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Gamma Options of the TESLA*HERA Complex

S. Sultansoy

Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany
Department of Physics, Faculty of Sciences, Ankara University, Turkey
Institute of Physics, Academy of Sciences, Baku, Azerbaijan

In addition to the TESLA based $\gamma\gamma$ and γe colliders:

1. γp collider

A.K. Ciftci et al., Nucl. Instrum. Meth. A365 (1995) 317

2. γA collider

R. Brinkmann et al., DESY 97-239 (1997)

3. FEL γA collider

H. Aktas et al., Nucl. Instrum. Meth. A428 (1999) 271

4. Fixed target

S. Alekhin et al., Eur. Phys. J. C11 (1999) 301

See also:

1) Proceedings of the First Int. Workshop on Linac-Ring Type ep and γp Colliders (9-11 April 1997, Ankara, Turkey), published in Turkish J. Phys. 22 (1998) 525-775.
2) S. Sultansoy, Turkish J. Phys. 22 (1998) 575.

Linac-on-Ring Colliders: two directions

First paper on linac-on-ring colliders:

P.L. Csonka and J. Rees, NIM 96 (1971) 149

First direction: high energy lepton-hadron and photon-hadron colliders

Today, linac-ring type $e-p$ machines seem to be the main way to TeV scale in lepton-hadron collisions:
M. Tigner, B. Wiik and F. Willeke, Proc. of the 1991 IEEE Particle Accelerators Conference (6-9 May 1991, San Francisco, California), Vol. 5, p. 2910;

however, it is possible that in future $\mu-p$ machines can be added (depending on solution of principal issues of basic $\mu^+\mu^-$ colliders):
I.F. Ginzburg, Turkish J. Phys. 22 (1998) 607.

Recent review:
S. Sultansoy, preprint DESY 99-159, AU-HEP-99/02 (1999)

Options:
γp colliders (first estimations in S. Sultanov, ICTP preprint IC/89/409),
eA and γA colliders.

Second direction: high luminosity particle factories

Linac-ring type $e^- - e^+$ colliders were proposed as $\varphi-$, $c-\tau-$, $B-$ and $Z-$ factories with $L \geq 10^{34} cm^{-2} s^{-1}$

TESLA$\otimes$HERA Complex

HERA: ep luminosity upgrade
eA option
polarised proton beam

TESLA: e^+e^- with $\sqrt{s} = 0.5(\rightarrow 0.8)$ TeV
$\gamma\gamma$ with $\sqrt{s} \approx 0.4(\rightarrow 0.64)$ TeV
γe with $\sqrt{s} \approx 0.45(\rightarrow 0.72)$ TeV
e^-e^- with $\sqrt{s} = 0.5(\rightarrow 0.8)$ TeV

TESLA$\otimes$HERA: ep with $\sqrt{s} \approx 1.05(\rightarrow 1.79)$ TeV
γp with $\sqrt{s} \approx 0.95(\rightarrow 1.63)$ TeV
eA option
γA option
FEL γA option

cp.: LEP$\otimes$LHC: ep with $\sqrt{s} \approx 1.37$ TeV
eA option

Beams

E_p = 820 GeV → 920 GeV → 1 TeV; $E_A = Z \times E_p$

E_e = 250 GeV → 500 GeV → 0.8 TeV

E_γ ≈ 200 GeV → 400 GeV → 0.65 TeV

FEL γ: $\omega_0 = 0.1 \div 10$ keV
$\omega_{eff} = 0.1 \div 10$ MeV in the nucleus rest frame

TESLA*HERA vs LEP*LHC

ep options	HERA	TESLA*HERA	LEP*LHC
E_e [TeV]	0.0275	0.50 → 0.80	0.0673
E_p [TeV]	0.92	0.92 → 1.00	7.00
E_e / E_p	0.030	0.54 → 0.80	0.0096
$\sqrt{s_{ep}}$ [TeV]	0.318	1.35 → 1.78	1.37
L_{ep} [$10^{30} cm^{-2}s^{-1}$]	70	1<??<100	120

TESLA*HERA: better (?) kinematics
+ gamma options

LEP*LHC: higher luminosity

γp collider

useful formulas and design:
A.K. Ciftci et al., Nucl. Instrum. Meth. A365 (1995) 317

recent parameters: S. Sultansoy, DESY 99-159 (1999)

E_e=0.5 TeV ; $n_e=1.5\cdot10^{10}$; $n_\gamma=0.65\cdot n_e$;
n_b=4950 in pulse (bunch spacing 192 ns);
f=5 Hz (pulse frequency); $\sigma_e(=\sqrt{\sigma_x\sigma_y})$=52 nm

E_p=0.92 TeV ; $n_p=30\cdot10^{10}$; σ_p=6.25 μm ; β_p^*=5 cm
"dynamic focusing":
R. Brinkmann and M. Dohlus, DESY-M-95-11 (1995)

Fig. (15-16 from A.K. Ciftci et al.): General schematic view

Fig. 1: Luminosity dependence on the distance z between CR and IP for $\lambda(\omega_0)\lambda(e)= -0.9$, 0 and 0.9

Fig. 2: Mean helicity of the high energy photons as a function of z

Fig. 3: Luminosity distribution as a function of the γp invariant mass at z=10 m for $\lambda(\omega_0)\lambda(e)= -0.9$, 0 and 0.9

Fig. 4: Luminosity distribution as a function of the γp invariant mass for $\lambda(\omega_0)\lambda(e)= -0.9$ at z=0.5, 6 and 12 m

γA collider

Fig. 5: Luminosity dependence on the distance z between CR and IP for γC option.

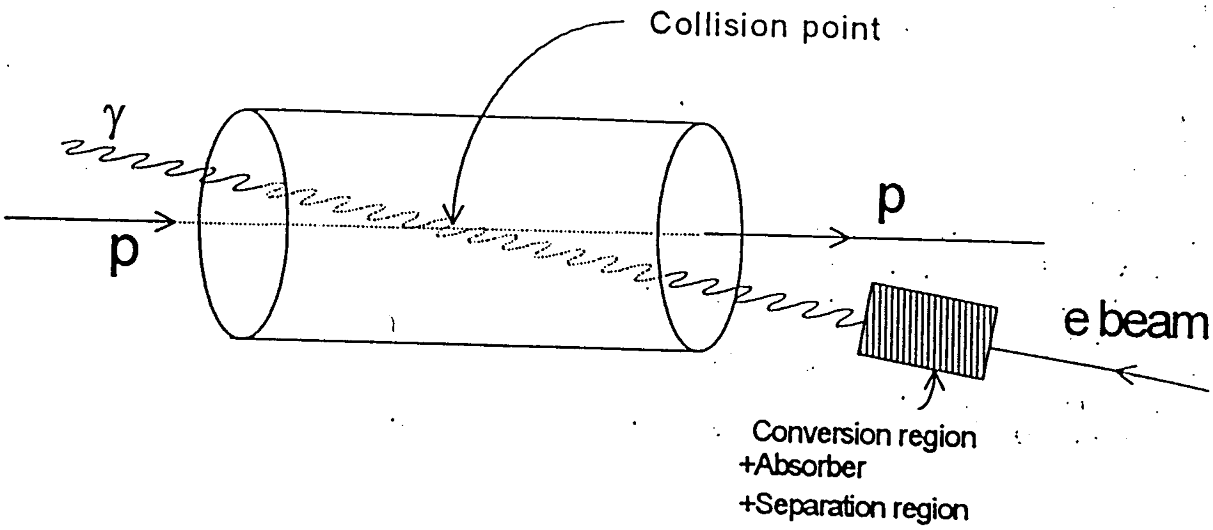


Fig. 15. General schematic view of the proposed design.

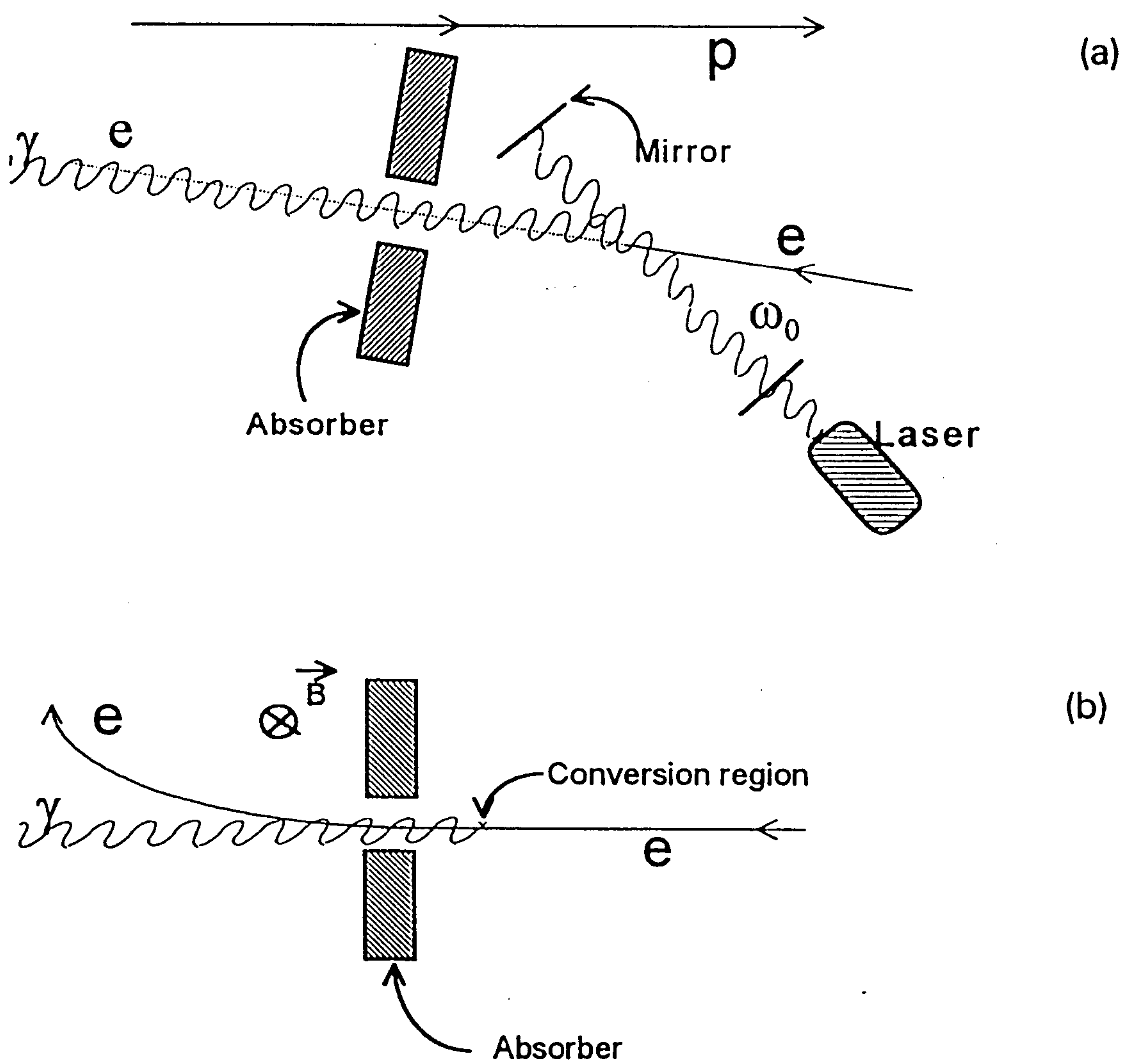
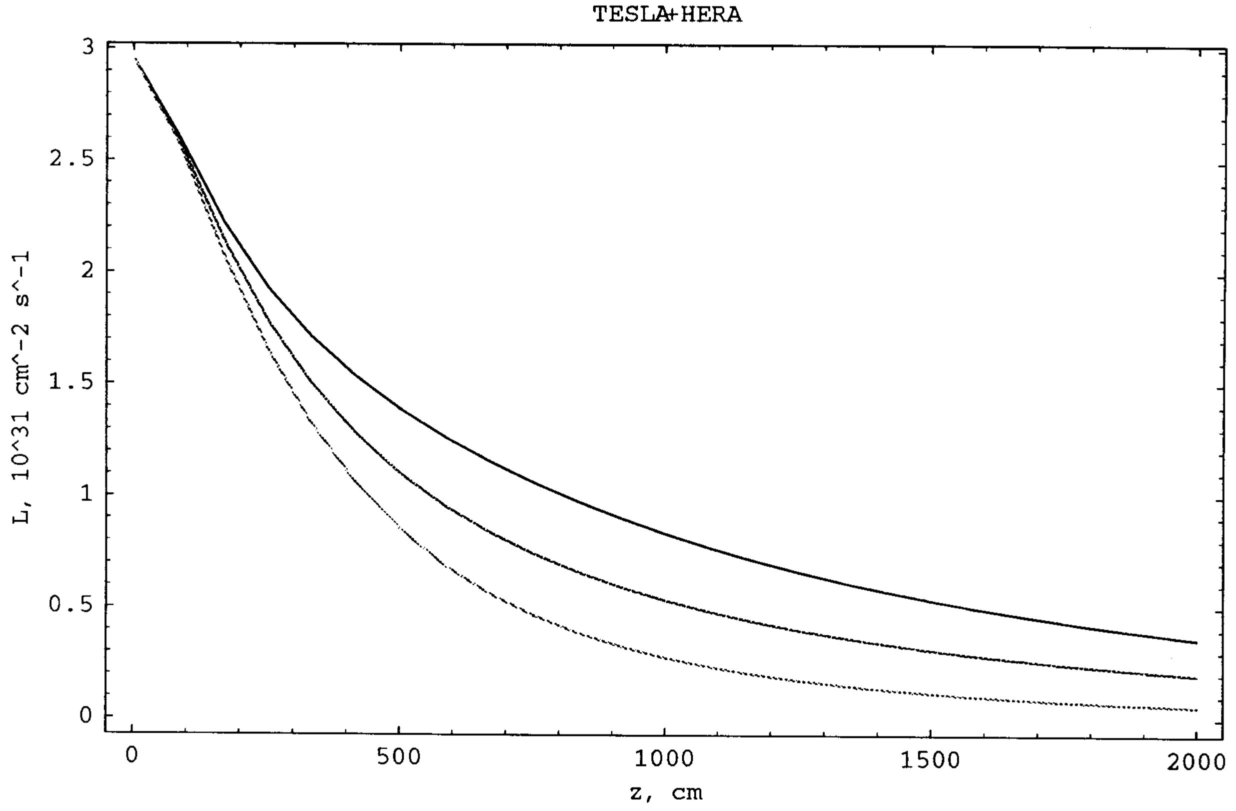
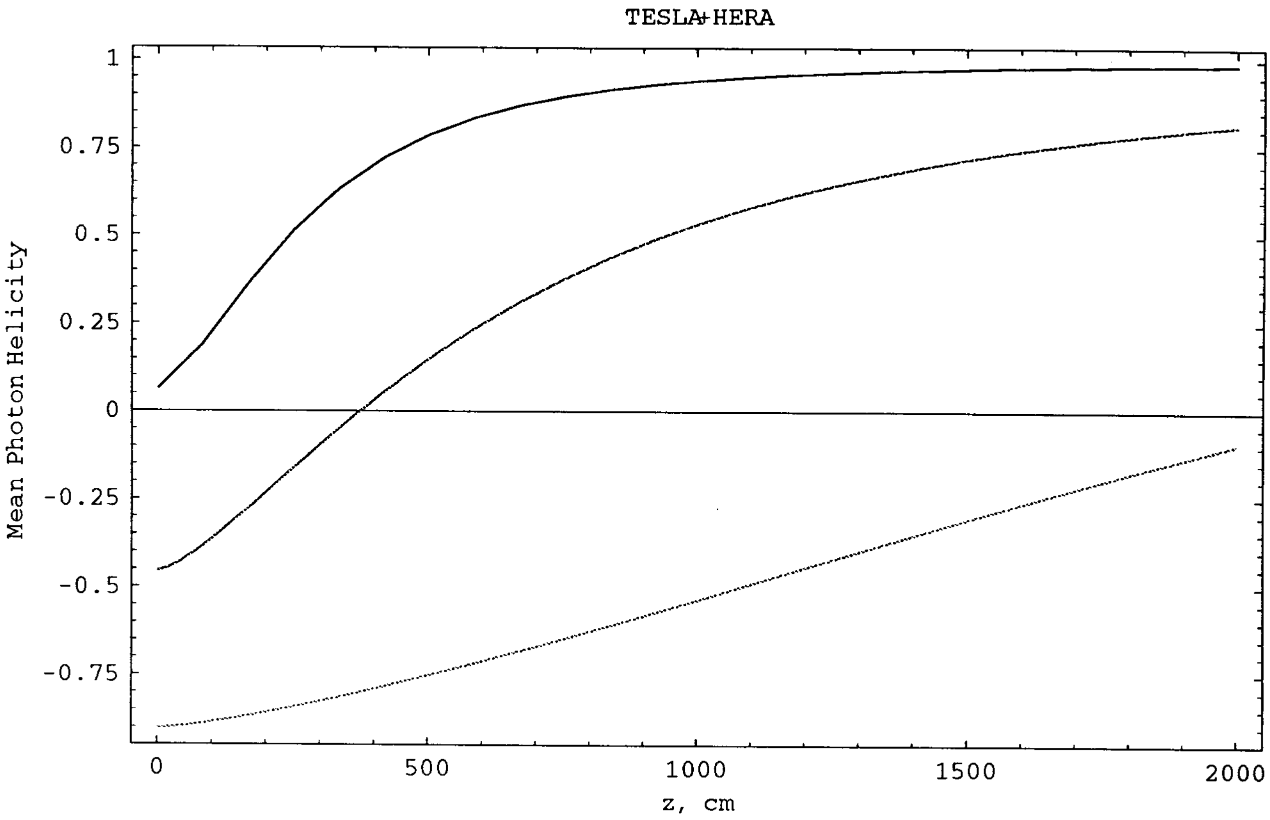
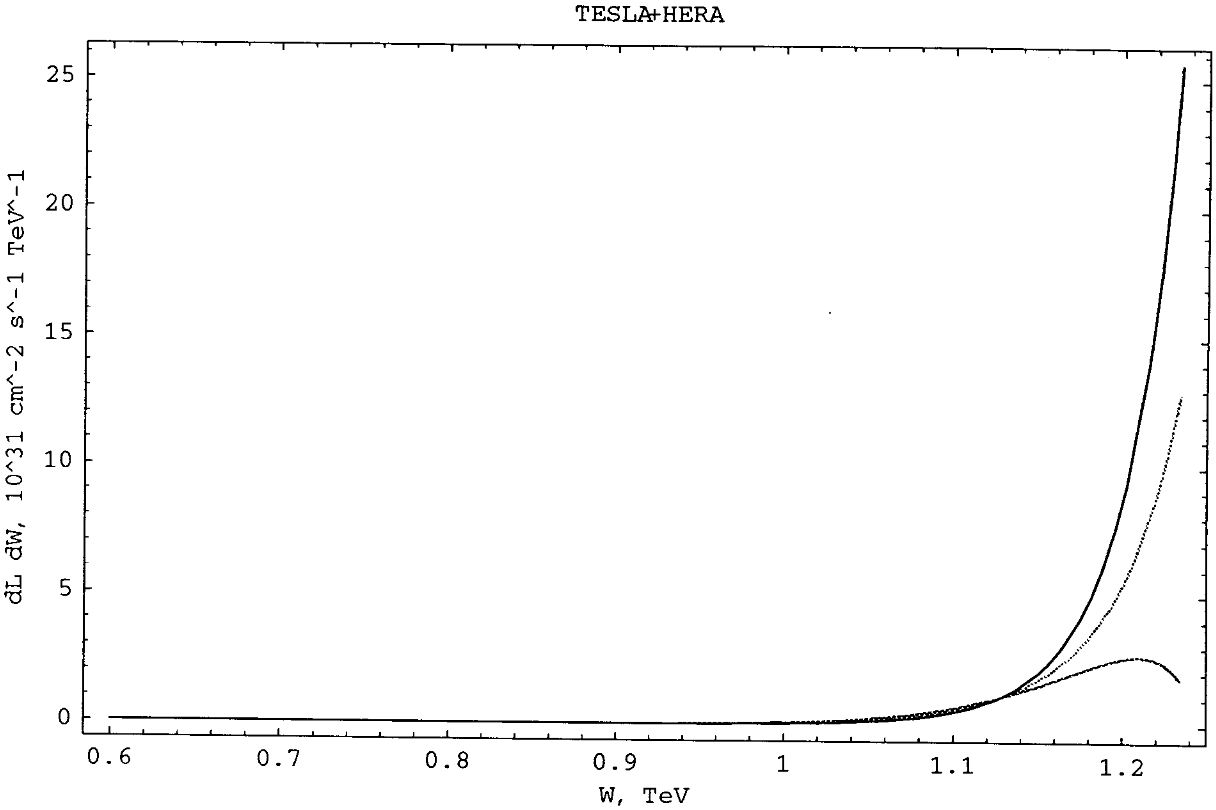
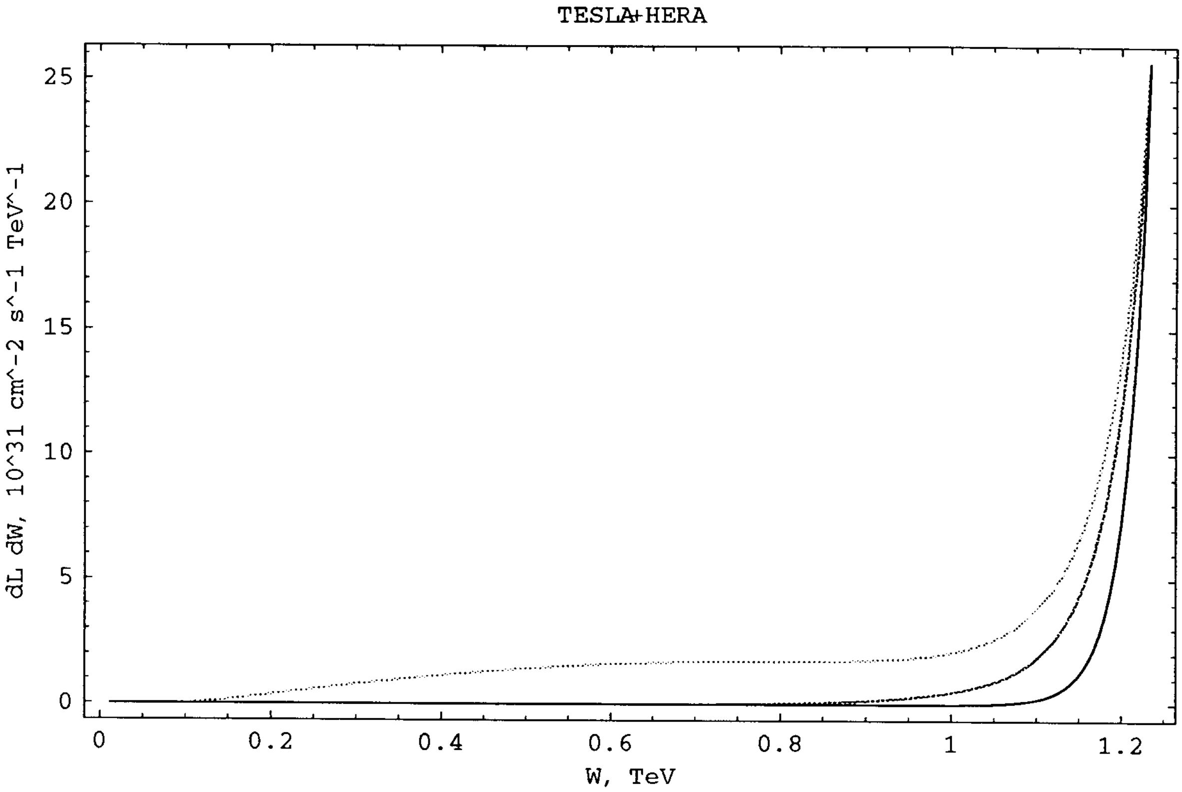


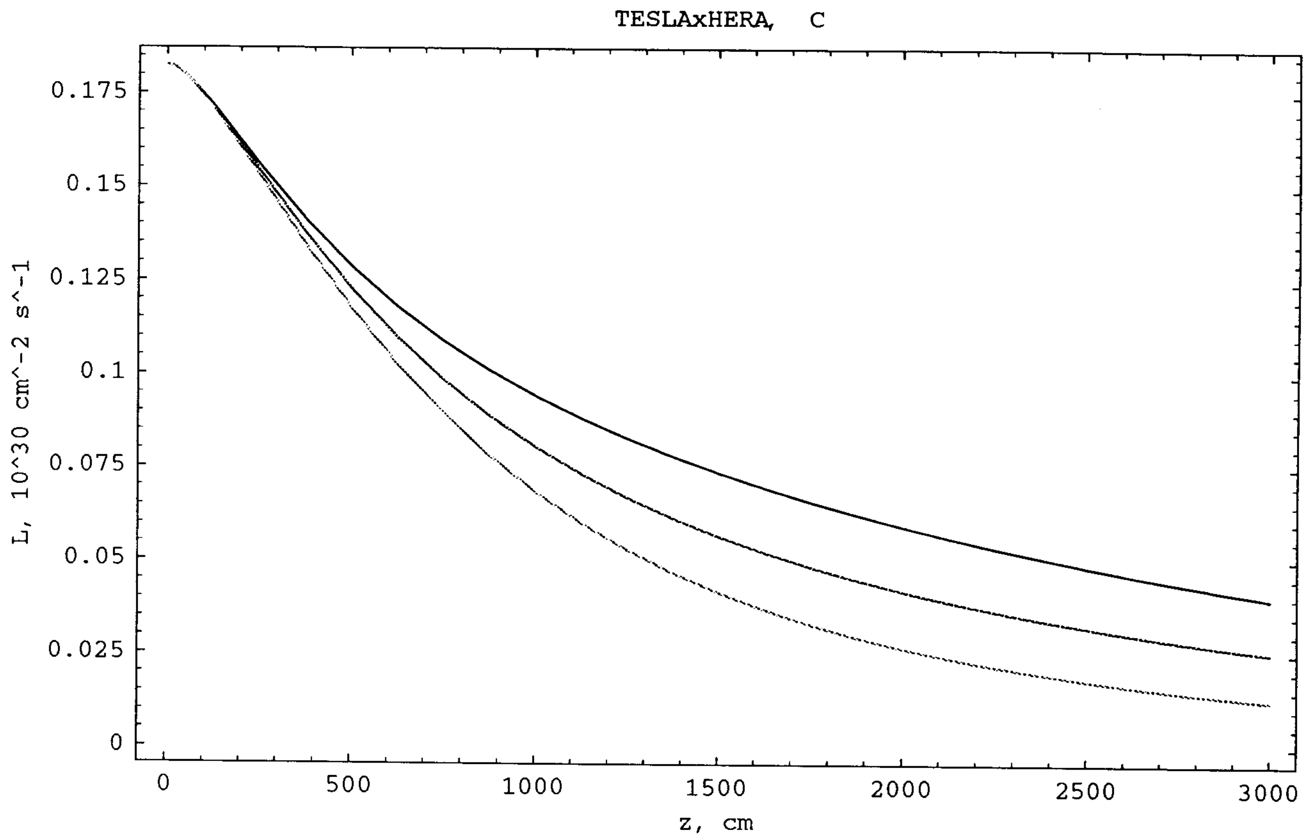
Fig. 16. Schematic view of the part of the design between the conversion region and the detector. (a) Horizontal plane, (b) vertical pla


TESLA+HERA
L, 10^31 cm^-2 s^-1
z, cm
0
0.5
1
1.5
2
2.5
3
0
500
1000
1500
2000


TESLA+HERA
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
Mean Photon Helicity
0
500
1000
1500
2000
z, cm


TESLA+HERA
dL dW, 10^31 cm^-2 s^-1 TeV^-1
25
20
15
10
5
0
0.6
0.7
0.8
0.9
1
1.1
1.2
W, TeV


TESLA+HERA
dL dW, 10^31 cm^-2 s^-1 TeV^-1
25
20
15
10
5
0
0
0.2
0.4
0.6
0.8
1
1.2
W, TeV


TESLAxHERA, C
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
L, 10^30 cm^-2 s^-1
0
500
1000
1500
2000
2500
3000
z, cm

Conclusion on machine parameters

$L_{ep,\gamma p} = (3-5)\cdot 10^{30} cm^{-2} s^{-1}$ can be achieved within (moderate) upgrade of HERA and TESLA parameters

→ $(1-2)\cdot 10^{31} cm^{-2} s^{-1}$ "dynamic" focusing scheme
→ $\approx 10^{32} cm^{-2} s^{-1}$ cooling in HERA ring

$L_{eA,\gamma A} \bullet A = (5-10)\cdot 10^{29} cm^{-2} s^{-1}$ can be achieved at least for light nuclei

→ $(1-3)\cdot 10^{30} cm^{-2} s^{-1}$ "dynamic" focusing scheme
→ $\approx 10^{31} cm^{-2} s^{-1}$ cooling in HERA ring

TESLA $\otimes$ HERA can be (and should be?) the first lepton-hadron (and photon-hadron) collider with $\sqrt{s} > 1$ TeV

More activity is needed both in:

accelerator (further exploration of "dynamic" focusing scheme, a search for effective cooling methods etc.)

and physics search program (especially γp and γA options)

aspects.

FEL $\gamma \otimes A$ Colliders

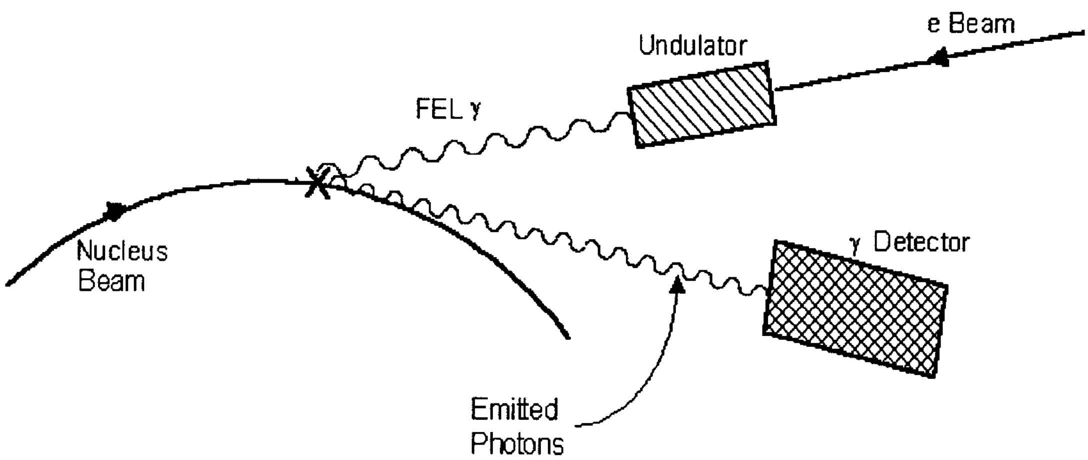


Fig.1: General schematic view of the proposed design

$\omega_0 \rightarrow E_\gamma = 2\gamma_A \omega_0$ in the rest frame of the nucleus

turn to the ground state at $l = \gamma_A \cdot \tau_A \cdot c$ from the CP

emitted photons will be seen in detector as high energy γ 's
$E_{\gamma,lab}^{\max} = 2\gamma_A E_\gamma$

TESLA FEL $\gamma \otimes A$ HERA

For HERA: $\gamma_A \approx 980 \cdot \frac{Z}{A}$

Therefore:

0.1-12 keV (TESLA FEL) $\rightarrow$ 0.1-10 MeV
Nucleus rest frame

$L_{\gamma C} = 5 \cdot 10^{31} cm^{-2} s^{-1}$

Example: 4438 keV excitation of ^{12}C

$J_{exc} = 2,\; J_0 = 0,\; \Gamma \approx 10^{-2} eV,\; B_{in} = B_{out} = 1$

ω_0 =4529 eV, l =4 mm, $\sigma^{res} = 6 \cdot 10^{-22} cm^2$,

$$\sigma^{av} \approx \sigma^{res} \cdot \frac{\Gamma}{\Delta E_\gamma} \approx 1.5 \cdot 10^{-27} cm^2$$

$6.5 \cdot 10^9$ **events per day**

Physics at γp (and γA) colliders

first paper:

S. Alekhin et al., Int. J. Mod. Phys. A 6 (1991) 23

review's:

Z. Aydin et al., Int J. Mod. Phys. A 11 (1996) 2019

R. Brinkmann et al., DESY 97-239 (1997)

S. Sultansoy, Turkish J. Phys. 22 (1998) 575
pp. 588-590 are presented

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for the

Proceedings of the First Int. Workshop on Linac-Ring Type ep and γp Colliders (9-11 April 1997, Ankara, Turkey), published in Turkish J. Phys. 22 (1998) 525-775

Contact Prof. S. Atag
e-mail: Satilmis.Atag@science.ankara.edu.tr

Table 1. Center of mass energies and kinematics of ep colliders

	$\sqrt{s_{ep}}$, TeV	E_c/E_p
HERA	0.3	1/30
LHC×LEP	1.2	1/120
HERA×TESLA	1(2.4)	1/4
LHC×TESLA	2.6(6.5)	1/5
VLHC×LSC	17(24)	1/6

The situation is illustrated by Table 1.

Let us remind that confirmation of recent results [59] from HERA will favor new *ep* machines. Physics search program of HERA×TESLA based *ep* collider is considered in [60].

5.2. Physics at γp Colliders

Below we illustrate physics search potential of future γp machines As samples we use HERA×TESLA(1 TeV×0.3 TeV) with $L_{\gamma p}^{int} = 500pb^{-1}$ and LHC×TESLA(7 TeV×1.5 TeV) with $L_{\gamma p}^{int} = 5fb^{-1}$.

5.2.1. SM Physics

• Total cross-section at TeV scale can be extrapolated from existing low energy data as $\sigma(\gamma p \to hadrons) \sim 100 - 200\mu b$, which corresponds to $\sim 10^{11}$ hadronic events per working year

- Two-jet events (large p_t)
  HERA×TESLA: 10^4 events with $p_t >$ 100 GeV
  LHC×TESLA: 10^4 events with $p_t >$ 500 GeV

- $t\bar{t}$ pair production
  HERA×TESLA: 10^3 events per year
  LHC×TESLA: 10^5 events per year

- $b\bar{b}(c\bar{c})$ pair production
  HERA×TESLA: 10^8 events
  LHC×TESLA: 10^9 events

the region of extremely small $x_g \sim 10^{-6} - 10^{-7}$ can be investigated (phenomenon of inverse evolution of parton distributions)

- W production
  HERA×TESLA: 10^5 events
  LHC×TESLA: 10^6 events

$\Delta\kappa_W$ can be measured with accuracy of 0.01 (0.001 taking into account γ polarization?)

- Higgs boson production ($\gamma p \to WH + X$)
  HERA×TESLA: 20 events at $m_H = 100$ GeV
  LHC×TESLA: 1000 events at $m_H = 100$ GeV and 100 events at $m_H = 300$ GeV

- Fourth SM family quarks (discovery limits for 100 events per year)
  HERA×TESLA: $m_{u_4} = 250$ GeV, $m_{d_4} = 200$ GeV
  LHC×TESLA: $m_{u_4} = 1000$ GeV, $m_{d_4} = 800$ GeV

5.2.2. Beyond the SM Physics

Below we present discovery limits for 100 events per year:

- γp colliders are ideal machines for u^*, d^* and Z_8 search
  HERA×TESLA: $m_{u^*} = 0.9$ TeV, $m_{d^*} = 0.7$ TeV, $m_{Z_8} = 0.7$ TeV
  LHC×TESLA: $m_{u^*} = 5$ TeV, $m_{d^*} = 4$ TeV, $m_{Z_8} = 4$ TeV

- single l_q production
  HERA×TESLA: 0.7 TeV
  LHC×TESLA: 3 TeV

- pair l_q production
  HERA×TESLA: 0.3 TeV
  LHC×TESLA: 1.7 TeV

- SUSY should be realized at preonic level, however for MSSM particles we have (neglecting SUSY CKM mixings)

		HERA × TESLA	LHC × TESLA
	$m_{\widetilde{W}} = m_{\widetilde{d}}$	0.25 TeV	0.9 TeV
$\gamma p \to \widetilde{W}\widetilde{q} + X$	$m_{\widetilde{d}}\,(m_{\widetilde{W}} = 0.1$ TeV)	0.5 TeV	2 TeV
	$m_{\widetilde{W}}\,(m_{\widetilde{d}} = 0.1$ TeV)	0.3 TeV	1.2 TeV
	$m_{\widetilde{g}} = m_{\widetilde{q}}$	0.2 TeV	0.8 TeV
$\gamma p \to \widetilde{g}\widetilde{q} + X$	$m_{\widetilde{g}}\,(m_{\widetilde{q}} = 0.1$ TeV)	0.4 TeV	2 TeV
	$m_{\widetilde{q}}\,(m_{\widetilde{g}} = 0.1$ TeV)	0.3 TeV	1 TeV
	$m_{\widetilde{\gamma}} = m_{\widetilde{q}}$	0.15 TeV	0.2 TeV
$\gamma p \to \widetilde{\gamma}(\widetilde{Z})\widetilde{q} + X$	$m_{\widetilde{q}}\,(m_{\widetilde{\gamma}} = 0.1$ TeV)	0.2 TeV	0.4 TeV
	$m_{\widetilde{q}}\,(m_{\widetilde{Z}} = 0.1$ TeV)	0.17 TeV	0.3 TeV
$\gamma p \to \widetilde{q}^c\widetilde{q} + X$		0.25 TeV	0.8 TeV

5.3. Physics at γ-nucleus colliders

Center of mass energy of LHC×TESLA based γ-nucleus collider corresponds to $E_\gamma \sim$ PeV in the lab system. At this energy range cosmic ray experiments have a few events per year, whereas γ-nucleus collider will give few billions events. Very preliminary list of physics goals contains:

o total cross-sections to clarify real mechanism of very high energy γ-nucleus interactions

o investigation of hadronic structure of the photon in nuclear medium

o according to the VMD, proposed machine will be also ρ-nucleus collider

o formation of the quark-gluon plasma at very high temperatures but relatively low nuclear density

o gluon distribution at extremely small x_g in nuclear medium ($\gamma A \to Q\overline{Q} + X$)

o investigation of both heavy quark and nuclear medium properties ($\gamma A \to J/\Psi(\Upsilon) + X$, $J/\Psi(\Upsilon) \to l^+l^-$)

o existence of multi-quark clusters in nuclear medium and few-nucleon correlations.

6. Conclusion or Dreams for Next Century

There are strong arguments favoring that the rich spectrum of new particles and/or interactions will manifest themselves at TeV scale. An exploration of this scale at constituent