Closeout from the 6th meeting of CLIC ACE

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Charge

- Committee was been asked to comment on:
  - The status and progress of the ongoing CLIC R&D activities
  - The R&D program and the correspondent planning for the post CDR phase of the project
  - Comment on critical technical systems corresponding to ACE's specific concerns (Damping Ring) and systems with major investments envisaged in the post CDR phase (Two-Beam modules, CTF3 upgrade and new drive beam facility) will be treated in detail.

Strategy

- Develop design covering 500 GeV → 3 TeV cms energy
  - Energy range will be determined by LHC
  - Agree with development of a staged approach
- Feasibility being demonstrated in 2011
  - Echo comments from 2010: be clear about ‘feasibility’
  - Manage community’s expectations
- Development of the cost
  - Benefit of TBA: higher energy reach and lower cost but this comes with increased risk
  - Need enough engineering to understand cost drivers and justify cost models
  - Manage community’s expectations

CDR Plans

- Three volumes
- Vol 1: The CLIC accelerator and site facilities Dec 2011
    - CLIC concept with exploration over multi-TeV energy range up to 3 TeV
    - Feasibility study of CLIC parameters optimized at 3 TeV (most demanding)
    - Application to 500 GeV as first stage and intermediate energy range
    - No cost figures (peer review postponed)
  - – First draft of text by April !!
- Vol 3: CLIC study summary
    - Comprehensive summary of vol1 and 2 findings for European Strategy
    - Staging scenario up to energy compatible with LHC Physics
    - Including cost issues and cost drivers for R&D mitigation in next phase
    - Proposing objectives and work plan of post CDR phase
  - – Complete in March 2012
- Agree with strategy but still concerned that the schedule is aggressive

Progress on Feasibility

System	Item	Feasibility Issue	Unit	Nominal	Achieved	How	Feasibilit	Comments
Two Beam Acceleration	Drive beam generation	Fully loaded accel effic	%	97	95	CTF3	✓	Novel scheme fully demonstrated in CTF3 in spite o lower current since beam dynamics more sensitive than nominal due to lower energy (250MeV/2Gev)
		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)	nsec	240	140	CTF3	✓	
		Intensity stability	1.E-03	0.75	< 0.6	CTF3	2011	End of DBA. To be demonstrated for combined bean
		Drive beam linac RF phase	Deg (1GHZ)	0.05	0.035	CTF3, XFEL	✓	Achieved in CTF3, XFEL design
	Beam Driven RF power generation	PETS RF Power	MW	130	>130	TBTS/SLAC	✓	BD rate at nominal power and pulse lenght, measure on Klystron driven PETS. Beam driven tests under way in CTF3
		PETS Pulse length	ns	170	>170	TBTS/SLAC	✓	
		PETS Breakdown rate	/m	< 1·10-7	≤ 2.4 10-7	TBTS/SLAC	✓	
		PETS ON/OFF	-	@ 50Hz	-	CTF3/TBTS	2011	Prototype under fabrication for tests with beam
		Drive beam to RF efficiency	%	90%	-	CTF3/TBL	2012	TBL with 8 (16) PETS in 2011(12) for 30(50%) efficiency. Benchmark beam simulation for safe extrapolation of high efficiency at high drive beam
		RF pulse shape control	%	< 0.1%	-	CTF3/TBTS	2011-2012	
	Accelerating Structures (CAS)	Structure Acc field	MV/m	100	100	CTF3 Test Stand, SLAC, KEK	✓	Nominal performances of 3 structures without damping. 2 structure with damping features reached 85 MV/m at nominal BR still under RF conditionning. Two nominal structures with high efficiency under
		Structure Flat Top Pulse length	ns	170	170		✓	
		Structure Breakdown rate	/m	< 3·10-7	5·10-5(D)		2011	
		Rf to beam transfer efficiency	%	27	15		2011	
	Two Beam Acceleration	Power producton and probe beam acceleration in Two beam	MV/m - ns	100 - 170	106 - <130	TBTS	2011	Power production in Two Beam Test Stand (TBTS) Probe beam acceleration by TwoBeamTestStand(TB
		Drive to main beam timing	psec	0.05	-	CTF3	2012	
		Main to main beam timing	psec	0.07	-	XFEL	2012	
Ultra low beam emittance & sizes	Ultra low Emittances	Emitttance generation H/V	nm	500/5	3000/12	ATF, NSLS/SLS + simulation	✓	Relax emittances achieved in ATF
		Emittance preservation: Blow-up	nm	160/15	160/15		2011-12	Simulation + alignment/stability
	Alignment	Main Linac components	microns	15	10 (princ.)	Mod.Test Bench	2011	Principle demonstrated in CTF2, to be adapted to long distances and integrated in Two Beam Module i
		Final-Doublet	microns	2 to 8			2011	
	Vertical stabilisation	Quad Main Linac	nm>1 Hz	1.5	0.13 (principle)	Stabilisation Test Bench	2011-12	Adaptation to quad prototype and detector environment in 2010. Integrated in Two Beam Module with beam till 2012.
		Final Doublet (with feedbacks)	nm>4 Hz	0.2				
Operation and Machine Protection System (MPS)		72MW@2.4GeV				CTF3 simulations	2011-12	Report integrating LHC experience under preparation
		13MW@1.5TeV						

- Excellent progress despite major setbacks

Plans for 2012-2016

Activity	Description	Deliverables (2016)	Total material budget
Cost studies, Civil engineering, Proj, Implementation	Update and improve CLIC cost model & civil engineering studies	• Technical Design (TD) and Project Implementation Plan (PIP) of CLIC Zero • Improved cost model, feedback to CLIC baseline review	4 MCHF
Beam physics studies	Beam physics and overall design	• Review of the CLIC baseline design • Stability and alignment, timing and phasing, stray fields and dynamic vacuum • Studies towards CLIC Zero	3 MCHF
CTF3 +	CTF3 consolidation and upgrade	• Consolidation and upgrade (higher energy, stability, reliability) • Drive beam phase feed-forward experiments • Upgrade and operate TBL as 12 GHz power production facility • Operation with beam of a long string of CLIC two-beam modules	43 MCHF
CLIC Zero	Injector for the CLIC drive beam generation complex	• Build and commission 30 MeV Drive Beam injector with nominal CLIC parameters • Build and commission a few Drive Beam accelerator nominal modules • Participation to Technical Design of full CLIC Zero facility	42 MCHF (~ 30 MCHF)
RF Structures	design and fabrication of 12 GHz accelerating structures & PETS and associated R&D	• Build and test about 120 accelerating structures • Build and test about 10 PETS prototype • Establish quality control, brazing and assembly procedures for structure fabrication at CERN • Precision machining center at CERN	29 MCHF
RF test infrastructure	Building, commissioning and operation of high-power RF test stands	• Four 12 GHz klystron-based RF high-power test stations, for about 8 slots, running before 2016 • Continue high-power testing at 11.4 GHz (KEK and SLAC) • Contribution to high-power testing in CTF3+ (TBL)	13 MCHF
Prototypes of critical components	Technical R&D – design, build and test prototypes of CLIC critical components	• R&D and prototypes of two-beam modules alignment and stabilization systems • Prototype of final focus quadrupole and stabilization system • Several nominal CLIC two-beam modules, mechanically tested, possibly beam tested • R&D and prototyping of critical beam instrumentation • Design and studies of machine protection system • DR superconducting wiggler prototypes, test with beam, extraction kickers prototypes • Dynamic vacuum assessment • Contribution to the CLIC Zero • DB RF system and powering	40 MCHF++

Resource Planning

- Available resources will be limited
  - Personnel from CERN decreasing
    - Collaborations will be very important
  - List of topics appears to be growing
    - Need to prioritize and be clear about goals

- Design effort evolves from research effort towards a development effort (focused enabling research)
  - Engineering studies of structures and modules are key
    - Will likely need multiple iterations
  - CTF3 will be a major part of development effort
    - Focus on well defined demonstrations/experiments
  - Develop plans for a full CLIC injector
    - Don't demand too much of CTF3

Low Emittance Beam Generation

- Lot of work made in damping ring studies and design
  - Addressed all the topics stressed by the committee in the 2010
  - Improved (adiabatically) the ring design to ameliorate potential problems (e.g. IBS). It seems that the space for further improvements in the “optics” is small (=>design close to an optimum).
  - Further improvements possible with a lot of R&D and engineering (e.g. higher gradients Quads, wigglers etc..). This is foreseen anyway.
  - The 2 GHz RF frequency option poses a lot of feasibility issues. RF requirements and collective effects greatly relaxed with the 1GHz RF frequency adoption…
  - A delay loop/line has to be added after the DR with a potential degradation of the beam parameters. The impact should be studied and included in the luminosity budget. We feel that this is not a feasibility issue, rather a performances one.

Low Emittance Beam Generation

- Damping Ring (Continued…)
  - Should give scrutiny to the component-level and system-level performance requirements on the delay loop. Any chances of relaxing the tolerances by reoptimizing the parameters or by introducing FDBK/FDFDs?
  - Integrate a sufficient amount of **tuning knobs** in the delay loop.
  - Integrate a sufficient amount of **diagnostic** tools / systems in the beamline downstream of the DR/delay loop.

  - RF System under study and design based on existing systems.
  - Several solutions possible and under analysis/comparison
  - Sychronous phase spread correction techniques well studied and several options avaliable (frequency mismatch looks attractive, simpler RF System and less RF power needed)

Low Emittance Beam Generation

- Damping Ring (Continued…)
  – Integration with the DR under way
    Impedance being modeled and included in the budget
    like to see drawings with the RF cavities in the ring (including SR and MPS collimation…)
  - Collective effects are being studied and integrated in the modeling.
  - Still too early to judge their impact on the overall performances.
  - Several solutions are under study to ameliorate some of them but several iterations are needed to decide which one to adopt (e.g. Carbon coating for e-cloud strongly affects the Ring impedance)
  – As general comment: from the work presented it looks like the expertise to carry on the DR design effort is present.
  – It seems that all the aspects and problems are being addressed, although probably more FTE's of what is currently available would be needed for the TDR phase.
  – Good effort in building international team focused on Low Emittance Storage Rings.

Low Emittance Preservation

- Linac and BDS tuning presented in previous ACE's, comments reminders:
  - Extensive simulations but complex problem (and simulations)
  - Wakefield effect on beam dynamics is ~10x SMALLER than SLC but emittances are also much smaller → tight tolerances
  - Performance relies on high resolution diagnostics whose requirements are not far from existing demonstrations but challenge is frequently in implementation → TDR development
  - Some significant cost implications which may need iteration

  - Some improvements shown in the BDS tuning performances
  - Possible implication in moving QD0 outside the detector (not clear why the bandwidth is not affected) are extremely attractive.
  - QD0 stabilization might be much easier to achieve.
  - High ξ optics for CLIC could be studied at KEK ATF2

Alignment and Stabilization

- Stabilization tolerances are challenging
  - 1 nm @ >1Hz on main linac quads. A lot of progress made and now it seems achievable (in the LAB).
  - Implementation in the Linac Modules to be (under) studied
  - Good progress on feedback studies =>

  Probably it will reduce the requirements on the stabilization tolerances

  Good model under development on how the machine evolves in time and what is needed to maintain the performance as long as possible. More work is foreseen.
- Alignment

  - Several alignment techniques studied with good redundancy between them. The required tolerances seem achievable.

  – Need to think about cost thresholds

CAS - Feasibility Issues (grad. Performance)

- Critical feasibility issues
  - Demonstrate nominal CLIC stuc with damping features at the design gradient (100MV/m), pulse length (240ns) and BDR (3E-7/m/pulse).
- Observation
  - T18 satisfied the feasibility goals.
  - Struc fab/assy and testing work is progressing, as stated in the previous ACE.
  - New results with TD18 and T24. → Design improvement with TD24, and
  - TD24 (2 units) to be tested soon.
- Remark
  - Commend the hard work and progress (as usual!)
- Recommendation
  - Make every effort to ensure that studies with TD24 proceed as scheduled.
  - Develop plans to go beyond 2011.
    - Accumulate more statistics
    - Accumulate more manufacturing & test experiences at CERN
    - Important to increase number of test stations at CERN
    - Assess the relative merits of **klys-based** vs CTF-based facilities for further high-power testing acc struc; decide the actions to take; start soon.

CAS – Additional Design + Demo Issues

- Important additional issues are
  - HOM damping material and its integration in the assy procedure
  - Design + manufacturing of fully-equipped acc struc packages
  - Integration of the acc struc packages in the module design
  - Beam operation – effects of BDs, alignment (optical survey vs BB), tuning…

- Observation
  - Systematic and impressive engineering work on track
  - CERN group rapidly catching up with (and going beyond) what the previous engineering effort has reached at NLC/GLC.
  - Many of the related engineering efforts are (partially) an integral part of CTF3 efforts and elsewhere, wherever applicable.

- Recommendation
  - An **expert review** could be useful for re-assessing the details of manufacturing + assy procedures (sequence + order of brazing etc).
  - Establish first the design and manufacturing procedure that result in an acc structure package that works. Then a cost reduction effort follows.
  - Map out the plans on which aspects of beam operation issues be addressed where, when and how; identify requirements on the needed facilities.

PETS - Feasibility Issues

- Critical feasibility issues are to
  - Demonstrate nominal PETS with damping features at the design power (136MW) with design pulse length (240ns) with BDR (< 1E-7/m/pulse) with ON/OFF feature (<20ms) and DB → RF eff of 90%.

- Observation
  - Feasibility issues in the power, pulse length and BDR met in various creative test setups, despite limitations in CTF3.
  - ON/OFF scheme in prototyping for testing w. beam.
  - TBL w. 8 PETS in 2011 for 30% and 16 PETS in 2012 for 50% eff will be performed

- Remark
  - Commend the hard work and progress (as usual!)

- Recommendation
  - Make every effort to ensure that the studies with **ON/OFF** proceed as scheduled.
  - The same goes for the **TBL** test on "deceleration" in 2011 and 2012.
  - Cross examinations of results from Klys-based vs beam-based test benches would be a "plus", whenever possible.

2Beam Acc Modules

- Observation
  - Basic implementation scheme for the 2-beam modules has been updated / defined.
  - Engineering work associated with the latest scheme of the 2-beam module (1st generation) has begun.
  - Impressive progress in integration of a comprehensive set of analysis + thoughts on: beam dynamics, RF, cooling, alignment and installation.
- Remark
  - Commend the hard + well-integrated work by all who are involved.
  - Powerful 3D CAD is fully taken advantage of.
  - ACE would like to better understand cost benefit of implementing wire-alignment scheme.
- Recommendation
  - Should focus on demo'ing the 1st generation hardware system that nominally works and try to **remove "rough edges" first**.
  - Prepare and schedule an extensive internal review when the 1st gen. system is completed. Allocate a sufficient amount of time for it.
  - Be prepared for 2 or 3 iterations before going to many module production and be careful not to commit to a major scale manufacturing effort, before feeling comfortable with the design. More useful to develop step-wise evolutionary scenario.

CTF3 and Beyond - quick comments

- Observation
  - CTF3 is
    - the unique test bench for feasibility-demos driving beam generation and two-beam acceleration.
    - an important test bench for benchmarking performance of PETS and CAS.
  - CTF3 is limited in terms of available beam energy / current / pulse length and system availability, and cannot easily be a facility for testing the full-CLIC-spec beams (DB / MB) for an extended period.
  - ACE commends a large and almost heroic amount of concerted efforts by all despite some limitations.
- Recommendation
  - Sort out the performance problems at CTF3 into
    - near-fundamental limitations vs
    - relatively straightforward, "a reasonable budget/FTEs can fix this" types.
  - Map out which type of CTF3 performance probs are the limiting factors in addressing the remaining CLIC feasibility issues, design optimization issues, etc.
    - Develop a structured description
  - Develop a proposal with associated cost to go beyond 2013.

Drive Beam feasibility issues

System	Item	Feasibility Issue	Unit	Nominal
Two Beam Acceleration	Accelerating Structures (CAS)	Structure Acc field	MV/m	100
		Structure Pulse length	ns	240
		Structure Breakdown rate	/m MV/m.ns	< 3·10-7
	Two Beam Acceleration	Power producton and probe beam acceleration in Two beam module	MV/m - ns	100 - 240
		Drive to main beam timing stability	psec	0.05
		Main to main beam timing stability	psec	0.07
Ultra low beam emittance & sizes	Ultra low Emittances	Emitttance generation H/V	nm	500/5
		Emittance preservation: Blow-up	nm	160/15
	Alignment	Main Linac components	microns	15
		Final-Doublet	microns	2 to 8
	Vertical stabilisation	Quad Main Linac	nm>1 Hz	1.5
		Final Doublet (assuming feedbacks)	nm>4 Hz	0.2
Operation and Machine Protection System (MPS)		72MW@2.4GeV		
		main beam power of 13MW@1.5TeV		

Principles have been demonstrated in CTF3 despite lower current and lower energy

Drive Beam Generation

- Demonstrated in CTF3
  - Efficiency of fully loaded linac
  - Combined beam current
- To be improved
  - Injector: substitute thermoionic (needs multiple SHB and generates satellites) by photoinjector
    Run in a reliable way and assess lifetime
  - Stability: selected improvement after identification of jitter sources and operational experience

PETS

- Demonstrated PETS on klystron driven test stands
  - Measured BDR and pulse length
  - Fabrication & assembly: find the best procedure to get performance but compare different solutions (ex. clean room really needed ?)

- Still to be tested at CTF3
  - ON/OFF device to be tested with beam in 2011
  - Deceleration of beam in TBL with 8 structures (4 PETS to be installed, 8 PETS for summer 2011 but w/o ON/OFF)

  - TBL deceleration is an important feasibility demonstration

Drive Beam Rf Power Sources

- Significant cost drivers
  - Highly efficient sources have multiple benefits
- Design exists for drive beam accelerator structures
  - CTF3 structures provide feasibility demonstration
- Plan being developed to engage EU research community and industry in developing next generation sources
  - Excellent program with broad benefits
- Different technologies should be compared
  - Optimize modulator/klystron/structure system
- Rf phase jitter → tight modulator stability but detailed values need further understanding

Final Comments

- CLIC team has resources to complete CDR
  - Major technical issues have well developed plan of attack
  - Present design seems stable; CDR schedule has no float
- Making progress in costing
  - Some cost information will be required to understand benefits
  - Will likely need to iterate on designs in next phase
  - Understand cost for achievement of tolerance thresholds
- Working on plan for next phase
  - TDR must address systems-level feasibility and operation
  - Advise focusing CTF3 on dedicated experiments
  - Develop plans for CLIC0 as a production facility
- Should think about how to engage community