Scope of Presentation:

Future prospects at BES-III and the BINP SuperB \( \text{c/}\tau \)

Physics Prospects and Status of Belle-II and SuperB
Future prospects at BES-III and the BINP SuperB $c/\tau$
BES-III Datasets and Future Plans

(Xiaoyan Shen)

- 2009: 106M $\psi(2S)$ (4*CLEO-c $\psi(2S)$ sample)
  225M J/$\psi$ 4*BESII J/$\psi$ sample
- 2010: 900 pb$^{-1}$ $\psi(3770)$
- 2011: 1800 pb$^{-1}$ $\psi(3770)$ (3.5*CLEO-c $\psi(3770)$ sample)
  470 pb$^{-1}$ $\psi(4040)$
- 2012: tau mass, $\psi(2S)$: 0.4 billion, J/$\psi$: 1 billion, R scan

Looking to the future...

2013: $E_{cm}=4260$ and 4360 MeV for “XYZ” studies, R scan
2014: $E_{cm}=4170$ MeV for $D_s$ (~2.4 fb$^{-1}$)
2015-...? Additional 10 fb$^{-1}$ $\psi(3770)$ data

BESIII is scheduled to run another 8-10 years from now
Physics program:

- High statistic spectroscopy and search for exotics
  - Charm and charmonium spectroscopy
  - Spectroscopy of the highly excited Charmonium states (complementary to Bottomonium)
  - Light hadron spectroscopy in charmonium decays
- Precision charm physics
  - Precision charm→precision CKM (strong phases, $f_D$, $f_{Ds}$, form-factors...)
  - Unique source of coherent $D^0/D^0\bar{b}$ar states ($D^0$ mixing, CPV in mixing, strong phases for $\phi_3$ measurements at SuperB and LHC)
- Precision $\tau$-physics with polarized beams
  - Lepton universality, Lorentz structure of $\tau$-decay...
  - CP and T-violation in $\tau$ and $\Lambda_c$ decays
  - LFV decays ($\tau\rightarrow\mu\gamma$)
  - Second class currents (with kinematical constraints at threshold)
- Two photon physics and light hadronic cross section via ISR
BINF Super c/τ Factory (B. Shwartz, Tau2012 Nagoya)

Technical specifications:
- Beam energy from 1.0 to 2.5 GeV
- Peak luminosity is $10^{35}$ cm$^{-2}$s$^{-1}$ at 2 GeV
- Electrons are polarized longitudinally at IP
- On-line energy monitoring ($\sim$5-10 x 10$^{-5}$)

Main design features:
- Two rings with Crab Waist collision scheme and single interaction point
- Sub-mm beta-y at IP
- Preserving of damping parameters (by 4 SC wigglers) through the whole energy range to optimize the luminosity
- 5 Siberian snakes to obtain the longitudinally polarized electrons for the whole energy range
- Highly effective positron source (50 Hz top-up injection)
- Polarized electron source
- 2.5 GeV full energy linac
BINP Super $c/\tau$ Factory

Artistic view of future machine

Conceptual Design Report:
200 signatories from Germany, Israel, Italy, Slovenia, Russia

In 2012: project was included in top list of the 6 projects approved for further development by the Russian Governmental Commission on the Innovations and High Technologies
MOU between Cabibbo Lab and BINP

Source: CabibboLab/INFN  Content: Press Release  Date Issued: 11 September 2012

A major agreement was recently signed between the Nicola Cabibbo Laboratory Consortium (CLC) and the Budker Institute for Nuclear Physics (BINP) in Novosibirsk, Russia. The Memorandum of Understanding (MoU) will enable the joint development of projects for the construction of a SuperB Factory (B particles factory) in Rome and a SuperC-Tau Factory (C and tau particles factory) in Novosibirsk.
Physics Prospects and Status of Belle-II and SuperB

Specific talks in parallel sessions:
WG II Tues Horii, Lindemann
WG IV Sunday Finocchiaro
WG V Monday Onuki
WG VII Monday Branchini, Asner

Plus...
a host of presentations at this meeting in theory and experiment on what this exciting future holds
Physics Program

SuperKEKB and SuperB Accelerators

The Detectors

Status
Physics program
Overview

• \( \text{e}^+\text{e}^- \) collider with centre-of-mass near \( \Upsilon(4S) \)
  - just above threshold for B-meson pair production
    - no fragmentation

• Luminosity 100x previous generation \( \text{e}^+\text{e}^- \) collider \( \mathcal{L}=10^{34} \rightarrow 10^{36} \text{ cm}^{-2} \text{ s}^{-1} \)
  - 5-10 \( \times 10^{10} \) b, c, \( \tau \) pairs (50-75 ab\(^{-1}\))

• Operate with asymmetric beam energies to give boost to CM allowing for time dependent CPV measurements
Physics at e+e- Super Flavour Factories

- Test CKM at 1% level
  - CPV in B decays from new physics (non-CKM)
- B-recoil technique for B->K(*)ll, B->τν, B->D*τν
- τ physics: lepton flavour violations, g-2, EDM, CPV, V_{us}...
- Charm: mixing, CPV,...
- Many other topics:
  - \( \Upsilon(5S) \) physics, ISR radiative return, spectroscopy, Dark Sector probe, low mass Higgs...
- With polarised beam: Precision EW physics
- Physics motivation is independent of LHC
  - If LHC finds NP, precision flavour input essential
  - If LHC finds no NP, high statistics B and τ decays are unique way of probing >TeV scale physics
Need both LHCb and $e^+e^-$

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<td>$B \rightarrow \tau \nu, \mu \nu$</td>
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<td>$B \rightarrow K^{(*)}\mu \bar{\nu}$</td>
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<td>$S$ in $B \rightarrow K_s^{0}\pi^0\gamma$</td>
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<td>$S$ (other penguin modes)</td>
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<td>$A_{CP} (B \rightarrow X_s \gamma)$</td>
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<td>BR($B \rightarrow X_s \gamma$)</td>
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<td>BR($B \rightarrow X_s ll$)</td>
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<td>BR($B \rightarrow K^{(*)}ll$)</td>
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<td>$B_s \rightarrow \mu \mu$</td>
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<td>$\beta_s$ from $B_s \rightarrow J/\psi \phi$</td>
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<td>$B_s \rightarrow \gamma \gamma$</td>
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<td>Mixing parameters</td>
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<td>CP Violation</td>
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<td>Precision Electroweak</td>
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<td>$\sin^2 \theta_W$ at $\Upsilon(4S)$</td>
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<td>$\sin^2 \theta_W$ at $Z$-Pole</td>
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- **Experiment:** No Result
- **Theory:** Moderately precise, Precise
- **LHCb:** Moderately clean, Very precise
- **SuperB:** Clean, needs Lattice, Clean

- Benefit from polarised $e^-$ beam
- Very precise with improved detector
- Statistically limited: Angular analysis with $>75$ ab$^{-1}$
- 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 $\mu$
- Clean NP search
- Theoretically clean
- B fragmentation limits interpretation


Need both LHCb and $e^+e^-$

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<td>$\alpha$</td>
<td>$\sim 1 \text{ fb}^{-1}$</td>
<td>$5 \text{ fb}^{-1}$</td>
<td>$75 \text{ ab}^{-1}$</td>
<td>$50 \text{ fb}^{-1}$</td>
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<td>$\beta$ from $b \rightarrow c\bar{c}s$</td>
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<td>$B_d \rightarrow J/\psi \pi^0$</td>
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<td>$B_s \rightarrow J/\psi K^0_s$</td>
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<td>V_{cb}</td>
<td>$ exclusive</td>
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LHCb can only use $\rho\pi$

$\beta$ theory error $B_d$

$\beta$ theory error $B_s$

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

**LHCb**

- Modes where the final states are charged only.
- $B_s$
- $B_c$, $\Lambda_b$
- ....

**B factories**

- Modes with $\gamma$, $\pi^0$.
- Modes with $\nu$.
- $\tau$ decays.
- $K_S$ vertex.
Need both LHCb and $e^+e^-$

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<th>Observable</th>
<th>Expected th. accuracy</th>
<th>Expected exp. uncertainty</th>
<th>Facility</th>
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<tr>
<td>CKM matrix</td>
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<td>$</td>
<td>V_{ub}</td>
<td>$ $[K \to \pi\nu]$</td>
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<td>$</td>
<td>V_{cb}</td>
<td>$ $[B \to X_s\nu\nu]$</td>
<td>**</td>
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<tr>
<td>$</td>
<td>V_{ub}</td>
<td>$ $[B_d \to \pi\nu]$</td>
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<tr>
<td>$\sin(2\phi_1)$ $[e\bar{e}K_S^0]$</td>
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<td>$8 \cdot 10^{-3}$</td>
<td>Belle II/LHCb</td>
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<td>$\phi_2$</td>
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<td>1.5°</td>
<td>Belle II</td>
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<td>$\phi_3$</td>
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<td>3°</td>
<td>LHCb</td>
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<td>CPV</td>
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<td>$S(B_s \to \psi\phi)$</td>
<td>**</td>
<td>0.01</td>
<td>LHCb</td>
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<tr>
<td>$S(B_s \to \phi\phi)$</td>
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<td>0.05</td>
<td>LHCb</td>
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<td>$S(B_d \to \phi K)$</td>
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<td>0.05</td>
<td>Belle II/LHCb</td>
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<td>$S(B_d \to \eta K)$</td>
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<td>0.02</td>
<td>Belle II</td>
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<td>$S(B_d \to K^*(\to K_S^0\pi^0)\gamma)$</td>
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<td>0.03</td>
<td>Belle II</td>
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<td>$S(B_s \to \phi\gamma)$</td>
<td>***</td>
<td>0.05</td>
<td>LHCb</td>
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<tr>
<td>$S(B_d \to \rho\gamma)$</td>
<td>***</td>
<td>0.15</td>
<td>Belle II</td>
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<tr>
<td>$A^{SL}_{SL}$</td>
<td>***</td>
<td>0.001</td>
<td>LHCb</td>
</tr>
<tr>
<td>$A^{SL}_{SL}$</td>
<td>***</td>
<td>0.001</td>
<td>LHCb</td>
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<tr>
<td>$A_{CP}(B_d \to s\gamma)$</td>
<td>+</td>
<td>0.005</td>
<td>Belle II</td>
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<td>rare decays</td>
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<td>$B(B \to \tau\nu)$</td>
<td>**</td>
<td>3%</td>
<td>Belle II</td>
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<td>$B(B \to D\tau\nu)$</td>
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<td>3%</td>
<td>Belle II</td>
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<tr>
<td>$B(B_d \to \mu\nu)$</td>
<td>**</td>
<td>6%</td>
<td>Belle II</td>
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<td>$B(B_s \to \mu\nu)$</td>
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<td>10%</td>
<td>LHCb</td>
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<td>$B(B_s \to K\mu\mu)$</td>
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<td>0.05</td>
<td>LHCb</td>
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<td>$B(B \to \pi\nu\nu)$</td>
<td>***</td>
<td>30%</td>
<td>Belle II</td>
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<td>$B(B \to s\gamma)$</td>
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<td>4%</td>
<td>Belle II</td>
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<td>$B(B_s \to \gamma\gamma)$</td>
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<td>$0.25 \cdot 10^{-6}$</td>
<td>Belle II (with 5 ab$^{-1}$)</td>
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<td>$B(K \to \pi\nu\nu)$</td>
<td>**</td>
<td>10%</td>
<td>$K$-factory</td>
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<td>$B(K \to e\nu\nu)/B(K \to \mu\nu)$</td>
<td>***</td>
<td>0.1%</td>
<td>$K$-factory</td>
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<td>charm and $\tau$</td>
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<tr>
<td>$B(\tau \to \mu\gamma)$</td>
<td>***</td>
<td>$3 \cdot 10^{-9}$</td>
<td>Belle II</td>
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<td>$</td>
<td>q/p</td>
<td>_{D}$</td>
<td>***</td>
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<tr>
<td>$arg(q/p)_{D}$</td>
<td>***</td>
<td>1.5°</td>
<td>Belle II</td>
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Belle II Collaboration comparisons with LHCb assuming integrated luminosities: 
Belle II: 50 ab$^{-1}$
LHCb: 10 fb$^{-1}$

J. Michael Roney
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<tbody>
<tr>
<td>$\tau \to \mu \gamma \times (10^{-9})$</td>
<td>$&lt; 44$</td>
<td>$&lt; 2.4$</td>
<td>$&lt; 5.0$</td>
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<tr>
<td>$\tau \to e \gamma \times (10^{-9})$</td>
<td>$&lt; 33$</td>
<td>$&lt; 3.0$</td>
<td>$&lt; 3.7$ (est.)</td>
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<tr>
<td>$\tau \to \ell \ell \ell \ell \times (10^{-10})$</td>
<td>$&lt; 150 - 270$</td>
<td>$&lt; 244$</td>
<td>$&lt; 2.3 - 8.2$</td>
<td>$&lt; 10$</td>
<td>$&lt; 24$</td>
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**$B_{u,d}$ Decays**

| BR($B \to \tau \nu$) ($\times 10^{-4}$) | $1.64 \pm 0.34$ | $0.05$ | $0.04$ | $1.1 \pm 0.2$ | |
| BR($B \to \mu \nu$) ($\times 10^{-6}$) | $< 1.0$ | $0.02$ | $0.03$ | $0.47 \pm 0.08$ | |
| BR($B \to K^{*+} \nu \nu$) ($\times 10^{-6}$) | $< 80$ | $1.1$ | $2.0$ | $6.8 \pm 1.1$ | |
| BR($B \to K^{+} \nu \bar{\nu}$) ($\times 10^{-6}$) | $< 160$ | $0.7$ | $1.6$ | $3.6 \pm 0.5$ | |
| BR($B \to X_{\tau} \gamma$) ($\times 10^{-4}$) | $3.55 \pm 0.26$ | $0.11$ | $0.13$ | $0.23$ | $3.15 \pm 0.23$ |
| $A_{CP}(B \to X_{(s+d)} \gamma)$ | $0.060 \pm 0.060$ | $0.02$ | $0.02$ | $\sim 10^{-6}$ | |
| $B \to K^{*+} \mu^+ \mu^-$ (events) | $250^c$ | $8000$ | $10-15k^d$ | $7-10k$ | $100,000$ | - |
| BR($B \to K^{*+} \mu^+ \mu^-$) ($\times 10^{-6}$) | $1.15 \pm 0.16$ | $0.06$ | $0.07$ | $1.19 \pm 0.39$ | |
| $B \to K^{+} \nu \bar{\nu}$ (events) | $165$ | $400$ | $10-15k$ | $7-10k$ | $5,000$ | - |
| BR($B \to K^{+} \nu \bar{\nu}$) ($\times 10^{-6}$) | $1.90 \pm 0.17$ | $0.05$ | $0.07$ | $1.19 \pm 0.39$ | |
| $A_{FB}(B \to K^{*+} \ell^+ \ell^-$) | $0.27 \pm 0.14^e$ | $0.040$ | $0.03$ | $-0.089 \pm 0.020$ | |
| $B \to X_{s} \ell^+ \ell^-$ (events) | $280$ | $8,600$ | $7,000$ | $1.59 \pm 0.11$ | |
| BR($B \to X_{s} \ell^+ \ell^-$) ($\times 10^{-6}$) | $3.56 \pm 0.12^h$ | $0.08$ | $0.10$ | $-0.1$ to $0.1$ | |
| $S$ in $B \to K^{0}_{s} \pi^0 \gamma$ | $-0.15 \pm 0.20$ | $0.03$ | $0.03$ | $\pm 0.015$ | |
| $S$ in $B \to \eta K^{0}$ | $0.59 \pm 0.07$ | $0.01$ | $0.02$ | $\pm 0.02$ | |
| $S$ in $B \to \phi K^{0}$ | $0.56 \pm 0.17$ | $0.15$ | $0.03$ | $0.03$ | |

**$B_s^0$ Decays**

| BR($B^0_s \to \gamma \gamma$) ($\times 10^{-6}$) | $< 8.7$ | $0.3$ | $0.2 - 0.3$ | $0.4 - 1.0$ | |
| $A_{SL}^0$ ($\times 10^{-3}$) | $-7.87 \pm 1.96^i$ | $j$ | $4$, $5$, (est.) | $0.02 \pm 0.01$ | |

**D Decays**

| $x$ | $0.63 \pm 0.20^%$ | $0.06%$ | $0.02%$ | $0.04%$ | $0.02%$ | $\sim 10^{-2}$ |
| $y$ | $(0.75 \pm 0.12)%$ | $0.03%$ | $0.01%$ | $0.03%$ | $0.01%$ | $\sim 10^{-2}$ |
| $(y_{CP})$ | $(1.11 \pm 0.22)%$ | $0.02%$ | $0.03%$ | $0.05%$ | $0.01%$ | $\sim 10^{-2}$ |
| $\sqrt{d/p}$ | $(0.91 \pm 0.17)%$ | $8.5%$ | $2.7%$ | $3.0%$ | $3%$ | $\sim 10^{-2}$ |
| $\sqrt{d/p}$ | $-10.2 \pm 9.2$ | $4.4$ | $1.4$ | $1.4$ | $2.0$ | $\sim 10^{-2}$ |

**Other processes Decays**

| $\sin^2 \theta_W$ at $\sqrt{s} = 10.58 \text{ GeV}/c^2$ | $0.0002$ | $i$ | clean | | | | | | |

From Meadow’s et al arXiv:1109.5028v2
Need both LHCb and $e^+e^-$

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<td>5 fb$^{-1}$</td>
<td>75 ab$^{-1}$</td>
<td>50 ab$^{-1}$</td>
<td>50 fb$^{-1}$</td>
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<tr>
<td>$\alpha$ from $u\bar{u}d$</td>
<td>6.1°</td>
<td>5°$^a$</td>
<td>1°</td>
<td>1°</td>
<td>$^b$</td>
<td>1 – 2°</td>
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<td>$\beta$ from $c\bar{s}$ (S)</td>
<td>0.8° (0.020)</td>
<td>0.5° (0.008)</td>
<td>0.1° (0.002)</td>
<td>0.3° (0.007)</td>
<td>0.2° (0.003)</td>
<td>clean</td>
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<tr>
<td>$S$ from $B_d \rightarrow J/\psi \pi^0$</td>
<td>0.21</td>
<td>?</td>
<td>0.014</td>
<td>0.021 (est.)</td>
<td>?</td>
<td>clean</td>
</tr>
<tr>
<td>$S$ from $B_s \rightarrow J/\psi K^0_S$</td>
<td>?</td>
<td>1°</td>
<td>1.5°</td>
<td>?</td>
<td>0.9°</td>
<td>clean</td>
</tr>
<tr>
<td>$\gamma$ from $B \rightarrow DK$</td>
<td>11°</td>
<td>$\sim$ 4°</td>
<td>1°</td>
<td>1.5°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>V_{cb}</td>
<td>$ (inclusive) %</td>
<td>1.7</td>
<td>0.5%</td>
<td>0.6 (est.)</td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>V_{cb}</td>
<td>$ (exclusive) %</td>
<td>2.2</td>
<td>1.0%</td>
<td>1.2 (est.)</td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>V_{ub}</td>
<td>$ (inclusive) %</td>
<td>4.4</td>
<td>2.0%</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>V_{ub}</td>
<td>$ (exclusive) %</td>
<td>7.0</td>
<td>3.0%</td>
<td>5.0</td>
<td></td>
</tr>
</tbody>
</table>

From Meadow’s et al
arXiv:1109.5028v2
...there are a few $3\sigma$ effects in the flavour sector that can only be probed with $e^+e^-$-machines

Most recently: $BABAR$’s $3.4\sigma$ evidence for an excess of $B$ decays to $D(\ast)\tau\nu$ compared to SM expectations

$$BF(B \to D(\ast)\tau\nu)/BF(B \to D(\ast)\ell\nu)$$

Measure the ratios to minimize systematic errors

NB: this result kills Type II 2HDM

(see D. Lopes Pegna’s talk on $BABAR$, D. Zander is showing the Belle result & S. Fajfer’s on the theory in WG II Sun. am)
Many physics channels best studied with e^+e^- super flavour factories

a few from that long list...
Rare Leptonic Decays

- $B^+ \rightarrow \tau^+ \nu$ & $B^\pm \rightarrow \mu^\pm \nu$ directly sensitive to charged higgs.
- important SM parameters $V_{ub}$ and $f_B$.

$$BF(B \rightarrow \ell \nu)_{SM} = \frac{G_F^2 m_B}{8 \pi} \left( m_\ell^2 \right) \left( 1 - \frac{m_\ell^2}{m_B^2} \right)^2 f_B^2 \left| V_{ub} \right|^2 \tau_B$$

$BF(B \rightarrow \tau \nu)_{SM} = [1.20 \pm 0.25] \times 10^{-4}$

$BF(B \rightarrow \mu \nu)_{SM} \sim 5 \times 10^{-7}$ will be measured to $\sim 5 - 6\%$

Measure $BF(B \rightarrow \tau \nu)_{SM} / BF(B \rightarrow \mu \nu)_{SM}$ removes $f_B \left| V_{ub} \right| \rightarrow$ search for new physics
Can use ratio of tau:mu BF to remove common factors and systematics. Errors on ratio dominated by muon measurement $\sim 5\%-6\%$
Lepton Flavour Violation

- e.g. $\tau^\pm \rightarrow \mu^\pm \gamma$ or $\tau^\pm \rightarrow \ell^\pm \ell^\mp \ell^\pm$
- Polarization helps suppress backgrounds, mainly $e^+ e^- \rightarrow \gamma_{ISR} \tau^+ \tau^-$ and identify nature of signal if observed

SuperB, 75 ab$^{-1}$

<table>
<thead>
<tr>
<th>Process</th>
<th>Expected 90% CL upper limit</th>
<th>3$\sigma$ evidence reach</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B(\tau \rightarrow \mu \gamma)$</td>
<td>$2.4 \times 10^{-9}$</td>
<td>$5.4 \times 10^{-9}$</td>
</tr>
<tr>
<td>$B(\tau \rightarrow e \gamma)$</td>
<td>$3.0 \times 10^{-9}$</td>
<td>$6.8 \times 10^{-9}$</td>
</tr>
<tr>
<td>$B(\tau \rightarrow \ell \ell \ell \ell)$</td>
<td>$2.3-8.2 \times 10^{-10}$</td>
<td>$1.2-4.0 \times 10^{-9}$</td>
</tr>
</tbody>
</table>

cf 90% cl Limits on $B(\tau \rightarrow \mu \gamma)$: <4.5x10$^{-8}$ (Belle)
<4.4x10$^{-8}$ (BaBar)

Future Prospects at e+e- Machines

J. Michael Roney
*The key role of LFV and EDMs*

...and there is no doubt that if MEG will see a positive signal, then all other LFV searches would be extremely important to understand the nature of the effect.

E.g.: SUSY with minimally broken $U(3)^5$
SuperB polarised beam

- SuperB is the only $e^+e^-$ high-$\mathcal{L}$ B-factory with a polarised beam: has a unique, and rich, precision electroweak program
- Left-Right Asymmetries ($A_{LR}$) yield measurements of unprecedented precision of the neutral current vector couplings ($g_V$) to each of five fermion flavours, $f$:
  - beauty (D)
  - charm (U)
  - tau
  - muon
  - electron

Recall: $g_V^f$ gives $\theta_W$ in SM

\[
\begin{align*}
g_A^f &= T_3^f \\
g_V^f &= T_3^f - 2Q_f \sin^2 \theta_W
\end{align*}
\]

\[
A_{LR} = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} \propto g_V^f = T_3^f - Q_f \sin^2 \theta_W
\]

Driven by $\gamma - Z$ interference at $\sqrt{s} = 10.58$ GeV

Similar to SLD's measurement at the Z pole
SuperB polarised beam
**SuperB polarised beam**

Comparisons with present neutral current vector coupling uncertainties

Physics Report Vol 427, Nos 5-6 (2006), ALEPH, OPAL, L3, DELPHI, SLD

**c-quark:** SuperB ~7 times more precise  
**b-quark:** SuperB ~5 times more precise
SuperB polarised beam

Existing tension in data from the Z-Pole:

For a 125GeV Higgs,

\[ g_{Vb} \sim 2.8\sigma \text{ from SM} \]
\[ g_{Ab} \sim 3.1\sigma \text{ from SM} \]

\[ g_{Rb} = (g_{Vb} - g_{Ab})/2 \] is \( 3\sigma \) from SM

SuperB is the only facility in foreseeable future that will be able to experimentally address this \( 3\sigma \) deviation

ALEPH, OPAL, L3, DELPHI, SLD

J. Michael Roney
Super Flavour Factory Accelerators
Colliders... luminosity trends

Future Prospects at e+e- Machines

J. Michael Roney
How to get to $\mathcal{L}=10^{36} \text{ cm}^{-2}\text{s}^{-1}$ ...

J. Seeman, HEPAP, May 2009

• Crossing angle IR with large Piwinski angle (DA\(\Phi\)NE, KEKB)

• Very low IR vertical and horizontal beta functions (ILC)

• Low horizontal and vertical emittances (Light sources)

• Ampere beam currents (PEP-II, KEKB)

• Crab waist scheme (Frascati, DA\(\Phi\)NE) – SuperB only
Crab waist off

Waist line is orthogonal to the axis of one bunch
Crab waist on

All particles in both beams collide in the minimum $\beta_y$ region, with a net luminosity gain

Waist line aligned to the axis of the other beam
Crab waist Proven at DAΦNE & being deployed at SuperB

- DAΦNE e+e- collider at Frascati with Ecm @ Φ (1020 MeV)
- Upgraded to test crab waist scheme
- Crab Waist effectiveness successfully demonstrated in working collider
- Gains of ~ factor of 2 in luminosity
SuperKEKB - upgrade from KEKB

<table>
<thead>
<tr>
<th>Parameters</th>
<th>KEKB</th>
<th>SuperKEKB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LER</td>
<td>HER</td>
</tr>
<tr>
<td>Beam energy</td>
<td>$E_b$</td>
<td>3.5</td>
</tr>
<tr>
<td>Half crossing angle</td>
<td>$\varphi$</td>
<td>11</td>
</tr>
<tr>
<td>Horizontal emittance</td>
<td>$\varepsilon_x$</td>
<td>18</td>
</tr>
<tr>
<td>Emittance ratio</td>
<td>$\kappa$</td>
<td>0.88</td>
</tr>
<tr>
<td>Beta functions at IP</td>
<td>$\beta_x^<em>/\beta_y^</em>$</td>
<td>1200/5.9</td>
</tr>
<tr>
<td>Beam currents</td>
<td>$I_b$</td>
<td>1.64</td>
</tr>
<tr>
<td>Beam-beam parameter</td>
<td>$\xi_y$</td>
<td>0.129</td>
</tr>
<tr>
<td>Luminosity</td>
<td>$L$</td>
<td>$2.1 \times 10^{34}$</td>
</tr>
</tbody>
</table>

- Small beam size & high current to increase luminosity
- Large crossing angle
- Change beam energies to solve the problem of LER short lifetime

Touschek worse at lower energies
### SuperB Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Base Line HER (e+)</th>
<th>Low Emittance HER (e+)</th>
<th>High Current HER (e+)</th>
<th>Tau/Charm (prelim.) HER (e+)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LUMINOSITY</strong></td>
<td>cm^{-2} s^{-1}</td>
<td>1.00E+36</td>
<td>1.00E+36</td>
<td>1.00E+36</td>
<td>1.00E+35</td>
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<tr>
<td>Energy</td>
<td>GeV</td>
<td>6.7</td>
<td>6.7</td>
<td>6.7</td>
<td>2.58</td>
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<tr>
<td>Circumference</td>
<td>m</td>
<td>1250.4</td>
<td>1258.4</td>
<td>1258.4</td>
<td>1258.4</td>
</tr>
<tr>
<td>X-Angle (full)</td>
<td>mrad</td>
<td>66</td>
<td>66</td>
<td>66</td>
<td>66</td>
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<tr>
<td>Piwinski angle</td>
<td>rad</td>
<td>22.88</td>
<td>18.60</td>
<td>32.36</td>
<td>26.30</td>
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<tr>
<td>$\beta_x$ @ IP</td>
<td>cm</td>
<td>2.6</td>
<td>3.2</td>
<td>2.6</td>
<td>3.2</td>
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<tr>
<td>$\beta_y$ @ IP</td>
<td>cm</td>
<td>0.0253</td>
<td>0.0205</td>
<td>0.0179</td>
<td>0.0145</td>
</tr>
<tr>
<td>Coupling (full current)</td>
<td>%</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.5</td>
</tr>
<tr>
<td>$\varepsilon_x$ (without IBS)</td>
<td>nm</td>
<td>1.97</td>
<td>1.82</td>
<td>1.00</td>
<td>0.91</td>
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<tr>
<td>$\varepsilon_x$ (with IBS)</td>
<td>nm</td>
<td>2.00</td>
<td>2.46</td>
<td>1.00</td>
<td>1.23</td>
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<tr>
<td>$\sigma_x$ @ IP</td>
<td>pm</td>
<td>5</td>
<td>6.45</td>
<td>2.5</td>
<td>3.07</td>
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<td>$\sigma_y$ @ IP</td>
<td>pm</td>
<td>7.21</td>
<td>0.872</td>
<td>5.09</td>
<td>0.874</td>
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<tr>
<td>$\Sigma_x$</td>
<td>$\mu$m</td>
<td>11.433</td>
<td>8.085</td>
<td>15.944</td>
<td>29.732</td>
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<tr>
<td>$\Sigma_y$</td>
<td>$\mu$m</td>
<td>0.050</td>
<td>0.030</td>
<td>0.076</td>
<td>0.131</td>
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<tr>
<td>$\sigma_1$ (0 current)</td>
<td>mm</td>
<td>4.69</td>
<td>4.29</td>
<td>4.73</td>
<td>4.34</td>
</tr>
<tr>
<td>$\sigma_1$ (full current)</td>
<td>mm</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.4</td>
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<tr>
<td>Beam current</td>
<td>mA</td>
<td>1892.2</td>
<td>2443</td>
<td>1460.0</td>
<td>1888</td>
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<tr>
<td>Buckets distance</td>
<td>#</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ion gap</td>
<td>%</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
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<tr>
<td>RF frequency</td>
<td>Hz</td>
<td>4.76E+08</td>
<td>4.76E+08</td>
<td>4.76E+08</td>
<td>4.76E+08</td>
</tr>
<tr>
<td>Number of bunches</td>
<td></td>
<td>978</td>
<td>978</td>
<td>1956</td>
<td>1956</td>
</tr>
<tr>
<td>N. Particle/bunch</td>
<td></td>
<td>5.08E+10</td>
<td>6.56E+10</td>
<td>3.92E+10</td>
<td>5.06E+10</td>
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<tr>
<td>Tune shift x</td>
<td></td>
<td>0.0021</td>
<td>0.0033</td>
<td>0.0017</td>
<td>0.0025</td>
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<tr>
<td>Tune shift y</td>
<td></td>
<td>0.0970</td>
<td>0.0971</td>
<td>0.0891</td>
<td>0.0892</td>
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<tr>
<td>Long. damping time</td>
<td>msec</td>
<td>13.4</td>
<td>20.3</td>
<td>13.4</td>
<td>20.3</td>
</tr>
<tr>
<td>Energy Loss/turn</td>
<td>MeV</td>
<td>2.11</td>
<td>0.865</td>
<td>2.11</td>
<td>0.865</td>
</tr>
<tr>
<td>$\sigma_1$ (full current)</td>
<td>dE/E</td>
<td>6.43E-04</td>
<td>7.34E-04</td>
<td>6.43E-04</td>
<td>7.34E-04</td>
</tr>
<tr>
<td>CM $\sigma_E$</td>
<td>dE/E</td>
<td>5.00E-04</td>
<td>5.00E-04</td>
<td>5.00E-04</td>
<td>5.26E-04</td>
</tr>
<tr>
<td>Total lifetime</td>
<td>min</td>
<td>4.23</td>
<td>4.48</td>
<td>3.05</td>
<td>3.00</td>
</tr>
<tr>
<td>Total RF Power</td>
<td>MW</td>
<td>17.88</td>
<td>12.72</td>
<td>30.48</td>
<td>3.11</td>
</tr>
</tbody>
</table>

**Baseline + other 2 options:**
- Lower y-emittance
- Higher currents (twice bunches)

**Baseline:**
- Higher emittance due to IBS
- Asymmetric beam currents

**Tau/charm threshold running at 10^{35}**

RF power includes SR and HOM

J. Michael Roney
To get \(x40\) higher luminosity

To get \(x40\) higher luminosity

KEKB to SuperKEKB
The Detectors
Reuse BaBar components: magnet, DIRC bars, barrel CsI calorimeter.

- New silicon; add Layer 0 with smaller beam pipe
- New way to read out DIRC
- New forward calorimeter
- Possible forward PID
- Likely backward EMC
Drift Chamber with ionization “cluster counting” improves particle ID

Prototype in TRIUMF test beam with $e^+, \mu^+, \pi^+$ at 140–350 MeV/c. $\mu/\pi$ separation $\approx$ SuperB $\pi/K$ separation at 2–3 GeV/c, use TOF for independent beam particle ID
Drift Chamber with ionization “cluster counting” improves particle ID

No. clusters vs Truncated Mean
Blue = muons, Red = Pions
Belle II Detector

**EM Calorimeter:**
- CsI(Tl), waveform sampling (barrel)
- Pure CsI + waveform sampling (end-caps)

**Beryllium beam pipe**
- 2cm diameter

**Vertex Detector**
- 2 layers DEPFET + 4 layers DSSD

**Central Drift Chamber**
- He(50%):C₂H₆(50%), small cells, long lever arm, fast electronics

**Particle Identification**
- Time-of-Propagation counter (barrel)
- Prox. focusing Aerogel RICH (fwd)

**KL and muon detector:**
- Resistive Plate Counter (barrel outer layers)
- Scintillator + WLSF + MPPC (end-caps, inner 2 barrel layers)

**Electrons (7GeV)**

**Positrons (4GeV)**
SVD: 4 DSSD lyr → 2 DEPFET lyr + 4 DSSD lyr
CDC: small cell, long lever arm
ACC+TOF → TOP+A−RICH
ECL: waveform sampling (+pure CsI for endcaps)
KLM: RPC → Scintillator +MPPC (endcaps, barrel inner 2 lyrns)
**PID Devices**

**Barrel PID: Time of Propagation Counter (TOP)**

- **MCP-PMT**
- **Focus mirror** (sphere, $r=7000$)
- **Quartz radiator**
- **Focusing mirror**
- **Small expansion block**
- **Hamamatsu MCP-PMT** (measure $t$, $x$ and $y$)

**Endcap PID: Aerogel RICH (ARICH)**

- **Aerogel radiator**
  - $n \approx 1.05$
- **Hamamatsu HAPD + new ASIC**
- **200mm**
- **Cherenkov photon**

**Future Prospects at e+e- Machines**

J. Michael Roney
Status and outlook
SuperB Status (Ministerial approval press release, Dec 2010)

The Italian Government Funds the Super-B Accelerator

The Ministry for Education, University and Research has decided to select the SuperB project conducted by the Italian National Institute of Nuclear Physics (INFN) as one of its "flagship projects" in Italy over the next few years and has delivered an initial funding for 2010 as a part of a multiannual funding program. Reconstructing the history of the universe by researching the most infrequent events using high-precision technology. This is the INFN SuperB, the particle accelerator based in Italy and with international involvement, which the Ministry for Education, University and Research has decided to sponsor and finance. A large interest has been expressed by many countries. Meanwhile physicists from the United States, Germany, France, Russia, the United Kingdom, Israel, Canada, Norway, Spain, Poland are taking part to the design effort. The purpose of the project is to conduct top-level basic research, developing innovative techniques with an important impact in terms of technology and other research areas. In the words of the ministerial decree, "the project involves entities and Universities, as well as companies in various business sectors. It is expected to have a number of effects on relevant issues for the country, especially as regards the expansion of basic scientific perspectives and specific applications concerning particle detection, advanced simulation techniques, nanometre metrology, and others." Istituto Italiano di Tecnologia (IIT) is cooperating to the project with INFN. It will be in fact possible the use of the accelerator as a high brilliancy light source. The machine will be equipped with several photon channels, allowing the extension of scientific program to physics of matter and biotechnology.

The SuperB project basic assumption is that particle accelerators, smaller than the current "giants", operated at a low energy, can allow excellent scientific results complementary to the high energy frontier.

J. Michael Roney

Future Prospects at e+e- Machines
SuperB Status

- SuperB approved as the first in a list of 14 “flagship” projects within the Italian National Research Plan
- National Research Plan endorsed by “CIPE” (institution responsible for infrastructure long term plans)
- A financial allocation of 256 Million Euros over six years approved for the “SuperB Flavour Factory” (total cost and request ~twice that, assuming PEP-II equipment re-use)
- Cabibbo Lab created on Oct 7, 2011
  - Major step forward: first major particle physics accelerator lab to be created in a generation
  - Legal structure needed in order to spend funds, sign MOUs
  - MOUs with various institutions and labs completed or nearing completion
    - Most recently completed MOU with Budker Institute
SuperB Status

• SuperB Collaboration formally in place since March 2012
• Cabibbo Lab management in place April 2012
• First hires in May/June 2012

• International Review Committee set up by Italian Ministry of Science (MIUR) to examine the Cost and Schedule of the SuperB project
  ▫ Committee received costing document in July 2012
  ▫ Report of the committee expected this autumn

• Ministerial review for all Flagship projects in autumn 2012
Tor Vergata University campus

SuperB Site

About 4.5 Km

LNF
Detailed site view

Well within vibration budget
SuperB Status - key milestones

- Site selection: summer 2011
- Machine and Detector TDR end 2012
- Start civil engineering 2013
- Start machine installation early 2014
- First collisions 2018
SuperKEKB/Belle II Status

Funding

• ~100 MUS for machine approved in 2009 -- Very Advanced Research Support Program (FY2010-2012)

• Full approval by the Japanese government in December 2010; the project was finally in the JFY2011 budget as approved by the Japanese Diet end of March 2011

• Most of non-Japanese funding agencies have also already allocated sizable funds for the upgrade of the detector.

construction started in 2010!

Fortunately little damage during the March 2011 earthquake → no delay

• Ground breaking ceremony in November 2011

• SuperKEKB and Belle II construction proceeding according to the schedule.
1/3 of new dipole magnets have been installed in LER. (July 9, 2012)

Three magnets per day! Total ~100

- Installing the 4 m LER dipole over the 6 m HER dipole (remain in place).
- All LER dipoles are scheduled to be installed this year.
Entirely new LER beam pipe with ante-chamber and Ti-N coating

Beam pipe is made of aluminum.

Fabrication of the LER arc beam pipe section is completed

Future Prospects at e+e- Machines

J. Michael Roney
Damping ring construction started in Jan 2012
The schedule is likely to shift by a few months because of a new construction/commissioning strategy for the final quads.
Summary

- BES III: 2015- taking 10 fb⁻¹ ψ(3770); runs another 8-10yrs
- Promising developments for c/τ factory in Novosibirsk
- SuperB e⁺e⁻ flavour factories provide extremely broad and exciting physics program with sensitivity to new physics that is complementary to the LHC.
- Flexibility in ways that these machines can achieve 100× luminosity with beam currents and power comparable to current facilities
- SuperB is hosted in CabibboLab: world’s newest HEP accelerator lab - Italian parliament approved funding for ~ first half; undergoing cost and schedule review now for the balance; ground breaking in 2013
- SuperKEKB received Japanese Diet approval for complete project in 2011, construction proceeding well!
Additional slides
### SuperB funding profile: INFN Piano Triennale 2011-13

<table>
<thead>
<tr>
<th>Componenti Super B</th>
<th>Y1</th>
<th>Y2</th>
<th>Y3</th>
<th>Y4</th>
<th>Y5</th>
<th>Y6</th>
<th>Y7</th>
<th>Y8</th>
<th>Y9</th>
<th>Y10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sviluppo Acceleratore (130 M€)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Costruzione infrastrutture, Sviluppo damping rings, Sviluppo transfer lines, Messa in funzione linac, Damping lines transfer lines, Costruzione facility end-user</td>
<td>20</td>
<td>50</td>
<td>60</td>
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<td></td>
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<tr>
<td>Sviluppo Centri Calcolo (43 M€)</td>
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<td></td>
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<tr>
<td>Sviluppo progettazione costruzione centro di calcolo per analisi dati</td>
<td>5</td>
<td>15</td>
<td>23</td>
<td></td>
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<td>Completamento Acceleratore (126 M€)</td>
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<td>Installazione componenti negli archi acceleratore, Installazione zona di interazione, Messa in funzione acceleratore</td>
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<td>Utilizzo installazione (80 M€)</td>
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<td>Costi operazione e manutenzione acceleratore</td>
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<td>Totale Infrastrutture tecniche (379 M€)</td>
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<td>Overheads INFN (34.3 M€ equivalente al 9%)</td>
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<td>Cofinanziamento INFN (150 M€)</td>
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<td>Costo Totale del progetto (563.3 M€)</td>
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</table>
Super Flavour Factory Physics Program Summary

B Physics at the \( \Upsilon(4S) \)

A. New Physics in CP violation
   1. \( \Delta S \) measurements

B. Theoretical aspects of rare decays
   1. New physics in \( B \to K^{(*)}\nu\bar{\nu} \) decays
   2. \( \bar{B} \to X_s\gamma \) and \( \bar{B} \to X_s\ell^+\ell^- \)
   3. Angular analysis of \( B \to K^{*}\ell^+\ell^- \)
   4. \( \bar{B} \to X_d\gamma \) and \( \bar{B} \to X_d\ell^+\ell^- \)

C. Experimental aspects of rare decays
   1. \( B \to K^{(*)}\nu\bar{\nu} \)
   2. \( B \to \ell\nu \) and \( B \to \ell\nu\gamma \)
   3. Experimental aspects of \( \bar{B} \to X_s\gamma \)
   4. Inclusive and exclusive \( b \to s\ell^+\ell^- \)
   5. More on \( B \to X_{s/d}\ell^+\ell^- \) with a hadron tag

D. Determination of \( |V_{ub}| \) and \( |V_{cb}| \)
   1. Inclusive Determination of \( |V_{ub}| \)
   2. Inclusive Determination of \( |V_{cb}| \)

E. Studies in Mixing and CP Violation in Mixing
   1. Measurements of the mixing frequency and CP asymmetries
   2. New Physics in mixing
   3. Tests of CPT

F. Why measure \( \gamma \) precisely (and how)?

G. Charmless hadronic \( B \) decays

H. Precision CKM

Future Prospects at e+e- Machines

J. Michael Roney
Super Flavour Factory Physics Program Summary

Electroweak neutral current measurements

Spectroscopy
A. Introduction
B. Light Mesons
C. Charmonium
D. Bottomonium
   1. Regular bottomonium
   2. Exotic bottomonium
E. Interplay with other experiments

Direct Searches
A. Light Higgs
B. Invisible decays and Dark Matter
C. Dark Forces

τ physics
A. Lepton Flavor Violation in τ decay
   Predictions from New Physics models
   LFV in the MSSM
   LFV in other scenarios
   SuperB experimental reach
B. CP Violation in τ decay
C. Measurement of the τ electric dipole moment
D. Measurement of the τ g − 2
E. Search for second-class currents
Charm Physics
A. On the Uniqueness of Charm
B. $D^0 - \bar{D}^0$ Oscillations
   1. Experimental Status
   2. Combination of measurements and CPV
   3. Measurements of strong phases
   4. Theoretical Interpretation
   5. Measuring $x_D$ and $y_D$ at SuperB
   6. Projections for mixing measurements at SuperB
   7. Estimated sensitivity to CPV from mixing measurements
C. CP Violation
   1. Generalities
   2. SM Expectations
   3. Experimental Landscape
   4. Littlest Higgs Models with T Parity – A Viable Non-ad-hoc Scenario
D. Rare Decays
   1. $D^0 \rightarrow \mu^+ \mu^-, \gamma \gamma$
   2. $D \rightarrow l^+ l^- X$
E. Experimental possibilities for rare decay searches at SuperB
   1. $D \rightarrow l^+ l^- X$
F. A case for Running at the $D \bar{D}$ threshold?