The Future of Heavy Flavor Physics

Marcello A. Giorgi
Università di Pisa & INFN Pisa

October 27,2008

SLAC

Outline

Present status in Flavor

Constraints on CKM parameters

Leptonic sector

Flavor

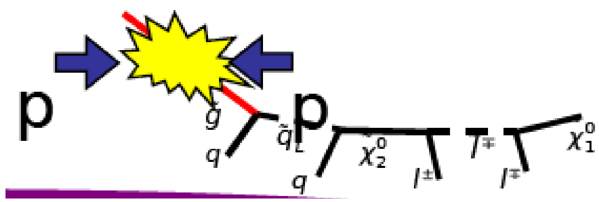
….. to New Physics

Re ference to most of material on SuperB Physics can be found in Proceeding of the VI SuperB Workshop Valencia(Spain) January 8-15,2008

How move to New Physics

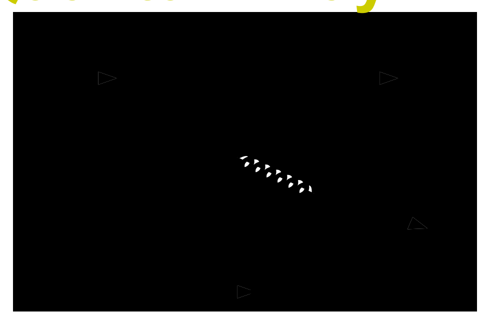
Move to New Physics in two ways:

Relativistic way



LHC (Energy Frontier)

Quantum way



Flavor (High precision measurements)

The two ways are complementary

S …

After the famous BNL experiment in 1964 with the discovery of CP Violation in the kaon mixing [J.H.Christenson, J.W. Cronin, V.L Fitch and R. Turlay. Phys Rev Lett.13(1964)] from the observation of the BF($K_L \to \pi+ \pi-$)=(1.076 ± 0.08) x 10^{-3}, more recently (1999) the CP violation in the decay (direct CP violation) has been established.

At CERN [A.Lai *et al.* Phys Lett B 465 (1999), Eur. Phys. J. C 22(2001) and J.R.Batley *et al.* Phys. Lett. B 544(2002)] and at FNAL [A.Alavi-Harati et al. Phys Rev. Lett. 83(1999), Phys. Rev. D67(2003), Phys. Rev. LD70(2004), ERRATUM] the double ratio

$$(\Gamma(K_L \to \pi^0 \pi^0)\, \Gamma(K_S \to \pi^+ \pi^-)) / (\Gamma(K_S \to \pi^0 \pi^0)\, \Gamma(K_L \to \pi^+ \pi^-)) = |\eta_{00} / \eta_{+-}| \cong 1-6\, \mathrm{Re}(\varepsilon' / \varepsilon)$$

was measured and found different from 1 giving Re(ε'/ε) = (1.66 ± 0.26) x 10^{-3} different from 0 as implied by the CKM picture.

The Kaon saga after more than 40 years of accurate measurements is not ended.

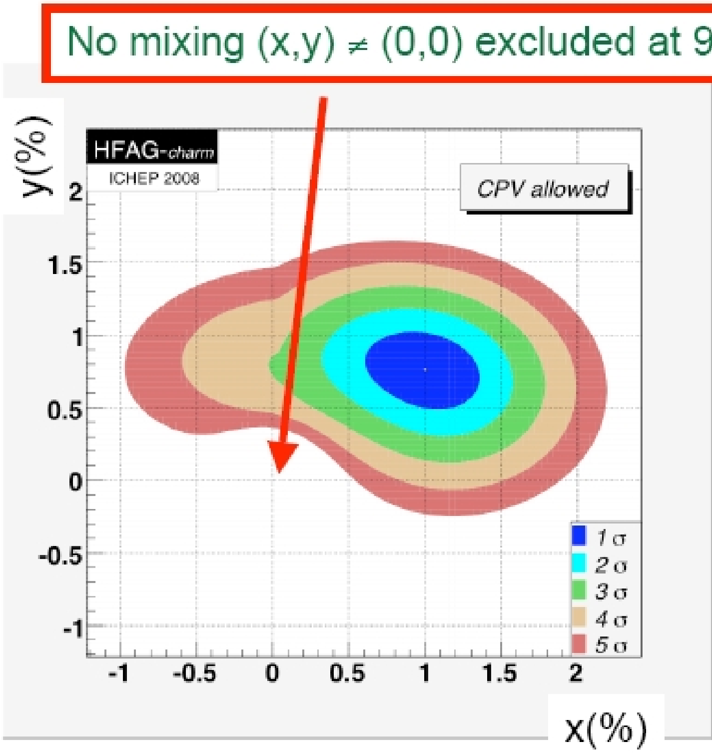
c……. (1-5 σ plots)New Physics accessible from Charm if CPV?

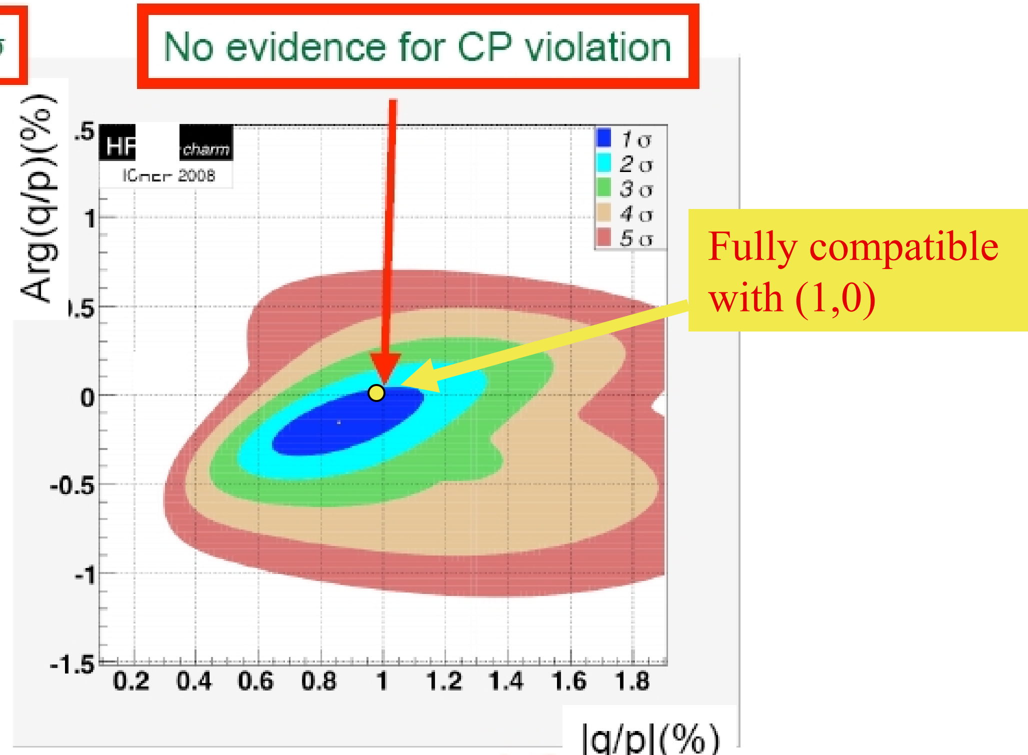
- 2007 BABAR & BELLE:Charm mixing in $D^0\,\overline{D^0}$ decay

D^0-$\overline{D}^0$ Mixing:

New HFAG Average for ICHEP08

http://www.slac.stanford.edu/xorg/hfag/charm/index.html





$x = 1.00 \pm^{0.24}_{0.25}$ % 3.4σ

$y = 0.76 \pm^{0.17}_{0.18}$ % 4.1σ

$|q/p| = 0.86 \pm^{0.17}_{0.15}$

$\mathrm{Arg}(q/p) = (8.8 \pm^{7.6}_{7.2})^o$

and b…

From b experiments is coming the confirmation and the triumph of CKM.

Thanks to the measurements of the CP asymmetries and rare b decays, mainly at e^+ e^- Bfactories PEPII and KEKB but also at FNAL Tevatron

(2006 B_s oscillations from CDF and D0

The mixing parameter $x(B_s) = \Delta M(B_s) / \Gamma(B_s) \cong 25$ and no evidence for $\Delta\Gamma(B_s) \neq 0$.

$$CDF: \Delta M(B_s) = (1.17 \pm 0.01) x 10^{-2}\, eV - (17.77 \pm 0.12) ps^{-1}$$
$$D0: \Delta M(B_S) = (1.25 \pm 0.13) x 10^{-2}\, eV - (19 \pm 2) ps^{-1}$$

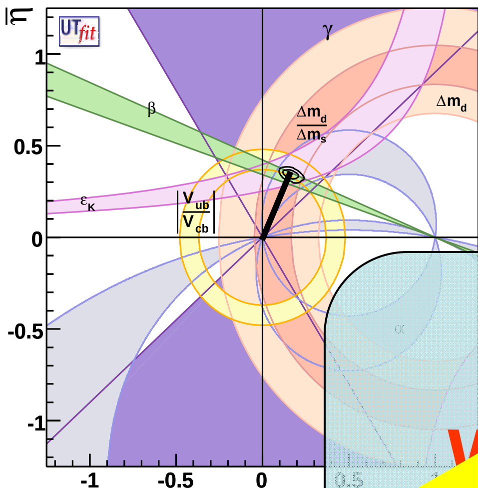
The SM prediction is : $\Delta M(B_S) = (1.20^{+0.43}_{-0.10}) x 10^{-2}\, eV - (18.3^{+6.5}_{-1.5})\, ps^{-1}$

Great achievements on flavor from e+e- factories PEPII and KEKB

1. 2001 CP violation in B sector from Time dependent analysis
2. 2003 Discovery of new charm particles start a new spectroscopy season with D_{sJ}
3. 2004 Direct CP violation in B sector
4. 2006 Limits on MSSM parameters from $B \rightarrow \tau\nu$
5. 2008 η_b discovery

(Some) Results of B-Factories

Unitarity Triangle precision measurements



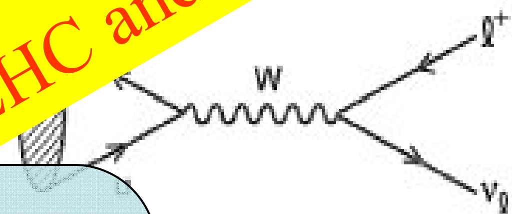
Spectroscopy of new, unexpected states

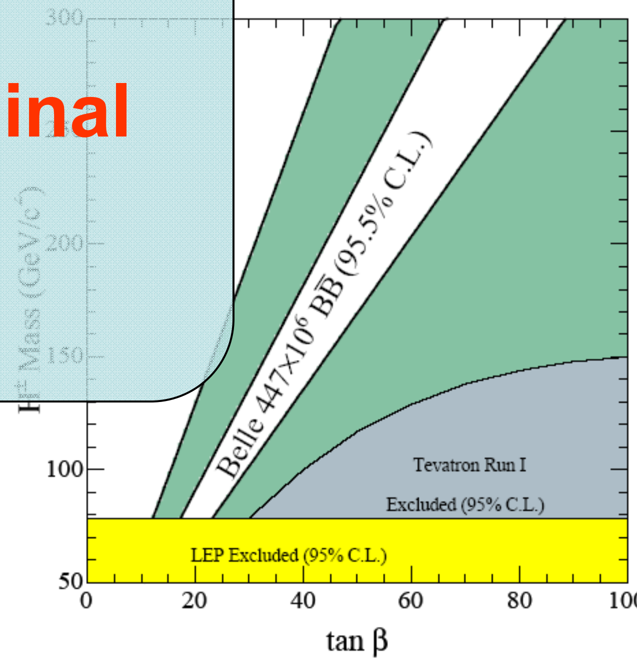
New DK state(s) at 2.86GeV/c²

B→

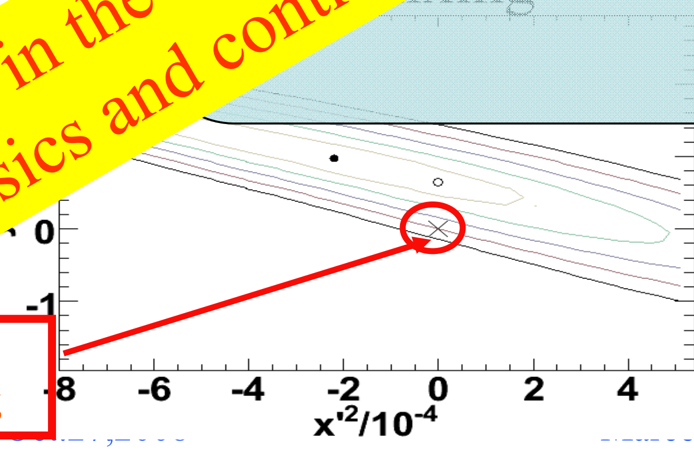
SM

ers





ixing



No Mixing

W… d the original goals

What in the next decade will e+ e- factories say about new physics and contribute as complementary to LHC and LHCb ?

To new Physics:Constraints on CKM+ rare lepton decays

Precise measurements of CKM parameters in quark sector, challenging new physics can come from a wide spectrum of future projects (some approved, some close to approval, some….):

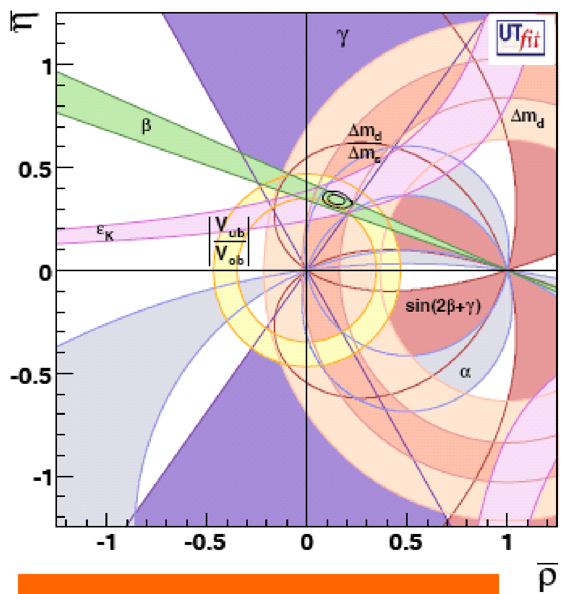
In Kaons there are projects for a next generation of experiments :

$K^+ \rightarrow \pi^+ \nu \bar{\nu}$ and $K^0 \rightarrow \pi^0 \nu \bar{\nu}$

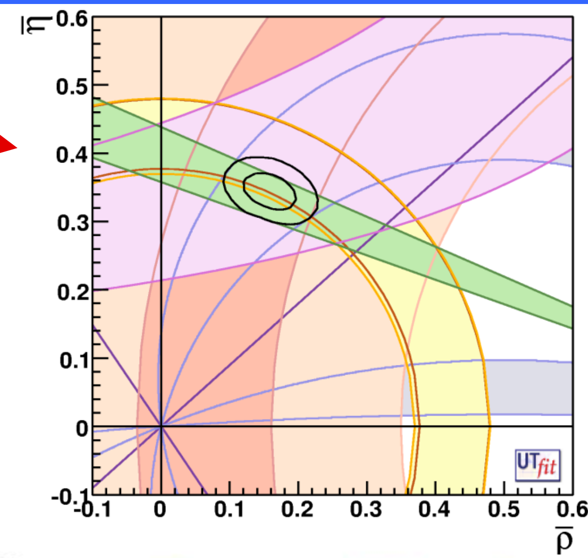
at CERN and at JPARC .

Dedicated experiments on μ-e LVF at PSI (running) , at JPARC and FNAL in future. In b, c and τ : LHCb at CERN, BES upgrade, KEKB + SuperKEKB, Super c- τ at Novosibirsk and SuperB studying very rare processes in quark and lepton sectors.

Improving CKM precision



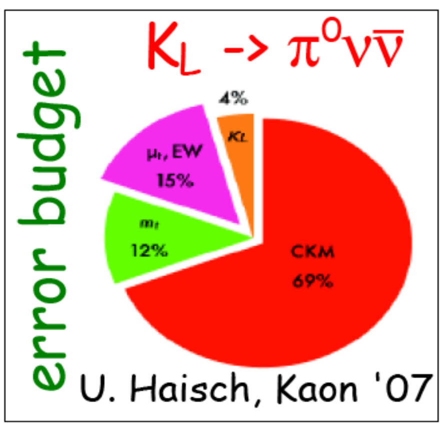
NOW !



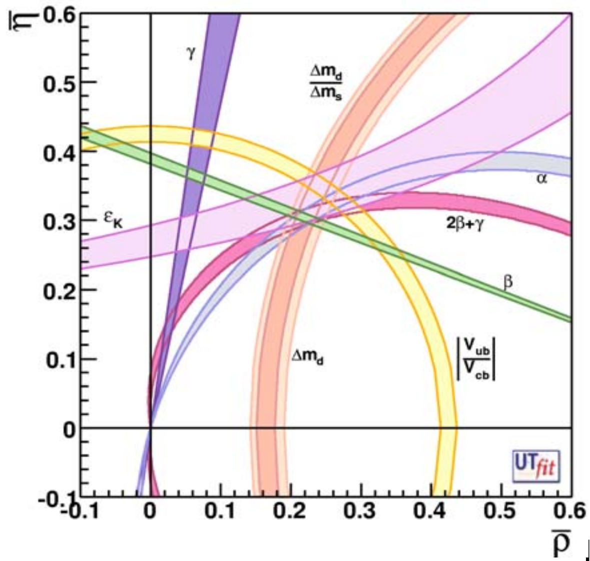
ρ = 0.163 ± 0.028
η = 0.344± 0.016

ρ = ± 0.0028
η = ± 0.0024

Improving CKM is crucial to look for NP



75 ab-1 SuperB and Lattice calculation improvement

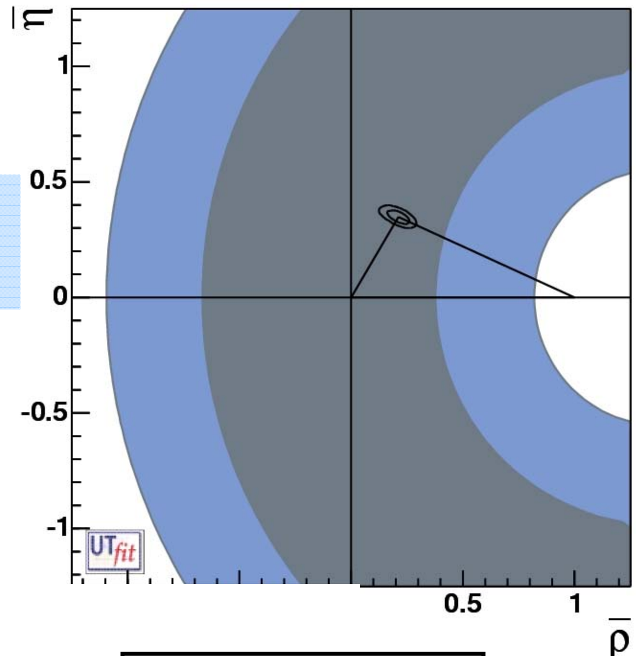


K+ → π+νν science (or) fiction

If NA62 approved

("4.4" events)
BR(exp) = 2 x BR(SM)

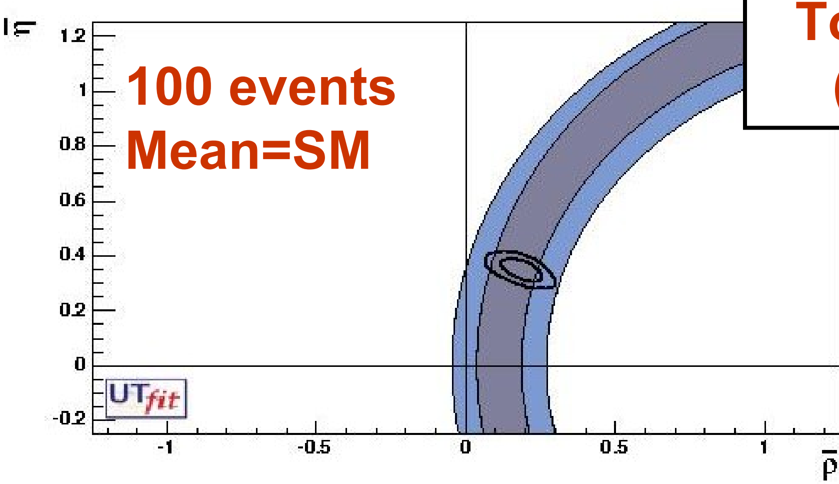
Today

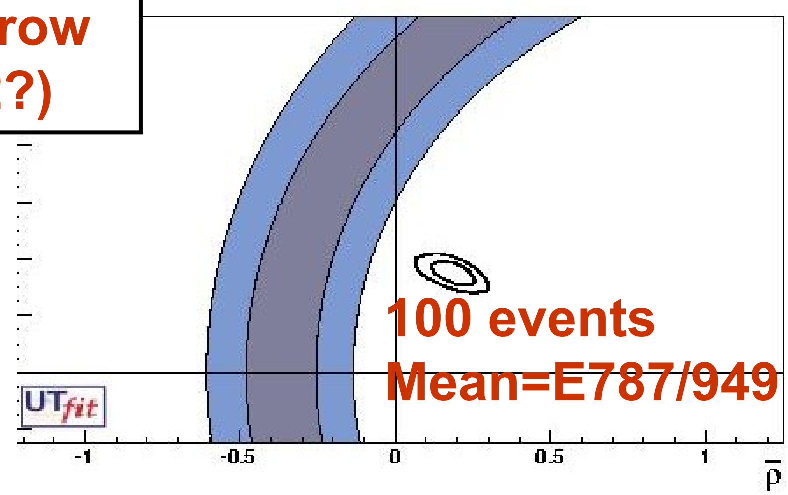


?

?

Tomorrow (2012?)



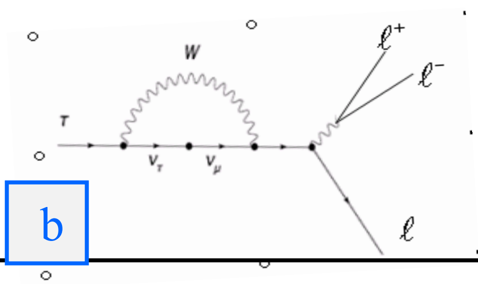


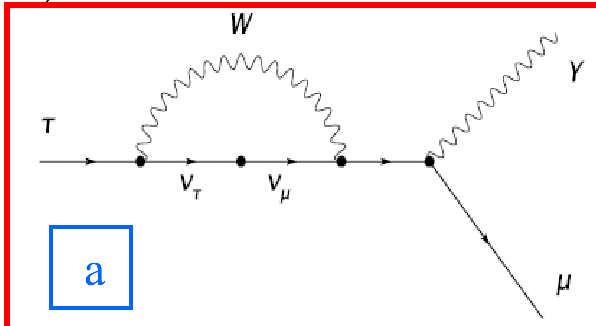
LFV in tau and muon decay

Standard Model allows LFV.In charged leptons it can occur in loops with expected low branching fractions. Es: expected Br ($\tau \rightarrow \mu\gamma$) <O ($10^{-40} \div 10^{-54}$)

Even less in 3 leptons

For this contribution b



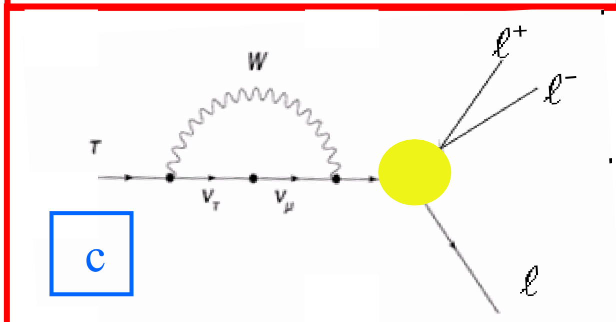


a

But with all contributions c becomes larger than b and c expected same order of a :

$$Br(\tau \to \mu\gamma) = \frac{3\alpha}{32\pi}\left|\sum_{i=1,2} U^*_{\tau i} U_{\mu i} \frac{\Delta m^2_{ii}}{m^2_W}\right|^2 < 10^{-54}$$

$$\Delta m^2_{ij} = m^2_{\nu i} - m^2_{\nu j}$$



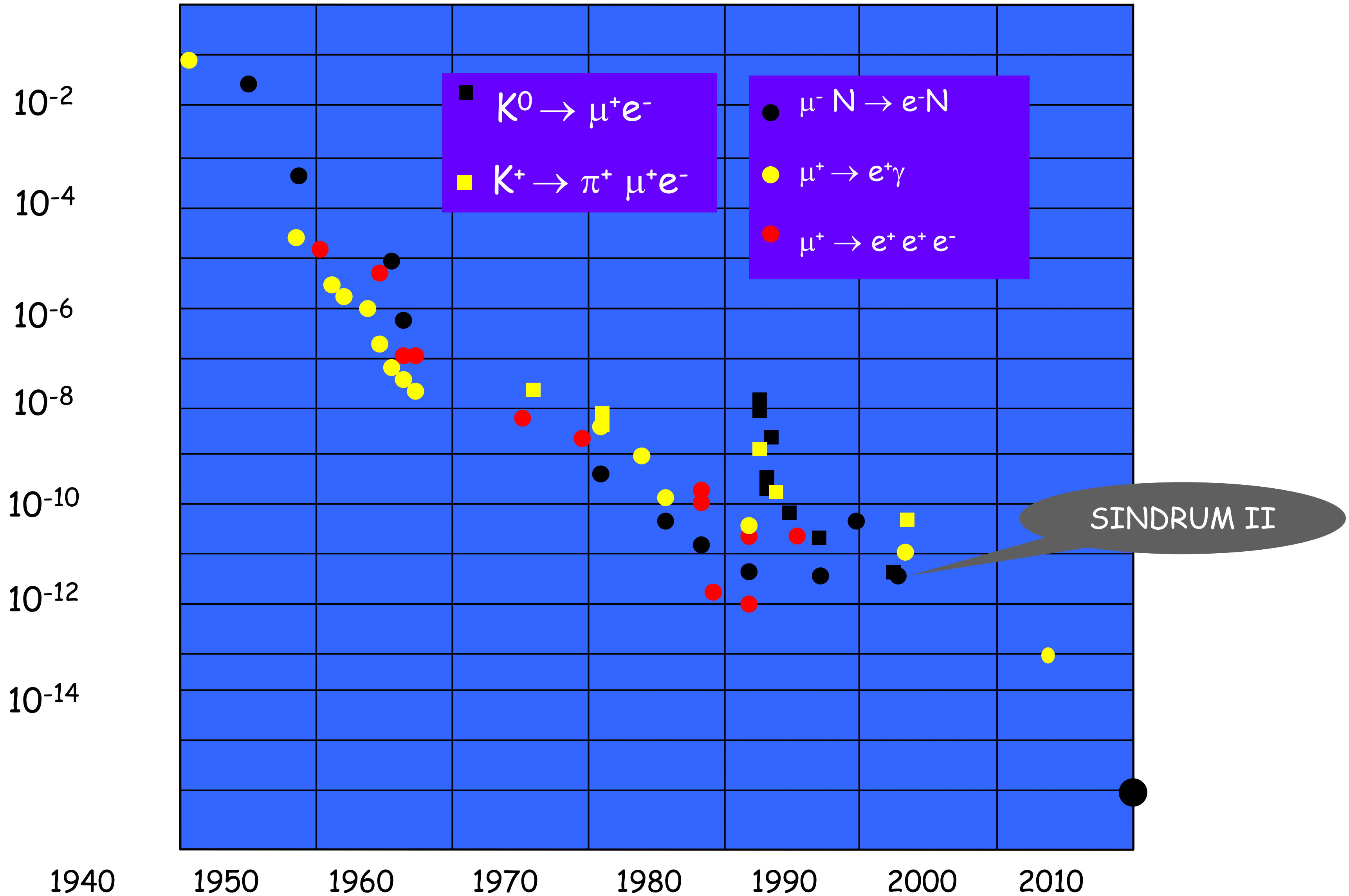
c

90% CL limits

Br ($\tau^- \to e^-\gamma$)	<	12×10^{-8}
Br ($\tau^- \to \mu^-\gamma$)	<	4.1×10^{-8}
Br ($\tau^- \to e^-\gamma$)	<	11×10^{-8}
Br ($\tau^- \to \mu^-\gamma$)	<	6.7×10^{-8}

Observable lepton decays with FV will allow a clear indication of New Physics.Many New Physis models predict strong enhancement of violating decays of μ and τ. In many models measurable and even quite large τ BR [O(10^{-8})] are expected.

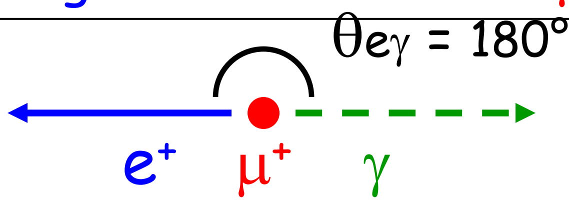
History of Lepton Flavor Violation Searches no tau



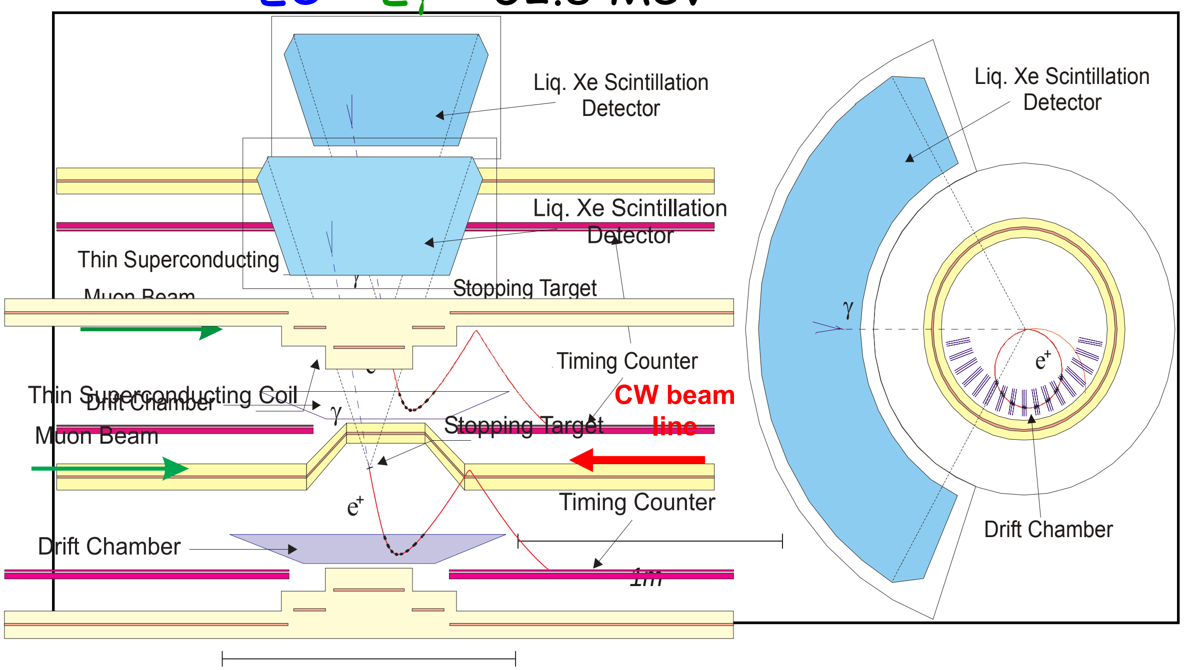
MEG: $\mu \rightarrow e\gamma$ search at PSI: sensitive to 10^{-13} BRs

SUSY SU(5) predictions	SUSY SO(10) predictions
$BR(\mu \rightarrow e\gamma) \approx 10^{-14} \div 10^{-13}$	$BR_{SO(10)} \approx 100\ BR_{SU(5)}$

Easy signal selection with μ^+ at rest



$E_e = E_\gamma = 52.8$ MeV



Detector outline

- Stopped beam of $3\ 10^7\ \mu$ /sec in a 150 μm target

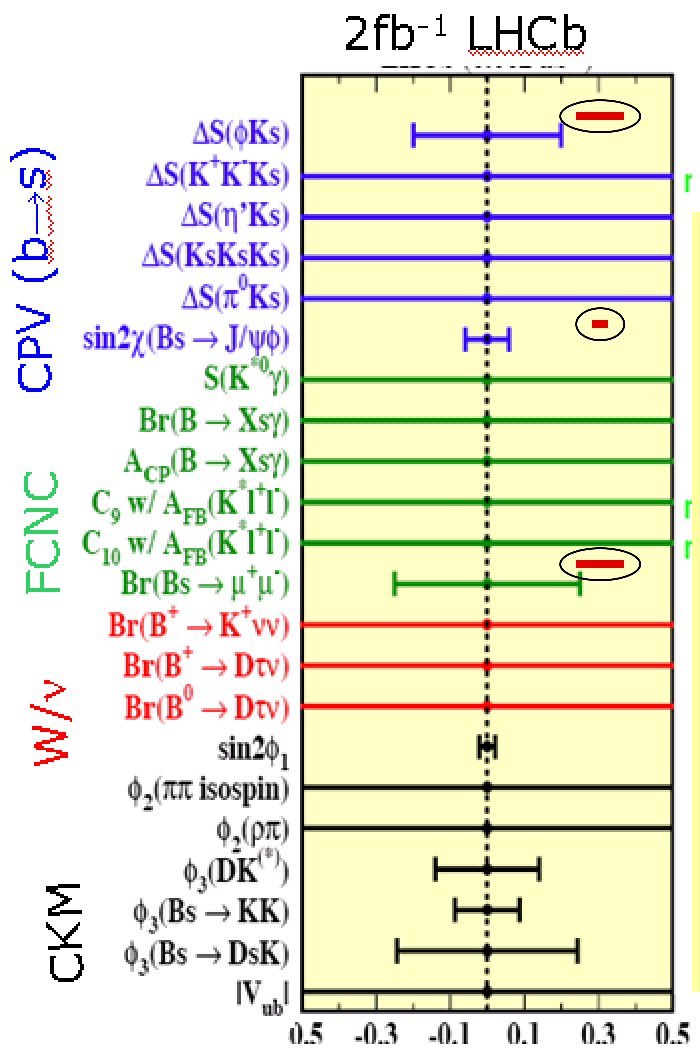
Photon detector

- Liquid Xenon calorimeter for γ detection (scintillation)
  - fast: 4 / 22 / 45 ns
  - high LY: ~ 0.8 * NaI
  - short X_0: 2.77 cm
- 1 MeV Cockroft-Walton for continuous calorimeter calibration

Positron spectrometer

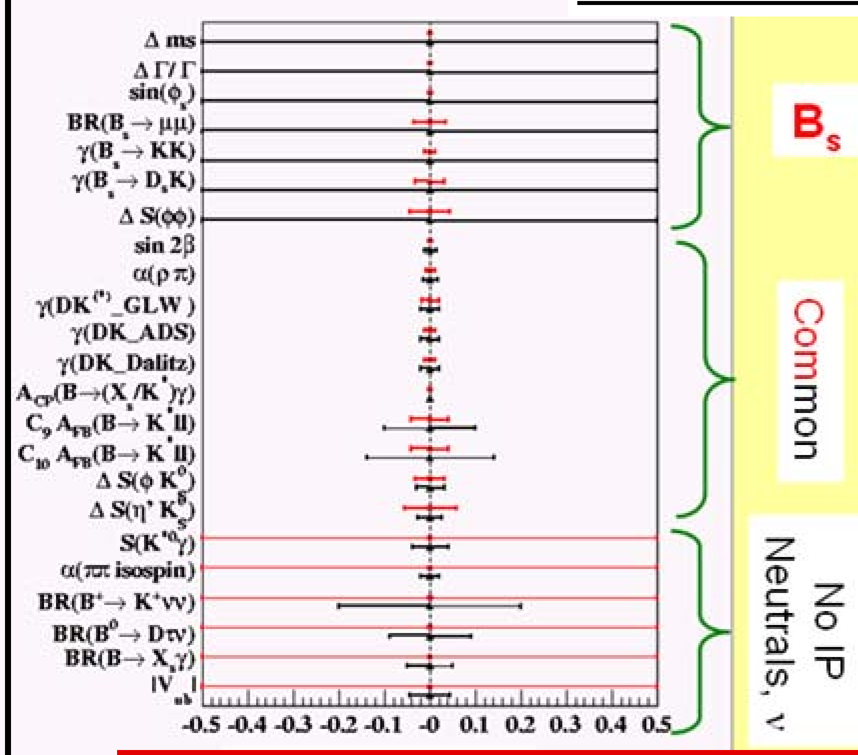
- Solenoid spectrometer & drift chambers for e^+ momentum
- Scintillation counters for e^+ timing

From LHCb, expect:



LHC upgrade with 100fb^{-1}

Observable	Sensitivity
$S(B_s \to \phi\phi)$	$0.01 - 0.02$
$S(B_d \to \phi K^0_S)$	$0.025 - 0.035$
$\phi_s\ (J/\psi\phi)$	0.003
$\sin(2\beta)\ (J/\psi K^0_S)$	$0.003 - 0.010$
$\gamma\ (B \to D^{(*)}K^{(*)})$	$< 1^\circ$
$\gamma\ (B_s \to D_s K)$	$1 - 2^\circ$
$\mathcal{B}(B_s \to \mu^+\mu^-)$	$5 - 10\%$
$\mathcal{B}(B_d \to \mu^+\mu^-)$	3σ
$A_T^{(2)}(B \to K^{*0}\mu^+\mu^-)$	$0.05 - 0.06$
$A_{FB}(B \to K^{*0}\mu^+\mu^-)\ s_0$	$0.07\ \mathrm{GeV}^2$
$S(B_s \to \phi\gamma)$	$0.016 - 0.025$
$A^{\Delta\Gamma_s}(B_s \to \phi\gamma)$	$0.030 - 0.050$
charm x'^2	2×10^{-5}
mixing y'	2.8×10^{-4}
CP y_{CP}	1.5×10^{-4}



Only LHCb

F.Muheim

SuperLHCb vs. SuperB at 50 ab^{-1}

Marcello A. Giorgi

Super flavor factory projects

Machine project	Cms Energy (GeV)	Mode	Polarization of e^- beam >80% for τ	Luminosity ($cm^{-2}\ s^{-1}$)
Super c-τ BINP (Russia)	$3.0 \div 4.5$	Symmetric	Yes	$1 \div 2\ 10^{35}$
SuperKEKB (Japan)	10.58	Asymmetric	No	$2 \div 8\ 10^{35}$
Super*B*- Roma	10.58 4.0	Asymmetric	Yes	$1 \div 4\ 10^{36}$

Super*B* *is expected to integrate 75 ab*$^{-1}$ *in 5 years*

B Physics @ Y(4S)

	ab^{-1})	SuperB (75 ab^{-1})
in(2β) $(J/\psi K^0)$	0.018	0.005 (†)
os(2β) $(J/\psi K^{*0})$	0.30	0.05
in(2β) (Dh^0)	0.10	0.02
os(2β) (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 (∗)
$S(K^0_S K^0_S K^0_S)$	0.15	0.02 (∗)
$S(K^0_S \pi^0)$	0.15	0.02 (∗)
$S(\omega K^0_S)$	0.17	0.03 (∗)
$S(f_0 K^0_S)$	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° (∗)
$2\beta+\gamma$ $(D^{(*)\pm}\pi^\mp,\ D^\pm K^0_S \pi^\mp)$	20°	5°

Observable	B Factories (2 ab^{-1})	SuperB (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%
$\mathcal{B}(B \to K\nu\bar{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

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}	
$D^0 \to K^0_S\pi^+\pi^-$	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}
$D^0 \to K^0_S e^+e^-$, $D^0 \to K^0_S\mu^+\mu^-$	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}
$D^0 \to K^0_S e^\pm\mu^\mp$	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}

τ Physics

s	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}
$\mathcal{B}(\tau \to \ell K^0_S)$	2×10^{-10}

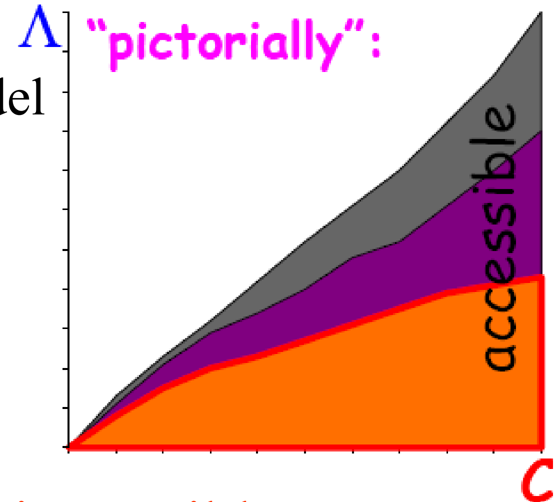
B_s Physics @ Y(5S)

	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°
$A^s_{\rm SL}$	0.006	0.004
$A_{\rm CH}$	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°

Marcello A. Giorgi

High Luminosity potential

- Flavour precision measurements sensitive to New Physics (NP)
  - Measure interference effect in known processes
  - Measure decays: rare or forbidden in Standard Model
- NP effects governed by
  - New Physics Scale NP(Λ)
  - Effective coupling C
    - Different Intensities (from interactions)
    - Different Patterns (for instance from simmetries)



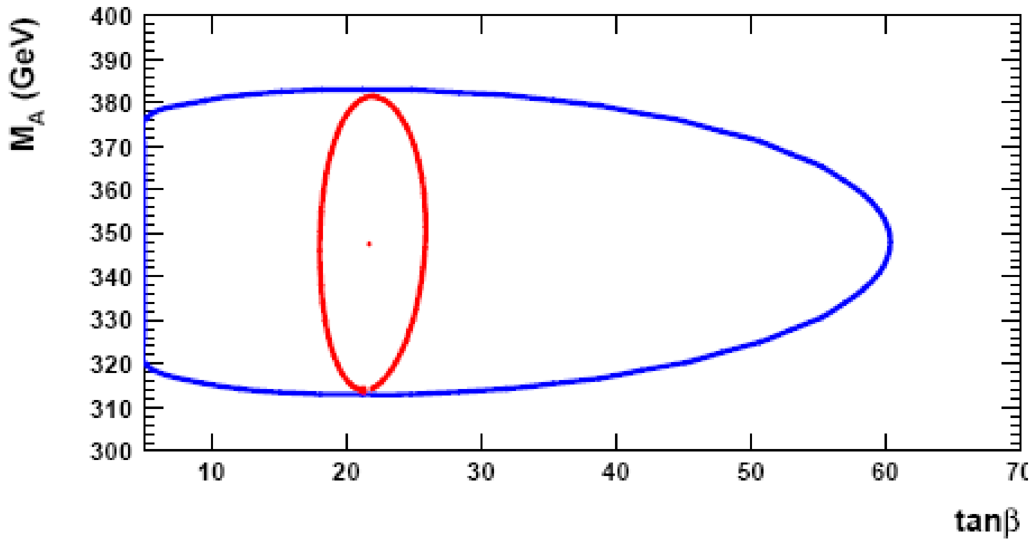
With 7-10x1010 pair bb, cc, ττ (75-100 ab^{-1}) it is possible

NP(Λ) found at LHC
- Determine couplings FV e CPV of NP
- Look for heavier states
- Study the flavour structure of NP

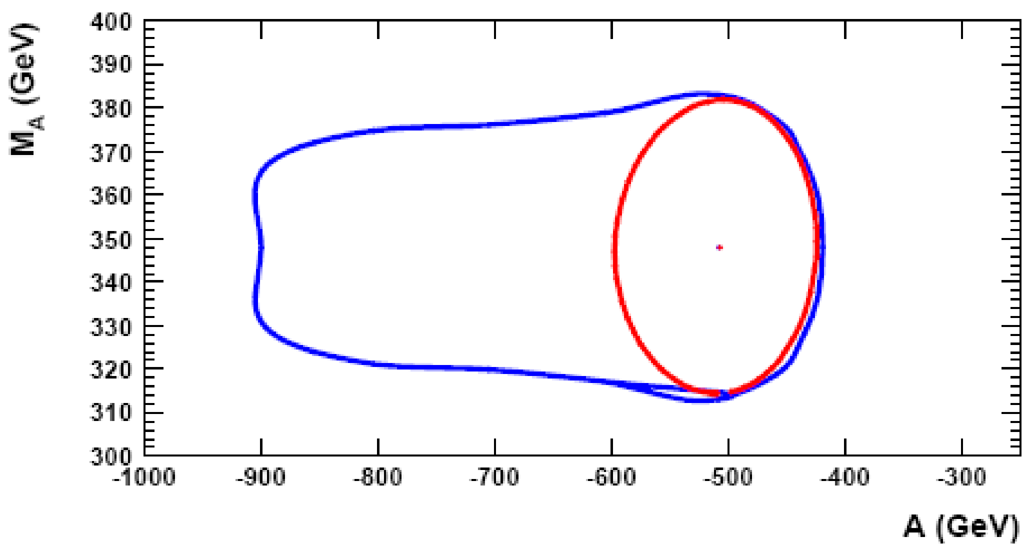
NP(Λ) not found at LHC
- Look for indirect signals of NP
- Link them to explaining NP models
- Constrain regions in parameter space with NP(Λ) sensitivity up several tens of TeV.

Some channels as τ LFV clear segnals of NP

COMPLEMENTARY: LHC and Flavour with 75 ab^{-1}



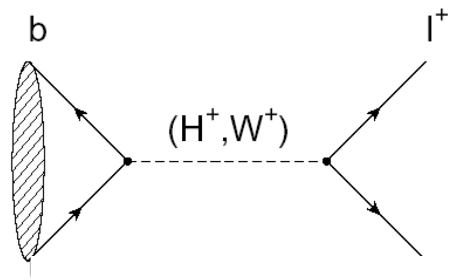
IF LHC DISCOVERS SUPERSYMMETRY



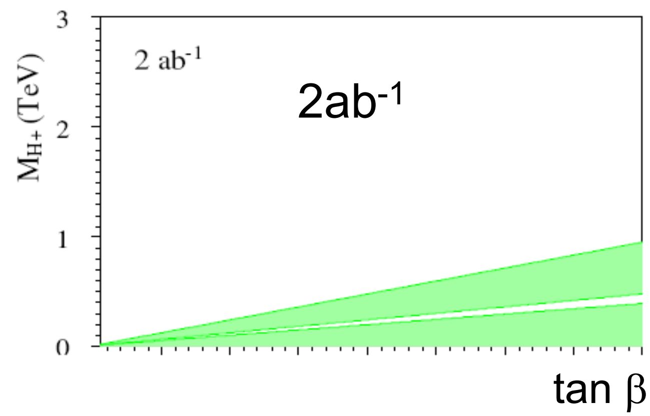
Red are LHC+EW constraints+SuperB

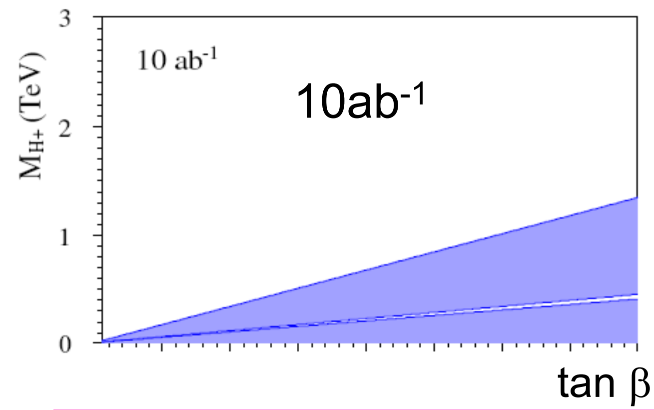
Blue is LHC alone

Higgs-mediated NP in MFV at large tanβ



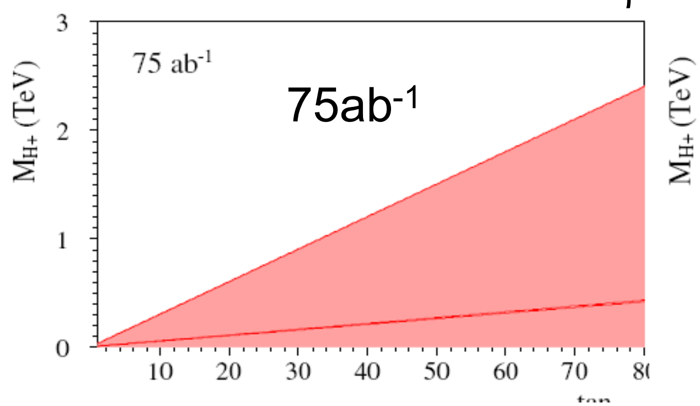
$$BR(B\to\tau\nu)=BR_{SM}(B\to\tau\nu)\left(1-\frac{m_B^2}{M_H^2}\tan^2\beta\right)^2$$





2ab^{-1}

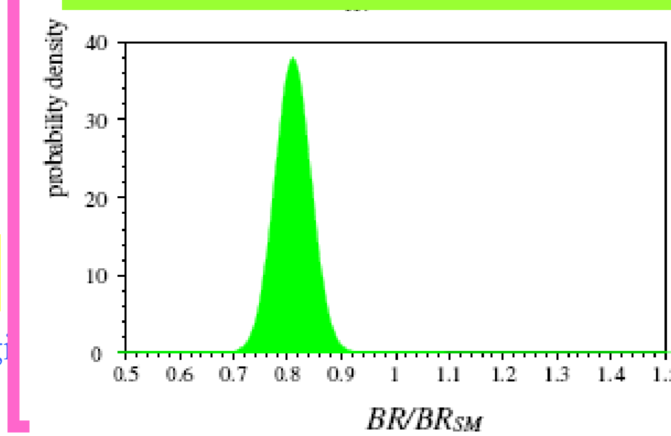
M_H~0.4-0.8 TeV for tanβ~30-60



SuperB -75ab^{-1}

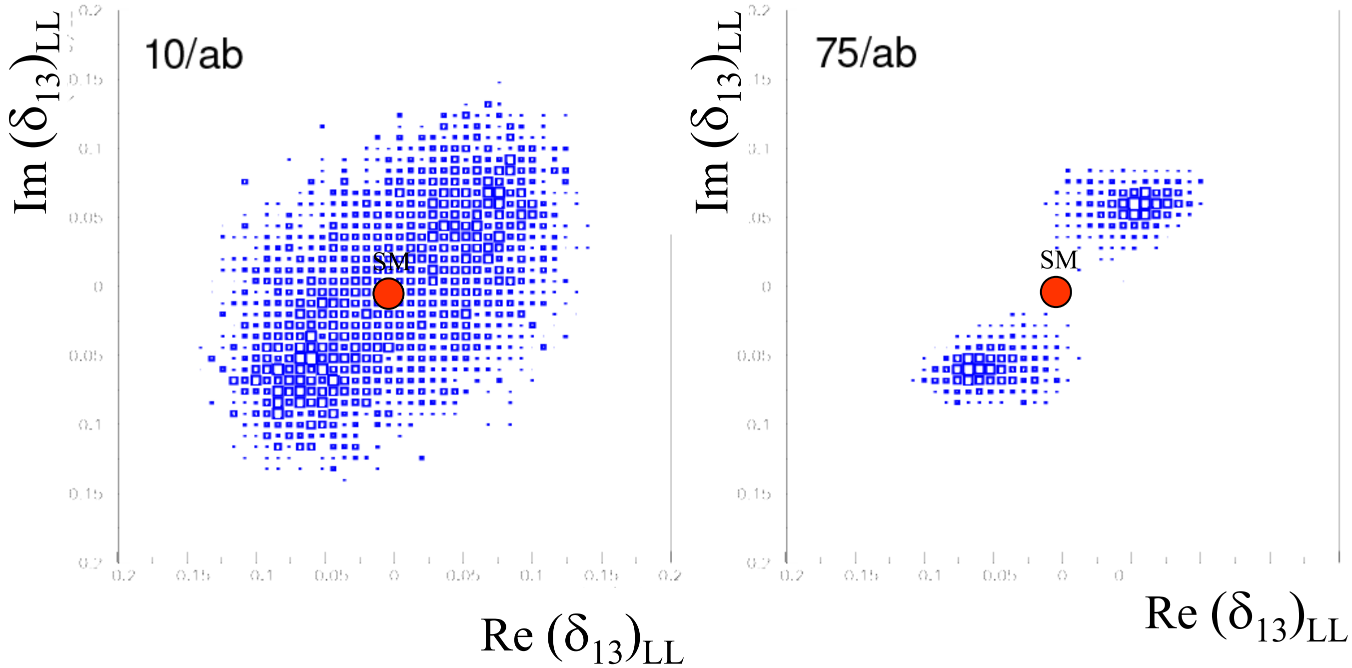
M_H~1.2-2.5 TeV for tanβ~30-60

How signal would like with MH=350GeV



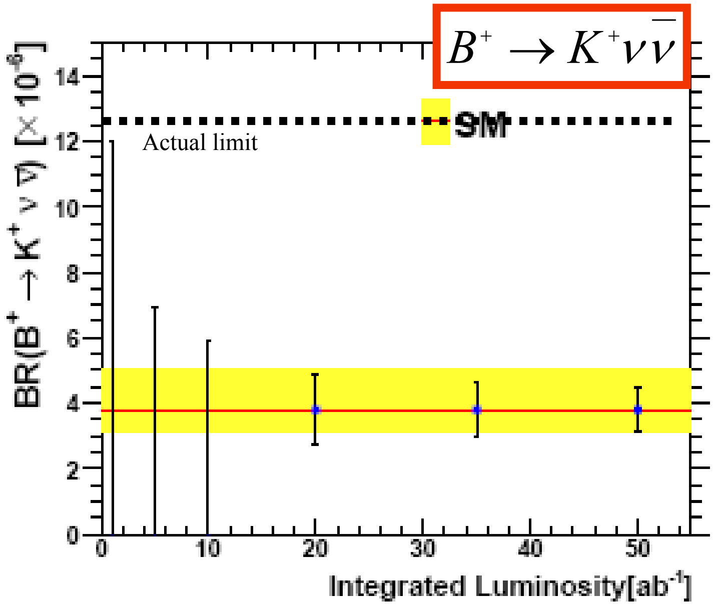
Importance of having very large sample ≥75ab^{-1}

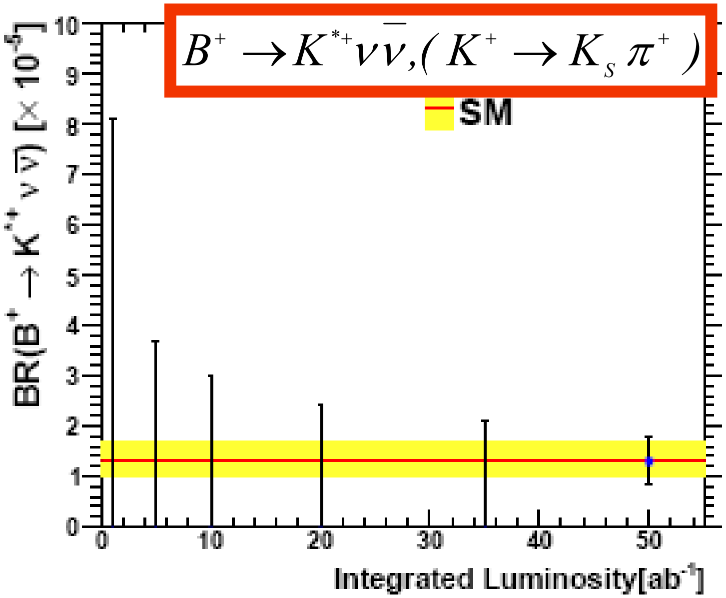
Determination of coupling [in this case : $(\delta_{13})_{LL}$] with 10 ab^{-1} and 75 ab^{-1}



Importance of having very large sample >75ab^{-1}

Some comparison: Current→ $10ab^{-1}$→ $75ab^{-1}$

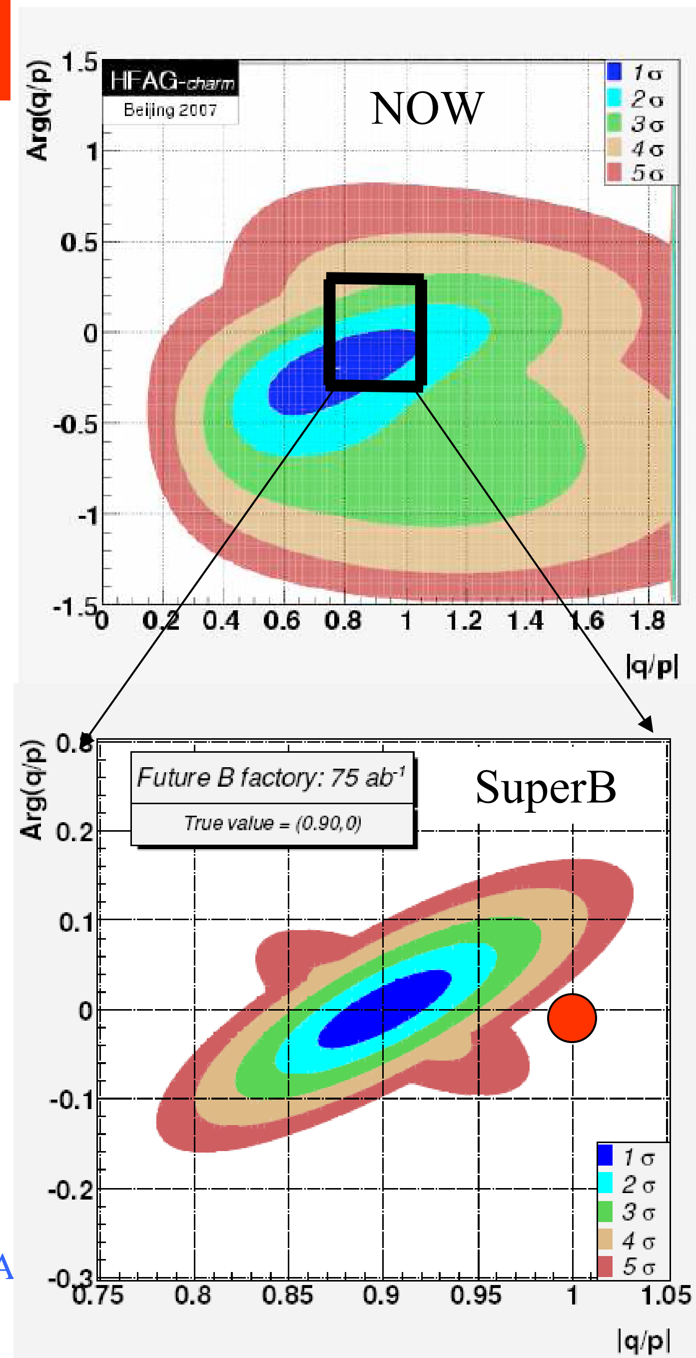




Mode	Sensitivity		
	Current	Expected (10 ab^{-1})	Expected (75 ab^{-1})
$\mathcal{B}(B \to X_s\gamma)$	7%	5%	3%
$A_{CP}(B \to X_s\gamma)$	0.037	0.01	0.004–0.005
$\mathcal{B}(B^+ \to \tau^+\nu)$	30%	10%	3–4%
$\mathcal{B}(B^+ \to \mu^+\nu)$	not measured	20%	5–6%
$\mathcal{B}(B \to X_s l^+l^-)$	23%	15%	4–6%
$A_{\rm FB}(B \to X_s l^+l^-)_{s_0}$	not measured	30%	4–6%
$\mathcal{B}(B \to K\nu\bar{\nu})$	not measured	not measured	16–20%
$S(K_S^0\pi^0\gamma)$	0.24	0.08	0.02–0.03

CP Violation in charm from mixing

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}	
	$\|q/p\|$	3×10^{-2}	
	ϕ	2°	
$\psi(3770) \to D^0\overline{D}^0$	x^2		$(1-2) \times 10^{-5}$
	y		$(1-2) \times 10^{-3}$
	$\cos\delta$		$(0.01-0.02)$



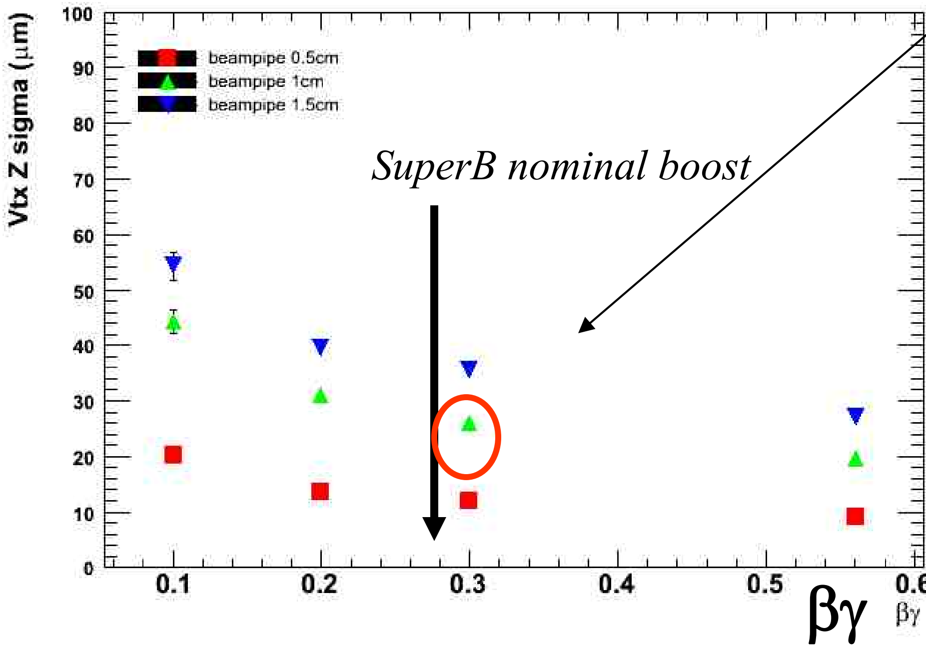
Achievable in SuperB but also in 10^{35} Super τ charm

Charm

- Charm events at threshold are very clean: pure DD, no additional fragmentation
- High signal/bkg ratio: optimal for decays with neutrinos.
- Quantum Coherence: new and alternative CP violation measurement wrt to $\Upsilon(4S)$. Unique opportunity to measure D^0-D^0 relative phase.
- Increased statistics is not an advantage running at threshold: cross-section 3x wrt 10GeV but luminosity 10x smaller.
- SuperB lumi at 4 GeV = 10^{35} $cm^{-2}s^{-1}$ produces ~10^9 DD pairs per month of running. (using Cleo-c cross-section measurement $[\sigma(e^+e^- \rightarrow D^0D^0) \sim 3.6$ nb $] + [\sigma(e^+e^- \rightarrow D^+D^-) \sim 2.8$ nb$] \sim 6.4$ nb)
- Time-dependent measurements at 4 GeV **only** possible at SuperB to extract Phase .

Time dependent measurements at DD threshold: only possible at SuperB

- Proper time resolution dominated by decay vertex resolution.
  - Production vertex precisely determined thanks to nm beamspot dimensions



With Super*B* lumi at 4 GeV = 10^{35} cm^{-2}s^{-1} expected ~10^9 $D\bar{D}$ per month

$\beta\gamma ct = 0.28 \times 120\ \mu m \sim 30 \mu m$

Average flight distance similar to vertex resolution $\rightarrow \sigma_t \sim \tau$

SuperB is also a τ factory → golden measurement LFV

(Complementarity with $\mu \to e\gamma$)

Process	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}

90% CL limits

Belle:

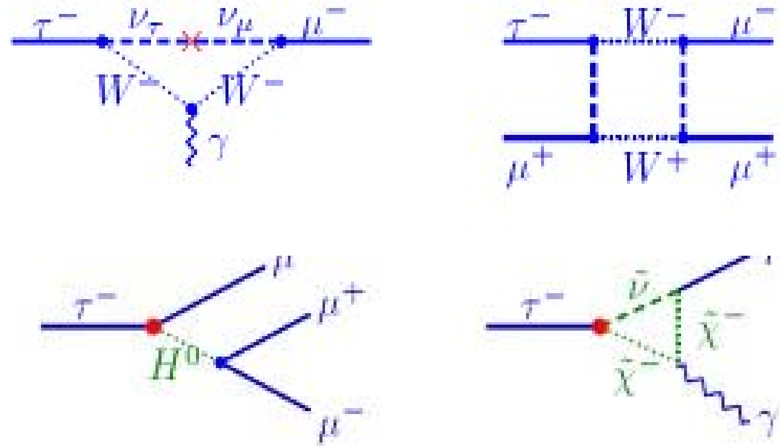
$Br(\tau^- \to e^-\gamma) < 12 \times 10^{-8}$

$Br(\tau^- \to \mu^-\gamma) < 4.1 \times 10^{-8}$

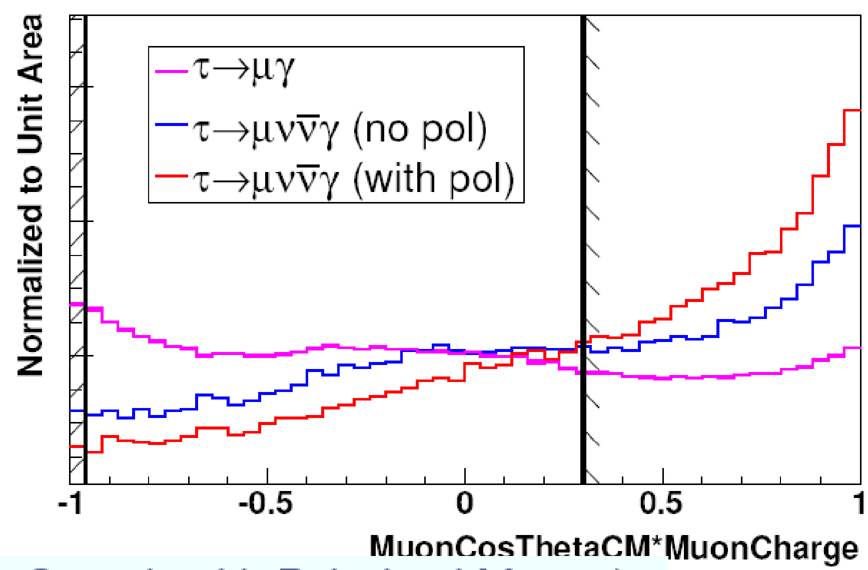
BaBar:

$Br(\tau^- \to e^-\gamma) < 11 \times 10^{-8}$

$Br(\tau^- \to \mu^-\gamma) < 6.7 \times 10^{-8}$



Further improvements if polarized beams.



Optimization of BKG rejection is in progress. Pol. Helps also to discriminate models. In some model there is a strong effect on the angular distribution of μ from signal:

(see hep-ph/9604296, Y.Kuno, Y.Okada, $\mu \to e\gamma$ Search with Polarized Muons)

Comparison with Snowmass points on Tau using also Polarization

SuperB with 75 ab-1, evaluation assuming the most conservative scenario about syst. errors

1 a	250	100	-100	10	>0
1 b	400	200	0	30	>0
2	300	1450	0	10	>0
3	400	90	0	10	>0
4	300	400	0	50	>0
5	300	150	-1000	5	>0

- NP predictions for experimentally constrained SUSY in a number of standard scenarios B.C.Allanach *et al.*, hep-ph/0202233

LFV	Snowmass points predictions						Super*B*	
	1 a	1 b	2	3	4	5	90% UL	**5σ disc**
$\mathrm{BF}(\tau \to \mu\gamma) \times 10^{-9}$	4.2	7.9	0.18	0.26	97	0.019	**1÷2**	5
$\mathrm{BF}(\tau \to 3\mu) \times 10^{-12}$	9.4	18	0.41	0.59	220	0.043	200	880

SuperKEKB worse by a factor 2.5 and 4.5 in $\tau \to \mu\gamma$ and >5 in $\tau \to 3\mu$

Tau g-2

Start with the expt. with μ

$$\Delta a_\mu = a_\mu^{exp} - a_\mu^{SM} \approx (3 \pm 1) \times 10^{-9}$$

assume Super*B* at 75 fb^{-1}, 80% e^- beam polarization

extend to all tau decay channels

combine 2 measurement methods for Re$\{F_2\}$

studies on simulated events show no limiting syst. effects

	Snowmass points predictions						Super*B*
	1 a	1 b	2	3	4	5	exp. resolution
$\Delta a_\mu \times 10^{-9}$	3.1	3.2	1.6	1.4	4.8	1.1	
$\Delta a_\tau \times 10^{-6}$	0.9	0.9	0.5	0.4	1.4	0.3	**<1**

SuperKEKB, without beam polarization, expected worse by factor ≈ 10, and worse systematics

Make use of all the informations (total x-section,angular distribution, f-b asymmetry.
Measure Re and Im parts

Luminosity

For gaussian bunches:

$$\mathcal{L} = f_{\text{coll.}} \times \frac{N_{e^+} N_{e^-}}{4\pi \sigma_x \sigma_y} \times R_l$$

geometrical Reduction factor

N_e^+ (N_e^-) is the number of positrons (electrons) in a bunch

f_{coll} is the collision frequency

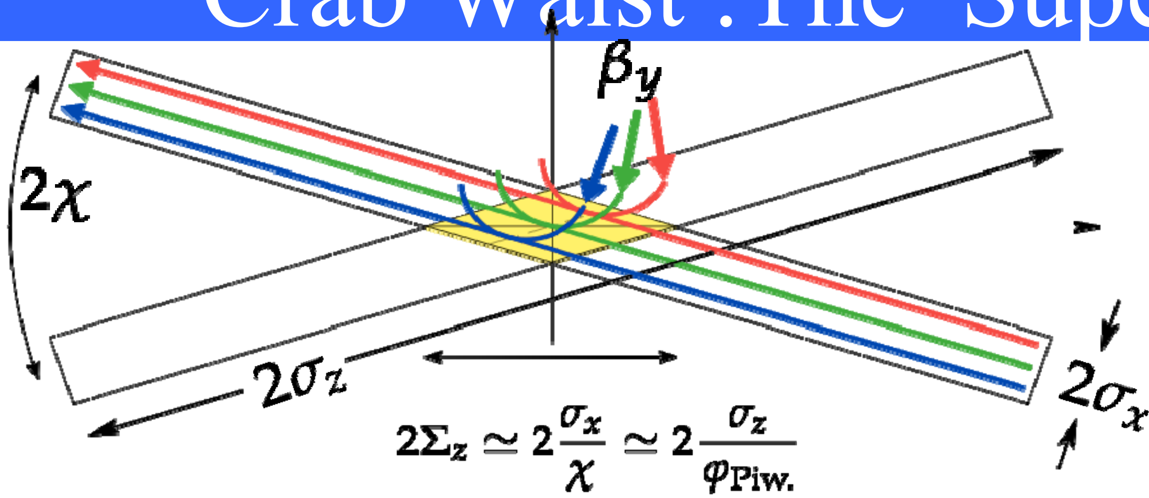
σ_x (σ_y) is the horizontal (vertical) r.m.s. size at the I.P.

R_l is the Luminosity Reduction factor by incomplete overlap: crossing angle and "hour glass" effect.

•TRADITIONAL (brute force): increase the numerator Currents increase: from 1A on 2 A up to 4.1 A on 9.4 A- **Wall Plug Power**, HOM,CSR: hard to surpass 5 10^{35} cm^2s^{-1} **Crab <u>Crossing</u>** to increase $\mathbf{R_l}$ and to optimize beam dynamic

•Super*B*: decrease the denominator (same currents as PEP-II) Bunch sizes: from $\sigma_y = 3\mu m$ down to σ_y = 40 nm Luminosity: 10^{36} cm^2s^{-1} (baseline) . **Crab <u>Waist</u>** and large **Piwinsky** angle to optimize beam dynamic

Crab Waist :The SuperB solution



- Crab waist: modulation of the y-waist position, particles collides a same β_y realized with a sextupole upstream the IP.
- Minimization of nonlinear terms in the beam-beam interaction: reduced emittance growth, suppression of betatron and sincro-betatron coupling
- Maximization of the bunch-bunch overlap: luminosity gain
- Low wall power

SuperB and Super c-τ are based on the crabwaist concept invented in 2006 by P.Raimondi in 2006.

TESTED IIN LNF WITH DAFNE (500 MeV beams)

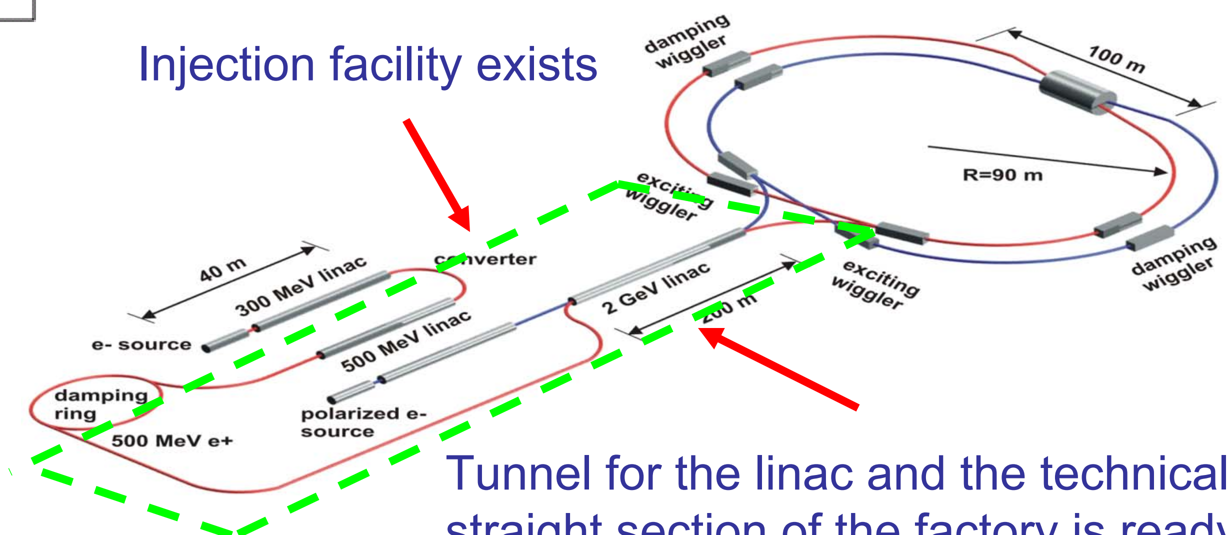
Layout of Novosibirsk Project based on Crab Waist Concept

From the talk by Anton Bogomyagkov

Tune shift ξ_y	0.13
Particles per bunch	$7 \cdot 10^{10}$
Luminosity, $\mathrm{cm}^{-2}\mathrm{sec}^{-1}$	$1 \cdot 10^{35}$
Hour glass $\frac{\sigma_x}{\theta \beta_y}$	1.095
Piwinski angle $\varphi = \frac{\sigma_z \theta}{\sigma_x}$	12.021

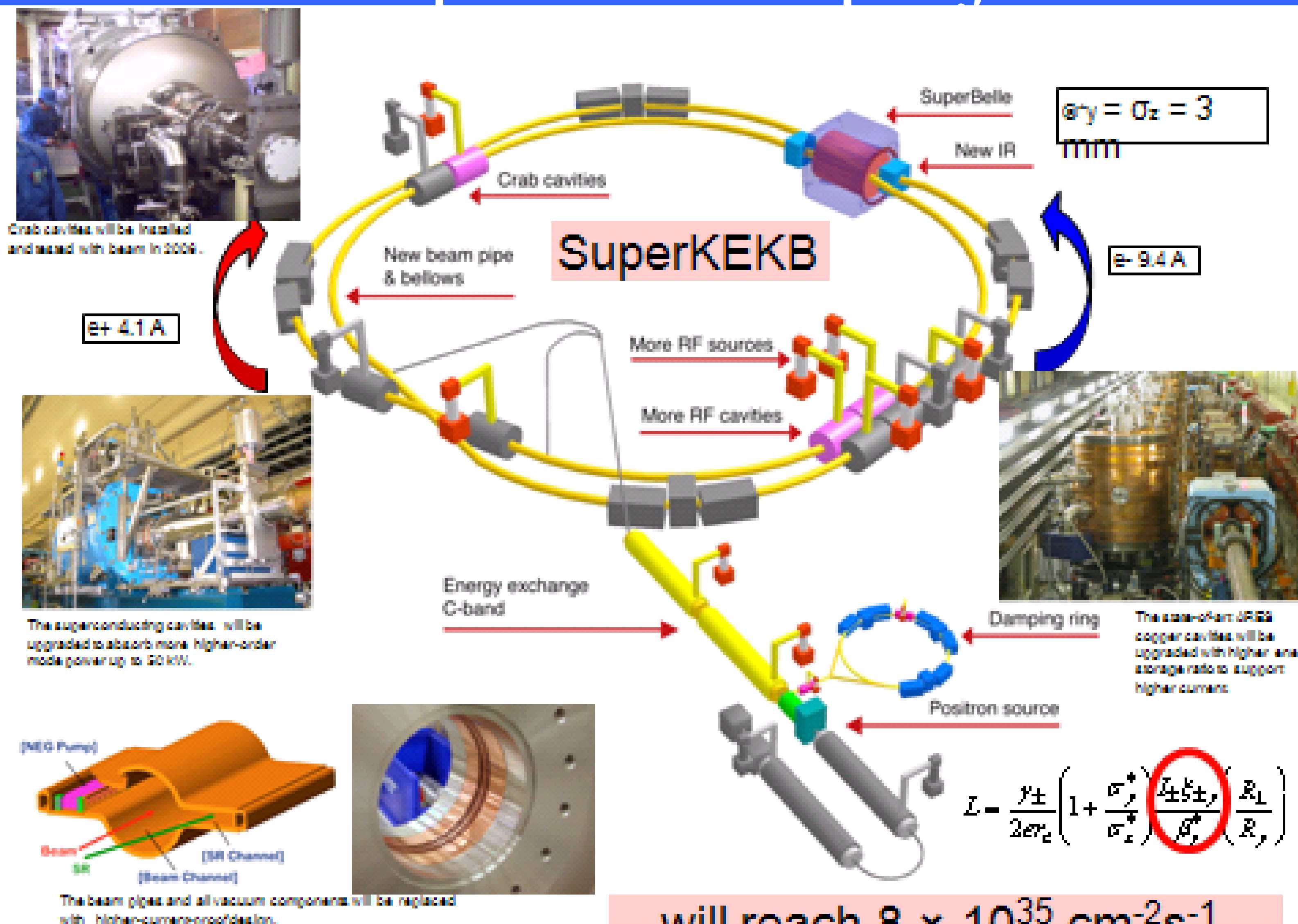
Energy, GeV	2
Beam current, A	1.36
Number of bunches	295
β_x, mm	20
β_y, mm	0.76
ε_x, nm rad	10
Coupling $\varepsilon_y/\varepsilon_x$, %	1
Beam length σ_z, cm	1
Crossing angle, mrad	34

Injection facility exists



Tunnel for the linac and the technical straight section of the factory is ready

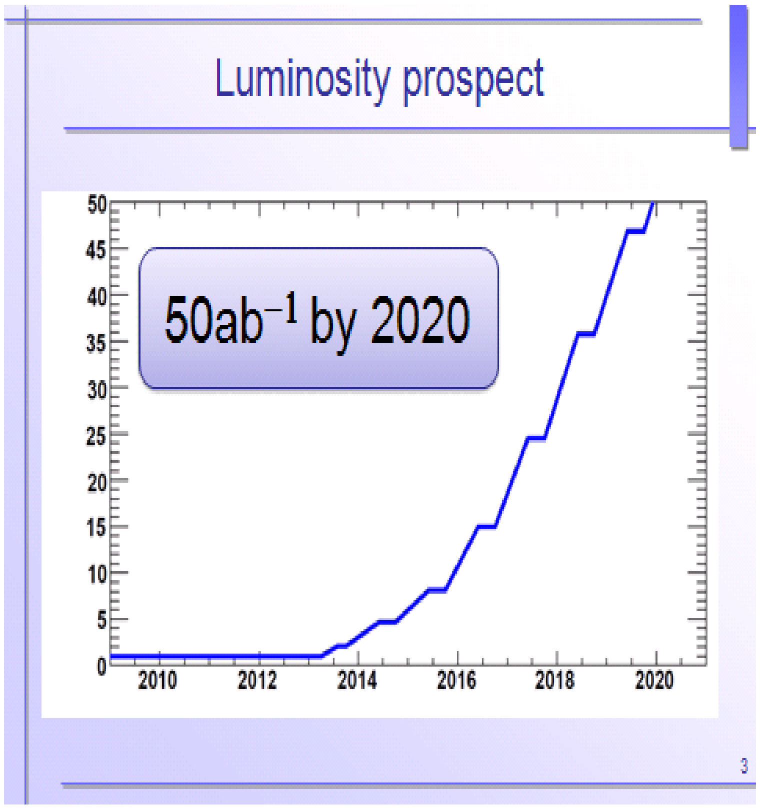
SuperKEKB project



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

will reach 8×10^{35} cm^{-2}s^{-1}.

SuperKEKB

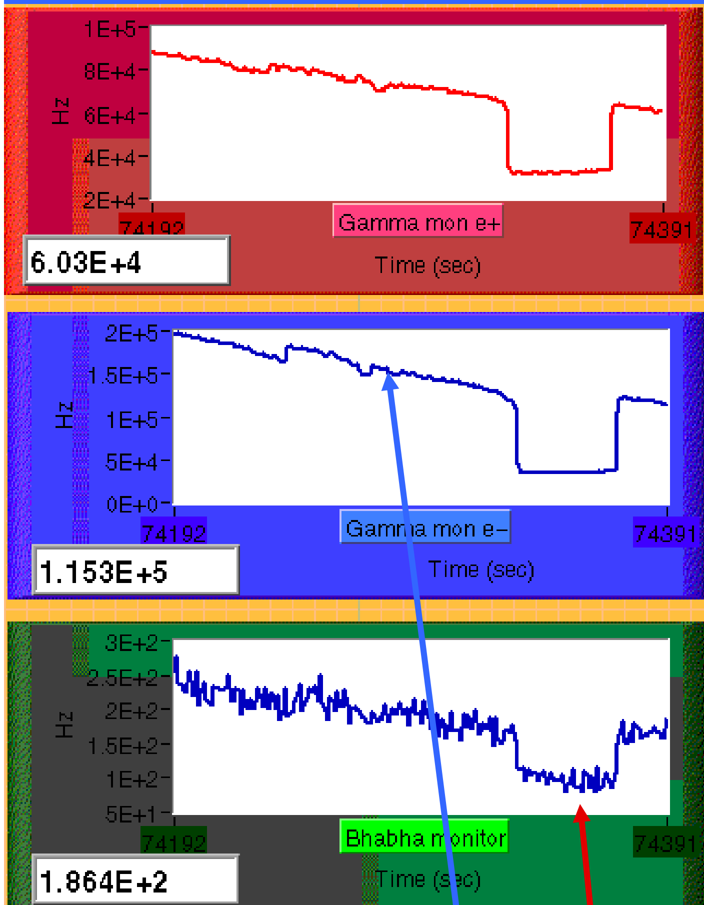


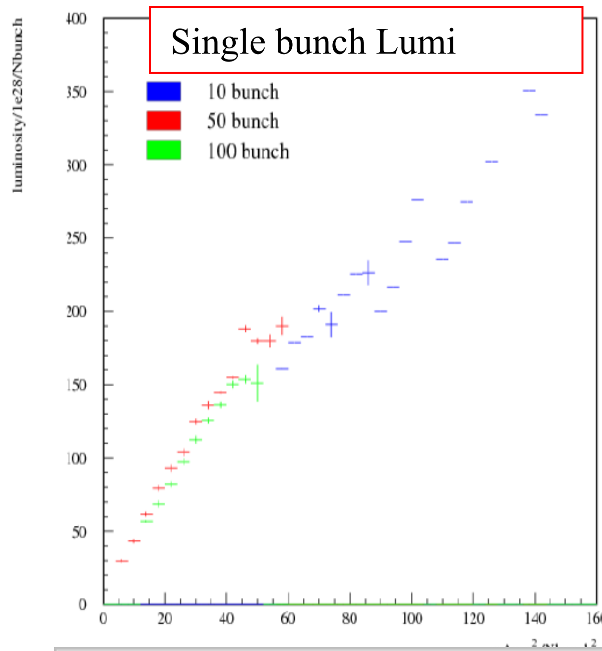
Machine Parameters of SuperKEKB

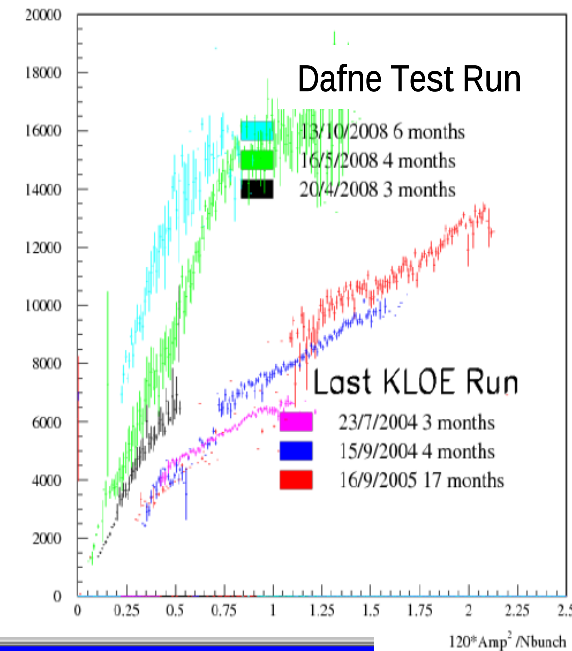
	symbol	LER	HER	unit
Beam Energy	E	3.5	8.0	GeV
Beam current	I	9.4	4.1	A
Circumference	C	3016		m
Number of bunches	n_b	5018		
Number of particles	N/bunch	11.8	5.1	$\times 10^{10}$
Emittance	ε_x	9		nm
Emittance ratio	$\varepsilon_y/\varepsilon_x$	0.5		%
Beta (hor.) at IP	β_x^*	200		mm
Beta (ver.) at IP	β_y^*	3		mm
Bunch length	σ_z	3		mm
Crossing angle	θ_x^*	30 to 0		mrad
Beam-Beam (hor.)	ξ_x	0.36		
Beam-Beam (ver.)	ξ_y	0.43		
RF AC plug power	P_{AC}	73		MW
Luminosity	L	8.0		$\times 10^{35}$ cm^{-2}s^{-1}

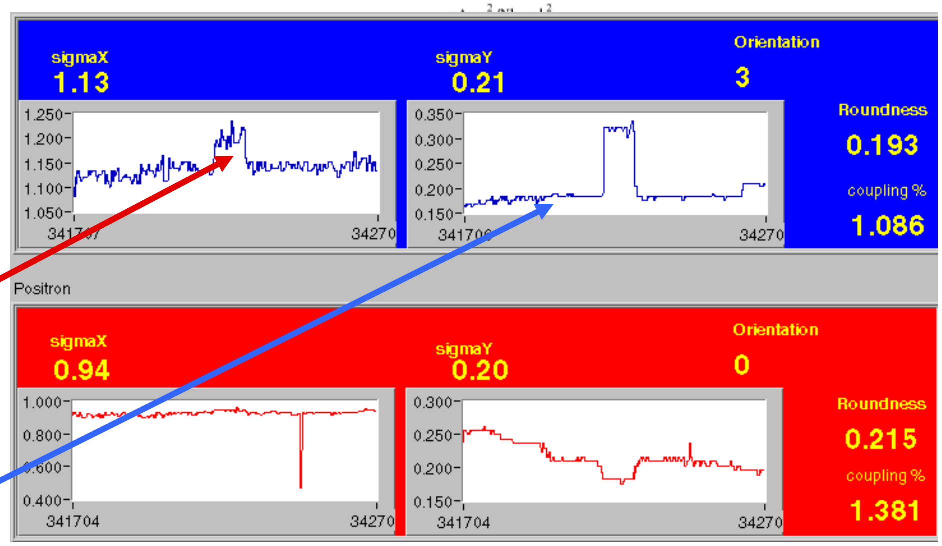
Luminosity stable above 2.0×10^{32} reached

Dafne test (Luminosity)









Crab OFF

Crab ON

Blow-up in beam sizes and decrease Bhabha rates with crab sexts for one ring OFF (other ring ON)

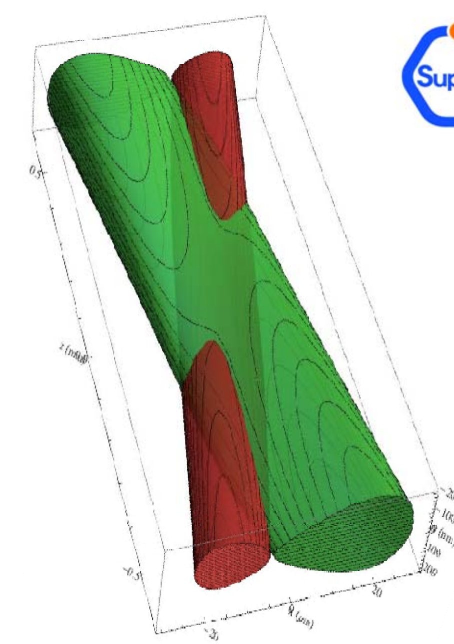
SuperB parameters with higher Wall

PARAMETER	Nominal LER (e+)	Nominal HER (e-)	Upgrade LER (e+)	Upgrade HER (e-)
Energy (GeV)	4	7	4	7
Luminosity x 10^{36}	1.0		2.0	
Circumference (m)	1800	1800		
Revolution frequency (MHz)	0.167			
Eff. long. polarization (%)	0	80		
RF frequency (MHz)	476			
Momentum spread ($x10^{-4}$)	7.9	5.6	9.0	8.0
Momentum compaction ($x10^{-4}$)	3.2	3.8	3.2	3.8
Rf Voltage (MV)	5	8.3	8	11.8
Energy loss/turn (MeV)	1.16	1.94	1.78	2.81
Number of bunches	1251			
Particles per bunch ($x10^{10}$)	5.52			
Beam current (A)	1.85			
Beta y* (mm)	0.22	0.39	0.16	0.27
Beta x* (mm)	35	20		
Emit y (pm-rad)	7	4	3.5	2
Emit x (nm-rad)	2.8	1.6	1.4	0.8
Sigma y* (microns)	0.039	0.039	0.0233	0.0233
Sigma x* (microns)	9.9	5.66	7	4
Bunch length (mm)	5		4.3	
Full Crossing angle (mrad)	48			
Wigglers (#) 20 meters each	0	0	2	2
Damping time (trans/long)(ms)	40/20	40/20	28/14	28/14
Luminosity lifetime (min)	6.7		3.35	
Touschek lifetime (min)	13	20	6.9	10.3
Effective beam lifetime (min)	4.5	5.1	2.3	2.5
Injection rate pps ($x10^{11}$) (100%)	2.6	2.3	5.1	4.6
Tune shift y (from formula)	0.15		0.20	
Tune shift x (from formula)	0.0043	0.0025	0.0059	0.0034
RF Power (MW)	17		25	

150m needed for Polarization

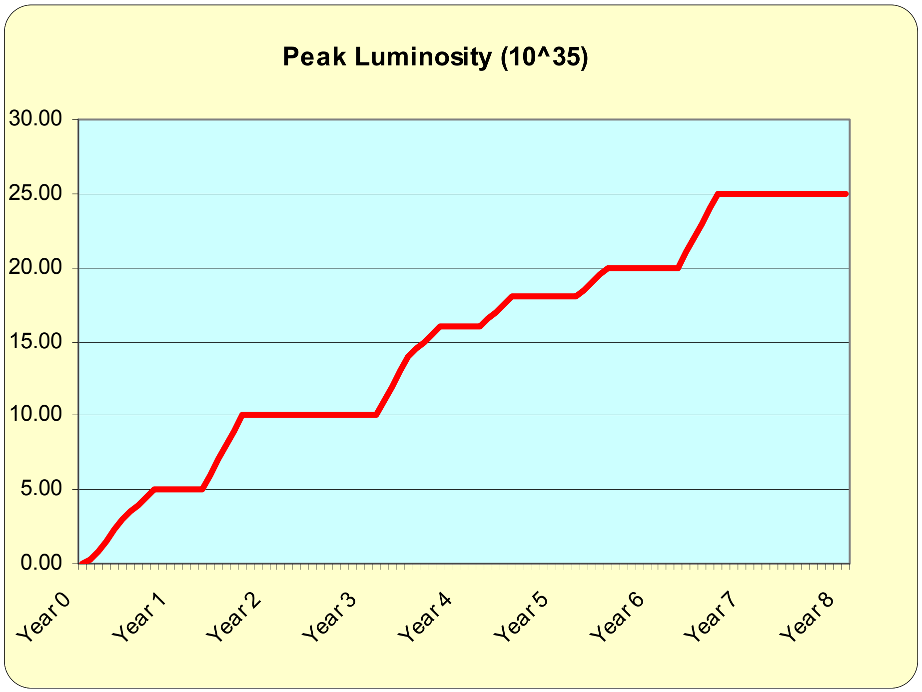
Doubling currents with a factor 2 in Wall power we can double the luminosity

LEB HEB

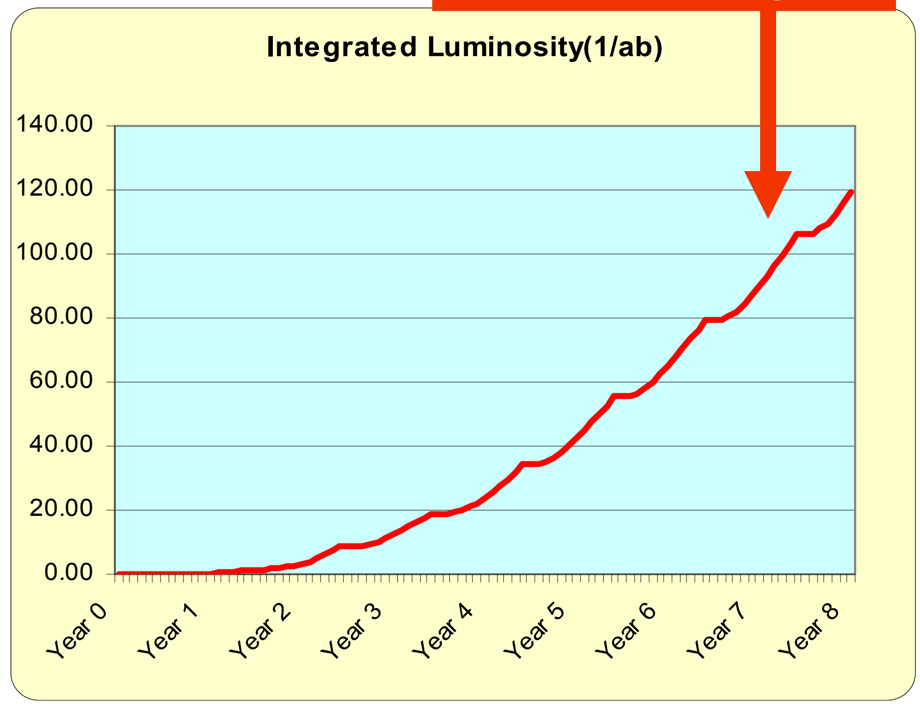


Asymmetric bunch size to optimize beam lifetime (Touschek effect)

SuperB expected LUMI



>80ab-1 in 7th year



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

END

LFV prediction by model

		$\tau \to \mu\gamma$	$\tau \to lll$
SM + ν mixing	Lee, Shrock, PRD 16 (1977) 1444 Cheng, Li, PRD 45 (1980) 1908	10^{-54} – 10^{-40}	10^{-14}
SUSY Higgs	Dedes, Ellis, Raidal, PLB 549 (2002) 159 Brignole, Rossi, PLB 566 (2003) 517	10^{-10}	10^{-7}
SM + heavy Maj ν_R	Cvetic, Dib, Kim, Kim , PRD66 (2002) 034008	10^{-9}	10^{-10}
Non-universal Z'	Yue, Zhang, Liu, PLB 547 (2002) 252	10^{-9}	10^{-8}
SUSY SO(10)	Masiero, Vempati, Vives, NPB 649 (2003) 189 Fukuyama, Kikuchi, Okada, PRD 68 (2003) 033012	10^{-8}	10^{-10}
mSUGRA + Seesaw	Ellis, Gomez, Leontaris, Lola, Nanopoulos, EPJ C14 (2002) 319 Ellis, Hisano, Raidal, Shimizu, PRD 66 (2002) 115013	10^{-7}	10^{-9}

Some predictions are already excluded by the present results.

Some can be tested soon by combined statistics of Babar and Belle