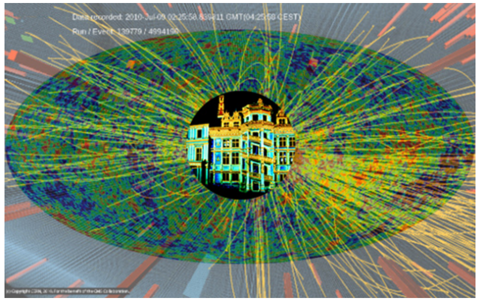
23rd Rencontres de Blois
Particle Physics and Cosmology



Beyond the Standard Model Physics at future B Factories and LHCb

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Kobayashi-Maskawa Institute

Nagoya University

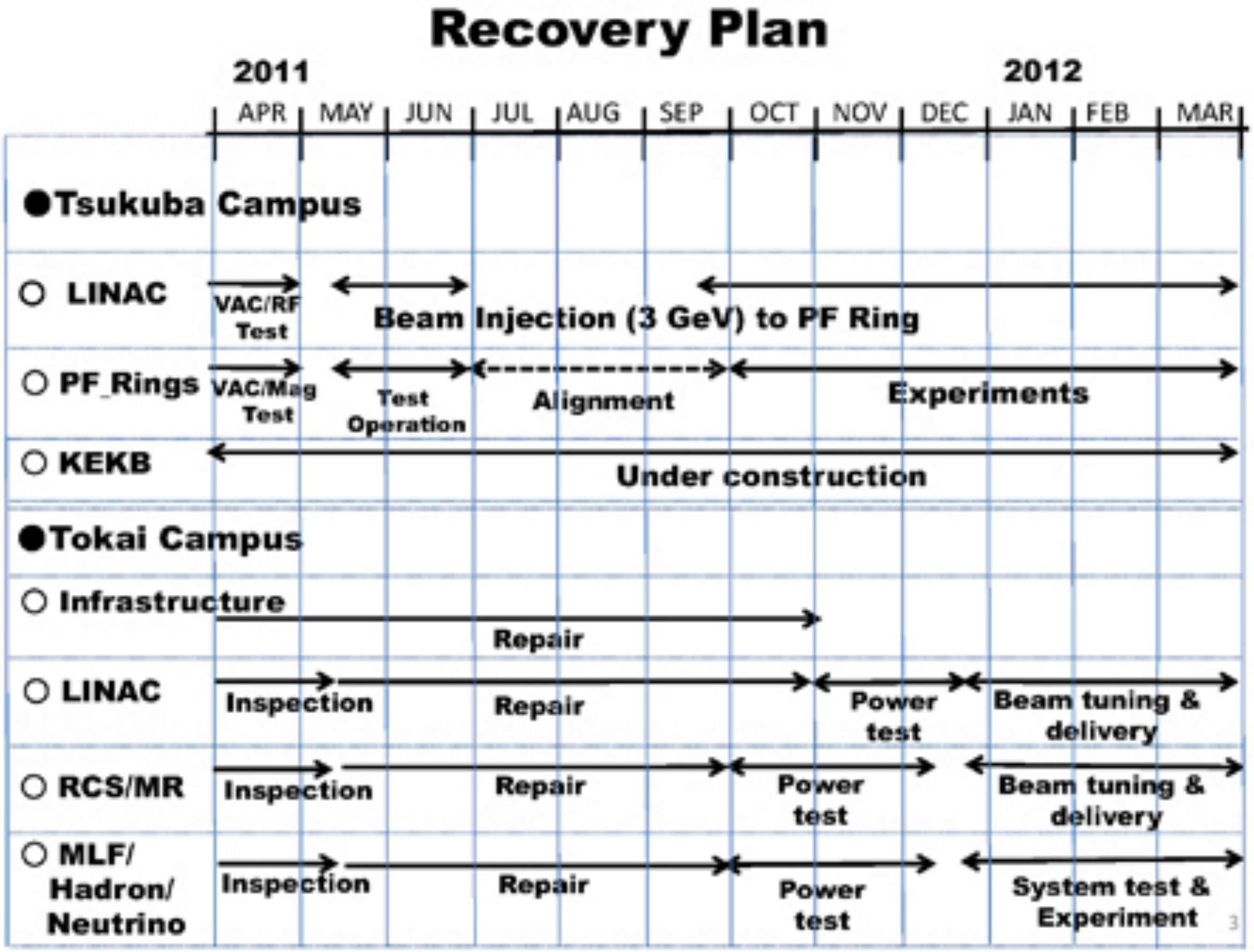
On the earthquake

As is now well known, Japan suffered a terrible earthquake and tsunami on March 11, which has caused tremendous damage, especially in the Tohoku area. Fortunately, all KEK personnel and users are safe and accounted for. The injection linac did suffer significant but manageable damage, and repairs are underway. The damage to the KEKB main rings appears to be less serious, though non-negligible. No serious damage has been reported so far at Belle. Further investigation is necessary. We would like to convey our deep appreciation to everyone for your generous expressions of concern and encouragement.

Information can be found in the KEK home page:
http://www.kek.jp/intra-e/

Recovery Plan

See DG’s corner in HP for damage report and recovery plan.



Talk Outline

- Introduction:
  Why do we need continue B programs ?
- Key measurements & physics cases
  Some examples
- Status of "future B factories"
  Accelerator & detector upgrades

Main players in this talk (references)

Belle II

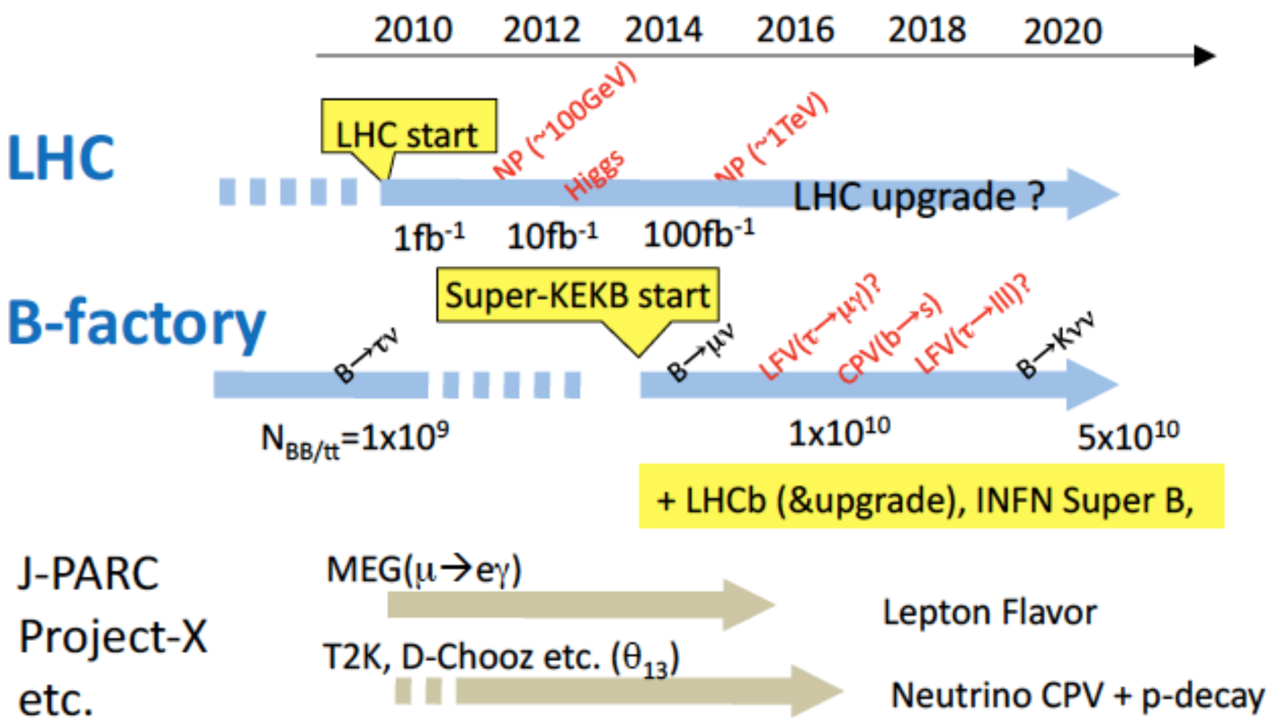
SuperB

LHCb

Apologies:
I cannot cover all subjects (there a lot).
I do not cover flavor physics at ATLAS/CMS.

Introduction

- We hope that New Physics will be seen directly at LHC (ATLAS/CMS).
  - Reasons to believe a TeV scale NP: hierarchy problem, unification of coupling constants,…
- If NP exists at a TeV scale, there is good chance to see effects in heavy flavor (B/D/τ) decays.



2010's = The decade of finding New Physics

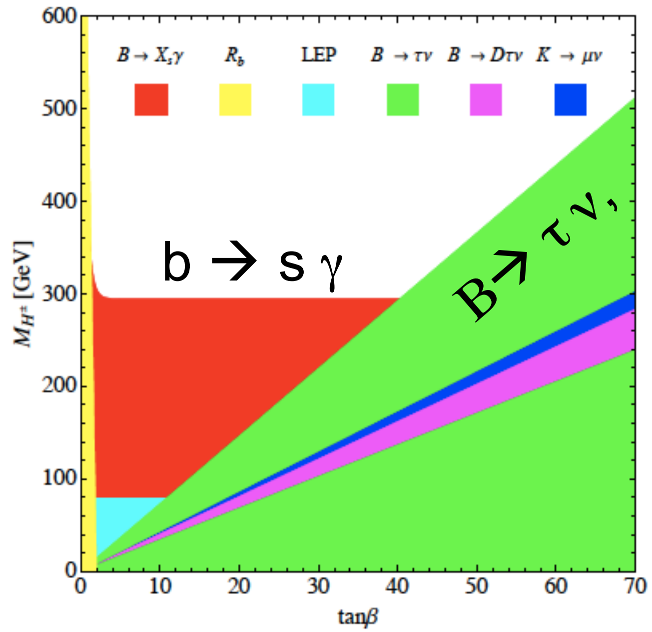
Role of Flavor Physics

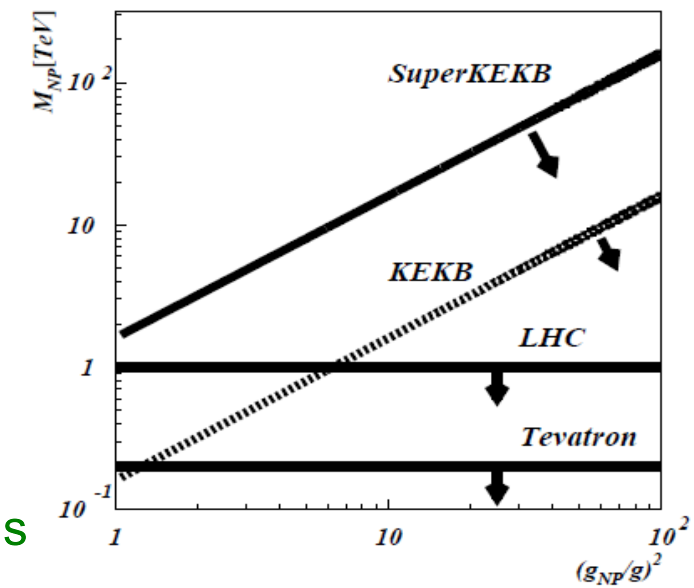
U. Haisch,
arXiv: 0805.2141

- Lessons from history:
  - GIM → charm quark
  - CPV → 3rd generation
  - B-B mixing → heavy top quark

- Also presently, flavor physics observables constrain NP most severely.
  - $b \to s \gamma$ $B \to \tau \nu$
  - $B_s \to \mu+\mu-$

- No sharp mass threshold for NP in flavor physics.
  Sensitivity reaches
  - O(1TeV) if MFV scenario
  - O(100TeV) if large flavor violating couplings





Pattern of deviation

If NP is found, flavor physics observables provide useful information to test the NP models.

SUSY models

Flavor physics observables

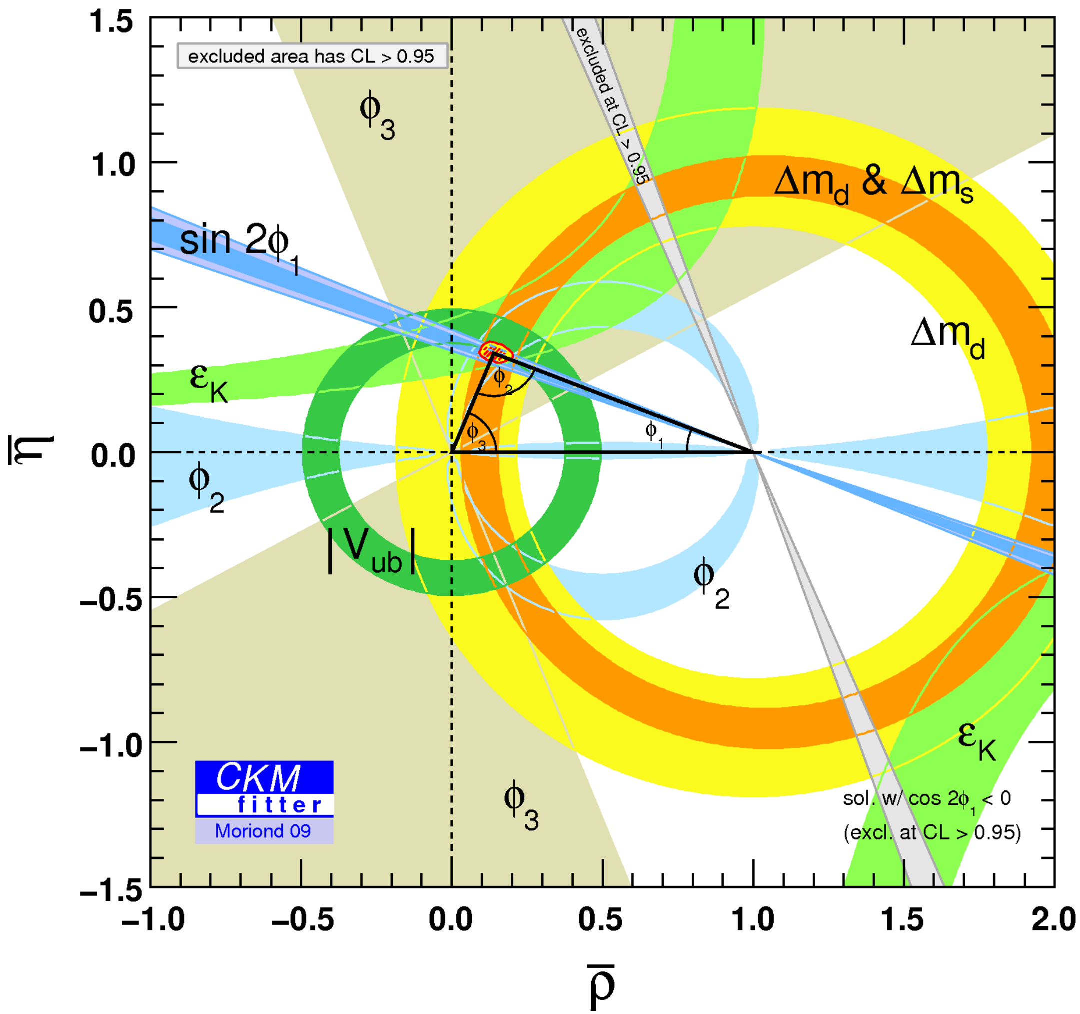
	mSUGRA	$MSSM+\nu_R$ degenerate	$MSSM+\nu_R$ non-degenerate	$SU(5)+\nu_R$ degenerate	$SU(5)+\nu_R$ non-degenerate	U(2) FS
$A_{CP}(s\gamma)$						✔
$S(K^*\gamma)$				✔	✔	✔
$S(\rho\gamma)$				✔	✔	✔
$S(\phi K_S)$				✔	✔	✔
$S(B_s \to J/\psi\ \phi)$				✔	✔	✔
$\mu \to e\gamma$		✔		✔	✔	?
$\tau \to \mu\gamma$		✔	✔	✔	✔	?
$\tau \to e\gamma$			✔		✔	?

…

[based on T.Goto et.al. PRD77, 095010(2008)]

✔:deviation from SM expected

Current Status of CP/CKM



2008 Nobel Prize in Physics

M. Kobayashi

T. Maskawa

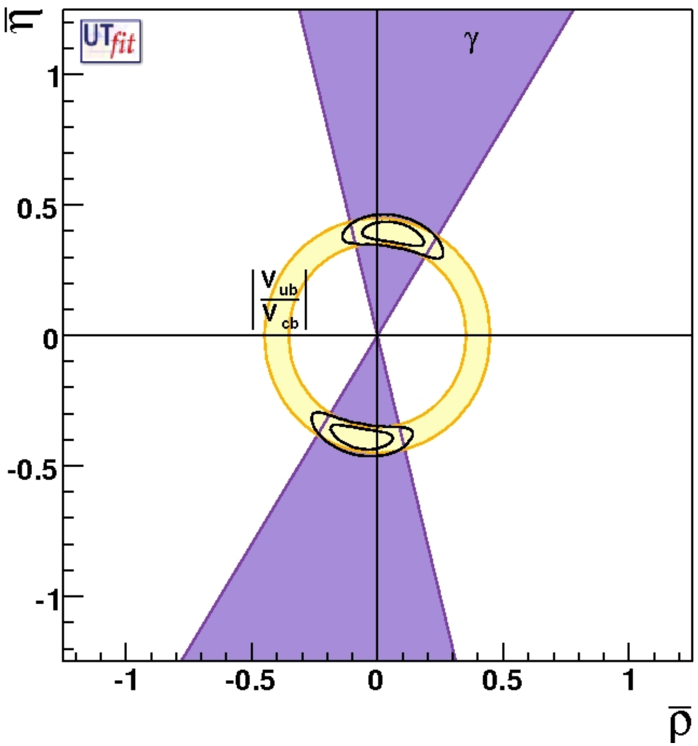
Similar plot by the UT-fit group

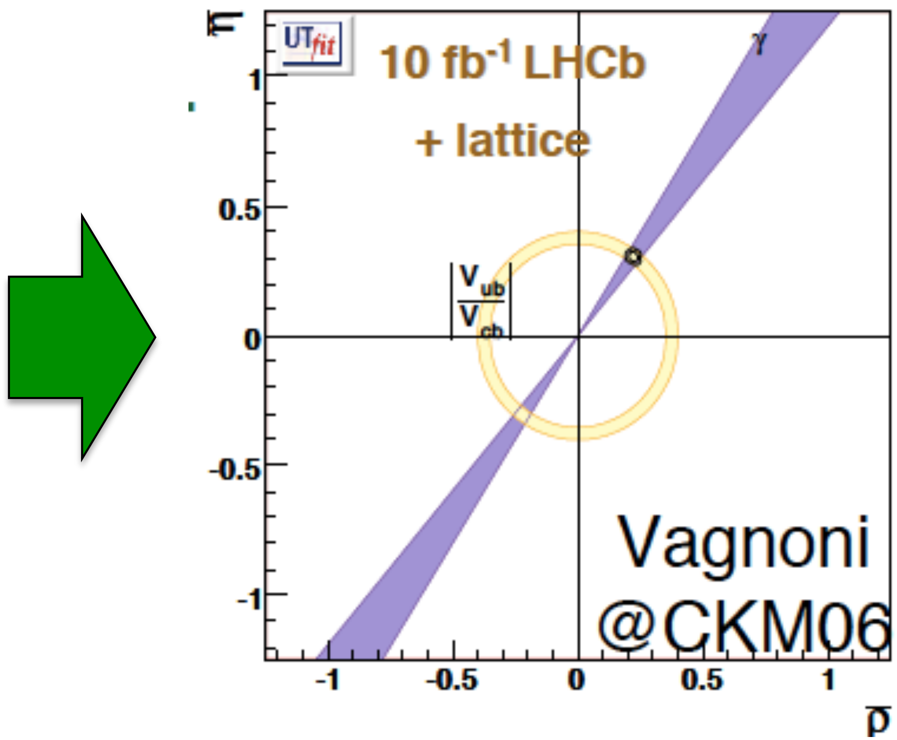
Still room for modifications by NP at O(0.1) !

Still room for improvement

- There are tree and loop diagrams involved in the CKM fit.
- We should determine the apex from $|V_{ub}|$ and ϕ_3 more precisely and compared it to that from loop processes.

$$\phi_3(\gamma) = (73^{+19}_{-24})^\circ$$ from B→DK





Limits on NP from $B_{d,s}$ mixing

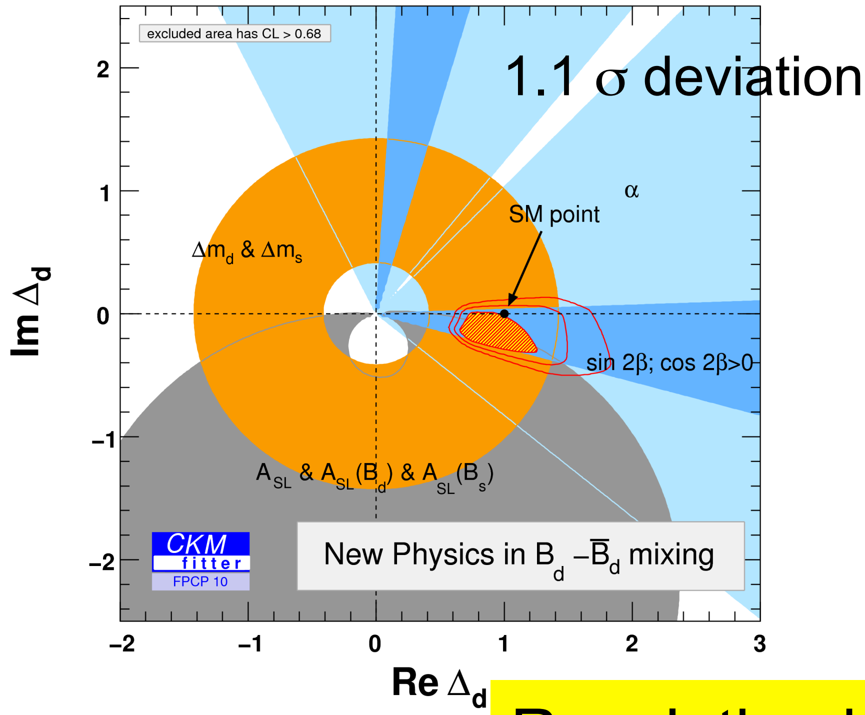
- NP effects in B-B mixing can be expressed as;

$$\langle B^0 | H^{SM+NP}_{\Delta B=2} | \overline{B}^0 \rangle = \Delta^{NP}_{d,s} \langle B^0 | H^{SM}_{\Delta B=2} | \overline{B}^0 \rangle, \quad \Delta^{NP}_{d,s} = \mathrm{Re}\,\Delta_{d,s} + \mathrm{Im}\,\Delta_{d,s}$$

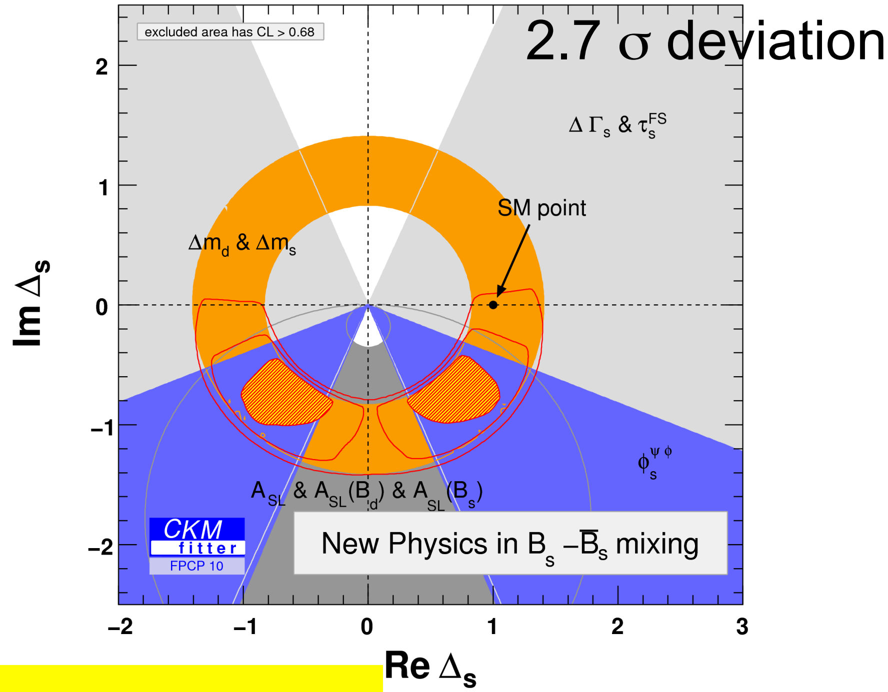
- Possible NP in Δm, weak phases, A_{SL} & $\Delta\Gamma$
- No NP in tree observables $|V_{ij}|$ and γ (ϕ_3).

CKM fitter @ FPCP2010
B($B\rightarrow\tau\nu$) removed.

B_d mixing



B_s mixing

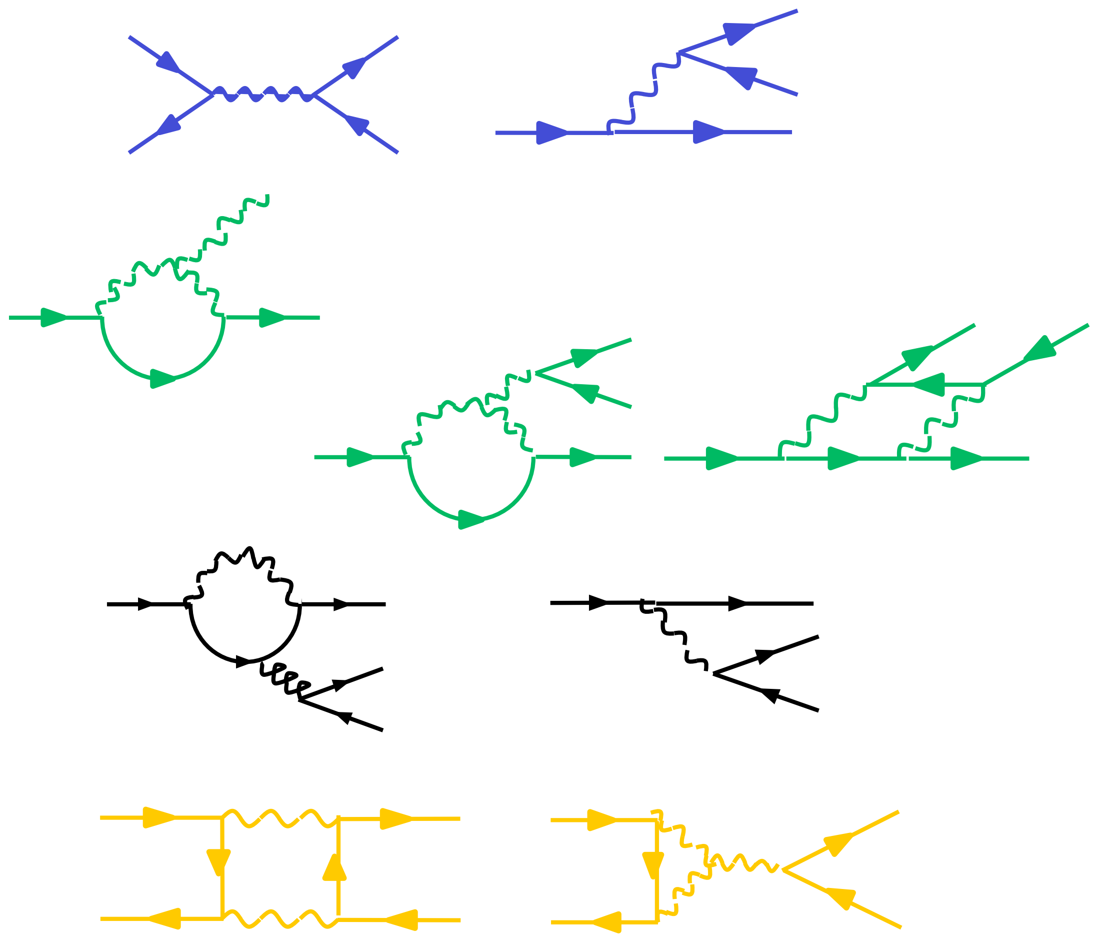


Resolution is not enough !

Many channels to probe NP

There are many places to look for NP in rare B decays.

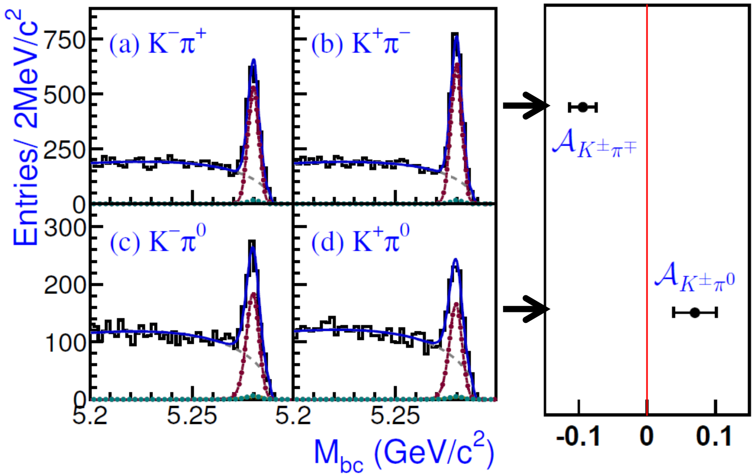
- $B \rightarrow l\nu$, $\tau\nu$, $D\tau\nu$
- $b \rightarrow s\gamma$
- $b \rightarrow sll$
- $b \rightarrow sg + b \rightarrow u\bar{q}q$
- $B_{s,d} \rightarrow ll$



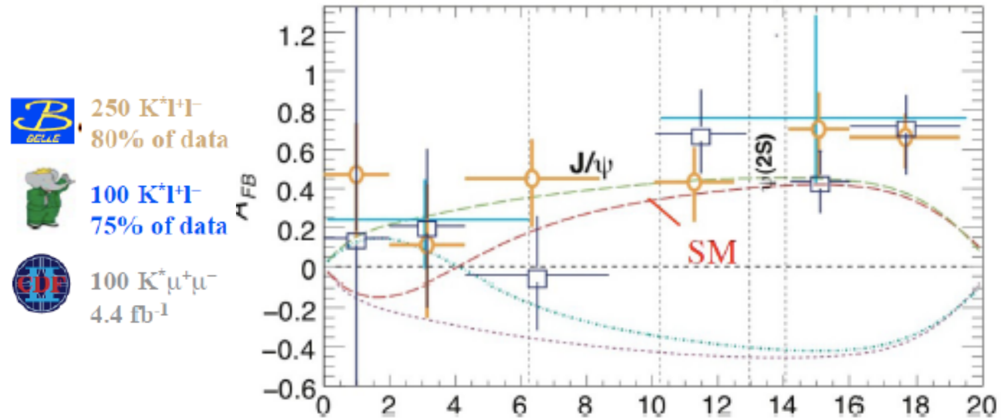
+ D decays & τ decays

Some hints in existing B factory data

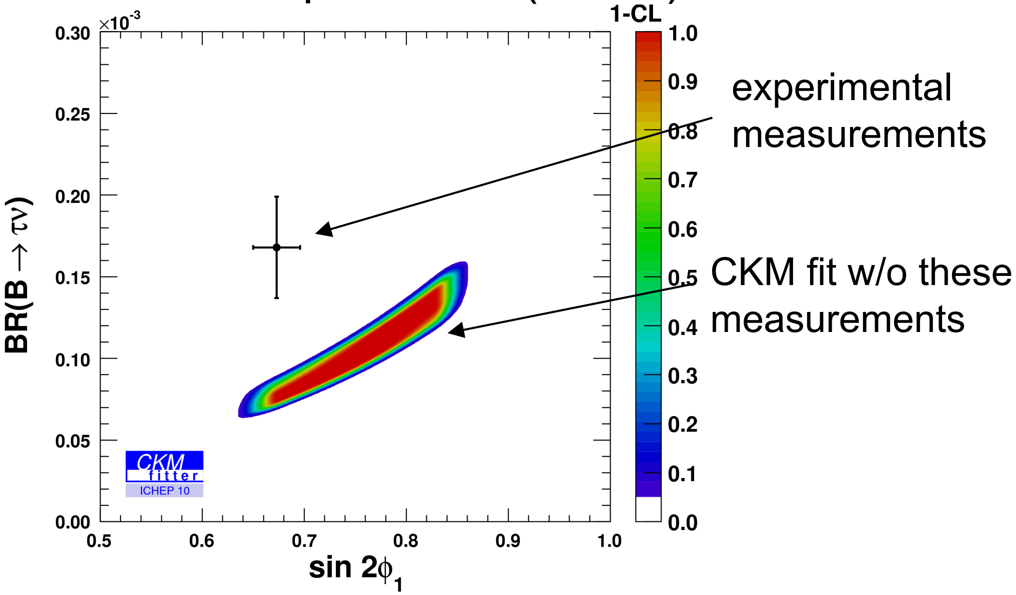
Kπ puzzle: $A_{CP}(B^0 \to K^+\pi^-) \neq A_{CP}(B^+ \to K^+\pi^0)$



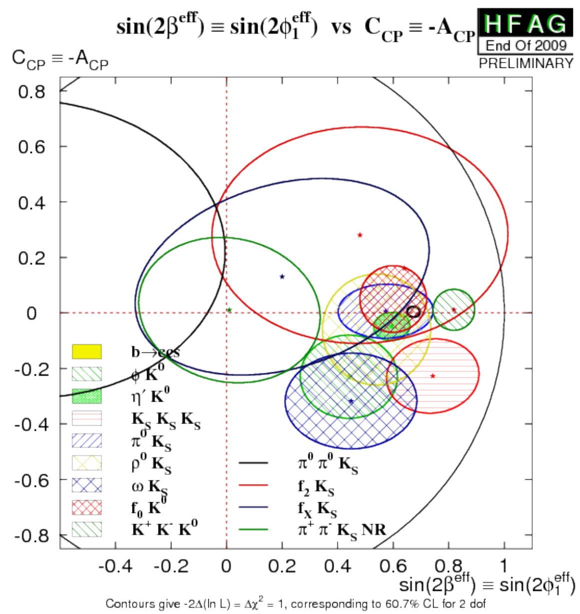
Forward-backward asymmetry in B→K*l+l-



2.8σ difference between direct and indirect $\sin 2\varphi_1$ and BR(B→τν)



CPV in b→s penguin modes



Coming Opportunities

2014 2015 2016 2017 2018 2019 2020

e+e-

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

$L_{peak} = 8 \times 10^{35} cm^{-2} s^{-1}$

$L_{int} = 50 ab^{-1}$ by ~2020

SuperKEKB /Belle II

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

Hadron machine

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

LHCb

Phase 1

Phase 2

(Don' take the end-point of each arrow seriously)

Key Measurements at Belle II

Belle II

CPV in b→s modes

FCNC b→sγ

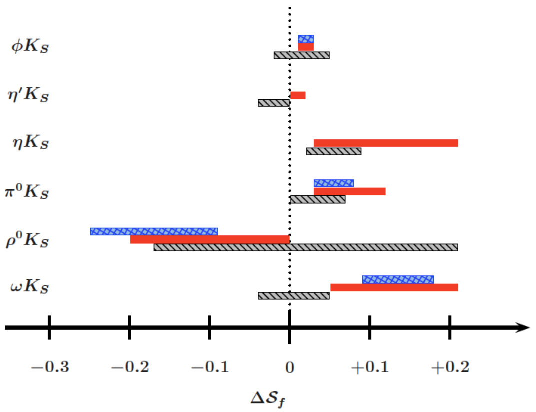
b→sll

Tauonic decays

LFV tau decays

Precision CKM

QCD correction/error in ΔS

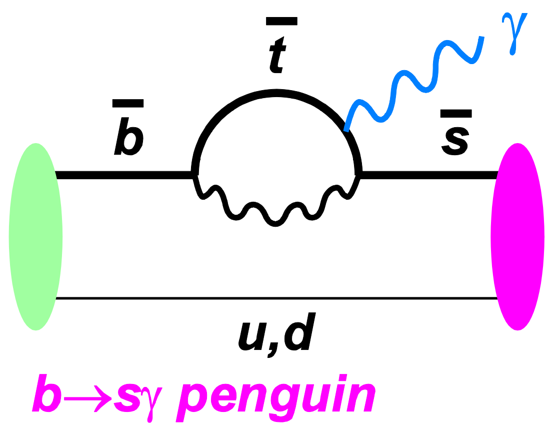


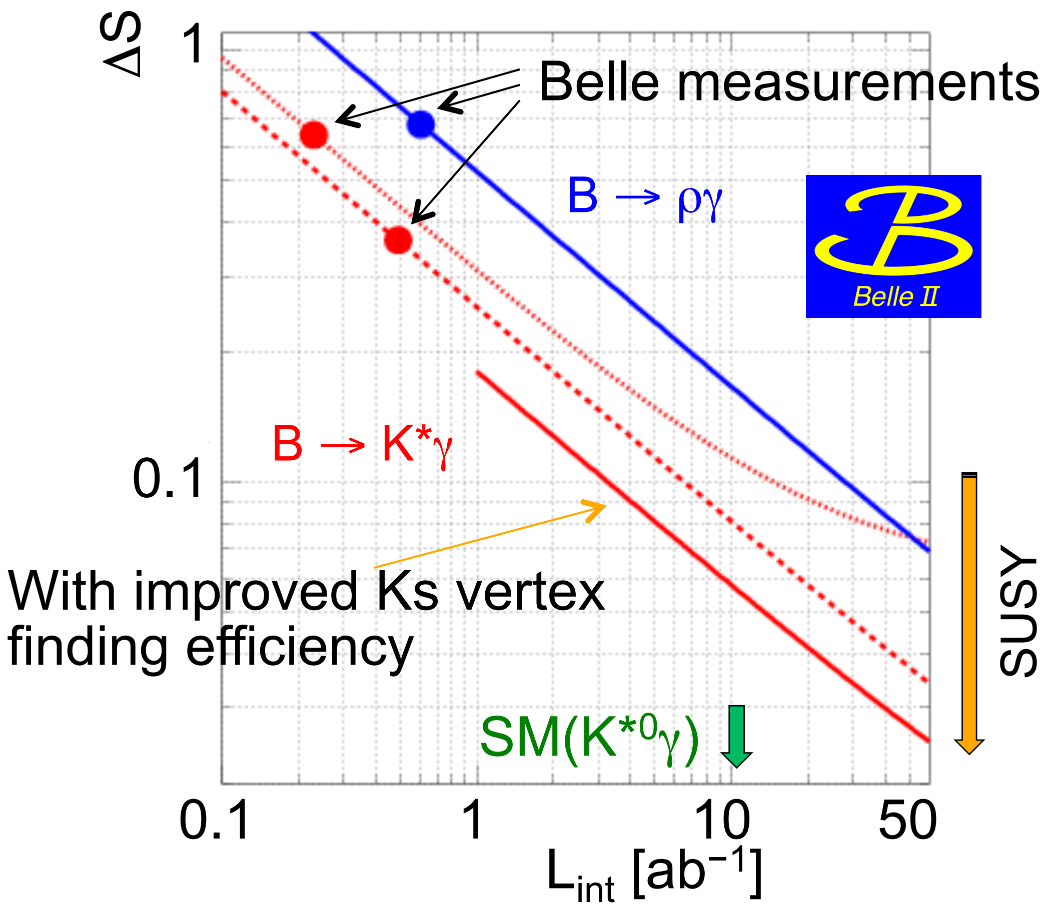
	Belle'06 ($\sim$0.5ab^{-1})	5ab^{-1}	50ab^{-1}
$\Delta S(\phi K^0)$	**0.22**	0.073	**0.029**
$\Delta S(\eta' K^0)$	**0.11**	0.038	**0.020**
$\Delta S(K_S K_S K_S)$	**0.33**	0.105	**0.037**
$\Delta S(K_S \pi^0 \gamma)$	**0.32**	0.10	**0.03**
$Br(X_s \gamma)$	**13%**		
$A_{CP}(X_s \gamma)$	**0.058**	0.01	**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 !

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 !





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

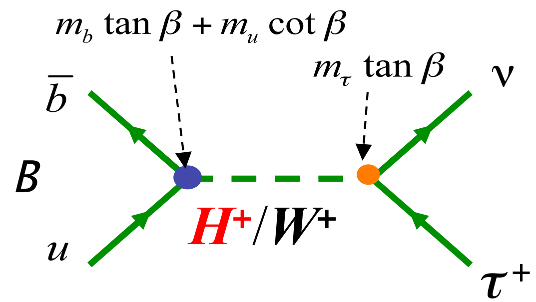
In SM,

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

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

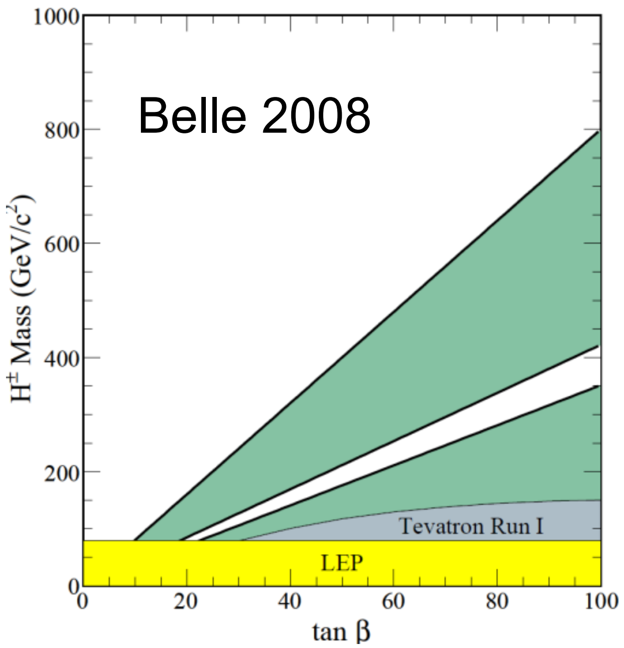
$\Delta S(\rho^0\gamma) = 0.075$ @ 50 ab^{-1}

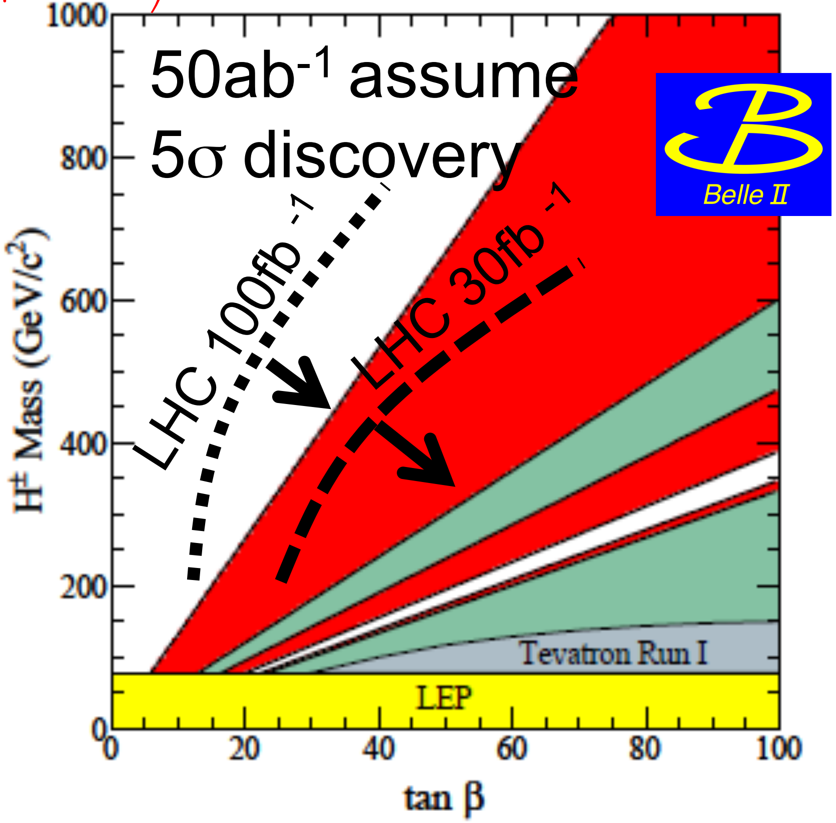
B→τν: Search for charged Higgs



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, $Br = Br_{SM} \times r_H, \; r_H = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$

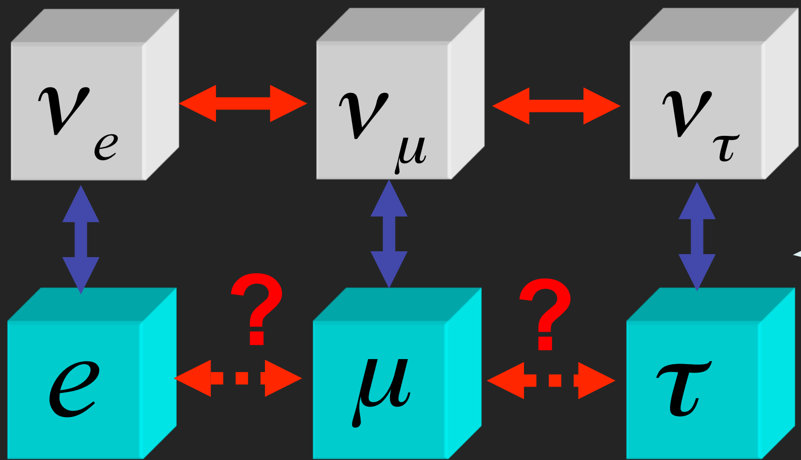




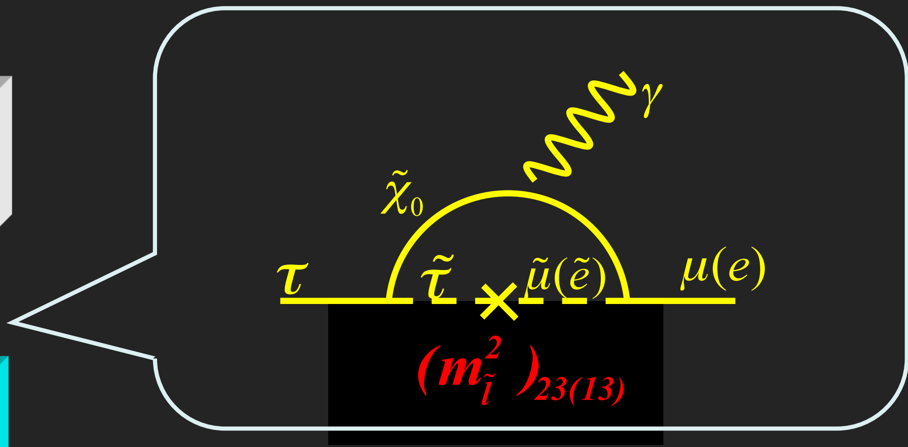
- *B→τν/Dτν* probes *b-H*$^\pm$*-u*, *b-H*$^\pm$*-c* couings to compare *b-H*$^\pm$*-t coupling* from LHC high P_T programs.

Lepton Flavor Violation

Quarks have flavor mixing.
Neutrino mixing has been found.
What about charged leptons ?



(Original figure by Dr. Kuno / Osaka Univ.)



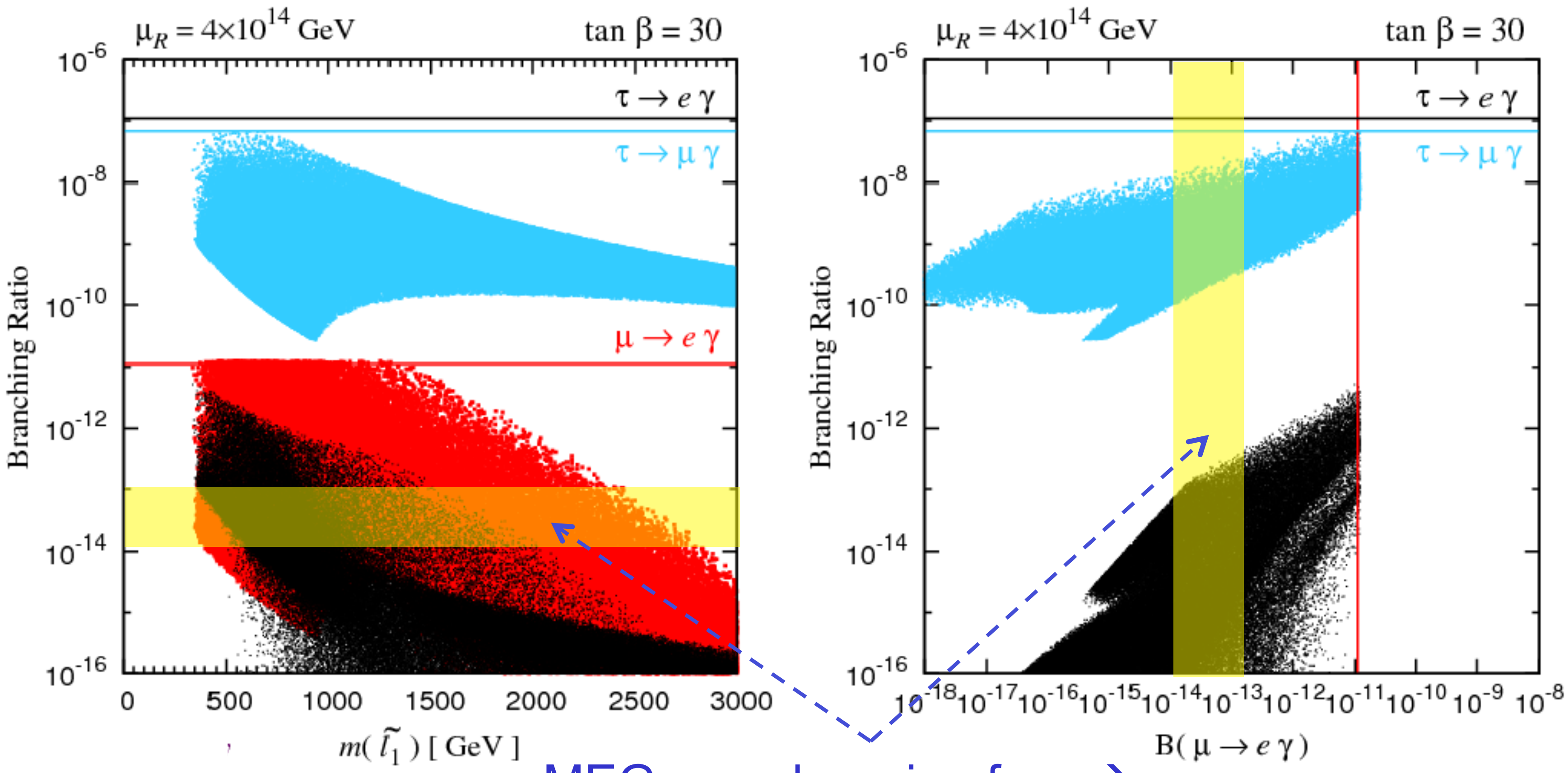
τ decays probe mixings between 3⇔2 and 3⇔1 generations.

B factory is also a tau factory

SUSY-GUT

Goto, Okada, Shindou & Tanaka
PRD77, 095010 (2008)

- SU(5)+ν_R, non-degenerate ν_R(I), normal Hierarchy



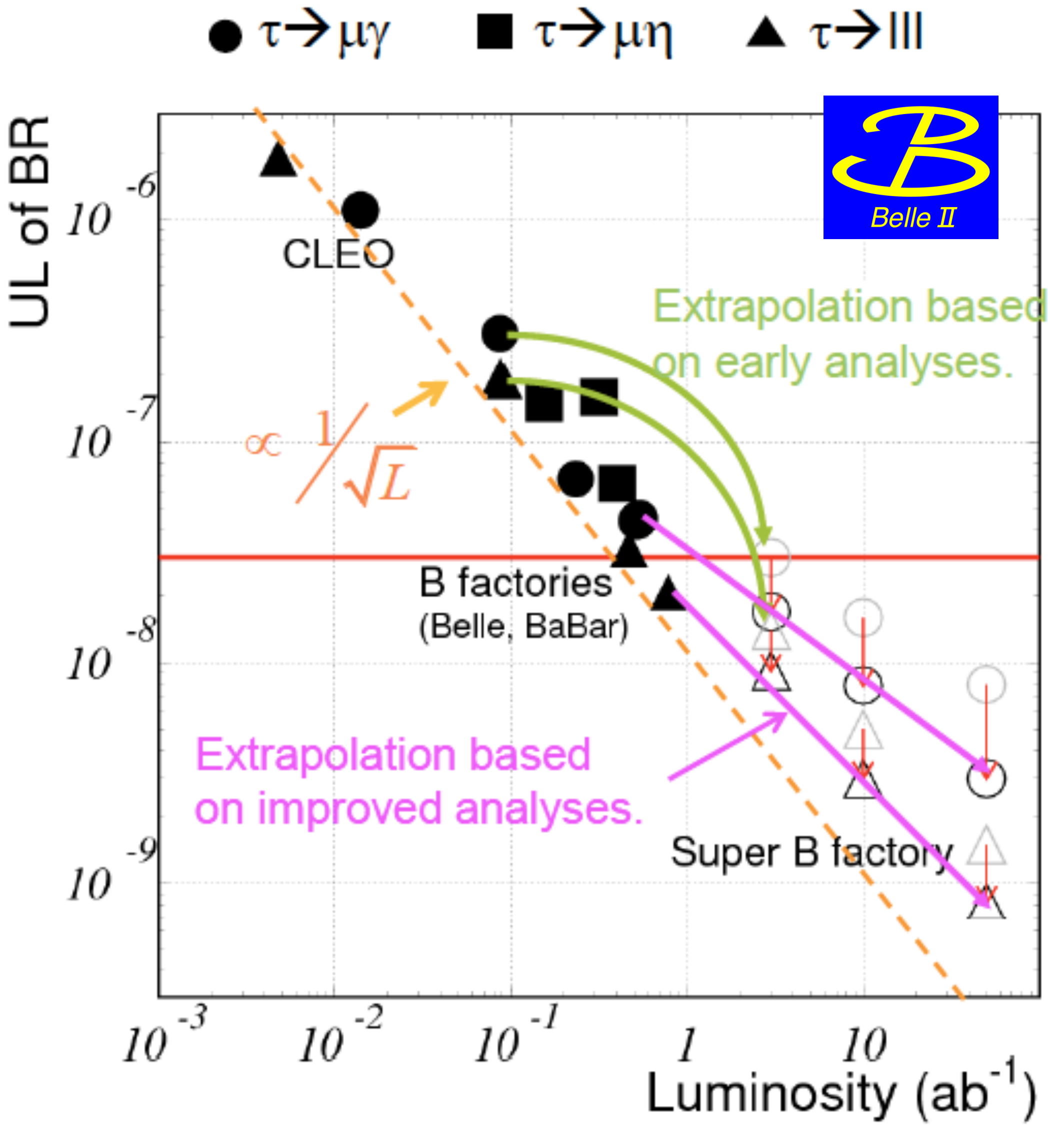
MEG search region for μ→eγ

If MEG find μ→eγ at ~10^{-13}, good chance to see also τ→μγ at $10^{-8\rightarrow-10}$
Even if MEG does not, still important to search for τ→μγ.

Future prospects

- Super B-factory:
  L_{int} = 10→50ab^{-1}
  N_τ = (1→5) x 10^{10}
- Recent improvement in the analysis
  - BG understanding
  - Intelligent selection
- At 50 ab^{-1}
  Br(τ→μγ) < O(10^{-9})
  Br(τ◊lll) < O(10^{-10})

Good chance to see NP !



Studies by Super B

B Physics @ Y(4S)

Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\sin(2\beta)$ $(J/\psi K^0)$	0.018	0.005 (†)
$\cos(2\beta)$ $(J/\psi K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
$\cos(2\beta)$ (Dh^0)	0.20	0.04
$S(J/\psi \pi^0)$	0.10	0.02
$S(D^+D^-)$	0.20	0.03
$S(\phi K^0)$	0.13	0.02 (∗)
$S(\eta' K^0)$	0.05	0.01 (∗)
$S(K_S^0 K_S^0 K_S^0)$	0.15	0.02 (∗)
$S(K_S^0 \pi^0)$	0.15	0.02 (∗)
$S(\omega K_S^0)$	0.17	0.03 (∗)
$S(f_0 K_S^0)$	0.12	0.02 (∗)
γ $(B \to DK, D \to CP$ eigenstates$)$	$\sim 15^\circ$	2.5°
γ $(B \to DK, D \to$ suppressed states$)$	$\sim 12^\circ$	2.0°
γ $(B \to DK, D \to$ multibody states$)$	$\sim 9^\circ$	1.5°
γ $(B \to DK$, combined$)$	$\sim 6^\circ$	1–2°
α $(B \to \pi\pi)$	$\sim 16^\circ$	3°
α $(B \to \rho\rho)$	$\sim 7^\circ$	1–2° (∗)
α $(B \to \rho\pi)$	$\sim 12^\circ$	2°
α (combined)	$\sim 6^\circ$	1–2° (∗)
$2\beta + \gamma$ $(D^{(*)\pm}\pi^\mp, D^\pm K_S^0 \pi^\mp)$	20°	5°

Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\lvert V_{cb}\rvert$ (exclusive)	4% (∗)	1.0% (∗)
$\lvert V_{cb}\rvert$ (inclusive)	1% (∗)	0.5% (∗)
$\lvert V_{ub}\rvert$ (exclusive)	8% (∗)	3.0% (∗)
$\lvert V_{ub}\rvert$ (inclusive)	8% (∗)	2.0% (∗)
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%
$\mathcal{B}(B \to \rho\gamma)$	15%	3% (†)
$\mathcal{B}(B \to \omega\gamma)$	30%	5%
$A_{CP}(B \to K^*\gamma)$	0.007 (†)	0.004 († ∗)
$A_{CP}(B \to \rho\gamma)$	~ 0.20	0.05
$A_{CP}(b \to s\gamma)$	0.012 (†)	0.004 (†)
$A_{CP}(b \to (s+d)\gamma)$	0.03	0.006 (†)
$S(K_S^0 \pi^0 \gamma)$	0.15	0.02 (∗)
$S(\rho^0\gamma)$	possible	0.10
$A_{CP}(B \to K^*\ell\ell)$	7%	1%
$A^{FB}(B \to K^*\ell\ell)s_0$	25%	9%
$A^{FB}(B \to X_s\ell\ell)s_0$	35%	5%
$\mathcal{B}(B \to K\nu\bar{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

τ Physics

	Sensitivity
$\mathcal{B}(\tau \to \mu\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to e\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to \mu\mu\mu)$	2×10^{-10}
$\mathcal{B}(\tau \to eee)$	2×10^{-10}
$\mathcal{B}(\tau \to \mu\eta)$	4×10^{-10}
$\mathcal{B}(\tau \to e\eta)$	6×10^{-10}
$\mathcal{B}(\tau \to \ell K_S^0)$	2×10^{-10}

B_s Physics @ Y(5S)

Observable	Error with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}	0.03 ps^{-1}
Γ	0.07 ps^{-1}	0.01 ps^{-1}
β_s from angular analysis	20°	8°
A_{SL}^s	0.006	0.004
A_{CH}	0.004	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\lvert V_{td}/V_{ts}\rvert$	0.08	0.017
$\mathcal{B}(B_s \to \gamma\gamma)$	38%	7%
β_s from $J/\psi\phi$	10°	3°
β_s from $B_s \to K^0\bar{K}^{*0}$	24°	11°

Charm mixing and CP

Mode	Observable	$\Upsilon(4S)$ (75 ab^{-1})	$\psi(3770)$ (300 fb^{-1})
$D^0 \to K^+\pi^-$	x'^2	3×10^{-5}	
	y'	7×10^{-4}	
$D^0 \to K^+K^-$	y_{CP}	5×10^{-4}	
$D^0 \to K_S^0\pi^+\pi^-$	x	4.9×10^{-4}	
	y	3.5×10^{-4}	
	$\lvert q/p\rvert$	3×10^{-2}	
	ϕ	2°	
$\psi(3770) \to D^0\overline{D}^0$	x^2		$(1-2) \times 10^{-5}$
	y		$(1-2) \times 10^{-3}$
	$\cos\delta$		$(0.01-0.02)$

Charm FCNC

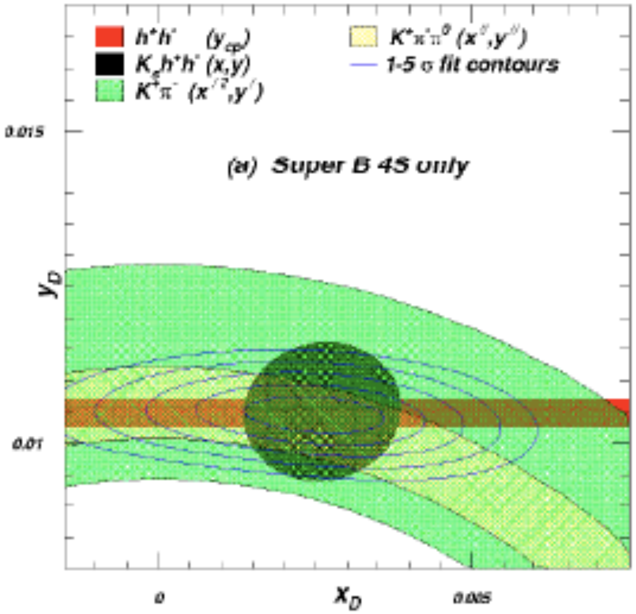
	Sensitivity
$D^0 \to e^+e^-$, $D^0 \to \mu^+\mu^-$	1×10^{-8}
$D^0 \to \pi^0 e^+e^-$, $D^0 \to \pi^0\mu^+\mu^-$	2×10^{-8}
$D^0 \to \eta e^+e^-$, $D^0 \to \eta\mu^+\mu^-$	3×10^{-8}
$D^0 \to K_S^0 e^+e^-$, $D^0 \to K_S^0\mu^+\mu^-$	3×10^{-8}
$D^+ \to \pi^+e^+e^-$, $D^+ \to \pi^+\mu^+\mu^-$	1×10^{-8}
$D^0 \to e^\pm\mu^\mp$	1×10^{-8}
$D^+ \to \pi^+e^\pm\mu^\mp$	1×10^{-8}
$D^0 \to \pi^0 e^\pm\mu^\mp$	2×10^{-8}
$D^0 \to \eta e^\pm\mu^\mp$	3×10^{-8}
$D^0 \to K_S^0 e^\pm\mu^\mp$	3×10^{-8}
$D^+ \to \pi^-e^+e^+$, $D^+ \to K^-e^+e^+$	1×10^{-8}
$D^+ \to \pi^-\mu^+\mu^+$, $D^+ \to K^-\mu^+\mu^+$	1×10^{-8}
$D^+ \to \pi^-e^\pm\mu^\mp$, $D^+ \to K^-e^\pm\mu^\mp$	1×10^{-8}

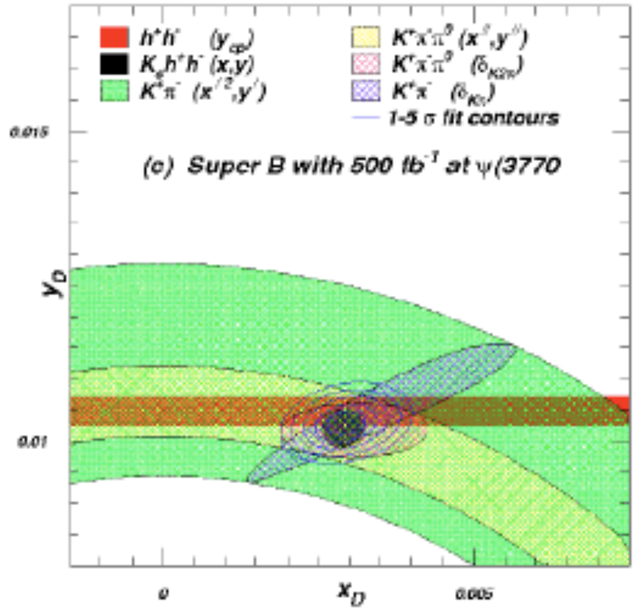
M. Giorgi, ICHEP2010

Running at Charm Threshold

F. Wilson
@ Beauty 2011

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



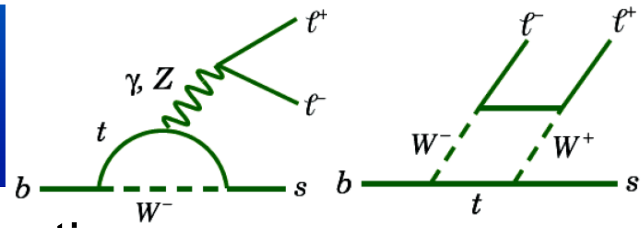


	Now	SuperB	SuperB+BES	SuperB +BES+φ(3770)
x (x 10^3)	±3	±0.7	±0.4	±0.2
y (x 10^3)	±2	±0.2	±0.2	±0.1
$\delta_{k\pi}$	±10°	±3°	±2°	±1°
$\delta_{k\pi\pi}$	±20°	±5°	±3°	±1°

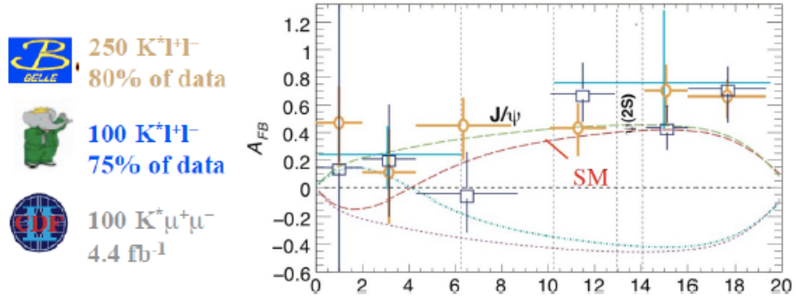
Key measurements at LHCb (+ Upgrade)

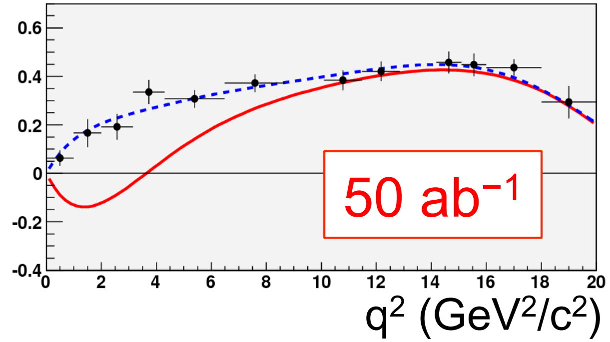
Type	Observable	Current precision	LHCb ($5\ fb^{-1}$)	Upgrade ($50\ fb^{-1}$)	Theory uncertainty
Gluonic penguin	$S(B_s \to \phi\phi)$	-	0.08	0.02	0.02
	$S(B_s \to K^{*0}\bar{K}^{*0})$	-	0.07	0.02	< 0.02
	$S(B^0 \to \phi K_S^0)$	0.17	0.15	0.03	0.02
B_s mixing	$2\beta_s\ (B_s \to J/\psi\phi)$	0.35	0.019	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	$\gamma\ (B \to D^{(*)}K^{(*)})$	$\sim 20°$	$\sim 4°$	0.9°	negligible
	$\gamma\ (B_s \to D_s K)$	-	$\sim 7°$	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 /Super B measure $X_s l^+ l^-$





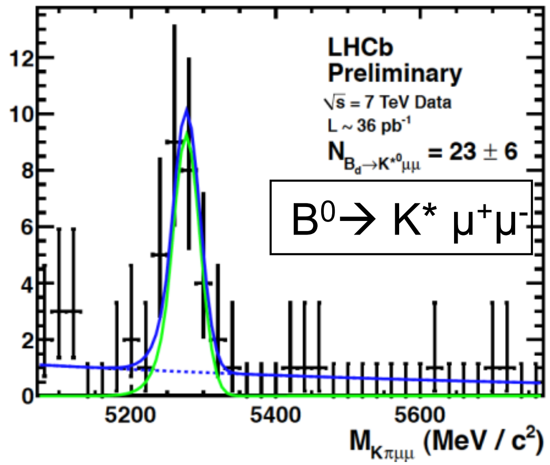
Present LHCb

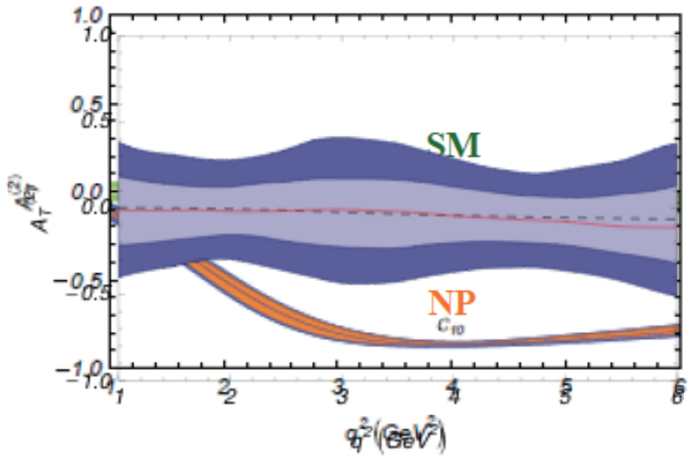
- Zero crossing in SM:

  $s_0 = (4.36+0.36-0.33)\ \mathrm{GeV}^2$
- Measure s_0 to 0.4 GeV^2 in 2-3 years

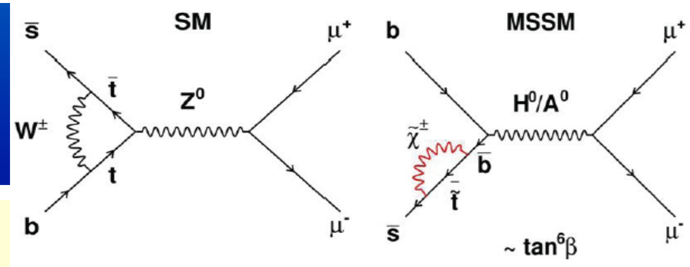
LHCb upgrade

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

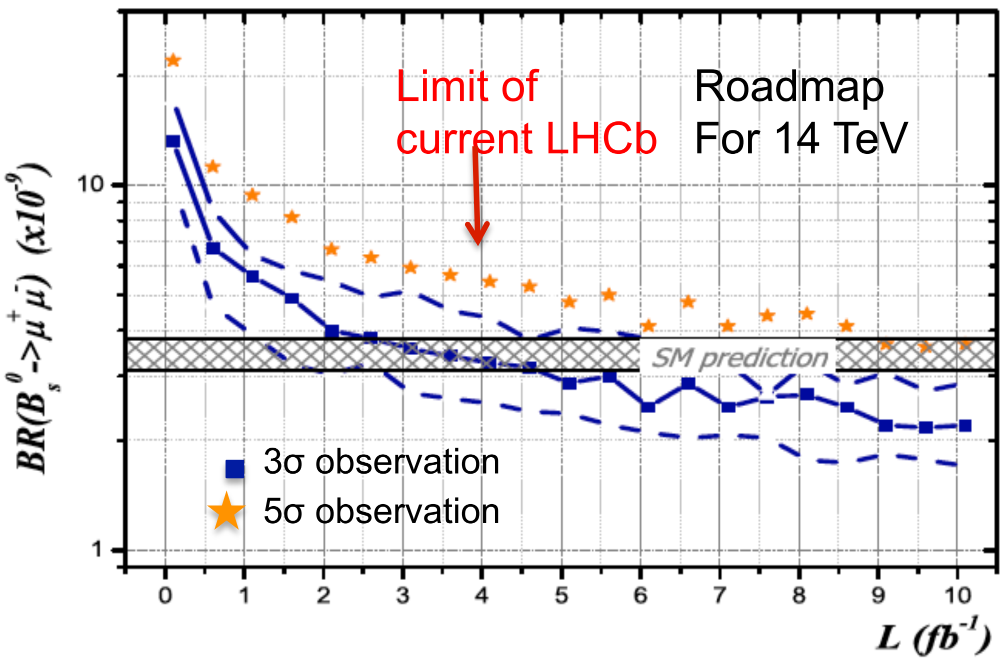


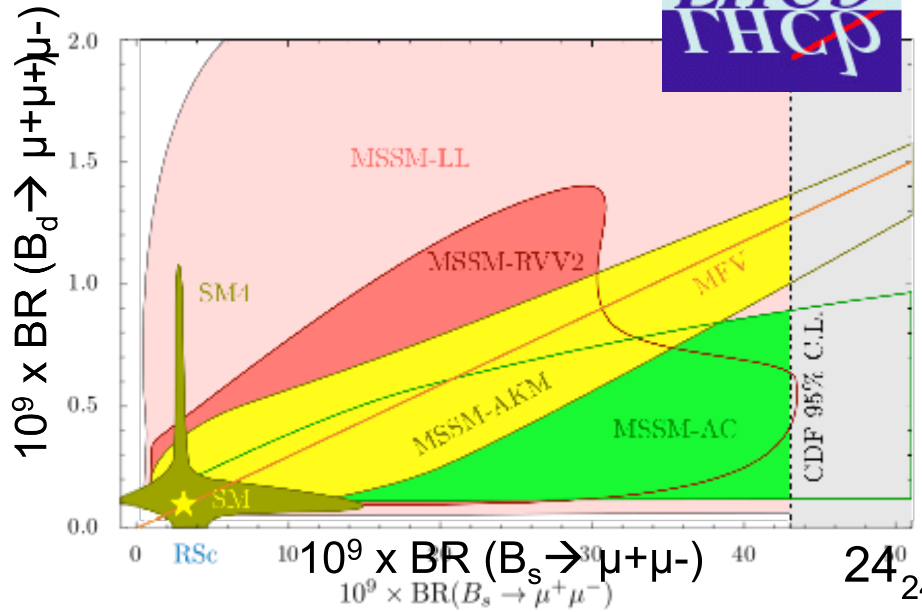


$B_{s,d} \rightarrow \mu^+\mu^-$



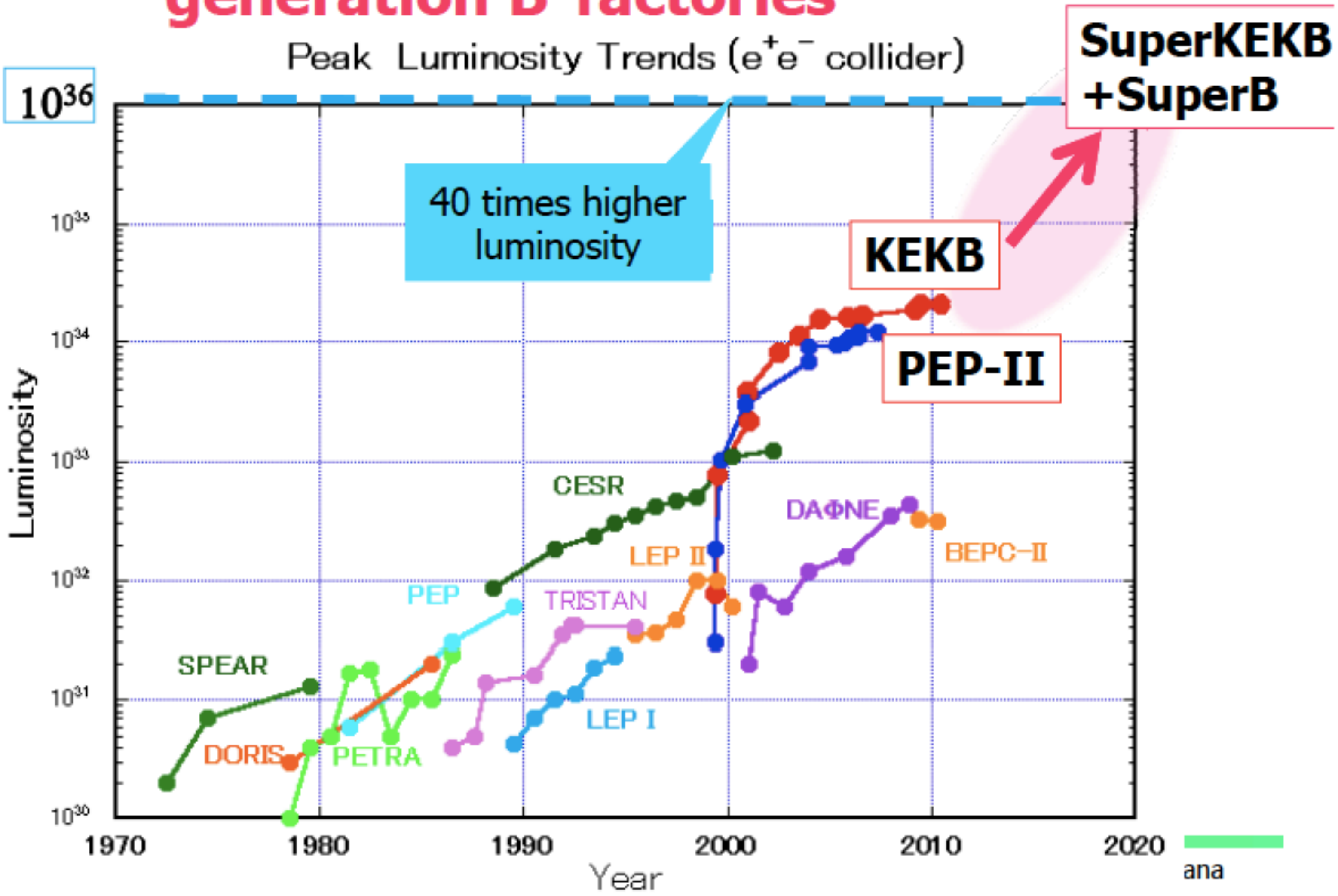
- Exploit statistical power LHCb
- Sensitivity of current limit (43 10^{-9} @ 90% C.L. with 40 pb^{-1}) in agreement with MC roadmap
- Measurement of f_s/f_d is currently stat. limited
- Upgrade:
  - SM {BR ($B_s \rightarrow \mu^+\mu^-$)} can be measured to 8% precision @ 50 fb^{-1}
    - Strong constraints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





Super B factories

Need O(100x) more data → Next generation B-factories



KEKB アップグレード

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

1) Smaller β_y^*

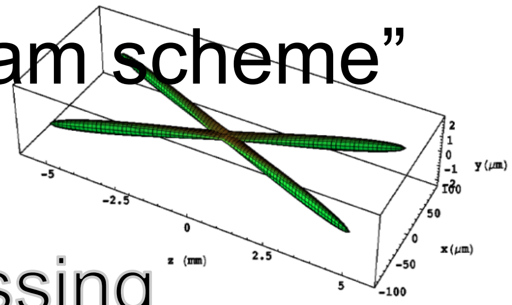
2) Increase beam currents

3) Increase ξ_y

Invented by P. Raimondi for SuperB

"Nano-beam scheme"

Crab crossing



SuperKEKB Design Parameters

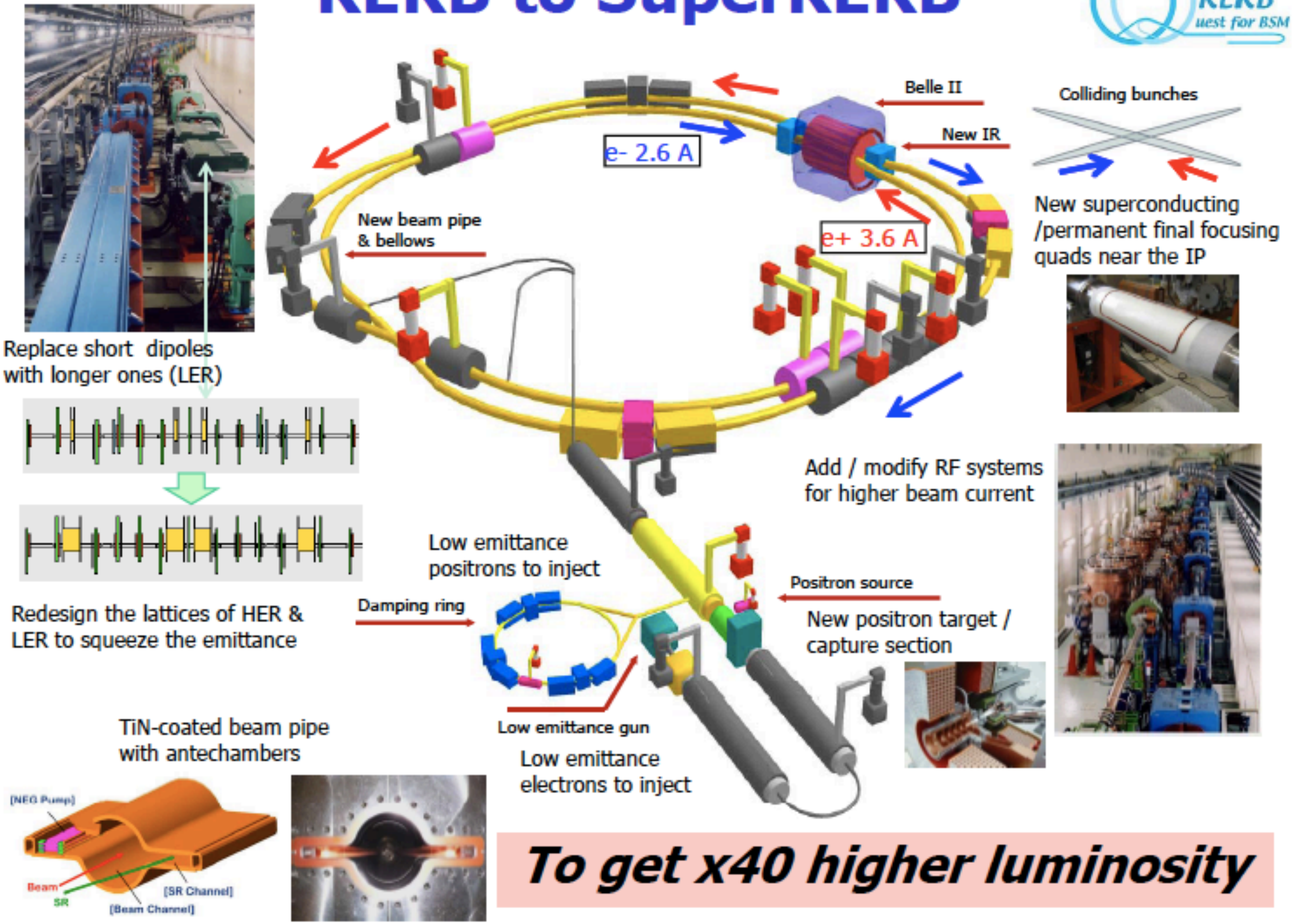
Machine design parameters

parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
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	5.0	nm
Emittance ratio	κ	0.88	0.66	0.27	0.25	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.31	mm
Beam currents	I_b	1.64	1.19	3.60	2.60	A
beam-beam parameter	ξ_y	0.129	0.090	0.0886	0.0830	
Luminosity	L	2.1×10^{34}		8×10^{35}		$cm^{-2}s^{-1}$

- **Small beam size & high current** to increase luminosity
- **Large crossing angle**
- **Change beam energies** to solve the problem of LER short lifetime

M. Iwasaki, ICHEP2010

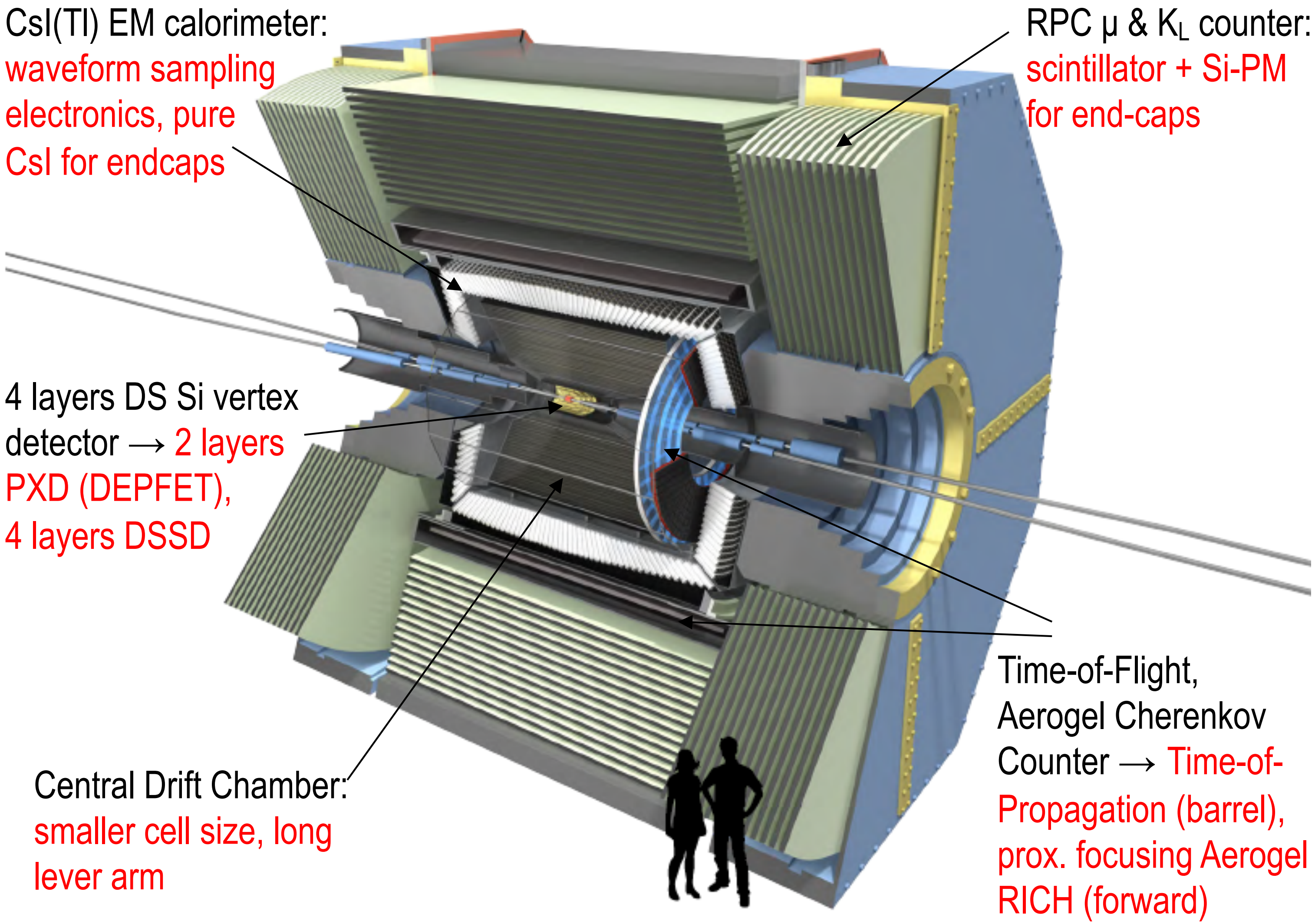
KEKB to SuperKEKB



To get x40 higher luminosity

Belle II Detector

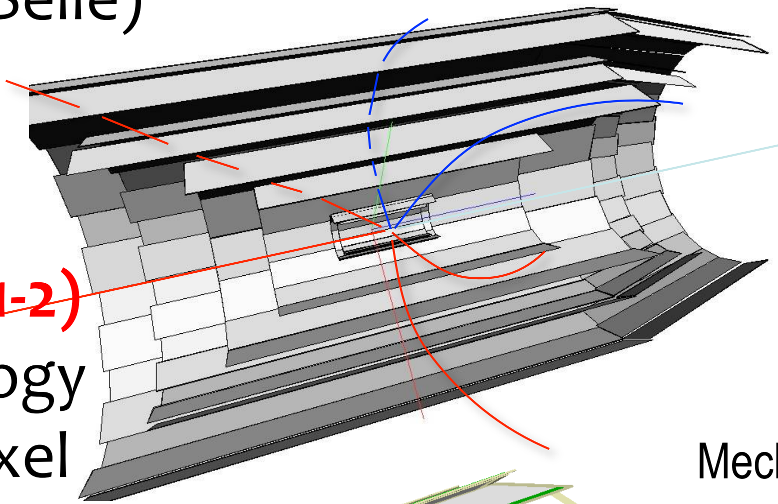
- Deal with higher background (10-20×), radiation damage, higher occupancy, higher event rates (L1 trigg. 0.5→30 kHz)
- Improved performance and hermeticity

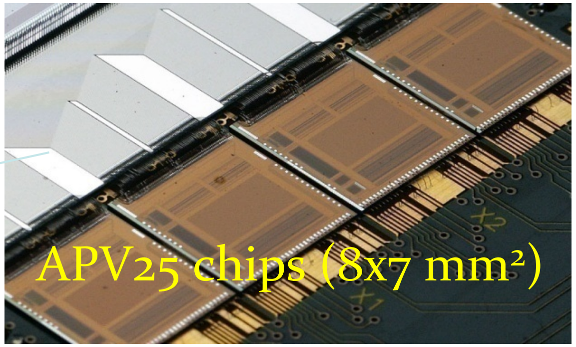


Vertex Detector w/ silicon pixels and strips

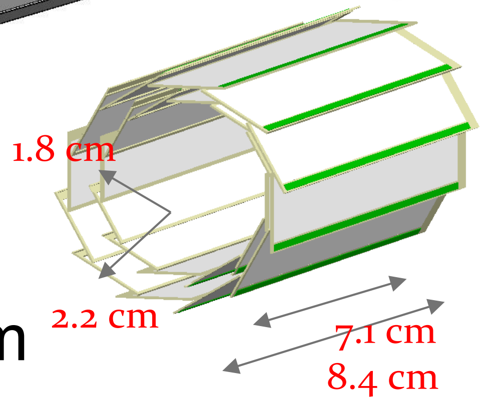
Outer radius 10 cm → 14 cm
- Better tracking efficiency/ self tracking
- Larger acceptance for Ks (30% larger than Belle)

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

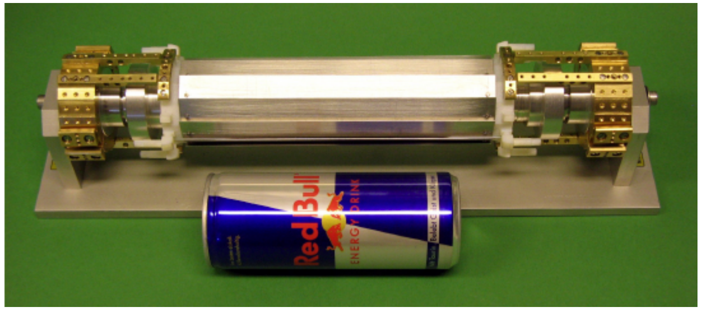




Pixel layer (Layer 1-2)
- DEPFET technology
- 50μm x 75μm pixel



Mechanical mockup of pixel detector



IP resolution σ_{z0}~50μm

Particle ID

Novel ring imaging Cherenkov detectors to provide >4σ K/π separation up to 4GeV/c

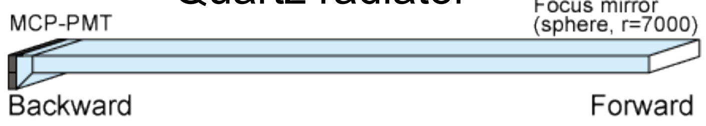
Barrel: TOP (Time-Of-Propagation)

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

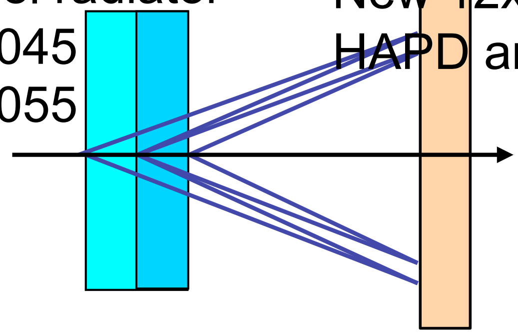
- Proximity focusing RICH w/ hydrophobic aerogel radiator (λ_T>40mm)
- Multiple radiators with different indices (n=1.045-1.050) to correct emission point uncertainty

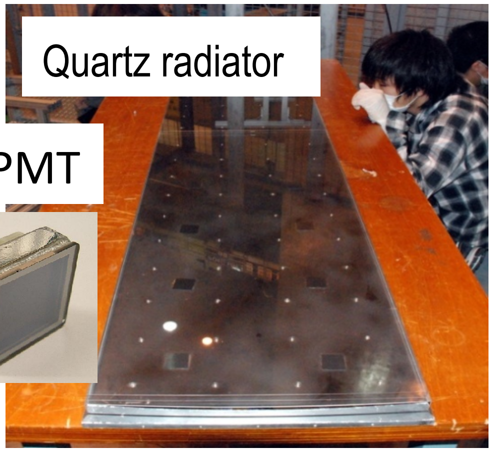
Aerogel radiator

n1=1.045

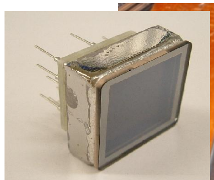
n2=1.055

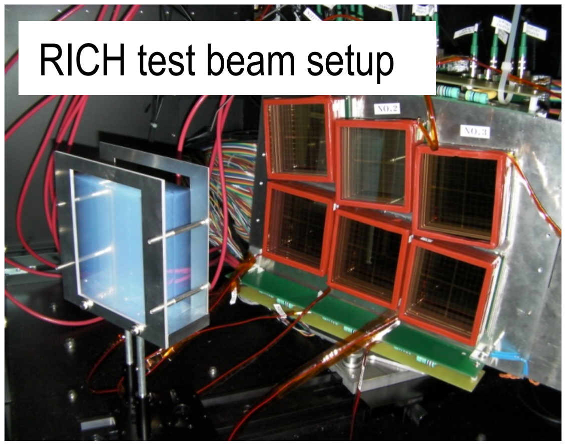
New 12x12ch HAPD array

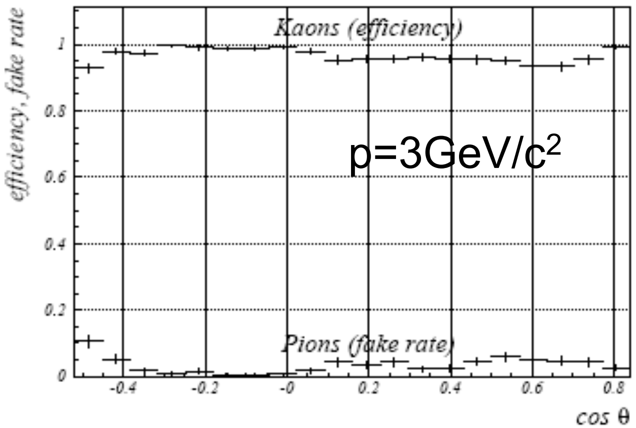




MCP-PMT







KEKB to Super-KEKB

KEKB/Belle completed at 9:00am, June 30, 2010

Super-KEKB budget has been approved.

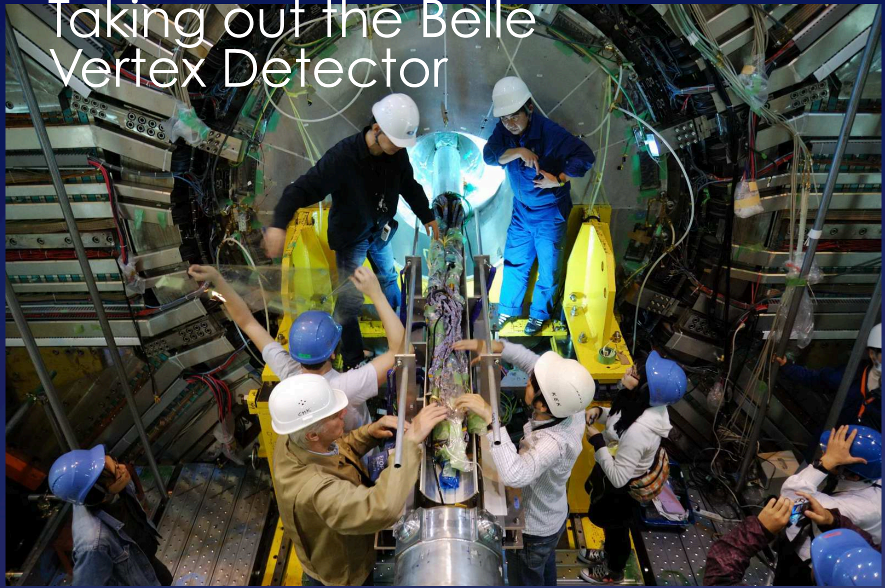
- Damping ring (~5.8M$, FY2010)
- "Very Advanced Research Supprt Program" (~100M$, FY2010-2012)

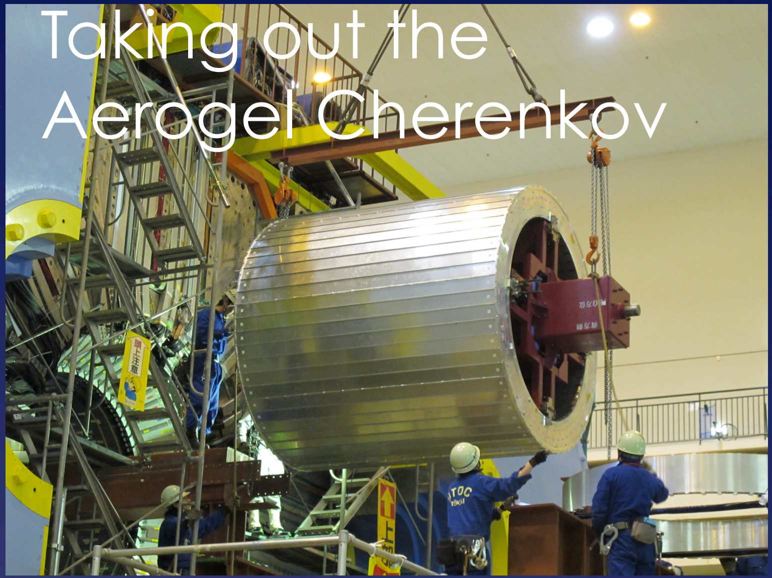
+ ~60 oku-yen/year for three years

Jan-March 2011 : *full approval* by the Diet and Japanese government

→ Start construction (FY2010-2013)
Start commissioning (end of 2014)

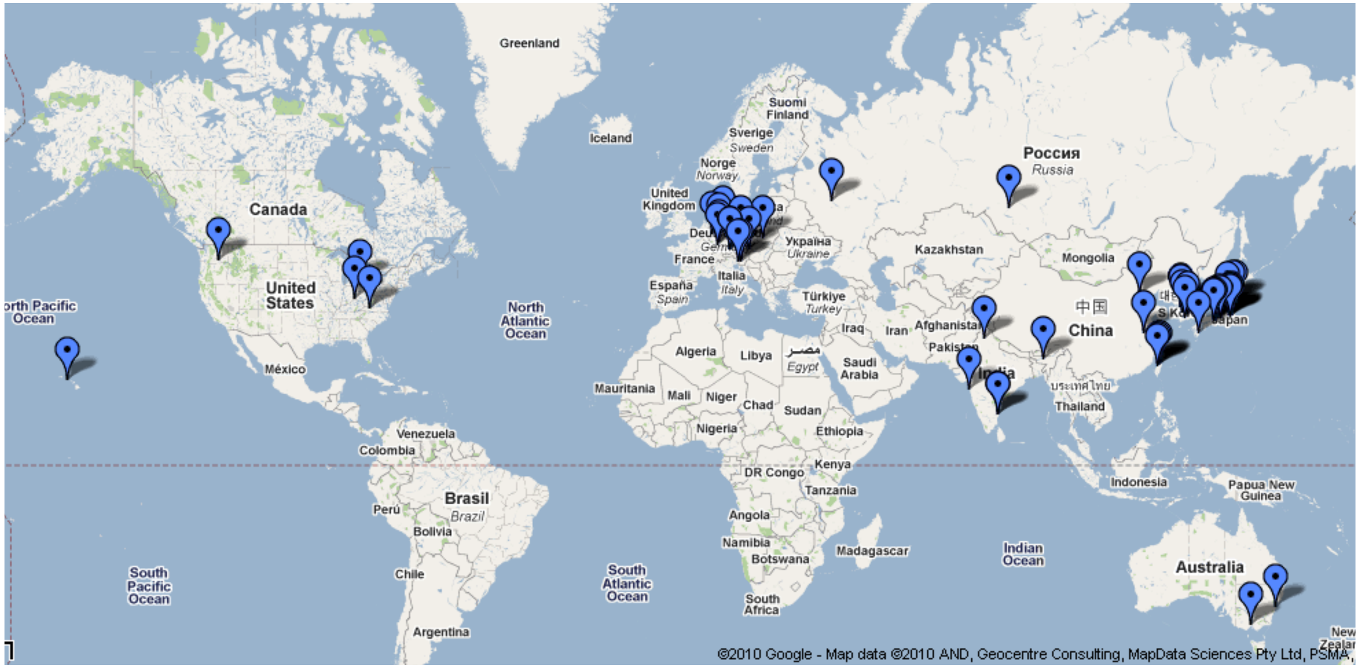
Belle Disassembly



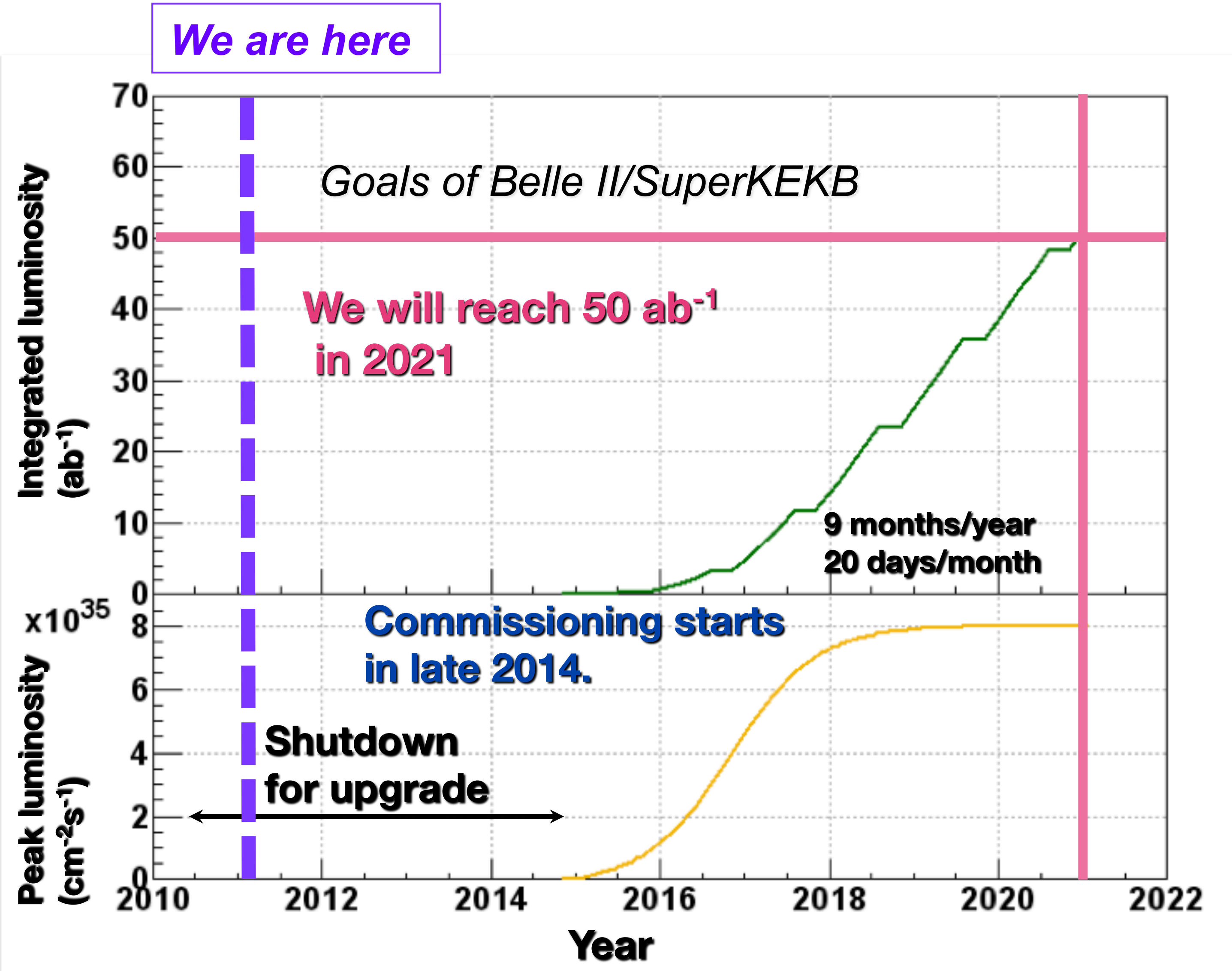


Belle II Collaboration

384 members, 57 institutions from 13 countries



SuperKEKB luminosity profile



Super B Machine Design

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

Parameter	Units	Base Line HER (e+)	Base Line LER (e-)	Low Emittance HER (e+)	Low Emittance LER (e-)	High Current HER (e+)	High Current LER (e-)	Tau/Charm (prelim.) HER (e+)	Tau/Charm (prelim.) 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	7.241	8.872	5.099	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)

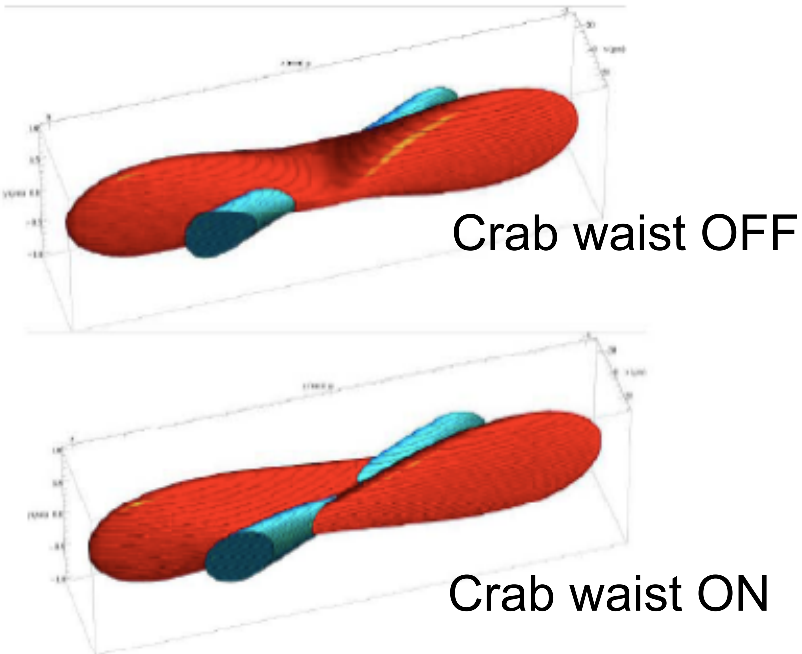
Baseline:
- Higher emittance due to IBS
- Asymmetric beam currents

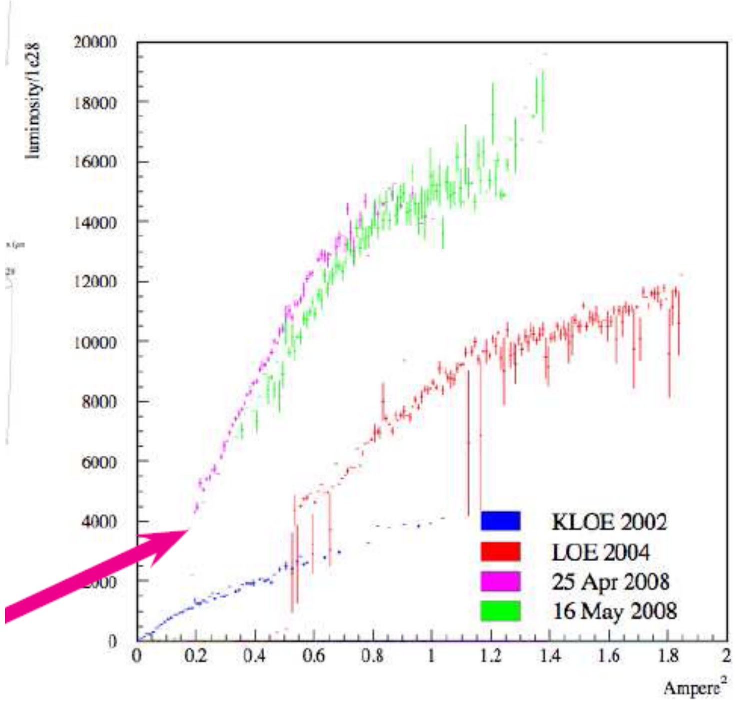
RF power includes SR and HOM

M. Giorgi, ICHEP2010

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

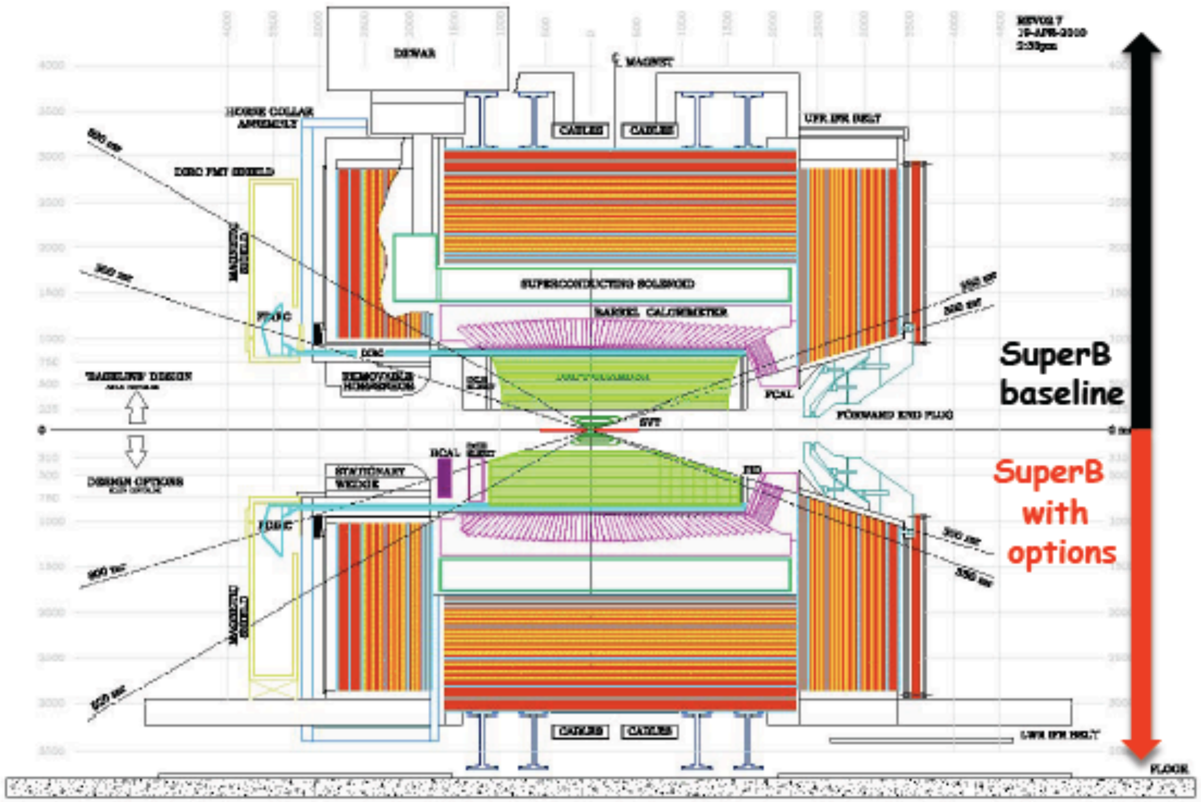




Super B Detector

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)

Approval Milestones in Italy

- **April 2010**: SuperB becomes one of 14 Italian National Research Program (PNR) Flagship Projects
  - Cooperation between INFN and IIT (Italian Institute of Technology)
    - ➔ HEP experiment and light source
- **Dec. 2010:** Approval by Ministry of Instruction, University and Research and Parliment with 19 M€ provided as first part of a multi-year funding plan.
- **April 2011:** Full Italian government approval of the PNR, including 250M€ for SuperB

Interactions News Wire #14 - 11
19 April 2011 http://www.interactions.org
****
Source: INFN
Content: Press Release
Date Issued: 19 April 2011
****

- **http://www.interactions.org/cms/?pid=1030662**

The Italian Government Approved the Long-Term Funding for SuperB

The Italian Minister for Instruction, University and Research, Mariastella Gelmini announced today that *the long-term funding of the SuperB Factory was appproved by the Italian government. The project, sponsored by the National Institute of Nuclear Physics is one of 14 flagship projects of the National Plan for Research in Italy.*

+135M€ in-kind contribution through usage of PEP II and BaBar components.

LHCb upgrade

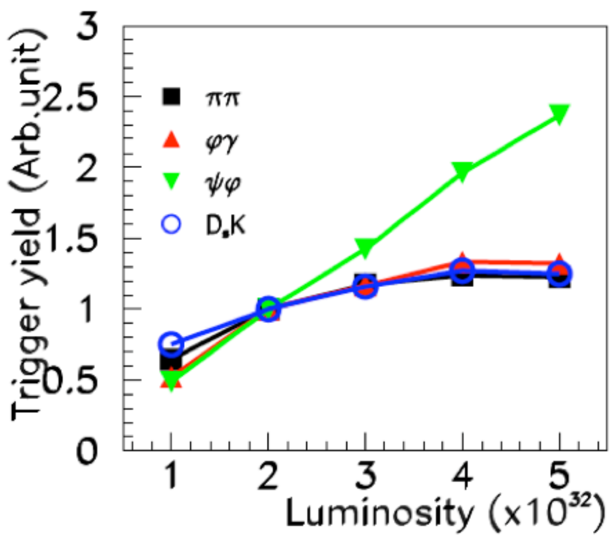
LoI submitted to LHCC in March [CERN-LHCC-2011-01]

Baseline for LHCb upgrade

- Increase luminosity to $L \sim 1\times10^{33} cm^{-2}s^{-1}$
- 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

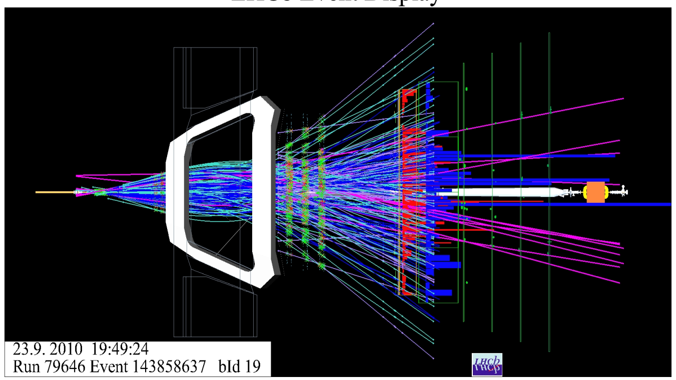
- Bandwidth & rate limitation of L0 trigger
- Efficiency for hadronic channels flattens out at $L \sim 2\text{-}3\times10^{32} cm^{-2}s^{-1}$.
- Can accumulate 1fb-1 / year.



Pile-up:

- Expcted pile-up rate at $L \sim 1\times10^{33} cm^{-2} s^{-1}$ with 25ns BX-ings: $\mu \sim 2.3$.
- Detectors work already at $\mu=2.7$ in 2010 run ($L=1.6\times10^{32} cm^{-2}s^{-1}$, $n_b=344$)

LHCb Event Display

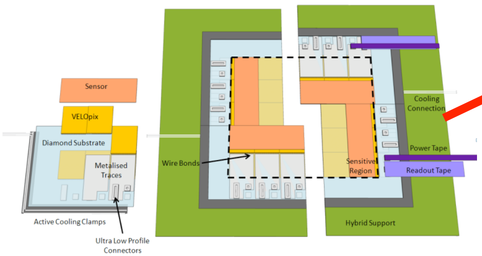


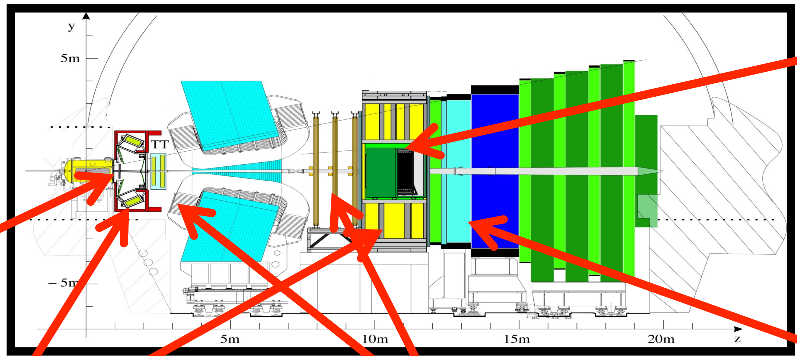
LHCb Upgrade

cf) A. Shopper @ Physics at LHCb
M. Merk @ Beauty 2011

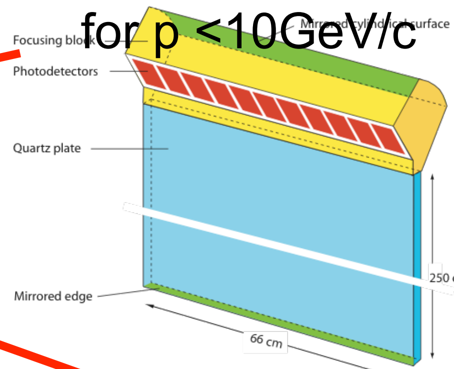
- Readout detector at 40MHz to run full software trigger.
  - Replace all sub-detector front-end electronics to 40MHz readout.
- Replace all silicon detectors attached to the current 1MHz readout.
  - VELO, IT, TT, RICH HPD’s
- Remove some detectors due to increased occupancies.
  - RICH1 aerogel, M1,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

New VELOPIX
w/ 55mm×55mm
Timepix chip



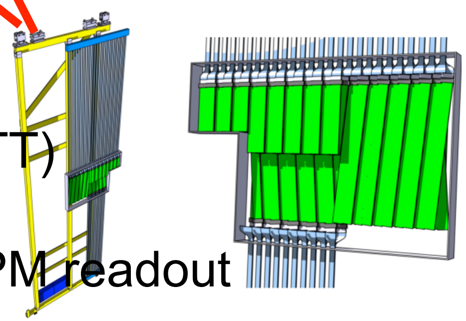


New PID TORCH
for p <10GeV/c



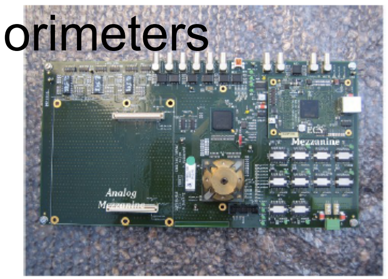
MA-PMT for
RICH1,2

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



New electronics for
calorimeters

New digital electronics prototype



Summary

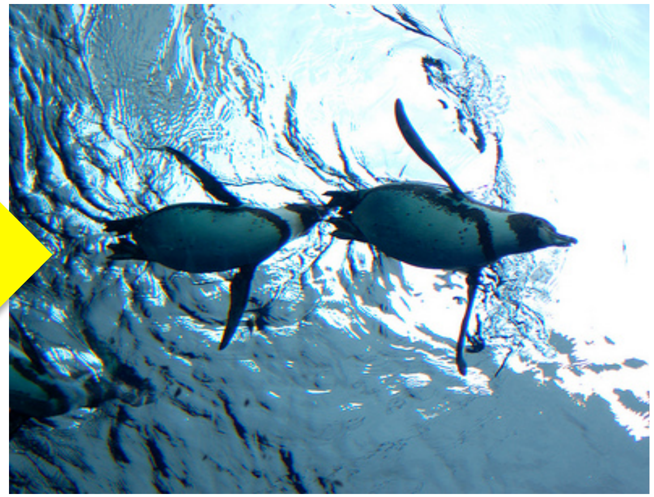
- Heavy flavor physics will play crucial roles to find & study NP, and is complementary to high P_T LHC physics.
  - No mass threshold.
  - Off-diagonal couplings

→ "Elucidation of New Physics"

- There are good prospects:
  - SuperKEKB / Belle II
  - INFN Super B
  - LHCb upgrade

} Both projects are funded

R&D's to allow 40MHz readout in progress.



Starting to swim !

Backup

References

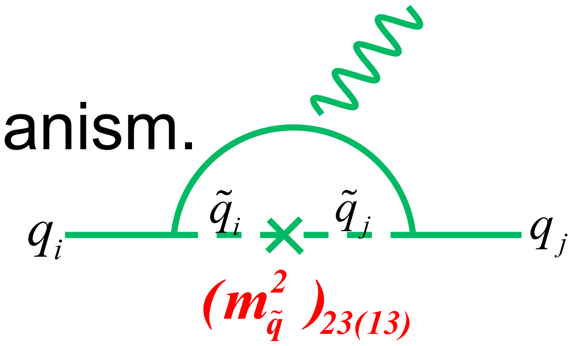
- Belle II Technical Design Report,arXiv:1011.0352
- Physics at Super B Factory, arXiv:1002.5012
- sBelle Design Study Report, arXiv:0810.4084

- 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/)

In case of SUSY…

- The squark/slepton mass matrix
  - Sensitive to SUSY breaking mechanism.



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

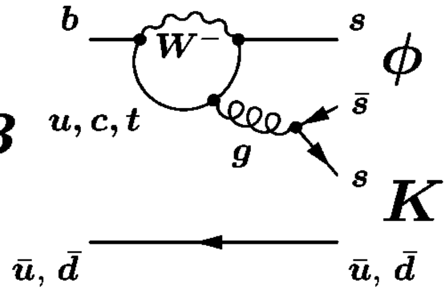
Off-diagonal terms
Flavor Physics
Luminosity frontier

Diagonal terms:
LHC/ILC
Energy frontier

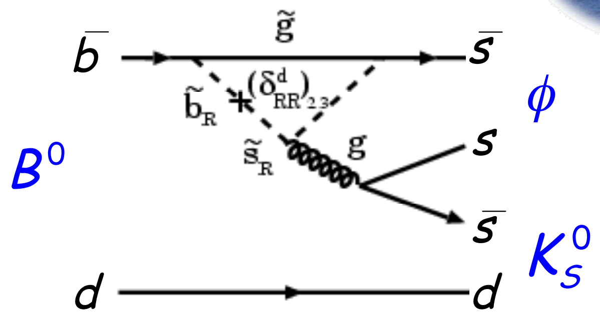
B and τ are in the 3rd generation ("hub" quark & lepton)
→ probe for both 3→2, 3→1 transitions.

CPV in b→s Penguins

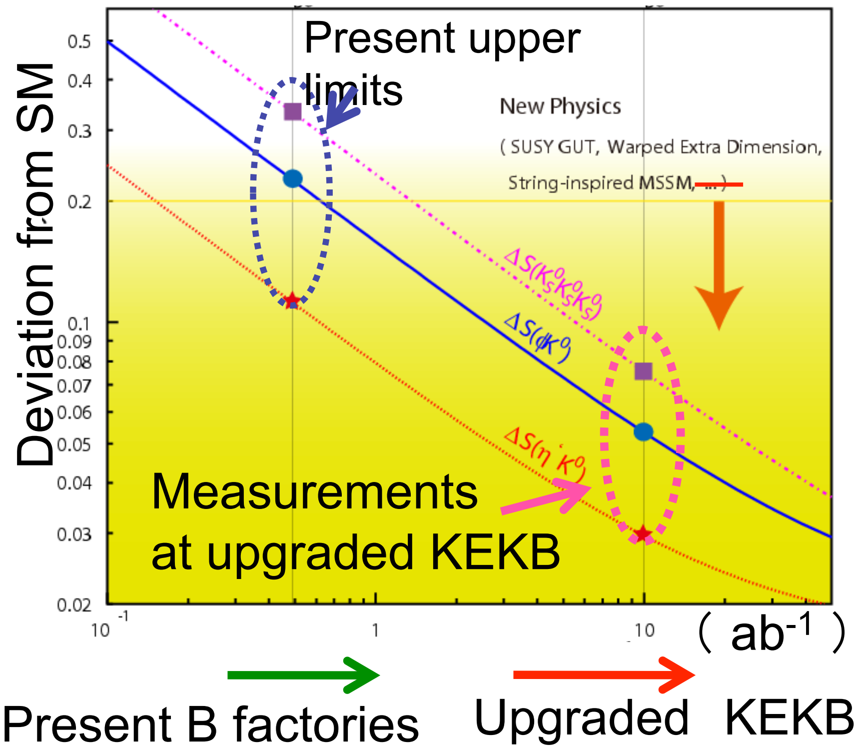
SM

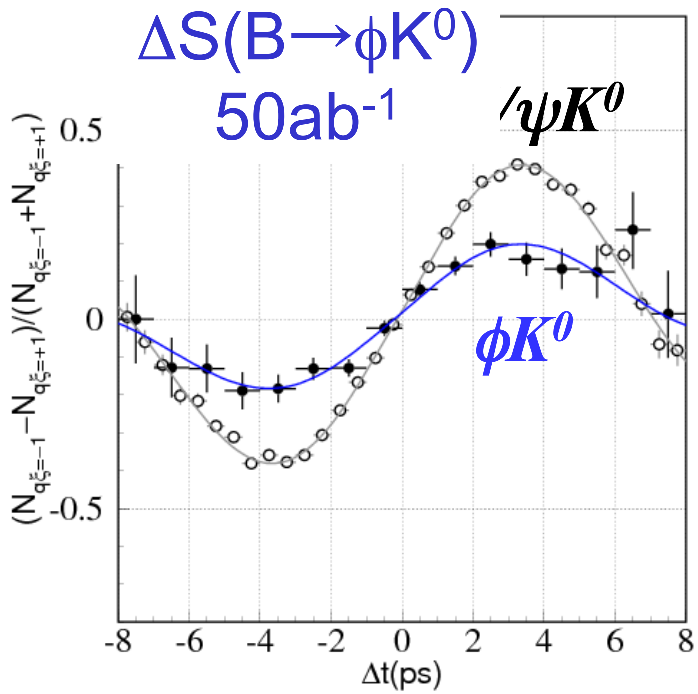


NP



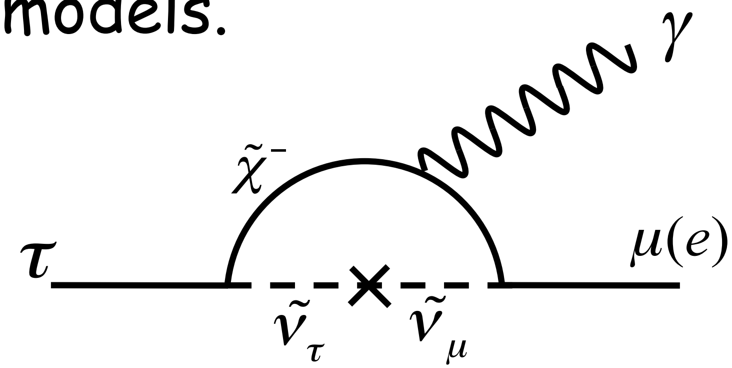
$$A_{CP}(t) = \sin 2(\phi_1 + \phi_{NP}) \times \sin(\Delta m_d t)$$

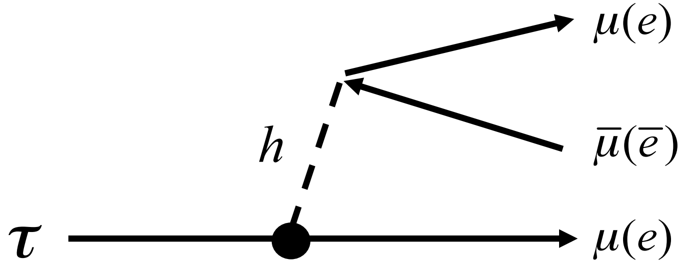




NP signature in $\tau \to \ell\gamma, \ell\ell\ell$

- The two decays have different sensitivity for different NP models.



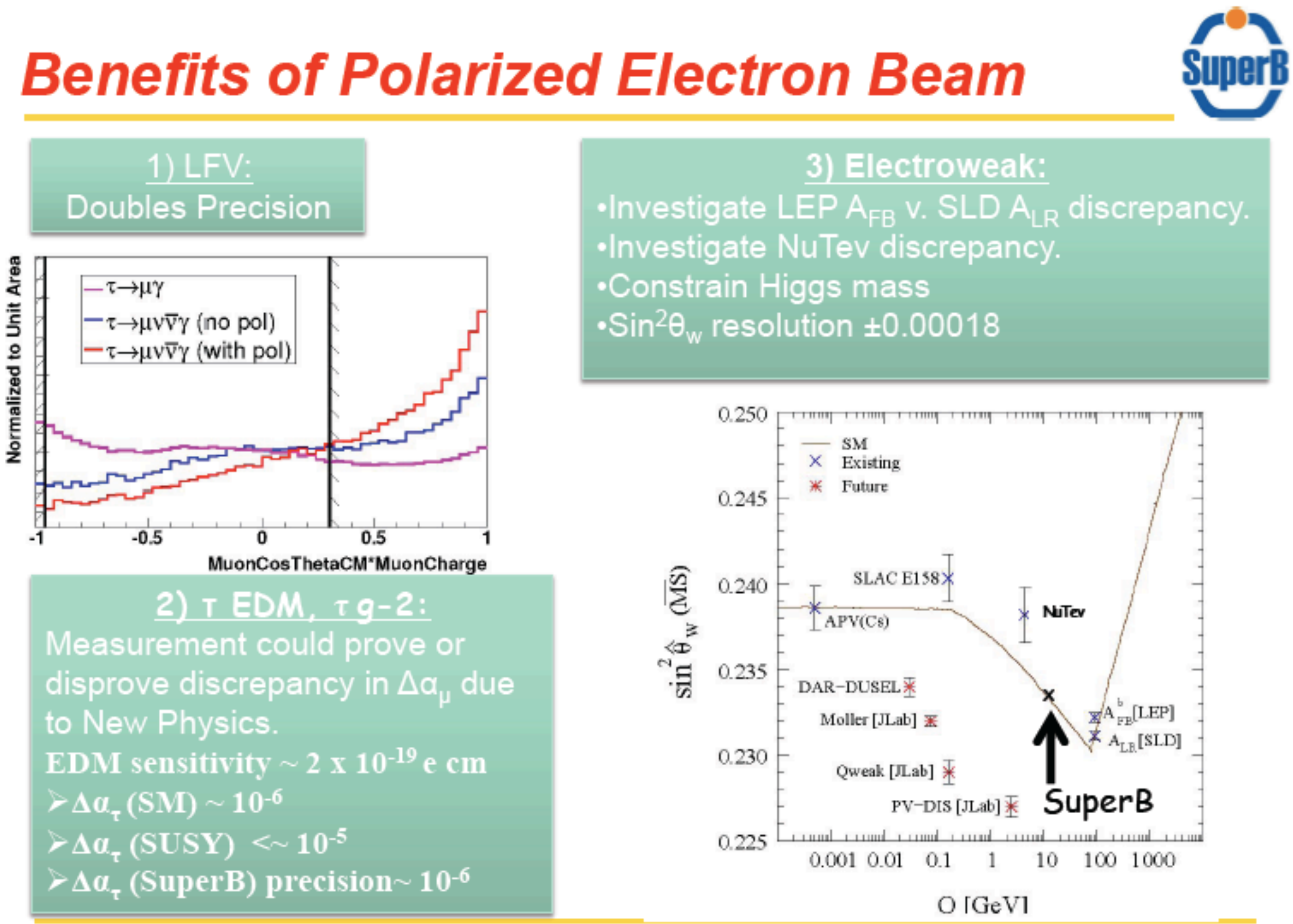


	Reference	τ◊μγ	τ◊μμμ
SM + heavy Maj ν_R	PRD 66(2002)034008	10^{-9}	10^{-10}
Non-universal Z'	PLB 547(2002)252	10^{-9}	10^{-8}
SUSY SO(10)	PRD 68(2003)033012	10^{-8}	10^{-10}
mSUGRA+seesaw	PRD 66(2002)115013	10^{-7}	10^{-9}
SUSY Higgs	PLB 566(2003)217	10^{-10}	10^{-7}

Searches in various LFV modes help to discriminate NP models.

Polarized beam

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



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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.