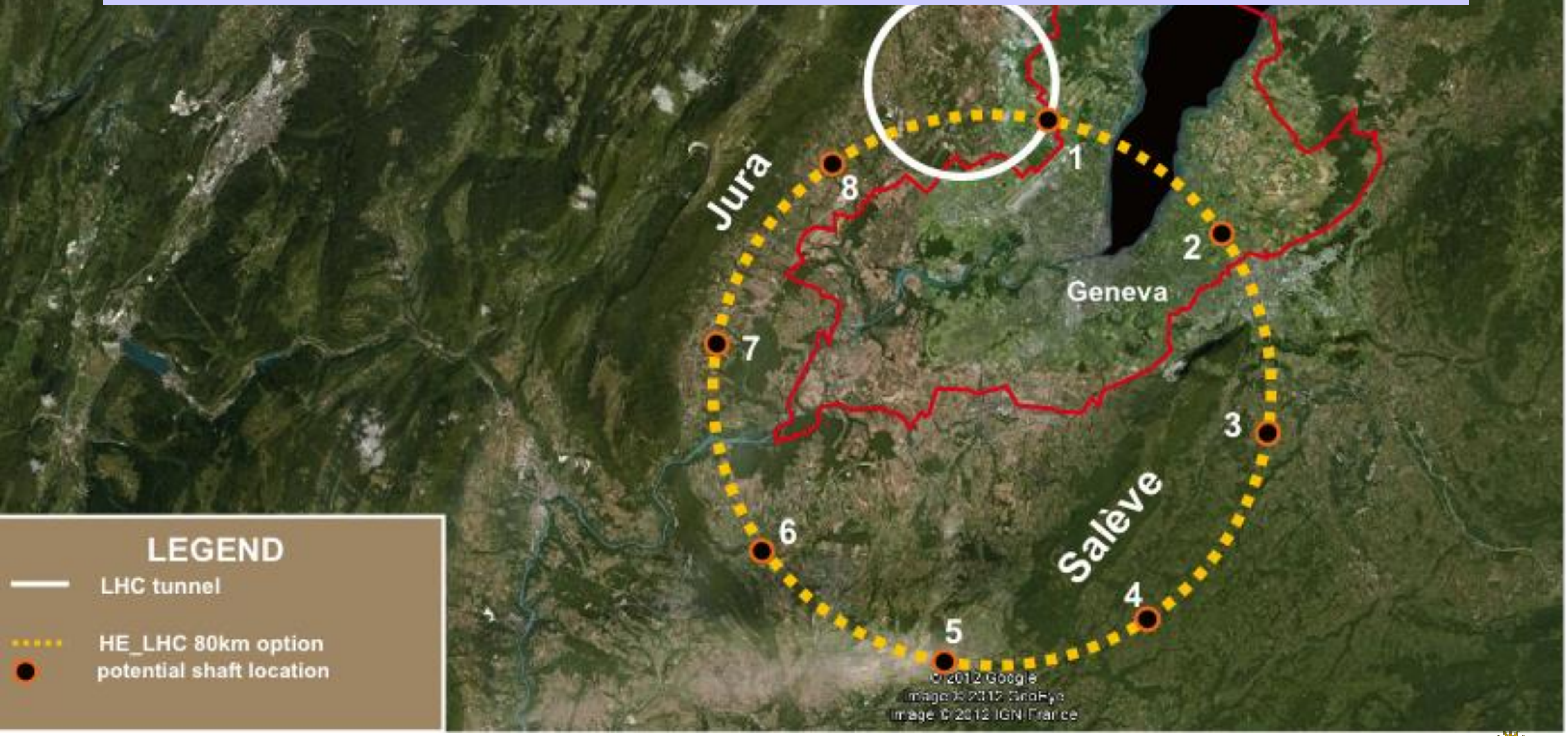
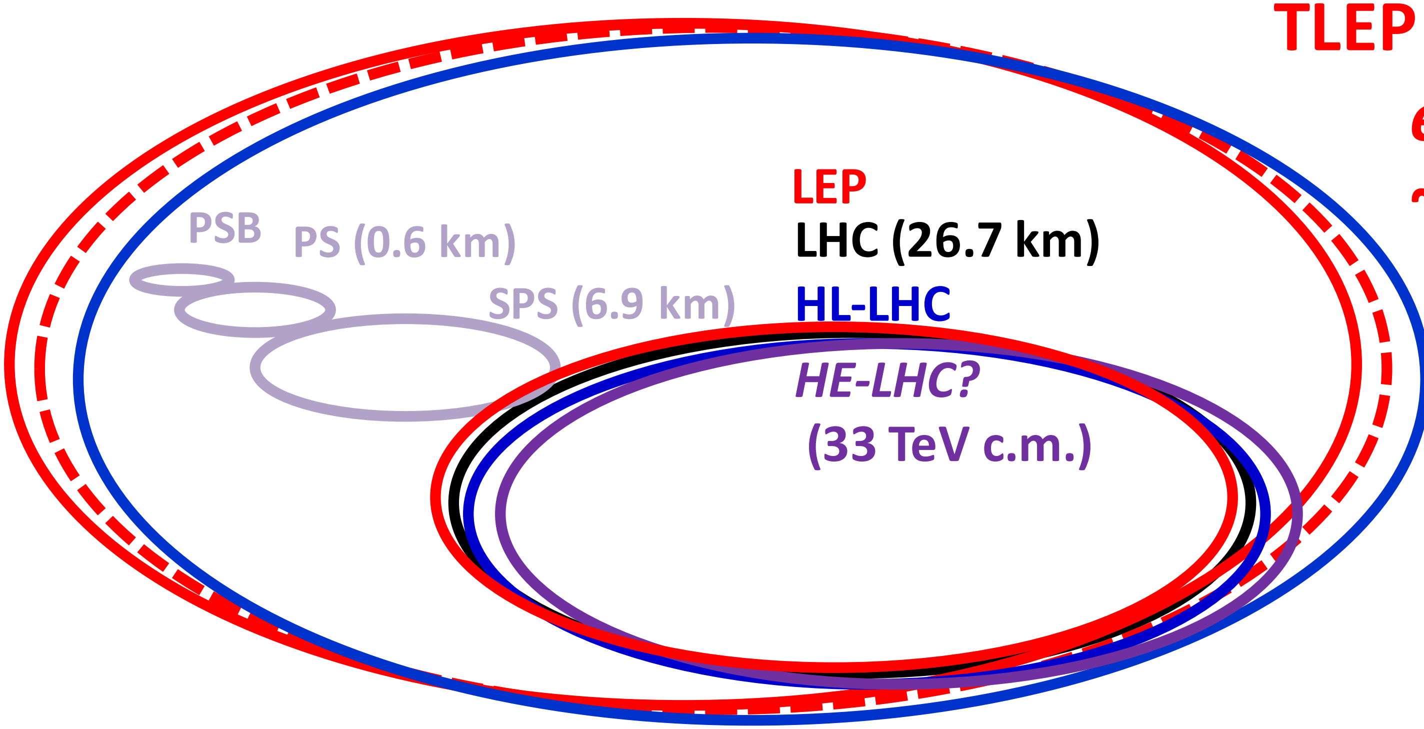
TLEP

Precision physics at the Electroweak scale
TeraZ, OkuW, MegaHiggs and Megatops



possible long-term strategy



TLEP (80-100 km, e^+e^-, up to ~350 GeV c.m.)

VHE-LHC (*pp*, up to 100 TeV c.m.)

“same” detectors!?

& ***e***$^{\pm}$ **(120 GeV)–*p* (7, 16 & 50 TeV)** collisions **([(V)HE-]TLHeC)**

≥50 years of e^+e^-, *pp*, *ep/A* physics at highest energies

What are the possibilities offered by a circular e+e- machine located in the 80-100 km tunnel that will eventually contain also a 100 TeV pp collider?

-- very powerful machine as you will see

++ offers a feasible multi-step long-term strategy :

- **-1- the tunnel and TLEP**
- **-2- 100 TeV pp collider with 16 T magnets**
- **-3- e-p, e-ion, p-ion, ion-ion etc…**

in 2035 the LEP/LHC tunnel will have been used for 46 years…

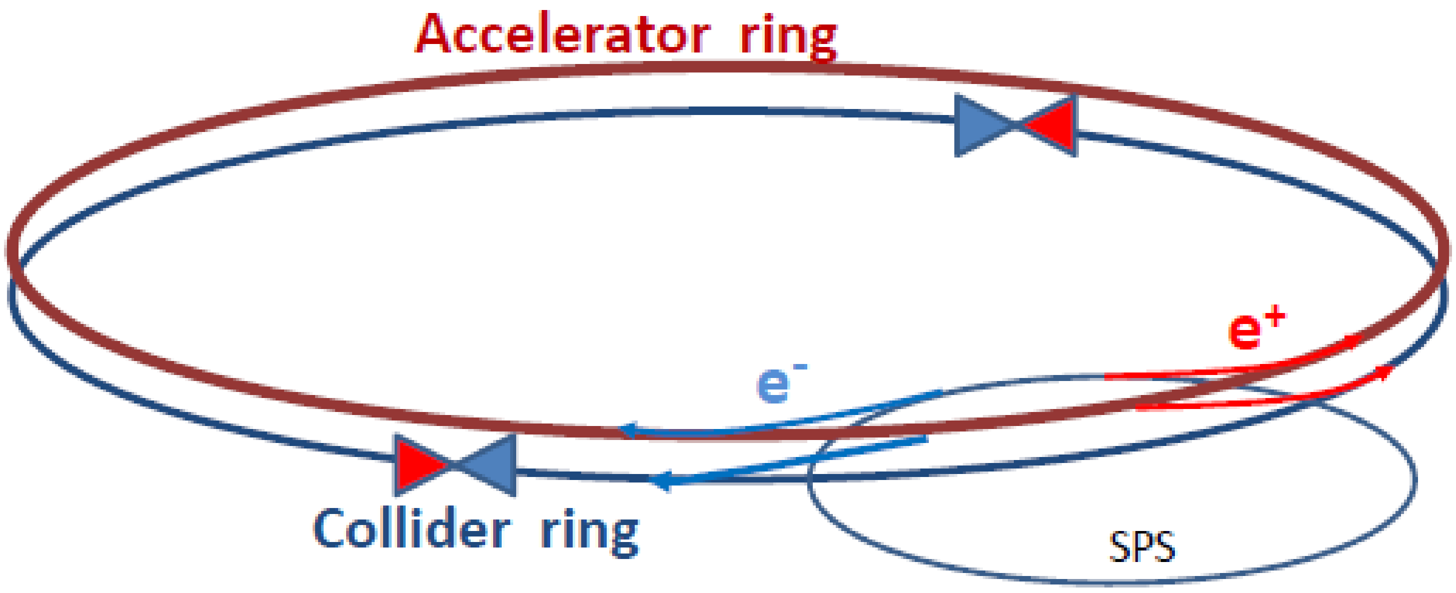
the TLEP/VHE-LHC tunnel would be used for > 50 years!

How can one increase over LEP2 (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 and a small value of β_y^*

electrons and positrons have a much higher chance of interacting

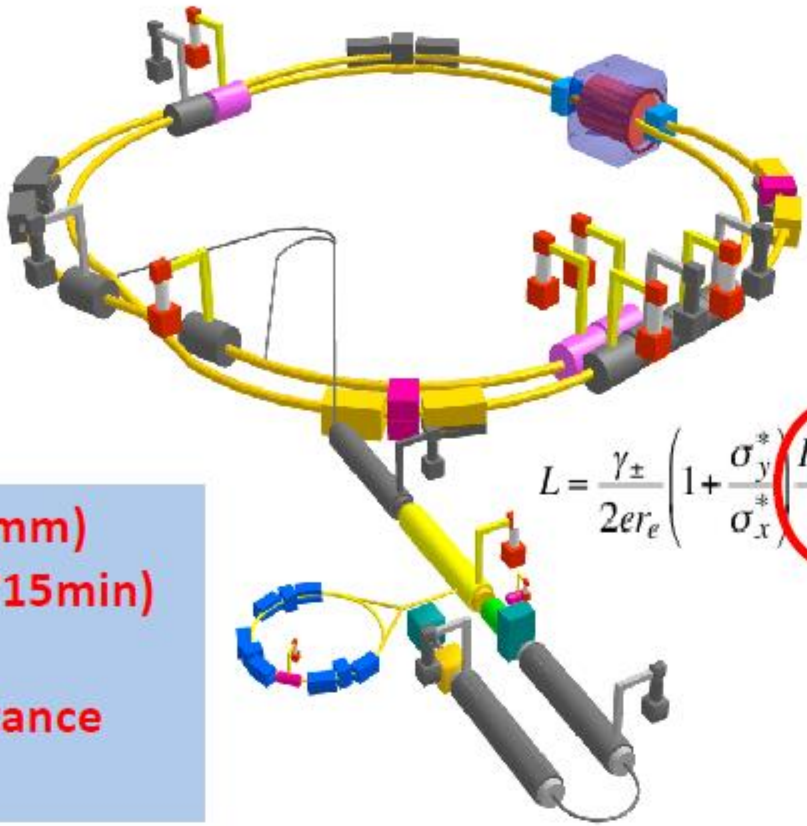
- ➔ much shorter lifetime (few minutes)
  - ➔ feed beam continuously with a ancillary accelerator



Storage ring has separate beam pipes for e+ and e- for multibunch operation

SuperKEKB – TLEP demonstrator!

beam commissioning will start in early 2015



$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$$

- β_y*=300 μm (TLEP: 1 mm)
- lifetime 5 min (TLEP: ~15min)
- $\varepsilon_y/\varepsilon_x$=0.25% (~TLEP)
- off momentum acceptance
- e^+ production rate

Important properties of circular e+e- machines:

-- luminosity

-- center-of-mass definition

-- beam polarization and energy calibration

-- IP backgrounds, repetition rate etc…

-- note that at Z peak operate at 40MHz beam Xing

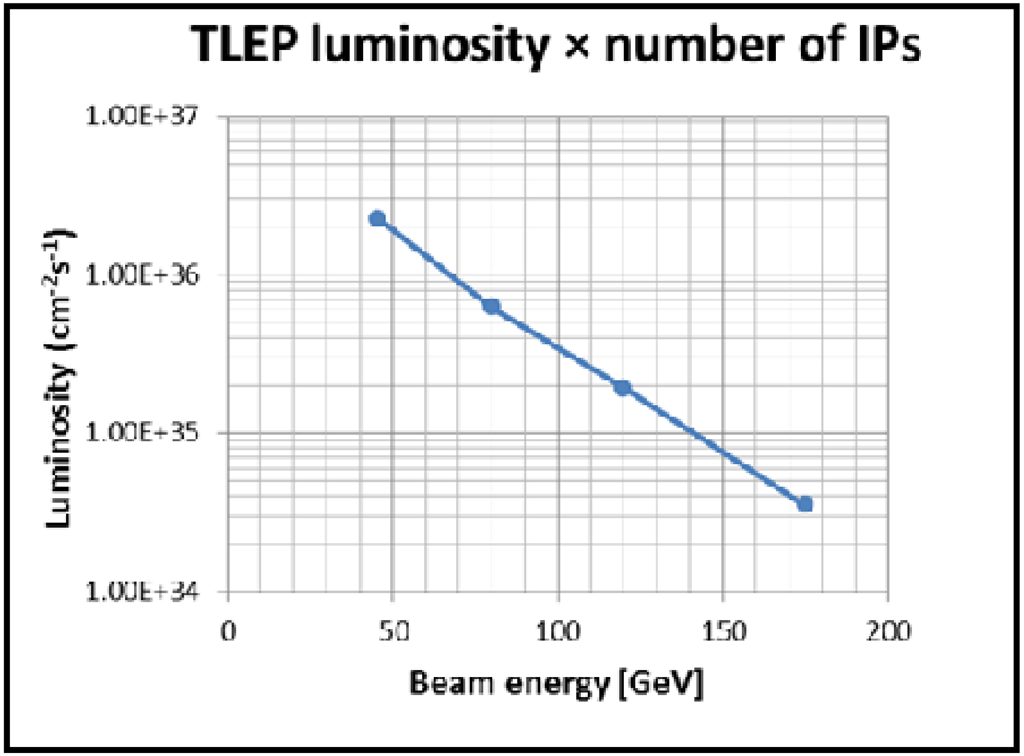
Table 1: TLEP parameters at different energies

	TLEP Z	TLEP W	TLEP H	TLEP t
E_{beam} [GeV]	45	80	120	175
circumf. [km]	80	80	80	80
beam current [mA]	1180	124	24.3	5.4
#bunches/beam	4400	600	80	12
#e^-/beam [10^{12}]	1960	200	40.8	9.0
horiz. emit. [nm]	30.8	9.4	9.4	10
vert. emit. [nm]	0.07	0.02	0.02	0.01
bending rad. [km]	9.0	9.0	9.0	9.0
κ_ε	440	470	470	1000
mom. c. α_c [10^{-5}]	9.0	2.0	1.0	1.0
$P_{loss,SR}$/beam [MW]	50	50	50	50
β^*_x [m]	0.5	0.5	0.5	1
β^*_y [cm]	0.1	0.1	0.1	0.1
σ^*_x [μm]	124	78	68	100
σ^*_y [μm]	0.27	0.14	0.14	0.10
hourglass F_{hg}	0.71	0.75	0.75	0.65
E^{SR}_{loss}/turn [GeV]	0.04	0.4	2.0	9.2
V_{RF},tot [GV]	2	2	6	12
$\delta_{max,RF}$ [%]	4.0	5.5	9.4	4.9
ξ_x/IP	0.07	0.10	0.10	0.10
ξ_y/IP	0.07	0.10	0.10	0.10
f_s [kHz]	1.29	0.45	0.44	0.43
E_{acc} [MV/m]	3	3	10	20
eff. RF length [m]	600	600	600	600
f_{RF} [MHz]	700	700	700	700
δ^{SR}_{rms} [%]	0.06	0.10	0.15	0.22
$\sigma^{SR}_{z,rms}$ [cm]	0.19	0.22	0.17	0.25
$\mathcal{L}$/IP[10^{32}cm^{-2}s^{-1}]	5600	1600	480	130
number of IPs	4	4	4	4
beam lifet. [min]	67	25	16	20

TLEP: A HIGH-PERFORMANCE CIRCULAR e^+e^- COLLIDER TO STUDY THE HIGGS BOSON

M. Koratzinos, A.P. Blondel, U. Geneva, Switzerland; R. Aleksan, CEA/Saclay, France; O. Brunner, A. Butterworth, P. Janot, E. Jensen, J. Osborne, F. Zimmermann, CERN, Geneva, Switzerland; J. R. Ellis, King's College, London; M. Zanetti, MIT, Cambridge, USA.

http://arxiv.org/abs/1305.6498.



CONSISTEN T SET OF PARAMETERS FOR TLEP TAKING INTO ACCOUNT BEAMSTRAHLUNG

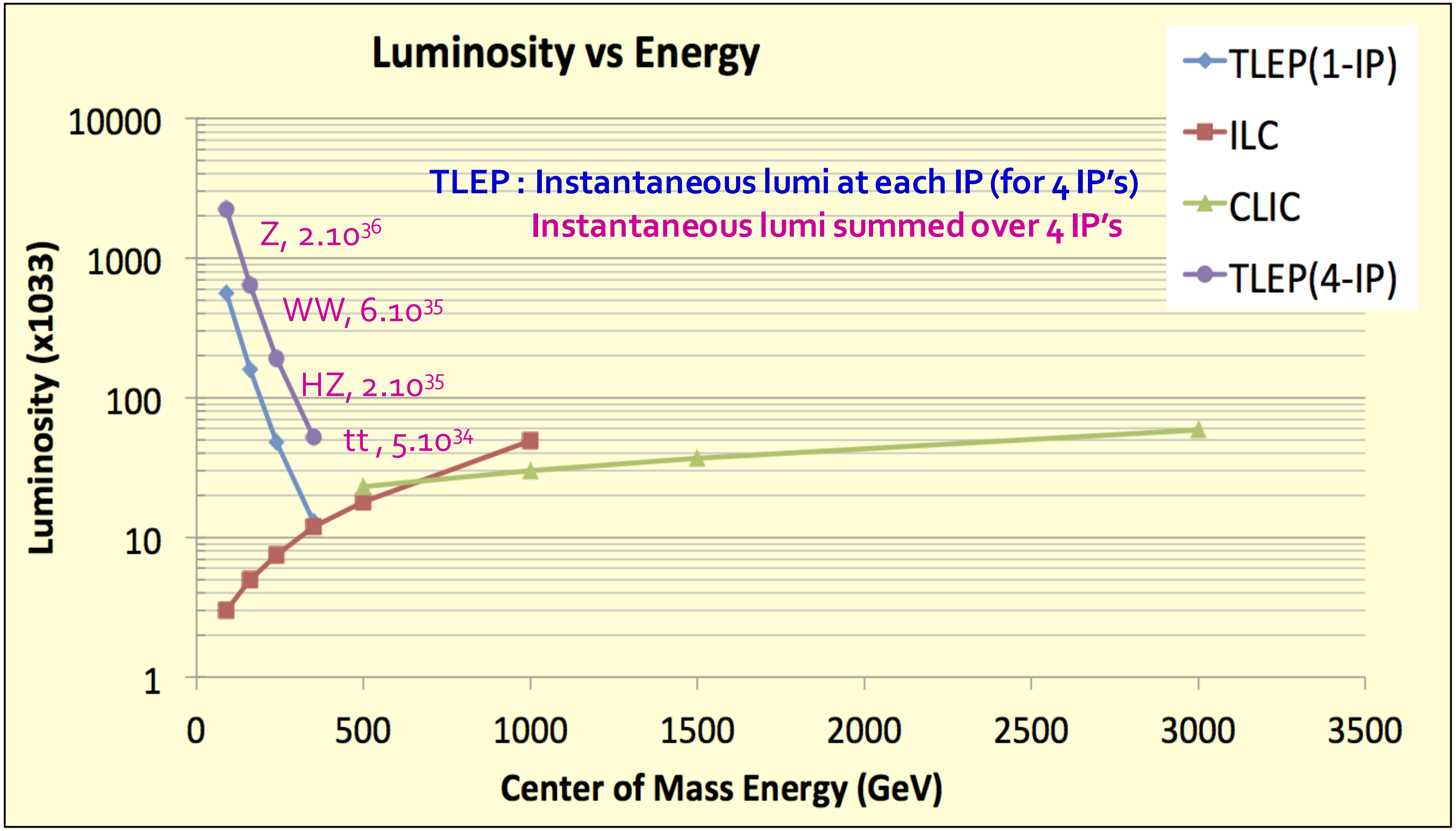
TLEP: PARAMETERS & STATISTICS

($e^+e^- \to ZH$, $e^+e^- \to W^+W^-$, $e^+e^- \to Z$,[$e^+e^- \to t\bar{t}$])

	TLEP-4 IP, per IP	Stats (4IP)
circumference	80 km	
max beam energy	175 GeV	
no. of IPs	4	
Luminosity/IP at 350 GeV c.m.	$1.3\text{x}10^{34}$ $cm^{-2}s^{-1}$	10^6 $t\bar{t}$ pairs **10 ILC**
Luminosity/IP at 240 GeV c.m.	$4.8\text{x}10^{34}$ $cm^{-2}s^{-1}$	2 10^6 ZH evts **30 ILC**
Luminosity/IP at 160 GeV c.m.	$1.6\text{x}10^{35}$ $cm^{-2}s^{-1}$	10^8 WW pairs **100 ILC**
Luminosity/IP at 90 GeV c.m.	5.6 10^{35} $cm^{-2}s^{-1}$	10^{12} Z decays **1000 ILC**

at the *Z* pole repeat the LEP physics programme in a few minutes…

Luminosity of e+ e- colliders



- **Luminosity : Crossing point between circular and linear colliders ~ 400 GeV**

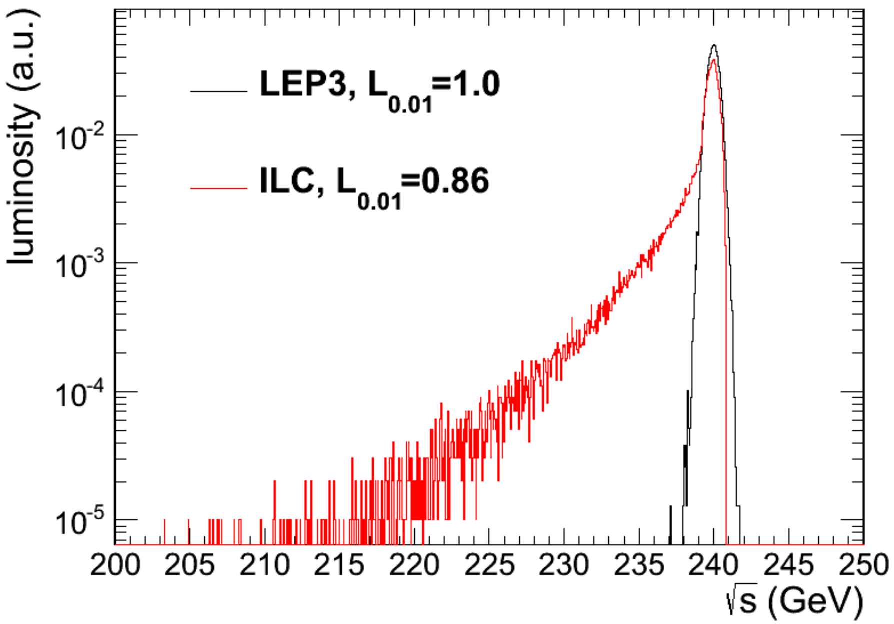
  As pointed out by H. Shopper in 'The Lord of the Rings' (Thanks to Superconducting RF…)

- **Circular colliders can have several IP's . Sum scales as ~$(N_{IP})^{0.5-1}$**

  use 4 IP machine as more reliable predictions using LEP experience

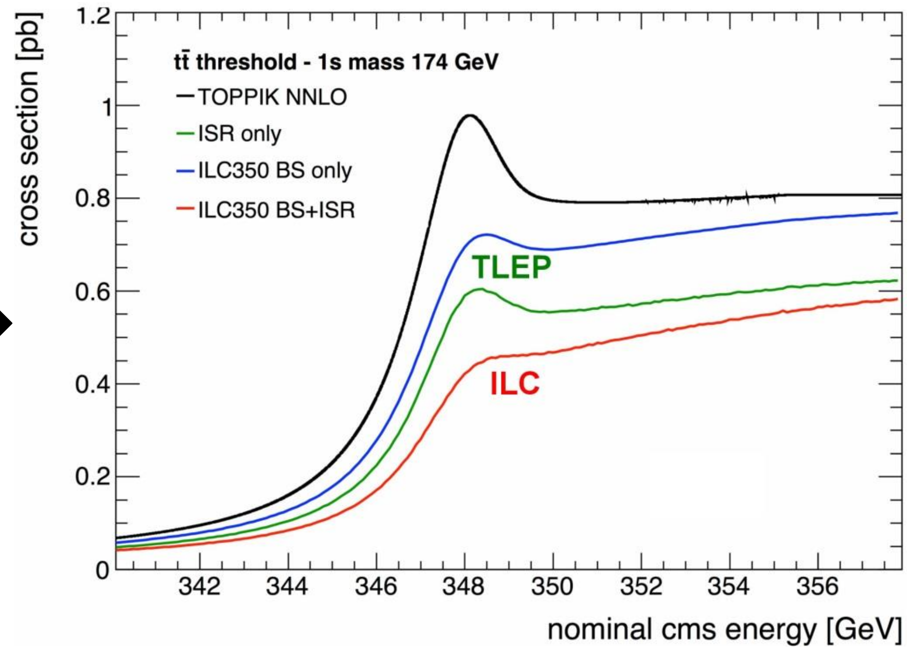
BEAMSTRAHLUNG and energy definition

Luminosity *E* spectrum



➔

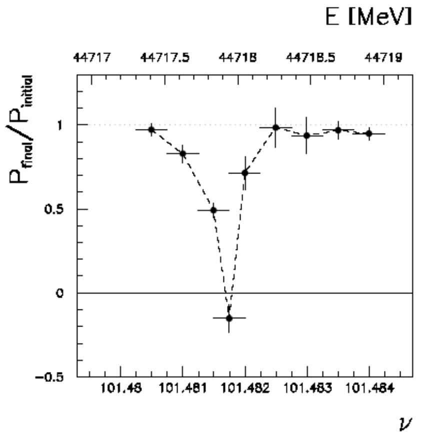
Effect on top threshold



Beamstrahlung @TLEP is important for machine design but benign for physics:
particles are either lost or recycled on a synchrotron oscillation.
➔ some increase of energy spread but no change of average energy
Little resulting systematic error – cross-check wrt orbit of 'single' bunches

Little EM background in the experiment, no issue for luminosity measurement,
but shielding against synchrotron radiation has to be designed.

Beam polarization and E-calibration @ TLEP



Precise meast of E_{beam} by resonant depolarization

~100 keV each time the meast is made *LEP →*

At LEP transverse polarization was achieved routinely at Z peak.

instrumental in 10^{-3} measurement of the Z width in 1993

led to prediction of top quark mass (179+- 20 GeV) in Mar'94

Polarization in collisions was observed *(40% at BBTS = 0.04) →*

At LEP beam energy spread destroyed polarization above 61 GeV

$\sigma_E \propto E^2/\sqrt{\rho}$ ➔ *At TLEP transverse polarization up to at least 81 GeV (WW threshold)*

to go to higher energies requires spin rotators and siberian snake (see spares)

TLEP: use 'single' bunches to measure the beam energy continuously

→*no interpolation errors due to tides, ground motion or trains etc…*

<< 100 keV beam energy calibration around Z peak and W pair threshold.

Δm_Z~0.1 MeV, $\Delta\Gamma_Z$~0.1 MeV, Δm_W ~ 0.5 MeV

EXPERIMENTS ON BEAM-BEAM DEPOLARIZATION AT LEP

R. Assmann*, A. Blondel*, B. Dehning, A. Drees°, P. Grosse-Wiesmann, H. Grote, M. Placidi, R. Schmidt, F. Tecker†, J. Wenninger

PAC 1995

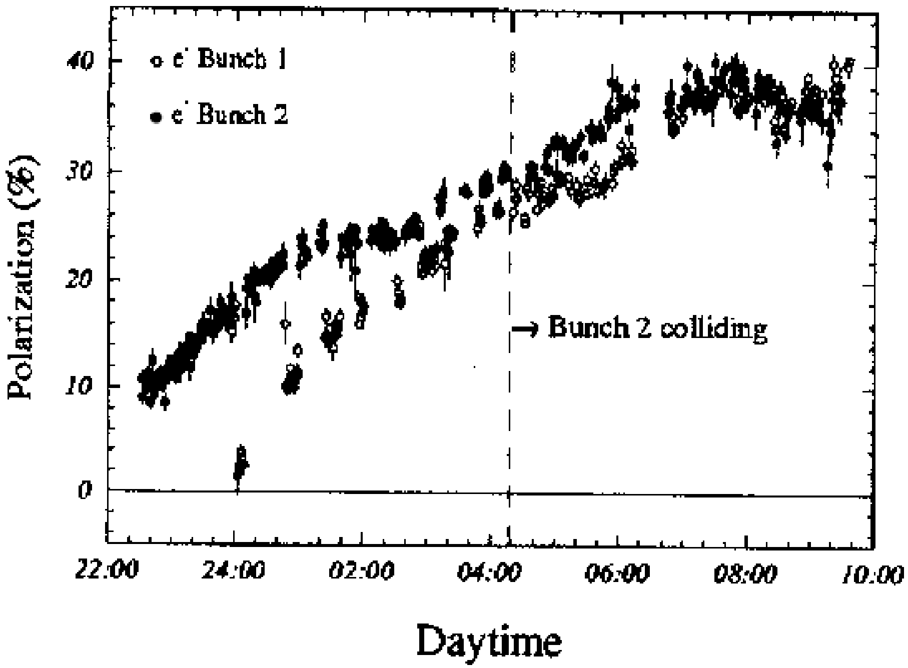


Figure. 3. Polarization level during third experiment

- With the beam colliding at one point, a polarization level of 40 % was achieved. The polarization level was about the same for one colliding and one non colliding bunch.
- It was observed that the polarization level depends critically on the synchrotron tune : when Q_s was changed by 0.005, the polarization strongly decreased.

experiment performed at an energy of 44.71 GeV the polarization level was 40 % with a linear beam-beam tune shift of about 0.04/IP. This indicates, that the beam-beam depolarization does not scale with the linear beam-beam tune shift at one crossing point. Other parameters as spin tune and synchrotron tune are also of importance.

This was only tried 3 times!
Best result: P = 40% , ξ^*_y= 0.04 , one IP
Assuming 4 IP and ξ^*_y= 0.01 ➔

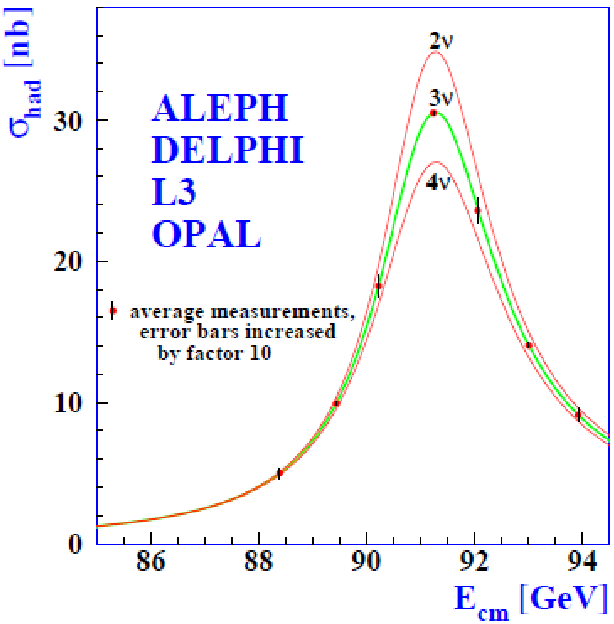
reduce luminositiy somewhat, 10^{11} Z @ P=40%

TERA-Z and Oku-W

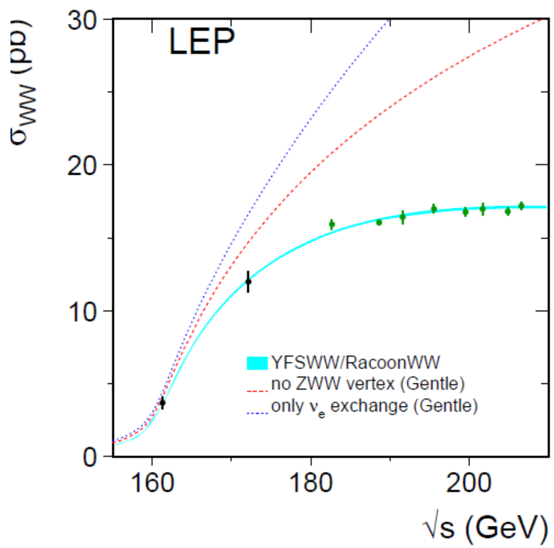
Precision tests of the closure of the Standard Model

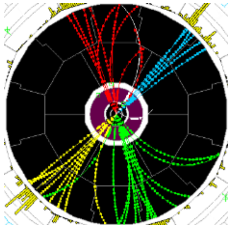
Precision tests of EWSB

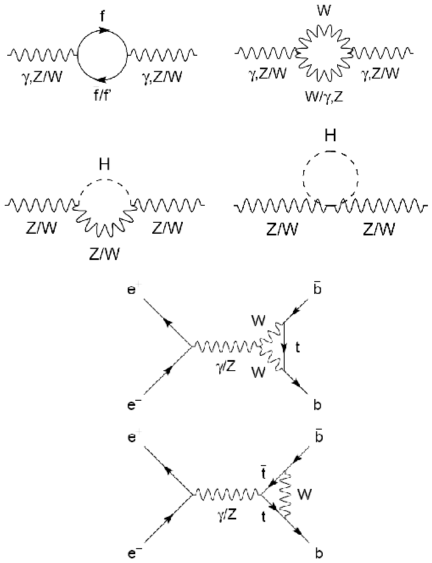
Z pole ssymmetries, lineshape



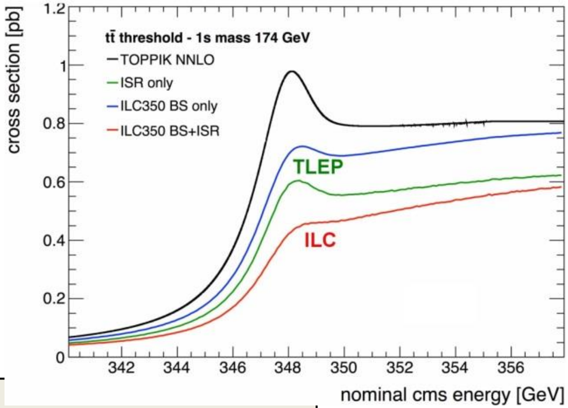
WW threshold scan







tt threshold scan



TLEP : Repeat the LEP1 physics programme every 15 mn

Transverse polarization up to the WW threshold

- Exquisite beam energy determination (10 keV)

Longitudinal polarization at the Z pole

- Measure $\sin^2\theta_W$ to 2.10^{-6} from A_{LR}
- Statistics, statistics: 10^{10} tau pairs, 10^{11} bb pairs, QCD and QED studies etc…

EWRCs

relations to the ... measured G_F, ... QED ... order:

$- \alpha/\pi\ (m_{top}/m_Z)^2$

$- \alpha/4\pi \log (m_h/m_Z)^2$

$\varepsilon_3 = \cos^2\theta_W\ \alpha/9\pi \log (m_h/m_Z)^2$

$\delta_{vb} = 20/13\ \alpha/\pi\ (m_{top}/m_Z)^2$

$\Delta\rho$: $\equiv \varepsilon_1$

$$\Gamma_\ell = (1+\Delta\rho)\frac{G_F\, m_Z^3}{24\pi\sqrt{2}}\left(1+\left(\frac{g_{V\ell}}{g_{A\ell}}\right)^2\right)\left(1+\frac{3}{4}\frac{\alpha}{\pi}\right)$$

ε_3

$$\sin^2\theta_W^{eff}\cos^2\theta_W^{eff} = \frac{\pi\alpha(M_Z^2)}{\sqrt{2}\, G_F\, m_Z^2}\ \frac{1}{1+\Delta\rho}\ \frac{1}{1-\frac{\varepsilon_3}{\cos^2\theta_W}}$$

δ_{vb}

$$\Gamma_b = (1+\delta_{vb})\,\Gamma_d\,\left(1 - \text{mass corrections } \alpha\, m_b^2/M_Z^2\right)$$

ε_2

$$M_W^2 = \frac{\pi\alpha(M_Z^2)}{\sqrt{2}\, G_F \sin^2\theta_W^{eff}} \ldots (\ldots \varepsilon_3 + \varepsilon_2)$$

$\sin^2\theta_W^{eff}$ is defined ...

$$\sin^2 \ldots \frac{g_{V\ell}}{g_{A\ell}} = \sin^2\theta_W^{eff}{}_{lept}$$

... obtained from asymmetries at the Z.

also

$$M_W^2 = \frac{\pi\alpha}{\sqrt{2}\, G_F}\cdot\frac{1}{\left(1-\frac{M_W^2}{M_Z^2}\right)}\ \frac{1}{(1-\Delta r)}$$

Δr

$$\Delta r = \Delta\alpha - \frac{\cos^2\theta_W}{\sin^2\theta_W}\Delta\rho + 2\frac{\cos^2\theta_W}{\sin^2\theta_W}\varepsilon_3 + \frac{c^2-s^2}{s^2}\varepsilon_2$$

There is much more than the W mass!

complete formulae at 2d order including strong corrections are available in fitting codes

e.g. ZFITTER , GFITTER

Will need to be improved for TLEP!

Words of caution:

1. TLEP will have 5.10^4 more luminosity than LEP at the Z peak, 5.10^3 at the W pair threshold.
Predicting achievable accuracies with statistical errors decreasing by 250 is very difficult. The study is just beginning.

2. The following table are 'plausible' precisions based on my experience and knowledge of the present limitations, most of which from higher order QED corrections (ex. production of additional lepton pairs etc..).
Many can have experimental cross-checks and errors may get better.

3. The most serious issue is the luminosity measurement which relies on the calculations/modeling of the low angle Bhabha scattering cross-section.
This dominates the measurement of the hadronic cross section at the Z peak thus the determination of N_ν (test of the unitarity of the PMNS matrix)

4. The following is only a sample of possibilities. With 10^{12} Z decays, there are many, many more powerful studies to perform at TERA-Z
e.g. flavour physics with 10^{11} $\bar{b}b$, $\bar{c}c$, 10^{10} $\tau\tau$ etc…

TLEP

A Sample of Essential quantities:

X	Physics	Present precision		TLEP target Precision –TBS	TLEP key	Issues
M_Z MeV/c2	Input	91187.5 ±2.1	Z Line shape scan	<±0.1 MeV/c2 (solid)	E_cal	QED corrections
Γ_Z MeV/c2	$\Delta\rho$ (T) (no $\Delta\alpha$!)	2495.2 ±2.3	Z Line shape scan	<±0.1 MeV/c2 (solid)	E_cal	QED corrections
R_ℓ	α_s, δ_b	20.767 ± 0.025	Z Peak	± 0.002 - 0.0002	Statistics	QED corrections
N_ν	Unitarity of PMNS, sterile ν's	2.984 ±0.008	Z Peak	±0.001 (?)	environment ->lumi meast	QED corrections to Bhabha scat.
R_b	δ_b	0.21629 ±0.00066	Z Peak	±0.00002 - 5	Statistics, small IP	Hemisphere correlations
A_{LR}	$\Delta\rho$, ε_3, $\Delta\alpha$ (T, S)	0.1514 ±0.0022 (SLD)	Z peak, polarized	±0.000015 (solid)	4 bunch scheme	Polarization in collisions
M_W MeV/c2	$\Delta\rho$, ε_3, ε_2, $\Delta\alpha$ (T, S, U)	80385 ± 15	Threshold scan	0.5 (solid)	E_cal & Statistics	
m_{top} MeV/c2	Input	173200 ± 900	Threshold scan	10	E_cal & Statistics	

Measurement of A_{LR}

electron bunches	$1\Leftarrow$	2	3	$4\Leftarrow$
positron bunches	1	$2\Rightarrow$	3	$4\Rightarrow$
cross sections	σ_1	σ_2	σ_3	σ_4
event numbers	N_1	N_2	N_3	N_4

$$\sigma_1 = \sigma_u (1 - P^-_e A_{LR})$$

$$\sigma_2 = \sigma_u (1 + P^+_e A_{LR})$$

$$\sigma_3 = \sigma_u$$

$$\sigma_4 = \sigma_u [1 - P^+_e P^-_e + (P^+_e - P^-_e) A_{LR}]$$

Verifies polarimeter with experimentally measured cross-section ratios

statistics $\Delta A_{LR} =$ 0.0025 with about 10^6 Z^0 events,

ΔA_{LR} = 0.000015 with 10^{11} Z and 40% polarization in collisions.

$\Delta \sin^2\theta_W^{eff}$ (stat) = O(2.10^{-6})

At the moment we do not know for sure what is the most sensible scenario

LHC offered 3 possible scenarios: (could not lose)

Discover that there is nothing in this energy range.

➔ This would have been a great surprise and a great discovery!

NO

Discover SM Higgs Boson and that nothing else is within reach

➔ Most Standard scenario great discovery!

So far we are here

Discover many new effects or particles great discovery!

But....

Keep looking in 13/14 TeV data!

Also: understand scaling of LHC errors with luminosity

Answer in 2018

High precision

High energy

BE PREPARED!

Recommendation from European Strategy (2)

d) To stay at the forefront of particle physics, Europe needs to be in a position to propose an ambitious post-LHC accelerator project at CERN by the time of the next Strategy update, when physics results from the LHC running at 14 TeV will be available.

CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. These design studies should be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide.

The two most promising lines of development towards the new high energy frontier after the LHC are proton-proton and electron-positron colliders. Focused design studies are required in both fields, together with vigorous accelerator R&D supported by adequate resources and driven by collaborations involving CERN and national institutes, universities and laboratories worldwide. The Compact Linear Collider (CLIC) is an electron-positron machine based on a novel two-beam acceleration technique, which could, in stages, reach a centre-of-mass energy up to 3 TeV. A Conceptual Design Report for CLIC has already been prepared. Possible proton-proton machines of higher energy than the LHC include HE-LHC, roughly doubling the centre-of-mass energy in the present tunnel, and VHE-LHC, aimed at reaching up to 100 TeV in a new circular 80km tunnel. A large tunnel such as this could also host a circular e^+e^- machine (TLEP) reaching energies up to 350 GeV with high luminosity.

CERN Medium term plan -- June 2013:

CERN/SPC/1012
CERN/FC/5747
CERN/3069

- studies for high-energy proton-proton and electron-positron colliders in a new 80-100 km circular tunnel have already started. The aim is to have available Conceptual Design Reports by the time of the next update of the European Strategy for Particle Physics.

NB. What ICFA decided to discontinue are the ICFA-beam dynamics workshops on Higgs Factories -- not the studies of course!

Design Study : http://tlep.web.cern.ch

can suscribe for work, informations, newsletter , etc…

Global collaboration: collaborators from Europe, US, Japan, China →

Next events: TLEP workshops 25-26 July 2013, Fermilab

16-18 October 2013, CERN

+ Joint VHE-LHC+ TLEP kick-off meeting in February 2014

The first 250 subscribers:

Some interesting statistics can be found below. More details can be found on the TLEP web site.

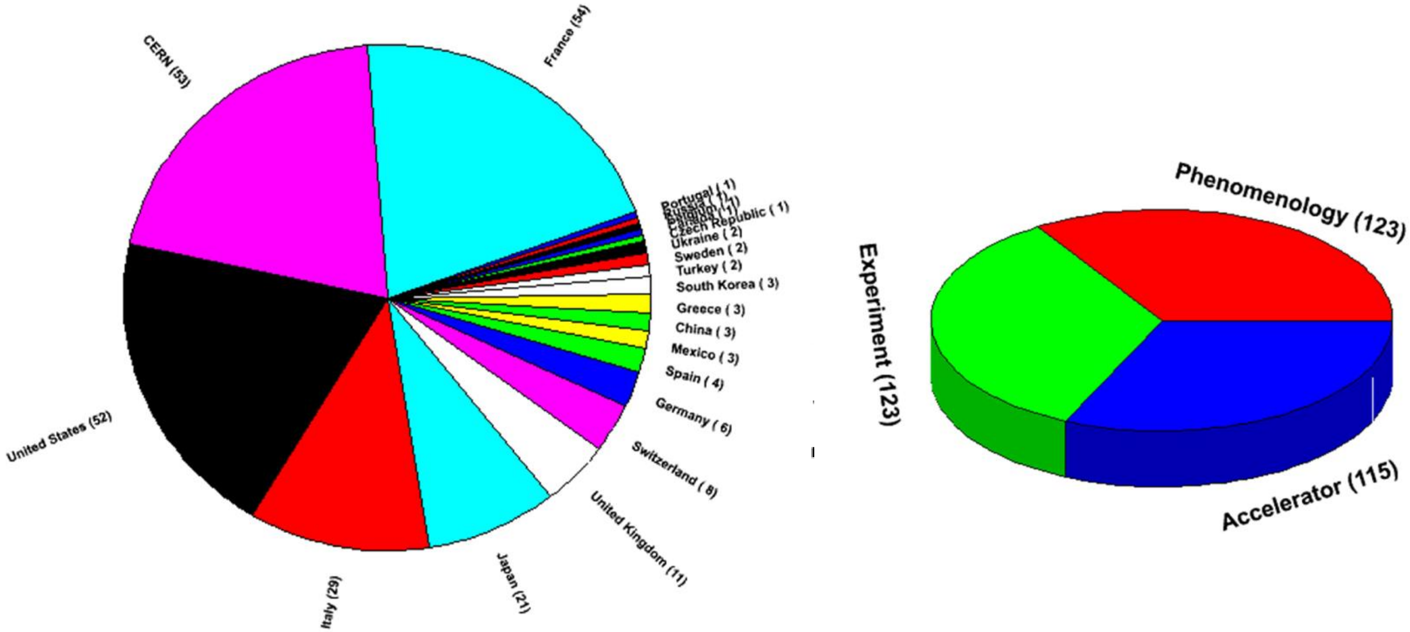
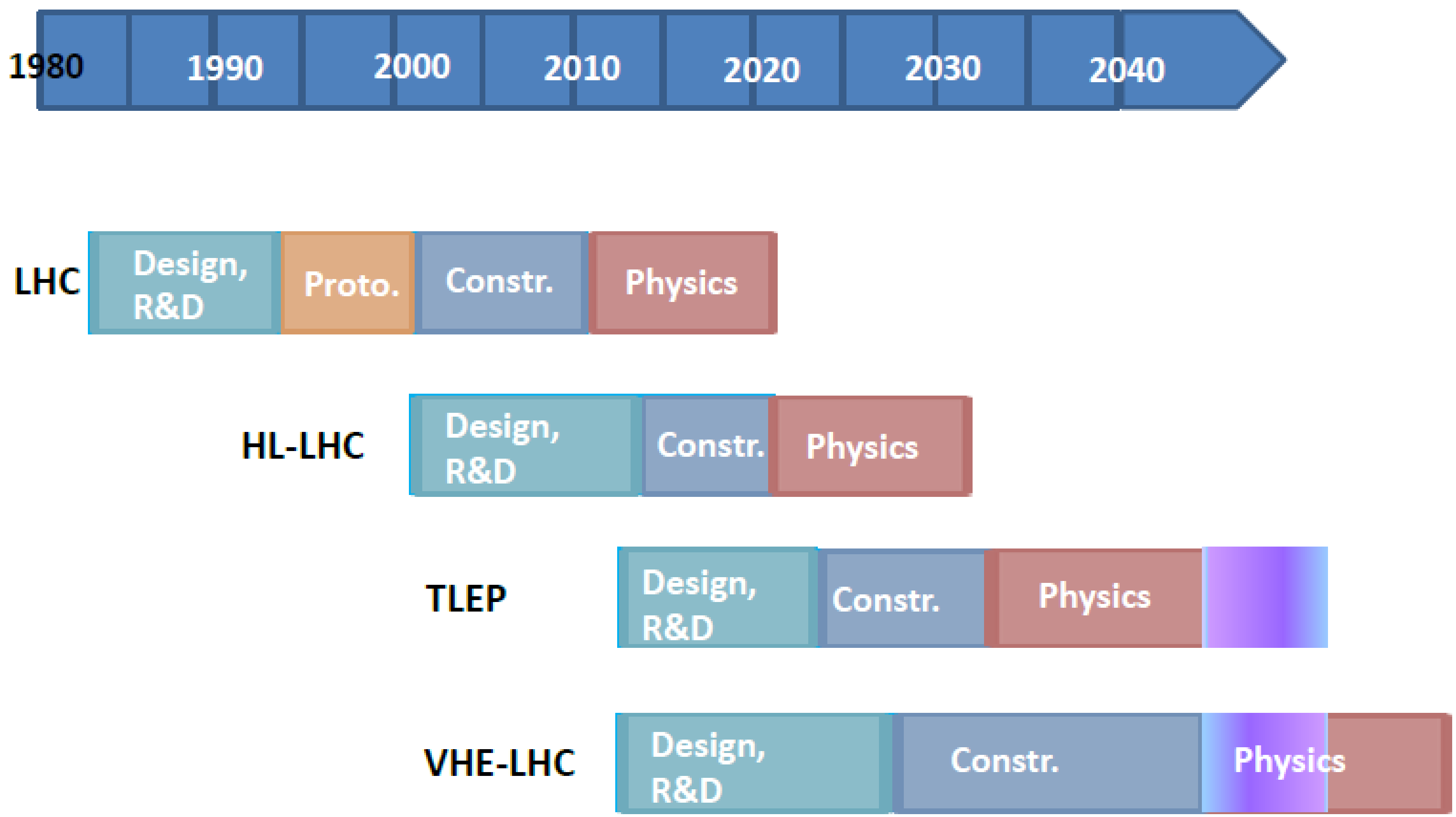


Figure 1 Left : distribution of the first 200 subscribers on the basis of the institute's country. Right: distribution between accelerator, experiment and phenomenology.

The distribution of the country of origin reflects the youth of the TLEP project and the very different levels of awareness in the different countries.

The audience is remarkably well balanced between Accelerator, Experiment, and Phenomenology

possible long-term time line



Zimmermann

Conclusions

- **Discovery of H(126) focuses studies of the next machine**
  - News ideas emerging for Higgs factories and beyond

- **A large e+e- storage ring collider seems the best complement to the LHC**
  - Couple Permil precision on Higgs Couplings (see P. Janot's talk)
  - Unbeatable precision on EW quantities (m_Z, Γ_Z, m_W, A_{LR}, R_b etc, etc.....)
  - Most mature technology and safe luminosity estimates.
  - A first step towards a 100 TeV proton proton collider and a long term vision.

The numbers speak for themselves!

- **Results of the LHC run at 14 TeV will be a necessary and precious input**
  - Towards an ambitious medium and long term vision
  - In Europe: Decision to be taken by 2018
  - Design study recommended and being organized : tlep.web.cern.ch

Some guidance from theorists:

New physics affects the Higgs couplings

SUSY $\frac{g_{hbb}}{g_{h_{SM}bb}} = \frac{g_{h\tau\tau}}{g_{h_{SM}\tau\tau}} \simeq 1 + 1.7\% \left(\frac{1\text{ TeV}}{m_A}\right)^2$, for tanβ = 5

Composite Higgs $\frac{g_{hff}}{g_{h_{SM}ff}} \simeq \frac{g_{hVV}}{g_{h_{SM}VV}} \simeq 1 - 3\% \left(\frac{1\text{ TeV}}{f}\right)^2$

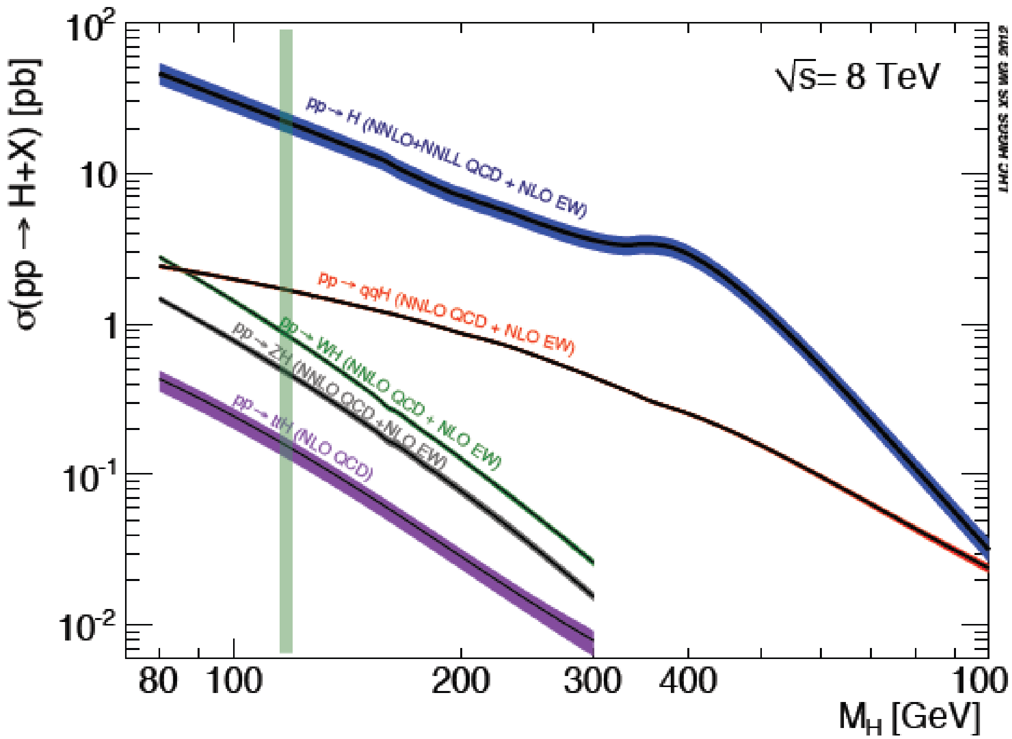
Top partners $\frac{g_{hgg}}{g_{h_{SM}gg}} \simeq 1 + 2.9\% \left(\frac{1\text{ TeV}}{m_T}\right)^2, \quad \frac{g_{h\gamma\gamma}}{g_{h_{SM}\gamma\gamma}} \simeq 1 - 0.8\% \left(\frac{1\text{ TeV}}{m_T}\right)^2$

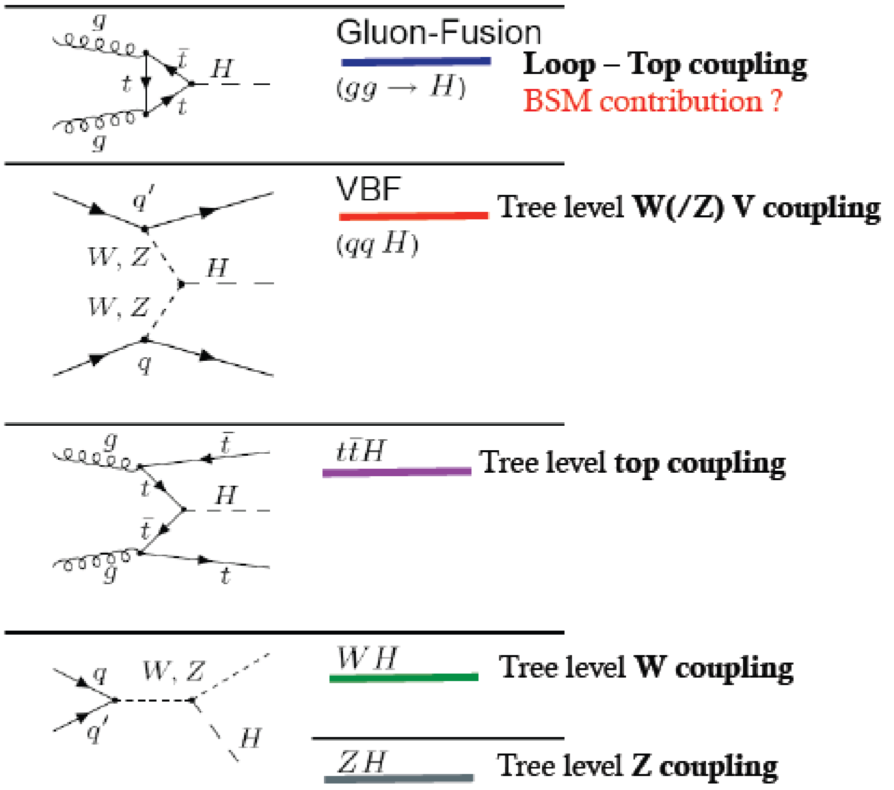
Other models may give up to 5% deviations with respect to the Standard Model

Sensitivity to "TeV" new physics needs per-cent to sub-per-cent accuracy on couplings for 5 sigma discovery.

LHC discovery/(or not) at 13 TeV will be crucial to understand the strategy for future collider projects

R.S. Gupta, H. Rzehak, J.D. Wells, "How well do we need to measure Higgs boson couplings?", arXiv:1206.3560 (2012)
H. Baer et al., "Physics at the International Linear Collider", in preparation, http://lcsim.org/papers/DBDPhysics.pdf





The LHC is a Higgs Factory !

1M Higgs already produced – more than most other Higgs factory projects.
15 Higgs bosons / minute – and more to come (gain factor 3 going to 13 TeV)

Difficulties: several production mechanisms to disentangle and significant systematics in the production cross-sections σ_{prod} .
Challenge will be to reduce systematics by measuring related processes.

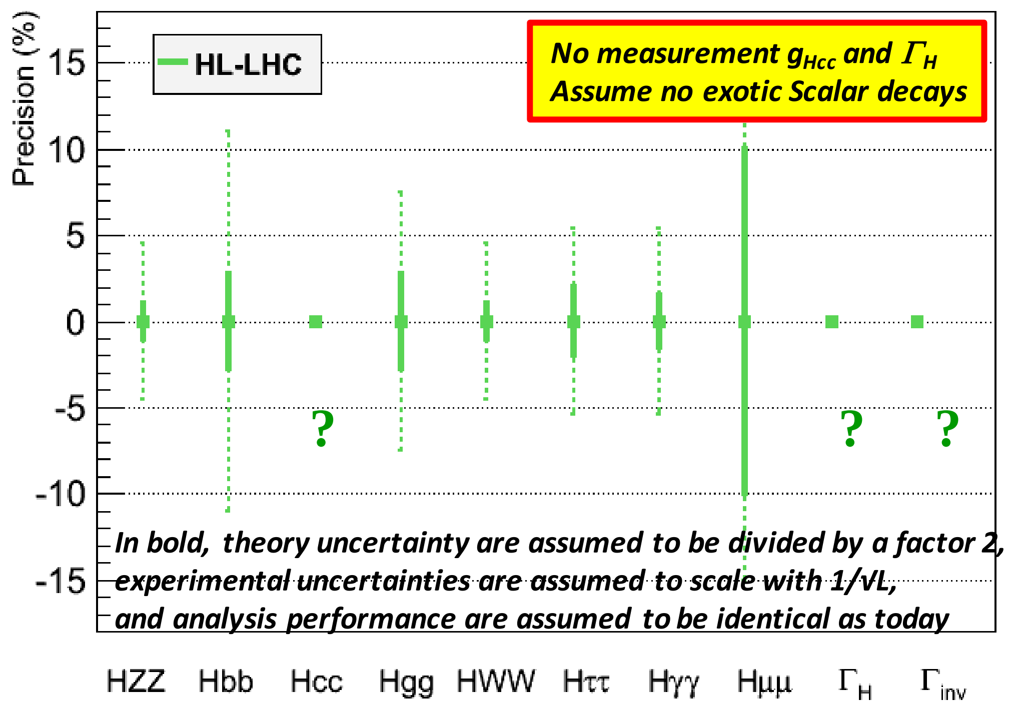
$\sigma_{i \to f}^{\ observed} \propto \sigma_{prod} \dfrac{(g_{Hi})^2 (g_{Hf})^2}{\Gamma_H}$ **extract couplings to anything you can see or produce from**
if i=f as in WZ with H→ ZZ → absolute normalization

HL-LHC (≡3 ab^{-1} at 14 TeV):

Highest-priority recommendation from European Strategy

c) The discovery of the Higgs boson is the start of a major programme of work to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier.
The LHC is in a unique position to pursue this programme.

	LHC	**HL-LHC**
End date	2021	2030-35?
$\mathbf{N_H}$	1.7 x 10^7	1.7 x 10^8
Δm_H **(MeV)**	100	50
$\Delta g_{H\gamma\gamma}/g_{H\gamma\gamma}$	6.5 – 5.1%	5.4 – **1.5%**
$\Delta g_{Hgg}/g_{Hgg}$	11 – 5.7%	7.5 – **2.7%**
$\Delta g_{Hww}/g_{Hww}$	5.7 – 2.7%	4.5 – **1.0%**
$\Delta g_{HZZ}/g_{HZZ}$	5.7 – 2.7%	4.5 – **1.0%**
$\Delta g_{HHH}/g_{HHH}$	--	< 30%
$\Delta g_{H\mu\mu}/g_{H\mu\mu}$	<30%	<10%
$\Delta g_{H\tau\tau}/g_{H\tau\tau}$	8.5 – 5.1%	5.4 – **2.0%**
$\Delta g_{Hcc}/g_{Hcc}$	--	--
$\Delta g_{Hbb}/g_{Hbb}$	15 – 6.9%	11 – **2.7%**
$\Delta g_{Htt}/g_{Htt}$	14 – 8.7%	8.0 – **3.9%**

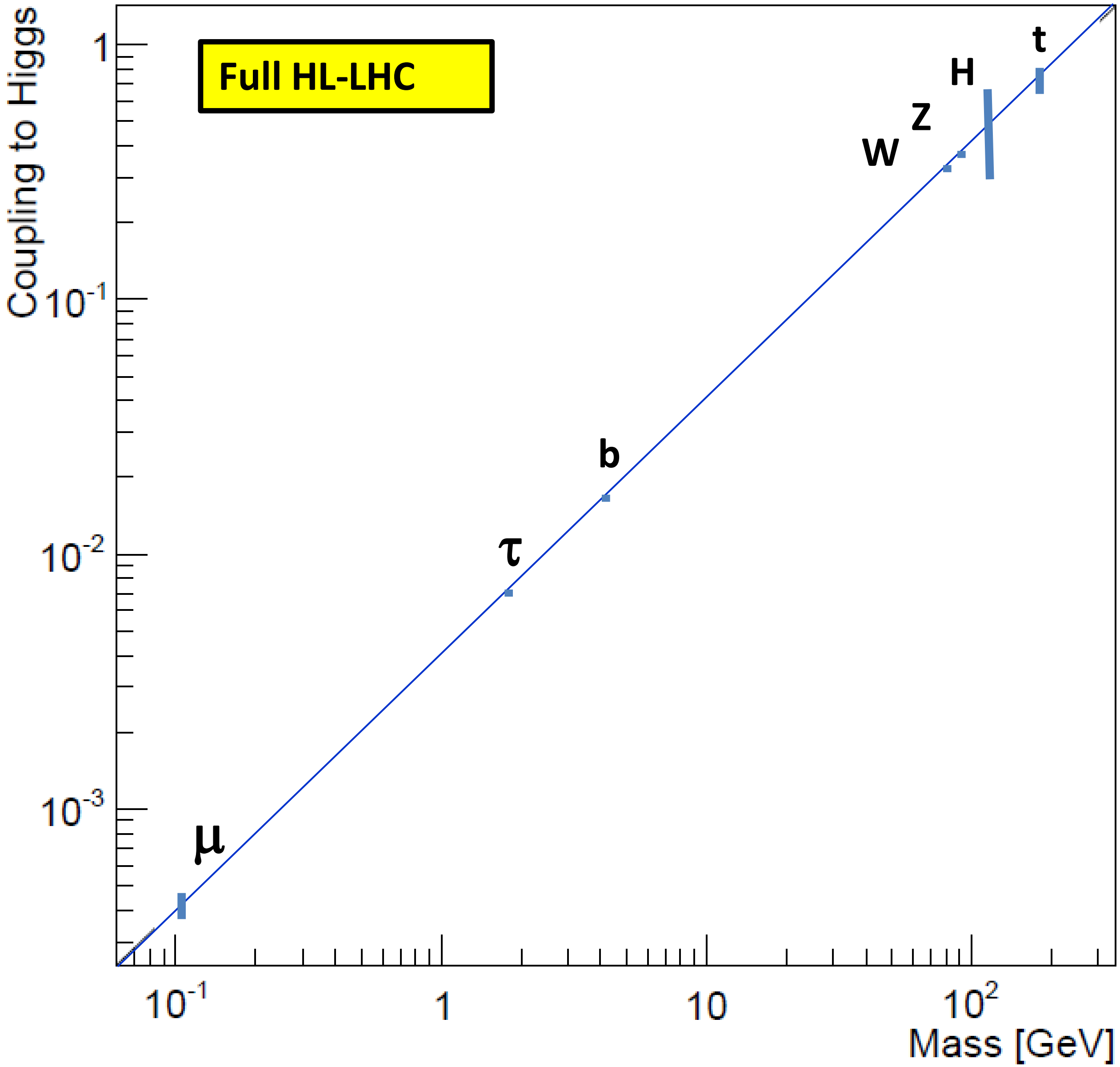


Coupling measurements with precision :

- **in the range 6-15% with LHC - 300 fb^{-1}**
- **in the range 1-4% with HL-LHC - 3000 fb^{-1}**

NB: at LEP theory errors improved by factor 10 or more….

B. Mele



Full HL-LHC
Coupling to Higgs
1
10⁻¹
10⁻²
10⁻³
10⁻¹
1
10
10²
Mass [GeV]
μ
τ
b
W
Z
H
t

Conclusions and outlook (my own view)

A project for the next 50 years

The discovery of the H(126) scalar boson opens the way to precise investigations:

-- HL-LHC
-- A lepton collider of sufficient luminosity and precision
-- Best performance with an e+e- circular machine TLEP in a large (80km) tunnel

-- First step towards 100 TeV Very Large Hadron Collider

-- Choice when LHC results at 13 TeV available → 2017-18

in 2035 the LEP/LHC tunnel will have been used for 46 years…

the TLEP/VHE-LHC tunnel would be used for > 50 years!

Obtaining longitudinal polarization at higher energies requires a cancellation of depolarization effects by reducing the spin-tune spread associated with the energy spread. Siberian snake solutions [11] invoking combinations of spin rotators situated around the experiments and polarization wigglers are being discussed. They take advantage of the fact that the TLEP arcs have very low fields and can be overruled by polarization wigglers suitably disposed around the ring. These schemes will need to be worked out and simulated before the feasibility of longitudinal polarization in high energy collisions can be asserted.

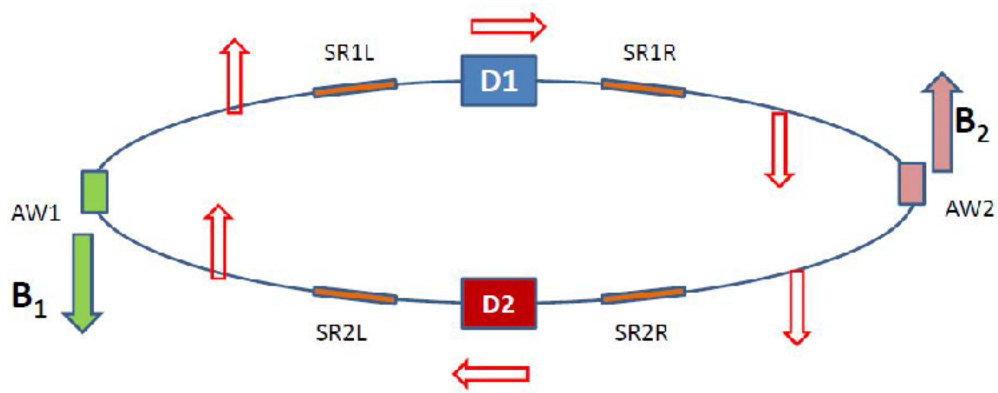
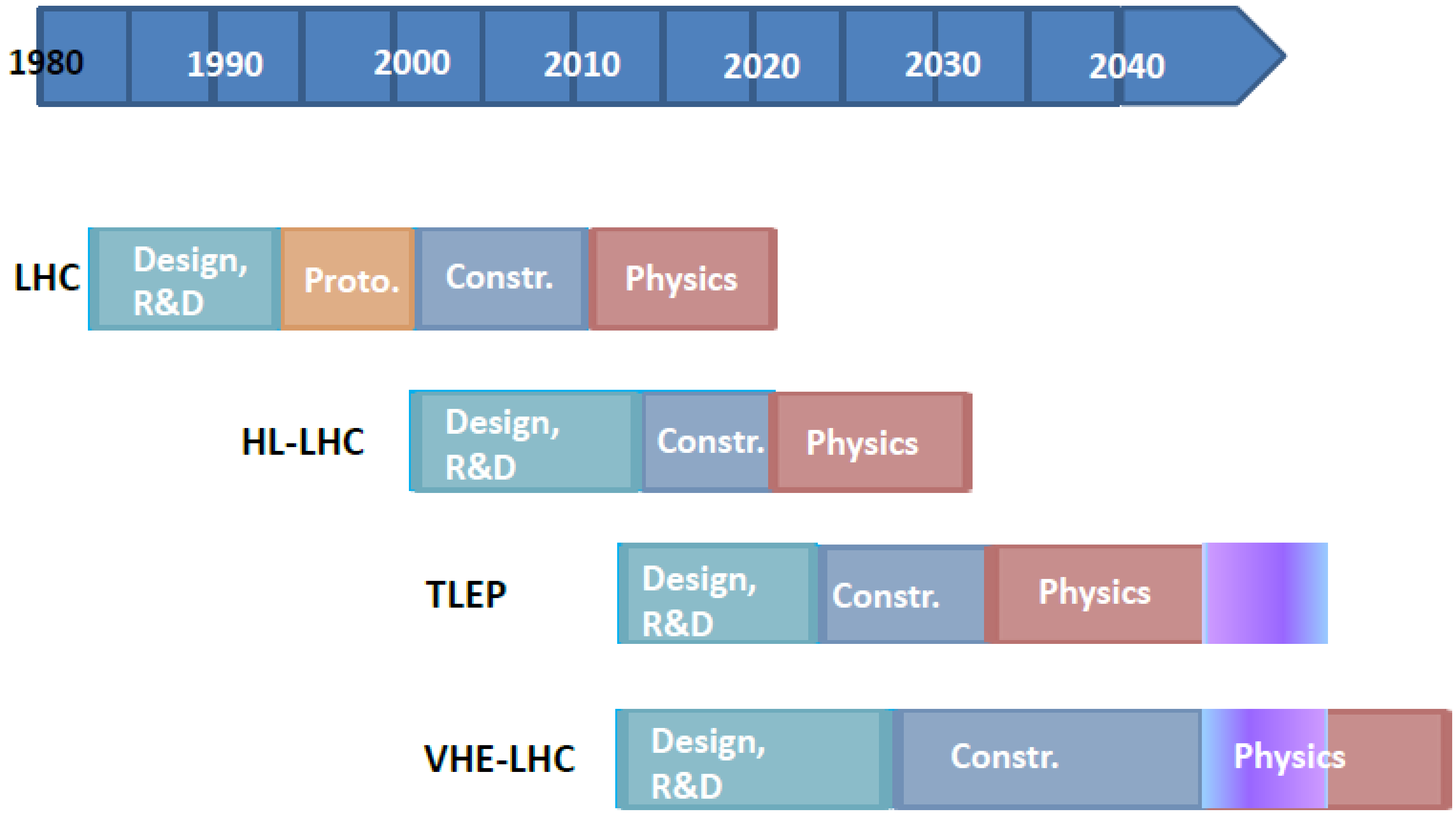


Figure 6: A possible scheme to obtain longitudinal beam polarization at high energies ($E_{beam} >> M_Z/2$) with TLEP: taking advantage of the weakness of the magnetic field in the arcs, the polarization is generated dominantly by strong asymmetric wigglers of opposite polarities (AW1 and AW2) in two halves of the ring. The transverse polarization obtained this way is rotated to longitudinal in the experimental straight sections in detector D1, by 90 degrees spin rotators (SR1L, etc..), and brought back to vertical (but reversed) in the following arc, and similarly for the next experimental straight section, D2. The scheme easily generalizes to the situation with four IPs. This scheme generates a spin transport with an integer part of the spin tune equal to zero. The spin polarization of the electrons is shown. Given separated beam pipes for the e^+ and e^- beams, they can be exposed to wigglers of opposite polarity, providing polarization of positrons can be chosen parallel to that of the electrons. In this way highly polarized e^+e^- systems at the collision point can be obtained. Polarization can be reversed by reversing the wiggler polarity. The possibility of depolarizing a fraction of the bunches in this scheme, to provide a normalization of polarimetry from the measured cross-sections, is being investigated.

possible long-term time line



Zimmermann