Accelerators of the Future

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Under this title, assigned to me by the Organizing Committee, I would like to report to you on a Seminar held at KEK in Japan, May 14-19, 1984, under the auspices of ICFA.

As a start, I refer you to transparency No. 1. We here all know that High Energy Physics is an active branch of Science, currently traversing one of its most exciting periods. But its importance transcends that of a scientific activity. It is, and has been for several decades, a model of international collaboration.

Now as to ICFA, the International Committee for Future Accelerators, about which some of you know perhaps less than I would like you to know: The main purpose of this Committee, founded in 1975 in New Orleans, was to further the cause of the World Accelerator, a Very Big Accelerator (VBA) to be built by the various regions of the world jointly - presumably when its size and cost made its construction by a single region alone impractical. ICFA, as you all know, has not met this challenge to this date. It has instead done a number of other useful things. ICFA has organized two workshops, which have, respectively, produced designs for a large circular machine (essentially a "desertron"), and for a linear collider (essentially an SLC). ICFA has formulated these guidelines which have been accepted by the directors of all major laboratories and which guarantee today free access to their facilities by "outside" users.

The background for the KEK Seminar were the numerous ongoing accelerator projects (see Transparency No. 2) as well as the various options for the future (the American SSC, the hadron collider in the LEP tunnel = LHC, a large linear collider in the US, and an analogous machine in Siberia). Transparencies No.3 through 5 give you the details of the programme.

It should be mentioned that the various people who helped convening the Seminar had been instructed to promote the participation of people under 40. Notwithstanding this instruction, the Seminar was in this one respect rather a failure. Transparency No. 6 shows the age distribution of the actual participants, with the shaded area indicating the group whose future was being discussed.

I shall now read to you, essentially verbatim, the Conclusions which I presented at the end of the KEK Seminar:

"To summarize this Seminar is, for me as the chairman of ICFA, a rather delicate task. Were I a simple participant, foolhardy enough to accept the task of condensing the contents of 3 days of formal presentations and discussions into a short summary, then I would have more freedom to present my general impressions in addition to reciting facts and figures. Indeed, these facts and figures serve mainly to formulate scenarios, while the choice between these scenarios is the key issue where, at least at the present moment, emotional arguments were occasionally been evoked. Such arguments can be summarized only through impressions, and my own would be, of necessity, subjective, and thus ruled out of order. Fortunately -- or unfortunately, depending on one's idiology -- we have here reached the clear conclusion that ICFA's role should be to facilitate collaboration rather than to arbitrate between options.

"ICFA is a creature of IUPAP, and both I's stand for "international", actually the I in ICFA rather signifies "interregional". Nevertheless, I shall reiterate that there are two kind of internationalism, i.e. idealistic and pragmatic. The first, starting from the inherently transnational nature of science, wants to go international wherever possible -- perhaps to strengthen the bonds between different nations or to show the way for other undertakings. The second, the pragmatic one, wants to go international (or, really, interregional) only when forced by outer constraints to do so. This latter point of view, expressed by as great a leader in our field as R.R. Wilson, is not as embarassing as it seems; CERN was founded for this reason, and emulated later by others, both within and without HEP. The comparison between comparable facilities in two regions could, as emphasized here by Boyce McDaniel, even be constructive. It should however not be forgotten that each of those regions would have to convince their authorities of this added advantage of "separate but equal". I should on the other hand add, as a summarizer, that it was pointed out here (by T. Ekelof) that the "idealistic" approach has hidden pragmatic advantages.

Time does not permit me to analyze these in detail.

"The survey of on-going accelerator projects has convinced us that the world of high-energy physics will be swinging towards the end of the eighties or at worst at the beginning of the "naughty nineties", -- HERA, LEP, SLC, Tevatron and Tristan will all be running or in fact will have been running for a number of years! Nay, it is even probable, if not certain, that some striking discovery will already have been made at one or the other of these accelerators. It is only regrettable that another great and fundamentally distinct facility, UNK, is proceeding at a relatively slow rate. This remark is not intended as a criticism of our Soviet colleagues, who have shown themselves so inventive in accelerator physics (just think of phase stability, cooling, electron polarization, RF quadrupoles), but rather as a form of moral support by the international community.

"Two more signs of health: 1) with HERA, a second major Western European center is launched with a new transnational way of financing which many here have proposed as a funding mode for anticipated interregional projects; 2) BEPC is proceeding well in Beijing, showing that China, a country with still so many "practical" needs to be fulfilled, has the wisdom to invest in the frontiers of science. As W.K.H. Panofsky has pointed out here, such comparatively small projects can have large value for the international community.

"The two theoretical talks on Tuesday p.m., both delivered on and with energy and luminosity, were intended to show us the way where flowers bloom in the desert. To put is more bluntly, they gave us reasons for the energy scale that we ought to investigate in the "naughty nineties". Their main points were (a) that an "available" c.m. energy of 1-2 TeV is needed, (b) that this "available" energy is, for hadron colliders, only 1/5 to 1/10 of the total c.m. energy, and (c) that e^+e^- colliders might have, as seen by the theorists, some distinct advantages. It must be said that there is at present no detailed design and hence no price tag for a SSLC's of the requisite size. Nevertheless, this option, pursued with admirable persistence in Siberia, should not be lost out of sight for one moment of the next few years.

"It is well- known that, except for the Bevatron and the $S\bar{p}pS$, the glories of every accelerator have come from discoveries not predicted, or at least not emphasized, by theorists. "Who needs them?" might some intrepid voyagers exclaim (there are 1000 theorists in Japan alone!). Their usefulness, at least in this context, is illustrated by the following anecdote. Before telling it, I must explain that Austrians consider Germans to be pedantic and punctilious, while Germans think of Austrians as being sloppy and disorganized. A German tourist riding on the Austrian railway, noticed that his train was 20 minutes behind schedule. He remarked to the conductor: "What a slovenly country: What do you people really need a time-table for?!" To which the conductor replied: "Sir, if we did not have a time-table, you would not know how late we are...". Anyhow, to quote myself, "Last year's (decade's) discovery is this year's (decade's) calibration", to which Feynman added "and next year's (decade's) background".

"In the nineties, we-- that is the "shaded group in my graph -- should then explore masses around 1-2TeV, presumably with hadron colliders. Zacharov promised us SUSY particles at a mere bargain mass of 0.1 TeV, and he also emphasized that for large values of τ the antiquark content of $\bar{p}$'s makes up for their smaller absolute flux.

"The subsequent panel discussion on detector related machine and instrumentation issues taught us mainly two things: (1) The requested luminosities of the next generation of hadron colliders will stretch the current experimental techniques to their very limit, and, in some cases, perhaps beyond. (2) The megabit data flow might cause indigestion and perhaps even constipation. To throttle it by reducing the intake of luminosity is not a recommended, if expensive, remedy. In this context the critical comments of Carlo Rubbia, who has never posed as a pessimist, ought to be heeded.

"Clearly this is an area where much effort, as coordinated as possible, is needed. It is also an area where cooperation between experimentalists and machine designers is more critical than ever. Fortunately, the panel convened at KEK suggested that ICFA initiate panels to promote international collaboration.

"The talks on future options were rather different. The hadron colliders, SSC and LHC, were presented as well within the reach of current technologies, if not necessarily of currentregional budgets (actually, the most ambitious option for the LHC would require the development of the technology for the series fabrication of 10-T superconducting magnets).

At this point, I would like to depart briefly from my written conclusions, and present to you (transparency No. 7) an informal comparison between various possible SSC and LHC models. The authors of this comparison do not wish to be identified, but

they are what you vaguely refer to as "generally well-informed sources". Some comments are in order: (a) the reduction of the SSC luminosity from 1 to 0.5 represents the hypothesis that, all things being equal, it should be harder to achieve a given luminosity in a machine of larger circumference; (b) in the cost estimate for the LHC with 6.5 Tesla magnets, figures for magnets of the same strenght proposed for the SSC were taken over.

"The linear colliders, probably the most rewarding devices of this century, were viewed in different lights by the two leading experts. Skrinsky, proposing an evolutionary, say Darwinian, construction approach, was cautiouslyoptimistic, while Richter, perhaps more along the Lysenko line, spoke very pedagogically, but with surprising understatement, about parameters for 1+1 TeV. As was later pointed out pointedly, the relatively close turn-on of the SLC may provide a shock treatment to its very originator and a benefit to all of us. Good luck, SLAC!

"Having dedicated my Wednesday afternoon, together with one of our founding fathers, to Tokyo art galleries, I cannot honestly report on what was said. My personal knowledge of the speakers and my fear of making yet more enemies inspires me to say that the talks must have been excellent.

The Sessler panel on Future R&D cooperation produced the unanimous suggestion that ICFA had found itself another valuable task -- to organize standing panels for international collaboration in the following areas:

A.1 Super-conducting Magnets and Cryogenics
A.2 Super-conducting RF
A.3 Surface and Material Physics related to Accelerator Technologies
A.4 Beam Dynamics
A.5 New Acceleration Schemes
B.1 Instrumentation Innovation and Development
B.2 Physics Advice on Future Requirements for New Accelerators."

"In yesterday's meeting, as I have already had the pleasure to report, ICFA has agreed to do so either for at least several of these areas. This is a very positive step indeed.

"We had a so-called "WHAT" panel discussing possible scenarios for the nineties. The frank exchanges that took place, in regard to the proposed SSC and the potential LHC, prompted me earlier to refer to the "naughty" nineties. The interdependence of the projects, even if clearly meant as regional undertakings, was perhaps not sufficiently stressed by the panel, nor discussed by interventions from the floor."

Once again departing from my prepared script, I would like to present to you (Transparency No. 8) various scenarios that were mentioned in the discussion. Scenario I leaves the hadron collider to Europe, with the US concentrating on an SSLC, an Super-SLC. Scenario II lets CERN put antiprotons in the LEP tunnel, while the SSC in the US is delayed until, say, 96, when the construction of a Super-SSC starts. CERN ultimately builds at LEP an e-p facility Dep. In S cenario III, the SSC goes on as currently planned, CERN forgoes the hadron option and builds CEP, while simultaneously an European effort on a Super-SLC (the ESCLC) is started.

"It should be noted that L. Lederman injected a note of internationalism by mentioning the possibility that the SSC be built à la HERA -- presumably however only in certain circumstances. Leon Lederman even called it a "possible VBA".

"There are good reasons on both sides of the Atlantic for building these hadron colliders, and perhaps even good reasons for building them both. I am confident that the proper balance will be found by the time the next seminar of this type will be held, and I am relieved(but not necessarily happy) that it's not ICFA's job to arbitrate.

"The final session was that of the "How" panel, which you might have called the "ways and means committee", followed by vigorous audience participation. As was pointed out, we can't use our know-how if we don't have a know-what. It did however not become ICFA's task to solve this logical puzzle, since it was agreed by a clear consensus that ICFA's charge was to facilitate the construction of new high-energy accelerators rather than to arbitrate between various national and regional options. This clarification, and the consequent simplification of our tasks, makes it easier and also more important to carry out those new tasks that have been handed to us with enthusiasm and vigor. There is, we all know it, no room in our field for people who lack these two qualities.

"The greatness of our field lies not only in its uninterrupted chain of successes in uncovering and explaining the structure of matter on deeper and deeper levels, but also in the incessant rate at which novel techniques of acceleration and detection have so far always been invented and actually put into practice. If we don't want Livingston's exponential plot to flatten out, and we certainly do not, then we should not put all our hopes into the VBFA (very brute-force accelerator), but we should strive for a VBIA (very brillant idea accelerator). I can forecast already how the VBIA might

come about:

(These acronyms are clarified in Transparency No. 8).

"The basic idea will probably be invented by an immigrant, from another country or region. The flaws of this idea will then be castigated and ultimately corrected by somebody in yet another region. Several regions will engage in a race to design a practical accelerator, to the great benefit of all. ICFA will say that the VBIA is not the VBA in its charter, and will not arbitrate. The machine will however be built, perhaps à la HERA, and be freely accessible to rich and poor alike under ICFA guidelines. Perhaps the sole conclusion is that all countries of the world should allow free emigration and immigration. Thank you".

After the closing of the open KEK Seminar, IFCA met and formulated their own conclusions. These are reproduced on Transparency No. 9.

0. HEP is good

1. ICFA exists and should be good

2. Summary of ICFA Seminar at KEK (potentially good)

3. Conclusions of ICFA after KEK seminar (you judge)

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ACCELERATOR FACILITIES NOW UNDER CONSTRUCTION

NAME	LOCATION	PARTICLES	ENERGY	COMPLETION DATE (estimated)
BEPC	Beijing, China	e^+e^-	2.8 + 2.8 GeV	1988
TRISTAN	KEK, Japan	e^+e^-	30 + 30 GeV	1986
SLC	SLAC, USA	e^+e^-	50 + 50 GeV	1986
LEP	CERN, Geneva	e^+e^-	100 + 100 GeV (initially 50 + 50 GeV)	1988
TEVATRON I	FNAL, USA	$p\bar{p}$	1 + 1 TeV	1986
HERA	DESY, Germany	$e^{\pm}p$	30 + 820 GeVp	1990
UNK	Serpukhov, USSR	p	600 GeV	1990
		p	3 TeV	1992-93

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Tue, May 15

I. Introductory speeches, esp VFW

2. Surveys of on-going accelerator projects (Skrinsky) – all 15m

	BEPC	Yu
	LEP	Schopper
	SLC	Panofsky
a.m.	Tevatron	Tollestrup
	Tevatron	Ozaki
	UNK	Myznikow
	(HERA)	Wiik
	Physics w. E and L (Theory, Sugawara)	

Ellis, J. 45m

Zacharov 45m

Panel: Detector Related Machine and 2l Instrumentation Issues (Ekelof)

Amaldi, Breidenbach, Kase Orito, Schinzel, Wolf

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May 16, Wednesday

a.m.

Future options (Nguyen Van Hieu)

SSC	Tigner
LEP/HC	Briatti
LC (US)	Richter
LC (USSR)	Skrinsky

p.m.

HERA Wiik

Examples of collaboration in R&D

S.C. Magnets	Hinakayashi
Beam Dynamics in LC	Skrinsky
Exotics	Pellegrini
Fabjan	Detectors

May 17, Thursday

a.m. Panel Discussion on Future R&D Coll. (Session)

Briatti, Kimura, Tigner, Voss, Yarba

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May 17, Thursday

p.m. Panel Discussion: Cooperation in Accelerator Construction (Panofsky)

= "WHAT" Panel

Leduman, Rubbia, Sandweiss, Schopper, Skrinsky

May 18, Friday

a.m. Panel Discussion on Cooperation
3l in Acc. Construction (Specific Aspects) VLT

= "HOW Panel"

Baldin, Nishikawa, Rechter, Samios, Soergel, Yamaguchi

May 18, Friday

p.m. Closed ICFA

May 19, Sat.

Discussion of Conclusion (VLT)

Closing Lecture (Nishikawa)

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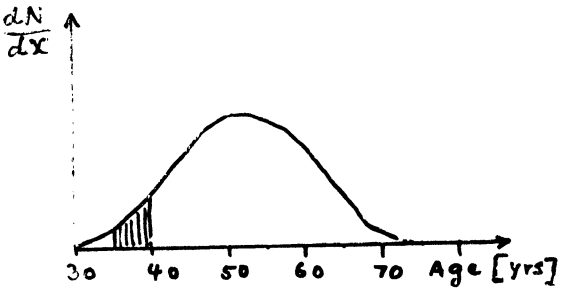

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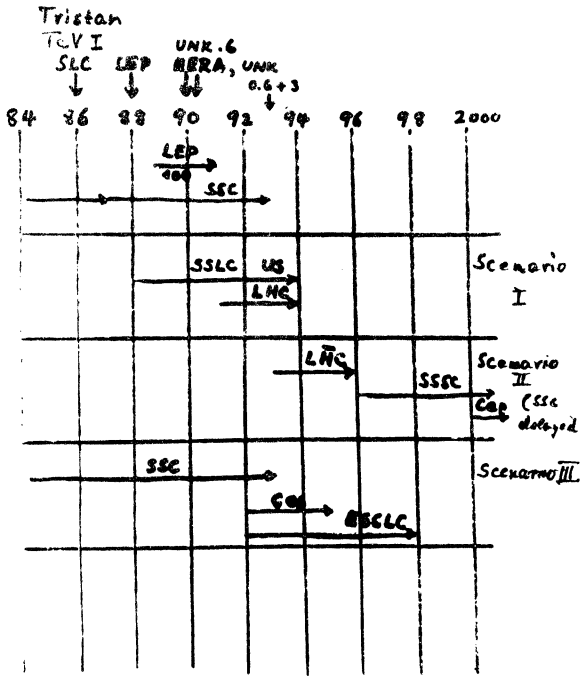
	SSC			LHC (LEP)		
E_{CM} [TeV]	40			12	14.5	18
B [T]	3	5	6.5	6.5	8	10
$2\pi R$ [km]	164	113	90	27		
Rel. $\mathcal{L}$ [$10^{32}/cm^2 s$]	1			1		
Rel. observed M	1			.55	0.6	0.67
stored energy [MJ]	816	566	448	85	93	105
Rel. $\mathcal{L}$	0.5			1		
Rel. observed M	0.84			0.55	0.6	0.67
	"1"			0.65	0.71	0.81
Rel. cost	0.99	1.12	1.0	0.16	0.2	0.27 ?
pp				0.12		

7



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Dictionary of Acronyms :

VBA = Very Big Accelerator
= World Machine

VBFA = Very Brute Force Accelerator

VBIA = Very Brilliant Idea Accelerator

8'

CONCLUSIONS OF ICFA

1. ICFA notes with satisfaction that our field is now in a scientifically very exciting state and holds great promise for the future.

2. Based on the consensus of the participants in the KEK seminar, ICFA views its major current role as facilitating the construction of high-energy accelerators and not as arbitrating among various national or regional options.

3. ICFA intends to do its utmost to promote international collaboration in all phases of the construction and use of such facilities. In particular, ICFA wishes to reiterate strongly its 1981 guidelines concerning the open access to all major accelerators.

4. ICFA approves the suggestion that it sponsor panels on specialized topics, such as advanced accelerator and detector R and D. The need for such panels should be reviewed periodically. ICFA will explore ways and means to ensure wide distribution of the reports etc. produced by such panels. ICFA hopes for the widest possible international representation on these panels. It appears that the constitution of some of the following panels would be useful at this time: -
   a. Super-conducting Magnets and Cryogenics
   b. Beam Dynamics
   c. New Accelerator Schemes
   d. Future Instrumentation Innovation and Development

5. ICFA proposes that seminars of the type now convened at KEK should be held regularly in order to review the status of our field and to anticipate future activities. They should be organized every two to four years, their occurrence being conditioned by the prevailing situation.

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