LHeC

towards a Conceptual Design Report for a Large Hadron Electron Collider at CERN

5-140 GeV on 1-7 TeV $e^{\pm}p$, also eA

Max Klein
University of Liverpool and Cockcroft Institute
H1 and ATLAS

Physics

Machine

Detector

DRAFT 27.10.

Report on an **ongoing** ECFA-CERN study (2007-2009)
on behalf of the LHeC Steering Group.
ICFA Seminar, SLAC, Stanford, October 29, 2008
http://www.lhec.org.uk

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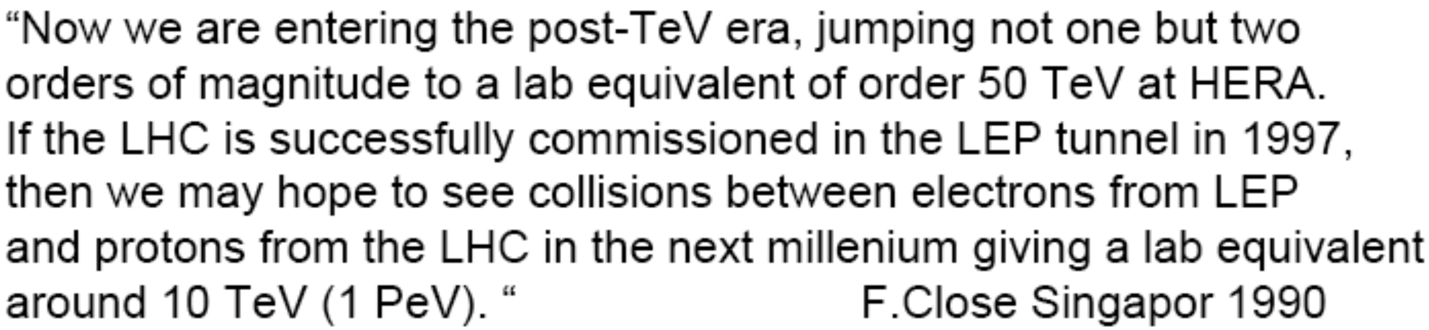
ep with the LHC

three ECFA CERN Studies

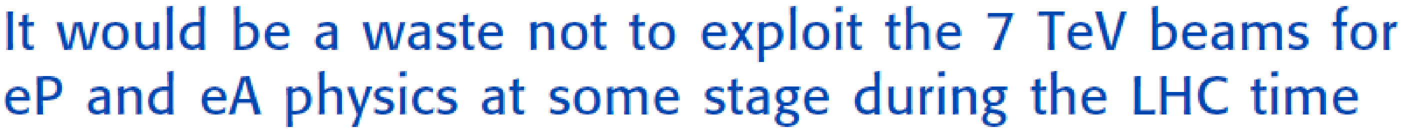
If a hadron collider will be built in the LEP tunnel then ep collisions are really a must

G.Altarelli et al, **Lausanne LHC Workshop 1984**, Proc. p549



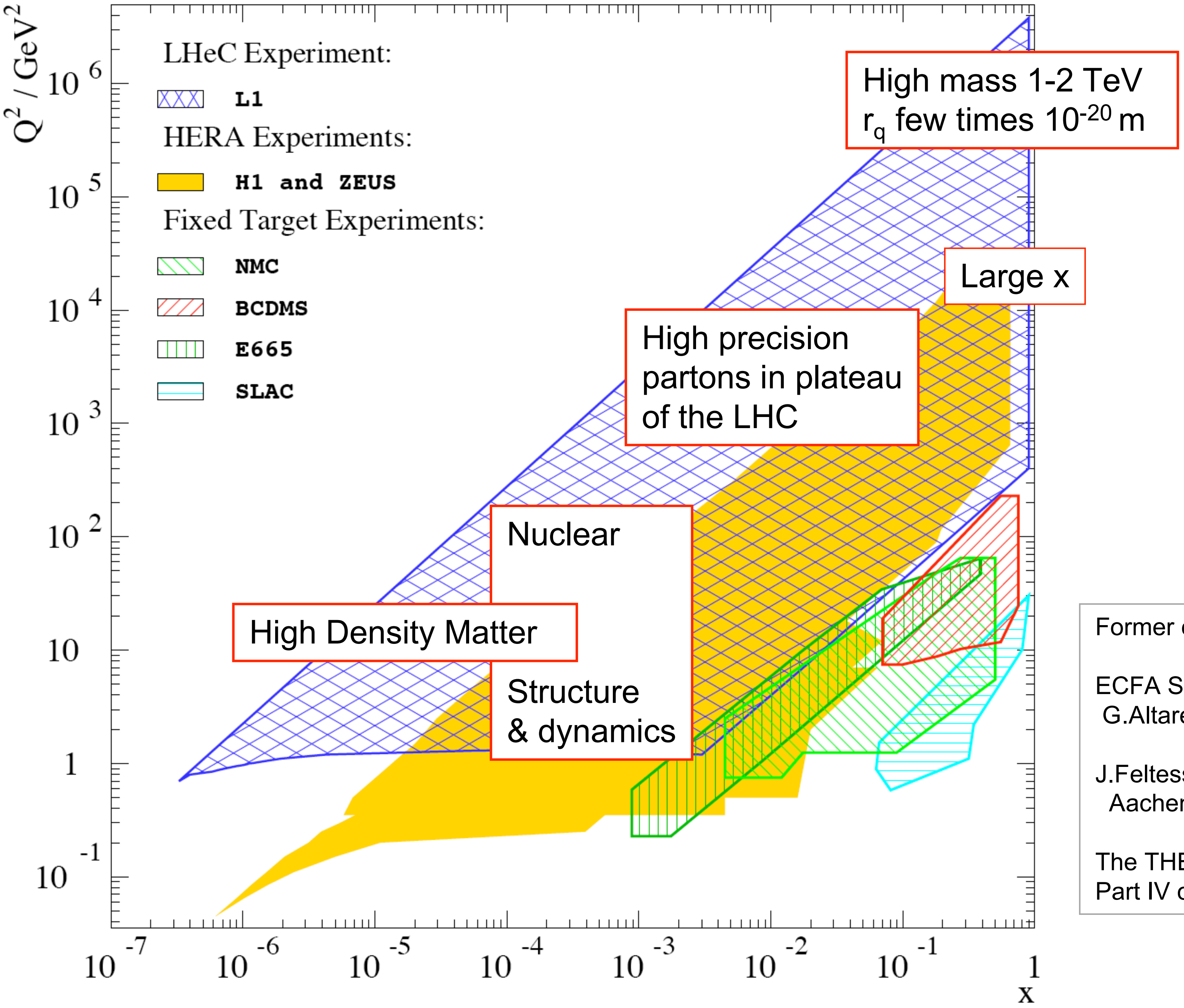
“Now we are entering the post-TeV era, jumping not one but two orders of magnitude to a lab equivalent of order 50 TeV at HERA. If the LHC is successfully commissioned in the LEP tunnel in 1997, then we may hope to see collisions between electrons from LEP and protons from the LHC in the next millenium giving a lab equivalent around 10 TeV (1 PeV). “ F.Close Singapor 1990

Aachen Workshop 1990



It would be a waste not to exploit the 7 TeV beams for eP and eA physics at some stage during the LHC time

G.Altarelli et al, **Divonne LHeC Workshop 2008**



High mass 1-2 TeV
r_q few times 10^{-20} m

Large x

High precision
partons in plateau
of the LHC

Nuclear

High Density Matter

Structure
& dynamics

Former considerations:

ECFA Study 84-10
G.Altarelli et al.

J.Feltesse, R.Rueckl et al.
Aachen Workshop (1990)

The THERA Book (2001)&
Part IV of TESLA TDR

Max Klein LHeC ICFA08

Towards the CDR by 2009

Scientific Advisory Committee

Guido Altarelli (Rome)
Stan Brodsky (SLAC)
Allen Caldwell -chair (MPI Munich)
Swapan Chattopadhyay (Cockcroft)
John Dainton (Liverpool)
John Ellis (CERN)
Jos Engelen (CERN)
Joel Feltesse (Saclay)
Lev Lipatov (St.Petersburg)
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Guenter Rosner (Glasgow, NuPECC)
Alexander Skrinsky (Novosibirsk)
Anthony Thomas (Jlab)
Steven Vigdor (BNL)
Frank Wilczek (MIT)
Ferdinand Willeke (BNL)

ECFA + CERN in 11/07
set the task to work out a
CDR within 2 years on the
physics, machine and
detector for a TeV energy
ep collider based on the LHC

DIS workshops since 2005.
ECFA-CERN: Divonne - 9/08.

Steering Group

Oliver Bruening	(CERN)
John Dainton	(Cockcroft)
Albert DeRoeck	(CERN)
Stefano Forte	(Milano)
Max Klein - chair	(Liverpool)
Paul Newman	(Birmingham)
Emmanuelle Perez	(CERN)
Wesley Smith	(Wisconsin)
Bernd Surrow	(MIT)
Katsuo Tokushuku	(KEK)
Urs Wiedemann	(CERN)

1st ECFA-CERN Workshop on the LHeC

Divonne, 1-3.9.2008

Accelerator Design [RR and LR]

Oliver Bruening (CERN), John Dainton (Cockcroft/Liverpool)

Interaction Region and Forward/Backward Detectors

Bernhard Holzer (DESY), Uwe Schneeekloth (DESY), Pierre van Mechelen (Brussels)

Detector Design

Peter Kostka (DESY), Rainer Wallny (UCLA), Alessandro Polini (Bologna)

New Physics at Large Scales

Emmanuelle Perez (CERN), Georg Weiglein (Durham)

Precision QCD and Electroweak Interactions

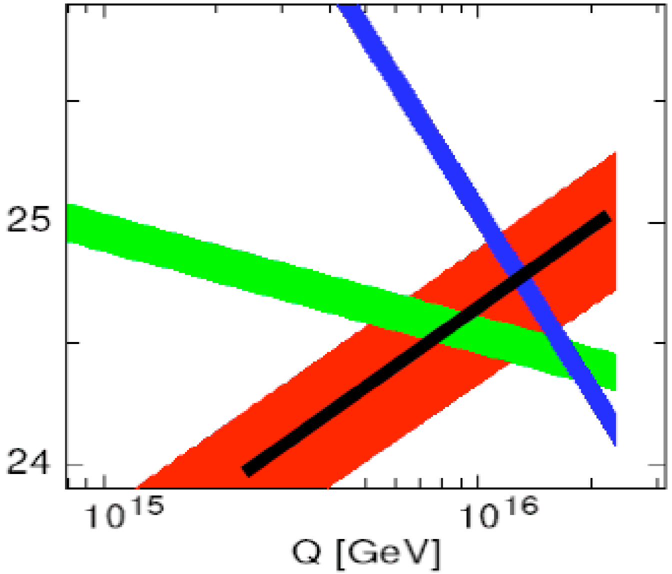
Olaf Behnke (DESY), Paolo Gambino (Torino), Thomas Gehrmann (Zuerich)

Physics at High Parton Densities [small x and eA]

Nestor Armesto (CERN), Brian Cole (Columbia), Paul Newman (B'ham), Anna Stasto (MSU)

Strong Coupling Constant

Simulation of α_s measurement at LHeC



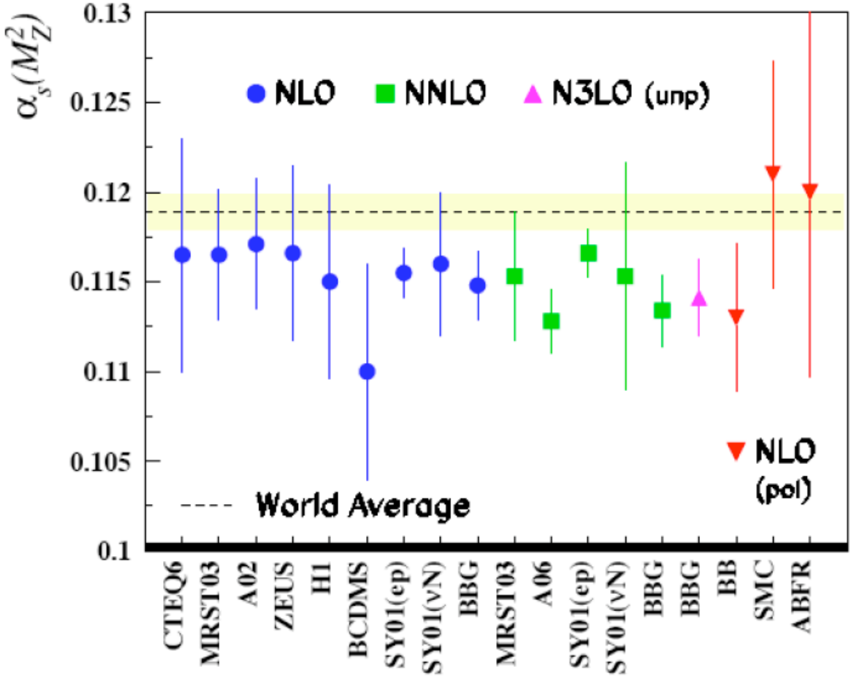
DATA	exp. error on α_s
NC e⁺ only	0.48%
NC	0.41%
NC & CC	**0.23% :=(1)**
(1) γ_h>5°	0.36% :=(2)
(1) +BCDMS	0.22%
(2) +BCDMS	0.22%
(1) stat. *= 2	0.35%

Worst of all measured coupling constants

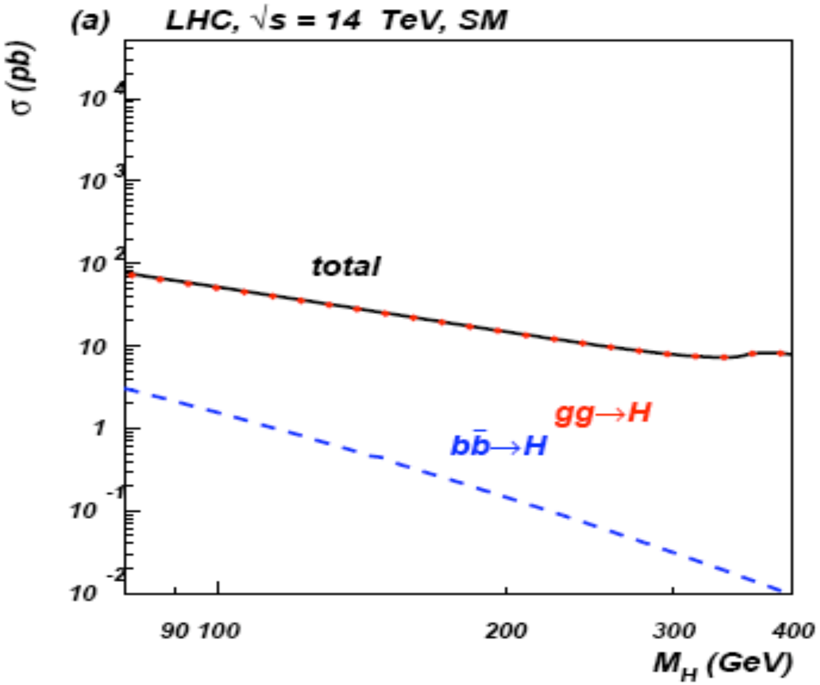
DIS tends to be lower than world average

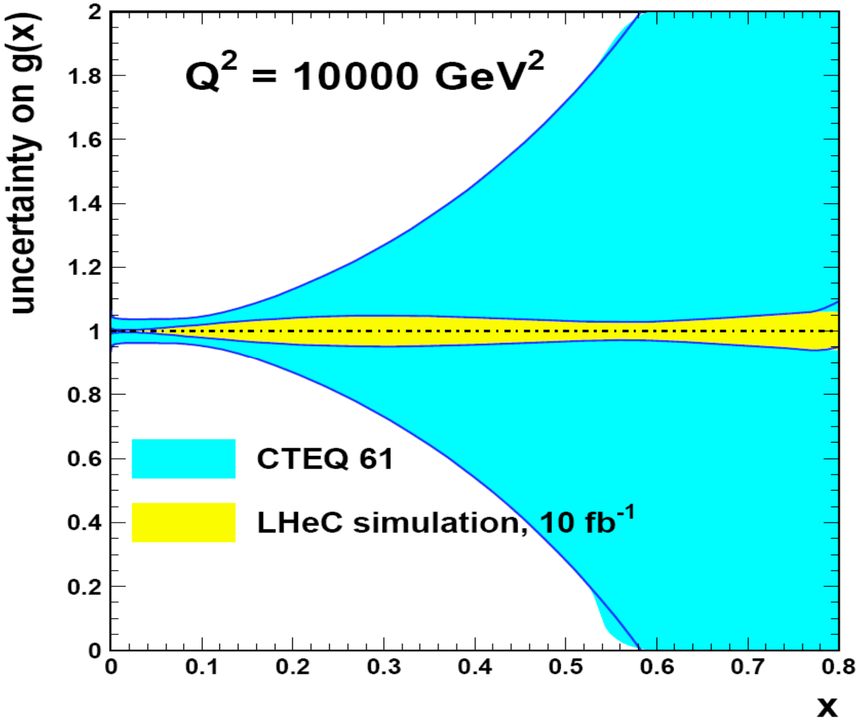
LHeC: per mille accuracy indep. of BCDMS.
Challenge to experiment and to h.o. QCD

Blumlein et al '06



Gluon - SM Higgs

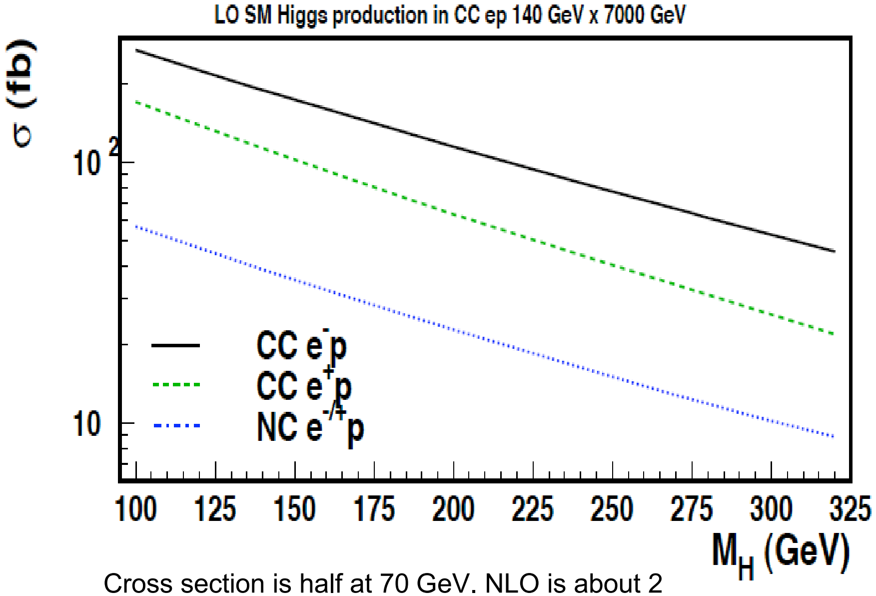




In SM Higgs production is gluon dominated

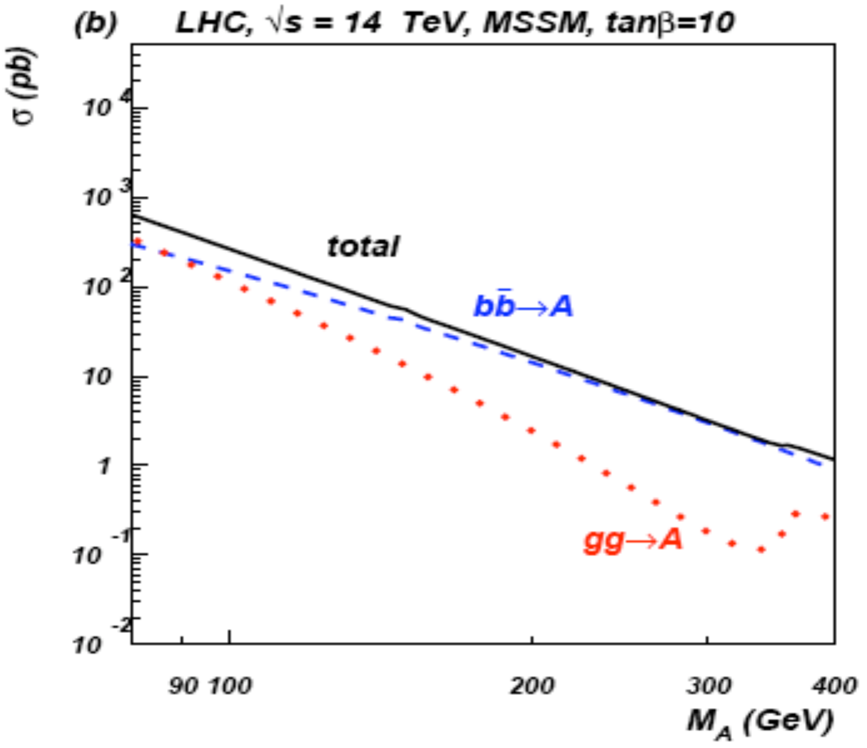
LHeC: huge x,Q^2 range for xg determination

WW to Higgs fusion has sizeable ep xsection



Cross section is half at 70 GeV. NLO is about 2

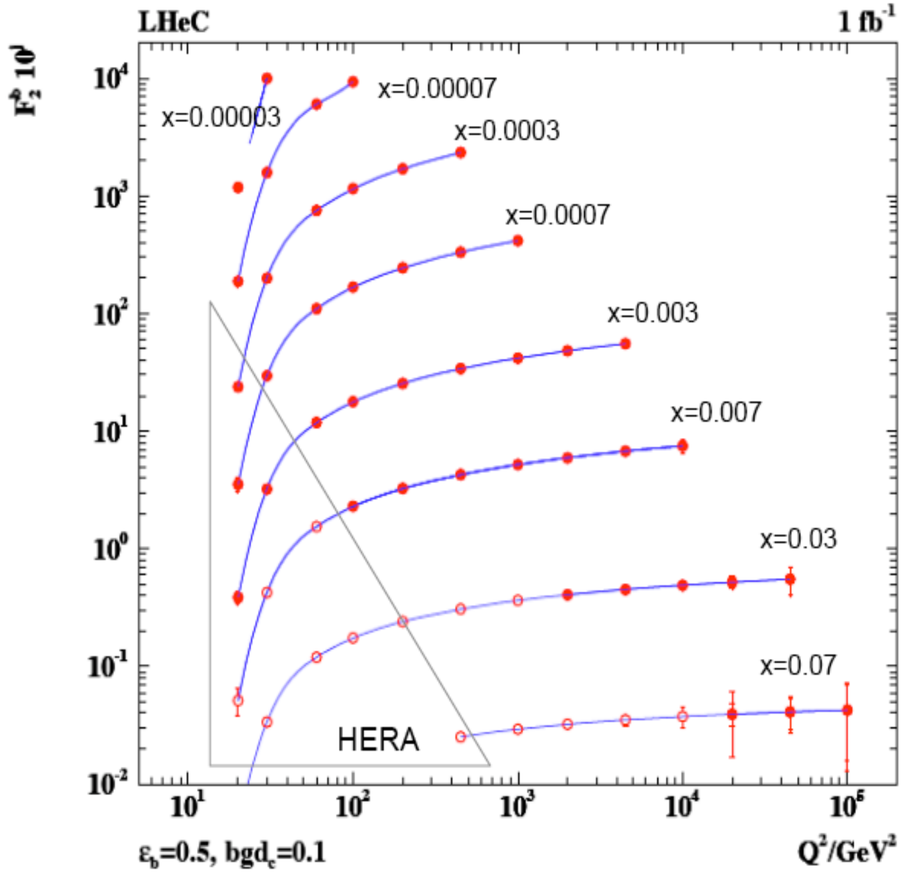
Beauty - MSSM Higgs



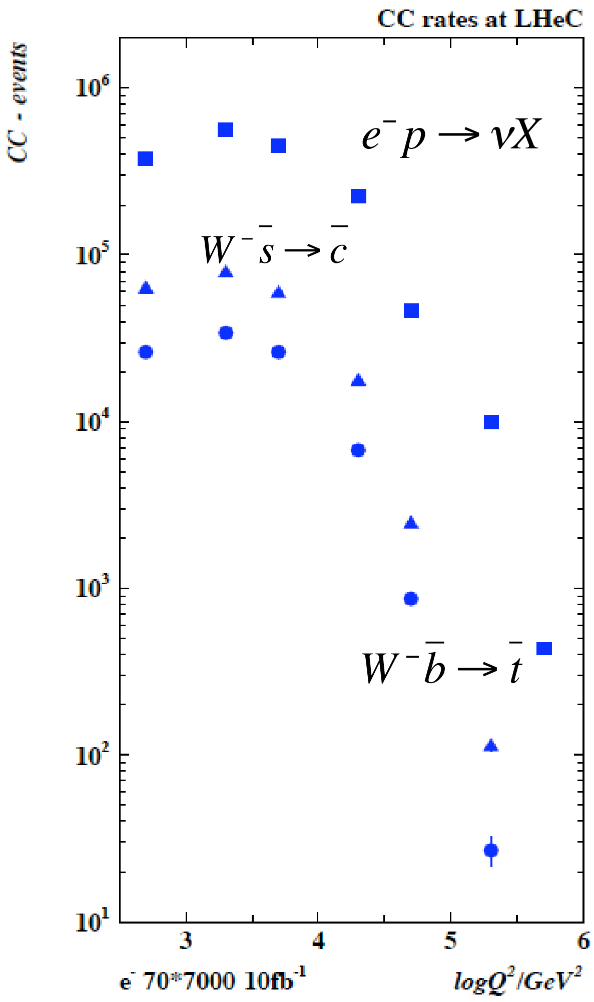
In MSSM Higgs production is b dominated

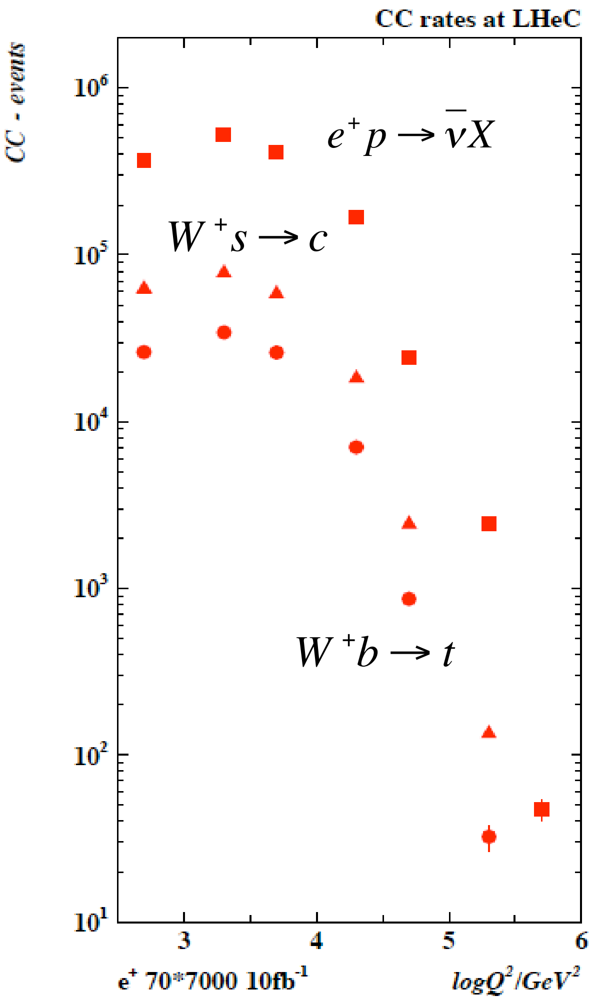
First measurements of b at HERA can be turned to precision measurement of bdf.

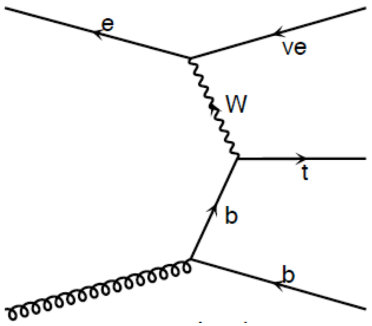
LHeC: higher fraction of b, larger range, smaller beam spot, better Si detectors



(Anti) top and strange production in CC



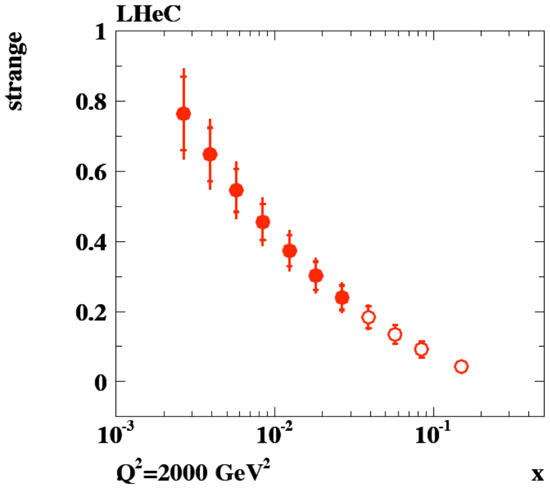




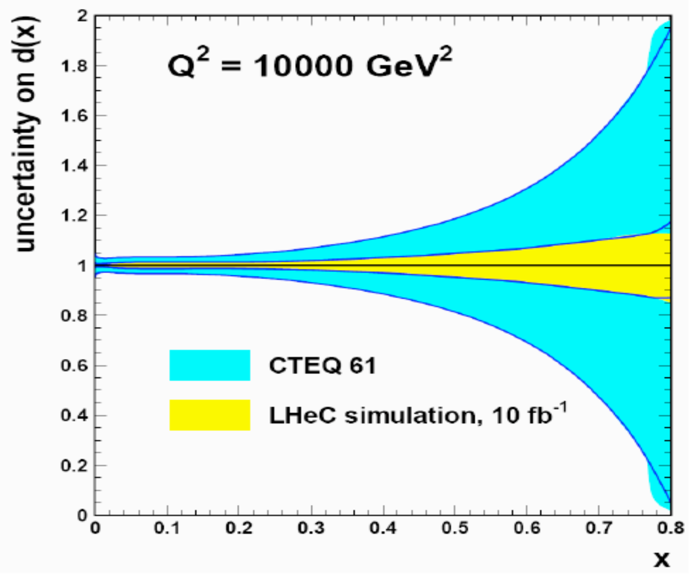
LHeC is a single top and tbar quark factory

CC t cross section O(5)pb

S, sbar-df for the 1st time.



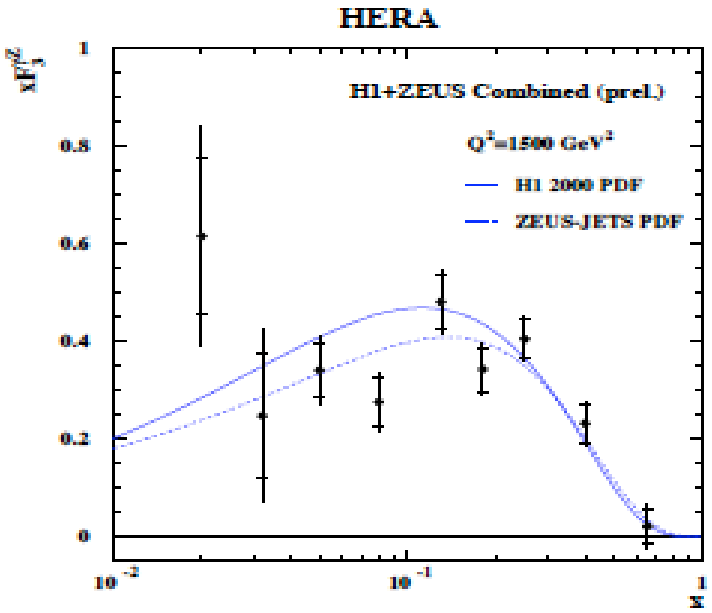
Light Quark Distributions

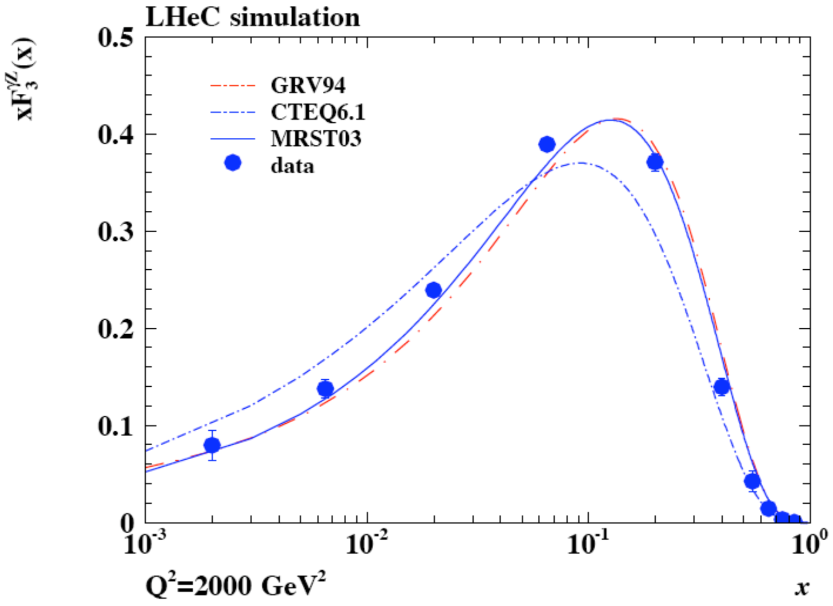


d and u at high x: a longstanding puzzle
NC/CC: free of HT, nuclear corrections.
Essential for predictions at high x

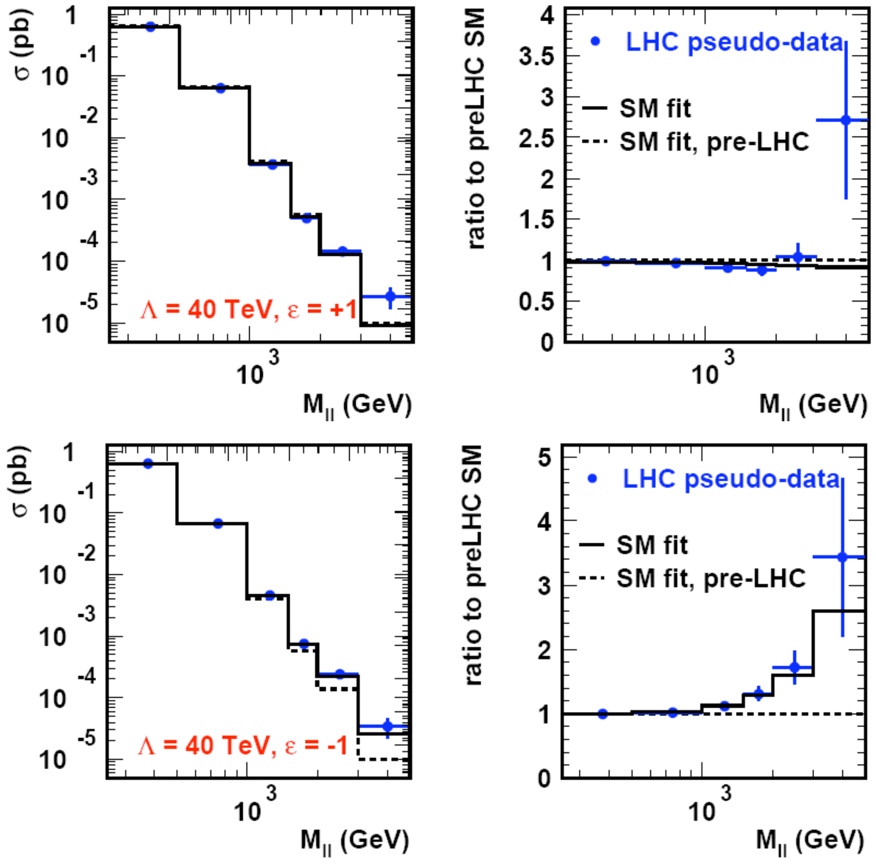
LHeC is an electroweak machine.
e.g.: Charge asymmetry in NC measures
valence quarks down to x ~10^{-3} at high Q^2

$$\boxed{xF_3^{\gamma Z} = \frac{x}{3}(2u_v + d_v)}$$

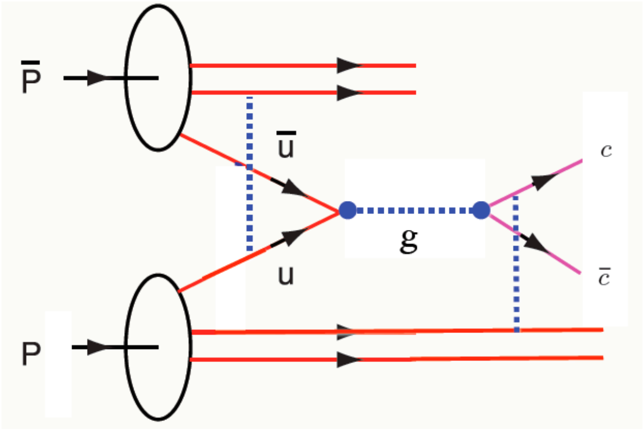




pdf’s and new physics at the LHC

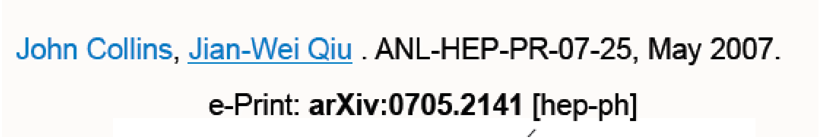


Blue & red data points = NP scenario (Λ= 40 TeV)
Black curve = SM cross-sections
NP may be accommodated by HERA/BCDMS DGLAP fit. It can not by the fit to also LHeC.
(recall high Et excess at the Tevatron which disappeared when xg became modified)



Factorisation is violated in production of high p_T particles (IS and FS i.a.s).

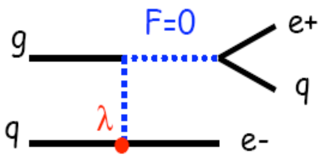
Important, perhaps crucial, to measure pdf’s in the kinematic range of the LHC. cf also ED limits vs pdf’s.

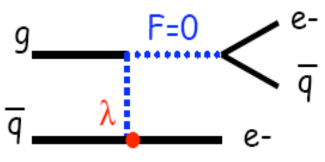


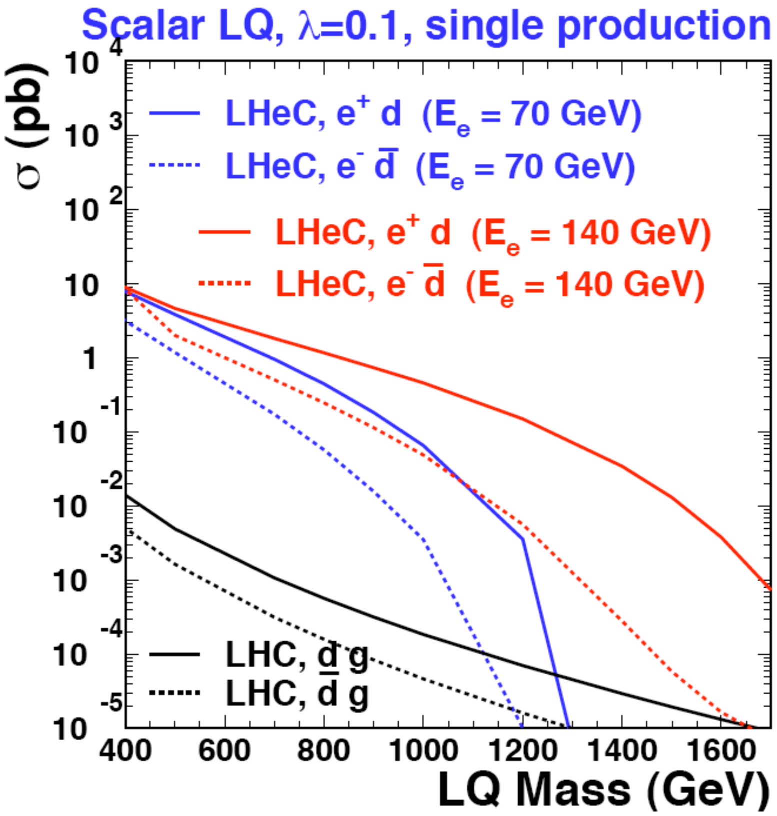
John Collins, Jian-Wei Qiu . ANL-HEP-PR-07-25, May 2007.

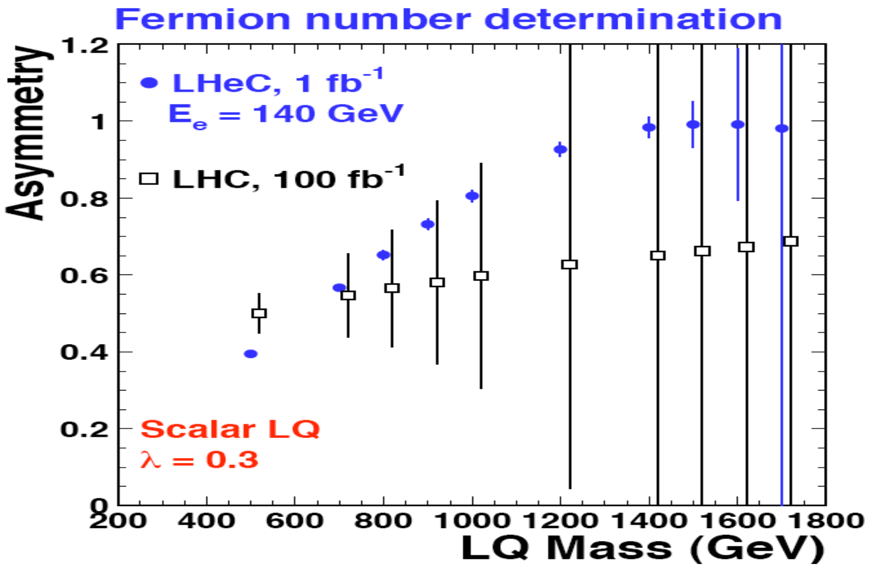
e-Print: **arXiv:0705.2141** [hep-ph]

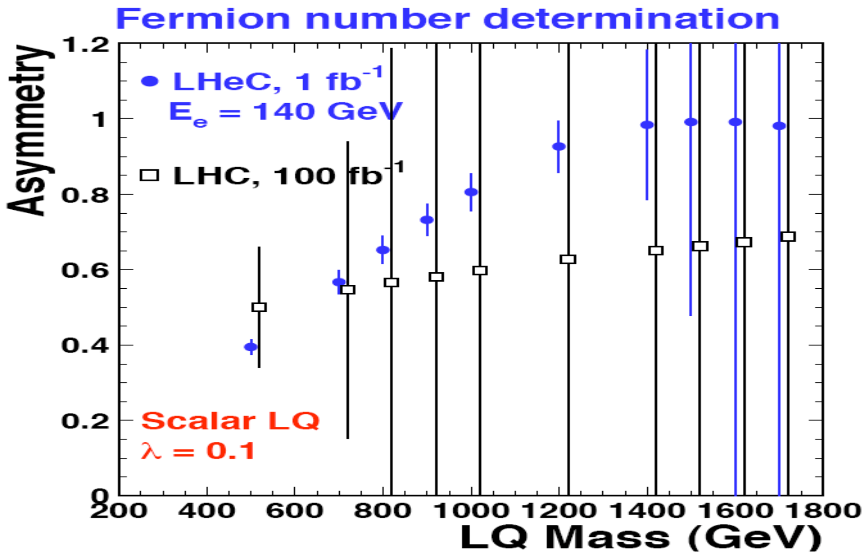
LQ Quantum Numbers





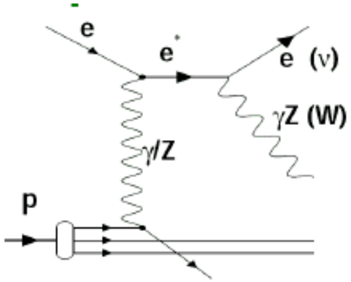


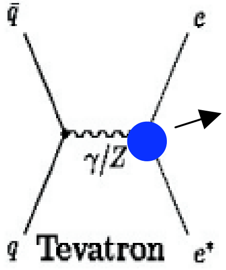




Charge asymmetry much cleaner in ep than in pp. Similar for simultaneous determination of coupling and quark flavour

Electron-Boson Resonances : excited electrons



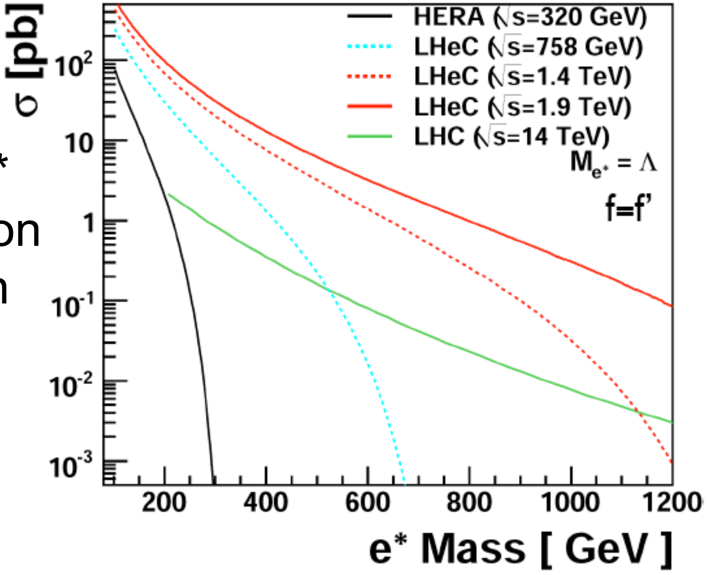


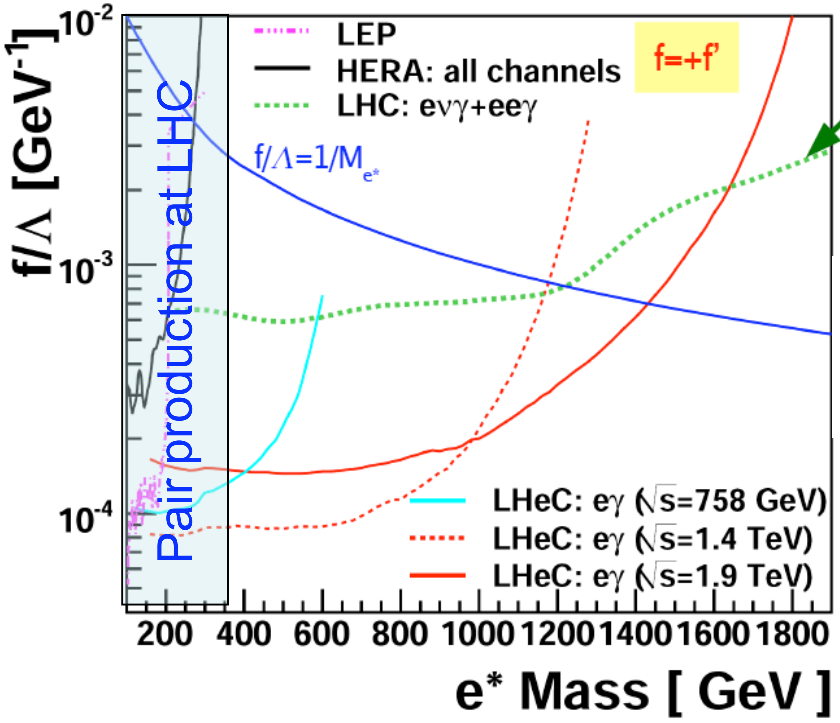
coupling
~ f / Λ

[Hagiwara et al. ZPC 29(1985)115]

[Boudjema et al. ZPC 57(1990)425]

Single e* production x-section





[Phys. Rev D 65 (2002) 075003]

LHeC prelim. analysis, looking at e* → eγ

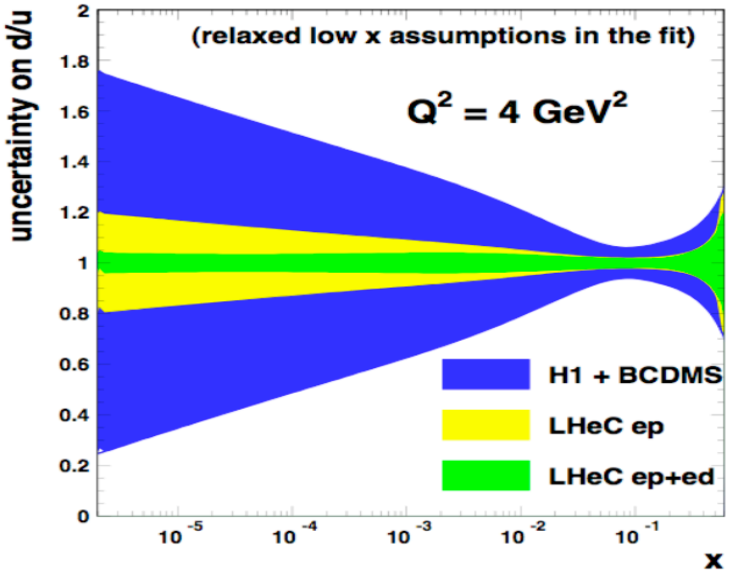
- If LHC discovers (pair prod) an e*: LHeC would be sensitive to much smaller f/Λ couplings
- Discovery potential for higher masses

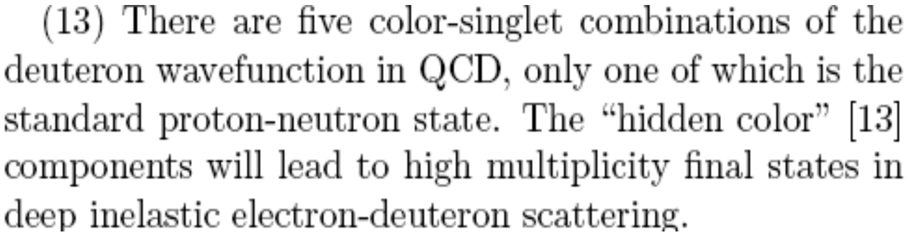
LHeC sensitivity,
with L=10 fb^{-1} for Ee=70/20 GeV
with L=1 fb^{-1} for Ee=140 GeV

N. Trinh, E. Sauvan

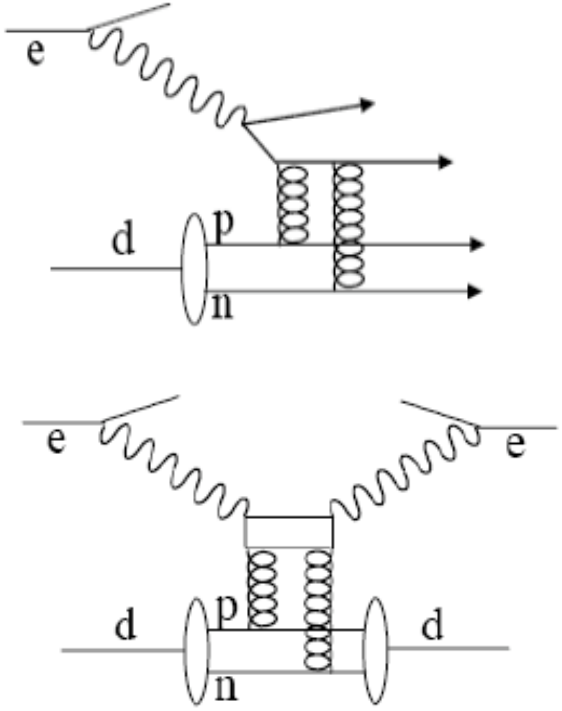
Neutron Structure (ed → eX)

d/u at low x from deuterons



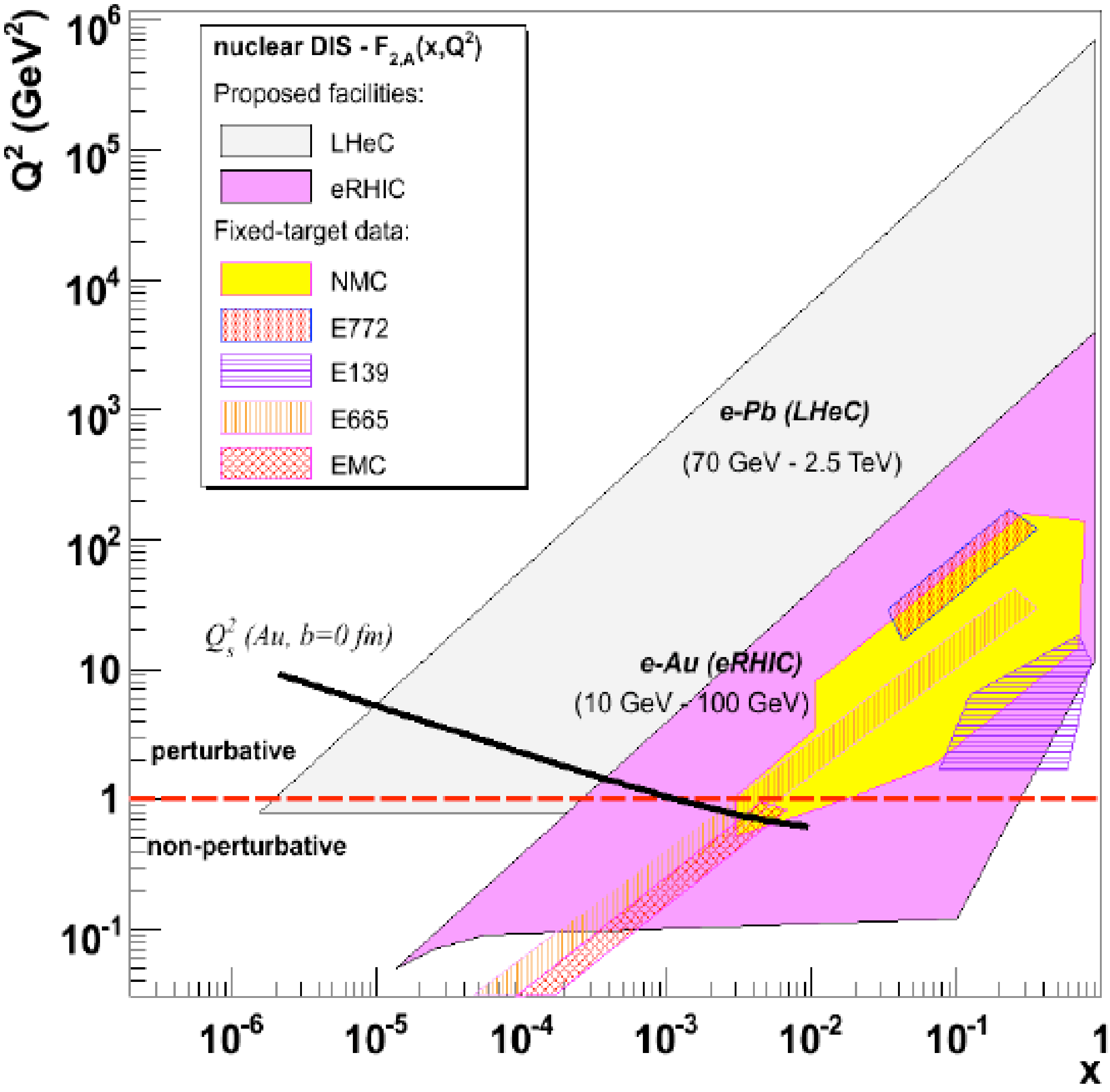

(13) There are five color-singlet combinations of the deuteron wavefunction in QCD, only one of which is the standard proton-neutron state. The "hidden color" [13] components will lead to high multiplicity final states in deep inelastic electron-deuteron scattering.

crucial constraint on evolution (S-NS), improved α_s



In eA at the collider, test Gribovs relation between shadowing and diffraction, control nuclear effects at low Bjorken x to high accuracy

DdE, arXiv:0706.4182



DIS eA Kinematics

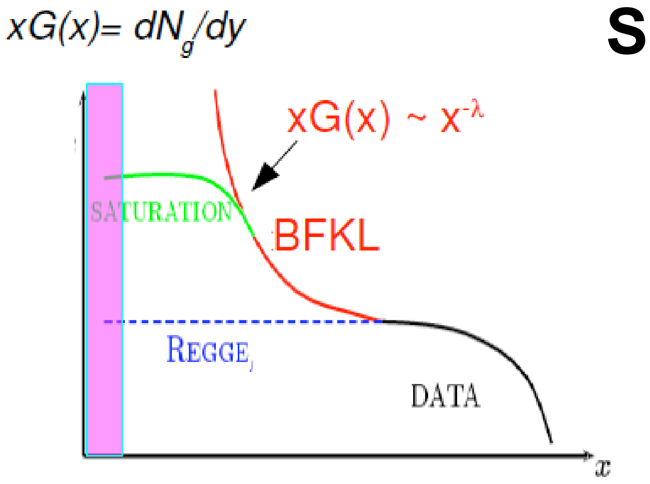
LHeC extends kinematic range of partonic structure of nuclei by 3-4 orders of magnitude.

It accesses saturation effects at low x in DS region.

eRHIC with nuclei could be complementary.

LHeC-A appears natural complement and possible extension of ALICE physics programme.

Saturation?

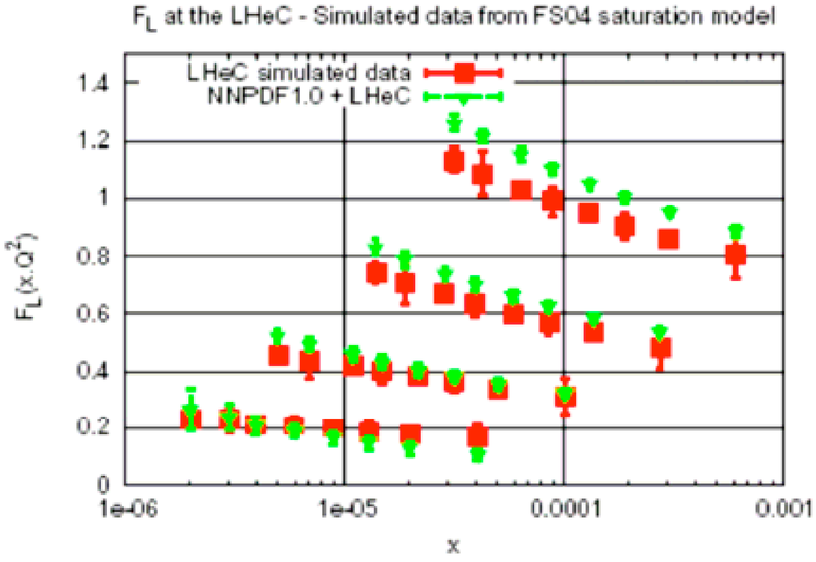


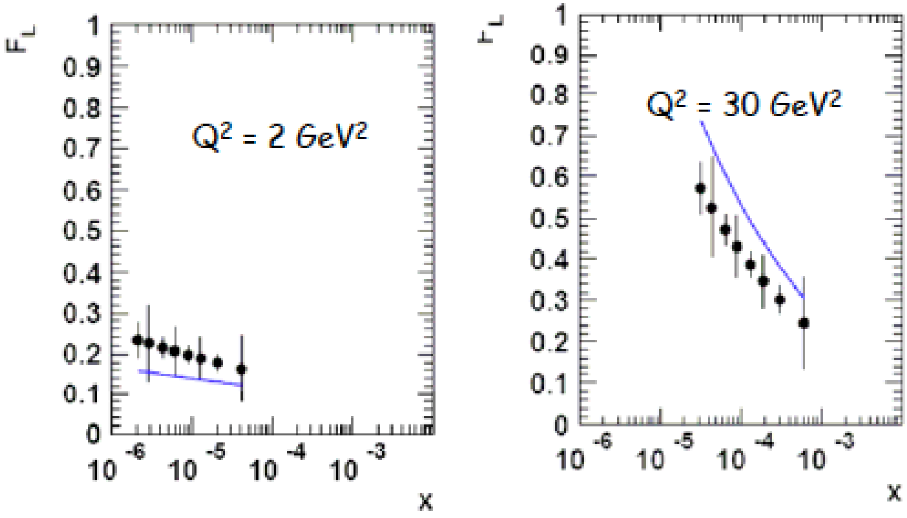
Cross sections shall saturate because of unitarity.
(notice link to superhigh energy neutrino physics)

A new phase of matter:
density high but coupling is small (CGC).

HFS, fwd jets, unintegrated pdf's, diffraction, F_L
The dynamics at low x is not settled with HERA
(energy too small, no nuclei)

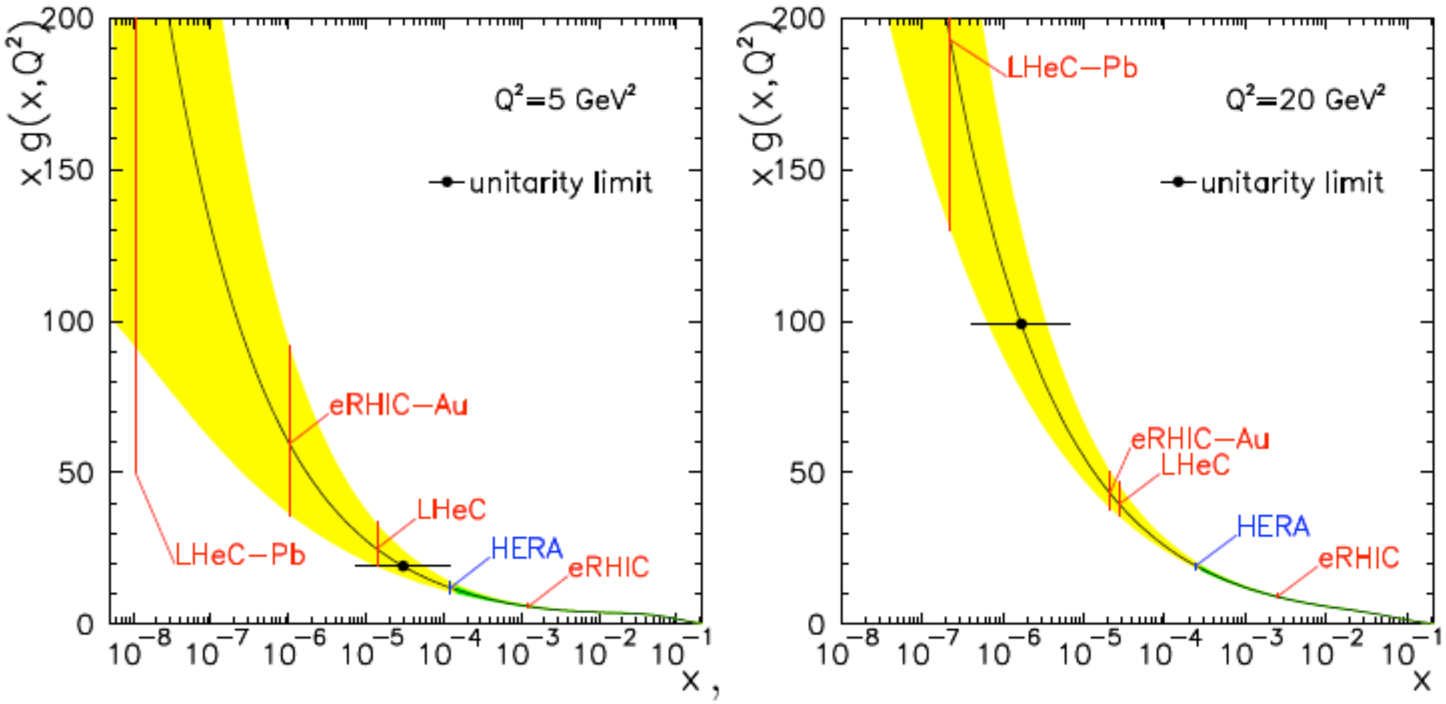
LHeCsat data in NNPDF1.0





Measurements of F_2 and F_L at LHeC should allow to establish saturation in DIS range

Nuclei - gluon density amplification



High density

$$\frac{g_A/\pi r_A^2}{g_p/\pi r_p^2} = A^{1/3}\frac{g_A}{A g_p}$$

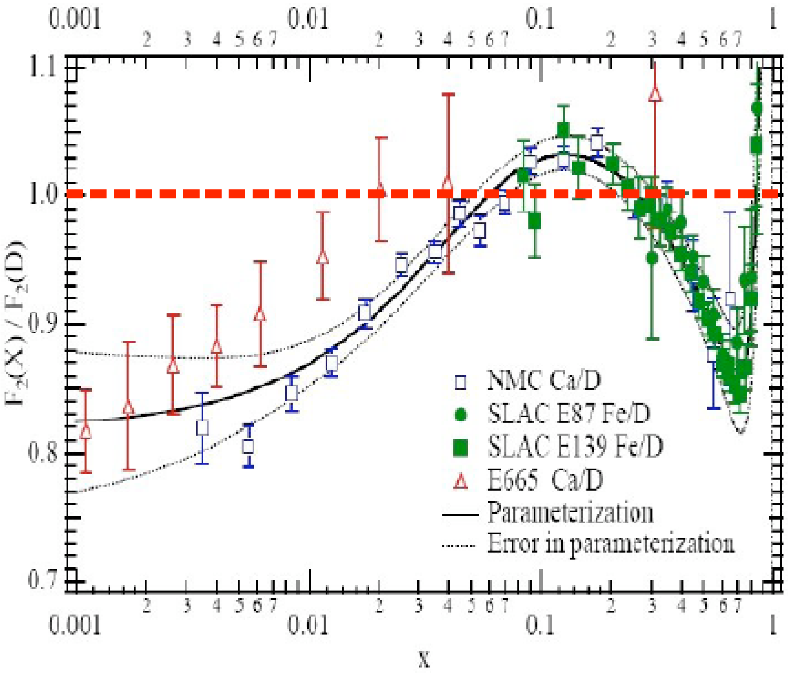
Unitarity

$$\boxed{xg(x,Q^2) \le \frac{1}{\pi N_c \alpha_s(Q^2)} Q^2 R^2 \simeq \frac{Q^2}{\alpha_s}}$$

Striking effects predicted:

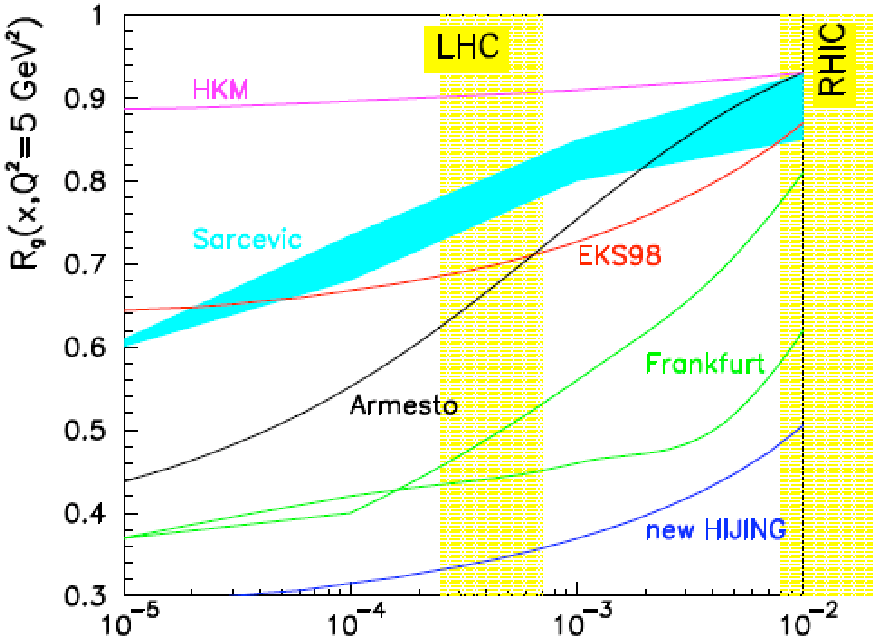
Bj → black disc limit $F_2 \sim Q^2 \ln(1/x)$
~50% diffraction
colour opacity, change of J/Ψ(A) …

Need eA collider data to determine nuclear parton distributions in the kinematic range of ion collisions at the LHC



See e.g. M.Arneodo

Phys. Rept. 240 (94) 301



K.Eskola et al. JHEP 0807 (08)102

Saturation - Black Hole Duality.?

4d Perturbative QCD

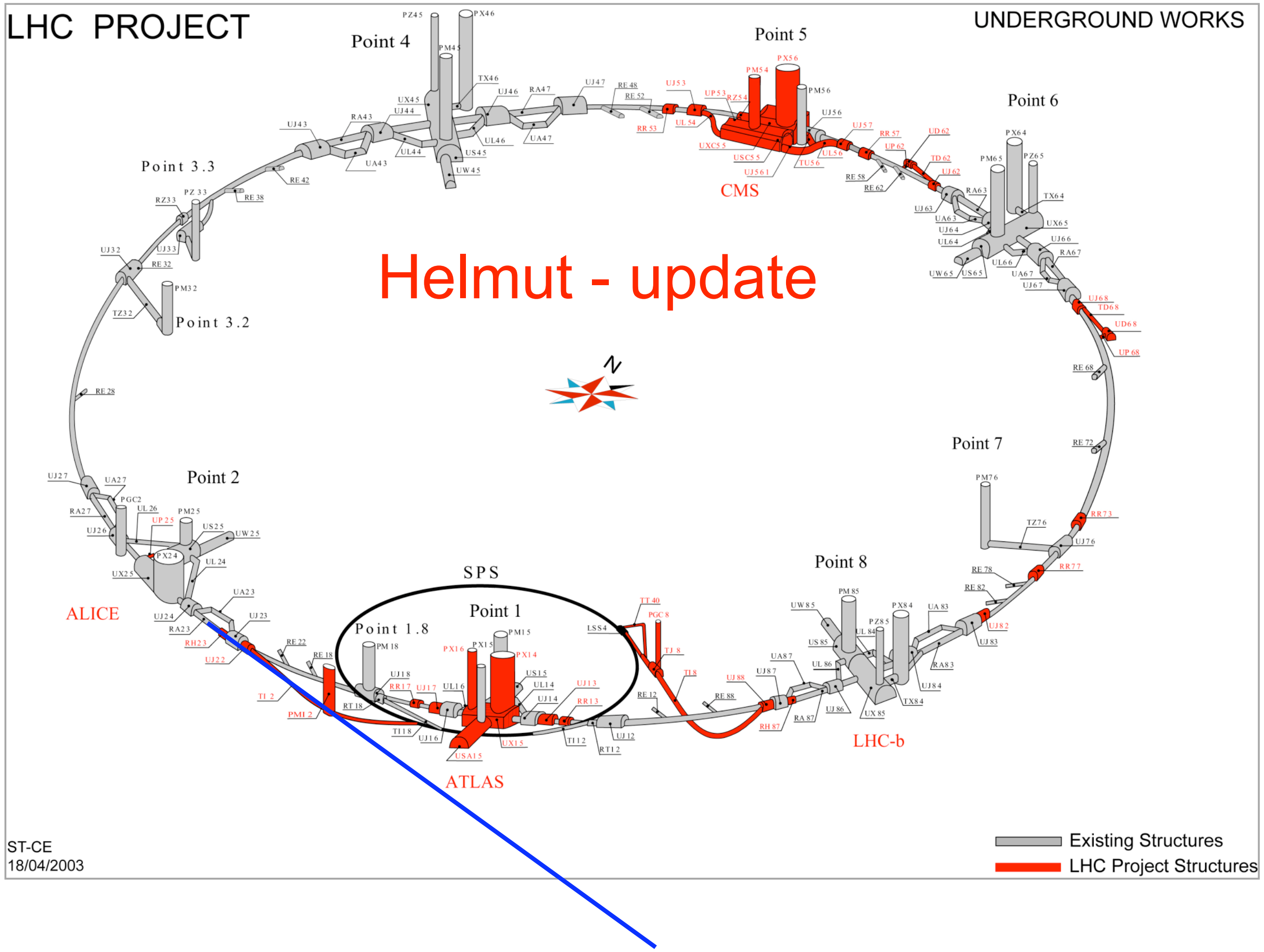
1. Dilute/dense transition
2. Geometric scaling
3. Critical exponent 2.44
4. IR/UV competition

5d Tiny Black hole

1. Flat/black hole transition
2. CSS
3. Critical exponent 2.58
4. Gravity/kinetic competition

Agustin Sabio Vera (Divonne)

Machine Considerations and Studies



Helmut - update

generalities

simultaneous ep and pp

power limit set to 100MW

IR at 2 or 8

p/A:

SLHC - high intensity p
(LPA/50ns or ESP/25ns)

Ions: via PS2
new source for deuterons

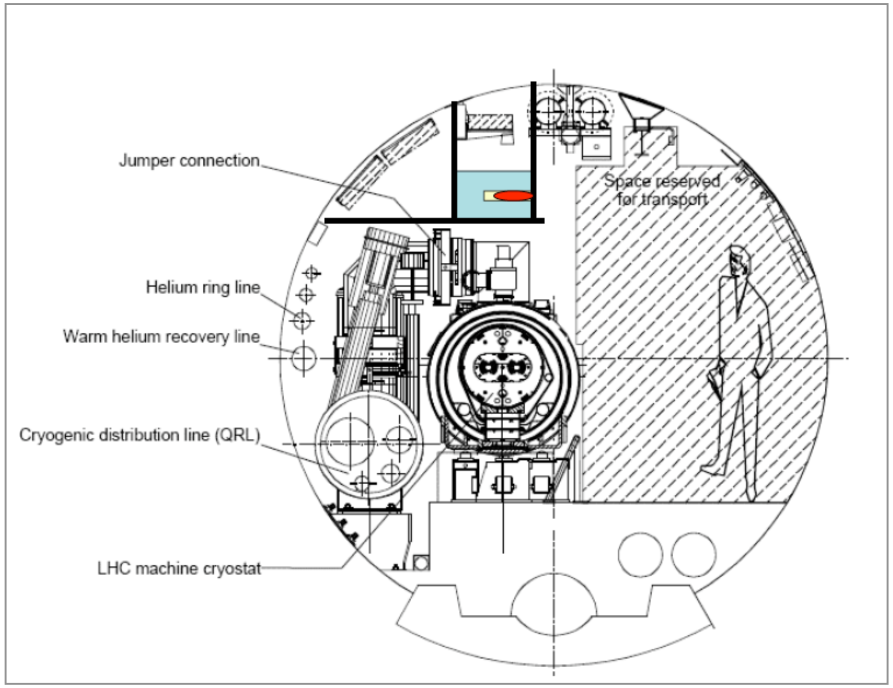
e Ring:

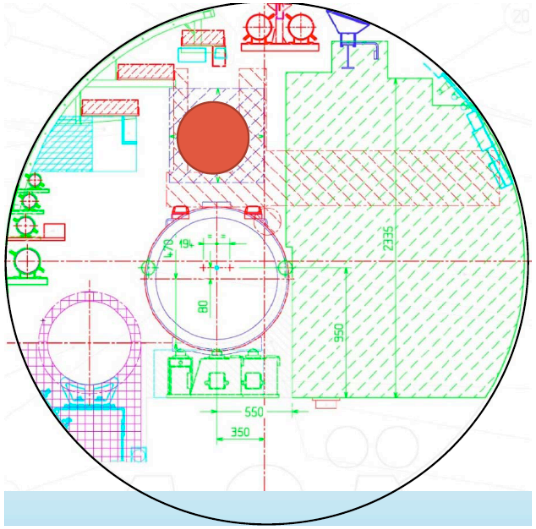
bypasses: 1 and 5
[use also for rf]

injector: SPL, or dedicated

e LINAC:

limited to ~6km (Rhone)
for IP2, longer for IP8
CLIC/ILC tunnel.?





e Ring Further Considerations

Mount e on top of p - feasible at first sight
needs further, detailed study of pathway

Installation: 1-2 years during LHC shutdowns.
LEP installation was ~1 year into empty tunnel.
Radiation load of LHC pp will be studied.

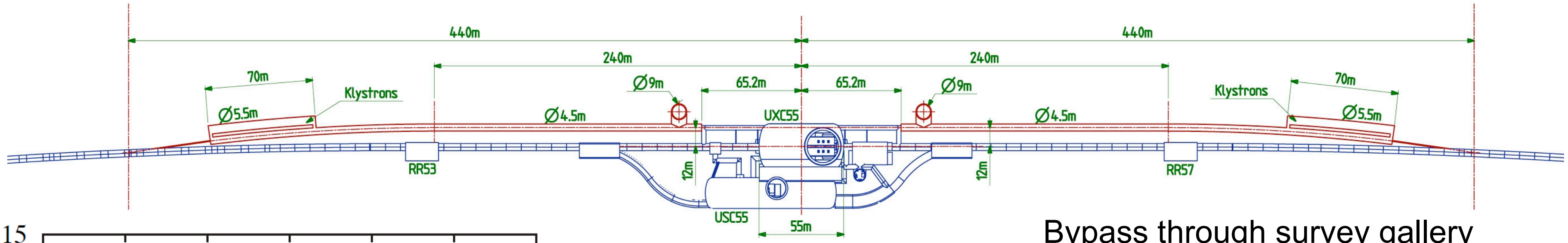
Injection:
LEP2 was 4 10^{11} e in 4 bunches
LHeC is 1.4 10^{10} in 2800 bunches
may inject at less than 20 GeV.

Power for 70 (50) GeV E_e fits into bypasses:

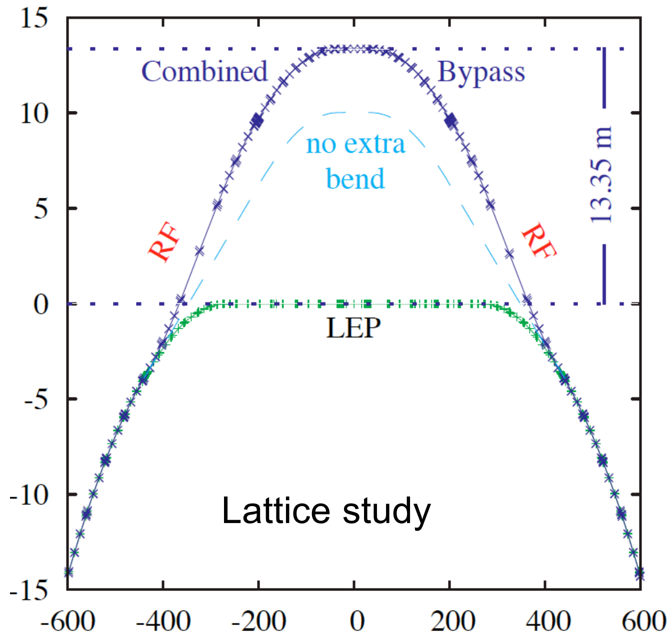
SC system at 1.9° K (1 GHz)
r.f. coupler to cavity: 500 kW CW - R+D
9 MV/cavity.
100(28) cavities for 900(250)MV
cavity: beam line of 150 (42) m
klystrons 100 (28) at 500kW
plus 90 m racks ..
gallery of 540 (150) m length required.

Bypass

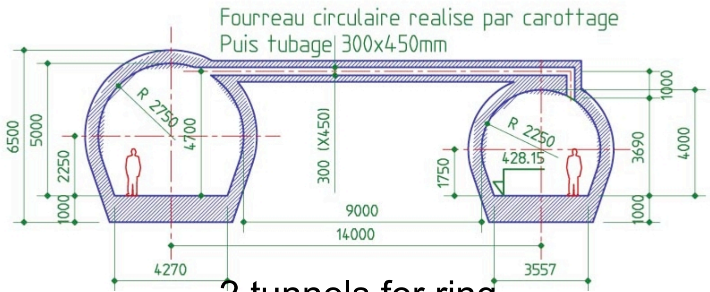
point 5



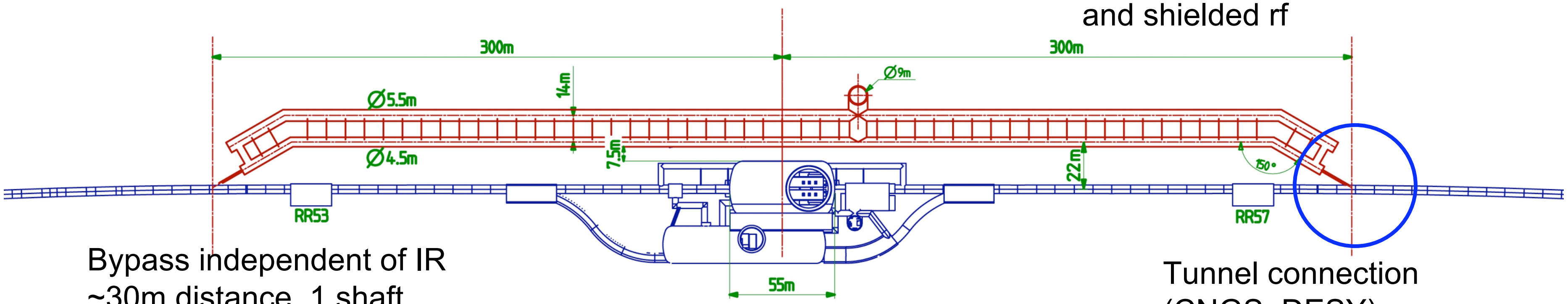
Bypass through survey gallery
13m distance, 2 shafts



Lattice study



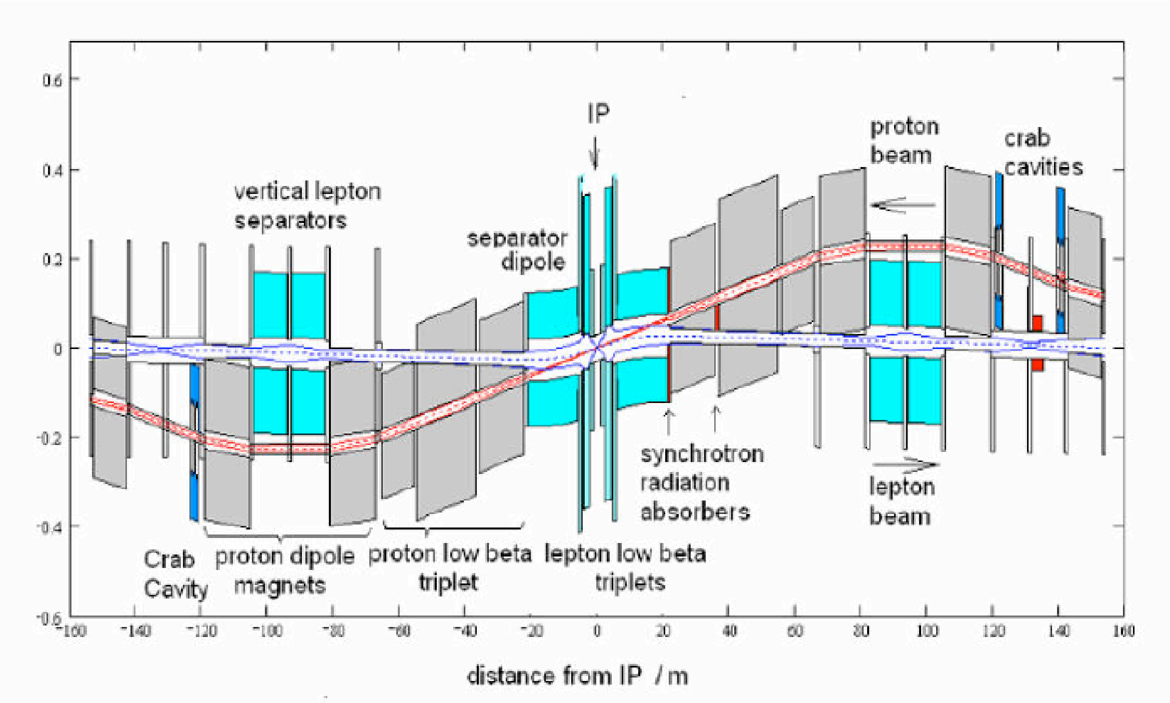
2 tunnels for ring
and shielded rf



Bypass independent of IR
~30m distance, 1 shaft

Tunnel connection
(CNGS, DESY)

IR Design



builds on F.Willeke et al, 2006 JINST 1 P10001

simultaneous ep and pp operation.
design for 70 GeV on 7000 GeV

Need low x (1°) and hi L (10° ?)

Separation (backscattering)

Synchrotron radiation (100 keV E_{crit})

Crab cavities
(profit from LHC developments)

e optics and beam line

p optics

Magnet designs for IR

S shaped IR for Linac-Ring option.

…

Input/experience from
HERA, LHC, ILC, eRHIC, SUPER-B

Luminosity: Ring-Ring

$$L = \frac{N_p \gamma}{4\pi e \varepsilon_{pn}} \cdot \frac{I_e}{\sqrt{\beta_{px}\beta_{py}}} = 8.3 10^{32} \cdot \frac{I_e}{50mA} \frac{m}{\sqrt{\beta_{px}\beta_{pn}}} cm^{-2} s^{-1}$$

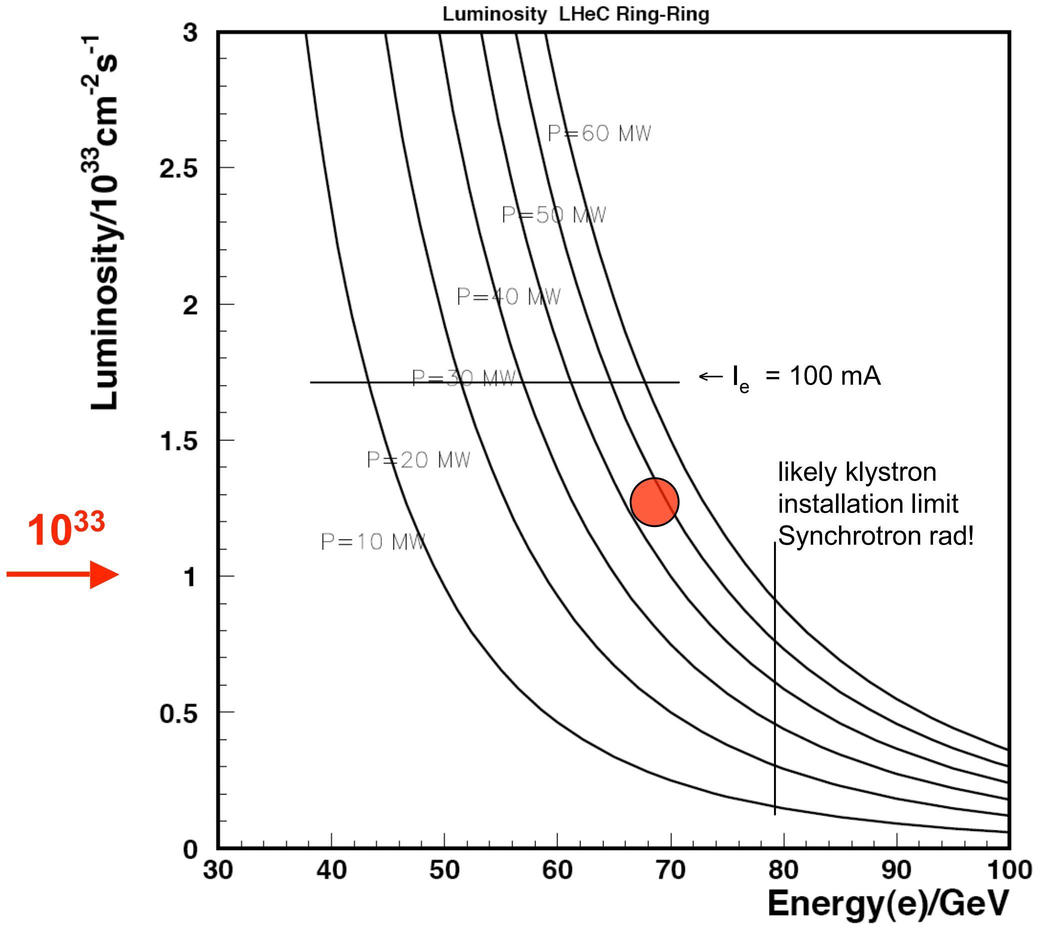
$\varepsilon_{pn} = 3.8 \mu m$

$N_p = 1.1 \cdot 10^{11}$

$\sigma_{p(x,y)} = \sigma_{e(x,y)}$

$\beta_{px} = 1.8m$

$\beta_{py} = 0.5m$



$$I_e = 0.35mA \cdot \frac{P}{MW} \cdot \left(\frac{100GeV}{E_e}\right)^4$$

Power to beam ~ 50 MW:
50 (70) GeV: 4 (1) 10^{33}cm^{-2} s^{-1}
2x larger for ESP (‘ultimate’) beam

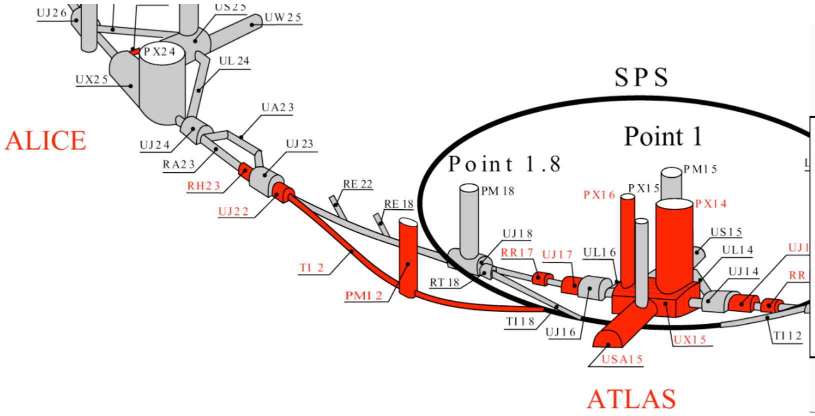
HERA was 1-5 10^{31} cm^{-2} s^{-1}

At E_e=50 GeV: $\int$ L~100 fb^{-1} /a
SLHC: L near to 10^{34}cm^{-2} s^{-1}

Ten times lower than SLHC, but
300 times higher than HERA II
and no pile up ….

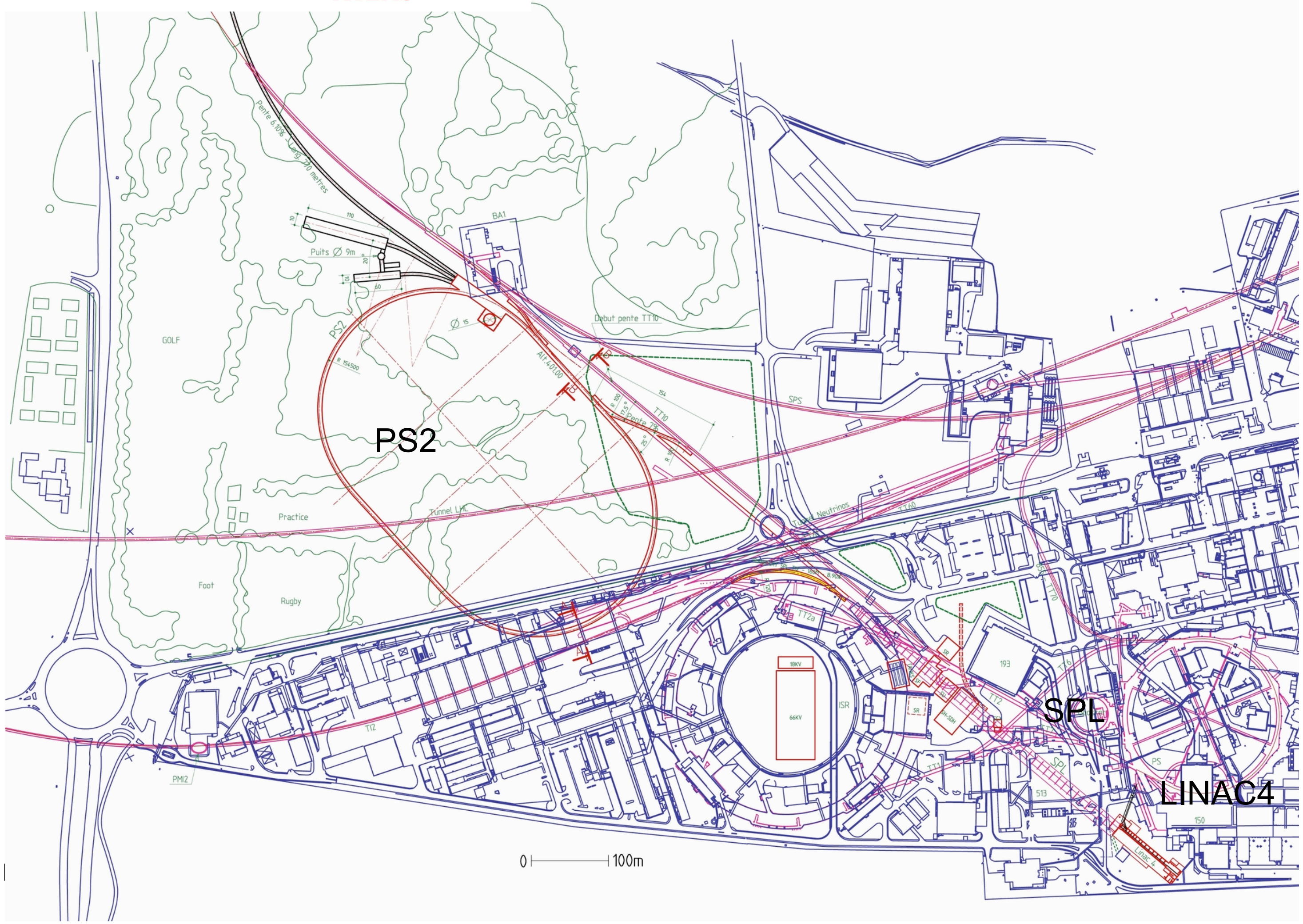
● F.Willeke et al (JINST 2006)

cf also A.Verdier 1990, E.Keil 1986



e injector from SPL to Point 2 via TI2

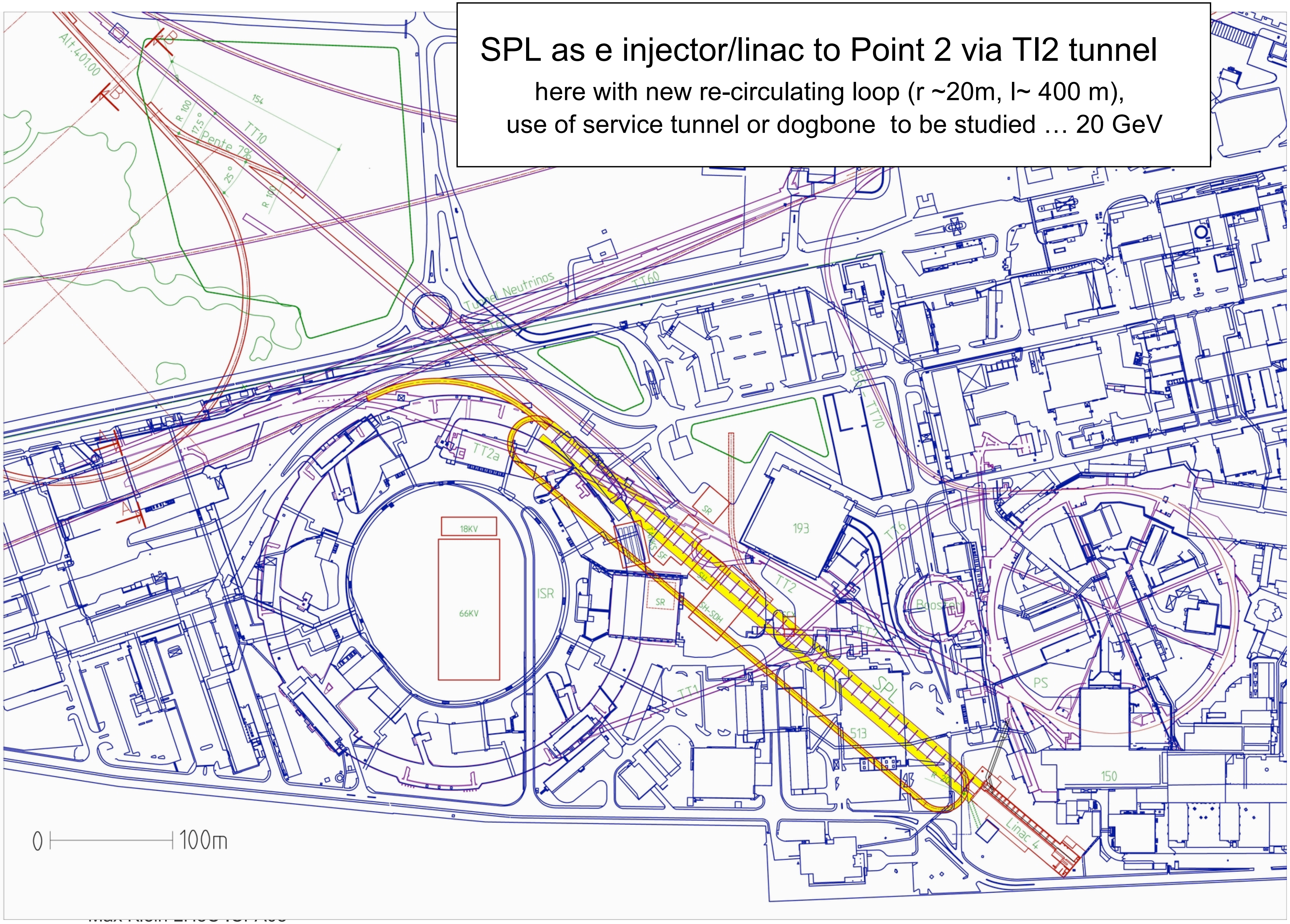
Alternative injectors considered too
(cf H. Burkhard, DIS08, Proceedings)



Max

SPL as e injector/linac to Point 2 via TI2 tunnel

here with new re-circulating loop (r ~20m, l~ 400 m),
use of service tunnel or dogbone to be studied … 20 GeV



Luminosity: Linac-Ring

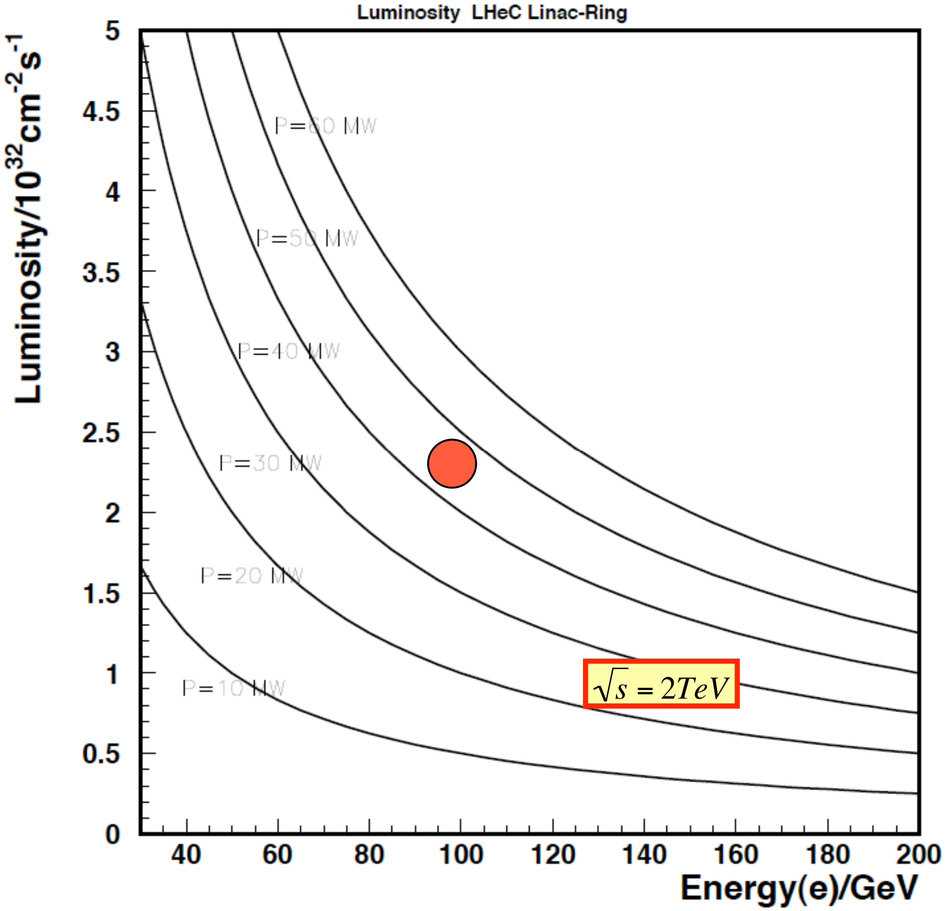
$$L = \frac{N_p \gamma}{4\pi e \varepsilon_{pn} \beta^*} \cdot \frac{P}{E_e} = 5 \cdot 10^{32} \cdot \frac{P/MW}{E_e/GeV} cm^{-2} s^{-1}$$

M.Tigner, B.Wiik, F.Willeke, Acc.Conf, SanFr.(1991) 2910

SLHC - LPA

cf R.Garoby EPS07,
J.Koutchouk et al PAC07

$$\varepsilon_{pn} = 3.8 \mu m$$
$$N_p = 5 \cdot 10^{11}$$
$$\beta^* = 0.10 m$$



LINAC is not physics limited in energy, but will be cost/length + power limited

- ➢10^{32} are in reach at large E_e.

LINAC - no periodic loss+refill,
~twice as efficient as ring…
8,4,3fb^{-1} /year at (50)100[150] GeV

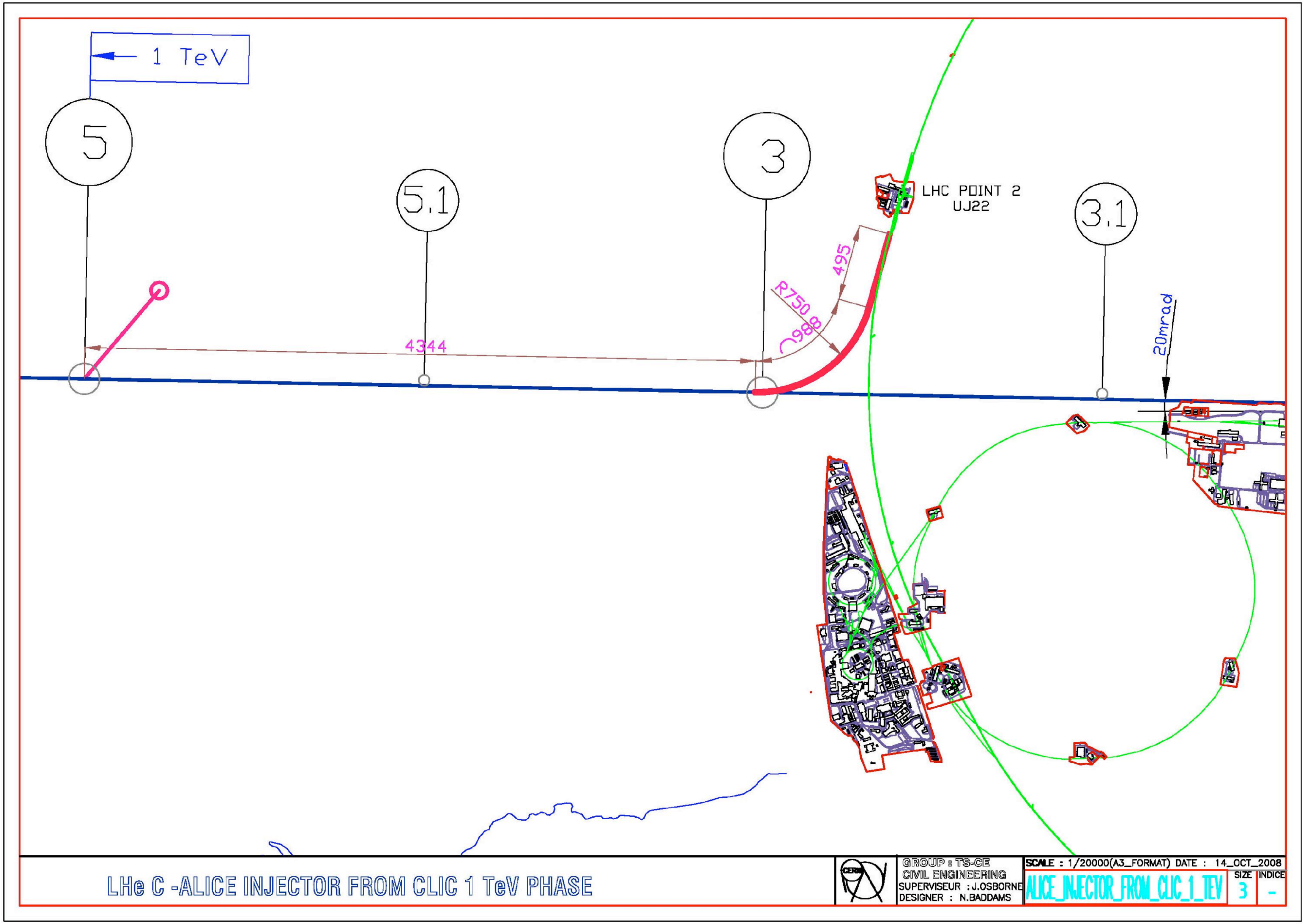
Significantly higher luminosity may be achieved with energy recovery which needs further consideration

Note: positron source challenge:

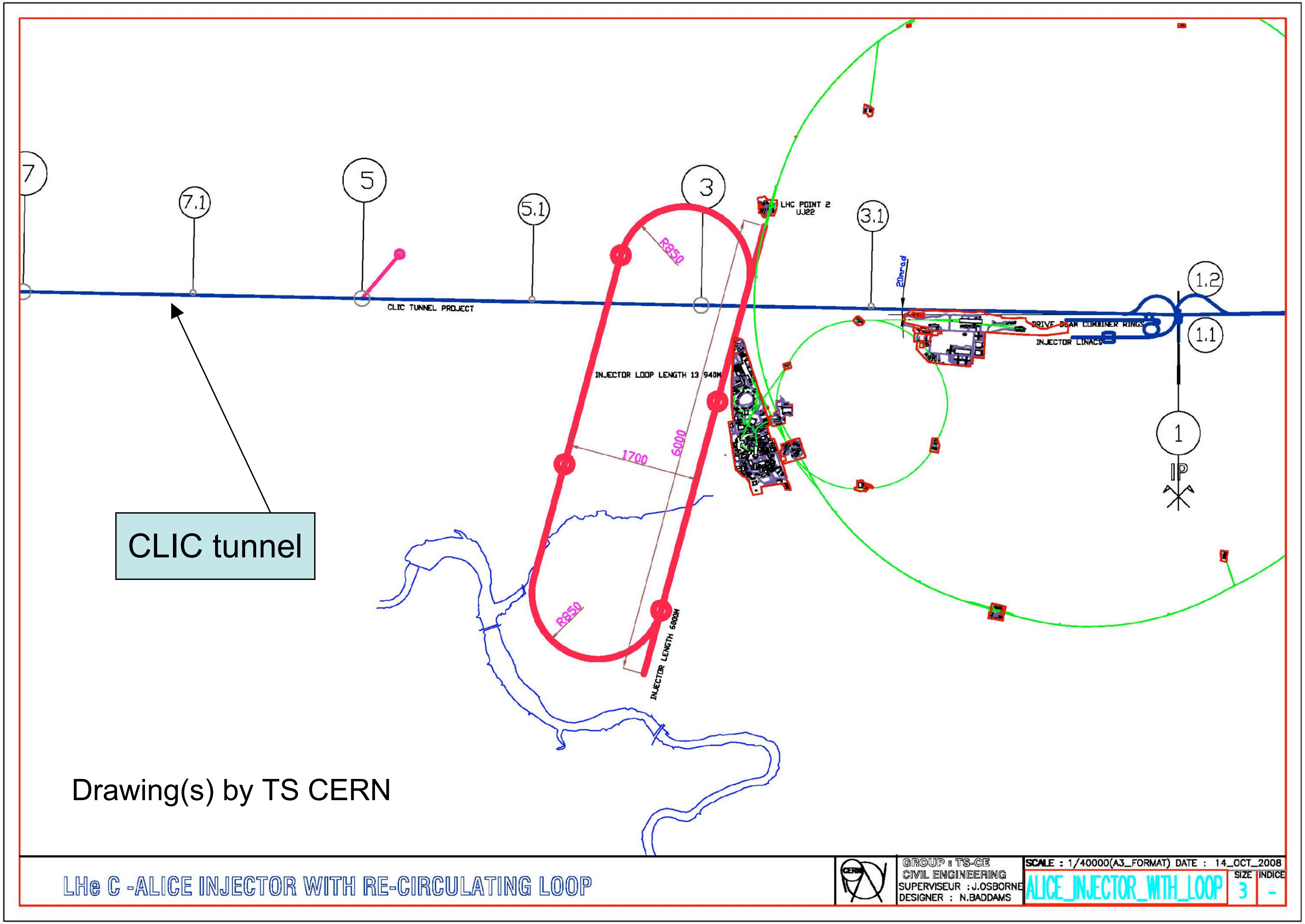
LHeC 10^{32} needs few times 10^{14} /sec

e- energy [GeV]	30	100 ●	100
comment	SPL* (20)+TI2	LINAC	LINAC
#passes	4+1	2	2
wall plug power RF+Cryo [MW]	100 (1 cr.)	100 (3 cr.)	100 (35 cr.)
bunch population [10^9]	10	3.0	0.1
duty factor [%]	5	5	100
average e- current [mA]	1.6	0.5	0.3
emittance $\gamma\varepsilon$ [μm]	50	50	50
RF gradient [MV/m]	25	25	13.9
total linac length β=1 [m]	350+333	3300	6000
minimum return arc radius [m]	240 (final bends)	1100	1100
beam power at IP [MW]	48	48	30
e- IP beta function [m]	0.06	0.2	0.2
ep hourglass reduction factor	0.62	0.86	0.86
disruption parameter D	56	17	17
luminosity [10^{32} cm^{-2} s^{-1}]	**5**	**2.2**	**1.3**

proton parameters: LPA upgrade SLHC: N_b=5x10^{11}, 50 ns spacing, $\gamma\varepsilon$=3.75 μm, β^*=0.1 m, σ_z=11.8 cm

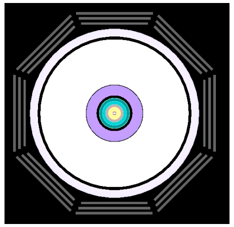


LHe C -ALICE INJECTOR FROM CLIC 1 TeV PHASE

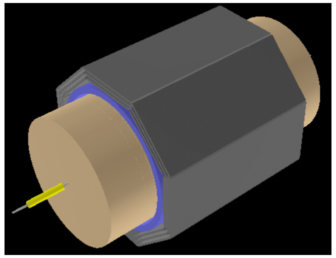


CLIC tunnel

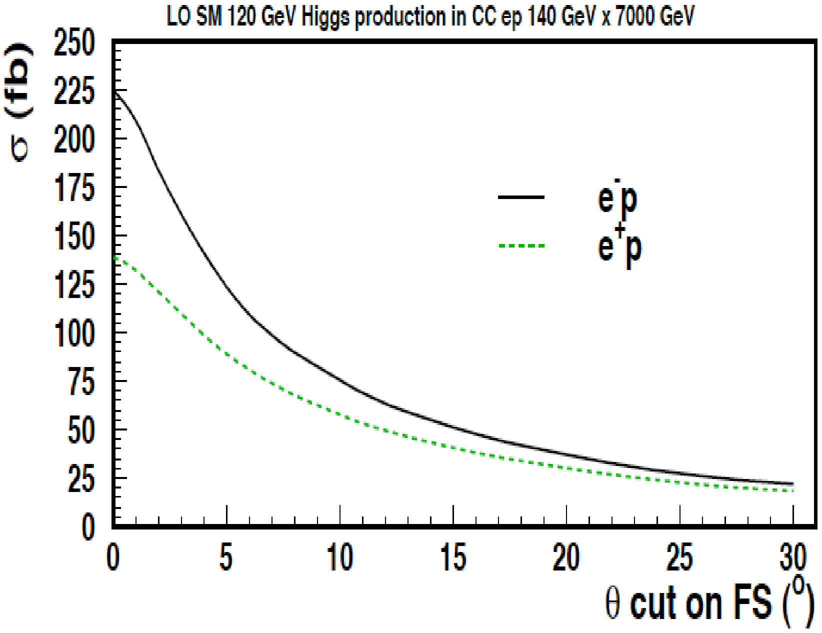
Drawing(s) by TS CERN



Detector Design Considerations



Large fwd acceptance at high luminosity

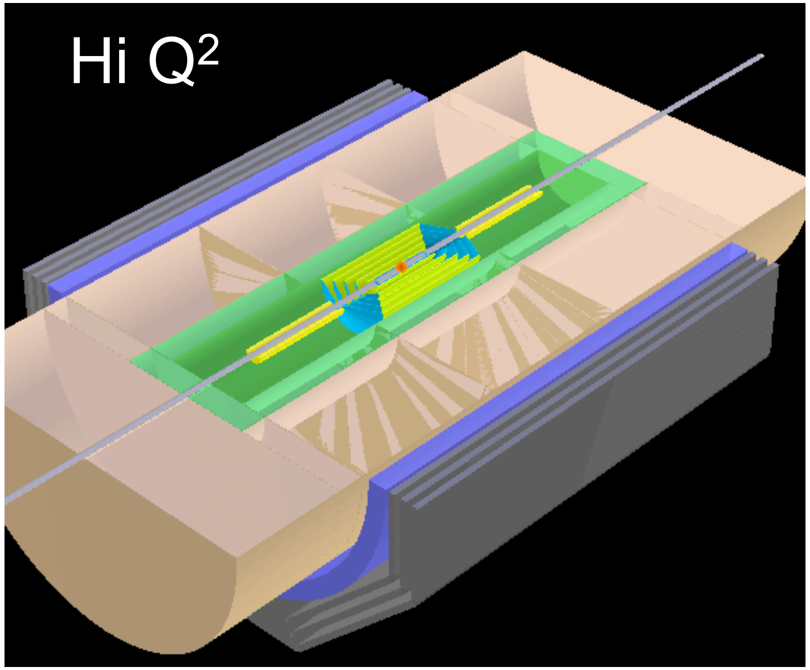


Forward tagging of p,n,d
Backward tagging of e,γ
Tagging of c and b in max. angular range
High resolution final state (Higgs to bbar)

High precision tracking and calorimetry

Largest possible acceptance	1-179°	7-177°
High resolution tracking	0.1 mrad	0.2-1 mrad
Precision electromagnetic calorimetry	0.1%	0.2-0.5%
Precision hadronic calorimetry	0.5%	1%
High precision luminosity measurement	0.5%	1%
	LHeC	HERA

L1 - Design - Tentative

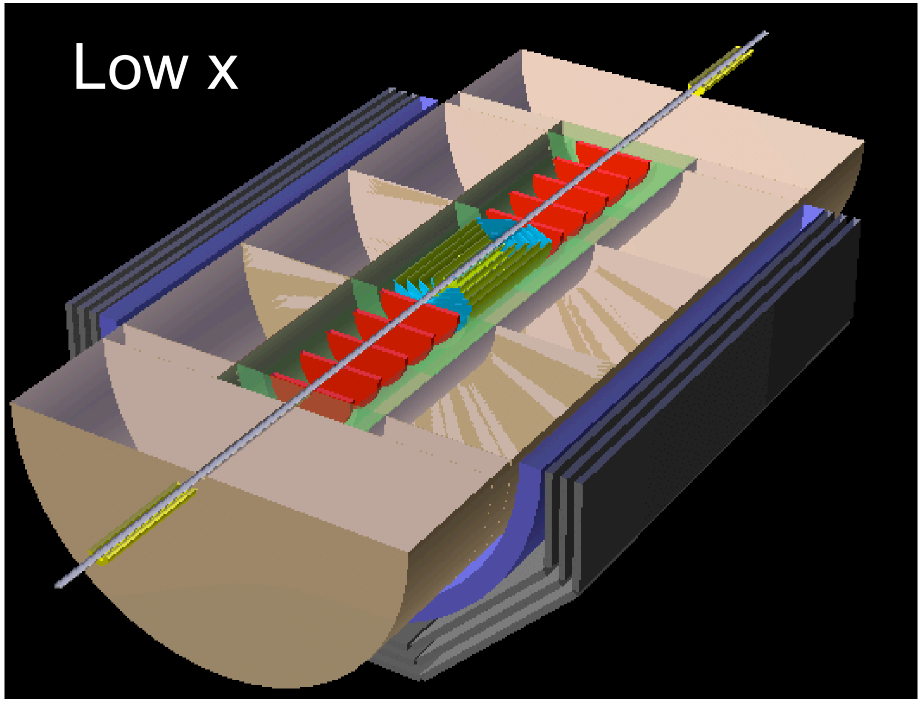


Tracking

Central: Si Pixels, GOSSIP [Gas on Slimmed Si Pixels]
[1m radius for 0.05% * pt in 2T field]

Fwd/Bwd: Telescopes of similar technology

Muon Chambers



Calorimetry

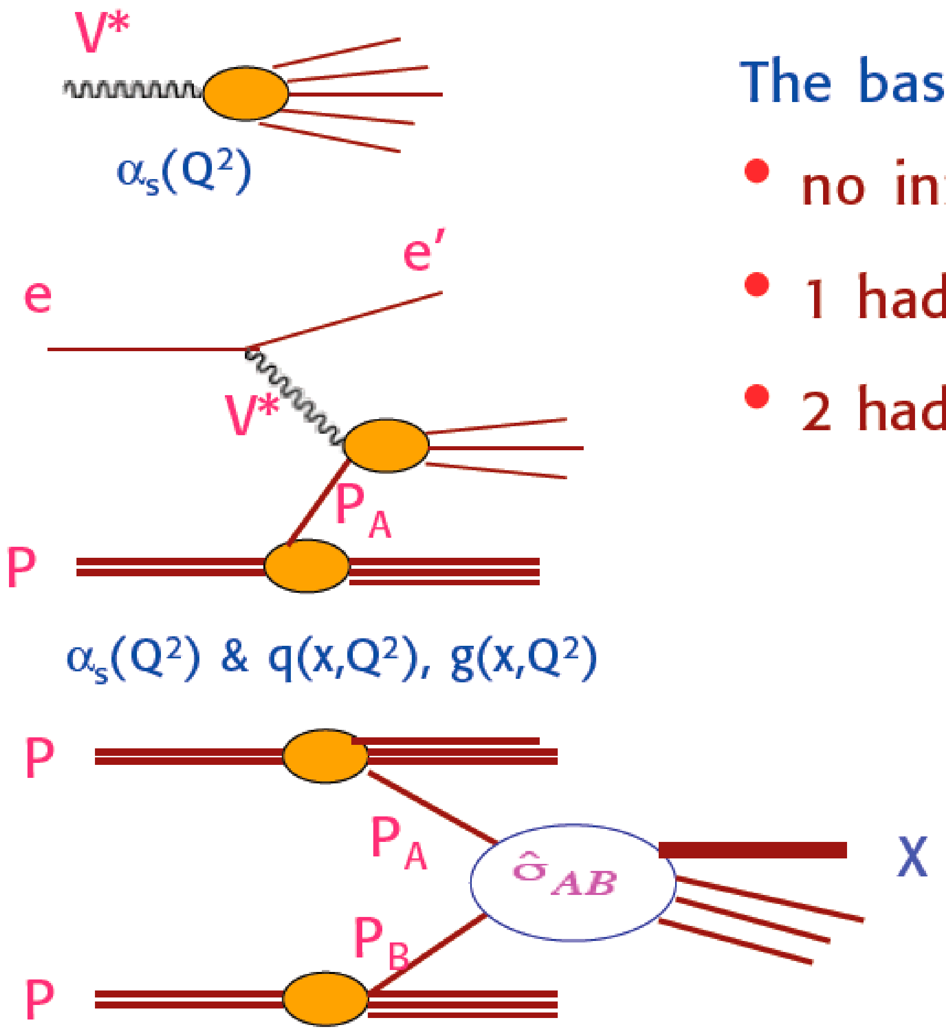
Fwd: 20 X_0, 15 λ
Calice W/Si (elm) fwd TeV jets
Pb/Sc (hadr)

Central: LAr/Pb (elm), tail catcher

Bwd: 20 X_0, 5 λ
Pb/Sc (Spacal)

Dimensions r_solenoid=3m, l_solenoid=6m

R&D on active magnets



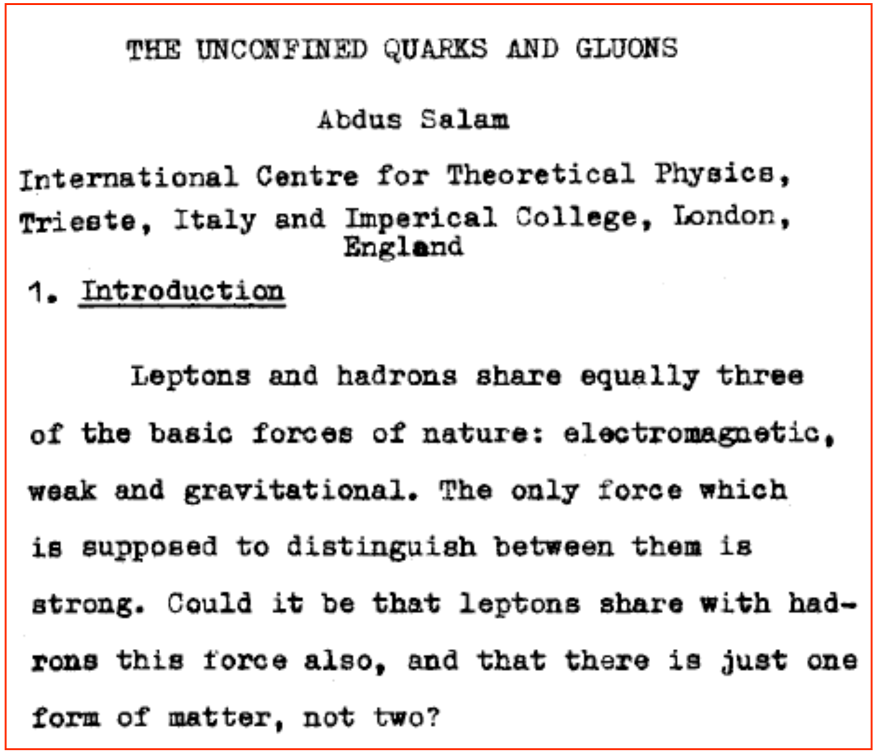
The basic experimental set ups:

- no initial hadron (....LEP, ILC, CLIC)
- 1 hadron (....HERA, LHeC)
- 2 hadrons (....SppS, Tevatron, LHC)

Progress in particle physics needs their continuous interplay to take full advantage of their complementarity

G.Altarelli, Divonne

History



THE UNCONFINED QUARKS AND GLUONS

Abdus Salam

International Centre for Theoretical Physics,
Trieste, Italy and Imperical College, London,
England

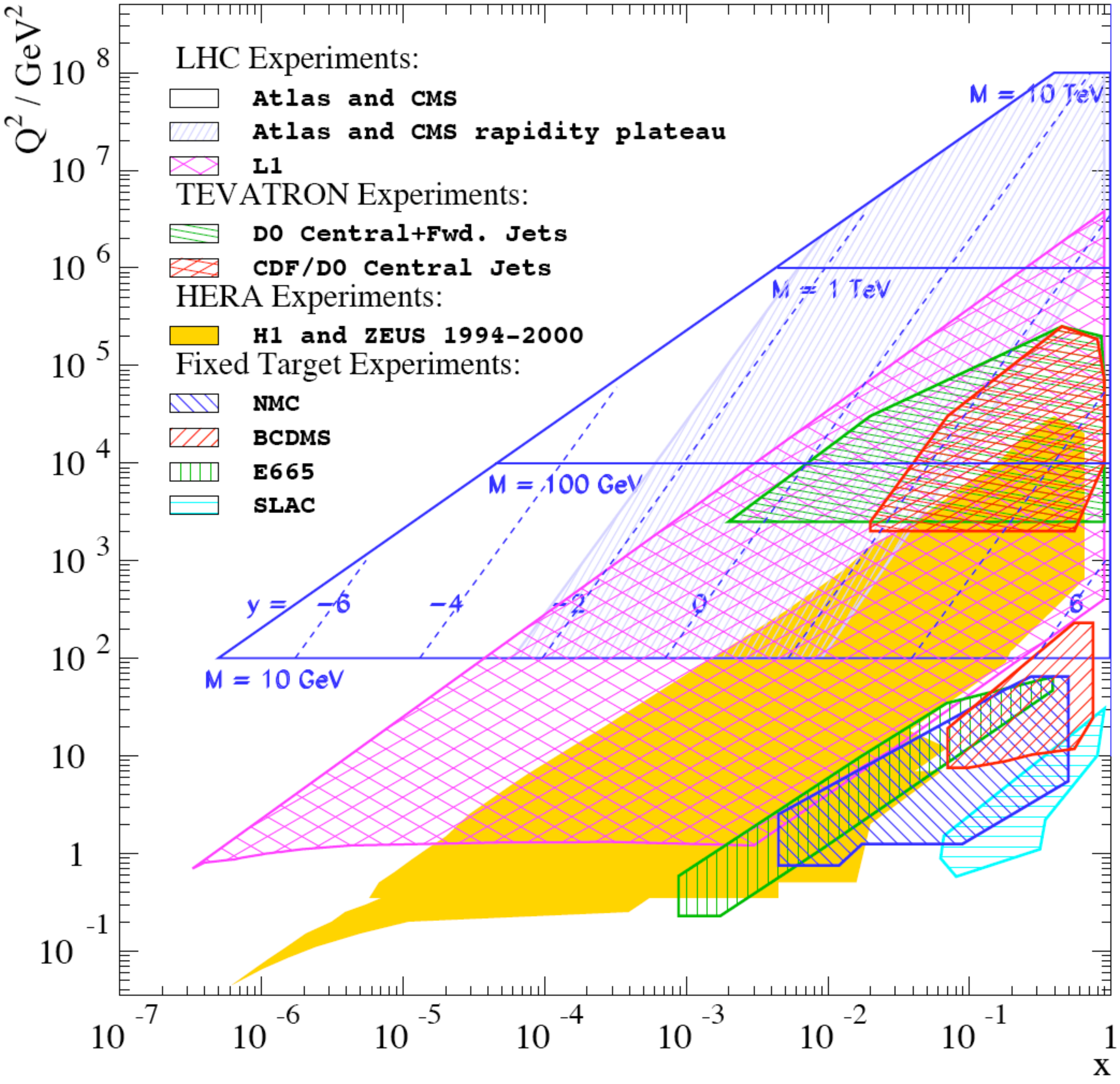
1. Introduction

Leptons and hadrons share equally three of the basic forces of nature: electromagnetic, weak and gravitational. The only force which is supposed to distinguish between them is strong. Could it be that leptons share with hadrons this force also, and that there is just one form of matter, not two?

ICHEP1976 Tbilissi..

Pati, Salam on GUT's

50.000 times Q^2 with perhaps
5 times the length for a Linac.


Q^2 / GeV^2
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x
LHC Experiments:
Atlas and CMS
Atlas and CMS rapidity plateau
L1
TEVATRON Experiments:
D0 Central+Fwd. Jets
CDF/D0 Central Jets
HERA Experiments:
H1 and ZEUS 1994-2000
Fixed Target Experiments:
NMC
BCDMS
E665
SLAC
M = 10 TeV
M = 1 TeV
M = 100 GeV
M = 10 GeV
y = −6
−4
−2
0
2
4
6

Summary

To be written

Participants in Accelerator LHeC Study

Backup slides

Lepton Polarisation

Self polarization / depolarization.

- Electrons in storage rings can become spin POLARIZED due to emission of synchrotron radiation: Sokolov–Ternov effect (1964).

- The polarization is perpendicular to the machine plane.

- The maximum value is $P_{st} = 92.4\%$.

- Sync. radn. also excites orbit motion. This leads to DEPOLARIZATION!

- The attainable polarization results from a balance between polarization and depolarization.

$$P_\infty \approx P_{st} \frac{1}{1 \ + \ (\frac{\tau_{dep}}{\tau_{st}})^{-1}}$$

- Depolarization is worst at RESONANCES:

$$\nu_s = k_0 + k_1 Q_1 + k_2 Q_2 + k_3 Q_3$$

At high energy the synchrotron sideband resonances take control:

$$\text{Strength scale :} \qquad \xi = (\frac{a\gamma\,\sigma_\delta}{Q_s})^2$$

- Overall, roughly at each energy:

$$\tau_{dep}^{-1} \ \propto \ (\text{a polynomial in } \gamma^{2N}) \times \tau_{st}^{-1}$$

- For longitudinal polarization the polarization vector must be rotated into the longitudinal direction before an IP and back to the vertical afterwards ===> spin rotators.

- Depolarization can be strongly enhanced by misalignments, regions where the polarization vector is horizontal between spin rotators etc, etc.....

LEP: 46 GeV 1993. R. Assmann et al. reached 57 percent by tuning the orbit for many hours: $\tau_{\rm pol} \le 300$ min and $\xi = O(1)$

The good news: at 70 GeV $\tau_{\rm pol} \approx\le 36$ min (scales like γ^{-5}).

The bad news: depolarization is relatively much stronger than at 46 GeV.

The way forward

Plan for polarization from the start! Polarization can never be an after thought!

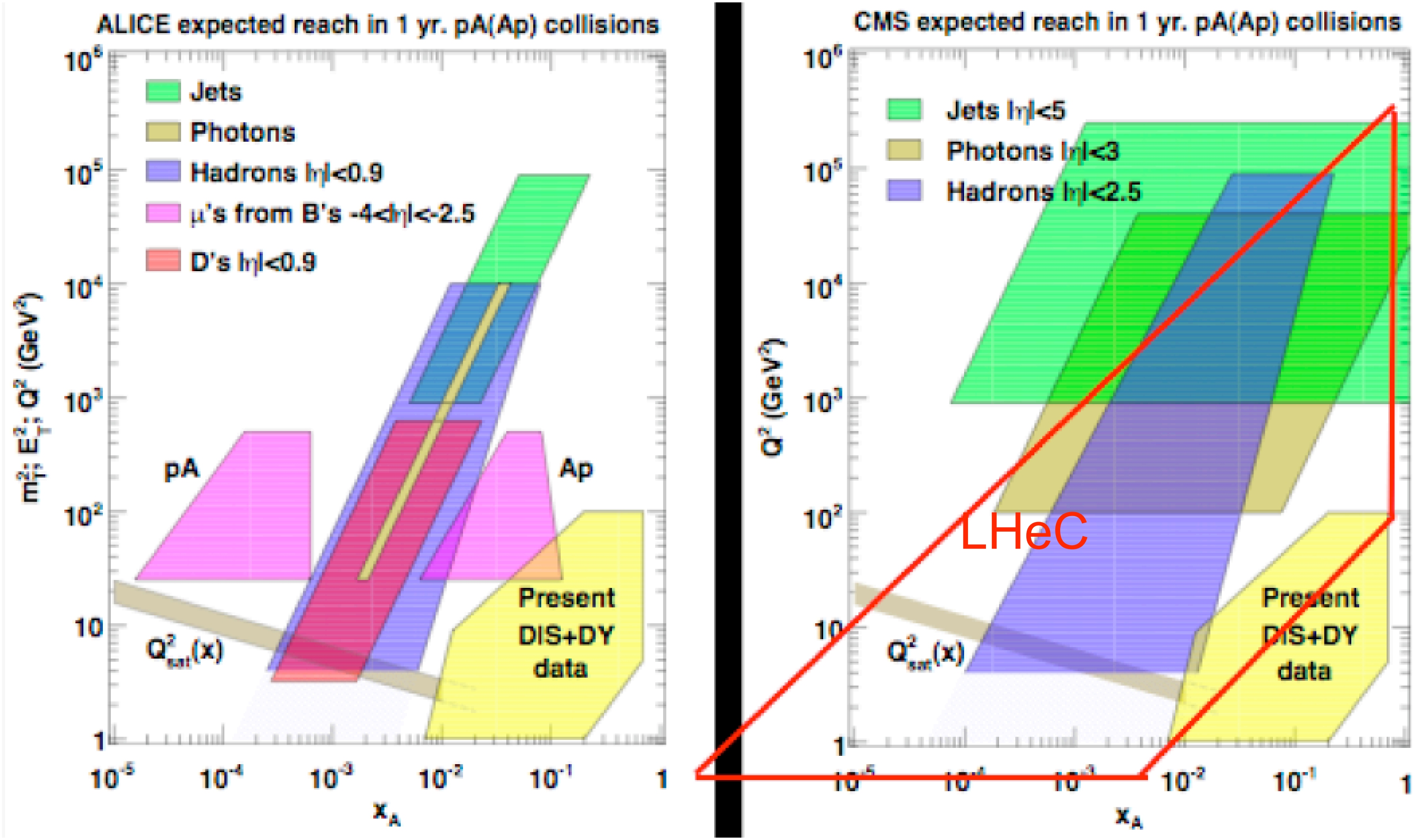
Begin NOW with intense careful study based on experience to investigate tricks.

- Need very good alignment – better than at LEP.
- Siberian Snakes to suppress the effect of energy spread and synchrotron motion on spin motion?
  These are essential in proton rings to suppress depolarising resonances during acceleration (e.g., RHIC).
  But in electron rings they kill the S-T effect if the synchrotron radiation is evenly distributed around the ring!!!
- Can an arrangement be found based on a correct snake layout combined with uneven synchrotron radiation from super bends?

D.Barber

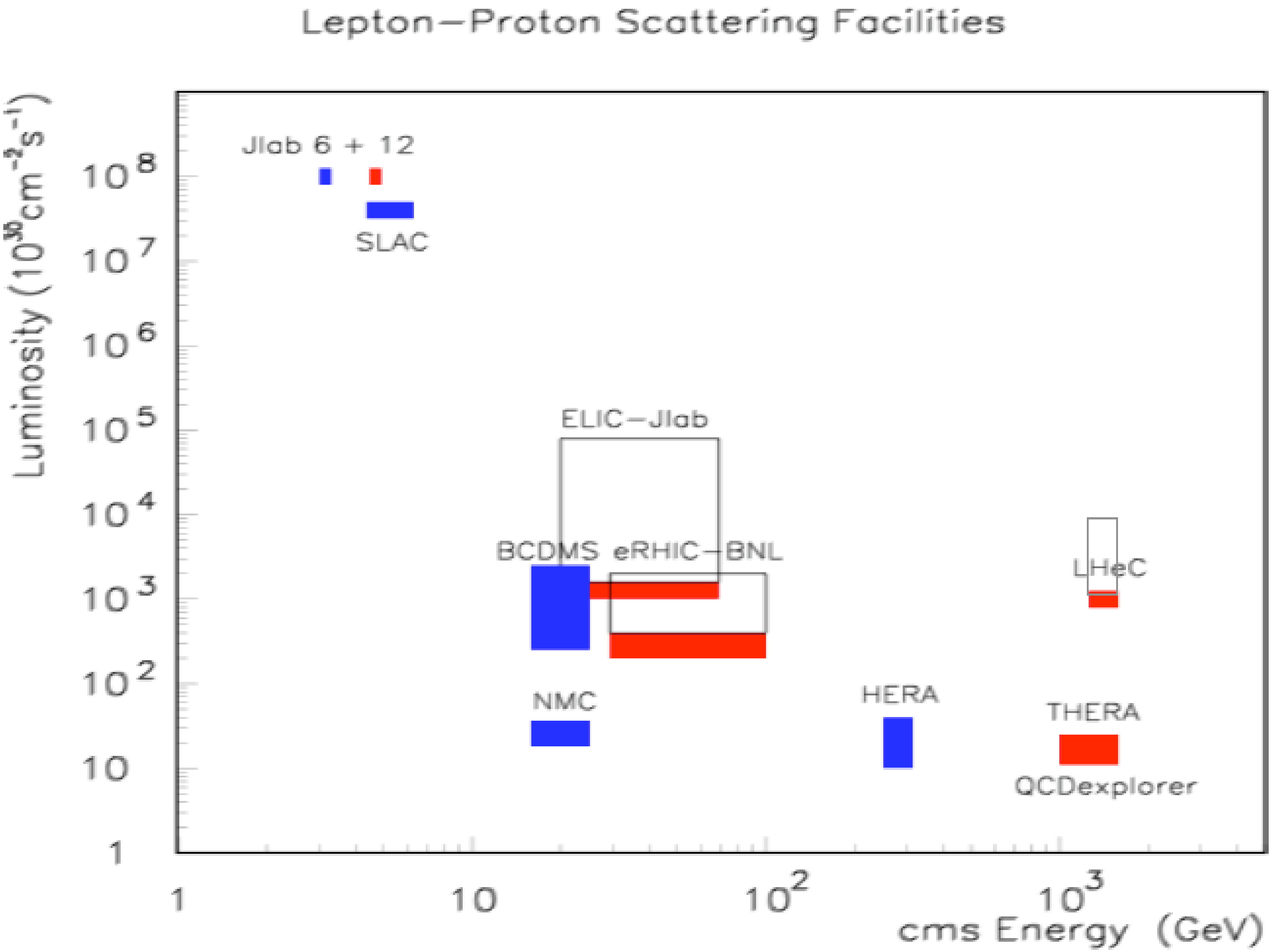
LHeC

Complementarity of Ap and ep

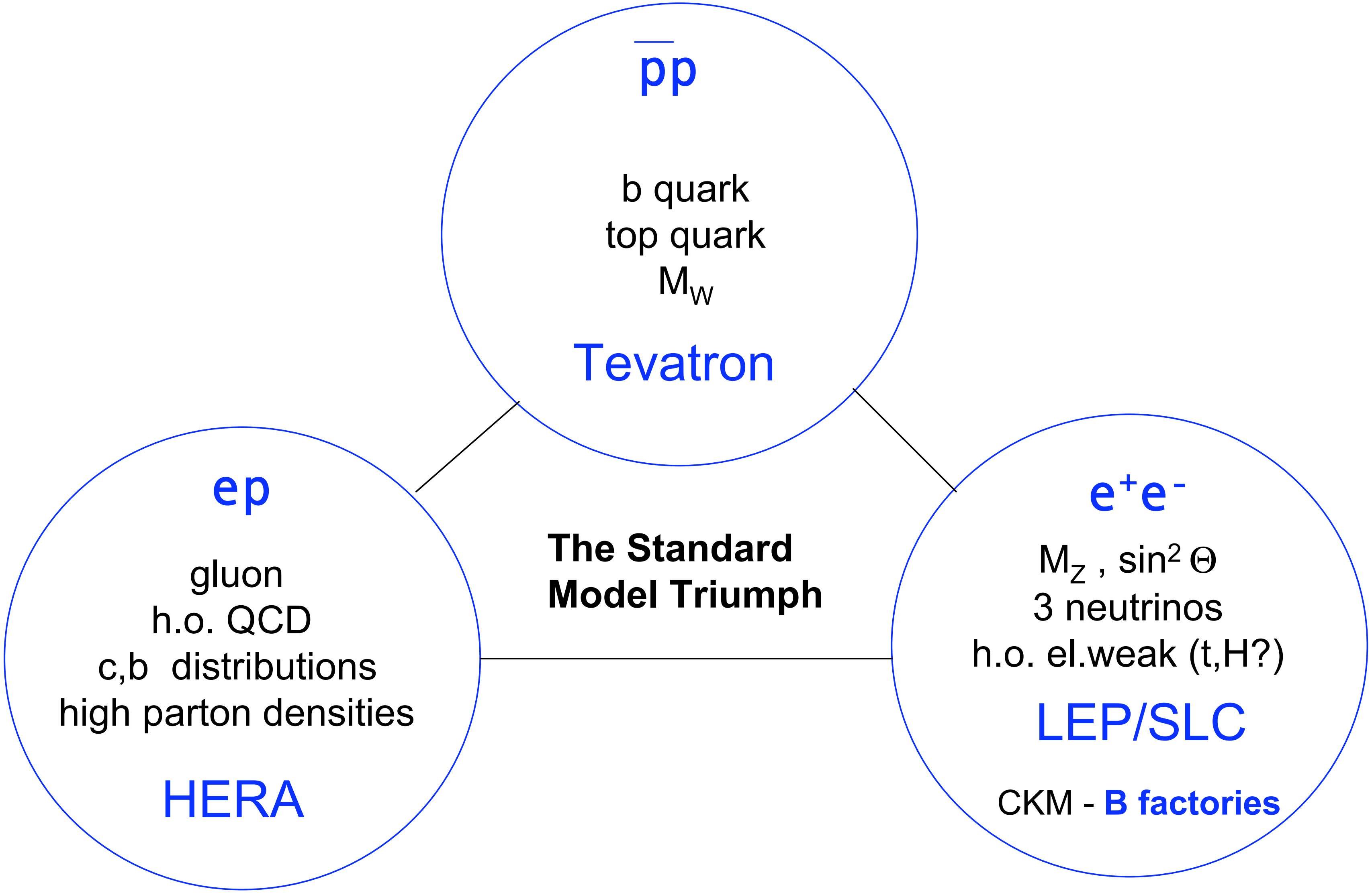


D'Enterria Divonne

Note that DY is not DIS


Lepton−Proton Scattering Facilities
Luminosity $(10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1})$
cms Energy (GeV)
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10
1
1
10
10^2
10^3
Jlab 6 + 12
SLAC
ELIC−Jlab
BCDMS
eRHIC−BNL
LHeC
NMC
HERA
THERA
QCDexplorer

The Past - Fermi Scale [1985-2010]



$\bar{p}p$

b quark
top quark
M_W

Tevatron

ep

gluon
h.o. QCD
c,b distributions
high parton densities

HERA

The Standard Model Triumph

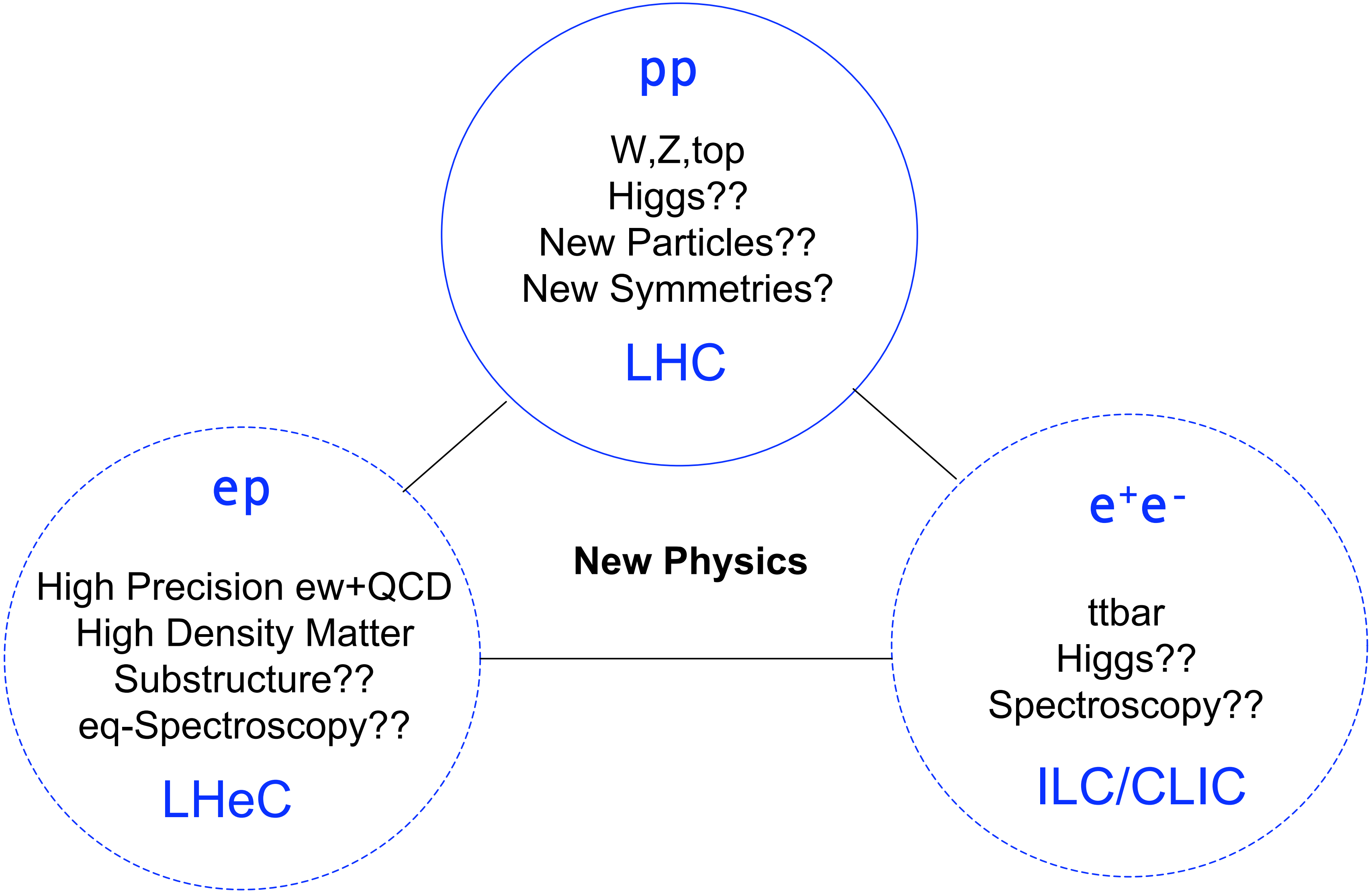
e^+e^-

M_Z , $\sin^2 \Theta$
3 neutrinos
h.o. el.weak (t,H?)

LEP/SLC

CKM - **B factories**

The Future - TeV Scale [2008-2033..]



pp

W,Z,top
Higgs??
New Particles??
New Symmetries?

LHC

ep

High Precision ew+QCD
High Density Matter
Substructure??
eq-Spectroscopy??

LHeC

New Physics

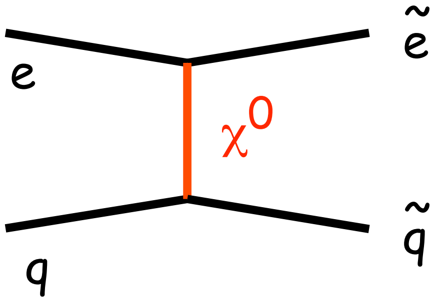
e^+e^-

ttbar
Higgs??
Spectroscopy??

ILC/CLIC

Max Klein LHeC ICFA08

Supersymmetry (R-parity conserved)

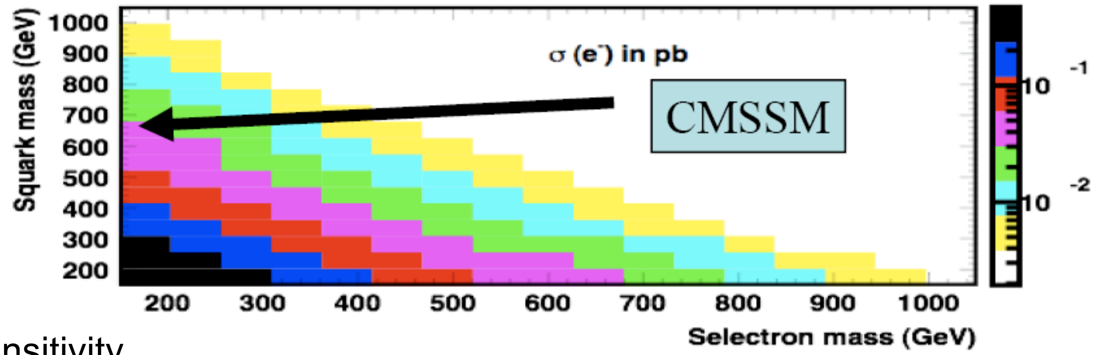


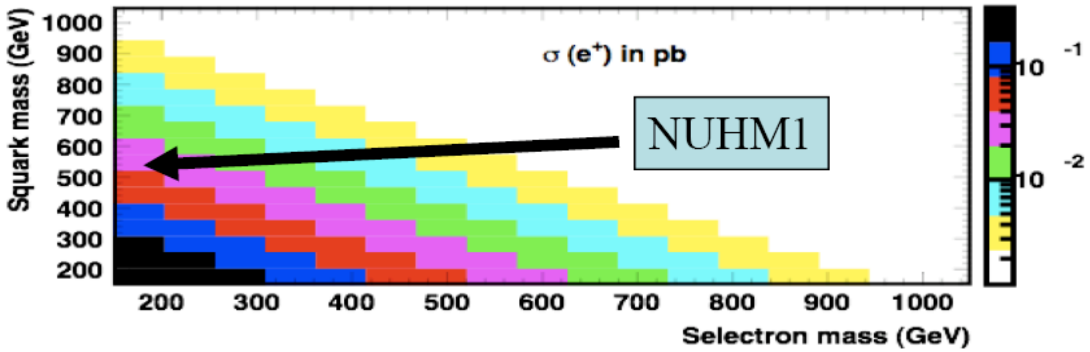
Pair production via t-channel exchange of a neutralino.
Cross-section sizeable when ΣM below ~ 1 TeV.
Such scenarios are “reasonable”.

E.g. global SUSY fit to EW & B-physics observables plus cosmological constraints (O. Buchmueller et al, 2008), within two SUSY models (CMSSM & NUHM) leads to masses of ~ (700, 150) GeV.

SUSY cross-section at LHeC:
about 15 fb for these scenarios.

tan β = 10, M_2 = 380 GeV, μ = -500 GeV

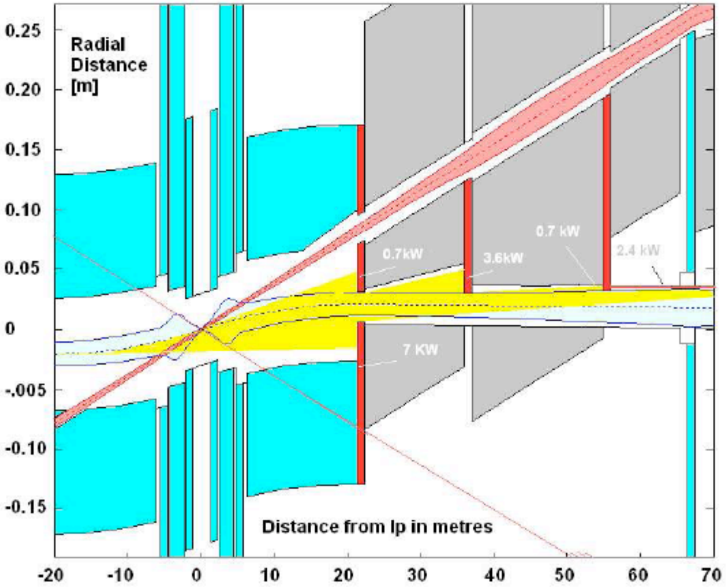




Added value w.r.t. LHC to be studied :

- could extend a bit over the LHC slepton sensitivity
- precise mass measurements
- relevant information on χ^0 sector

Design Details

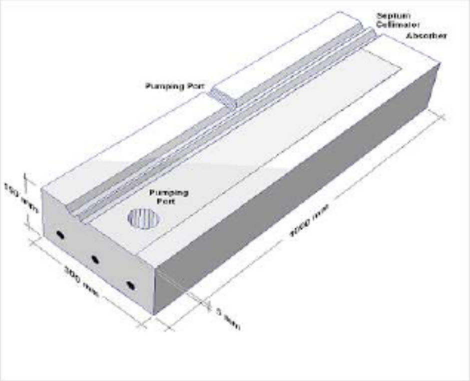


Synchrotron radiation **fan**

and HERA type absorber

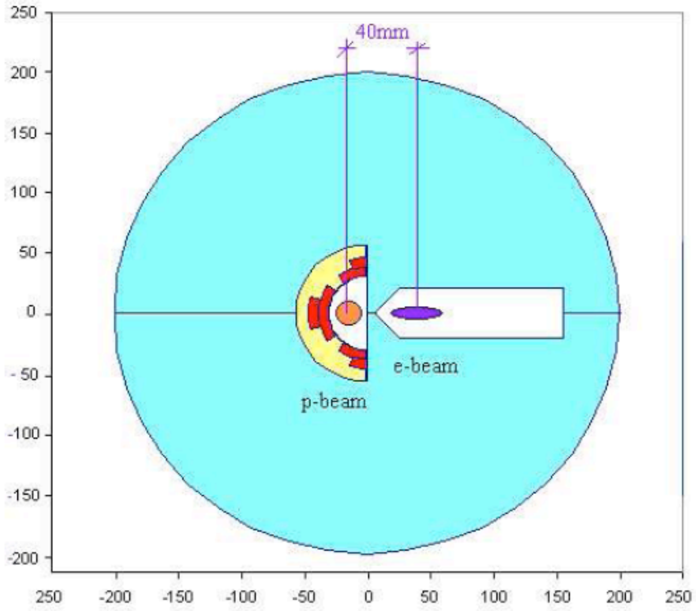
$9.1 kW$

$E_{crit} = 76 keV$

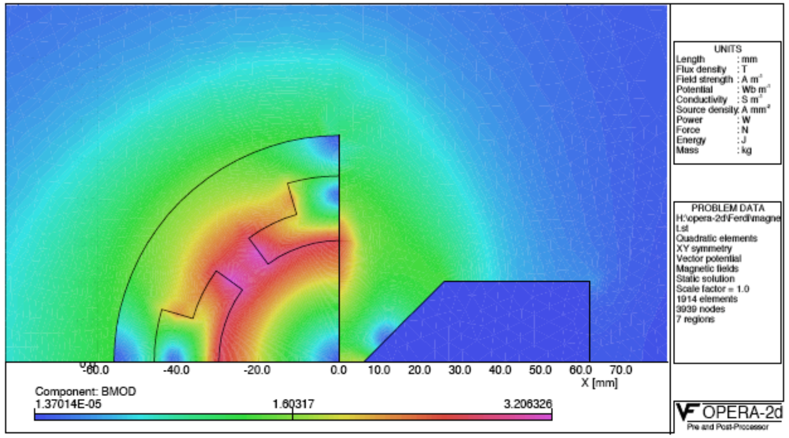


100W/mm^2

cf also W.Bartel
Aachen 1990



First p beam lens: septum quadrupole.
Cross section and Field calculation



LHeC

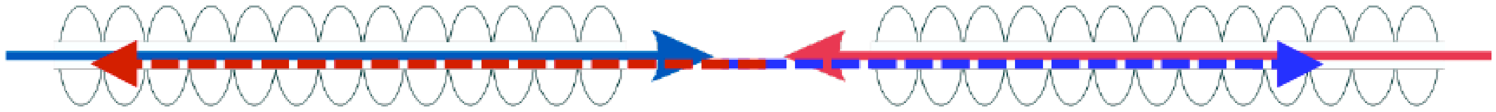
View from UPS54 Survey Gallery into CMS Cavern on Walkways

Energy Recovery

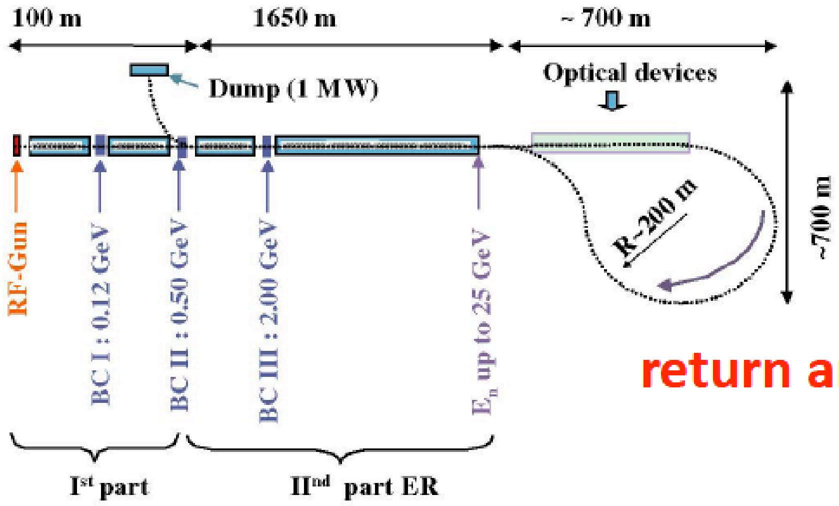
Jlab: **recirculating linac**, 99.5% of energy recovered at 150 MeV and 10 mA, ~98% recovery at 1 GeV and 100 μA with beam swung between 20 MeV to 1 GeV, plans for multi-GeV linacs withcurrents of ~100 mA

S. Chattopadhyay

M. Tigner, "A possible apparatus for electron clashing-beam experiments," Nuovo Cim.37:1228-1231 (1965).



J. Sekutowicz et al, "Proposed continuous wave energy recovery operation of an XFEL," Phys.Rev.ST Accel.Beams 8:010701,2005, up to 98% efficient



return arc

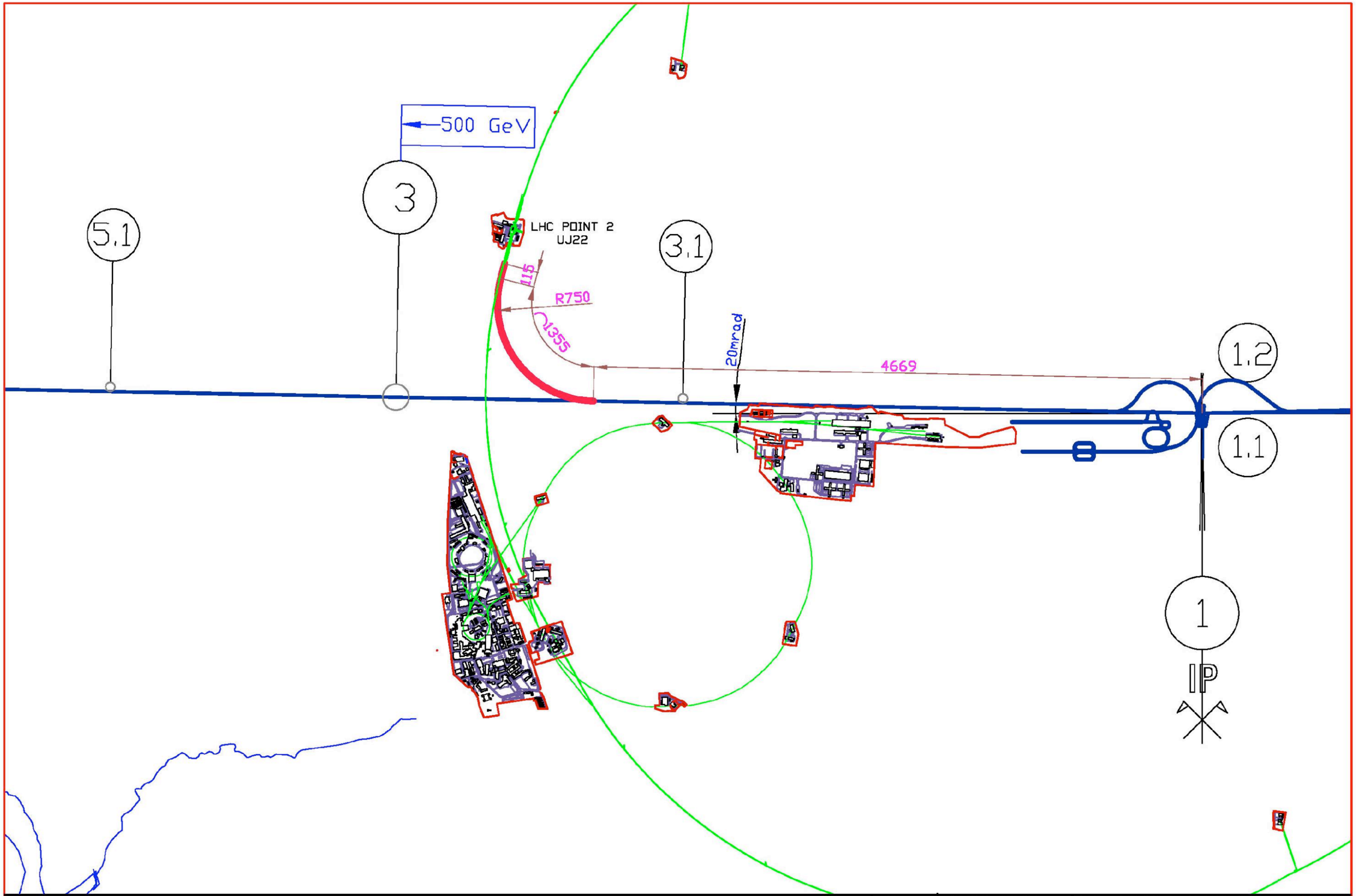
Parameters for pulsed Linacs for 140 GeV, $10^{32}cm^{-2}s^{-1}$

SC technology

NC technology

	X FEL 20 GeV	LHeC 140 GeV, $10^{32}cm^{-2}s^{-1}$	LHeC 140 GeV, $10^{32}cm^{-2}s^{-1}$
I_{Beam} during pulse	5 mA	11.4 mA	0.4 A
N_E	$0.624\cdot10^{10}$	$5.79\cdot10^{10}$	$6.2\cdot10^{10}$
Bunch spacing	0.2 μs	0.8 μs	25 ns
Pulse duration	0.65 ms	1.0 ms	4.2 μs
Repetition rate	10 Hz	10 Hz	100 Hz
G	23.6MV/m	23.6MV/m	20.0 MV/m
Total Length	1.27 km	8.72 km	8.76 km
P_{Beam}	0.65 MW	16.8 MW	16.8 MW
Grid power for RF plant	4 MW	59 MW	96 MW
Grid power for Cryoplant	3 MW	20 MW	-
P_{Beam}/P_{AC}	10%	21%	18%

H.Braun, DIS08 workshop, cf also EPAC paper and F.Zimmermann here.



LHe C -ALICE INJECTOR FROM CLIC 500 GeV PHASE

GROUP : TS-CE
CIVIL ENGINEERING
SUPERVISEUR : J.OSBORNE
DESIGNER : N.BADDAMS

SCALE : 1/20000(A3_FORMAT) DATE : 14_OCT_2008
ALICE_INJECTOR_FROM_CLIC_500_GEV
SIZE 3
INDICE -

The Goal of the Workshops is a CDR by December 2009.

Accelerator Design [RR and LR]

Closer evaluation of technical realisation: injection, magnets, rf, power efficiency, cavities, ERL…

What are the relative merits of LR and RR? Recommendation.

Interaction Region and Forward/Backward Detectors

Design of IR (LR and RR), integration of fwd/bwd detectors into beam line.

Infrastructure Definition of infrastructure - for LR and RR.

Detector Design A conceptual layout, including alternatives, and its performance [ep and eA].

New Physics at Large Scales

Investigation of the discovery potential for new physics and its relation to the LHC and ILC/CLIC.

Precision QCD and Electroweak Interactions

Quark-gluon dynamics and precision electroweak measurements at the TERA scale.

Physics at High Parton Densities [small x and eA]

QCD and Unitarity, QGP and the relations to nuclear, pA/AA LHC and SHEν physics.

Divonne, 1.-3.9.08

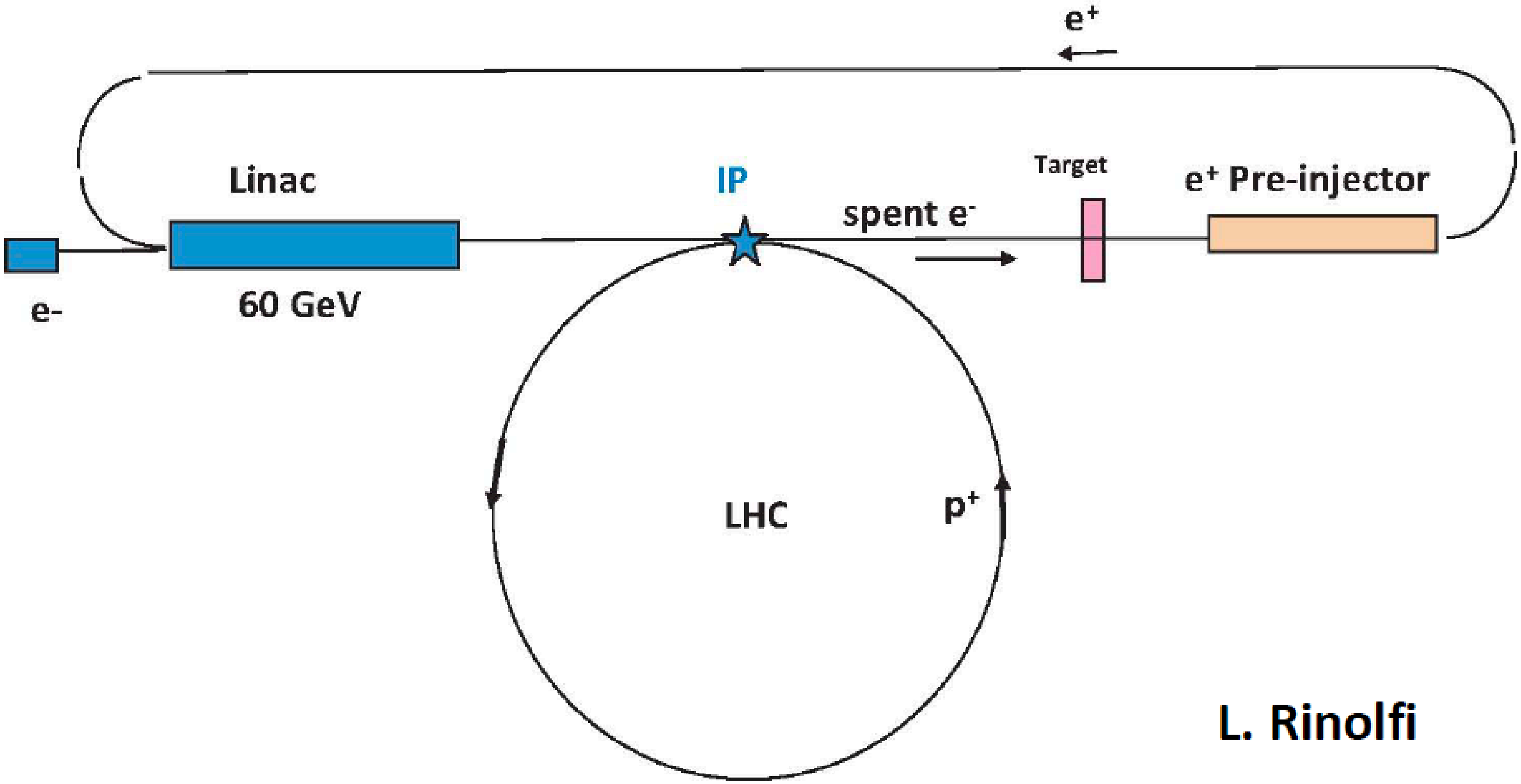
e- source

the e- beam can be produced from a polarized dc gun (e.g. SLC, E-158, or NLC type), with 90% polarization

depending on the bunch charge a normalized emittance between 10 and 100 μm is expected after bunching and acceleration

this is much (~3 orders of magnitude) smaller than might be hoped for in a ring at 70 GeV beam energy

e+ production



L. Rinolfi

schematic linac-ring collider with integrated e+ production

A first ‘complete’ design for 10^{33}

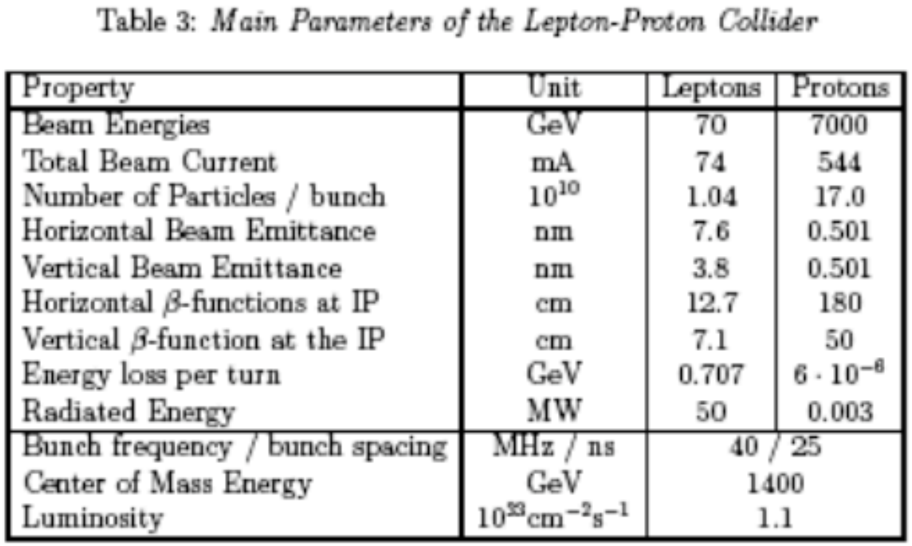
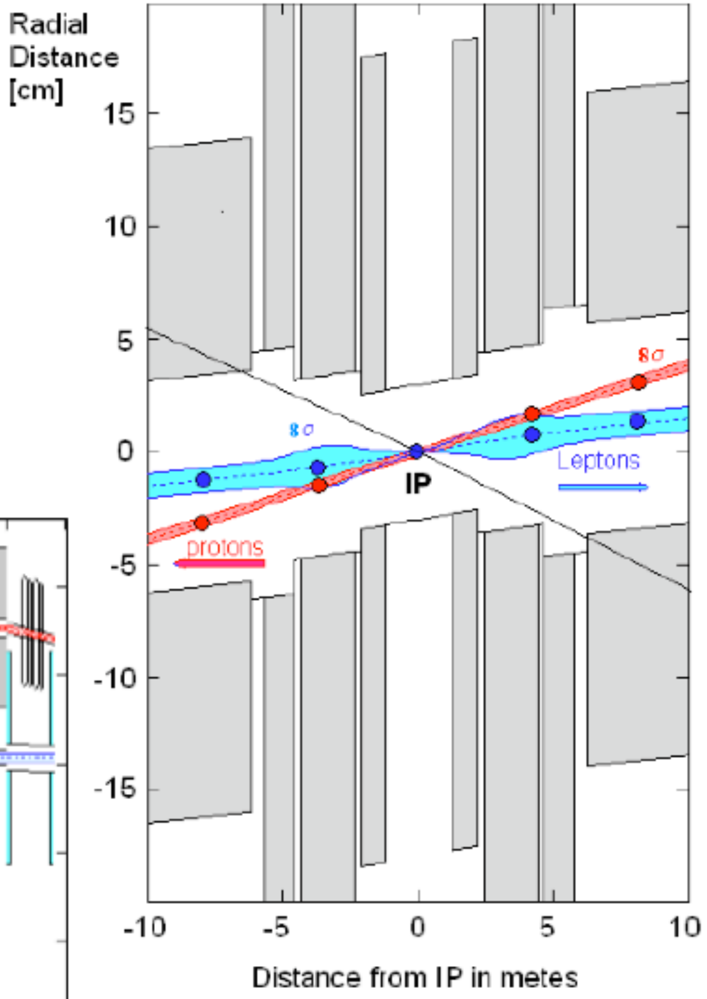
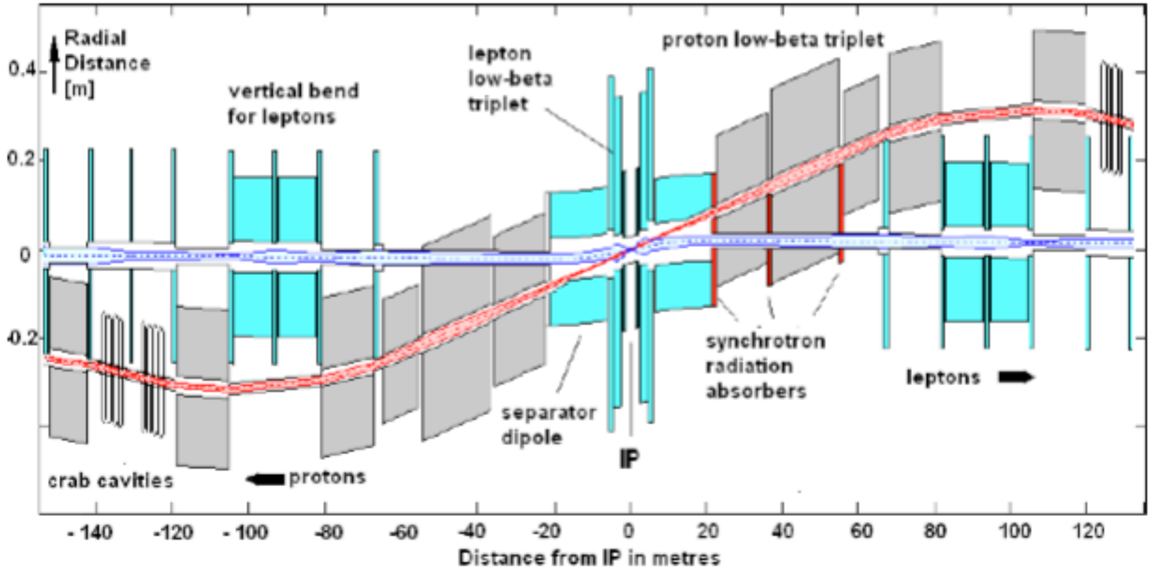


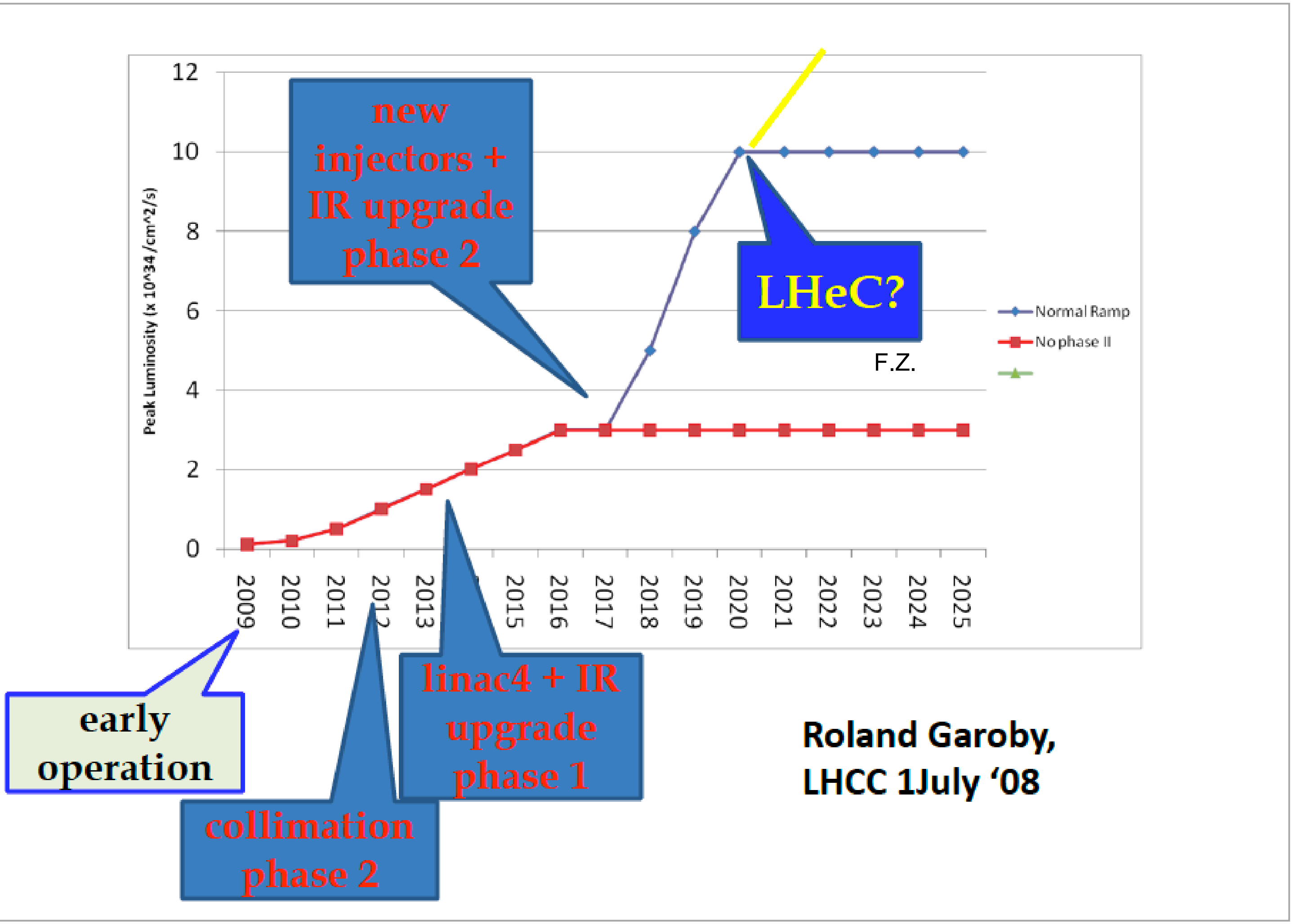
Table 3: *Main Parameters of the Lepton-Proton Collider*

Property	Unit	Leptons	Protons
Beam Energies	GeV	70	7000
Total Beam Current	mA	74	544
Number of Particles / bunch	10^{10}	1.04	17.0
Horizontal Beam Emittance	nm	7.6	0.501
Vertical Beam Emittance	nm	3.8	0.501
Horizontal β-functions at IP	cm	12.7	180
Vertical β-function at the IP	cm	7.1	50
Energy loss per turn	GeV	0.707	$6 \cdot 10^{-6}$
Radiated Energy	MW	50	0.003
Bunch frequency / bunch spacing	MHz / ns	40 / 25	
Center of Mass Energy	GeV	1400	
Luminosity	$10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	1.1	



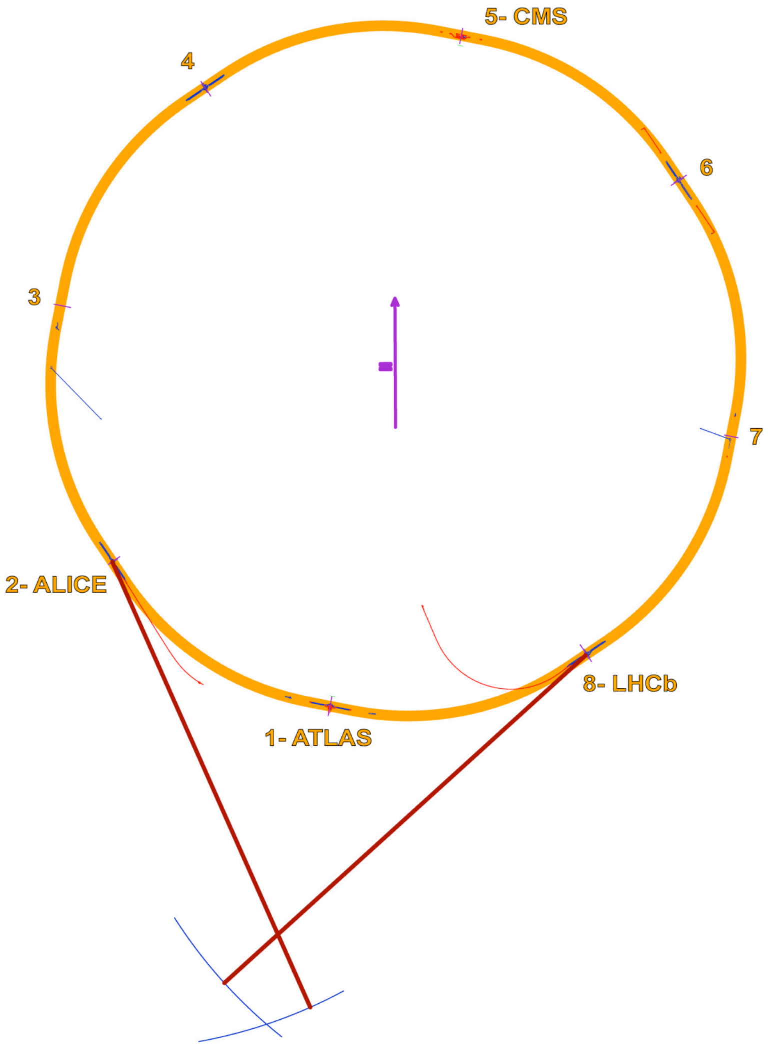


LHC Time Schedule

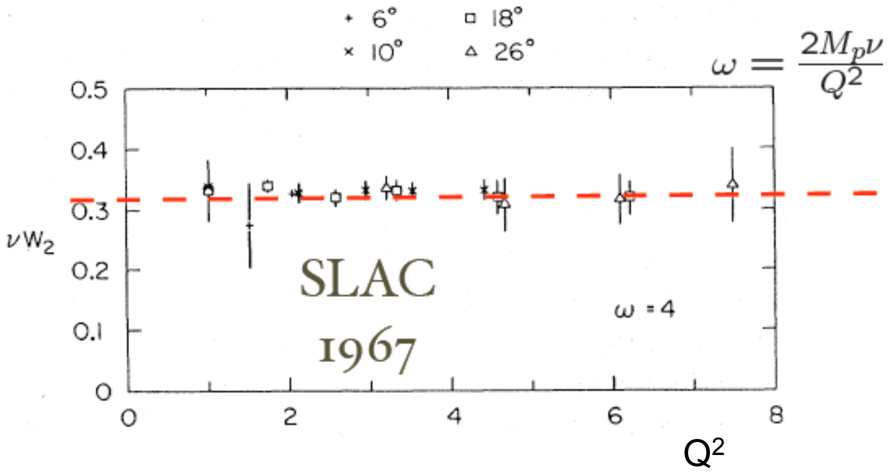


Roland Garoby, LHCC 1July '08

LINAC - Sites



The LHeC is a PeV equivalent fixed target ep scattering experiment, at 50 000 times higher energy than the pioneering SLAC MIT experiment. It may need a LINAC not much longer than the 2mile LINAC to the right, perhaps a ring. Its physics potential is extremely rich. Its technology is at hand, apart from some desirable further developments.



$$\omega = \frac{2M_p\nu}{Q^2}$$

That proposal was remarkably humble..

The LHeC would be a tribute to Pief P. and Bjoern W.