Physics Potential of SuperB

A major new European particle physics project

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On behalf of the SuperB Project
Hadron 2011, June 13th 2011

Outline

- Unique Selling Points (USPs)
- Tour of SuperB Physics
- Accelerator Design Status
- Detector Design Status
- Project Funding
- Latest news on Project Site
- Conclusion and Outlook

Unique Selling Points (USPs)

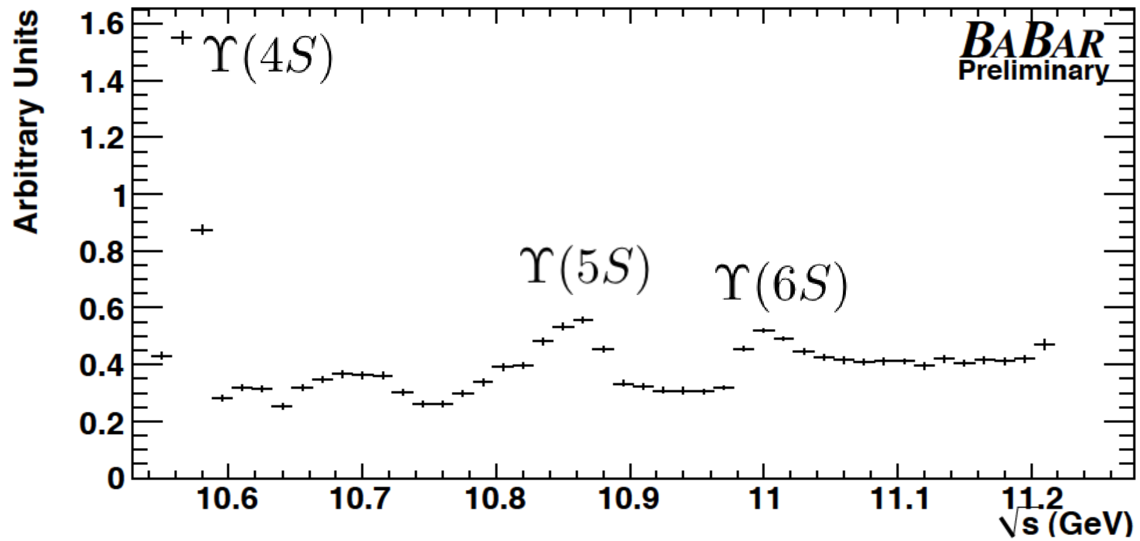
- New European Accelerator Facility to be sited in Italy, ready by ~2016
  - At $\Upsilon(4S)$, 6.7 GeV positrons on 4.18 GeV electrons, 1.3 km circumference
- High Luminosity (100 x current records)
  - $\geq 10^{36}$ cm^{-2} s^{-1} 15 ab^{-1}/year rising to 40 ab^{-1}/year in later years
  - 1 ab^{-1} => 1 billion B-meson pairs, 1 billion D-mesons and 1 billion tau pairs
  - 75 ab^{-1} by ~2022
- Polarization
  - 60%-85% polarization of electron beam
  - Improves physics reach by factor of 2 in some regions (e.g. LFV)
- $\psi(3770)$ to $\Upsilon(5S)$ and beyond
  - Can scan a large energy range.
  - Switching from low-energy to high-energy running very quick (no more than a few weeks if magnets need to be swopped).
- Charm Threshold Running
  - ~4 months running at 10^{35} cm^{-2} s^{-1} equivalent to 20 x future BES-III dataset.
  - Can we measure β_c? And the charm Unitarity Triangle?
- Light Source
  - 30 x brighter than ESRF or Diamond Light Source.
- Computing
  - On the scale of a non-upgraded LHC experiment.

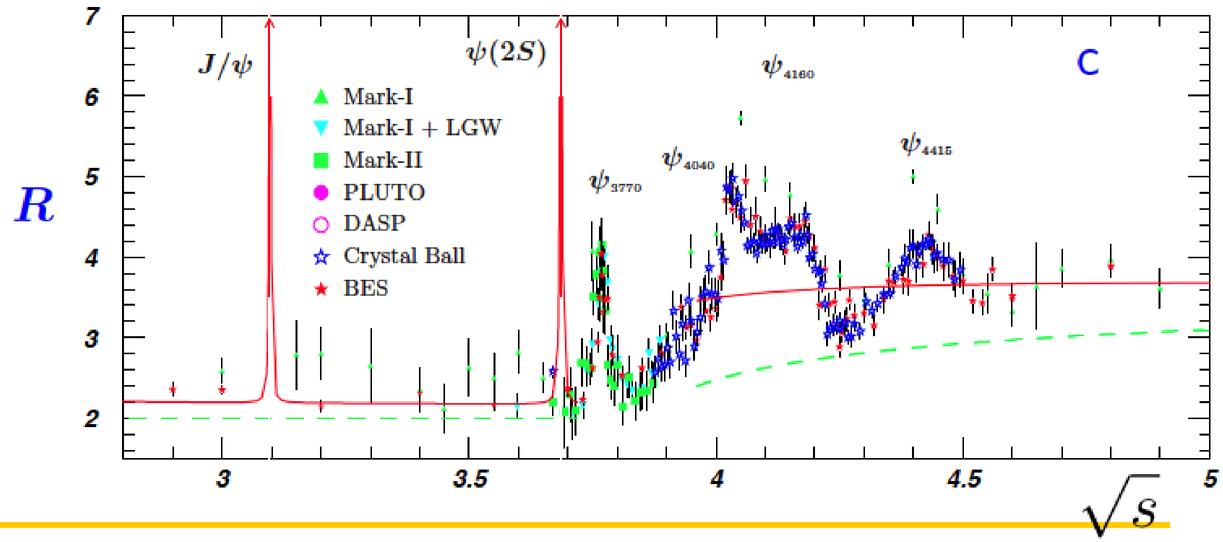
SuperB Physics Goals – Executive Summary

- Identify the flavour structure of New Physics.
- Different New Physics models predict a different hierarchy of results => multiple measurements needed.
- Sensitive to New Physics through flavour properties; CP Violation asymmetries in B and D decays; and rare decays.
- Probe New Physics scales up to 10-100 TeV through indirect measurements.
- Tests both the quark and lepton sectors.
- Golden Channels (good SM prediction + good experimental resolution) e.g. inclusive $b\rightarrow s\gamma$, $B\rightarrow K\upsilon\bar{\upsilon}$, $B\rightarrow\tau\upsilon$, $\tau\rightarrow\mu\upsilon\bar{\upsilon}$
- Interplay with Lattice QCD predictions.
- Physics capabilities published in arXiv:1008.1541.

Data sample

- ➢ Υ(4S) region:
  - o 75ab^{-1} at the Υ(4S)
  - o Also run above / below the Υ(4S)
  - o ~75 x10^9 B, D and τ pairs
- ➢ ψ(3770) region:
  - o ~150 fb^{-1} per month at threshold running
  - o Also run at nearby resonances
  - o ~2 x 10^9 D pairs





Physics : What will the CKM look like in 2022?

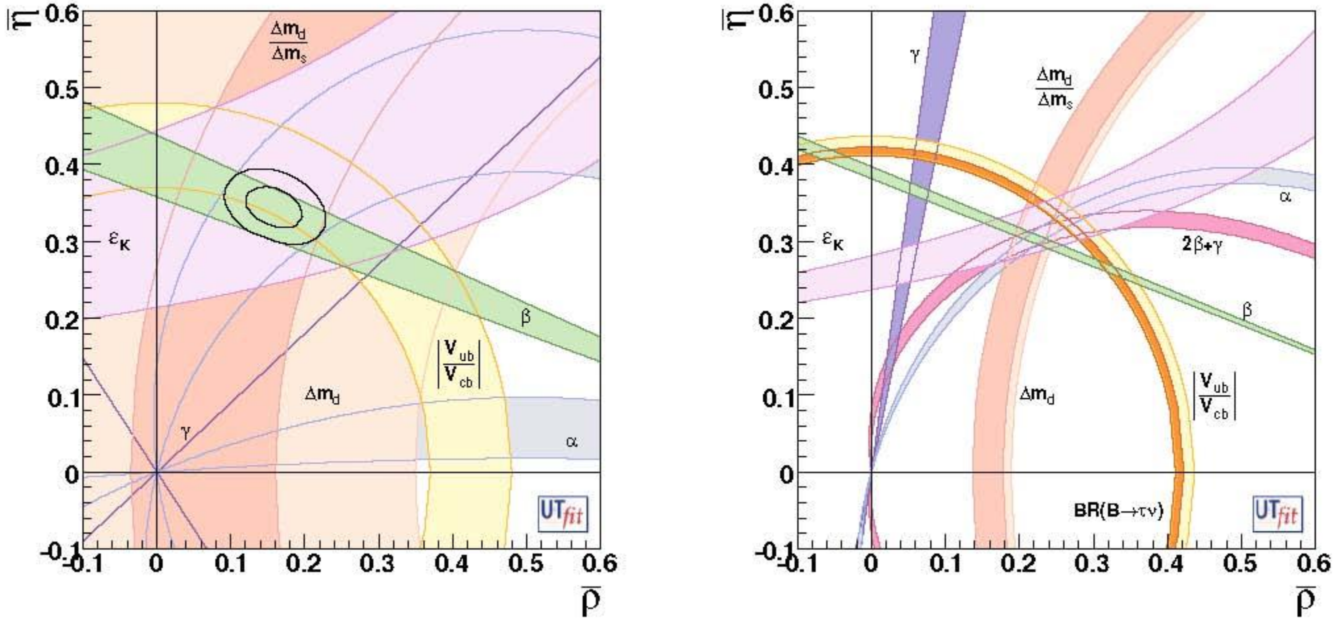


Figure 2-1. *Regions corresponding to 95% probability for $\bar{\rho}$ and $\bar{\eta}$ selected by different constraints, assuming present central values with present errors (left) or with errors expected at SuperB (right).*

CKM observable	Precision ($75\,\mathrm{ab}^{-1}$)	Theory uncertainty
β ($c\bar{c}s$)	0.1°	clean
α	$1-2^\circ$	dominant
γ	$1-2^\circ$	clean
$\lvert V_{cb}\rvert$ (inclusive)	1.0%	dominant
$\lvert V_{cb}\rvert$ (exclusive)	1.0%	dominant
$\lvert V_{ub}\rvert$ (inclusive)	2.0%	dominant
$\lvert V_{ub}\rvert$ (exclusive)	3.0%	dominant

Physics: Interplay – The Golden Matrix

- Combine measurements to elucidate structure of new physics.

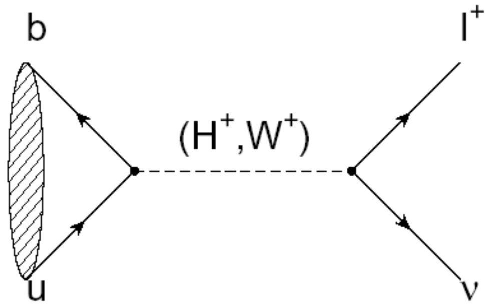
	Observable/mode	H^+ high $\tan\beta$	MFV	non-MFV	NP Z penguins	Right-handed currents	LTH	SUSY AC	SUSY RVV2	SUSY AKM	SUSY δLL	SUSY FBMSSM
✓	$\tau \to \mu\gamma$							★★★	★★★	★	★★★	★★★
✓	$\tau \to \ell\ell\ell$						★★★					
✓	$B \to \tau\nu, \mu\nu$	★★★(CKM)										
✓	$B \to K^{(*)+}\nu\overline{\nu}$			★	★★★			★	★	★	★	★
✓	S in $B \to K^0_S\pi^0\gamma$					★★★						
✓	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	★★									★★★	

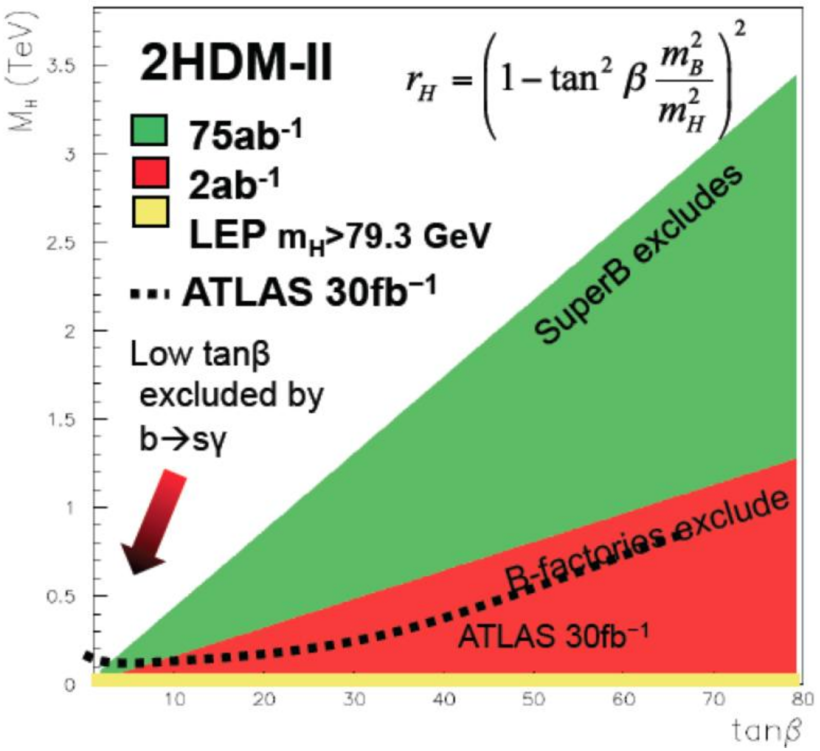
✓ = SuperB can measure these modes

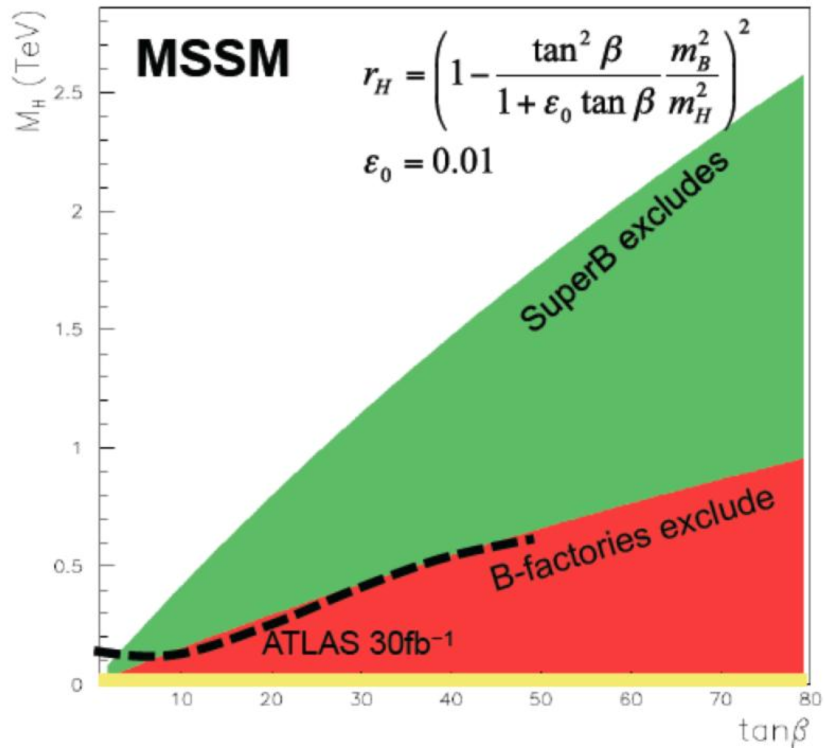
More information on the golden matrix can be found in arXiv:1008.1541, arXiv:0909.1333, and arXiv:0810.1312.

Physics : Charged Higgs (2HDM and MSSM)

- Higgs-mediated Minimal Flavour Violation
- Multi-TeV search capability for large tan(β).
- Includes SM uncertainty ~20% from V_{ub} and f_B.
- $B^0 \to l^+ l^-$ and $B^0 \to l^- \tau^+$ also sensitive to non-SM Higgs







Physics: Spectroscopy and exotic resonances

- *Ideal laboratory for testing high- and low-energy QCD.*
- *Search for hybrids, molecules and tetraquarks.*
- *Predicting unexpected resonances is hard!*

Some expected samples in $50 ab^{-1}$:

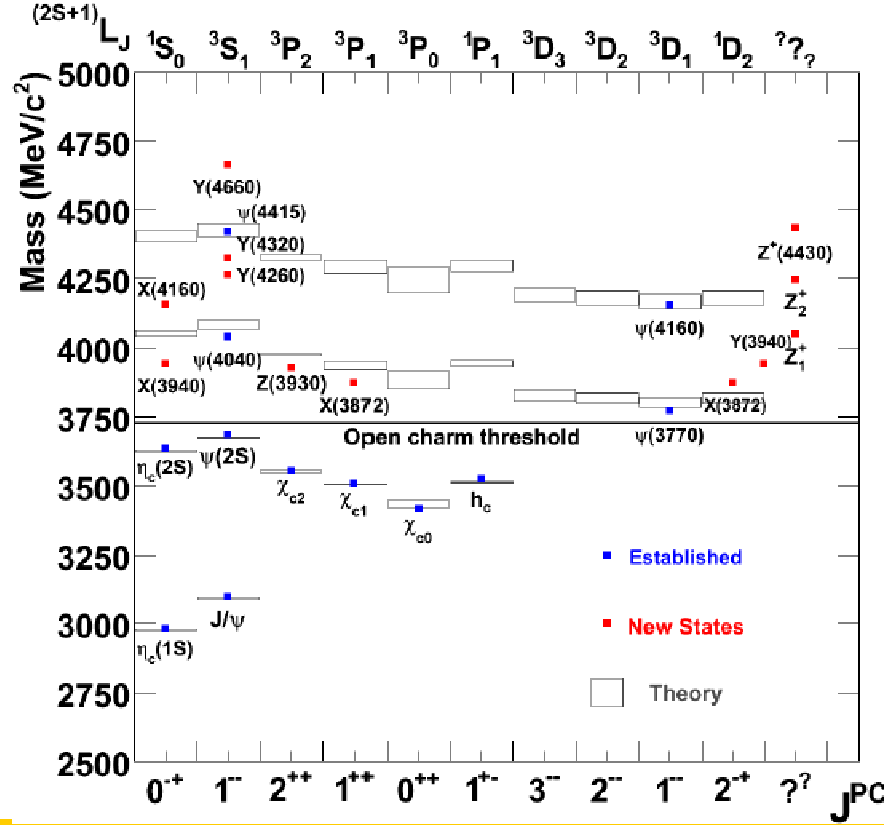
$B \to X(3872)K$: ~10,000 events

$\mathrm{Y}(4260) \to \mathrm{J}/\psi\pi^+\pi^-$: ~30,000 events

$\mathrm{Y}(4350) \to \psi(2\mathrm{S})\pi^+\pi^-$: ~3000 events

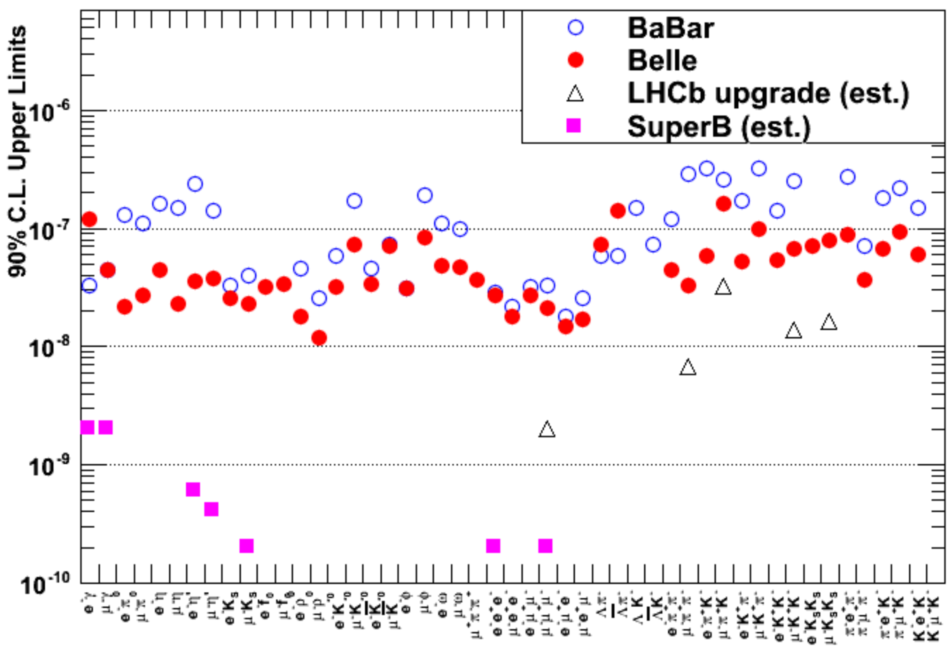
$\mathrm{Y}(4660) \to \psi(2\mathrm{S})\pi^+\pi^-$: ~3000 events

$\mathrm{Z}^+(4050), \mathrm{Z}_2^+(4430)$: $10^3 - 10^6$ $B \to \mathrm{J}/\psi\pi^+K, \psi(2\mathrm{S})\pi^+K$

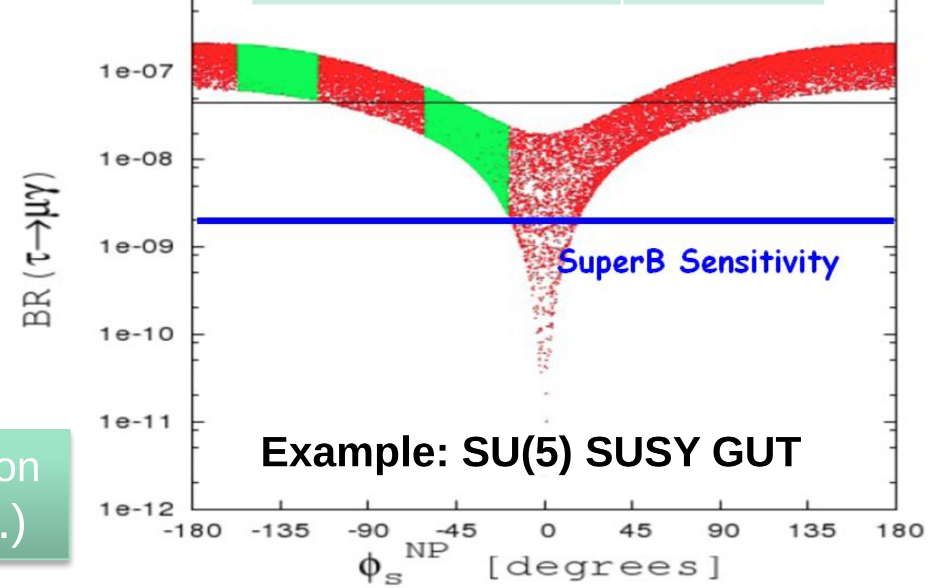


Physics - Lepton Flavour Violation

- Many models predict LFV at the level that can be detected at SuperB
- LFV also sensitive to other observable such as μ->eγ (MEG), θ_{13} (T2K) and B_s mixing phase (LHCb)
- Polarization doubles sensitivity (not included in numbers below)



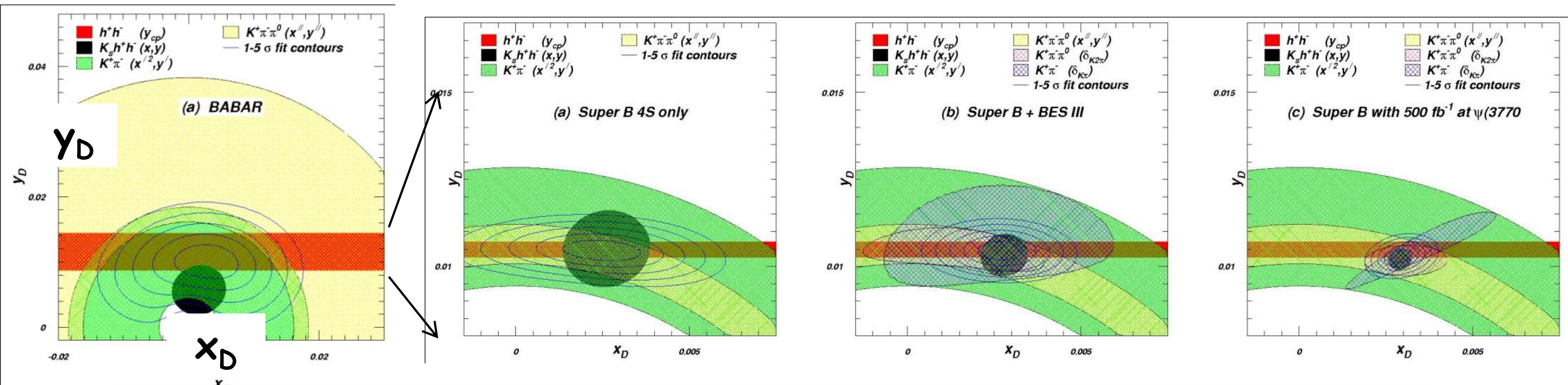
Model	BF(τ→μγ)
mSUGRA+seesaw	10^{-7}
SUSY+SO(10)	10^{-8}
SM+seesaw, Z'	10^{-9}
SUSY+Higgs	10^{-10}
SM + υ mixing	10^{-40}



Over 50 τ decays can be measured (not to mention spectral functions, second class currents, α_s etc...)

Physics - Charm and Charm CPV

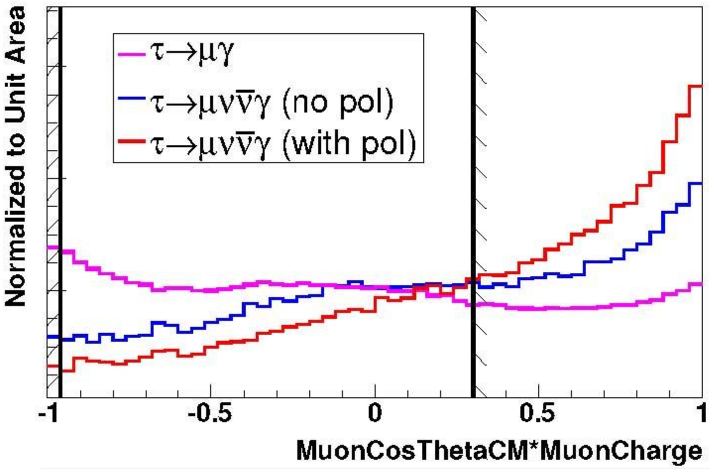
- CPV in SM very small => CPV indicates New Physics
- Measure strong phases
- Charm Unitarity Triangle (β_c, $|V_{cd}|$, $|V_{cs}|$, and more..?)



	Now	SuperB	SuperB+BES	SuperB+BES+φ(3770)
x (x 10^3)	±3	±0.7	±0.4	±0.2
y (x 10^3)	±2	±0.2	±0.2	±0.1
$\delta_{k\pi}$	±10°	±3°	±2°	±1°
$\delta_{k\pi\pi}$	±20°	±5°	±3°	±1°

Benefits of Polarized Electron Beam

1) LFV:
Doubles Precision



2) τ EDM, τ g-2:

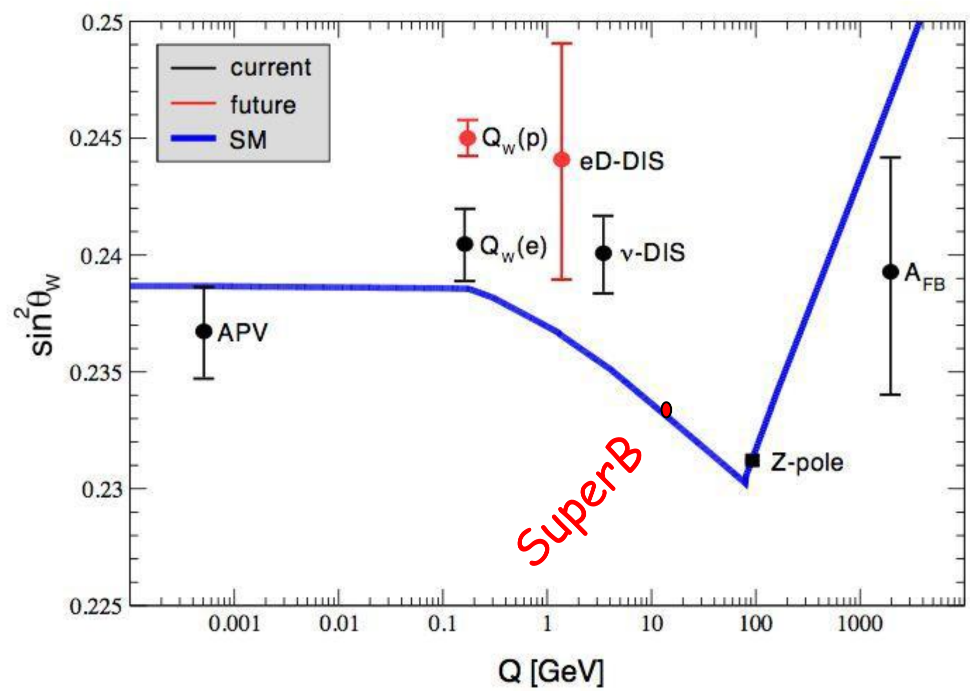
Measurement could prove or disprove discrepancy in $\Delta\alpha_\mu$ due to New Physics.

EDM sensitivity ~ 2 x 10^{-19} e cm

- **$\Delta\alpha_\tau$ (SM) ~ 10^{-6}**
- **$\Delta\alpha_\tau$ (SUSY) <~ 10^{-5}**
- **$\Delta\alpha_\tau$ (SuperB) precision~ 10^{-6}**

3) Electroweak:

- Investigate LEP A_{FB} v. SLD A_{LR} discrepancy.
- Investigate NuTev discrepancy.
- Constrain Higgs mass
- $\sin^2\theta_W$ resolution ±0.00018
- Perhaps measure even at ψ(3770)



Machine Parameters are stable

Table 3.1: Super*B* parameters for baseline, low emittance and high current options, and for tau/charm running.

		Base Line		Low Emittance		High Current		Tau-charm	
Parameter	**Units**	**HER (e+)**	**LER (e-)**	**HER (e+)**	**LER (e-)**	**HER (e+)**	**LER (e-)**	**HER (e+)**	**LER (e-)**
LUMINOSITY	$cm^{-2} s^{-1}$	1.00E+36		1.00E+36		1.00E+36		1.00E+35	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18	2.58	1.61
Circumference	m	1258.4		1258.4		1258.4		1258.4	
X-Angle (full)	mrad	66		66		66		66	
β_x **@ IP**	cm	2.6	3.2	2.6	3.2	5.06	6.22	6.76	8.32
β_y **@ IP**	cm	0.0253	0.0205	0.0179	0.0145	0.0292	0.0237	0.0658	0.0533
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.5	0.5	0.25	0.25
Emittance x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
Emittance y	pm	5	6.15	2.5	3.075	10	12.3	13	16
Bunch length (full current)	mm	5	5	5	5	4.4	4.4	5	5
Beam current	mA	1892	2447	1460	1888	3094	4000	1365	1766
Buckets distance	#	2		2		1		1	
Ion gap	%	2		2		2		2	
RF frequency	MHz	476.		476.		476.		476.	
Revolution frequency	MHz	0.238		0.238		0.238		0.238	
Harmonic number	#	1998		1998		1998		1998	
Number of bunches	#	978		978		1956		1956	
N. Particle/bunch (10^{10})	#	5.08	6.56	3.92	5.06	4.15	5.36	1.83	2.37
σ_x **effective**	μm	165.22	165.30	165.22	165.30	145.60	145.78	166.12	166.67
σ_y **@ IP**	μm	0.036	0.036	0.021	0.021	0.054	0.0254	0.092	0.092
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
Σ_x **effective**	μm	233.35		233.35		205.34		233.35	
Σ_y	μm	0.050		0.030		0.076		0.131	
Hourglass reduction factor		0.950		0.950		0.950		0.950	
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.097	0.097	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Longitudinal damping time	msec	13.4	20.3	13.4	20.3	13.4	20.3	26.8	40.6
Energy Loss/turn	MeV	2.11	0.865	2.11	0.865	2.11	0.865	0.4	0.17
Momentum compaction (10^{-4})		4.36	4.05	4.36	4.05	4.36	4.05	4.36	4.05
Energy spread (10^{-4}) (full current)	dE/E	6.43	7.34	6.43	7.34	6.43	7.34	6.43	7.34
CM energy spread (10^{-4})	dE/E	5.0		5.0		5.0		5.0	
Total lifetime	min	4.23	4.48	3.05	3	7.08	7.73	11.4	6.8
Total RF Wall Plug Power	MW	16.38		12.37		28.83		2.81	

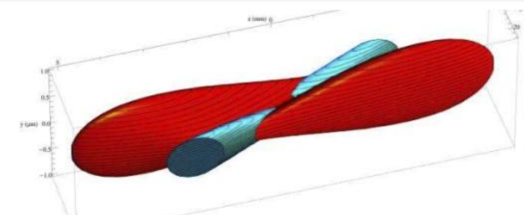
arXiv:1009.6178

Tau/charm threshold running

Flexibility built in, no single critical element

Upgradable to 4x higher lumi

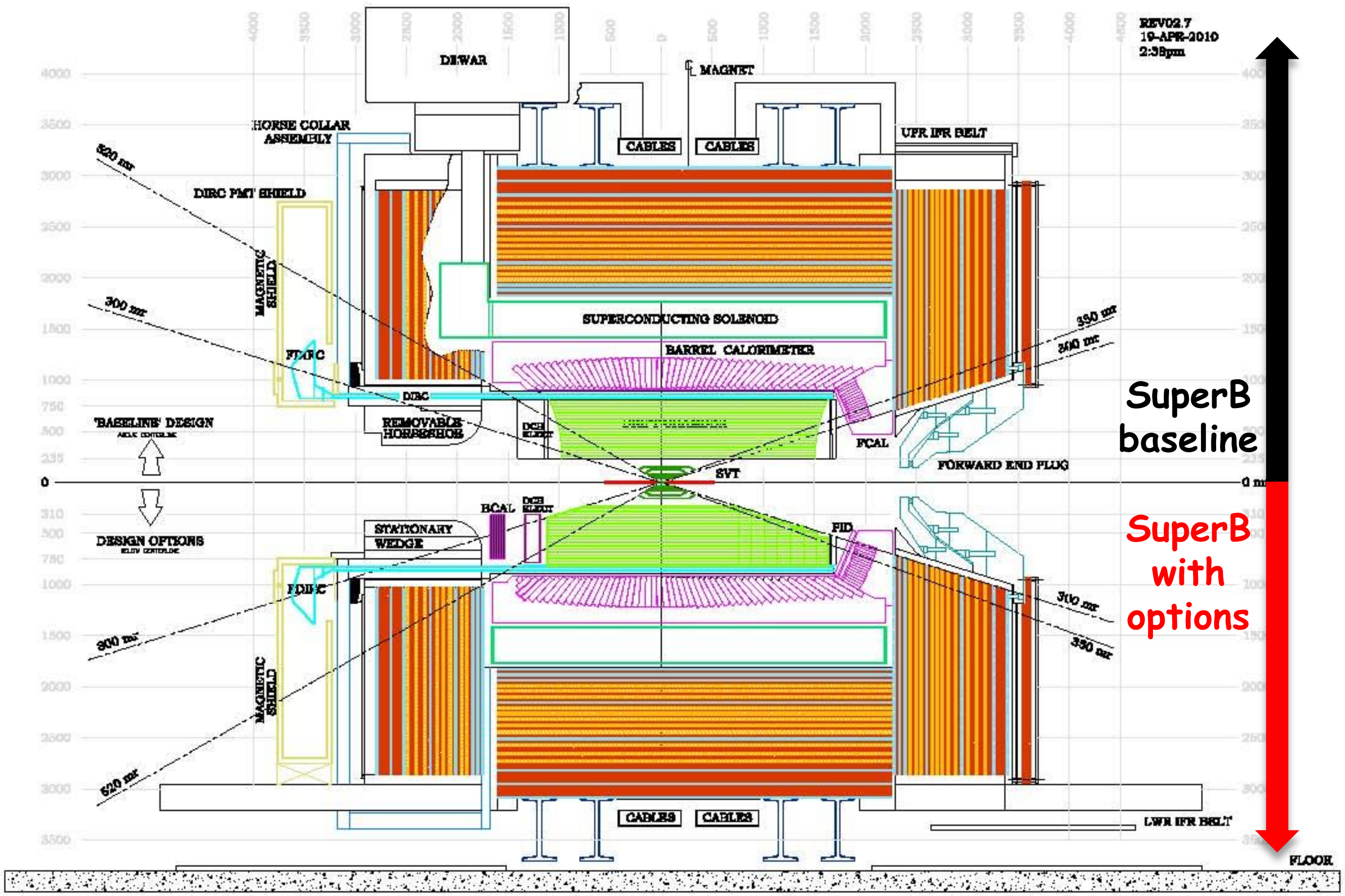
Piwinski angle and crab-waist crossing test at DaΦne



Low power < 20MW

Detector Design [arXiv:1007.4241]

Reuses much of BaBar e.g. CsI crystals



SuperB baseline

SuperB with options

Double Vertex resolution

Improved hermiticity

TOF Forward PID

Cluster counting in drift chamber (improves dE/dx)

Backward EMC

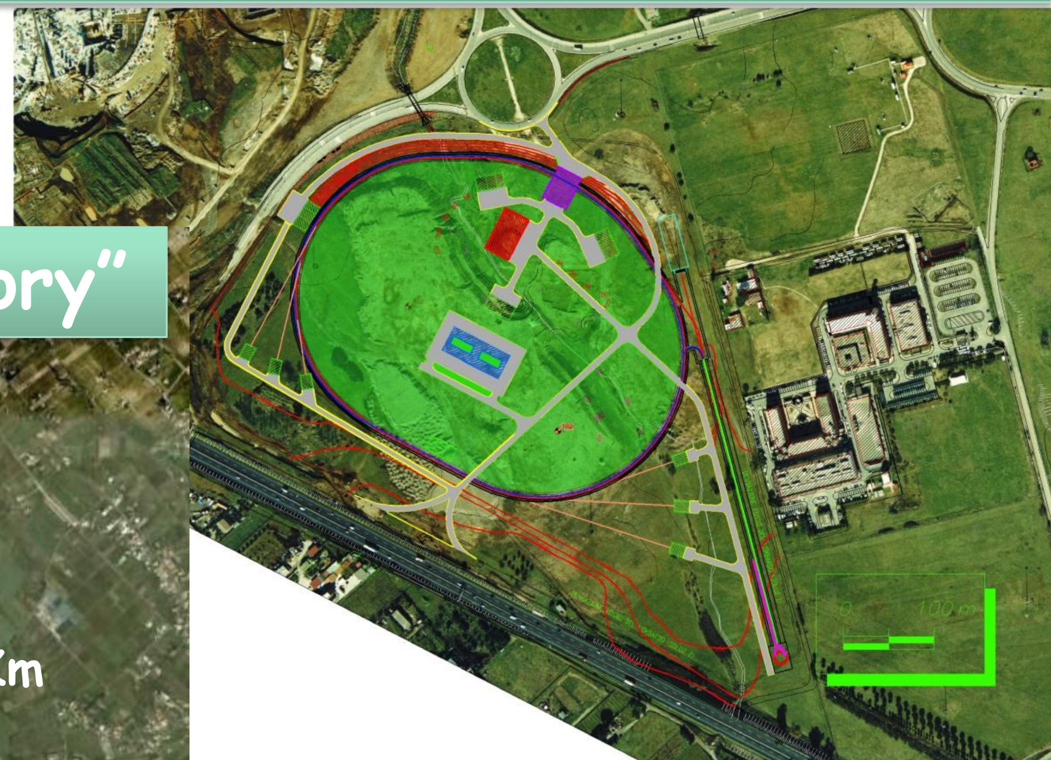
Optimized IFR (muons)

SuperB – Funding and Developments

- SuperB approved through primary law by Italian parliament, December 14th/15th 2010.
- Parliament also approved INFN "Piano Triennale" 2010-2012 funding profile which includes SuperB.
- SuperB is a "Progetti Bandiera" national flagship project. 8% of national research budget allocated to flagship projects.
- Funding:
  - 19M€ in 2010, 50M€ per year thereafter until EOY 2015. SuperB is the only project receiving multi-year funding so far.
  - ~120M$ in-kind contribution from US through use of PEP-II machine components and BaBar detector.
  - 50M€ allocated for Tier 2 Grid computing centres in Southern Italy.
  - ~100M€ via Italian Institute of Technology (IIT) for beam-lines.
- Only ~25M€ needed from international collaborators for detector
- Conclusion: solid funding in an uncertain financial world.

Site Decision announced May 30th 2011

Tor Vergata University Campus



"N. Cabibbo Laboratory"

Frascati

Conclusion, Outlook and Opportunities

- August 2010: Physics, Accelerator, Detector reports published.
- SuperB has been approved by the Italian Government, December 2010, as a "Flagship" project.
- A unique opportunity for Europe and International Collaboration.
- The necessary funding is in place.
- First beams in ~2016. 15 ab^{-1}/year rising to 40 ab^{-1}/year.
- Site selection announced May 30th 2011.
- Present participation in preparation by Italy, Canada, France, Germany, Poland, Russia, Spain, UK, US.
- Collaboration is still growing. Working towards TDR. Opportunities in detector, accelerator, computing and physics.
- Spokesperson: Marcello.Giorgi@pi.infn.it

Backup

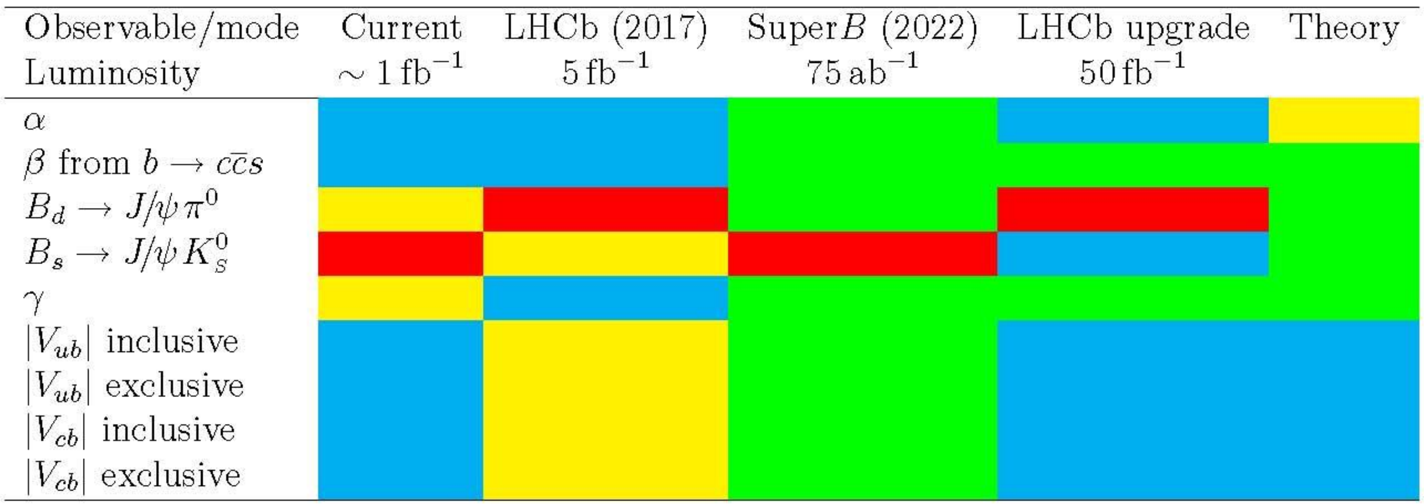
Golden measurements: General

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

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	
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	
S (other penguin modes)	Yellow	Yellow	Green	Blue	Yellow	Right handed currents
A_{CP} $(B \to X_s\gamma)$	Blue	Yellow	Green	Yellow	Yellow	SuperB measures many more modes
BR$(B \to X_s\gamma)$	Blue	Yellow	Green	Yellow	Yellow	systematic error is main challenge
BR$(B \to X_s ll)$	Yellow	Red	Green	Red	Green	control systematic error with data
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	Clean NP search
CP Violation	Red	Blue	Green	Green	Green	
Precision Electroweak						
$\sin^2\theta_W$ at $\Upsilon(4S)$	Red	Red	Green	Red	Green	Theoretically clean
$\sin^2\theta_W$ at Z-Pole	Red	Blue	Red	Green	Yellow	b fragmentation limits interpretation

Golden Measurements: CKM

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



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.