Discussion Summary

1. What is beam-beam limit in hadron colliders?
2. Long-range effect and compensation (by wire)
3. Head-on effect and compensation (by electron lens)
4. Other simulations

What is the beam-beam limit in hadron colliders?

- ISR / SppS?

- Tevatron
  - Long-range effects limit beam lifetime
  - Pacman effect limits lifetime of 3 proton bunches
  - Proton intensity limited by Z-driven instability
  - Anti-proton intensity limited by injectors

- RHIC
  - Beam lifetime determines ξ_{max}
  - Background has limited intensity in past

- LHC
  - How does radiation damping affect beam-beam limit (e.g. background)?
  - Possible tests at DAΦNE with wiggler off?

Long-range effect/compensation (by wire)

- What is the minimum separation needed?
  - 10 σ sufficient from simulation
  - Existing machines suggest about 5 σ sufficient (Tevatron, RHIC experiments, ?)
  - Systematic data from RHIC/SPS wire experiments

⇒ Systematic investigation of lifetime vs. separation is of high importance

  - Tune scan in RHIC with wire on/off desirable
  - Would complement tune scan in SPS

Long-range compensation (by wire)

- Explain RHIC/SPS observations in wire experiments
  - Main observable in experiment is loss rate, transverse profiles usable sometimes
  - Parametric dependence should be reproduced in simulations (onset of loss at certain wire distance, for example)
  - Absolute loss rates can probably not be reproduced (may be easier for strongly enhanced beam-beam effect)
  - Need error bars for observations

Long-range compensation (by wire)

- Space reserved in LHC (3m)
- No wire design yet
  (but wires exist in SPS & RHIC)
- Expect a 1 σ increase in DA for DC wire
- Modulated wire strength can address pacman effects
  - Design of power supply challenging
  - 40 MHz oscillations with changing amplitude
    looks like the most promising solution (F. Caspers)
  - Not clear who can build such a ps
  - May loose RHIC as test bed in ~2 years

Head-on compensation (by e-lens)

- Tevatron e-lens investigations
  - Should measure effect of ver. tune shift in more detail (partial compensation better than anticipated)
  - Quality of e-beam (can still be improved)
  - Demonstration of reduced tune footprint with e-lens very desirable
    - Appears to be difficult for pbars ($\Delta Q=0.01$, Schottky spectrum with many lines) and p (?)
  - Study interplay between e-lens and nonlinearities in the ring

Head-on compensation (by e-lens)

Study items for RHIC/LHC (from Vladimir):

- Will (truncated) Gaussian e-current improve beam lifetime (reduce diffusion)?
- Is there a better distribution than Gaussian?
- Study e-p interaction in bending sections
- Lifetime deterioration of e-p misalignments
- Effect of low-frequency variations in e-current, shape and position on beam lifetime
- Ion cleaning inefficiencies
- Interactions wire compensators
- Effect on coherent stability or strong-strong effects

Head-on compensation (by e-lens)

Design considerations

- Location in ring
- E-energy and current
- Choice of gun technology
- Is a DC e-lens sufficient (may have different answer for RHIC and LHC)?

Crab cavities

- Useful in a number of upgrade scenarios
- Have now experience from KEKB
- Idea currently pursued for LHC only by R. Calaga
- Evaluation for LHC requires a test in a hadron ring
  - Large effort for superconducting rf system
  - Long lead-time before results can be expected

Other simulations

- Explain measured multi-bunch spectra
  - Successful for proton operation in RHIC (T. Pieloni), BTF gates for specific bunches desirable
  - Can this be done for the Tevatron?

- Crossing angle-effect
  - Effect of synchro-betatron resonances have not been studied for the LHC
  - Different algorithms used by K. Hirata and Y. Cai
  - SLAC (Yunhai) could apply expertise to LHC to have one prediction
  - RHIC can provide some data, may be more can be generated

$\Rightarrow$ Effect of crossing angle needs to be studied

Workshop statistics

- 35 participants from 9 institutions (Europe, Asia, North America)

- 25 presentations in
  - Machine performances
  - General simulations
  - Long range effects, simulation, and compensation
  - Head-on effects, simulation, and compensation