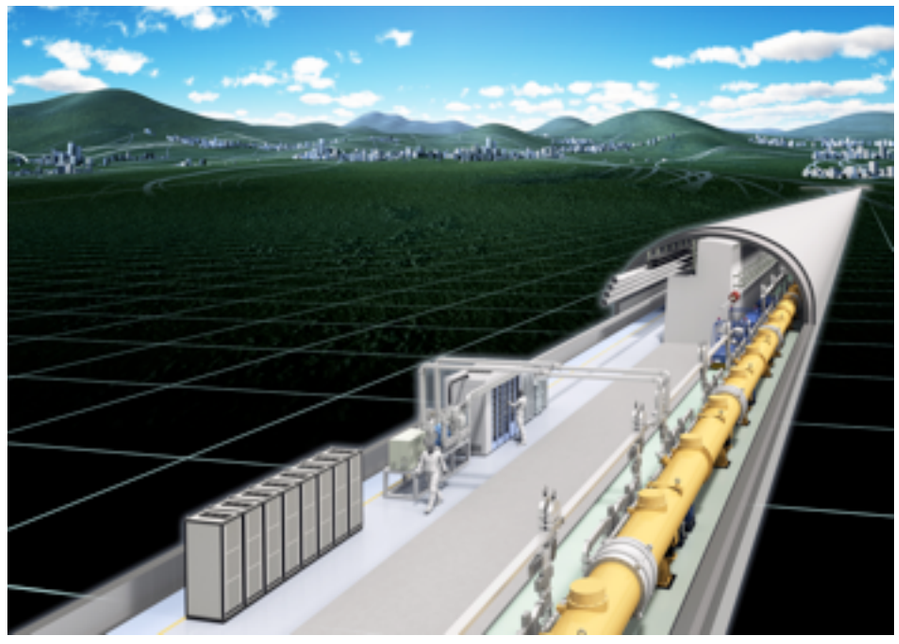
The linear road to a Higgs Factory and beyond

Eckhard Elsen



Contribution to the EPS HEP Conference 2013, Stockholm

HEP 2013
Stockholm
18-24 July 2013

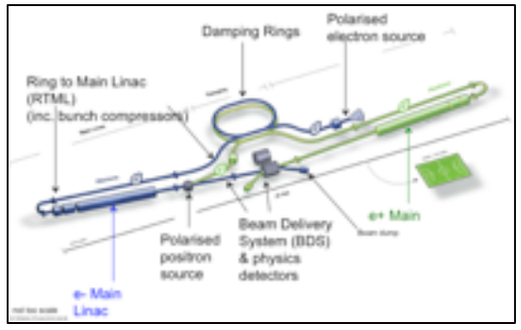
LC projects - strategies

- European Strategy priorities related to the Energy Frontier:
  - LHC and LHC luminosity upgrades (until ~2030)
  - Higgs and BSM physics in long term programme

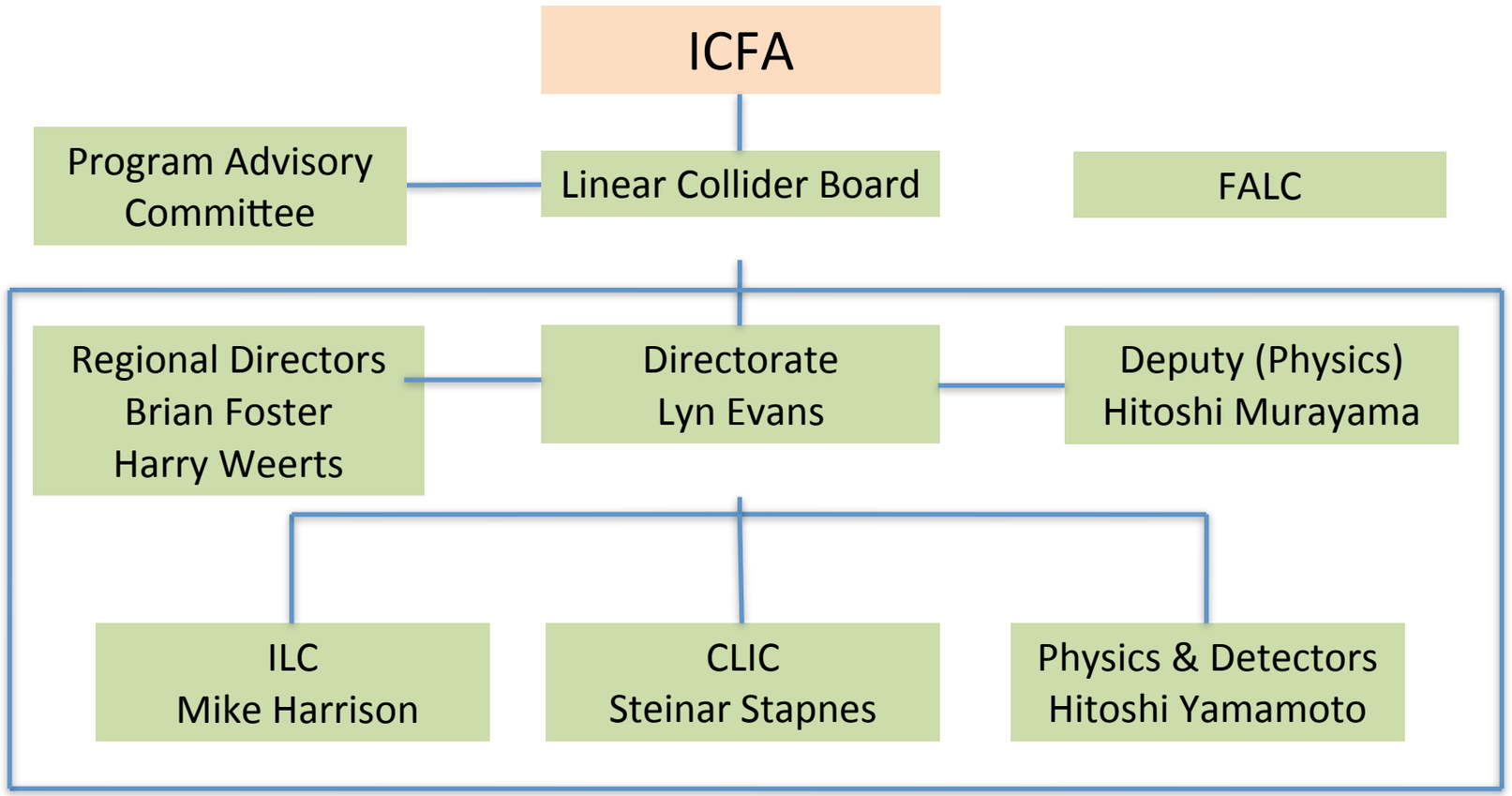
- What are the best machines to access such physics directly post-LHC…we don't know but we can prepare main options the next years towards next strategy update (~2018)
  - Two alternatives considered; higher energy hadrons (HE-LHC or VHE-LHC), or highest possible energy e^+e^- with CLIC

- ILC in Japan will explore the Higgs in detail, starting at 250 GeV
  - maps out the Higgs sector in particular

- In accordance with this, pursue three connected activities:
  - **ILC** project development – towards a **construction project** and dependent on developments in Japan
  - **CLIC** as option for the **energy frontier**
  - Common activities wherever possible



Organization of LCC



LCC Objectives

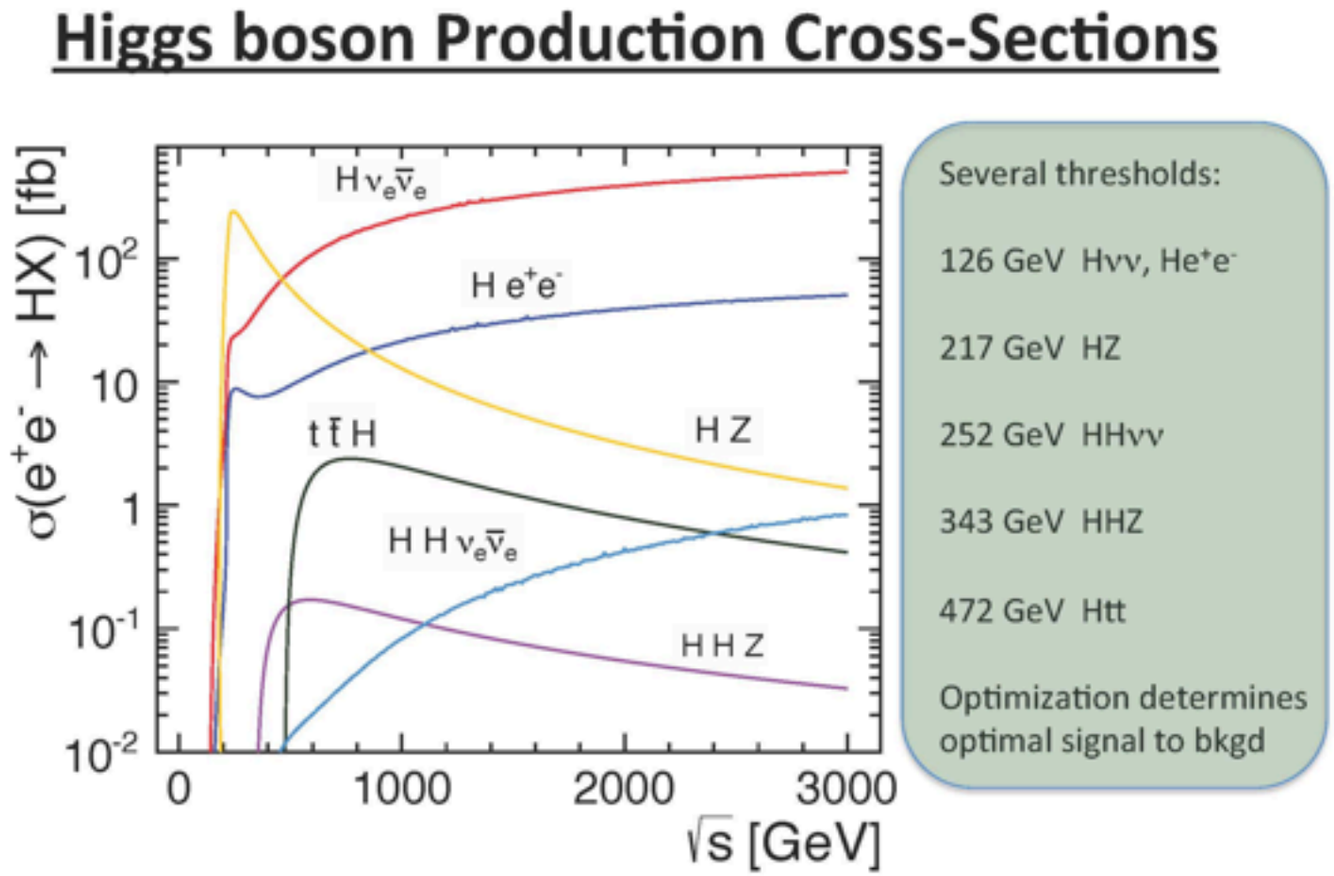
- Support the construction of a staged linear collider in Japan.

- Support long-term R&D on CLIC, the only credible way we have today to access multi-TeV leptons, as a possible future option after LHC.

- Exploit the synergy between ILC and CLIC. Prepare a plan for the sharing of the work.

Physics case for the Linear Collider

- Higgs physics (SM and non-SM)
  - various couplings and thresholds
- Top
- SUSY
- Higgs strong interactions
- New Z' sector
- Contact interactions
- Extra dimensions
- ....



Lebrun et al., arXiv:1209.2543

Model-independent Global Fit for Couplings

Canonical ILC program

250 GeV: 250 fb^{-1}
500 GeV: 500 fb^{-1}
1 TeV: 1000 fb^{-1}

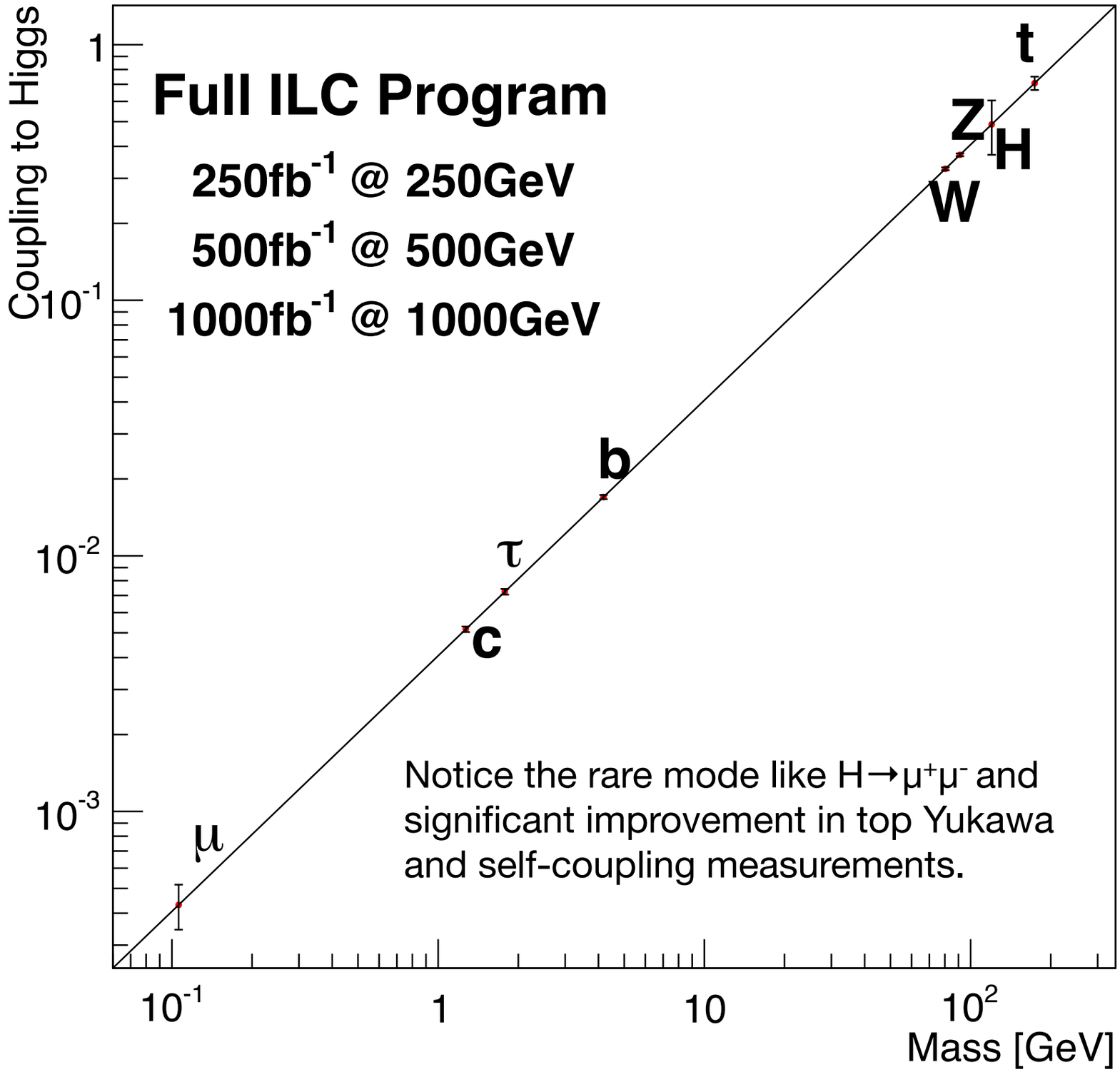
($M_H = 125$ GeV)

P(e-,e+)=(-0.8,+0.3) @ 250, 500 GeV P(e-,e+)=(-0.8,+0.2) @ 1 TeV

coupling	250 GeV	250 GeV + 500 GeV	250 GeV + 500 GeV + 1 TeV
HZZ	1.3%	1.3%	1.3%
HWW	4.8%	1.4%	1.4%
Hbb	5.3%	1.8%	1.5%
Hcc	6.5%	2.9%	2.0%
Hgg	7.0%	2.5%	1.8%
Hττ	5.7%	2.5%	2.0%
Hγγ	25%	12%	5.2%
Hμμ	-	-	16%
Γ_0	11%	5.9%	5.6%
Htt	-	16%	3.8%
HHH	-	104%	26%

Mass Coupling Relation

After Canonical ILC Program



Higgs studies at higher energies

Higgs self-coupling

ILD: HH→bbbb

Junping Tian

prospects

effect of positron polarisations P(e⁻) = -0.8

P(e⁺)	0	+0.3 (+0.2)	+0.6 (+0.4)
ZHH @ 500 GeV	50%	44%	40%
vvHH @ 1 TeV	20%	18%	16%

ILC Luminosity Upgrade — Tim Barklow's talk

3.2 ab⁻¹ ~ 6 years @ 500 GeV; 5 ab⁻¹ ~ 6 years @ 1 TeV

	TDR-Upgrade
ZHH @ 500 GeV	44%--> 35%
vvHH @ 1 TeV	18%--> 11%

ILD: HH →bbWW*

Masakazu Kurata

- Higgs self coupling analysis using the events with H→WW* is ongoing.
  - Multi variate analysis to reject the backgrounds
  - Unfortunately, c jet analysis doesn't give significant contribution
  - Total sensitivity is ~1.4σ

CLIC: HH→bbbb

Ways to increase the number of signal events

Polarization significantly increases the signal cross section e.g. from 0.63 fb (unpolarized) to 1.37 fb (-80%, +30%)

collision energy Polarization e^-/e^+	√s = 1.4 TeV unpolarized	√s = 1.4 TeV -80% / +30%	√s = 3.0 TeV unpolarized	√s = 3.0 TeV -80% / +30%
Δ σ(HHνν)	≈ 22%	≈ 18%	≈ 10%	≈ 7%
$\Delta \lambda_{HHH}$	≈ 26%	≈ 22%	≈ 16%	≈ 11%

Numbers with polarized beams obtained by scaling signal and background cross sections, ignoring polarization-dependent changes to kinematic properties.

all cross section values: mH = 120 GeV

Other Channels contributing
at 1.4 TeV: ZHH cross section ~50% of HHνν
at 3.0 TeV: ZHH cross section < 10% of HHνν

Z boson fusion diagrams (electrons in final state) < 15% of W boson fusion cross section

Note:
m_H = 126 GeV results in slightly smaller signal cross sections
σ(HHνν) = 0.15 fb at 1.4 TeV
σ(HHνν) = 0.59 fb at 3.0 TeV
both with unpolarized beams

Jan Strube

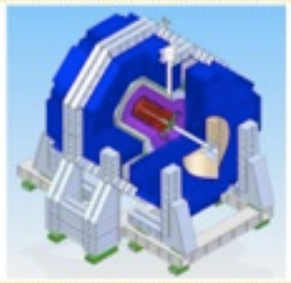
Detectors

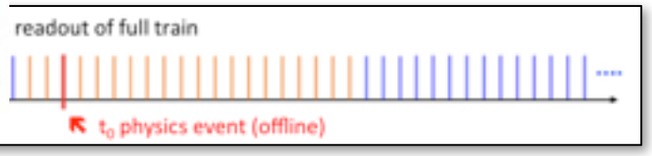
ILD: International Large Detector

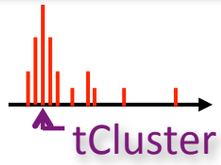
- "Large" : tracker radius 1.8m
- B-field : 3.5 T
- Tracker : TPC + Silicon
- Calorimetry : high granularity particle flow
- ECAL + HCAL inside large solenoid

SiD: Silicon Detector

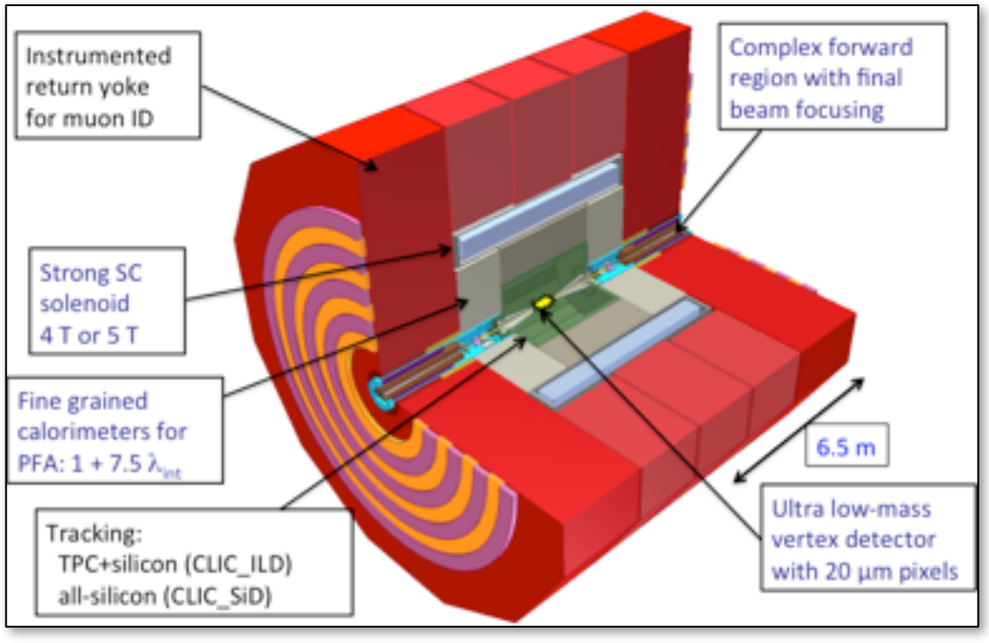
- "Small" : tracker radius 1.2m
- B-field : 5 T
- Tracker : Silicon
- Calorimetry : high granularity particle flow
- ECAL + HCAL inside large solenoid





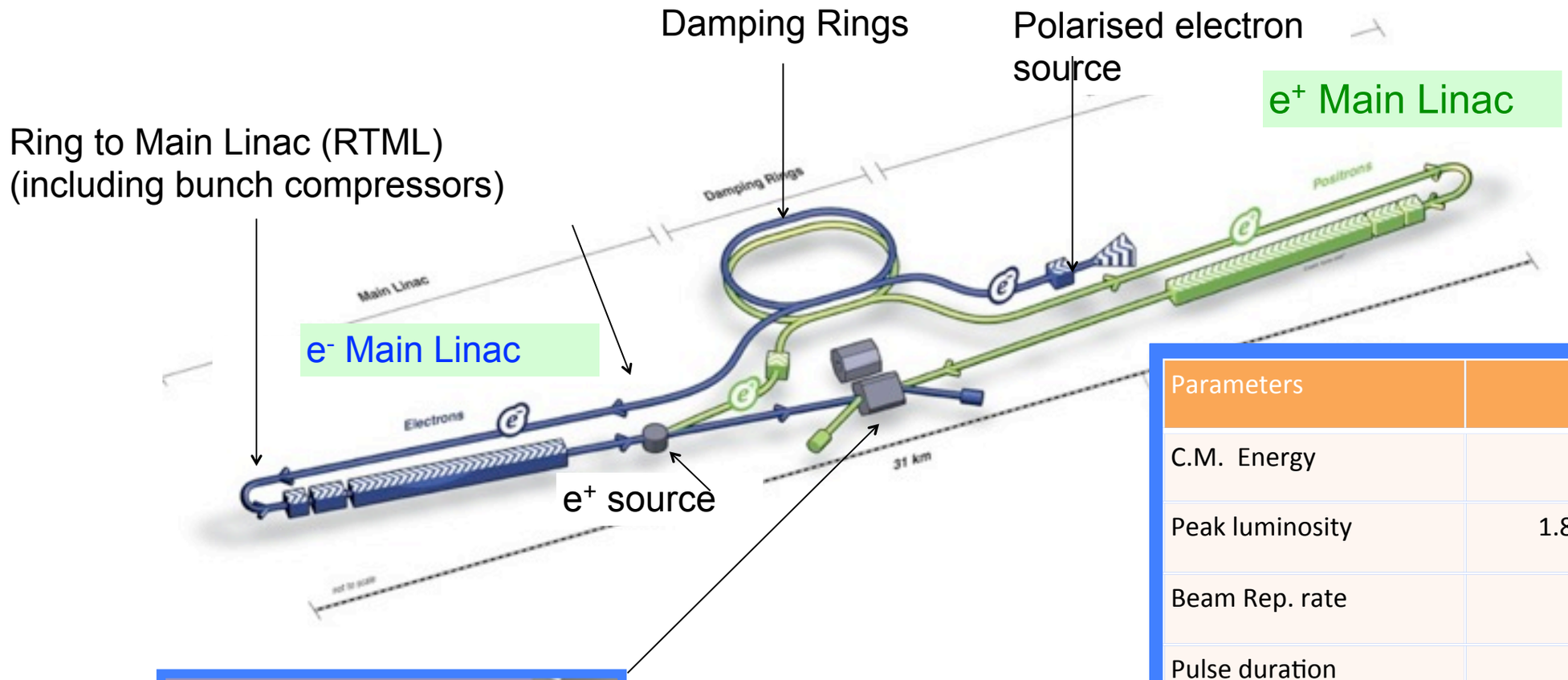


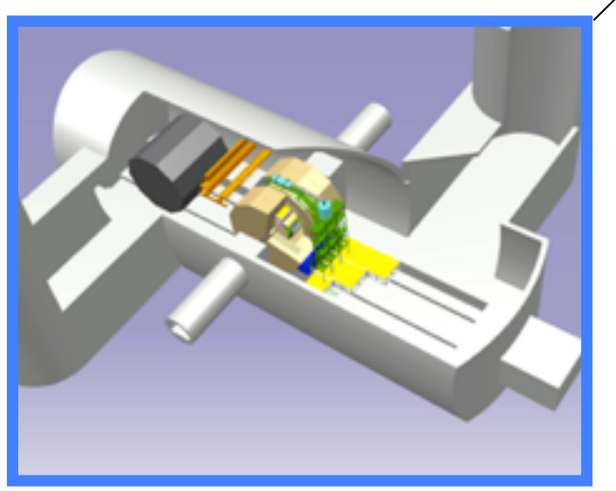
CLIC detectors based on ILC concepts:



- CLIC timing structure demanding:
- Detailed GEANT 4 simulation
  - Consider in particular pair background and γγ-processes
- Studied using full reconstruction with background
  - Make full use of timing and fine granularity to reconstruct the physics objects with very high precision
- Shown to be fully compatible with high precision e+e- physics

ILC Layout



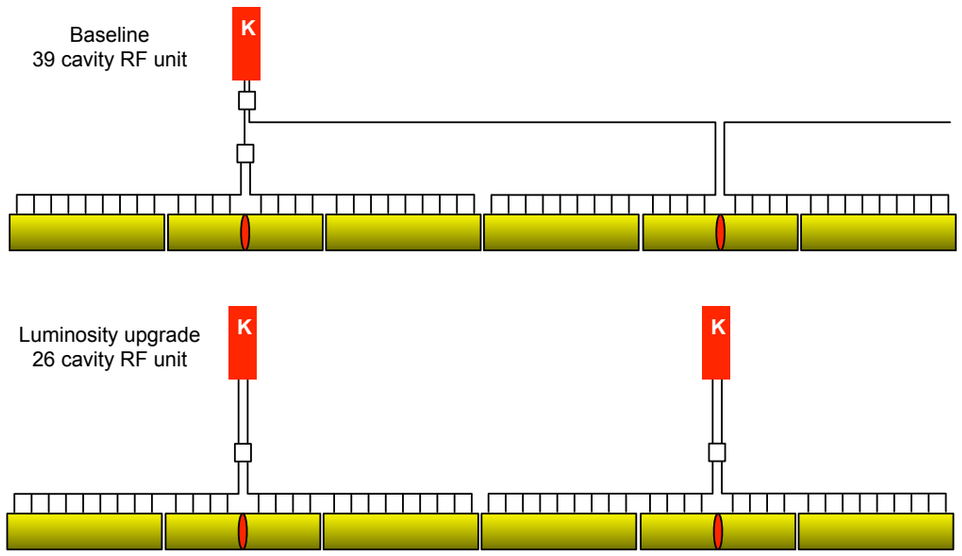


Parameters	Value
C.M. Energy	500 GeV
Peak luminosity	1.8×10^{34} cm^{-2}s^{-1}
Beam Rep. rate	5 Hz
Pulse duration	0.73 ms
Average current	5.8 mA (in pulse)
Field in SCRF acc. cavity	31.5 MV/m ± 20% $Q_0 = 10^{10}$

ILC nominal parameters

Centre-of-mass energy	E_{CM}	GeV	200	230	250	350	500
Luminosity pulse repetition rate		Hz	5	5	5	5	5
Positron production mode			10 Hz	10 Hz	10 Hz	nom.	nom.
Estimated AC power	P_{AC}	MW	114	119	122	121	163
Bunch population	N	$\times 10^{10}$	2	2	2	2	2
Number of bunches	n_b		1312	1312	1312	1312	1312
Linac bunch interval	Δt_b	ns	554	554	554	554	554
RMS bunch length	σ_z	µm	300	300	300	300	300
Normalized horizontal emittance at IP	$\gamma\epsilon_x$	µm	10	10	10	10	10
Normalized vertical emittance at IP	$\gamma\epsilon_y$	nm	35	35	35	35	35
Horizontal beta function at IP	β_x^*	mm	16	14	13	16	11
Vertical beta function at IP	β_y^*	mm	0.34	0.38	0.41	0.34	0.48
RMS horizontal beam size at IP	σ_x^*	nm	904	789	729	684	474
RMS vertical beam size at IP	σ_y^*	nm	7.8	7.7	7.7	5.9	5.9
Vertical disruption parameter	D_y		24.3	24.5	24.5	24.3	24.6
Fractional RMS energy loss to beamstrahlung	δ_{BS}	%	0.65	0.83	0.97	1.9	4.5
Luminosity	L	$\times 10^{34}$ cm^{-2} s^{-1}	0.56	0.67	0.75	1.0	1.8
Fraction of L in top 1% E_{CM}	$L_{0.01}$	%	91	89	87	77	58
Electron polarisation	P_-	%	80	80	80	80	80
Positron polarisation	P_+	%	30	30	30	30	30
Electron relative energy spread at IP	$\Delta p/p$	%	0.20	0.19	0.19	0.16	0.13
Positron relative energy spread at IP	$\Delta p/p$	%	0.19	0.17	0.15	0.10	0.07

ILC with planned luminosity upgrade



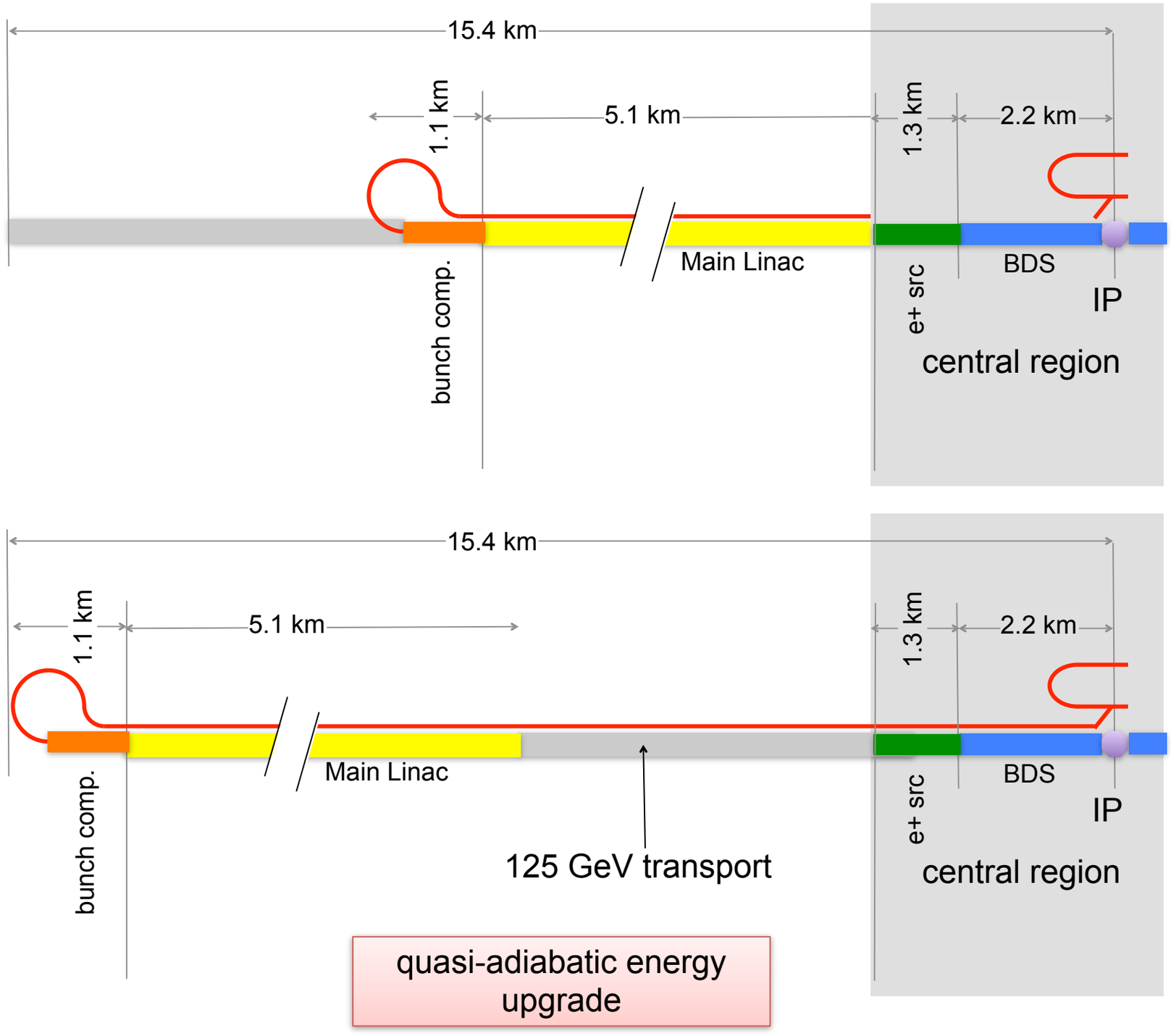
		Baseline	L upgrade
Gradient	MV/m	31.5	31.5
Bunch spacing	ns	554	366
Bunch charge	nC	3.2	3.2
Bunches per pulse		1312	2625
Beam current	mA	5.8	8.8
Beam pulse length	μs	727	961
Q_{ext} (matched)	$\times 10^6$	5.5	3.6
Fill time	μs	927	613
RF pulse length	ms	1.65	1.57
RF to beam power eff.		44 %	61 %

Double number of klystrons

$\varepsilon_{RF \to beam}$ increases; cold machines more efficient with long pulses

ILC 250 GeV staging options

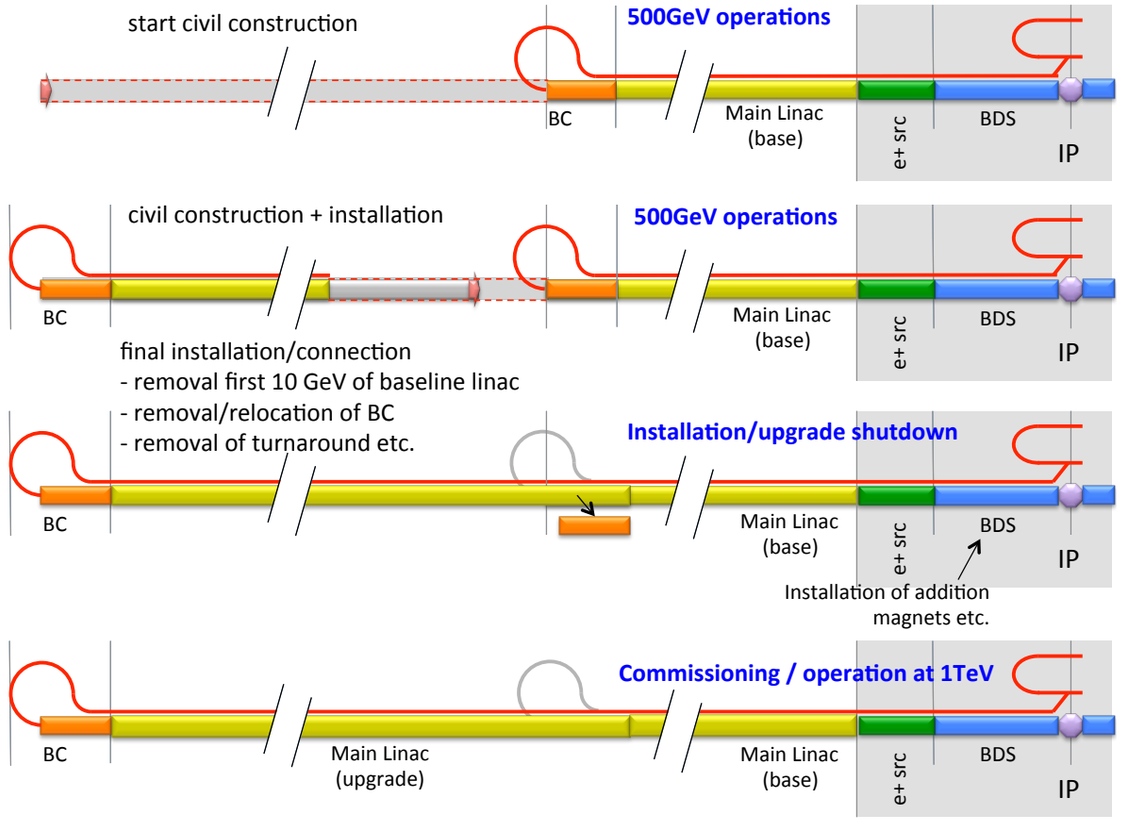
- Option 1
  - 1/2 RTML long transfer line
- Common
  - Full length tunnel
  - BDS
    - for 1 TeV
    - 1/2 magnets
  - 10 Hz mode e^- linac
- Option 2
  - 5 km transport @ 125 GeV
  - full RTML long transfer line



ILC TeV upgrade

- construction during operation
- shutdown for "connection" and installation of additional magnets in focussing section
- 3 variants depending on expectations for increase of gradient (31.5 MV/m or 45 MV/m). Linac length varies from 17.5 km to 25 km.

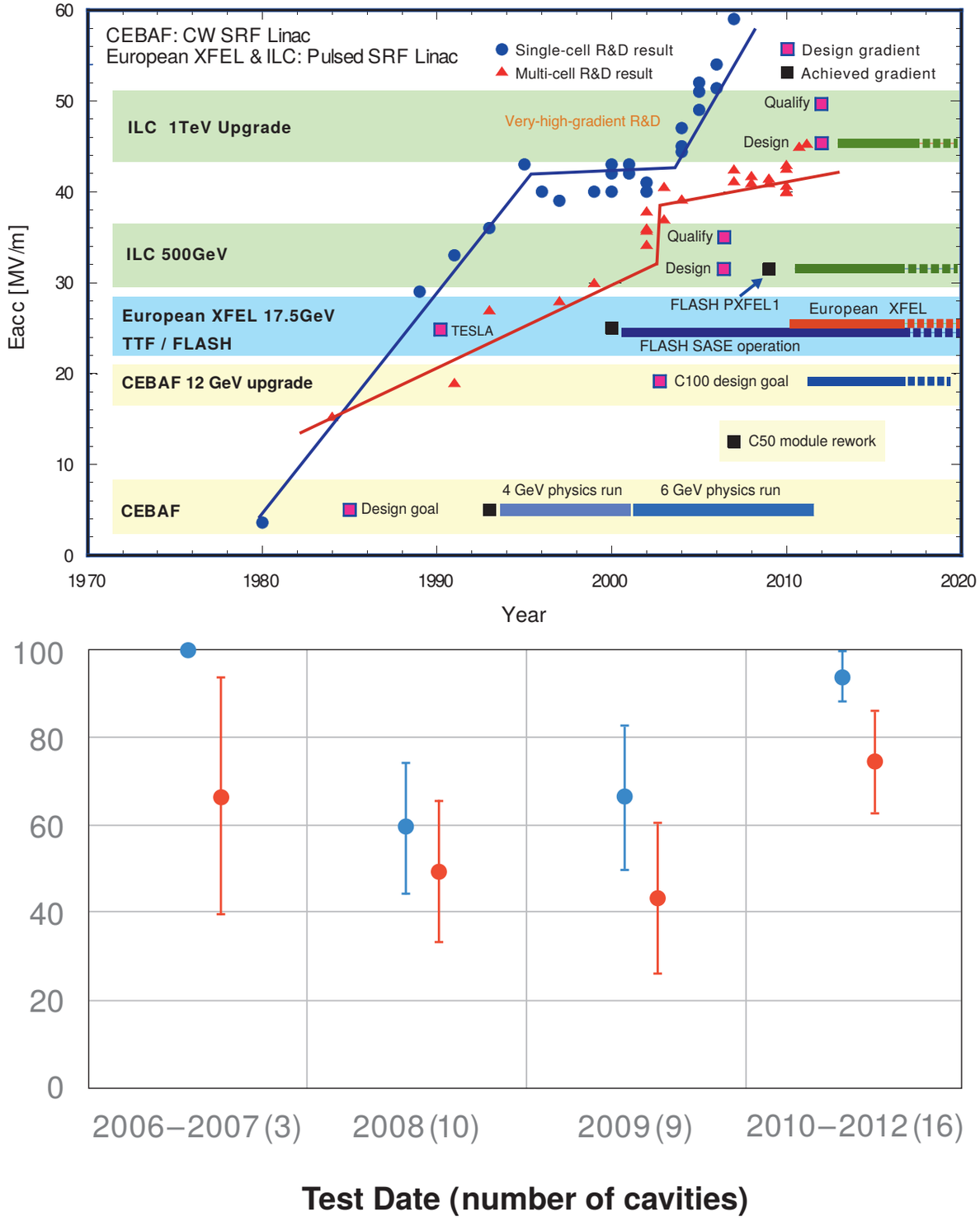
		500 GeV	TeV Upgrade			
		Baseline	Scenario A	Scenario B		Scenario C
				upgrade	base	
Energy range	GeV	15–250	15–500	15–275	275–500	15–500
Gradient	MV/m	31.5	31.5	45	31.5	45
Num. of cavities		7400	15 280	8190	7090	10 700
				total cavities: 15280		
Linac length	km	12	25	9.5	11.5	17.5
				total length: 21.0		

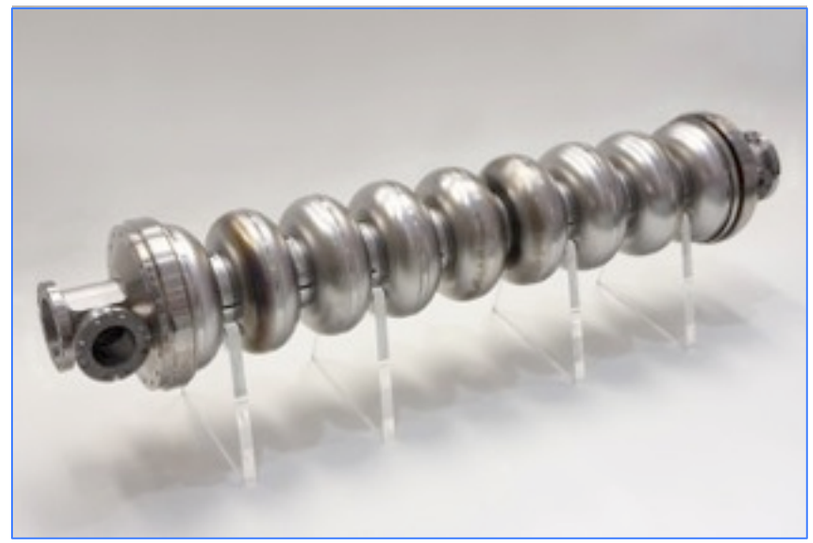


Milestones passed towards TDR

- SCRF technology and beam acceleration:
  - Cavity gradient specified: 31.5 MV/m
    - ILC SCRF cavity R&D
      - gradient progress: E_{acc} = <37 MV/m>,
        record: 46 MV/m at DESY in 9-cell TESLA style cavity
      - system engineering: S1-Global program with global participation
- electron cloud mitigation
  - Cesr-TA
- nano-beam handling
  - ILC requires a beam size ~ 6 nm (vertical):
    - Progress in KEK-ATF:
      - achieved ~70 nm (at 1.3 GeV), goal is 37 nm
        corresponding to 10 nm (at 250 GeV, ILC)

Progress in ILC SCRF Cavity Gradient



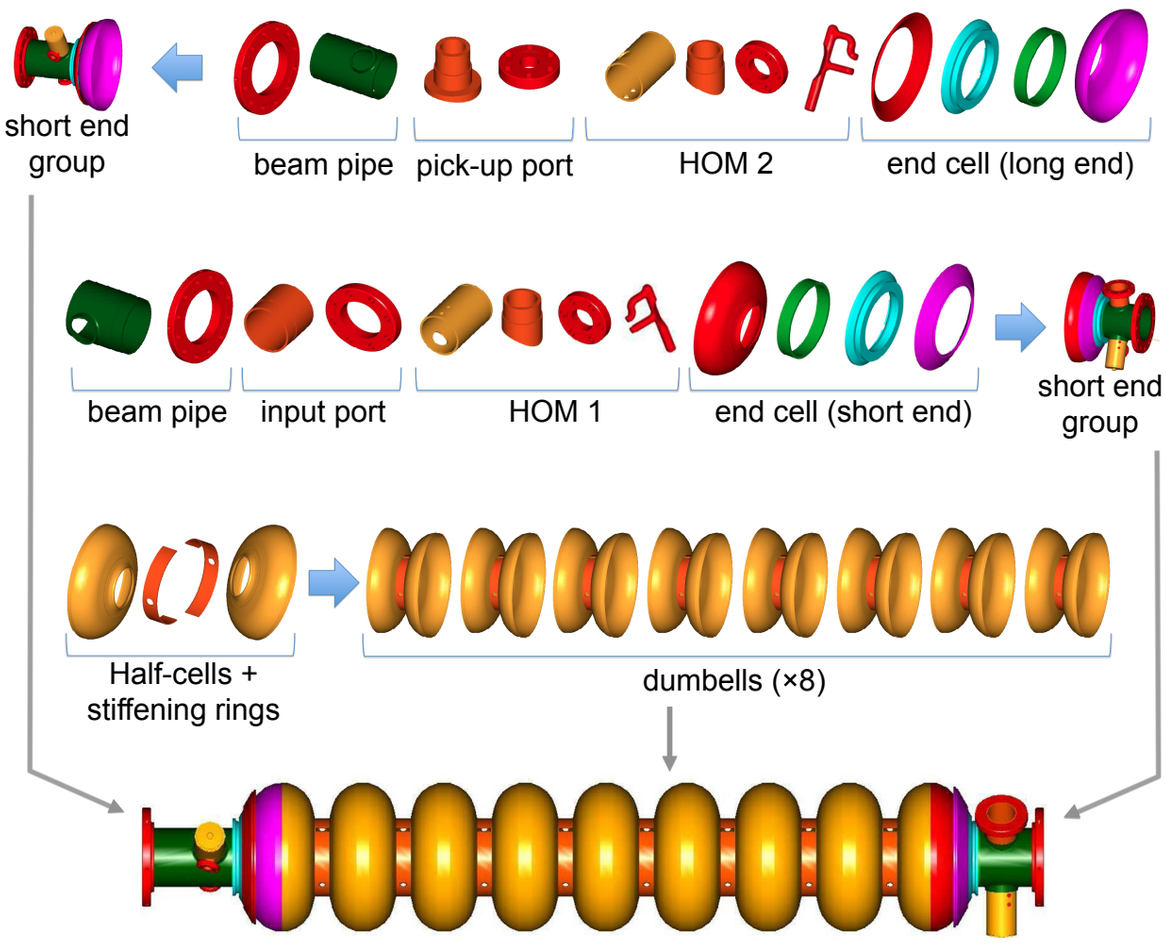


- **>28 MV/m yield**
- **>35 MV/m yield**

Yield: 94% @ 28 MV/m

$\langle E_{acc} \rangle$ = 37.1 MV/m

Progress in 1.3 GHz ILC cavity production



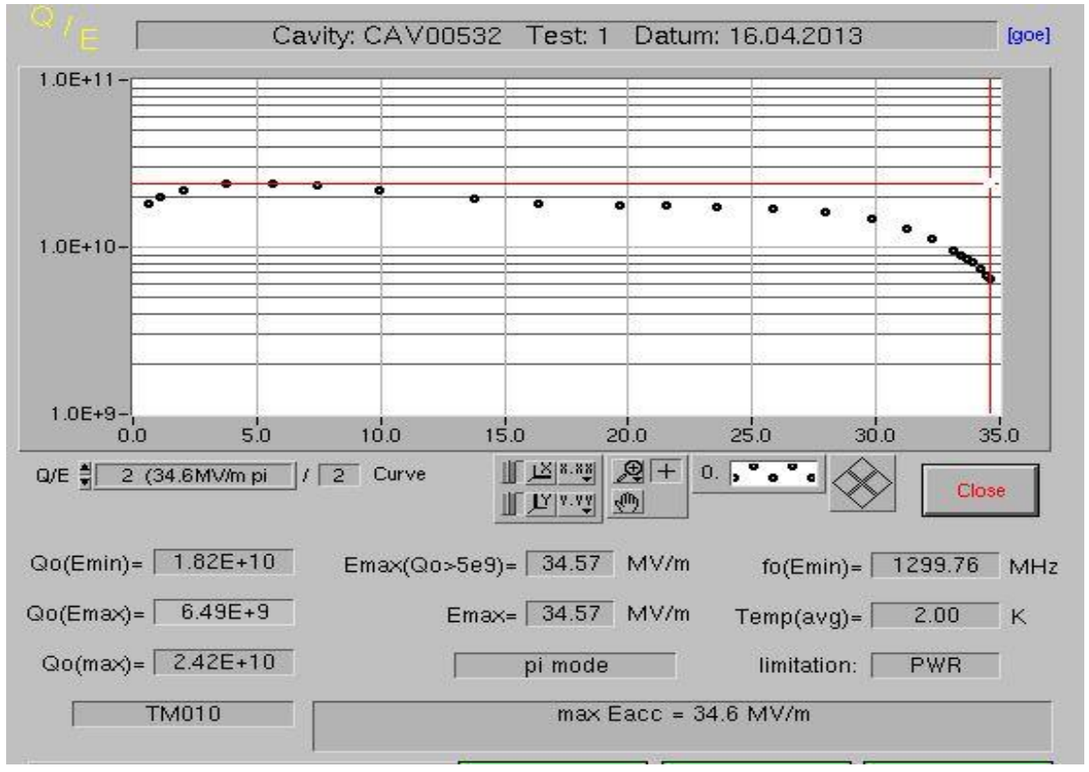
- Industrialisation of cavity has been successful globally
  - Number of qualified vendors has tripled
  - Key to global approach of construction

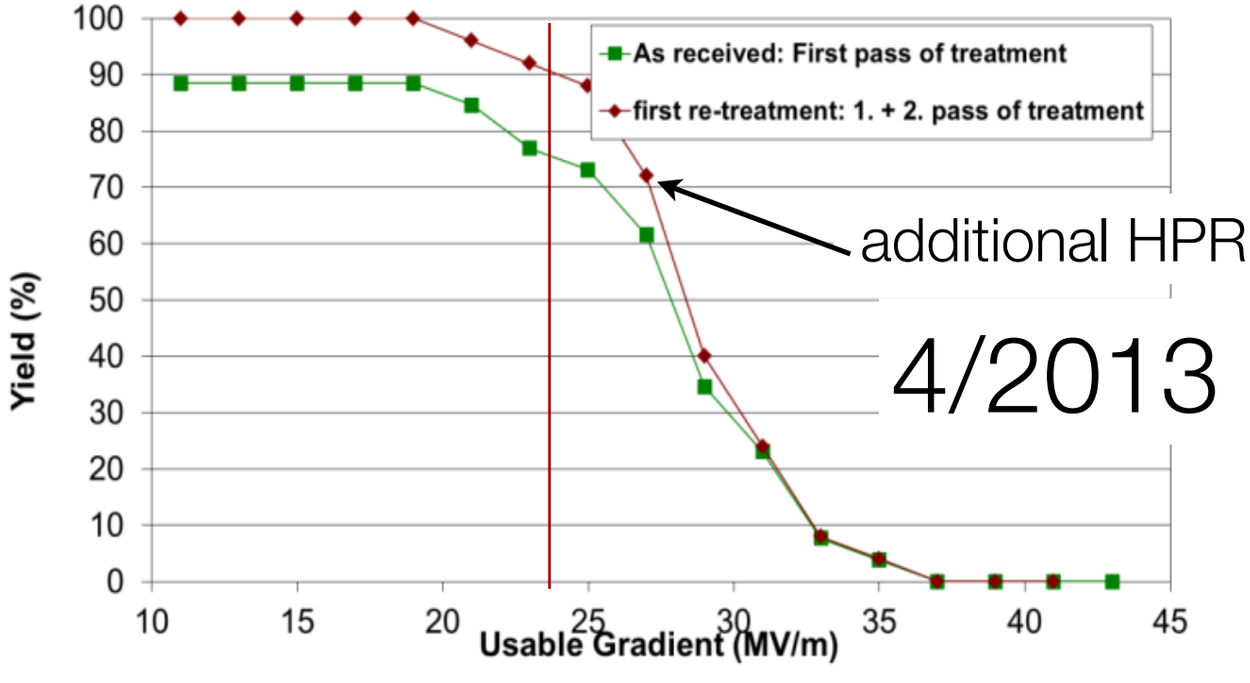
year	# 9-cell cavities qualified	Labs achieving 35 MV/m processing	Companies achieving 35 MV/m fabrication
2006	10	DESY	ACCEL, ZANON
2011	41	DESY, JLAB, FNAL, KEK	RI, ZANON, AES, MHI
2012	(45)	DESY, JLAB, FNAL, KEK, Cornell	RI, ZANON, AES, MHI, Hitachi

SCRF cavity production for European XFEL

Industrial cavity production

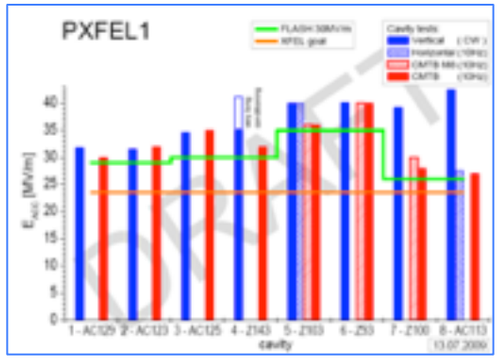
- Start-up of mass production looks promising
- 800 cavities in ~2 years
- now receiving nominal rate for 1 cryomodule/week; from both vendors

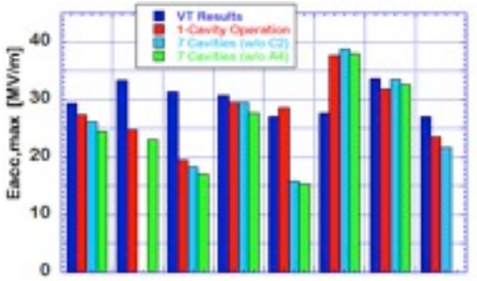


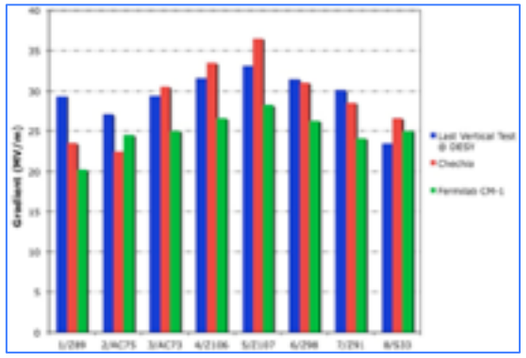


SCRF beam acceleration tests

- DESY: FLASH
  - SCRF-CM string + Beam,
    - ACC7/PXFEL1 $<E_{acc}>$ = 32 MV/m
  - 9 mA beam, 2009
  - 800μs, 4.5mA beam, 2012
- KEK: STF
  - S1-Global: complete, 2010
  - Cavity string : < 26 MV/m>
  - Quantum Beam : 6.7 mA, 1 ms,
  - CM1 & beam, 2014 ~2015
- FNAL: NML/ASTA
  - CM1 test complete
  - CM2 operation, in 2013
  - CM2 + Beam, 2013 ~ 2014







Technical Design Report completed

2007

2011

ILC Technical Progress Report (“*interim report*”)

AD&I

2013

~250 pages
Deliverable 2

~300 pages
Deliverables
1,3 and 4

Reference Design Report

Technical Design Report

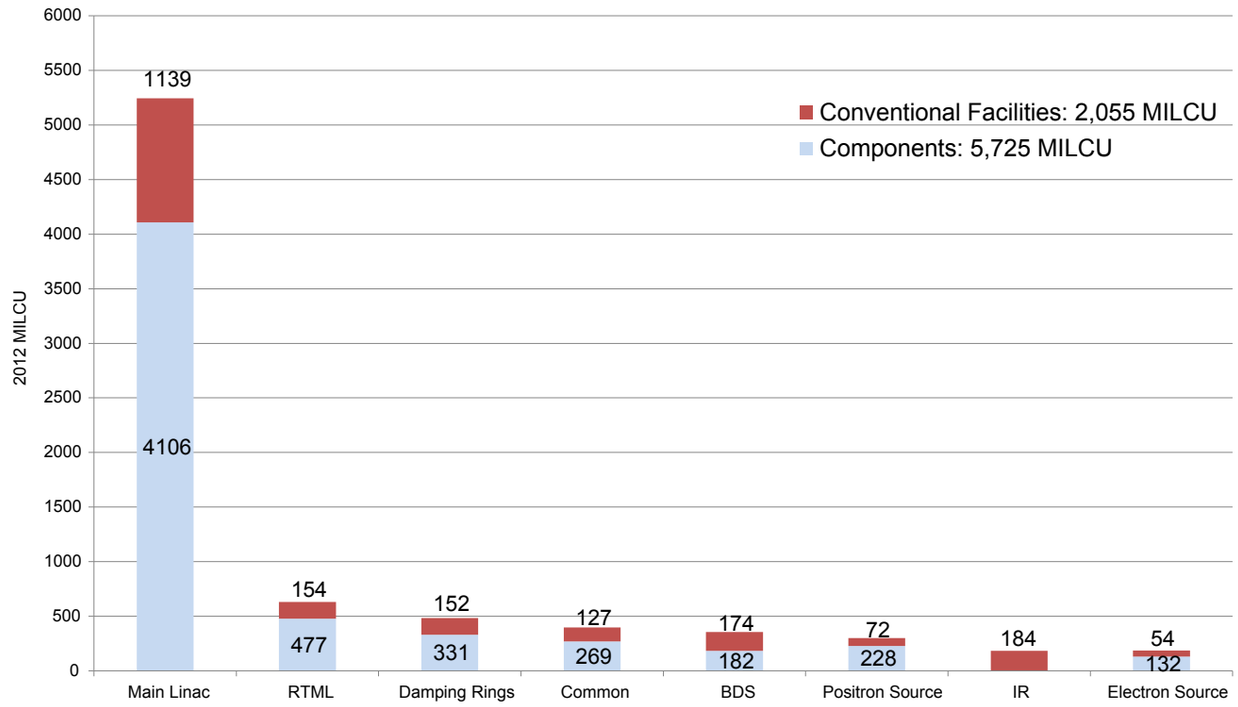
TDR handover to ICFA

ILC ready to go

…and 2400 signatories agreed

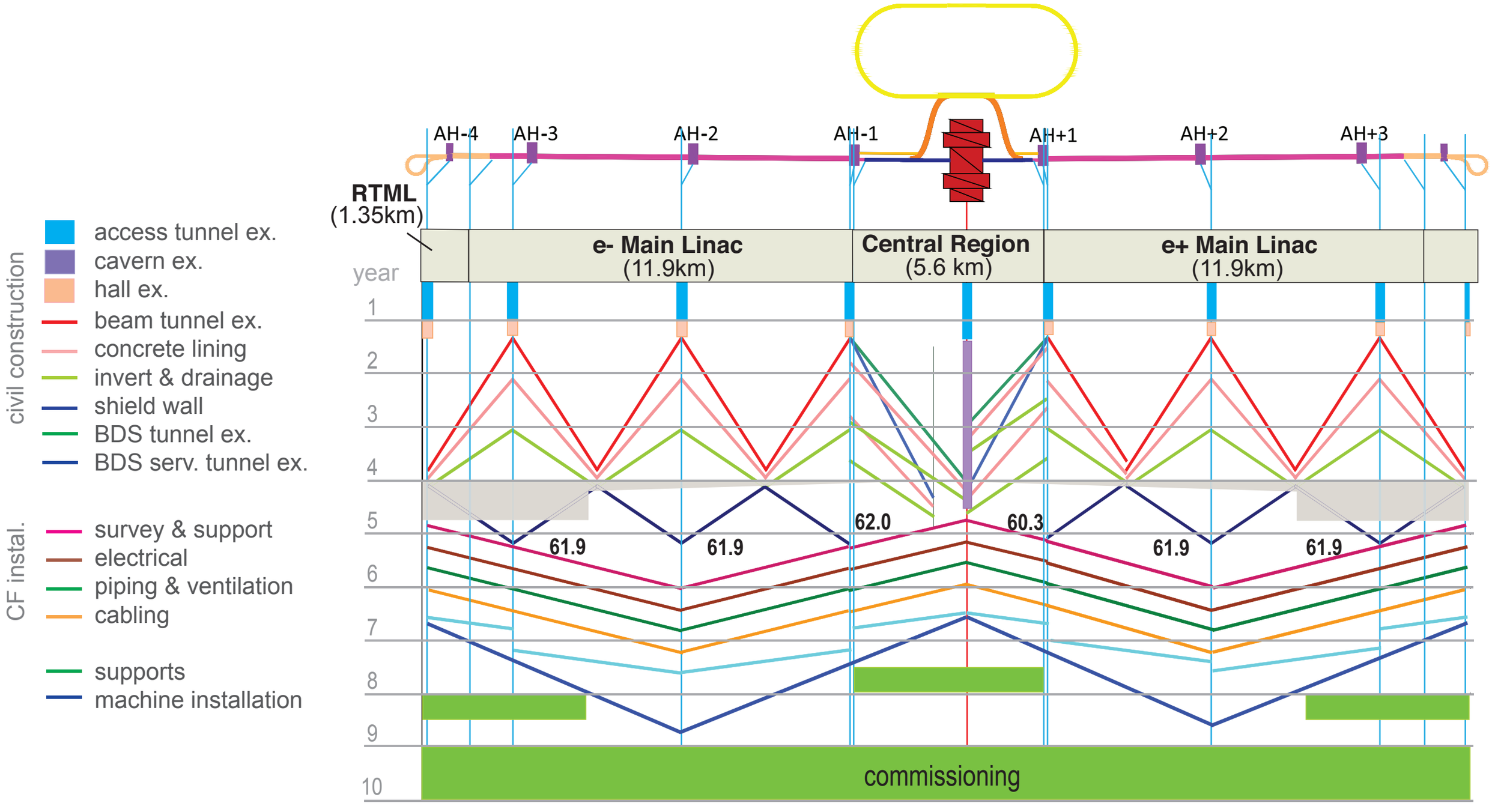
ILC TDR cost estimate

- TDR contains a detailed cost estimate
  - includes comparison to RDR
  - 7.78 bn ILCU
    1 ILCU = $1 US as of 1.1.2012
- 22.6 M person hours in addition (lab staff or hired)



Largest cost in main linac components – attractive for a global project

ILC construction and commissioning



ILC Technical Board – in LCC phase

LCC Directorate

ILC Collaboration

"Technical Organization"

Director – Mike Harrison (BNL)
Deputy Director – Hitoshi Hayano (KEK)

Technical Board
Nobuhiro Terunuma (KEK)
Yasuchika Yamamoto (KEK)
Nick Walker (DESY)
Olivier Napoly (CEA)
Marc Ross (SLAC)
Nikolay Solyak (Fermilab)

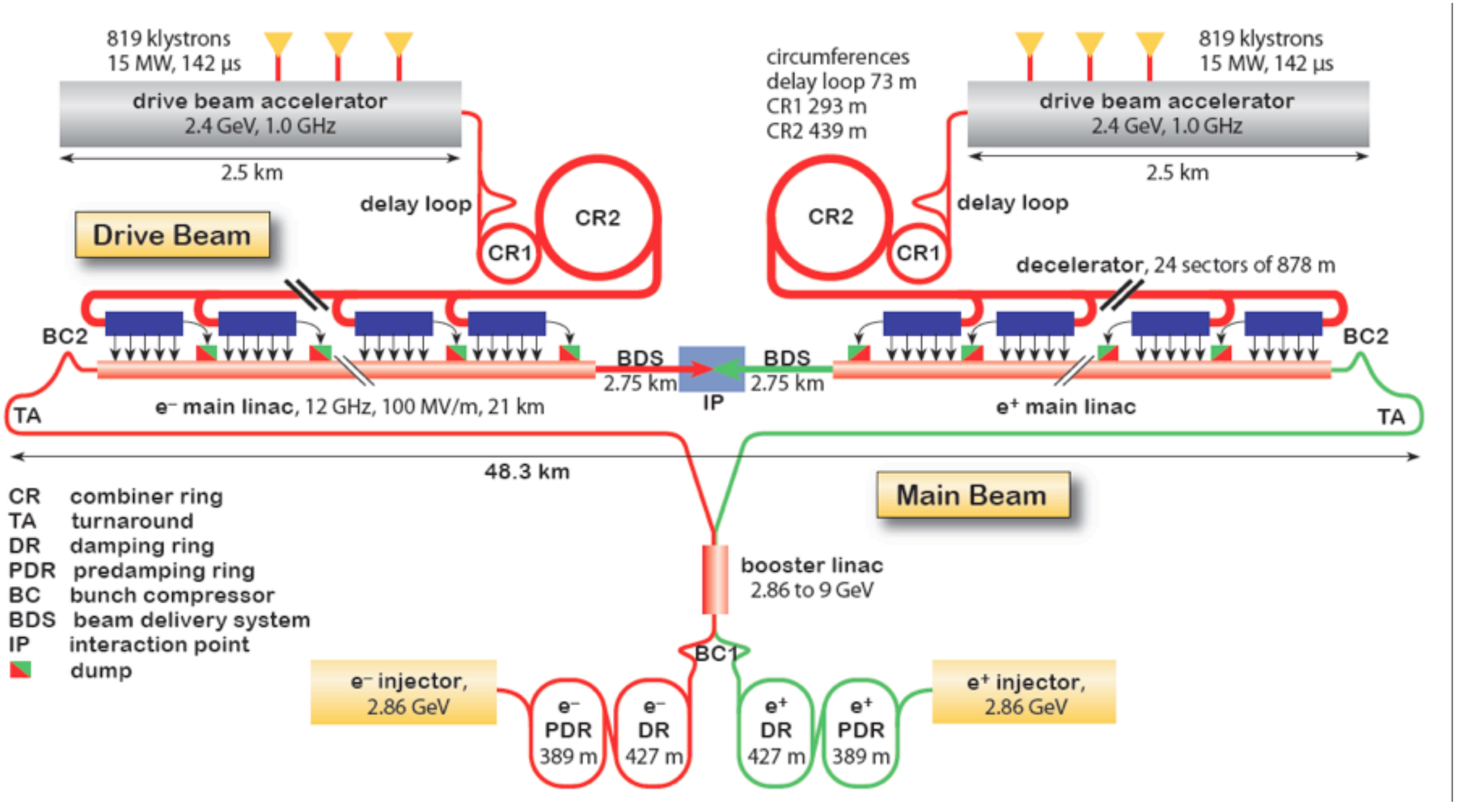
KEK LC Project Office

Organization at KEK

Head: Akira Yamamoto
Deputy: H. Hayano (Acc.)
K. Fujii (Phys/Det)
T. Shidara (General)

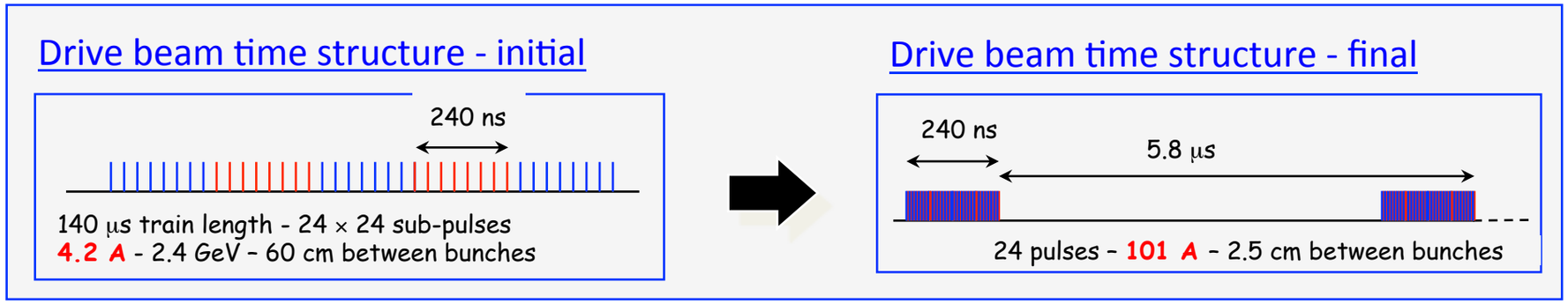
Working Groups

CLIC Layout at 3 TeV

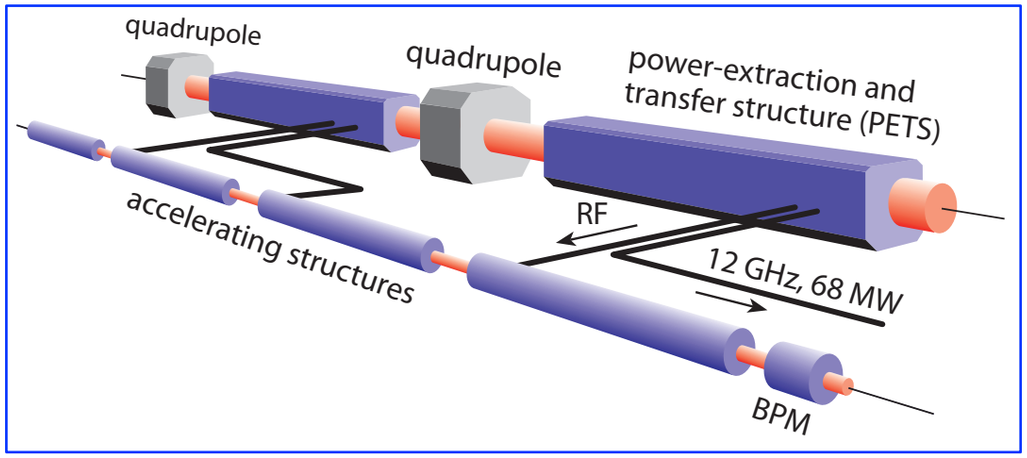


CLIC key elements

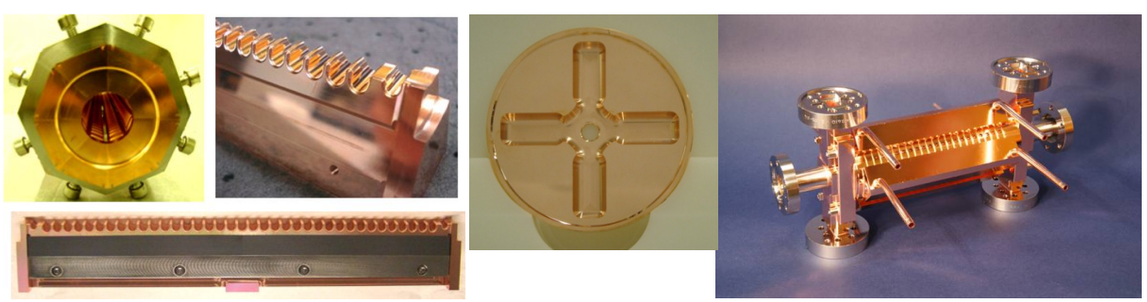
Compression of drive beam 4.2 A to 101 A



Power extraction from drive beam and transfer to main beam

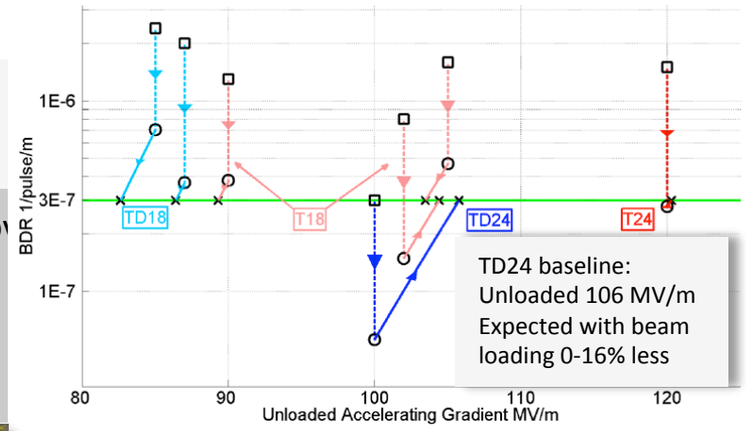


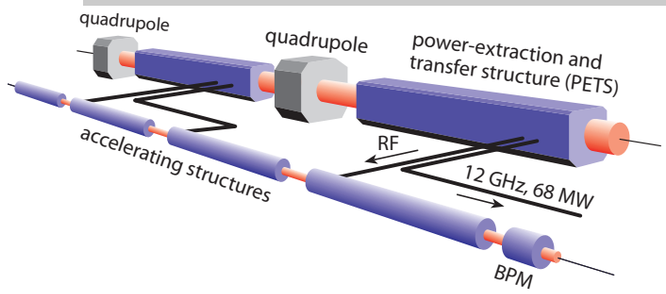
Accelerating structure

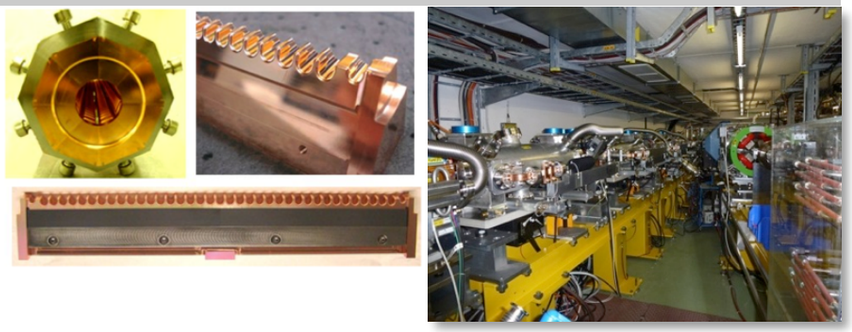


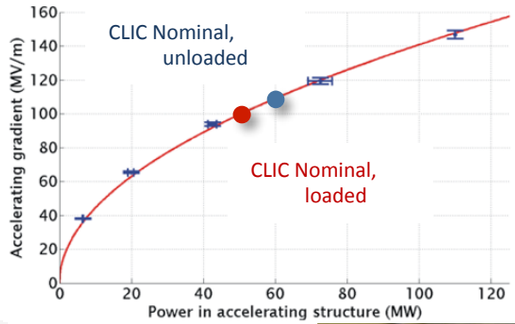
Conclusion of CLIC CDR studies

Main linac gradient	–	Ongoing test close to or on target
	–	Uncertainty from beam loading being tested
Drive beam scheme	–	Generation tested, used to accelerate test beam abov specifications, deceleration as expected
	–	Improvements on operation, reliability, losses, more deceleration studies underway

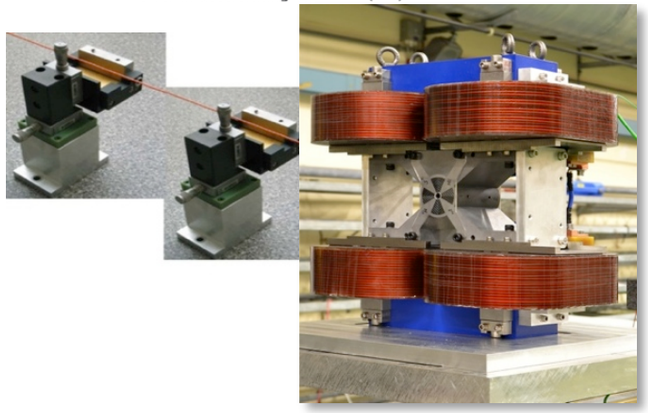








Luminosity	–	Damping ring like an ambitious light source, no show stopper
	–	Alignment system principle demonstrated
	–	Stabilisation system developed, benchmarked, better system in pipeline
	–	Simulations on or close to the target
Operation & Machine Protection	–	Start-up sequence and low energy operation defined
	–	Most critical failure studied and first reliability studies
Implementation	–	Consistent three stage implementation scenario defined
	–	Schedules, cost and power developed and presented
	–	Site and CE studies documented



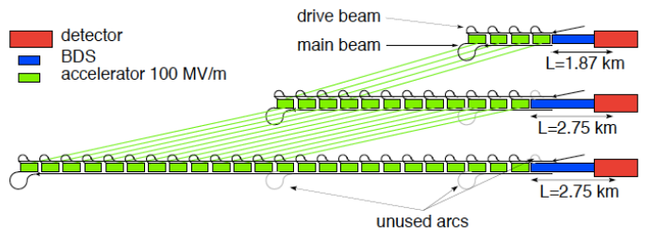
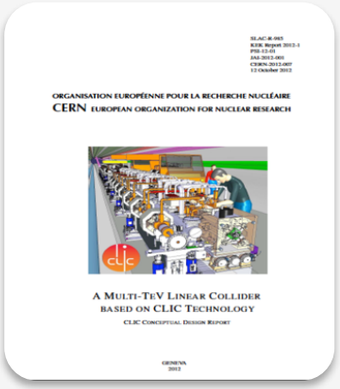


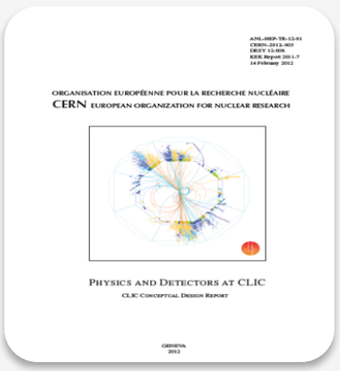
Fig. 3.6: Simplified upgrade scheme for CLIC staging scenario B.

The CLIC CDR documents



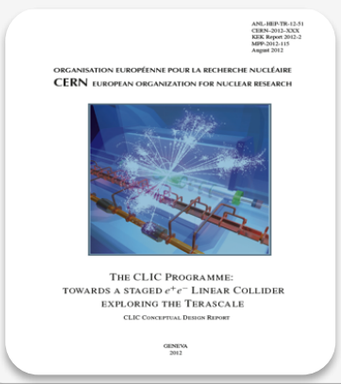
Vol 1: The CLIC accelerator and site facilities

- CLIC concept with exploration over multi-TeV energy range up to 3 TeV
- Feasibility study of CLIC parameters optimized at 3 TeV (most demanding)
- Consider also 500 GeV, and intermediate energy range
- https://edms.cern.ch/document/1234244/



Vol 2: Physics and detectors at CLIC

- Physics at a multi-TeV CLIC machine can be measured with high precision, despite challenging background conditions
- External review procedure in October 2011
- http://arxiv.org/pdf/1202.5940v1



Vol 3: "CLIC study summary"

- Summary and available for the European Strategy process, including possible implementation stages for a CLIC machine as well as costing and cost-drives
- Proposing objectives and work plan of post CDR phase (2012-16)
- http://arxiv.org/pdf/1209.2543v1

In addition a shorter overview document was submitted as input to the European Strategy update, available at: http://arxiv.org/pdf/1208.1402v1

An input document to Snowmass 2013 has also been submitted: http://arxiv.org/abs/1305.5766

Possible CLIC stages studied

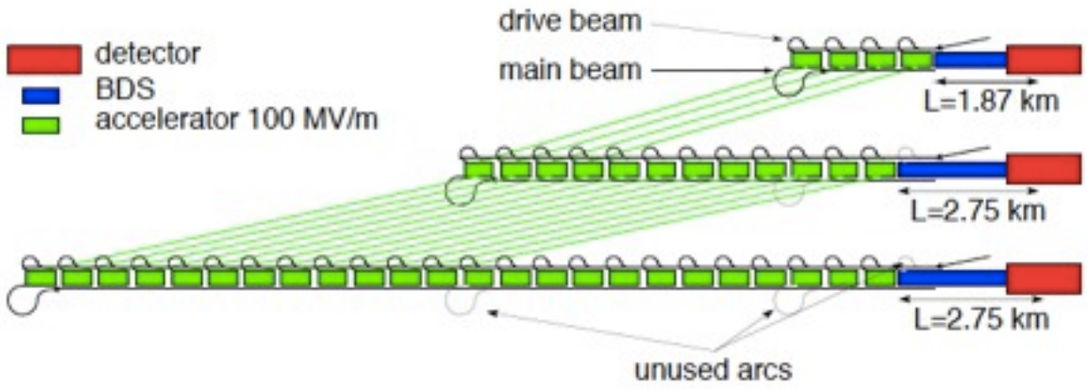


Fig. 3.6: Simplified upgrade scheme for CLIC staging scenario B.

Key features:
- High gradient (energy/length)
- Small beams (luminosity)
- Repetition rates and bunch spacing (experimental conditions)

Table 1: Parameters for the CLIC energy stages of scenario A.

Parameter	Symbol	Unit	Stage 1	Stage 2	Stage 3
Centre-of-mass energy	$\sqrt{s}$	GeV	500	1400	3000
Repetition frequency	f_{rep}	Hz	50	50	50
Number of bunches per train	n_b		354	312	312
Bunch separation	Δt	ns	0.5	0.5	0.5
Accelerating gradient	G	MV/m	80	80/100	100
Total luminosity	$\mathscr{L}$	10^{34} cm^{-2}s^{-1}	2.3	3.2	5.9
Luminosity above 99% of $\sqrt{s}$	$\mathscr{L}_{0.01}$	10^{34} cm^{-2}s^{-1}	1.4	1.3	2
Main tunnel length		km	13.2	27.2	48.3
Charge per bunch	N	10^9	6.8	3.7	3.7
Bunch length	σ_z	µm	72	44	44
IP beam size	σ_x/σ_y	nm	200/2.6	~ 60/1.5	~ 40/1
Normalised emittance (end of linac)	$\varepsilon_x/\varepsilon_y$	nm	2350/20	660/20	660/20
Normalised emittance (IP)	$\varepsilon_x/\varepsilon_y$	nm	2400/25	—	—
Estimated power consumption	P_{wall}	MW	272	364	589

Table 2: Parameters for the CLIC energy stages of scenario B.

Parameter	Symbol	Unit	Stage 1	Stage 2	Stage 3
Centre-of-mass energy	$\sqrt{s}$	GeV	500	1500	3000
Repetition frequency	f_{rep}	Hz	50	50	50
Number of bunches per train	n_b		312	312	312
Bunch separation	Δt	ns	0.5	0.5	0.5
Accelerating gradient	G	MV/m	100	100	100
Total luminosity	$\mathscr{L}$	10^{34} cm^{-2}s^{-1}	1.3	3.7	5.9
Luminosity above 99% of $\sqrt{s}$	$\mathscr{L}_{0.01}$	10^{34} cm^{-2}s^{-1}	0.7	1.4	2
Main tunnel length		km	11.4	27.2	48.3
Charge per bunch	N	10^9	3.7	3.7	3.7
Bunch length	σ_z	µm	44	44	44
IP beam size	σ_x/σ_y	nm	100/2.6	~ 60/1.5	~ 40/1
Normalised emittance (end of linac)	$\varepsilon_x/\varepsilon_y$	nm	—	660/20	660/20
Normalised emittance	$\varepsilon_x/\varepsilon_y$	nm	660/25	—	—
Estimated power consumption	P_{wall}	MW	235	364	589

CLIC physics potential

LHC complementarity at the energy frontier:

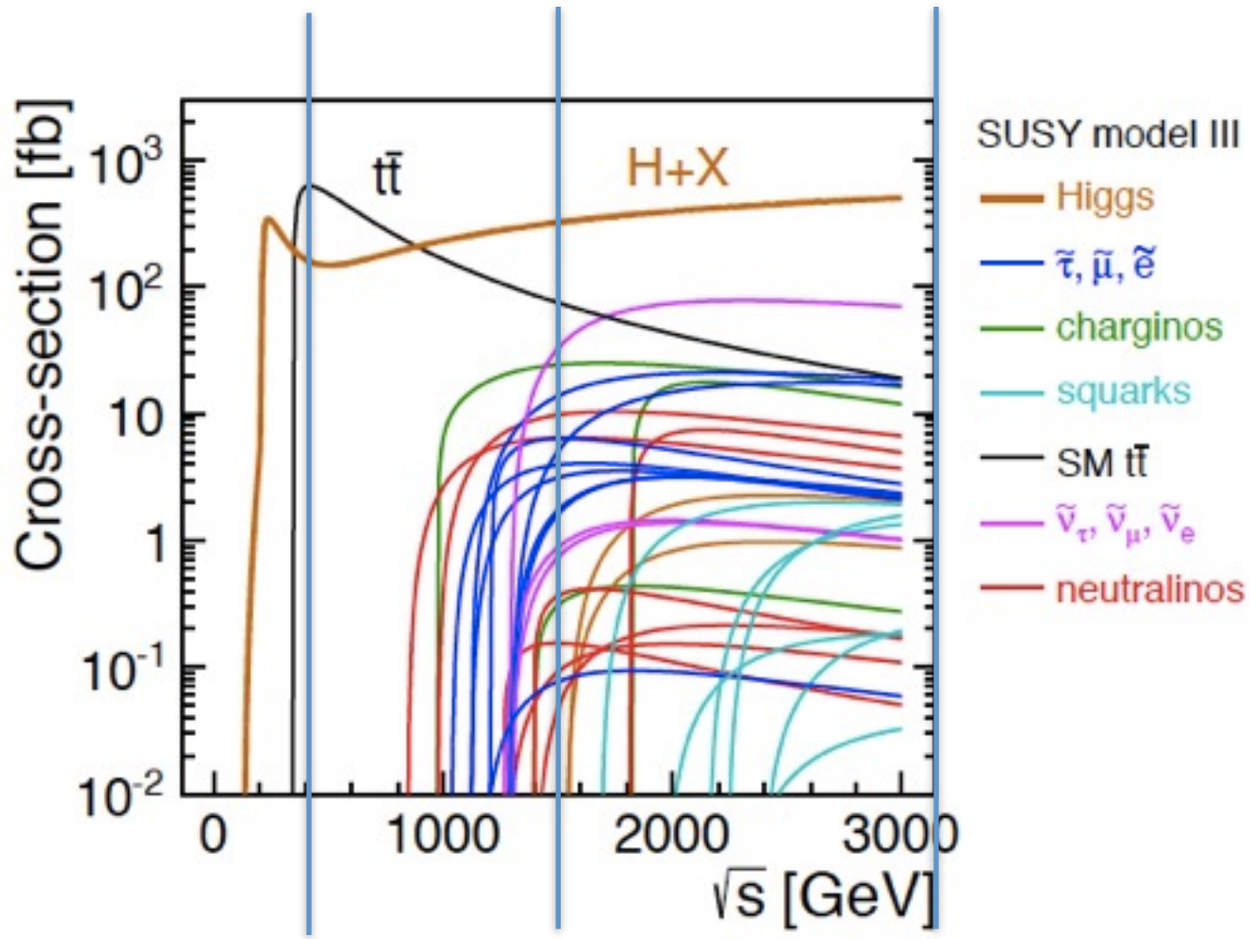
- How do we build the optimal machine given a physics scenario (partly seen at LHC ?)

Examples highlighted in the CDR:

- Higgs physics (SM and non-SM)
- Top
- SUSY
- Higgs strong interactions
- New Z' sector
- Contact interactions
- Extra dimensions

Detailed studies at 350 (500), 1400 and 3000 GeV for these processes

Operation at lower than nominal energy



Stage 1: ~350-375 GeV => Higgs and top physics
Stage 2: ~1.5 TeV => ttH, vvHH + New Physics (lower mass scale)
Stage 3: ~3 TeV => New Physics (higher mass scale)

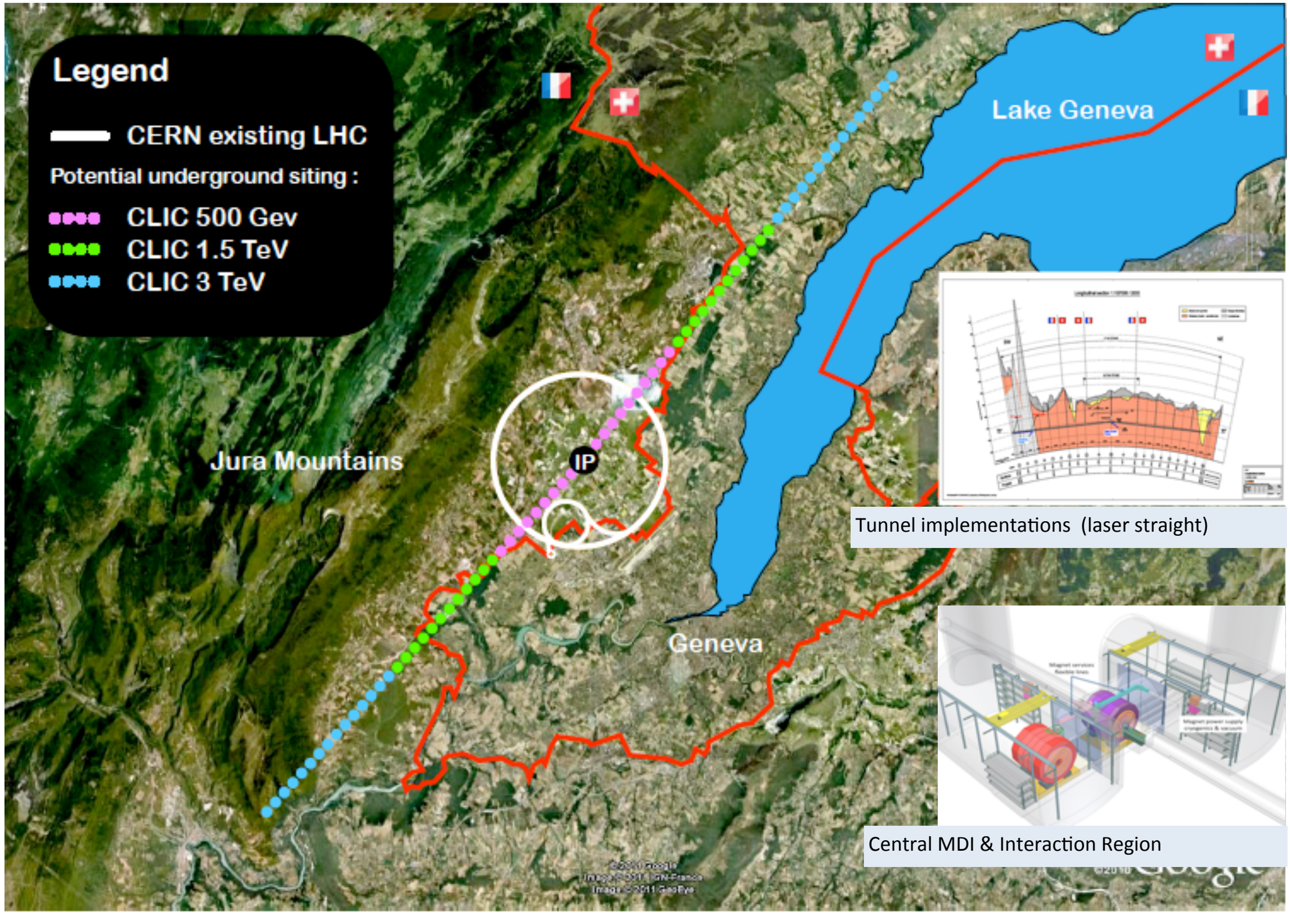
SUSY Benchmark Results (1.4 TeV)

$\sqrt{s}$ (TeV)	Process	Decay mode	SUSY model	Measured quantity	Unit	Generator value	Stat. error
1.4	Sleptons production	$\tilde{\mu}_R^+\tilde{\mu}_R^- \to \mu^+\mu^-\tilde{\chi}_1^0\tilde{\chi}_1^0$	III	σ	fb	1.11	2.7%
				$\tilde{\ell}$ mass	GeV	560.8	0.1%
				$\tilde{\chi}_1^0$ mass	GeV	357.8	0.1%
		$\tilde{e}_R^+\tilde{e}_R^- \to e^+e^-\tilde{\chi}_1^0\tilde{\chi}_1^0$		σ	fb	5.7	1.1%
				$\tilde{\ell}$ mass	GeV	558.1	0.1%
				$\tilde{\chi}_1^0$ mass	GeV	357.1	0.1%
		$\tilde{\nu}_e\tilde{\nu}_e \to \tilde{\chi}_1^0\tilde{\chi}_1^0 e^+e^- W^+W^-$		σ	fb	5.6	3.6%
				$\tilde{\ell}$ mass	GeV	644.3	2.5%
				$\tilde{\chi}_1^\pm$ mass	GeV	487.6	2.7%
1.4	Stau production	$\tilde{\tau}_1^+\tilde{\tau}_1^- \to \tau^+\tau^-\tilde{\chi}_1^0\tilde{\chi}_1^0$	III	$\tilde{\tau}_1$ mass	GeV	517	2.0%
				σ	fb	2.4	7.5%
1.4	Chargino production	$\tilde{\chi}_1^+\tilde{\chi}_1^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0 W^+W^-$	III	$\tilde{\chi}_1^\pm$ mass	GeV	487	0.2%
				σ	fb	15.3	1.3%
	Neutralino production	$\tilde{\chi}_2^0\tilde{\chi}_2^0 \to h/Z^0h/Z^0\tilde{\chi}_1^0\tilde{\chi}_1^0$		$\tilde{\chi}_2^0$ mass	GeV	487	0.1%
				σ	fb	5.4	1.2%

SUSY Benchmark Results (3 TeV)

$\sqrt{s}$ (TeV)	Process	Decay mode	SUSY model	Measured quantity	Unit	Generator value	Stat. error
3.0	Sleptons production	$\tilde{\mu}_R^+\tilde{\mu}_R^- \to \mu^+\mu^-\tilde{\chi}_1^0\tilde{\chi}_1^0$	II	σ	fb	0.72	2.8%
				$\tilde{\ell}$ mass	GeV	1010.8	0.6%
				$\tilde{\chi}_1^0$ mass	GeV	340.3	1.9%
		$\tilde{e}_R^+\tilde{e}_R^- \to e^+e^-\tilde{\chi}_1^0\tilde{\chi}_1^0$		σ	fb	6.05	0.8%
				$\tilde{\ell}$ mass	GeV	1010.8	0.3%
				$\tilde{\chi}_1^0$ mass	GeV	340.3	1.0%
		$\tilde{e}_L^+\tilde{e}_L^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0 e^+e^- hh$ $\tilde{e}_L^+\tilde{e}_L^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0 e^+e^- Z^0Z^0$		σ	fb	3.07	7.2%
		$\tilde{\nu}_e\tilde{\nu}_e \to \tilde{\chi}_1^0\tilde{\chi}_1^0 e^+e^- W^+W^-$		σ	fb	13.74	2.4%
				$\tilde{\ell}$ mass	GeV	1097.2	0.4%
				$\tilde{\chi}_1^\pm$ mass	GeV	643.2	0.6%
3.0	Chargino production	$\tilde{\chi}_1^+\tilde{\chi}_1^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0 W^+W^-$	II	$\tilde{\chi}_1^\pm$ mass	GeV	643.2	1.1%
				σ	fb	10.6	2.4%
	Neutralino production	$\tilde{\chi}_2^0\tilde{\chi}_2^0 \to h/Z^0h/Z^0\tilde{\chi}_1^0\tilde{\chi}_1^0$		$\tilde{\chi}_2^0$ mass	GeV	643.1	1.5%
				σ	fb	3.3	3.2%
3.0	Production of right-handed squarks	$\tilde{q}_R\tilde{q}_R \to q\bar{q}\tilde{\chi}_1^0\tilde{\chi}_1^0$	I	Mass	GeV	1123.7	0.52%
				σ	fb	1.47	4.6%
3.0	Heavy Higgs production	$H^0A^0 \to b\bar{b}b\bar{b}$	I	Mass	GeV	902.4	0.3%
				Width	GeV		31%
		$H^+H^- \to t\bar{b}b\bar{t}$		Mass	GeV	906.3	0.3%
				Width	GeV		27%

CLIC near CERN



Tunnel implementations (laser straight)

Central MDI & Interaction Region

Possible luminosity examples

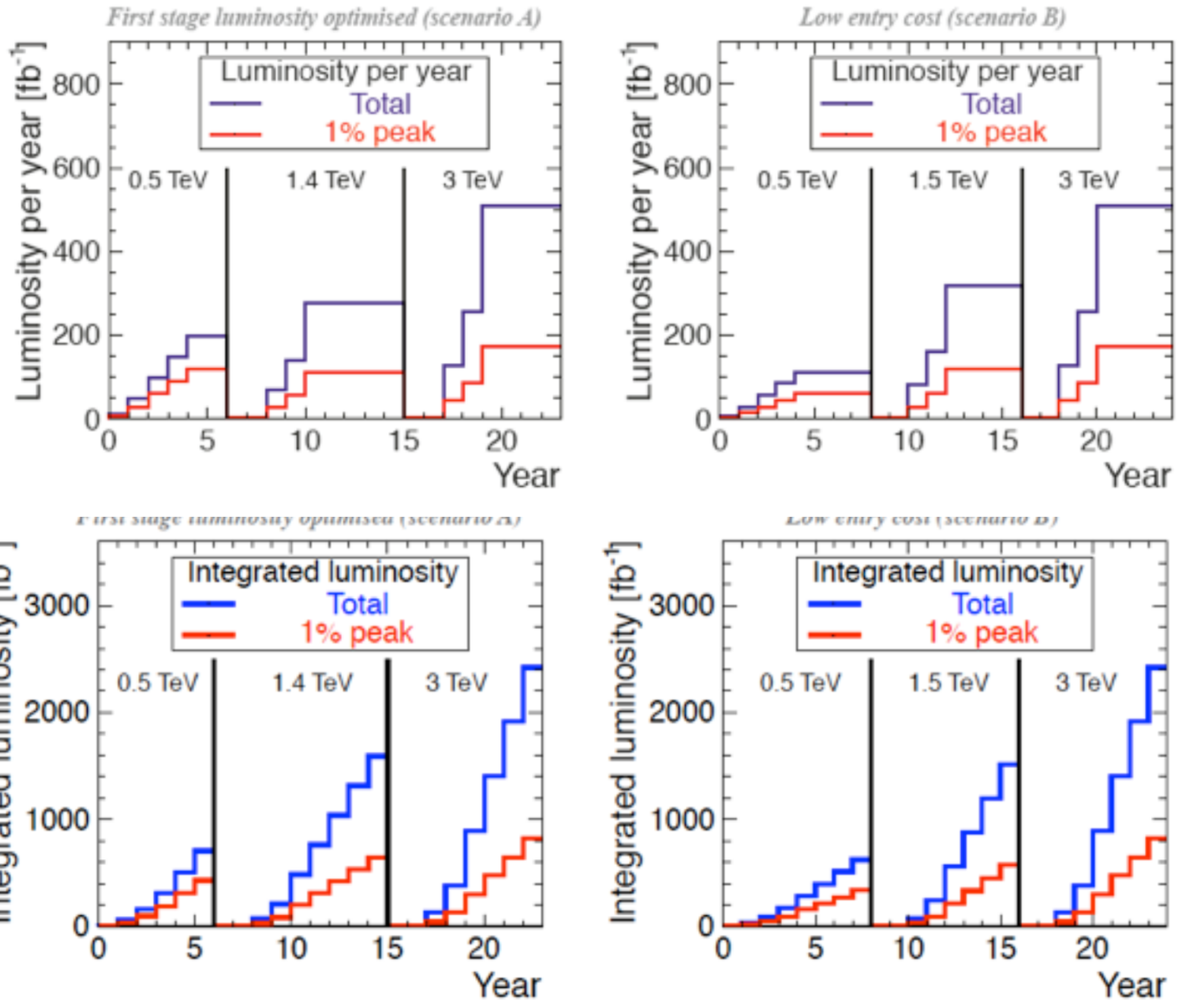
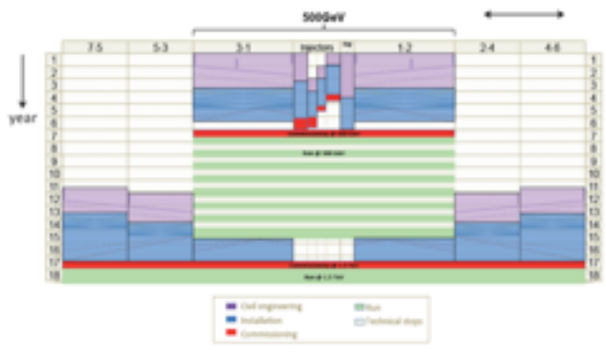


Fig. 5.2: Integrated luminosity in the scenarios optimised for luminosity in the first energy stage (left) and optimised for entry costs (right). Years are counted from the start of beam commissioning. These figures include luminosity ramp-up of four years (5%, 25%, 50%, 75%) in the first stage and two years (25%, 50%) in subsequent stages.

Based on 200 days/year at 50% efficiency (accelerator + data taking combined)

Target figures: >600 fb^{-1} at first stage, 1.5 ab^{-1} at second stage, 2 ab^{-1} at third stage



Power/energy consumption

Considering 150 days per year of normal operation at nominal power and a luminosity ramp-up in the early years at each stage of collision energy, the development of yearly energy consumption can be sketched.

Re-optimize parts
- Reduced current density in normal-conducting magnets
- Reduction of heat loads to HVAC
- Re-optimization of accelerating gradient with different objective function

Efficiency
- Grid-to-RF power conversion
- Permanent or super-ferric superconducting magnets

Energy management
- Low-power configurations in case of beam interruption
- Modulation of scheduled operation to match electricity demand: Seasonal and Daily
- Power quality specifications

Waste heat recovery
- Possibilities of heat rejection at higher temperature
- Waste heat valorization by concomitant needs, e.g. residential heating, absorption cooling

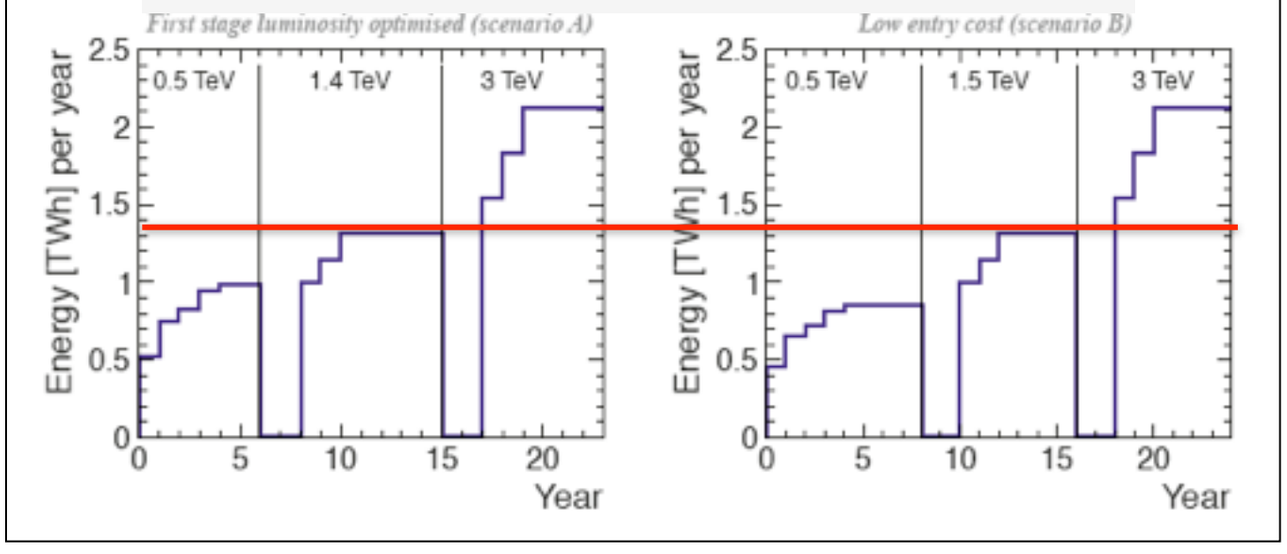
Beyond:
Scale with inst. luminosity – i.e. running at the very end of the project lifetime might be power limited and require more time.

Staging scenario	$\sqrt{s}$ (TeV)	$\mathscr{L}_{1\%}$ ($\mathrm{cm}^{-2}\mathrm{s}^{-1}$)	$W_{main\ beam}$ (MW)	$P_{electric}$ (MW)
A	0.5	$1.4 \cdot 10^{34}$	9.6	272
	1.4	$1.3 \cdot 10^{34}$	12.9	364
	3.0	$2.0 \cdot 10^{34}$	27.7	589
B	0.5	$7.0 \cdot 10^{33}$	4.6	235
	1.5	$1.4 \cdot 10^{34}$	13.9	364
	3.0	$2.0 \cdot 10^{34}$	27.7	589

Table 5.2: Residual power without beams for staging scenarios A and B.

Staging scenario	$\sqrt{s}$ (TeV)	$P_{waiting\ for\ beam}$ (MW)	$P_{shutdown}$ (MW)
A	0.5	168	37
	1.4	190	42
	3.0	268	58
B	0.5	167	35
	1.5	190	42
	3.0	268	58

CERN energy consumption 2012: 1.35 TWh



CLIC Costs

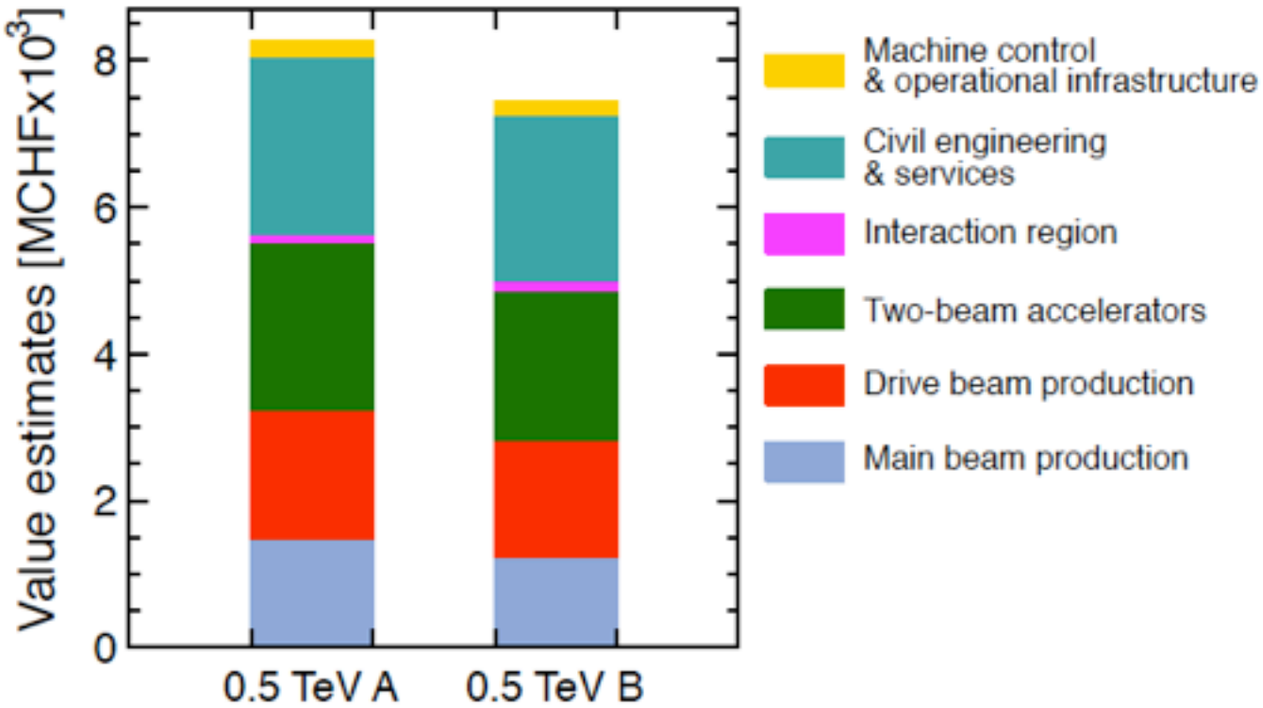


Fig. 6: Cost structure of the CLIC accelerator complex at 500 GeV for scenarios A and B.

Caveats:

- Uncertainties 20-25%
- Possible savings around 10%
- However – first stage not optimised (work for next phase), parameters largely defined for 3 TeV final stage

CLIC Accelerator Activities 2012-18

An optimised machine:

- Higgs mass scale known and much improved cost and power models allow significant optimization
- Re-baselining studies ongoing (~375 GeV, ~1.5 TeV, 3 TeV) – including more work on a klystron based initial phase
- Overall design and system optimisation, technical parameters for all systems
- Cost, power/energy optimisation, scheduling, site including specific developments/studies

System tests:

- Studies of drive-beam stability and RF units, beam-loading experiments, deceleration, RF power generation and two beam acceleration with complete modules, as well as beam based alignment/beam delivery system/final focus studies
- CTF3+ programme
- ATF, FACET for luminosity performance and various other smaller programmes for specific technology developments
- Continuing/increasing links to light source community related to low emittance rings and X-band based FELs design studies

Energy reach:

- Linked to X-band technology development and industrialisation
- Increase test-capacity (several sites)
- Detailed studies and optimisation of all the critical RF elements (main structures the most central) as well as further industrialisation

Luminosity performance:

- Overall performance simulation and optimisation of each system – in some case linked to experimental benchmarking and/or tests (some examples below)
- Damping ring designs including experimental development and studies
- Main linac alignment and stability, wakefield studies, BBA alignment
- Final focus optimisation and studies
- Overall performance, reliability, robustness and risk studies

Technical developments:

- Critical elements, for performance, costs or power consumption, industrial developments or as needed for systemtest (some examples below)
- Module development including complete modules (RF, alignment/stability, magnets, instrumentation, vacuum, cooling, controls) for lab and CTF3
- RF power systems development (1 GHz)
- Alignment and stability methods and hardware

Current CLIC Collaboration

ACAS (Australia)
Aarhus University (Denmark)
Ankara University (Turkey)
Argonne National Laboratory (USA)
Athens University (Greece)
BINP (Russia)
CERN
CIEMAT (Spain)
Cockcroft Institute (UK)
ETH Zurich (Switzerland)
FNAL (USA)
Gazi Universities (Turkey)
Helsinki Institute of Physics (Finland)
IAP (Russia)
IAP NASU (Ukraine)
IHEP (China)
INFN / LNF (Italy)
Instituto de Fisica Corpuscular (Spain)
IRFU / Saclay (France)
Jefferson Lab (USA)
John Adams Institute/Oxford (UK)
Joint Institute for Power and Nuclear Research SOSNY /Minsk (Belarus)
John Adams Institute/RHUL (UK)
JINR
Karlsruhe University (Germany)
KEK (Japan)
LAL / Orsay (France)
LAPP / ESIA (France)
NIKHEF/Amsterdam (Netherland)
NCP (Pakistan)
North-West. Univ. Illinois (USA)
Patras University (Greece)
Polytech. Univ. of Catalonia (Spain)
PSI (Switzerland)
RAL (UK)
RRCAT / Indore (India)
SLAC (USA)
Sincrotrone Trieste/ELETTRA (Italy)
Thrace University (Greece)
Tsinghua University (China)
University of Oslo (Norway)
University of Vigo (Spain)
Uppsala University (Sweden)
UCSC SCIPP (USA)

What are the next steps?

Geological survey of the 2 Japanese ILC sites

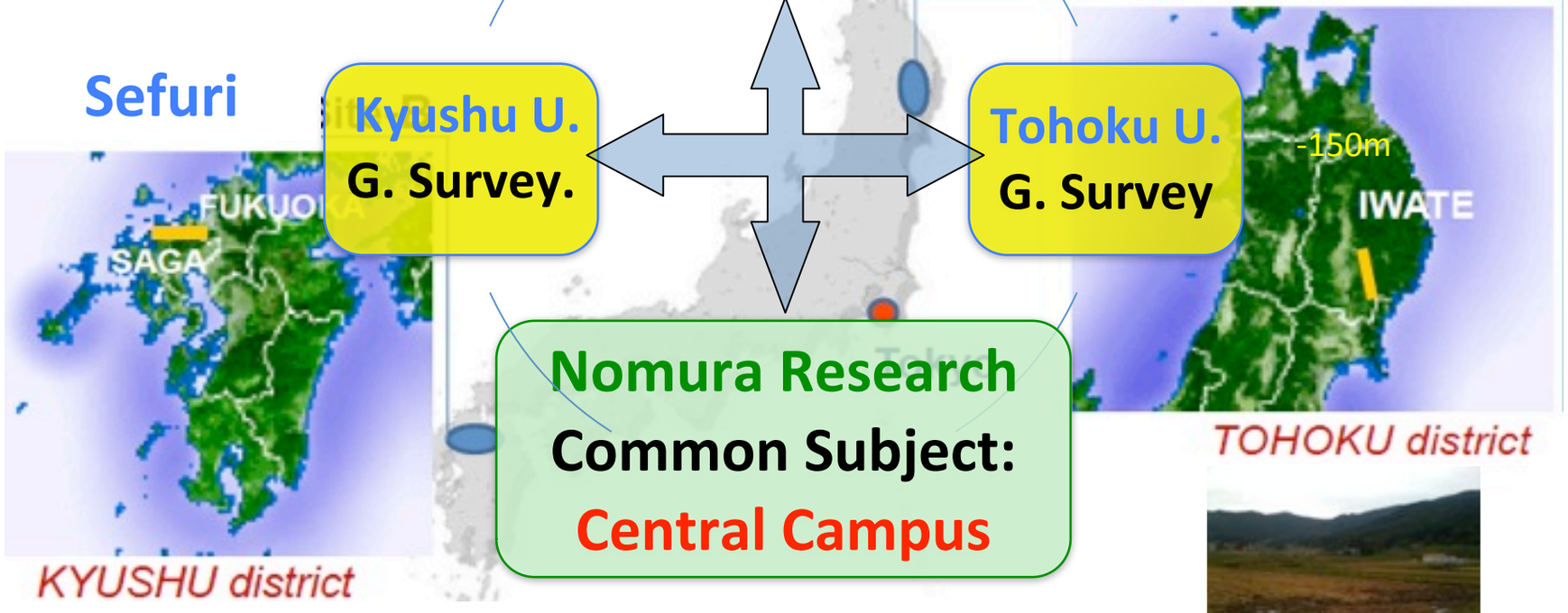
KEK

Kitakami

Sefuri

Kyushu U.
G. Survey.

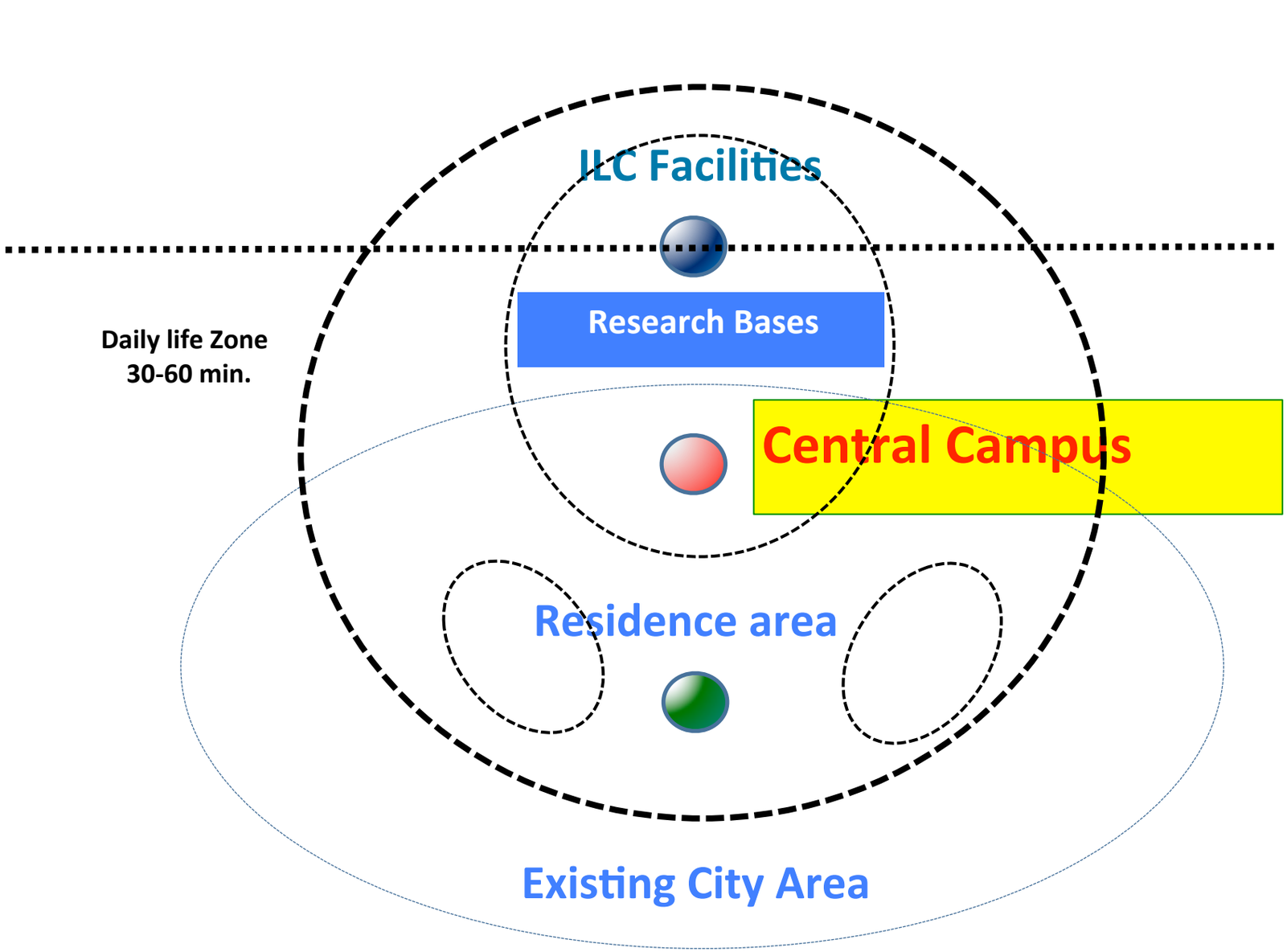
Tohoku U.
G. Survey



Nomura Research
Common Subject:
Central Campus

Reports to be completed summer 2013

Considerations for ILC location



A concept: Relative distance from main campus such that in reach within ≤ ~ 30 min.

Estimate of persons at ILC laboratory

	Under construction Peak (year 8)	Operation start (year 11)	In operation (year 15)	In operation (year 20)
Laboratory Staffs *#1*	1,600	1,200	1,200	1,200
Experiment participants *#2*	500	700	800	1,000
Laboratory Support *#3*	300	300	400	500
Total	2,400	2,200	2,400	2,700

#1: including the regular/permanent staff and temporary staff (Post-Doc),
#2: including researchers, engineers and students for two experiments,
#3: including subcontracted specialist to support acc. & exp. activities

General Plan for ILC Central Campus

- Major facilities:
  - Offices
  - Laboratory
  - Meeting rooms
  - Visitor's accommodation
- General services
- Parking
- Utility plant, etc.

- Assuming:
- ~ 100,000 m^2
- in total floor area

Classification	Assuming facilities	
	Facilities	Area(m^2)
Offices	Research office University & Institute	35,000
laboratory facilities	Control center Assembly hall Technology development hall	33,000
meeting and exchange	Lecture hall Meeting room	3,500
Accommodation	Dormitory Visitor accommodation	23,000
Service facilities	Reception, Users office Library, exhibition hall Cafeteria, Convenient store Health care & Training center	3,200
Transportation	Parking, Bus Terminal	-
Energy plant, etc.		1,100
Total		99,800

Case studies : Zoning and Facility Layout

High-Rise

30000 m^2

flat

40000 m^2

Spacious

80000 m^2

European Assets
XFEL test facilty AMTF at DESY

- Cold RF test of all XFEL superconducting cavities before cryomodule module assembly, 800 cavities, rate 6/week, 2 of 2 vert. test stands in operation
- Complete cold performance test of all XFEL cryomodules before tunnel installation: RF, vacuum, cryo-losses, tuner, quad,
  100 cryomodules, rate: 1/week, 1 of 3 test stands in cryomodule commissioning
- Cold test of all superconducting magnet packages before cryomodule assembly,
  100 magnets, 1/week, 1 of 1 stand in operation
- Assembly and tests of RF Waveguides at Waveguide Assembly and Test Facility, in operation

AMTF
Test stands

European assets
XFEL module assembly

- New and complex infrastructure build at CEA, Saclay
- Clean Room Cold Coupler Area (IS04-CC-WS1)
  - Cold coupler assembly
- Clean Room String Assembly Area (ISO4-SA-WS1, ISO4-SA-WS2)
  - String connections (1 gate valve + 8 cavities + 1 Qpole unit)
- Roll-out Area (RO-WS1, RO-WS2)
  - HOM tuning, magnetic shielding, tuners,…
  - 2Ph-tube welding, cold-mass connection
- Alignment Area (AL-WS1, AL-WS2)
  - Cavity and quadrupole fine alignment
  - Coupler shields and braids, tuner electric tests
- Cantilever Area (CA-WS1)
  - Welding of 4K and 70 K shields, super insulation
  - Quad current lead
  - Insertion into vacuum vessel and string alignment
- Coupler Area (CO-WS1, CO-WS2)
  - Warm couplers + coupler pumping line
  - Control operations (electrical, RF)
- Shipment Area (SH-WS1, SH-WS2)
  - CEA-Alsyom “acceptance test”
  - End-caps closing, N2-insulation, loading.

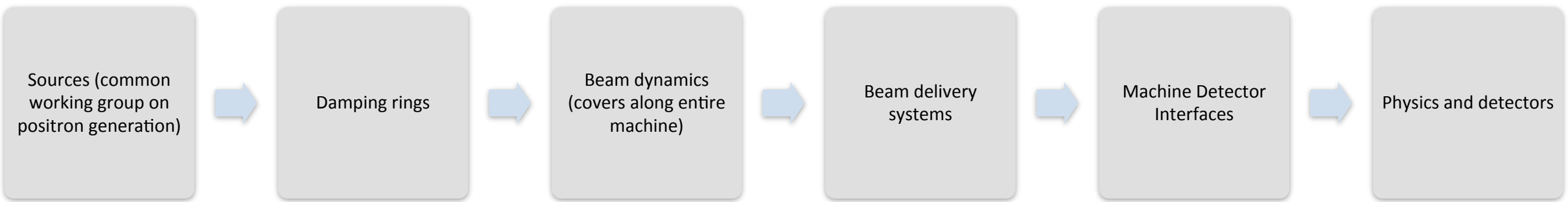
In full production, this chain of workstations will be fully occupied with 7 cryomodules (XMn-6 @ WS1,…, XMn @ WS7) stationed for one week.

Joint European effort to ILC

- European contributions to ILC construction obviously possible – based on XFEL construction and reaching considerably further

- Significant work and expertise – and huge common potential with CLIC related to “luminosity performance/critical systems and associated system tests”:

- CERN, Spain, UK, Italy, France … : Sources, damping rings, beam-delivery systems, instrumentation, stability/alignment



Summary

- Major milestones achieved for CLIC (CDR 2012) and ILC (TDR 2013)
- The Higgs discovery – and future measurements – set up a clear scenario for linear colliders (to complement the results from LHC)

- CLIC programme for 2018 defined (being revised now after the Strategy document), collaboration based developments of key aspects of the technology

- ILC may enter construction in Japan
  - Site choice next, followed by statements by government ? Involvement by other regions, Europe and US, is key
  - Europe well prepared to contribute technically

- European Strategy welcomes the Japanese initiative and supports R&D for CLIC