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TBC: Dynamic Cluster Formation in Pixilated Detectors

Given charge spread in particle detection and charge sharing between multiple detecting elements, clusters of hit pixels are inevitable in pixilated detectors, and the problem is, of course, worse for smaller pixel sizes. At the same time, in order to optimize the detective quantum efficiency (DQE) and the throughput, it is important to produce one and only one "winning"pixel address per hit and to
produce this winner in the front-end circuitry rather than downstream in the data acquisition firmware. Therefore, the problems of cluster finding and resolution in front-end electronics are becoming more
and more important.
In some cases, clusters are hard-wired as arrays of detector elements. If a particle deposits its
charge entirely within a particular array of detector elements, then its location will be properly
determined, but if the charge is distributed between two or more hard-wired arrays, then more than
one hit location will be registered and the data acquisition system will be forced to resolve the problem
in firmware or software. In other cases, the cluster finding algorithms assume a fixed size and shape,
but they are not hard-wired to a particular location. Each pixel can view itself as being at the center of
its own array. Again, if charge spread or particle angle or energy pushes the charge cloud beyond the
assumed array borders, then the hit location cannot be properly resolved within the front-end chip
itself. Dynamic cluster formation is a means by which any cluster, regardless of size or shape, can be
formed. This will allow the constituents of the dynamic cluster to arbitrate with one another to
determine which pixel or pixels are the centers of the particle hit or hits. The challenge is to perform
dynamic cluster formation with a minimum of circuit complexity so that it can be employed in smaller
pixel sizes.
Complicating the problem of dynamic cluster formation is the problem of time walk. Charge
distribution from particle detection is not uniform among the pixels. Therefore, the propagation delay
through the different front ends affected by the passage of a particle will not be uniform. The timeover-
threshold will not be uniform either. Therefore, some method is necessary not only to determine
which detector elements are members of a dynamic cluster, but also when the arbitration among them
has concluded.
A novel method of dynamic cluster formation is proposed. It is a two step process. The first
step is to form the cluster on the fly by determining its edges with a self-triggered process. On the
inside of a cluster, charge deposition has exceeded a user-defined threshold; on the outside of the
cluster this has not happened. Linkage is accomplished by tying the members of the cluster to a
common timing signal that maintains arbitration until all cluster members agree that arbitration is over.
The second step is the arbitration itself and, theoretically speaking, any arbitration method
implementable in silicon is usable.
The prototype arbitration algorithm is called C8 or "Compare 8"and it has been implemented in
a readout chip for x-rays. The actual method used to convert the C8 algorithm into a Dynamic Cluster C8
algorithm is presented here. The explanation will be general, but the emphasis will be on its
implementation targeting 3D chip integration technology.

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