SuperB Status

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Ferrara, July 4, 2011

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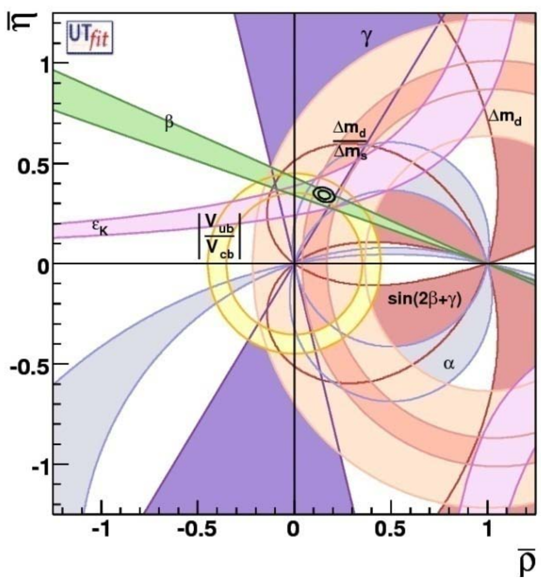
Outline

- The Physics Case.
- The Machine.
- The Detector.
- The SuperB Approval Process.

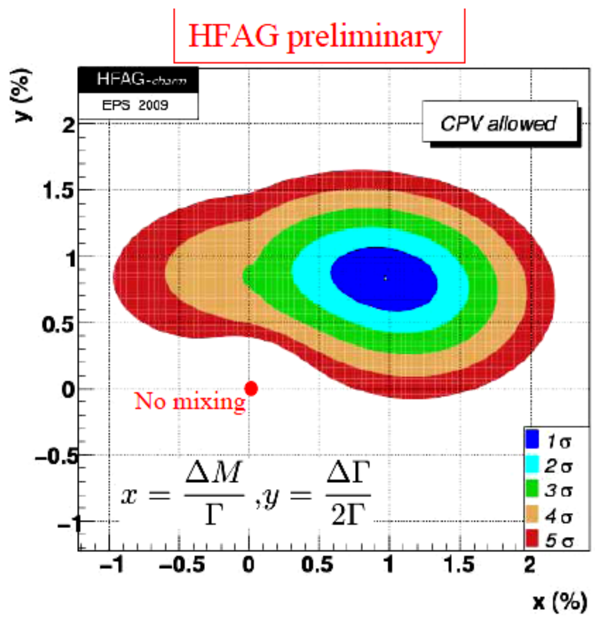
The B-Factories: a Story of Success

- BaBar and Belle together have collected ~1.5 ab^{-1} of data.
- Huge harvest of physic results.
  - Well beyond the original goals.
  - The PDG book has gotten significantly thicker.
  - Already some limits on New Physics models.

Unitarity Triangle precision measurements

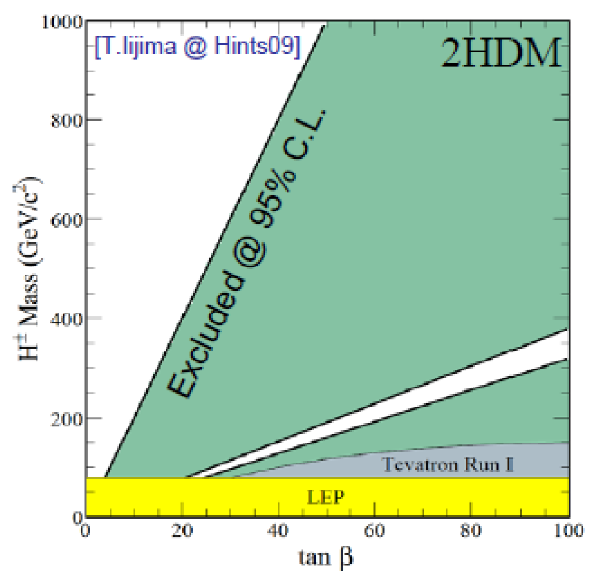


D^0 Mixing



$B^+ \to \tau^+ \nu$

Limits on 2HDM/MSSM models

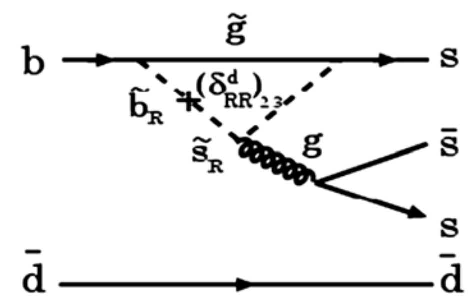


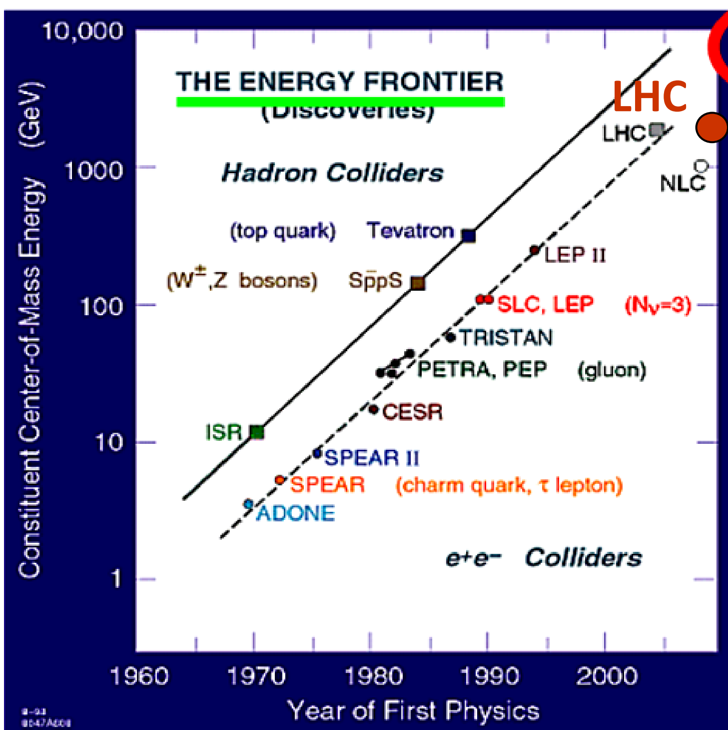
2HDM: W.-S Hou PRD 48 2342 (1993)
MSSM: G. Isidori arXiv:0710.5377
Unparticles: R. Zwicky PRD77 036004 (2008)

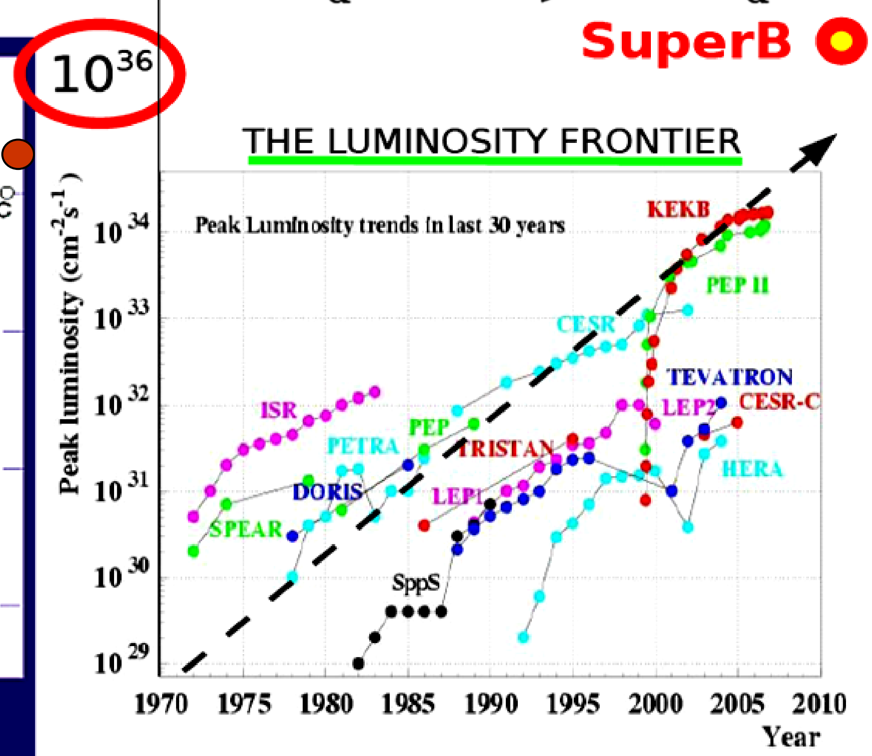
The Quest for New Physics

The relativistic path:
Increase the energy and look for direct production of new particles.

The quantum path:
Increase the luminosity and look for effects of physics beyond the standard model in loop diagrams.

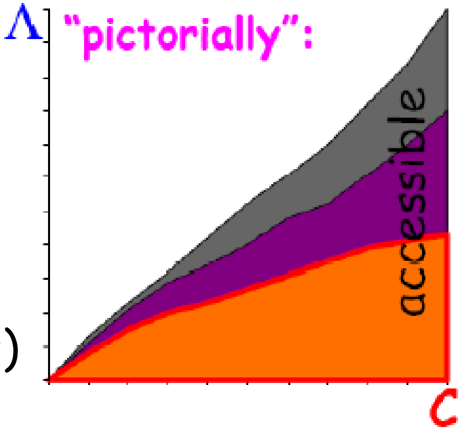






High Luminosity Flavor Factory Complementary to Energy Frontier

- Precision measurements in the flavor sector are sensitive to New Physics (NP)
  - Interference effects in known processes
  - SM rare or forbidden decays
- NP effects are controlled by
  - NP scale: Λ
  - Effective couplings: C
    - Different coupling intensity (different interactions)
    - Different patterns (e.g. because of symmetries)



- With 5-10x10^{10} bb, cc, $\tau\tau$ pairs (50-100 ab^{-1}) one can:

LHC finds NP(Λ)

- Determine detailed structure of couplings of NP
- Look for heavier states
- Study NP flavor structure

LHC does not find NP(Λ)

- Look for indirect NP signals
- Connect them to models
- Exclude regions in parameters space

Some phenomena as LFV in τ decays are unambiguous signals of NP

B Physics @ Υ(4S)

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

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

Charm mixing and CP

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

Charm FCNC

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

τ Physics

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}

B_s Physics @ Υ(5S)

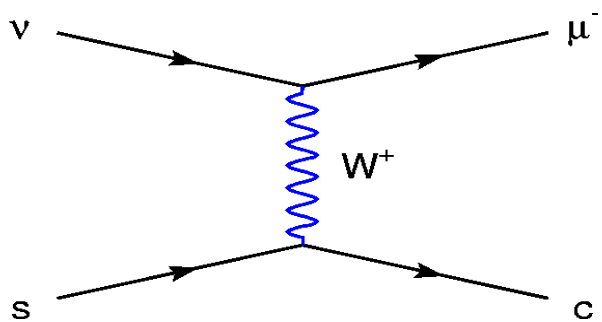
Observable	Error with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}	0.03 ps^{-1}
Γ	0.07 ps^{-1}	0.01 ps^{-1}
β_s from angular analysis	20°	8°
A_{SL}^s	0.006	0.004
A_{CH}	0.004	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\lvert V_{td}/V_{ts}\rvert$	0.08	0.017
$\mathcal{B}(B_s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

arXiv:1008.1541 [hep-ex]

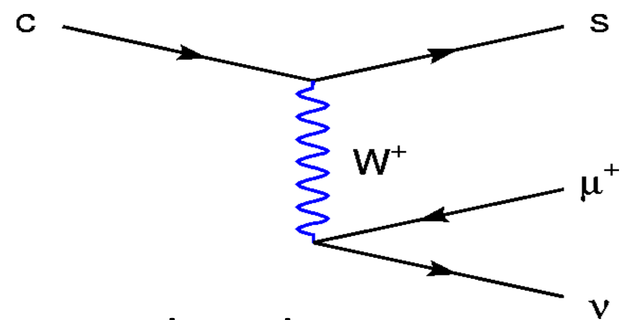
Physics at a Super B Factory

- Test of CKM Paradigm at 1% level.
  - CPV in B decays from the new physics (non CKM).
- The B recoil technique: B -> $K^{(*)}$ ll, B->$\tau\nu$, B->$D^{(*)}\tau\nu$
- τ physics: lepton flavor violations, g-2, EDM, CPV.
- Many more topics: Υ(5S), CPV in charm, new hadrons, …
- Physics motivation is independent of LHC.
  - If LHC finds NP, precision flavor physics is compulsory.
  - If LHC finds no NP, high statistics B/τ decays would be a unique way to search for the >TeV scale physics (=TeV scale in case of MFV).

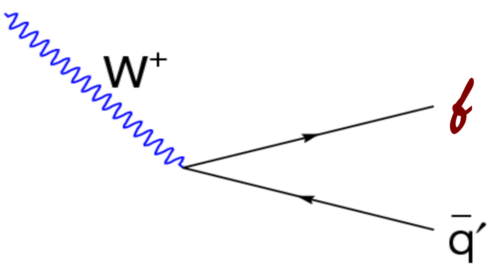
Weak Charged Current Interactions



neutrino scattering



charm decay



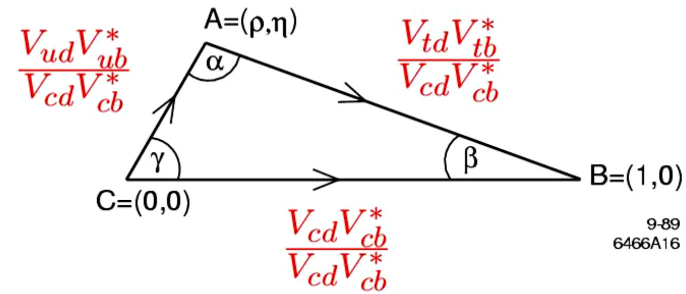
$$\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix} \begin{pmatrix} \nu_e \\ e^- \end{pmatrix} \begin{pmatrix} \nu_\mu \\ \mu^- \end{pmatrix} \begin{pmatrix} \nu_\tau \\ \tau^- \end{pmatrix}$$

As a first approximation, the weak charged current interaction couples fermions of the same generation. The Standard Model explains couplings between quark generations in terms of the Cabibbo-Kobayashi-Maskawa (CKM) matrix.

The CKM Paradigm

The Cabibbo-Kobayashi-Maskawa (*CKM*) matrix transforms flavor eigenstates to weak eigenstates at the quark level:

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$



$\beta = \phi_1;\ \alpha = \phi_2; \gamma = \phi_3$

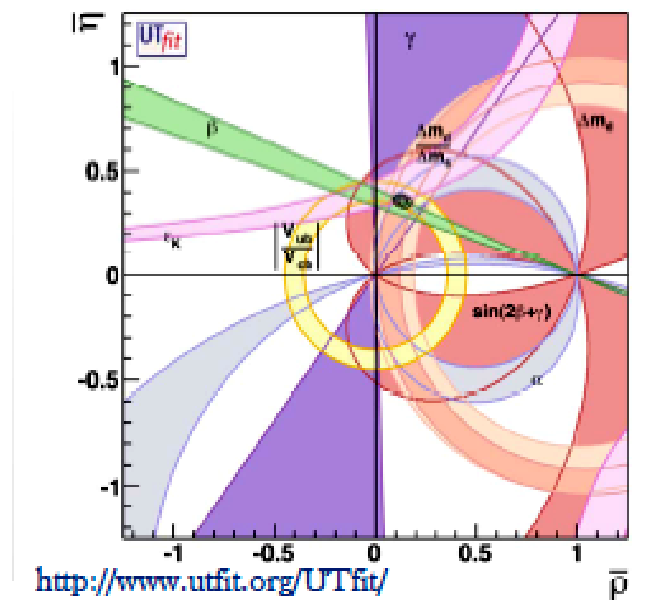
The *CKM* matrix should be unitary:

$$\begin{pmatrix} V_{ud}^* & V_{cd}^* & V_{td}^* \\ V_{us}^* & V_{cs}^* & V_{ts}^* \\ V_{ub}^* & V_{cb}^* & V_{tb}^* \end{pmatrix} \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$e.g., \quad V_{ub}V_{ud}^* + V_{cb}V_{cd}^* + V_{tb}V_{td}^* = 0$$

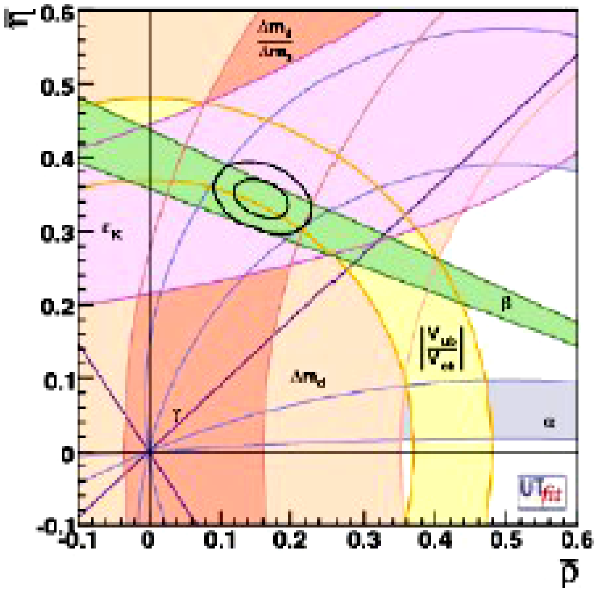
In the Wolfenstein parameterization:

$$V_W = \begin{pmatrix} 1 - \frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1 - \frac{1}{2}\lambda^2 - iA^2\lambda^4\eta & A\lambda^2 \\ A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

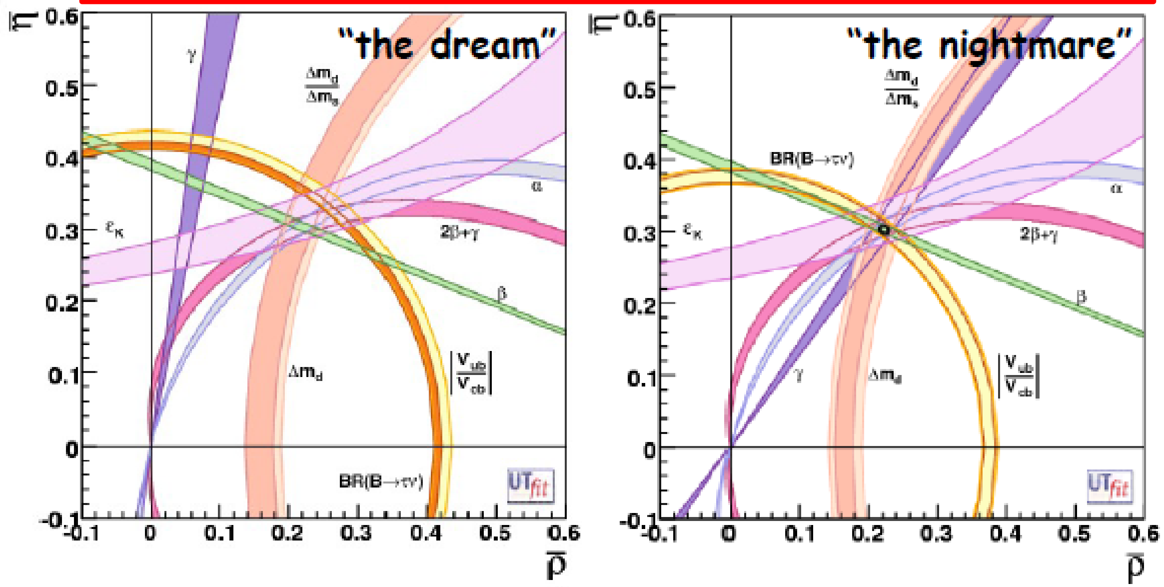


Test of CKM Paradigm

Today



With a Super Flavor Factory @ 75 fb^{-1}

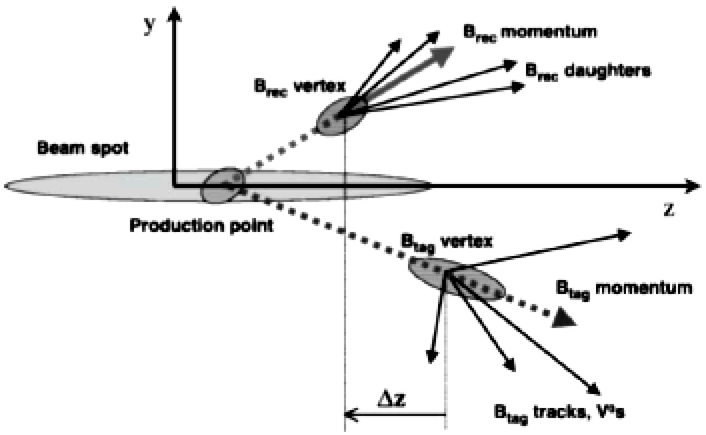


Generalized UT fits:

CKM at 1% in the presence of NP!

Today	with a Super Flavor Factory
$\bar{\rho} = 0.187 \pm 0.056$	± 0.005
$\bar{\eta} = 0.370 \pm 0.036$	± 0.005

Time Dependent Analysis



$\Delta t \approx \Delta z/(\beta\gamma)$

BaBar: $\beta\gamma$=0.56

SuperB: $\beta\gamma$=0.28

✓ $f_+(f_-)$: Δt distribution function for B^0 ($\overline{B}^0$) tagged events (not accounting for experimental effects)

$$f_{\pm}(\Delta t) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}}[1 \pm Ssin(\Delta m \Delta t) \mp Ccos(\Delta m \Delta t)]$$

✓ S and C related to CPV in the interference between mixing and decay (CKM angles, i.e. f = J/Ψ Ks, S =sin2β) and direct CPV + indirect CPV, risp.

Time Dependent Analysis: BaBar vs SuperB

Changes in two main ingredients:

- Δt resolution: SuperB boost < BaBar boost -> smaller Δz, worst Δt.
  - To cure this:
    - Add SVT layer 0, reducing SVT inner radius from 3.32 cm to 1.60 cm.
    - Reduce beam spot size.
    - Lower material budget in the beam pipe.
  - Preliminary studies: Δt determined with comparable precision wrt BaBar

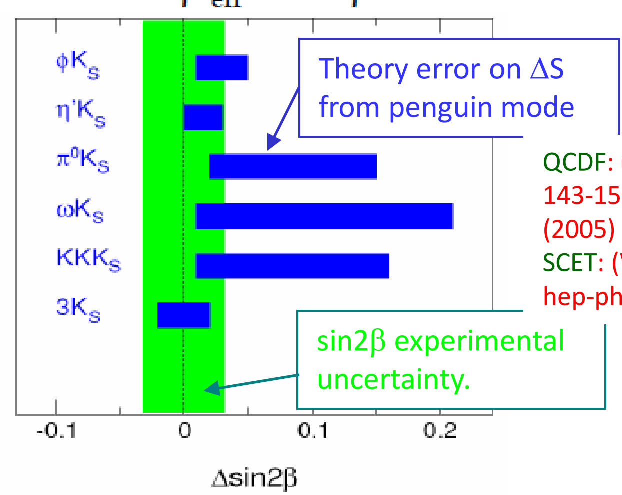
- Flavor tagging algorithm:
  - BaBar: Neural Network approach to isolate high momentum lepton and K and soft π (from D* decay)
    - Figure of merit: $Q = \varepsilon_{tag}(1-2\omega)^2$
    - ε_{tag} = tagging efficiency, ω=mistag probability
    - Resolution on S and C: $\sigma_{S,C} \propto \frac{1}{\sqrt{Q}}$
  - SuperB: expect to increase Q thanks to larger tracking coverage, improved PID, better vertexing

Status of β Measurements

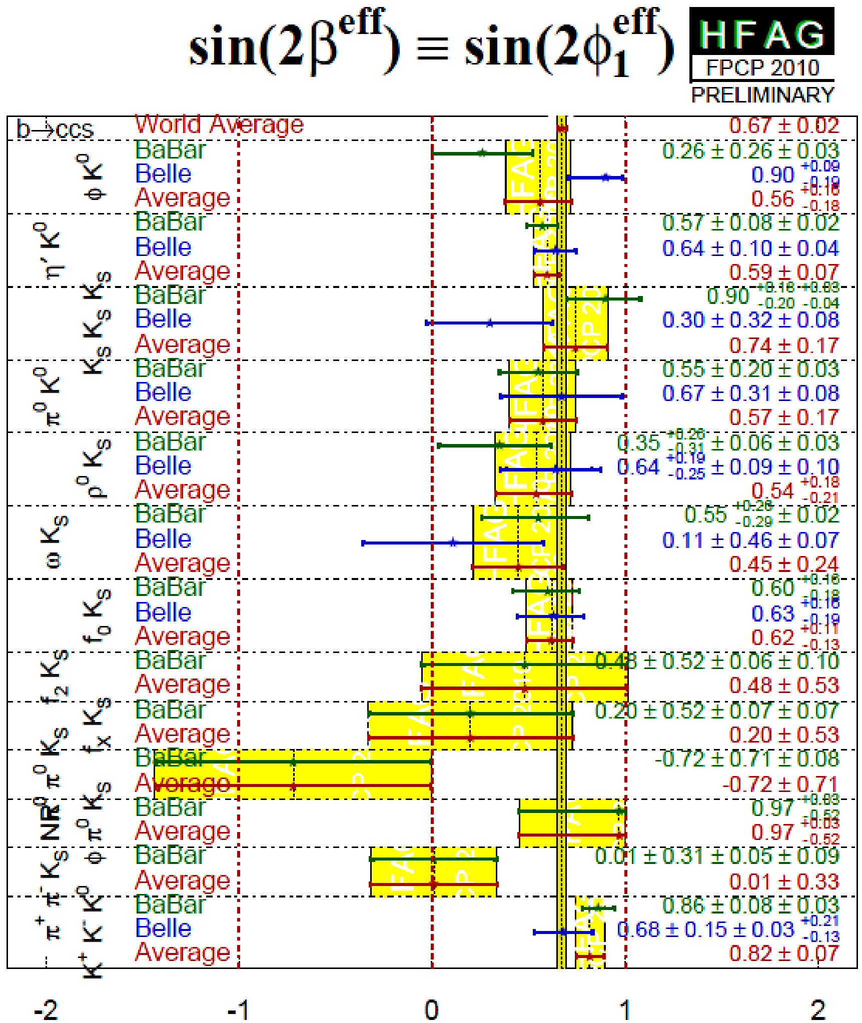
- Golden modes: three and penguin diagrams have ~ same weak phase -> measure β
- Penguin dominated modes: interference between diagrams with different weak phases.
  - Discrepancies with respect to β from golden modes is hint of new physics in loop diagram.

some of recent QCDF estimates

$\sin 2\beta^{f}_{eff} - \sin 2\beta$



QCDF: (Beneke, PLB620 (2005), 143-150, Cheng et al., PRD72 (2005) 094003 etc.
SCET: (Williamson & Zupan, hep-ph/0601214)



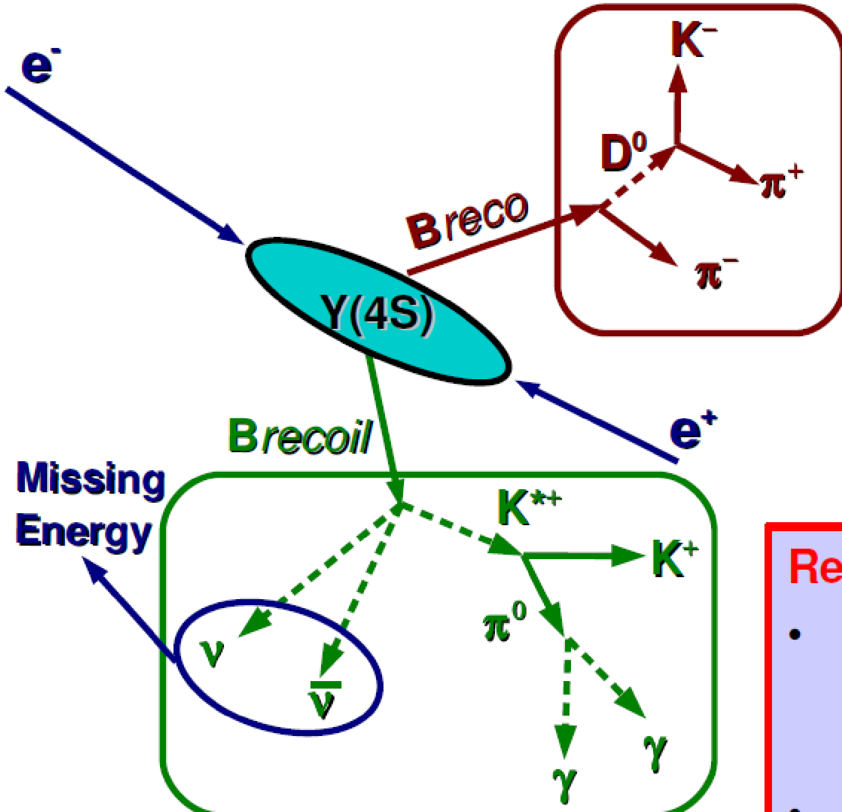
β @ SuperB

- Summary of β measurement with current precision and integrated luminosity of 75 ab^{-1}.
  - Scale statistics error and reducible systematic by luminosity.
  - Detector performance improvement not accounted for.

Mode	Current Precision			Predicted Precision (75 ab^{-1})		
	Stat.	Syst.	Th.	Stat.	Syst.	Th.
$J/\psi K^0_S$	0.022	0.010	< 0.01	0.002	0.005	< 0.001
$\eta' K^0_S$	0.08	0.02	0.014	0.006	0.005	0.014
$\phi K^0_S \pi^0$	0.28	0.01	–	0.020	0.010	–
$f_0 K^0_S$	0.18	0.04	0.02	0.012	0.003	0.02
$K^0_S K^0_S K^0_S$	0.19	0.03	0.013	0.015	0.020	0.013
ϕK^0_S	0.26	0.03	0.02	0.020	0.010	0.005
$\pi^0 K^0_S$	0.20	0.03	0.025	0.015	0.015	0.025
ωK^0_S	0.28	0.02	0.035	0.020	0.005	0.035
$K^+ K^- K^0_S$	0.08	0.03	0.05	0.006	0.005	0.05
$\pi^0 \pi^0 K^0_S$	0.71	0.08	–	0.038	0.045	–
ρK^0_S	0.28	0.07	0.14	0.020	0.017	0.14
$J/\psi \pi^0$	0.21	0.04	–	0.016	0.005	–
$D^{*+} D^{*-}$	0.16	0.03	–	0.012	0.017	–
$D^+ D^-$	0.36	0.05	–	0.027	0.008	–

arXiv:1008.1541 (2010)

Recoil Analysis Technique (1)



B*reco*: full (partial) reconstruction of one B into a hadronic (semi-leptonic) final state

B*recoil*: look for the signal signature, e.g. $K^{(*)}$ not accompanied by additional (charged+neutral) particles + **Missing Energy**

Recoil technique at B-Factories:

- search for rare decays ($\sim 10^{-5}$) with missing energy
  (Not possible at hadronic machines)
- Several benchmark channels at SuperB: $B\to\tau\nu$, $B\to K^{(*)}\nu\nu$, ...

Recoil Analysis Technique (2)

- Aim: collect as many as possible fully/partially reconstructed B mesons in order to study the properties of the Brecoil
- 1st step: reconstruction $D \to$ hadrons

$D^{*+} \to D^0\pi^+$	$D^0 \to K^-\pi^+$	$D^+ \to K^-\pi^+\pi^-$
$D^{*0} \to D^0\pi^0$	$D^0 \to K^-\pi^+\pi^0(\gamma\gamma)$	$D^+ \to K^-\pi^+\pi^-\pi^0$
$D^{*0} \to D^0\gamma$	$D^0 \to K^-\pi^+\pi^+\pi^-$	$D^+ \to K^0_S\pi^+$
	$D^0 \to K^0_S\pi^+\pi^-$	$D^+ \to K^0_S\pi^+\pi^-\pi^+$
		$D^+ \to K^0_S\pi^+\pi^0$

2nd step:

Hadronic *Breco*: $B \to DX$

- Use D as a seed and add X to have system compatible with B hypothesis

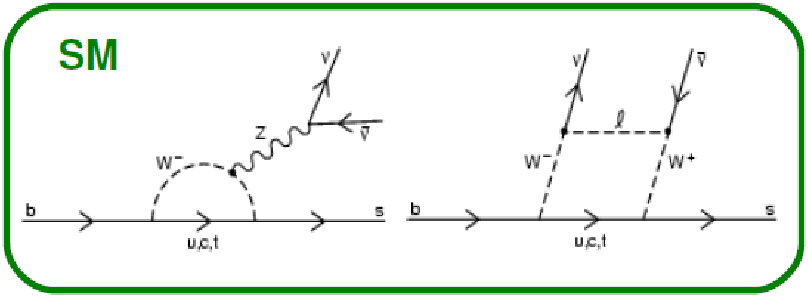
  ($X = n\pi^\pm\ mK^\pm\ rK^0_S\ q\pi^0$ and $n+m+r+q<6$)
- Sample of 1100 B decay modes with different purities
- Kinematics completely constrained ☺
- Low reconstruction efficiencies ☹ (~0.4%)

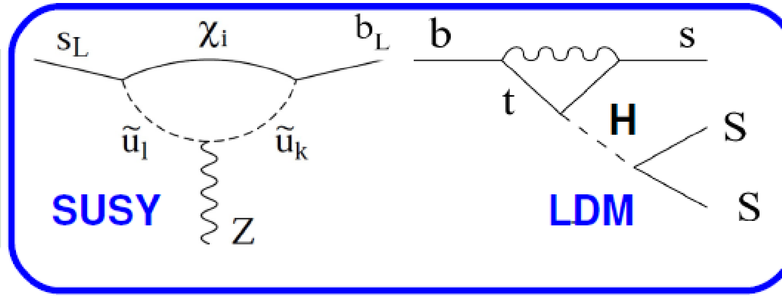
Semi-Leptonic *Breco*: $B \to D^{(*)}l\nu$

- Use D as a seed and a lepton to form a Dl pair ($l = e^\pm, \mu^\pm$)
- Sample of 14 B decay modes
- Kinematics is unconstrained due to neutrino ☹
- Higher reconstruction efficiencies (~2.0%) ☺

$B \longrightarrow K^{(*)} \nu\nu$

- **Electroweak penguin (loop diagram) radiated processes ($b \to s$):**
  - Flavor changing neutral current (FCNC) prohibited in SM at tree level
  - Sensitive New Physics (NP): Susy particles, light dark matter (LDM), ...



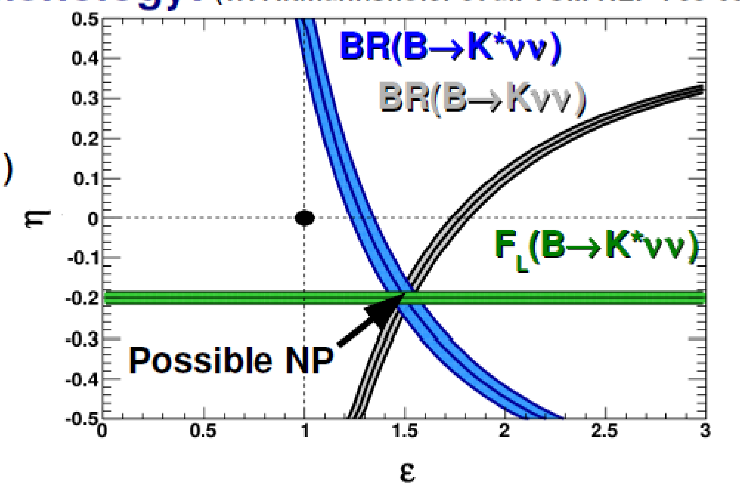


- **$b \to s\nu\nu$ model independent phenomenology:** (W. Altmannshofer et al. TUM-HEP-709-09)

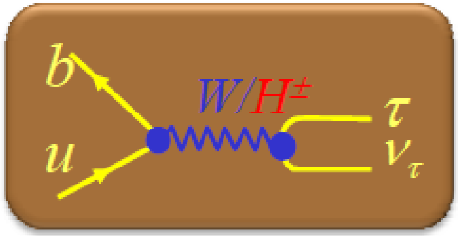
  - $BR(B \to K\nu\nu) = (4.5 \pm 0.7) \times 10^{-6} (1-2\eta)\varepsilon^2$
  - $BR(B \to K^*\nu\nu) = (6.8 \pm 1.1) \times 10^{-6} (1+1.31\eta)\varepsilon^2$
  - $F_L(B \to K^*\nu\nu) = (0.54 \pm 0.01)(1+2\eta)/(1+1.31\eta)$

$$\frac{d\Gamma}{d\cos\theta} \propto \frac{3}{4}(1 - \langle F_L \rangle)\sin^2\theta + \frac{3}{2}\langle F_L \rangle \cos^2\theta$$

θ(helicity) = angle between:
- K* direction in B rest frame
- K direction in K* rest frame

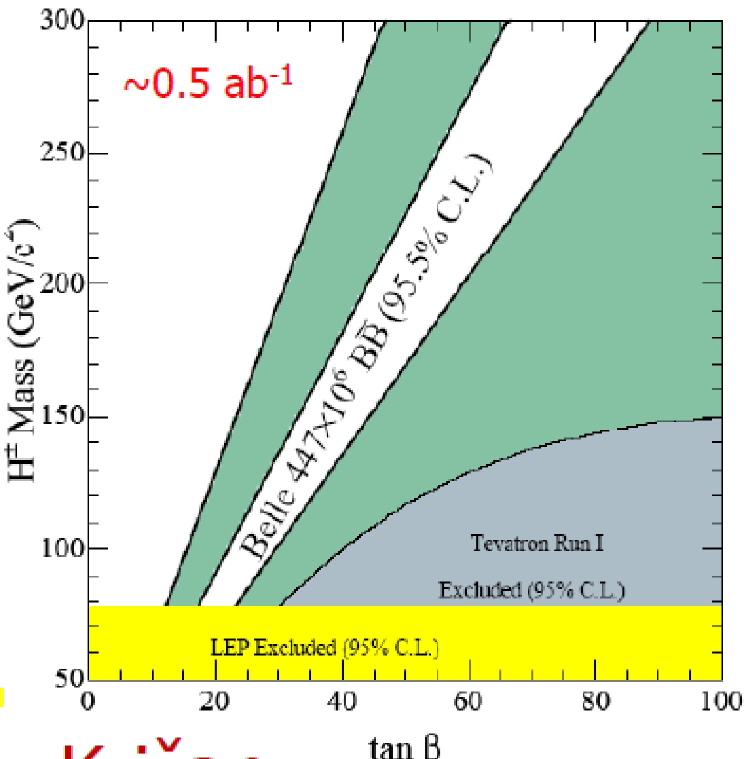


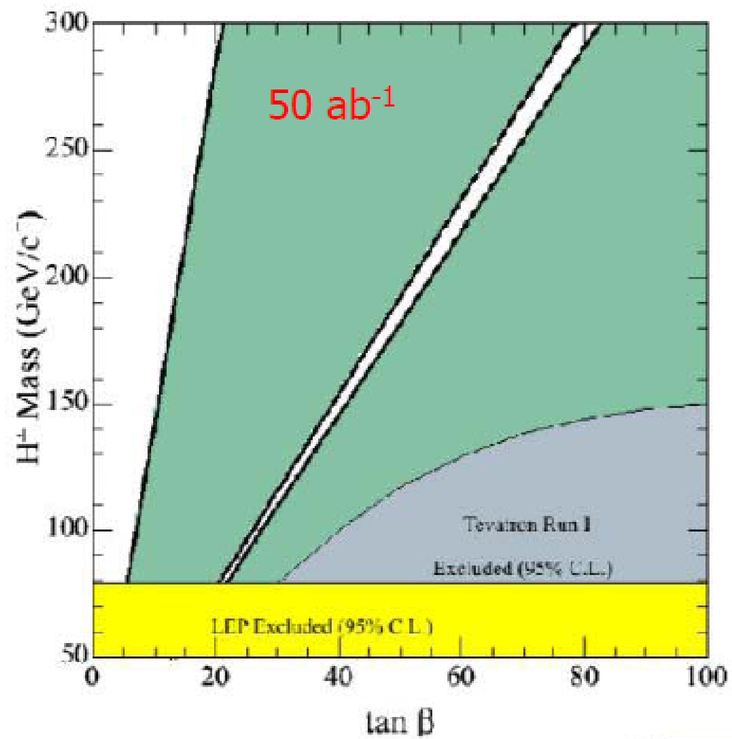
Charged Higgs limits from $B^- \to \tau^- \nu_\tau$



$$r_H = \frac{BF(B \to \tau\nu)}{BF(B \to \tau\nu)_{SM}} = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

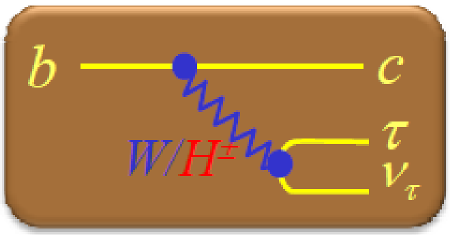
→ limit on charged Higgs mass vs. tanβ





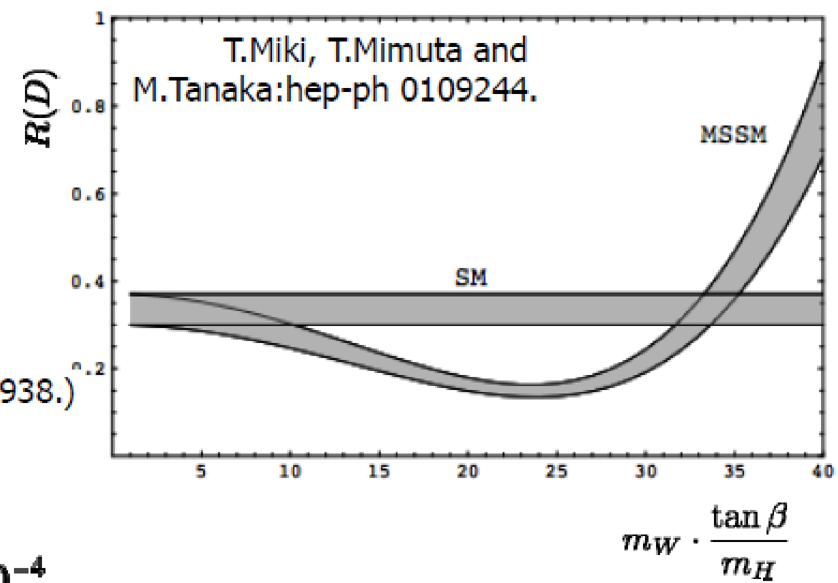
$B \to D^{(*)} \tau \nu$

Semileptonic decay sensitive to charged Higgs



Ratio of τ to μ,e could be reduced/enhanced significantly

$$R(D) \equiv \frac{\mathcal{B}(B \to D\tau\nu)}{\mathcal{B}(B \to D\ell\nu)}$$



Compared to $B \to \tau\nu$

1. Smaller theoretical uncertainty of R(D)

   (For $B \to \tau\nu$,
   There is O(10%) f_B uncertainty from lattice QCD)

2. Large expected Br (Ulrich Nierste arXiv:0801.4938.)

$$\mathcal{B}(B^- \to D^0\tau^-\bar{\nu}_\tau)^{SM} = (0.71 \pm 0.09)\%$$
$$\mathcal{B}(\bar{B}^0 \to D^+\tau^-\bar{\nu}_\tau)^{SM} = (0.66 \pm 0.08)\%$$
$$\mathcal{B}(B \to \tau\nu) = [1.65^{+0.38}_{-0.37}(stat)^{+0.35}_{-0.37}(syst)] \times 10^{-4}$$

3. Differential distributions can be used to discriminate W^+ and H^+
4. Sensitive to different vertex $B \to \tau\nu$: H-b-u, $B \to D\tau\nu$: H-b-c
   (LHC experiments sensitive to H-b-t)

Peter Križan

Lepton Flavor Violation in τ Decays (1)

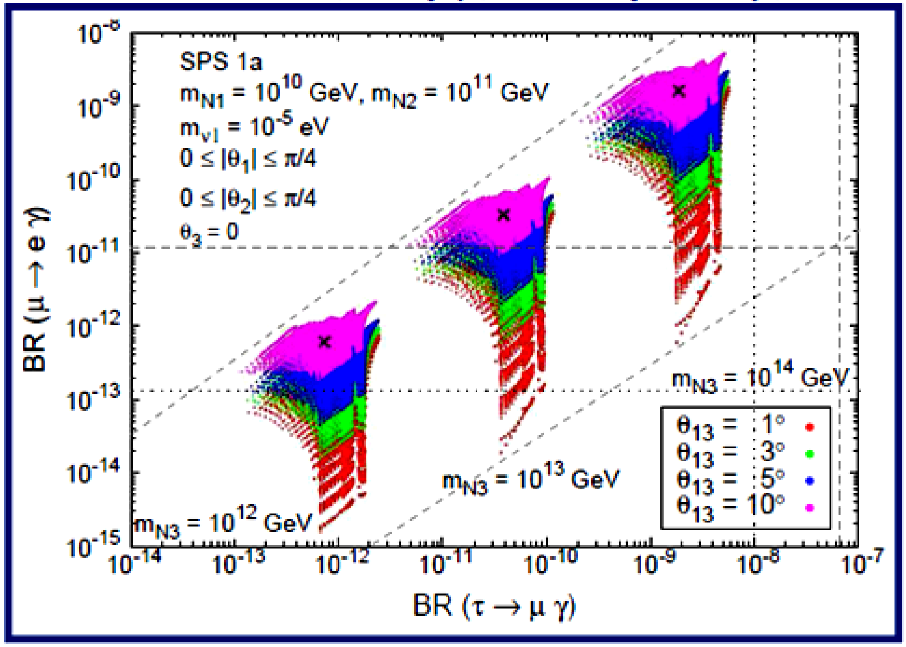
- constrained **MSSM-seesaw** and **NUHM SUSY** expectations from
  - S. Antusch, E. Arganda, M.J. Herrero, A.M. Texeira, JHEP11(2006)090, arXiv:hep-ph/0607263v2
    E. Arganda, M.J. Herrero, J. Portoles, JHEP06(2008)079, arXiv:0803.2039v3 [hep-ph]
    + several other refs. in 2010 Super*B* physics report
  - G.Isidori and P.Paradisi in the 2010 Super*B* physics report itself

Snowmass Points and Slopes reference points

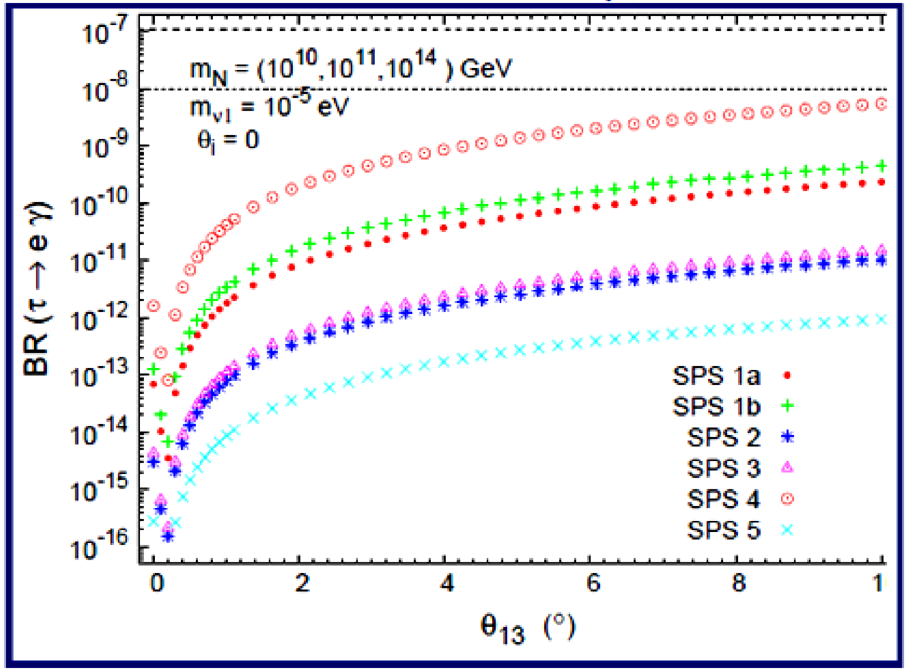
SPS	$M_{1/2}$ (GeV)	M_0 (GeV)	A_0 (GeV)	$\tan\beta$	μ
1 a	250	100	-100	10	> 0
1 b	400	200	0	30	> 0
2	300	1450	0	10	> 0
3	400	90	0	10	> 0
4	300	400	0	50	> 0
5	300	150	-1000	5	> 0

Lepton Flavor Violation in τ Decays (2)

CMSSM BF($\tau \to \mu\gamma$) vs. BF($\mu \to e\gamma$)



CMSSM BF($\tau \to e\gamma$)

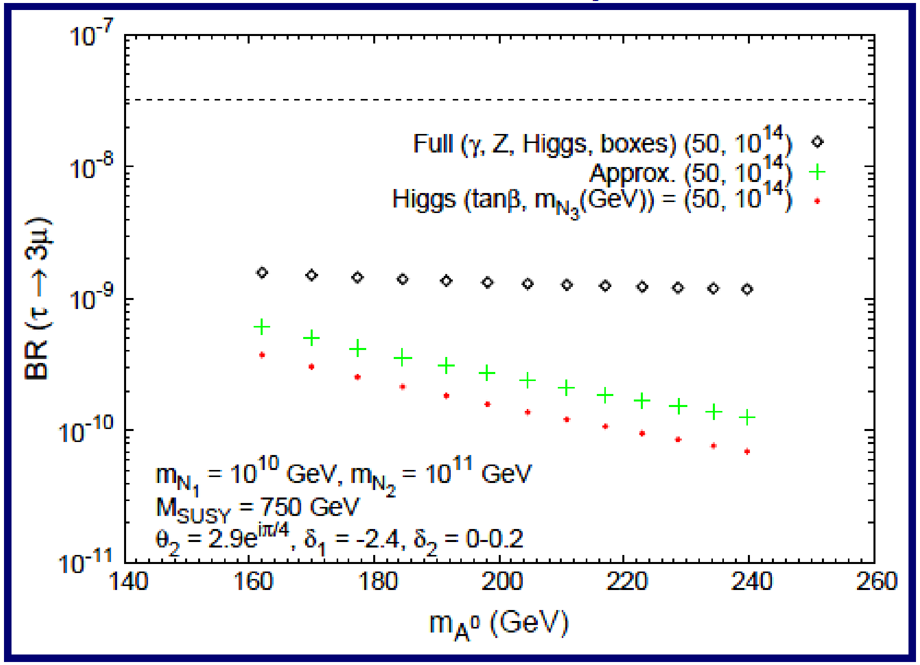


N_i = right-handed neutrinos
ν_i = left-handed neutrinos
θ_i = N complex mixing angles
θ_{13} refers to PNMS mixing matrix
other info on JHEP11(2006)090

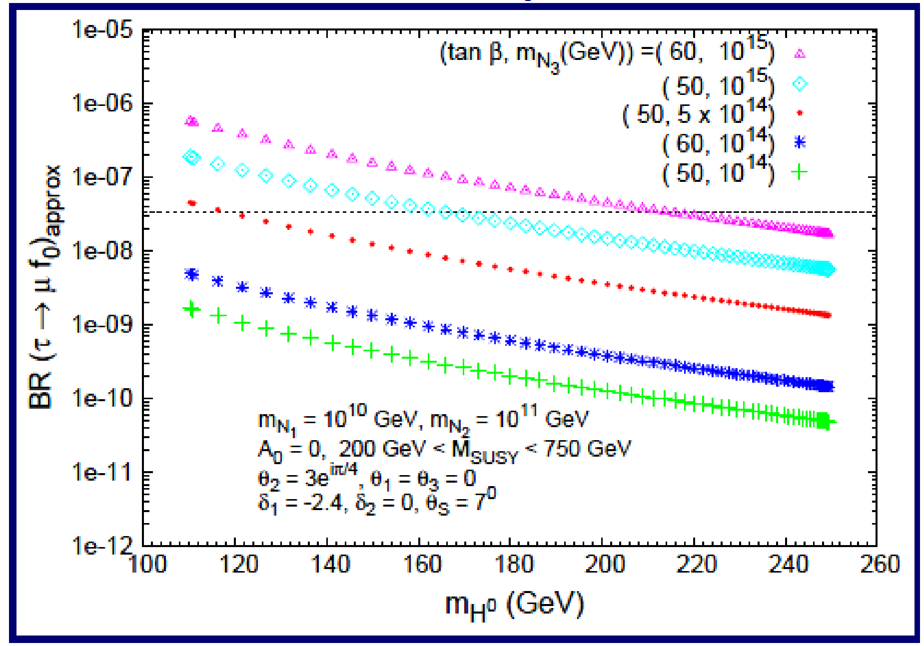
- tau LFV decays up to present limits for some SPS points
- $\tau \to \mu\gamma$ complementary to θ_{13}-sensitive $\mu \to e\gamma$

Lepton Flavor Violation in τ Decays (3)

NUHM BF($\tau \to 3\mu$)



NUHM BF($\tau \to \mu f_0(980)$)



δ_1, δ_2 parametrize non-universal Higgs masses
other info in JHEP06(2008)079 for left plot
other info in arXiv:0812.2692v1 [hep-ph] for right plot

- with NUHM Super*B* may be more sensitive to $\tau \to \mu f_0(980)$, $\tau \to \mu\eta$ than to $\tau \to \mu\gamma$

SuperB Sensitivity to $\tau \rightarrow \mu \gamma$, $\tau \rightarrow e \gamma$

- start from BABAR 2010, Phys.Rev.Lett.104:021802,2010, arXiv:0908.2381v2 [hep-ex]
- use BABAR efficiency, scale expected background with ratio of luminosity
  - i.e. analysis not re-optimized for SuperB
- assume 35% reduction of signal region from smaller beam-spot, better vertex detector (better resolution is planned to compensate smaller boost)
- assume 20% efficiency increase for photons from better hermeticity, DIRC redesign
- approximate frequentistic upper limits, only Poissonian BKG uncertainty
- at least 5 observed events for evidence

process	efficiency	expected background	expected 90% CL upper limit	3σ evidence reach
BF($\tau \rightarrow \mu \gamma$)	7.3%	335	$2.4 \cdot 10^{-9}$	$5.4 \cdot 10^{-9}$
BF($\tau \rightarrow e \gamma$)	3.9%	149	$3.0 \cdot 10^{-9}$	$6.8 \cdot 10^{-9}$

SuperB Sensitivity to $\tau \to 3\ell$

- start from BABAR 2010, PhysRevD.81.111101(2010), arXiv:1002.4550v1 [hep-ex]
- selection requirements re-optimized for best upper limit at Super*B*
  - fair simulation of background through lepton mis-id
  - only very approximate simulation of BKG from true leptons or Bhabha/dimuon events
- no detector improvement has been assumed
- approximate frequentistic upper limits, only Poissonian BKG uncertainty
- at least 5 observed events for evidence
- Super*B* sensitivity improvement ~150

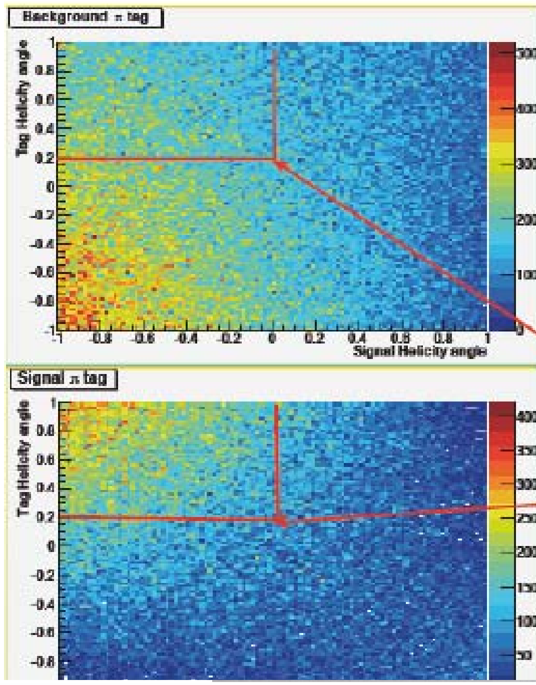
Process	Expected 90% CL upper limit	3σ evidence reach
$\mathrm{BF}(\tau \to \ell\ell\ell)$	$2.3\text{–}8.2 \cdot 10^{-10}$	$1.2\text{–}4.0 \cdot 10^{-9}$

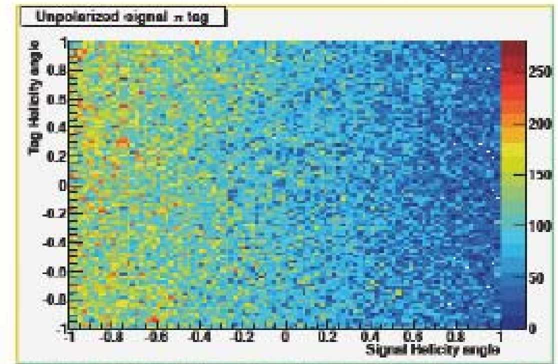
LFV in τ Decays with Polarization

τ-> μνν
background

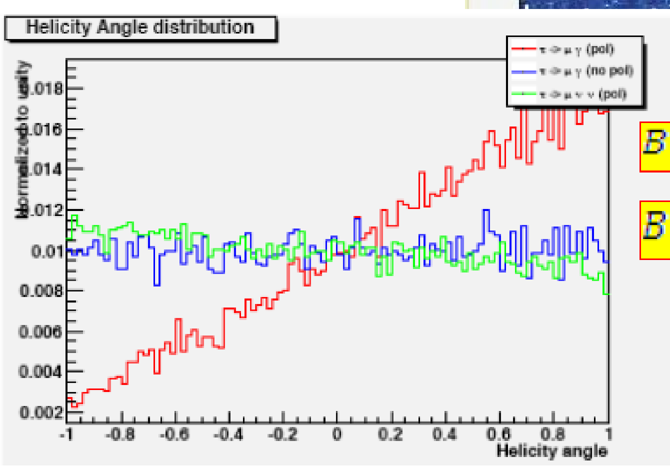
τ-> μγ vs τ->πν
cos(helicity)

signal





Applying a rectangular cut
eff. on signal ~40-45%
bkg retained ~ 10-15%



$B(\tau \to \mu\gamma)$ $2 \times 10 - 9$

$B(\tau \to e\gamma)$ $2 \times 10 - 9$

→

$B(\tau \to \mu\gamma)$ $1 \times 10 - 9$

$B(\tau \to e\gamma)$ $1 \times 10 - 9$

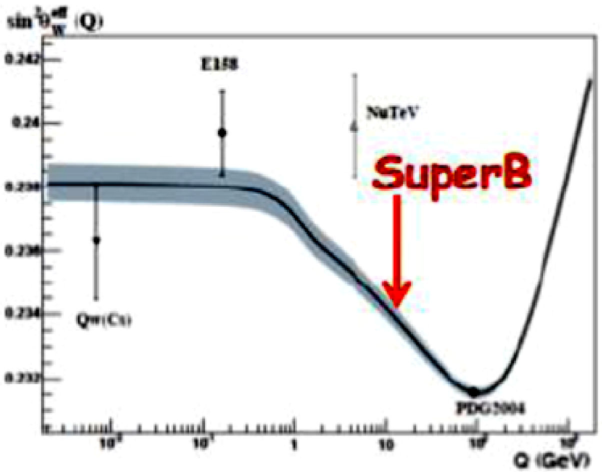
Sensitivity improves at least by a factor 2.
Equivalent to a factor 4 increase in luminosity.

CPV in τ Decays

- SM predictions in general very small
  ($\tau^\pm \to K^\pm \pi^0 \nu$ *CP* asymmetry $O(10^{-12})$, 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 $\langle\xi\rangle = (-2.0 \pm 1.8){\cdot}10^{-3}$
  - data calibration with $\tau \to \pi\pi\pi\nu$
- extrapolating at Super*B*, $\sigma_{\langle\xi\rangle} \approx 2.4{\cdot}10^{-5}$
  - assume also systematics scale with $1/\sqrt{\mathcal{L}}$
  - will update the extrapolation using **Belle analysis presented at Tau10**
- beam polarization can provide extra equivalent luminosity (to be studied)

Electroweak Measurement with Polarization

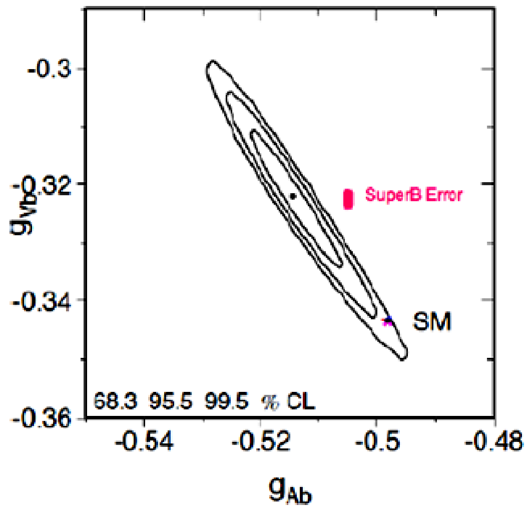


$$A_{LR} = \frac{\sigma(P)-\sigma(-P)}{\sigma(P)+\sigma(-P)} = \frac{16}{\sqrt{2}} \left(\frac{G_F q^2}{4\pi\alpha}\right) \left(\frac{g_A^e \; g_V^b}{Q_b}\right) P$$

- Measurable for all $B^0\,\bar{B}^0$ and $B^+\,B^-$ final states, both resonant and continuum.
- **All** QCD corrections included in the **single** form factor that cancels in the asymmetry.
- Very clean measurement, no **large** theoretical corrections (in progress...)

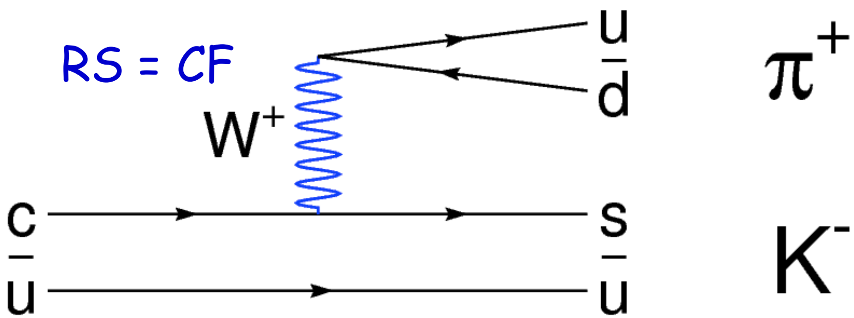
$\Rightarrow$ Excellent opportunity to measure g_V & $\sin^2\theta_W$ at SuperB with polarized beams!!

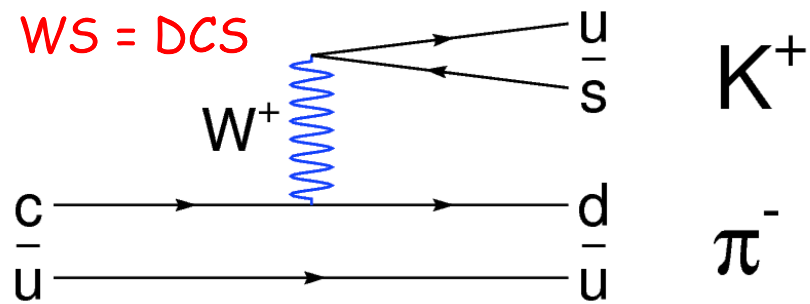
0.5% polarization syst.
0.3% stat. error
→ 0.0021



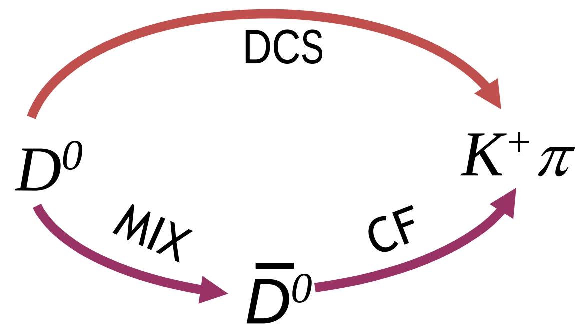
Important point :
The L-R luminosity asymmetry has to be very well controlled.
Possibly done using monitoring using Bhabhas. Thought needed

Charm Mixing: Time-Evolution of $D^0 \to K\pi$ Decays





DCS and mixing amplitudes interfere to give a "quadratic" WS decay rate (x, y << 1):



$$\frac{\Gamma_{WS}(t)}{e^{-t/\tau}} \propto R_D + \sqrt{R_D}\, y' \left(\frac{t}{\tau}\right) + \left(\frac{x'^2 + y'^2}{4}\right)\left(\frac{t}{\tau}\right)^2$$

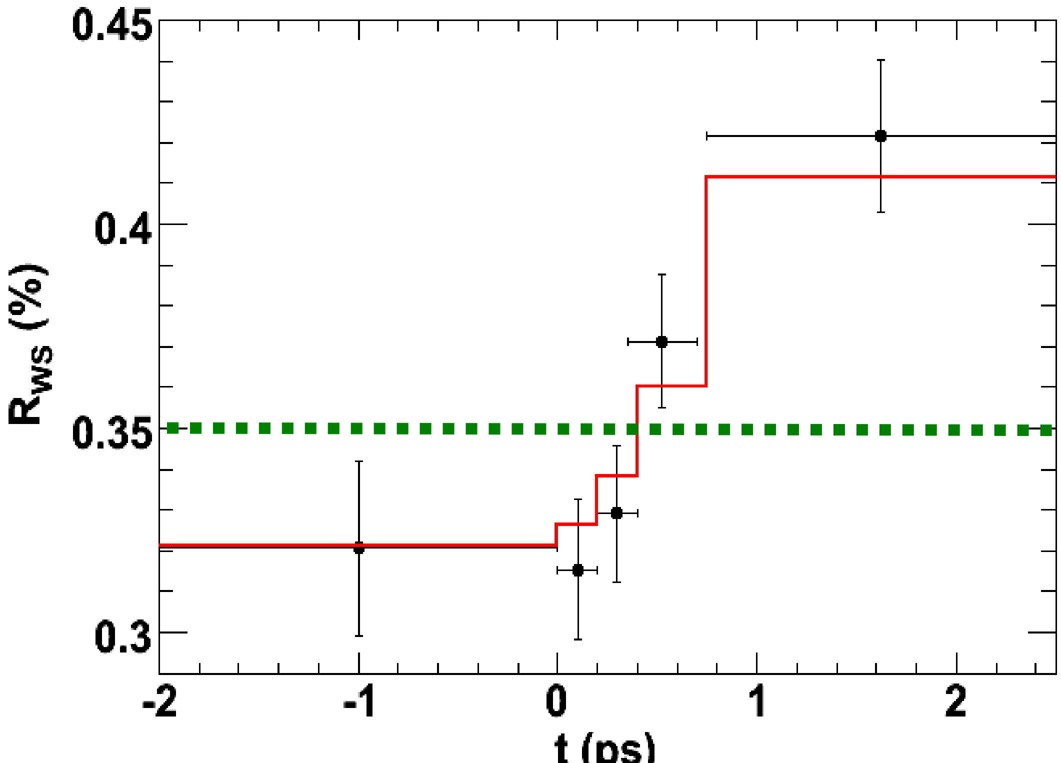
$$x' = x\cos\delta + y\sin\delta \qquad y' = y\cos\delta - x\sin\delta$$

δ is the phase difference between DCS and CF decays.

Simplified Fit Strategy & Validation

Rate of WS events clearly increases with time:

$$\frac{\Gamma_{\rm WS}(t)}{e^{-t/\tau}} \propto R_D + \sqrt{R_D}\, y' \left(\frac{t}{\tau}\right) + \left(\frac{x'^2 + y'^2}{4}\right)\left(\frac{t}{\tau}\right)^2$$



Consistent with prediction from full likelihood fit

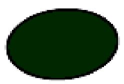
χ^2=1.5

Inconsistent with no-mixing hypothesis: χ^2=24

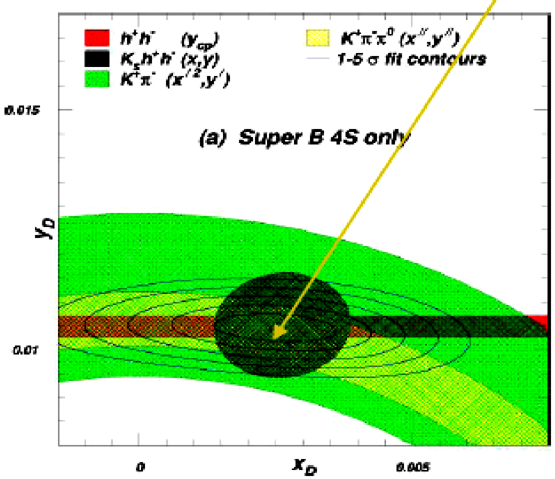
Running at Open Charm Threshold: 500 fb^{-1} at $\Psi(3770)$

- Decays of $\Psi(3770) \rightarrow D^0 D^0$ produce coherent $(C=-1)$ pairs of D^0's. Quantum correlations in their subsequent decays allow measurements of strong phases.
  - Required for improved measurement of CKM angle γ.
  - Also required for D^0 mixing studies

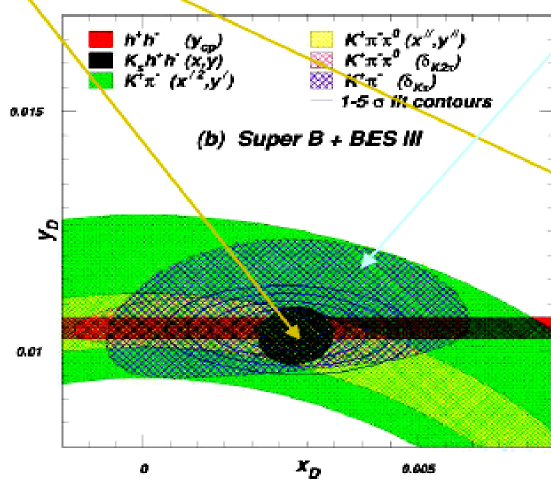
- Dalitz plot model uncertainty shrinks



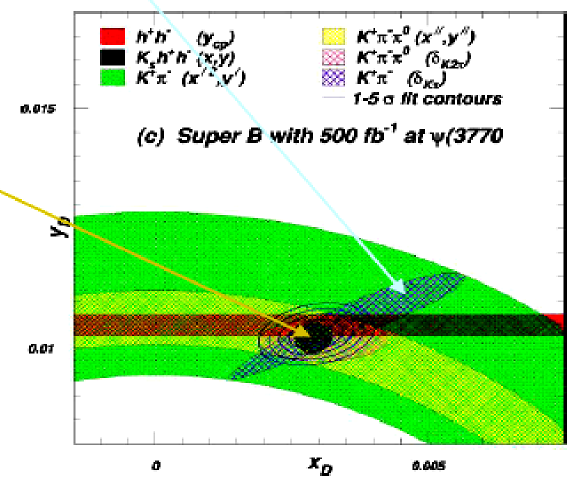
- Information on overall strong phase is added



Fit	$x \times 10^3$	$y \times 10^3$	$\delta^\circ_{K+\pi-}$	$\delta^\circ_{K+\pi-\pi^0}$
(b)	$xxx^{+0.72}_{-0.75}$	$xxx \pm 0.19$	$xxx^{+3.7}_{-3.4}$	$xxx^{+4.6}_{-4.5}$
Stat.	(0.18)	(0.11)	(1.3)	(2.9)



Fit	$x \times 10^3$	$y \times 10^3$	$\delta^\circ_{K+\pi-}$	$\delta^\circ_{K+\pi-\pi^0}$
(c)	$xxx \pm 0.42$	$xxx \pm 0.17$	$xxx \pm 2.2$	$xxx^{+3.3}_{-3.4}$
Stat.	(0.18)	(0.11)	(1.3)	(2.7)



Fit	$x \times 10^3$	$y \times 10^3$	$\delta^\circ_{K+\pi-}$	$\delta^\circ_{K+\pi-\pi^0}$
(d)	$xxx \pm 0.20$	$xxx \pm 0.12$	$xxx \pm 1.0$	$xxx \pm 1.1$
Stat.	(0.17)	(0.10)	(0.9)	(1.1)

Uncertainty in x_D improves more than that of y_D

Summary of Physics Goals and special requirements

- Increase by O(10) the precision of BaBar & Belle.
- Challenge CKM at the level of 1%.
- Improve sensitivity for LFV in τ decays by a factor between 10 and 100.
- Explore T-violation in τ.
- Search for magnetic structure of τ.
- Explore CPV in Charm also with time dependent asymmetries.
- Great new Spectroscopy exploration.

In SuperB option for beam polarization and possibility to run in asymmetric mode at charm threshold

This rich menu can be effectively mined with 75 ab^{-1} in 5 years at $\Upsilon(4S)$ and a few months at Charm threshold with peak luminosity of 10^{35} cm^{2} s^{-1}.

Machine:
Parameter Requirements from Physics

Parameter	Requirement	Comment
Luminosity (top-up mode)	$\geq 10^{36}$ cm^{-2}s^{-1} @ $\Upsilon(4S)$	It can extend up to an ultimate peak luminosity of 4 10^{36} cm^{-2}s^{-1}
Integrated luminosity	75 ab^{-1}	Based on a “New Snowmass Year” of 1.5 x 10^7 seconds (PEP-II experience-based)
CM energy range	τ threshold to Υ (5S)	
Minimum boost	$\beta\gamma = 0.28$ (≈4x7 GeV)	1 cm beampipe radius. First measurement at 1.5 cm
e^- Polarization	60-85%	Enables τ CP and T violation studies, measurement of τ g-2 and improves sensitivity to lepton flavor-violating decays. Detailed simulation, needed to ascertain a more precise requirement, are in progress.

The Super Flavor Factories

	SuperB	Super KEKB
Peak Luminosity	$>10^{36}$	0.8×10^{36}
Integrated Luminosity	75 ab^{-1}	50 ab^{-1}
Site	Green Field	KEKB Laboratory
Collisions	mid 2016	2015
Polarization	80% electron beam	No
Low energy running	10^{35} @ charm threshold	No
Approval status	Approved	Approved

How to get 100 times more luminosity ?

$$L = 2.17 \times 10^{34} \frac{n \xi_y E I_b}{\beta_y^*}$$

ξ_y	Vertical beam-beam parameter
I_b	Bunch current (A)
n	Number of bunches
β_y^*	IP vertical beta (cm)
E	Beam energy (GeV)

Present day B-factories

	PEP-II	KEKB
E(GeV)	9x3.1	8x3.5
I_b	1x1.6	0.75x1
n	1700	1600
I (A)	1.7x2.7	1.2x1.6
β_y^* (cm)	1.1	0.6
ξ_y	0.08	0.11
L ($\times 10^{34}$)	1	2

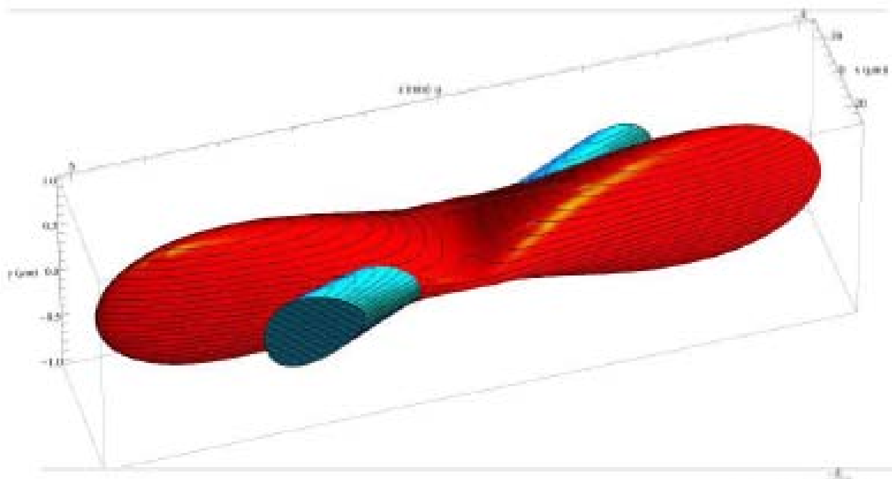
Answer:

Increase	I_b
Decrease	β_y^*
Increase	ξ_y
Increase	**n**

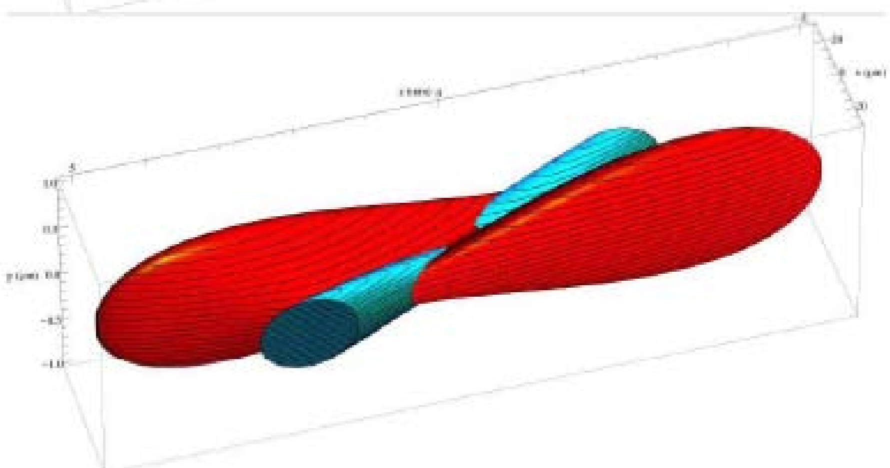
A New Idea

- Pantaleo Raimondi came up with a new scheme to attain high luminosity in a storage ring:
  - Change the collision so that only a small fraction of one bunch collides with the other bunch
    - Large crossing angle
    - Long bunch length
  - Due to the large crossing angle the effective bunch length (the colliding part) is now very short so we can lower β_y* by a factor of 50
  - The beams must have very low emittance – like present day light sources
    - The x size at the IP now sets the effective bunch length
  - In addition, by crabbing the magnetic waist of the colliding beams we greatly reduce the tune plane resonances enabling greater tune shifts and better tune plane flexibility
    - This increases the luminosity performance by another factor of 2-3

How the Crabbed Waist Works



Crab-sextupoles off:
waist line is orthogonal to the axis of the beam



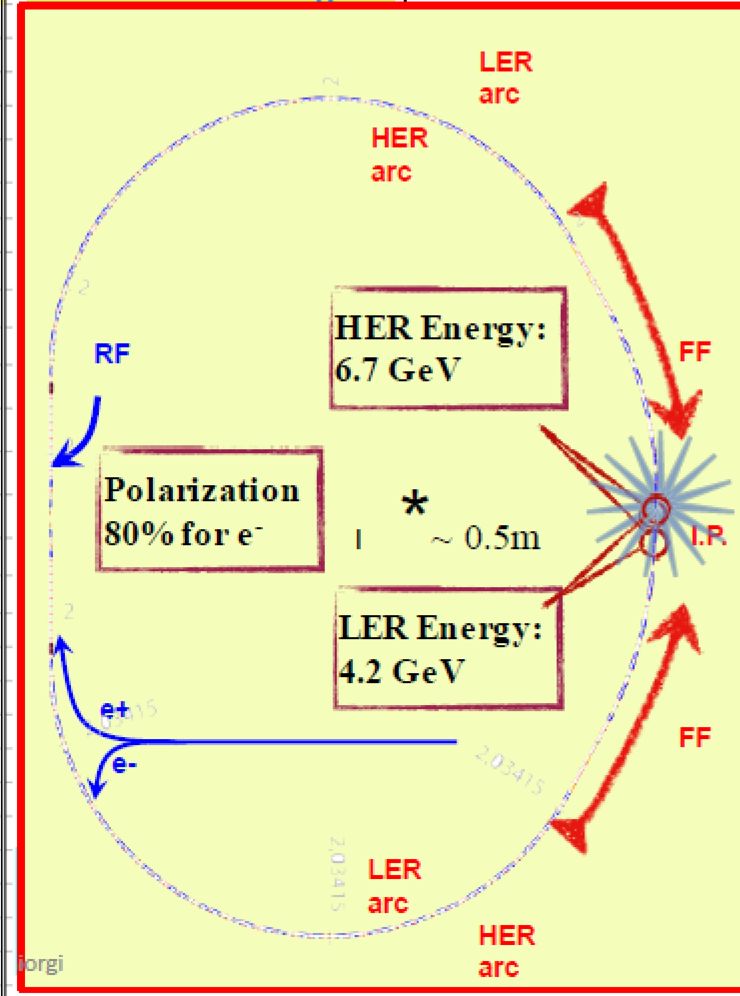
Crab-sextupoles on:
waist moves parallel to the axis of other beam: maximum particle density in the overlap between bunches

All particles in both beams collide in the minimum β_y region, with a net luminosity gain

SuperB Parameters

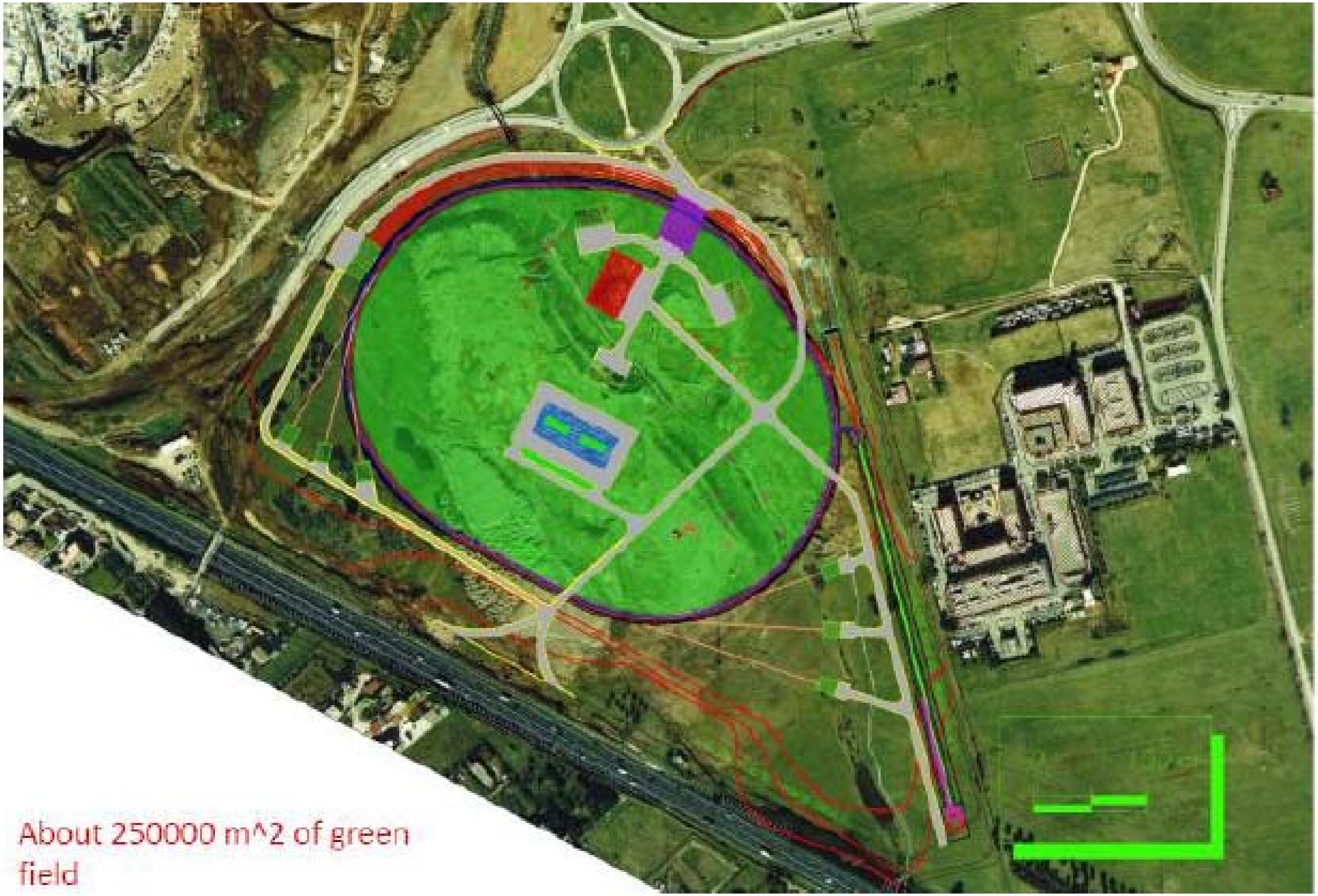
Parameter	Units	Base Line HER (e+)	Base Line LER (e-)	Low Emittance HER (e+)	Low Emittance LER (e-)	High Current HER (e+)	High Current LER (e-)	Tau/Charm (prelim.) HER (e+)	Tau/Charm (prelim.) LER (e-)
LUMINOSITY	$cm^{-2}\ s^{-1}$	1.00E+36		1.00E+36		1.00E+36		1.00E+35	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18	2.58	1.61
Circumference	m	1258.4		1258.4		1258.4		1258.4	
X-Angle (full)	mrad	66		66		66		66	
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
β_x @ IP	cm	2.6	3.2	2.6	3.2	5.06	6.22	6.76	8.32
β_y @ IP	cm	0.0253	0.0205	0.0179	0.0145	0.0292	0.0237	0.0658	0.0533
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.5	0.5	0.25	0.25
ε_x (without IBS)	nm	1.97	1.82	1.00	0.91	1.97	1.82	1.97	1.82
ε_x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
ε_y	pm	5	6.15	2.5	3.075	10	12.3	13	16
σ_x @ IP	μm	7.244	8.872	[illegible]	6.274	10.060	12.370	18.749	23.076
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.054	0.092	0.092
Σ_x	μm	11.433		8.085		15.944		29.732	
Σ_y	μm	0.050		0.030		0.076		0.131	
σ_L (0 current)	mm	4.69	4.29	4.73	4.34	4.03	3.65	4.75	4.36
σ_L (full current)	mm	5	5	5	5	4.4	4.4	5	5
Beam current	mA	1892	2447	1460	1888	3094	4000	1365	1766
Buckets distance	#	2		2		1		1	
Ion gap	%	2		2		2		2	
RF frequency	Hz	4.76E+08		4.76E+08		4.76E+08		4.76E+08	
Harmonic number		1998		1998		1998		1998	
Number of bunches		978		978		1956		1956	
N. Particle/bunch		5.08E+10	6.56E+10	3.92E+10	5.06E+10	4.15E+10	5.36E+10	1.83E+10	2.37E+10
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.0970	0.0971	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Long. damping time	msec	13.4	20.3	13.4	20.3	13.4	20.3	26.8	40.6
Energy Loss/turn	MeV	2.11	0.865	2.11	0.865	2.11	0.865	0.4	0.166
σ_E (full current)	dE/E	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.94E-04	7.34E-04
CM σ_E	dE/E	5.00E-04		5.00E-04		5.00E-04		5.26E-04	
Total lifetime	min	4.23	4.48	3.05	3.00	7.08	7.73	11.41	6.79
Total RF Power	MW	17.08		12.72		30.48		3.11	

Tau/charm threshold running



J.Seeman

The Nicola Cabibbo Lab (Tor Vergata)



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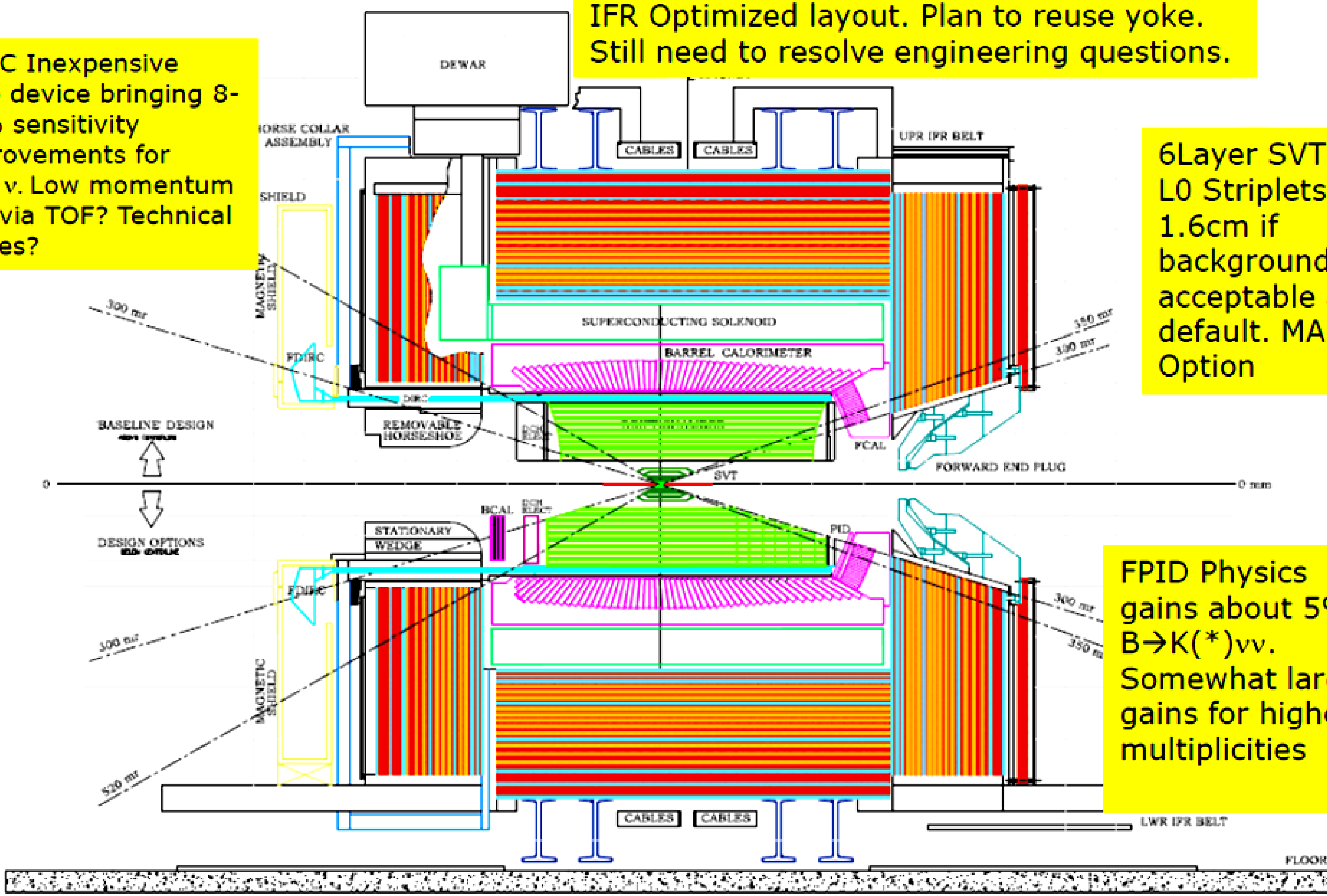
Detector Layout

IFR Optimized layout. Plan to reuse yoke. Still need to resolve engineering questions.

BEMC Inexpensive Veto device bringing 8-10% sensitivity improvements for B→τ ν. Low momentum PID via TOF? Technical Issues?

6Layer SVT L0 Striplets @ 1.6cm if background is acceptable as default. MAPS Option



FPID Physics gains about 5% in B→K(*)νν. Somewhat larger gains for higher multiplicities

Detector Evolution, from BaBar to SuperB

- CDR Baseline based on BaBar. It reuses
  - Fused Silica bars of the DIRC
  - DIRC & DCH Support
  - Barrel EMC CsI(Tl) crystals and mechanical structure
  - Superconducting coil & flux return (with some redesign)

- Some elements have aged and need replacement. Others require moderate improvements to cope with the high luminosity environment, the smaller boost (4x7 GeV), and the high DAQ rates.
  - Small beam pipe technology
  - Thin silicon pixel detector for first layer, and a new 5 layer SVT.
  - New DCH with CF mechanical structure, modified gas and cell size
  - New Photon detection for DIRC fused silica bars
  - Possible Forward PID system (TOF in Baseline option)
  - New Forward calorimeter crystals (LYSO).Backward veto
  - Minos-style extruded scintillatorfor instrumented flux return
  - Electronics and trigger-x100 real event rate

Outline of Computing Activities

- Design of the SuperB computing model.
  - R&D program that will finish with the completion of the Computing TDR (end 2012).
- Development and support of the simulation software tools and of the computing production infrastructure needed for carrying out the detector design and performance evaluation studies for the Detector TDR.
  - Bruno: detailed simulation based on the Geant4 toolkit.
    - Used to evaluate machine background rate and particle fluxes in different sub-detectors.
  - FastSim: a faster parametric simulation and reconstruction code that can be directly interfaced with the BaBar analysis code.
    - Used to estimate the impact of different sub-detector options on a large set of physics analysis.
  - A suite of production tools capable of fully exploiting the existing HEP world wide Grid computing infrastructure. Over 12 billion events produced so far.
  - A set of collaborative tools to support day by day document and code development.

Baseline Computing Model

- Baseline is an extrapolation of BaBar computing model to a luminosity 100 times larger.
  - Need to evaluate impact of distributed computing environment and of multi/many-core architecture.
- "Raw data" from the detector will be permanently stored, and reconstructed in a two step process:
  - a "prompt calibration" pass on a subset of the events to determine calibration constants.
  - a full "event reconstruction" pass on all the events that uses the constants derived in the previous step.
- Monte Carlo data will be processed in the same way.
- Selected subset of Detector and MC data, the "skims", will be made available for different areas of physics analysis.
  - Very convenient for analysis.
  - Increase the storage requirement because the same events can be present in more than one skim.
- Improvements in constants, reconstruction code, or simulation may require reprocessing of the data or generation of new simulated data.
  - Require the capability of reprocessing in a given year all the data collected in previous years.

Summary of computing resources needed in a typical year of SuperB data taking at nominal luminosity.

Parameter	typical Year
Luminosity (ab^{-1})	15
Storage (PB)	
Tape	113
Disk	52
CPU (KHep-Spec06)	
Event data reconstruction	210
Skimming	250
Monte Carlo	670
Physics analysis	570
Total	1700

Development of the Model

- For the Computing TDR:
  - Work on R&D projects
  - All major design choices should be in place for TDR.
- First two years after the Computing TDR:
  - A preliminary version of a fully-functional offline system is built and validated via dedicated data challenges.
  - The collaboration can start using it for detector and physics simulation studies.
- Remaining time before the start of the data taking:
  - Further extensive test and development cycles to bring the system to its full scale.
  - Acquisition and deployment of dedicated computing resources.
  - Consolidation and validation of the distributed computing infrastructure.

Where We Are and Where We Go

- Italian government has approved and funded SuperB so far with 250 M€.
- INFN is to prepare Mou's with SLAC for the reuse of components of PEPII and Babar. We will know soon the amount of this in kind contribution.
- We expect reciprocal contribution from Russia to the Italian contribution to IGNITOR for Nuclear Fusion as in the Italian-Russian agreement.
- In the next few months a Consortium at national level (CabibboLab) will be formed to start the construction phase (IIT will be one partner).
- Move in future (end 2012?) towards CabibboLab ERIC.
- TDR should be completed for Detector Accelerator Computing.
- On Physics we intend to start soon the activity for the SuperBPhysics Book, a comprehensive document on Flavor.

Forming the Collaboration

- A governance committee for the detector collaboration is being formed with a wide consultation inside the SuperB community.

- It has been started in Elba and Mauro Morandin is in charge of assembling the committee.

SuperKEKB/Belle II Funding Status

- 5.8 oku yen (~MUSD) for Damping Ring (FY2010)
- 100 oku yen for machine -- Very Advanced Research Support Program (FY2010-2012)

Continue efforts to obtain additional funds to complete construction as scheduled.

Several non-Japanese funding agencies have already allocated sizable funds for the upgrade.

→construction started!

Press Release

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Press Release

KEKB upgrade plan has been approved

June 23, 2010
High Energy Accelerator Research Organization (KEK)

The MEXT, the Japanese Ministry that supervises KEK, has announced that it will appropriate a budget of 100 oku-yen (approx $110M) over the next three years starting this Japanese fiscal year (JFY2010) for the high performance upgrade program of KEKB. This is part of the measures taken under the new "Very Advanced Research Support Program" of the Japanese government.

"We are delighted to hear this news," says Masanori Yamauchi, former spokesperson for the Belle experiment and currently a deputy director of the Institute of Particle and Nuclear Studies of KEK. "This three- year upgrade plan allows the Belle experiment to study the physics from decays of heavy flavor particles with an unprecedented precision. It means that KEK in Japan is launching a renewed research program in search for new physics by using a technique which is complementary to what is employed at LHC at CERN."

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Summary and Outlook

- A super B-factory with 100 times the luminosity of present day B-factories is now feasible.
- SuperB and SuperKEKB designs have converged to the "Italian" scheme of low emittance beams with a large crossing angle and a longer (more typical) bunch length.
  - Both projects have been approved and funded.
- A very high luminosity B-factory is a strong compliment to the energy frontier (LHC):
  - There are hundreds of new entries in the particle data book from the data generated by the B-factories.
  - The surprising fact is that the B-factories have NOT found any new physics.
  - The Standard Model is (amazingly) still intact.
- A super B-factory will push the Standard Model limits into regions where SUSY models and Higgs models start making predictions.
  - The LHC alone may have a hard time digging out all of the new physics.
  - A complimentary super B-factory could be a great help in finding any new physics.