XXXII Physics in Collision – Sep. 13^{th} 2012

The SuperB Factory: Physics Prospects and Project Status

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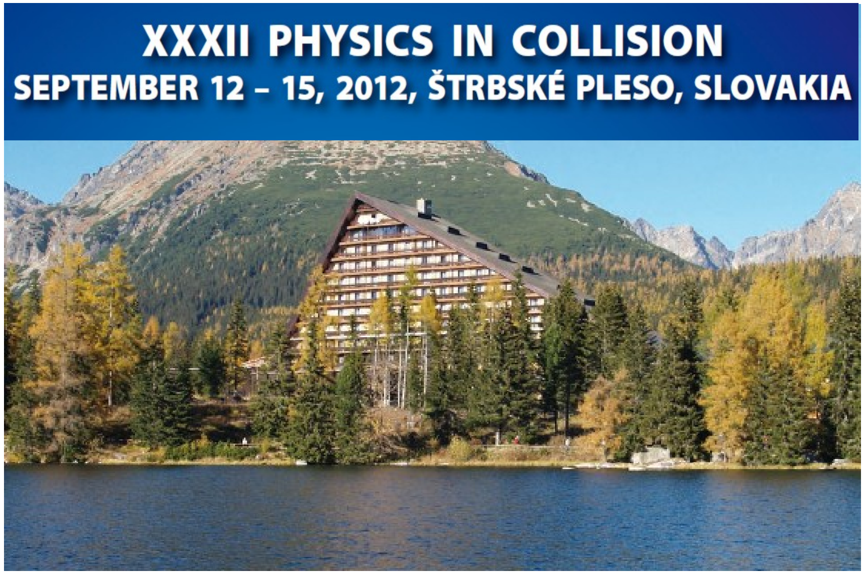
On behalf of the SuperB Collaboration



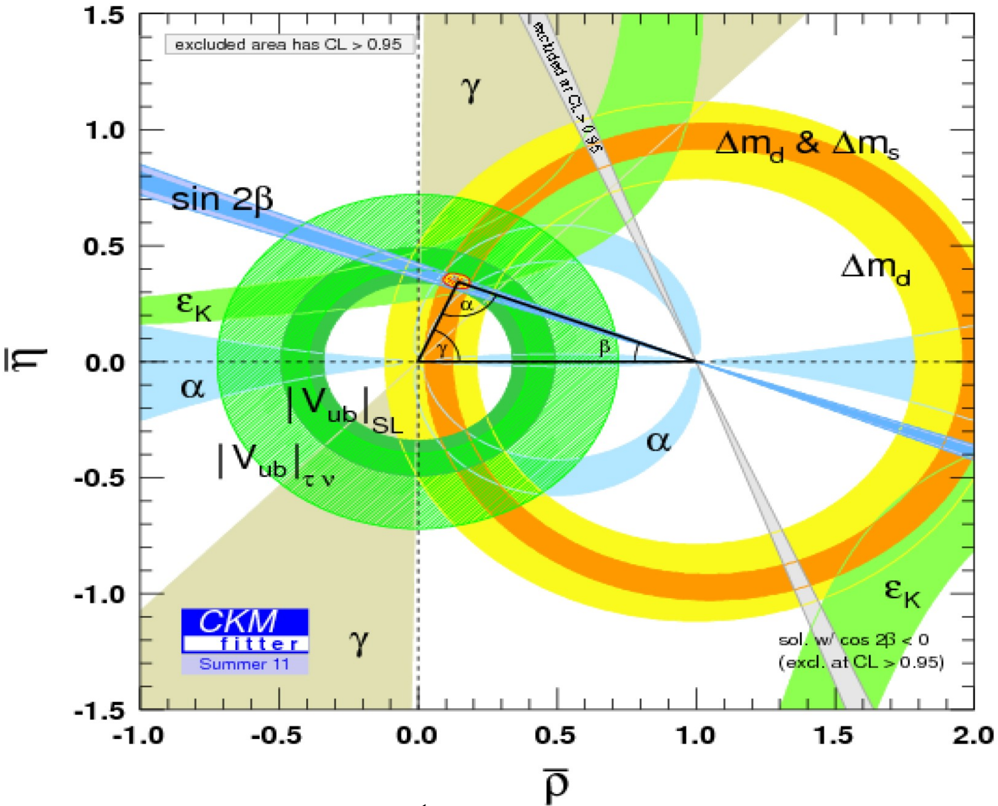
Outline

- **Introduction**
- **The SuperB project**
  - The SuperB physics programme: some highlights
- **Summary**

Introduction

Flavour physics and New Physics Searches

- **BaBar, Belle, Tevatron:** defined current flavour physics landscape
  - Substantially confirm CKM picture to leading order
  - No evidence on NP (but perhaps few glimpses)
  - Placed constraints (indirect) on NP that wont be superseded well into the LHC era (e.g. H^+ searches)



- **SuperB is expected to start data taking in 2018, and 1st full run expected to be completed one year after**
  - LHCb will for sure have re-defined some flavour physics areas
  - LHC may or may not have found NP particles
  - In any scenario SuperB results will be used to constrain the flavour dynamics at high energy

The SuperB Project

SuperB Project: brief summary

- Υ(4S) - peak asymmetric energy e^+e^- Super Flavour Factory
- Detector: moderately improved BABAR detector
- Accelerator:
  - **100xB-factories luminosity.** Same power by squeezing beams (ILC)
  - **80% polarized electron beam** further defines the already clean initial e^+e^- state
- L = 10^{36} $cm^{-2}s^{-1}$ around the Υ(4S) and 10 times less at the charm threshold
  - Y(4S): coherent B mesons & time-dep. measurements, charm hadrons, tau leptons
  - Charm threshold: coherent D mesons & time-dep. measurements, tau leptons
  - Emphasis: new physics sensitivity competitive and complementary with LHC experiments
  - Don't forget: e^+e^- clean data for precision measurements in almost every energy-accessible topic (with neutrals or missing momentum)

SuperB project: brief story

- **2010:** SuperB has been selected as the 1st project of the Flagship Projects of the National Research Plan
- **Dec. 2010:** SuperB has been approved and funded (250M for infrastructure)
- **Jan 2011:** Tor Vergata has been chosen as the site for SuperB
  - Strong support from the UNTorVergata
  - Closeness to LNF allows important synergies
- **May 30th 2011:** Project kick-off day at Elba
- **The Nicola Cabibbo Laboratory was born:**
  - **Jul. 2011:** INFN approved ⇒ MoU between INFN and UNTorVergata
  - **Sep. 2011:** Minister signed the authorization of the CabibboLab.
    - An initial 19M was transferred to the consortium
    - The General Director has been appointed: Roberto Petronzio
  - **Phases of the consortium**
    - Initially an Italian consortium (IIT will joint soon)
    - Foreseen the evolution in an ERIC (European Research Infrastructure Consortium)
- **Outlook:**
  - Accelerator workpackage structure is defined: Alessandro Variola
  - Actual construction will start by end 2012 – begin 2013
  - Data taking is expected around 2018

SuperB Physics Programme

SuperB Physics programme

- **$B_{u,d,s}$ physics:**
  - Rare decays
  - CKM angles and sides
  - CPT
- **D physics:**
  - Mixing
  - CP Violation
  - Rare Decays
  - Quantum correlations based measurements
- **Tau physics:**
  - Charged Lepton Flavour Violation (LFV)
  - CP Violation
  - τ EDM
  - τ g-2
  - Precision $|V_{us}|$ measurements
- **Precision electro-weak physics**
- **Spectroscopy**

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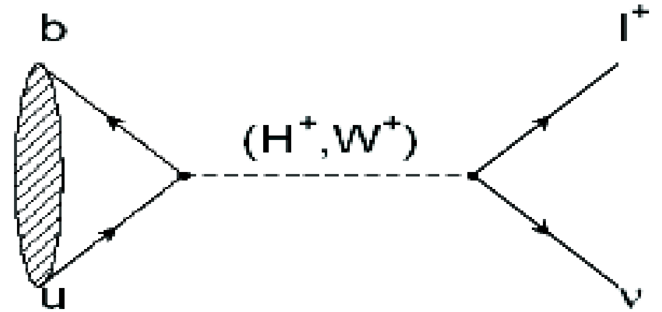
Will cover a couple of highlights in this talk

$B_{u,d,s}$ physics

$B_{u,d}$ Rare decays: $B^{\pm}\rightarrow l^{\pm}\nu$

SM:

$$Br(B\rightarrow l\nu)=\frac{G_F^2 m_B}{8\pi} m_l^2 \left(1-\frac{m_l^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$



- Expected BR ~10^{-4} for $B^+\rightarrow\tau^+\nu$
- Much smaller for
  - $B^+\rightarrow\mu^+\nu$ (~10^{-7})
  - $B^+\rightarrow e^+\nu$ (~10^{-11})

  due to helicity suppression

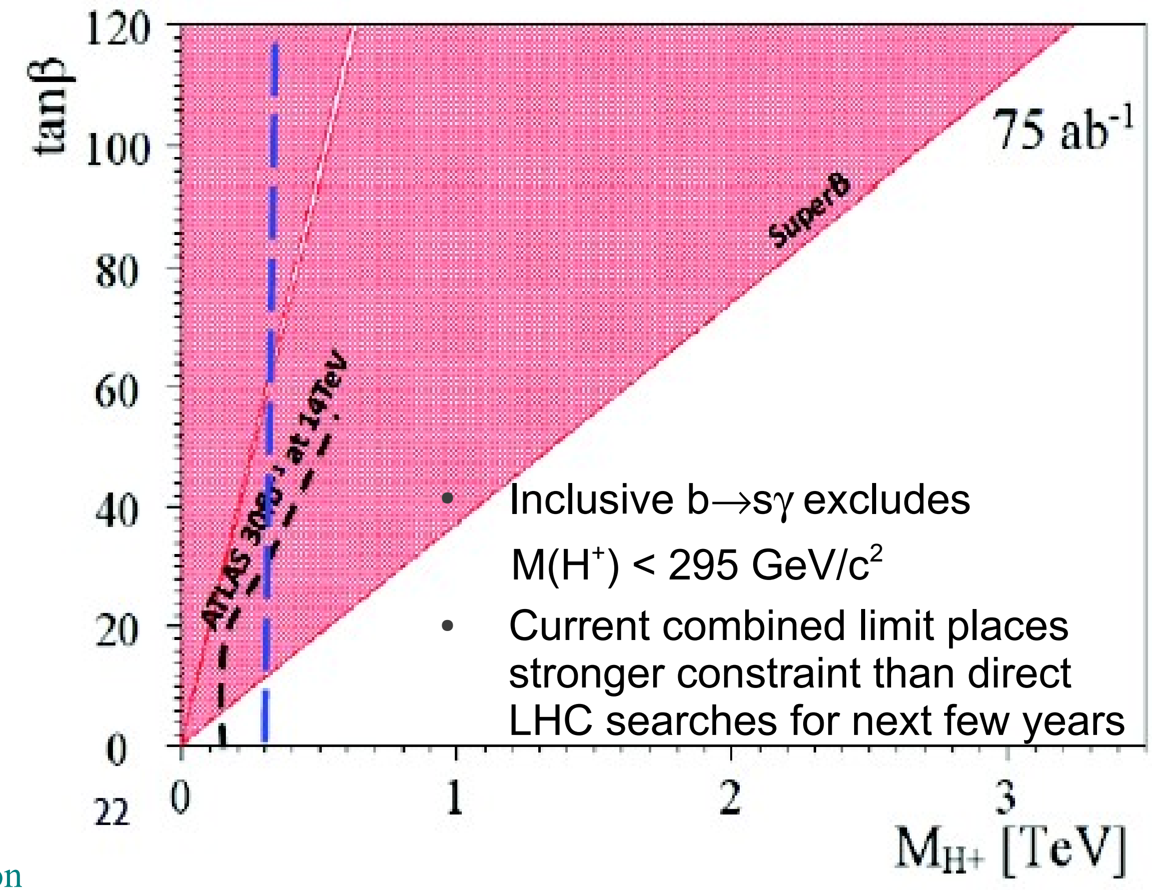
NP:

- Rate modified by presence of H^+
- $Br(B\rightarrow l\nu) = Br_{SM} \times r_H$
- HDM (PRD 48 (1993) 2342)

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

- SUSY (J. Phys G 29 (2003) 2311)

$$r_H = \left(1-\frac{\tan^2\beta}{1+\bar{\epsilon}_0\tan\beta}\,\frac{m_B^2}{m_H^2}\right)^2$$

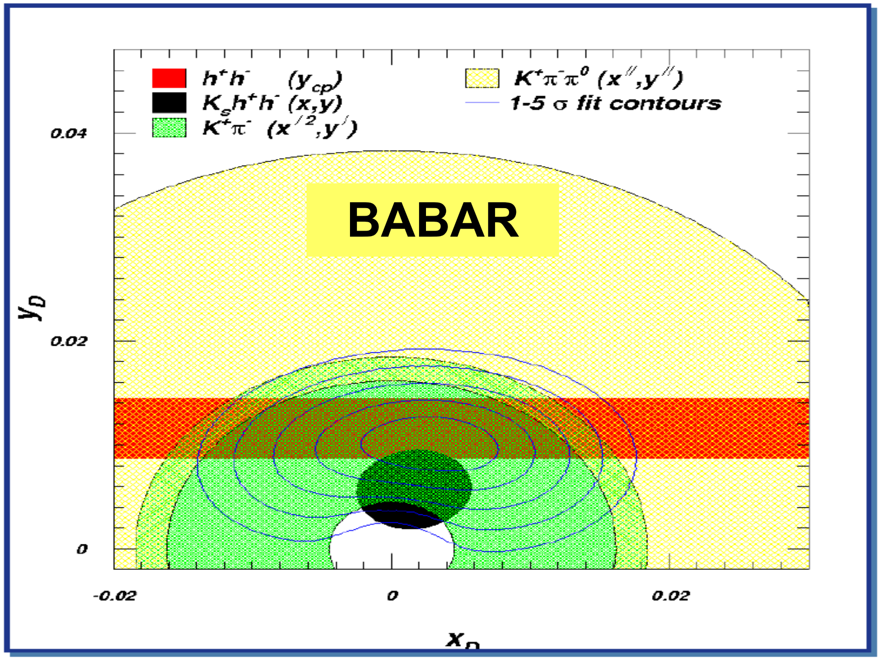


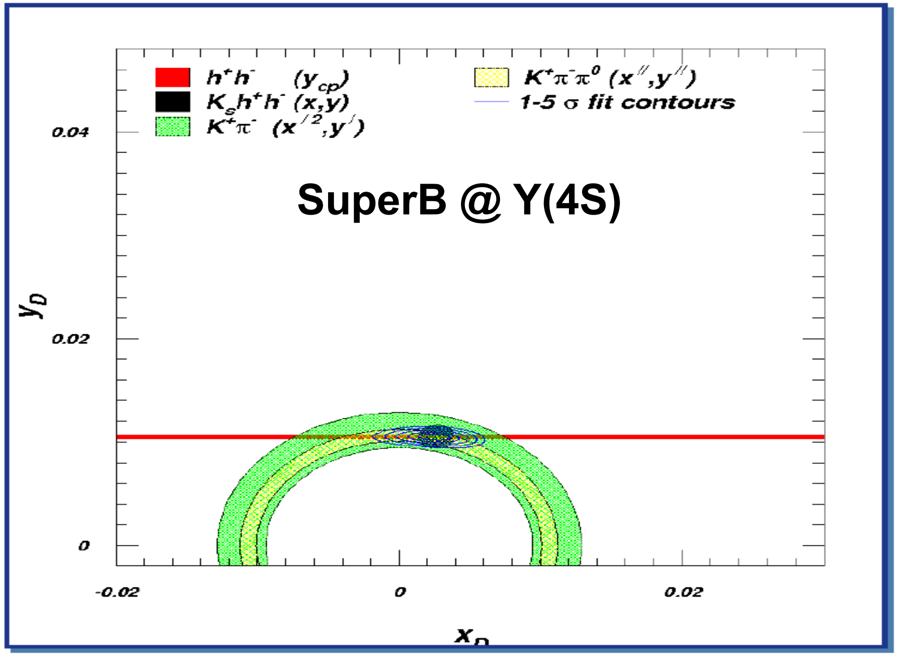
- Inclusive $b\rightarrow s\gamma$ excludes $M(H^+) < 295$ GeV/c^2
- Current combined limit places stronger constraint than direct LHC searches for next few years

Charm physics

Charm mixing

- **D mixing parameters:** $x \equiv \frac{M_1 - M_2}{\Gamma} = \frac{\Delta M}{\Gamma}, \quad y \equiv \frac{\Gamma_1 - \Gamma_2}{2\Gamma} = \frac{\Delta\Gamma}{2\Gamma}$
- **Many D mesons from SuperB data collected at Υ(4S). Expect significant improvements w.r.t current results**





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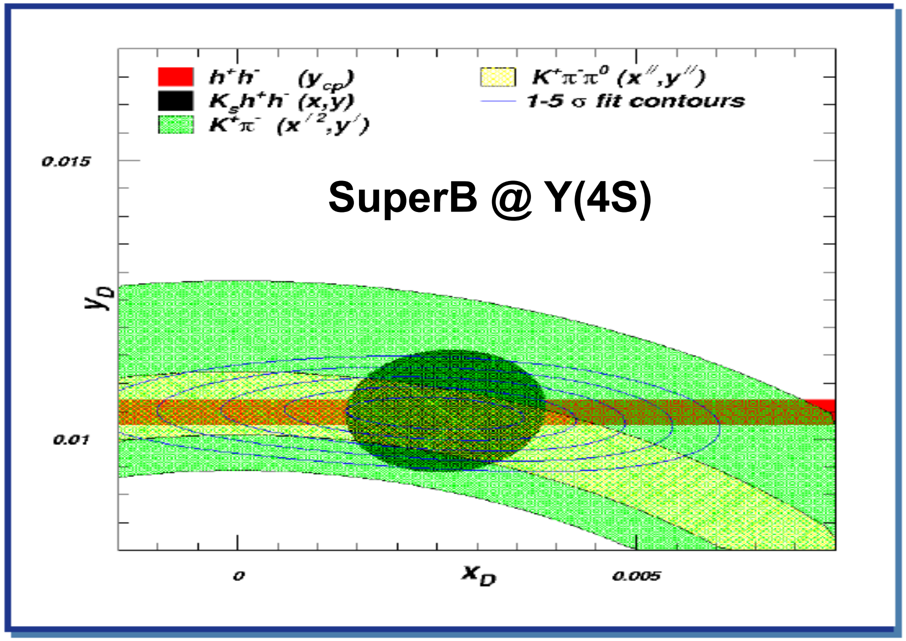

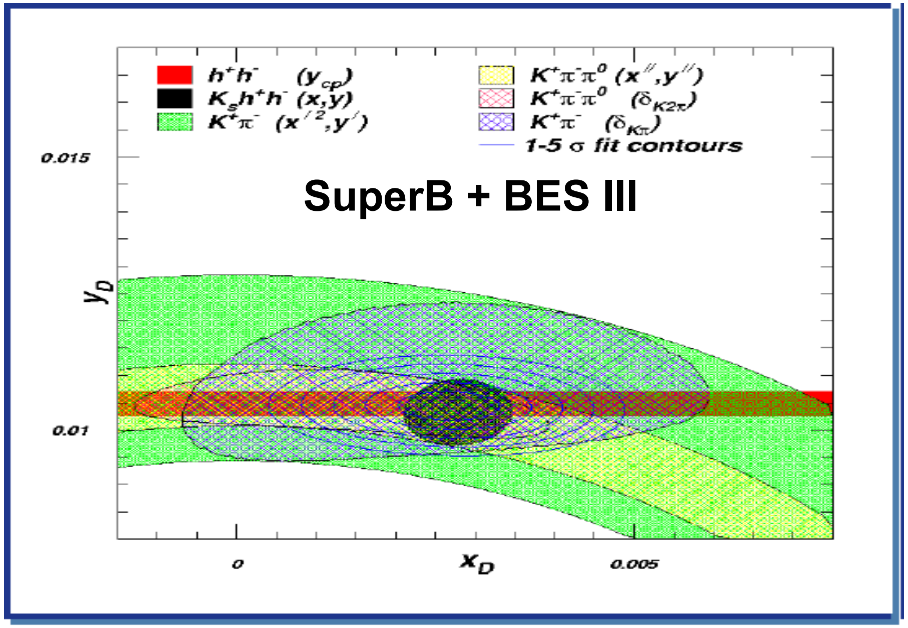

- **Additional improvement combining SuperB and BES III data (10ab^{-1} at charm threshold)**
- **But SuperB expects to collect 500ab^{-1} at charm threshold**

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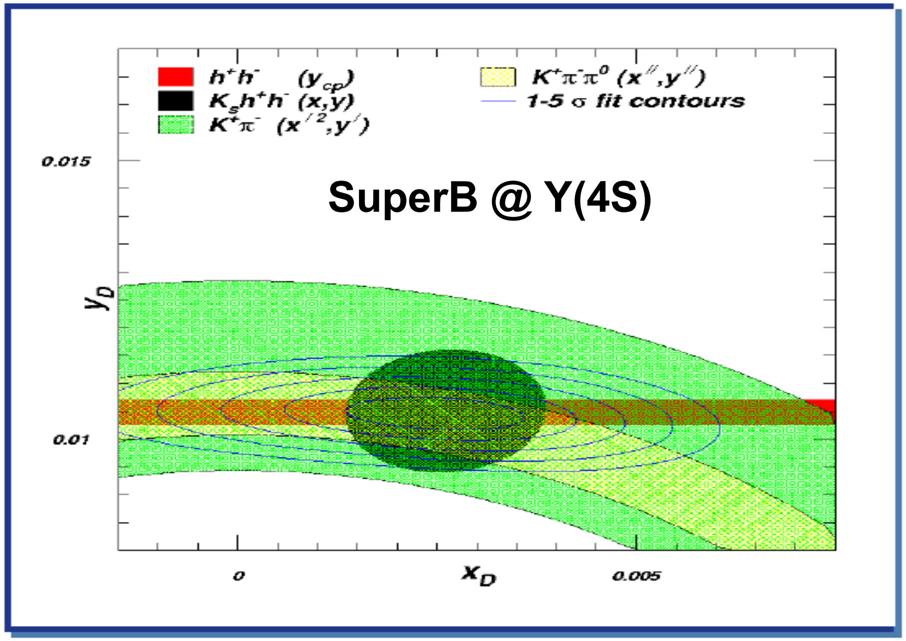
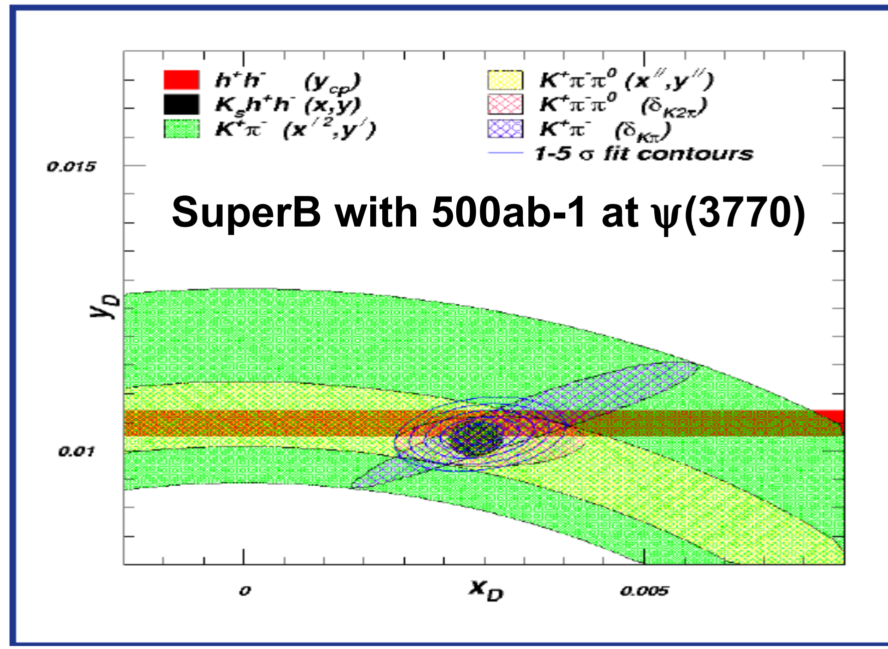




- **Furthermore: SuperB Charm threshold data useful for measuring the γ CKM angle in B→DK modes ⇒ Strong phase measurement in D→Kππ Dalitz plot**

Interplay

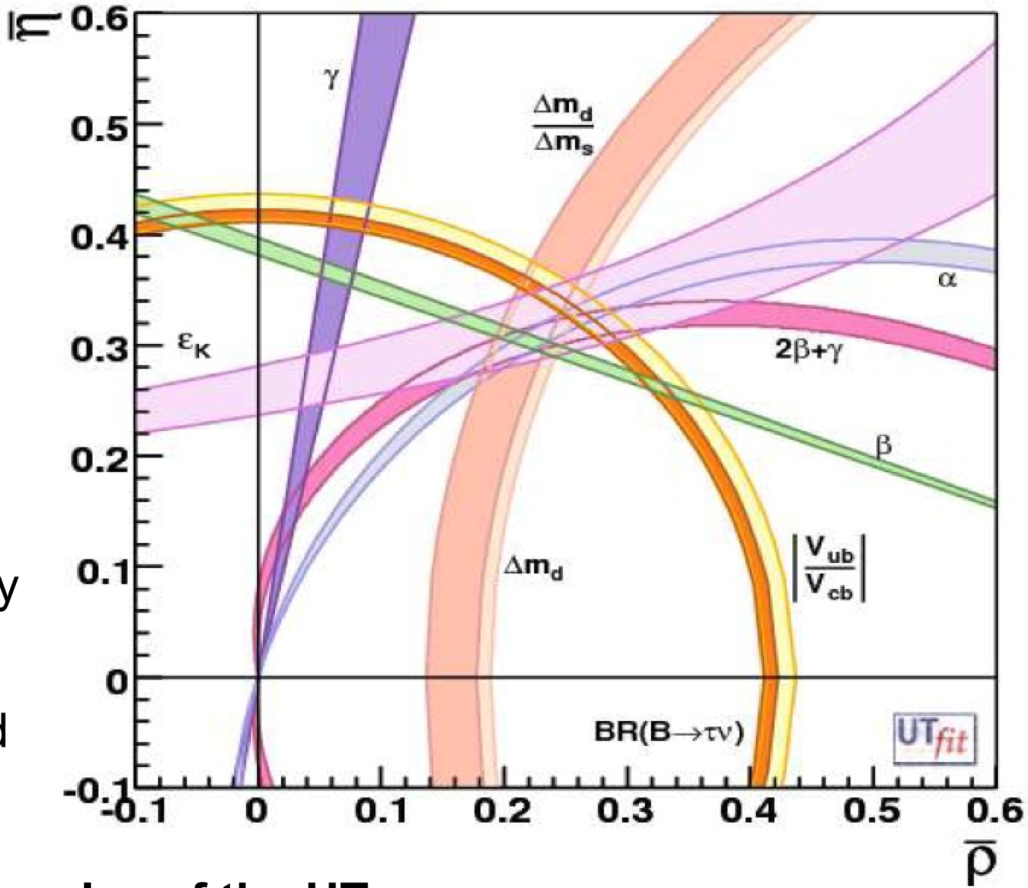
Precision CKM constraints. From 10% to 1%

- **Unitatiry Triangle (UT) Angles**
  - $\sigma(\alpha)$ = 1-2°
  - $\sigma(\beta)$ = 0.1°
  - $\sigma(\gamma)$ = 1-2°
- **CMK Matrix elements**
  - $|V_{ub}|$: Inclusive σ = 2%

    Exclusive σ = 3%
  - $|V_{cb}|$: Inclusive σ = 1%

    Exclusive σ = 1%
  - $|V_{us}|$: can be measured precisely using τ decays
  - $|V_{cd}|$ and $|V_{cs}|$: can be measured at/near charm threshold

The "dream" scenario at 75ab^{-1}



- **SuperB Measures the sides and angles of the UT**

Summary and outlook

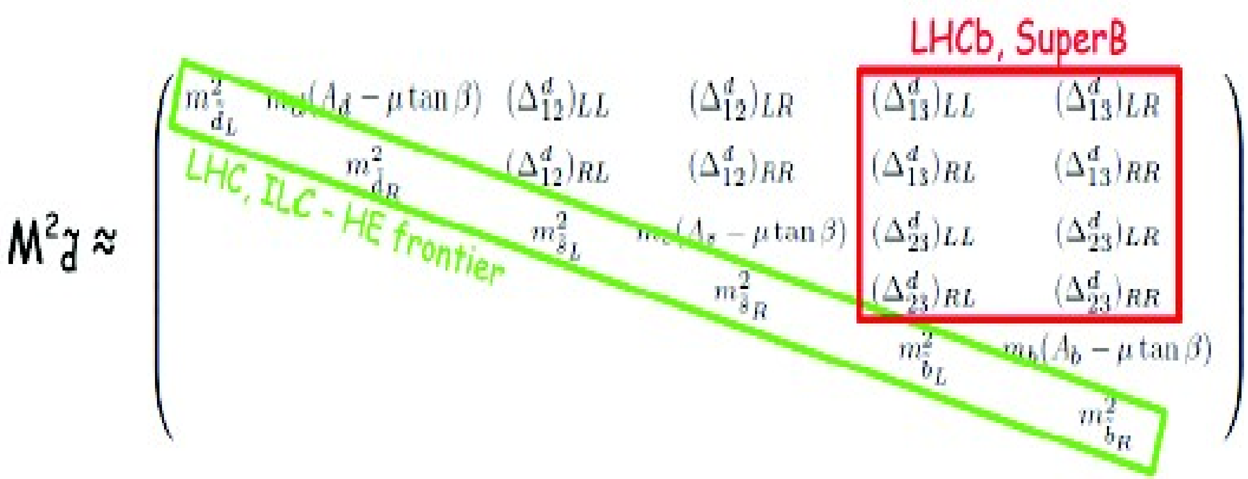
- **SuperB can probe NP observables in wide range of decays**
  - Pattern of deviation from SM can be used to identify structure of NP
  - Clean experimental environment with clean signals in many modes
  - Polarized e^- beam benefit τ LFV searches
  - Charm threshold running adds more observables and improves SuperB potential
  - Measure angles and sides of Unitarity triangle
  - Measure other CKM matrix elements at charm threshold and using τ data
- **SuperB is currently working on Technical Design Report (TDR) for 2012**
- **SuperB Physics Book will follow time later**
- **Plenty of areas for newcomers to work on**

Backup

Flavour and NP energy scale: an example

- **Consider MSSN with generic squark mass matrices as an illustration of SUSY**
  - Simple model general enough to illustrate the issue
  - Model is being constrained by LHC

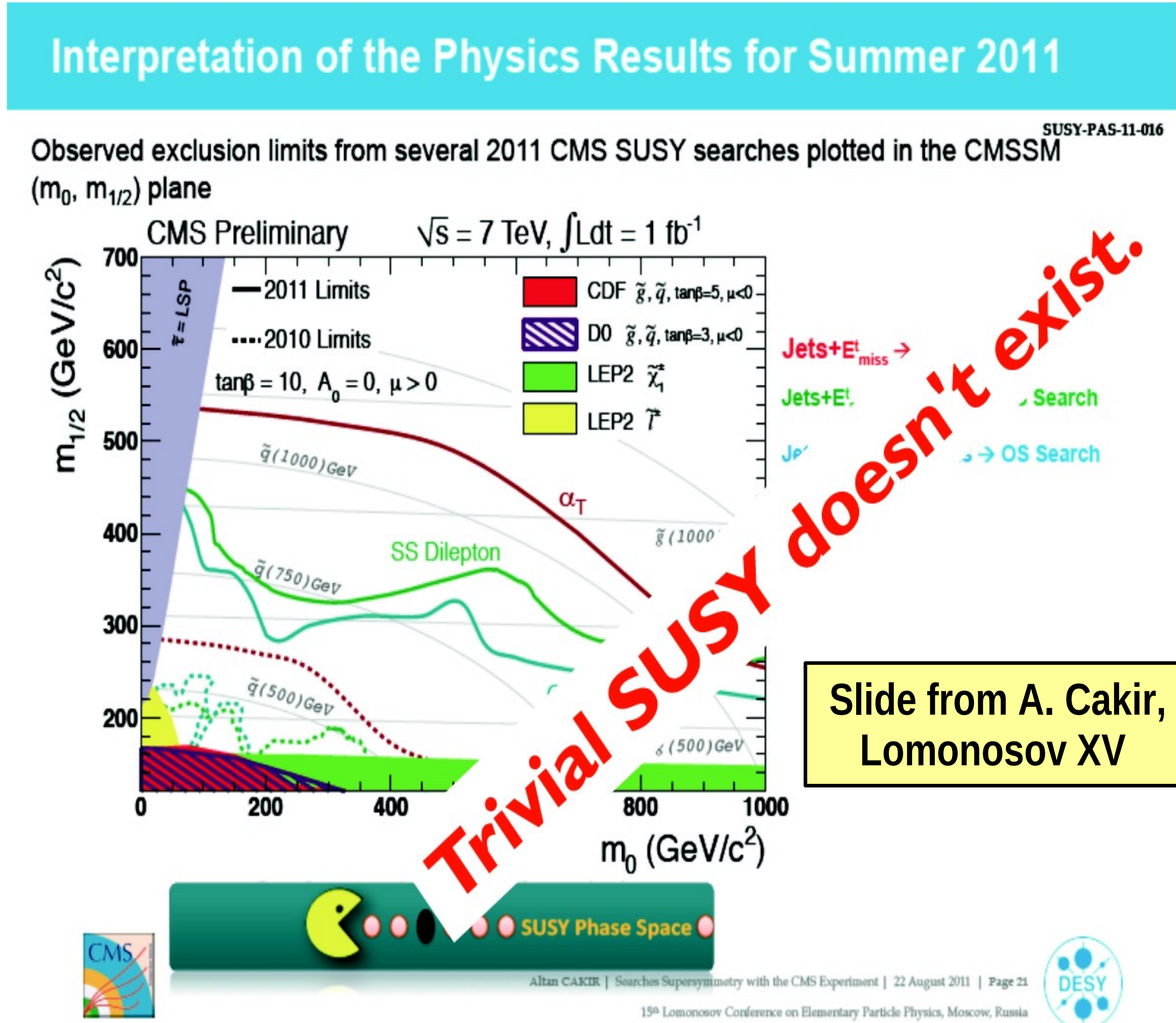
- Similar structure for $M^2_{\tilde{u}}$
- Δ's are related to NP mass scale



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

LHC results on SUSY

- **So far no evidence for SUSY**
- **The SUSY mass scale seems that can be above the 1TeV scale**
- **Interesting implications for some of SuperB measurements**
- **SuperB needs to make sure that its benchmark processes and assumed scales evolve as these contour are updated**



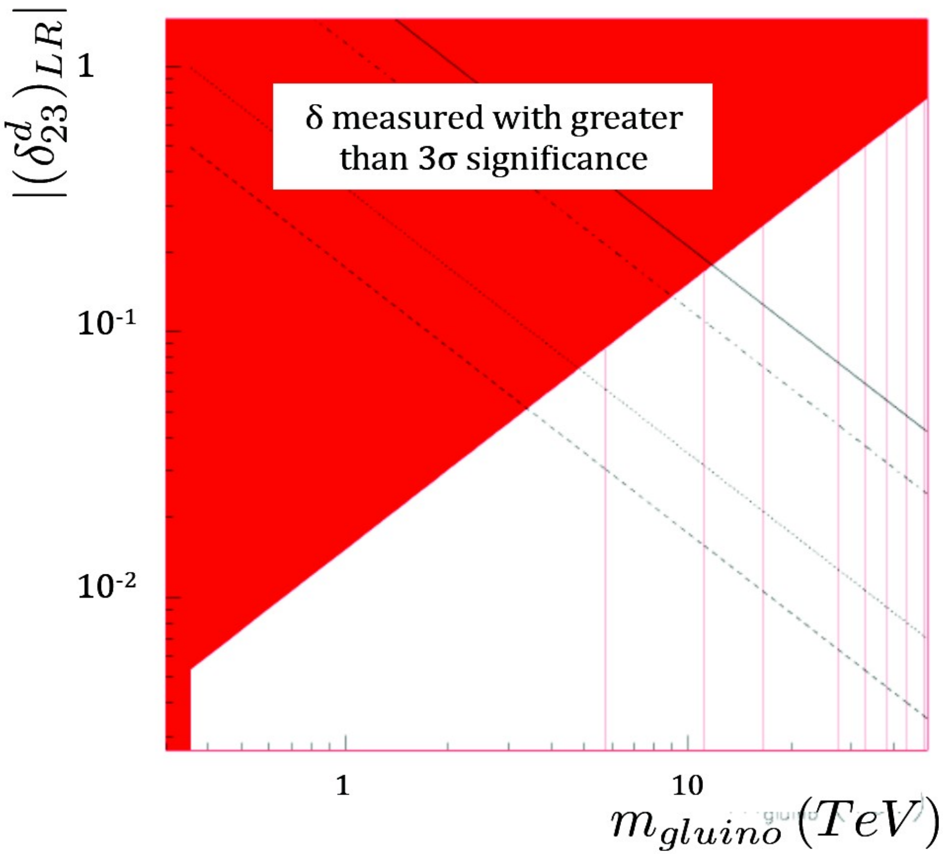
Flavour and NP energy scale: an example

- **Consider MSSN with generic squark mass matrices as an illustration of SUSY**
  - Simple model general enough to illustrate the issue
  - Model is being constrained by LHC
  - Use mass insertion approx. with $m_{\tilde{q}} \sim m_{\tilde{g}}$ to constrain couplings:

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

  - LHC constraints on gluino mass mean couplings are non-zero, and SuperB can provide an upper bound on Λ_{NP}
  - Can constrain the $(\delta_{ij})^q_{AB}$'s using

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



Hall et al., Nucl Phys. B 267 415-432 (1986)
Ciuchini et al., help-ph/0122397

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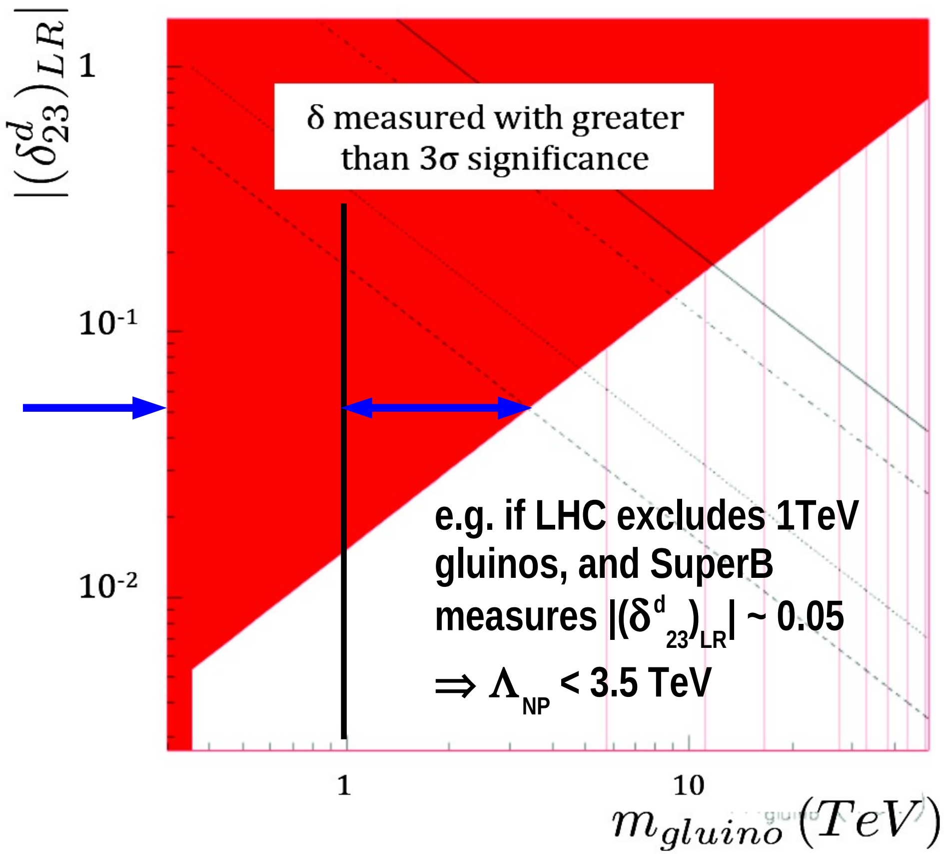

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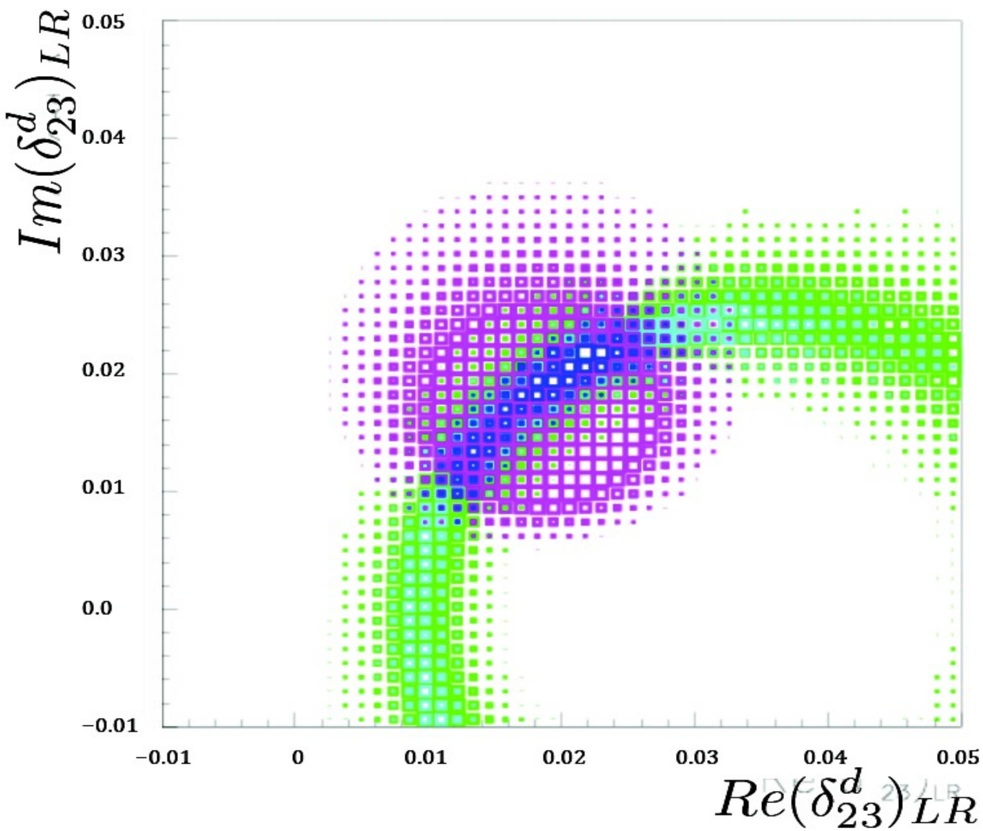

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SuperB Physic studies started in ~2005

This Talk is an overview. More details can be found in the following references:

- The discovery potential of a SuperB B factory, **arXiv: 0503261 [hep-ex]**
- Conceptual design report, **arXiv: 0709.0451 [hep-ex]**
- Valencia retreat proceedings, **arXiv: 0810.1312 [hep-ex]**
- SuperB white paper: Detector, **arXiv: 1007.4241 [hep-ex]**
- SuperB white paper: Accelerator, **arXiv: 1009.6178 [hep-ex]**
- SuperB white paper: Physics, **arXiv: 1008.1541 [hep-ex]**
- Impact Document: **INFN/AE_11/1, LAL-11-200, SLAC-R-14548, MZ-TH 11/25**
  arXiv: 1109.5028 [hep-ex]

INFN/AE_11/1, LAL-11-200, SLAC-R-14548, MZ-TH/11-25

The impact of Super$B$ on flavour physics

July 1, 2011

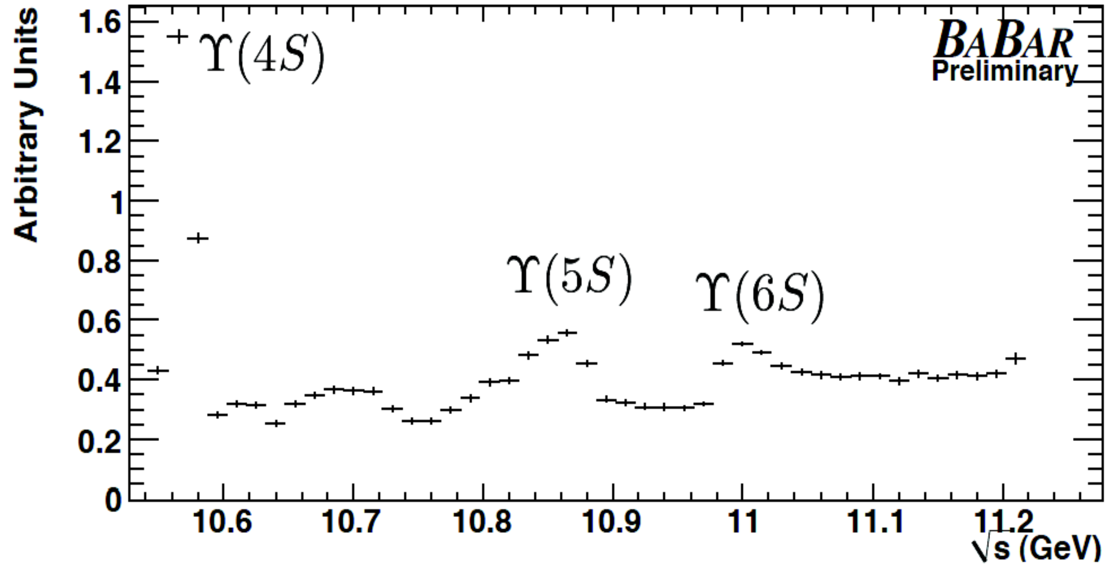
Abstract

This report provides a succinct summary of the physics programme of Super$B$, and describes that potential in the context of experiments making measurements in flavour physics over the next 10 to 20 years. Detailed comparisons are made with Belle II and LHCb, the other B physics experiments that will run in this decade. SuperB will play a crucial role in defining the landscape of flavour physics over the next 20 years.

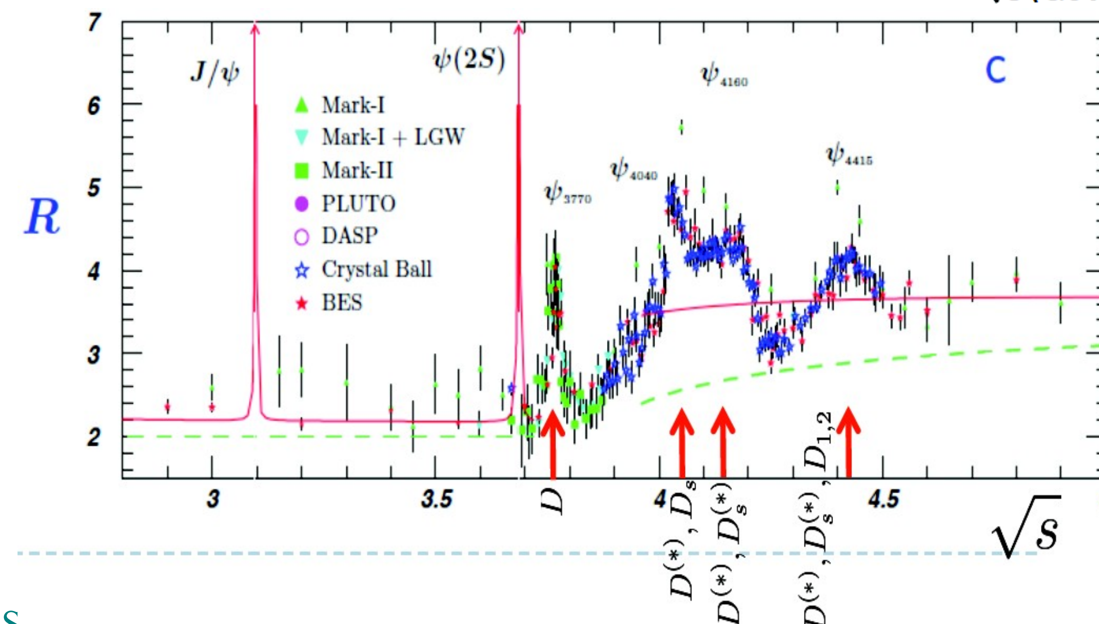
SuperB Data Samples

Data Samples Available at SuperB

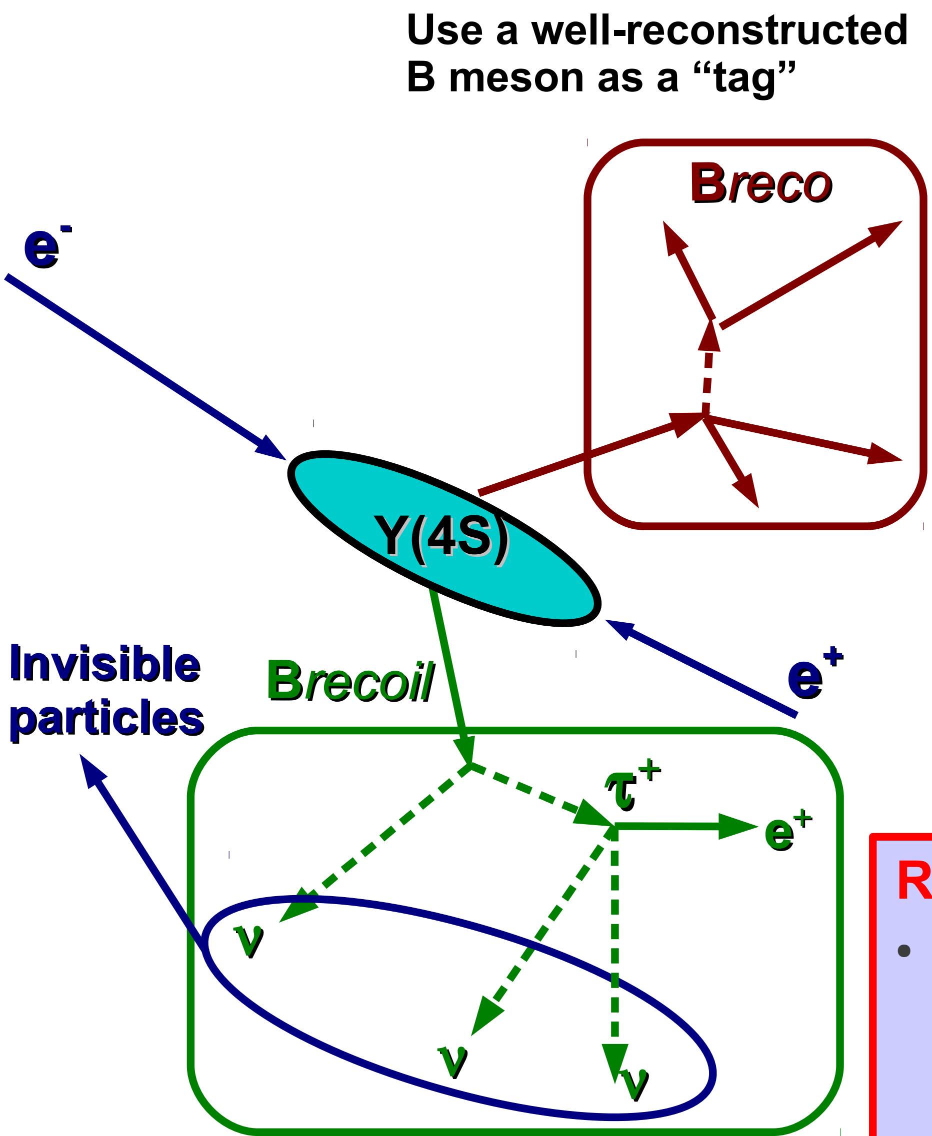
- **Υ(4S) region:**
  - 75ab^{-1} at Υ(4S) with 5 years of running
  - Also run above/below Υ(4S). ~1ab^{-1} at Υ(5S)
  - ~75×10^{9} B, D and τ pairs



- **ψ(3770) region:**
  - 500fb^{-1} at threshold
  - Also run at nearby resonances
  - ~2×10^{9} D pairs at threshold in a few months of running



Rare decays: Recoil Analysis Technique



Use the fact that the B mesons are actually produced through Y(4S) at B-factories

Breco (B_{tag}): full (partial)
reconstruction of one B into a hadronic (semi-leptonic) final state

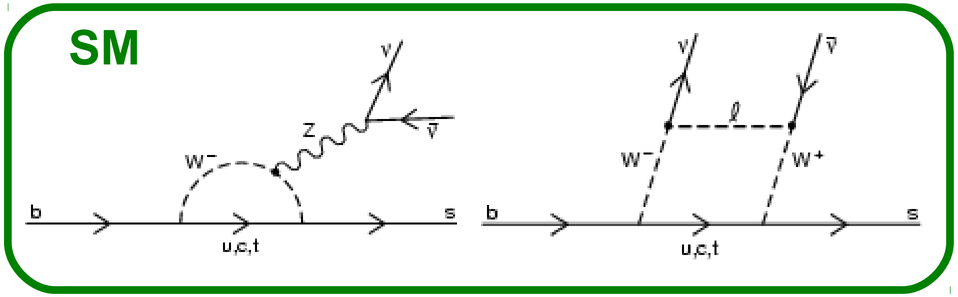
Brecoil (B_{sig}): look for the signal
signature, e.g. τ^+ not accompanied by additional (charged+neutral) particles + **Missing Energy**

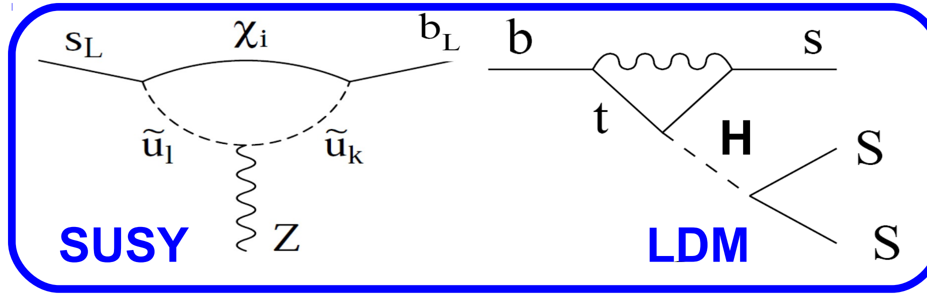
Recoil technique at B-Factories:

- search for rare decays ($\sim 10^{-5}$) with missing energy

  (Not possible at hadronic machines)

$B_{u,d}$ Rare decays: $B\rightarrow K^{(*)}\nu\nu$



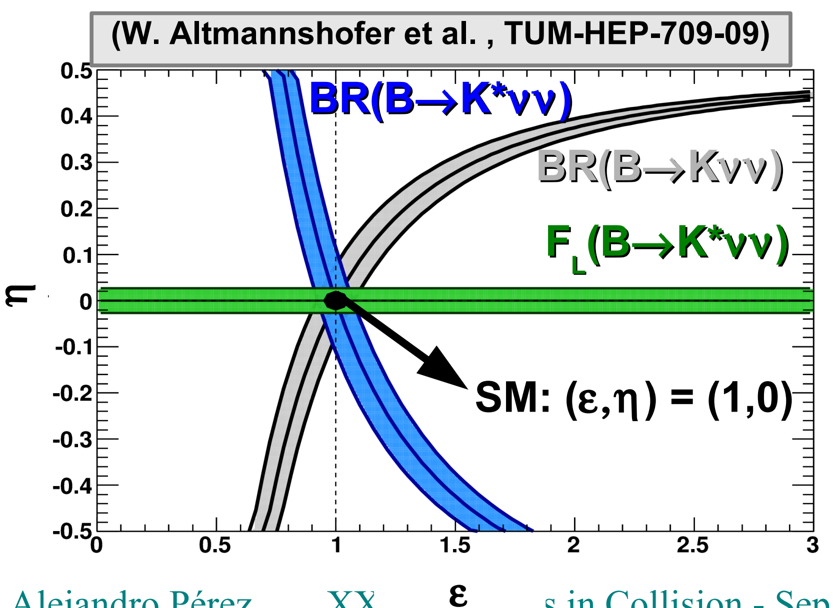


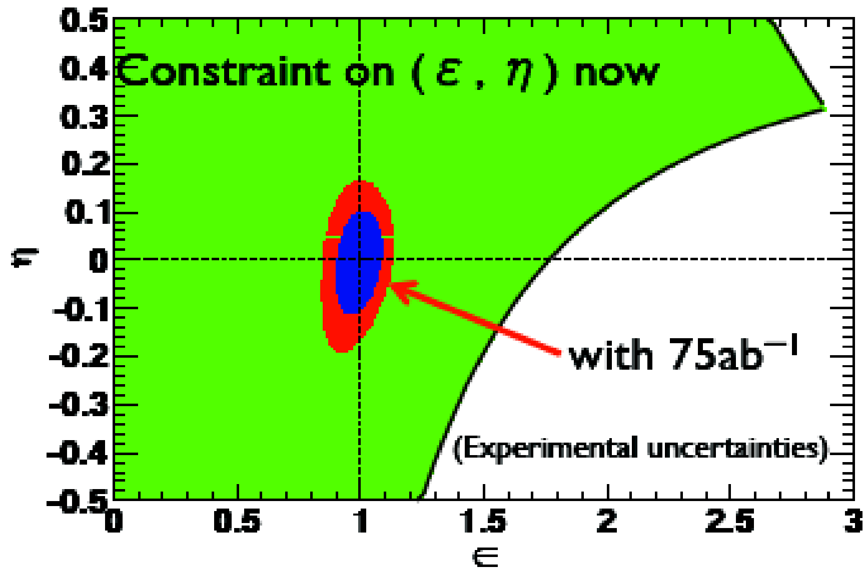
- **$b\rightarrow s\nu\nu$ model independent phenomenology:**

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

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

- Need 75ab^{-1} to observe pseudo-scalar and vector modes
- With more than 75ab^{-1} we could measure polarization





$B_{u,d}$ Rare decays: $b \to s l^+ l^-$

- **SuperB is complementary to LHCb in this subject**

- **SuperB can measure both inclusive and exclusive modes:**
  - Cross-checks to understand source of NP
  - Important as theory uncertainties are usually smaller for inclusive modes
  - Expect: 10-15k $B \to K^* \mu^+ \mu^-$ and $B \to K^* e^+ e^-$

- **SuperB can study all lepton flavours :**
  - Equal amounts of μ and e final states can be measured
    - Need both lepton flavours to measure all NP observables
    - LHCb will accumulate slight more events in the $B \to K^* \mu^+ \mu^-$ mode
    - Expect superior statics w.r.t LHCb for $B \to K^* e^+ e^-$ mode
    - S/B ~0.3 for SuperB and ~1.0 for LHCb
  - Can also search for $B \to K^* \tau^+ \tau^-$ mode
  - Can constrain Majorana ν's using like sign final states ($B^+ \to K^- l^+ l^+$)
  - Also of interest for $D_s \to K^* l^+ l^-$ decays final states near charm threshold

TDCPV in $B_{u,d}$ decays: CKM β and α angles

- **SuperB can do many redundant measurements of the CKM angles that are potential probes of NP**

Redundant measurements of β CKM

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	–	–	–

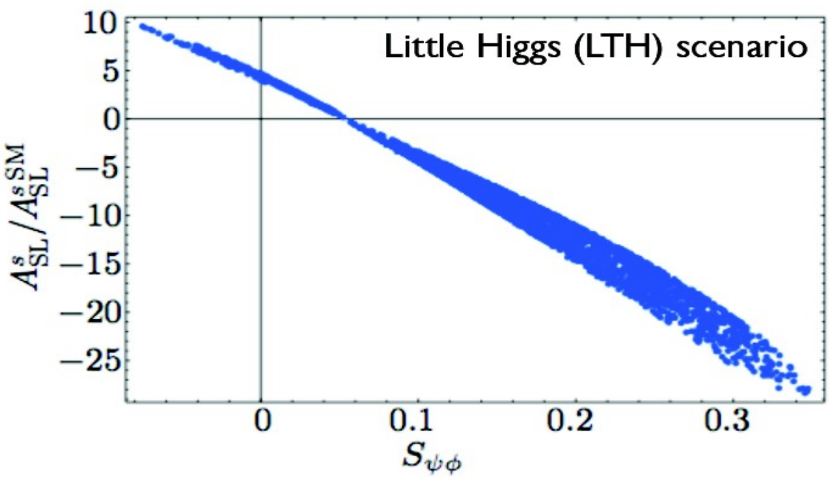
- **Can also measure α using several modes: ππ, ρπ, ρρ and $a_1\pi$**

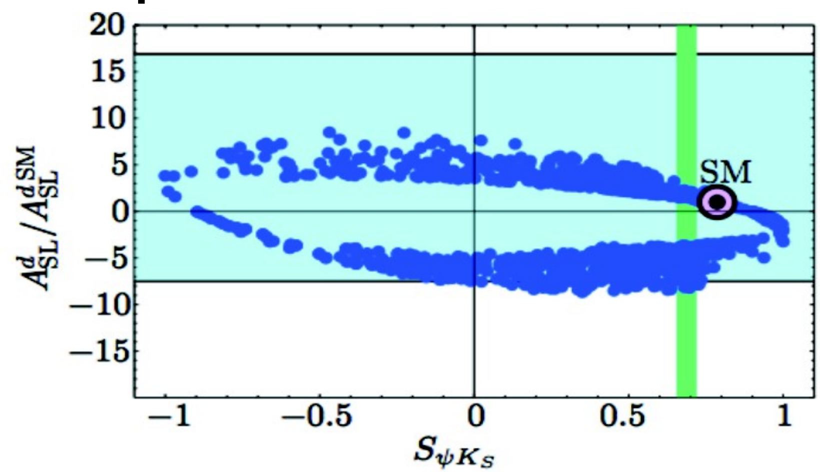
B_s decays

- The plan is to accumulate 1ab^{-1} at $\Upsilon(5S)$
- Can cleanly measure semi-leptonic asymmetry (A^s_{SL})

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

- Expects $\sigma(A^s_{SL}) \sim 0.004$ @ 1ab^{-1}
- Correlation with other observables can help to discriminate NP scenarios





- SuperB can also study rare decays with many neutral particles in the final state which can be enhanced by NP

  e.g. $B_s \to \gamma\gamma$ can be enhanced by SUSY

Rare D decays

- **Use $\Upsilon(4S)$ and charm threshold data to search for rare decays**

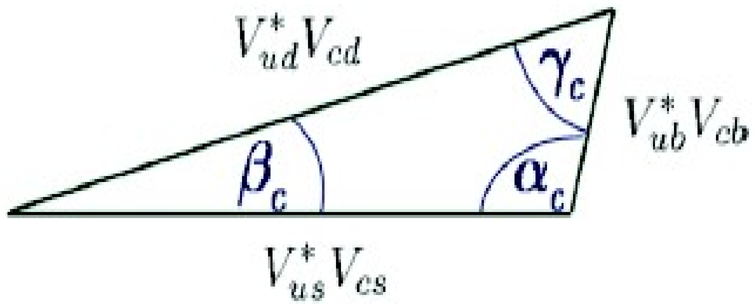
- **$D\to\gamma\gamma$:**
  - Allows to measure long distance (LD) contribution $D\to\mu^+\mu^-$ mode and to understand if it exhibits NP

    $Br(D\to\mu^+\mu^-)_{LD} = 3.0\times10^{-5}\, Br(D\to\gamma\gamma)$
  - $Br(D\to\gamma\gamma)_{SM} \sim 1.0\times10^{-8}$
  - Threshold running and recoil technique will play a significant role

- **$D\to\nu\nu$ (+γ): (work in progress)**
  - Helicity suppressed in SM
  - Sensitive to new invisible scalar particles (e.g. Dark matter)
  - Need to use recoil technique at charm threshold
  - $\nu\nu$ final state: irreducible backgrounds going down beam-pipe. Difficult analysis
  - $\nu\nu+\gamma$ final state: may be another story

CPV in mixing for D decays

- **The charm cu triangle has one unique element: β_c (CPV mixing phase)**



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

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

$$\alpha_c = (111.5 \pm 4.2)^\circ$$
$$\beta_c = (0.0350 \pm 0.0001)^\circ$$
$$\gamma_c = (68.4 \pm 0.1)^\circ$$

- **Precision measurement of mixing phase in many channels (< 2°)**
- **Constrain $\beta_{c,eff}$ using $D \to \pi\pi$ Isosping analysis (similar to B-decays)**
  - Search for NP and constraint $\beta_{c,eff} \sim 1^\circ$
  - Can only fully explore in an e^+e^- environment
  - Data from charm threshold completes the set of 5 $|V_{ij}|$ to measure

  $\Rightarrow$ needs SuperB to perform a full test of the unitatiry triangle

See arXiv: 1106.5075

Charm mixing: Summary

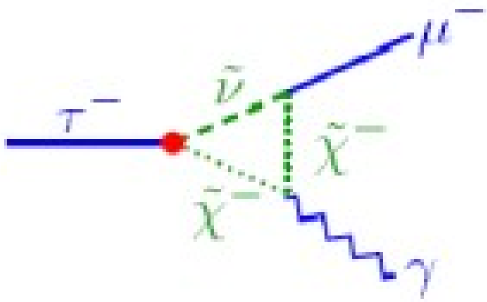
Strategy	Decay	$\sigma(\lvert q_D/p_D\rvert) \times 10^2$	$\sigma(\phi_M)^\circ$
HFAG (direct *CPV* allowed):			
Global χ^2 fit	<All modes>	± 18	± 9
Asymmetries a_z:			
x_D	<All modes>	± 1.8	–
y_D	<All modes>	± 1.1	–
y_{CP}	K^+K^-	± 3.8	–
y'	$K^+\pi^-$	± 4.9	–
x'^2	$K^+\pi^-$	± 4.9	–
x''	$K^+\pi^-\pi^0$	± 5.4	–
y''	$K^+\pi^-\pi^0$	± 5.0	–
TDDP (*CPV* allowed):			
Model-dependent	$K_S^0 h^+h^-$	± 8.4	± 3.3
BES III DP model	$K_S^0 h^+h^-$	± 3.7	± 1.9
Super*B* DP model	$K_S^0 h^+h^-$	± 2.7	± 1.4
SL Asymmetries a_{SL}:			
75 ab^{-1} at $\Upsilon(4S)$	$X\ell\nu_\ell$	± 10	
500 fb^{-1} at $\psi(3770)$	$K\pi$	± 10	
500 fb^{-1} at $\psi(3770)$	$X\ell\nu_\ell$	TBD	

- **Can perform a precision measurement of charm mixing**
- **TDCPV: precise measurement of mixing phase**

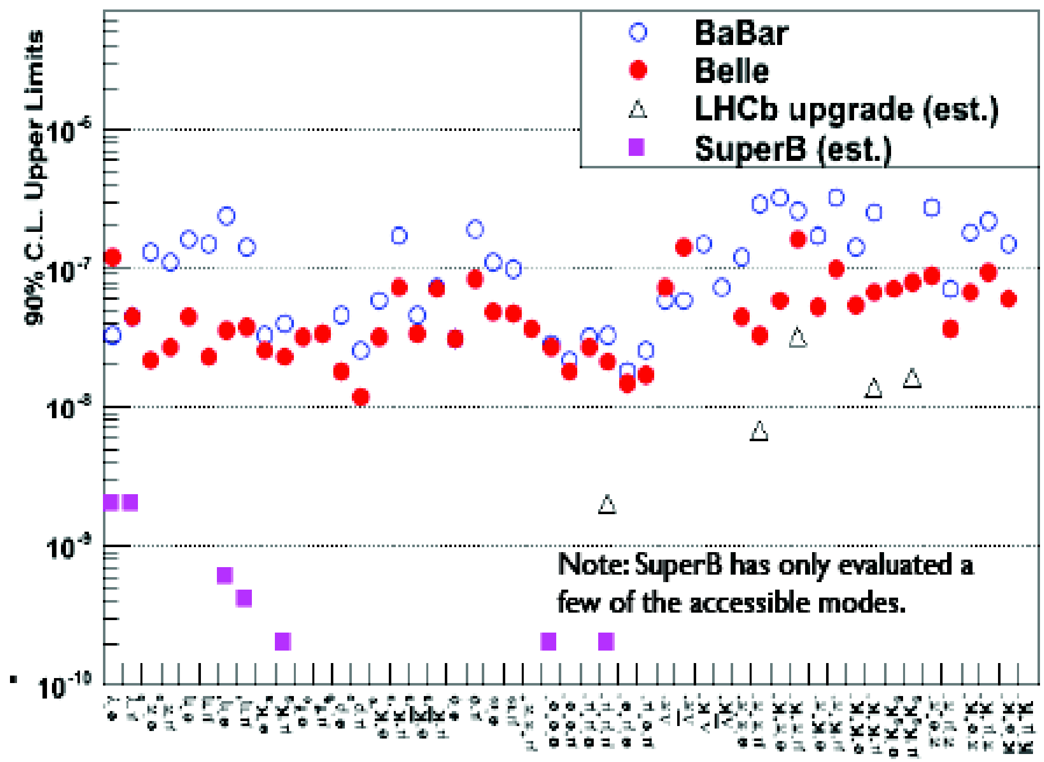
τ physics

Lepton Flavour Violation (LFV)

- **ν mixing leads to low level of charged LFV (B ~ 10^{-54})**
  - Possible enhancement with NP
  - Searching transition from 3rd to 2nd and 1st generation: $\tau \rightarrow \mu, e$



- Two order of magnitude improvements at SuperB over current limits
- Hadron machine are not competitive
- e^- 80% polarization helps to suppress backgrounds

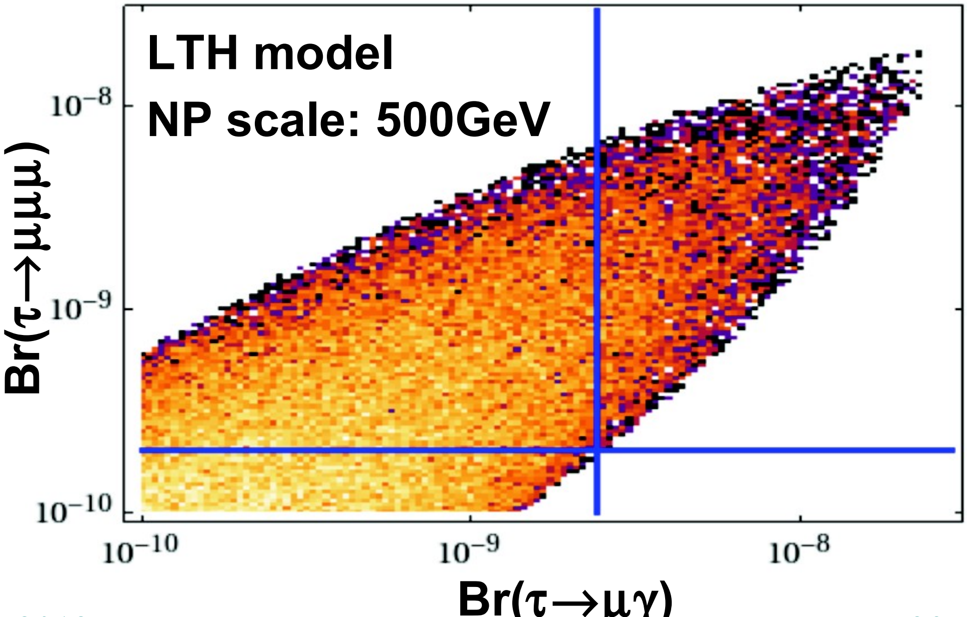


$\tau \to \mu\gamma$ and 3μ: LFV golden modes

- **Golden modes only cleanly accessible in e^+e^- environment**
- **Models where LFV amplitude is dominated by EDM operator (e.g. MSSM) it is expected that $Br(\tau \to \mu\mu\mu)/Br(\tau \to \mu\gamma) \sim \alpha_e$**
- **In other models (e.g. LHT) the ratio could be of order one**
  - Very favourable to SuperB which could observe $\tau \to \mu\mu\mu$
  - In this case many models, including MSSM, would be ruled out

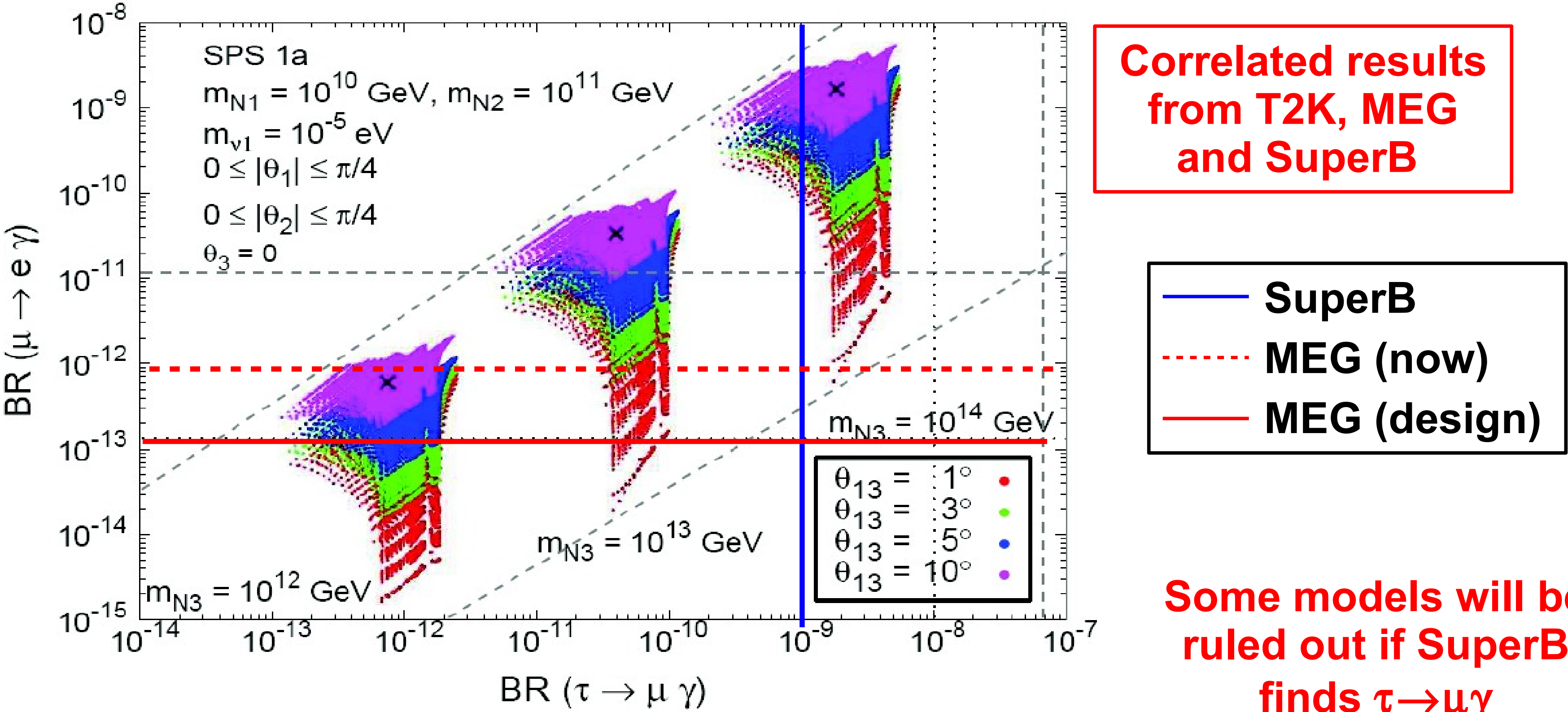
TABLE III: Expected 90% CL upper limits and 3σ evidence reach on LFV decays with 75 ab^{-1} with a polarized electron beam.

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}
$\mathcal{B}(\tau \to \ell\ell\ell)$	$2.3–8.2 \times 10^{-10}$	$1.2–4.0 \times 10^{-9}$



LFV: SuperB and other experiments

- **An example:** SUSY seasaw = CMSSM + $3\nu_R$ + ν
- **$\tau\to\mu\gamma$ upper limit at SuperB with**
  - **θ_{13}:** neutrino mixing/CPV, T2K...
  - **$\mu\to e\gamma$**: MEG



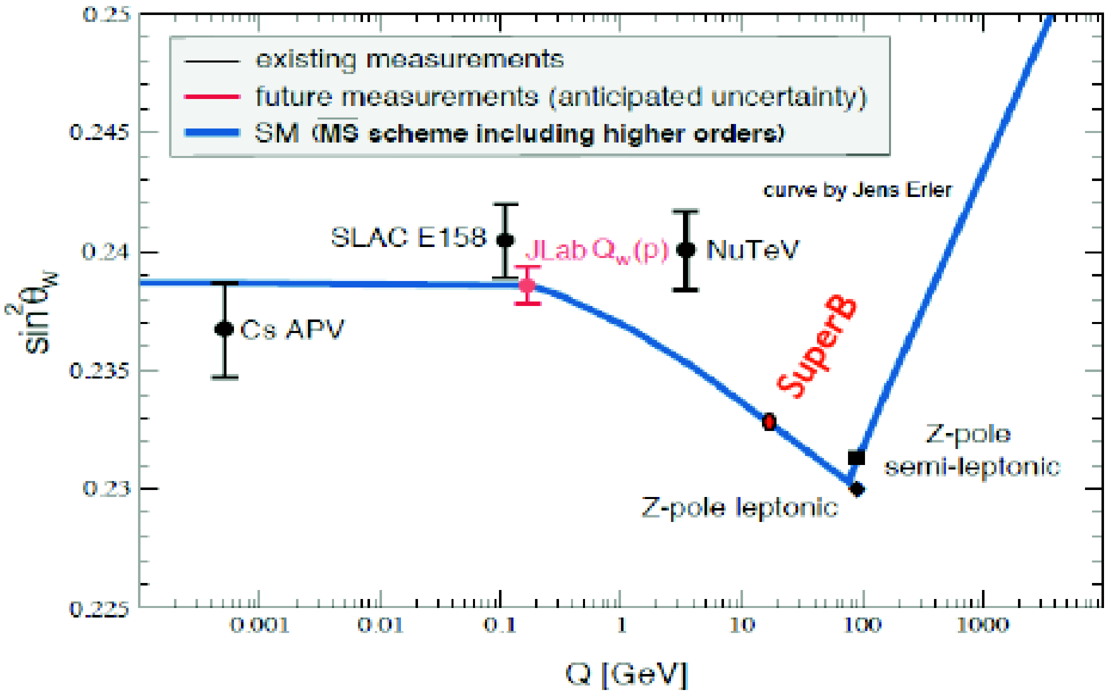
Correlated results from T2K, MEG and SuperB

Some models will be ruled out if SuperB finds $\tau\to\mu\gamma$

Other Topics

Precision Electro-weak measurements

- **$\sin^2\theta_w$ can be measured with polarized e^- beams**
  - Measurement at √s = Υ(4S) theoretically clean (no b fragmentation uncertainties as at Z pole). Same precision as LEP/SLC at the Z-pole
  - Measurement feed in electro-weak fits. If deviation from SM can perform measurement at ψ(3770) to understand nature of deviation



Plot adapted from Qweak proposal (JLAB E02-020)

Measure LR asymmetry in

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

Complements measurements planned/underway at lower energies (Qweak/MESA)

Sensitivity of SuperB to specific NP Models

- **Combine the measurements to elucidate structure of NP**

	Observable/mode	H^+ high $\tan\beta$	MFV	non-MFV	NP Z penguins	Right-handed currents	LTH	SUSY AC	SUSY RVV2	SUSY AKM	SUSY δLL	SUSY FBMSSM
✓	$\tau \to \mu\gamma$							★★★	★★★	★	★★★	★★★
✓	$\tau \to \ell\ell\ell$						★★★					
✓	$B \to \tau\nu, \mu\nu$	★★★(CKM)										
✓	$B \to K^{(*)+}\nu\bar{\nu}$			★	★★★			★	★	★	★	★
✓	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)							★	★	★	★★★	★★★
	$B_s \to \mu\mu$							★★★	★★★	★★★	★★★	★★★
	β_s from $B_s \to J/\psi\phi$							★★★	★★★	★★★	★	★
✓	a_{sl}						★★★					
✓	Charm mixing							★★★	★	★	★	★
✓	CPV in Charm	★★									★★★	

✓ = SuperB can measure it

Size of the effect in a given model/scenario

★★★ **Large**

★★ **Medium**

★ **Observable, but small**

Observable/mode	Current now	LHCb (2017) $5\,\mathrm{fb}^{-1}$	Super$B$ (2021) $75\,\mathrm{ab}^{-1}$	Belle II (2021) $50\,\mathrm{ab}^{-1}$	LHCb upgrade (10 years of running) $50\,\mathrm{fb}^{-1}$	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						
$\mathrm{BR}(B \to \tau\nu)$ ($\times 10^{-4}$)	1.64 ± 0.34		0.05	0.04		1.1 ± 0.2
$\mathrm{BR}(B \to \mu\nu)$ ($\times 10^{-6}$)	< 1.0		0.02	0.03		0.47 ± 0.08
$\mathrm{BR}(B \to K^{*+}\nu\bar{\nu})$ ($\times 10^{-6}$)	< 80		1.1	2.0		6.8 ± 1.1
$\mathrm{BR}(B \to K^{+}\nu\bar{\nu})$ ($\times 10^{-6}$)	< 160		0.7	1.6		3.6 ± 0.5
$\mathrm{BR}(B \to X_s\gamma)$ ($\times 10^{-4}$)	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	-
$\mathrm{BR}(B \to K^*\mu^+\mu^-)$ ($\times 10^{-6}$)	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	-
$\mathrm{BR}(B \to K^*e^+e^-)$ ($\times 10^{-6}$)	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		-
$\mathrm{BR}(B \to X_s\ell^+\ell^-)$ ($\times 10^{-6}$) [g]	3.66 ± 0.77 [h]		0.08	0.10		1.59 ± 0.11
S in $B \to K_S^0\pi^0\gamma$	-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_s^0 Decays						
$\mathrm{BR}(B_s^0 \to \gamma\gamma)$ ($\times 10^{-6}$)	< 8.7		0.3	$0.2 - 0.3$		0.4 - 1.0
A_{SL}^s ($\times 10^{-3}$)	-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).
$\arg\{q/p\}$ (°)	-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
		$5\,\mathrm{fb}^{-1}$	$75\,\mathrm{ab}^{-1}$	$50\,\mathrm{ab}^{-1}$	$50\,\mathrm{fb}^{-1}$	
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

- **The SuperB measurements of these quantities will be among the very best for the foreseeable future.**