The physics of the new facilities
Super Flavour Factories

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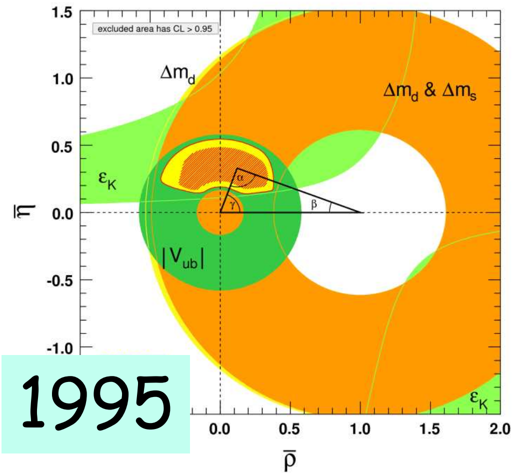
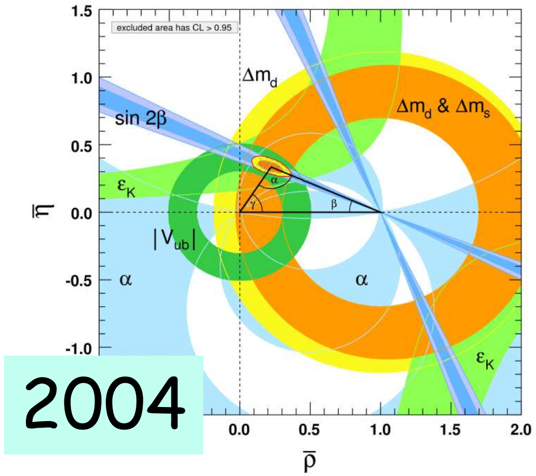
Pisa

9th Franco-Italian Meeting on B Physics
Flavour Physics in the light of the recent results at LHC

18-19 February 2013, LAPP

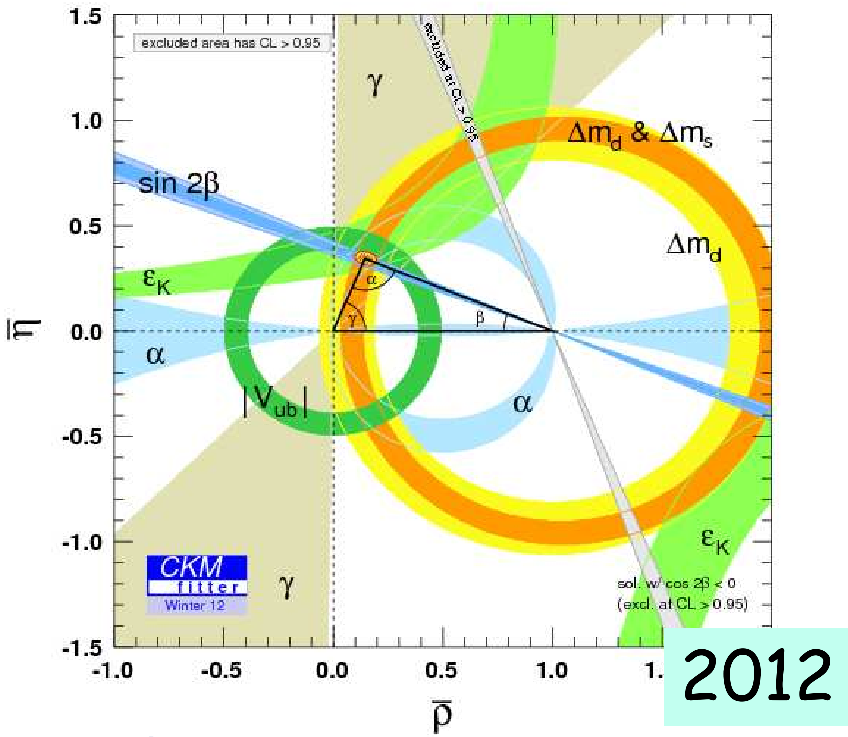
B-factories and now LHCb confirm SM on CPV and flavour physics





- The CKM describes all the flavour-changing processes in the SM
- Amazing progress in the last 20 years; the SM remains intact, but still a whole lot still to learn

http://ckmfitter.in2p3.fr

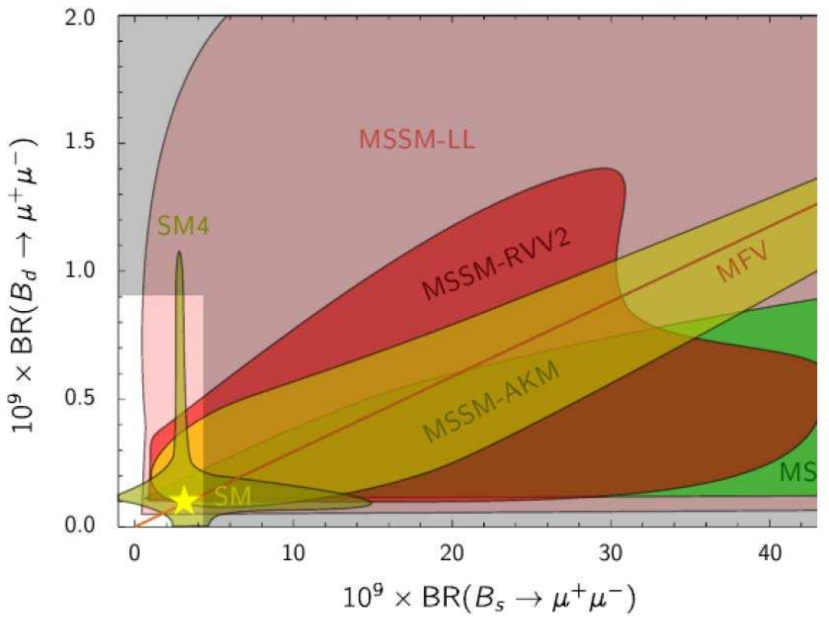


from N.Harnev, Discrete 2012

LHCb $B_{s,d} \to \mu^+\mu^-$ confirms SM and rules out large areas of NP

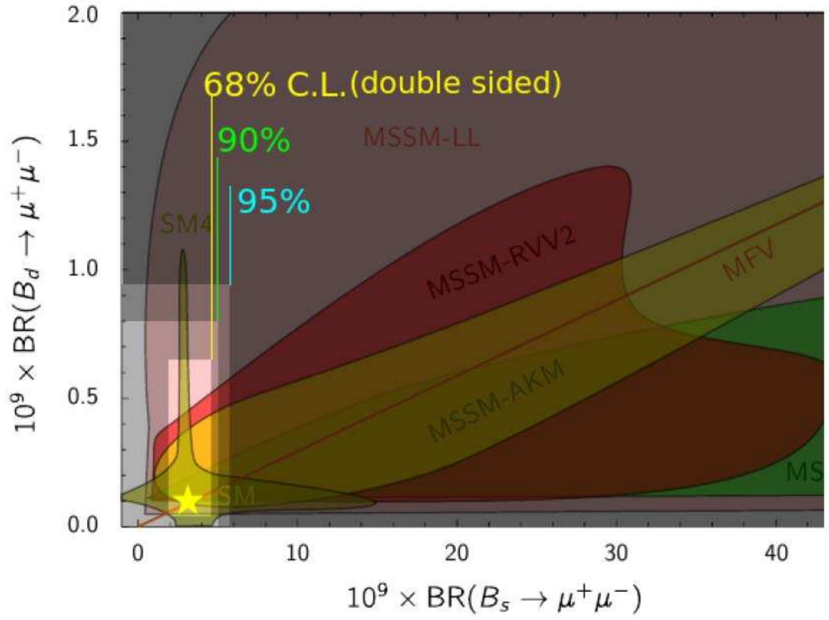
Status in June 2012 (LCC combination)

$\mathcal{B}r\ (B_s^0 \to \mu^+\mu^-) < 4.2 \cdot 10^{-9}$ at 95% C.L.
$\mathcal{B}r\ (B^0 \to \mu^+\mu^-) < 8.1 \cdot 10^{-10}$ at 95% C.L.



Status in November 2012 (LHCb only)

$\mathcal{B}r\ (B_s^0 \to \mu^+\mu^-) = (3.2^{+1.5}_{-1.2}) \cdot 10^{-9}$
$\mathcal{B}r\ (B^0 \to \mu^+\mu^-) < 9.4 \cdot 10^{-10}$ at 95% C.L.

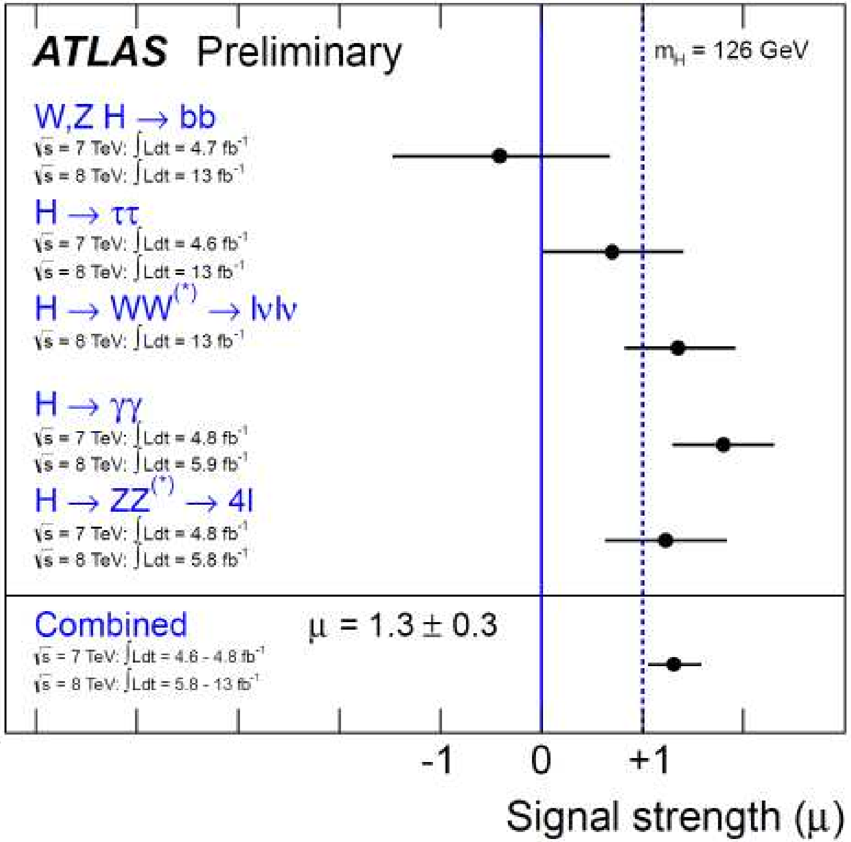


Straub Moriond 2012 (http://phys.davidstraub.de/files/dstraub-moriond12.pdf)

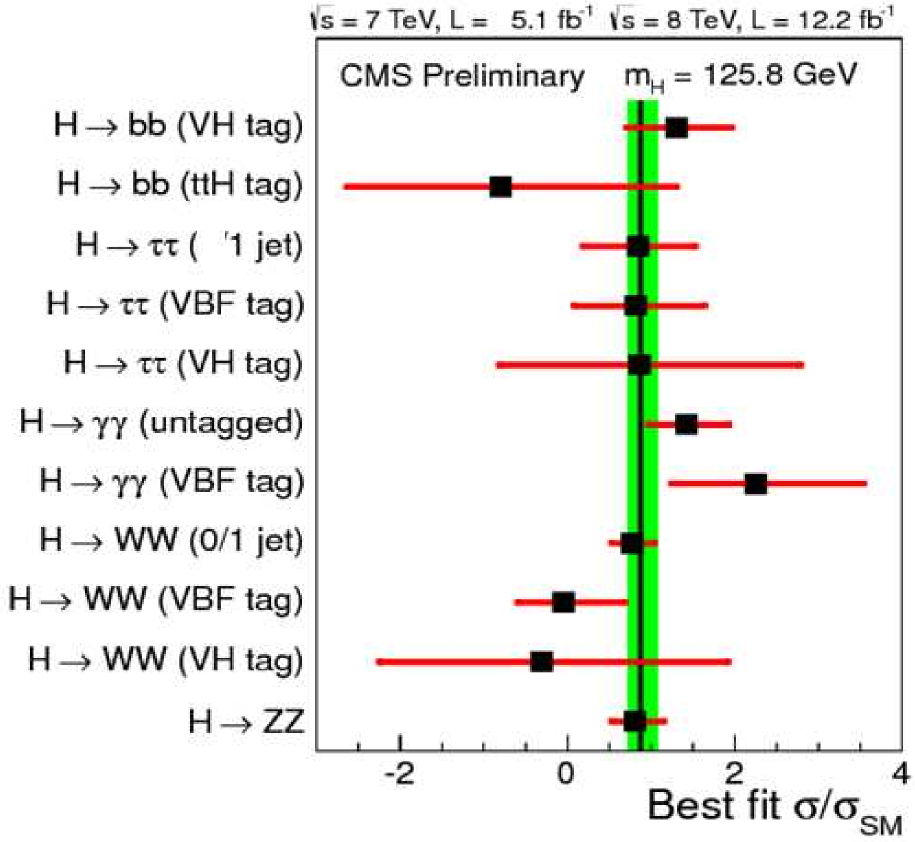
from N.Harnev, Discrete 2012

LHC Higgs measurements confirm the SM

Best–fit Higgs mass m_H :
126.0 ± 0.4 (stat) ± 0.4 (syst) GeV



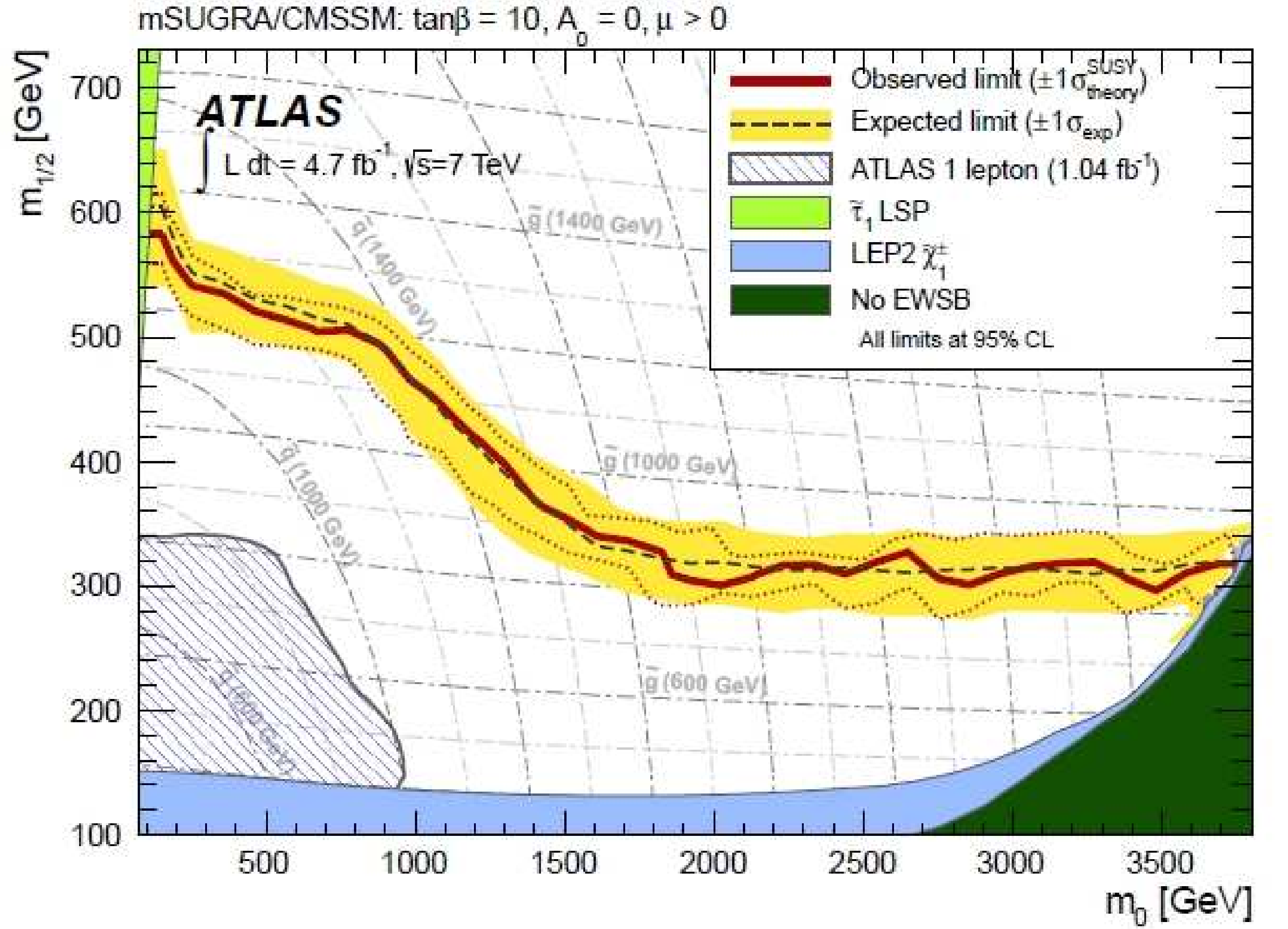
- M=125.8 ±0.4 (stat) ± 0.4 (syst) GeV



- σ/σ_{SM}=0.88±0.21

status on November 2012

"Light" CMSSM ruled out

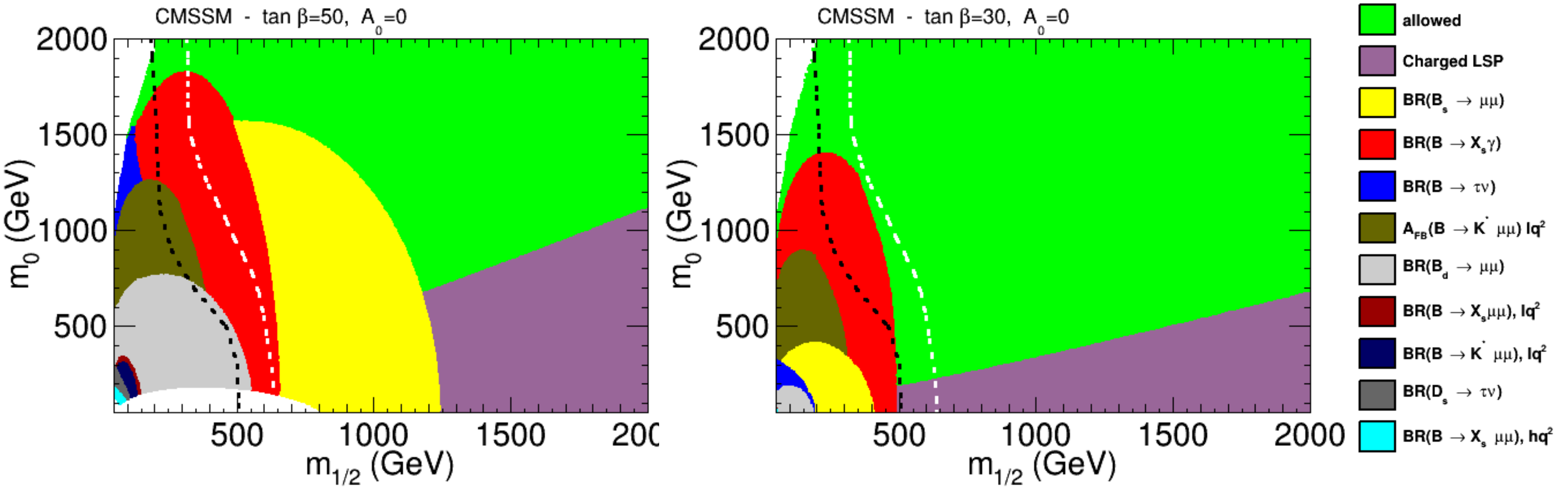


ATLAS Aug 2012, arXiv:1208.4688 [hep-ex]

Today LHC confirms the SM and does not indicate where to look for NP

- ♦ large amount of stringent bounds on many possible NP models
- ♦ future NP signals will probably be **small**, to comply with present bounds
- → need **larger energies** and / or **quite larger intensities**
- → combination of diverse experimental results can help
  - ▶ improve the statistical evidence for NP
  - ▶ discriminate between different NP models
- → **different facilities** increase the variety of the experimental probes
  - ▶ here: contribution from e^+e^- high intensity (Super) Flavour Factories

Flavour Physics can provide very effective bounds on NP



Dashed black line: CMS exclusion limit with 1.1 fb^{-1} data
Dashed white line: CMS exclusion limit with 4.4 fb^{-1} data

FM, SuperIso v3.2

Nazila Mahmoudi LAPP – Feb. 18th, 2013 22 / 28

NP signals in heavy hadrons & leptons at the intensity frontier

- **heavy hadrons**
  - NP can compete/interfere with SM amplitudes in forbidden / suppressed / mixing&CPV processes
  - CPV in B mesons ideal because CKM matrix makes it maximal and relatively well calculable
  - in SM, D mixing and CPV are smaller and less precisely predicted
  - in several cases matching progress in lattice QCD is required
  - facilities:
    - LHCb, asymmetric e^+e^- B-factories: BABAR/Belle → ~~SuperB~~ /BelleII
    - e^+e^- factories around the c-tau threshold also useful but no B mesons
- **(charged) heavy leptons**
  - (charged) Lepton Flavour Violation
    - clean, mostly QCD-free SM prediction, unambigous NP signal detection
    - NP effects less direct than for hadrons (typically, unknown mass-scale heavy neutrino sector)
    - possibly related to neutrino mixing, esp. θ_{13}
  - best facilities: e^+e^- Super-Flavour-Factories (both around the $\Upsilon(4S)$) and tau-charm threshold)
    - ~~beam polarization~~ would increase the experimental reach

Super Flavour Factories

- two main directions
  - asymmetric e^+e^- B-factories around the $\Upsilon(4S)$
    - BelleII, ~~Super*B*~~
    - compete with and complement LHCb on B physics
    - charm physics, tau physics including LFV
    - clean environment facilitates many precision measurements and NP searches
    - ~~beam polarization~~ would provide additional benefits for tau and EW physics
  - e^+e^- $c - \tau$ factories above and close to charm and tau thresholds
    - BESIII, Novosibirsk c-tau proposal, Italian Super c-tau (hypothesis to recover Super*B* funds)
    - precision measurements on charm mesons and tau leptons (also tau LFV)
    - asymmetric energies allow a wider range of time-dependent measurements
- both factories complementary and competitive to other planned or operating high intensity facilities (like MEG, Mu2e, g–2, kaon precision experiments, etc.)

digression: Lattice QCD progress, V.Lubicz, Arcetri, Feb 2010, 1

Cost of the "SuperB" lattice simulation

Simulation parameters

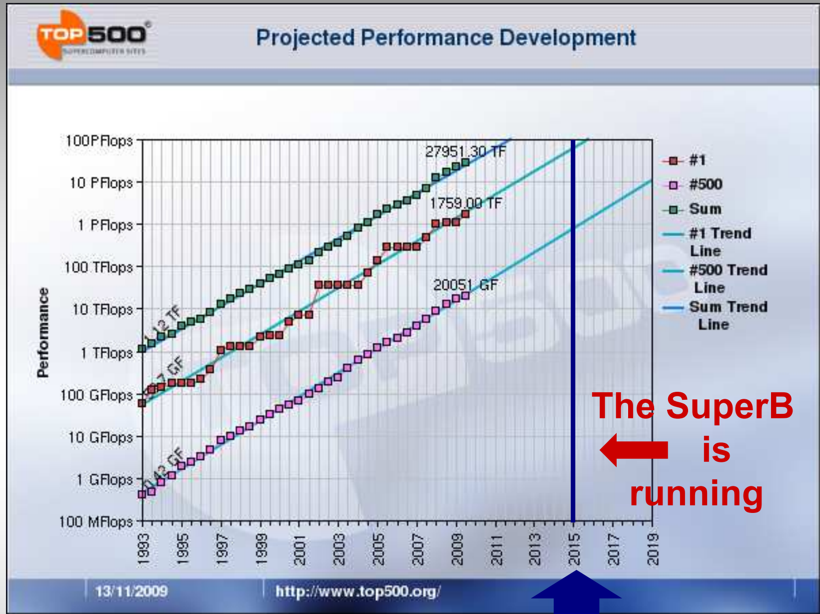
Nconf = 120

a = 0.033 fm
[1/a = 6.0 GeV]

$\hat{m}/m_s$ = 1/12
[M_π = 200 MeV]

L_s = 4.5 fm
[V = $136^3 \times 270$]

~ 3 PFlop-years



The SuperB is running

Affordable with 1-10 PFlops available for Lattice QCD in 2015 !

VL @

digression: Lattice QCD progress, V.Lubicz, Arcetri, Feb 2010, 2

V.Lubicz @
Villa Mondragone
Monte Porzio Catone - Italy
13 - 15 November 2006

Hadronic matrix element	Current latt. error (2006)	6 TFlop Year [2009]	60 TFlop Year [2011 LHCb]	1-10 PFlop Year [2015 SuperB]
$f_+^{K\pi}(0)$	0.9% (22% on 1-f_+)	0.7% (17% on 1-f_+)	0.4% (10% on 1-f_+)	**< 0.1% (2.4% on 1-f_+)**
$\hat{B}_K$	11%	5%	3%	**1%**
f_B	14%	3.5 - 4.5%	2.5 - 4.0%	**1 – 1.5%**
$f_{Bs}B_{Bs}^{1/2}$	13%	4 - 5%	3 - 4%	**1 – 1.5%**
ξ	5% (26% on ξ-1)	3% (18% on ξ-1)	1.5 - 2 % (9-12% on ξ-1)	**0.5 – 0.8 % (3-4% on ξ-1)**
$\mathcal{F}_{B \to D/D^* l\nu}$	4% (40% on 1-$\mathcal{F}$)	2% (21% on 1-$\mathcal{F}$)	1.2% (13% on 1-$\mathcal{F}$)	**0.5% (5% on 1-$\mathcal{F}$)**
$f_+^{B\pi}, \ldots$	11%	5.5 - 6.5%	4 - 5%	**2 – 3%**
$T_1^{B\to K^*/\rho}$	13%	----	----	**3 – 4%**

digression: Lattice QCD progress, V.Lubicz, Arcetri, Feb 2010, 3

THE 2009 STATUS REPORT

Hadronic matrix element	Lattice error in 2006	Lattice error in 2009	6 TFlop Year [2009]	60 TFlop Year [2011 LHCb]	1-10 PFlop Year [2015 SuperB]
$f_+^{K\pi}(0)$	0.9%	**0.5%**	0.7%	0.4%	**< 0.1%**
$\hat{B}_K$	11%	**5%**	5%	3%	**1%**
f_B	14%	**5%**	3.5 - 4.5%	2.5 - 4.0%	**1 – 1.5%**
$f_{Bs}B_{Bs}^{1/2}$	13%	**5%**	4 - 5%	3 - 4%	**1 – 1.5%**
ξ	5%	**2%**	3%	1.5 - 2 %	**0.5 – 0.8 %**
$\mathcal{F}_{B\to D/D^*l\nu}$	4%	**2%**	2%	1.2%	**0.5%**
$f_+^{B\pi}$,...	11%	**11%**	5.5 - 6.5%	4 - 5%	**2 – 3%**
$T_1^{B\to K^*/\rho}$	13%	**13%**	----	----	**3 – 4%**

The expected accuracy has been reached! (except for Vub)

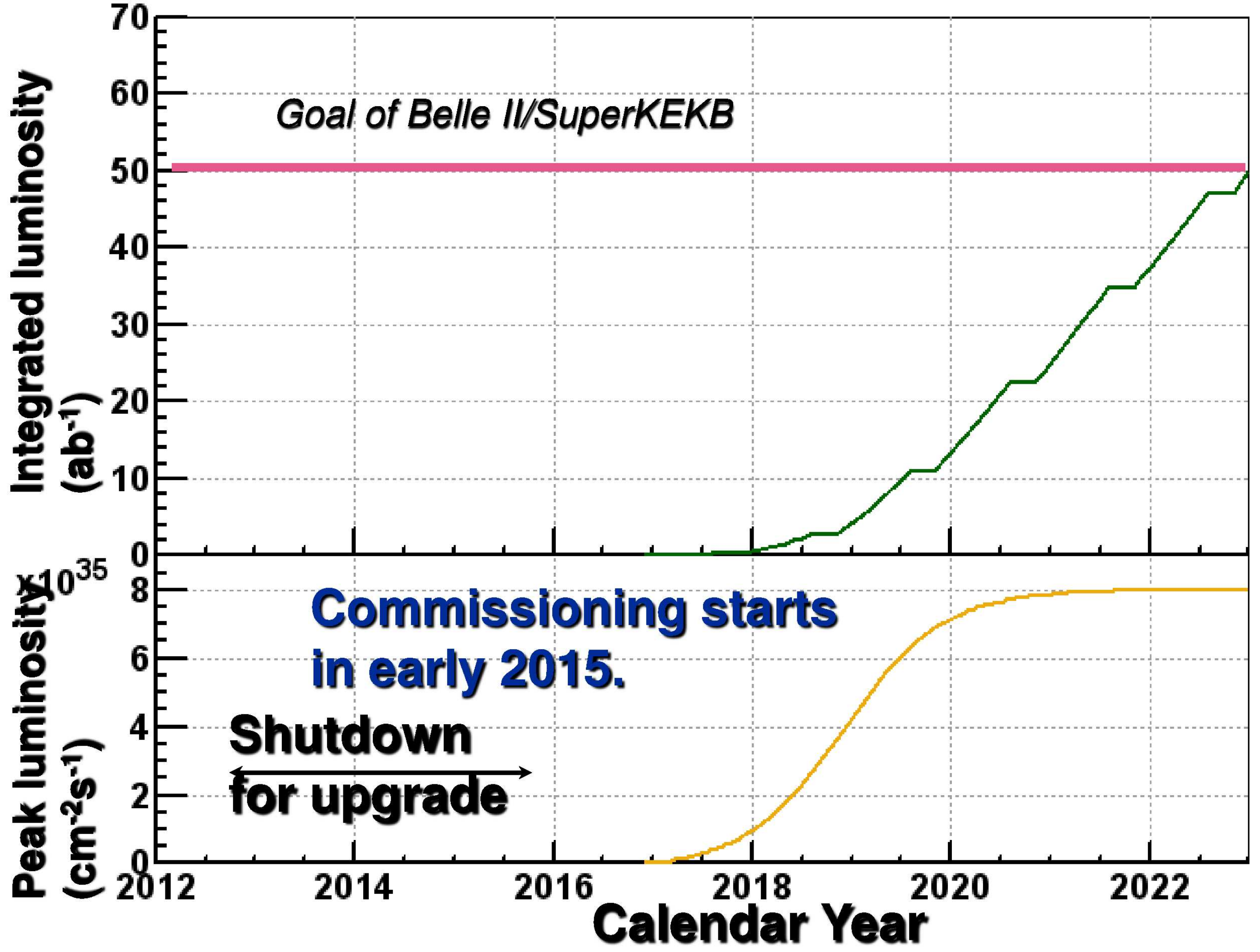
Super *B*-factories

- Super*B* has been recently canceled
- BelleII on the other hand appears to be well on track
- BelleII experimental reach is equivalent to Super*B*, with the following exceptions:
  - beam polarization
  - ability to run at the charm threshold
- other differences
  - BelleII design luminosity 80% of Super*B*
  - BelleII was scheduled to begin earlier than Super*B*
- studies done for Super*B* here reported can be expected to approximately hold for BelleII as well

Main features of BelleII

- **$\Upsilon(4S)$-peak asymmetric energy e^+e^-, design luminosity $\approx 0.8{\cdot}10^{36}\,\mathrm{cm^{-2}s^{-1}}$**
- goal to collect $50\,\mathrm{ab}^{-1}$ of data starting from 2016 over 5 years
- standard general purpose detector similar to Belle and *BABAR*
  - improvements mainly on speed, computing power, mass storage
- real challenge: increase storage ring luminosity by $\sim 100\times$ with a limited increase of electrical power

BelleII luminosity projection – M.Yamauchi, Dec 2012

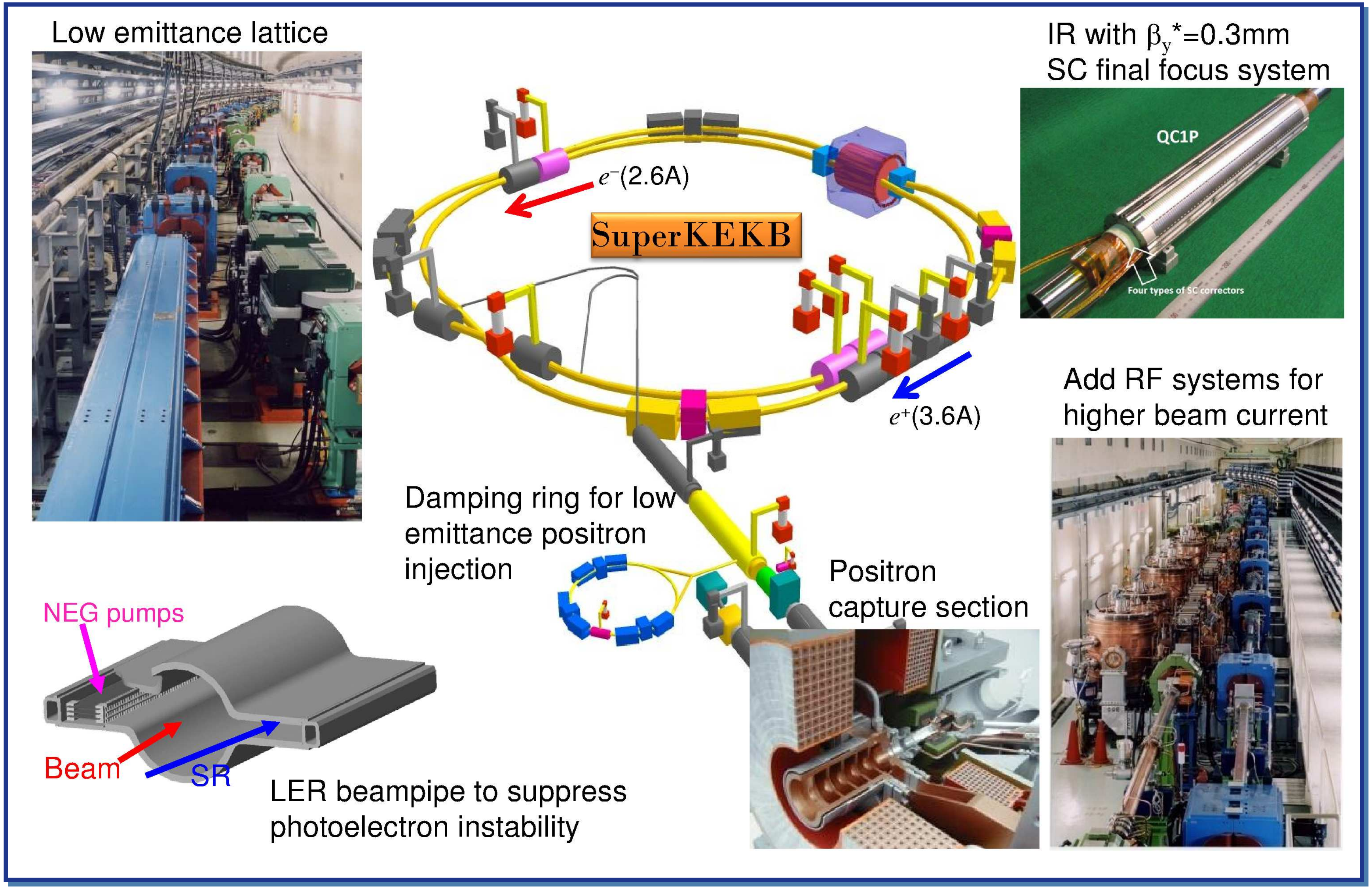


BelleII collaboration – M.Yamauchi, Dec 2012

- ~420 collaborators from 70 institutions in 20 countries
- Spokesperson:

  Peter Krizan (Ljubljana)
- Series of open collaboration meetings in 2008.03 ~2012.11

SuperKEKB upgrade – M.Yamauchi, Dec 2012



SuperKEKB Machine parameters – M.Yamauchi, Dec 2012

Parameter	Units	KEKB		SuperKEKB	
		HER (e^-)	LER (e^+)	HER (e^-)	LER (e^+)
Circumference	m	3016.3		3016.3	
Energy	GeV	8	3.5	7	4
Crossing angle	mrad	22		83	
β_x at IP	cm			2.5	3.2
β_y at IP	mm	5.9	5.9	0.30	0.27
ε_x (emittance)	10^{-9} m	24	18	5.3	3.2
Emittance ratio	%			0.35	0.40
σ_z	mm	6	6	5	6
Beam current	mA	1190	1640	2620	3600
σ_x at IP	10^{-6} m			7.75	10.2
σ_y at IP	10^{-9} m	940	940	59	59
ξ_x (tune shift)				0.0028	0.0028
ξ_y		0.090	0.129	0.0875	0.09
Luminosity	$cm^{-2}\ s^{-1}$	2×10^{34}		8×10^{35}	

High beam current

Nanobeam

x40

Beam pipe production at BINP – M.Yamauchi, Dec 2012

Basic design of the vacuum system is near completion, and mass production of main components is going on:

- Al beam pipes with an antechamber for LER arc sections of 2 km length
- Cu beam pipes for the wiggler sections and the straight sections

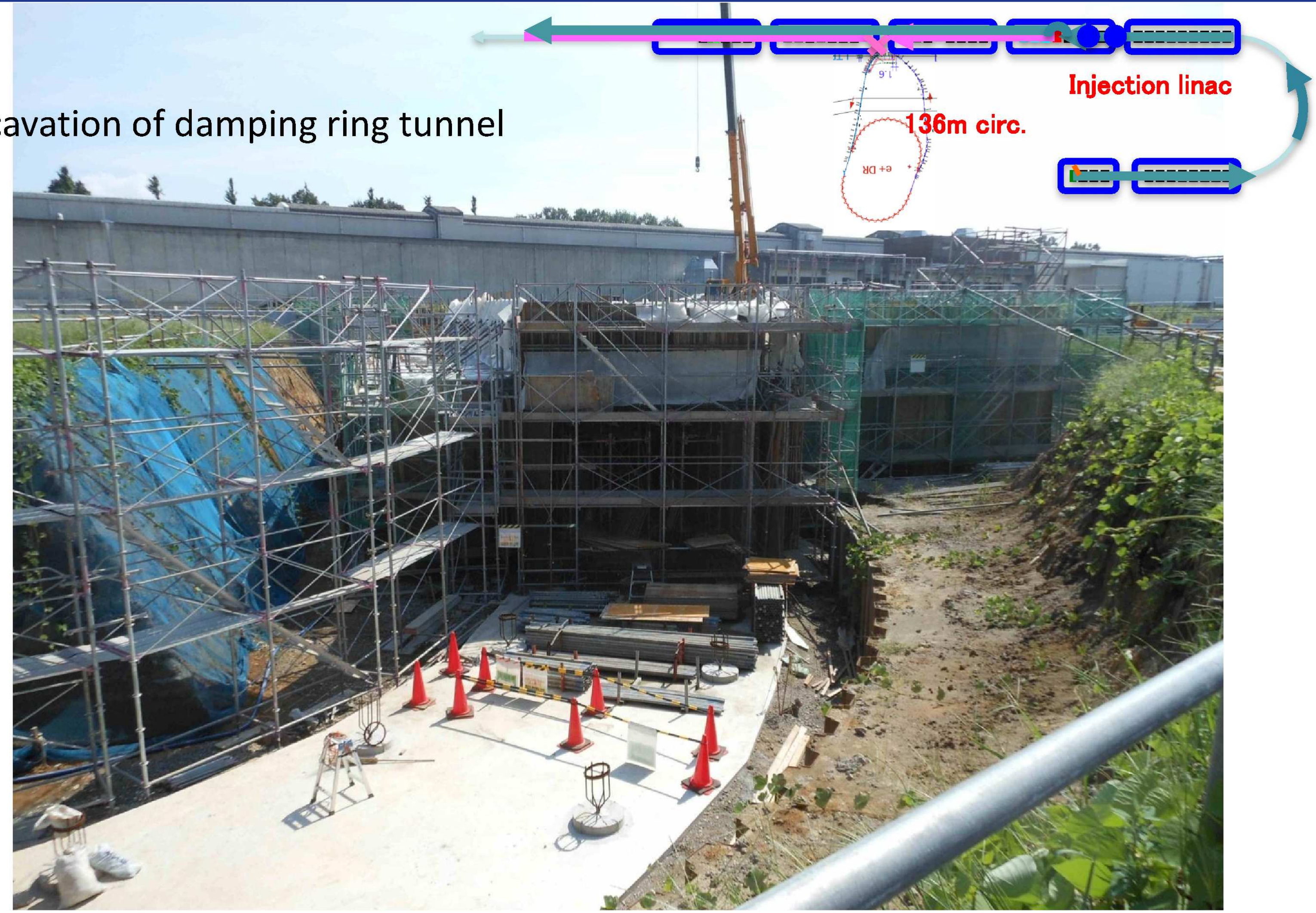
10

Installation of the new bending magnet – M.Yamauchi, Dec 2012

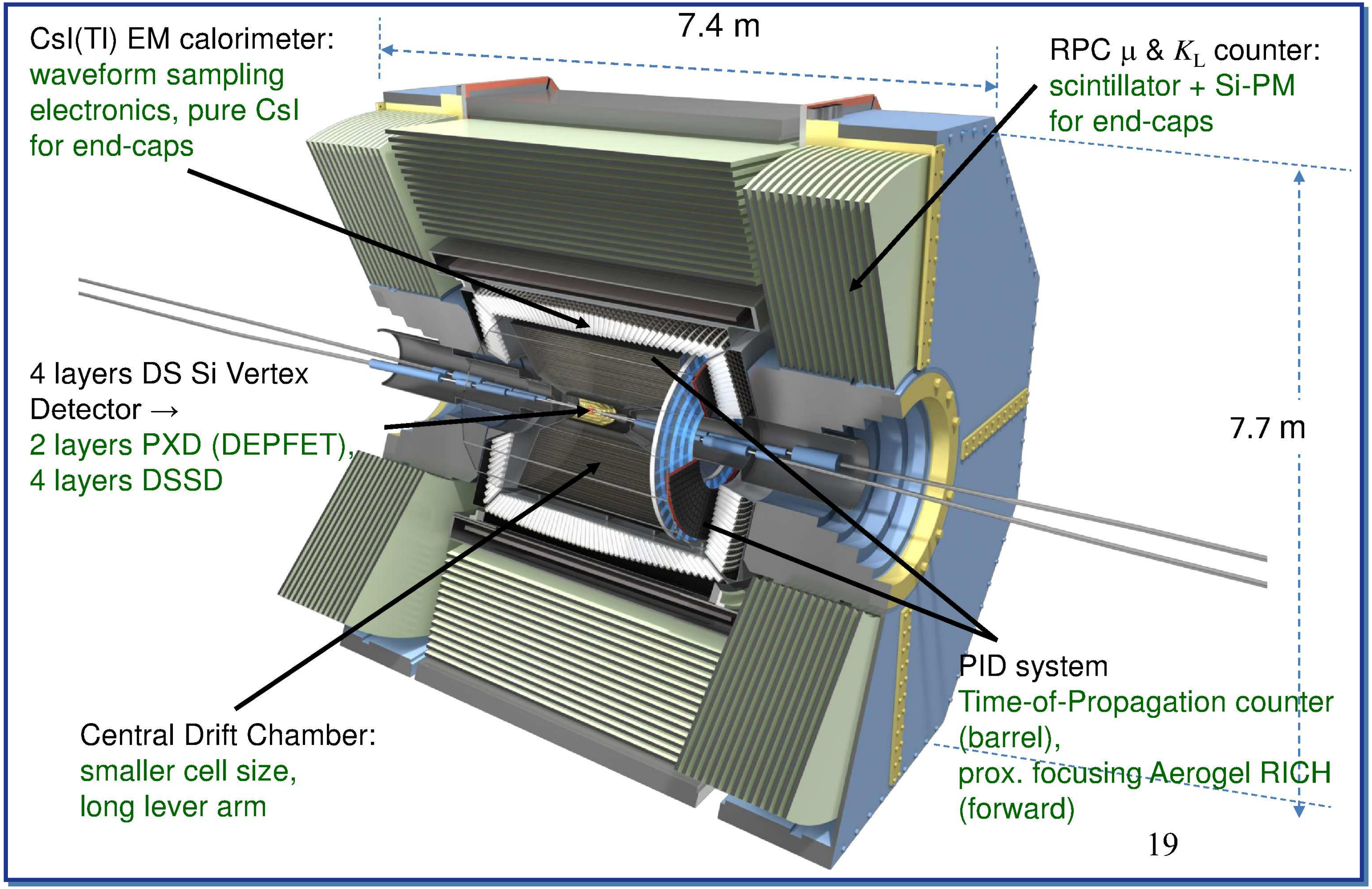
Field mapping

Positron Damping Ring – M.Yamauchi, Dec 2012

Excavation of damping ring tunnel



Belle II Detector Upgrade – M.Yamauchi, Dec 2012



Super *B*-factories physics studies produced several documents

Super*B*

2005 Hewett et al., The Discovery Potential of a Super B factory, **hep-ph/0503261**

2007 Conceptual Design Report, **arXiv:0709.0451 [hep-ex]**

2008 Valencia retreat proceedings, **arXiv:0810.1312 [hep-ex]**

2010 SuperB white paper: Physics, **arXiv:1008.1541 [hep-ex]**

2011 The impact of SuperB on flavour physics, **arXiv:1109.5028v2 [hep-ex]**

BelleII

2010 Physics at Super B Factory, **arXiv:1002.5012 [hep-ex]**

Super*B* golden modes that also hold for BelleII

(indirect searches for NP need 1) good exp. precision & 2) good theory understanding)

$B_{u,d}$ Physics

- $B^+ \to \tau^+\nu$, $B^+ \to \mu^+\nu$, $B^+ \to K^{(*)+}\nu\bar{\nu}$, $b \to s\gamma$, $b \to s\ell\ell$
- precision $\sin 2\beta$ measurements in $b \to s$ penguins

τ Physics

- Lepton flavour violation in tau decays: especially $\tau \to \mu\gamma$ and $\tau \to 3\ell$

Charm Physics

- D^0 mixing parameters and *CP* violation (limited theory precision)

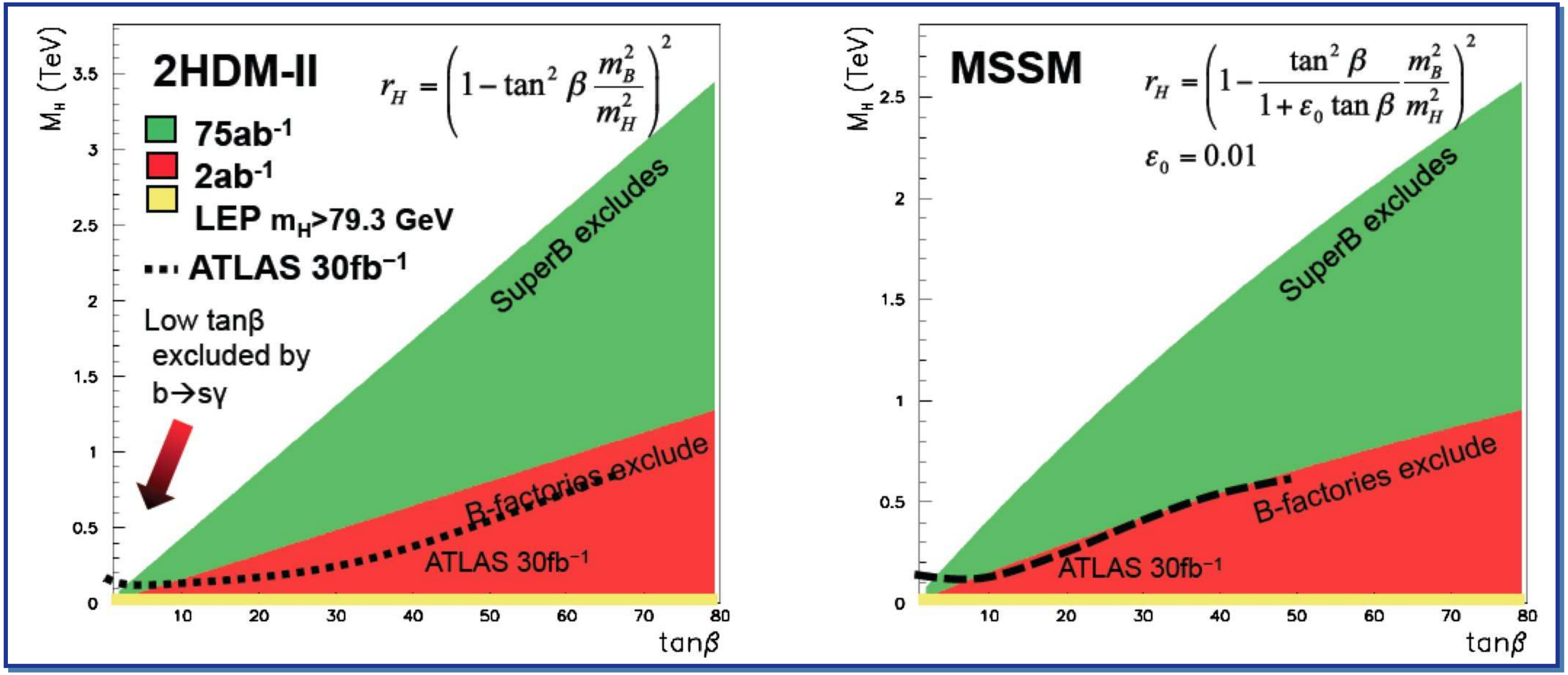
Other Physics

- Direct searches for non-standard light Higgs bosons, Dark Matter and Dark Forces

$\mathcal{B}(B \to \tau\nu)$

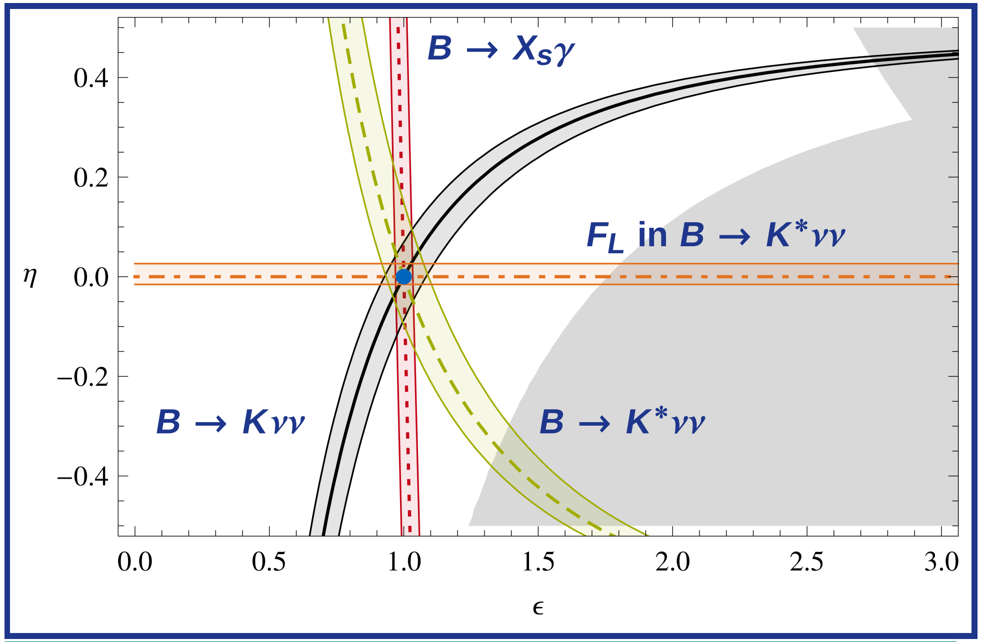
- helicity suppressed, reasonably clean SM prediction
  - within SM, rate proportional to $|V_{ub}|^2$ and f_B^2
- NP charged Higgs interferes negatively, reducing $\mathcal{B}(B \to \tau\nu)$
  - NP effect is larger in $\mathcal{B}(B \to \tau\nu)$ vs. $\mathcal{B}(B \to \mu\nu)$
- non trivial selection and bkg suppression because of neutrinos in final state
- Super*B* offers ideal conditions
  - clean events, hermetic detector, well defined initial state, just 2 *B*s
  - ⟶ tag other side with reconstructed *B*
  - ⟶ study “extra-energy” distribution with data for bkg subtraction
- 3% measurement of SM prediction possible

$\mathcal{B}(B \to \tau\nu)$ constrains NP charged Higgs parameters

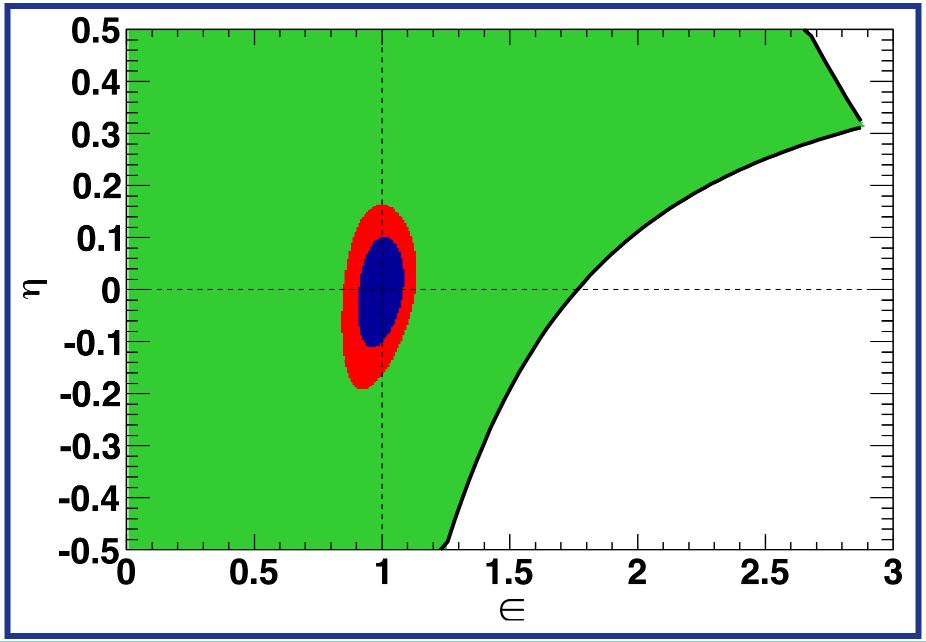


- $r_H = \mathcal{B}(B \to \tau\nu)/\mathcal{B}_{SM}(B \to \tau\nu)$ exclusion plots assume measurement = SM prediction
- ATLAS exclusion limit for 30 fb^{-1} at 14 TeV computed using arXiv:0901.0512

Constraints on NP from $B \to K^0 \nu\nu$, $B \to K^* \nu\nu$, $B \to X_s \gamma$ inclusive



hypothetical future constraints on SM deviations
W.Altmannshofer et al., arXiv:0902.0160 [hep-ph]

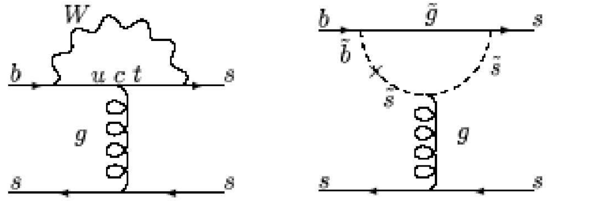


present vs. Super*B* 75 ab^{-1} constraints
(Super*B* comparison document)

W.Altmannshofer et al., arXiv:0902.0160 [hep-ph]: combining 4 observables provides good test of modified *Z*-penguin contributions, non-MFV interactions, RH currents, . . .

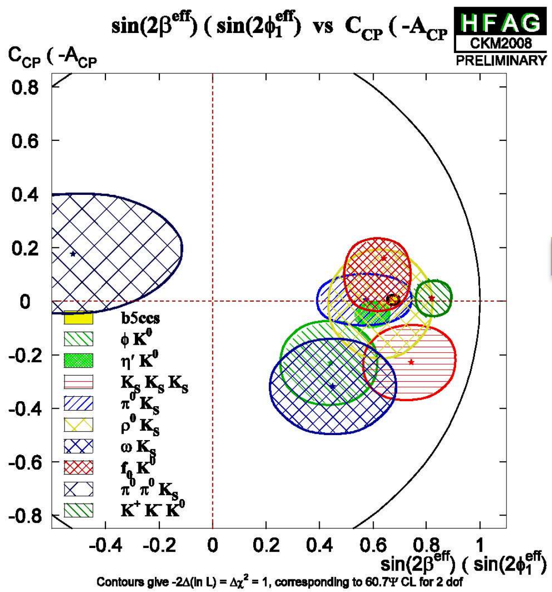
CPV in $b \to s$ penguins – M.Yamauchi, Dec 2012

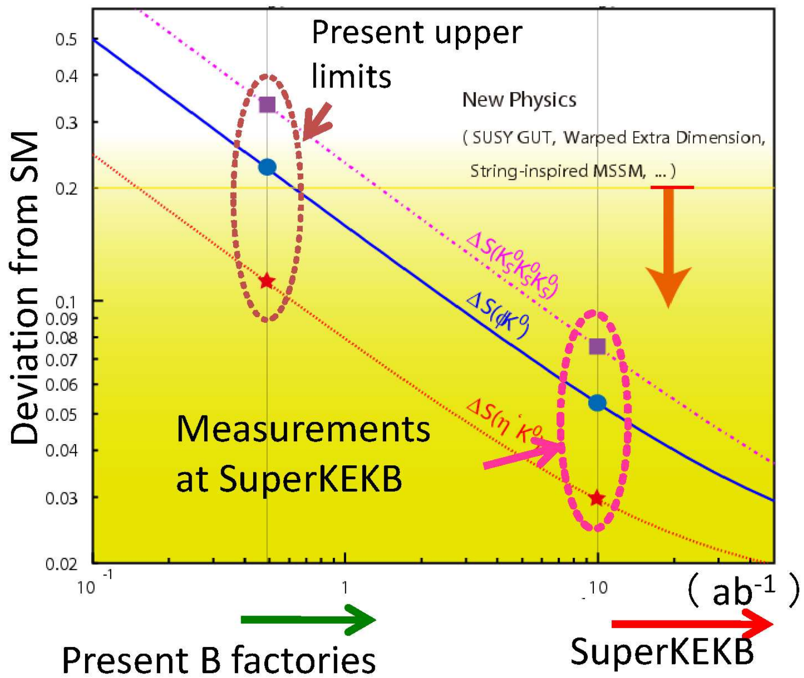
In general, new physics contains new sources of flavor mixing and CP violation.



SM SUSY contribution

- In SUSY models, for example, SUSY particles contribute to the $b \to s$ transition, and their CP phases change CPV observed in $B \to \phi K$, $\eta' K$ etc.





T-dependent CPV to search for L-R symmetric NP – M.Danilov, ICHEP 2012

$B \to K^* (\to K_S \pi^0)\gamma$
t-dependent CPV

SM:
$S_{CP}^{K^*\gamma} \sim -(2m_s/m_b)\sin 2\phi_1 \sim -0.04$

Left-Right Symmetric Models:
$S_{CP}^{K^*\gamma} \sim 0.67 \cos 2\phi_1 \sim 0.5$

D. Atwood et al., PRL79, 185 (1997)
B. Grinstein et al., PRD71, 011504 (2005)

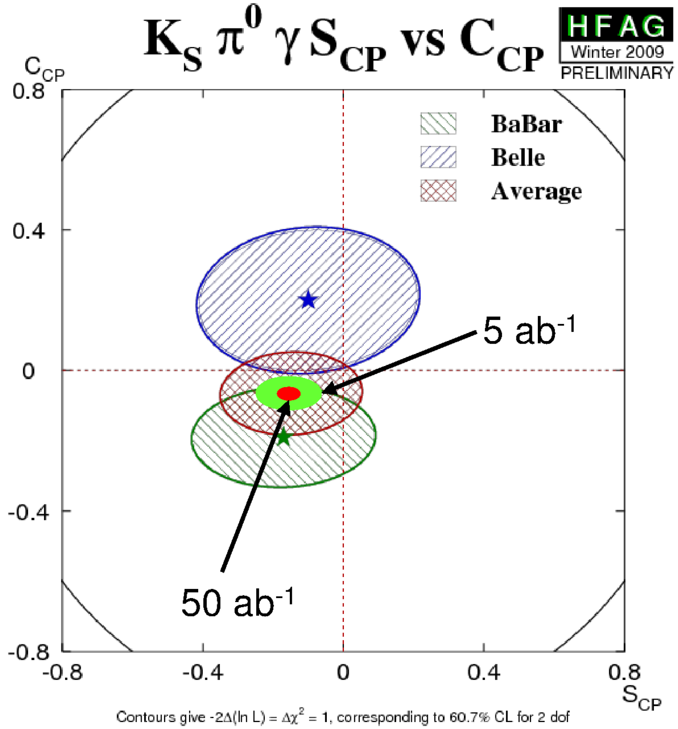
$S_{CP}^{K_S\pi^0\gamma} = -0.15 \pm 0.20$
$A_{CP}^{K_S\pi^0\gamma} = -0.07 \pm 0.12$

HFAG, Summer'11

$\sigma(S_{CP}^{K_S\pi^0\gamma}) =$ 0.09 @ 5 ab^{-1}
0.03 @ 50 ab^{-1}
(~SM prediction)

t-dependent decays rate of $B \to f_{CP}$;
S and A: CP violating parameters

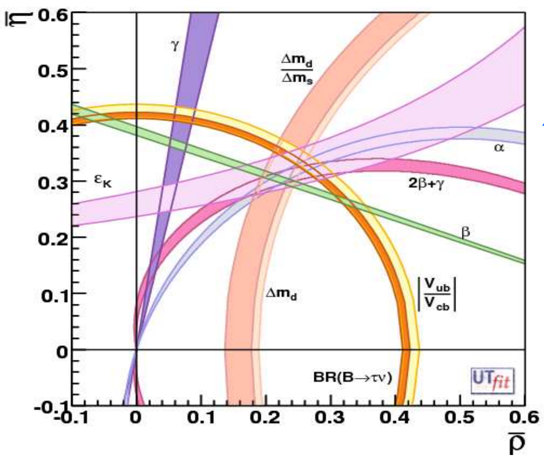
$$P(B^0 \to f;\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau}[1 + S_{CP}^f \sin(\Delta m \Delta t) + A_{CP}^f \cos(\Delta m \Delta t)]$$



Expected sensitivity for UT parameters at 50 fb^{-1} – M.Danilov, ICHEP 2012

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

BELLEII in many cases is more sensitive to UT parameters than LHCb

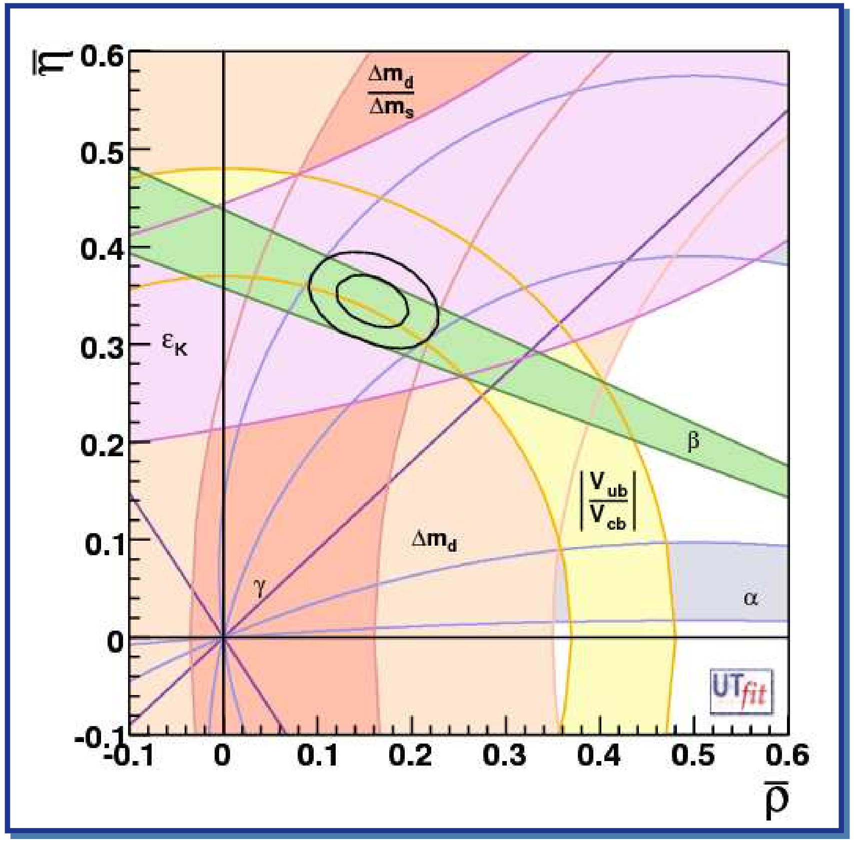


UT with present central values but with 50ab^{-1} errors

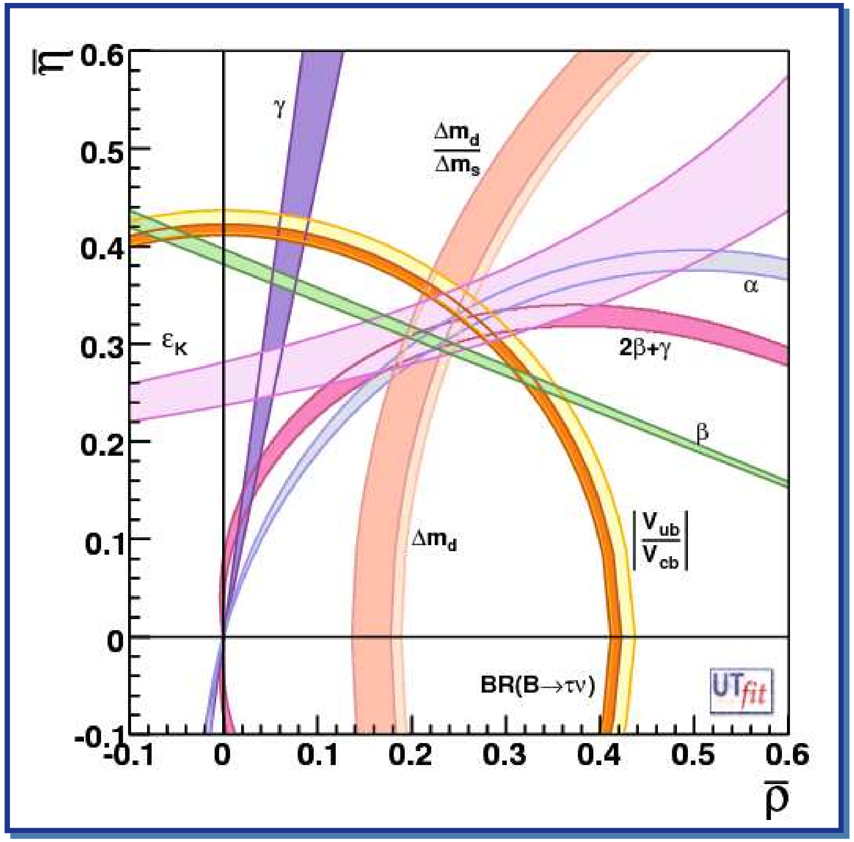
New phases can lead to inconsistency of UT.

From ∼10% to ∼1% experimental precision on CKM

CKM fit in 2006



possible fit with Super*B* & improved lattice QCD



- bands show 95% constraints, 2006 values assumed for the Super*B* fit

SuperB $\Upsilon(4S)$ B Physics reach, 1

Observable	B Factories (2 ab^{-1})	SuperB (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°

† exp. syst. limited

∗ theory syst. limited

most measurements with π^0, γ, ν, many K^0's cannot be done at LHCb

Super*B* $\Upsilon(4S)$ *B* Physics reach, 2

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 (†)
$S(K^0_S\pi^0\gamma)$	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%
$\mathcal{B}(B \to K\nu\overline{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\overline{\nu})$	–	possible

† exp. syst. limited

∗ theory syst. limited

most measurements with π^0, γ, ν, many K^0's cannot be done at LHCb

Methods and processes where Super B factory can provide important insight into NP complementary to other experiments:
(shown are expected sensitivities @ 50 ab-1)

E_{miss}:
$\mathcal{B}(B\to\tau\nu)$, $\mathcal{B}(B\to X_c\tau\nu)$, $\mathcal{B}(B\to h\nu\nu)$,...
±3% ±3% ±30%

Inclusive:
$\mathcal{B}(B\to s\gamma)$, $A_{CP}(B\to s\gamma)$, $\mathcal{B}(B\to s\ell\ell)$, ...
±6% $\pm 5\cdot 10^{-3}$ $\pm 1\cdot 10^{-7}$

Neutrals:
$S(B\to K_S\pi^0\gamma)$, $S(B\to\eta' K_S)$, $S(B\to K_SK_SK_S)$, $\mathcal{B}(\tau\to\mu\gamma)$, $\mathcal{B}(B_s\to\gamma\gamma)$, ...
±0.03 ±0.02 ±0.03 $\pm 3\cdot 10^{-9}$ $\pm 3\cdot 10^{-7}$

Missing mass technique: *Spectroscopy(Zb,…), Inclusive Production (Double Charm),*

Detailed description of physics program at Super B factories at:

A.G. Akeroyd et al., arXiv: 1002.5012
Physics at Super B Factory

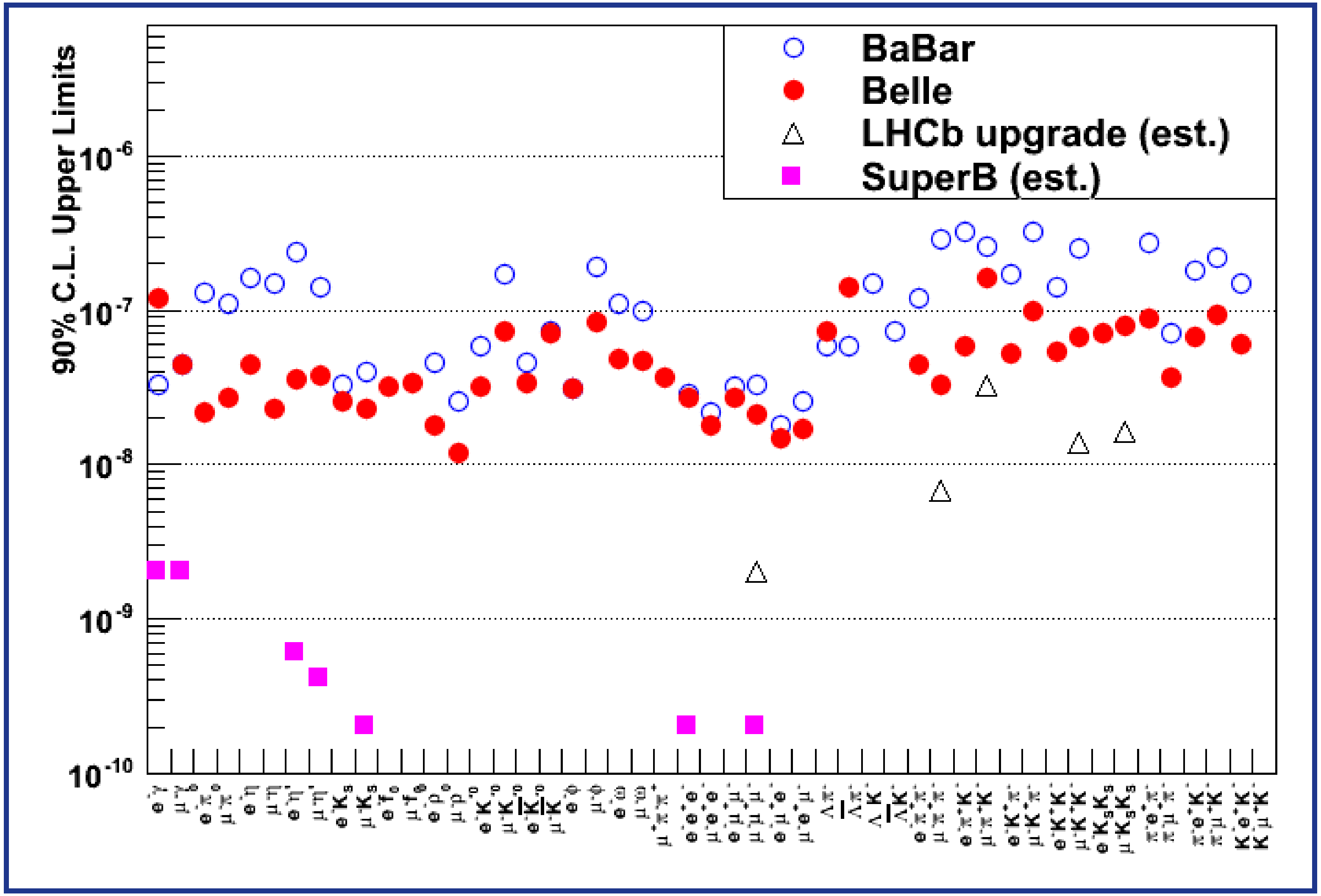
B. O'Leary et al., arXiv: 1008.1541
Super$B$
Progress Reports
Physics

[from M.Danilov, ICHEP 2012]

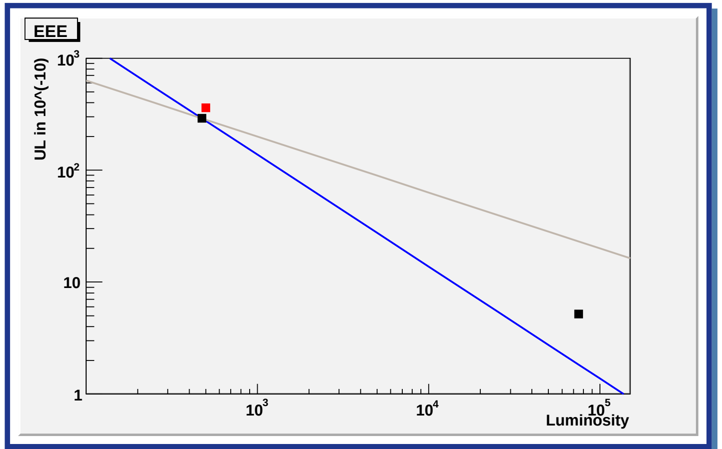
NP searches with Tau Lepton Flavour Violating decays

- many NP models predict tau LFV within the plannes Super *B*-factories sensitivity
- **unambiguous NP probe**, **negligible theory uncertainties**
- Super *B*-factorie complementary with MEG
  ($\mu \to e\gamma$ can be accidentally suppressed, tau measurements are complementary)
- best channels: $\boldsymbol{\tau \to \mu\gamma, \tau \to 3\ell, \tau \to \mu\rho, \tau \to \mu\eta}$

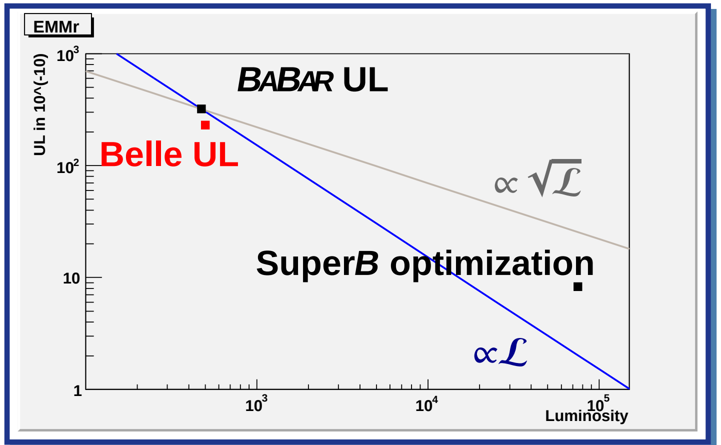
Super*B* 10–100 times more sensitive than *BABAR* to tau LFV modes



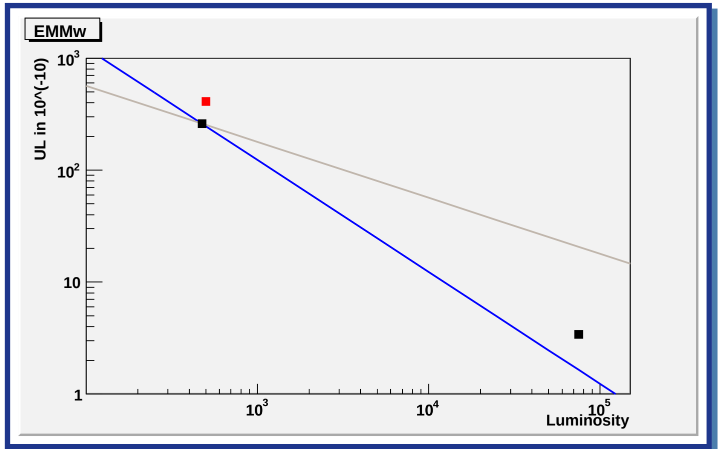
$\tau \to 3\ell$ 90% CM upper limit extrapolations: $\propto \mathcal{L}$ vs. $\propto \sqrt{\mathcal{L}}$ vs. re-optimization



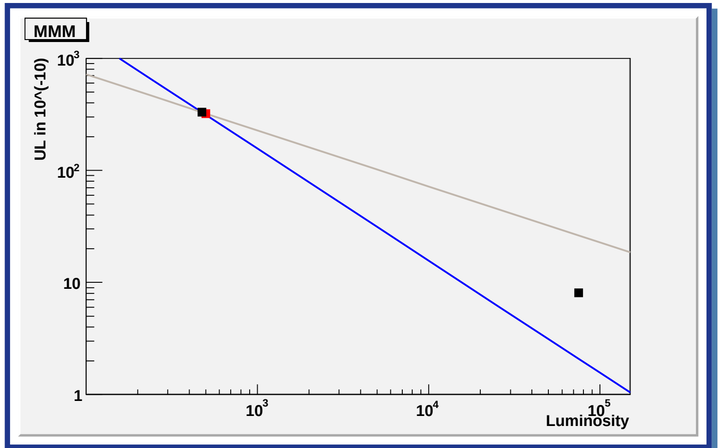
$\tau \to eee$



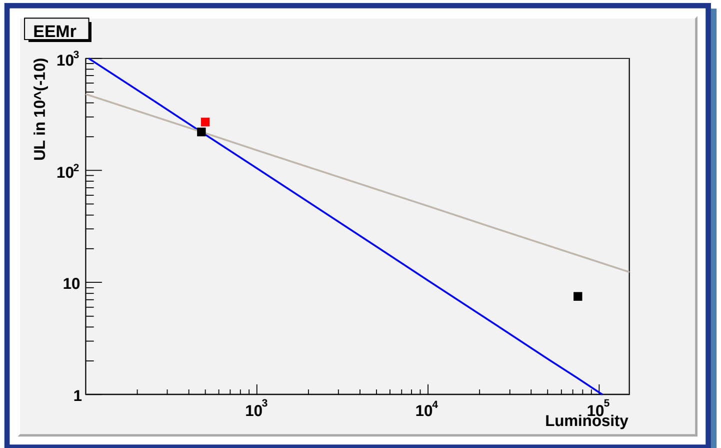
$\tau \to e\mu{+}\mu{-}$



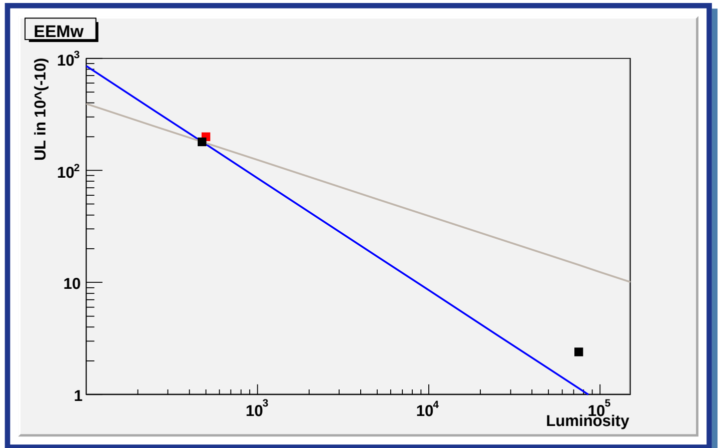
$\tau{-} \to e{+}\mu{-}\mu{-}$



$\tau \to \mu\mu\mu$

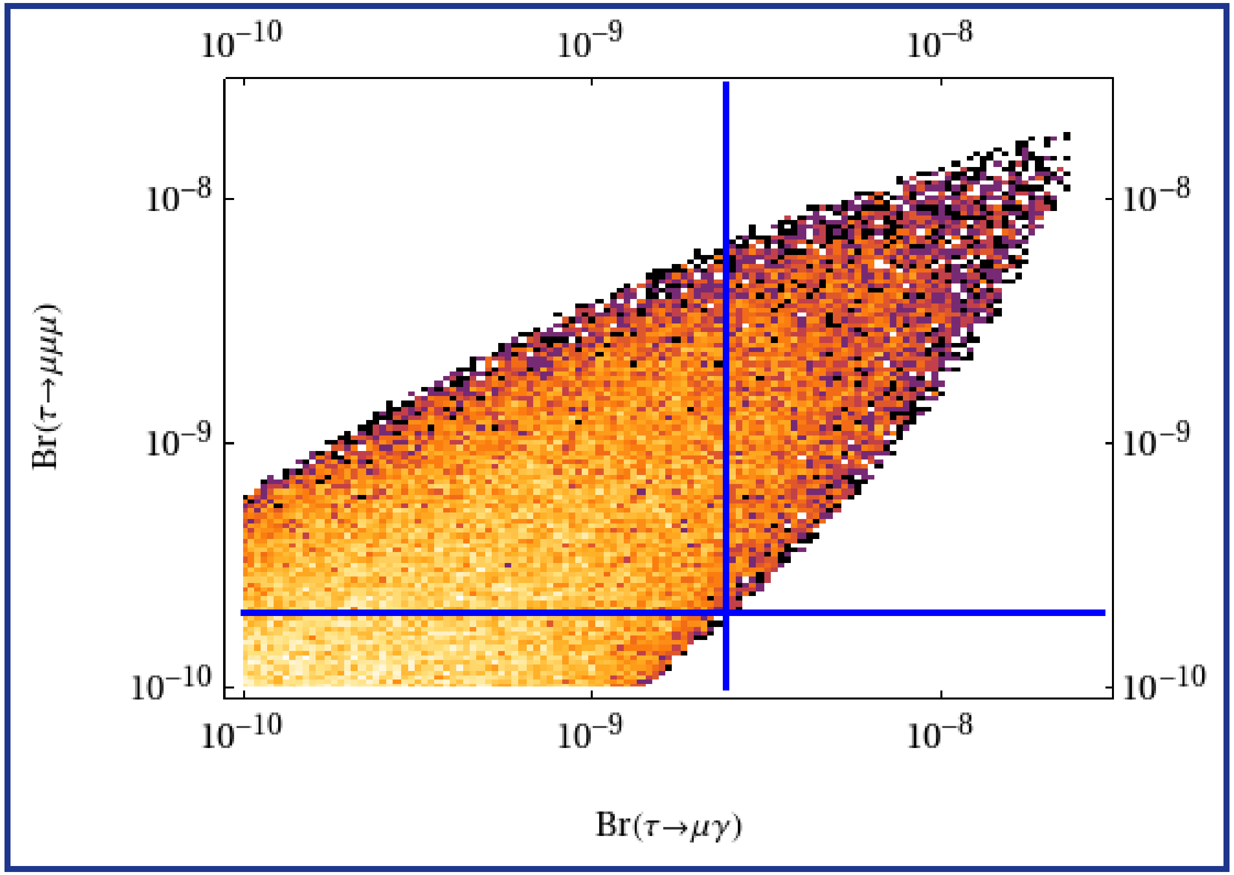


$\tau \to \mu e{+}e{-}$



$\tau{-} \to \mu{+}e{-}e{-}$

Super*B* $\tau \to \ell\gamma$ constraints on LHT model with breaking scale at 500 GeV



- Super*B* reach from arXiv:1109.5028v2 [hep-ex] The impact of SuperB on flavour physics
- NP predictions from M. Blanke et al. arXiv:0906.5454

Tau *CPV* at Super*B*

- SM predictions in general very small
  ($\tau^{\pm} \to K^{\pm}\pi^{0}\nu$ *CP* asymmetry $\mathcal{O}(10^{-12})$, D. Delepine et al., PRD 72, 033009 (2005), hep-ph/0503090)
- small SM *CP* asymmetry in $\tau^{\pm} \to K_S\pi^{\pm}\nu$ from *CPV* in $K^0\overline{K}^0$
  $3.3{\cdot}10^{-3} \pm 2\%$ relative, I.I.Bigi & A. I. Sanda, PLB 625, 47 (2005), hep-ph/0506037
- most NP models do not induce measurable tau CPV
- R-parity violating SUSY → CPV related asymmetries up to 10%, saturating existing limits
  - sizable asymmetries in $\tau \to K\pi\nu_\tau$, $\tau \to K\eta^{(\prime)}\nu_\tau$, and $\tau \to K\pi\pi\nu_\tau$
- CLEO, PRL 88, 111803 (2002), hep-ex/0111095, 13.3 fb^{-1}, $\tau \to K_S\pi\nu$

→ optimal asymmetry observable $\langle\xi\rangle$ **= (–2.0 ± 1.8)·10^{-3}**

  - data calibration with $\tau \to \pi\pi\pi\nu$
- extrapolating at Super*B*, $\sigma_{\langle\xi\rangle} \approx 2.4{\cdot}10^{-5}$

Super*B* D^0–mixing reach using $\Upsilon(4S)$ data

Super*B* 75 ab^{-1} at $\Upsilon(4S)$

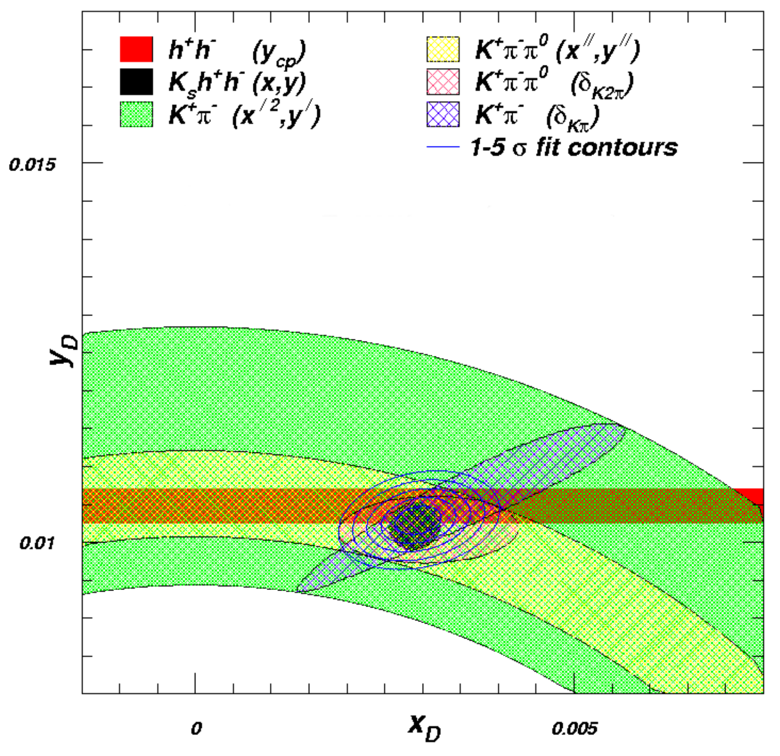
Parameter	$x \times 10^3$	$y \times 10^3$	$\delta_{K\pi}$ (°)	$\delta_{K\pi\pi}$ (°)
σ (stat)	0.18	0.11	1.3	2.7
σ (stat) +(syst)	0.42	0.17	2.2	$^{+3.3}_{-3.4}$

Super*B* 75 ab^{-1} at $\Upsilon(4S)$ with 0.5 ab^{-1} charm threshold run

(measure *D* strong phases on entangled *D*'s at charm threshold)

Parameter	$x \times 10^3$	$y \times 10^3$	$\delta_{K\pi}$ (°)	$\delta_{K\pi\pi}$ (°)
σ (stat)	0.17	0.10	0.9	1.1
σ (stat) +(syst)	0.20	0.12	1.0	1.1

(SuperB white paper: Physics, **arXiv:1008.1541 [hep-ex]**)



Sensitivity of Super*B* to specific NP models

list of NP models, full description in

- W.Altmannshofer, A.J.Buras, S.Gori, P.Paradisi, D.M.Straub, Anatomy and Phenomenology of FCNC and CPV Effects in SUSY Theories, arXiv:0909.1333 [hep-ph]
- arXiv:1109.5028v2 [hep-ex] The impact of SuperB on flavour physics

AC	(SUSY) abelian model by Agashe and Carone based on a U(1) flavour symmetry
RVV2	(SUSY) non-abelian model by Ross, Velasco-Sevilla and Vives
AKM	(SUSY) non-abelian model by Antusch, King and Malinsky
δLL	(SUSY) purely left-handed currents with CKM-like mixing angles
FBMSSM	flavour-blind MSSM
GUT-CMM	SUSY GUT
SSU(5)	SUSY GUT SU(5)
LHT	Littlest Higgs with T-parity
RS	Randall-Sundrum

Sensitivity of flavour golden modes to specific NP models

	Observable/mode	H^+ high $\tan\beta$	MFV	non-MFV	NP Z penguins	Right-handed currents	LTH	SUSY AC	SUSY RVV2	SUSY AKM	SUSY δLL	SUSY FBMSSM
✓	$\tau \to \mu\gamma$							★★★	★★★	★	★★★	★★★
✓	$\tau \to \ell\ell\ell$						★★★					
✓	$B \to \tau\nu, \mu\nu$	★★★(CKM)										
✓	$B \to K^{(*)+}\nu\overline{\nu}$			★	★★★			★	★	★	★	★
✓	S in $B \to K_S^0\pi^0\gamma$					★★★						
✓	S in other penguin modes			★★★(CKM)		★★★		★★★	★★	★	★★★	★★★
✓	$A_{CP}(B \to X_s\gamma)$			★★★		★★		★	★	★	★★★	★★★
✓	$BR(B \to X_s\gamma)$		★★★	★		★						
✓	$BR(B \to X_s\ell\ell)$			★	★	★						
✓	$B \to K^{(*)}\ell\ell$ (FB Asym)							★	★	★	★★★	★★★
	$B_s \to \mu\mu$							★★★	★★★	★★★	★★★	★★★
	β_s from $B_s \to J/\psi\phi$							★★★	★★★	★★★	★	★
✓	a_{sl}						★★★					
✓	Charm mixing							★★★	★	★	★	★
✓	CPV in Charm	★★									★★★	

✓ = SuperB can measure this

More information on the golden matrix can be found in arXiv:1008.1541, arXiv:0909.1333, and arXiv:0810.1312.

Super*B* reach compared (1), Isidori/Nir/Perez, Ann.Rev.Nucl.Part.Sci. 60, 355 (2010)

Observable	SM prediction	Theory error	Present result	Future error	Future Facility
$\|V_{us}\|$ $[K \to \pi \ell \nu]$	input	$0.5\% \to 0.1\%_{Latt}$	0.2246 ± 0.0012	0.1%	K factory
$\|V_{cb}\|$ $[B \to X_c \ell \nu]$	input	1%	$(41.54 \pm 0.73) \times 10^{-3}$	1%	Super*B* 50 ab^{-1}
$\|V_{ub}\|$ $[B \to \pi \ell \nu]$	input	$10\% \to 5\%_{Latt}$	$(3.38 \pm 0.36) \times 10^{-3}$	4%	Super*B* 50 ab^{-1}
γ $[B \to DK]$	input	$< 1^\circ$	$(70^{+27}_{-30})^\circ$	3°	LHCb
$S_{B_d \to \psi K}$	$\sin(2\beta)$	$\lesssim 0.01$	0.671 ± 0.023	0.01	LHCb
$S_{B_s \to \psi \phi}$	0.036	$\lesssim 0.01$	$0.81^{+0.12}_{-0.32}$	0.01	LHCb
$S_{B_d \to \phi K}$	$\sin(2\beta)$	$\lesssim 0.05$	0.44 ± 0.18	0.1	LHCb
$S_{B_s \to \phi \phi}$	0.036	$\lesssim 0.05$	—	0.05	LHCb
$S_{B_d \to K^* \gamma}$	few $\times$ 0.01	0.01	-0.16 ± 0.22	0.03	Super*B* 50 ab^{-1}
$S_{B_s \to \phi \gamma}$	few $\times$ 0.01	0.01	—	0.05	LHCb
A^d_{SL}	-5×10^{-4}	10^{-4}	$-(5.8 \pm 3.4) \times 10^{-3}$	10^{-3}	LHCb
A^s_{SL}	2×10^{-5}	$< 10^{-5}$	$(1.6 \pm 8.5) \times 10^{-3}$	10^{-3}	LHCb

Super*B* reach compared (2), Isidori/Nir/Perez, Ann.Rev.Nucl.Part.Sci. 60, 355 (2010)

Observable	SM prediction	Theory error	Present result	Future error	Future Facility
$A_{CP}(b \to s\gamma)$	< 0.01	< 0.01	-0.012 ± 0.028	0.005	Super*B* 50 ab^{-1}
$\mathcal{B}(B \to \tau\nu)$	1×10^{-4}	$20\% \to 5\%_{Latt}$	$(1.73 \pm 0.35) \times 10^{-4}$	5%	Super*B* 50 ab^{-1}
$\mathcal{B}(B \to \mu\nu)$	4×10^{-7}	$20\% \to 5\%_{Latt}$	$< 1.3 \times 10^{-6}$	6%	Super*B* 50 ab^{-1}
$\mathcal{B}(B_s \to \mu^+\mu^-)$	3×10^{-9}	$20\% \to 5\%_{Latt}$	$< 5 \times 10^{-8}$	10%	LHCb
$\mathcal{B}(B_d \to \mu^+\mu^-)$	1×10^{-10}	$20\% \to 5\%_{Latt}$	$< 1.5 \times 10^{-8}$	[?]	LHCb
$A_{FB}(B \to K^*\mu^+\mu^-)_{q_0^2}$	0	0.05	(0.2 ± 0.2)	0.05	LHCb
$B \to K\nu\bar{\nu}$	4×10^{-6}	$20\% \to 10\%_{Latt}$	$< 1.4 \times 10^{-5}$	20%	Super*B* 50 ab^{-1}
$\lvert q/p\rvert_{D-mixing}$	1	$< 10^{-3}$	$(0.86^{+0.18}_{-0.15})$	0.03	Super*B* 50 ab^{-1}
ϕ_D	0	$< 10^{-3}$	$(9.6^{+8.3}_{-9.5})^\circ$	2°	Super*B* 50 ab^{-1}
$\mathcal{B}(K^+ \to \pi^+\nu\bar{\nu})$	8.5×10^{-11}	8%	$(1.73^{+1.15}_{-1.05}) \times 10^{-10}$	10%	*K* factory
$\mathcal{B}(K_L \to \pi^0\nu\bar{\nu})$	2.6×10^{-11}	10%	$< 2.6 \times 10^{-8}$	[?]	*K* factory
$R^{(e/\mu)}(K \to \pi\ell\nu)$	2.477×10^{-5}	0.04%	$(2.498 \pm 0.014) \times 10^{-5}$	0.1%	*K* factory
$\mathcal{B}(t \to c\,Z,\gamma)$	$\mathcal{O}\left(10^{-13}\right)$	$\mathcal{O}\left(10^{-13}\right)$	$< 0.6 \times 10^{-2}$	$\mathcal{O}\left(10^{-5}\right)$	LHC (100 fb^{-1})

Super*B* vs. LHCb for 5 NP models (P.Paradisi, Super*B* meeting, Dec 2011)

	SSU(5)	AC	RVV2	AKM	δLL	FBMSSM	
$S_{\phi K_S}$	★★★	★★★	●●	■	★★★	★★★	SuperB
$A_{CP}(B \to X_s\gamma)$	■	■	■	■	★★★	★★★	
$B \to K^{(*)}\nu\bar{\nu}$	■	■	■	■	■	■	
$\tau \to \mu\gamma$	★★★	★★★	★★★	■	★★★	★★★	
$D^0 - \bar{D}^0$	■	★★★	■	■	■	■	SuperB
$A_{7,8}(B \to K^*\mu^+\mu^-)$	■	■	■	■	★★★	★★★	vs.
$A_9(B \to K^*\mu^+\mu^-)$	■	■	■	■	■	■	LHCb
$S_{\psi\phi}$	★★★	★★★	★★★	★★★	■	■	LHCb
$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★★★	
ϵ_K	★★★	■	★★★	★★★	■	■	
$K^+ \to \pi^+\nu\bar{\nu}$	■	■	■	■	■	■	
$K_L \to \pi^0\nu\bar{\nu}$	■	■	■	■	■	■	
$\mu \to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	
$\mu + N \to e + N$	★★★	★★★	★★★	★★★	★★★	★★★	
d_n	★★★	★★★	★★★	★★★	●●	★★★	
d_e	★★★	★★★	★★★	●●	■	★★★	
$(g-2)_\mu$	★★★	★★★	★★★	●●	★★★	★★★	

elaboration using information in W.Altmannshofer, A.J.Buras, S.Gori, P.Paradisi, D.M.Straub, Anatomy and Phenomenology of FCNC and CPV Effects in SUSY Theories, arXiv:0909.1333 [hep-ph]

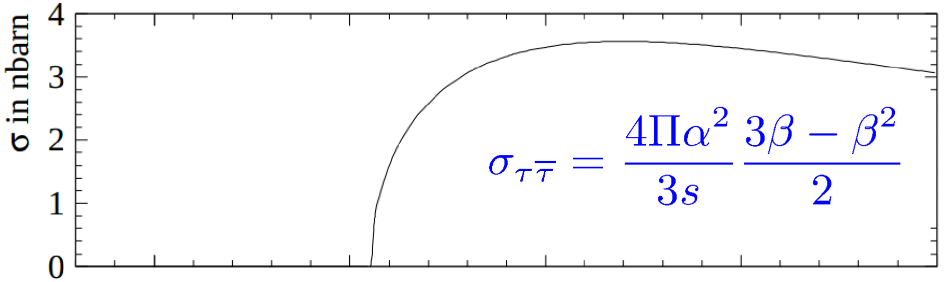
Tau Physics at Super charm-tau factory

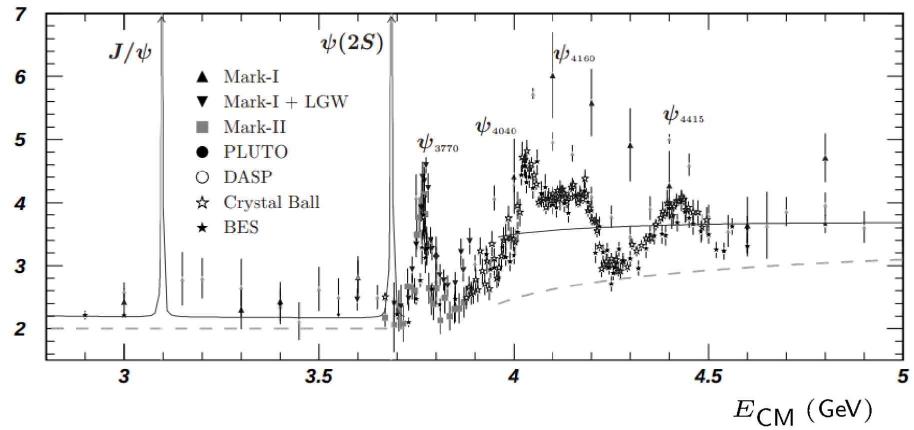
Super charm-tau factory

- $\sigma_{\tau\overline{\tau}}(m_{\tau\overline{\tau}}) \simeq 0.1\,\text{nb}$
- $\sigma_{\tau\overline{\tau}}(\Psi(3770)) = 2.5\,\text{nb}$
- $\sigma_{\tau\overline{\tau}}(4.25\,\text{GeV}) = 3.5\,\text{nb}$ (max)
- $\mathcal{L} \simeq 10^{35}\,\text{cm}^{-2}\text{s}^{-1}$
- integrated $\mathcal{L} = 7.5\,\text{ab}^{-1}$
- **Number of $\tau\overline{\tau} \approx 2.3 \cdot 10^{10}$**

SuperB

- $\sigma_{\tau\overline{\tau}}(\Upsilon(4S)) = 0.92\,\text{nb}$
- $\mathcal{L} \simeq 10^{36}\,\text{cm}^{-2}\text{s}^{-1}$
- integrated $\mathcal{L} = 75\,\text{ab}^{-1}$
- **Number of $\tau\overline{\tau} = 6.9 \cdot 10^{10}$**



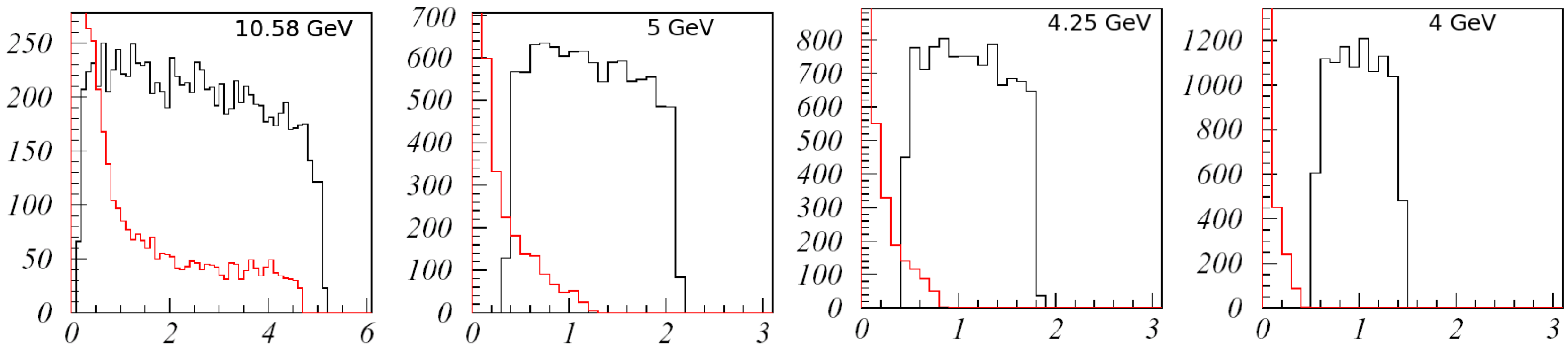


Super charm-tau factory: LFV $\tau \to \mu\gamma$ sensitivity

- BR expected 90% CL upper limit for SuperB with $75\,\mathrm{ab}^{-1} = 2.4 \cdot 10^{-9}$
  (SuperB physics reports)
- BR sensitivity of $\tau{-}c$ factory with $7\,\mathrm{ab}^{-1} \approx \mathbf{10^{-9}}$
  A.V.Bobrov, A.E.Bondar, Search for $\tau \to \mu\gamma$ decay at Super $c{-}\tau$ factory, Nucl.Phys.B (Proc.Suppl.) 225 (2012), arXiv:1206.1909 [hep-ex], (PHIPSI 2011 proceegings)
  - Monte Carlo simulation of expected backgrounds
  - less bkg from ISR than at $\Upsilon(4S)$ (see next slide)
- beam polarization provides additional benefits in sensitivity and New Physics models testing

Super charm-tau factory: at low CM energies, less bkg from ISR photons

- $\tau \to \mu\gamma$ background from ISR photon + SM $\tau \to \mu\nu\overline{\nu}$ decay
- at $c{-}\tau$ factory, ISR photon has lower energy than the photon from $\tau \to \mu\gamma$
  - H.Hayashii, "Search for $\tau \to \mu/e\gamma$ at the Super-τ−charm Factory", Tau 2008 Workshop Satellite meeting on the Super τ−charm factory



Super charm-tau factory: other Tau Physics topics

- references:
  - Physics at BES-III, J. of Modern Physics A24.1 supp (2009), arXiv:0809.1869 [hep-ex]
  - “A PROJECT OF SUPER c–τ FACTORY IN NOVOSIBIRSK”, Conceptual Design Report, 2011, Budker, Novosibirsk
- improve lepton universality tests (tau mass and leptonic BRs)
- close to threshold, it is possible to tag a single tau hadronic decay with $2m_\tau E_{\text{had}} = m_\tau^2 + m_{\text{had}}^2$
- measuring hadronic BRs and spectra one may obtain the most precise experimental measurements of α_s, V_{us} and m_s
- study of the Lorentz structure of the leptonic decays (EW test)
- CPV in tau decay (both rate asymmetry and angle differential asymmetry)

Conclusion

- Super B-factory BelleII is on track to begin data-taking in 2016
- BelleII will provide several valuable heavy flavour measurements that are not feasible elsewhere
- BelleII will provide the best facility for tau physics LFV searches and measurements
- a super charm-tau factory could provide a valuable facility for charm and tau physics, which may be competitive in some areas like search for LFV in $\tau \to \mu\gamma$