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Joint workshop of the FJ- and FK-PPL
Bordeaux, France
May 26, 2014

B T D

project B_04

Report on: Investigation of a contribution to the inner tracker and to physics analysis in the Belle II experiment at SuperKEKB

2ond year proposal: Contribution to the preparation of the Belle II detector operation at SuperKEKB and of the physics analysis.

Outline :

- Introduction:
  - the SuperKEKB collider and the Belle II experiment
- Status and new project:
  - New physics search with TDCPV asymmetry
  - Low momenta estimation based on dE/dx
  - Study of the SuperKEKB background with PLUME
- Requested support to the TYL/FJPPL
- Conclusion

KEK-JAPAN

IPHC Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

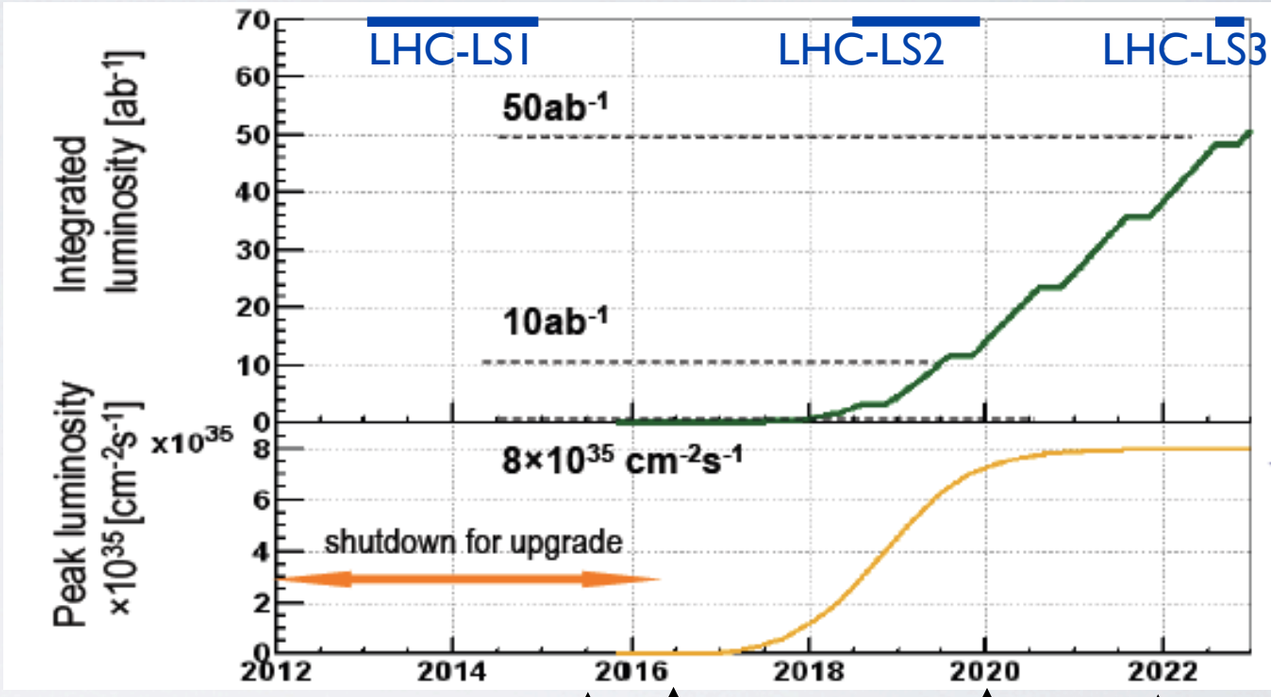
Belle II

The SuperKEKB collider

- Asymmetric beams: e^- 7 GeV - e^+ 4 GeV.
  Collisions $E_{c.m.} = M_{\Upsilon(4S)}$ and $M_{\Upsilon(5S)}$.
- Increased currents: ~2×KEKB to limit backgrounds.
- Small beam transverse size: ~KEKB/20 in y,
  $\sigma_x \times \sigma_y$ ~ 10 μm × 60 nm.
- Large Piwinski crossing-angle:
  22 mrad (KEKB) → 83 mrad (SuperKEKB)

➢ Instantaneous luminosity x40:

0.8×10^{36} cm^{-2} s^{-1}

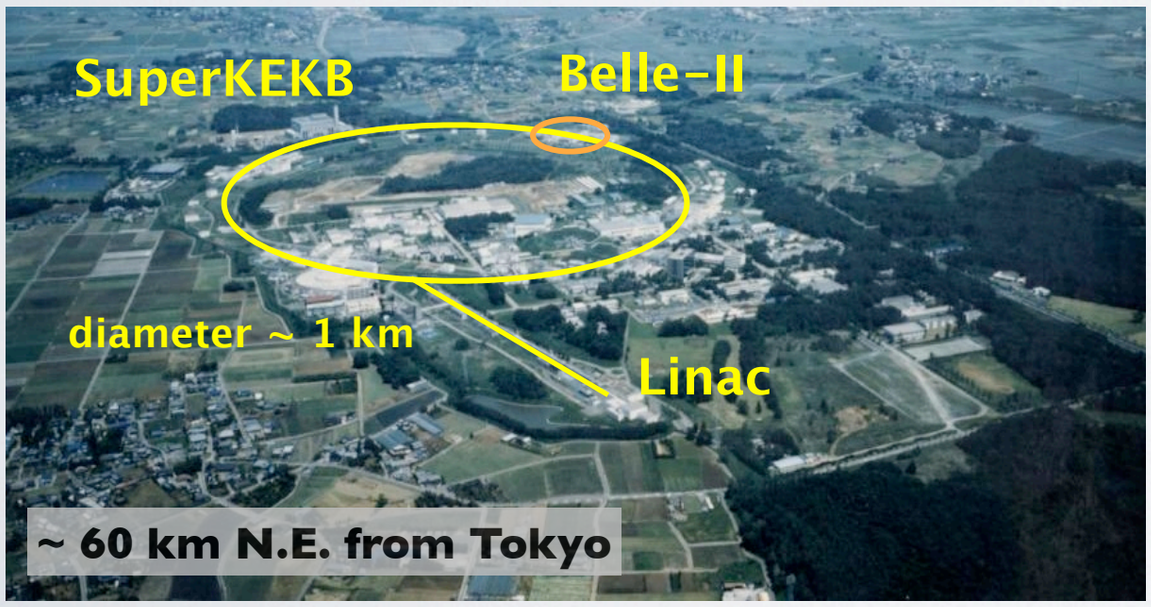


October 2016: start of data taking

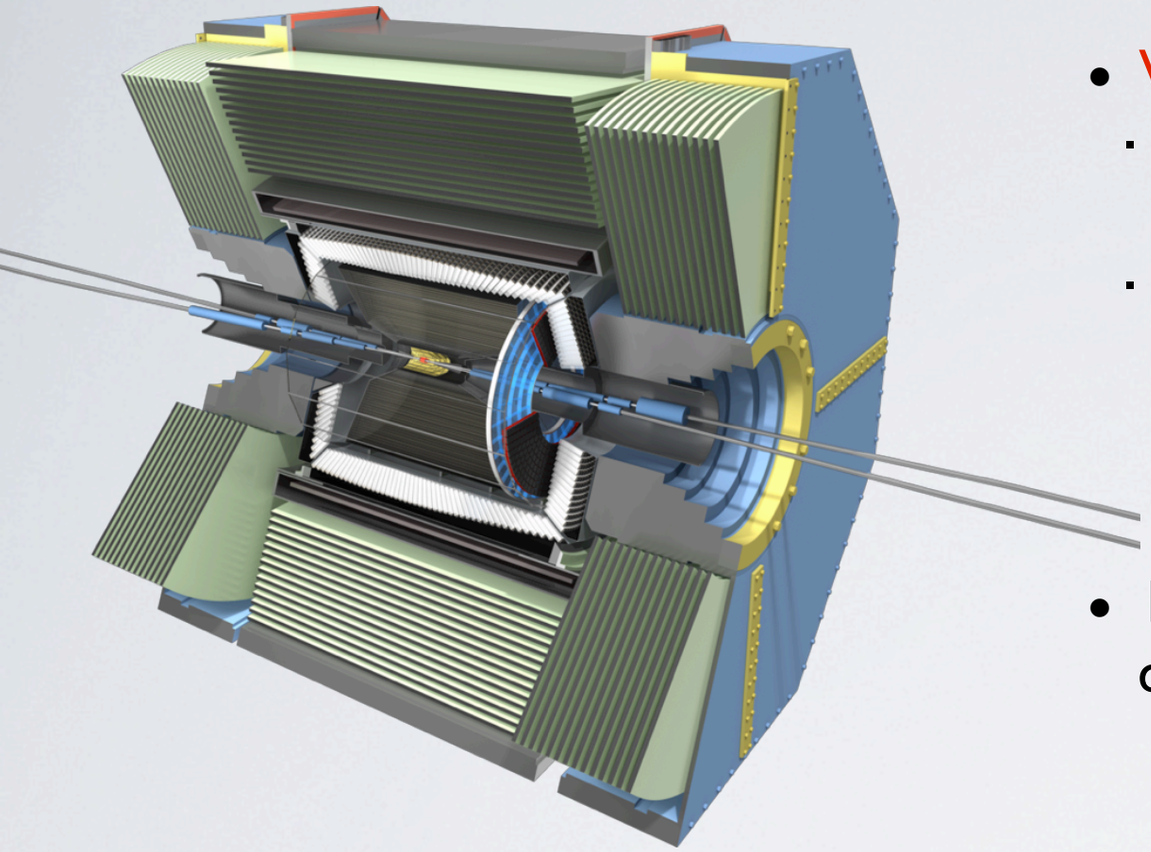
end 2022: 50 ab^{-1} on tape

mid 2015: BEAST II collider commissioning until 10^{34} cm^{-2} s^{-1} reached.

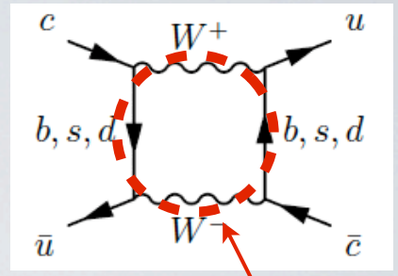
~2020: 10 ab^{-1} on tape



The Belle II experiment



- Where/what is the physics Beyond SM?
  - Two programs in parallel: intensity frontier and energy frontier.
  - Belle II : physics program covering both the quark and the charged lepton sectors, investigating quantum ways to discover and understand physics BSM.



- Experiment progress status: construction and delivery of accelerator and detector is ongoing.

- **Report on the 2013-14 project:**

  Investigation of a contribution to the inner tracker and to physics analysis in the Belle II experiment at SuperKEKB

  · Fruitful discussions between the Belle II collaboration and the IPHC group thanks to stays in France and in Japan supported by FJPPL:
  - 3 travels to KEK: I. Ripp-Baudot
  - 3 travels to IPHC-Strasbourg (and LAL-Orsay): S. Tanaka, K. Trabelsi, Y. Ushiroda.

  In particular discussion on the possible use of the PLUME detector to study the background within the inner tracking volume during the commissioning phase.

  · Studies performed: assess inner tracker performances.
  - low momentum estimation based on dE/dx, (Belle2 note in preparation)
  - sensitivity to the charm unitarity triangle β_c angle, (PhD thesis 2015)
  - accuracy on sin2β with $B^0 \to J/\psi K^0_s$ and $B^0 \to \varphi K^0_s$. (Master thesis 2014)

- **Presentation of the 2014-15 proposal:**

  Contribution to the preparation of the Belle II detector operation at SuperKEKB and of the physics analysis.

  ➢ Focus on the characterisation of the machine induced background with PLUME.
  (parallel with the LAL-Orsay proposition)

report 2013-14

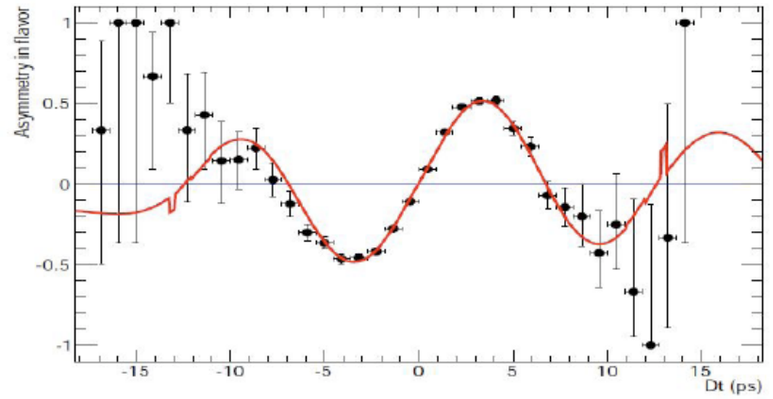
New physics search with Time Dependent Analyses

- CP asymmetry between $\Gamma(M^0 \to f_{CP})$ and $\bar{\Gamma}(\bar{M}^0 \to f_{CP})$ as a function of time:
  CPV in interference between decay and oscillation ➛ sensitivity to the UT angles β_i.

  ➛ impact of inner tracker performances?

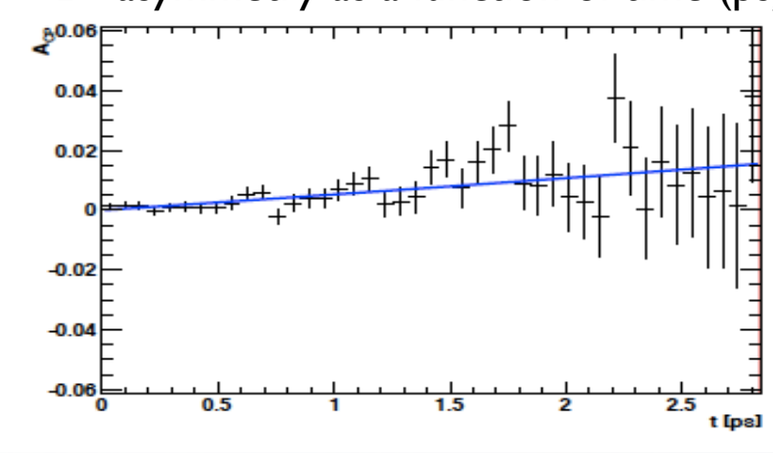
- $M^0 = B^0$:
  - Comparison between $B \to J/\psi K_s$ tree and $B \to \varphi K_s$ loop diagrams
    ➛ sensitive to new physics.
  - Total uncertainty dominated by systematics in Belle II.
    Main syst. is due to tag vertex resolution.
  - Results of our study: impact of the flight time resolution.
  - Result of a Master thesis (N.Vololoniaina, Master-2 2014).

B^0 asymmetry as a function of time (ps)



- $M^0 = D^0$ (from continuum):
  - Based on Phys.Rev. D84 (2011) 114009: $\sin 2\beta_c$ from $D^0 \to K^+K^-$ and $D^0 \to \pi^+\pi^-$ decays.
  - Unexpected high direct CPV observed by LHCb and others (unconfirmed).
  - Test of new particle couplings with up-type quarks.
  - Theoretical predictions difficult (long distances).
  - Results of our study:
    - Sensitivity to β_c studied with a Fast Simu, as a function of: D^0 statistics, vertex resolution and flavour mistag.
    - Event kinematics studied with Belle II Full Simulation.
    - Preliminary: uncertainty on β_c ~ 1-2° in Belle II.
  - Part of a PhD thesis (R. Maria, defense 2015).

D^0 asymmetry as a function of time (ps)



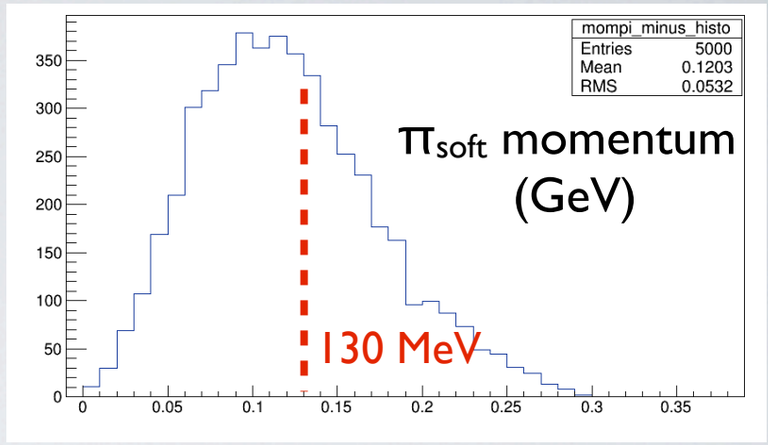
report 2013-14

Low momentum estimation

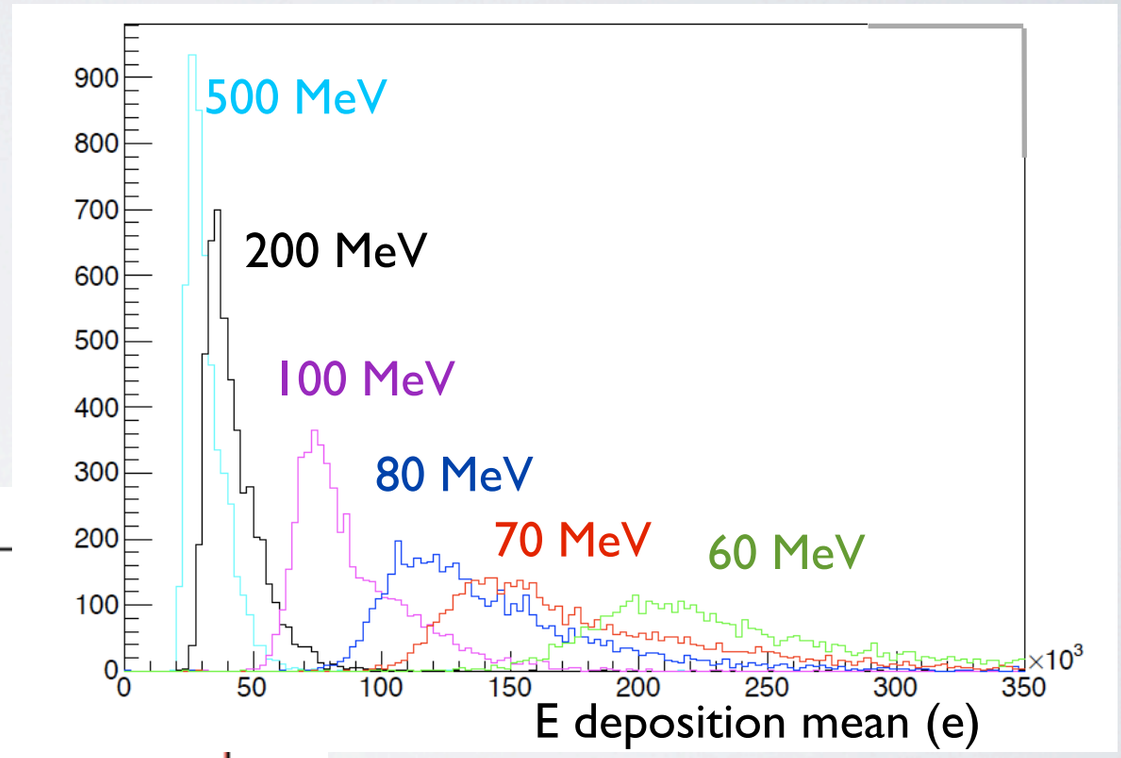
- Momentum < 130 MeV: inner tracker standalone tracking
  - ➔ worse momentum resolution from helix fit.
  - ➔ use dE/dx ~ $1/\beta^2$ in 6 silicon layers to estimate momentum.

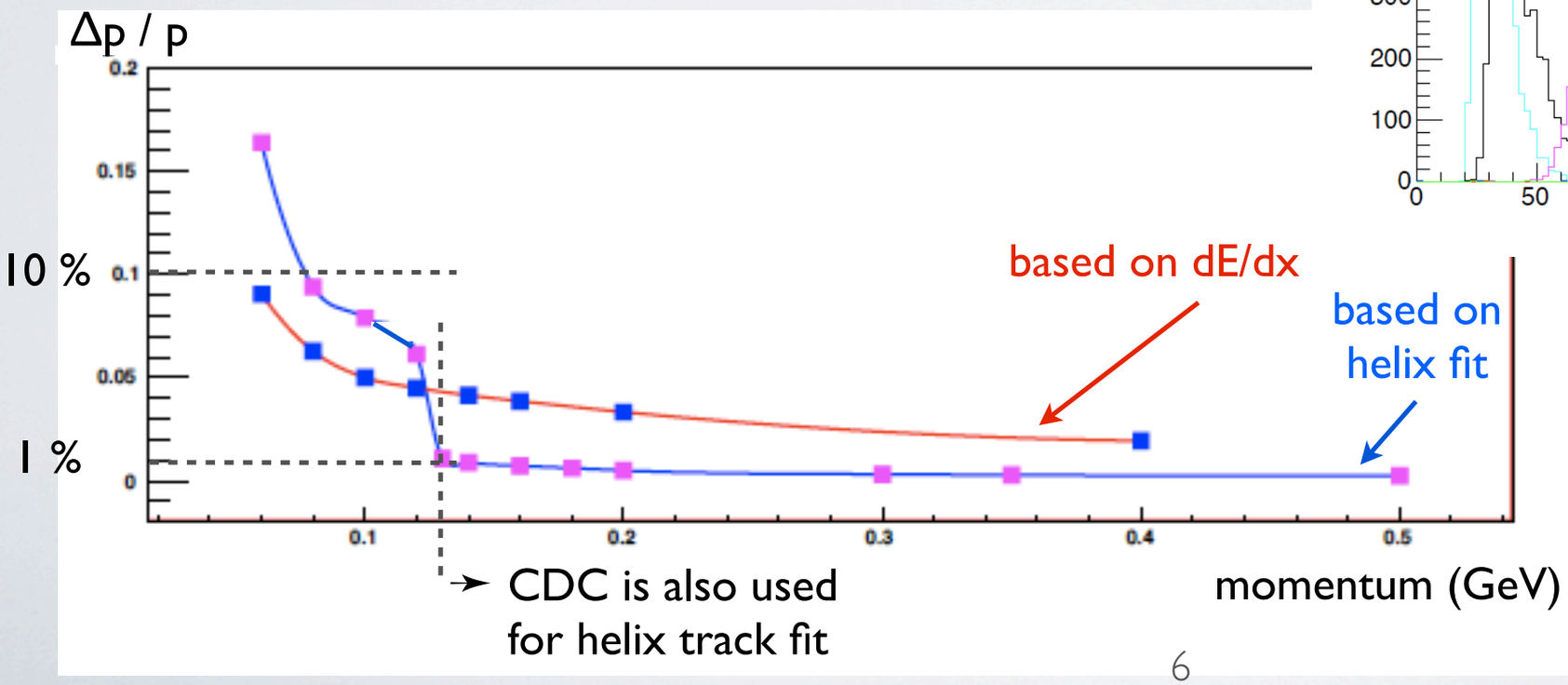
    Analogue output in 4 double-sided strips (10 bits) and 2 pixel layers (5 bits).

    cf. : H. Bichsel, NIM A562 (2006) 154-197
    ALICE: arXiv:hepex/0104006v1



- Motivation:
  - Improve Δp/p, may further improve vertexing.
  - dE/dx may be further used in track quality index (fake rejection) and in background rejection (machine induced QED e-pairs).

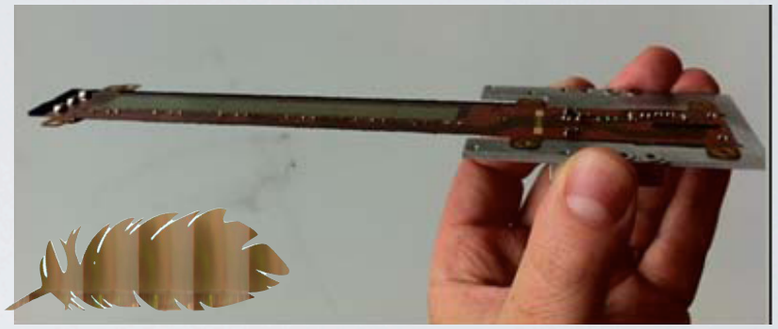




- Study completed, Belle2 note in preparation.

new project 2014-15

Commissioning of SuperKEKB



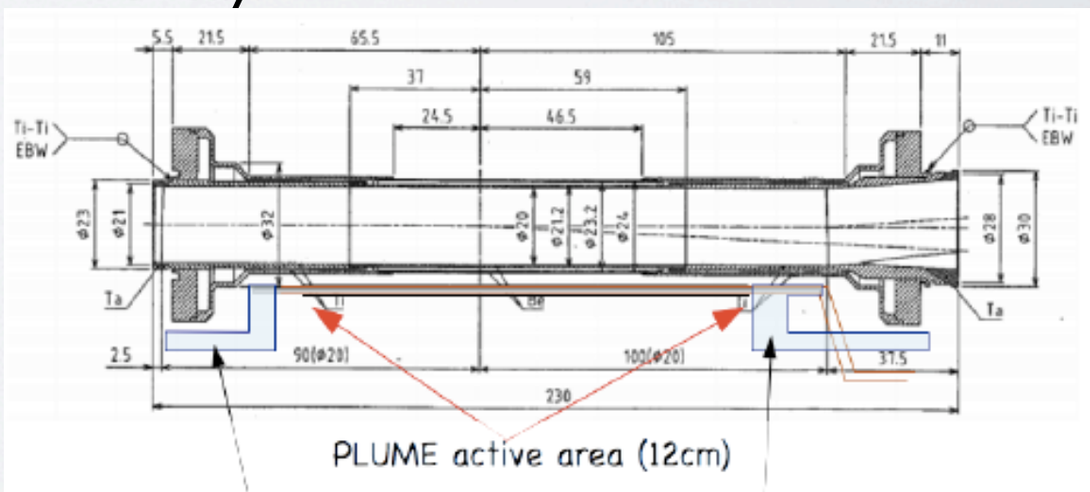
- With the double-sided PLUME ladder:
  - Couting rate: 10^6 cm^{-2} s^{-1}
    Material budget ~0.3 % X_0
  - 2 ladders built and tested in CERN-SPS in 2011
    6 to 10 ladders M26 expected end of 2014.
    New ladders may be equipped with MISTRAL (ALICE-ITS) > end of 2015.
  - Tracking with 2 points measured by one double-sided pixelated layer:
    measured angular resolution: 0.11±0.01° (perpendicular tracks) and 0.2±0.1° (tilted tracks)
  - Unique opportunity to perform a collider test of PLUME:
    - assess system integration aspects of CMOS pixel sensors developed at IPHC.
    - step towards "intelligent trackers" based on performance flexibility according to radius.

    ➛ major interest for a future ILC experiment.

- Background study in the inner tracking volume during BEAST II: $\frac{dN^3}{dzd\theta d\varphi}$
  - Background measurement at an intense nano-beam collider:
  - Important inputs to validate difficult simulations.
  - Synergy with SuperKEKB MDI developments at LAL-Orsay.

    ➛ major interest for a future ILC experiment.

- Supports which will be investigated:
  - TYL/FJPPL.
  - JSPS (Strasbourg), Maison du Japon.
  - ANR.

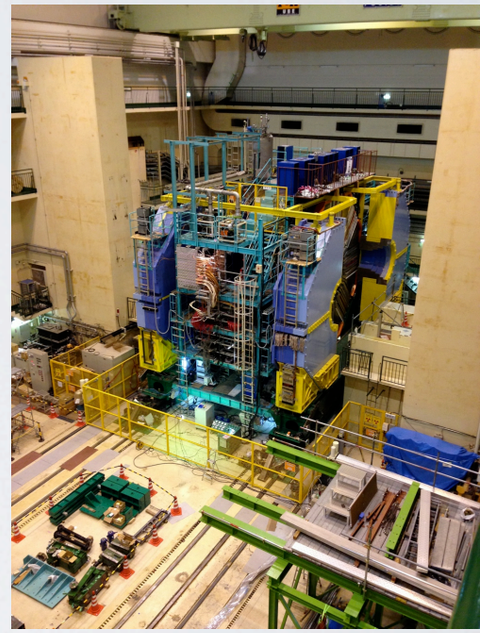


TYL/FJPPL B_04 PROJECT

- Members:

At IPNS/KEK:

- Yutaka USHIRODA: technical coordinator,
- Shuji TANAKA: inner tracking system coordinator (integration aspects),
- Hiroyuki NAKAYAMA: background/commissioning co-coordinator.
- Kazutaka SUMISAWA: vertexing.



At IPHC/IN2P3:

- Isabelle RIPP-BAUDOT: principal investigator,
- Jérôme BAUDOT: PLUME coordinator.
- Robert MARIA: PhD student 2012-15.

- Funding requests:

- IN2P3: 3 travels to Japan - 7230 €
- KEK: 3 travels to France - 870 k¥

Conclusion

- SuperKEKB will deliver collisions with the highest instantaneous luminosity in the world.
- The Belle II detector and the SuperKEKB collider SuperKEKB are on the way to be delivered. Collider commissioning will start mid of 2015 and data taking in Fall 2016.
- Belle II will play a crucial role in the search and the understanding of beyond SM physics, with a physics program complementary to energy frontier experiments, but also to LHCb and other intensity frontier experiments.
- Thanks to last year support, fruitful discussions enabled to complete several studies in Belle II, related to inner tracker performances:
  - Sensitivity on the charm β_c unitarity triangle angle measured from time dependent D^0 and $\bar{D}^0$ decay rates.
  - Study of the syst. uncertainty due to time resolution in the sin2β measurement.
  - Estimation on low momentum based on dE/dx measured in silicon detectors.
- Future project: we propose to use PLUME during the Belle II commissioning, aiming at:
  - Characterisation of the SuperKEKB beam-induced background,
  - Assess CMOS pixel sensors system-integration aspects.

  ➛ major interest in the frame of a future ILC experiment.

thank you for your attention!

PLUME-1, -2 performances

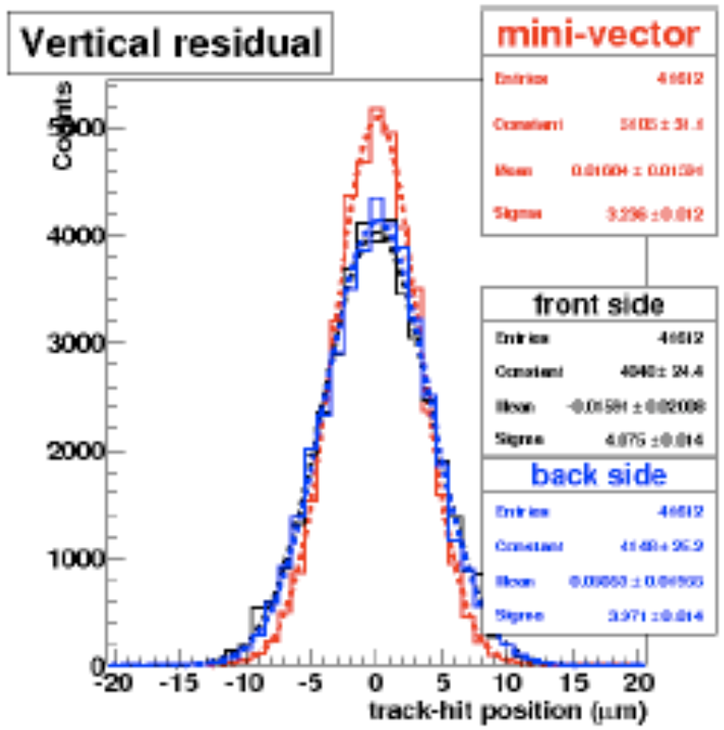
- **Basic features of PLUME-1 or 2**
  - ✗ Square pixels: 18.4x18.4 μm^2
  - ✗ Sensitive area 127.2x10.6 mm^2
    - ➔ $8x10^6$ pixels
    - ➔ Current "cracks" (non-optimized cut)

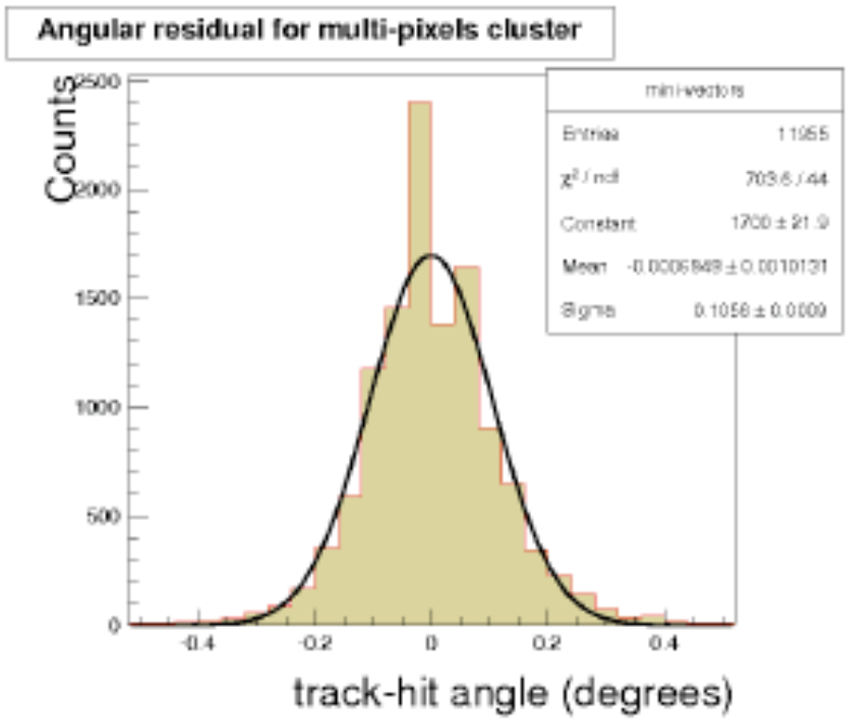
      ~ 500 μm
  - ✗ Integration time = readout time = 115 μs
  - ✗ MIP detection efficiency (T≃30°C)
    - ➔ 100% up to 300 kRad

      combined with $10^{13} n_{eq}/cm^2$
    - ➔ Up to 1 Mrad
      some loss in efficiency
      (not dramatic for BEAST purpose)
  - ✗ Count rate ≳ 10^6 $cm^2.s^{-1}$

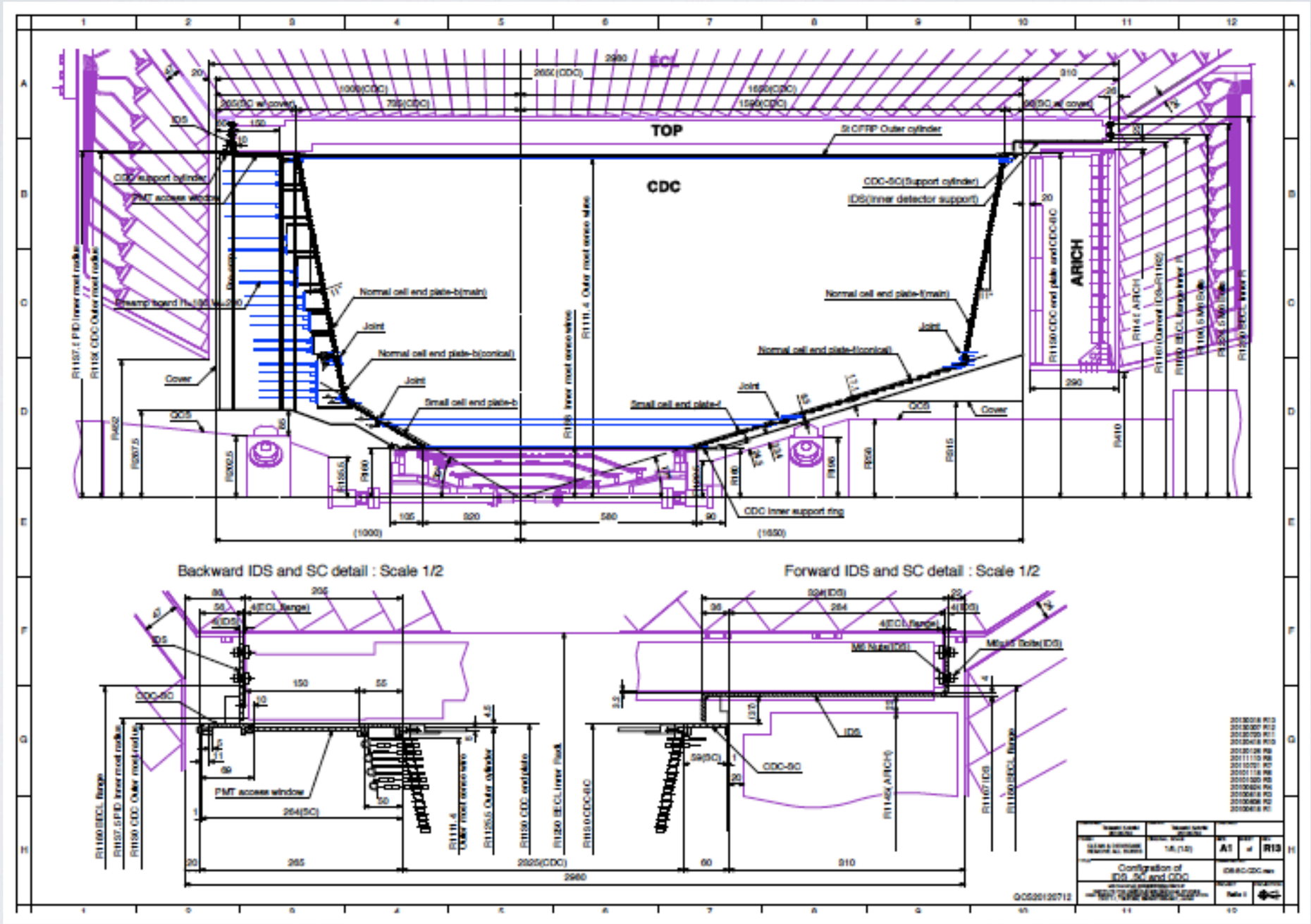
- **Double-sided layer features**
  - ✗ Validated with 120 GeV π beam (2011)

Incident angle (°)	0	40	60
σ(point) (μm)	2.5±0.1	2.8±0.1	-
σ(angle) (°)	0.11±0.01	0.2±0.1	-
<pixel multiplicity>	2.5	3.3	5.7



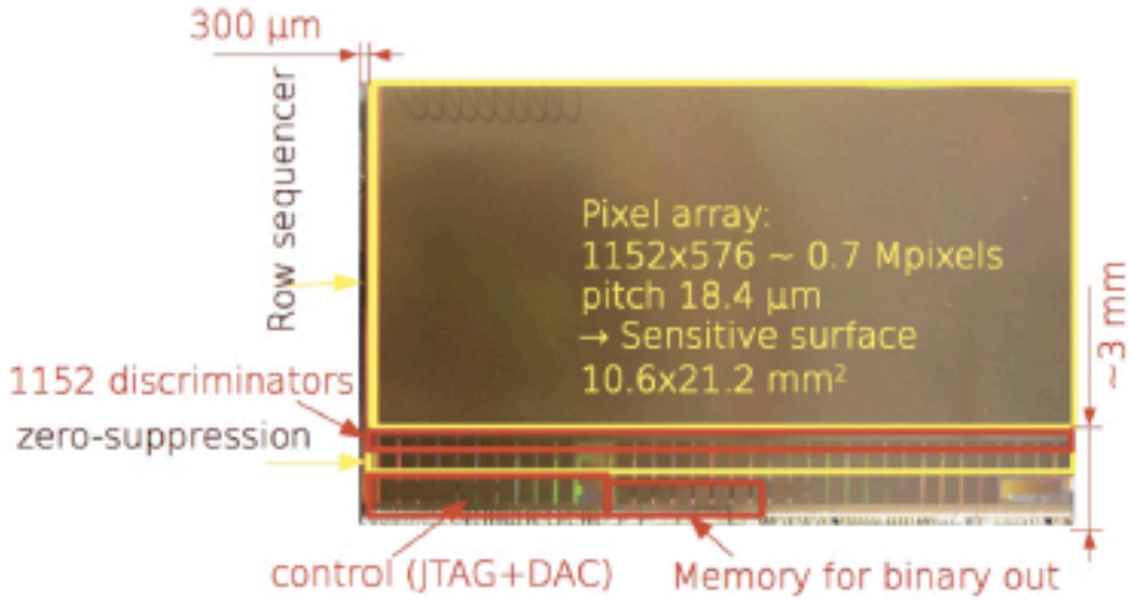


inner tracking volume during the SuperKEKB commissioning

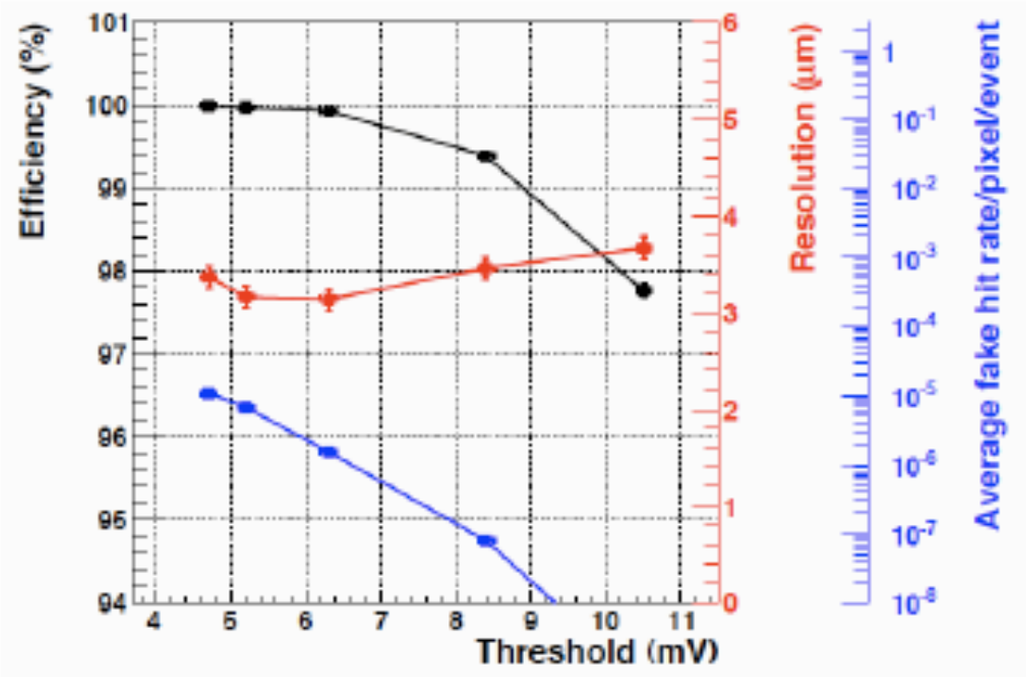


MIMOSA 26

- Fabrication and specification
  - Technology 0.35 μm AMS OPTO-process
  - Fabricated in 2009 and 2010
  - Sensitive layer: 14 μm thick, resisitivity > 400 Ω.cm
  - Thinned to 50 μm
  - Operating temperature ~30°C

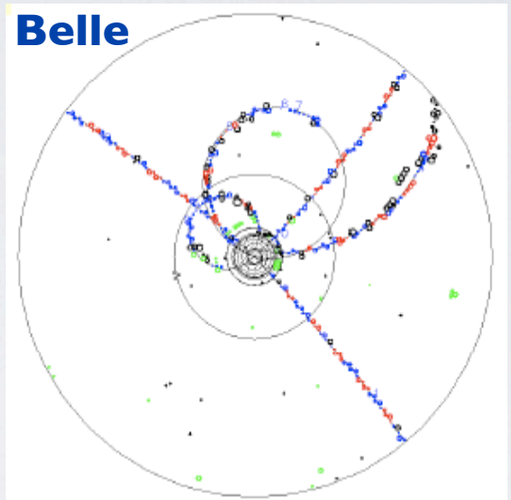


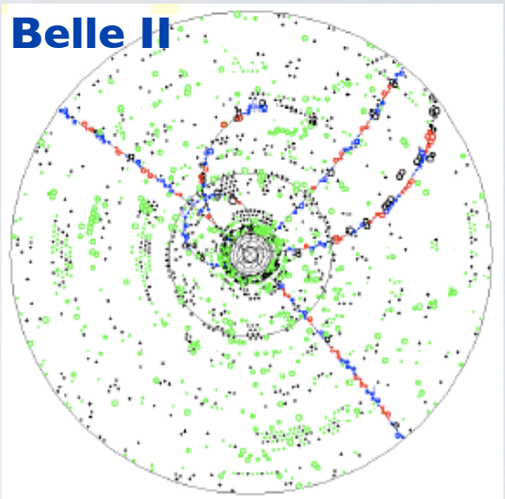
- Performances
  - Rolling-shutter steering
    Readout-time = integration time = 112 μs
  - Binary output
  - Spatial resolution ≃ 3μm
  - Hit rate sustainable > 10^6 $cm^{-2}.s^{-1}$
  - Radiation tolerance (100% det. eff./MIP)
    - Ionizing dose: 300 kRad
    - Non-ionizing fluence: 10^{13} n_{eq}/cm^2



Flight time resolution

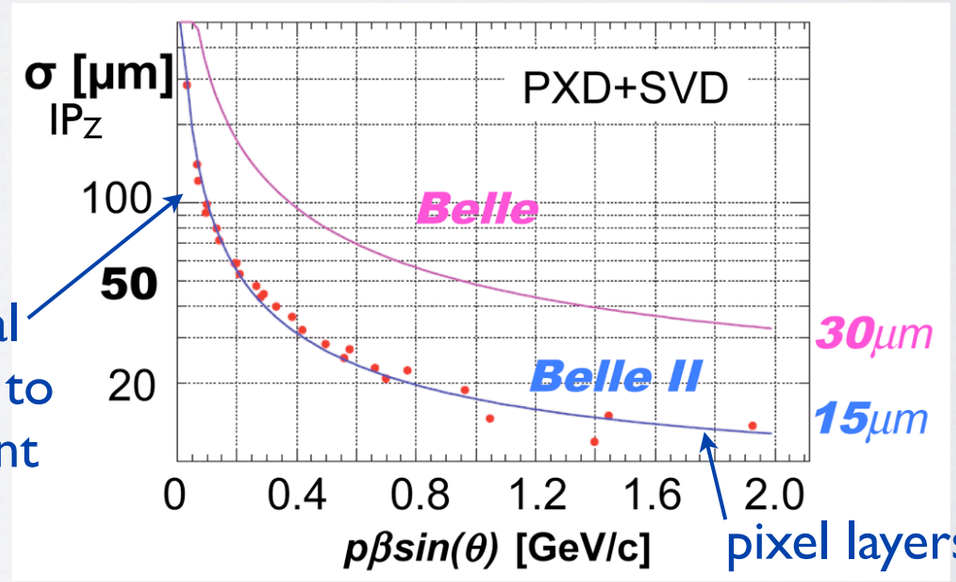
- Resolution on distance between the 2 decay vertices: crucial in all time dependent CPV studies in B and D decays.
- Increased machine induced backgrounds
  ➛ higher occupancy rate:
  impact on track reconstruction.
- Reduced beam asymmetry: $\beta\gamma = 0.28$
  (was 0.42 at KEKB)
  ➛ smaller Δz and worse $\sigma(\Delta t)$
  (D mesons from continuum less impacted).





- Therapy:
  · Add 2 innermost layers of pixels close to IR,
  · Smaller beam spot,
  · Beam pipe radius decreased to 1 cm.

  ➛ Expected precision on Δt
  2× better than in Belle.



- Also to be considered to further improve $\sigma(\Delta t)$:
  · Improvement of tracking algorithms.
  · Investigate the added value of an upgraded pixelated light inner tracker taking data ~2020.

Analyses des résultats

Résumer :

- Les incertitudes sur S_f dans le canal $B^0 \to J/\psi + Ks$

	$N_{sig} B^0 \to J/\psi + Ks$	Erreur stat	Erreur syst
Belle	$12649(776.10^6 B\bar{B})$	0.023	0.012
Babar	$15481(465.10^6 B\bar{B})$	0.028	0.012
Belle II	$\approx 40000(5ab^{-1})$	0.016	0.012
Stage	$40000(5ab^{-1})$	0.00819/0.0132	$+0.0056/0.0124$ $-0.002/0.0198$

- Les incertitudes sur S_f dans le canal $B^0 \to \phi + Ks$

	$N_{sig}(B^0 \to \phi + Ks)$	Erreur stat	Erreur syst
Belle			
Babar			
Belle II	$3100(5ab^{-1})$	0.07	0.012
Stage	$3100(5ab^{-1})$	0.03524/0.06284	$+0.0057/0.0114$ $-0.0023/0.0202$