Tr. J. of Physics
22 (1988) , 681 – 684.

Main Parameters of Linac- Ring Type e-Nucleus and γ- Nucleus Colliders

Ş. TÜRKÖZ
Department of Physic Faculty of Science
Ankara University
06100 Tandoğan, Ankara - TURKEY

Abstract

The main parameters of linac-ring type e-nucleus and γ-nucleus colliders are considered. It is shown that the reasonable luminosities at the multi-TeV energies can be achieved.

1. Introduction

The proposed linac-ring type *ep* and γp colliders as the fourth way to investigate TeV scale physics [1],[2] could be used, with some modification, as e-nucleus and $\gamma-$nucleus collider to investigate the properties of nuclei at TeV scale regime. Since LHC will give opportunity to accelerate nuclei also, the construction of e^+e^- collider or a special e-linac at CERN will allow researches on $e-$nucleus and $\gamma-$nucleus collisions at multi-TeV scale. Therefore, we estimate basic parameters for such machines with the example of a chosen nucleus (namely lead nucleus). When it comes to electron beam, it is considered to be produced by TESLA, CLIC, and special Linac. Similar considerations can be done for HERA at DESY with TESLA. At first, we look at the parameters of *e-Pb* colliders. After that, the parameters of γ-*Pb* colliders are estimated.

2. Parameters of e-Pb Colliders

With respect to physicist there are two important parameters for a collider: the center of mass energy and the luminosity. The first one, the center of mass energy $\sqrt{s}$, can be easily obtained from the parameters of Pb and $e-$ beams given in Table 1 :$\sqrt{s} = 67$ TeV for LHC+CLIC, $\sqrt{s} = 48$ TeV for LHC+TESLA, $\sqrt{s} = 26$ TeV for LHC+LINAC.

These values for $\sqrt{s}$ are very high in comparision to the present values that can be reached by other type colliders.

The luminosity of *e-Pb* collisions is given by the following expresion,

Table 1. Main parameters of lead and electron beams

PARAMETERS	Pb (LHC)	CLIC	TESLA	e-Linac
Max. beam energy (TeV)	574	2	1	0.3
Particles per bunch, n (10^{10})	0.009	0.6	5.15	0.08
Bunches per ring, k_p	608	-	-	-
Repition frequency, $f_{rep}(HZ)$	-	1700	10	5×10^5
Bunches per puls train, k_e	-	4	800	1
Horizantal beam size, σ_x	15 μm	90 nm	640 nm	1 μm
Vertical beam size, σ_y	15 μm	8 nm	100 nm	1 μm
Bunch length, σ_z	7.5 cm	170 μm	1000 μm	1000 μm

$$\mathcal{L}_{e-Pb} = n_e f_e \frac{n_{Pb}}{s_{eff}} \tag{1}$$

where $f_e = f_{rep}k_e$ and s_{eff} is the larger of s_{Pb} and s_e. At first sight, s_e is very smaller than s_{Pb} (See Table 1). However, the multiple use of Pb bunches requires the stability of them after collisions with electron bunches. The stability condition is given by

$$\frac{n_e}{s_e} = \frac{7\times10^{18}}{Z_{Pb}}\frac{E_{Pb}}{TeV}\frac{cm}{\beta_{Pb}}\Delta Q_{Pb}\frac{1}{cm^2} \tag{2}$$

where n_e is the number of electrons in a bunch. The transverse area, s_e, is equal to $4\pi\sigma_x\sigma_y$, where σ_x and σ_y are horizontal and vertical sizes of the electron bunch at the collision point. E_{Pb}, β_{Pb} and ΔQ_{Pb} are the energy, the amplitude function at the intersection point and the tune shift of the lead beam, respectively. Z_{Pb}=82 is the electric charge of the lead nucleus. Usually the restriction $\Delta Q \leq 0.003$ holds for hadron colliders. In our case admitted values for ΔQ_{Pb} may be larger because lead bunches make only one collision per revolution. In Table 2 the lower limits for s_e are given for proposals under consideration by choosing ΔQ_{Pb} to be equal to 0.003, 0.01 and 0.03. Also, we consider two values of β_{Pb}, namely $\beta_{Pb} = 0.5$m (as in the case of LHC *Pb*-*Pb* collider) and $\beta_{Pb} = 0.1$m. The second value is permitable because it satisfies restriction $\beta_{Pb} > \sigma_z$=7.5 cm. One must compare the values of $(s_e)_{min}$ from Table 2 with $s_{Pb} = 30.7\times10^{-6}$cm^2 for $\beta_{Pb} = 0.5$m and $s_{Pb} = 6.1\times10^{-6}$cm^2 for $\beta_{Pb} = 0.1$m and substitute the larger ones into Eq. (1) in order to obtain the corresponding luminosities of e-Pb colliders, which are given in Table 3.

It is necessary to the collisions that the bunch spacings of the electron and *Pb*-beam must be adjusted to be commensurate with each other. Further increase in luminosity values can, in principle, be achieved by increasing n_{Pb} or decreasing the emittance of the lead beam but one must be careful with space charge effects.

Table 2. Values of (s_{min}) in $10^{-6}cm^2$

ΔQ_{Pb}	0.003		0.03		0.01	
$\beta_{Pb}(m)$	0.5	0.1	0.5	0.1	0.5	0.1
CLIC	2	0.4	0.20	0.04	0.6	0.12
TESLA	18	3.6	1.80	0.36	5.4	1.08
e-Linac	0.28	0.056	0.028	0.0056	0.072	0.014

Table 3. Luminosities of e-Pb coll. in $10^{28}cm^{-2}s^{-1}$

	LHC+CLIC		LHC+TESLA		LHC+Linac	
$\beta_{Pb}(m)$	0.5	0.1	0.5	0.1	0.5	0.1
$\mathcal{L}$	0.013	0.065	0.132	0.66	0.128	0.64

3. Parameters of γ-Pb Colliders

By inverse scattering of laser photons from the electron beam, one can transform electron bunches into the bunches of high energy real γ's and then collide them with lead bunches from LHC. The parameters of γ beam as well as the discussion of a number of nontrivial design problems can be found in Ref.[3]. The energy of converted photons, E_γ, is restricted by the condition $y_{max} = 0.83$ (where $y = E_\gamma/E_e$) to avoid the decrease in the number of converted photons due to the background effects in the conversion region. Therefore,the following maximal values of the center of mass energy are obtained: $\sqrt{s} = 61$ TeV for LHC+CLIC, $\sqrt{s} = 44$ TeV for LHC+TESLA, $\sqrt{s} = 24$ TeV for LHC+LINAC.

The stability condition (2) does not take place for γ-nucleus colliders, therefore luminosity is given by

$$\mathcal{L}_{\gamma-Pb} = 2n_e f_e \frac{n_{Pb}}{s_{Pb}} \tag{3}$$

where we suppose that $n_\gamma = n_e$ (one-to-one $e \to \gamma$ conversion) and factor 2 reflects that s_γ is much smaller than s_{Pb}. The results for proposals under consideration are given in Table 4.

Table 4. Luminosities of gamma-Pb coll. in $10^{28}cm^{-2}s^{-1}$ and luminosities per collision $10^{23}cm^{-2}$

	LHC+CLIC		LHC+TESLA		LHC+Linac	
$\beta_{Pb}(m)$	0.5	0.1	0.5	0.1	0.5	0.1
$\mathcal{L}$	0.026	0.13	0.26	1.32	0.26	1.28
$\mathcal{L}/coll.$	0.2	1.0	1.6	8.0	0.025	0.125

We also present the values of luminosities per collision. Multiplying these values by $4 \times 10^{-26} cm^2$ (exterpolated total cross section of γ-Pb collision) one obtains the number of events per collision. We see that this number is less than one for all proposals.

4. Conclusion

The above calculations indicate that the center of mass energy and luminosity parameters are reasonable for a physics research program. The two order of magnitude drop in the luminosity in compared to conventional colliders are compensated by the same amount of increase in the cross section. As for the physics program that can be persued by such a colliders, first of all we can do particle physics in a nuclear medium. We can study the creation and propagation of exotic particles in nuclear enviroment. Quark clusters, nucleon correlations, gluon distribution at small x_g, etc. can be investigated. The hadronic component of the photon can be investigated in nuclear enviroment specially, $\rho-$ component of the photon as predicted by Vector Dominance Model (VDM) allows us to use γ-nucleus collider as ρ-nucleus collider.(Ref.[4]).

References

[1] S. Sultansoy, "Four Ways to TeV-Scale", This proceedings.

[2] A. K. Ciftci, This proceedings.

[3] A.K. Çiftçi, S. Sultansoy, Ş. Türköz and Ö. Yavaş, *Nucl. Instr. and Meth.* **A 365** (1995) 317.

[4] Z. Z. Aydin et. al., Proceedings of 28th ICHEP, Edits. Z. Ajduk, A. K. Wroblewski, Warsaw, Poland, 23-31 july 1996, p.1752.