

## FUTURE LEPTON HADRON COLLIDERS

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### ABSTRACT

Main parameters of future lepton-hadron colliders are estimated. Namely, THERA and Linac\*LHC based  $ep$ ,  $\gamma p$ ,  $eA$ ,  $\gamma A$  and FEL $\gamma A$  colliders are considered. The physics search potential of these machines are considered.

### 1 Introduction

It is known that lepton-hadron collisions have been playing a crucial role in exploration of deep inside of matter. Today, THERA (TESLA on HERA) and Linac\*LHC can be considered as realistic candidates for future lepton-hadron and photon hadron colliders. We discuss the main parameters and physics search potential of the lepton-hadron colliders and draw the attention of the high energy and nuclear physics communities to future  $ep$ ,  $eA$ ,  $\gamma p$ ,  $\gamma A$  and FEL  $\gamma A$  collider facilities.

### 2 TESLA\*HERA Based Lepton-Hadron Colliders

It is known that the TESLA Collider will be a powerful tool for exploration of the multi-hundred GeV scale [1]. Taking into account the possible polarized proton and nucleus options for HERA will provide a number of additional opportunities to investigate lepton-hadron and photon hadron interactions at TeV scale. Recently, the

work on TESLA TDR has been finished, and TESLA $\otimes$ HERA based  $ep, \gamma p, eA$  and  $\gamma A$  colliders are included into TESLA project. Main parameters of TESLA $\otimes$ HERA based  $ep$  collider are given in [2]. It is seen that one has  $L_{ep} = 4.1 \cdot 10^{30} \text{ cm}^{-2}\text{s}^{-1}$  with  $E_e = 250 \text{ GeV}$  and  $E_p = 1 \text{ TeV}$ . Also two additional versions ( $E_e = E_p = 500 \text{ GeV}$  with  $L_{ep} = 2.5 \cdot 10^{31} \text{ cm}^{-2}\text{s}^{-1}$  and  $E_e = E_p = 800 \text{ GeV}$  with  $L_{ep} = 1.6 \cdot 10^{31} \text{ cm}^{-2}\text{s}^{-1}$ ) have been mentioned in TESLA TDR. In principle, TESLA $\otimes$  HERA based  $ep$  collider will extend the HERA kinematics region by an order in both  $Q^2$  and  $x$  and, therefore, the parton saturation regime can be achieved. Main parameters and physics search potential of THERA based  $\gamma p$  collider are given in [3, 4]. Main limitations for  $eA$  option comes from fast emittance growth of nucleus beam due to intra-beam scattering. In our opinion  $\gamma A$  option is the most promising option of TESLA $\otimes$ HERA complex, because it will give unique opportunity to investigate small  $x_g$  region in nuclear medium. Colliding of TESLA FEL beam with nucleus bunches from HERA may give a unique possibility to investigate "old" nuclear phenomena in rather unusual conditions. The main idea is very simple [5]: ultra-relativistic ions will see laser photons with energy  $\omega_o$  as a beam of photons with energy  $2\gamma_A\omega_o$ , where  $\gamma_A$  is the Lorentz factor of the ion beam. The region  $0.1\div 10 \text{ MeV}$ , which is matter of interest for nuclear spectroscopy, corresponds to  $0.1\div 10 \text{ keV}$  lasers, which coincide with the energy region of TESLA FEL.

### 3 Linac\*LHC Based Lepton-Hadron Colliders

The center-of-mass energies which will be achieved at different options of this machine [6] are an order larger than those at HERA are and  $\sim 3$  times larger than the energy region of TESLA $\otimes$ HERA. Center-of-mass energy and luminosity for this option are  $\sqrt{s} = 5.29 \text{ TeV}$  and  $L_{ep} = 8 \cdot 10^{31} \text{ cm}^{-2}\text{s}^{-1}$ . 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 standard model and new physics research. Using  $\gamma p$  option of this collider thousands di-jets with  $p_t > 500 \text{ GeV}$  and hundreds thousands single W bosons will be produced, hundred millions of  $\bar{b}b$ - and  $\bar{c}c$ - pairs will give opportunity to explore the region of extremely small  $x_g$  etc. Details on main parameters and physics search potential of Linac\*LHC based  $eA, \gamma A$  and FEL  $\gamma A$  colliders can be found in [4, 6]. The CLIC, an electron-positron collider with  $\sqrt{s} = 3 \text{ TeV}$  and  $L_{ee} = 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ , is considered as one of the future options for post-LHC era at CERN. The work on CLIC\*LHC based  $ep, \gamma p, eA, \gamma A$  and FEL  $\gamma A$  options is under progress.

## 4 Conclusions

It seems that neither HERA nor LHC $\otimes$ LEP will be the end points for lepton-hadron colliders. We see that TeV scale linac-ring type  $ep$  machines will give an opportunity to go far in this direction (see Table 1). In addition, more knowledge on the subject can be found in [7].

Table 1: *Future lepton-hadron colliders: a) First stage (2010-2015).*

	TESLA $\otimes$ HERA	LEP $\otimes$ LHC	e $\otimes$ RHIC
$\sqrt{s}$ , TeV	1.0 $\rightarrow$ 1.6	1.37	0.1
$E_l$ , TeV	0.25 $\rightarrow$ 0.8	0.0673	0.01
$E_p$ , TeV	1	7	0.25
$L$ , $10^{31} \text{ cm}^{-2} \text{ s}^{-1}$	1-10	12	46
Additional options	$eA, \gamma p, \gamma A, FEL\gamma A$	$eA$	$eA, FEL\gamma A$

b) *Second stage (2015-2020).*

	Linac $\otimes$ LHC	CLIC based
$\sqrt{s}$ , TeV	5.29	3
$E_l$ , TeV	1	1.5
$E_p$ , TeV	7	1.5
$L$ , $10^{31} \text{ cm}^{-2} \text{ s}^{-1}$	10-100	10
Additional options	$eA, \gamma p, \gamma A, FEL\gamma A$	$eA, \gamma p, \gamma A, FEL\gamma A$

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## References

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