LINEAR COLLIDER COLLABORATION

Status and plans of the Compact Linear Collider Study

- Introduction
- CLIC status
- 380 GeV collider optimisation
- R&D highlights
- Conclusions and outlook

Steffen Doebert

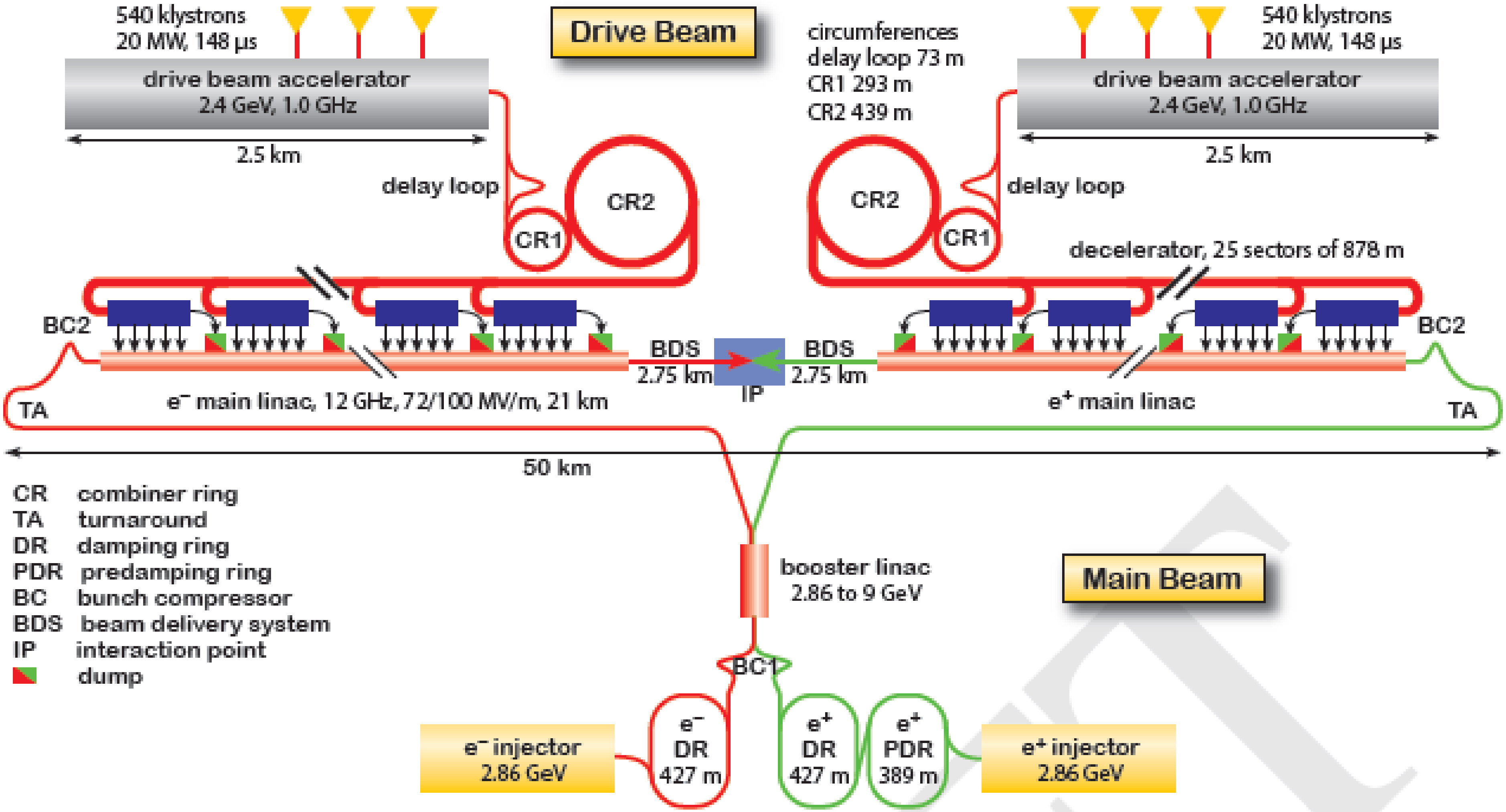
CERN

On behalf of the CLIC Accelerator Collaboration

Thanks to all colleagues for their contributions

ICHEP 2016, Chicago

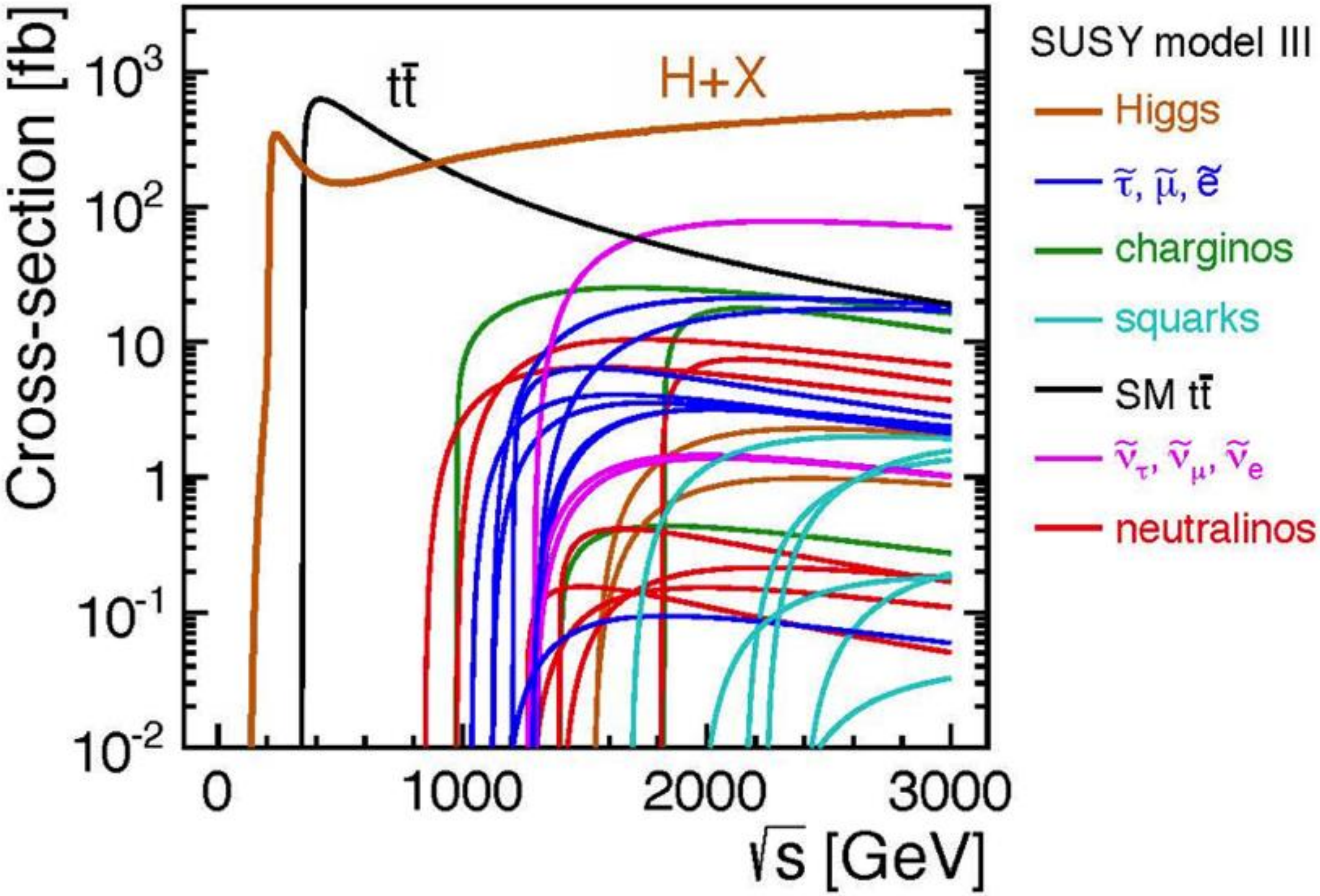
New CLIC layout 3 TeV



CLIC physics context

Energy-frontier capability for electron-positron collisions,

for precision exploration of potential new physics that may emerge from LHC



Timeline

LINEAR COLLIDER COLLABORATION

2013-19 Development Phase

Develop a Project Plan for a staged implementation in agreement with LHC findings; further technical developments with industry, performance studies for accelerator parts and systems, as well as for detectors

5 year Preparation Phase

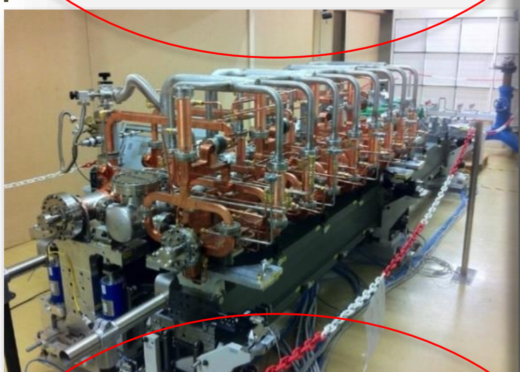
Finalise implementation parameters, Drive Beam Facility and other system verifications, site authorisation and preparation for industrial procurement.

Prepare detailed Technical

Construction Phase

Stage 1 construction of CLIC, in parallel with detector construction.

Preparation for implementation of further stages



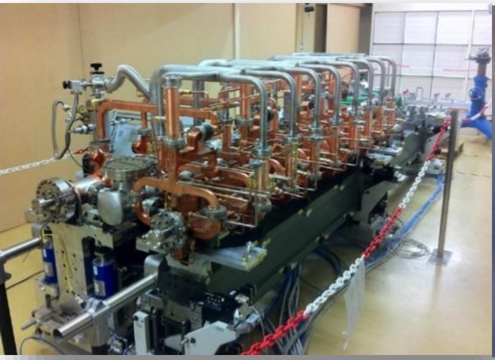
Accelerator collaboration with ~50 institutes
Detector collaboration operative with ~27 institutes

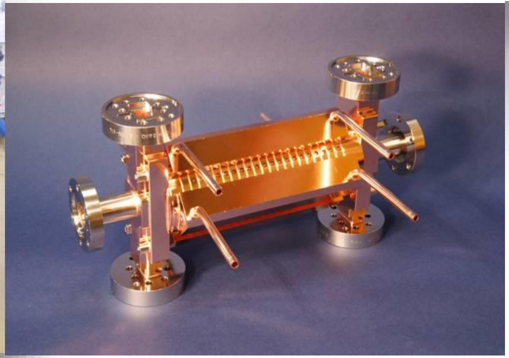
2019-20 Decisions

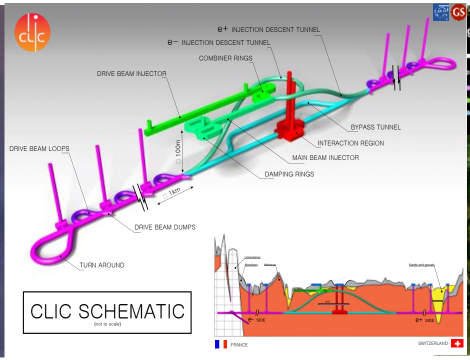
On the basis of LHC data and Project Plans (for CLIC and other potential projects as FCC), take decisions about next project(s) at the Energy Frontier.

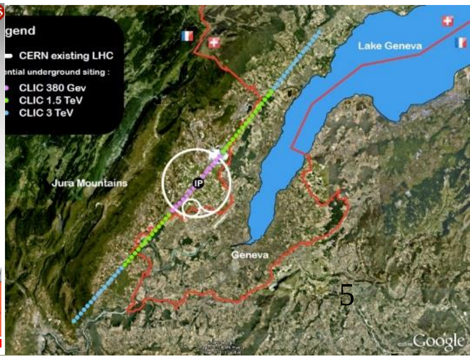
CLIC status and plans

- ❑ Post CDR Development phase
- ❑ Parameter optimization in particular first stage at 380 GeV and subsequent staging
- ❑ Optimize Cost, Power and schedule
- ❑ Key-technical developments including preparations for industrialization
- ❑ Performance verifications in test facilities, CTF3, FACET, ATF
- ❑ Promoting CLIC technology for FEL's and medical applications





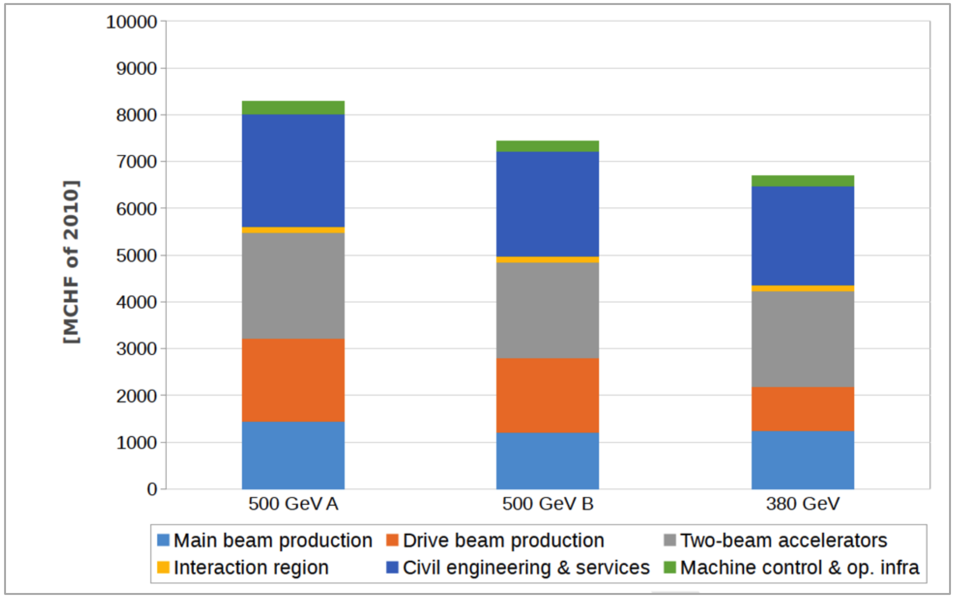




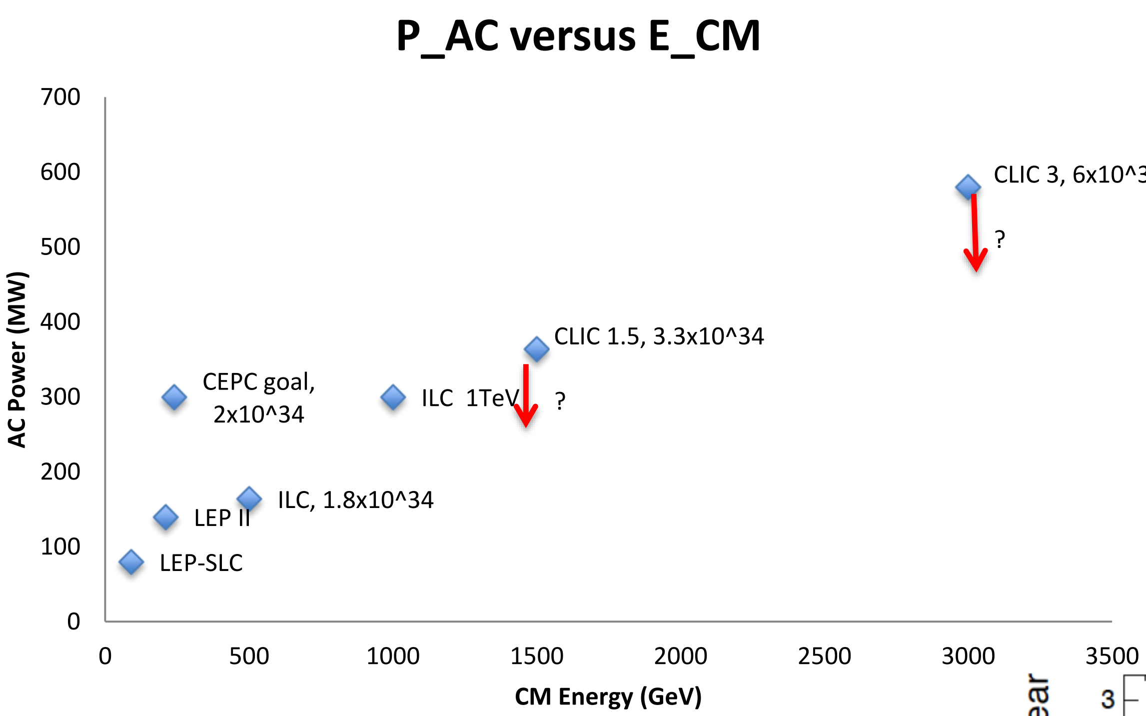
LINEAR COLLIDER COLLABORATION

Power&Cost optimisation

- ❑ Development of very efficient power source
- ❑ Development of adjustable permanent magnets
- ❑ Parameter optimization, beam quality
- ❑ Running scenarios
- ❑ Alternative designs
- ❑ Energy recovery



Power and Energy



CERN energy consumption 2012: 1.35 TWh

Energy consumption being studied, Can we optimize the way we run these machines ?

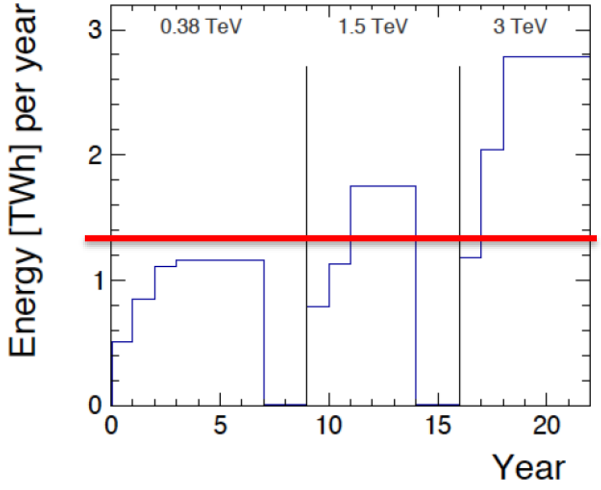
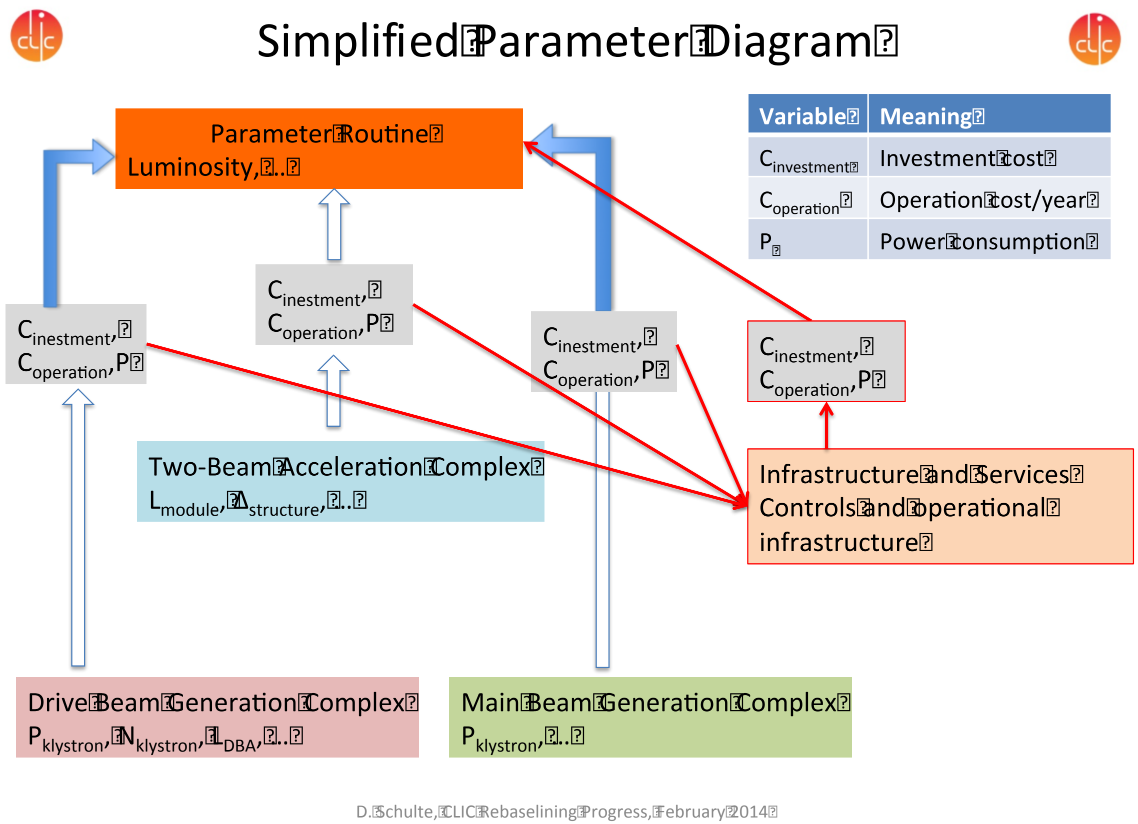


Figure 24: Estimated yearly energy consumption of CLIC [TWh/year].

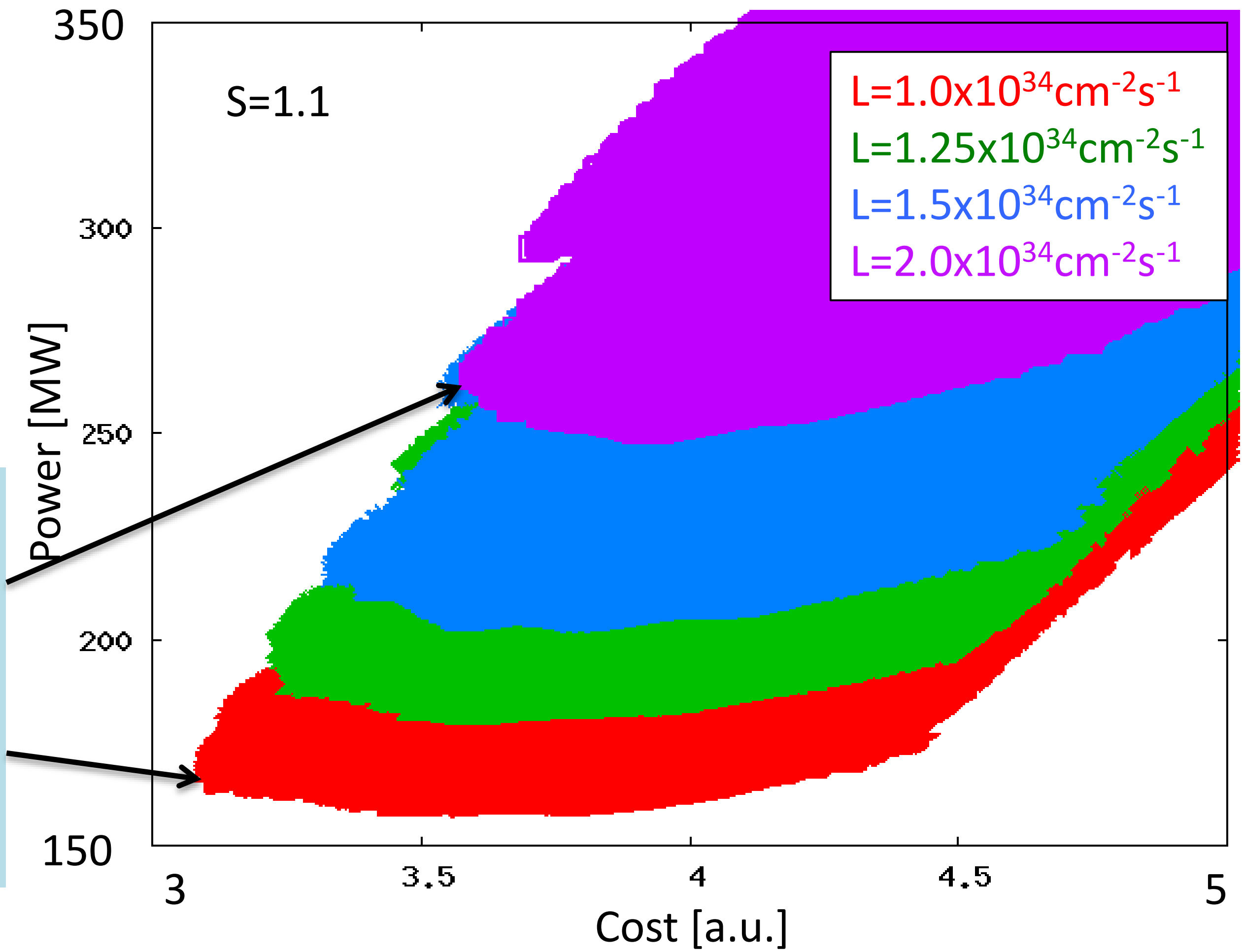
380 GeV stage optimization



Parameter model

- Does not contain BDS and experiments
- Main beam injector power scaled with charge per train

Example output (380 GeV)



Luminosity goal impacts minimum cost
For $L=1\times10^{34}cm^{-2}s^{-1}$ to $L=2\times10^{34}cm^{-2}s^{-1}$:

Costs 0.5 a.u.
And O(100MW)

Cheapest machine is close to lowest power consumption => small potential for trade-off

LINEAR COLLIDER COLLABORATION

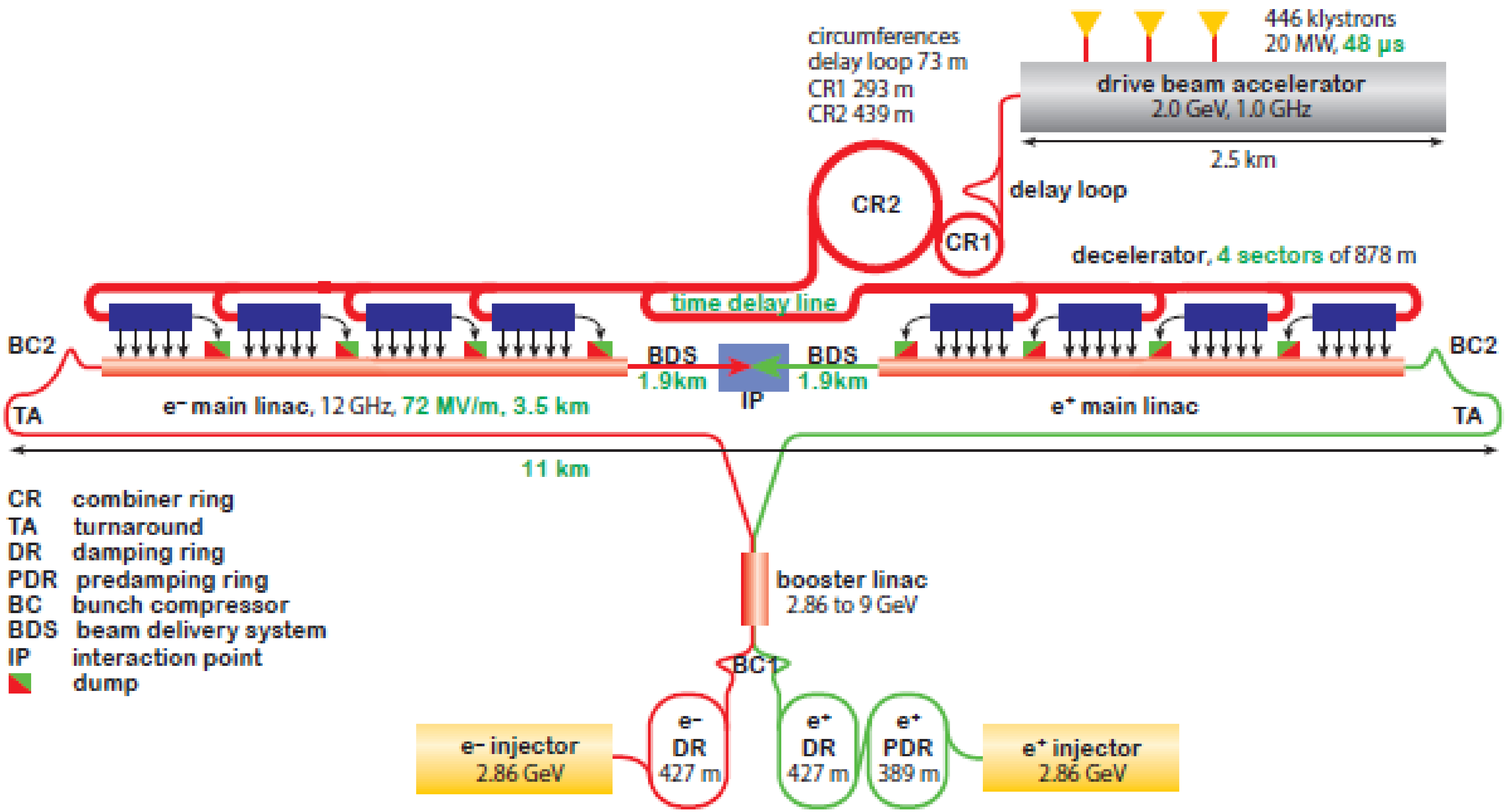
Current rebaselined parameters

Table 9: Parameters for the CLIC energy stages. The power consumptions for the 1.5 and 3 TeV stages are from the CDR; depending on the details of the upgrade they can change at the percent level.

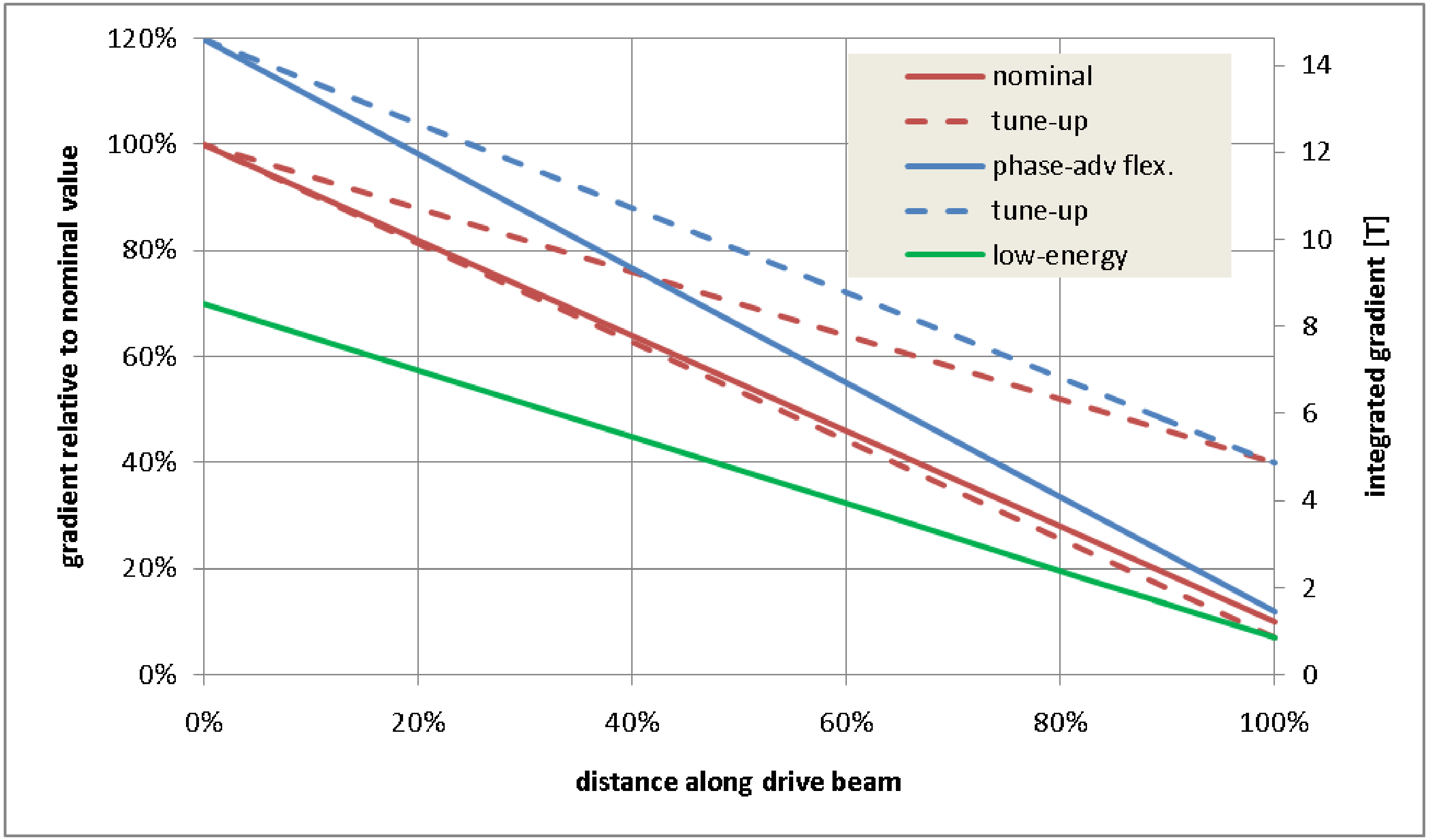
Parameter	Symbol	Unit	Stage 1	Stage 2	Stage 3
Centre-of-mass energy	$\sqrt{s}$	GeV	380	1500	3000
Repetition frequency	f_{rep}	Hz	50	50	50
Number of bunches per train	n_b		352	312	312
Bunch separation	Δt	ns	0.5	0.5	0.5
Pulse length	τ_{RF}	ns	244	244	244
Accelerating gradient	G	MV/m	72	72/100	72/100
Total luminosity	$\mathscr{L}$	10^{34} cm^{-2}s^{-1}	1.5	3.7	5.9
Luminosity above 99% of $\sqrt{s}$	$\mathscr{L}_{0.01}$	10^{34} cm^{-2}s^{-1}	0.9	1.4	2
Main tunnel length		km	11.4	29.0	50.1
Number of particles per bunch	N	10^9	5.2	3.7	3.7
Bunch length	σ_z	µm	70	44	44
IP beam size	σ_x/σ_y	nm	149/2.9	$\sim$ 60/1.5	$\sim$ 40/1
Normalised emittance (end of linac)	$\varepsilon_x/\varepsilon_y$	nm	920/20	660/20	660/20
Normalised emittance (at IP)	$\varepsilon_x/\varepsilon_y$	nm	950/30	—	—
Estimated power consumption	P_{wall}	MW	252	364	589

"Updated Baseline for a staged Compact linear Collider", to be published

New CLIC layout 380 GeV

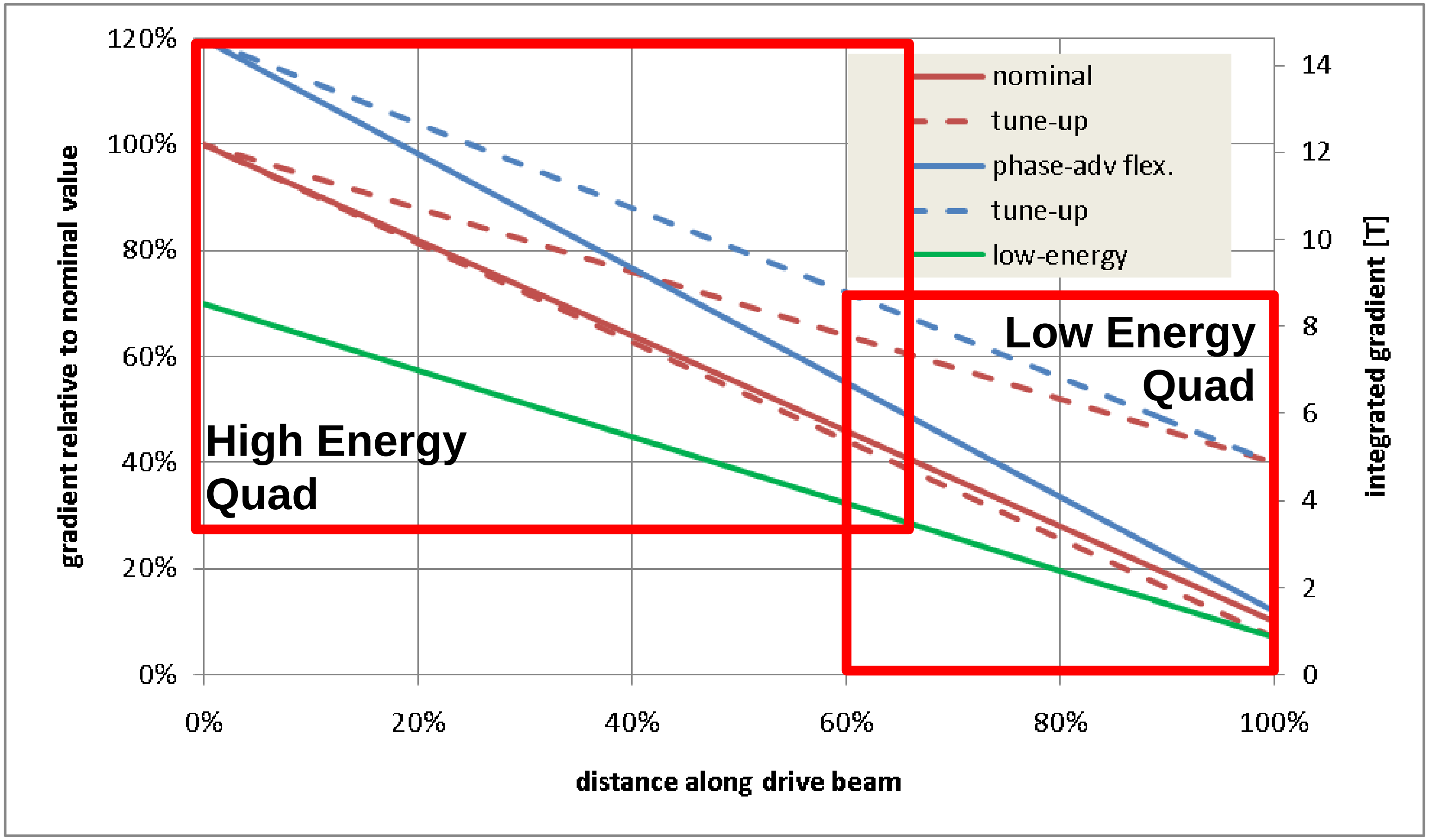


Drive beam quadrupoles (40 MW @ 3 TeV)



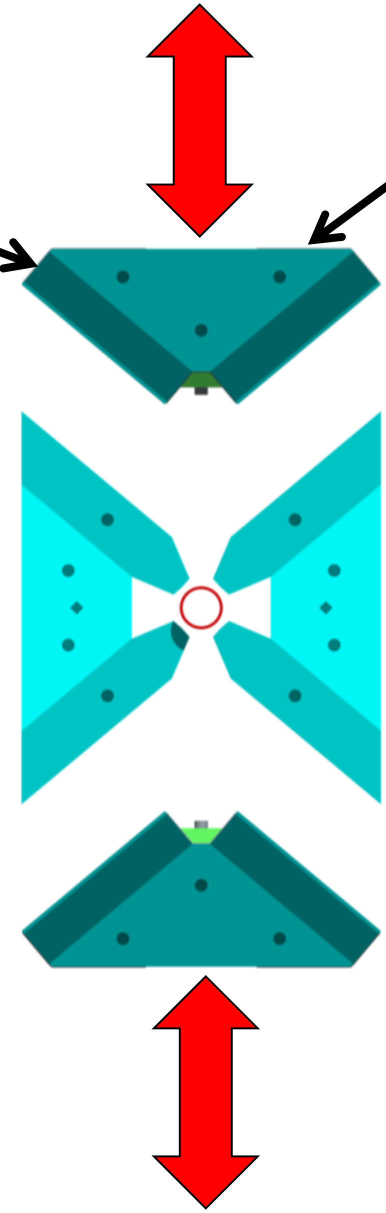
High energy quad – Gradient very high
Low energy quad – Very large dynamic range

Permanent Magnet solution



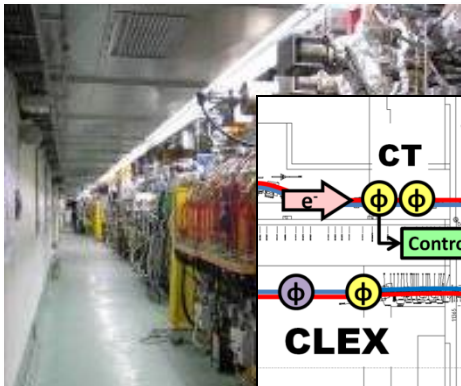
High energy quad – Gradient very high
Low energy quad – Very large dynamic range

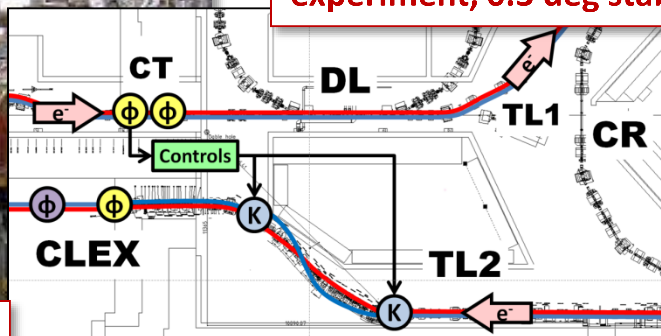
PM engineering concept



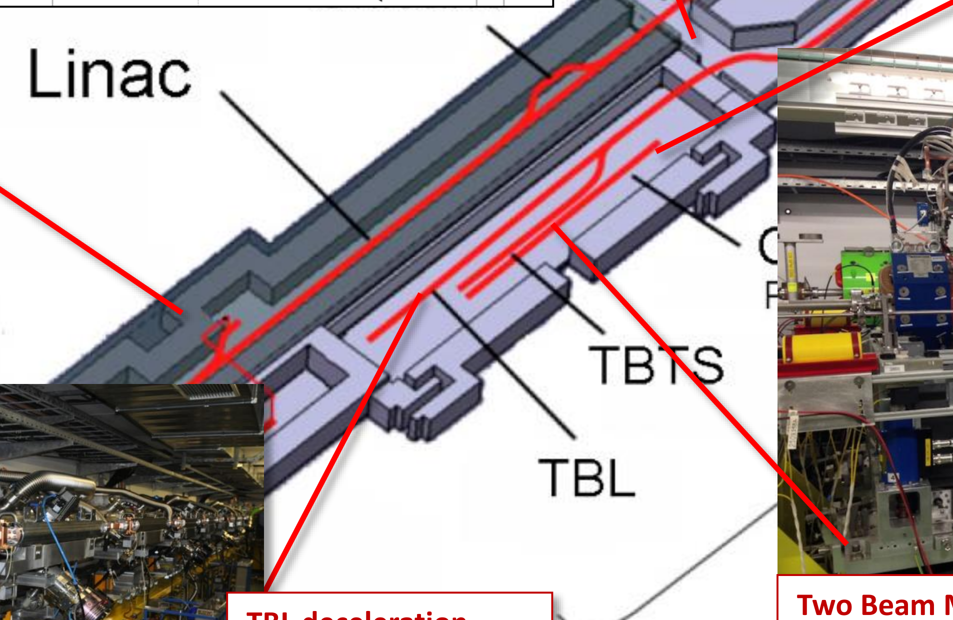
Jim Clarke, STFC

CTF3: 2016



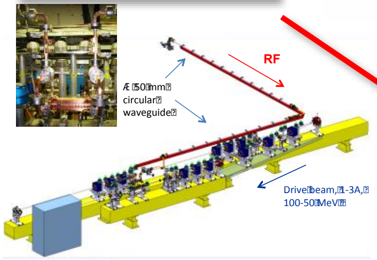


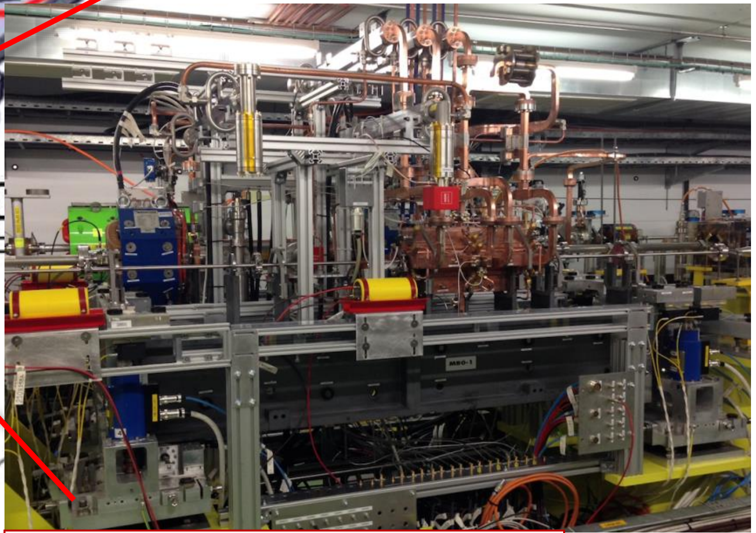
Phase feed-forward experiment, 0.3 deg stability



Diagnostics R&D using CALIFES

Dogleg Beam loading experiment





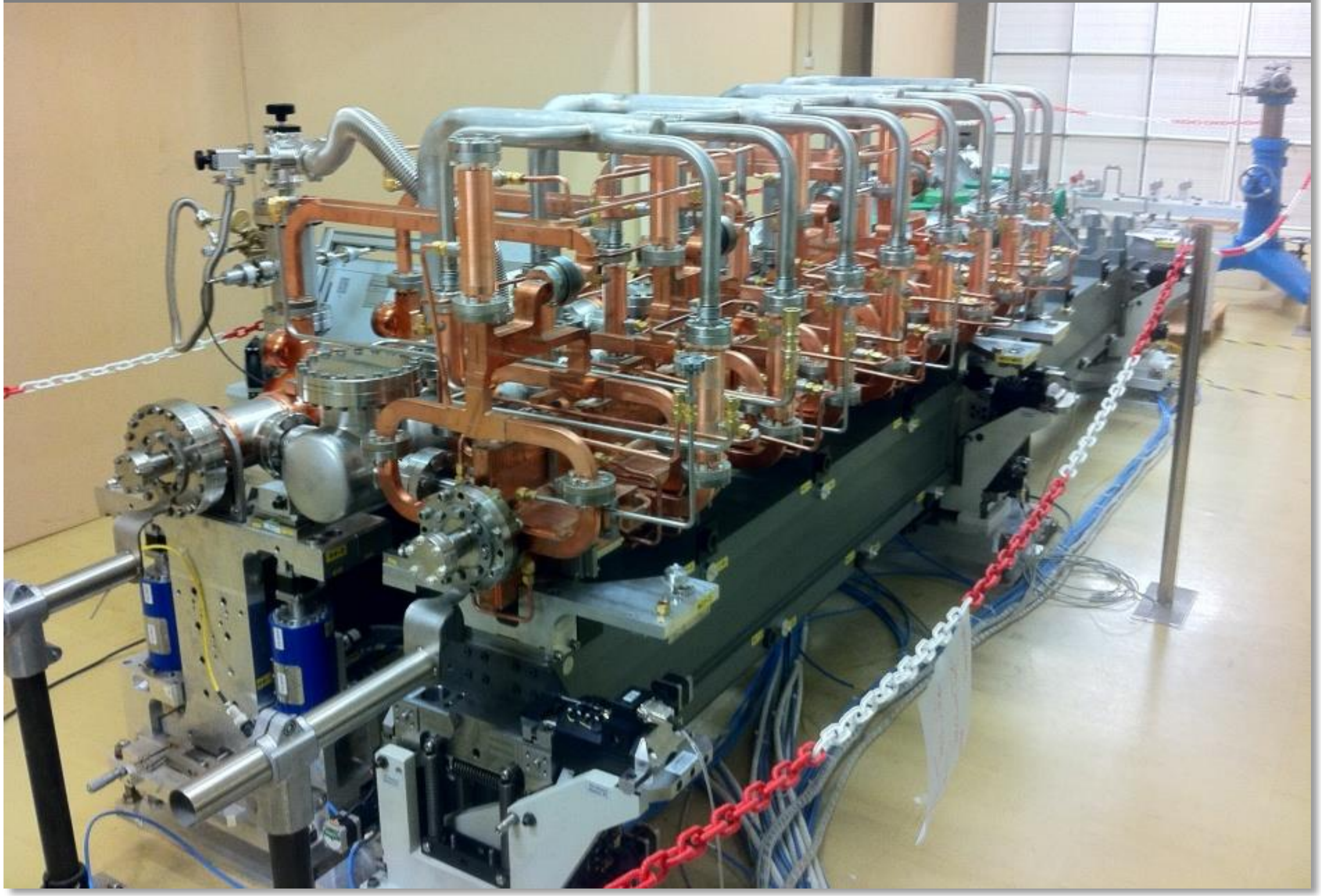
TBL deceleration
>50 % deceleration
1.3 GW rf power

Two Beam Module,
Wake-field monitors ~ 5 um resolution
150 MV/m acceleration,

CLIC two beam module

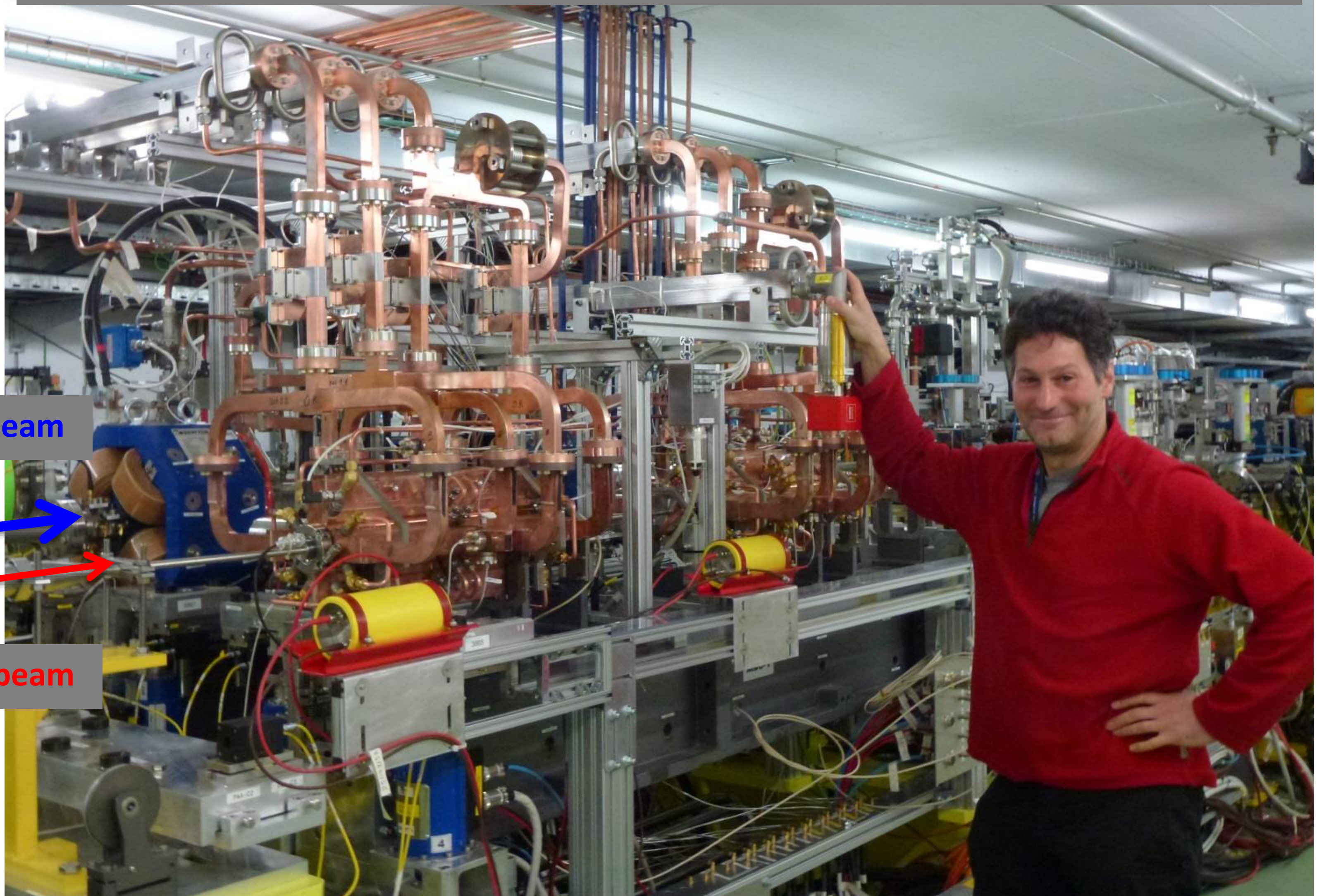
Module mechanical characterization test stand:

active alignment (10 um), fiducialisation + stabilization (PACMAN)



CLIC two beam module

Fully functioning 2-beam acceleration module in CTF3
(two beam acceleration, wake field monitors, alignment)

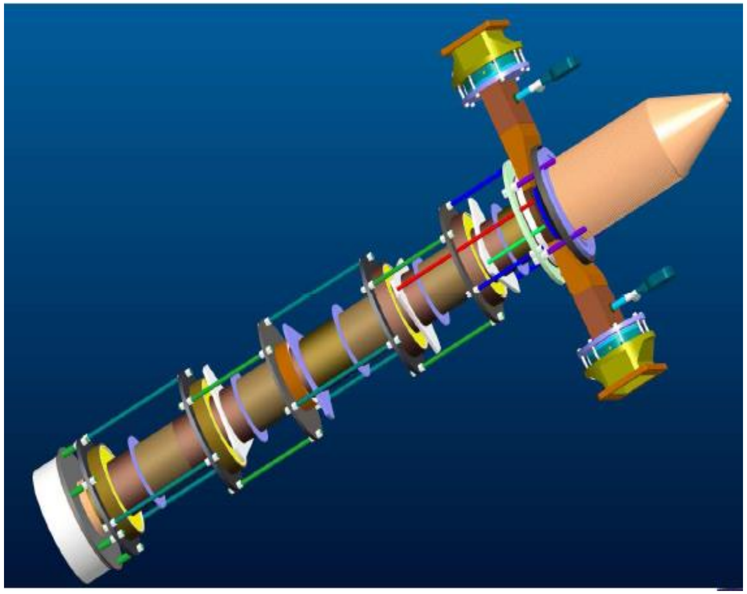


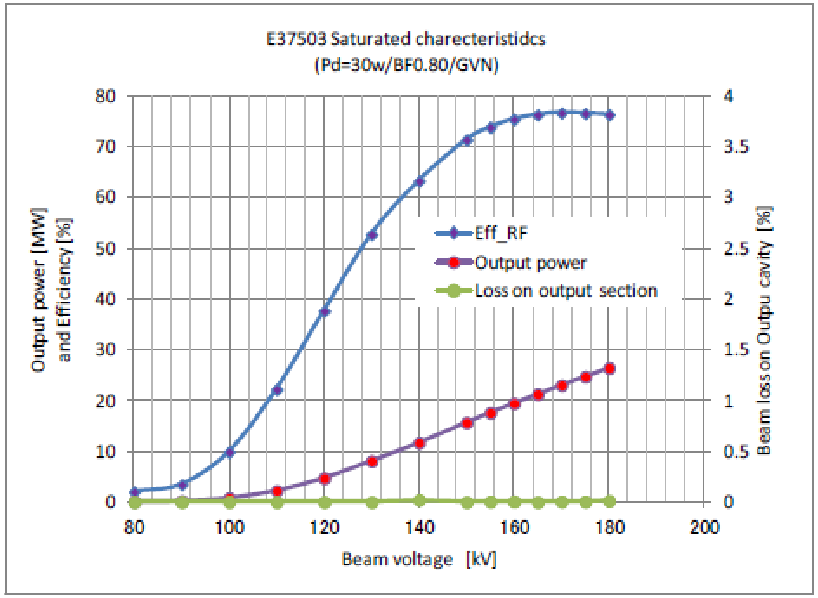
Very high efficiency power sources

Multi beam klystrons
1 GHz, 20 MW, 150 ms, 50 Hz, > 70% efficiency

Thales Electron Devices:
10 beam multi beam klystrons
77 % efficiency calculated

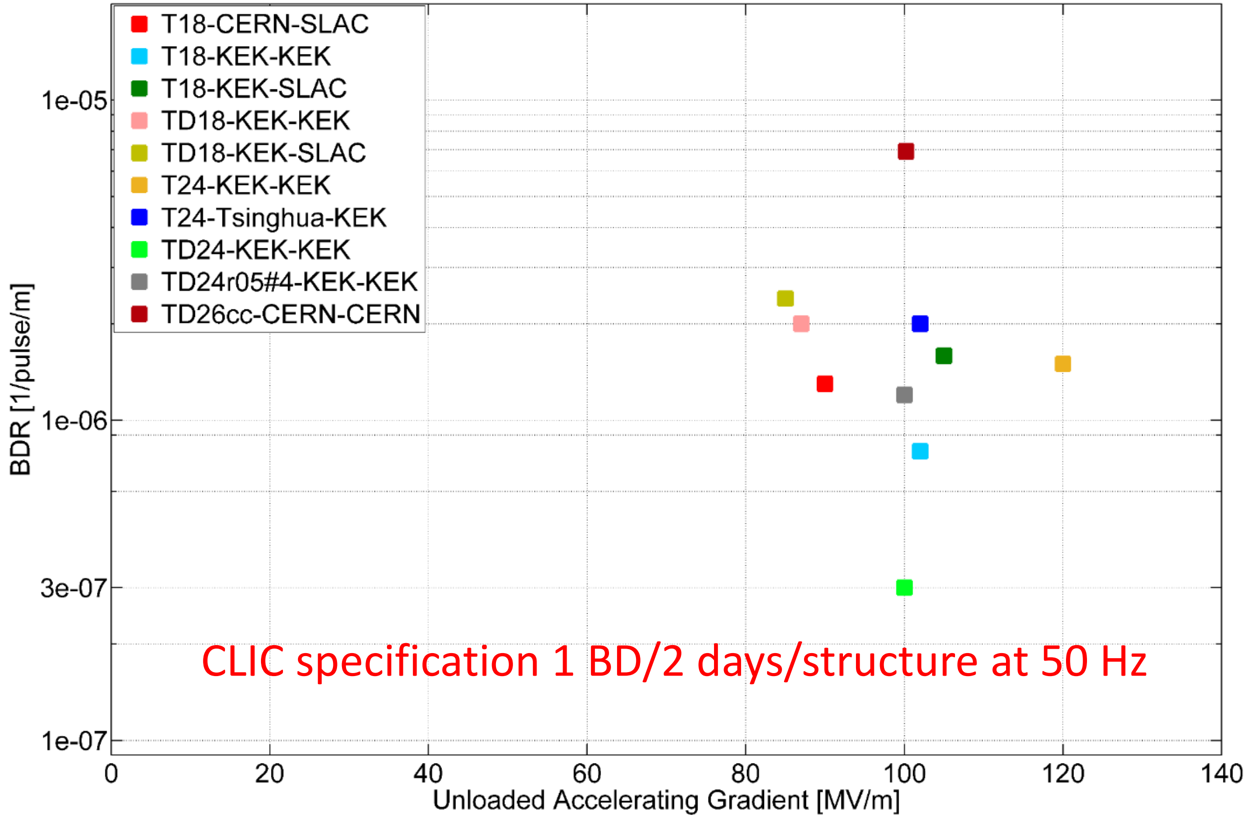
Toshiba:
6 beam multi beam klystrons
75 % efficiency calculated





Delivery and test in summer 2016

CLIC accelerating structure

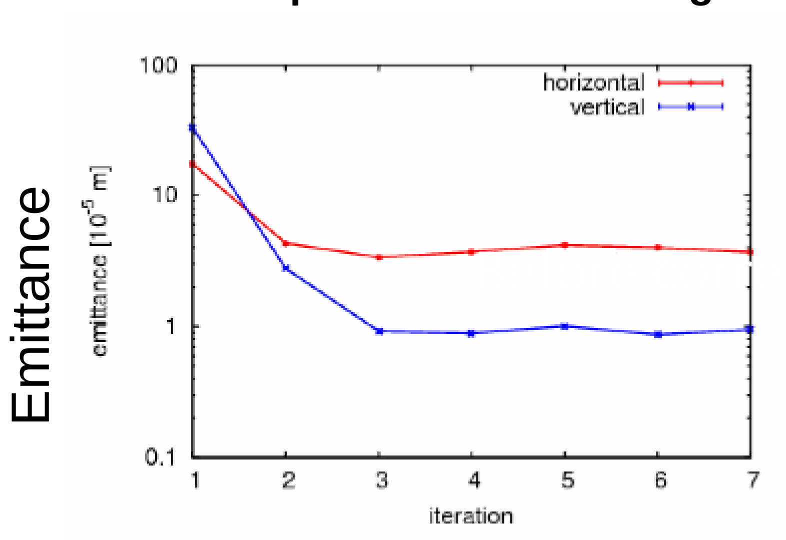


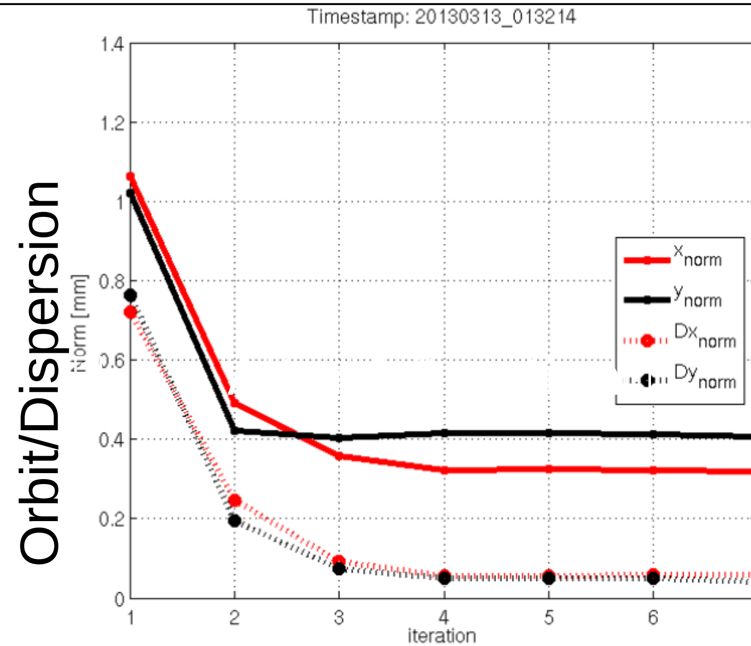
11.994 GHz X-band
100 MV/m
Input power ≈50 MW
Pulse length ≈200 ns
Repetition rate 50 Hz

Increasing testing capabilities for x-band at CERN, 3 klystron based test stands available

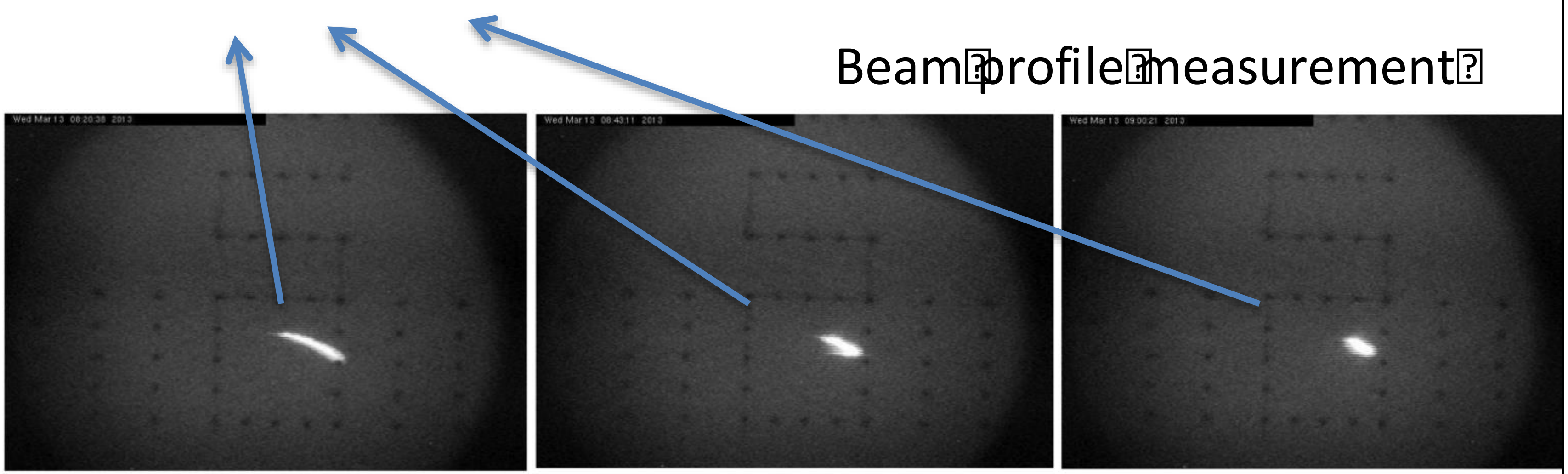
Beam tuning at FACET (SLAC)

Dispersion-free steering





Beam profile measurement

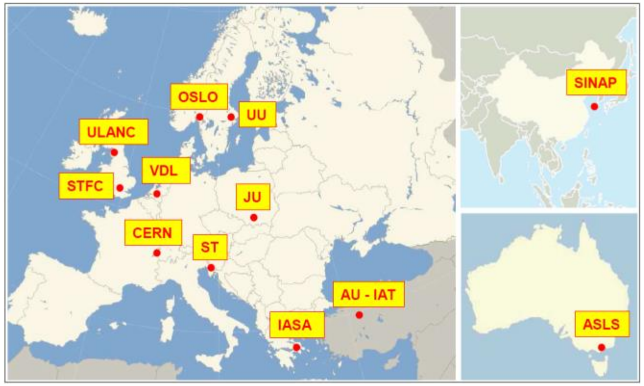


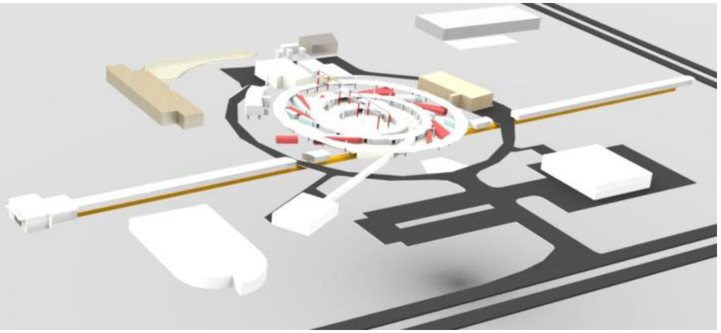
Conclusions

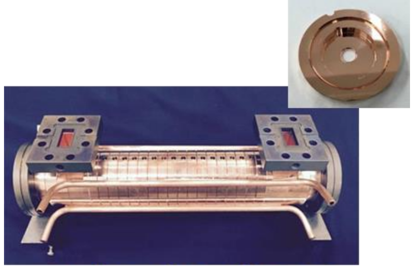
- Preparation phase 2016-19 is well defined and in line with European Strategy
- Prepared to align with LHC physics outcomes as results become available
- Aim to provide optimized staged approach up to 3 TeV with costs and power not excessive compared with LHC, with an initial 380 GeV stage (Watch out for" "Updated Baseline for a staged Compact linear Collider", tbp)
- Excellent progress key technology developments:
  X-band structures, high efficiency power source, two beam modules, drive beam components, permanent magnets, alignment
- Successful performance verifications, drive beam (CTF3), main beam emittance conservation (FACET) and final focus studies (ATF)
- Healthy collaborations for CLIC accelerator studies

Selected collaborations on applications of X-band and high-gradient

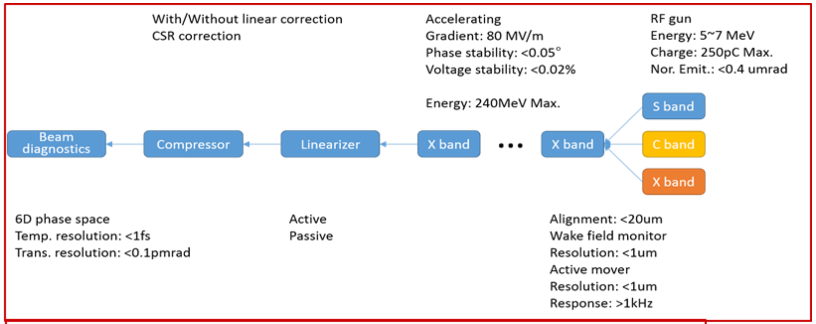
- XbFEL H2020 design study to be resubmitted in 2017.
- XBox3-B to Australian light source, Monash University proposal.
- X-band deflector and accelerating structure testing for X-band option for XFEL at SINAP.
- X-band linearizer system with Fermi@Trieste and SwissFEL







X-band Deflector

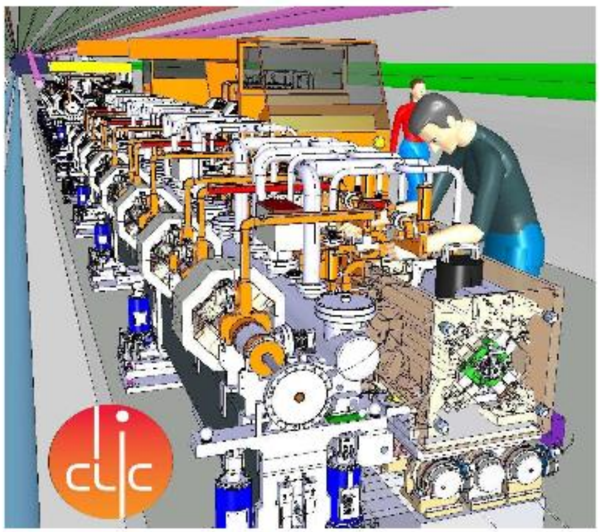


X-band Accelerator Test Facility plan at SINAP

CDR (2012)

SLAC-R-985
KEK Report 2012-
PSI-12-01
JAI-2012-001
CERN-2012-007
12 October 2012

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH



A MULTI-TEV LINEAR COLLIDER
BASED ON CLIC TECHNOLOGY

CLIC CONCEPTUAL DESIGN REPORT

GENEVA
2012

ANL-HEP-TR-12-01
CERN–2012–003
DESY 12-008
KEK Report 2011-7
14 February 2012

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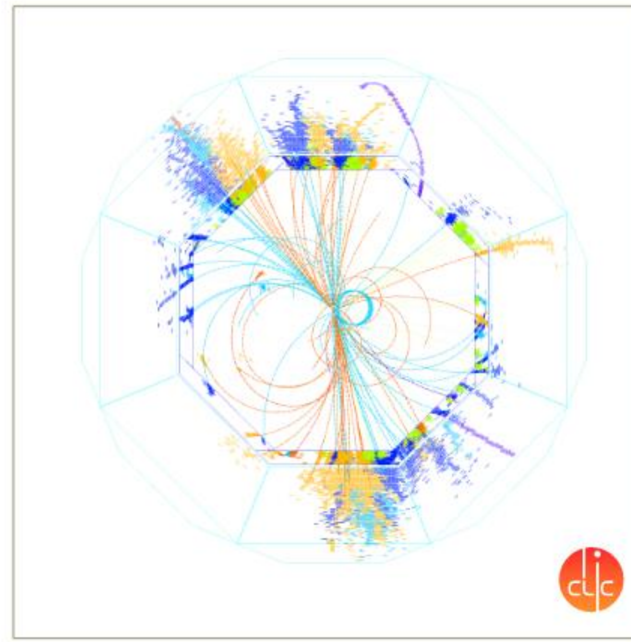


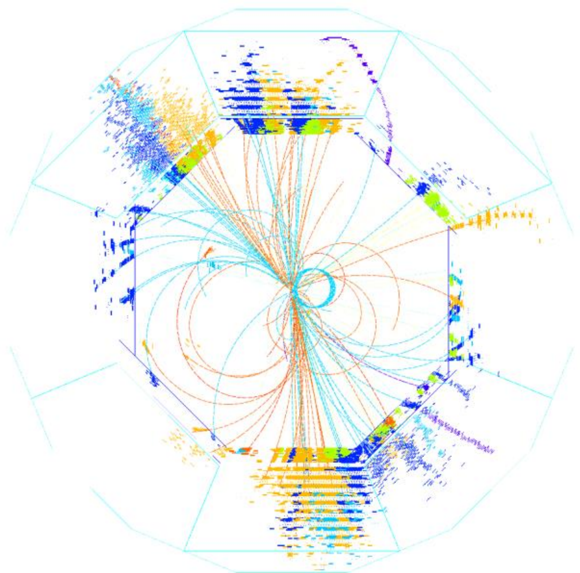
PHYSICS AND DETECTORS AT CLIC

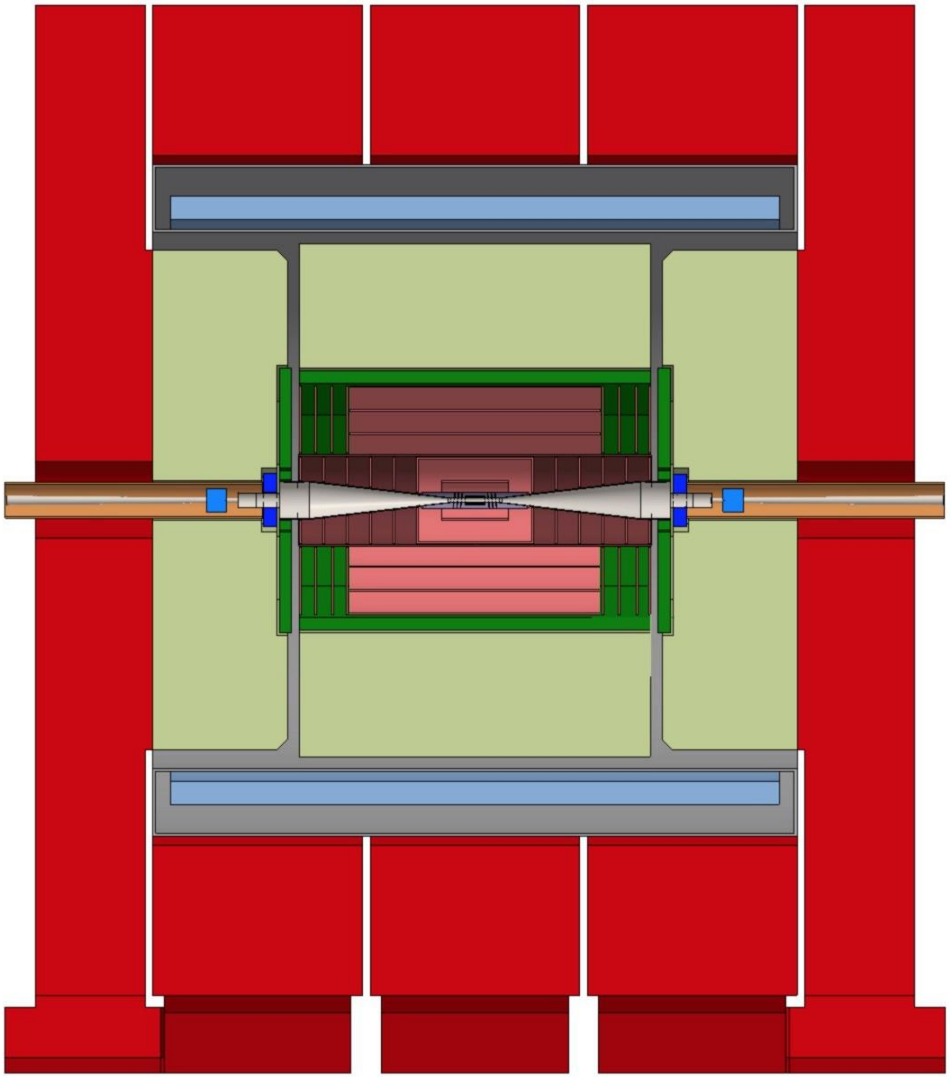
CLIC CONCEPTUAL DESIGN REPORT

CLIC detector concept

ILC concepts adapted to a single detector for CLIC:

- **Highly-granular, deep calorimeter**
- **4T solenoid**
- **Low-mass Si tracking system**
- **Precision vertexing close to IP**
- **10ns time-stamping**





CLIC energy staging (CDR)

Energy-staging exercise for updated base line