Perspectives at the Superflavor Factories

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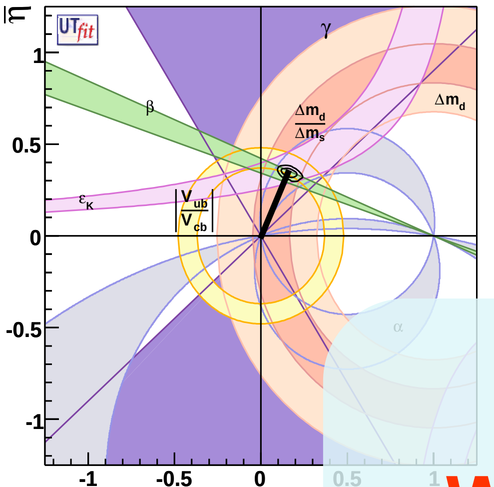
Great achievements from e+e- factories PEPII and KEKB

Flavour Physics was recently in the front line of the stage thanks to the e+ e- factories.

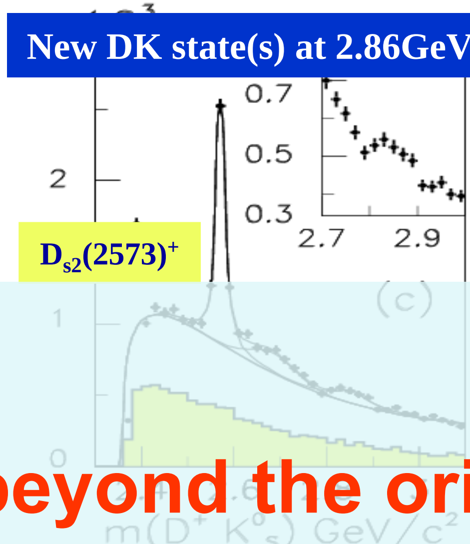
1. 2001 CP violation in B sector from Time dependent analysis
2. 2003 Discovery of new charm particles start a new spectroscopy season with D_{sJ}
3. 2004 Direct CP violation in B sector
4. 2006 Limits on MSSM parameters from $B \rightarrow \tau\nu$
5. 2007 Charm mixing from D^0 D^0bar decay
6. 2008 η_b discovery

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

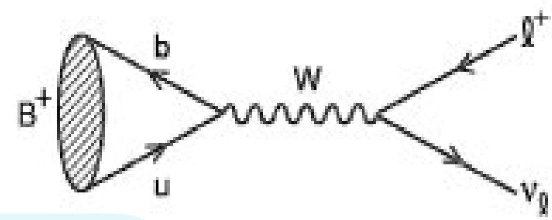
Unitarity Triangle precision measurements

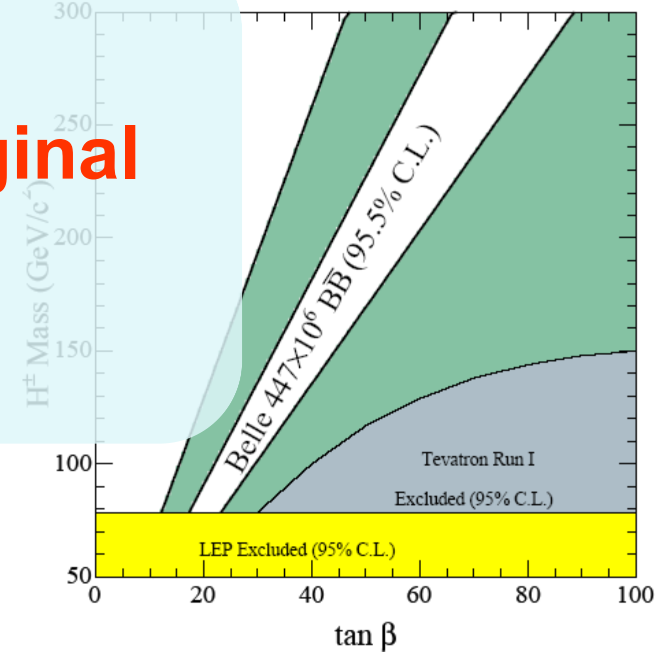


Spectroscopy of new, unexpected states



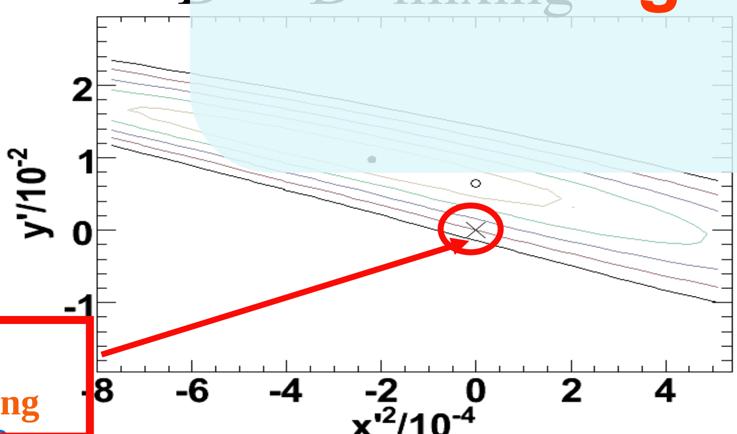
$B \rightarrow \tau\nu$ setting limits on MSSM parameters





Well beyond the original goals

$D^0 - \overline{D}^0$ mixing



No Mixing

Constraints on CKM

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 : $K^+ \to \pi^+ \nu\bar{\nu}$ at Cern(P326), Kloe at upgraded DaΦne, (a K0pi0 like experiment $K_L^0 \to \pi^0 \nu\bar{\nu}$????).

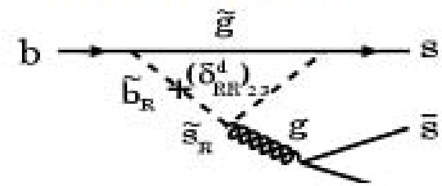
In charm, τ and b:

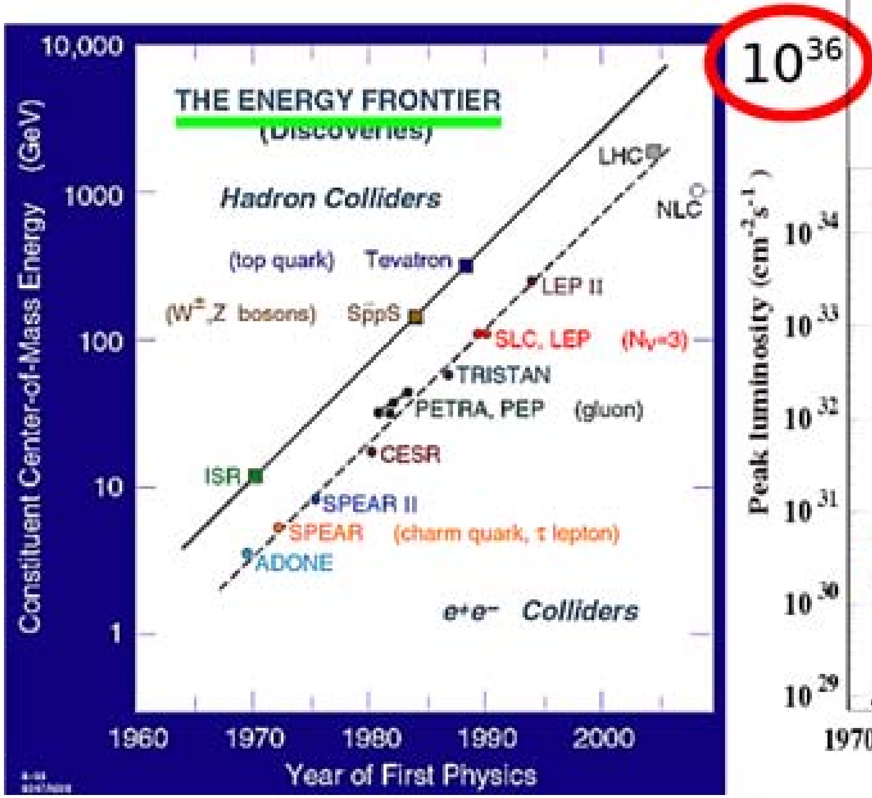
- BES upgrade, KEKB upgrade,
- Super c- τ at Novosibirsk and
- SuperB

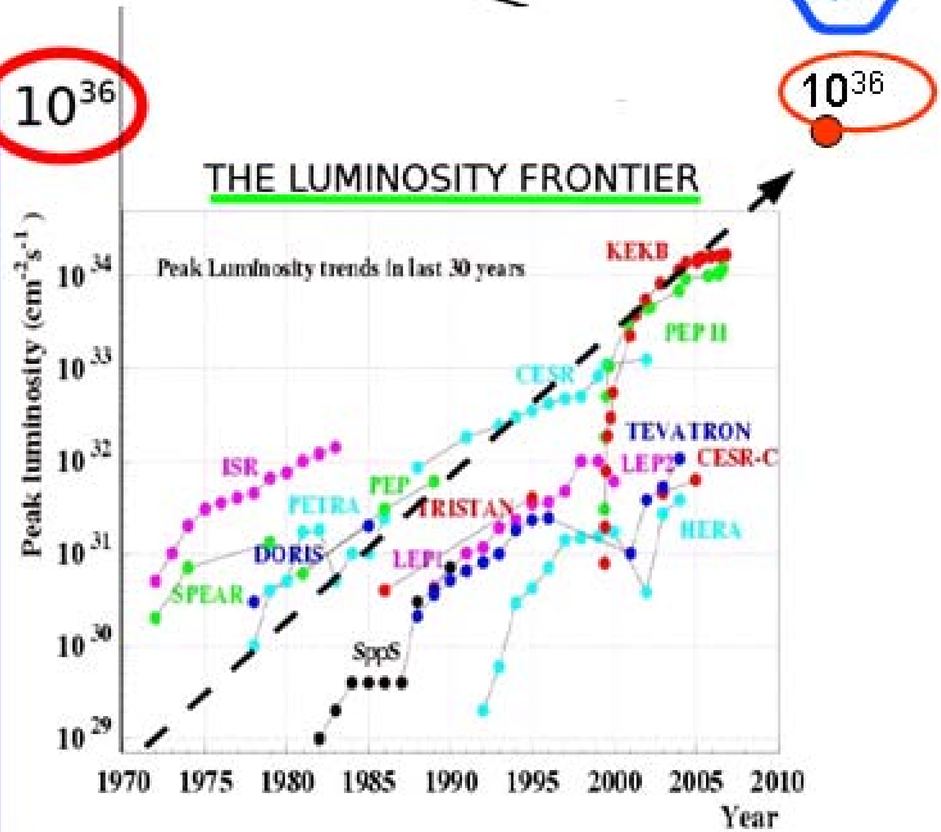
Two frontiers for the exploration of New Physics

Relativistic way

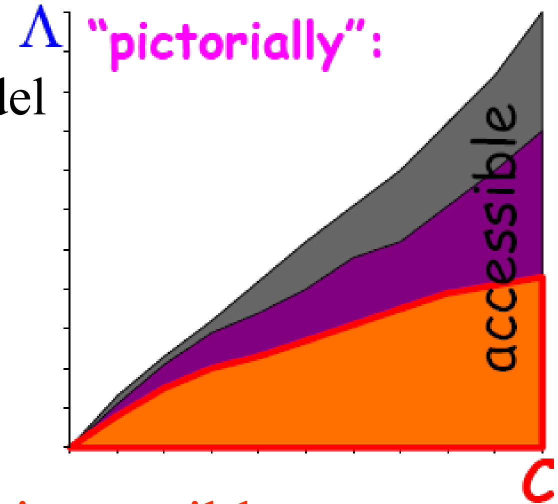
Quantum way







- 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

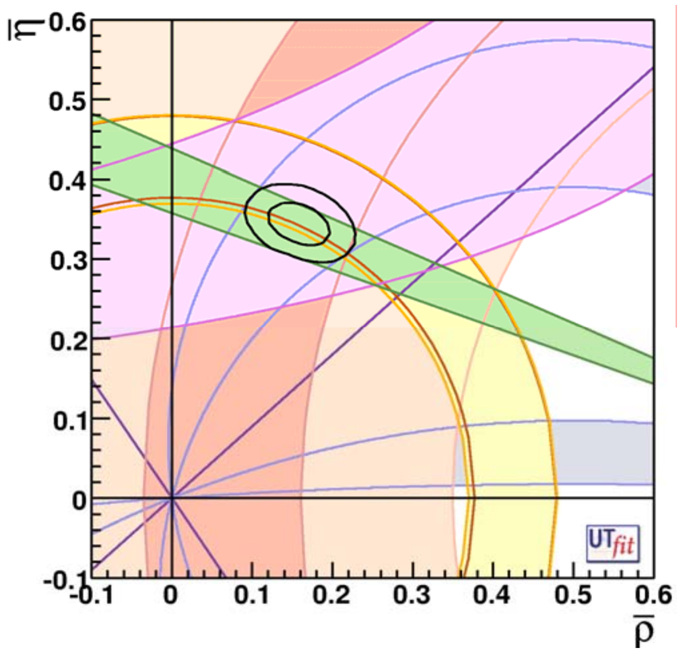
NP(Λ) not found at LHC

- 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.

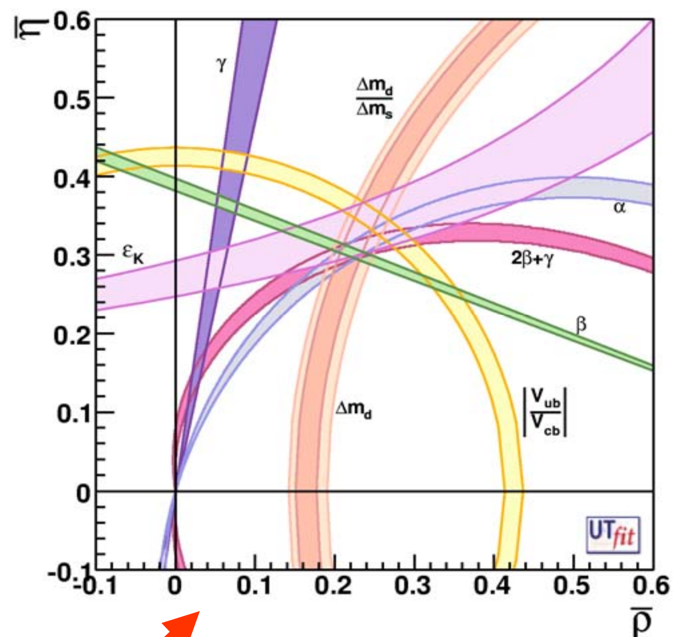
Some channels as τ LFV clear segnals of NP

NP sensitivity with 75 ab^{-1}

Today



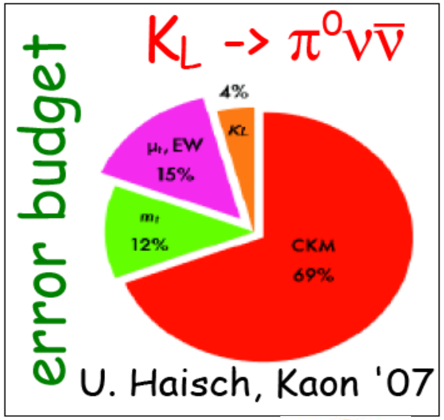
SuperB+Lattice improvements



ρ = 0.163 ± 0.028
η = 0.344± 0.016

ρ = ± 0.0028
η = ± 0.0024

Improving CKM is crucial to look for NP



B Physics @ Y(4S)

Observable	ab^{-1})	Super$B$ (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})	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%
$\mathcal{B}(B \to K\nu\bar{\nu})$	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}
$D^0 \to \pi^0e^+e^-,\ D^0 \to \pi^0\mu^+\mu^-$	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}
$D^0 \to \pi^0e^\pm\mu^\mp$	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)

Observable	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_{SL}	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°

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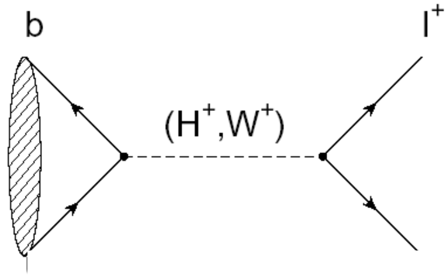
SOME EXAMPLES

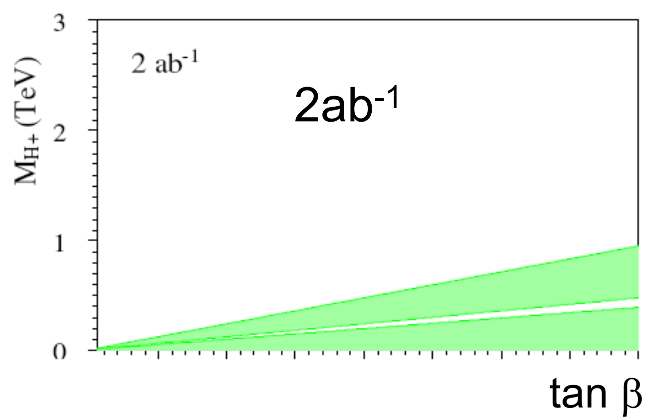
Higgs-mediated NP in MFV at large tanβ

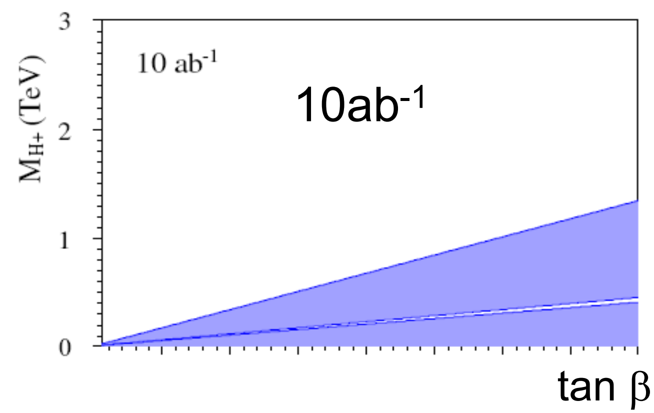


$$BR(B\rightarrow\tau\nu)=BR_{SM}(B\rightarrow\tau\nu)\left(1-\frac{m_B^2}{M_H^2}\tan^2\beta\right)^2$$

2ab-1

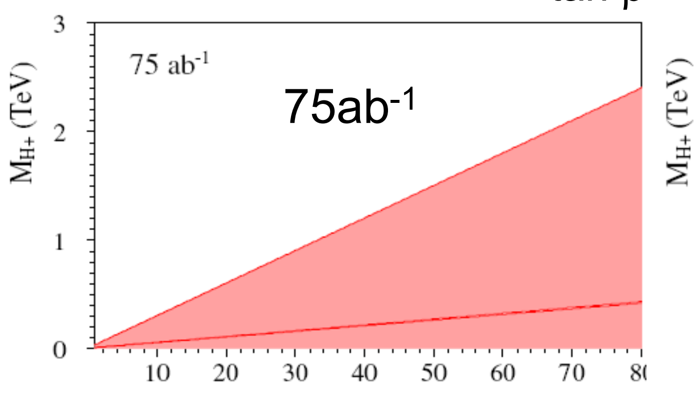
M_H~0.4-0.8 TeV for tanβ~30-60



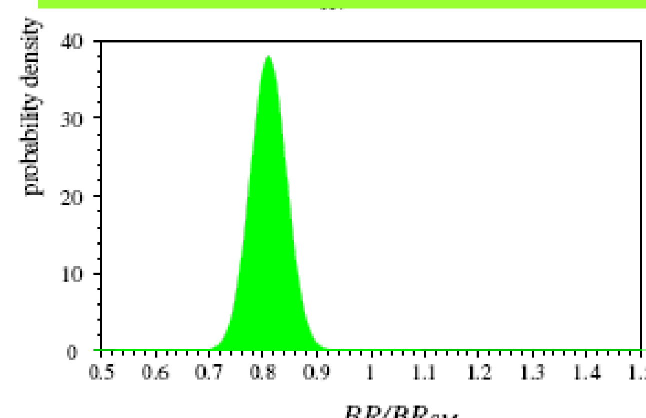


SuperB -75ab-1

M_H~1.2-2.5 TeV for tanβ~30-60

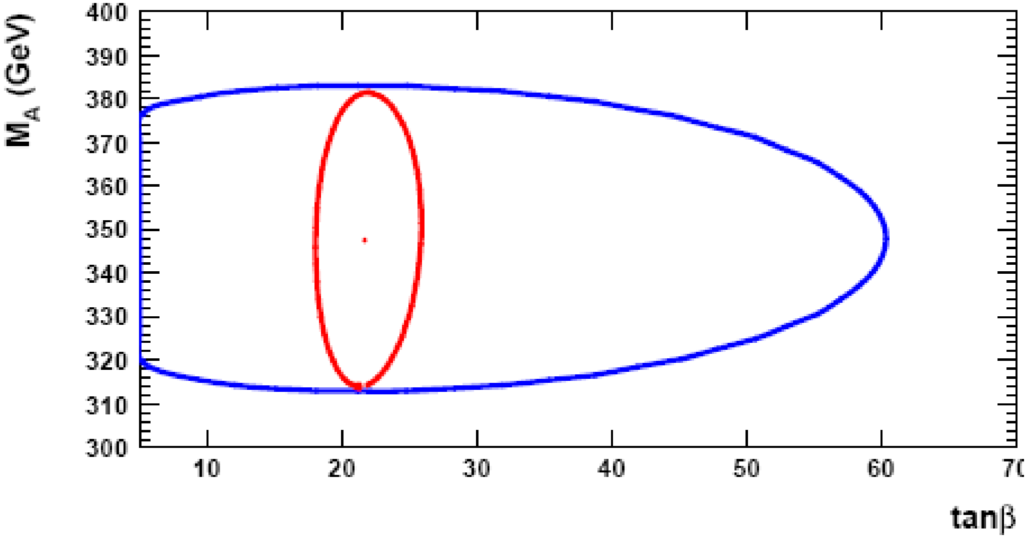


How signal would like with MH=350GeV

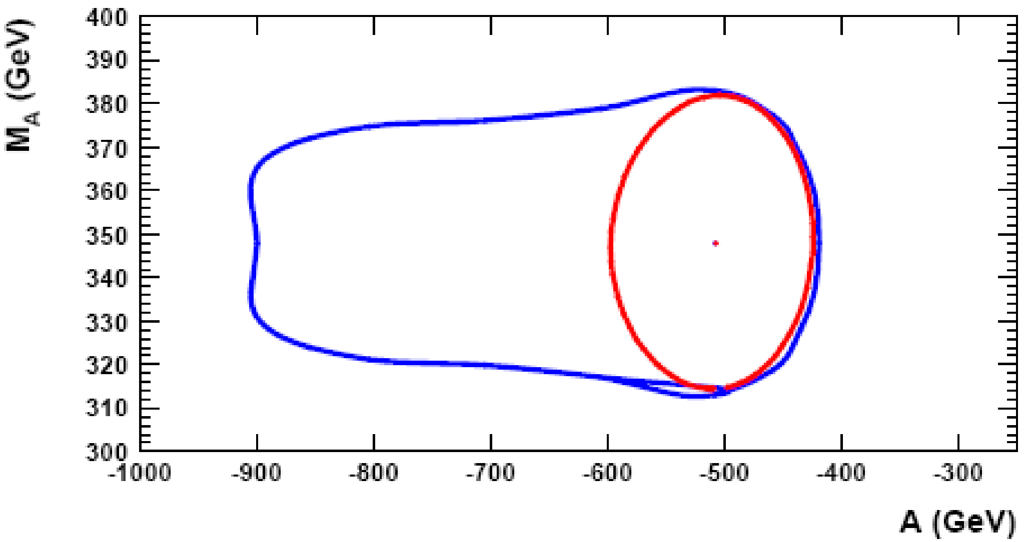


Importance of having very large sample ≥75ab-1

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



IF LHC DISCOVERS SUPERSYMMETRY



Red are LHC+EW constraints+SuperB

Blue is LHC alone

MFV : SNOWMASS points

SPS	$M_{1/2}$ (GeV)	M_0 (GeV)	A_0 (GeV)	$\tan\beta$	μ
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

	SPS1a	SPS4	SPS5
$\mathcal{R}(B \to s\gamma)$	0.919 ± 0.038	0.248	0.848 ± 0.081
$\mathcal{R}(B \to \tau\nu)$	0.968 ± 0.007	0.436	0.997 ± 0.003
$\mathcal{R}(B \to X_s l^+ l^-)$	0.916 ± 0.004	0.917	0.995 ± 0.002
$\mathcal{R}(B \to K\nu\bar{\nu})$	0.967 ± 0.001	0.972	0.994 ± 0.001
$\mathcal{B}(B_d \to \mu^+\mu^-)/10^{-10}$	1.631 ± 0.038	16.9	1.979 ± 0.012
$\mathcal{R}(\Delta m_s)$	1.050 ± 0.001	1.029	1.029 ± 0.001
$\mathcal{B}(B_s \to \mu^+\mu^-)/10^{-9}$	2.824 ± 0.063	29.3	3.427 ± 0.018
$\mathcal{R}(K \to \pi^0\nu\bar{\nu})$	0.973 ± 0.001	0.977	0.994 ± 0.001

SPS4 ruled out by present values of B→sγ.

SPS1a is the least favorable for flavour, <u>but SuperB and only SuperB</u> can observe 2 σ deviations in several observables

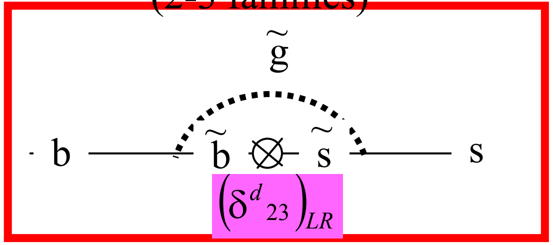
MSSM+generic soft SUSY breaking terms

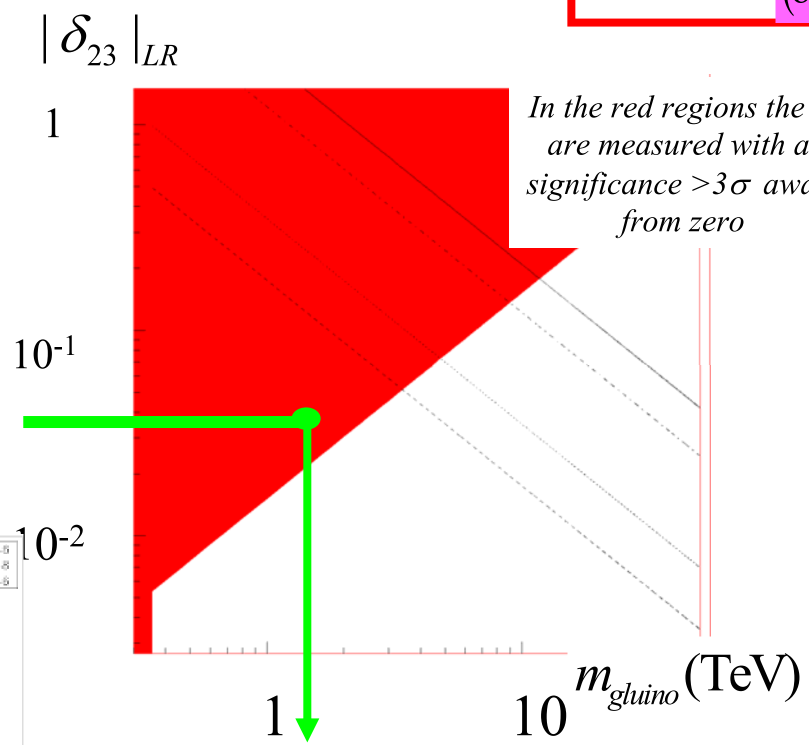
Flavour-changing NP effects in the squark propagator

→ NP scale SUSY mass $\tilde{m} \sim m_{\tilde{g}}$

→ flavour-violating coupling $(\delta^q_{ij})_{AB} \equiv \frac{(M^2_{ij})^q_{AB}}{\tilde{m}^2}$

New Physics contribution (2-3 families)



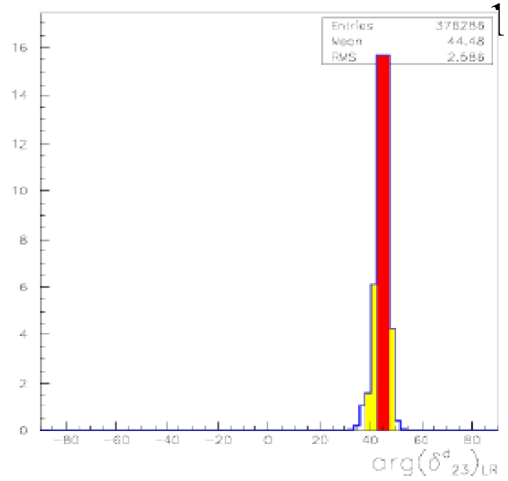


In the red regions the δ are measured with a significance $>3\sigma$ away from zero

$|\delta_{23}|_{LR} = (0.026 \pm 0.005)$

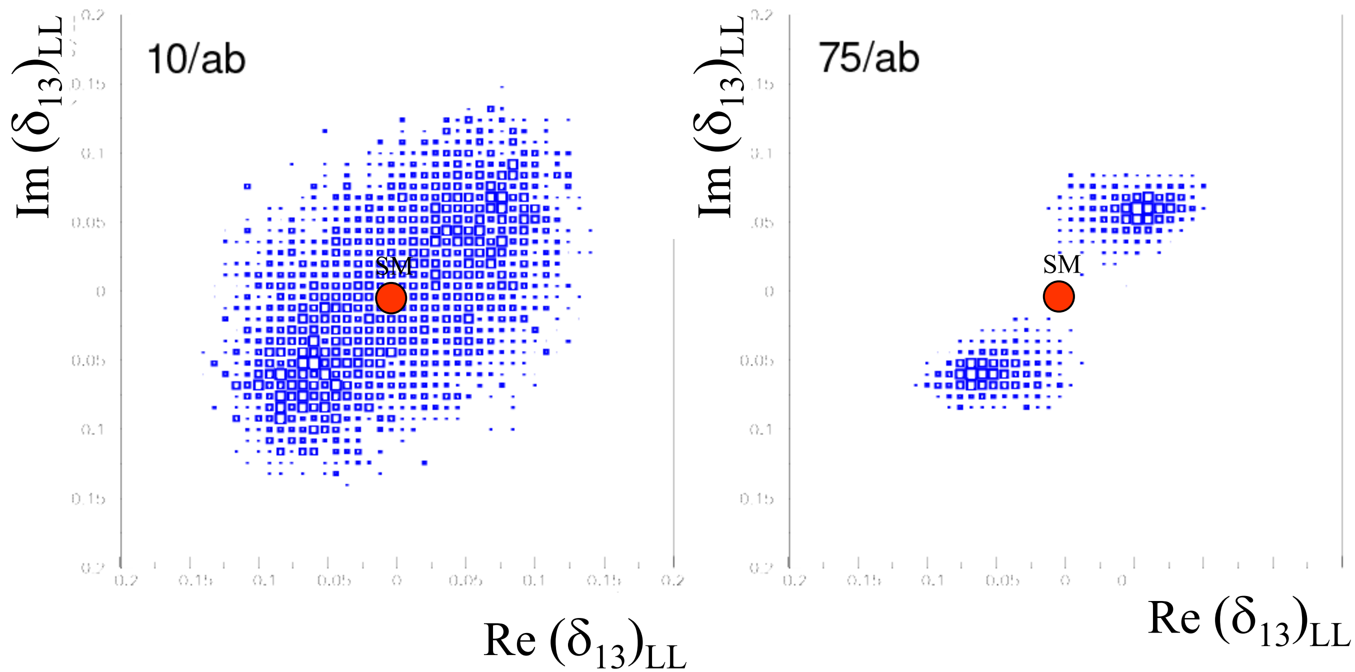
$\mathrm{Arg}(\delta_{23})_{LR} = (44.5 \pm 2.6)^o$

1 TeV



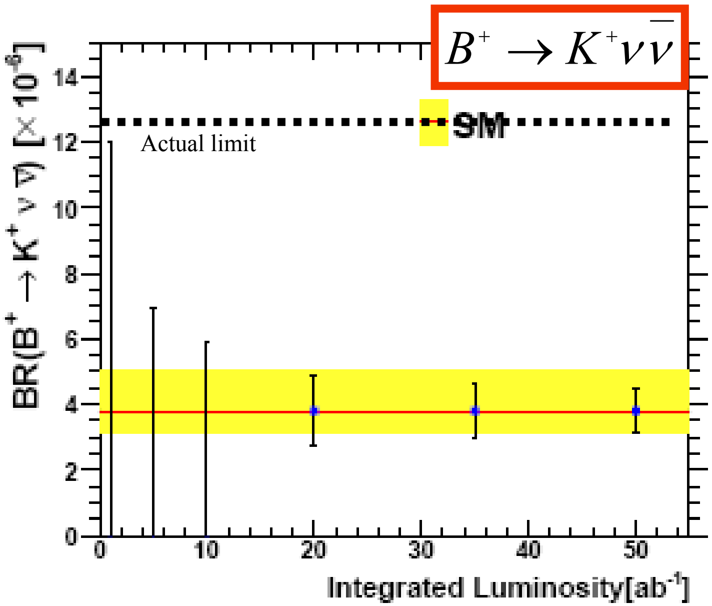
Determination of coupling [in this case : $(\delta_{13})_{LL}$]

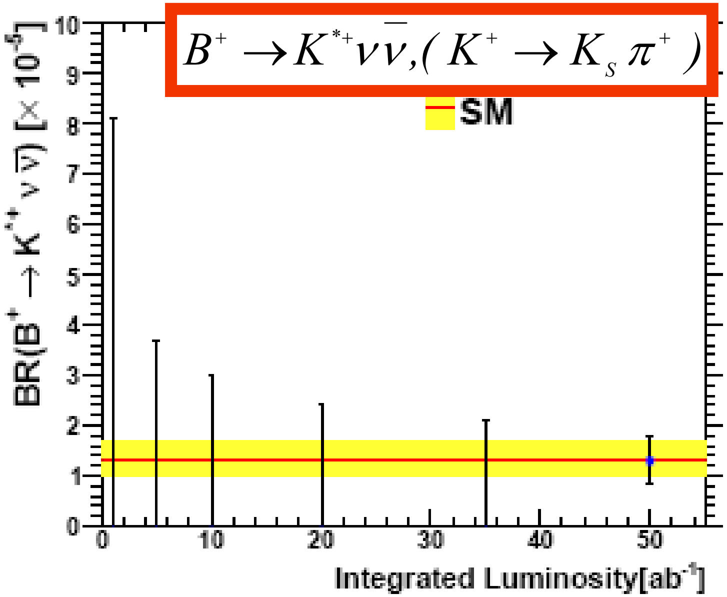
with 10 ab^{-1} and 75 ab^{-1}



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

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



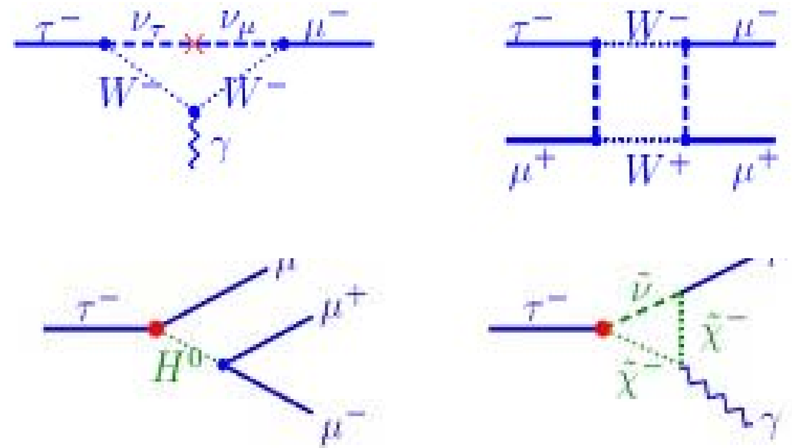


Mode	Sensitivity		
	Current	Expected (10 ab^{-1})	Expected (75 ab^{-1})
$\mathcal{B}(B \to X_s \gamma)$	7%	5%	3%
$A_{CP}(B \to X_s \gamma)$	0.037	0.01	0.004–0.005
$\mathcal{B}(B^+ \to \tau^+ \nu)$	30%	10%	3–4%
$\mathcal{B}(B^+ \to \mu^+ \nu)$	not measured	20%	5–6%
$\mathcal{B}(B \to X_s l^+ l^-)$	23%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

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

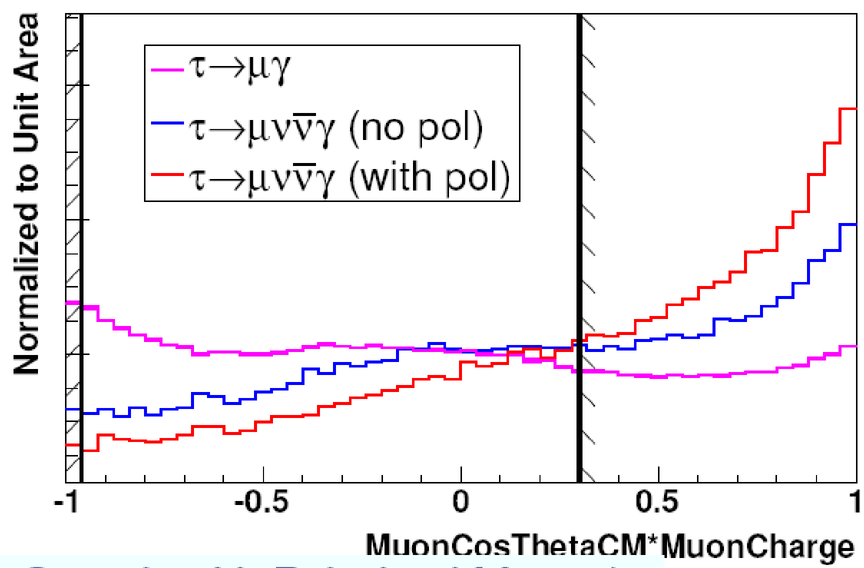
Br $(\tau^- \to e^-\gamma)$ < 12×10^{-8} (BELLE)

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}

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

SPS	$M_{1/2}$ (GeV)	M_0 (GeV)	A_0 (GeV)	$\tan\beta$	μ
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

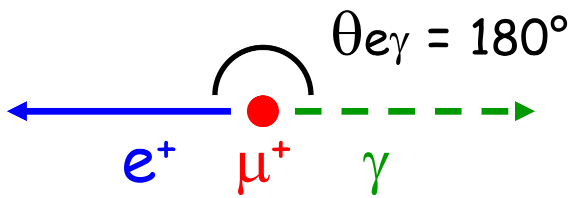
LFV	Snowmass points predictions						Super*B*	
	1 a	1 b	2	3	4	5	90% UL	**5σ disc**
$BF(\tau \to \mu\gamma) \times 10^{-9}$	4.2	7.9	0.18	0.26	97	0.019	**1÷2**	5
$BF(\tau \to 3\mu) \times 10^{-12}$	9.4	18	0.41	0.59	220	0.043	200	880

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

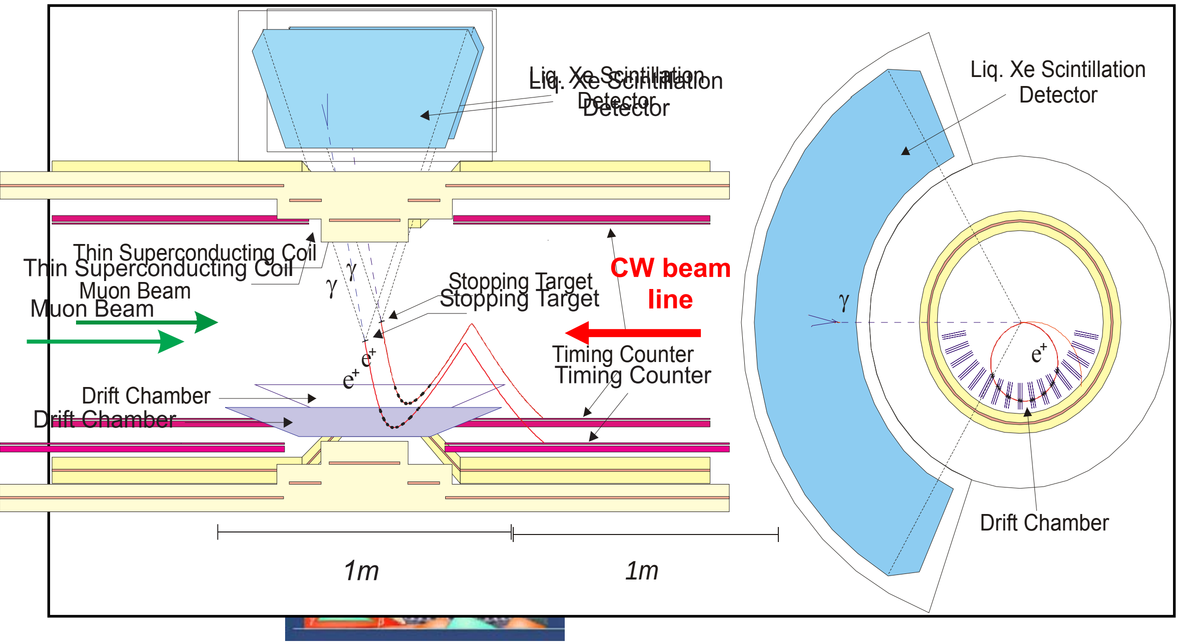
$\mu \to e\gamma$ search at PSI: sensitive to 10^{-13} BRs

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

Easy signal selection with μ^+ at rest



$E_e = E_\gamma = 52.8$ MeV



Detector outline

- Stopped beam of 3 10^7 μ /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

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 $\mathrm{Re}\{F_2\}$

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

Charm Physics

Charm physics using the charm produced at $\Upsilon(4S)$

Charm physics at threshold

0.3 ab^{-1}

Consider that running 4 month at threshold we will collect 1000 times the stat. of CLEO-C ~ 10 times of futire BESIII

Strong dynamics and CKM measurements

@threshold(4GeV)

D decay form factor and decay constant @ 1% — ξ~1%, exclusive V_{ub} ~ few %

Dalitz structure useful for γ measurement — syst. error on γ from Dalitz Model <1°

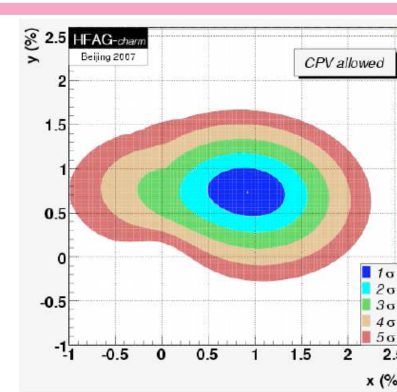
Rare decays FCNC down to 10^{-8}

@threshold(4GeV)

Channel	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}

D mixing

Better studied using the high statistics collected at $\Upsilon(4S)$

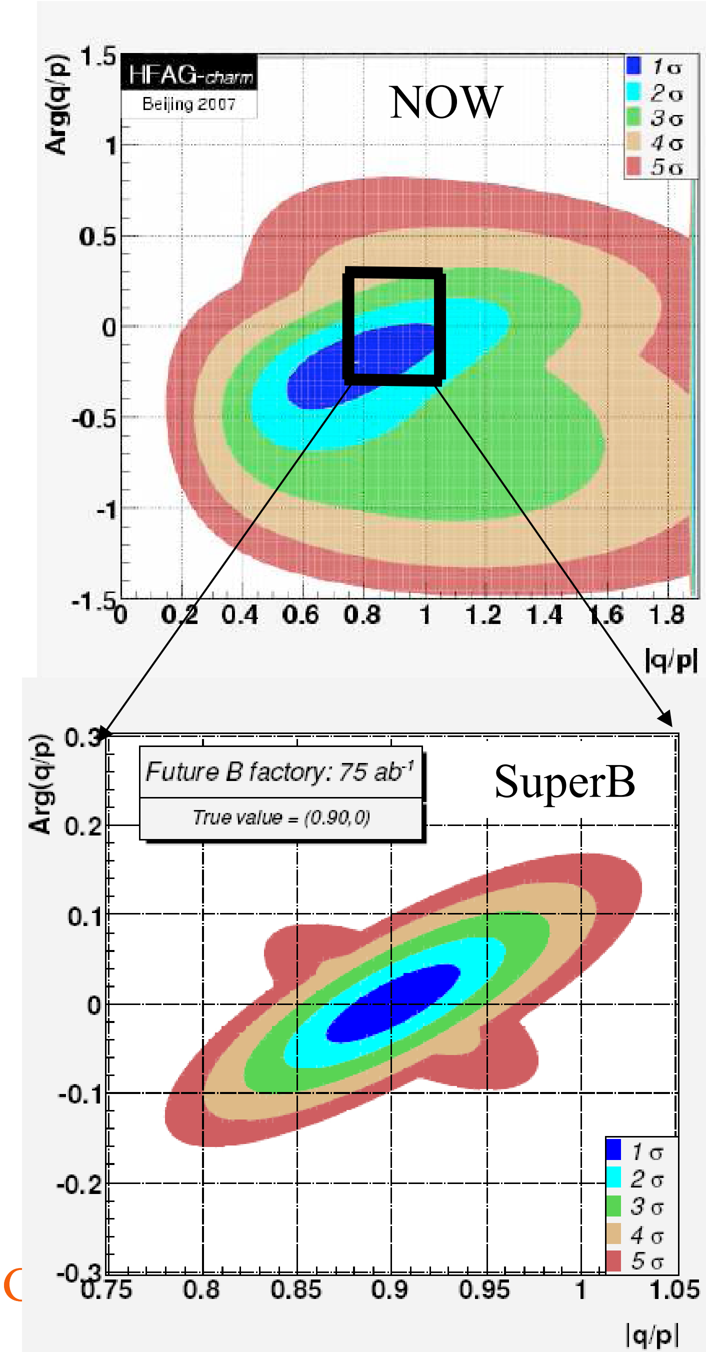


Mode	Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$D^0 \to K^+K^-$	y_{CP}	2–3×10^{-3}	5×10^{-4}
$D^0 \to K^+\pi^-$	y'_D	2–3×10^{-3}	7×10^{-4}
	x'^2_D	1–2×10^{-4}	3×10^{-5}
$D^0 \to K^0_S\pi^+\pi^-$	y_D	2–3×10^{-3}	5×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}
Average	y_D	1–2×10^{-3}	3×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}

CP Violation in mixing could now addressed

CP Violation in charm

Mode	Observable	$\Upsilon(4S)$ ($75\ \mathrm{ab}^{-1}$)	$\psi(3770)$ ($300\ \mathrm{fb}^{-1}$)
$D^0 \to K^+\pi^-$	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		$(1-2)\times10^{-5}$
	y		$(1-2)\times10^{-3}$
	$\cos\delta$		$(0.01-0.02)$



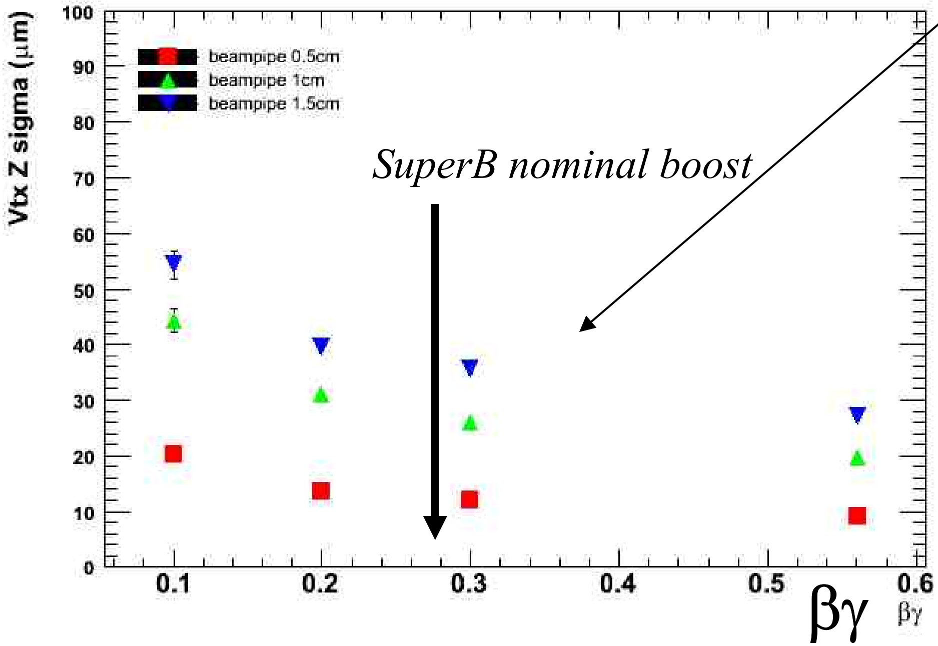
Charm

- 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

$\sigma(e^+e^-\rightarrow D^0D^0)$~3.6 nb + $\sigma(e^+e^-\rightarrow D^+D^-)$~2.8 nb ~ 6.4 nb)

- Time-dependent measurements at 4 GeV only possible at SuperB.

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



SuperB lumi at 4 GeV = 10^{35} $cm^{-2}s^{-1}$ produces ~10^9 $D\bar{D}$ per month

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

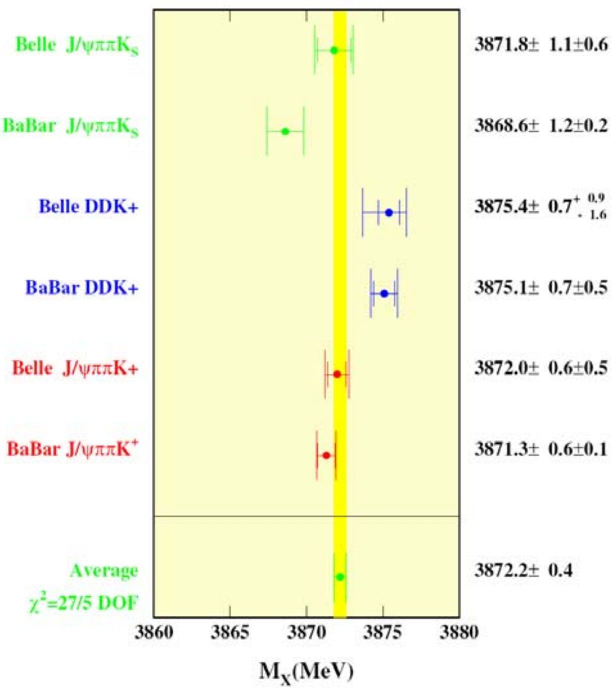
Average flight distance similar to vertex resolution $\rightarrow \sigma_t \sim \tau$

Resolution is still adequate for time dependent measurements

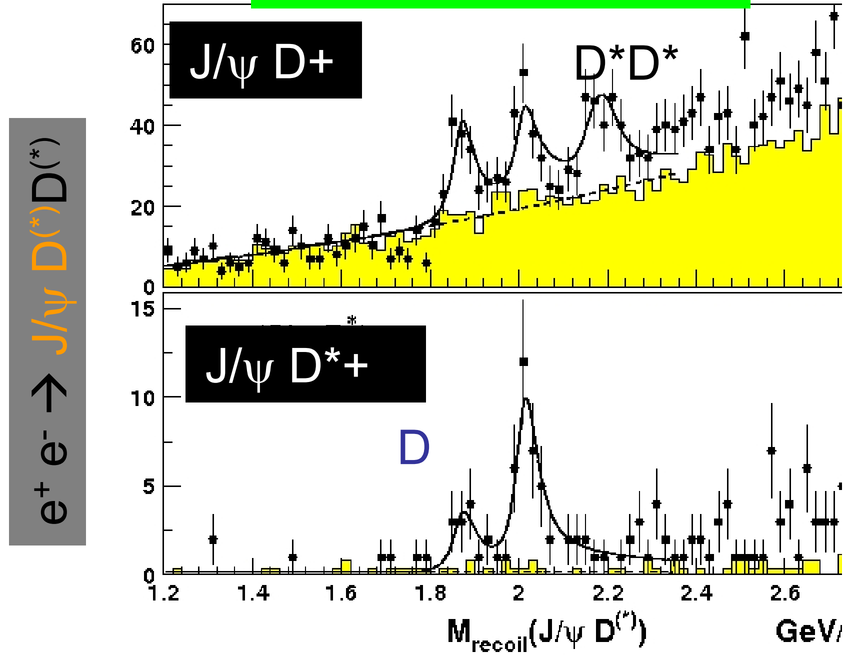
Error on lifetime $\approx \sqrt{\frac{\tau^2 + \sigma_t^2}{N}} = \sqrt{2}\frac{\tau}{\sqrt{N}}$ (wrt perfect resolution)

TWO STATES? X(3872) & X(3876) ?

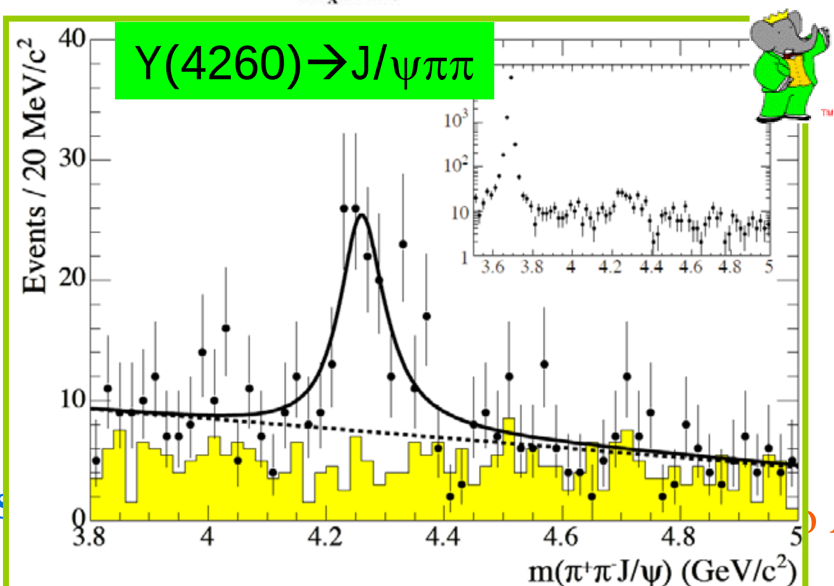
Predicted by tetraquark



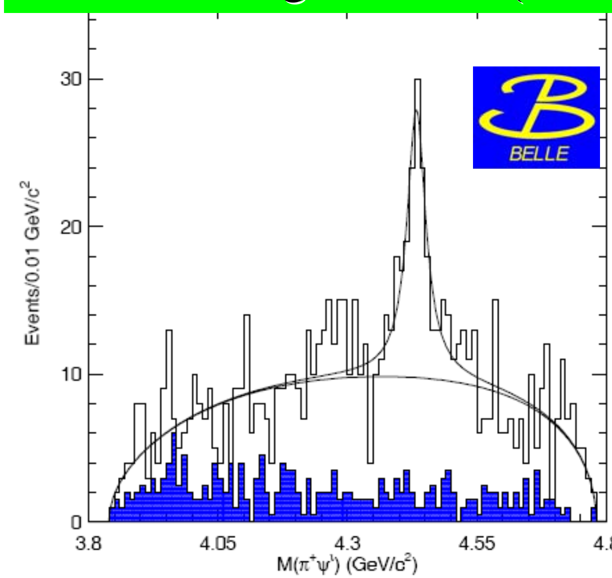
X(4160)→ D*D*



Y(4260)→J/ψππ



The first charged state: Z(4430)!



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÷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	$1 \div 4\ 10^{36}$ $1\ 10^{35}$

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

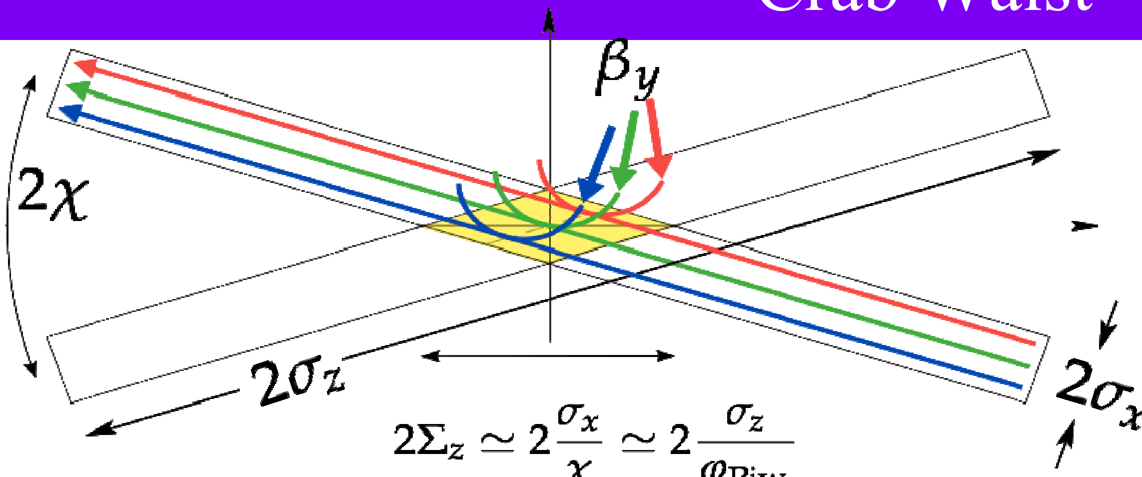
σ_x (σ_y) is the horizontal (vertical) r.m.s. size at the I.P.

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 Crossing to increase $\mathbf{R_l}$ and to optimize beam dynamic

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

Crab Waist

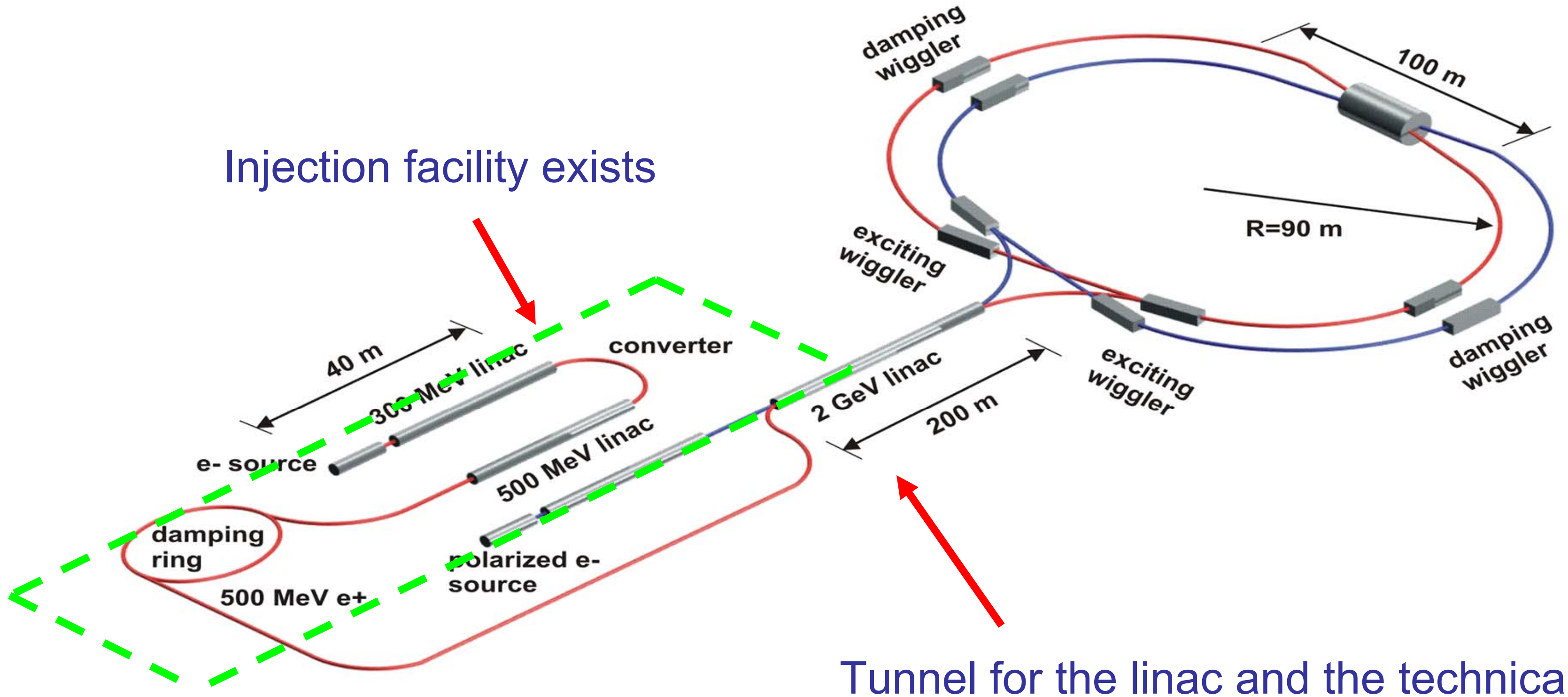


$$2\Sigma_z \simeq 2\frac{\sigma_x}{\chi} \simeq 2\frac{\sigma_z}{\varphi_{\text{Piw.}}}$$

- 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. Background not exceeding too much the present Babar, thanks to low current, crossing angle and a careful design of the Interaction Region.

Injection facility exists



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

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

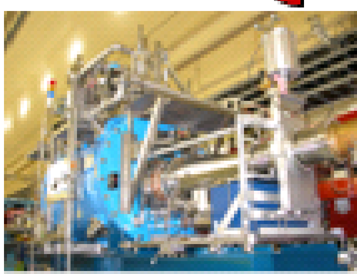
Tune shift ξ_y	0.13
Particles per bunch	$7 \cdot 10^{10}$
Luminosity, $\mathrm{cm}^{-2}\mathrm{sec}^{-1}$	$1 \cdot 10^{35}$
Hour glass $\frac{\sigma_x}{\theta\beta_y}$	1.095
Piwinski angle $\varphi = \frac{\sigma_z\theta}{\sigma_x}$	12.021

- No bend for incoming beam.
- No longitudinal field integral over each final focus lens.
- Longitudinal field is compensated before each final focus lens.
- Interaction region length less than 100 m.
- Place for CRAB sextupole.

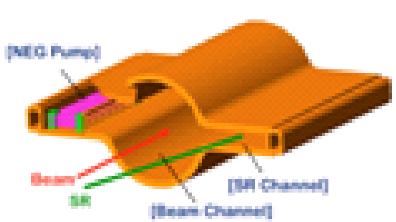
From the talk by Anton Bogomyagkov

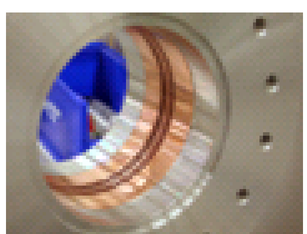
SuperKEKB project

Crab cavities will be installed and tested with beam in 2006.

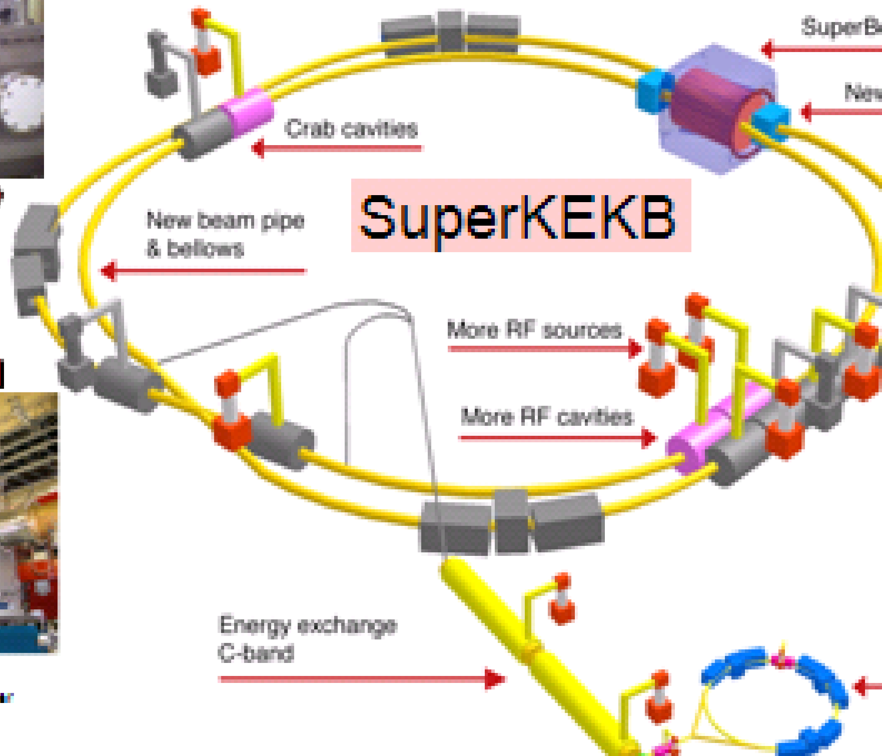


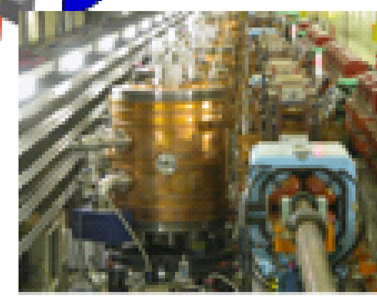
The superconducting cavities will be upgraded to absorb more higher-order mode power up to 50 kW.





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



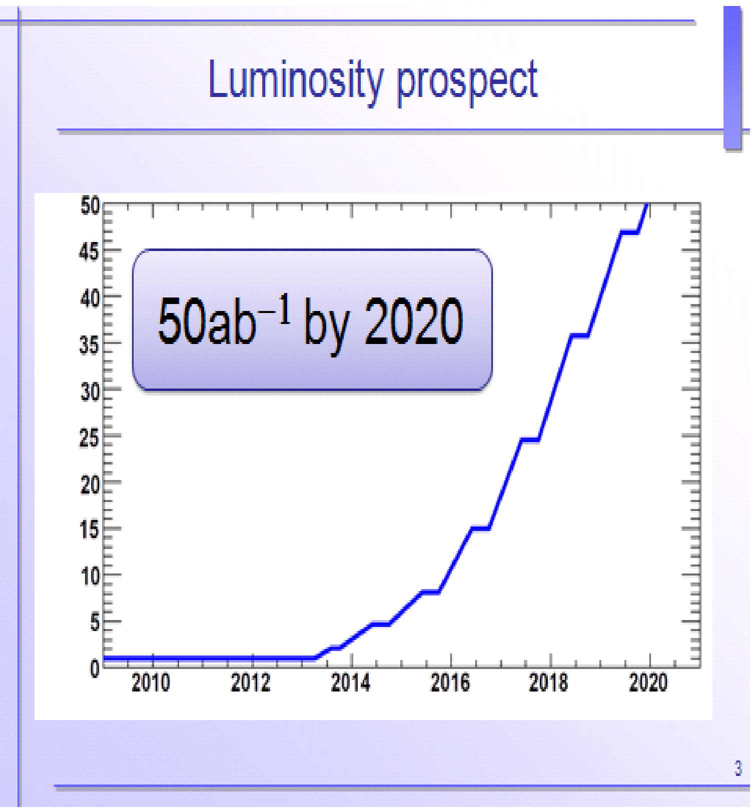


The state-of-art ARES copper cavities will be upgraded with higher energy storage ratio to support higher current.

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

will reach 8×10^{35} cm^{-2}s^{-1}.

SuperKEKB

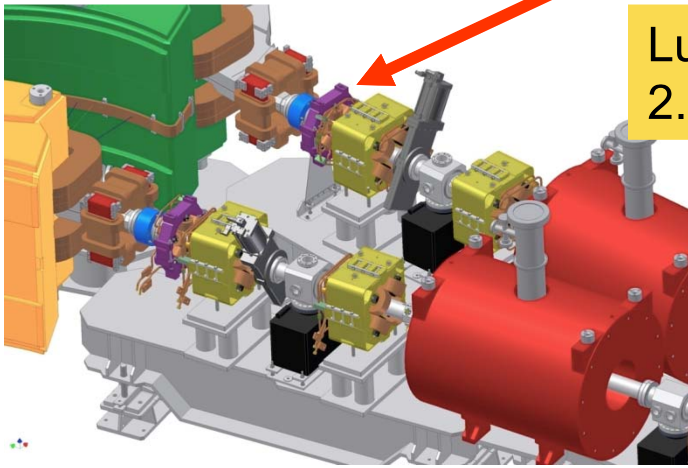


Machine Parameters of SuperKEKB

	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	$x10^{10}$
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		$x10^{35}$ $cm^{-2}s^{-1}$

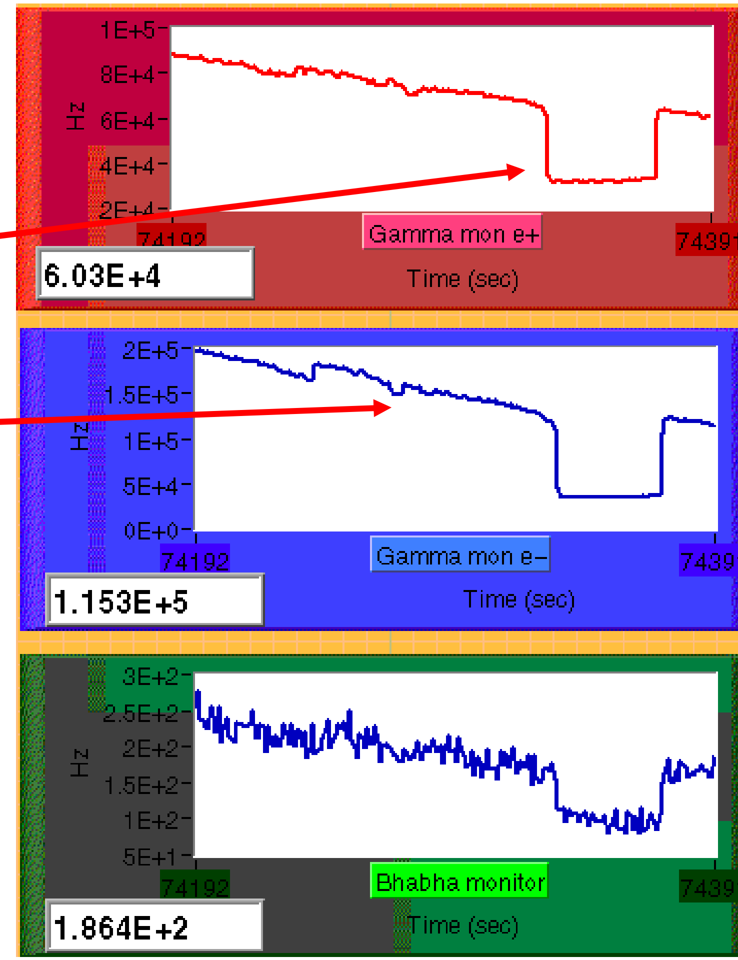
After 7th year integrated Luminosity can grow at rate of ~10÷12 ab^{-1}/year

SuperB Test of crab waist at DaΦne (LNF)



Luminosity stable above 2.0x1032 reached

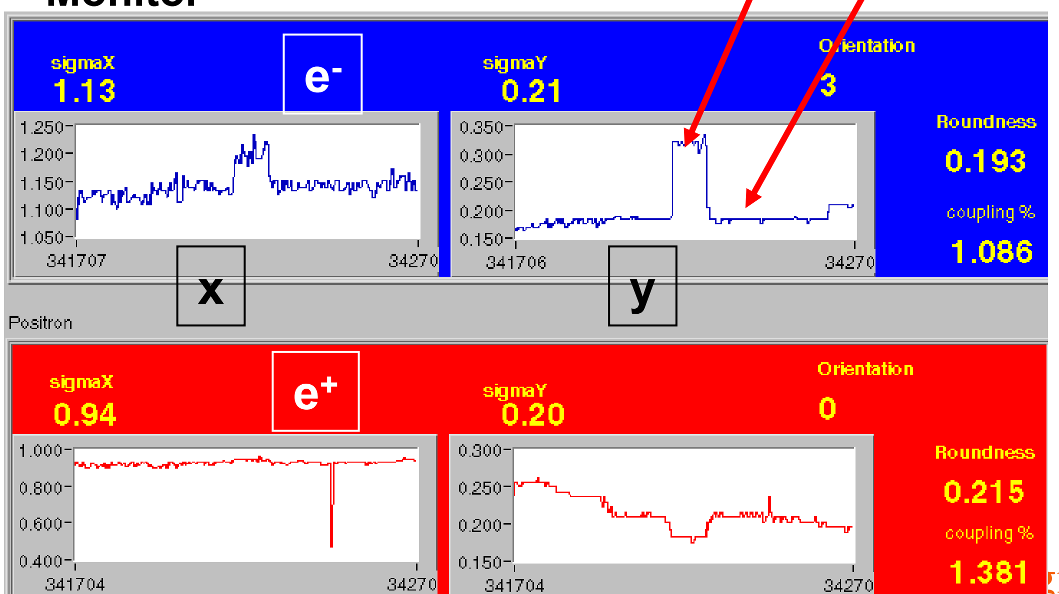
LUMINOMETERS



Crab OFF

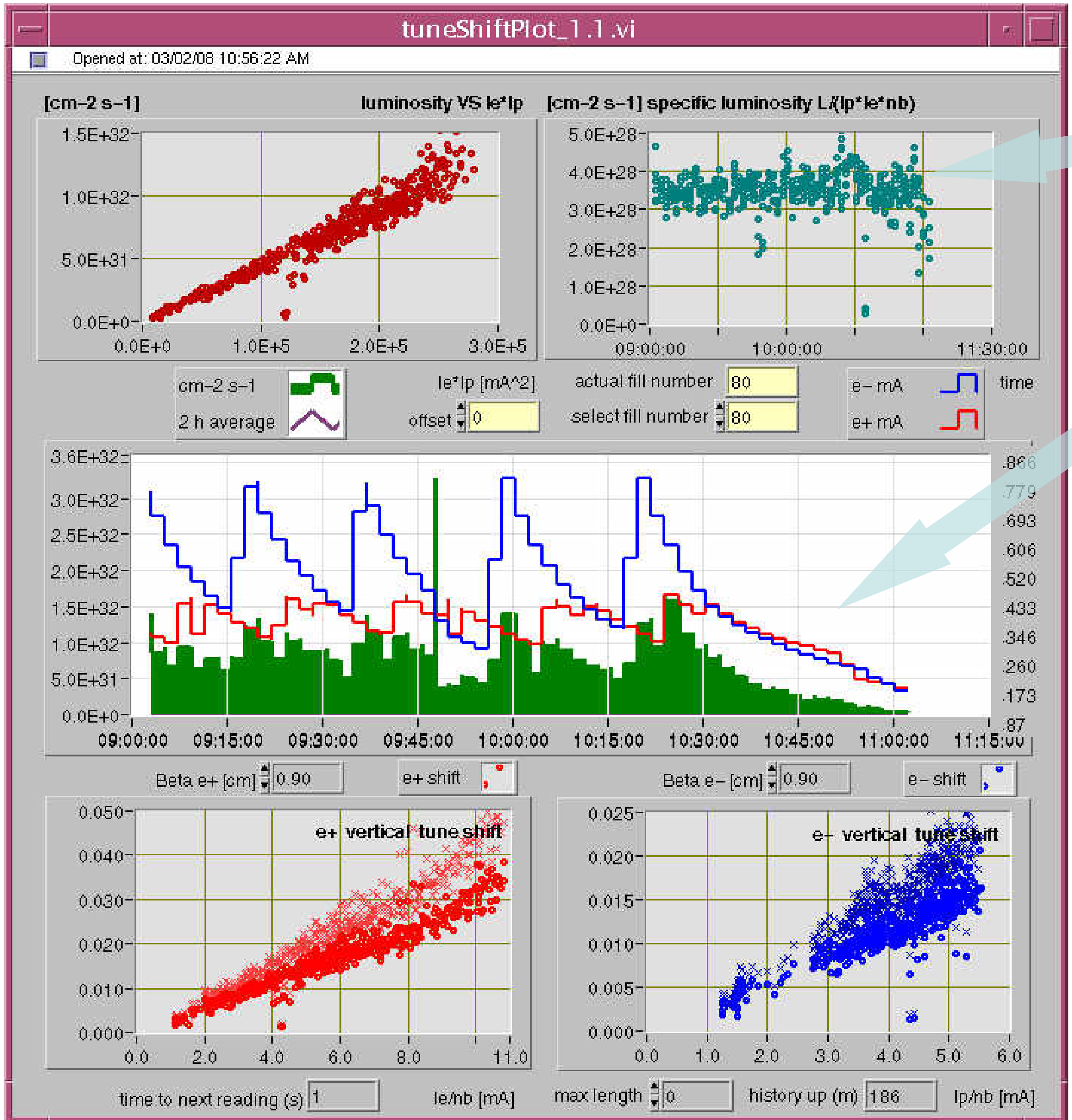
Crab ON

Transverse beam dimensions at the Synchrotron Light Monitor



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

Specific luminosity



- Specific Luminosity(vs time) does not depends on beam currents
- headrom for luminosity improvements

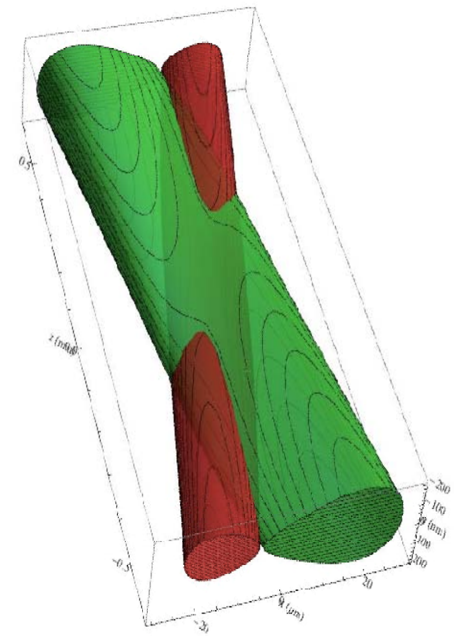
SuperB parameters with higher Wall Power

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

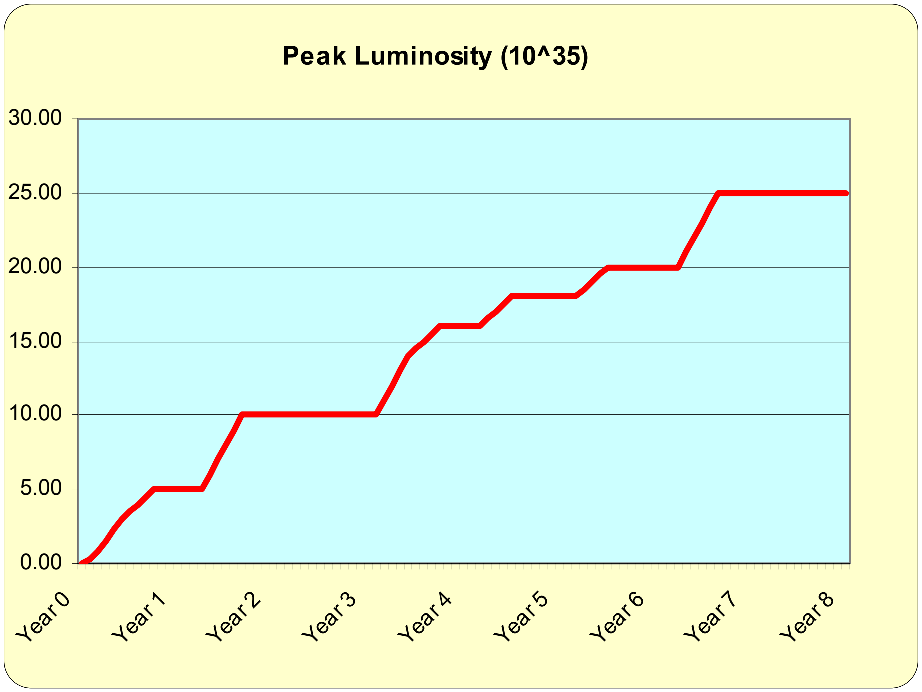
LEB HEB

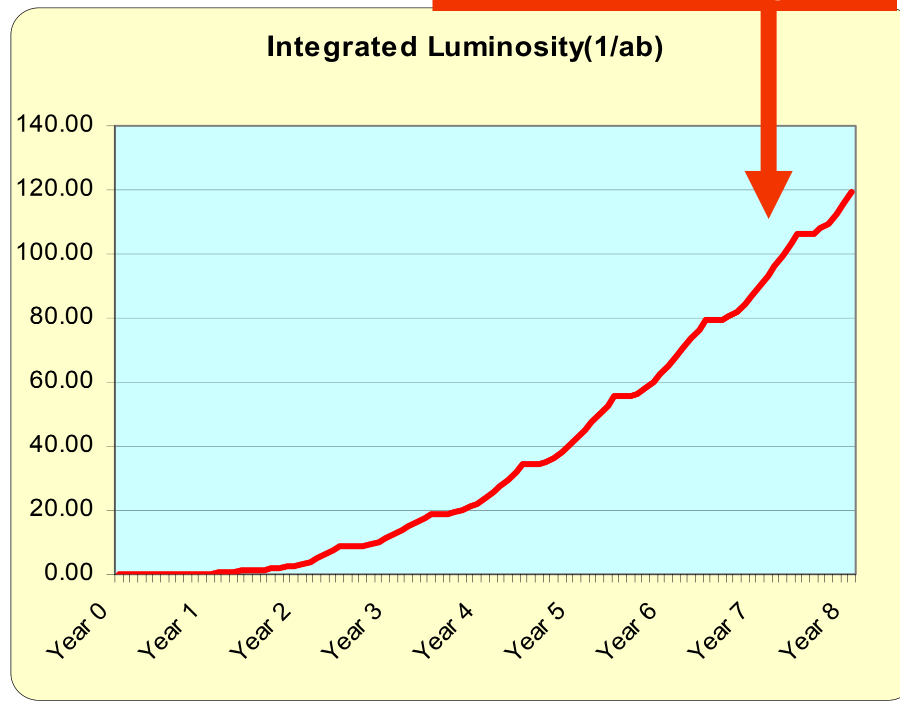


Asymmetric bunch size to optimize beam lifetime (Touschek effect)

SuperB expected LUMI

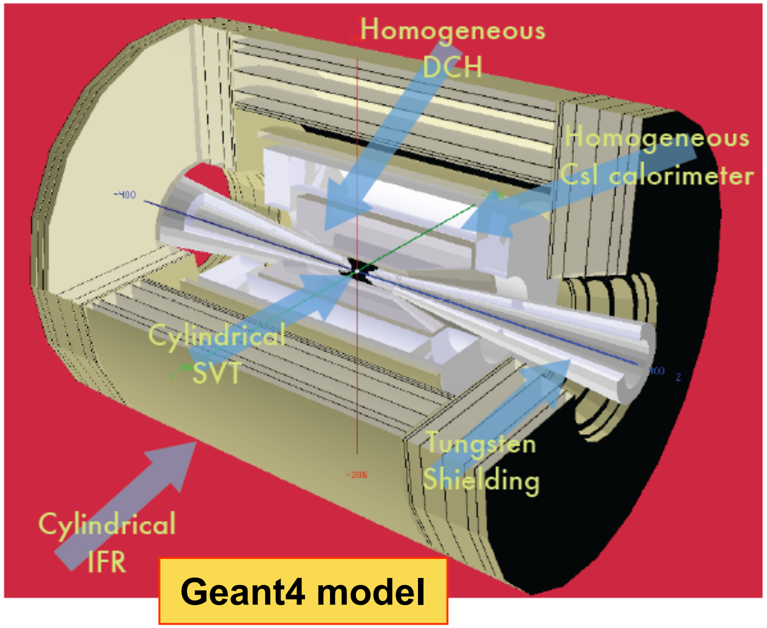
>80ab-1 in 7th year

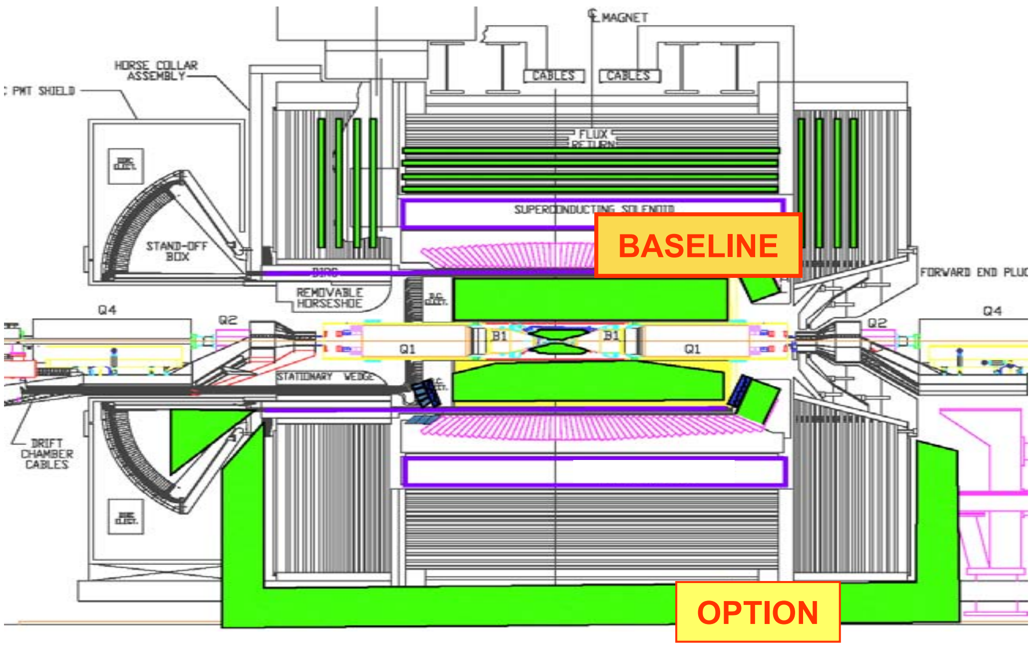




After 7th year integrated Luminosity can grow at rate of ~40 ÷ 60 ab^{-1}/year

Detector Layout – Reuse parts of Babar





Test beam goals for 2008-2010

Silicon Vertex Tracker
- MAPS pixel devices: resolution, efficiency, readout speed
  - (now under test at CERN !)
- Advanced trigger systems (Associative Memories)

Drift Chamber
- Cell size, shape, and gas mixture

Particle ID system (forward system)
- Radiators (Aerogel, NaF)
- Photon detector (MCP, MAPMTs, SiPM)
- Timing for TOF system

Electromagnetic Calorimeter
- Forw: LYSO Crystals leakage, resolution, mechanical structure
- Back: Lead-scintillator calorimeter resolution

Instrumented Flux Return
- Scintillator, fibers, photon detector, readout electronics

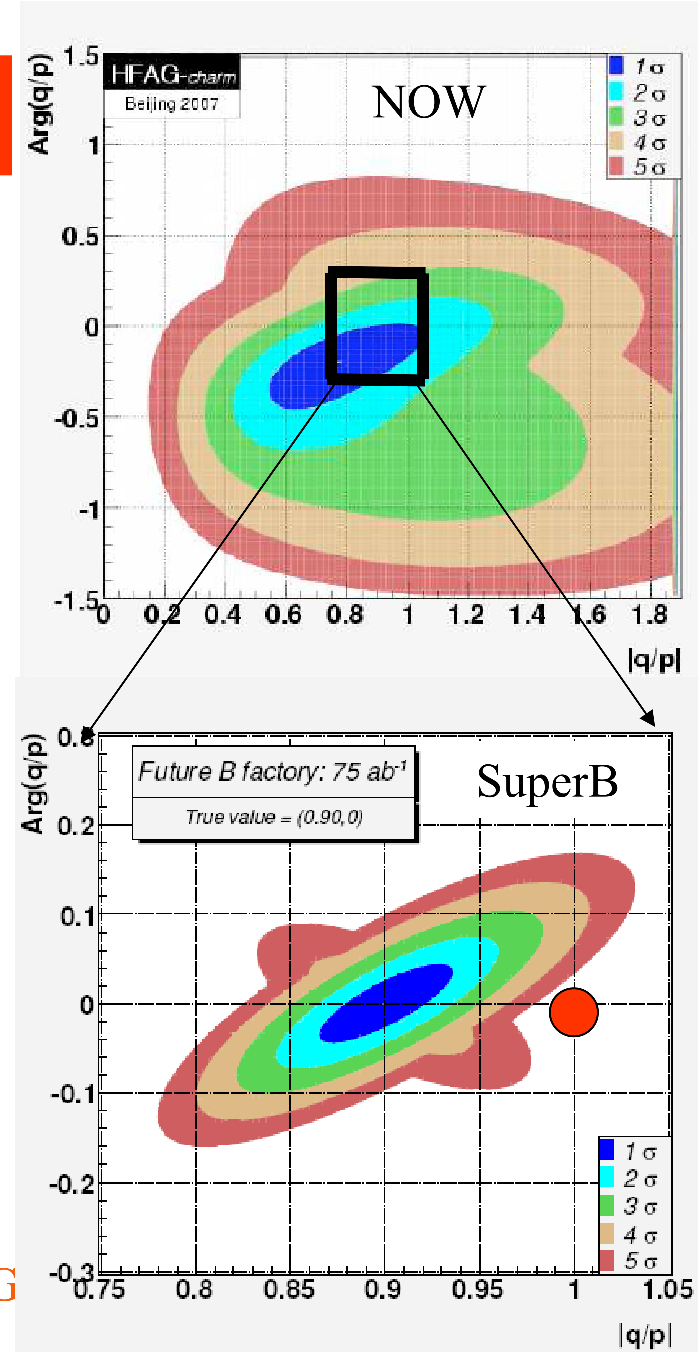
END

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 .

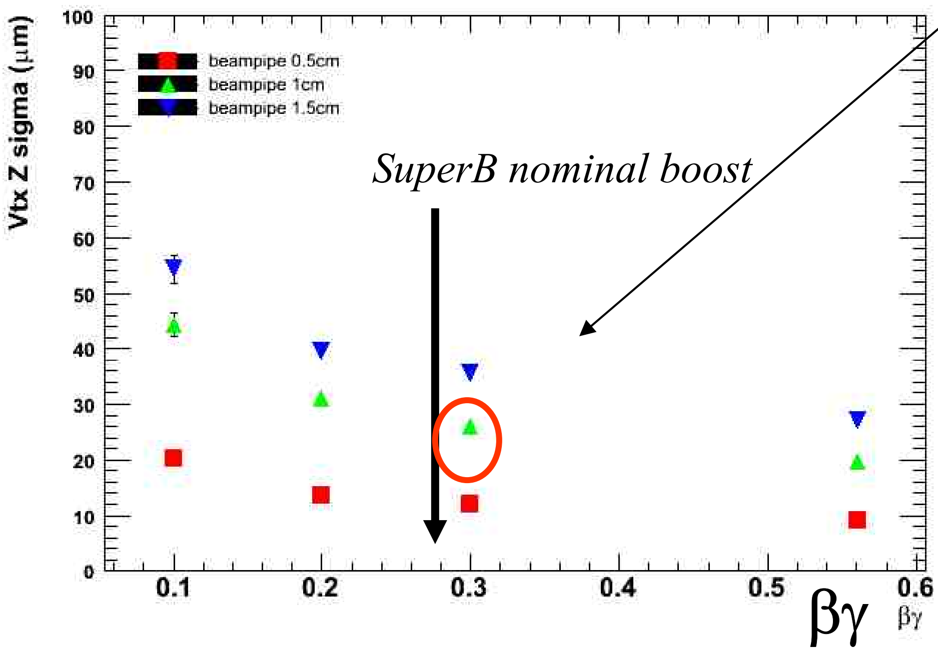
CP Violation in charm from mixing

Mode	Observable	$\Upsilon(4S)$ ($75\ \mathrm{ab}^{-1}$)	$\psi(3770)$ ($300\ \mathrm{fb}^{-1}$)
$D^0 \to K^+\pi^-$	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		$(1-2) \times 10^{-3}$
	$\cos\delta$		$(0.01-0.02)$



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 $\rightarrow \sigma_t \sim \tau$