A Circular e+e- Collider to Study H(125) Properties - Accelerator

Zimmermann, F (CERN)

17 June 2013

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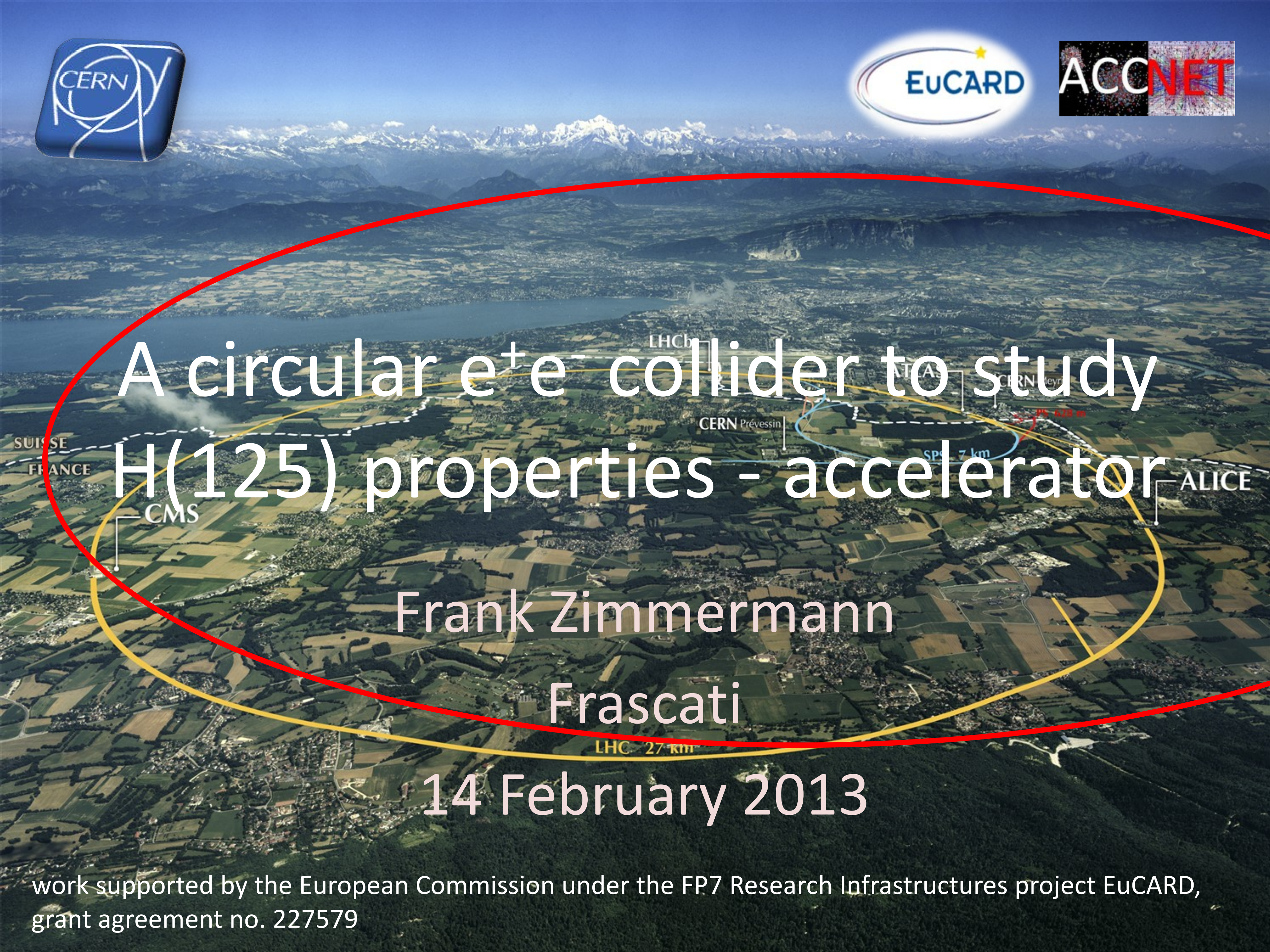
This work is part of EuCARD Work Package **4: AccNet: Accelerator Science Networks**.



A circular e^+e^- collider to study H(125) properties - accelerator

Frank Zimmermann

Frascati

14 February 2013

work supported by the European Commission under the FP7 Research Infrastructures project EuCARD, grant agreement no. 227579

outline

- motivation
- machine proposals
- parameters, lifetime, key concepts
- various features
- a long-term strategy
- HF quality indicators
- the path forward

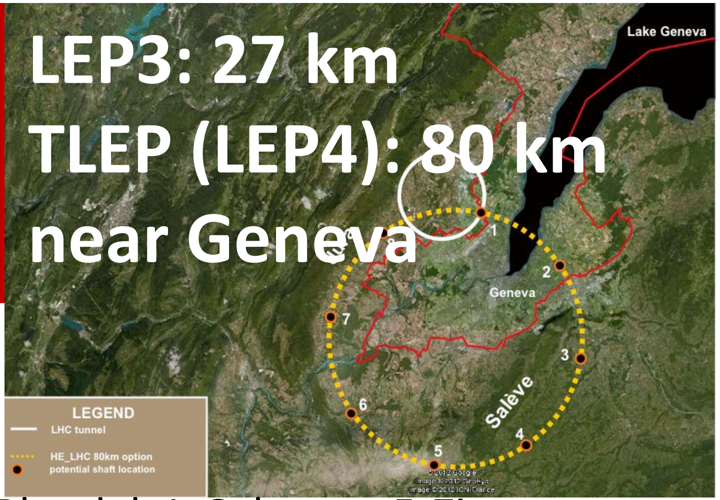
circular HFs – a few examples

SuperTRISTAN in Tsukuba: 40 km

K. Oide, KEK

SLAC/LBNL design: 27 km

Y. Cai, SLAC

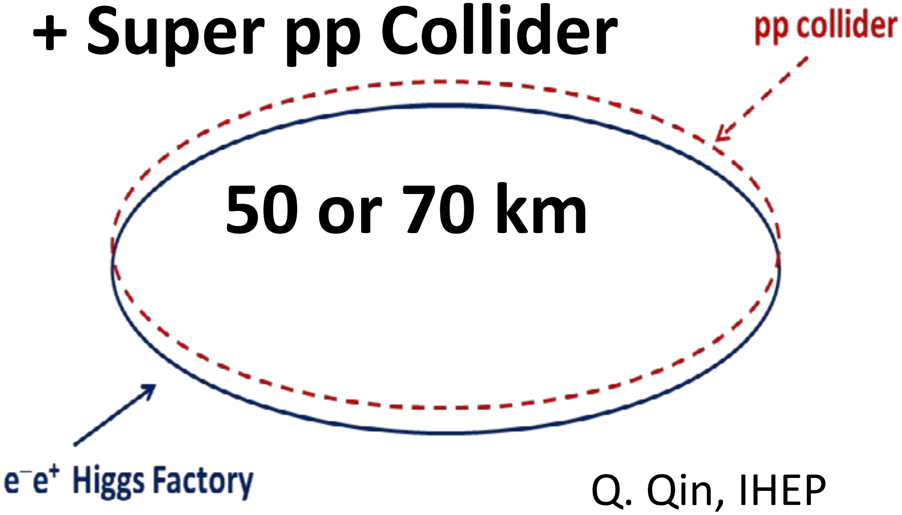


LEP3: 27 km

TLEP (LEP4): 80 km near Geneva

A. Blondel, J. Osborne, F. Zimmermann

IHEP Chinese HF + Super pp Collider



50 or 70 km

Q. Qin, IHEP

FNAL site filler, 16 km

& FNAL VLLC 233 km ring

T. Sen, E. Gianfelice-Wendt, Y. Alexahin, FNAL

LEP3, TLEP (LEP4)

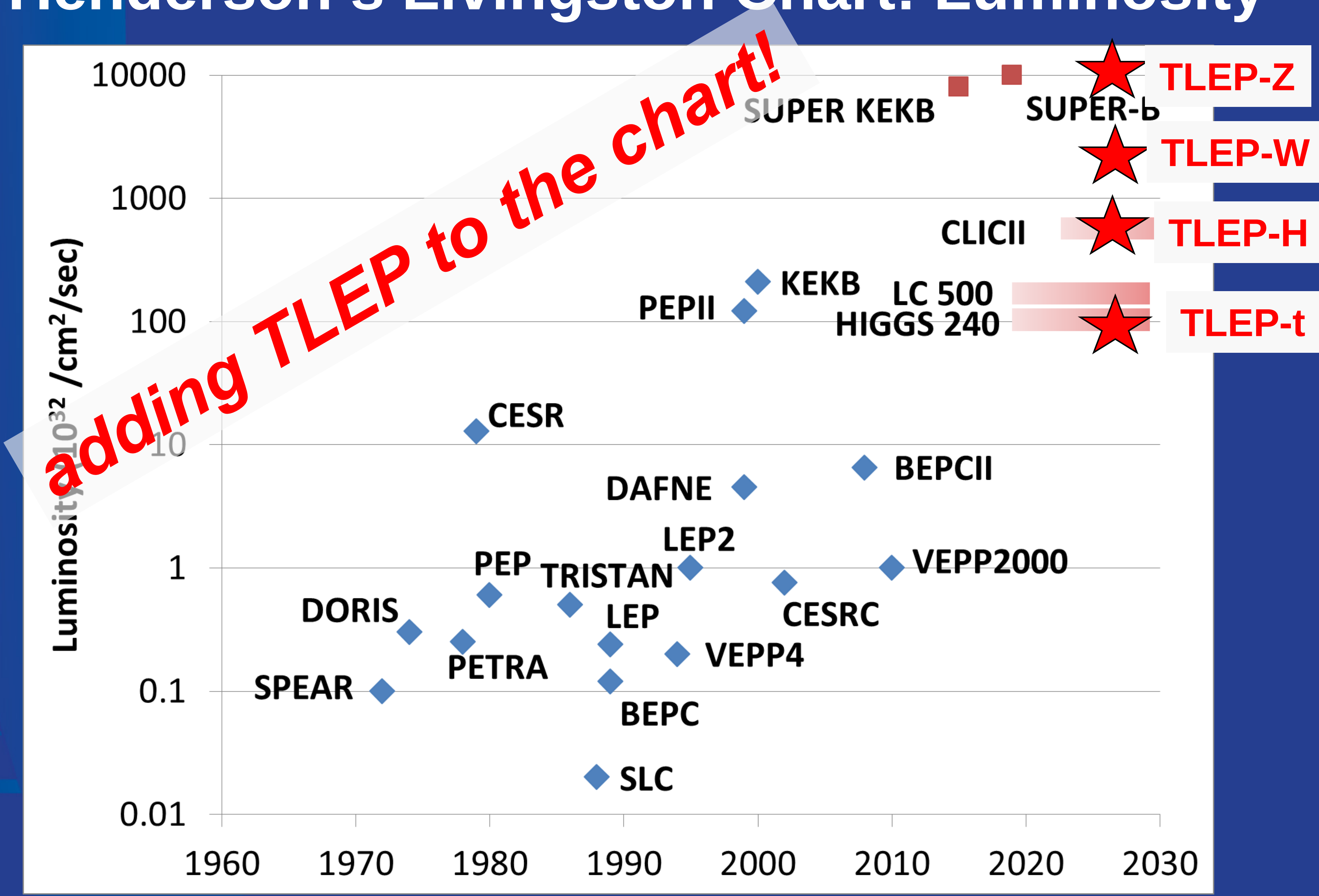
(e^+e^- -> ZH, $e^+e^- \rightarrow W^+W^-$, $e^+e^- \rightarrow Z$,[$e^+e^- \rightarrow t\bar{t}$])

key parameters

	LEP3	TLEP (LEP4)
circumference	26.7 km	80 km
max beam energy	120 GeV	175 GeV
max no. of IPs	4	4
luminosity at 350 GeV c.m.	-	$0.7\text{x}10^{34}$ cm^{-2}s^{-1}
luminosity at 240 GeV c.m.	10^{34} cm^{-2}s^{-1}	$5\text{x}10^{34}$ cm^{-2}s^{-1}
luminosity at 160 GeV c.m.	$5\text{x}10^{34}$ cm^{-2}s^{-1}	$2.5\text{x}10^{35}$ cm^{-2}s^{-1}
luminosity at 90 GeV c.m.	$2\text{x}10^{35}$ cm^{-2}s^{-1}	10^{36} cm^{-2}s^{-1}

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

S. Henderson's Livingston Chart: Luminosity



Stuart Henderson, Higgs Factory Workshop, Nov. 14, 2012

circular HFs – beam lifetime

LEP2:

- beam lifetime ~ 6 h
- dominated by radiative Bhahba scattering with cross section σ~0.215 barn

(H. Burkhardt)

LEP3:

- with L~10^{34} $\mathrm{cm}^{-2}\mathrm{s}^{-1}$ at each of several IPs:

  $\tau_{\text{beam,LEP3}}$~18 minutes from rad. Bhabha scattering

  → solution: top-up injection (A. Blondel)

- **additional beam lifetime limit due to beamstrahlung:**

  (1) large momentum acceptance ($\eta \geq 3\%$), and/or

  (2) flat(ter) beams and/or

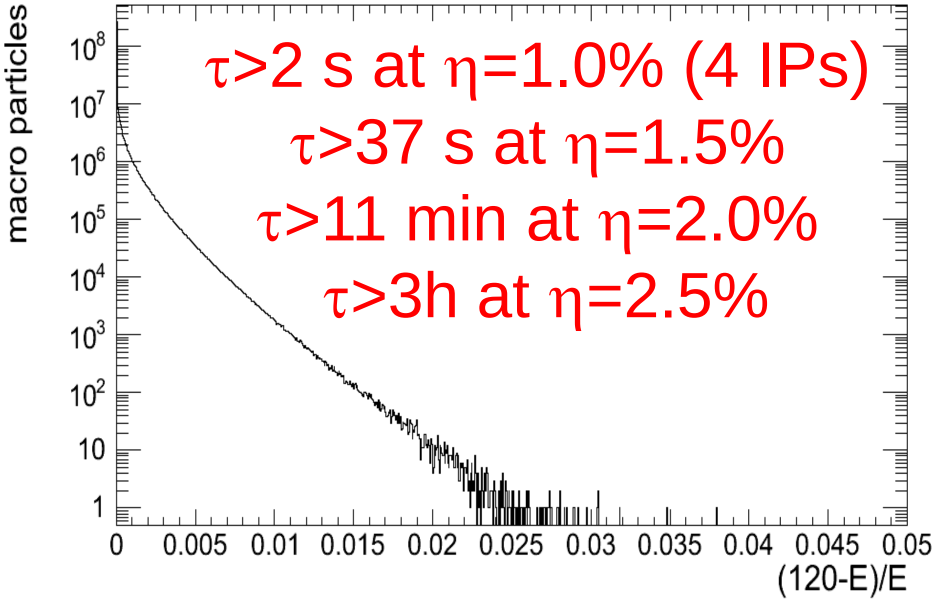
  (3) fast replenishing

(V. Telnov, K. Yokoya, M. Zanetti)

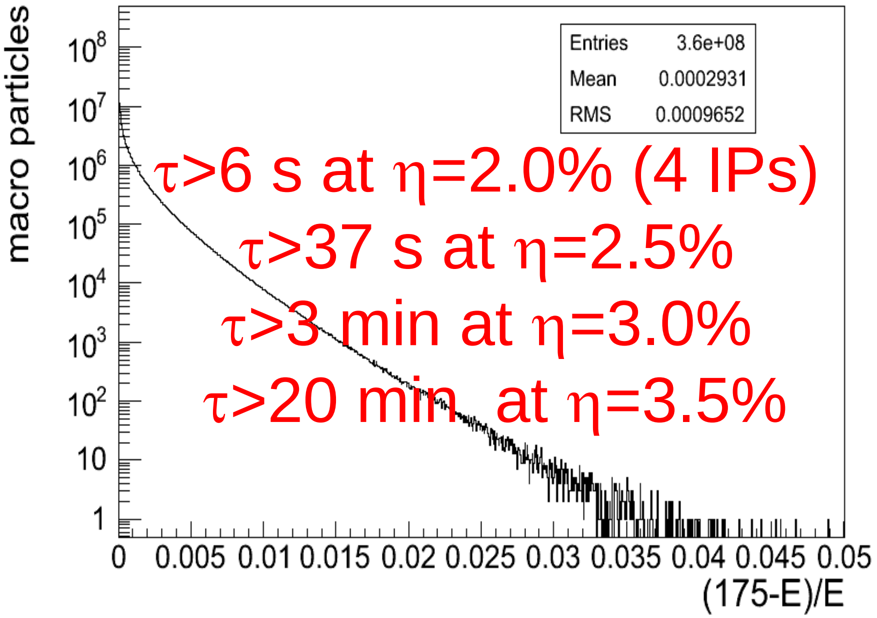
circular HFs – beamstrahlung

- simulation w 360M macroparticles
- τ varies exponentially w energy acceptance η
- post-collision *E* tail → lifetime τ

TLEP at 240 GeV:


τ>2 s at η=1.0% (4 IPs)
τ>37 s at η=1.5%
τ>11 min at η=2.0%
τ>3h at η=2.5%

TLEP at 350 GeV:

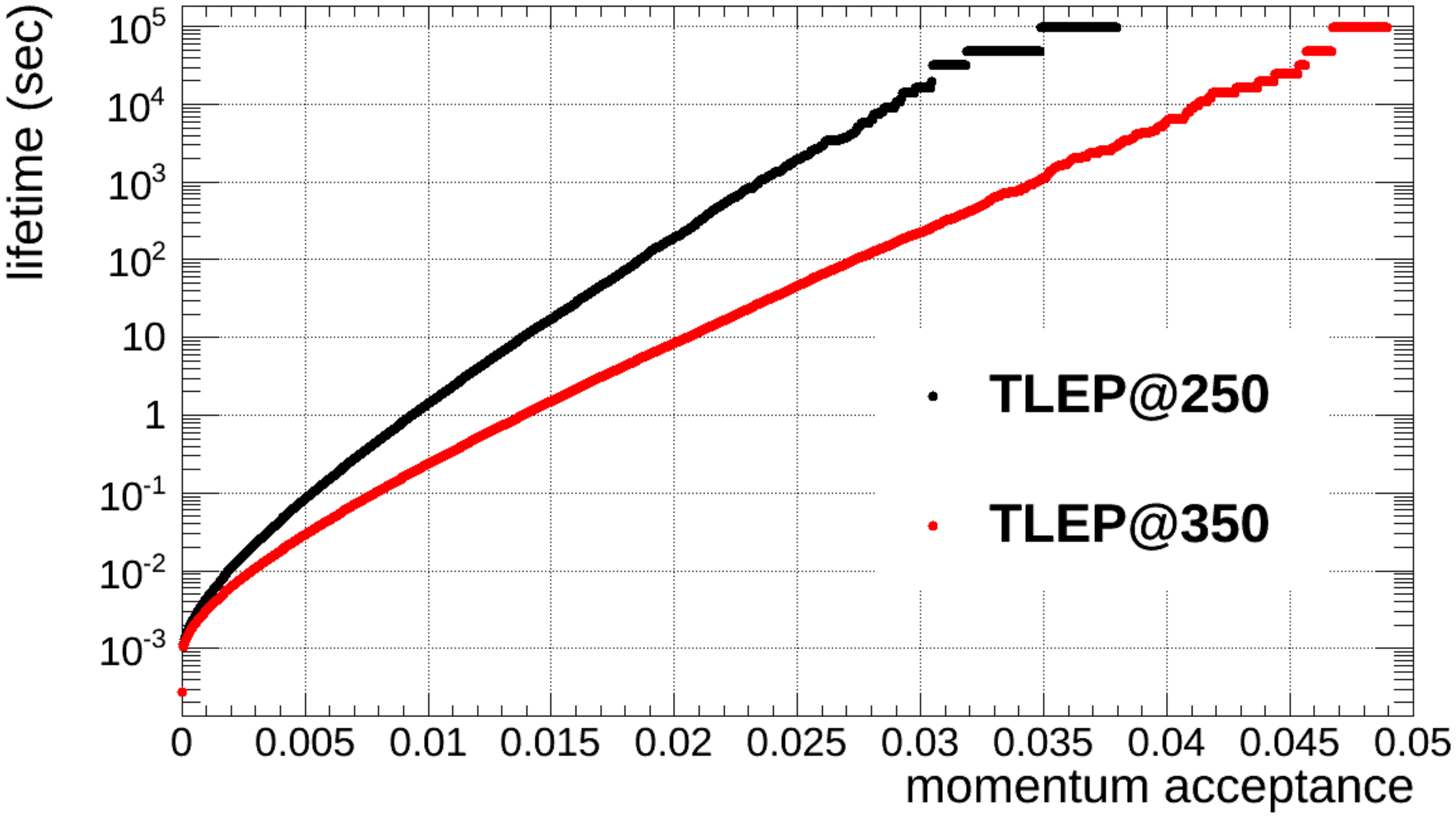

τ>6 s at η=2.0% (4 IPs)
τ>37 s at η=2.5%
τ>3 min at η=3.0%
τ>20 min at η=3.5%

M. Zanetti (MIT)

circular HFs – beamstrahlung

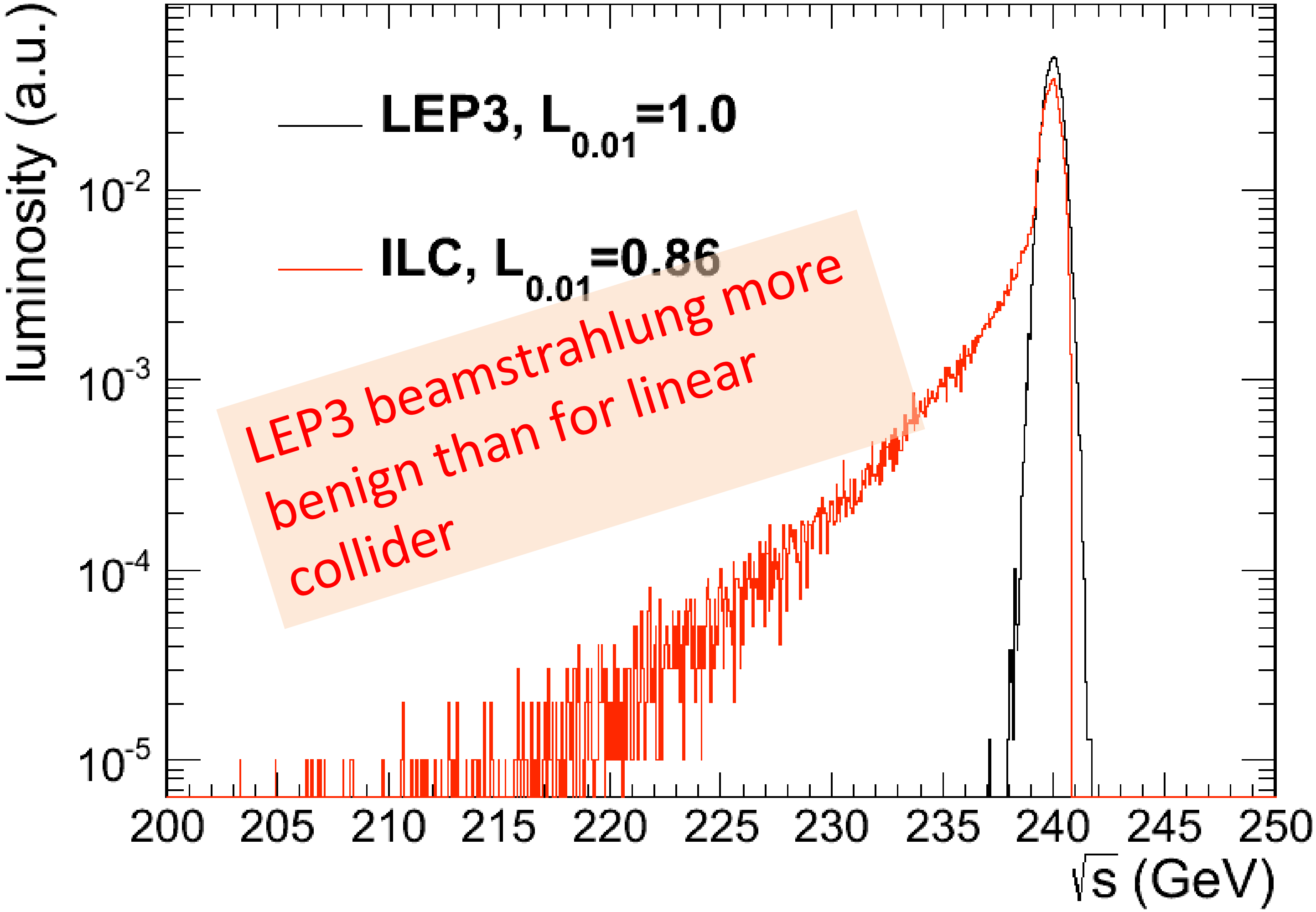
- simulation w 360M macroparticles
- τ varies exponentially w energy acceptance η
- post-collision *E* tail → lifetime τ

beam lifetime versus acceptance η for 1 IP:



beamstrahlung luminosity spectrum

LEP3 & ILC:



LEP3 beamstrahlung more benign than for linear collider

M. Zanetti (MIT)

luminosity formulae & constraints

$$L=\frac{f_{rev}n_bN_b^2}{4\pi\sigma_x\sigma_y}=(f_{rev}n_bN_b)\left(\frac{N_b}{\varepsilon_x}\right)\frac{1}{4\pi}\frac{1}{\sqrt{\beta_x\beta_y}}\frac{1}{\sqrt{\varepsilon_y/\varepsilon_x}}$$

$$(f_{rev}n_bN_b)=\frac{P_{SR}\,\rho}{8.8575\times10^{-5}\,\frac{\mathrm{m}}{\mathrm{GeV}^{-3}}E^4}$$ *SR radiation power limit*

$$\frac{N_b}{\varepsilon_x}=\frac{\xi_x2\pi\gamma(1+\kappa_\sigma)}{r_e}$$ *beam-beam limit*

$$\frac{N_b}{\sigma_x\sigma_z}\frac{30\,\gamma r_e^2}{\delta_{acc}\,\alpha}<1$$ *>30 min beamstrahlung lifetime (Telnov) → N_b, β_x*

→minimize $\kappa_\varepsilon=\varepsilon_y/\varepsilon_x$, $\beta_y\sim\beta_x(\varepsilon_y/\varepsilon_x)$ and respect $\beta_y\geq\sigma_z$

LEP3/TLEP parameters -1

soon at SuperKEKB:
β_x*=0.03 m, β_Y*=0.03 cm

	LEP2	LHeC	LEP3	TLEP-Z	TLEP-H	TLEP-t
beam energy E_b [GeV]	104.5	60	120	45.5	120	175
circumference [km]	26.7	26.7	26.7	80	80	80
beam current [mA]	4	100	7.2	1180	24.3	5.4
#bunches/beam	4	2808	4	2625	80	12
#e-/beam [10^{12}]	2.3	56	4.0	2000	40.5	9.0
horizontal emittance [nm]	48	5	25	30.8	9.4	20
vertical emittance [nm]	0.25	2.5	0.10	0.15	0.05	0.1
bending radius [km]	3.1	2.6	2.6	9.0	9.0	9.0
partition number J_ε	1.1	1.5	1.5	1.0	1.0	1.0
momentum comp. α_c [10^{-5}]	18.5	8.1	8.1	9.0	1.0	1.0
SR power/beam [MW]	11	44	50	50	50	50
β^*_x [m]	1.5	0.18	0.2	0.2	0.2	0.2
β^*_y [cm]	5	10	0.1	0.1	0.1	0.1
σ^*_x [μm]	270	30	71	78	43	63
σ^*_y [μm]	3.5	16	0.32	0.39	0.22	0.32
hourglass F_{hg}	0.98	0.99	0.59	0.71	0.75	0.65
ΔE^{SR}_{loss}/turn [GeV]	3.41	0.44	6.99	0.04	2.1	9.3

SuperKEKB:$\varepsilon_y/\varepsilon_x$=0.25%

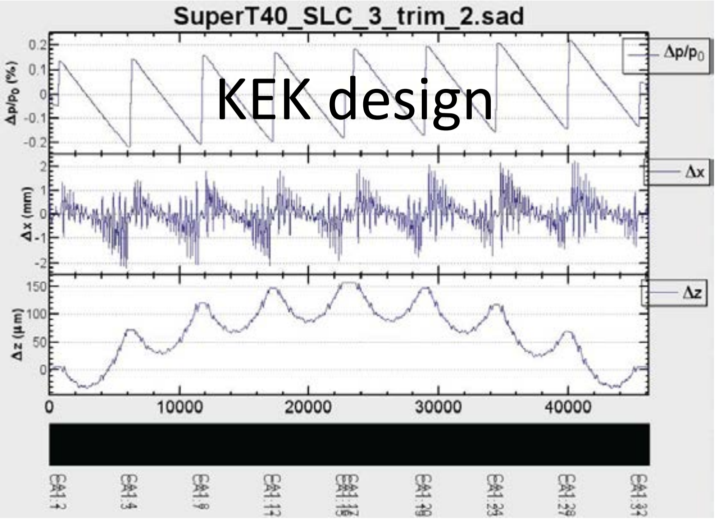
LEP3/TLEP parameters -2

LEP2 was not beam-beam limited

	LEP2	LHeC	LEP3	TLEP-Z	TLEP-H	TLEP-t
$V_{RF,tot}$ [GV]	3.64	0.5	12.0	2.0	6.0	12.0
$\delta_{max,RF}$ [%]	0.77	0.66	5.7	4.0	9.4	4.9
ξ_x/IP	0.025	N/A	0.09	0.12	0.10	0.05
ξ_y/IP	0.065	N/A	0.08	0.12	0.10	0.05
f_s [kHz]	1.6	0.65	2.19	1.29	0.44	0.43
E_{acc} [MV/m]	7.5	11.9	20	20	20	20
eff. RF length [m]	485	42	600	100	300	600
f_{RF} [MHz]	352	721	700	700	700	700
δ^{SR}_{rms} [%]	0.22	0.12	0.23	0.06	0.15	0.22
$\sigma^{SR}_{z,rms}$ [cm]	1.61	0.69	0.31	0.19	0.17	0.25
L/IP[10^{32}cm^{-2}s^{-1}]	1.25	N/A	94	10335	490	65
number of IPs	4	1	2	2	2	2
Rad.Bhabha b.lifetime [min]	360	N/A	18	74	32	54
Υ_{BS} [10^{-4}]	0.2	0.05	9	4	15	15
n_γ/collision	0.08	0.16	0.60	0.41	0.50	0.51
ΔE^{BS}/collision [MeV]	0.1	0.02	31	3.6	42	61
ΔE^{BS}_{rms}/collision [MeV]	0.3	0.07	44	6.2	65	95
critical SR energy [MeV]	0.81	0.18	1.47	0.02	0.43	1.32

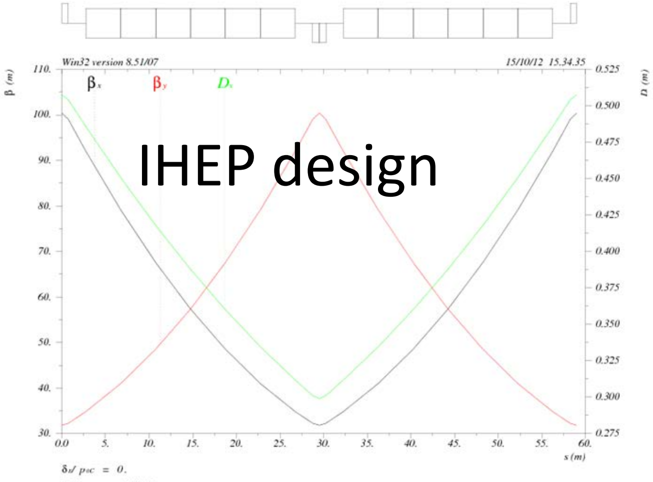
LEP data for 94.5 - 101 GeV consistently suggest a beam-beam limit of ~0.115 (R.Assmann, K. C.)

circular HFs – arc lattice



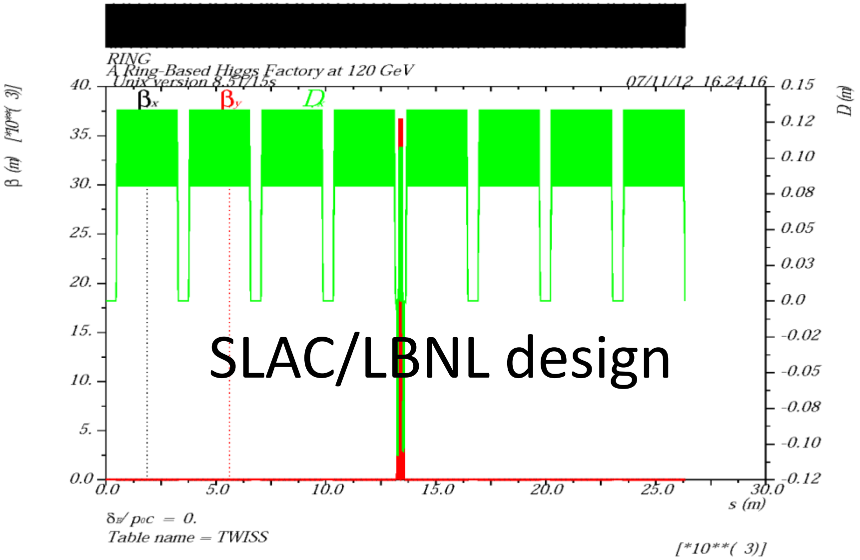
KEK design

K. Oide



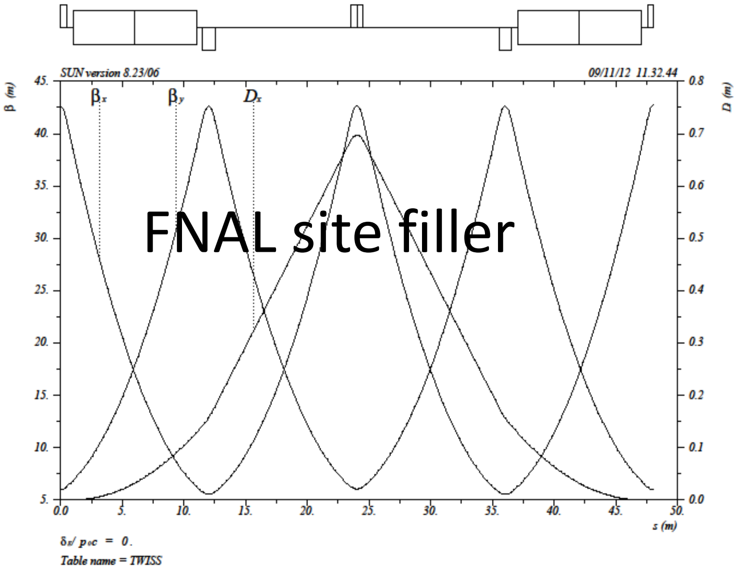
IHEP design

Q. Qin



SLAC/LBNL design

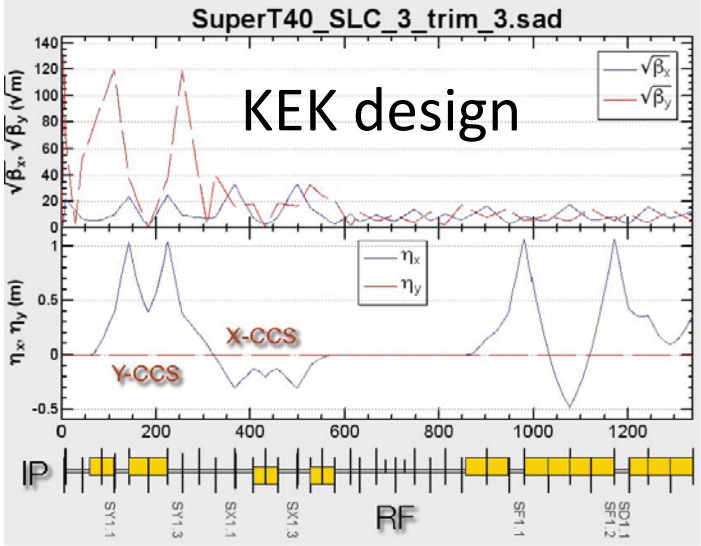
Y. Cai



FNAL site filler

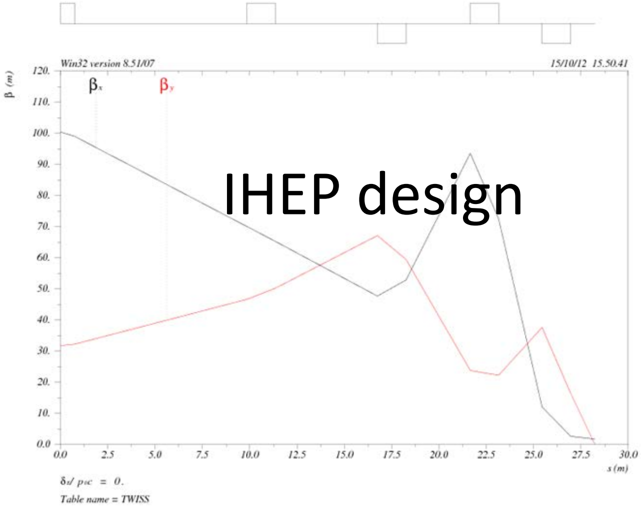
T. Sen, E. Gianfelice-Wendt, Y. Alexahin

circular HFs – final-focus design



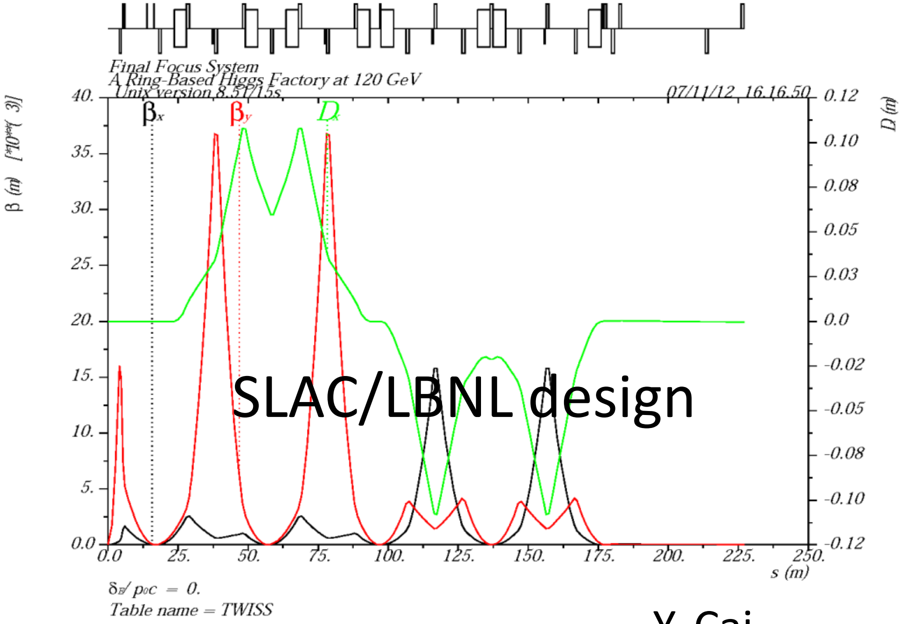
KEK design

K. Oide



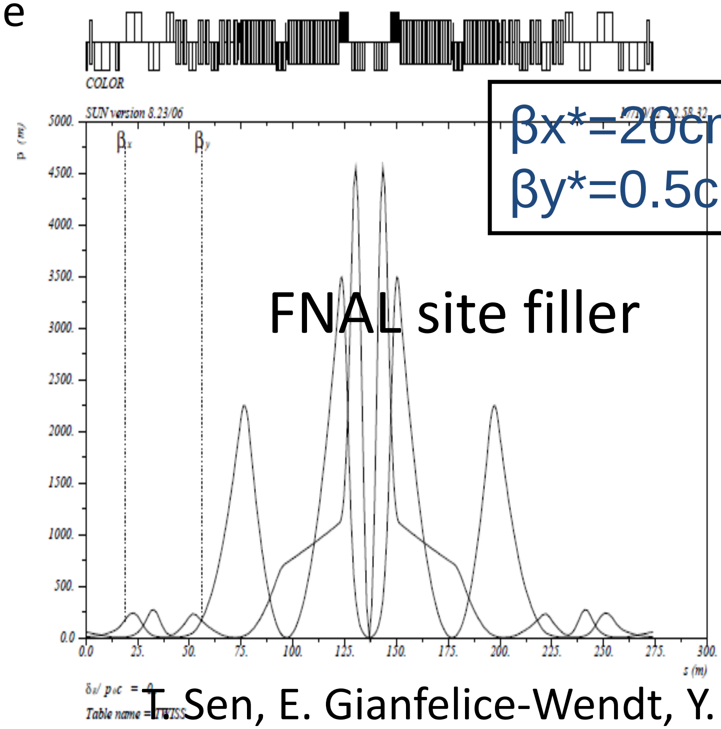
IHEP design

Q. Qin



SLAC/LBNL design

Y. Cai

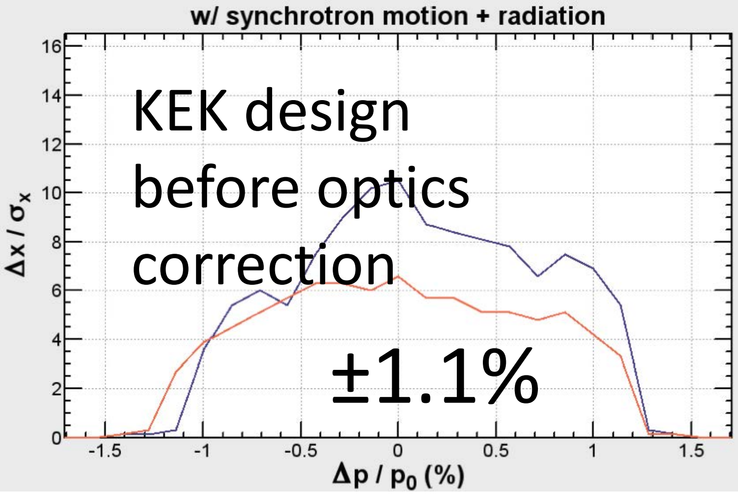


FNAL site filler

β_x^*=20cm,
β_y^*=0.5cm

T. Sen, E. Gianfelice-Wendt, Y. Alexahin

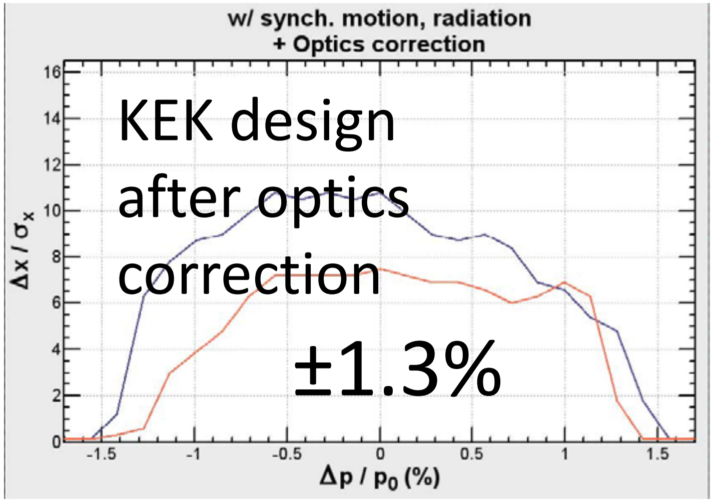
circular HFs - momentum acceptance



KEK design before optics correction

±1.1%

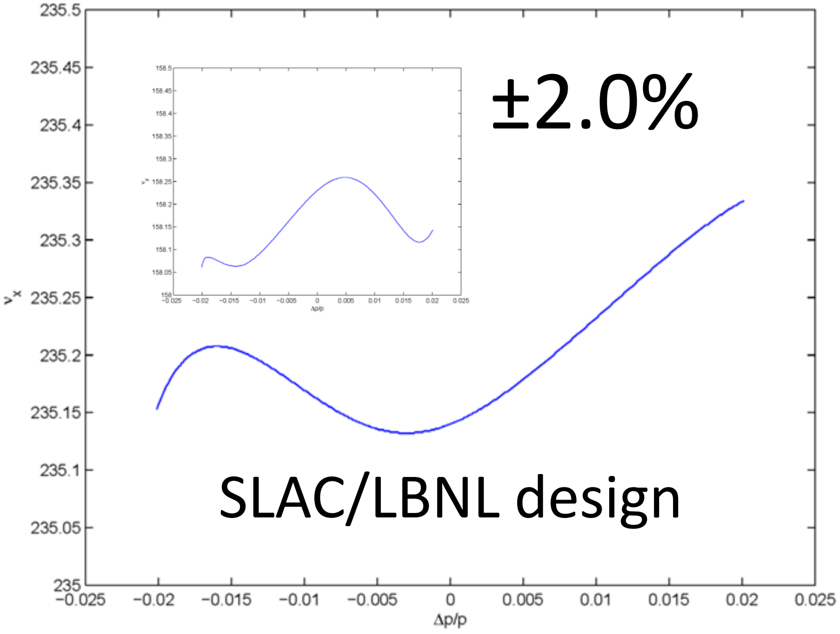
with synchrotron motion & radiation (sawtooth)



KEK design after optics correction

±1.3%

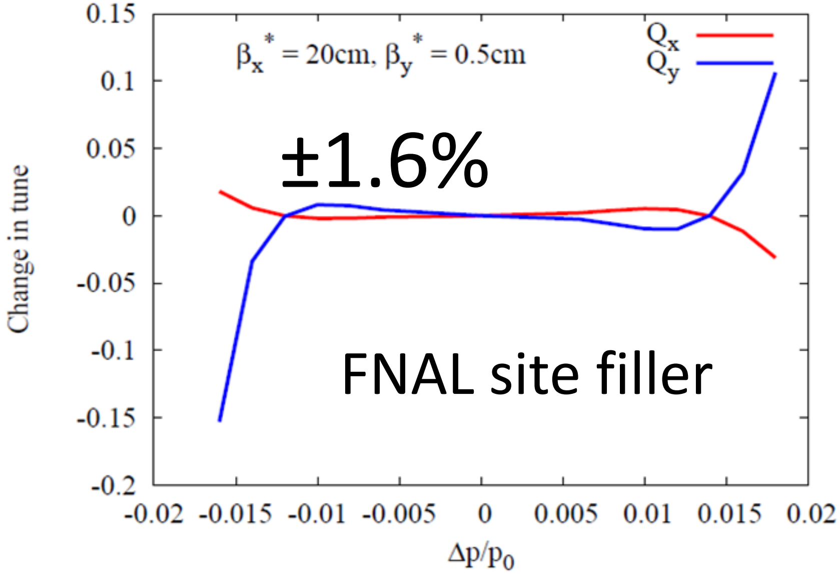
K. Oide



±2.0%

SLAC/LBNL design

Y. Cai



±1.6%

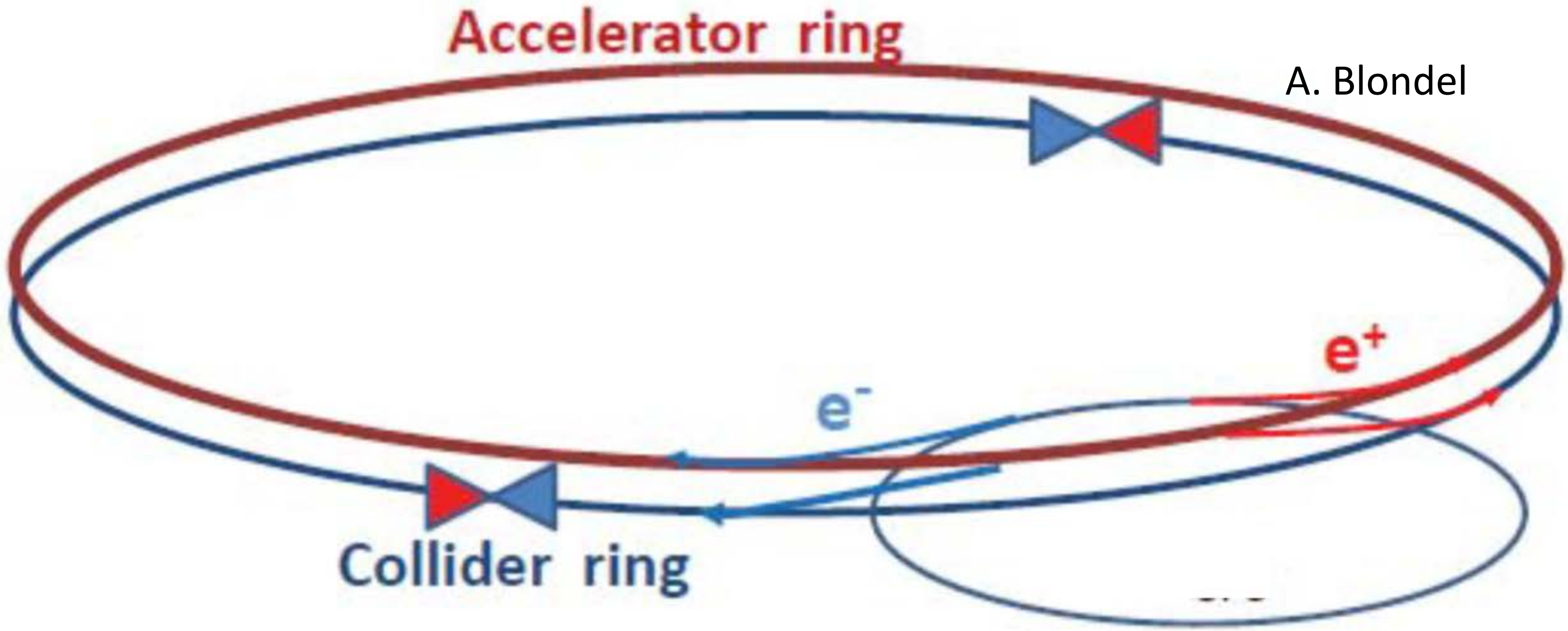
FNAL site filler

T. Sen, E. Gianfelice-Wendt, Y. Alexahin

circular HFs – top-up injection

double ring with top-up injection

supports short lifetime & high luminosity



A. Blondel

top-up experience: PEP-II, KEKB, light sources

top-up injection

SPS as LEP injector accelerated $e^{\pm}$ from 3.5 to 20 GeV (later 22 GeV) on a very short cycle: acceleration time = 265 ms or about 62.26 GeV/s

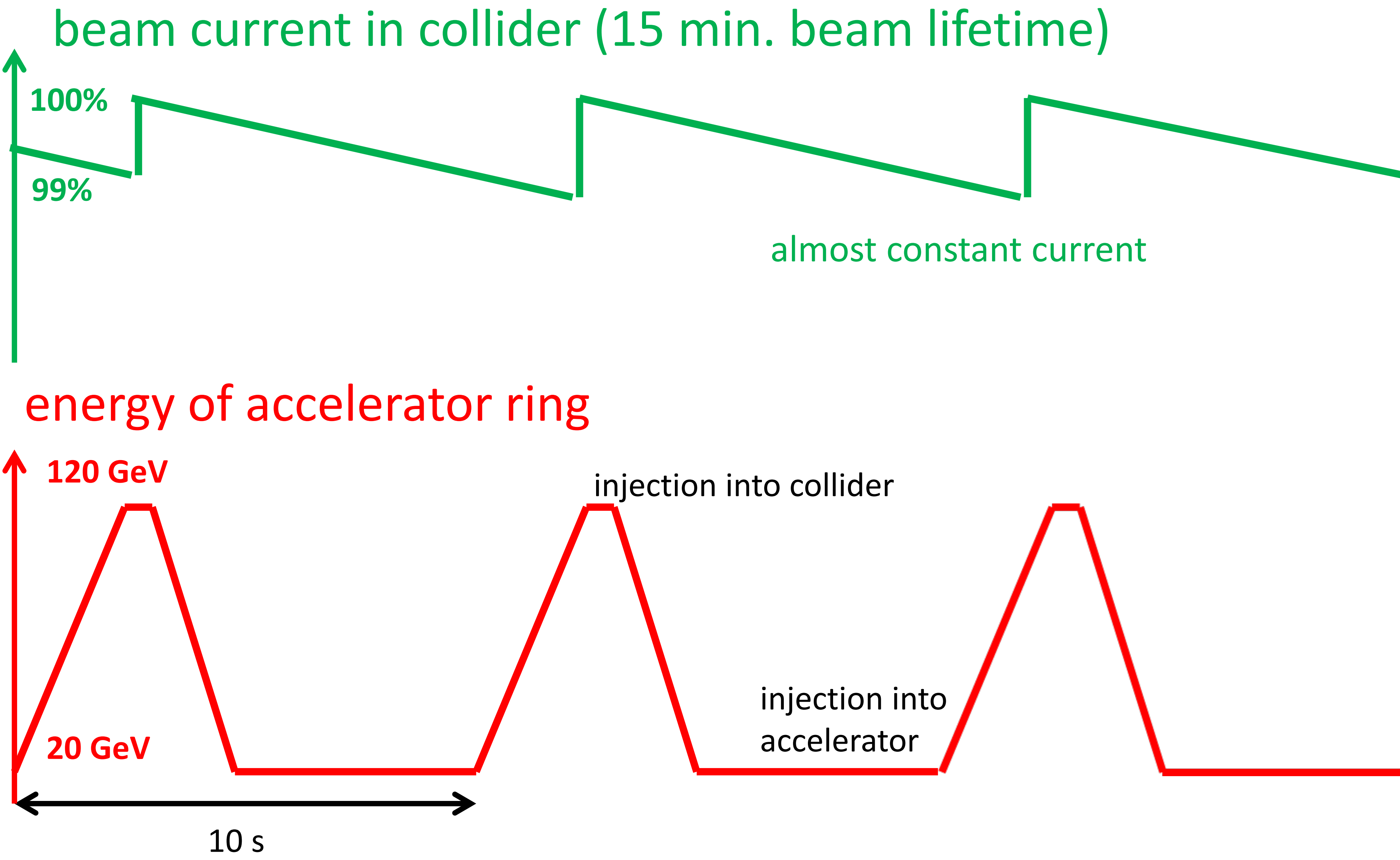
Ref. K. Cornelis, W. Herr, R. Schmidt, "Multicycling of the CERN SPS: Supercycle Generation & First Experience with this mode of Operation," Proc. EPAC 1988

assuming injection from the SPS into the top-up accelerator at the same energy of 20 GeV and final energy of 120 GeV: acceleration time = 1.6 seconds

total cycle time = 10 s looks conservative (→ **refilling ~1% of the LEP3** beam, for τ_{beam}~16 min)

Ghislain Roy & Paul Collier

top-up injection: schematic cycle



beam current in collider (15 min. beam lifetime)

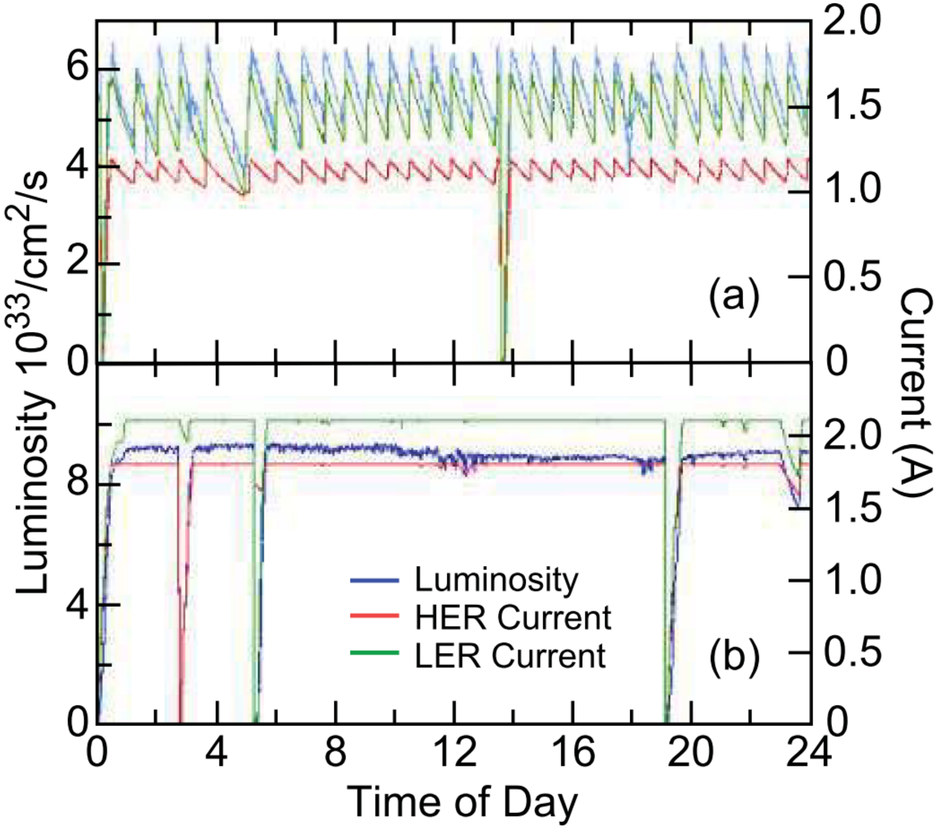
almost constant current

energy of accelerator ring

injection into collider

injection into accelerator

top-up injection at PEP-II/BaBar



Before Top-Up Injection

After Top-Up Injection

average ≈ peak luminosity (H≈1)!

J. Seeman

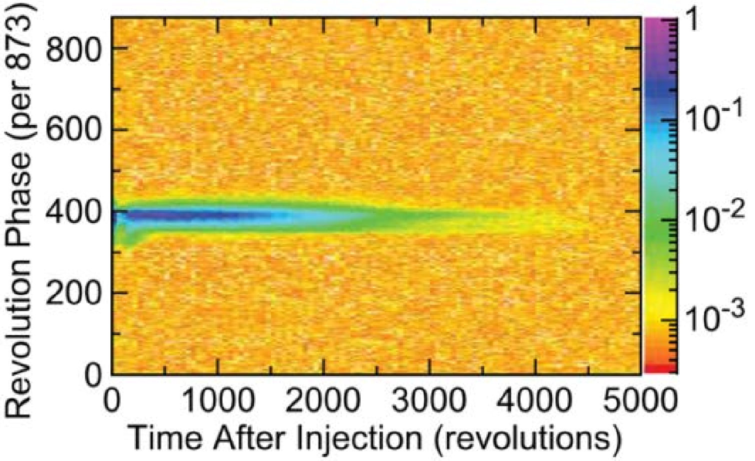
PEP-II: Luminosity and beam currents for a 24-hour period (a) before and (b) after the implementation of trickle injection.

top-up injection: feasibility

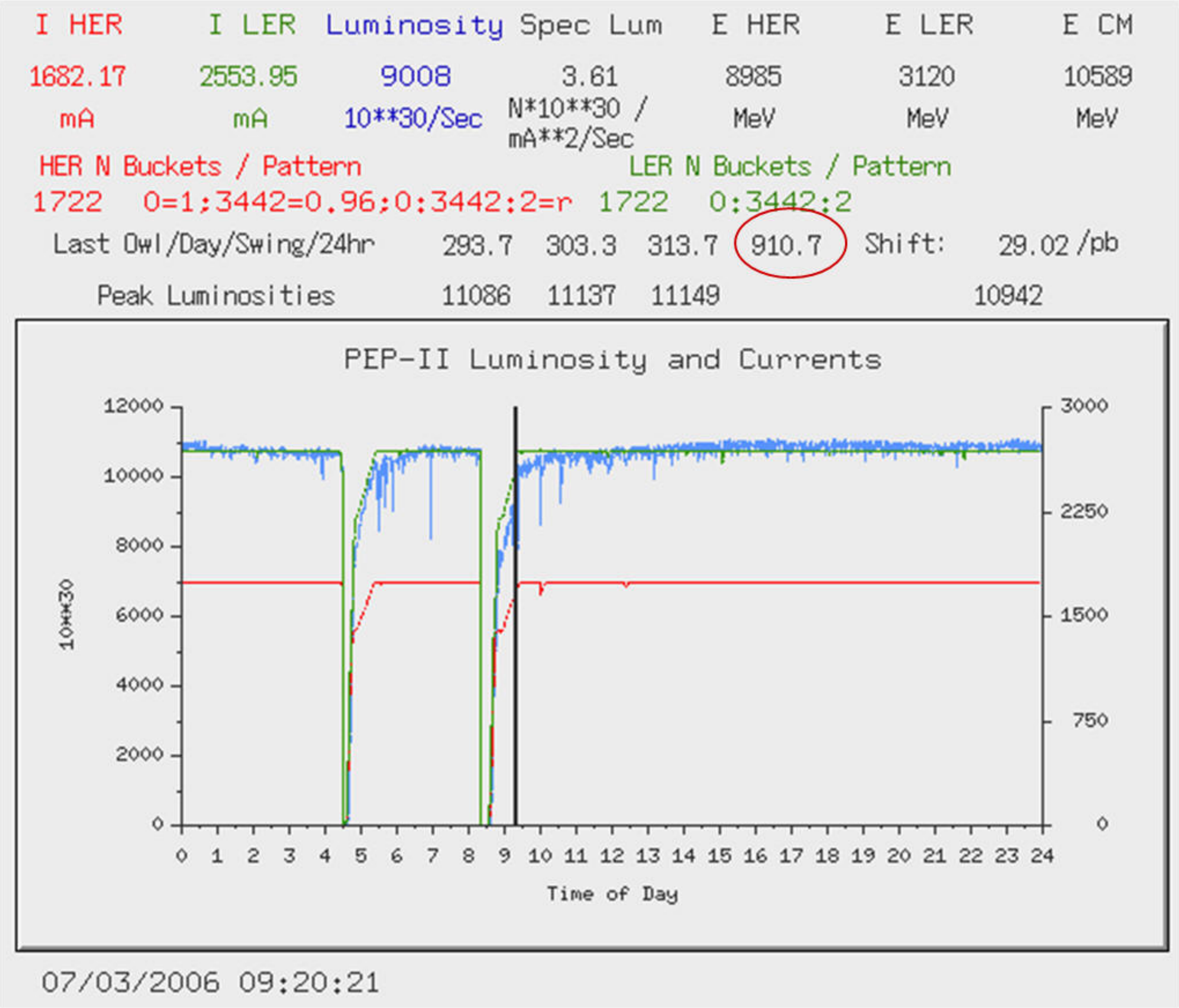
HF 2012 conclusions (John Seeman, SLAC):

- Top-up injection will work for a Circular Higgs Factory.
- A full energy injector is needed.
- A synchrotron injector will work the best, but is more than is needed (60 Hz!).
- A rapidly ramped storage ring is likely adequate (4 sec).
- The detectors will need to mask out the buckets with damping injected bunches during data taking as had been done for PEP-II/BaBar:

<u>BaBar trigger masking:</u>
Mask all of ring a few tens of turns.
Mask injected bunch area for 1250 turns or about 0.9 msec.



PEP-II Hübner factor



I HER	I LER	Luminosity	Spec Lum	E HER	E LER	E CM
1682.17 mA	2553.95 mA	9008 10**30/Sec	3.61 N*10**30 / mA**2/Sec	8985 MeV	3120 MeV	10589 MeV

HER N Buckets / Pattern
1722 0=1;3442=0.96;0:3442:2=r

LER N Buckets / Pattern
1722 0:3442:2

Last Owl/Day/Swing/24hr 293.7 303.3 313.7 910.7 Shift: 29.02 /pb

Peak Luminosities 11086 11137 11149 10942

07/03/2006 09:20:21

J. Seeman,
7 Dec. 2012

for one day (July 3, 2006): *H*≈0.95

for one month (August 2007): *H*≈0.63

Circular Collider & SR Experience

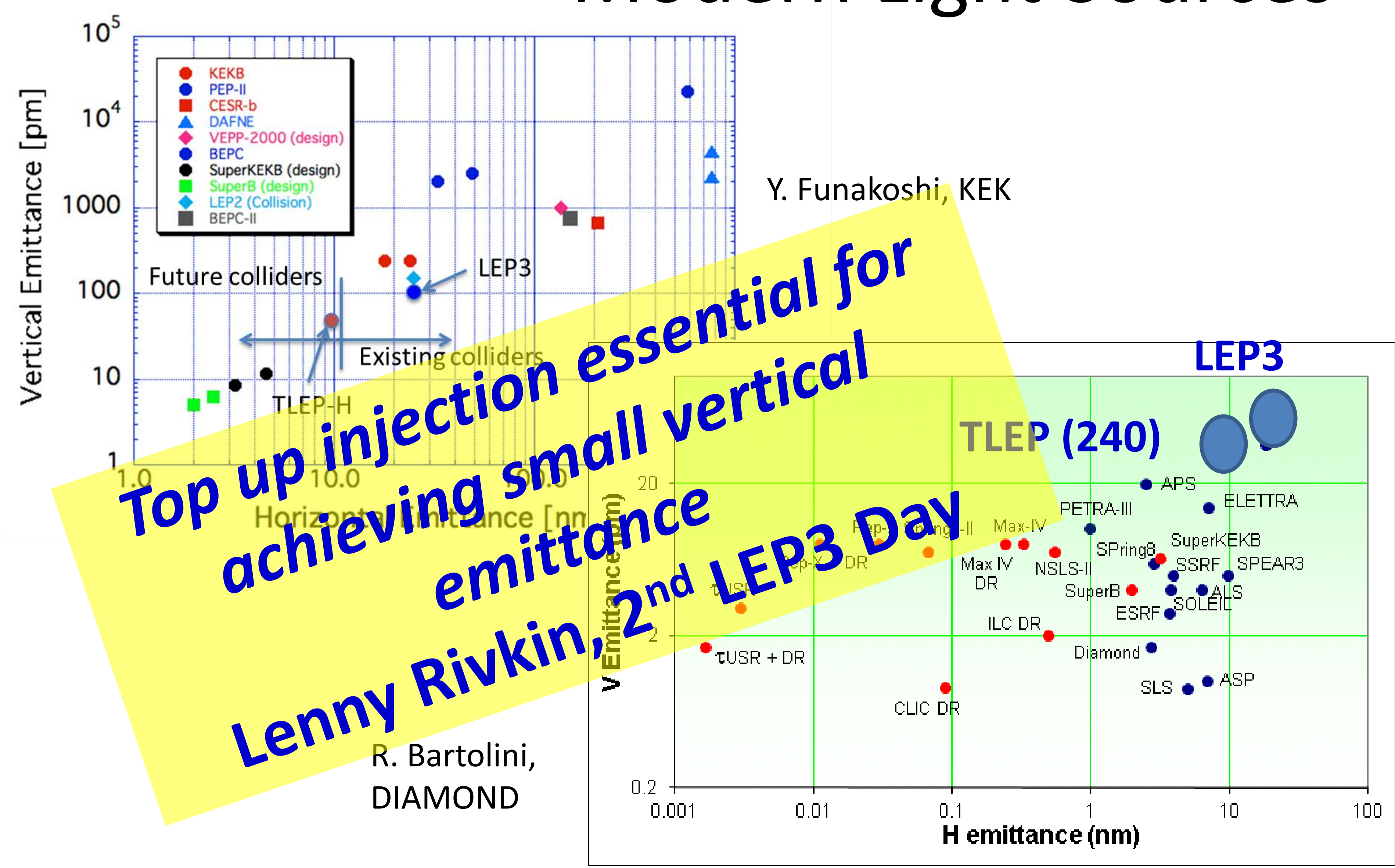
…
CESR
BEPC
LEP
Tevatron
LEP2
HERA
DAFNE
PEP-II
KEKB
BEPC-II
LHC
SuperKEKB (soon)

3rd generation light sources

1992	**ESRF**, France (EU)	6 GeV
	ALS, US	1.5-1.9 GeV
1993	**TLS**, Taiwan	1.5 GeV
1994	**ELETTRA**, Italy	2.4 GeV
	PLS, Korea	2 GeV
	MAX II, Sweden	1.5 GeV
1996	**APS**, US	7 GeV
	LNLS, Brazil	1.35 GeV
1997	**Spring-8**, Japan	8 GeV
1998	**BESSY II**, Germany	1.9 GeV
2000	**ANKA**, Germany	2.5 GeV
	SLS, Switzerland	2.4 GeV
2004	**SPEAR3**, US	3 GeV
	CLS, Canada	2.9 GeV
2006:	**SOLEIL**, France	2.8 GeV
	DIAMOND, UK	3 GeV
	ASP, Australia	3 GeV
	MAX III, Sweden	700 MeV
	Indus-II, India	2.5 GeV
2008	**SSRF**, China	3.4 GeV
2009	**PETRA-III**, Germany	6 GeV
2011	**ALBA**, Spain	3 GeV

well understood technology &
typically exceeding design performance
within a few years

Emittances in Circular Colliders & Modern Light Sources



Y. Funakoshi, KEK

R. Bartolini, DIAMOND

Top up injection essential for achieving small vertical emittance

Lenny Rivkin, 2nd LEP3 Day

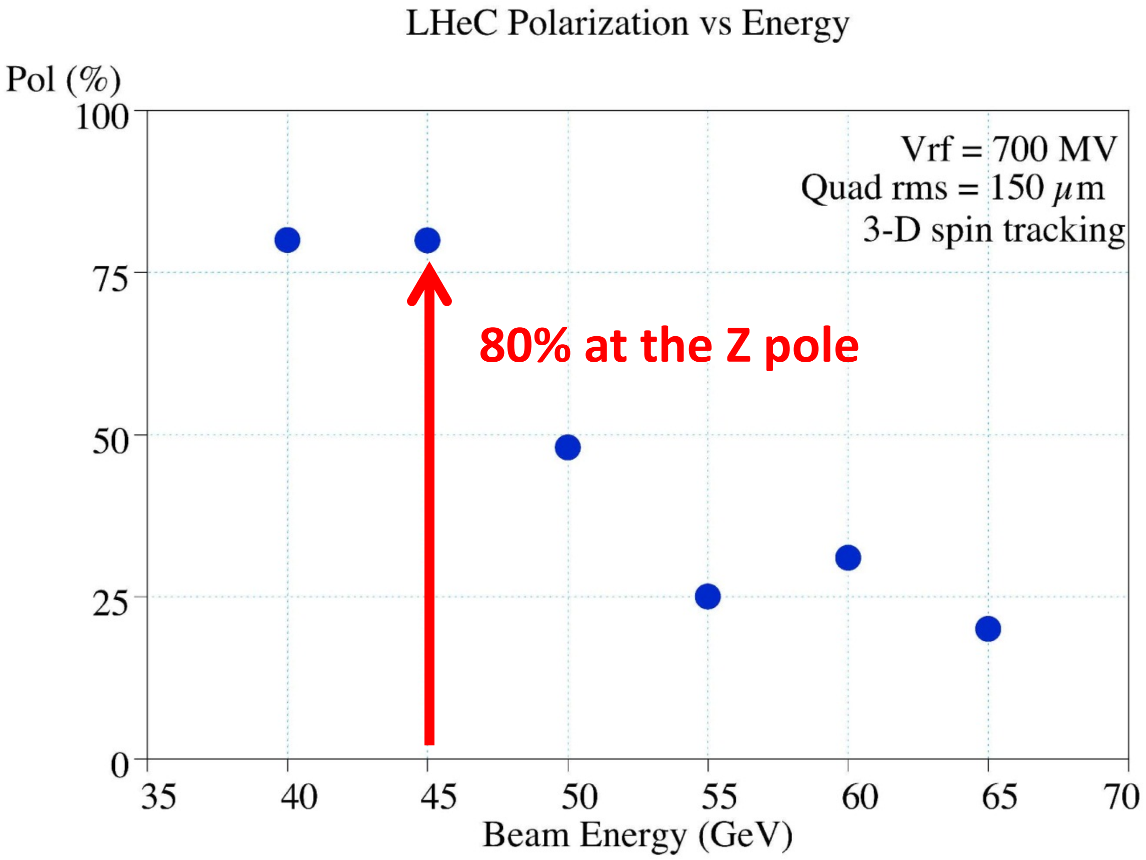
circular HFs: synchroton-radiation heat load

	PEPII	SPEAR3	LEP3	TLEP-Z	TLEP-H	TLEP-t
E (GeV)	9	3	120	45.5	120	175
I (A)	3	0.5	0.0072	1.18	0.0243	0.0054
rho (m)	165	7.86	2625	9000	9000	9000
Linear Power (W/cm)	101.8	92.3	30.5	8.8	8.8	8.8

LEP3 and TLEP have 3-10 times less SR heat load per meter than PEP-II or SPEAR! (though higher photon energy)

N. Kurita, U. Wienands, SLAC

TLEP polarization



LHeC equilibrium polarisation vs ring energy, full 3-D spin tracking results (D. Barber, U. Wienands, in LHeC CDR, J. Phys. G: Nucl. Part. Phys. 39 075001)

> *"… by adopting the levels of alignment that are now standard for synchrotron-radiation sources and by applying harmonic closed-orbit spin matching, there is reason to hope that high polarisation in a flat ring can … be obtained"*

TLEP3 key components

- tunnel
- SRF system
- cryoplants
- magnets
- injector ring
- detectors

tunnel is main cost:
3x LEP tunnel = 2.1 BCHF
9x LHeC tunnel cost estimate = 2.25 BCHF
inofficial/official TLEP tunnel cost ~2.5 BCHF

TLEP3 key issues

- SR handling and radiation shielding
- optics effect energy sawtooth [separate arcs?! (K. Oide)]
- beam-beam interaction for large Q_s and significant hourglass effect
- IR design with even larger momentum acceptance
- integration in LHC tunnel (LEP3)
- Pretzel scheme for TERA-Z operation?
- impedance effects for high-current running at Z pole

A. Fasso
3rd TLEP3 Day

NEUTRON PRODUCTION BY LEP SYNCHROTRON RADIATION USING EGS

W.R.Nelson and J.W.N.Tuyn

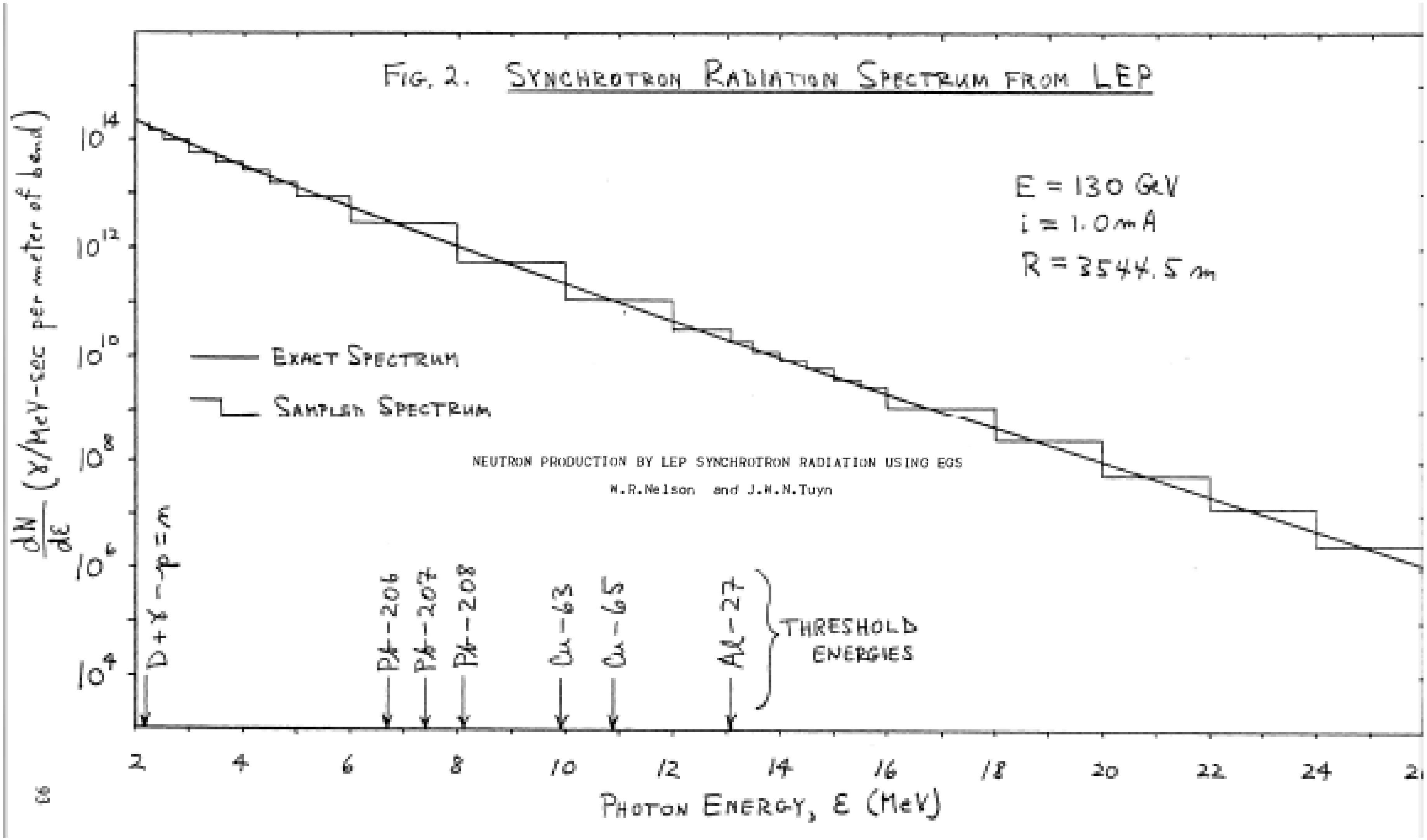


FIG. 2. SYNCHROTRON RADIATION SPECTRUM FROM LEP

transverse impedance & TMCI

LEP bunch intensity was limited by TMCI: **$N_{b,thr}$~5x10^{11} at 22 GeV**

LEP3 with 700 MHz: **at 120 GeV we gain a factor 5.5 in the threshold**, **which almost cancels a factor $(0.7/0.35)^3$ ~ 8** arising from the change in wake-field strength due to the different RF frequency

LEP3 Q_s~0.2, LEP Q_s~0.15: further **25% increase** in TMCI threshold?

only ½ of LEP transverse kick factor came from SC RF cavities

LEP3 beta functions at RF cavities might be smaller than in LEP

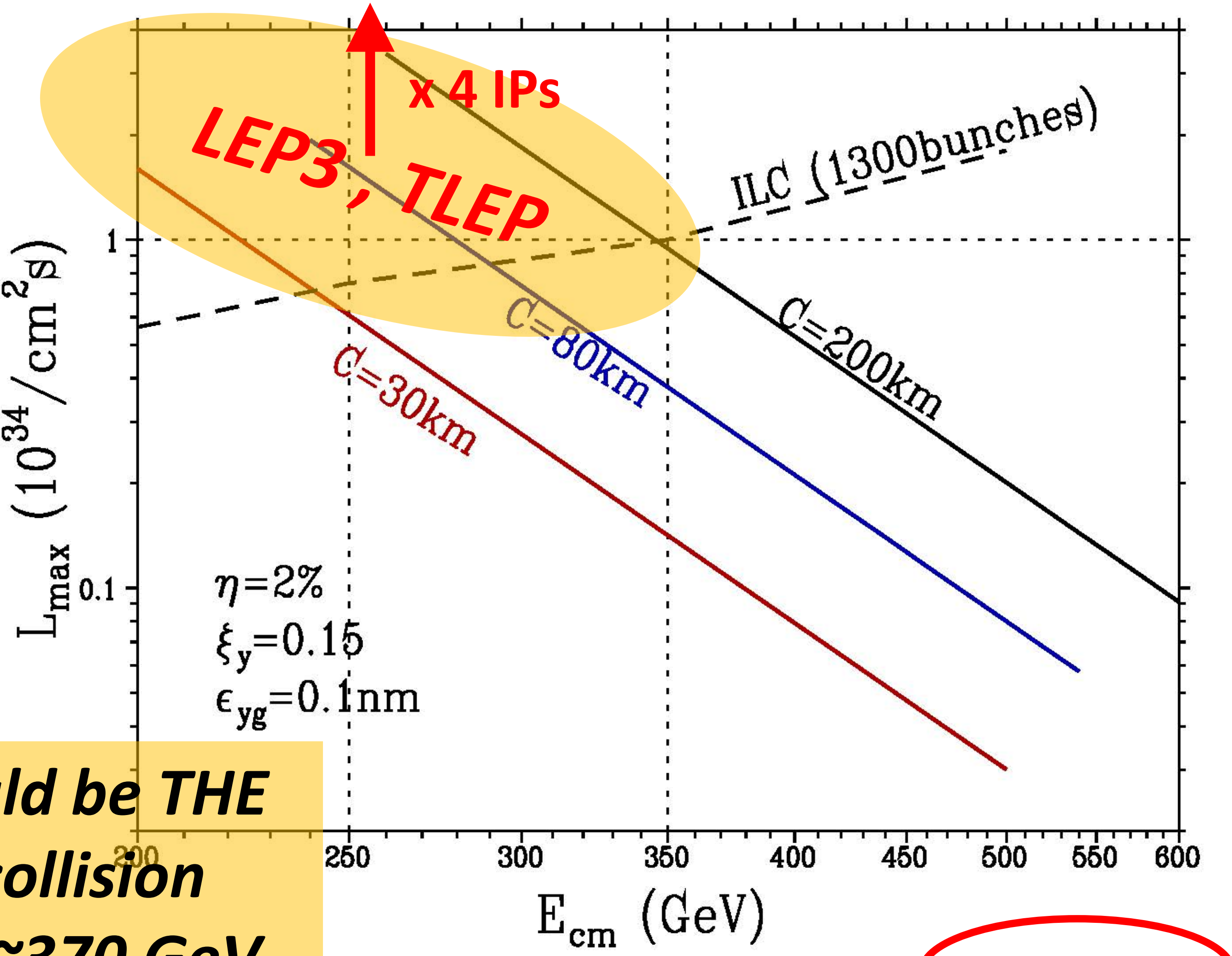
LEP3 bunch length (2-3 mm) is shorter than at LEP injection (5-9 mm)

M. Lamont, SL-Note-98-026 (OP)

Circular & Linear HF: peak luminosity vs energy

example with

- $\eta=2\%$
- $\xi_y=0.15$
- $\varepsilon_{gy}=0.1\text{nm}$



***LEP3/TLEP* would be THE choice for e^+e^- collision energies up to ~370 GeV**

K. Yokoya, KEK

vertical rms IP spot sizes in nm

in regular font: achieved

in italics: design values

LEP2	3500
KEKB	940
SLC	500
LEP3	***320***
TLEP-H	***220***
ATF2, FFTB	72 (35), 65
SuperKEKB	*50*
SAPPHiRE	***18***
ILC	*5 – 8*
CLIC	*1 – 2*

β_y^*: 5 cm→ 1 mm

LEP3/TLEP will learn from ATF2 & SuperKEKB

recent comment by eminent German particle physicist:
"TLEP is much riskier and its performance highly uncertain; while the ILC performance numbers are very conservative" [?]

extrapolation from past experience

	LEP2→TLEP-H	**SLC→ILC 250**
peak luminosity	x400	x2500
energy	x1.15	x2.5
vertical geom. emittance	x1/5	x1/400
vert. IP beam size	x1/15	x1/150
e^+ production rate	x1/2 !	x65
commissioning time	<1 year → ?	>10 years →?

a glance at LHC & LHC upgrades

LHC is the 1st Higgs factory!

E_{CoM}=8-14 TeV, $\widehat{L}\sim10^{34}$cm^{-2}s^{-1}

total cross section at 8 TeV: 22 pb

1 M Higgs produced so far – more to come

15 H bosons / min – and more to come

8 → 14 TeV: ggH x1.5 F. Cerutti, P. Janot

HL-LHC (~2022-2030)

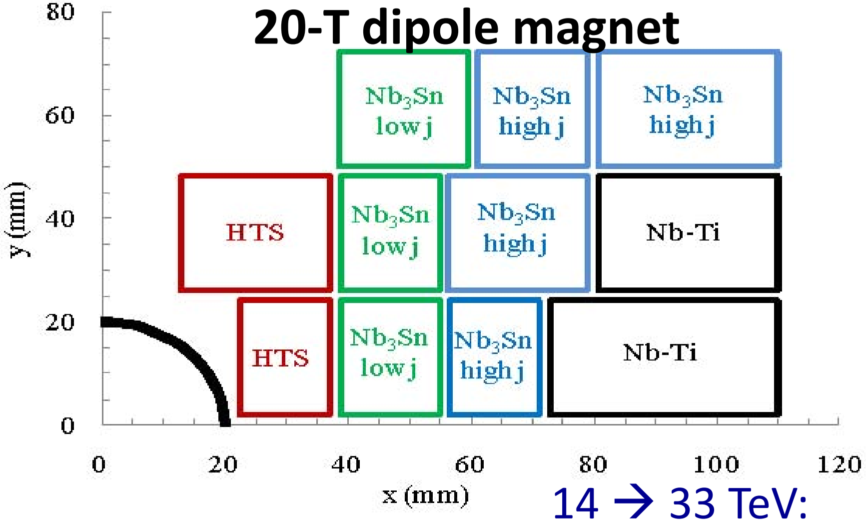
will deliver ~9x more H bosons!

E_{CoM}=14 TeV, $\widehat{L}\sim5\text{x}10^{34}$cm^{-2}s^{-1}

with luminosity leveling

HE-LHC: in LHC tunnel (2035-)

E_{CoM}=33 TeV, $\widehat{L}=5\text{x}10^{34}$cm^{-2}s^{-1}



20-T dipole magnet

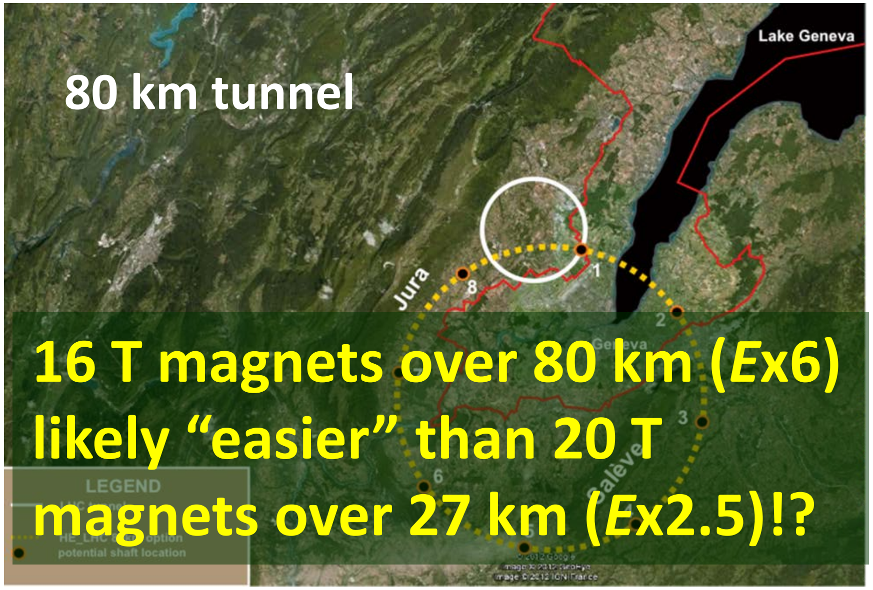
14 → 33 TeV:

ggH→ HH x6

E. Todesco, L. Rossi, P.. McIntyre

VHE-LHC: new 80 km tunnel

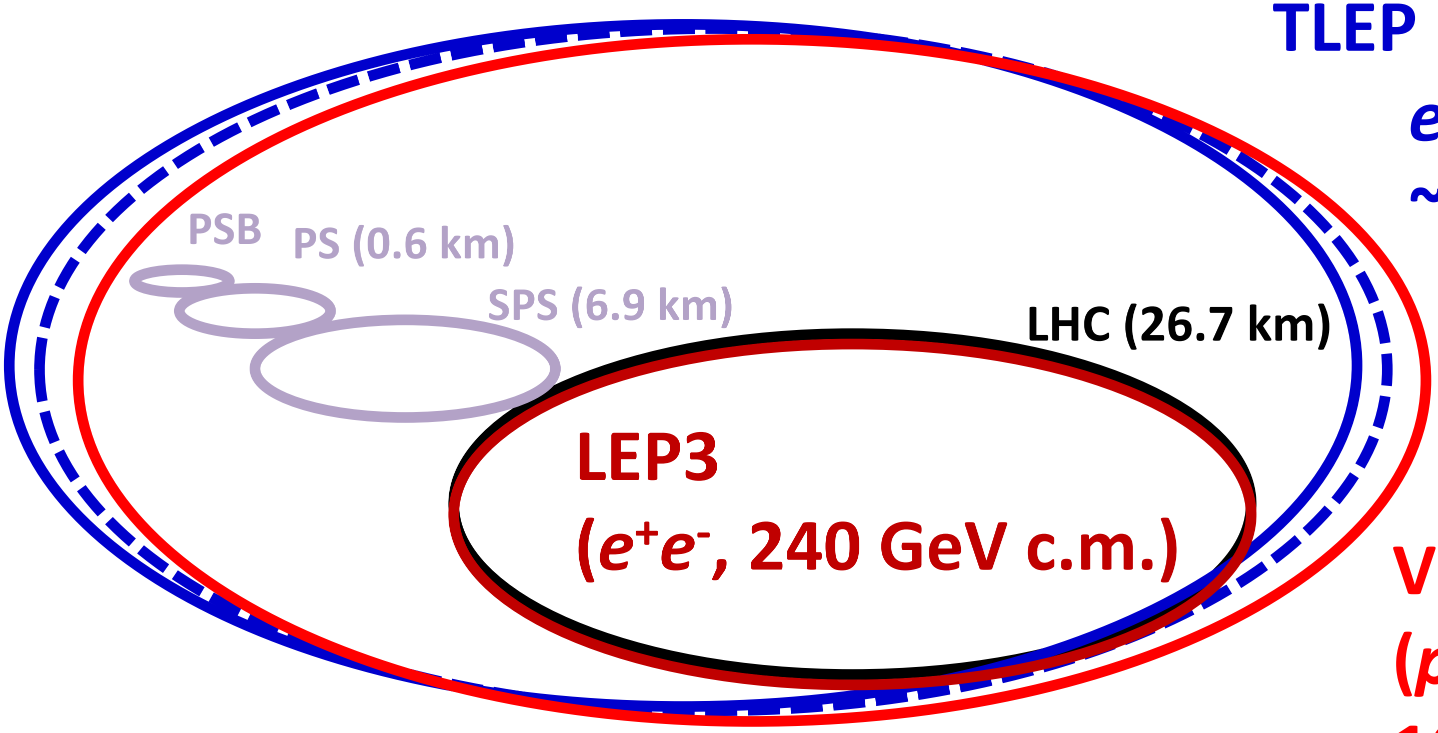
E_{CoM}=84-104 TeV, $\widehat{L}=5\text{x}10^{34}$cm^{-2}s^{-1}



16 T magnets over 80 km (*E*x6)
likely “easier” than 20 T
magnets over 27 km (*E*x2.5)!?

J. Osborne, C. Waaijer, S. Myers

possible long-term strategy



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

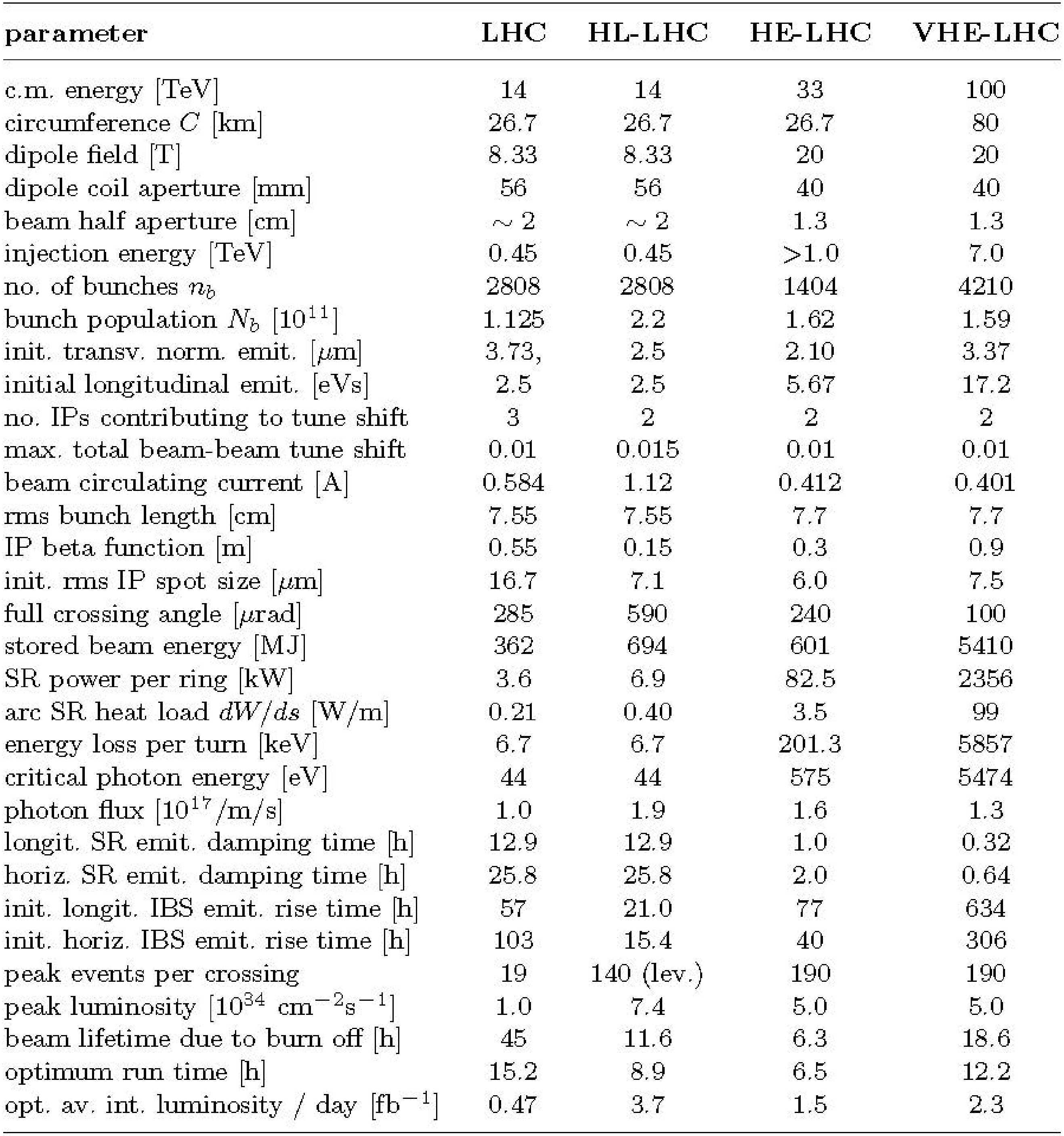
VHE-LHC
(*pp*, up to
100 TeV c.m.)
same detectors!

(E. Meschi)

also: ***$e^\pm$* (120 GeV) – *p* (7 & 50 TeV)** collisions

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

parameters for *LHC* *HL-LHC*, *HE-LHC* and *VHE-LHC* (examples)



parameter	LHC	HL-LHC	HE-LHC	VHE-LHC
c.m. energy [TeV]	14	14	33	100
circumference C [km]	26.7	26.7	26.7	80
dipole field [T]	8.33	8.33	20	20
dipole coil aperture [mm]	56	56	40	40
beam half aperture [cm]	~ 2	~ 2	1.3	1.3
injection energy [TeV]	0.45	0.45	>1.0	7.0
no. of bunches n_b	2808	2808	1404	4210
bunch population N_b [10^{11}]	1.125	2.2	1.62	1.59
init. transv. norm. emit. [μm]	3.73,	2.5	2.10	3.37
initial longitudinal emit. [eVs]	2.5	2.5	5.67	17.2
no. IPs contributing to tune shift	3	2	2	2
max. total beam-beam tune shift	0.01	0.015	0.01	0.01
beam circulating current [A]	0.584	1.12	0.412	0.401
rms bunch length [cm]	7.55	7.55	7.7	7.7
IP beta function [m]	0.55	0.15	0.3	0.9
init. rms IP spot size [μm]	16.7	7.1	6.0	7.5
full crossing angle [μrad]	285	590	240	100
stored beam energy [MJ]	362	694	601	5410
SR power per ring [kW]	3.6	6.9	82.5	2356
arc SR heat load dW/ds [W/m]	0.21	0.40	3.5	99
energy loss per turn [keV]	6.7	6.7	201.3	5857
critical photon energy [eV]	44	44	575	5474
photon flux [10^{17}/m/s]	1.0	1.9	1.6	1.3
longit. SR emit. damping time [h]	12.9	12.9	1.0	0.32
horiz. SR emit. damping time [h]	25.8	25.8	2.0	0.64
init. longit. IBS emit. rise time [h]	57	21.0	77	634
init. horiz. IBS emit. rise time [h]	103	15.4	40	306
peak events per crossing	19	140 (lev.)	190	190
peak luminosity [10^{34} cm^{-2}s^{-1}]	1.0	7.4	5.0	5.0
beam lifetime due to burn off [h]	45	11.6	6.3	18.6
optimum run time [h]	15.2	8.9	6.5	12.2
opt. av. int. luminosity / day [fb^{-1}]	0.47	3.7	1.5	2.3

O. Dominguez
& F. Zimmermann

parameters for *TLHeC* & *VHE-TLHeC* (examples)

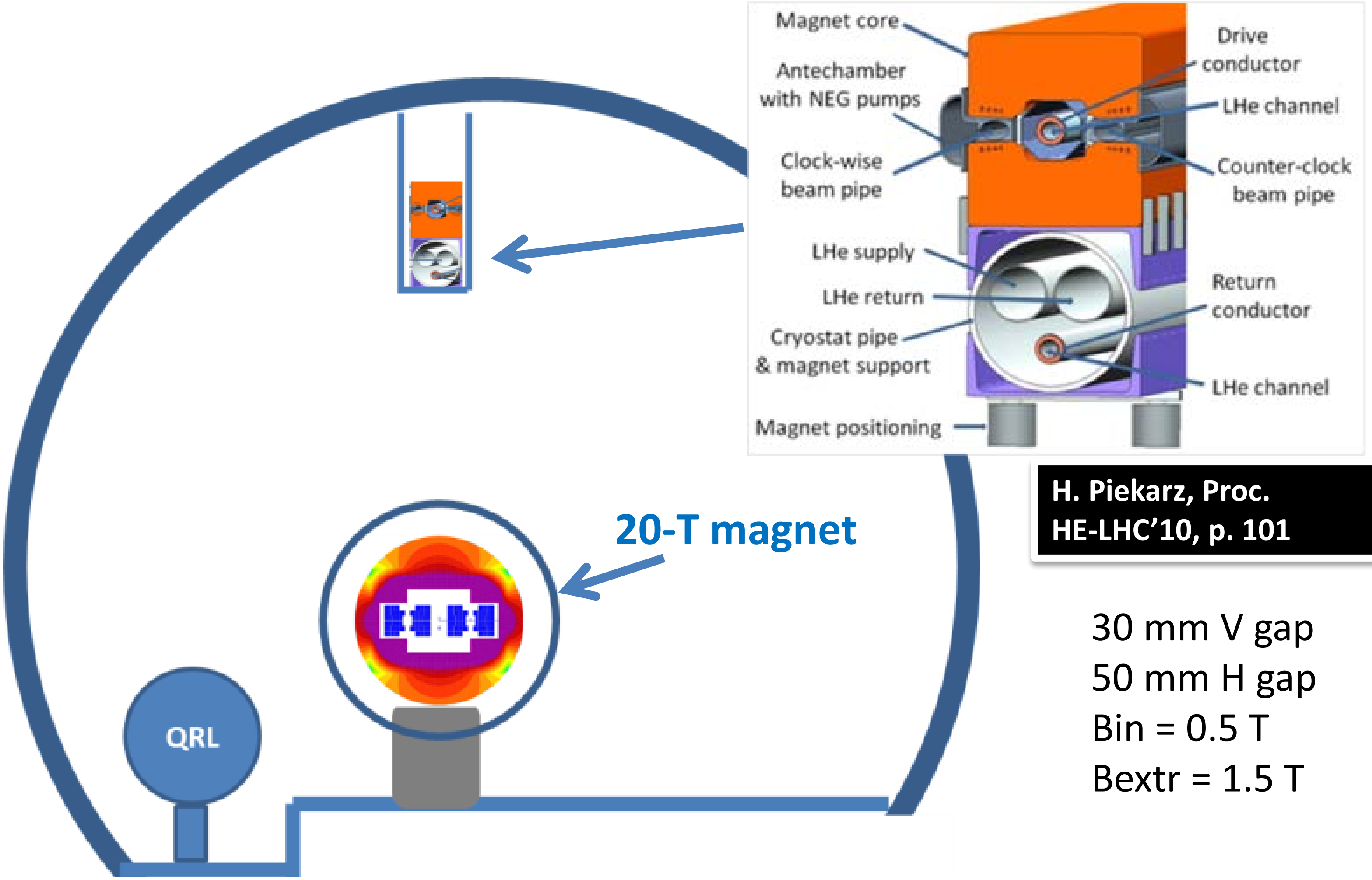
collider parameters	**TLHeC**		**VHE-TLHeC**	
species	$e^{\pm}$	p	$e^{\pm}$	p
beam energy [GeV]	**120**	**7000**	**120**	**50000**
bunch spacing [μs]	3	3	3	3
bunch intensity [10^{11}]	5	3.5	5	3.5
beam current [mA]	24.3	51.0	24.3	51.0
rms bunch length [cm]	0.17	4	0.17	2
rms emittance [nm]	10,2	0.40	10,2	0.06
$\beta_{x,y}^*$[cm]	2,1	60,5	0.5,0.25	60,5
$\sigma_{x,y}^*$ [μm]	15, 4		6, 2	
beam-beam parameter ξ	0.05, 0.09	**0.03,0.01**	0.07,0.10	**0.03,0.007**
hourglass reduction	**0.63**		**0.42**	
CM energy [TeV]	1.8		4.9	
luminosity [10^{34}cm^{-2}s^{-1}]	**0.5**		**1.6**	

arrangement in VHE-LHC tunnel

Lucio Rossi
CLIC workshop
28 Jan. 2013

VHE-LHC injector ring "LER"

(using transmission line magnet)

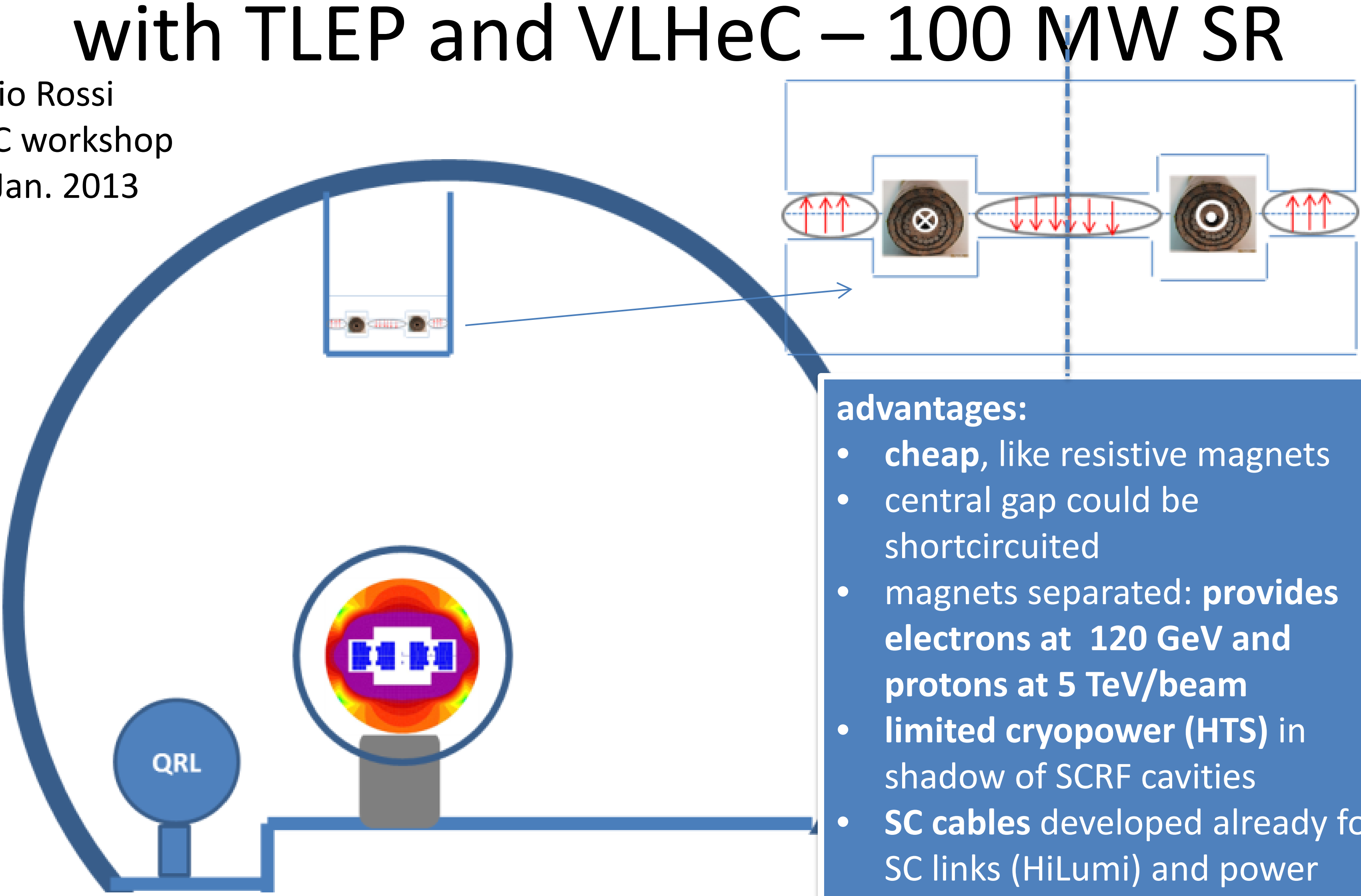


H. Piekarz, Proc. HE-LHC'10, p. 101

30 mm V gap
50 mm H gap
Bin = 0.5 T
Bextr = 1.5 T

VHE-LHC's LER magnets compatible with TLEP and VLHeC – 100 MW SR

Lucio Rossi
CLIC workshop
28 Jan. 2013

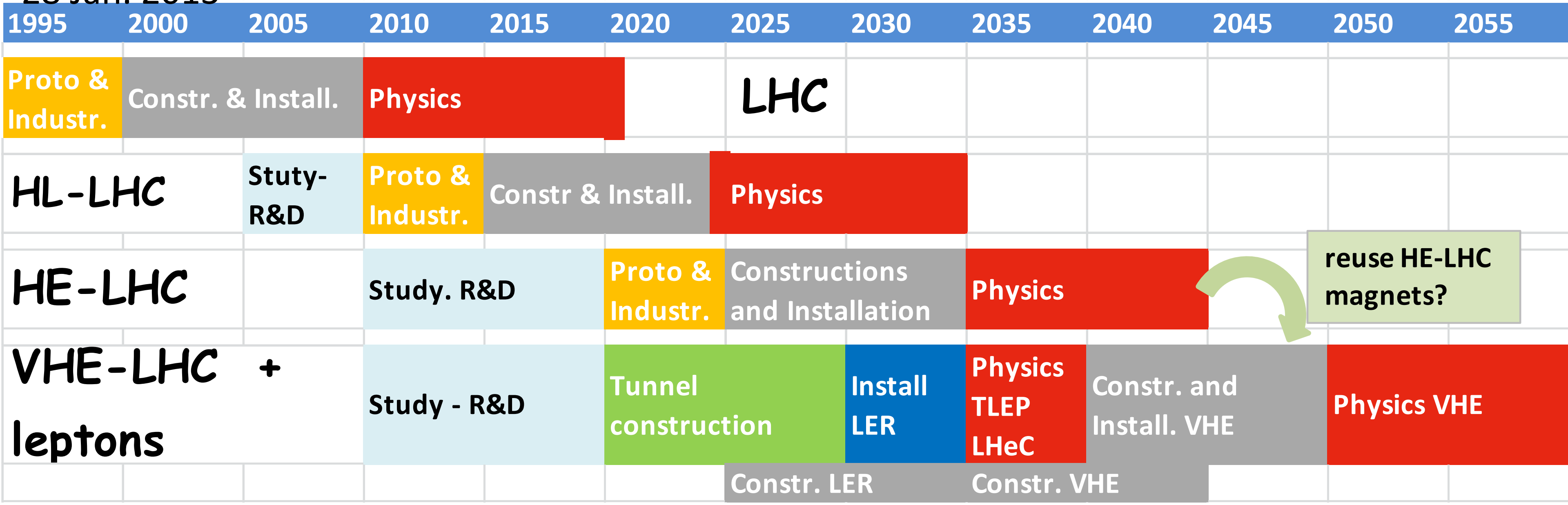


advantages:

- **cheap**, like resistive magnets
- central gap could be shortcircuited
- magnets separated: **provides electrons at 120 GeV and protons at 5 TeV/beam**
- **limited cryopower (HTS)** in shadow of SCRF cavities
- **SC cables** developed already for SC links (HiLumi) and power applications
- **SR taken at 300 K**

Lucio Rossi
CLIC workshop
28 Jan. 2013

Lucio Rossi’s «plan for all»


1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055

LHC: Proto & Industr. | Constr. & Install. | Physics

HL-LHC: Stuty-R&D | Proto & Industr. | Constr & Install. | Physics

HE-LHC: Study. R&D | Proto & Industr. | Constructions and Installation | Physics

reuse HE-LHC magnets?

VHE-LHC + leptons: Study - R&D | Tunnel construction | Install LER | Physics TLEP LHeC | Constr. and Install. VHE | Physics VHE

Constr. LER | Constr. VHE

2017-2020 is critical time!

according to Physics needs, the 80 km tunnel can:

- be alternative to HE-LHC
- or be complementary to HE-LHC
- **accomodate at negligible extra-cost TLEP and VLHeC**
- **modular detector design allows evolution from TLEP-H/TLHeC to VHE-LHC**

Mikhail S. Gorbachev

If what you have done yesterday
still looks big to you,
you haven’t done much today.

maximum TLEP luminosity

Mike Koratzinos

maximum theoretical luminosity is

$$L = \boxed{\frac{(f_{rev} n_b N_b)}{2}} \boxed{\frac{\gamma}{r_e}} \boxed{\xi_y} \boxed{\frac{R_{hourglass}}{\beta_y^*}}$$

$$\boxed{= 1.7 \times 10^{16} \times \rho[km]}$$

total power limit (100 MW SR)

$$\boxed{\text{Max. of } 0.1}$$

Beam-beam limit

$$\boxed{= 8.42 \times 10^{17} cm^{-1}}$$

at 120 GeV

For LEP3 this is $=6cm^{-1}$ ($0.6/0.1cm^{-1}$). For TLEP $=0.75/0.1cm^{-1}$. Difficult to go beyond this without nanobeam /crab-waist scheme

$$\boxed{L_{max} = 4.3 \times 10^{33}\ cm^{-1}s^{-1} \times \rho[km]}$$

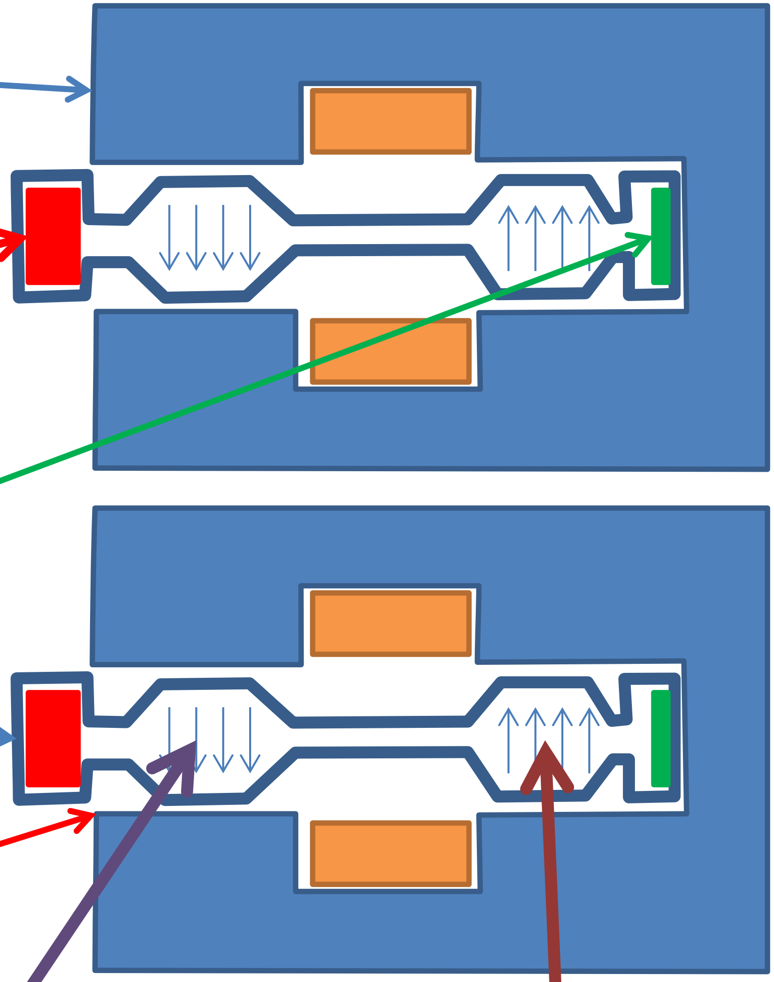
even higher TLEP luminosity?

- charge compensation (CC) – counteracting the electric field of the incoming beam by a second beam of opposite charge
- 4-beam collisions at DCI, Orsay, 1971

  - not a spectacular success
- new idea (V. Telnov, M. Koratzinos): use charge compensation to **suppress beamstrahlung and push luminosity in crab-waist scheme**

Mike Koratzinos

artist’s impression of CC-TLEP



main ring magnets

Thermal power management

Vacuum management

Vacuum chamber

Accelerator ring magnets

Clockwise e+ anticlockwise e-

Clockwise e- anticlockwise e+

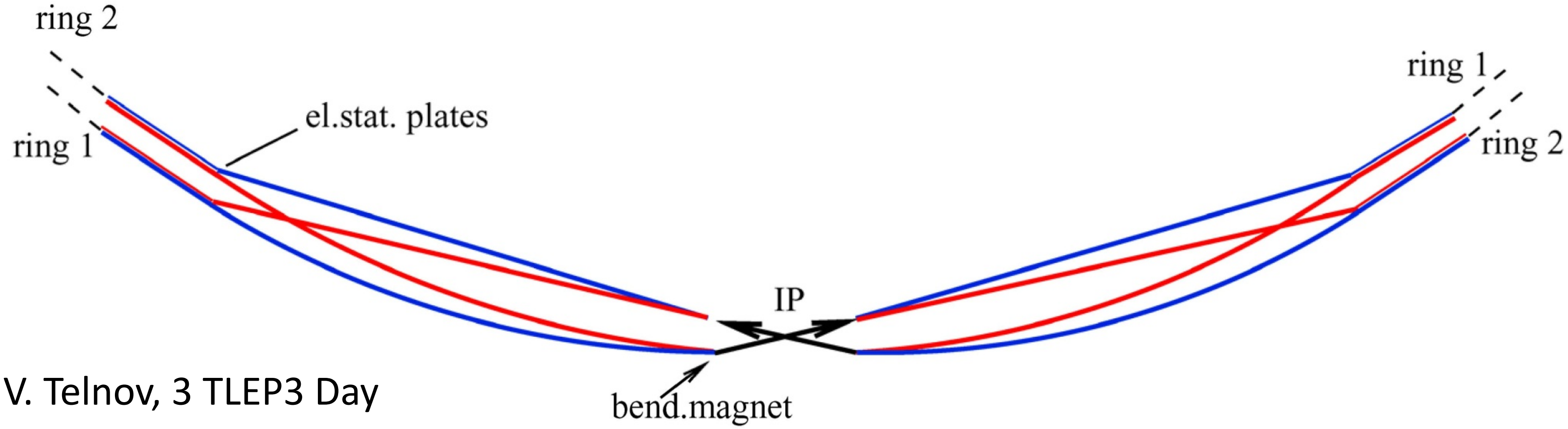
Valery Telnov’s estimate for CC TLEP

$$\frac{\Delta N}{N} = \frac{(\xi_c / \xi_{nc})^{1/2}}{(L_c / L_{nc})^{3/2}}$$

here
c-charge compensated
nc-noncompensated

The above consideration shows that the increase of the luminosity by a factor of 10 looks possible for all energies above 2E=240 GeV. A possible gain could reach a factor 25-40 for 2E=400-500, but this requires unrealistically high degree of neutralization (< 0.5-1%).

Scheme of a charge compensated crab-waist e+e- ring collider



V. Telnov, 3 TLEP3 Day

HF quality indicators

- readiness / maturity
- cost , electrical power
- peak luminosity , #IPs
- integrated luminosity
  - Hübner (*H*) factor = integrated lumi/(peak lumi x calendar time for physics)

    $H_{\mathrm{LEP}} \approx 0.2$, $H_{\mathrm{LHC}} \approx 0.2$, $H_{\mathrm{KEKB}} \approx 0.7$, $H_{\mathrm{PEP\text{-}II}} \approx 0.7$
- commissioning time
- expandability

HF Accelerator Quality (My Opinion)

	Linear C.	Circular C.	LHeC	Muon C.	γ–γ C.
maturity	☺	☺ ☺	☺ ☺	☹	☹
size	☹	☹	☺	☺☺	☺
cost	☹	☺ - 😐	☺	☹	☺
power	😐	😐	😐	😐	😐
#IPs	1	4	1	1	1
com. time	10 yr	2 yr	2 yr	10 yr	5 yr
H factor	0.2 (SLC)	0.5 (1/2 PEP-II)	0.2?	0.1?	0.1?
Higgs/IP/yr	7 k [10 k]	20-100 k	5 k	5 k	10 k
expanda-bility	1-3TeV e^+e^-, γγ C.	100 TeV *pp*	γγ C.	10 TeV μμ	LC later

inspired by S. Henderson, FNAL

the path forward

- set up **international collaboration(s) & work structure**
  - **ERC proposal** on large-acceptance IR design by Rogelio Tomas
  - TLEP **Design Study Proposal** for ECFA
  - **INFN-LNF could play a key role!**
- goal: publish **TLEP Conceptual Design Study Report by end of 2014!**

ERC Consolidation Grant Proposal "LEAF" – *Draft*

PI: Rogelio Tomas

includes international network for feeding new ideas, guidance, local support for experimental tests, review & collaboration

R. Tomas Part B1 LEAF

European Research Council

ERC Consolidator Grant 2013

Research proposal [Part B1][1]

(to be evaluated in Step 1)

Design of low-beta* insertions with extremely large (>3%) momentum acceptance for a future Higgs factory

LEAF

Cover Page:

Name of the Principal Investigator (PI): Rogelio Tomas Garcia

- Name of the PI's host institution for the project: CERN
- Proposal full title: Design of low-beta* insertions with extremely large momentum acceptance (>3%)
- Proposal short name: LEAF
- Proposal duration in months: 96 months

A unique Higgs-like particle has been discovered in 2012 by two LHC experiments. This has triggered recent proposals for highest-energy circular e+e- colliders which could explore this novel particle with unprecedented luminosity thanks to vertical beam sizes of a few 100 nm at the Interaction Point (IP), requiring about a factor 50 lower vertical beta function at the collision point than LEP2, the highest-energy lepton collider operated so far, and at least 15% more energy. The performance of such machines may be restricted by the effect of "beamstrahlung" (synchrotron radiation in the field of the opposing beam emitted during the collision) together with a limited momentum acceptance, i.e. the off-momentum dynamic aperture, which represents a completely novel type of lifetime limitation for a storage-ring collider. The ultimate luminosity which can be achieved in a circular Higgs factory is directly related to the off-momentum dynamic aperture over a radiation damping time (typically 10-100 turns for the machines considered). **The goal of the proposed project is to develop a low-beta* interaction region (IR) for a storage-ring collider, such that particles with an energy error of 3% or more, suddenly introduced by the emission of high energetic beamstrahlung photons, survive over 10 to 100 turns until they are damped back to the core of the beam thanks to the strong synchrotron radiation in the arcs. The luminosity of circular Higgs factories is directly related to off-momentum dynamic aperture. The proposed study will explore a large set of modifications to established final-focus designs together with additional non-linear elements in the collider arcs to control possible remaining aberrations. The new IR concepts and designs derived for this circular machine are likely to generate significant spin off, for example design and performance improvements for linear colliders, muon storage rings, light sources, and medical accelerators. In particular, there is a strong synergy with the laser-beam collision interaction region in the Compton storage ring for a polarized positron source. In the case of the Compton-scattering based intense positron source, electrons circulating in the Compton ring undergo large energy changes when they collide with a laser beam at a focal point.**

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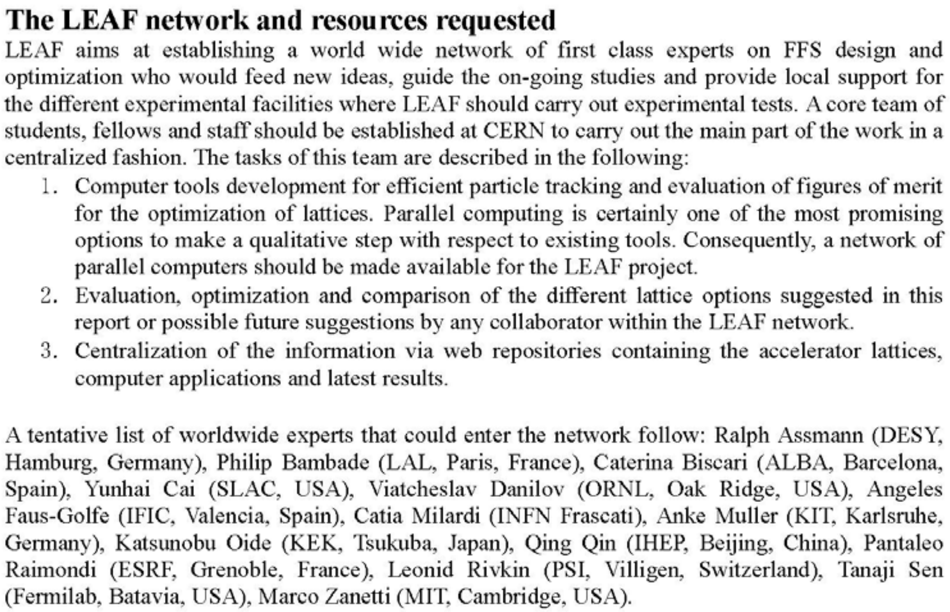
[1] Instructions for completing Part B1 can be found in the Guide for Applicants for the Consolidator Grant 2013 Call.



The LEAF network and resources requested

LEAF aims at establishing a world wide network of first class experts on FFS design and optimization who would feed new ideas, guide the on-going studies and provide local support for the different experimental facilities where LEAF should carry out experimental tests. A core team of students, fellows and staff should be established at CERN to carry out the main part of the work in a centralized fashion. The tasks of this team are described in the following:

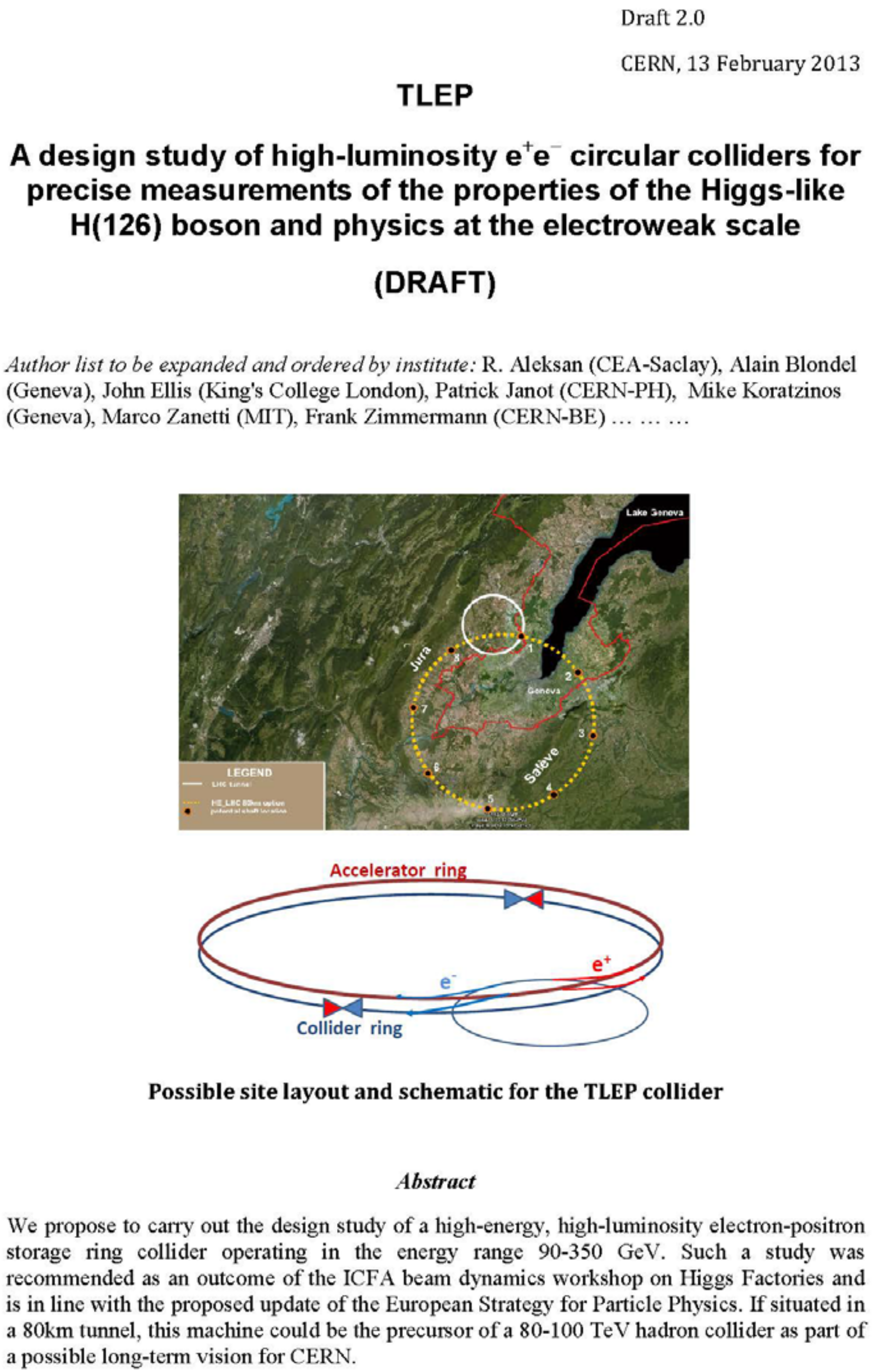
1. Computer tools development for efficient particle tracking and evaluation of figures of merit for the optimization of lattices. Parallel computing is certainly one of the most promising options to make a qualitative step with respect to existing tools. Consequently, a network of parallel computers should be made available for the LEAF project.
2. Evaluation, optimization and comparison of the different lattice options suggested in this report or possible future suggestions by any collaborator within the LEAF network.
3. Centralization of the information via web repositories containing the accelerator lattices, computer applications and latest results.

A tentative list of worldwide experts that could enter the network follow: Ralph Assmann (DESY, Hamburg, Germany), Philip Bambade (LAL, Paris, France), Caterina Biscari (ALBA, Barcelona, Spain), Yunhai Cai (SLAC, USA), Viatcheslav Danilov (ORNL, Oak Ridge, USA), Angeles Faus-Golfe (IFIC, Valencia, Spain), Catia Milardi (INFN Frascati), Anke Muller (KIT, Karlsruhe, Germany), Katsunobu Oide (KEK, Tsukuba, Japan), Qing Qin (IHEP, Beijing, China), Pantaleo Raimondi (ESRF, Grenoble, France), Leonid Rivkin (PSI, Villigen, Switzerland), Tanaji Sen (Fermilab, Batavia, USA), Marco Zanetti (MIT, Cambridge, USA).

draft work topics: TLEP accelerator

- parameter optimization with regard to lifetime and luminosity, at different energies, & different tunnels
- RF system design, prototyping & integration for collider and accelerator ring
- optics design for collider ring including low-beta IRs, off-momentum dynamic aperture, different energies
- beamstrahlung: lifetime, steady state beam distribution, dependence on tune etc.
- beam-beam interaction with large hourglass effect
- emittance tuning studies, errors, tolerances, etc.
- optics design and beam dynamics for the accelerator ring, ramping speed etc
- impedance budget, CSR, instabilities
- cryogenics system design
- magnets design: collider ring dipole, accelerator ring dipole, low-beta quadrupole
- radiation, shielding, cooling for 100 MW SR power
- vacuum system design
- engineering study of 80-km tunnel
- design of injector complex including e+ source, and polarized e- source
- machine detector interface, integration of accelerator ring at detector (s), low-beta quadrupoles, shielding (e.g. against beamstrahlung)?
- injection scheme
- polarization, Siberian snakes, spin matching, acceleration & storage, polarized sources

(19 September 2012)



Draft 2.0

CERN, 13 February 2013

TLEP

A design study of high-luminosity e^+e^- circular colliders for precise measurements of the properties of the Higgs-like H(126) boson and physics at the electroweak scale

(DRAFT)

Author list to be expanded and ordered by institute: R. Aleksan (CEA-Saclay), Alain Blondel (Geneva), John Ellis (King's College London), Patrick Janot (CERN-PH), Mike Koratzinos (Geneva), Marco Zanetti (MIT), Frank Zimmermann (CERN-BE) … … …

Possible site layout and schematic for the TLEP collider

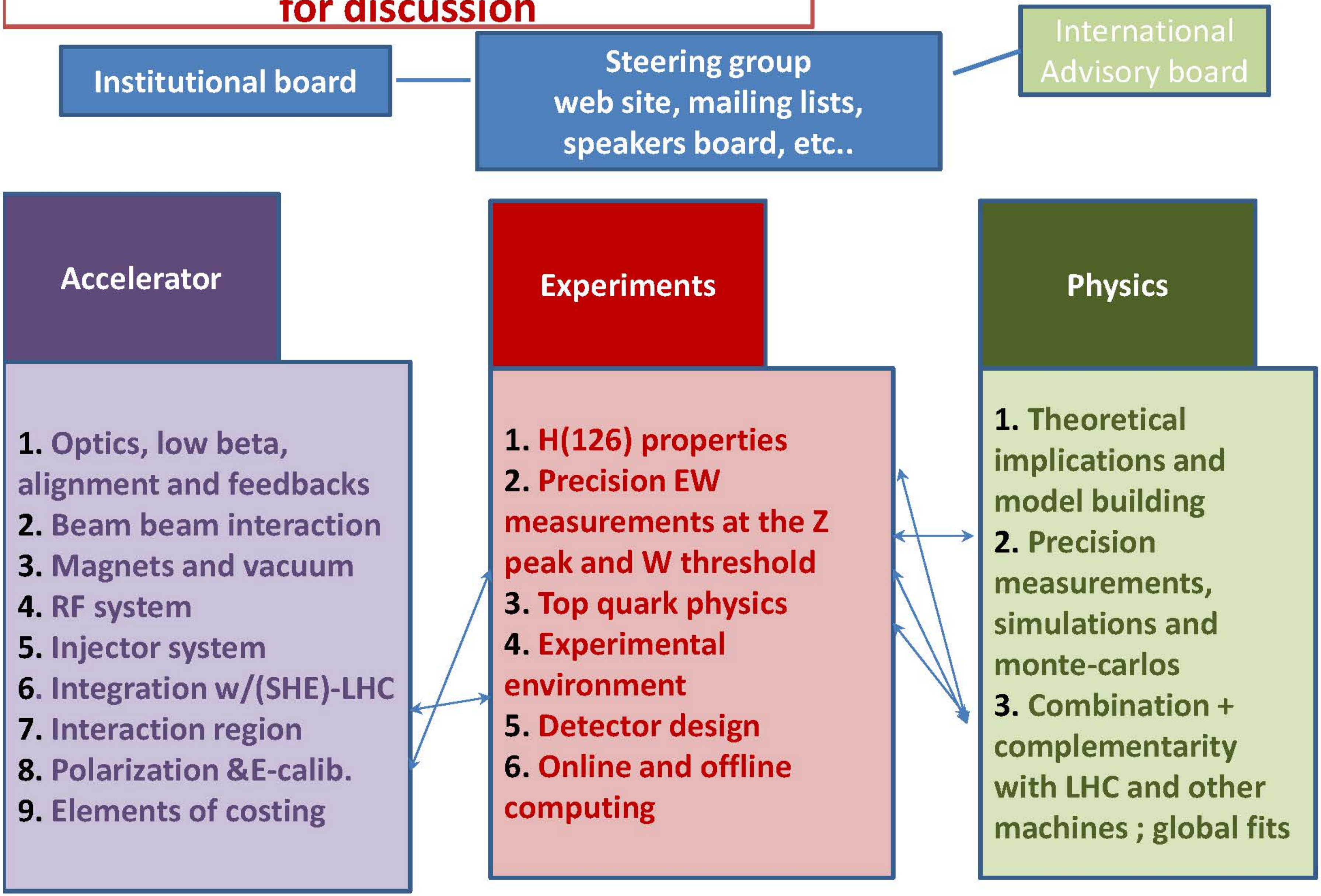
Abstract

We propose to carry out the design study of a high-energy, high-luminosity electron-positron storage ring collider operating in the energy range 90-350 GeV. Such a study was recommended as an outcome of the ICFA beam dynamics workshop on Higgs Factories and is in line with the proposed update of the European Strategy for Particle Physics. If situated in a 80km tunnel, this machine could be the precursor of a 80-100 TeV hadron collider as part of a possible long-term vision for CERN.

TLEP Design Study Proposal

to be submitted to ECFA

TLEP design study –preliminary structure for discussion



Institutional board

Steering group
web site, mailing lists, speakers board, etc..

International Advisory board

Accelerator

1. Optics, low beta, alignment and feedbacks
2. Beam beam interaction
3. Magnets and vacuum
4. RF system
5. Injector system
6. Integration w/(SHE)-LHC
7. Interaction region
8. Polarization &E-calib.
9. Elements of costing

Experiments

1. H(126) properties
2. Precision EW measurements at the Z peak and W threshold
3. Top quark physics
4. Experimental environment
5. Detector design
6. Online and offline computing

Physics

1. Theoretical implications and model building
2. Precision measurements, simulations and monte-carlos
3. Combination + complementarity with LHC and other machines ; global fits

summary

- **TLEP is a great opportunity for HEP!**
  - unparalleled "*ZH*" luminosity in 4 IPs, allowing for highest-precision Higgs studies
  - also Tera-Z and Mega-W factory, + t-tbar studies
  - future conversion into 100 TeV pp collider with lots of synergies (tunnel, cryo, detectors), & *ep* option
- LEP3 as backup
- **TLEP3 accelerator R&D to address key issues**
  - radiation shielding
  - IR optics, beam-beam effects, and injector ring
  - tunnel, RF system, arc magnets,…
- plans for **international collaboration & CDSR**

TLEP events & references

A. Blondel, F. Zimmermann, *"A High Luminosity e^+e^- Collider in the LHC Tunnel to study the Higgs Boson,"* arXiv:1112.2518v1, 24.12.'11

K. Oide, *"SuperTRISTAN - A possibility of ring collider for Higgs factory,"* KEK Seminar, 13 February 2012

1st EuCARD LEP3 workshop, CERN, 18 June 2012

A. Blondel et al, *"LEP3: A High Luminosity e+e- Collider to study the Higgs Boson,"* arXiv:1208.0504, submitted to ESPG Krakow

P. Azzi et al, *"Prospective Studies for LEP3 with the CMS Detector,"* arXiv:1208.1662 (2012), submitted to ESPG Krakow

2nd EuCARD LEP3 workshop, CERN, 23 October 2012

P. Janot, *"A circular e^+e^- collider to study H(125),"* PH Seminar, CERN, 30 October 2012

ICFA Higgs Factory Workshop: Linear vs Circular, FNAL, 14-16 Nov. '12

A. Blondel, F. Zimmermann, *"Future possibilities for precise studies of the X(125) Higgs candidate,"* CERN Colloquium, 22 Nov. 2012

3rd TLEP3 Day, CERN, 10 January 2013

4th TLEP mini-workshop, CERN, 4-5 April 2013

https://espace.cern.ch/LEP3 https://cern.ch/accnet

“A circle is a round straight line with a hole in the middle.”

Mark Twain,
in "English as She Is Taught",
Century Magazine, May 1887

back-up slides

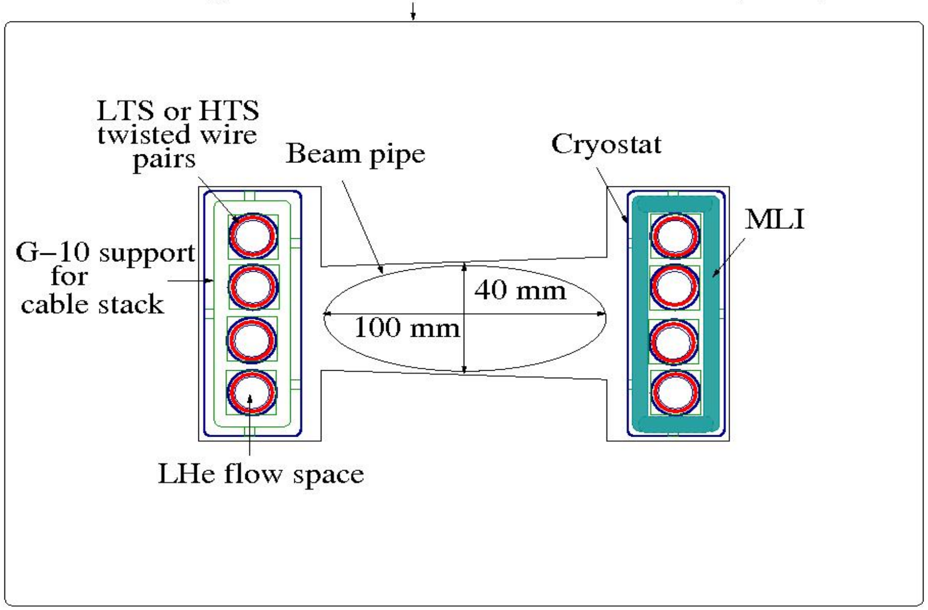
Circular HF HiTech option

H. Piekarz,
1st EuCARD LEP3 Day

transmission-line HTS/LTS magnets

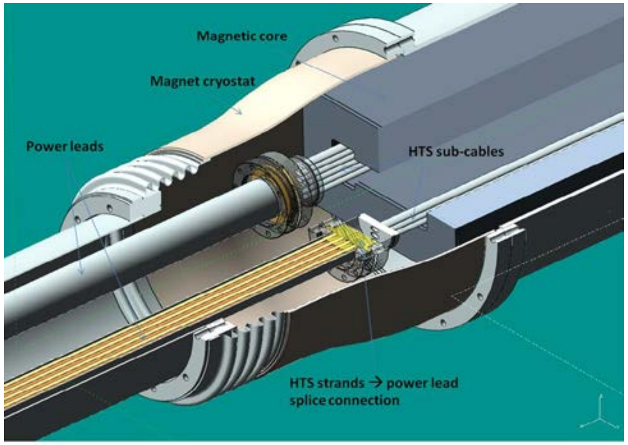
SC magnets require typically 10 x less space than NC magnet of the same field and gap; the magnet weight is very significantly reduced.

schematic HTS/LTS LEP3 magnet

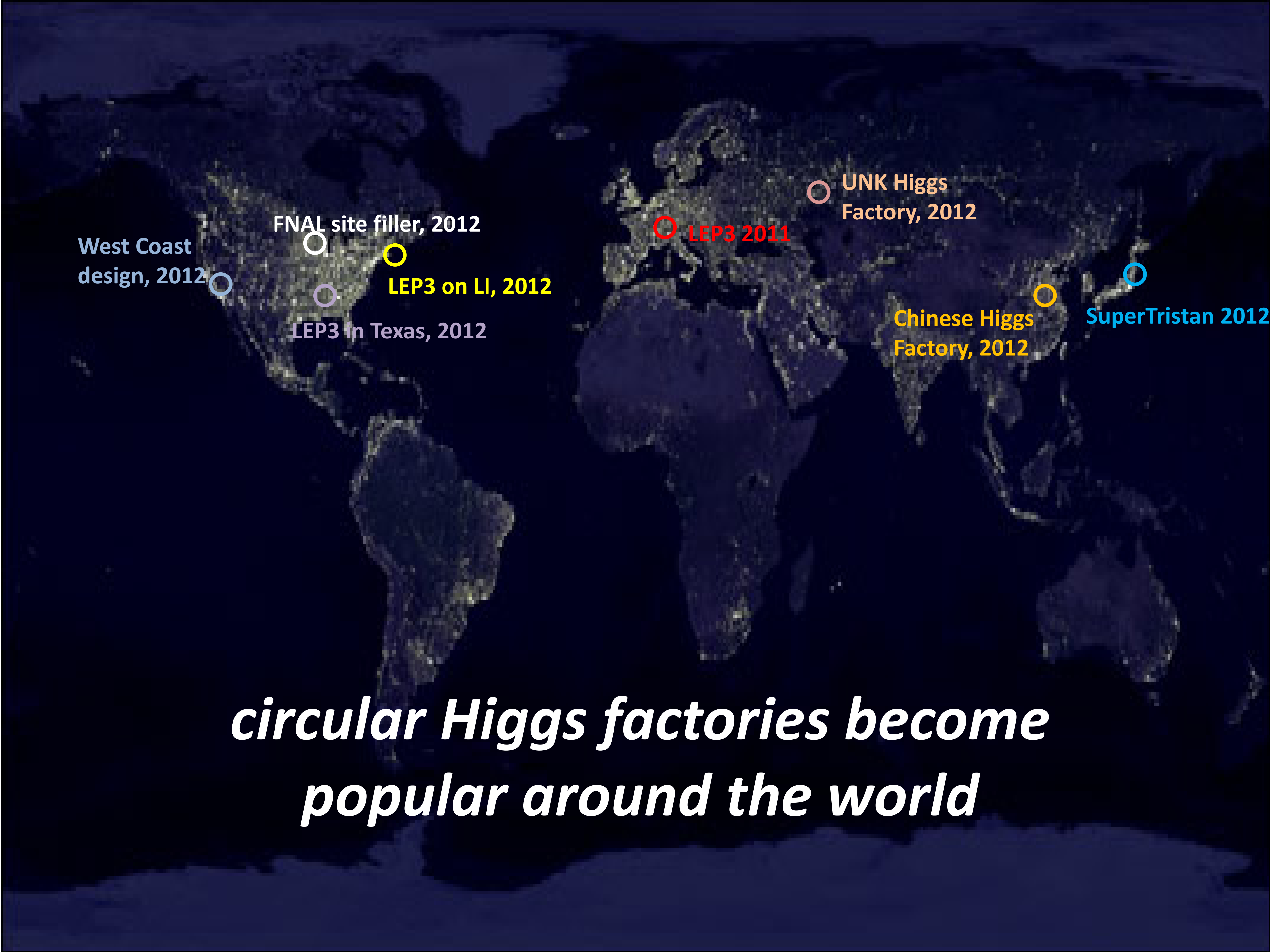


HTS prototype dipole at FNAL

Test: B_{max} = 0.5 T, I_{max} = 27 kA, dB/dt_{max} = 10 T/s , T_{max} ~ 25 K



acceleration time ~0.1 s, total cycle ~1 s; fast SC magnets might support 1 minute lifetime in collider ring!



circular Higgs factories become popular around the world