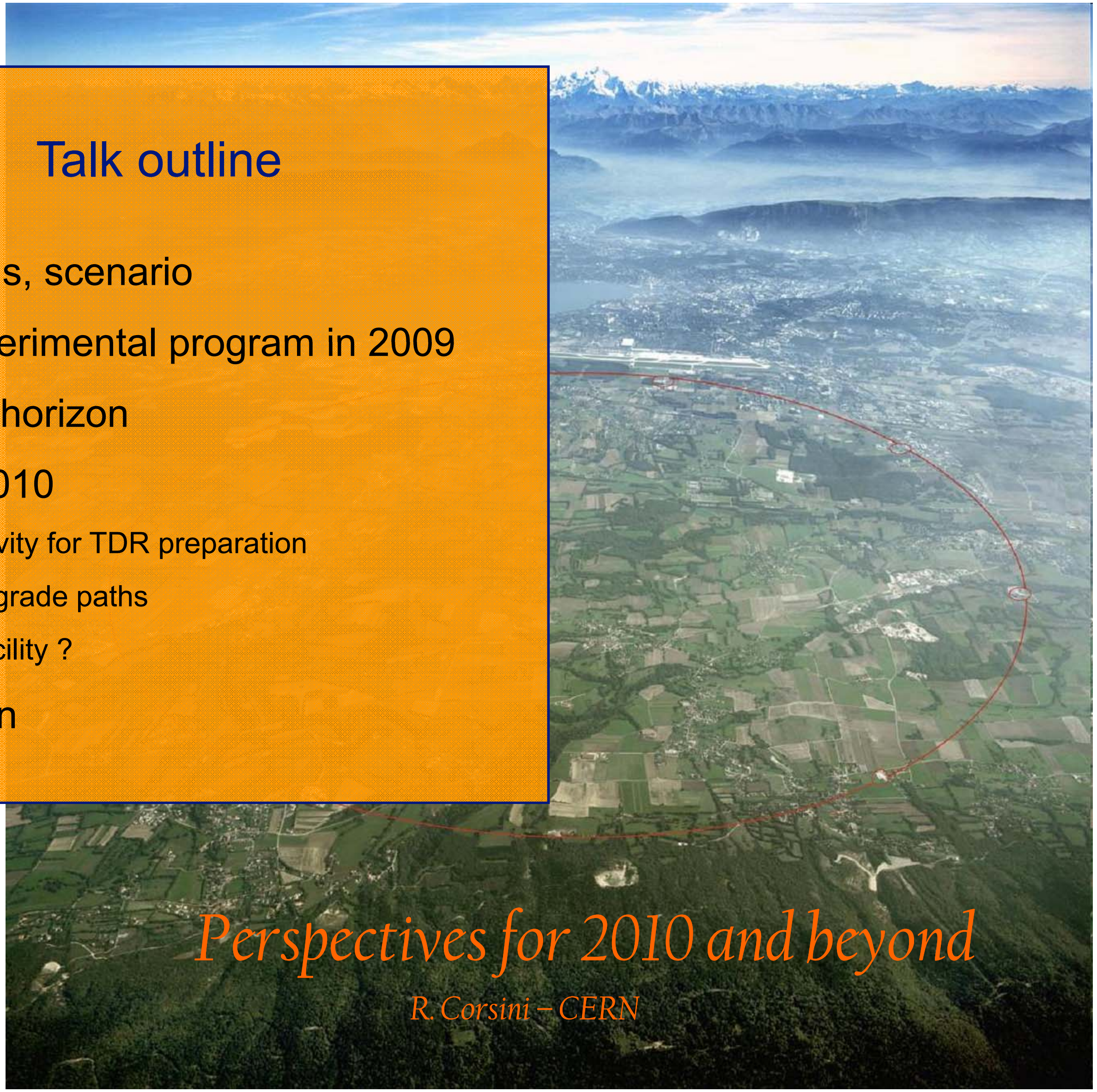
Talk outline

- Motivations, scenario
- CTF3 experimental program in 2009
- The 2010 horizon
- Beyond 2010
  - R&D activity for TDR preparation
  - CTF3 upgrade paths
  - A new facility ?
- Conclusion



Motivations & Scenario

CLIC Work Plan until 2010:

- Demonstrate feasibility of CLIC technology (R&D on critical feasibility issues)
- Design of a linear Collider based on CLIC technology
  http://clic-study.web.cern.ch/CLIC-Study/Design.htm
- Estimation of its cost (capital investment & operation)
- CLIC Physics study and detector development
  http://clic-meeting.web.cern.ch/clic-meeting/CLIC_Phy_Study_Website/default.html

Conceptual Design Report to be published in 2010 including:

- Physics, Accelerator and Detectors
- Results of feasibility study
- Preliminary performance and cost estimation

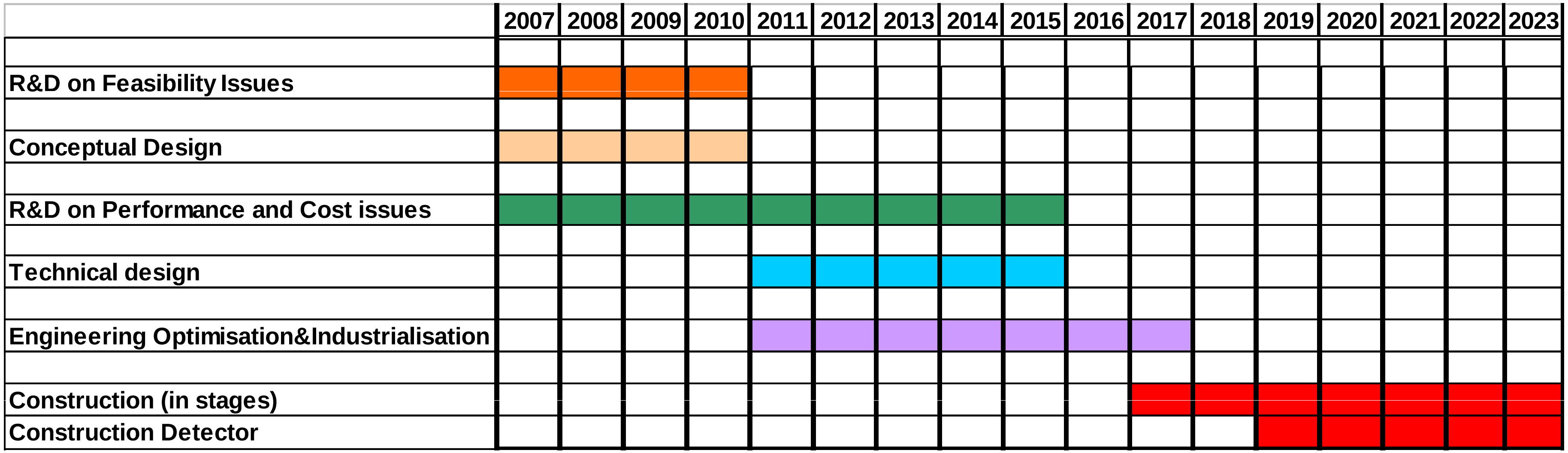
R&D Issues classified in three categories:

- critical for feasibility → fully addressed by specific R&D to be completed before 2010
  results in CDR
- critical for performance
- critical for cost → being addressed now by specific R&D to be completed before 2015
  first assessments in CDR
  results in Technical Design Report (TDR) with consolidated performance & cost

Tentative long-term CLIC scenario

Shortest, Success Oriented, Technically Limited Schedule

Technology evaluation and Physics assessment based on LHC results
for a possible decision on Linear Collider with staged construction starting with the lowest energy required by Physics

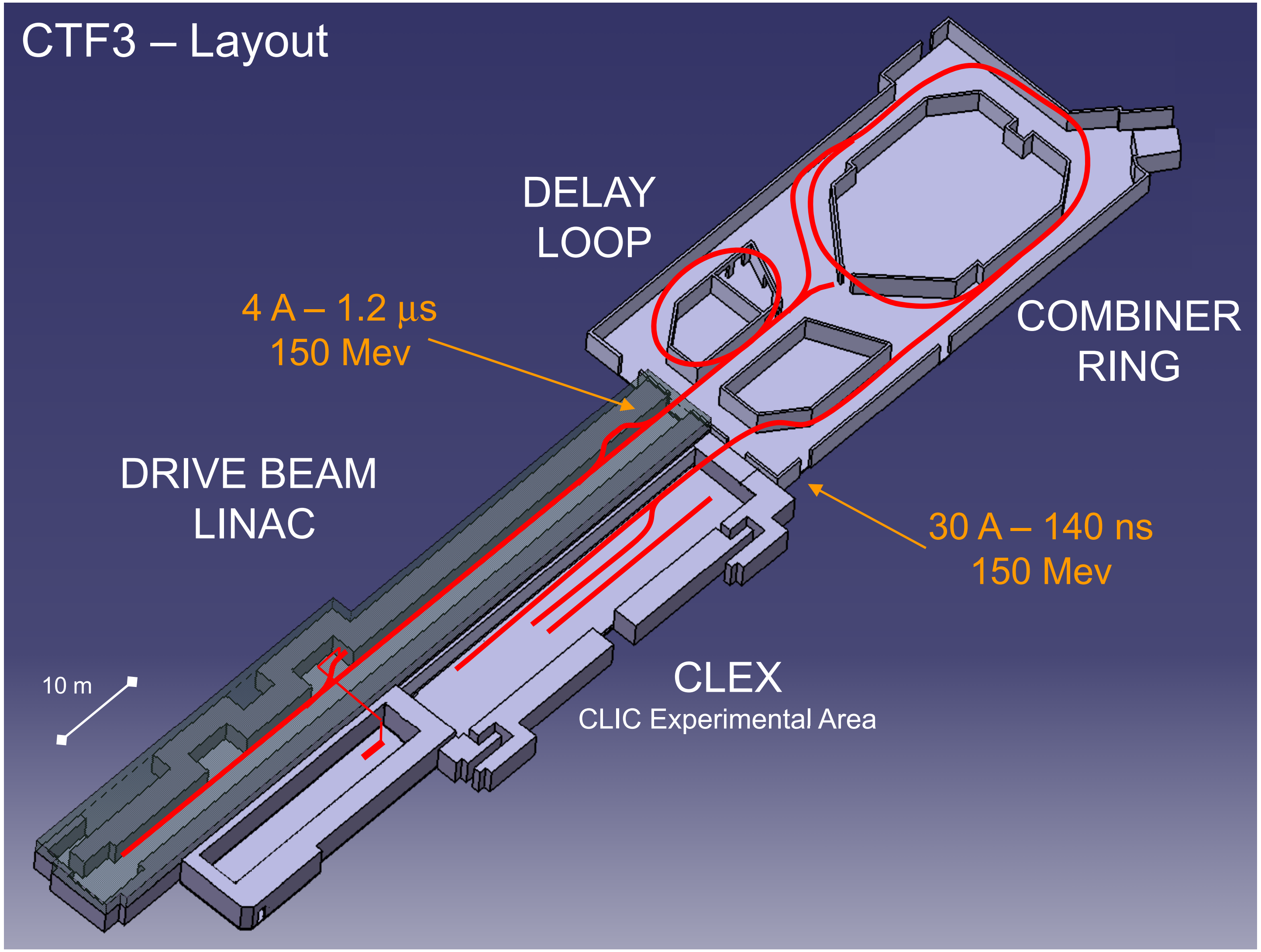


Conceptual Design Report (CDR)

Technical Design Report (TDR)

Project approval ?

First Beam?

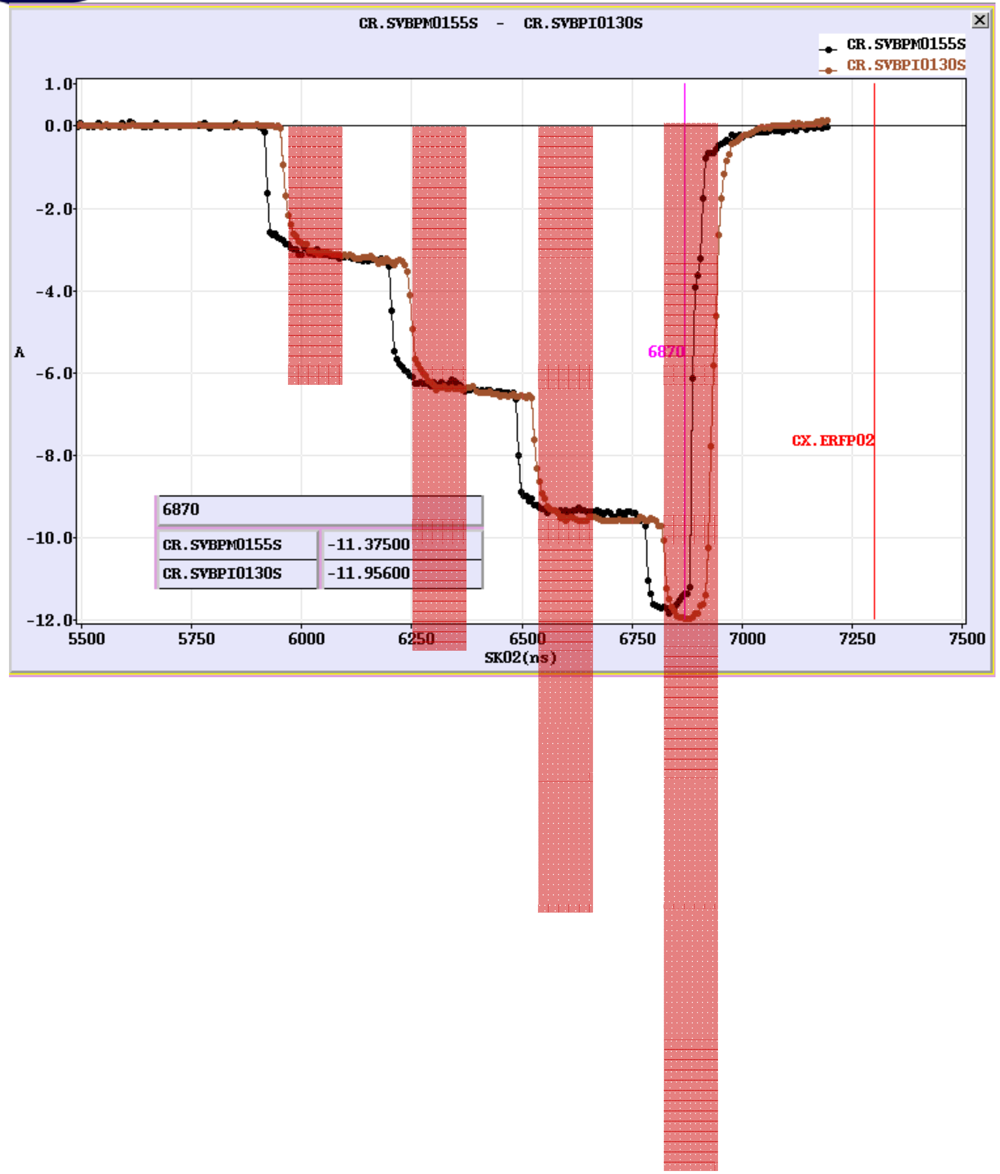

CTF3 – Layout
DELAY LOOP
4 A – 1.2 µs
150 Mev
COMBINER RING
DRIVE BEAM LINAC
30 A – 140 ns
150 Mev
10 m
CLEX
CLIC Experimental Area

CTF3 has a well defined program until 2010

- Prove CLIC RF power source scheme:
  - Drive Beam acceleration (full beam loading – 95% efficiency)
  - Bunch recombination (reach nominal current ~ 30 A , combination factor 2 x 4)
  - Two-beam acceleration of test beam in relevant sub-unit (100 MV/m with beam, TBTS in CLEX)
  - Drive beam deceleration (down to 50% of initial energy, TBL in CLEX)
  - Power production in PETS (12 GHz, 135 MW, 240 ns, TBTS & TBL)
- Provide RF power to validate CLIC components (less important after frequency change to 12 GHz):
  - Accelerating structures, RF distribution, PETS ⇒ Stand-alone 12 GHz power source

A warning - CTF3 is scaled down from CLIC:

	CLIC	CTF3
Drive Beam energy	2.4 GeV	150 MeV
compression / frequency multiplication	24 (Delay Loop + 2 Combiner Rings)	8 (Delay Loop + 1 Combiner Ring)
Drive Beam current	4.2 A x 24 → 100 A	3.5 A x 8→ 28 A
RF Frequency	1 GHz	3 GHz
train length in linac	140 μs	1.4 μs
energy extraction	90 %	~ 50 %



Where are we now for drive beam generation ?

Factor 4 combination in ring, delay loop by-passed

Additional requirements for a drive beam concept demonstration in CTF3 ?

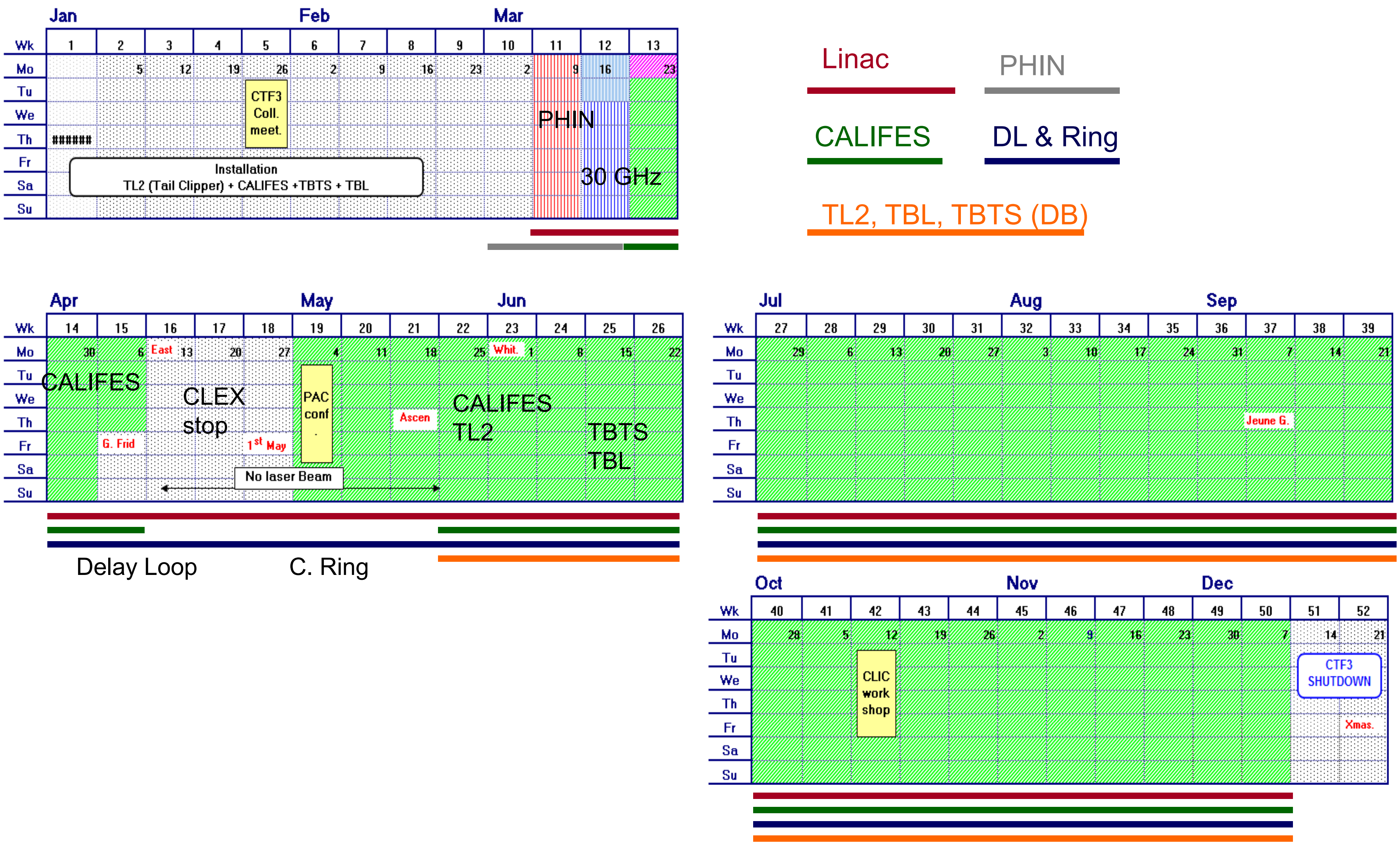
ISSUE	GOAL
• Emittance conservation	final ε_N < 150 π mm mrad
• Longitudinal beam dynamics	final bunch length < 1 mm rms
• Phase & current stability along the pulse	Flat-top in produced RF power < 1 %
• Pulse-to-pulse current fluctuations	below 1 % (actually better, in CR!)
• Losses control	Overall losses (from girder 4) < 10 % ?

- Others…

CTF3 in 2009

2009 CTF3 experimental program

Schedule



2009 CTF3 experimental program

Goals

• 30 GHz:	One structure test (TM02) + breakdown studies
• PHIN	Beam characterization, reach ½ of nominal bunch charge ?
• CALIFES	Beam characterization, beam to TBTS (most likely still reduced current)
• Delay Loop	Back in operation, retrieve combination x 2 (~ 7 A)
• Combiner Ring	Final optics checks, isochronicity, put together with DL (> 24 A)
• TL2	Complete commissioning, bunch length control, > 20 A transported to users
• TBTS	PETS to nominal power/pulse length (15 A, recirculation) Beam commissioning of probe beam line First accelerating structure tests (one structure ? – CLIC G) Two-beam studies (deceleration/acceleration), initial breakdown kicks studies
• TBL	PETS validation (100 MW, need > 20 A), beam line studies (2-3 PETS ?)
• Others	CDR studies in CRM, beam dynamics benchmarking, stability studies, control of beam losses…

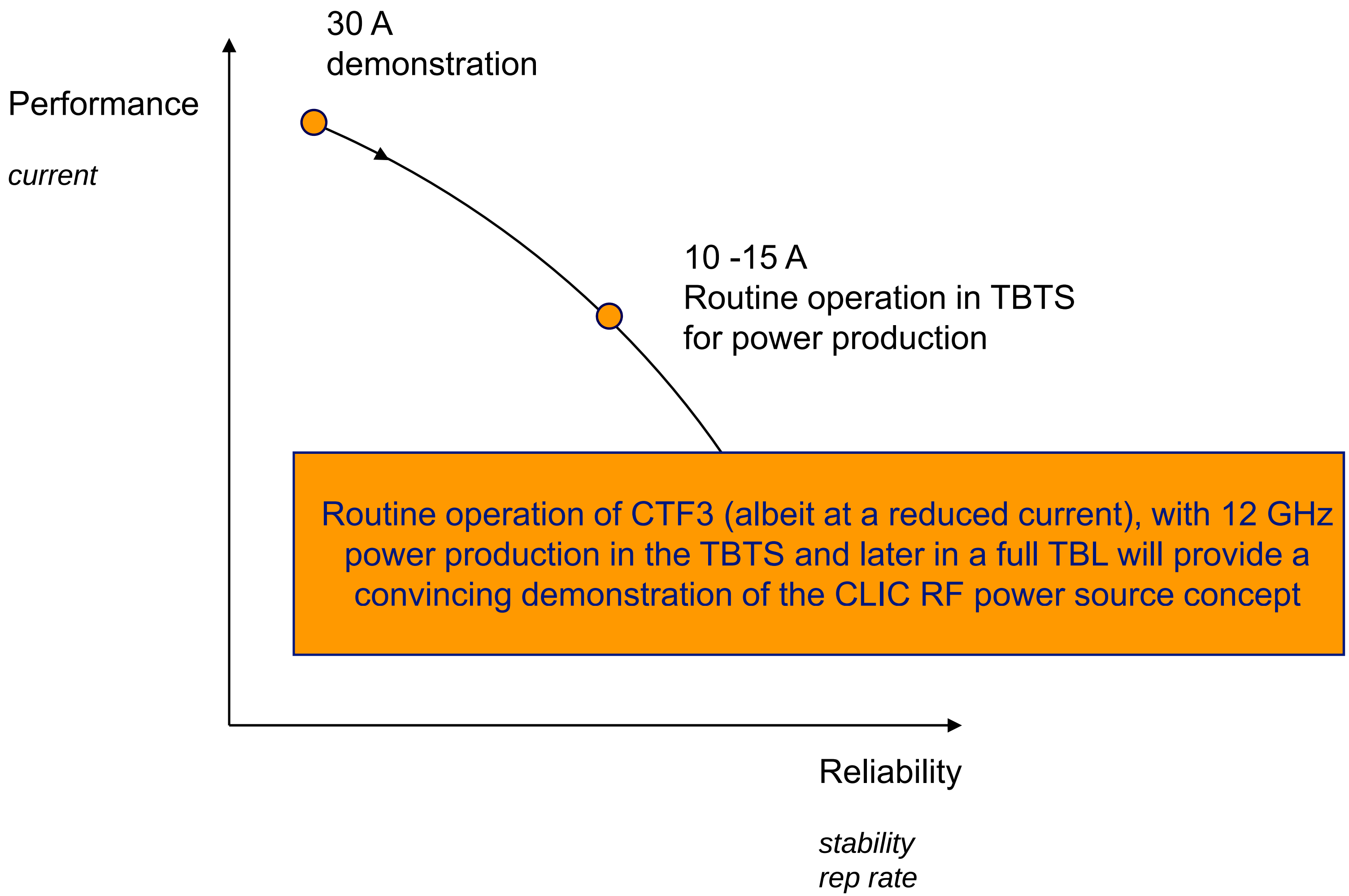
The 2010 Horizon

2010 CTF3 experimental program

(Main) Goals

- Finish whatever was not possible to complete, full parameters (~ 30 A in CLEX)
- PHIN nominal bunch charge, phase coding, long term test ?
- CALIFES nominal parameters
- TBL running in with many (8?) PETS, deceleration experiment
- TBTS test a few ACS, nominal gradient with beam
  complete breakdown kicks, beam loading compensation demonstration ?
- Final assessments on stability & availability, higher rep rate…

Performance vs reliability



What next ?

Tentative long-term CLIC scenario

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Technology evaluation and Physics assessment based on LHC results
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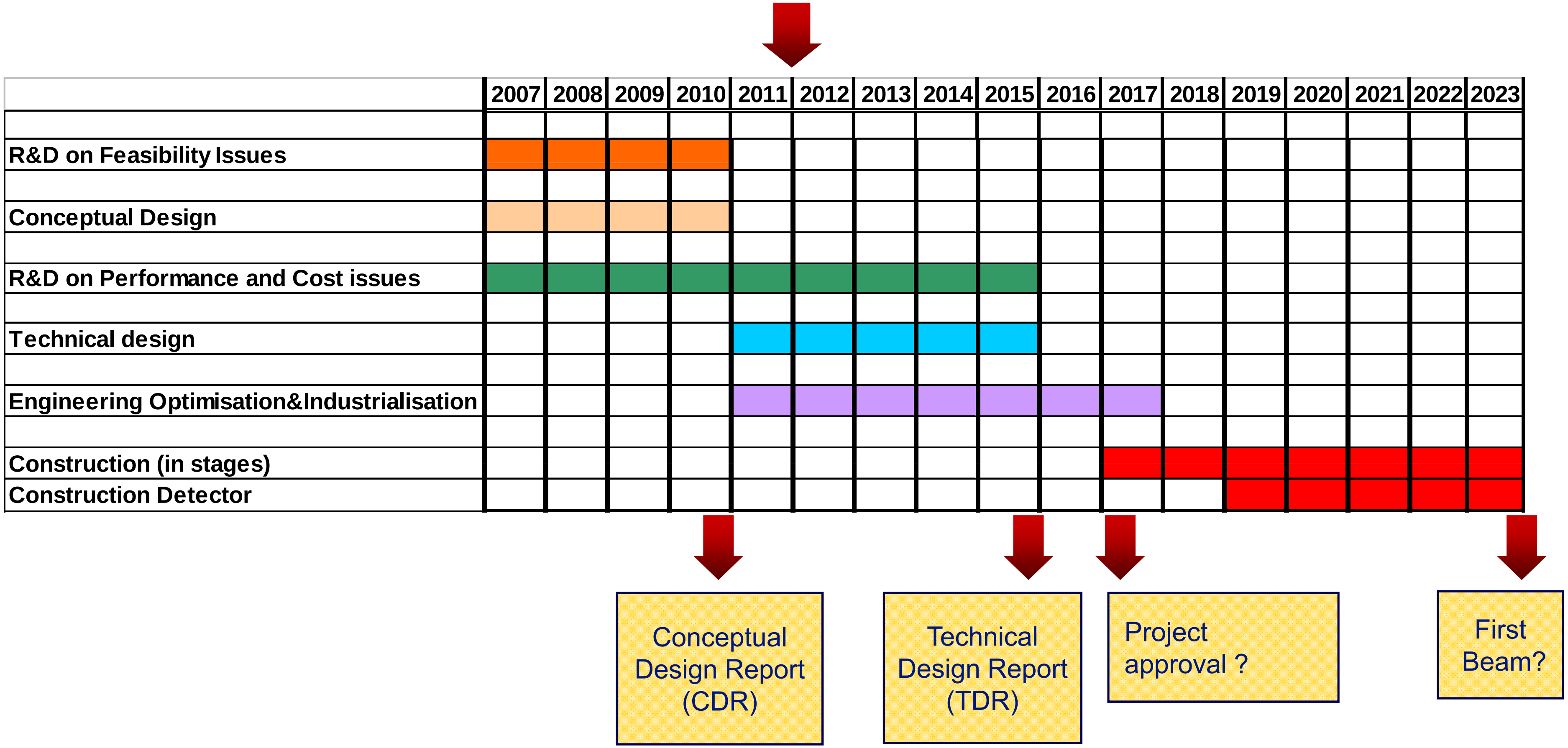


CERN DG's talk to Staff
3 October '08

Prospects for Scientific Activities over the Period 2012 - 2016

To be decided in 2010-2011 in light of first physics results from LHC, and designed and R&D results from the previous years. This programme could most probably comprise:

- An LHC luminosity increase requiring a new injector (SPL and PS).

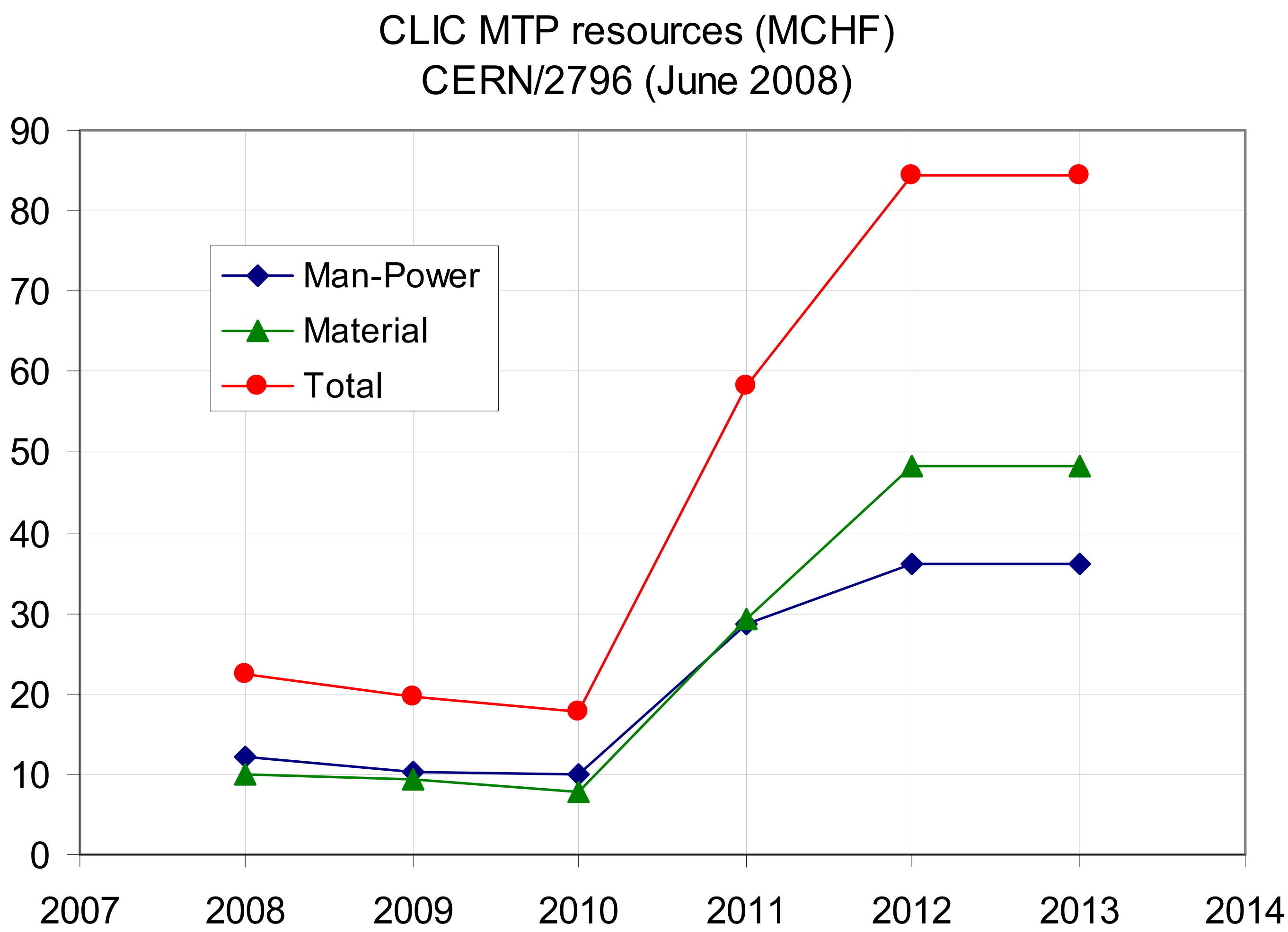
  The total cost of the investment over 6 years (2011-2016: 1000-1200 MCHF + a staff of 200-300 per year. Total budget: ~200-250 MCHF per year.

- Preparation of a Technical Design for the CLIC programme, for a possible construction decision in 2016 after the LHC upgrade (depending on the ILC future).
  Total CERN M + P contribution + ~250 MCHF + 1000-1200 FTE over 6 years.

- Enhanced infrastructure consolidation: 30 MCHF + 40 FTEs from 2011.

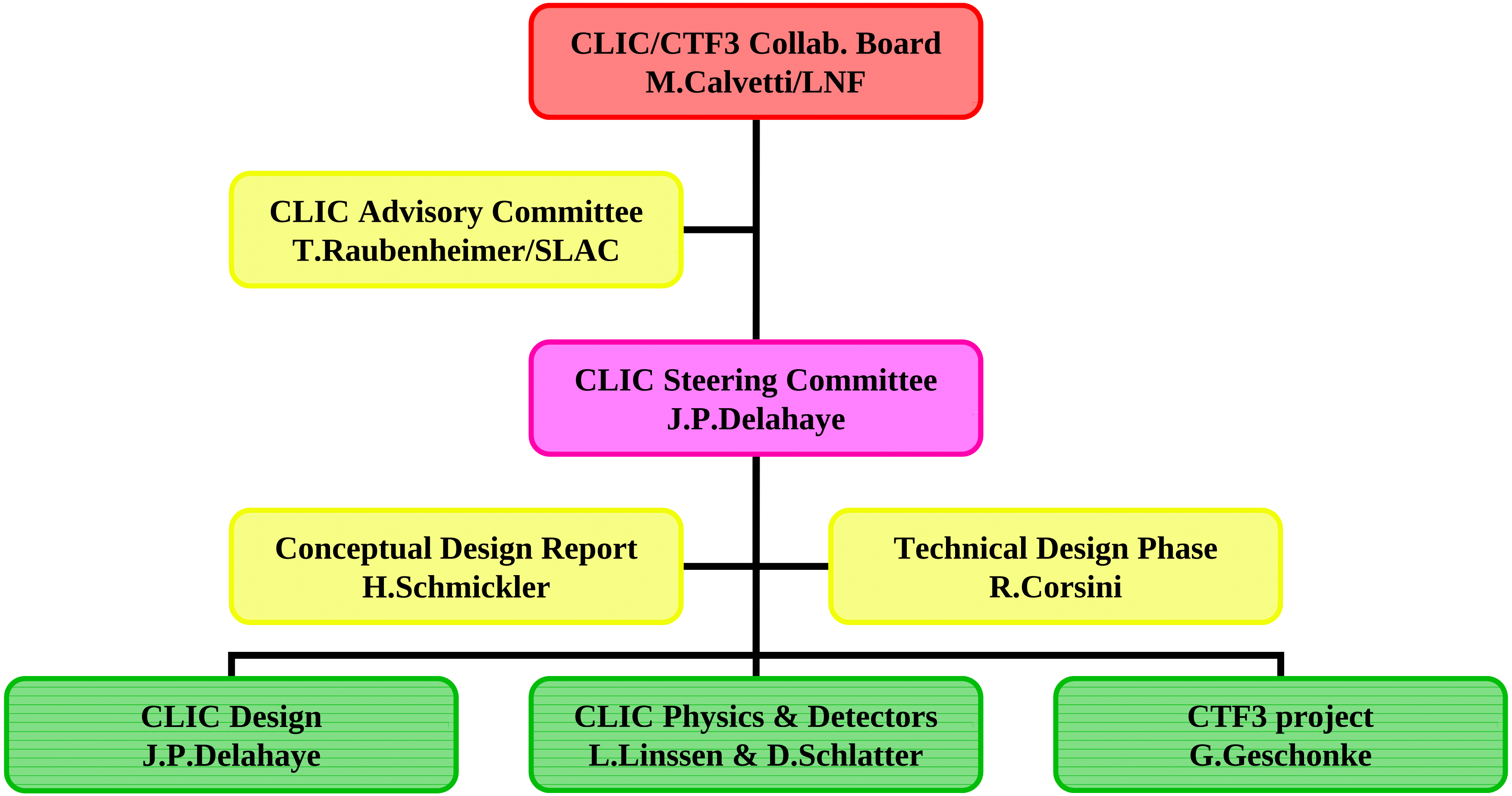
NB: Over the period 2012-2016. Effective participation of CERN in another large progra... cted resou... l Design. This s... proved or if a new, more ambitious level of activities and support is envisaged in the European framework.

N.B.: Expect additional significant contribution from outside CERN, up to the same level


CLIC MTP resources (MCHF)
CERN/2796 (June 2008)
90
80
70
60
50
40
30
20
10
0
2007
2008
2009
2010
2011
2012
2013
2014
Man-Power
Material
Total

CLIC organizational chart

http://clic-meeting.web.cern.ch/clic-meeting/CTF3_Coordination_Mtg/Table_MoU.htm



CLIC TDR phase preparation task force

Task Force mandate:

- Analysis of the issues still to be addressed:
    - completion of the feasibility related issues if necessary
    - performance and cost related issues

- Elaborate a *proposal of the necessary tasks to be done from mid 2010 up to 2015/16*.

  That should include in particular the motivation, description and expected results of:
    - A possible upgrade of CTF3
    - A possible new facility if necessary
    - R&D on specific subjects
    - Prototyping of critical items
    - Industrialisation of major components
    - Finalisation of design and cost
    - Technical Design Report including consolidated performance and cost

- *Estimate the (M&P) necessary resources and timescale*

- Describe the proposal (concerning both accelerator and detector) in a document to be available by mid 2009 at the latest with a preliminary report with main strategy by May 2009 for discussion at the ACE

Table of CLIC feasibility issues

	SYSTEMS (level n)	Critical parameters	Feasibility issue	Performance issue	Cost issue
Structures	**Main beam acceleration structures** Demonstrate nominal CLIC structures with damping features at the design gradient, with design pulse length and breakdown rate .	RF power facilities (SLAC, KEK, CERN, SACLAY… + CTF3)			
	Decelerator structures Demonstrate nominal PETS with damping features at design power, with design pulse length, breakdown rate on/off capability				
Drive Beam	**Validation of drive Beam** - production - phase stability , potential feedbacks - MPS appropriate for beam power	CTF3			
Two Beam	**Test of a relevant linac sub-unit with both beams**				
Beam Physics	**Preservation of low emittances (main linac + RTML)**	Absolute blow-up Hor: 160nradm Vert: 15 nradm	X	X	
Stabilization	**Main Linac and BDS Stabilization**	Main Linac : 1 nm vert (>1 Hz) BDS: 0.15…1 nm vert (>4 Hz) depending on implementation of final doublet girder	X	X	X
Operation and reliability	**Commissioning strategy** **Staging of commissioning and construction** **MTBF, MTTR** **Machine protection**	Handling of drive beam power of 72 MW	X	X	X

Matching critical issues & test facilities

	SYSTEMS (level n)	Critical parameters	Crucial design choice or fesibility	Performance issue	Cost issue	Relevant Facilities (also valid for ILC)
Structures	Main beam acceleration structures Demonstrate nominal CLIC structures with damping features at the design gradient, with design pulse length and breakdown rate .	100 MV/m 240 ns 3·10-7 BR/(pulse*m)	X	X	X	CTF2&3 (2005-2010) Test Stand (2009-2010) SLAC/NLCTA SLAC/ASTA KEK/NEXTEF
	Decelerator structures Demonstrate nominal PETS with damping features at design power, with design pulse length, breakdown rate on/off capability	136 MW 240 ns	X		X	CTF3 (2005-2010) CTF3/TBTS (2008-2010) CTF3/TBL (2009-2010) SLAC ASTA
Drive Beam	Validation of drive Beam - production - phase stability , potential feedbacks - MPS appropriate for beam power	NA	X	X		CTF3 (2005-2010) CTF3/TBL (2009-2010) X-FEL LCLS
Two Beam	Test of a relevant linac sub-unit with both beams	NA	X			CTF3/TBTS (2008-2010)
Beam physics	Ultra-low emittances - Generation of low-emittances (damping rings)	Hor:500 nradm Vert: 5 nradm		X		ATF (2008-10): 3000/12 CESRTA:Electron Cloud NSLSII: Hor 2000nradm SLS: Vert 10nm
	- Preservation of low emittances (main linac + RTML)	Absolute blow-up Hor: 160nradm Vert: 15 nradm	X	X		Beam simulations LCLS SCSS
	- Beam focusing to small dimensions (BDS)	Hor: 40 nm Vert: 1 nm		X		ATF2 (2006-2012) Hor: 200 nm Vert: 36 (20) nm

List of issues/options to be explored to get to the TDR

- Completion of feasibility demonstration (basic information on feasibility should be already available, but...)
- R&D on critical issues (performance + cost, e.g. stabilization & alignment)
- Prototyping of critical components for performance (small number items, e.g. final doublet quads, sc wigglers)
- Prototyping (and possibly pre-series) of critical components for cost (e.g. drive beam modulators/klystrons)
- Start industrialization of mass produced components (e.g. RF structures, RF components...) ?
- Integration of components in large number modular sub-systems (two-beam modules)
- Test of full (small?) sub-systems, critical for performance (e.g. D.B. Injector, positron source...)
- Tests at existing test facilities on specific issues (e.g. phase stability, electron cloud, IBS…)
- R & D on diagnostics, machine protection ?
- Need (larger) facilities for RF conditioning/testing ?

CTF3 after 2010

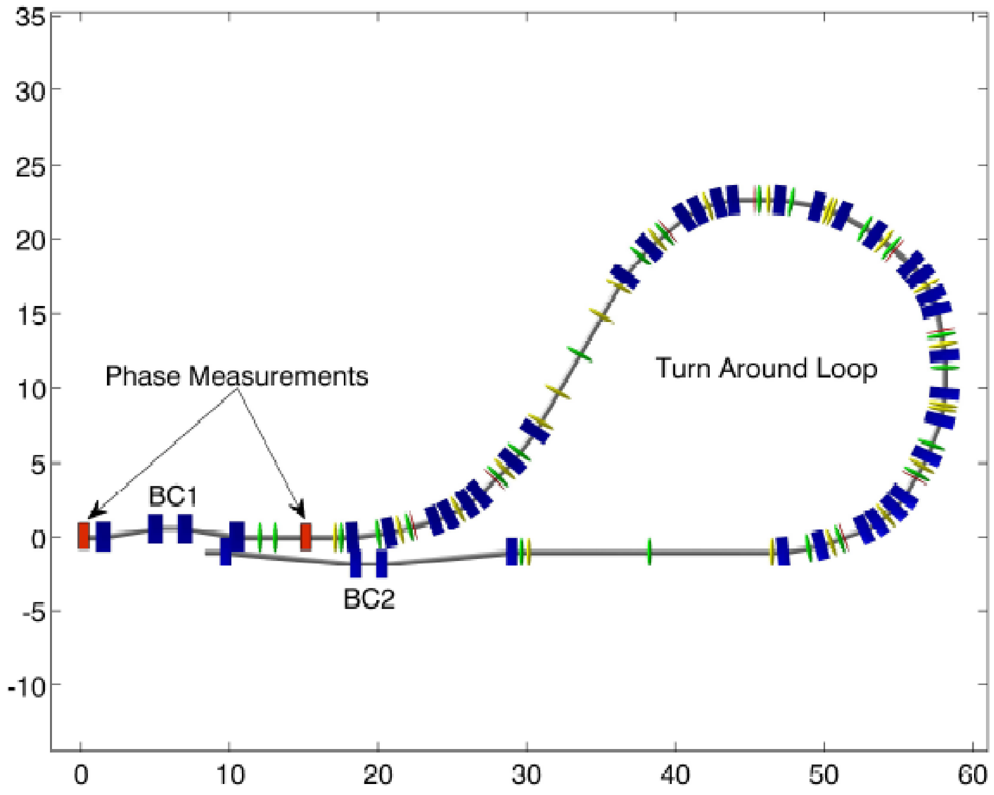
CTF3 Specific experiments – evolution paths

- Beam loading compensation experiment (control of RF pulse shape)
- Beam loading compensation full demonstration (need CALIFES upgrade – 1 klystron)
- Phase stability / measurements / feed-forward
- Photo-injector option full implementation ?
- CTF3 “reasonable upgrade” + 3 klystrons (CALIFES, test + CALIFES defl + phin, girder 14)
- CTF3 upgraded to X-band testing plant (1/2 nominal current, 2 PETS chained, DB dump in DL)
- Rep rate upgrade, up to 50 Hz (shielding – control of beam losses!)
- One, then several modules in TBTS, with ~ nominal parameters (need PETS priming or recirculation)
- Instrumentation development for LC – Instrumentation Test Beamline ?

Phase stability / measurements / feed-forward

0.2 degrees phase stability @ 12 GHz required for CLIC drive beam

- Final feedforward shown
  - requires timing reference (FP6)
  - phase measurement/prediction (FP7)
  - tuning chicane (PSI)
- Measure phase and change of phase at BC1
- Adjust BC2 with kicker to compensate error
- One could also measure phase and energy at BC1



Phase stability / measurements / feed-forward

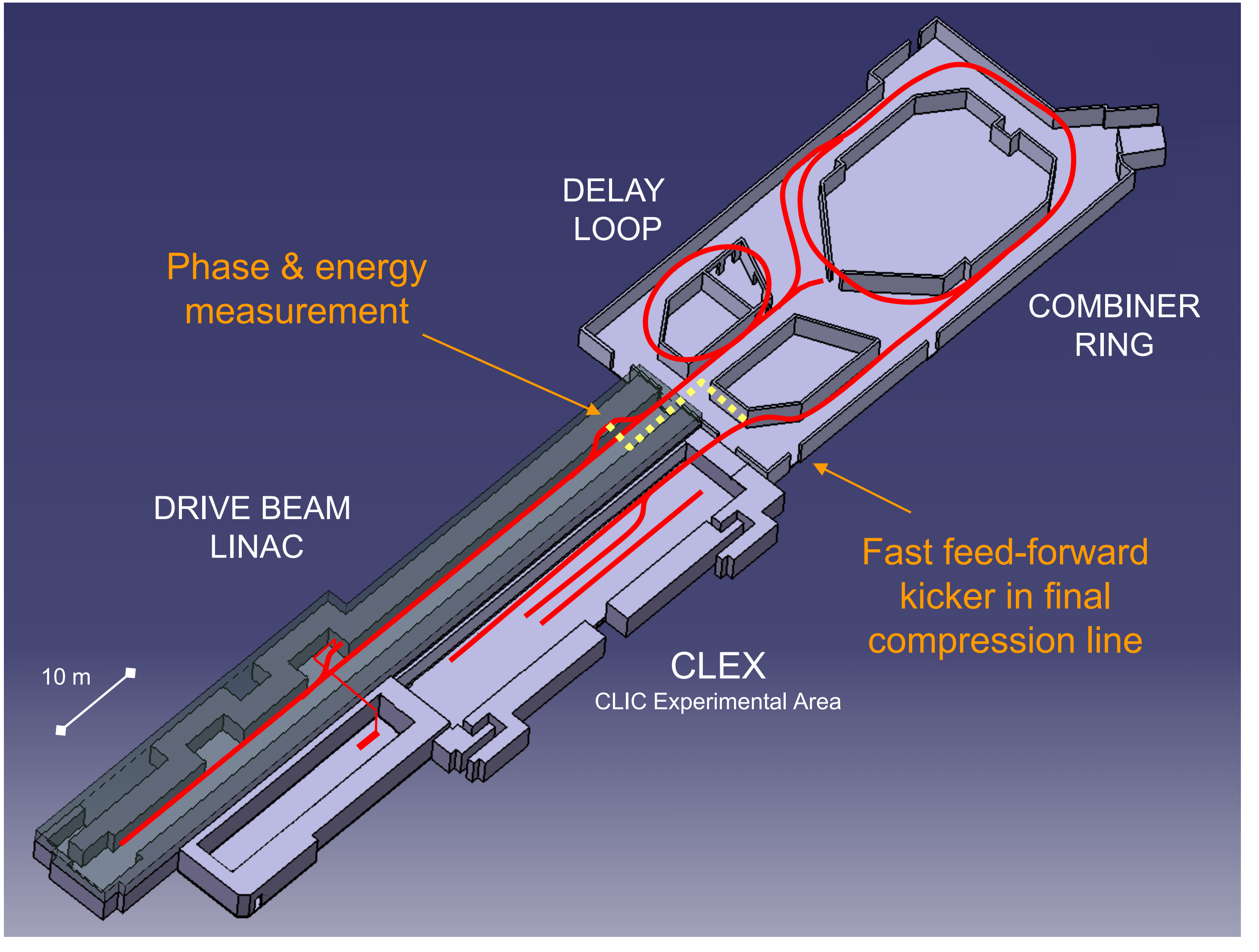
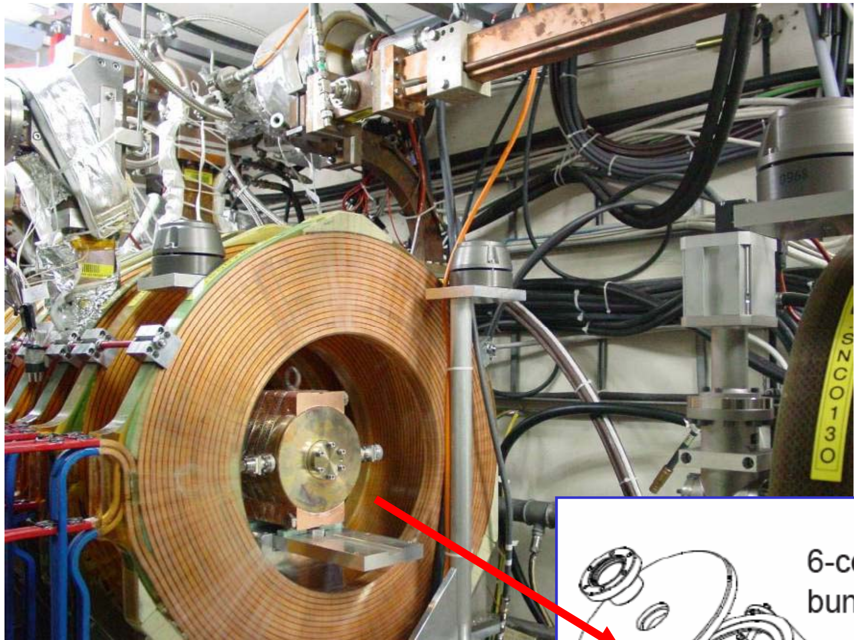
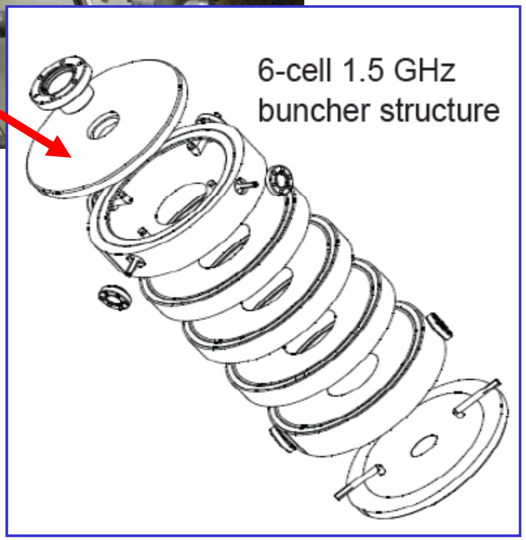


Photo-injector option full implementation

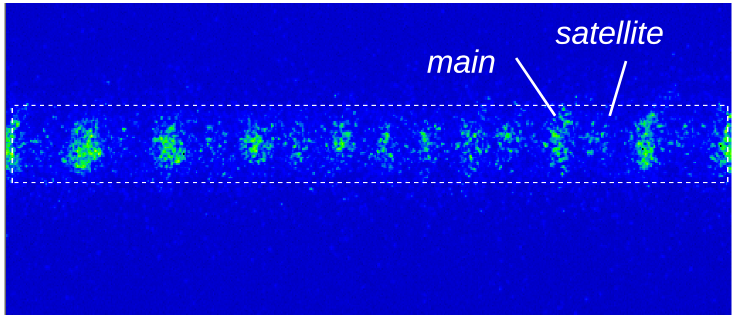
Fast phase switch from SHB system - phase coding

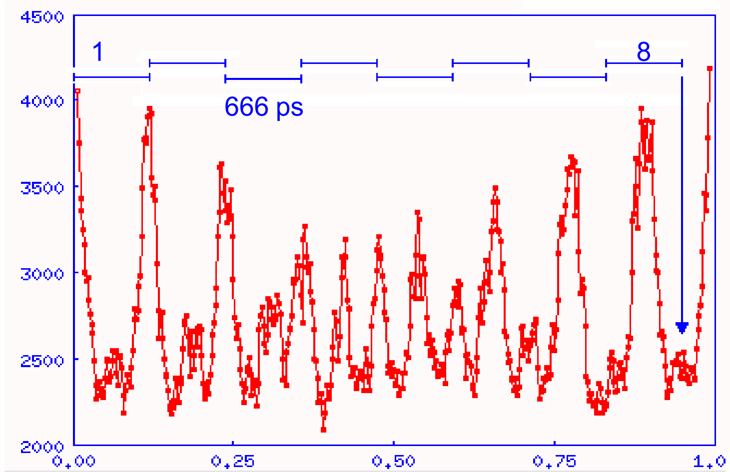




3 TW Sub-harmonic bunchers, each fed by a wide-band TWT

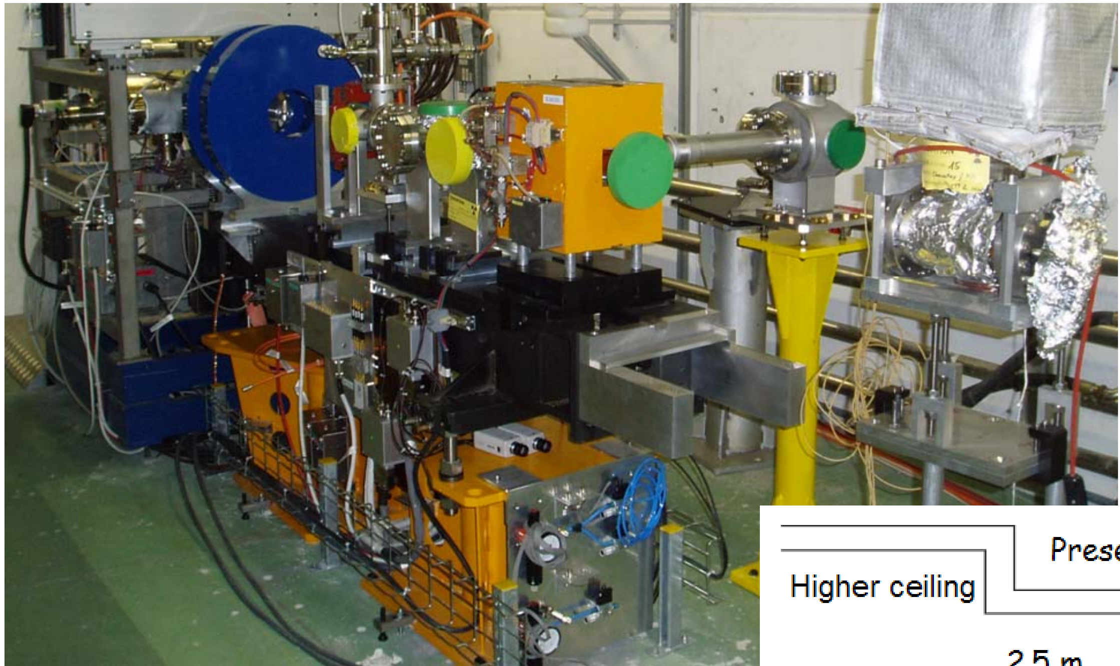
Streak camera image

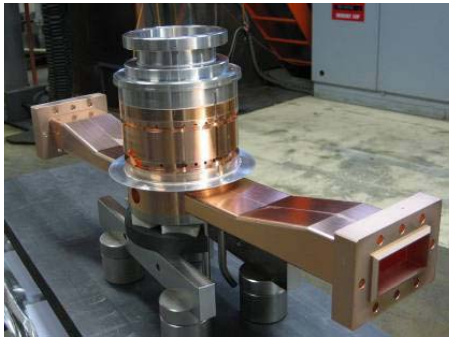


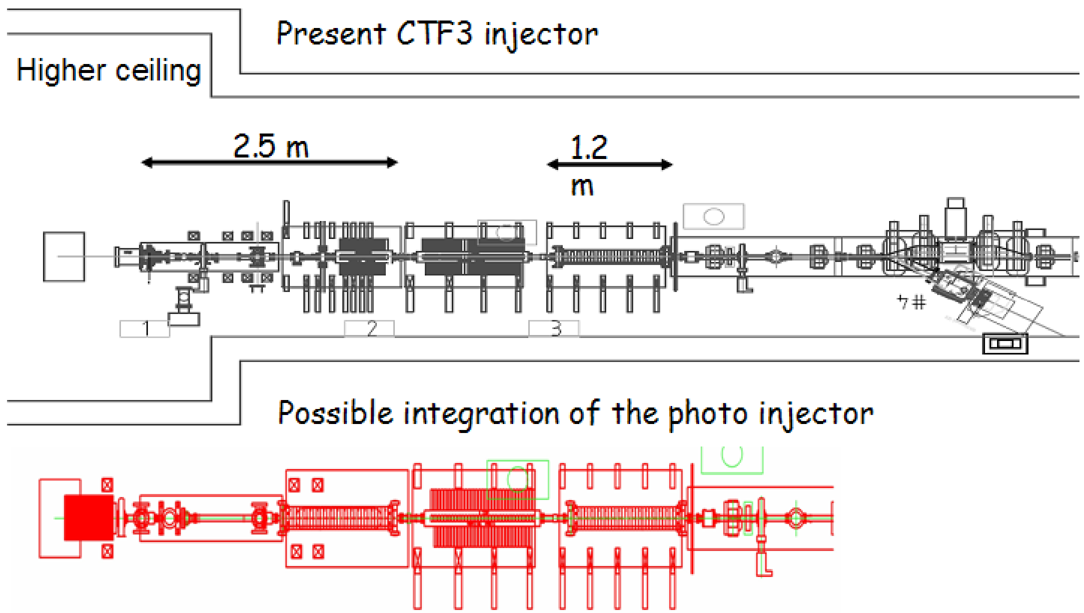


$8.5 \cdot 666 \text{ ps} = 5.7 \text{ ns}$

Photo-injector option full implementation





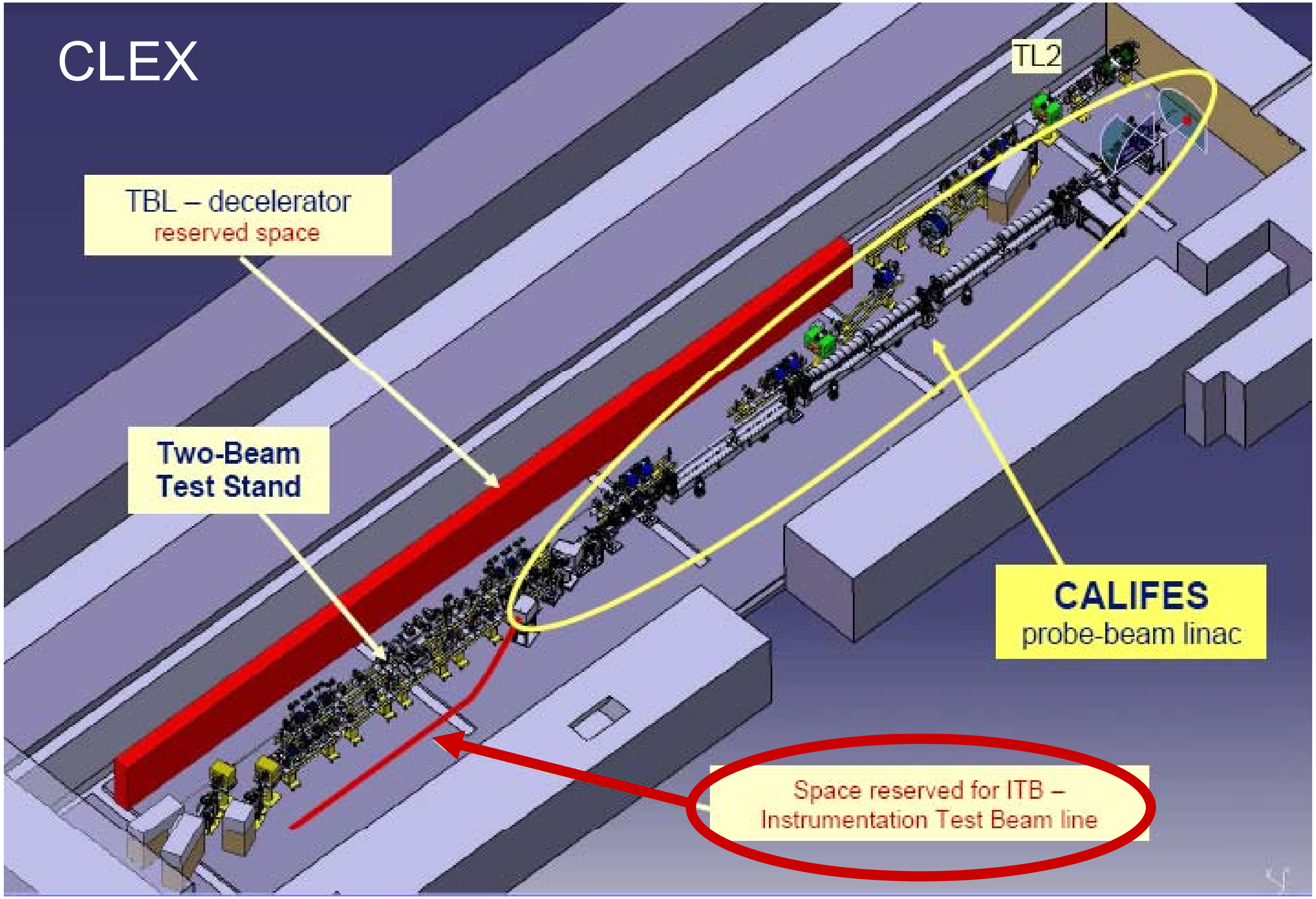


- Smaller transverse emittance
- Shorter bunches, no energy tails
- No satellites
- Lower current

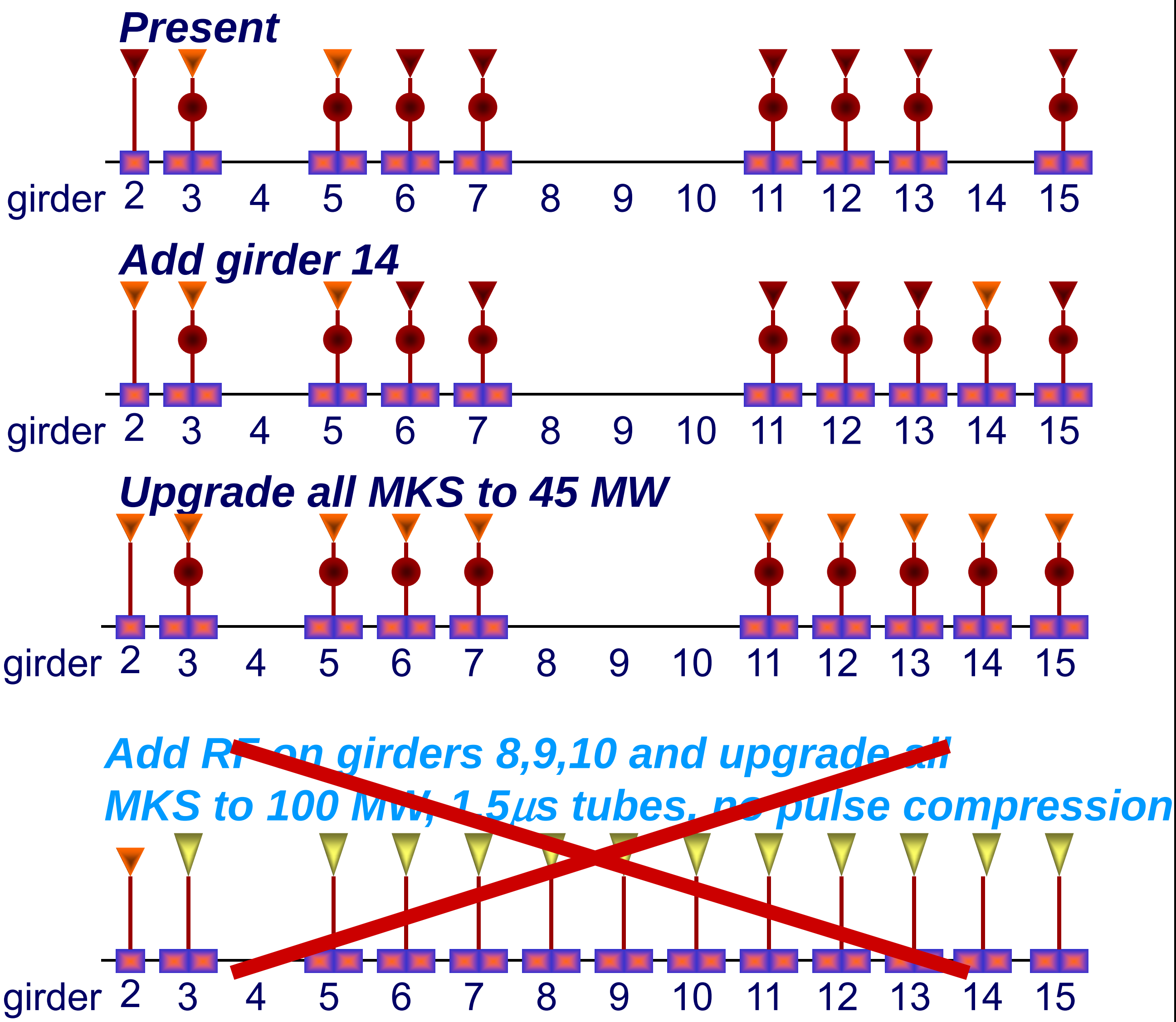
Single bunch option will allow

- Check and correction of beam optics with high precision
- CSR measurements with high precision in DL, CR and TL2 bunch compressor.
- δ response of PETS and beam instrumentation
- …

Instrumentation Test Beamline



CTF3 klystron upgrade



I_{Linac}[A]	I_{CLEX}[A]	T [MeV]
0.1 3.6 4.9	0.72 25.9 34.9	246 156 125
0.1 3.6 4.9	0.72 25.9 34.9	279 179 143
0.1 3.6 5.3	0.72 25.9 38.2	303 203 154
0.1 3.6 5.3	0.72 25.9 38.2	402 270 206

CTF3 klystron upgraded to X-band testing plant

Advantages

- \+ Up to 16 RF ports with nominal power & pulse length
- \+ Cheaper than several stand-alone X-band sources
- \+ Gives incentive to consolidate drive beam operation towards large facility standards

Problems

- \- No individual pulse-length control of test slots
  (unless Igor has a smart idea)
- \- Pulse length obtained only sacrificing power – or need priming
- \- Increase of rep. rate up to 50 Hz desirable,
  but requires substantial increase of radiation shielding

But don't say that you don't believe in testing structures with a drive beam RF source.

If you don't believe this, there is no point to continue to work on CLIC !

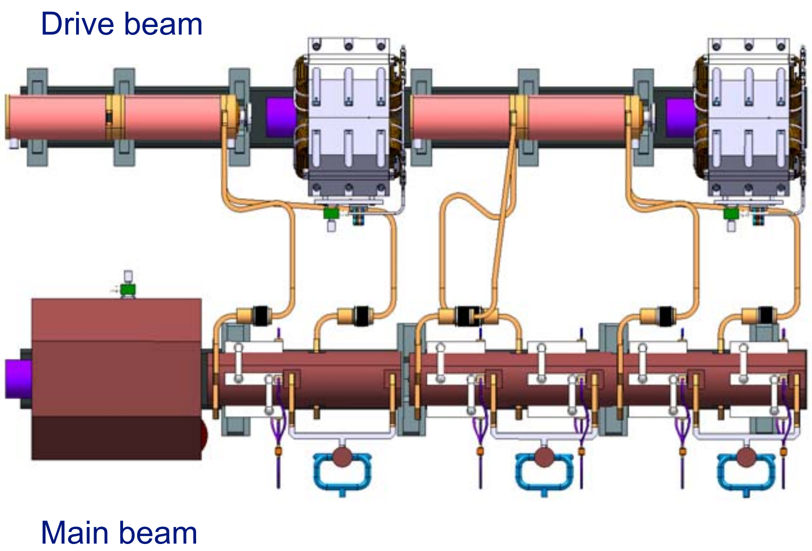
CLIC 3 TeV needs 144000 accelerating structures. If every structure needs four days of RF processing before installation in the tunnel and we want to build CLIC over 7 years we need

$$\frac{144000 \times 2}{7 \times 365} = 113 \text{ RF slots}$$

CTF3 with a drive beam linac upgraded as outlined before and a TBL extended to 43 PETS could provide **86 RF slots** !

Two-beam modules in TBTS

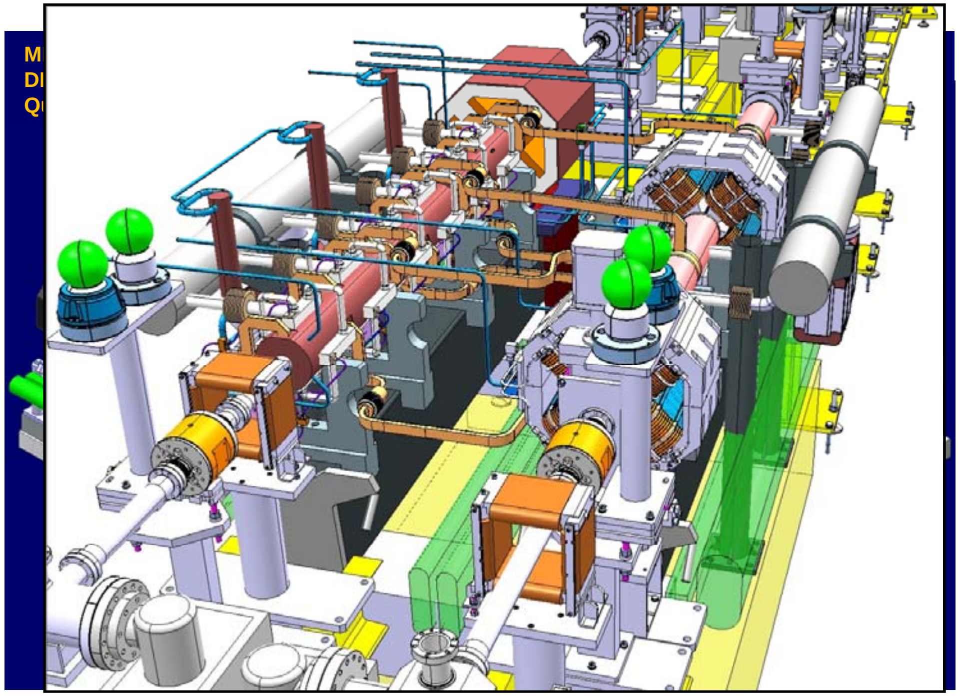
- Module design and integration have to be studied for different configurations. Potential advantages and drawbacks are being evaluated for each configuration.
- Integration of the systems in terms of space reservation has been done for all the module types and detailed design started for the main systems, such vacuum, cooling, alignment, stabilisation …
- Important aspects of cost are raised and basic parameters provided for other areas of the study.
- Goal: build prototype → test with beam of a few modules in CTF3 from 2010



20760 modules (2 m long)

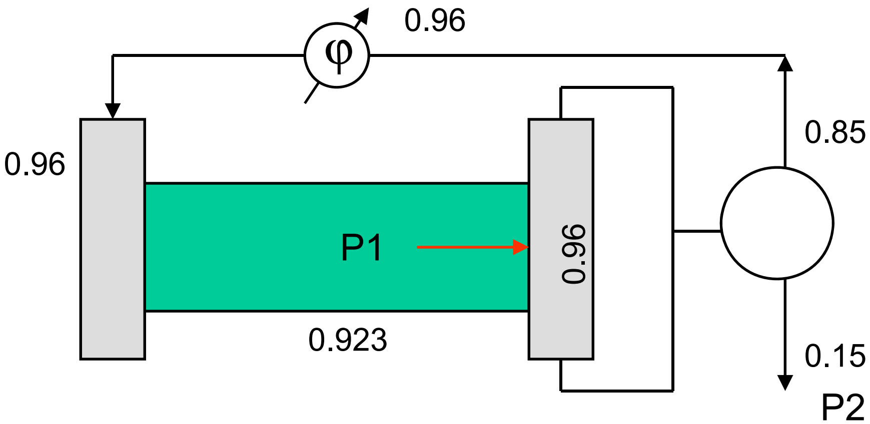
71460 power prod. structures PETS (drive beam)

143010 accelerating structures (main beam)

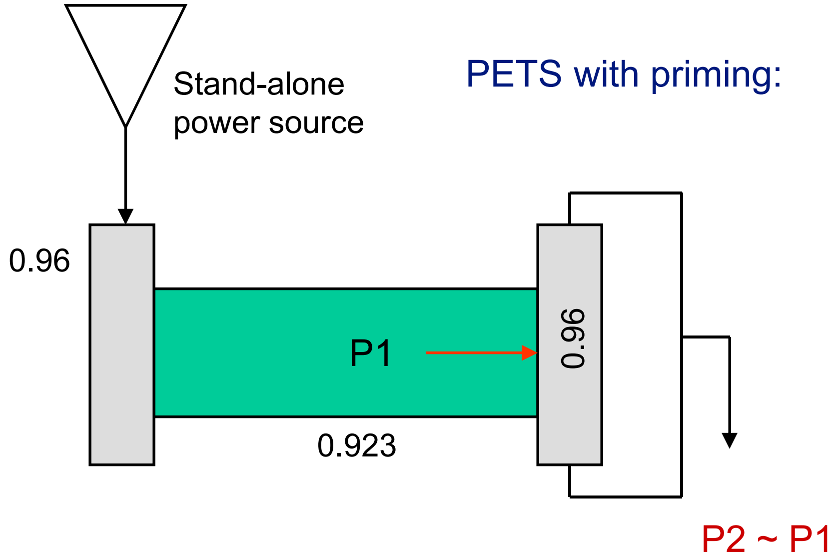


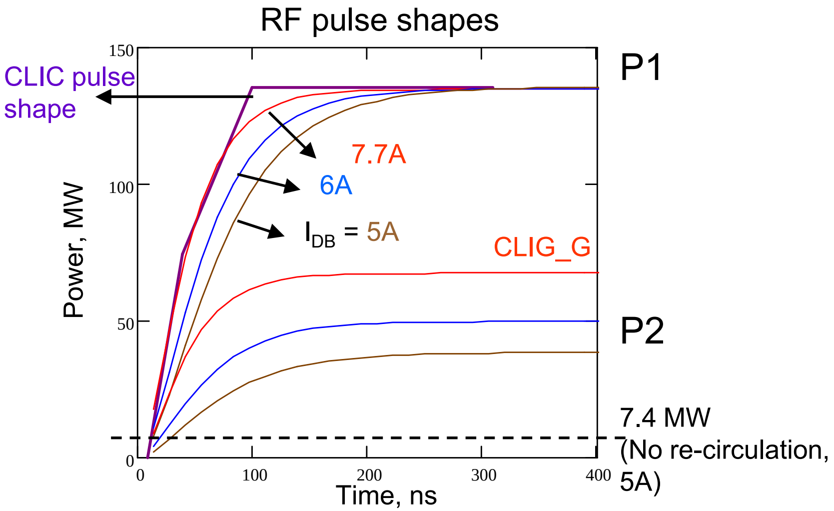
CTF3 cannot provide 100 A drive beam
⇒ PETS recirculation or priming for nominal power

PETS with recirculation schematic:



PETS with priming:



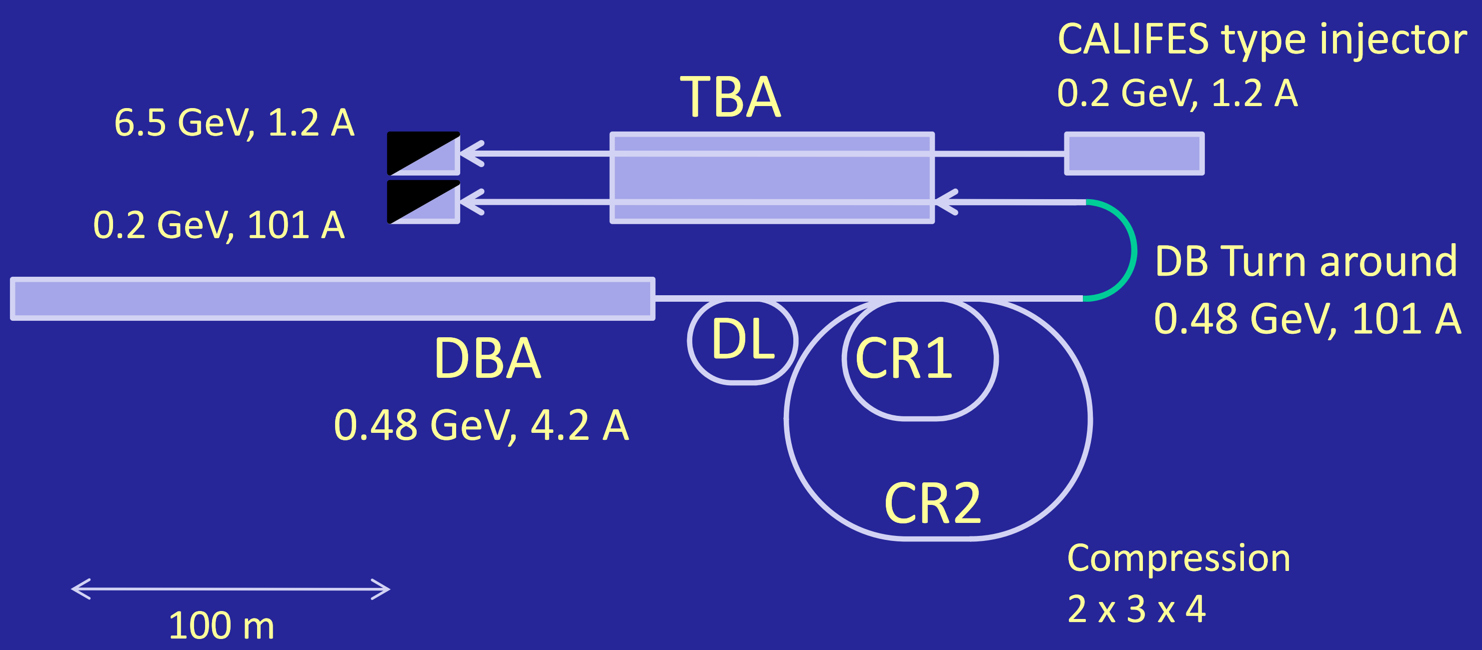


RF input power needed for 135 MW nominal output

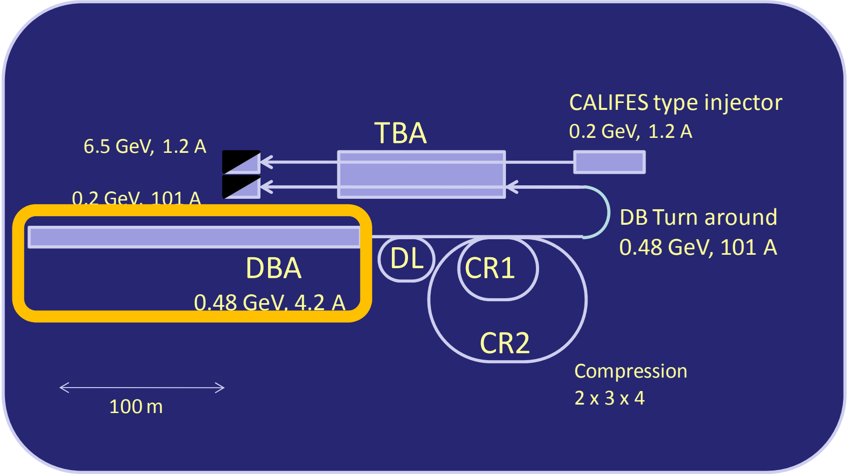
DB current	P1
5 A	80 MW
10 A	40 MW
15 A	12 MW

Perspectives for 2010 and beyond

A new facility ?



all components nominal and re-usable for CLIC



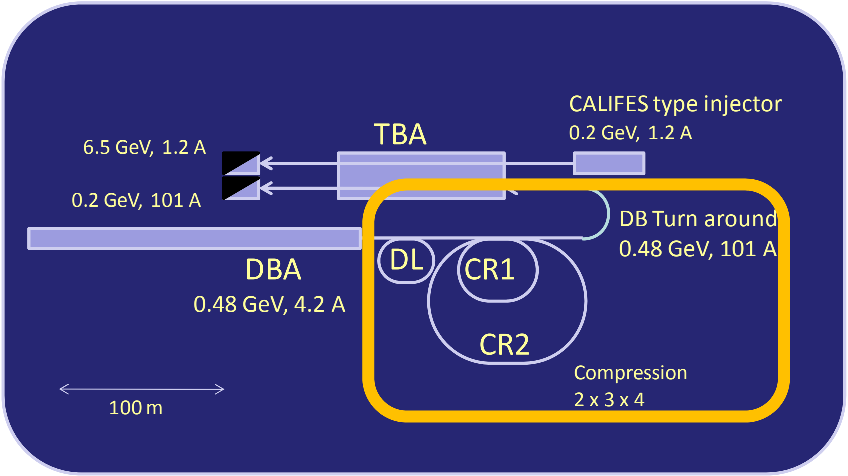
Drive Beam Accelerator DBA

- Nominal CLIC DBA injector
  (thermionic or Photo injector, depending on results of PHIN tests)
- 2 nominal accelerator modules
  equipped with nominal 33 MW, 1 GHz, 50 Hz, 140µs pulse length klystrons
  development of nominal drive beam klystrons & modulators required
- 58 nominal accelerator modules with reduced pulse length klystrons (6 µs)

Total length ≈ 200 m, nominal 4.2 A beam

final energy 0.48 GeV instead of 2.4 GeV for CLIC
6µs pulse length instead of 140µs, *for economy, sufficient to produce one nominal bunch train*

all hardware nominal and re-usable for CLIC !



Delay Loop + Combiner Rings + Turnaround

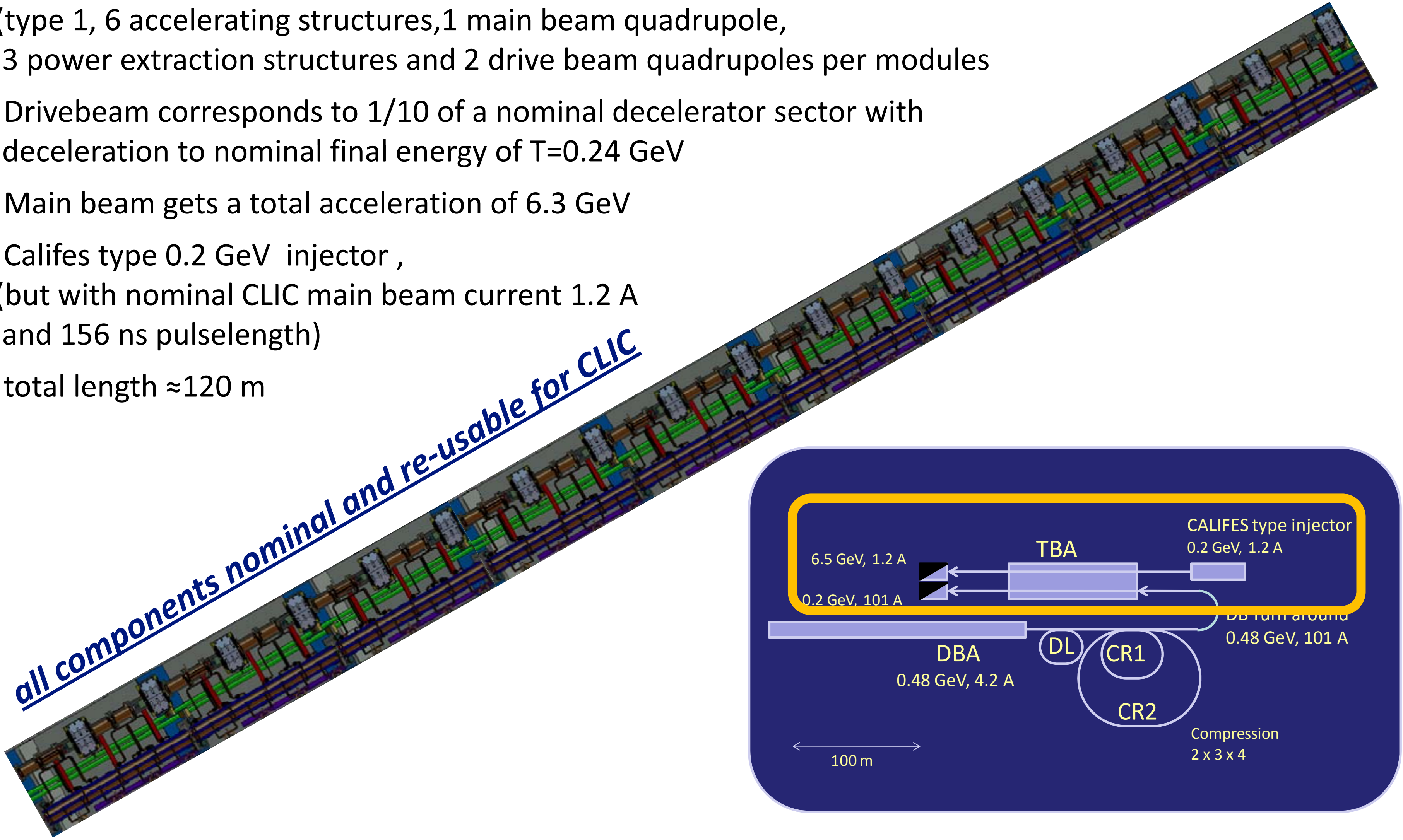
– Nominal CLIC Delay Loop, 2 x current multiplication
– Nominal CLIC combiner ring 1 , 3 x current multiplication
– Nominal CLIC combiner ring 2 , 4 x current multiplication
– Nominal DB turnaround with bunch compressor

Total beamline length ≈800 m, ***all components nominal and re-usable for CLIC***

Magnets operate at 1/5 of nominal strength.

Two Beam Demonstrator

- 46 nominal CLIC modules
  (type 1, 6 accelerating structures,1 main beam quadrupole,
  3 power extraction structures and 2 drive beam quadrupoles per modules
- Drivebeam corresponds to 1/10 of a nominal decelerator sector with deceleration to nominal final energy of T=0.24 GeV
- Main beam gets a total acceleration of 6.3 GeV
- Califes type 0.2 GeV injector ,
  (but with nominal CLIC main beam current 1.2 A
  and 156 ns pulselength)
- total length ≈120 m



Tentative schedule for CLIC R&D 2010-2016

<table>
<tr><td colspan="2">Year</td><td>2010</td><td>2011</td><td>2012</td><td>2013</td><td>2014</td><td>2015</td><td>2016</td></tr>
<tr><td rowspan="4">CTF3+</td><td>module test</td><td>design</td><td>build</td><td>commision</td><td colspan="4"></td></tr>
<tr><td>TBL+</td><td>finish TBL program</td><td>modify</td><td>X RF test</td><td>X RF test</td><td>X RF test</td><td>X RF test</td><td>X RF test</td></tr>
<tr><td>phase feedforward</td><td>design</td><td>build</td><td colspan="2">commision & run</td><td colspan="3"></td></tr>
<tr><td>general</td><td colspan="2">consolidation</td><td colspan="5"></td></tr>
<tr><td rowspan="6">Next facility towards CLIC</td><td>DBA Injector</td><td></td><td colspan="2">Design</td><td>build</td><td>commission</td><td colspan="2"></td></tr>
<tr><td>Nominal DBA modules</td><td></td><td colspan="2">Design</td><td colspan="2">build</td><td colspan="2">commission</td></tr>
<tr><td>Economy DBA modules</td><td colspan="3"></td><td colspan="3">build</td><td>commission</td></tr>
<tr><td>combiner rings</td><td></td><td colspan="2">Design</td><td colspan="3">build</td><td>commission</td></tr>
<tr><td>TBA</td><td></td><td colspan="2">Design</td><td colspan="3">build</td><td>commission</td></tr>
<tr><td>civil engineering</td><td>Design</td><td colspan="2">build</td><td colspan="4"></td></tr>
<tr><td colspan="2" rowspan="2">Stand alone
X-band sources</td><td colspan="3">build & commission additional test ports</td><td colspan="4"></td></tr>
<tr><td colspan="7">RF test program</td></tr>
<tr><td colspan="2">X-band structure development</td><td colspan="7">continuation</td></tr>
<tr><td colspan="2">Design & beam dynamics studies</td><td colspan="7">continuation</td></tr>
<tr><td colspan="2">LC Detector R&D</td><td colspan="7">continuation</td></tr>
</table>

+ possibly other R&D programs to be defined…

Conclusions

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