Super B Factories

"Super KEKB" (Japan)

SuperB (Italy)

FPCP09 29-May-2009

Y.Sakai KEK

Now: ~10 years of B-factories

Scenario when we started …

Step1

Discovery of CPV in B decay ← **2001 summer !**

Step2

Precise test of KM(CPV) and SM

This conference

Hints for NP ?

Step3

Search/Evidence for New Physics

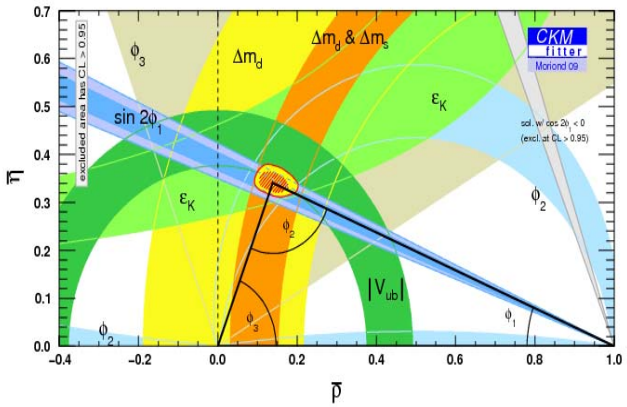
Need >50(75) ab^{-1} data

SuperB-factory **(L ~10^{36}cm^{-2}s^{-1})**

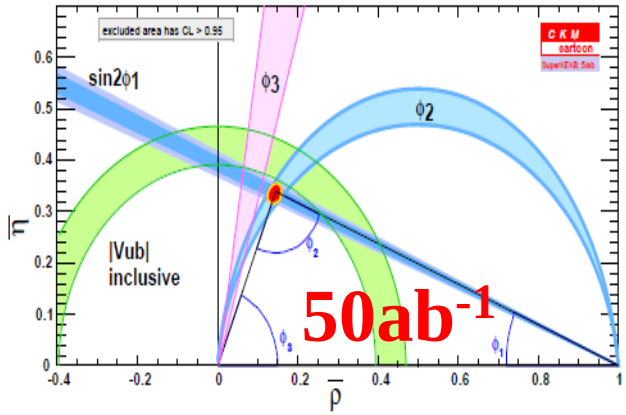
Physics Prospects (example)

CKM UT triangle

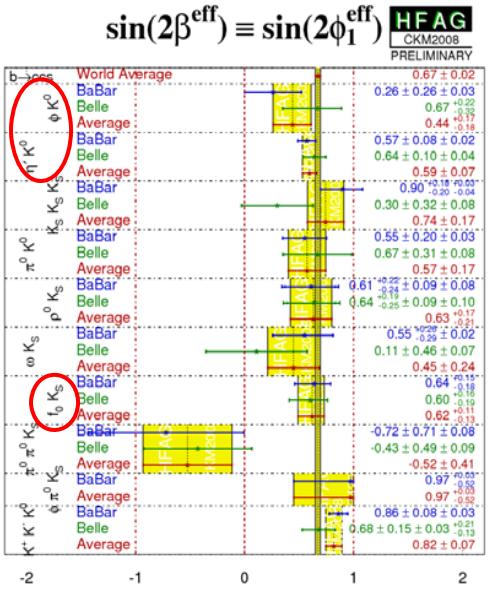
Now



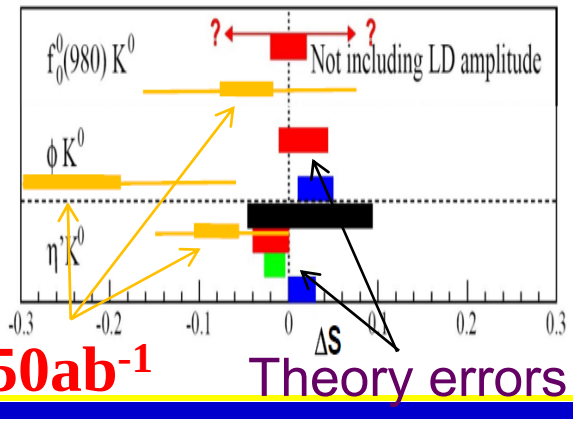
NP effect



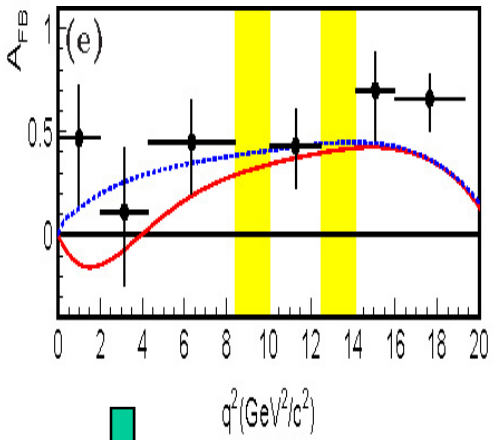
$\sin(2\beta^{eff}) \equiv \sin(2\phi_1^{eff})$



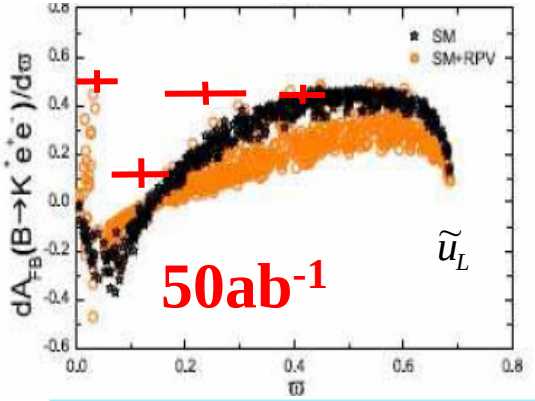
New CP phase



$B \to K^* l^+ l^-$: A_{FB}



NP on $C_{7,9,10}$

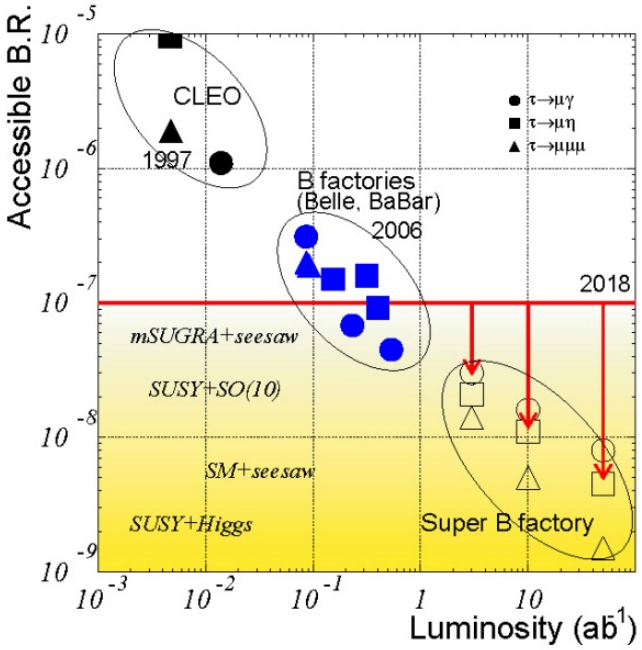


Y.-G. Xu et al., PRD74, 114019 (2006)

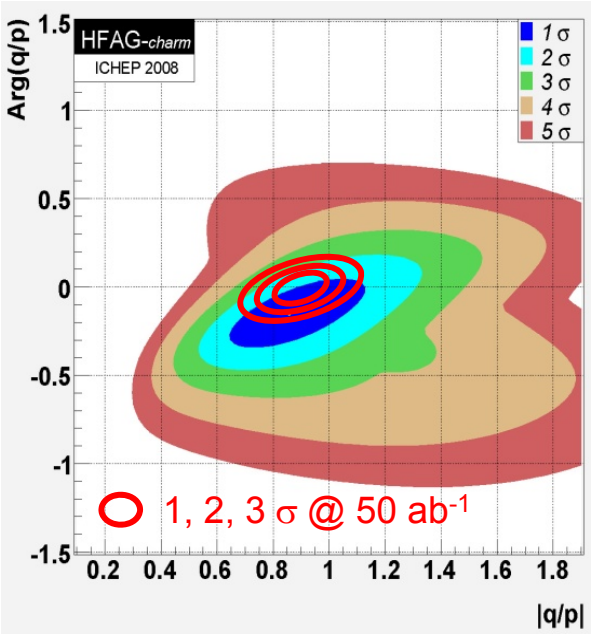
Physics Prospects (2)

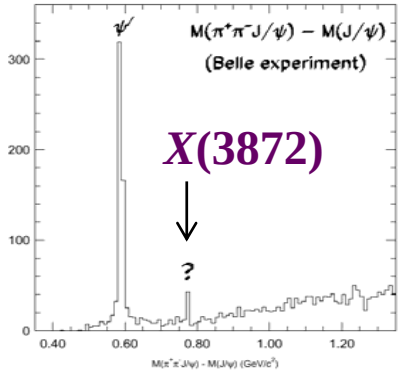
Also, Super-Factory for τ/charm and Spectroscopy !

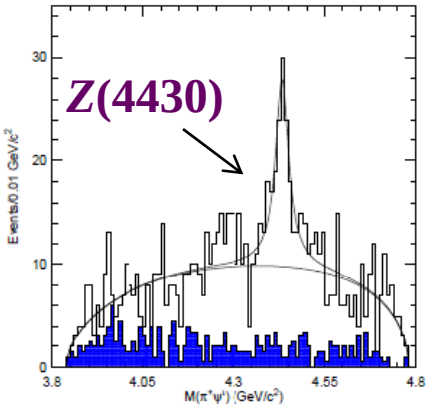
τ LFV decays



D^0-mixing







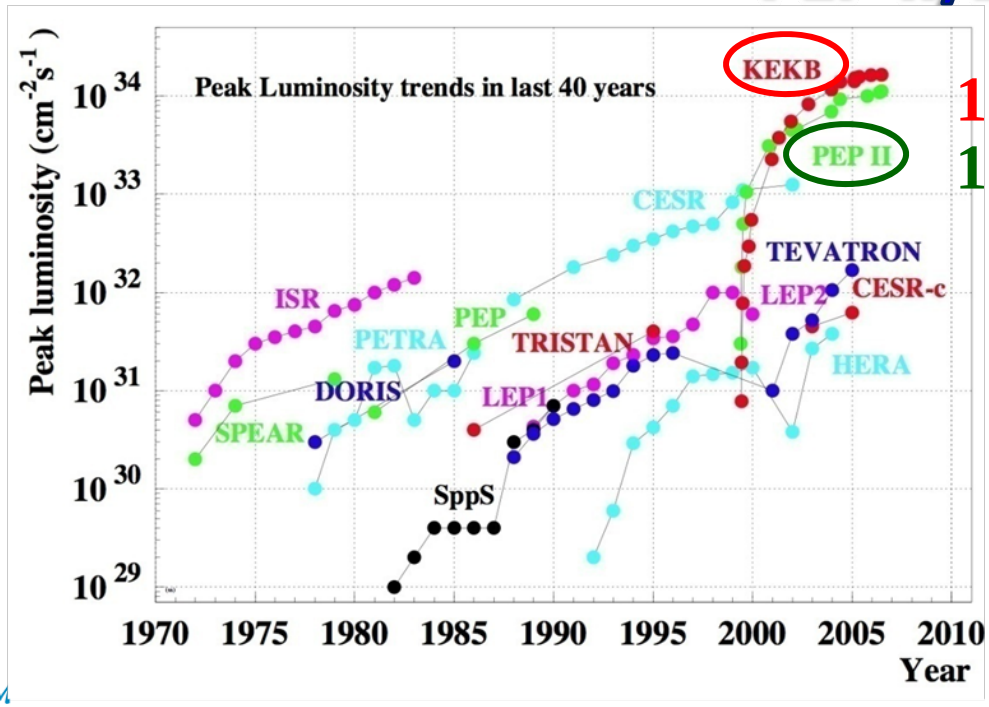
LFV, CPV in D/τ : Clear New Physics !

(Polarization, τ/charm threshold energy: benefit)

?

KEKB/Belle (Japan)

PEP-II/BaBar (US)



1.96×10^{34}

1.2×10^{34}

"Super KEKB" (Japan)

SuperB (Italy)

Two Strategies

Lorentz factor

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

Classical electron radius

Beam size ratio

Geometrical reduction factors due to crossing angle and hour-glass effect

x ~5	• Increase beam current, I	
~5	• Larger beam-beam par, ξ_y	
~0.5	• Smaller β^*_y	<1/20 +low emittance
~50	(short bunch)	(long bunch)

High Current approach

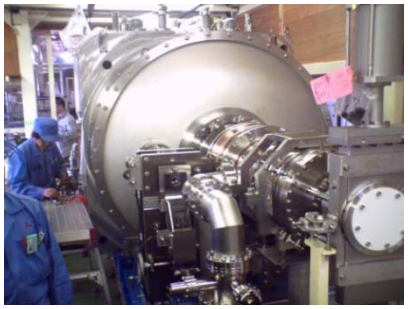
Brute force
Realizable

baseline **"Super KEKB" (Japan)**

Nano-beam approach

New scheme
Risk ?

SuperB (Italy)



Crab cavities installed and undergoing testing in beam

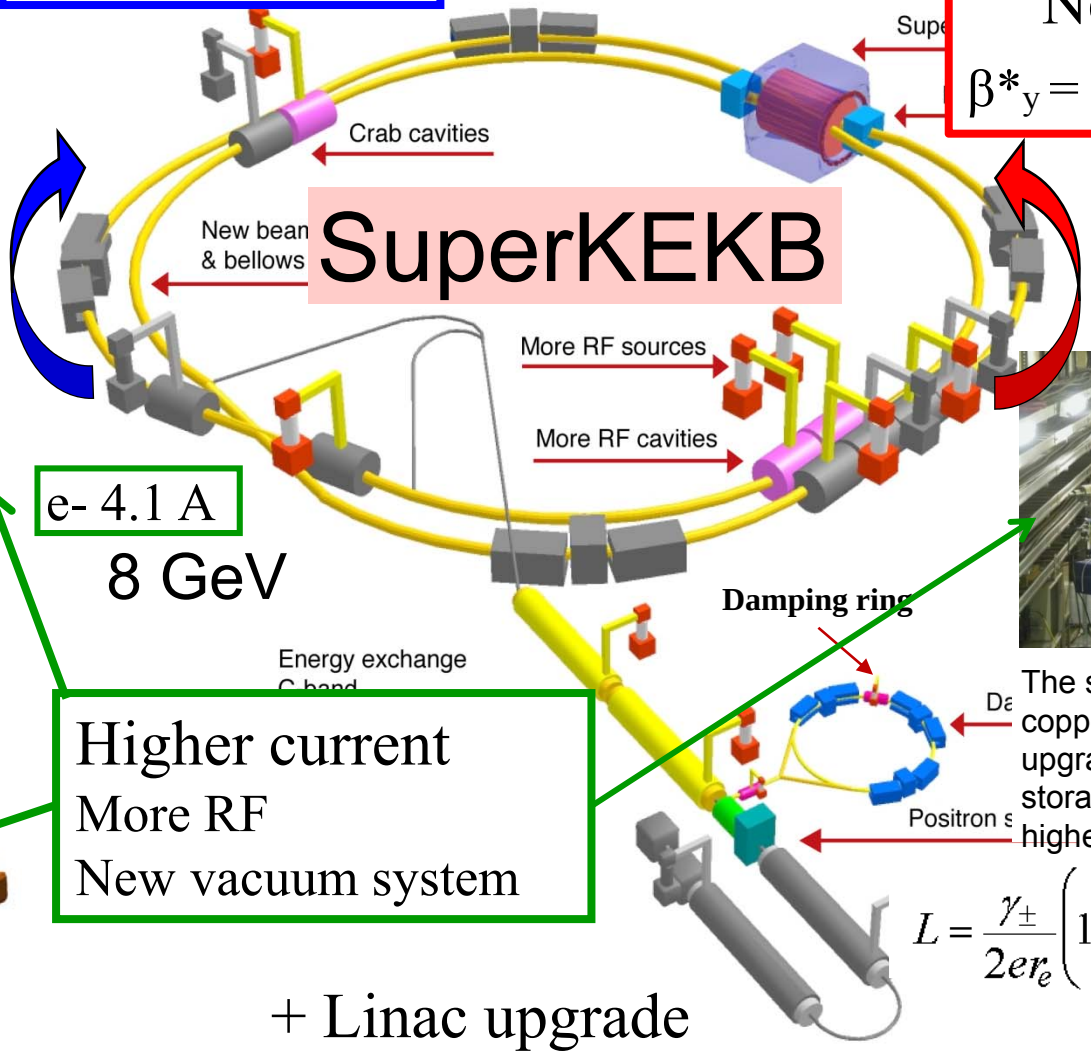
Crab crossing

New IR

$\beta^*_y = \sigma_z = 3$ mm

3.5 GeV

e+ 9.4 A



e- 4.1 A

8 GeV

The superconducting cavities will be upgraded to absorb more higher-order mode power up to 50 kW.

The state-of-art ARES copper cavities will be upgraded with higher energy storage ratio to support higher current.

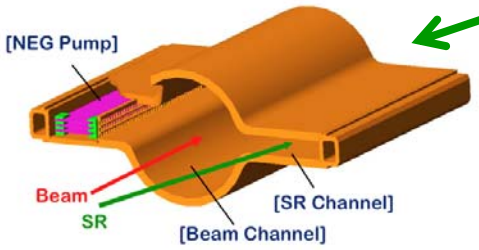
Higher current

More RF

New vacuum system

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

+ Linac upgrade



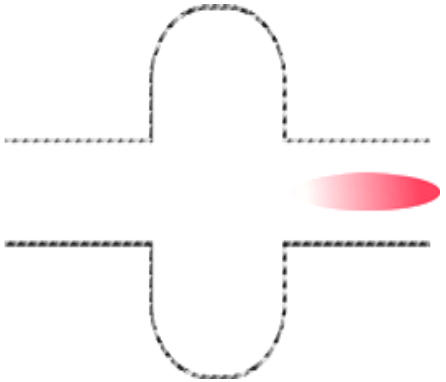
The beam pipes and all vacuum components will be replaced with higher-current design.

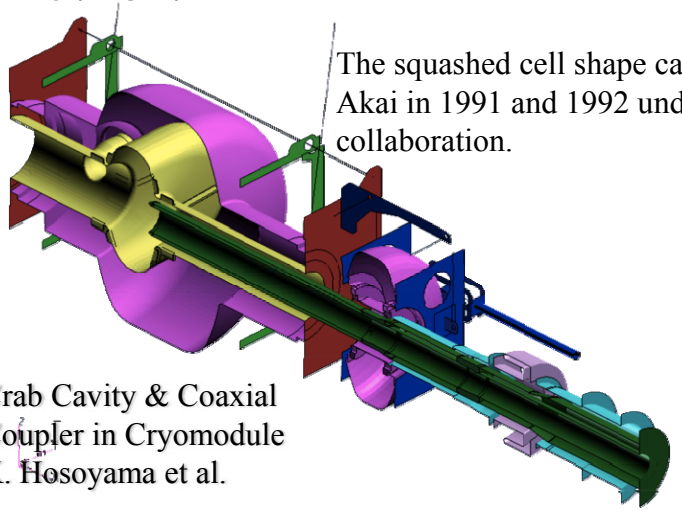
Aiming 8×10^{35} cm^{-2}s^{-1}

Super KEKB uest for BSM

Crab Crossing / Cavity

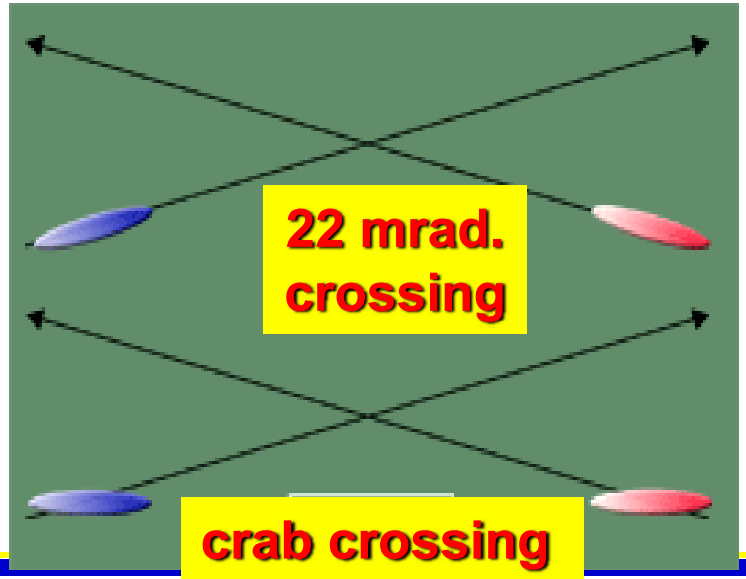
- Boost the beam-beam parameter > 0.15 .

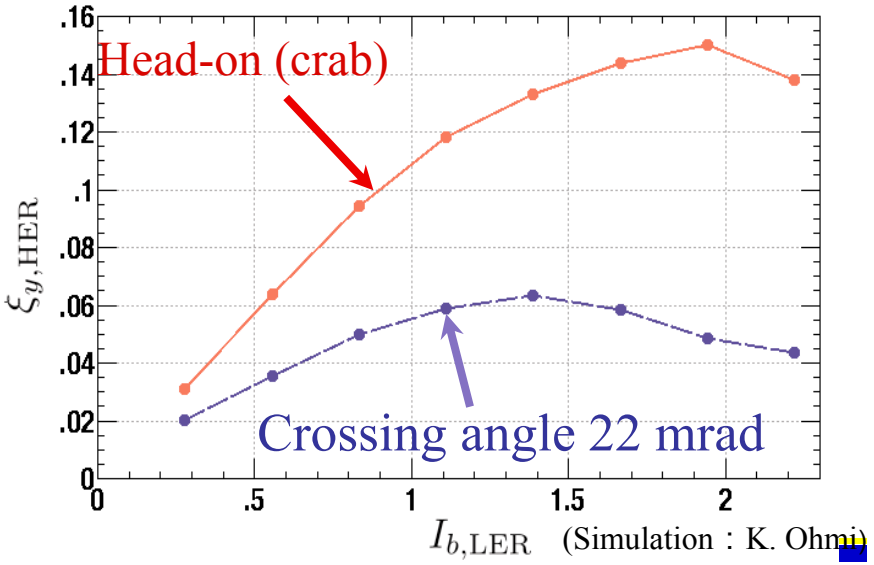




The squashed cell shape cavity studied by K. Akai in 1991 and 1992 under KEK-Cornell collaboration.

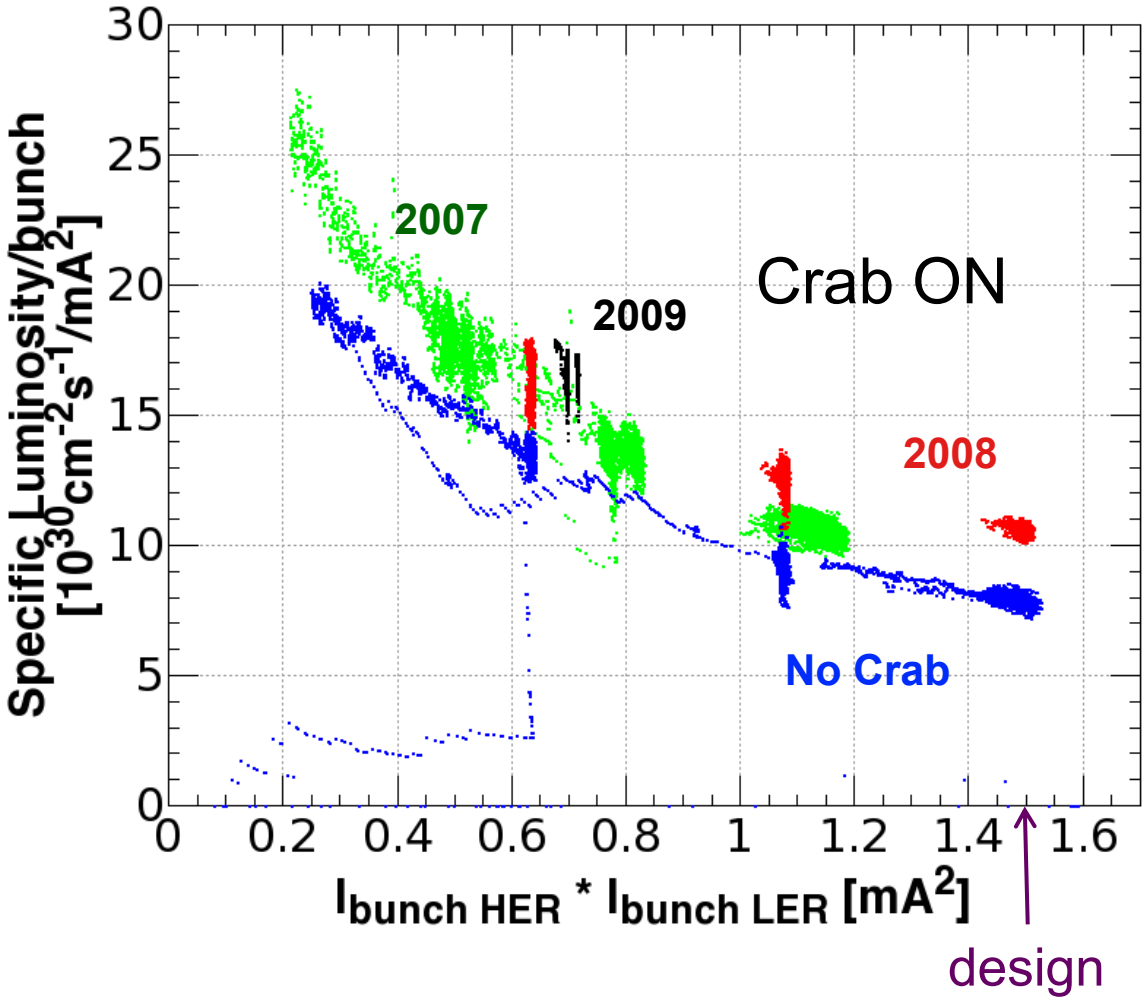
Crab Cavity & Coaxial Coupler in Cryomodule
K. Hosoyama et al.

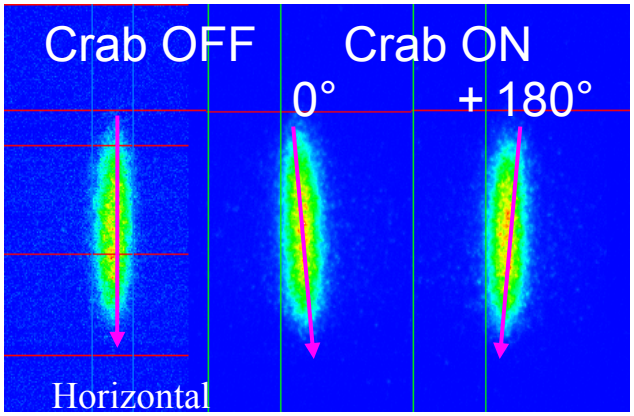




(Simulation : K. Ohmi)

Lum. with Crab Crossing





HER(1.43MV)

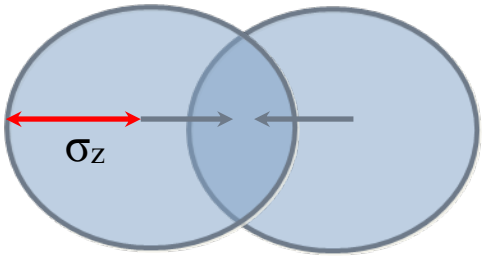
Crabbing: successful !

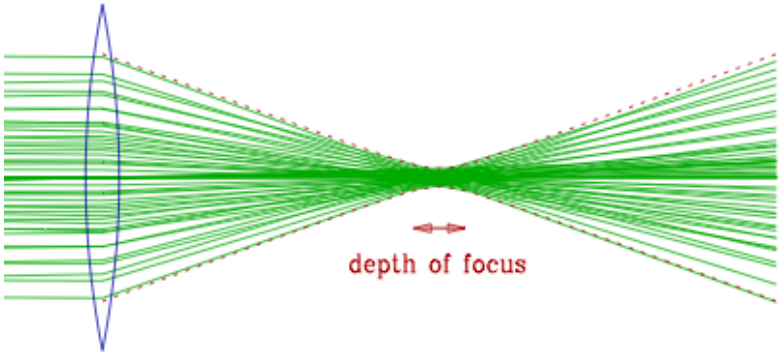
L = 1.96 x10^{34}(6-May)
higher than w/o Crab
(new skew sextupoles)

Specific Lum:
increased ~30%

Still study going on

CSR (Coherent Synchrotron Rad.)





Hourglass condition: $\beta_y^* >\sim \sigma_z$

Beam size changes along Z

Recent simulation study

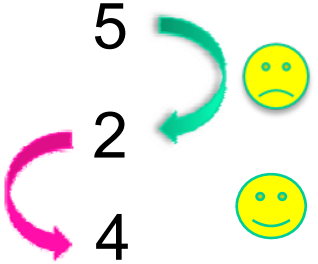
Short bunch: SR ~coherent

→ increase energy spread, bunch size

Traveling waist(focus) can recover

β_x^* 40cm → 20cm

LER(σ_z)	Lum(10^{35})
3mm	5
5mm	2
5mm	4
5mm	~6

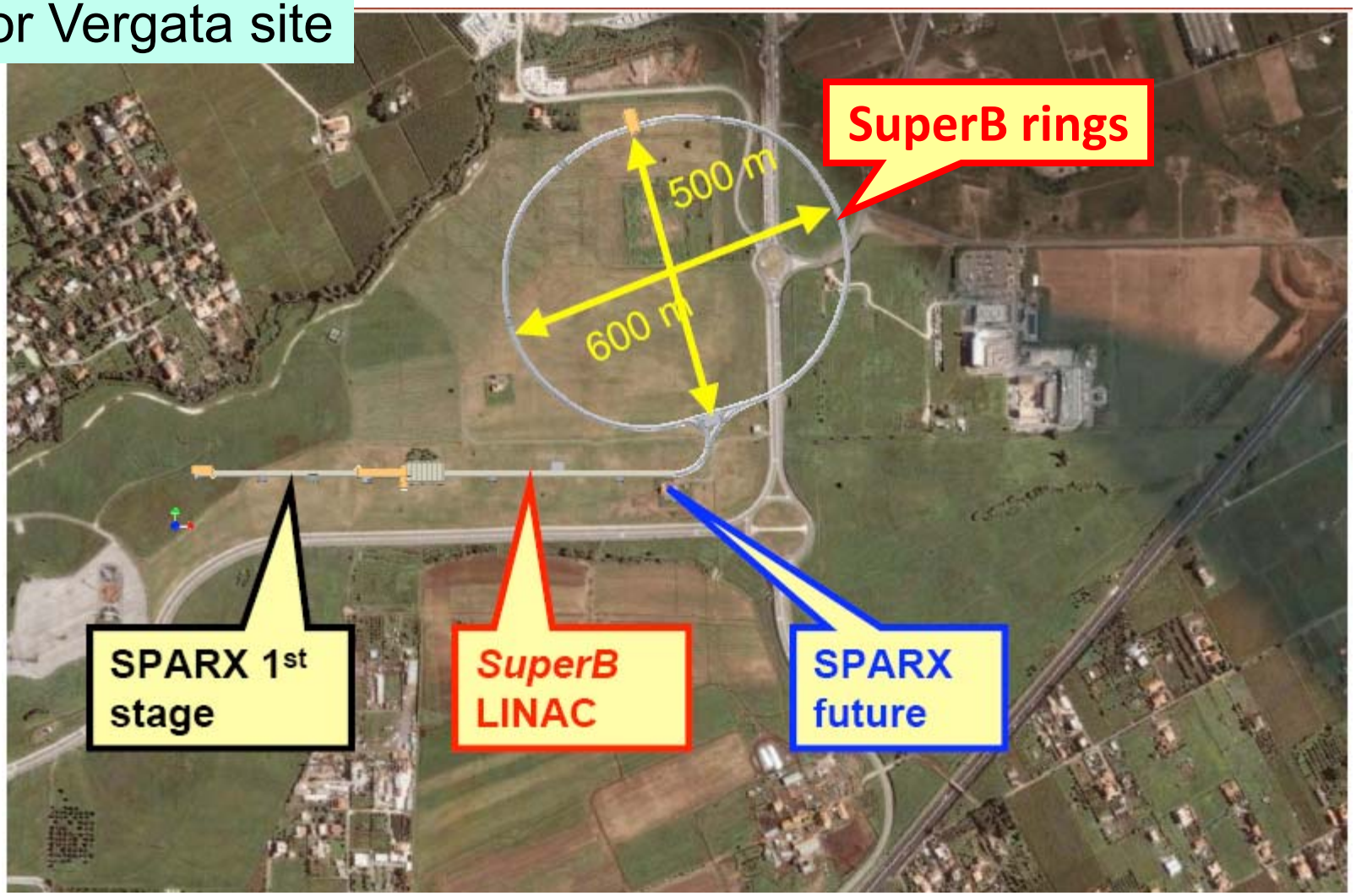


"Realistic" baseline design done: ~5 x 10^{35}

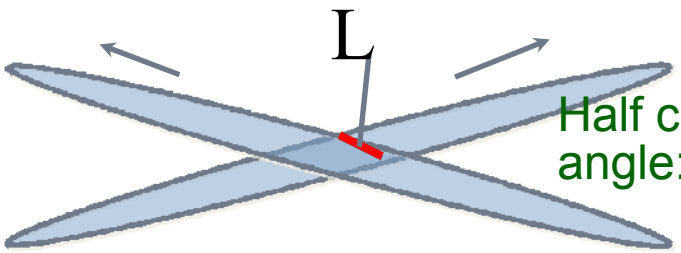
(KEKB, PEP-II exceeded design Lum. x 2~4 !)

SuperB (Italy)

Tor Vergata site



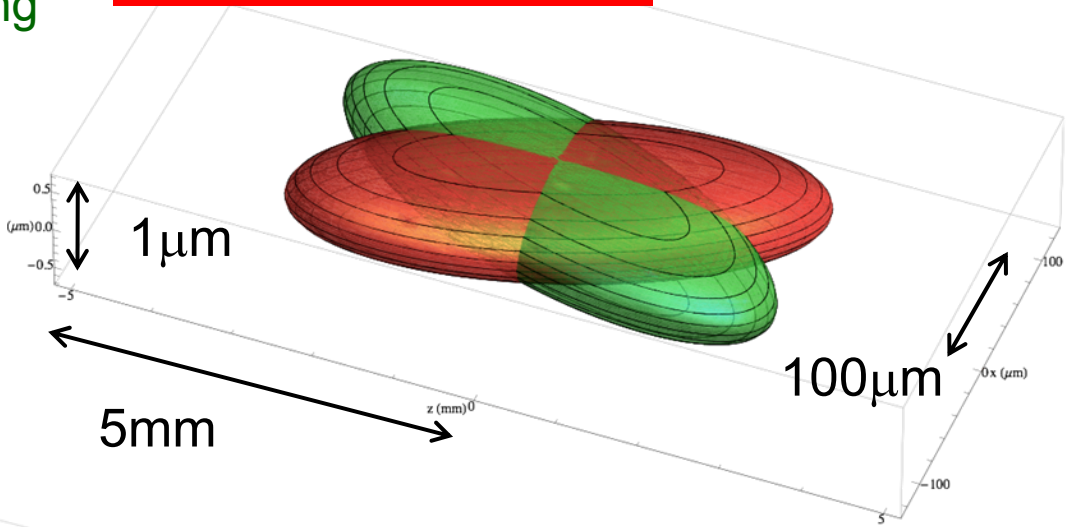
Nano-Beam Scheme



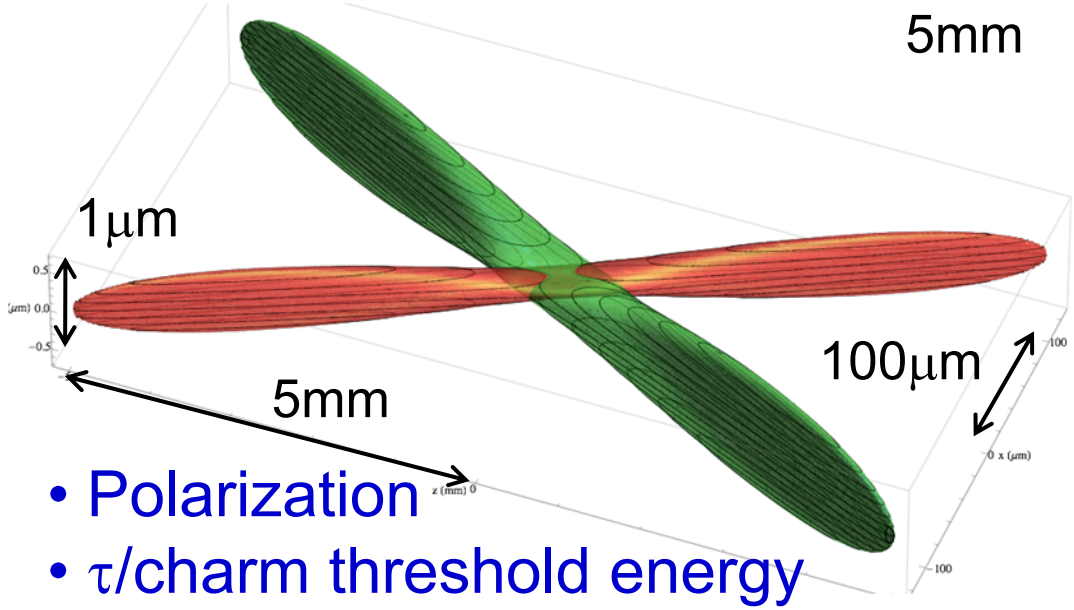
Hourglass condition:

$\beta_y^* >\sim L=\sigma_x/\phi$

present KEKB (w/o crab)



SuperB

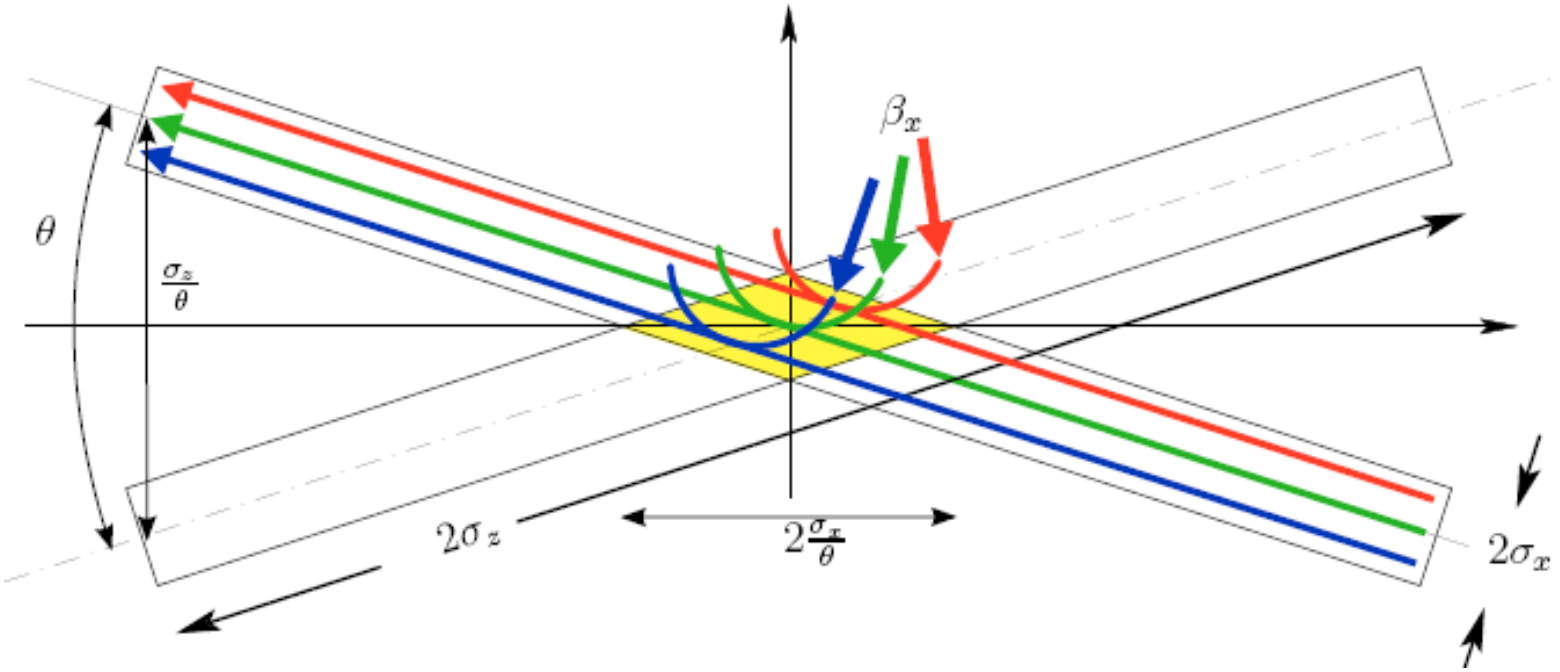


$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

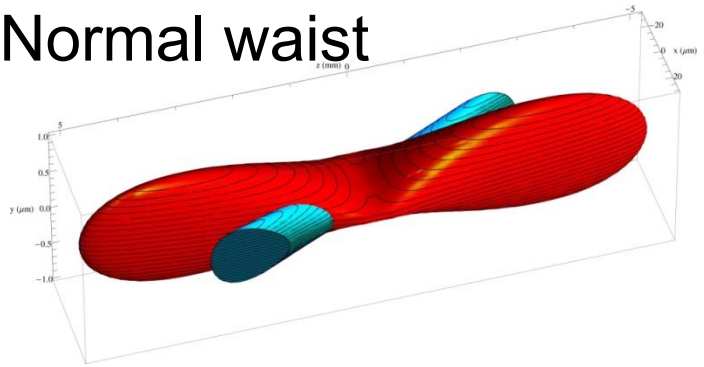
$$L = \frac{N_+ N_- f}{4\pi\sigma_x^*\sigma_y^*}R_L$$

- Polarization
- τ/charm threshold energy

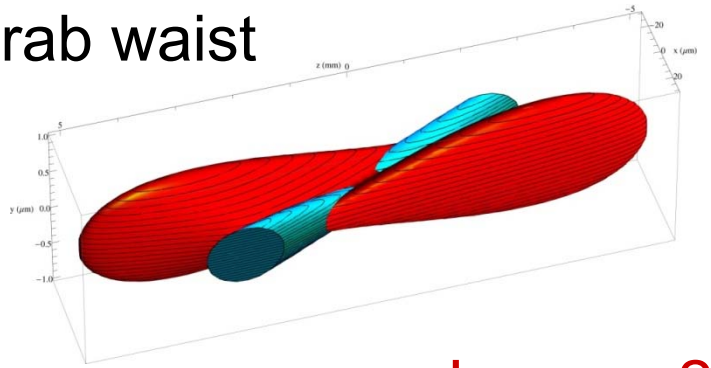
Crab Waist (P.Raimondi)



Normal waist



Crab waist

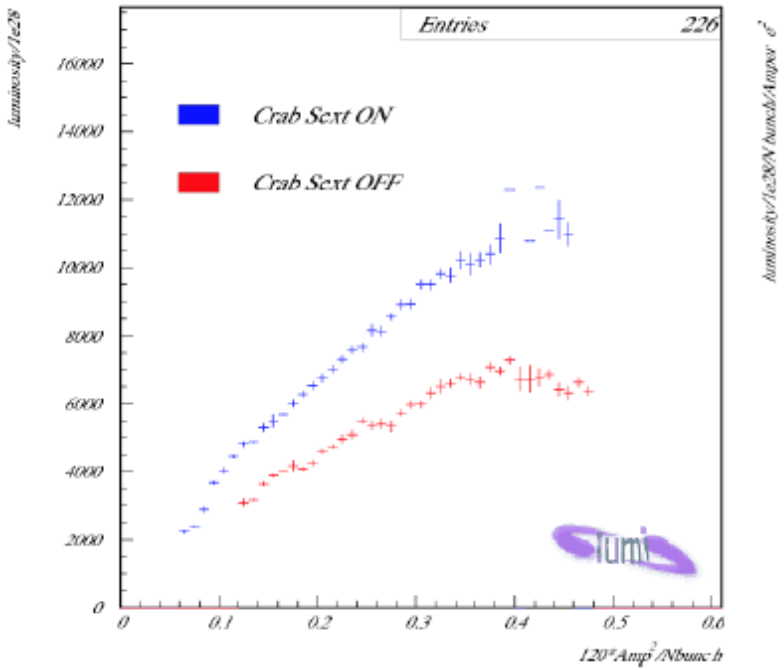


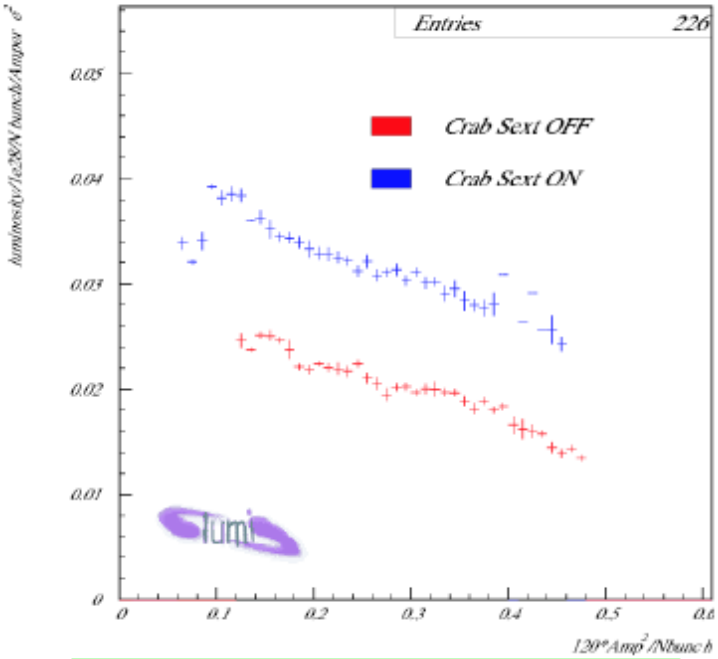
All particles from both beams collide in the minimum β_y region : Lum ~ x2

DAFNE Crab Waist Test

Luminosity, crab ON/OFF

Luminosity | **95 Bunches** | **Specific Luminosity**





$$L_{sp} = \frac{N_b \, L_{peak}}{I^+ I^-} \; [cm^{-2} s^{-1} / A^2]$$

SuperB: design updates

LER/HER	Unit	June 2008	Jan. 2009	$2N_b$, $I_b/\sqrt{2}$	$4\varepsilon_y$, $2N_b$
E+/E-	GeV	4/7	4/7	4/7	4/7
L	$cm^{-2}\ s^{-1}$	$1x10^{36}$	$1x10^{36}$	$1x10^{36}$	$1x10^{36}$
I^+/I^-	Amp	1.85 /1.85	2.00/2.00	2.82/2.82	4.00/4.00
N_{part}	$x10^{10}$	5.55 /5.55	6/6	4.23/4.23	6/6
N_{bun}		1250	1250	2500	2500
I_{bunch}	mA	1.48	1.6	1.13	1.6
$\theta/2$	mrad	25	30	30	30
β_x^*	mm	35/20	35/20	35/20	35/20
β_y^*	mm	0.22 /0.39	0.21 /0.37	0.21 /0.37	0.21 /0.37
ε_x	nm	2.8/1.6	2.8/1.6	2.8/1.6	2.8/1.6
ε_y	pm	7/4	7/4	7/4	28/16
σ_x	µm	9.9/5.7	9.9/5.7	9.9/5.7	9.9/5.7
σ_y	nm	39/39	38/38	38/38	77/77
σ_z	mm	5/5	5/5	5/5	5/5
ξ_x	X tune shift	0.007/0.002	0.005/0.0017	0.005/0.0017	0.005/0.0017
ξ_y	Y tune shift	0.14 /0.14	0.125/0.126	0.125/0.126	0.062/0.063
RF stations	LER/HER	5/6	5/6	5/8	7/11
RF wall plug power	MW	16.2	18	25.5	39.3

Biagini

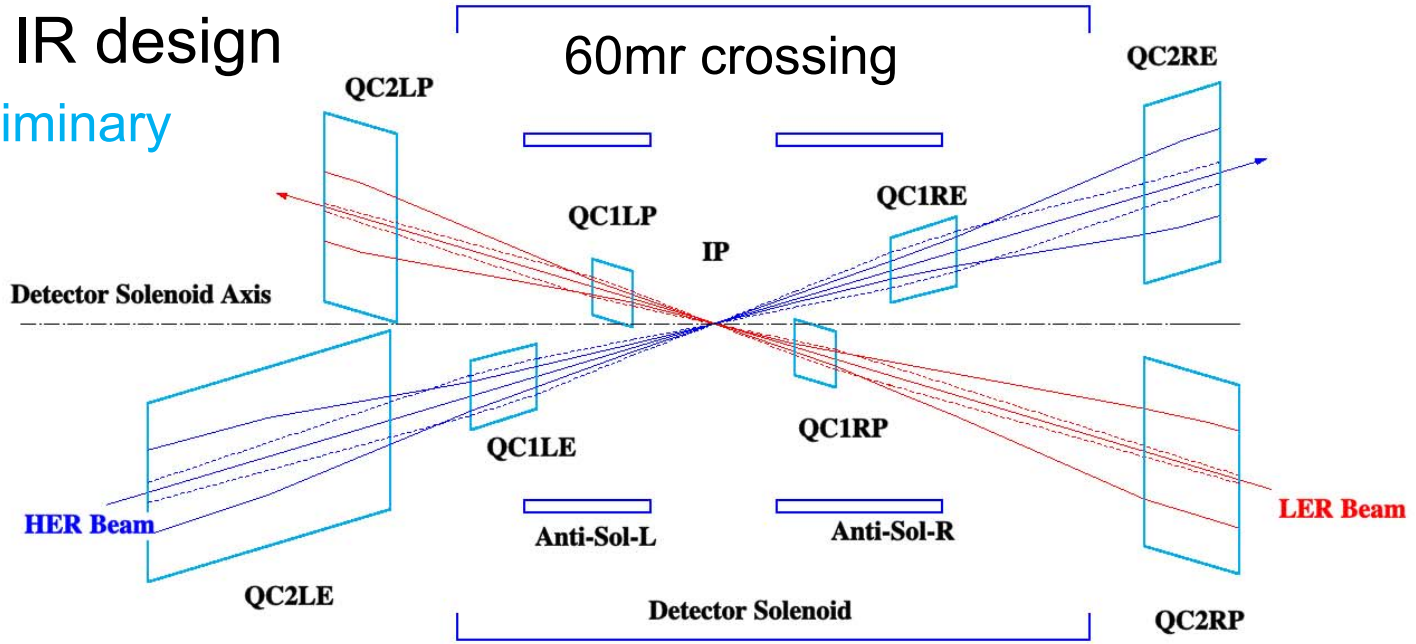
SuperKEKB: Nano-Beam Opt.

Started design study : Major components are common

Change: IR components, Bending magnets

New IR design

preliminary



Decision in 2009 fall

Low ε is already achieved in LC R&D (KEK ATF)

Comparison of Parameters

	KEKB Design	KEKB Achieved (): with crab	SuperKEKB High-Current Option	SuperKEKB Nano-Beam Option
β_y^* (mm)(LER/HER)	10/10	6.5/5.9 (5.9/5.9)	3/6	0.21/0.37
ε_x (nm)	18/18	18/24	24/18	2.8/1.6
σ_y(μm)	1.9	1.1 (0.84)	0.85/0.73	0.070/0.052
ξ_y	0.052	0.108/0.056 (**0.120/0.089**)	0.3/0.51	0.07/0.07
σ_z (mm)	4	~ 7	5(LER)/3(HER)	6
I_{beam} (A)	2.6/1.1	1.8/1.45 (1.60/1.13)	9.4/4.1	3.70/2.13
$N_{bunches}$	5000	1387 (1585)	5000	2778
Luminosity (10^{34} cm^{-2} s^{-1})	1	1.76 (**1.96**)	53	80

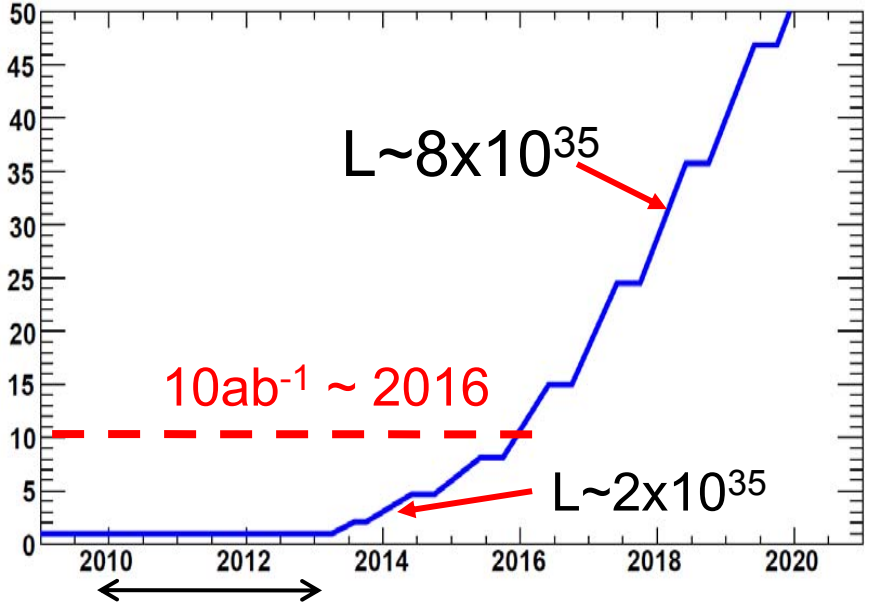
under study

High Current Option includes crab crossing and travelling focus.
Nano-Beam Option does not include crab waist.

Luminosity Prospect

Super KEKB uest for BSM

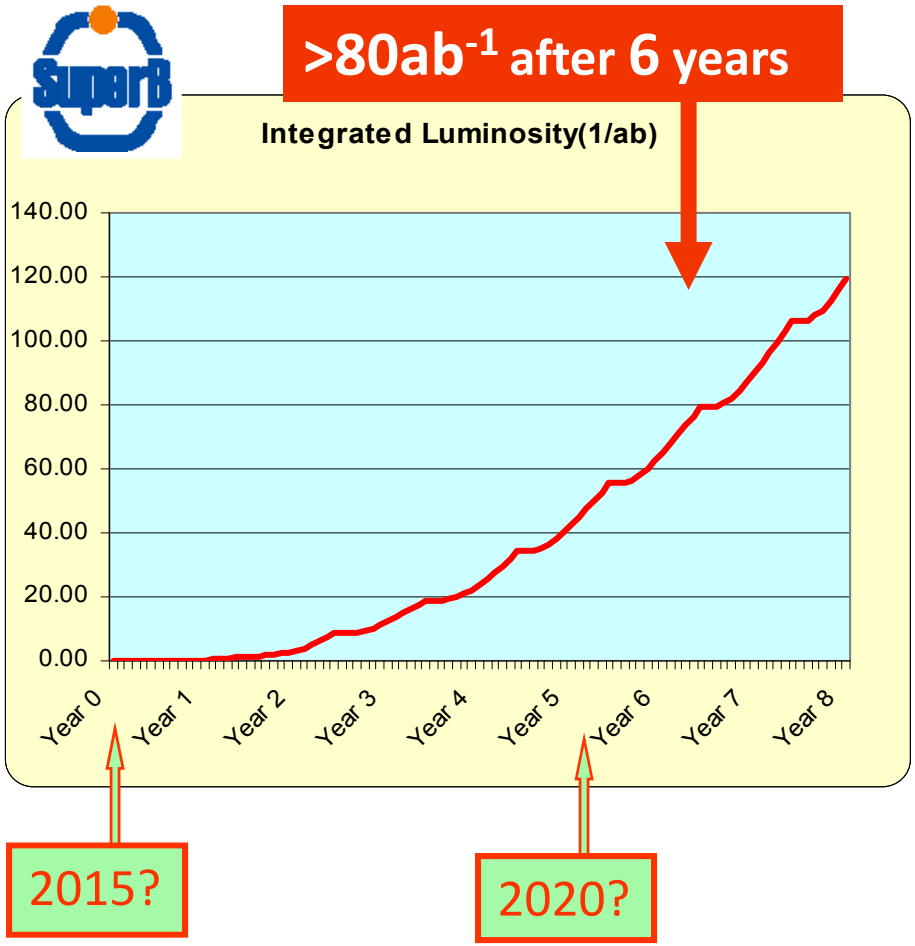
50ab^{-1} by ~2020



3year shutdown
for upgrade

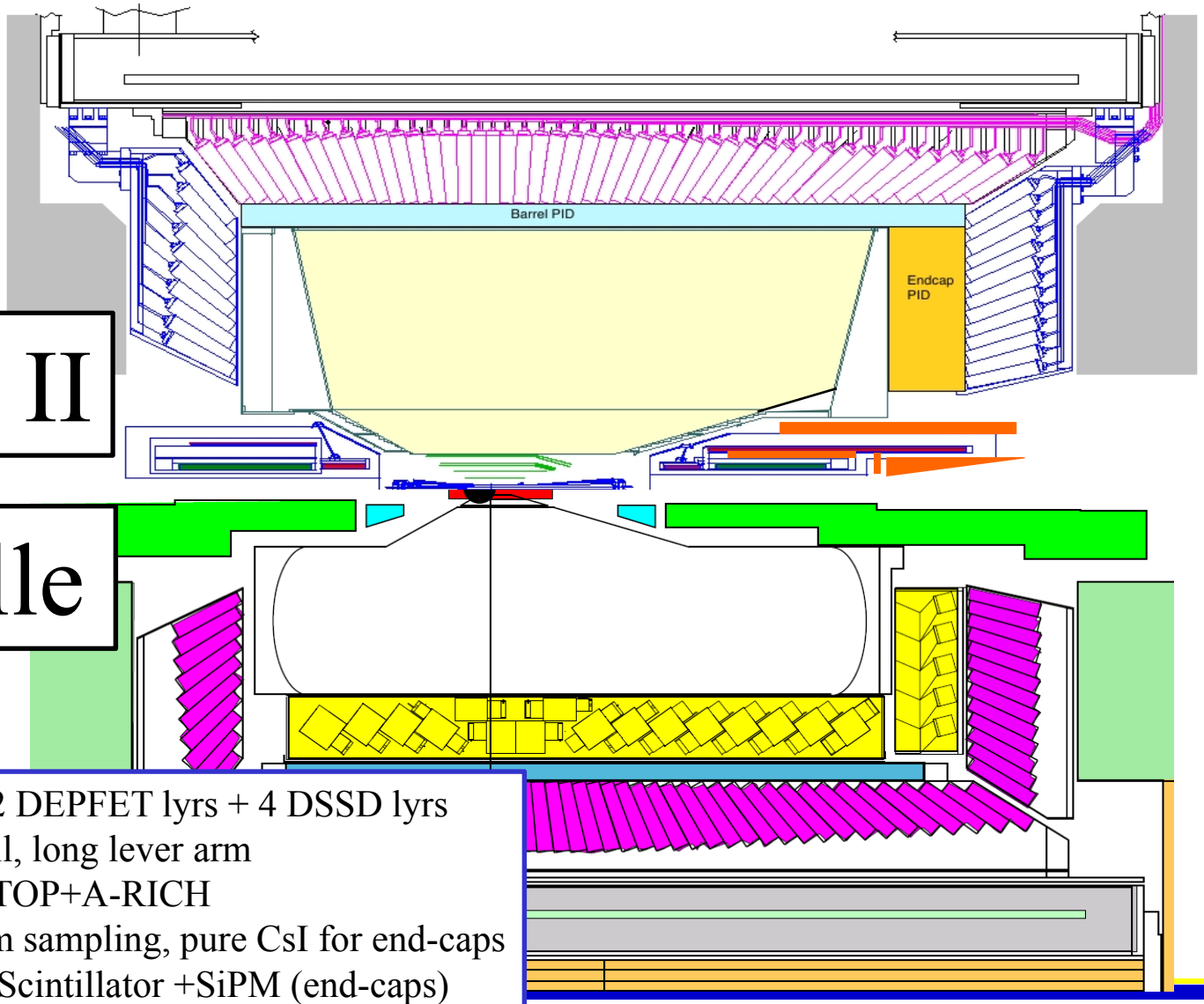
SuperB

>80ab^{-1} after 6 years



SuperKEKB Baseline Detector

Super KEKB uest for BSM

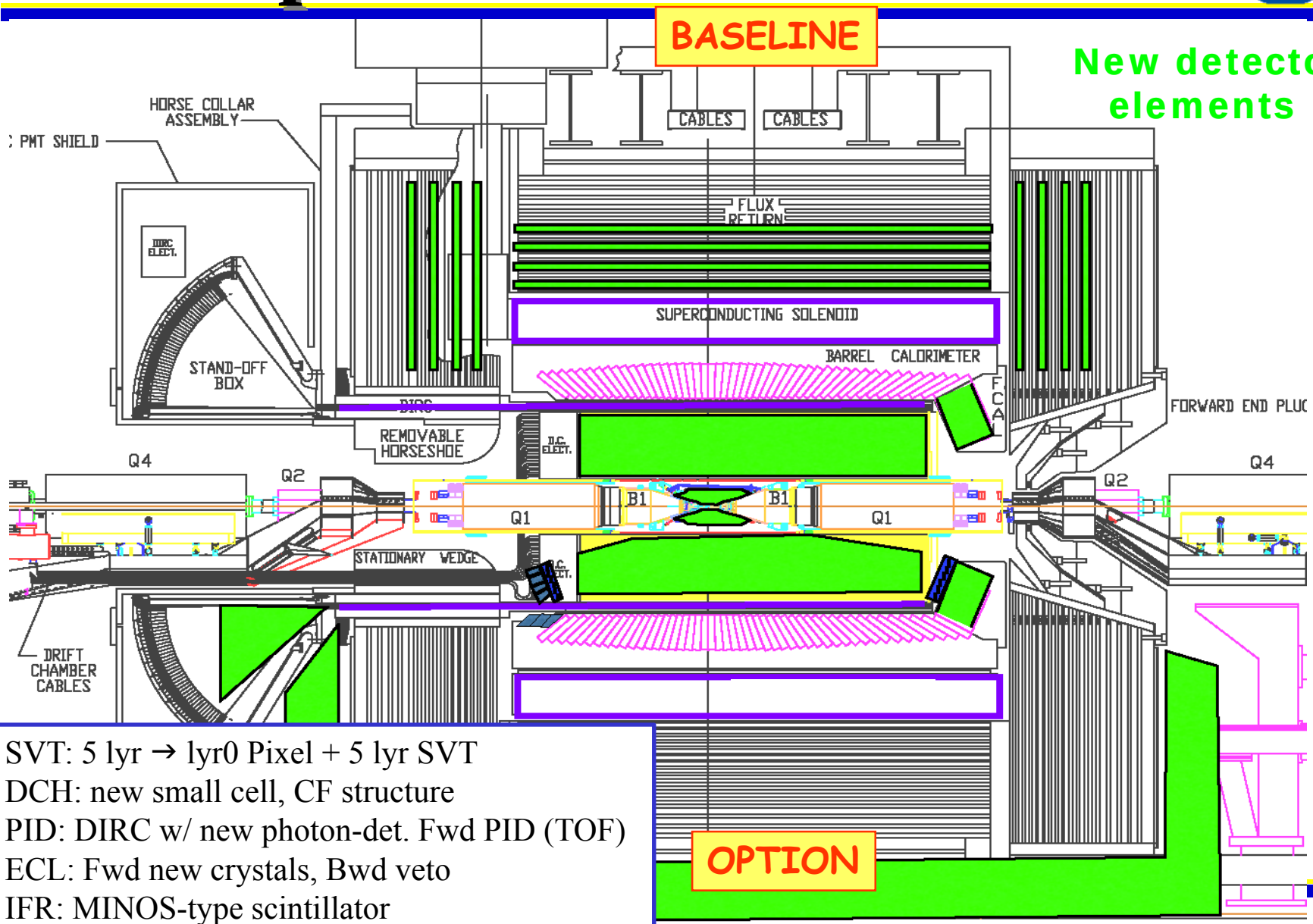


Belle II

Belle

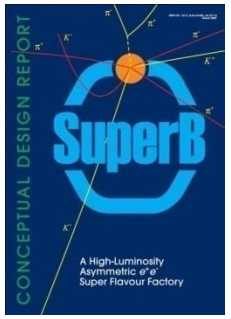
SVD: 4 lyr → 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling, pure CsI for end-caps
KLM: RPC → Scintillator +SiPM (end-caps)

SuperB: Baseline Detector



SVT: 5 lyr → lyr0 Pixel + 5 lyr SVT
DCH: new small cell, CF structure
PID: DIRC w/ new photon-det. Fwd PID (TOF)
ECL: Fwd new crystals, Bwd veto
IFR: MINOS-type scintillator

Progress / Plan



arXiv:0709.0451

2007.09: CDR; 320 signatures, ~85 institutes

2008.06: Mini MAC formed (Chair: J.Dorfan)

↓ recommendation

2008.12: TDR phase was approved by INFN

15M € /3 years (2009-2011)

Management structure formed

Director: M.Georgi

Deputies: D.Hitlin, D.Leith, G.Wormser

Accelerator: J.Seeman

Detector: F.Forti, B.Ratcliff

TDR ready by end of 2010

2009.04: 2nd MAC:

further endorsement

2009.06: General Meetnig

Workshop on New Physics with SuperB
14th-17th April 2009

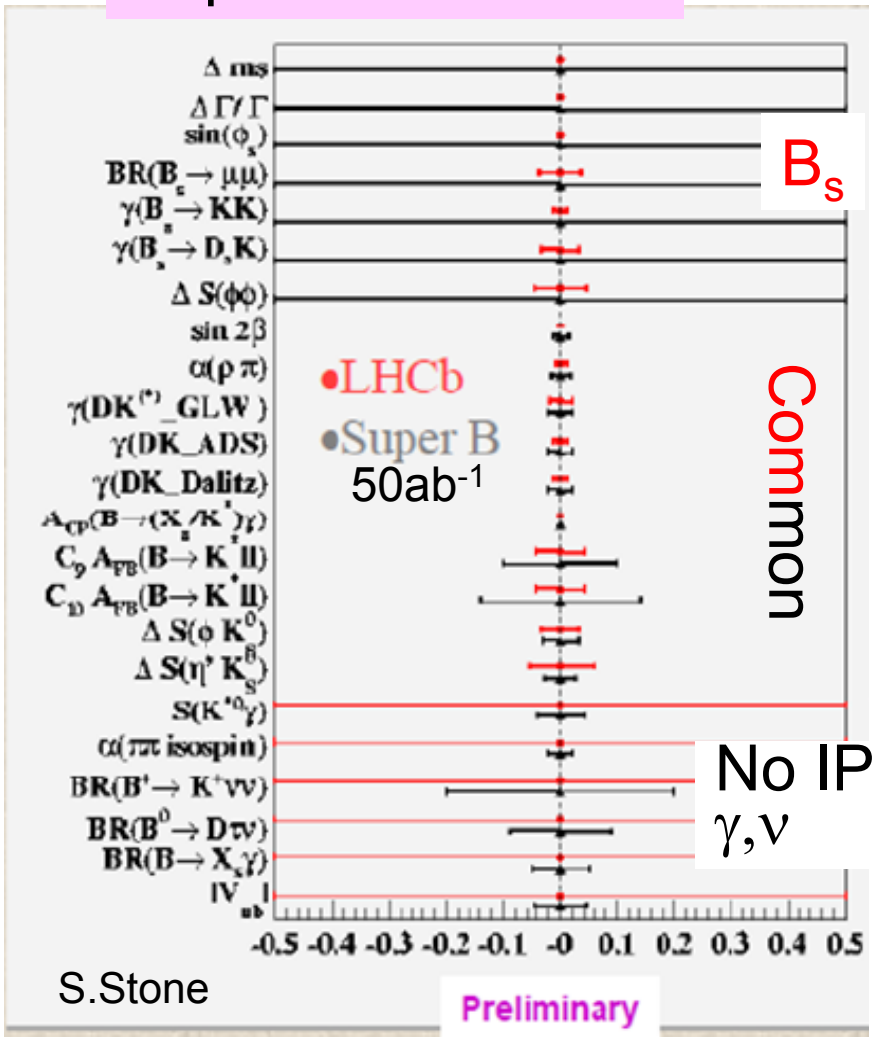
Progress / Plan

2004.06: LoI for SuperKEKB
2008.01: KEK Roadmap
SuperKEKB is identified as high priority
2008.12: New collaboration (Belle II) formed officially
13 countries, 43 institutes
Spokesperson selection in progress
2009.03: BPAC (Chair: T.Nakada) endorsement
2009.03: FY2008/9 supplemental budget:
~5M$ for Belle II upgrade
2009.05: ~27M$ for KEKB upgrade R&D

2009.07: 3rd Open Belle II
collab. meetnig

Complementary with LHC

Super BF vs LHCb



NP Flavor couplings

$$(m^2_{\tilde{q}})_{ij} = \begin{pmatrix} m^2_{11} & m^2_{12} & m^2_{13} \\ m^2_{21} & m^2_{22} & m^2_{23} \\ m^2_{31} & m^2_{32} & m^2_{33} \end{pmatrix}$$

Diagonal: Energy frontier (LHC, ILC)

Off-diagonal: Lum. Frontier (Super BF, LHCb)

- Settle NP models
- Search higher scale NP

Summary

- Excellent performances of B-factories
- Successful Physics Results + Need/Hints of NP

⇨ **Super B-factories: L ~10^{36}, >50 ab^{-1} data**
Complementary to LHC(b)

Two Super B-factory projects are going on

SuperB(Italy): Nano-beam (low emittance)
Crab-waist tested at DAFNE
INFN fund for TRD phase → management structure

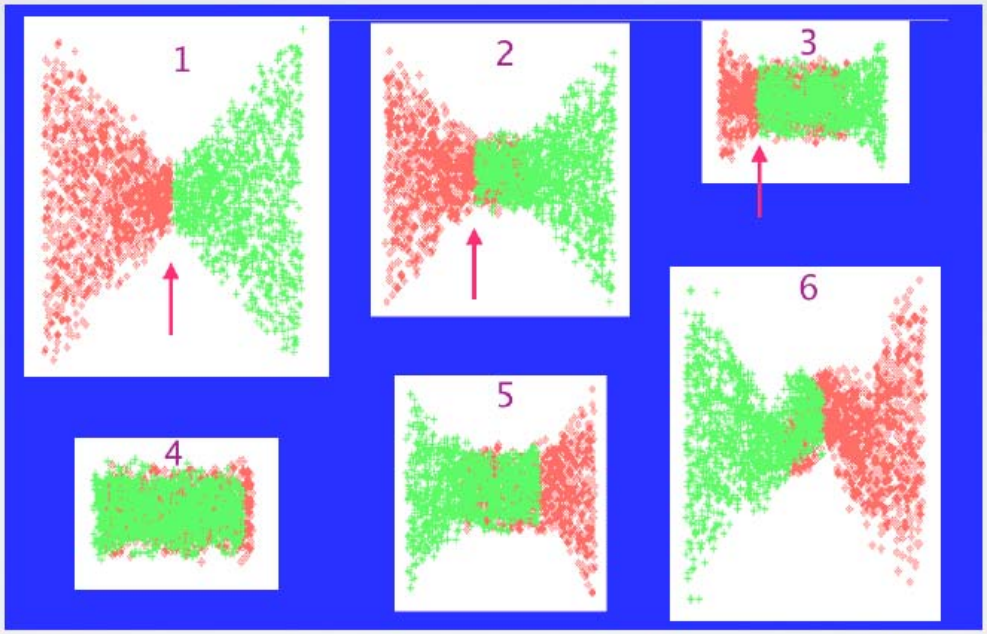
SuperKEKB(Japan): High current (baseline ~done)
→ Nano-beam option design: decision in Fall
"Belle II" collaboration formed
Upgrade construction partially funded

Welcome to join !

Backup

Traveling waist(focus) scheme

- Known technique for a linear collider (Balakin, et al).
- Move vertical waist backward along z.



N. Walker

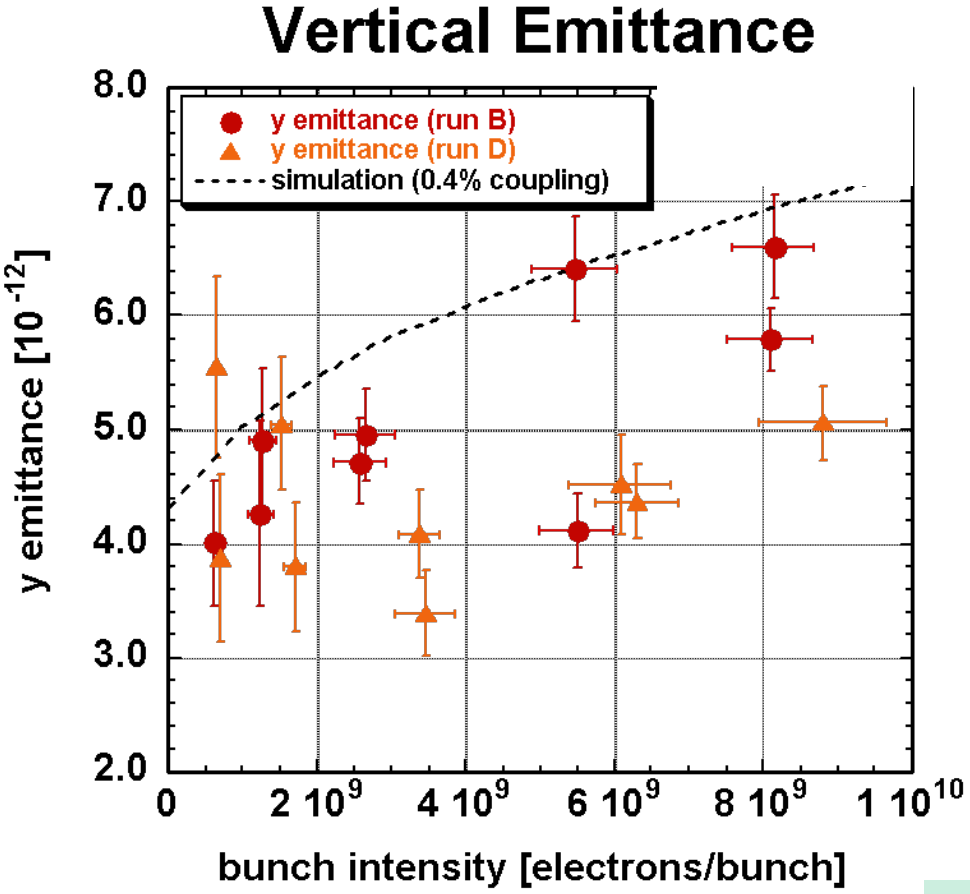
- Two crab cavities, each sits in the middle of -I pair of sextupoles, are necessary for a ring.
- Very hard to accommodate them in the HER.

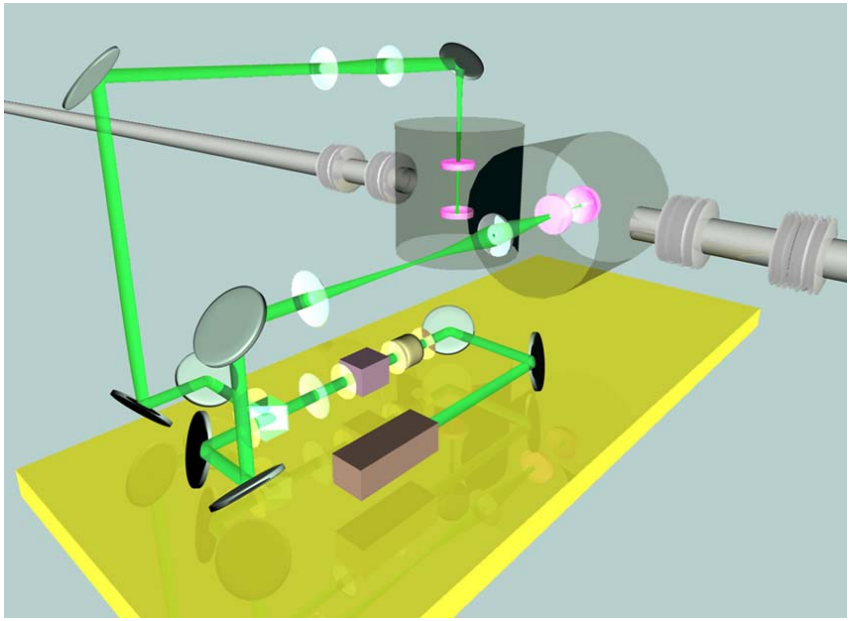
KEK ATF: Low ε achievement

Linear collider R&D

ε_y ~ 4 pm

Laser wire beam size monitor





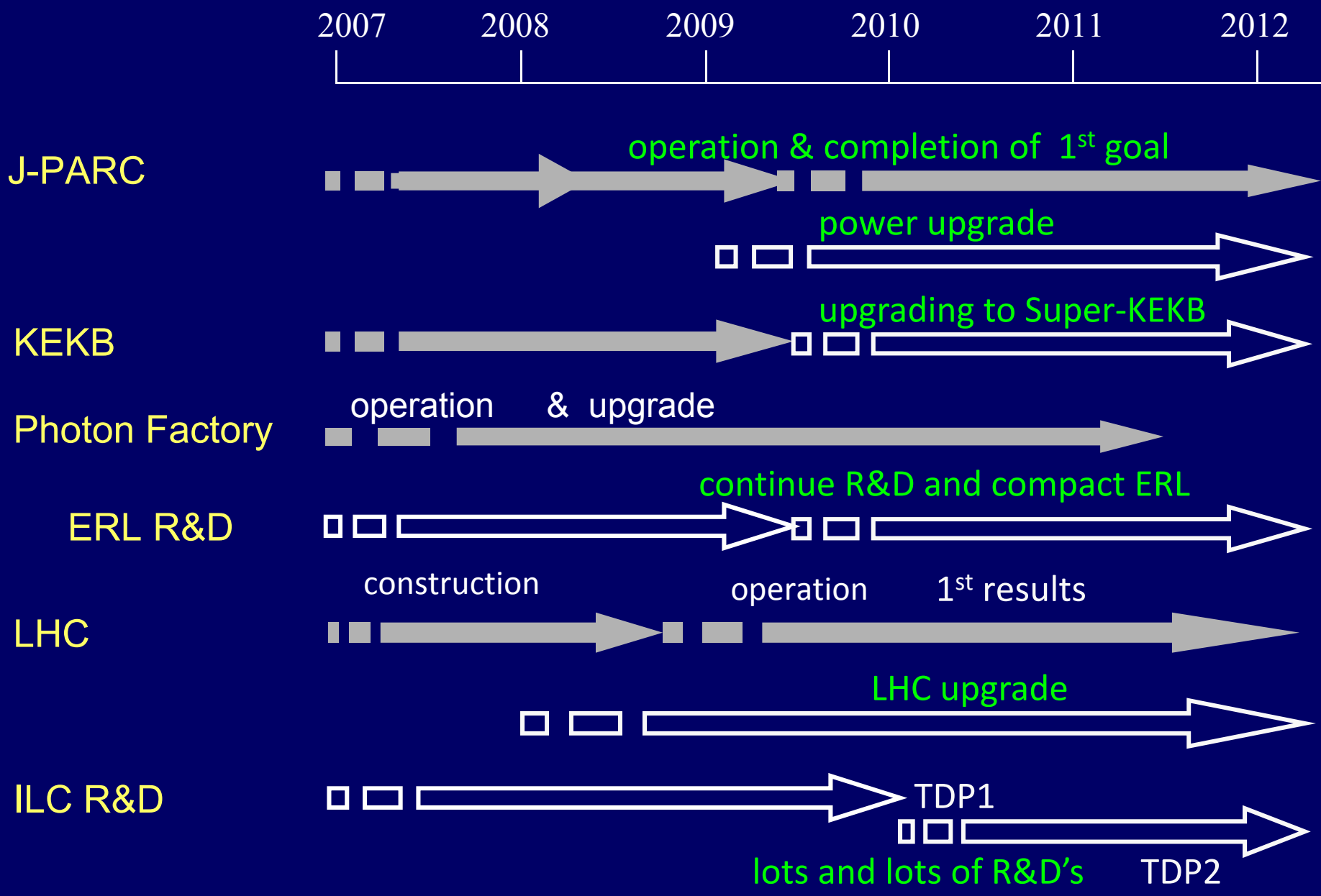
300mW 532nm Solid-state Laser
Fed into optical cavity

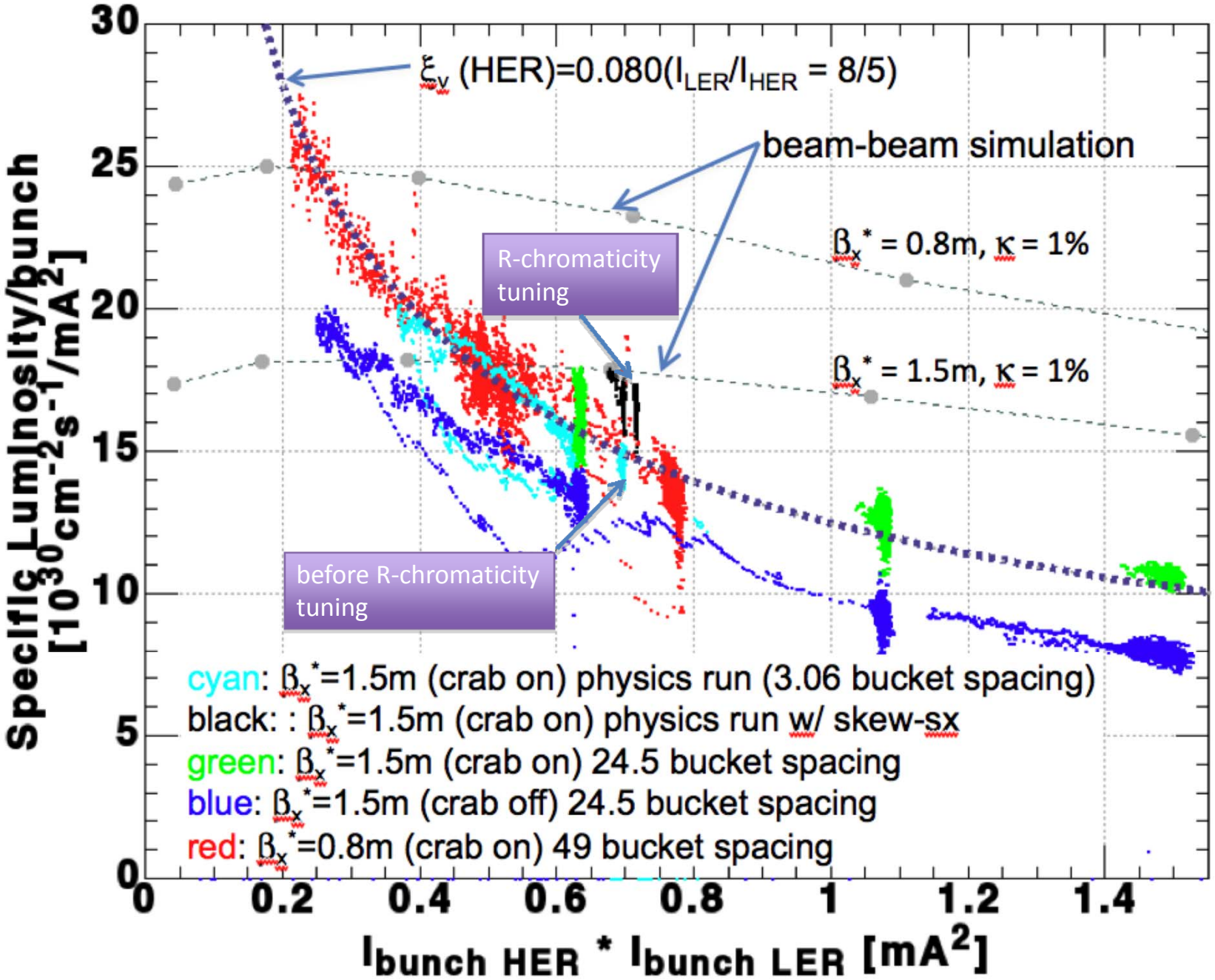
Position resolution: 2μm

PRL 92, 054082 (2004)

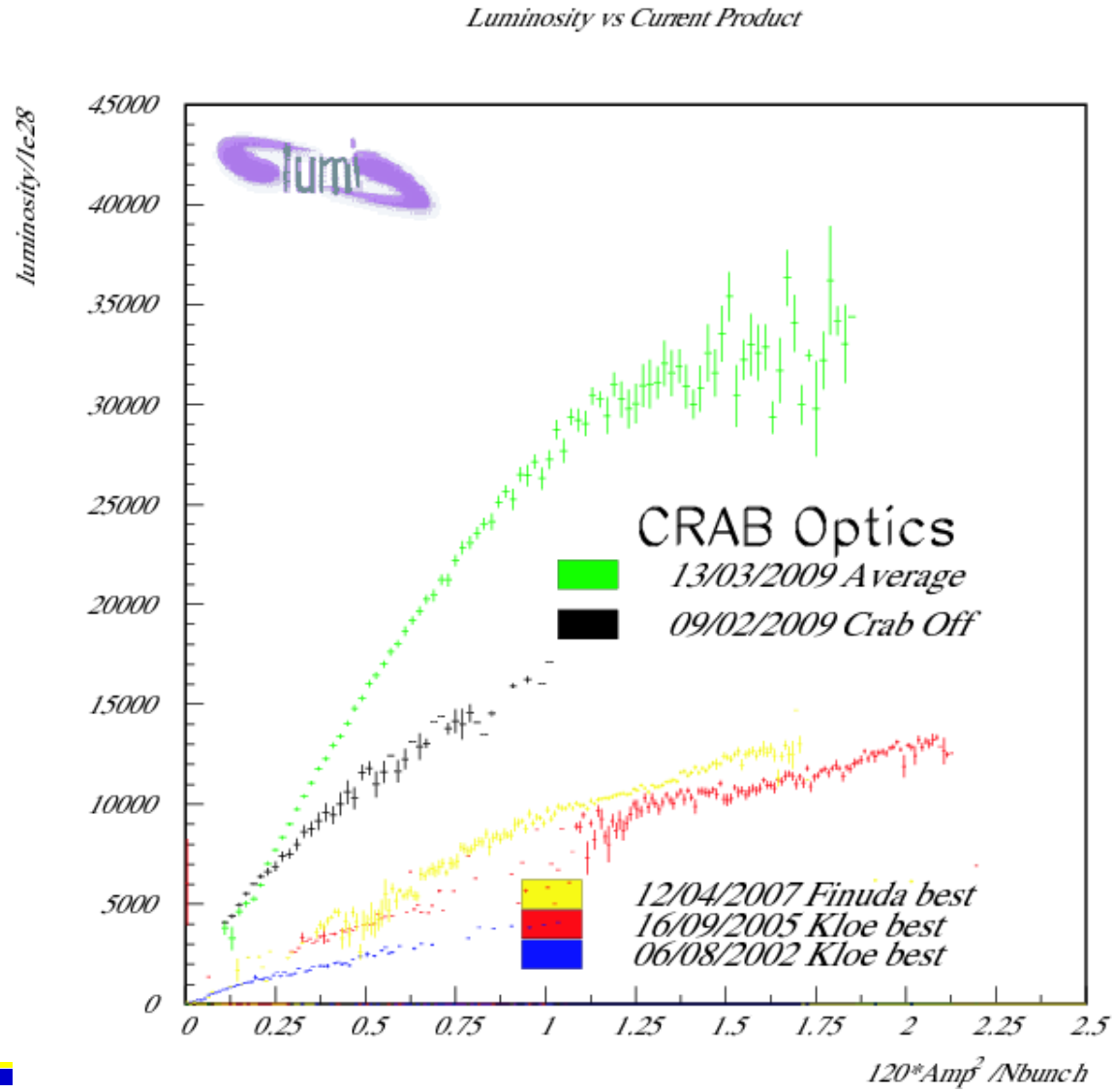
Summary of KEK Roadmap

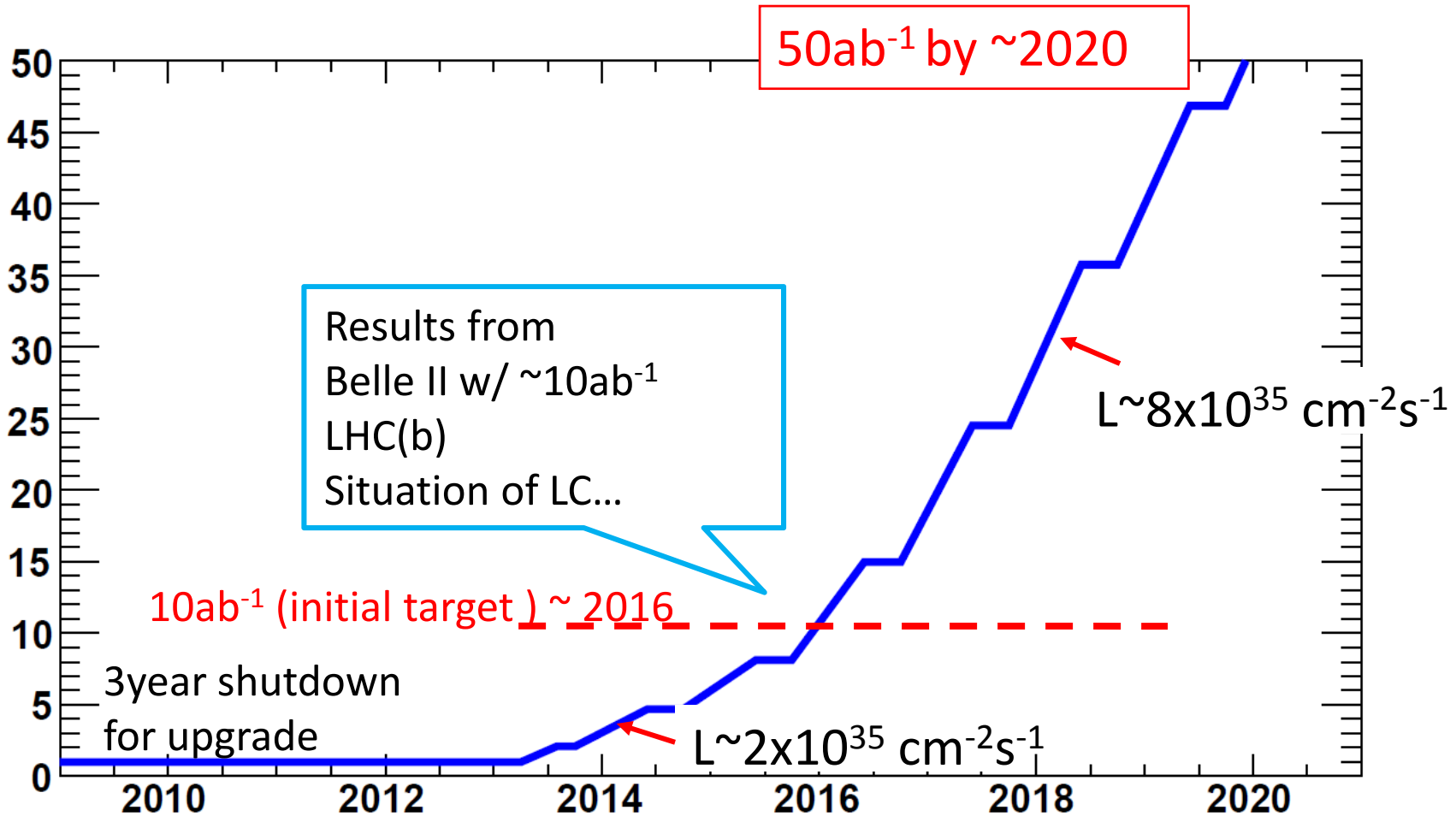
(A.Suzuki)




ξ_y (HER)=0.080(I_{LER}/I_{HER} = 8/5)
beam-beam simulation
β_x^* = 0.8m, κ = 1%
β_x^* = 1.5m, κ = 1%
R-chromaticity tuning
before R-chromaticity tuning
cyan: β_x^*=1.5m (crab on) physics run (3.06 bucket spacing)
black: : β_x^*=1.5m (crab on) physics run w/ skew-sx
green: β_x^*=1.5m (crab on) 24.5 bucket spacing
blue: β_x^*=1.5m (crab off) 24.5 bucket spacing
red: β_x^*=0.8m (crab on) 49 bucket spacing
Specific Luminosity/bunch [$10^{30}cm^{-2}s^{-1}/mA^2$]
$I_{bunch\ HER} * I_{bunch\ LER}$ [mA^2]
0
5
10
15
20
25
30
0.2
0.4
0.6
0.8
1
1.2
1.4

Proof of Crab Waist principle in Dafne

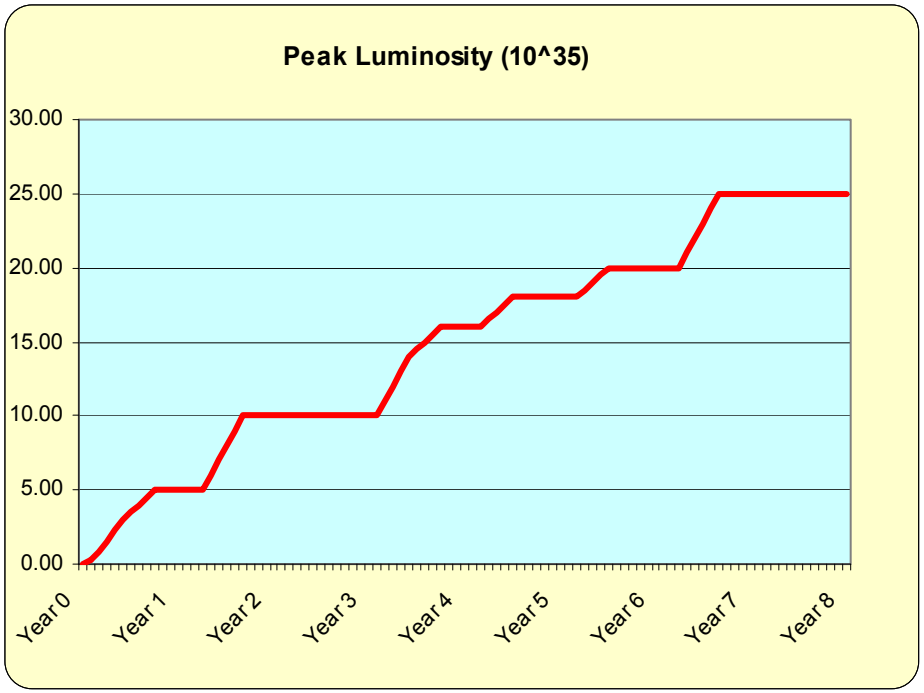


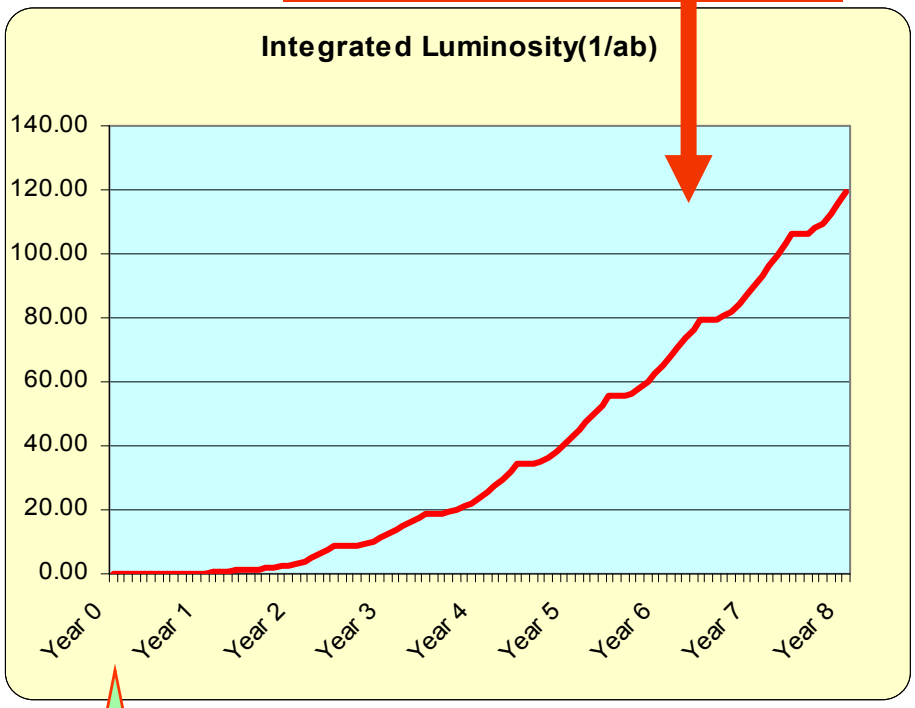

50ab-1 by ~2020
Results from
Belle II w/ ~10ab-1
LHC(b)
Situation of LC…
10ab-1 (initial target) ~ 2016
3year shutdown
for upgrade
L~2x10^35 cm-2s-1
L~8x10^35 cm-2s-1
50
45
40
35
30
25
20
15
10
5
0
2010
2012
2014
2016
2018
2020

With 7th year integrated Luminosity can grow at rate of ~40 ÷ 60 ab^{-1}/year

expectation

>80ab^{-1} after 6 years





With more money a second interaction can be included in SuperB, without compromising on Luminosity!

2015?

From SuperB Machine Advisory Committee meeting

April 23rd-24th :second meeting of the SuperB Machine Advisory Committee in Frascati

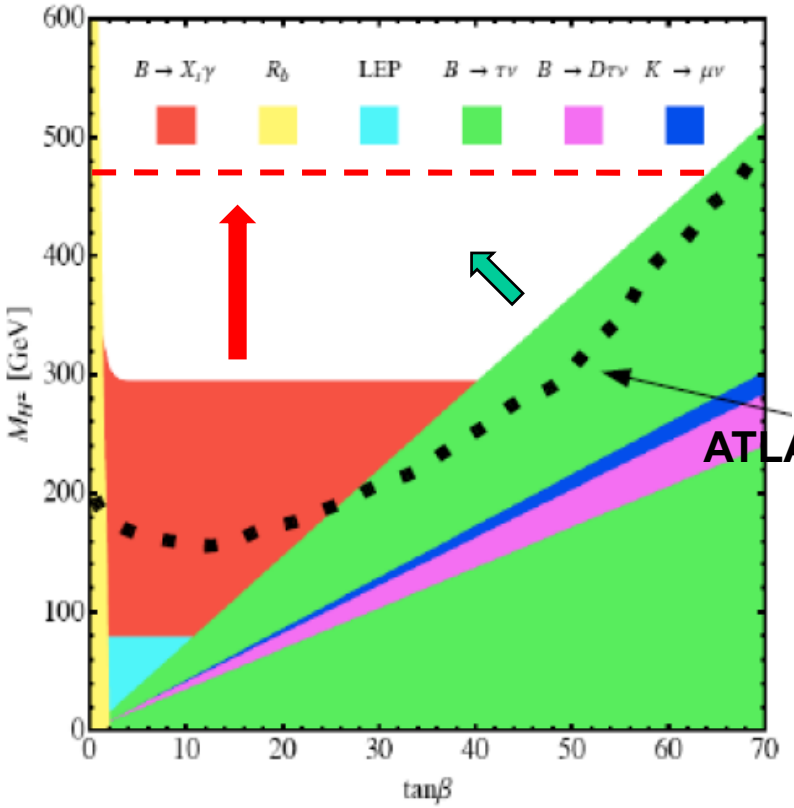
(chaired by J. Dorfan) composed by well known international machine experts.

Outcome of the meeting :

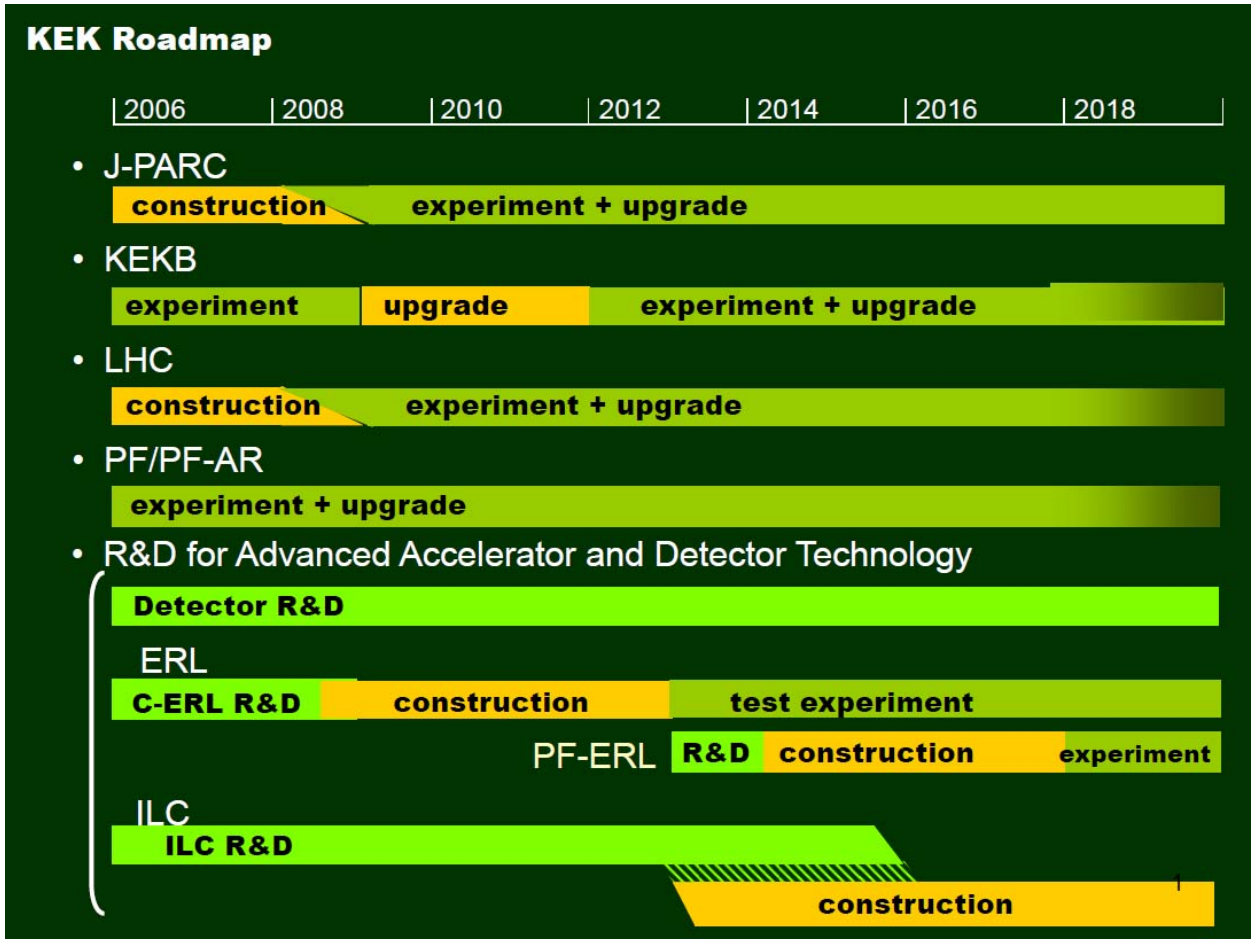
"MAC now feels secure in enthusiastically encouraging the SuperB design team to proceed to the TDR phase, with confidence that the design parameters are achievable".

This result recognizes the validity of the novel beam-beam technology called "crab-waist" developed in the INFN Frascati National Lab and successfully tested by an international team at the Dafne collider during 2008.

$H^{\pm}$ Even current constraints are competitive



U. Haisch arXiv:0805.2141 [hep-ph]
(presented at FPCP 2008)


KEK Roadmap
2006
2008
2010
2012
2014
2016
2018
J-PARC
construction
experiment + upgrade
KEKB
experiment
upgrade
experiment + upgrade
LHC
construction
experiment + upgrade
PF/PF-AR
experiment + upgrade
R&D for Advanced Accelerator and Detector Technology
Detector R&D
ERL
C-ERL R&D
construction
test experiment
PF-ERL
R&D
construction
experiment
ILC
ILC R&D
construction