$B^+ \to l^+ \nu(\gamma)$ at SuperB

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8th January 2008,
SuperB Workshop VI,
IFIC, Valencia

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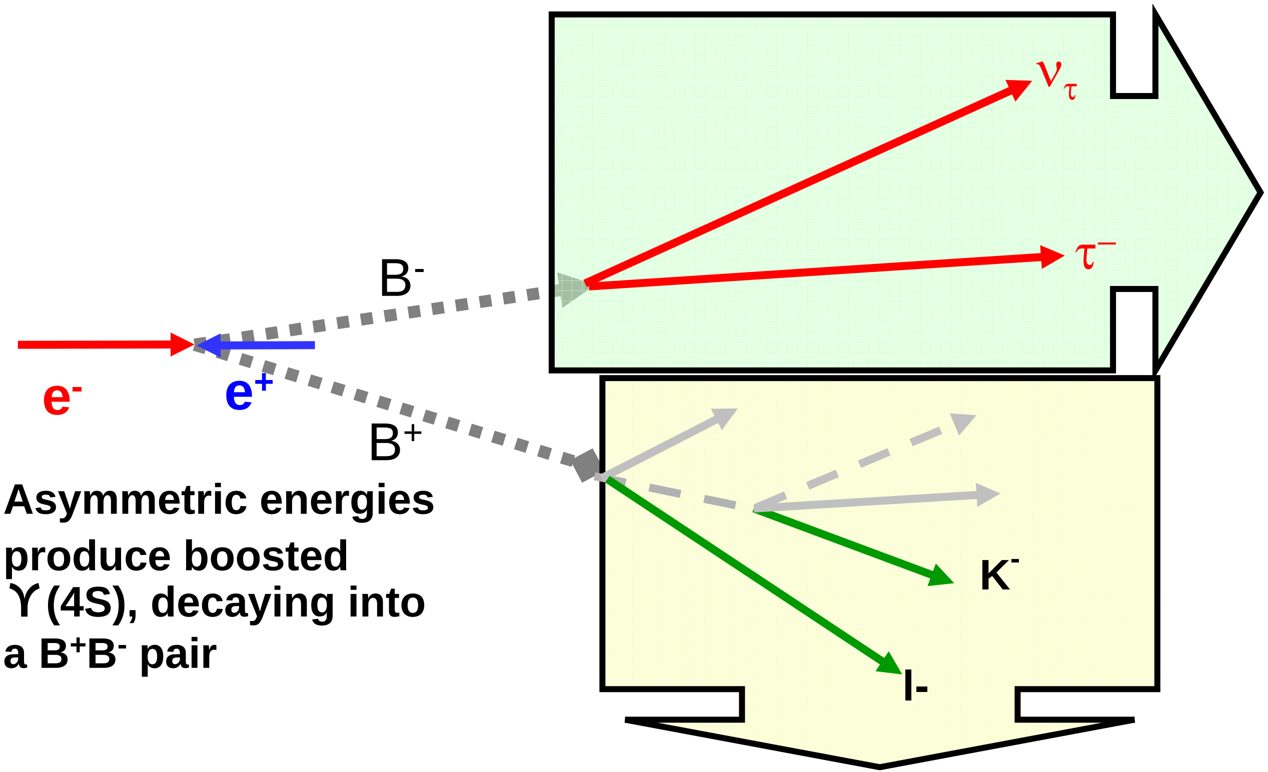
Outline

- Current Measurements
- CDR Prediction
- Physics issues
- Detector issues
- Other remarks

Reconstructing an event



Reconstruct signal via the decay products of the τ lepton from the rest of the event (B_{SIG})

Asymmetric energies produce boosted Υ(4S), decaying into a B^+B^- pair

Fully (Hadronic Tag) or Partially (Semi-leptonic Tag) reconstruct the non-signal B in the event (B_{TAG}).

Tag efficiency ~ few per mille.

Hadronic Tag

- B_{TAG}:

$$\varepsilon(B_{TAG}) = 0.15\%$$

$$B^+ \to \bar{D}^{(*)0}\pi^+, \bar{D}^{(*)0}\rho^+, \bar{D}^{(*)0}a_1^+, \bar{D}^{(*)0}\bar{D}_s^{(*)+} + \ldots$$

- B_{SIG}:

$$\left.\begin{array}{l}\left.\begin{array}{l}\tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau \\ \quad\;\, \to e^-\bar{\nu}_\mu\nu_\tau \\ \quad\;\, \to \pi^-\nu_\tau \\ \quad\;\, \to \pi^-\pi^0\nu_\tau\end{array}\right\}\text{71\% of } \tau \text{ decays} \\ \quad\;\, \to \pi^-\pi^+\pi^-\nu_\tau\end{array}\right\}$$

81% of τ Decays [3π mode only used by Belle; and is low purity]

Semileptonic Tag

- B_{TAG}: $B^- \to D^0 l^- \nu X$ $\varepsilon(B_{TAG}) = 0.066\%$
  - X = nothing, π^0 or γ

- B_{SIG}:

$$\left.\begin{aligned} \tau^- &\to \mu^- \bar{\nu}_\mu \nu_\tau \\ &\to e^- \bar{\nu}_\mu \nu_\tau \\ &\to \pi^- \nu_\tau \\ &\to \pi^- \pi^0 \nu_\tau \end{aligned}\right\} \text{71\% of } \tau \text{ decays}$$

Current Measurements

- Hadronic Tag:
  - Belle : $\tau^+\nu$ PRL **97** 251802 (2006)
  - BaBar : $\tau^+\nu$ arXiv:0708.2260 [Submitted to PRD-RC]
    other modes being worked on.
- Semileptonic Tag:
  - Babar: $\tau^+\nu$ arXiv:0705.1820 [Submitted to PRD]

Experiment	Tag	Data Sample (fb^{-1})	Result	Significance
		$B^+ \to \tau^+\nu$		
Belle	Hadronic	414	$(1.79^{+0.56}_{-0.49}{}^{+0.46}_{-0.51}) \times 10^{-4}$	3.5σ
BaBar	Hadronic	346	$(1.8^{+0.9}_{-0.8} \pm 0.4) \times 10^{-4}$	2.2σ
	SL	346	$(0.9 \pm 0.6 \pm 0.1) \times 10^{-4}$	–
		$B^+ \to \mu^+\nu$		
Belle		140	$< 2 \times 10^{-6}$	–
		$B^+ \to e^+\nu$		
		Work in progress.		

- c.f. SM expectation of $O(10^{-4}, 10^{-5}, 10^{-9})$, for τ, μ, and e modes which depends on $|V_{ub}|$ and f_B

$$\mathcal{B}(B^+ \to \ell^+\nu) = \frac{G_F^2}{8\pi} f_B^2 \, |V_{ub}|^2 \, \tau_{B+} M_{B+} m_\ell^2 \left(1 - \frac{m_\ell^2}{M_{B+}^2}\right)^2$$

CDR Prediction: $\tau^+\nu$

- "Realistic predictions require detailed knowledge of the calorimeter response, and of beam-backgrounds".

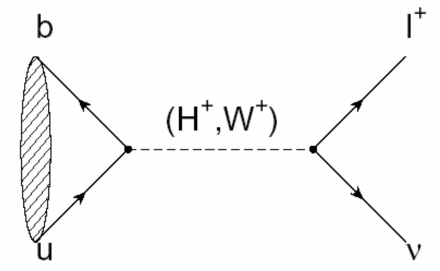
- Statistical error will be 3-4% with 75 ab^{-1}.

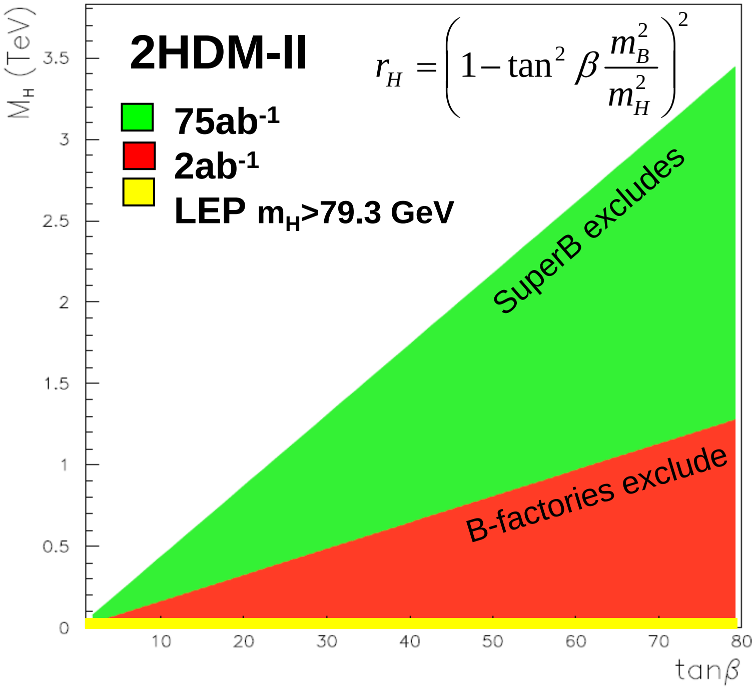
- Must control the systematic uncertainties better than current measurements (~10%). CDR estimate was that this could be reduced to 4% through:
  - Better understanding of backgrounds: control studies of modes like $B \to D^{(*)} l \nu$.
  - Improved detector performance (better K^0_L coverage, improved calorimeter coverage/resolution).
  - Lower boost : gives better solid angle coverage to understand backgrounds.

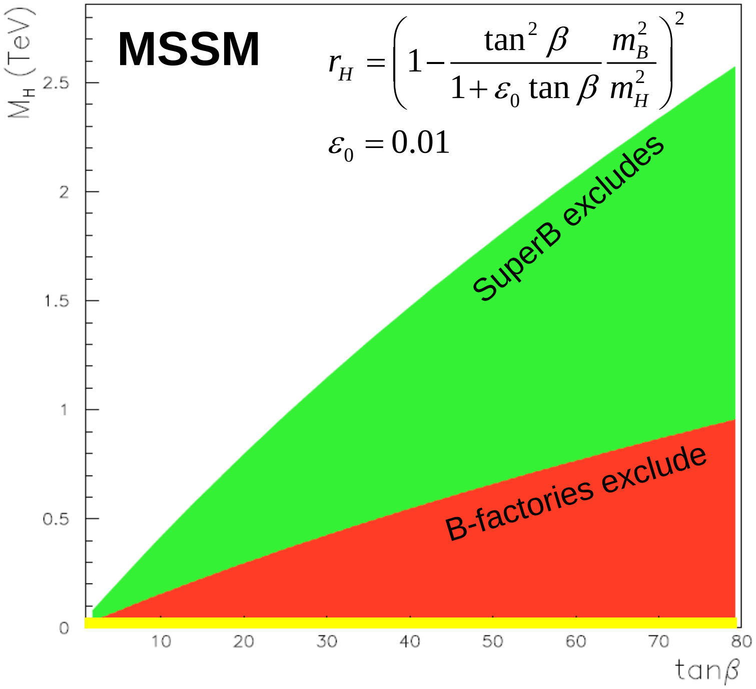
NP & $B^+ \to \tau^+ \nu$

- Higgs mediated MFV:

$$r_H = \frac{\mathcal{B}_{SM+NP}}{\mathcal{B}_{SM}}$$







- Multi TeV search capability for large tanβ.

95% exclusion plots

CDR Prediction: $\mu^+\nu$, $e^+\nu$ $(+\gamma)$

- Need good lepton and photon identification: IFR and EMC performance.
  - $\mu^+\nu$: clean with $\mathcal{B} \sim 5\mathrm{x}10^{-7}$.
    - Aiming for a 5% (stat) measurement with similar systematic uncertainty.
  - $e^+\nu$: expected $\mathcal{B} \sim 10^{-9}$.
  - $l^+\nu\gamma$: not helicity suppressed, useful to improve understanding of hadronic branching fraction calculations for decays like $B \rightarrow \pi\pi$.
    - Expected $\mathcal{B} \sim 10^{-6}$

Physics Issues

- Understanding of a_1 line-shape for improved control of Hadronic tag?
  - What is reconstructed as $D^{*0}a_1^+$ (*as the cuts let in more than just* a_1)?
    - a_1 width varies from 230 to 521 MeV in the PDG.
    - Analyses cut at 300 MeV when selecting the B_{Tag} mode $D^{*0}a_1^+$.
    - Other similar mass particles have the same final state and can interfere [e.g. a_2, $\pi(1300)$].

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- NP exclusion vs. NP discovery plot!
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- NP exclusion vs. NP discovery plot!
  - We want to compare our discovery potential to the LHC discovery potential.
- ... expand analysis to multi-dimensional fit?

Detector Issues

- Current systematic errors related to the detector are:
  - PID : 2% (2-6% for Belle)
  - π^0 : 1.4 (3% for Belle)
  - Tracking : 5.8% (1-3% for Belle)

- How does this channel benefit from:
  - Improved μ/K^0_L efficiency.
  - Improved calorimeter performance/hermiticity.
  - Improved PID performance/hermiticity.

- SuperB beam background conditions?

Detector Issues

- [the result of discussion with Steve Robertson after lunch this afternoon]

- How well will we understand the material in the SuperB detector?
  - Need a flexible simulation designed so that we can change the geometry to easily account for ‘forgotten’ material.
  - In the early days of SuperB data taking we need to be able to tune physics process simulation in Geant4 so that it is realistic: e.g.
    - See the shower shape variable data/MC comparison in BaBar is not perfect even now. This has serious ramifications on how we perform an analysis like $B^+\rightarrow l^+\nu$. Ideally want an accurate MC so that we minimise correction factors [scales & shifts] to any distributions we need to rely on when extracting signals.

Other remarks

- Fast simulation can be used to make quick estimates of performance.

- SuperB simulation required to thoroughly test analysis.
  - Flexible enough to tune early in the experiments lifetime, with a good understanding of material in the inner part of the detector and between crystals/modules in the Calorimeter.

- Better understanding of tag side efficiency needs coordinated effort (best started at BaBar and Belle)
  - Better under standing of branching fractions, and other analysis factors like line-shapes that may affect efficiency determination.

- Better understanding of τ decay branching fractions?