January 15, 2006 CLNS 06/1951

FEW COMMENTS ON THE STATUS OF DETECTOR FOR ILC[1]

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Abstract. We analyze situation with detector and FF optics for ILC at present. Looks like some important options escaped from attention of designers.

INTRODUCTION

It comes out that there are 3+1 detector variants under development so far [1], [2]. Although it looks like there are only minor differences in design (except variant [2]), we concluded, that some *important features were not even discussed so far* or discussed too superficially. So the goal of this message is to attract attention to some of these features.

According to our readings the features not discussed adequately are:

1). *Different energy of colliding beams.* One can recall the success of asymmetric B-factory. It is natural to keep in mind the same possibility for ILC, where this opportunity might be even more important, especially as we learned that Higgs boson is not generated in *s*-channel.

2). As the SC accelerating structure is a standing wave type, it allows acceleration in *both* directions. One can consider the possibility to work at *double energy with a stationary target*. For this action, the beam accelerated in the first linac must be redirected traverse IP into another one. The phasing could be arranged in a relatively simple way, but the optics need to be specially designed for this. It's better to consider this beforehand.

3). *Zero crossing angle* initiated by NLC/JLC type machines mostly. Crossing angle is not required for ILC beam pattern. Zero angles give huge advantages in optics, preventing from SR in magnetic field of detector and degradation of luminosity. So we think, that only this option must be kept in detector design. Unfortunately we can't see engineering realization (up to drawings, not a concept) of gamma-gamma IP, especially in evacuation of used electrons, having extremely a wide spectrum (~100%). So the gamma-gamma option must be evaluated only after such design is represented finally. Even so, a zero crossing angle makes realization of gamma-gamma scheme a much easier task.

4). We pointed out some time ago, that Iron *yoke of detector is not its inevitable part* [3], [4]. Strictly speaking its function is only in helping of muon identification. This function could be easily overcome with the latest technologies, see [2].

5). *Monochromatization* –the ability to arrange collision at IP in such a way, that low energy particles from the first beam collide with the higher energy ones in the opposing beam. This idea was considered for circular machines a long time ago [6], [7], [8]. For a single pass system, as the ILC is, realization of such program becomes much easier procedure. Despite significant SR energy spread generated during

[1] Electronic version is available at http://www.lns.cornell.edu/public/CLNS/2006/CLNS06-1951/clns06-1951.pdf

collision, this might be important for measurements at narrow resonances, including low energy option (Giga-Z).

6). *Work with nonzero dispersion at IP*. This might be useful for monochromatization and to simplify the FF optics.

7). *Adiabatic focusing at IP*. Focusing arranged with *multiplet* of quadrupoles, rather than a doublet so that the strength of the lenses changes slowly from lens to lens.

8). Peculiarity for registering of collisions with *both polarized beams*. Registration of back-forward asymmetries of secondary products is the main task for operation with polarized particles. This question requires special attention.

So we are considering in brief, each of these items here.

1. COLLIDING BEAMS WITH DIFFERENT ENERGY[2]

The usefulness of this option is evident. Mostly successful confirmation is in usage of asymmetric B-factories. In ILC the energy of each beam can be changed easily. We can say even, that there must be significant effort applied to keep the energy the same in both beams. For the energy measurements and keeping its value fixed, some spectrometry and feedback is required.

The distance passed by particle from the point of its creation can be estimated by transforming the lifetime of this short-living particle resonance to the Lab frame. The g-factor defined naturally by extra energy over the mass of resonance. On the other hand, the minimal distance defined by resolution of vertex system. So one can envision, that the energy difference could reach few tens of *GeV*. Although it is not a problem in general, this possibility must be kept in mind. Also it will be some task to decide what energy *each* of the beams (electron and positron) must have.

Significant asymmetry in energy immediately brings on agenda asymmetrical design of detector. Better if detector is flexible enough to be ready for making such rearrangements from the very beginning. Iron-free detector (see lower) is the best candidate for such a mission.

2. DOUBLE ENERGY IN EXPERIMENTS WITH STATIONARY TARGET

There is some interest to investigate collisions with stationary target or even with proton beam accelerated in proton ring (electron-proton collider). Although electron–proton beams suggest some particular location near proton machine (FermiLab, CERN, DESY), stationary target experiments can be arranged anywhere relatively easily. Stationary target have some positive features, such as dense media, possibility to prepare frozen polarized target and so on. Such option was demonstrated for solid Hydrogen target.

It is naturally to carry these experiments with double energy. As the ILC accelerating structure is a standing wave one (in contrast with NLC/JLC and DESY S-band option), this *structure can accelerate particles in both directions*. So with arrangement of appropriate phasing, the particles accelerated in the first linac can be redirected through IP into second linac, where the energy can be doubled. After extraction while passed this

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[2] We mentioned this option in CBN05-18, see at http://www.lns.cornell.edu/public/CBN/2005/CBN05-18/CBN05-18.pdf

second linac, the beam with double energy directed to the stationary target areas. So the operation with zero crossing angles is a useful peculiarity here, avoiding the presence of bending magnets here (for ~20mrad maximal angle).

Originally VLEPP has a standing wave accelerating structure operating at 7 GHz. So this option was suggested here [16]. Later, while switched to 14 GHz, the structure was transformed into traveling wave-type and this possibility was lost.

3. ZERO CROSSING ANGLE[3]

Mostly initiated by NLC/JLC type machines, the nonzero crossing angle is absolutely unnecessary for ILC like pattern. Meanwhile zero angles give huge advantages in optics, preventing from SR at IP and so on. Zero angle collisions significantly improve situation with alignment of collision planes for flat beams. So we think that only this option must be kept in detector design.

In ILC, the bunches are following with the time separation t ~300 ns (for 2820 bunches in the train). So the first bunch from opposing beam met by the bunch from the first beam at the distance $l = \frac{1}{2}ct \cong$ 50m from IP. This distance is absolutely enough for spatial separation of used bunch from the incoming one.

Unfortunately we could not see real engineering realization of gamma-gamma IP, especially in evacuation of used electrons, having an extremely wide spectrum, just conceptual pictures. So the gamma-gamma option must be evaluated only after such a design is represented finally. Even so, evacuation of used electrons, widely spread in energy, is much easier task for zero crossing angle option.

Let us represent some brief estimation. First, the magnet rigidity for 1-TeV beam comes to $(HR) = pc/e \cong 3\cdot 10^6[kG\cdot cm]$. The beam size after interaction defined by energy and angular spread generated at IP and by values of dispersion and envelope functions there. Emittance increase can be estimated as $\Delta\gamma\varepsilon \propto \alpha \cdot r_0 N$, where α is numerical factor ~0.1-1, N stands for the bunch population, r_0 is classic electron radius. For $N \cong 10^{10}$ the last estimation goes to $\Delta\gamma\varepsilon \propto 2.8\cdot 10^{-15} \times 10^{10} \cong 3\cdot 10^{-5} m\cdot rad$. For β –function having its value of the order $\beta \cong 100m$, the beam size goes to be

$$\sigma_{used} \cong \sqrt{\frac{\Delta\gamma\varepsilon\cdot\beta}{\gamma}} \cong \sqrt{\frac{3\cdot 10^{-5}\cdot 100}{2\cdot 10^{6}}} \cong 4\cdot 10^{-5} m \equiv 40 \mu m$$

Also, the energy spread can be estimated as

$$\Delta E / E \cong \frac{r_0^3 N^2 \gamma}{\sigma_{\parallel} \cdot (\sigma_x + \sigma_y)^2} \qquad (1)$$

where $\sigma_{\parallel}$ stands for longitudinal dimension, σ_x, σ_y for horizontal and vertical dimensions respectively. It looks significant, depending on aspect ratio $R = \sigma_x / \sigma_y$. The losses goes to be $\Delta E / E \cong$ 3-4% for ILC.

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[3] This scenario was suggested for VLEPP originally.

In principle these numbers allow to have undulator after IP using appropriate powerful optics.

To deflect the used beam to its 10 s_{used} in desire to avoid parasitic crossing, the kick angle must be

$$J \cong \frac{10 s_{used}}{L} \cong \frac{\int Hdl}{(HR)} \ , \tag{2}$$

where L stands for the distance from the kicker to the septum. Estimating L˜ 40m, $10 s_{used}$ @ $4 \cdot 10^{-2} cm$ (i.e. 0.4mm), one can obtain J @ $4 \cdot 10^{-2} / 4000$ @ 10^{-5} and

$$\grave{0}\, Hdl \ @ \ (HR)J \ @ \ 30kG \cdot cm \, .$$

Suggesting that the kicker has a length of ~100 cm, the field comes to H @ 300 Gauss only. So at this point, 40 m apart from kicker, the beams have parasitic crossing and are separated by 10 s_{used}=0.4mm.

This number can be increased by increasing the field in the kicker. Say the field is increased ten times, up to 3 kG, then the separation comes to 4mm. This separation is more than enough for placement of a septum magnet here. If we suggest Lambertson/Picconi type of magnet with septum ~4 mm, which is absolutely guarantied. This kicker must have a sum of pulse and rise/down times less that 300ns, so one can agree that this is technically an absolutely guaranteed device.

So the scheme is the following, see Fig.1. The beam kicked *vertically* by kicker located few meters aside of IP point. At distance ~30 m from the kicker the Lambertson/Picconi magnet is installed which deflects the beam *horizontally* (in addition to vertical motion given by kicker). This magnet with rather relaxed magnetic parameters needs to be design to accept SR from 1 TeV beam generated in kicker. As the beam sized here expanded due to 30-m distance, there are no apparent problems in absorption of SR. Cross section of incoming beam is negligible compared with the cross section of the out-coming one. This circumstance also helps in the design of this magnet.

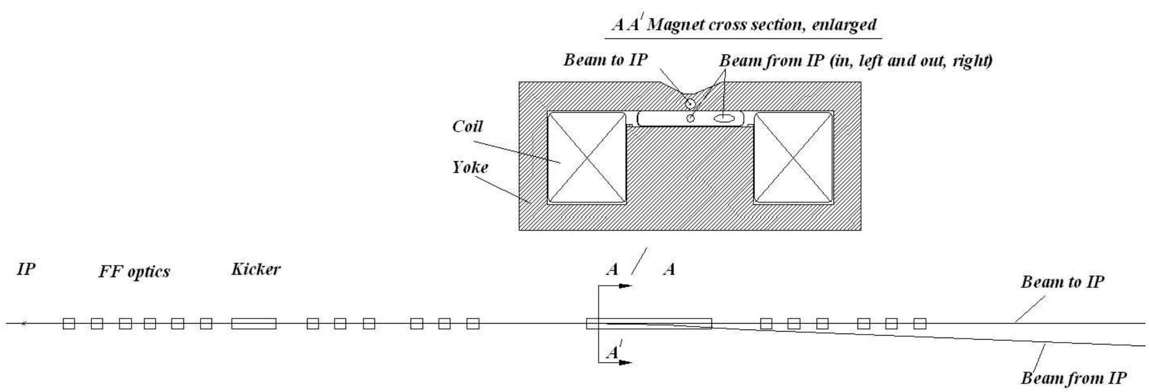


Figure 1: Zero crossing angle scheme, top view. Kicker operates in vertical direction (out from the view to the plane of Figure). Distance between kicker and the Lambertson/Picconi magnet ~40m. Scaled cross section of this magnet is represented in upper part of Figure.

To compensate the beam size generated by energy spread, one can use the schemes with achromatic bends, which includes pairs of magnets with appropriate quadrupoles in between. By feeding a pair of these magnets (operating in a vertical plane) in series (one of these is the kicker) one can compensate the jitter introduced by variation in the feeding current.

The problem with SR radiation generated in kicker, which illuminates the septum can be considered in a bit more detail here. Characteristic energy (in M*eV*) for the quantum radiated by electron in magnetic field is

$$\hbar\omega / e = \tfrac{3}{2}\gamma^3\hbar c / \rho e \;\rightarrow\; \hbar\omega[MeV] \cong 665\cdot E^2[TeV]\cdot B[T] \;. \tag{3}$$

So for 1 TeV beam in field 1kG=0.1 T ($\rho = (HR)/H \cong 3\cdot 10^6$cm), the critical energy goes to be $\hbar\omega_c \cong$ 66MeV. As the number of the photons radiated in the magnet goes to be

$$N_\gamma \cong \alpha\gamma\theta \tag{4}$$

where $\alpha \cong e^2/\hbar c \cong 1/137$ is a fine structure constant, then total energy radiated by single bunch with population N goes to be

$$E_{tot} \cong \hbar\omega\cdot N_\gamma \cong N\hbar\omega\cdot\alpha\gamma\theta \;\; . \tag{5}$$

The last formula in out case yields the total energy radiated per bunch as big as

$$E_{tot} \cong 10^{10} 9.6\cdot 1.610^{-19} 10^{6} \cong 1.5\cdot 10^{-2}\, J.$$

This brings total average power radiated by beam (5Hz, 2820 bunches) to $P \cong 211$W. The area at the septum, where this power deposited is $S \cong \pi\cdot(\sigma^2_{used} + L^2\theta^2) \cong 10^{-2}\, cm^2$, brining the power density to $W = P/S \cong 20$ *kW/cm*^{2}. As the energy of photon is rather high, 66MeV or so, the energy deposited deep *inside* material. The hot end of septum must be built with material able to withstand this energy deposition. Usage of mask made from Pyrolytic Graphite (PG) allows drastic reduction of volume density of energy deposition. No doubt, this power density can be tolerated with appropriately cooled system.

4. DETECTOR WITHOUT IRON YOKE

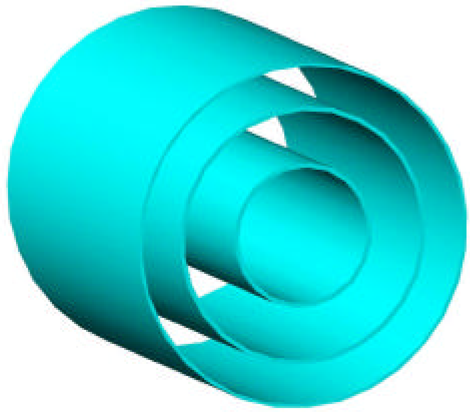
We brought attention to the circumstance several times that an iron yoke is not required for normal operation of detector [3], [4]. Developers of detector [2] came to this conclusion from the different approach.

We continue our consideration of an iron-free detector with a *three-solenoidal* system. The advantages here include the possibility to use the magnetic-field-free gap between inner solenoid and next to it for pixel calorimeters and other instrumentation. Although a two coil magnetic system can be considered as an extreme case for the three coil one.

The three coil system is represented in Fig. 2. Here the flux captured in inner solenoid,

$$\Phi = \int_S B\, ds = 2\pi\int_0^{r1} B(r)\cdot r\cdot dr \cong \pi\times r_1^2\times B_0 \;, \tag{6}$$

is re-directed inside the space between the two outside ones. In this space the direction of magnetic field is opposite to the direction of field inside inner solenoid. So the flux is closed.



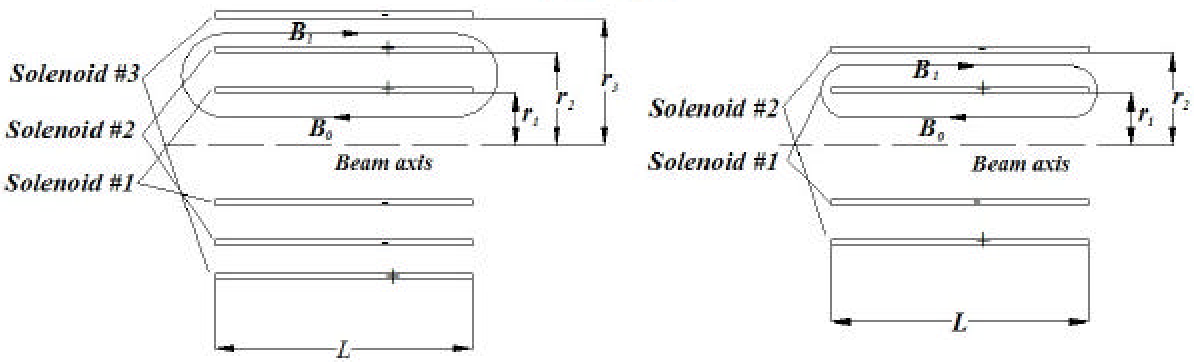


Figure 2: Geometry of three–coil system, left. At the right there is represented the situation when two coils from the left figure merged together (r_1=r_2). Signs "+" and "–" indicate direction of solenoidal current circulating in the coil.

Magnetic field and the current in each solenoid can be found from the simple condition

$$B_0 \times r_1^2 = B_1 \times (r_3^2 - r_2^2)\ , \tag{7}$$

which is just a reflection of conservation of the flux. When two coils merge together, the last formula simplified to the following

$$B_0 \times r_1^2 = B_1 \times (r_2^2 - r_1^2)\ , \tag{8}$$

Magnetic field $B \cong NI/L$, where NI stands for the total current running in the coil. So the volume between coils at r_1 and r_2 (solenoid 2 and 1) can be made practically free from magnetic field. The last circumstance might be useful in some cases.
Let us estimate the fields ratio for typical values which are $r_1 \cong 2.5$m, $L \cong 5$ m , $B_0 \cong 5$ T. So if $r_2 \cong 4$m (1.5 m radial space between inner solenoid and the next one), $r_3 \cong 5$m, then in first case (thee coils), magnetic field value in return space between solenoid 3 and 2 comes to

$$B_1 = B_0 \frac{r_1^2}{r_3^2 - r_2^2} \cong 5 \frac{2.5^2}{5^2 - 4^2} \cong 3.5\,\mathrm{T} \qquad (9)$$

and in the second case (two coils) magnetic field goes to

$$B_1 = B_0 \times \frac{r_1^2}{r_2^2 - r_1^2} \cong 5 \times \frac{2.5^2}{4^2 - 2.5^2} \cong 3.2\,\mathrm{T} \qquad (10)$$

One can easily scale these figures to any appropriate radii. One might consider the placement of two outer solenoids practically at the outer housing of detector.

We would like to remind that the Iron itself might cost $35M easily, one can refer to this number in publications at ILC web-site. The cost of detector with SC coils is much lower. At least one SC coil is present in any detector anyway, so the cost of other two must be compared with the cost of iron, its tooling, transportation, and installation. Mostly impressive advantage of Iron-free detector is a functional flexibility, easy commissioning in addition to lowered cost. The last allows fabrication of two (or even more) detectors for experiments. We called this concept *modular detector*.

Field inside inner and outer solenoids (and between) can be made homogeneous to the level required by adding the wires at the end of each solenoid (Helmholtz-type coils). Optimization of such system takes very short time with appropriate code (MERMAID). Magnetic mapping allow proper reconstruction of trajectory practically with any field distribution, however.

We are happy to learn, that variant #4 *in detector design* [2] *is absolutely in line with our vision of situation* [3]-[5].

5. MONOCHROMATIZATION

Monochromatization was considered for circular machines a long ago [6], [7], [8]. For a single pass linear collider this can be done much easier. For this purposes the optics must be designed so it generates nonzero dispersion at IP. In addition, the sign of dispersion must be opposite for the beam approaching IP from opposite sides.

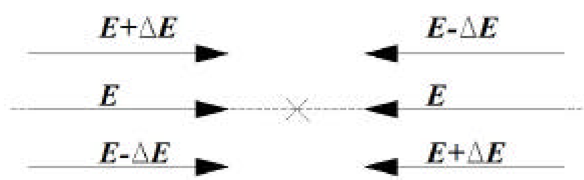


Figure 3: Collision with nonzero dispersion. Sign of dispersion is opposite for the beams approaching IP from opposing sides.

In one instance situation for ILC looks a bit more complicated at IP, than for circular machines, where radiation is negligibly small. Basically this phenomenon at IP for ILC is limiting the luminosity practically through radiation. Really, the losses by SR due to beamstrahlung for flat beams, when radial size is much bigger, than the vertical one, $s_x >> s_y$

$$\left(\frac{\Delta E}{E}\right)_{\max} \cong \frac{r_0^3 g\, N^2}{s_x^2 s_s}, \tag{11}$$

where s_s stands for longitudinal dimension. For ILC these losses comes to 0.04 i.e 4%.

It is interesting, that if the optics designed allows monochromatization, then the energy acceptance of FF optics becomes unlimited practically. In its turn this allows wider energy spread in linac.

6. WORK WITH NONZERO DISPERSION AT IP

Dispersion h defined as a (transverse) displacement for the particle trajectory having zero initial conditions for displacement and its derivative at starting point, but with energy other, than equilibrium [13]. As the focusing properties depend on energy of particle one can expect, that focal point is shifted for particle having different energy. One can say that dispersion is a manifestation of chromatic aberration or simply speaking chromaticity of focusing system.

As always, for compensation of chromaticity of quadrupole the sextupoles are used in places, when dispersion has nonzero value. Basic requirement is that the focal distance defined by quadrupole, $G = H' \equiv \partial H/\partial x$ and sextupole $S = \frac{1}{2}H'' \equiv \frac{1}{2}\partial^2 H/\partial x^2$ now

$$F \cong \frac{\int\left(G(s) + S(s)\cdot h\frac{\Delta p}{p} + \ldots\right)ds}{(HR)\cdot\left(1 + \frac{\Delta p}{p} + \ldots\right)} \tag{12}$$

not depending on momentum if $S = G/h$. $(HR) \cong pc/e$ stands for magnetic rigidity. Such type of compensation called local compensation of chromaticity and is in use in circular machines for a long time.

So basically the quadrupole lens must be followed by sextupole, which has field dependence $H = Sx^2 = \frac{1}{2}H''x^2 \equiv \frac{1}{2}\partial^2 H/\partial x^2 \cdot x^2$ and the strength adjusted to the local dispersion. One can see, that the slope of transverse field dependence is different for particles located in opposing side of the sextupole. Physically this looks like represented in Fig. 3 below

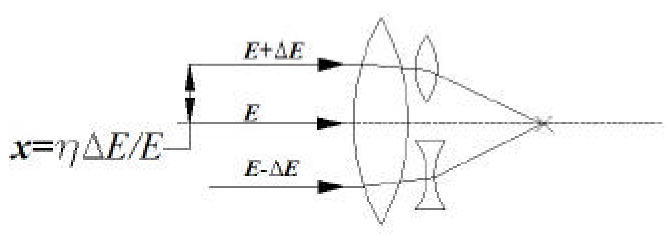


Figure 3: Zero dispersion at IP. Its derivative is not zero, however. This figure one can find in tutorials explaining the method of compensation the chromaticity.

Although this picture is used often for explanation of compensation of chromaticity, it was newly investigated seriously for real FF optics. Meanwhile this is a very promising approach. General philosophy broadly in use now requires zero *dispersion and its derivative* at IP. So chromaticity of final lens compensated in other place, where dispersion is non zero. To generate dispersion the bending magnets required (displacement in a lens can serve this purposes also).

One peculiarity associated with focusing by quadrupoles is that chromatic aberration at the out of such system could not be a zero. This is well known theorem [12], [13]. This effect defined by integral along all trajectories as the chromatic aberration

$$\Delta x_e \cong \delta \cdot x_0 S(s_{IP}) \cdot \int_0^{s_{IP}} C'^2(s)\,ds \cong \delta \cdot x_0 S(s_{IP}) \cdot \int_0^{Sip} kC^2(s)\,ds \propto \delta \int_0 k\beta(s)\,ds \ . \qquad (13)$$

where $S(s)$ and $C(s)$ stands for sin-like and cos-like trajectories starting at the entrance of focusing system and the one having at the entrance transverse displacement x_0, δ –is relative energy deviation, $k = G(s)/(HR)$. At the right (11) the formula expressed as a function of integral of focusing parameter, weighted by envelop function. This chromatic effect can be expressed for parallel beam at the input as

$$\Delta x_e \cong -2S(s_{IP}) \cdot \Delta L \cdot \delta \cdot x_0 , \qquad (14)$$

where $\Delta L = \frac{1}{2}\int_0^s x'^2(s)\,ds$ is a path length difference between central trajectory One can see, that *chromatic aberration in focal plane is strictly connected with lengthening of trajectory* while the energy is changed, so the dispersion free optics must be an isochronous one [14]. So that is why the presence of magnets is inevitable, if one wants to have zero chromaticity, so a particle with different energy "cuts" the pathlength. Formally this described by introduction in (13) additional terms with sextupoles and bending magnets.

In mostly optical schemes compensation of chromaticity of FF lenses made in places far from these lenses as one could see from (13), the chromatic aberration is integral effect. All attempts so far were made to cancel this dependence by introduction of bending magnets and dispersion to correct chromaticity of final lenses by appropriately installed sextupoles. Mostly bright example of this is FFTB [15].

So we are attracting attention, that zero dispersion and its derivative is not the only possibility for FF. Although for generation of dispersion, the presence of bending magnets is required anyway.

So the option with nonzero dispersion at IP is in close connection with possibility of monochromatization, illuminated in previous section. This scheme is represented in Fig.4.

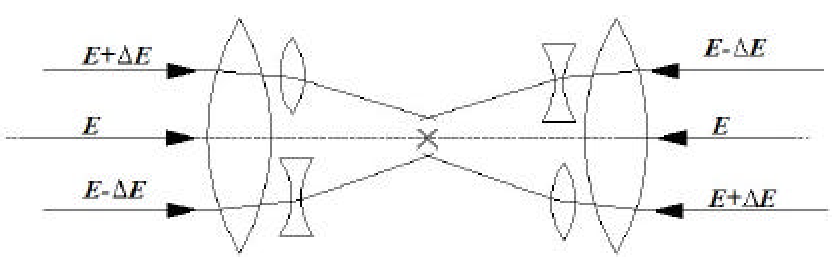


Figure 4: Monochromatization requires nonzero dispersion at IP.

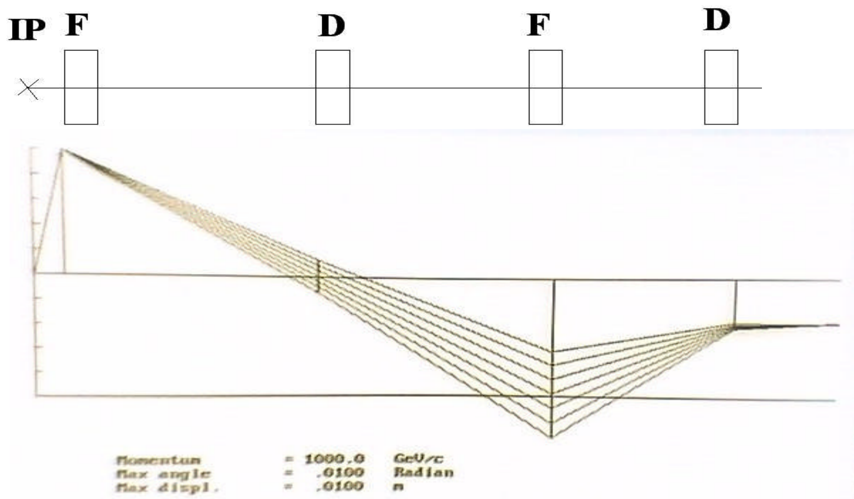


Figure 5: Illustration of partial compensation of chromaticity of final lens. IP located at the left. Different lines correspond to different trajectories having energy deviation for neighboring trajectories 0.5%.

One can see from Fig.5, that nonzero crossing angle can also be arranged with passing the beam out of axis of final lens.

It is interesting that in one publication made at the beginning of linear collider activity, there was described an attempt to compensate chromaticity of envelop function by appropriately phased quadrupoles [16].

7. ADIABATIC FOCUSING AT IP

Plasma adiabatic focuser was introduced in [9]. Although it was straightforward, we extended the concept to the focusing system with quadrupoles, [4]. Adiabaticity treated here in a sense, that betatron phase shift Δj per each lens in optical system is much smaller, that p , $\Delta j << p$. For doublet FF system, indeed the tune shift per each final lens$\sim p/2$ what is just reflection of the fact, that particle crosses IP from one extreme position in the bunch to the opposite one, so the sum phase shift must be $\sim p$. The condition of adiabaticity can be expressed also in terms of variation of envelop function as $\Delta b / b << 1$. These definitions are more or less adequate, as the betatron phase shift is $\Delta j \cong \int ds / b(s)$. One can come to the same result formally, taking into account, that around IP $b(s) = b^* + s^2 / b^*$ and the last integral comes to $\sim p$, if integration limits wider, than value of envelop function b^* at IP, not depending on b^*.

The arrangement of focusing with multiple quadrupoles was described in [4]. There are a few peculiarities defining the focusing process. As we could see from formula (13) chromaticity at any arbitrary location defined by integral along particle’s trajectory a prior arriving to this point.

All these lenses, having decreasing aperture when approaching IP, can be installed inside solenoid and based to the coil enclosure at the entrance. This in its turn allows drastic reduction of sensitivity to vibrations.

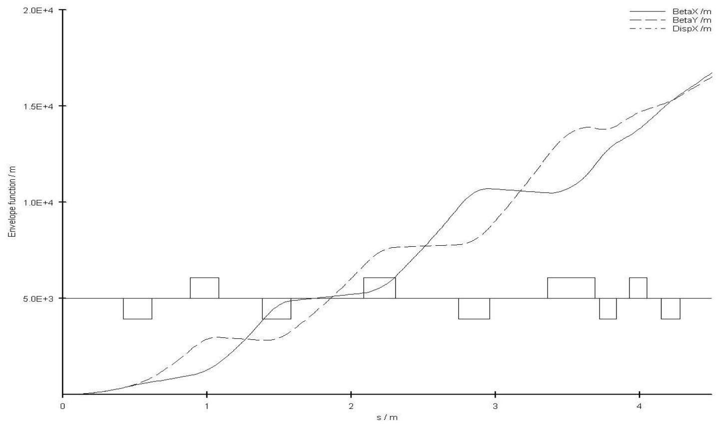


Figure 6: Envelope function behavior for the multiplet of lenses around IP. IP supposed to be at *s*=0, left point at abscise axis. Beta-functions for x and y directions at IP in this example is chosen equal the same with values 0.05cm. Beam energy is 1 TeV [4].

One can see from this picture, that the sequence of lenses with opposing polarities yield cancellation of chromaticity by integration in significant part, and residual dispersion used for collisions with monochromatization. Specific variation of envelop function, remaining practically constant in two neighboring lenses helps in this cancellation.

8. BOTH POLARIZED BEAMS

This option is strongly defended in [10]. Our personal opinion expressed in [11] is more radical, namely we think, that there is no reason to build ILC, if polarization *in both beams* is not present from the very beginning. For the purposes of usage advantages of both polarized beams, detector must be able to register particles as close to the axis as possible. Iron free detector with zero crossing angle allows to do this in mostly natural way.

CONCLUSIONS

Despite a colossal job performed by detector community, it looks like some mostly interesting possibilities and options for ILC Detector are just touched.

Our vision is that dispersion at IP can be kept nonzero, and the flat beam size can be held by the energy spread rather than increased radial envelop function value. This approach allows easy introduction of monochromatization for ILC and makes chromaticity compensation an easy job.

It looks like a variant of detector [2] is the most attractive one and it is nice, that the idea of an iron-free detector coming on agenda actively. In combination with some other innovations illuminated in this publication, development of this type of detector is the only right way to go.

Zero collision angle for e^+e^- collisions looks like guarantied. It allows to easy the process of tuning luminosity, eliminate its degradation and avoid usage of crab compensation for elimination of this degradation.

The physical community has enough time ahead, but proper direction in development is crucial here.

Work supported by NSF.

REFERENCES

[1] K. Mönig, *"The Three Detector Concepts*", ECFA LC Workshop, Vienna, 2005.
[2] J. Hauptman, *"A New Concept"*, ECFA LC Workshop, Vienna, 2005.
[3] A. Mikhailichenko, *"Do Detector Need a Yoke?*", (Cornell U., LEPP), CBN 01-20, October 6, 2001, 6pp.
[4] A. Mikhailichenko, *"Detector for Linear Collider*", (Cornell U., LEPP), CBN 02-3, 2002. See: http://www.lns.cornell.edu/public/CBN/2002/CBN02-3/CBN02-3.pdf
[5] A. Mikhailichenko, R. Settles, unpublished Note, Cornell, 2002.
[6] A.Renieri, Frascati preprint INF-75/6(R)(1975).
[7] P.V.Vorob'ev, A.A. Mikhailichenko, *"To the possibility of Collision with Equalized Energy in Damping Ring*", unpublished note, Novosibirsk BINP, 1974.
[8] A.A. Zholents, O.N.Nejevenko, *"RF Monochromatization of Energy of Particle Interaction in Damping ring*", XIII International Conference on High Energy Accelerators, Novosibirsk, 1986. Proceedings edited by A.N.Skrinsky, Novosibirsk, Nauka, vol. 1, pp.70-72.
[9] P.Chen, K.Oide, A.M.Sessler, S.S. Yu, *"Plasma-Based Adiabatic Focuser*", Phys. Rev. Lett., vol.64,n 11, pp.1231-1234, 1990.
[10] G. Moortgat-Pick, *et. al.*, "*Revealing Fundamental Interactions: the Role of Polarized Positrons and Electrons at the Linear Collider*", CERN-PH-TH/2005-036, SLAC-PUB-11087.
[11] A.Mikhailichenko, *"Why polarized Positrons should be in the Base Line of Linear Collide*r", CLNS 04-1894. See: http://www.lns.cornell.edu/public/CLNS/2004/CLNS04-1894/CLNS04-1894.pdf
[12] V.I. Kotov, V.V. Miller, *"Focusing and Mass-separation of High Energy Particles*", Moscow, Atomizdat, 1969, UDK 621.384.8.
[13] K. Steffen, *"High Energy Beam Optics"*, NY-London-Sydney, 1965.
[14] B.de Raad, CERN AR/Int. GS/62-5, Geneva (1962).
[15] V. Balakin *et al.*. ,*"Focusing of Submicron Beams for TeV Scale e+ e- Linear Colliders*", SLAC-PUB-6691, SLAC-PUB-95-6691, Mar 1995. 4pp. Published in Phys.Rev.Lett.74: 2479-2482, 1995
[16] V.E.Balakin, A.N.Skrinsky, *"VLEPP –Status Report*", XIII International Conference on High Energy Accelerators, Novosibirsk, 1986. Proceedings edited by A.N.Skrinsky, Novosibirsk, Nauka, vol. 2, pp.101-108.