Design your own B-meson CP Violation Experiment

1. Which accelerator, and why, would you prefer to use for your experiment:
   - e^+e^- or $p\bar{p}$?
   - pp or $p\bar{p}$?
   - fixed target or collider?
   - any other?

   Mention pro's and con's of each option.

2. Select you favourite collider. At which energy do you want to make collisions? Why?

3. You are going to measure the CP asymmetry in $B_s \to D_s^{\mp}K^{\pm}$, which has a branching ratio of about 10^{-4}. How many B_s particles must be produced to obtain a precision of 1^o on the CP angle γ?

4. In the CP asymmetry you measure the decay rates:
   $B_s \to D_s^{\mp}K^{\pm}$ and $\overline{B}_s \to D_s^{\pm}K^{\mp}$
   - How would you tag the flavour of the B_s at production?
   - Are there intrinsic limits to this precision?
   - How would you calibrate the wrong tag fraction using other data?

5. To select events of the type $B_s \to D_s^{\mp}K^{\pm}$ and also of another decay mode $B_s \to J/\psi\phi$, a large amount of background must be rejected.
   - What are the specific signatures of the two signal decays that can be used to reject background? Think of quantities that can be used at trigger time and quantities that can be used off-line.
   - In one of the two decays there is a potentially very dangerous for the CP measurement from another B_s decay. Do you know which one? How can you reject that background, i.e. which detector technology would you use?

6. Give the formula to reconstruct the decay time of a B meson in an observed event in terms of directly "detectable" quantities.
   What are the subdetectors required and what is their importance?

7. Make a sketch of your detector that measures CP violations with B decays

Hints or points to consider

To chose your favorite collider:

- e^+e^- at $\Upsilon(4S)$: electromagnetic production, clean, no B_s, coherent production (i.e. only time dependent CPV, requires asymmetric beams, good flavor tagging)
- e^+e^- at $\Upsilon(5S)$: B_s, lower cross section, not coherent
- e^+e^- at Z-peak ("tera-factory"): Weak production, not coherent
- pp collisions: stronhg production (stats!), "messy", backgrounds, ...
- Fixed target collider: low cross section vs long decay distance
- pp vs $p\overline{p}$: "colour drag" asymmetry cross check wrt pp.

To calculate the number of events for 1^o angle γ measurement:

- How many perfectly measured (ie. undiluted) events needed?
  - How many purely signal B_s decays needed
  - Fraction of collisions that produce a b-quark
  - Fraction of those where a B_s meson is created (guess it)
  - Fraction of B_s mesons that decay into the signal final state
  - $\Rightarrow$ Calculate the number of perfect;y measured events
- Next introduce experimental measurement effects ("dilutions")
  - Acceptance, efficiency (make a guess)
  - Dilution from background and resolution (make a guess)
  - How many events will be accepted by the trigger?
  - What is the tagging dilution factor?
  - $\Rightarrow$ Calculate the *total* number of needed collisions.
- $\Rightarrow$ How long of running does it take in your collider?