Technology developments for The CLIC accelerator

Outline:

•The CLIC accelerator studies

•Detectors at CLIC, the physics goals

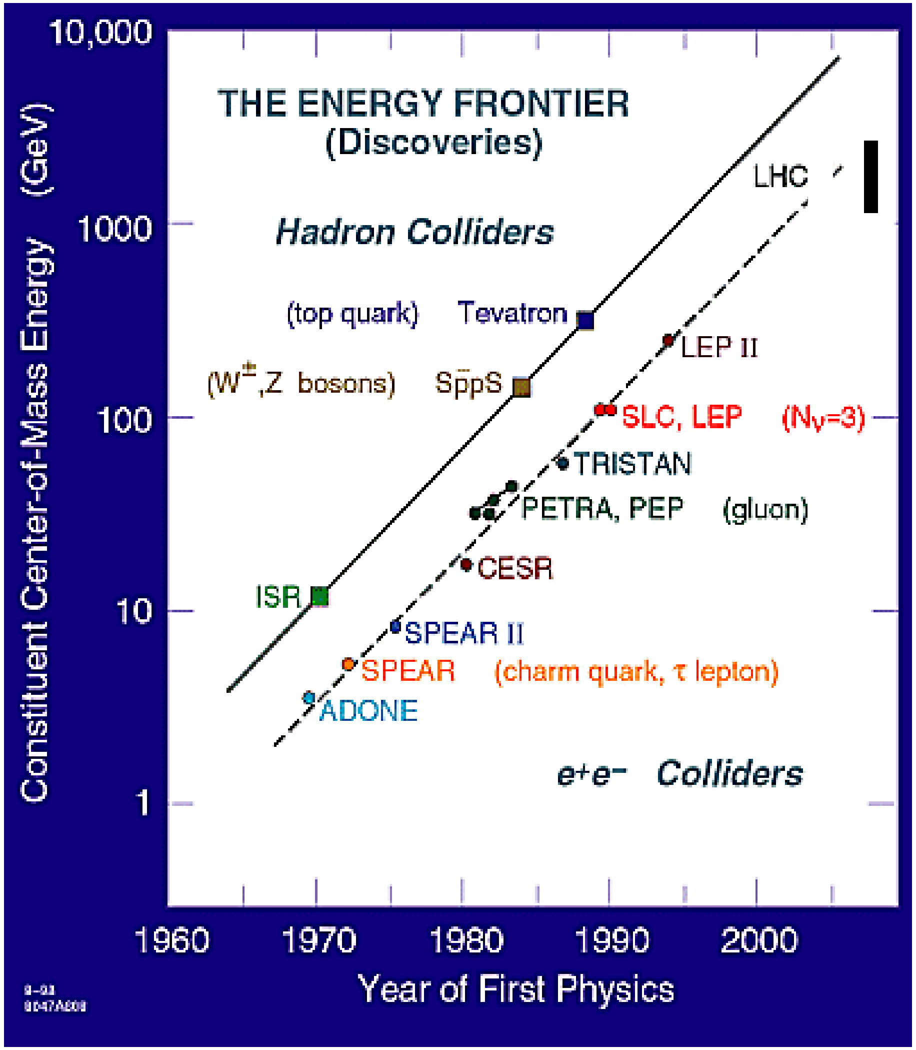
•Timelines and program of the coming years

•Specific subjects of CLIC technology development

•Summary

Hermann Schmickler on behalf of the CLIC study team
RUPAC 2012, St.Petersburg, Russia

Path to higher energy



- History:
  - Energy constantly increasing with time
  - Hadron Collider at the energy frontier
  - Lepton Collider for precision physics

- LHC online now
- Consensus to build Lin. Collider with E_{cm} > 500 GeV to complement LHC physics (*European strategy for particle physics* by CERN Council)

A little e+e- Linear Collider rational:

Basic parameters of any Linear Collider : **High Energy + Luminosity**

Energy:

High accelerating gradient: ILC (superconducting RF) : 35 MV/m

→ **CLIC (warm RF) : 100 MV/m**

→ important scaling between max. gradient and RF-Pulse length: CLIC: 140 ns only!

→ need power source that can generate a 140 ns several GW power pulse:

→ NO klystrons (pulse compression needed, maintenance of 10000 + units)

→ Generate a much longer power pulse into a SECOND beam (possible with about 1000 klystrons) and then compress this second beam in time!

→ use compressed second beam as power source for the main beam

→ **two beam acceleration scheme**

Luminosity:

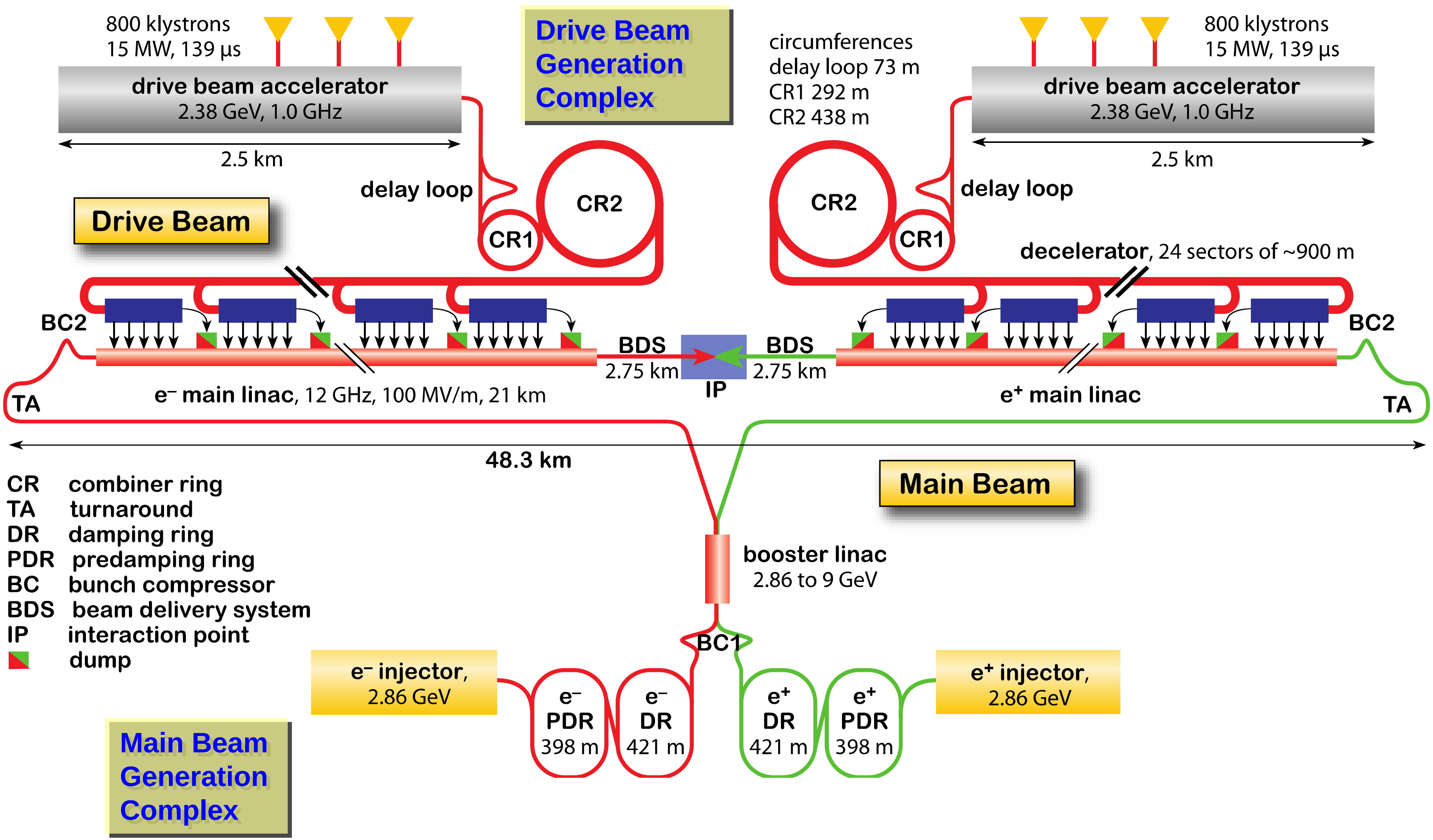
Luminosity needs high beam intensity and small beam sizes at the interaction point.

→ Small beam size: use of damping rings (synchrotron radiation for damping)

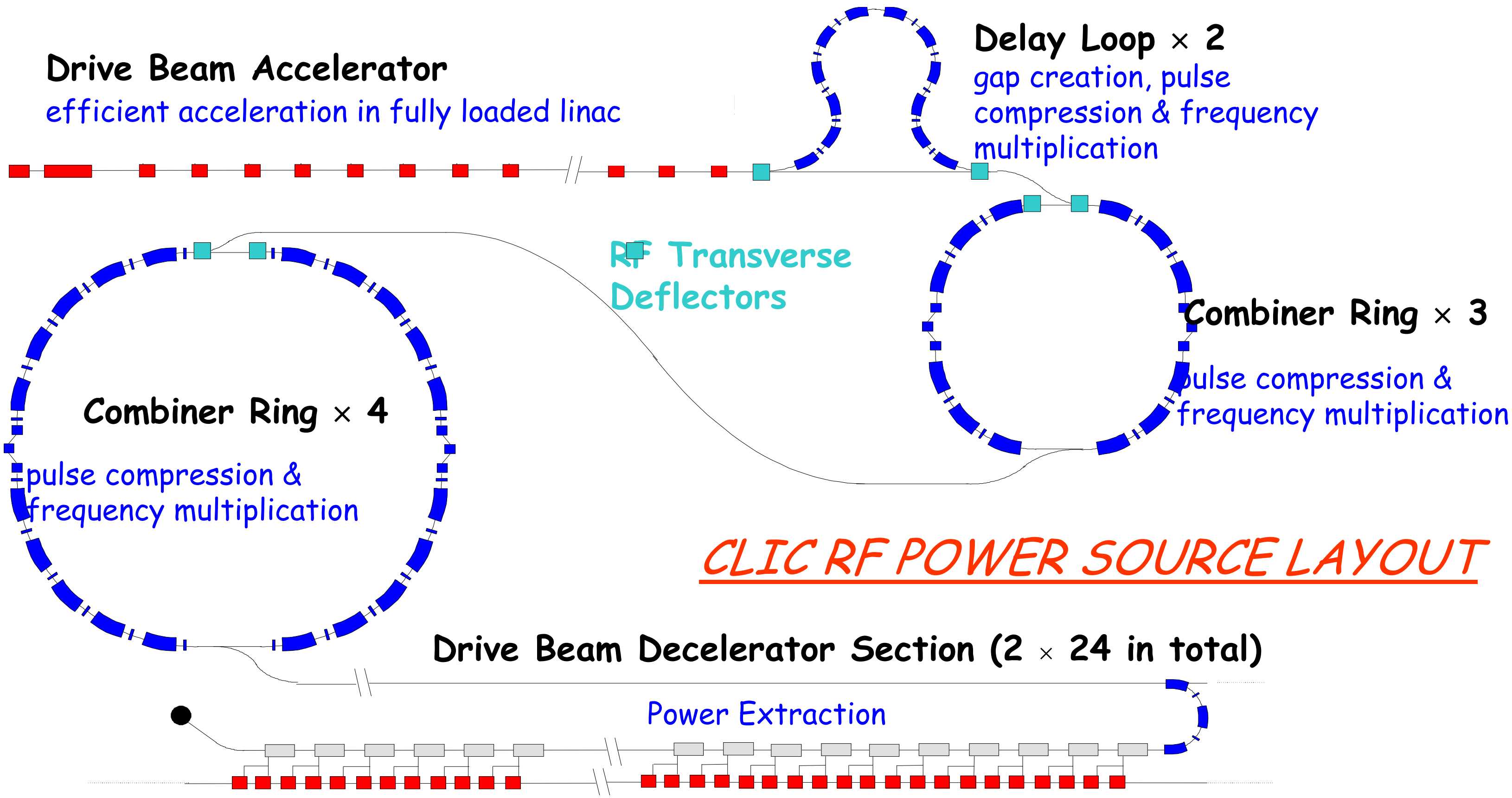
+ strong focusing quadrupoles at interaction point

+ all possible technologies to preserve small beam sizes in accelerating linac

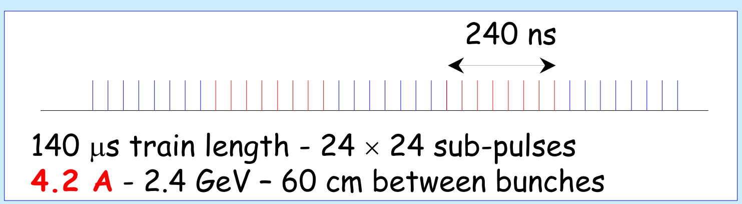
CLIC Layout for 3 TeV cms energy



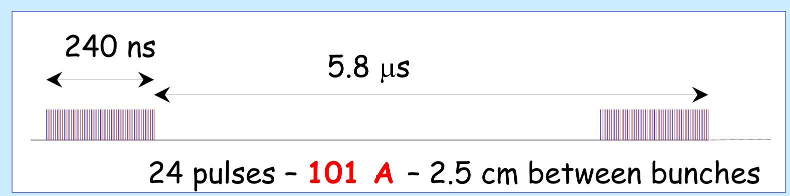
CLIC Power Source Concept



Drive beam time structure - initial



Drive beam time structure - final



Current CLIC&CTF3 Collaboration

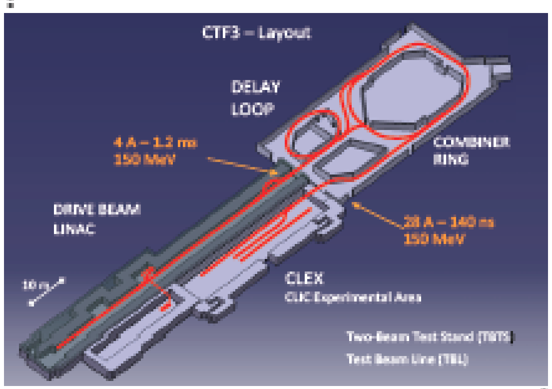
CLIC multi-lateral collaboration - 44 Institutes from 23 countries

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 (Russia)
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)

CLIC project time-line

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.



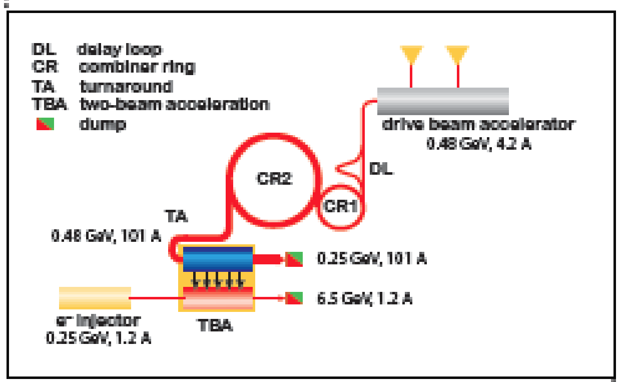
2016-17 Decisions

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.



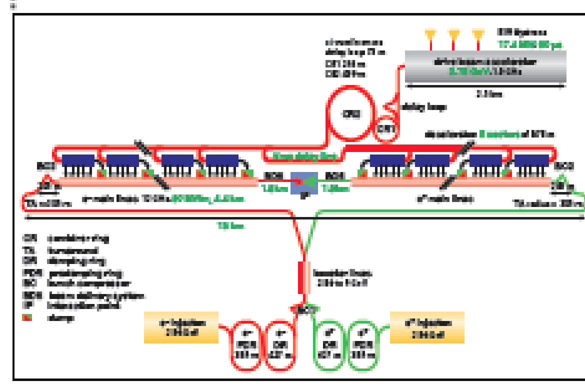
2022-23 Construction Start

Ready for full construction and main tunnel excavation.

2023-2030 Construction Phase

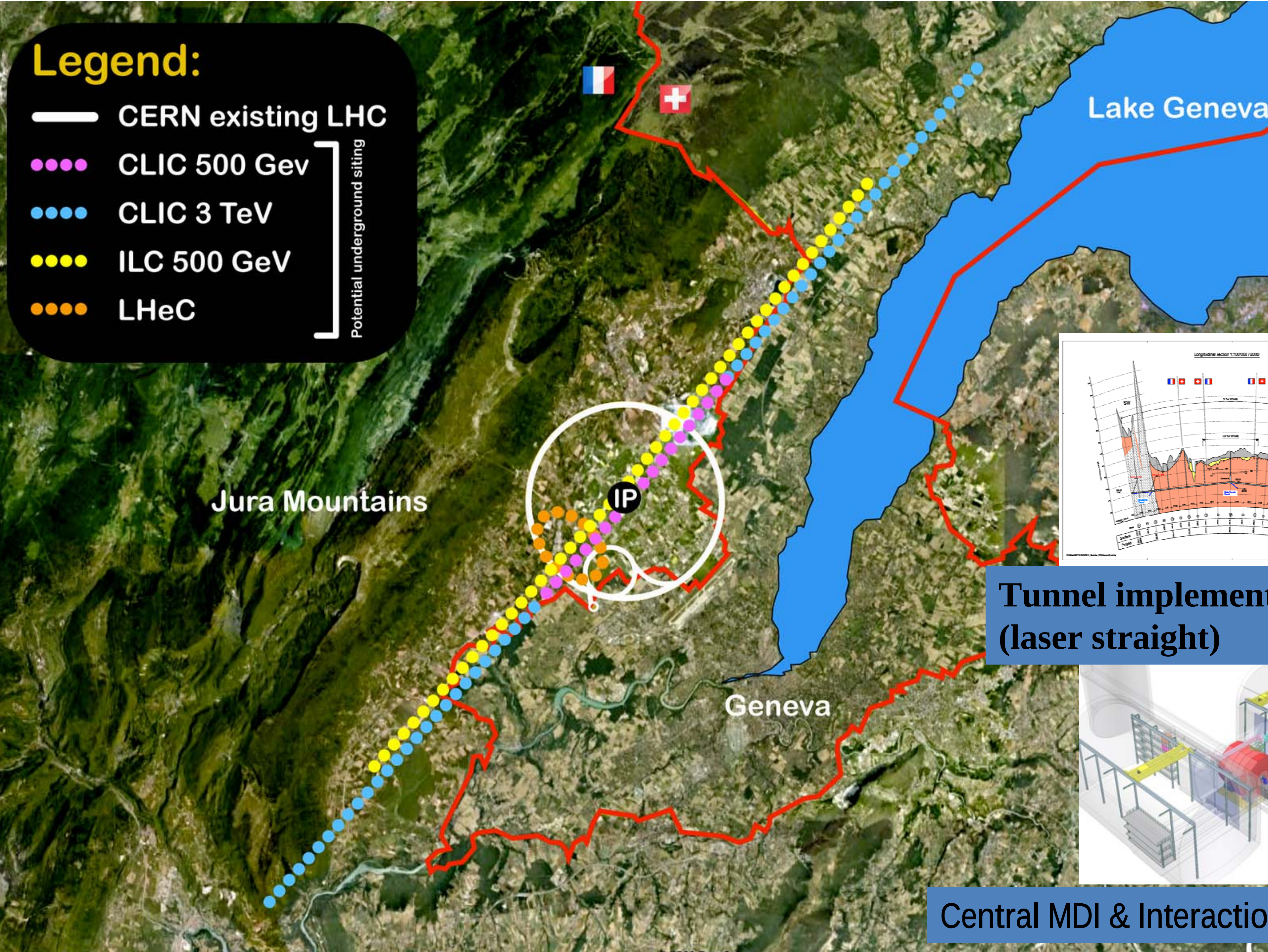
Stage 1 construction of a 500 GeV CLIC, in parallel with detector construction.

Preparation for implementation of further stages.



2030 Commissioning

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


Legend:
CERN existing LHC
CLIC 500 Gev
CLIC 3 TeV
ILC 500 GeV
LHeC
Potential underground siting
Lake Geneva
Jura Mountains
IP
Geneva
Tunnel implement
(laser straight)
Central MDI & Interactio

Volume 1:

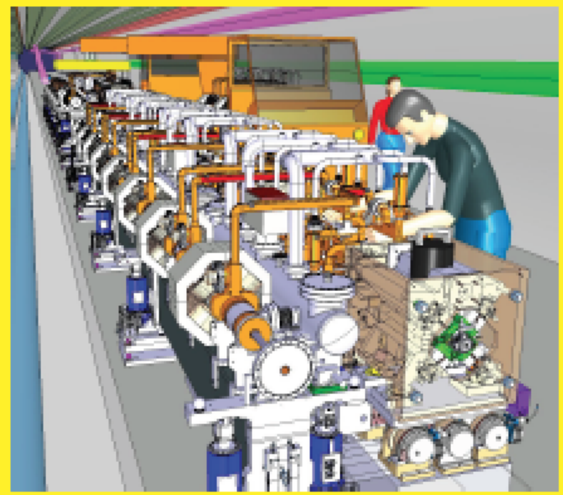
Submitted to Yellow Report team, answer received (mainly related to figures), placement of logo, etc - etc … iterations in progress

CERN ref number not there yet

Link:
http://project-clic-cdr.web.cern.ch/project-CLIC-CDR/CDR_Volume1.pdf

SLAC-R-985
KEK Report 2012-1
PSI-12-01
JAI-2012-001
CERN-???
2 August 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

Volume 3:

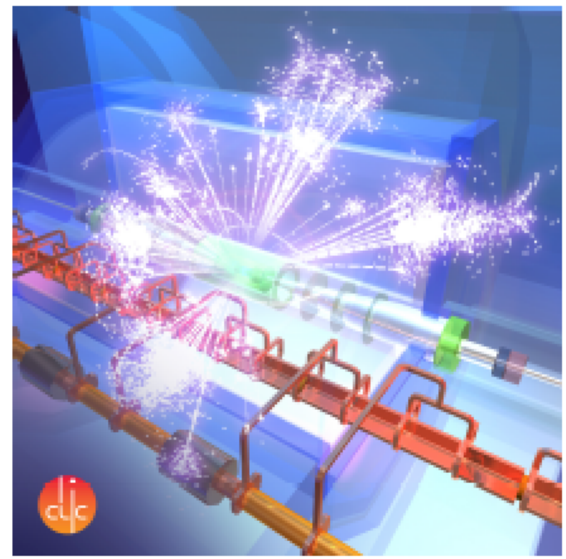
Submitted to Yellow Report team and accepted, (being) launched for test-print.
CERN ref number given.

Links:
https://edms.cern.ch/document/1235960/

To get printed document:
https://indico.cern.ch/conferenceDisplay.py?confId=203399

ANL-HEP-TR-12-51
CERN-2012-005
KEK Report 2012-2
MPP-2012-115
8 August 2012

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



THE CLIC PROGRAMME:
TOWARDS A STAGED e^+e^- LINEAR COLLIDER
EXPLORING THE TERASCALE

CLIC CONCEPTUAL DESIGN REPORT

GENEVA
2012

CLIC technology developments (list not complete….)

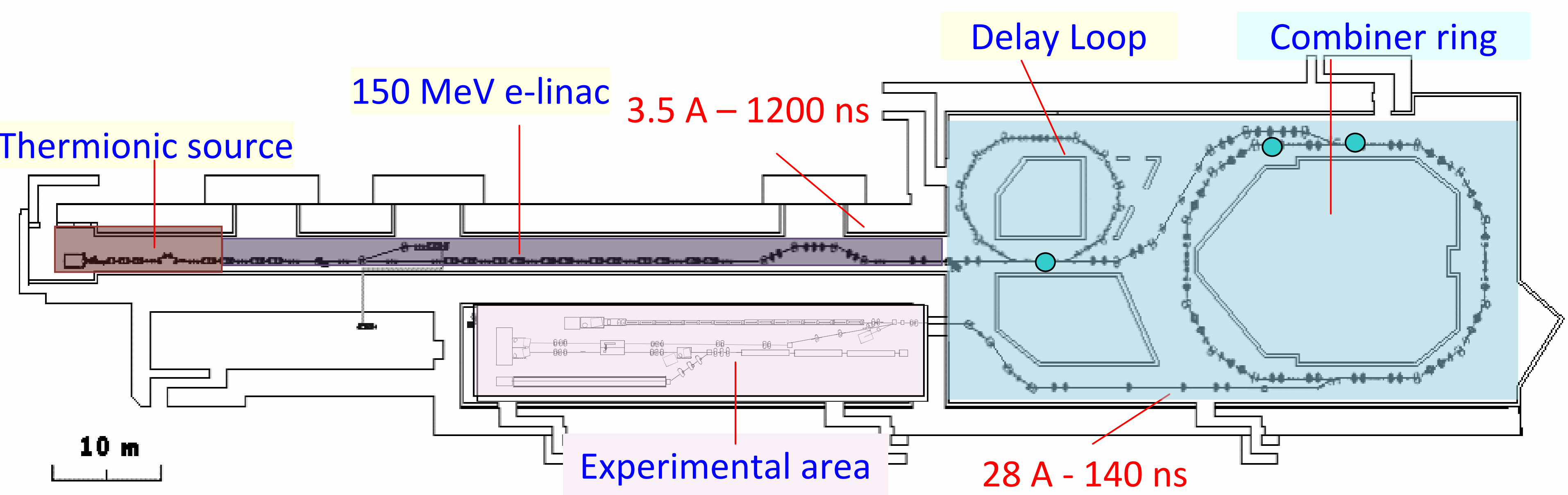
X-band RF (12 GHz) : series production of high gradient accelerating structures, Power extraction structures,
→ test-stands for testing

DB generation: 15 MW 1 GHz klystrons with high efficiency (>70%)
→developments with industry
Low ripple modulators (10-4 level)
→ CERN driven R&D together with several institutes
→continuation of the present CTF3 program at CERN

High luminosity related:

Collaboration with various light sources for the generation of ultra low emittance beams
-Specific technology developments:
-Alignment systems and remote actuators for main linac
-Quadrupole stabilization against ground motion and technical noise
-Two beam module integration

CLIC Test Facility (CTF3)



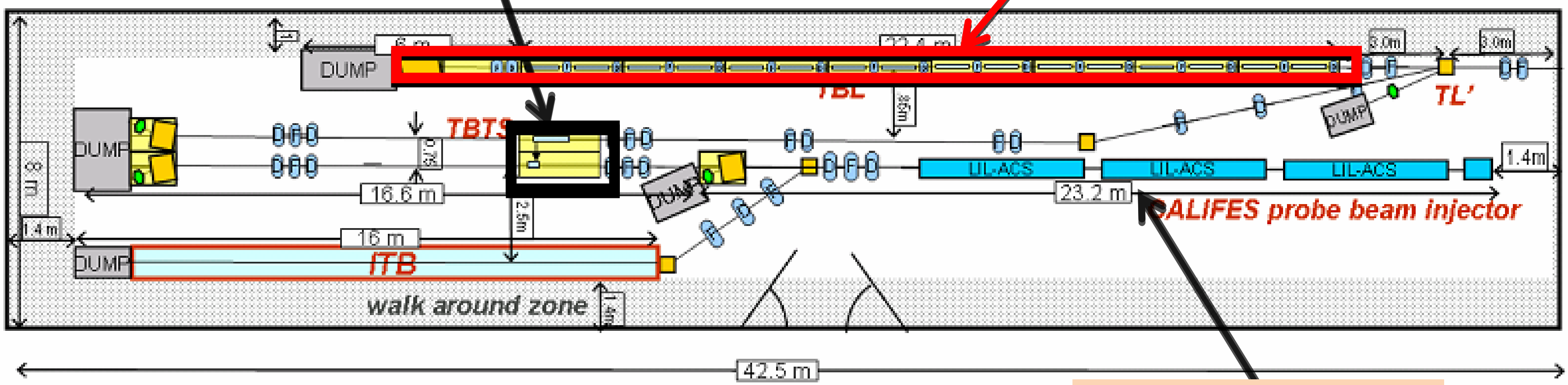
parameter	unit	CLIC	CTF3
accelerated current	A	4.2	3.5
combined current	A	101	28
final energy	MeV	2400	≈ 120
accelerated pulse length	μs	140	1.2
final pulse length	ns	240	140
acceleration frequency	GHz	1	3
final bunch frequency	GHz	12	12

Recycled infrastructure
- made it affordable
- causes lots of headache

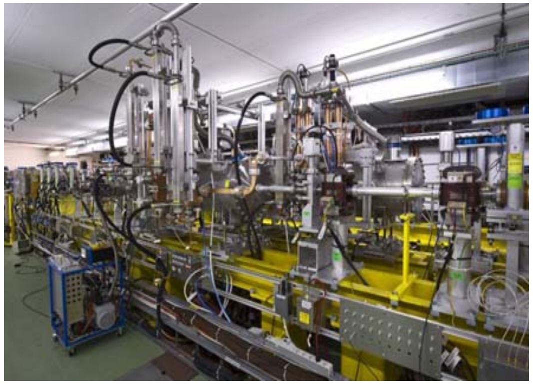
Drive Beam Deceleration and Module: CLEX

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

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



Main beam injector



Drive Beam Combination

29 A reached, routinely 25A

Significant increase of transverse emittance

Current jitter increases to O(0.1%-1%)

Focus has been on current

•will now further improve beam quality

CTF3 specific issues need to be addressed and limits identified

•RF pulse compression

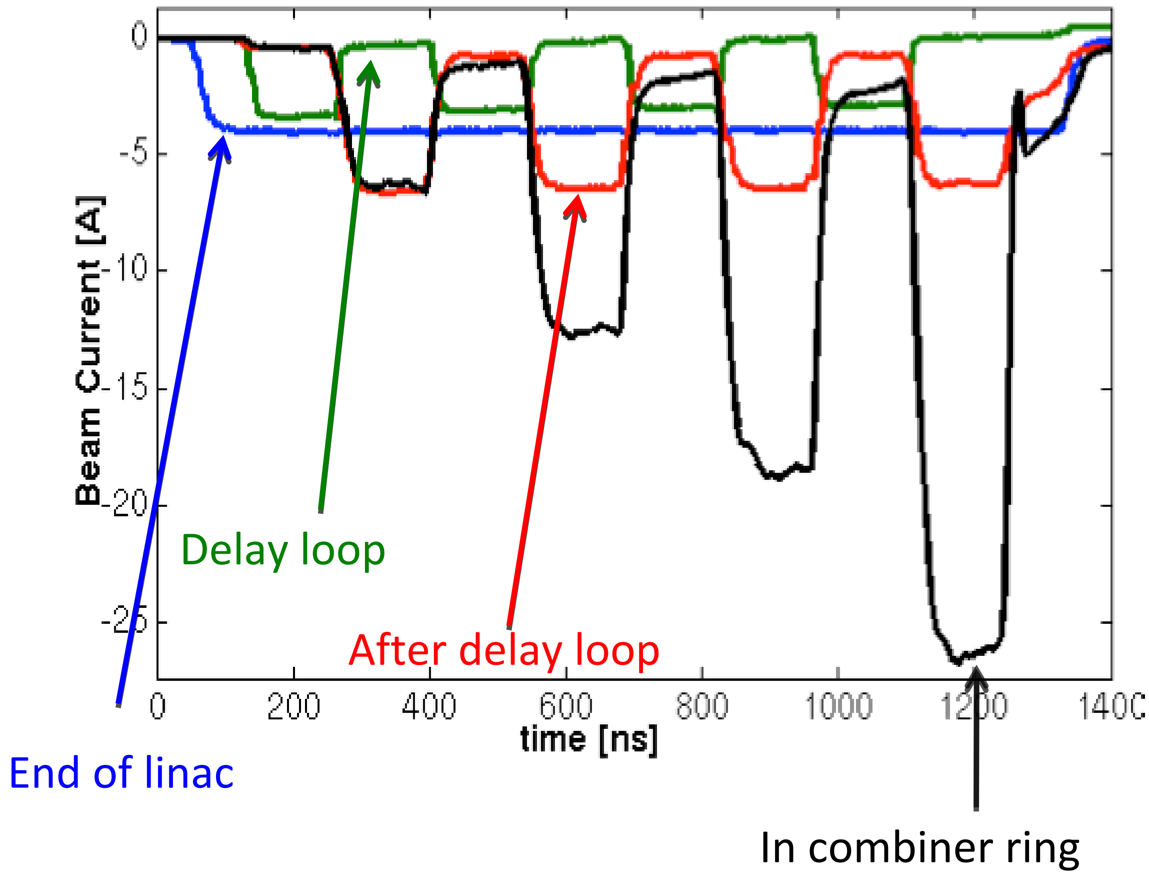
•Beam energy in combiner ring is 5% of that in CLIC

•Geometric emittance 20 times larger

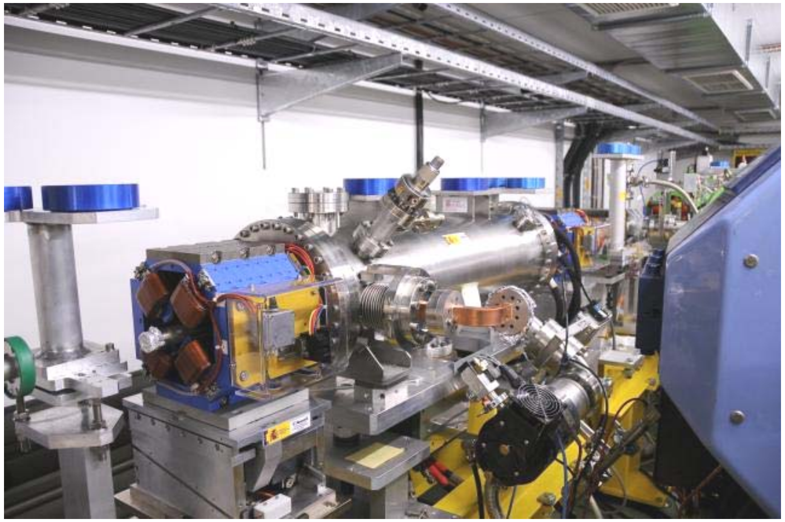
• …

• …

Current measurement in CTF3



TBL: Drive Beam Deceleration



9 out of 16 PETS installed

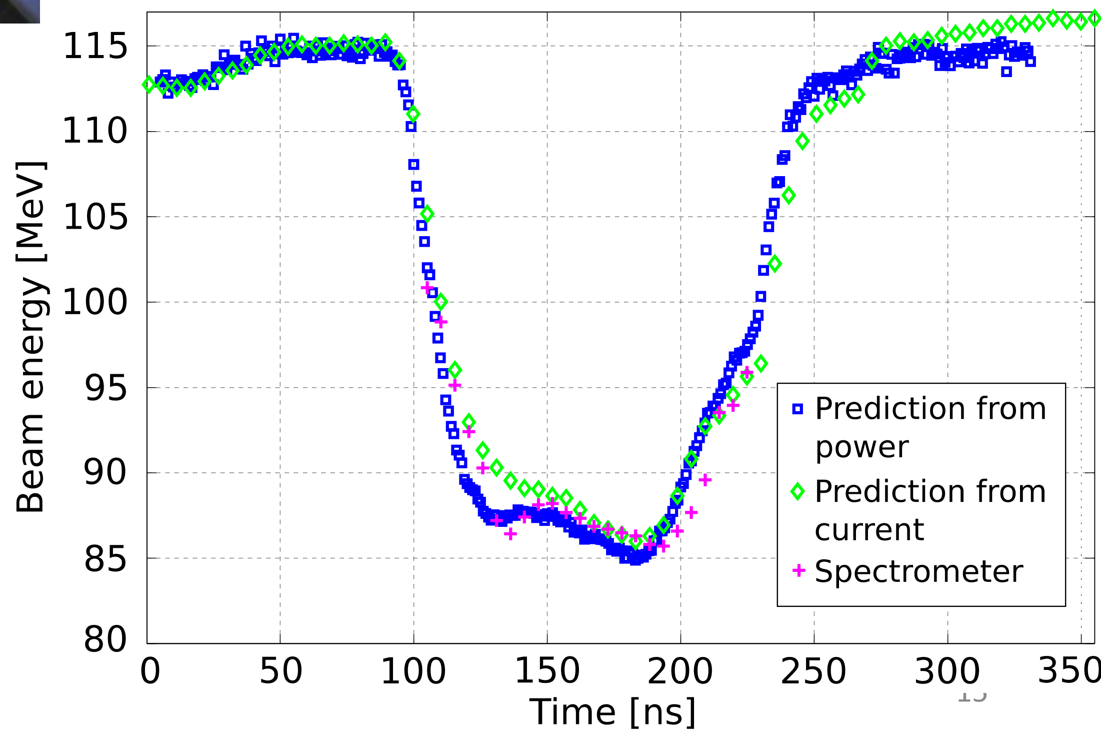
Rest will come this year

~26% deceleration

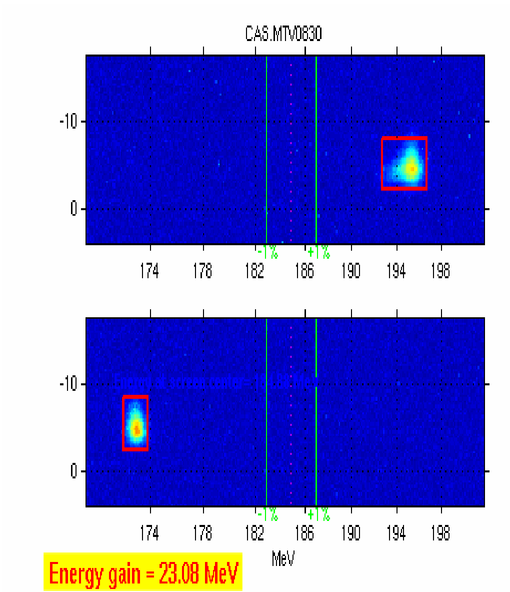
Final goal is 50% deceleration

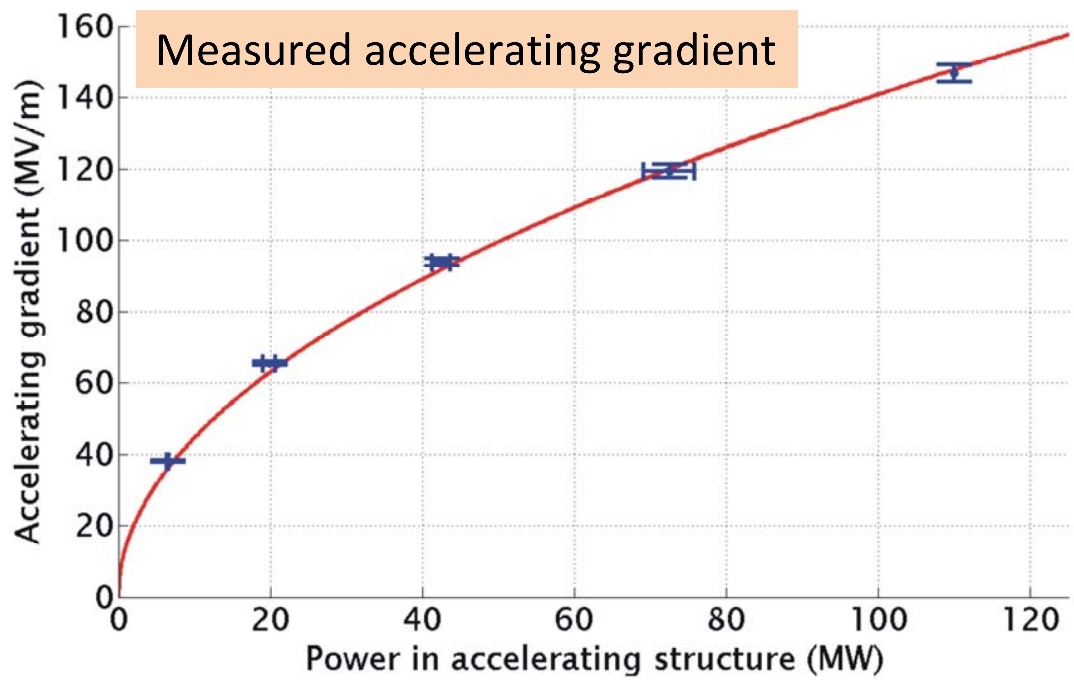
Measured in TBL:
Up to 21A current
- optics understood
- no losses in TBL

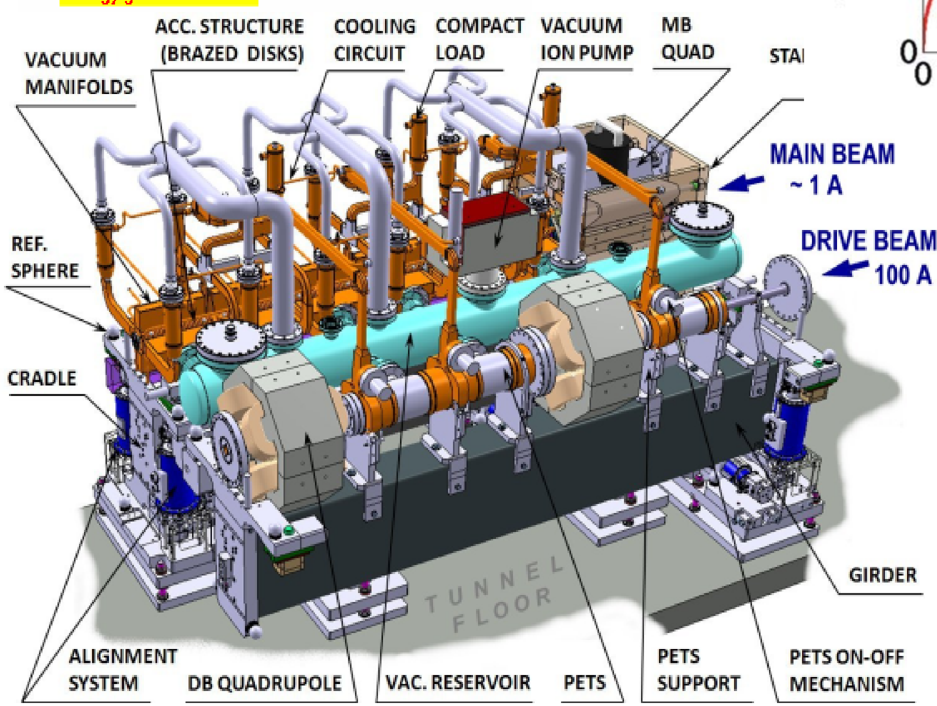
Good agreement
- power production
- beam current
- beam deceleration



TBTS: Two Beam Acceleration

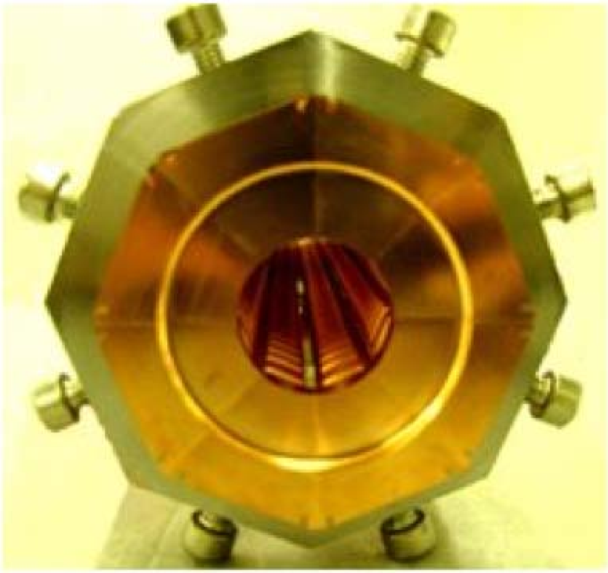


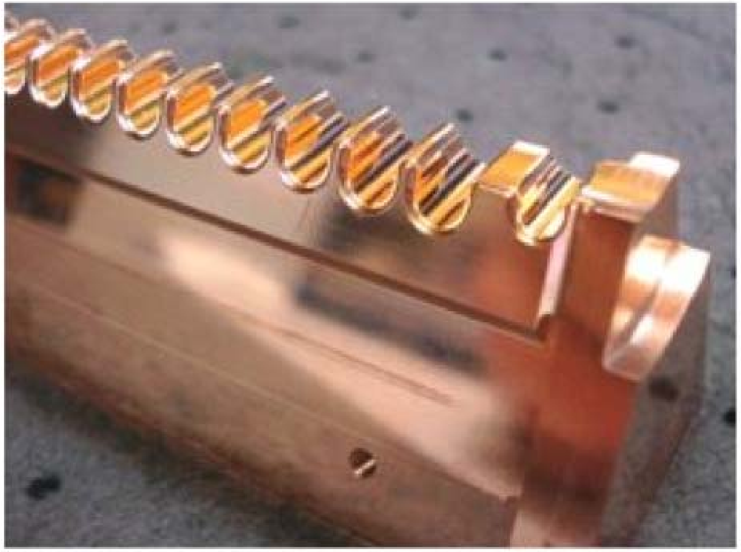




Maximum gradient
145 MV/m

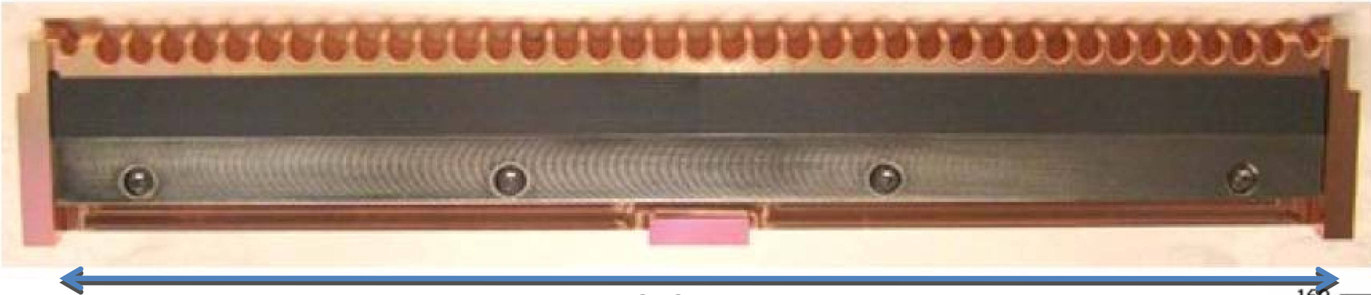
Consistency between
- produced power
- drive beam current
- test beam acceleration





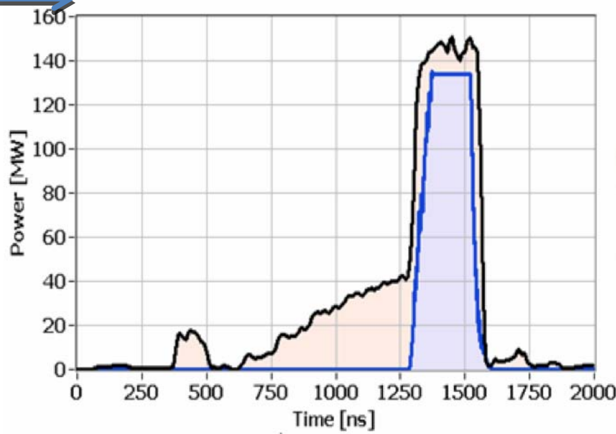
Designed with more margin than accelerating structures

P_{out}≈130MW



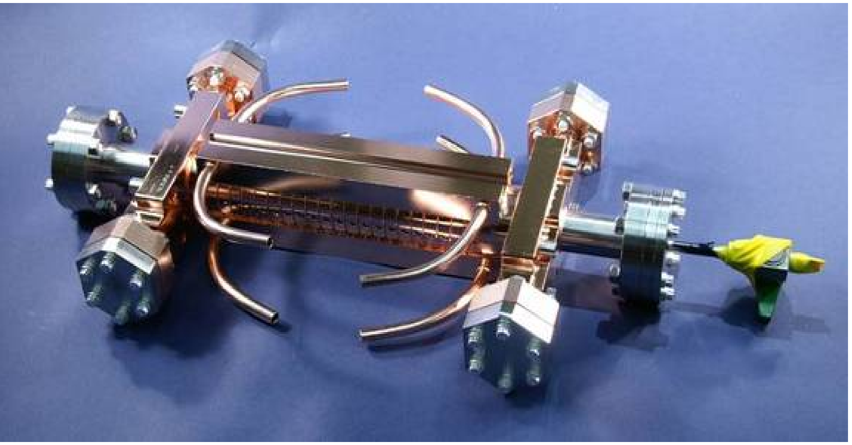
0.25m

Pulse used for measurement and nominal pulse (blue)

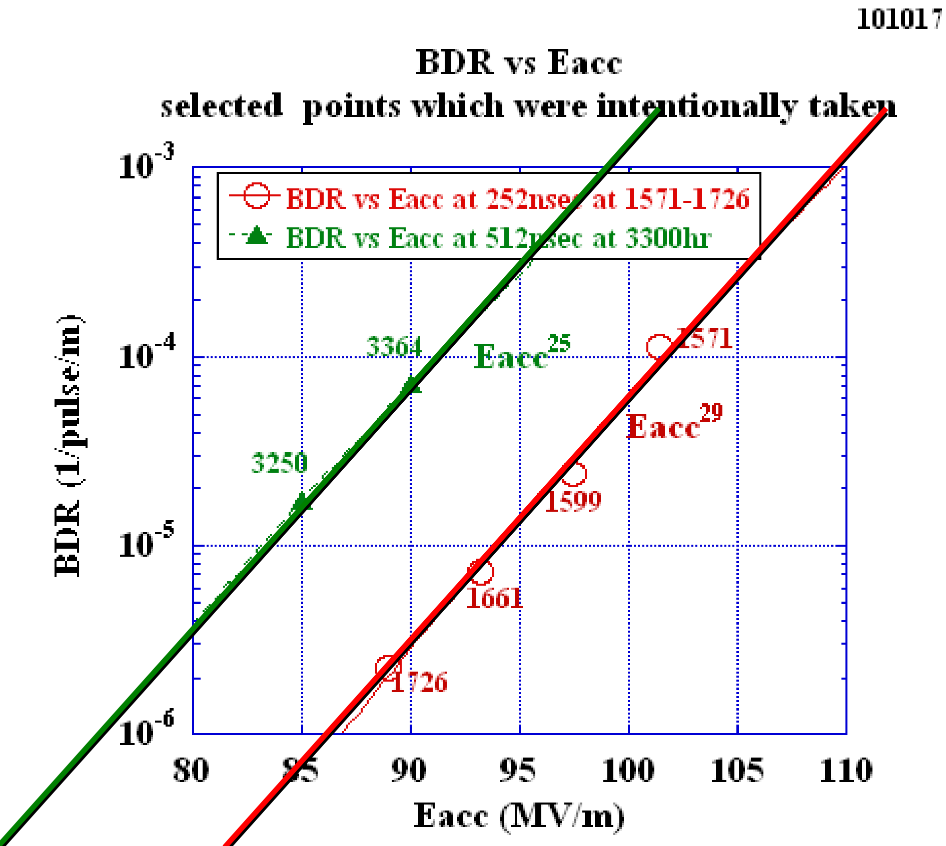


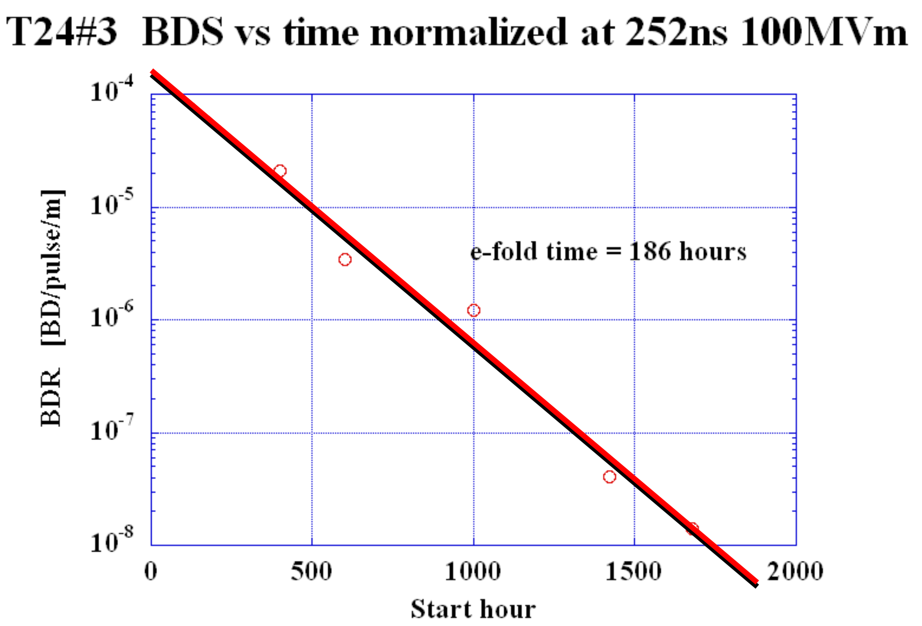
Measurements at SLAC:
No breakdown last O(8 10^6 pulses)
-> P consistent with p≤10^{-7}/m/pulse

Accelerating Structure



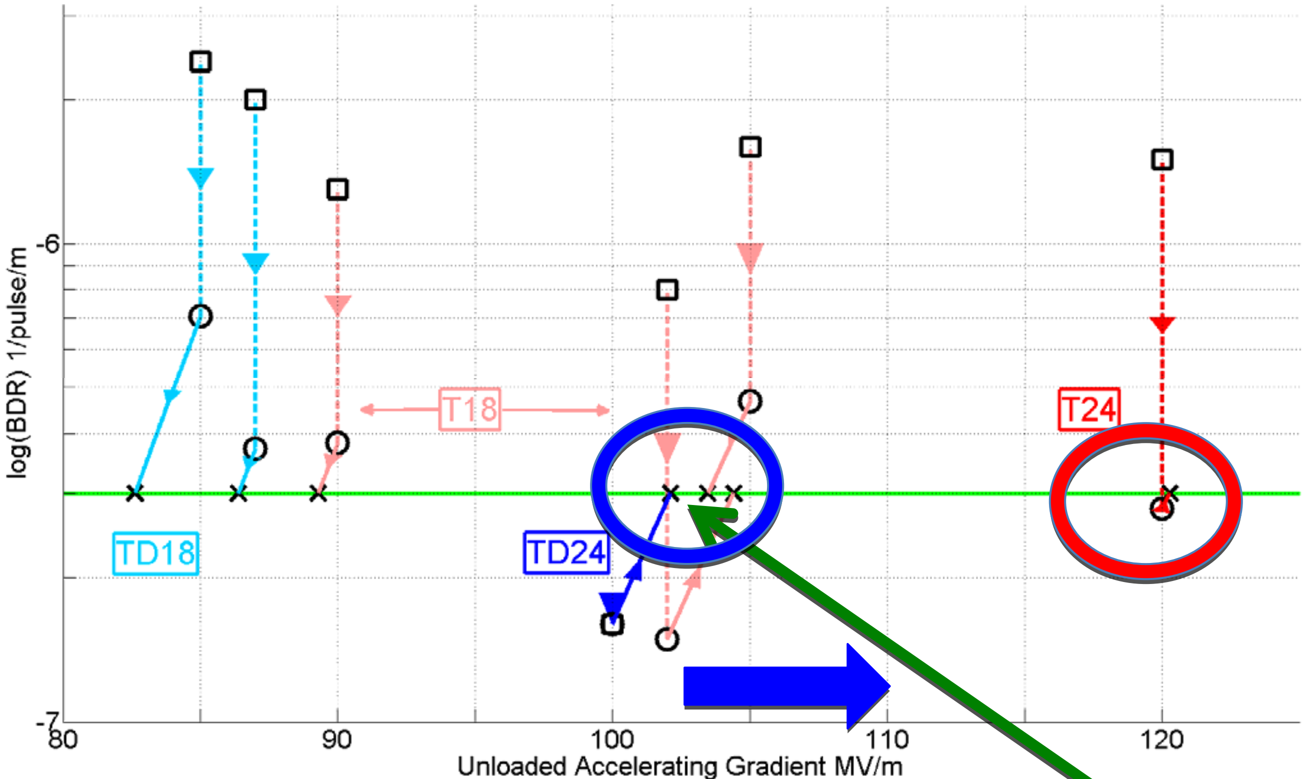
- Require <1% probability of even a single break down in any structure
  - $p \leq 3x10^{-7} m^{-1} pulse^{-1}$
- Design based on empirical constraints





Achieved Gradient

Tests at KEK and SLAC



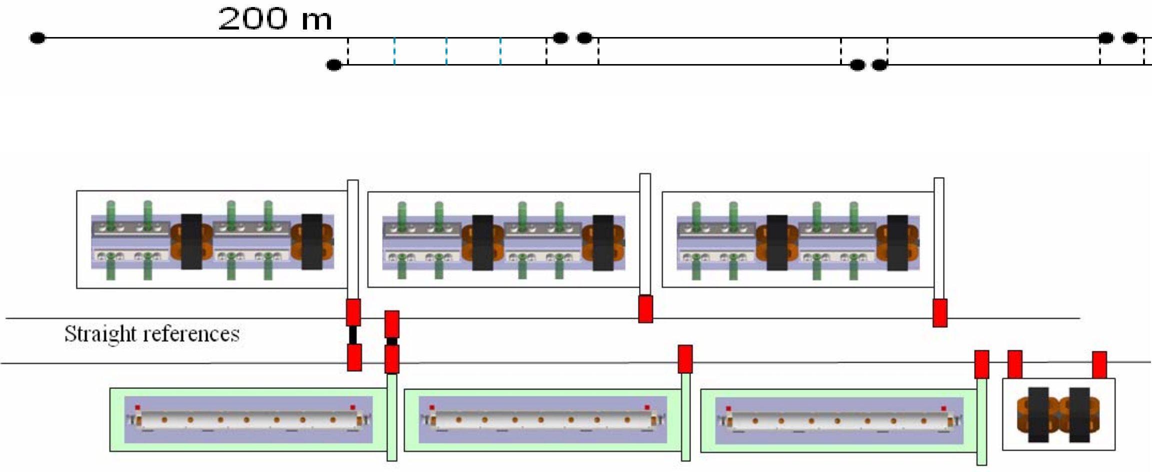
Measurements scaled according to

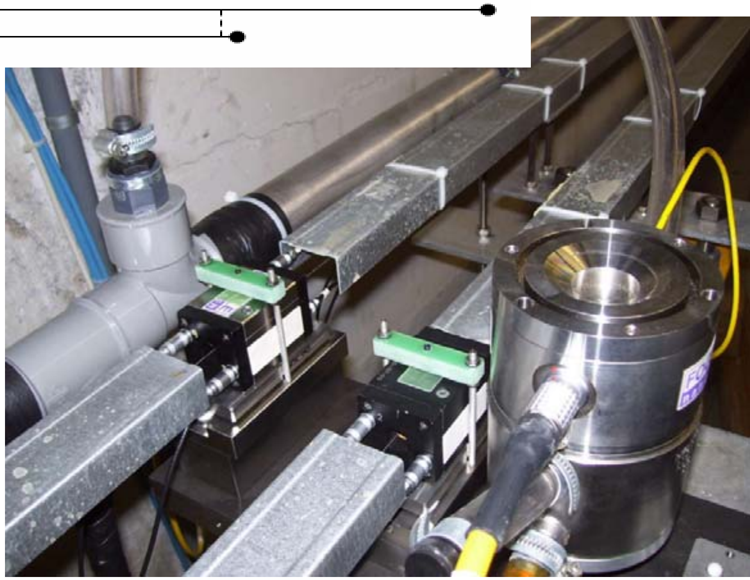
$$p \propto G^{30} \tau^{5}$$

Unloaded 103MV/m Expected with beam loading 86-103 MV/m

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

Pre-alignment System

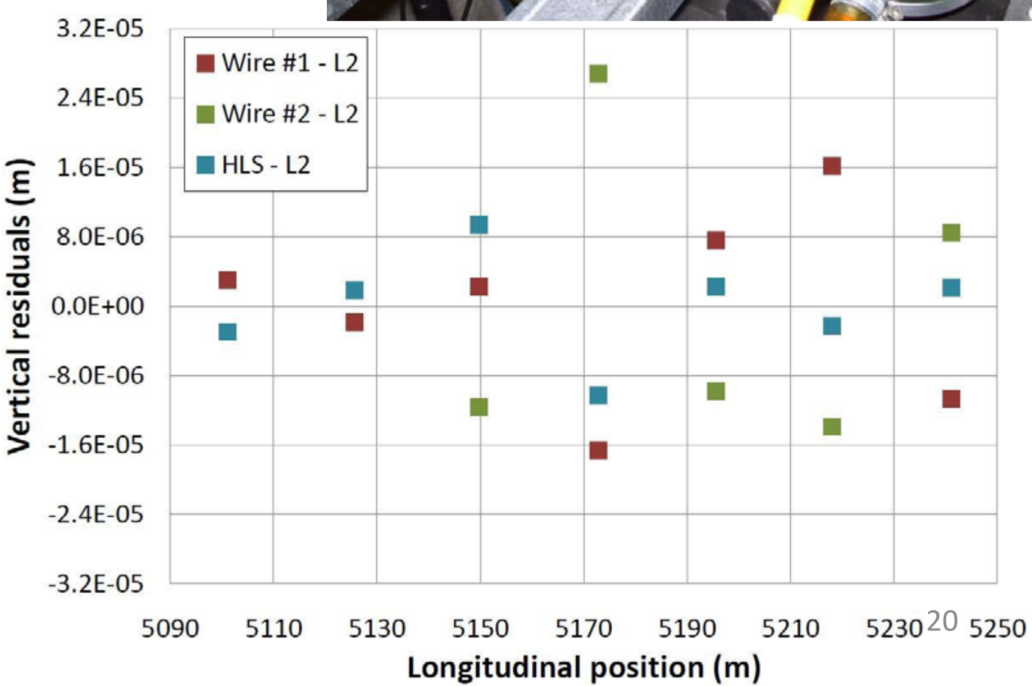




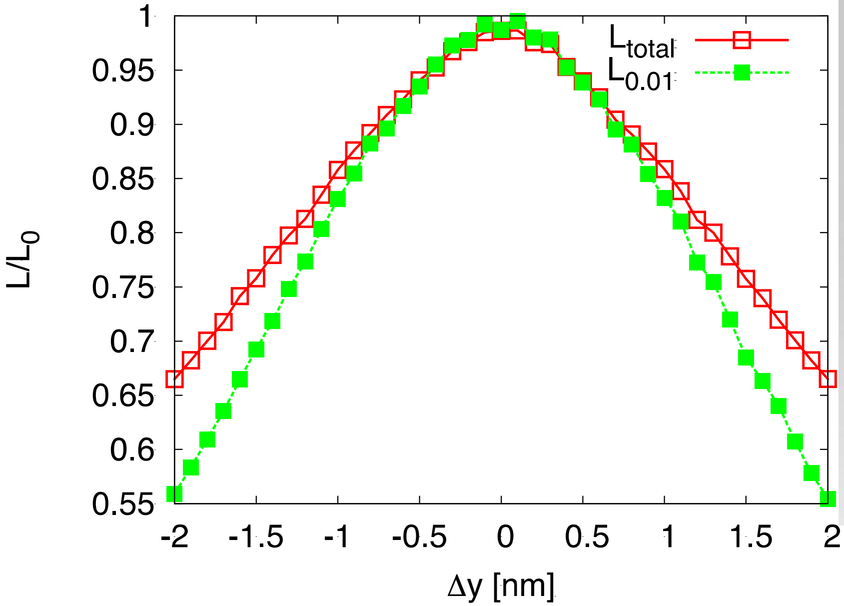
- Required accuracy of reference point is 10µm

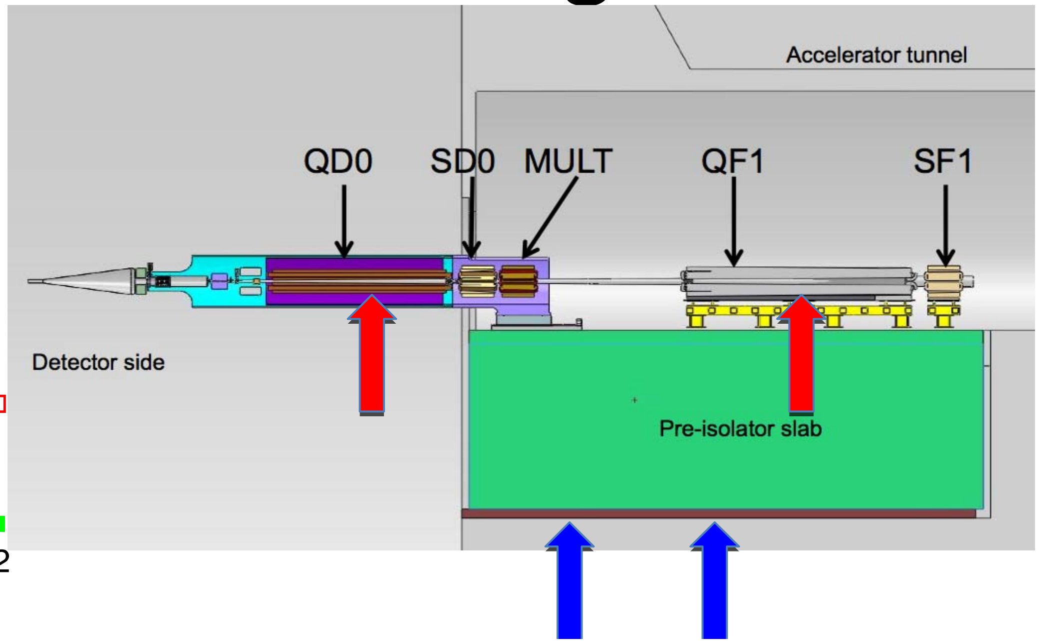
- Test of prototype shows
  - vertical RMS error of 11µm
  - i.e. accuracy is approx. 13.5µm

- Improvement path identified



Ground Motion and Its Mitigation

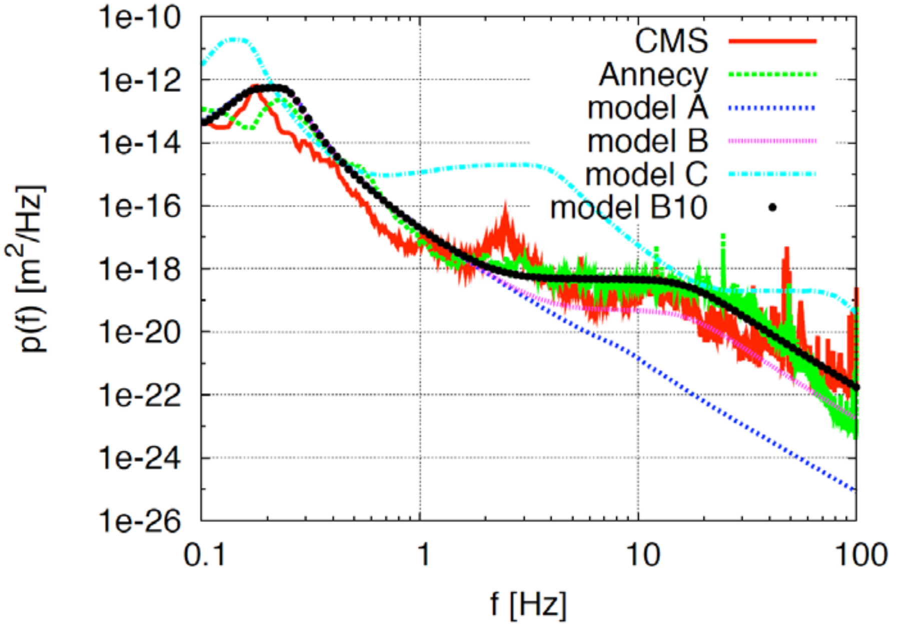




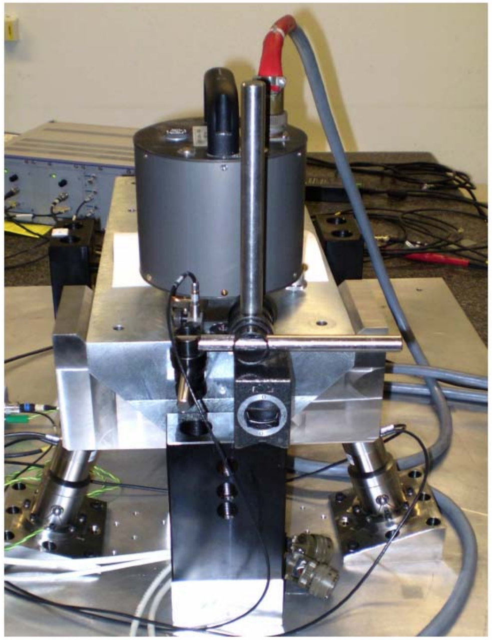
Natural ground motion can impact the luminosity

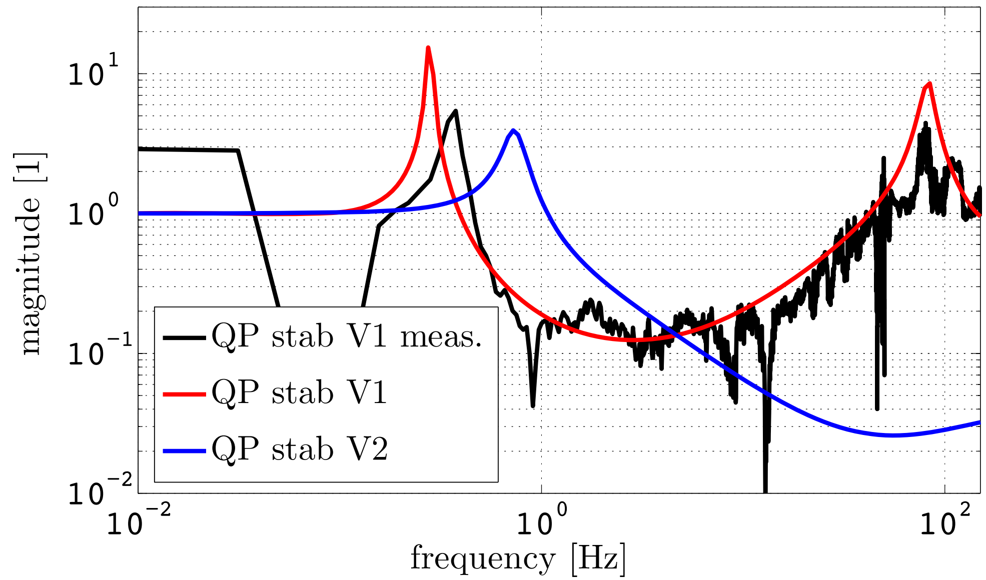
- typical quadrupole jitter tolerance O(1nm) in main linac and O(0.1nm) in final doublet

-> develop stabilisation for beam guiding magnets

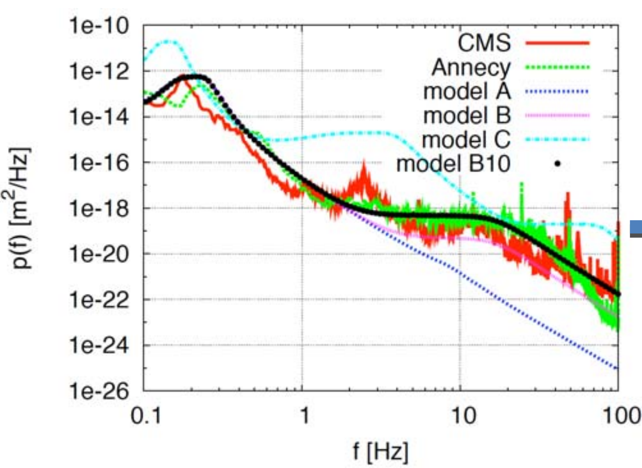


Active Stabilisation Results





Luminosity achieved/lost [%]	
	B10
No stab.	53%/68%
Current stab.	108%/13%
Future stab.	118%/3%



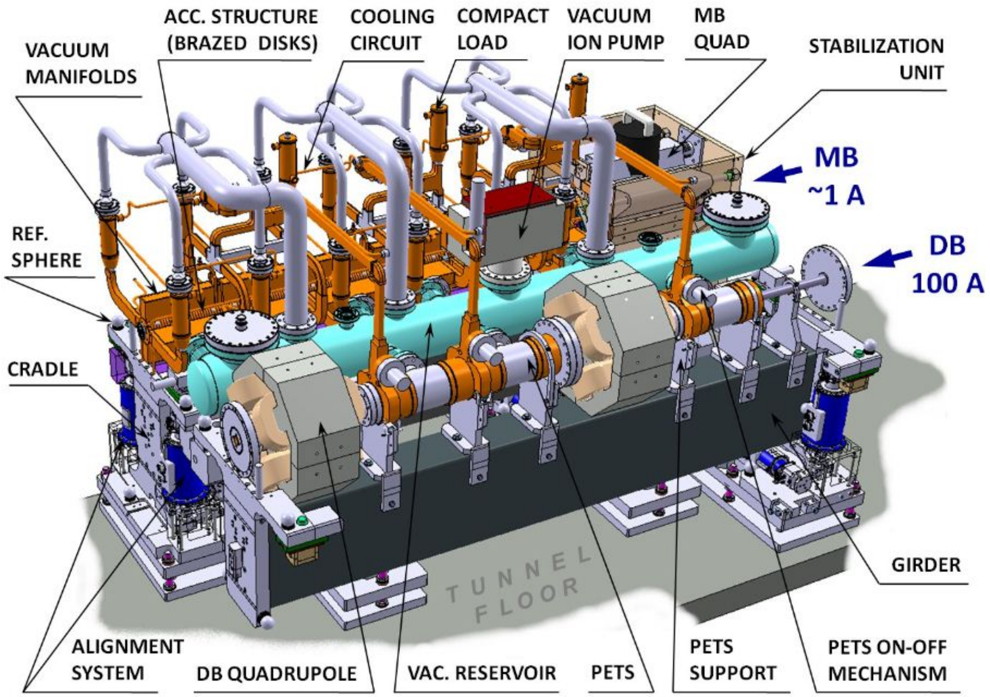
Code

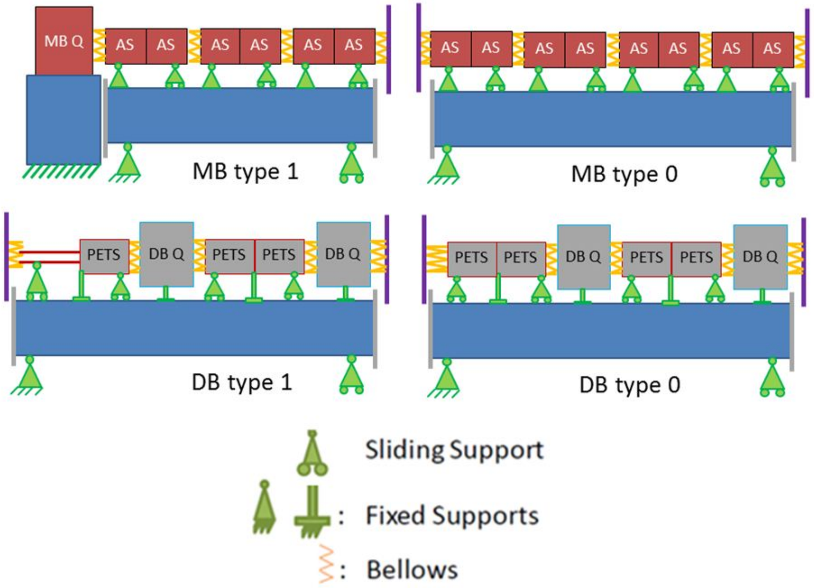
Machine model
Beam-based feedback

Close to/better than target

1. CLIC MODULES

CLIC module type 1

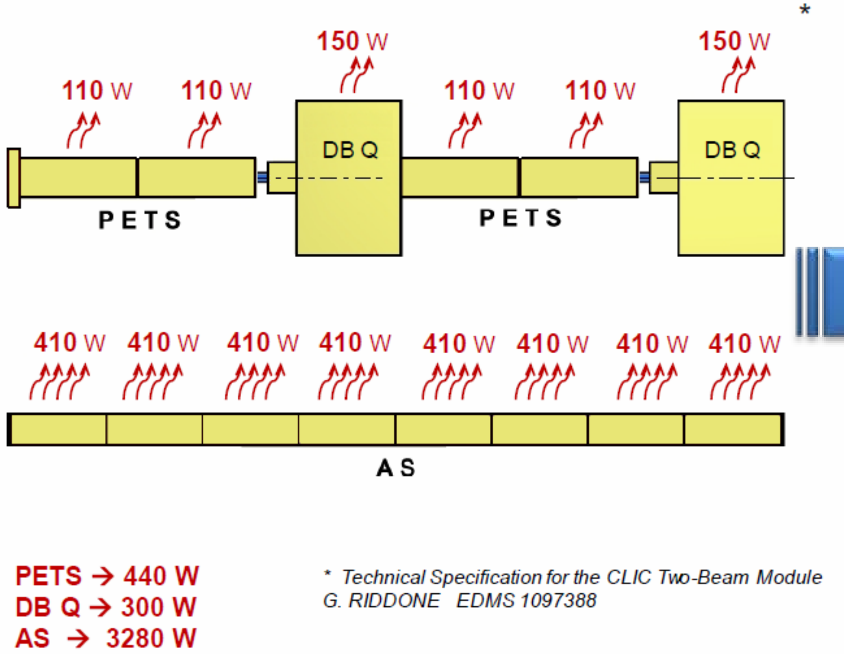


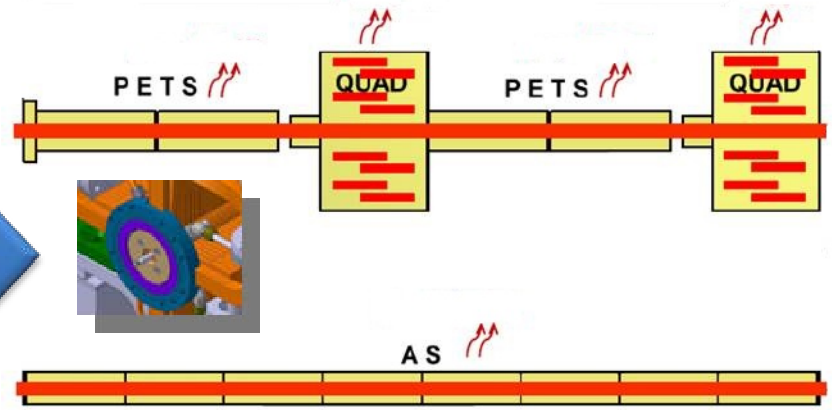


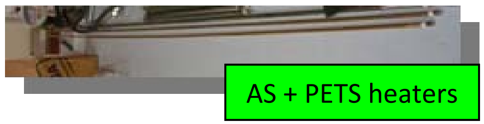
Constraints for CLIC module type 1

G. Riddone, A. Samoshkin, CLIC
Test Module meeting 25.07.2011

- Experimental conditions to be reproduced:

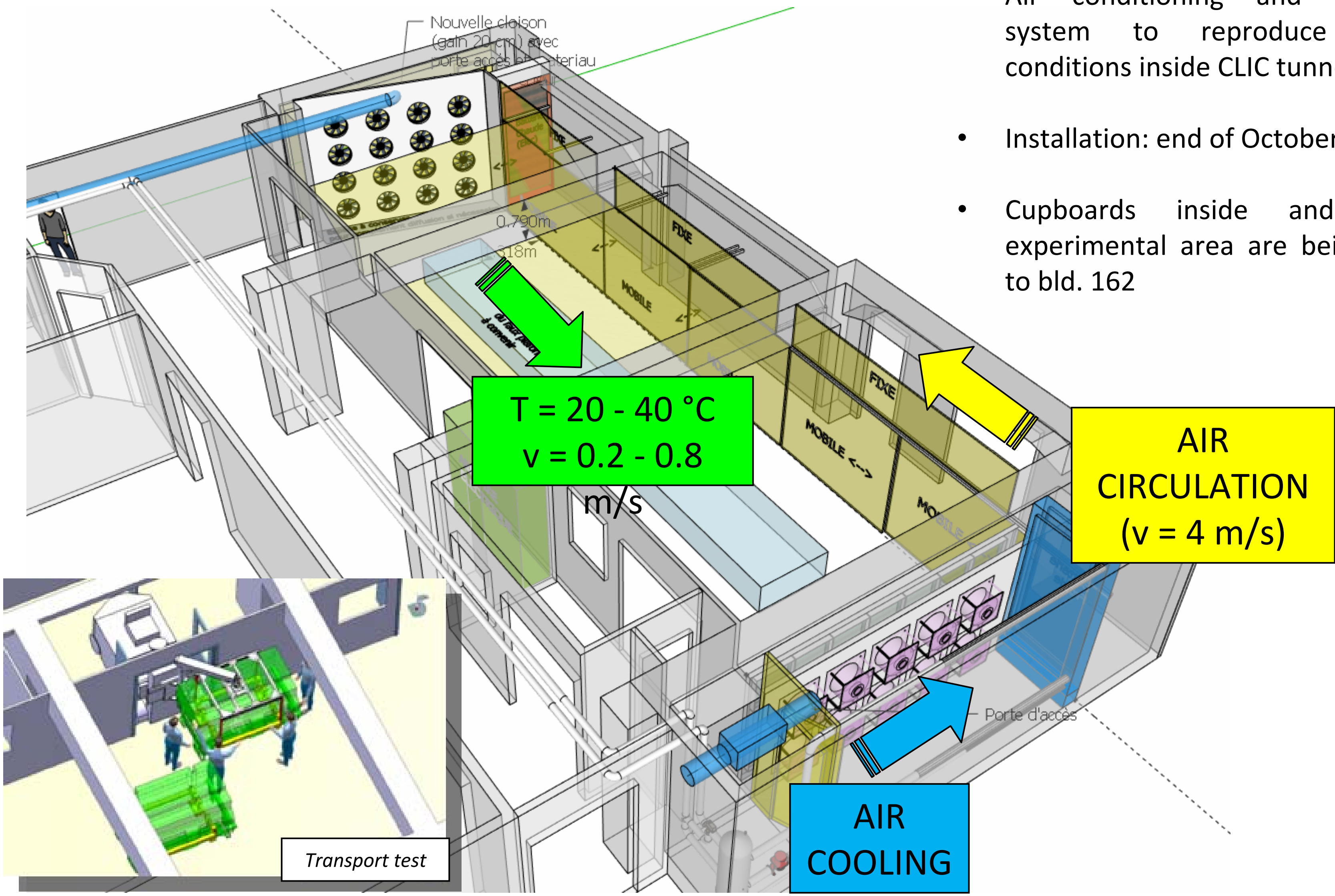






GROUP	HEATER						
	Q.TY	*S/N*	*Dimensions (mm)*	*Voltage*	*P_{max} (W)*	*I_{max} (A)*	*Operating condition*
8 AS	1	0680/TC31-80/6065W240V/SF	Ø8 x 2032	240V AC	6095	25.4	50%
2 PETS unit	1	S/N 0680/TS44-80/2175W240V/SF	Ø11.17 x 2032		2175	9.1	20%
2 DBQ	8+8=16	CSS-303200_220v	Ø12.7 x 76		3200	13.3	9%
TOTAL					**11470**	**47.8**	**35%**

- Air conditioning and ventilation system to reproduce thermal conditions inside CLIC tunnel
- Installation: end of October 2012
- Cupboards inside and outside experimental area are being moved to bld. 162



Transport test

5. MEASUREMENTS

Measuring arm Romer Multi Gage

•With a length of 60 cm, this kind of portable CMM allows to measure fiducials by probing or by one point. According to Romer, the maximum permissible error is less than 18 µm.

Micro-Triangulation system

•The principle of Micro-Triangulation is to use the full potential of a theodolite by substituting a CCD camera instead of the eye of an operator.

•This method has clearly demonstrated its high precision capability on the 2 m long mock-up where a precision about 10 µm along each axis has been obtained in the determination of the illuminated fiducials locations.

Fiducials dedicated to Micro-triangulation

The aluminium main part of this fiducial (made in CERN) is equipped with a breakthrough ceramic ball with a diameter of 8 mm, a removable drawer which contain a LED allows to illuminate the accurate ball.

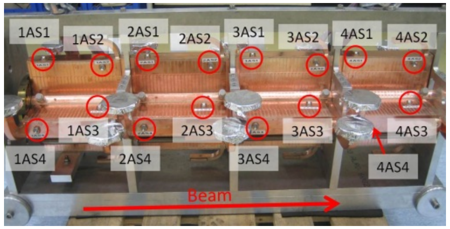
Laser tracker Leica AT401

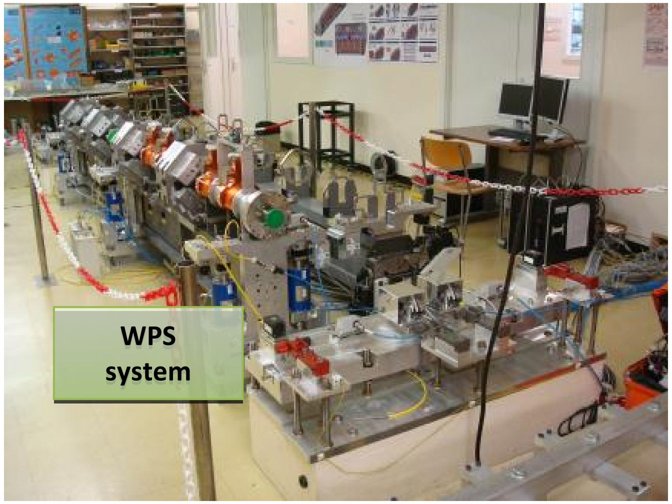
•According to simulation calculations, the expected accuracy of AT401 measurements on a girder and its components is about 5 µm rms (up to 40 °C).

•Fiducials are measured with respect to a fixed reference system.

•Measurements taken from different stations can be elaborated and combined together.

•The measuring device must be at the same temperature of the parts to be measured.





S. Griffet et al.

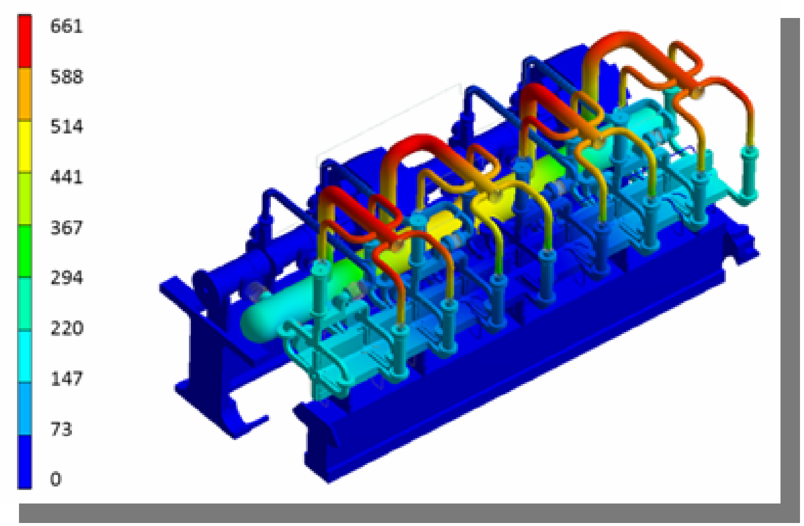
Resulting temperatures inside the modules

Temperature [°C]	Prototype type 0
Max temp. of module	43
Water output temp. MB	35
Water output temp. DB	30

Resulting displacements on the DB and MB lines due to thermal, vacuum and gravity loads

Displacements [μm] (location and load type)	Prototype type 0
MB (RF load)	183
DB (RF load)	47
MB (vacuum load)	30
DB (vacuum load)	131
MB (gravity load)	27
DB (gravity load)	40

Deformed shape of prototype module type 0 due to applied thermal RF loads (values in μm)



(SAS = 820 W, PETS unit = 78 W, T_{amb} = 25 °C)

R. Raatikainen

Conclusion

Main linac gradient	– Ongoing test close to or on target – Uncertainty from beam loading
Drive beam scheme	– Generation tested, used to accelerate test beam, deceleration as expected – Improvements on operation, reliability, losses, more deceleration (more PETS) to come
Luminosity	– Damping ring like an ambitious light source, no show stopper – Alignment system principle demonstrated – Stabilisation system developed, benchmarked, better system in pipeline – Simulations seem on or close to the target

- So called “CLIC feasibility” demonstrated by prototyping and by simulations over the past 10…15 years. Results documented in Vol1. of the CDR

-Next 5 years detailed technical designs and further performance tests in order to prepare a decision for construction.

-Still actively looking for collaborations on specific subjects