CLOSING REMARKS

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1 INTRODUCTION

First, I should like to make a simple classification of the topics that I have heard during the last two and a half days and to comment on the points that impressed me. For the second part, I should like to speculate on what can be done and on what might be done in the future.

One overriding and very clear classification is the broad division between the mature field of ABS methods and the uncharted territory of linear colliders that was featured towards the end of the workshop. For the former, I will attempt a more detailed classification (Figure 1), but the latter is so different that it fits better into speculations for the future.

ABS Methods: **Least squares fit** **Harmonic analysis** **Numeric minimisation/maximisation** **Local corrections** **…**	
Acting on:	**Situation:**
• **Transverse position (steering)** • **Transverse phase space (matching)** • **Energy** • **Longitudinal phase space (matching)** • **Losses**	• **Open loop or closed loop** • **Static or dynamic** • **First turn or operation** • **Rings** • **Transfer lines (beam mismatched, errors in lattice, both)**
Supported by Monitors	

Figure 1 Classification of ABS Methods

2 ABS METHODS

It is immediately noticeable that all the correction methods mentioned in Figure 1 are of a venerable age. Under the general title of Least Squares Fit, it is assumed that fits with other norms and the various recipes for inverting and conditioning matrices are all bundled together.

2.1 Least Squares Fit and Harmonic Method

I can personally vouch for more than 25 years of usage for these two methods [1] and I can claim to have been at the birth of Bruno Autin's MICADO [2]. Both the Least Squares and the Harmonic methods were tested at the start of the CERN ISR and they both corrected the orbit without any significant difference in the numerical results, but alas disaster struck the Harmonic Method. As you are well aware, the Harmonic Method distributes the correction over all power supplies and, since the ISR was far better aligned than the designers of the corrector magnets had ever dared to hope, the supplies were sitting there trying to hold, in many cases, currents of less than one percent. The supplies crashed all too frequently and the computer could not keep track of them, but with the 'best group of correctors method' (later to become MICADO), the corrections were concentrated in a few supplies at reasonable current levels and, since this method was flexible, it could avoid those correctors that were temporarily down. Of course, the correctors were modified to control at zero reliably, the computer was taught not to lose track of supplies, but the Harmonic Method did not survive. At least, I thought that it had not survived until I gratefully heard it mentioned in the talks about DAPHNE. Later it featured quite prominently in the ESRF talk, it was then billed as a filter for faulty pickups in the SPS COCU package and, finally, it made its last appearance in the talk from KEK. At last I felt relieved that my initial faith in the method had been vindicated.

When I said that these methods were very old, I was thinking that they had stayed virtually unchanged by the years, but then I was impressed by the CEBAF talk and given scientific tests to remove correctors and monitors and then to add virtual monitors. This sounded good for times of budget austerity, so I am sure the method will be a great success.

2.2 Numeric minimisation/maximisation

The virtual operator of CRYRING and GANIL doing their 'trial and error' searches inspired me and the studies at CATANIA justified my enthusiasm.

- Firstly, for problems such as betatron matching, I feel that the 'trial and error' methods (with a good algorithm for minimisation/maximisation) could be better than the Least Squares Fit approach. I am thinking particularly of the Courant and Snyder perturbation equations. The dipole perturbation equation is excellent and is weakly affected by the dipole errors, whereas the gradient equation is more sensitive to gradient errors. In other words, it is necessary to be close to the solution for the gradient perturbation equation to work efficiently with the least squares method.
- Secondly, I was intrigued by the idea of programming a neural net that would learn from its experience and be second to none for setting up a machine.

2.3 Local correction

I was a little sad to hear that ESRF had dropped the use of local bump corrections. However, ELEKTRA came to the rescue with local four (and even five) magnet bumps. They had tackled the problem of 'leakage' successfully and local bumps are alive and well.

Before leaving the subject of "Methods", I have two comments:

2.4 Losses

I am wondering to what degree beam loss measurements can be integrated into a correction algorithm for high intensity machines. I will mention this later.

2.5 Hysteresis

I should like to recall a comment made by Stanley Pruss of FNAL. He mentioned changes in the injection conditions following different ramps in the FNAL ring. He reasonably ascribes this to hysteresis effects because the ring does not complete the same cycle each time. What seems more surprising to me is that there has been little, or no mention, of hysteresis effects in relation to applying correction algorithms. In the ISR this was essential, if Monday's orbit was to be the same as Thursday's orbit. The orbit correctors had to be:

- Either, cycled and all corrections applied using this standard cycle. If, for example, the value in a corrector had to be reduced, the full cycle had to be completed to perform the change.
- Or, a hysteresis model had to be applied. This was necessary when beam was in the machine, for example, when measuring luminosity by making vertical bumps in the crossing regions.

3 'ACTING ON' (SEE FIGURE 1)

To a certain degree, this list is ordered according to an increasing potential for future work as one moves down the list. At the same time, one is aware of how much this progress depends on the development of better monitors and control systems.

4 'SITUATION' (SEE FIGURE 1)

In the next box, there is a range of distinctions that affect the details of the problems. The situation is different for the first-turn commissioning compared to routine operation, it is different for open and closed loops, for fast and slow loops and so on. On the surface, the situations look very different, but the underlying principles are often the same.

5 'MONITORS' (SEE FIGURE 1)

All the algorithms rely on the performance of the monitors. Again, many monitors are of a venerable age, but there are also exciting new developments that have been described during this meeting, such as Optical Transition Radiation (OTR), diamond scintillators for fast particle counting and SQUIDS for low current measurements.

6 COMMENTS

I always used to repeat the maxim that 'a machine is as good as its diagnostics'. Well, my education has been improved, so now I say that

'a machine is as good as its diagnostics and its algorithms',

but what is there to look forward to, or expect in the future? After all the least squares fit is difficult to upgrade. Well, this will certainly sound schizophrenic, like the stereotype committee where one half writes the first part of the sentence and the other half writes the rest, but

'the ABS field is mature, but vigorous and developing steadily'

and it is in the monitors, control systems and software packages that many wonders will still come to pass and in the new field of linear collider alignment that creativity will abound. Let us be more precise.

6.1 Monograph

To underline the maturity aspect, I could see a very successful monograph on ABS techniques being published. Perhaps, one of you would like to take up this challenge.

6.2 Universal packages.

Also under the title of maturity, I see several successful user packages. The Beam Optics package [3] is offered in a yellow report and sports the power of Mathematica™. For COCU [4], we heard John Miles stress the 'vanilla flavour' of everything from the "C" programming language to the control room coffee, which means that COCU is eminently portable. Remember, we were told it is used in eight laboratories and that in CERN it is accessed 11'000 times per month. The synchrotron radiation laboratories are excellent public relation examples for ABS. They always talk of microns, have many monitors in medium sized rings, have fast and slow loops, and so on. ELEKTRA showed us a beautiful package that was based on the solid foundation of the COCU and MICADO work horses, but looking modern and with just buttons on the front panel (GLOC) - no more formatted command lines.

I am sure that you can see the logical extrapolation of this. Small laboratories and new installations cannot always afford to have specialist staff, such as ABS experts. The larger laboratories are happy to donate their packages but are reticent to provide an after-sales service. I would therefore expect to see commercial ABS packages appearing in the near future. Perhaps, commercial packages already exist and I am unaware of them, but if they do not then, I believe that will not be long in coming.

Monitors is one area where large laboratories have spawned small firms and it would be logical for those monitor builders to add an ABS system to their catalogues. It would also be sensible and beneficial for these firms to join this forum and I am sure they would also be pleased to sponsor it.

6.3 Related and new fields

- Modelling the accelerator or transfer line is a subject that could be included in the ABS forum. In fact, this is more a prerequisite than a spin-off.
- Collimation also fits into this scheme. Certainly setting up a collimation scheme relies on prior closed-orbit measurements and perhaps the beam losses on the collimators (especially the secondary collimators) could be part of the diagnostic system.
- Linear Collider operation. This uncharted territory will keep the field young and vigorous. There are several rival ideas and their relative merits will be the subject of much work in test facilities over the coming years.

Finally, let me thank you all for having listened to me and for having patiently taught me so much about your art over the last few days.

Reference:

[1] B. Autin, P.J. Bryant, Proc. 8th Int. Conf. on H.E. Accels, (CERN 1971), p515-17.

[2] B. Autin, Y. Marti, CERN ISR-MA/73-17, (March 1973).

[3] B. Autin (editor), CERN 98-06, (August 1998)

[4] D. Brandt, W. Herr, J. Miles, R. Schmidt, Nucl. Instru. & Meths, A293, (1990), p 305.