Scaling of e+e- Ring Collider

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e^+e^- Ring Colliders

- Lots of proposals since LEP3 proposal a year ago
- Except for the local issues
  - Can be accommodated in existing tunnel? (LHC)
  - If new tunnel, does it fit with future plans of the lab? (LHeC, HELHC, VLHC, etc)
- Problems are common to all the proposals
- The only parameters are
  - Ring size
  - site power limitation

Common Features of e^+e^- Ring Colliders

- High luminosity ~10^{34} $cm^{-2}s^{-1}$ causes short beam life time due to radiative Bharbha scattering
  - ➢ Top-up injection needed
  - ➢ one more ring
- Bunch collision frequency (5-50kHz) much lower than in B factories (10-100MHz)
  - because synch.rad.power must be reduced
    → reduce total current , keeping luminosity
    →increase bunch charge & decrease # of bunches
  - hence, LC-like collision frequency and bunch charge
    →beamstrahlung similar to LC

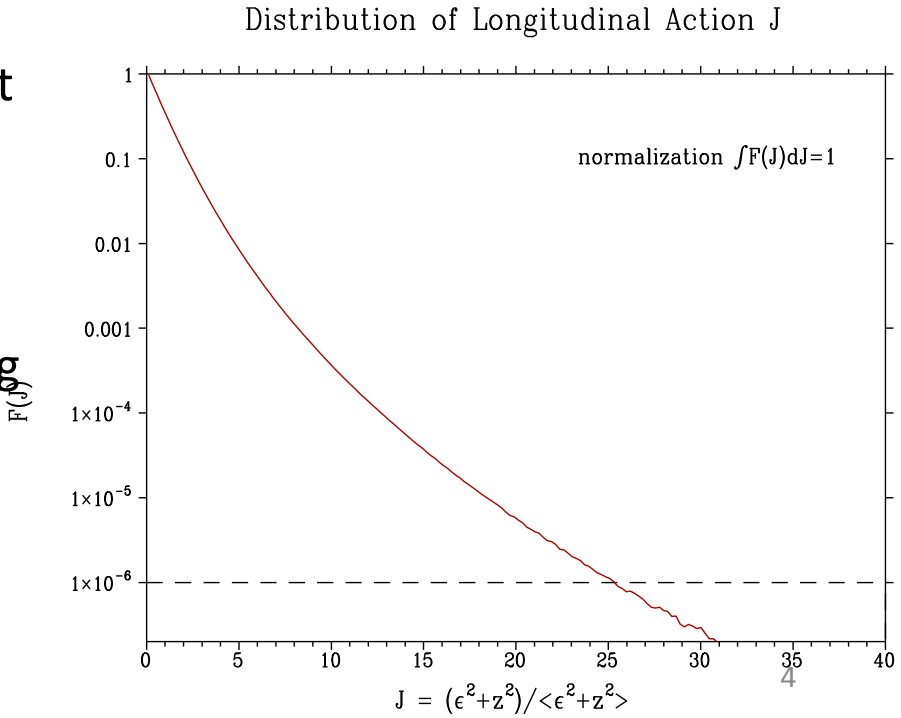
Limitation of e^+e^- Ring Colliders

- Beamstrahlung at high-energy tail causes significant energy loss of electrons/positron

$$\Upsilon_{max} \approx \frac{2Nr_e^2\gamma}{\alpha\sigma_z\sigma_x}, \qquad (\sigma_x \gg \sigma_y)$$

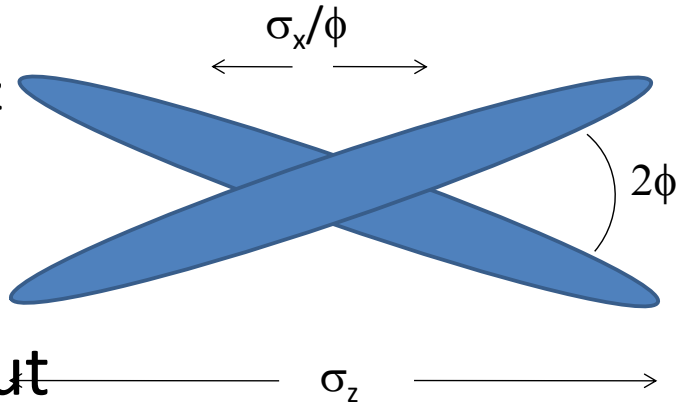
$$\frac{dW}{d\omega} \propto \exp\left[-\frac{2\omega}{3\Upsilon E_e}\right], \qquad (\Upsilon E_e \ll \omega \ll E_e)$$

- Particles with large energy loss cannot circulate around the ring (momentum band-width)
- Affects the beam life time
- Hence, ring colliders are much more fragile than LCs against beamstrahlung
  - Once accelerator is OK, then beamstrahlung in ring colliders is milder than in LC for physics



Nanobeam Scheme (or Crab Waist)

- large crossing angle >> σ_x/σ_z
  (no crab cavity compensation)
- merits
  - effectively short bunch without using high RF voltage
  - this makes smaller beta possible
- But does not help in solving the beamstrahlung issue



Luminosity Scaling of e^+e^- Ring Colliders

V. Telnov, arXiv:1203.6563v, 29 March 2012

- For given Upsilon, the momentum band width must be

$$\eta \equiv [\Delta p/p]_{max} \gtrsim 15\Upsilon$$

- Then, the luminosity at beamstrahlung limit and tune-shift limit is given by

$$\mathcal{L} \propto \frac{\rho P_{SR}}{E^{13/3}} \left(\frac{\xi_y \eta^2}{\varepsilon_{g,y}}\right)^{1/3}$$

P_{SR} : syn.rad.power

ρ : bending radius

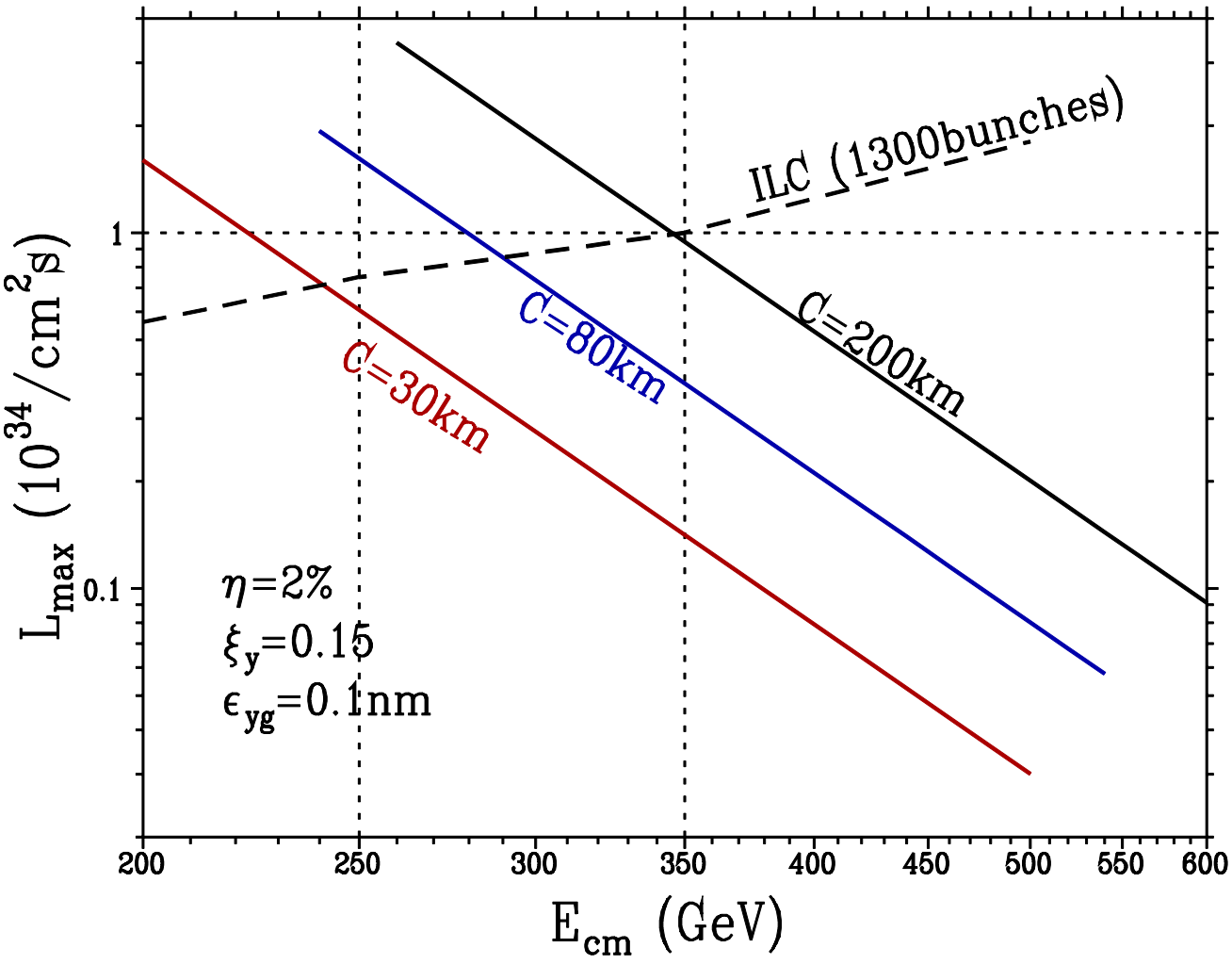
ξ_y : tune-shift

$\varepsilon_{g,y}$: geometric emit.

Luminosity vs. Energy

example with

- η=2%
- ξ_y=0.15
- ε_{gy}=0.1nm



R&D Items of Ring Colliders (1)

- Momentum band-width
  - RF bucket height must be > η (OK with a higher V_{RF})
  - Transverse acceptance of off-momentum particles is an issue
  - Arc is OK (light sources accept > 4%)
  - FFS is not easy
    - chromaticity $L^*\eta/\beta_y^*$ large
    - 2% is perhaps feasible (non-educated guess)
- But what is "momentum band width"?
  - Usually, track particles with given amplitude (constant energy or constant synchrotron oscillation amplitude) over several damping times.
  - Synchrotron tune very high
  - Damping is very fast
  - It does not make much sense to track particles with constant energy or constant synchrotron/betatron amplitude
  - Possible tracking to guarantee beamlife
    - track 10-100 particles over desired life (10^7 turns)
    - including
      - exact lattice
      - synchrotron oscillation
      - synchrotron radiation in the arc
      - beam-beam kick by Erskine-Basetti
      - Beamstrahlung by Erskine-Basetti
    - And see how many particles survive

R&D Items of Ring Colliders (2)

- Vertical emittance
  - light sources can reach ε_{gy} ~ 1pm at low energy
  - still far above the fundamental limit due to radiation opening angle ($1/\gamma$)
  - but what about colliders at high energy?
- Synchrotron radiation power O(100MW)
  - 4x LEP2
  - critical energy > MeV
  - How large is the AC power?
  - RF coupler
  - Vacuum
  - cryogenics
- IR region design
  - very small beta
  - different beam energy for e+ and e- due to beamstrahlung O(0.1%)

Last page of my LCWS12 talk

(personal) Conclusions

- ILC/CLIC Higgs factory are obvious if 500GeV is feasible
  - cost and staging issues
  - CLIC has maturity problem for early start
- e^+e^- Ring Colliders
  - Technology not trivial
    - Good exercise of accelerator physics (till an LC starts)
  - LEP3 (27km, 240GeV) & TLEP (80km, 350GeV) are just at the border of feasibility
  - Can be a choice if higher energy with e^+e^- is not needed at all
- γ-γ Colliders
  - technology immature
  - good target as a second stage of linear colliders
- Those who are not satisfied with personal conclusions, go to FNAL ➔