ep with

TESLA * HERA.

$$s = 4 \cdot (200 \cdots 500) * (300 \cdots 1000)\ \mathrm{GeV}^2$$

$$Q^2 \lesssim 2 \cdot 10^6\ \mathrm{GeV}^2 .$$

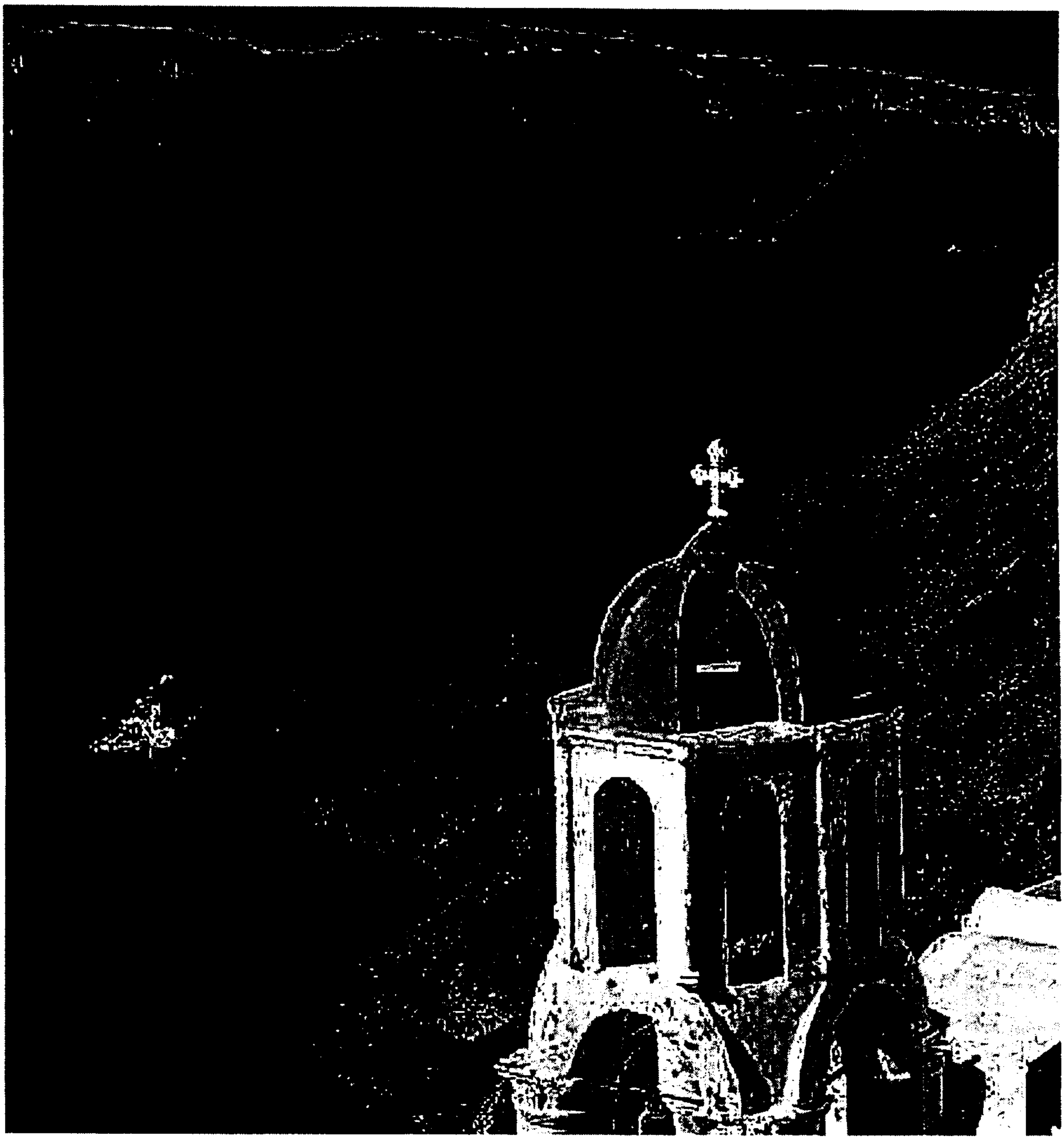
meeting at DESY. 8/9.2.2000. M. Klein

- history

- kinematics and detector issues

- rates and luminosity

- organization and goals



THERA

ancient Thera on mountain Messavouno (369m).

south-east of Aegean island Santorini

ingenuitive water pipe system. 3000 years ago. doric period.

CONTENTS

Seminar on ep and ee storage rings. Oct. 73. DESY 73/66

~ 17 years before first ep collisions were observed.

you look younger when it begins

G. Weber, DESY   B. Wiik, DESY   K. Johnsen, CERN

K. Steffen, DESY   G. Rees, Rutherford   M. Tigner, Cornell

D. Gray, Rutherford   G.A. Voss, DESY   J.T. Thomson, Daresbury

G. Saxon, Daresbury   B. Richter, SLAC

T. Elioff, Berkeley   R. Chasman, Brookhaven   H. Schopper DESY

B. Richter, SLAC

J. Kouptsidis, H. Wiedemann,   H.D. Schulz,   N. Lehmart,

alle DESY

H.G. Ebeling, B. Hellwig,   A. Febel, H. Kumpfert,   H. Nagel

alle DESY

M. Conversi,
Frascati

J. Perez-y-Jorba,
Orsay

W.K.H. Panofsky,
SLAC

C. Bernardini,
Frascati

(from left to right)

CERN 78-02
Intersecting Storage
Rings Division
27 February 1978

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CHEEP

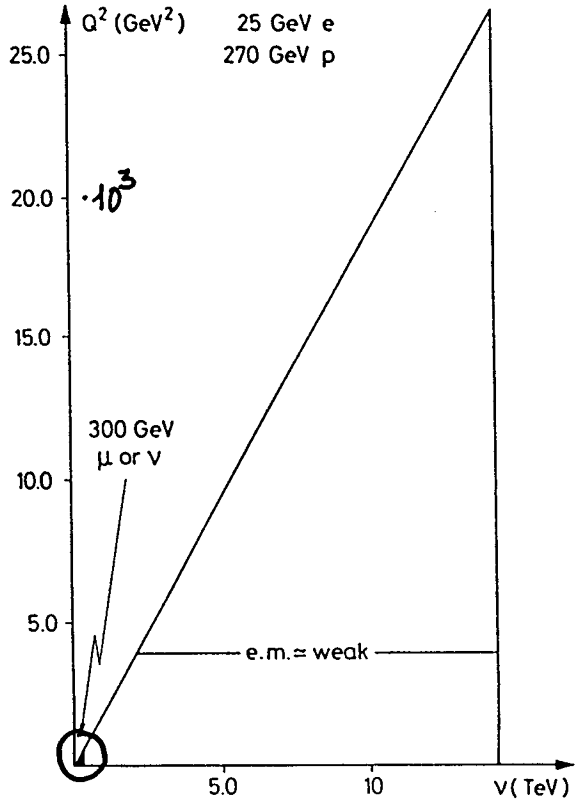
AN e-p FACILITY IN THE SPS

CHEEP Study Groups
J. Ellis, B.H. Wiik and K. Hübner (editors)

G E N E V A
1978

INTRODUCTION

It was proposed*) in late 1976 to install in the CERN SPS tunnel an electron storage ring capable of reaching 25 GeV (30 GeV), and to collide the electrons (positrons) with the protons in the main ring.



The kinematical region which can be exploited with this option is shown here. Also shown is the region which now is under investigation with the 300 GeV muon and neutrino beams available at the CERN SPS and at FNAL. This program can be extended by nearly two orders of magnitude in Q^2 and ν using CHEEP -- the CERN High-Energy Electron Proton Option. This extention would make it possible, for the first time, to explore the electromagnetic and the weak interaction in a region of Q^2 comparable to the characteristic mass of the weak interaction squared.

Early in 1977 an ECFA Study Group was formed, with a strong CERN participation. The aim of this group was to assess the physics interest of a high-energy electron-proton facility, identify possible experimental problems and investigate the detectors needed to exploit the physics, and to establish the technical feasibility of the scheme put forward. The present report is a summary of the work done in the Study Group.

The physics interest

The study of neutral and charged weak currents is one of the prime motivations for constructing a large electron-proton colliding beam facility. Present and foreseeable experiments only probe the weak interaction at values of $\sqrt{Q^2}$ which are small compared to the characteristic mass-scales of the weak interaction. Unitarity effects should become important at centre-of-mass energies of a few hundred GeV, while gauge theories suggest a unification with electromagnetism on a boson mass scale around 100 GeV. Measurements at CHEEP will extend weak interaction investigations into a new regime where $\sqrt{Q^2}$ is comparable with these scales. Measurements at such large values of Q^2 will presumably provide the answers to some crucial questions:

---

*) R. Billinge, H. Hoffmann, A. Hofmann, K. Hübner, A. Hutton, K. Johnsen, E. Jones, B.W. Montague, B.H. Wiik and C. Zettler, IEEE Trans. Nuclear Sci. NS-24, No. 3 (1977) 1191.

Wiik
Llewellyn Smith.
DESY 77/38

need to understand the answers and to establish a new list

Any new facility should give access to a large unexplored kinematical region with sufficient luminosity to investigate what now seem to be the most profound problems in particle physics. With an electron-proton colliding beam facility one can attack questions such as:

- What is the structure of the weak interaction ? • at larger scales
- What mechanism, if any, will damp the rising weak cross section at high energy ? W
- Do the intermediate vector bosons – $W^{\pm}$ and Z^{o} – exist ? Yes
- How will the neutral current affect the scattering of charged leptons ? • THERA is the γZ machine.
- Are the weak and electromagnetic interactions different manifestations of a single force ? Yes.
- To what extent does the point-like behaviour of hadrons revealed by deep inelastic ν, μ and e experiments persist at higher energies ? • → $2 \cdot 10^{-19}$ m
- Do scaling violations have the characteristic features expected if the strong interactions are described by a gauge theory ? little doubt
- Are there additional heavy leptons ? • FCNC
- Are there further hadronic degrees of freedom beyond charm ? little chance

Chart

Machine	Original "Purpose"	Unexpected achievement/output
Cosmotron	Multi π production	Props of strange particles
Bevatron	Antiproton	Resonances
CERN PS BNL AGS	?	2 ν's , SU(3) , SU(6) , CP neutral currents, Regge ---
e^+e^-	QED π, p form factor	multihadron production
SLAC	Form factors, resonance prod.	deep inelastic (rich source of secondary beams)
ISR	Quarks, W's ?	Inclusive reactions (hadronic scaling), large p_T, rising σ_{pp}
NAL CERN II	Quantitative ν physics(?) ?	??
Very high energy e^+e^-, eN storage rings	Scaling? eN → eH+ --- ? Neutral Currents? eN → ν + --- ? ?	??

"the Grassmann question"

⇒ a proposal for THERA requires to think and write about HERA.

the obvious? list

- non-linear, non pert. gluon interaction dynamics ?

  $xg / \pi r_p^2$? saturation.

- precision test of pQCD to high orders

  $\delta\alpha_s \simeq 0.0003$ C. Pascaud, MK.

- high Q^2 substructure, new particles, electroweak str. function

- charm and beauty factory

- photon structure

- nuclear and polarized interactions

  ⋮

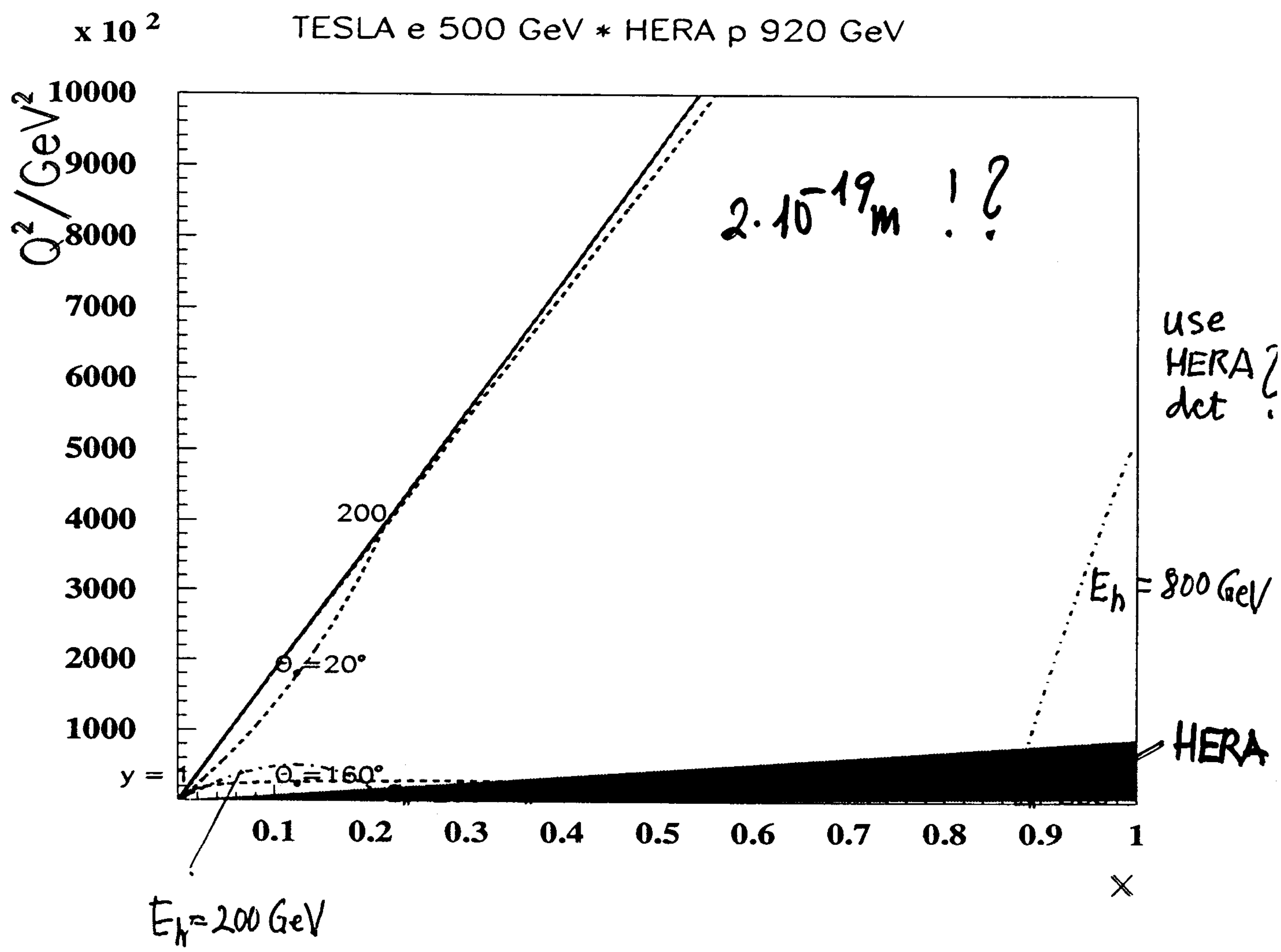
theory.

- if string theory is correct, the fundamental objects are not quarks or leptons, but a collection of particle like, string like, membran like objects.

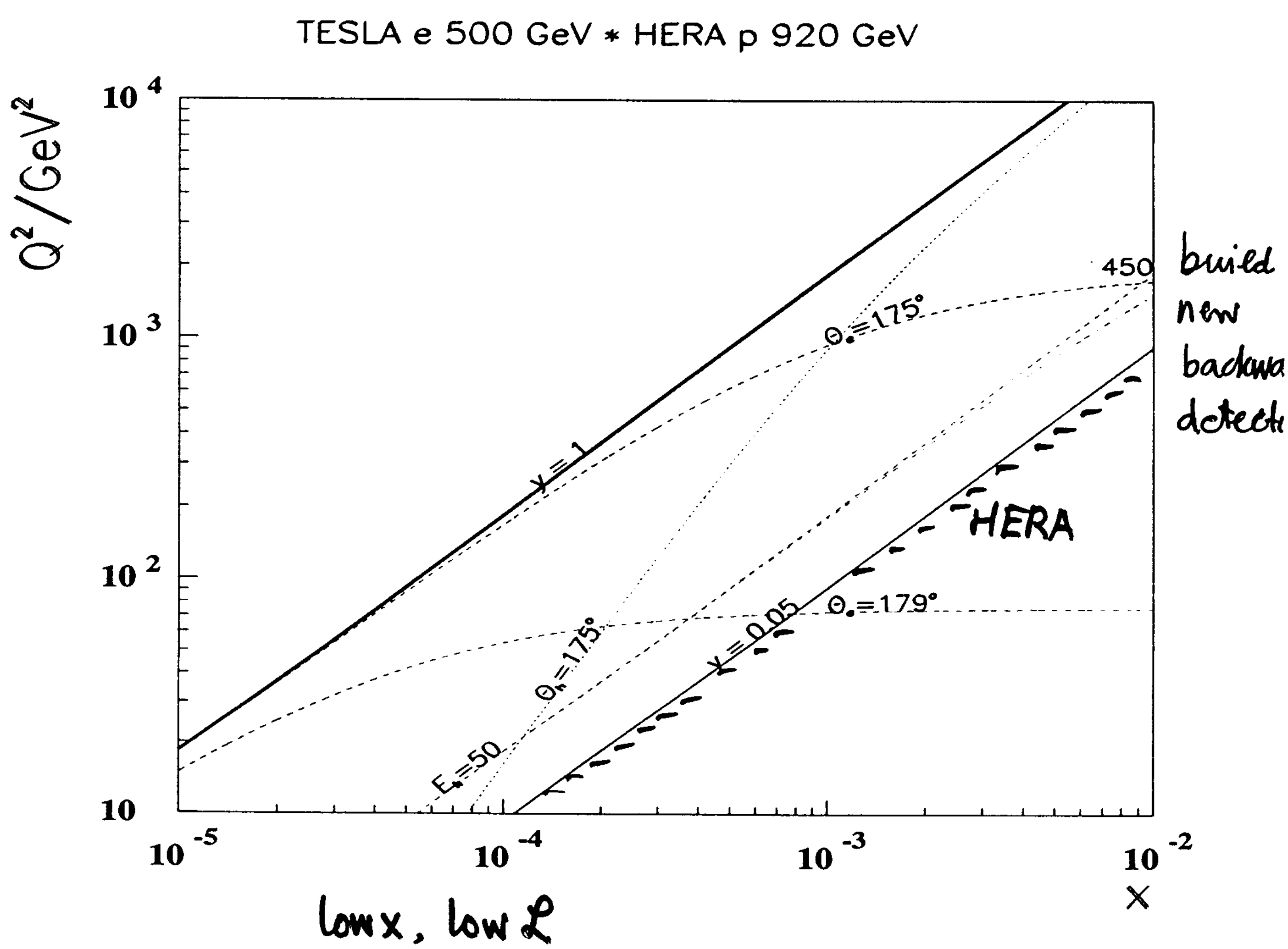
- due to extra dimensions the Planck scale could be 3 TeV
  ∴ hard scattering may produce mostly black holes

- gravitational excitations of ("provatons") a tower of Kaluza-Klein modes in extra dimensions could give rise to a missing E_T signature in collider experiments

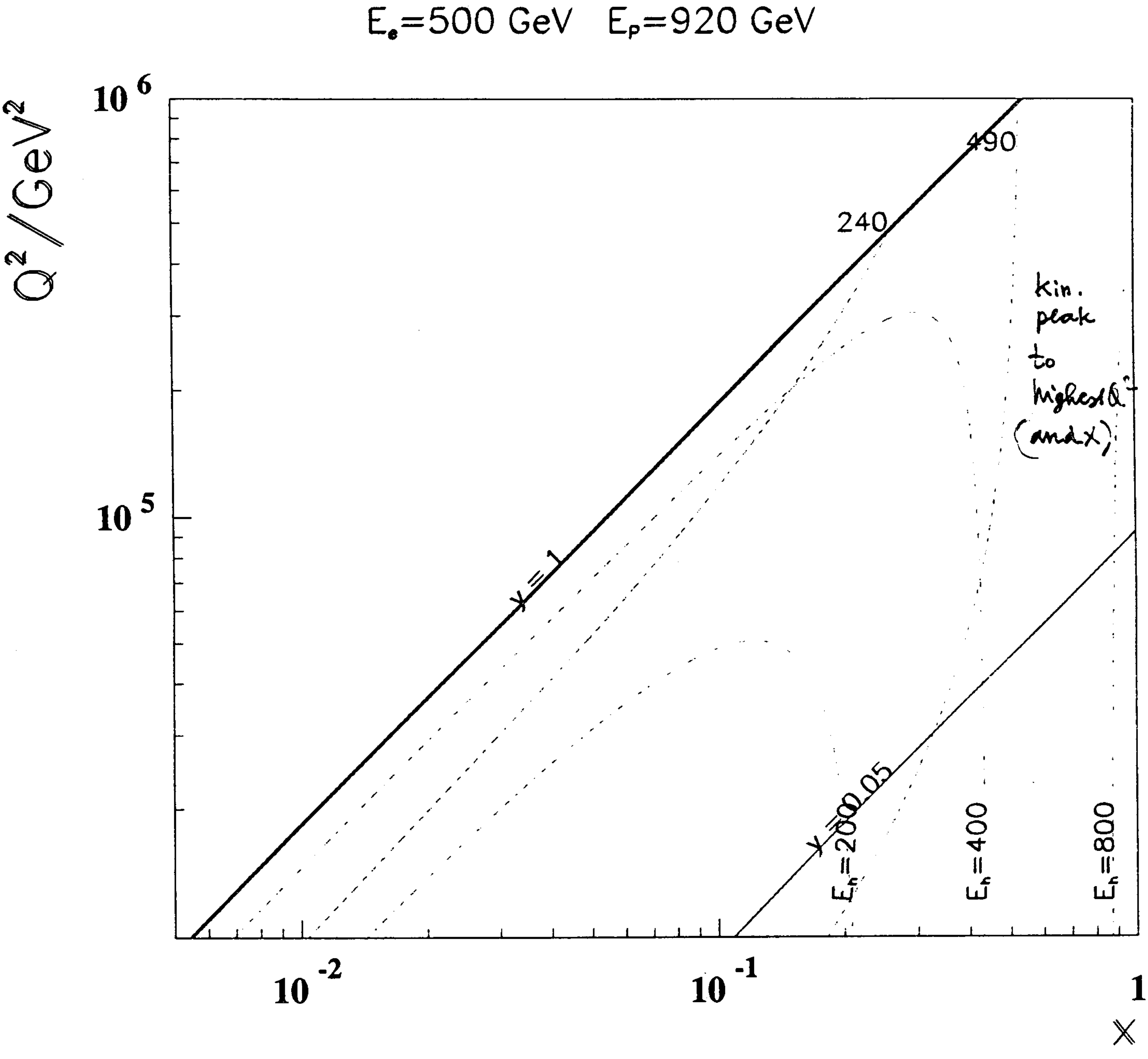
J. Lykken "Physics Needs for Future Accelerators"
Stanford LY Symposium hep-ph/0001319.



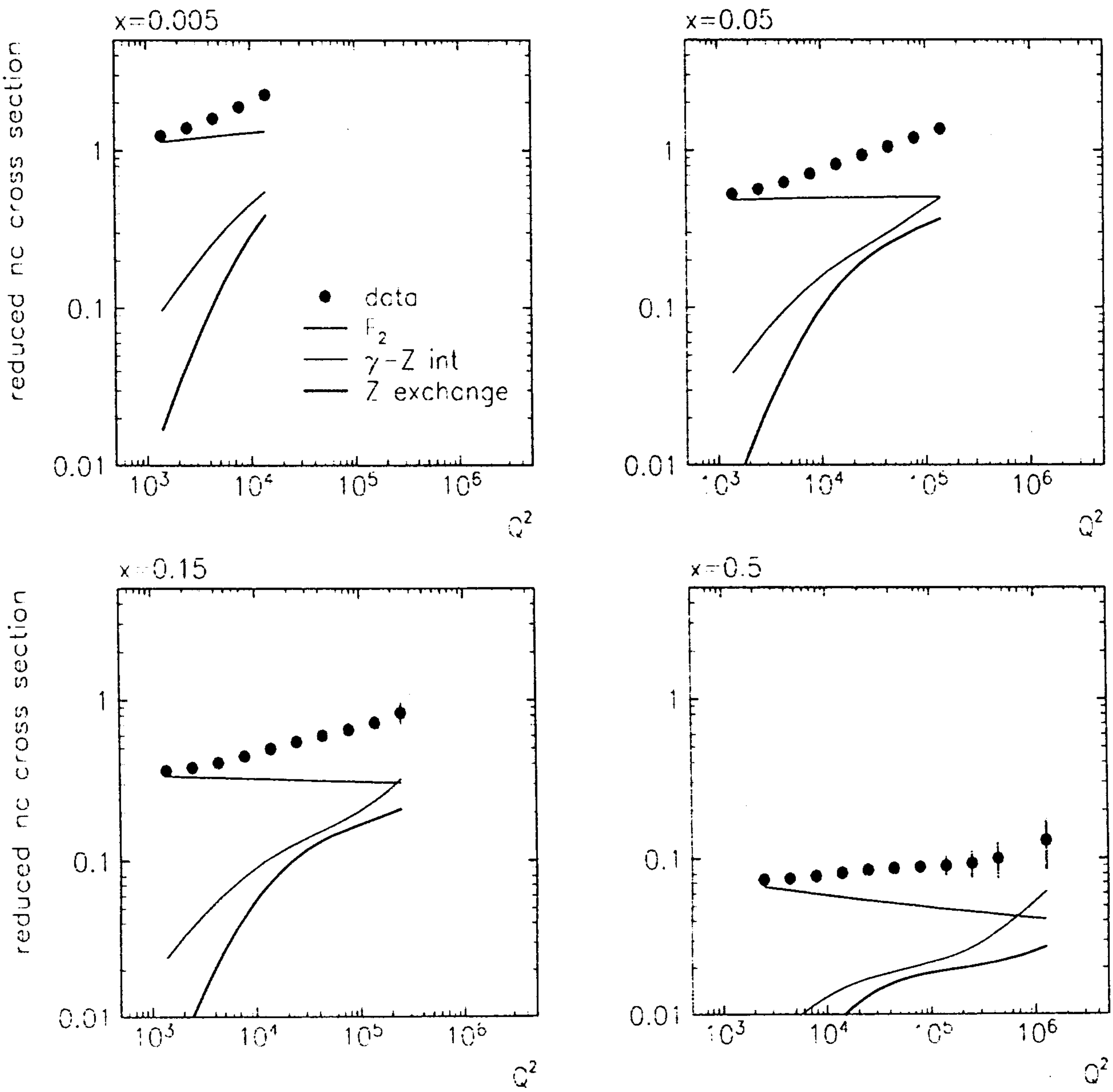
TESLA e 500 GeV * HERA p 920 GeV
x 10 2
Q2/GeV2
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
y = 1
200
Θe=20°
Θe=160°
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
x
2·10-19m !?
use HERA det ?
Eh = 800 GeV
HERA
Eh=200 GeV



TESLA e 500 GeV * HERA p 920 GeV
Q2/GeV2
10 4
10 3
10 2
10
10 -5
10 -4
10 -3
10 -2
x
450
Θe=175°
y = 1
Θh=175°
Eh=50
y = 0.05
Θe=179°
HERA
buid new backwa detect
low x, low L

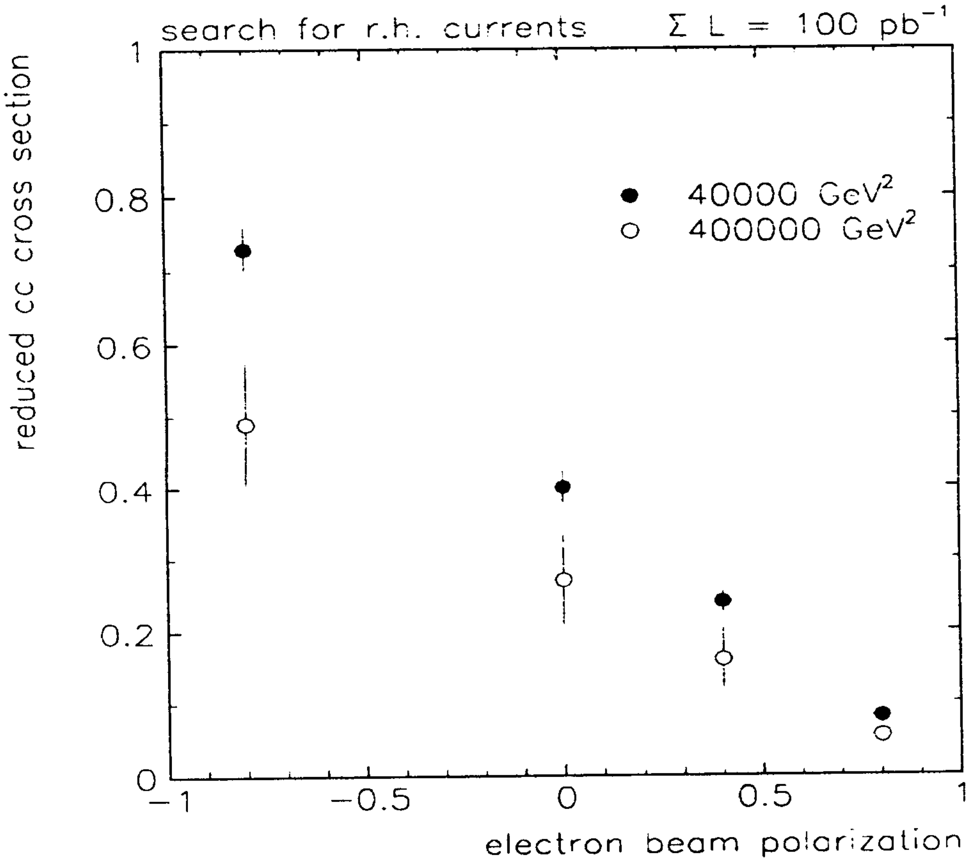


E_e=500 GeV E_p=920 GeV
Q^2/GeV^2
10^6
10^5
490
240
kin. peak to highest Q^2 (and x)
y=1
y=0.05
E_h=200
E_h=400
E_h=800
10^{-2}
10^{-1}
1
x



- $e^- p$ neutral current cross section, $\lambda = -0.8$
- fully simulated statistics (200pb^{-1}) and systematics
- σ_r rising with Q^2 due to Z coupling for all x
- strong dependence on polarization

high polarization !



Inelastic Lepton Scattering

C.H. Llewellyn Smith

CERN, Geneva

need NEW ideas, they may be

Caution: Most of this written version of my talk is in the form of notes based directly on the view graph transparencies. It is rough, incomplete and unreliable.

General boundary conditions:

After approval complition time of ~ 8 years

Financing, construction and operation by international collaboration

We want a linear collider <u>and</u> a Xray FEL

The described site is at DESY unless..

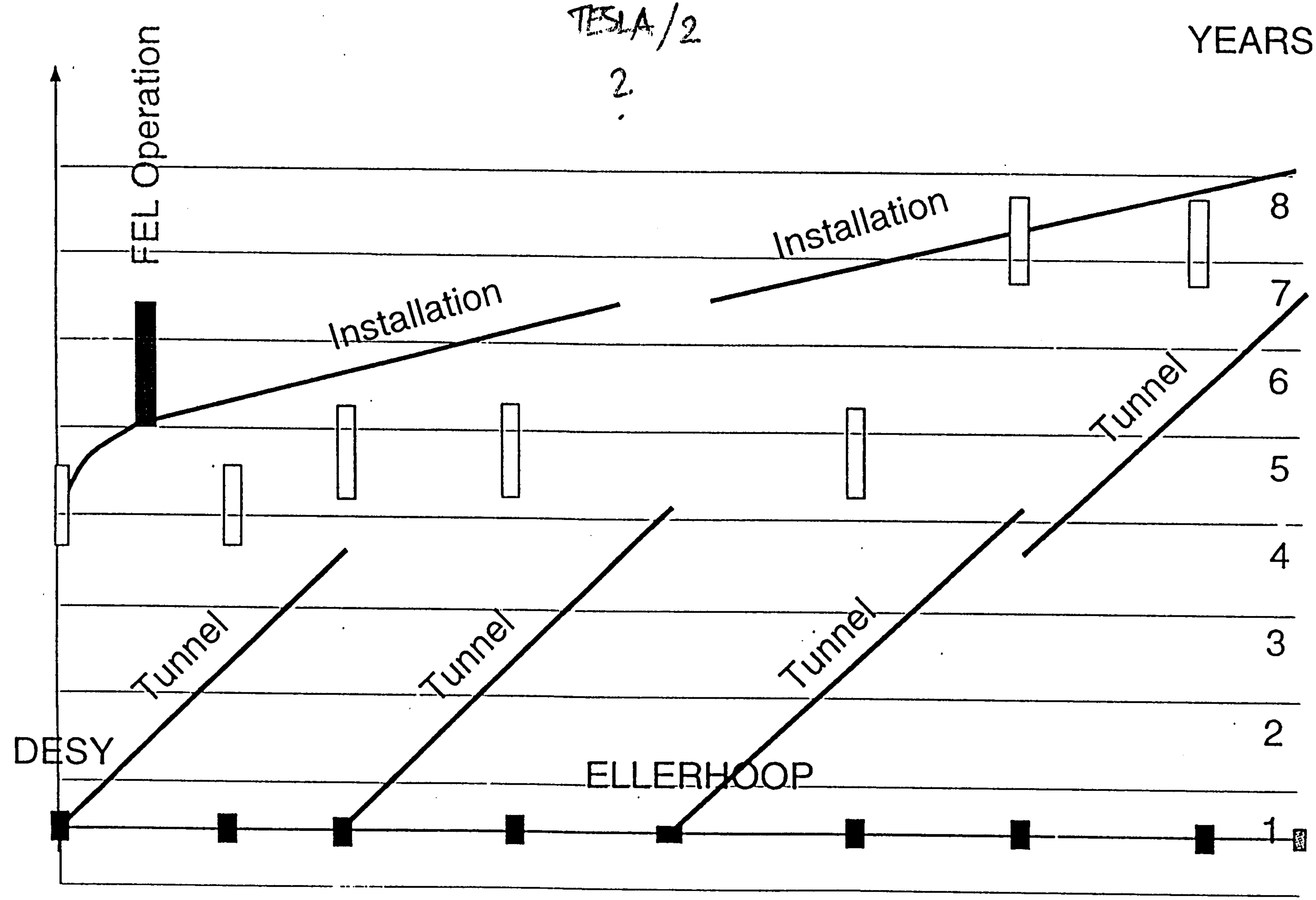
D. Trines

TESLA workshop

Zeuthen 2.2.2000.

ep with TESLA/2

2.

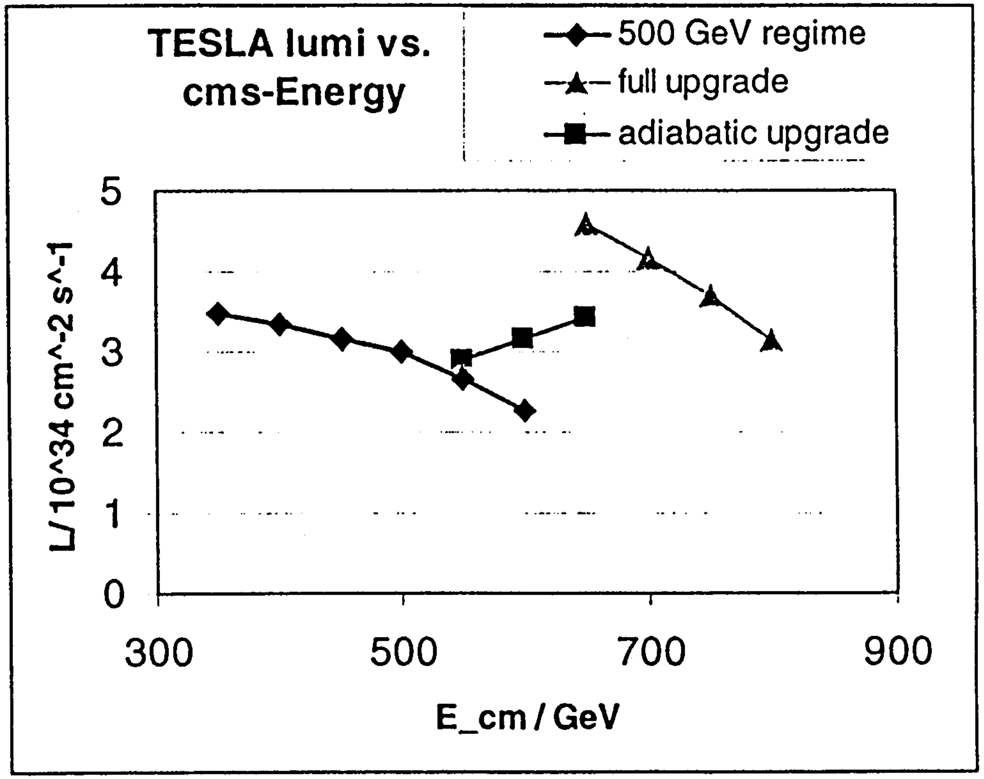


Energy variation, adiabatic upgrade and max. E_{cm}

- energy range around E_{cm} = 500 GeV: adjust I_{beam} and Q_{ext} for optimum beam power

- full upgrade: max. E_{cm} defined by g = 35 MV/m, reduce rep. rate 5Hz-->3Hz, double RF power (600 klystrons p. linac) and reduce emittance for high lumi

- adiabatic upgrade: add klystrons only in part of linac, operate those sections @35 MV



R. Brinkmann, Zeuthen, TESLA workshop.

Machine parameters and Luminosity

$$L \propto P_{beam} \cdot \sqrt{\frac{\delta_B}{\varepsilon_y}}$$

luminosity estimates depend on time and effort.

keep beamstrahlung $\delta_B \approx 2.5\%$ constant

with parameter set proposed autumn 1997:

increase L from $\mathbf{0.7 \cdot 10^{34}}$ $cm^{-2}\,s^{-1}$ to $\mathbf{3 \cdot 10^{34}}$ $cm^{-2}\,s^{-1}$

by:

1. $P_{beam} = 8.3$ MW --> 11.3 MW ($L \times 1.37$)
2. $\varepsilon_y = 25 \cdot 10^{-8}$ m --> $3 \cdot 10^{-8}$ m ($L \times 2.8$)

the effort depends on physics and time.

An Electron-Proton Collider in the TeV Range

M. Tigner, Cornell Univ., Ithaca, NY
B. Wiik, F. Willeke, DESY, Hamburg, FRG

Abstract

In ep colliding beam measurements, approximate equality of electron and quark energies is desirable for good detection efficiency. In the TeV CM energy regime, synchrotron radiation makes this requirement very expensive to meet using a storage ring for the electrons. Here we review a scheme,[1] that ameliorates this problem by using a superconducting linac for electron acceleration. Parameter lists show that such an approach may be practical for the next generation ep collider beyond HERA. An example of a 300 GeV electron beam colliding with the HERA p ring is shown in some detail. Examples up to $\sqrt{s} = 12$ TeV are given.

1 INTRODUCTION

Access to ep physics with ep colliders beyond HERA CM energies will require increase of the beam energy product as well as maintenance of a mainimum ratio of e to p energy to maintain reasonable production angles. Its inherent freedom from synchrotron radiation and its geometric flexibility suggest an electron linac on proton storage ring configuration for future. higher energy, ep colliders. The luminosity needed for useful physics together with the accelerator physics and technology limits to stored proton beam densities and interaction region optics work together to demand linac parameters that can be met only with rf superconductivity technology. A schematic layout of such a facility is shown in Figure 1 in which head-on collision of an electron and proton beam are arranged.

2 LUMINOSITY

As shown below, the achievable luminosity is constrained by the electron beam power. the intrabeam scattering limited emittance of the proton beam and the practical limits to focusing strength at the IP.

Assuming round beams and equal transverse beam sizes for e and p at the crossing point then

$$L = \frac{N_e N_p f_b \gamma_p}{4\pi\epsilon_p\beta^*} \qquad (1)$$

where ϵ_p is the normalized proton beam emittance or mean square beam size divided by betatron parameter, N_e, N_p the numbers of electrons and protons per bunch and f_b their collision frequency. γ_p is the proton Lorentz factor.

0780391-0

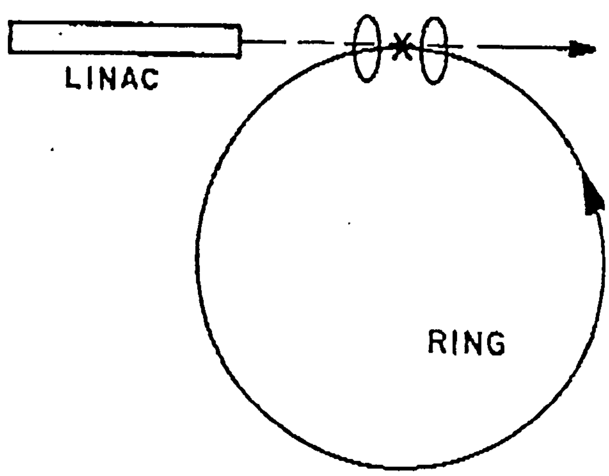


Figure 1: Layout of Linac on Ring e-p Collider

Once the e-beam energy is chosen, then the total electr beam current $I_e = N_e \cdot e \cdot f_b$ is, limited by the allow electron beam power or $I_e = P_e/E_e$ and from (1), L independent of N_e and f_b as long as their product is co stant. Numerically

$$L = 1.66 \times 10^{31} s^{-1} cm^{-2} N_p/10^{11} \cdot P_e/10^8 \text{watt} \cdot 0.3\text{TeV}/E_e \cdot \gamma_p/1000 \cdot 10^{-6}\text{m}/\epsilon_p \times 10\text{cm}/\beta^*$$

Table 1 displays some possible examples for future intere

Table 1

E_p (TeV)	E_e (TeV)	$\sqrt{s}$ (TeV)	L ($10^{32} cm^{-2} s^{-1}$)
1.0	0.10	0.632	1.1
	0.20	0.894	0.56
	0.30	1.200	0.38
8.0	0.30	3.098	3.0
	0.50	4.000	1.75
	1.00	5.657	0.88
20.0	1.00	8.944	2.25
	2.00	12.649	1.13

Luminosities for various proton and electron energies. All have $N_p = 3 \times 10^{11}$, $P_e = 60$MW, $\epsilon_p = 0.8 \times 10^{-6}$m, $\beta^* = 10$cm.

IEEE S. Francisco 1990

Tr. J. of Physics
22 (1998) , 661 – 666.

International Workshop on Linac-Ring
Type *ep* and γp Colliders

Interaction Region and Luminosity Limitations for the TESLA/HERA e/p Collider

R. BRINKMANN
DESY, Notkestr.85, D-22603 Hamburg - GERMANY

1. Introduction

The concept of combining a proton storage ring with an electron linac to achieve e/p collisions becomes particularly attractive when a future Linear Collider is constructed close to a laboratory site where a high energy proton ring already exists. In this case, the e/p collider can be realized with comparatively low additional investment. By comparing the linac pulse structure and the available beam power for different Linear Collider approaches [1], it is rather obvious that the superconducting TESLA linac would be by far the best one suited for a linac/ring e/p machine. An additional argument results from the fact that the TESLA cavities are of the standing-wave type so that both linacs of the e^+e^- collider could be used to accelerate an electron beam in the same direction, whereas in conventional accelerating structures (travelling-wave) reversal of the beam direction is impossible. In order to be specific, I will also consider only the HERA-p ring as a possible candidate for the linac/ring collider. The considerations of the tunnel geometry for the planned TESLA Linear Collider at the DESY site [2] take this option into account and foresee the linac starting tangential to the existing HERA ring. It would, of course, be possible to construct the machine in a very similar fashion at Fermilab (using the TEVATRON) or at CERN (using the future LHC ring).

Linac/ring e/p colliders have been discussed by several authors (see e.g. [3, 4, 5]). In the following a somewhat more detailed discussion of the limitations concerning the interaction parameters and luminosity for the TESLA/HERA case will be given.

2. Basic Parameters

The problem of achieving a high luminosity in this type of machine results from the fact that the average bunch collision rate is orders of magnitude smaller than in the HERA ring, because the e-linac has to be operated in a low duty cycle pulsed mode: Whereas the collision frequency at HERA is about 10 MHz, the bunch frequency foreseen for TESLA is only about 5.6 kHz [2]. Going to CW-operation in the TESLA linac would lead to excessive requirements for the cryogenic plant and for the RF- system average power.

Table 2. Proposed parameters of the TESLA/HERA e/p collider.

Center-of-mass energy [GeV]	905
p-bunch charge $N_p[10^{11}]$	2
# p-bunches in HERA	110
bunch spacing Δt_b [ns]	192
p-beam norm. emittance $\epsilon_{x,y}[10^{-6}$ m]	2, 0.2
IBS growth time [h]	$\approx$2
p-beam $\beta_{x,y}(=\sigma_z)$ at IP [m]	0.2, 0.2
p-beam energy spread σ_p/p	2×10^{-4}
e-bunch charge $N_e[10^{10}]$	2.5
beam size at IP $\sigma_{x,y}[\mu m]$	21, 6.8
p-beam tune shift ΔQ	0.002, 0.007
Luminosity $[10^{31} cm^{-2} s^{-1}]$	1.3

References

[1] G. Loew (ed.), International Linear Collider Technical Review Committee Report, SLAC-R-95-471, 1995, Internet: www.slac.stanford.edu/xorg/ilc-trc/ilc-trchome.html.

[2] Conceptual Design of a 500 GeV e^+e^- Linear Collider with Integrated X-ray Laser Facility, DESY 97-048 and ECFA 97-182, 1997, Internet: www-mpy.desy.de/lc- cdr/tesla/tesla.html.

[3] P. Grosse-Wiesmann, *Nucl. Instr. Meth.*, **A 274** (1989) 21.

[4] M. Tigner, B.H. Wiik and F. Willeke, Proc. Particle Acc. Conf. San Francisco 1991, Vol. 5, p. 2910.

[5] Z.Z. Aydin, A.K. Çiftçi and S. Sultansoy, *Nucl. Instr. Meth.,* **A 351** (1994) 261.

[6] A. Piwinski, Intrabeam Scattering, Proc. 9th Int. Conf. High Energy Acc., Stanford 1974.

[7] M. S. Zolotorev and A. A. Zholents, SLAC-PUB-6476 and LBL 35469, 1994.

[8] Y. Derbenev and A. N. Skrinsky, On Electron Cooling at High Energy, Novosibirsk preprint 79-87, 1979.

[9] D. Cline *et al.*, *IEEE Trans. Nucl. Science*, **NS 26** (1979) 3472.

[10] R. Brinkmann and M. Dohlus, DESY-M-95-11, 1995.

- current ↗ if 250 GeV = 2 · 125 GeV
- dynamic focussing to reduce β_p^*
- p cooling with 2h cooling time

high Lumi at TESLA requires machine R&D.

– "competition" –

⊕ ELFE cf. P. Hoyer hep-ph/9911486 (99.)

Electron Laboratory for Europe

high intensity, continuous electron beam with good energy resolution at 15..30 GeV

"using the HERA ring as a stretcher for achieving a high duty factor"

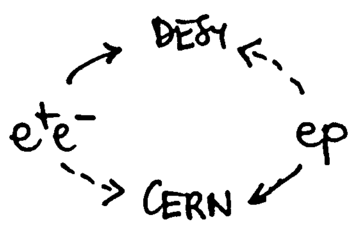
R. Brinkmann et al.
NP A622 (1997) 187c

also ELFE @ CERN
with LEP rf. cavities.

⊕ PETRA as synchrotron radiation facility.

– alternative –

⊕ LEP(?) · LHC $\sqrt{s} \simeq 1.6$ TeV. asymmetric luminosity.



--- 20 years ago

— ?

i believe it is worth a serious effort

and a duty if one looks back to the

big efforts of the previous generation to

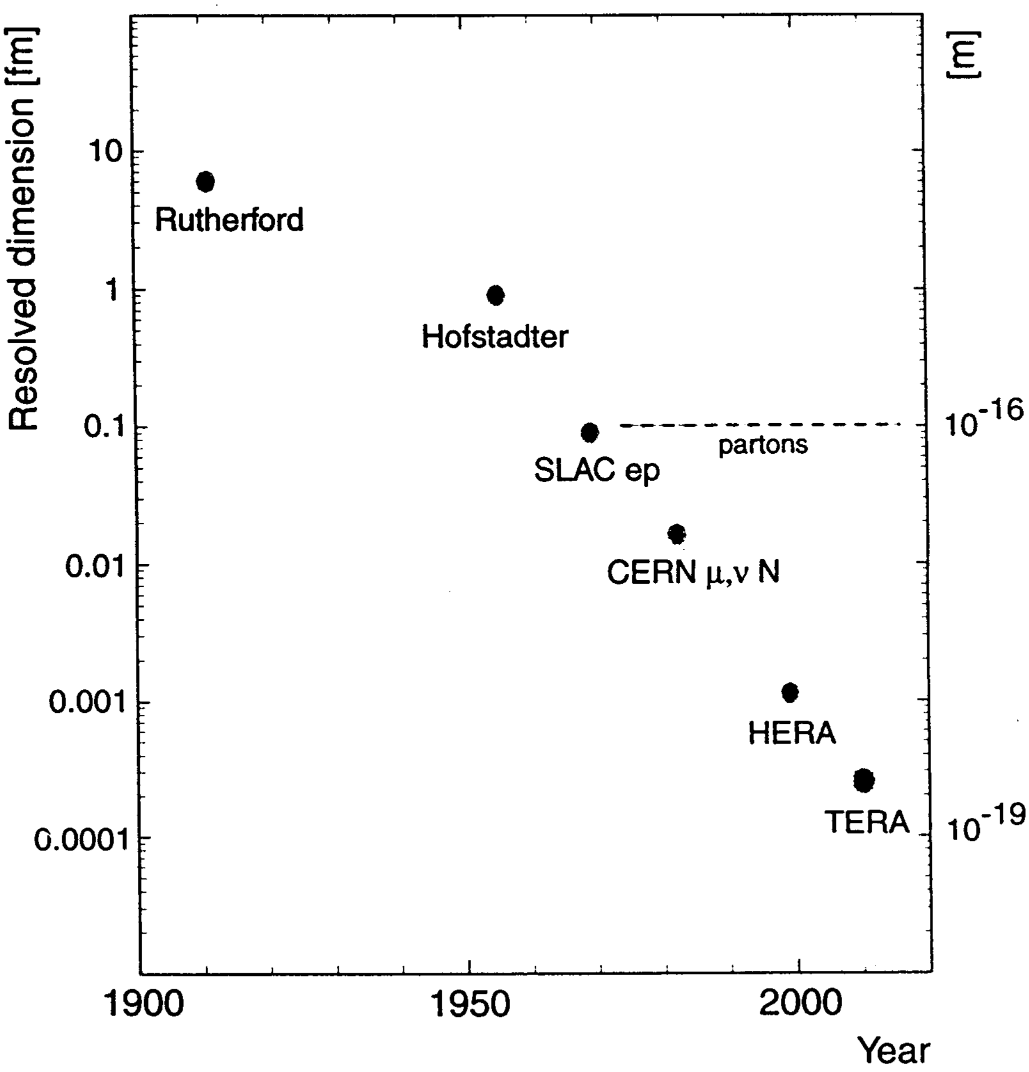
ensure a future of our science and of

lepton-nucleon scattering physics in particular.

needs not less ingenuity than Thera

had when settling on a mountain with

water 400m below.



everything beyond 2010 means later than expected

organization

+ 8/9.2. 2000 initial meeting

  physics, subdivision in groups, how to reach our goal to ensure a future for ep physics

  5. sided copies by tomorrow!

+ spring / prior to DIS 2000 *)

  informal, open workshop at ... date ...

  *) cf.
  A.De Roeck DIS98
  Y. Sirois DIS99.

+ October 2000

  "ep Physics with THERA" workshop

+ December 2000 or January 2001

  "ep Physics with THERA" written report of enough pages and contribution to Technical Design Report for TESLA.