Searches for New Physics at the Belle II Experiment

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Super-KEKB
A $e^+e^-$ collider runs at $Y(4S)$ resonance to produce B meson pairs.

Belle/KEKB: $\sim 1\text{ab}^{-1}$, BaBar/PEP-II: $\sim 0.5\text{ab}^{-1}$, Belle II/SuperKEKB: $\sim 50\text{ab}^{-1}$
How to achieve 40x luminosity

• Nano beam:
  • Small current increase (2-3x)
  • Smaller $\beta_y^*$ (20x) via superconducting focus magnets

<table>
<thead>
<tr>
<th></th>
<th>E (GeV)</th>
<th>$\beta_y^*$ (mm)</th>
<th>$\beta_x^*$ (cm)</th>
<th>$\varphi$ (mrad)</th>
<th>$I$ (A)</th>
<th>$L$ (cm$^{-2}$s$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KEKB</td>
<td>3.5/8.0</td>
<td>5.9/5.9</td>
<td>120/120</td>
<td>11</td>
<td>1.6/1.2</td>
<td>2.1 x 10$^{34}$</td>
</tr>
<tr>
<td>SuperKEKB</td>
<td>4.0/7.0</td>
<td>0.27/0.30</td>
<td>3.2/2.5</td>
<td>41.5</td>
<td>3.6/2.6</td>
<td>80 x 10$^{34}$</td>
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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

- KL and muon detector:
  - Resistive Plate Counter (barrel)
  - Scintillator + WLSF + MPPC (end-caps)

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

- US contribution

- electron (7GeV)

- positron (4GeV)
Constraining the CKM UT

With much higher luminosity, the uncertainties on the CKM UT triangle could be substantially reduced.
$b \rightarrow s \gamma$ decays

- Suppressed in SM, sensitive to NP.
- For $B^0 \rightarrow K_S \pi^0 \gamma$, the CP asymmetry is estimated as $S \approx -0.04$

Buchalla et al., EPJC 57, 309 (2008); arXiv:0801.1833
Charged Higgs: $B^+ \rightarrow \tau^+ \nu$

- Helicity suppressed. NP could interfere charged Higgs and change the BR.

$$\Gamma(B^+ \rightarrow \tau^+ \nu_\tau) = \Gamma^{SM}(B^+ \rightarrow \tau^+ \nu_\tau)[1 - (m_B^2/m_H^2) \tan^2 \beta]^2$$

- Hadronic or semi-leptonic tags
- Signal: fitting ECL distribution. Peak near zero indicates $\tau \rightarrow l\nu\nu, \pi\nu$ decays.

Belle, I. Adachi et al., (2008), 0809.3834
World average is $\sim 5\sigma$ from the SM. Belle II should resolve this discrepancy.
Direct CPV: $B \rightarrow K\pi$

- $A_{CP}$ should be the same for $K\pi^-$ and $K\pi^0$.
- Belle measurement showed they are different:

$$A_{CP}(K^+\pi^0) - A_{CP}(K^+\pi^-) = 0.164 \pm 0.035 \pm 0.013$$
Direct CPV: $B \rightarrow K\pi$

By using the sum rule:

$$A_{CP}^{K^{+}\pi^{-}} + A_{CP}^{K^{0}\pi^{+}} + \frac{B(B^{+} \rightarrow K^{0}\pi^{+})\tau_{B^{0}}}{B(B^{0} \rightarrow K^{+}\pi^{-})\tau_{B^{+}}} = A_{CP}^{K^{+}\pi^{0}} + 2\frac{B(B^{+} \rightarrow K^{+}\pi^{0})\tau_{B^{0}}}{B(B^{0} \rightarrow K^{+}\pi^{-})\tau_{B^{+}}} + A_{CP}^{K^{0}\pi^{0}} + 2\frac{B(B^{0} \rightarrow K^{0}\pi^{0})}{B(B^{0} \rightarrow K^{+}\pi^{-})}$$

CPV in $D^0$ – $\bar{D}^0$ Mixing

Now

50 ab$^{-1}$

More precise results with higher luminosity

Current measurements give many constraints on NP models (see Golowich et al., PRD76, 095009 (2007)).

http://www.slac.stanford.edu/xorg/hfag/charm/CHARM15/results_mix_cpv.html
τ Lepton Flavour Violation

SM prediction: BR(LFV) $\sim 10^{-25}$

Possible NP in LFV:
- slepton mixing
- $H^{++}$ Zee-Babu models
- Neutral Higgs boson
- Majorana neutrinos
- Seesaw mechanisms
Dark Sector

- Dark matter suggests dark sector.
- Dark photon: $A'$, to be in $\text{MeV} \sim \text{GeV}$ mass.
- Probing method:
  - Leptonically decaying dark photons through mixing.
  - Sub-GeV dark matter in invisible decays.

Current and projected limits, radiative production of dark photon, decay to SM particles (C. Hearty, B2TIP 2014)
Schedule

Installation and commissioning plan

Luminosity schedule
Summary

• Upgrade of Super-KEKB and Belle II is on going.

• Physics opportunities on Belle II:
  • Constraining on CKM UT
  • Probing charged Higgs
  • New sources of CPV
  • Lepton Flavour Violation
  • Dark sectors

• Belle II will start operation in 2016.