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ERRATUM

ICFA PANEL DISCUSSION ON FUTURE ACCELERATORS*

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Please note that the title for this publication has been changed to:

A PERSPECTIVE ON FUTURE ACCELERATORS

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Invited talk presented at the ICFA Seminar on Future Perspectives in High Energy Physics, Upton, New York, October 5–10, 1987

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I. INTRODUCTION

Ladies and gentlemen, let me begin with an apology for being late to this important meeting. I have a conflicting engagement, but I expect to arrive tonight and will be with you tomorrow. I appear in this virtual state by invitation of our chairman, Yoshio Yamaguchi, who flatters me by believing that my perspective is important.

I assume that you have already heard, or will soon hear, much about the future of proton machines and so I will not spend any time on that topic other than to say that the goal of achieving parton collision energies sufficient to produce particles of around 1 TeV mass is an important one for high energy physics. Proton machines are now the quickest way to get there. I will spend my time talking about the future of electron-positron colliders.

It is generally agreed that reaching collision energies much beyond the energy available from LEP II requires the construction of advanced linear colliders if these machines are to be built in a cost-effective fashion. It is interesting to note – especially on this occasion – that the modern, high energy, high luminosity

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linear collider was born at the first ICFA workshop which was held at Fermilab nine years ago. That workshop brought together people from all over the world who were interested in advanced electron-positron colliders, and I believe it is fair to say that the work done there led directly to both the SLC and to the broad interests expressed by scientists in all of the regions of the world for still more advanced electron-positron colliders.

The high energy physics community is a relatively small one, and it is still possible for one person to know most of the people working it, and to have serious discussions with them. It is from those discussions that I know that my European, Japanese, and Soviet colleagues are as interested as I am in building the machine which, for ecumenical reasons, I call the NLC, or Next Linear Collider.

It is important to all of us to consider how to manage cooperation in this area without rousing interregional rivalries, or at least without rousing them prematurely. Toward this end I have a modest proposal to make, but before making that proposal I will briefly discuss some of the scientific and technical issues which must be resolved before such a machine can be built and then return to internationalism.

II. PHYSICS ISSUES

In principle, electron-positron colliders have two great advantages over proton colliders. These are:

1. Democracy – all cross-sections are of the order of one unit of R as long as the particles produced have electromagnetic or weak charge.
2. Cleanliness – lepton and hadron yields are comparable and peripheral processes are small at large P_T and distinguishable with simple cuts.

Unfortunately, the cross-sections of interest are small at high energies as is the case for proton colliders as well. Figure 1 shows the cross-section as a function of center-of-mass energy. The annihilation cross-section drops like E^2 and has a structure corresponding to the known narrow resonances. As about 100 GeV in the center of mass a new peripheral process involving W exchange appears and starts to rise, and this becomes comparable to the annihilation cross-section in region of the 1 TeV. I have marked the figure, which I borrowed from Ugo Amaldi, showing the region of the NLC which spans the range from 1/2 – 2 TeV in the center of mass.

Any machine that we build must have enough luminosity to produce sufficient events to study the physics that we are interested in, and I define that as about 1000 events per 10^7 seconds per unit of R. This implies that the luminosity required is

$$\mathcal{L} = 10^{33} \left(E^{\star}[\mathrm{TeV}]\right)^2 \ \mathrm{cm}^{-2} \ \mathrm{s}^{-1} \quad .$$

By this criteria a machine with a center-of-mass energy of 1/2 TeV requires a luminosity of about 3×10^{32}, while one of 2 TeV requires a luminosity of 4×10^{33}.

III. ACCELERATOR ISSUES

With this very crude collection of requirements as input Figure 2 gives our view at SLAC of the accelerator issues. One might build an NLC at the lower bound of interesting energies with moderate extensions of present technology, but machines with energies of 1 TeV or above are going to require new approaches. This is illustrated in Table 1 which compares the parameters of the SLC, a 1 TeV collider built using SLC technology, and a 1 TeV machine using one of several possible approaches to new technology; pulsed, high power rf sources at much higher frequency than the SLC. I think one can build the "SLC technology" machine, but I would hate to have to pay for 60 km of it, or to pay the operating costs for 1/2 gigawatt of power. New technology can shrink the length and shrink the power requirements.

Table 1

SLC Compared to "OLD" and New Technology 1 TeV NLC

	SLC	SLC Technology	New Technology
Energy (GeV)	100	1000	1000
Repetition Rate (Hz)	180	360	90
Luminosity (cm^{-2} s^{-1})	6×10^{31}	10^{33}	10^{33}
Accelerator Gradient (MV/m)	20	20	200
RF Frequency (GHz)	2.86	2.86	11.4
Peak RF Power per M. of Accelerator (MW)	20	20	1200
Length (km)	3	60	5
Wall Plug Power (MW)	50	500	100
$\sigma_x \times \sigma_y$	1.6×1.6	0.4×0.4	1×0.005

There is a great deal to do in accelerator R&D to create the technology base required for an economical and efficient NLC. There are four areas that need considerable work:

Theoretical studies
Low emittance sources
Efficient and stable accelerators
High precision final focus

While the largest amount of money will be involved in the accelerator and its power sources to drive the NLC, an enormous amount of work is required in all of these areas. It is very difficult for any one laboratory to do all the work required for one particular approach to this type of machine, and it is probably impossible for any one laboratory to afford the resources and manpower required to investigate many of the promising alternatives.

IV. A MODEST PROPOSAL

Our goal at SLAC is to complete the R&D required in time to start the construction of our version of the NLC in the mid-90's $\pm$ a couple of years. I believe the goals of our European, Japanese and Soviet colleagues are identical. Thus we ought to be able to work out a method to avoid duplication and to move the whole effort along faster and more economically than if one group tried to do it all.

My proposal is simply to do the R&D internationally. Make it a mix of coordinated and collaborative work, for we will all move faster that way and there are no secrets in accelerator physics anyway.

Governments and circumstances in the future will determine where and when a machine is built. We can argue about that later and cooperate now, for that cooperation will serve all of our best long-range interests.

Who knows? Perhaps if we get into the habit we can even get together on building such a machine.

V. ROLE OF ICFA

Is there a role for ICFA in all of this? I will be interested in hearing the panel discussion on accelerator R&D which is scheduled for later in the week. My own personal opinion is that ICFA is best at facilitating long-range R&D work, and so should probably concentrate its efforts on the R&D required to go beyond the NLC while leaving NLC to the actors in our drama.

As to the NLC program itself, we probably should all get together some time in the fall of '88 and have an extended workshop on where we are and where we are going. SLAC would be happy to host it.

FIGURE CAPTIONS

Figure 1: Cross-section versus center-of-mass energy for electron-positron reactions. The region between 0.5 and 2 TeV is the region of the NLC. The figure is from U. Amaldi, CERN EP 87-95, with additions.

Figure 2: A rough estimation of technology requirements for linear colliders in the Luminosity – Energy plane.

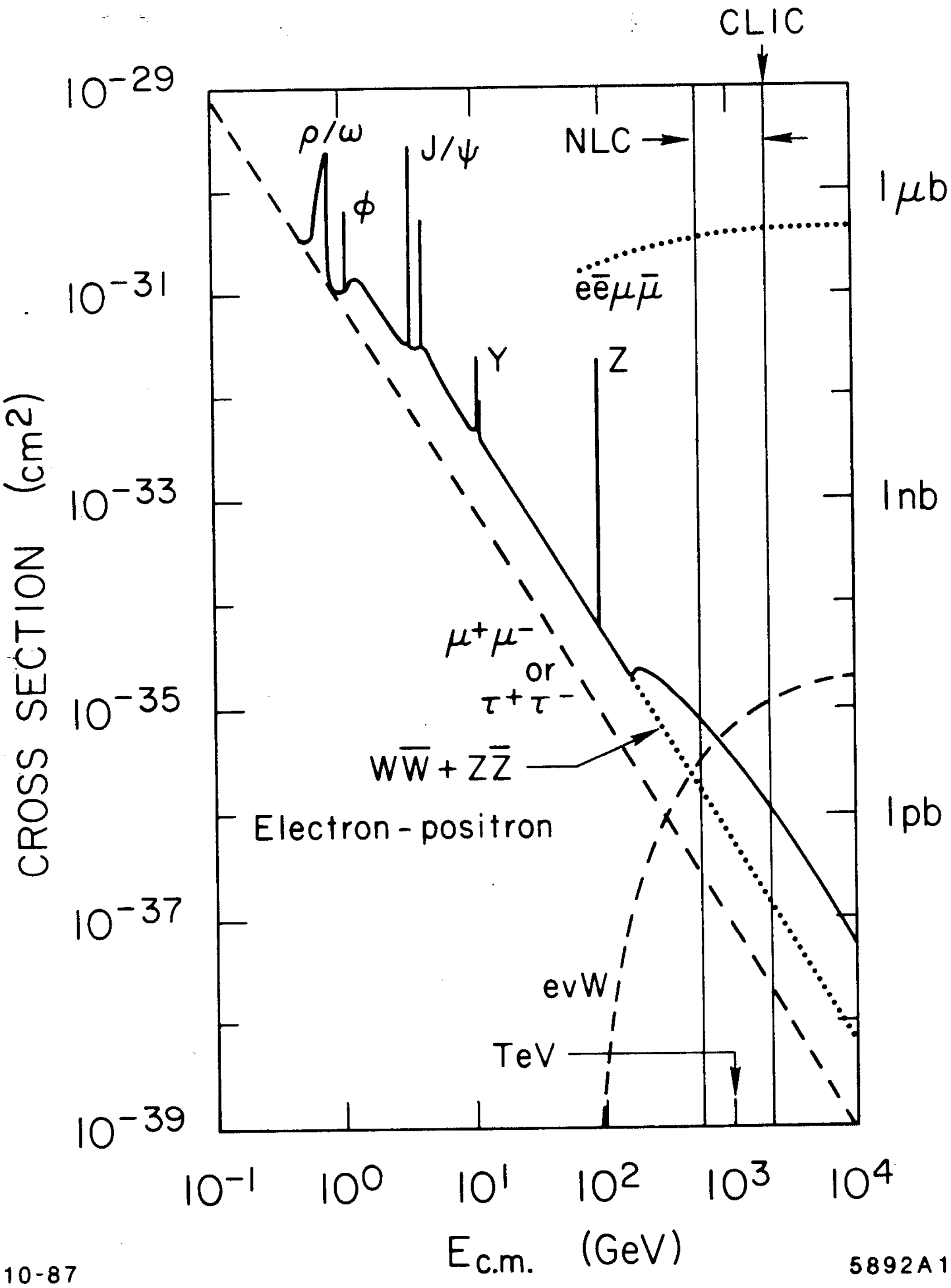
CLIC
NLC
ρ/ω
φ
J/ψ
Υ
Z
1 μb
1 nb
1 pb
eēμμ̄
μ+μ−
or
τ+τ−
WW̄ + ZZ̄
Electron - positron
eνW
TeV
10−29
10−31
10−33
10−35
10−37
10−39
CROSS SECTION (cm2)
10−1
100
101
102
103
104
Ec.m. (GeV)
10-87
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Fig. 1

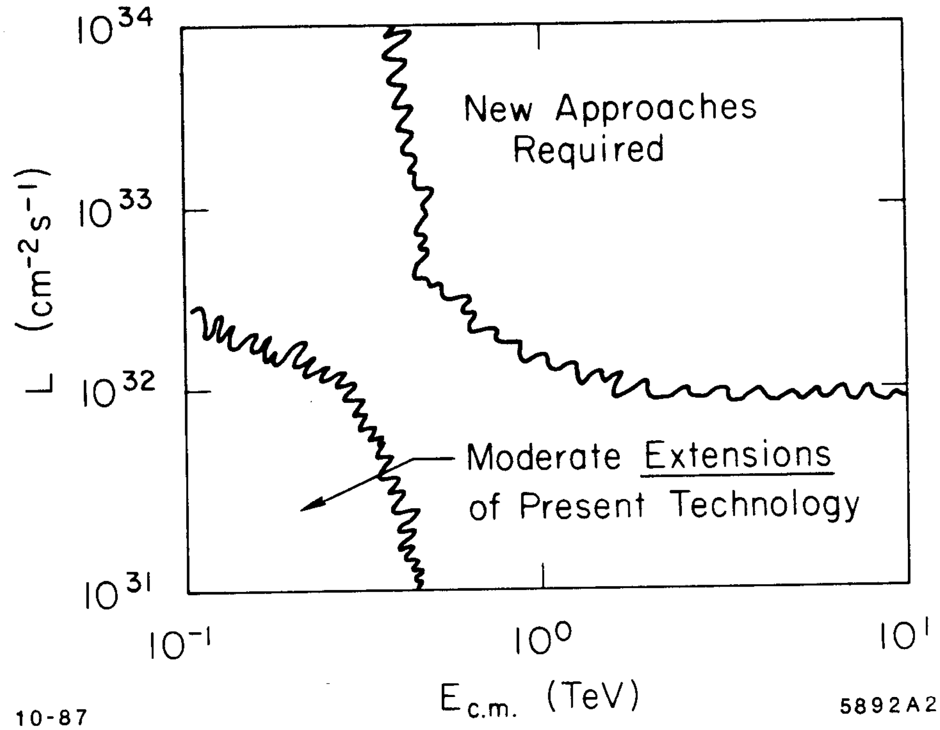
New Approaches Required
Moderate Extensions of Present Technology
10^{34}
10^{33}
10^{32}
10^{31}
L (cm^{-2}s^{-1})
10^{-1}
10^{0}
10^{1}
$E_{c.m.}$ (TeV)
10-87
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Fig. 2