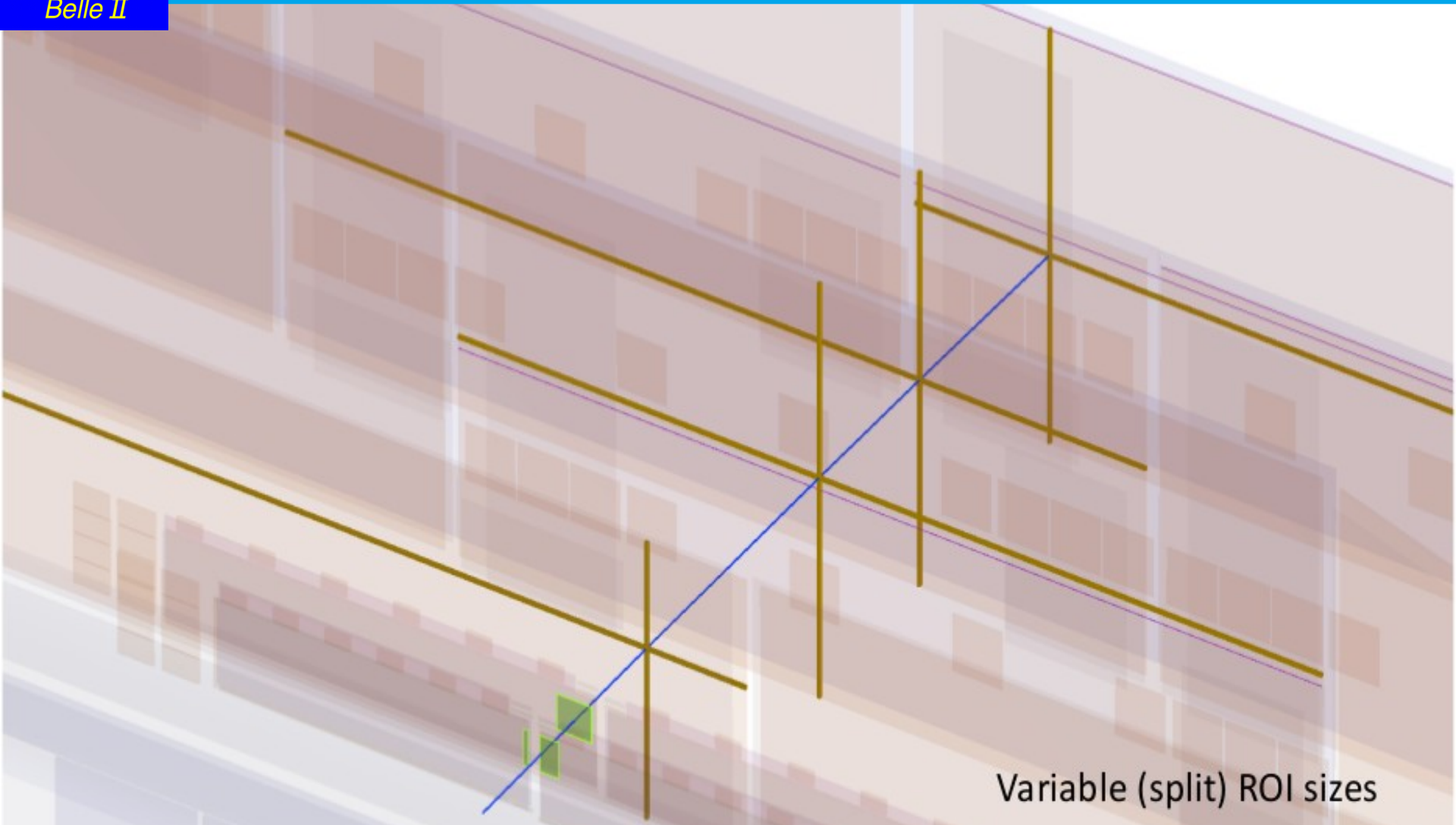
HitMaps



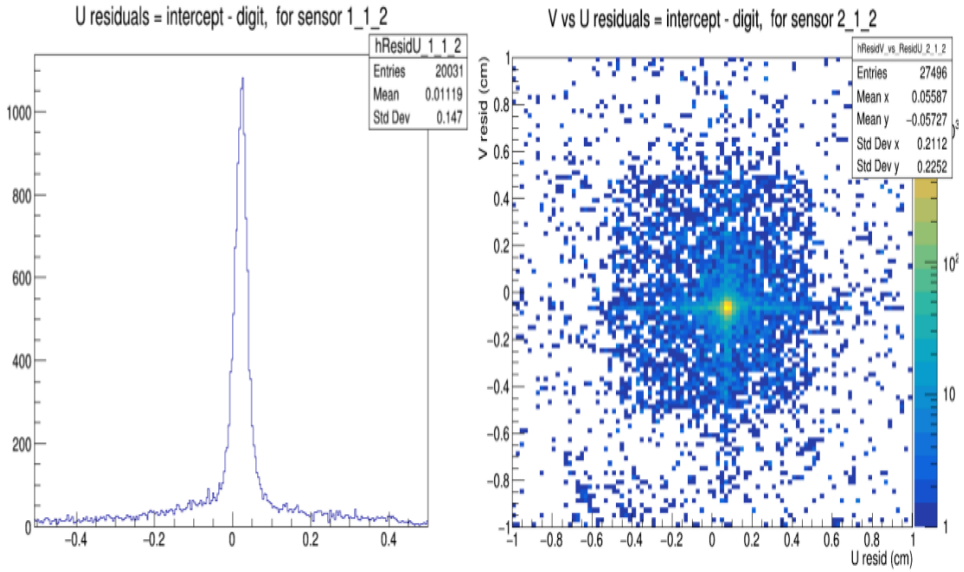
SVD status

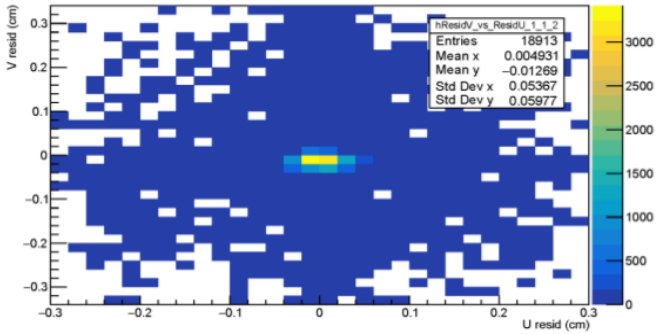
- ✔ very stable running
- ✔ reasonable sensor noise

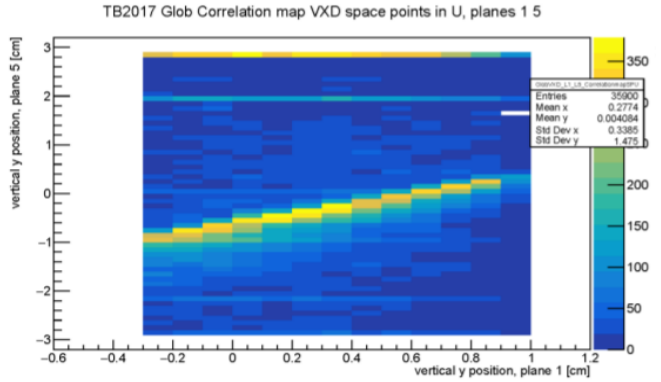
VXDTF2 Online Region Of Interest Selection



VXD Track Finder (VXDTF)



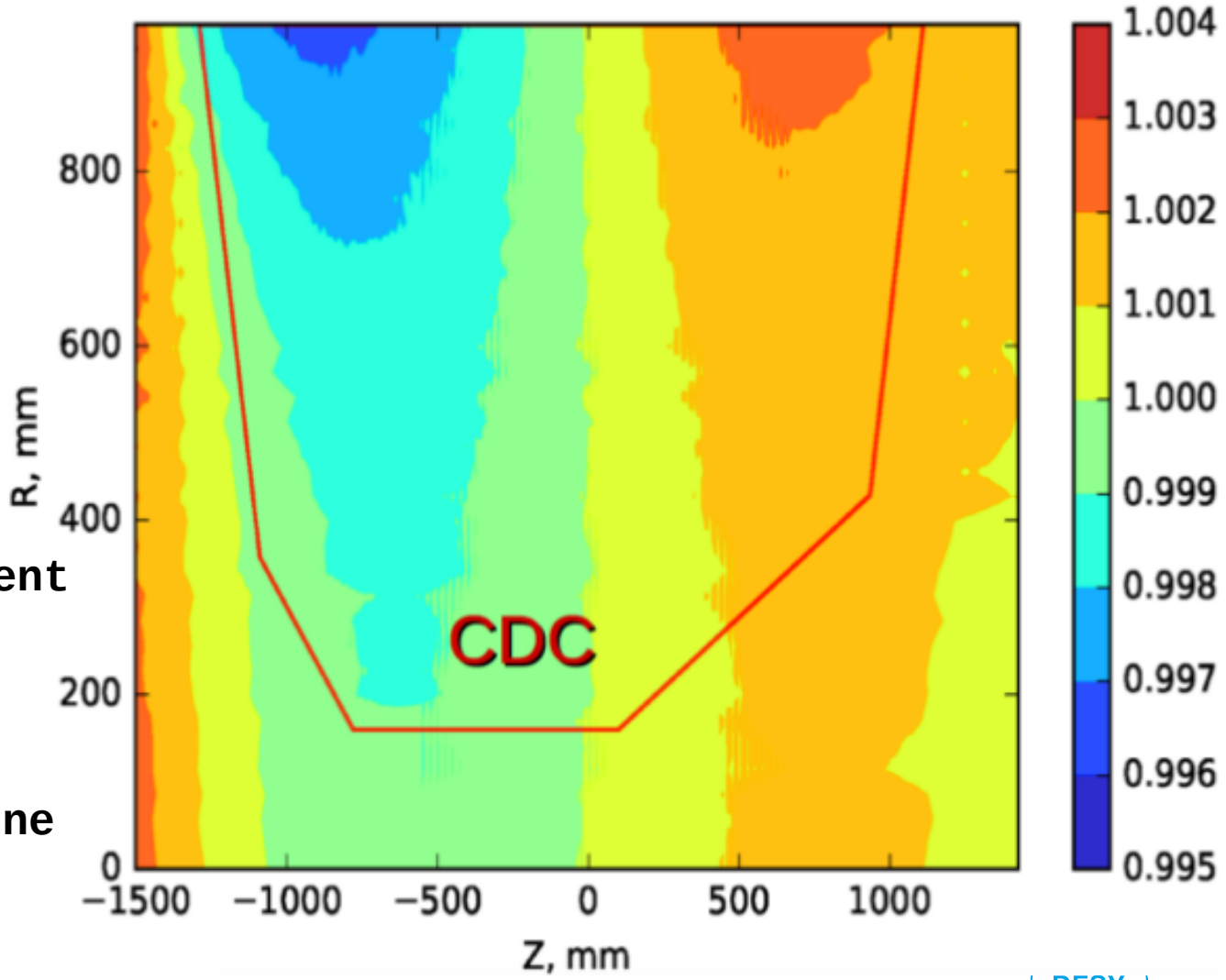




- ✔ magnetic field scans
  - ✔ energy scan at 1T magnetic field
    - ✔ angular scan at 1T and 2.4 GeV
      - ✔ trigger rate tests
        - ✔ temperature scans

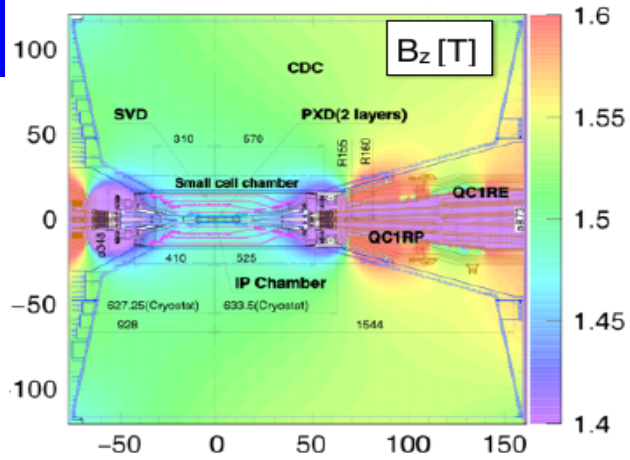
Solenoidal field measurement

- ✔ understand field better than 0.1%
- ✔ reasonable agreement between data and simulation
- ✔ data can be used for the further tune of the simulation

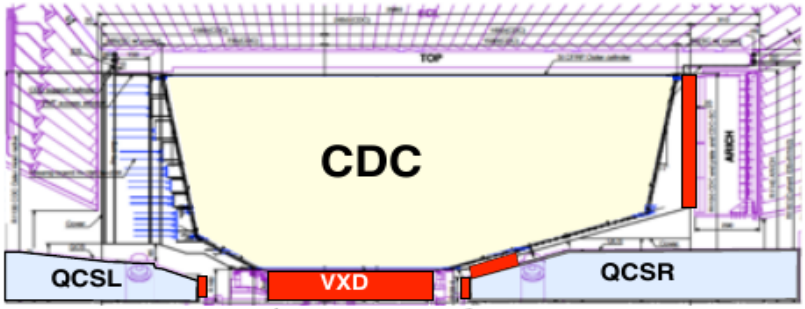


B-field measurement

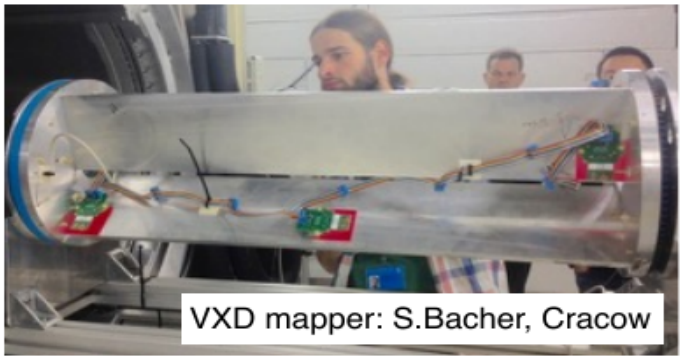
Calculated stray fields of QCSL/R



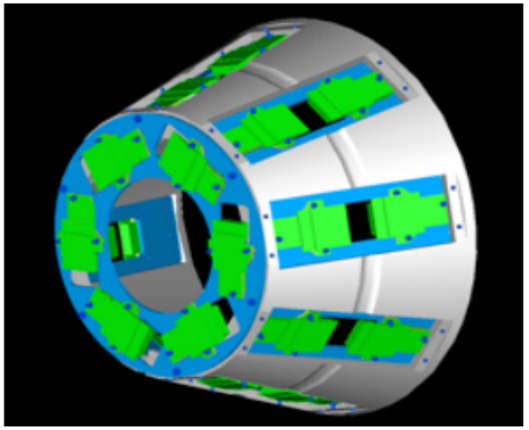
Instrumented regions for 2nd campaign in 2017



Functionality test in PCMAG Dec 2016

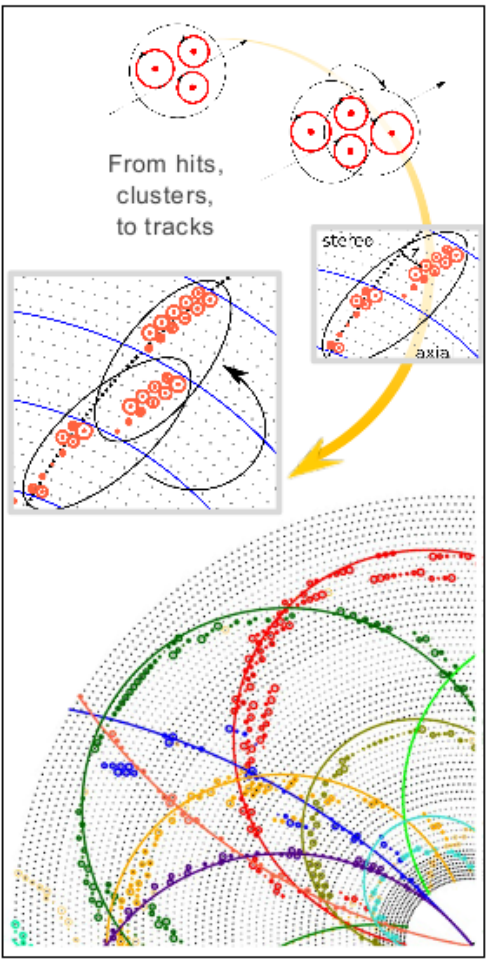


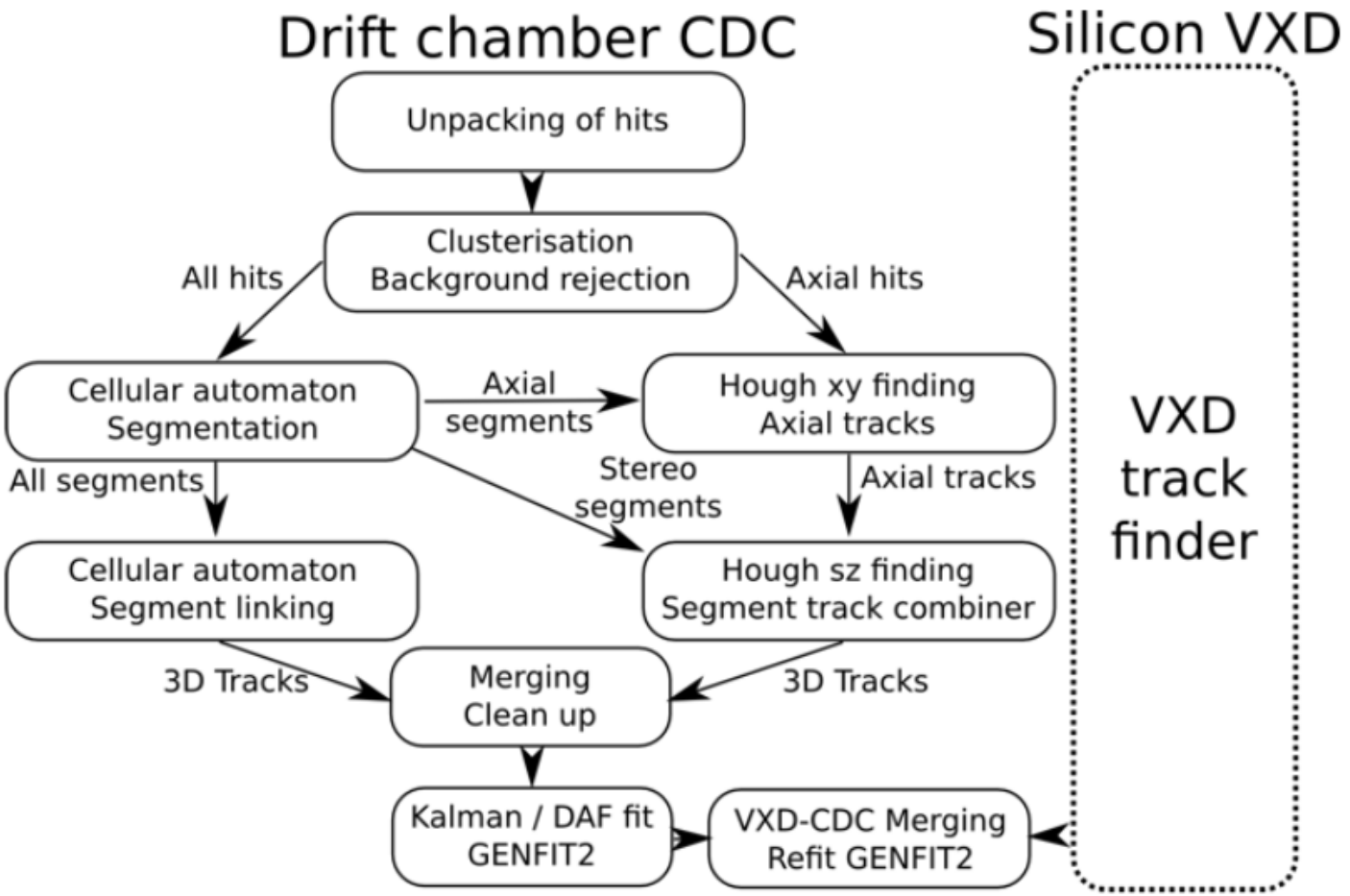
Installation test on QCSR Feb 2017



- ✔ **Belle II QCS fringe fields ~100 larger than in Belle case**
- ✔ **need to understand combined field of solenoid and QCS magnets**

From hits to the tracks



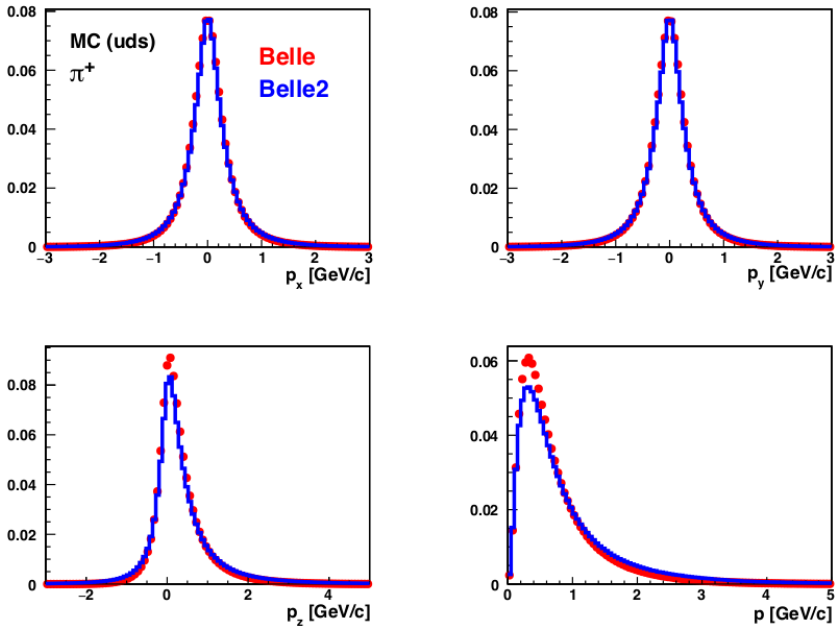


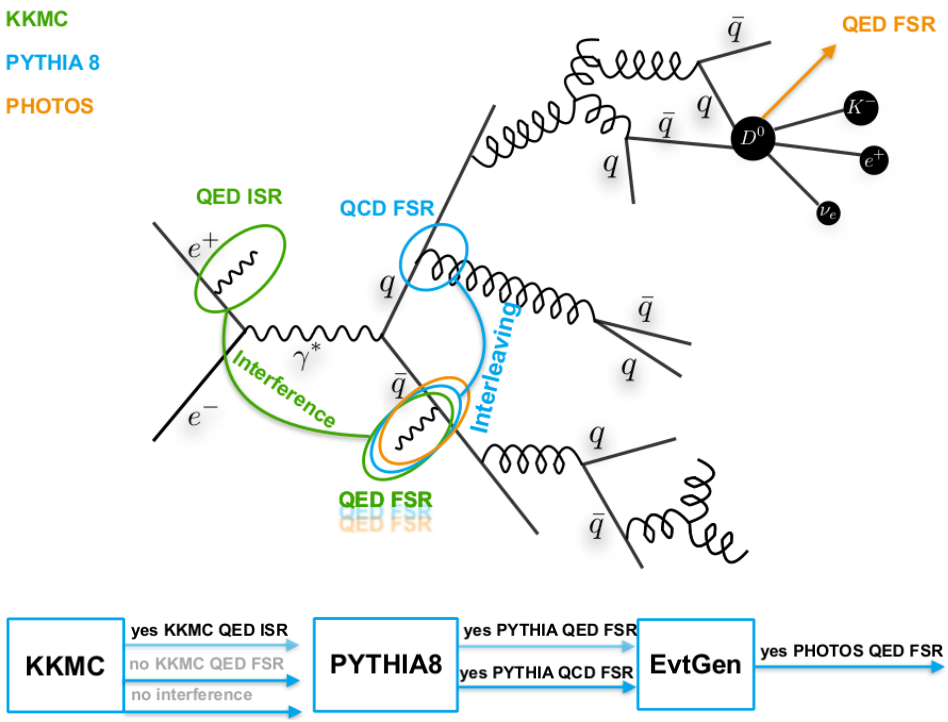
✔ cosmic ray test underway at KEK

PYTHIA8 tuning for Belle II

Belle MC → Belle II MC

- ✔ EvtGen → KKMC
- ✔ PYTHIA6 → PYTHIA8





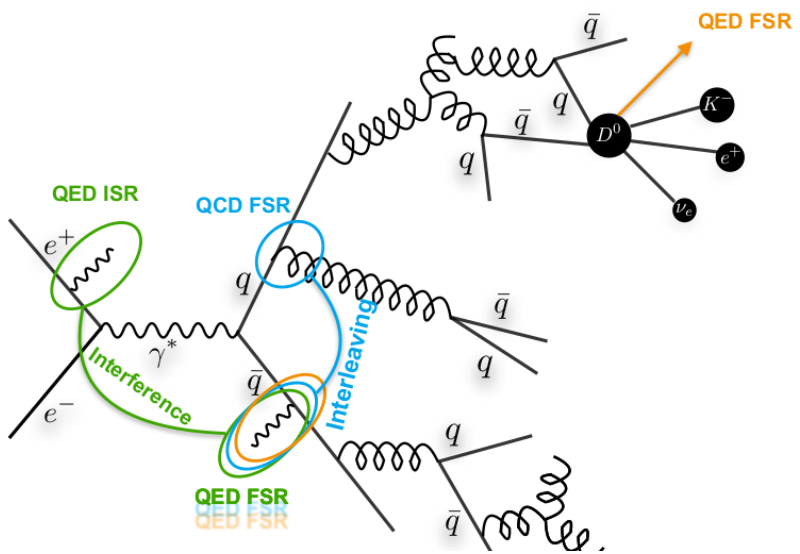
- ✔ no one-to-one correspondence between PYTHIA6 and PYTHIA8 parameters
- ✔ recover PYTHIA8 based MC parameter list
- ✔ examine new parameters

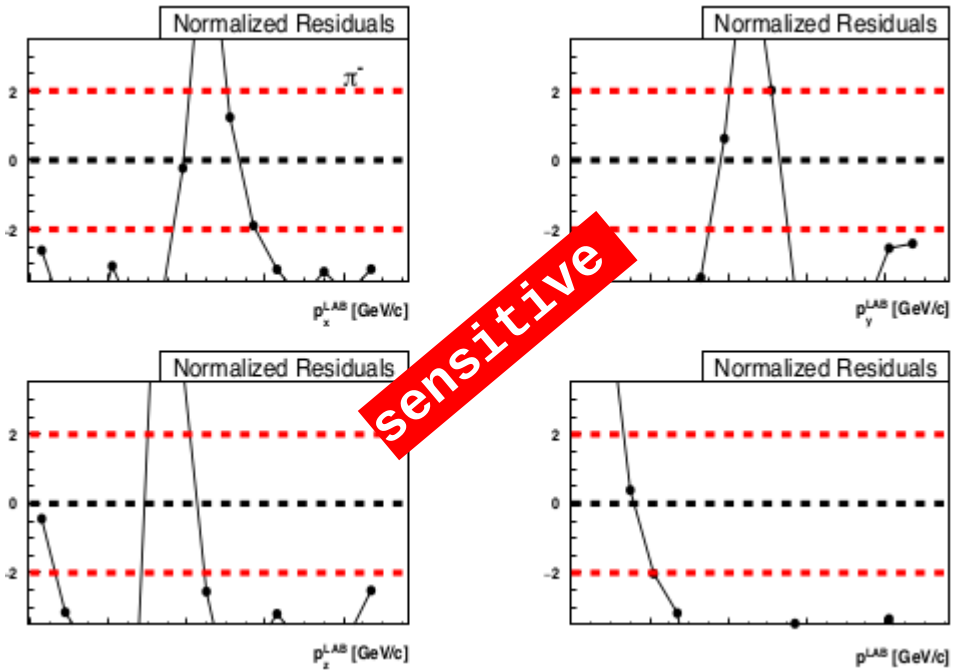
PYTHIA8 tuning for Belle II

Sensitivity checks

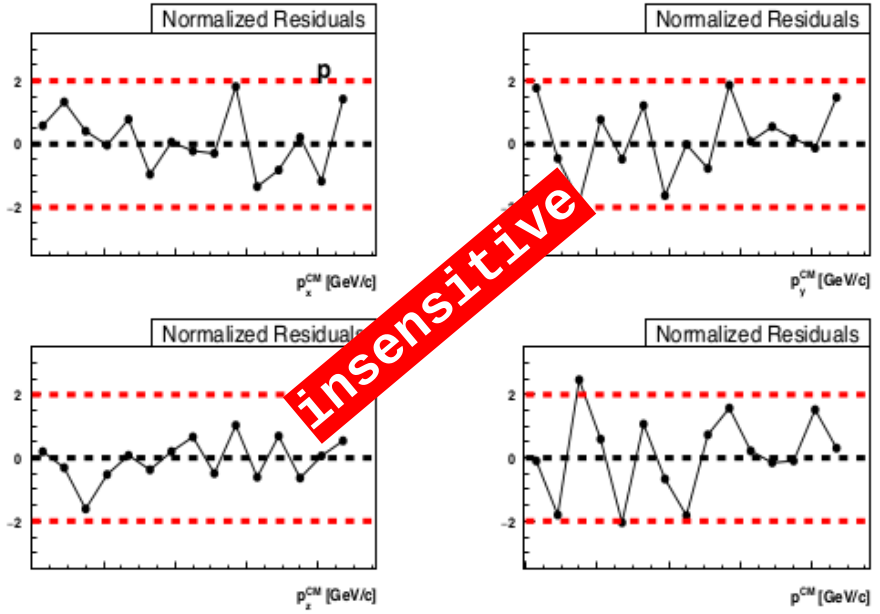
- ✔ reference sample
- ✔ modified sample

KKMC
PYTHIA 8
PHOTOS





sensitive



insensitive

- ✔ parameter list for the tuning

Simultaneous fit of 14 parameters

✔ parameter list

- StringFlav:etaSup
- StringFlav:etaPrimeSup
- StringFragmentation:stopMass
- StringZ:aLund
- StringZ:bLund
- StringZ:rFactC
- StringPT:sigma
- StringPT:enhancedFraction
- StringPT:enhancedWidth
- StringFlav:probStoUD
- StringZ:aExtraSQuark
- StringZ:aExtraDiquark
- StringFlav:mesonUDvector
- StringFlav:mesonSvector

✔ particle list

π^+, π^-, π^0

K^+, K^-, Λ

$\eta, \eta', \gamma, \bar{p}$

D^0, D_0^*

✔ kinematic variables

z, p_t

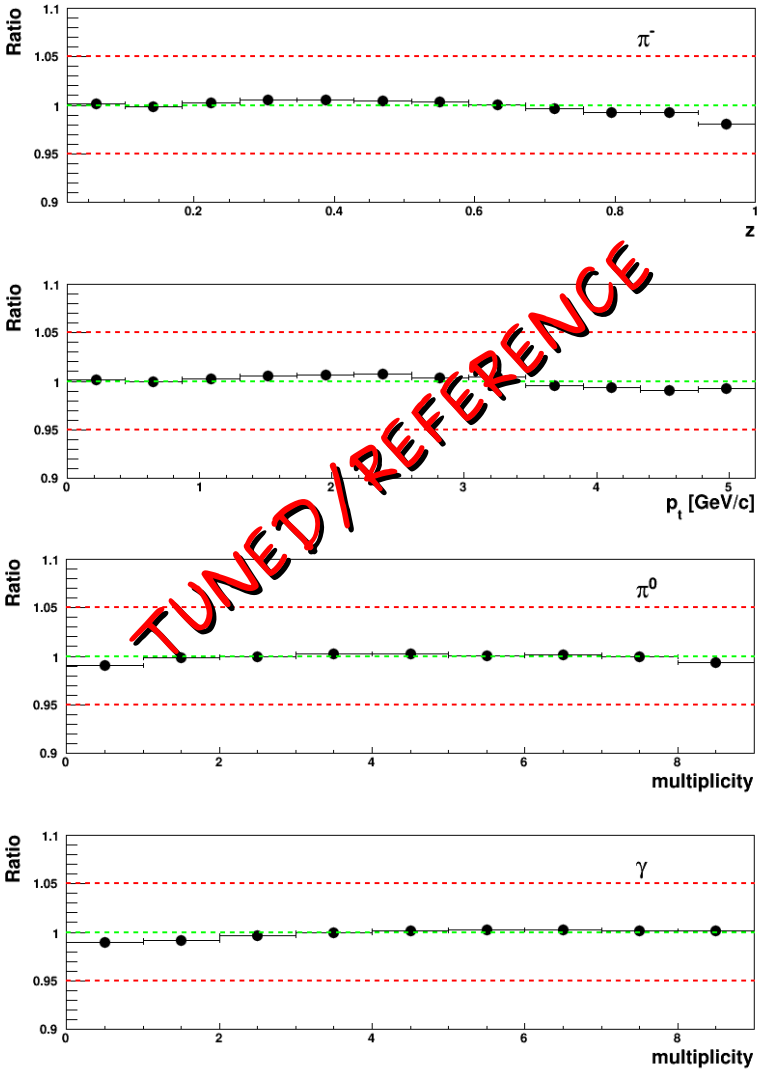
multiplicities

thrust, R_2

✔ ~ 1500 generated samples

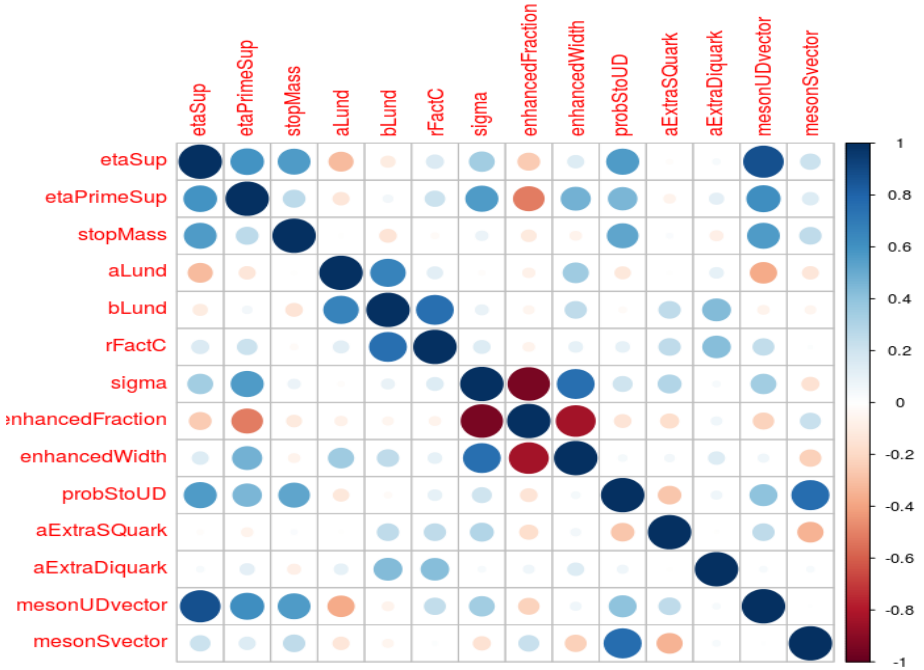
✔ ~ 40TB disk space

Professor tool for tuning

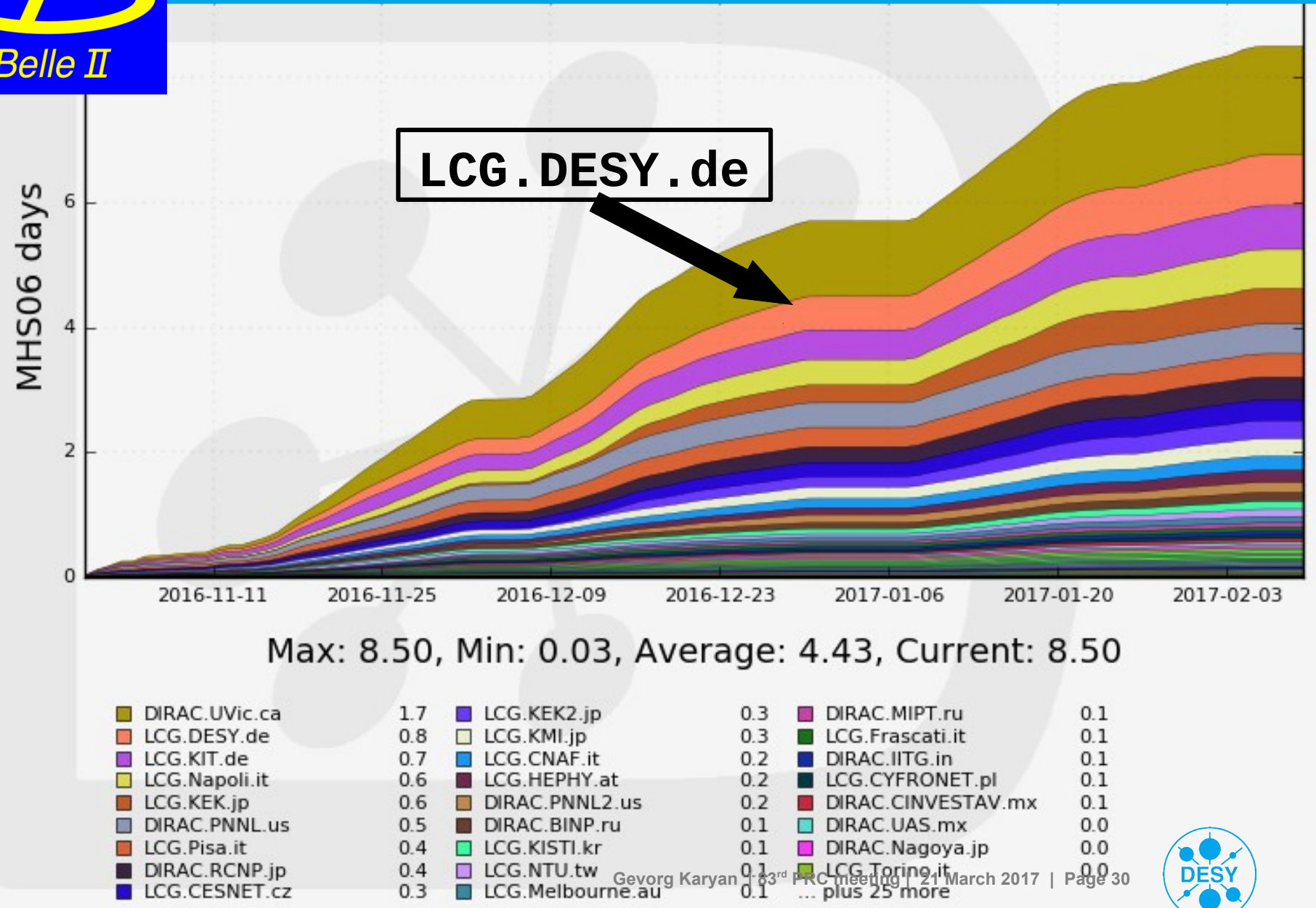


✔ tuning procedure validation

✔ parameter correlations



Computing


LCG.DESY.de
MHS06 days
0
2
4
6
2016-11-11
2016-11-25
2016-12-09
2016-12-23
2017-01-06
2017-01-20
2017-02-03
Max: 8.50, Min: 0.03, Average: 4.43, Current: 8.50
DIRAC.UVic.ca 1.7
LCG.DESY.de 0.8
LCG.KIT.de 0.7
LCG.Napoli.it 0.6
LCG.KEK.jp 0.6
DIRAC.PNNL.us 0.5
LCG.Pisa.it 0.4
DIRAC.RCNP.jp 0.4
LCG.CESNET.cz 0.3
LCG.KEK2.jp 0.3
LCG.KMI.jp 0.3
LCG.CNAF.it 0.2
LCG.HEPHY.at 0.2
DIRAC.PNNL2.us 0.2
DIRAC.BINP.ru 0.1
LCG.KISTI.kr 0.1
LCG.NTU.tw 0.1
LCG.Melbourne.au 0.1
DIRAC.MIPT.ru 0.1
LCG.Frascati.it 0.1
DIRAC.IITG.in 0.1
LCG.CYFRONET.pl 0.1
DIRAC.CINVESTAV.mx 0.1
DIRAC.UAS.mx 0.0
DIRAC.Nagoya.jp 0.0
LCG.Torino.it 0.0
... plus 25 more
Generated on 2017-03-02 13:38:19 UTC

Belle II Monte Carlo campaigns

- second contributor (~10%)
  - at DESY 10% of resources used for VO 'belle'

Grid services for Belle II :

- replicating some KEK Grid services(VOMS,CVMFS stratum-1)

Belle II collaborative services:

- migration from KEK to the DESY is finished
  - 75% of Belle II members have DESY credentials to access collaborative services at DESY
  - Belle II Membership Management System(B2MMS) is being worked on

DESY IT infrastructure services and tools for Belle II Collaborative Services (B2CS).

- ✔ DESY user registry - User registration
- ✔ Dcontent 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)
- ✔ Simpa - Mailing list services (lists.belle2.org)
- ✔ Indico - Meeting organization (indico.belle2.org)
- ✔ Invenio - Document management (docs.belle2.org)
- ✔ Logbook - Electronic logbook (elog.belle2.org)
- ✔ Buildbot - On a set of VMs (b2-master.belle2.org)

Efforts & achievements

- ✔ first lepton flavor dependent angular analysis is published
- ✔ 12 CO_2 vacuum isolated flex lines were produced at DESY and installed at KEK on December 2016
- ✔ VXD beam test (February 2017)
- ✔ preparation for combined field measurements (April 2017)
- ✔ cosmic ray tests for tracking is underway
- ✔ PYTHIA8 tuning procedure is validated (February 2017)
- ✔ migration of collaboration services from KEK to DESY is finished

Efforts & achievements