INTERNATIONAL COOPERATION IN DETECTOR RESEARCH AND DEVELOPMENT

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1. Introduction

This report on aspects of international collaborations dealing with research and development (R&D) of detectors followed a Round Table on 'Detector-Related Machine and Instrumentation Issues'. Both contributions focused on a hadron collider in the $\sqrt{s} \approx 20$ to 40 TeV range, and with luminosities up to $L \sim 10^{33}$ cm^{-2} s^{-1}, i.e. interaction rates approaching 100 MHz.

Such issues had already been studied during several workshops [1], reaching conclusions which were also voiced by the members of the 'Round Table':

- Conceptually the technical problems of the required instrumentation appear solvable and those experimental studies feasible for which the construction of such a machine is advocated;

- The extrapolation from the known experimental environment at storage rings is very large: close to a hundred times larger c.m. energies at ten to a hundred times higher interaction rates;

- Experimentation at the '1 TeV mass scale' will rely heavily on the relatively novel tool of hadronic calorimetry replacing the familiar method of charged-particle momentum spectroscopy.

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With the Round Table discussion as a starting point, this report attempts to analyse which and in what form interregional R&D on detectors may prepare us for experimentation at such a hadron machine. Calorimetry is used as an example to illustrate the range of developments required. Present forms of collaborations are described, and it is shown that plausible extrapolations should provide a reasonable framework for the future. Collaboration with industry is expected to strengthen as our search for detectors producing increasingly refined information is pursued and I highlight this topic by commenting on the 'Japanese style'. An important and very successful aspect of interregional collaboration concerns the definition of standards in the field of data acquisition. The present level of co-ordination is described and possible future directions are indicated.

2. EXAMPLE CALORIMETRY: PREPARING ITS FUTURE ROLE

So far, high-energy physics experimentation has predominantly relied on charged-particle momentum analysis; typical momentum resolution $\Delta p/p \sim 0.01\ p$ (GeV/c) (at least at storage ring detectors). With increasing energies emphasis is shifting from the detection of individual particles to the reconstruction of particle systems as the signature of energetic constituents, created in the collision or themselves decay products of massive states. For useful sensitivity the reconstruction of the complete system -its invariant mass- at the few percent level is required; this implies the measurement of all particles -charged and neutral, strongly, electromagnetically, and weakly interacting- and is only possible with calorimetric techniques. Apart from this fundamental physics motivation, the instrumental improvement of the calorimetric energy measurement, $\sigma(E)/E \sim E^{-1/2}$, further enhances its benefit.

The insistence on measuring simultaneously all particles belonging to a multijet system has several important consequences:

- discrimination between particles belonging to a jet and the multitude of soft particles as a by-product of the collision. This requires adequate jet-defining algorithms, sufficiently high spatial granularity, and a very large dynamic range in signal response.

- The electromagnetically interacting particles, photons and electrons, leave a characteristic signature, frequently used for identification. Isolated muons may perhaps be identified in a calorimeter through their minimum ionizing signature, but their momenta cannot be determined calorimetrically. Therefore, an unbiased total-energy experiment must include a muon detector providing commensurate muon momentum detection.

-Neutrinos (and weakly-interacting neutrino-like objects, e.g. certain supersymmetric particles) are identified and their momenta evaluated through the absence of an energy deposit, resulting in an apparent momentum imbalance or 'missing' momentum. This technique requires a fine-grain detector of sufficient angular resolution.

Calorimetry is a relatively young experimental tool. It will require conceptual developments of the method (Table 1) as well as instrumental work (Table 2) to refine it to a level imposed by the physics and accelerator environment. Both lines of R&D will require different resources and skills, as will be developed in Section 3.

There is unanimous and rather deep concern about the many implications of experimentation at collision rates approaching 100 MHz. This appears to be the principal difficulty, and it will require many conceptual and technical developments to overcome it. During these preparatory years it will be very important to evaluate potential detection techniques not only in the laboratory and the test beam, but also assess their performance in physics experiments which ressemble from a detector point the experimental environment at a super-collider (see Section 3.1).

I mention just a few points to indicate the present state and lines of future work:

At the CERN Intersecting Storage Rings (ISR) luminosities of 1.8 x 10^{32} cm^{-2} s^{-1} were achieved with the Axial Field Spectrometer in

Table 1

Calorimetry: Methodical developments

Topic	Action
Energy resolution of jets versus calorimeter performance	The need to evaluate 'jet' algorithm data may be obtained by using SPS /Tevatron beams
Angular resolution for single particles or jets	Only very limited data available- tests; simulation + tests (?)
Role of longitudinal momentum balance	Physics, detector and machine interrelated question
Auxiliary measurements:	
- position of event vertex	Needed for invariant mass
- privileged particles:	
muon momentum	Evaluate existing concepts;
electrons	Isolated: feasible; inside jet: impossible?
high-p_T photons	Needs case study.
simulation	
electromagnetic cascade	EGS (SLAC) de facto world standard;
hadronic cascade	enormously helpful to use the same simulation code everywhere.

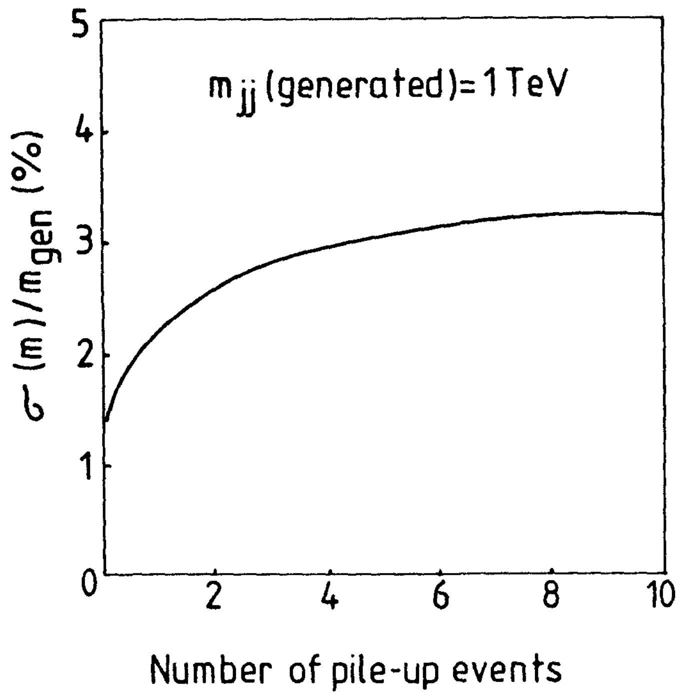

Fig. 1: Estimate of the degradation of the two-jet invariant mass resolution as a function of the number of minimum bias events being detected during the sensitive detection time. A hadronic energy resolution of $\sigma(E)/E = 0.38/\sqrt{E}$ was assumed and the jet particles measured in a jet cone of $\alpha = 45°$ half opening angle (adapted from Ref. 1).

Table 2

Calorimetry: Technological Developments

Requirement	Solution	Open questions
Response independent of particle type	Uranium compensation Other methods?	Response for energies E $\geq$ 100 GeV? Improved understanding of compensation mechanism.
Spatial uniformity	Favour charge-collect. (ion chamber mode)	Suitability of room-temperature liquids or silicon as active R/O?
Short integration time ($\leq$ 50 ns)	Fast liquid argon; Si, scintillator	In U-cal charact. time of compensation mechanism is $\geq$ 50 ns.
Dense active R/O	Scint; LA; Si	Benefits and trade-offs of very compact calorimeter (very short radiation and interaction length). Systems integration!
High granularity	Favours charge-collecting R/O	Practical aspects: cables, electronics, data volume!
Monitoring of performance below 1% level		- Relative energy scale - Absolute energy scale (beams, resonances.etc.)
Radiation resistance	Charge collection in liquids	Different techniques may be used in different regions of rapidity.

operation (momentum analysis and calorimeter). Based on the successful operational experience a physics proposal was submitted with the aim to study very rare events for which the highest luminosities were required [2]. Similarly, at a super-collider these extreme collision rates will not be useful to all experiments, but only to those aiming to study the very rare processes, for which the maximum luminosity is absolutely essential. One example, studied in detail during the Lausanne Workshop [1], emphasizes the very close connection between the precise physics aims and the corresponding technical requirements. The estimate of the invariant mass resolution for a di-jet system (each jet with p = 0.5 TeV/c) is shown in Fig. 1 together with its degradation due to the accidental overlap of 'minimum bias' events. Even a pile-up of 10 additional 'average' events, as would be the case with a detector of 100 ns integration time at 100 MHz collision rate, would degrade the invariant mass resolution not significantly. More generally, the high rate performance of a detector depends critically on the characteristic features of the rare events of interest, compared with the background of average events, which are characterized by a relatively low particle density and low momenta.

So far we stressed only the changing role of calorimetry but in parallel that of the tracking and momentum analysis will require reassessment. Whilst the physics case for large-volume spectrometers at the super-collider has yet to be argued convincingly, tracking will be essential for several auxiliary measurements:

- selection and position information on the event vertex associated with the event of interest is necessary for good multijet mass resolution;
- tracking and signing of leptons may be advantageous;
- measurements of secondary decay vertices for particle identification may be required.

There are formidable tasks for tracking devices considering the very high rate requirements and many instrumental questions will need to be addressed:

- the form of the magnetic field;
- the trade-off between magnetic field strength and spatial resolution of the tracking device;
- the evaluation of different vertex chamber techniques and possible applications to large tracking chambers;
- the study of techniques for second coordinate determination along the wire direction;
- the luminosity lifetime of the detectors.

3. LEVELS OF DETECTOR RESEARCH AND DEVELOPMENT

In the preceding section the example of calorimetry was used to emphasize that these developments will require a parallel approach at different levels:

i) Technological developments in detector physics, usually require efforts commensurate with university facilities ('home institute') and should preferentially be carried out there.

ii) Large-scale evaluation of a method or an instrument necessitates the facilities of a large accelerator laboratory. Increasingly, such work is being done by consortia of groups with different physics but common detector interests.

iii) Standardization: world-wide collaboration and co-ordination, primarily in the area of signal processing and data acquisition, have been very successful and important.

3.1 R & D detector physics and technology

In recent years an impressive arsenal of detection techniques has been made available to us. These developments became essential because of the increasing energy range of accelerators and storage rings, with their greater variety of physics programmes; our motivation to gather increasingly more detailed and complete information about increasingly more complex interactions forces us to continuously improve the cost/performance ratio of our experiments. These trends will continue as shown in Table 3, which gives an incomplete list of areas where future work will be advantageous. The size and scope of these studies makes them particularly well suited for the intellectual environment of universities:

- progress in many of the areas will require an interdisciplinary approach (chemistry, solid state, microelectronics);
- frequently this research is well suited to the training of the students;
- there may be cross-fertilization of methods and techniques between high-energy physics and other sciences;
- the appreciation of high-energy physics by the other sciences will be enhanced.

Benefits are undisputed, and increased effort in this direction is well justified. A particularly important role could and should be played by the National Laboratories or Academy Institutes in catalysing increased participation of university departments in this field. Attention to practical problems will be helpful, e.g. access to documentation which is not always easily available, particularly in smaller institutes. The required systematic and detailed summaries of detector activities exist only in some very rare cases [3], but I am encouraged that an ECFA-organized Europe-wide survey on microprocessor activities could serve as a model for similar exceedingly useful documentation efforts [4].

Table 3

EXAMPLES OF R&D TOPICS OF INTERDISCIPLINARY CHARACTER

Scintillators

efficiency, response to densely ionizing particles; crystals; gaseous, liquid scintillators.

Charge transport

- in gases: drift with low diffusion, low/high saturated v_D, magnetic field; UV-ionizing (large-area single-photon detectors!);
- in liquids: same as above; role of impurities (& diagnostics), recombination.

Radiation damage

solids (semiconductors, scintillators)
gases (wire detectors).

X-ray detection

At the other end of the spectrum of detector R&D we find the large-scale evaluations of an expensive instrument or the concepts of a new detector method, requiring access to facilities provided at only a few centres. These 'tests' represent a major commitment in money, manpower, and beam time resources comparable in scale to typical major high-energy physics experiments of a few years ago. A clear indication of the level of the efforts involved is the trend to share the load between different groups with different physics interests but similar detector needs. A few examples of 'test' collaborations will amplify this point.

i) Ring-Imaging Cherenkov (RICH) tests: One R&D effort on this method is at present being carried out at the CERN Super Proton Synchrotron (SPS) by a group participating in a CERN $p\bar{p}$ Collider experiment (UA2) and by a second group with an approved LEP experiment (DELPHI). Besides jointly developing this novel technique, the groups are preparing RICH counters to be installed in the UA2 experiment in the coming months. This will ensure the essential step needed to assess a new method in the rough experimental environment and to prove its worth by the level of new physics results. These two groups were recently approached by yet a third group committed to a totally different physics programme and interested in evaluating certain aspects of the method which was not originally planned by the other two groups. But the spirit of interregional collaboration, very characteristic of high-energy physics, is perhaps best illustrated by the fact that the DELPHI expertise in these detectors was freely transferred to an experiment at Stanford, which has decided to adopt these techniques and which plans to operate their experiment at SLAC in direct competition with DELPHI.

ii) Uranium calorimeter tests: The only existing large instrument of this kind is at present being jointly tested by members of a group with an approved SPS physics programme and by representatives of several European universities interested in the HERA physics programme. The efforts are being shared and arrangements made to ensure that the somewhat different test requirements imposed by the different physics programmes will be met. Besides the study of technical questions of interest to the groups and of more general interest attempts are being made to evaluate the physics performance of such instruments.

iii) As a third example I mention the test of a uranium/liquid argon hadron calorimeter, planned for 1985 at the CERN SPS. This device will measure energies in the TeV range with $\leq$ 1% energy resolution and with a time response which would be adequate for operation at a hadron collider with $L = 10^{33}\ cm^{-2}\ s^{-1}$. Technically it will therefore be very similar to the super-collider calorimeters under consideration, albeit with a ten times smaller sensitive area.

Rather generally, experimentation and the necessary detector development for the SPS and Tevatron fixed-target programmes can be considered of direct relevance for future facilities (HERA, Super-collider). Novel experimental methods such as calorimetry can be evaluated now in an experimental environment. It is also a very effective way to combining goal-oriented detector development with participation in a physics programme.

The scale of these development efforts with their diverse constituencies suggests increased participation of the Programme Committee in the allocation of beam time, in reviewing the goals, and in monitoring the progress. As for experiments, the status reports and Committee Minutes would be a useful means of disseminating information. The groups involved in these frequently unique tests share the responsibility to carry out rather complete evaluations even if this goes beyond their own immediate physics requirements.

4. COLLABORATION WITH INDUSTRY

Typically, half of the experimental construction budget is spent on contracts with industry, yet their relations with the high-energy physics community have not always received adequate attention. Efforts to attract or develop interested industries have been sporadic, but our drive for more finely tuned and diversified instrumentation has strongly increased the need for joint effort. Broadly one may distinguish two categories, which will be descrived below with some examples.

4.1. Joint development and construction

We cannot point to many striking examples of successful collaboration in this area. There are many obstacles, such as the technical and commercial risks associated with such ventures or inadequate contractual provisions. The field is therefore strongly marked by the enterpreneurship of some companies, or, more precisely, of individuals in these companies, who have a certain style when dealing with this special market. Amongst some of the recent successes (apart from collaboration in the field of electronics) can be counted the development of silicon microstrip detectors, of photomultipliers with 50 cm diametre spherical cathodes, and of vacuum photodiodes and triodes, or the construction of large, intricately shaped parts made from composite materials.

This delicate art of collaboration with industry has been most successfully cultivated by our hosts, and I wish to describe this 'Japanese style'. As one example I quote the impressive construction of the time projection chamber (TPC) for the TOPAZ detector. This chamber will have a length and diameter of 260 cm and will be operated at 4 atm. The signal end-plates carry 16 x 180 proportional wires and are read out by approximately 12,000 signal channels. The physics group has ordered, or is in progress of ordering, from industry -with price, delivery, and performance guarantee- the following items: pressure vessel, high-tension field cage, end-plates with wires, and possibly the digital electronics. The physicists of course participate closely in the prototype stage and in the definition of the critical parameters. In parallel, studies are carried out in the industrial R&D laboratories, and I get (from the outside) the impression of a highly integrated collaboration, where the physicists provide the conceptual input and industry contributes with the technical and managerial know-how.

Several reasons explain the attitude of the Japanese industry:

- High-energy physics projects present one of the few ways of participating in very advanced technology, in a country where there are no major military or space programmes. Spin-off and the reputation resulting from these high technology collaborations are highly valued.

- Industry effectively uses the resources available at the high-energy laboratories, which provide special test facilities, test and performance data, etc.
- Japanese industry does not always expect financial profit from these collaborations. It is considered part of their R&D effort and some of their own R&D money is used for it.
- However, these collaborations are always undertaken with the expectation of long-term business advantages.

4.2. Supply of special goods

This is the more traditional role of industry, the supply of electronics instrumentation being a typical, rather successful, example. However, a coherent policy towards industry has not yet emerged, which is reflected in a lack of continuity in our business relations. One of the difficulties comes from the very large fluctuations that characterize the demands in our field on a time scale which is much shorter than the typical industrial scale of 10-15 years. As an example, during the last few years more than 100 tons of scintillator were used in only a few major experiments. Contrast this with the LEP experiments, for which very little sheet scintillator will be required.

However, even with the big fluctuations in demand, and with the typically rather small quantities required, we may still be an interesting customer for companies who can tailor a standard product or production line to our specific requirements (example: acrylic scintillator is delivered by the acrylics industry).

Apart from these general comments, a few simple guidelines may help to improve industrial contacts:

- make actively available any technical information produced by our instruments (high-statistics reliability evaluation; long-term stability of instruments; ageing of photomultipliers; radiation damage to integrated circuits and Si detectors, scintillator crystals, or Pb glass; properties of materials, evaluation of electronics circuits, etc.).
- recognize and periodically evaluate technological spin-off [5];

- improve contacts with industry: industry participation in conferences [6] or industry exhibits at the major laboratories;
- facilitate contacts with newcomers (provide an 'early warning system' for emerging technologies, issue technical summaries of proposals, include an industry column in laboratory journals).

Finally, I wish to show with a few examples that sometimes very spectacular successes may be achieved with an imaginative combination of resources, skills, and goodwill, frequently involving the central laboratories, universities, institutes, industry, and government agencies.

i) Uranium metal procurement for hadron calorimeters

European and US institutions collaborated in the construction of a large hadron calorimeter for an ISR experiment for which approximately 200 tons of depleted uranium metal were required [7]. The group suggested that, through discussion between the CERN and BNL directorates and their counterparts in the US Department of Energy (DOE) having responsibility for High Energy Physics programmes, an agreement might be reached to obtain this metal on loan from the DOE reserve - a prerequisite if such an instrument were to be built within available funding. Not only was agreement obtained, but also the numerous technical and political difficulties of this novel approach overcome. This network of contacts and negotiations made possible the construction of the calorimeter, which subsequently, through the operation, demonstrated the superiority of uranium calorimeters for hadronic energy measurements. Under a similar arrangement the Soviet participants in the L3 LEP experiment plan to obtain several hundred tons of uranium from the Soviet authorities for the construction of the L3 hadron calorimeter.

ii) Procurement of BGO crystals for the L3 LEP experiment

The exceptional performance characteristics of these crystals for photon energy measurements induced this group into using these crystals for their LEP experiment. When proposed, it was anticipated that the world production rate was insufficient and the world price far too high. The strategy planned to achieve this new level of price and availability is the following, unusually elaborate, collaboration: the raw chemical substances are provided by the USSR part of the collaboration; they are subsequently purified and shipped to the People's Republic of China (which has a group participating in this experiment), where the crystals are grown for later use at CERN. This solution might result in improved and cheaper production methods which would make this material accessible to many other experiments.

iii) Our needs for unusual or rare materials in especially large quantities is steadily growing. Already people are considering the advantages of calorimeters where scintillator is replaced by thousands of square metres of silicon-detectors, provided a price reduction of a factor of 100 is obtained. Thus one can imagine constellations combining unique resources in different countries to obtain such products.

These examples will suffice to indicate that within our geographically and culturally widespread interregional collaborations, the imaginative combination of resources and skills may provide us with instruments of an effective value far beyond the means or capability of an individual region. One should stress the fact that for these large scale procurement operations all regions may co-operate very effectively and productively, frequently in a in a very complementary way.

5. INTERREGIONAL COLLABORATION ON STANDARDIZATION

5.1 Standards for signal processing

This is perhaps the area with the longest history of successful collaboration. The advantages of standardization in this area are undisputed with benefits not limited to an individual experiment. Already in the early 1960's the need for standardization was recognized, which led to the first universally accepted Nuclear Instrumentation Modules (NIM). Subsequently, during the 1970's the CAMAC standard was developed -mostly through European initiatives- which defines the protocol of communication between signal processing units and a data-acquisition computer, as well as their mechanical and electrical environment. It became the rather universally accepted standard for electronics instrumentation in high energy physics, making also some inroads into industrial control applications. Although CAMAC was well adapted to experiments in the 1970's it was too limited for the new generation of detectors of the 1980's. A new standard FASTBUS was elaborated, this time initiated by US laboratories. The definition of the mechanical and electrical environment reflects the large increase in the number of signal channels and defines the protocol for interactions with several computers and intelligent controllers. From its early conception the US/NIM Committee (responsible for the US nuclear instrumentation), together with ESONE, their European counterpart, elaborated the specifications. In 1980 a preliminary version was jointly issued as a basis for co-ordinated investigations of hardware and software, culminating in specifications, issued by the US Department of Energy and the European Economic Community in 1984, followed by endorsement by several International Standards Committees. Since then, ESONE has set up an 'Advanced Systems Study Group' to co-ordinate the implementation of general-purpose software and hardware. In a relatively short time this new standard has won the acceptance of the experimental community (the LEP experiments, the Tevatron Collider experiments, SLAC experiments, TRISTAN experiments) and intensive industry support.

The secret of this success? It is a general-purpose 'product', not tailored to the details of an experiment. The NIM and ESONE Committees are relatively small groups of highly motivated professionals, representing in a rather democratic way the many smaller laboratories as well as the few major centres.

Repeated attempts have been made to extend these concepts of standardization to other areas, e.g. to define 'standardized' signal processing blocks, but so far these efforts have met with only limited success: the typical number of units per experiment is in the range of 10^4-10^5 and is rather well matched to present techniques of custom circuit fabrication. It is an order of magnitude below the economically attractive technique of custom integration. However, a few notable exceptions may indicate a changing trend:

- a fast (300 MHz) discriminator shift/register was developed for chamber readout at BNL and was subsequently commercialized;
- a 128 channel charge amplifier with sample-and-hold and built-in register for multiplexing sampled signals to a common ouput was jointly developed between SLAC, the University of Stanford and CERN;

- an internationally co-ordinated effort is being made to obtain custom integration of the electronics required for handling the FASTBUS protocol on modules. This would primarily save board space and power, perhaps even money. The industrial collaboration is jointly financed by CERN, FNAL, NBS, TRIUMF, and SLAC.
- The Munich Max Planck Institute for High-Energy Physics and the Dortmund University Institute for Micro-Electronics are collaborating in the production of a general purpose CMOS preamplifier for the readout of Si strips detectors, TPC's, and other detectors requiring low-noise charge amplifiers.

I will end this section by noting a few examples where increased interregional collaboration would be helpful:

- SLAC is working on a μVAX-FASTBUS board for trigger and event filtering;
- Emulators, an example of a very successful SLAC-initiated- CERN followed co-operation, are increasingly being used;
- coordination in the field of networks, emulators, and off-line requirements is being tackled on a Europe-wide scale by the 'Computer Coordination Committee'.

5.2. Standards for data management

The needs of the LEP experiments gave a strong impetus to the efforts to arrive at a standardized environment for data handling and processing. ECFA was instrumental in setting up various working groups which surveyed the needs and made recommendations that could be accepted on a Europe-wide basis. A few timely examples may indicate present directions:

i) EPIO stands for EP-division-Input-Output-package. It comprises the definition of a 'carrier' format for any kind of data, and a set of routines for reading and writing. Originally developed for the experiments at the CERN $p\bar{p}$ Collider, it is being ever more widely used in CERN experiments for all I/O operations from data recording to DST analysis.

Memory Managers: several approaches have been developed, such as HYDRA or, more recently, ZBOOK and BOS. These are packages to handle the dynamic management of data 'banks' and associated book keeping chores. A new system (ZEBRA) is under active preparation at CERN and will be recommended for general use.

iii) Source-Code Managers: the need here is for a method of maintaining and updating source code, and distributing it to the several different makes of main-frame. Despite its advancing years, the CERN-written PATCHY is almost unique for fulfilling these two functions, although the commercial product HISTORIAN is currently being evaluated. Computing away from CERN could not be done on the many different machines of outside laboratories without such facilities.

iv) Standards for Detector Simulation: There are three aspects of detector simulation:

1) the physics event generator (e.g. ISAJET, Lund model);
2) definition of detectors and tracking to them;
3) detailed simulation of detector response (e.g. EGS for electromagnetic showers);

For (1) and (3) there will always need to be a wide choice to cover the various applications. For example, EGS is extremely expensive in computer time, and faster, cruder simulations are often sufficient.

For item (2) there is a discernible trend towards GEANT as a standard package, and it is to be noted that present developments of GEANT place considerable emphasis on displaying events and detectors on the whole range of 'screens'.

It is interesting to note that European efforts to arrive at certain standard utility programs are not yet matched by equivalent efforts in the in other regions, e.g. the United States. With ever-growing collaborations a stronger degree of co-operation would provide obviously important benefits.

6. Conclusions

We have a conceptual understanding of the experimental requirements at a future hadron collider in the 10 to 40 TeV range, although the technical difficulties, particularly associated with 100 MHz collision rates, are formidable.

Reassessement of various experimental methods and the reliance on calorimetry as the principal tool suggest different levels of collaboration:

i) A wide spectrum of detector physics R&D will be desirable, one well-suited to the interdisciplinary university environment. National institutes might act as catalysts.

ii) Large-scale expensive 'tests', including the evaluation of the physics performance of a new method are required. Intergroup collaborations will carry out these tests. The help of programme committees and large laboratories is required.

Wide-spread interregional collaborations facilitate the procurement of rare or unusual products.

It is in our own interests to nurture our relations with industry.

Standardization in signal and data handling has been very successful, and it provides the basis for physics on an interregional scale. The methods by which this has been accomplished may be borrowed by other groups who wish to achieve similar results.

I have concentrated on those positive aspects which should prepare us for the next round of experimentation. We have not forgotten and have all suffered from the problems encountered in interregional dealings -essentially of a bureaucratic nature and origin- which stifle these efforts and which range from mere irritation to major stumbling blocks. This is the dimmer side of the interregional style, but its discussion belongs to the history books.

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References

[1] Proceedings of the following workshops:
Second ICFA workshop on possibilities and limitations of accelerators and detectors, Les Diablerets, Switzerland, (1979) (Ed. U. Amaldi);
DPF summer study on elementary particle physics and future facilities, Snowmass, Colorado (1982) (Ed. R. Donaldson, R. Gustafson and F. Paige);
DPF workshop on collider detectors, LBL, Berkeley (1983) (Ed. S.C. Loken and P. Nemethy);
DPF workshop on pp options for the Supercollider, Chicago Ill., (1984) (Ed. J.E. Pilcher and A.R. White);
CERN-ECFA workshop on feasibility of hadron colliders in the LEP tunnel, Lausanne and CERN, March 1984, (Ed. M. Jacob).

[2] The Axial Field Spectrometer Collaboration, CERN/ISRC/82-17.

[3] A. Peisert and F. Sauli, Drift and Diffusion of electrons in gases: a compendium, CERN Yellow Report (to be published).

[4] ECFA working group on Data Processing Standards: Microprocessors in European High-Energy Physics Experiments, ECFA 82/58.

[5] H. Schmied: Etude de l'Utilité Economique des Contrats du CERN, CERN 75-6.

[6] E. Bertolluci et al., Organizers of the "2nd Pisa Meeting on Advanced Detectors". In a 'Round Table with Industry' about 50 companies participated in specialized working groups and a product exhibit. Castiglione della Pescaia, Italy (1983).

[7] O. Botner et al., JEEE-Trans. Vol. NS-28 (1981) 510.