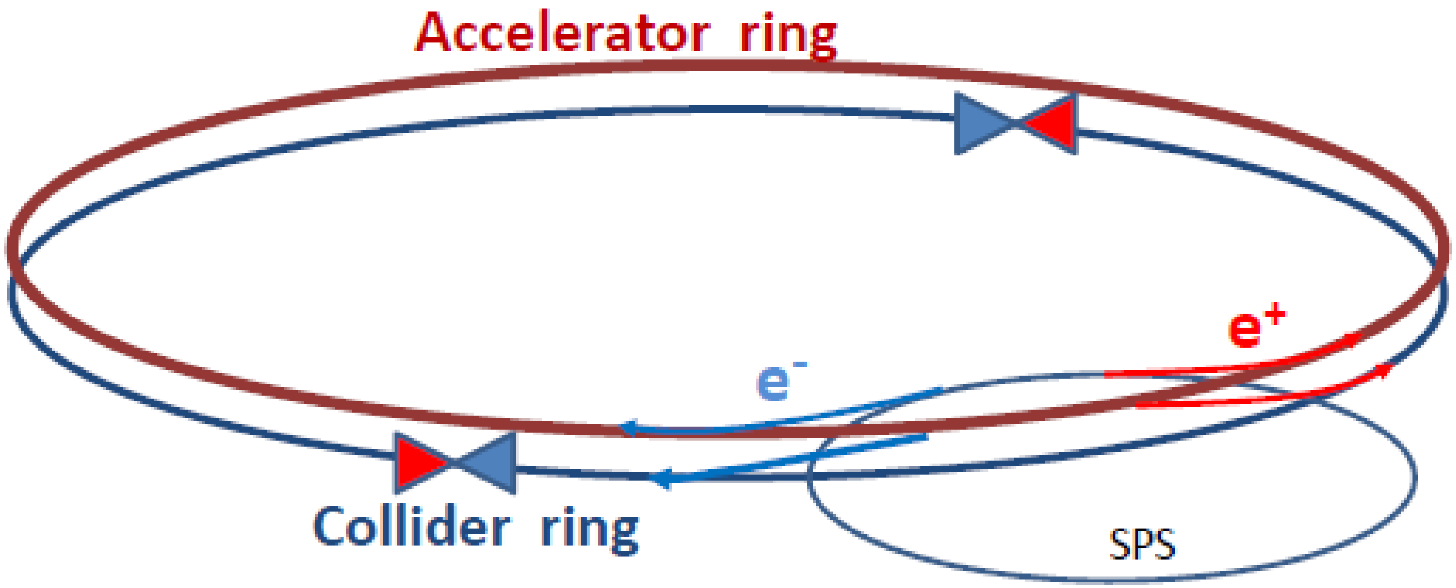
LEP3

A high Luminosity e^+e^- Collider in the LHC tunnel to study the Higgs Boson



Genesis

As the Higgs became cornered below 140 GeV/c^2 in Grenoble, the question was raised around the corridors 'what about a new e+e- colliding ring' ?

Raised the 'LEP3' at the EPS-HEP ECFA session in Grenoble (July 2011) and got such feedback:

Subject: LEP3
From: Klaus Desch <desch@physik.uni-bonn.de>
Date: 23.07.2011 18:21
To: Alain Blondel <alain.blondel@cern.ch>

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Dear Alain,

back-of-the evelope: LEP2 could deliver ~1 pb-1/day at 208 GeV for 20 MW at the
beam-beam-limit

Higgsfactory: needs ~500 fb-1 -> needs factor ~500 or so higher luminosity ->
              power (naïve) 20 MW * 500 * 240^4 / 208^4
              = prohibitive in LHC tunnel


Cheers,
```

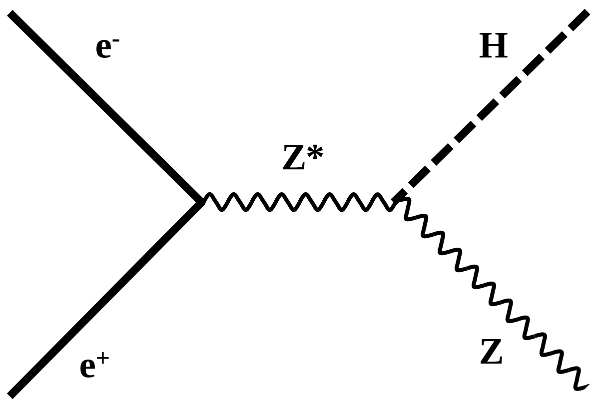
the end?
or
the challenge?

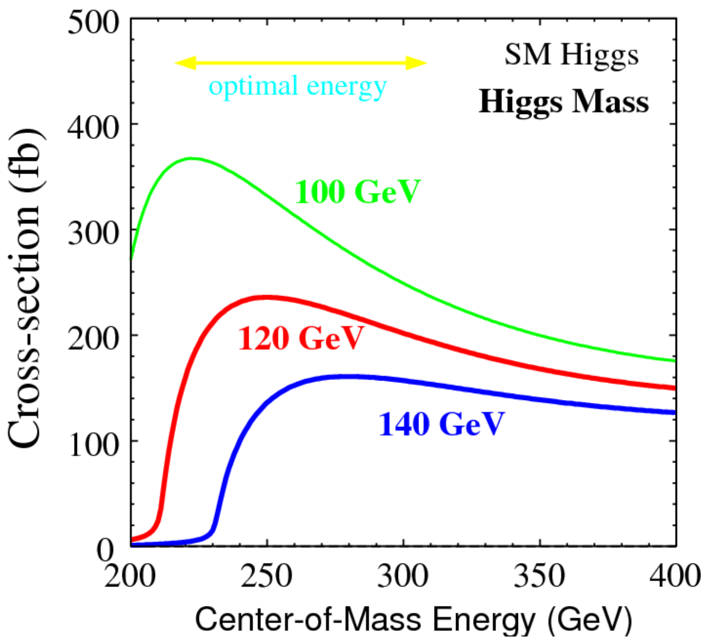
Higgs production mechanism

Assuming that the Higgs is light, in an e^+e^- machine it is produced by the "higgstrahlung" process close to threshold

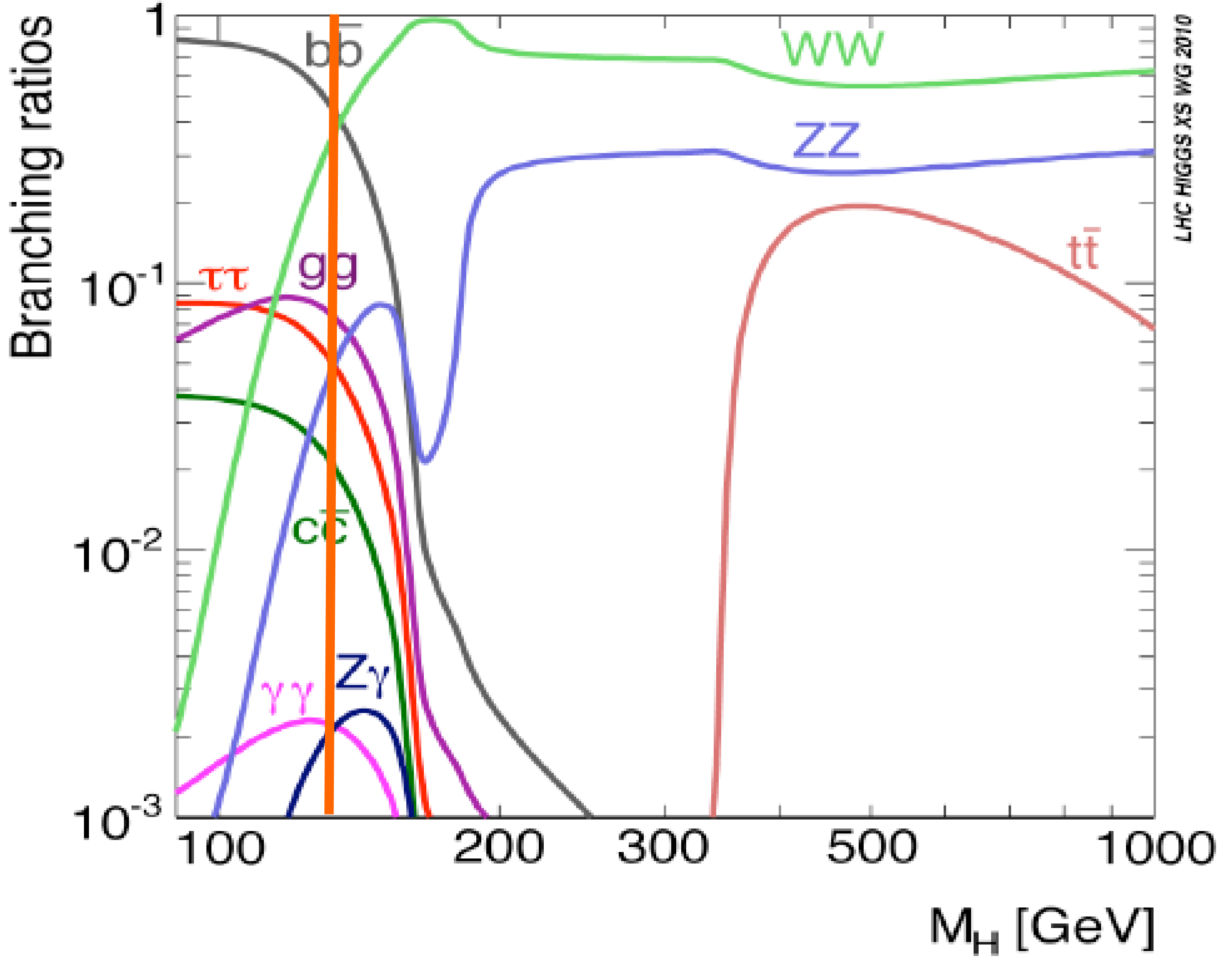
Production xsection has a maximum at near threshold

$10^{34}/cm^2/s$ ➔ 20'000 HZ events per year.





For a Higgs of 125GeV, a centre of mass energy of 240GeV is sufficient
➔ kinematical constraint near threshold for high precision in mass, width, selection purity



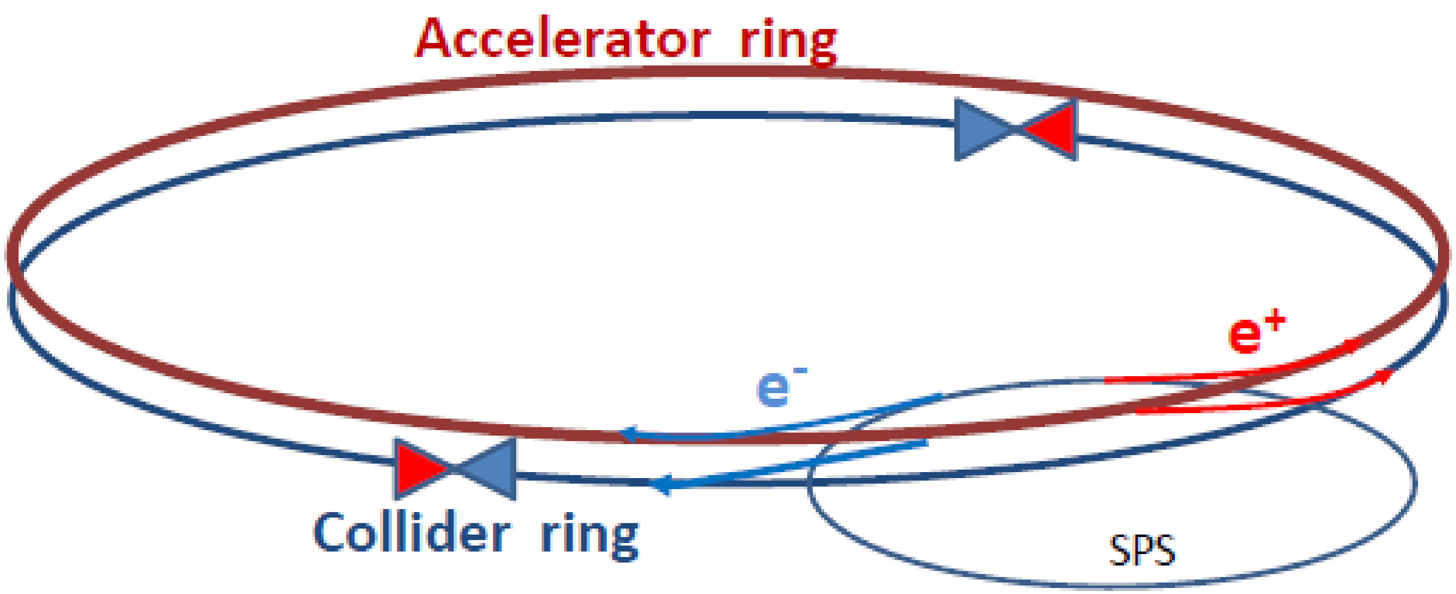
125 GeV is really a good place to be:

$\bar{b}$b , WW, gg, ττ, ZZ, $\bar{c}$c are all above a few % and γγ is ~maximal

How can one increase over LEP 2 (average) luminosity by a factor 500 without exploding the power bill?

Answer is in the B-factory design: a very low vertical emittance ring with higher intrinsic luminosity

electrons and positrons have a much higher chance of interacting
- ➔ **much shorter lifetime (few minutes)**
  - ➔ **feed beam consituously with a ancillary accelerator**



Extrapolating from LEP2

(remarkably scarce) litterature on last year of LEP2 says:
went up to 104.5 GeV per beam
beam lifetime was ~100 minutes, burned by interactions
beam power was 20MW (would be 45 MW at 120 GeV/beam)
β^* was 5cm and beam-beam tuneshift ξ^* was 0.12

➔ LEP2 was NOT at the beam beam limit

Excel spread sheet says:

with β^*= 2mm and reducing horizontal emittance you can get to ξ^* =0.15
and a life time of O(minute) (you need higher frequency RF → ILC !)

➔ instantaneous luminosity is 100 times higher ☺!
but this machine is unuseable unless … one refills all the time
➔ B factory – which I realized at the ICFA meeting in October 2011
refilling continuously gives you the other factor 5.

At that point I needed professional help; Franck Zimmermann
got all excited, and quickly confirmed (3 days!) that he could apply the
LHeC optics to get the desired result! (see his presentation)

	LEP2	LHeC	LEP3	DLEP
b. energy E_b [GeV]	104.5	60	120	120
circumf. [km]	26.7	26.7	26.7	53.4
beam current [mA]	4	100	7.2	14.4
#bunches/beam	4	2808	4	60
$\#e-$/beam [10^{12}]	2.3	56	4.0	16.0
horiz. emit. [nm]	48	5	25	10
vert. emit. [nm]	0.25	2.5	0.10	0.05
bending rad. [km]	3.1	2.6	2.6	5.2
part. number J_ε	1.1	1.5	1.5	1.5
mom. c. α_c [10^{-5}]	18.5	8.1	8.1	2.0
SR p./beam [MW]	11	44	50	50
β^*_x [m]	1.5	0.18	0.2	0.2
β^*_y [cm]	5	10	0.1	0.1
σ^*_x [μm]	270	30	71	45
σ^*_y [μm]	3.5	16	0.32	0.22
hourglass F_{hg}	0.98	0.99	0.67	0.75
E^{SR}_{loss}/turn [GeV]	3.41	0.44	6.99	3.5
$V_{RF,tot}$ [GV]	3.64	0.5	12.0	4.6
$\delta_{max,RF}$ [%]	0.77	0.66	4.2	5.0
ξ_x/IP	0.025	N/A	0.09	0.05
ξ_y/IP	0.065	N/A	0.08	0.05
f_s [kHz]	1.6	0.65	3.91	0.91
E_{acc} [MV/m]	7.5	11.9	20	418
eff. RF length [m]	485	42	606	376
f_{RF} [MHz]	352	721	1300	1300
δ^{SR}_{rms} [%]	0.22	0.12	0.23	0.16
$\sigma^{SR}_{z,rms}$ [cm]	1.61	0.69	0.23	0.17
L/IP[10^{32}cm^{-2}s^{-1}]	1.25	N/A	107	142
number of IPs	4	1	2	2
beam lifetime [min]	360	N/A	16	22
Υ_{BS} [10^{-4}]	0.2	0.05	10	8
n_γ/collision	0.08	0.16	0.60	0.25
ΔE^{BS}/col. [MeV]	0.1	0.02	33	12
ΔE^{BS}_{rms}/col. [MeV]	0.3	0.07	48	26

LEP3: A HIGH LUMINOSITY e^+e^- COLLIDER IN THE LHC TUNNEL TO STUDY THE HIGGS BOSON

A.P. Blondel, U. Geneva, Switzerland; F. Zimmermann, CERN, Geneva, Switzerland;
M. Koratzinos, Geneva, Switzerland; M. Zanetti, MIT, Cambridge, Massachusetts, USA

IPAC 2012 Paper

Table 1: Example parameters of LEP3 and DLEP compared with LEP [5, 6] and LHeC ring design [2]. Beamstrahlung (BS) effects were estimated from analytical formulae [7, 8].

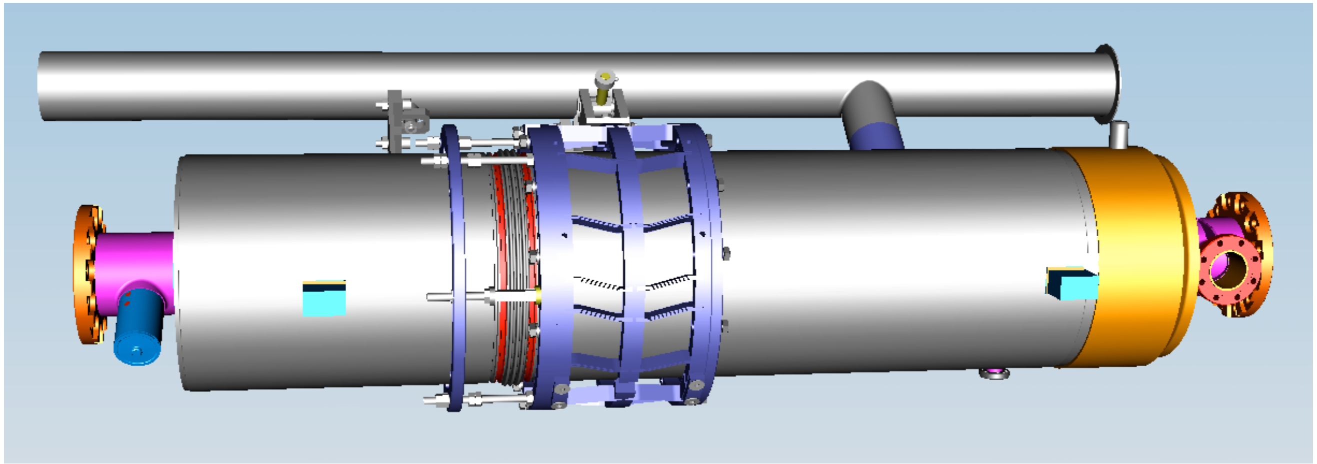
The RF system

The energy loss per turn of a single electron at 120GeV is 7GeV (3.5 GeV at LEP2)

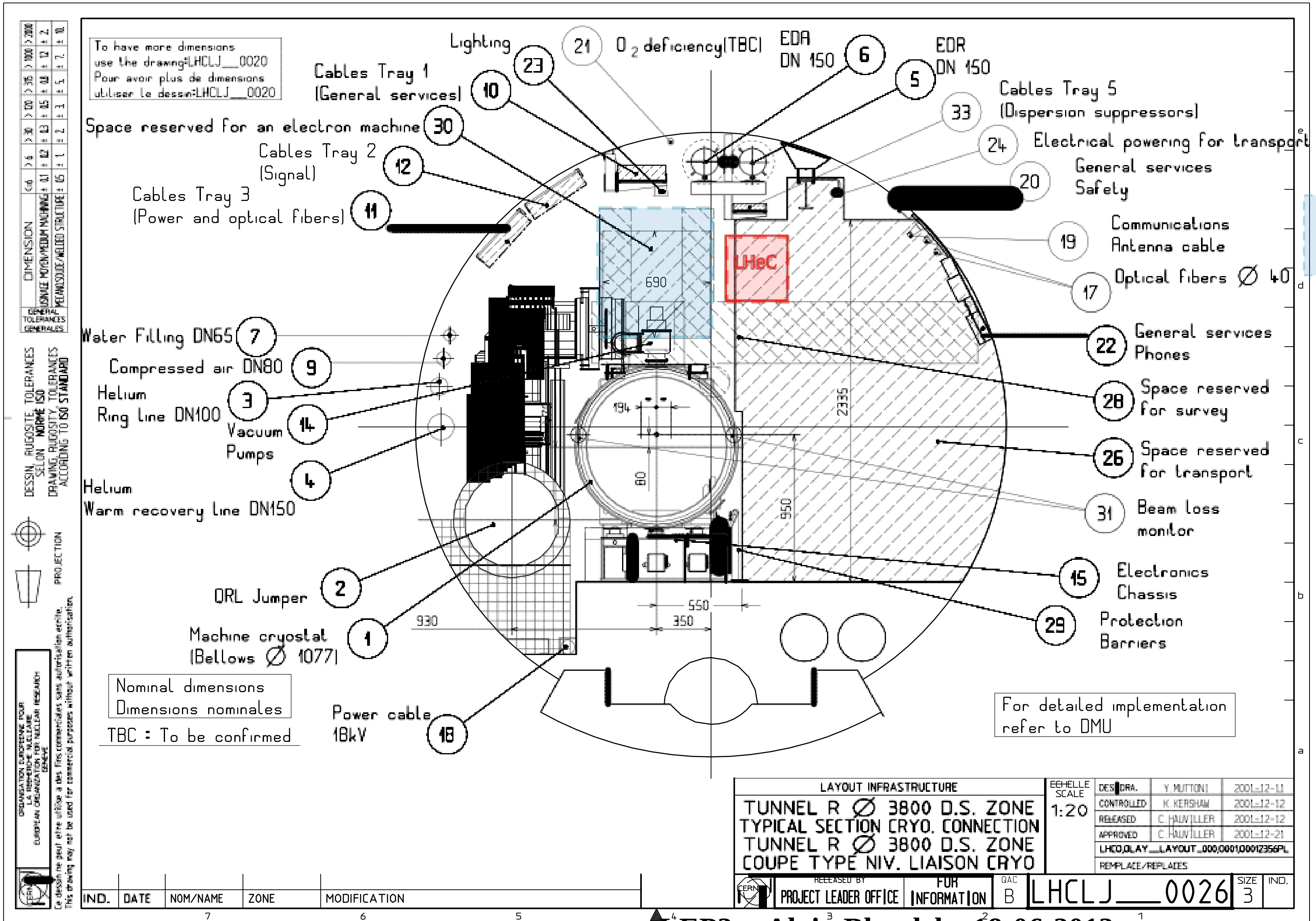
A good candidate for the RF system would be ILC-developed SC accelerating cavities at a frequency of 1.3 GHz RF and gradient of 18MV/m
help reduce the bunch length, thus enabling a smaller β_y^*.

The total length of the RF system is therefore around 500m, similar to that of LEP2.

Cryo power needed is less than half that of the LHC.



LHeC space considerations



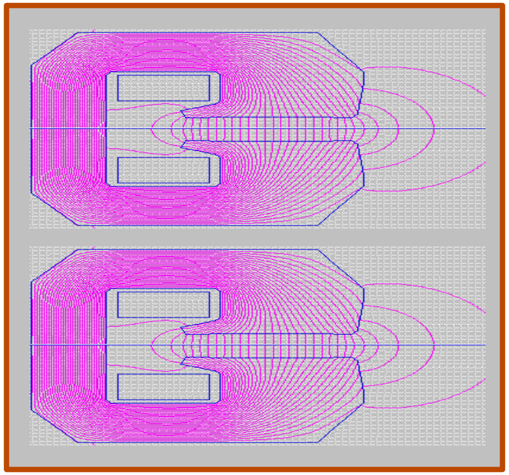
: LHeC

: Space reserved for future e^+e^- machine

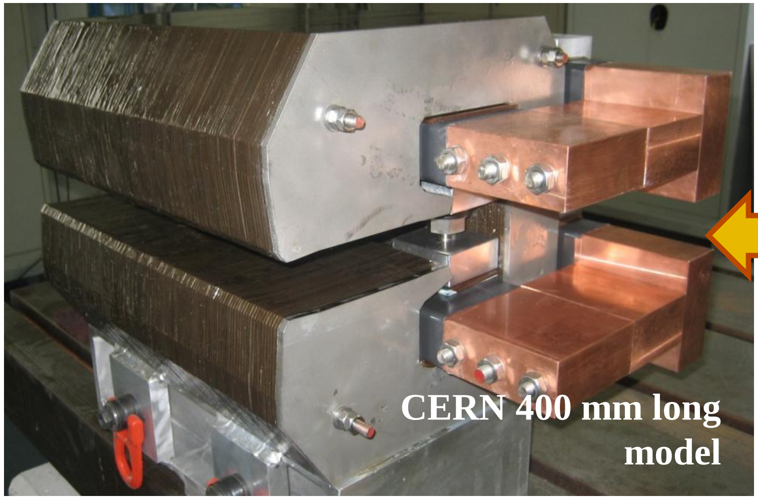
The LHeC ring is displaced due to the requirement of keeping the same circumference as the LHC ring. LEP3 has no such requirement

The low field dipoles

Another synergy with LHeC, although LEP3 wold require a “double decker” magnet



LEP3 Artist’s impression



CERN 400 mm long model

Prototypes of LHeC designs: Compact and lightweight to fit in the existing tunnel, yet mechanically stable

BINP short model

Objections

Objections have come primarily from the ILC/CLIC community.

-- machine is not upgradable to higher energies
  -- the answer really depends on what LHC finds, can or cannot do!

-- raised issue with the beamstrahlung reducing the life time
  -- we had not thought of it…
    Frank Zimmermann solved that problem by enlarging
    the energy acceptance of the ring.

Quite a few people find that

LEP3 is exciting!

It provides an economical (or even feasible) solution

-- to study the X(125) with high precision
-- and to perform many precision measurements on H, W, Z

within our lifetimes.

The machine is not 'easy' but should be reasonably 'safe' from the point of view of achieving the performance

Questions: I PHYSICS

Suppose LEP3 concept works, … and that X(125) really exists.

A can LHC study X(125) and answer enough questions
or do we need a complementary machine?

shopping list:
branching ratios, invisible width
mass, width, spin-parity
3-H and 4-H self couplings
……

I have some doubts about the red ones…

B <u>is LEP3 really the complementary machine one needs?</u>

C are the LHC detectors OK or do we want new ones?

D can they accommodate low beta insertions and luminosity monitors?

Questions: II ACCELERATOR

Among the many questions that should be addressed in more detail:
1) a comparison of cost and performance for the proposed double ring separating the accelerator and collider and for a single combined ring;
2) a total of about 15 GV of RF acceleration is needed : 9 GV for the storage ring and 6 GV for the accelerator - it will be necessary to determine the optimum RF gradient as a compromise between cryopower and space requirement, and the optimum RF frequency with regard to impedance, RF efficiency and bunch length [in this paper we consider the use of high-frequency ILC-type cavities];
3) the LHeC lattice has reduced the effective bending radius compared with LEP while one would rather like to increase it instead;
4) the performance may perhaps be further improved by using even smaller value of β^*_y and e.g. the technique of crab waste-crossing[15];
6) the performance at 91.2 E_{cm} (the Z peak), possibly with polarized beams

7) the co-habitation of such a double machine with the LHC would require careful examination of the layout of both machines - for the single LHeC ring no show-stopper has been found [7];

9) the ramping speed of the accelerator ring;
10) the positron source;
11) the limit on the single bunch charge;
12) the top-up scheme, e.g. injecting new bunches at full intensity or refilling those already colliding;

and

13) the alternative possibility of building a new larger tunnel and storage ring(s) with twice the LEP/LHC circumference, which we call DLEP. Possible DLEP parameters are listed in Table 2, alongside those for LEP3. Naturally, in the long-distant future a DLEP tunnel could also house a proton collider ring with a beam energy about four times higher than the LHC (assuming two times stronger magnets). Rings with a circumference of 30.6 km and 50 km were proposed during the LEP design in 1979 and 1976, respectively, requiring part of the tunnel to be located in the rocks of the Jura, at a depth of 860 m under the crest [16]. The circumference of DLEP should be optimized in order to avoid Hirata-Keil resonances [17] in case the machine is later used for lepton-hadron collisions with the LHC.

Collision ☹

EuCARD LEP3

chaired by Frank Zimmermann (CERN), Marco Zanetti (Massachusetts Inst. of Technology (US))

Monday, 18 June 2012 from **08:00** to **21:30** (Europe/Zurich)
at **CERN** (**6-R-012**)

Description EVO Coordinates: http://tinyurl.com/LEP3Day-EVO

https://indico.cern.ch/conferenceDisplay.py?confId=193791

Monday, 18 June 2012

08:00 - 08:10	Welcome *10'* Speaker: Alain Blondel (Universite de Geneve (CH)) Material: **Slides**
08:10 - 08:40	Physics landscape and LEP3 motivation *30'* Speaker: Patrick Janot (CERN)
08:40 - 09:10	LEP3 machine design options *30'* Speaker: Dr. Frank Zimmermann (CERN)
09:10 - 09:30	Theory perspective on precision Higgs measurements *20'* Speaker: Christophe Grojean (CERN)
09:30 - 10:00	Restriction on the energy and luminosity of e+e- storage rings due to beamstrahlung *30'* Speaker: Prof. Valery Telnov (Budker INP, Novosibirsk, Russia)
10:00 - 10:20	LEP3 beamstrahlung simulations *20'* Speaker: Marco Zanetti (Massachusetts Inst. of Technology (US))
10:20 - 10:40	Comment on LEP3 beamstrahlung *20'* Speaker: Kaoru Yokoya (KEK)
10:40 - 11:00	Coffee break
11:00 - 11:20	CMS@LEP3 physics studies *20'* Speaker: Markus Klute (Massachusettes Institute of Technology)
11:20 - 11:30	Beam-beam limit in high-energy lepton colliders *10'* Speaker: Dr. Ralph Wolfgang Assmann (CERN)
11:30 - 11:50	LEP2 synchrotron-radiation issues *20'* Speaker: Dr. Jose Miguel Jimenez (CERN)
11:50 - 12:05	Cell magnets design for LEP3 *15'* Speaker: Attilio Milanese (CERN)
12:05 - 12:20	Options for final focusing quadrupoles *15'* Speaker: Michele Modena (CERN)
12:20 - 12:40	Infrastructure questions and options *20'* Speaker: m Koratzinos (Physics Department)
12:40 - 13:40	Lunch break
13:40 - 14:00	80-km tunnel *20'* Speaker: John Andrew Osborne (CERN)
14:00 - 14:30	Fast ramping dipole design & status *30'* Speaker: Dr. Henryk PIEKARZ (FNAL)
14:30 - 14:50	Hitch-hiker guide to the LEP3 RF system *20'* Speaker: Andy Butterworth (CERN)
19:30 - 21:30	BBQ @ Alain's: 590 route d'Ornex FRANCE 01280 Prevessin-Moens *590 route d'Ornex FRANCE 01280 Prevessin-Moens*

Goal of meeting:

I- first acquaintance

II- what are the most burning questions?
do we have the answers?

III- organize towards regular 'collaboration' as felt necessary
(steering group, regular meetings etc…)

IV- delineate a plan of work for a 'design study'
-- what kind of manopower is needed

V- prepare statement for European Strategy