CLIC Status

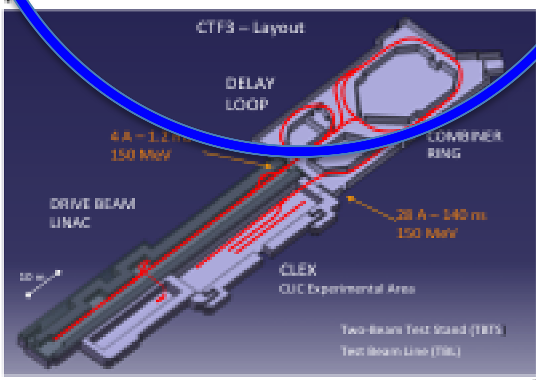
D. Schulte for the CLIC collaboration

Timeline

From Steinar

2012-16 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.



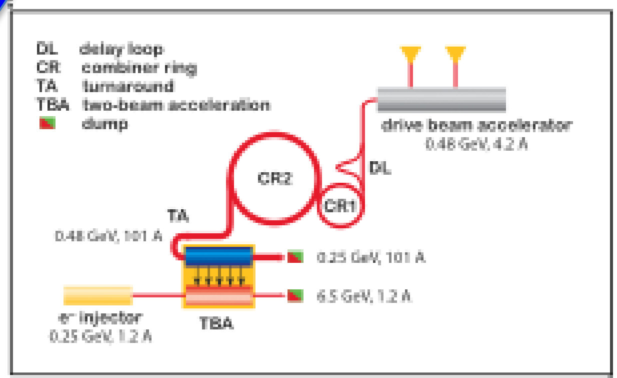
2016-17 Decisions

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

2017-22 Preparation Phase

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

Prepare detailed Technical Proposals for the detector-systems.



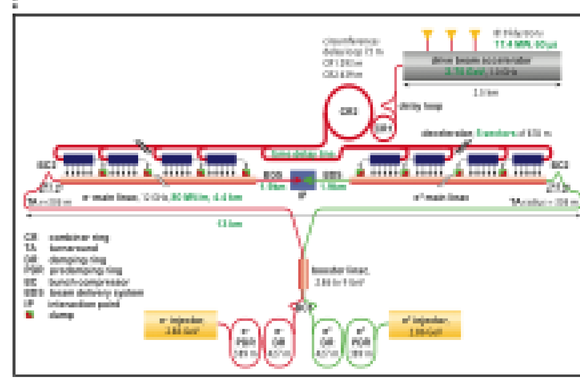
2022-23 Construction Start

Ready for full construction and main tunnel excavation.

2023-2030 Construction Phase

Stage 1 construction of a 500 GeV CLIC, in parallel with detector construction.

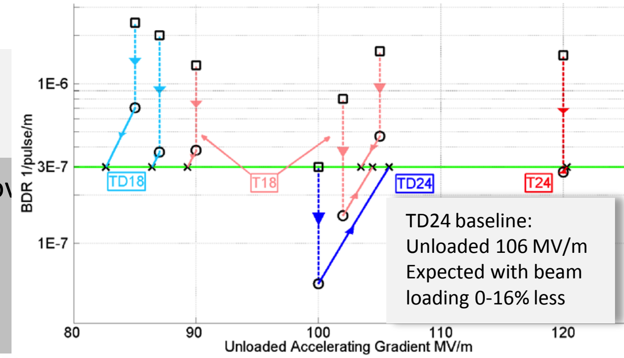
Preparation for implementation of further stages.



2030 Commissioning

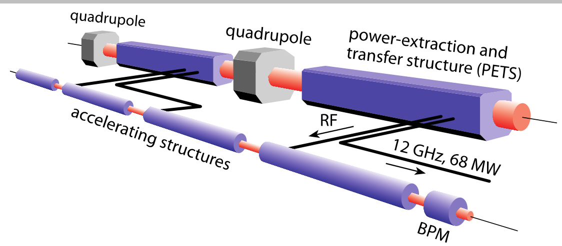
From 2030, becoming ready for data-taking as the LHC programme reaches completion.

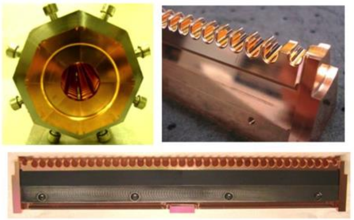
Conclusion of the Accelerator CDR Studies

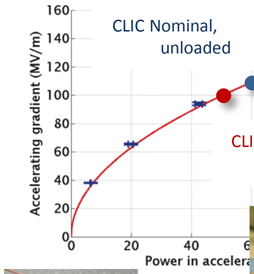


Main linac gradient
- Ongoing test close to or on target
- Uncertainty from beam loading being tested

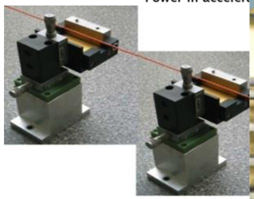
Drive beam scheme
- Generation tested, used to accelerate test beam abov specifications, deceleration as expected
- Improvements on operation, reliability, losses, more deceleration studies underway

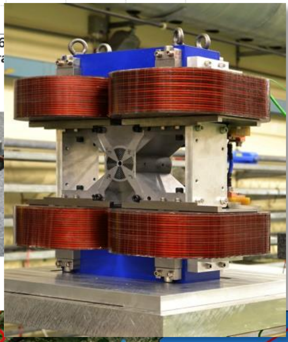






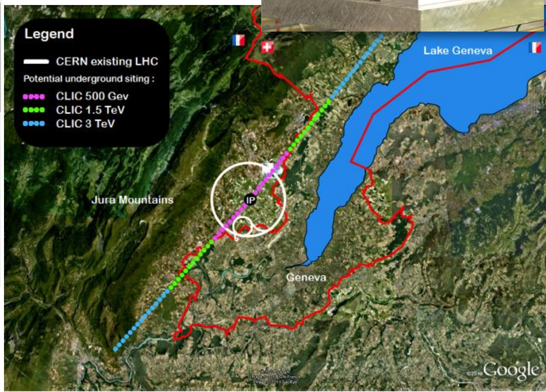
Luminosity
- Damping ring like an ambitious light source, no show stopper
- Alignment system principle demonstrated
- Stabilisation system developed, benchmarked, better system in pipeline
- Simulations on or close to the target





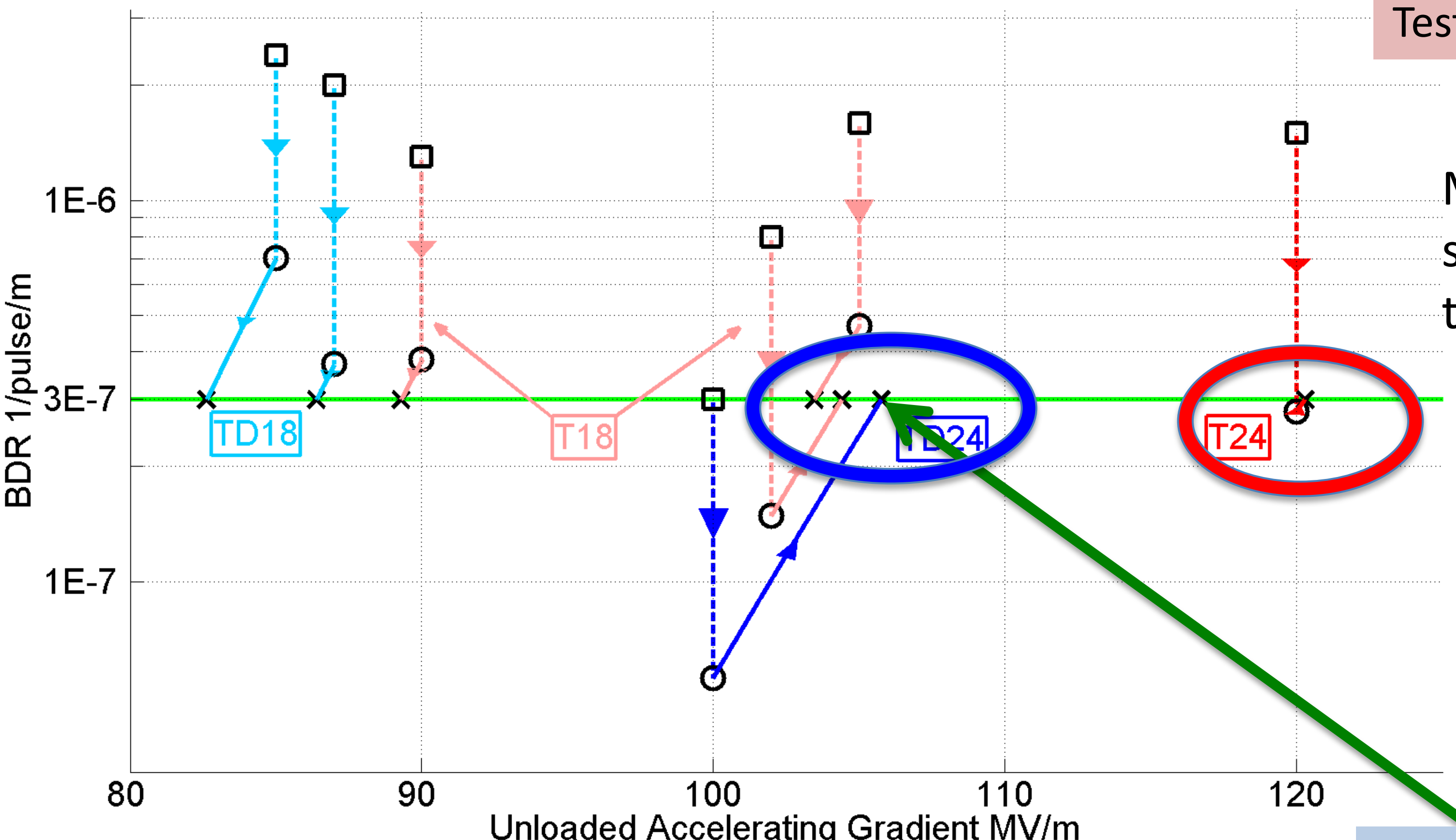
Operation & Machine Protection
- Start-up sequence and low energy operation defined
- Most critical failure studied and first reliability studies

Implementation
- Consistent staged implementation scenario defined
- Schedules, cost and power developed and presented
- Site and CE studies documented



Achieved Gradient for CLIC

Tests at KEK and SLAC



Measurements scaled according to

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

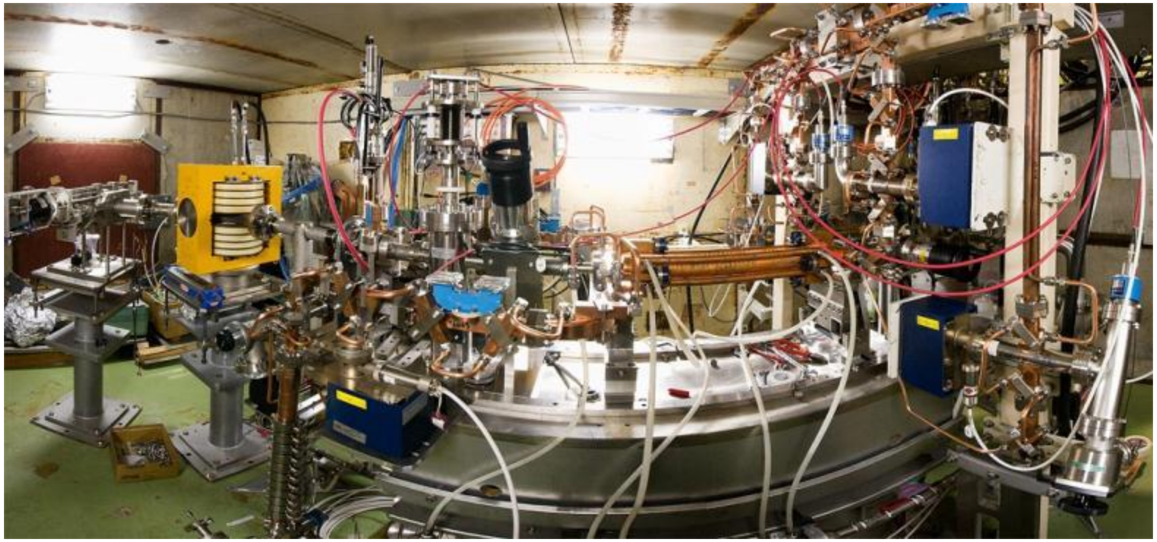
Unloaded 106MV/m
With loading 0-16% less

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

RF Team

Klystron-based Test Stands for CLIC

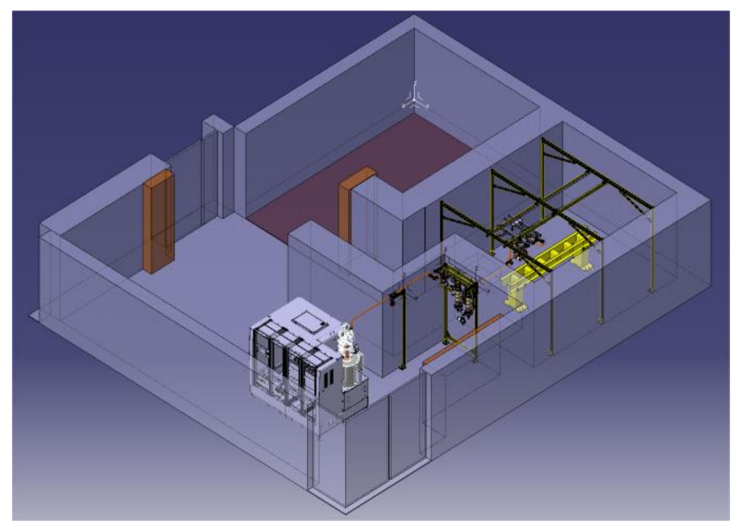
NEXTEF at KEK



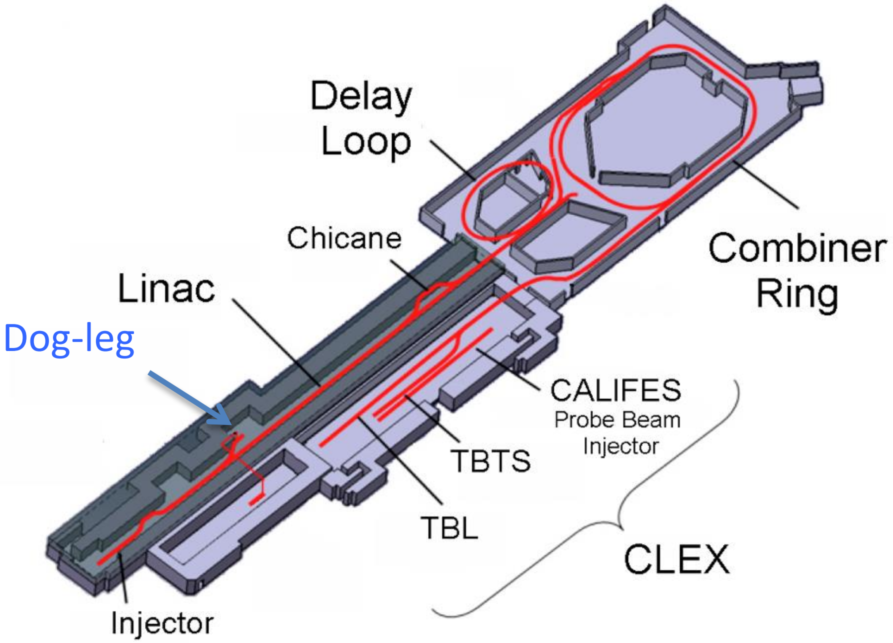
ASTA at SLAC?

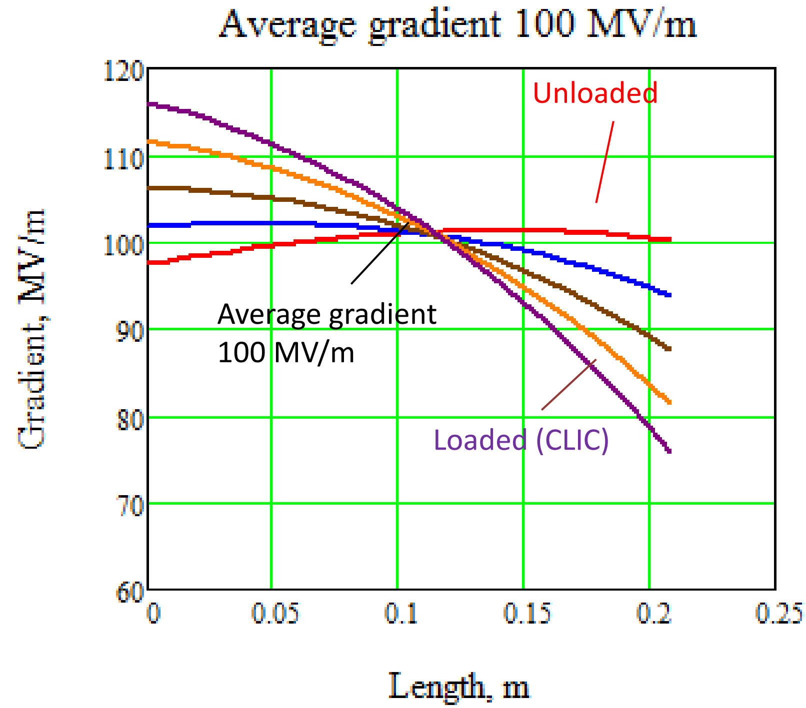
XBox1 at CERN operational with SLAC klystron

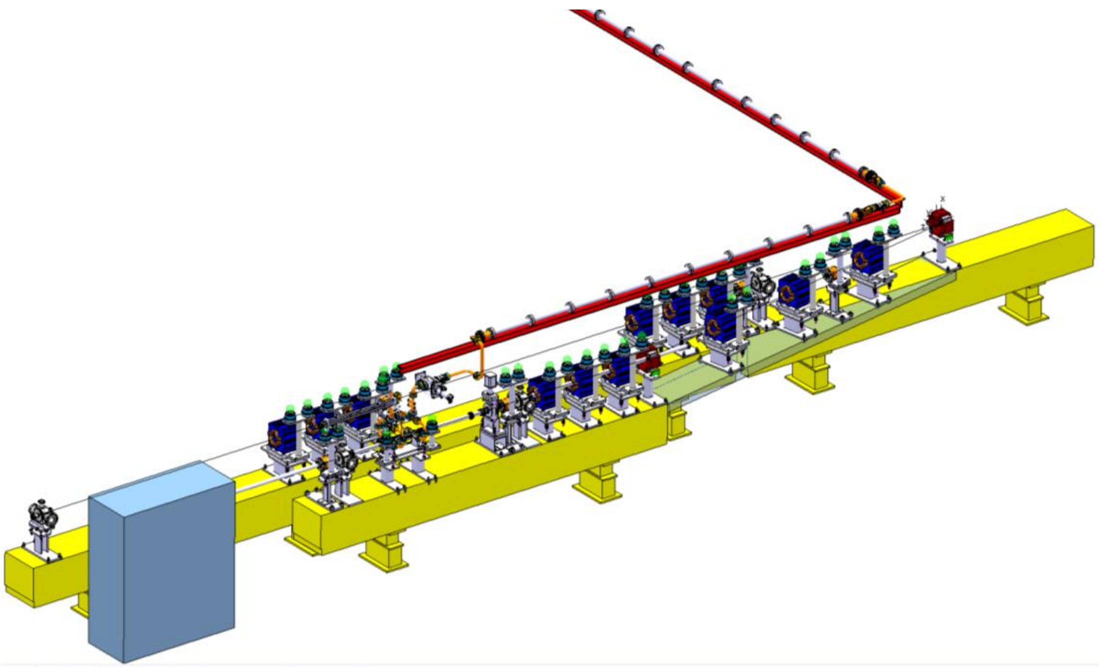
XBox2 at CERN, industrial klystron should be ready this year



Beam Loading Test Facility





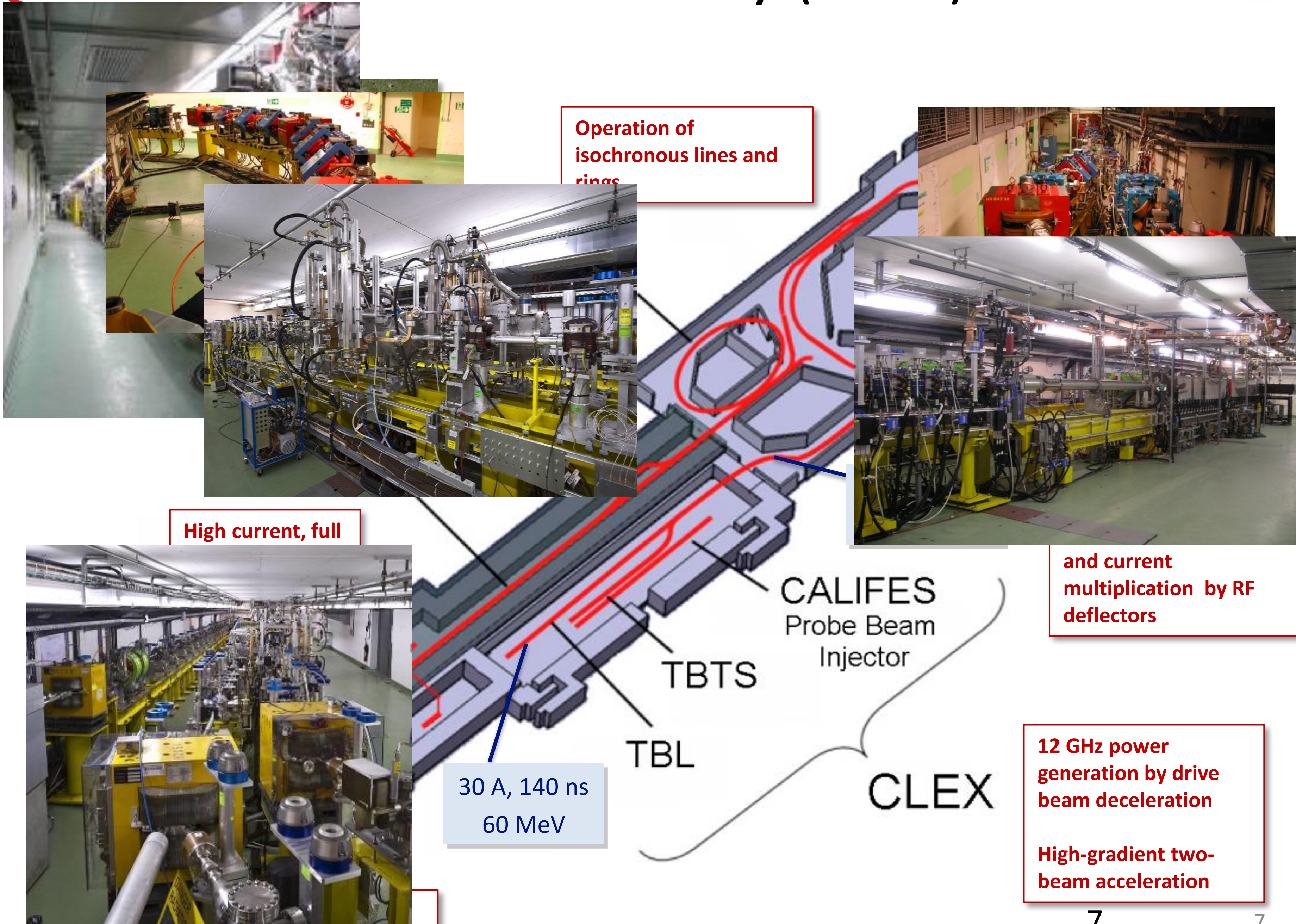


Test stand in CTF3 dog-leg to test gradient
with beam loading

- Structure can be power with klystron
- Can send drive beam through structure

System is commissioned
Conditioned structure to come in summer

CLIC Test Facility (CTF3)



Operation of isochronous lines and rings

High current, full

and current multiplication by RF deflectors

12 GHz power generation by drive beam deceleration

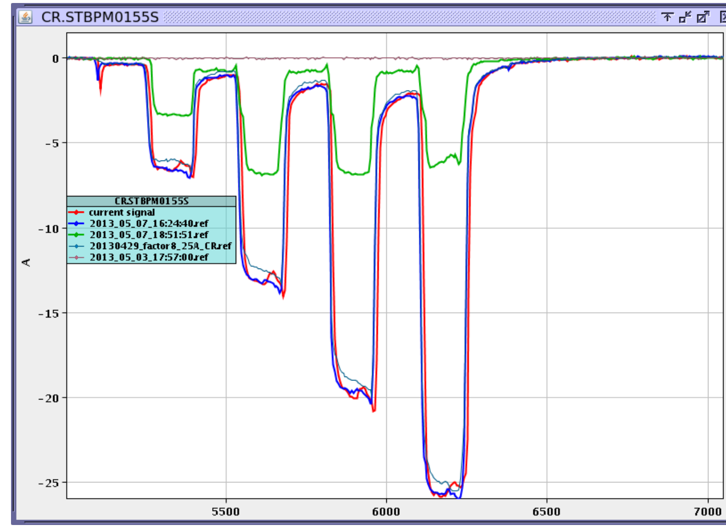
High-gradient two-beam acceleration

Recent CTF3 Results

- Operation with 8 times combination now routine
- New feedbacks added to improve phase stability

Goal is to achieve

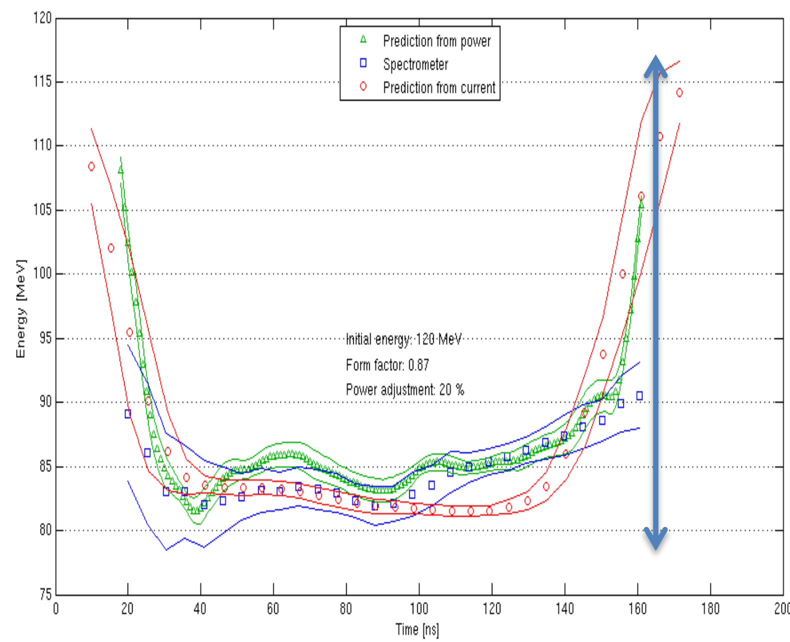
- $\varepsilon_x = \varepsilon_y \cong 150$ µm also for factor 8, currently ε_x=550µm due to orbit error
- Charge stability $\sigma_Q \approx 10^{-3}$ for factor 8



- Deceleration increased from 30% to 35%
- Decelerator BPM prototype tested (stripline, LAPP)
- Good understanding of the optics

Goal is to reach 40% deceleration

More results and more details in Roberto's talk

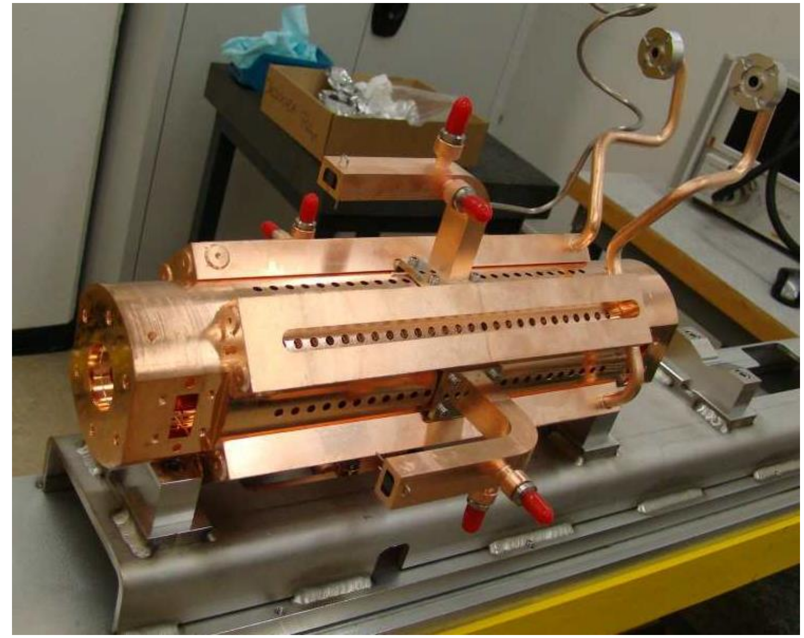


CTF3 Team

Recent CTF3 Results

CEA IRFU - Saclay

- Structure with wakemonitor installed in TBTS
- Resolution is very good

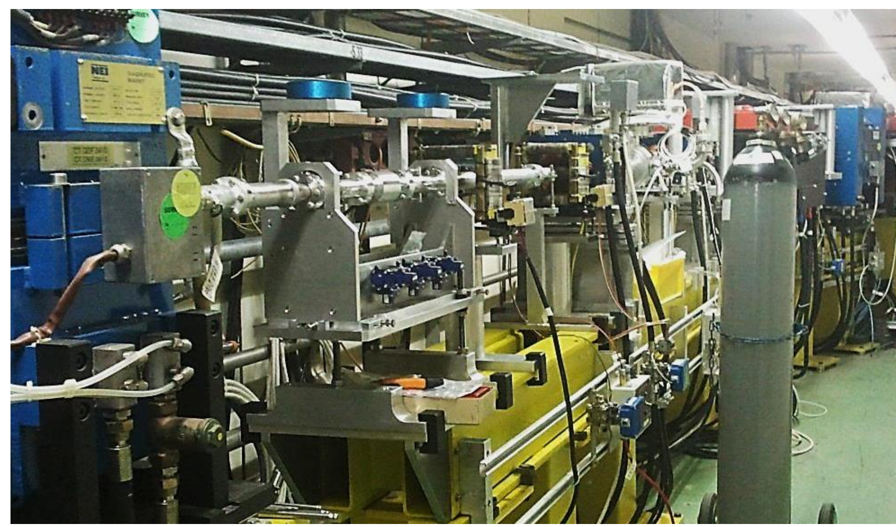


Feedforward to correct drive beam phase

Phase monitors successfully tested

Goal:

- Install kickers and amplifiers (FONT5) in summer
- First tests in autumn



CTF3 Team

INFN Frascati
JAI/Oxford

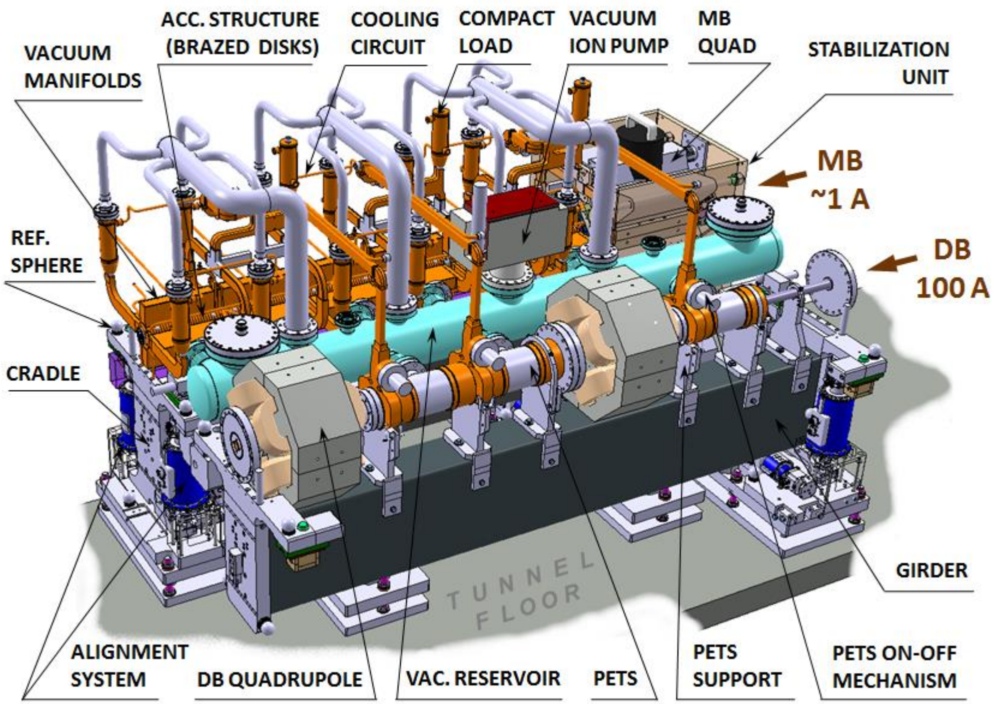
CLIC Drive Beam Front End Hardware Prototypes and Plans

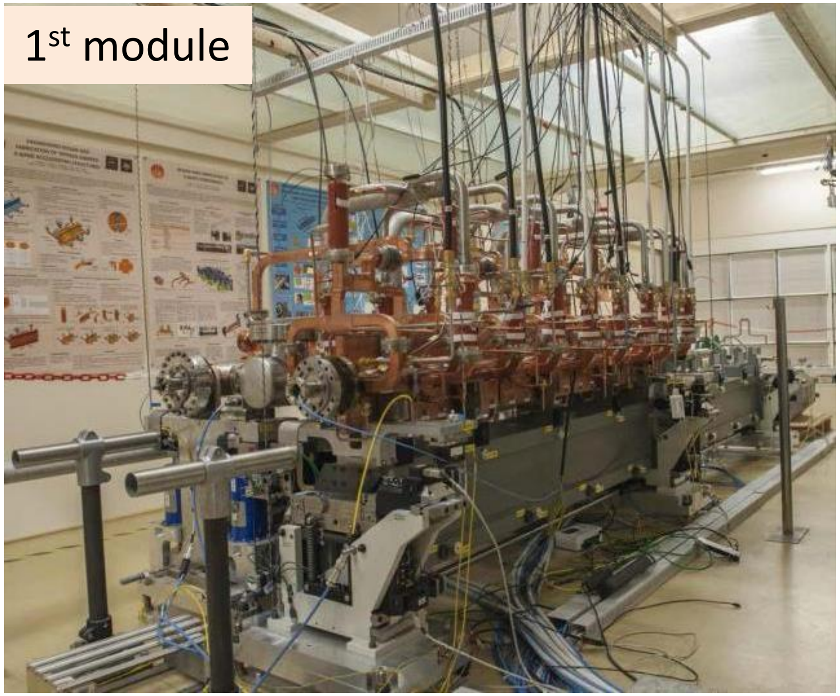
Preliminary Schedule

Task	2013	2014	2015	2016
Gun test area	prepare gun test area	ready for first tests	testing with HV modulator	testing
Gun	design	Prototype, first tests	gun tests	
SHB Buncher	fabrication	testing low power	testing high power	
500 MHz power source	specifications	purchase	needed for test	
1 GHz structure	specs, mech. design	construction	low power test	high power test
Diagnostis	design	design	tests in gun area ?	
LLRF	specs	fabrication+test	ready for klystron test	
1 GHz klystrons	tender, contract	Design review	Receive first prototype	Klystron 2
1 GHz Modulator	R&D	R&D	Receive first MDK	MDK2
1 GHz rf test stand	specs, location	prepare	Receive MDK, klystron	Ready for testing
RF stability	Measure CTF3, DESY?	Measure SLAC ?		

Steffen Doebert et al.

CLIC Two-beam Module



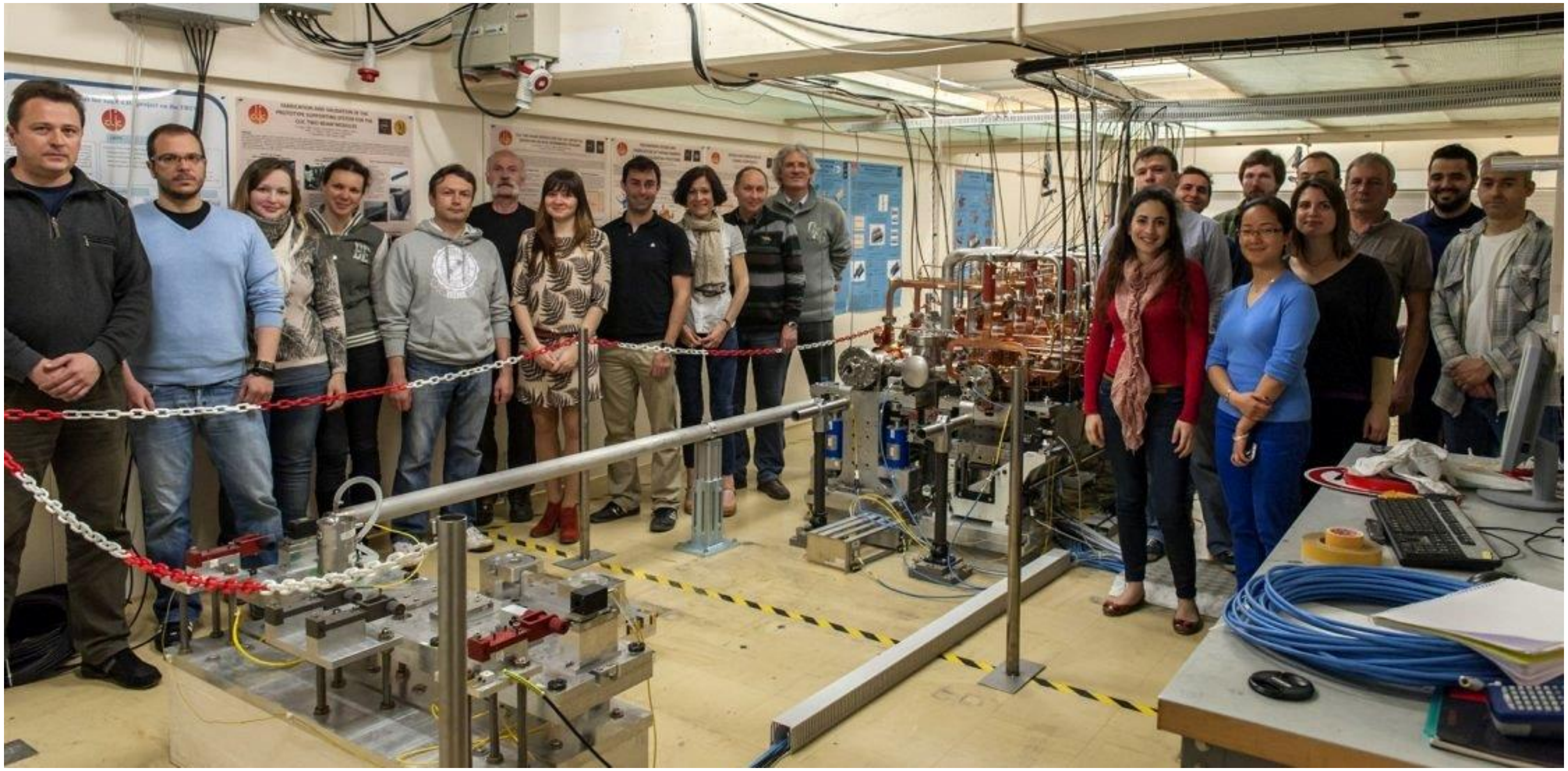


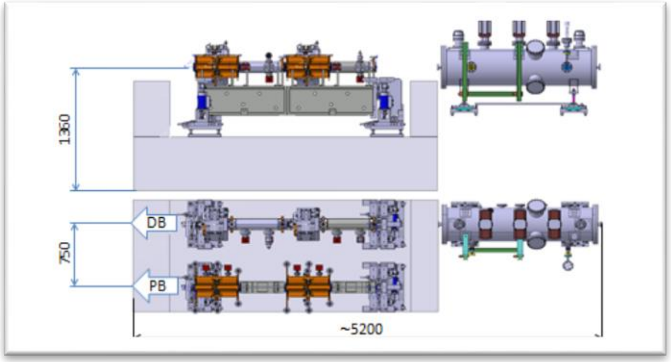
Module program until 2016:

- 4 modules in the lab (thermo-mechanical validation), first one being successfully tested
- 3 modules in CLEX (tests with beam and RF), first under fabrication to be ready end of the year

G. Riddone, Module Team

Test-module Test





Module with existing PETS priming

SiC girder at Boostec (FR)

All safety measures implemented (power dissipation ~7 kW per module)

DAQ and control system (Labview based) tested and validated

First tests promising and in line with FEA simulations

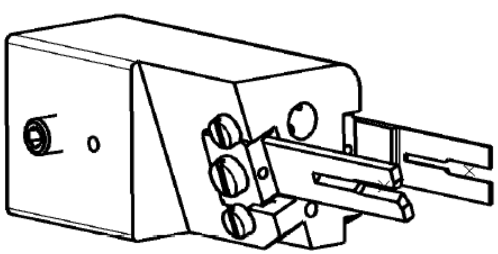
Instrumentation Example: ODR Monitor

Setup (chemically etched target)

Silicon TARGET

Silicon Carbide MASK

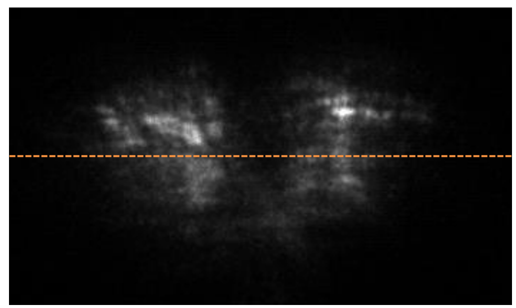
Photographs by Lilian REMANDET

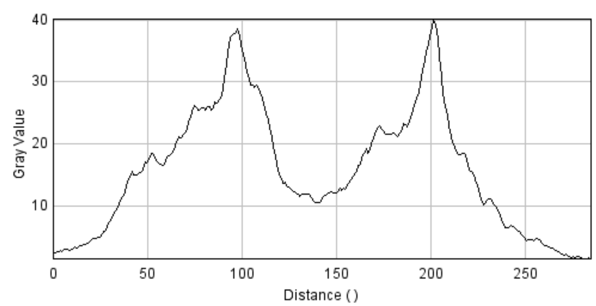


ODR (optical diffraction radiation)

First molecular adhesion target results at CESR-TA

Vertical direction

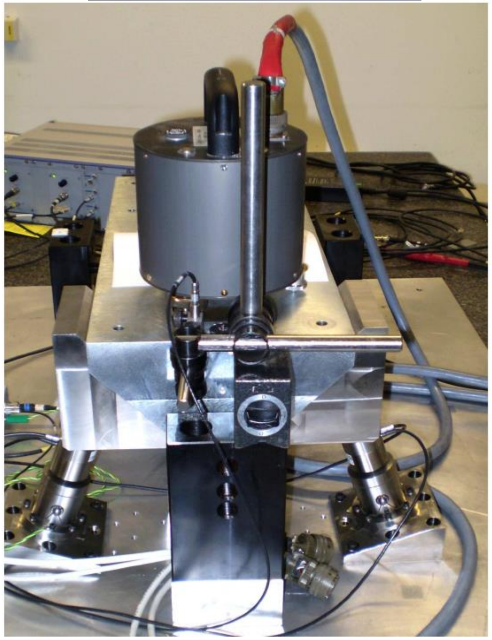


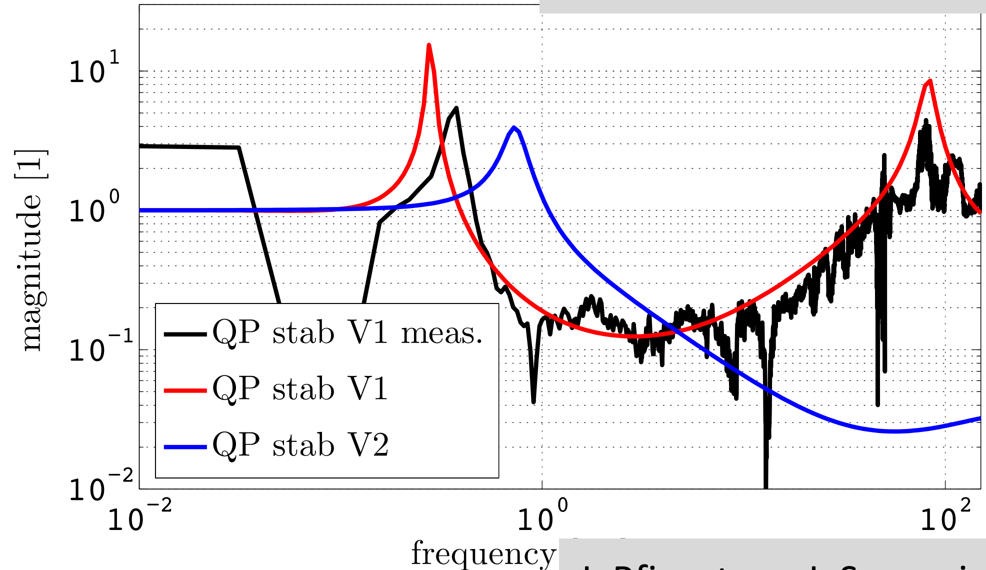


Goals:
Beam lifetime
…
Single turn interference images

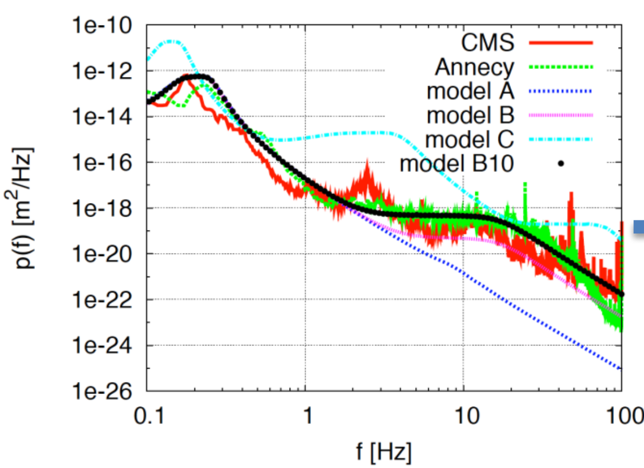
Active Stabilisation Results

K. Artoos, A. Jeremie et al.





J. Pfingstner, J. Snuverink et al.



Code

Machine model
Beam-based feedback

Luminosity achieved/lost

	B10
No stab.	53%/68%
Current stab.	~~108%/13%~~ 114%/7%
Future stab.	118%/3%

Close to/better than target

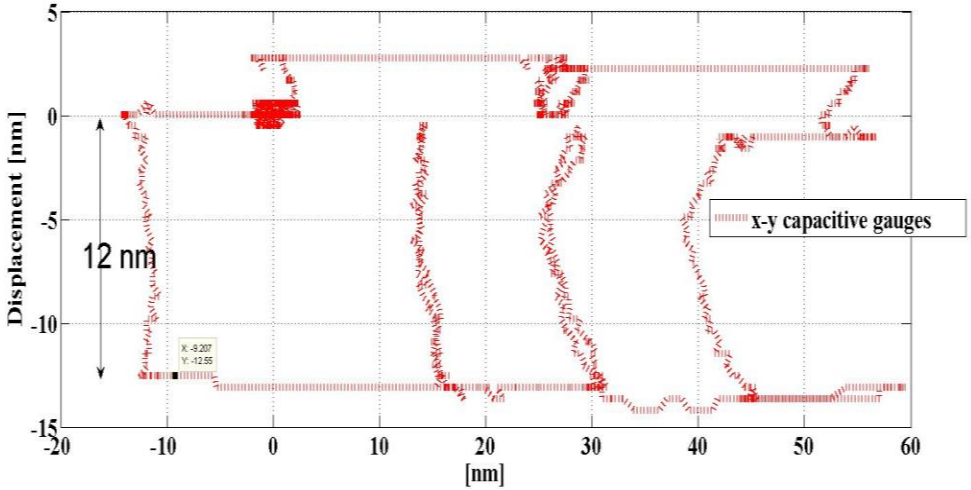
D. Schulte, CLIC Status, May 2013

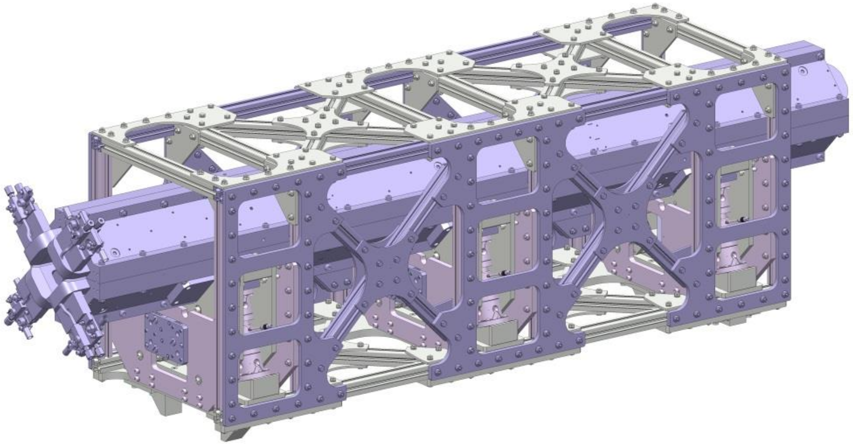
Stabilisation Progress

Integrated studies of ground motion, hardware and beam allowed to define new specifications for motion sensors

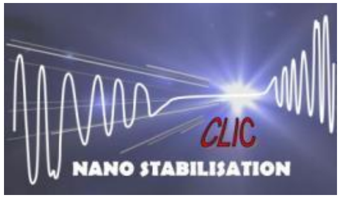
New sensor is being developed
First promising results

Position verified to be 0.25nm





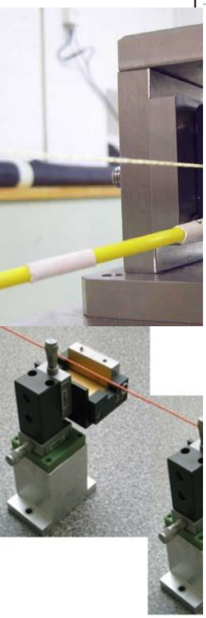
Prototypes for module under production
Long magnet design

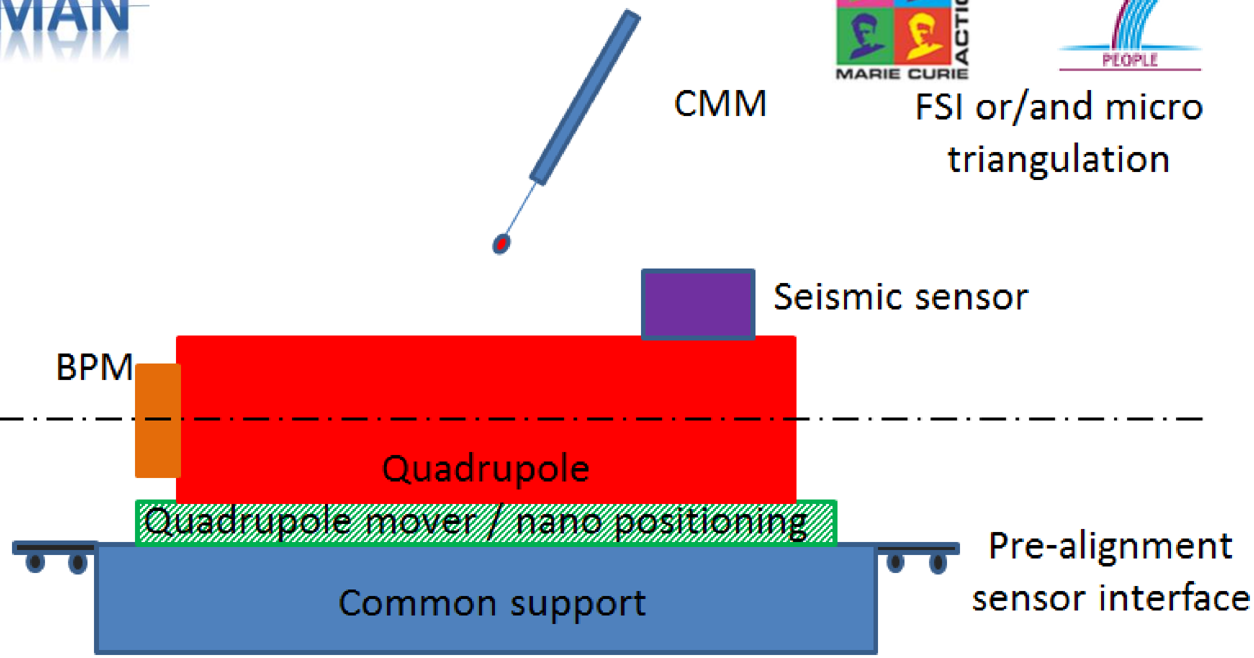


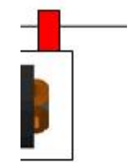
Main Linac Alignment

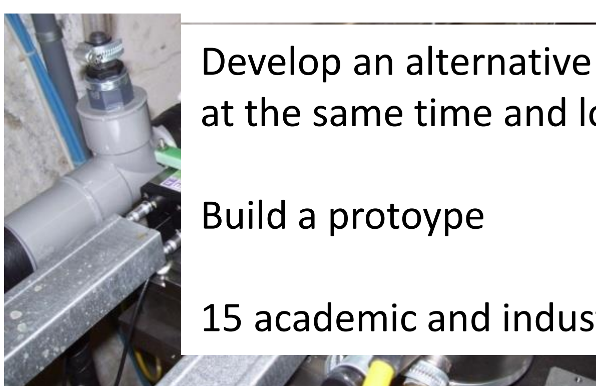
H. Mainaud Durand et al.

Stabilise quadrupole O(1nm) @ 1Hz





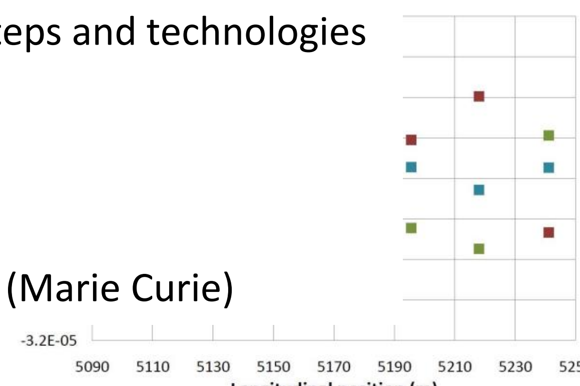




Develop an alternative solution integrating all the alignment steps and technologies at the same time and location (CMM machine)

Build a protoype

15 academic and industrial partners, EC funds 10PhD students (Marie Curie)



Beam Delivery Progress

Optimisation for lower energies is ongoing, reduction of beta-functions appears possible

ATF2 is an important test facility

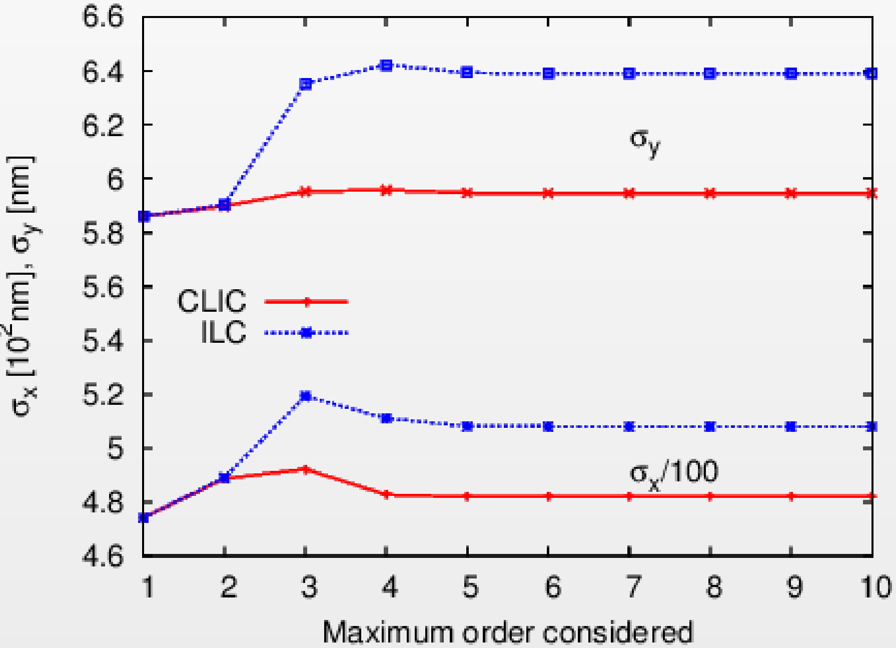
- we contribute to the operation and to specific experiments -> see Rogelio Tomas on Tuesday

CLIC FFS design can be applied to ILC

Could use similar hardware, in particular hybrid final focus magnet could be interesting

-> Michele Modena

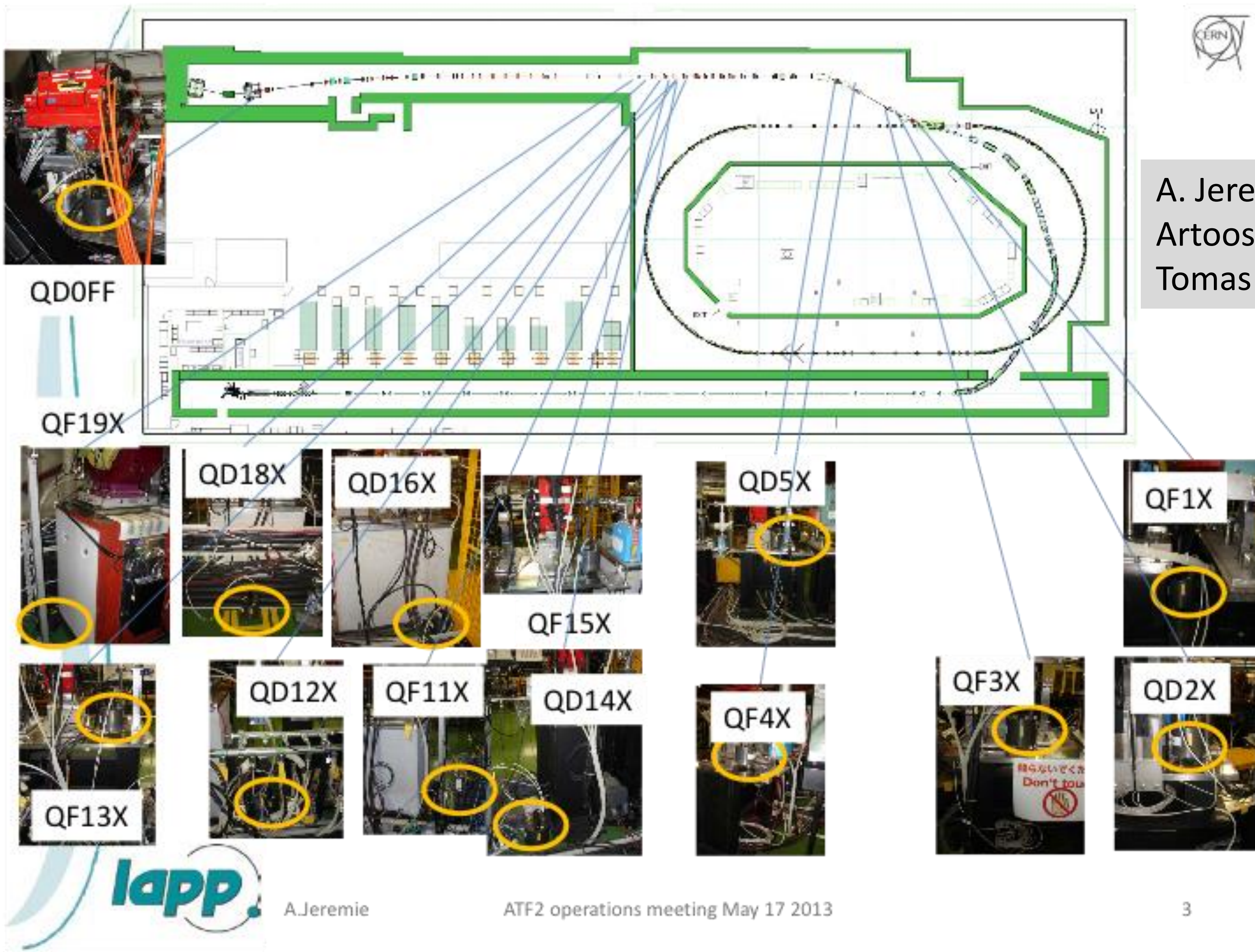
R. Tomas et al.



Placet+GuineaPig

Parameter	ILC	CLIC-based
Length [m]	800	553
β_x^*/β_y^* [mm]	11/0.48	11/0.48
$\sigma_x^{\rm core}$ [nm]	499.3	483.7
$\sigma_y^{\rm core}$ [nm]	6.03	5.89
$\mathcal{L}_T$ [10^{34} cm^{-2}s^{-1}]	1.39	1.47
$\mathcal{L}_{1\%}$ [10^{34} cm^{-2}s^{-1}]	0.86	0.89

Stabilisation Experiment



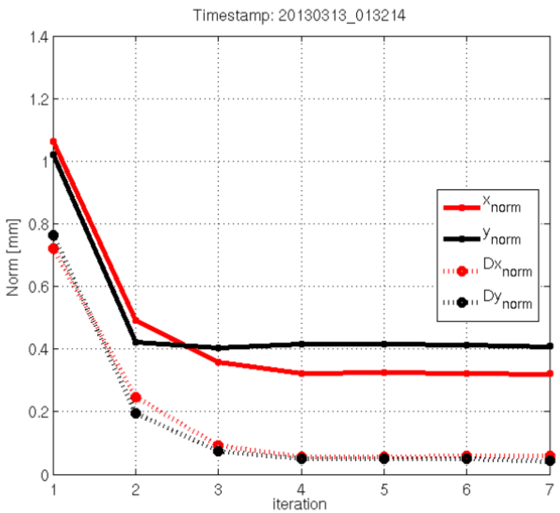
A. Jeremie, K. Artoos, R. Tomas et al.

CLIC Beam-Based Alignment tests at FACET

Dispersion-free Steering (DFS) proof of principle – March 2013

A. Latina,
J. Pfingstner,
E. Adli,
D. Schulte

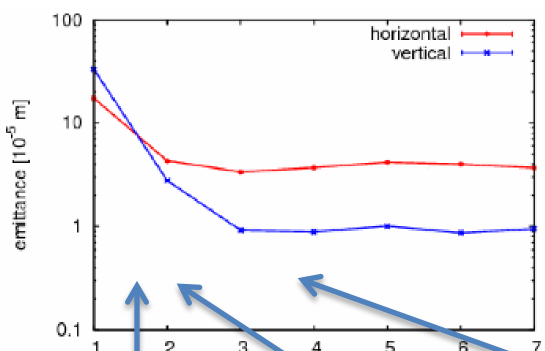
Orbit/Dispersion



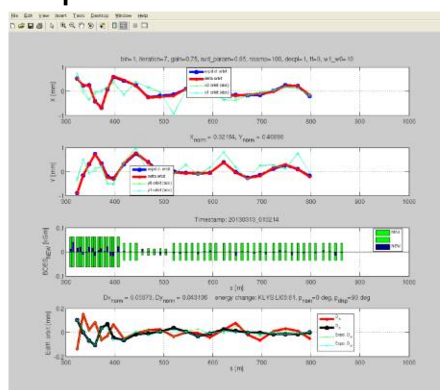
DFS correction applied to 500 meters of the SLC linac

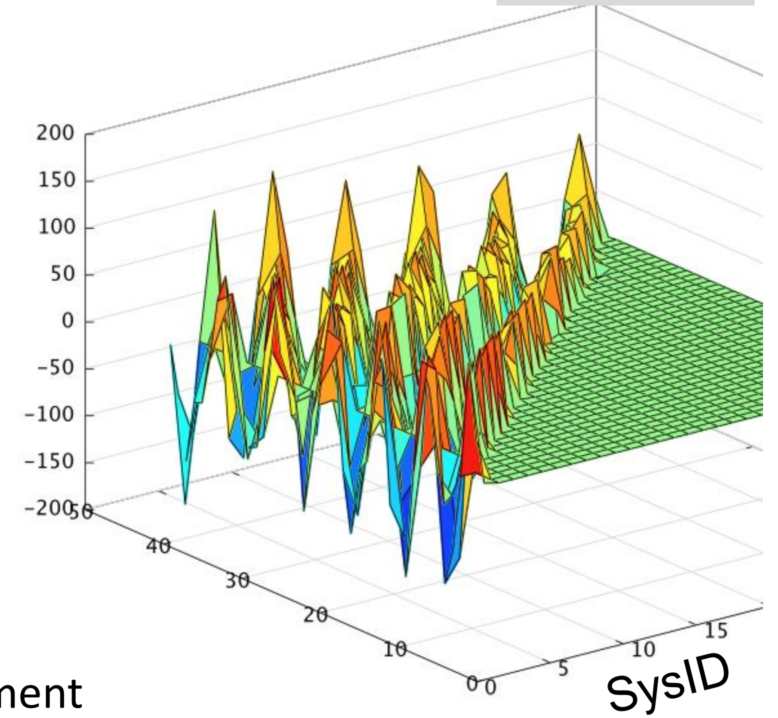
- SysID algorithms for model reconstruction
- DFS correction with GUI
- Emittance growth is measured

Emittance

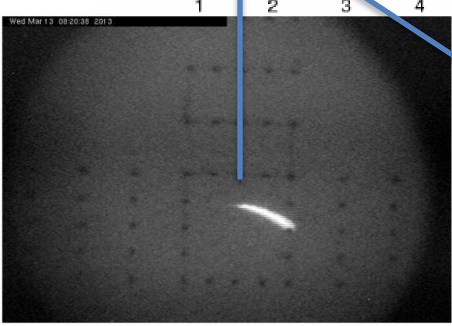


Graphic User Interface:

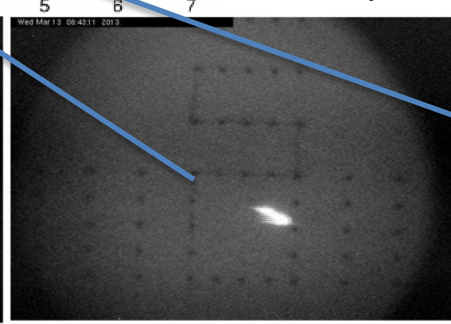




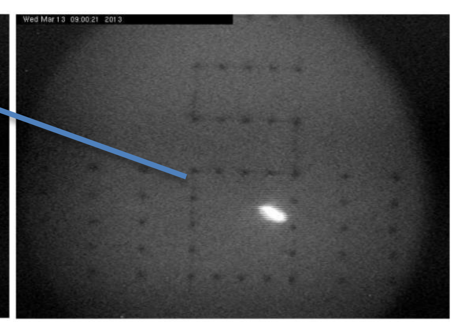
Beam profile measurement



Before correction



After 1 iteration

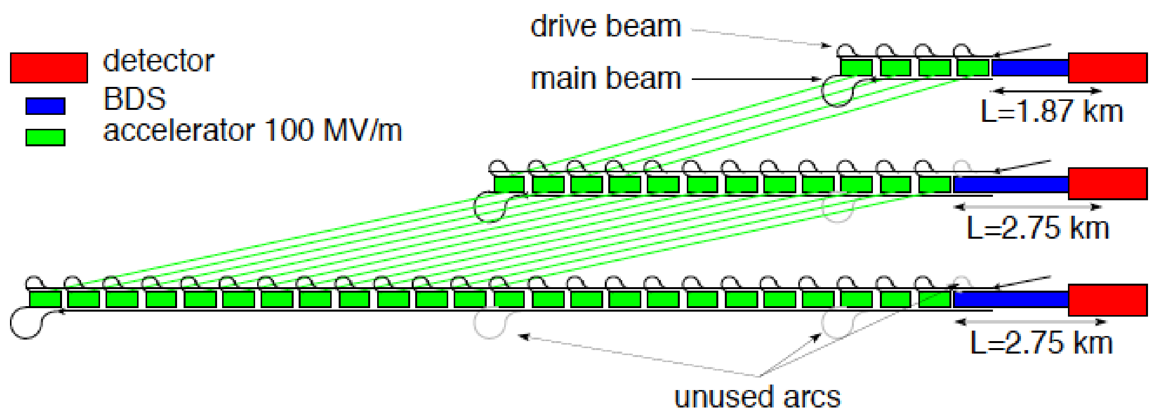


After 3 iterations

Incoming oscillation/dispersion is taken out and flattened; emittance in LI11 and emittance growth significantly reduced.

Rebaselining: Goals for Next Phase

- Iterate on energy choices
  - Stage optimised for 375GeV for Higgs and top
  - 1-2TeV depending on physics findings, will still also do Higgs
  - 3TeV as current ultimate energy, includes more Higgs
- Focus on optimisation of first energy stage
  - But consider upgrades



- Identify, review and implement cost and power/energy saving options
  - Identify and carry out required R&D
- Re-optimise parameters (global design)
  - Develop an improved cost and power/energy consumption model
  - Iterations needed with saving options
- Study alternatives
  - E.g. first stage with klystrons

- Need to remain flexible, since we are waiting for LHC findings
  - But have some robustness of specific solutions and can anticipate this to some extent

Rebaselining Status

- Ingredients are
  - Automatic structure design
  - Automatic beam parameter and machine design
  - Automatic costing
- Automatic structure design
  - Old procedure is available
  - Improved version using better understanding of RF limitations is in preparation
- Automatic parameter choice and machine design
  - Improved modelling of damping ring, further limitations in preparation, in particular electron cloud and impedances
  - BDS with smaller beta-functions at lower energies being studied
  - Automatic injector design is in preparation
- Automatic costing
  - Cost from CDR used for main linac
  - More recent understanding for drive beam generation

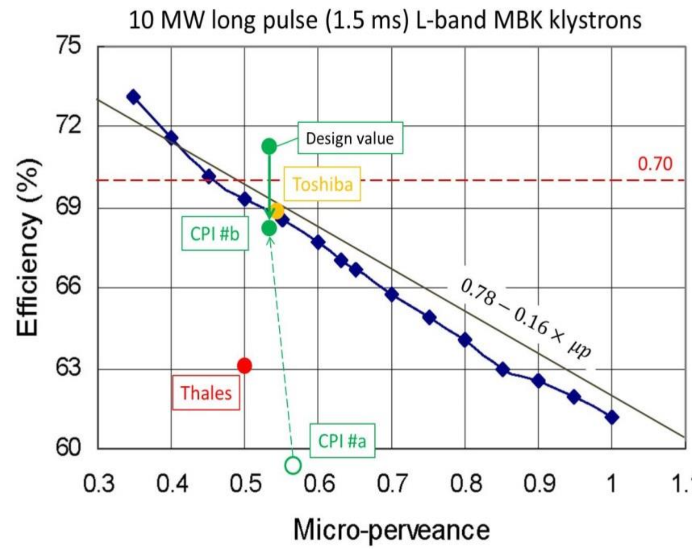
CLIC Drive Beam Klystron Based on ILC Design

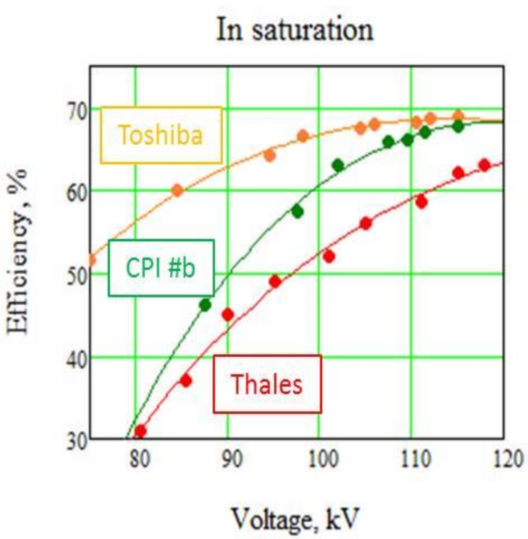
Thales

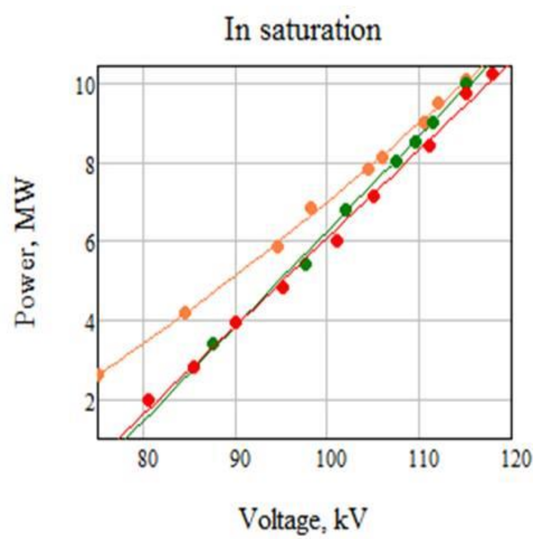
Toshiba

CPI #a

CPI #b





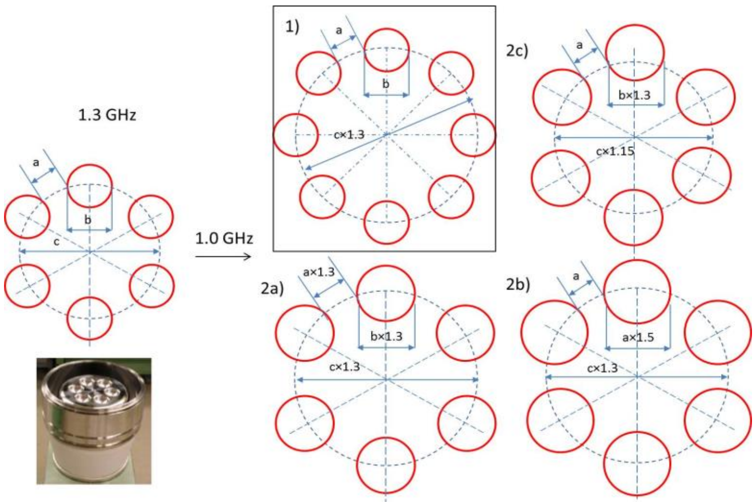


RF efficiencies (67.8%, 68.8%) validate feasibility of CLIC target at 1GHz (70%)

I. Syratchev

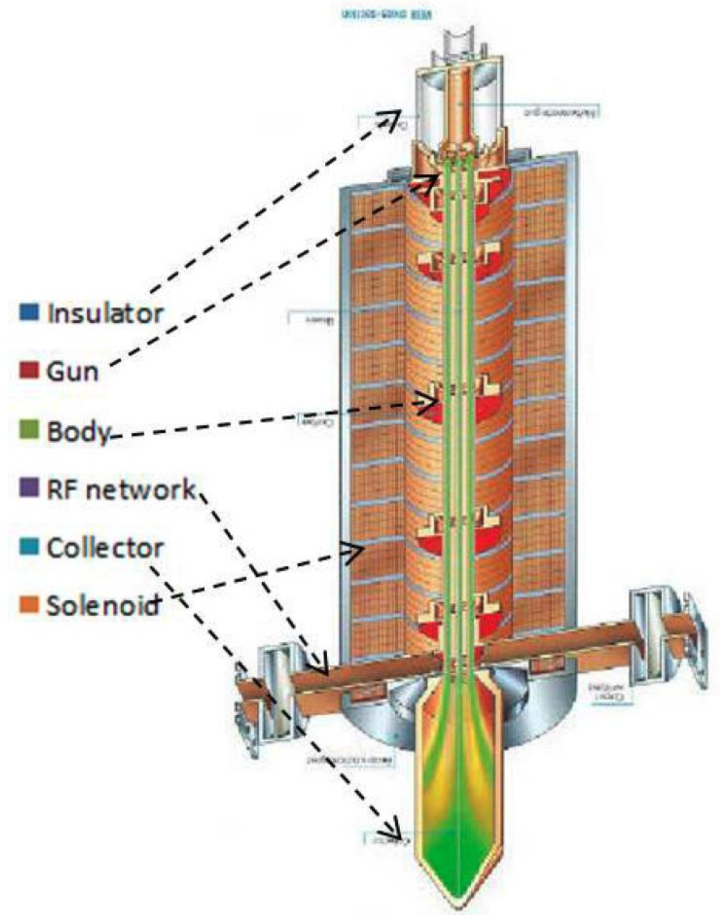
20 MW L-band Klystron for CLIC

Gun topology scaling scenarios



Recommended parameters of the L-band klystron for CLIC

Parameter	
Frequency, GHz	1.0
N beams	6
Cathode diam., cm	4.94
Cathode loading A/cm^2	1.76-1.96
μ−perveance/beam	0.45
Peak power (max), MW	20-25
Cathode Voltage, kV	160 - 180
Cathode current, A	180-202
Efficiency, %	>70



20+MW at 1GHz corresponds to 10MW at 1.3GHz

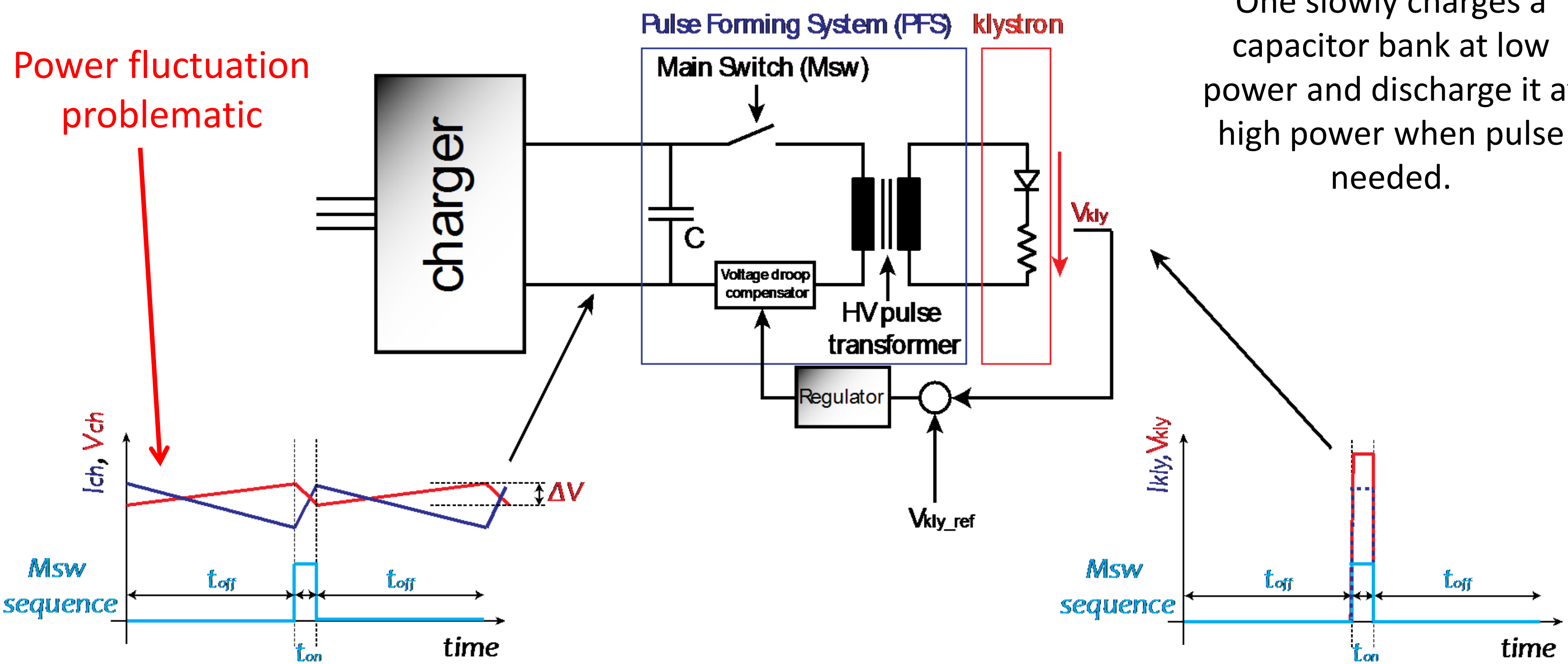
Cost derived by detailed study of components

Call for tender in preparation

Modulator

Power fluctuation problematic

One slowly charges a capacitor bank at low power and discharge it at high power when pulse needed.



Study integrated klystron+modulator system
High phase stability requirement

Novel topologies are being studied
- at 400V and at O(18kV)
- simulations are promising
- validation of components and full prototypes planned

ETHZ, LAVAL,
U. Nottingham, CERN

D. Aguglia et al.

Some Identified Savings

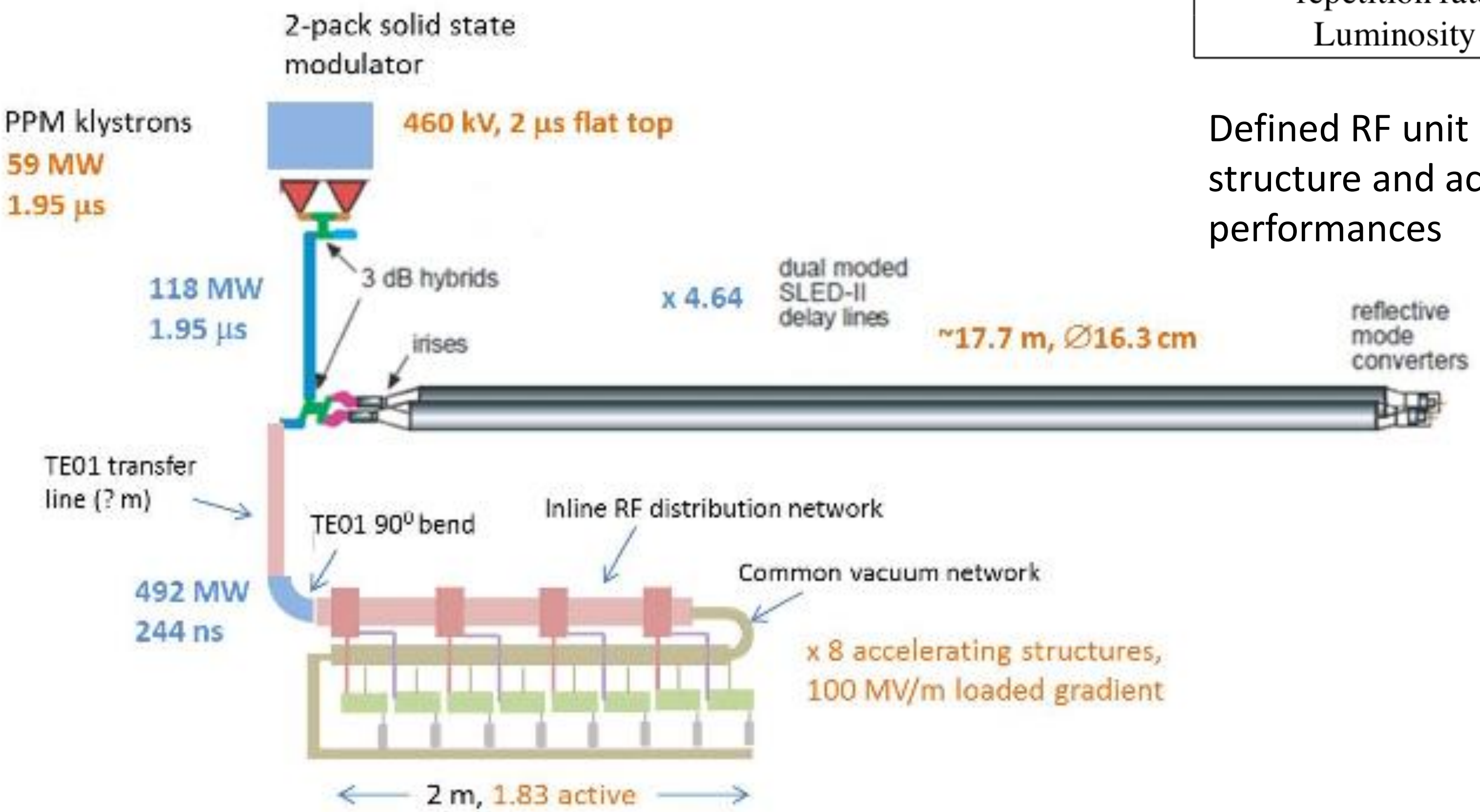
- Electron pre-damping ring can be removed with good electron injector
- Dimension drive beam accelerator building and infrastructure are for 3TeV, dimension to 1.5TeV results in large saving
- Possible drive beam accelerator klystron power has been underestimated
- Potential to use cheaper material for the drive beam accelerator structures
- Systematic optimisation of injector complex linacs in preparation
- Power consumption:
  - Has been calculated running overheads flat out
  - Obviously to conservative

Study of Klystron-based Alternative

Only interesting for first energy stage at 375GeV cms
Would need ~30,000 klystrons at 3TeV

Simple parametric cost study has shown that nominal structure CLIC_G is very good for klystron-based approach
Can use the same structure for drive beam and klystron-based option

Linac energy overhead	10%
Linac filling factor	≈ 0.75
Number of klystrons	4484
Number of structures	17936
Active length/single linac	2.242 km
Length/single linac:	3 km
bunches/pulse	312
particles/bunch	$3.72 \cdot 10^9$
repetition rate	50 Hz
Luminosity	$10^{34}\text{cm}^{-2}\text{s}^{-1}$



Defined RF unit based on this structure and achieved klystron performances

D. S. et al.

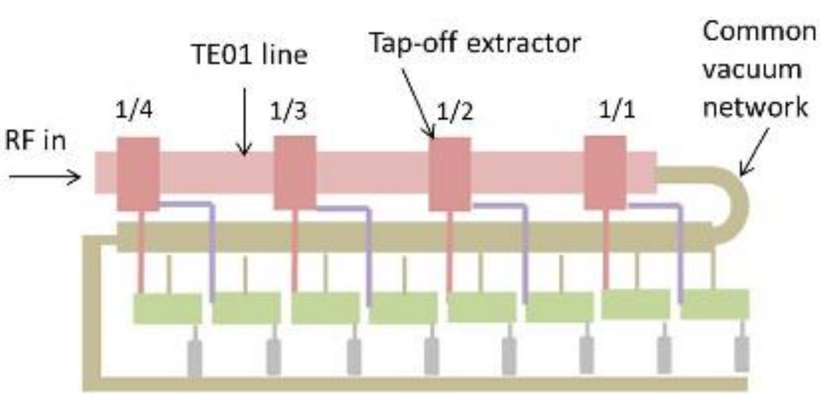
Study of Klystron-based Alternative II

Reduced klystron power compared to NLC/JLC

Fairly mature

Improved designs being made

General	
structures per unit	8
Unit length [m]	2.0
Energy gain per unit [MeV]	183
Klystron	
Pulse length [ns]	1950
Peak power [MW]	59
Voltage [kV]	460
Current [A]	234
Efficiency [%]	55
Dual moded SLED II pulse compressor	
One delay line length [m]	17.7
Output pulse length [ns]	244
Output power [MW]	490
Power gain	4.64
CLIC_G accelerating structure	
Structure length [m]	0.23
Input RF power [MW]	61.3
Gradient (loaded) [MV/m]	100



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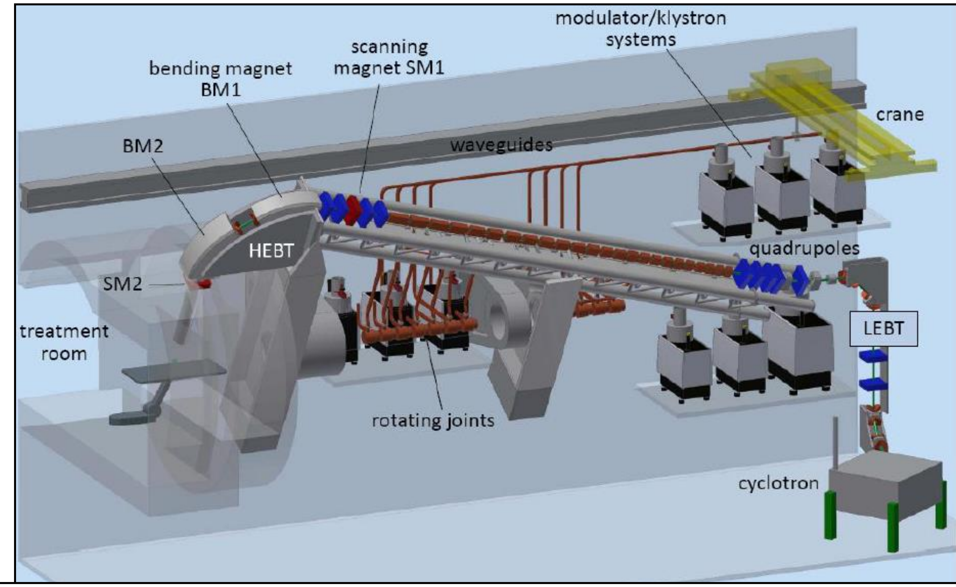
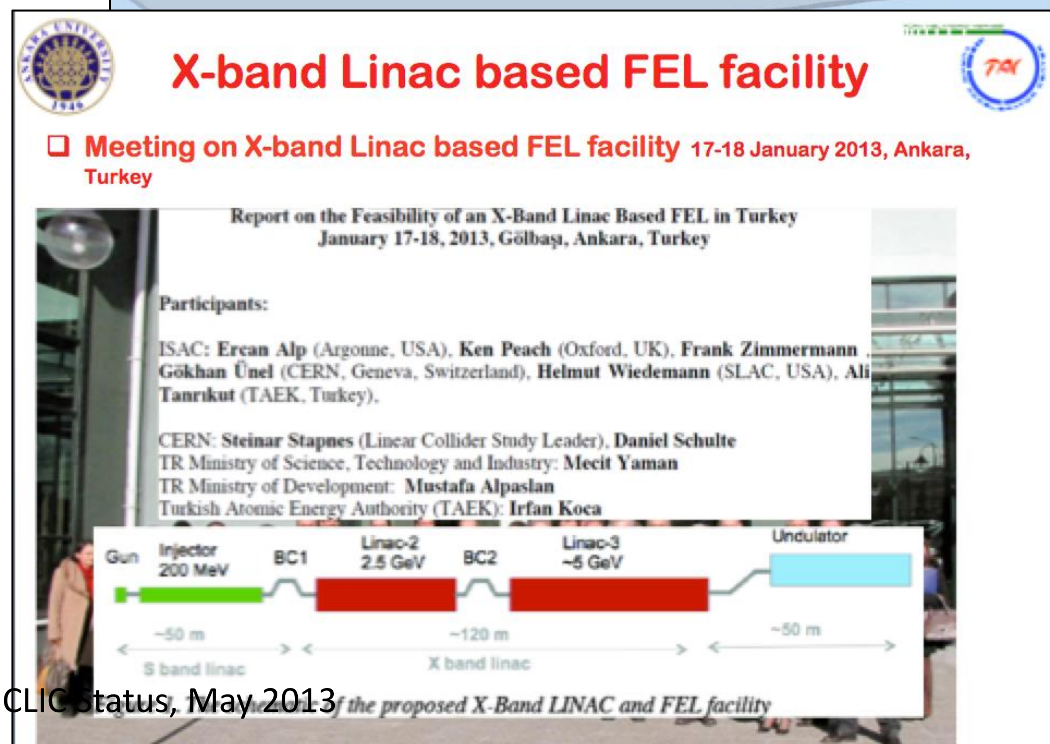
Links to Other Applications

Introduction	*Steinar STAPNES*
Council Chamber, CERN	08:30 - 08:40
CLIC activities/plans	*Walter WUENSCH*
Council Chamber, CERN	08:40 - 08:55
PSI activities/plans	*Dr. Ricardo ZENNARO*
Council Chamber, CERN	08:55 - 09:10
Trieste/Fermi plans	*Dr. Gerardo D'AURIA*
Council Chamber, CERN	09:10 - 09:25
TERA activities/plans	*Ugo AMALDI*
Council Chamber, CERN	09:25 - 09:40
Shanghai activities/plans	*Dr. Qiang GU et al.*
Council Chamber, CERN	09:40 - 09:55
Tsinghua	*Jiaru SHI*
Council Chamber, CERN	09:55 - 10:10
ALBA	*Mr. Francis PéREZ*
Council Chamber, CERN	10:10 - 10:25
Coffee	
Council Chamber, CERN	10:25 - 10:45
SLAC activities/plans	*Prof. Sami TANTAWI*
Council Chamber, CERN	10:45 - 11:00
Ankara/Turkish activities/plans	*Avni AKSOY*
Council Chamber, CERN	11:00 - 11:15
MAX-lab	*Mrs. Francesca CURBIS*
Council Chamber, CERN	11:15 - 11:30
Argonne activities/plans	*Dr. Wei GAI*
Council Chamber, CERN	11:30 - 11:45
Short discussion	
Council Chamber, CERN	11:45 - 12:00

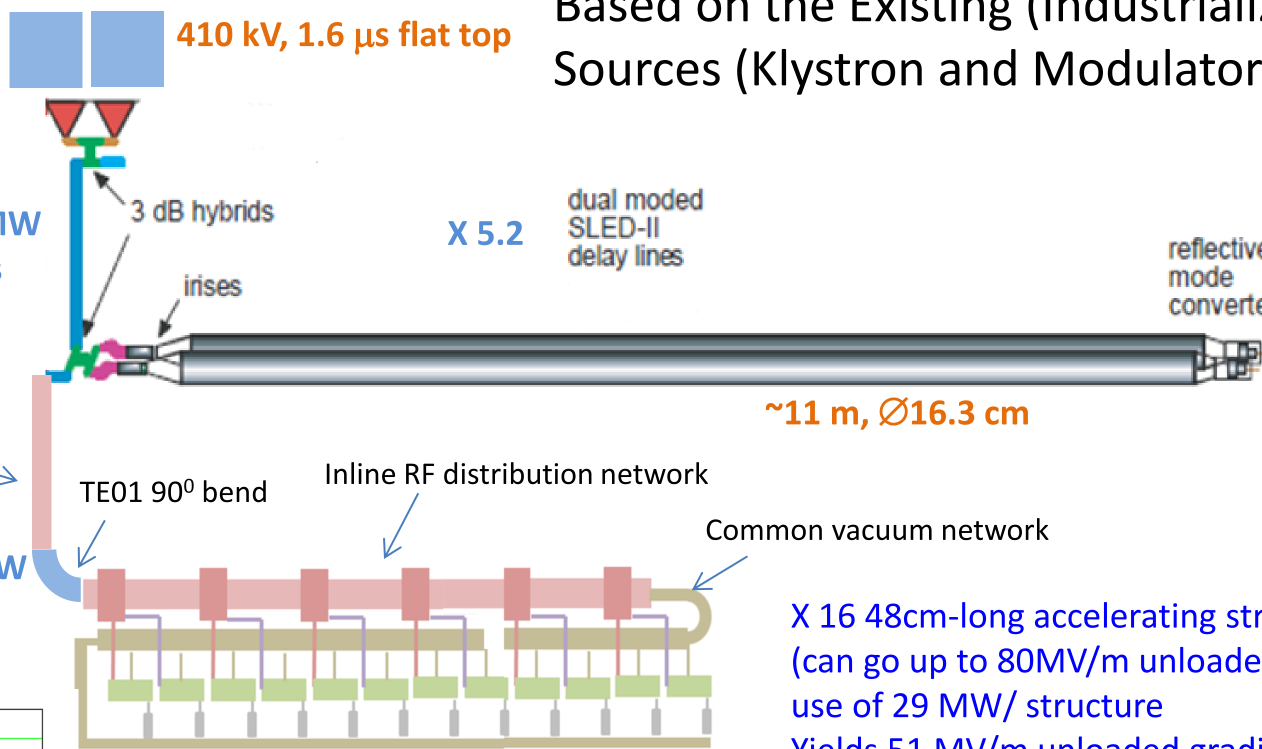




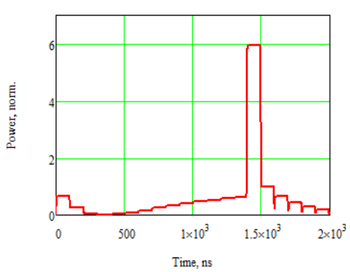
Example of Electron Linac RF Unit Layout

Based on the Existing (Industrialized) RF Sources (Klystron and Modulator)

I. Syratchev



X 16 48cm-long accelerating structures
(can go up to 80MV/m unloaded)
use of 29 MW/ structure
Yields 51 MV/m unloaded gradient



This unit should provide ~391 MeV acceleration beam loading.
Need 15 RF units for 6GeV FEL.
Better structures should be possible
Future CLIC klystrons would save O(20%)

Thanks to the Growing CLIC Collaboration

CLIC multi-lateral collaboration - 48 Institutes from 25 countries

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)

Conclusion

- The CDR volumes document
  - The feasibility studies for CLIC
  - A staged approach to implement the project

- The work on the development phase is progressing
  - Rebaselining is on the way with focus also on low energy
  - The hardware development programme is being implemented
  - Focus on cost and industrialisation

- Collaborations are formed to promote the use of CLIC technology for other applications

- Thanks to the CLIC collaboration for the slides and work presented
- My excuses to those whose work I could not present this time and to those whose name did not appear explicitly