To: **PPESP** **6 September 1999**

From: **Linear Collider Flavour Identification (LCFI) Collaboration**

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Subject: **Statement of Interest : Development of a Vertex Detector for the TESLA Linear Collider**

The LCFI Collaboration is working hard on the R&D programme for which we were approved by the PPESP last October. The scientific goals of this programme can be summarised as follows:

1) to establish the vertex detector performance required to satisfy the physics goals of a TeV-scale e^+e^- linear collider (LC), of which the most important may be the discovery of the SM and perhaps SUSY Higgs bosons, the measurements of their branching ratios and the discovery and measurement of the properties of SUSY or other exotic particles in a variety of electroweak symmetry breaking scenarios. These studies are ongoing, particularly as the theoretical situation evolves, and as the boundary conditions imposed by the linear collider experimental environment become more clearly established.

2) to influence those boundary conditions, as far as possible extending the physics reach of the collider. So far, this has consisted in reducing machine backgrounds and thereby reducing the minimal beam-pipe radius, which is a very critical performance parameter for physics. Progress has been made in both the North American and European accelerator concepts in the design of collimation systems, absorption of pair background and in reaching agreement on a moderately high field detector solenoid, all of which are important for background suppression.

3) to design a vertex detector best matched to the physics requirements, while respecting the irreducible machine backgrounds and other boundary conditions.

4) to carry out R&D aimed at demonstrating the feasibility of constructing such a vertex detector, optimised for the physics goals.

Items 1) to 3) are well under way, and we are developing the very advanced infrastructure for 4) at some of the collaborating institutes. The most challenging aspects (discussed fully in our proposal of September 1998) are the development of ultra-thin detector layers, and of CCDs which can be read out at 50 MHz with the required noise performance.

At the time of writing our proposal, it was believed that the detector requirements for the two main linear collider options (TESLA in DESY and the US-Japanese X-band design) were

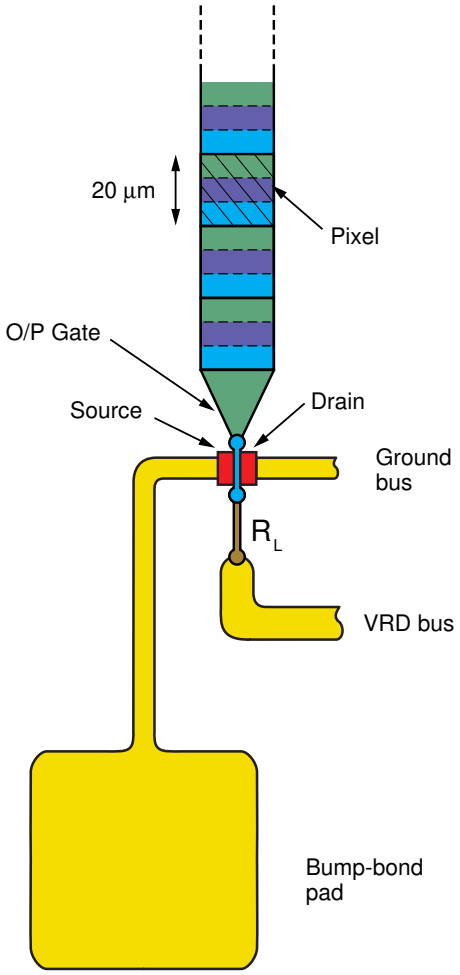


Fig. 1 Possible individual readout circuit capable of being integrated at a pitch of 20 μm (simpler than standard floating gate output circuit, but comparable noise performance).

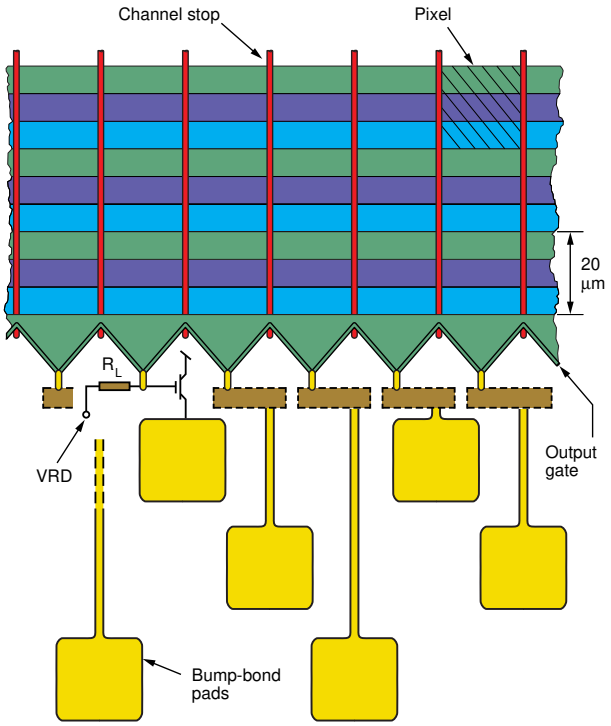


Fig. 2 Possible column-parallel CCD architecture with bond pads on an acceptable pitch for bump bonding.

broadly similar. The fact that TESLA operates at a 36 times lower bunch train frequency, with (other things being equal) a correspondingly higher integrated background was to be handled by inhibiting collisions immediately after each hardware trigger. Such a scheme has been used successfully in fixed target experiments, and provides a simple solution in conditions of low trigger rate. What has emerged in the 1998/9 ECFA/DESY series of workshops is that, despite the low cross-sections for physics processes at the future LC, one can by no means assume low trigger rates. Unusual supersymmetry scenarios (GMSB, anomaly-mediated SB etc) may lead to events which are difficult to disentangle from background. Indeed, it is precisely these scenarios which are of the highest interest, since such events will almost certainly be lost by the first level triggers at LHC. In order to guarantee that such events be captured at the future LC, both the European and North American groups have recently evolved an 'untriggered' mode of data acquisition, in which all raw data from the detector are stored through the bunch train, and filtered by a large farm of fast processors between trains. This strategy takes advantage of the particular time structure of the LC environment, combined with the availability of fast switches and inexpensive fast processors, to permit sophisticated event filtering in which one can expect to select non-pointing gammas, small puffs of energy in calorimeters and other subtle event signatures.

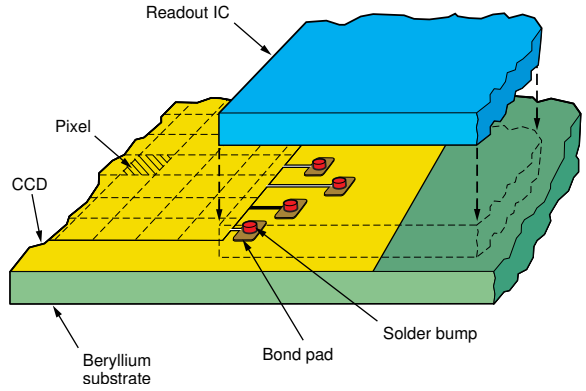
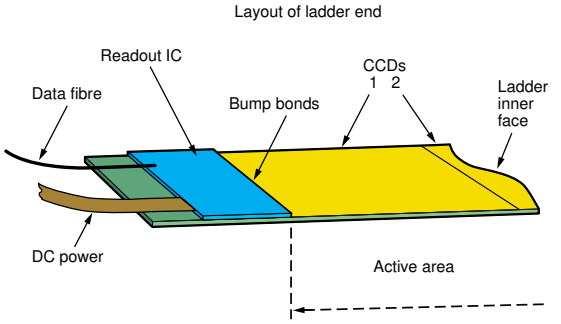


Fig. 3 Scheme for bump-bonding readout IC to edge of CCD beyond the active area.



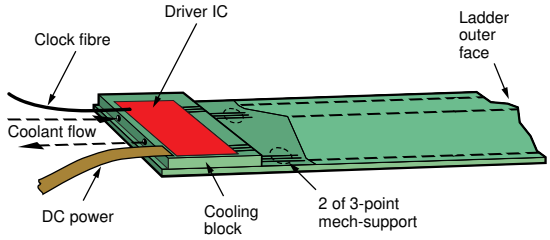


Fig. 4 Possible ladder layout with readout IC on the inward-facing surface and driver IC on the other side. All this additional material is outside the solid angle coverage of the vertex detector.

While this development has substantially strengthened the case for complementary physics reach between the LC and the LHC, it has created a complication for the vertex detector and some other systems. In the case of the X-band machine, it was always intended for the CCD-based vertex detector to integrate the signal and background through the bunch train, so this is compatible with the new DAQ arrangements. However, the situation for TESLA has had to be reconsidered. One option is always to regress to an active pixel technology, but this imposes severe penalties in terms of performance (much larger pixels, less precise spatial measurements, thicker layers) and should be avoided if the physics potential is not to be compromised. The preferable option is to speed up the CCD readout so that the TESLA bunch train (~ 900 μs) can be subdivided into approximately 30 sub-trains. This could be done by a change of CCD architecture so that, instead of having a readout register with readout circuits at intervals of N columns (N typically 10 to 100), one would dispense with this register and have a readout circuit for each column. This 'column-parallel' architecture implies a readout IC bump-bonded to the edge of the CCD, adjacent to the active volume of the vertex detector (see Figs 1-3). In addition, in order to achieve the desired readout time (~ 25 μs in a typical design), it will be necessary to clock the CCDs with a parallel clock frequency of ~ 50 MHz, which implies also a locally mounted driver circuit (Fig 4).

Having discussed these ideas with CCD designers, custom IC designers and other users of these devices (notably in the astronomy community) it is clear that such a column-parallel detector (including the challenging off-CCD circuits) would have potential for widespread applications beyond particle physics. Our suggestion is to consider this as a potential successor to the R&D programme which is currently supported by the PPESP. This programme (which includes the requirements for 50 MHz readout, albeit without the additional challenges of the column-parallel architecture) forms a logical first step towards the full TESLA functionality. By the end of this programme (approximately 3 years from now) we expect that the accelerator technology for the future LC will have been selected. If this is TESLA, we would envisage submitting a new proposal to the PPESP to make the

further step to the column-parallel detector. Conversely, if the X – band technology is chosen, this will not be needed. However, it is clear that the ideas for the fast-readout column-parallel detector have struck a resonance with other areas of science. If effort were available, it is clear that the expertise in the HEP community in subjects such as mixed analogue and digital IC design could be very effectively applied to this problem, and that the payoff could be enormous. Low-noise CCD detector systems with readout speeds 100 times those currently available would open doors in a numerous application areas. Regardless of the prospects for TESLA, and consequently of funding via the PPESP, it is possible that some inter-disciplinary detector R&D programme will support these developments. One possibility under discussion is for a joint development with the US astronomy community (via JPL). Assuming that this or some other source of funding does not materialise in the meantime, and that TESLA goes forward as an approved project, we would envisage that a level of support of approximately £100 K over the period 2002-2004 would be requested from the PPESP for this project.