

Beam-Beam Interaction

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Special Beam Physics Symposium
in Honor of Yaroslav Derbenev's 70th
Birthday, Aug.3.2010, JLAB

Personal History

- Started research work late 1979's
- Design of TRSTAN
 - used to be e-p collider project
 - Started construction as e+e- collider
 - Somebody had to think of polarization (electron, proton)
 - I was interested in polarization
- Derbenev-Kondratenko works on radiative polarization in early 1970's
 - Hard to understand. Need Lifshitz!
- Somehow designed TRSTAN e-p with longitudinal electron polarization, without really understanding D-K.
- Electron Polarization Workshop at DESY in March 1982
 - Met with Anatoliy, giving impressive talk
 - This was my start of understanding D-K radiative polarization, 10 years after D-K.

Early Days of Beam-Beam

- Slava's work only in early stage before 1965
- Beam-beam theory got into computer-simulation already in 1970's. Perhaps, uninteresting for Slava.
- Early generation of computer simulation
 - Eberhart Keil, Steve Meyers,
 - Bob Sieman, Krishnagopal, Tennyson.....
- Experiences had already said beam-beam limit was ~ 0.06 for electron, orders of magnitude lower for proton.
- Can we reproduce these numbers by simulation?
 - Poor computer power
 - Strong-strong unrealistic for ring colliders
 - ~ 1000 particles for weak-strong
- Inclusion of everything
 - Radiation damping
 - Lattice complication, in particular tune survey
 - All 6D effects
- Gradually evolved closer to reality (driven by evolution of computer power)
 - But still we had to assume a certain number for beam-beam limit in collider design

Evolution of Colliders has been driving Beam-Beam Theory

- From single-ring, headon, single (or a few) bunches
 - AdA, ADONE, SPEAR, DORIS, CESR, PETRA, PEP, TRISTAN, LEP
- To two-rings: PEP-II, KEKB
- hadron colliders larger and larger
 - → parasitic collisions
- Linear colliders since mid 1980's

Ideas for Beam-Beam

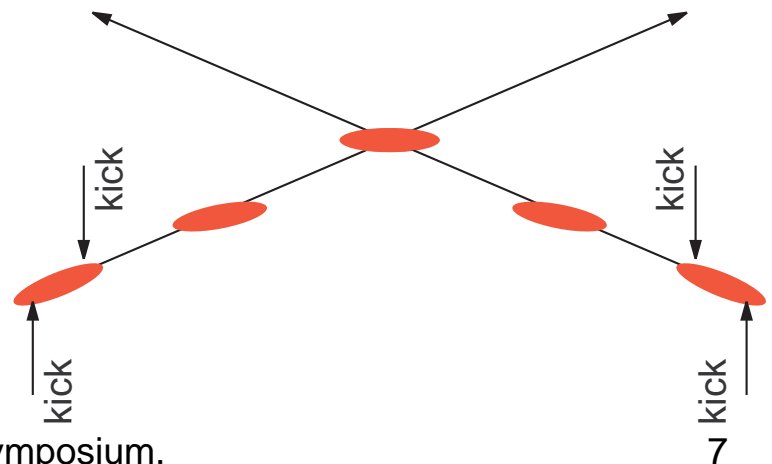
- Large crossing angle
- Crab crossing
- Traveling focus
- Electron lens
- Wire compensation
- Crab waist

Crossing Angle

- Early work by Piwinski
 - Crossing angle excites synchro-beta resonances
 - Crossing angle hated
 - Crab crossing
 - By-product of linear collider
- New era of crossing angle
 - large crossing angle can give higher luminosity (K.Hirata, etc)
 - → crab waist

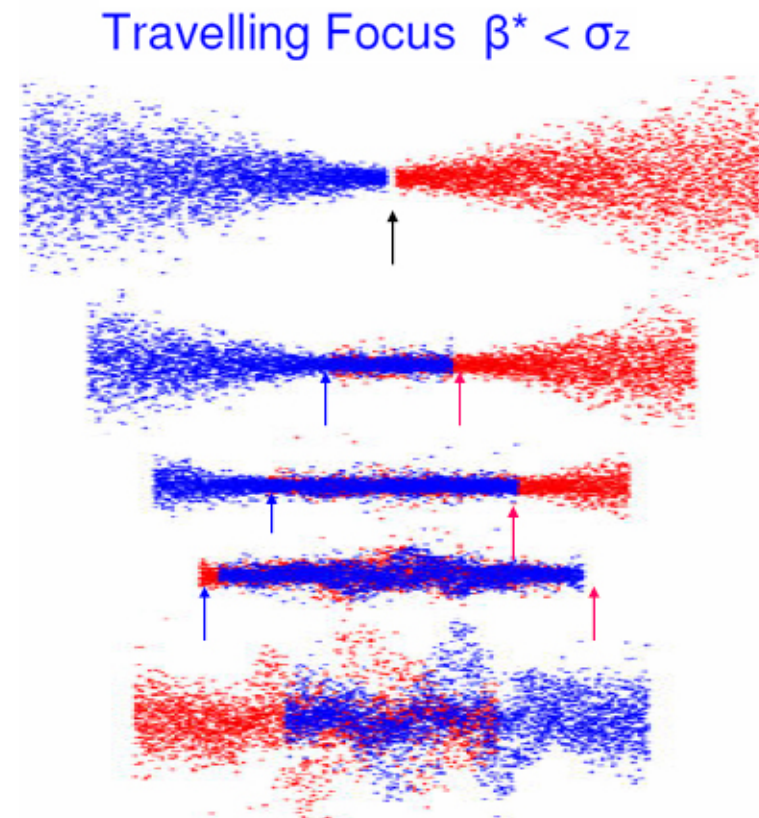
Crab Crossing

- First proposed for LC by R.Palmer in 1987
- By now indispensable to any LC (ILC, CLIC)
- Application to ring colliders (eliminate Piwinski effects)
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 - Expected factor >2 gain in luminosity
 - Actually, < 1.5



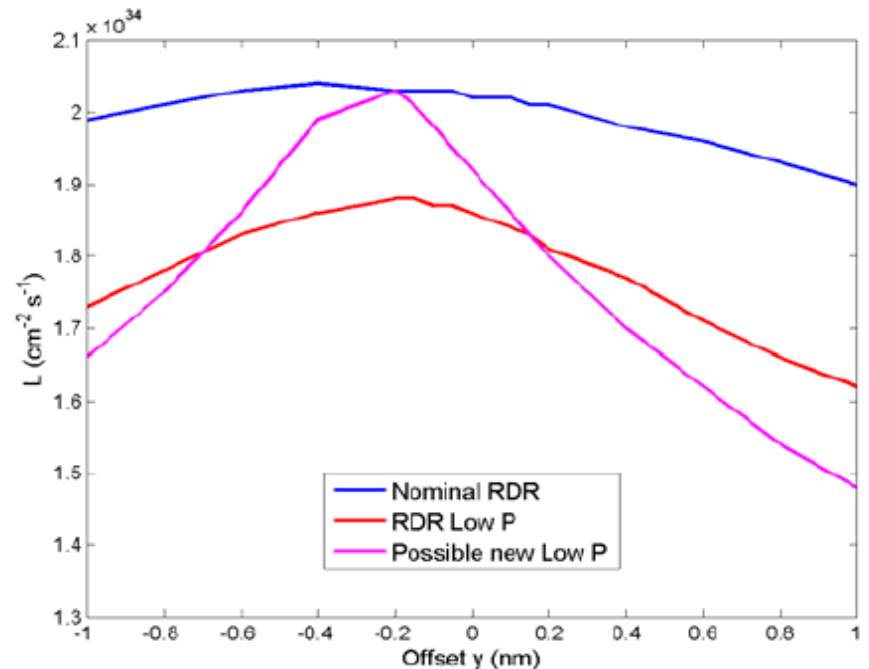
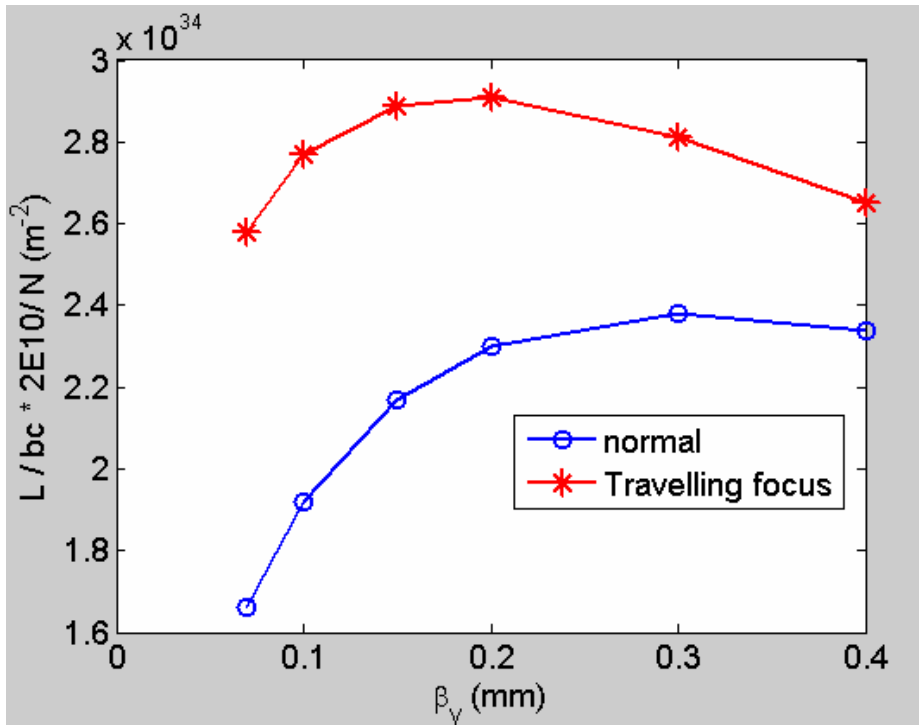
Traveling Focus

- First proposed by V. Balakin to overcome hour-glass effect
- Make use of large disruption parameter (almost no effect at zero current)
- VLEPP adopted $Dy = O(100)$



Traveling Focus (2)

- Revival for ILC
 - $Dy = 15\sim 30$
- Highly sensitive to errors
- So far, no application to ring colliders

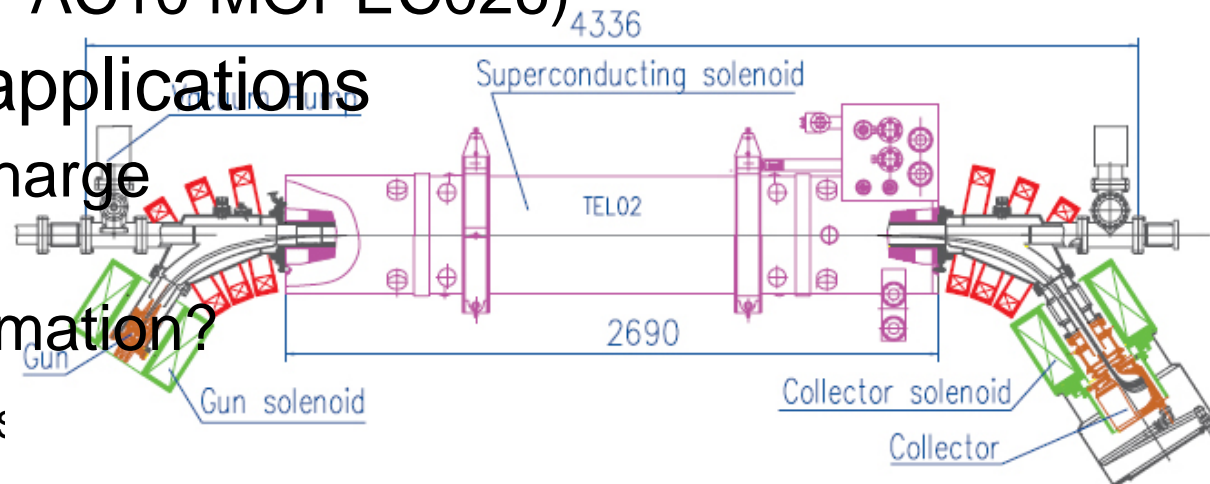


Compensation by Electron Lens

- Can compensate for head-on as well as long-range beam-beam
 - V.Shiltsev et.al. PRST-AB 2-071001(1999)
- Long-range BB compensation
 - V.Shiltsev et.al. PRST-AB 11-103501(2008)
- Next step to head-on compensation (IPAC10)
 - Gaussian beam needed
 - Plan at RHIC (IPAC10 MOPEC026)

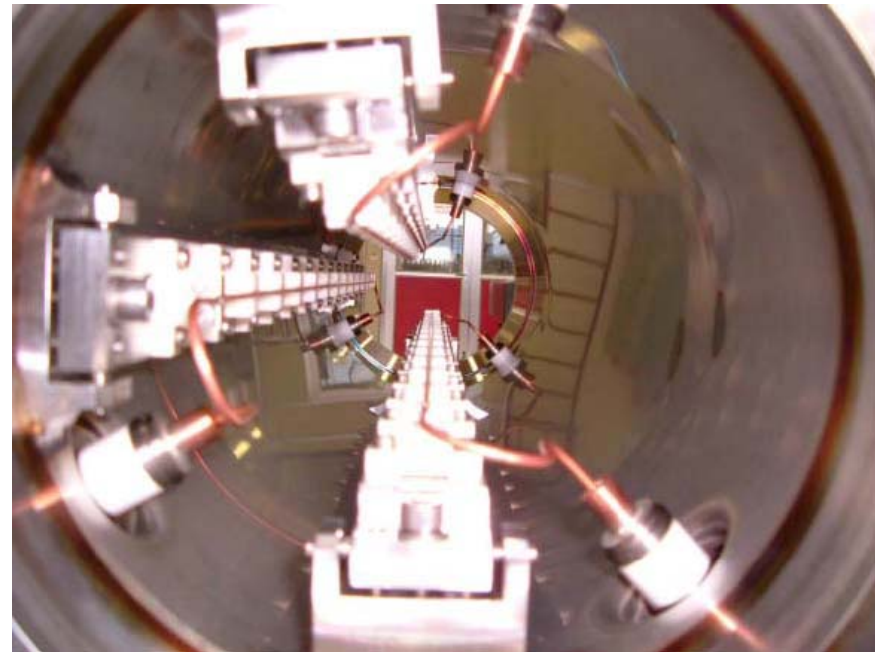
- Other possible applications

- Proton space-charge compensation
- LHC beam collimation?



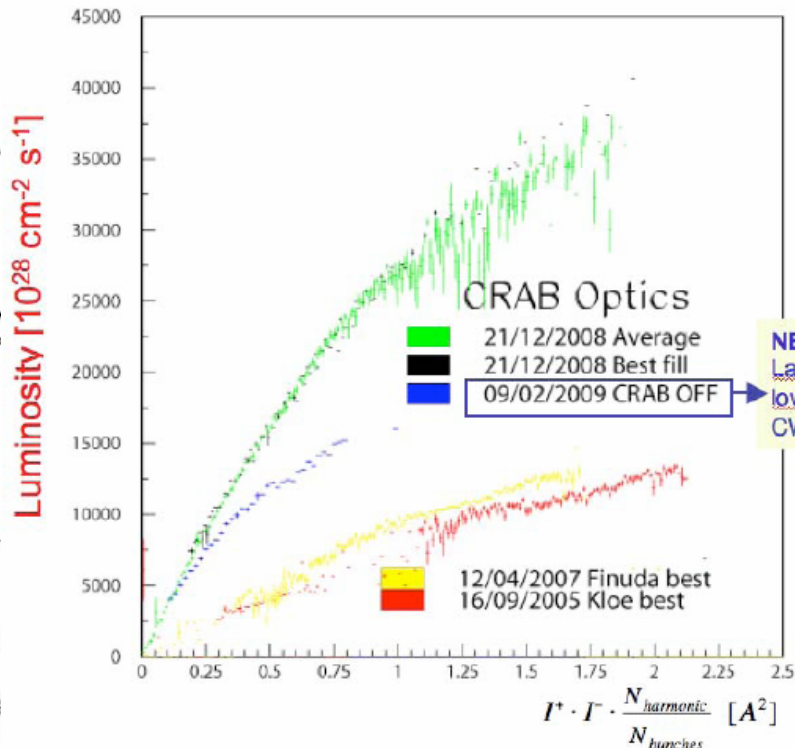
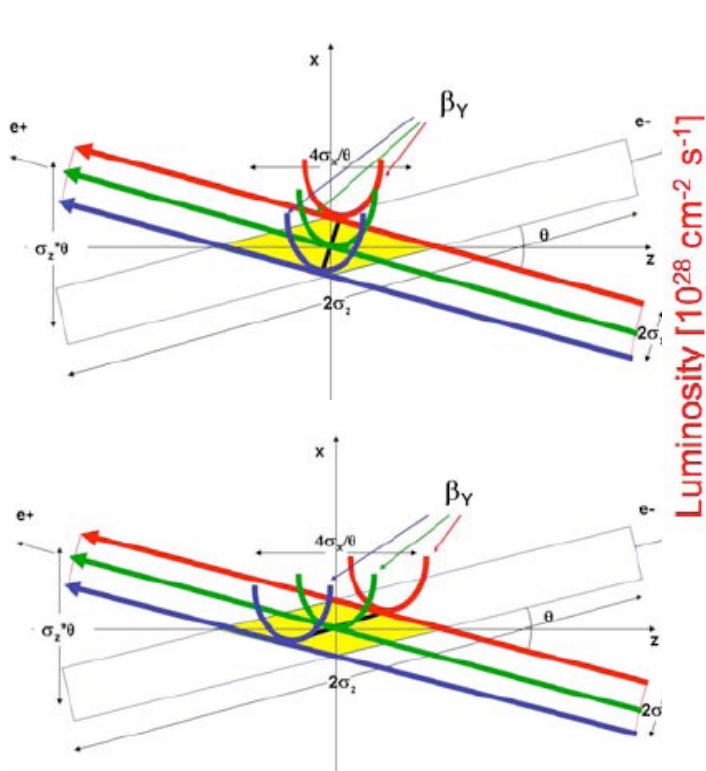
Compensation by Wire

- Compensation of long-range beam-beam
 - J.P.Koutchouk, PAC2001, p1681
- Experiments at SPS
 - EPAC04 WEPLT045
- Test at RHIC
 - Observed improvement of beam life (IPAC10 TUPD065)



Crab Waist

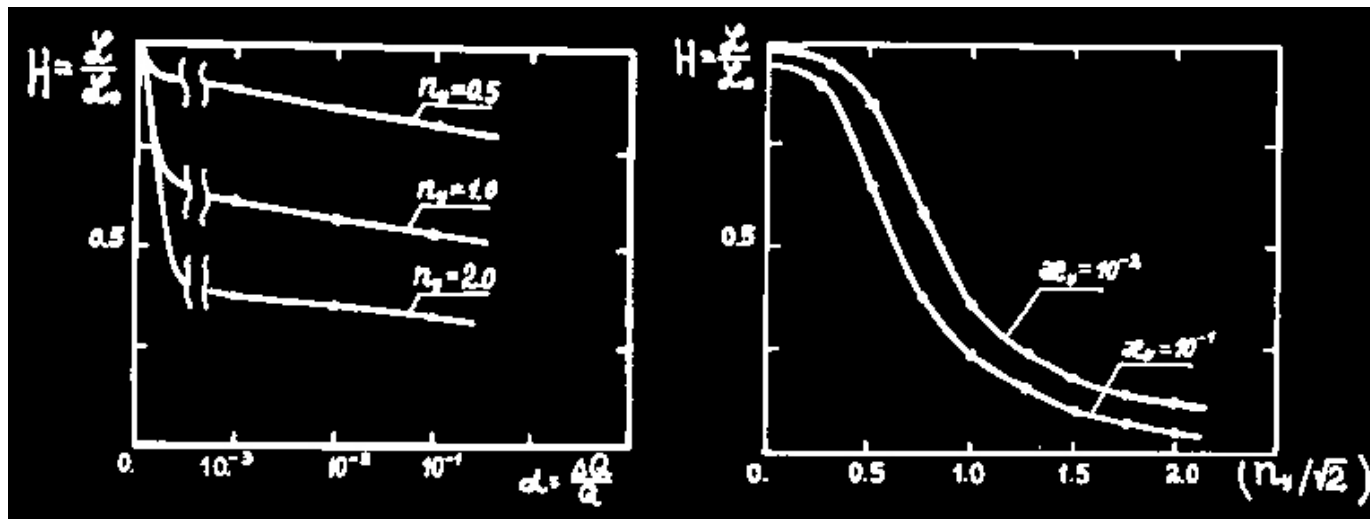
- P.Raimondi, 2006
- Large crossing angle: $\sigma_z \phi \gg \sigma_x$
- Eliminate side effects by crab waist, introducing pair of sextupoles (Twist location along the on-coming bunch center)
- Allows long bunch and low current, but requires high precision
- Confirmed at DAΦNE
- SuperKEKB (almost approved) adopts crab waist



NEW COLLISION SCHEME:
 Large Piwinski angle $\psi = 1.9$
 low- β $\beta_y^* = 9.0$ [mm]
 CW sextupoles off

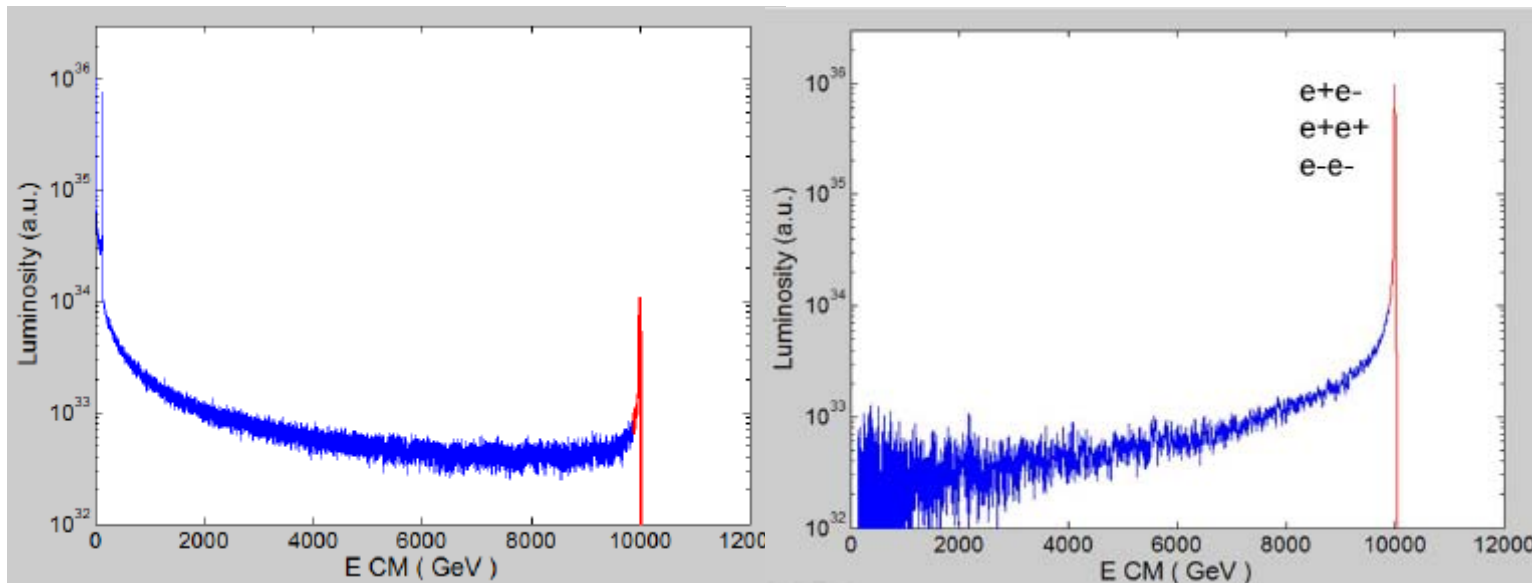
4-Beam Compensation

- Neutralize the beams by mixing e+e- beam
- First tried at DCI – unsuccessful
 - Turned out to be dynamically unstable (Ya.S.Derbenev, SLAC TRANS 151, 1973)
- 4-Beam Compensation in LC
 - Purpose is to eliminate beamstrahlung
 - Turned out to be unstable against incomplete charge cancellation and position offset for large disruption parameter D_y (N.Solyak, INP88-44, 1988)



4-Beam Compensation in LC

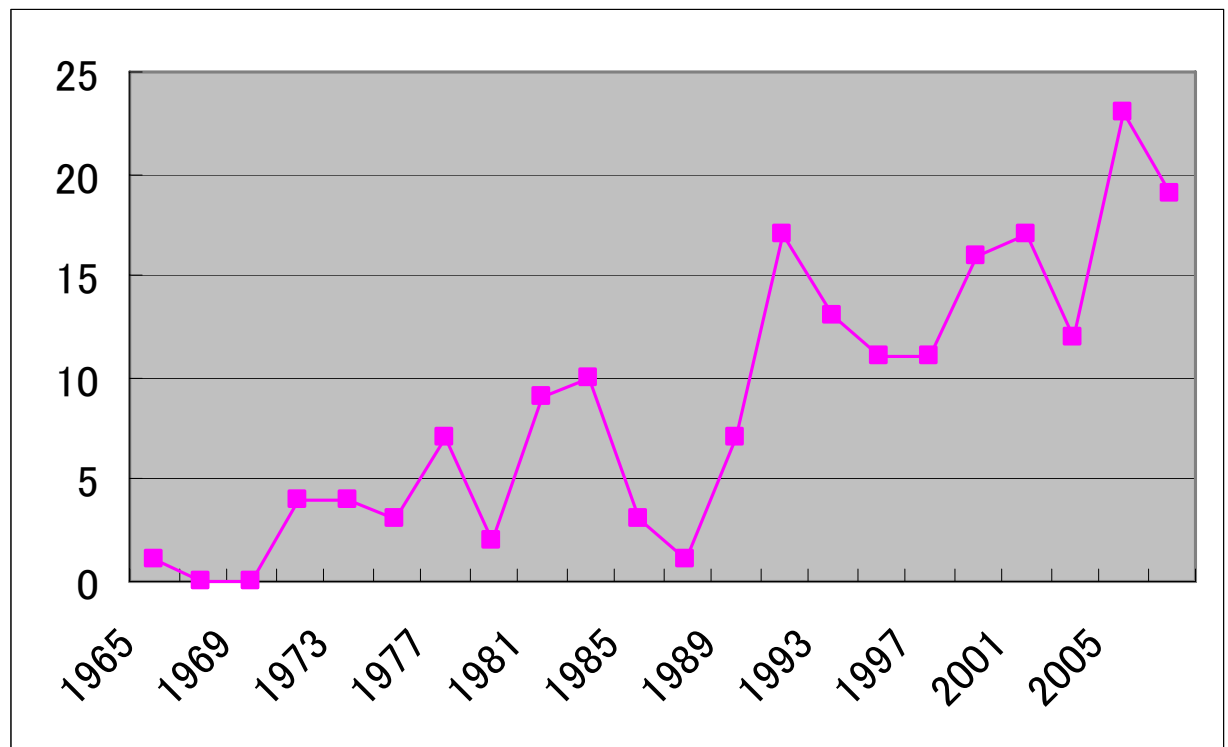
- $D_y = 15 \sim 30$ in ILC
- But will be smaller for multi-TeV collider
- Plasma colliders
 - Typical beamstrahlung parameter Y
Several 10^3 to several 10^4 for 10TeV collider
 - $D_y < 1$ reasonable



A.Seryi, Apr.2010 (private com.) 2x5TeV, $Y=4.4E4$, $D_y=0.44$, 99%
compensation, compensating beam energy spectrum,
Aug3.2010, JLAB

Hope Slava to be back to B-B

Number of papers in PAC with 'beam-beam' on the title



Slava's 70th Birthday Symposium,
Aug3.2010, JLAB