Future Opportunities for Heavy Flavor Physics Experiments

Toru Iijima

Kobayashi-Maskawa Institute

Nagoya University

October 5, 2011

Talk Outline

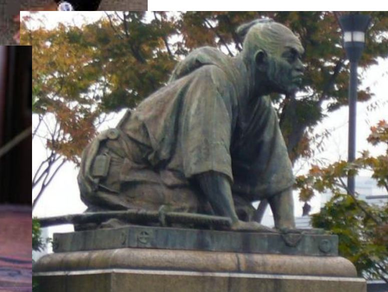
- LHCb Upgrade
- Super B Factories
  - SuperKEKB / Belle II
  - INFN SuperB
- Charm-Tau Factories

\+ K decays
(requested by conveners)

In 25 min !

Apology

in case of missing your favorite experiments and subjects !



If you are still unhappy,…

Role of Flavor Physics

Variety of observables w/ different sensitivity to NP models.

➡ Clarify if NP exists in the TeV scale.

➡ Elucidation of new physics.

	AC	RVV2	AKM	δLL	FBMSSM	LHT	RS
$D^0-\bar{D}^0$	★★★	★	★	★	★	★★★	?
ϵ_K	★	★★★	★★★	★	★	★★	★★★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★	★★★	★★★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★	★	?
$A_{\rm CP}(B\to X_s\gamma)$	★	★	★	★★★	★★★	★	?
$A_{7,8}(B\to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★	★★	?
$A_9(B\to K^*\mu^+\mu^-)$	★	★	★	★	★	★	?
$B\to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★	★	★
$B_s\to\mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★	★
$K^+\to\pi^+\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$K_L\to\pi^0\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$\mu\to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
$\tau\to\mu\gamma$	★★★	★★★	★	★★★	★★★	★★★	★★★
$\mu+N\to e+N$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
d_n	★★★	★★★	★★★	★★	★★★	★	★★★
d_e	★★★	★★★	★★	★	★★★	★	★★★
$(g-2)_\mu$	★★★	★★★	★★	★★★	★★★	★	?

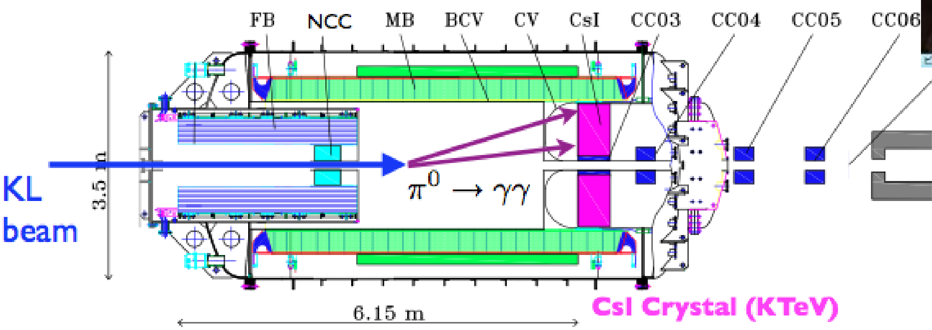
Table 8: "DNA" of flavour physics effects for the most interesting observables in a selection of SUSY and non-SUSY models ★★★ signals large effects, ★★ visible but small effects and ★ implies that the given model does not predict sizable effects in that observable.

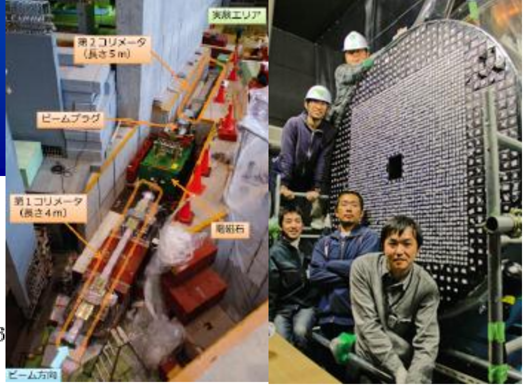
W. Altmannshofer, A. J. Buras, S. Gori, P. Paradisi, D. M. Straub, Nucl. Phys. B830, 17-94 2010.

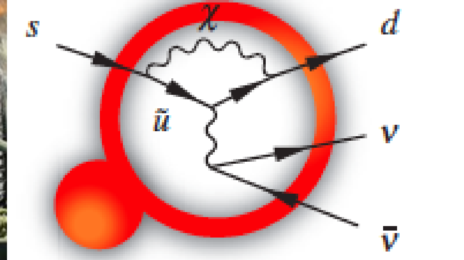
$K \rightarrow \pi \nu \bar{\nu}$

New K_L beam line @ J-PARC

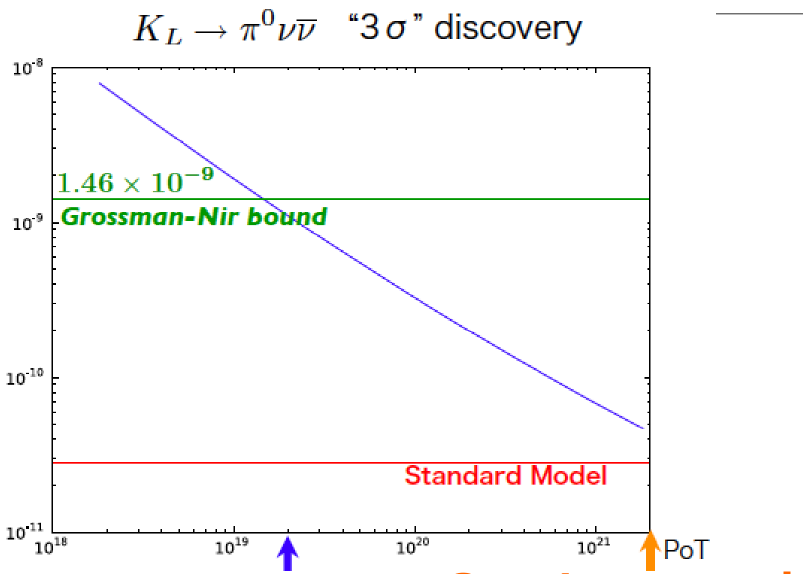
KOTO@J-PARC $K_L^0 \rightarrow \pi^0 \nu \bar{\nu}$







CsI calorimeter

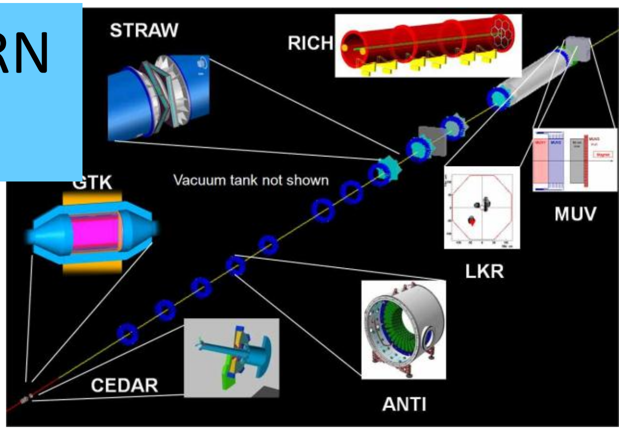


by 2013

Step1 proposal (290kW)

➡ 10^{-13} (Step2) dep.on acc. power upgrade

NA62@CERN $K^+ \rightarrow \pi^+ \nu \bar{\nu}$

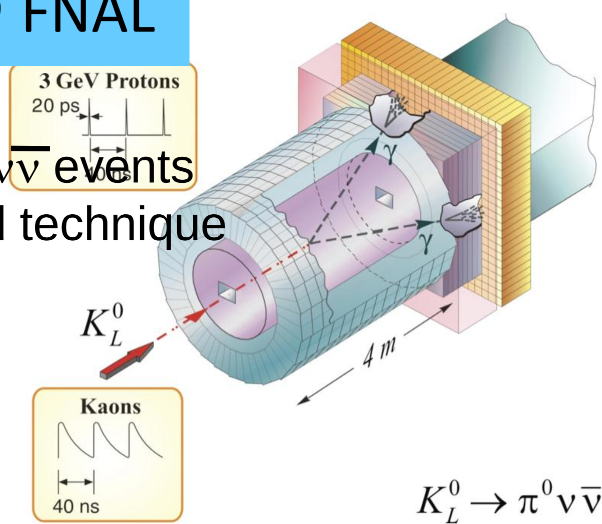


~80 $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ in 2years

Technical run in 2012.

Project-X @ FNAL

~1000 $K^0 \rightarrow \pi^0 \nu \bar{\nu}$ events w/ TOF-based technique



LHCb Upgrade

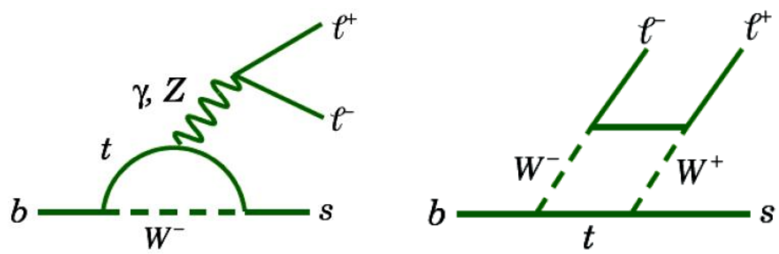
- Peak luminosity: $L_{peak} = 10^{32} \rightarrow 10^{33}\ cm^{-2}s^{-1}$
- Integrated luminosity: $L_{int} = 5 \rightarrow 50fb^{-1}$ ($1 \rightarrow 10fb^{-1}$/year)

Key measurements at LHCb

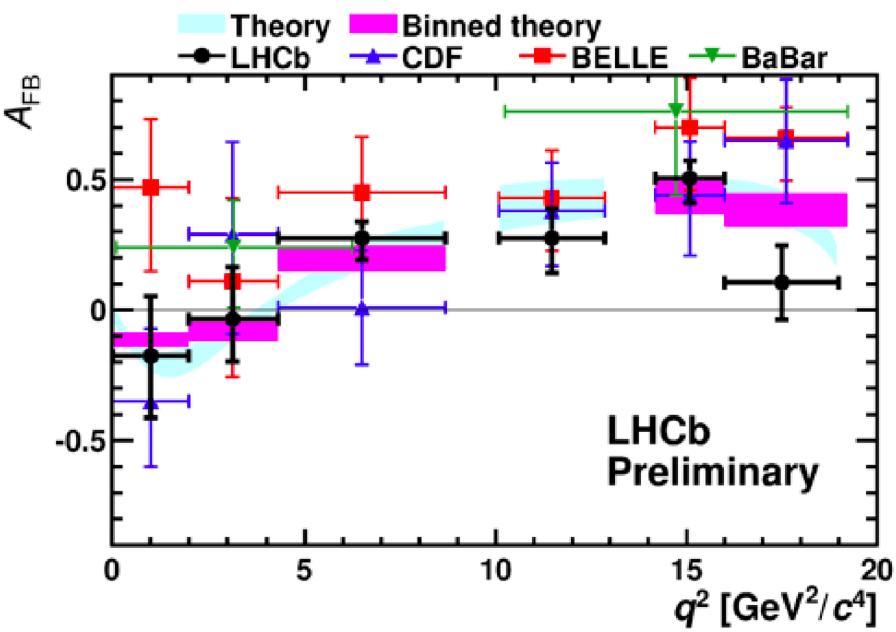
Type	Observable	Current precision	LHCb (5 fb^{-1})	Upgrade (50 fb^{-1})	Theory uncertainty
Gluonic penguin	$S(B_s \to \phi\phi)$	-	0.08	0.02	0.02
	$S(B_s \to K^{*0}\bar{K}^{*0})$	-	0.07	0.02	< 0.02
	$S(B^0 \to \phi K^0_S)$	0.17	0.15	0.03	0.02
B_s mixing	$2\beta_s\ (B_s \to J/\psi\phi)$	0.35	0.019	0.006	~ 0.003
Right-handed currents	$S(B_s \to \phi\gamma)$	-	0.07	0.02	< 0.01
	$\mathcal{A}^{\Delta\Gamma_s}(B_s \to \phi\gamma)$	-	0.14	0.03	0.02
E/W penguin	$A_T^{(2)}(B^0 \to K^{*0}\mu^+\mu^-)$	-	0.14	0.04	0.05
	$s_0\, A_{\rm FB}(B^0 \to K^{*0}\mu^+\mu^-)$	-	4%	1%	7%
Higgs penguin	$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	30%	8%	$< 10\%$
	$\frac{\mathcal{B}(B^0 \to \mu^+\mu^-)}{\mathcal{B}(B_s \to \mu^+\mu^-)}$	-	-	$\sim 35\%$	$\sim 5\%$
Unitarity triangle angles	$\gamma\ (B \to D^{(*)}K^{(*)})$	$\sim 20^\circ$	$\sim 4^\circ$	0.9°	negligible
	$\gamma\ (B_s \to D_sK)$	-	$\sim 7^\circ$	1.5°	negligible
	$\beta\ (B^0 \to J/\psi\, K^0)$	1°	0.5°	0.2°	negligible
Charm CPV	A_Γ	2.5×10^{-3}	2×10^{-4}	4×10^{-5}	-
	$A_{CP}^{dir}(KK) - A_{CP}^{dir}(\pi\pi)$	4.3×10^{-3}	4×10^{-4}	8×10^{-5}	-

$B \to K^*\mu^+\mu^-$

- FCNC processes sensitive to NP via angular distribution.
- LHCb measures also $B^+ \to K^+ \mu^+\mu^-$, $B_s \to \phi\, \mu^+\mu^-$, $\Lambda_b \to \Lambda^* \mu^+\mu^-$
- Belle II /SuperB can measure also $X_s l^+ l^-$



Present

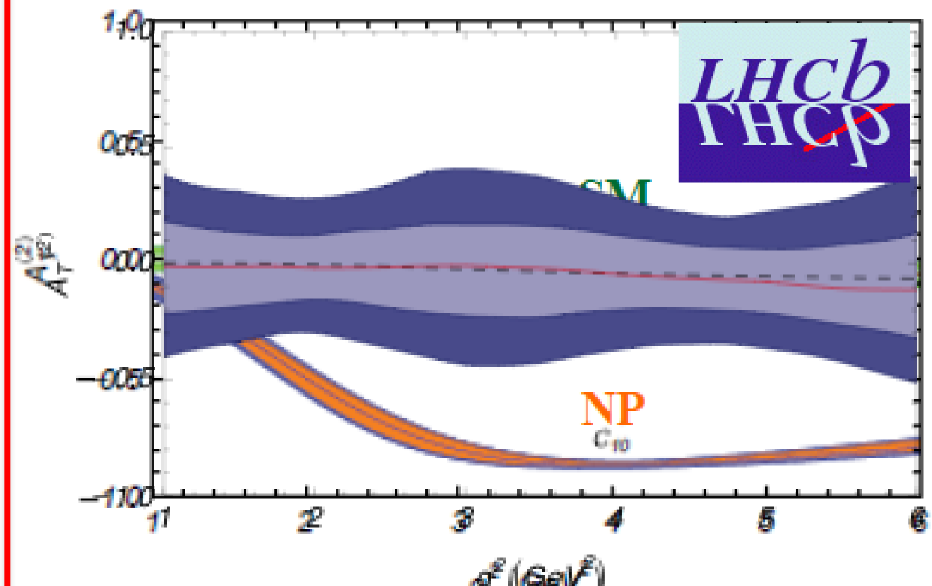


LHCb upgrade

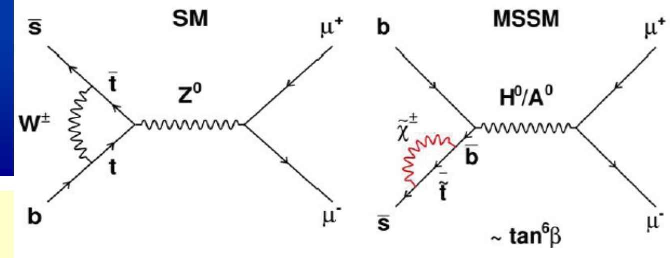
- More kinematic variables, e.g. transversity asymmetry $A_T^{(2)}$ sensitive to new RH currents

$A_T^{(2)}$: 0.14(5fb^{-1}) → 0.04(50fb^{-1})

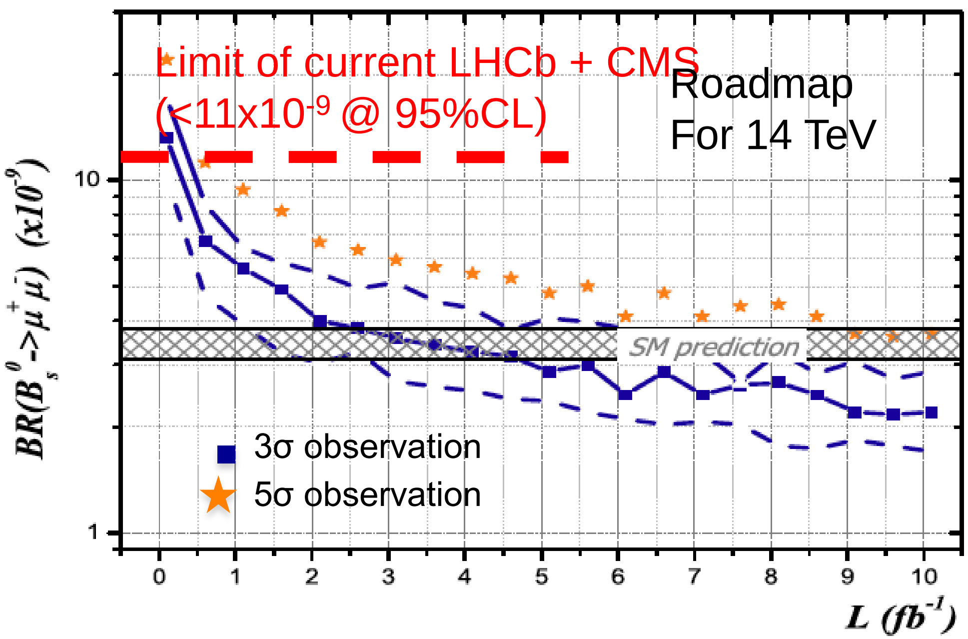
S_0 (zero cross): 4% → 1%

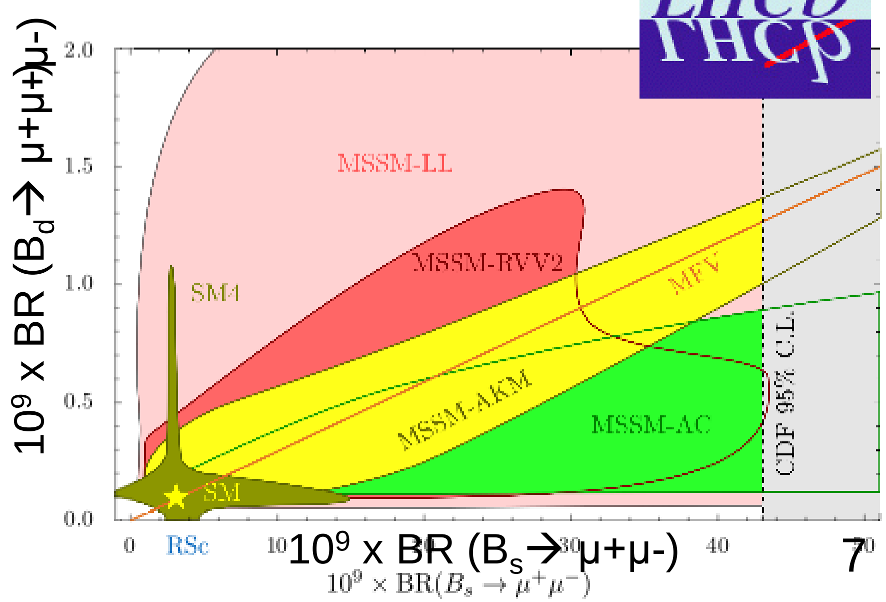


$B_{s,d} \to \mu^+\mu^-$



- Exploit statistical power LHCb
- Sensitivity of current limit (43×10^{-9} @ 90% C.L. with 40 pb^{-1}) in agreement with MC roadmap
- Measurement of f_s/f_d is currently stat. limited
- Upgrade:
  - SM {BR ($B_s \to \mu^+\mu^-$)} can be measured to 8% precision @ 50 fb^{-1}
    - Strong constraints for NP models
  - Correlation $B_s \to \mu^+\mu^-$ vs $B_d \to \mu^+\mu^-$ can be done in upgrade ≈ 35%
    - Challenge: low BR $B_d \to \mu^+\mu^-$ and background



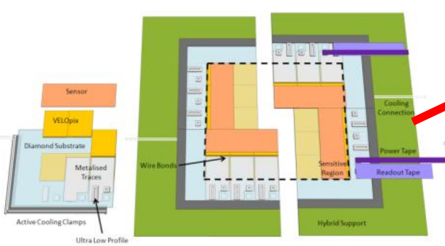


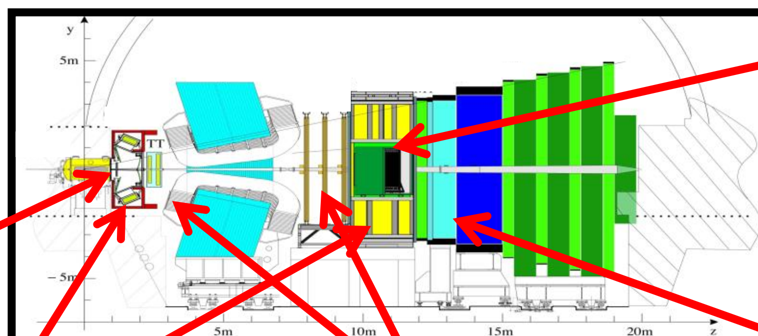
LHCb Upgrade

Limitation at present LHCb: 2-3x10^^{32}cm^{-2}s^{-1} (L0 trigger)

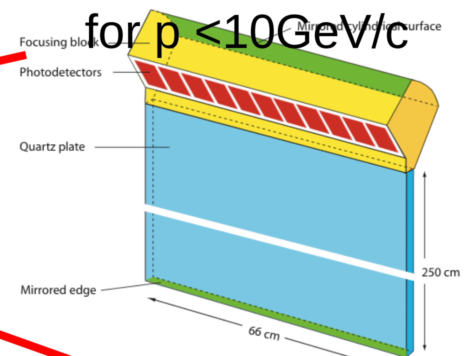
- Readout detector at 40MHz to run full software trigger.
  - Replace all sub-detector front-end electronics to 40MHz readout.
  - Replace all silicon detectors attached to the current 1MHz readout (VELO, IT, TT, RICH HPD's).
- Remove some detectors due to increased occupancies (RICH1 aerogel, M1, possibly PS&SPD).
- New PID to cover low momentum region (TORCH)

New VELOPIX
w/ 55mm × 55mm
Timepix chip



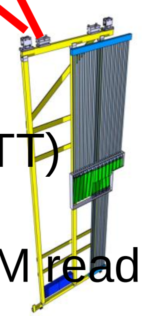


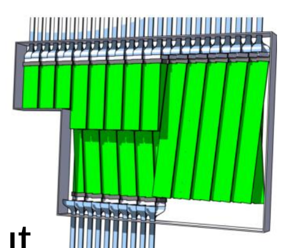
New PID TORCH
for p <10GeV/c



MA-PMT for
RICH1,2

New Tracker (IT,TT)
•Silicon strips
•Sci fiber w/ Si-PM readout



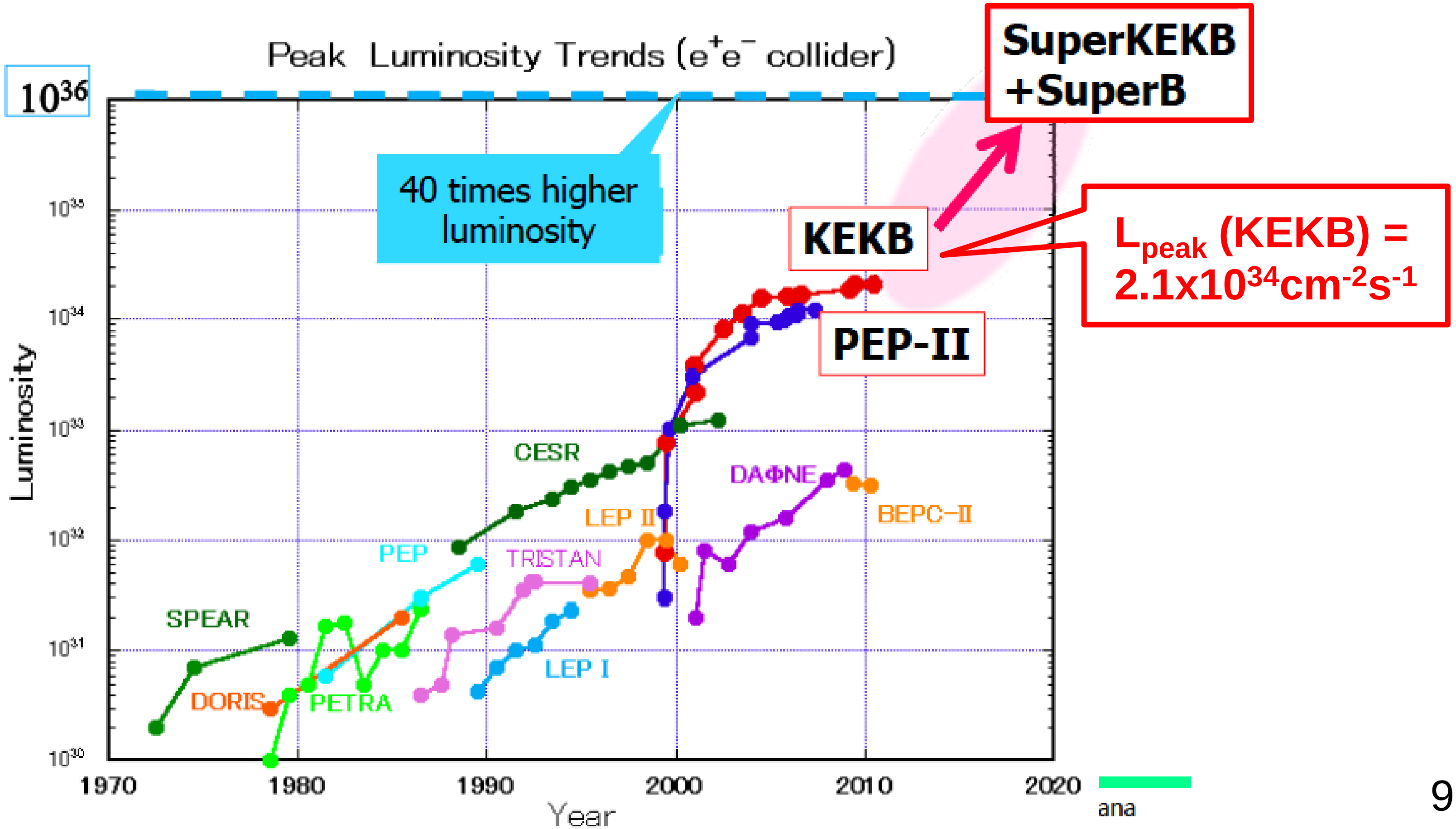


New electronics for
calorimeters

New digital electronics prototype

Super B Factories

- Target luminosity: L_{peak} =(0.8-1.0) x $10^{36}cm^{-2}s^{-1}$
  L_{int} >50-75 ab^{-1} by early 2020's.
- Production rate: ~10^{10} BB, $\tau^{+}\tau^{+}$ and charms per year.



Key Measurements at Belle II

CPV in $b \to s$ modes

FCNC $b \to s\gamma$

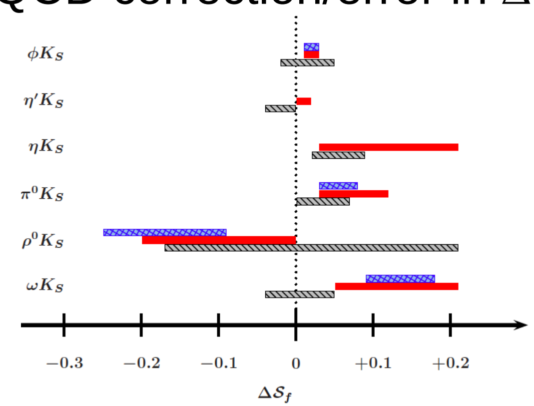
$b \to sll$

Tauonic decays

LFV tau decays

Precision CKM

QCD correction/error in ΔS

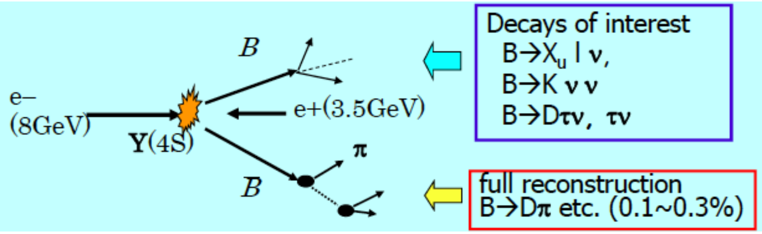


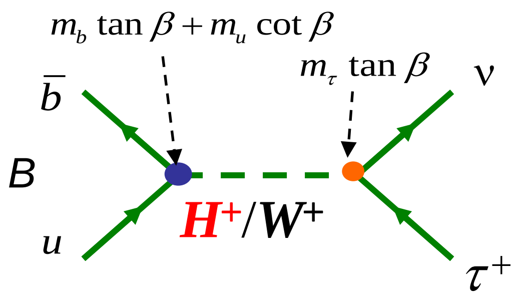
	Belle'06 (~0.5ab^{-1})	5ab^{-1}	50ab^{-1}
$\Delta S(\phi K^0)$	**0.22**	0.073	**0.029**
$\Delta S(\eta' K^0)$	**0.11**	0.038	**0.020**
$\Delta S(K_S K_S K_S)$	**0.33**	0.105	**0.037**
$\Delta S(K_S \pi^0 \gamma)$	**0.32**	0.10	**0.03**
$Br(X_s \gamma)$	**13%**		
$A_{CP}(X_s \gamma)$	**0.058**	0.01	**0.005**
C_9 [$A_{FB}(K^*ll)$]	**---**	11%	**4%**
C_{10} [$A_{FB}(K^*ll)$]	**---**	13%	**4%**
$Br(B^+ \to K^+ \nu\nu)$	**<9Br(SM)**	**33ab^{-1} for 5σ discovery**	
$Br(B^+ \to \tau\nu)$	**3.5σ**	10%	**3%**
$Br(B^+ \to \mu\nu)$	**<2.4Br(SM)**	**4.3ab^{-1} for 5σ discovery**	
$Br(B^+ \to D\tau\nu)$	**---**	7.9%	**2.5%**
$Br(\tau \to \mu\gamma)$	**<45**	<30	**<8**
$Br(\tau \to \mu\eta)$	**<65**	<20	**<4**
$Br(\tau \to 3\mu)$	**<209**	<10	**<1**
$\Delta \sin 2\phi_1$	**0.026**	0.016	**0.012**
$\Delta\Phi_2$ ($\rho\pi$)	**68° —95°**	3°	**1°**
$\Delta\Phi_3$(Dalitz)	**20°**	7°	**2.5°**
ΔV_{ub} (incl.)	**7.3%**	6.6%	**6.1%**

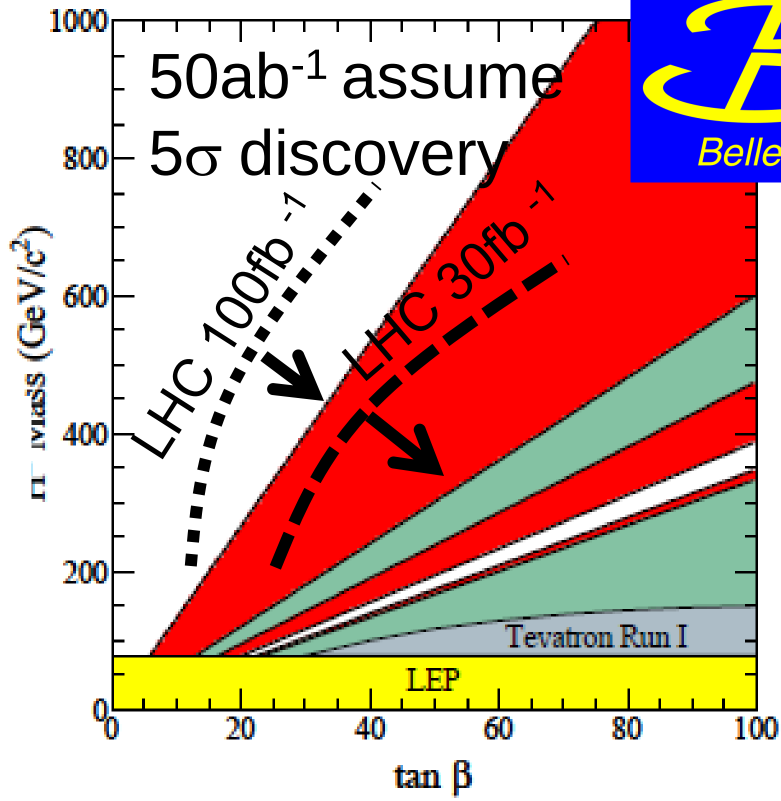
Ultimate measurements down to theory error !

Search for charged Higgs ($B \to \tau\nu$)

Super B factories can measure the missing energy modes by fully reconstructing one of the B mesons.



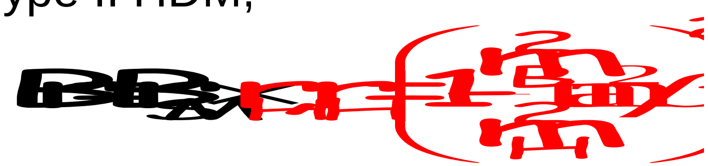




In SM,

$$\mathcal{B}(B^- \to \ell^- \bar{\nu}) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

In Type II HDM,

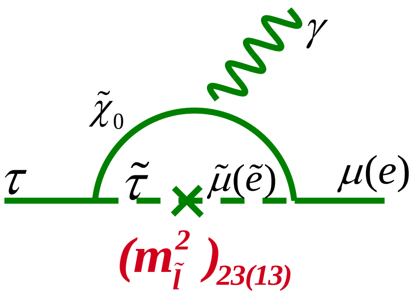


- $B \to \tau\nu / D\tau\nu$ probes b-$H^{\pm}$-u, b-$H^{\pm}$-c couings to compare b-$H^{\pm}$-t *coupling* from LHC high P_T programs.

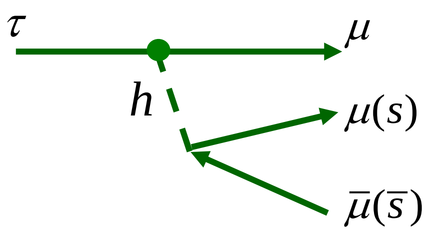
LFV in τ Decays

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}

$\tau \rightarrow l\gamma$

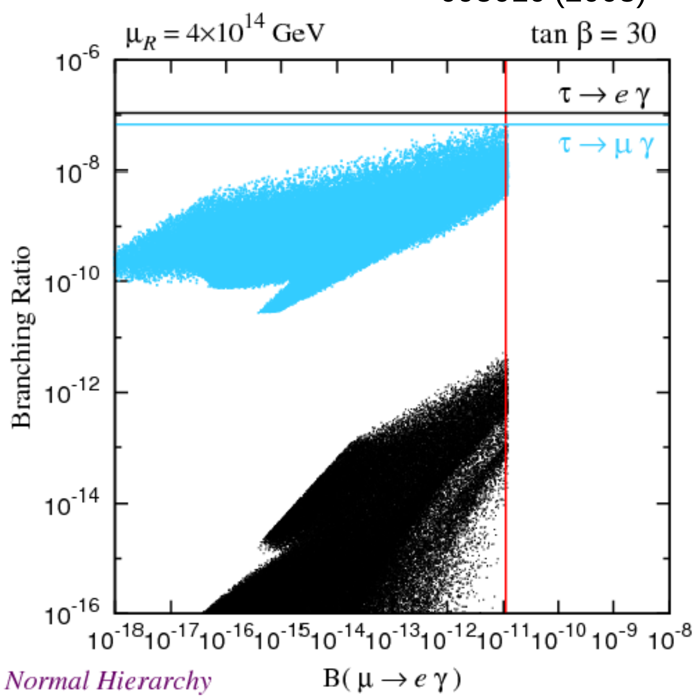


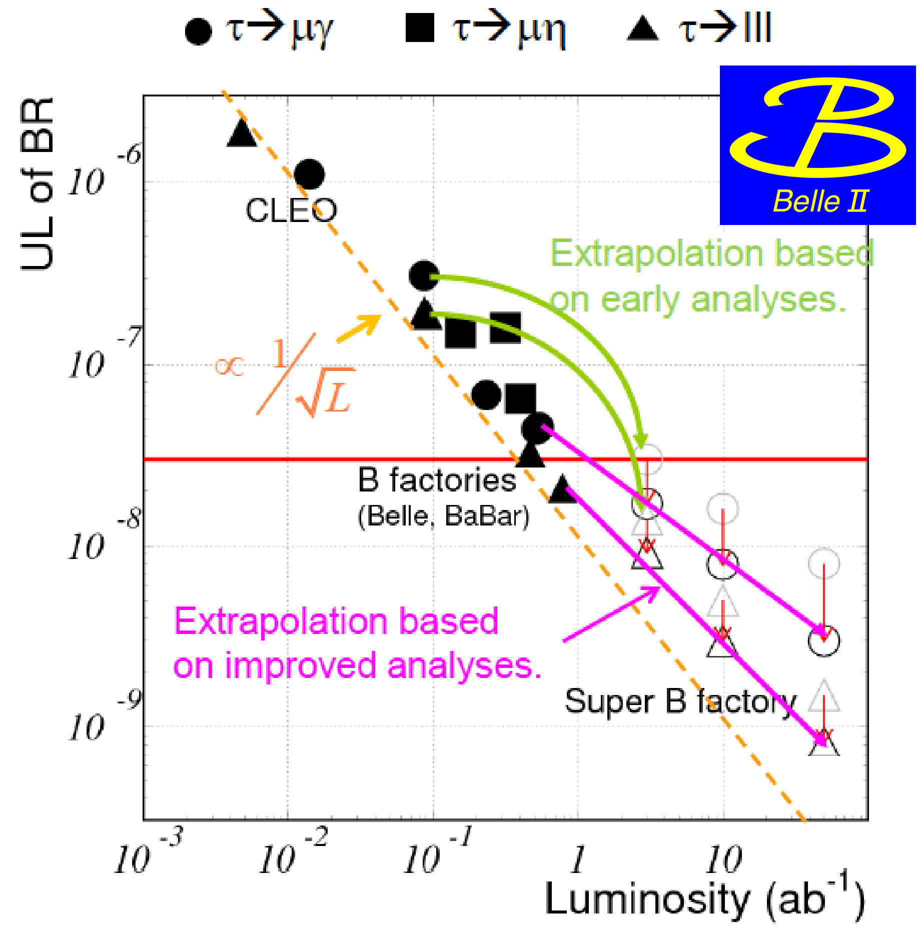
$\tau \rightarrow 3l, l\eta$



SU(5)+ν_R, non-degenerate ν_R(l), Normal hierarchy

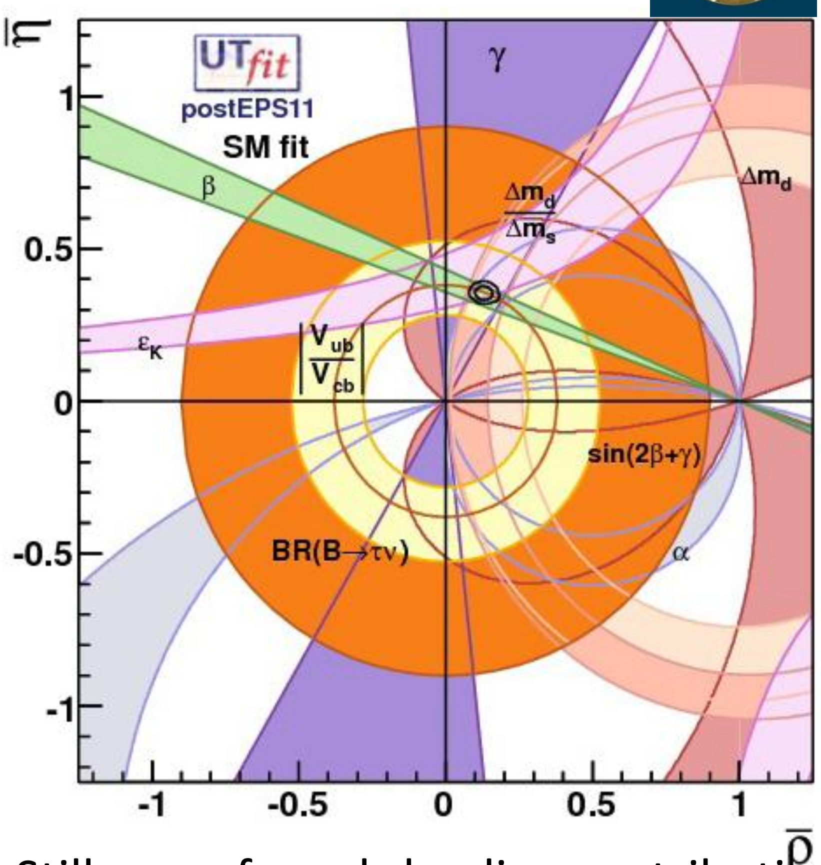
Goto et al.,PRD77, 095010 (2008)



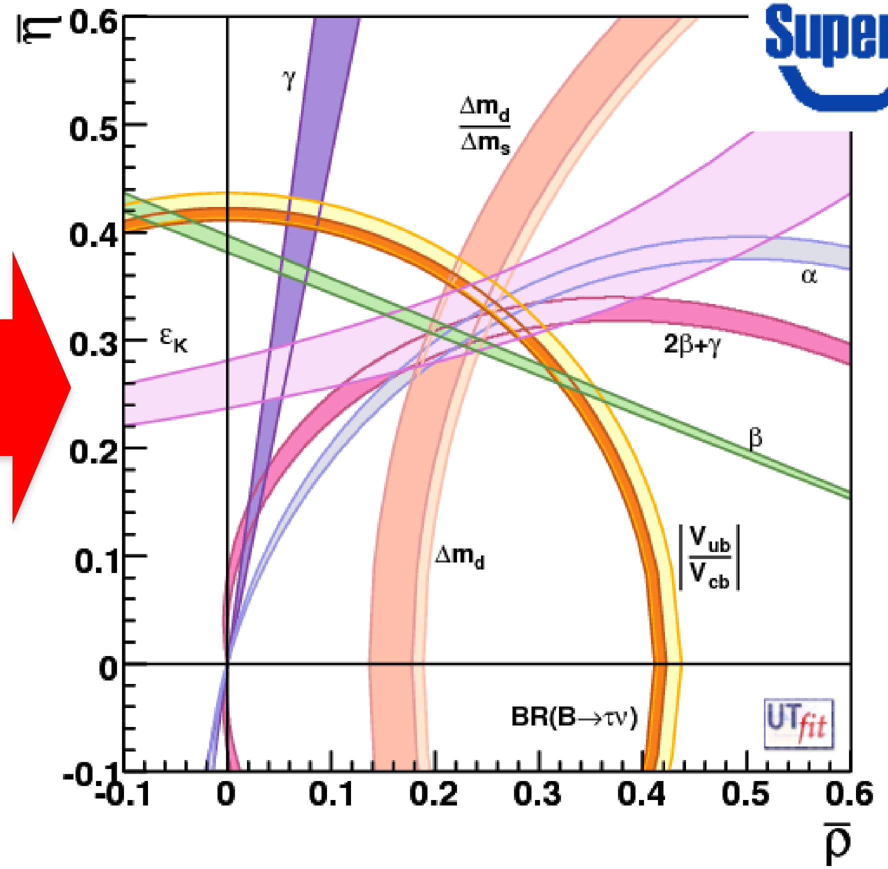


Precision CKM constraints

Success of the B Factires
(SLAC/KEK)



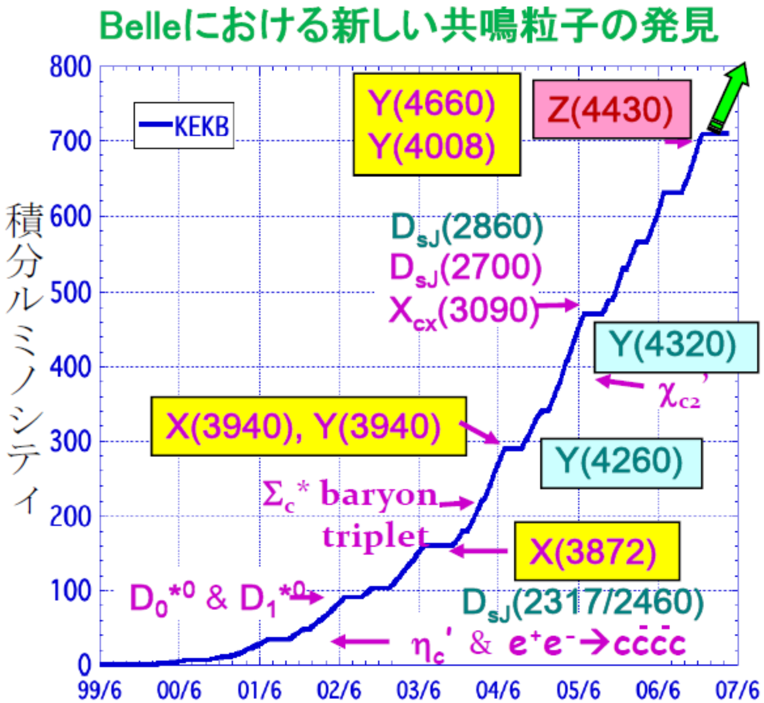
The "dream" scenario with 75ab^{-1}

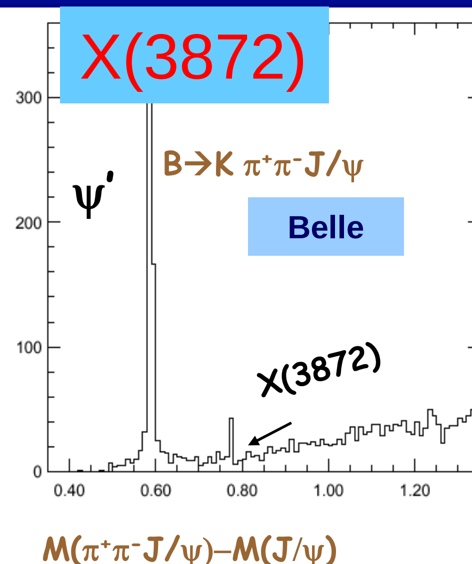


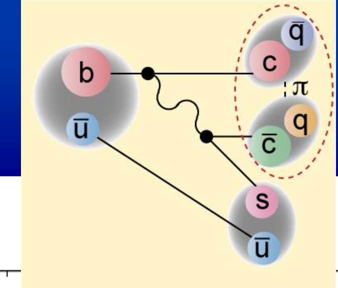
- Still room for sub-leading contribution from NP at O(0.1)
- There are tree and loop diagrams involved.

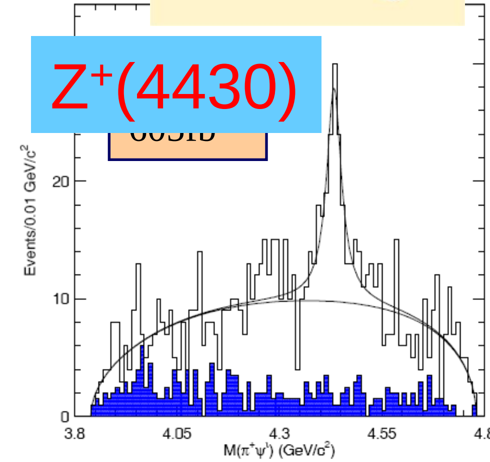
LHCb and Tau-charm will also contribute here.

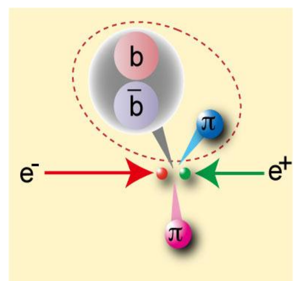
Hadron Spectroscopy

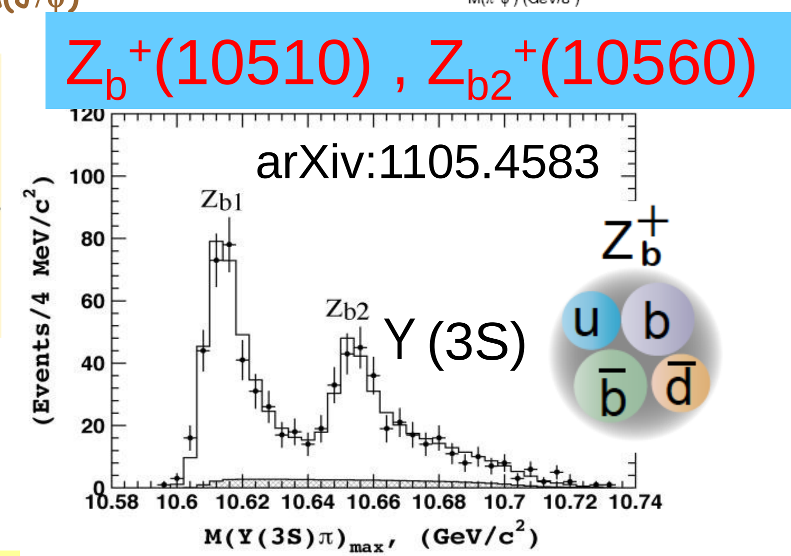




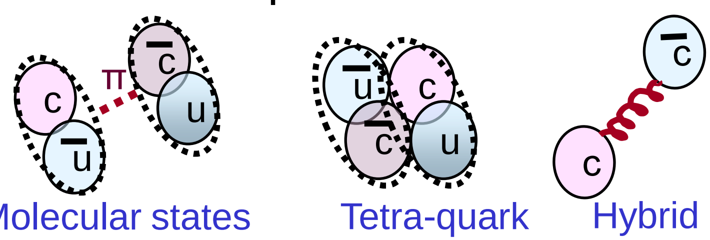








Possible interpretations



Future heavy flavor experiments enable us to search for new states and to study their detailed properties (J^{PC}, decay modes etc.)

How to achieve "Super Luminosity"

Luminosity formula

Stored current

Beam-beam parameter

Lorentz factor

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

Classical electron radius

Beam size ratio 1~2% @IP

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

0.8~1 (short bunch)

Vertical β at the IP

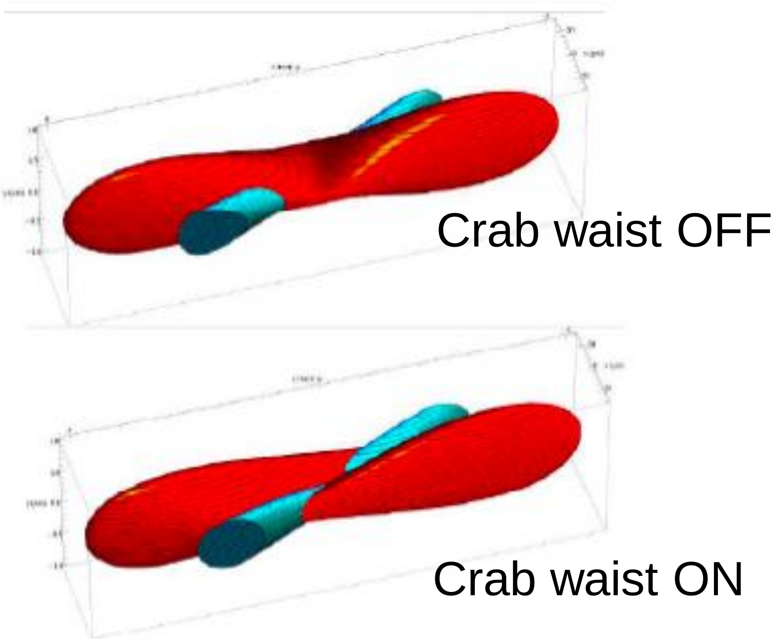
For higher Luminosity;	In case of KEKB → SuperKEKB	
1) Vertical β function at IP (β_y^*):	5.9 → 0.27/0.30mm	(x20)
2) Increase beam currents:	1.7/1.4 → 3.6/2.7 A	(x 2)
3) Increase ξ_y	0.09 → 0.09	(x 1)

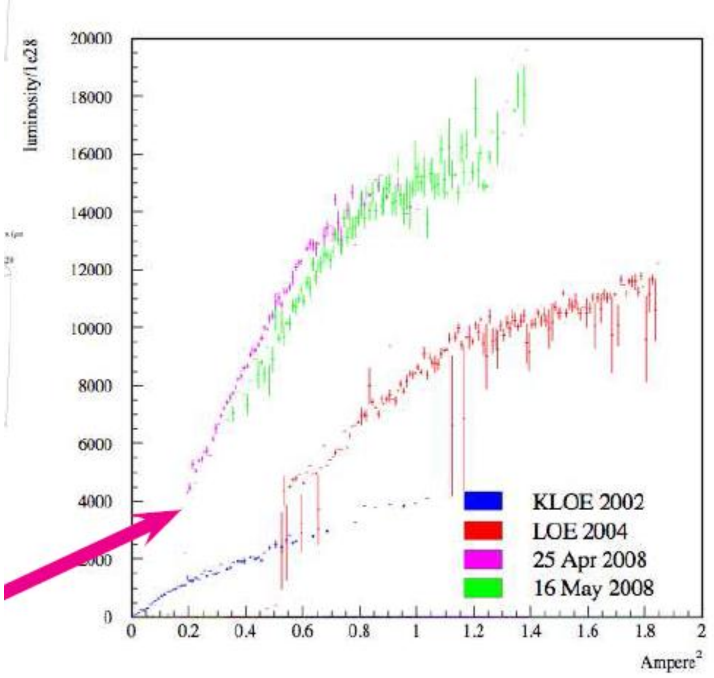
Basic concept: "Nano-beam scheme"

Invented by P. Raimondi for SuperB

Nano-beam collision w/ Crab Waist

- Invented by P. Raimondi
- Move y-waist along z with a sextupole on both sides at proper phase.
- The concept has been successfully tested at DAFNE



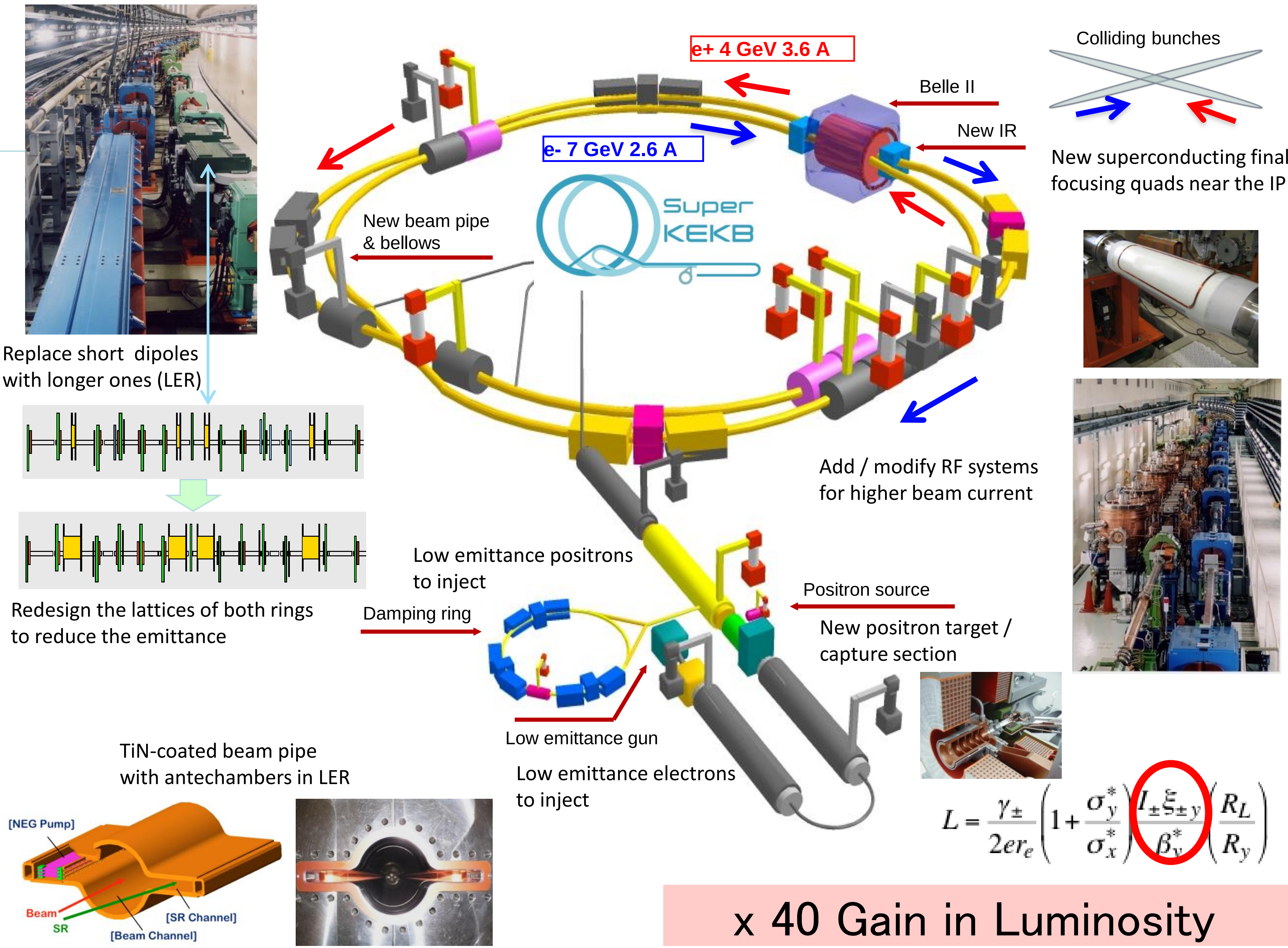


Machine Parameters

		SuperKEKB		SuperB (base line)	
Parameters	unit	LER	HER	LER	HER
Circumference	m	3016.3		1258.4	
Energy	GeV	4	7	4.18	6.7
Half x-ing angle	mrad	41.5		33	
β_x^* / β_y^* at IP	mm	32 / 0.27	25 / 0.31	32 / 0.205	26 / 0.253
Hor. emittance (ε_x)	nm	3.2	5.0	2.46	2.00
σ_x / σ_y at IP	μm	10.2/0.059	7.75/0.059	8.872 / 0.036	7.211 / 0.036
Beam-beam (ξ_y)		0.0886	0.0830	0.0971	0.0970
$N_{bunches}$		2500		978	
Beam currents	A	3.6	2.6	2.447	1.892
Luminosity	$cm^{-2}s^{-1}$	0.8×10^{36}		1.0×10^{36}	

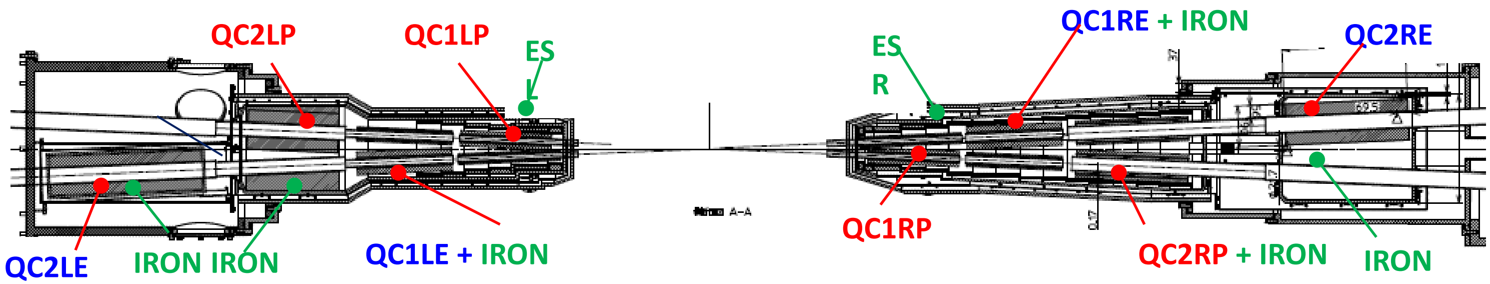
Compared to KEKB/PEP II

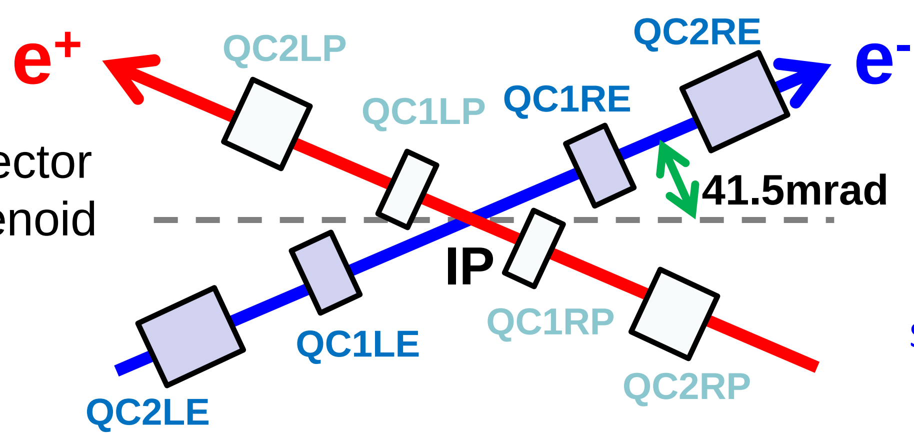
- Smaller beam size and higher currents.
- Larger (half) crossing angle than (11mrad @ KEKB)
- Less energy asymmetry (higher E_{LER}) for longer Touschek lifetime (LER).


e+ 4 GeV 3.6 A
e- 7 GeV 2.6 A
Colliding bunches
Belle II
New IR
New superconducting final focusing quads near the IP
SuperKEKB
New beam pipe & bellows
Replace short dipoles with longer ones (LER)
Redesign the lattices of both rings to reduce the emittance
Add / modify RF systems for higher beam current
Low emittance positrons to inject
Damping ring
Positron source
New positron target / capture section
Low emittance gun
Low emittance electrons to inject
TiN-coated beam pipe with antechambers in LER
[NEG Pump]
Beam
SR
[Beam Channel]
[SR Channel]
$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$
x 40 Gain in Luminosity

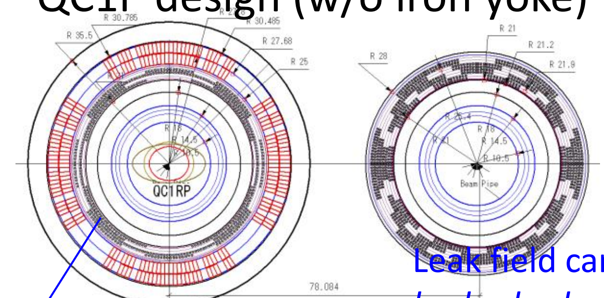
SuperKEKB IR

- New final focusing system based on the nano-beam scheme.
  - Consists of 8 superconducting magnets
  - Final focusing Q-magnets for each beam
  - Crossing angle 83 mrad to bring the FF magnets closer to IP





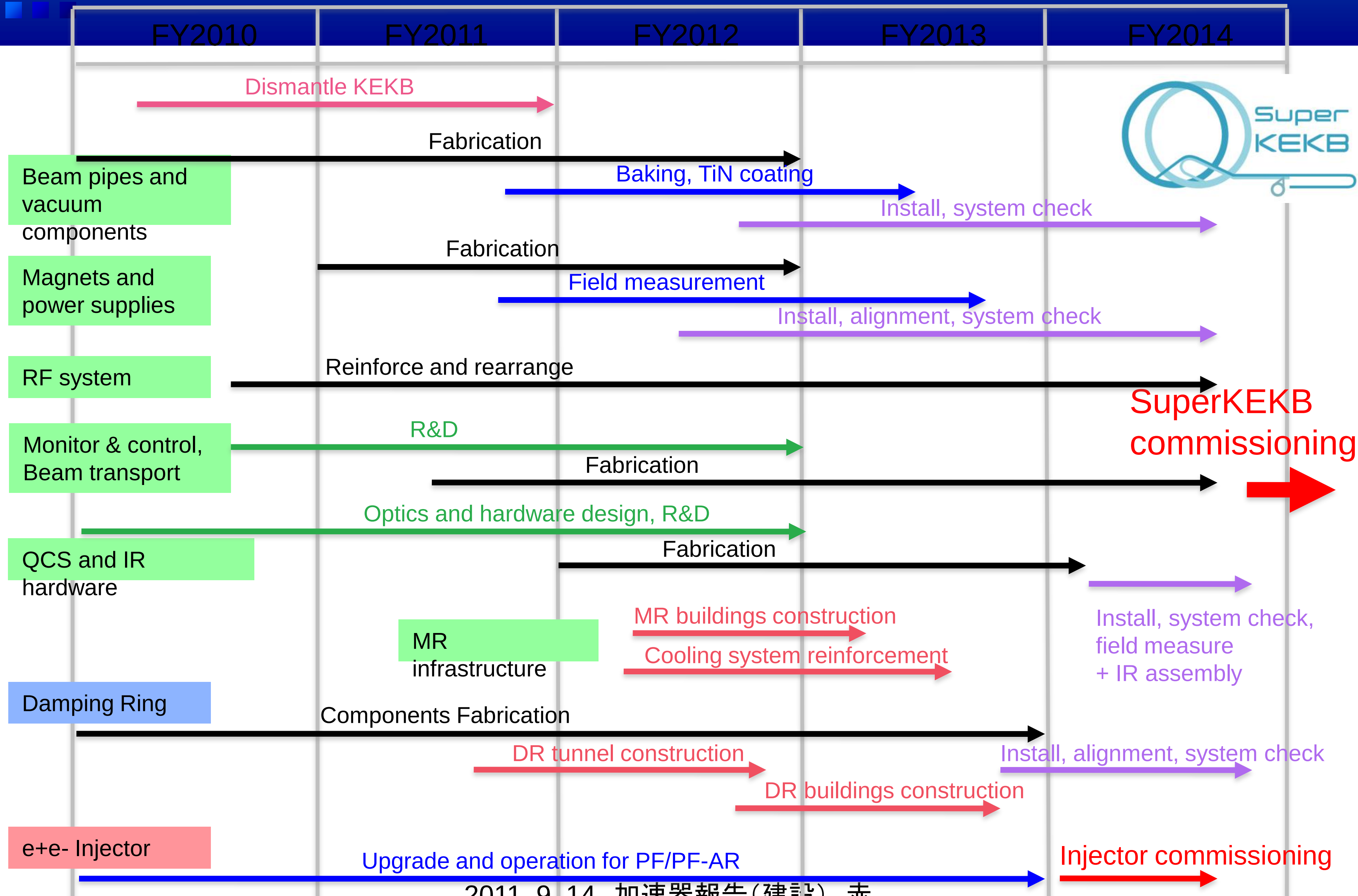
QC1P design (w/o iron yoke)



The 1st R&D QC1P magnet with correctors will be tested in October.

SuperKEKB construction schedule

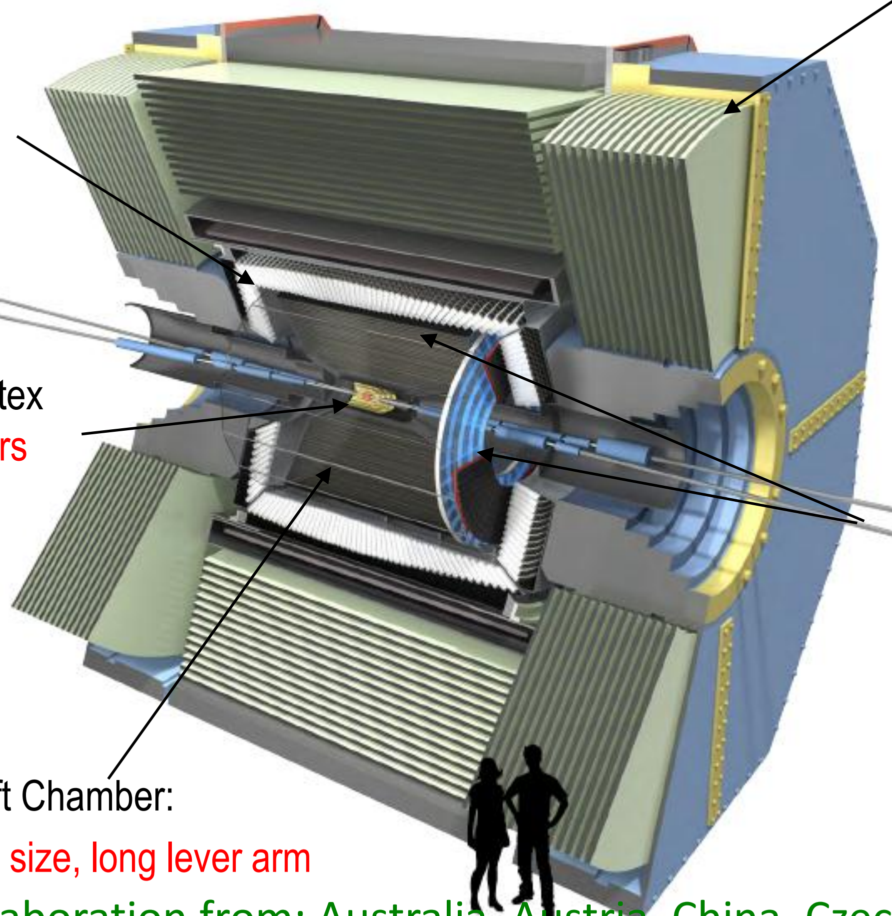
Revised on Sep. 10, 2011



Belle II Detector

Belle II T-shirts
1300 Yen

- Deal with higher background (10-20 ×), radiation damage, higher occupancy, higher event rates (L1 trigg. 0.5→30 kHz)
- Improved performance and hermeticity



CsI(Tl) EM calorimeter:
waveform sampling electronics, pure CsI for endcaps

RPC μ & K_L counter:
scintillator + Si-PM for end-caps

4 layers DS Si vertex detector → 2 layers PXD (DEPFET), 4 layers DSSD

Time-of-Flight, Aerogel Cherenkov Counter →
Time-of-Propagation (barrel), prox. focusing Aerogel RICH (forward)

Central Drift Chamber:
smaller cell size, long lever arm

Belle II

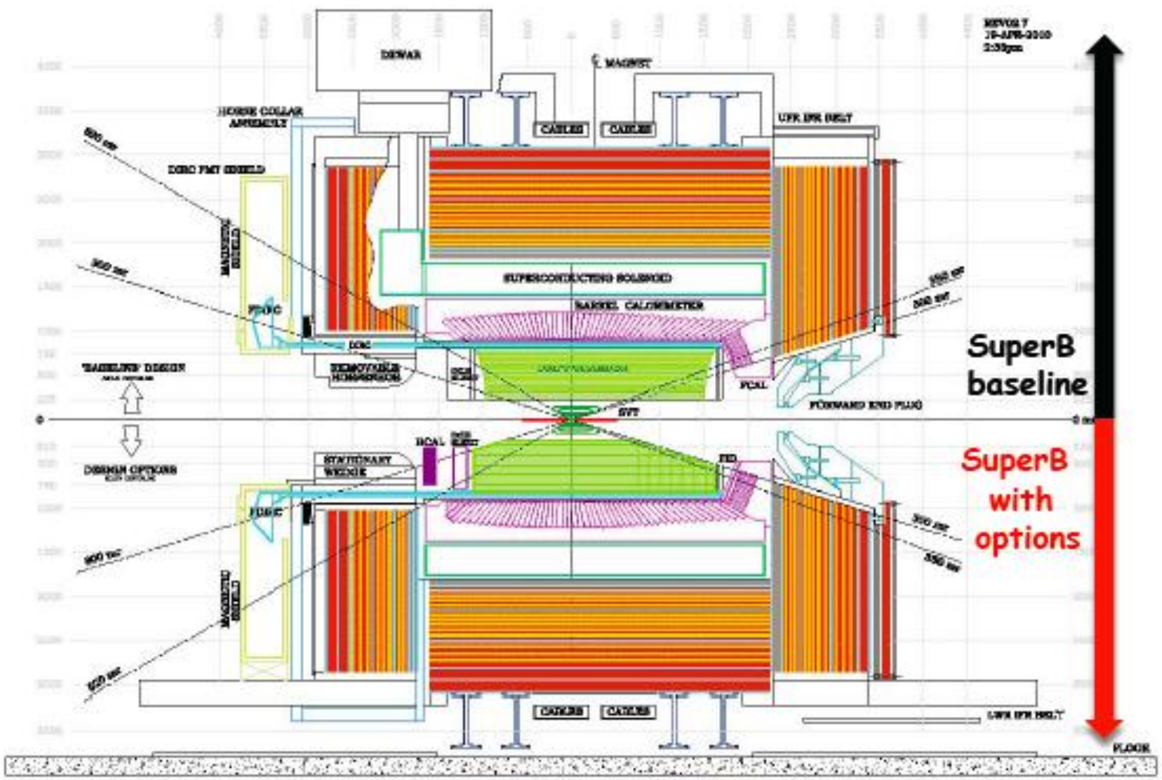
International collaboration from: Australia, Austria, China, Czech, Germany, Inida, Korea, Poland, Russia, Saudi Arabia, Slovenia, Spain, Taiwan, USA, Japan

SuperB Detector

F. Wilson @ Beauty 2011

Detector Design [arXiv:1007.4241]

Reuses much of BaBar e.g. CsI crystals



Double Vertex resolution

Improved hermiticity

TOF Forward PID

Cluster counting in drift chamber (improves dE/dx)

Logging rate: 1.9 Gbytes/sec

Backward EMC

Optimized IFR (muons)

Italy, France, Canada, UK, Poland, US, Russia, China, Spain, Germany, Norway, Israel,…

SuperB Status

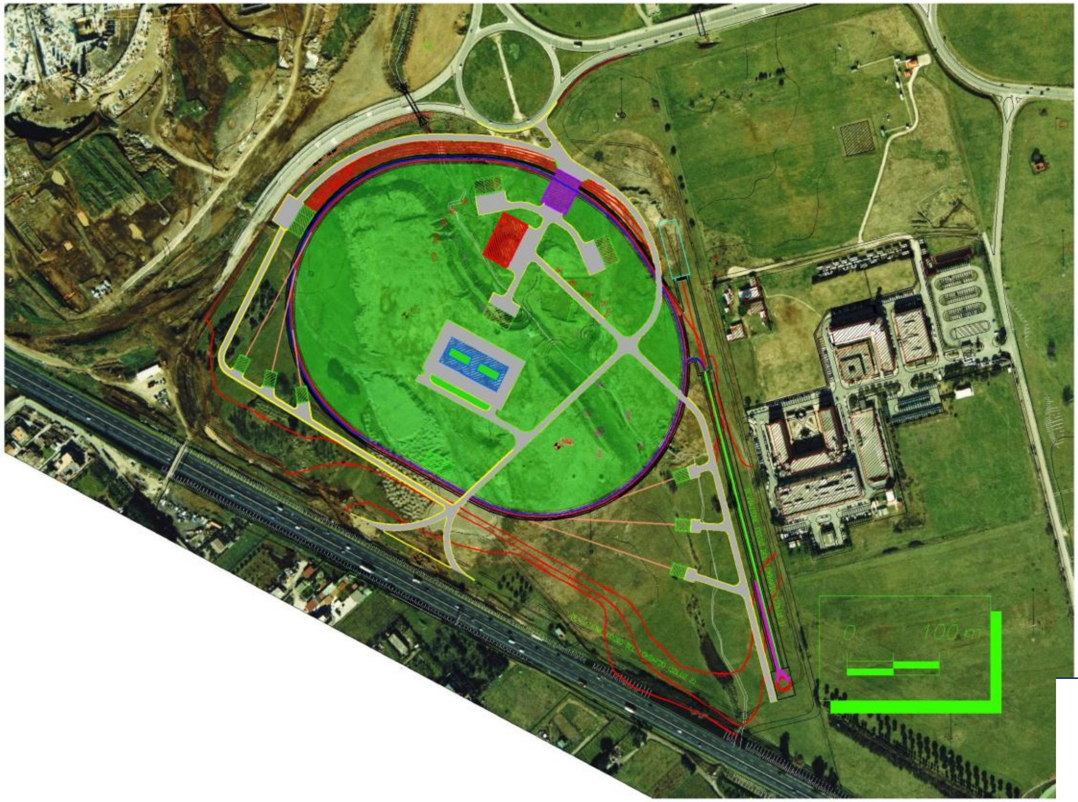
- SuperB is approved by the Italian governement!
- 19 M€ received in 2010, 50 M€ will follow in 2011
  - First large scale project in Europe besides CERN since HERA in ~1985
- First beams in ~2016. 15 ab^{-1} per year
- Site has been decided (on Tor Vergata University Campus)
- A national consortium « Nicola Cabibbo Laboratory » is being created being INFN, IIT, Tor Vergata University and Italian Ministry of Research.

The 1st collaboration meeting at QMUL (Sept.13-*, 2011)

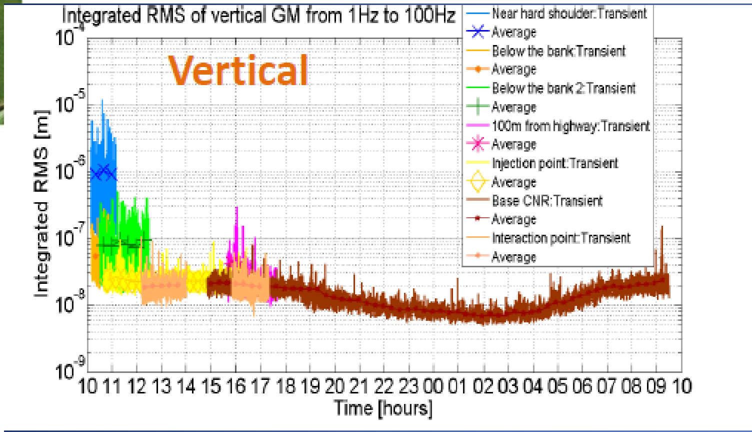
SuperB

SuperB site

- The site has been decided; Tor Vergata !



The international site review committee visiting the Tor Vergata site.



- The site vibration has been measured, and seems to be small enough (10-30nm all around the ring).

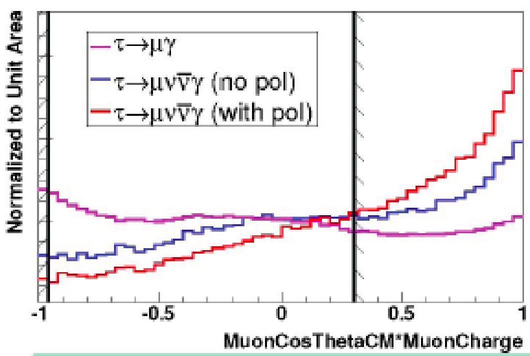
Polarized electron beam

- Longitudinal polarization (~80%) improves LFV sensitivity.
- If LFV found, it provides information on helicity nature of NP.
- Also, τ EDM, τ g-2, $\sin^2\theta_W$, …

F. Wilosn
@ Beauty2011

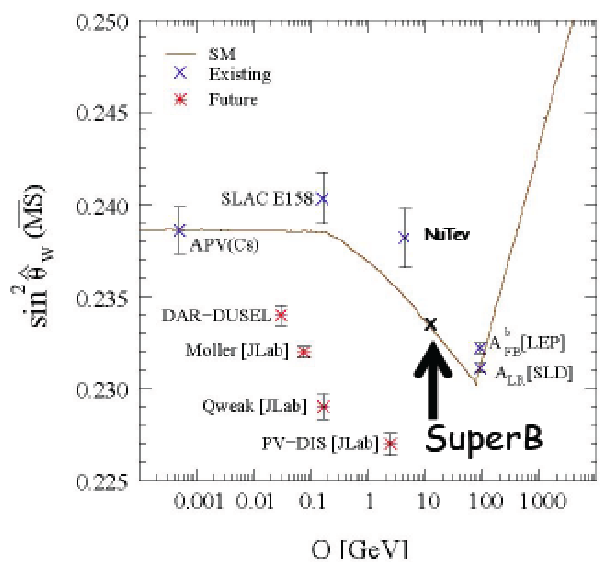
Benefits of Polarized Electron Beam

1) LFV:
Doubles Precision



2) τ EDM, τ g-2:
Measurement could prove or disprove discrepancy in $\Delta\alpha_\mu$ due to New Physics.
EDM sensitivity ~ 2 x 10^{-19} e cm
- $\Delta\alpha_\tau$ (SM) ~ 10^{-6}
- $\Delta\alpha_\tau$ (SUSY) <~ 10^{-5}
- $\Delta\alpha_\tau$ (SuperB) precision~ 10^{-6}

3) Electroweak:
- Investigate LEP A_{FB} v. SLD A_{LR} discrepancy.
- Investigate NuTev discrepancy.
- Constrain Higgs mass
- $\sin^2\theta_W$ resolution ±0.00018

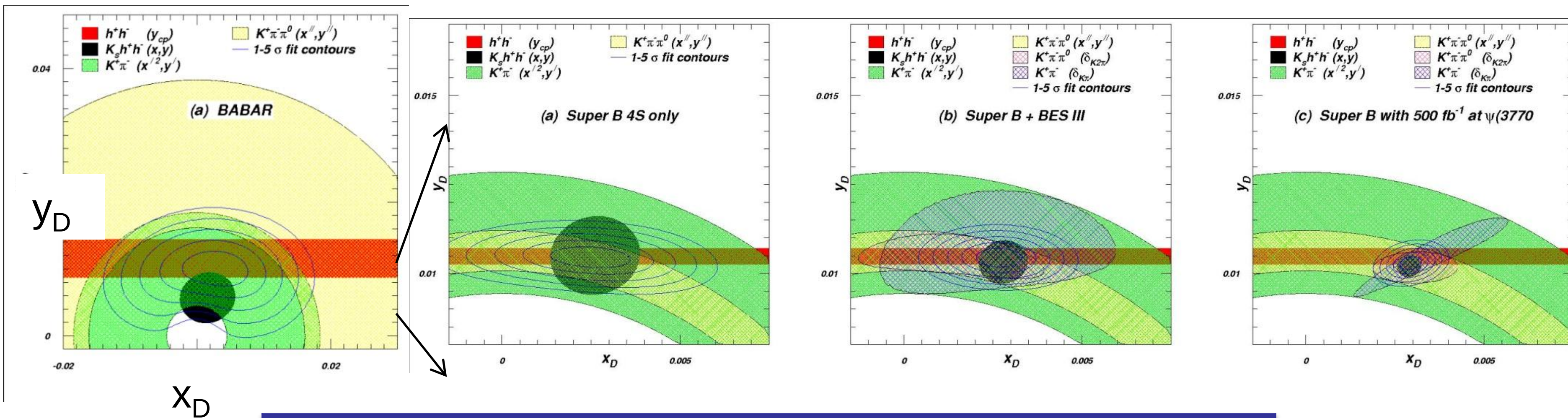


Running at Charm Threshold

F. Wilson
@ Beauty 2011

- Decays of $\psi(3770) \rightarrow D^0 D^0$ produce coherent C=-1 pairs of D^0's.
- → precision D mixing, CPV using quantum correlations.

Strong-phase measurement greatly reduce the error.



	Now	SuperB	SuperB+BES	SuperB +BES+φ(3770)
x (x 10^3)	±3	±0.7	±0.4	±0.2
y (x 10^3)	±2	±0.2	±0.2	±0.1
$\delta_{K\pi}$	±10°	±3°	±2°	±1°
$\delta_{K\pi\pi}$	±20°	±5°	±3°	±1°

Design luminosity = $10^{35} cm^{-2} s^{-1}$ at tau-charm

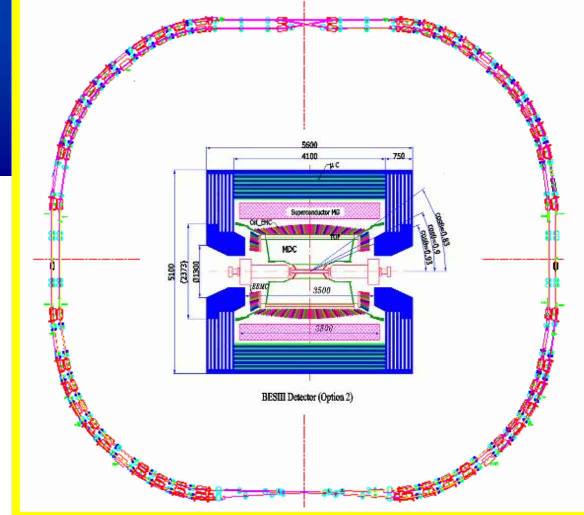
Physics at τ - Charm Factory

- Precision charm physics
  - Precision charm$\rightarrow$ precision CKM (strong phases, f_D, f_{Ds} …)
  - High sensitivity search for rare processes (rare D & Λ_c decays, CPV, mixing)
- Precision τ-physics with polarized beams
  - Lepton universality, Lorentz structure of τ-decay…
  - CPV
  - LFV decays
  - Second class currents
- High statistic spectroscopy and search for exotics
  - Charm and charmonium spectroscopy
  - Light hadron spectroscopy in charmonium decays ($N_{J/\psi}$~10^{12})

(Alex Bondar @ ECFA2010 meeting)

BEPC II Plan

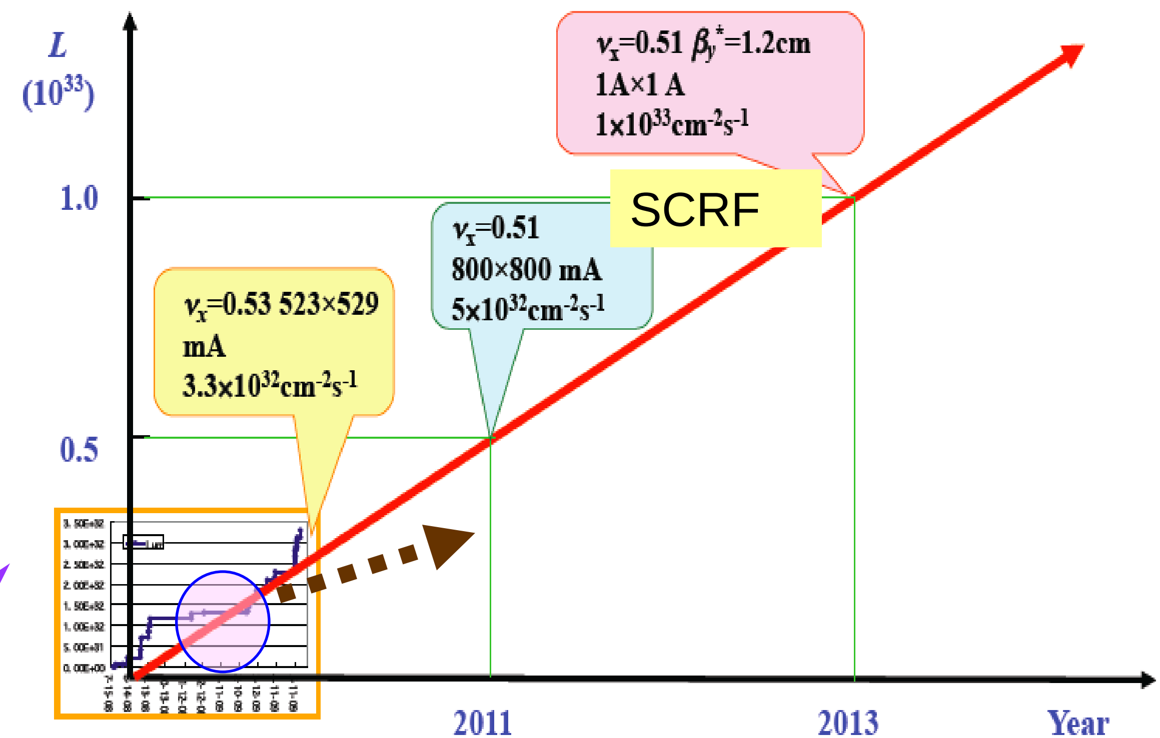
Hesheng Cheng
@ ECFA2010 meeting



On-going upgrade

- To increase single bunch current in collision
- To enhance beam-beam parameter towards 0.04
- To move horizontal tune to 0.51
- To increase colliding bunch number and pattern
- Squeeze β_y^*

BEPCII luminosity plan



Long-term upgrades

(under discussion)

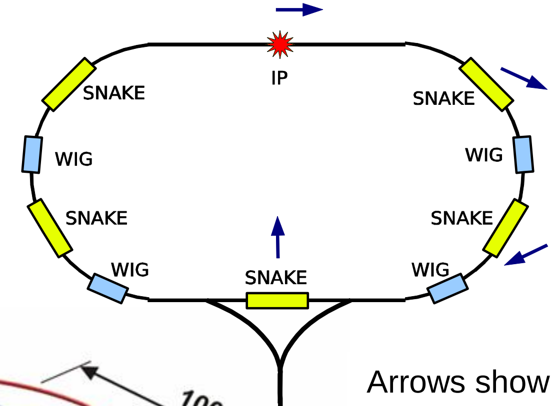
- Increasing beam energy? (2.3GeV now)
- Crab-waist for higher luminosity
- Collision with polarized beam
  - •Physics requirements
  - •e- beam plaization? location for rotators ?

Super Charm Tau Factory at BINP

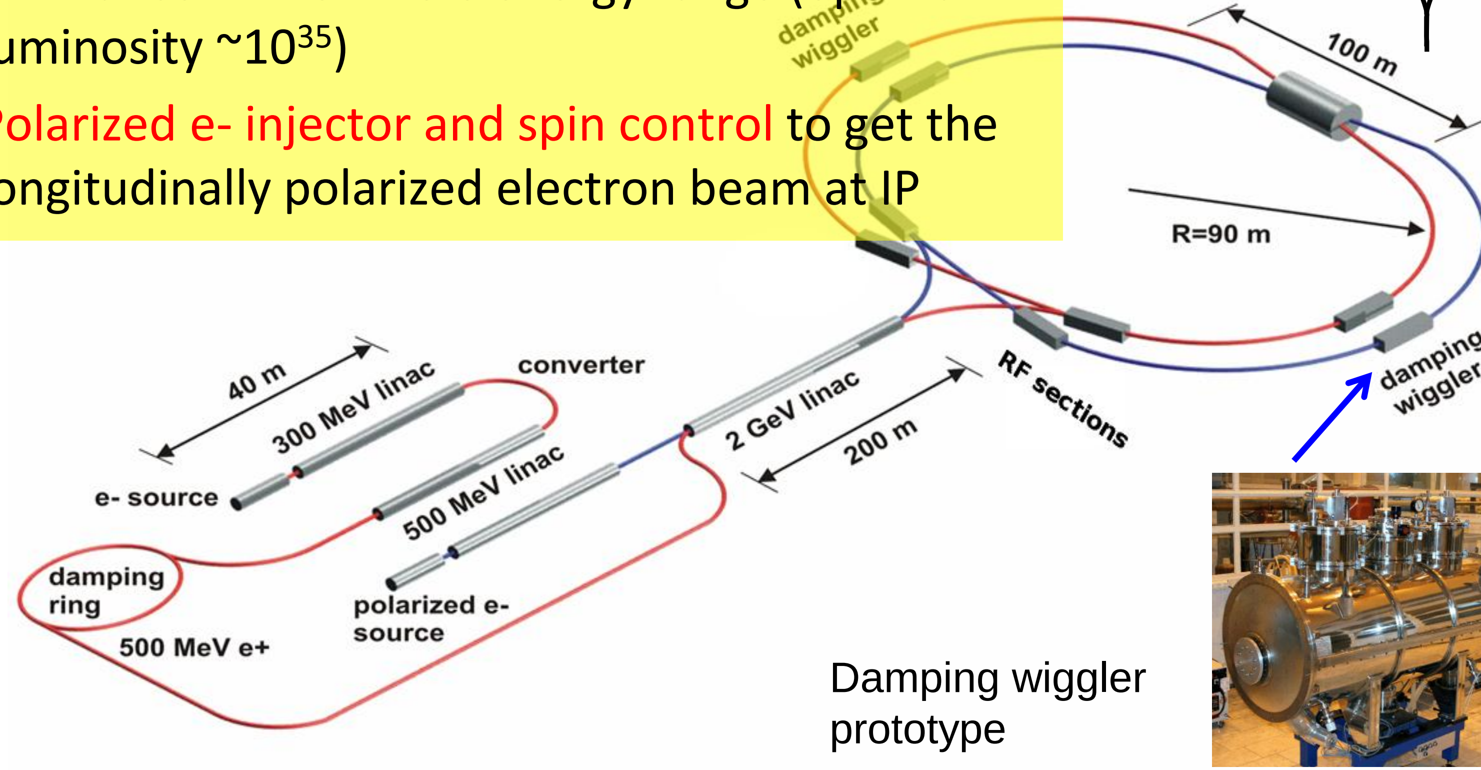
E_{beam} = 1.0 - 2.5 GeV : L_{peak} = 10^{35} $cm^{-2}s^{-1}$ (2 GeV): Polarized e^- beam

Main features:

- Two rings with a single interaction point
- Nano Beams + Crab waist collision
- SC wigglers to keep the same damping and emittance in the whole energy range (optimal luminosity ~10^{35})
- Polarized e- injector and spin control to get the longitudinally polarized electron beam at IP



Arrows show the electrons spin direction

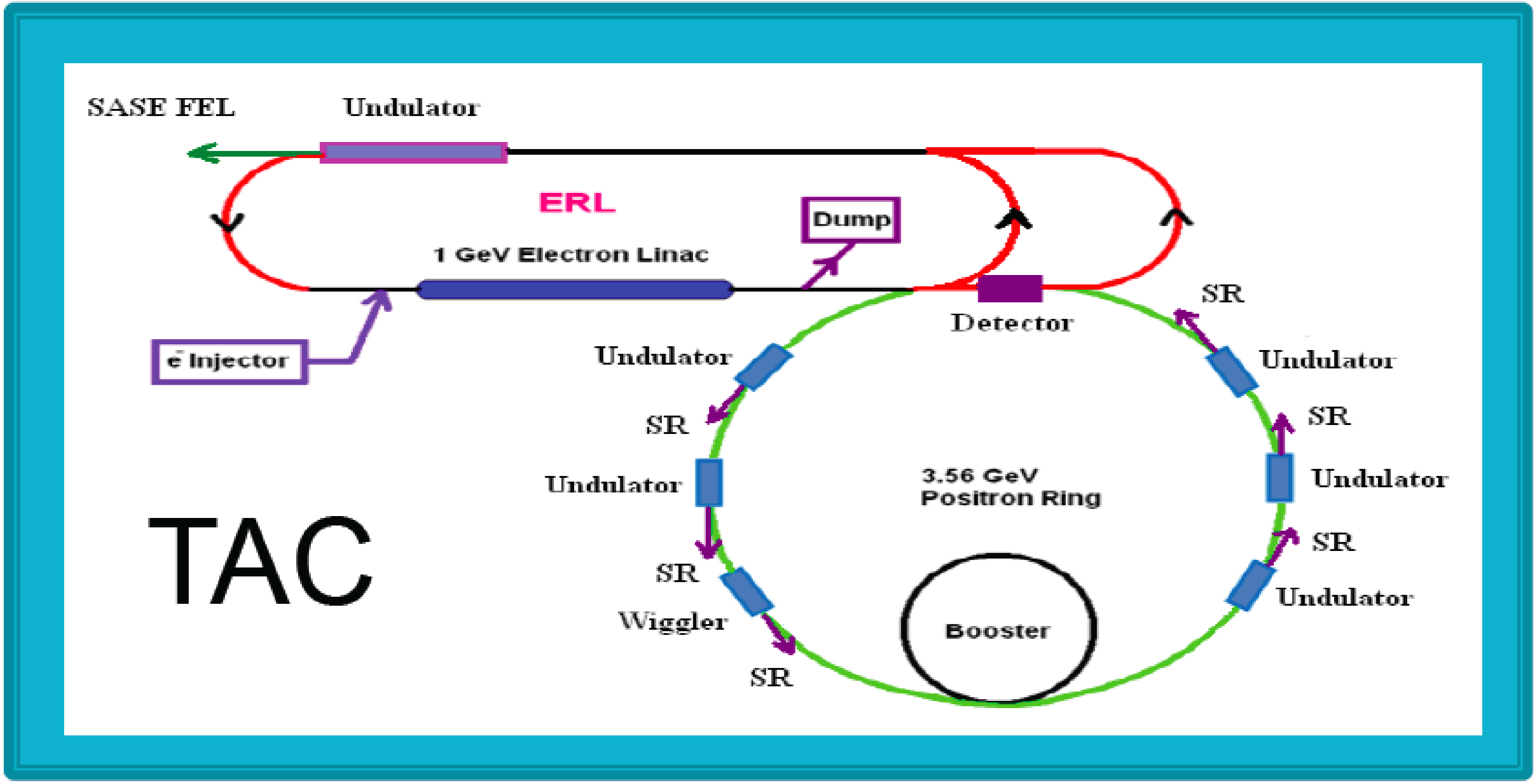


Damping wiggler prototype

Linac-Ring Type c-τ Factory

- An option of the Turkish Accelerator Center (TAC).
- Positron ring (3.56 GeV) + Electron ERL (1 GeV) ➡ $\beta\gamma = 0.68$
- $L_{peak} = 1.4 \times 10^{35} cm^{-2}s^{-1}$.

(Saleh Sultansoy @ ECFA2010 meeting)



Summary

Good prospect for heavy flavor programs !

2014 2015 2016 2017 2018 2019 2020

Large production rate
Various B hadrons: B_s, Λ_b,…

$L_{peak} = 10^{32} cm^{-2} s^{-1}$
$L_{int} = 5 fb^{-1} (1 fb^{-1}/yr)$

$L_{peak} = 10^{33} cm^{-2} s^{-1}$
$L_{int} = 50 fb^{-1} (5 fb^{-1}/yr)$

LHCb

Phase 1

Phase 2

Clean environment
Coherent B pair production
Good hermeticity, γ, π^0 detection

SuperKEKB /Belle II

$L_{peak} = 8 \times 10^{35} cm^{-2} s^{-1}$
$L_{int} = 50 ab^{-1}$ by ~2020

Belle II

Super B

Polarization (80%)
Operation at TauCharm

$L_{peak} = 10^{36(35)} cm^{-2} s^{-1}$ [4S(t-charm)]
$L_{int} = 75 ab^{-1}$ by ~2022

SuperB

& More opportunities;
Super Charm-Tau Factories.

How long will these penguins swim ?

Backup

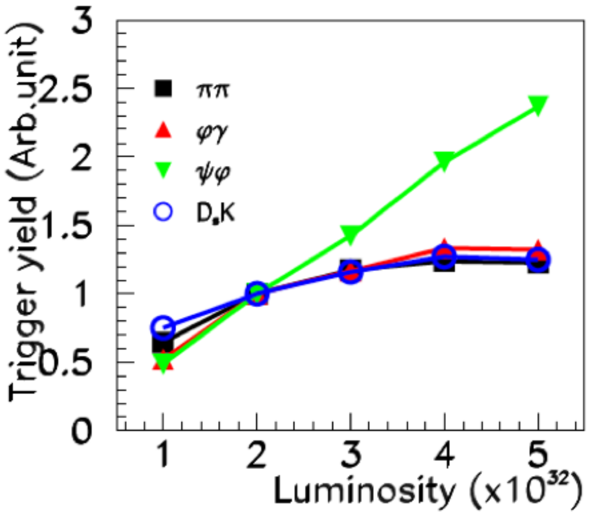
LHCb upgrade

LoI submitted to LHCC in March [CERN-LHCC-2011-01]

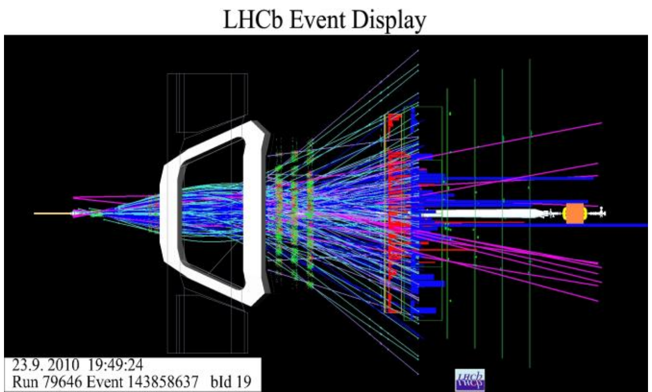
Baseline for LHCb upgrade

- Increase luminosity to $L \sim 1 \times 10^{33} cm^{-2} s^{-1}$
- Upgrade readout electronics and DAQ architecture to 40MHz
- Collect $\sim 5 fb^{-1}$/year and $\sim 50 fb^{-1}$ in 10 years

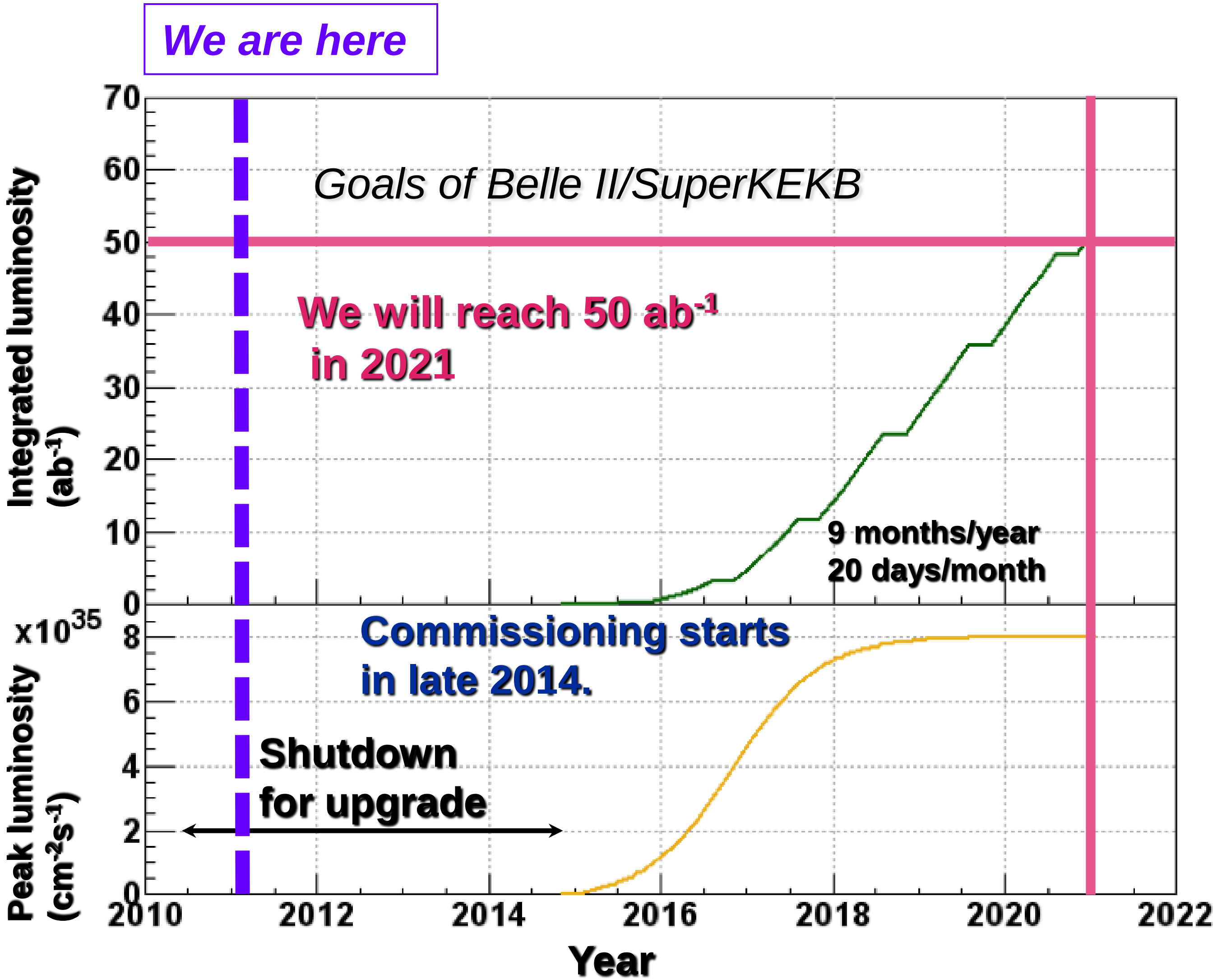
Main limitation of current detectors
•Bandwidth & rate limitation of L0 trigger
•Efficiency for hadronic channels flattens out at $L \sim 2\text{-}3 \times 10^{32} cm^{-2} s^{-1}$.
•Can accumulate 1fb-1 / year.



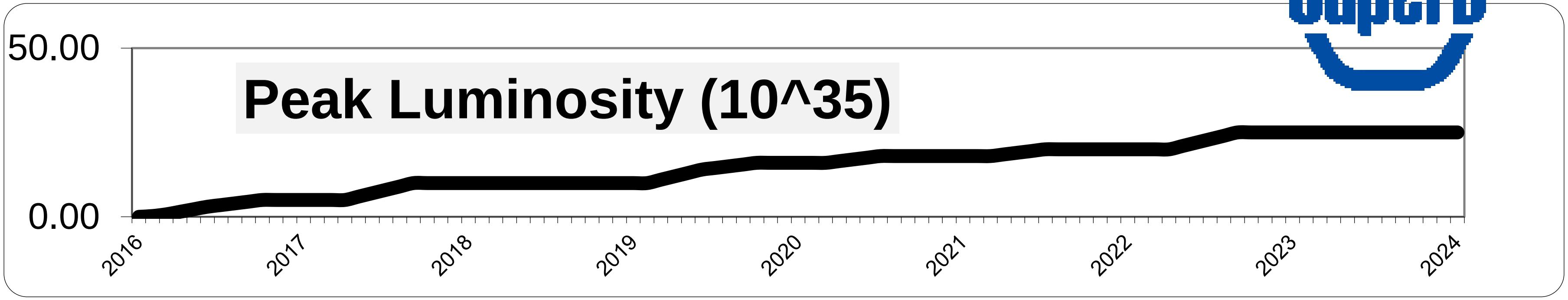
Pile-up:
•Expcted pile-up rate at $L \sim 1 \times 10^{33} cm^{-2} s^{-1}$ with 25ns BX-ings: $\mu \sim 2.3$.
•Detectors work already at $\mu = 2.7$ in 2010 run ($L = 1.6 \times 10^{32} cm^{-2} s^{-1}$, $n_b = 344$)

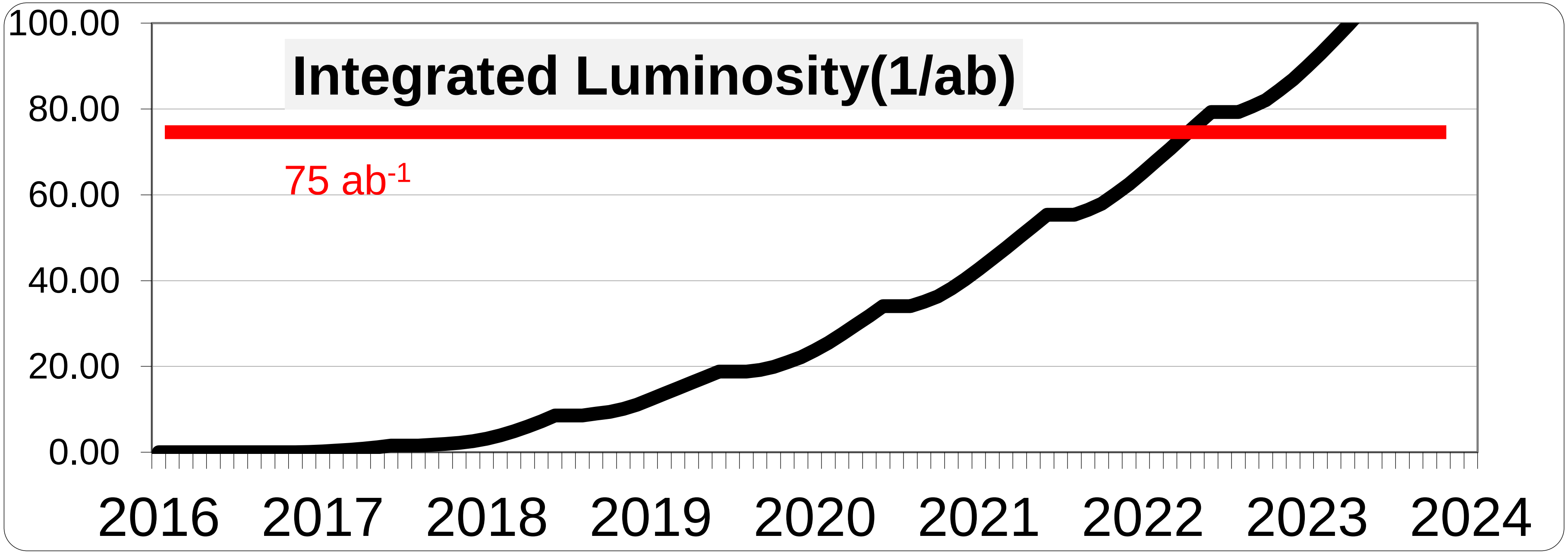


SuperKEKB luminosity profile



SuperB Luminosity Model





Super B Machine Design

Parameters for 1×10^{36} Lumi (max 4×10^{36})

Parameter	Units	Base Line		Low Emittance		High Current		Tau/Charm (prelim.)	
		HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY	$cm^{-2} s^{-1}$	1.00E+36		1.00E+36		1.00E+36		1.00E+35	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18	2.58	1.61
Circumference	m	1258.4		1258.4		1258.4		1258.4	
X-Angle (full)	mrad	66		66		66		66	
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
β_x @ IP	cm	2.6	3.2	2.6	3.2	5.06	6.22	6.76	8.32
β_y @ IP	cm	0.0253	0.0205	0.0179	0.0145	0.0292	0.0237	0.0658	0.0533
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.5	0.5	0.25	0.25
ε_x (without IBS)	nm	1.97	1.82	1.00	0.91	1.97	1.82	1.97	1.82
ε_x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
ε_y	pm	5	6.15	2.5	3.075	10	12.3	13	16
σ_x @ IP	μm	7.211	8.872	5.000	6.274	10.060	12.370	18.749	23.076
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.054	0.092	0.092
Σ_x	μm	11.433		8.085		15.944		29.732	
Σ_y	μm	0.050		0.030		0.076		0.131	
σ_L (0 current)	mm	4.69	4.29	4.73	4.34	4.03	3.65	4.75	4.36
σ_L (full current)	mm	5	5	5	5	4.4	4.4	5	5
Beam current	mA	1892	2447	1460	1888	3094	4000	1365	1766
Buckets distance	#	2		2		1		1	
Ion gap	%	2		2		2		2	
RF frequency	Hz	4.76E+08		4.76E+08		4.76E+08		4.76E+08	
Harmonic number		1998		1998		1998		1998	
Number of bunches		978		978		1956		1956	
N. Particle/bunch		5.08E+10	6.56E+10	3.92E+10	5.06E+10	4.15E+10	5.36E+10	1.83E+10	2.37E+10
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.0970	0.0971	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Long. damping time	msec	13.4	20.3	13.4	20.3	13.4	20.3	26.8	40.6
Energy Loss/turn	MeV	2.11	0.865	2.11	0.865	2.11	0.865	0.4	0.166
σ_E (full current)	dE/E	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.94E-04	7.34E-04
CM σ_E	dE/E	5.00E-04		5.00E-04		5.00E-04		5.26E-04	
Total lifetime	min	4.23	4.48	3.05	3.00	7.08	7.73	11.41	6.79
Total RF Power	MW	17.08		12.72		30.48		3.11	

Tau/charm threshold running at 10^{35}

Baseline + other 2 options:
- Lower y-emittance
- Higher currents (twice bunches)

Baseline:
- Higher emittance due to IBS
- Asymmetric beam currents

RF power includes SR and HOM

M. Giorgi, ICHEP2010

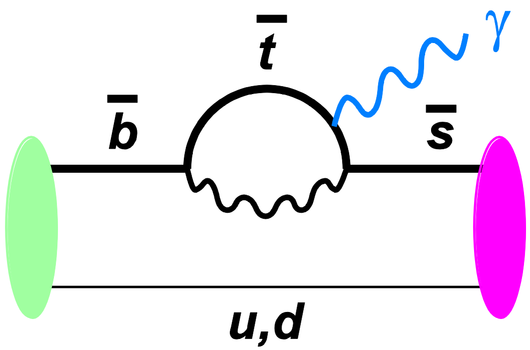
Observable/mode	Current now	LHCb (2017) $5\,\mathrm{fb}^{-1}$	Super$B$ (2021) $75\,\mathrm{ab}^{-1}$	Belle II (2021) $50\,\mathrm{ab}^{-1}$	LHCb upgrade (10 years of running) $50\,\mathrm{fb}^{-1}$	theory now
τ Decays						
$\tau \to \mu\gamma$ ($\times 10^{-9}$)	< 44		< 2.4	< 5.0		
$\tau \to e\gamma$ ($\times 10^{-9}$)	< 33		< 3.0	< 3.7 (est.)		
$\tau \to \ell\ell\ell$ ($\times 10^{-10}$)	$< 150 - 270$	< 244 [a]	$< 2.3 - 8.2$	< 10	< 24 [b]	
$B_{u,d}$ Decays						
BR($B \to \tau\nu$) ($\times 10^{-4}$)	1.64 ± 0.34		0.05	0.04		1.1 ± 0.2
BR($B \to \mu\nu$) ($\times 10^{-6}$)	< 1.0		0.02	0.03		0.47 ± 0.08
BR($B \to K^{*+}\nu\bar{\nu}$) ($\times 10^{-6}$)	< 80		1.1	2.0		6.8 ± 1.1
BR($B \to K^{+}\nu\bar{\nu}$) ($\times 10^{-6}$)	< 160		0.7	1.6		3.6 ± 0.5
BR($B \to X_s\gamma$) ($\times 10^{-4}$)	3.55 ± 0.26		0.11	0.13	0.23	3.15 ± 0.23
$A_{CP}(B \to X_{(s+d)}\gamma)$	0.060 ± 0.060		0.02	0.02		$\sim 10^{-9}$
$B \to K^*\mu^+\mu^-$ (events)	250[c]	8000	10-15k[d]	7-10k	100,000	-
BR($B \to K^*\mu^+\mu^-$) ($\times 10^{-6}$)	1.15 ± 0.16		0.06	0.07		1.19 ± 0.39
$B \to K^*e^+e^-$ (events)	165	400	10-15k	7-10k	5,000	-
BR($B \to K^*e^+e^-$) ($\times 10^{-6}$)	1.09 ± 0.17		0.05	0.07		1.19 ± 0.39
$A_{FB}(B \to K^*\ell^+\ell^-)$	0.27 ± 0.14[e]	[f]	0.040	0.03		-0.089 ± 0.020
$B \to X_s\ell^+\ell^-$ (events)	280		8,600	7,000		-
BR($B \to X_s\ell^+\ell^-$) ($\times 10^{-6}$)[g]	3.66 ± 0.77[h]		0.08	0.10		1.59 ± 0.11
S in $B \to K_S^0\pi^0\gamma$	-0.15 ± 0.20		0.03	0.03		-0.1 to 0.1
S in $B \to \eta' K^0$	0.59 ± 0.07		0.01	0.02		± 0.015
S in $B \to \phi K^0$	0.56 ± 0.17	0.15	0.02	0.03	0.03	± 0.02
B_s^0 Decays						
BR($B_s^0 \to \gamma\gamma$) ($\times 10^{-6}$)	< 8.7		0.3	$0.2 - 0.3$		0.4 - 1.0
A_{SL}^s ($\times 10^{-3}$)	-7.87 ± 1.96 [i]	[j]	4.	5. (est.)		0.02 ± 0.01
D Decays						
x	$(0.63 \pm 0.20)\%$	0.06%	0.02%	0.04%	0.02%	$\sim 10^{-2}$ [k]
y	$(0.75 \pm 0.12)\%$	0.03%	0.01%	0.03%	0.01%	$\sim 10^{-2}$ (see above).
y_{CP}	$(1.11 \pm 0.22)\%$	0.05%	0.03%	0.05%	0.01%	$\sim 10^{-2}$ (see above).
$\lvert q/p \rvert$	$(0.91 \pm 0.17)\%$	10%	2.7%	3.0%	3%	$\sim 10^{-3}$ (see above).
$\arg\{q/p\}$ ($^\circ$)	-10.2 ± 9.2	5.6	1.4	1.4	2.0	$\sim 10^{-3}$ (see above).
Other processes Decays						
$\sin^2\theta_W$ at $\sqrt{s} = 10.58\,\mathrm{GeV}/c^2$			0.0002	[l]		clean

Observable/mode	Current now	LHCb (2017)	SuperB (2021)	Belle II (2021)	LHCb upgrade (10 years of running)	theory now
		$5\,\text{fb}^{-1}$	$75\,\text{ab}^{-1}$	$50\,\text{ab}^{-1}$	$50\,\text{fb}^{-1}$	
α from $u\bar{u}d$	6.1°	$5^{\circ\,a}$	1°	1°	^{b}	$1-2^\circ$
β from $c\bar{c}s$ (S)	0.9° (0.024)	0.5° (0.008)	0.1° (0.002)	0.3° (0.007)	0.2° (0.003)	clean
S from $B_d \to J/\psi\pi^0$	0.21		0.014	0.021 (est)		clean
S from $B_s \to J/\psi K^0_S$		?			?	clean
γ from $B \to DK$	11°	$\sim 4^\circ$	1°	1.5°	0.9°	clean
$\lvert V_{cb}\rvert$ (inclusive) %	1.7		0.5%	0.6 (est.)		dominant
$\lvert V_{cb}\rvert$ (exclusive) %	2.2		1.0%	1.2 (est.)		dominant
$\lvert V_{ub}\rvert$ (inclusive) %	4.4		2.0%	3.0		dominant
$\lvert V_{ub}\rvert$ (exclusive) %	7.0		3.0%	5.0		dominant

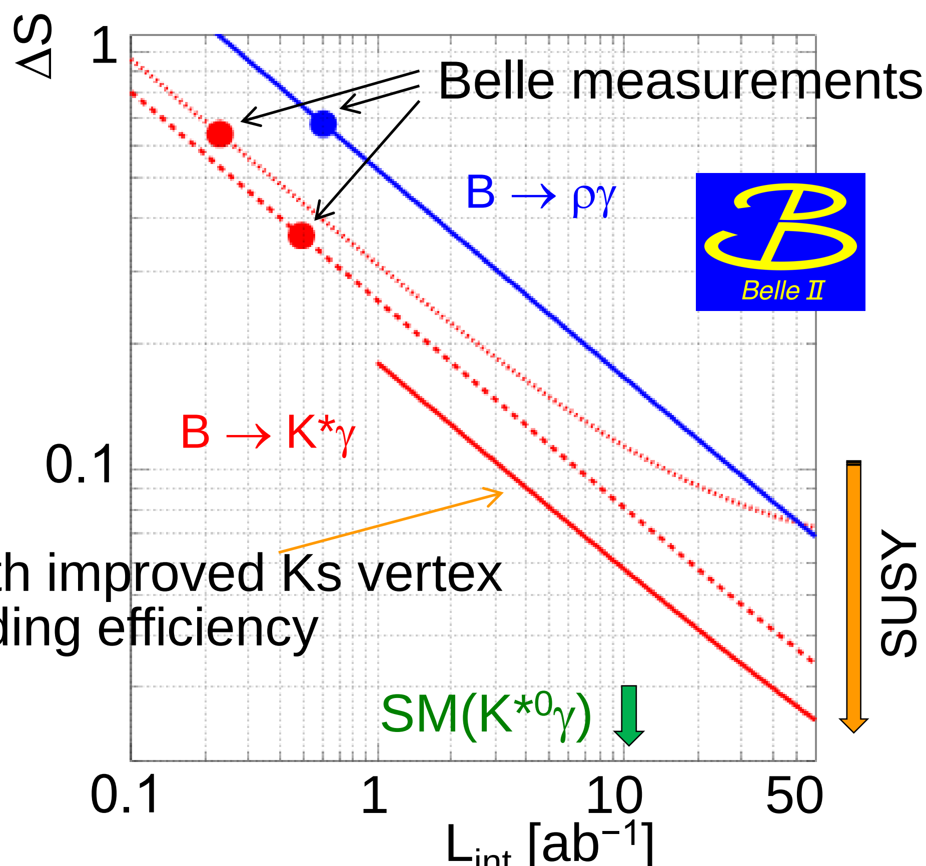
- With the exceptions of y_{CP} and K*μμ, there are no planned or existing experiments that will surpass SuperB precision in these modes for at least the next two decades.
- The best place to measure the other 33 golden modes is SuperB!

Photon polarization in b → s(d) γ

- In SM, photons from b→s(d)γ processes are left handed, therefore, (almost) no CPV.
- If unknown right handed current exists, CPV may arise ➡ clear NP signal !



b→sγ penguin



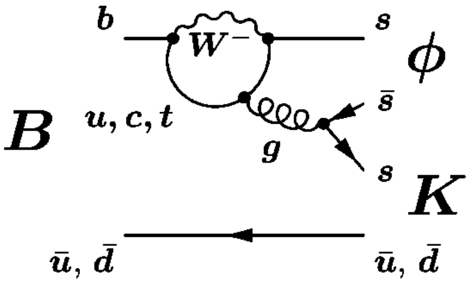
Possible deviation from SM
O(1): Warped extra dim.
O(1): L-R symmetric model
O(0.1): SUSY SU(5)

In SM,
$|S(K^{*0}\gamma)| < 0.02$, $S(\rho^0\gamma) \sim 0$

$\Delta S(K^{*0}\gamma) = 0.027$ @ 50 ab^{-1}
$\Delta S(\rho^0\gamma) = 0.075$ @ 50 ab^{-1}

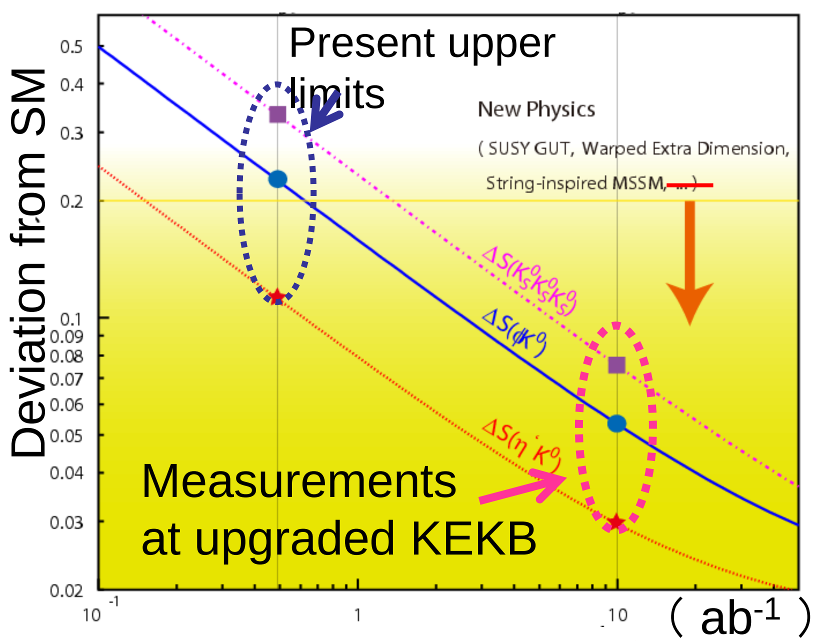
CPV in b→s Penguins

SM

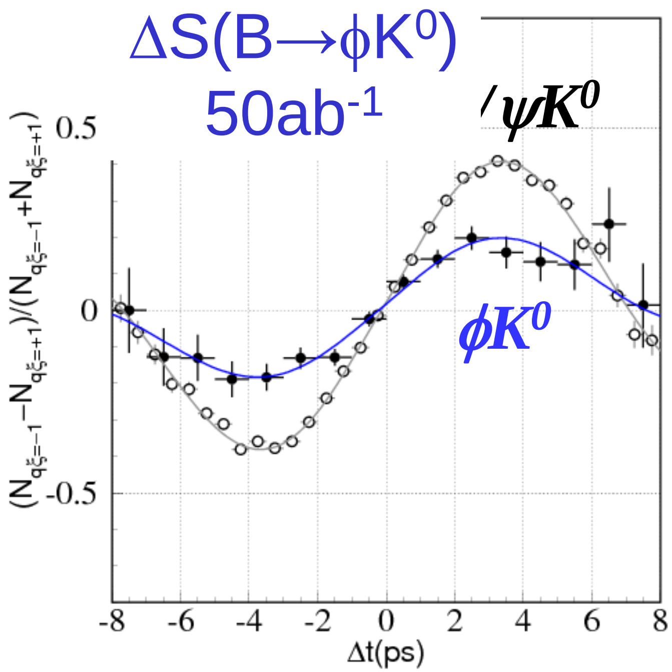


NP

$$A_{CP}(t) = \sin 2(\phi_1 + \phi_{NP}) \times \sin(\Delta m_d t)$$



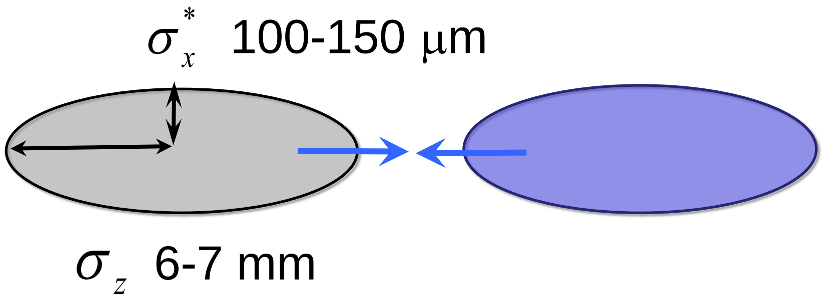
Present B factories   Upgraded KEKB



Collision Scheme

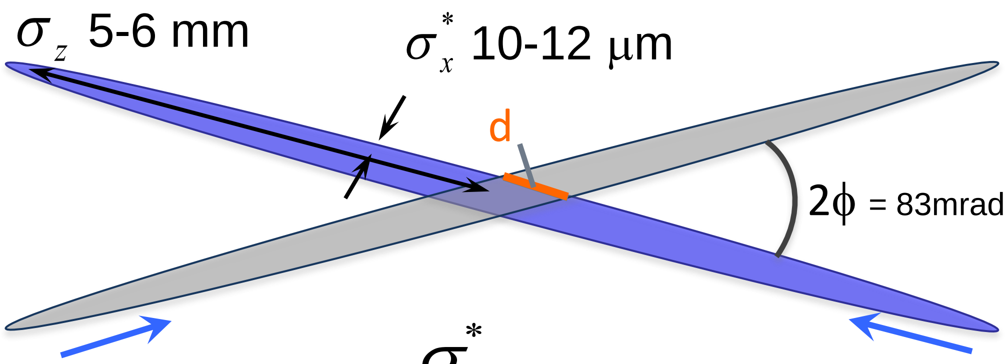
Y. Ohnishi et al.

KEKB head-on (crab crossing)



overlap region = bunch length

Nano-Beam SuperKEKB



$$d = \frac{\sigma_x^*}{\phi}$$

Half crossing angle: ϕ

overlap region << bunch length

Hourglass requirement

$\beta_y^* \geq \sigma_z$ ~ 6 mm

$\beta_y^* \geq \frac{\sigma_x^*}{\phi}$ ~ 300 μm

Vertical beta function at IP can be squeezed to ~300μm.
Need small horizontal beam size at IP.
→ low emittance, small horizontal beta function at IP.

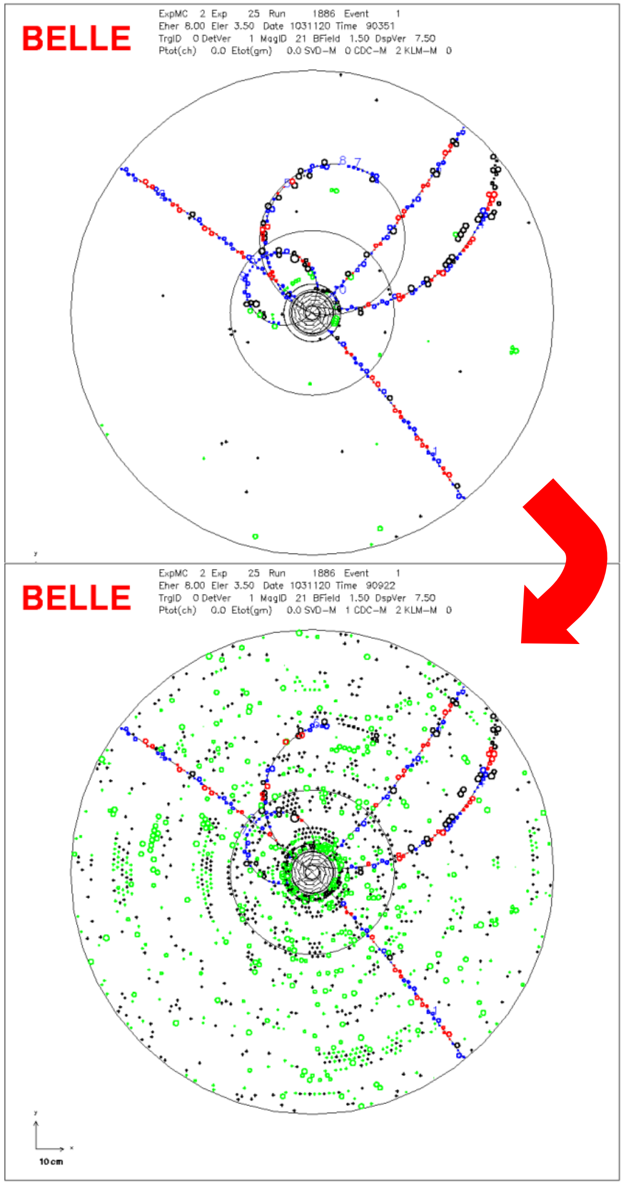
Detector Upgrade

Issues

- **Higher background (×20)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- **Higher event rate (×10)**
  - higher rate trigger, DAQ and computing
- **Require special features**
  - low p μ identification ← $s\mu\mu$ recon. eff.
  - hermeticity ← ν “reconstruction”

Possible solution:

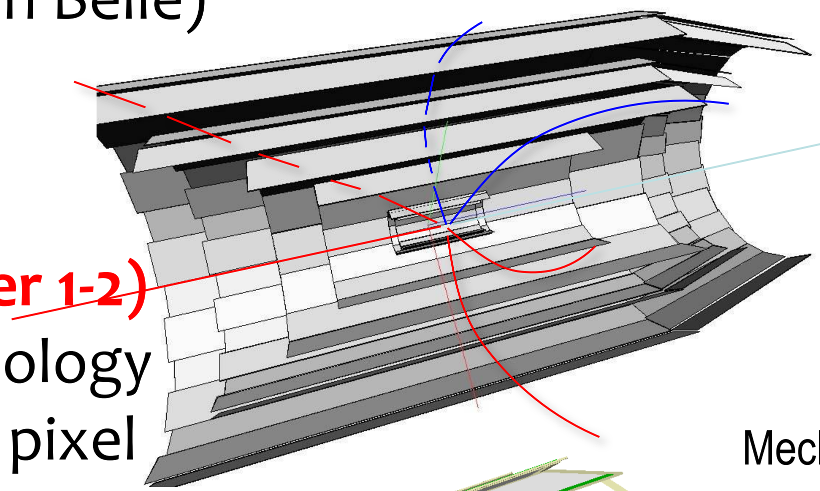
- Replace inner layers of the vertex detector with a silicon striplet/pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace endcap calorimeter by pure CsI.
- Faster readout electronics and computing system.

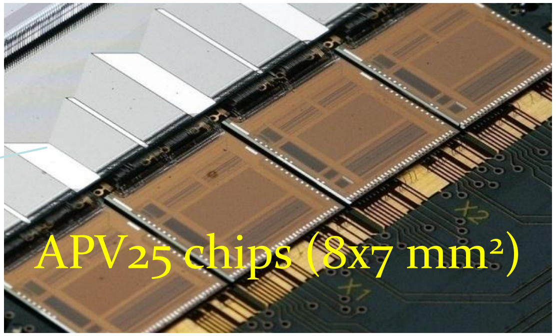


Vertex Detector w/ silicon pixels and strips

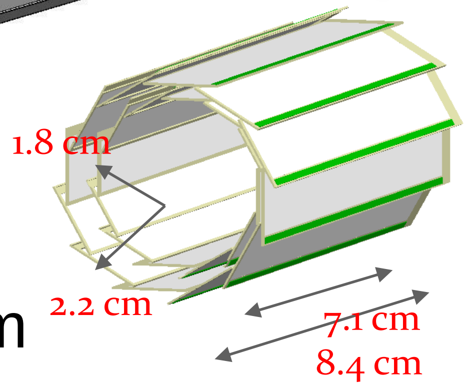
Outer radius 10 cm → 14 cm
- Better tracking efficiency/ self tracking
- Larger acceptance for Ks (30% larger than Belle)

Silicon strip layer (Layer 3-6)
- 300 μm thick, DSSD
- Readout by APV25 ASIC (50ns shaping time)





Pixel layer (Layer 1-2)
- DEPFET technology
- 50μm x 75μm pixel



Mechanical mockup of pixel detector

IP resolution σ_{z0}~50μm

Particle ID

Barrel: TOP (Time-Of-Propagation)

Focusing TOP concept:

•Reconstruct image of internally reflected Cherenkov in (X, T).

•Measure also Y w/ focusing mirror to correct chromatic dispersion effect.

Quartz radiator

Focusing mirror

Small expansion block

Hamamatsu MCP-PMT

(σ_{TTS}~40ps/photon)

Endcap: Aerogel RICH

•Proximity focusing RICH w/ hydrophobic aerogel radiator (λ_T>40mm)

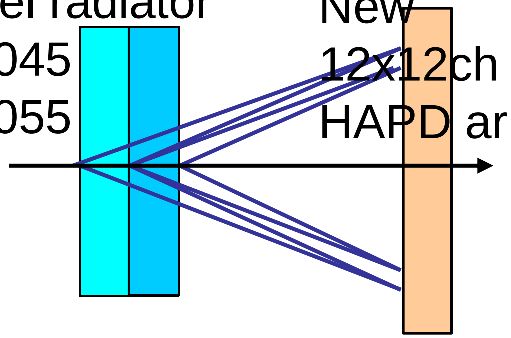
•Multiple radiators with different indices (n=1.045-1.050) to correct emission point uncertainty

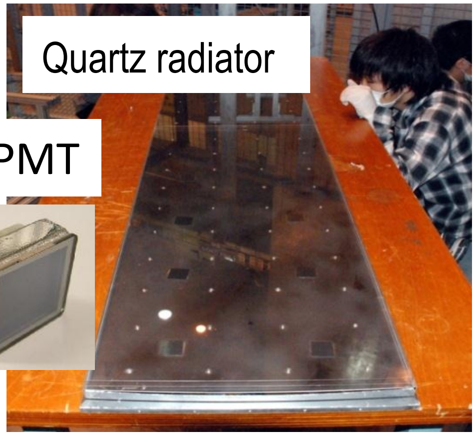
Aerogel radiator

n1=1.045

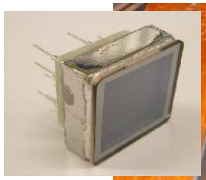
n2=1.055

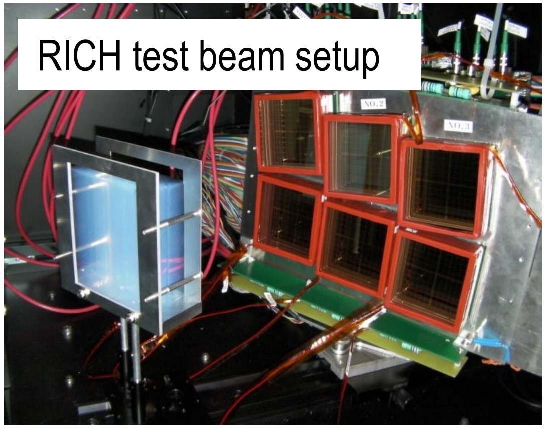
New 12x12ch HAPD array

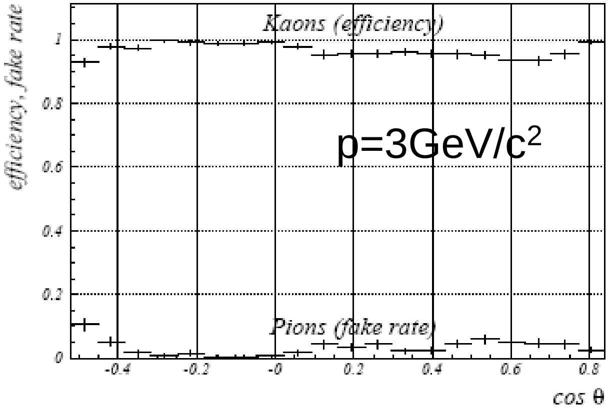




MCP-PMT



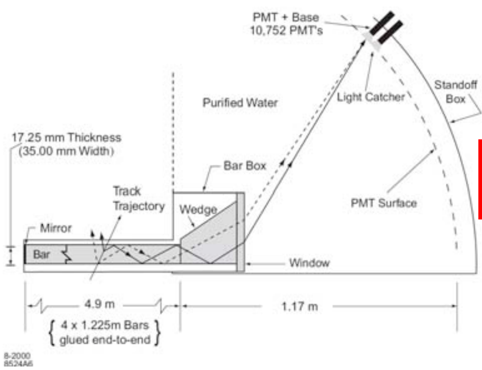


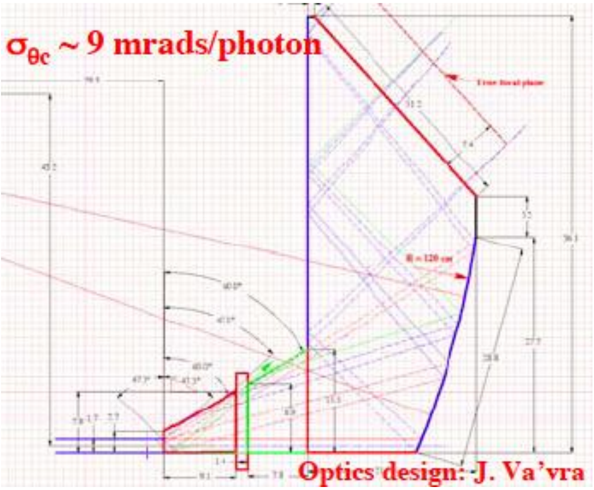


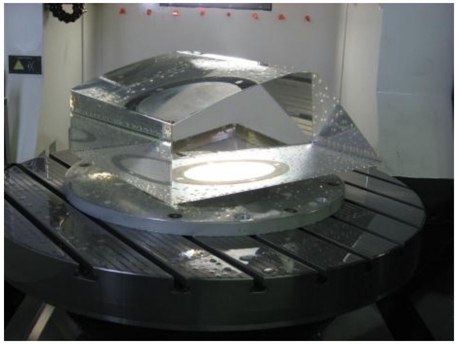
SuperB PID: FDIRC

- Focusing block + highly pixilated photodetectors
- x 10 better timing resolution than the BaBar DIRC
- x 25 smaller volume than the BaBar DIRC
- 3D imaging to correct the chromatic dispersion and reduce backgrounds.

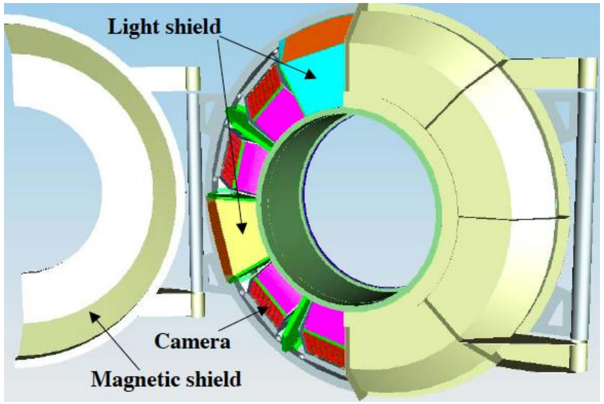
BaBar DIRC



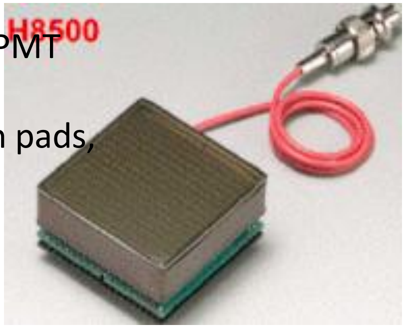


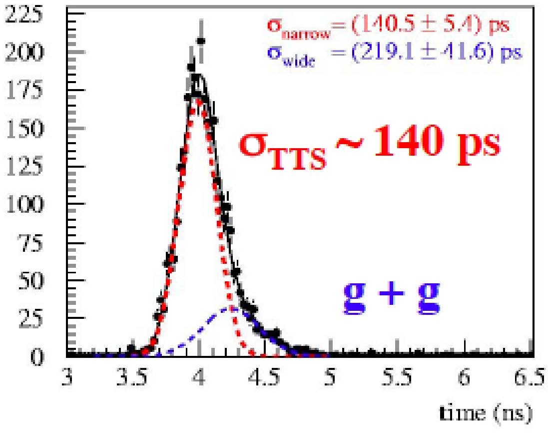


FBLOCK prototype



H8500 MaPMT
64 pixels,
6mmx6mm pads,





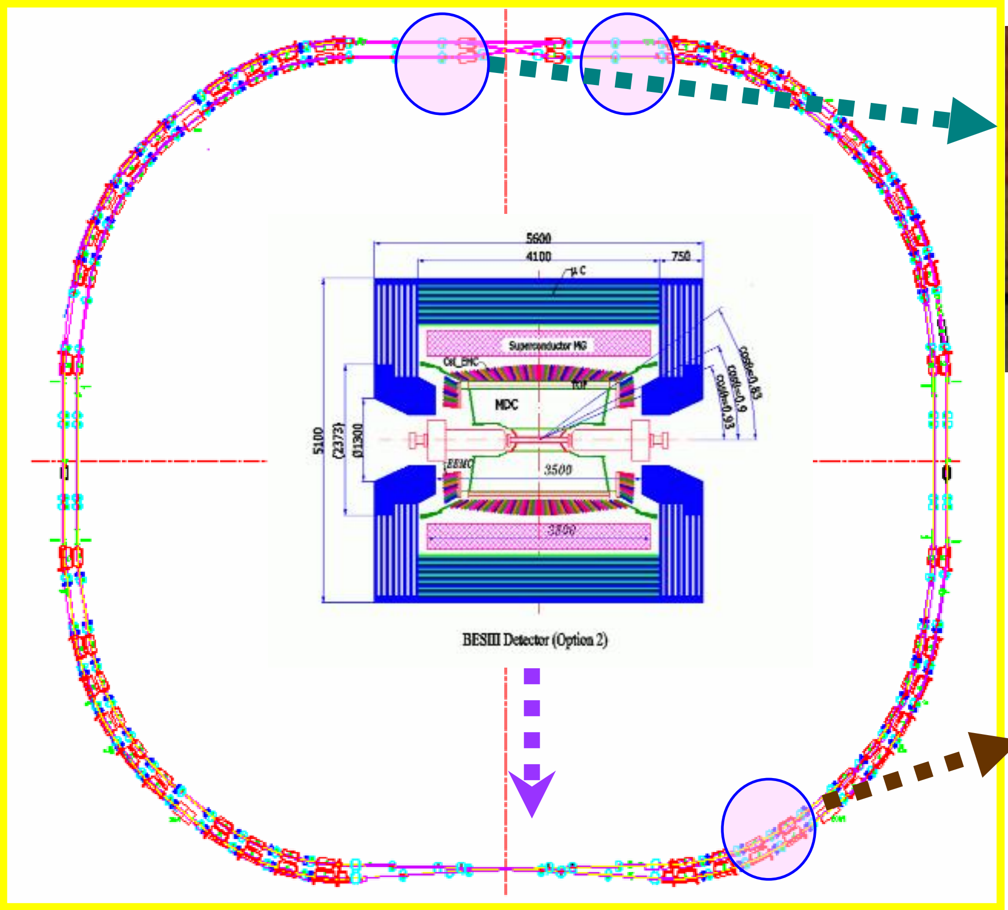
Performance of BEPCII Storage Ring

Parameters	Design	Accept test result	
		BER	BPR
Energy (GeV)	1.89	1.89	1.89
Beam current. (mA)	910	650	700
Bunch current. (mA)	9.8	>10	>10
Bunch number	93	93	93
RF voltage	1.5	1.6	1.6
ν_s @ V_{RF}= 1.5MV	0.033	0.032	0.032
β_x^* / β_y^* (m)	1.0/0.015	~1.0/0.0135	~1.0/0.0135
Injection rate (mA/min)	200 e^-/50 e^+	>200	>50
L ($10^{33}cm^{-2}s^{-1}$)	1.0	0.33	

Factor of 33 improvement in luminosity at May 2009

BEPCII at Beijing

- A high luminosity double-ring collider (E_{beam}=1-2.3 GeV).
- Luminosity: $L_{peak} = 1x10^{33}cm^{-2}s^{-1}$ ($0.33x10^{33}cm^{-2}s^{-1}$ now).
- BES III runs from 2008..



SC RF

Two rings

BINP SCT Machine Parameters

Energy	1.0 GeV	1.5 GeV	2.0 GeV	2.5 GeV
Circumference	780 m			
Emittance hor/ver	8 nm/0.04 nm @ 0.5% coupling			
Damping time hor/ver/long	30/30/15 ms			
Bunch length	16 mm	11 mm	10 mm	10 mm
Energy spread	$10.1 \cdot 10^{-4}$	$9.96 \cdot 10^{-4}$	$8.44 \cdot 10^{-4}$	$7.38 \cdot 10^{-4}$
Momentum compaction	$1.00 \cdot 10^{-3}$	$1.06 \cdot 10^{-3}$	$1.06 \cdot 10^{-3}$	$1.06 \cdot 10^{-3}$
Synchrotron tune	0.007	0.010	0.009	0.008
RF frequency	508 MHz			
Harmonic number	1300			
Particles in bunch	$7 \cdot 10^{10}$			
Number of bunches	390 (10% gap)			
Bunch current	4.4 mA			
Total beam current	1.7 A			
Beam-beam parameter	0.15	0.15	0.12	0.095
Luminosity	$0.63 \cdot 10^{35}$	$0.95 \cdot 10^{35}$	$1.00 \cdot 10^{35}$	$1.00 \cdot 10^{35}$

References

- Belle II Technical Design Report,arXiv:1011.0352
- Physics at Super B Factory, arXiv:1002.5012
- sBelle Design Study Report, arXiv:0810.4084

- Super B Progress Report-- Physics, arXiv:1008.1541
- Super B Progress Report– Accelerator, arXiv:1009.6178
- Super B Progress Report-- Detector, arXiv:1007.4241

- LHCb Upgrade LoI, CERN-LHCC-2011-001
  available at LHCb HP (http://lhcb.web.cern.ch/lhcb/)

Talks at 88th ECFA meeting; http://indico.cern.ch/conferenceDisplay.py?confId=111130