Perspectives for a CALIFES test facility beyond 2016

R. Corsini

Context

- CTF3 went well beyond its initial task of demonstrating CLIC two-beam scheme feasibility
- Has a well established scientific program until end 2016

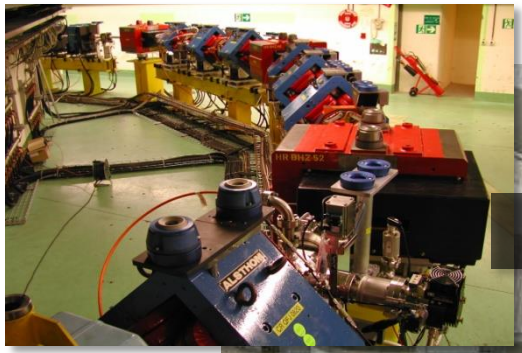
- Definitely want to stop CTF3 after that (limited resources)

➔ *What next?*

- Additional considerations:
  - Initial plan was to evolve gradually towards DB front-end, shifting resources from CTF3 to the front-end, however this is now delayed and resources are somewhat lower
  - CONCERN: no local (CERN) real testing capability with beam (diagnostics and components) beyond 2016

➔ May keep using part of the CTF3 Installation (*CALIFES*) for testing after 2016. Possibly interesting beyond CLIC scope (within and outside CERN).

CLIC Test Facility (CTF3)



DELAY LOOP

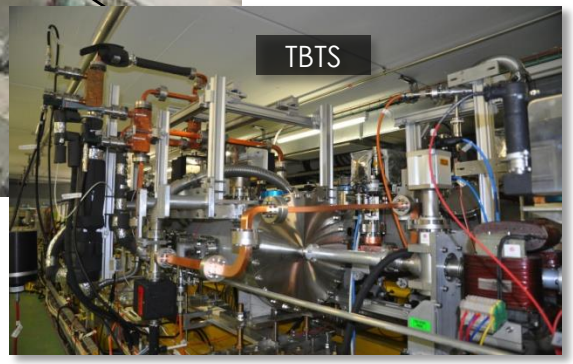
CERN

COMBINER RING

CLEX

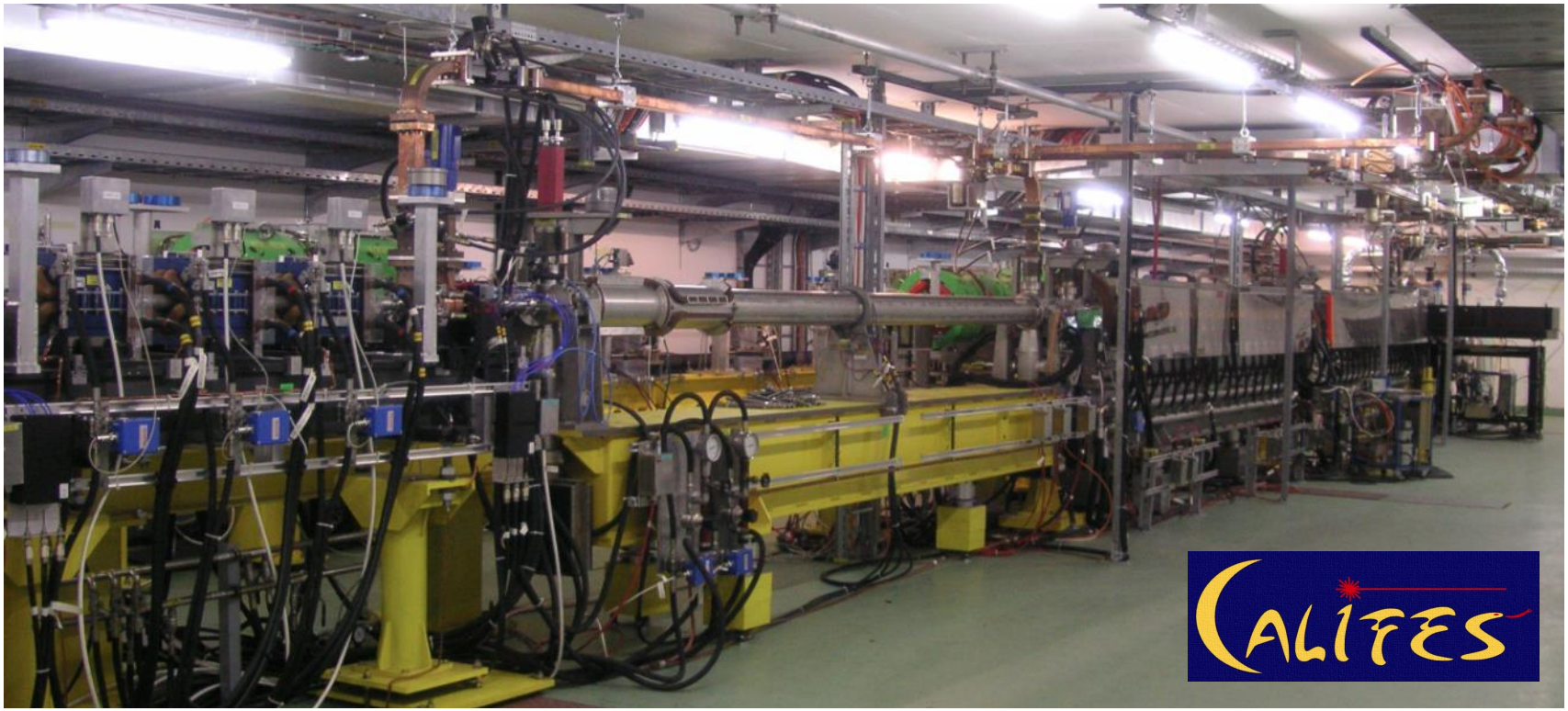
DRIVE BEAM LINAC

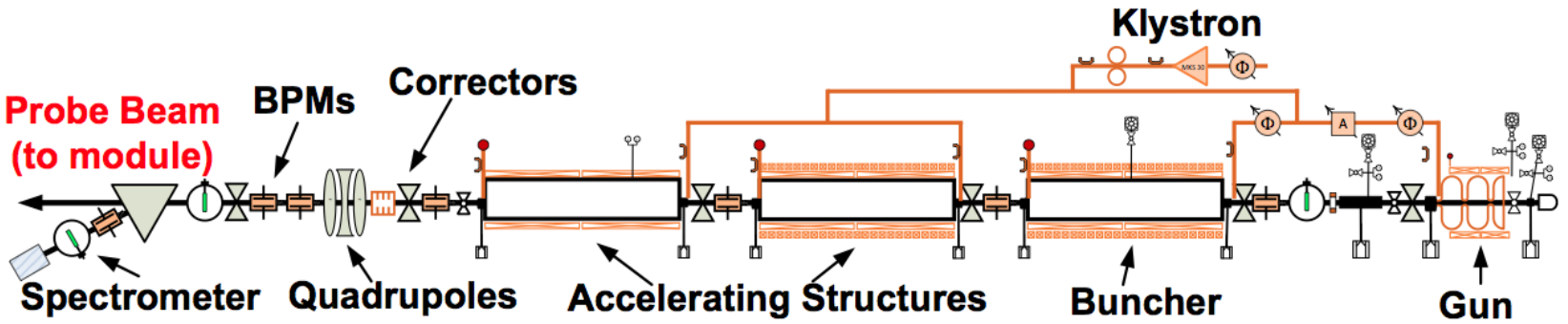
TBL



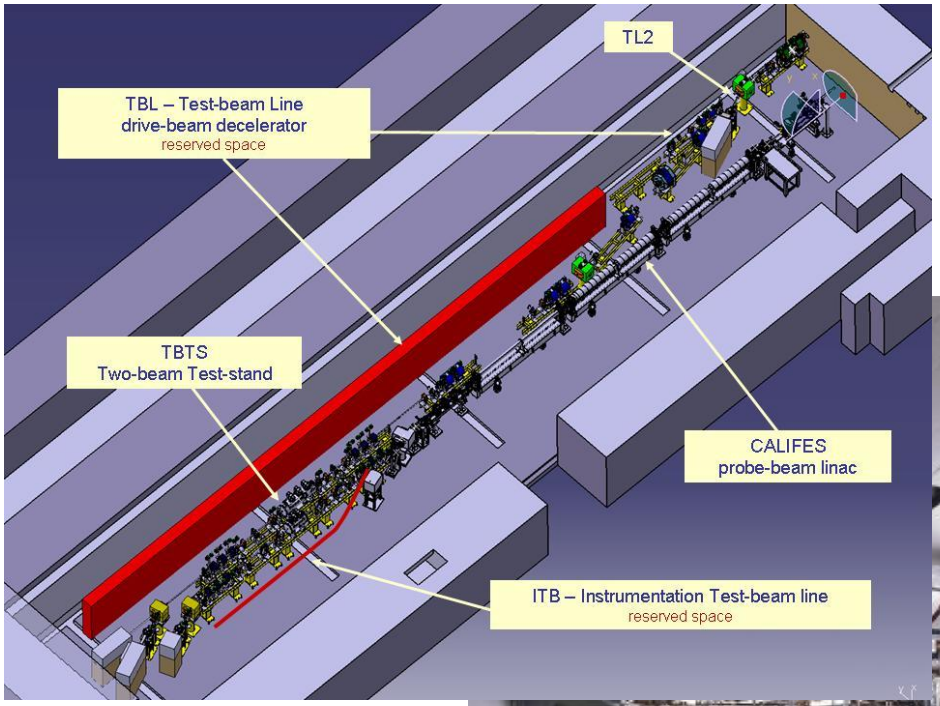
TBTS

CALIFES


CALIFES


Klystron
Probe Beam
(to module)
BPMs
Correctors
Spectrometer
Quadrupoles
Accelerating Structures
Buncher
Gun

CALIFES hall & infrastructure

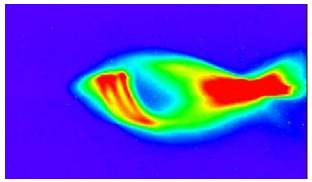


CLEX

- Convenient hall (42 x 8 x 2.6 m^3) with proper concrete shielding (2.8 m) and large access.
- Instrumentation & klystron gallery just above
- An up-to-date Laser lab, (80 m laser beam line, partly under vacuum)
- Fully equipped (conditioned air, water, access control. No crane.

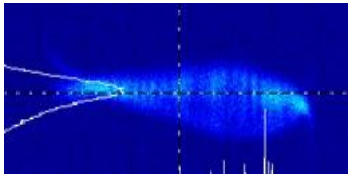
CALIFES

Parameters	Specified	Verified	Comment
Energy	200 MeV	205 MeV	Without bunch compression
Norm. emittance	< 20 π mm.mrad	4 π mm.mrad	With reduced bunch charge
Energy spread	< ± 2 %	± 0.5 %	
Bunch charge	0.6 nC	0.65 nC	With new photocathode
Bunch spacing	0.667 ns	0.667 ns	Laser driven
Nb of bunches	1-32-226	from 1 to 300	Limited by RF pulse length
rms. bunch length	< 0.75 ps	1-2 ps and above	
Repetition rate	0.8 – 5 Hz	0.8 – 5 Hz	Upgrade possibility to 10 Hz



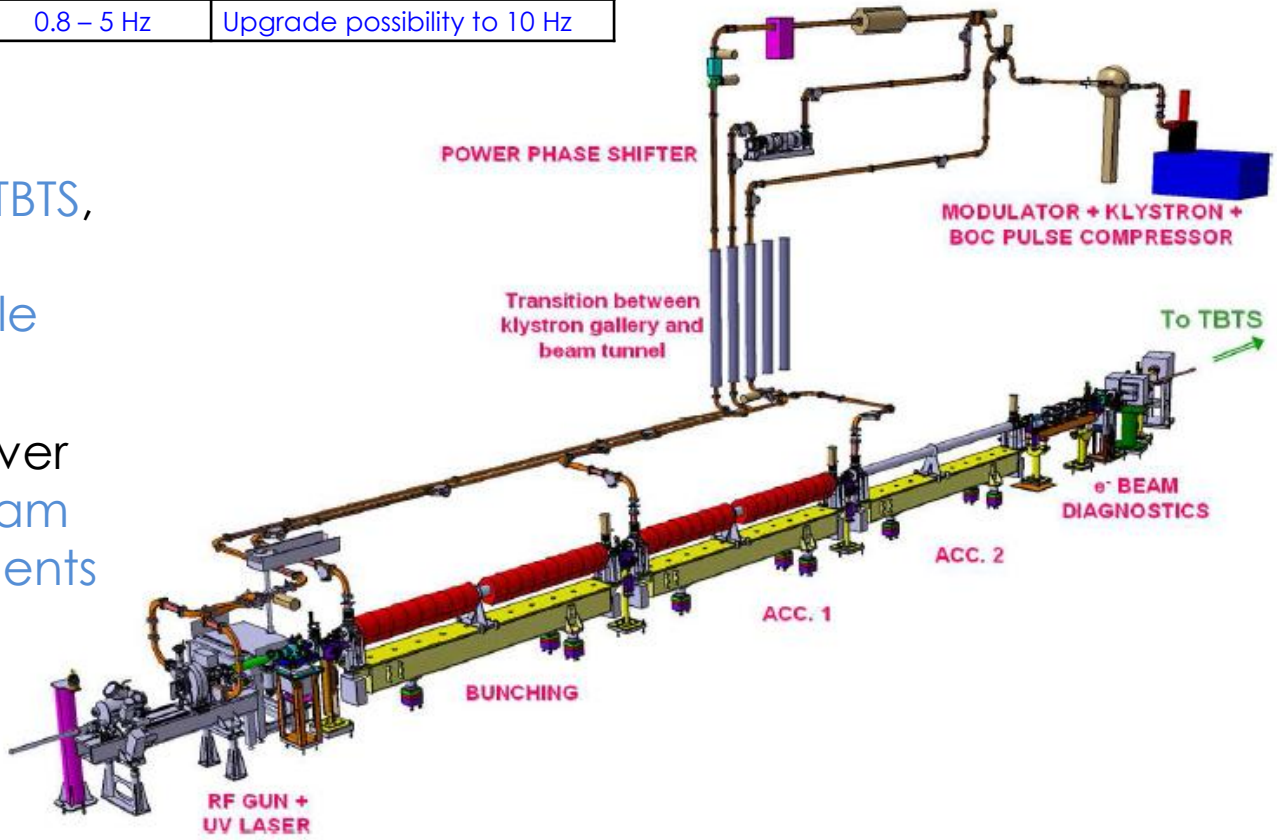
CALIFES

Swiss FEL injector (courtesy Simona Bettoni)



- Up to now used on TBTS, from November:
  ➔ Two-Beam module

- Growing activities over the last years on beam diagnostic/components testing

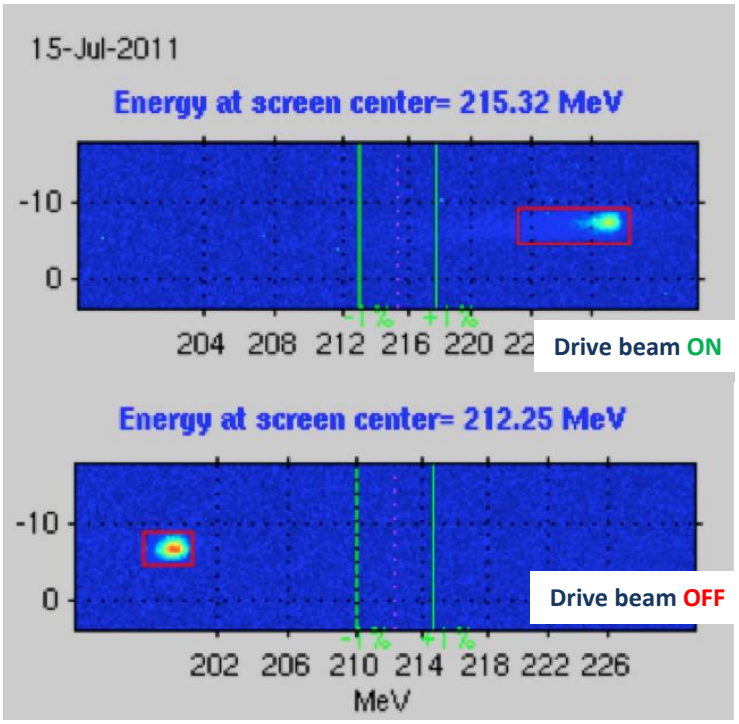


Two beam acceleration in TBTS

Two-Beam Acceleration demonstration in TBTS

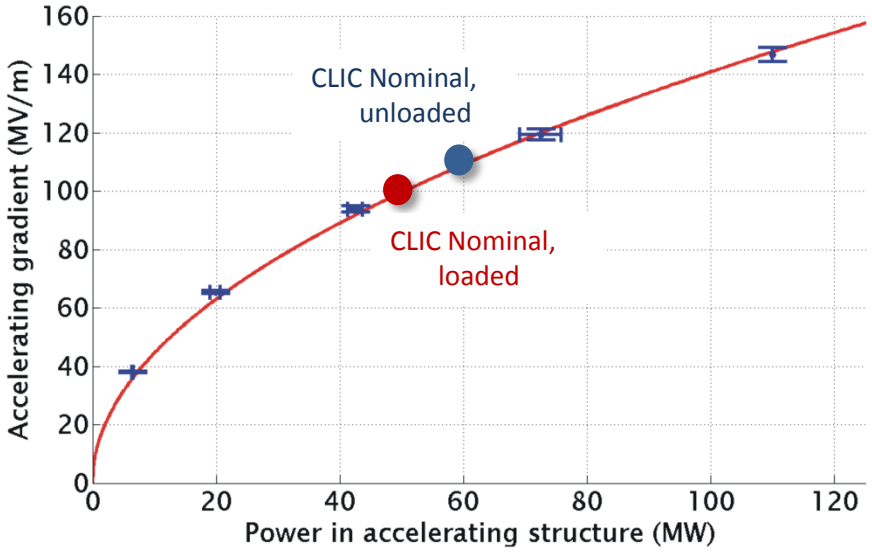
Up to 145 MV/m measured gradient

Good agreement with expectations (power vs. gradient)

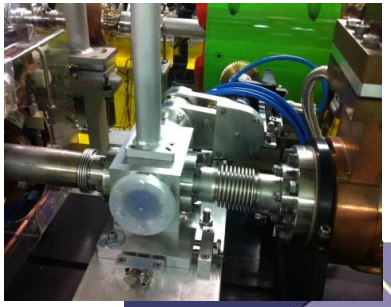


Maximum stable probe beam acceleration measured: 31 MeV

⇒ Corresponding to a gradient of **145 MV/m**



Beam Diagnostic Tests in CLEX

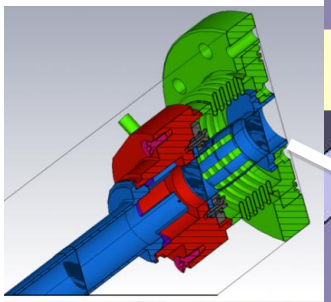


Electro-optic bunch profile monitor in CALIFES

(CERN-Dundee University)

Stripline Drive Beam BPM in TBL

(CERN-LAPP)



Cavity Main Beam BPM in CALIFES/TBTS

(CERN-JAI at Royal Holloway)

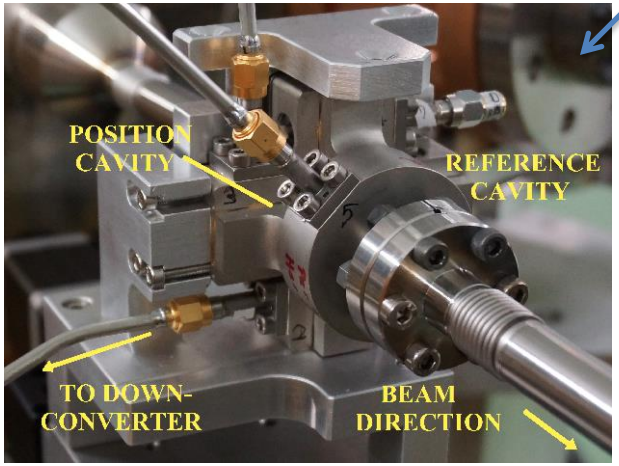
Recent CLIC diagnostics tests

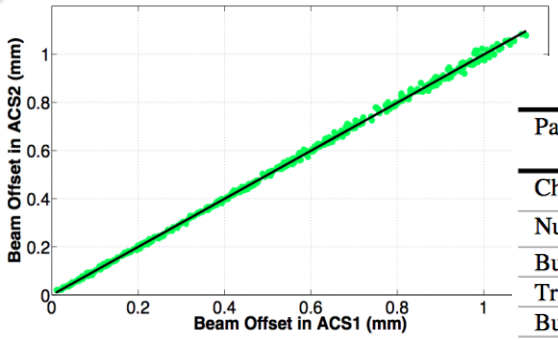
Main linac BPMs

Table 1: CLIC Main Linac BPM specifications

Nominal bunch charge [nC]	0.6
Bunch length (RMS) [μm]	44
Batch length [ns]	156
Bunch spacing [ns]	0.5
Beam pipe radius [mm]	4
BPM time resolution [ns]	<50
BPM spatial resolution [nm]	<50
BPM stability [nm]	<100
BPM accuracy [μm]	<5
BPM dynamic range [μm]	±100
BPM resonator frequency [GHz]	14

Under further development and testing at CTF3





Resolution tested in CTF3

Wake-field monitors

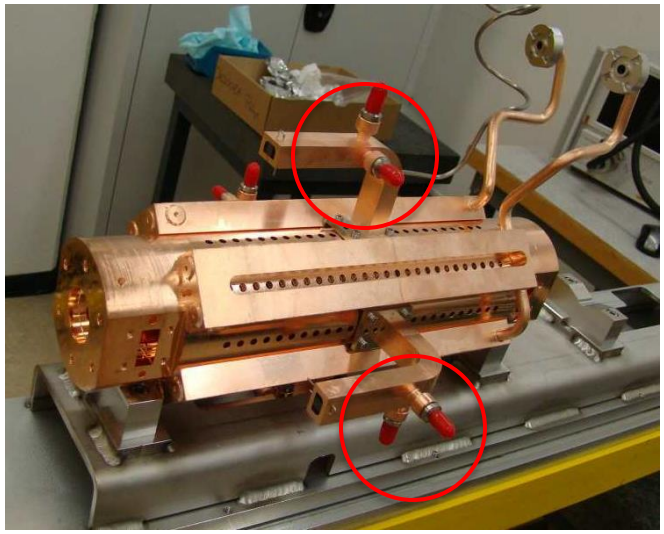
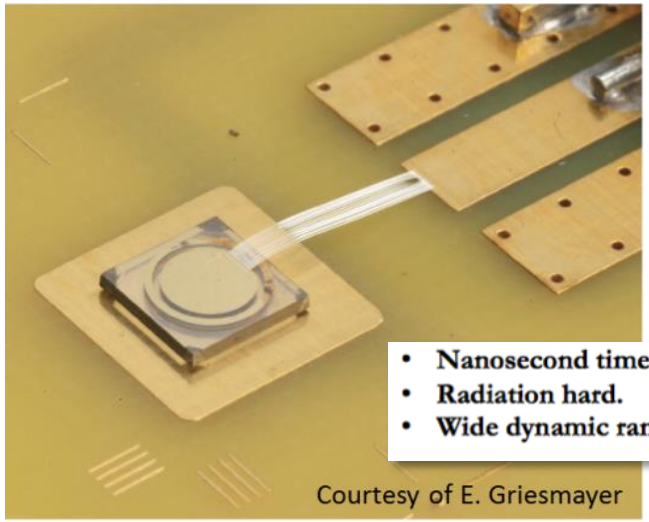


Table 1: Wakefield Monitor Specifications

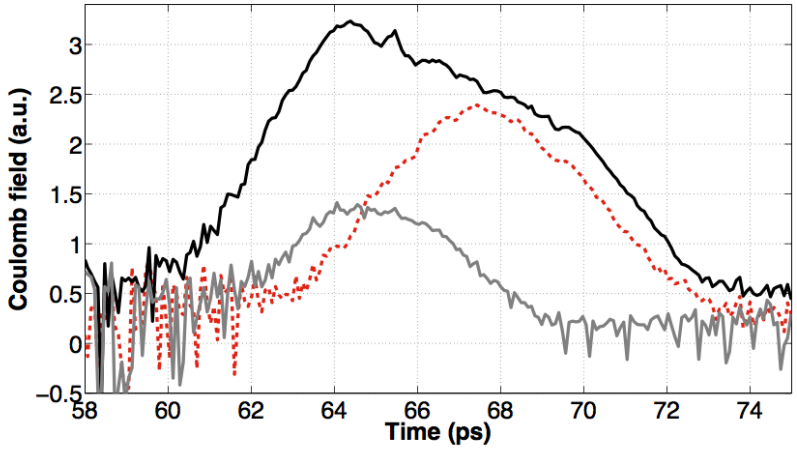
Parameters	CLIC commissioning	CLIC operation
Charge / bunch (nC)	0.06	0.6
Number of bunches	1-312	312
Bunch length (μm)	45-70	45-70
Train length (ns)	156	156
Bunch Spacing (ns)	0.5	0.5
Accuracy (μm)	5	5
Resolution (μm)	5	< 5
Range (mm)	± 2	± 0.1
Beam Aperture (mm)	~5.5	~5.5

Other recent (CLIC) diagnostics tests

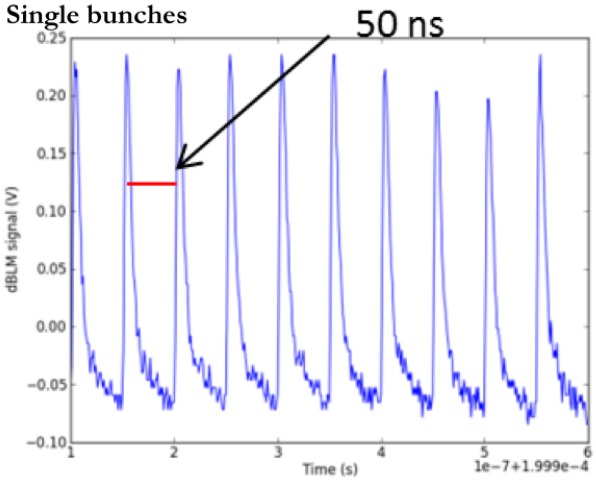
Diamond Beam Loss Monitor

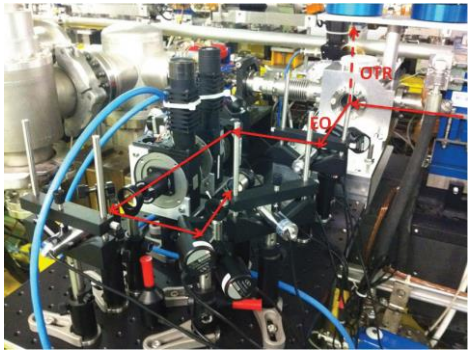


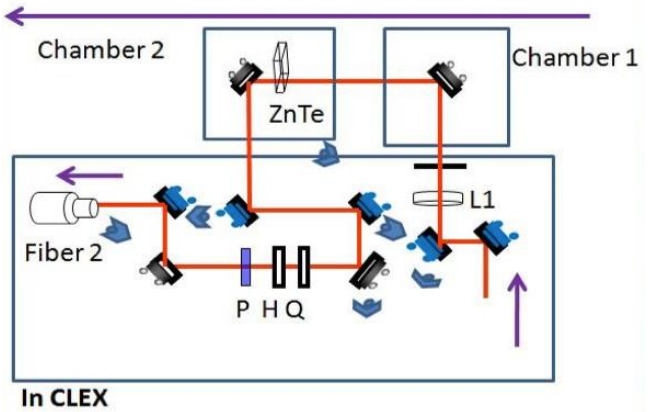
EOS bunch length monitor



Bunch temporal structure measured with a longitudinal profile monitor based on electro-optic spectral decoding for different bunch charges.

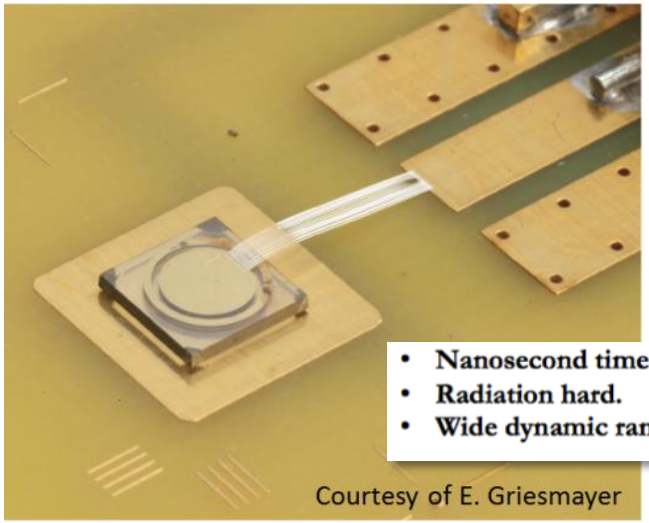




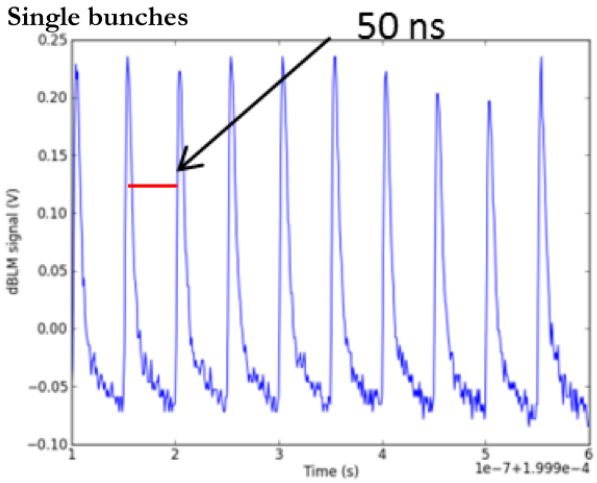


Time resolved beam loss using diamond BLM

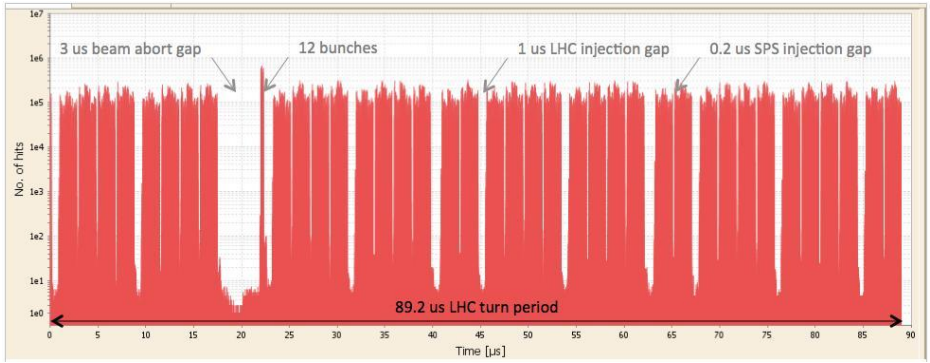
Diamond Beam Loss Monitor



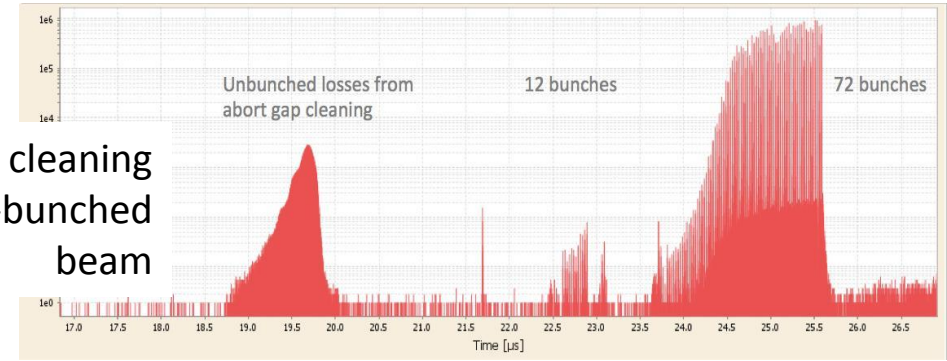
- Nanosecond time resolution.
- Radiation hard.
- Wide dynamic range (1e – 5E9e).

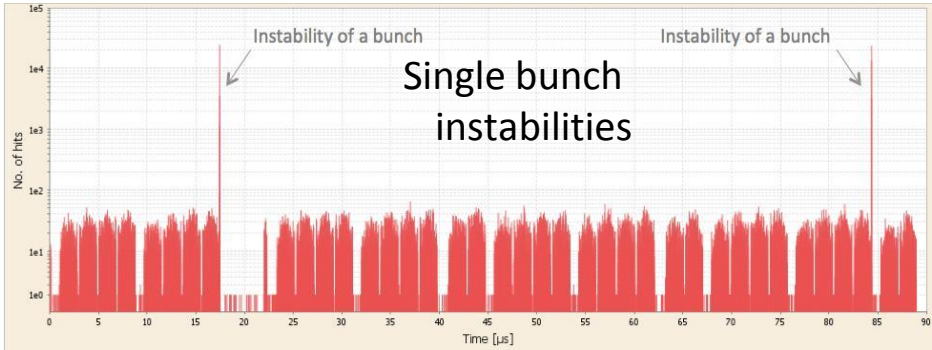


LHC bunch structure near abort gap



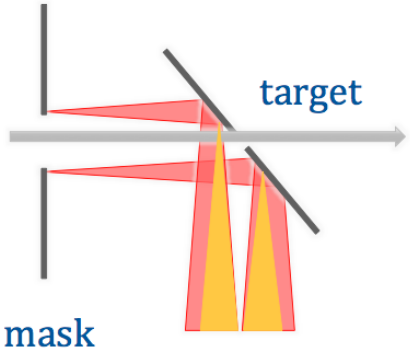
Abort cleaning and un-bunched beam





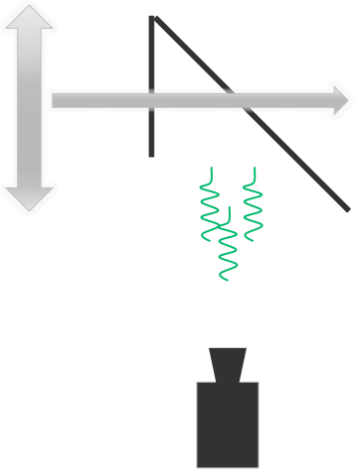
Other recent (CLIC) diagnostics tests

OTR interference



Mask (FW) and target
(BW interference

- Vertical position of OTR screen assembly determines distance
- Same ODR geometrical configuration
- Single screen OTR
- Between 0.5 and 1 L_c fourfold increase of OTR signal

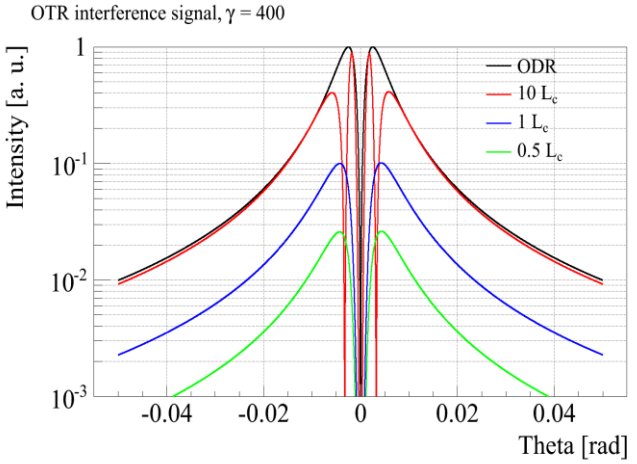


When ODR screen distance is << than coherence length $L_c = \frac{\lambda}{\pi(\gamma^{-2}+\vartheta^2)}$: fields interfere *coherently i. e.* signal only when mask, target have different width.

Need for simulation tool of interference: Zemax, physical propagation (B. Bolzon, T. Aumeyr).

Need for an experimental benchmark

S. Mazzoni, T. Lefevre



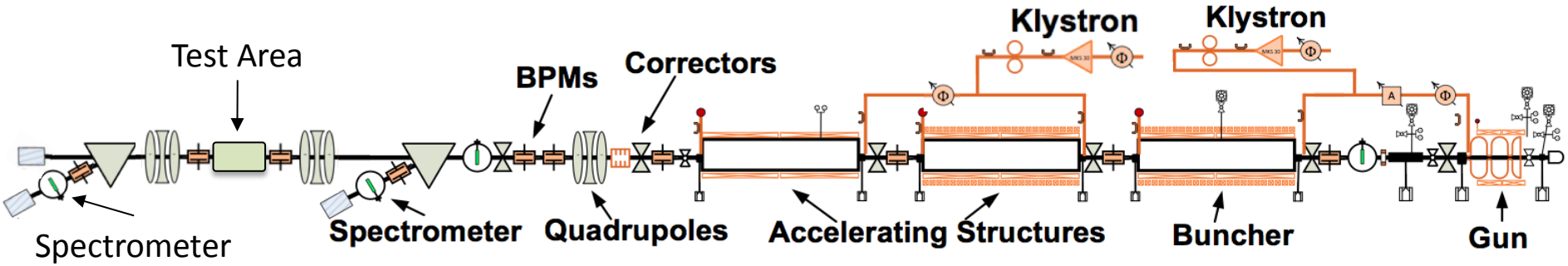
Rationale for CALIFES as a test facility beyond 2016

- Need to keep beam test capability on CLIC diagnostics (and other issues) locally at CERN after CTF3 stop
- Potential interest of other projects/groups from CERN (AWAKE? LHC? …) and outside – beam diagnostics and other
- Possibility of beam tests during long shut-downs
- Keep experimental electron expertise alive at CERN, including laser and photo-cathodes – again link with AWAKE
- Provide training ground for young accelerator physicists at CERN and collaborating institutes
- …

Future CALIFES – minimum configuration

Present

Future: CALIFES for beam instrumentation test



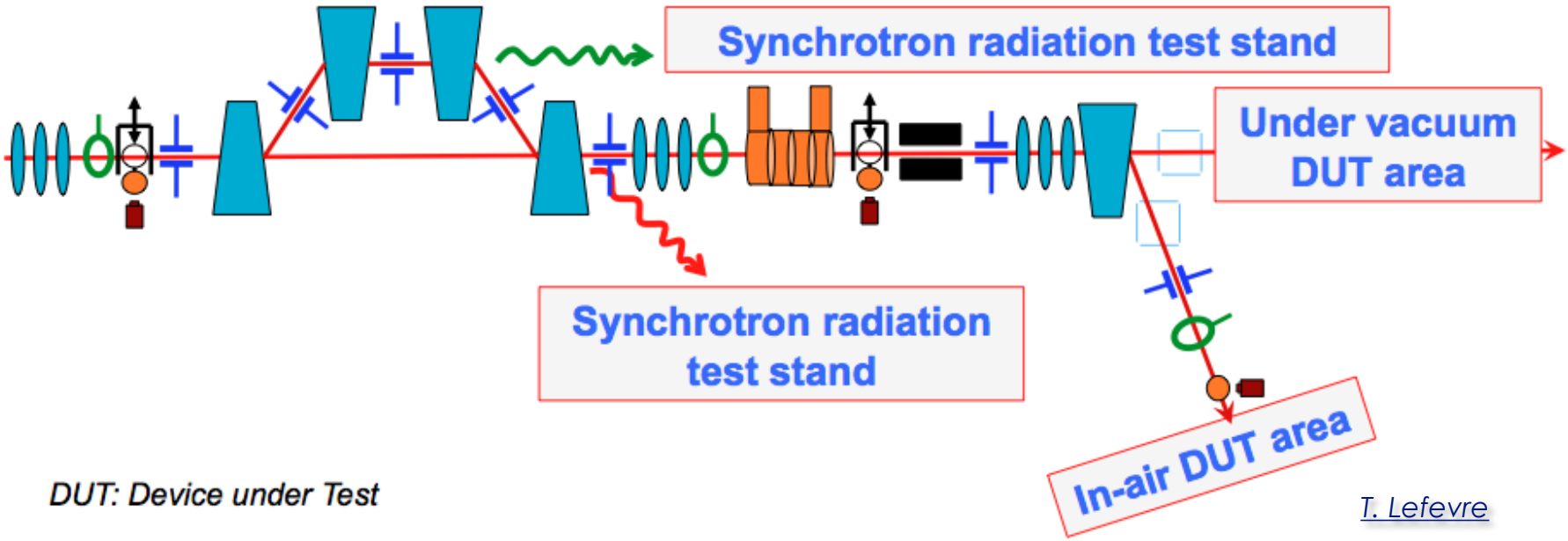
- Add an available S-band klystron + modulator
  - More RF power (beam energy), more flexibility (power in 1st structure, phase in structures 2 and 3), possibility of running without RF pulse compression
- Reconfigure present TBM area as test area
- Most (all) hardware already existing

"Ultimate" test area layout to cover BI needs

Magnetic chicane
Shorten or lenghthen
100fs up to 200ps

RF deflector
for crabbing

Collimator
- Reduce the bunch intensity before the DUT zones
- Reduce bunch length further in combination with RF deflector



DUT: Device under Test

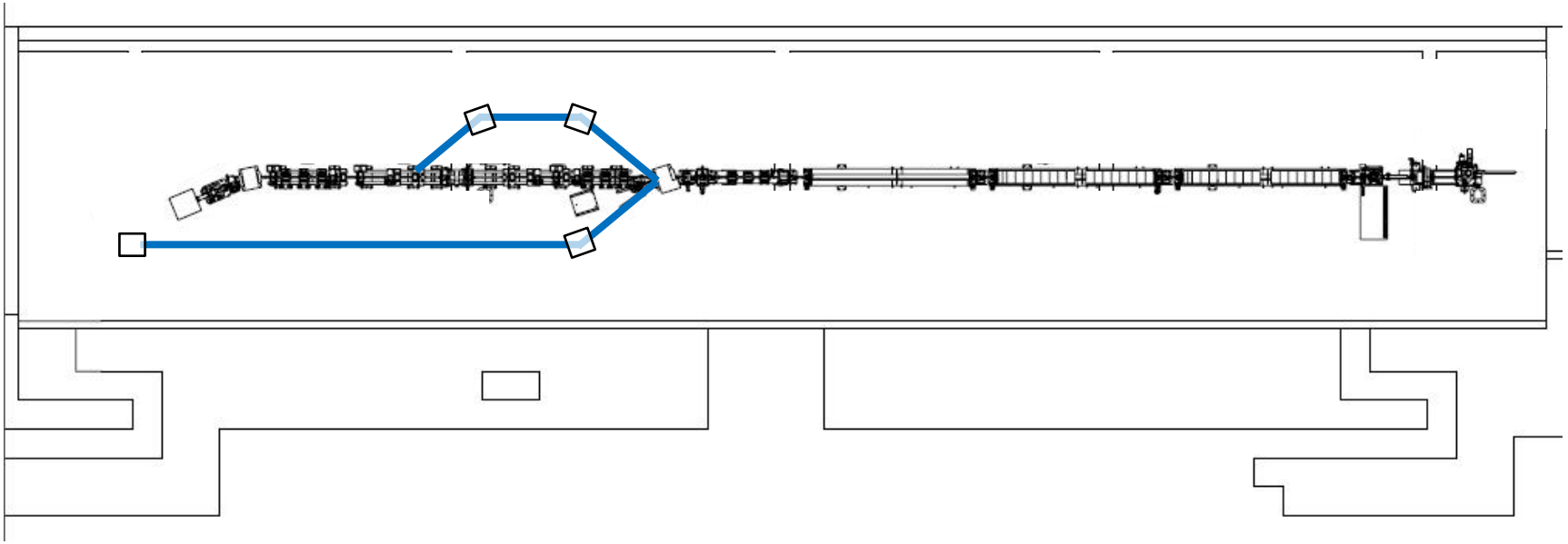
T. Lefevre

Use for diagnostics tests

Synchrotron radiation source

- **Testing optical detectors with short photon probes over a wide range of wavelength (IR, visible, UV)**
- **Possible use for developing**
  - Beam halo monitor, longitudinal density monitor, …

Previous studies – the Instrumentation Beam Line



- A preliminary study has been done: *"Short Pulse Capabilities of the Instrumentation Beam Line – V. Ziemann – 6 May 2010"*
  - Short pulses (200 fs – 35 μm) are necessary to mimic the CLIC main beam for instrumentation tests
  - Pulses of 20 μm are achievable with a chicane R_{56} = 2 cm and energy encoding of 10^{-3} , maximum energy reduced to 78% of the on-crest one
- Other option ➔ four-bend chicane
- All equipment will be available from the DB lines (magnets, powers, chambers…)

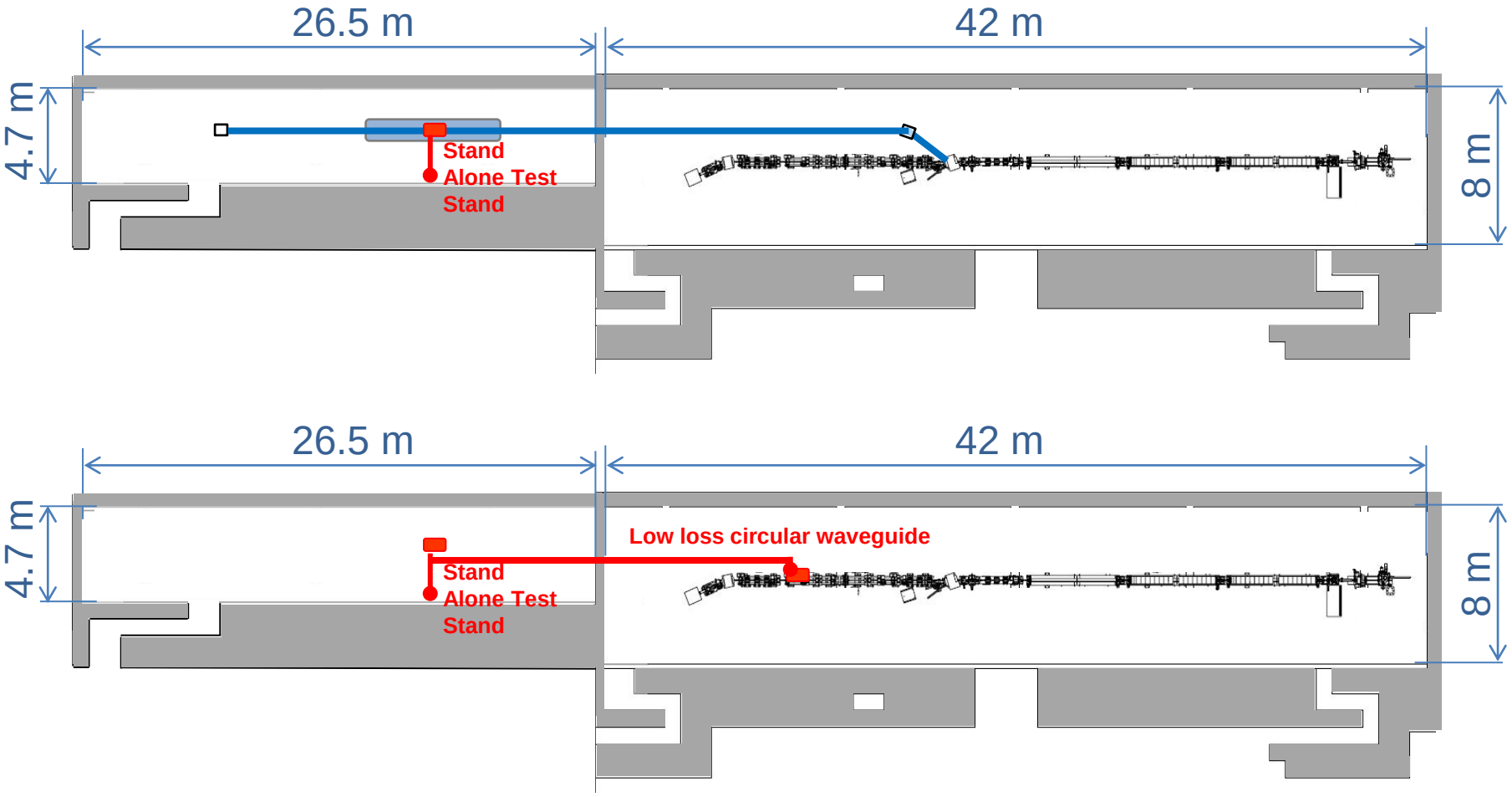
Bunch length flexibility

- In many cases a (very) short bunch length is required
- May be accessible using a magnetic chicane or dogleg (need some compression studies, implications on off-crest phase, short range wake-fields)
- Other possibility, RF deflector + collimator (crabbing). May also implement a two-deflector solution (RF bump) to remove crabbing
- Should continue bunch compression studies in CALIFES 2015-2016 with streak camera, EOS and possibly RF deflector

X-band

- CALIFES may provide an unique opportunity to test X-band structures/modules with beam
- XBOX1 located very close (distance comparable to present low-loss line for dog-leg beam loading experiment)
- Straight-forward solution: connect to XBOX1 for beam testing in CLEX
- An upgraded CALIFES beam may be not too far from what is needed for FELs: "Playing ground" for X-band FEL beam studies and developments
- Future possibility: test a full X-band module (for X-band FEL or klystron-based CLIC) – may need an additional modulator/klystron
- Add more? …

Layouts?


26.5 m
42 m
4.7 m
8 m
Stand
Alone Test
Stand
26.5 m
42 m
4.7 m
8 m
Low loss circular waveguide
Stand
Alone Test
Stand

Summary of possible evolutions

- Keep CALIFES for beam instrumentation test
  - Add an available S-band klystron, modify waveguides
  - Add a chicane, another dedicated klystron for deflector
  - Change the deflector to a CR one
  - Closed RF bump + collimator for bunch length control
  - (Switch for the PHIN gun for higher charge)

- (Push the beam line toward the X-Box1 in CTF2)
- Or transport the 12 GHz power to CLEX
  - Add a 12 GHz crab cavity for bunch length diagnostic
  - (Add an undulator, a Compton scattering experiment…)

- Produce special beam for Wakefield study
  - 2 bunches of different energies with adjustable delay
  - Single bunch, short range wakes (A. Latina)

Some consideration on resources

- Given the present CTF3 material budget/manpower, one may roughly evaluate the resources needed to keep CALIFES running after 2016 to about:
  - 200-300 kCHF/year (including M to P – students and PJAS)
  - About 5 FTEs (staff and fellows)
- The above would include a minimum upgrade (1 ½ additional klystron, rearrangement of test area)
- Will do a more precise evaluation, including more ambitious upgrade options

Outlook

- CALIFES may be a reasonably cheap multi-purpose test facility
  - Useful within the CLIC study – potentially much wider interest
  - (Would help if enough support should come from outside the CLIC study or/and outside CERN)
- Minimum to medium upgrades will enhance flexibility/usefulness
- Connection to XBox1 seems logical step
  - Possibilities of further upgrades
- Need more refined cost/resource assessment and evaluation of scientific case
- Develop an integrated proposal, considering other beyond CTF3 options.

ADDITIONAL CONSIDERATIONS, MATERIAL FOR DISCUSSION

List of potential options (non exhaustive…)

- Shut-down CTF3 completely and re-use for other scopes the buildings and whatever hardware may be requested (3 GHz power stations, magnets, power supplies…)

- Refurbish CTF3 as part of new lepton injection chain at CERN (potential interest for SPS damping ring tests, plasma wake-field experiments in AWAKE, future lepton accelerators…)

  F. Tecker

- Keep CALIFES probe beam injector running as a generic test facility for testing diagnostics and other components. May include additional X-band powering.

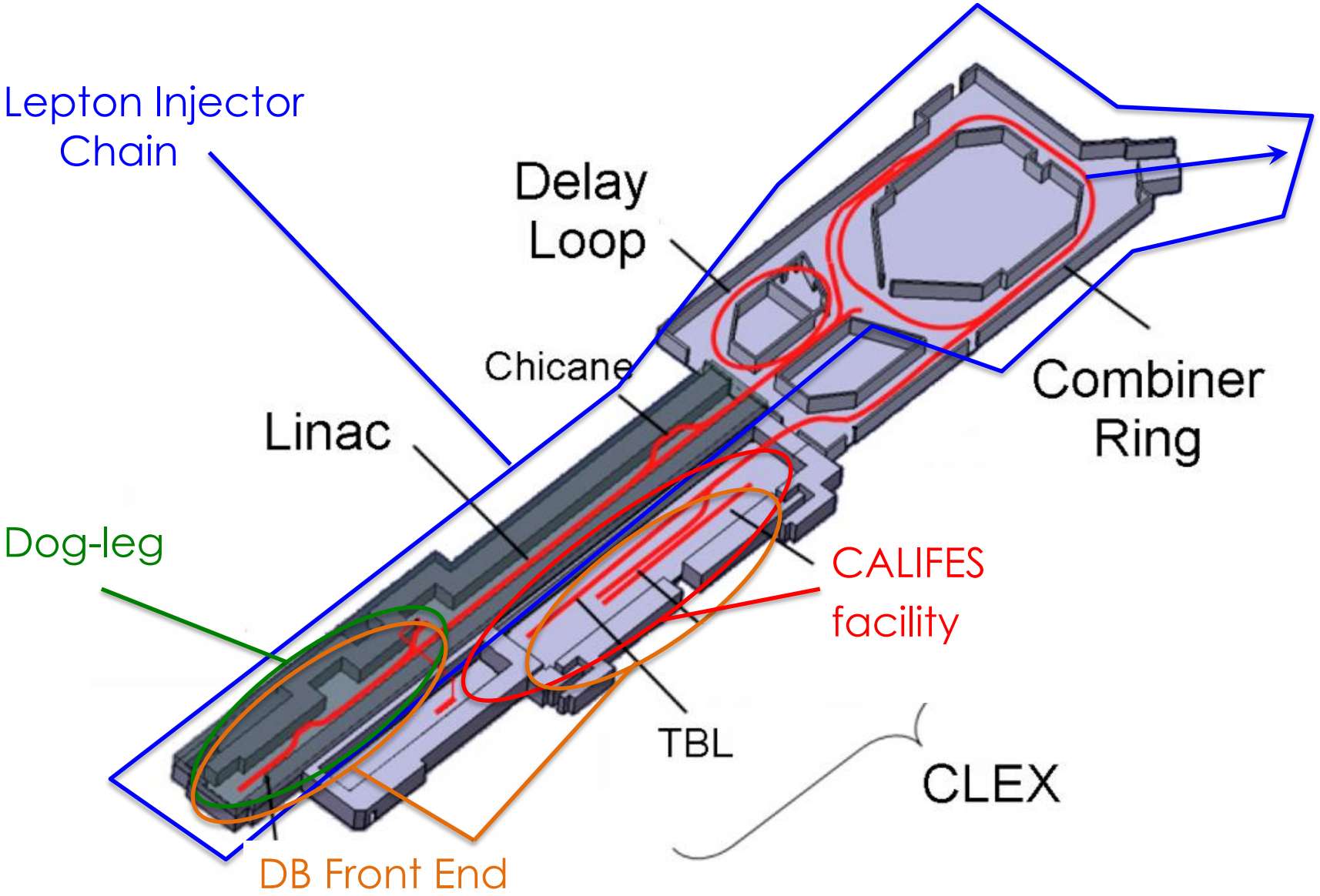
  W. Farabolini

- House the DB Front-End in CTF3 (CLEX or Linac?). Possible option: plug Front-End before the CTF3 linac.

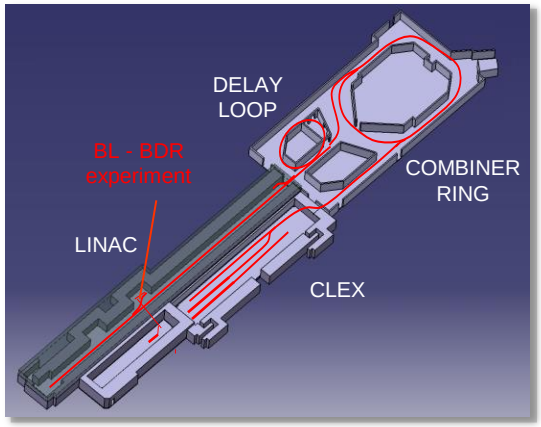
  S. Doebert

- Extend CTF3 running limited to first part of the linac, for X-band beam loading tests. Option: use dog-leg for X-band RF production - testing?

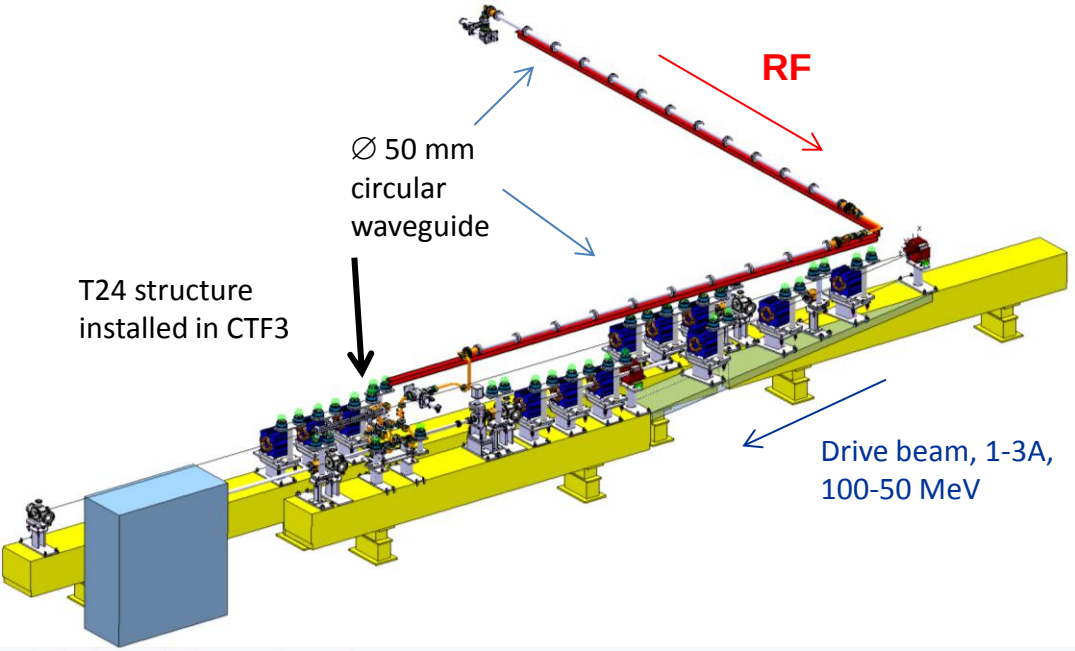
Options


Lepton Injector Chain
Delay Loop
Chicane
Linac
Combiner Ring
Dog-leg
CALIFES facility
TBL
CLEX
DB Front End

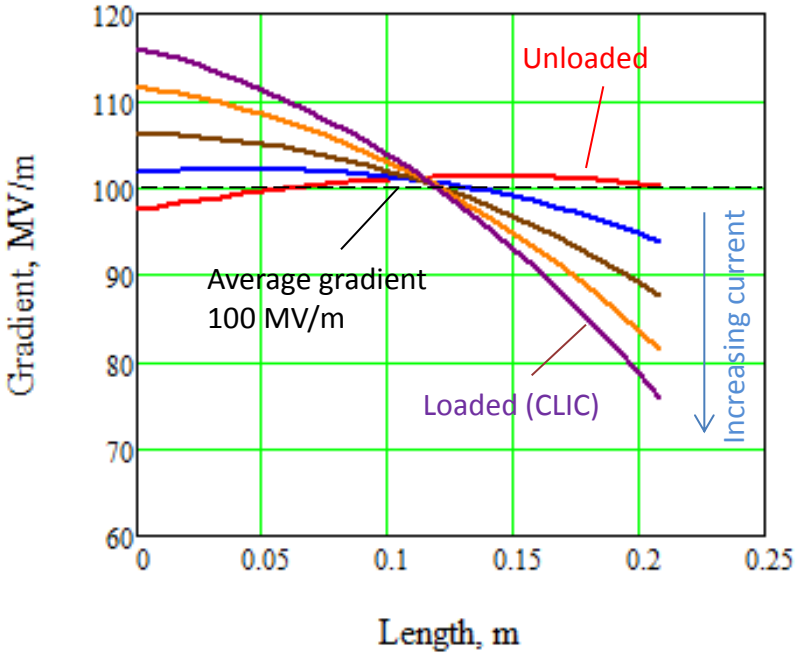
Beam Loading run beyond 2016



- From here to 2016 ~ 3 test slots (one per year) – not a large statistics
- In this time scale could have a new CLIC structure prototype from rebaselining
- May want to test it, especially if the gradient profile turns out to be different from the present one
- Need relative small infrastructure – 5 MKS, first 50 m of linac



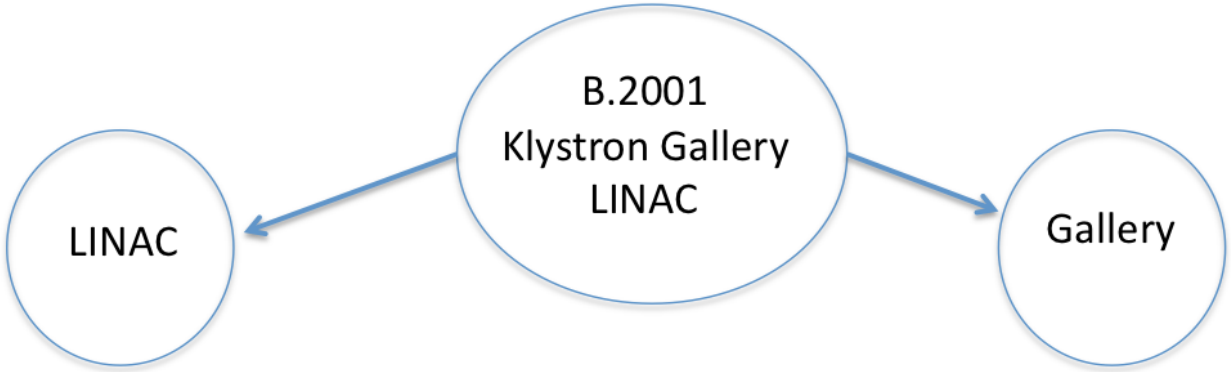
Gradient along the structure



CTF3 Decommissioning issues

G. McMonagle

Example of clearing out an area



Controlled area
Not INB .. No INB paperwork needed ☺
Each item that is removed needs RP control
(full time RP technician in situe necessary)
Timescale …… some weeks maybe months
Storage area needed for activated items
Storage area needed for non activated items

No radiation issues as installation is not activated
Mainly klystron modulators
Magnet Power supplies
Control racks
Any requests for reusing components?
Significant manpower needed for removal and reinstallation

CTF3 Decommissioning & re-use issues

G. McMonagle

- Simplest solution close the complex and lock the doors
- Continue running CTF3
  - Costs
    - New access control system needed
    - Upgrade of modulator controls (get rid of non supported CAMAC)
    - manpower
- Reuse the Linac and rings for electron injector to PS
  - Costs
    - New access control system needed
    - Upgrade of modulator controls (get rid of non supported CAMAC)
    - manpower
- CLEX
  - Keep CALIFES operational
    - New access control system needed SOLVED
- New DB injector test area
    - Use LINAC area but probably need civil engineering work in CTF2 area to allow modulators and klystrons to be installed (too large for gallery)
- CTF2
  - Continued PHIN tests, X band test area
    - New access system needed SOLVED

Additional considerations II

- Decommissioning ≠ zero resources !

G. McMonagle

- It may be wise to "mothball" CTF3, also to keep open the possibility to re-start CTF3 after 2016 if needed (new module generation?) and according to CERN priorities
- Hovever, this clashes with requests to re-use CTF3 buildings and equipment…

- The shut-down paradox:

  "Given an accelerator facility, the cost of running it is in general lower or equal than the cost of a shut-down".

CONCLUSIONS

- Many options for decommissioning/re-use/transformation of CTF3 area & equipment.
- Not all option consistent with each other
- Main limitation will come from resources
- Very good start in evaluating possible options
- Still need quite some work, especially on evaluation of resources
- Should come back with a well laid out plan (with a few options) by end 2014

RESERVE

Yearly cost of CTF3 running

2012 running, relevant budget codes in blue

CLIC -EV		Budget Code Description	Charged to Budget Code (kCHF)	Annual Open Commitment (kCHF)
ABP	61440	CLIC-EV Drive Beam Phase Feed-forward and feedbacks	56	10
	61441	CLIC-EV Two-Beam module string	23	0
	61442	CLIC-EV Accelerator Beam System Tests	0	0
	61725	CLIC-EV General	480	23
	Total of ABP:		559	33
ABT	65776	CLIC-EV Kickers and Septas	2	0
	Total of ABT:		2	0
BI	64778	CLIC-EV Instrumentation	180	14
	Total of BI:		180	14
EPC	68725	CLIC-EV Power Converters	39	2
	68727	CLIC-EV Drive Beam Front-End (Modulators)	2	0
	Total of EPC:		41	2
OP	67700	CLIC-EV Operation, Consolidation & Upgrades	105	76
	Total of OP:		105	76
RF	69727	CLIC-EV RF	1433	149
	69792	CLIC-EV TBL+	67	3
	69793	CLIC-EV CLIC0 Drive Beam	0	38
	Total of RF:		1500	190
STI	63736	CLIC-EV CLIC0 Photoinjector & Laser	247	16
	Total of STI:		247	16
VSC	86756	CLIC-EV Vacuum	51	17
	Total of VSC:		51	17
Total of CLIC-EV:			2686	350
		Include some consolidation and upgrade	2053	273

Yearly cost of CTF3 running

Codes	Equipment	Charged 2012 (kCHF)	Planned 2013 (kCHF)	Spent 2013 (kCHF)
67700+	Operation and Manpower (PhDs, PJAS)	200	380	340
65776	Kickers and Septas	2	4	13
64778	Instrumentation	180	230	170
68725	Power Converters	39	35	26
69727	Modulators	260	1323	
	Klystrons	550		890 (1200)
	Waveguides, networks, various manpower …	350		
	TWTs	100		
86756	Vacuum	51	44	58
63763	CLIC0 Photoinjector & Laser	80	50	50
TOTAL		**1812**	**2066**	

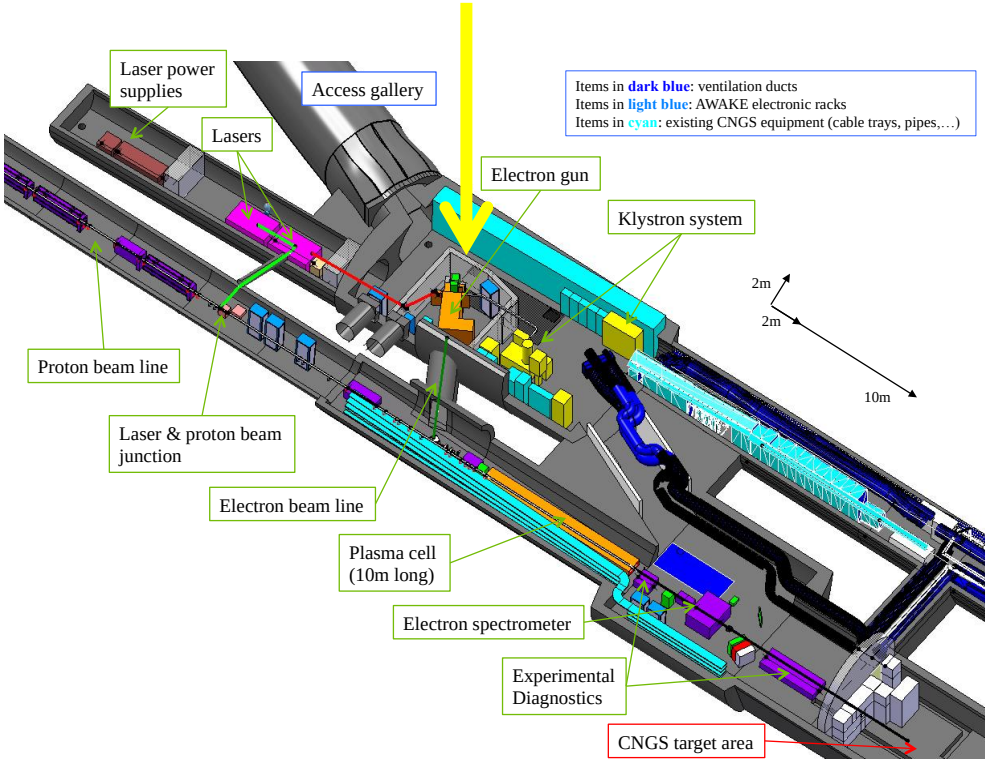
Taking out upgrades, divided by sub-systems

1550 (1860)

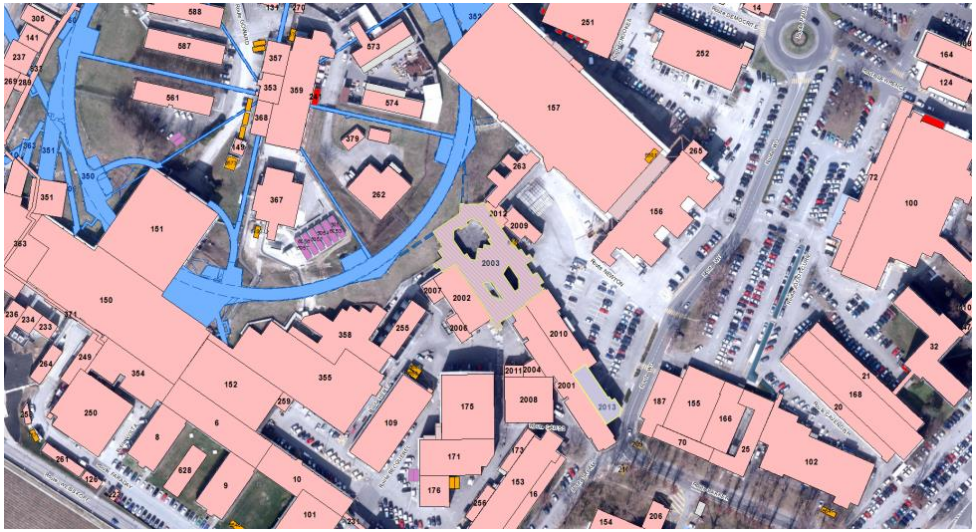
+ Manpower: about 15 FTE, including M to P

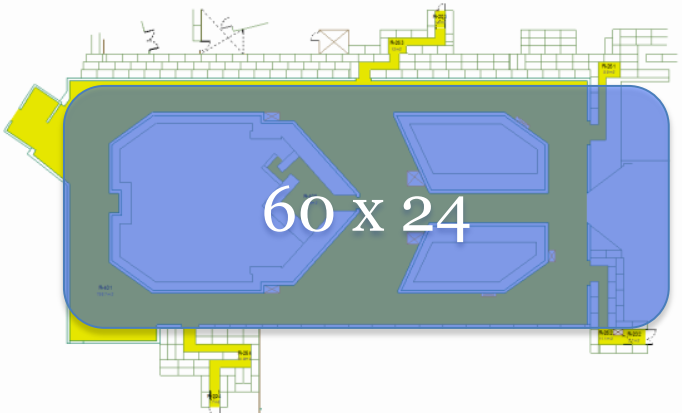
Contribution to AWAKE

- Awake needs 20 MeV electron source with low charge, small emittance and possibly short bunches
- One CTF3-type Klystron-Modulator would be needed to power the injector
- PHIN (Califes) type gun could be used
- Some diagnostics, vacuum equipment and magnets might be useful
- CTF-team experience would be likely helpful as well
- Test facility and pre-commissioning in CTF2 area?



Building re-use, an example: ERL Test Facility





Currently CTF3 to end operation in 2017
Size could be ok when annexing some parts of the current Linac buildings
Complicated topology. Could be easier to re-assemble

Could accommodate quench tests in CTF2 and CTF3 buildings

Already crowded area

N. Catalan-Lasheras
LHeC Workshop 2014