The Super*B* τ/Charm Task Force
A Progress Report

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Super*B* III
SLAC

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The τ /Charm Task Force

- It is beyond a cliché that a (Super)*B* Factory is also a (Super)τ/charm or (Super)Flavo(u)r Factory
- Thus Super*B* can do a great deal of τ /charm physics in addition to *B* physics
- The question arises as to whether there is a motivation to provide the capability to take data in the 4 GeV region, as well as in the 10 GeV region
  - That is, are there specific physics topics that substantially benefit from threshold kinematics?
- The purpose of the τ /charm Task Force is to address this question and make recommendations as to whether to include low energy running capability in the Super*B* design
  - The work of the Task Force is proceeding well, but is not yet complete
- The is a progress report: the Task Force has not yet reached any collective conclusions

τ /charm Task Force Members

- David Asner, John Back, Jose Bernabéu, Marcello Giorgi, David Hitlin (chair), Antimo Palano, Frank Porter, Patrick Roudeau
- Conference calls are held (almost) weekly
- The goal is to produce a set of comparison tables and a recommendation on including the capability of running Super*B* at energies below the Υ(4S)
  - A related question is whether or not to include the capability of longitudinal polarization of the electron beam to facilitate new physics searches in τ physics

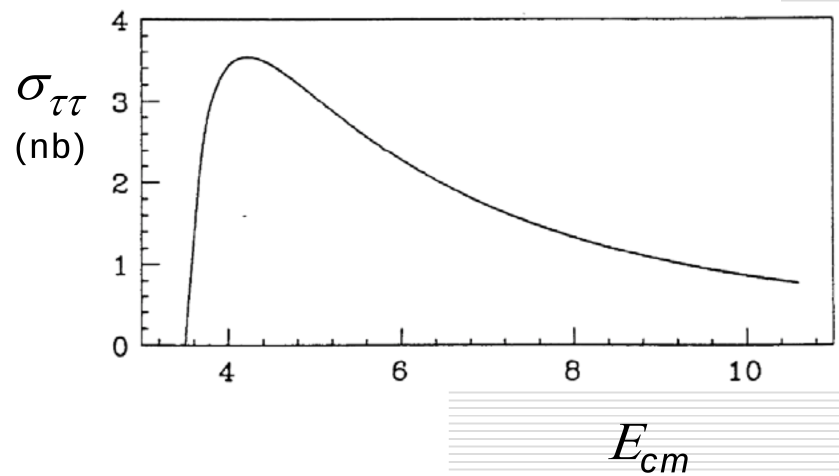
Working assumptions

- CLEO-c: .75 fb^{-1} at $\psi(3770)$ and .75 fb^{-1} at $\psi(4170)$ by 2008
- BESIII: 20 fb^{-1} at $\psi(3770)$ and 12 fb^{-1} at $\psi(4170)$ (8 years)
- *BABAR*+Belle: 2 ab^{-1} total in ~2009
- Super*B*: at E_{cm}=10.58: 10^{36}, 1 year: 15 ab^{-1}
  5 years: 75 ab^{-1}

  in 4 GeV region: ~10^{35}; 1 year: 1.5 ab^{-1}

E_{cm}(GeV)	4.24	10.58
$\sigma_{\tau\tau}$ (nb)	3.5	0.89
$\mathcal{L}$ ($cm^{-2}s^{-1}$)	1.6×10^{35}	10^{36}
$\tau\tau$ pairs per Snowmass year (1.5×10^{7} s)	8.4×10^{9}	13.4×10^{9}

τ production cross section

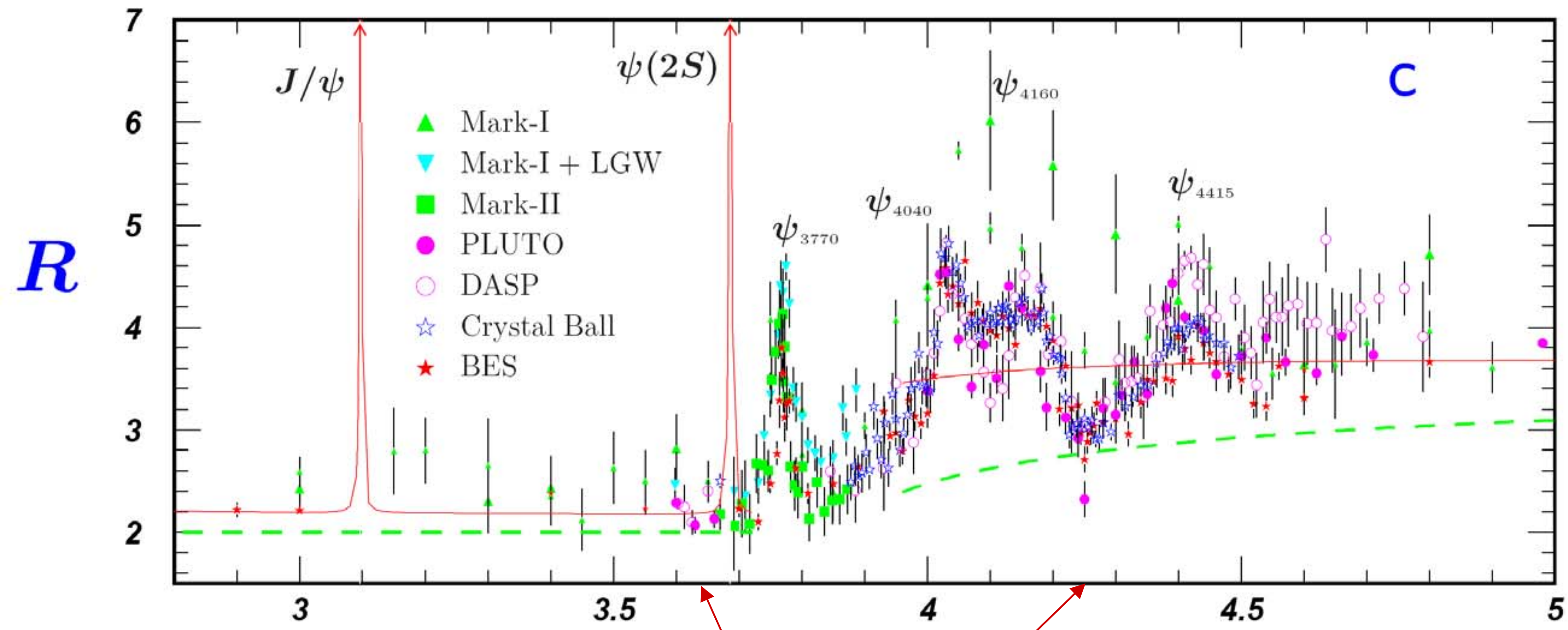


Super*B* sample sizes

E_{cm}(GeV)	4.24	10.58
$\sigma_{\tau\tau}$ (nb)	3.5	0.89
$\mathcal{L}$ (cm^{-2}s^{-1})	1.6 x 10^{35}	10^{36}
$\tau\tau$ pairs per Snowmass year	8.4x10^{9}	1.34x10^{10}

E_{cm}(GeV)	3.77	10.58
$\sigma_{D\bar{D}}$ *or* $\sigma_{c\bar{c}}$ (nb)	6	.34
$\mathcal{L}$ (cm^{-2}s^{-1})	1.3 x 10^{35}	10^{36}
$D\bar{D}$ ($c\bar{c}$) pairs per Snowmass year	1.2x10^{10}	5x10^{9}

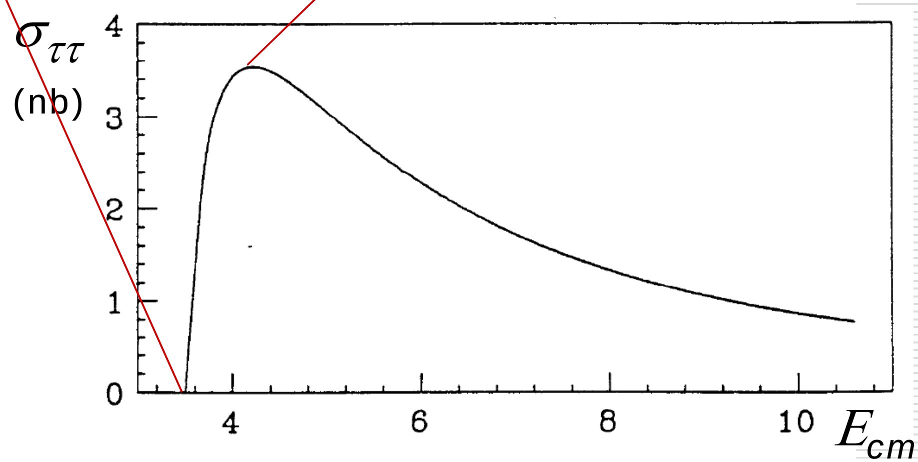
Charm cross section



Running strategy:

Time divided between:

ψ, ψ(2S), ψ(3770), ψ(4040), ψ(4160), charmed baryons, τ threshold scan, ……..



Charm physics opportunities

- Charmed mesons
  - Absolute branching fractions
  - CKM physics
  - Dalitz plots
  - Rare decays
  - $D\overline{D}$ mixing
  - *CP* violation
- Charmed baryons
  - Λ_c Absolute Branching Fractions
  - Form factors
- Precision R scan
- Charmonia
  - Study of J/ψ , ψ', χ_{cj}
  - Y(4260), ψ(4160), ψ(4040)

Which topics are better addressed at Ecm ~4 GeV, and which at ~10 GeV ?

τ physics opportunities

- QCD tests + α_s
  - Non-strange spectral function (much better resolution!)
  - Strange spectral function (real measurement, v/a, ...)
  - Second class currents
  - Chiral perturbation theory
- Exclusive decays
  - Branching ratios
  - Light meson spectroscopy
- Michel parameters
- τ lifetime – universality tests
- V_{us} from inclusive decays
- *CP* violation in τ production and decay
- Rare decays LFV
- Neutral current couplings
- ν_τ mass

Which topics are better addressed at Ecm~4 GeV, and which at ~10 GeV ?

Methodology

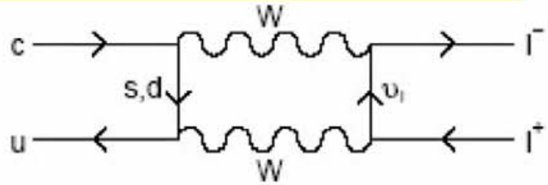
- Measurement capability is mainly evaluated by scaling from existing data sets
  - In, for example, rare decays with little or no anticipated background, scaling is done as $1/\int \mathcal{L}dt$
  - When background is expected, as $1/\sqrt{\int \mathcal{L}dt}$
  - Systematic limits are also being considered
    - With high statistics, can trade statistics for reduced systematic errors, but this is difficult to estimate with any degree of precision
  - In some rare decay cases, naïve scaling by sample size may favor high energy, but background may be better at the $\psi(3770)$

Rare Charm Decays

The absence of FCNC in kaons lead to the prediction of charm,
Large B mixing (a FCNC process) was evidence for heavy top
FCNC in charm have so far been less informative, & less studied
Short distance charm FCNC are much more highly suppressed by the GIM mechanism than down type quarks due to the large mass difference between up type quarks

$D^0 \to e^+e^- \quad (\mathcal{B} \sim 10^{-23})$

$D^0 \to \mu^+\mu^- \quad (\mathcal{B} \sim 3\times 10^{-13})$



The lepton flavor violating mode $D^0 \to e^\pm\mu^\mp$ is strictly forbidden.

Beyond the Standard Model, New Physics may enhance these, e.g., R-parity violating SUSY:

$\mathcal{B}\left(D^0 \to e^+e^-\right)$ up to 10^{-10}

$\mathcal{B}\left(D^0 \to \mu^+\mu^-\right)$ up to 10^{-6}

$\mathcal{B}\left(D^0 \to e^\pm\mu^\mp\right)$ up to 10^{-6}

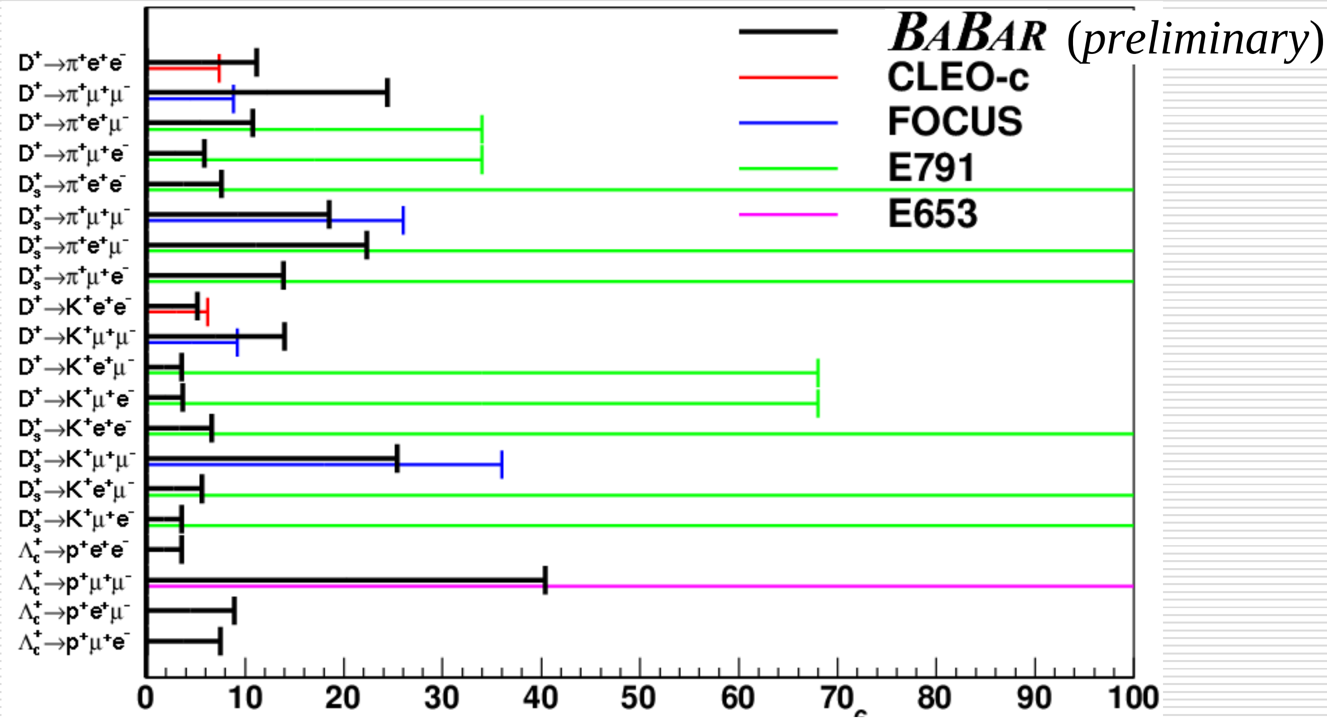
Best limits are from BABAR

(Burdman et al., Phys. Rev. D66, 014009).

I.Shipsey DIF06

Charm FCNC Branching Fraction Limits

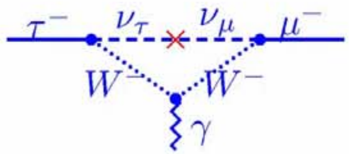
P. Jackson, Charm 2006

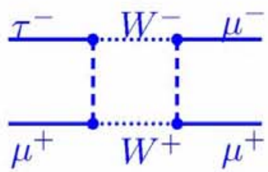


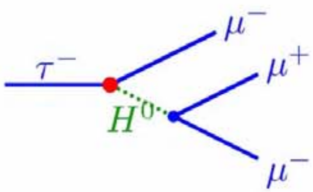
Upper limits on BF ($x10^{-6}$) at 90% CL

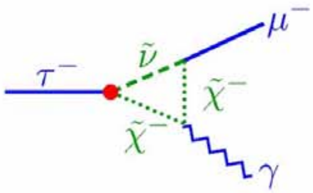
	$\mathcal{L}$ (fb^{-1})	BF Limits
BABAR	250	1-3 x 10^{-5}
Super*B*	50000	6 – 18 x 10^{-7}

Theoretical expectations for $\tau - LFV$







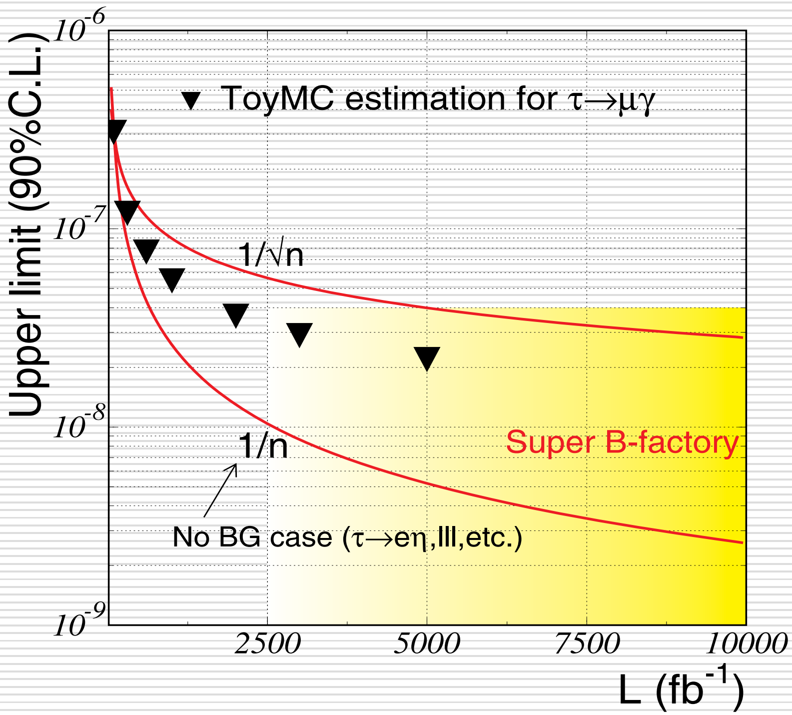


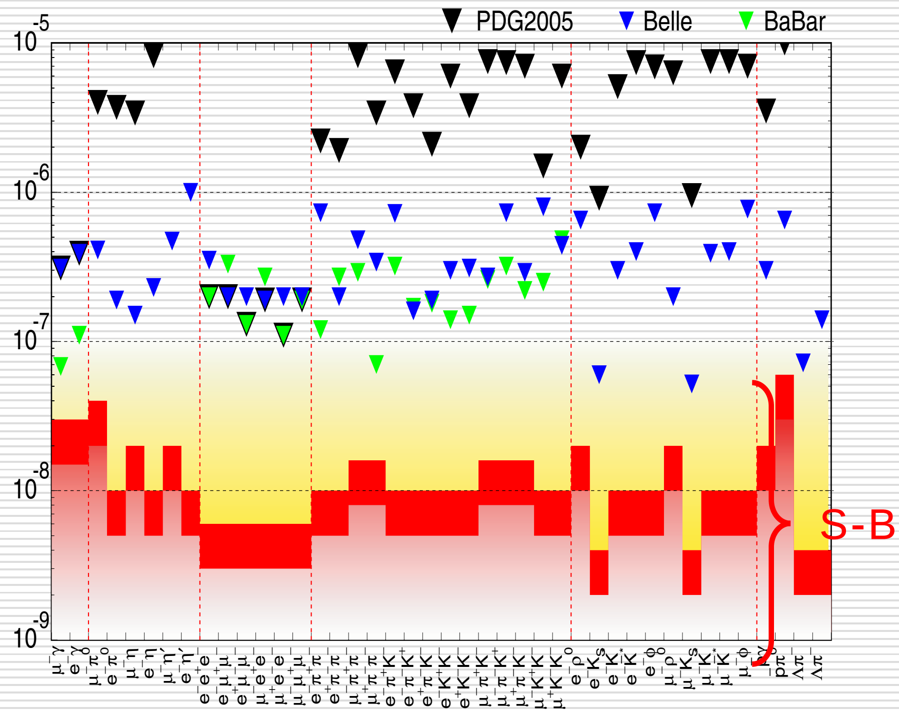
Model	$\tau \to \ell\gamma$	$\tau \to \ell\ell\ell$	Ref.
SM + lepton mixing	10^{-40}	10^{-14}	hep-ph/9810484
SM + left-h. heavy Dirac neutrino	$< 10^{-18}$	$< 10^{-18}$	SJNP25(1977)340
SM + right-h. heavy Majorana neutrino	$< 10^{-9}$	$< 10^{-10}$	PRD66(2002)034008
SM + left and right-h. neutral singlets	$< 10^{-8}$	$< 10^{-9}$	PRD66(2002)034008
mSUGRA + seesaw	$< 10^{-7}$	$< 10^{-9}$	hep-ph/0206110, hep-ph/9911459, etc
SUSY $SU(5)$	$< 10^{-4}$		hep-ph/0303071
SUSY flipped $SU(5)$	$< 10^{-7}$		hep-ph/0304130
SUSY $SO(10)$	$< 10^{-8}$	$< 10^{-10}$	hep-ph/0209303, hep-ph/0304190
SUSY anomalous $U(1)$	$< 10^{-7}$		hep-ph/0308093
neutral SUSY Higgs	$< 10^{-10}$	$< 10^{-7}$	hep-ph/0304081
charged SUSY Higgs triplet		$< 10^{-7}$	hep-ph/0209170
MSSM+nonuniversal soft SUSY breaking	$< 10^{-10}$	$< 10^{-6}$	hep-ph/0305290
Non universal Z' (technicolor)	$< 10^{-9}$	$< 10^{-8}$	PLB547(2002)252
two Higgs doublet III	$< 10^{-15}$	$< 10^{-17}$	hep-ph/0208117
extra dimensions	$< 10^{-11}$		hep-ph/0210021

Olga Igonkina DIF06

Future prospects

- SuperB : >50 times more data





- BR sensitivity: ~1/n for negligible BG case
  ~1/√n for BG dominated modes

Hadronic $D^0, D^{\pm}, D_s^{\pm}$ decays

Process	CLEO-c	BESIII	B-factory	Super-B (1)	Super-B (5)
Normalization Modes					
$D^0 \to K\pi$	1.25%		2.1%		
$D^+ \to K\pi\pi$	1.4%				
$D_s^+ \to KK\pi$	4%				
Cabibbo Favored BF					
D^0[1]	0.35%/track,1.1%/K_S^0,2.0%/π^0				
D^+[1]	0.35%/track,1.1%/K_S^0,2.0%/π^0				
D_s^+[1]	0.35%/track,1.1%/K_S^0,2.0%/π^0				
CF Dalitz Plots					
$D \to K^-\pi^+\pi^0$					
$D^+ \to K^-\pi^+\pi^+$					
$D_s^+ \to K^-K^+\pi^+$					
SCS Dalitz Plots					
$D^0 \to \pi\pi\pi^0$					
DCS Dalitz Plots					
$D \to K^+\pi^-\pi^0$					
Inclusive BF					
K (D^0, D^+, D_s^+)					
η (D^0, D^+, D_s^+)	4.0%(sys.)[3]				
η' (D^0, D^+, D_s^+)	4.7%(sys.)[3]				
ϕ (D^0, D^+, D_s^+)	3.4%(sys.)[3]				
Dalitz Plots -impact					
D^0 (CKM angle γ[4])	6^o(sys.)	$< 2^o$(sys.)	7^o	$< 3^o$	$\sim 1^o$
D^0 (D had BF)	okay[5]	okay[5]			
D^+ (D had BF)	okay[5]	okay[5]			
D_s^+ (D had BF)	okay[5]	okay[5]			
SCS BF					
$D^0 \to \pi\pi$	3%[6]				
$D^0 \to \pi\pi\pi^0$	3%[6]				
$D^0 \to \pi\pi\pi^0\pi^0$[6]	6%				
$D^+ \to \pi\pi^0$	5%[6]				
$D^+ \to \pi\pi^0\pi^0$	6%[6]				
DCS BF					
$D^0 \to K^0\pi^0$					
$D^+ \to K^0\pi^+$					

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Exclusive semileptonic decays

Process	CLEO-c	BESIII	B-factory	Super-B (1)	Super-B (5)	Comment
$D^0 \to K\ell\nu$ (BF)		0.2%[7]	0.75%			$\|Vcs\|$
$D^+ \to K\ell\nu$ (BF)		0.3%[7]				$\|Vcs\|$
$D \to K\ell\nu$ (α_{pole})						$\|Vcs\|$
$D \to K\ell\nu$ (m_{pole})						$\|Vcs\|$
$D \to (K^*, K\pi)\ell\nu$ (BF)						$\|Vcs\|$
$D \to (K^*, K\pi)\ell\nu$ (α_{pole})						$\|Vcs\|$
$D \to (K^*, K\pi)\ell\nu$ (m_{pole})						$\|Vcs\|$
$D^0 \to \pi\ell\nu$ (BF)	2.3%	0.4%[7]	2.8%			$\|Vcd\|$, $\|Vub\|$
$D^+ \to \pi\ell\nu$ (BF)		0.8%[7]				$\|Vcd\|$, $\|Vub\|$
$D \to \pi\ell\nu$ (α_{pole})						$\|Vcd\|$, $\|Vub\|$
$D \to \pi\ell\nu$ (m_{pole})						$\|Vcd\|$, $\|Vub\|$
$D \to (\eta, \rho, \omega, \pi\pi)\ell\nu$ (BF)						$\|Vcd\|$, $\|Vub\|$
$D \to (\eta, \rho, \omega, \pi\pi)\ell\nu$ (α_{pole})						$\|Vcd\|$, $\|Vub\|$
$D \to (\eta, \rho, \omega, \pi\pi)\ell\nu$ (m_{pole})						$\|Vcd\|$, $\|Vub\|$
$D_s \to \phi\ell\nu$ (BF)		1.2%[7]				
$D_s \to \eta\ell\nu$ (BF)						
$D_s \to (\eta, \phi)\ell\nu$ (α_{pole})						
$D_s \to (\eta, \phi)\ell\nu$ (m_{pole})						
$D_s \to (K, K^*, K\pi)\ell\nu$ (BF)						
$D_s \to (K, K^*, K\pi)\ell\nu$ (α_{pole})						
$D_s \to (K, K^*, K\pi)\ell\nu$ (m_{pole})						

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Semileptonic, leptonic decays

Process	CLEO-c	BESIII	B-factory	Super-B (1)	Super-B (5)	Comment
$D \to \ell X$ (BF)						
$D \to \ell X$ (e, μ spectra)						
$D \to \nu X$ (BF)						
$D \to \nu X$ (ν spectrum)						
$D_s \to \ell X$ (BF)						
$D_s \to \ell X$ (e, μ spectra)						

Process	CLEO-c	BESIII[7]	B-factory	Super-B (1)	Super-B (5)	Comment
$D \to \mu\nu$	9%[9]	2%				f_D, f_B
$D \to e\nu$	1e-3[9]	(e-5,e-6)				NP
$D_s \to \mu\nu$	9%[9]	2%				f_{D_s}, f_{B_s}
$D_s \to \tau\nu$		1.5%				f_{D_s}, f_{B_s}, NP
$D_s \to e\nu$						NP
$D \to ee$	3e-6[8]	3e-8				
$D \to \mu\mu$	3e-6[8]	3e-8				
$D \to e\mu$	3e-6[8]	3e-8				

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Rare decays

Process	CLEO-c[8]	BESIII[7]	B-factory	Super-B (1)	Super-B (5)	Comment
Radiative						
$D \to \rho\gamma$	4e-6	(e-5,e-6)				
$D \to \omega\gamma$	2e-5	(e-5,e-6)				
$D \to \phi\gamma$	1e-5	(e-5,e-6)				
$D \to K^*\gamma$	3e-5	(e-5,e-6)				
$D \to \gamma\gamma$	3e-6	5e-8				
Leptonic						
$D \to ee$	3e-6	3e-8				
$D \to \mu\mu$	3e-6	3e-8				
$D \to e\nu$	1.5e-5[9]					
$D_s \to e\nu$						
GIM suppressed						
$D^0 \to \pi^0 ee$	1e-5	5e-8				
$D^0 \to \pi^0 \mu\mu$		5e-8				
$D^0 \to \eta ee$	2.5e-5	1e-7				
$D^0 \to \eta\mu\mu$		1e-7				
$D^0 \to K^0_S ee$	1.8e-5	1e-7				
$D^0 \to K^0_S \mu\mu$		1e-7				
$D^+ \to hee$	4e-6[10]	3e-8				
$D^+ \to h\mu\mu$		3e-8				
LFV						
$D \to e\mu$	3e-6	3e-8				
$D^0 \to \pi^0 e\mu$		5e-8				
$D^0 \to \eta e\mu$		1e-7				
$D^0 \to K^0_S e\mu$		1e-7				
$D^+ \to he\mu$		3e-8				
LNV						
$D^+ \to he^+e^+$	2.4e-6[10]	3e-8				
$D^+ \to h\mu^+\mu^+$		3e-8				
$D^+ \to he^+\mu^+$		3e-8				
$D_s^+ \to K^-e^+e^+$						
$D_s^+ \to K^-\mu^+\mu^+$						
$D_s^+ \to K^-e^+\mu^+$						

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Charm mixing, *CP*, *T* violation, Λ_c

Process	CLEO-c	BESIII	B-factory[11]	Super-B (1)	Super-B (5)	Comment
Time Dependent						
hadronic (95% C.L.)						
$x'^2/2$	-	-	$< 0.016\%$			
y'	-	-	$< 1\%$			
$\delta_{K\pi}$	-	-	-			
CP eigenstate (1σ)						
y	-	-	2e-3			
A_Γ	-	-	2e-3			
Semileptonic (95% C.L.)						
R_M	-	-	4e-4			
Dalitz Plots (95% C.L.)						
x			0.5%			
y			0.3%			
Quantum Correlation[12]						
x	2.5%		-	-	-	-
y	1.2%		-	-	-	-
$\cos\delta_{K\pi}$	0.13		-	-	-	-

Process	CLEO-c	BESIII	B-factory	Super-B (1)	Super-B (5)	Comment
Cabibbo Favoured						
SCS						
DCS						
Mixing						
Dalitz-plots						
T-odd Correlations						

Process	CLEO-c	BESIII	B-factory	Super-B (1)	Super-B (5)	Comment
$\Lambda_c \to pK\pi$	-	-				
$\Lambda_c \to \Lambda\ell\nu$	-	-				
$\Lambda_c \to \ell X$	-	-				

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CKM

Process	CLEO-c	BESIII	B-factory	Super-B (1)	Super-B (5)	Comment
$\|V_{cd}\|$	2%					
$\|V_{cs}\|$						
$\|V_{cb}\|$						
$\|V_{ts}\|$						
$\|V_{td}\|$						
$\|V_{ub}\|$						
CKM angle α						
$\pi\pi\pi^0$ Dalitz plot						
$\rho\pi$						
$\rho\rho$						
CKM angle β						
tree						
penguin						
CKM angle γ						
ADS						
GLW						
Dalitz						
4-Body						

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D^0 Dalitz plot examples

$D^0 \to \pi^+\pi^-\pi^0$

Resonance	Current (%)	CLEO-c	BESIII	B factory total	Super$B$ 1 year	Super$B$ 5 years
ρ^+	$76.5 \pm 1.8 \pm 2.5$	± 0.40	± 0.08	± 0.12	± 0.04	± 0.02
ρ^0	$23.9 \pm 1.8 \pm 2.1$	± 0.40	± 0.08	± 0.12	± 0.04	± 0.02
ρ^-	$32.3 \pm 2.1 \pm 1.3$	± 0.47	± 0.09	± 0.14	± 0.05	± 0.02
NR	$2.7 \pm 0.9 \pm 0.2$	± 0.20	± 0.04	± 0.06	± 0.02	± 0.01

$D^0 \to K_S^0\pi^-\pi^0$

Resonance	Current (%)	CLEO-c	BESIII	B factory total	Super$B$ 1 year	Super$B$ 5 years
$K^{*+}\pi^-$	$0.34 \pm 0.13^{+0.36}_{-0.05}$	± 0.04	± 0.01	± 0.01	± 0.003	± 0.001
$\bar{K}^0\rho^0$	$26.7 \pm 1.1^{+0.9}_{-2.8}$	± 0.36	± 0.07	± 0.07	± 0.03	± 0.01
$\bar{K}^0\omega$	$0.81 \pm 0.19^{+0.18}_{-0.10}$	± 0.06	± 0.01	± 0.01	± 0.005	± 0.002
$K^{*-}\pi^+$	$66.3 \pm 1.3^{+2.4}_{-4.3}$	± 0.42	± 0.08	± 0.09	± 0.03	± 0.01
$\bar{K}^0 f_0(980)$	$4.2 \pm 0.5^{+1.1}_{-0.4}$	± 0.16	± 0.03	± 0.03	± 0.01	± 0.005
$\bar{K}^0 f_2(1270)$	$0.36 \pm 0.22^{+0.32}_{-0.19}$	± 0.07	± 0.01	± 0.01	± 0.005	± 0.002
$\bar{K}^0 f_0(1370)$	$9.8 \pm 1.4^{+2.6}_{-3.6}$	± 0.45	± 0.09	± 0.09	± 0.03	± 0.02
$K_0^*(1430)^-\pi^+$	$7.2 \pm 0.7^{+1.4}_{-1.3}$	± 0.23	± 0.04	± 0.05	± 0.02	± 0.01
$K_2^*(1430)^-\pi^+$	$1.1 \pm 0.2^{+0.5}_{-0.3}$	± 0.06	± 0.01	± 0.01	± 0.005	± 0.002
$K^*(1680)^-\pi^+$	$2.3 \pm 0.5^{+0.7}_{-1.4}$	± 0.16	± 0.03	± 0.03	± 0.01	± 0.005
NR	$0.7 \pm 0.7^{+2.11}_{-0.63}$	± 0.23	± 0.04	± 0.05	± 0.02	± 0.01

John Back

D branching fractions

Channel	*BABAR* or Belle present	*BABAR*+Belle final 2 ab^{-1}	Super*B* 1 year 15 ab^{-1}	Super*B* 5 years 75 ab^{-1}
$D^+ \to \pi^+\pi^0$ (10^{-3})	$1.22 \pm 0.1 \pm 0.08 \pm 0.08$	$\pm 0.02 \pm 0.08 \pm$	$\pm 0.009 \pm 0.080 \pm$	$\pm 0.004 \pm 0.080$:
$D^+ \to K^+\pi^0$ (10^{-4})	$2.46 \pm 0.46 \pm 0.24 \pm 0.16$	$\pm 0.11 \pm 0.24 \pm$	$\pm 0.042 \pm 0.24 \pm$	$\pm 0.019 \pm 0.24 \pm$
$D_s \to \phi\pi^+$	$0.0481 \pm 0.0052 \pm 0.0038$	$\pm 0.0012 \pm 0.0032$	$\pm 0.0004 \pm 0.0032$	$\pm 0.0002 \pm 0.00$:
$D^0 \to e^+e^-$	$< 1.2 \times 10^{-6}$	$< 0.3 \times 10^{-6}$	$< 0.11 \times 10^{-6}$	$< 0.05 \times 10^{-6}$
$D^0 \to \mu^+\mu^-$	$< 1.3 \times 10^{-6}$	$< 0.3 \times 10^{-6}$	$< 0.12 \times 10^{-6}$	$< 0.05 \times 10^{-6}$
$D^0 \to e^\pm\mu^\mp$	$< 0.81 \times 10^{-6}$	$< 0.2 \times 10^{-6}$	$< 0.07 \times 10^{-6}$	$< 0.03 \times 10^{-6}$

Limits are all 90% C.L.

Frank Porter

D branching ratios

Channel	*BABAR* or Belle present	*BABAR*+Belle final 2 ab^{-1}	Super*B* 1 year 15 ab^{-1}	Super*B* 5 years 75 ab^{-1}
$\frac{D_s^*\to D_s\pi^0}{D_s^*\to D_s\gamma}$	$0.062 \pm 0.005 \pm 0.006$	$\pm 0.0011 \pm 0.0056$	$\pm 0.0004 \pm 0.0056$	$\pm 0.0002 \pm 0.0056$
$\frac{D^{*0}\to D^0\pi^0}{D^{*0}\to D^0\gamma}$	$1.74 \pm 0.02 \pm 0.13$	$\pm 0.004 \pm 0.09$	$\pm 0.0016 \pm 0.08$	$\pm 0.0007 \pm 0.08$
$\frac{D_s\to\mu\nu}{D_s\to\phi\pi}$	$0.136 \pm 0.017 \pm 0.006$	$\pm 0.0056 \pm 0.0060$	$\pm 0.0020 \pm 0.0059$	$\pm 0.0009 \pm 0.0059$
$\frac{D^0\to\pi^-e^+\nu}{D^0\to K^-e^+\nu}$	$0.0809 \pm 0.0080 \pm 0.0032$	$\pm 0.0030 \pm 0.0018$	$\pm 0.0011 \pm 0.0013$	$\pm 0.0005 \pm 0.0013$
$\frac{D^0\to\pi^-\mu^+\nu}{D^0\to K^-\mu^+\nu}$	$0.0677 \pm 0.0078 \pm 0.0047$	$\pm 0.0029 \pm 0.0030$	$\pm 0.0011 \pm 0.0026$	$\pm 0.0005 \pm 0.0025$
$\frac{D^0\to\phi\gamma}{D^0\to K^+K^-}$	$0.0631 \pm 0.0016 \pm 0.00033$	$\pm 0.0003 \pm 0.0003$	$\pm 0.00012 \pm 0.0002$	$\pm 0.00005 \pm 0.0002$
$\frac{D^0\to\phi\pi^0}{D^0\to K^+K^-}$	$0.194 \pm 0.006 \pm 0.009$	$\pm 0.0012 \pm 0.0085$	$\pm 0.0004 \pm 0.0084$	$\pm 0.0002 \pm 0.0084$
$\frac{D^0\to\phi\eta}{D^0\to K^+K^-}$	$0.0359 \pm 0.0114 \pm 0.0018$	$\pm 0.0023 \pm 0.0015$	$\pm 0.0008 \pm 0.0014$	$\pm 0.0004 \pm 0.0014$

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D^0 mixing, *CP* violation

$$x \equiv \frac{\Delta m}{\Gamma}, \qquad y \equiv \frac{\Delta\Gamma}{2\Gamma}, \qquad R_{\rm mix} \equiv \frac{x^2+y^2}{2}$$

$$Y \equiv \frac{\tau^0}{\langle\tau\rangle} - 1, \quad \Delta Y \equiv \frac{\tau^0}{\langle\tau\rangle} A_\tau, \quad \tau^0 = \tau(D^0 \to K^-\pi^+), \quad \langle\tau\rangle = \frac{\tau(D^0 \to CP+) + \tau(\bar{D}^0 \to CP+)}{2},$$

$$A_\tau = \langle\tau|H_D|D^0\rangle$$

Channel	*BABAR* or Belle present	*BABAR*+Belle final 2 ab^{-1}	Super*B* 1 year 15 ab^{-1}	Super*B* 5 years 75 ab^{-1}
$R_{\rm mix}$ (semi-leptonic)	$0.0023 \pm 0.0012 \pm 0.0004$	$\pm 0.00025 \pm 0.00025$	$\pm 0.00009 \pm 0.00024$	$\pm 0.00004 \pm 0.00024$
Y (%) $(K^-\pi^+, K^-K^+, \pi^+\pi^-)$	$0.8 \pm 0.4 \pm 0.45$	$\pm 0.09 \pm 0.3$	$\pm 0.03 \pm 0.3$	$\pm 0.014 \pm 0.3$
ΔY (%) $(K^-\pi^+, K^-K^+, \pi^+\pi^-)$	$-0.8 \pm 0.6 \pm 0.2$	$\pm 0.13 \pm 0.2$	$\pm 0.05 \pm 0.2$	$\pm 0.021 \pm 0.2$

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τ decay

Process	Current	BESIII	B-factory	Super-B (1)	Super-B (5)	Comment
$B(\tau^- \to \mu^- \gamma)$	$< 6.8 \times 10^{-8}$					
$B(\tau^- \to e^- \gamma)$	$< 1.1 \times 10^{-7}$					
$B(\tau^- \to e^- e^+ e^-)$	$< 2.0 \times 10^{-7}$					
$B(\tau^- \to \mu^- \mu^+ \mu^-)$	$< 1.9 \times 10^{-7}$					
$B(\tau^- \to \mu^- e^+ e^-)$	$< 1.9 \times 10^{-7}$					
$B(\tau^- \to \mu^- \mu^+ e^-)$	$< 2.0 \times 10^{-7}$					
$B(\tau^- \to e^- \pi^+ \pi^-)$	$< 1.2 \times 10^{-7}$					
$B(\tau^- \to \mu^- \pi^+ \pi^-)$	$< 2.9 \times 10^{-7}$					
$B(\tau^- \to \mu^- K_S^0)$	$< 4.9 \times 10^{-8}$					
$B(\tau^- \to e^- K_S^0)$	$< 5.6 \times 10^{-8}$					
$A_{CP}(\tau^- \to K^- \pi^0 \nu)$						

τ EDM limits with a polarized beam

Unpolarized $$A_{NT} = -\alpha_{-}\alpha_{+}\frac{\pi\beta}{4(3-\beta^2)}\frac{2m_\tau}{e}d_\tau^\gamma$$

Polarized: $$A_N^{\mp} = \frac{\sigma_L^{\mp}-\sigma_R^{\mp}}{\sigma_L^{\mp}+\sigma_R^{\mp}} = \alpha_{\mp}\frac{3\pi}{8(3-\beta^2)}\gamma\beta\frac{2m_\tau}{e}d_\tau^\gamma$$

where $$\sigma_L^{\mp} = \int_0^{2\pi} d\phi_{\pm}\left[\int_0^{2\pi} d\phi_{\mp}\frac{d^2\sigma^S}{d\phi_- d\phi_+}\bigg|_{Pol(e^-)}\right]$$

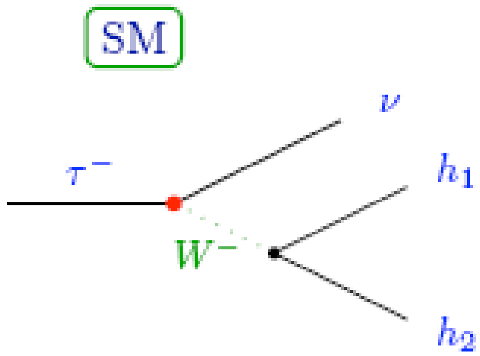
$\Upsilon(4S)$

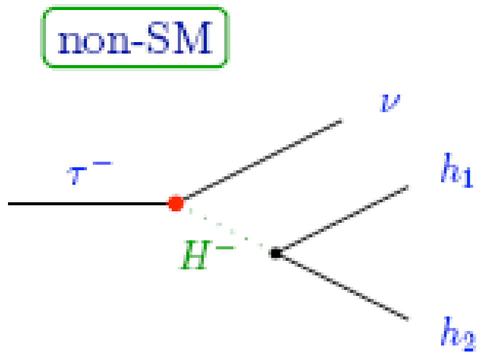
J. Bernabéu,
G.A. González-Sprinberg,
J. Vidal

$$\sigma_R^{\mp} = \int_0^{2\pi} d\phi_{\pm}\left[\int_0^{2\pi} d\phi_{\mp}\frac{d^2\sigma^S}{d\phi_- d\phi_+}\bigg|_{Pol(e^-)}\right]$$

Polarized beam limits	*BABAR*+Belle Total (2 fb^{-1})	Super*B* 1 year	Super*B* 5 years
$\lvert\Re e(d_\tau^\gamma)\rvert$ e-cm	$<10^{-19}$	$<3.4\times10^{-20}$	$<1.5\times10^{-20}$

CP violation in τ decay





$$F_v = \frac{m_\rho^2}{m_\rho^2 - s - i m_\rho \Gamma_\rho(s)}$$

$$F_s = |\Lambda| e^{i\Theta_{CP}} |f_s| e^{i\delta_s},$$

$$f_s = 1 \text{ or BW(scalar } h_1 h_2)$$

Interference between F_v and F_s due to CP violation would show up as a difference in decay angle distribution of τ^- and τ^+

CP violation in τ decay

- Unpolarized τ's
  - Measure $\mathcal{B}$'s of τ decays with two or more hadrons

$$\mathcal{B}(\tau^- \to \pi^- \pi^0 \nu_\tau) \neq \mathcal{B}(\tau^+ \to \pi^+ \pi^0 \overline{\nu}_\tau)$$

    Interpretation of any observed CPV requires understanding of inelastic final state interactions
  - Measure *CP* or *T*-violating correlations in $\tau^+\tau^-$ decays
- Polarized τ's
  - Search for *T*-odd rotationally invariant products, e.g.

$$w_{e^-} \cdot \left(p_{\pi^+} \times p_{\pi^0} \right)$$

in τ^+ and τ^- decays such as

$$\tau^- \to \pi^- \pi^0 \nu_\tau, \tau^- \to K^- \pi^0 \nu_\tau, \tau^- \to \pi^- \pi^+ \pi^- \nu_\tau, \tau^- \to K^- \pi^+ \pi^- \nu_\tau$$

  - Search for T-odd correlation between τ polarization and μ polarization in $\tau^- \to \mu^- \overline{\nu}_\mu \nu_\tau$ decay

CP violation in τ decay

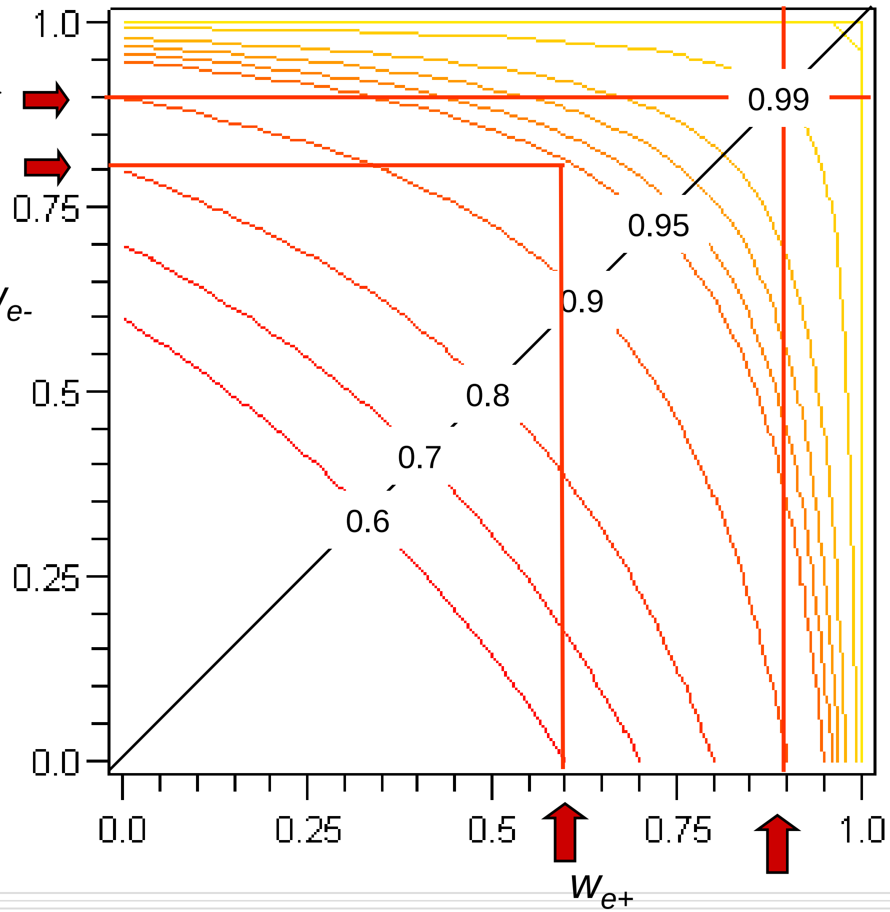
- Y.S. Tsai, Phys Rev D55, 3172 (1995)
  - Longitudinal polarization

$$w_{e^-} = \frac{N_{e^-\to} - N_{e^-\leftarrow}}{N_{e^-}} \qquad w_{e^+} = \frac{N_{e^+\to} - N_{e^-\leftarrow}}{N_{e^+}}$$

  - The τ polarization is

$$P = \frac{w_{e^-} + w_{e^+}}{1 + w_{e^-} w_{e^+}}$$

  - For $w_{e^-} = 0.8, w_{e^+} = 0$: $P = 0.8$
    while for $w_{e^-} = 0.8, w_{e^+} = 0.6$: $P = 0.945$
  - For $w_{e^-} = 0.9, w_{e^+} = 0$: $P = 0.9$
    while for $w_{e^-} = 0.9, w_{e^+} = 0.9$: $P = 0.994$



Comparison of τ/charm and Super*B*

- BEPCII $\mathcal{L}=10^{33}$ SBF $\mathcal{L}=10^{36}$ SBF(4GeV) $\mathcal{L} \cong 10^{35}$
- FOM for measuring CPV in τ decay (Tsai):
  z component of τ polarization averaged over cross section:

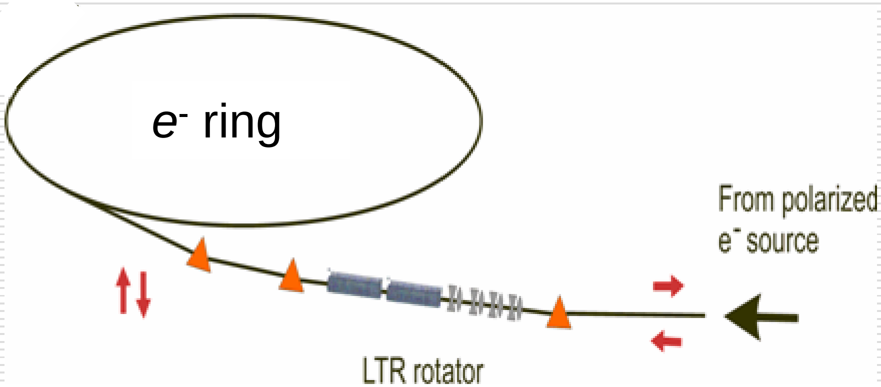
$$\mathrm{FOM}=\mathcal{L}\times(w_{e^-}+w_{e^+})\times\sqrt{1-a^2}\,a^2(1+2a),\ \text{where } a=2m_\tau/\sqrt{s}$$

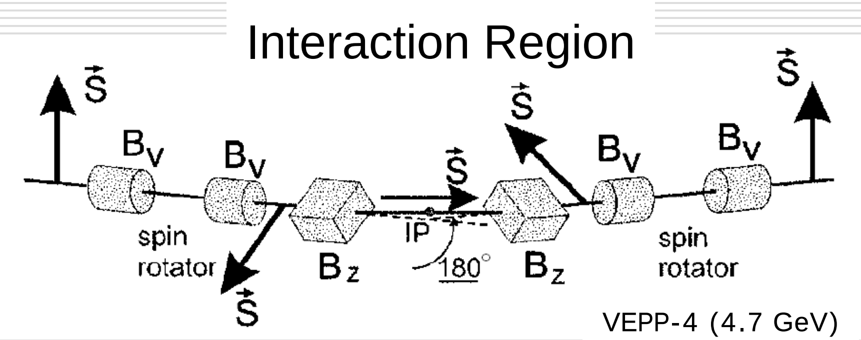
- For equal longitudinal polarization

Machine	FOM/FOM BEPCII
BESIII@ $\sqrt{s}=4$ GeV	1
SBF @ $\Upsilon(4S)$	178
SBF @ $\sqrt{s}=4$ GeV	100

Longitudinal polarization at the IP

- Producing longitudinal polarization at the IP requires a series of systems, which must be designed in from the start
  - Longitudinally polarized e^- source (90% polarization)
  - Rotate e^- spin to vertical and inject into e^- ring
  - Lattice must be designed to avoid depolarizing resonances
  - Rotate e^- spin to longitudinal before IP and restore to transverse after IP





See presentation by I. Koop

Conclusion

- The Task Force will complete the tables in the next few weeks, will then identify specific physics topics of interest, and then evaluate the merits of running in the 4 GeV region and the additional capital cost, if any, for doing so