New Physics Search Potential of SuperB

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Outline

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- Physics Motivation and Reach
- Project Status
- Accelerator
- Detector
- Summary

Project Synopsis

- Precision Flavor Physics Measurements
  - Flavor physics observables provide crucial, complementary information for understanding new physics in the LHC era
  - x10 better precision than present B-Factories
- Very High Luminosity
  - Asymmetric e^+e^- collider in the 10 GeV region
  - Collect 75 ab^{-1} in 5 years
  - Luminosity = 10^{36} $cm^{-2}s^{-1}$
- Innovative Accelerator Concept
  - Allows x100 increase in luminosity compared to BaBar with no increase in wall plug power
  - Polarized e^- beam
  - Ability to run near charm threshold
  - Upgrade path to $4x10^{36}$ $cm^{-2}s^{-1}$
- Re-uses Major Pieces of Equipment
  - Both accelerator (PEP-II) and detector (BaBar)
  - ~135M€ value
- **Approved by the Italian Government!**
  - Multi-year funding commitment

Physics at SuperB

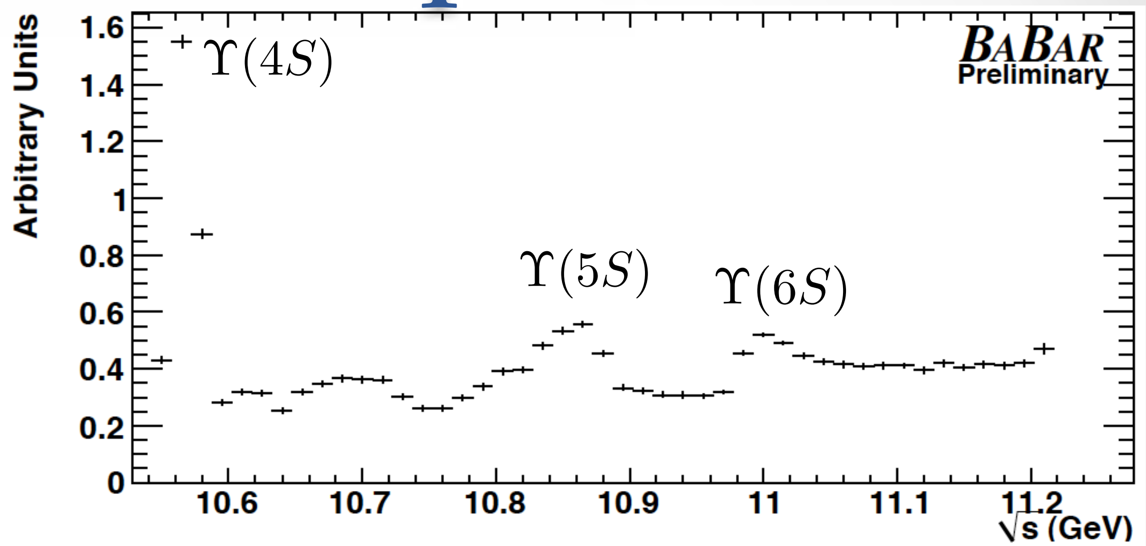
- Extremely Broad Frontier Physics Program
  - Precision (~1%) test of CKM
    - Will measure angles and sides of Unitarity Triangle at $\Upsilon(4S)$
    - Measure other CKM elements at charm threshold
    - Pattern of deviation, if any, from SM can diagnose the New Physics being seen
  - Program of τ physics, including LFV, EDM, CPV, g-2
  - Precision EW physics with polarized beam
  - And much more!
    - CPV at charm threshold
    - Low-energy e^+e^- physics via ISR (radiative return)
    - Spectroscopy and exotics
    - Search for light dark matter and light Higgs
    - The $\Upsilon(5S)$ region (B_S physics)

Physics at SuperB

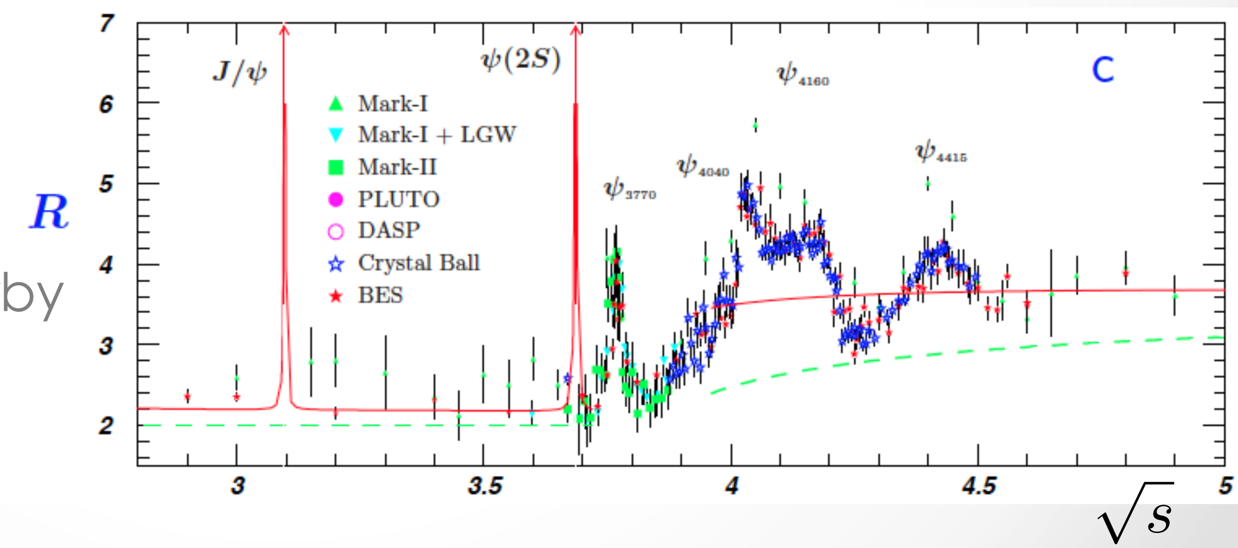
- Discovery Science: Strong Physics Motivation Independent of LHC Findings
    - If LHC finds NP, essential to measure flavor couplings
    - If LHC does not find NP, unique approach to multi-TeV scale through precision measurements
- Clean, High-Precision Experimental Environment
    - Excellent detector with good hadronic PID, γ detection, lepton ID, etc.
    - *B*-recoil technique for decays like $B \rightarrow \tau\nu$, $B \rightarrow D^{*}\tau\nu$, etc.
    - Polarized e^- beam for cleaner τ LFV studies and precision EW
    - Ability to run in Υ region as well as at lower energies
- **Clean signals in a wide variety of modes and physics channels**

Data sample

- $\Upsilon(4S)$ region:
  - 75 ab^{-1} at the 4S
  - Also run above / below the 4S
  - ~75 x10^9 *B*, *D* and τ pairs



- ψ(3770) region:
  - 500 fb^{-1} at threshold
  - Also run at nearby resonances
  - ~2 x 10^9 *D* pairs

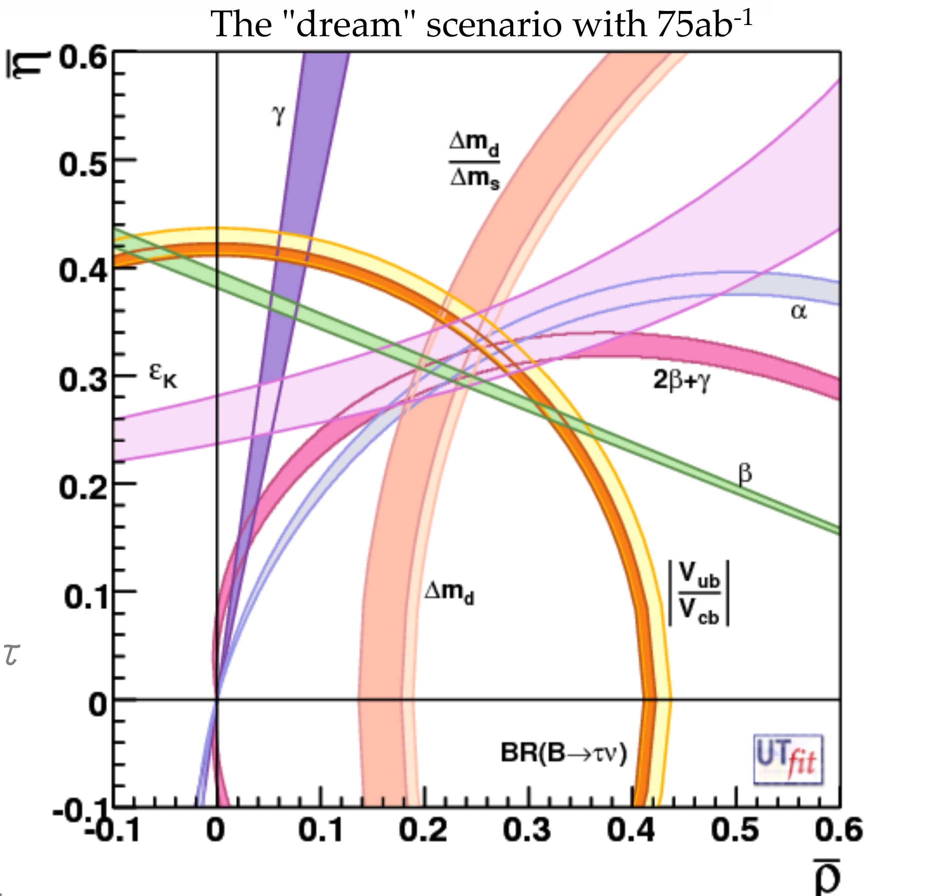


Some Topics of Interest for SuperB

- Precision determination of CKM parameters
  - Measurements of α, β, γ, f_B, Δm_d, V_{ub} and V_{cb}
- Sensitive searches for charged lepton flavor violation (LFV) in rare τ decays
  - LFV in rare τ decays
  - CP violation in τ decay and T violation in τ production
  - Limits on a τ EDM and anomalous magnetic moment
- Measurements of *CP*-violating asymmetries in rare penguin-dominated *B* and *D* decays
  - Modes such as $B \rightarrow \phi K_S$ or $B \rightarrow \eta' K_S$
  - *CP*-violating asymmetries in FCNC decays such as $b \rightarrow s\gamma$ and $b \rightarrow sll$
  - Sensitive searches for *CP* violation in D^0 decays
- Measurements of kinematic distributions and branching ratios in rare *B* and *D* decays
  - Forward-backward asymmetry in $b \rightarrow sll$ decays
  - Branching fraction for $B \rightarrow \tau \nu_\tau$ decay
- Sensitive studies of the rich spectroscopy found in Υ decays and searches for exotic states

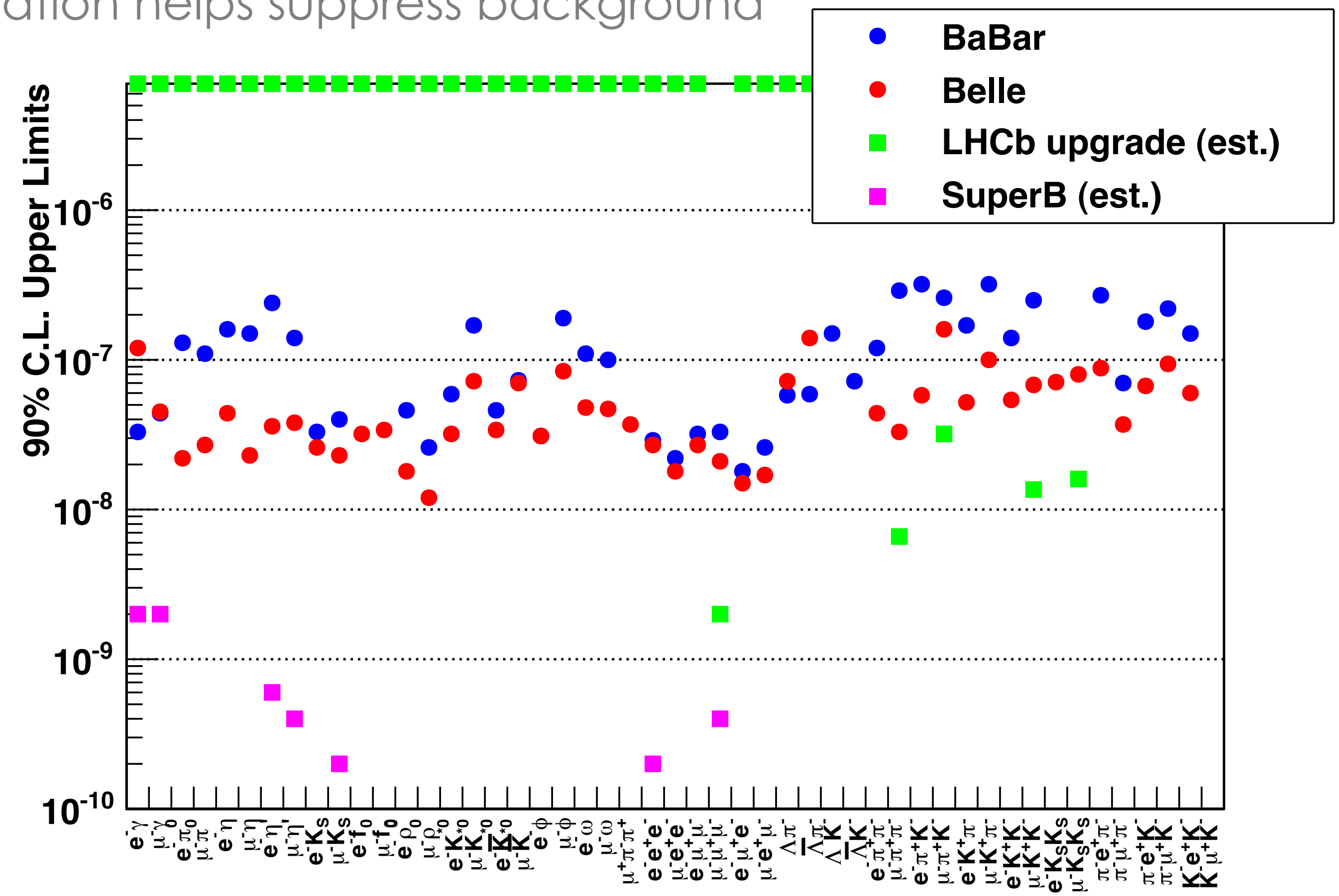
Precision CKM Constraints

- Unitarity Triangle Angles
  - $\sigma(\alpha) = 1\text{–}2°$
  - $\sigma(\beta) = 0.1°$
  - $\sigma(\gamma) = 1\text{–}2°$
- CKM Matrix Elements
  - $|V_{ub}|$
    - Inclusive $\sigma = 2\%$
    - Exclusive $\sigma = 3\%$
  - $|V_{cb}|$
    - Inclusive $\sigma = 1\%$
    - Exclusive $\sigma = 1\%$
  - $|V_{us}|$
    - Can be measured precisely using τ decays
  - $|V_{cd}|$ and $|V_{cs}|$
    - can be measured at/near charm threshold.
- SuperB measures the sides and angles of the Unitarity Triangle



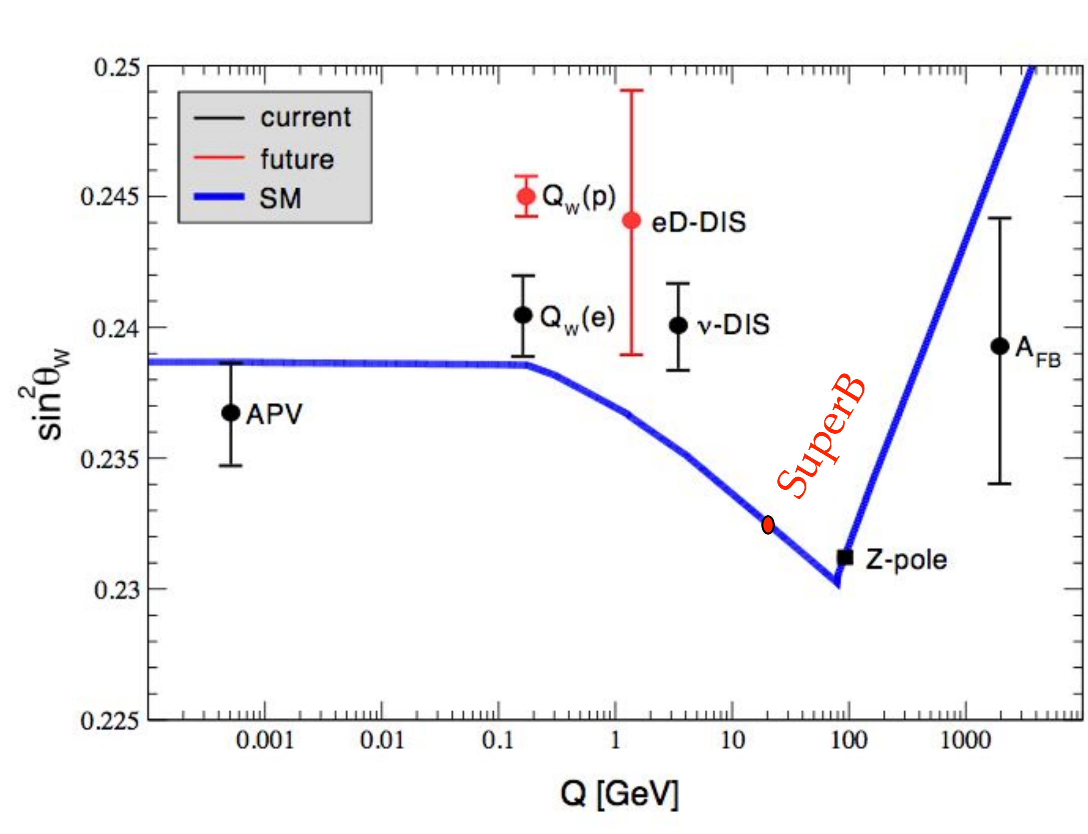
τ Lepton Flavor Violation (LFV)

- ν mixing leads to a low level of charged LFV ($B \sim 10^{-54}$).
  - Enhancements to observable levels are possible with new physics.
- e^- beam polarisation helps suppress background
- One to two orders of magnitude improvement at SuperB over current limits



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



Measure LR asymmetry in:

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

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

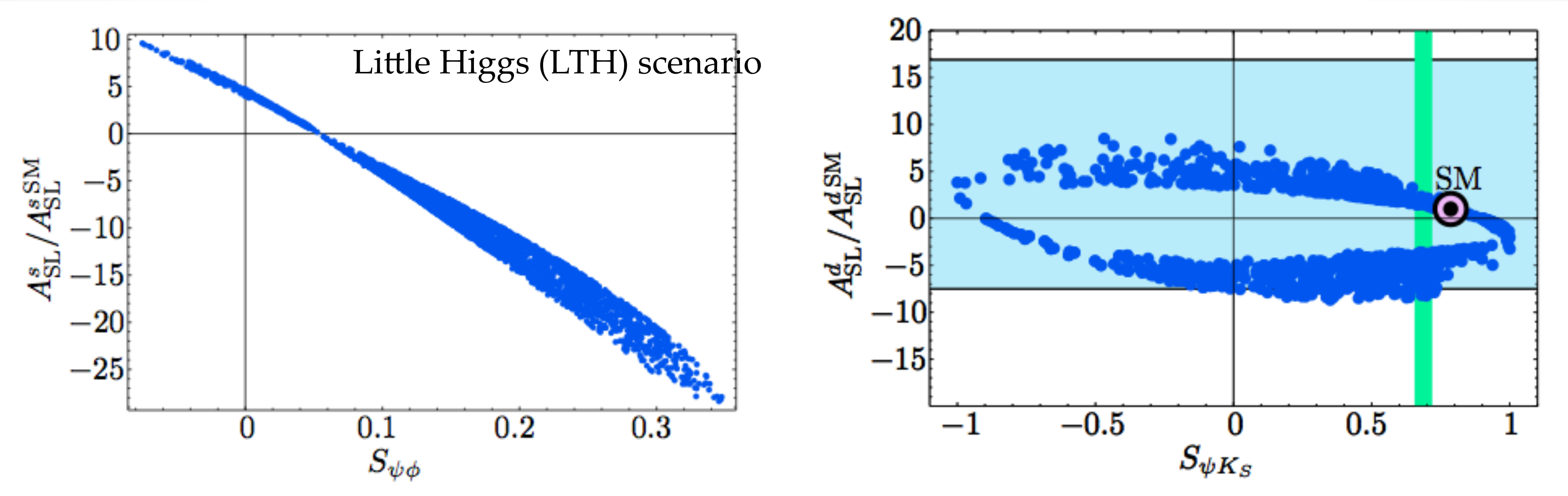
Can also perform crosscheck at ψ(3770).

B_s physics

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

$$A^s_{\rm SL} = \frac{\mathcal{B}(B_s \to \overline{B}_s \to D_s^{(*)-} l^+ \nu_l) - \mathcal{B}(\overline{B}_s \to B_s \to D_s^{(*)+} l^- \nu_l)}{\mathcal{B}(B_s \to \overline{B}_s \to D_s^{(*)-} l^+ \nu_l) + \mathcal{B}(\overline{B}_s \to B_s \to D_s^{(*)+} l^- \nu_l)} = \frac{1 - |q/p|^4}{1 + |q/p|^4} .$$

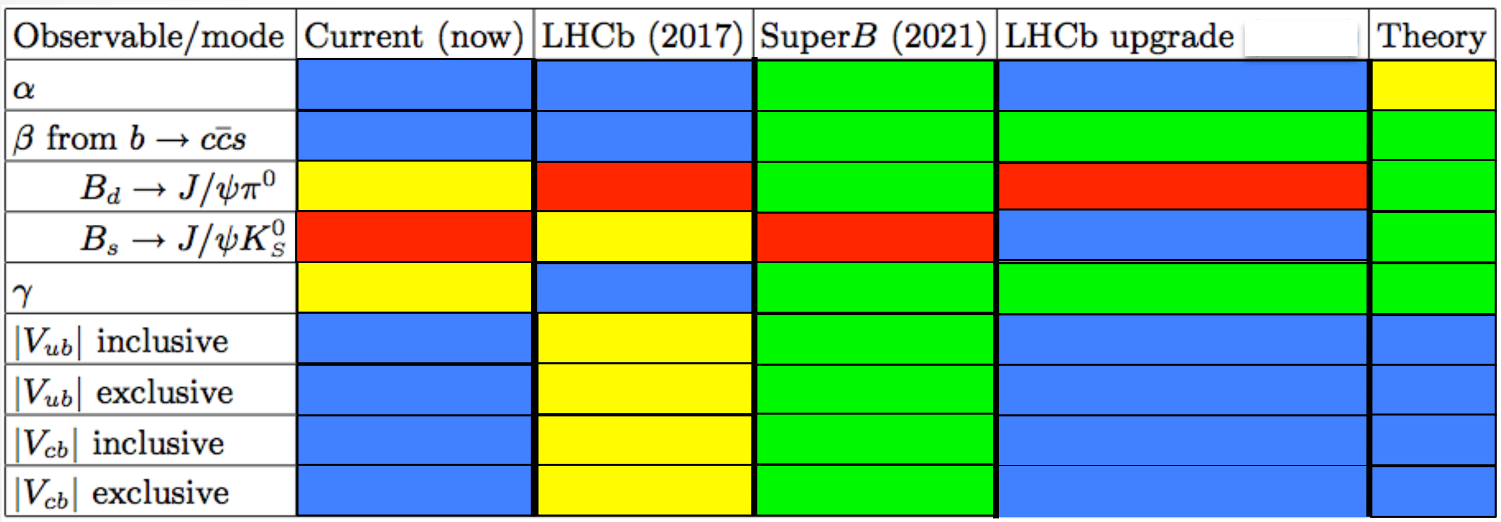
$$\sigma(A^s_{SL}) \sim 0.004 \text{ with a few } ab^{-1}$$



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

Golden Measurements: CKM

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



LHCb can only use $\rho\pi$

βtheory error B_d
βtheory error B_s

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

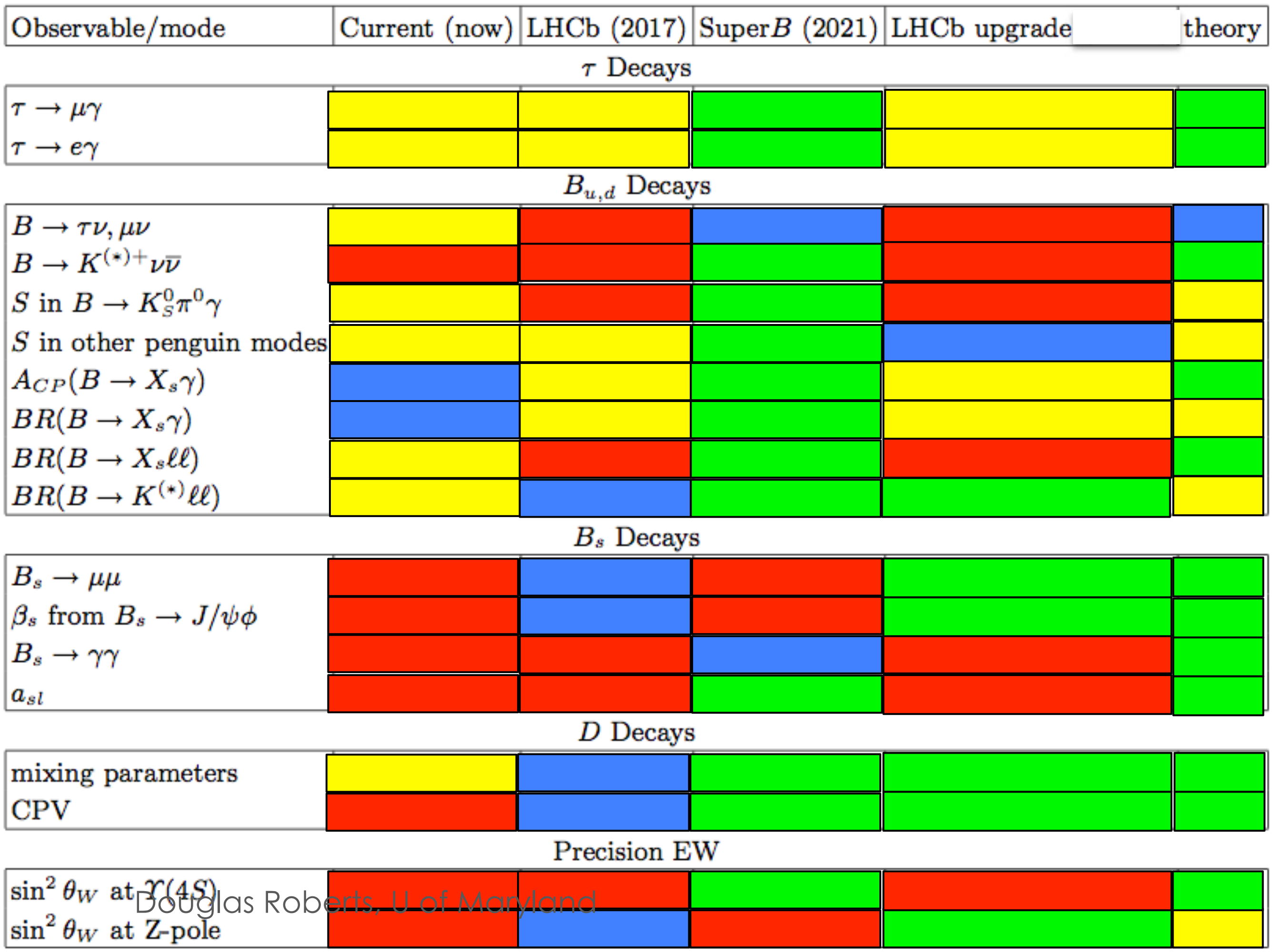
Experiment: No Result Moderate Precision Precise Very Precise

Theory: Moderately clean Clean Need lattice Clean

Golden Measurements: General

Experiment: No Result | Moderate Precision | Precise | Very Precise

Theory: Moderately clean | Clean Need lattice | Clean



Benefit from polarised e⁻ beam

very precise with improved detector

Stat. limited: Angular analysis with >75ab^{-1}

Right handed currents

SuperB measures many more modes

systematic error is main challenge

control systematic error with data

SuperB measures e mode well, LHCb does μ

Clean NP search

Theoretically clean

b fragmentation limits interpretation

Project Status: Approval!

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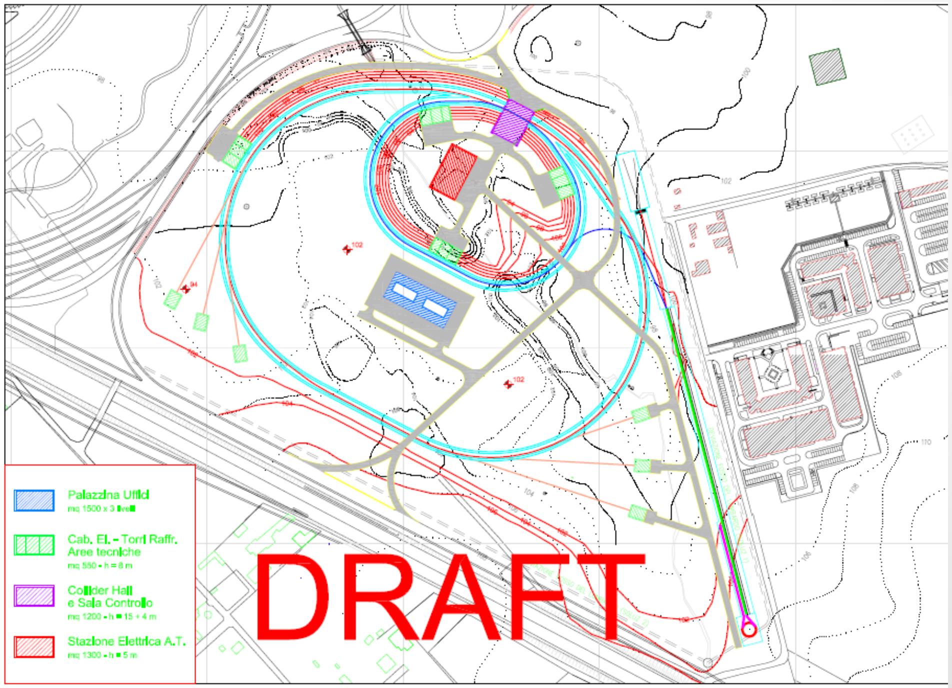
Project Status

- April 2010: SuperB becomes one of 14 Italian National Research Program (PNR) Flagship Projects
  - Cooperation between INFN and IIT (Italian Institute of Technology)
  - HEP experiment and light source
- December 2010: Approval by Ministry of Instructions, University and Research and Parliament
  - 19M€ provided as first part of a multi-year funding plan
- April 2011: Full Italian government approval of the PNR, including 250M€ for SuperB

Site Selection

- Facility will be constructed at Tor Vergata
  - About 4.5 km from existing Frascati Laboratory
  - "Nicola Cabibbo Laboratory"

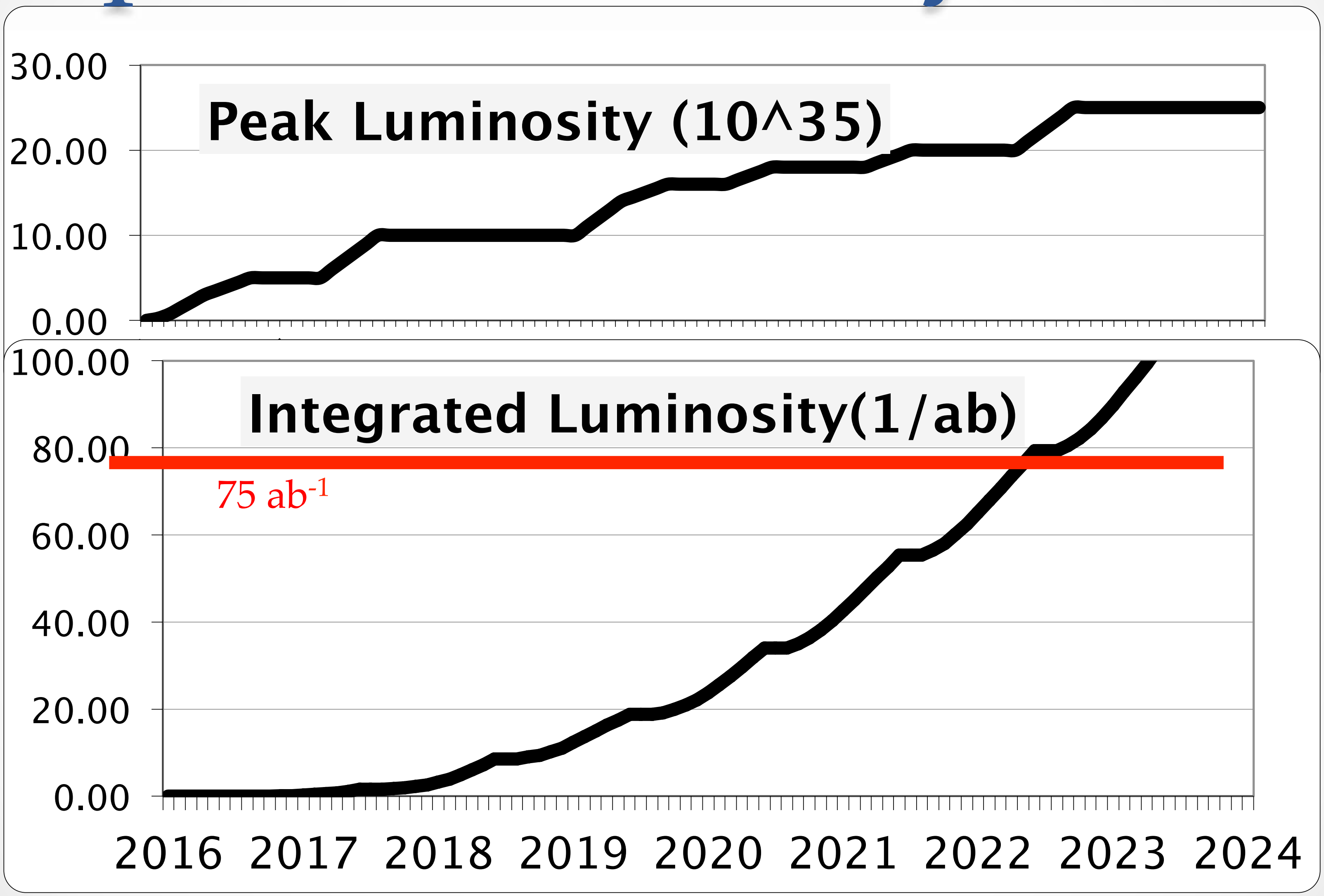


Accelerator

Requirements From Physics

Parameter	Requirement	Comment
Luminosity (top-up mode)	10^{36} cm^{-2}s^{-1} @ $Y(4S)$	Baseline/Flexibility with headroom at 4. 10^{36} cm^{-2}s^{-1}
Integrated luminosity	75 ab^{-1}	Based on a "New Snowmass Year" of 1.5 x 10^7 seconds (PEP-II & KEKB experience-based)
CM energy range	τ threshold to $Y(5S)$	For Charm special runs (still asymmetric……)
Minimum boost	$\beta\gamma$ ≈0.237 ~(4.18x6.7GeV)	1 cm beam pipe radius. First measured point at 1.5 cm
e^- Polarization Boost up to 0.9 in runs at low energy under evaluation for charm physics	≥80%	Enables τ *CP* and *T* violation studies, measurement of τ *g*-2 and improves sensitivity to lepton flavor-violating decays. Detailed simulation, needed to ascertain a more precise requirement, are in progress.

SuperB Luminosity Model

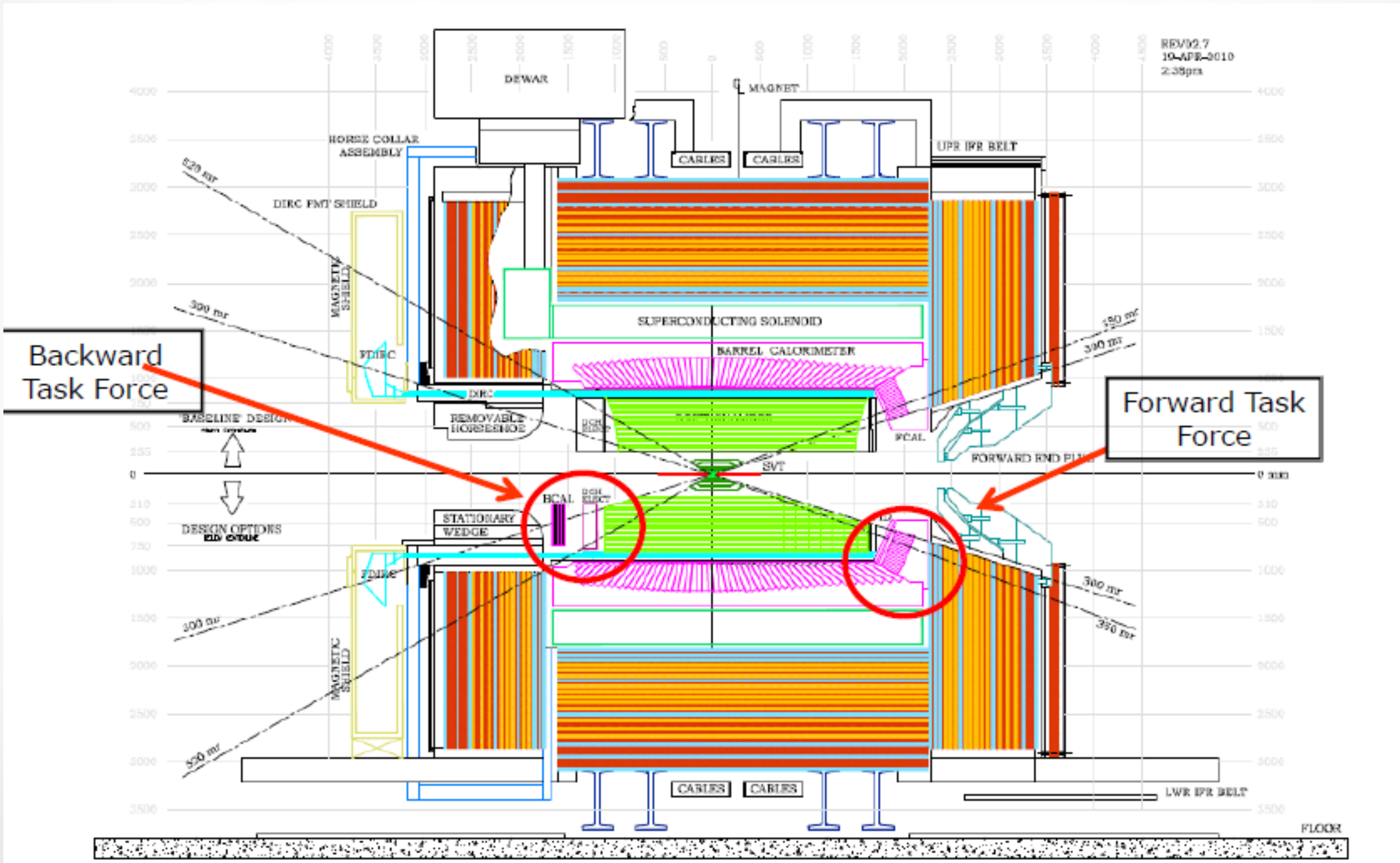


Detector

From BaBar to SuperB

- SuperB detector based on the "BaBar Prototype". It re-uses:
  - Fused Silica bars from the BaBar DIRC (PID, ring imaging Cerenkov detector)
  - PID and Drift Chamber support structure
  - Barrel calorimeter CsI(Tl) crystals and mechanical structure
  - Superconducting coil and flux return (with some redesign)
- Still require moderate design improvement and R&D to cope with new machine IR, high luminosity environment, smaller boost, and high DAQ rates
  - Small beam pipe technology
  - This silicon pixel detector for first layer and new 5-layer silicon vertex detector
  - New drift chamber with modified gas and cell size
  - New photon camera for DIRC bars
  - Possible forward PID system
  - New forward calorimeter crystals
  - Backward calorimeter veto option
  - Extruded scintillator for flux return
  - Electronics, trigger, computing…

SuperB Detector



Conclusion

- The SuperB project has recently been approved by the Italian Government!
- The site has been officially selected: "Nicola Cabibbo Laboratory"
- First beams expected in 2016
- Detector R&D is progressing, with expected completion of a TDR before 2012 and transition to construction phase
- Collaboration is still forming…
- Exciting Flavor Physics program, complementary to LHC physics program