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Note on electronics and detector R&D for ECFA

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The call by ECFA for input towards a medium-long term detector R&D program, the Roadmap Panel, nine taskforces, and the detailed questionnaire for the planning of future electronics, testify of a high level of concern and ambition. However, the schedule is very tight and times are difficult for preliminary discussions and contacts with colleagues at different institutes.

Detectors and electronics

In the Roadmap Panel there is apparently no member with specific background in microelectronics design and technology. However, during the last 3 decades the relevance of custom chip design for successful experiments has become increasingly obvious. Now that silicon devices penetrate every aspect of life, it should be clear that also the future of scientific instruments will be determined by the mastering of microelectronics. If particle physics wants to profit from natural advantages of this nanotechnology, adequate investments must be made in specialists, contacts and know-how, and hands-on experience. With the nm dimensions of the active elements in the circuits approaching a few atomic distances, there is exciting potential that the energetic elementary particles in our experiments can interact directly with these silicon-based components, such as e.g. the status of memory cells, but in a controlled manner. While such dreams are not yet near to reality, there is immediate need to implement much more advanced silicon CMOS technologies, with nodes in the range 28nm -14nm, in the experiment upgrades during the following 5-10 years. The aims should be to enhance granularity in all detector components, especially the trackers and calorimeters; to introduce <100ps timing slots during the LHC beam crossings which would allow increased luminosity, even 1000 interactions per crossing; to tag in situ primary and other vertices or anomalies; and yet to keep energy dissipation within existing limits. Especially, energy saving is the hallmark of the newest technology nodes, such as the 7nm of TSMC.

Currently, our chip design teams are orders of magnitude smaller than in design houses or industry, and collaboration between institutes is still in its infancy. It must be recognized that nanoelectronics projects need training and prototyping longtime in advance, with expensive iterations and evaluation, including radiation testing. In our case, the initial engineering cost, each time several millions, can not be earned back afterwards by the sale of hundreds of millions of chips, but can be justified by the improved capabilities of the instruments. Contacts with major foundries luckily exist via CERN, which helps to create a common, recognizable interface towards industrial suppliers, even if the sales volume for science remains very small. For the moment, also funding in the institutes as well as at CERN, is far from sufficient to seriously explore the newer technologies. This domain should receive staffing and financial support that is similar to that for magnet development on the accelerator side, because efficient accelerators are hardly justified if the experiment hardware is not efficient, with maximum capability.

An essential aspect of the nanoelectronics circuit world is the continuous exchange of ideas and know-how, mostly via personal contacts, courses and via conferences such as the IEEE-IEDM and IEEE-ISSCC. Participation from particle physics scientists and technical people has been very low-level over the years, and should be encouraged.

Word of warning

In his 'Opinion-Comment' article in the CERN Courier of January 2021 the ECFA outgoing chair Jorg D'Hondt stipulates that transformational, blue sky R&D will be included in the accelerator and detector roadmaps. Against this background, my note also intends to warn for an excess of formalized planning and rigidity in the allocation of resources in whatever roadmaps will appear. Obviously, the ever more expensive instruments for particle physics research and the high cost of operating these, demand careful financial behaviour. However, as I illustrate with a few examples, the strong point in our community always has been tolerance and relative freedom for initiatives from bottom-up. Scientific as well as technical staff has been throughout the decades very motivated to find solutions for impossible tasks, or simplifications and cost savings for too complex and expensive plans.

Personal experience over now 48 years at CERN motivates this note, and justifies exposing some historical detail. Indeed history shows that it nearly is impossible to plan for transformational developments, and the WWW coming from CERN is the most cited example.

Closer to the detector innovations, I can refer to the first silicon microstrip detector, which nobody asked for, but which I designed originally to enable counting of the high density muon flux in the SPS neutrino beam. The bill for the first set of 6 devices was CHF 24 000, while at the same moment a >300kCHF R&D was initiated to study track distortions in the BEBC bubble chamber. It became quickly clear that by chance with the precise, parallel silicon detector we had made a key contribution to other people's problems with charmed particles.

A second example is the introduction of radiation-hard chips by design, instead of using the much more expensive, special and mostly secret steps in manufacturing technology. This new approach was based on know-how via contacts with RCA in Princeton, with IMEC in Leuven, the Naval Research Lab in Washington and numerous scientists via the professional IEEE conferences. The use of deep submicron technology with thin gate oxide, in 1997 starting with 0.25µm CMOS, was never formally proposed nor approved by a committee. It came from bottom up, and soon convinced the community by the excellent results. This then allowed the LHC experiments to install detectors with hundreds of thousands of channels, and to operate in the severe environment without major trouble over nearly 10 years.

Some recommendations

1. Please allow sufficient flexibility in the roadmap plans;

2. Silicon CMOS custom design will be the main enabler for innovation during the next decades, and therefore specific R&D should be resourced with a lot more professional staff, and adequate budgets at CERN and in the combined member-state institutes: at least >20 MCHF/y. Some of this R&D money can be recovered later on, because of better preparation for following, real projects;

3. Performance improvement projects of the experiments can be achieved in steps, quite immediately, and at much lower cost than that of the new accelerator, which will come slowly anyway;

4. Eventually, with nm dimensions the electronics will become the detector, with sensitivity to, and in-situ characterization of, single quanta;

5. Personal contacts and exchange between particle physics scientists and technicians from our side, and the nano-world on the other side are essential for optimal innovation.