LINAC*LHC BASED ep, γp, eA, γA and FELγ-A COLLIDERS

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Abstract

Main parameters of various colliders which can be realized if a special 1 TeV energy linear electron accelerator or corresponding linear collider is constructed tangential to LHC, are estimated. It is shown that $L_{ep}=10^{32}cm^{-2}s^{-1}$ at $\sqrt{s_{ep}}=5.29$ TeV can be achieved within moderate upgrade of LHC parameters. Then, γp collider, with the same luminosity and $\sqrt{s}=4.82$ TeV can be realized by using Compton backscattering of laser beam off the electron beam. Concerning the nucleus beam, $LA=10^{31}cm^{-2}s^{-1}$ can be achieved at least for light and medium nuclei both for eA and γA options. Finally, colliding of the FEL beam from an electron linac with nucleus beams from LHC will give a new opportunity to investigate nuclear spectroscopy and photo-nuclei reactions.

1 INTRODUCTION

The center of mass energies which will be achieved at different options of this machine are an order larger than those at HERA and ~3 times larger than the energy region of TESLA⊗HERA, LEP⊗LHC and μ-ring⊗TEVATRON (see the review [1]). In principle, luminosity values are ~7 times higher than those of corresponding options of the TESLA⊗HERA complex due to higher energy of protons. Following [1-4] below we consider electron linac with $P_e≈60$ MW (Table 1) and upgraded proton beam from LHC (Table 2). The reasons for choosing superconducting linac, instead of conventional warm linacs (NLC, JLC) or CLIC, are listed in [2].

2 MAIN PARAMETERS OF ep COLLIDER

According to Tables 1 and 2, center of mass energy and luminosity for this option are $\sqrt{s}=5.29$ TeV and $L_{ep}=10^{32}cm^{-2}s^{-1}$, respectively, and an additional factor 3-4 can be provided by the “dynamic” focusing scheme [5]. Further increasing will require cooling at injector stages (work on the subject is under development [6]). This machine, which will extend both the Q^2 –range and *x*-range by more than two order of magnitude comparing to those explored by HERA, has a strong potential for both SM and BSM research.

3 MAIN PARAMETERS OF γp COLLIDER

The advantage in spectrum of the back-scattered photons and sufficiently high luminosity (for details see ref. [7,8]), $L_{\gamma p}>10^{32}cm^{-2}s^{-1}$ at $z=0$, will clearly manifest itself in a searching of different phenomena. The physics search potential of this option is reviewed in [9]. For example, thousands di-jets with $p_t>500$GeV and hundreds thousands single W bosons will be produced, hundred millions of b^*b and c^*c pairs will give opportunity to explore the region of extremely small x_g etc.

In Fig. 1 the dependence of luminosity on the distance *z* between interaction point (IP) and conversion region (CR) is plotted (for corresponding formulae see [8]). In Fig. 2 we plot luminosity distribution as a function of γp invariant mass $W_{\gamma p}=2\sqrt{E_\gamma E_p}$ at $z=5$ m. In Fig. 3 this distribution is given for the choice of $\lambda_e=0.8$ and $\lambda_0=-1$ at three different values of the distance between IP and CR.

4 MAIN PARAMETERS OF eA COLLIDER

In the case of LHC nucleus beam intra beam scattering (IBS) effects in main ring are not crucial because of large value of γ_A. The main principal limitation for heavy nuclei coming from beam-beam tune shift may be weakened using flat beams at collision point. Rough estimations show that $L_{eA}\cdot A>10^{31}cm^{-2}s^{-1}$ can be achieved at least for light and medium nuclei [1, 10]. By use of parameters of nucleus beams given in Table 3 one has $L_{eC}\cdot A=10^{31}cm^{-2}s^{-1}$ and $L_{ePb}\cdot A=1.2\cdot10^{30}cm^{-2}s^{-1}$, correspondingly.

5 MAIN PARAMETERS OF γA COLLIDER

Limitation on luminosity due to beam-beam tune shift is removed in the scheme with deflection of electron beam after conversion [8]. The dependence of luminosity on the distance between interaction point and conversion region for γC and γPb options are plotted in Figs. 4 and 5, respectively. As it is seen from the plots, $L_{\gamma C}\cdot A=0.8\cdot10^{31}cm^{-2}s^{-1}$ and $L_{\gamma Pb}\cdot A=10^{30}cm^{-2}s^{-1}$ at $z=5$ m.

The physics search potential of this option, as well as that of previous three options, needs more investigations from both particle and nuclear physics view points.

6 FELγ–A COLLIDER

The ultra-relativistic ions will see laser photons with energy ω_0 as a beam of photons with energy $2\gamma_A\omega_0$, where γ_A is the Lorentz factor of the ion beam. For LHC $\gamma_A=(Z/A)\gamma_p=7446(Z/A)$, therefore, 0.1÷ 10 keV photons, produced by the linac based FEL, correspond to 0.5÷50

MeV in the nucleus rest frame. The huge number of expected events [11] and small energy spread of colliding beams will give opportunity to scan an interesting region by adjusting the FEL energy.

Table 1. Parameters of special electron linac

Electron energy, GeV	1000
No of electrons per bunch, 10^{10}	0.7
Bunch length, mm	1
Bunch spacing, ns	100
No of bunches per pulse	5000
Pulse Length, μs	1000
Repetition rate, Hz	10
Beam power, MW	56
Normalised emittance, 10^{-6}m	10
Beta function at IP, cm	200
$\sigma_{x,y}$ at IP, μm	3.3
Beta function at CR, cm	2
$\sigma_{x,y}$ at CR, μm	0.33

Table 2. Upgraded parameters of LHC proton beam

Proton energy, GeV	7000
No of protons per bunch, 10^{10}	40
Bunch spacing, ns	100
Normalised emittance, 10^{-6}m	0.8
Bunch length, cm	7.5
Beta function at IP, cm	10
$\sigma_{x,y}$ at IP, μm	3.3

Table 3. Parameters of C and Pb beams

	C	Pb
Nucleus energy, TeV	42	574
Particles per bunch, 10^{10}	1	0.01
Normalised emittance, 10^{-6}m	1.25	1.4
Bunch length, cm	7.5	7.5
Beta function at IP, cm	10	10
$\sigma_{x,y}$ at IP, μm	5.8	6.9
Bunch spacing, ns	100	100

7 CONCLUSION

The proposed complex, if realised, will open new horizons for both the particle and the nuclear physics. Therefore, it is necessary to continue the efforts on both machine and physics search potential aspects.

8 ACKNOWLEDGEMENTS

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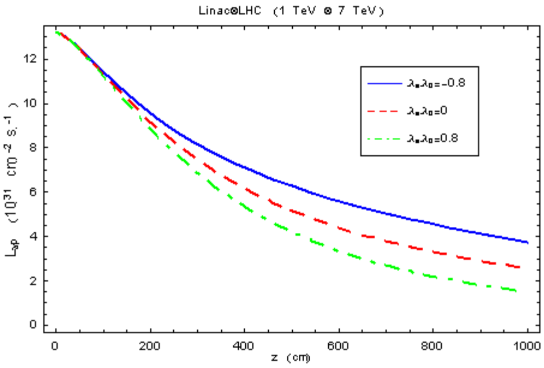

Figure 1. The dependence of luminosity on the distance z for γp collider.

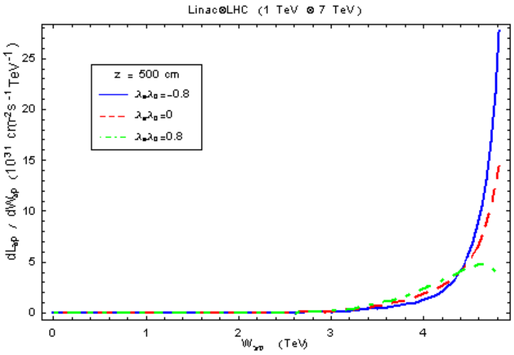

Figure 2. Luminosity distribution as a function of γp invariant mass at z=5m for choice of three different electron polarization.

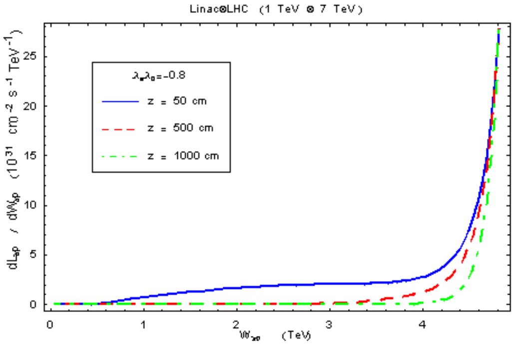

Figure 3. Luminosity distribution as a function of γp invariant mass for three different z values.

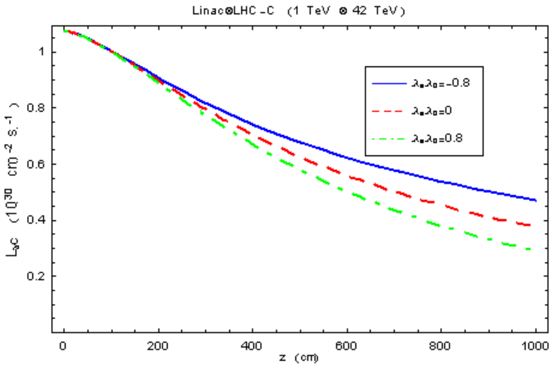

Figure 4. The dependence of luminosity on the distance for γC collider.

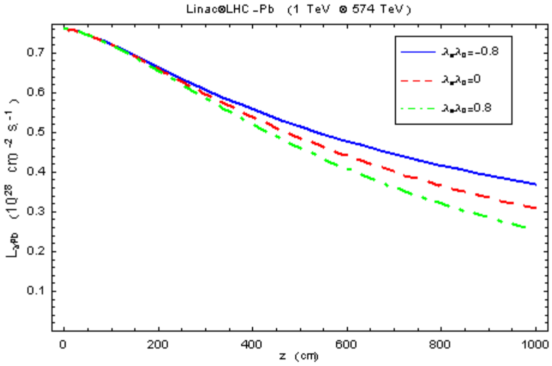

Figure 5. The dependence of luminosity on the distance z for γPb collider.