The Belle II Experiment

Doris Yangsoo Kim
Soongsil University

On behalf of the Belle II Experiment

July 29, 2014

Flavor Physics Conference
Xth Rencontres du Vietnam

Outline

- Introduction: The Super B Factory Project
- SuperKEK
- Belle II: The Detector
- Belle II: Offline Computing & Software
- Summary

Introduction

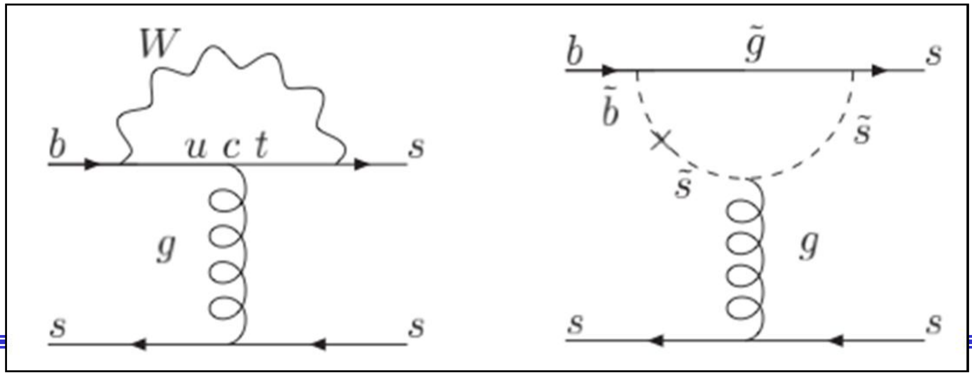
The Super B Factory Project

Upgrade of KEKB/Belle

	KEKB		SuperKEKB	
Luminosity:	2.1×10^{34}	$\rightarrow$	$8 \times 10^{35}\ cm^{-2}s^{-1}$	(x 40)
Total Data:	1 ab^{-1}	$\rightarrow$	50 ab^{-1}	(x 50)
Detector:	Belle	$\rightarrow$	Belle II	

Physics at a Super B Factory

- Precision test of CKM unitarity matrix
  - More data → Over-constraining of unitarity triangle
  - Search for deviations from the Standard Model
- There is a good chance to see new phenomena:
  - CP Violation from the new physics .
  - Lepton flavor violations in τ decays.
  - Search for the charged Higgs boson in $B \rightarrow \tau\nu$, $D(*)\tau\nu$ decays.
  - New particles affecting the flavor changing neutral current.
  - More topics: CP Violation in charm mesons, new hadrons, …



Examples of Belle II Expectation

Observable	SM theory	Current measurement (early 2013)	Belle II * ($50\,\text{ab}^{-1}$)
$S(B \to \phi K^0)$	0.68	0.56 ± 0.17	± 0.018
$S(B \to \eta' K^0)$	0.68	0.59 ± 0.07	± 0.011
α from $B \to \pi\pi, \rho\rho$		$\pm 5.4°$	$\pm 1°$
γ from $B \to DK$		$\pm 11°$	$\pm 1.5°$
$S(B \to K_S \pi^0 \gamma)$	< 0.05	-0.15 ± 0.20	± 0.035
$S(B \to \rho\gamma)$	< 0.05	-0.83 ± 0.65	± 0.07
$A_{\rm CP}(B \to X_{s+d}\,\gamma)$	< 0.005	0.06 ± 0.06	± 0.005
$A^d_{\rm SL}$	-5×10^{-4}	-0.0049 ± 0.0038	± 0.001
$\mathcal{B}(B \to \tau\nu)$	1.1×10^{-4}	$(1.64 \pm 0.34) \times 10^{-4}$	$\pm 3\%$
$\mathcal{B}(B \to \mu\nu)$	4.7×10^{-7}	$< 1.0 \times 10^{-6}$	$\gg 5\sigma$
$\mathcal{B}(B \to X_s\gamma)$	3.15×10^{-4}	$(3.55 \pm 0.26) \times 10^{-4}$	$\pm 6\%$
$\mathcal{B}(B \to K^{(*)}\nu\bar{\nu})$	3.6×10^{-6}	$< 1.3 \times 10^{-5}$	$\pm 30\%$
$\mathcal{B}(B \to X_s \ell^+\ell^-)$ $(1 < q^2 < 6\,\text{GeV}^2)$	1.6×10^{-6}	$(4.5 \pm 1.0) \times 10^{-6}$	$\pm 0.10 \times 10^{-6}$
$A_{\rm FB}(B^0 \to K^{*0}\ell^+\ell^-)$ zero crossing	7%	18%	5%
$\lvert V_{ub}\rvert$ from $B \to \pi\ell^+\nu$ $(q^2 > 16\,\text{GeV}^2)$	$9\% \to 2\%$	11%	2.1%

Courtesy: Youngjoon Kwon @ Beauty2014
Snowmass (arXiv:1311.1076) + BPAC 2014 update(*)

SuperKEKB

Luminosity Increase by a Factor 40

- “Nano-Beam” scheme of Pantaleo Raimondi for SuperB.

2 times better→

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

Lorentz factor

Classical electron radius

Beam size ratio at IP 1-2% (flat beam)

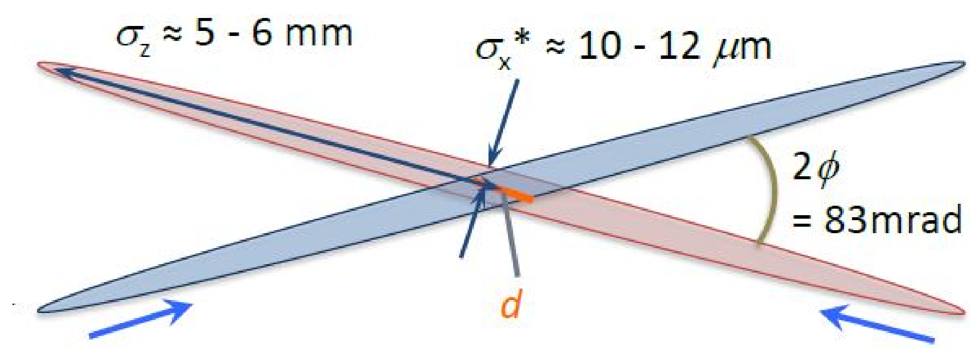
Beam current

Beam-beam parameter

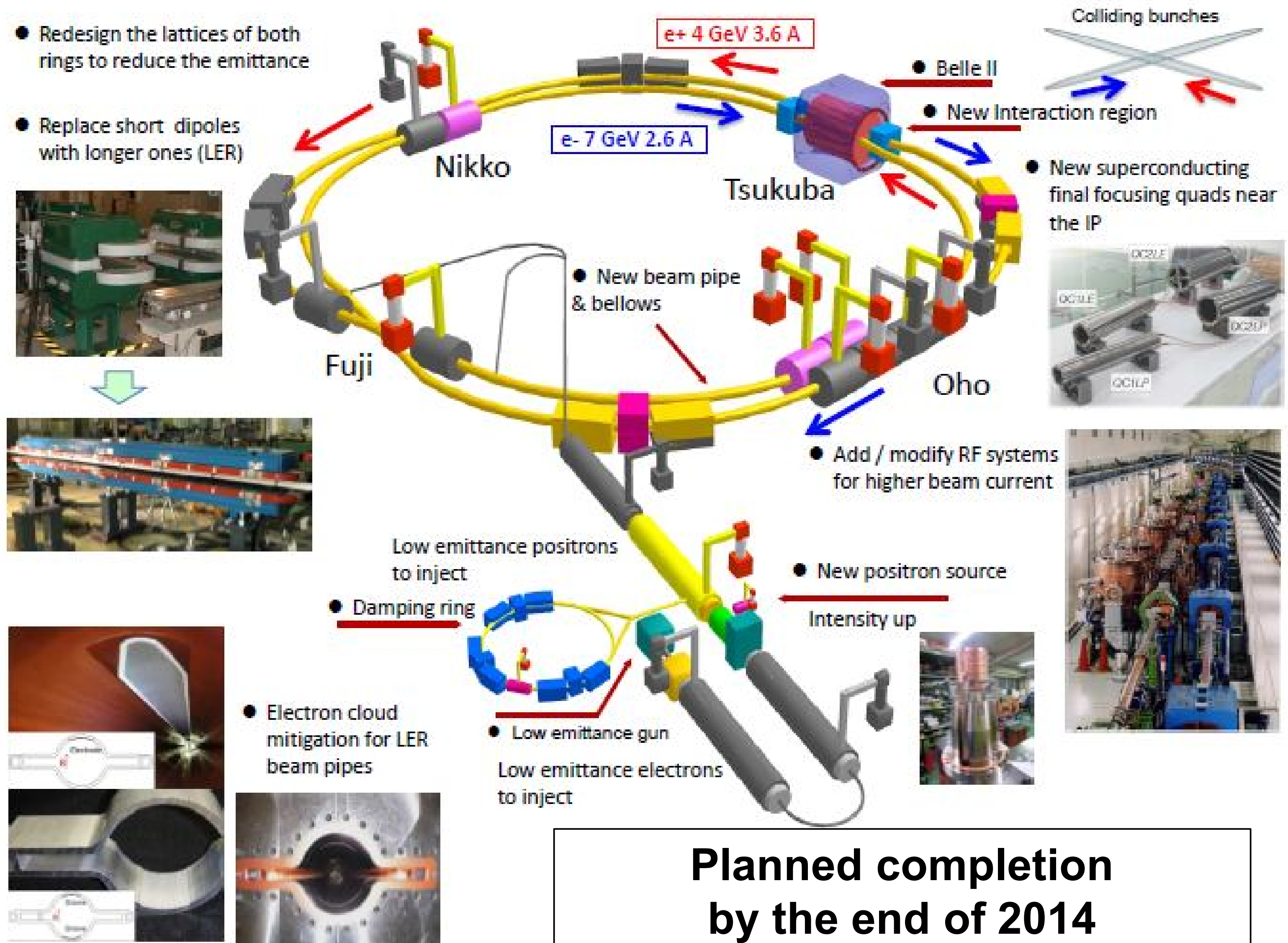
Vertical beta function at IP

←20 times better

Geometrical reduction factors (crossing angle, hourglass effect)



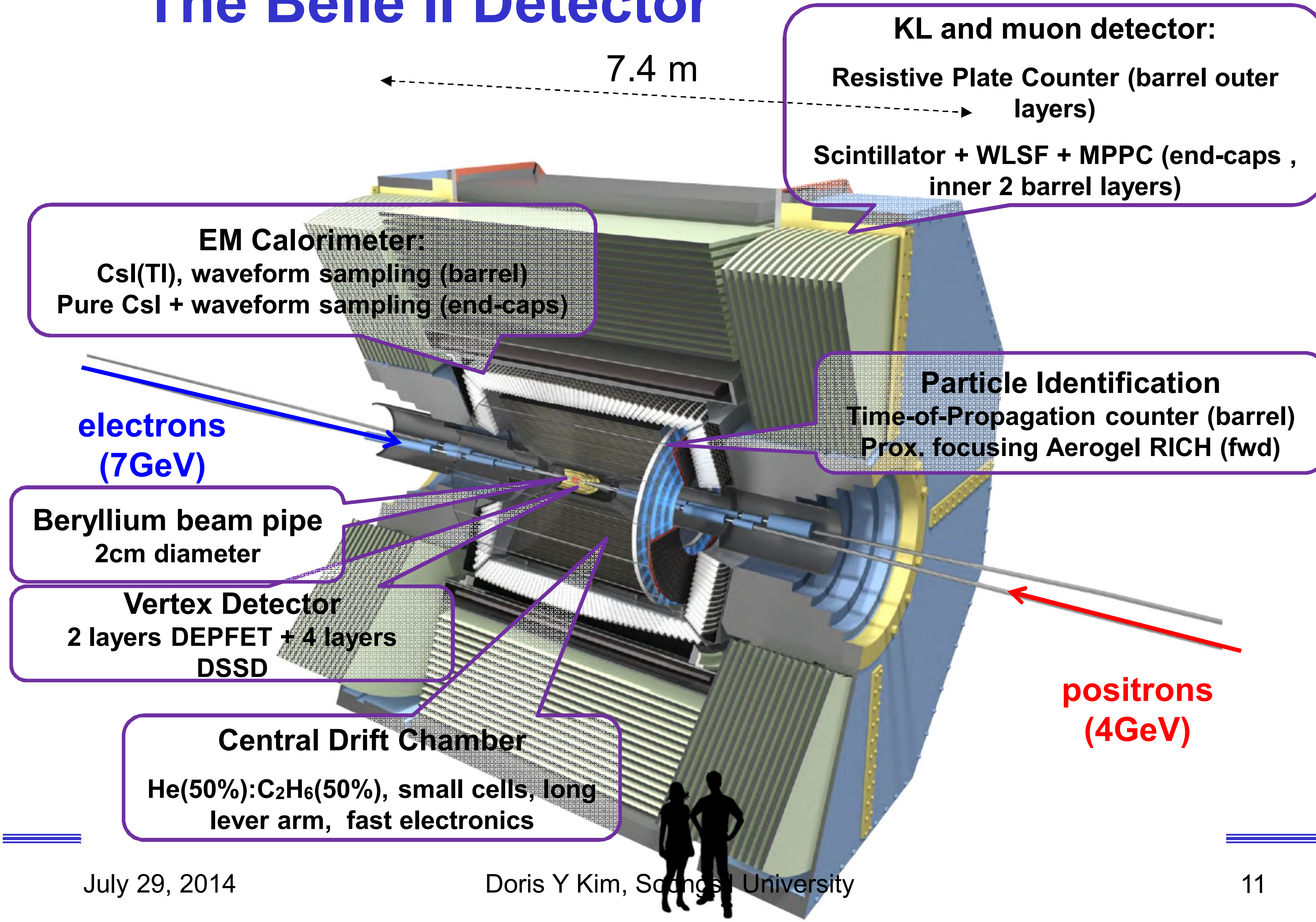
SuperKEKB Upgrade Status



Planned completion by the end of 2014

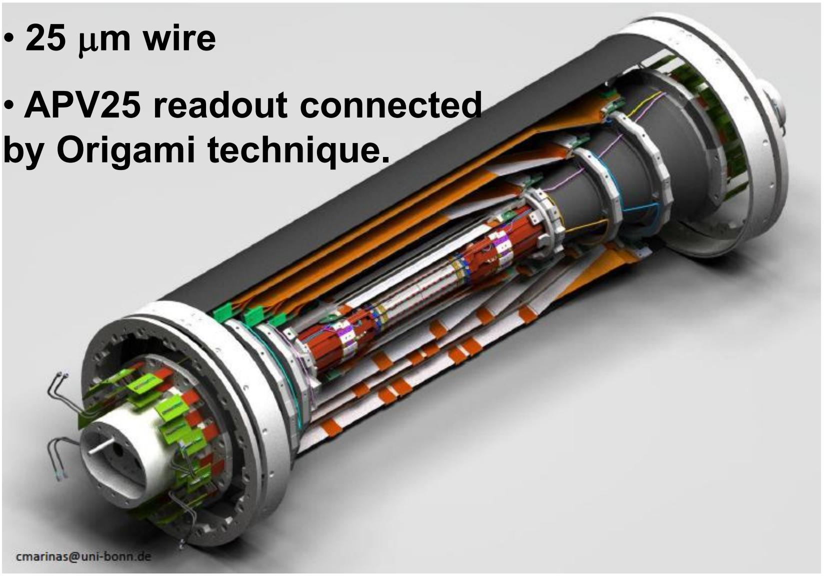
Belle II: The Detector

The Belle II Detector



Vertex Detector

- Slant structure for SVD layers
- 25 μm wire
- APV25 readout connected by Origami technique.



- Beampipe r = 10 mm
- DEPFET (Pixels): Emphasis on low material budget. Sensor and assembly module production finished. Final electronics being tested.

  Layer 1 & 2 r = 14 & 22 mm

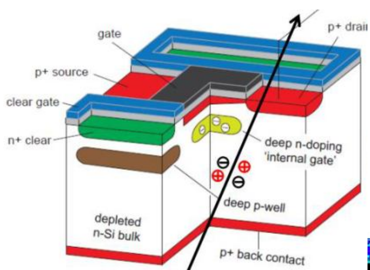
  $\sigma \sim 15\ \mu$m, time resolution 20 μs

- DSSD (Double sided silicon detectors) Mass production will start August 2014.

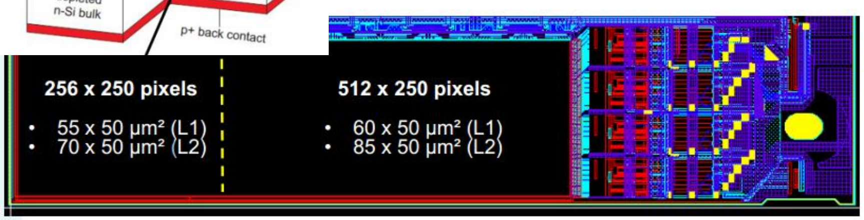
  Layer 3 to 6 r = 38, 80, 115, & 140 mm

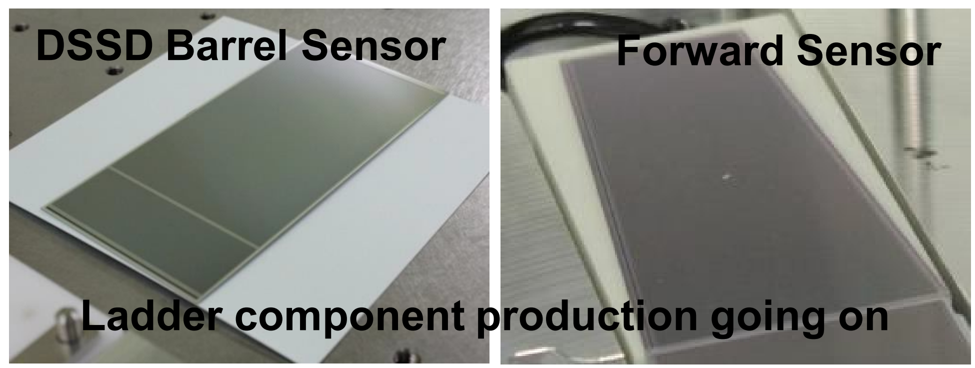
  Time resolution 3 ns

- PXD + SVD: Use SVD to reduce PXD data size.
  Decay position resolution 10 μm
  VXD only tracking is possible.



Depleted p-channel Field Effect Transistor



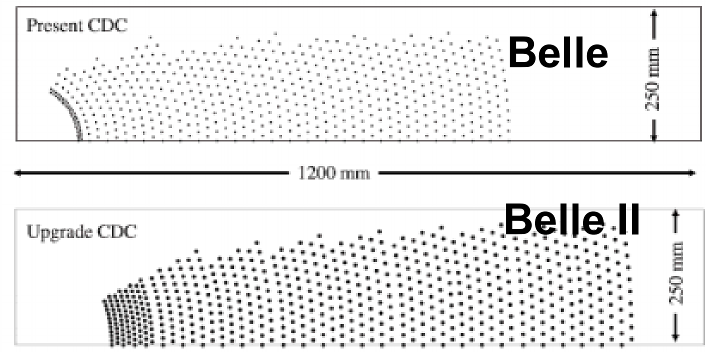


Central Drift Chamber

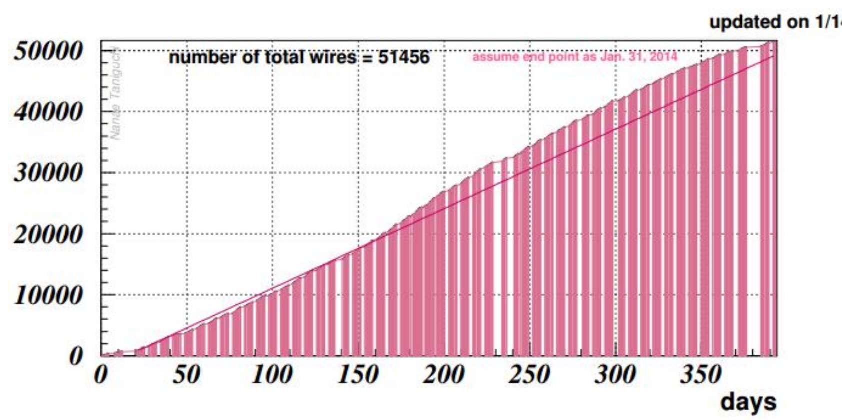
$\sigma_p / p \sim 0.3\% + 0.1\% \times p(GeV)$ in $B = 1.5T$

$\sigma(dE/dx) \sim 6\%$

Parameter	Belle	Belle II
Inner radius	77mm	160mm
Outer radius	880mm	1,130mm
No of sense wires	8,400	14,330



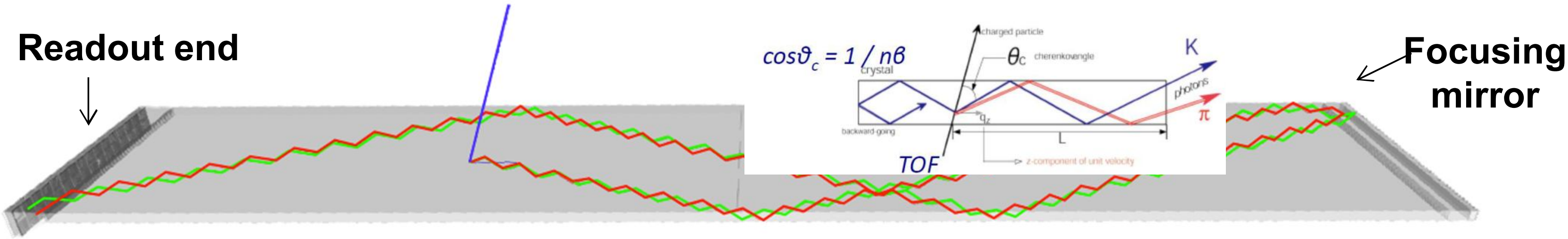
- **Inner chamber: Small-cell to counter high background.**
- **Wiring is finished in June 2014**
- **Currently checking gas leak**
- **Planned cosmic ray test coming.**

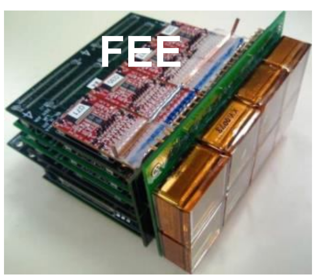


Particle Identification (TOP)

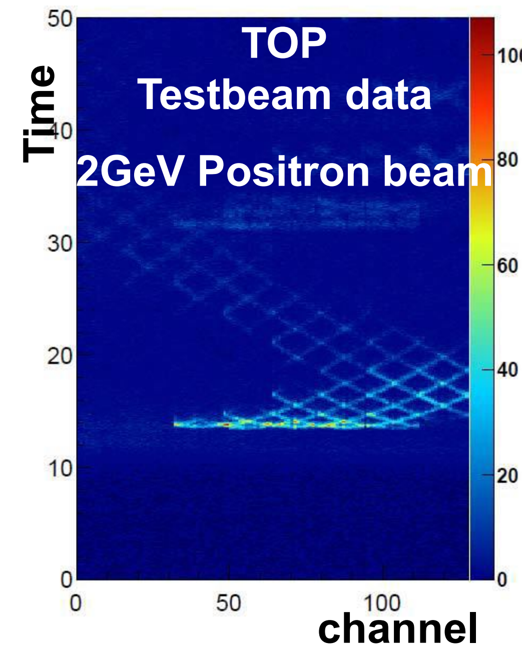
TOP (Time of Propagation counter): A RICH type detector (σ < 100ps)

A GEANT4 event display of a 2 GeV pion and kaon interacting in a TOP quartz bar.



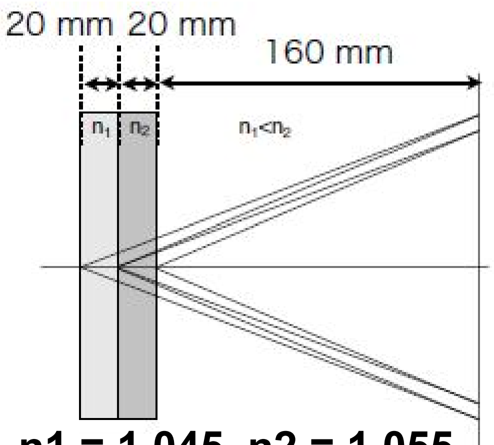


- **Successful prototype in 2013.**
- **PMT : Mass production is completed. Inspection on-going.**
- **FEE: High-speed waveform sampling ASICs. Final electronics production and validation starts late 2014.**
- **Quarz optics: Mass production is on-going.**
- **Quartz bar box: Al honeycomb panels +PEEK material to support the optics.**



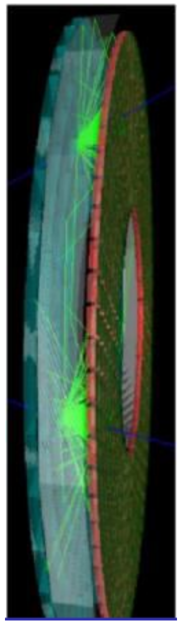
Particle Identification (ARICH)

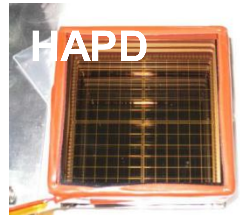
Aerogel Ring Image Cherenkov Detector for forward endcap

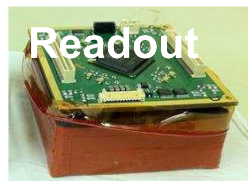


n1 = 1.045, n2 = 1.055

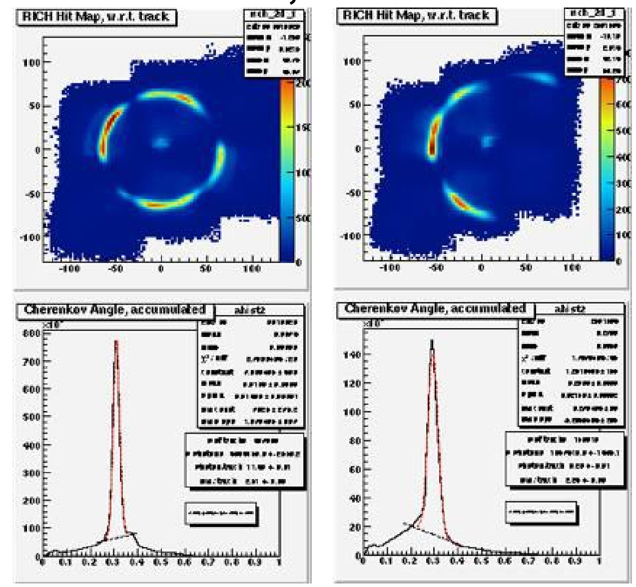
Proximity focusing due to limited space

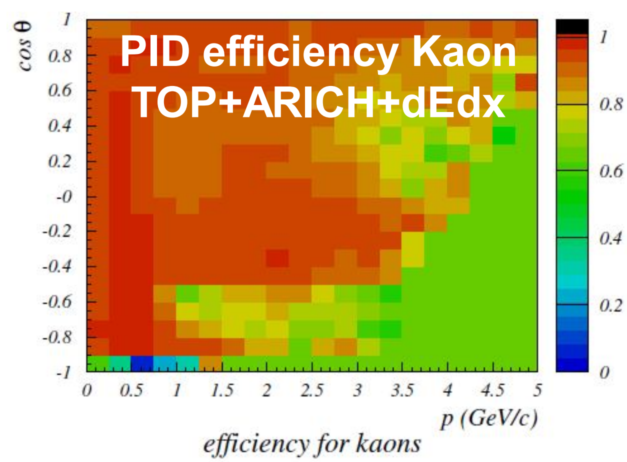






Testbeam: K/π separation = 5.5σ for 120 GeV/c, 0° hadron beam

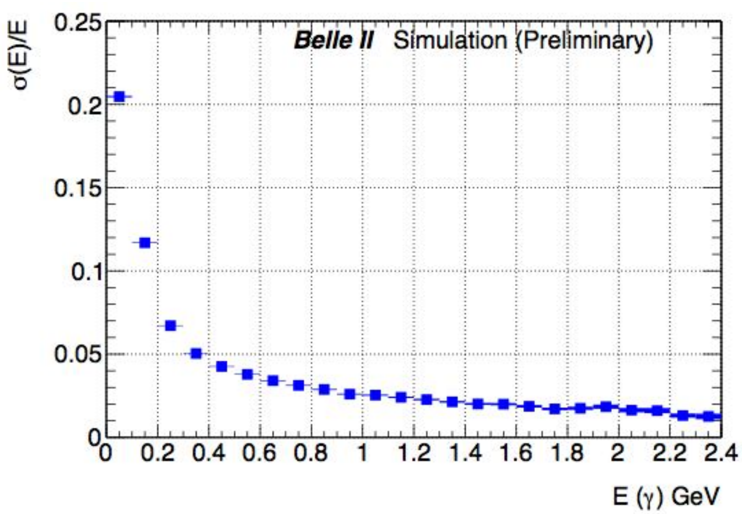




- **HAPD: Mass production started last September.**
- **Readout: ASIC production completed. Front-end board design being finalyzed.**
- **Radiator: Mass production of aerogel finished. Inspection on-going.**

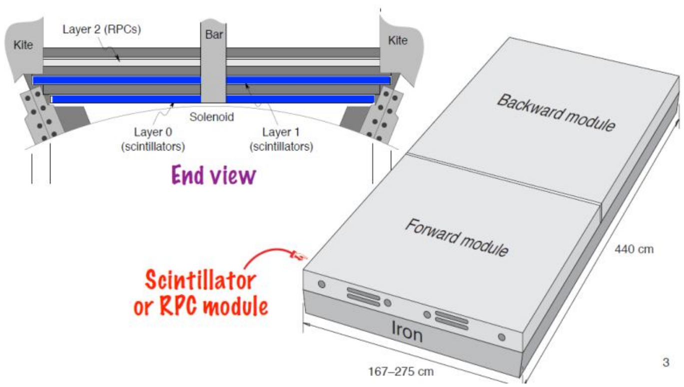
EM Calorimeter

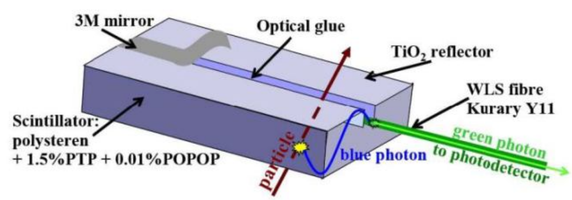
- **Barrel**
  - **CsI(Tl) crystals reused. New electronics with 2MHz wave form sampling. All 6624 channels tested with new electronics and alive.**
  - **Cosmic ray test this summer.**
- **Endcap**
  - **The old crystals will be refurbished with new preamplifiers and readout.**
  - **Bias filter is modified. Pedestal, test pulse position, cosmic peak position tested.**
  - **The system will be installed in 2015.**
  - **Upgrade planned to pure CsI to deal high background issue. Ongoing R&D.**

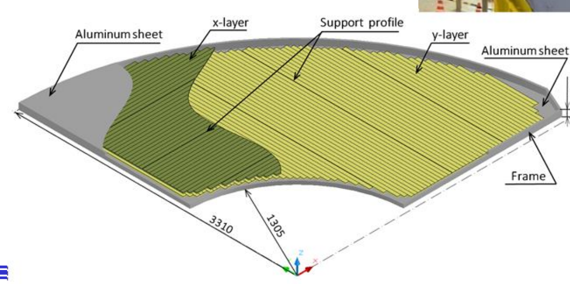


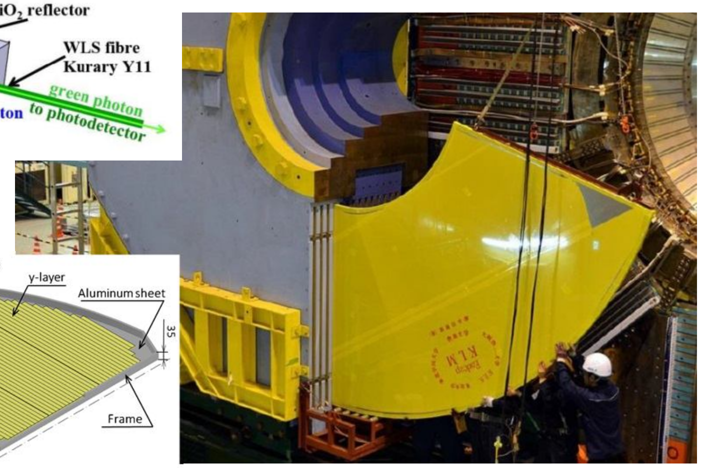
K_L + Muon Detector

- **Barrel**
  - **Belle RPC's will be reused.**
  - **Two inner layers are replaced by scintillator strips in 2013.**
  - **Various integration test with new FEE going on in 2014 (@KEK later).**
- **Endcap**
  - **RPC's are replaced with scintillators to fight neutron background.**
  - **56 forward sectors were installed in April 2014.**
  - **46 backward sectors will be installed this summer.**
  - **~ 99% geometrical acceptance. Better PID efficiency. σ < 1ns.**









Belle II: Offline Computing & Software

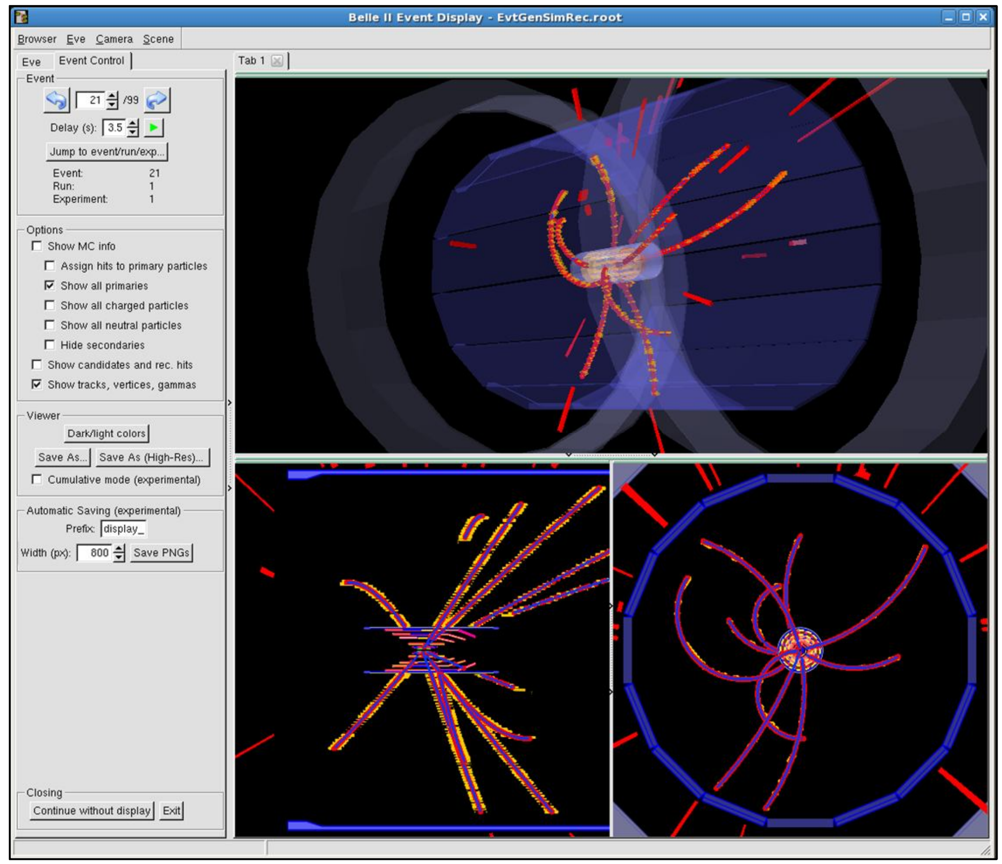
The Offline Software System

- A “framework” system with dynamic module loading, parallel processing, Python steering, and ROOT I/O. Use of GRID with Dirac.
- Full detector simulation with Geant4
- Code management systems at KEK: The Subversion software
- All common linux operating systems supported: SL, Fedora, Ubuntu, etc
- C++ 11 and gcc 4.7
- Formatting tool: astyle
- Building: scons, buildbot
- Documentation: Doxygen, Twiki
- Issue tracking: Redmine
- Ideas from ILC, LHCb, CDF, Alice
- 3rd party: ROOT, boost, CLHEP, etc. Global Developers

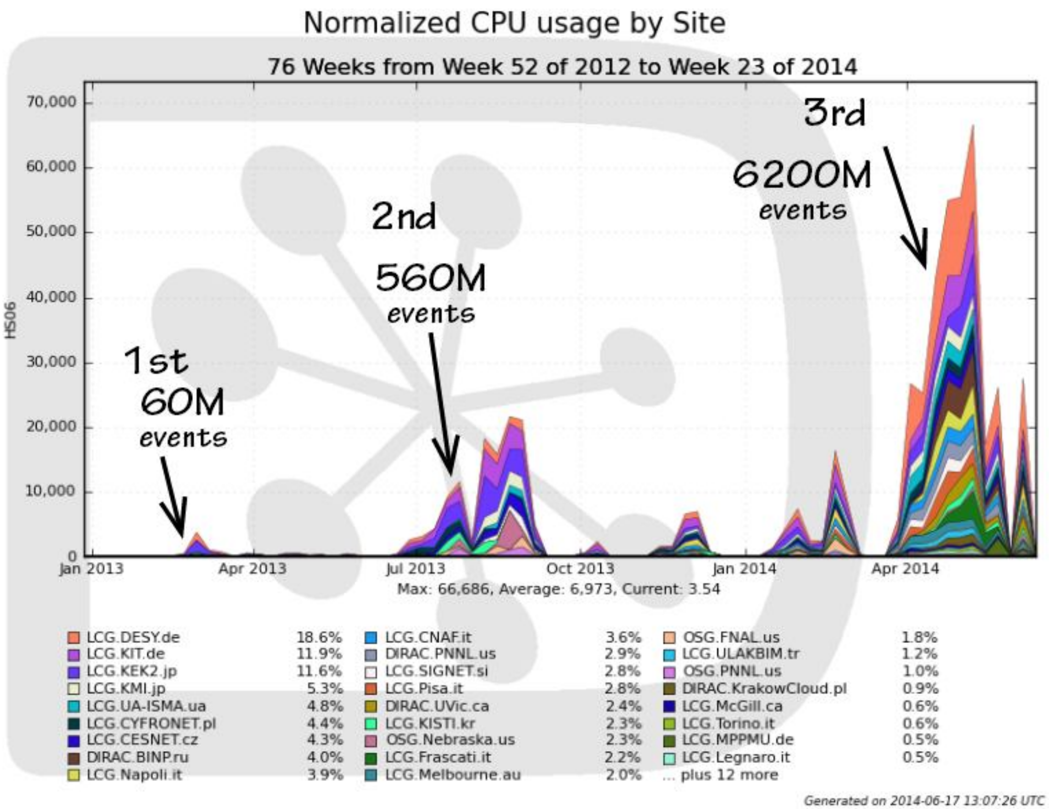
In Development: Tools & Event Display

- Tracking with
  - **Finder: Old Belle algorithm or New including Legendre.**
  - **New fitting**
- Alignment with Millepede II
  - **The framework successfully applied to VXD testbeam data.**
- Dedicated Database studies
- PID tools in testing.
- Analysis tools are being created.
- Full cycle of gen / sim / rec / analysis tested.

- Display: basf2 + ROOT with OpenGL support



MC Campaigns



15 countries/regions

27 sites (+ 2 non-Belle II sites)

HEPHY (Vienna) and MPPMU (Munich) joined recently

GRID, Cloud, local cluster is available

First official release of MC samples

BB generic decay/continuum

tau pair

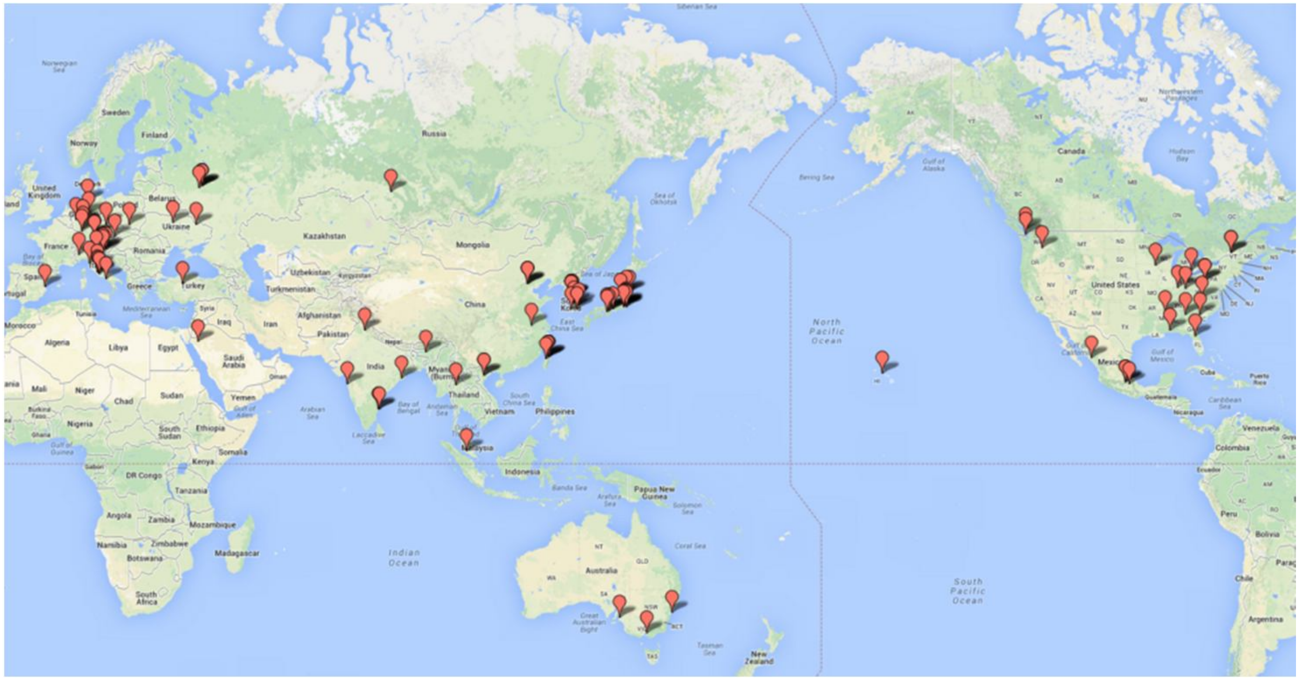
(corresponding to $100 fb^{-1}$ w/ and w/o BG)

Trans-pacific / trans-atlantic network data tranfer challenge

- Roughly two MC campaigns per year as challenge data sets.
- Latest set: ~ 6 billion MC events generated in April and May in the DIRAC framework.

Summary

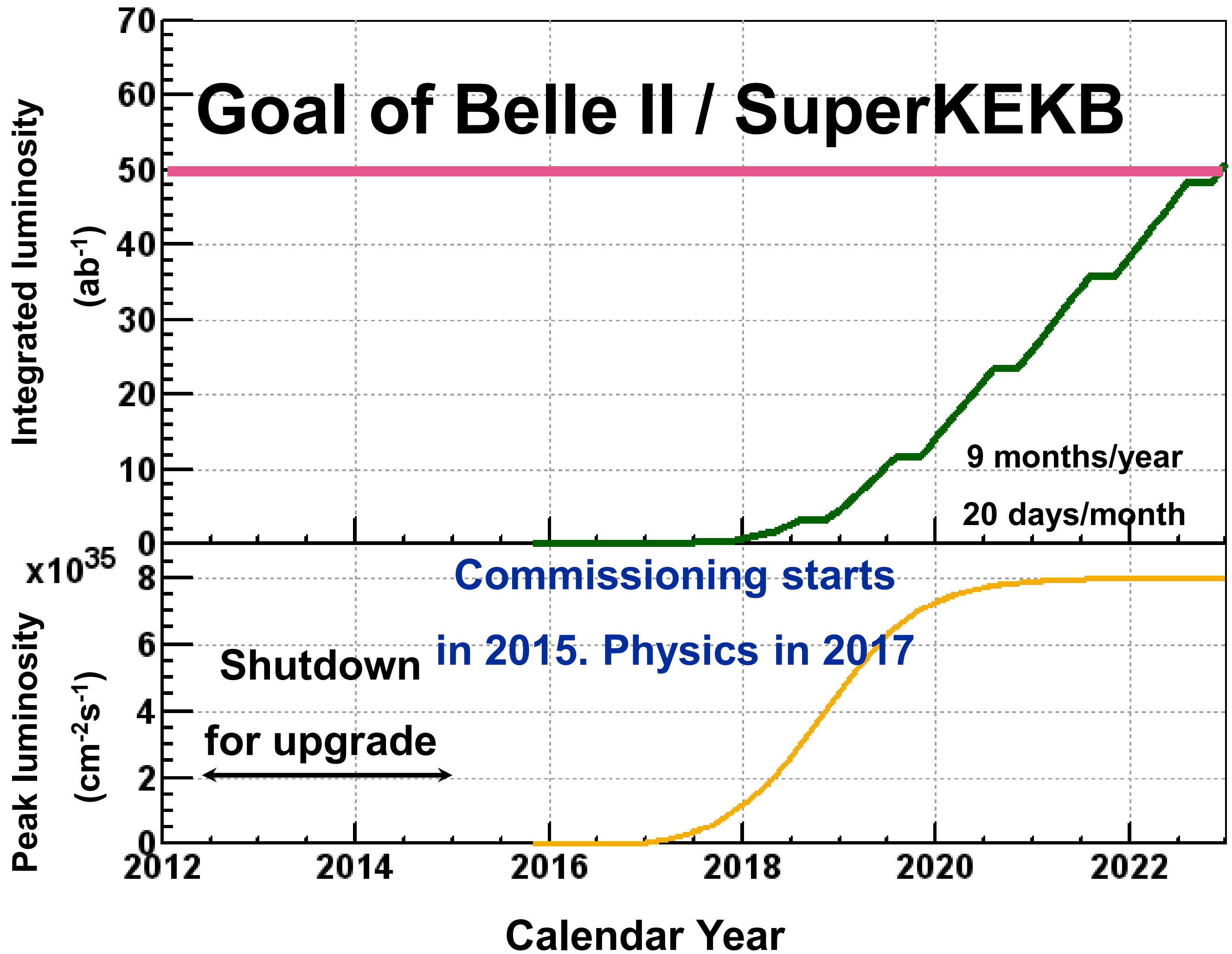
Final Remarks



- Belle II (June 30, 2014): ~ 600 scientists, 97 institutions, 23 countries
- Many projects going on actively.
- Physics run expected in 2017.
- Many thanks for the colleagues who provided valuable ideas, data and plots for this talk.

Extra Slides

Luminosity Projection



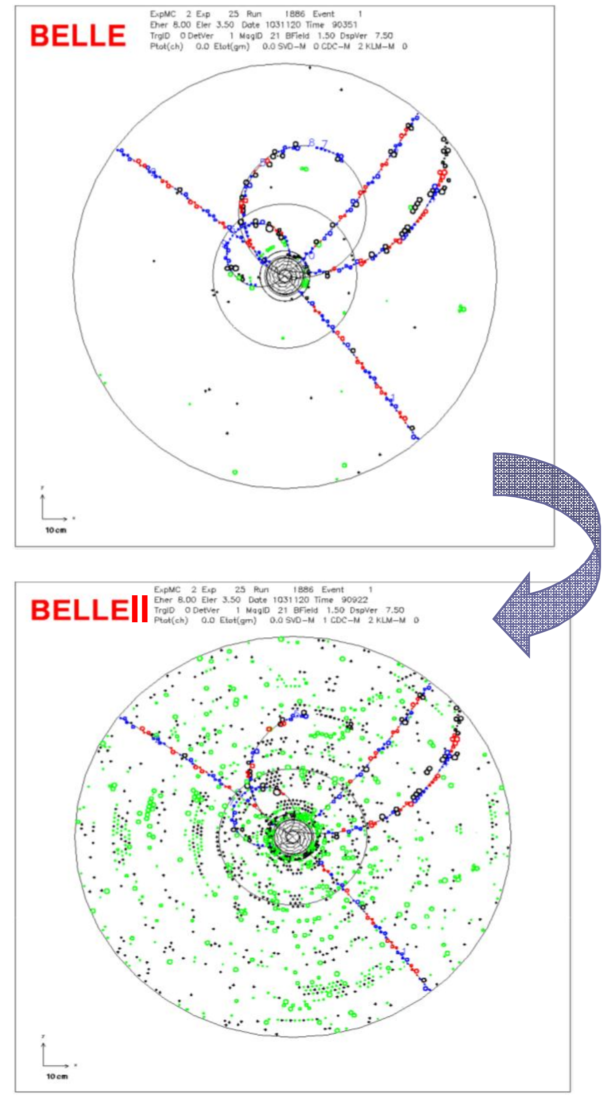
Beam Parameters: KEKB vs SuperKEKB

	KEKB Design	KEKB Achieved (Crab)	SuperKEKB Nano-Beam	
Energy (GeV) (LER/HER)	3.5/8.0	3.5/8.0	4.0/7.0	
β_y^* (mm)	10/10	5.9/5.9	0.27/0.30	×20
β_x^* (mm)	330/330	1200/1300	32/25	
ε_x (nm)	18/18	18/24	3.2/4.6	
$\varepsilon_y / \varepsilon_x$ (%)	1	0.85/0.64	0.27/0.28	
σ_y(mm)	1.9	0.94	0.048/0.062	
ξ_y	0.052	0.129/0.090	0.088/0.081	
σ_z (mm)	4	6 ~ 7	6/5	
I_{beam} (A)	2.6/1.1	1.64/1.19	3.6/2.6	×2
$N_{bunches}$	5000	1584	2500	
Luminosity (10^{34} cm^{-2} s^{-1})	1	2.11	80	

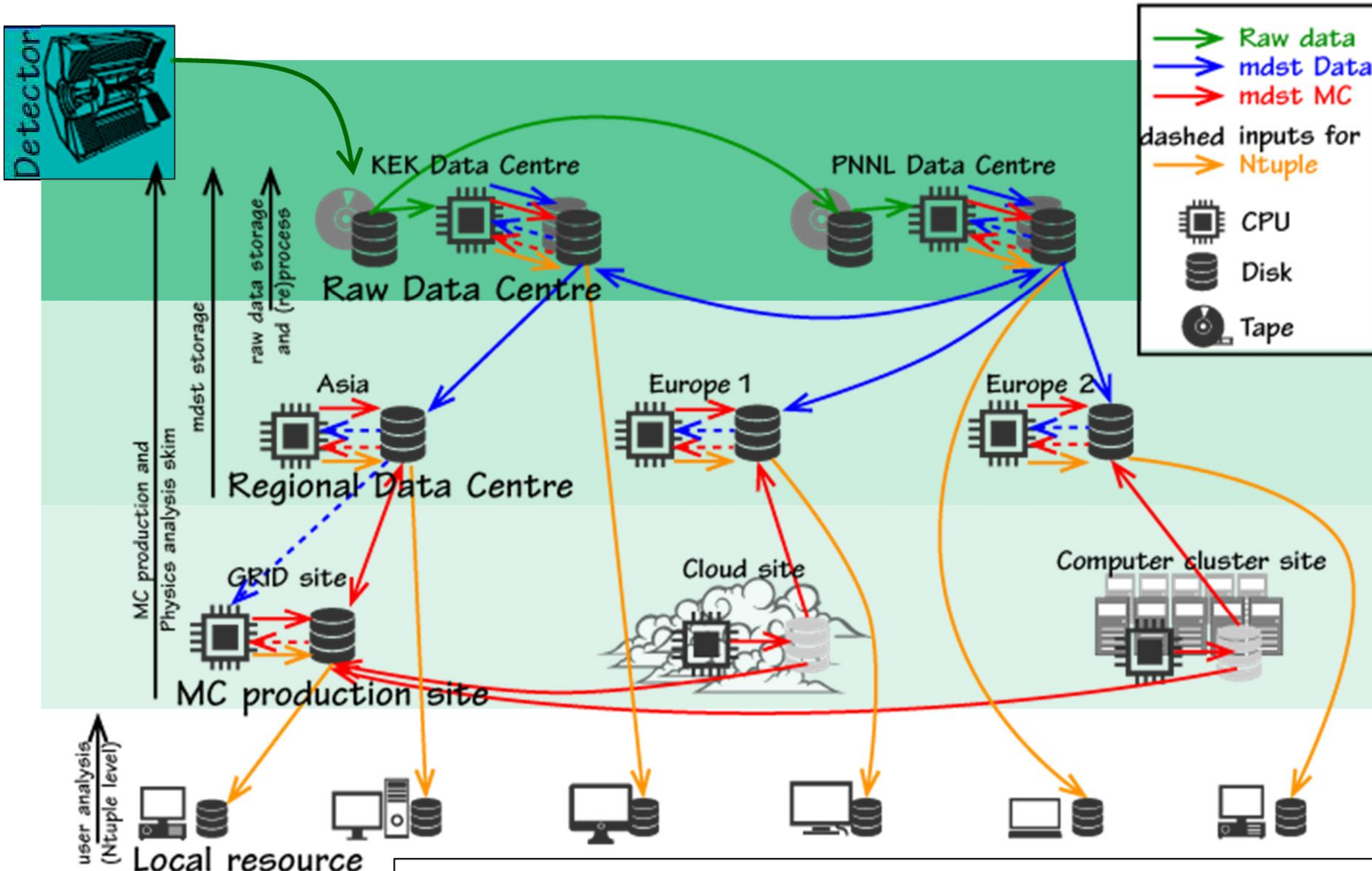
Courtesy: Ken-ichi Kanazawa @ ICHEP2014

Challenges to Belle II

- Higher background ($\times$ 10~20 of KEKB).
  - Touscheck scattering
  - Radiative Bhabha
  - 2-photon
  - More radiation damage, fake hits, pile-up
- Higher event rate ($\times$10)
  - L1 trigger rate: ~20 kHz
- Improvements planned:
  - Better hermitricity.
  - Better IP and secondary vertex resolution.
  - Better PID.



The Computing Model till 3rd Data Year



More raw data centers from 4th year