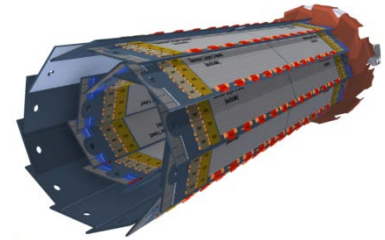


Project Review 2017

Dec 18, 2017

Felix Müller on behalf of the Belle group

Belle II - Team

Director:	Allen Caldwell
Group Leader:	Hans-Günther Moser
Senior:	Vladimir Chekelian, Christian Kiesling
Postdoc:	Luigi Li Gioi (deputy group leader), Felix Müller, Manfred Valentan (Schrödinger Stipendium)
PhD Student:	Fernando Abudinén, Philipp Leitl, Sara Pohl (TUM), Sebastian Skambraks (TUM), Hendrik Windel
Other students:	Mohammed Albalawi, Gregor Bös, Jakob Heidl, Eduard Prinker, Mansour Salman Eid Alatawi, Valerie Schönauer
Technical support:	Karlheinz Ackermann, Markus Fras, Stefan Horn, David Kittlinger, Christoph Knust, Ulrich Leis, Miriam Modjesch, Reinhard Sedlmeyer, Enrico Töpper, Sven Vogt, Andreas Wunderl

Belle II collaboration: ~700 members of 106 institutes in 25 countries

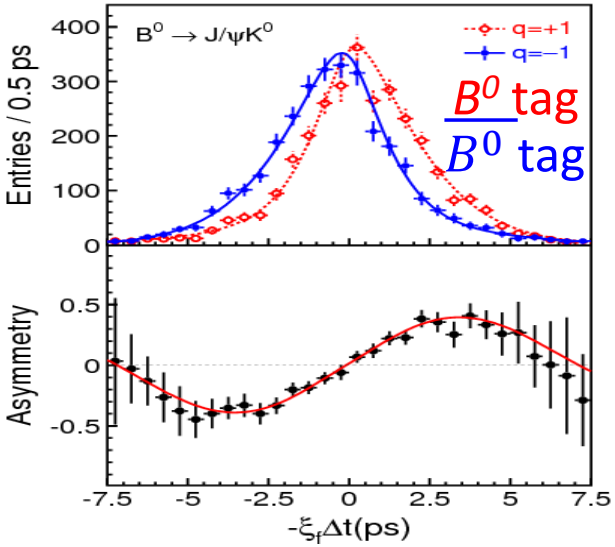
Major MPP contributions: pixel detector (concept), CO_2 cooling, mechanics, software physics preparations

Official Belle II Positions:

- Christian Kiesling – 2009 – June 2017: Project Leader of DEPFET collaboration
- Luigi Li Gioi – Physics group convener of time dependent CP violation & coordinator of the α,β working group of Belle II theory interface platform & contact person of Belle II Tier 2 in Garching
- Hans-Günther Moser – Institutional Board Chair

Physics at B factories

- Measurements of CKM matrix elements and angles of the unitarity triangle
- Observation of direct CP violation in **B** decays
- Measurements of rare decays (e.g., **B→τν, Dτν**)
- **b→s** transitions: probe for new sources of CP violation and constraints from the **b→sγ** branching fraction
- Forward-backward asymmetry (A_{FB}) in **b→sℓℓ** has become a powerful tool to search for physics beyond SM.
- Observation of **D** mixing
- Searches for rare **τ** decays
- Observation of new hadrons

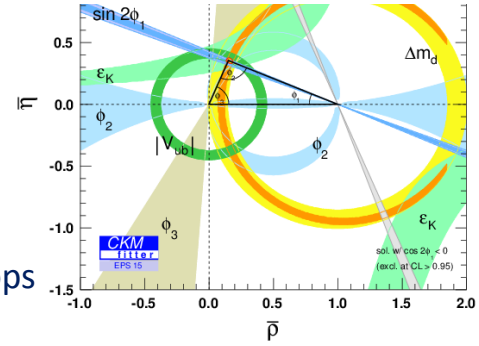


CP violation in B meson decays

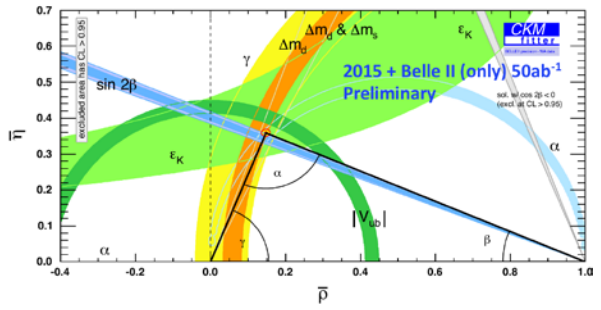
Motivation for upgrade:

- Measure CKM elements as precisely as possible
- Overconstrain the unitarity triangle
- Look for deviations from SM
- Indirect discovery of New Physics via loops

=> Need about 50 ab^{-1}

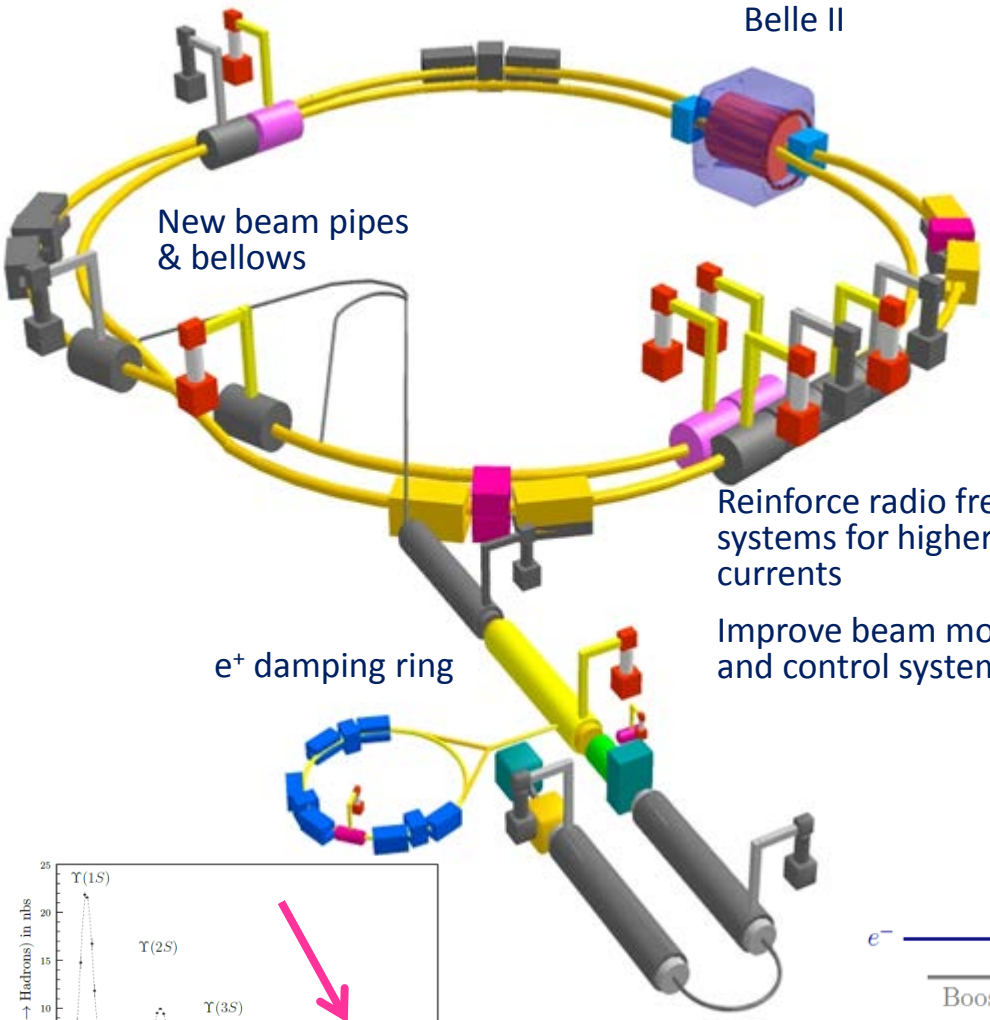


Babar/Belle



With 50 ab^{-1} (same central values)

Upgrade of the accelerator - SuperKEKB



Upgrade KEKB to reach
$L = 8 \times 10^{35}\ cm^{-2}s^{-1}$

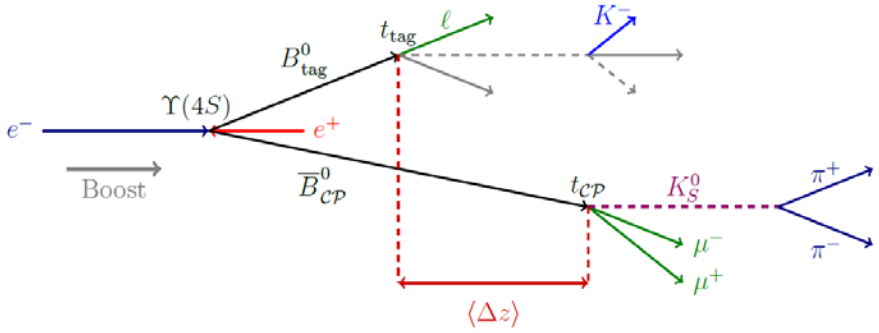
40x higher luminosity

Nano Beams: 10 µm x 50 nm
Increase beam current (x2)

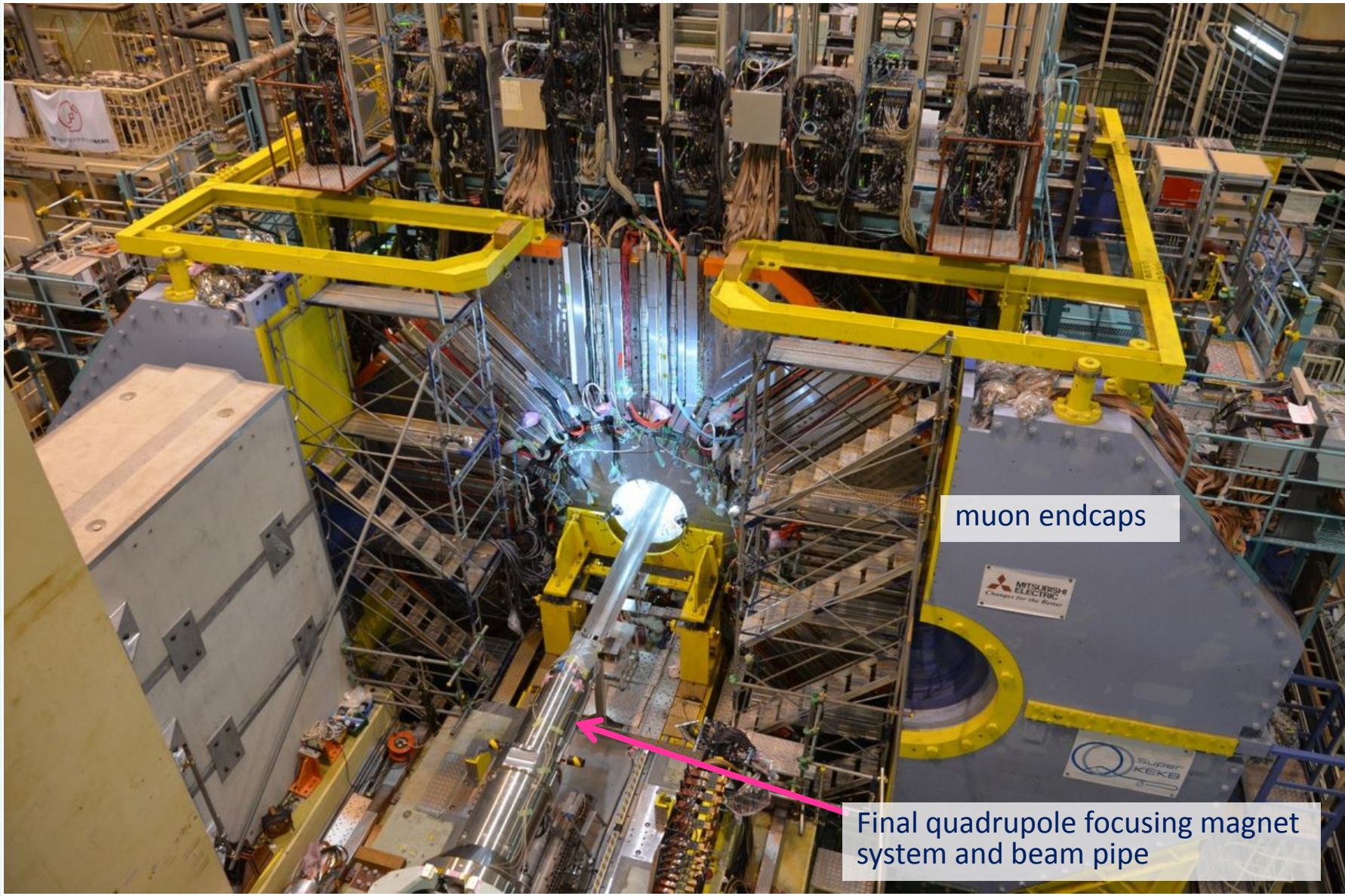
Reduce asymmetry (boost)

KEB:
βγ = 0.42 (8 GeV, 3.5 GeV)
<Δz> ≈ 200 µm

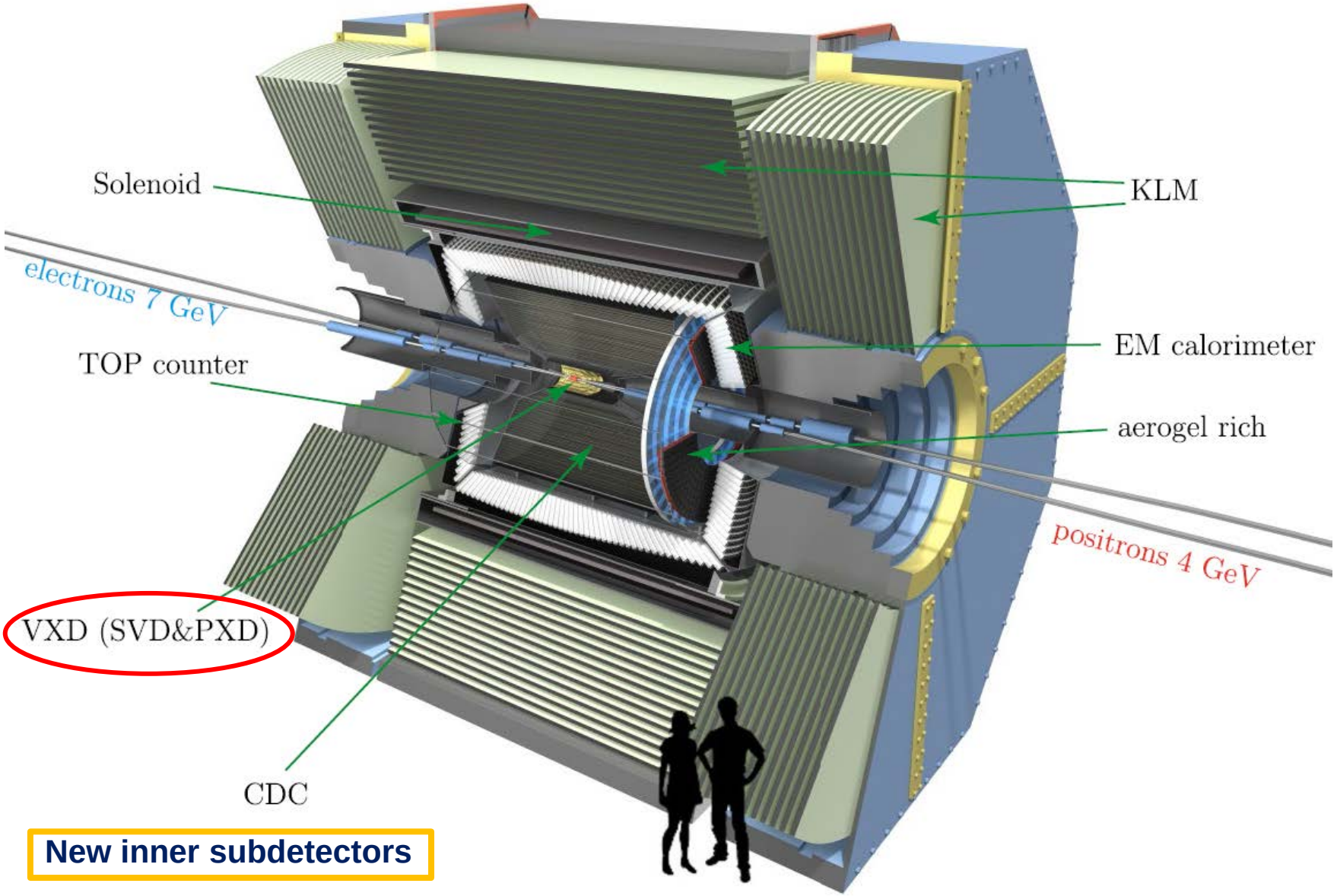
SuperKEKB:
βγ = 0.28 (7 GeV, 4 GeV)
<Δz> ≈125 µm



Belle II – Nov 20, 2017



Belle II Detector



New inner subdetectors

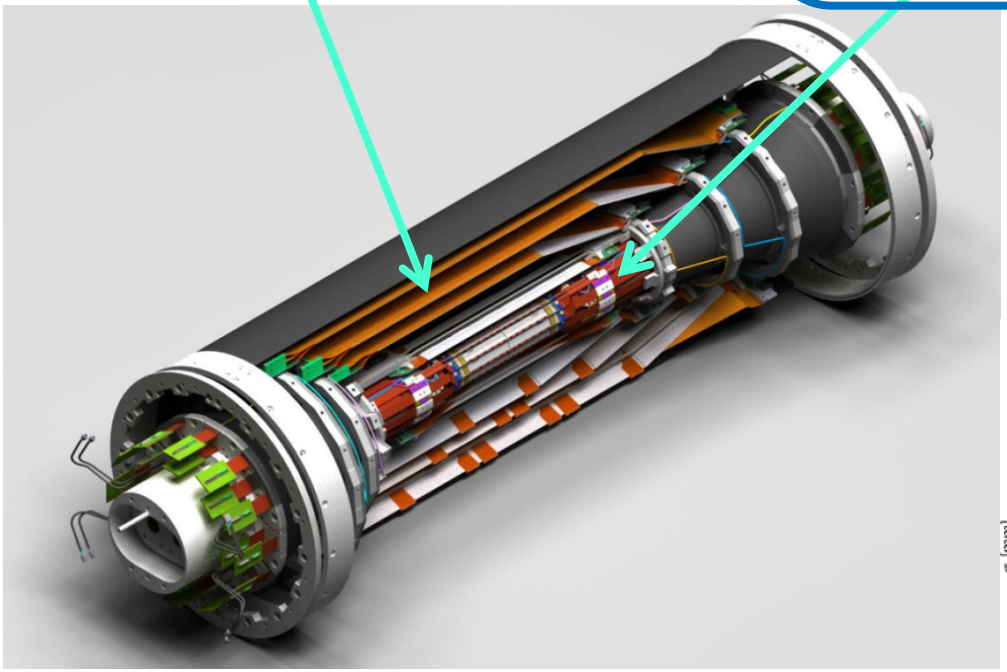
Tracking System at Belle II

SVD: 4 layer silicon strip detector (DSSD)
(R = 3.8, 8.0, 11.5, 14.0 cm)

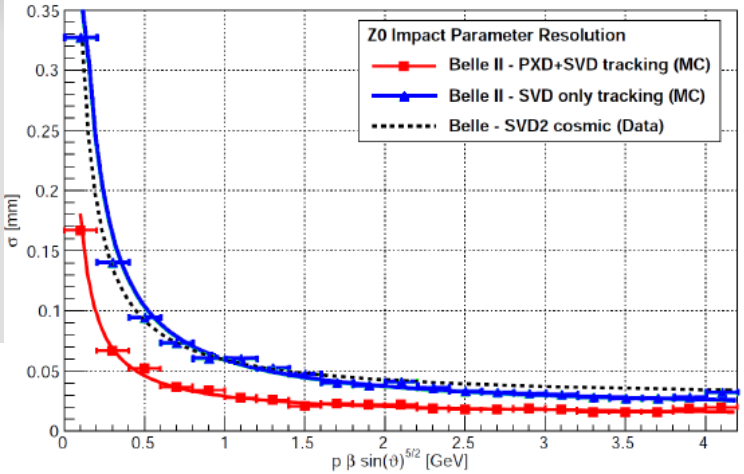
PXD: 2 layer Si pixel detector (DEPFET technology)
(R = 1.4, 2.2 cm)

monolithic sensor – 75 µm thick,
pixel size 50 x 55 µm² to 50 x 85µm² (depending on layer and z)

MPP contribution and also HLL, LMU, DESY, KIT, BN, GOE, HD, KIT, TUM, GIE, MZ



PXD improves impact parameter by ~2

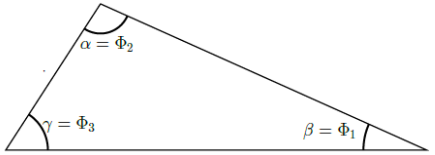


MPP activities – Physics preparation

- MPP activities focused on time dependent CP violation (TDCPV)
- Search of new Physics in time dependent CP violation measurements and precise measurement of the unitarity triangle parameters

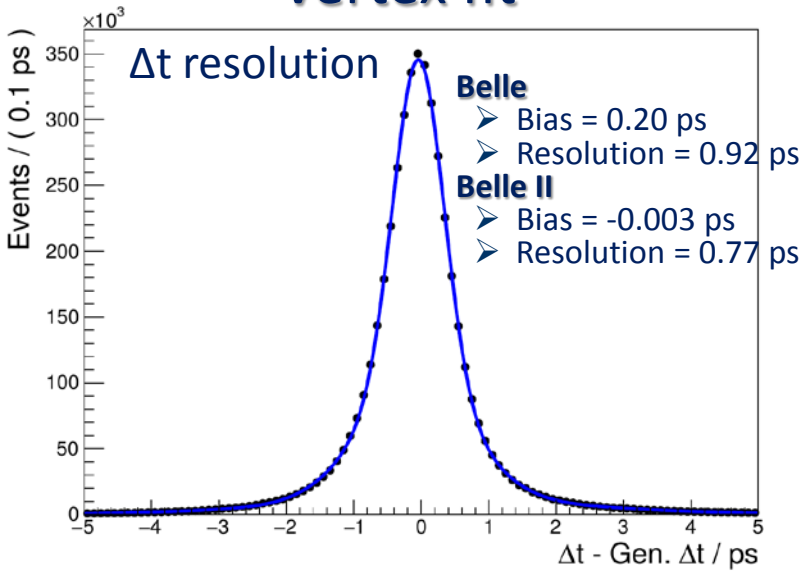
Fernando Abudinen, Vladimir Chekelian, Luigi Li Gioi,

- Coordination of the time dependent CP violation Belle II physics working group
- Coordination of the α/ϕ_2, β/ϕ_1
- Physics software development
- Institutional responsibility on Vertex fit and flavor tagging



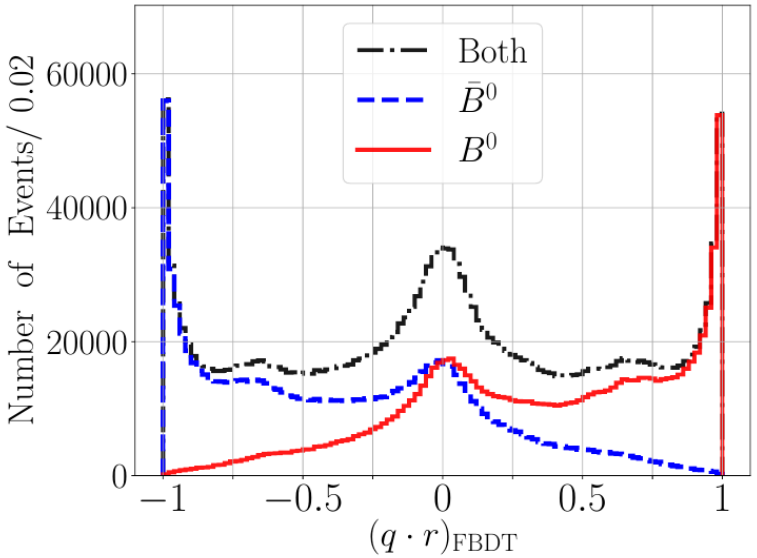
New software and hardware improves vertex fit and flavor tagging

Vertex fit



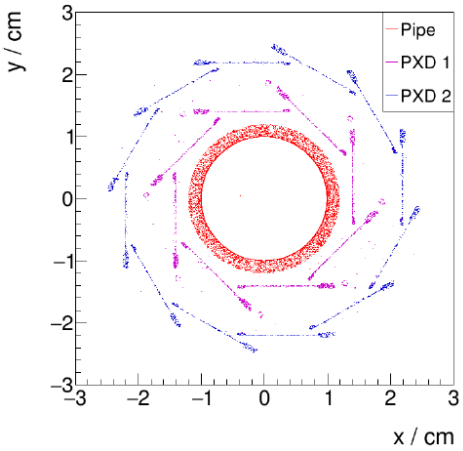
Better than Belle given the reduced boost

Flavor Tagging

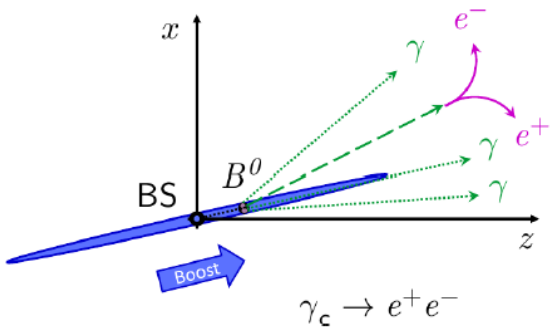


Belle II Monte Carlo: efficiency: 37 %

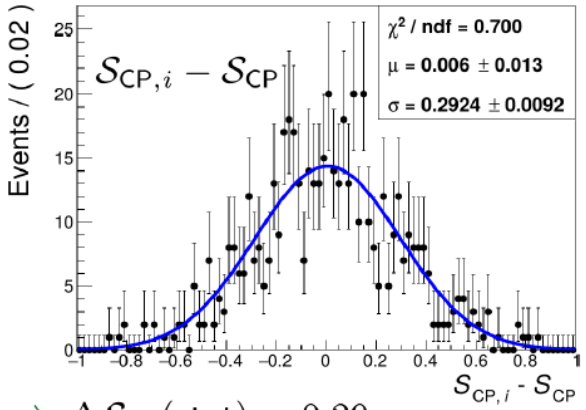
$B^0 \to \pi^0\pi^0$ Time dependent analysis



Photon conversion inside the Belle II detector

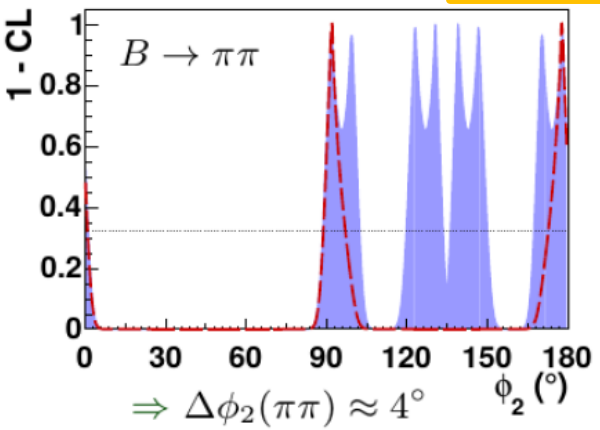


3 % of $B^0 \to \pi^0\,\pi^0$ events
~ 5 % including π^0 Dalitz decay

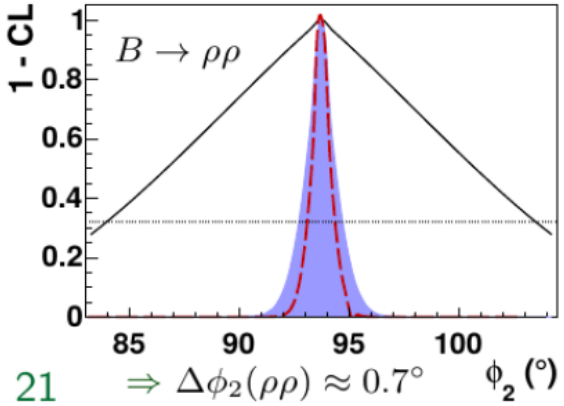


$\Rightarrow \Delta\mathcal{S}_{CP}(\text{stat}) = 0.29$

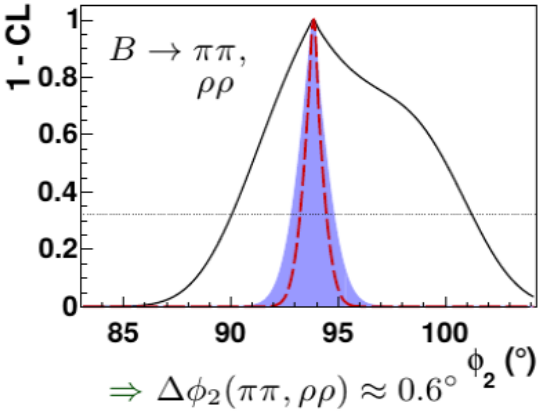
Combined isospin analysis to determine α/ϕ_2
First time new channel with high luminosity



$\Rightarrow \Delta\phi_2(\pi\pi) \approx 4°$



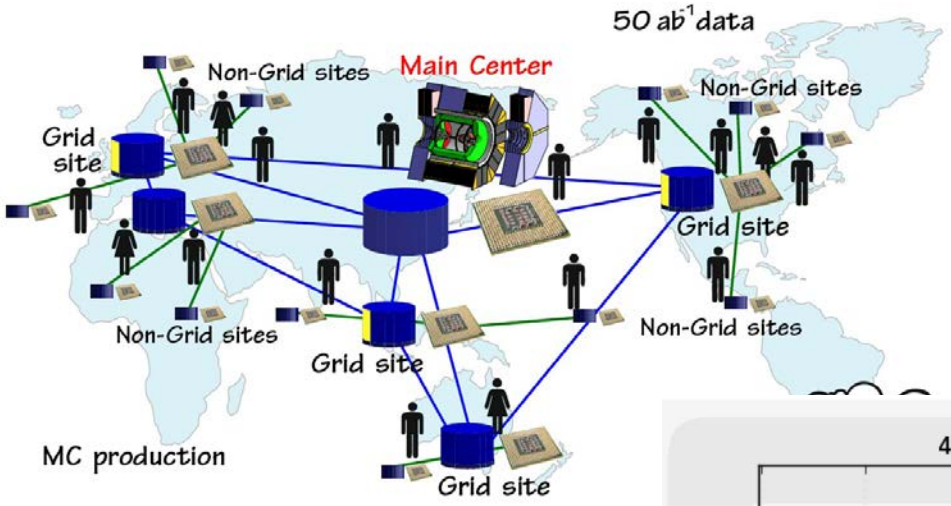
$\Rightarrow \Delta\phi_2(\rho\rho) \approx 0.7°$



$\Rightarrow \Delta\phi_2(\pi\pi, \rho\rho) \approx 0.6°$

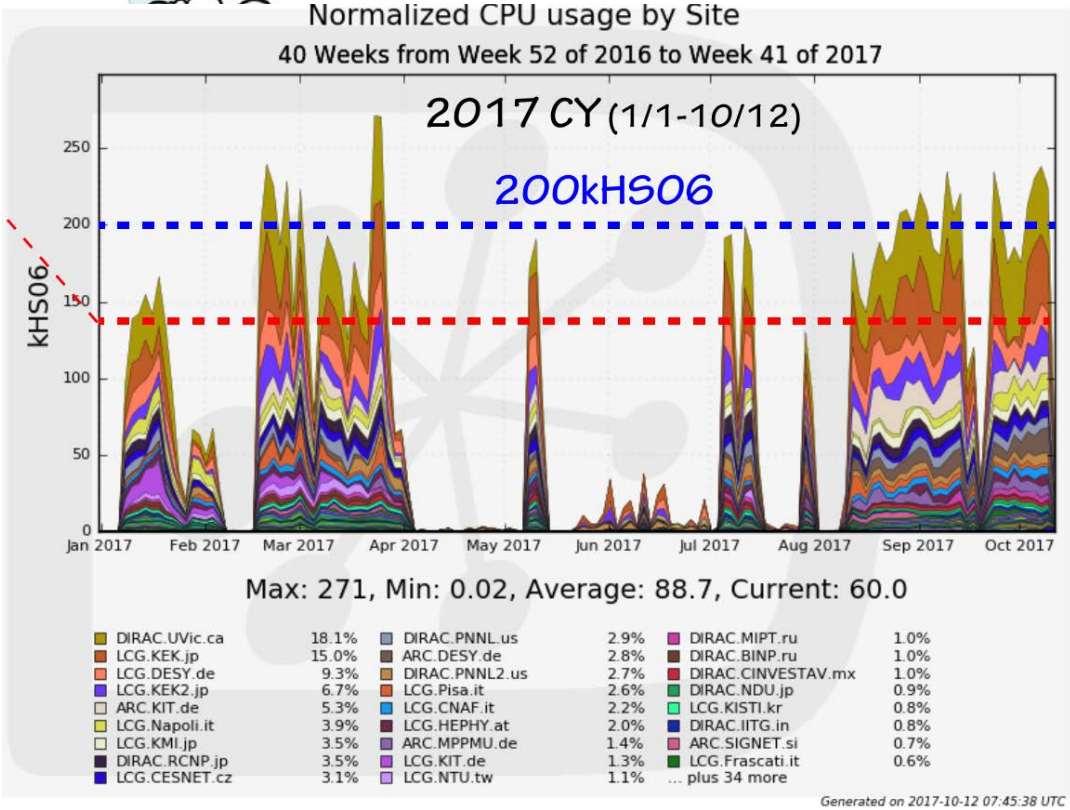
Fernando Abudinén

Computing



Luigi Li Gioi, Hans-Günther Moser

- Belle II adopts GRID computing
- Monte Carlo production and user analysis
- Large Germany contribution during last MC production



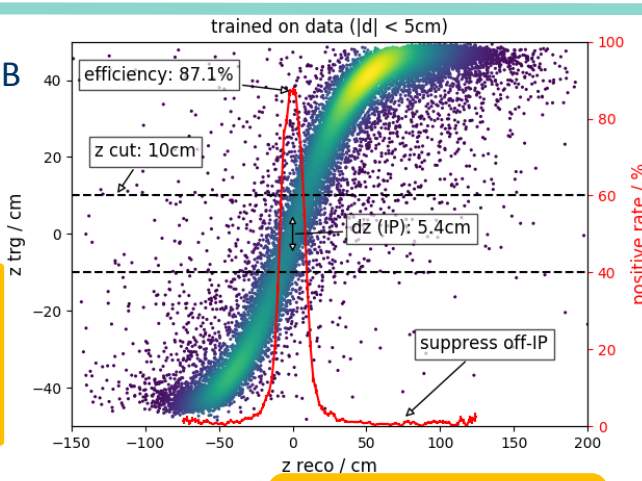
- Max Planck Computing and Data Facility (MPCDF) is a Belle II Tier-2
- Belle II MC production
- Smooth activities during 2017

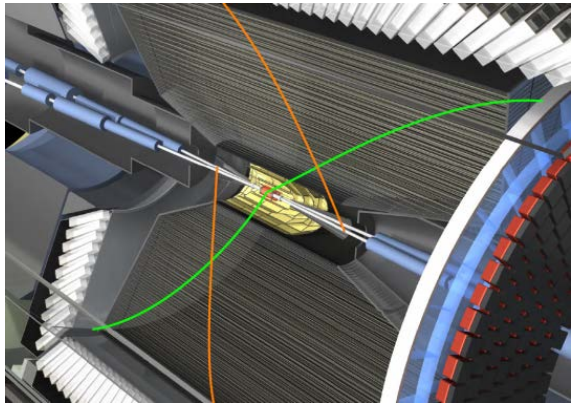
Significant contribution in MC data generation

Neural Network z-vertex trigger

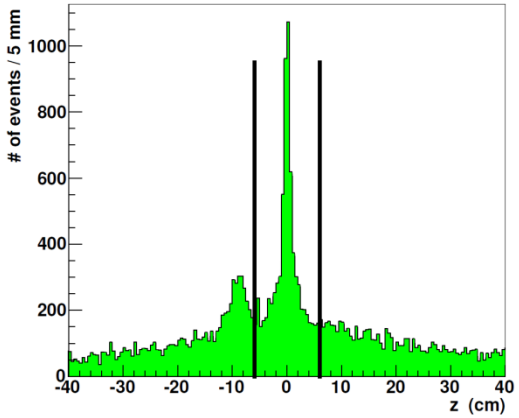
- SuperKEKB: increased luminosity and background compared to KEKB
- Standard central drift chamber trigger: minimum track multiplicity
- z-vertex resolution 2 cm ⟶ cut at ± 6 cm
- Pure 2 track trigger possible

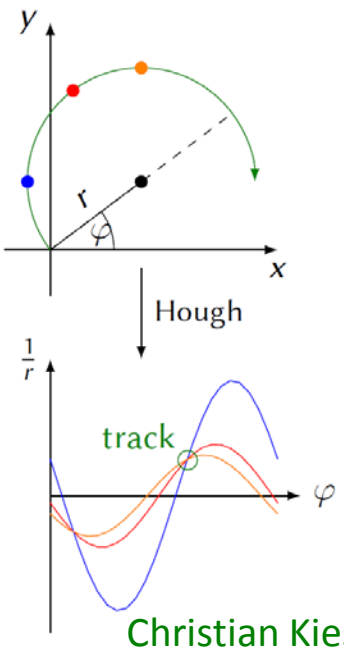
Neurotrigger is essential for data selection

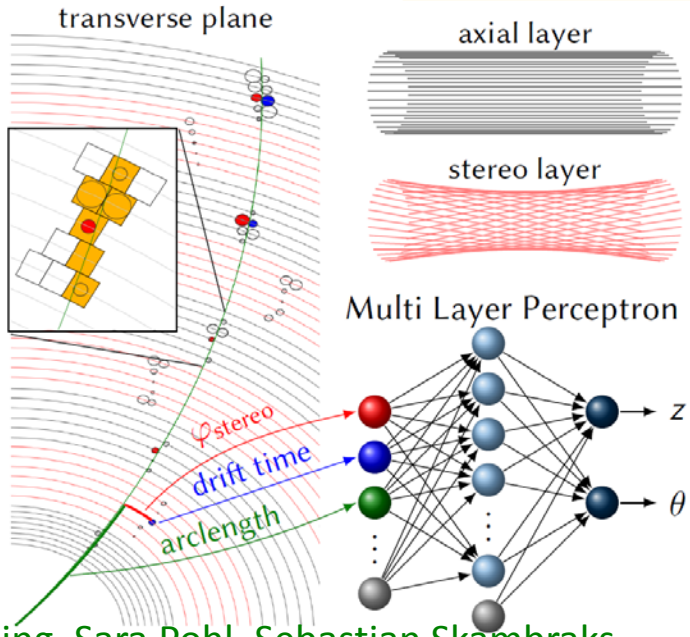


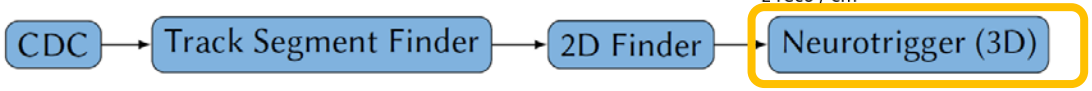


z distribution recorded in Belle



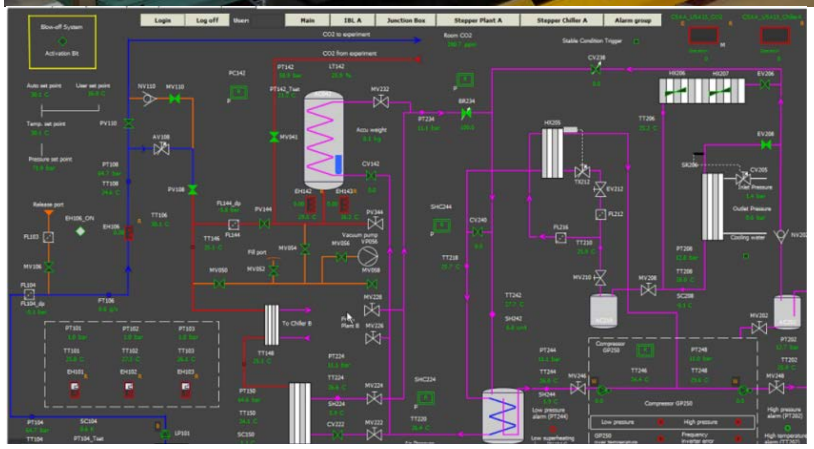






Christian Kiesling, Sara Pohl, Sebastian Skambraks

IB Belle – CO_2 cooling system for vertex detector



VXD needs 12 cooling circuits: (4 PXD, 8 SVD), 7/12 are in operation since November for Beast II

The CO_2 flow is split in the manifolds into these 12 branches (BWD: 8, FWD: 4)

Vacuum insulated flex lines transport the CO_2 to the dock boxes (connection to detector)

Furthermore: 14 N_2 lines for gas cooling (copper tubes)

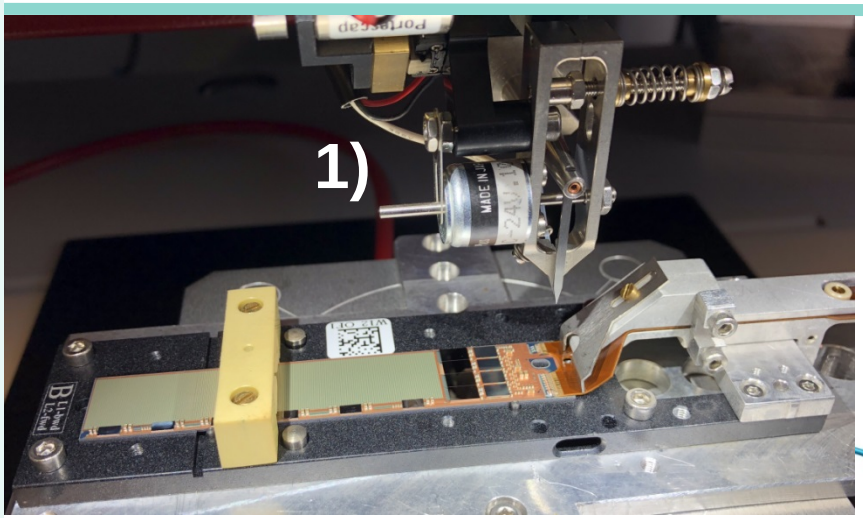
verified operation to cool down 3 kW to -35 °C

heater for fine tuning and tests are installed and commissioned

IB Belle built at MPP cools the entire Belle II vertex detector

Ulrich Leis, Hans-Günther Moser, Sven Vogt

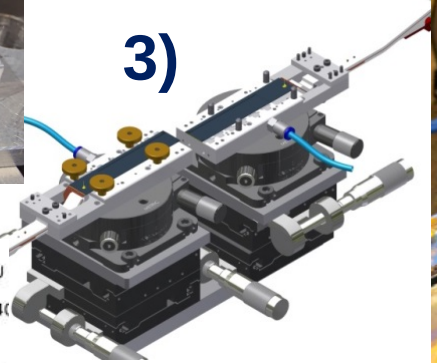
DEPFET Pixel Detector

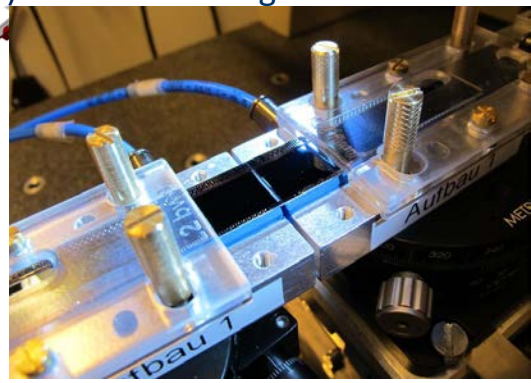


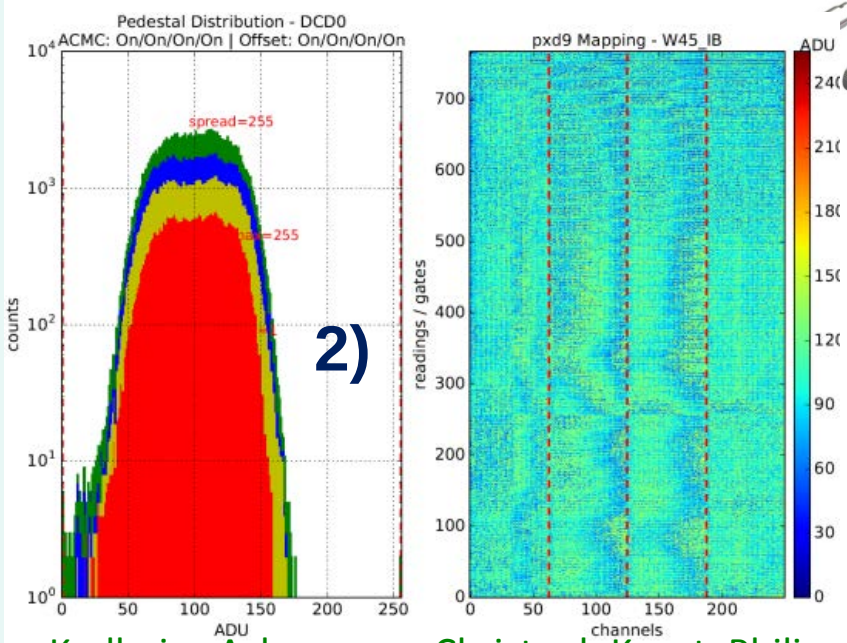
MPP tasks:

1) Kapton Attachment
2) Testing and characterization
3) Ladder gluing
4) Alignment measurements
5) Ladder testing

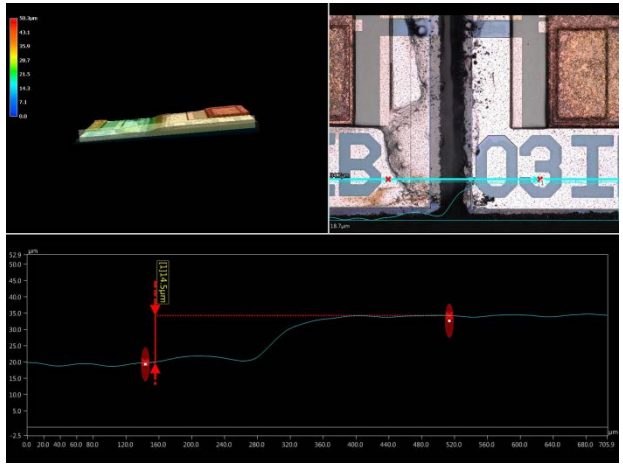
3)







4)



Karlheinz Ackermann, Christoph Knust, Philipp Leitl, Miriam Modjesch, Felix Müller, Enrico Töpper

Ladders for layer 1

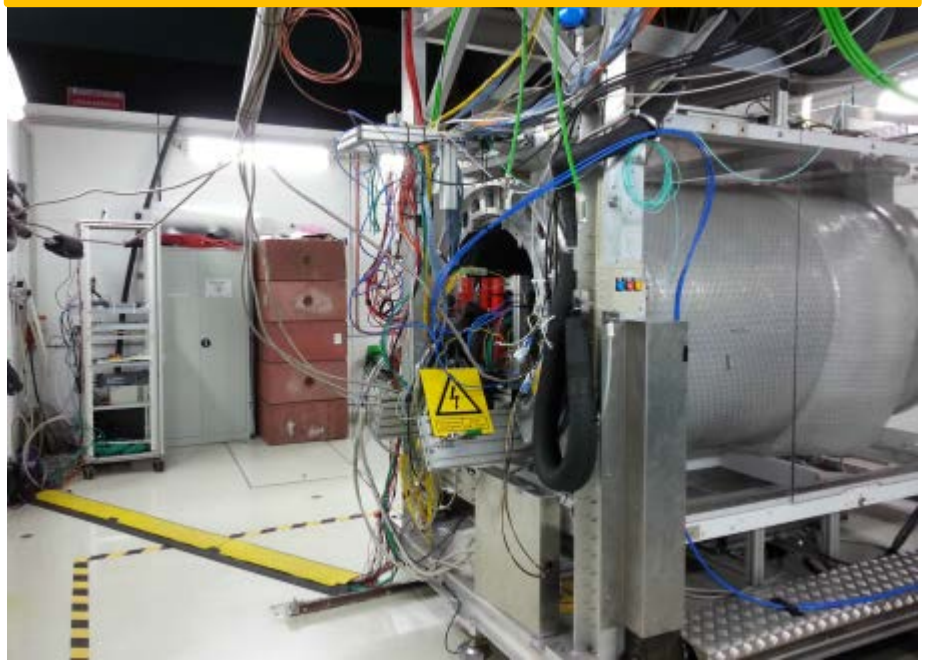
8 ladders for inner layer
12 ladders for outer layer

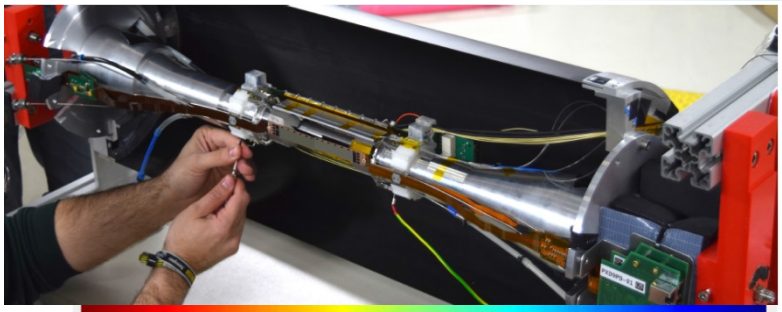
VXD combined beam tests at DESY (2016 + 2017)

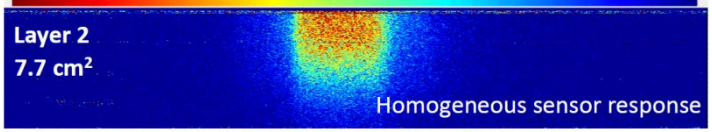
performance studies in beam tests

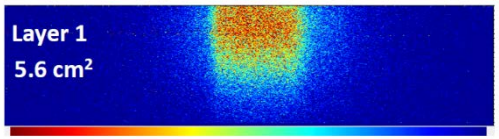
- 4 GeV electron beam
- 4 SVD layers + 2 PXD layers in 1 T solenoid field
- Full data acquisition chain
- Belle II slow control system
- CO2 cooling

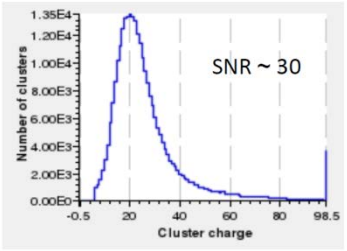
DEPFET Sensor proven to work in beam, CO_2 cooling concept verified

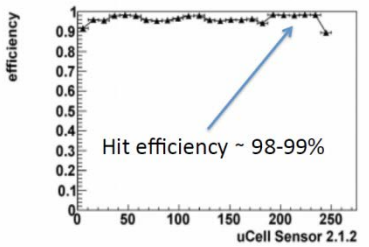




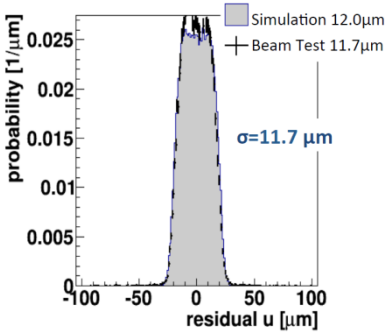




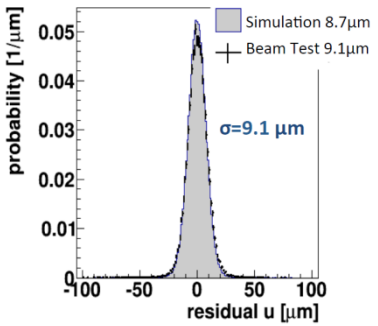




0° tilt: perp. incidence



30° tilt: many 2 pixel clusters



Karlheinz Ackermann, Felix Müller, Philipp Leitl

BEAST Phase 2 Installation

Karlheinz Ackermann, Stefan Horn, David Kittlinger,
Christian Kiesling, Reinhard Sedlmeyer,
Andreas Wunderl

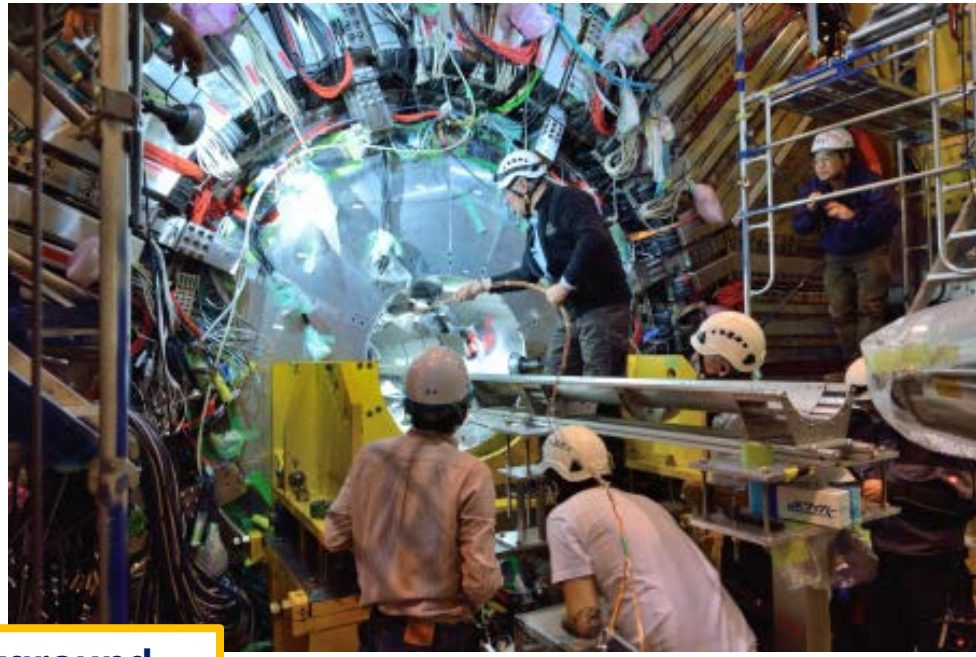
Motivation:

- Support & feedback for machine commissioning (e.g. collimator settings)
- Ensure radiation and background fits for VXD

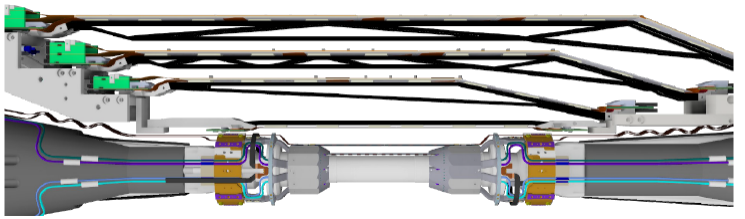
BEAST II detector:

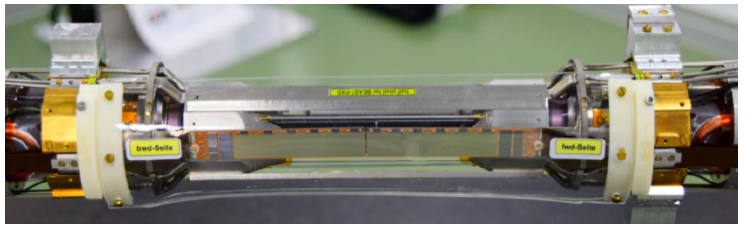
- 2 ladders PXD
- 4 ladders SVD
- Dedicated radiation monitors

VXD sensors in +x direction ⇒
highest QED rate



part of vertex detector to study background





Summary and Outlook

PXD:
- Electronic production
- Electronic tests
- Cooling system
- Mechanics
  - Installation method
  - Modules and detector assembly
  - Support structures

Beam Tests:
- 2016/2017 DESY telescope tests
- 2017-2018 (installation of) BEAST phase 2

Cosmic ray run	1. Feb 2018
HER & LER beams	23. Feb & 2. Mar 2018
BEAST Phase 2	Feb – Jun 2018
VXD installation preparations	Jun – Sep 2018
VXD installation	Oct – Nov 2018
Phase 3	Nov 2018
Data taking	Jan 2019

Belle II software preparations:
- Belle II theory interface platform
- Belle II physics software development
  - Vertexing
  - Flavor Tagging
  - Neural network z-vertex trigger
- RZG as Belle II Tier 2

PXD half-shell assembly and commissioning at DESY	Feb – May 2018
VXD assembly and commissioning at KEK	Jun– Sep 2018

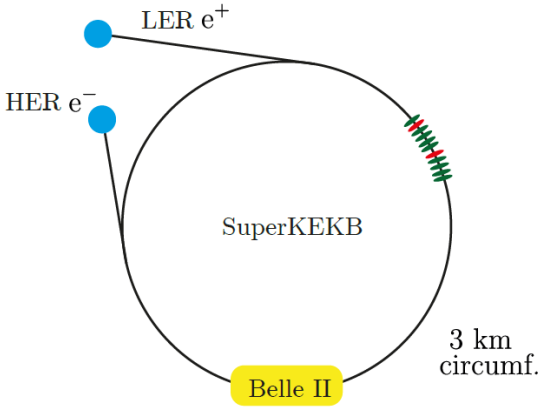
→ need MPP staff at KEK for commissioning and installation

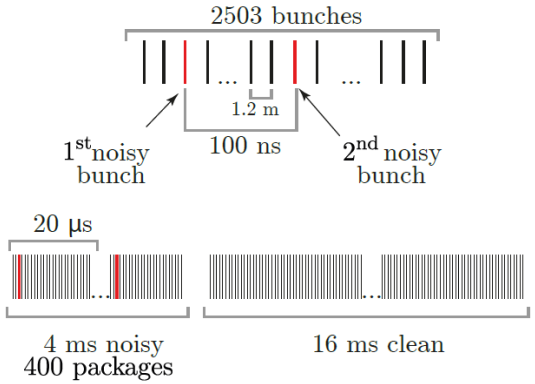
Looking forward to first data!

Backup

Measuring injection noise

Hendrik Windel; see talk of Frank Simon

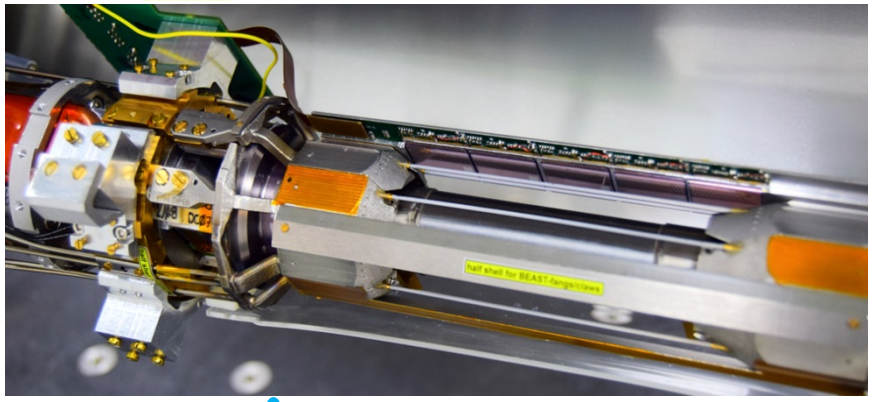


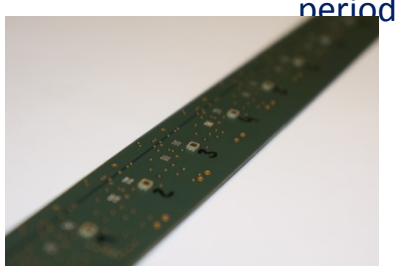


DEPFET frame readout needs 20µs (and covers a time interval of 40 µs)
=> Sensor filled with hits from freshly injected bunches => ~ 20 % dead time (4 ms / 20 ms)

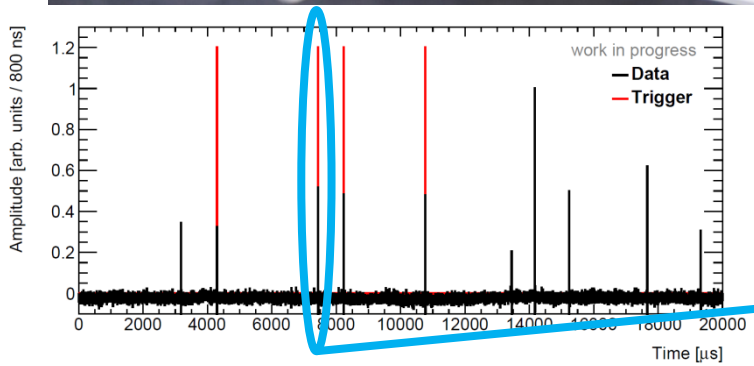
Gating : Sensor is made blind for a short time during high background (noisy bunch)

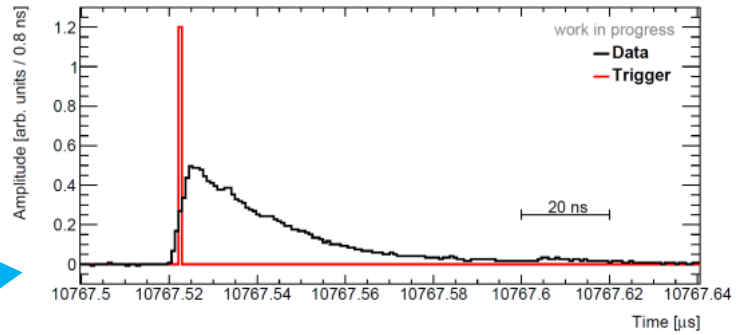
Signals detected in the clean period before are preserved





analyze damping time of injection noise

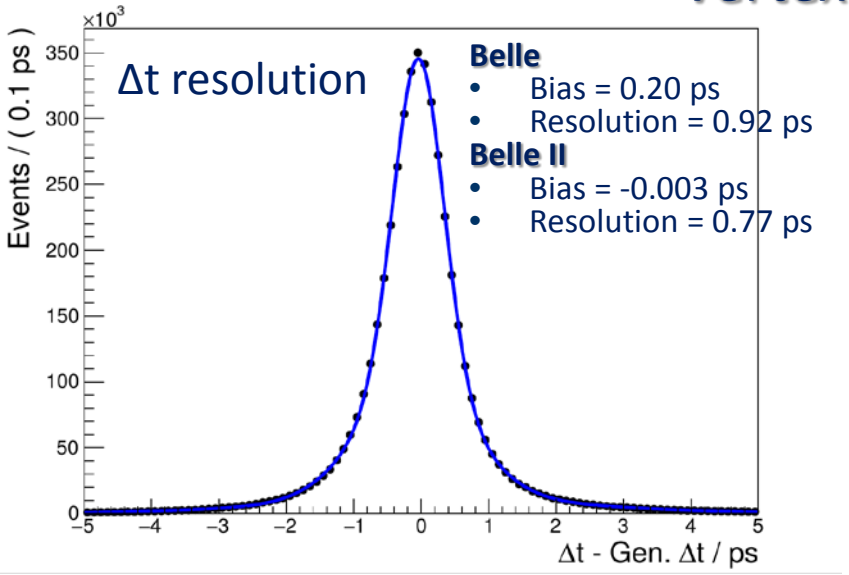


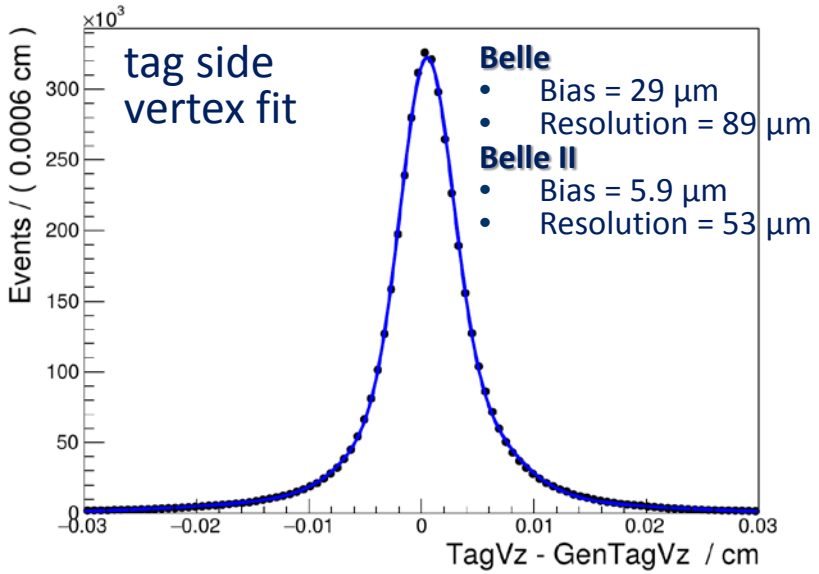


MPP activities – Physics preparation

- MPP activities focused on time dependent CP violation (TDCPV)
- Search of new Physics in time dependent CP violation measurements and precise measurement of the unitarity triangle parameters
- Coordination of the time dependent CP violation Belle II physics working group (Luigi Li Gioi)
- Coordination of the α/ϕ_1, β/ϕ_2 (Luigi Li Gioi)
- Physics software development
- Institutional responsibility on Vertex fit (Luigi Li Gioi) and flavor tagging (Fernando Abudinén)

Vertex fit

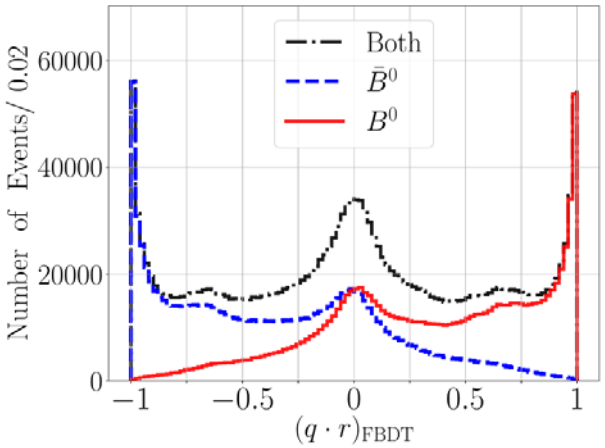




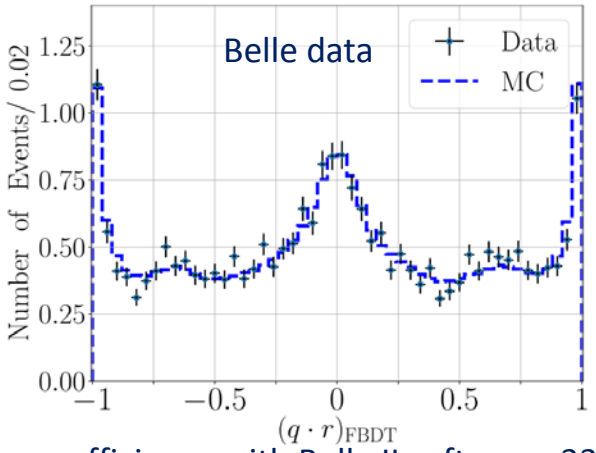
Better than Belle given the reduced boost

MPP activities – Physics preparation

Vertex fit



Belle II Monte Carlo: efficiency: 37 %



efficiency with Belle II software: 33 %
efficiency with Belle software: 29%

sin(2β) – expected errors

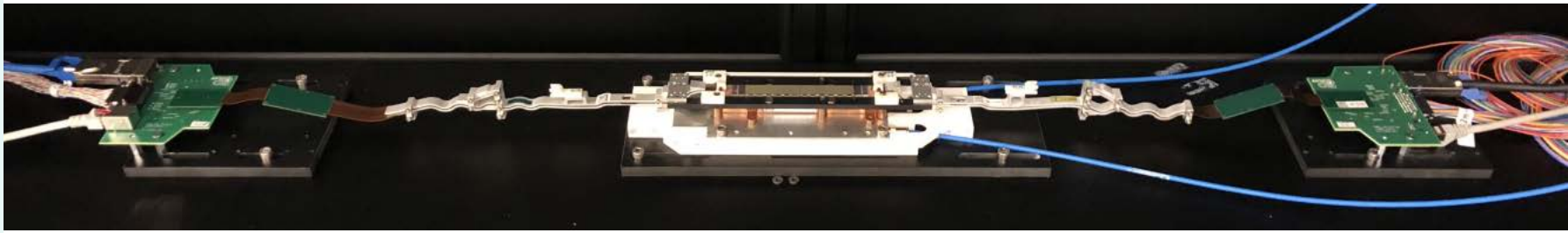
- sin(2β) will remain the most precise measurement on the Unitarity Triangle parameters
- In Belle II the measurement will be dominated by systematics errors concentrated in understand and reducing them

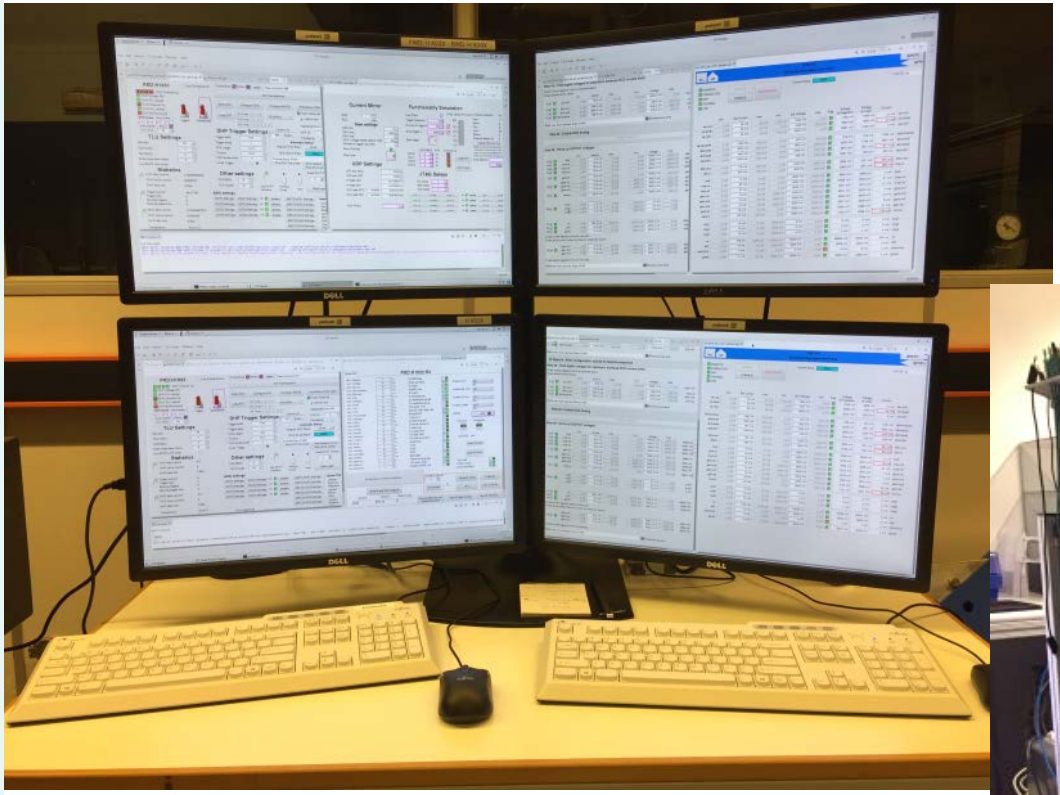
$$\mathcal{P}(\Delta t, q) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}}\left[1 + q\left(\mathcal{A}_{CP}\cos\Delta m_d \Delta t + \mathcal{S}_{CP}\sin\Delta m_d \Delta t\right)\right]$$

$b \to c\,\bar{c}\,s$

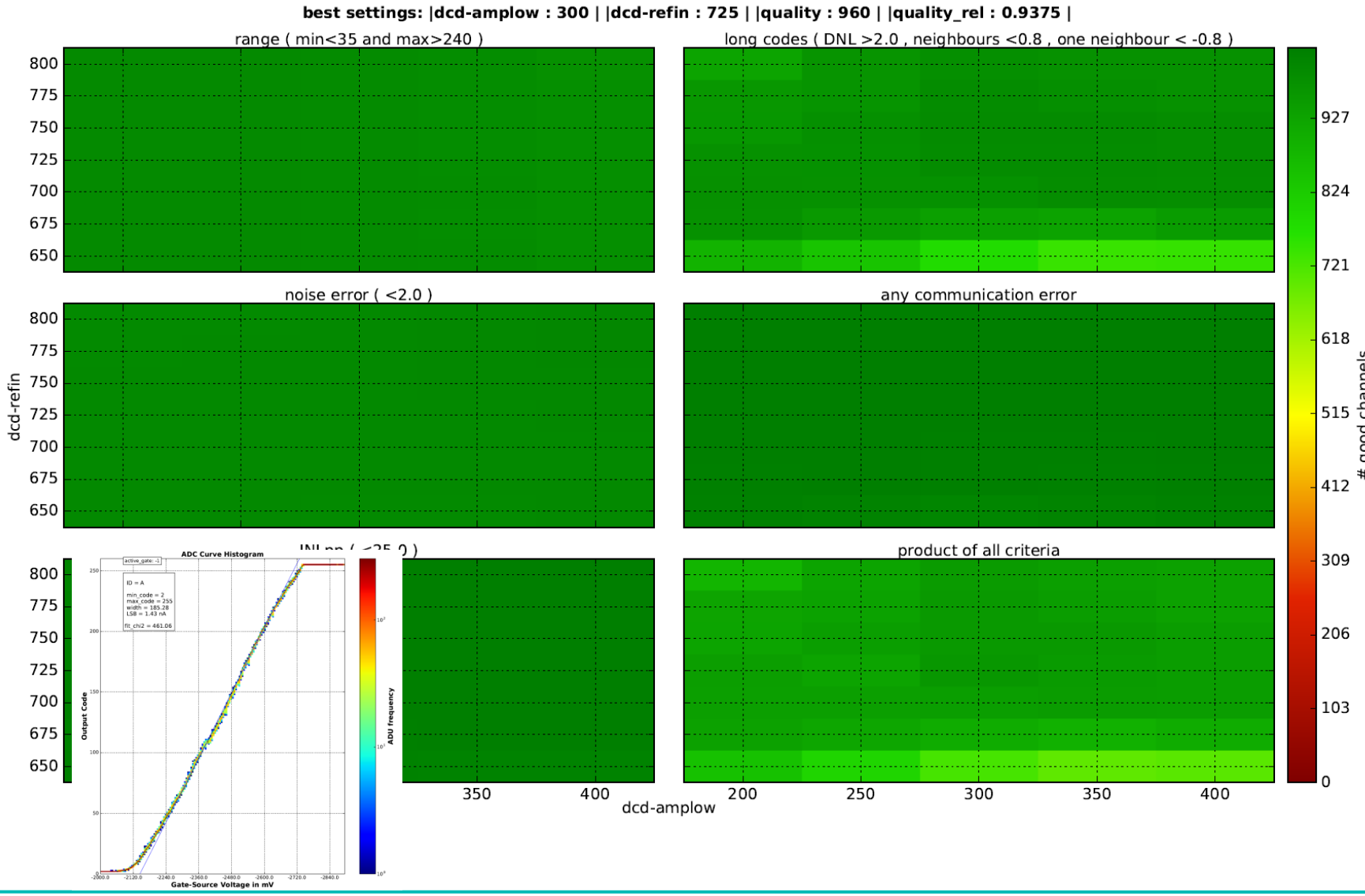
	No improvement	Vertex improvement	Leptonic categories
$S_{c\bar{c}s}$ (50 ab^{-1})			
stat.	0.0027	0.0027	0.0048
syst. reducible	0.0026	0.0026	0.0026
syst. irreducible	0.0070	0.0036	0.0035
$A_{c\bar{c}s}$ (50 ab^{-1})			
stat.	0.0019	0.0019	0.0033
syst. reducible	0.0014	0.0014	0.0014
syst. irreducible	0.0106	0.0087	0.0035

PXD module – setup

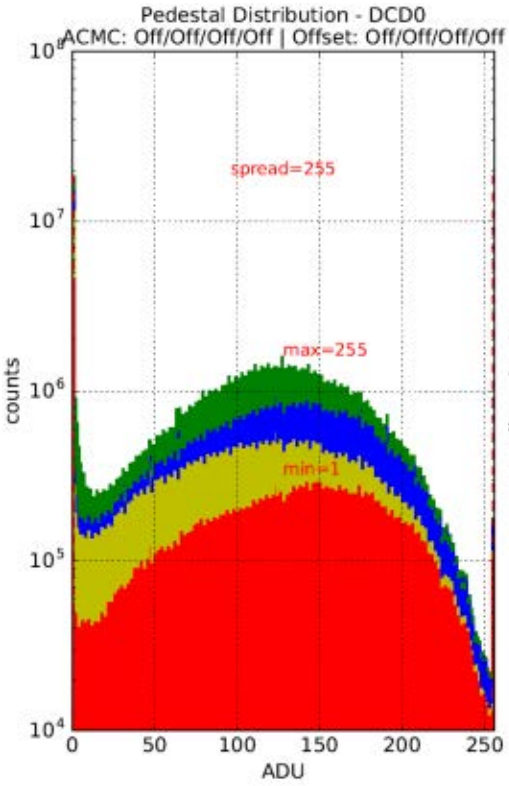


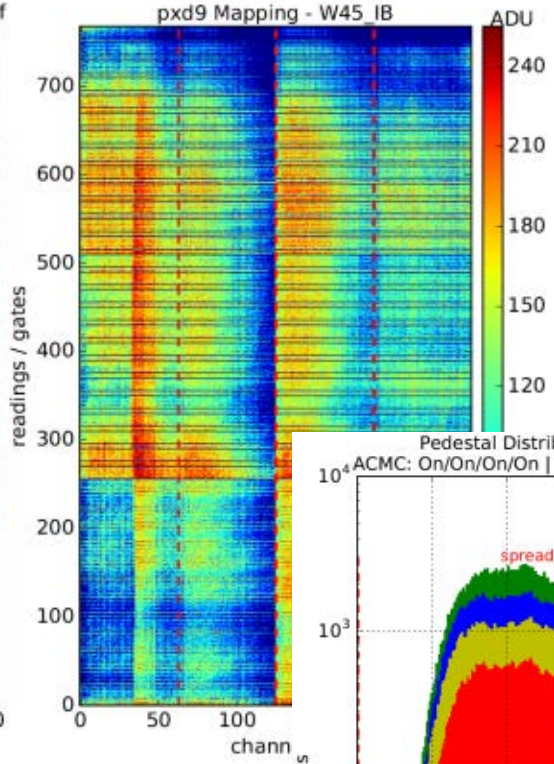


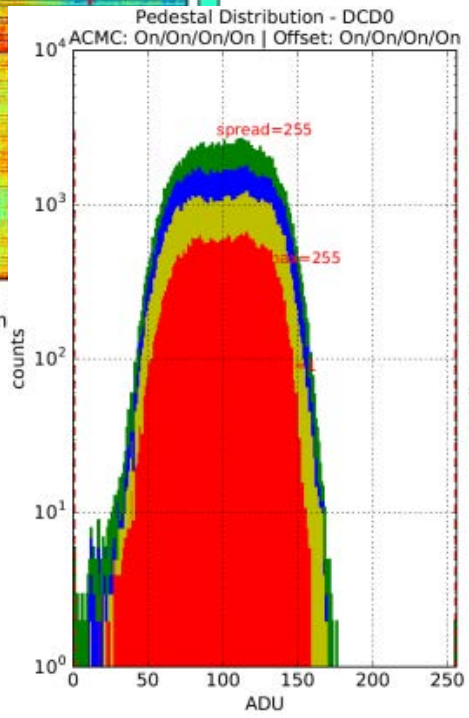
PXD setup – ADC curves

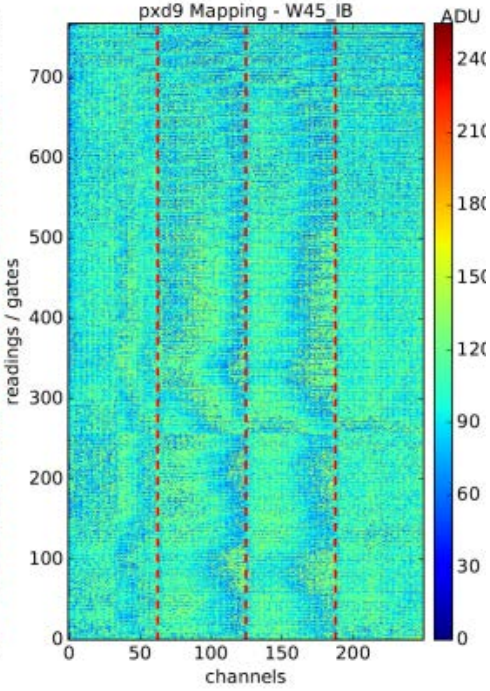


PXD module - Pedestal compression





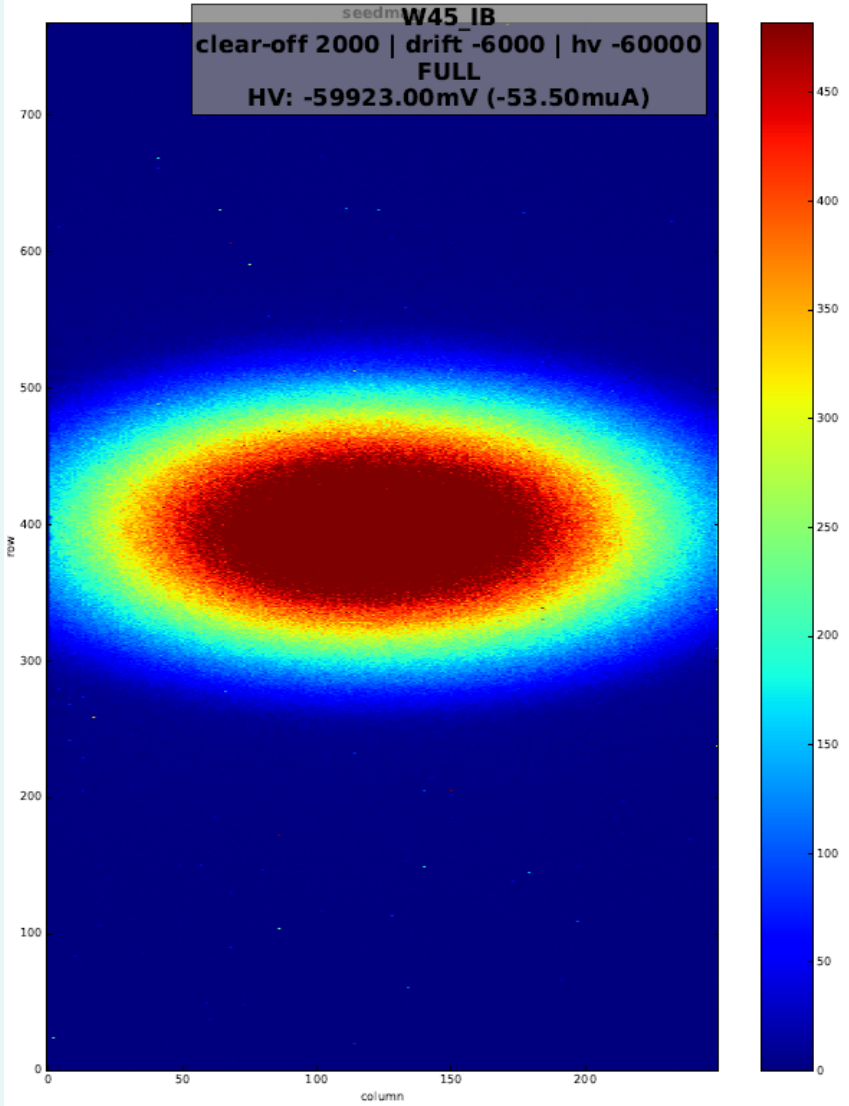


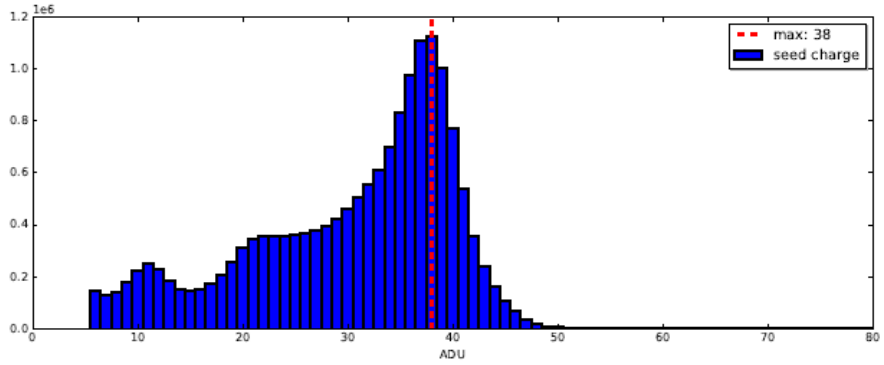


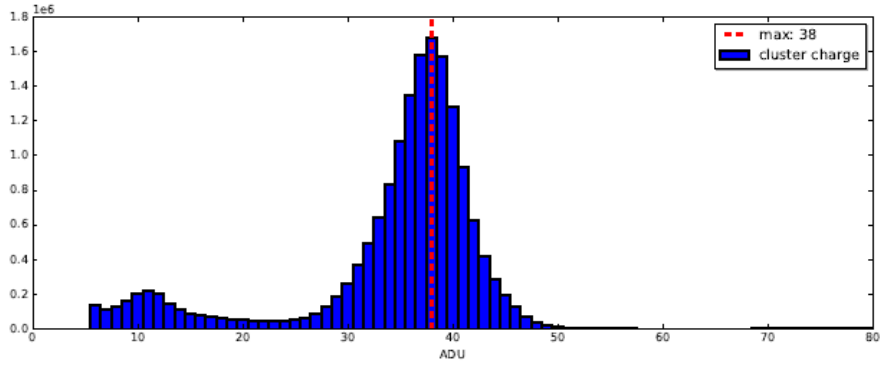
Using analog common mode correction and 2-bit offset correction

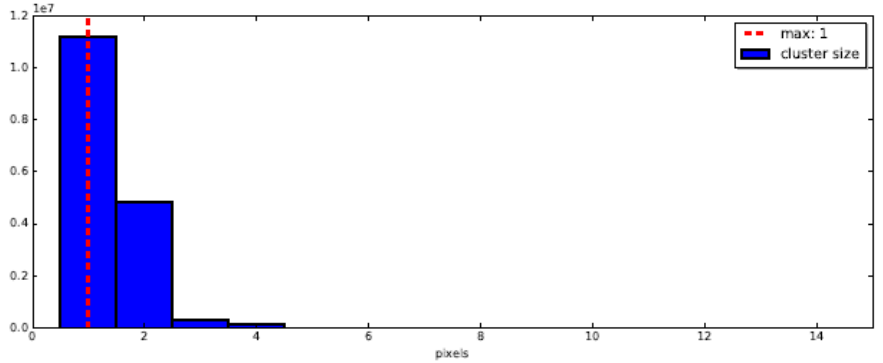
PXD Module – Source measurement

Cd109 γ source









PXD module – inter ASIC communication