UK involvement in SuperB

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Introduction:

As the focus of PPAP is to review areas of research, we have prepared a short summary of SuperB focussing on the practicalities of realizing a UK involvement in this future experiment. There are two e^+e^- Super Flavour Factory experiments currently under consideration within the international community: SuperB in Italy, and SuperKEKB in Japan. The physics program of SuperB is more ambitious than SuperKEKB. SuperB will record more data (75 ab^{-1} at the $\Upsilon(4S)$ resonance compared to 50 ab^{-1} for SuperKEKB) and is unique in being able to run with polarization of the e^- beam and at charm threshold, $\psi(3770)$, as well as at all the major $\Upsilon(NS)$ resonances (1S through 5S). The KEK proposal does not include all these options and is therefore not nearly as interesting. The Cockcroft Institute, the STFC Rutherford Appleton Laboratory and Queen Mary University of London are interested in participating in both the SuperB detector and the accelerator.

Timescale:

The relevant timescales for the SuperB project are as follows:

Initial Physics Design Study published December 2004.
Conceptual Design Report published March 2007.
Decision to host SuperB by the Italian Government, December 2009.
Preparation of a Technical Design Report: now through Feb 2011.
Construction Phase 2011-2015.
Commissioning and Data taking 2015 onward.

It is envisaged that a data sample of 75 ab^{-1} would be collected at the $\Upsilon(4S)$ resonance after 5 years of nominal data taking. Toward the end of this time period one would also perform dedicated runs at other resonances for new physics searches at low energy.

Finance:

The financing required to build SuperB would be a source of new money introduced into the field by the Italian government.

Machine:

The SuperB machine design was approved by the Machine Advisory Committee in April 2009. The novel accelerator techniques required to realize the SuperB are central to improving the luminosity of a number of colliders around the world. The DAΦNE facility has already seen a factor four improvement in instantaneous luminosity from the use of the crabbed waist technique that is key to the SuperB machine design. Experts from SLAC, CERN, KEK and Novosibirsk are actively seeking to work with SuperB machine experts to realize benefits elsewhere. Some of the accelerator expertise required to realise SuperB will also benefit any future linear collider.

Leading accelerator experts from the Cockcroft Institute in the UK have been invited to participate in R&D toward the realization of the machine, and anticipate working on core issues that will place the UK in a leading role within the machine group.

The Host Facility:

[1] Queen Mary University of London
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Two alternative sites are available, one on the Tor Vergata campus near Rome and the other on the INFN Frascati site. Both are feasible and initial quotes for construction costs have been obtained. Negotiations on contracts are currently underway but the management does not envisage any problem.

Detector:

The UK detector interest is in the possibility of designing and building a compact silicon vertex detector based on monolithic active pixel sensors. The maximum silicon area of this device would total approximately 1 m^2 of silicon, consisting of up to 5 concentric layers of pixel detectors. The underpinning pixel technology has been pioneered by STFC through the SPiDeR, CALICE and LCFI collaborations. A modest amount of R&D would be required in order to tailor a application-specific design to the SuperB detector and to handle the expected radiation environment.

Possible Cost of UK Involvement:

The cost of UK involvement will be commensurate with the level of UK participation at that time. This would be at a level that would be similar to or less than the investment in BaBar. It is estimated that the cost of developing such a detector would be $8.2M, or approximately £5.2M. In addition to this one would require 56 FTEs to develop and construct the detector. It is anticipated that the UK could contribute up to 50% of the cost of this system, limiting the UK exposure to £2.6M and 30FTEs. Given its expertise in pixel sensors and low-mass mechanics, the UK would probably focus on the sensors and mechanical support. Eight institutes signed a PRD working toward SuperB in 2006. As the current funding climate is conducive to people moving toward approved and funded projects, we would anticipate a similar number institutes being involved in the experiment after it becomes an official project.

Knowledge Exchange:

The detector and accelerator technology would bring substantial benefit to UK industry as well as the technical capability of the STFC accelerator and detector knowledge base. World leading STFC technology could be deployed in a modern experiment as a natural extension of existing R&D, and at the same time providing a demonstration of the viability of the technology for future silicon pixel detectors. Advances in accelerator technology will be driven by the need to achieve and maintain beams of unprecedented quality and stability; there will need to be developments, for example, in instrumentation and controls, and precision manufacture of components in the vacuum system. Leadership by the Cockcroft Institute in these areas will provide opportunities for UK industry in SuperB and in future accelerator projects.

Competitor Experiments:

The LHCb (upgrade) experiment is not a direct competitor of SuperB, both experiments are complementary and there are synergies between LHCb and SuperB on a number of measurements. The Belle-II collaboration is the only direct competitor for SuperB. The Belle-II collaboration originally concentrated on trying to realize a high current design for their machine. This was recently abandoned and they are now working on re-designing their machine to adopt the SuperB low-emittance strategy. The official start date for Belle-II is 2013 but this has not been updated since the change in accelerator design.

Why SuperB and not Belle-II?

- SuperB has a much broader physics program than Belle-II. This includes a 50% larger data sample at the $\Upsilon(4S)$, a polarized electron beam indispensable for τ physics (LFV, CP Violation, g-2 etc...), an ability to run at all the major $\Upsilon(NS)$ resonances (1S through 5S) and at the $\psi(3770)$ in order to study correlated neutral D meson pairs.

- The SuperB accelerator has been extensively reviewed and is considered viable by the Machine Advisory Committee, while the SuperKEKB machine is still undergoing significant redesigning efforts.
- The UK already has significant leadership roles on SuperB. The UK has a seat on the International Steering Committee and is involved in the physics design and computer simulation. This is something that can be used as a base for further consolidation of leadership.
- It would be easier (and cheaper) for the UK accelerator community to play a significant role in understanding machine operation of a European Super Flavour Factory than a more distant machine in Asia.
- SuperB is a regional European project that if realized, will enhance Europe's world leading role in particle physics. Supporting SuperB would benefit the UK in the future should we wish to host our facility (e.g. a neutrino factory).
- The different structures and cultures of the two collaborations mean that the UK can have a greater influence in the design, build a more significant detector component and have a higher physics impact on SuperB than Belle-II.

Physics:

There are many models of new physics, and these can enhance or suppress rates relative to the Standard Model in different ways. There is a *Golden Matrix* of measurements that SuperB can make that will disentangle the puzzle of new physics at or above the TeV scale. The physics case of SuperB includes precision measurements and new physics constraints through the study of B, D, Υ(NS) and τ particles. The highlights of these measurements include:

- Lepton Flavour Violation searches in τ decay. Current experimental limits are ~1 to 2×10^{-8} from the B factories for τ to 3 leptons. The LHC will not be able to improve significantly on these limits. A measurement from SuperB will reach sensitivities of a few 10^{-10}, a precision that will challenge a large number of models.
- $B\rightarrow l\nu$ decays constrain the charged Higgs mass vs. $\tan\beta$ more strongly than expected at the LHC. SuperB will be able to reach sensitivities above the TeV energy scale with this channel [this is a model independent energy reach]. Current limits from the B-factories are about factor of 20 stronger than the Tevatron.
- Measurements of inclusive $b\rightarrow s\gamma$ and $b\rightarrow sl^+l^-$ can be combined to constrain SUSY flavour couplings and establish if these are non-trivial at an energy scale of a TeV. Theoretically clean inclusive measurements are only possible in a clean environment.
- $\sin2\beta$ can be measured in tree and penguin modes and compared to SM expectations and other parameters such as $|V_{ub}|$. Current discrepancies are at a level of $\sim2.7\sigma$.
- Improved searches for light Higgs and Dark Matter candidates will be performed (more than 10 times better than existing experiments) using Υ decays.
- Precision measurements of charm decays would enable tests of new physics via CP violating observables and rare charm decays.
- A 16-20% measurement of the rate of $B\rightarrow K\nu\nu$ will be made. Using this we will able to constrain some models of new physics.
- In addition to the above highlights, one should also remember that the Standard Model physics programme of SuperB would reduce the 'CKM uncertainty budget' on new physics searches in rare kaon decays. For example, one would perform ~1° measurements of all angles of the unitarity triangle, reaching this precision with a number of different channels. Also measurements of branching fractions of B_S decays made using data recorded at Y(5S) would help the interpretation of a number of results from LHCb.