LHeC based γp & γA Colliders: Luminosity and Physics

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with A. Akay, H. Aksakal, A.K. Çiftçi, H. Karadeniz,
D. Schulte, G. Ünel and F. Zimmermann

- Introduction
- Energy Frontier
- QCD Explorer
- …

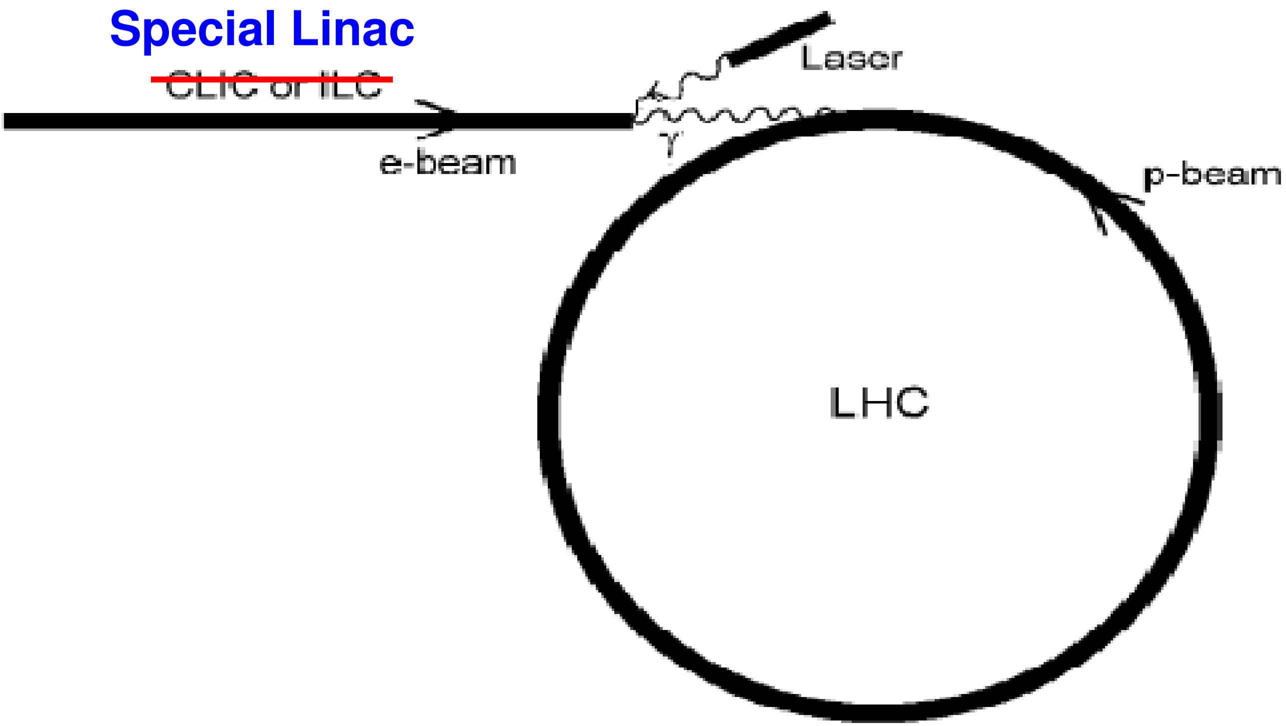


Fig. 1. Schematic of the proposed colliders.

Two kinds of New Physics

1. New Physics Beyond the SM (preons, SUSY and so on)

2. New Physics Within the SM structure [#]

Electroweak: massive neutrinos, fourth family (**LHC**)

Strong: small x_g etc (**LHeC/QCD Explorer**)

Hypothesis: QCD – Confinement
EW – Flavor Democracy

[#] In debris of the MSSM, SUGRA and so on, we forgot the SM itself. For example, MSSM-3 contains ~ 200 free parameters put by hand !!! (or **infinite** number of SUGRA points)

Two stages of the LHeC

1. QCD Explorer: $E_e = 50 – 100$ GeV

Mandatory

- PDF's for (s)LHC
- QCD basics

2. Energy Frontier: $E_e > 250$ GeV

Depends on LHC results

γ options: impossible at RR, not feasible with ERL

Few slides on Energy Frontier

from

Linac-Ring Type Colliders: Second Way to TeV Scale

(S. Sultansoy, EPS HEP 2003, Aachen)

Second Way to TeV Scale

Colliders	Hadron	Lepton	Lepton-Hadron
1990's	Tevatron	SLC/LEP	HERA
√s, TeV	2	0.1/0.1→0.2	0.3
L, 10^{31} cm^{-2} s^{-1}	1	0.1/1	1
2010's	LHC	"NLC"(TESLA)	"NLC"×LHC
√s, TeV	14	0.5→1.0(0.8)	3.7→5.3(4.7)
L, 10^{31} cm^{-2} s^{-1}	10^3	10^3	1-10
2020's	VLHC	CLIC	"CLIC"×VLHC
√s, TeV	200	3	34
L, 10^{31} cm^{-2} s^{-1}	10^3	10^3	10-100

Physics targets and achievable limits (following U. Amaldi in CERN 87-07, pp. 323-352)

“Comparing the physics potentialities of two* accelerators is a formidable task for at least three obvious reasons:

i) the unknown cannot be predicted;

ii) even after having agreed on a list of ‘expected’ new phenomena, the relative importance is subjective;

iii) tomorrow’s discovery may completely modify the ‘relevance’ weights given to selected phenomena”

* LHC (including LEP*LHC option) and CLIC

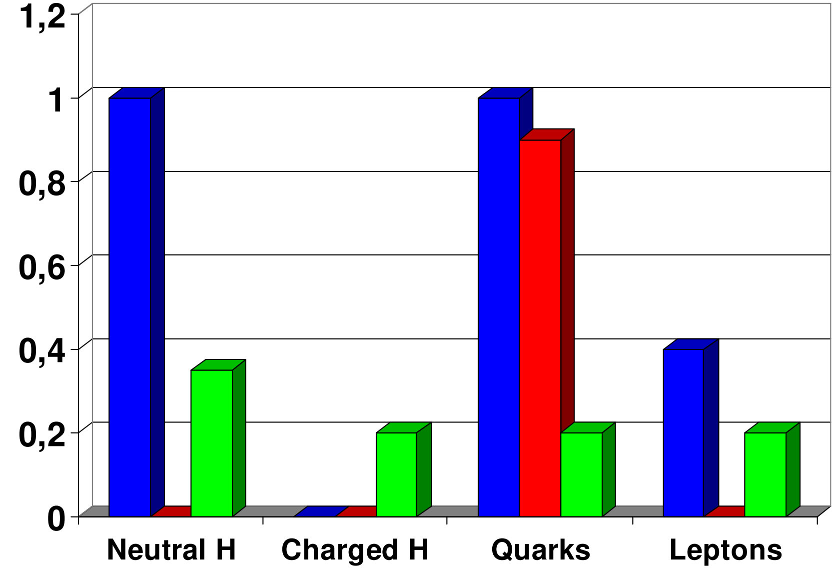
Summary of discovery limits for 12 different processes*

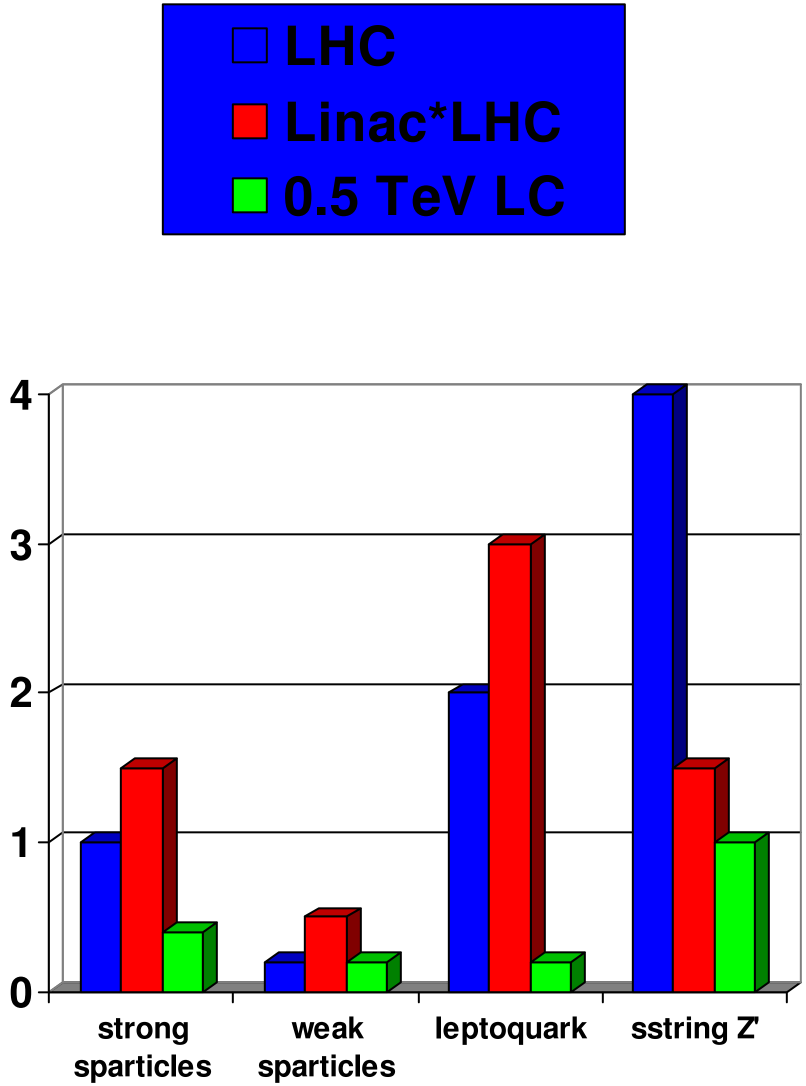
	1987	→	2003
pp	$\sqrt{s}$= 16 TeV, L= 10^{33} cm^{-2} s^{-1}	→	$\sqrt{s}$= 14 TeV, L= 10^{34} cm^{-2} s^{-1}
e^+e^-	$\sqrt{s}$= 2 TeV, L= (4) 10^{33} cm^{-2} s^{-1}	→	$\sqrt{s}$= 0.5 TeV, L= 10^{34} cm^{-2} s^{-1}
ep	$\sqrt{s}$= 1.5 TeV, L= 10^{32} cm^{-2} s^{-1}	→	$\sqrt{s}$= 3.7 TeV, L= 10^{32} cm^{-2} s^{-1} + γp option !!

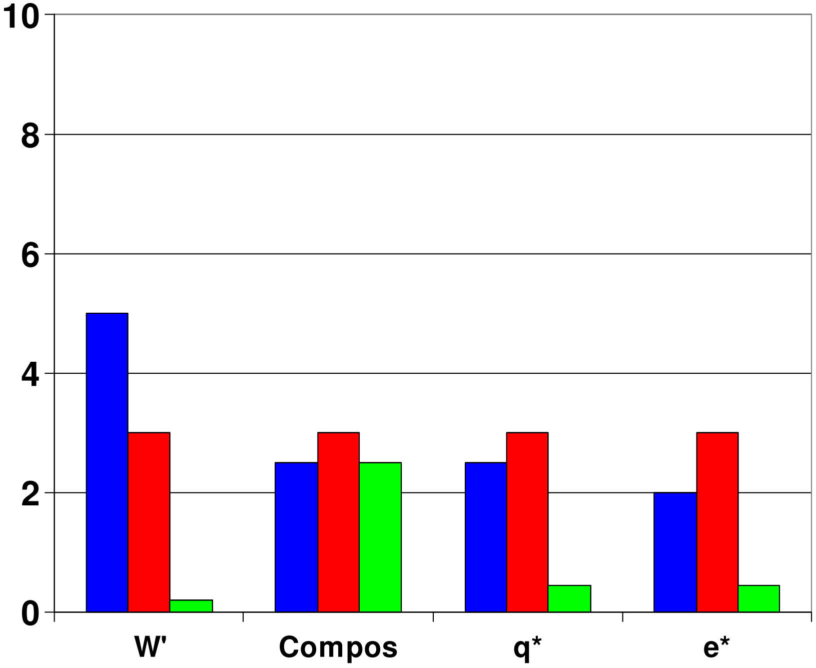
* Two principal additions during last years:

- extra dimensions (serious)
- infinite number of SUGRA points (curious)

Discovery limits in TeV (rescaled from U. Amaldi 87)







Let us turn to QCD Explorer stage

γ options require a lot of R&D (even more than ep options)

Therefore, we need strong physics motivation(s)

With $L_{\gamma p/\gamma A} = O(L_{ep/eA})$ **γ options are advantageous for a lot of processes …**

An Example: small x_g

The importance of small x_g region (at sufficiently high $Q^2 \sim 10$ GeV^2) exploration for strong interactions corresponds to the importance of the Higgs boson search for electro-weak interactions

	x_g	After detector cuts
1. Fixed Target	10^{-2}	-
2. HERA	10^{-4}	10^{-3}
3. e-RHIC	10^{-3}	?
4. THERA	10^{-5}	10^{-4}
5. QCD Explorer	10^{-5}	?
6. NLC*LHC	10^{-6}	?
7. CLIC*VLHC	10^{-7}	?

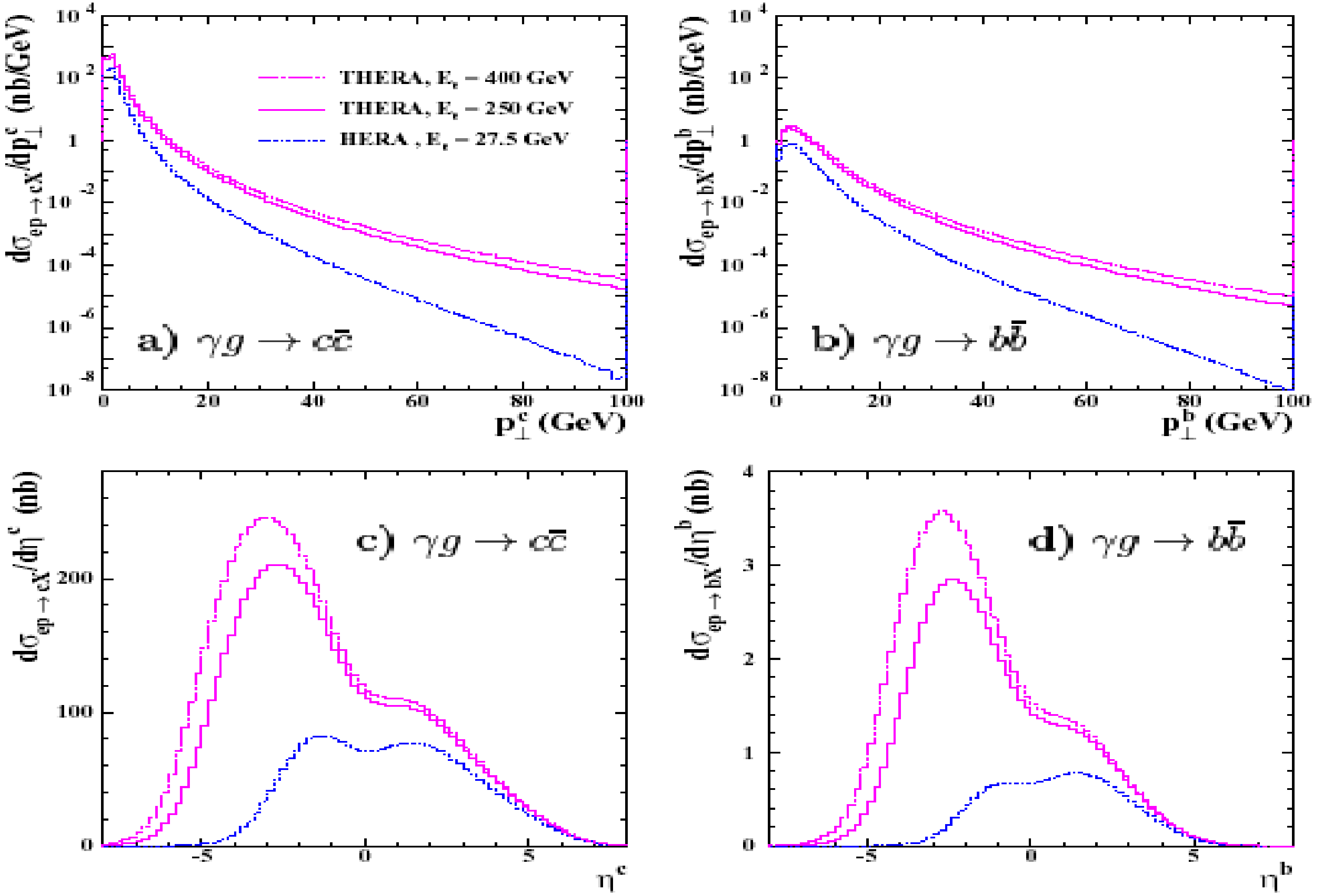


Figure 1: *The contribution of photon–gluon fusion to the differential cross sections $d\sigma/dp_\perp$ and $d\sigma/d\eta$ for charm ((a) and (c)) and beauty ((b) and (d)) production calculated in NLO QCD for $Q^2 < 1$ GeV^2. The solid and dashed magenta curves show the predictions for THERA operation with an electron energy of 250 GeV and 400 GeV, respectively, and $E_p = 920$ GeV. The predictions for the HERA case are indicated by the dash-dotted blue curves.*

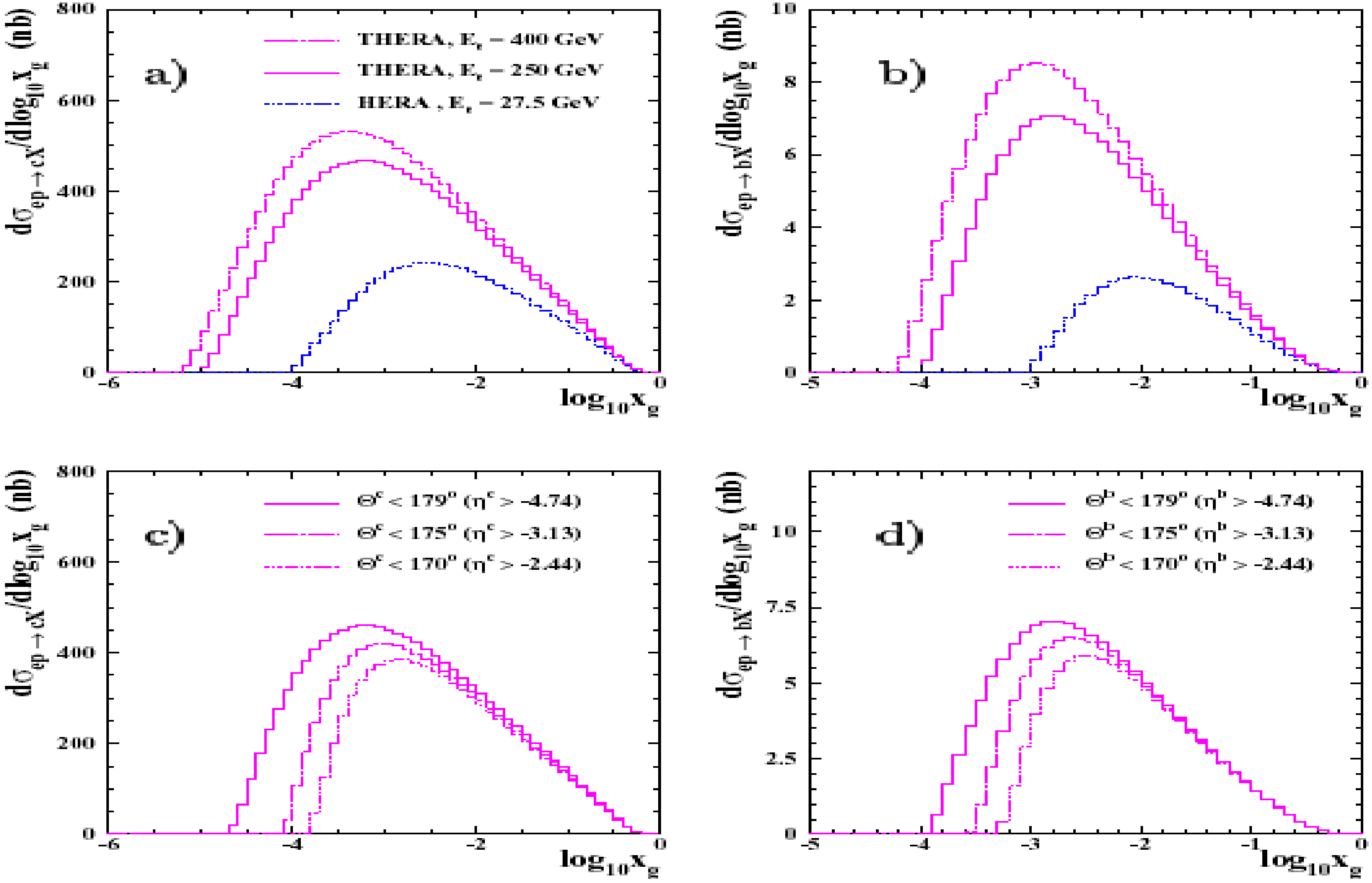


Figure 2: *The differential cross sections $d\sigma/d\log_{10}x_g$ for charm ((a) and (c)) and beauty ((b) and (d)) produced in the process of photon–gluon fusion. The cross sections were calculated within NLO QCD for $Q^2 < 1\,GeV^2$. In (a) and (b), the solid and dashed magenta curves show the predictions for THERA operation with an electron energy of 250 GeV and 400 GeV, respectively, and $E_p = 920\,GeV$. The predictions for the HERA case are indicated by the dash-dotted blue curves. In (c) and (d), the predictions for THERA with $E_e = 250\,GeV$ are shown with additional cuts $\theta^{c,b} < 179°$ (solid curves), $\theta^{c,b} < 175°$ (dashed curves) and $\theta^{c,b} < 170°$ (dash-dotted curves).*

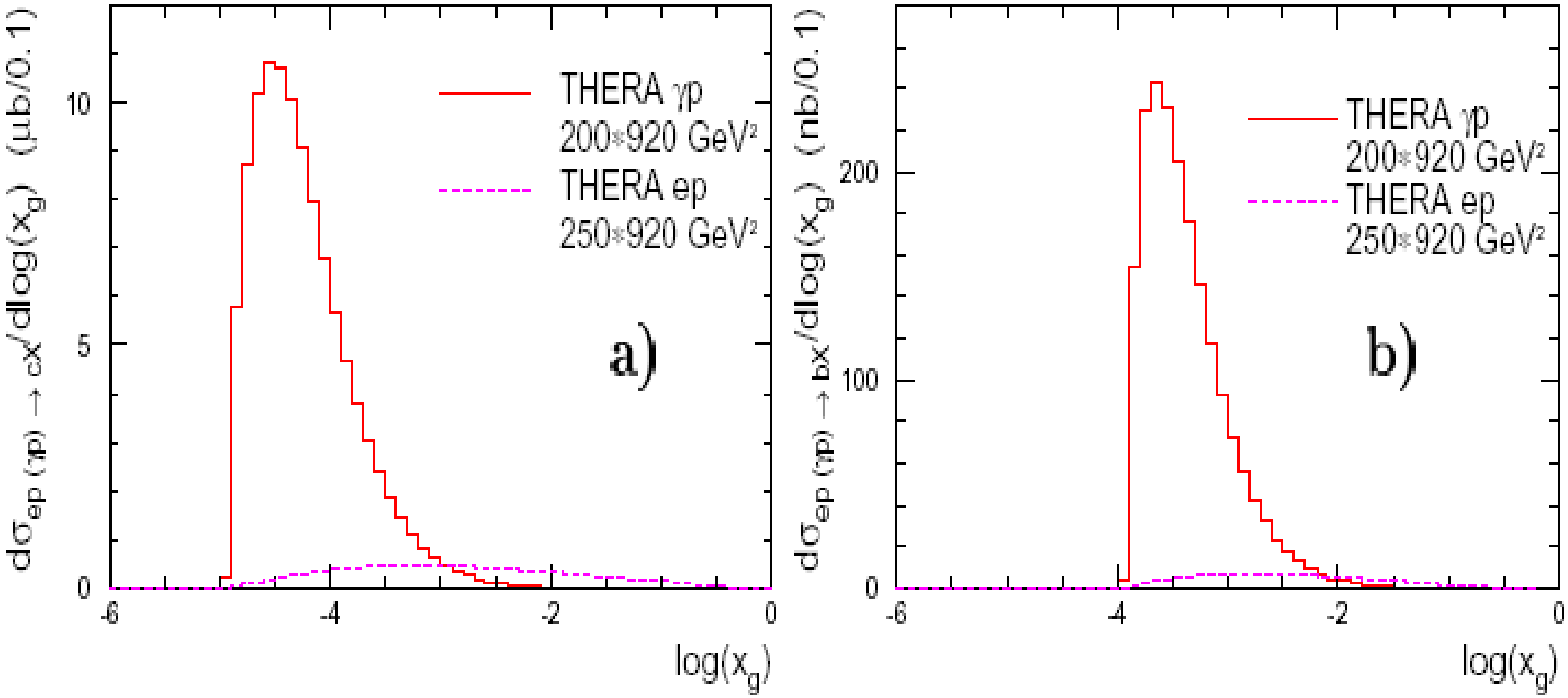
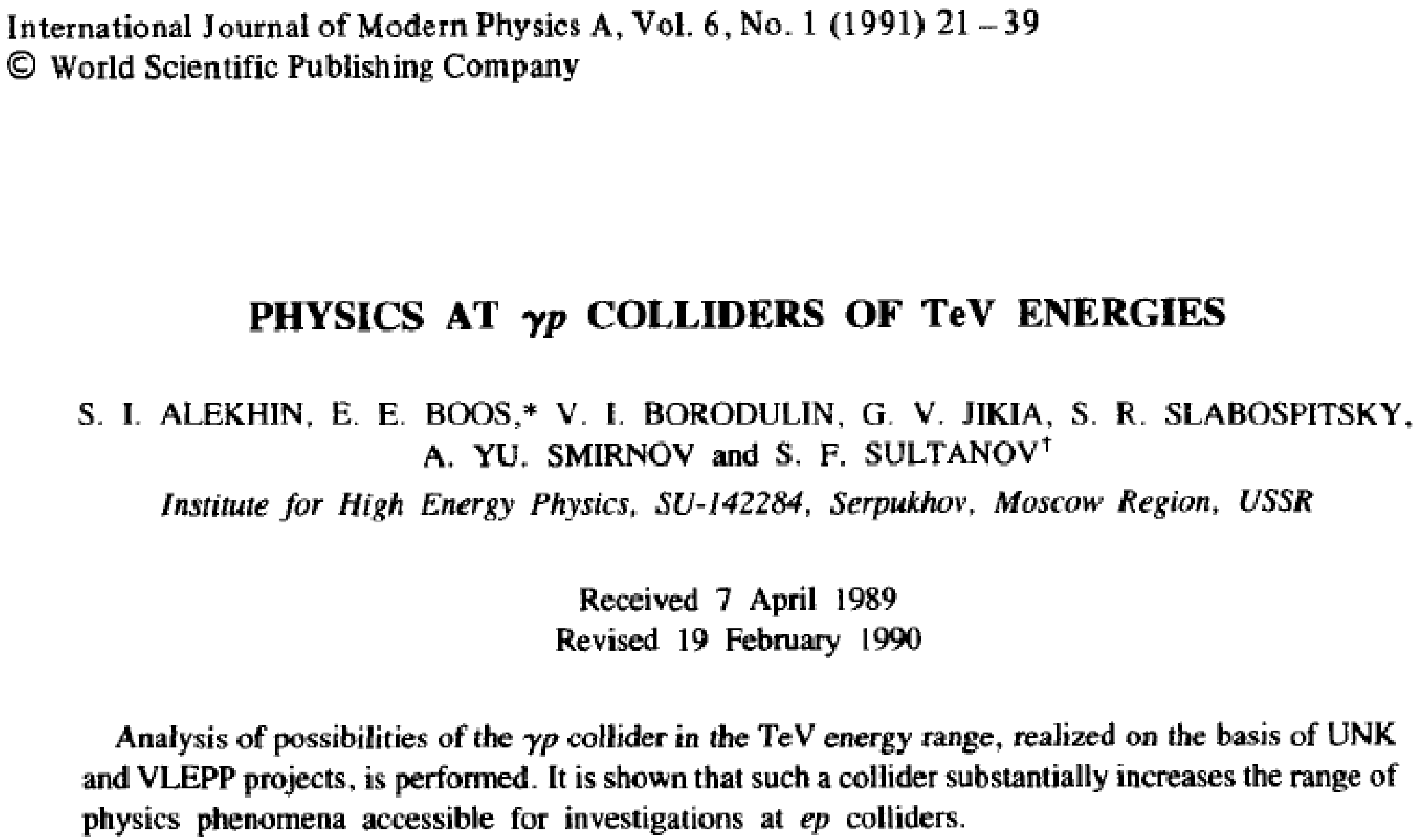


Figure 3: *Dependence of the differential cross section of (a) charm and (b) beauty production on x_g in γp and ep scattering at THERA.*

For QCD Explorer see Gökhan's presentation (tomorrow)

First (journal) paper



International Journal of Modern Physics A, Vol. 6, No. 1 (1991) 21 – 39

PHYSICS AT γp COLLIDERS OF TeV ENERGIES

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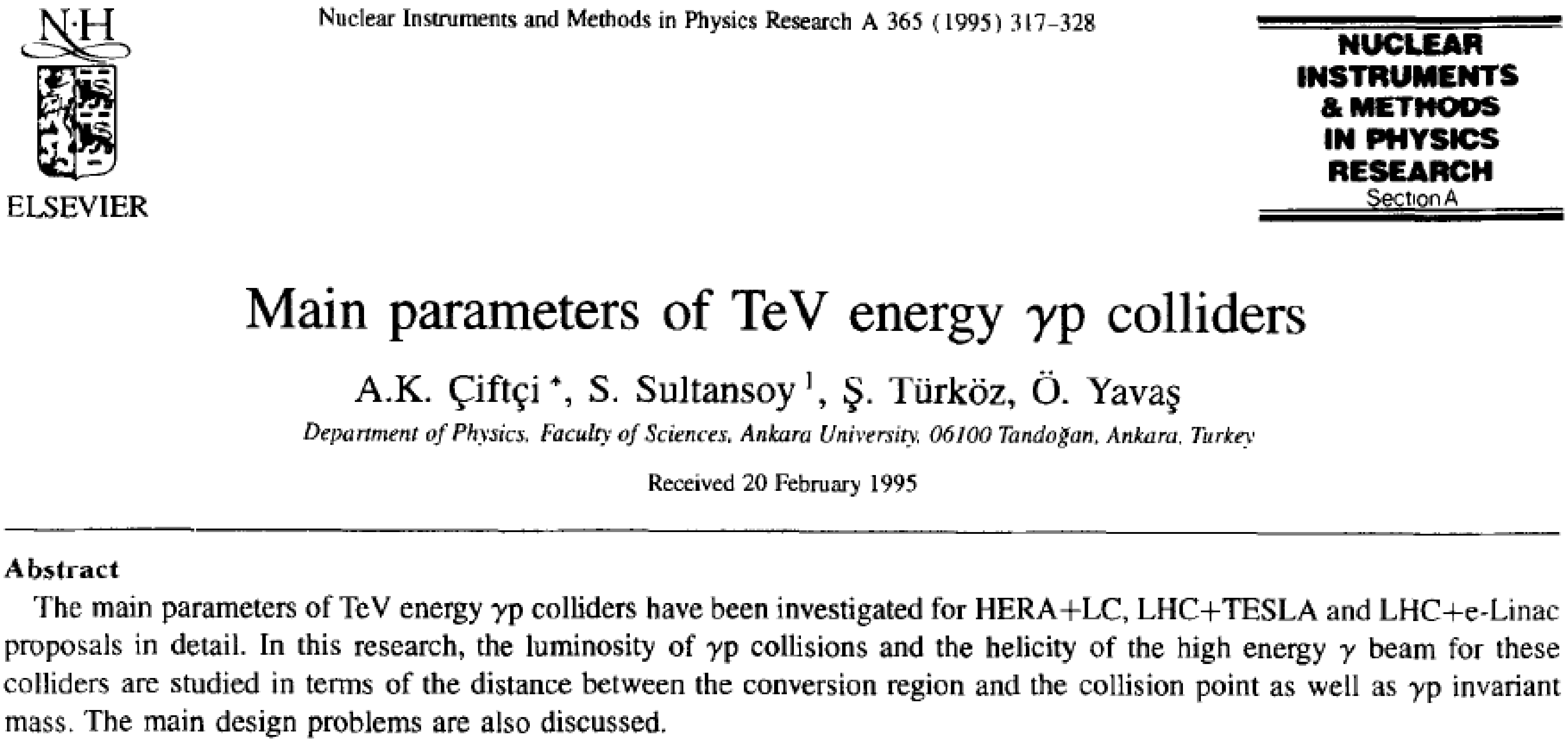
Received 7 April 1989
Revised 19 February 1990

Analysis of possibilities of the γp collider in the TeV energy range, realized on the basis of UNK and VLEPP projects, is performed. It is shown that such a collider substantially increases the range of physics phenomena accessible for investigations at *ep* colliders.

Basic paper



Nuclear Instruments and Methods in Physics Research A 365 (1995) 317–328

NUCLEAR
INSTRUMENTS
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RESEARCH
Section A

N·H
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Main parameters of TeV energy γp colliders

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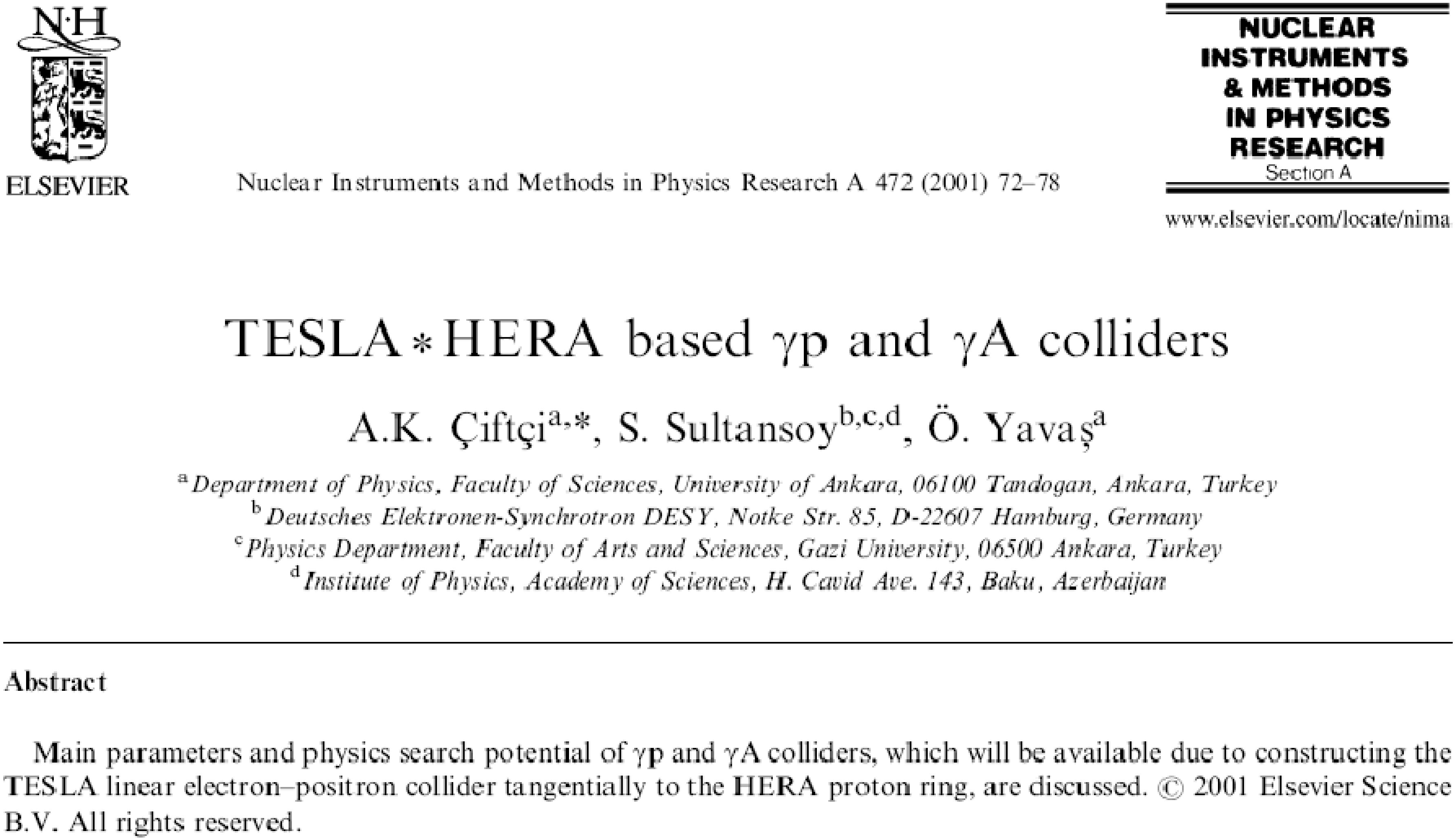
Received 20 February 1995

Abstract

The main parameters of TeV energy γp colliders have been investigated for HERA+LC, LHC+TESLA and LHC+e-Linac proposals in detail. In this research, the luminosity of γp collisions and the helicity of the high energy γ beam for these colliders are studied in terms of the distance between the conversion region and the collision point as well as γp invariant mass. The main design problems are also discussed.

TESLA*HERA paper



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Nuclear Instruments and Methods in Physics Research A 472 (2001) 72–78

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

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TESLA $*$ HERA based γp and γA colliders

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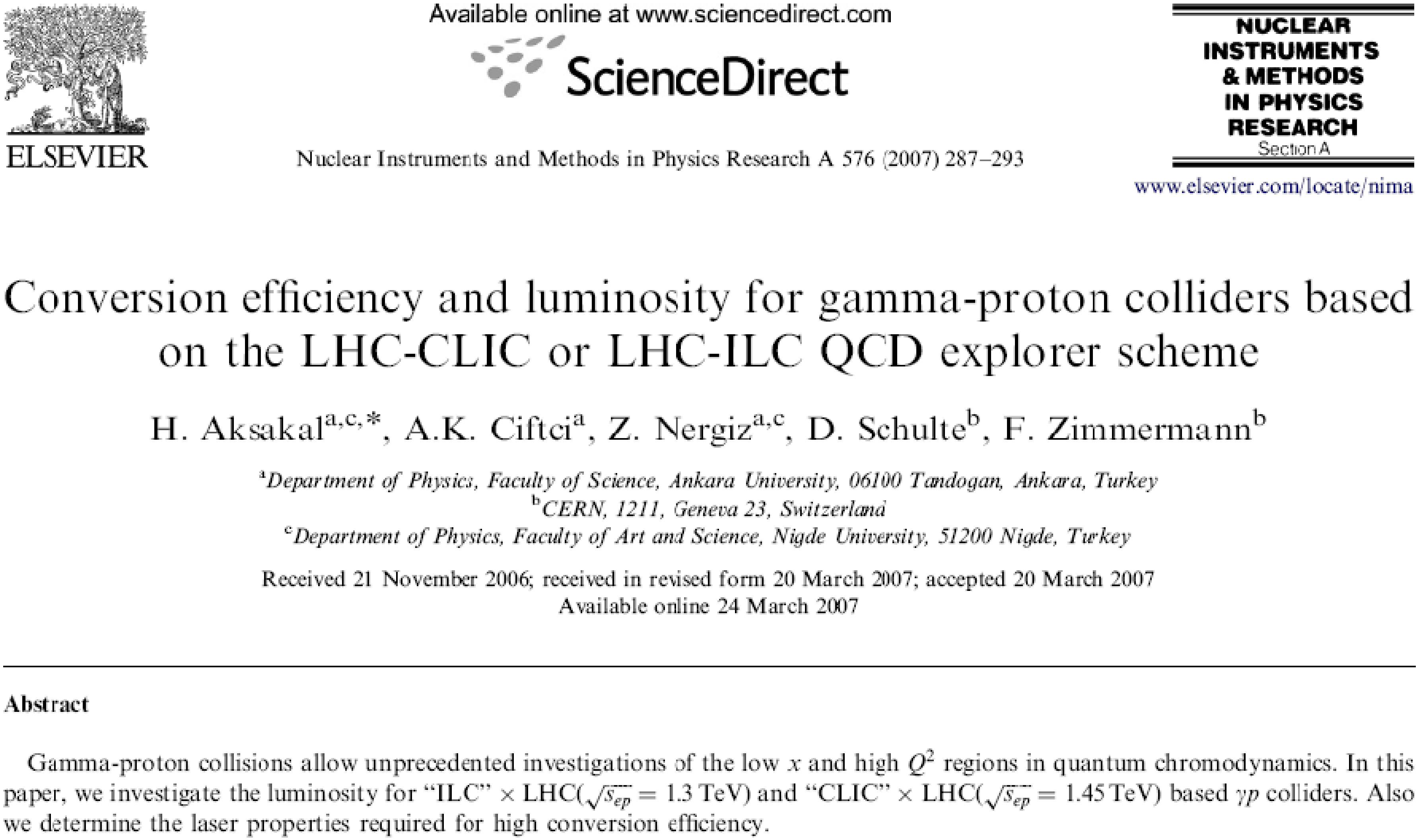
Abstract

Main parameters and physics search potential of γp and γA colliders, which will be available due to constructing the TESLA linear electron–positron collider tangentially to the HERA proton ring, are discussed.

Advanced paper



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Nuclear Instruments and Methods in Physics Research A 576 (2007) 287–293

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

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Conversion efficiency and luminosity for gamma-proton colliders based on the LHC-CLIC or LHC-ILC QCD explorer scheme

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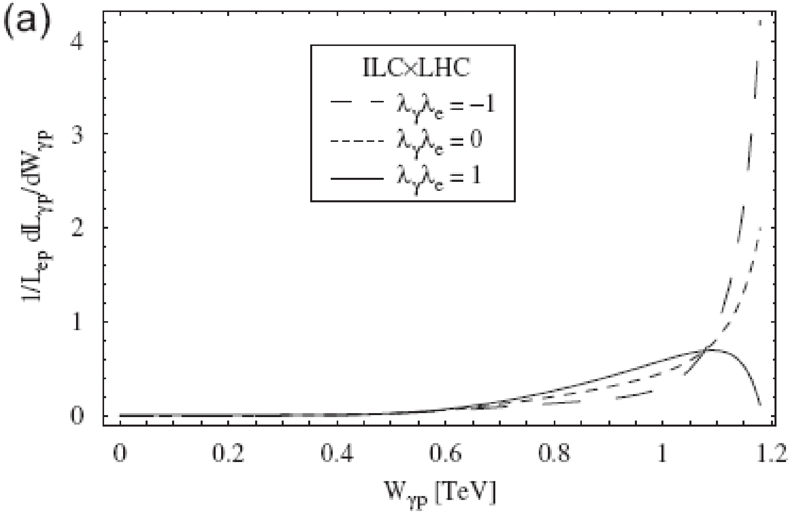
Abstract

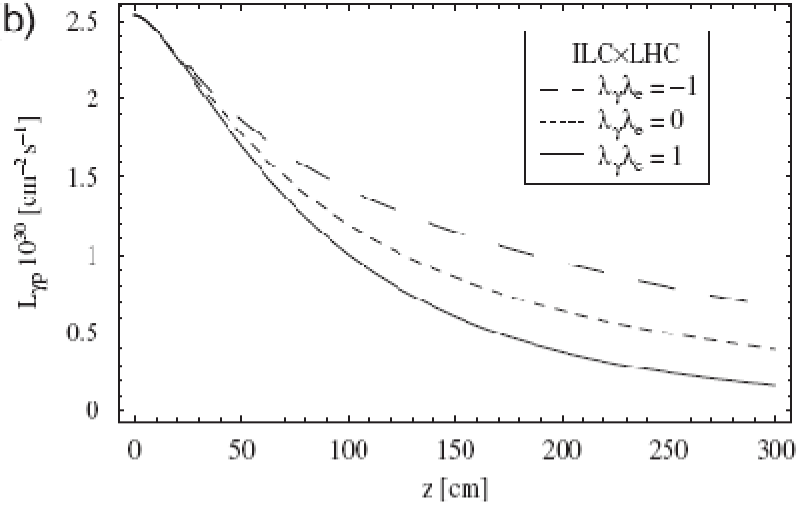
Gamma-proton collisions allow unprecedented investigations of the low x and high Q^2 regions in quantum chromodynamics. In this paper, we investigate the luminosity for "ILC" × LHC($\sqrt{s_{ep}} = 1.3$ TeV) and "CLIC" × LHC($\sqrt{s_{ep}} = 1.45$ TeV) based γp colliders. Also we determine the laser properties required for high conversion efficiency.

(a)



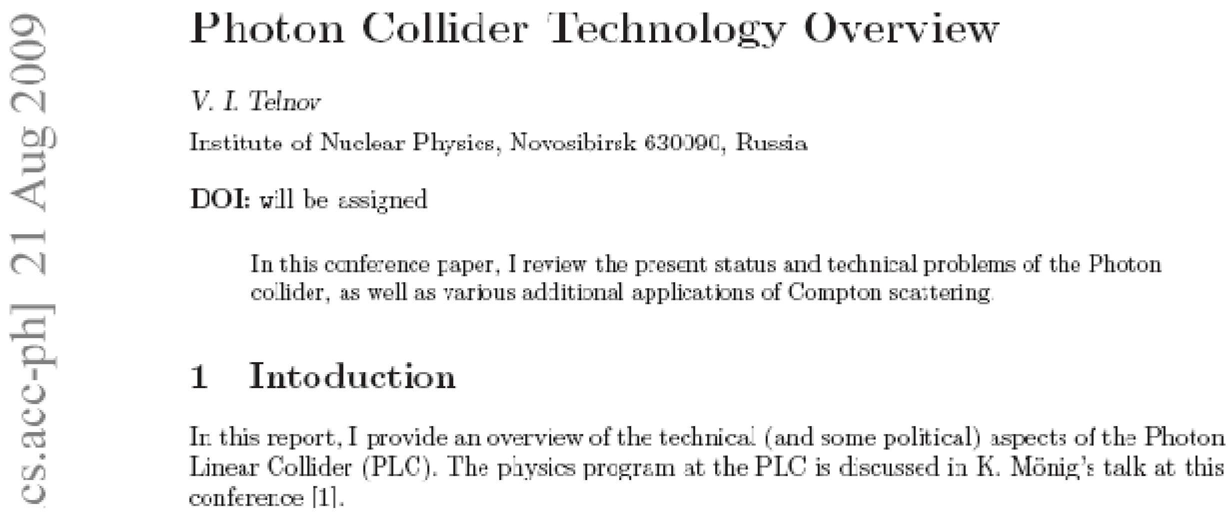
ILC×LHC
$\lambda_\gamma\lambda_e = -1$
$\lambda_\gamma\lambda_e = 0$
$\lambda_\gamma\lambda_e = 1$
$1/L_{ep}\, dL_{\gamma p}/dW_{\gamma p}$
0
1
2
3
4
0
0.2
0.4
0.6
0.8
1
1.2
$W_{\gamma p}$ [TeV]

(b)



ILC×LHC
$\lambda_\gamma\lambda_e = -1$
$\lambda_\gamma\lambda_e = 0$
$\lambda_\gamma\lambda_e = 1$
$L_{\gamma p}\, 10^{30}$ [$cm^{-2}s^{-1}$]
0
0.5
1
1.5
2
2.5
0
50
100
150
200
250
300
z [cm]

Laser(s)



cs.acc-ph] 21 Aug 2009

Photon Collider Technology Overview

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DOI: will be assigned

In this conference paper, I review the present status and technical problems of the Photon collider, as well as various additional applications of Compton scattering.

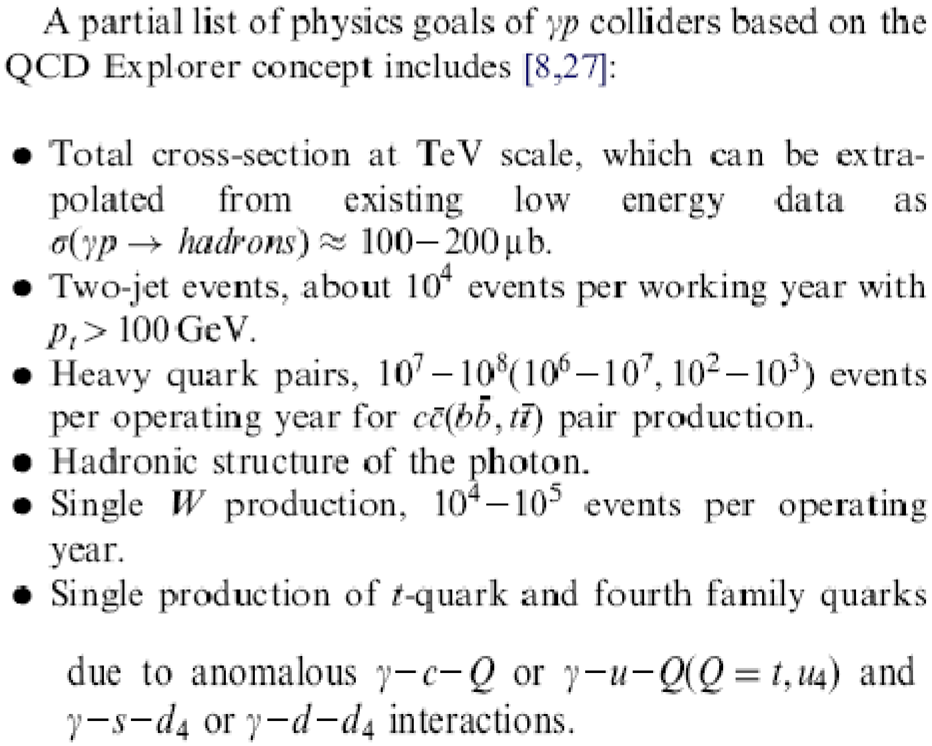
1 Intoduction

In this report, I provide an overview of the technical (and some political) aspects of the Photon Linear Collider (PLC). The physics program at the PLC is discussed in K. Mönig's talk at this conference [1].

- **γp** is analog of **γe**
- **advantage: larger z (CR-IP), m vs mm, disadvantage: proton beam line**
- **conventional lasers vs ERL FEL, …**

Physics at γp

Ankara Workshop April 1997



A partial list of physics goals of γp colliders based on the QCD Explorer concept includes [8,27]:

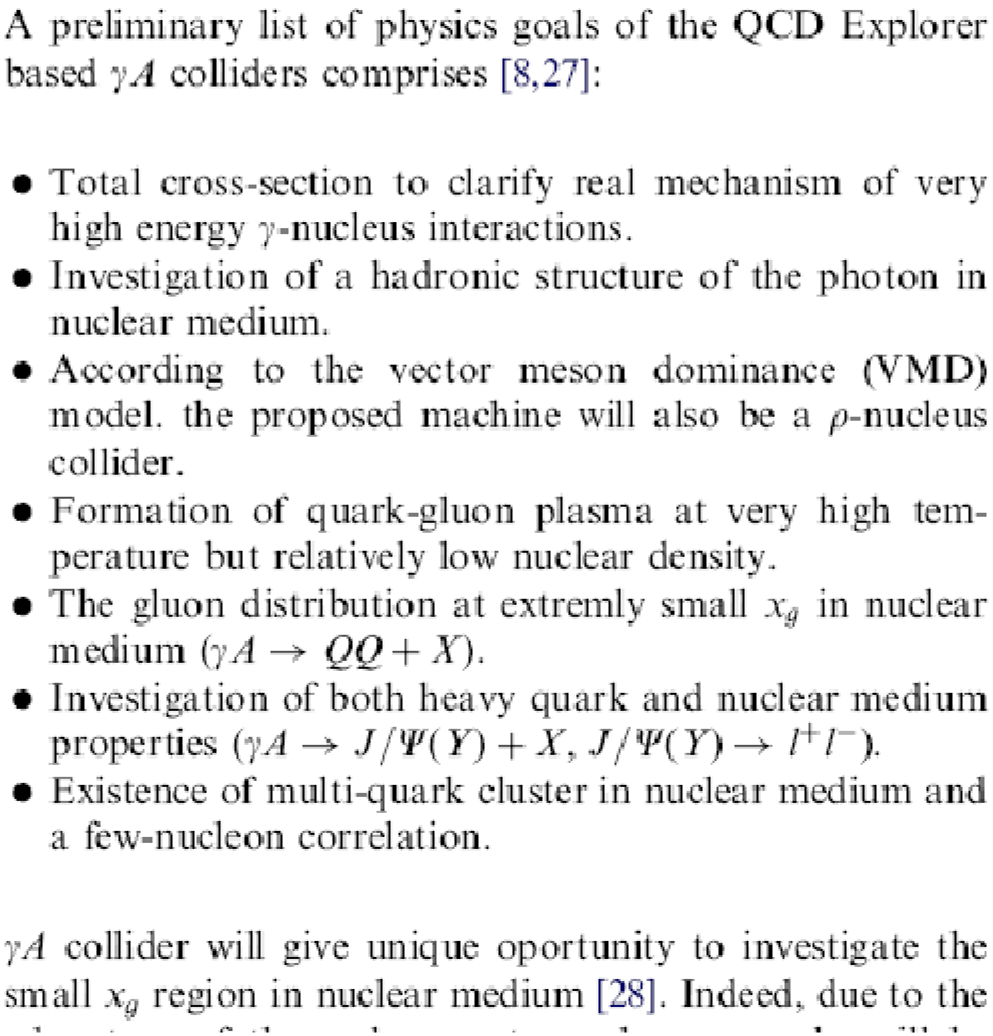
- Total cross-section at TeV scale, which can be extrapolated from existing low energy data as $\sigma(\gamma p \rightarrow hadrons) \approx 100-200\,\mu b$.
- Two-jet events, about 10^4 events per working year with $p_t > 100\,\mathrm{GeV}$.
- Heavy quark pairs, $10^7-10^8 (10^6-10^7, 10^2-10^3)$ events per operating year for $c\bar{c}(b\bar{b}, t\bar{t})$ pair production.
- Hadronic structure of the photon.
- Single W production, 10^4-10^5 events per operating year.
- Single production of t-quark and fourth family quarks

due to anomalous $\gamma-c-Q$ or $\gamma-u-Q(Q=t, u_4)$ and $\gamma-s-d_4$ or $\gamma-d-d_4$ interactions.

see presentations by A.K. Çiftçi and I.T. Çakır (tomorrow)

Physics at γA

Ankara Workshop April 1997



A preliminary list of physics goals of the QCD Explorer based γA colliders comprises [8,27]:

- Total cross-section to clarify real mechanism of very high energy γ-nucleus interactions.
- Investigation of a hadronic structure of the photon in nuclear medium.
- According to the vector meson dominance (VMD) model. the proposed machine will also be a ρ-nucleus collider.
- Formation of quark-gluon plasma at very high temperature but relatively low nuclear density.
- The gluon distribution at extremly small x_g in nuclear medium ($\gamma A \rightarrow QQ + X$).
- Investigation of both heavy quark and nuclear medium properties ($\gamma A \rightarrow J/\Psi(Y) + X, J/\Psi(Y) \rightarrow l^+ l^-$).
- Existence of multi-quark cluster in nuclear medium and a few-nucleon correlation.

γA collider will give unique oportunity to investigate the small x_g region in nuclear medium [28]. Indeed, due to the

Conclusion

- **QCD Explorer is mandatory, EF is not urgent**
- **γ options essentially enlarge physics search potential**
- **Laser parameters and CR&IR design depend on e-linac choice**

Back-up

from V. Telnov, 2009

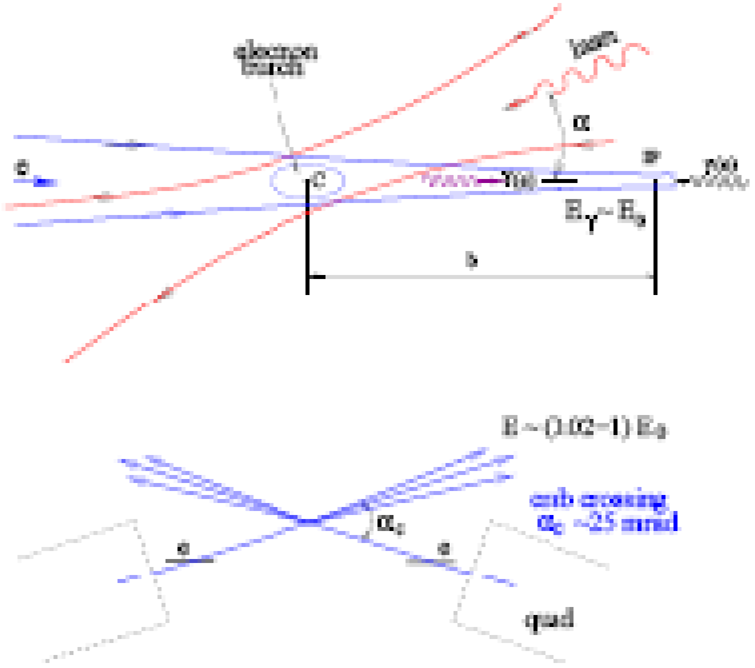
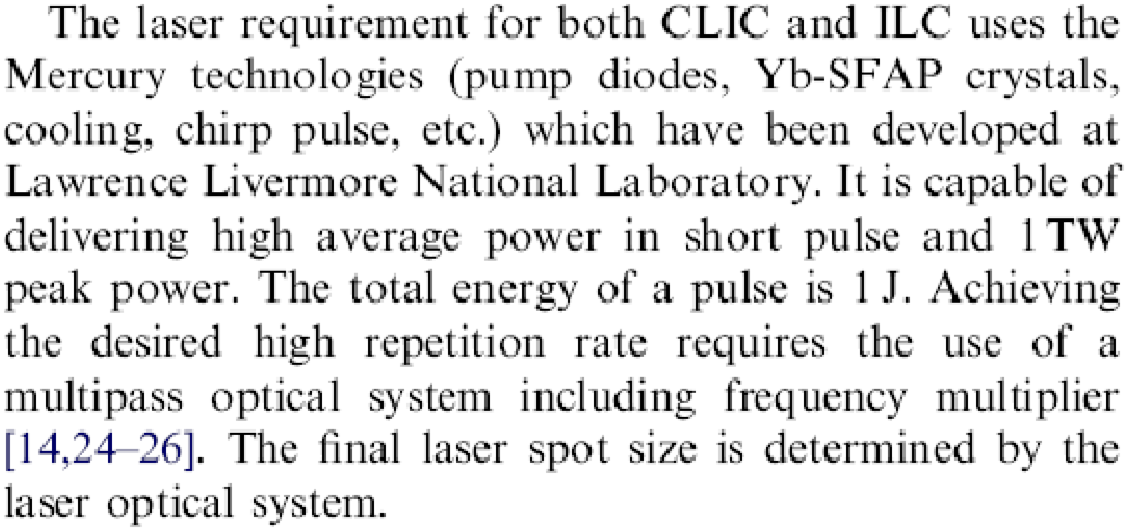


Figure 2: Scheme of $\gamma\gamma$, γe collider.

from H. Aksakal et al., NIM A 2007



The laser requirement for both CLIC and ILC uses the Mercury technologies (pump diodes, Yb-SFAP crystals, cooling, chirp pulse, etc.) which have been developed at Lawrence Livermore National Laboratory. It is capable of delivering high average power in short pulse and 1 **TW** peak power. The total energy of a pulse is 1 J. Achieving the desired high repetition rate requires the use of a multipass optical system including frequency multiplier [14,24–26]. The final laser spot size is determined by the laser optical system.