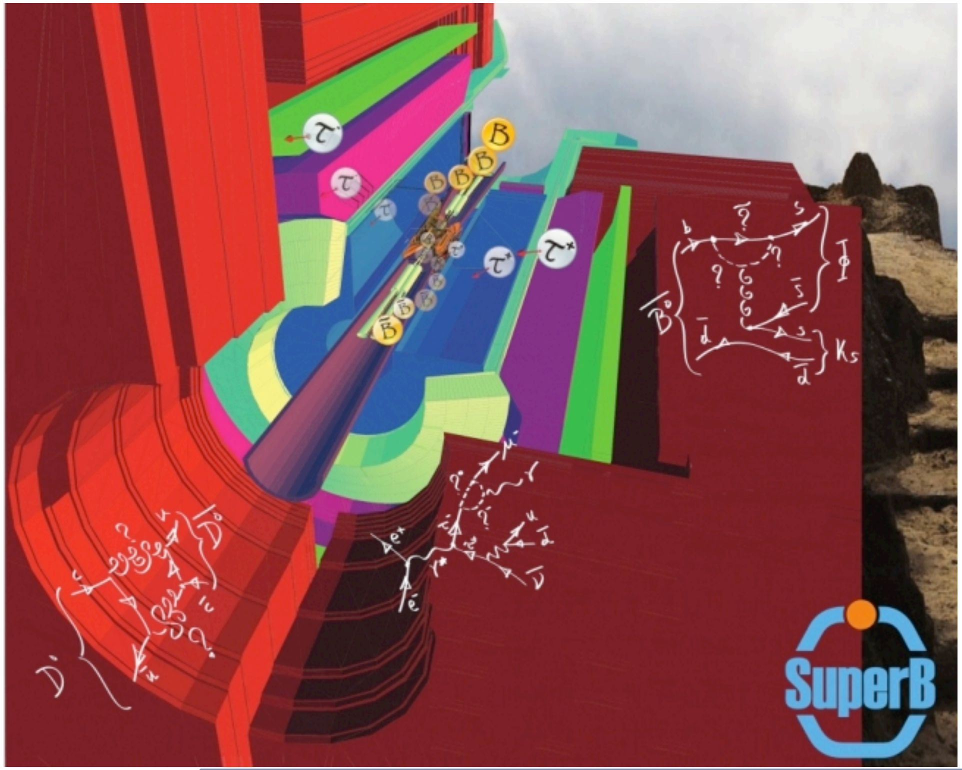

SuperB Complementarity of Super Flavour Factories with Hadron machines

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HCP, Paris, 14th November 2011

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Overview

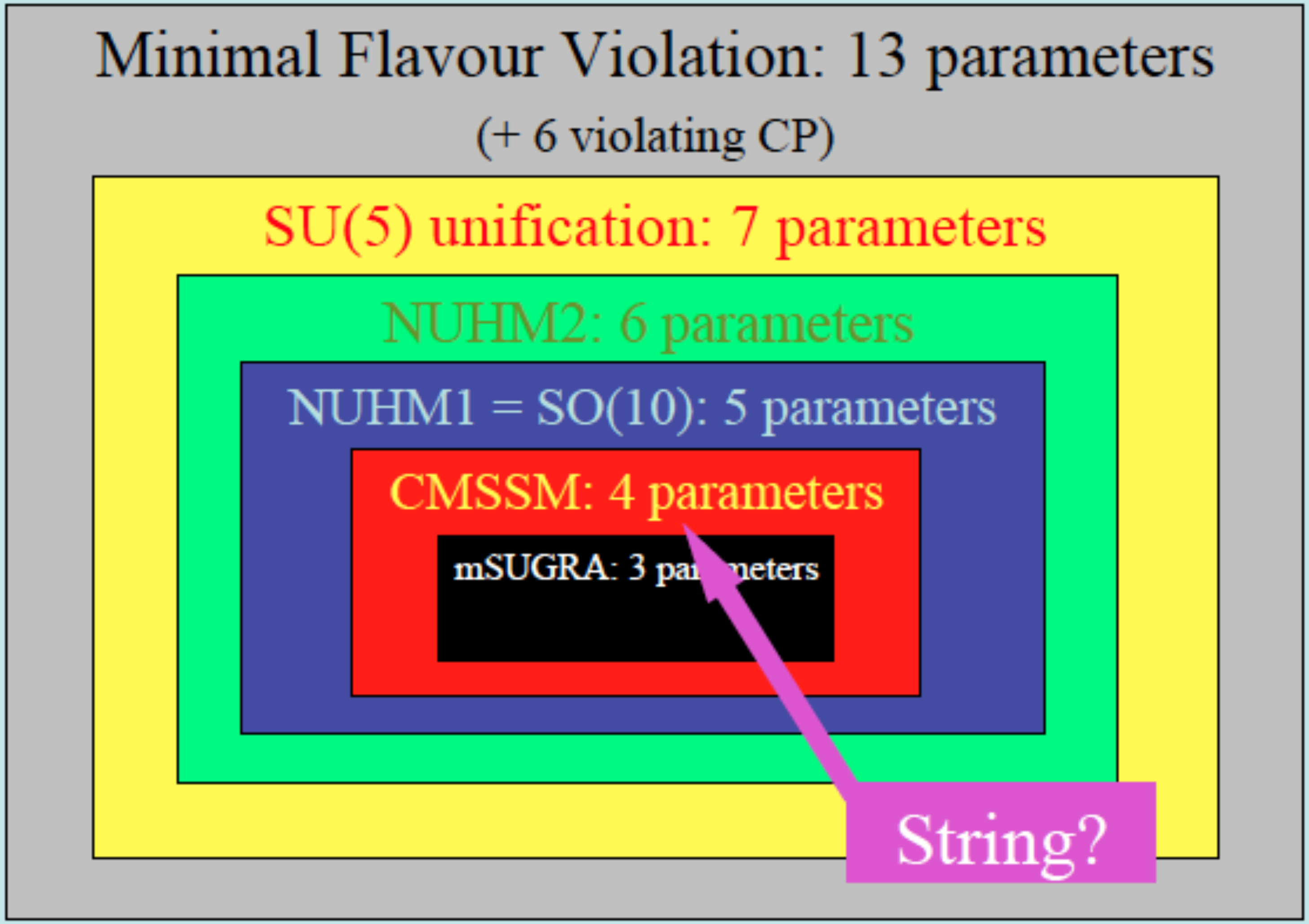
- Introduction
  - The Super Flavour Factories
  - The problem
- Λ_{NP}: the energy scale
- Other NP sensitive flavour observables
- Interplay between measurements
- Summary

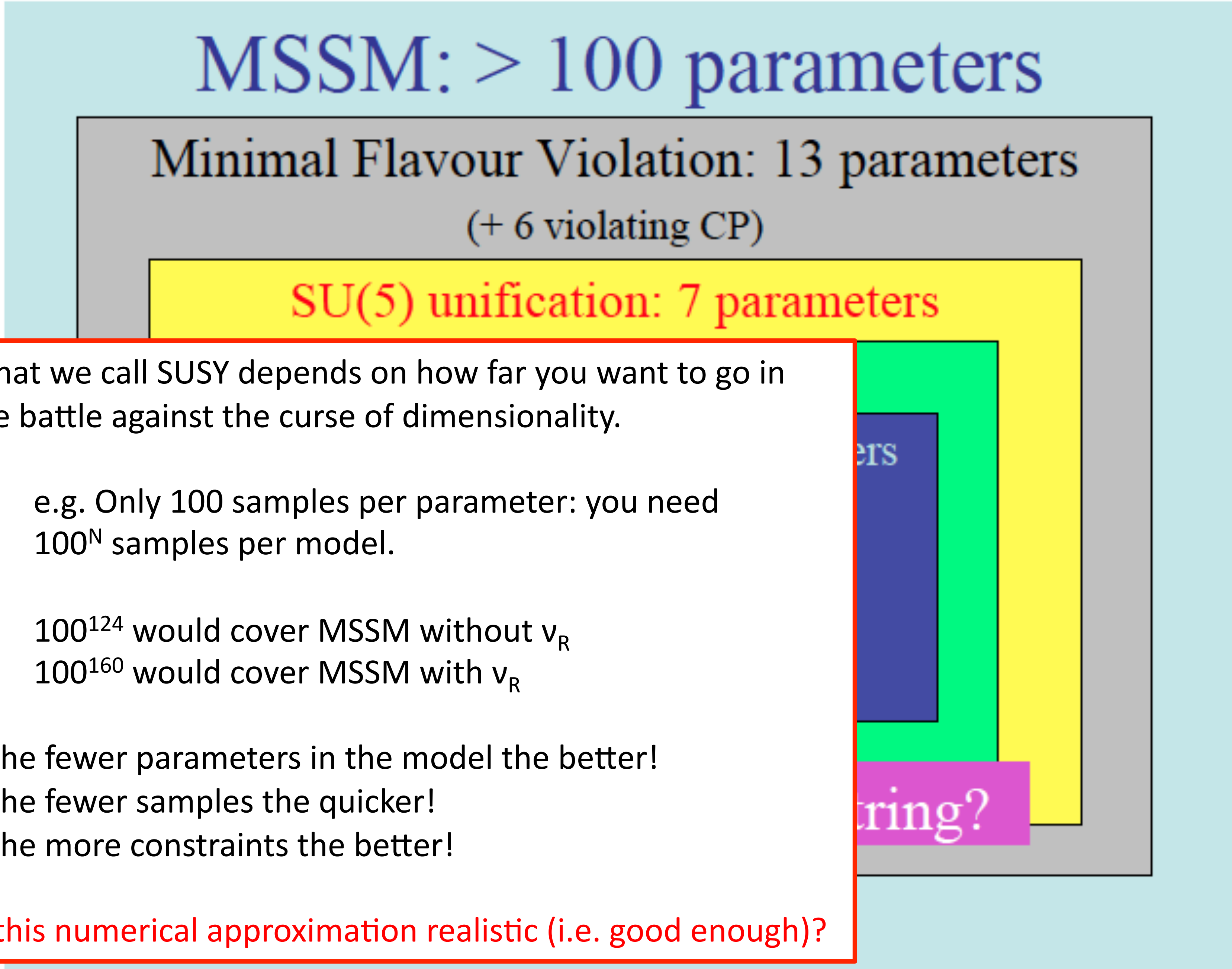
Introduction

- Current flavour physics landscape is defined by BaBar, Belle and the Tevatron.
  - We learned that CKM is correct at leading order.
  - Placed indirect constraints on NP that will last well into the LHC era. (e.g. H^+ searches).
  - Handed over to LHCb in the summer.

- SuperB will start taking data in 2016, and the first full run is expected in 2017.
  - LHCb will have re-defined some areas of flavour physics on that timescale [and take data through to 2017 shutdown].
  - LHC may (or may not) have found new particles.
    - Existing mass scale exclusions are model dependent.
  - In both scenarios results from SuperB can be used to constrain flavour dynamics at high energy.

MSSM: > 100 parameters





What we call SUSY depends on how far you want to go in the battle against the curse of dimensionality.

e.g. Only 100 samples per parameter: you need 100^N samples per model.

100^{124} would cover MSSM without ν_R
100^{160} would cover MSSM with ν_R

- The fewer parameters in the model the better!
- The fewer samples the quicker!
- The more constraints the better!

Is this numerical approximation realistic (i.e. good enough)?

Λ_{NP}: the energy scale

- The Super Flavour Factories don't operate at high energy
  - .... *what's the point of having them?*
  - Model dependent indirect probes for NP reach higher scales than can be attained at the LHC.
  - Model dependent direct searches for NP at the LHC have found nothing so far (unfortunately).

Scenario 1:

LHC finds NP incompatible with flavour data → something to fix in the theory

Scenario 2:

LHC finds NP compatible with flavour data → can use flavour data to start constraining couplings

Scenario 3:

LHC finds nothing → indirectly probe high energy effects.

e.g. B mixing and the top: everyone knew the top was light until ARGUS found B mixing to be large.

Λ_{NP}: the energy scale

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• Also the problem of decoding NP is not as simple as the days of the top quark searches.

We know something is missing but we don't know what we are looking for.

• Many viable models of NP: SUSY or some simple variant (mSUGRA/CMSSM/...), extra dimensions, 4^{th} generation, Little Higgs, etc. etc. etc. some are coupled to SM Higgs vs. no Higgs.

Each model guides a search, but only one model can be right
(and it's not necessarily one of these)

Λ_{NP}: the energy scale

- Example: Consider MSSM as an illustration of SUSY
  - Simple, and being constrained by the LHC but general enough to illustrate the issue:

e.g. MSSM: 124 (160 with ν_R) couplings, most are flavour related.

Δ's are related to NP mass scale.

LHCb, SuperB

$$M^2_{\tilde{d}} \approx \begin{pmatrix} m^2_{\tilde{d}_L} & m_d(A_d-\mu\tan\beta) & (\Delta^d_{12})_{LL} & (\Delta^d_{12})_{LR} & (\Delta^d_{13})_{LL} & (\Delta^d_{13})_{LR} \\ & m^2_{\tilde{d}_R} & (\Delta^d_{12})_{RL} & (\Delta^d_{12})_{RR} & (\Delta^d_{13})_{RL} & (\Delta^d_{13})_{RR} \\ & & m^2_{\tilde{s}_L} & m_s(A_s-\mu\tan\beta) & (\Delta^d_{23})_{LL} & (\Delta^d_{23})_{LR} \\ & & & m^2_{\tilde{s}_R} & (\Delta^d_{23})_{RL} & (\Delta^d_{23})_{RR} \\ & & & & m^2_{\tilde{b}_L} & m_b(A_b-\mu\tan\beta) \\ & & & & & m^2_{\tilde{b}_R} \end{pmatrix}$$

LHC, ILC - HE frontier

and similarly for $M^2_{\tilde{u}}$

- In many NP scenarios the energy frontier experiments will probe the diagonal elements of mixing matrices.
- Flavour experiments are required to probe off-diagonal ones.

Λ_{NP}: the energy scale

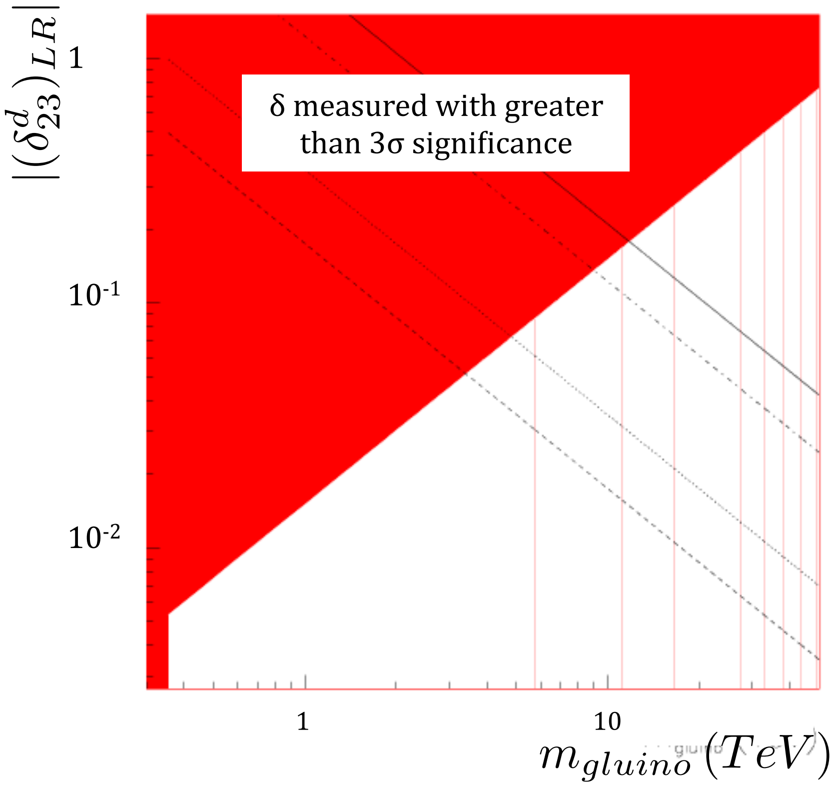
- e.g. MSSM with generic squark mass matrices.
- Use Mass insertion approximation with $m_{\tilde{q}} \sim m_{\tilde{g}}$ to constrain couplings:

$$(\delta^q_{ij})_{AB} = \frac{(\Delta_{ij})^q_{AB}}{m^2_{\tilde{q}}}$$

- Can constrain the δ^d_{ij}'s using

$$\mathcal{B}(B \to X_s \gamma)$$
$$\mathcal{B}(B \to X_s \ell^+ \ell^-)$$
$$\mathcal{A}_{CP}(B \to X_s \gamma)$$

Existing LHC constraints on the gluino mass, mean couplings are non-zero, so we can provide an upper bound on Λ_{NP}.



e.g. see Hall et al., Nucl. Phys. B **267** 415-432 (1986)
Ciuchini et al., hep-ph/0212397

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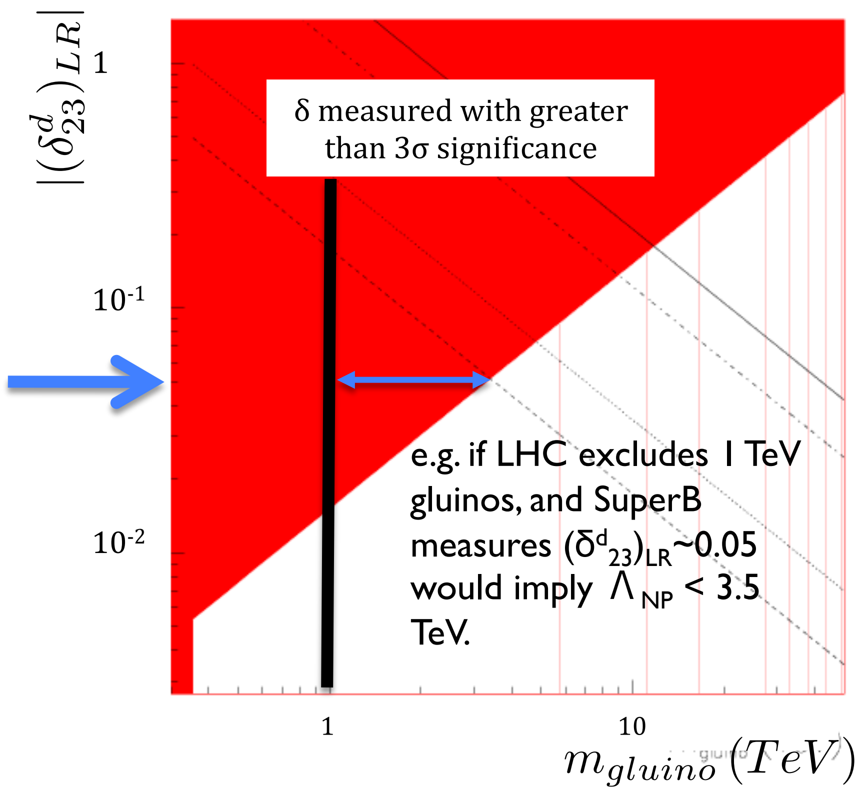

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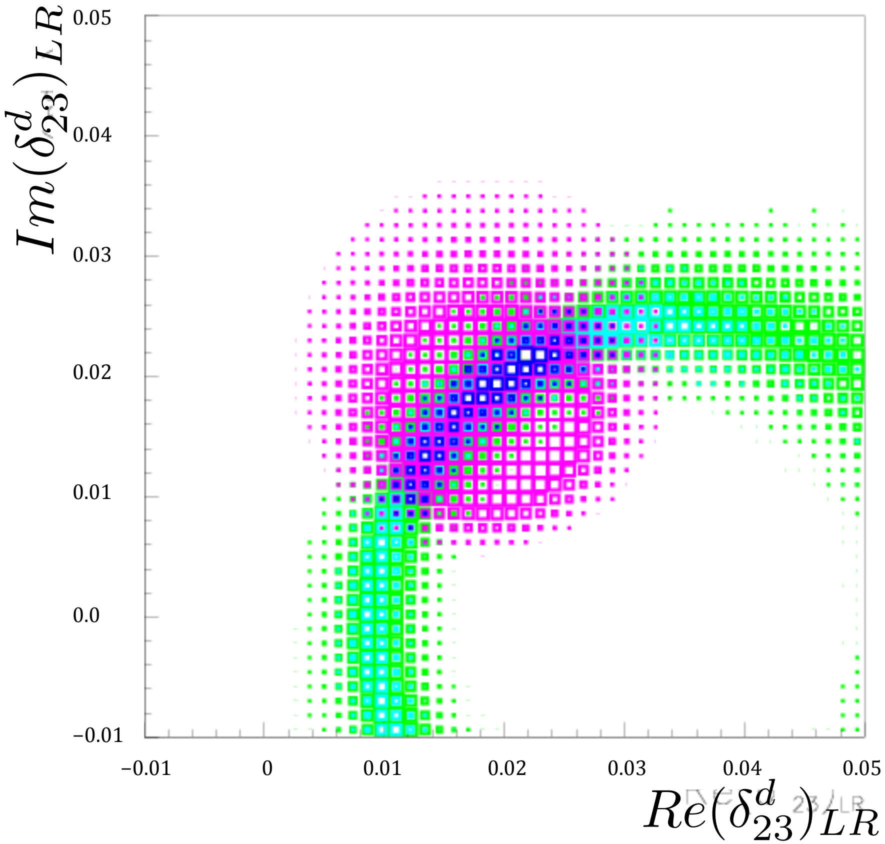
$$(\delta^q_{ij})_{AB} = \frac{(\Delta_{ij})^q_{AB}}{m^2_{\tilde{q}}}$$

- Can constrain the δ^d_{ij}'s using
  - (green) $\mathcal{B}(B \to X_s \gamma)$
  - (cyan) $\mathcal{B}(B \to X_s \ell^+ \ell^-)$
  - (magenta) $\mathcal{A}_{CP}(B \to X_s \gamma)$



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Other NP sensitive flavour observables

- LFV: τ decays
- B Physics
- D Physics
- Precision $\sin^2\theta_W$

See the following preprints for a more comprehensive overview:

arXiv:1109.5028 (SuperB Interplay)

arXiv:1008.1541 (SuperB)

arXiv:1002.5012 (Belle II)

arXiv:1110.3901 (recent review)

Complementary direct searches for low energy new physics (Higgs/Dark Forces/Dark Matter) are also possible

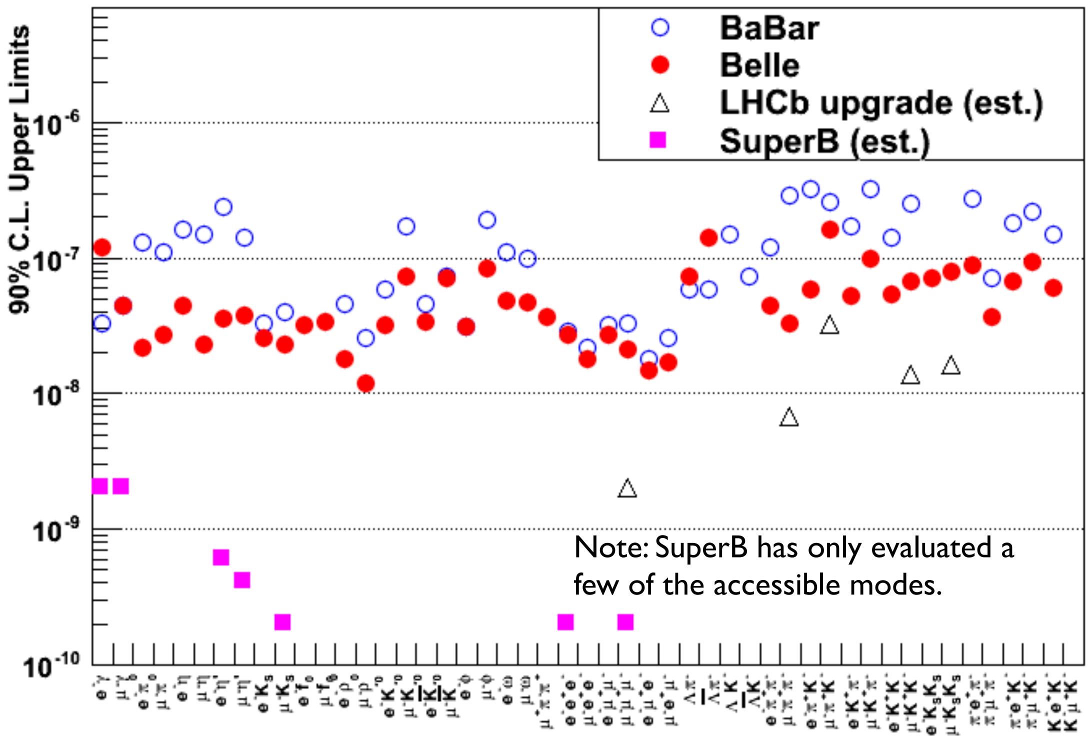
See for example the BaBar / Belle results in the previous talk by Giovanni Calderini and the above references.

Lepton Flavour Violation (LFV)

- ν mixing leads to a low level of charged LFV ($B{\sim}10^{-54}$).
  - Enhancements to observable levels are possible with new physics scenarios.
  - Searching for transitions from 3rd generation to 2nd and 1st, i.e.

$$\tau \longrightarrow \mu \text{ and } \tau \longrightarrow e$$

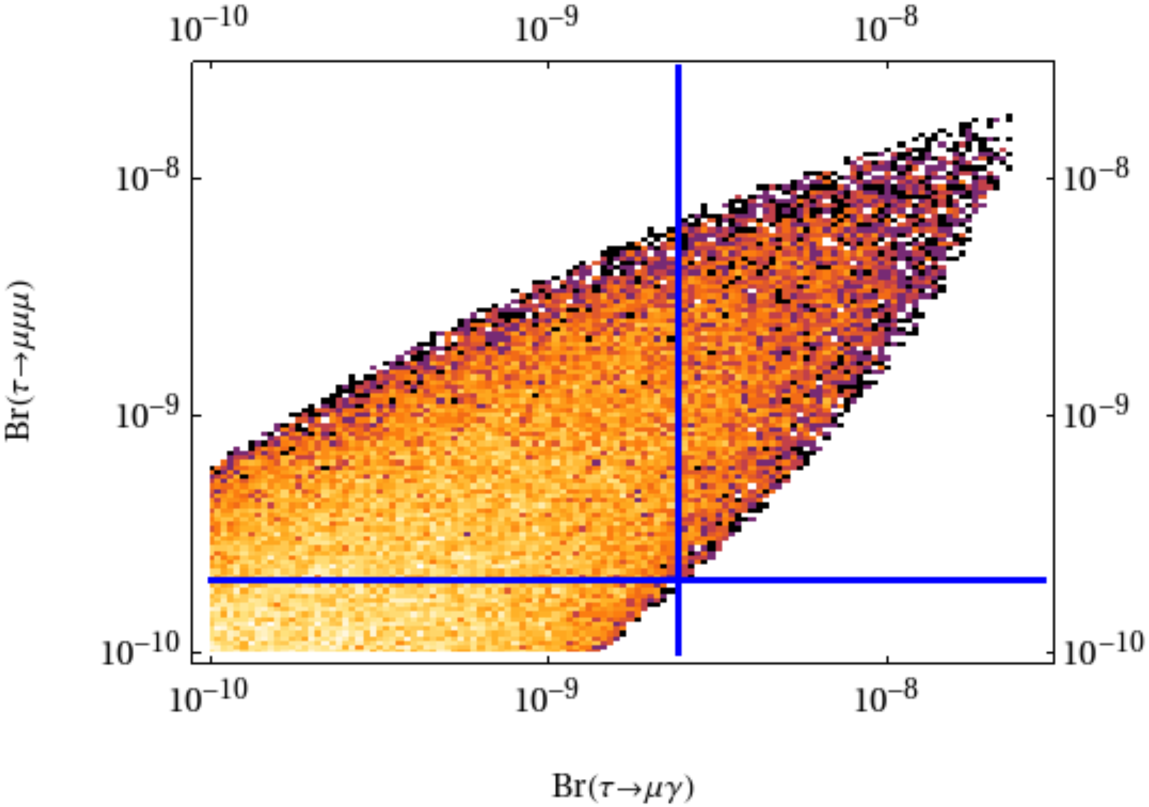
- ➢Two orders of magnitude improvement at SuperB over current limits.
- ➢Hadron machines are not competitive with e^+e^- machines for this with current methods.



- N.B. e^- beam polarisation helps suppress background.

The golden LFV modes: $\tau \longrightarrow \mu\gamma, 3\mu$

- Symmetry breaking scale assumed: 500GeV.



NP scale assumed: 500GeV.

Current experimental limits are at the edges of the model parameter space

SuperB will be able to significantly constrain these models, and either find both channels, or constrain a large part of parameter space.

c/o M. Blanke

M. Blanke et al. arXiv:0906.5454

Specific example: $\tau \to \mu\gamma$

- Only cleanly accessible in e^+e^- (golden modes: μγ, 3 lepton).

Model dependent NP constraint.

Correlated with other flavour observables: MEG, LHCb etc.

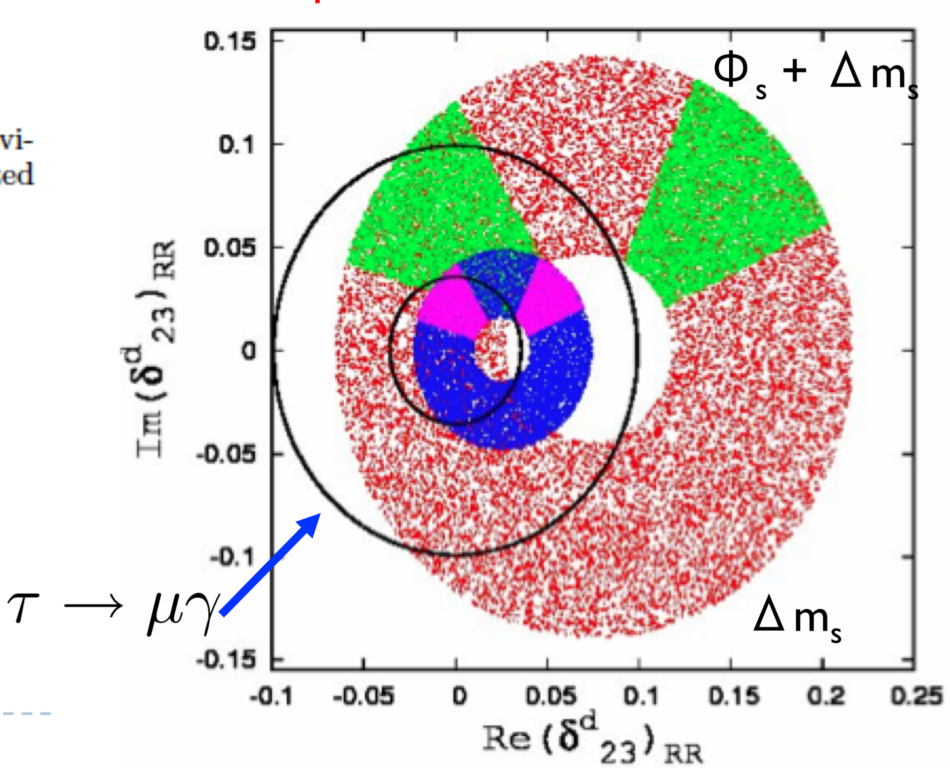
TABLE III: Expected 90% CL upper limits and 3σ evidence reach on LFV decays with 75 ab^{-1} with a polarized electron beam.

Process	Expected 90% CL upper limit	3σ evidence reach
$\mathcal{B}(\tau \to \mu\gamma)$	2.4×10^{-9}	5.4×10^{-9}
$\mathcal{B}(\tau \to e\gamma)$	3.0×10^{-9}	6.8×10^{-9}
$\mathcal{B}(\tau \to \ell\ell\ell)$	2.3–8.2×10^{-10}	1.2–4.0×10^{-9}

$m_{\tilde{q}} = 300\, GeV$ BLUE

$m_{\tilde{q}} = 500\, GeV$ RED

Not updated to latest results from LHCb

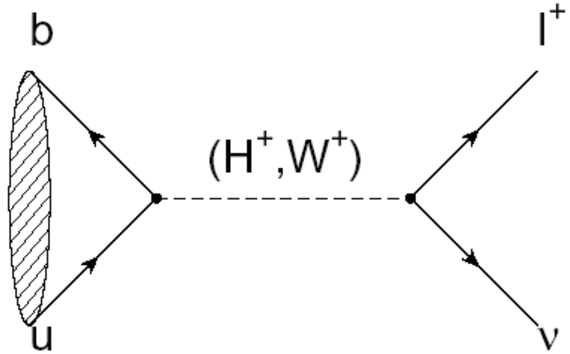


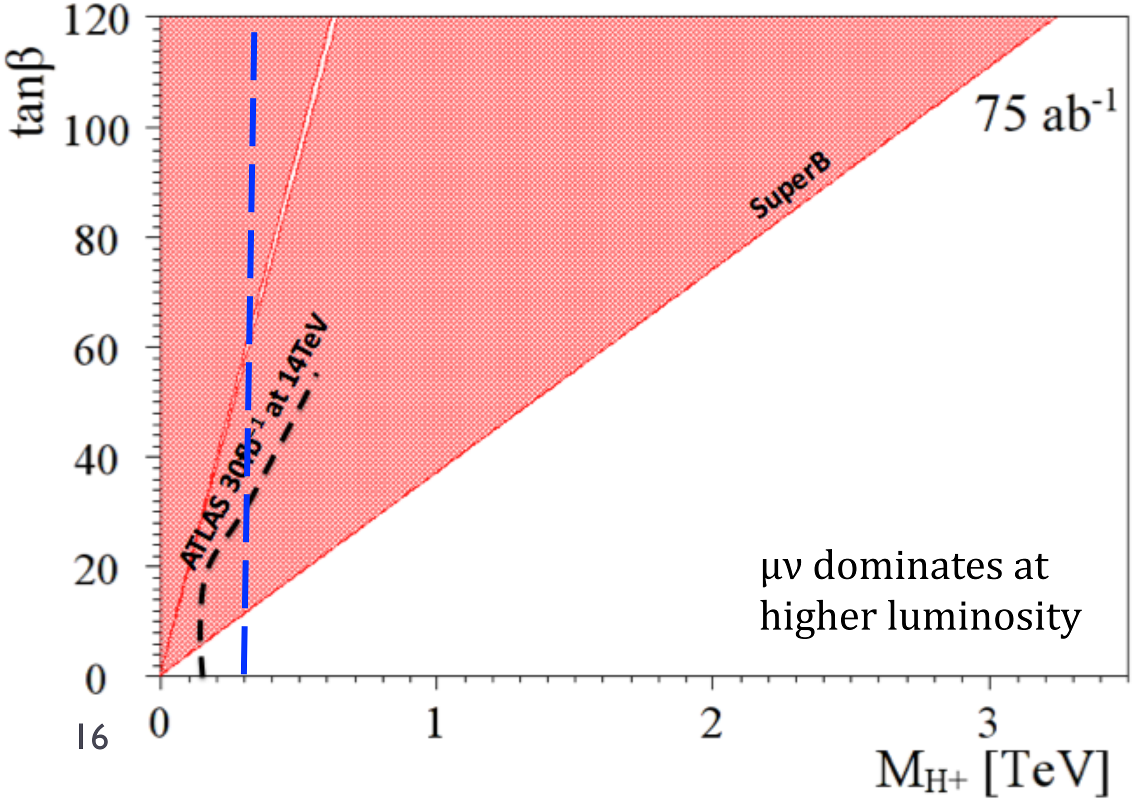
Parry and Zhang Nucl.Phys.B802:63-76,2008

$B_{u,d}$ physics: Rare Decays

- Example: $B^{\pm} \to \ell^{\pm}\nu$
  - Rate modified by presence of H^+

$$r_H = \frac{\mathcal{B}_{SM+NP}}{\mathcal{B}_{SM}}$$





$$r_H = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)$$

Currently the inclusive b to sγ channel excludes $m_{H+} < 295$ GeV/c^2.

The current combined limit places a stronger constraint than direct searches from the LHC for the next few years.

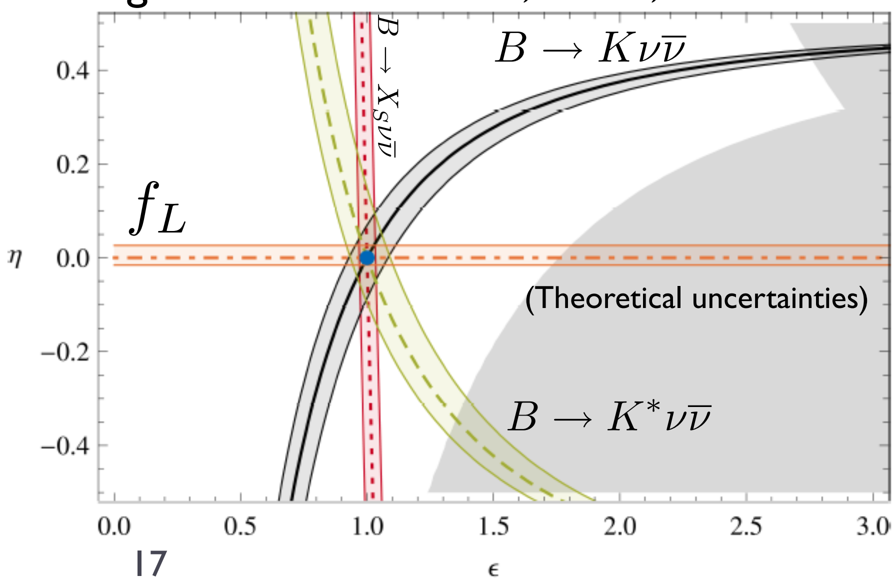
$B_{u,d}$ physics: Rare Decays

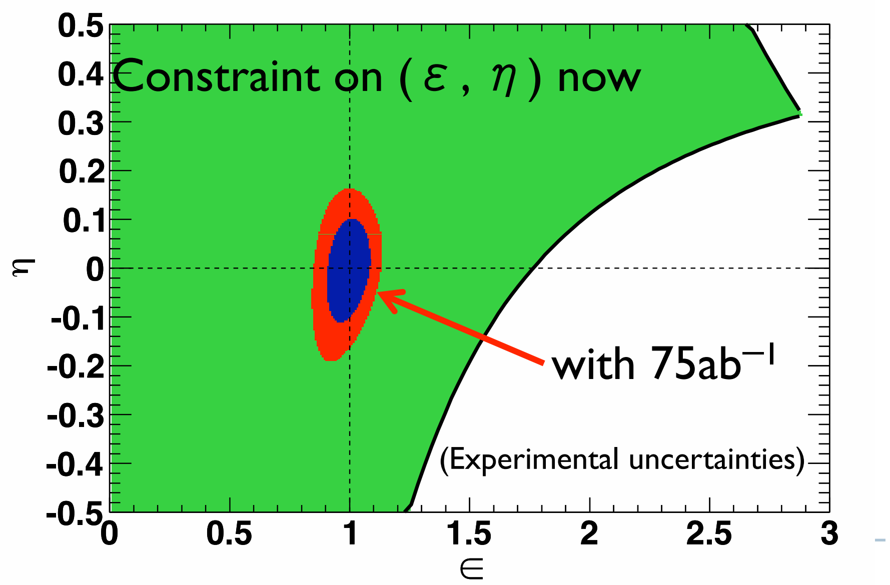
- Example: $B \to K^{(*)}\nu\overline{\nu}$
  - Need $75ab^{-1}$ to observe pseudoscalar and vector modes.
  - With more than $75ab^{-1}$ we could measure polarisation.

$$\epsilon = \frac{\sqrt{|C_L^\nu|^2 + |C_R^\nu|^2}}{|(C_L^\nu)^{\rm SM}|}\,, \qquad \eta = \frac{-{\rm Re}\,(C_L^\nu C_R^{\nu *})}{|C_L^\nu|^2 + |C_R^\nu|^2}$$

Sensitive to models with Z', RH currents and light scalar particles.

e.g. see Altmannshofer, Buras, & Straub





$b \rightarrow s l^+ l^-$

- SFFs can measure inclusive and exclusive modes:
  - Crosscheck results to understand source of NP.
  - Important as theory uncertainties differ.
  - e.g. expect: 10-15,000 $K^*\mu\mu$ and 10-15,000 K^*ee events at SuperB.

- SFFs can study all lepton flavours:
  - Equal amounts of μ and e final states can be measured.
    - Need both of these to measure all NP sensitive observables.
    - LHCb will accumulate slight more events in the $\mu\mu$ mode.
    - Expect ~20 times the statistics than LHCb for ee mode.
    - S/B~ 0.3, c.f. S/B~1.0 for LHCb: harder cuts at LHCb give a cleaner sample of events to study.
  - Can also search for $K^{(*)}\tau^+\tau^-$ decay.
  - ... and constrain Majorana ν's using like sign final states (LNV).
    - Also of interest for D_s decays to $K^{(*)}ll$ final states near charm threshold.

b→ sl$^+$l$^-$

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    - Also of interest for D_s decays to $K^{(*)}ll$ final states near charm threshold.

Together the data from SFFs and LHCb can be used to test all NP parameters related to these decays.

TDCPV in B decays (i.e. CKM angles β & α)

- There are many redundant measurements of the CKM angles that are potential probes of NP.

Mode	Current Precision			Predicted Precision (75 ab^{-1})			Discovery Potential	
	Stat.	Syst.	ΔS^f (Th.)	Stat.	Syst.	ΔS^f (Th.)	3σ	5σ
$J/\psi K^0_S$	0.022	0.010	0 ± 0.01	0.002	0.005	0 ± 0.001	0.02	0.03
$\eta' K^0_S$	0.08	0.02	0.015 ± 0.015	0.006	0.005	0.015 ± 0.015	0.05	0.08
$\phi K^0_S \pi^0$	0.28	0.01	–	0.020	0.010	–	–	–
$f_0 K^0_S$	0.18	0.04	0 ± 0.02	0.012	0.003	0 ± 0.02	0.07	0.12
$K^0_S K^0_S K^0_S$	0.19	0.03	0.02 ± 0.01	0.015	0.020	0.02 ± 0.01	0.08	0.14
ϕK^0_S	0.26	0.03	0.03 ± 0.02	0.020	0.005	0.03 ± 0.02	0.09	0.14
$\pi^0 K^0_S$	0.20	0.03	0.09 ± 0.07	0.015	0.015	0.09 ± 0.07	0.21	0.34
ωK^0_S	0.28	0.02	0.1 ± 0.1	0.020	0.005	0.1 ± 0.1	0.31	0.51
$K^+ K^- K^0_S$	0.08	0.03	0.05 ± 0.05	0.006	0.005	0.05 ± 0.05	0.15	0.26
$\pi^0 \pi^0 K^0_S$	0.71	0.08	–	0.038	0.045	–	–	–
ρK^0_S	0.28	0.07	-0.13 ± 0.16	0.020	0.017	-0.13 ± 0.16	0.41	0.69
$J/\psi \pi^0$	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	–	–	–

- Can also measure α using all modes: ππ, ρπ, ρρ, a_1π

TDCPV in B decays (i.e. CKM angles β & α)

- There are many redundant measurements of the CKM angles that are potential probes of NP.

Mode	Current Precision			Predicted Precision (75 [illegible]			[illegible]ial	
	Stat.	Syst.	ΔS^f (Th.)	Stat.	S[illegible]	[illegible]	[illegible]	[illegible]
$J/\psi K_S^0$	0.022	0.010	0 ± 0.01[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$\eta' K_S^0$	0.08	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ϕK^0[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.51
K[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]0.05	0.15	0.26
π[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]045	–	–	–
ρK[illegible]	[illegible]	[illegible]	[illegible]0.16	0.020	0.017	-0.13 ± 0.16	0.41	0.69
$J/$[illegible]	[illegible]	[illegible]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	–	–	–

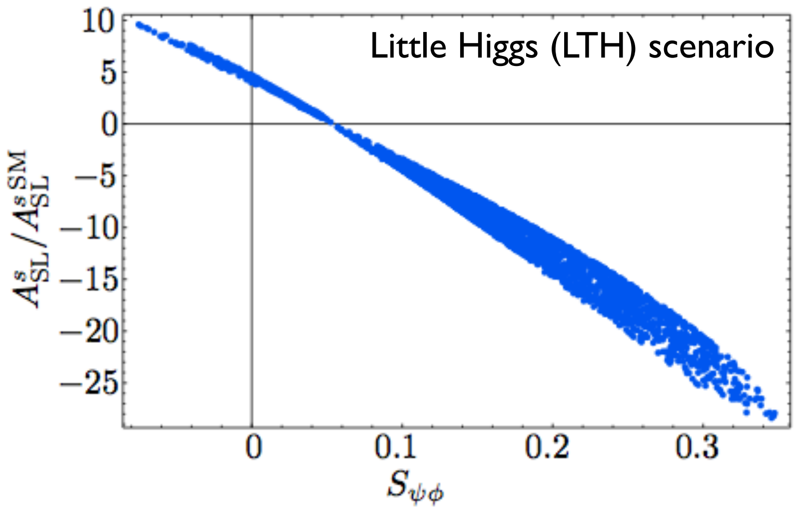
- Can also measure α using all modes: ππ, ρπ, ρρ, $a_1\pi$

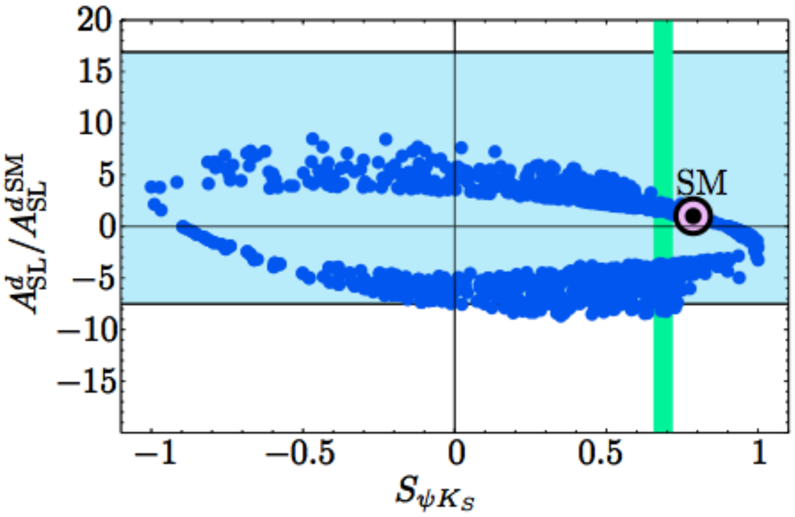
B_s physics

- Can cleanly measure A^s_{SL} using 5S data

$$A^s_{SL} = \frac{\mathcal{B}(B_s \to \overline{B}_s \to X^- \ell^+ \nu_\ell) - \mathcal{B}(\overline{B}_s \to B_s \to X^- \ell^+ \nu_\ell)}{\mathcal{B}(B_s \to \overline{B}_s \to X^- \ell^+ \nu_\ell) + \mathcal{B}(\overline{B}_s \to B_s \to X^- \ell^+ \nu_\ell)} = \frac{1 - |q/p|^4}{1 - |q/p|^4}$$

$$\sigma(A^s_{SL}) \sim 0.004 \text{ with a few } ab^{-1}$$





- SuperB can also study rare decays with many neutral particles, such as $B_s \to \gamma\gamma$, which can be enhanced by SUSY.

D Physics

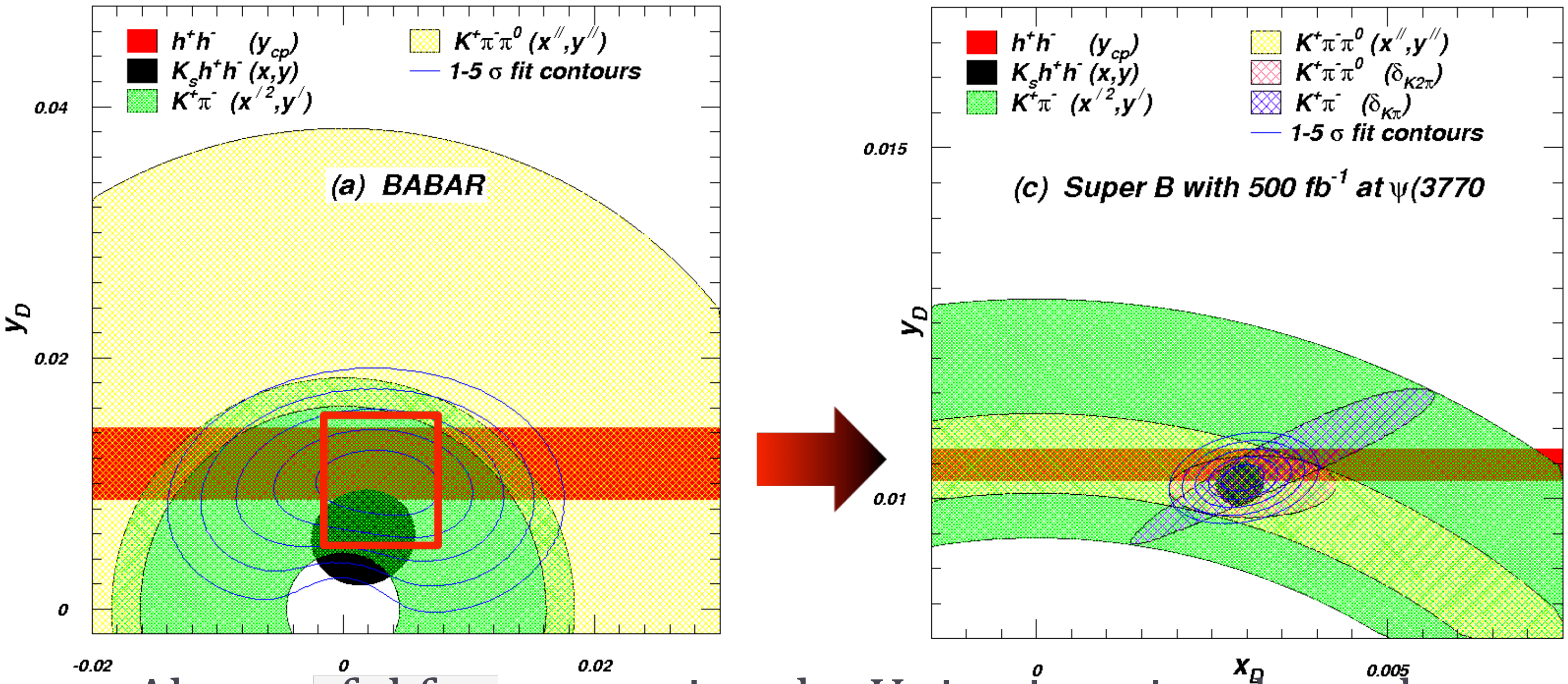
- The programme includes
  - Mixing [This talk]
  - CP Violation [This talk]
  - Quantum Correlation based measurements
  - Rare decays

There were a number of talks on charm physics at the threshold workshop a few weeks ago that contain more detail on the charm programme. Only a few highlights are shown here. For more details see:

http://indico.ihep.ac.cn/conferenceTimeTable.py?confId=2171#all.detailed

Charm Mixing

- Collect data at threshold and at the 4S.
  - Benefit charm mixing and CPV measurements.



  - Also useful for measuring the Unitarity triangle angle γ (strong phase in D→Kππ Dalitz plot).

Charm Mixing

- Collect data at threshold and at the 4S
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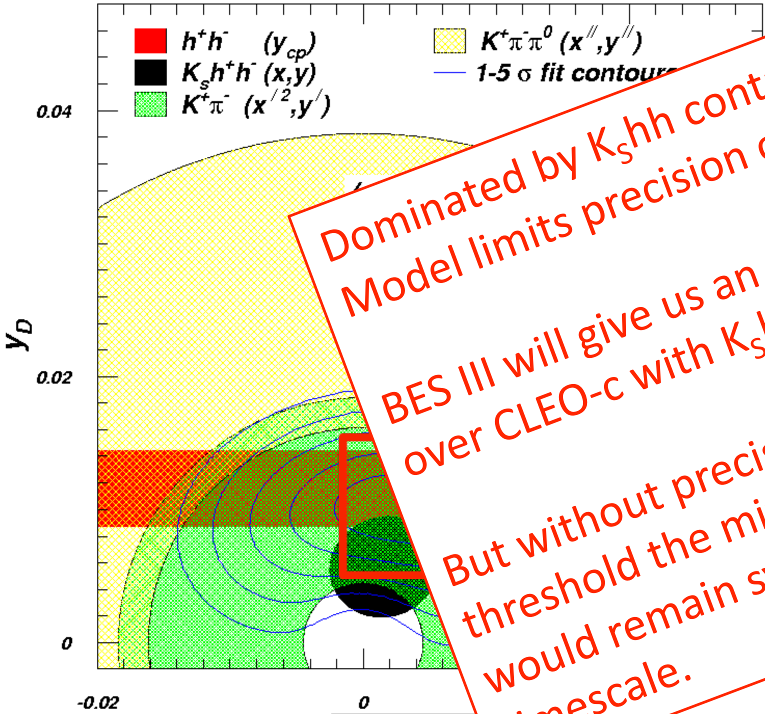
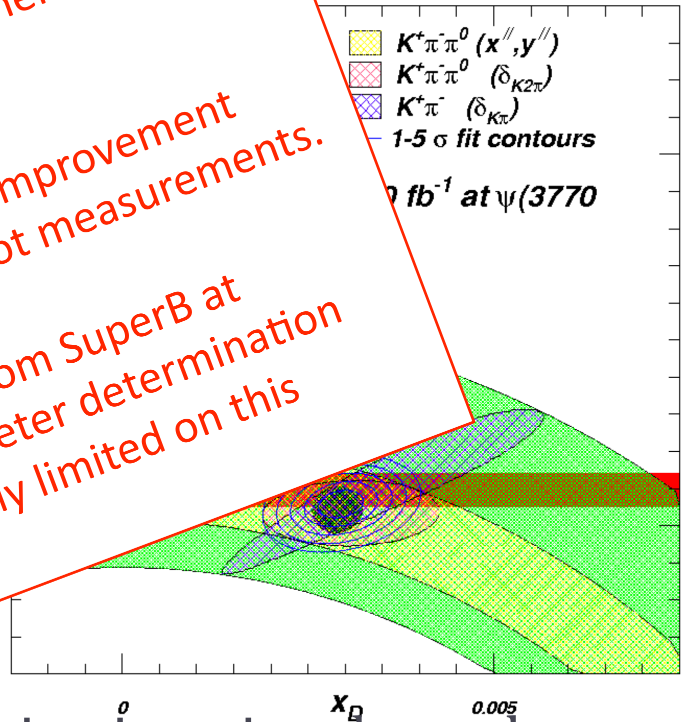




Dominated by $K_S$hh contribution, where the Dalitz Model limits precision on x and y.

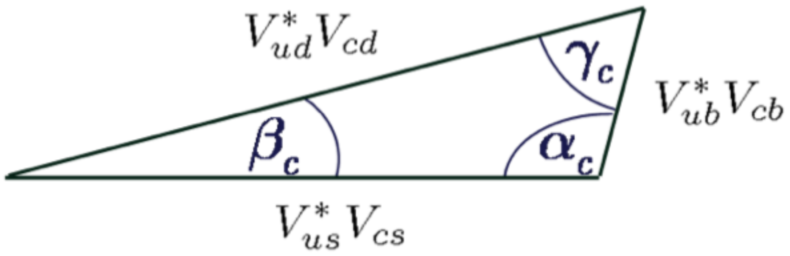
BES III will give us an important improvement over CLEO-c with $K_S$hh Dalitz plot measurements.

But without precision data from SuperB at threshold the mixing parameter determination would remain systematically limited on this timescale.

- Also useful fo … easuring the Unitarity triangle angle γ (strong phase in D→Kππ Dalitz plot).

The quest for the final angle of the CKM matrix: β_c

- The charm cu triangle has one unique element: β_c



$$\begin{aligned} \alpha_c &= \arg\left[-V_{ub}^* V_{cb}/V_{us}^* V_{cs}\right]. \\ \beta_c &= \arg\left[-V_{ud}^* V_{cd}/V_{us}^* V_{cs}\right], \\ \gamma_c &= \arg\left[-V_{ub}^* V_{cb}/V_{ud}^* V_{cd}\right], \end{aligned}$$

$$V_{ud}^* V_{cd} + V_{us}^* V_{cs} + V_{ub}^* V_{cb} = 0$$

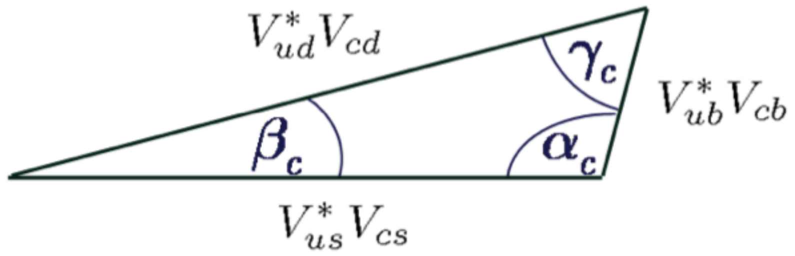
$$\begin{aligned} \alpha_c &= (111.5 \pm 4.2)^\circ \\ \beta_c &= (0.0350 \pm 0.0001)^\circ \\ \gamma_c &= (68.4 \pm 0.1)^\circ \end{aligned}$$

- Precision measurement of mixing phase in many channels (<2°)
- Asymmetry difference between KK and ππ sensitive to NP.
- Constrain $\beta_{c,\mathrm{eff}}$ using a $D \to \pi\pi$ Isospin analysis
  - Search for NP and constrain $\beta_{c,\mathrm{eff}} \sim 1^\circ$.
  - Can only fully explore in an e^+e^- environment.
  - Data from the charm threshold region completes the set of 5 $|V_{ij}|$ to measure: needs SuperB to perform an indirect test of the triangle.

AB, Inguglia, Meadows, arXiv:1106.5075 (accepted for publication in PRD)

The quest for the final angle of the CKM matrix: β_c

- The charm cu triangle has one unique element: β_c



$$\alpha_c = \arg\left[-V_{ub}^* V_{cb}/V_{us}^* V_{cs}\right].$$
$$\beta_c = \arg\left[-V_{ud}^* V_{cd}/V_{us}^* V_{cs}\right],$$
$$\gamma_c = \arg[\ \ldots\ V_{cb}/V_{ud}^* V_{cd}],$$

$\ldots \pm 4.2)^\circ$

$\ldots \pm 0.0001)^\circ$

$= (68.4 \pm 0.1)^\circ$

$V_{ud}^* V_{cd} + V_{us}^* V_{cs} + V_{ub}^* V \ldots$

New ideas from the large Super Flavour Factory community can strengthen the physics programme of LHCb (and vice versa)!

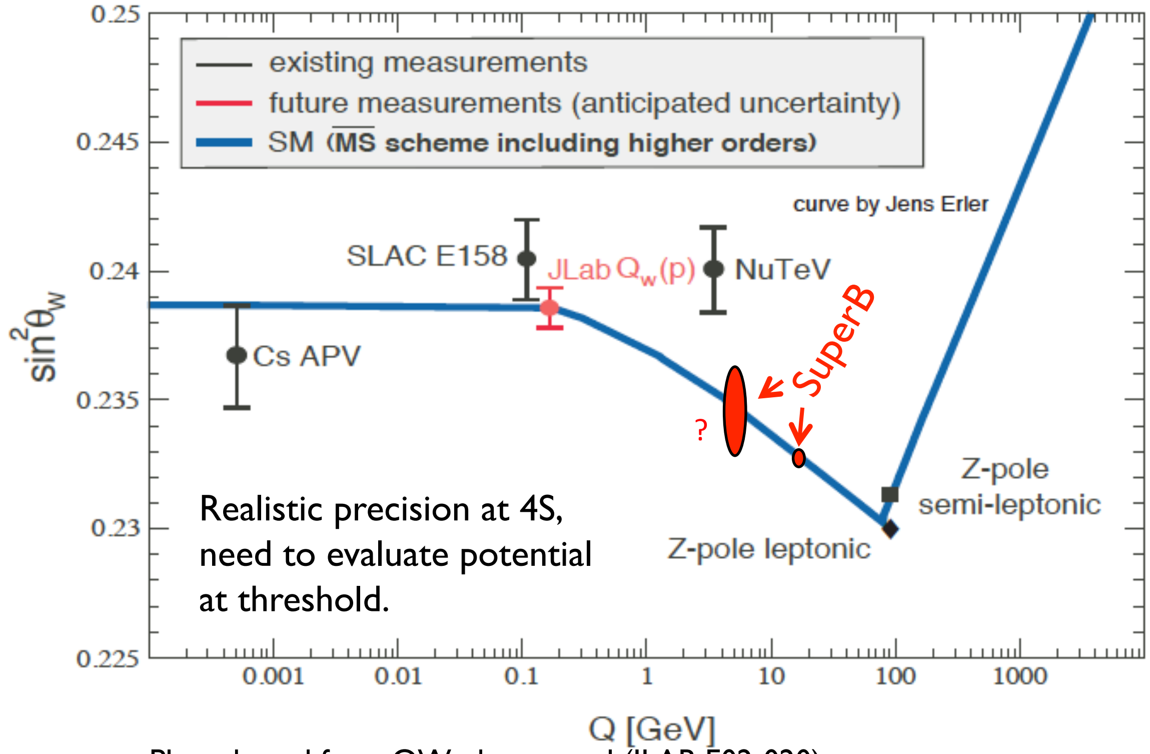
- Precision m... ...g phase in many channels (<2°)
- Asymmetry ... ...etween KK and ππ sensitive to NP.
- Constrain $\beta_{c,eff}$ ...sing a $D \to \pi\pi$ Isospin analysis
  - Search for NP and constrain $\beta_{c,eff} \sim 1^\circ$.
  - Can only fully explore in an e^+e^- environment.
  - Data from the charm threshold region completes the set of 5 $|V_{ij}|$ to measure: needs SuperB to perform an indirect test of the triangle.

AB, Inguglia, Meadows, arXiv:1106.5075 (accepted for publication in PRD)

Precision EW Physics

Precision Electroweak

- $\sin^2\theta_W$ can be measured with polarised e^- beam:
  - $\sqrt{s}=\Upsilon(4S)$ is theoretically clean, c.f. b-fragmentation at Z pole.



Plot adapted from QWeak proposal (JLAB E02-020)

Measure LR asymmetry in

$$e^+e^- \rightarrow b\bar{b}$$
$$e^+e^- \rightarrow c\bar{c}$$
$$e^+e^- \rightarrow \tau^+\tau^-$$
$$e^+e^- \rightarrow \mu^+\mu^-$$

at the Υ(4S) to same precision as LEP/SLC at the Z-pole.

Complements measurements planned/ underway at lower energies (QWeak/MESA).

This table concentrates on observables that SFFs can measure, with a few of the prime examples from hadron experiments to highlight that there are many things that need to be measured well.

Golden Measurements: General

	No Result	Moderately precise	Precise	Very precise
Experiment:	No Result (red)	Moderately precise (yellow)	Precise (blue)	Very precise (green)
Theory:		Moderately clean (yellow)	Clean, needs Lattice (blue)	Clean (green)

Observable/mode Luminosity	Current $\sim 1\,\mathrm{ab}^{-1}$	LHCb (2017) $5\,\mathrm{fb}^{-1}$	Super*B* (2022) $75\,\mathrm{ab}^{-1}$	LHCb upgrade $50\,\mathrm{fb}^{-1}$	Theory	
τ Decays						
$\tau \to \mu\gamma$	yellow	yellow	green	yellow	green	Benefit from polarised e^- beam
$\tau \to e\gamma$	yellow	yellow	green	yellow	green	
$B_{u,d}$ Decays						
$B \to \tau\nu, \mu\nu$	yellow	red	blue	red	blue	very precise with improved detector
$B \to K^{(*)+}\nu\overline{\nu}$	red	red	green	red	green	Statistically limited: Angular analysis with >75ab-1
S in $B \to K_S^0\pi^0\gamma$	yellow	red	green	red	yellow	Right handed currents
S (other penguin modes)	yellow	yellow	green	blue	yellow	SuperB measures many more modes
A_{CP} $(B \to X_s\gamma)$	blue	yellow	green	yellow	green	systematic error is main challenge
BR$(B \to X_s\gamma)$	blue	yellow	green	yellow	yellow	control systematic error with data
BR$(B \to X_s ll)$	yellow	red	green	red	green	
BR$(B \to K^{(*)} ll)$	yellow	blue	green	green	yellow	SuperB measures e mode well, LHCb does μ
B_s Decays						
$B_s \to \mu\mu$	red	blue	red	green	green	
β_S from $B_s \to J/\psi\,\phi$	red	blue	red	green	green	
$B_s \to \gamma\gamma$	red	red	blue	red	green	
a_{sl}	red	blue	green	green	green	
D Decays						
Mixing parameters	yellow	blue	green	green	green	
CP Violation	red	blue	green	green	green	Clean NP search
Precision Electroweak						
$\sin^2\theta_W$ at $\Upsilon(4S)$	red	red	green	red	green	Theoretically clean
$\sin^2\theta_W$ at Z-Pole	green	blue	red	green	yellow	b fragmentation limits interpretation

See backup slides for numerical estimates

This table concentrates on observables that SFFs can measure, with a few of the prime examples from hadron experiments to highlight that there are many things that need to be measured well.

Golden Measurements: CKM

- Comparison of relative benefits of SuperB ($75ab^{-1}$) vs. existing measurements and LHCb ($5fb^{-1}$) and the LHCb upgrade ($50fb^{-1}$).

Observable/mode Luminosity	Current $\sim 1\,\mathrm{fb}^{-1}$	LHCb (2017) $5\,\mathrm{fb}^{-1}$	Super*B* (2022) $75\,\mathrm{ab}^{-1}$	LHCb upgrade $50\,\mathrm{fb}^{-1}$	Theory
α	Blue	Blue	Green	Blue	Yellow
β from $b \to c\bar{c}s$	Blue	Blue	Green	Green	Green
$B_d \to J/\psi \pi^0$	Yellow	Red	Green	Red	Green
$B_s \to J/\psi K_S^0$	Red	Yellow	Red	Blue	Green
γ	Yellow	Blue	Green	Green	Green
$\lvert V_{ub}\rvert$ inclusive	Blue	Yellow	Green	Blue	Blue
$\lvert V_{ub}\rvert$ exclusive	Blue	Yellow	Green	Blue	Blue
$\lvert V_{cb}\rvert$ inclusive	Blue	Yellow	Green	Blue	Blue
$\lvert V_{cb}\rvert$ exclusive	Blue	Yellow	Green	Blue	Blue

LHCb can only use $\rho\pi$

β theory error B_d
β theory error B_s

Need an e^+e^- environment to do a precision measurement using semi-leptonic B decays.

	Red	Yellow	Blue	Green
Experiment:	No Result	Moderately precise	Precise	Very precise
Theory:		Moderately clean	Clean, needs Lattice	Clean

See backup slides for numerical estimates

The real power is in combination of results

Observable/mode	charged Higgs high $\tan\beta$	MFV NP low $\tan\beta$	non-MFV NP 2-3 sector	NP in Z penguins	Right-handed currents	LHT	SUSY AC	RVV2	AKM	δLL	FBMSSM	GUT-CMM
$\tau \to \mu\gamma$							★★★	★★★	★	★★★	★★★	★★★
$\tau \to \ell\ell\ell$						★★★						?
$B \to \tau\nu, \mu\nu$	★★★(CKM)											
$B \to K^{(*)+}\nu\overline{\nu}$			★	★★★			★	★	★	★	★	?
S in $B \to K_S^0\pi^0\gamma$			★★		★★★							
S in other penguin modes			★★★(CKM)		★★★		★★★	★★	★	★★★	★★★	?
$A_{CP}(B \to X_s\gamma)$			★★★		★★		★	★	★	★★★	★★★	?
$BR(B \to X_s\gamma)$		★	★★		★							★★
$BR(B \to X_s\ell\ell)$			★★	★	★							?
$B \to K^{(*)}\ell\ell$ (FB Asym)							★	★	★	★★★	★★★	?
a_{sl}^s			★★★			★★★						★★★
Charm mixing							★★★	★	★	★	★	
CPV in Charm	★★									★★★		

Summary

The real power is in combination of results

Observable/mode	charged Higgs high $\tan\beta$	MFV NP low $\tan\beta$	non-MFV NP 2-3 ...	...	...M	δLL	FBMSSM	GUT-CMM
$\tau \to \mu\gamma$						★★★	★★★	★★★
$\tau \to \ell\ell\ell$								?
$B \to \tau\nu, \mu\nu$	★							
$B \to K^{(*)+}\nu\overline{\nu}$						★	★	?
S in $B \to K_S^0\pi^0\gamma$								
S in other penguin m...						★	★★★	?
$A_{CP}(B \to X_s\gamma)$							★★★	?
$BR(B \to X_s\gamma)$								★★
$BR(B \to X_s\ell\ell)$								?
$B \to K^{(*)}\ell\ell$ (FB Asym)							★★★	?
a_{sl}^s								★★★
Charm mixing				★	★	★	★	
CPV in Charm						★★★		

This is only a partial view of the power of flavour physics:

Summarises the potential of Belle II and SuperB, but input required from: BESIII, LHCb (+ATLAS and CMS), NA62, KLOE, MEG, COMET, ...

- Need to reconstruct the NP Lagrangian from the global pattern observed.
- Need to combine results from several experiments.

- The community should work together to map out this matrix fully.

Backup

Lepton Number Violation Searches

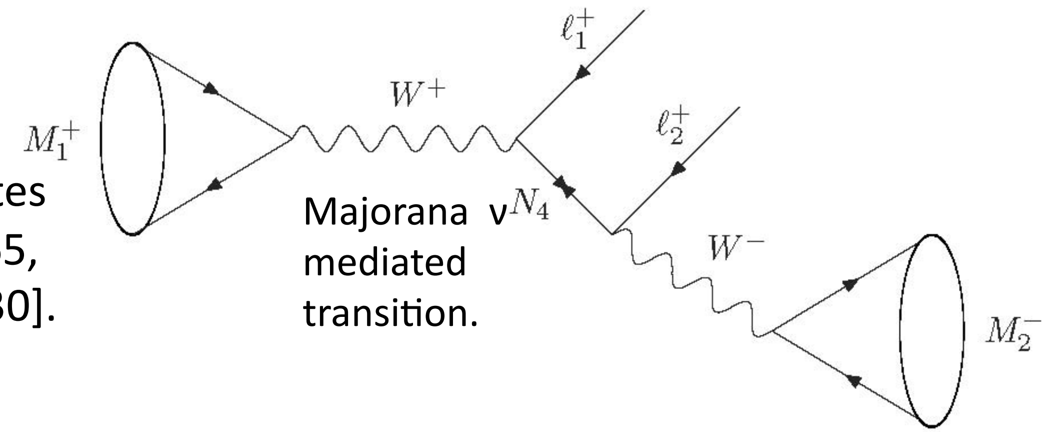
- SuperB will be able to search for LNV decays

  $B^+ \to X_{s,d}\ell^+\ell^+$

e.g. see Altre et al. arXiv:0901.3589

Previous searches for similar final states have been performed by CLEO [PRD 65, 111102 (2002)], Belle [arXiv:1110.0730].

Expect some results from BaBar and LHCb soon (?)



- Low background environment.
- Statistically limited.
- As with opposite sign final states, expect Super Flavour Factories to be better at searching for these final states than hadron experiments.

Estimates based on current (publically quantified) expectations

Observable/mode	Current now	LHCb (2017) 5 fb^{-1}	Super$B$ (2021) 75 ab^{-1}	Belle II (2021) 50 ab^{-1}	LHCb upgrade (10 years of running) 50 fb^{-1}	theory now
			τ Decays			
$\tau \to \mu\gamma$ ($\times 10^{-9}$)	< 44		< 2.4	< 5.0		
$\tau \to e\gamma$ ($\times 10^{-9}$)	< 33		< 3.0	< 3.7 (est.)		
$\tau \to \ell\ell\ell$ ($\times 10^{-10}$)	$< 150 - 270$	< 244 [a]	$< 2.3 - 8.2$	< 10	< 24 [b]	
			$B_{u,d}$ Decays			
BR($B \to \tau\nu$) ($\times 10^{-4}$)	1.64 ± 0.34		0.05	0.04		1.1 ± 0.2
BR($B \to \mu\nu$) ($\times 10^{-6}$)	< 1.0		0.02	0.03		0.47 ± 0.08
BR($B \to K^{*+}\nu\overline{\nu}$) ($\times 10^{-6}$)	< 80		1.1	2.0		6.8 ± 1.1
BR($B \to K^{+}\nu\overline{\nu}$) ($\times 10^{-6}$)	< 160		0.7	1.6		3.6 ± 0.5
BR($B \to X_s\gamma$) ($\times 10^{-4}$)	3.55 ± 0.26		0.11	0.13	0.23	3.15 ± 0.23
$A_{CP}(B \to X_{(s+d)}\gamma)$	0.060 ± 0.060		0.02	0.02		$\sim 10^{-6}$
$B \to K^*\mu^+\mu^-$ (events)	250[c]	8000	10-15k[d]	7-10k	100,000	-
BR($B \to K^*\mu^+\mu^-$) ($\times 10^{-6}$)	1.15 ± 0.16		0.06	0.07		1.19 ± 0.39
$B \to K^*e^+e^-$ (events)	165	400	10-15k	7-10k	5,000	-
BR($B \to K^*e^+e^-$) ($\times 10^{-6}$)	1.09 ± 0.17		0.05	0.07		1.19 ± 0.39
$A_{FB}(B \to K^*\ell^+\ell^-)$	0.27 ± 0.14[e]	[f]	0.040	0.03		-0.089 ± 0.020
$B \to X_s\ell^+\ell^-$ (events)	280		8,600	7,000		-
BR($B \to X_s\ell^+\ell^-$) ($\times 10^{-6}$)[g]	3.66 ± 0.77[h]		0.08	0.10		1.59 ± 0.11
S in $B \to K^0_S\pi^0\gamma$	-0.15 ± 0.20		0.03	0.03		-0.1 to 0.1
S in $B \to \eta' K^0$	0.59 ± 0.07		0.01	0.02		± 0.015
S in $B \to \phi K^0$	0.56 ± 0.17	0.15	0.02	0.03	0.03	± 0.02
			B^0_s Decays			
BR($B^0_s \to \gamma\gamma$) ($\times 10^{-6}$)	< 8.7		0.3	$0.2 - 0.3$		0.4 - 1.0
A^s_{SL} ($\times 10^{-3}$)	-7.87 ± 1.96 [i]	[j]	4.	5. (est.)		0.02 ± 0.01
			D Decays			
x	$(0.63 \pm 0.20\%$	0.06%	0.02%	0.04%	0.02%	$\sim 10^{-2}$ [k]
y	$(0.75 \pm 0.12)\%$	0.03%	0.01%	0.03%	0.01%	$\sim 10^{-2}$ (see above).
y_{CP}	$(1.11 \pm 0.22)\%$	0.02%	0.03%	0.05%	0.01%	$\sim 10^{-2}$ (see above).
$\lvert q/p \rvert$	$(0.91 \pm 0.17)\%$	8.5%	2.7%	3.0%	3%	$\sim 10^{-3}$ (see above).
$\arg\{q/p\}$ ($^\circ$)	-10.2 ± 9.2	4.4	1.4	1.4	2.0	$\sim 10^{-3}$ (see above).
			Other processes Decays			
$\sin^2\theta_W$ at $\sqrt{s} = 10.58\,\mathrm{GeV}/c^2$			0.0002	[l]		clean

Observable/mode	Current now	LHCb (2017)	Super$B$ (2021)	Belle II (2021)	LHCb upgrade (10 years of running)	theory now
		$5\,\text{fb}^{-1}$	$75\,\text{ab}^{-1}$	$50\,\text{ab}^{-1}$	$50\,\text{fb}^{-1}$	
α from $u\bar{u}d$	6.1°	$5^{\circ\,a}$	1°	1°	^{b}	$1-2^\circ$
β from $c\bar{c}s$ (S)	0.8° (0.020)	0.5° (0.008)	0.1° (0.002)	0.3° (0.007)	0.2° (0.003)	clean
S from $B_d \to J/\psi\pi^0$	0.21		0.014	0.021 (est.)		clean
S from $B_s \to J/\psi K^0_S$		?			?	clean
γ from $B \to DK$	11°	$\sim 4^\circ$	1°	1.5°	0.9°	clean
$\lvert V_{cb}\rvert$ (inclusive) %	1.7		0.5%	0.6 (est.)		dominant
$\lvert V_{cb}\rvert$ (exclusive) %	2.2		1.0%	1.2 (est.)		dominant
$\lvert V_{ub}\rvert$ (inclusive) %	4.4		2.0%	3.0		dominant
$\lvert V_{ub}\rvert$ (exclusive) %	7.0		3.0%	5.0		dominant

Estimates based on current (publically quantified) expectations