CepC workshop and goals

F. Bedeschi,
CepC workshop
Rome, May 2018

Outline

- Some history
- Many "uncertain" options
- The next steps
- Workshop goals

The Great Discovery!

INFN Istituto Nazionale di Fisica Nucleare

July 4th, 2012

- After the Higgs ... what next?

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- How to go beyond the SM?

The incompleteness of the SM

0. Which rationale for matter quantum numbers?

$|Q_p + Q_e| < 10^{-21} e$

1. Phenomena unaccounted for

neutrino masses, Dark matter, matter-antimatter asymmetry, inflation

2. Why $\theta \lesssim 10^{-10}$? $\theta G_{\mu\nu} \tilde{G}^{\mu\nu}$

Axions

3. $\mathcal{O}_i : d(\mathcal{O}_i) \leq 4$ only?

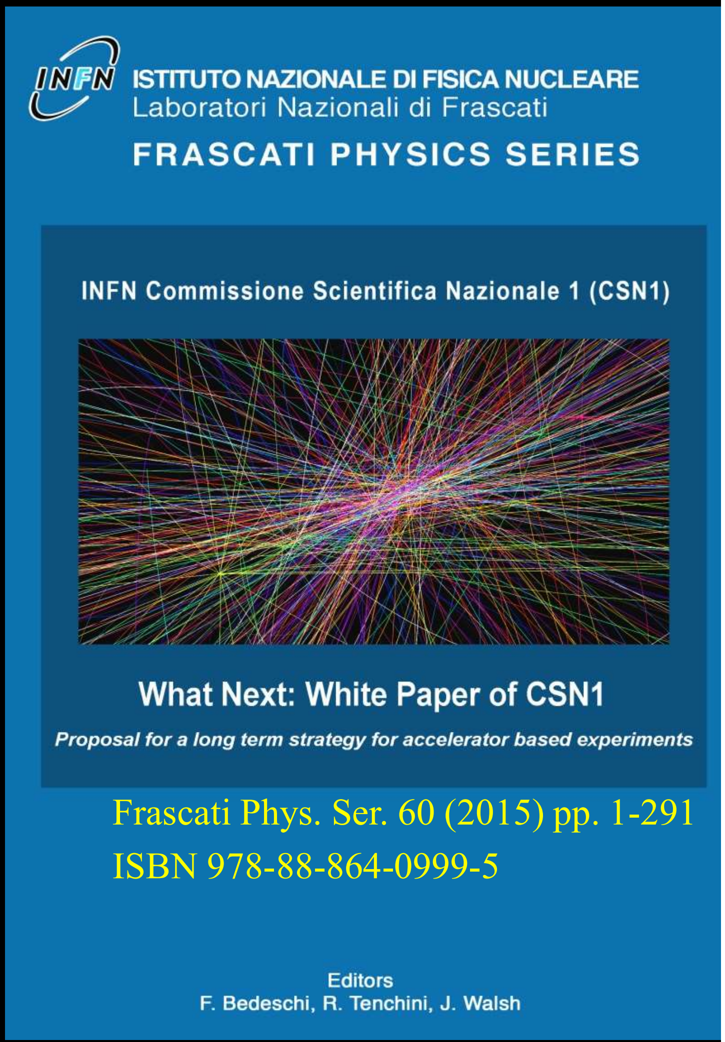
neutrino masses, Gravity, Are the protons forever?

4. Lack of calculability (a euphemism)

$\Rightarrow$ the hierarchy problem, the flavour paradox

R. Barbieri, Plank 2017

- After the Higgs ... what next?
- How to go beyond the SM?
- Italian community started an internal discussion
  - CSN1 community published summary
    - 1.5 yr of work by theorists and experimental physicists



Frascati Phys. Ser. 60 (2015) pp. 1-291
ISBN 978-88-864-0999-5

Recommendations

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  - CSN1 urges INFN to continue and strengthen its support of R&D for the development of new high field magnets and conventional or un-conventional accelerator structures

  - CSN1 supports INFN participation in studies and R&D related to the future colliders. <u>**Our community must be part of the planning of the future.**</u>

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  - Incubator for future machines and future experiments
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  - Incubator for future machines and future experiments
    - Limited funding at present
  - Presently 84 physicists involved at small fraction of research time
  - Three main lines of research:
    - EIC in the USA
    - Muon Collider R&D
    - Circular colliders: e+e- (main effort) and pp
      - Parallel work on FCC-ee and CepC given the major uncertainties and the obvious synergies
      - Some work on FCC-hh and SPPC

Additional comments

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- Muon Colliders could be the future of multiTeV lepton machines → new ideas are being explored
  - R&D important. If successful next to next machine
- An e+e- collider for a high precision study of EW phenomena is currently the preferred next big machine
    - Especially if it is a first step for a future very high energy pp
  - It has a well defined strong physics program
  - It is technically feasible NOW
  - The cost scale is similar to LHC, thus expensive but affordable

e^+e^- collider potential (1)

- Z pole, WW:
  - >> one-two orders of magnitude statistical precision than LEP, dominated by systematics
  - Eliminate parametric uncertainty from $\alpha_{EM}(Z)$, M_W, $\sin(\theta_W)$, ….
  - Need N^3LO SM corrections from theory → doable in 5-10 years
  - Outstanding flavor physics
- $t\bar{t}$:
  - > one order of magnitude better than LHC: mass, width, Yukawa
  - Few theory uncertainties in mass interpretation from threshold scan
  - Eliminate top related parametric uncertainties

e^+e^- collider potential (1)

	Observable	Measurement	Current precision	FCC-ee stat.	Possible syst.	Challenge
Z	m_Z (MeV)	Lineshape	91187.5 ± 2.1	0.005	< 0.1	QED corr.
	Γ_Z (MeV)	Lineshape	2495.2 ± 2.3	0.008	< 0.1 *	QED / EW
	R_l	Peak	20.767 ± 0.025	0.001	< 0.001	Statistics
	R_b	Peak	0.21629 ± 0.00066	0.000003	< 0.00006	$g \rightarrow bb$
	N_ν	Peak	2.984 ± 0.008	0.00004	< 0.004	Lumi meast
	$\sin^2\theta_W^{eff}$	$A_{FB}^{\mu\mu}$ (peak)	0.23148 ± 0.00016	0.000003	<0.000005 *	Beam energy
	$1/\alpha_{QED}(m_Z)$	$A_{FB}^{\mu\mu}$ (off-peak)	128.952 ± 0.014	0.004	< 0.004	QED / EW
	$\alpha_s(m_Z)$	R_l	0.1196 ± 0.0030	0.00001	<0.0002	New Physics
W	m_W (MeV)	Threshold scan	80385 ± 15	0.6	< 0.6	EW Corr.
	Γ_W (MeV)	Threshold scan	2085 ± 42	1.5	<1.5	EW Corr.
	N_ν	$e^+e^- \rightarrow \gamma Z$, $Z \rightarrow \nu\nu$, ll	2.92 ± 0.05	0.001	< 0.001	?
	$\alpha_s(m_W)$	$B_{had} = (\Gamma_{had}/\Gamma_{tot})_W$	B_{had} = 67.41 ± 0.27	0.00018	< 0.0001	CKM Matrix
t	m_{top} (MeV)	Threshold scan	173340 ± 760 ± 500	20	<40	QCD corr.
	Γ_{top} (MeV)	Threshold scan	?	40	<40	QCD corr.
	λ_{top}	Threshold scan	μ = 1.2 ± 0.3	0.08	< 0.05	QCD corr.
	ttZ couplings	$\sqrt{s}$ = 365 GeV	~30%	~2%	<2%	QCD corr

Courtesy of D. D'Enterria, FCC week 2018, Amsterdam

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~ factor 20 improvement over LEP including systematics

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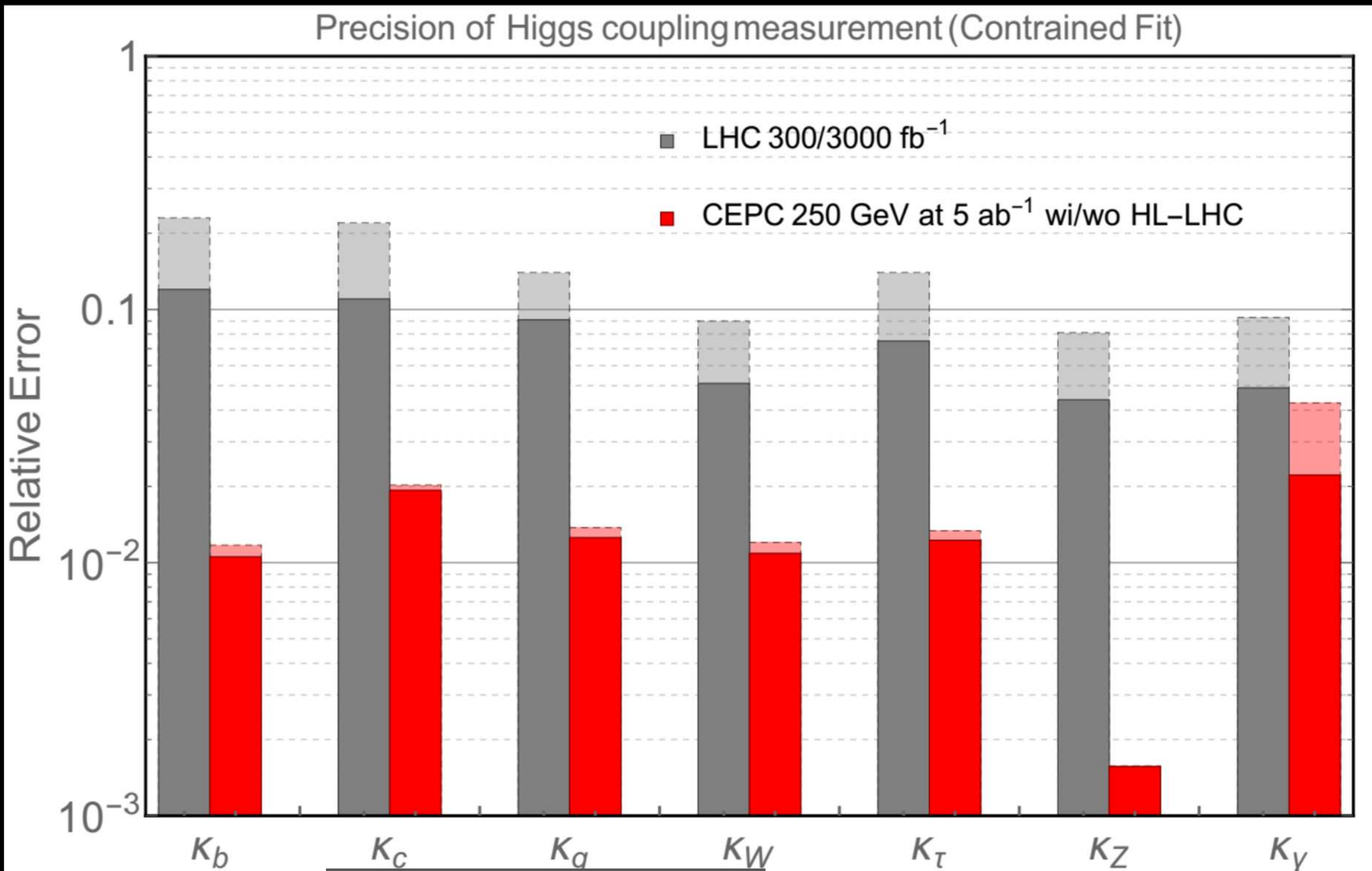
e^+e^- collider potential (2)

- ZH:
  - One order of magnitude better than LHC
  - No model dependence in BR measurements
  - Accessible scale for new physics ~ several TeV

$$\Lambda \gtrsim (1\ \mathrm{TeV}) / \sqrt{(\delta g_{HXX} / g_{HXX}^{SM})/5\%}$$

e^+e^- collider potential (2)



CepC pre-CDR, 2015

e^+e^- collider potential (2)

Parameter	Current* 7+8+13 TeV $\mathcal{O}$ (70 fb^{-1})	HL-LHC* 14 TeV (3 ab^{-1})	FCC-ee Baseline (10 yrs)	ILC Lumi upgrade (20 yrs)	CEPC Baseline (10 yrs)	CLIC Baseline (15 yrs)
σ(HZ)	–	–	0.4%	0.7%	0.5%	1.6%
g_{ZZ}	10%	2–4%	0.15%	0.3%	0.25%	0.8%
g_{WW}	11%	2–5%	0.2%	0.4%	1.6%	0.9%
g_{bb}	24%	5–7%	0.4%	0.7%	0.6%	0.9%
g_{cc}	–	–	0.7%	1.2%	2.3%	1.9%
$g_{\tau\tau}$	15%	5–8%	0.5%	0.9%	1.4%	1.4%
$g_{t\bar{t}}$	16%	6–9%	13%	6.3%	–	4.4%
$g_{\mu\mu}$	–	8%	6.2%	9.2%	17%	7.8%
$g_{e^+e^-}$	–	–	<100%	–	–	–
g_{gg}	–	3–5%	0.8%	1.0%	1.7%	1.4%
$g_{\gamma\gamma}$	10%	2–5%	1.5%	3.4%	4.7%	3.2%
$g_{Z\gamma}$	–	10–12%	(to be determined)			9.1%
Δm_H	200 MeV	50 MeV	11 MeV	15 MeV	5.9 MeV	32 MeV
Γ_H	<26 MeV	5–8%	1.0%	1.8%	2.8%	3.6%
Γ_{inv}	<24%	<6–8%	<0.45%	<0.29%	<0.28%	<0.97%

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The “uncertain” options

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  - ILC – Oldest project – Reviewed to death
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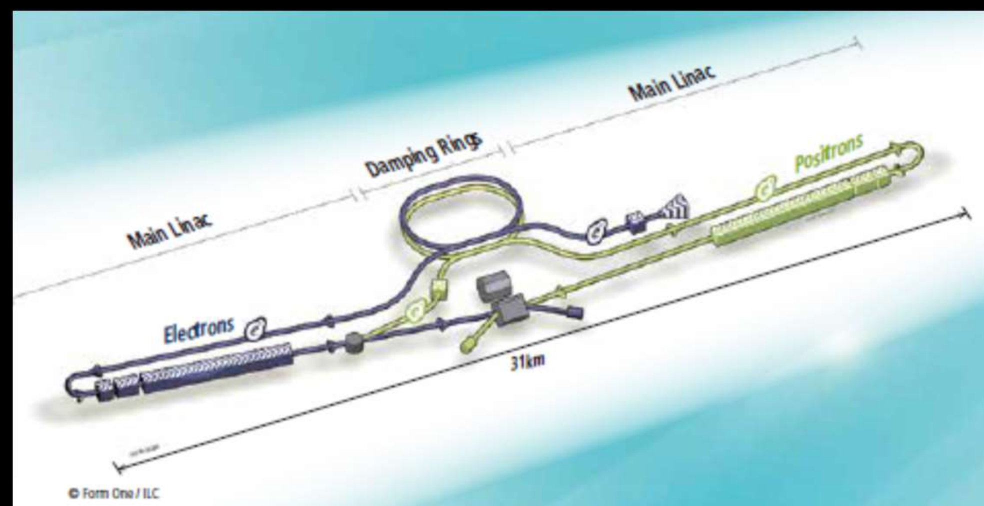

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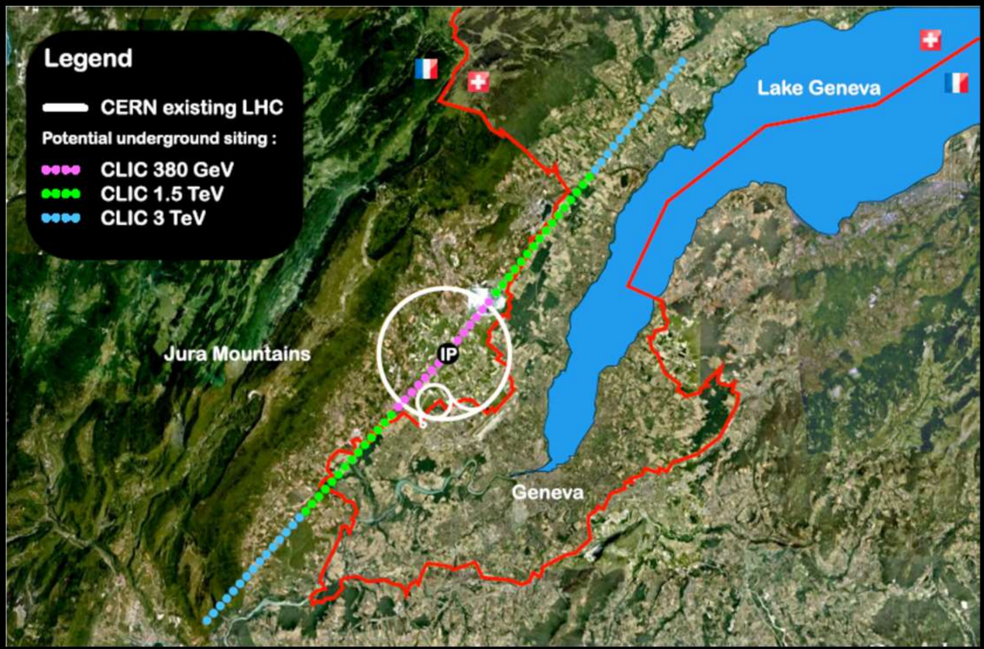

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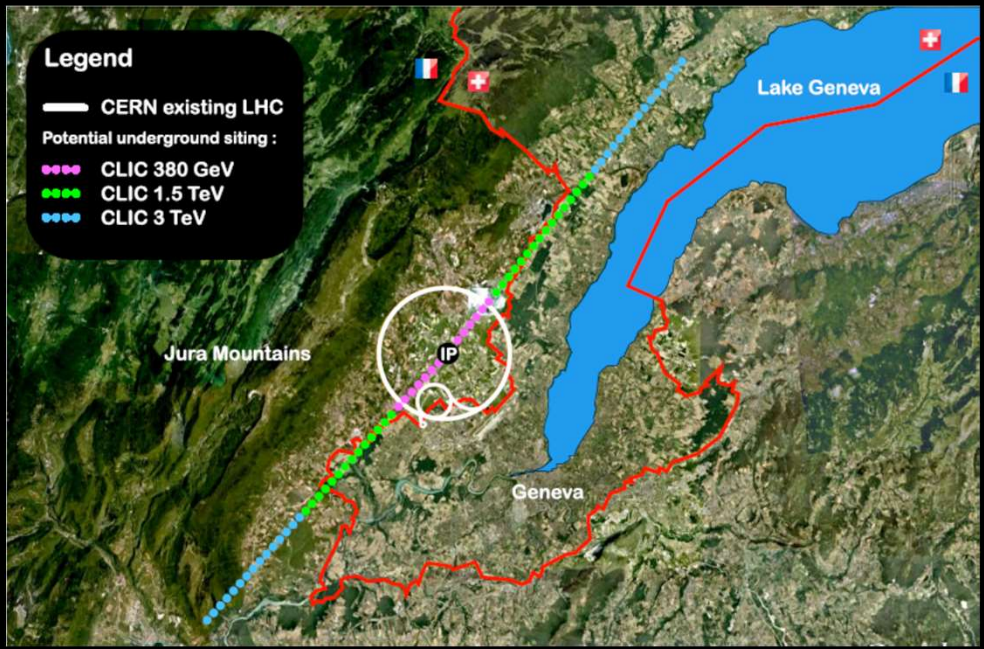

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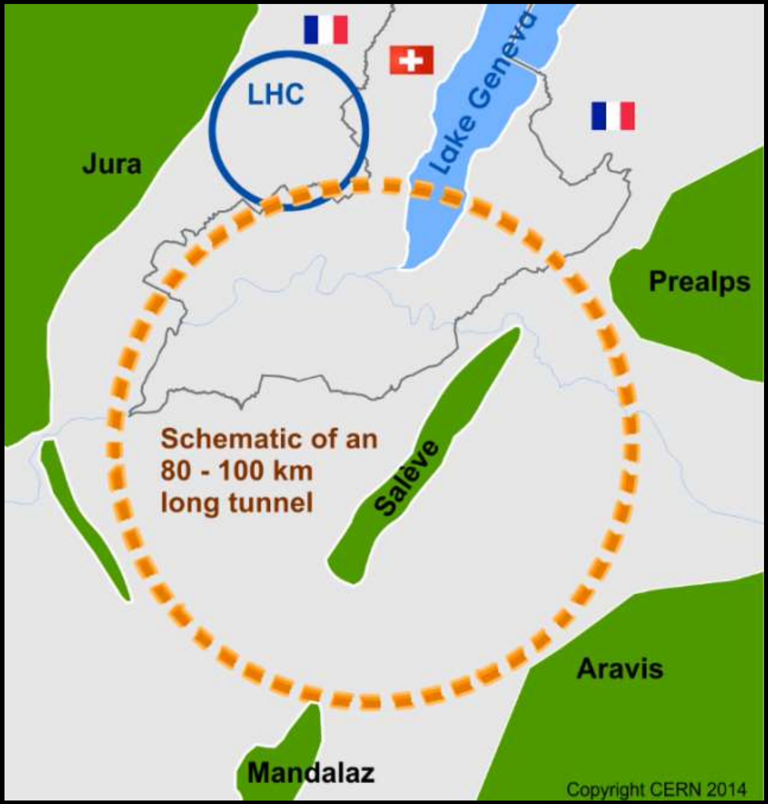

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  - CepC – Pre-CDR 2015
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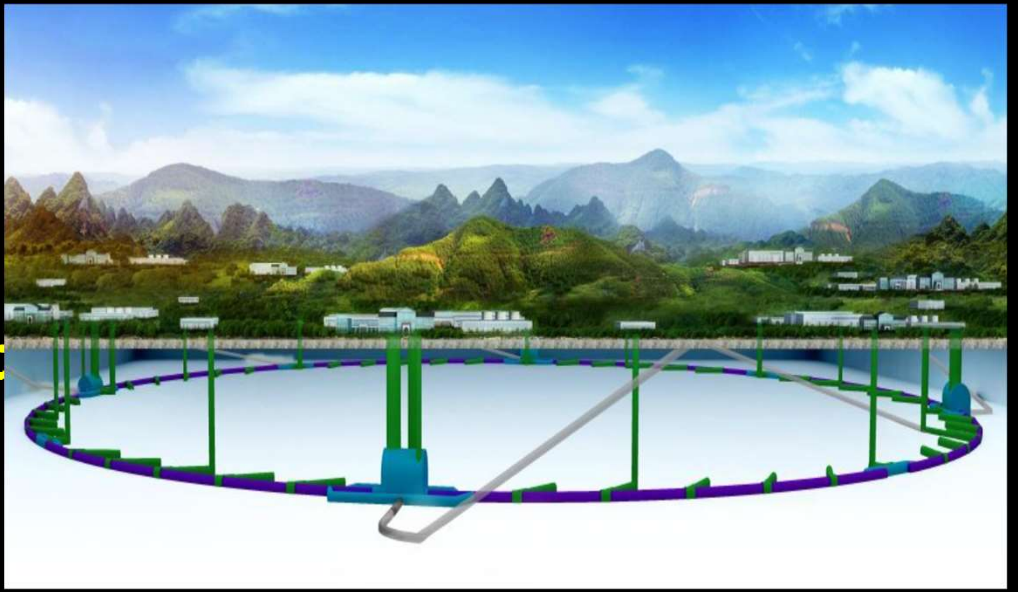
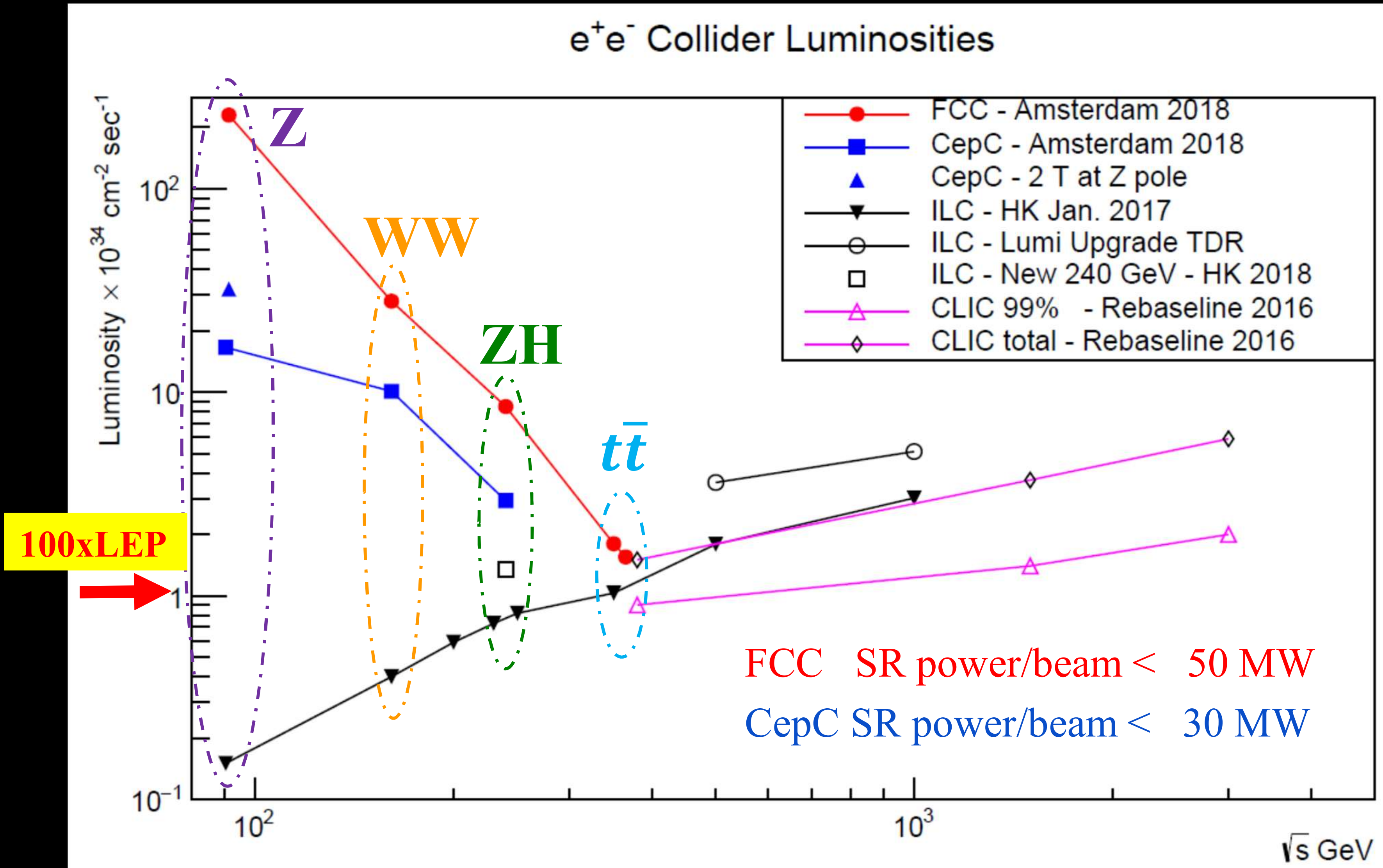


CepC, FCC, ILC, CLIC
luminosity comparison



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    - What will be pushed harder?
  - ESPP 2026 update (CERN decision time)

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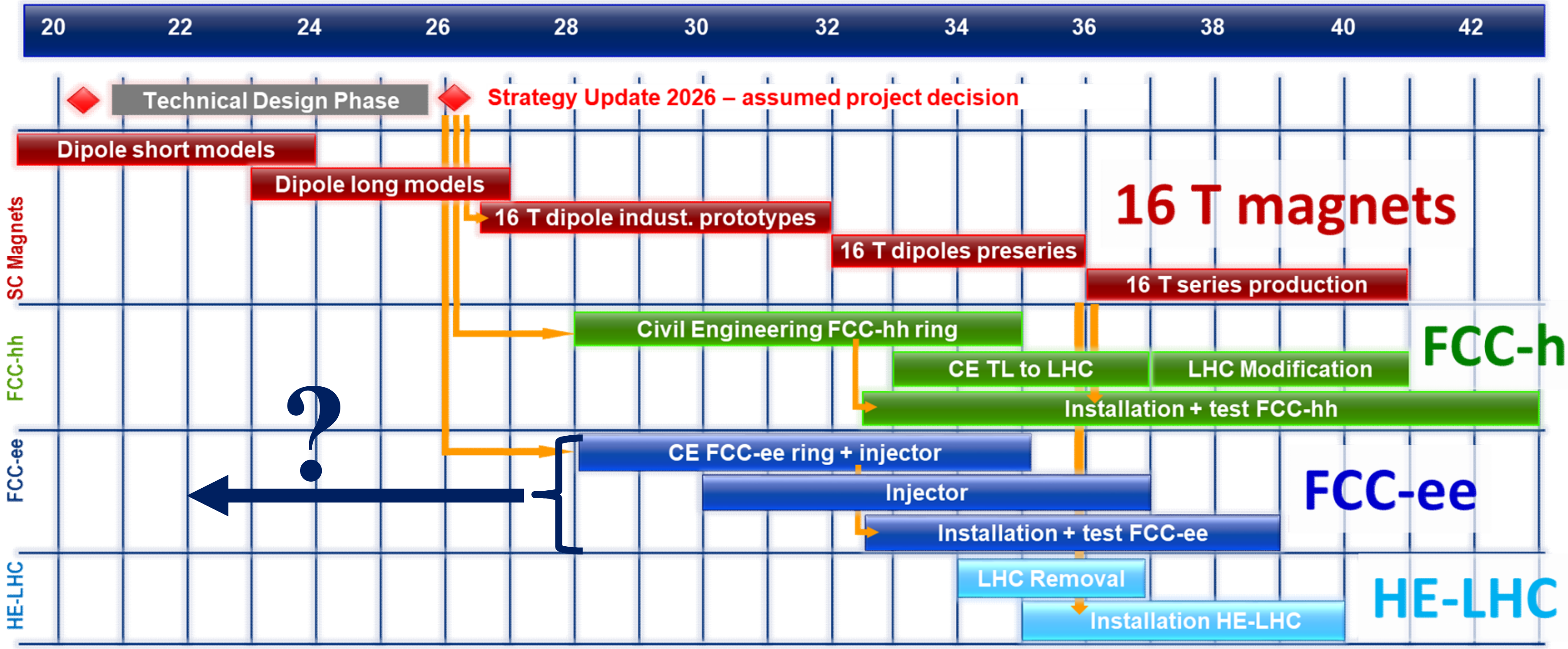
  - ESPP 2026 update (CERN decision time)
- CepC:
  - CDR by end of 2018
  - Working with MOST to be included in "Large international science projects" – 3-5 (6-10) preparatory/1-2 (2-4?) construction now-2020 (2035)

EU Schedule

❖ FCC proposed schedule



Courtesy of M. Benedikt, FCC week 2018, Amsterdam

China schedule

- CepC proposed schedule (ideal = optimistic)

design issues
R&D items
preCDR

design, funding
R&D program
Intl. collaboration
site study

seek approval, site decision
construction during 14th 5- year plan commissioning

Courtesy of Y. Wang, FCC week 2018, Amsterdam

Detectors for e+e- circular colliders

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- ILC/CLIC detectors already studied in considerable detail, so why bother?
- ILC/CLIC detectors are not optimized for circular colliders
  - Basic resolution requirements similar
  - Many common developments
  - Same solutions not always viable
  - Different optimizations

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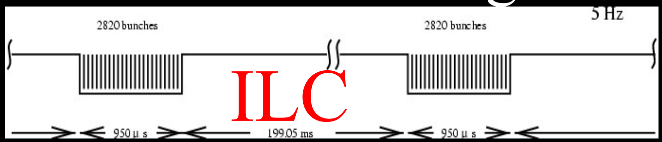

  - No large time gap
    - Cooling issues for PF calorimeter and vertex detector
    - TPC ion backflow
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Other drivers

- Extreme statistical resolution on Z pole
  - Acceptance systematics control is critical
    - Both charged and neutrals at few μm level
- Extreme systematics control required by luminometers

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- Present status of all e+e- options for the post-LHC era
  - Accelerator designs and associated constraints on detectors (Plenary+MDI)
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- Panel discussion:
  - Future collider options – What do we want in the ESPP 2020?
  - Beyond CDR's - How do we want to structure future R&D?

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- 2019-2025: major overlap with other activities draining human and financial resources
  - LHC upgrades
  - Many accelerator projects in China

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- I hope this workshop will be useful to the people of CepC and all enthusiasts of e+e- colliders