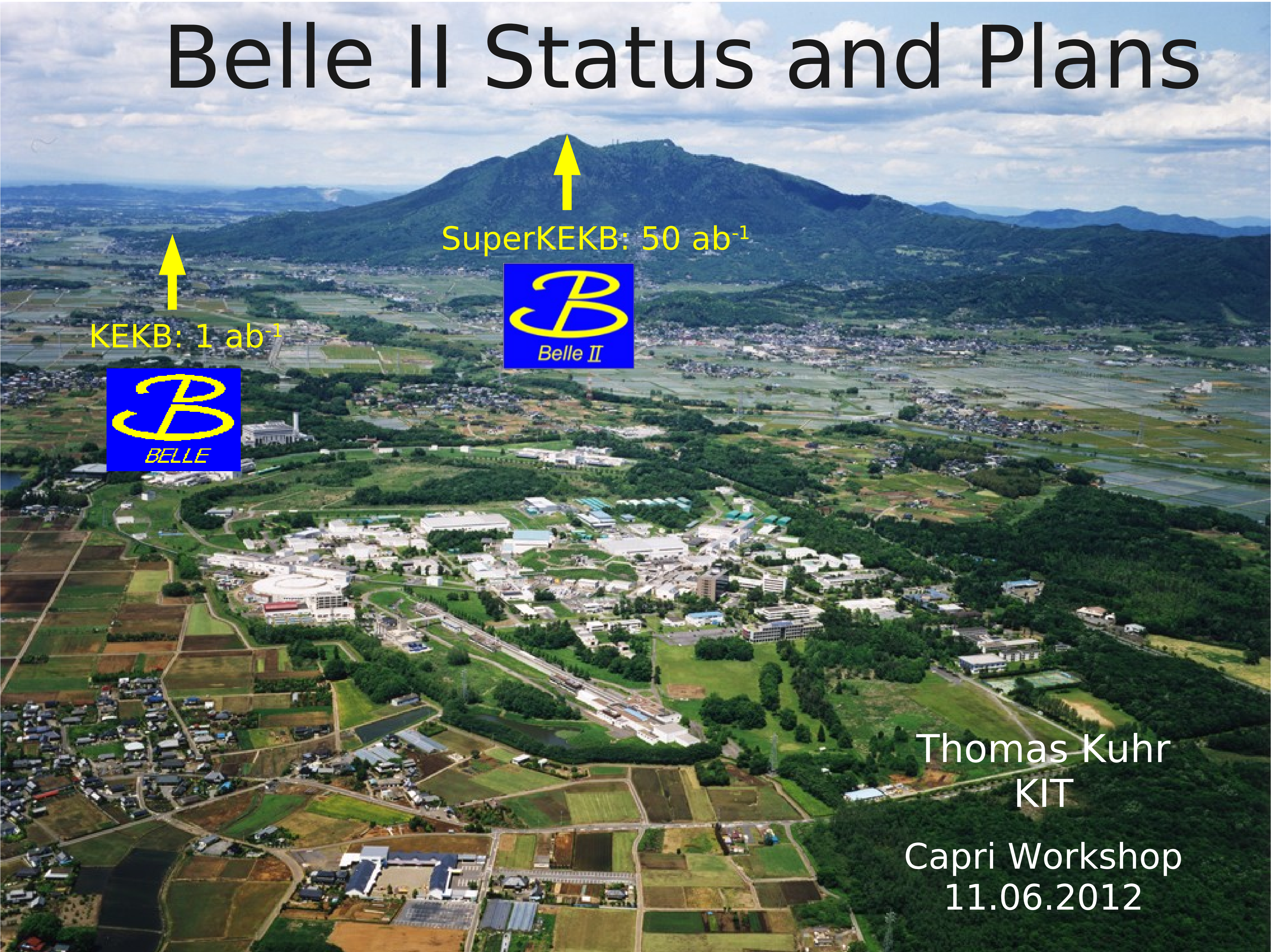
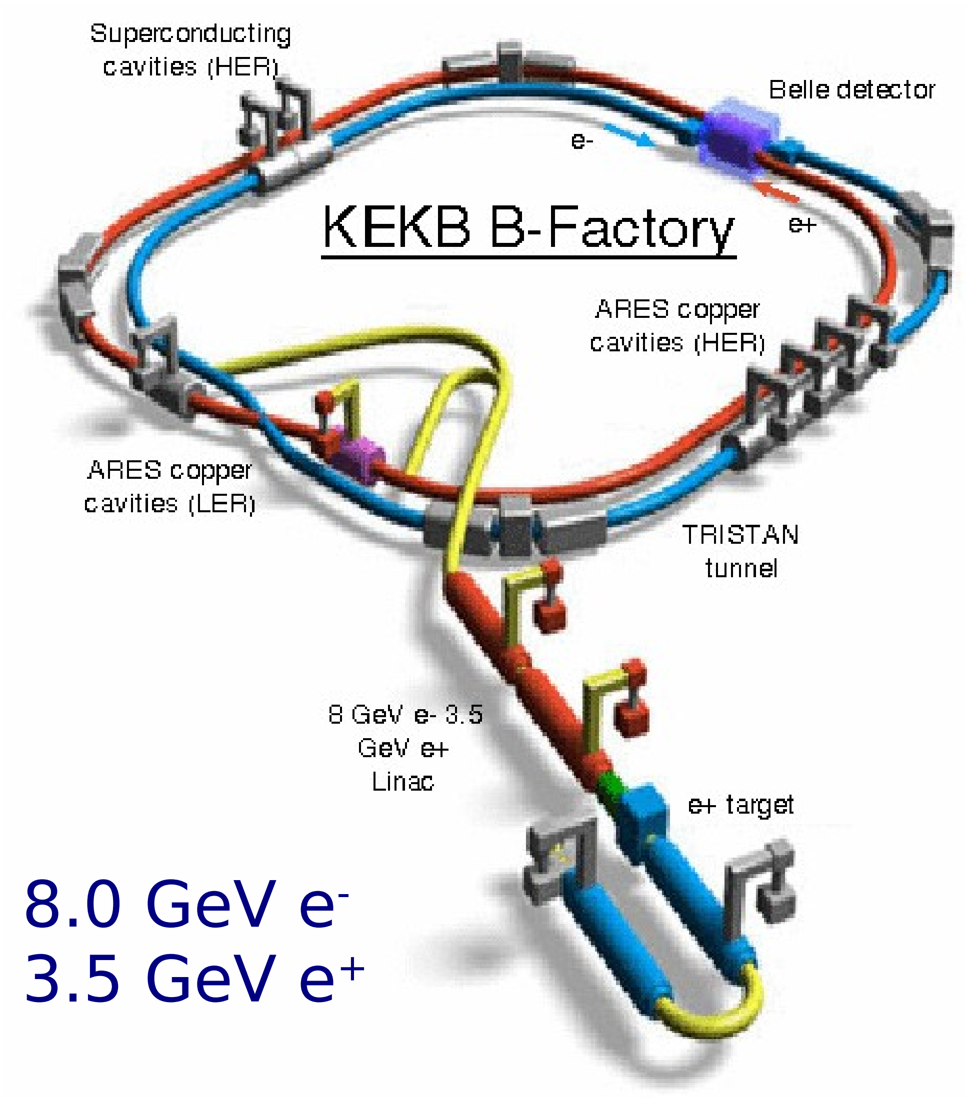
Belle II Status and Plans



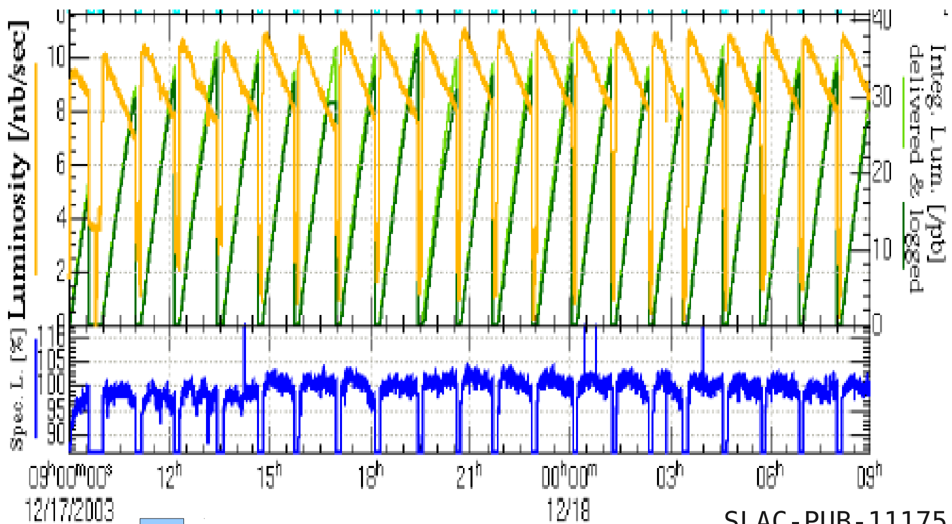
Thomas Kuhr
KIT

Capri Workshop
11.06.2012

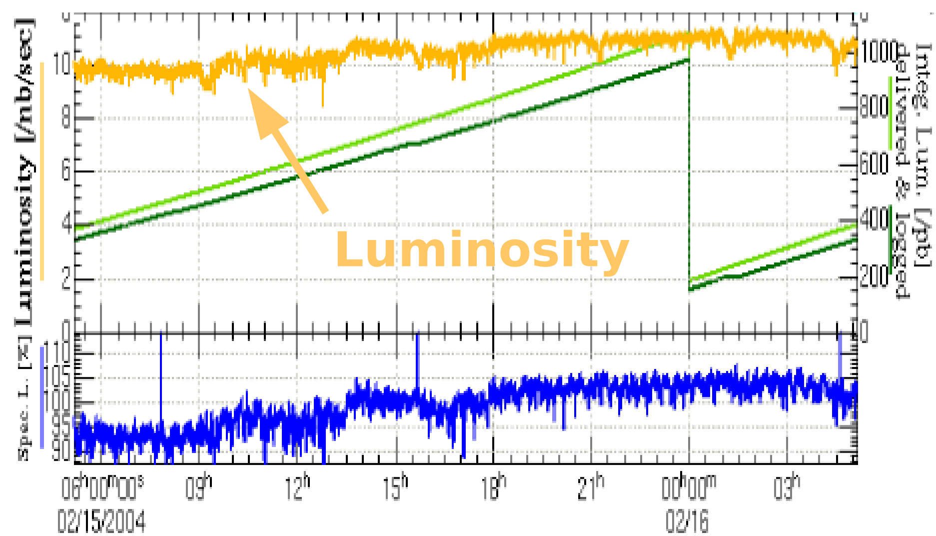
KEKB Accelerator



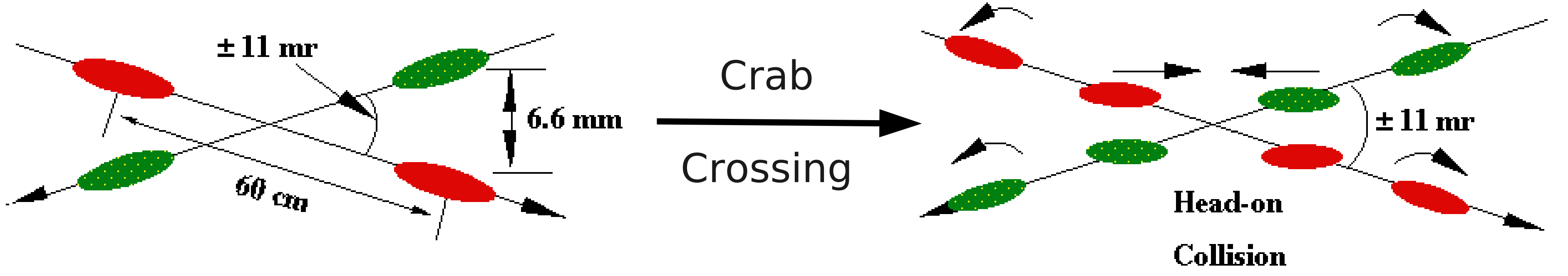
8.0 GeV e^-
3.5 GeV e^+

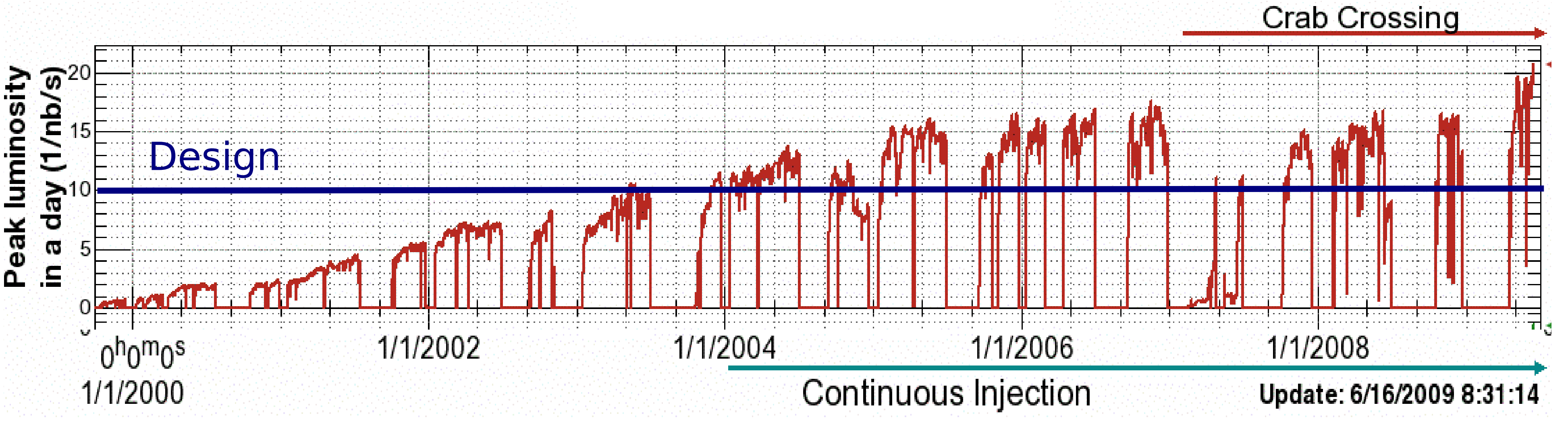


Continuous injection



KEKB Performance

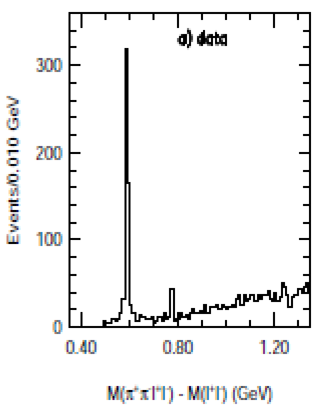


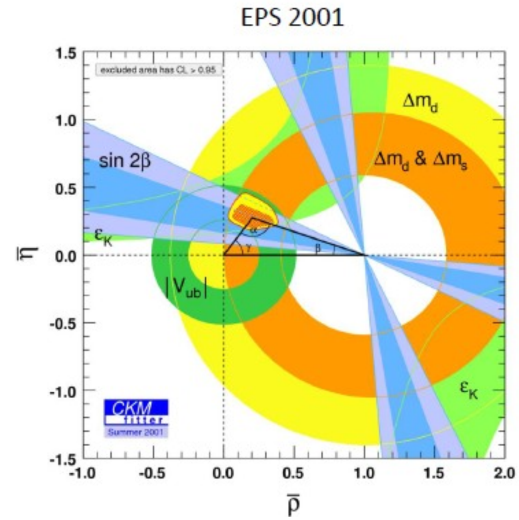


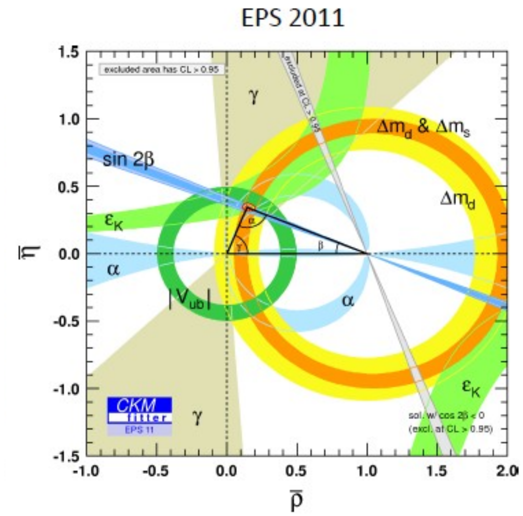
- World record luminosity: 2.1 x 10^{34} $cm^{-2}s^{-1}$ → Twice design
- 1 ab^{-1} of integrated luminosity

Achievements of B-factories

- Observation of mixing-induced CP violation in B^0 system
- Precision measurement of $\sin(2\Phi_1)$
- Observation of direct CPV in B decays
- Measurements of rare decays ($b \rightarrow s\gamma$, $b \rightarrow s l^+ l^-$, $B \rightarrow \tau\nu$, ...)
- Observation of D^0 mixing
- LFV searches in τ decays
- B_s physics at $\Upsilon(5S)$
- Observation of new (exotic) hadrons (η_b, h_b, $X(3872)$, Z_b^+, ...)



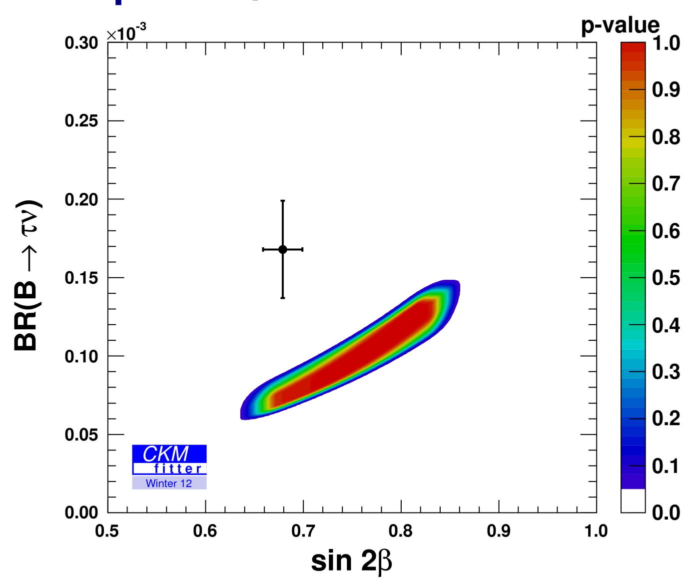


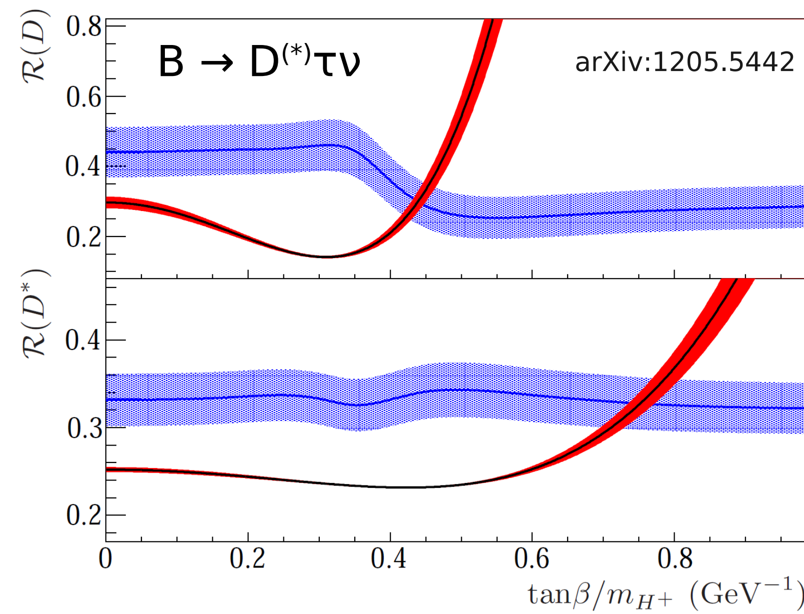


→ Very rich physics program!

Why A Super Flavor Factory?

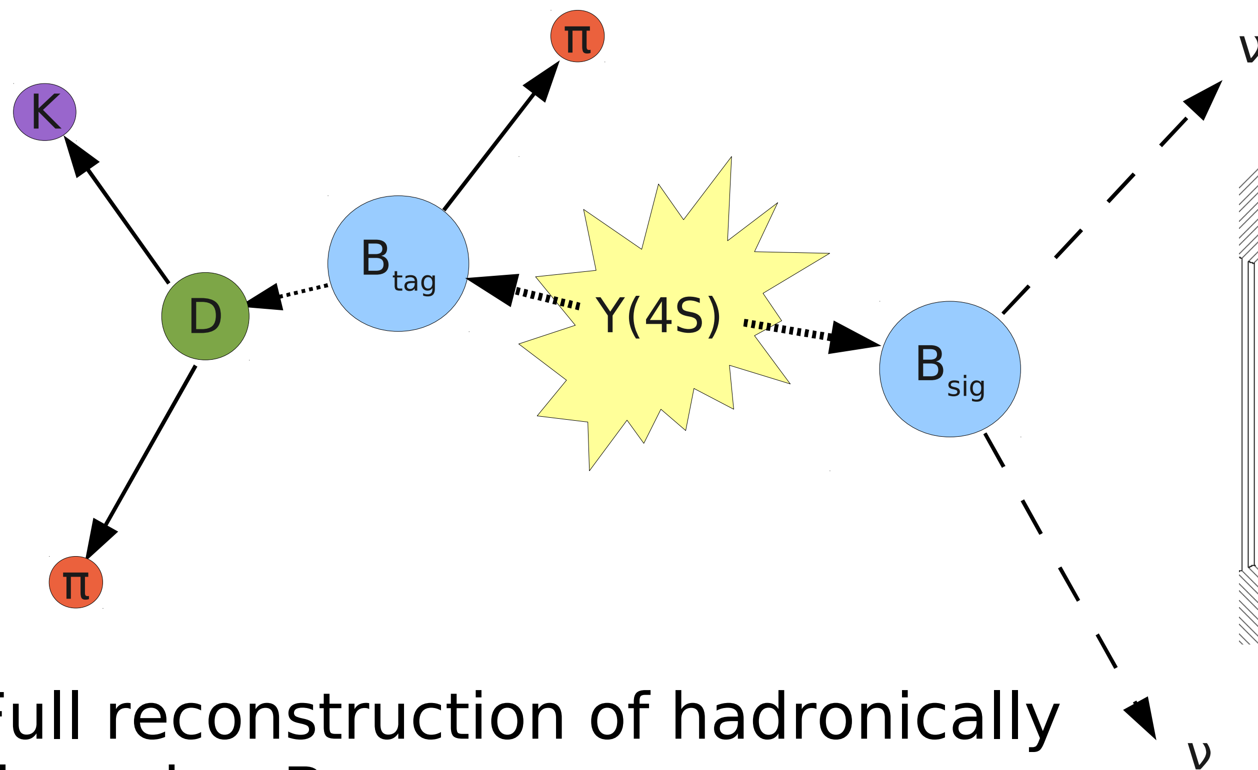
- We know there has to be New Physics somewhere
- Atlas and CMS have not found it (yet?)
- Precision flavor physics measurement may reveal the NP (like in the past)
- Some hints exist



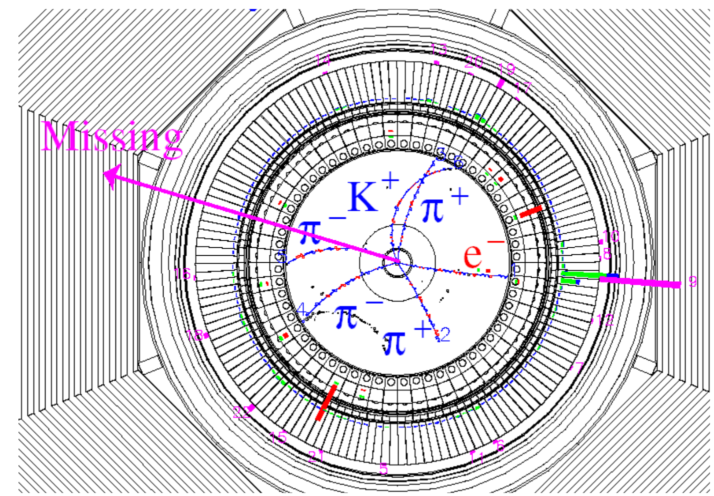


- Several measurements can only be done at B factories and are still limited by statistics

Full Reconstruction at B Factories



$$B^+ \to D^0\pi^+$$
$$(\to K\pi^-\pi^+\pi^-)$$
$$B^- \to \tau(\to e\nu\bar{\nu})\nu$$



- Full reconstruction of hadronically decaying B meson

→ Momentum and charge of signal B known

→ All remaining particles belong to the signal B

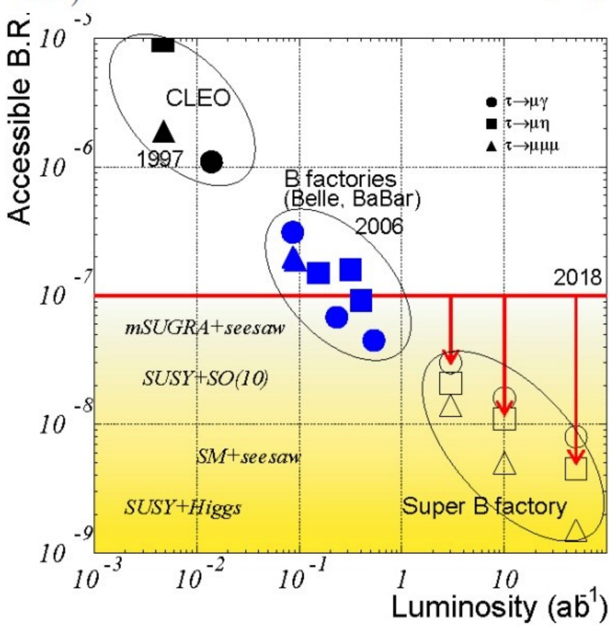
hermeticity!

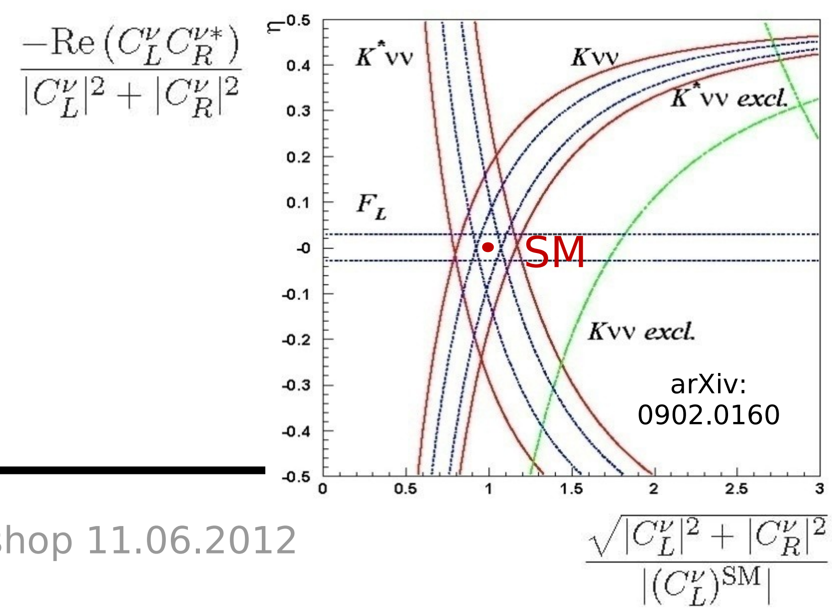
➢ Reconstruction of B → D$^{(*)}$τν, B → τν, B → Kνν, B → νν, ...

Projections for 50 ab^{-1}

arXiv:1002.5012

Observable	Belle 2006 ($\sim$0.5 ab^{-1})	SuperKEKB (5 ab^{-1})	SuperKEKB (50 ab^{-1})	†LHCb (2 fb^{-1})	†LHCb (10 fb^{-1})
Leptonic/semileptonic B decays					
$\mathcal{B}(B^+ \to \tau^+\nu)$	3.5σ	10%	3%	-	-
$\mathcal{B}(B^+ \to \mu^+\nu)$	†† $< 2.4\mathcal{B}_{SM}$	4.3 ab^{-1} for 5σ discovery		-	-
$\mathcal{B}(B^+ \to D\tau\nu)$	-	8%	3%	-	-
$\mathcal{B}(B^0 \to D\tau\nu)$	-	30%	10%	-	-
LFV in τ decays (U.L. at 90% C.L.)					
$\mathcal{B}(\tau \to \mu\gamma)$ $[10^{-9}]$	45	10	5	-	-
$\mathcal{B}(\tau \to \mu\eta)$ $[10^{-9}]$	65	5	2	-	-
$\mathcal{B}(\tau \to \mu\mu\mu)$ $[10^{-9}]$	21	3	1	-	-
$\mathcal{B}(B^+ \to K^+\nu\nu)$	†† $< 3\ \mathcal{B}_{SM}$		30%	-	-
$\mathcal{B}(B^0 \to K^{*0}\nu\bar{\nu})$	†† $< 40\ \mathcal{B}_{SM}$		35%	-	-

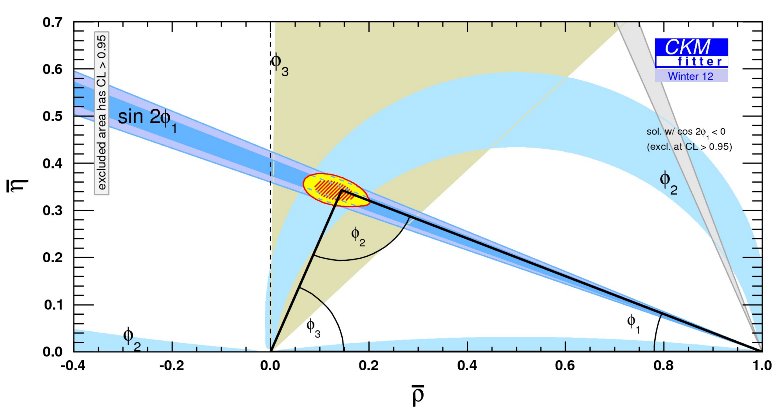


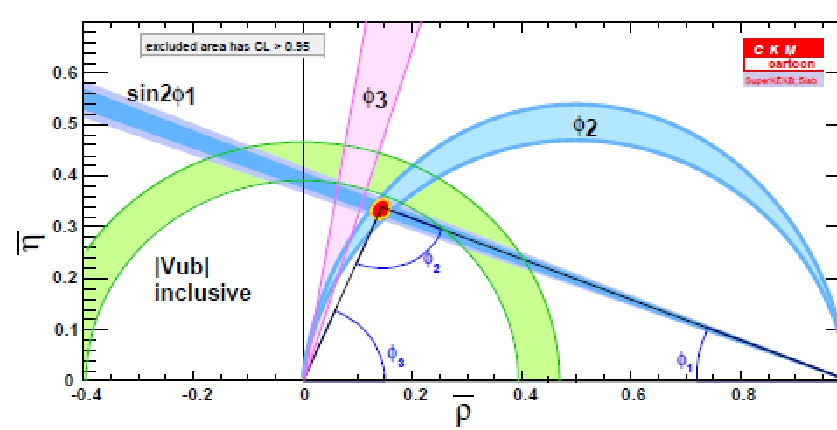


Projections for 50 ab^{-1}

arXiv:1002.5012

Observable	Belle 2006 (~0.5 ab^{-1})	SuperKEKB (5 ab^{-1})	SuperKEKB (50 ab^{-1})	†LHCb (2 fb^{-1})	†LHCb (10 fb^{-1})
Unitarity triangle parameters					
$\sin 2\phi_1$	0.026	0.016	0.012	~0.02	~0.01
ϕ_2 $(\pi\pi)$	11°	10°	3°	-	-
ϕ_2 $(\rho\pi)$	$68^\circ < \phi_2 < 95^\circ$	3°	1.5°	10°	4.5°
ϕ_2 $(\rho\rho)$	$62^\circ < \phi_2 < 107^\circ$	3°	1.5°	-	-
ϕ_2 (combined)		2°	$\lesssim 1^\circ$	10°	4.5°
ϕ_3 $(D^{(*)}K^{(*)})$ (Dalitz mod. ind.)	20°	7°	2°	8°	
ϕ_3 $(DK^{(*)})$ (ADS+GLW)	-	16°	5°	5-15°	
ϕ_3 $(D^{(*)}\pi)$	-	18°	6°		
ϕ_3 (combined)		6°	1.5°	4.2°	2.4°
$\lvert V_{ub}\rvert$ (inclusive)	6%	5%	3%	-	-
$\lvert V_{ub}\rvert$ (exclusive)	15%	12% (LQCD)	5% (LQCD)	-	-
$^{\dagger\dagger\dagger}\bar{\rho}$	20.0%		3.4%		
$^{\dagger\dagger\dagger}\bar{\eta}$	15.7%		1.7%		

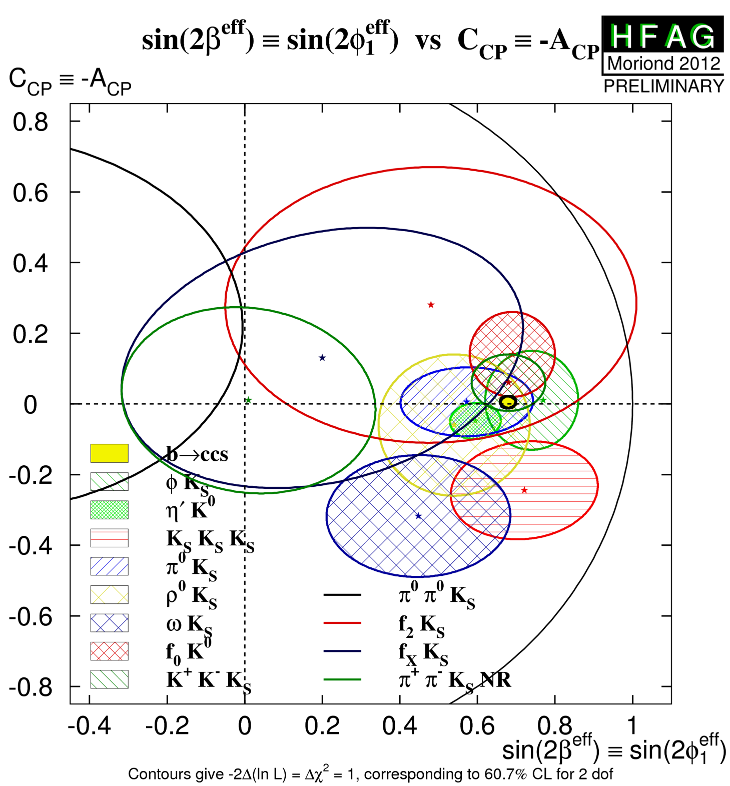


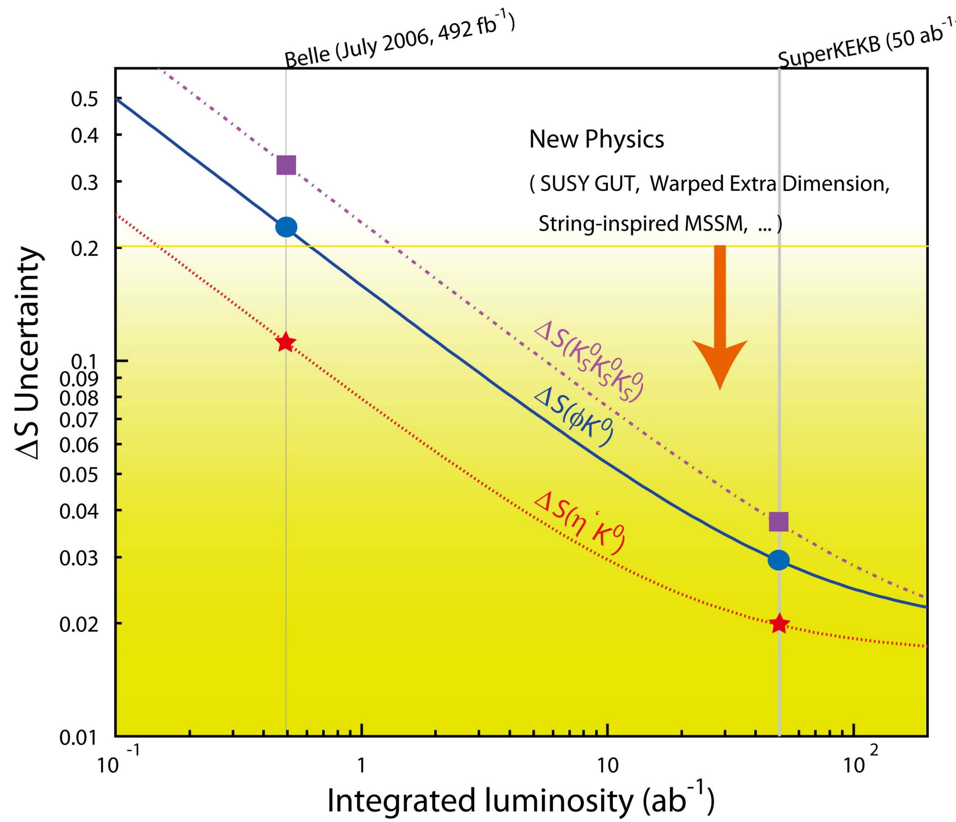


Projections for 50 ab^{-1}

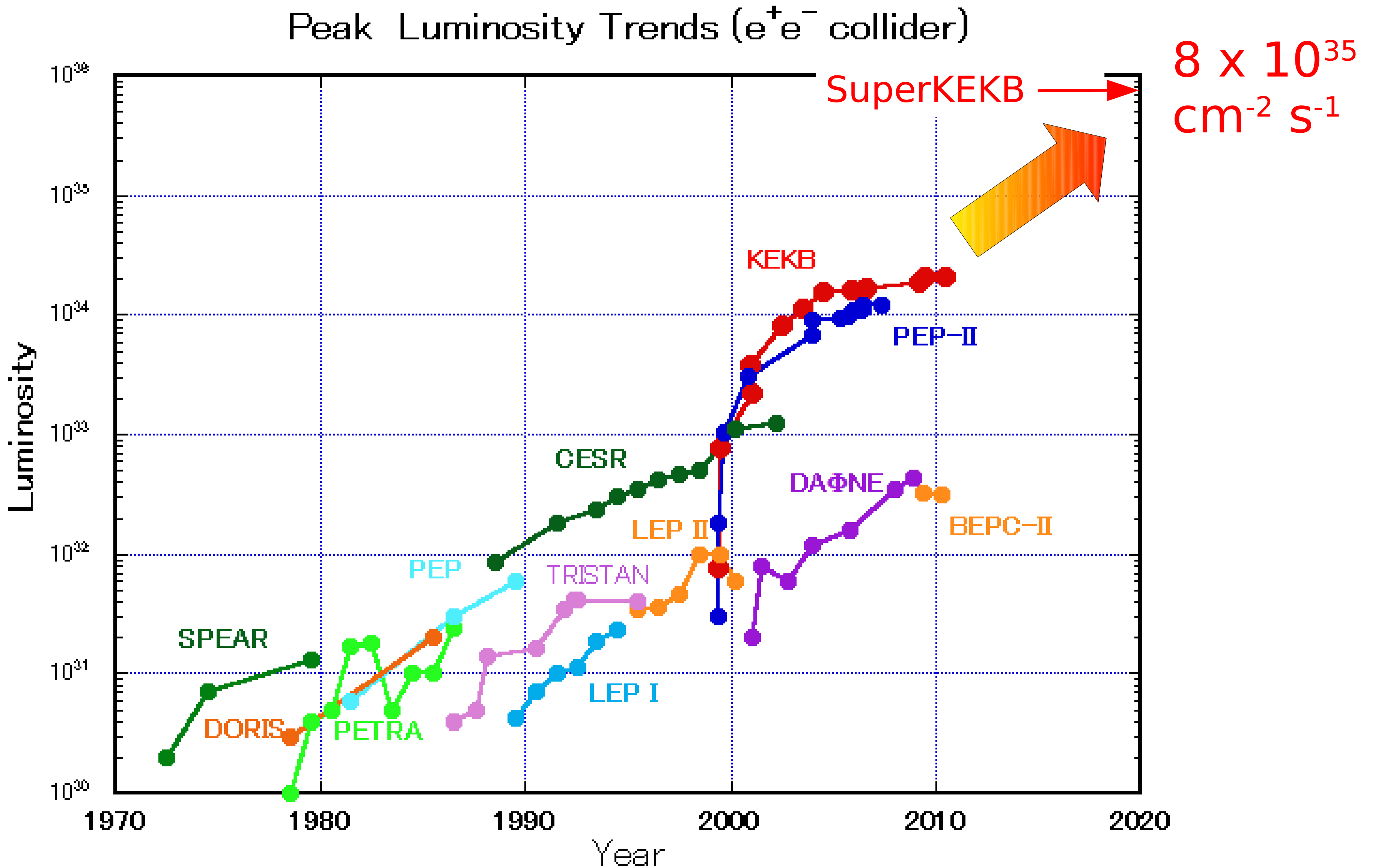
arXiv:1002.5012

Observable	Belle 2006	SuperKEKB		†LHCb	
	($\sim$0.5 ab^{-1})	(5 ab^{-1})	(50 ab^{-1})	(2 fb^{-1})	(10 fb^{-1})
Hadronic $b \to s$ transitions					
$\Delta\mathcal{S}_{\phi K^0}$	0.22	0.073	0.029		0.14
$\Delta\mathcal{S}_{\eta' K^0}$	0.11	0.038	0.020		
$\Delta\mathcal{S}_{K_S^0 K_S^0 K_S^0}$	0.33	0.105	0.037	-	-
$\Delta\mathcal{A}_{\pi^0 K_S^0}$	0.15	0.072	0.042	-	-
$\mathcal{A}_{\phi\phi K^+}$	0.17	0.05	0.014		
$\phi_1^{eff}(\phi K_S)$ Dalitz		3.3°	1.5°		





Aim For 50 ab^{-1}



Accelerator Design: Nano Beam Scheme

Invented by Pantaleo Raimondi for SuperB

Beam-Beam parameter $\xi_y \propto \sqrt{(\beta_y^*/\varepsilon_y)}$

Lorentz factor

Beam current

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

Geometrical reduction factors (crossing angle, hourglass effect)

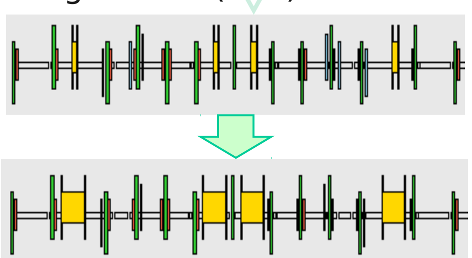
Vertical beta function at IP

Beam aspect ratio at IP

	β_x^* (cm)	β_y^* (mm)	ξ_y	ϵ_x (nm)	I_{beam} (A)	L ($cm^{-2}\ s^{-1}$)
KEKB w/ crab	120/120	5.9/5.9	0.13/0.09	18/24	1.6/1.2	2.11 x 10^{34}
SuperKEKB	3.2/2.5	0.27/0.31	0.09/0.08	3.2/5.0	3.6/2.6	**80 x 10^{34}**

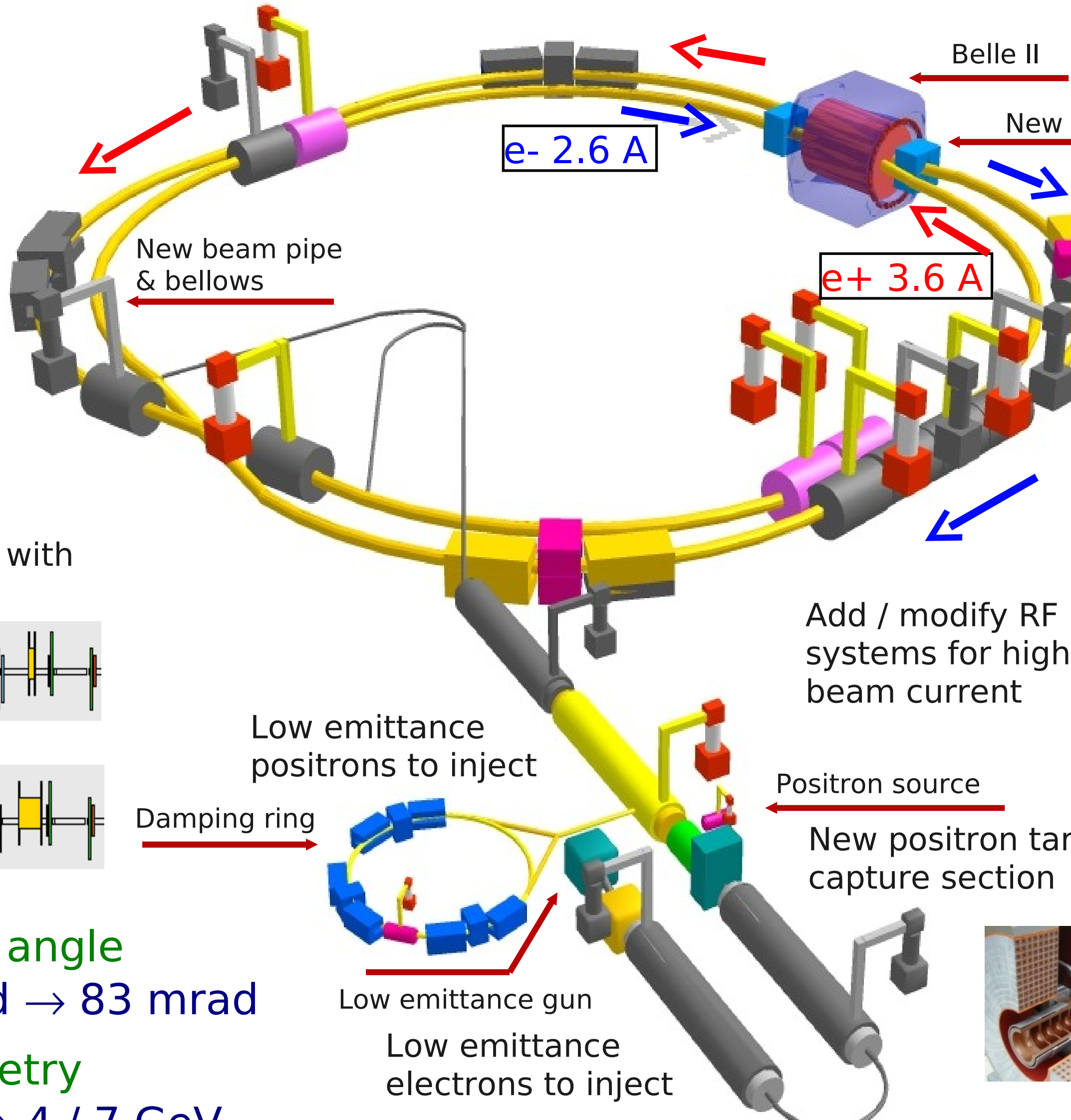
SuperKEKB Upgrade

Replace short dipoles with longer ones (LER)

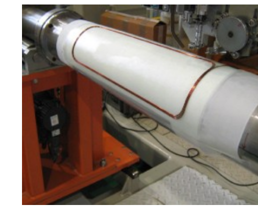


Larger crossing angle
$2\phi = 22$ mrad $\rightarrow$ 83 mrad

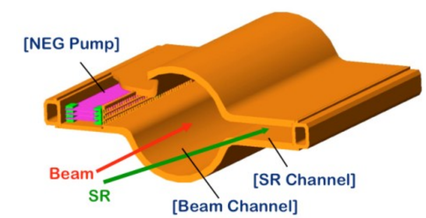
Smaller asymmetry
3.5 / 8 GeV $\rightarrow$ 4 / 7 GeV



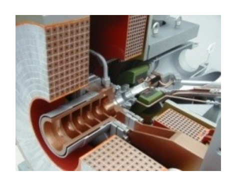
New superconducting /permanent final focusing quads near the IP



TiN-coated beam pipe with antechambers



Redesign the lattices of HER & LER to squeeze the emittance



SuperKEKB Construction

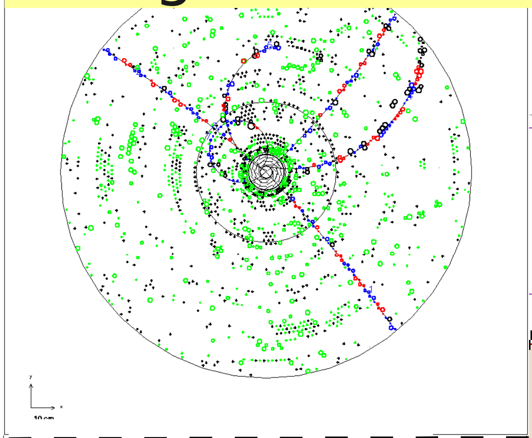
- Installation of first dipole magnet on February 7, 2012

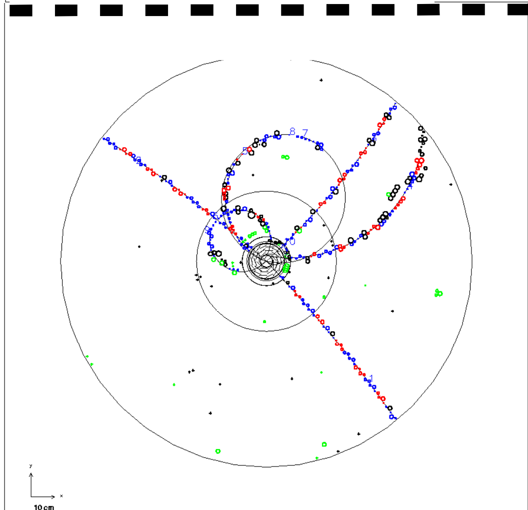
SuperKEKB Construction

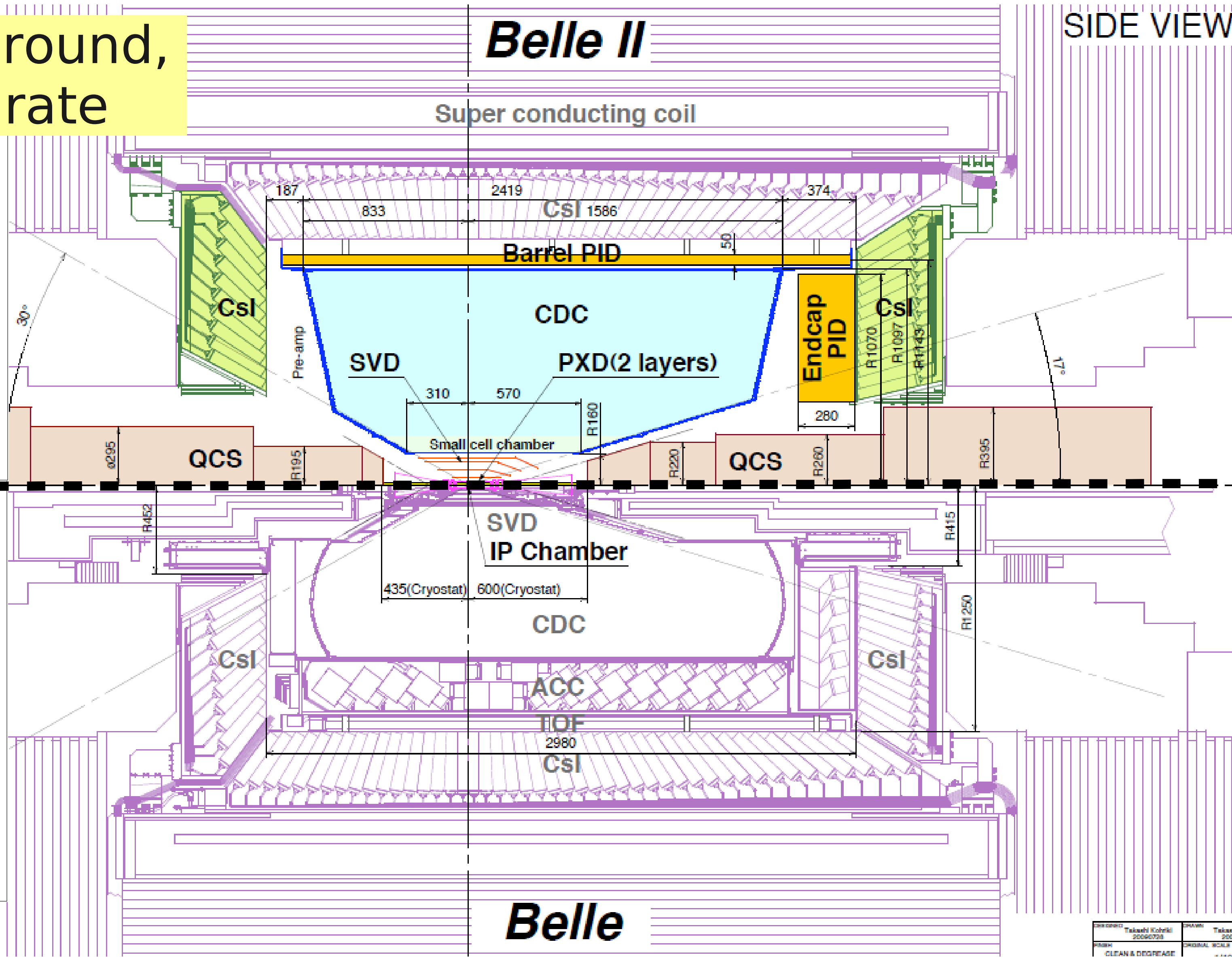
- Damping ring construction started

Belle II Detector Compared with Belle

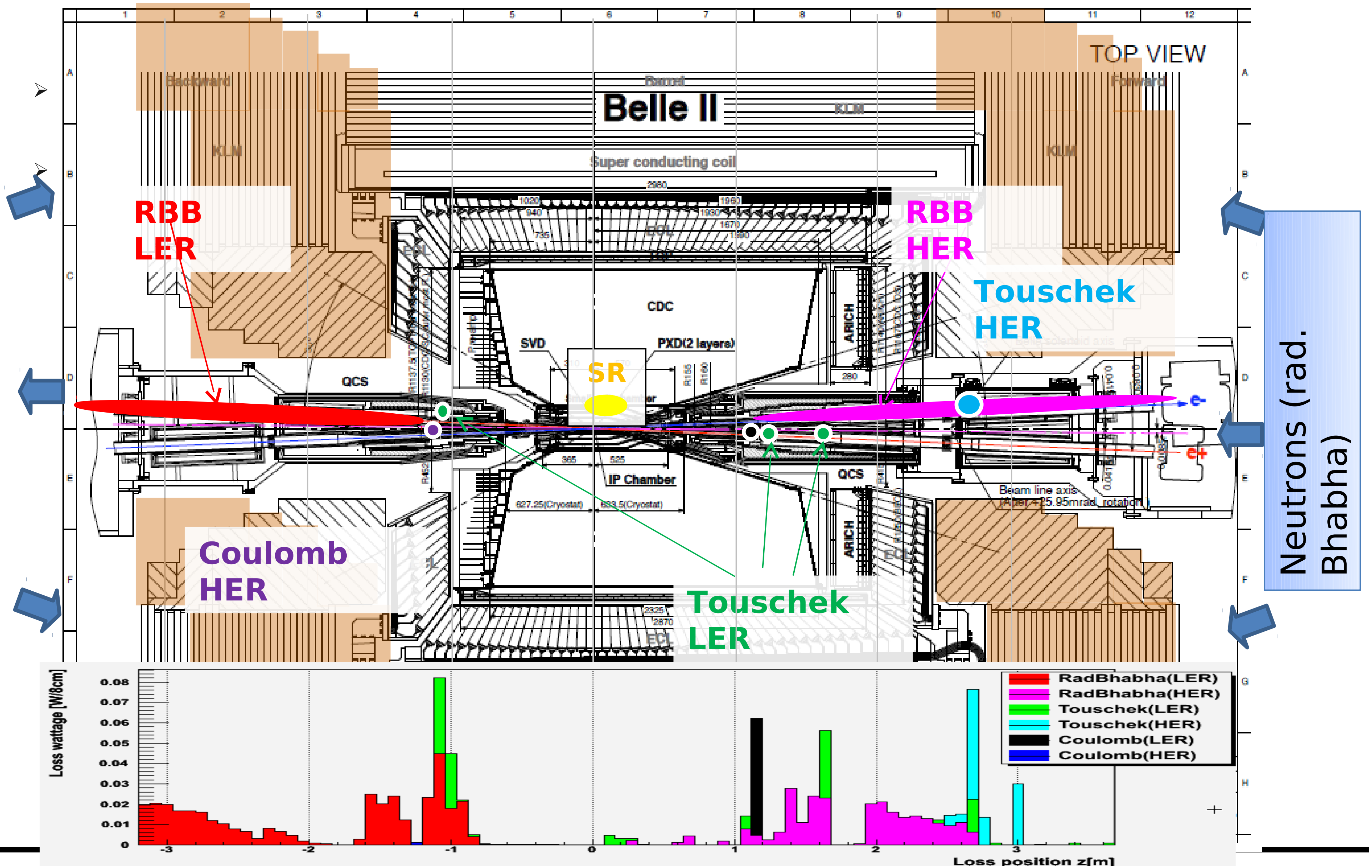
- Higher background, higher event rate



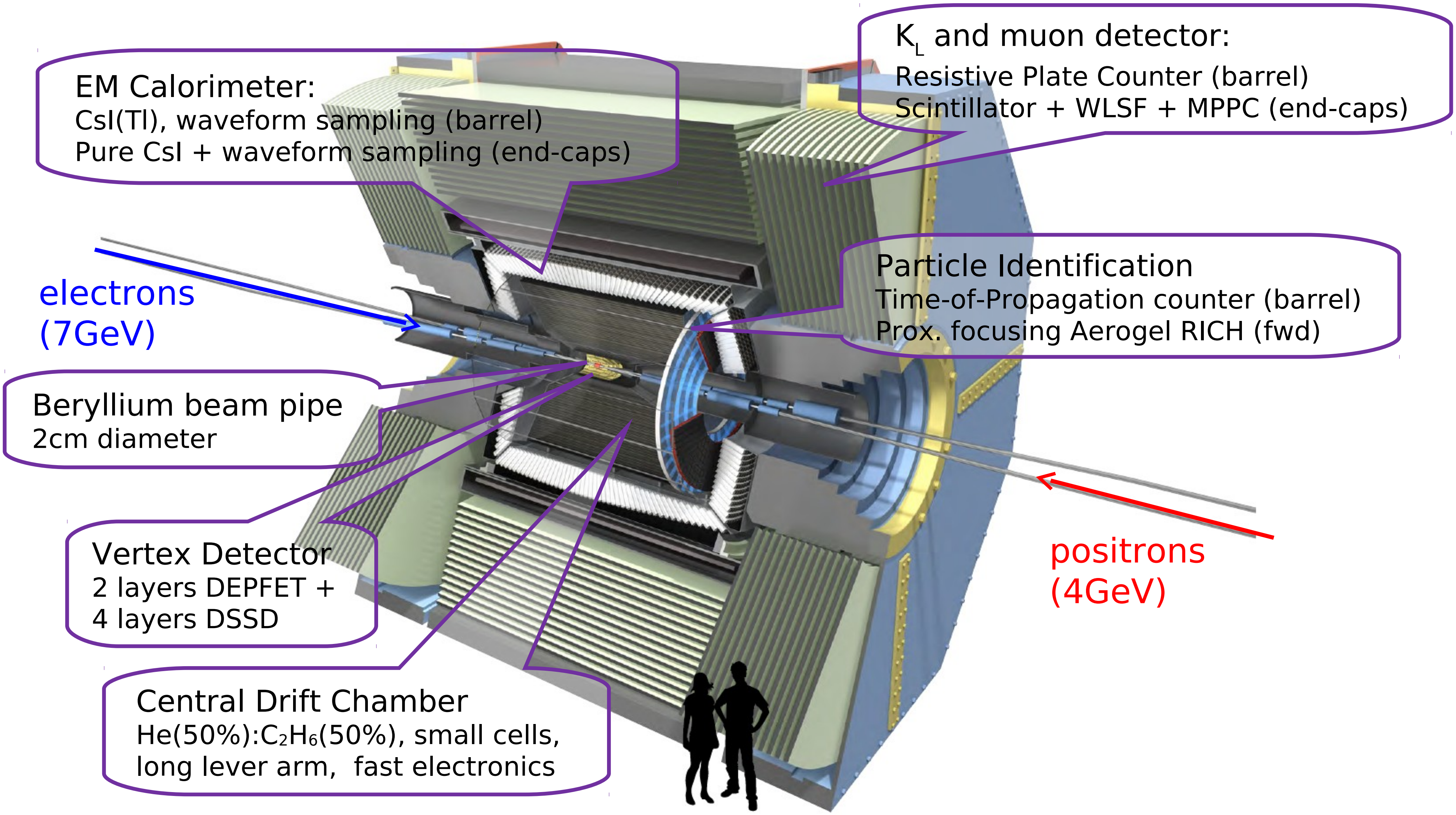




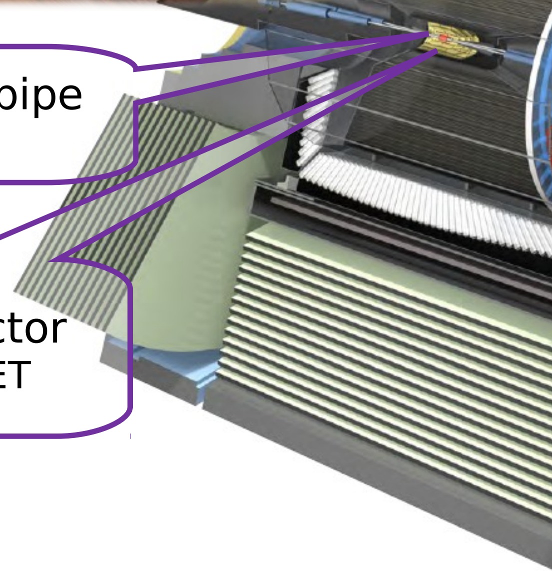
Background Simulation



Belle II Detector

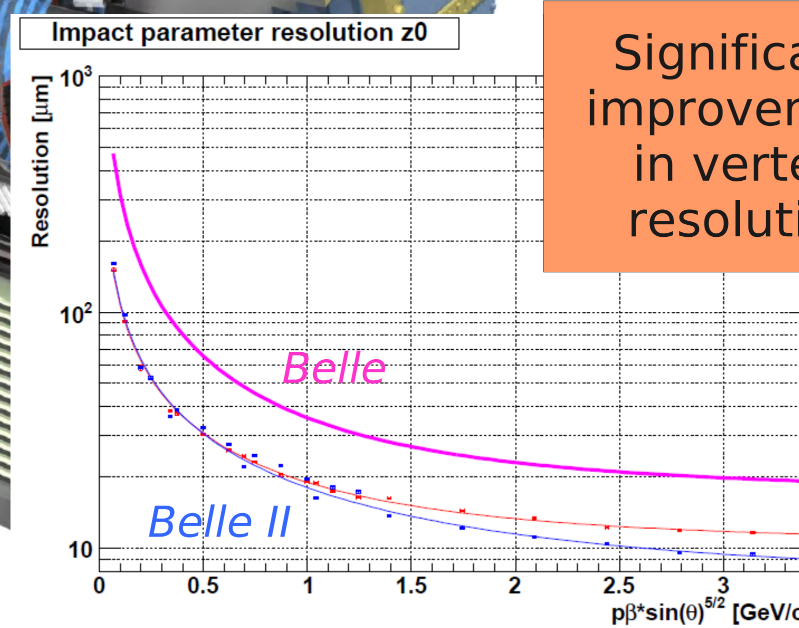


Beam Pipe and Pixel Detector



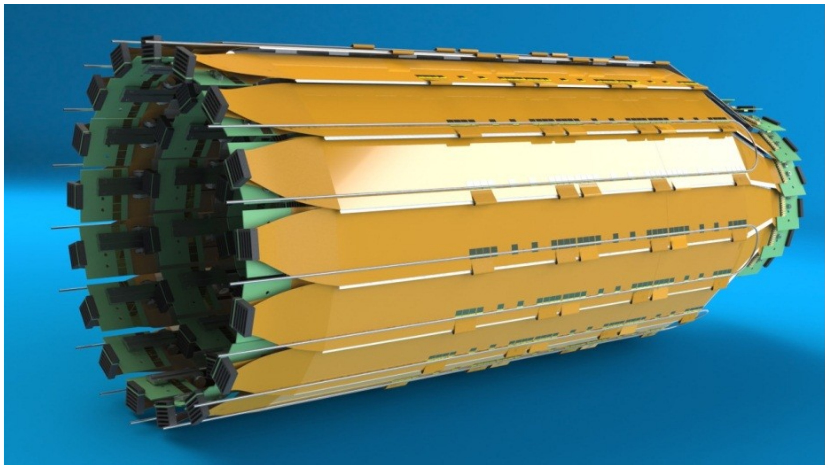
Beryllium beam pipe
2cm diameter

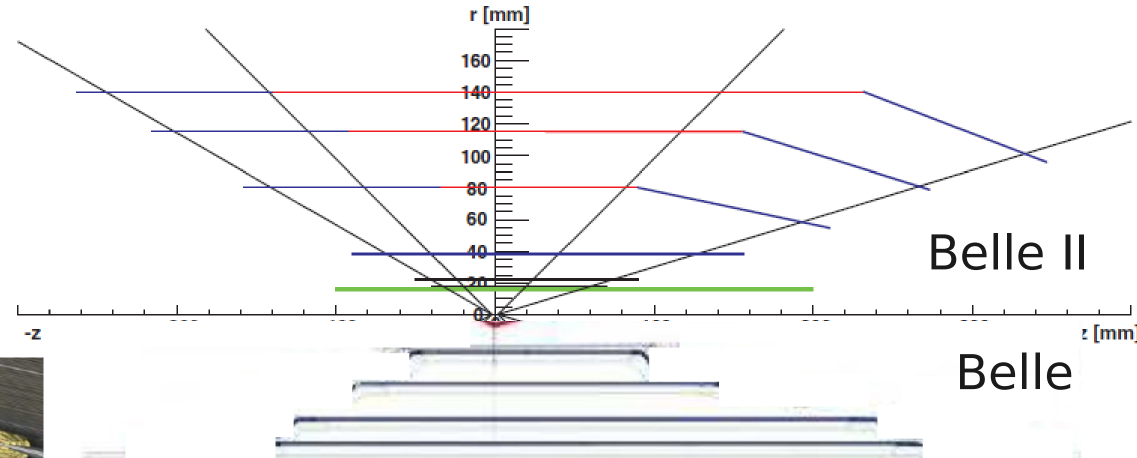
Vertex Detector
2 layers DEPFET



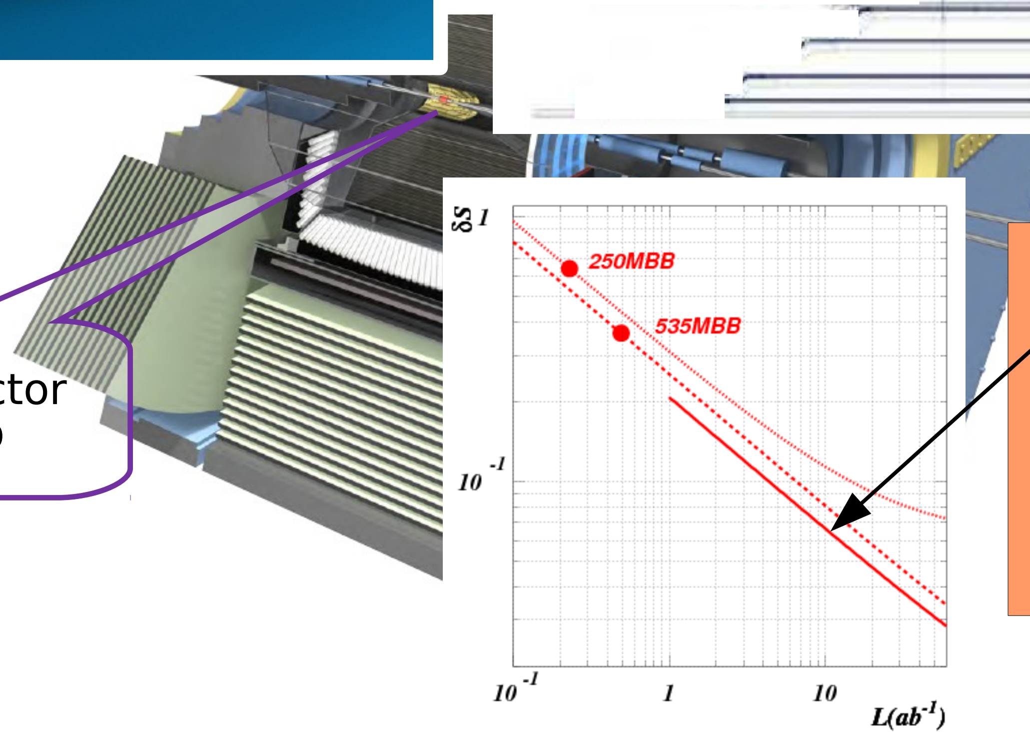
Significant improvement in vertex resolution

Silicon Strip Detector



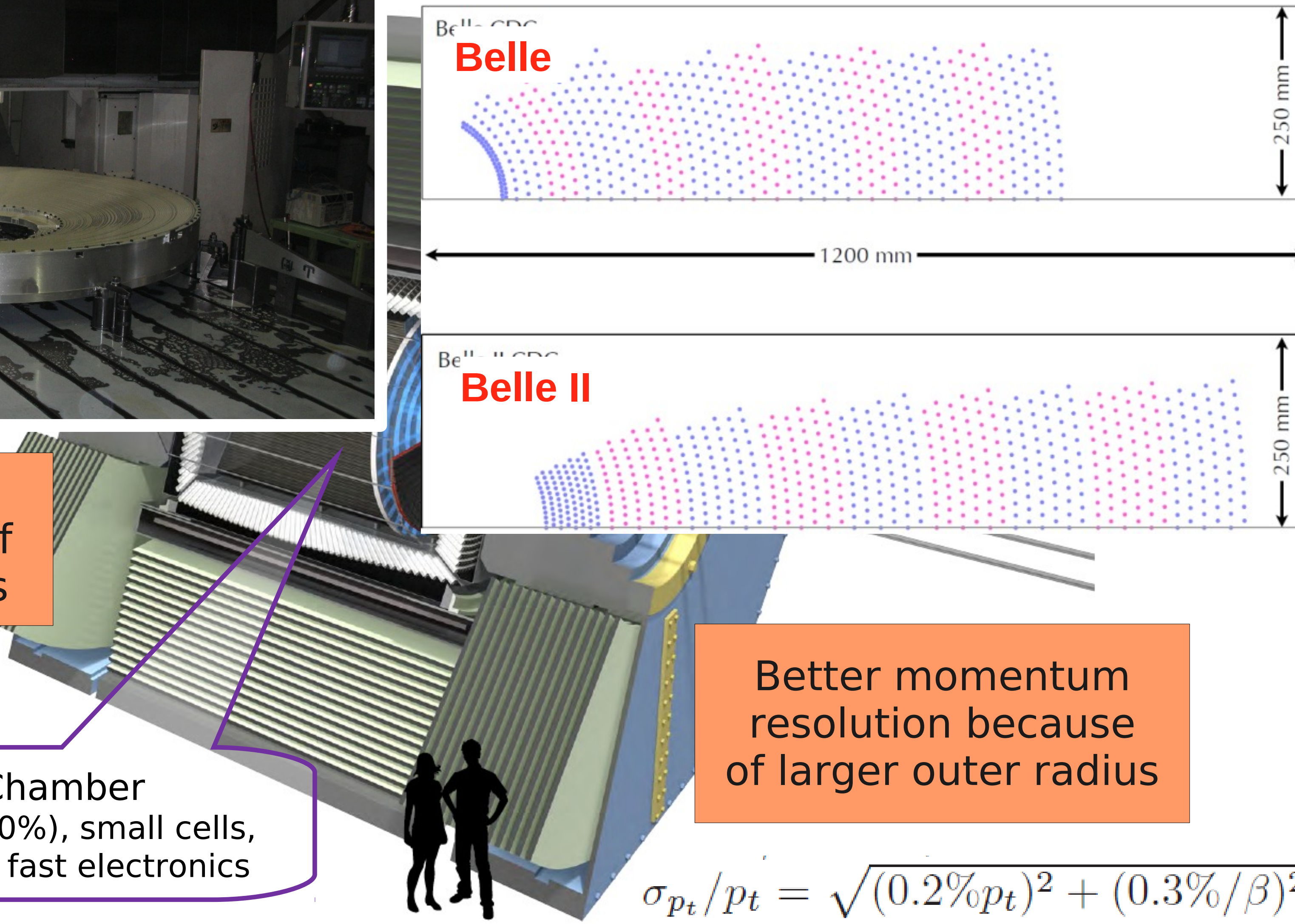


Vertex Detector
4 layers DSSD



Improvement in $\delta S(K_S\pi^0\gamma)$ because of larger K_S acceptance (by ~30%)

Drift Chamber



Reduced dead time because of new electronics

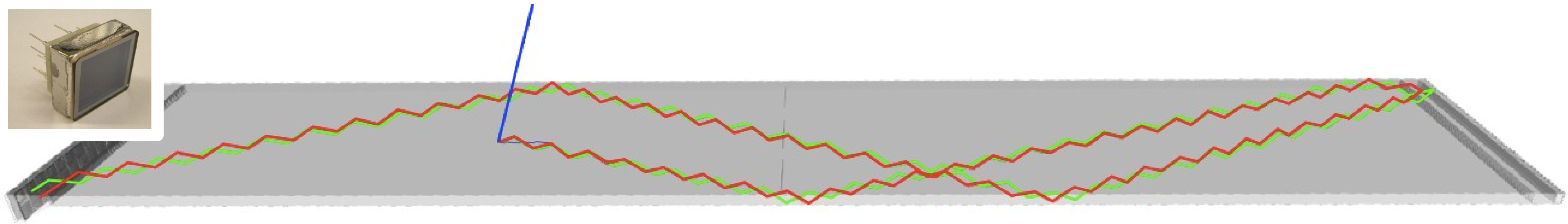
1-2 µs → 200 ns

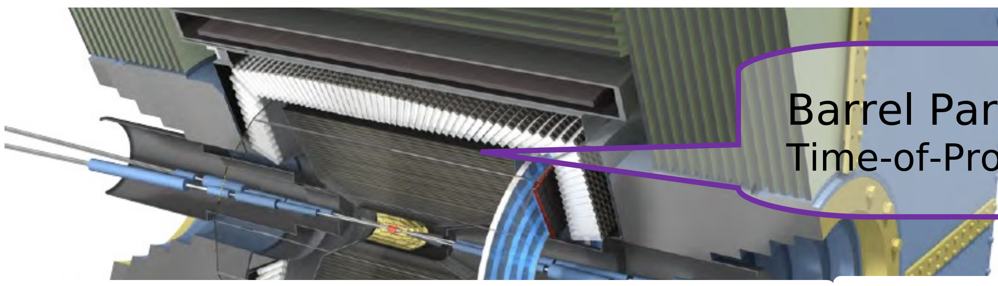
Central Drift Chamber
$He(50\%):C_2H_6(50\%)$, small cells, long lever arm, fast electronics

Better momentum resolution because of larger outer radius

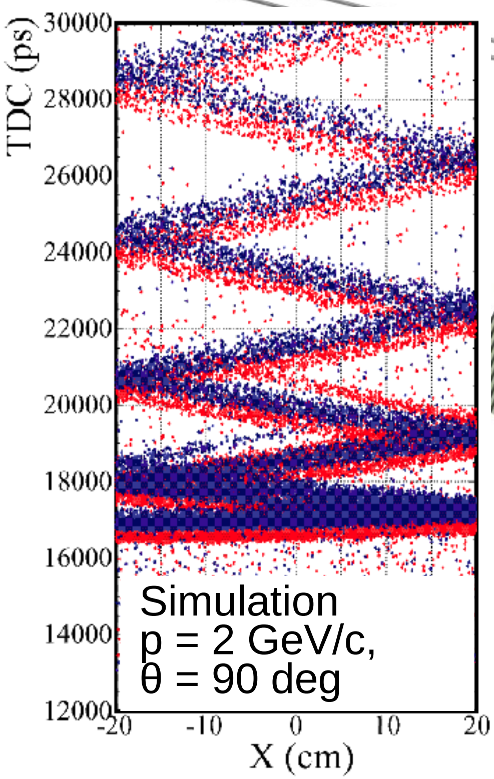
$$\sigma_{p_t}/p_t = \sqrt{(0.2\% p_t)^2 + (0.3\%/\beta)^2}$$

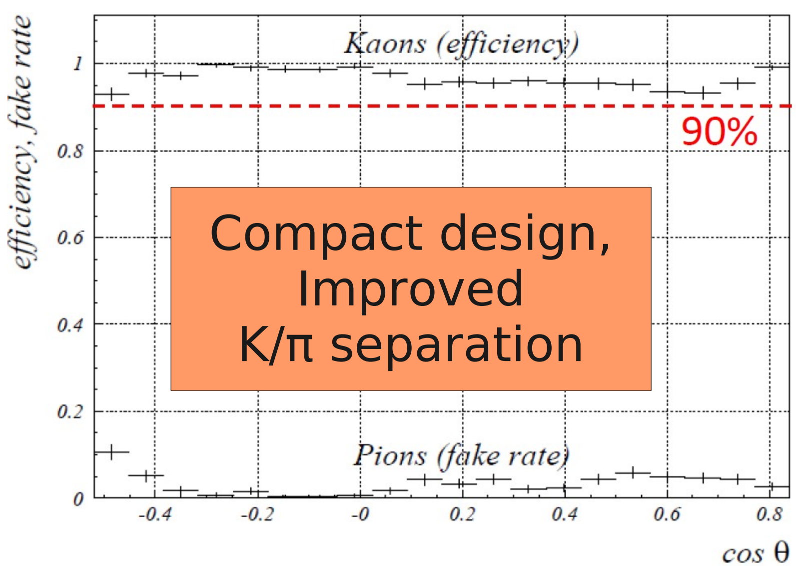
Barrel Particle Identification



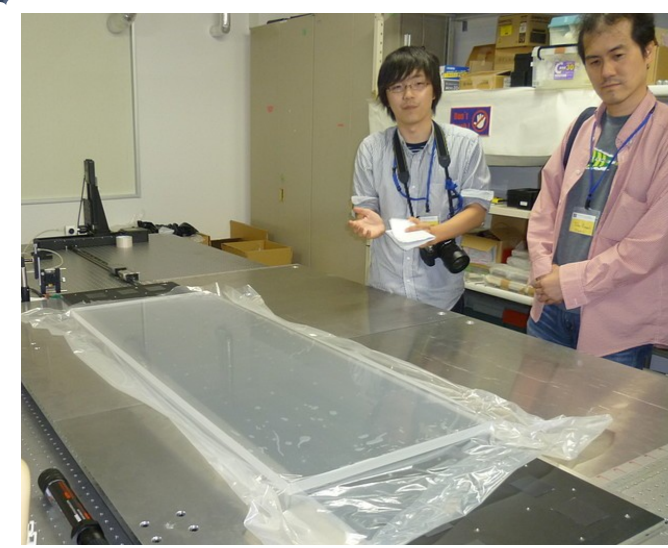


Barrel Particle Identification
Time-of-Propagation counter

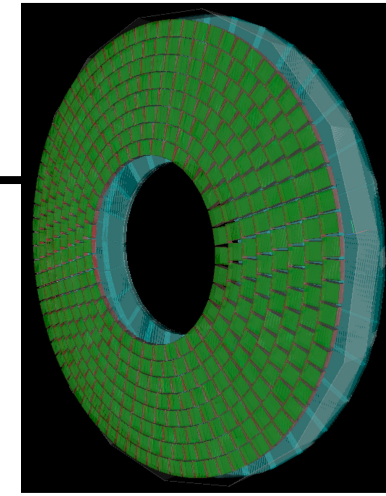


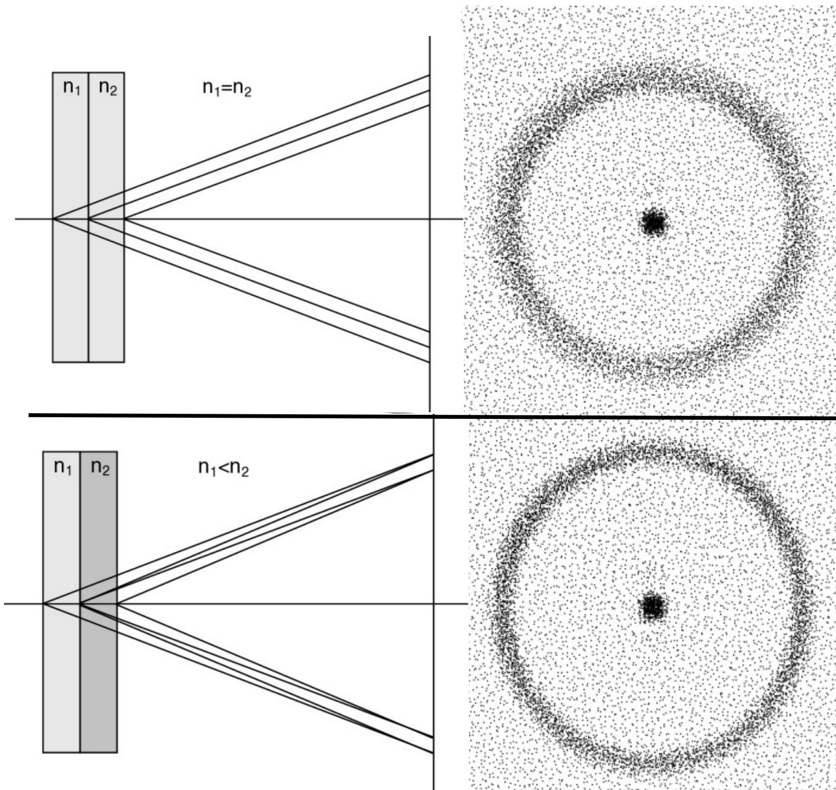


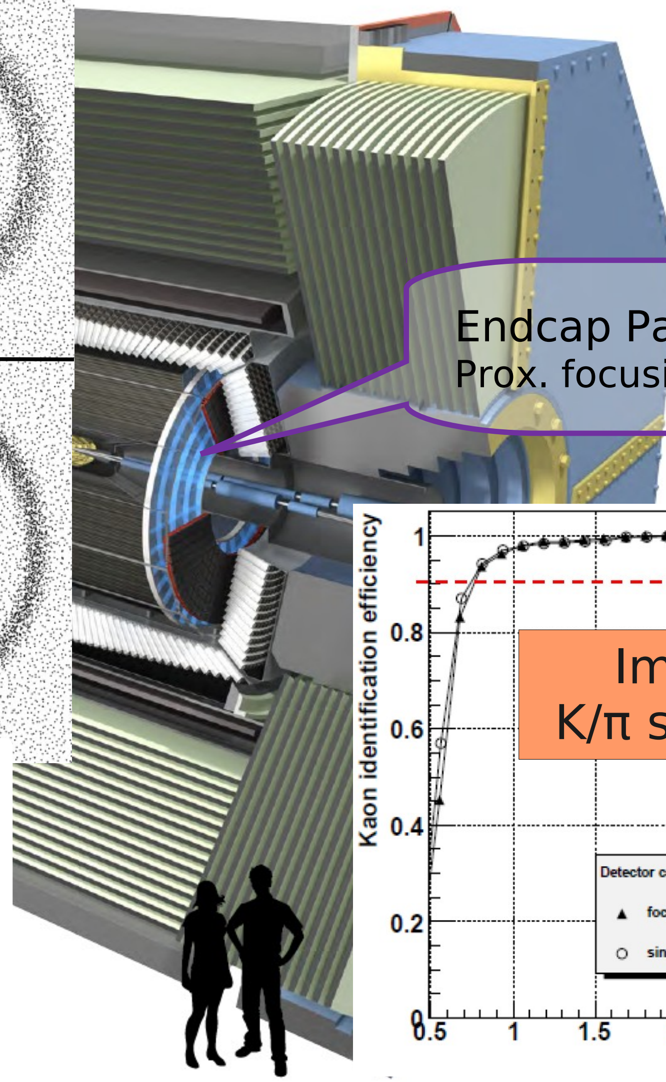
Compact design,
Improved
K/π separation



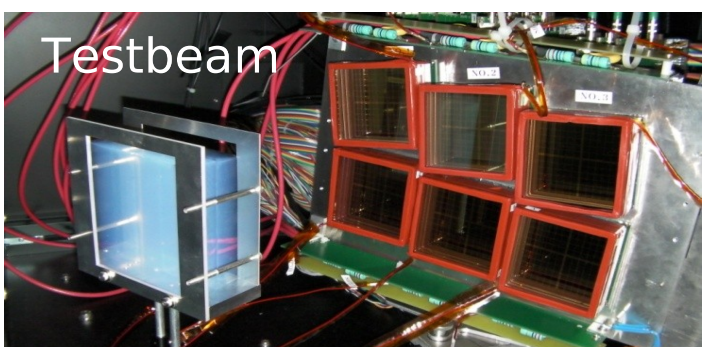
Endcap Particle Identification

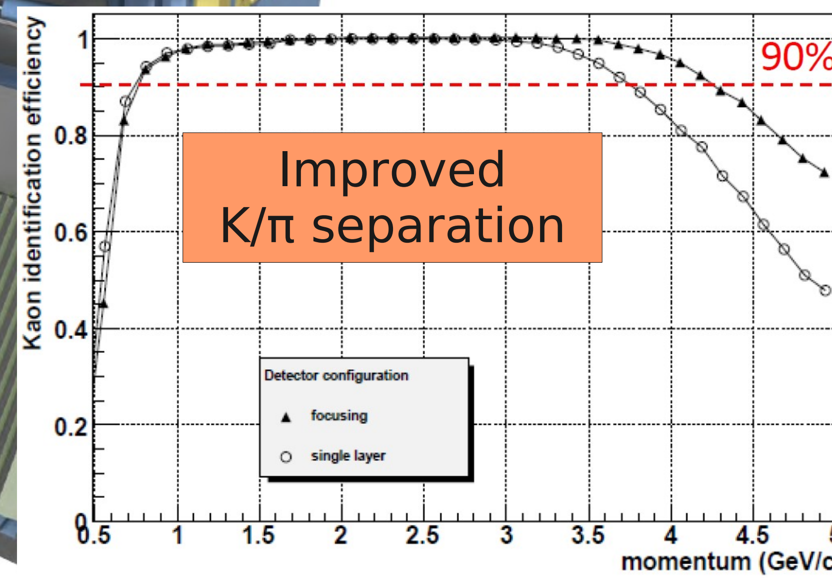






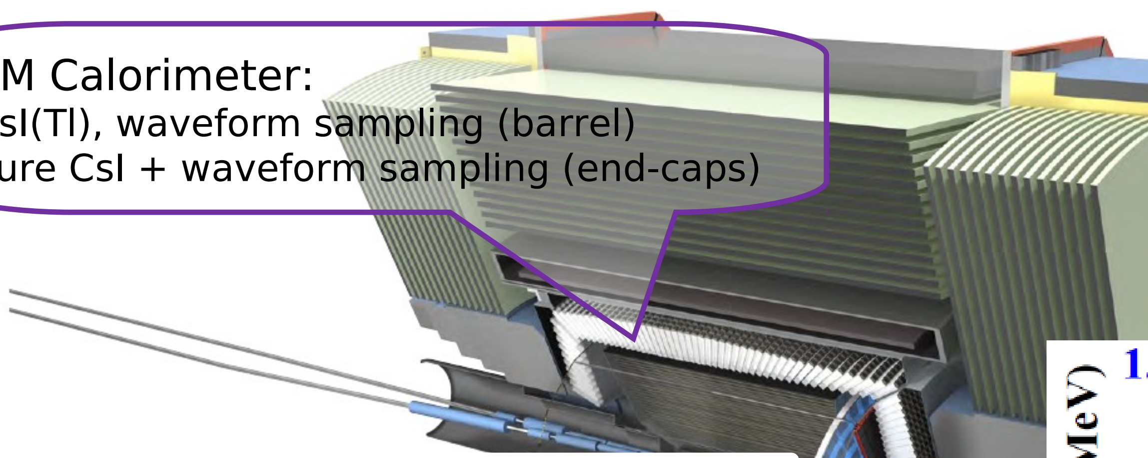
Endcap Particle Identification
Prox. focusing Aerogel RICH



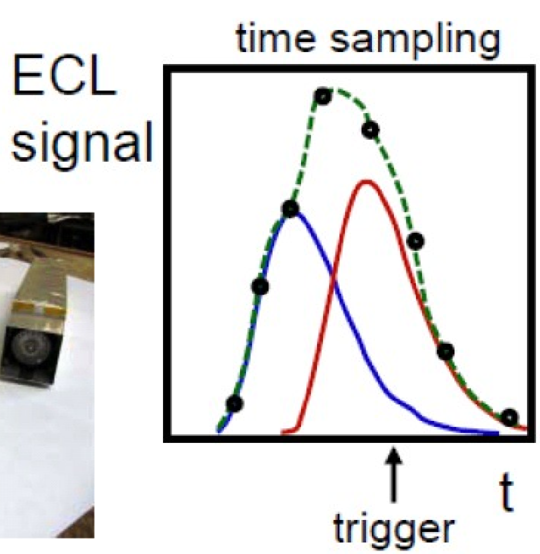


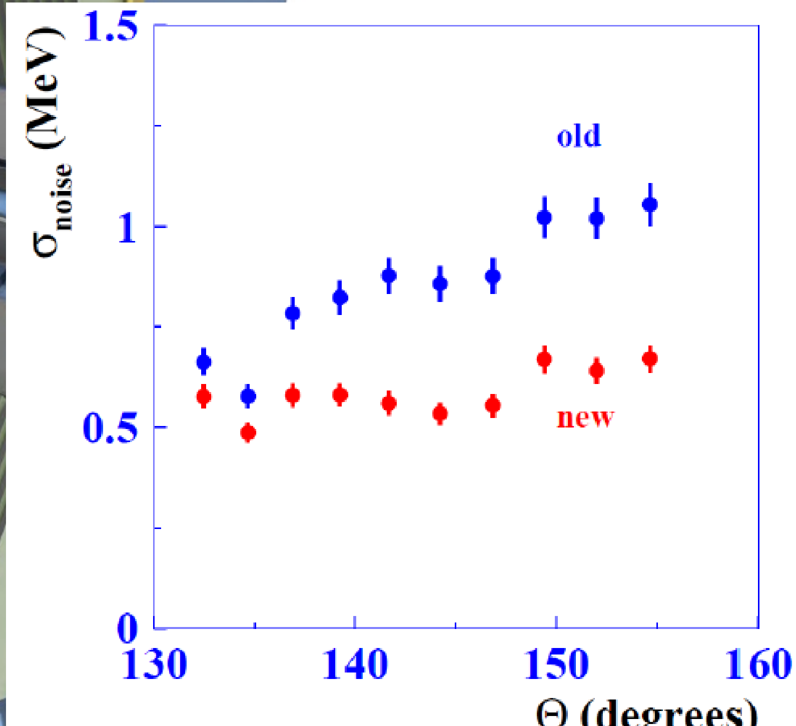
EM Calorimeter

EM Calorimeter:
CsI(Tl), waveform sampling (barrel)
Pure CsI + waveform sampling (end-caps)



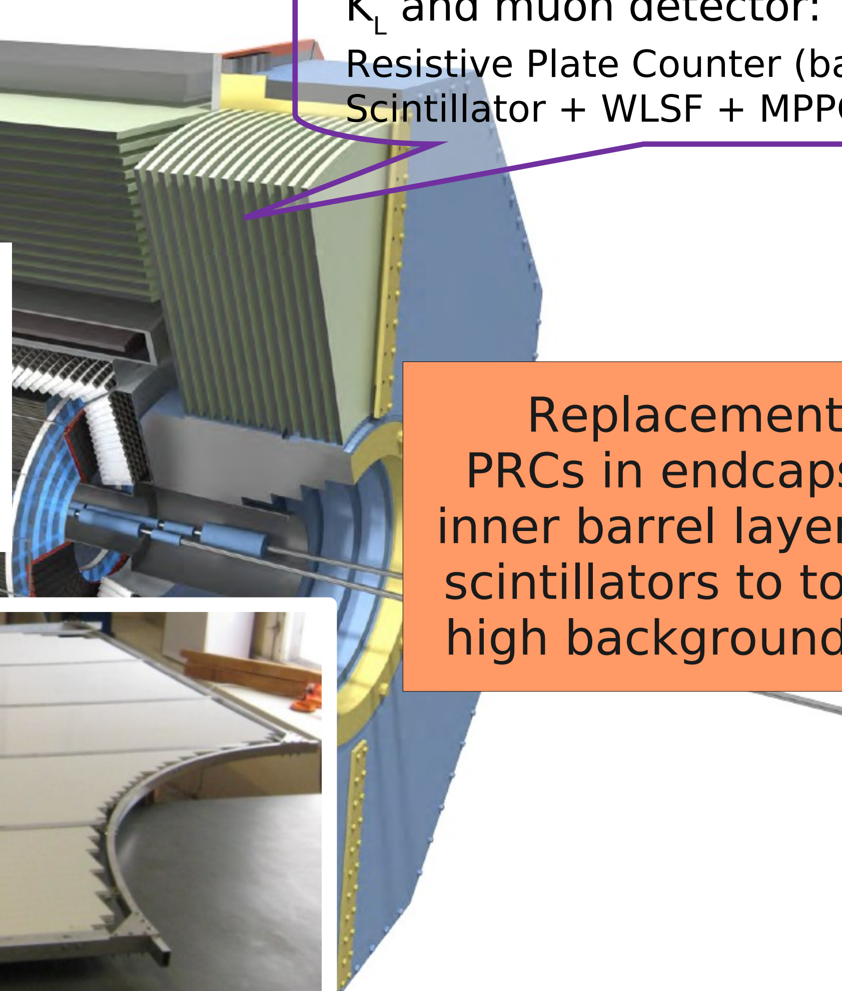
Better signal to background separation because of wave form sampling and pure CsI in endcaps

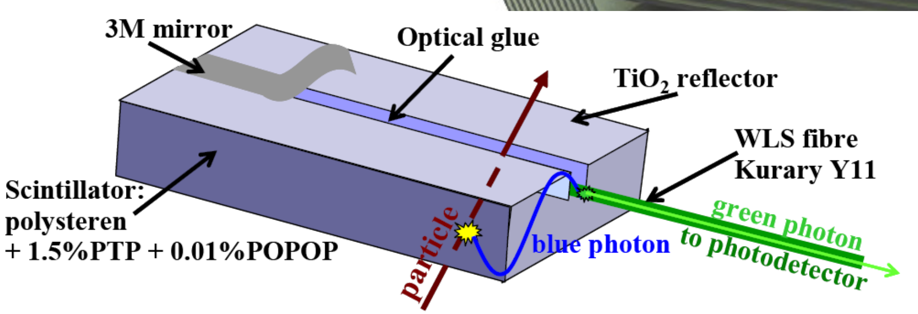


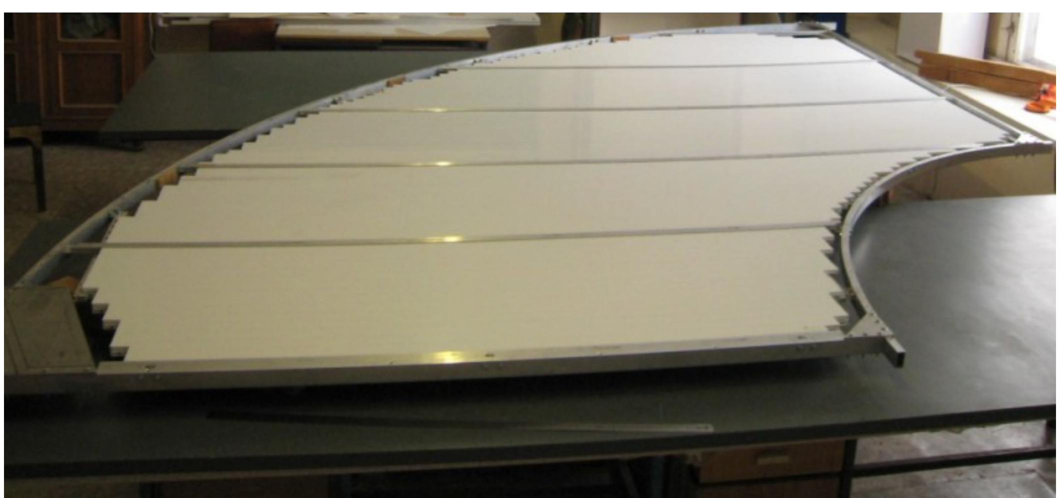


K_L and Muon Detector

K_L and muon detector:
Resistive Plate Counter (barrel)
Scintillator + WLSF + MPPC (end-caps)



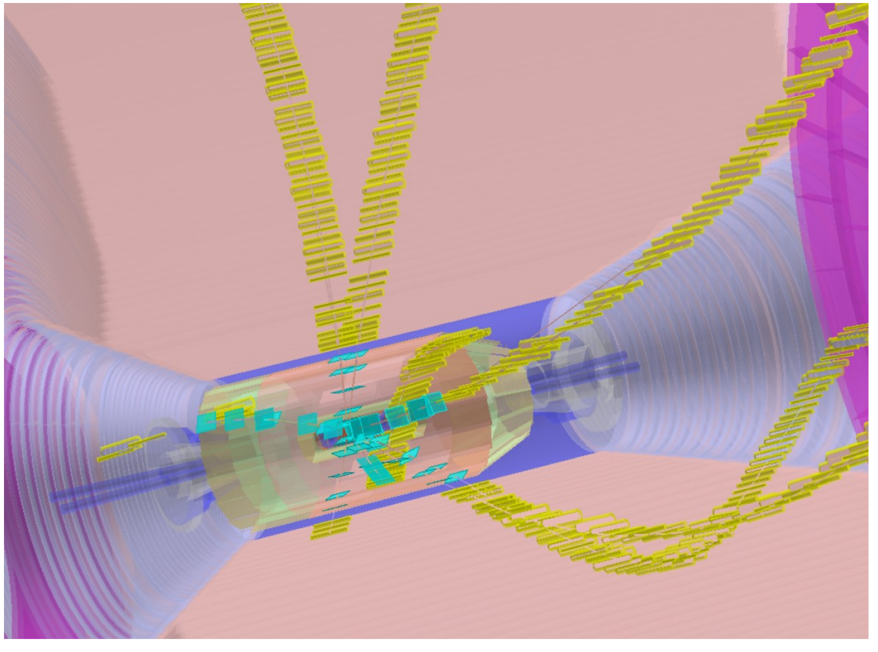


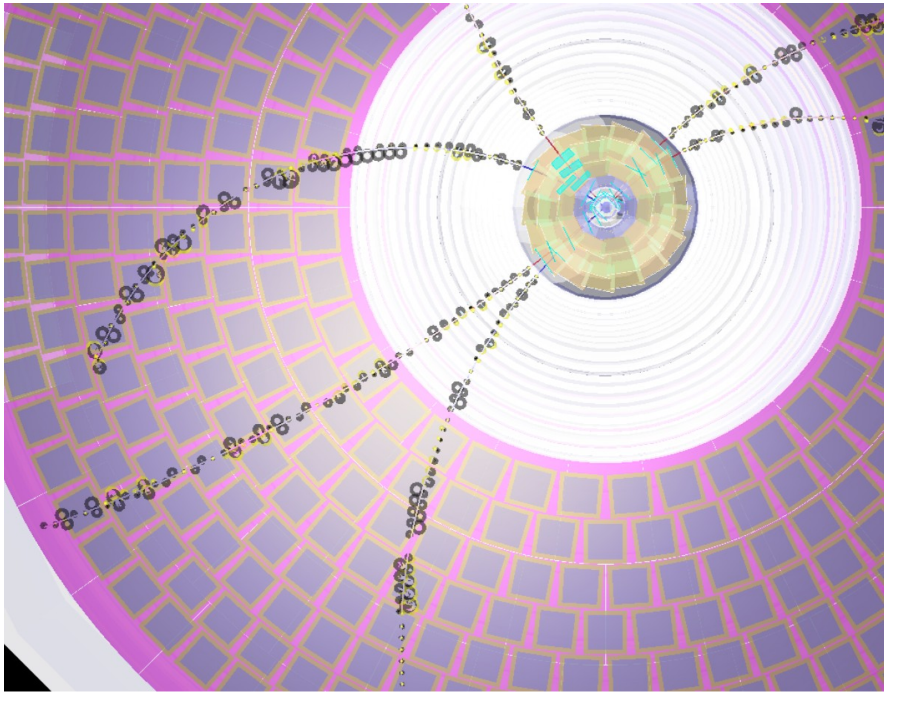


Replacement of PRCs in endcaps and inner barrel layers with scintillators to tolerate high background rates

Software Upgrade

- New framework with dynamic module loading, parallel processing, python steering, and root I/O
- Full detector simulation with Geant4
- Tracking with GenFit

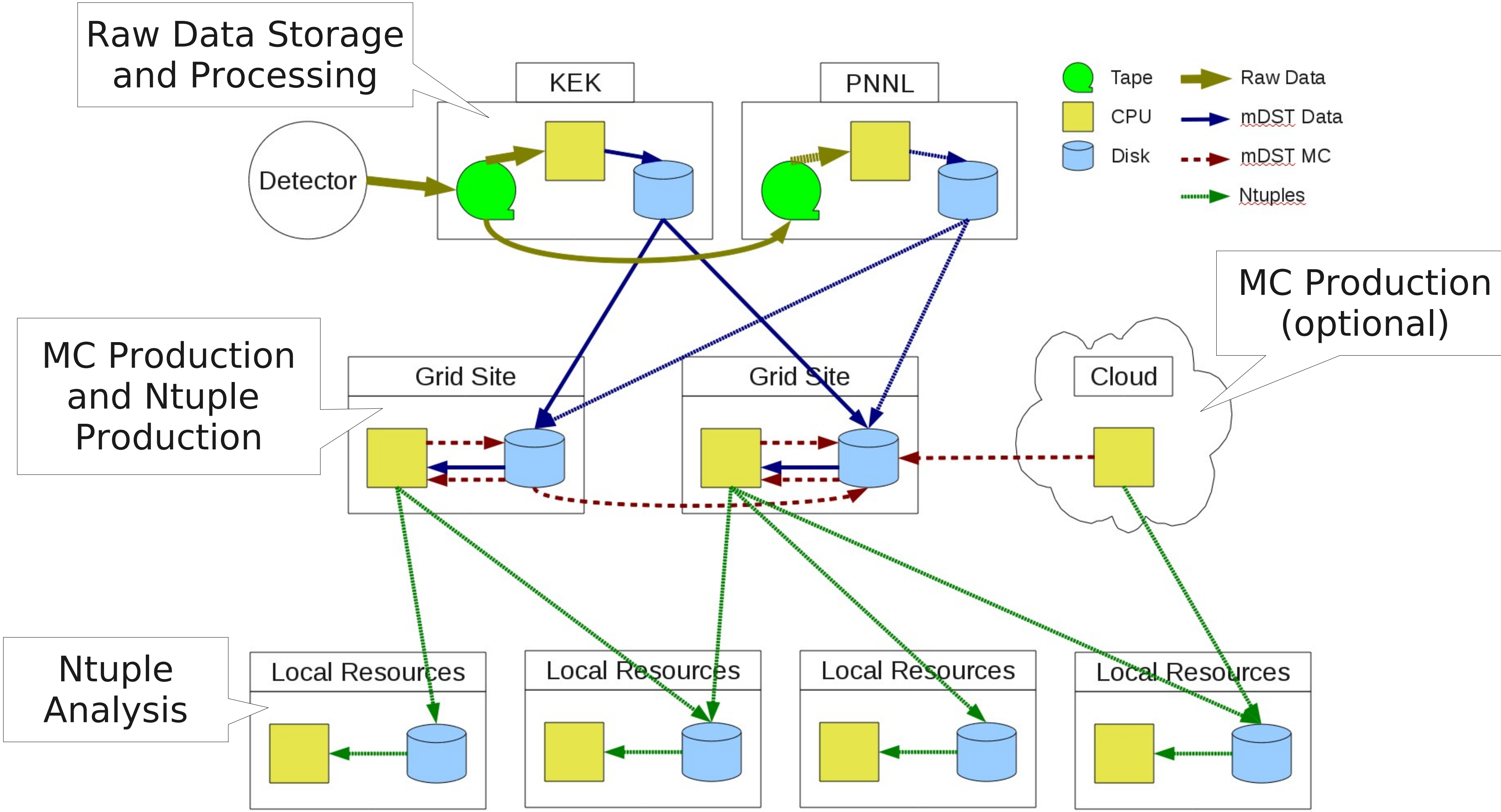




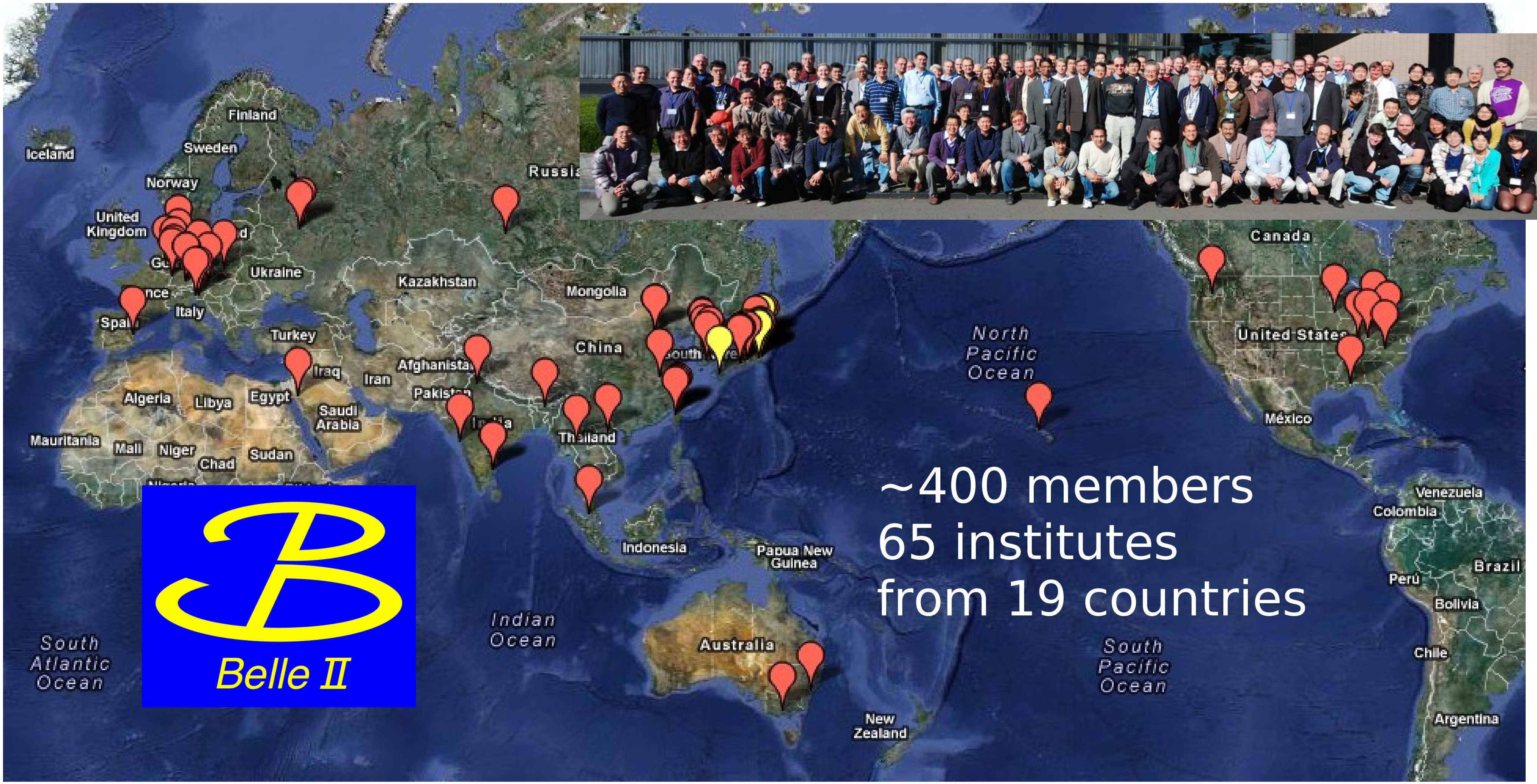
Estimated Data Rates

Experiment	Event Size [kB]	Rate [Hz]	Rate [MB/s]
High rate scenario for Belle II DAQ:			
Belle II	300	6,000	1,800
LCG TDR (2005):			
ALICE (HI)	12,500	100	1,250
ALICE (pp)	1,000	100	100
ATLAS	1,600	200	320
CMS	1,500	150	225
LHCb	25	2,000	50

Computing Model

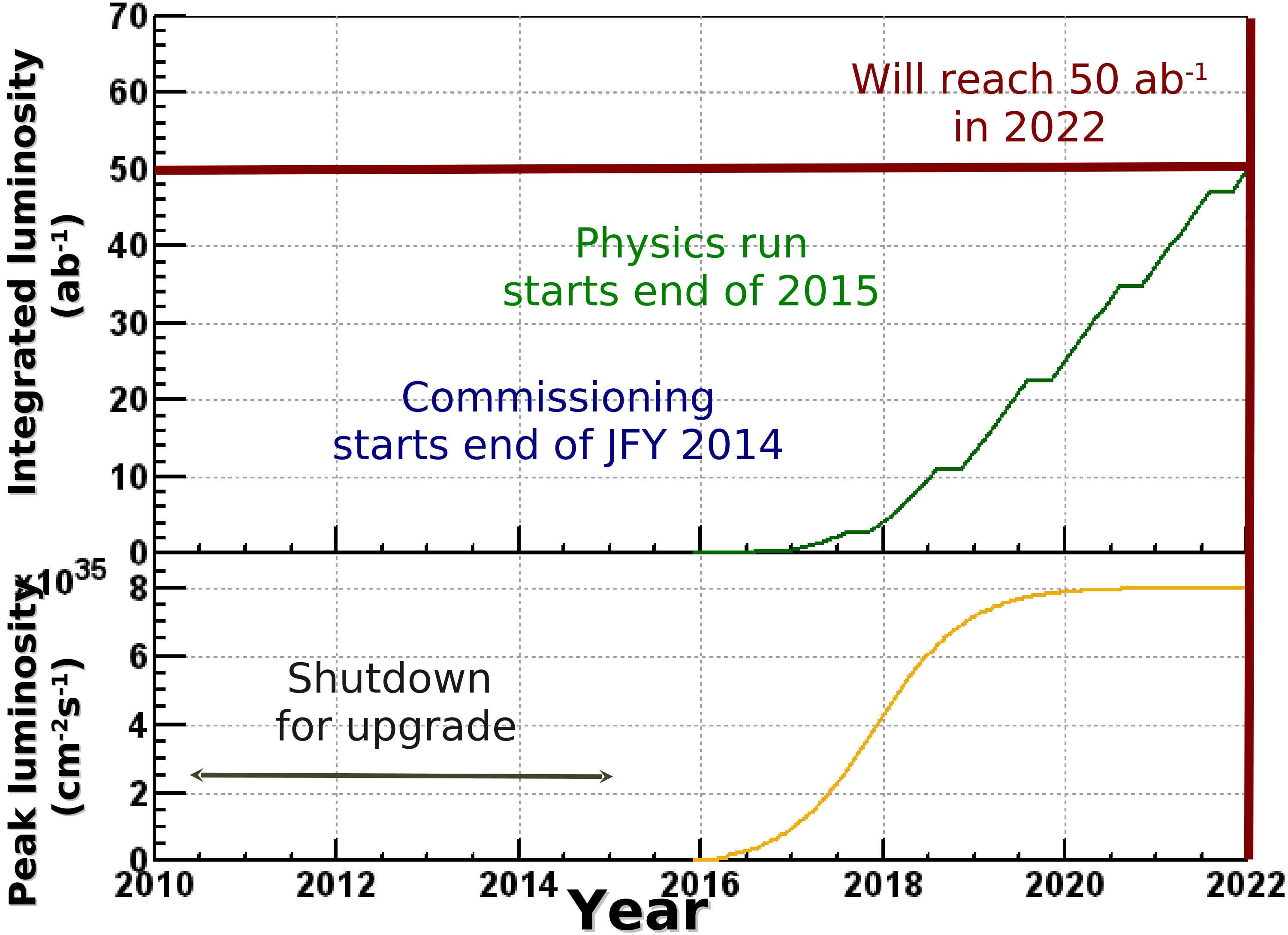


Belle II Collaboration



~400 members
65 institutes
from 19 countries

Schedule



Will reach 50 ab-1
in 2022
Physics run
starts end of 2015
Commissioning
starts end of JFY 2014
Shutdown
for upgrade
Integrated luminosity
(ab-1)
Peak luminosity
(cm-2s-1)
x10^35
70
60
50
40
30
20
10
0
8
6
4
2
0
2010
2012
2014
2016
2018
2020
2022
Year

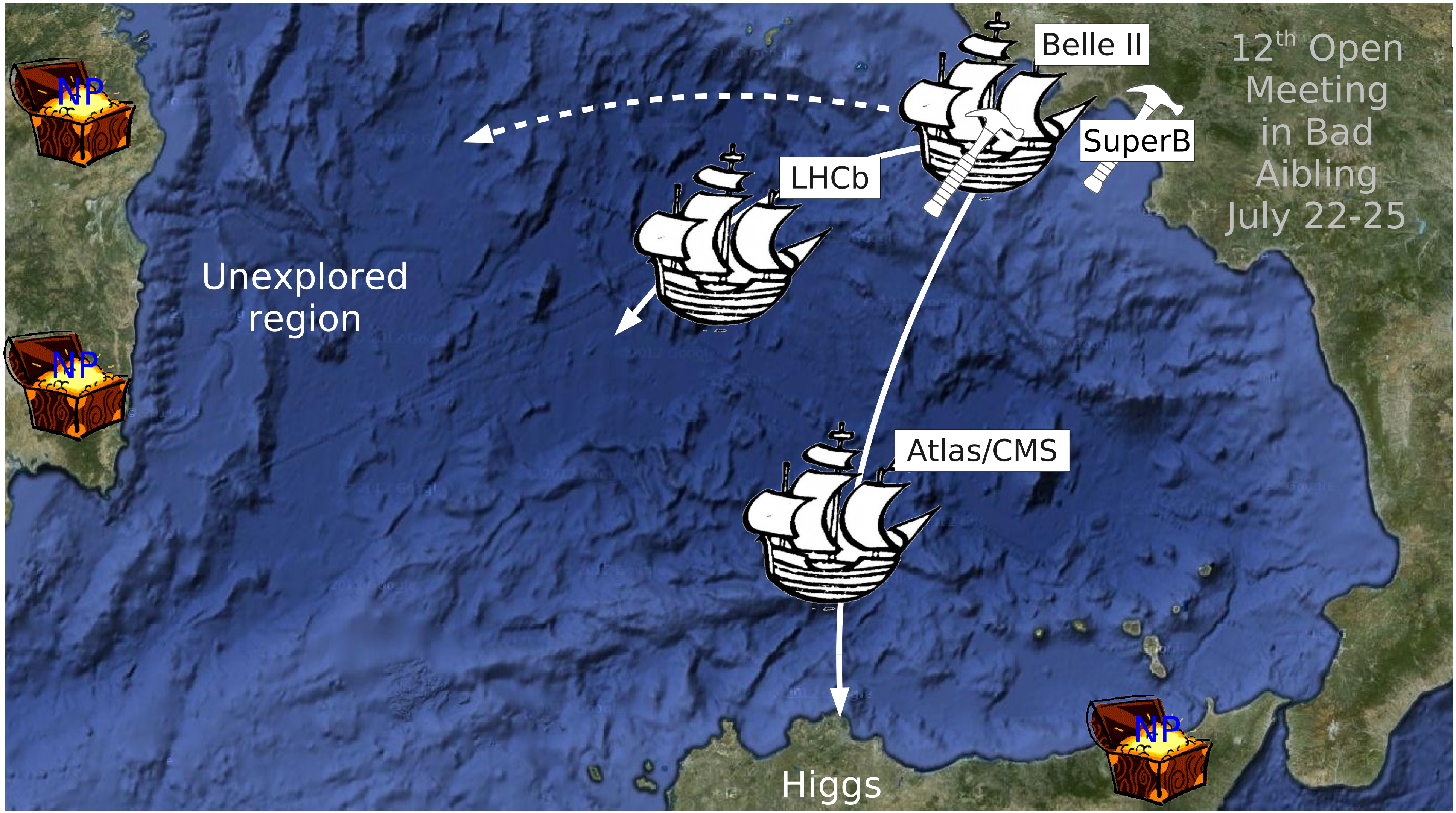
Funding Status

- SuperKEKB fully funded
  - Approved by Japanese government in December 2010 and by Japanese Diet (parliament) in March 2011
- Belle II detector 50% funded by Japanese government
- Funding in other countries requested or already approved
- → First MoU signed with German funding agencies Nov. 2011

Groundbreaking Ceremony

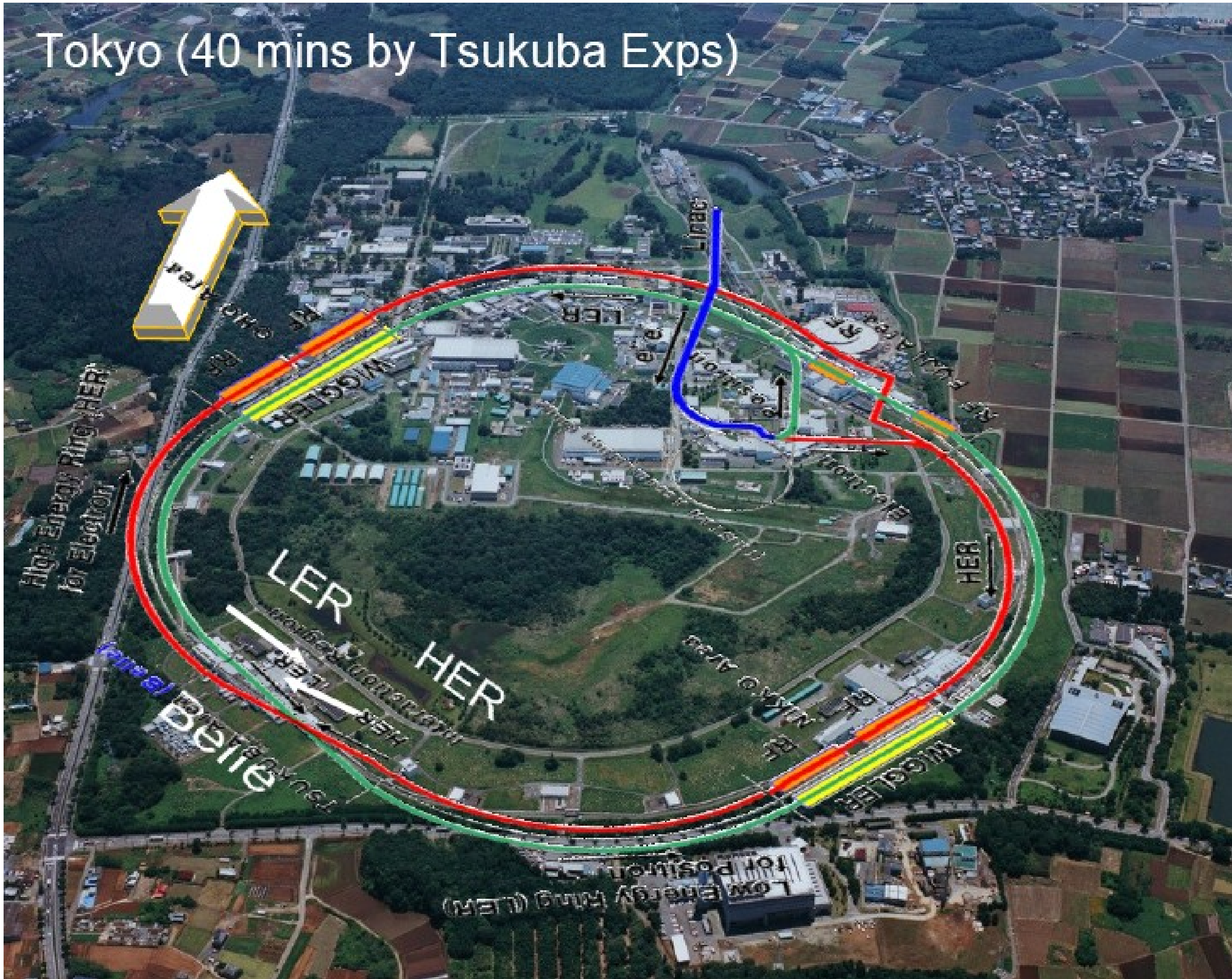
- November 18, 2011

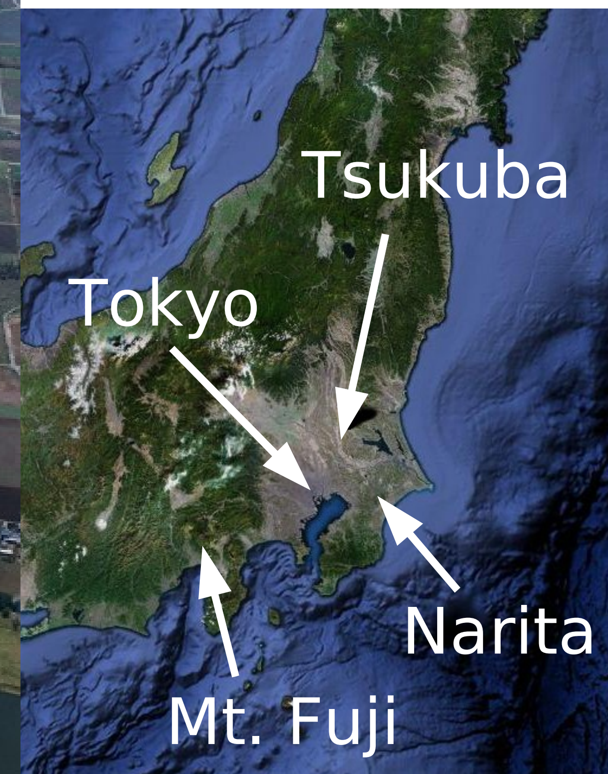
Conclusions



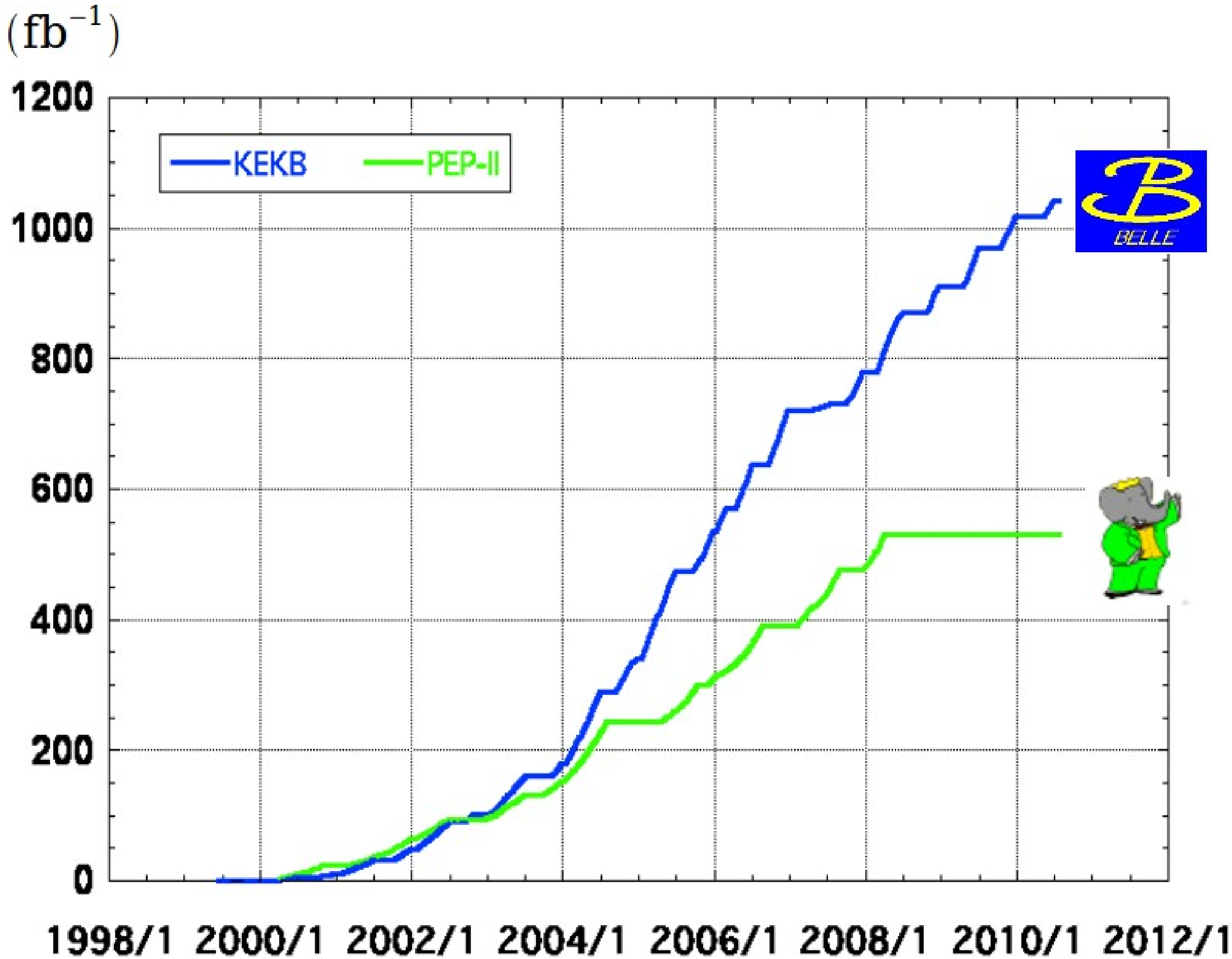
Backup

KEK Site


Tokyo (40 mins by Tsukuba Exps)
LER
HER
Belle


Tsukuba
Tokyo
Narita
Mt. Fuji

Belle and BaBar Datasets



$> 1\ ab^{-1}$

On resonance:

$\Upsilon(5S)$: 121 fb^{-1}

$\Upsilon(4S)$: 711 fb^{-1}

$\Upsilon(3S)$: 3 fb^{-1}

$\Upsilon(2S)$: 25 fb^{-1}

$\Upsilon(1S)$: 6 fb^{-1}

Off reson./scan:

$\sim 100\ fb^{-1}$

$\sim 550\ fb^{-1}$

On resonance:

$\Upsilon(4S)$: 433 fb^{-1}

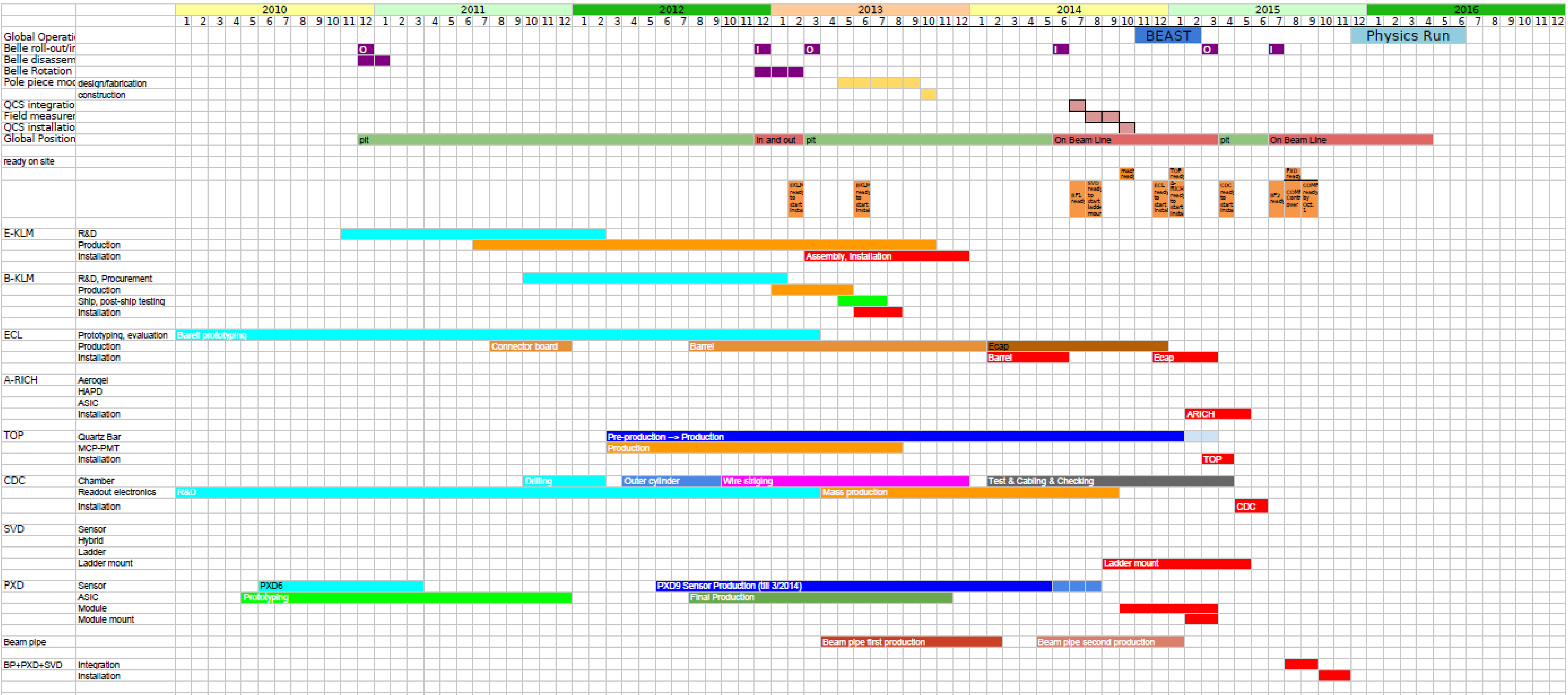
$\Upsilon(3S)$: 30 fb^{-1}

$\Upsilon(2S)$: 14 fb^{-1}

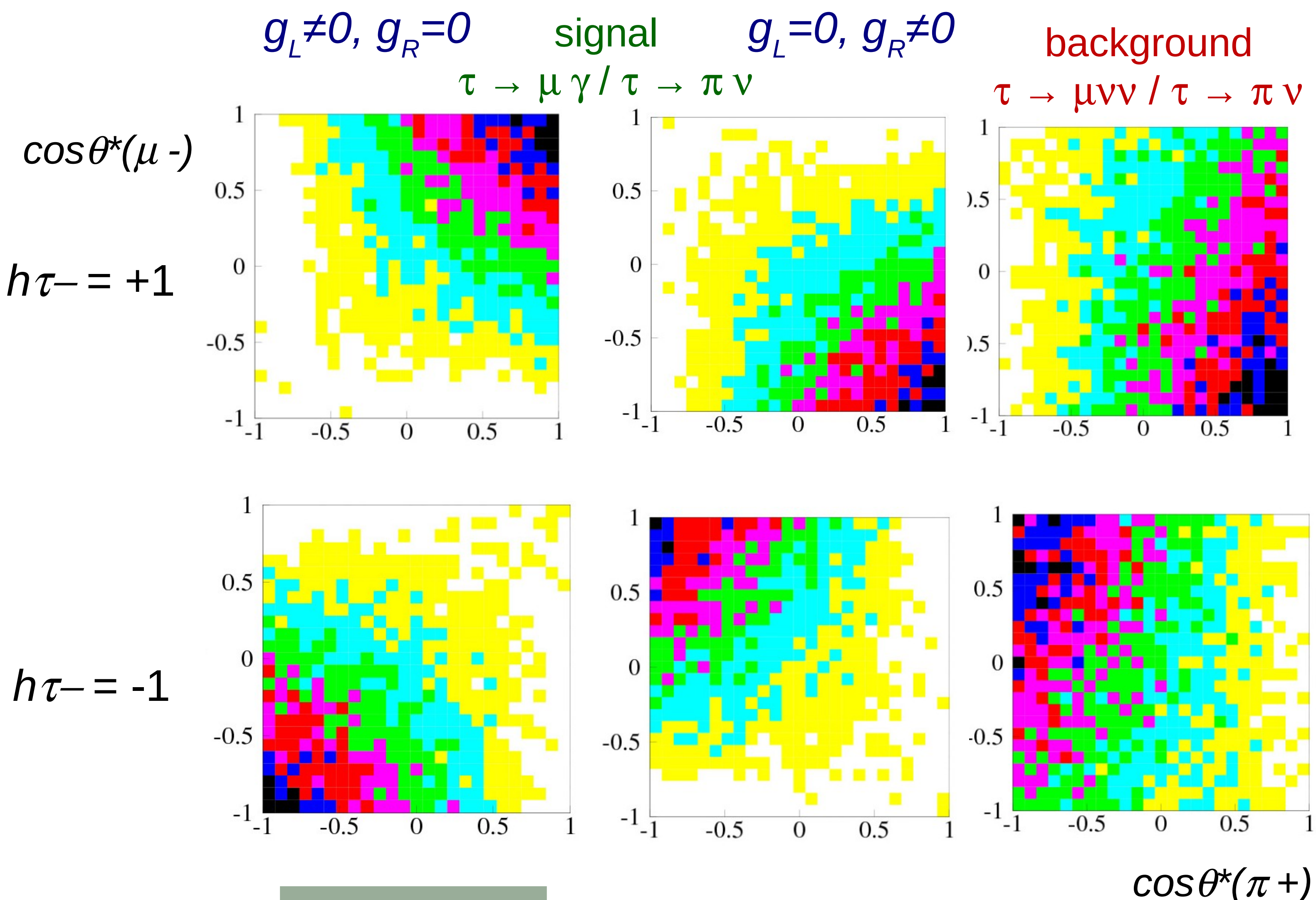
Off resonance:

$\sim 54\ fb^{-1}$

Detailed Schedule



τ → μγ



study by K.Hayaska