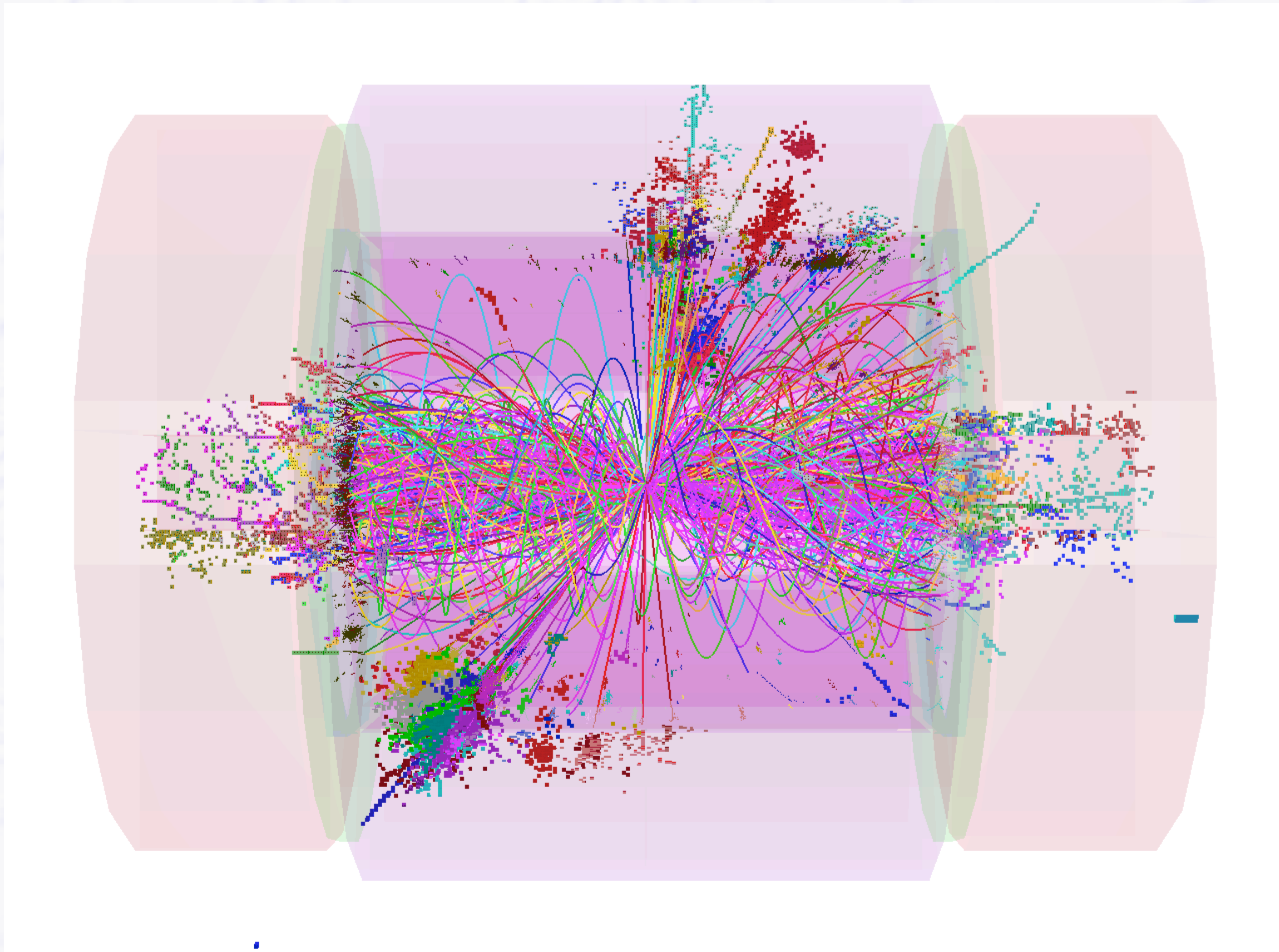
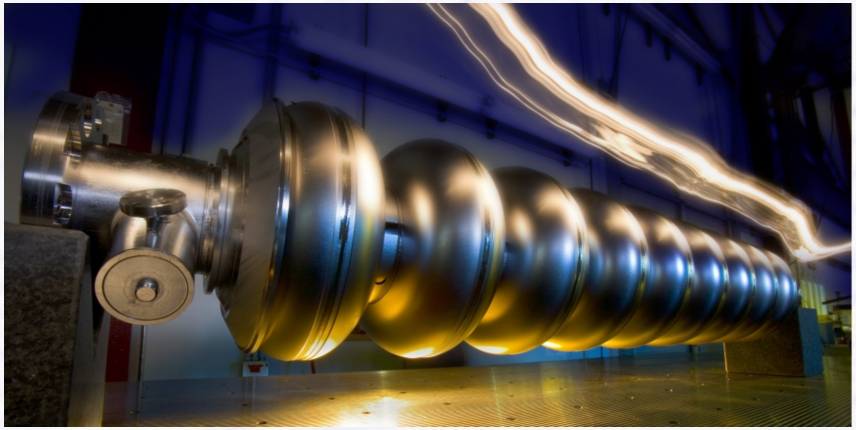
CLIC Status



$e^+e^- \rightarrow H^+H^- \rightarrow t\bar{b}b\bar{t}$ + background, E_{cm} = 3 TeV

ILC and CLIC Technologies

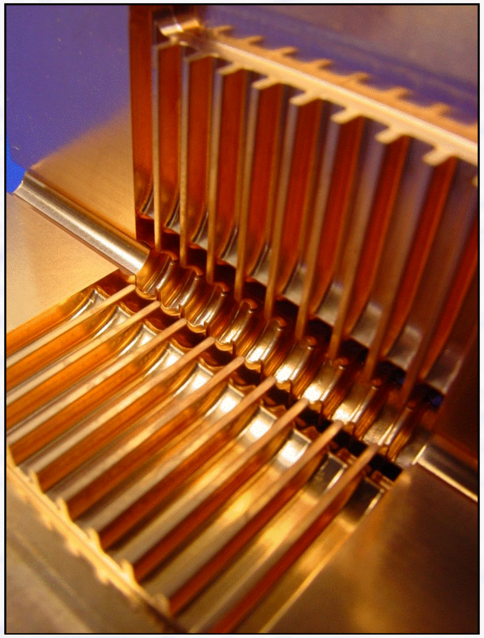
ILC



- Based on superconducting RF cavities
- Gradient 32 MV/m
- **Energy: 500 GeV, upgradeable to 1 TeV**
  (possible GigaZ factory at 90 GeV or ZZ factory at ~200 GeV is also considered)
- Detector studies focus mostly on 500 GeV

technology available

CLIC



- Based on 2-beam acceleration scheme (warm cavities)
- Gradient 100 MV/m
- **Energy: 3 TeV**, though will probably start at lower energy (~0.5 TeV)
- Detector study focuses on 3 TeV

feasibility still to be demonstrated

The CLIC Two Beam Scheme

Two Beam Scheme

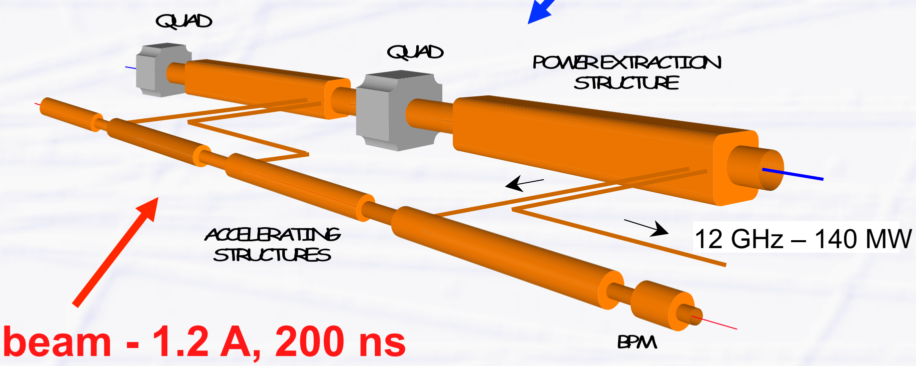
Drive Beam supplies RF power

- 12 GHz bunch structure
- low energy (2.4 GeV - 240 MeV)
- high current (100A)

Main beam for physics

- high energy (9 GeV – 1.5 TeV)
- current 1.2 A

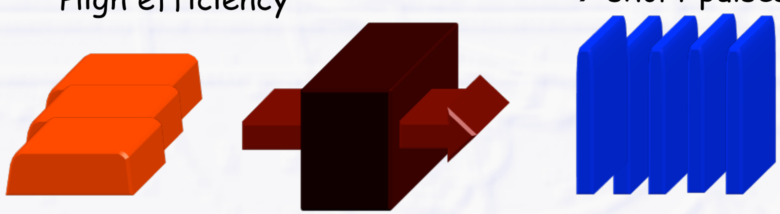
Drive beam - 100 A, 240 ns from 2.4 GeV → 240 MeV (deceleration by extraction of RF power)



Main beam - 1.2 A, 200 ns from 9 GeV → 1.5 TeV

'few' Klystrons
Low frequency
High efficiency

Accelerating Structures
High Frequency – High field
→ short pulses



Long RF Pulses
P_0 , τ_0

Electron beam manipulation :
Power compression,
Frequency multiplication

Short RF Pulses
$P_A = P_0 \times N$
$\tau_A = \tau_0 / N$

No individual RF power sources
→
CLIC itself is basically a ~50 km long klystron...

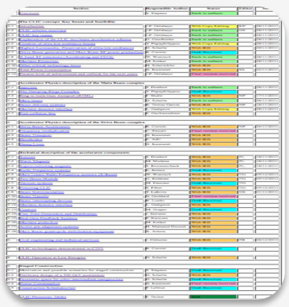
Main CLIC Parameters

- **CLIC is designed and optimized for √s = 3 TeV**
  - **also under study: 500 GeV initial**
  - **new: possible 1.5 TeV intermediate energy (no detailed studies yet)**

parameter	symbol		new	
centre of mass energy	E_{cm} [GeV]	500	1500	3000
luminosity	$\mathcal{L}$ $[10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}]$	2.3	3.8	5.9
luminosity in peak	$\mathcal{L}_{0.01}$ $[10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}]$	1.4	1.5	2
gradient	G [MV/m]	80	100	100
site length	[km]	13	28	48.3
charge per bunch	N $[10^9]$	6.8	3.7	3.7
bunch length	σ_z [μm]	70	44	44
IP beam size	σ_x/σ_y [nm]	200/2.26	?/?	40/1
norm. emittance	ϵ_x/ϵ_y [nm]	2400/25	660/20	660/20
bunches per pulse	n_b	354	312	312
distance between bunches	Δ_b [ns]	0.5	0.5	0.5
repetition rate	f_r [Hz]	50	50	50
est. power cons.	P_{wall} [MW]	240	340	560

The CLIC CDRs

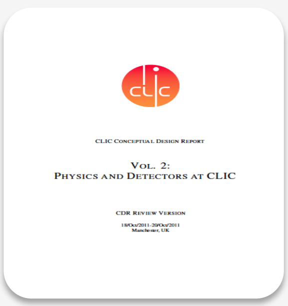
- **3 volumes of CLIC CDR under preparation in 2011/12**



Vol 1: The CLIC accelerator and site facilities (H.Schmickler)

- 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
- Complete by end of 2011, final editing before presented in the SPC In March 2012

http://project-clic-cdr.web.cern.ch/project-CLIC-CDR/



Vol 2: Physics and detectors at CLIC (L.Linssen)

- Physics at a multi-TeV CLIC machine can be measured with high precision, despite challenging background conditions
- External review procedure in October
- Completed end 2011, presented in SPC in December 2011 (Lucie Linssen)

http://lcd.web.cern.ch/LCD/CDR/CDR.html#Overview

Vol 3: "CLIC study summary" (S.Stapnes)

- 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)
- Summer 2012: Ready for the European Strategy Open Meeting

- Main information page: http://clic-study.org/accelerator/CLIC-ConceptDesignRep.php
- Signatory list for the CLIC CDR on the main information page: https://indico.cern.ch/conferenceDisplay.py?confId=136364

CLIC Signatories List

- https://indico.cern.ch/conferenceDisplay.py?confId=136364
  - (was) open until 6 February, 23h
  - anyone can sign: CDR contributors or/and supporters (accelerator, detector, physics)

CDR Signatories List

1308 signatories

- Subscribe here
- List of signatories
- CLIC website
- Linear Collider Detector @ CERN
- CLIC CDR Vol. 1 - Accelerator
- CLIC CDR Vol.2 - Physics and Detectors

CDR signatories help (please don't use this e-mail to sign up - help only!)

The CLIC Conceptual Design Report (CDR) summarizes the concept of a Linear Collider based on the CLIC technology, its physics case and the expected performance and design of the physics detectors. A draft version of CDR Volume 1 (CLIC Accelerator) and the final version of Volume 2 (Physics and Detectors) are available (links in the menu on the left).

You are cordially invited to subscribe to the CDR Signatories List:

- If you have made contributions to the CLIC accelerator or the Linear Colliders Physics and Detector studies, or intend to contribute in the future,

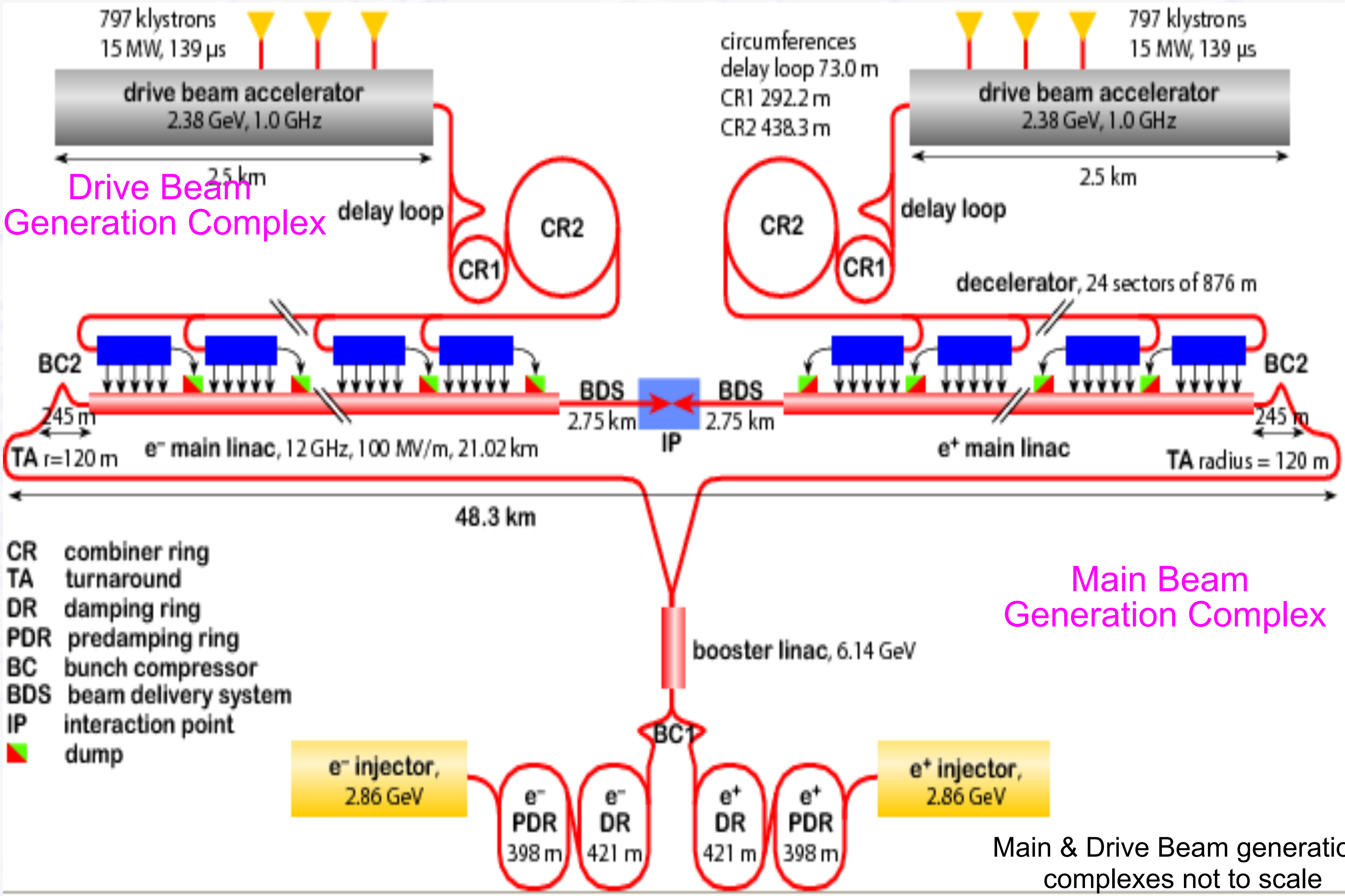
OR / AND

- If you wish to express support to the physics case and the study of a multi-TeV Linear Collider based on the CLIC technology, and its detector concepts[1].

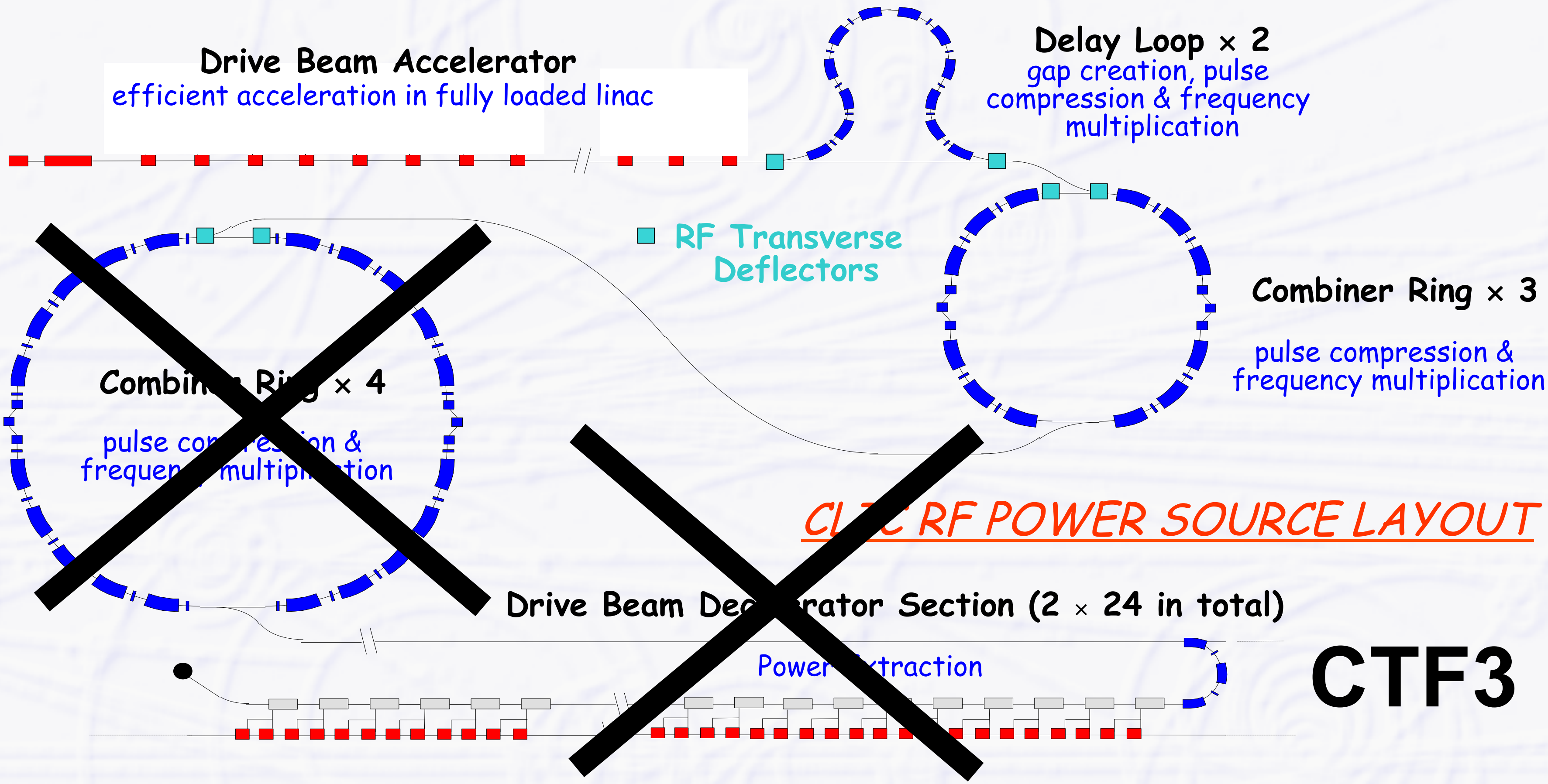
1 Note that signing the CDR does not imply an expression of exclusive support for CLIC versus other major collider options under development.

Dates: from 08 September 2011 08:00 to 06 February 2012 23:00
Timezone: Europe/Zurich
Location: *CERN*

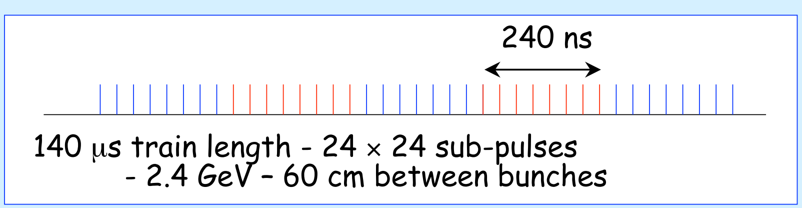
CLIC Layout 3 TeV



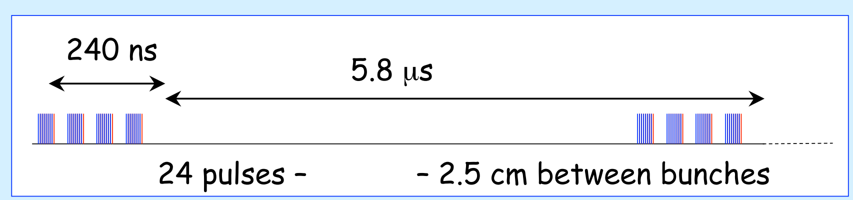
CLIC power source versus CLIC Test Facility 3

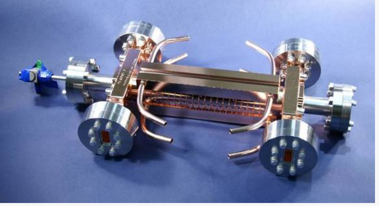


Drive beam time structure - initial

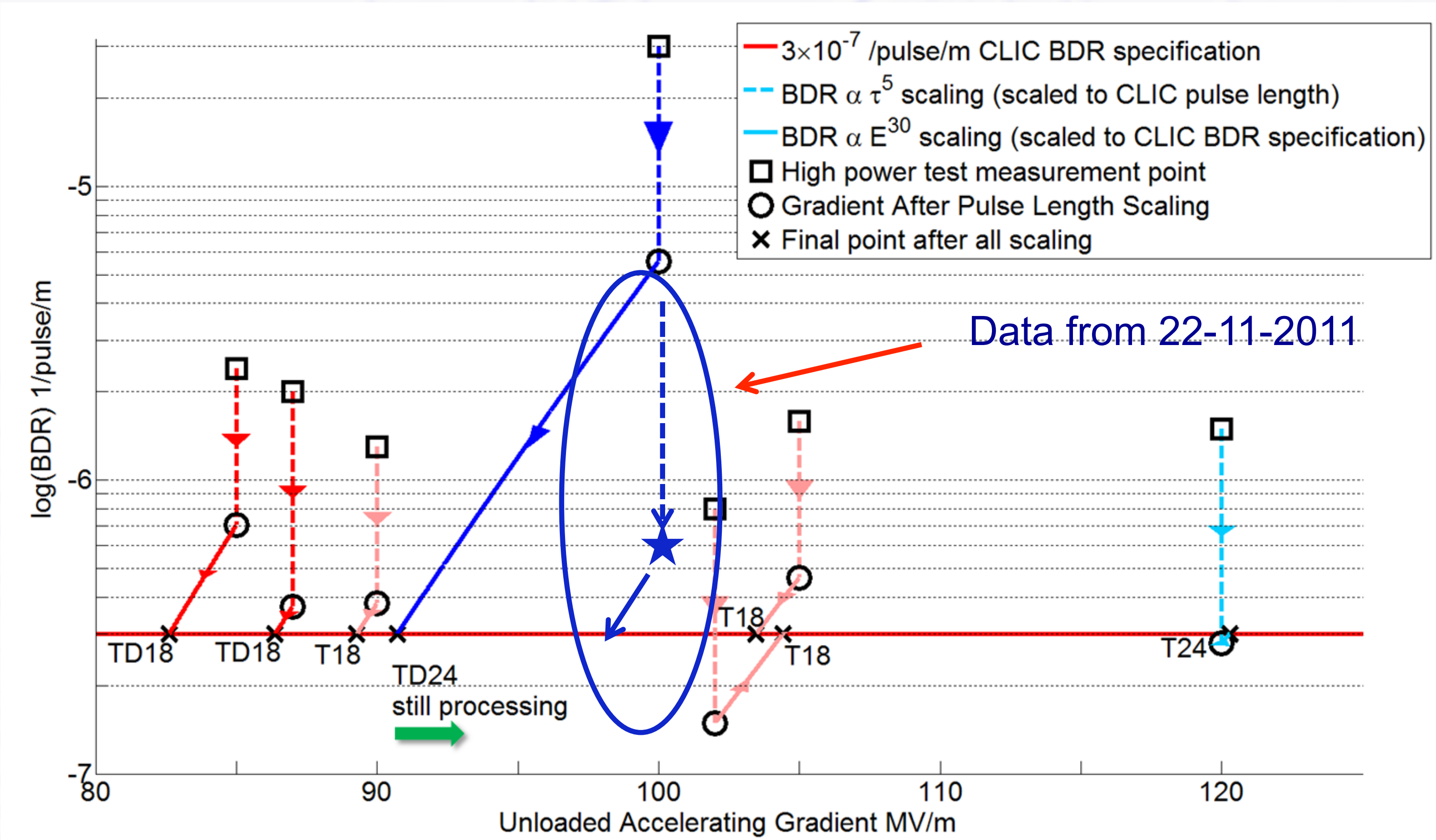


Drive beam time structure - final





Achieved Gradient



Measurements scaled according to:

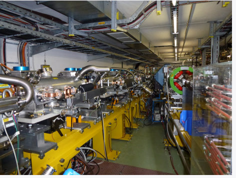
$$p \propto G^{30}\tau^{5}$$

Require breakdown probability 1% per pulse i.e. $\leq 3\text{x}10^{-7}\text{m}^{-1}\text{pulse}^{-1}$

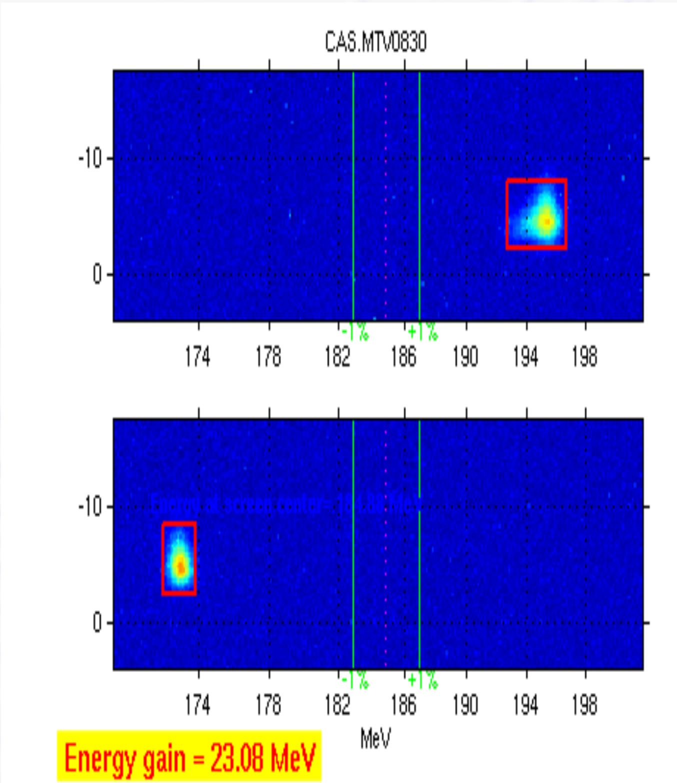
TD24:

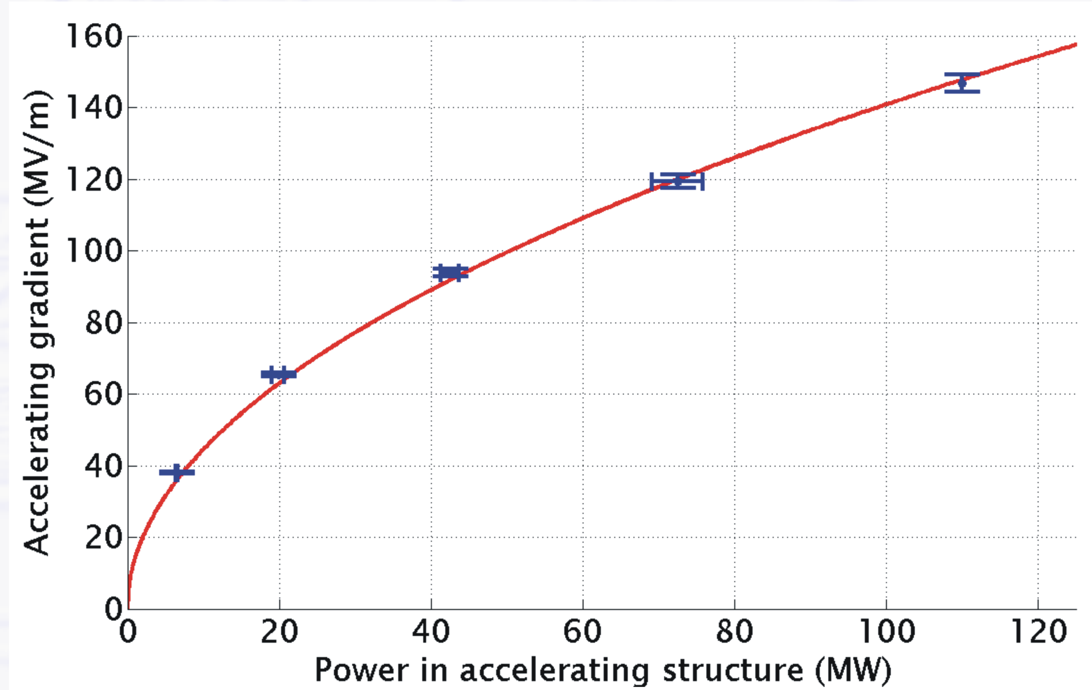
- September 15th @ KEK
- Mid-November @ SLAC
- Soon @ CERN

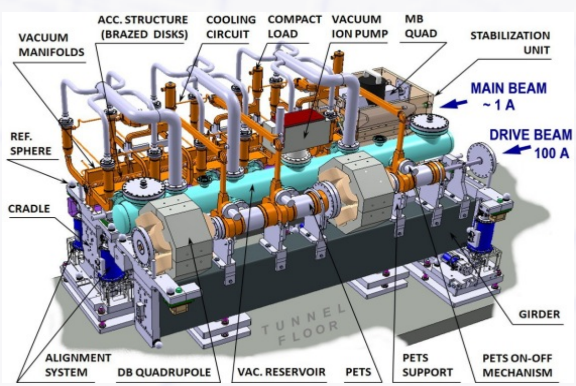
	Simple early design	More efficient fully optimised structure
No damping waveguides	T18	T24
Damping waveguides	TD18	TD24 = CLIC goal



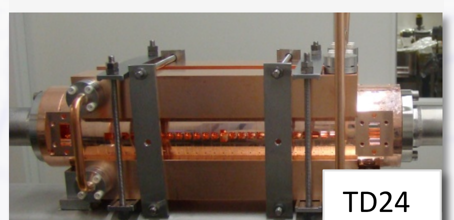
TBTS: Two Beam Acceleration







Maximum gradient
145 MV/m



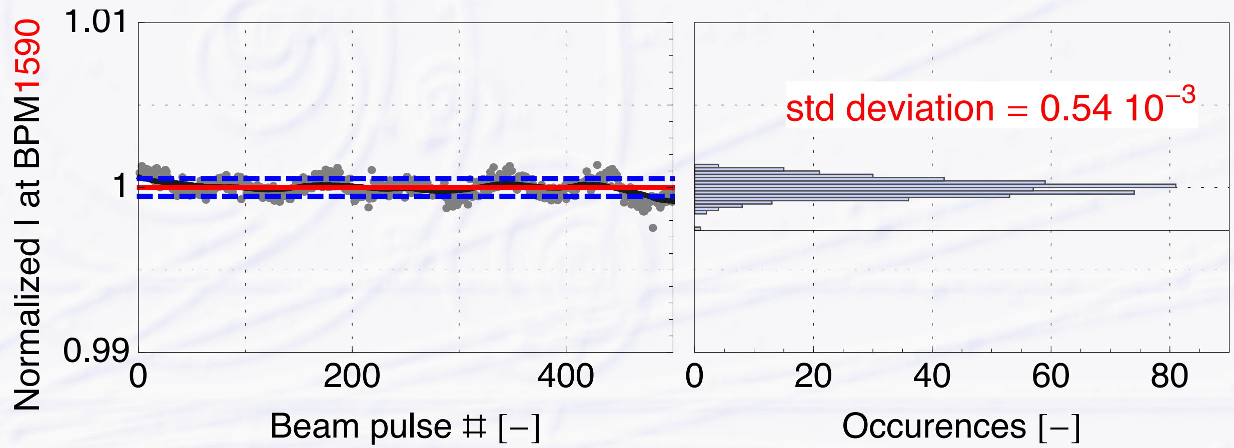
Consistency between
- produced power
- drive beam current
- test beam acceleration

CTF3 drive beam and experiments

Pulse charge measured at end of the linac (figure on the right):

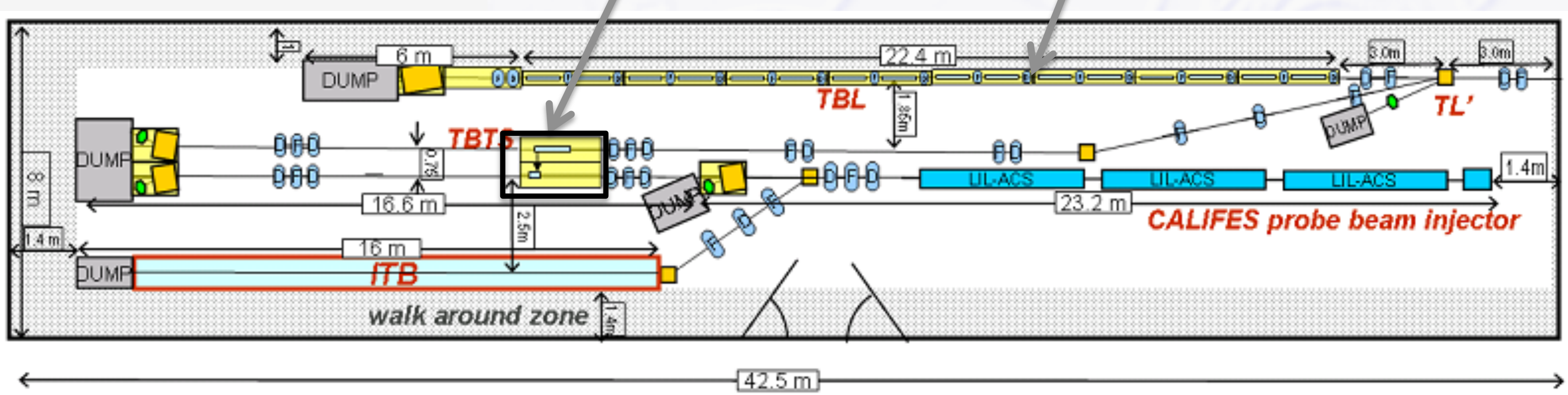
After factor 8 combination ~ 1% jitter, improvements underway, already showing significant improvement in a factor 4 combined beam. The issues are:

- RF pulse compression
- Beam energy in combiner ring is 5% of that in CLIC
- Geometric emittance 20 times larger
- Instrumentation/calibration

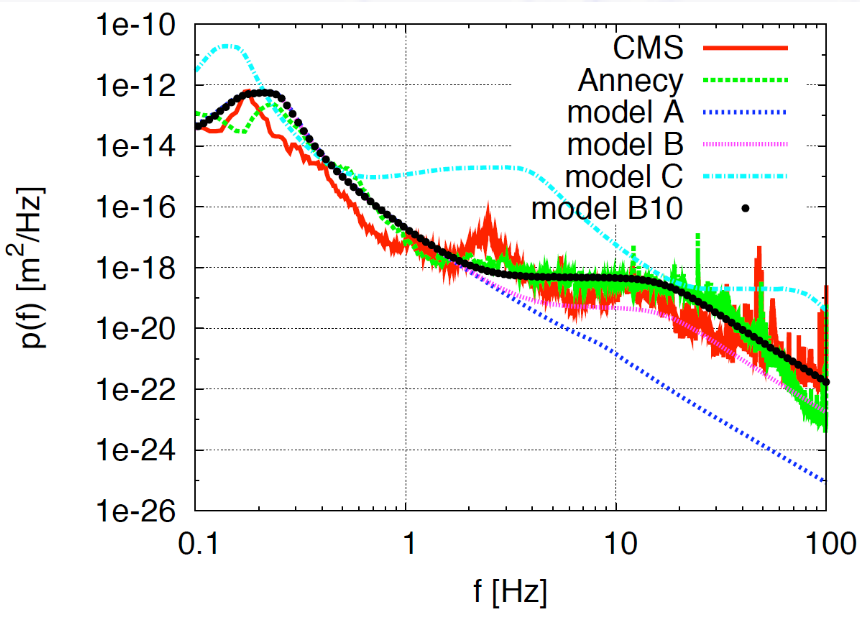


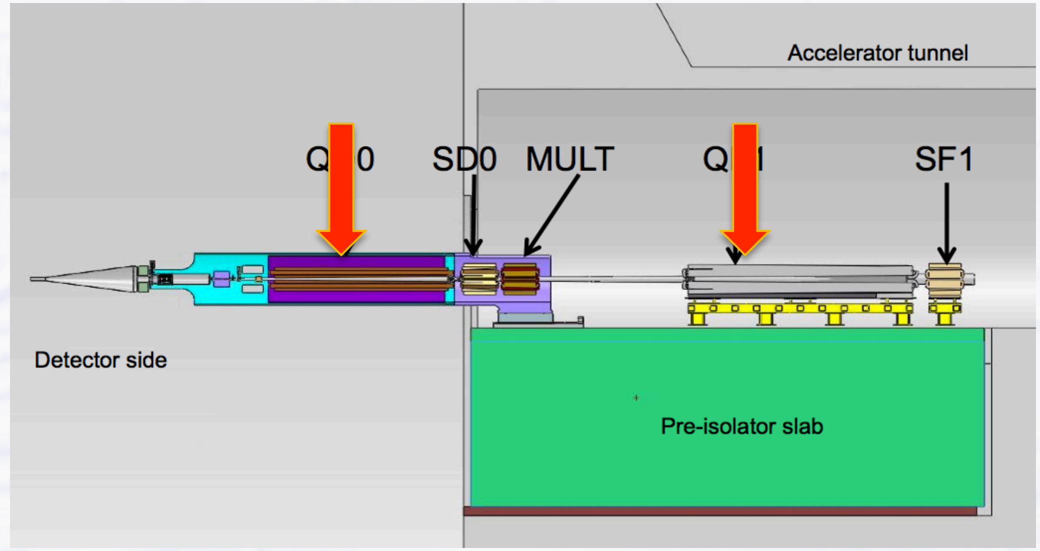
TBTS (two-beam test stand)
- power transfer to main beam
- module design

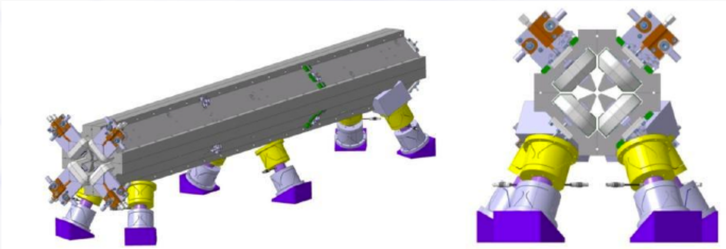
TBL (test beam line)
- drive beam stability during deceleration



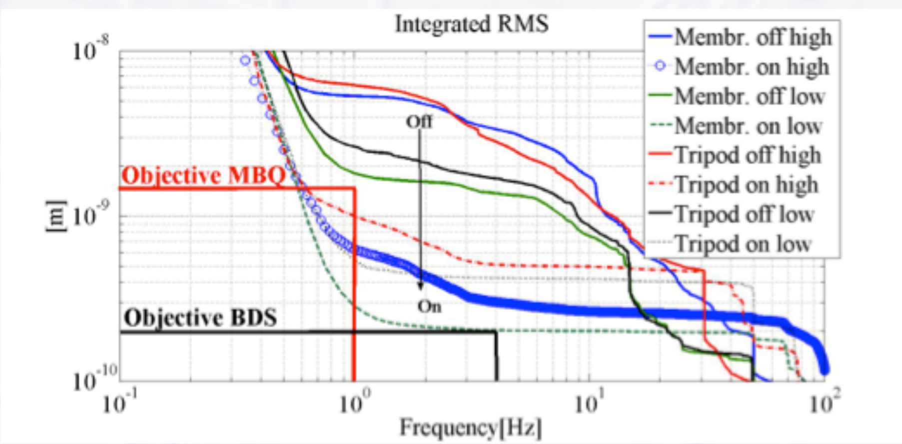
Stability: Ground Motion & Mitigation







Natural ground motion: typical quadrupole jitter tolerance *O*(1nm) in main linac and *O*(0.1nm) in final doublet

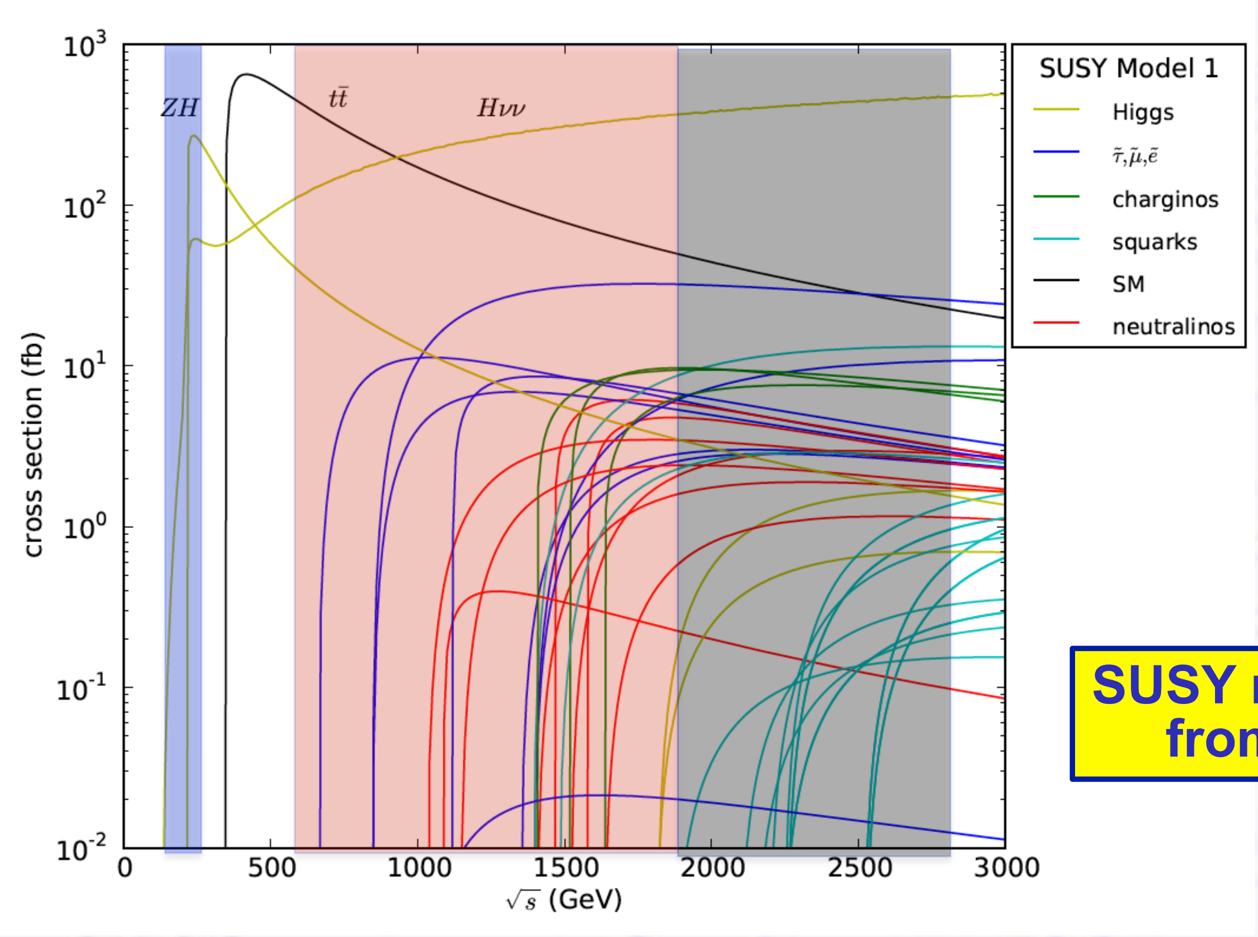


Luminosity achieved/lost [%]

	model A	model B10
No stab.	119%/2%	53%/68%
Current stab.	116%/5%	108%/13%
Future stab.		118%/ 3%

Energy Flexibility

- **SUSY discovery might require running a Linear Collider at various energies → energy flexibility is needed**
  - **CLIC @ 3 TeV is optimized for highest luminosity → luminosity drops significantly if running at lower energies → no "simple" energy scan**



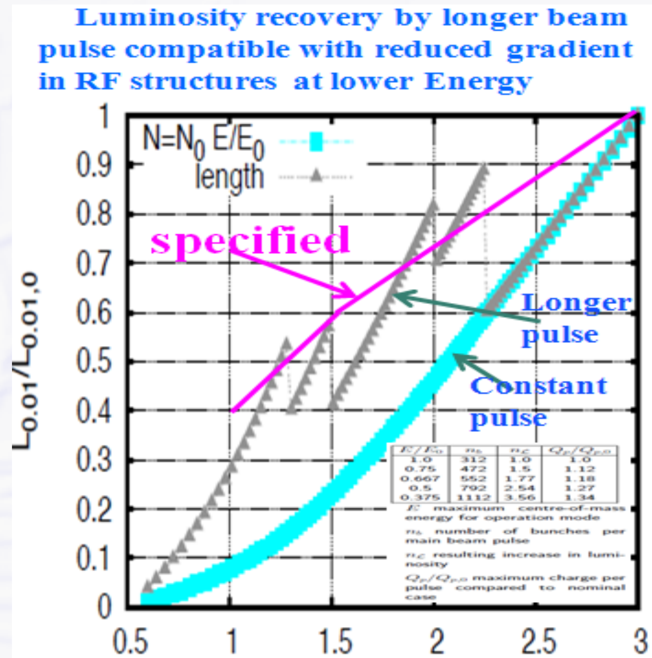
Way out:

increase pulse length (longer bunch train) at lower energy + staging of machine

→ luminosity drop compensated

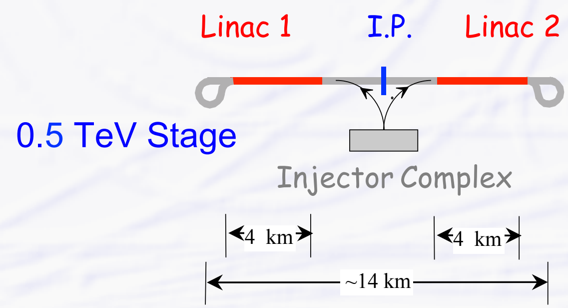
SUSY model 1 from CDR

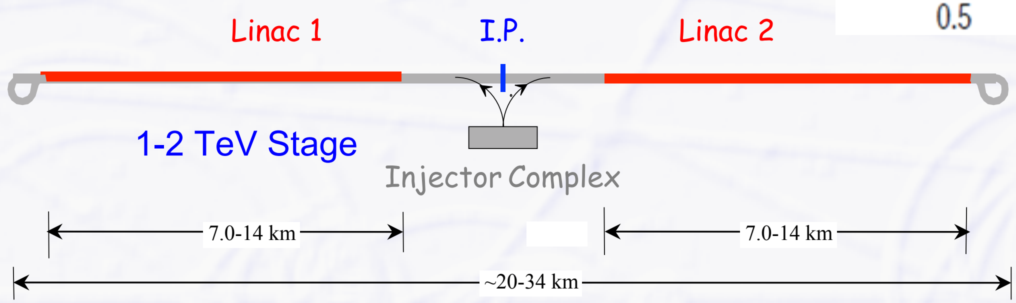
CLIC Implementation – in Stages?

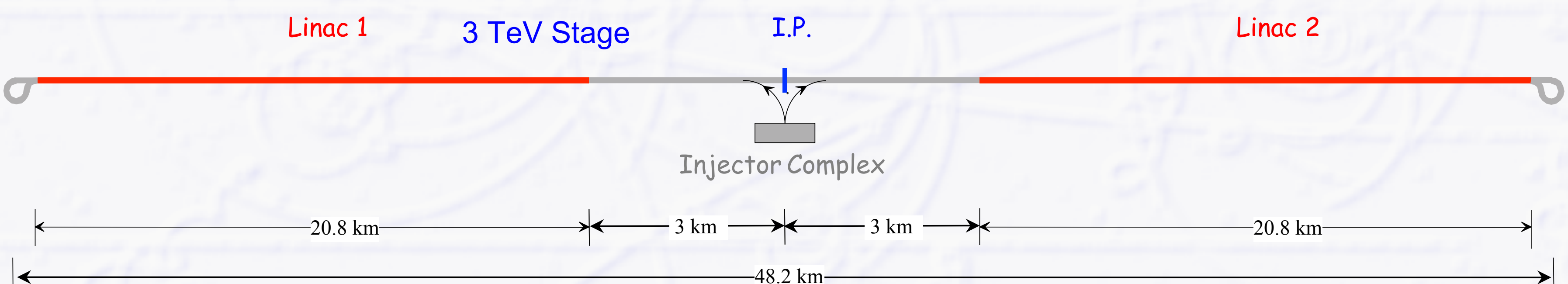


CLIC two-beam scheme compatible with energy staging to provide the optimal machine for a large energy range

Lower energy machine can run most of the time during the construction of the next stage. Physics results will determine the energies of the stages





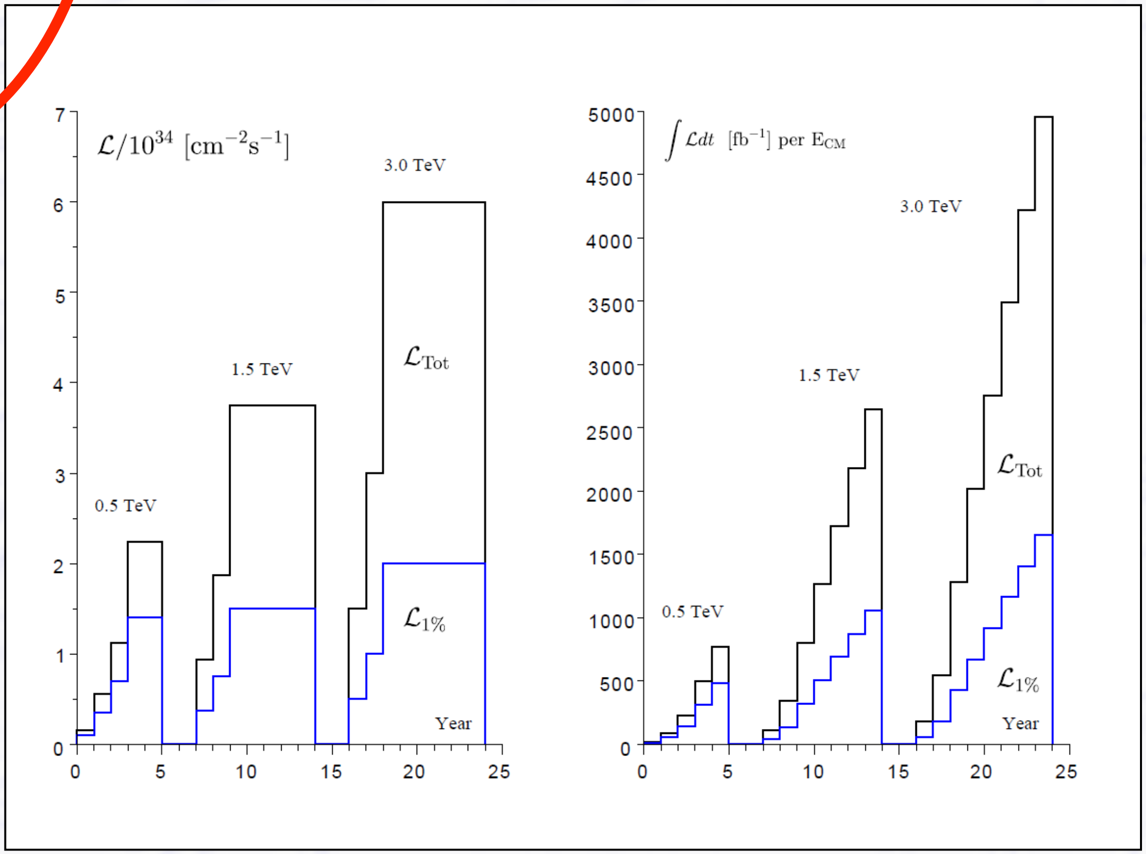


A possible Energy/Luminosity Scenario

- **Build and run in stages**
  - **5 years 500 GeV, $\mathcal{L}_{1\%}$ = 0.5 ab^{-1}**
    - **2 years stop**
  - **7 years 1.5 TeV, $\mathcal{L}_{1\%}$ = 1.0 ab^{-1}**
    - **2 years stop**
  - **8 years 3 TeV, $\mathcal{L}_{1\%}$ = 1.5 ab^{-1}**

physics requirements

177 beam days/year



Power Consumption

Table 2.13: The power map by technical components at 3 TeV for a luminosity $\mathscr{L}_{1\%} = 2 \times 10^{34}\,\text{cm}^{-2}\text{s}^{-1}$. The total power is 582 MW.

Component		Power [MW]	Fractional power
Radio-frequency (DB+MB)	RF	289	50 %
Magnets (DB+MB)		124	21 %
Cooling & Ventilation	CV	93	16 %
Network	NWork	28	5 %
Beam Instrumentation & Control	BIC	17	3 %
Detector & Area	Exp+Area	31	5 %

Table 2.14: Yearly energy and power consumption for the nominal 3 TeV CLIC.

	Power [MW]	Days	Energy [TWh]
Nominal operation mode	582	177	2.47
Fault-induced down-time	60	44	0.06
Programmed stops	60	144	0.21
Energy consumption per year			2.74

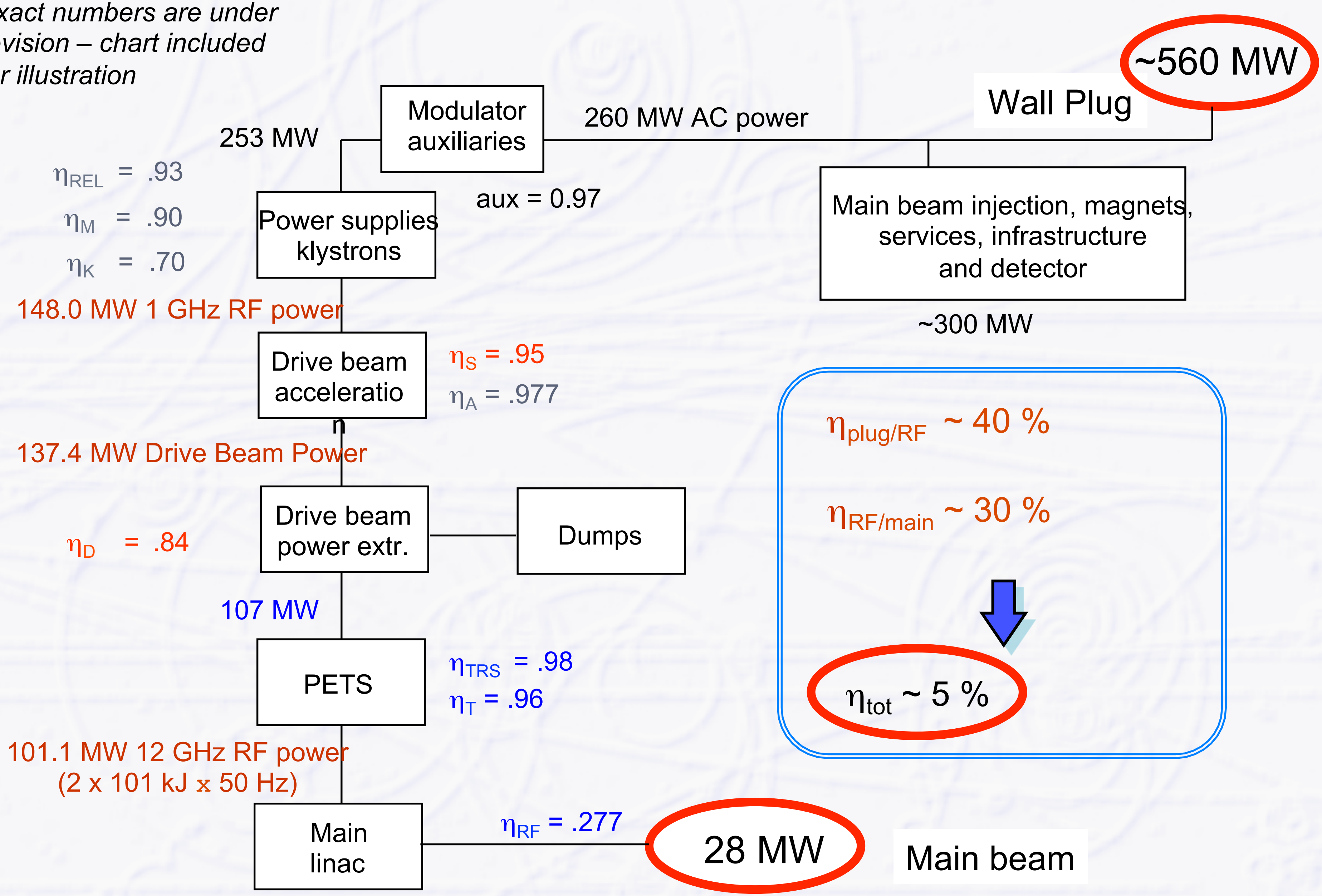
CERN: 1.2 TWh/y (pop. 13 k)

Canton Geneva: 3 TWh/y (pop. 466 k)

Hamburg: 13 TWh/y (pop. 1.8 M)

Power flow 3 TeV

Exact numbers are under revision – chart included for illustration

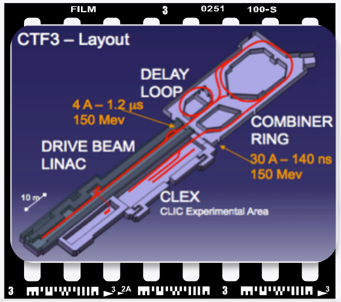


CLIC Feasibility Issues

- **CLIC feasibility not yet proven for all parameters**
  - **most issues expected to be solved within this/next year(s)**

System	Item	Feasibility Issue	Unit	Nominal Value	Achieved CLIC Value	Achieved CLIC How	Feasibility	Remaining issues
Two Beam Acceleration	Drive beam generation	Fully loaded accel effic	%	97	95	CTF3	✓	
		Freq&Current multipl	-	2*3*4	2*4	CTF3	✓	
		Combined beam current (12 GHz)	A	4.5*24=100	3.5*8=28	CTF3	✓	
		Combined pulse length (12 GHz)	ns	240	140	CTF3	✓	
		Intensity stability	1.E-03	0.75	< 0.6	CTF3	✓	
		Drive beam linac RF phase stability	Deg (1GHZ)	0.05	0.035	CTF3, XFEL	✓	
	Beam Driven RF power generation	PETS RF Power	MW	136	>140	CTF3/SLAC	✓	Cost
		PETS Pulse length	ns	176.5	>180	CTF3/SLAC	✓	
		PETS Breakdown rate	/m	< 1·10-7	≤ 2.4 10-7	CTF3/SLAC	✓	
		PETS ON/OFF	-	@ 50Hz	-	CTF3 (TBTS)	✓	
		Drive beam to RF efficiency	%	90%	-	CTF3 (TBL)	2012	Power
		RF pulse shape control	%	< 0.1%	-	CTF3 (TBTS)	2012	
	Accelerating Structures (CAS)	Accelerating field (loaded)	MV/m	100	100	CTF3 Test Stand, SLAC, KEK	✓	Cost
		Flat Top RF Pulse duration	ns	176.5	180		✓	
		RF Breakdown rate	/m	< 3·10-7	5·10-5(D)		✓	
		Rf to beam transfer efficiency	%	28.5	15		✓	Power
	Two Beam Acceleration	Power producton and probe beam acceleration in Two beam modules	MV/m - ns	100 - 170	145 - 130	TBTS	✓	Cost
		Drive to main beam timing stability	psec	0.05	-	CTF3	2012	Perf.
		Main to main beam timing stability	psec	0.07	-	XFEL	2012	Perf.
Ultra low beam emittance & sizes	Ultra low Emittances	Norm. Emitttance generation	H/V (nm)	500/5	3800/15	ATF, NSLS/SLS + simulation	✓ ✓	Perf.
		Emittance preservation: Blow-up	H/V (nm)	160/15	160/15		2012	Perf.
	Nanometer beam sizes	Strong focusing: β*eff to L* from IP	mm/m	0.1/3.5	2.0/1.0	ATF2	2012	Perf.
		Nanometer beam sizes at IP	H/V (nm)	40/1	70	FFTB	2012	Perf.
	Alignment	Main Linac components	µm	14-17	10 (princ.)	Align. & Mod. Test Bench	✓	Cost
		Beam Delivery System components	µm	10			2012	Cost
	Vertical stabilisation	Quad Main Linac	nm>1 Hz	1.5	0.13 (principle)	Stabilisation Test Bench	✓	Cost
		Final Doublet (with feedbacks)	nm>4 Hz	0.2			2012	Cost
Operation and Machine Protection System (MPS)		drive beam power of 72MW@2.4GeV	MW	14		CTF3 simulations	2012	Risk
		main beam power of 14MW@1.5TeV		72				Risk

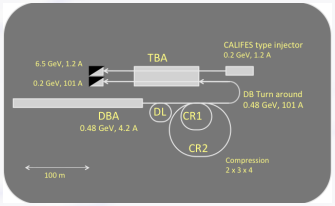
CLIC Project Time-Line



Final CLIC CDR and feasibility established, also input for the Eur. Strategy Update

From 2016 – Project Implementation phase, including an initial project to lay the grounds for full construction:

- CLIC 0 – a significant part of the drive beam facility: prototypes of hardware components at real frequency, final validation of drive beam quality/main beam emittance preservation, facility for reception tests – and part of the final project)
- Finalization of the CLIC technical design, taking into account the results of technical studies done in the previous phase, and final energy staging scenario based on the LHC Physics results, which should be fully available by the time
- Further industrialization and pre-series production of large series components with validation facilities

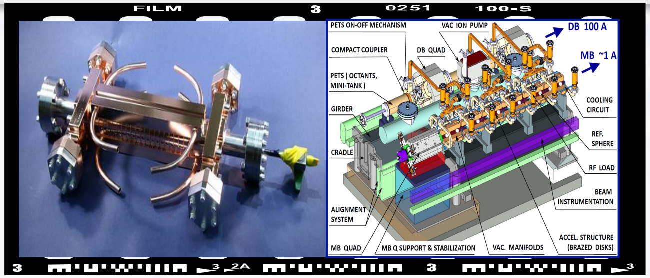


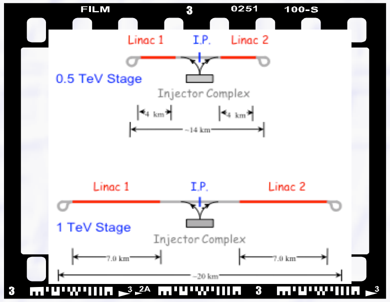
2004 - 2012 | 2012 - 2016 | 2016 - 2020 | ~ 2020 onwards

2011-2016 – Goal: Develop a project implementation plan for a Linear Collider:

- Addressing the key physics goals as emerging from the LHC data
- With a well-defined scope (i.e. technical implementation and operation model, energy and luminosity), cost and schedule
- With a solid technical basis for the key elements of the machine and detector
- Including the necessary preparation for siting the machine
- Within a project governance structure as defined with international partners

CLIC project construction – in stages, making use of CLIC 0





CLIC Summary

- CLIC CDR due to be ready
  - vol 1 (accelerator) March 2012
  - vol 2 (physics & detector) December 2011
  - vol 3 (executive summary) Summer 2012 (for European Strategy Process
- Progress in Feasibility Issues
  - remaining issues to be solved within next year(s)
- CLIC parameters are optimized for highest luminosity at highest energy (3 TeV)
  - no “simple” energy scan with constantly high luminosity possible
  - staging approach with variable pulse length to keep luminosity as high as possible
    - 500 GeV, 1.5(1.4) TeV, 3 TeV
- Power consumption is a concern
  - 562 MW, 2.7 TWh/year