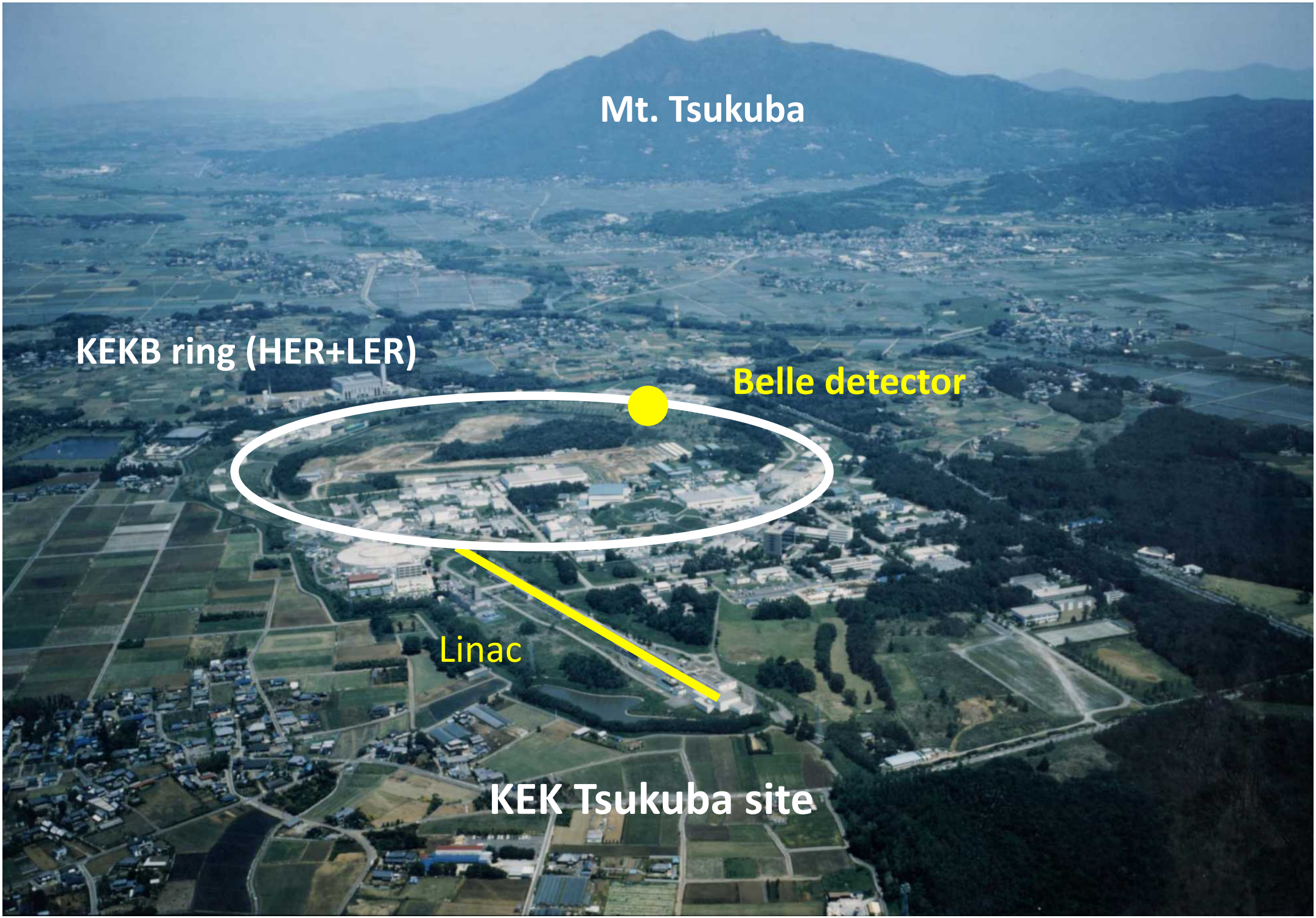
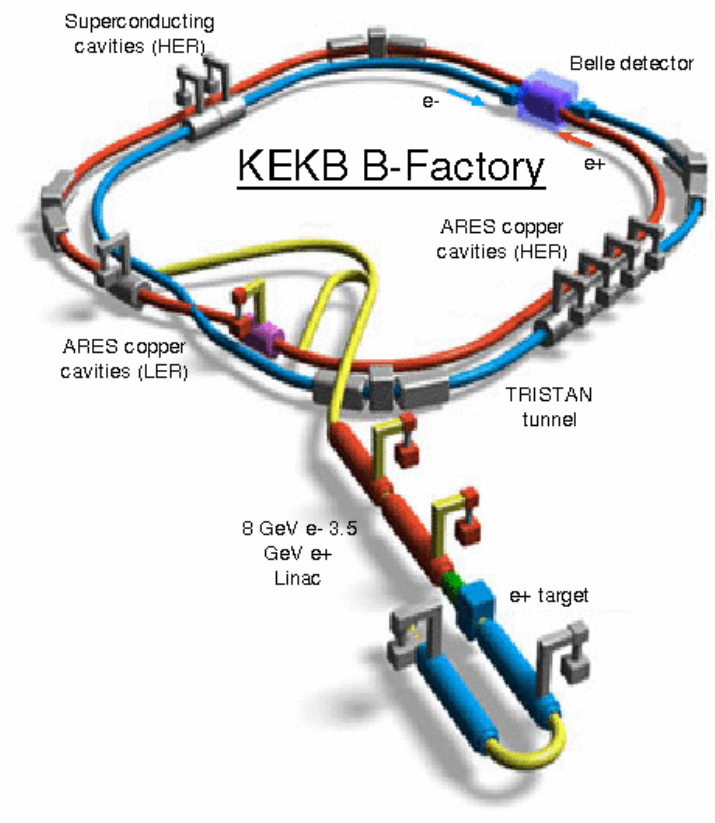
Belle II – machine/detector status

Christoph Schwanda (HEPHY Vienna)

Round table discussion


Mt. Tsukuba
KEKB ring (HER+LER)
Belle detector
Linac
KEK Tsukuba site

The asymmetric KEKB collider

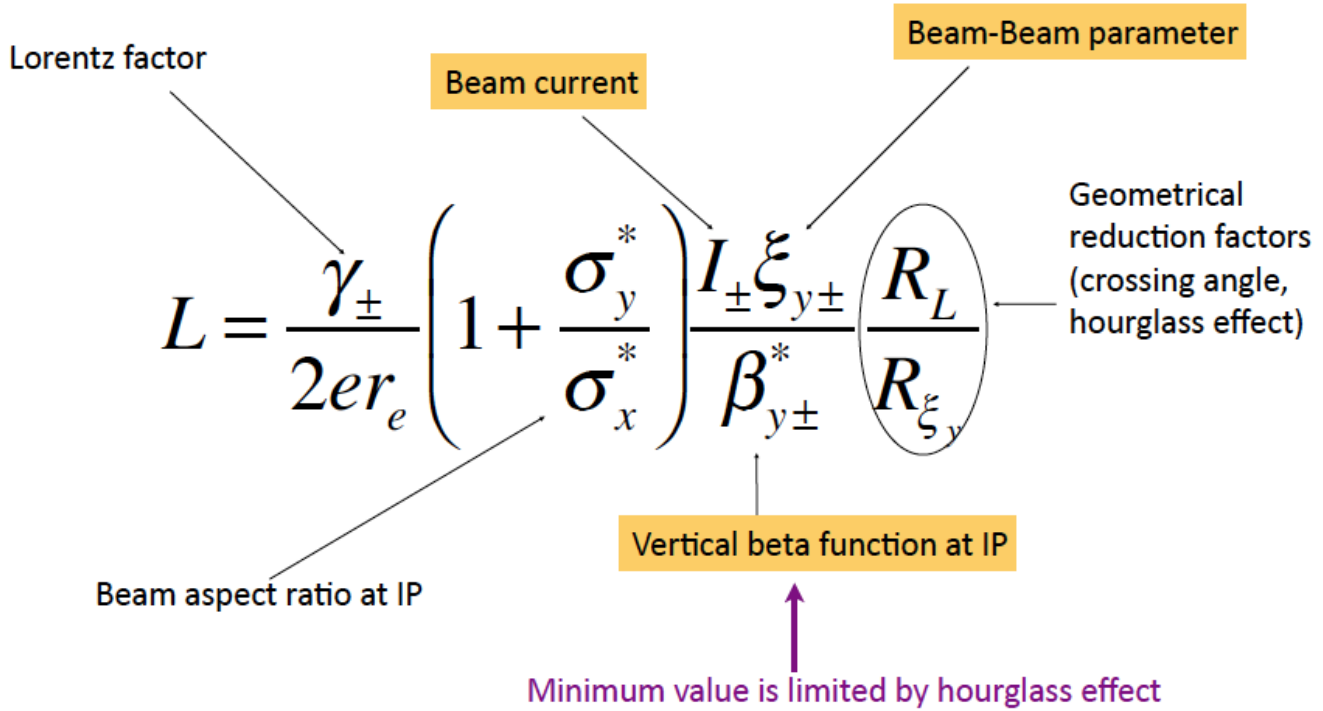


- Electron ring (HER): 8 GeV
- Positron ring (LER): 3.5 GeV
- Center of mass energy: 10.58 GeV (Y(4S) resonance → production of B pair at threshold)
- But also runs at Y(5S), …
- One interaction point (Belle)

1040/fb delivered since turn-on in 1999

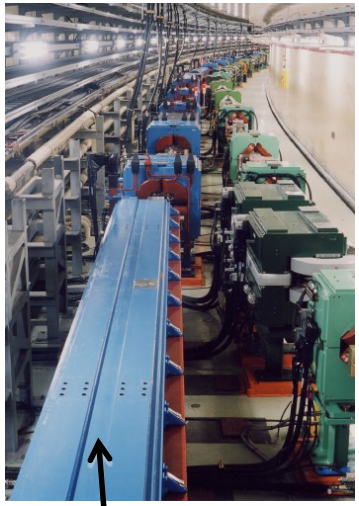
Ceremonial dump of last KEKB beam on June 30, 2010

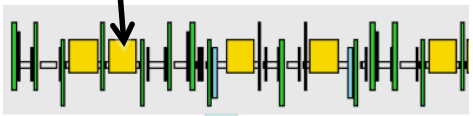
The factors determining luminosity

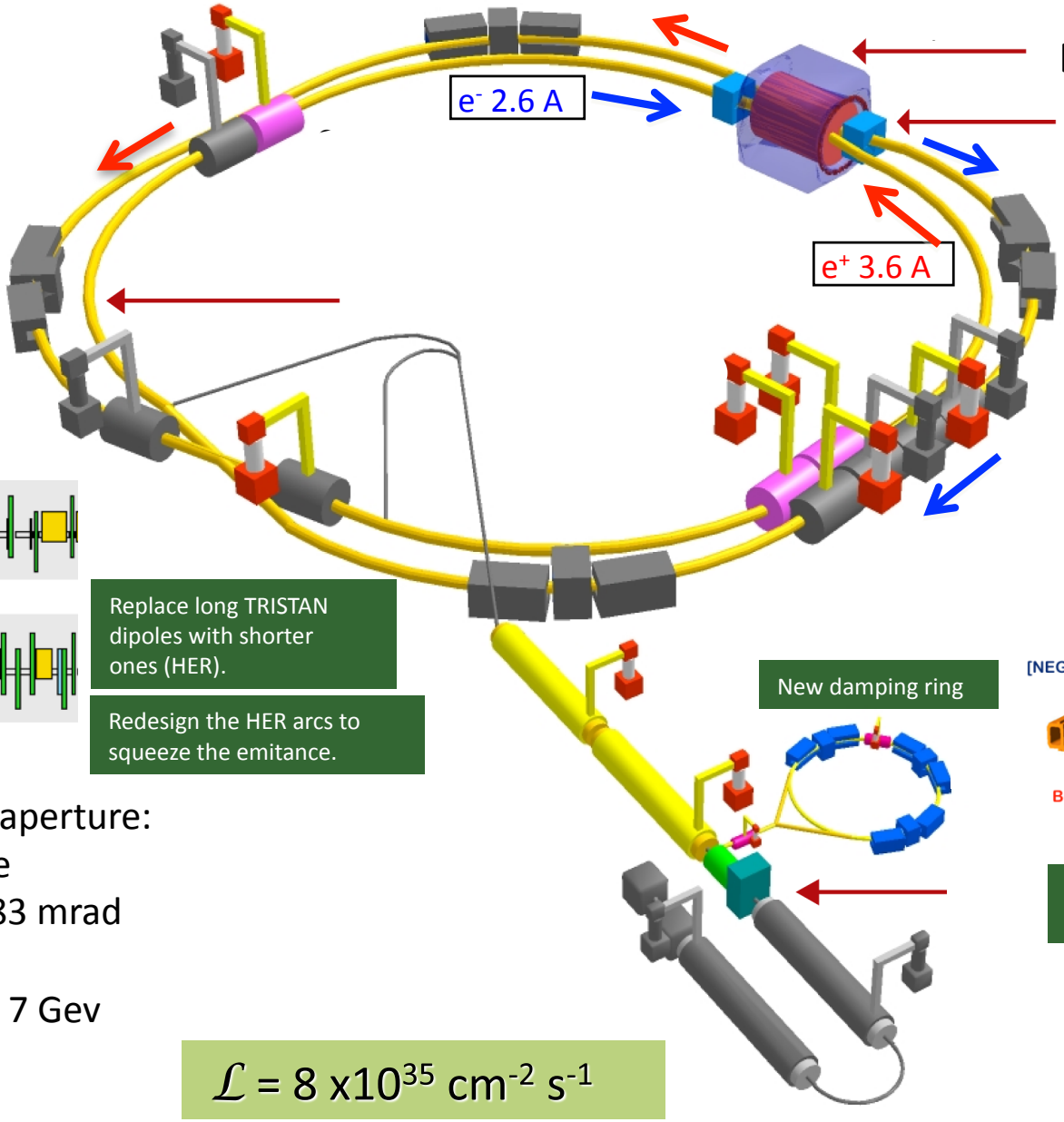


From KEKB to SuperKEKB

- The KEKB B factory will be upgraded to SuperKEKB using the same tunnel. The upgrade is based on the "nano beam" scheme, first proposed for SuperB in Italy
- Squeeze β^*_y as much as possible: 0.27/0.41 mm for LER/HER
- Assume the beam-beam parameter ξ_y achieved at KEKB: 0.09
- Change the beam energies from 3.5/8 GeV to 4/7 GeV (increase Touschek lifetime, mitigate effect of intra-beam scattering in LER)
- Reuse KEKB components as much as possible



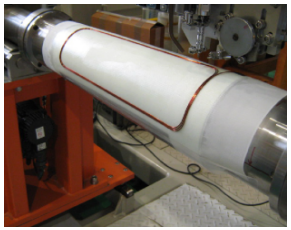




Belle II

New IR

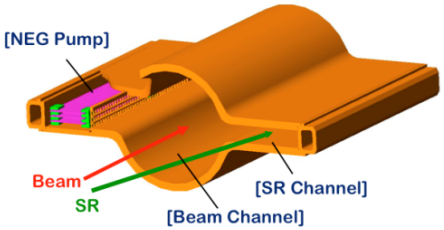
New Superconducting / permanent final focusing quads near the IP



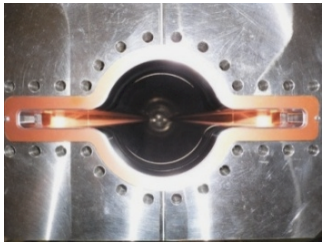
Replace long TRISTAN dipoles with shorter ones (HER).

Redesign the HER arcs to squeeze the emitance.

New damping ring



TiN coated beam pipe with antechambers



increasing dynamic aperture:
larger crossing angle
2ϕ = 22 mrad → 83 mrad
smaller asymmetry
3.5 / 8 GeV → 4 / 7 Gev
optimizing lattice:
τ_{beam} ~ 400 s
(target 600 s)

$\mathcal{L} = 8 \times 10^{35}\ cm^{-2}\ s^{-1}$

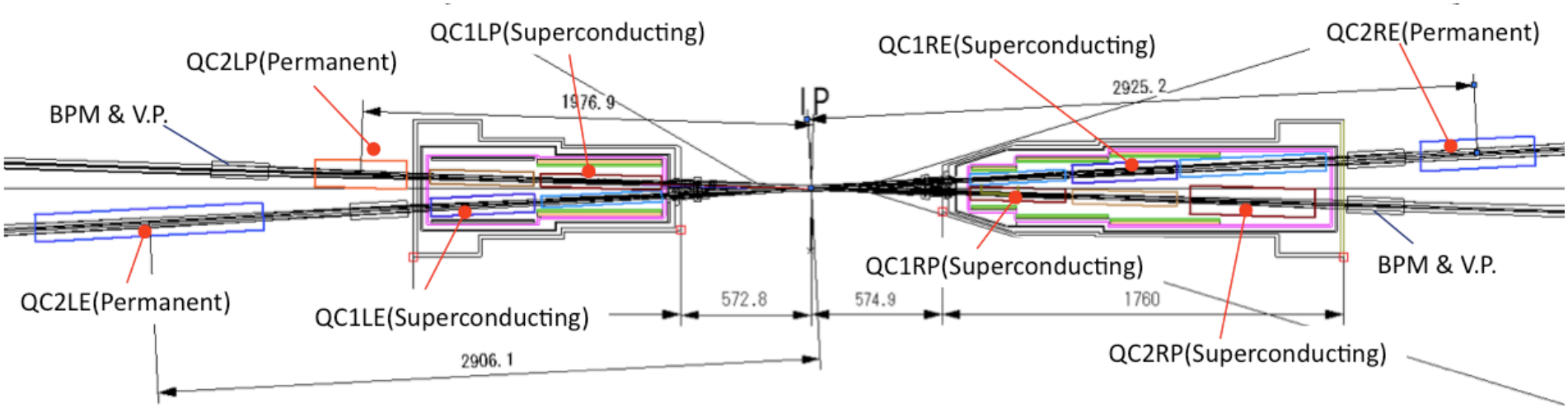
machine parameters

	KEKB Design	KEKB Achieved (with crab)	SuperKEKB High-Current Option	SuperKEKB Nano-Beam Scheme
β_y^* (mm)(LER/HER)	10/10	6.5/5.9 (5.9/5.9)	3/6	0.24/0.37
ε_x (nm)	18/18	18(15)/24	24/18	2.8/2.0
κ(%)	1	0.8-1	1/0.5	1.0/0.7
σ_y(μm)	1.9	1.1	0.85/0.73	0.084/0.072
ξ_y	0.052	0.108/0.056 (0.101/0.096)	0.3/0.51	0.09/0.09
σ_z (mm)	4	~ 7	5(LER)/3(HER)	5
I_{beam} (A)	2.6/1.1	1.8/1.45 (1.62/1.15)	9.4/4.1	3.6/2.1
$N_{bunches}$	5000	~1500	5000	2119
Luminosity (10^{34} cm^{-2}s^{-1})	1	1.76 (2.1)	53	80

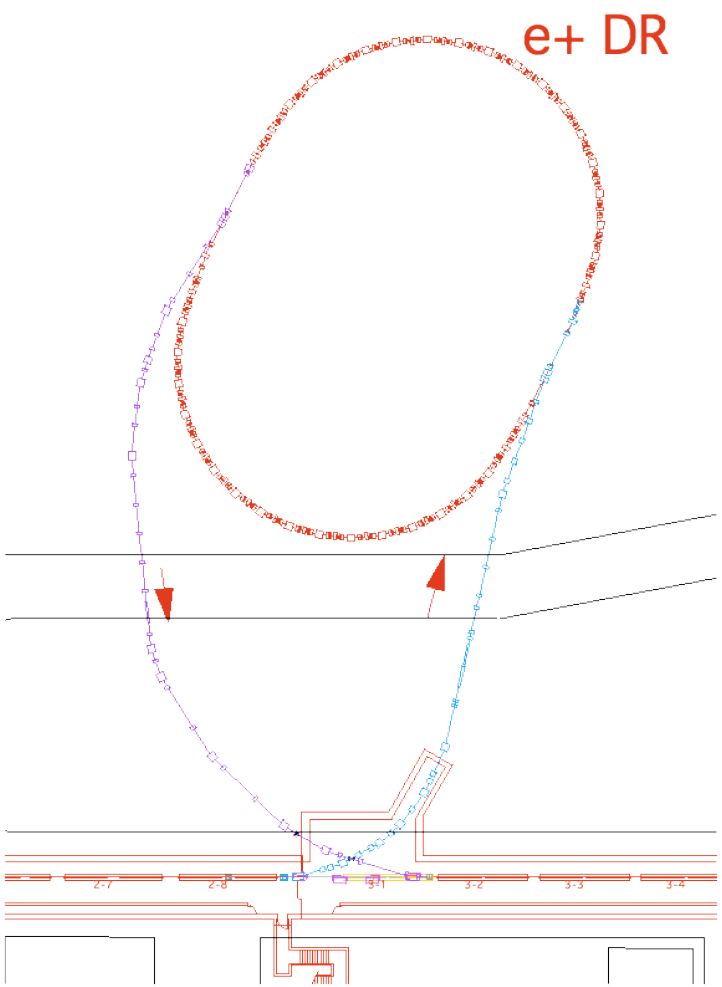
Major items to upgrade

- New ante-chamber beam pipes for both rings
  - 3km x 2 in total
  - Al/Cu for LER/HER
  - Mitigation techniques for suppression of electron cloud
- New IR optics
  - New superconducting/permanent magnets around IP
  - Optimization of the compensation solenoid
- Additional normal magnets to reduce emittance
  - Replace dipoles & change the wiggler layout for LER
- New HER arc lattice
- More precise magnet setting ⇔ power supplies
- Rearrangement of existing ARES cavities with additional power sources
- New positron damping ring and new positron target
- New RF gun for electrons with reduced emittance

IR design with superconducting and permanent magnets

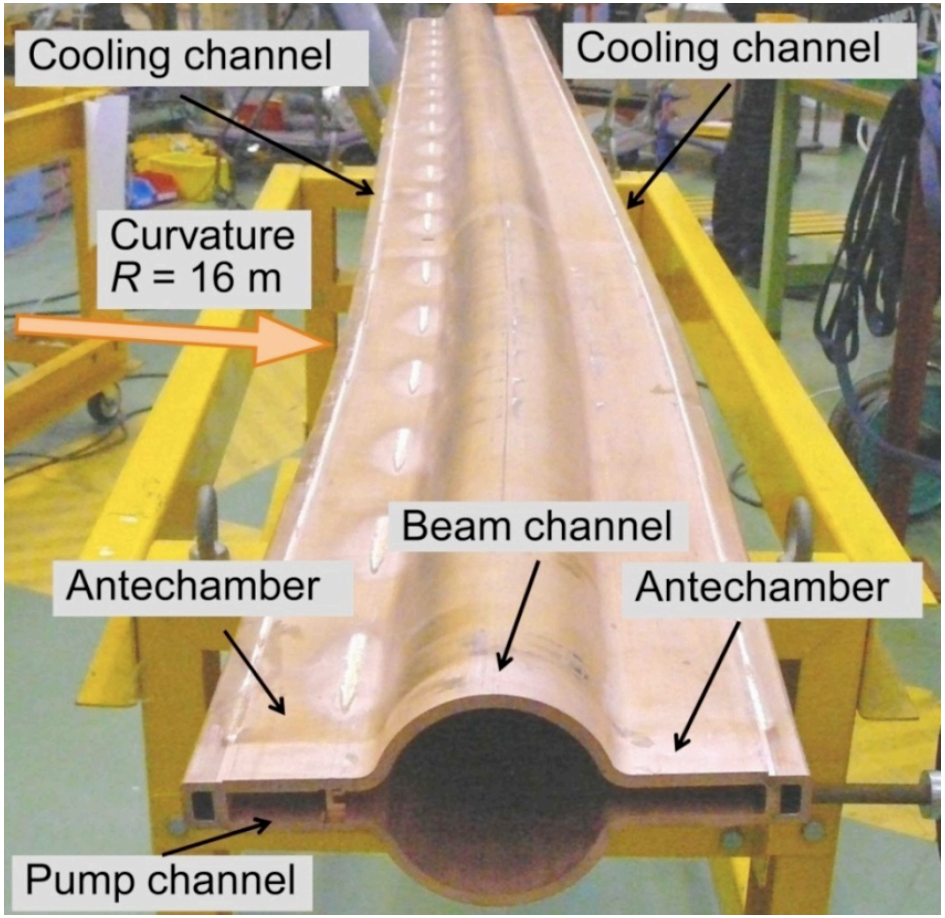


Positron damping ring



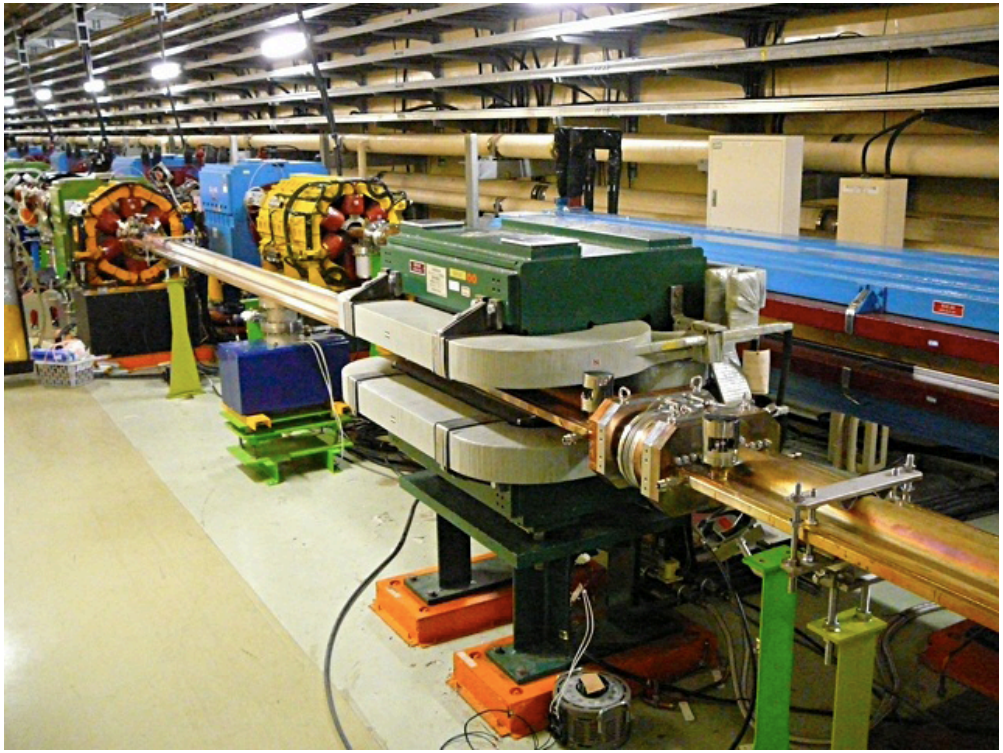
Energy	1.1		GeV
Number of bunch trains	2		
Number of bunches / train	2		
Circumference	135.50207		m
Maximum stored current	70.8		mA
Energy loss per turn	0.091		MV
Horizontal damping time	10.87		ms
Injected-beam emittance	1700		nm
Equilibrium emittance (h/v)	41.4 / 2.07		nm
Coupling	5		%
Emittance at extraction (h/v)	42.5 / 3.15		nm
Cavity voltage	0.5	1.0	MV
Bucket height	0.81	1.24	%
Energy spread	5.5×10^{-4}		
Synchrotron tune	0.0152	0.0216	
Equilibrium bunch-length	11.01	7.74	mm
Threshold due to CSR	9.51	8.46	nC / bunch
Phase advance/cell (h/v)	64.39 / 64.64		deg
Momentum compaction factor	0.0141		
Bend-angle ratio	0.35		
Number of normal-cells	40		
RF frequency	509		MHz
Chamber diameter(normal cell)	34		mm

Beam duct for SuperKEKB



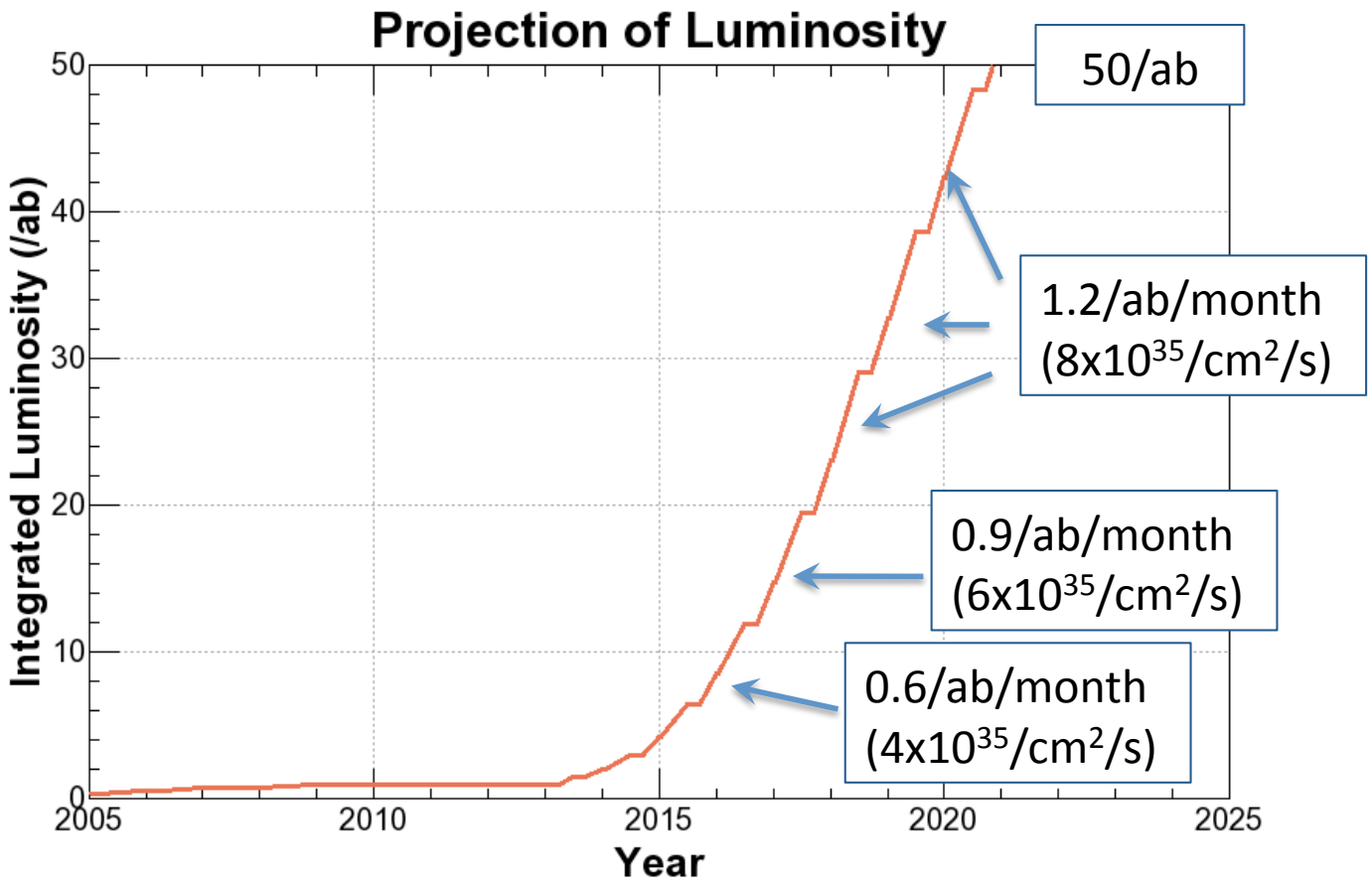
Features (compared to simple pipe)

- Low SR power density
- Low photoelectrons in beam pipe
- Low beam impedance



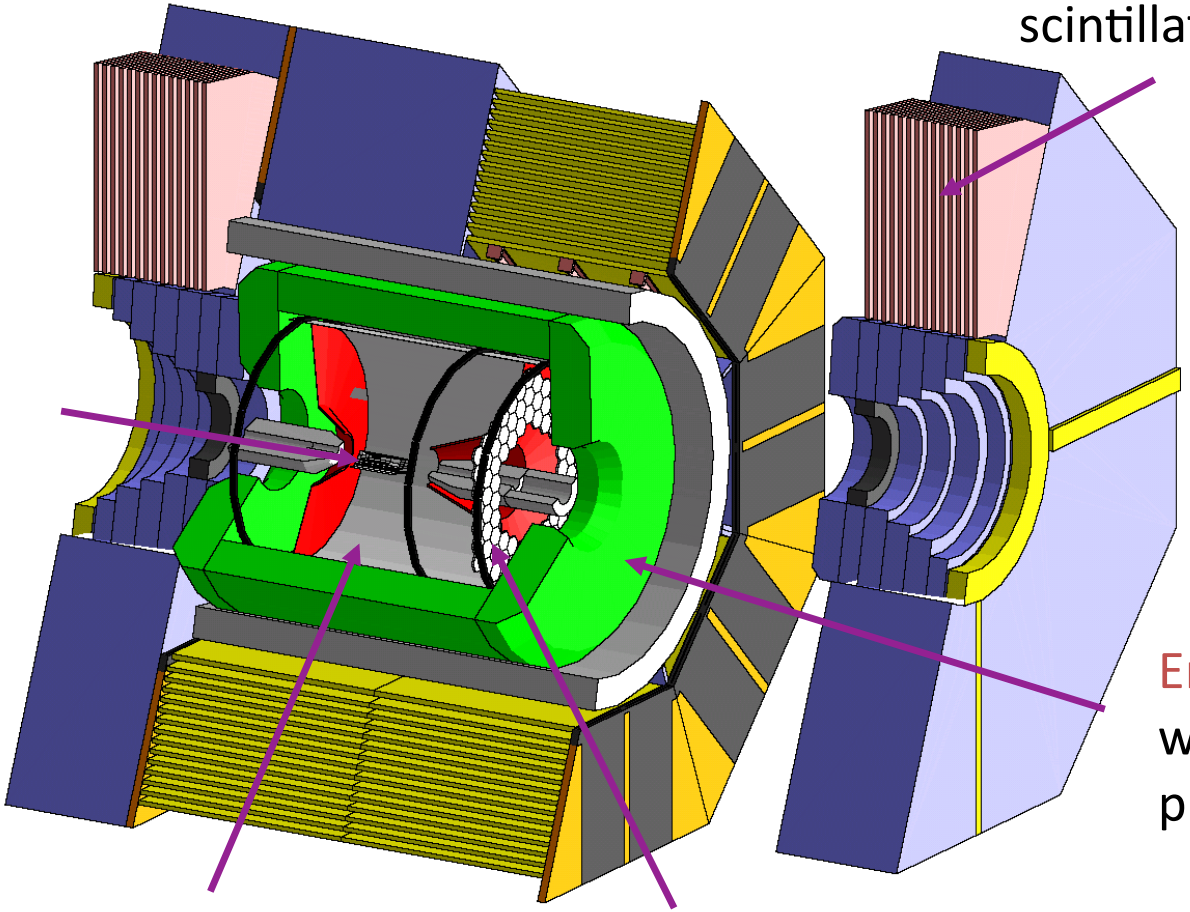
Ante-chamber being tested at KEKB

SuperKEKB luminosity prospect



Belle II detector

Muons, neutrals:
scintillator strips (endcaps)



Silicon:
2 lyrs pixel,
4 lyrs DSSD

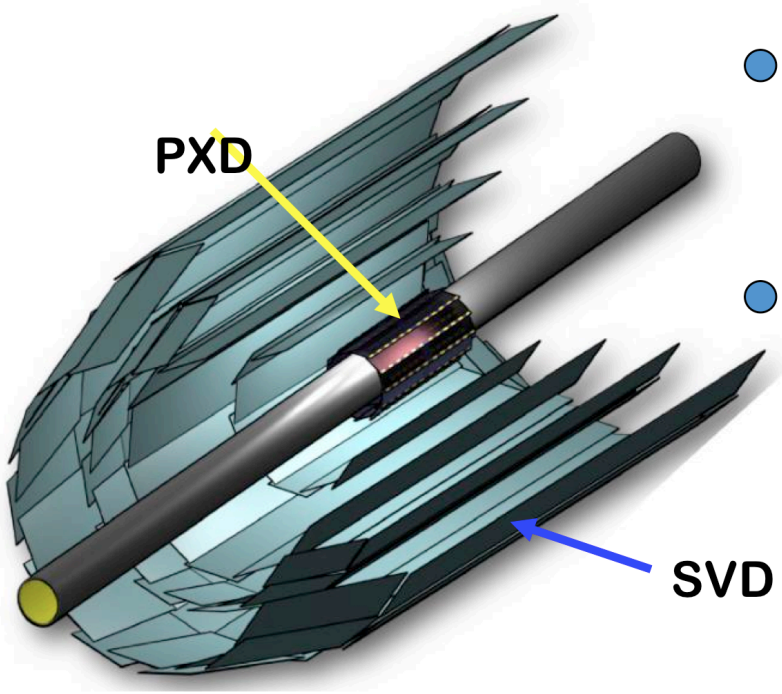
Em. calorimeter:
wave form sampling
pure CsI (endcaps)

Drift chamber:
smaller cell size

Particle ID:
ring imaging Cherenkov devices
(TOP in the barrel, ARICH in the forward)

Vertex Detector

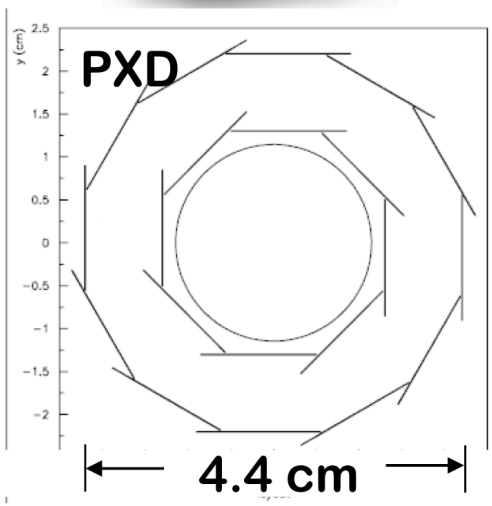
Nano beam option: 1 cm radius of beam pipe



„PXD“

- 2 layer Si pixel detector (DEPFET technology)
  (R = 1.3, 2.2 cm) monolithic sensor
  thickness 50 µm (!), pixel size ~50 x 50 µm²
- 4 layer Si strip detector (DSSD)
  (R = 3.8, 8.0, 11.5, 14.0 cm) ← „SVD“

Significant improvement in z-vertex resolution

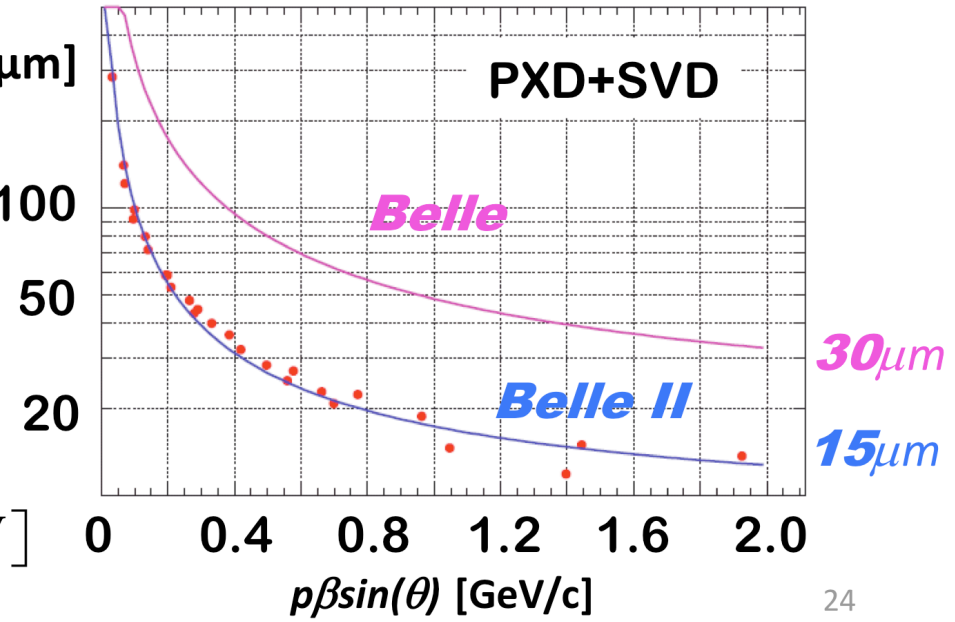


$$\sigma = a + \frac{b}{p\beta \sin^{5/2}\theta}$$

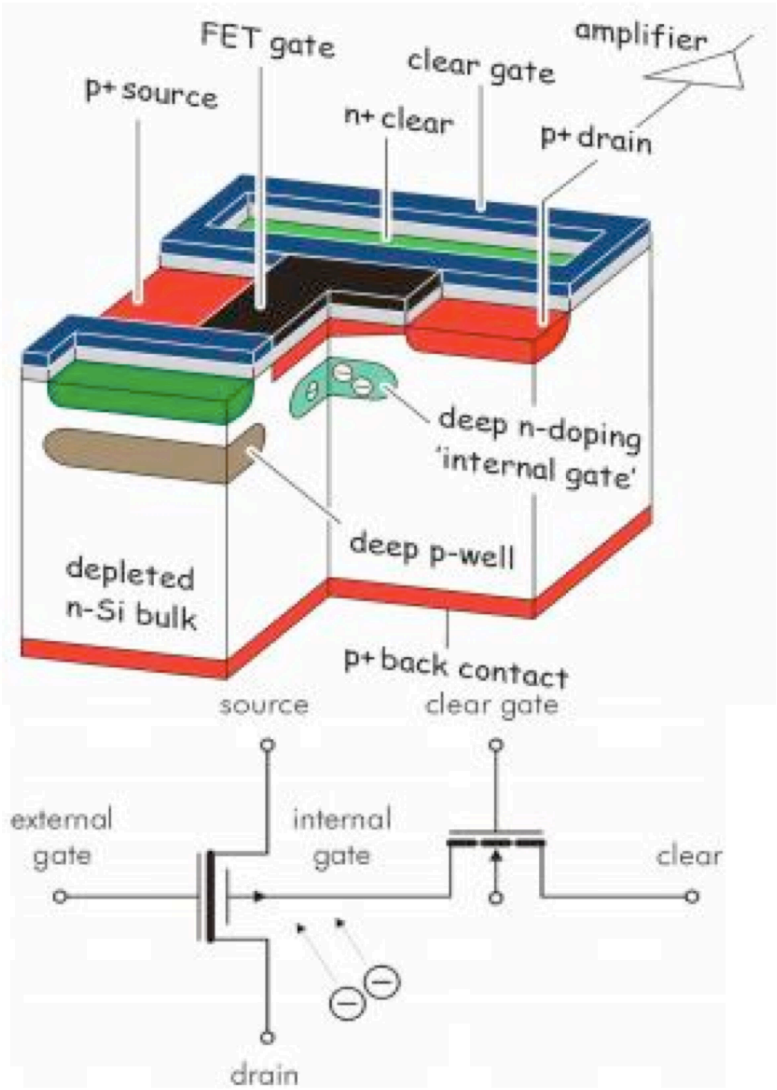
Belle II:

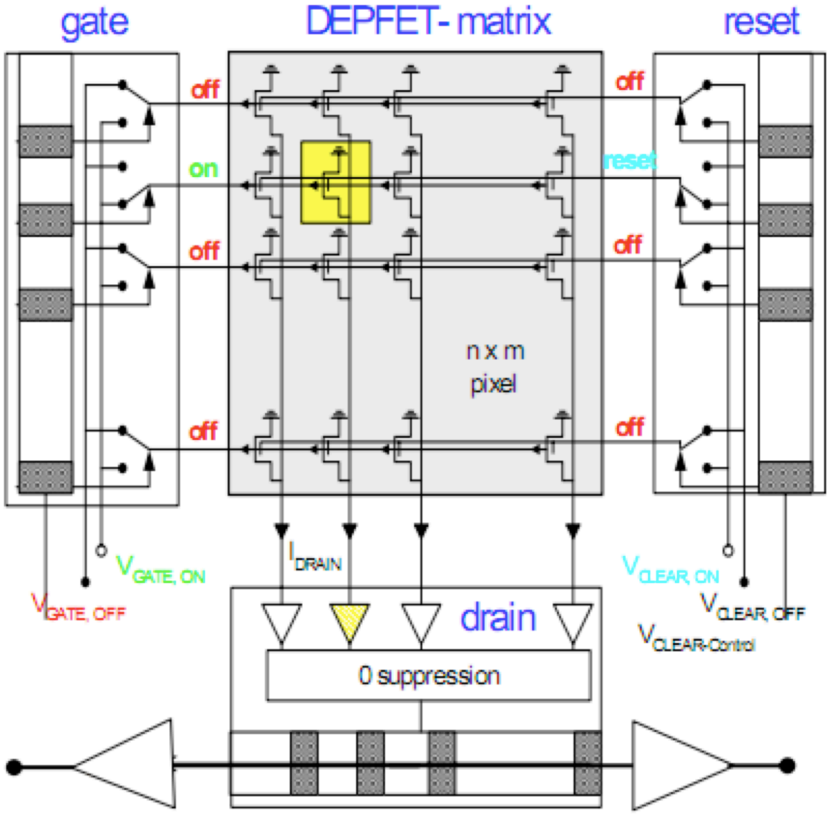
$a = 8.5\,[mm]$

$b = 9.6\,[mm\,\mathrm{GeV}]$



DEPFET





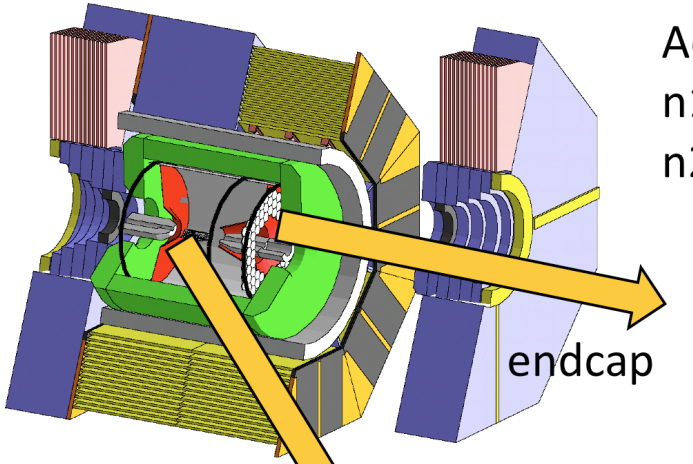
Fully depleted sensitive volume, charge collection by drift.

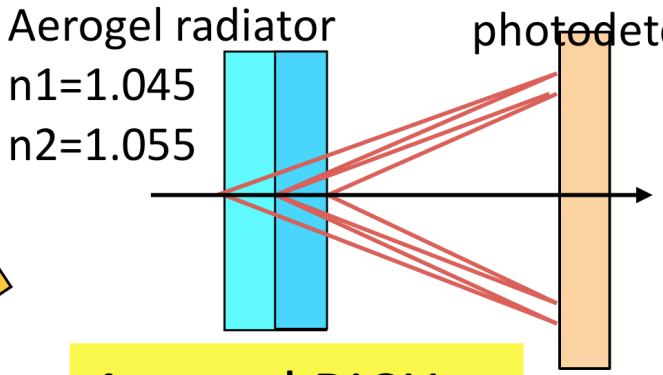
Internal amplification ->q-I conversion: 0.5 nA/e, scales with gate length and bias current(S/N will be ~100).

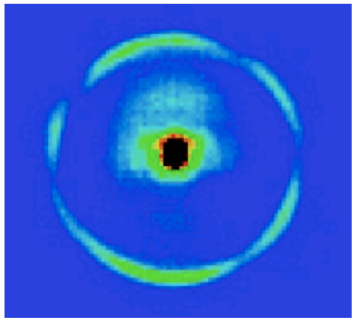
Charge collection in "off" state, read out on demand.

Particle ID

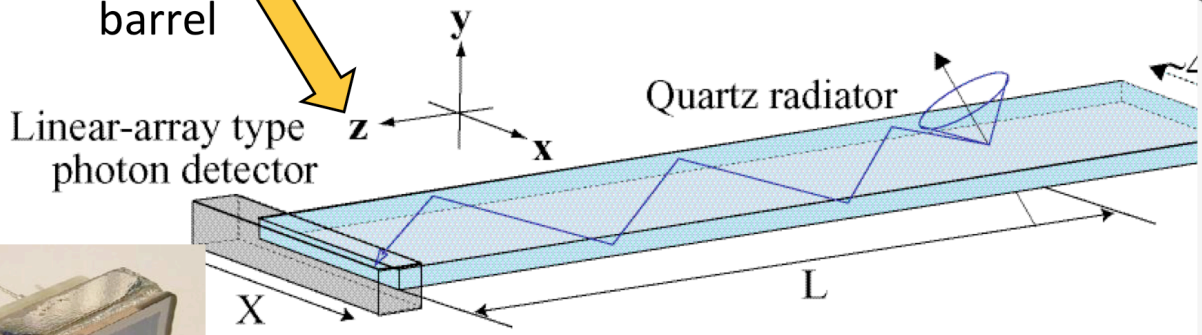
- Ring Imaging Cherenkov Detectors
- >4σ K/π separation up to 4GeV/c

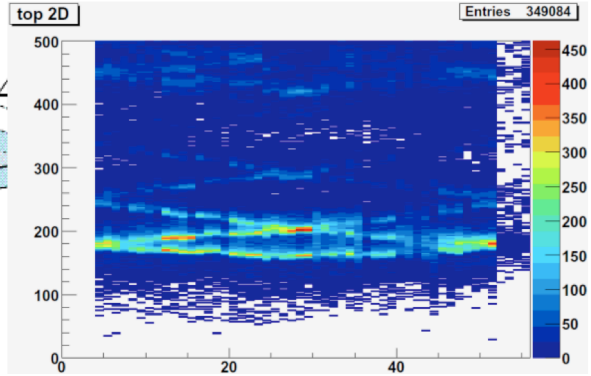


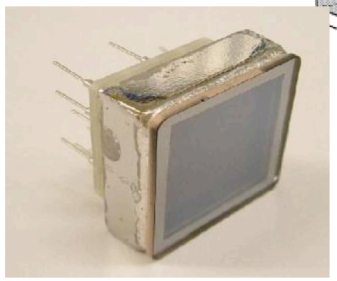




Aerogel RICH







TOP（Time-Of-Propagation）Counter

Belle-II collaboration

2004.06 SuperKEKB LoI

2008.01 KEK Roadmap

2008.03 1st Proto collaboration meeting

2008.10 Detector study report

2008.12 New collaboration, Belle-II, started

~300 collaborators from 43 institutions in 13 countries

~2010.3 4th and 5th open collaboration meetings

Baseline design fixed

- 501 pages TDR written
- Reviewed by BPAC in May

Recent funding news

KEKB upgrade plan has been approved

June 23, 2010 High Energy Accelerator Research Organization (KEK)

The MEXT, the Japanese Ministry that supervises KEK, has announced that it will appropriate a budget of 100 oku-yen (approx $110M) over the next three years starting this Japanese fiscal year (JFY2010) for the high performance upgrade program of KEKB. This is part of the measures taken under the new "Very Advanced Research Support Program" of the Japanese government.

"We are delighted to hear this news," says Masanori Yamauchi, former spokesperson for the Belle experiment and currently a deputy director of the Institute of Particle and Nuclear Studies of KEK. "This three- year upgrade plan allows the Belle experiment to study the physics from decays of heavy flavor particles with an unprecedented precision. It means that KEK in Japan is launching a renewed research program in search for new physics by using a technique which is complementary to what is employed at LHC at CERN."

Summary

- SuperKEKB/Belle-II is a top priority near-term project of Japanese HEP
- Baseline design frozen
- Details are yet to be worked out, in particular, machine detector interface issues
- Construction Cost : $340M
  - Appropriated
    - FY2009 stimulus money $35M
    - FY2010 line item : $5M for a positron accumulator ring
    - FY2010 stimulus money $100M
  - Requested
    - FY2011 ~$200M
- Operation cost ~$70M/year