ILC + CLIC status

Personal assessment

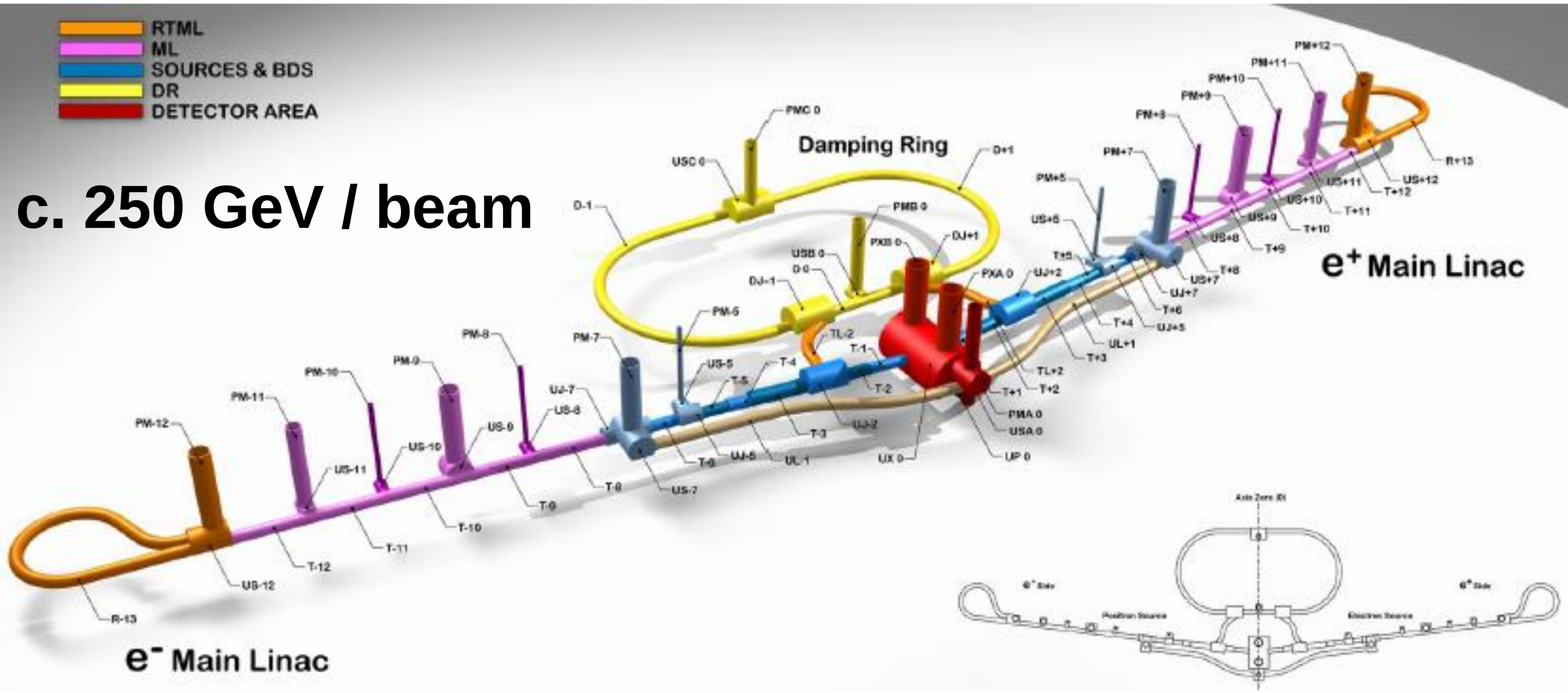
Philip Burrows

John Adams Institute, Oxford University

Some slides borrowed from Lyn Evans, Akira Yamamoto, Masauchi Yamauchi et al

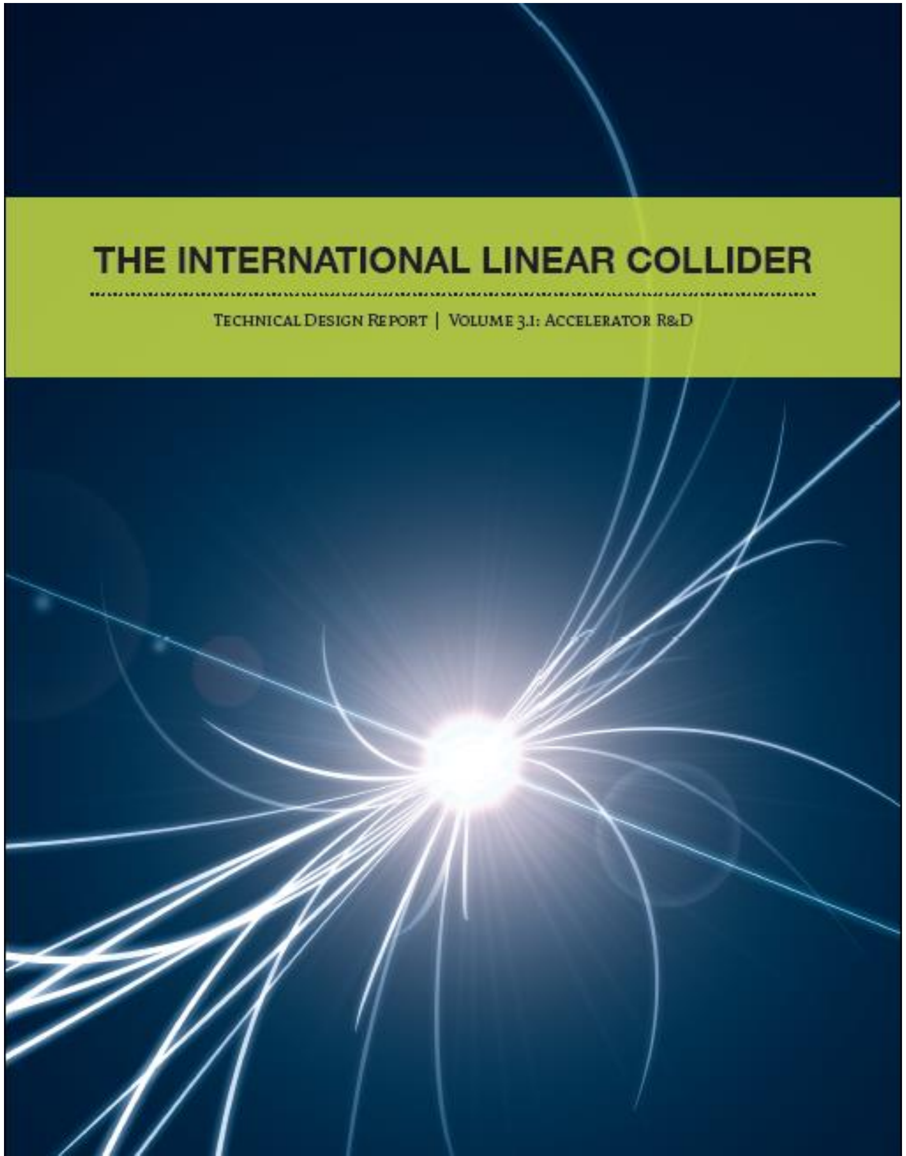
International Linear Collider (ILC)

c. 250 GeV / beam



31 km

ILC Technical Design Report



5 volumes

> 1000 pages

‘shovel-ready’

https://www.linearcollider.org/ILC/Publications/Technical-Design-Report

European particle physics strategy 2013

There is a strong scientific case for an electron-positron collider, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and whose energy can be upgraded.

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Europe looks forward to a proposal from Japan to discuss a possible participation.

Next Update of European Strategy: Approximate Timeline

September 2017:	**Appointment of Strategy Secretary and installation of Strategy Secretariat**
September 2018:	**Appointment of ESG and PPG by CERN Council; formal opening of the process**
2019:	**Preparation of the briefing book, including 1 or 2 town meetings**
January 2020:	**Drafting of the proposed strategy by the ESG**
March 2020:	**Discussion of proposed strategy by CERN Council**
May 2020:	**Adoption of new strategy by CERN Council**

New Mandate for LCB/LCC established in 2016

Main purpose over the next years:

Oversight on worldwide R&D efforts

- relevant R&D (mostly) done through other projects

Keep the successful close collaboration and synergy between ILC and CLIC

Promote LC in politics and general public

- thus establish close links to e.g. KEK ILC promotion office,
- CLIC collaboration and
- Outreach (communicators)

Keep possibility for common fund

- after endorsement by LCB, approval through FALC

Activities LCC

Linear Collider Collaboration:

Has started its work

One of the main topics is investigation of possible cost reduction for ILC

- Progress in technology, i.e. cavity gradient
- Staging: start version with 250 GeV cms energy
  i.e. above threshold for Higgs production

Details to be discussed at LCB meeting

- Note: full scientific potential of a linear electron-positron collider requires upgrade to cms energies beyond 250 GeV

R&D for ILC cost reduction

under US-Japan Cooperation in High Energy Physics

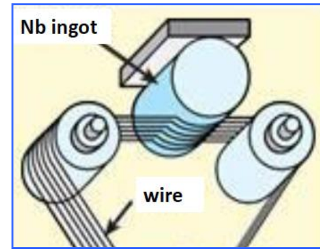
February 15, 2017
FALC Meeting

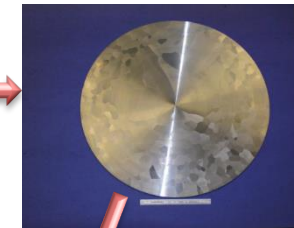
M.Yamauchi
KEK

1. Cost reduction in Nb material preparation

Optimize the ingot purity with a lower residual resistivity ratio (RRR).

Simplify the manufacturing method such as forging, rolling, slicing and tube forming.





	2016	2017	2018	2019
KEK Masashi Yamanaka	Feasibility study using 3-cell cavities (ongoing)		Preparing materials / Manufacture 8x9-cell cavities	Evaluation (Vertical&Horizontal tests)

Medium or High RRR sheet for cells

Low RRR tube for stiffener and beam pipe

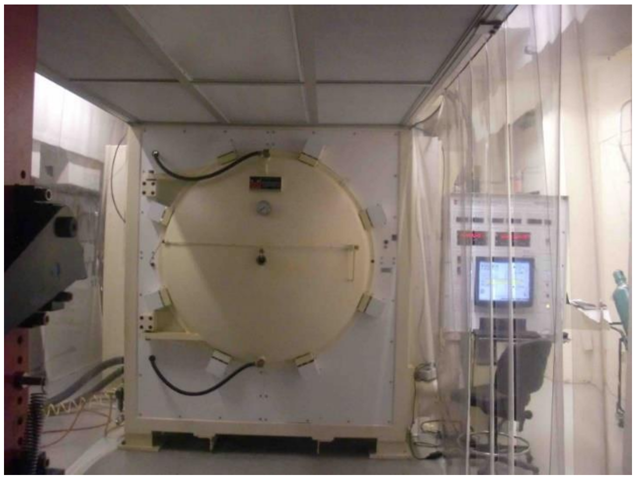
Quality of Nb for the end part will be optimized at this stage.

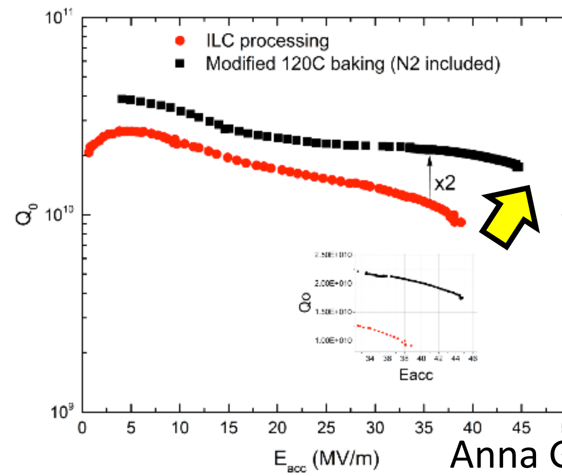
LINEAR COLLIDER COLLABORATION

2. High-Q high-gradient SRC with nitrogen infusion

Confirm reproducibility of the nitrogen infusion method to improve Q and field gradient of SC RF cavity. (Developed at FNAL)

High statistics test of the yield by fabricating 8 9-cell cavities.





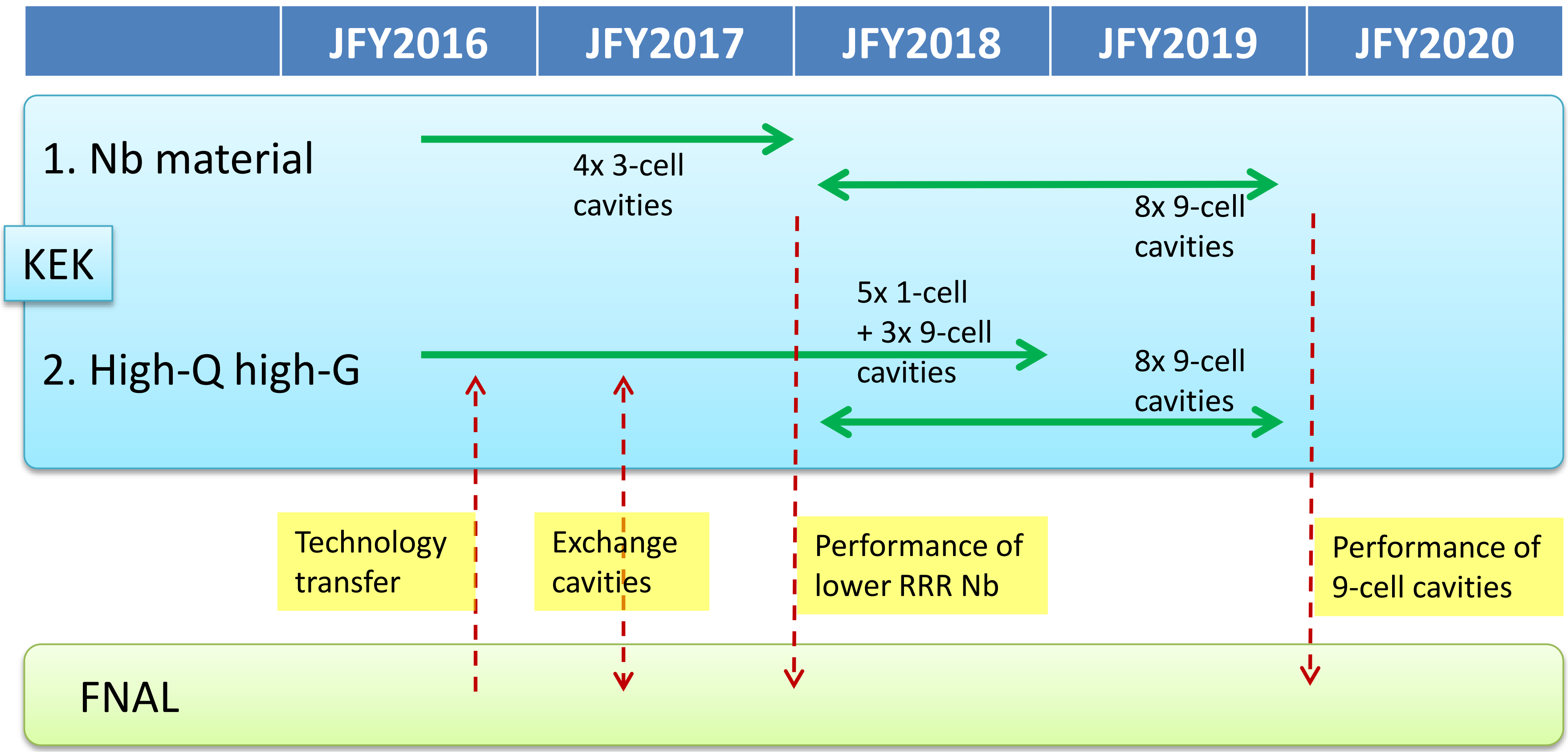
Anna Grassellino, FNAL

	2016	2017	2018	2019
KEK Hitoshi HAYANO	FNAL process	1 cell processing Preparation of vacuum furnace	Performance test 3-9cell performance 8 - 9cell cavities fabrication	Preparation for cryomodule Performance test

R&D Plans at worldwide Labs

	On-going	R&D: ML Cavity	Assoc. System	Cryomodule	RF
Fermilab	LCLS-II	N_2-infusion (HQ-HG)	Coupler		
JLab	LCLS-II	Nb-LG/FG (Ingot-sliced/rolled) , N_2-infusion			
DESY	EXFEL	N_2-infusion Nano-Lab study		High-performance CM	
INFN-LASA	ESS	Nb-LG/FG systematic study for ESS			
CEA/ CNRS-LAL	IFMIF ESS, SARAF	Vertical EP (VEP), N_2-Infusion	Magnetic shield Coupler	Assembly robotizing	
KEK	STF	Nb-LG/FG N_2-infusion	Coupler, Tuner Crab. C.		Marx M.
IHEP	ADS	N_2-infusion, In dustrialization		Industrialization	Marx M. h.e. Klystron
CERN	HL-LHC Hi-Isolde	Thin-film (Nb on Cu)	Coupler		h.e. Klystron
TRIUMF	ISAS-II, ARIEL	VEP, muSR			
(Cornell)		N_2-infusion, VEP			

Major interactions between KEK and FNAL



Impact on the ILC cost

Possible cost reduction

	ILC cost reduction
1. Nb material	2-3%
2. High-Q high-G	8-9%
sum	10-12%

ILC using CLIC technology

- The Chairman of LCB has requested a cost comparison of a 250 GeV start version of the superconducting machine with a klystron-based CLIC at 250 GeV.
- A preliminary estimate is to be presented at the next LCB meeting in Guangzhou in August.

Update on ILC Status in Japan

Wataru TODOROKI

Director, Office for Particle and Nuclear Research Promotion

February 15th, 2017

Present Status of MEXT

- MEXT set up an advisory panel for the ILC in May 2014 to proceed with focused investigation and discussions, based on the recommendation by the Science Council of Japan(SCJ).

- The advisory panel has investigated the ILC from various perspectives, including: scientific merit, validation of the Technical Design Report (TDR), and human resources. The panel now plans to move on to the next topic: organization and management.

- The DOE/MEXT Discussion Group was established in May 2016. Collaborative R&D programs for ILC cost reductions between KEK and FNAL will be launched in April 2017.

Recent Discussion by the Advisory

- Prof. Sachio Komamiya, former chair of the Linear Collider Board, explained the results of LCWS2016; and MEXT's advisory panelists commented as follows:

  - ✓ Direction to reduce cost seem appropriate. However, the reason why it will start at 250 GeV should be explained. It is necessary to evaluate accurately through precise measurements both the scientific merits and the staging plan of the ILC.

  - ✓ Even if the construction costs can be brought down by a certain extent, the cost remains still a large amount. Since scientific achievements derived from the ILC will be difficult for Japanese taxpayers to understand, effective explanation to convince them to accept the project will be required.

Recent Discussion by the Advisory

[FY 2017(March 2017 –)]

- Based on the recommendation of the Science Council of Japan, MEXT will set up a new working group under the advisory panel in order to discuss organization and management issues related to the ILC, especially for the international laboratory.

- The items to be discussed on this new working group include:

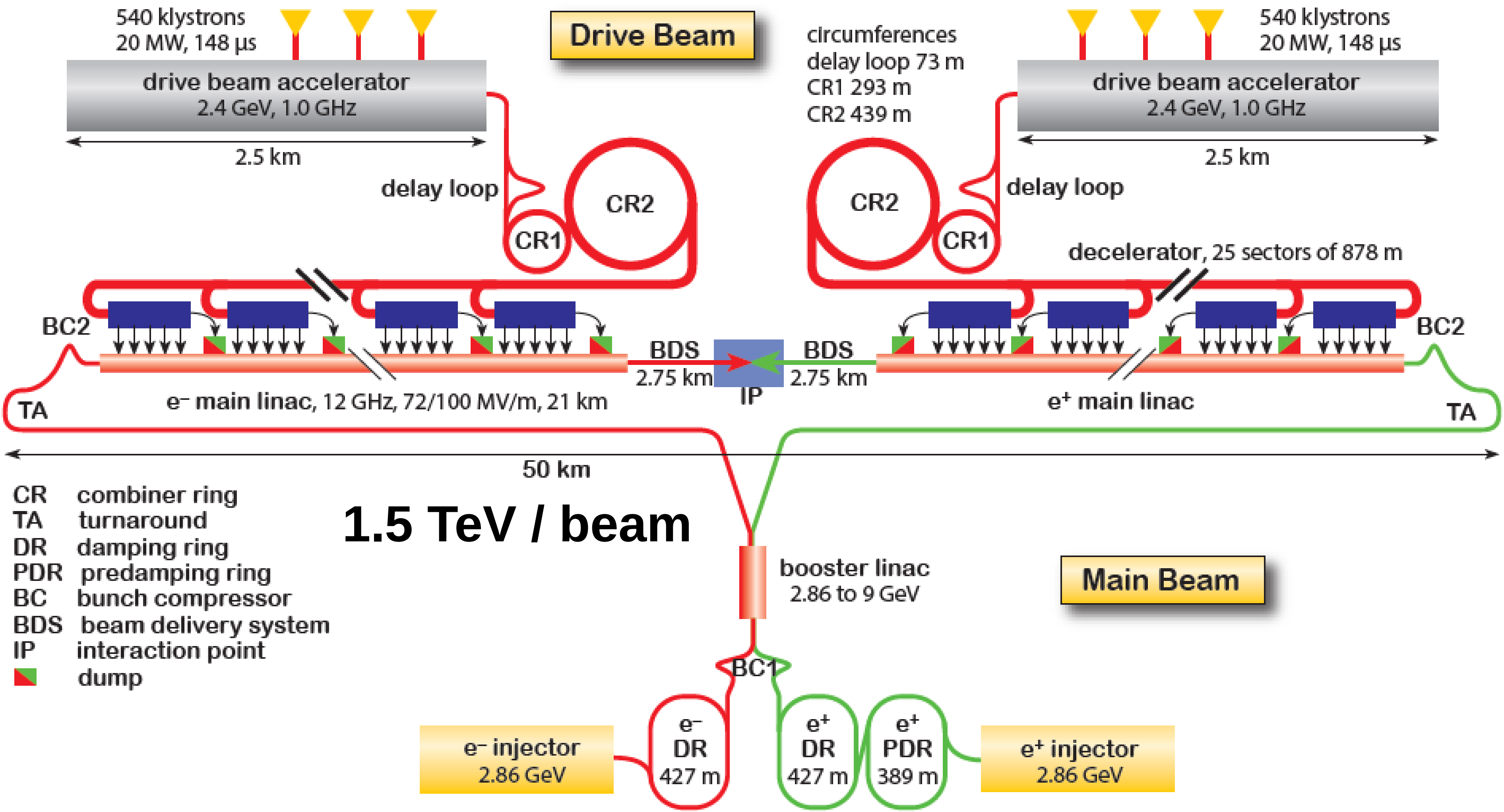
  - ✓ Organization and management
  - ✓ Surrounding environment
  - ✓ Cooperation scheme with domestic institutions

Recent Discussion by the Advisory

- In order to discuss these issues, MEXT has already commissioned a survey on large, international R&D projects such as LHC/CERN, ITER(International Thermonuclear Experimental Reactor), ISS(International Space Station), and ALMA(Atacama Large Millimeter/submillimeter Array). These precedents should provide important suggestions for the ILC.

- The results of this working group’s discussion can also be used in the DOE/MEXT discussion group because *management scheme* is one of the important items to be discussed there.

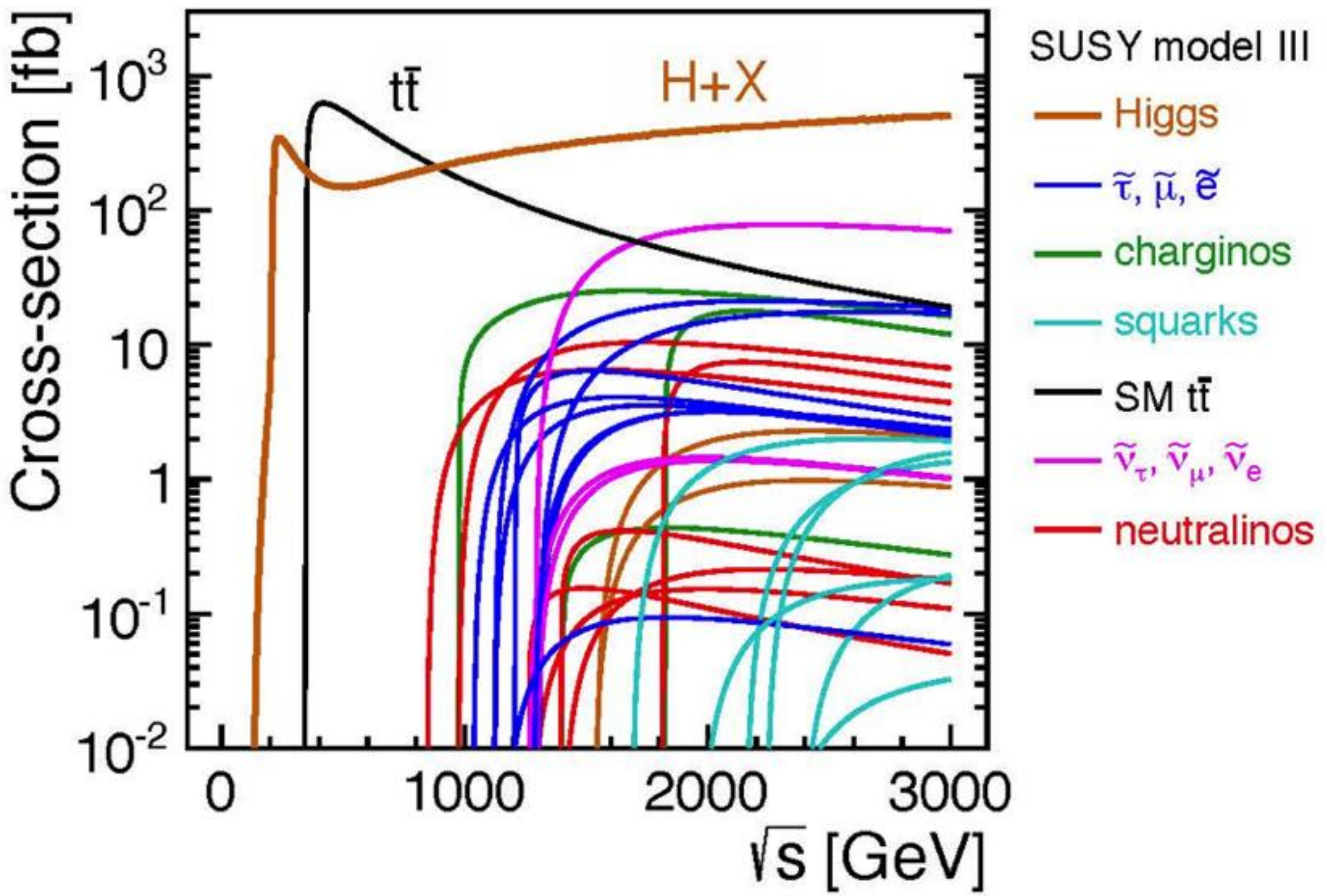
CLIC layout (3 TeV)



CLIC physics context

Energy-frontier capability for electron-positron collisions →

Precision exploration of potential new physics that may emerge from LHC



‘Rebaselining’

Optimize machine design w.r.t. cost and power for a staged approach to reach multi-TeV scales:

- ~ 380 GeV (optimised for Higgs + top physics)
- ~ 1500 GeV
- ~ 3000 GeV

Adapting appropriately to LHC + other physics findings

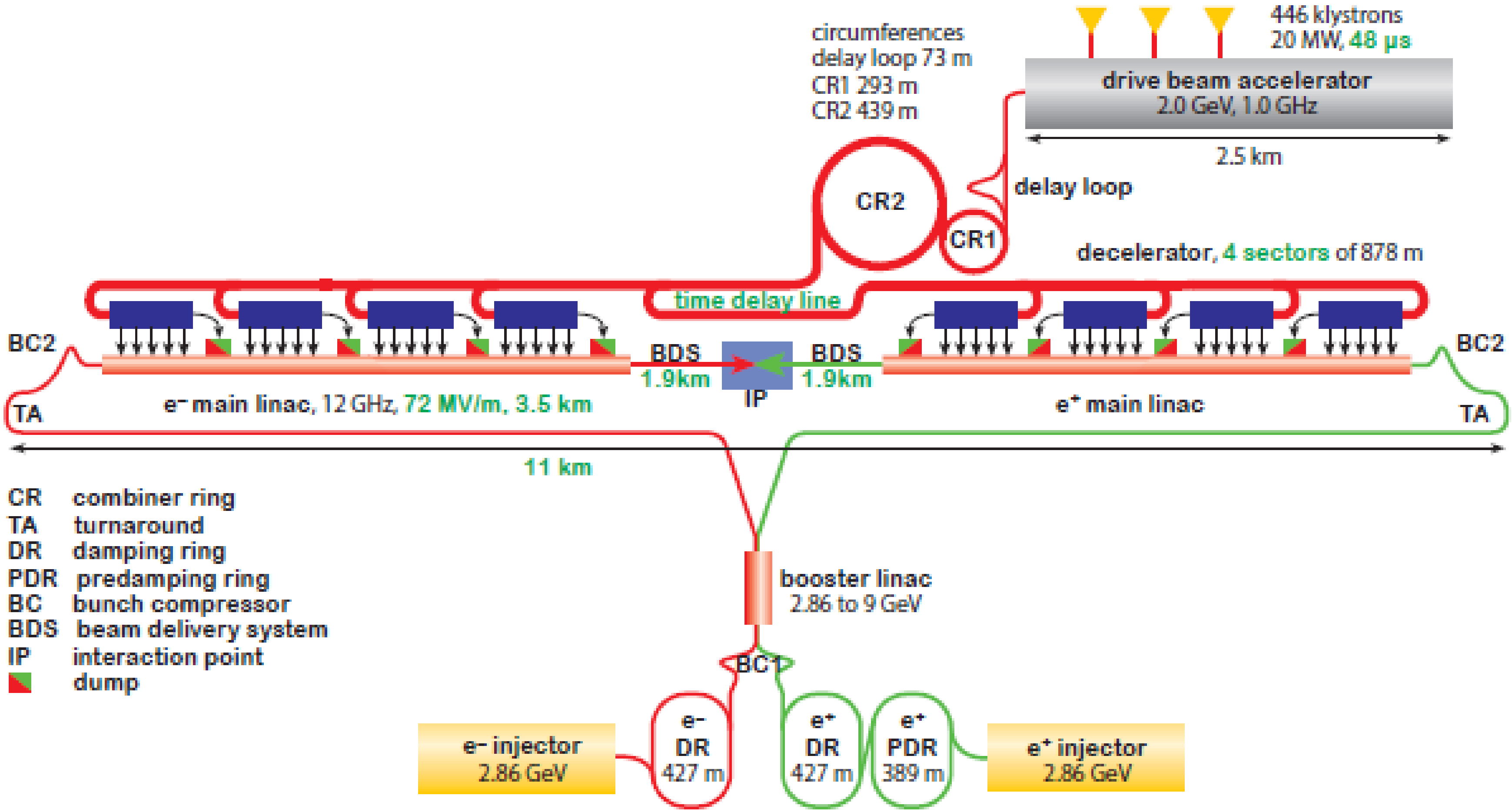
Possibility for first physics no later than 2035

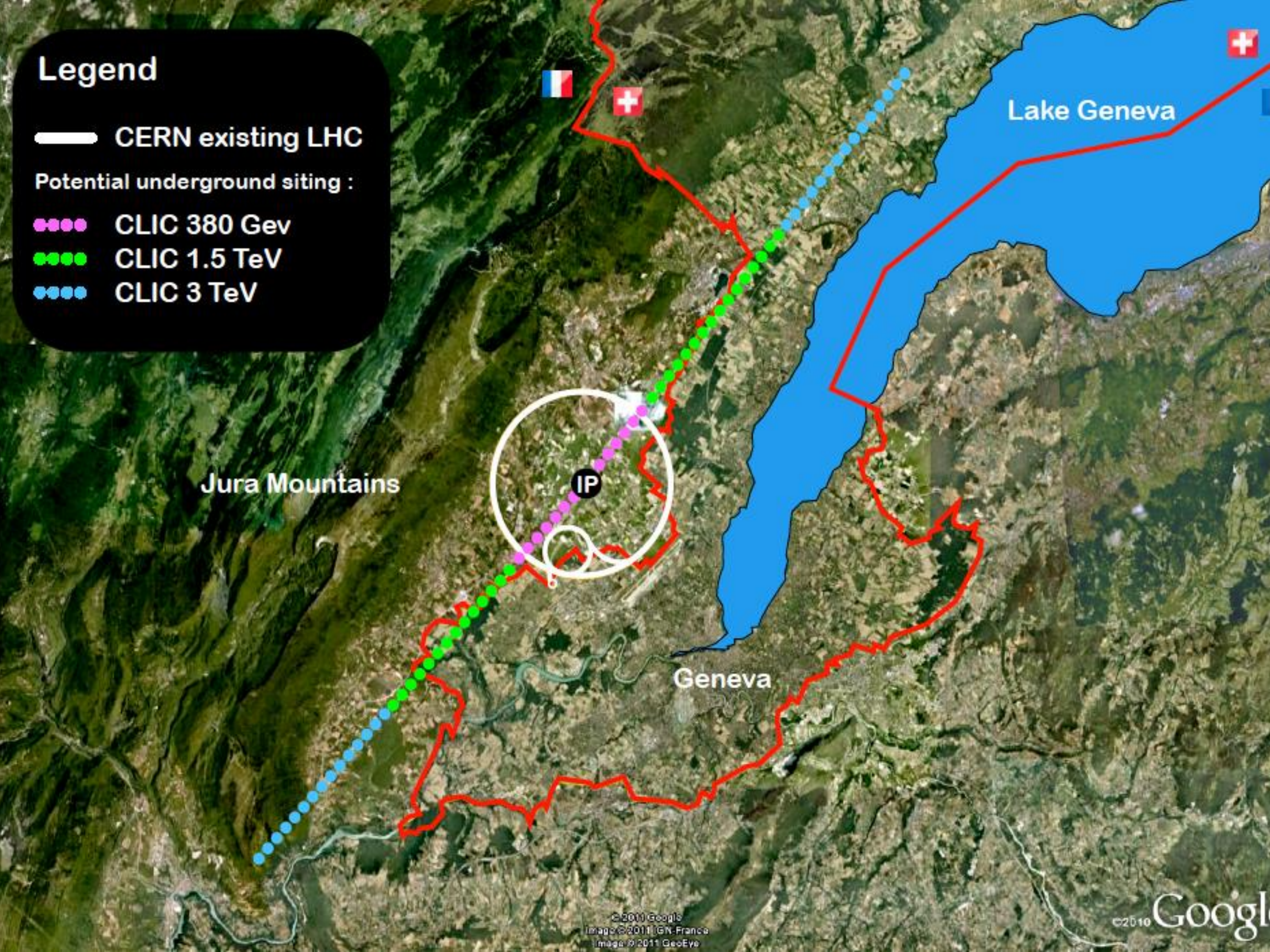
Project Plan to include accelerator, detector, physics

Rebaselining: first stage energy ~ 380 GeV

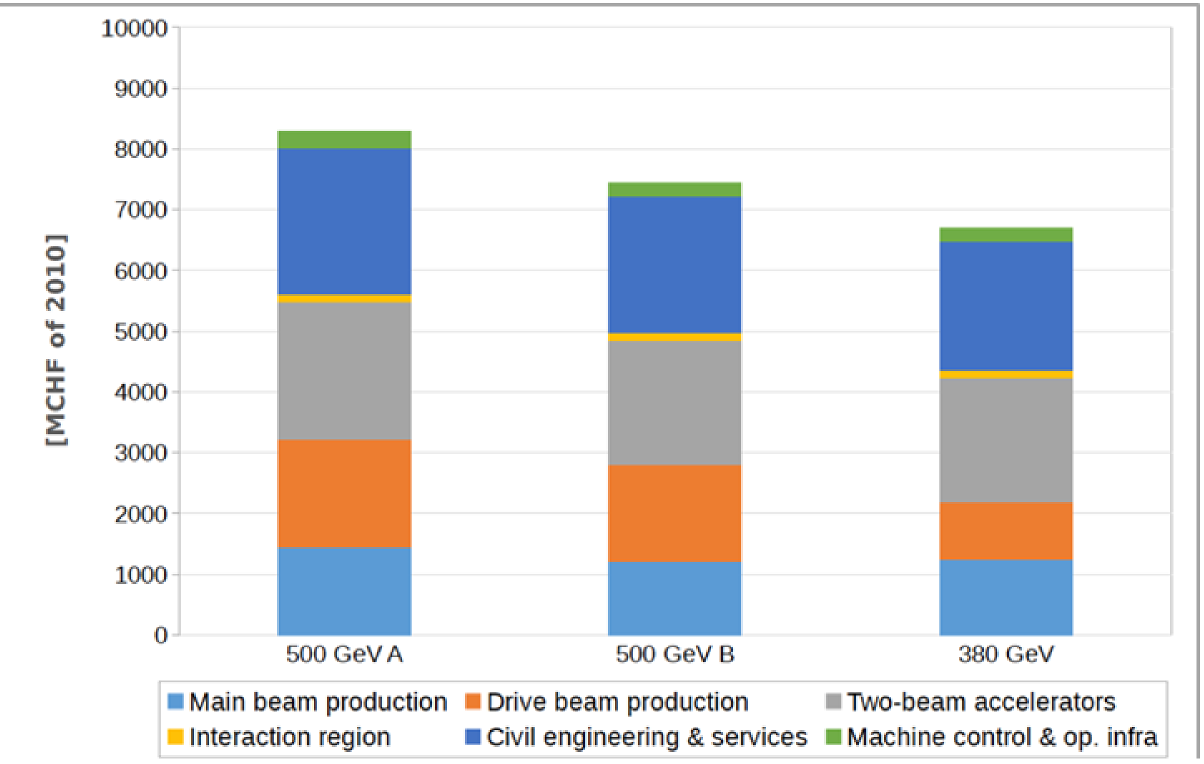
Parameter	Unit	380 GeV	3 TeV
Centre-of-mass energy	TeV	0.38	3
Total luminosity	$10^{34}cm^{-2}s^{-1}$	1.5	5.9
Luminosity above 99% of $\sqrt{s}$	$10^{34}cm^{-2}s^{-1}$	0.9	2.0
Repetition frequency	Hz	50	50
Number of bunches per train		352	312
Bunch separation	ns	0.5	0.5
Acceleration gradient	MV/m	72	100
Site length	km	11	50

New CLIC layout 380 GeV




Legend
CERN existing LHC
Potential underground siting :
CLIC 380 Gev
CLIC 1.5 TeV
CLIC 3 TeV
Lake Geneva
Jura Mountains
IP
Geneva

Preliminary cost estimate (380GeV)



For CDR 2012 WBS cost basis

Optimised structures, beam parameters and RF system

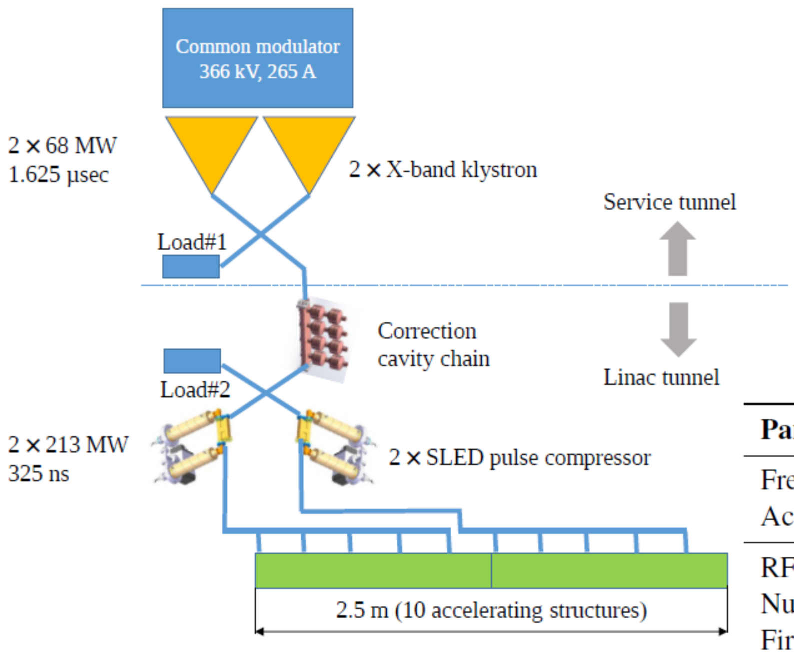
Some costs scaled from 500 GeV

Further optimisation ongoing

Table 11: Value estimate of CLIC at 380 GeV centre-of-mass energy.

	Value [MCHF of December 2010]
Main beam production	1245
Drive beam production	974
Two-beam accelerators	2038
Interaction region	132
Civil engineering & services	2112
Accelerator control & operational infrastructure	216
Total	6690

Klystron version (380 GeV)



First look at costs – preliminary

High-efficiency klystron work very promising – not yet included

Table 12: The parameters for the structure designs that are detailed in the text.

Parameter	Symbol	Unit	DB	K	DB244	K244
Frequency	f	GHz	12	12	12	12
Acceleration gradient	G	MV/m	72.5	75	72	79
RF phase advance per cell	$\Delta\phi$	°	120	120	120	120
Number of cells	N_c		36	28	33	26
First iris radius / RF wavelength	a_1/λ		0.1525	0.145	0.1625	0.15
Last iris radius / RF wavelength	a_2/λ		0.0875	0.09	0.104	0.1044
First iris thickness / cell length	d_1/L_c		0.297	0.25	0.303	0.28
Last iris thickness / cell length	d_2/L_c		0.11	0.134	0.172	0.17
Number of particles per bunch	N	10^9	3.98	3.87	5.2	4.88
Number of bunches per train	n_b		454	485	352	366
Pulse length	τ_{RF}	ns	321	325	244	244
Peak input power into the structure	P_{in}	MW	50.9	42.5	59.5	54.3
Cost difference (w. drive beam)	$\Delta C_{w.\,DB}$	MCHF	-50	(20)	0	(20)
Cost difference (w. klystrons)	$\Delta C_{w.\,K}$	MCHF	(120)	50	(330)	240

Rebaselining document

The Compact Linear Collider (CLIC) is a multi-TeV high-luminosity linear e^+e^- collider under development. For an optimal exploitation of its physics potential, CLIC is foreseen to be built and operated in a staged approach with three centre-of-mass energy stages ranging from a few hundred GeV up to 3 TeV. The first stage will focus on precision Standard Model physics, in particular Higgs and top measurements. Subsequent stages will focus on measurements of rare Higgs processes, as wells as searches for new physics processes and precision measurements of new states, e.g. states previously discovered at LHC or at CLIC itself. In the 2012 CLIC Conceptual Design Report, a fully optimised 3 TeV collider was presented, while the proposed lower energy stages were not studied to the same level of detail. This report presents an updated baseline staging scenario for CLIC. The scenario is the result of a comprehensive study addressing the performance, cost and power of the CLIC accelerator complex as a function of centre-of-mass energy and it targets optimal physics output based on the current physics landscape. The optimised staging scenario foresees three main centre-of-mass energy stages at 380 GeV, 1.5 TeV and 3 TeV for a full CLIC programme spanning 22 years. For the first stage, an alternative to the CLIC drive beam scheme is presented in which the main linac power is produced using X-band klystrons.

CERN-2016-004

arXiv:1608.07537

New reference plots for physics, luminosity, power, costs …

CERN scientific strategy: 3 main pillars

Full exploitation of the LHC:

- ❑ successful operation of the nominal LHC (Run 2, LS2, Run 3)
- ❑ construction and installation of LHC upgrades: LIU (LHC Injectors Upgrade) and HL-LHC

Scientific diversity programme serving a broad community:

- ❑ current experiments and facilities at Booster, PS, SPS and their upgrades (Antiproton Decelerator/ELENA, ISOLDE/HIE-ISOLDE, etc.)
- ❑ participation in accelerator-based neutrino projects outside Europe (presently mainly LBNF in the US) through CERN Neutrino Platform

Preparation of CERN's future:

- ❑ vibrant accelerator R&D programme exploiting CERN's strengths and uniqueness (including superconducting high-field magnets, AWAKE, etc.)
- ❑ design studies for future accelerators: CLIC, FCC (includes HE-LHC)
- ❑ future opportunities of scientific diversity programme ("Physics Beyond Colliders" Study Group)

Important milestone: update of the European Strategy for Particle Physics (ESPP), to be concluded in May 2020

F. Gianotti 11/1/17

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CLIC is vigorously preparing input for European Strategy PP Update:

- **Project Plan for CLIC as a credible post-LHC option for CERN**
- **Initial costs compatible with current CERN budget**
- **Upgradeable in stages over 20-30 years**

CLIC-UK programme

JAI:	**beam FB+FF, BPMs, beam dynamics**
	transverse beam size, Lumi optim …
ASTeC:	**permanent magnets, EO monitor**
CI/Lancaster:	**crab cavities, klystron efficiency**
CI/Manchester:	***main beam RF, crab cavities***
Dundee:	***longitudinal beam profile monitor***

2011-19, now in Phase 3: £13M programme CERN/UK

+ students

The Future?

Backup material

Particle Physics in China

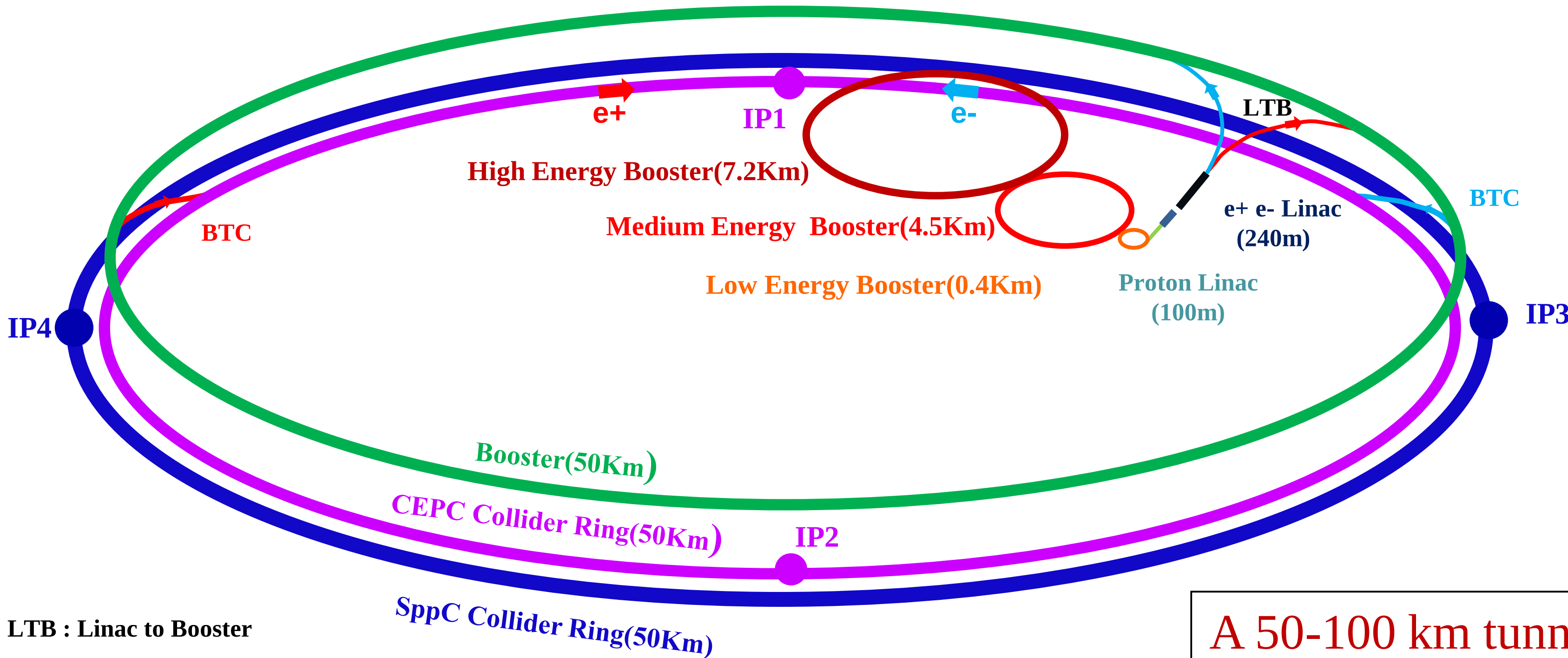
- Overview and Planning

Hesheng Chen

Institute of High Energy Physics

The Future: CEPC+SppC

Thanks to the discovery of the low mass Higgs boson, a circular Higgs factory is feasible



LTB : Linac to Booster

BTC : Booster to Collider Ring

A 50-100 km tunnel is relatively easier NOW in China

Science Goals

CEPC (e+e-: 90-250 GeV)

- **Higgs Factory: Precision study of Higgs(m_H, J^{PC}, couplings)**
  - Same as SM prediction ? Other Higgs ? Composite ? New properties ? CP effect ?
- **Z & W factory: precision test of SM**
  - New phenomena ? Rare decays ?
- **Flavor factory: b, c, τ and QCD studies**

SppC (pp: 50-100 TeV)

- **Directly search for new physics beyond SM**
- **Precision test of SM**
  - e.g., h^3 & h^4 couplings

Precision measurement & searches: Complementary with each other

Timeline (dream)

CPEC

- Pre-study, R&D and preparation work
  - Pre-study: 2013-15
    - **Pre-CDR for R&D funding request**
  - R&D: 2016-2020
  - Engineering Design: 2015-2020
- Construction: 2022-2028
- Data taking: 2029-2035

SppC

- Pre-study, R&D and preparation work
  - Pre-study: 2013-2020
  - R&D: 2020-2030
  - Engineering Design: 2030-2035
- Construction: 2035-2042
- Data taking: 2042 -

IHEP-CEPC-DR-2015-01

IHEP-EP-2015-01

IHEP-TH-2015-01

IHEP-CEPC-DR-2015-01

IHEP-AC-2015-01

Can be downloaded from

http://cepc.ihep.ac.cn/preCDR/volume.html

CEPC-SPPC

Preliminary Conceptual Design Report

Volume I - Physics & Detector

403 pages, 480 authors

The CEPC-SPPC Study Group

March 2015

CEPC-SPPC

Preliminary Conceptual Design Report

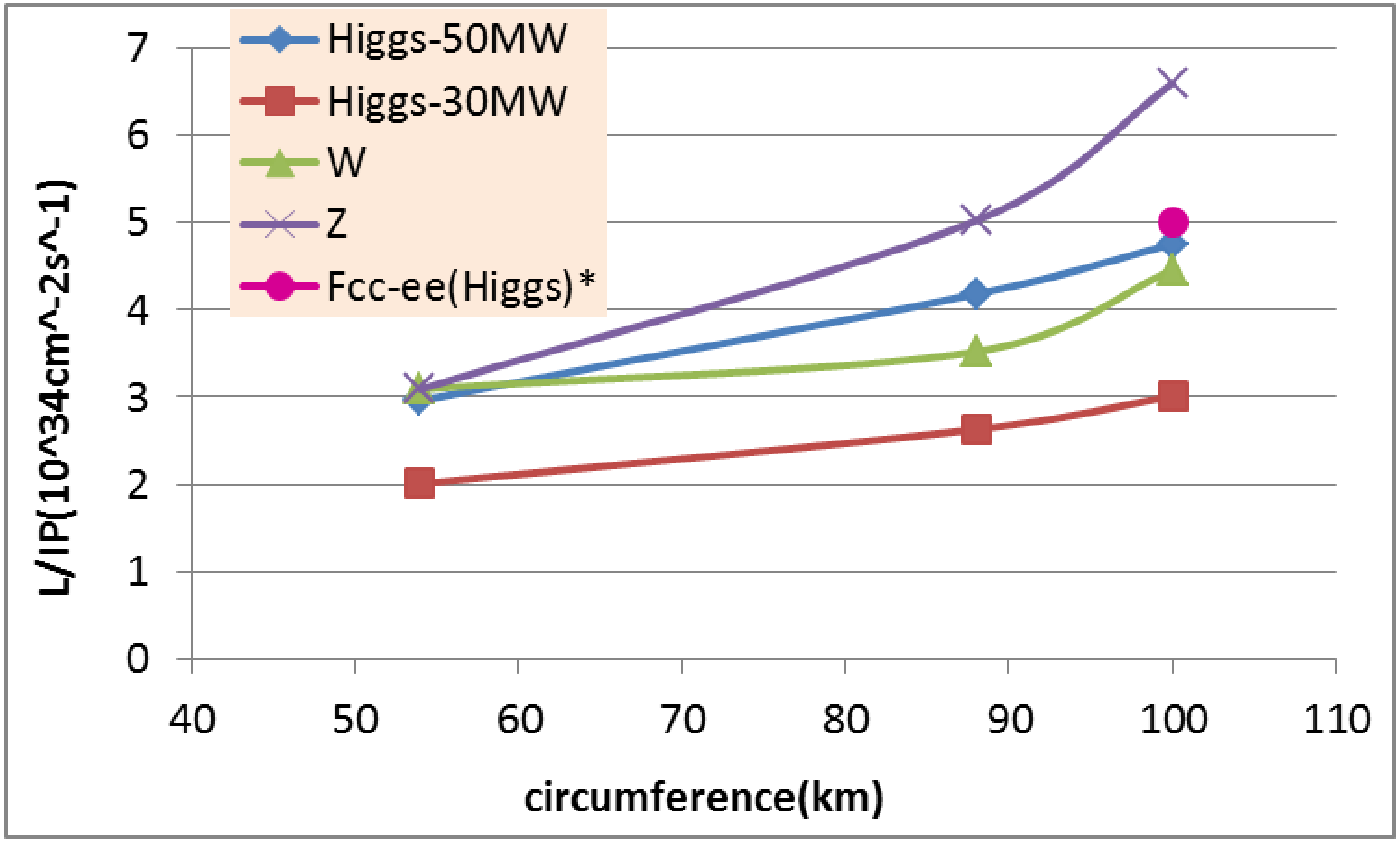
Volume II - Accelerator

328 pages, 300 authors

The CEPC-SPPC Study Group

March 2015

Partial Double Ring Luminosity



*Fabiola Gianotti, Future Circular ColliderDesign Study, ICFA meeting, J-PARC, 25-2-2016.

Current Status and the Plan

Pre-CDR completed

- No show-stoppers
- Technical challenges identified ➔ R&D issues
- Preliminary cost estimate

Working towards CDR

- A working machine on paper
- Ready to be reviewed by government at any moment

R&D issues identified and funding request underway

- Seed money from IHEP: 12 M RMB/3 years (1.7 MUSD)
- MOST: 35 M/5 yr from 2016, ~40 M to be asked next year
- NCDR: ~0.8 B RMB/5 yr, failed in a voting process
- CAS & CNSF: under discussion