Status of Belle II and SuperKEKB

D. Epifanov, The University of Tokyo

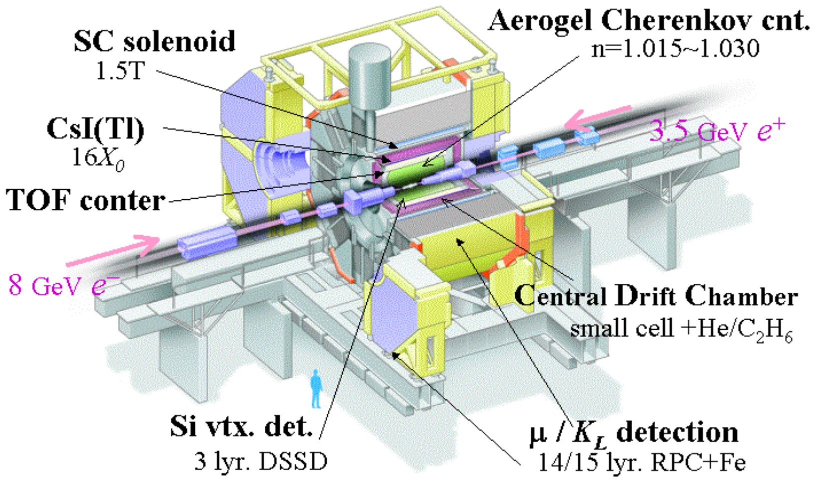
on behalf of Belle II collaboration

Outline:

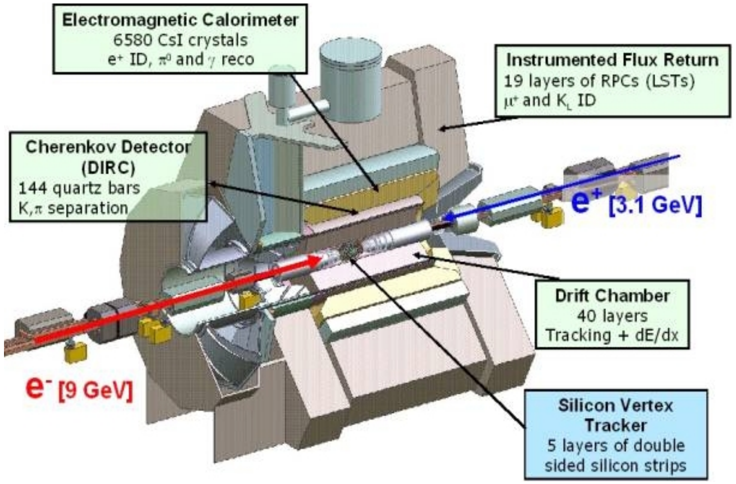
- Achievements at e^+e^- B factories
- Physics at the Super B Factory
- SuperKEKB collider
- Belle II detector
- Summary and Plans

Achievements at e^+e^- B factories

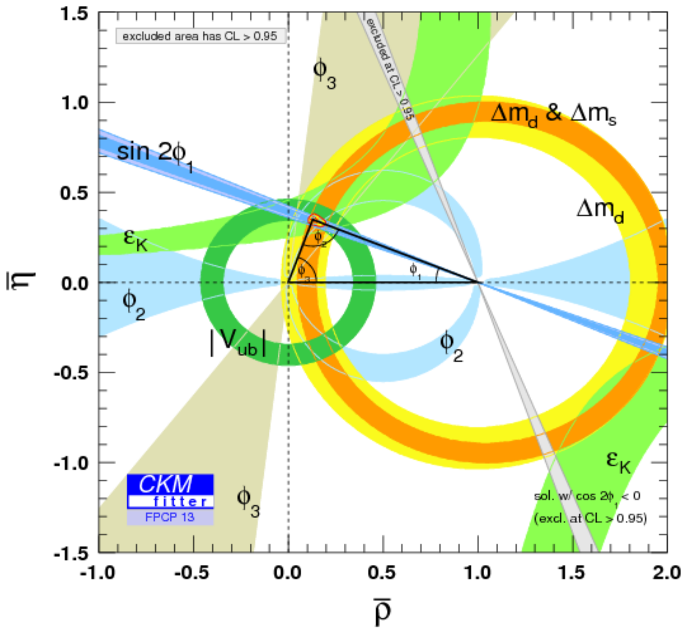
Belle at KEKB



BABAR at PEP-II



Both experiments were operated mostly at Υ(4S) resonance ($\sqrt{s} = 10.58\,GeV$) and collected the world largest statistics with $\int L dt \approx 1.5\,ab^{-1}$



- Discovery of CPV in B meson decays
- Confirmation of the Kobayashi-Maskawa mechanism for CPV in the Standard Model
- Precise measurement of CKM matrix elements

2008

Lots of important results from B factories:

- Observation of direct CPV in B decays
- $b \to s$ transitions: probe for new sources of CPV and constraints from the $b \to s \gamma$ branching fraction
- Forward-backward asymmetry in $b \to s\, l^+ l^-$ has become a powerful tool to search for physics beyond SM
- Search for the charged Higgs in the rare decays $B \to \tau \nu$, $D^{(*)} \tau \nu$
- Study of B_s decays
- Observation of new bottomonium-like states
- Observation of D^0-$\overline{D}^0$ mixing
- Search for CPV in D and D_s decays
- Observation of exotic charmonium states
- Search for lepton flavor violation (LFV) in τ decays
- Search for CPV and study of hadronic τ decays
- Precise measurement of the cross sections and dynamics of $\gamma\gamma$ -> hadrons and $e^+ e^- \to$ hadrons γ_{ISR} processes
- Search for CPTV in B and τ decays
- Search for heavy neutrinos in B decays

Talks from Belle & BaBar:

C. Park: Rare B meson decays from **Belle**

Z. Drasal: Time-dependent CPV in B mesons from **Belle**

R. Glattauer: Semileptonic B decays , Vub and Vcb from **Belle**

M. Nayak: CKM angle ϕ_3 from **Belle**

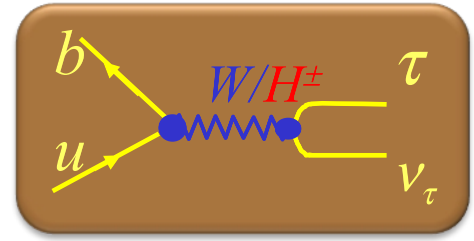
G. Mohanty: Charm mixing and CPV from **Belle**

V. Bhardwaj: Quarkonium(-like) exotic particles from **Belle**

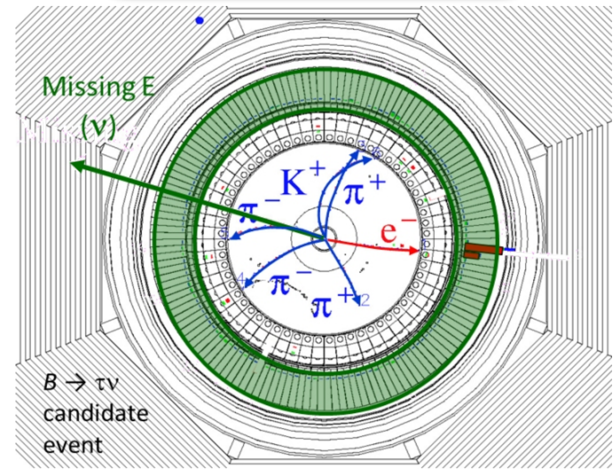
F. Bernlochner: B -> $D^{(*)}\tau\nu$ from **BaBar**

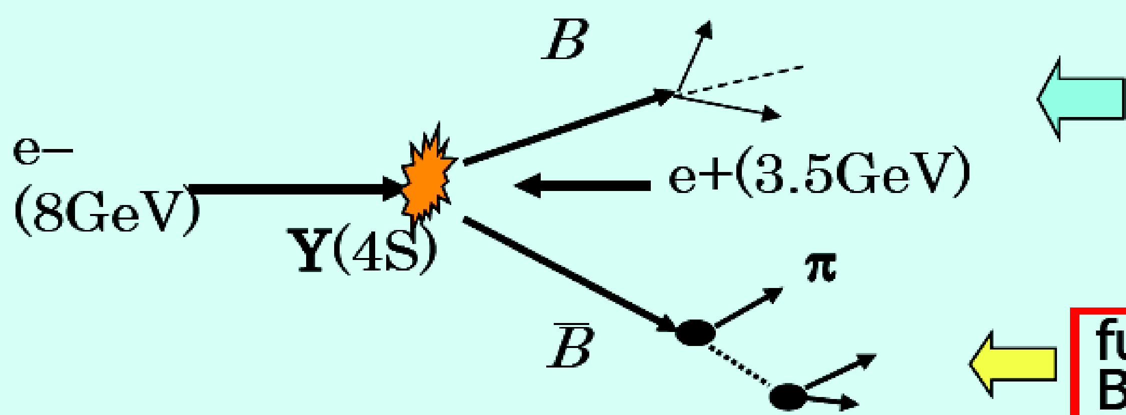
K.Flood: Low-mass Higgs, dark-sector bosons from **BaBar**

Advantages of e^+e^- B factories



- Two B mesons of different flavors are produced with precisely known momenta and energies, high flavor tagging efficiency.
- Reconstruction of $\pi^0 \to \gamma\gamma$, $K_S \to \pi\pi$, $\Lambda \to p\pi^-$. Detection of K_L. Particle identification capabilities for $e^\pm$, $\pi^\pm$, $\mu^\pm$, $K^\pm$, $p^\pm$ with high ID and low misID efficiencies.
- Clean detector environment, low level of background. Distinct signature and high trigger efficiency for signal events. No multiple interactions per event.
- Well studied detector. Developed calibration techniques, lots of methods to evaluate/calibrate systematic effects using experimental control samples.





Decays of interest
$B \to X_u\, l\, \nu$,
$B \to K\, \nu\, \nu$
$B \to D\tau\nu$, $\tau\nu$
$B \to \nu\nu$

full reconstruction
$B \to D\pi$ etc. (0.1~0.3%)

Offline B meson beam - poweful tool to study decays with neutrinos

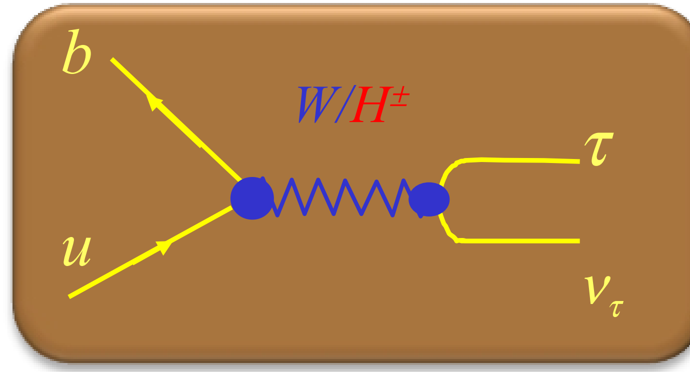
Search for New Physics at the Super B factory

- Precision CKM unitarity tests (better accuracy $\rightarrow$ overconstrain of unitarity triangle $\rightarrow$ search for deviations from SM)
- Effects of New Physics in B decays with missing energy:
  $B \rightarrow \tau\nu$, $B \rightarrow D^{(*)}\tau\nu$, $B \rightarrow h\,\nu\,\nu$, ...
- Flavor changing neutral currents (virtual contribution of new heavy particles in loops)
- Search for lepton flavor violation in B and τ decays
- Search for CPV in D and τ decays
- Charm studies (exotic states)
- Study of bottomonium and search for the dark matter in its transitions
- Study of the Lorentz structure of charged weak current in τ decays

Lots of measurements were statistically limited at B factories, $\times$100 increase in statistics is needed for the tests of the SM on the new level of precision.

B decays with τ lepton

- Recent study of $B \to \tau \nu$ using full reconstruction method at Belle: *PRL 110 131801 (2013)*

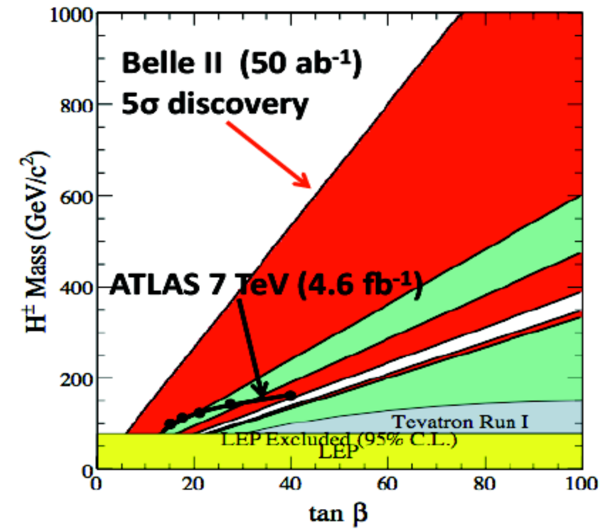


- Result is consistent with SM:

$$Br(B^- \to \tau^- \bar{\nu}_\tau) = (0.72 \pm^{0.27}_{0.25}(stat) \pm 0.11(syst)) \times 10^{-4}$$

- Sensitive to the charged Higgs (type II 2HDM) model:

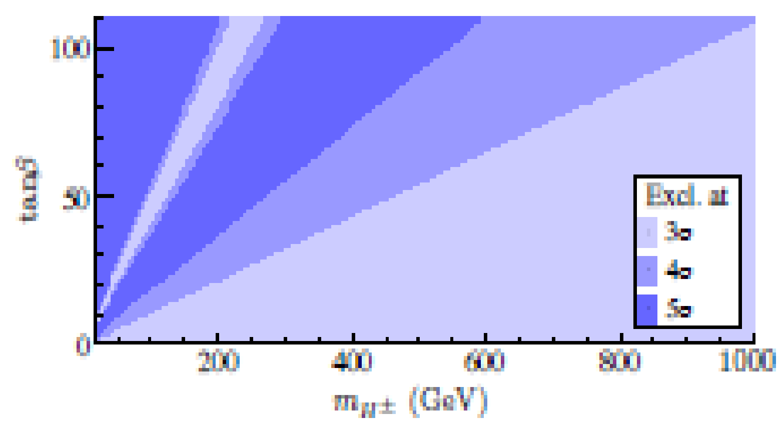
$$r_H = \frac{Br(B^- \to \tau^- \bar{\nu}_\tau)}{Br(B^- \to \tau^- \bar{\nu}_\tau)_{SM}} = \left(1 - \frac{M_B^2}{M_H^2} \tan^2\beta\right)^2$$



With B->D(*)τν BaBar excluded type II 2HDM in the full parameter space on the level of 3σ

3.4σ tension between measured R(D(*)) and SM expectation

PRD 88, 031102(R) (2013)



CPV in charm and τ

- In charm sector of SM CPV is expected to be ≤ 0.1%.
  Observation of large CPV in charm will be clear sign of New Physics.

- Example: Search for direct CPV in $D^+ \to K_S \pi^+$ at Belle. *PRL 109 021601 (2012)*

$$A_{CP} = \frac{\Gamma(D^+ \to K_S \pi^+) - \Gamma(D^- \to K_S \pi^-)}{\Gamma(D^+ \to K_S \pi^+) + \Gamma(D^- \to K_S \pi^-)} = A_{CP}^{\Delta C} + A_{CP}^{\bar{K}^0}, \quad A_{CP}^{\bar{K}^0} = (-0.345 \pm 0.008)\% \to \text{CPV in } K^0 - \bar{K}^0 \text{ mixing}$$

$$A_{CP}^{\Delta C} = (-0.018 \pm 0.094 \pm 0.068)\%$$ **agrees with SM**

CPV in charm and τ at Belle II at 10^{-4} level

- CPV is strongly suppressed in τ decays in the SM ($A_{SM}^{CP} \le 10^{-12}$)
  Observation of large CPV in τ decays is clean sign of New Physics

- Example: Search for CPV in τ decays with K_S in the final state

BABAR:
PRD 85 031102 (2012)

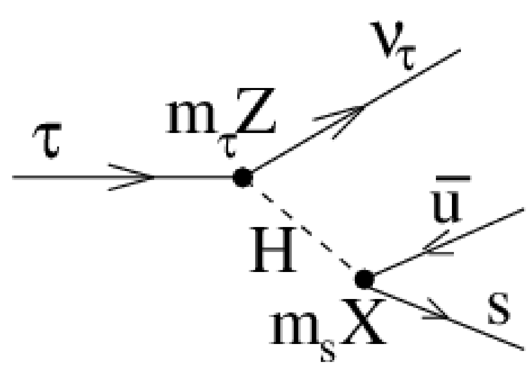
$$A_{CP} = \frac{\Gamma(\tau^+ \to K_S \pi^+ (\ge 0 \pi^0) \bar{\nu}_\tau) - \Gamma(\tau^- \to K_S \pi^- (\ge 0 \pi^0) \nu_\tau)}{\Gamma(\tau^+ \to K_S \pi^+ (\ge 0 \pi^0) \bar{\nu}_\tau) + \Gamma(\tau^- \to K_S \pi^- (\ge 0 \pi^0) \nu_\tau)} = (-0.36 \pm 0.23 \pm 0.11)\%,$$

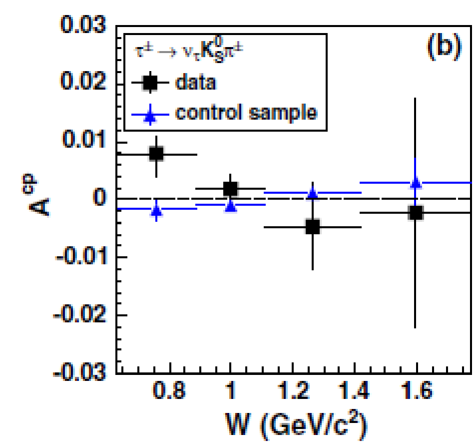
2.8σ deviation from SM expectation: $A_{CP}^{K^0} = (+0.36 \pm 0.01)\%$

Belle: PRL 107 131801 (2011)

Angular distributions were analyzed, $A_{CP}(W = M_{K_S\pi})$ was measured. MHDM has been constrained:

$$|\Im(XZ^*)| < 0.15 \frac{M_H^2}{1\ GeV^2/c^4}$$

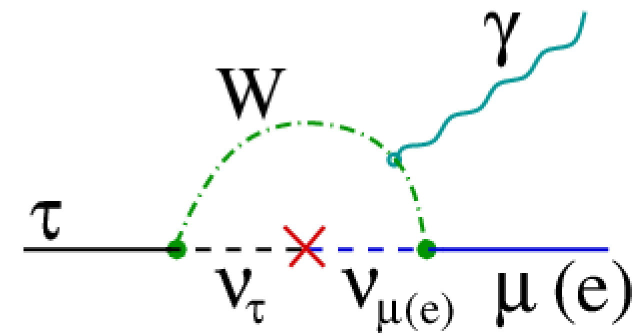




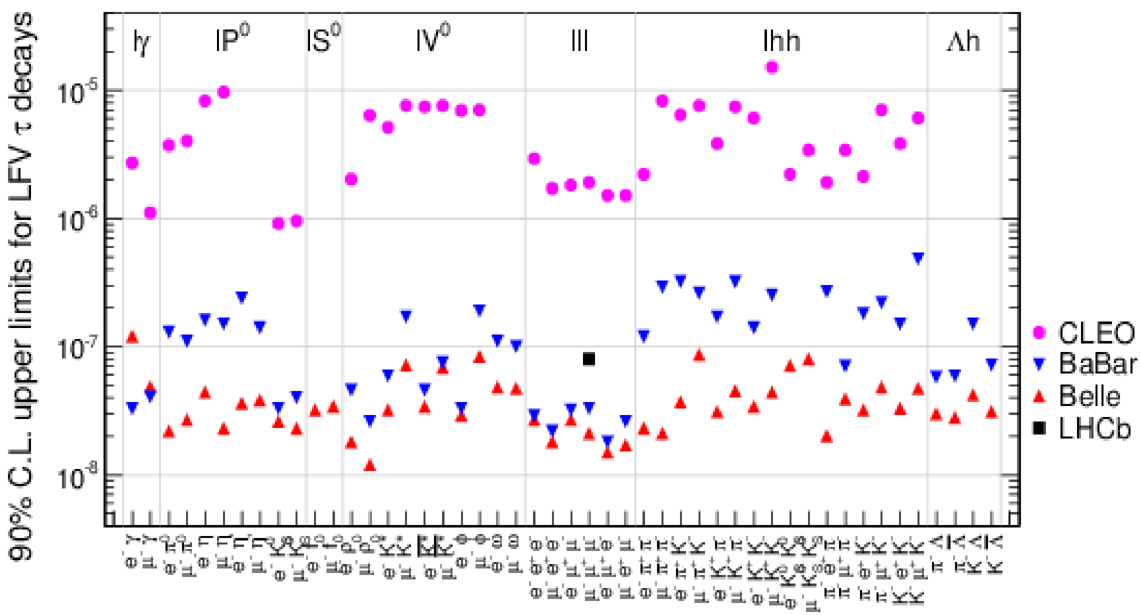
LFV in τ decays

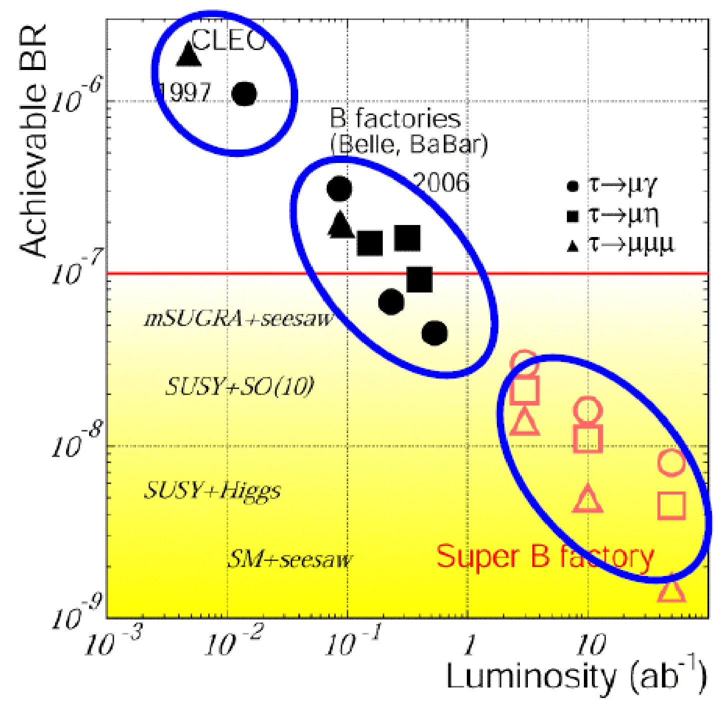
- In the SM: $BF(\tau^- \to l^- \gamma) \sim \left(\frac{\Delta m_\nu^2}{M_W^2}\right)^2 < 10^{-54}$
- Models beyond SM predict LFV with BF up to $\sim 10^{-7}$
- Advantage of **τ**: enhanced couplings to new particles, lots of decays → tests of different NP models

48 modes were analyzed at Belle and BABAR



model	Br(τ→μγ)	Br(τ→lll)
mSUGRA+seesaw	10^{-7}	10^{-9}
SUSY+SO(10)	10^{-8}	10^{-10}
SM+seesaw	10^{-9}	10^{-10}
Non-Universal Z′	10^{-9}	10^{-8}
SUSY+Higgs	10^{-10}	10^{-7}





Expected sensitivity: τ→lγ: BF~$10^{-8\div9}$ τ→lll: BF~$10^{-9\div10}$

Rich physics program at Belle II

Observable	SM prediction	Theory error	Present result	Future error	Future Facility
$\lvert V_{us}\rvert$ $[K \to \pi \ell \nu]$	input	$0.5\% \to 0.1\%_{\rm Latt}$	0.2246 ± 0.0012	0.1%	K factory
$\lvert V_{cb}\rvert$ $[B \to X_c \ell \nu]$	input	1%	$(41.54 \pm 0.73) \times 10^{-3}$	1%	Super-B
$\lvert V_{ub}\rvert$ $[B \to \pi \ell \nu]$	input	$10\% \to 5\%_{\rm Latt}$	$(3.38 \pm 0.36) \times 10^{-3}$	4%	Super-B
γ $[B \to DK]$	input	$< 1^\circ$	$(70^{+27}_{-30})^\circ$	3°	LHCb
$S_{B_d \to \psi K}$	$\sin(2\beta)$	$\lesssim 0.01$	0.671 ± 0.023	0.01	LHCb
$S_{B_s \to \psi \phi}$	0.036	$\lesssim 0.01$	$0.81^{+0.12}_{-0.32}$	0.01	LHCb
$S_{B_d \to \phi K}$	$\sin(2\beta)$	$\lesssim 0.05$	0.44 ± 0.18	0.1	LHCb
$S_{B_s \to \phi \phi}$	0.036	$\lesssim 0.05$	—	0.05	LHCb
$S_{B_d \to K^* \gamma}$	few $\times$ 0.01	0.01	-0.16 ± 0.22	0.03	Super-B
$S_{B_s \to \phi \gamma}$	few $\times$ 0.01	0.01	—	0.05	LHCb
$A^d_{\rm SL}$	-5×10^{-4}	10^{-4}	$-(5.8 \pm 3.4) \times 10^{-3}$	10^{-3}	LHCb
$A^s_{\rm SL}$	2×10^{-5}	$< 10^{-5}$	$(1.6 \pm 8.5) \times 10^{-3}$	10^{-3}	LHCb
$A_{CP}(b \to s\gamma)$	< 0.01	< 0.01	-0.012 ± 0.028	0.005	Super-B
$\mathcal{B}(B \to \tau \nu)$	1×10^{-4}	$20\% \to 5\%_{\rm Latt}$	$(1.73 \pm 0.35) \times 10^{-4}$	5%	Super-B
$\mathcal{B}(B \to \mu \nu)$	4×10^{-7}	$20\% \to 5\%_{\rm Latt}$	$< 1.3 \times 10^{-6}$	6%	Super-B
$\mathcal{B}(B_s \to \mu^+ \mu^-)$	3×10^{-9}	$20\% \to 5\%_{\rm Latt}$	$< 5 \times 10^{-8}$	10%	LHCb
$\mathcal{B}(B_d \to \mu^+ \mu^-)$	1×10^{-10}	$20\% \to 5\%_{\rm Latt}$	$< 1.5 \times 10^{-8}$	[?]	LHCb
$A_{\rm FB}(B \to K^* \mu^+ \mu^-)_{q_0^2}$	0	0.05	(0.2 ± 0.2)	0.05	LHCb
$B \to K \nu \bar{\nu}$	4×10^{-6}	$20\% \to 10\%_{\rm Latt}$	$< 1.4 \times 10^{-5}$	20%	Super-B
$\lvert q/p\rvert_{D-\rm mixing}$	1	$< 10^{-3}$	$(0.86^{+0.18}_{-0.15})$	0.03	Super-B
ϕ_D	0	$< 10^{-3}$	$(9.6^{+8.3}_{-9.5})^\circ$	2°	Super-B
$\mathcal{B}(K^+ \to \pi^+ \nu \bar{\nu})$	8.5×10^{-11}	8%	$(1.73^{+1.15}_{-1.05}) \times 10^{-10}$	10%	K factory
$\mathcal{B}(K_L \to \pi^0 \nu \bar{\nu})$	2.6×10^{-11}	10%	$< 2.6 \times 10^{-8}$	[?]	K factory
$R^{(e/\mu)}(K \to \pi \ell \nu)$	2.477×10^{-5}	0.04%	$(2.498 \pm 0.014) \times 10^{-5}$	0.1%	K factory
$\mathcal{B}(t \to cZ, \gamma)$	$\mathcal{O}(10^{-13})$	$\mathcal{O}(10^{-13})$	$< 0.6 \times 10^{-2}$	$\mathcal{O}(10^{-5})$	LHC ($100\,{\rm fb}^{-1}$)

G. Isidori et al, Ann. Rev. Nucl. Part. Sci. 60, 355 (2010)

Super B factory

LHCb

K factory

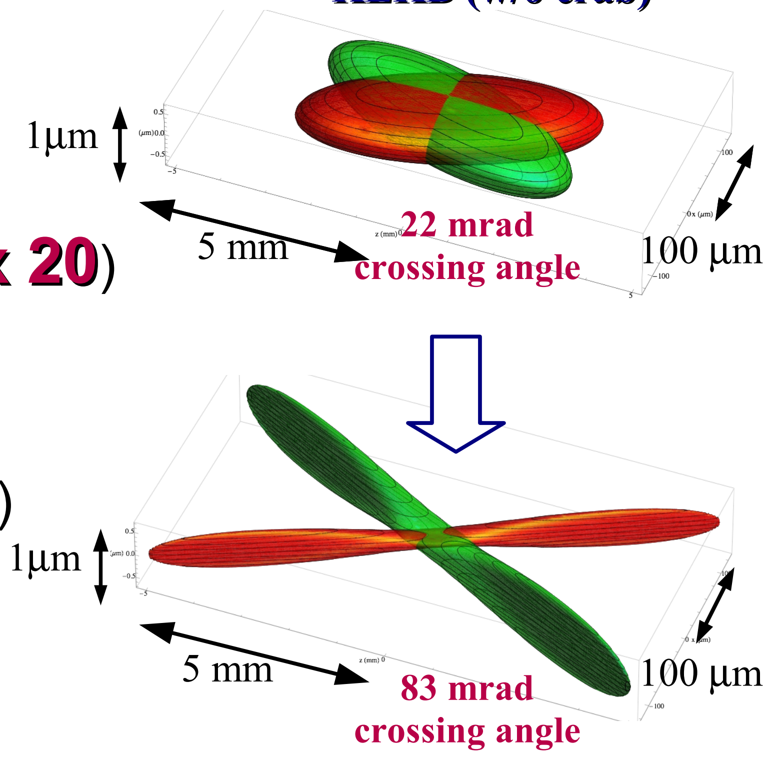
Complementarity to the other intensity frontier experiments (LHCb, BES-III, Super C-Tau ...)

- arXiv: 1002.5012
- arXiv: 1008.1541

Design concept of SuperKEKB

- **Nano-beam scheme proposed by P. Raimondi provides x 40 luminosity**
- Vertical β function (β^*_y) at IP: **5.9 → 0.27/0.30 mm** (**x 20**)
- Beam current: **1.7/1.4 → 3.6/2.6 A** (**x 2**)
- Beam-beam parameter: **0.13/0.09 → 0.09/0.08** (**x 1**)
- Beam size (σ_x/σ_y): 100/2 μm → 10 μm/**60 nm**
- Beam energy (LER/HER): **3.5/8.0 → 4.0/7.0 GeV**

KEKB (w/o crab)



SuperKEKB

$$L = \frac{\gamma_{e^\pm}}{2er_e}\left(1+\frac{\sigma^*_y}{\sigma^*_x}\right)\left(\frac{I_{e^\pm}\xi^{e^\pm}_y}{\beta^*_y}\right)\left(\frac{R_L}{R_{\xi_y}}\right)$$

Lorentz factor

Classical electron radius

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

Beam current

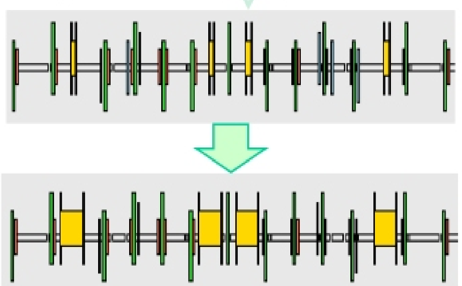
Beam-beam parameter

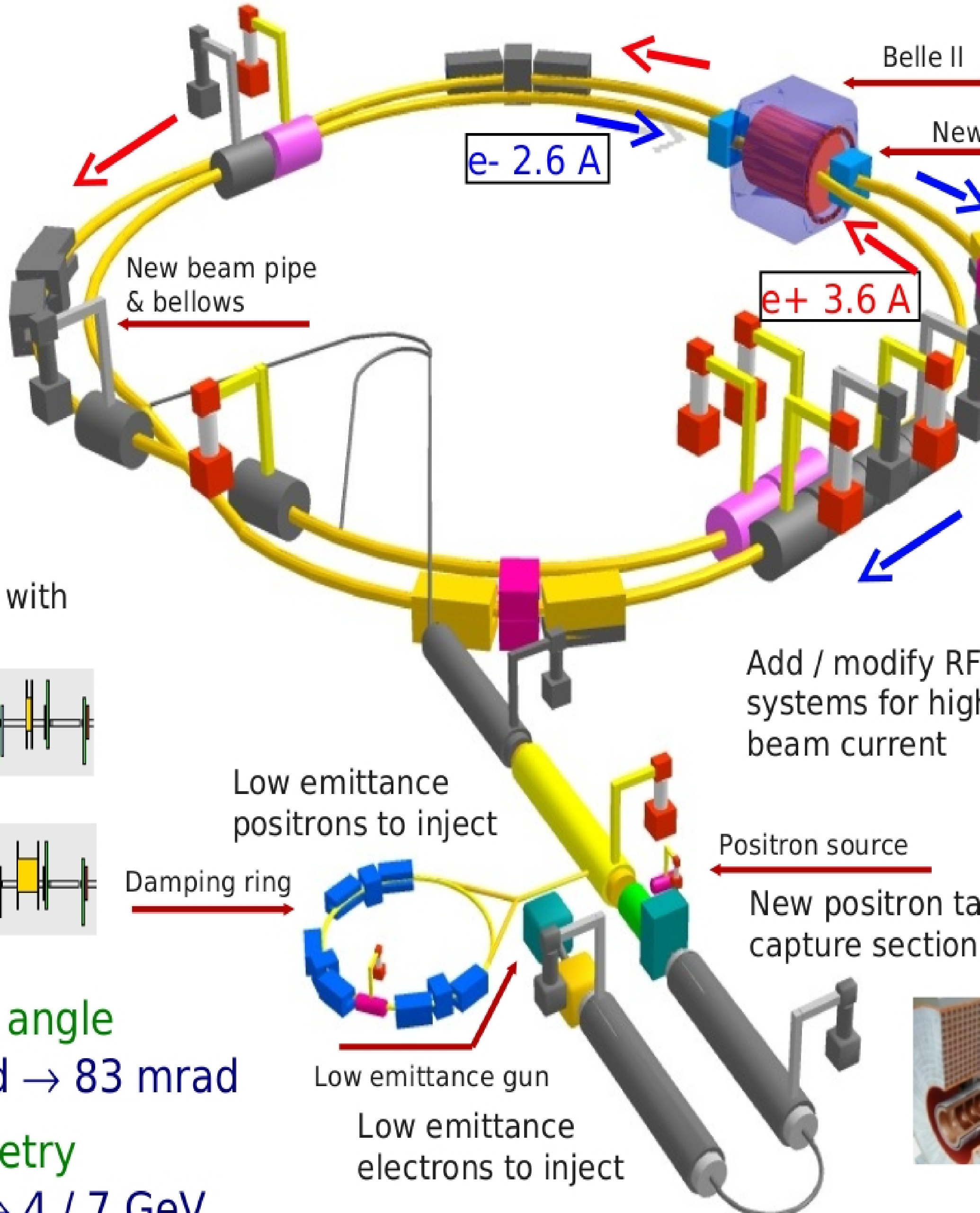
Vertical beta function at IP

Geometrical reduction factors (crossing angle, hourglass effect)

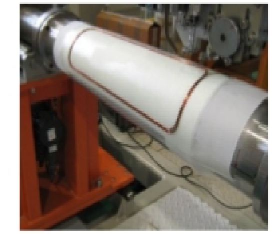
SuperKEKB

Replace short dipoles with longer ones (LER)

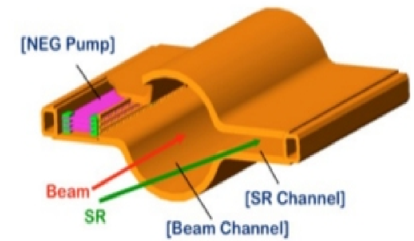




New superconducting /permanent final focusing quads near the IP



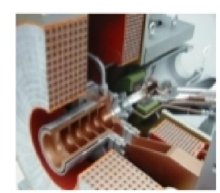
TiN-coated beam pipe with antechambers



Add / modify RF systems for higher beam current

Redesign the lattices of HER & LER to squeeze the emittance

New positron target / capture section



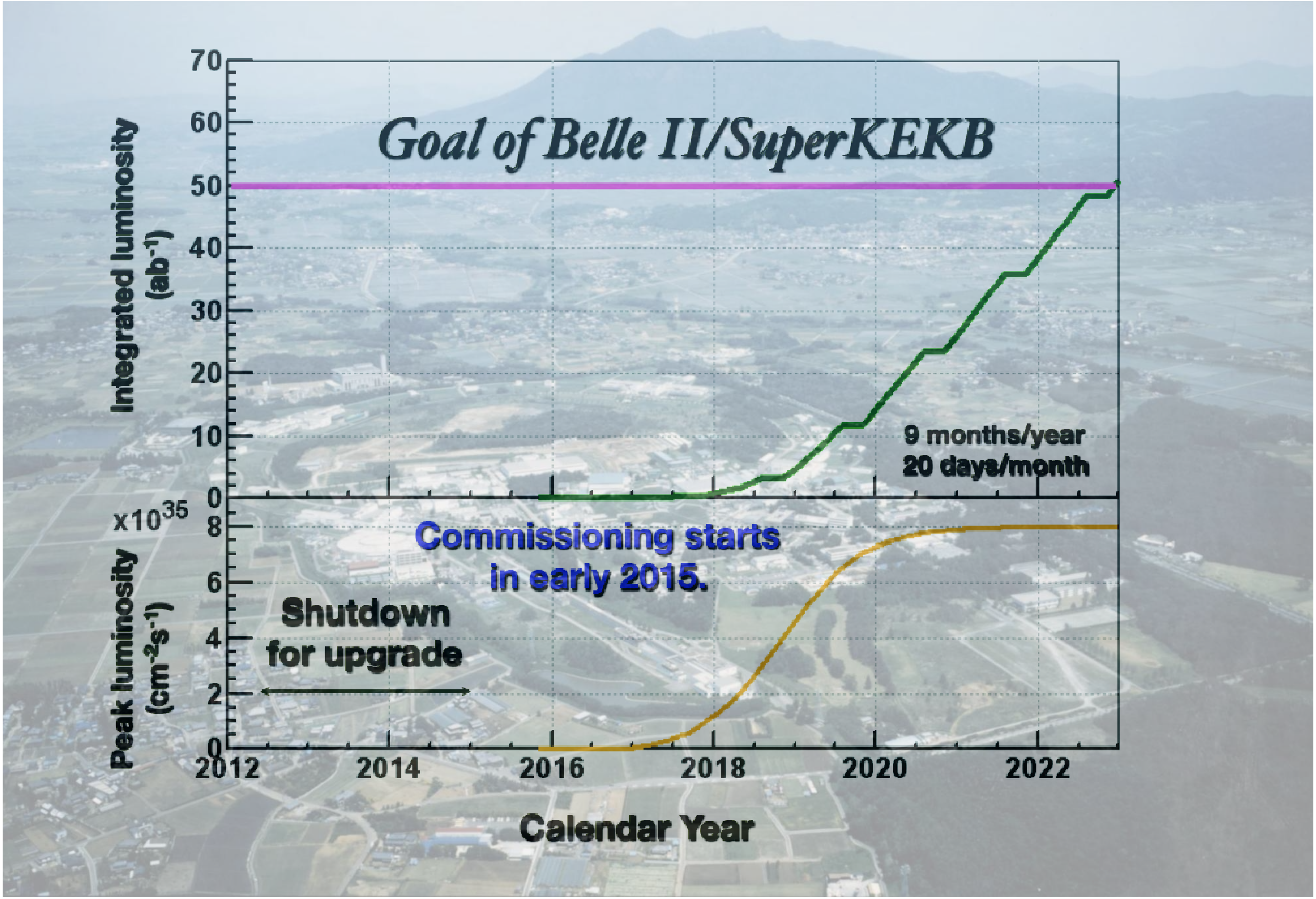
Larger crossing angle

2ϕ = 22 mrad $\rightarrow$ 83 mrad

Smaller asymmetry

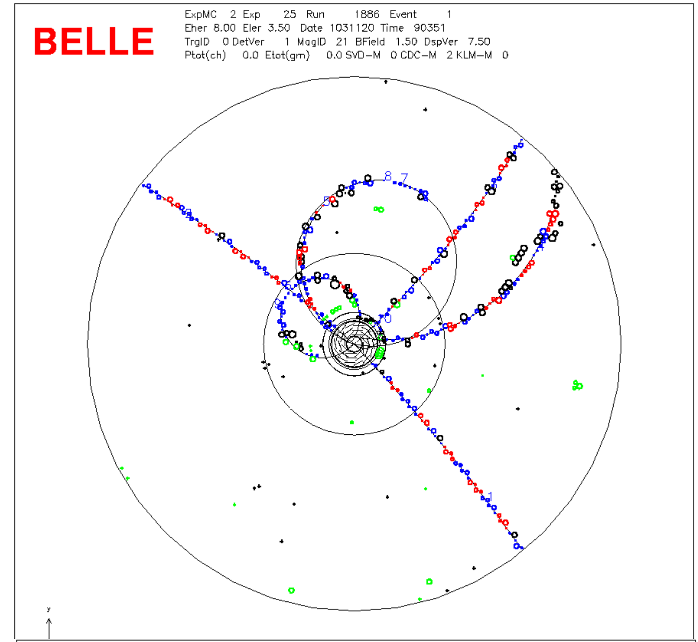
3.5 / 8 GeV $\rightarrow$ 4 / 7 GeV

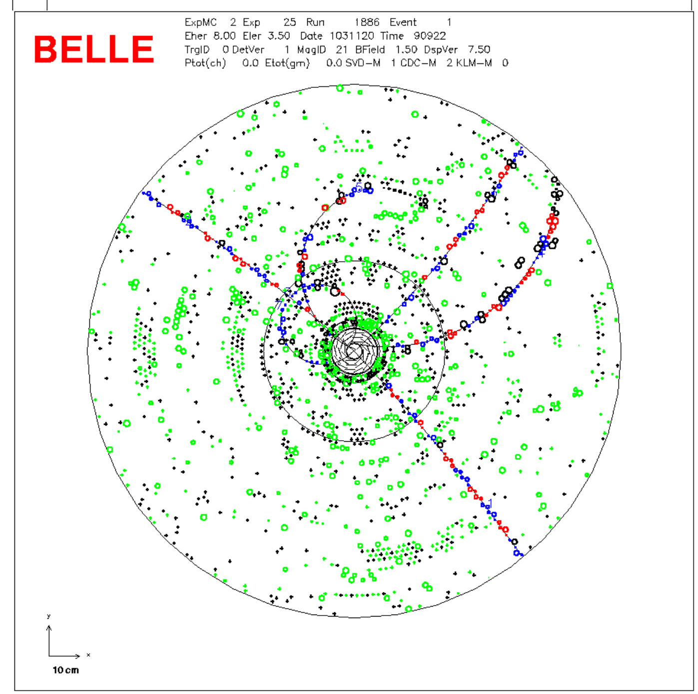
SuperKEKB luminosity projection



Experimental challenges at $L=8\text{x}10^{35}$ $1/cm^2/s$

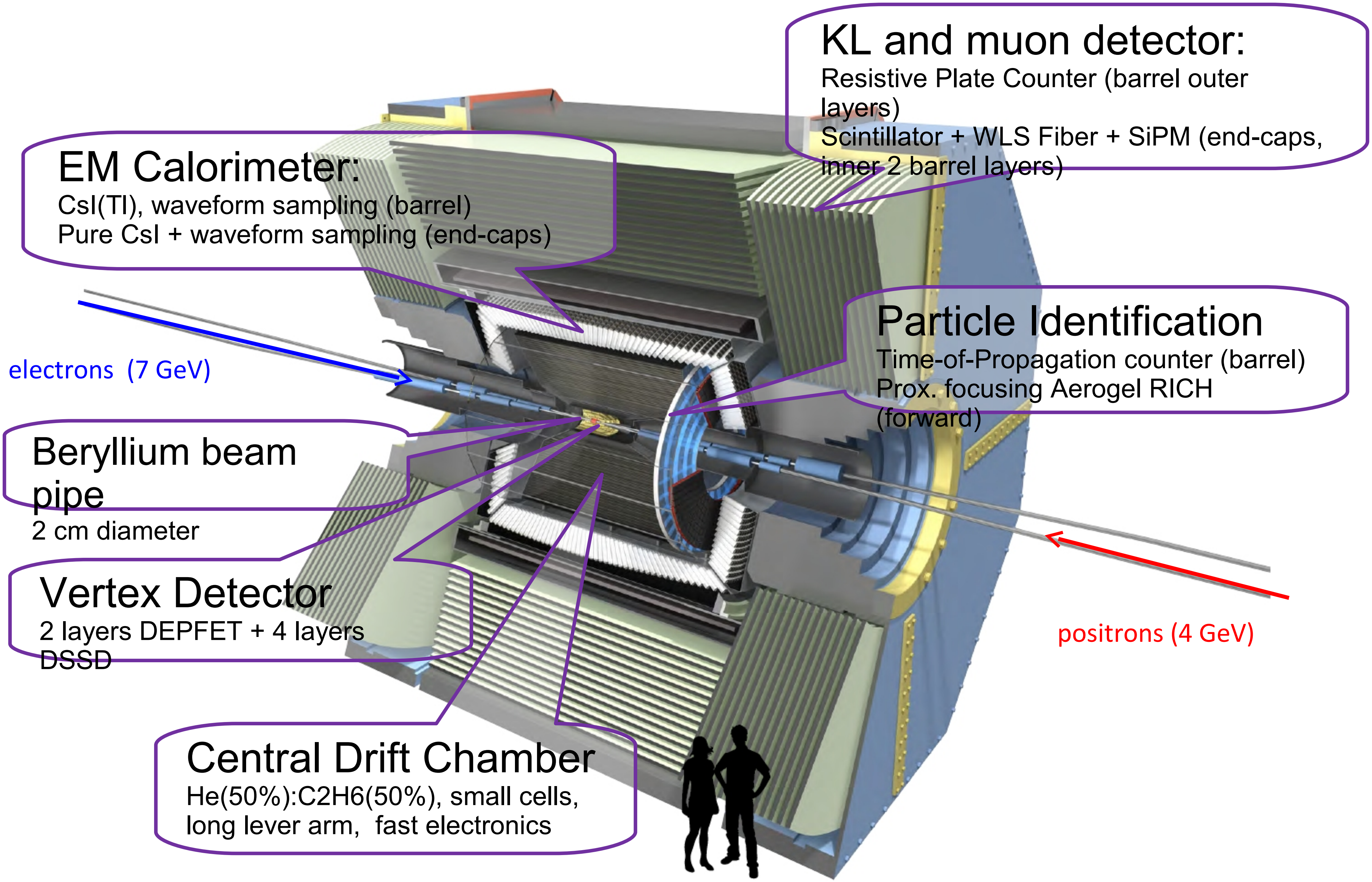
- **Higher background (x10÷20)**
  - ✓ **Radiative Bhabha events dominate**
  - ✓ **Fake hits and pileup noise in EM calorimeter**
  - ✓ **Radiation damage and higher occupancy**
- **Higher trigger rates (x40)**
  - ✓ **Level1 trigger (0.5→20 KHz)**
  - ✓ **High performance DAQ, computing**
- **Important improvements**
  - ✓ **Hermeticity of the detector**
  - ✓ **IP and secondary vertex resolution**
  - ✓ **K_s and π^0 reconstruction efficiency**
  - ✓ **$K^{\pm}/\pi^{\pm}$ separation**
  - ✓ **PID in the end-cap parts**



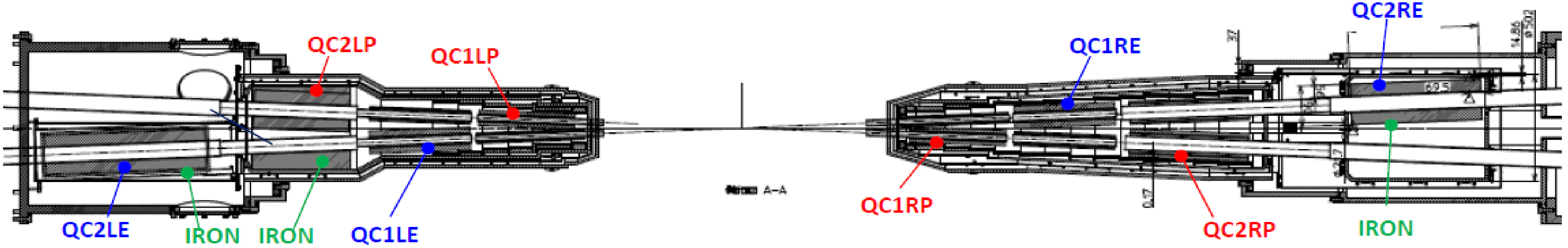


Belle II TDR arXiv: 1011.0352

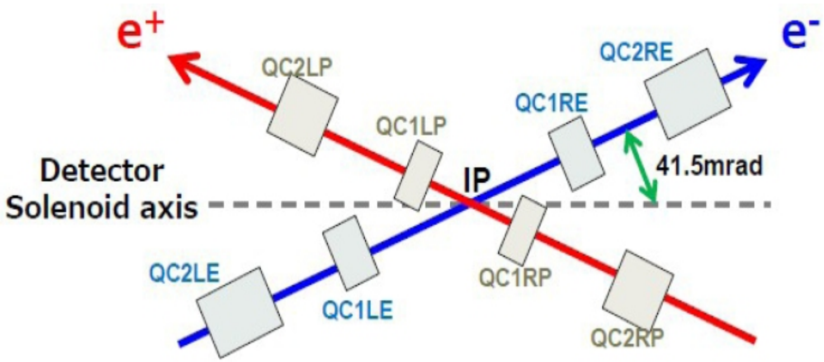
Belle-II detector



Interaction region



	Integral field gradient, (T/m)·m Solenoid field, T	Position from IP, mm	Magnet type
QC2RE	12.91 [34.9 T/m × 0.370m]	2925	S.C. + Iron Yoke
QC2RP	10.92 [27.17 × 0.4135]	1925	S.C. + Iron Yoke
QC1RE	24.99 [66.22×0.3774]	1410	S.C. + Iron Yoke
QC1RP	22.43 [66.52×0.3372]	935	S.C.
QC1LP	22.91 [67.94×0.3372]	-935	S.C.
QC1LE	26.67 [70.68×0.3774]	-1410	S.C. + Iron Yoke
QC2LP	10.96 [27.15 × 0.4135]	-1925	S.C. + Iron Yoke
QC2LE	14.13 [20.2×0.700]	-2700	S.C. + Iron Yoke

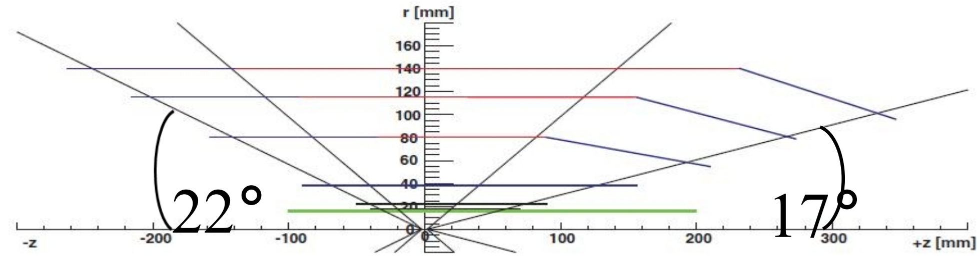


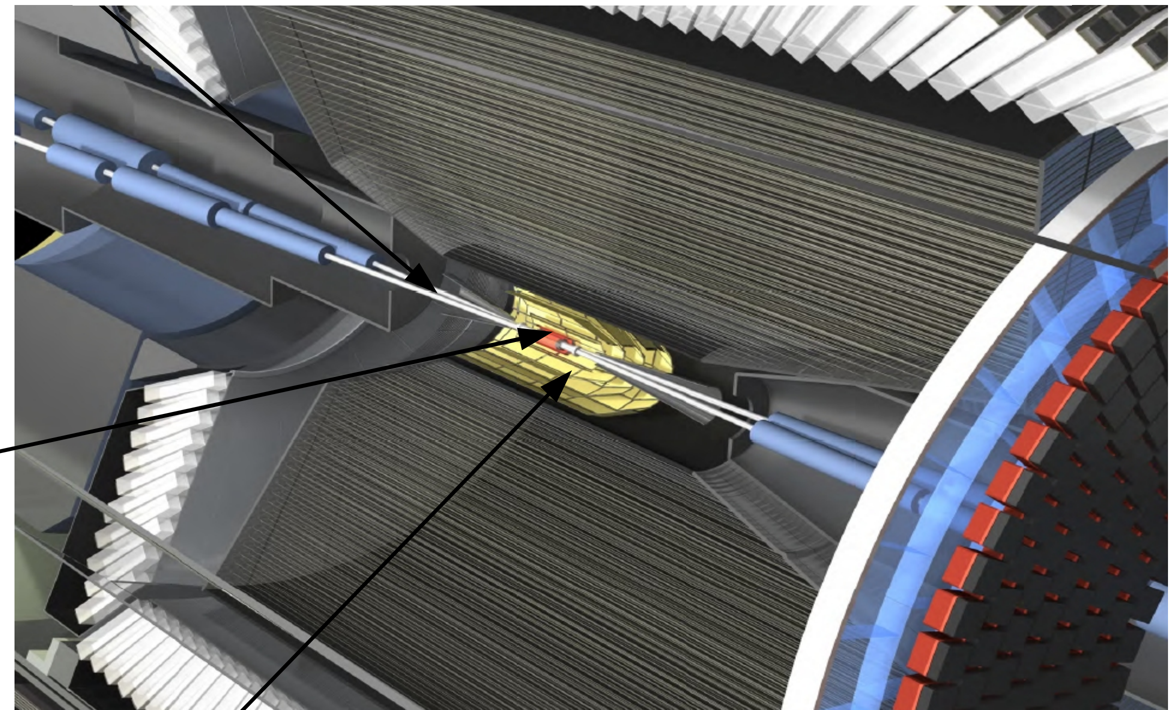
New final focusing system has been designed.

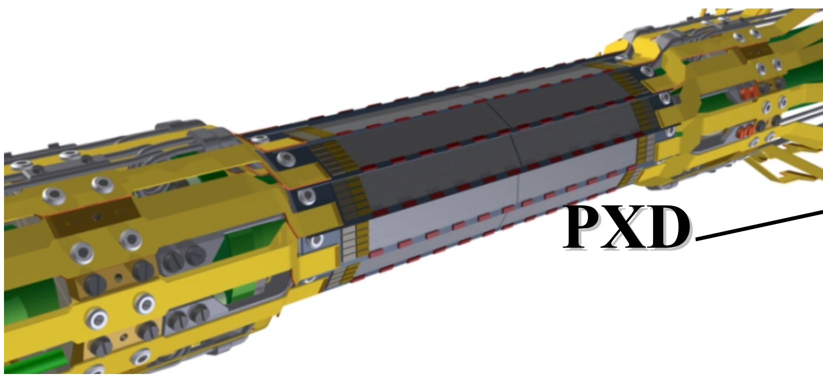
It consists of 8 quadrupole superconducting magnets.

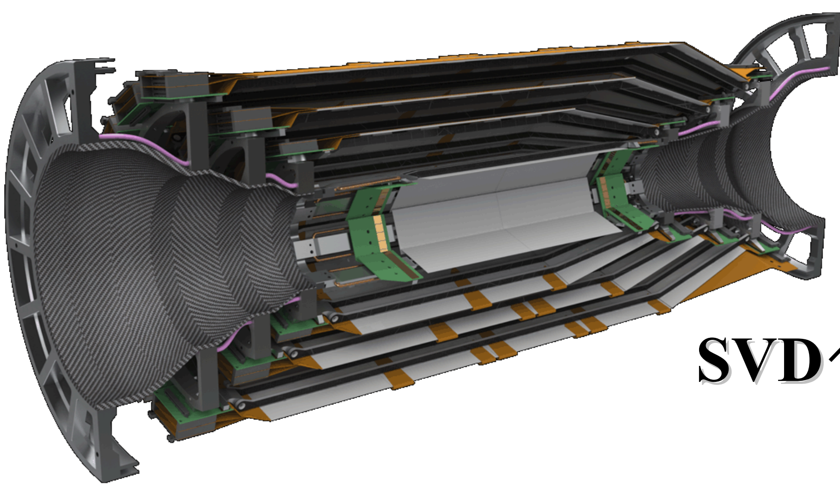
Crossing angle of 83 mrad was chosen to bring magnets closer to IP.

Belle II vertex region



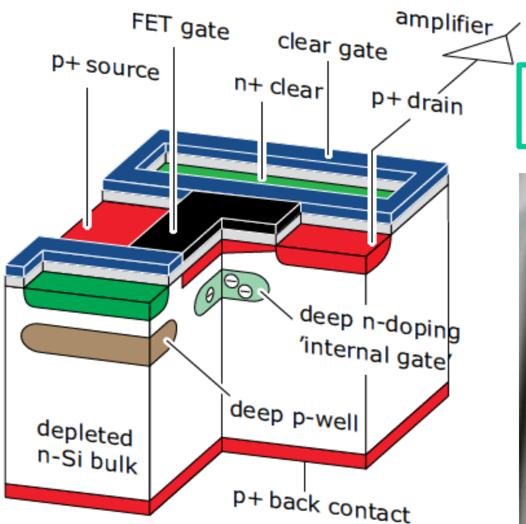




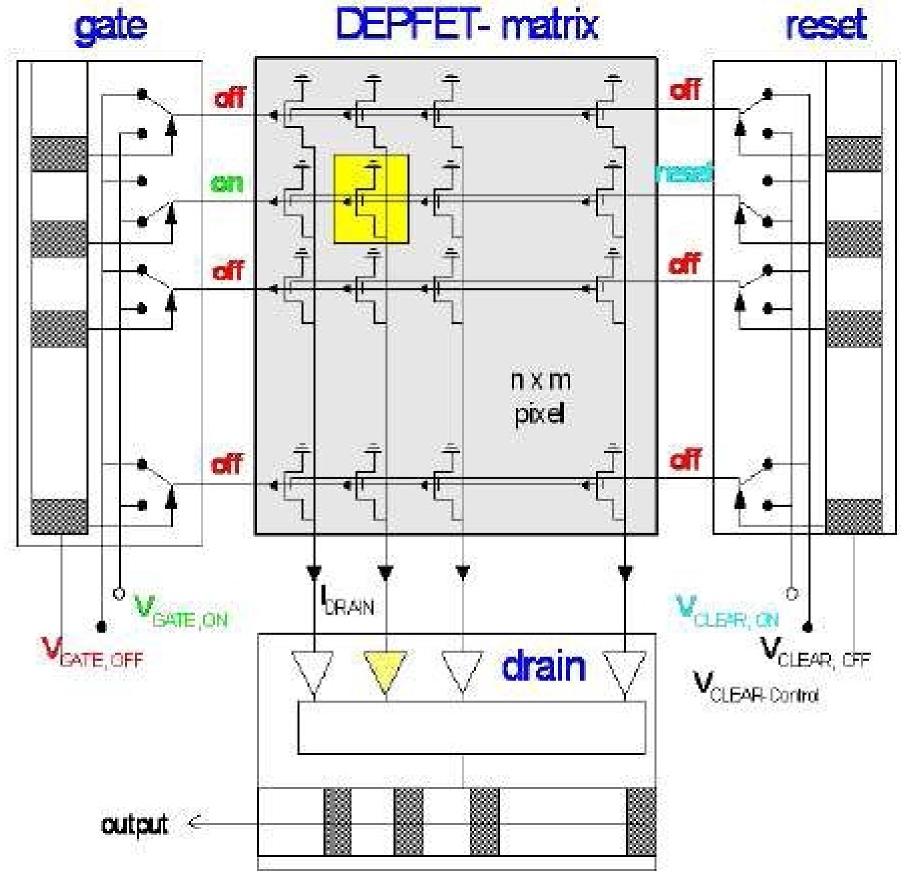


Beam Pipe	r = 10mm
PXD (2 layers DEPFET)	
Layer 1	r = 14mm
Layer 2	r = 22mm
SVD (4 layers DSSD)	
Layer 3	r = 38mm
Layer 4	r = 80mm
Layer 5	r = 105mm
Layer 6	r = 135mm

Pixel Vertex Detector (PXD)

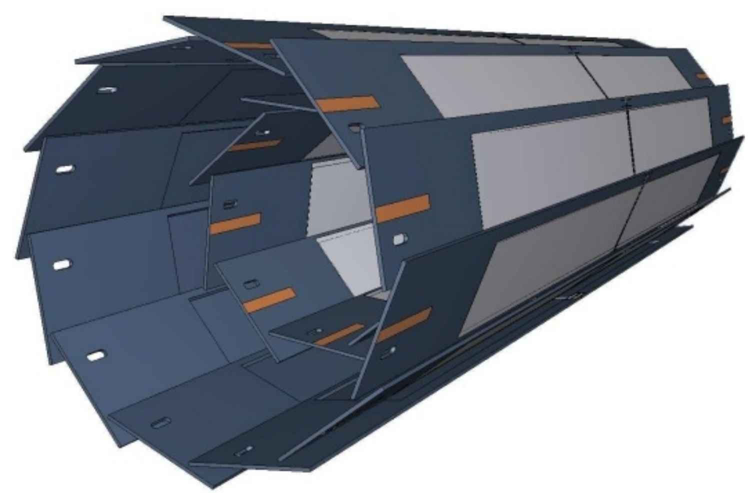


DEPFET pixel sensor



DEPFET:
http://aldebaran.hll.mpg.de/twiki/bin/view/DEPFET/WebHome

Mechanical mockup of the pixel detector

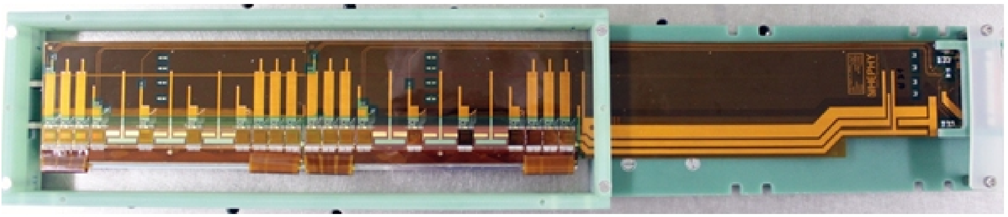


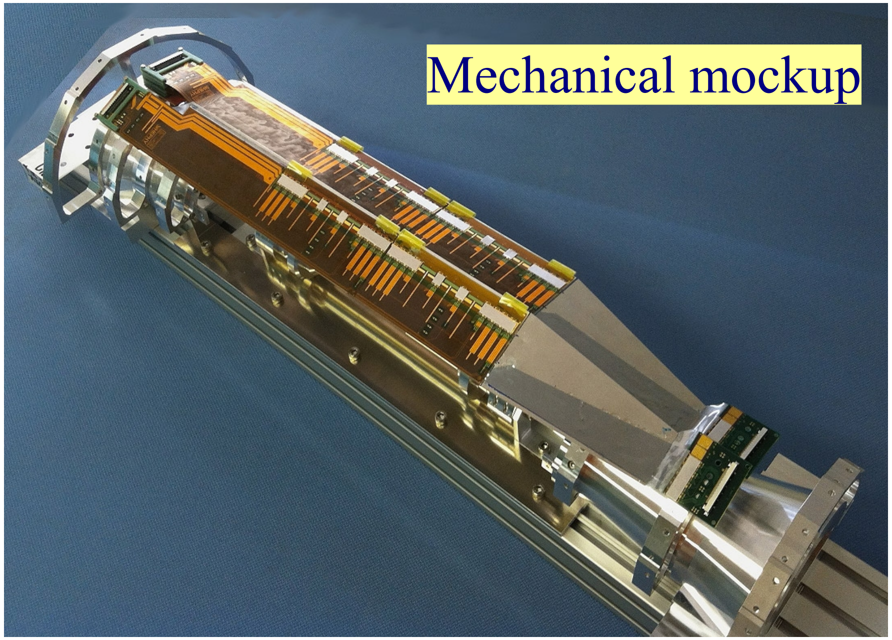
Silicon Vertex Detector (SVD)

4 layers of double-sided silicon strip detectors (DSSDs)

Origami chip-on-sensor

- A low-mass solution for double-sided readout
- Flex fan-out pieces wrapped to the opposite side

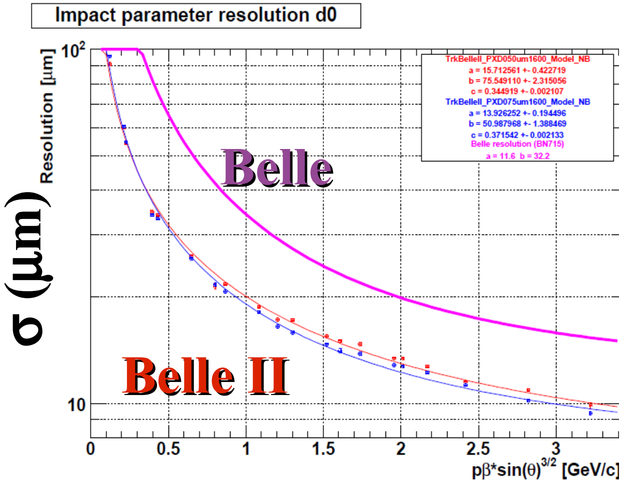


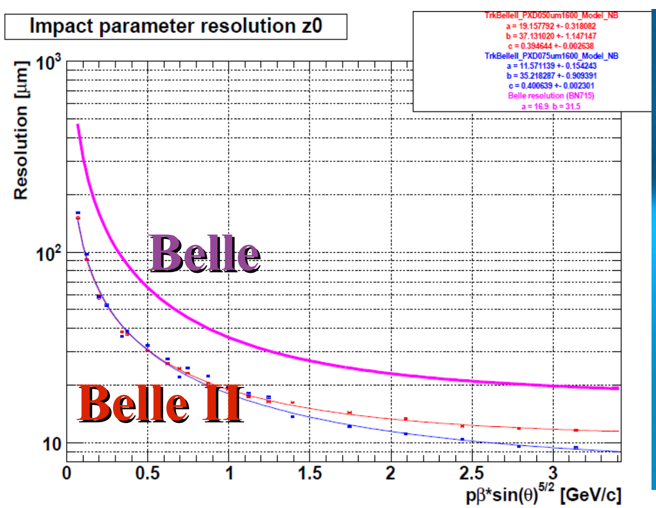


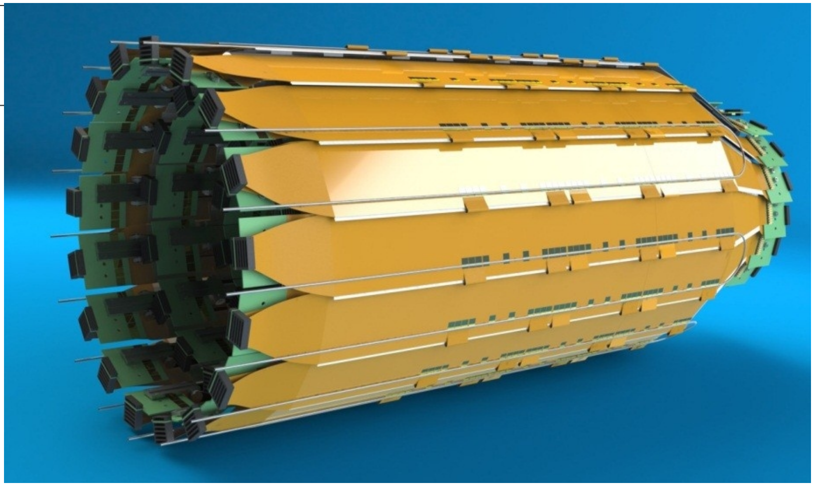
- **Fast strip readout with APV25 chip (50 ns), low occupancy**
- **Improved IP resolution and low momentum tracking (P_T<0.1 GeV/c), 30% larger efficiency for $K_S \to \pi^+\pi^-$ reconstruction with vertex information**

dr(R-φ) resolution

Z resolution







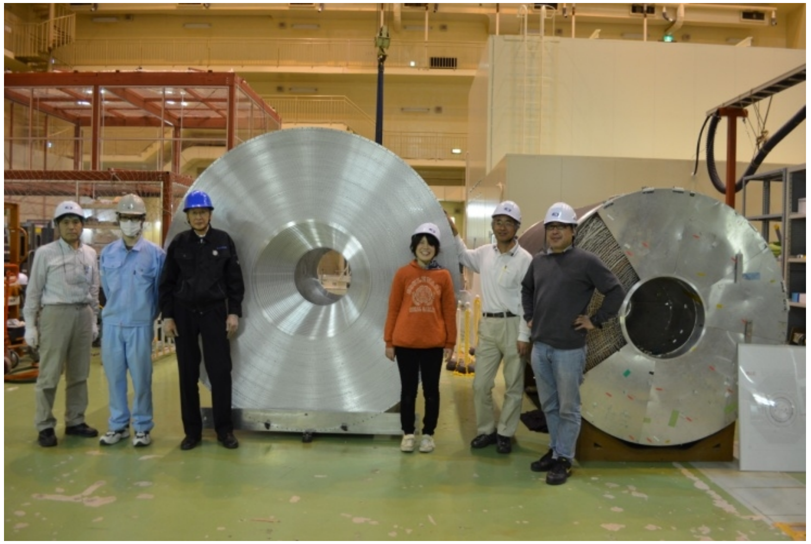
Central Drift Chamber (CDC)

- Larger outer radius
- Smaller cells near the beam pipe
- Faster readout electronics

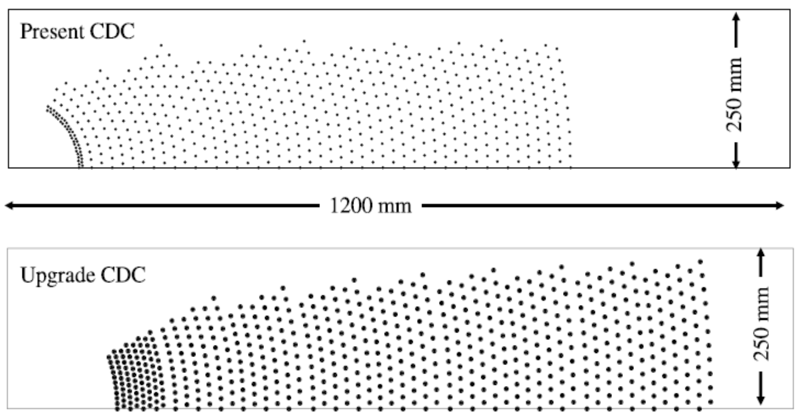
$$\sigma_{P_t}/P_t = 0.11\% P_t(\text{GeV}/c) \oplus 0.30\%/\beta$$

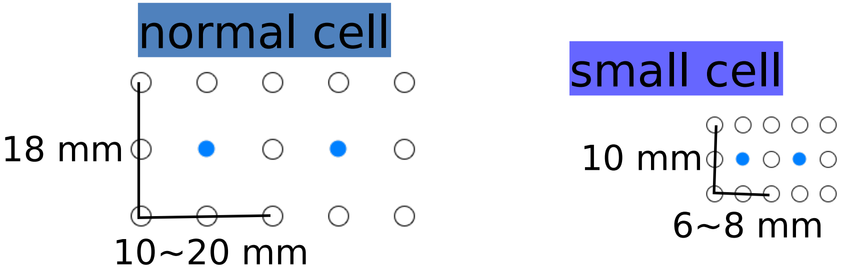
$$\sigma(dE/dx) \approx 6\%$$

	Belle	Belle II
inner most sense wire	r=88mm	r=168mm
outer most sense wire	r=863mm	r=1111.4mm
Number of layers	50	56
Total sense wires	8400	14336
Gas	$He:C_2H_6$	$He:C_2H_6$
sense wire	W(Φ30μm)	W(Φ30μm)
field wire	Al(Φ120μ)	Al(Φ120μm)
Number of wires	**41744**	**56576**



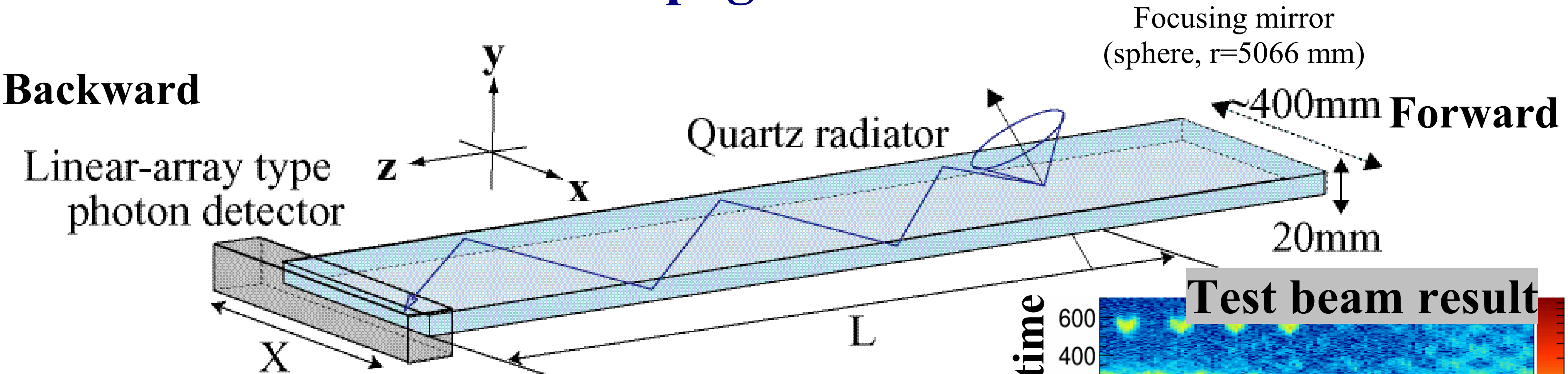
Wire Configuration

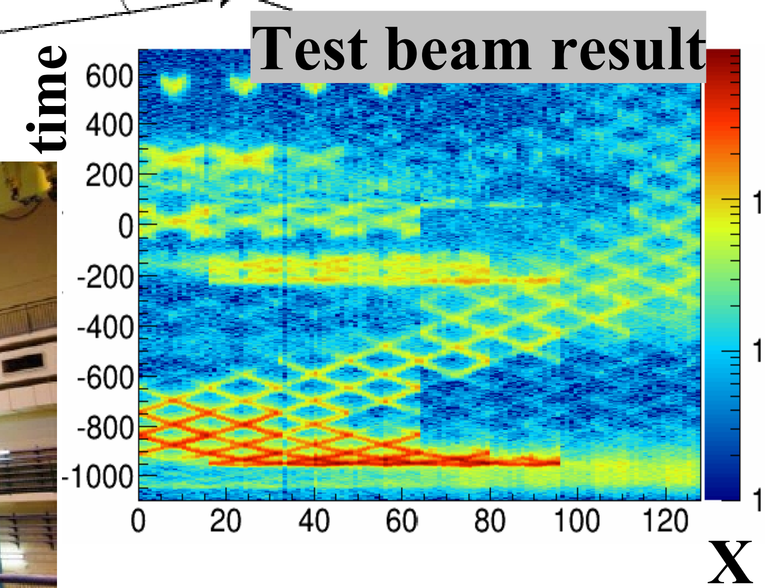




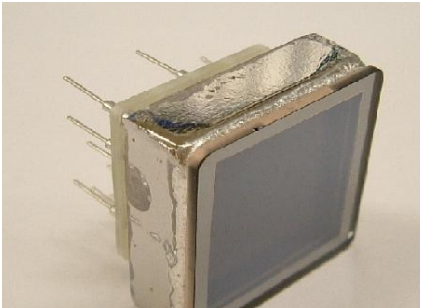
Belle II particle identification (barrel)

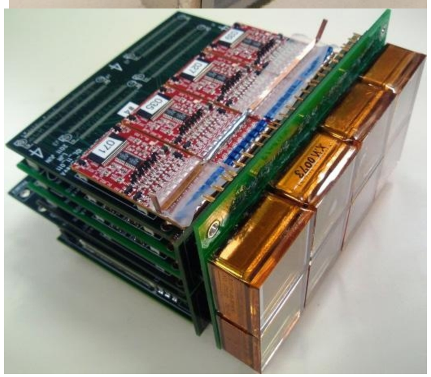
Time of Propagation Counter





Block of 32 16-channel Hamamatsu SL10 MCP-PMT (measure x, y and time, σ_t~40 ps)

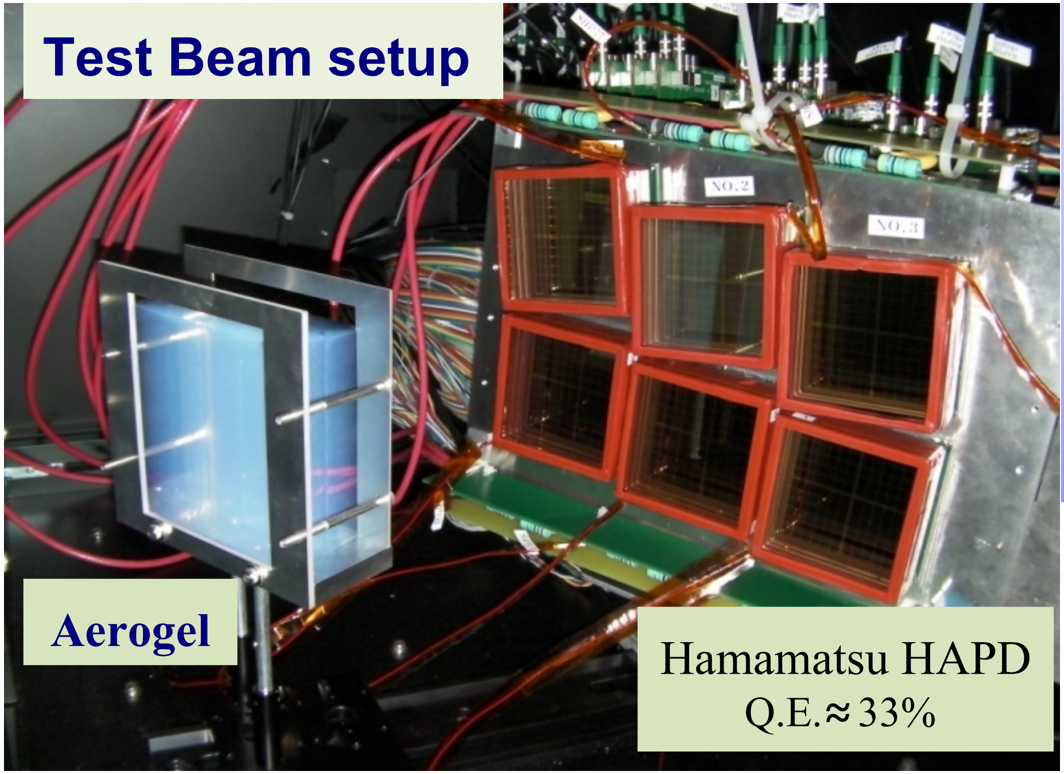


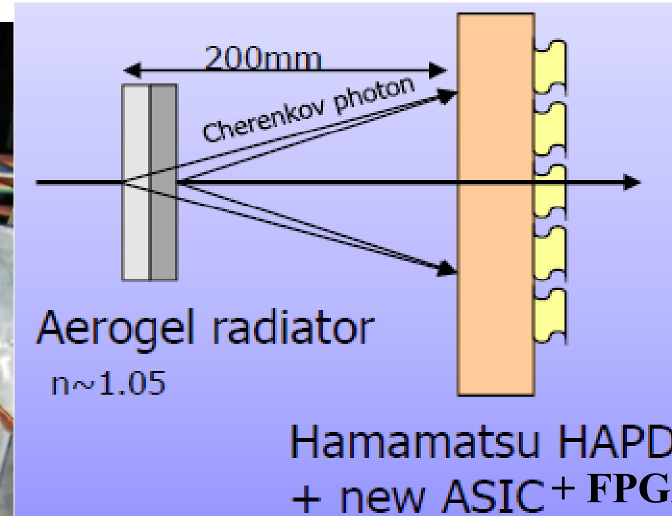


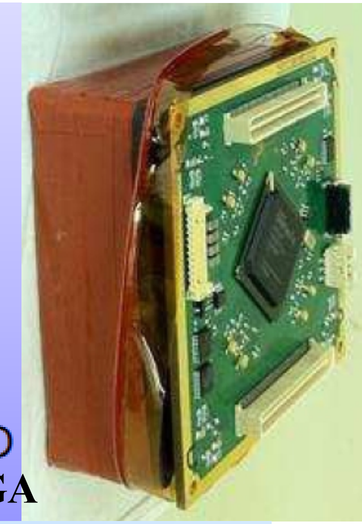
- Cherenkov ring imaging with precise time measurement.
- Measure internally reflected Cherenkov light pattern like in BABAR DIRC. Compact design, improved K/π separation.
- Reconstruct Cherenkov angle from two hit coordinates (X, Y) and time of propagation of photon.
- Focusing system to minimize chromatic effect.

Belle II particle identification (end-cap)

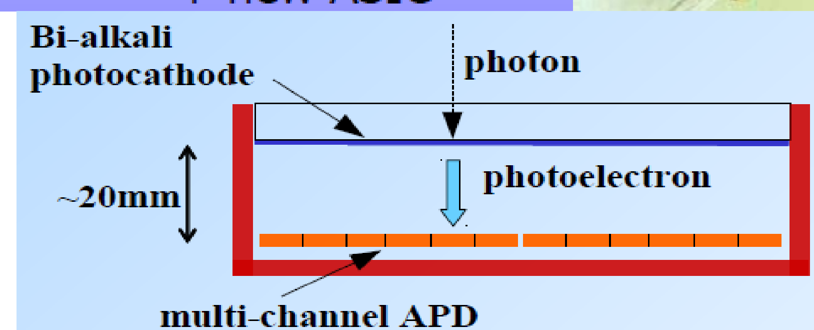
Aerogel RICH





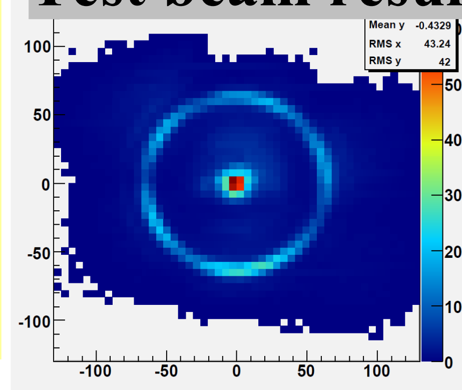


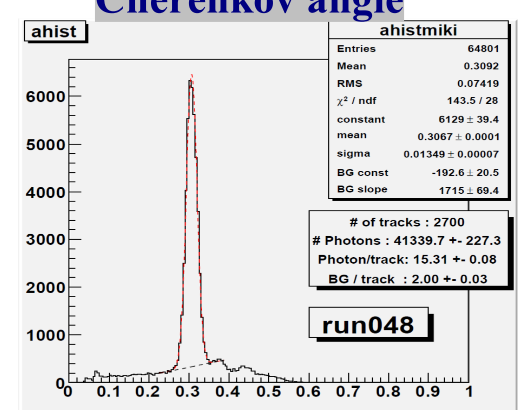
+ FPGA



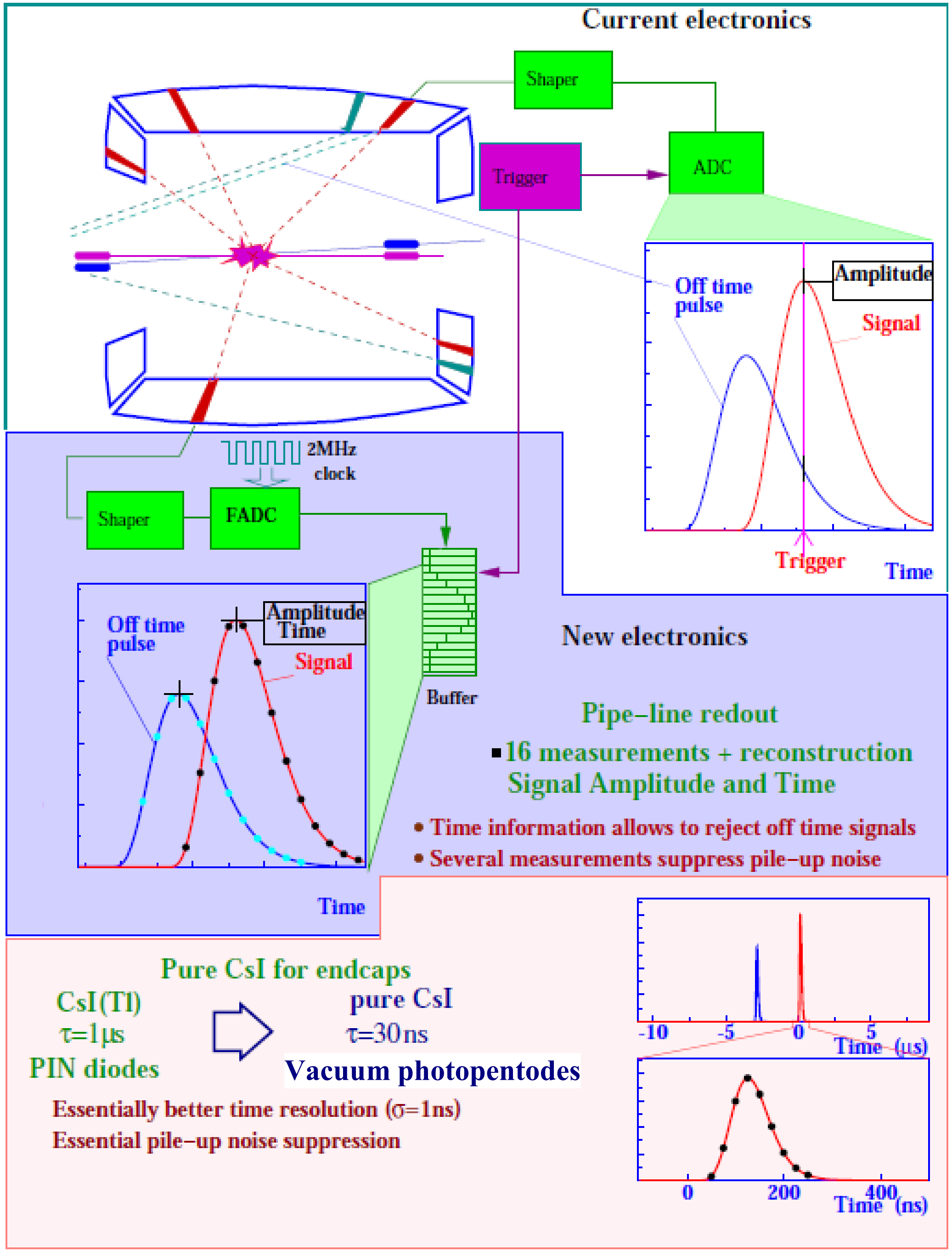
- **RICH** with a novel focusing two layer radiator *NIM A548 383 (2005).*
- 12x12 channel **H**ybrid **A**valanche **P**hoto-**D**etector (Hamamatsu) with 72x72 mm^2 area. In total 420 HAPDs.
- Electronics: ASIC+FPGA front-end Board → Merger Board → DAQ
- **6.6σ K/π** separation at P = 4 GeV/c !

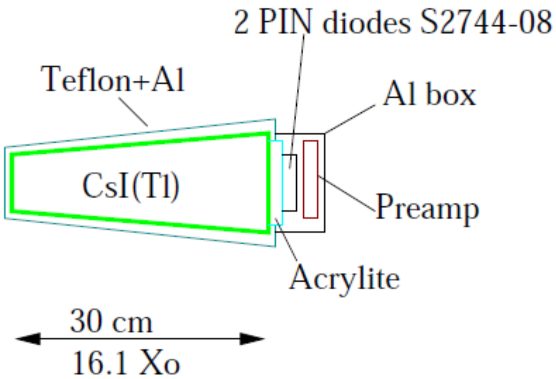
Test beam result

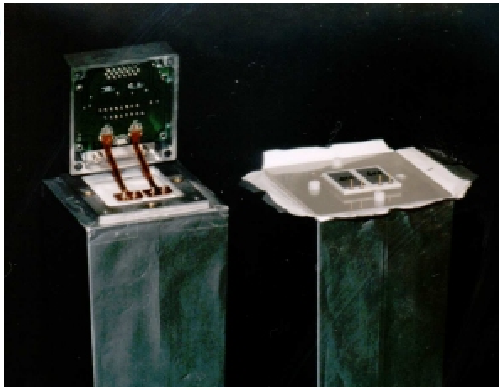




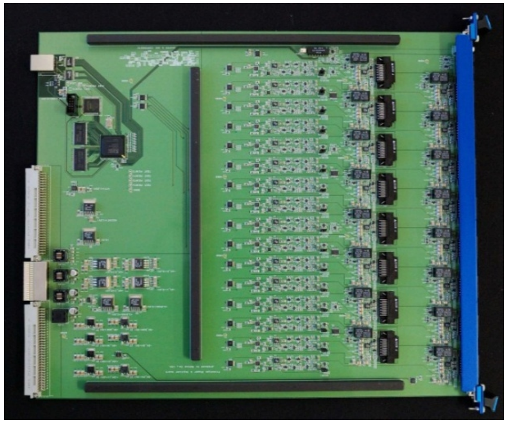
Electromagnetic calorimeter (ECL), barrel

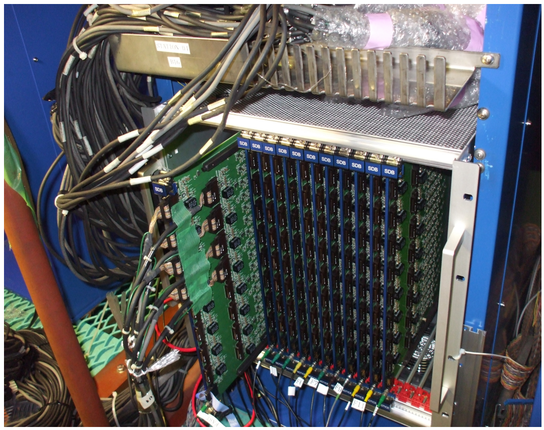




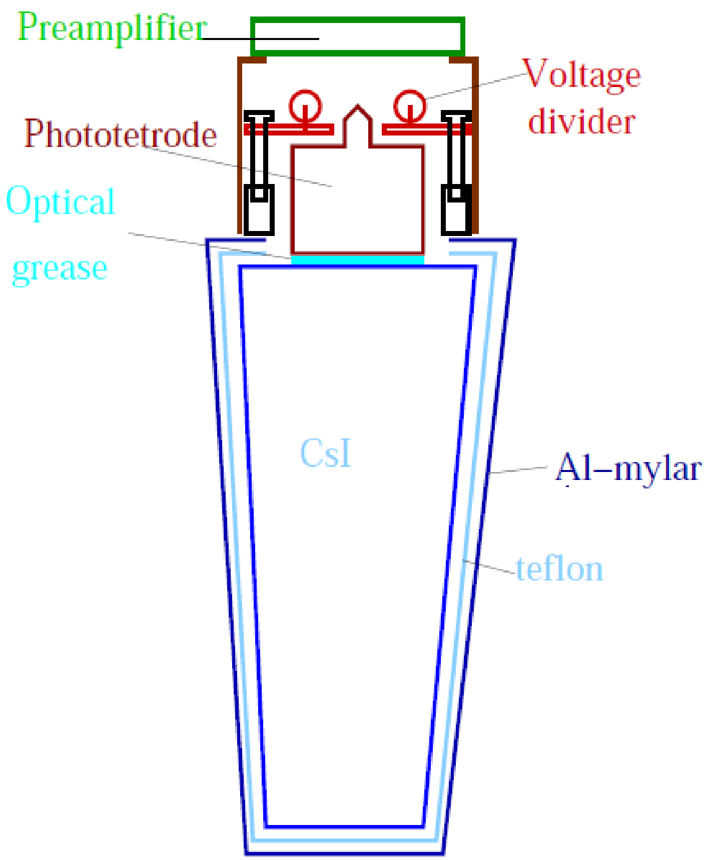


- **Barrel ECL** will be reused, new electronics with pipe-line readout and waveform analysis (16 ch Shaper-DSP board) has been developed and tested. 112 from 432 Shaper-DSP boards were produced, tested and delivered to KEK lab.
- All 6624 ECL barrel channels have been tested with new electronics (all are alive).
- Belle II DAQ electronics has been tested in the ECL data transfer runs with the frequency up to 30 kHz.
- In 2014 ECL electronics will be installed in detector.

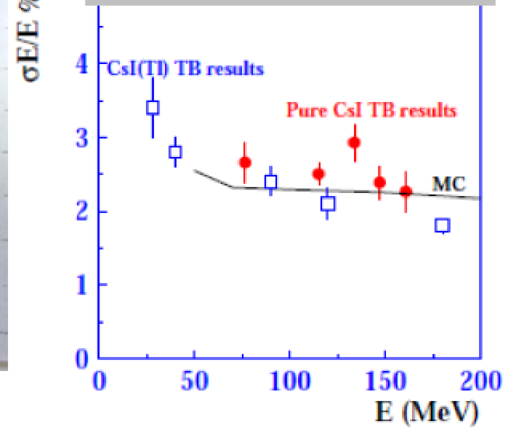




ECL end-cap upgrade



Test beam result

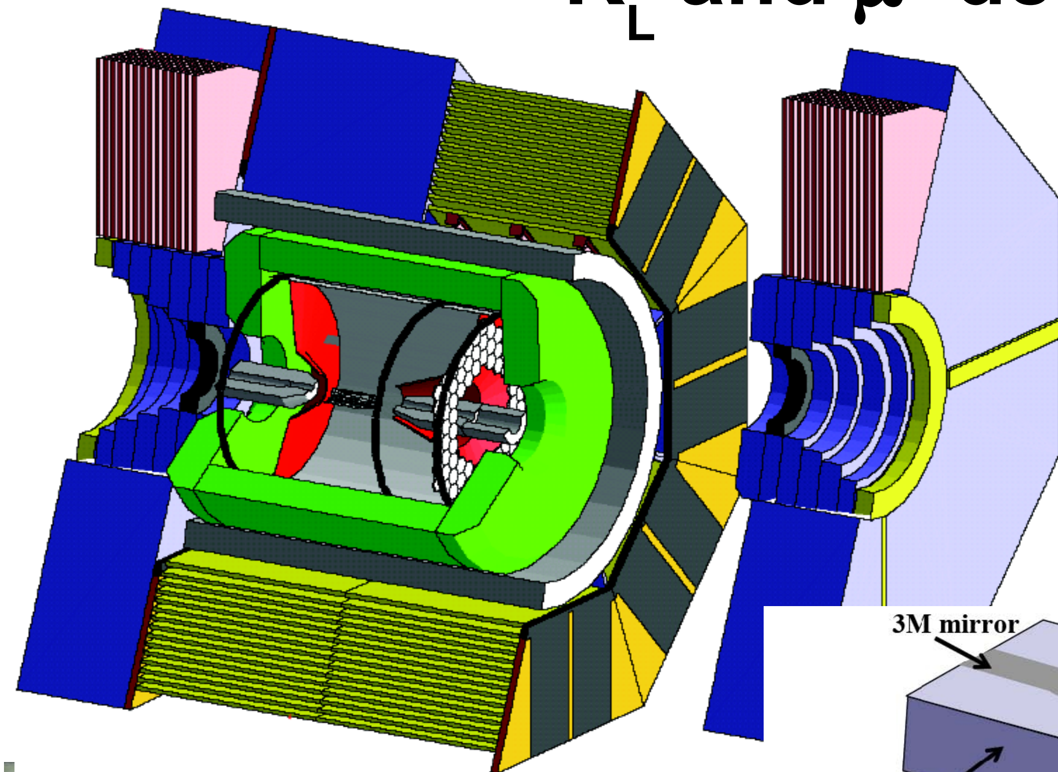


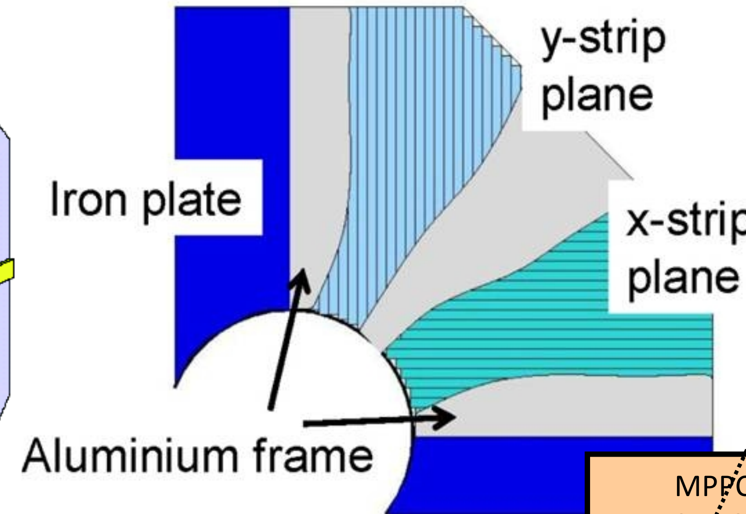
- At the first stage of the Belle II experiment we will reuse Belle end-cap ECL (1152 + 960 channels) (with new preamplifiers and readout electronics).
- **The main end-cap ECL upgrade option is to use CsI(pure) crystals and Hamamatsu photopentodes** (dedicated R&D showed good results):
  - ✓ Low pile-up noise and good energy and spatial resolution
  - ✓ Similar physical characteristics (as for CsI(Tl)), better radiation hardness
  - ✓ There are several crystal producers, acceptable price
- However there are some difficulties: no redundancy, notable dependency on magnetic field, completely new mechanical support is needed. To solve these difficulties **second R&D option was formulated: CsI(pure) + Si APD**
- In the CsI(pure) + Si APD option we are investigating APD from two producers: *Advanced Photonix*, *Hamamatsu Photonics.*
  The main problem is to reach admissible level of electronic noise.

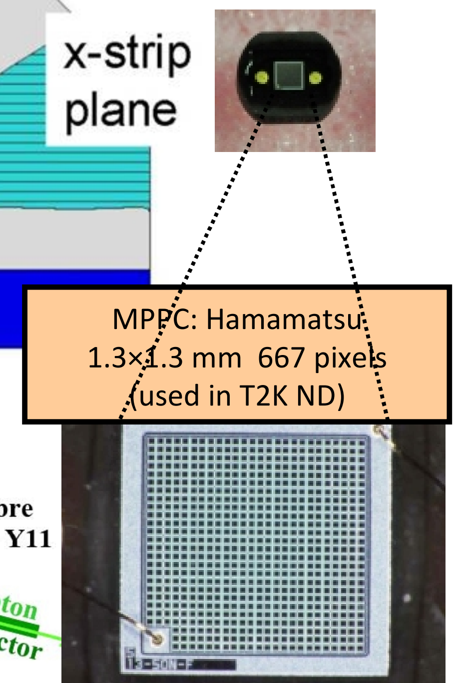
Hamamatsu APD S8664-1010

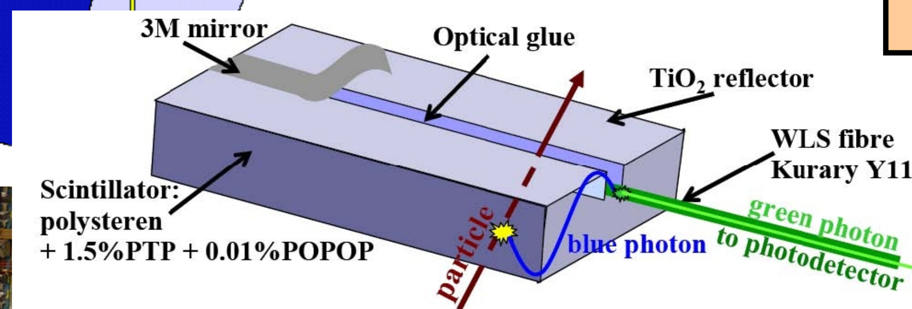
Advanced Photonix APD

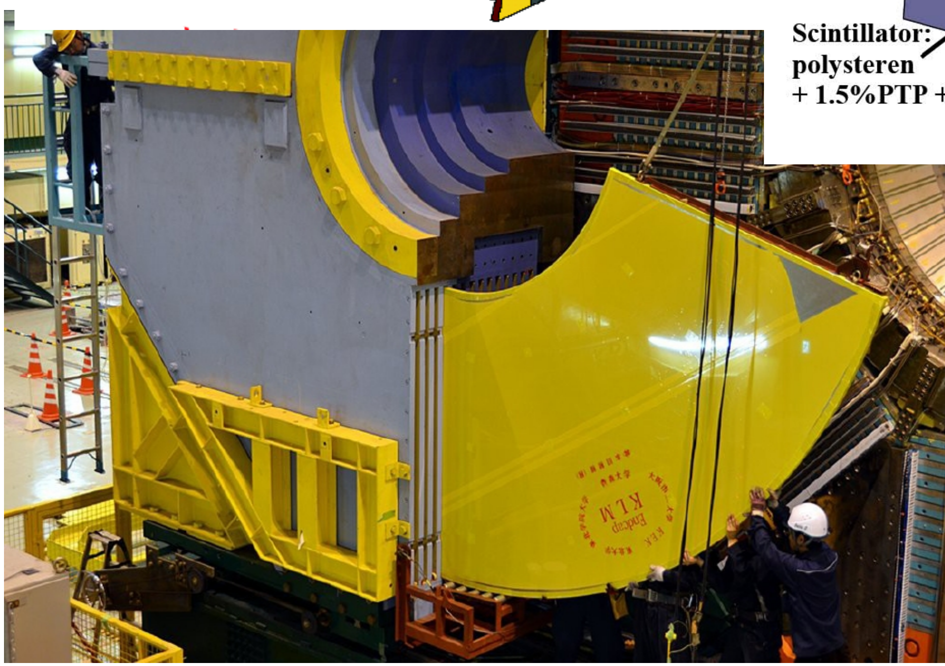
K_L and $\mu^{\pm}$ detector (KLM)





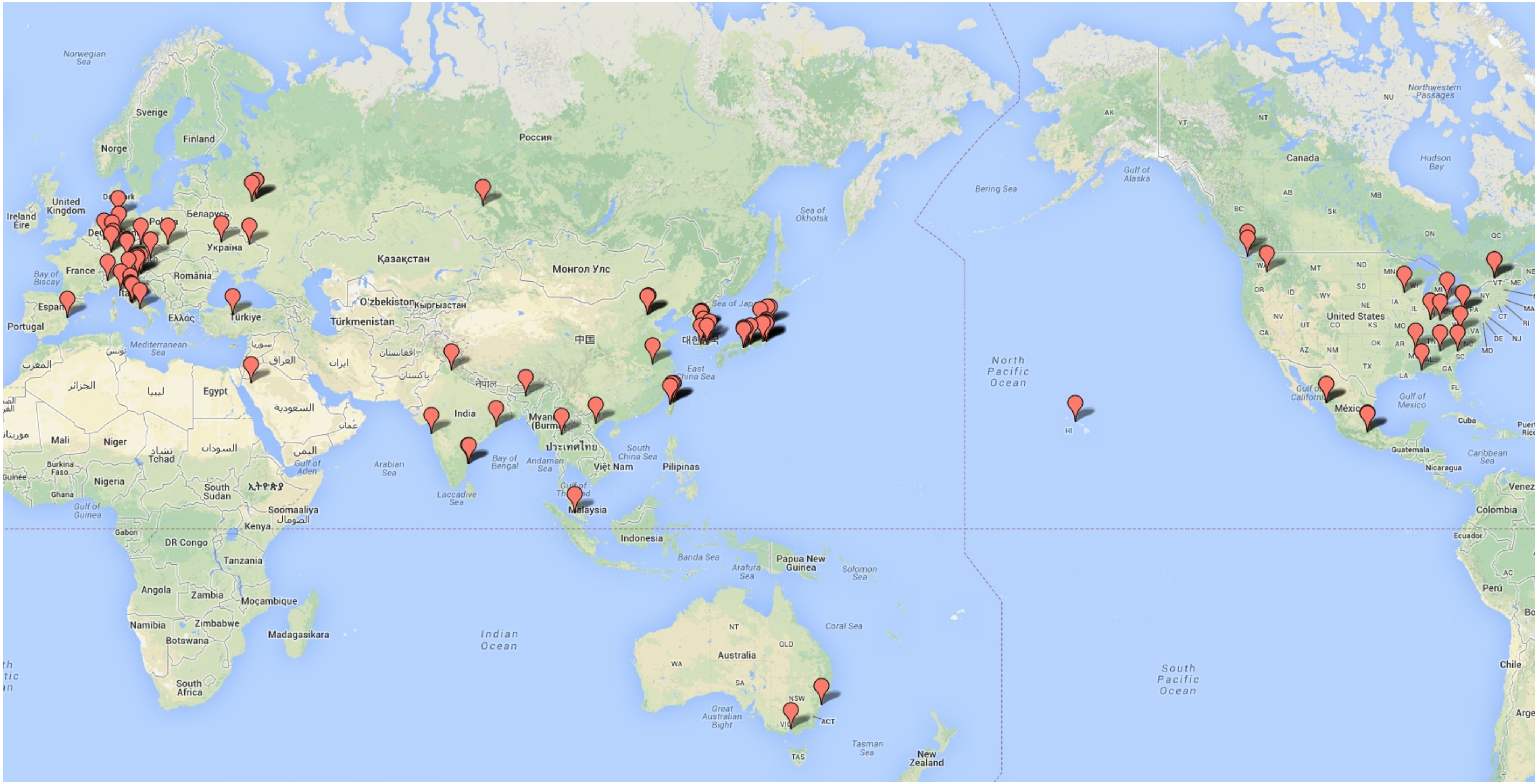






- **Barrel KLM:** Belle Resistive Plate Counters will be reused, two inner layers have been replaced by scintillator strips recently.
- **End-cap KLM:** Block with two orthogonal layers of scintillator strips (~120):
  - ✓ **Scintillator bar → WLS fiber → MPPC → Preamp.**
  - ✓ **In total about 30000 channels**
  - ✓ **>99% geometrical acceptance, better efficiency for K_L and μ, σ_t < 1 ns**

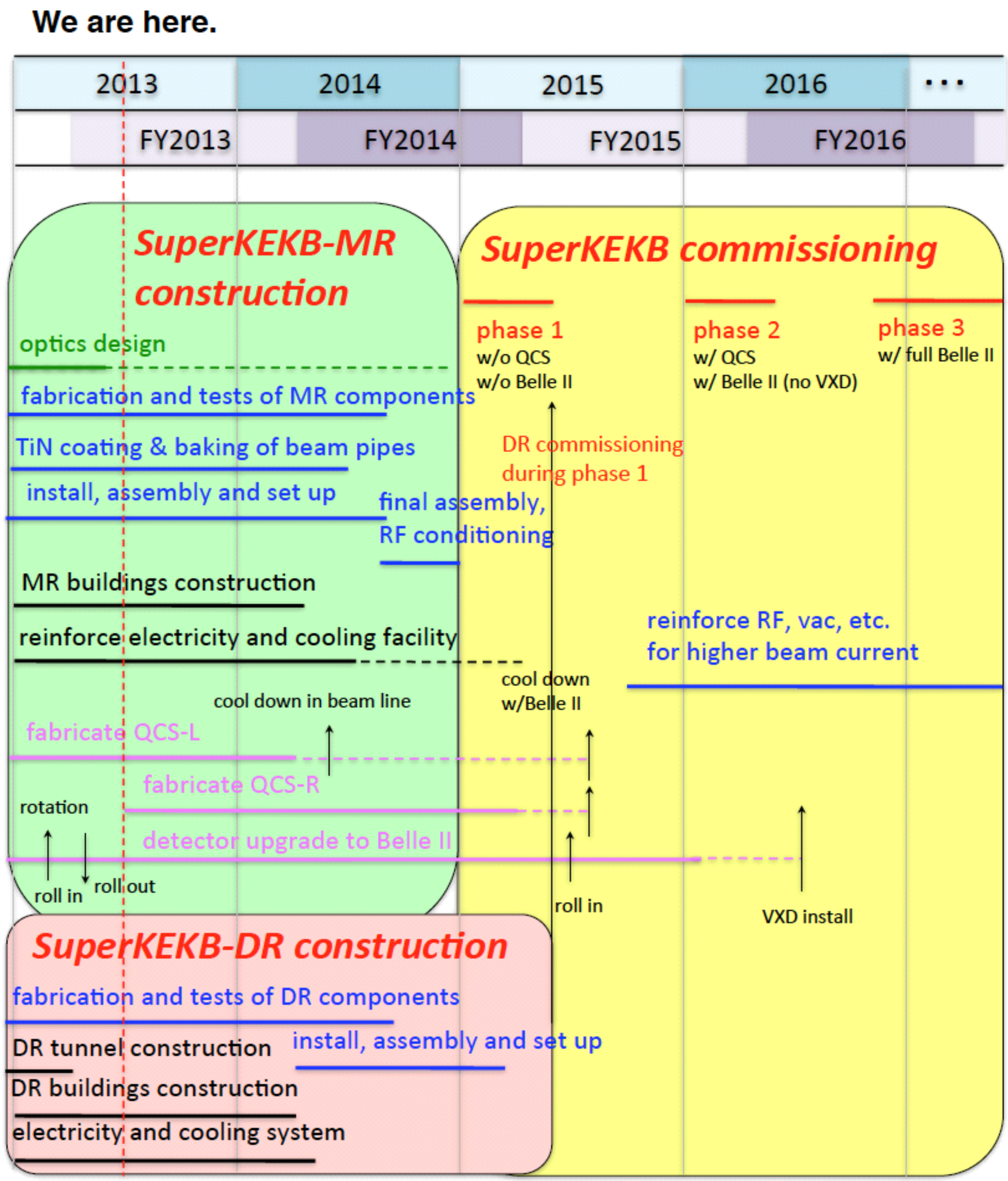
Belle II collaboration map



579 physicists from 97 institutes, 23 countries/regions

http://belle2.kek.jp

SuperKEKB / Belle II schedule



K. Akai

- Phase I:
  without QCS and Belle II
  Jan – May, 2015
- Phase II:
  with QCS and Belle II, without PXD+SVD
  Feb – June, 2016
- Phase III:
  Physics run with full Belle II detector starts in October, 2016

Summary and Prospects

- Successful e^+e^- B Factories, Belle and BABAR, raised lots of new intriguing questions in the flavor sector of the Standard Model. They proved the fruitfulness of the B Factory experimental strategy in the search for New Physics.
- Belle II at SuperKEKB is the only e^+e^- Super B Factory in the nearest future, which is competitive/complementary to the current and coming energy/intensity frontier experiments:
  - ✓ 40 times higher luminosity and 50 times larger statistics compared to Belle represent great challenge to both SuperKEKB accelerator and Belle II detector
  - ✓ It is fully approved, construction is going on and the first physics run is expected in 2016
  - ✓ International Belle II collaboration: 579 physicists, 97 institutes, 23 countries/regions
- **Lots of new exiting results are expected from Belle II experiment in the next decade !**

Groundbreaking ceremony: 18th November 2011

Backup slides

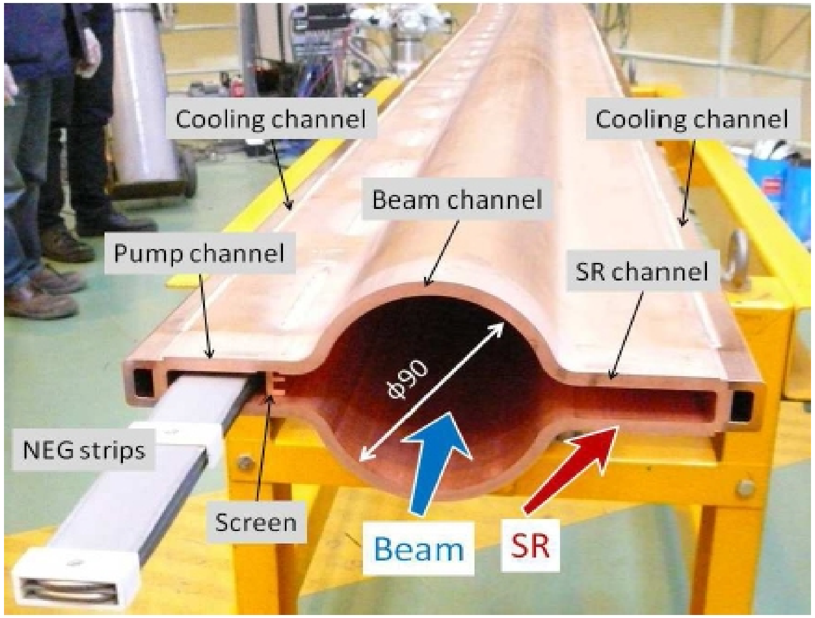
Accelerator design parameters

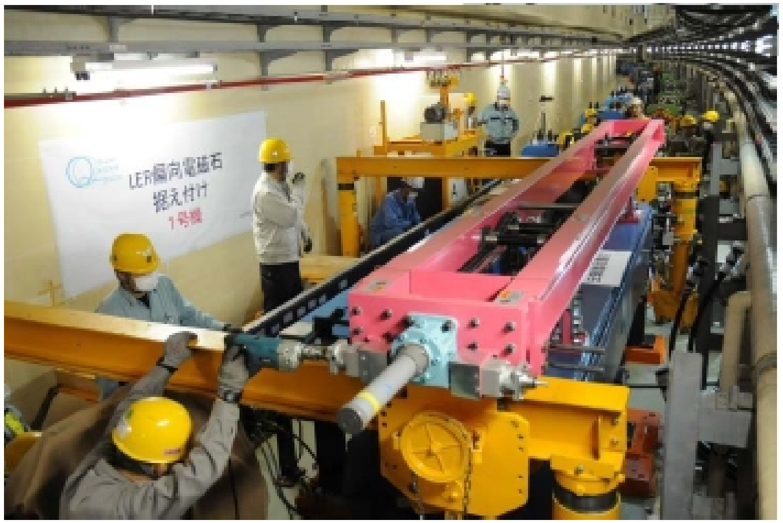
parameters		KEKB LER	KEKB HER	SuperKEKB LER	SuperKEKB HER	units
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	φ	11		41.5		mrad
Horizontal emittance	ε_x	18	24	3.2	4.6	nm
Emittance ratio	κ	0.88	0.66	0.37	0.40	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.30	mm
Beam currents	I_b	1.64	1.19	3.60	2.60	A
beam-beam parameter	ξ_y	0.129	0.090	0.0881	0.0807	
Luminosity	**L**	**2.1×10^{34}**		**8×10^{35}**		$cm^{-2}s^{-1}$

- **Change beam energies:**
  - ✓ **LER**: 3.5→4.0 GeV to suppress Touschek effect and increase beam lifetime
  - ✓ **HER**: 8.0→7.0 GeV to get lower emittance
- **Reuse KEKB tunnel and HER magnets**
- **Replace LER dipole magnets**

SuperKEKB construction progress

LER beam pipe with
ante-chamber and Ti-N coating



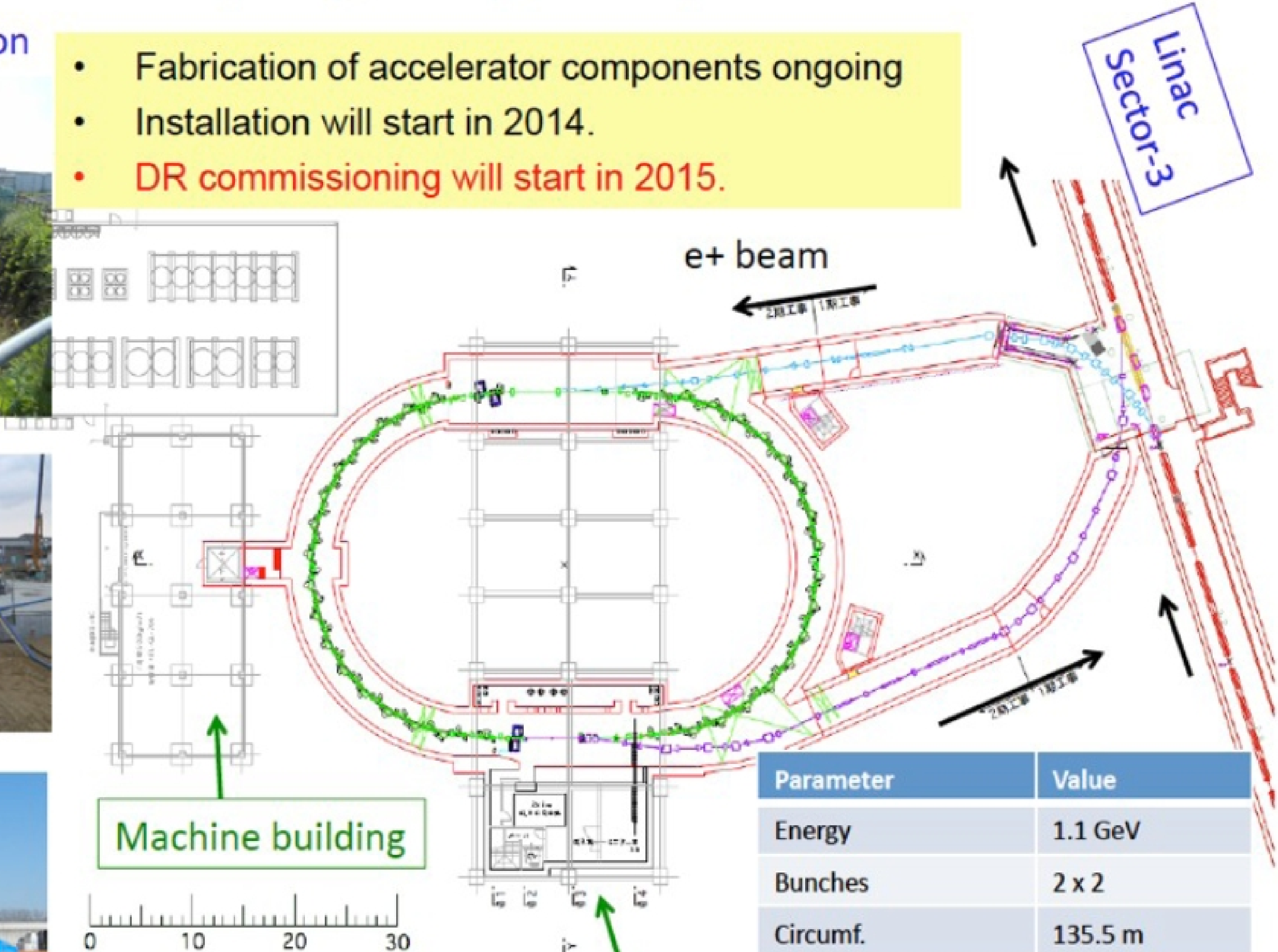


100 new LER bending magnets

New positron damping ring

DR tunnel construction

- Fabrication of accelerator components ongoing
- Installation will start in 2014.
- DR commissioning will start in 2015.



Parameter	Value
Energy	1.1 GeV
Bunches	2 x 2
Circumf.	135.5 m
H. damping	10.87 ms
Ext. emittance (H/V)	42.5/3.15 nm
Max. current	70.8 mA

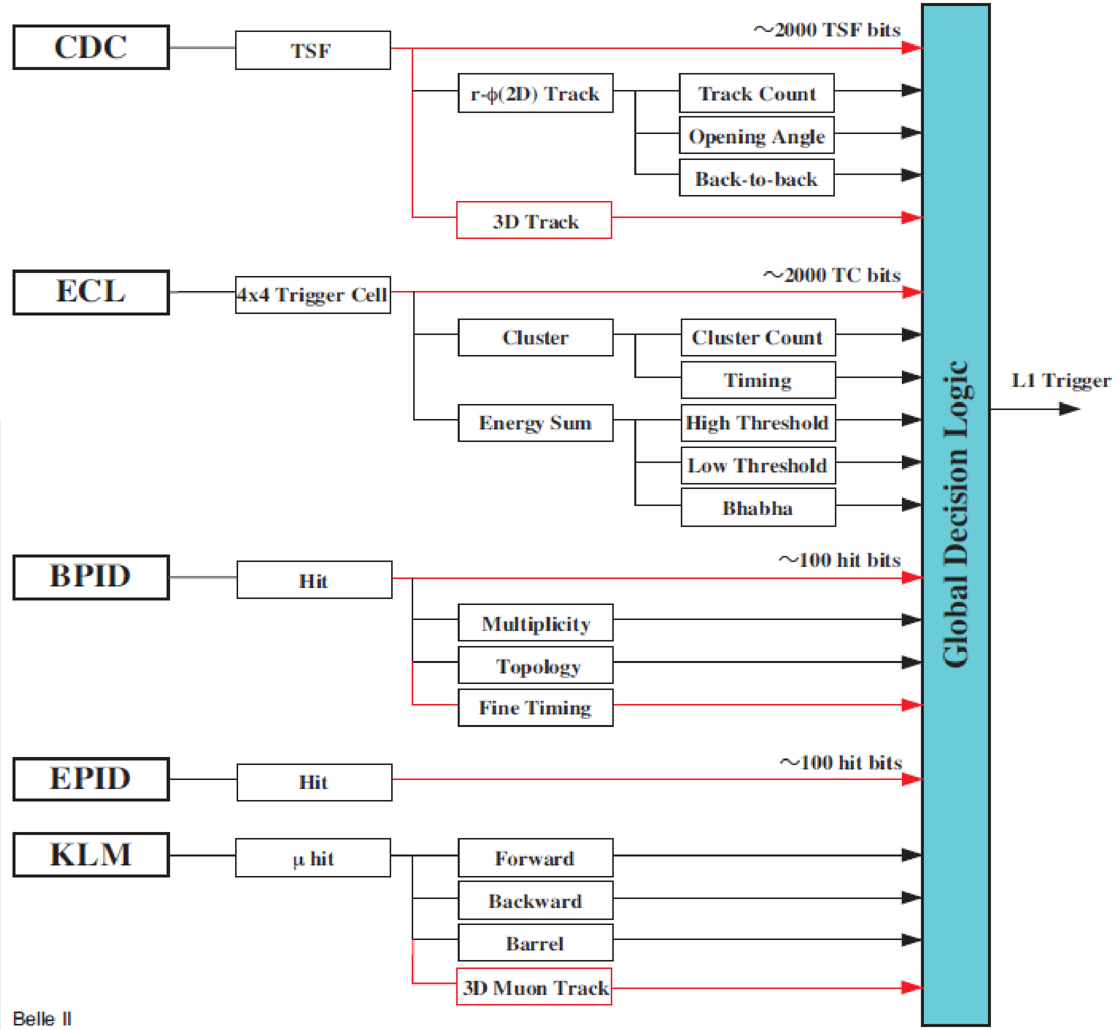
Belle II Trigger

For L = 8×10^{35} 1/cm^2/s

Physics process	Cross section (nb)	Rate (Hz)
$\Upsilon(4S) \to B\bar{B}$	1.2	960
Hadron production from continuum	2.8	2200
$\mu^+\mu^-$	0.8	640
$\tau^+\tau^-$	0.8	640
Bhabha ($\theta_{\rm lab} \geq 17°$)	44	350 [a]
$\gamma\gamma$ ($\theta_{\rm lab} \geq 17°$)	2.4	19 [a]
2γ processes ($\theta_{\rm lab} \geq 17°$, $p_t \geq 0.1$ GeV/c)	~ 80	~ 15000
Total	~ 130	~ 20000

[a] rate is pre-scaled by a factor of 1/100

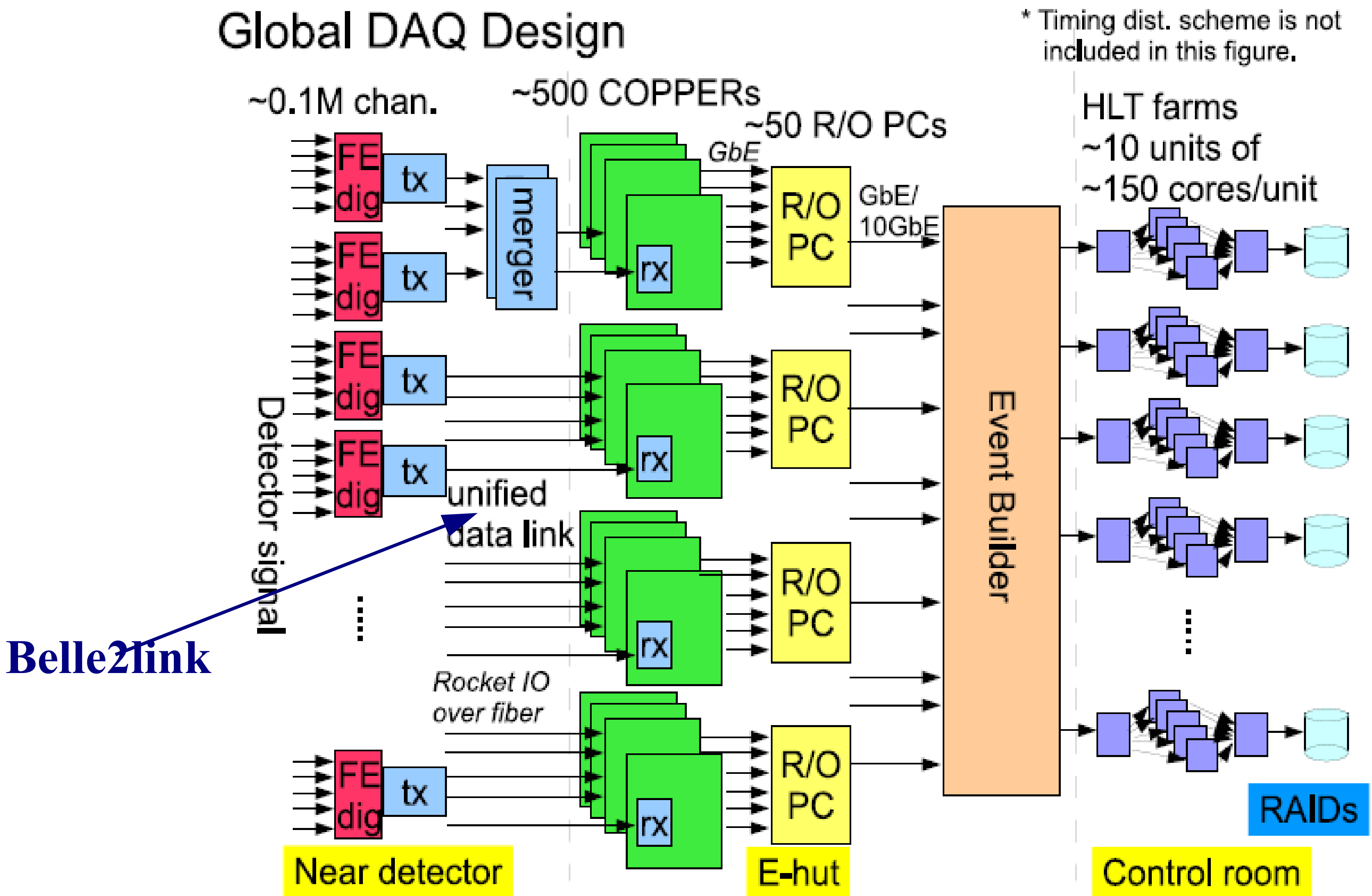
- **Beam collision frequency: 508 MHz**
- **Bunch separation: ~2 ns**
- **Good physics event rate: ~20 kHz**
- **Level-1(L1) trigger max. rate: 30 kHz**
- **Nominal beam background rate: 10 MHz**
- **Trigger time uncertainty : ~2 ns**
- **L1 trigger latency: 5 μs**
- **Min. L1 time between two events: 200 ns**



Three basic triggers:

CDC based "charged" trigger, **ECL based "neutral"** trigger and **TOP based fast trigger**, which provides signal ($\sigma_t < 2$ ns) to get event start time and identify out-of-time hits in PXD+SVD to reduce data volume.

Belle II Data Acquisition System (DAQ)



Experiment	Event Size [kB]	Rate [Hz]	Rate [MB/s]	HLT+OST [MB/s]
High rate scenario for Belle II DAQ				
Belle II	300	20000	6000	1200

Belle II Computing and Software

- New framework with dynamic module loading, parallel processing, python steering, and ROOT I/O
- Full detector simulation with Geant4
- Distributed computing based on DIRAC
- Can efficiently utilize GRID, Cloud and Local resources