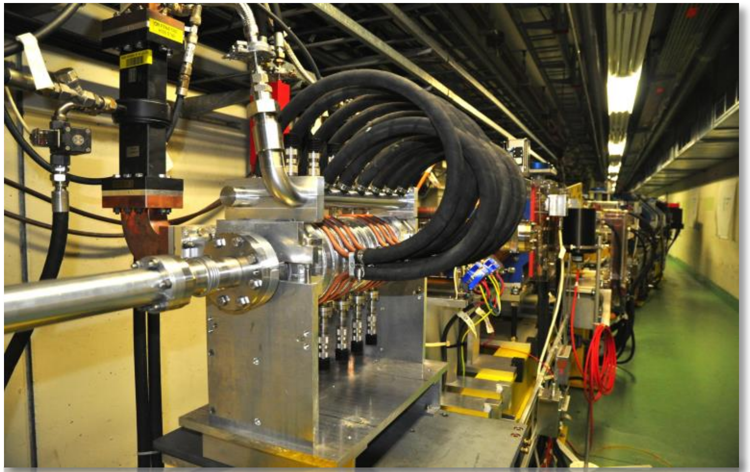
Beyond CTF3

Summary of Wednesday morning common session of DESIGN, SYSTEMTESTS & XBAND WGs on CERN based future facilities

R. Corsini



Motivation

- 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)

  ➔ need to develop a plan

- 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
  - No local (CERN) real testing capability with beam (diagnostics and components) beyond 2016
  - In present plan, no way to test new generation modules with beam

CLIC Test Facility (CTF3)

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…)

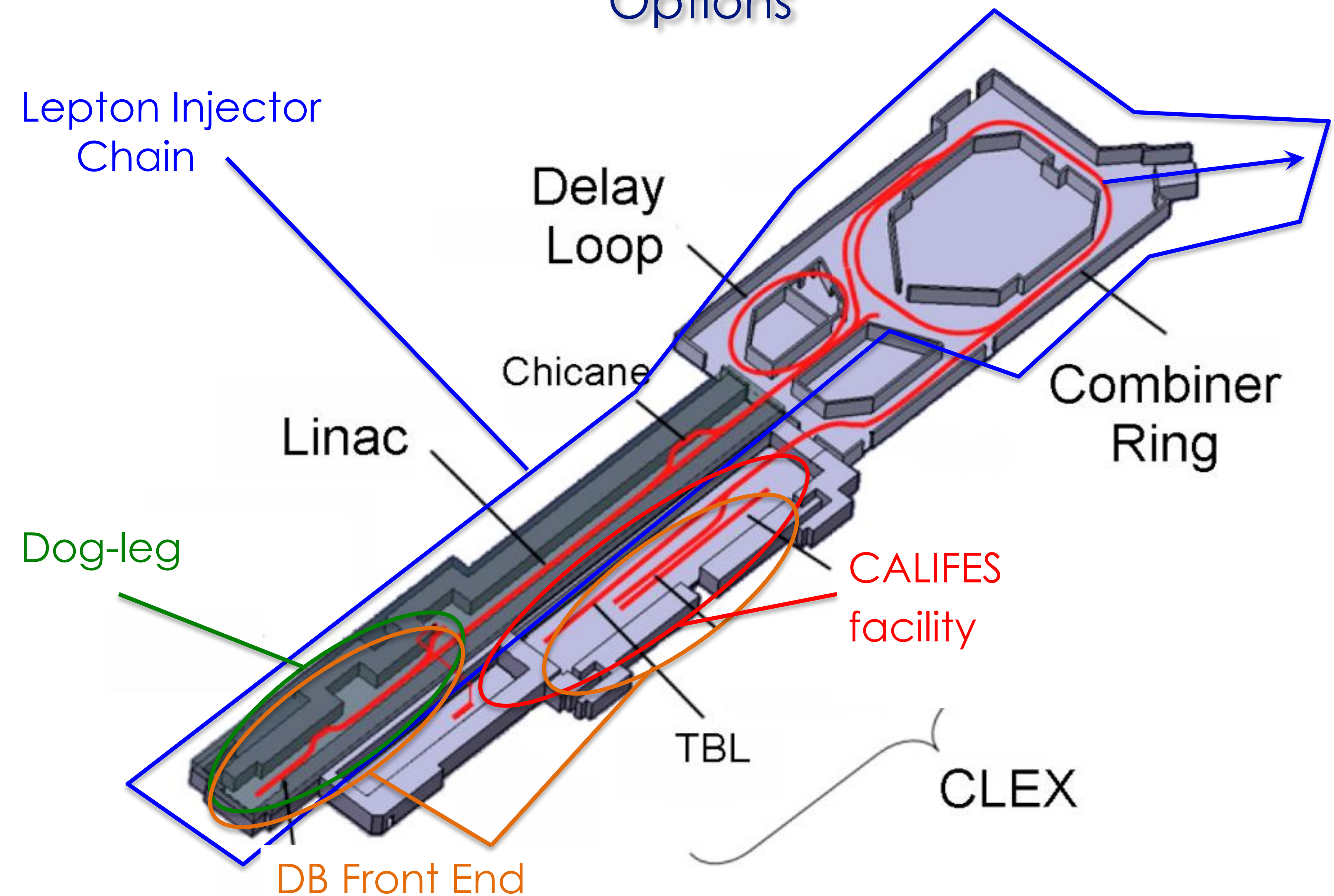
- Refurbish CTF3 as part of new lepton injection chain at CERN (potential interest for SPS damping ring tests, plasma wake-field experiments in AWAKE, future lepton accelerators…)
  F. Tecker

- 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

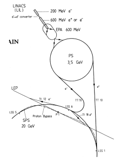
- House the DB Front-End in CTF3 (CLEX or Linac?). Possible option: plug Front-End before the CTF3 linac.
  S. Doebert

- 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

F. Tecker



CTF3 as lepton injector

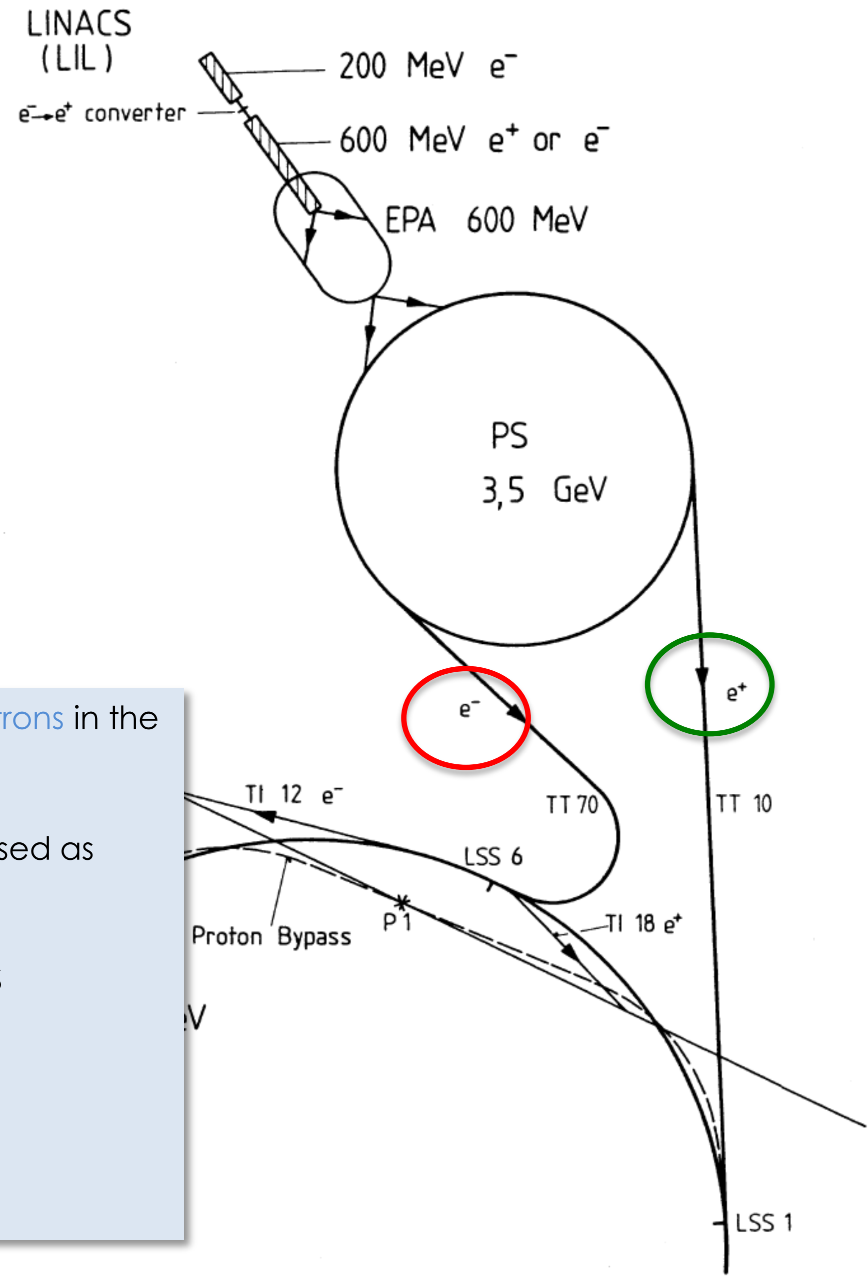
- Potentially there might be many motivations to revive the old lepton injector chain at CERN:
  - Tests in SPS as damping ring for CLIC & ILC
  - Beams for TLEP
  - Beams (drive) to AWAKE
  - …
- First exercise, restricted to SPS DR requirements, point out issues and identify cost drivers

- Given the constraints in SPS, a reasonable wiggler length is up to 10m (already 2m wiggler ➔ CLIC emittance at 2.6 GeV, with 'zero' current)

  - bunch current range up to 5e9 = 0.8nC interesting
  - bunch spacing in SPS: 5 ns for 200 MHz RF, h=4620
  - bunch length range: ~10-30mm
  - ENERGY range: 2.6 to 6.8 GeV

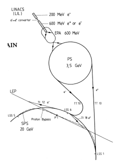
Lepton Injector complex

- Need to revive a “LEP-like” injector complex
- It should be transferred through PS to SPS
- Transfer line for positrons exists (TT10) but for electrons (TT70) completely dismantled
- Option: reverse polarities in PS, TT10, SP

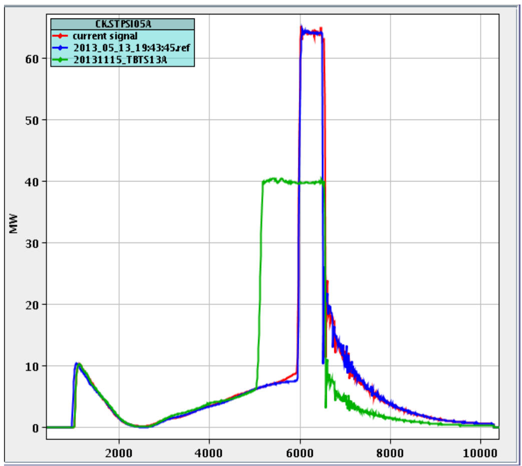


- Electrons or positrons– by default we will consider electrons in the following (but discuss both)

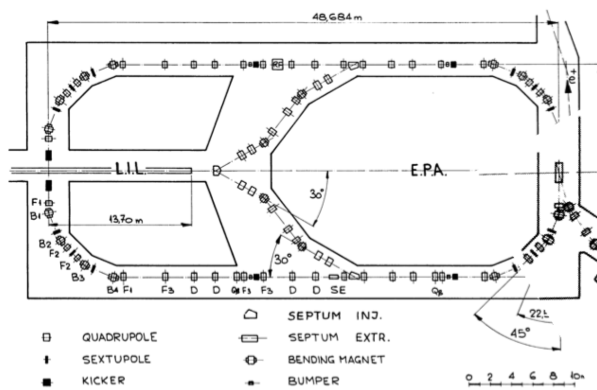
- Direct beam acceleration and transfer to the PS (CR used as transfer line):
  - Simple, no additional hardware
  - Single pulse to PS > SPS or need accumulation in PS
  - No emittance damping
  - Likely impossible for e+
- Beam accumulation/damping in CR
  - Needed for e+
  - Need cavity in CR, review injection/extraction…

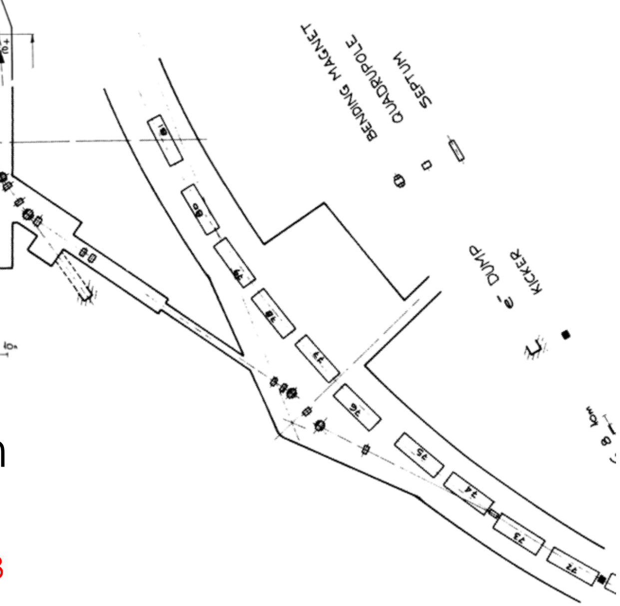


Beam energy and injection into PS

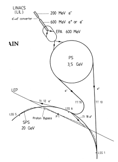


- CTF3 has ~125 MeV (full beam-loading)
- Short pulse + low charge + 1 additional MKS > gain of ~ 3 in energy
- final energy: ≥ 380 MeV
- CR & TL1 bends good up to 450 MeV





- replace CR wiggler by extraction septum
- rebuild ~40-50m long extraction line
- had energy spread acceptance: $0.6\ 10^{-3}$



From the linac to SPS

Linac bunch structure

Single bunch (train) – need laser

≥ 5 ns spacing

≥ 25 ns spacing

3 GHz short bunch pulse (possibly repeated a fev

PS RF acceptance

$$\left(\frac{\Delta E}{E_s}\right)_{\max} = \mp\beta\sqrt{-\frac{2e\hat{V}}{\pi h \eta E_s}}$$

- Maximum energy acceptance:
- E=400 MeV, η=-α=-0.027
- present 200 MHz system, h=420, 8*30kV
- => $\Delta E/E < 5.7\ 10^{-3}$

- 40/80 MHz systems have 2*/3*300kV, respectively
- => ΔE/E < 2% / 1.75%

- 40/80 MHz do not match with the CR rev. frequency
- maybe direct injection into PS

Limitations & Hardware needs

- Emittances looks OK even for direct transfer for e- (but not for e+)
- Bunch charge limitations to be checked without Robinson wigglers

Apart from beam acceleration, the RF system has the task of compensating for the synchrotron radiation loss at high energy (200 keV/turn at 3.5 GeV) and of providing an RF bucket that is large enough for adequate lifetime in the presence of quantum fluctuations. Furthermore, the bunches must have the appropriate longitudinal dimensions at peak energy so that they get trapped by the SPS RF system without instabilities. In order to fit the bunches into the SPS bucket with a sufficient margin,

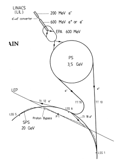
$$\sigma_s \leq (1/3\pi)\lambda_{RF}(SPS) = 0.16 \text{ m}$$

LEP Design Report

must hold[14]. Transverse stability[11] of the single bunch at nominal intensity requires, at 3.5 GeV,

$$\sigma_s(\sigma_\epsilon/E) \geq 1.4 \times 10^{-4} \text{ m}.$$

- Transfer lines PS > SPS OK for e+, not for e- (polarity switch?)
- Generation for e+
- RF cavity, extraction septum in CR (case of accumulation) ?
- Robinson wigglers ?
- Injection/extraction elements in PS, SPS
- …

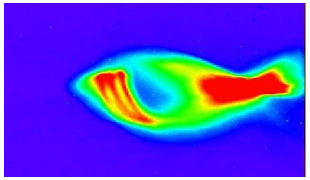


Outlook

- Assess different options (e+/e-, direct injection vs. accumulation…) and define one or two scenarios
- Define cost/resources needed for each scenario
- (Partly in parallel) have a look at requirements for different potential uses of a lepton injector chain at CERN

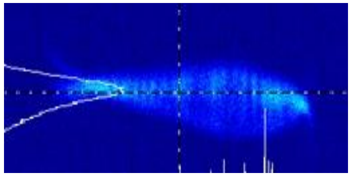
CALIFES

Parameters	Specified	Tested	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	1.4 ps ??	Still to be checked
Repetition rate	0.8 – 5 Hz	0.8 – 5 Hz	Upgrade possibility to 10 Hz



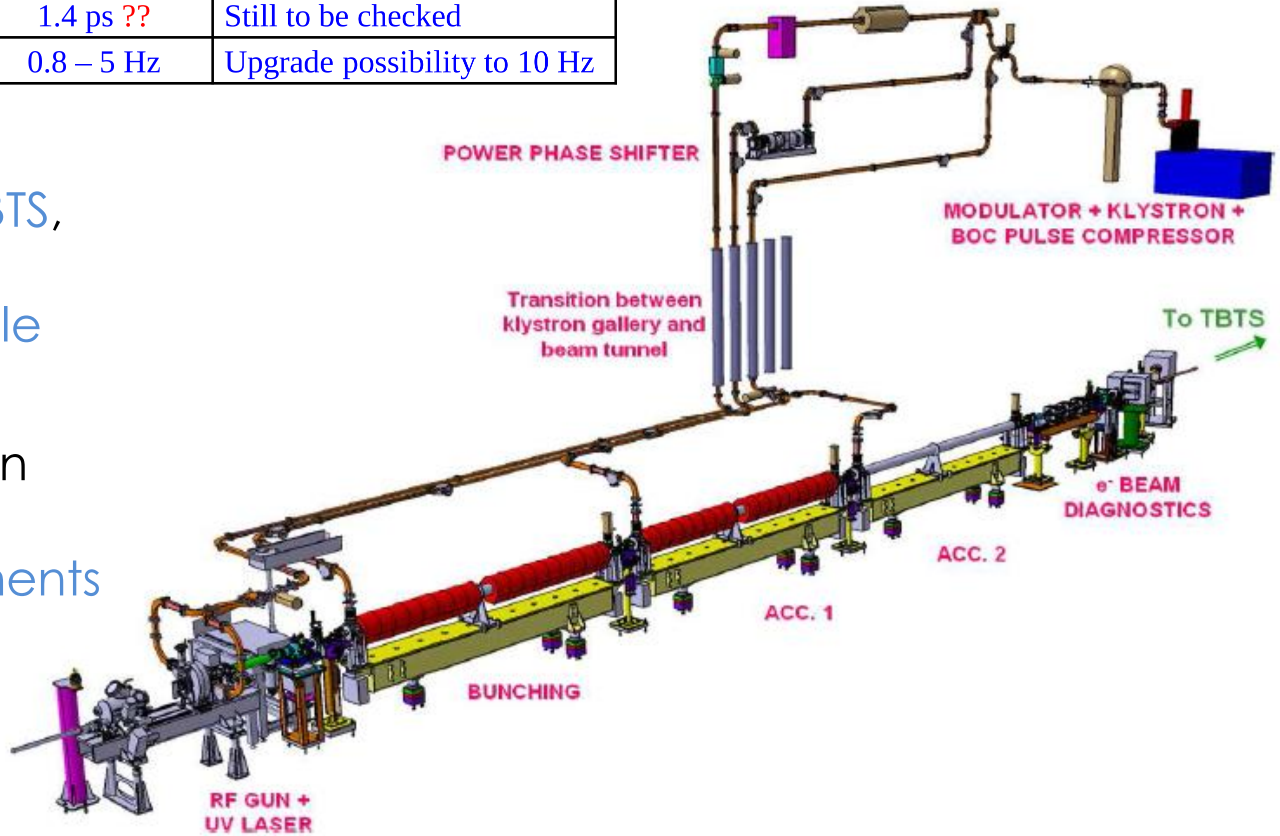
CALIFES

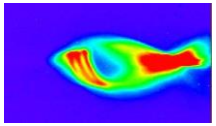
Swiss FEL from Simona



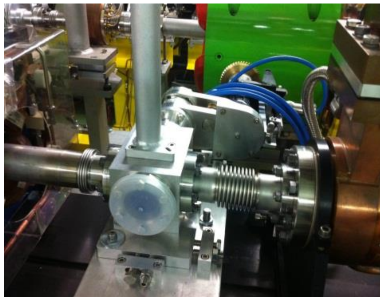
- Presently used on TBTS, from June:
  ➔ Two-Beam module

- Growing activities on beam diagnostic/components testing

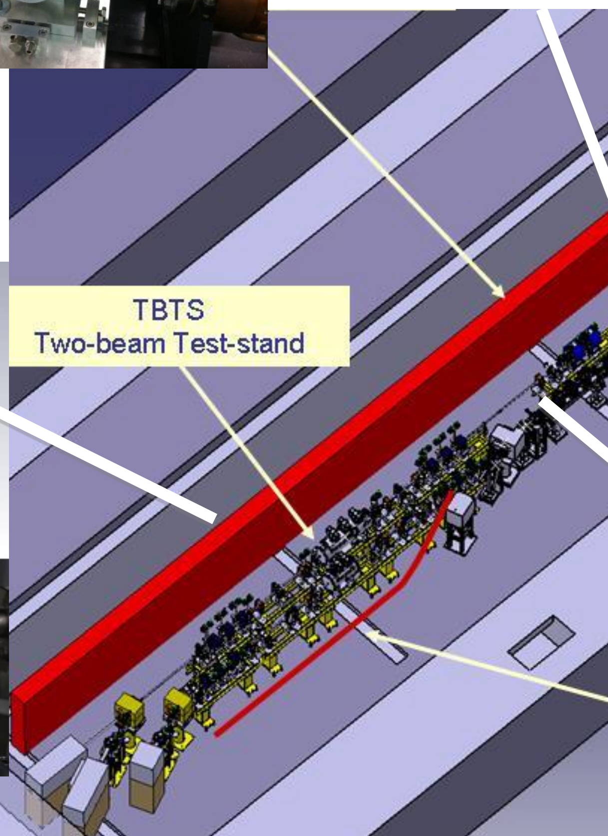




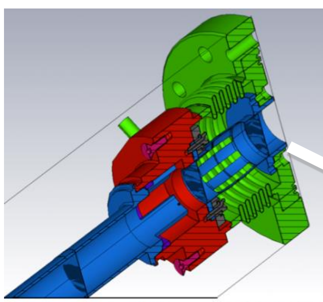
Present Beam Diagnostic Tests in CLEX



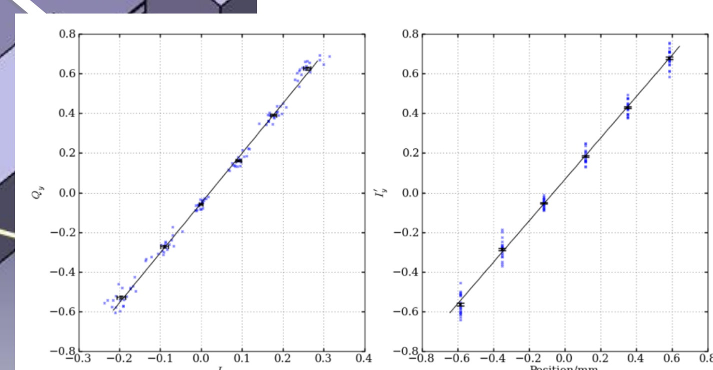
Electro-optic bunch profile monitor
in CALIFES
(CERN-Dundee University)

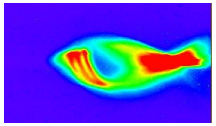


Stripline Drive Beam BPM in TBL
(CERN-LAPP)



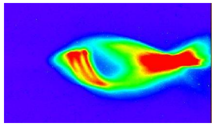
Cavity Main Beam BPM
in CALIFES/TBTS
(CERN-JAI at Royal Holloway)





Motivations, requirements and uses

- "TéPaFou' - A Beam Instrumentation Test Facility at CERN for CLIC but also for existing and future accelerators
  - with the present CERN accelerator schedule, every 3 years, we have 1-2 years long shutdown with no testing capabilities
- Electron linac is the cheapest way to provide relativistic beams
  - Beam energy : more than 150MeV
- Wish list for Beam parameters
  - Short and long bunches (100fs up to 200ps)
  - Large range of beam/bunch intensity
  - Possibility to study time to position correlation (Crabbing)
- Photo-injector is a best way to provide a medular bunch spacing
  - Single bunch capability
  - Possibly bunch spacing similar to CERN beams (1ns, 5ns, 25ns, 50ns, ..)
  - Pump – probe experiment (wakefield study, impedance measurement, ..)



Motivations, requirements and uses

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, …

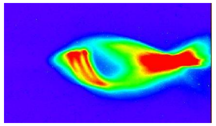
Under vacuum DUT area

- **Independent vacuum zone with easy access and pumping capabilities**
- **Including steering magnets to move the beam around**
- **Equipped with a Permanent instrumentation test stand**
    - Used for beam cross calibration: beam size, position and bunch length
    - But also using ...
        - BTV station for screen and imaging system development
        - Pick-up for providing fast EM signal for testing electronic acquisition system
        - Coherent diffraction slit as a source for GHz-THz
- **Possible use for developing**
    - Beam position monitor, Wall current monitor, fast beam transformer, Ionization gas monitor, Wire scanner…

In-air DUT area

- **Possibility to decrease the beam intensity to low or very low values**
- **Possible use for developing** Beam Loss monitors and Particle detectors

Study of MIP response, Time response study, Signal saturation studies, Space charge studies, Dose damage



Beam Diagnostic Tests – the future?

Machine layout to cover BI needs based on CALIFES

Short and long bunches (100fs up to 200ps)

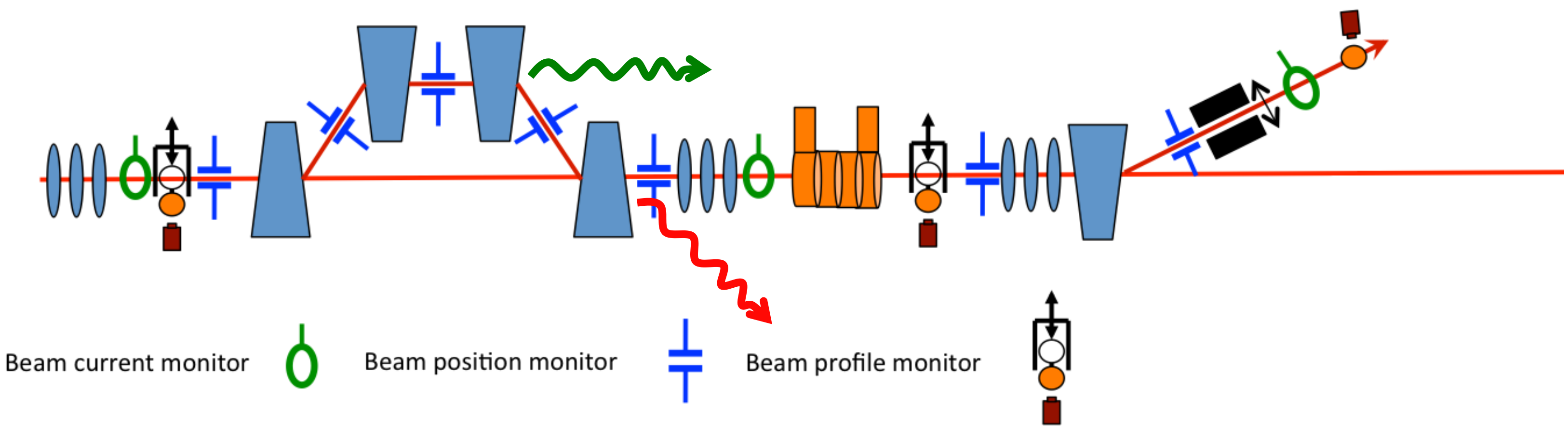
Time to position correlation

Large range of Bunch intensity

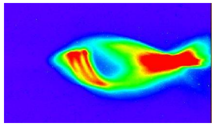
Magnetic chicane
Shorten or lenghthen

RF deflector
for crabbing

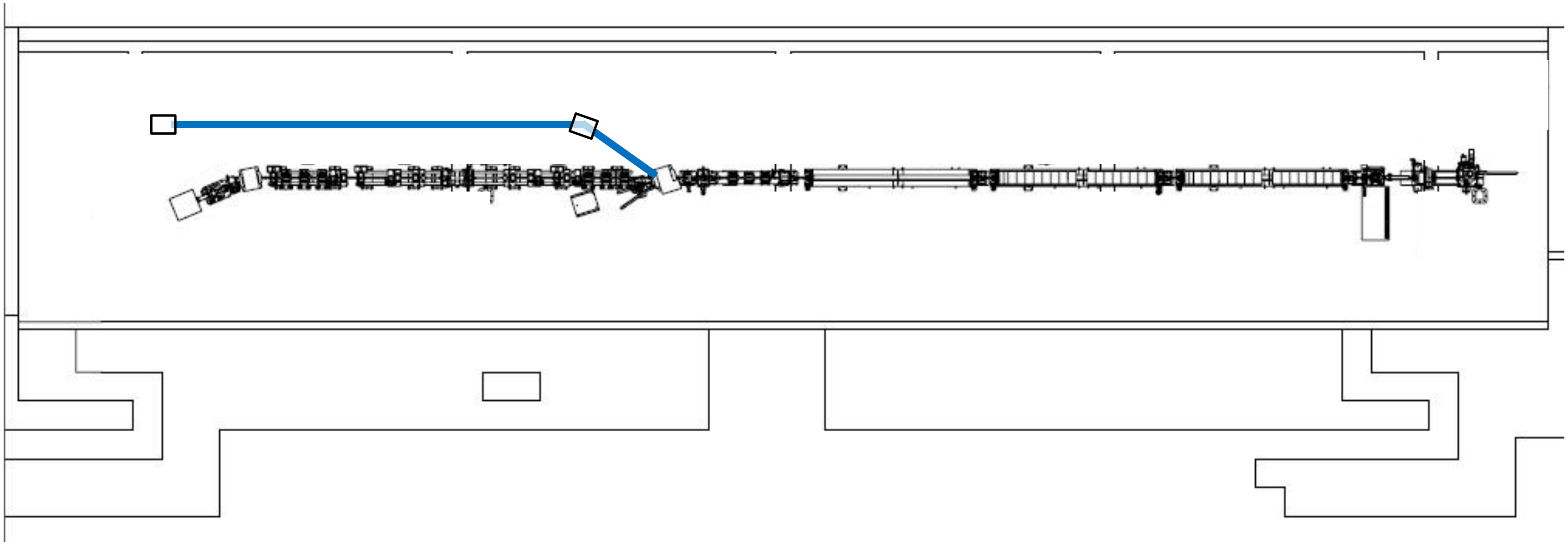
Collimator
Reducing the bunch intensity



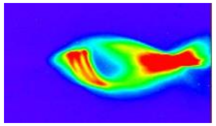
- Including SR test stand for infrared, visible and UV light: Several port available
- Including Testing area for beam instruments – Under Vacuum DUT
- Including Testing area for particle detectors – In air DUT – low intensity option



Previous studies – the Instrumentation Beam Line



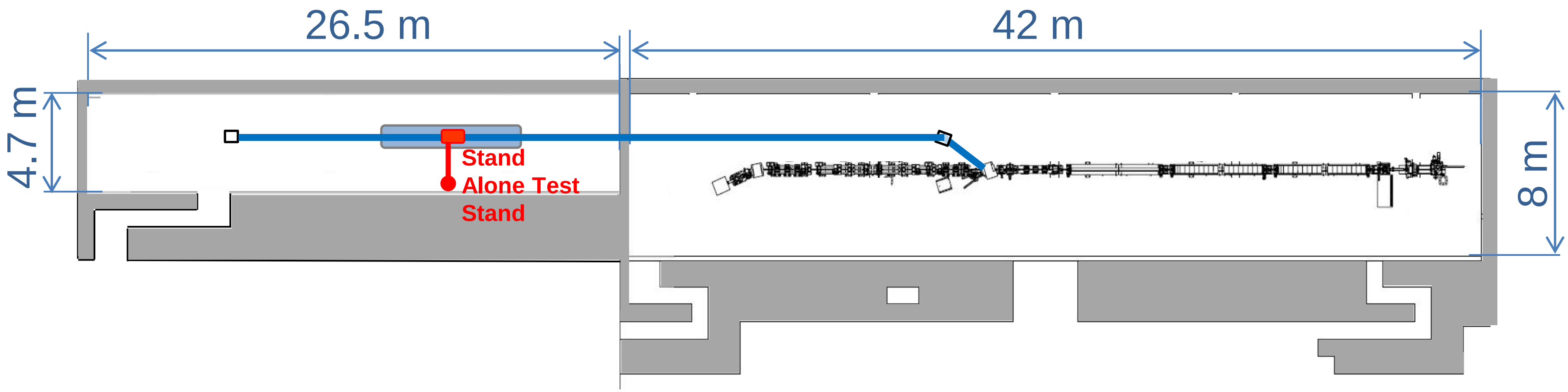
- A preliminary study has been done: *"Short Pulse Capabilities of the Instrumentation Beam Line – V. Ziemann – 6 May 2010"*
- Short pulses (200 fs – 35 μm) are necessary to mimic the CLIC main beam for instrumentation tests
- Pulses of 20 μm are achievable with a chicane R_{56} = 2 cm and energy encoding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

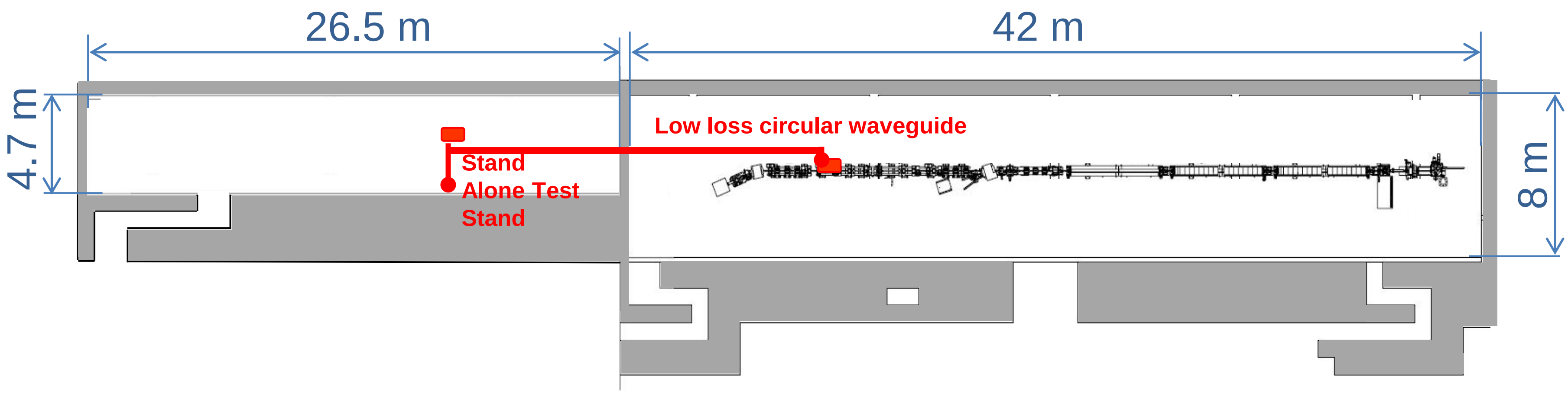


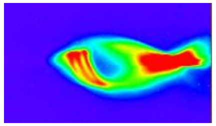
Possible evolutions

- Keep CALIFES for beam instrumentation test
  - Add an available S-band klystron
  - Switch for the PHIN gun
  - Add a chicane
- Produce special beam for Wakefield study
  - 2 bunches of different energies with adjustable delay
- Push the beam line toward the X-Box1 in CTF2
- Or transport the 12 GHz power to CLEX
  - Add an undulator, a Compton scattering experiment…
  - Add a 12 GHz crab cavity for bunch length diagnostic

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



Outlook

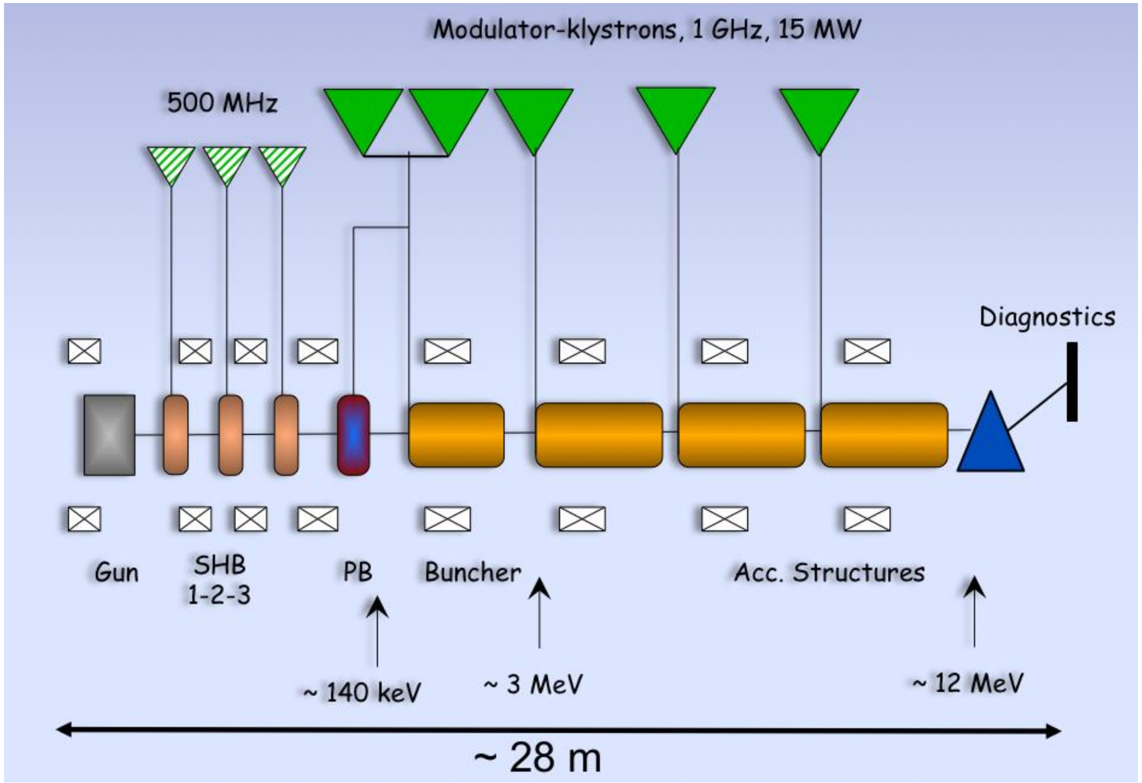
- CALIFES may be a reasonably cheap multi-purpose test facility
  - Useful within the CLIC study – potentially much wider interest
  - (My opinion: may have support - by the CERN management - only if enough interest is raised outside CLIC or/and outside CERN)

- Minimum to medium upgrades will enhance flexibility/usefulness

- Connection to XBox1 seems logical step
  - (My opinion: extend to larger X-Band infrastructure less obvious, unless external funding)

- Need cost/resource assessment, and evaluation of scientific case

DB Front-End

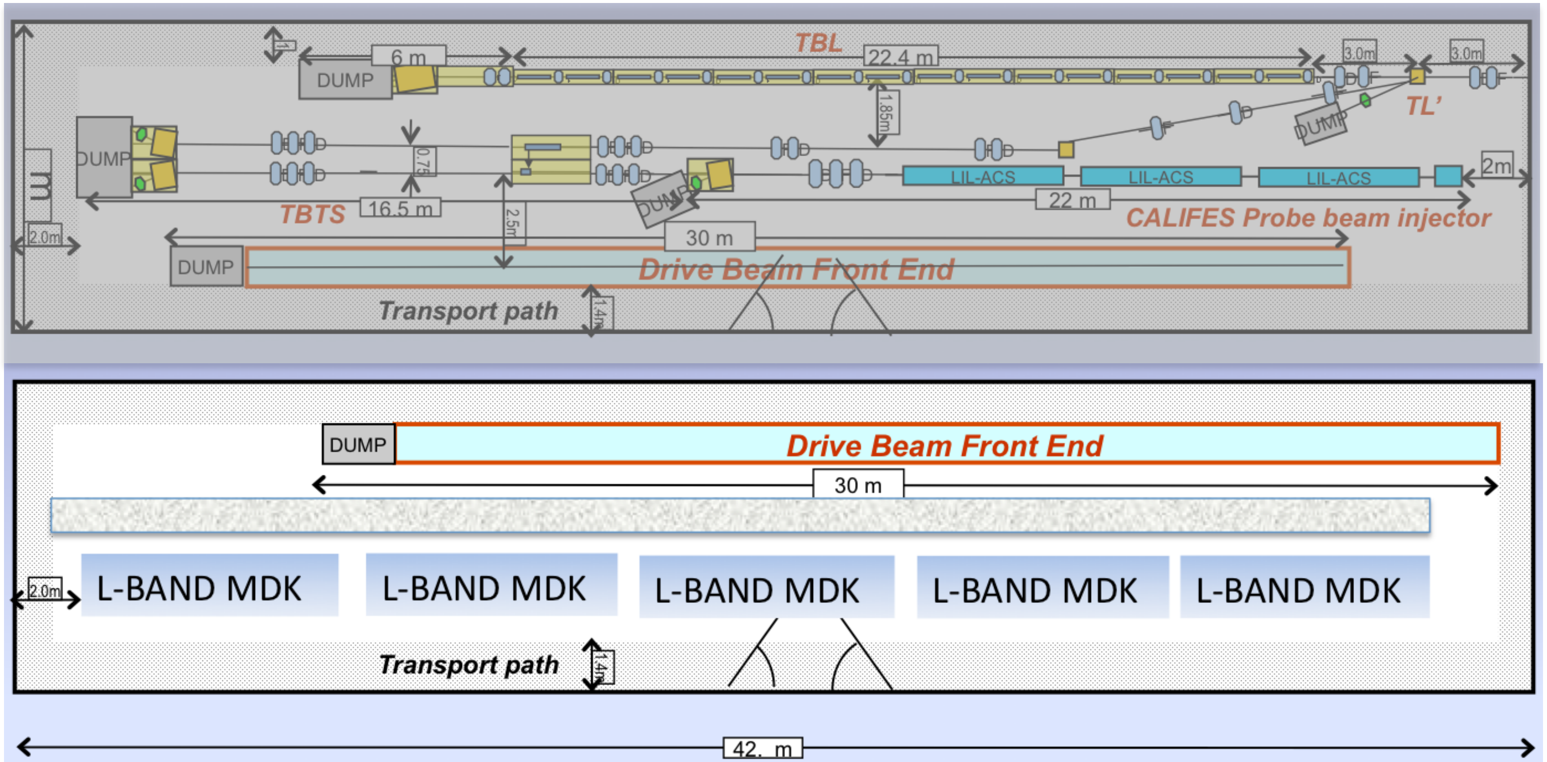


S. Doebert

- For time being only major component development:
  - GUN, SHB, high bandwidth 500 MHz source, 1 GHZ MBK, modulator and fully loaded accelerating structure

- From 2017 ➔ start putting together components for beam testing, need proper experimental hall.

Options: CLEX

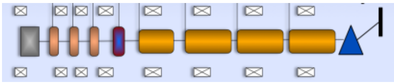


Drive Beam Front End: **~ 30 m**

Concerns:

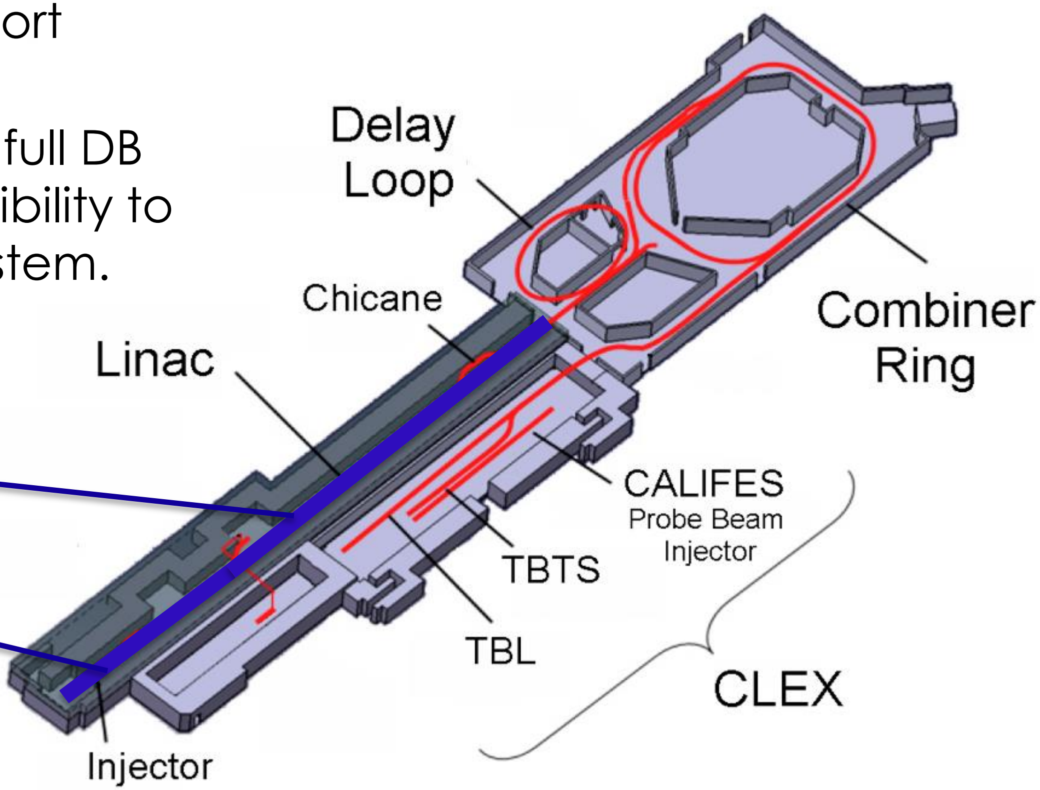
Shielding likely not sufficient for full beam power operation (350 KW)

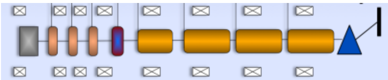
Extra Space for modulators and klystrons needed if not exclusively used for the front end



Options: CTF3 Linac

- Better shielding than CLEX
- Need to find place for modulator/klystrons
- Option: couple it with (part of) the present CTF3 linac. Will allow early beam testing at high energy (short pulse)
- Space for future expansion: the full DB injector (50 MeV) should fit. Possibility to further add satellite cleaning system.



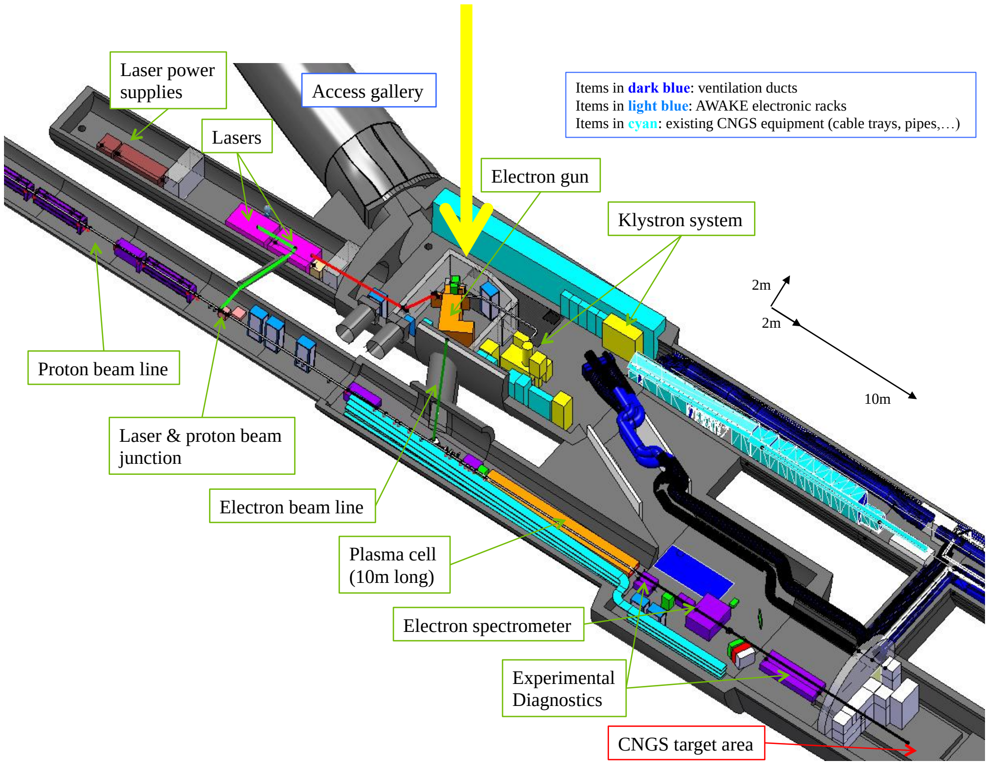


Outlook

- The CTF3 building is the natural place to host the DB front-end
- Linac tunnel option has better shielding and leaves more potential for future expansion
  - Need space for modulator-klystrons
  - Potential conflict with other proposals
  - Possibility to couple with existing CTF3 linac
- Need logistics/cost/resource assessment

Contribution to AWAKE

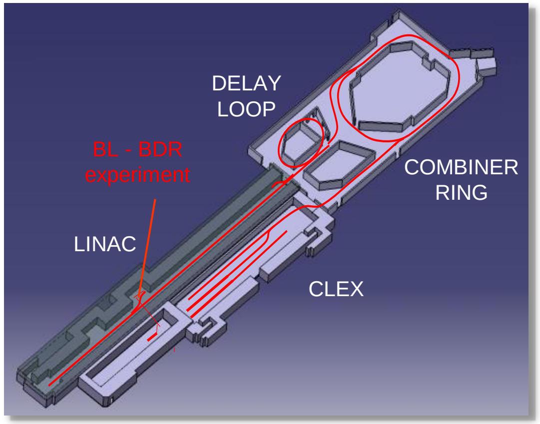
- Awake needs 20 MeV electron source with low charge, small emittance and possibly short bunches
- One CTF3-type Klystron-Modulator would be needed to power the injector
- PHIN (Califes) type gun could be used
- Some diagnostics, vacuum equipment and magnets might be useful
- CTF-team experience would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



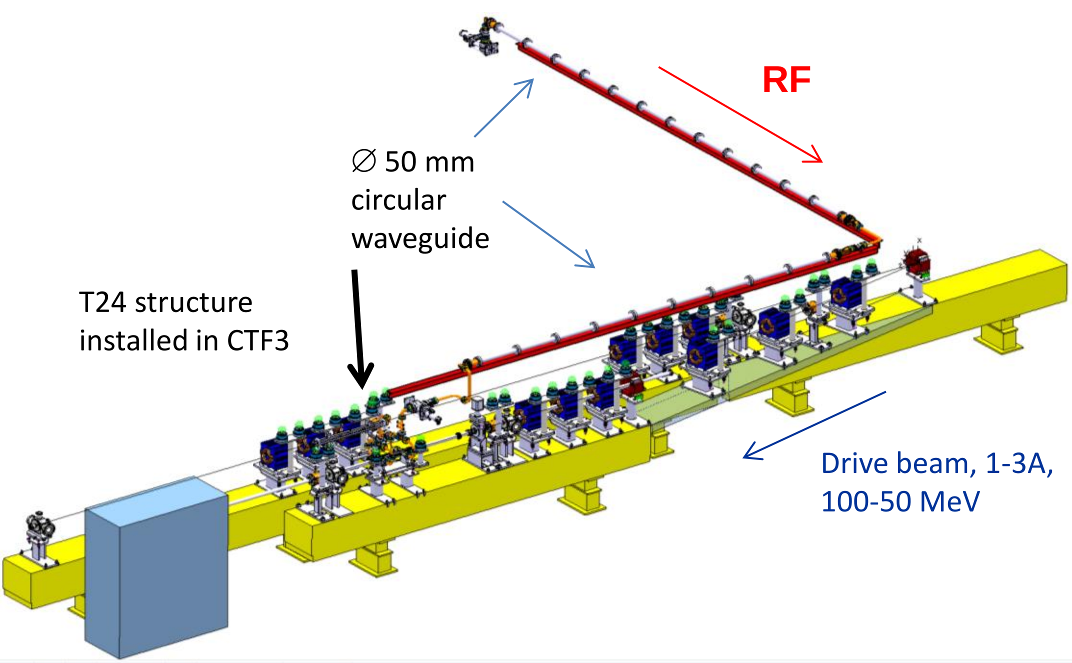
CTF3 Schedule

		Phase feed-forward & stability studies	Beam Loading / BDR experiment	Two-Beam Module	TBL Decelerator	Diagnostic Tests
2014	1	Commissioning	Beam tests (X-box n.a.)	TBTS program completion	Deceleration to 40% & RF shaping	Testing of EO bunch profile monitor, DB BPM, MB BPM
	2					
	3	Shut-down	RF Conditioning	Installation TBM	Installation of new tank	Installation
	4	Commissioning & tests	1st run	Commissioning	Deceleration to 50%	tests cont'd + OTR
2015	1	Shut-down + restart				
	2	Combined beams, femto-second timing	2nd run (shared with normal operation)	Complete commissioning & 1st run	RF conditioning & testing with drive beam	Available beam time
	3					
	4					
2016	1	Shut-down + restart		Module upgrade?	Shut-down + restart	
	2	Transverse feed-forward	3rd run (shared with normal operation)	2nd run	RF conditioning & testing with drive beam	Available beam time
	3					
	4					

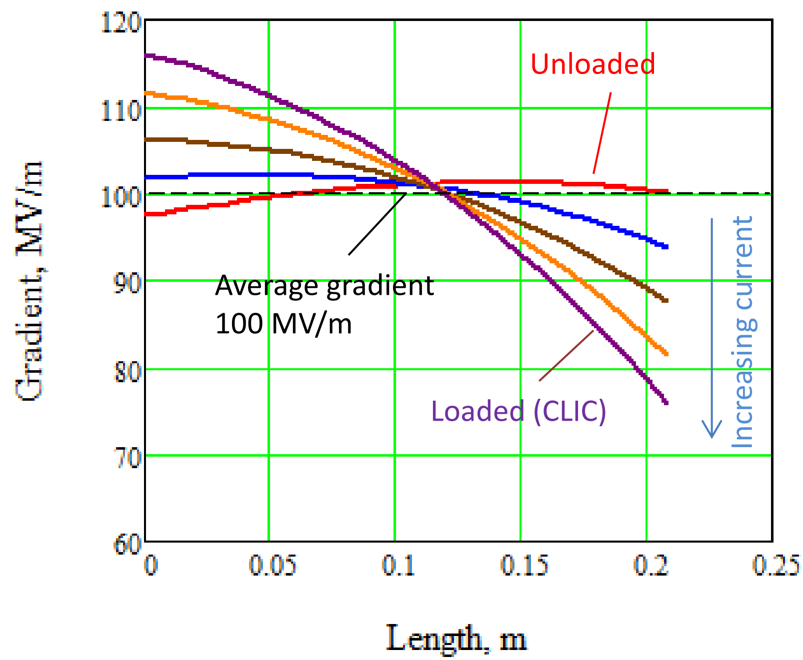
Beam Loading run beyond 2016



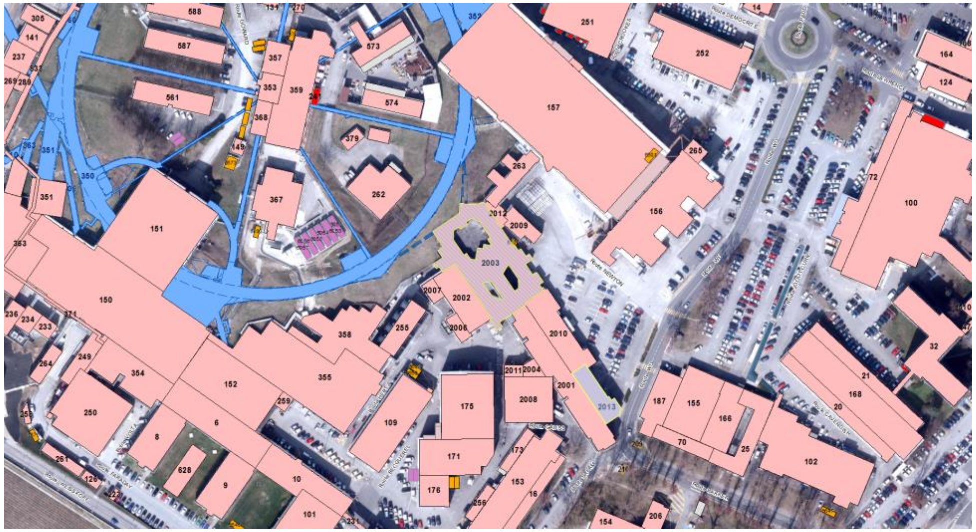
- From here to 2016 ~ 3 test slots (one per year) – <u>not a large statistics</u>
- In this time scale should have a new CLIC structure prototype from rebaselining
- May want to test it, especially if the gradient profile turns out to be different from the present one
- Need relative small infrastructure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

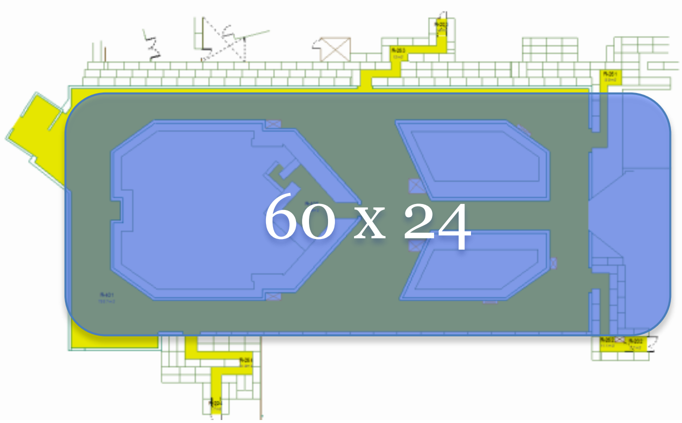


Gradient along the structure



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

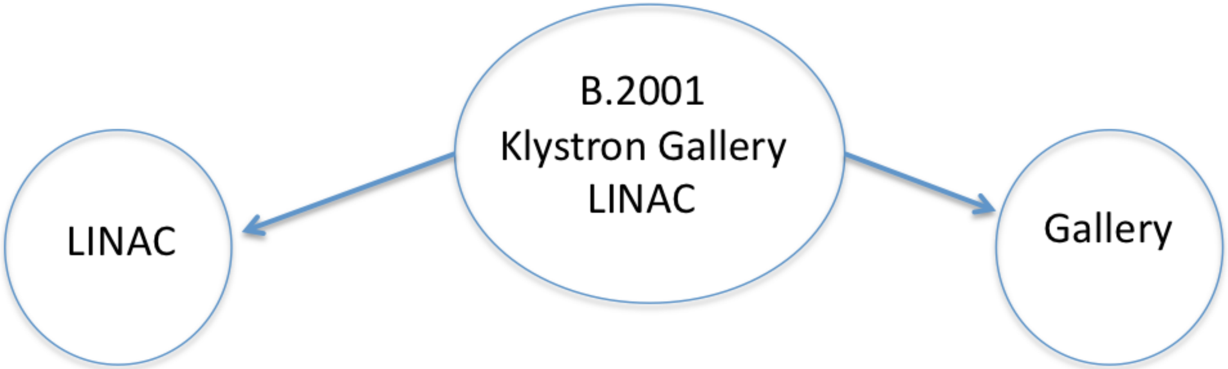
Already crowded area

N. Catalan-Lasheras
LHeC Workshop 2014

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
- 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

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	890 (1200)
	Klystrons	550		
	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