Future Facilities and LQCD

David Asner
Carleton University

Precision Flavor & LQCD

- Search for New Physics in flavor
  - Over constrain CKM determination of CP Violation
  - Search for deviations from Standard Model expectations in rare processes

- In order to claim observation of New Physics we need sufficient control over the Old Physics
  - Precision LQCD and precision experiment are required to elucidate New Physics

Flavor Physics Observables Sensitive to New Physics

$$\Delta m_K \quad \epsilon_K \quad \epsilon' / \epsilon_K \quad B(K_L \to \pi^0 \nu \bar{\nu}) \quad B(K^+ \to \pi^+ \nu \bar{\nu})$$

$$\Delta m_d \quad A_{SL}(B_d) \quad S(B_d \to J/\psi K_S) \quad S(B_d \to \phi K_S)$$

$$\alpha(B \to \pi\pi, \rho\pi, \rho\rho) \qquad \gamma(B \to DK) \qquad CKM \ \ fits$$

$$\Delta m_s \quad A_{SL}(B_s) \quad S(B_s \to J/\psi \phi) \quad S(B_s \to \phi\phi)$$

$$B(b \to s\gamma) \quad A_{CP}(b \to s\gamma) \quad S(B^0 \to K_S \pi^0 \gamma) \quad S(B_s \to \phi\gamma)$$

$$B(b \to d\gamma) \quad A_{CP}(b \to d\gamma) \quad A_{CP}(b \to (d+s)\gamma) \quad S(B^0 \to \rho^0 \gamma)$$

$$B(b \to s l^+ l^-) \quad B(b \to d l^+ l^-) \quad A_{FB}(b \to s l^+ l^-) \quad B(b \to s \nu \bar{\nu})$$

$$B(B_s \to l^+ l^-) \quad B(B_d \to l^+ l^-) \quad B(B^+ \to l^+ \nu)$$

$$B(\mu \to e\gamma) \quad B(\mu \to e^+ e^- e^+) \quad (g-2)_\mu \quad \mu \ \ EDM$$

$$B(\tau \to \mu\gamma) \quad B(\tau \to e\gamma) \quad B(\tau^+ \to l^+ l^- l^+) \quad \tau \ \ CPV \quad \tau \ \ EDM$$

$$B(D^+_{(s)} \to l^+ \nu) \qquad x_D \ \ y_D \qquad charm \ \ CPV$$

Flavor Physics Observables Sensitive to New Physics

$\Delta m_K \quad \epsilon_K \quad \epsilon'/\epsilon_K \quad B(K_L \to \pi^0 \nu \bar{\nu}) \quad B(K^+ \to \pi^+ \nu \bar{\nu})$

$\Delta m_d \quad A_{SL}(B_d) \quad S(B_d \to J/\psi K_S) \quad S(B_d \to \phi K_S)$

$\alpha(B \to \pi\pi, \rho\pi, \rho\rho) \quad \gamma(B \to DK) \quad CKM\ fits$

$\Delta m_s \quad A_{SL}(B_s) \quad S(B_s \to J/\psi\, \phi) \quad S(B_s \to \phi\phi)$

$B(b \to$ … $)$

Need Precision LQCD to connect precision observables to Standard Model expectations

$B(b \to d\gamma) \quad A_{CP}(b \to d\gamma) \quad A_{CP}(b \to (d+s)\gamma) \quad S(B^0 \to \rho^0 \gamma)$

$B(b \to s l^+ l^-) \quad B(b \to d l^+ l^-) \quad A_{FB}(b \to s l^+ l^-) \quad B(b \to s \nu \bar{\nu})$

$B(B_s \to l^+ l^-) \quad B(B_d \to l^+ l^-) \quad B(B^+ \to l^+ \nu)$

$B(\mu \to e\gamma) \quad B(\mu \to e^+ e^- e^+) \quad (g-2)_\mu \quad \mu\ EDM$

$B(\tau \to \mu\gamma) \quad B(\tau \to e\gamma) \quad B(\tau^+ \to l^+ l^- l^+) \quad \tau\ CPV \quad \tau\ EDM$

$B(D^+_{(s)} \to l^+ \nu) \quad x_D\ y_D \quad charm\ CPV$

Future Facilities and LQCD

1) Future experiments will provide focused & crisp challenges to theoretical techniques for QCD calculations

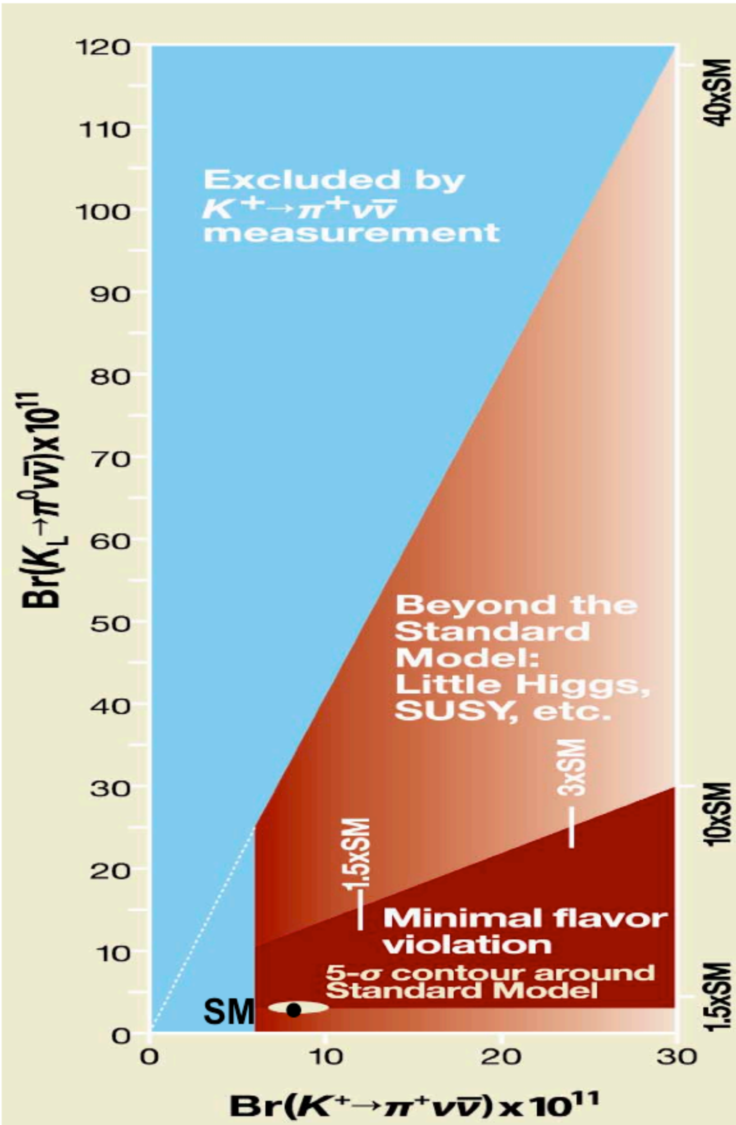
2) Future experiments will need precision results from LQCD that are validated with precision data

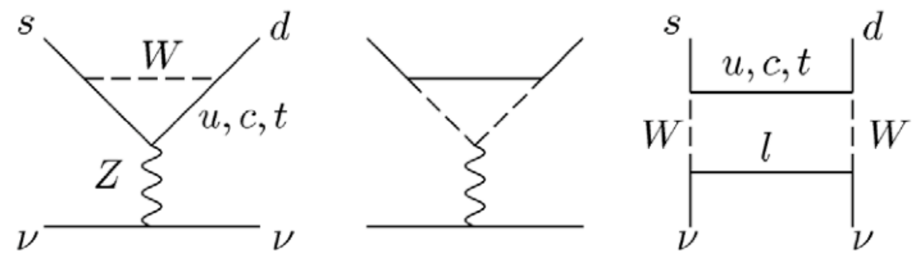
3) Many experiments are both providers to and customers of precision calculations

Future Experiments

- Kaon experiments - J-Parc, CERN, Project X
- BESIII (e^+e^- ~ 4 GeV)
  - First data in 2008 - eventually 20x CLEO-c
- LHCb
  - First data in 2008 - 10x luminosity upgrade after 2013
- Belle at upgraded KEKB (e^+e^- ~10 GeV)
  - Resume data taking 2012 - at $L = 2\times10^{35}$
- SuperB at Tor Vergata (e^+e^- ~4 GeV & ~10 GeV)
  - First data after 2014 - at $L>10^{36}$ ~10 GeV

Kaon Rare Decays: $K^+ \rightarrow \pi^+\nu\nu$, $K_L \rightarrow \pi^0\nu\nu$





SM Leading diagrams to $K \rightarrow \pi\nu\nu$ decays

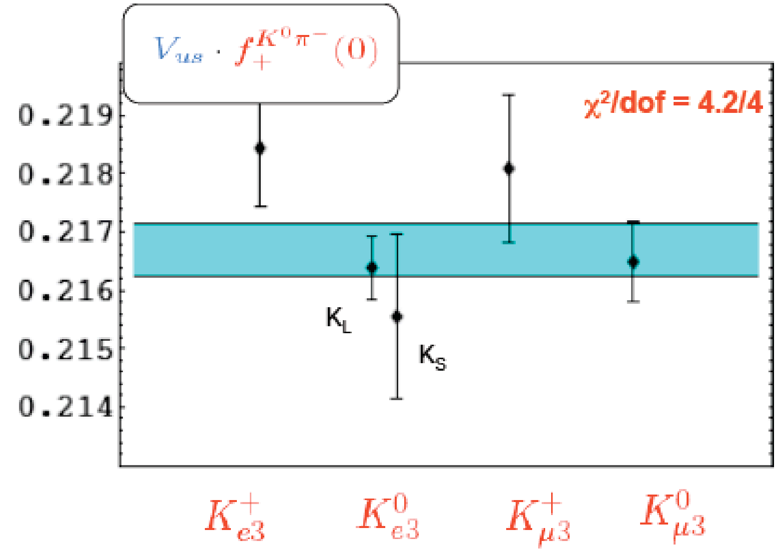
Future experiments:
SM rates with a 4 year run

$K^+ \rightarrow \pi^+\nu\nu$		$K_L \rightarrow \pi^0\nu\nu$	
CERN NA48 (2012)	~160	J-PARC I (2012)	~4
		J-PARC II (~2016)	~120
Potential FNAL (w/o Project X)	~400	Potential FNAL (w/o Project X)	~200
Potential FNAL (w/ Project X)	1200	Potential FNAL (w/ Project X)	~1200

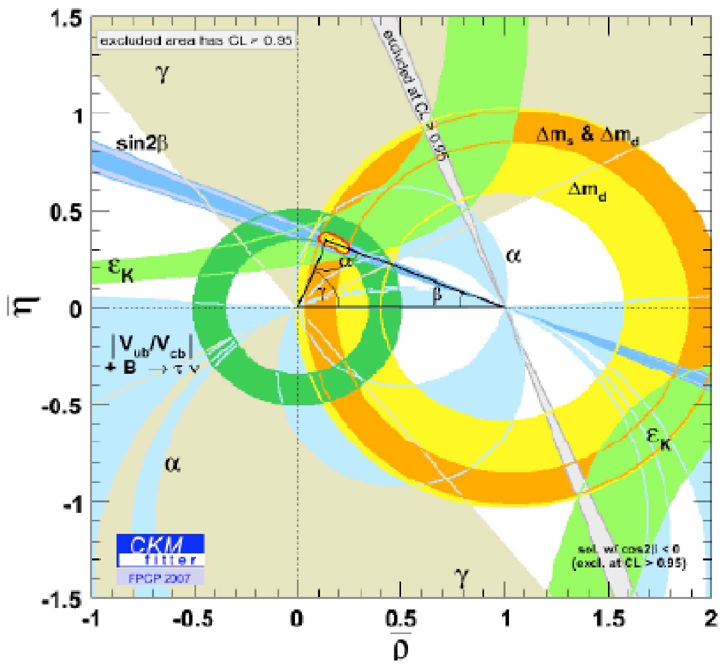
- Lattice QCD playing an important role now in:

- Precision determination of V_{us} which thereby tests first-row Unitarity.

- B_K: The ε_K coutour in the (ρ,η) plane

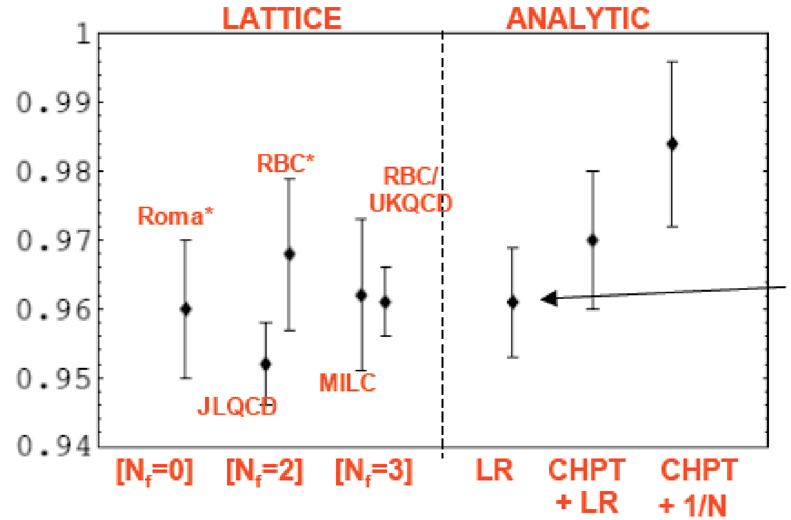


$$V_{us} \cdot f_+^{K^0\pi^-}(0) = 0.2167 \pm 0.0005$$



$$f_+^{K^0\pi^-}(0)$$

Summary on form factor and V_{us}



Vincenzo Cirigliano, Kaon 2007

Kaon Physics Wish list for Lattice QCD…

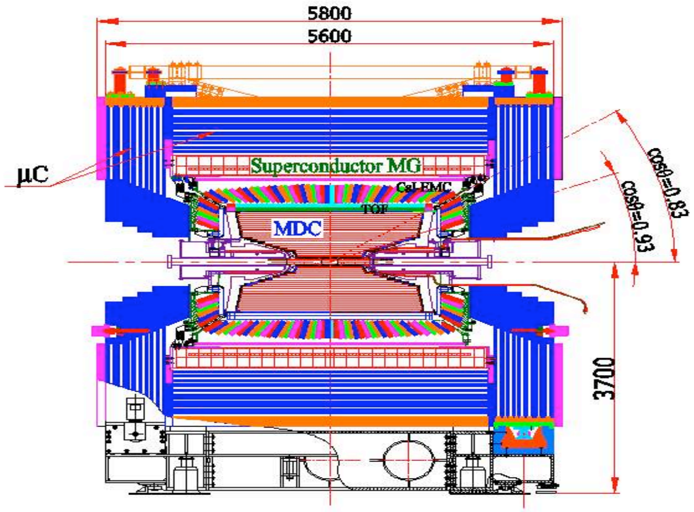
- Sub-percent control of $|V_{cb}|$ and m_c needed to interpret 1000 event measurements of $K \to \pi\nu\nu$.

- Direct CP violation in the $K^0 \to \pi\pi$, $Re(\varepsilon'_{\pi\pi}/\varepsilon_{\pi\pi})$.
  Work in Progress, Stay Tuned!

- Extracting the short-distance amplitudes of $K_L \to \pi^0 ee$, $K_L \to \pi^0 \mu\mu$ and $K_L \to \mu\mu$. This requires better, less model dependent understanding of the $K_L \to \gamma^*\gamma^*$ amplitude and radiative daughters. A 2% understanding of the "long-distance" component is motivated to extract the possible 10% short-distance component.

- Precision control of the $[K^+ \to e\nu(\gamma) / K^+ \to \mu\nu(\gamma)]$ ratio which is sensitive to BSM enhancements which can be as large as 2% (SUSY).

BES III @ BEPCII



BESIII Detector

BEPC II First collisions in 2008

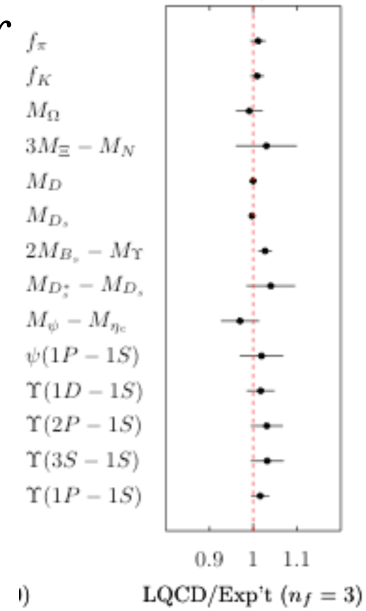
- Two ring e+e- machine E_{cm}=3.1 to 4.2 GeV
- Luminosity (6-10)x10^{33}
  - 1 yr - 10 billion J/ψ
  - 1 yr - 3 billion $\psi(2S)$
  - 3yrs (5 fb^{-1}/yrs)@ 3770 MeV 90M DD
  - 3yrs (3 fb^{-1}/yrs)@ 4170 MeV 6M $D_s^+D_s^-$

BES III

- Physics Program
  - Charmonium
  - Open Charm
- Detector Performance
  - Good tracking
  - Excellent EM calorimetry
  - Excellent lepton ID
  - Okay PID
  - No decay time resolution
- Background
  - Very low background
- Detailed Charm Studies
  - CLEO-c data
  - GEANT4 Monte Carlo

Charmonia and Bottomonia

- LQCD - single formalism relates D/B to ψ/Υ
  - Independent calibration in D/B
    - Form factors, decay constants, etc…
- >30 gold-plated quantities where few % LQCD calculations possible
  - Masses, Mass differences
  - Decay widths, Ratios of decay widths
  - Decay dynamics
- More Υ(nS) data after CLEO?
  - Most stringent lattice test
    - CLEO Γ_{ee} (Υ(2S))/ Γ_{ee}(Υ(1S)=0.457 ±0.006 (1.2%) - c.w. Lattice 0.48 ±0.05
  - Search for h_b, η_b
- CLEO-c ψ(2S) - 27 million → BESIII J/ψ 10 billion, ψ(2S) - 3 billion
  - Additional stringent LQCD tests
    - Hyperfine mass splittings
    - Forbidden M1 Transitions
  - Γ_{ee} (J/ψ, ψ(2S), ψ(3770))
    - CLEO Γ_{ee} (ψ(2S))/ Γ_{ee}(J/ψ) = 0.45 ± 0.02 (5%)



HPQCD+FERMILAB+MILC
PRL 92:022001, 2004.
(Updated)

Large number of stringent LQCD test in charmonia

Open Charm Tests QCD Calculations

- Focused & crisp challenges to theoretical techniques for QCD calculations - particularly techniques for non-perturbative QCD
  - Important if New Physics observed at LHC has strongly coupled sector

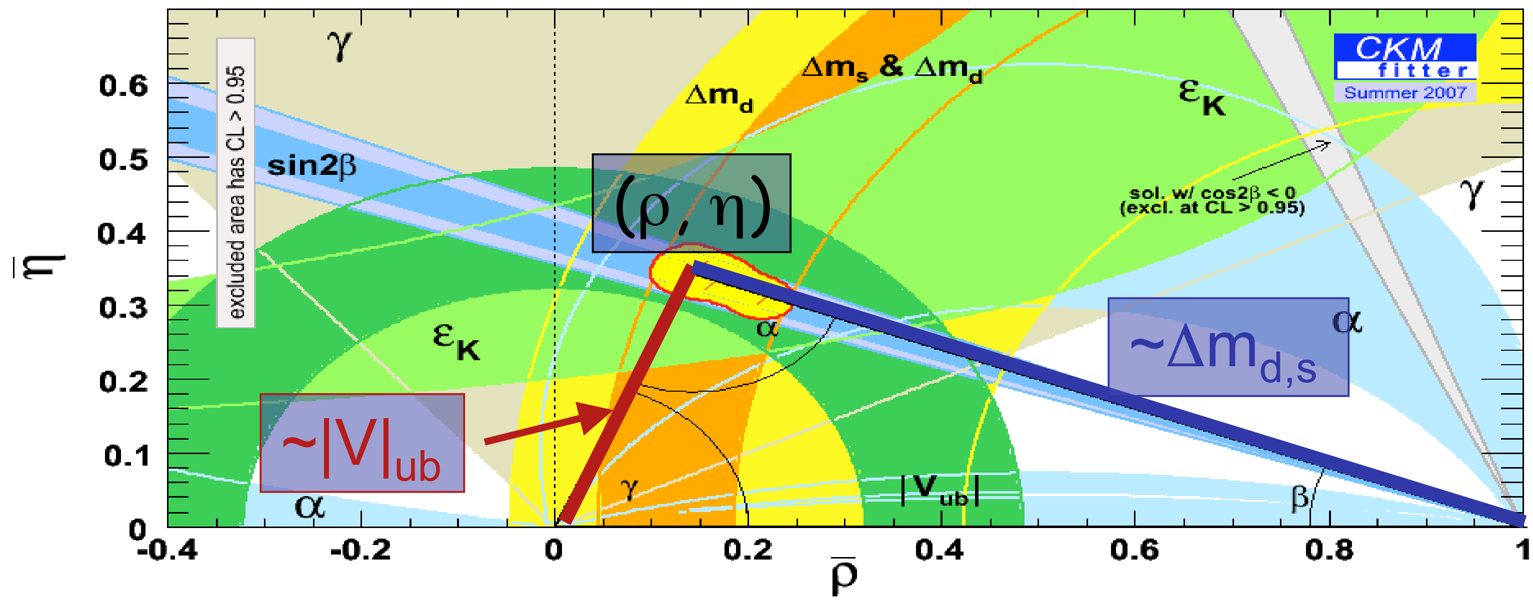
- Leptonic Decays
  - Measure decay constants f_D, f_{Ds} - stringent test of LQCD
  - Validated LQCD provides f_B, f_{Bs} - important for V_{ts}, V_{td}

- Semileptonic Decays + validated LQCD
  - Provide V_{cs}, V_{cd}, test CKM unitarity
  - Decay rates, q^2 dependence - stringent tests of LQCD
  - Improved V_{ub} - only with validated LQCD q^2 dependence calculation

"Charm" Experiments

- Charm Threshold (e^+e^- ~4 GeV)
  - Present: CLEO - ends data taking in 2008
  - Soon: BESIII - starts data taking in 2008
    - expect 20x CLEO data sample at BESIII
  - Future?: SuperB (INFN) - possible start 2014
    - expect 10x BESIII data sample in 1 month at SuperB
- B Threshold (e^+e^- ~10 GeV)
  - Present: BaBar - ends data taking in 2008
  - Present: Belle - ends data taking in 2009
  - Future?: KEKB upgrade $L=10^{35}$; SuperB (INFN) $L=10^{36}$
- Hadronic Production (Fixed target, ppbar, pp)
  - Past: FOCUS - 1996/7
  - Present: Tevatron - ends data taking in 2010
  - Soon: LHCb - starts data taking in 2008
    - Charm capability not fully evaluated
  - Future?: LHCb upgrade - does not require sLHC

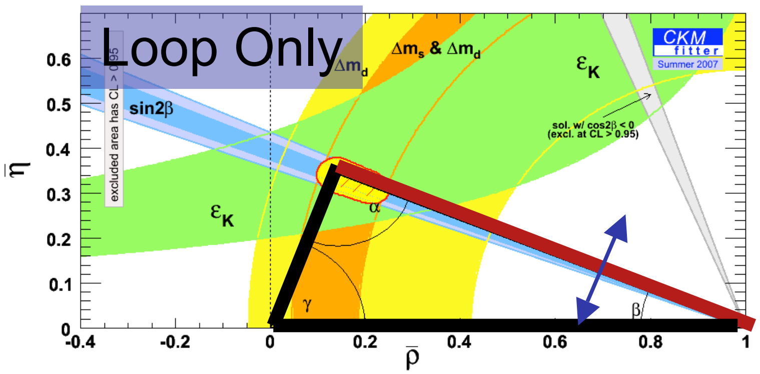
Over Constraining CKM Matrix

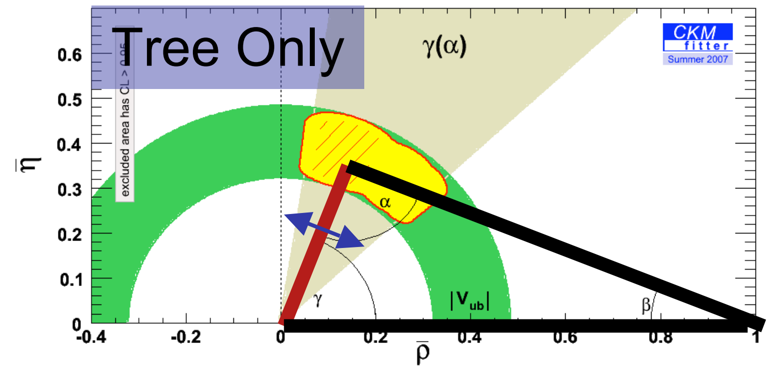


- Determination of Standard Model CP violation limited by theoretical uncertainties
- Precision charm measurements continue to hone theoretical techniques (ex. LQCD) enabling improved determination of apex (ρ, η)

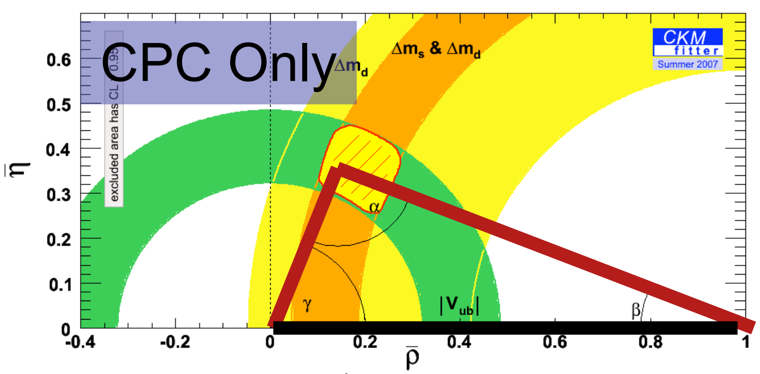
Search for New Physics

through inconsistent detemination of Standard Model CP Violation - (ρ,η) apex

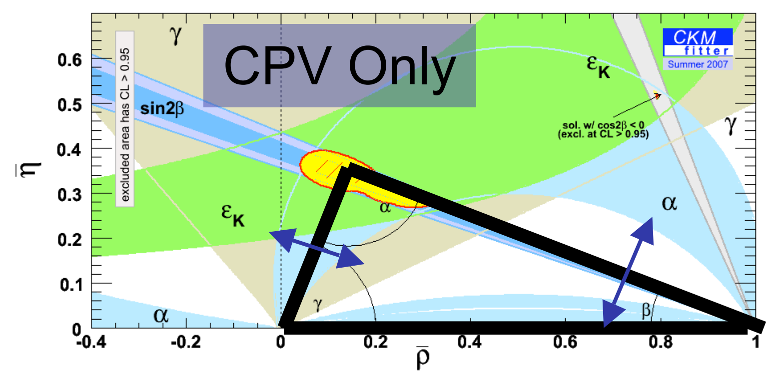




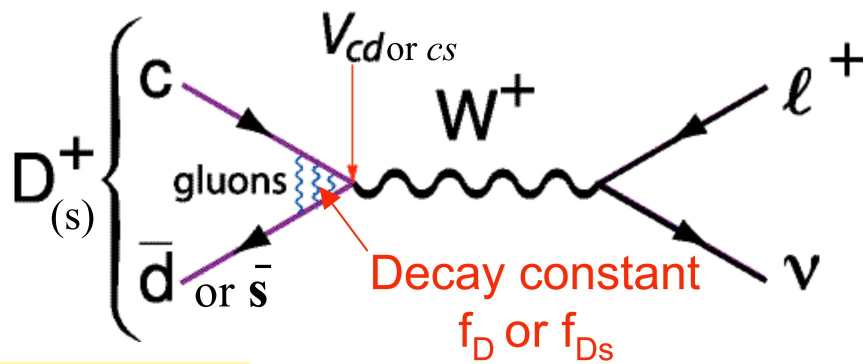
Charm measurements impact determination of sides and angles



QCD Meets Exp



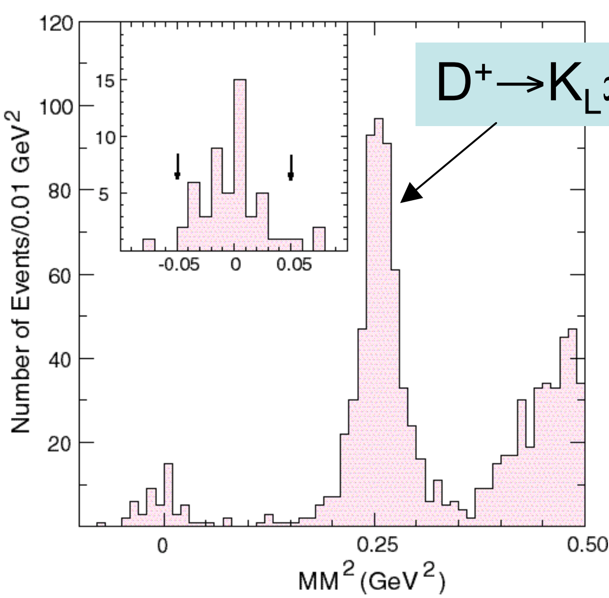
Leptonic Decays at CLEO-c

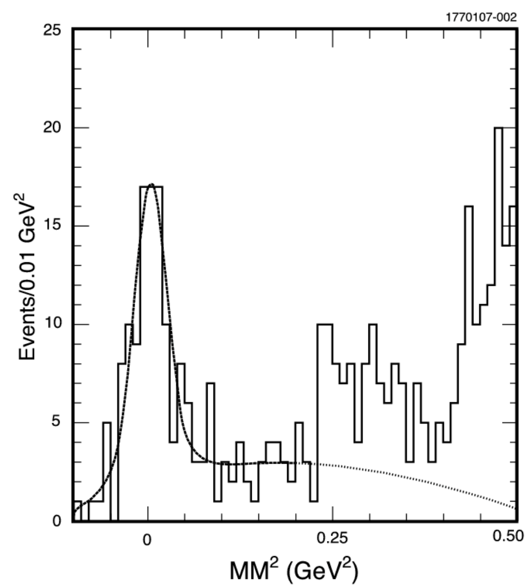


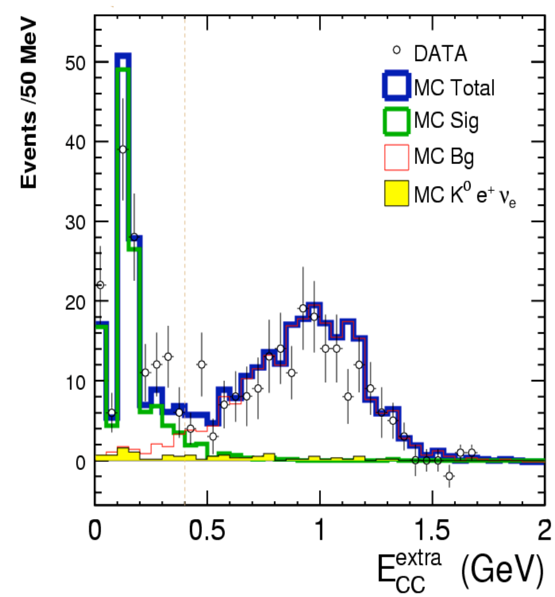
First and only measurement
$D^+ \to \mu^+\nu$

Most Precise
$D_s^+ \to \mu^+\nu$

Most Precise
$D_s^+ \to \tau^+\nu,\ \tau^+ \to e^+\nu$







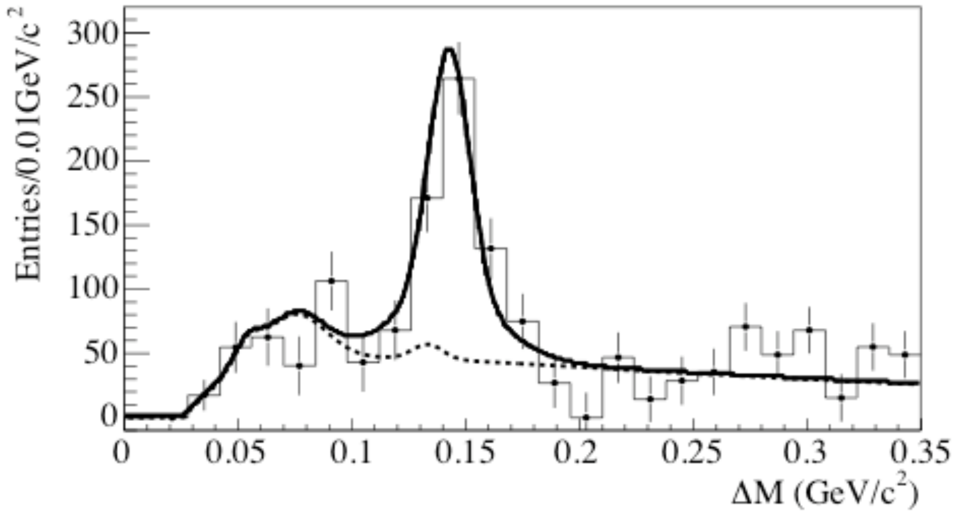
$f_{D^+} = (222.6 \pm 16.7^{+2.3}_{-3.4})$ MeV

$f_{Ds} = (274 \pm 10 \pm 5)$ MeV

BABAR & Belle $D_s \to \phi\pi$

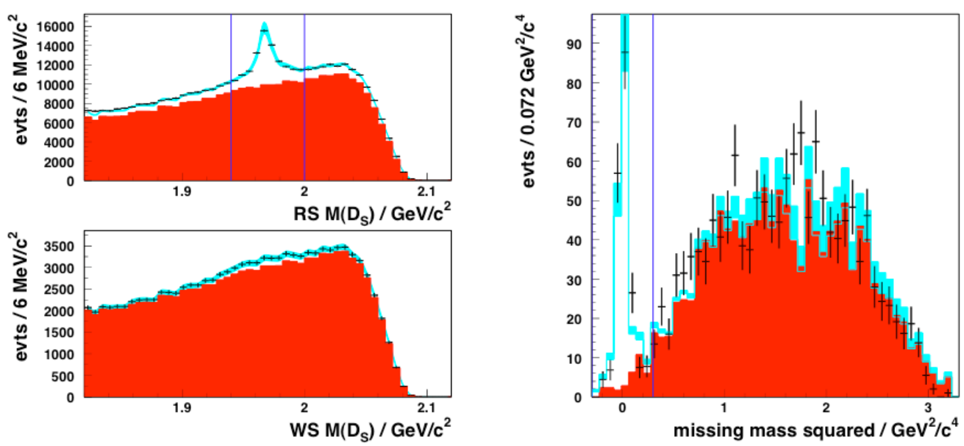
BaBar (230 fb^{-1})

- Select $e^+e^- \to cc$ events with high p D^0,D^+, D_s, D^{*+} close to B kinematic end-point
- Search for $D_s^* \to \gamma$ Ds $\to \gamma\mu\nu$ in the recoil
- $B(D_s \to \mu\nu)/B(D_s \to \phi\pi)$=0.143±0.018
- Use B(Ds $\to \phi\pi$) = (4.71±0.46)%
  BABAR PRD71 (2005) 091104, PRD74:031103,2006.
- $B(D_s \to \mu\nu)$ = (6.74±0.83±0.26±0.66)x10^{-3}
  f_{Ds} = (281 ± 17 ± 6 ± 14) MeV



Belle (548 fb^{-1})

- D_s momentum determined by full reconstruction of the recoil system e+e- $\to D^*_s$DKX, $D^*_s \to D_s\gamma$ where X=additional π,γ from fragmentation
- $B(D_s \to \mu\nu)$ = (6.44 ±0 .76 ± 0.52)x10^{-3}
  f_{Ds} = (275 ± 17 ±12) MeV



Summary: Decay Constants

- f_{Bs}/f_B is key ingredient in V_{ts}/V_{td}
- Lattice calculates $\frac{f_{B_s}\sqrt{B_{B_s}}}{f_B\sqrt{B_B}} = 1.210^{+0.047}_{-0.035}$
- Expect $f_{Bs}/f_B = f_{Ds}/f_D$ within a few %
  - From lattice still need $B_{Bs}/B_B \sim 1$
- Precision f_{Ds}/f_D enables precision V_{ts}/V_{td}
- f_D, f_{Ds} & f_{Ds}/f_D statistics limited after CLEO-c
- Need threshold data for f_D.
- For f_{Ds} : 0.5 fb^{-1} @4 GeV ≈ 2 ab^{-1} @10 GeV

Exp't	3.77 GeV	4.17 GeV	$\sigma(f_{Ds}/f_D)$
CLEO-c	281 pb^{-1}	314 pb^{-1}	8%
CLEO-c	800 pb^{-1}	630 pb^{-1}	5%
BESIII	20 fb^{-1}	12 fb-1	<2%
SuperB	~150 fb^{-1}	~200 fb^{-1}	<1%

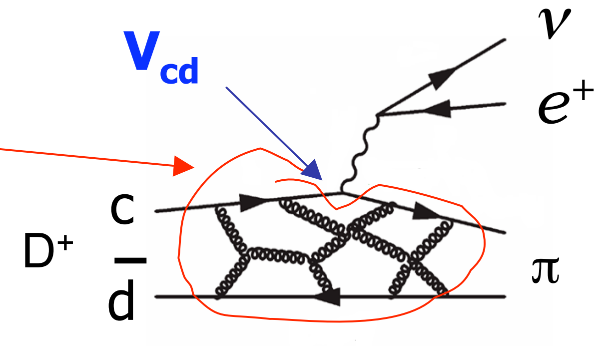
Semi-leptonic charm Decays, form factors, CKM elements, and tests of LQCD

Similar for D_s, B, B_s, …

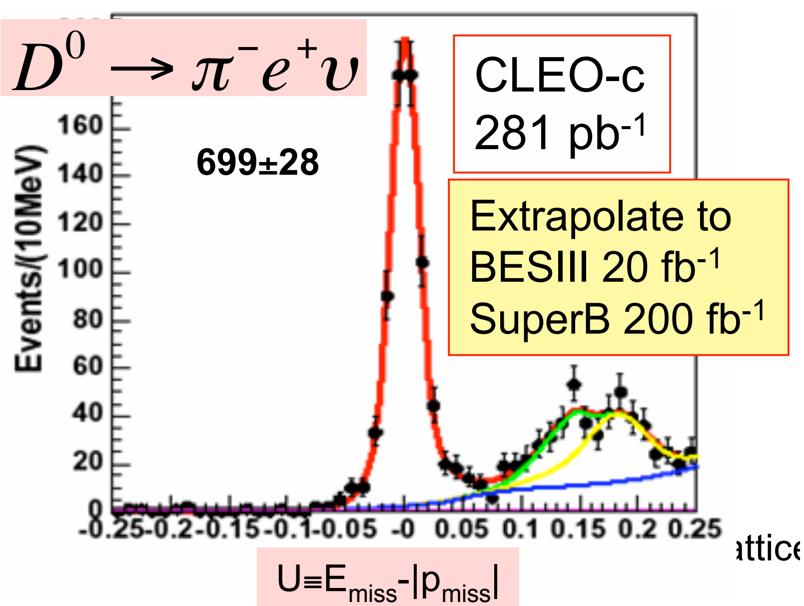
Form factor $f_+(q^2)$

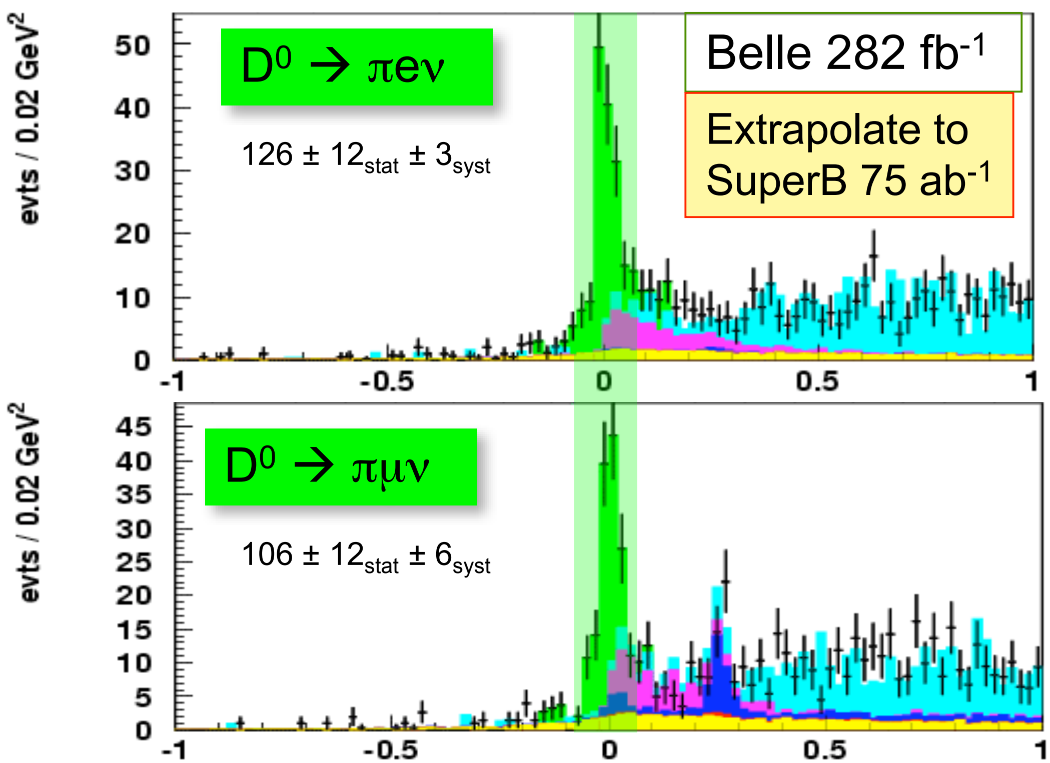
$$\frac{d\Gamma(B \to X \ell \nu)}{dq^2} = \frac{G_F^2 |V_{ub}|^2 P_P^3}{24\pi^3} \left| f_+(q^2) \right|^2$$

1000x luminosity at $\Upsilon(4S)$ has 1/7 Statistics of $\psi(3770)$ in $D \to \pi e \nu$ So BESIII has more reach than SuperB at 10 GeV



Challenge: understand QCD portion in a "simple" weak process





Another LQCD Crosscheck

- Combining the measured leptonic and semileptonic widths
- R_{sl} independent of V_{cd}

$$R_{sl} = \sqrt{\frac{\Gamma(D^+ \to \mu^+ \nu)}{\Gamma(D \to \pi \mu \nu)}}$$

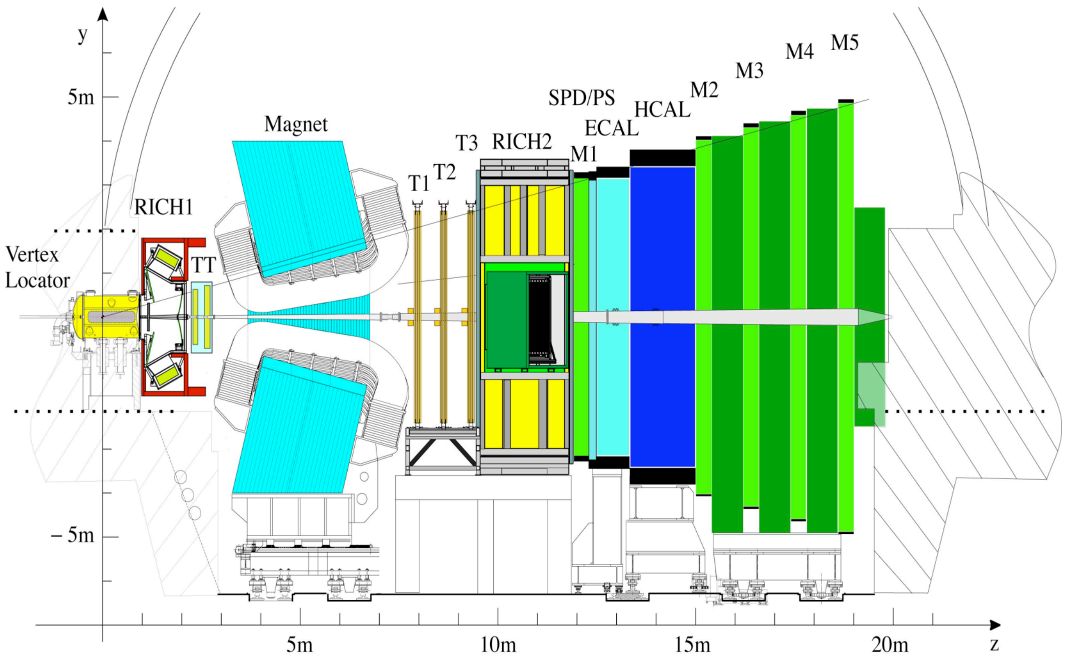
- Assume isospin invariance
- Find

$$R_{sl}^{th} = \sqrt{\frac{\Gamma(D^+ \to \mu^+ \nu)}{\Gamma(D \to \pi \mu \nu)}} = 0.212 \pm 0.028$$

$$R_{sl}^{\exp} = \sqrt{\frac{\Gamma(D^+ \to \mu^+ \nu)}{\Gamma(D \to \pi \mu \nu)}} = 0.237 \pm 0.019$$

- Theory and data in good agreement
  - BESIII (20 fb^{-1}) will provide 1% test

(Upgraded) LHC-b



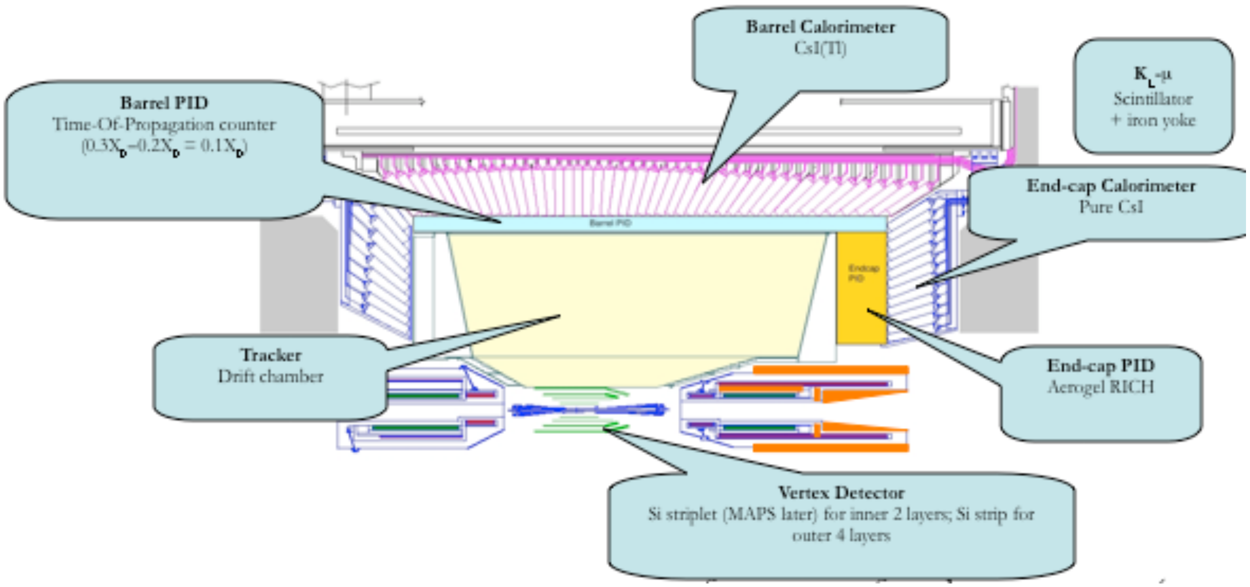
LHC

- First collisions in 2008, upgrade 2013?
- Proton-proton collision @14 TeV
- Luminosity ~1×10^{34}
- LHCb/upgrade L=2×10^{32}/2×10^{33}

(Upgraded) LHC-b

- Physics Program
  - b-physics (B, B_s, Λ_b)
  - Open Charm
  - Charm spectroscopy
- Detector Performance
  - Good tracking
  - Poor π^0, γ reconstruction
  - Poor K_S, Λ
  - Good lepton ID
  - Good PID
  - Excellent lifetime resolution
- Background
  - Substantial: hadron environment
- Detailed B Studies
  - Many, many
- Detailed Charm Studies
  - In progress

Super Belle @ Super KEKB



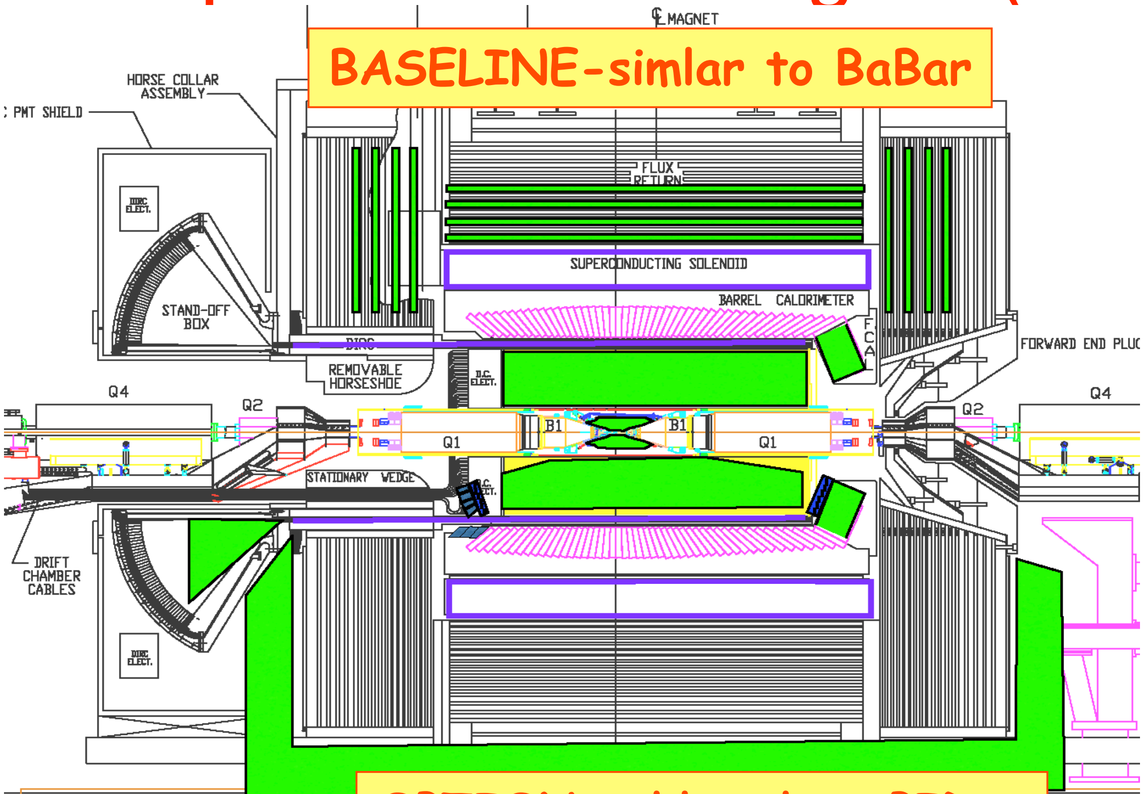
Super Belle

- Physics Program
  - B-physics
  - τ physics
  - Charm spectroscopy
  - Open Charm
  - charmonium
- Detector Performance
  - Excellent tracking
  - Excellent EM calorimetry
  - Excellent lepton ID
  - Excellent PID
  - Good decay time resolution
- Background
  - 20x Belle background
- Detailed Charm Studies
  - Belle and BABAR data
  - GEANT4 Monte Carlo

Super KEKB

- First collisions in 2012
- Asymmetric two ring e+e- machine
- E_{cm}~ 10 GeV, Luminosity ~10^{35}
- Anticipate Backgrounds 20x KEKB/Belle

Super B at Tor Vergata (10 GeV & 4 GeV)



BASELINE-simlar to BaBar

OPTION-add endcap PID and backward encap EM Cal

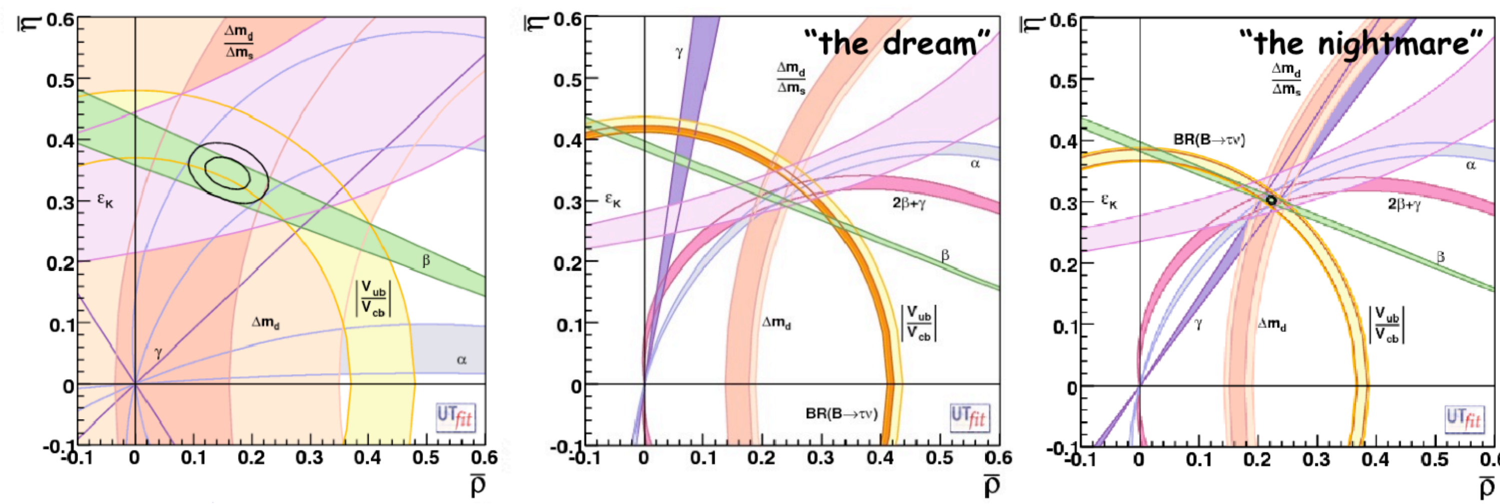
Machine

- First collisions in 2014+
- Asymmetric two ring e+e- machine
- E_{cm}~ 10 GeV, Luminosity ~10^{36}
- E_{cm}~ 4 GeV, Luminosity ~10^{35}

Super Flavor Factory

- Physics Program
  - B-physics
  - τ physics
  - Charm spectroscopy
  - Open Charm
  - charmonium
- Detector Performance
  - Excellent tracking
  - Excellent EM calorimetry
  - Excellent lepton ID
  - Excellent PID
  - Good decay time resolution
- Background
  - Lower than SuperBelle
- Detailed Charm Studies
  - Extrapolated from CLEO
- Charmonia running unlikely
- ~200 fb^{-1} (1 month) at each of
  - 3.77 GeV D^0, D^+
  - 4.17 GeV D_s
  - 4.24 GeV Peak of τ
  - 4.6 GeV Λ_c threshold

Precision CKM Projections



- All "B" experiments make Unitarity Triangle plots
  - (ρ,η) sensitivity to New Physics
- Assumptions
  - Improved LQCD precision
  - Consistency between Charm data & LQCD calculation

LQCD Projections

Measurement	Hadronic Parameter	Present Error	6 TFlops	60 TFlops	1-10 PFlops (Year 2015)
$K \to \pi l \nu$	$f_+^{K\pi}(0)$	0.9 %	0.7 %	0.4 %	$<$ 0.1 %
ε_K	$\hat{B}_K$	11 %	5 %	3 %	1 %
$B \to l \nu$	f_B	14 %	3.5-4.5 %	2.5-4.0 %	1.0-1.5 %
Δm_d	$f_{Bs}\sqrt{B_{B_s}}$	13 %	4-5 %	3-4 %	1-1.5 %
$\Delta m_d / \Delta m_s$	ξ	5 %	3 %	1.5-2 %	0.5-0.8 %
$B \to D/D^* l \nu$	$\mathcal{F}_{B \to D/D^*}$	4 %	2 %	1.2 %	0.5 %
$B \to \pi/\rho\, l \nu$	$f_+^{B\pi}, \ldots$	11 %	5.5-6.5 %	4-5 %	2-3 %
$B \to K^*/\rho\, (\gamma, l^+ l^-)$	$T_1^{B \to K^*/\rho}$	13 %	——	——	3-4 %

LHCb Summary

- First Year Highlights (0.5 fb^{-1})
  - CP Violation in $B_s \to J/\psi\phi$ - $\sigma(\phi_s)$ ~ 0.046
  - $B_s \to \mu\mu$ - extend CDF <4.7x10^{-8}, D0 <7.5x10-8, could exclude SM@ 90%
  - overtake B-factory limit - 1800 events compared to 225/ab^{-1} at Υ(4S)
- After 5 years (10 fb^{-1})
  - CP Violation in $B_s \to J/\psi\phi$ - $\sigma(\phi_s)$ ~ 0.009 (stat.)
  - $B_s \to \mu\mu$ – 5σ SM observation with 6 fb^{-1}
  - $B_s \to K^*\mu\mu$ - $\sigma(s_0)$ ~ 0.27 GeV^2
  - $R_K(B_s \to Kee / B_s \to K\mu\mu)$ - $\sigma(R_K)$ ~ 0.043(stat.) 15% from B-factories
  - $B_d \to K^*\gamma$ - A_{cp} < 1% also $B_s \to \phi\gamma$, $\Lambda_b \to \Lambda\gamma$
  - Sin(2β) $B \to J/\psi K_S$ ~σ(Sin(2β))-0.010 ~0.019 with 2ab^{-1} from B-factories
  - Sin(2β) $B \to \phi K_S$ ~σ(Sin(2β))-0.10 0.12 with 2ab^{-1} from B-factories
  - Mulitple determinations of γ comabined $\sigma(\gamma)$ ~ 2.5^0
  - Charm Program Too
    - Better precision on D mixing than B-factories
    - $D \to \mu\mu$ 10^{-12} sensitivity current limits 10^{-6}

$\Upsilon(4S)$ with 75 ab^{-1} and LQCD

- Part of very broad B, D, τ, physics program benefits from precision LQCD
  - Exclusive $|V_{ub}|$ and $|V_{cb}|$
    - $B \to \pi$ and $B \to D$ form factors at 1-2%
  - Leptonic $B \to \mu\nu(\gamma)$, $B \to l^+l^-$, Rate $\propto (f_B|V_{ub}|)^2$
    - f_B from LQCD to measure V_{ub}
    - V_{ub} from elsewhere - test LQCD calc.
    - Given both f_B and V_{ub} - New Physics probe
    -
  - Exclusive $b \to d\gamma$, $b \to s\gamma$, Ratio$\propto(|V_{td}|/|V_{ts}|)^2\xi^2$
    - Experimental error ~2%
    - Compare with $\Delta m_d / \Delta m_s$ - experimental error sub%

SuperB (10^{36}) Physics Reach

From SuperB: Conceptual Design Report hep-ex/0709.0451

Table 2-1. *The expected precision of some of the most important measurements that can be performed at SuperB. For comparison, we put the reach of the ... data driven methods of reducing the errors. See the text for further discussion of each measurement.*

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 (∗)
$S(K^0_S K^0_S K^0_S)$	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°

Table 2-2. *The expected precision of some of the most important measurements ... data driven methods of reducing the errors. See the text for further discussion of each measurement.*

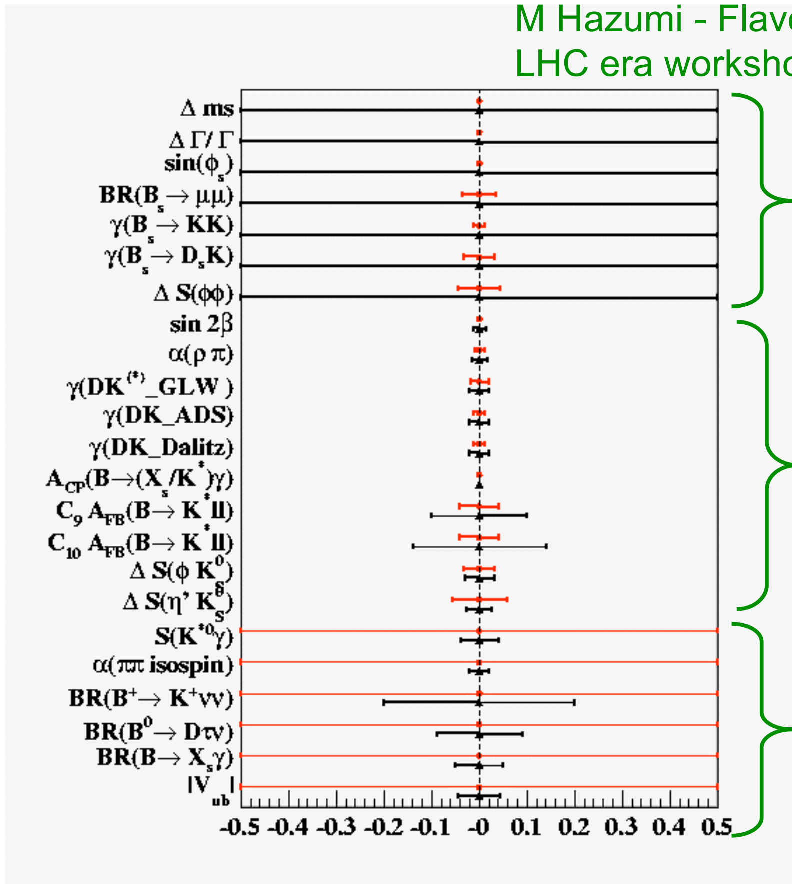
Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\|V_{cb}\|$ (exclusive)	4% (∗)	1.0% (∗)
$\|V_{cb}\|$ (inclusive)	1% (∗)	0.5% (∗)
$\|V_{ub}\|$ (exclusive)	8% (∗)	3.0% (∗)
$\|V_{ub}\|$ (inclusive)	8% (∗)	2.0% (∗)
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	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

SuperB & LHCb Upgrade

Sensitivity Comparison ~2020

LHCb 100 fb^{-1} vs Super-B factory 50 ab^{-1}

M Hazumi - Flavour in LHC era workshop



B_s only accessible to LHCb

Common

No IP
Neutrals, ν

Domain of B-factories

Summary

- LQCD - single formalism relates D/B to ψ/Υ
  - Independent calibration in D/B
    - Form factors, decay constants, etc…
  - $\Gamma_{ee}(\Upsilon(2S))/\Gamma_{ee}(\Upsilon(1S)$=45.7±0.6% (1.2%)
    - most stringent test of LQCD calculation to date
    - Need more $\Upsilon(1S),\Upsilon(2S),\Upsilon(3S)$ data?
  - Billions of J/ψ, $\psi(2S)$ expected soon from BESIII
- Charm Threshold Data
  - Expected BESIII sample - 20x CLEO-c
    - Precision LQCD tests <2% f_{Ds}/f_D
    - form factor analysis similar to K_{e3} requires 500 fb^{-1}
    - BESIII SM sensitivity of $c \to ul^+l^-$
    - Strong Phase measurements important for phase of V_{ub} and D mixing results
- New Physics observation in precision K, B physics requires precision understanding of SM expectations
- Kaon Experiments
  - Need sub% control of V_{cb}, m_c
  - SM expectation for Re($\varepsilon'_{\pi\pi}/\varepsilon_{\pi\pi}$)
  - $K_L \to \pi\mu\mu$ etc, need $K_L \to \gamma^*\gamma^*$
- $\Upsilon(4S)$ Data
  - New Physics reach depends on LQCD (and Charm data)
  - Precision V_{cb},V_{ub} need % form factors
  - New Physics probes need % f_B,f_{Bs}
  - Very broad B, D, τ program
  - 5 years at ~$10^{36} \to 75\ ab^{-1}$
    CPV D mixing - % level sensitivity
    Sensitive to SM LFV in τ decays
- LHCb
  - Master of B_s of physics
  - Complementary B_d
  - Better at rare charm than $\Upsilon(4S)$

Questions?

- Is onia data sufficient to validate lattice calculations?
  – Do we have enough $\Upsilon(nS)$?

- Is BESIII data sample sufficient to test precision LQCD calculations?
  – Charmonia - yes
  – Leptonic Decays - probably
  – Semileptonic Decays - no?

FYI

- Two Super B-factory Proposals are not equivalent
  10^{35} (Super KEKB), 10^{36} (SuperB)
  - 10^{35} (Super KEKB) more likely to occur
  - 10^{36} (SuperB) allows more than just precision (ρ,η)
    - Pattern of deviation from SM suppressed or forbidden B, D, τ processes is important for understanding NP observed (or not) at energy frontier.
    - SuperB is designed to also run near charm threshold
    - One polarized beam enhances tau studies
  - 10^{36} more demanding of LQCD calculations
- Searches for New Physics in Charm
  - Very low Standard Model rates for loop processes provide unique window to observe New Physics in rare charm processes
    - Rare Decays, CP Violation, Charm Mixing
    - NP can introduce new particles into loop
  - Different sensitivity to NP than B & K sectors
    - Particles/couplings in rare charm processes NOT the same as rare B, K