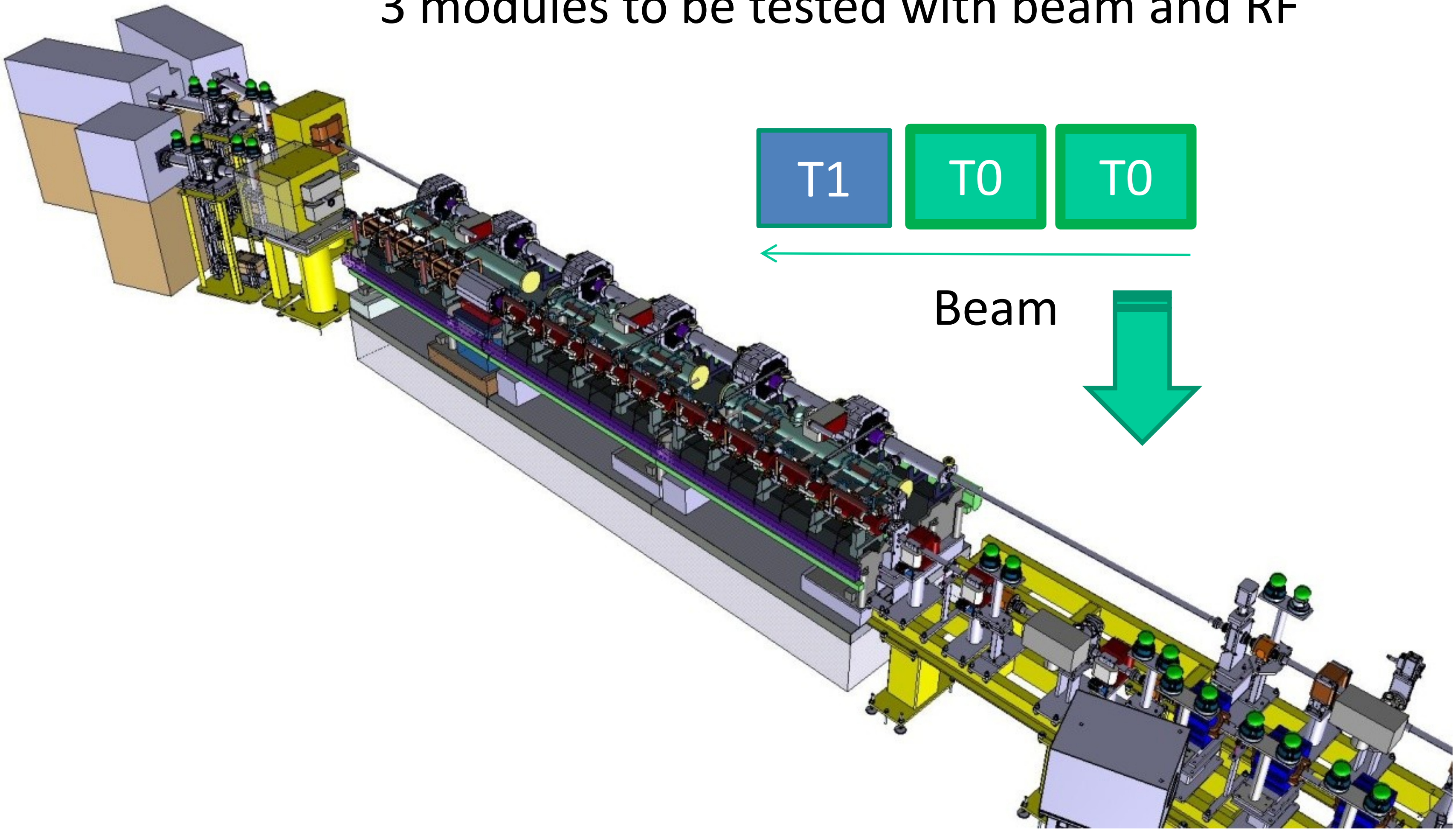
Scenarios for module string tests in CTF3

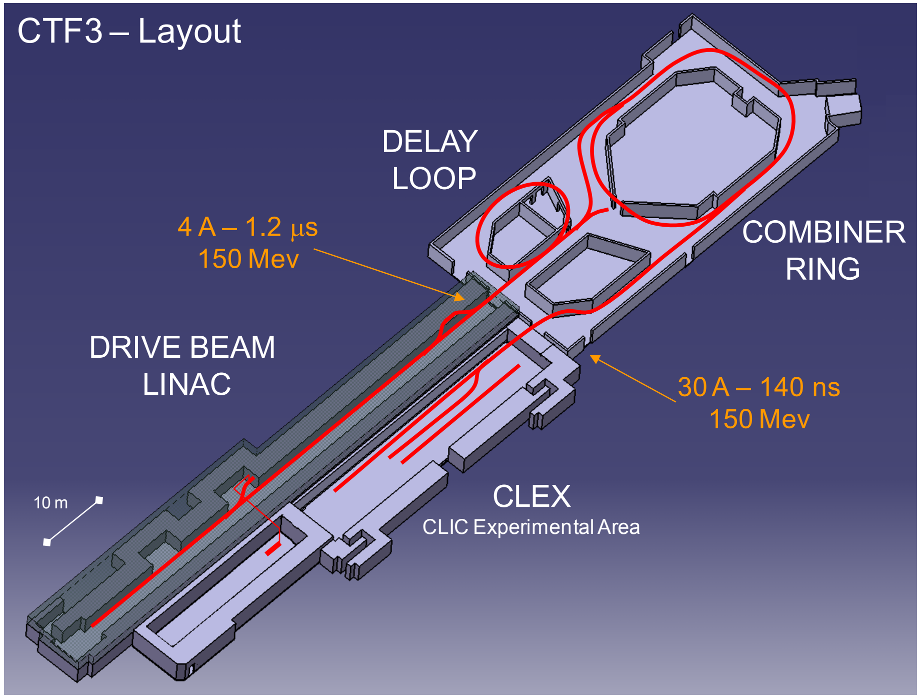
Next phase - Preliminary schedule

<table>
<tr><th></th><th colspan="4">2010</th><th colspan="4">2011</th><th colspan="4">2012</th><th colspan="4">2013</th><th colspan="4">2014</th><th colspan="4">2015</th><th colspan="4">2016</th></tr>
<tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>1</th><th>2</th><th>3</th><th>4</th><th>1</th><th>2</th><th>3</th><th>4</th><th>1</th><th>2</th><th>3</th><th>4</th><th>1</th><th>2</th><th>3</th><th>4</th><th>1</th><th>2</th><th>3</th><th>4</th><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td>CTF3 TBTS operation</td><td>inst.</td><td colspan="7">1-2 structures, beam loading, breakdown kick</td><td colspan="20"></td></tr>
<tr><td>CTF3 TBL operation</td><td colspan="4">Single PETS</td><td colspan="2">4 PETS</td><td colspan="2">8 PETS</td><td colspan="4">12 to 16 PETS</td><td colspan="16"></td></tr>
<tr><td>Modules lab</td><td colspan="4">initial tests, installation 2 modules</td><td colspan="4">further tests, installation 4 modules</td><td colspan="8">testing</td><td colspan="12">pre-series production, industrialization</td></tr>
<tr><td>Modules CTF3</td><td colspan="7"></td><td colspan="2">1 module inst.</td><td colspan="2">testing 1 module</td><td colspan="2">3 modules inst.</td><td colspan="7">testing 3 modules</td><td colspan="8">> upgrades?</td></tr>
<tr><td>CTF3 phase feedback</td><td colspan="7">design, hardware tests</td><td colspan="2">installation</td><td colspan="7">testing</td><td colspan="12"></td></tr>
<tr><td>CTF3 TBL+</td><td colspan="7"></td><td colspan="2">installation</td><td colspan="2">commissio-ning</td><td colspan="17">RF testing, potential upgrades</td></tr>
<tr><td>CLIC DB injector</td><td colspan="6">design</td><td colspan="5">Start component construction</td><td colspan="2">Start installation</td><td colspan="3">Start commissioning</td><td colspan="12">staged upgrade & testing</td></tr>
<tr><td>RF structures construction</td><td colspan="4">precision metrology, fabr. procedures</td><td colspan="12">up to 40 structures built, establish precision machining at CERN or elsewhere, 5 µm tolerances achieved</td><td colspan="12">more than 100 structures built, final cost optimization, pre-series with industry</td></tr>
<tr><td>RF test infrastructure</td><td colspan="2">CERN test stand inst.</td><td colspan="6">CERN test stand testing and upgrades (at least two slots)</td><td colspan="8">continue testing with increased capabilities, CERN or elsewhere, 5-10 slots</td><td colspan="12">testing, up to 120 accelerating structures plus PETS and RF components</td></tr>
<tr><td>Prototypes of critical components</td><td colspan="8">technical choices, design</td><td colspan="8">construction, hardware tests</td><td colspan="12">finalization, performance & cost optimization, industrialization for large scale components</td></tr>
<tr><td>Other systems, Civil Engineering…</td><td colspan="4">detailed program definition</td><td colspan="12">first phase (new baseline?)</td><td colspan="12">second phase (finalization, project implementation plan)</td></tr>
<tr><td>Beam physics studies</td><td colspan="6">CDR activities, feasibility studies</td><td colspan="10">Performance and cost optimization, new baseline?</td><td colspan="12">Finalization, preparation for commissioning, operational scenarios…</td></tr>
</table>

2nd phase (2013-2014)
3 modules to be tested with beam and RF



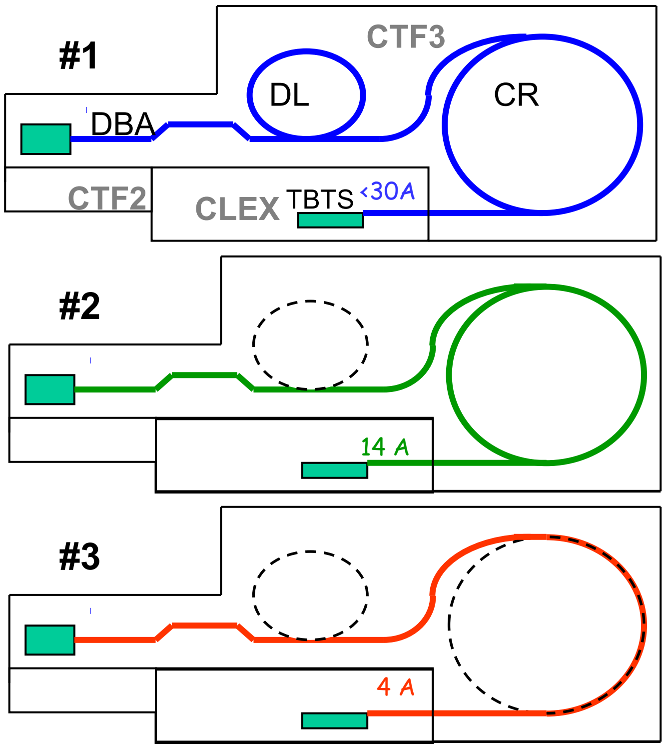
CTF3



Intrinsic limitations:

- Combined beam current, limited to ~ 30 A (could possibly be increased for shorter pulses)
- Pulse length limited to 140 ns (instead of 240 ns) @ 30 A – alternative: 15 A, < 280 ns
- Total drive beam peak power (at present ~ 3.5 GW – CLIC0 has 48 GW, CLIC 240 GW)

Different scenarios of RF power production in CTF3



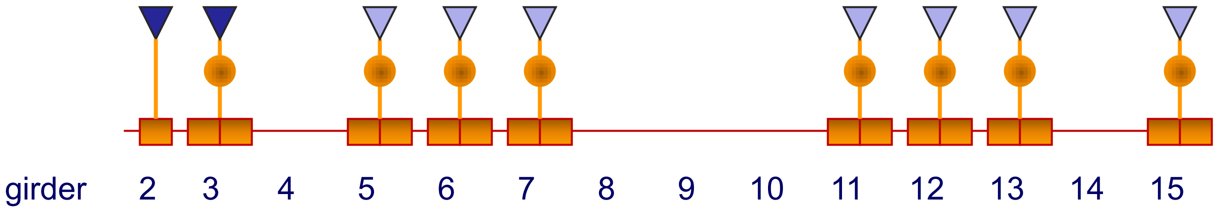
140 ns

< 280 ns

~ 1200 ns

CTF3 beam power upgrade

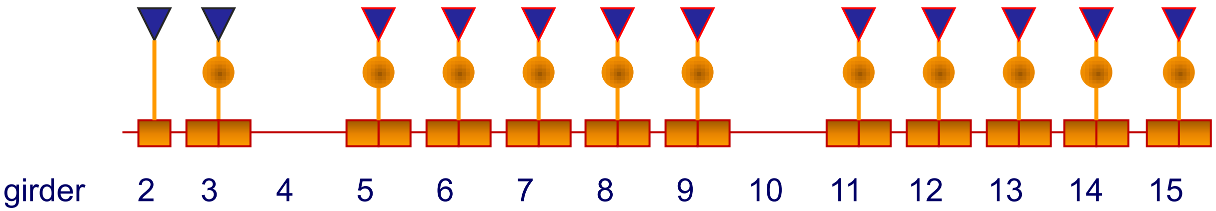
Present



About 120 MeV
for final beam current of
about 28 A

Total beam power 3.3 GW
e.g., enough to feed
24 accel. structures
(final drive beam energy 50 MeV)

Ultimate ?



About 200 MeV
for final beam current of
about 28 A

Total beam power 5.7 GW
e.g., enough to feed
50 accel. structures
(final beam energy 50 MeV)

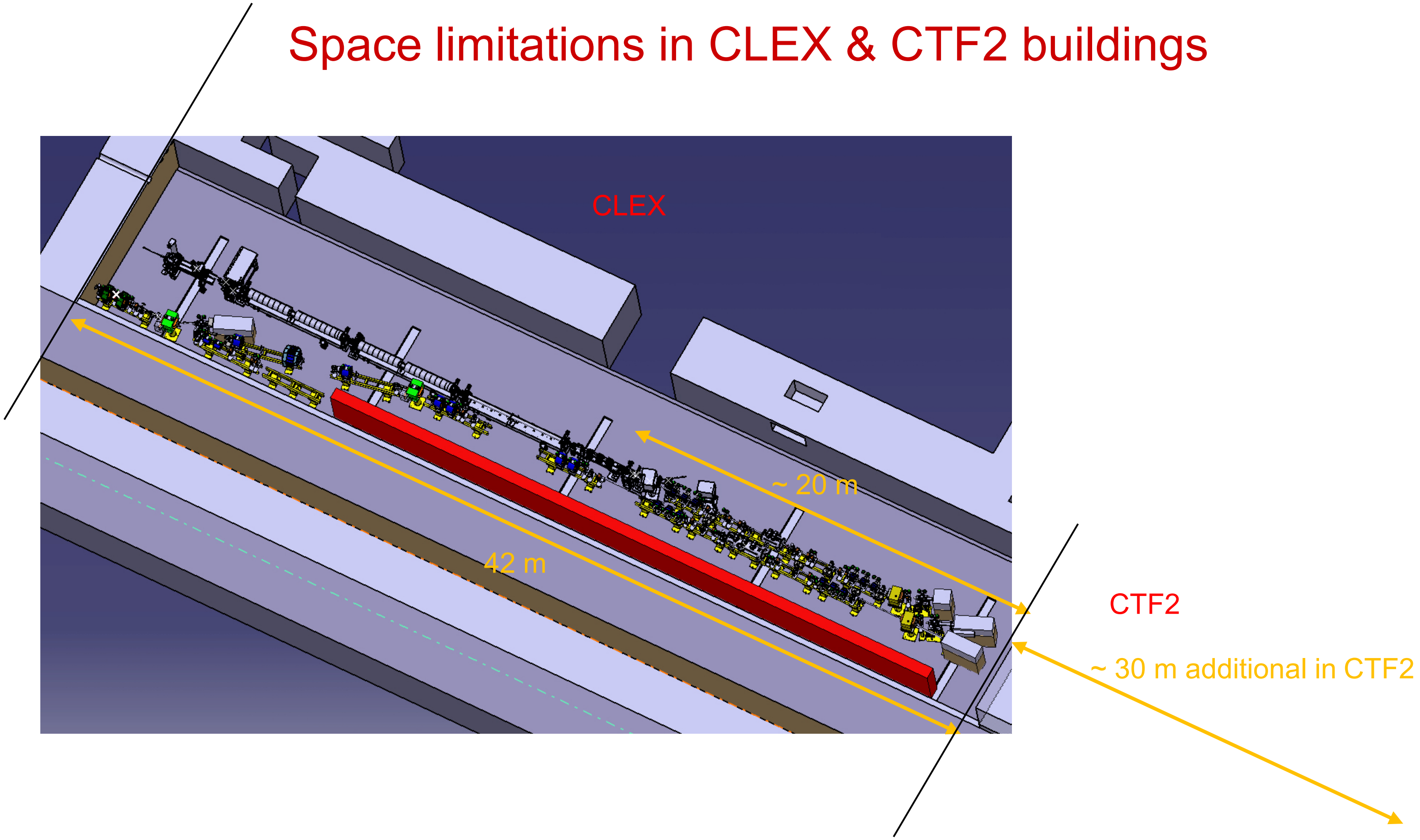
Assumptions for CTF3 beam power upgrade

- Need 3 additional power stations
- All modulators/klystrons upgraded to 45 MW nominal power
- RF pulse compression factor ~ 2 (about 38 MW/SICA input, including operational limits and losses)
- 1.4 μs long RF pulse (needed for combination factor 8)
- Keep girder 10 for diagnostics (emittance, momentum, energy spread)

What more could (?) still be done

- Add other power stations & structures (girder 10, CT line ?)
- Further upgrade klystrons
- Combine klystrons by two, double their number (space problem, maybe exceed structure limits…)

Space limitations in CLEX & CTF2 buildings

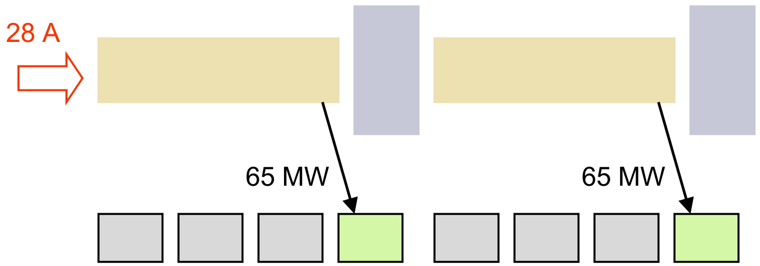


- If CALIFES is kept as it is now, about 50 m available, including CTF2
- About 25 modules maximum (more likely ~ 20)
- Maximum total accelerating structures: 200 (remember, we can fully feed only 50 at most!)

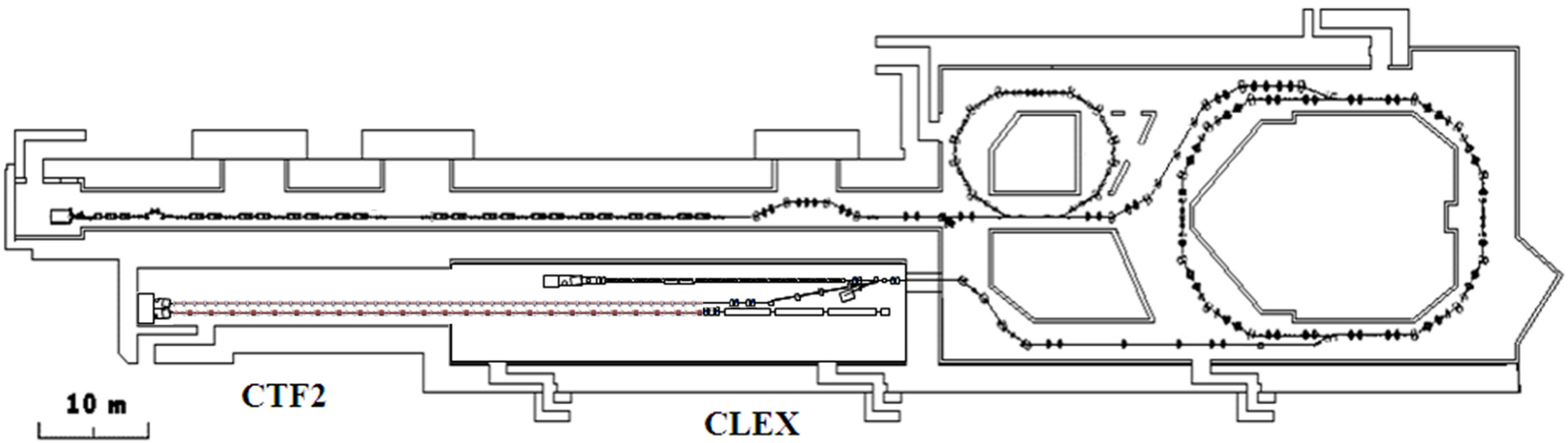
The different scenarios of the CLIC module operation in the CLEX (by Igor).

Boundaries:
The limited DB current will not allow to operate the CLIC PETS as it is. The PETS length must be changed (increased) to compensate lack of current partially. Following the current module layout, the maximal possible length of the PETS could be extended up to ~ 0.5 m (85 cells, c.f. 34 cells in the CLIC PETS).

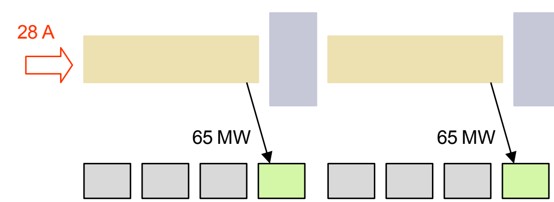
Consequences:
In this configuration, the PETS will barely (28A) produce the required 65 MW RF power and will be able to feed only one accelerating structure out of four. Another important outcome is that PETS itself will generate only half of the declared RF power.



One hypothesis of CTF3 upgrade as a demonstrator

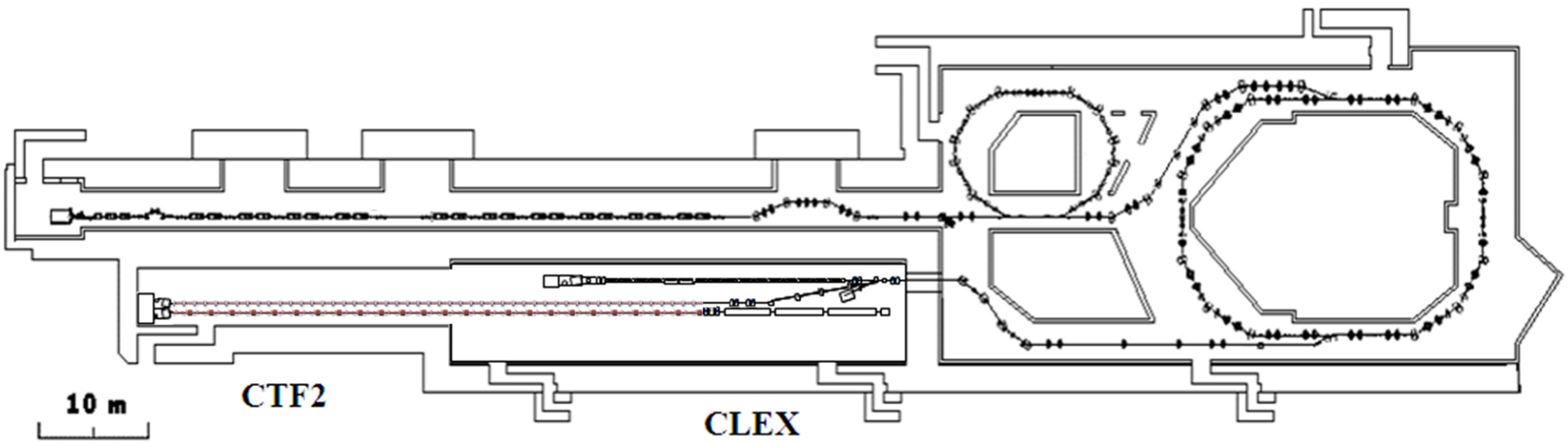


- < 25 modules, about 50 m
- 1 PETS (~ 0.5 m) feeding 1 accelerating structure, nominal power (65 MW)
- 50 structures (2 per module out of 8) can be fed
- Space for one or more quads per main beam module (FODO?)
- Total energy gain in main beam 1.2 GeV
- Final main beam energy about 1.4 GeV

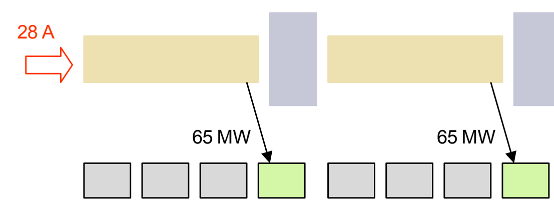


Main beam: periodic solution with module type 1 (quad + 6 acc), ~3 σ acceptance!
Add quads ~ 5 σ

Drawbacks

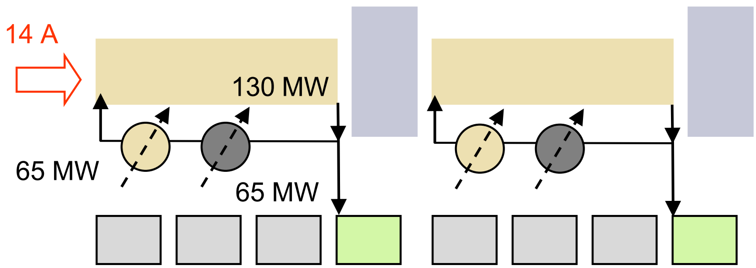


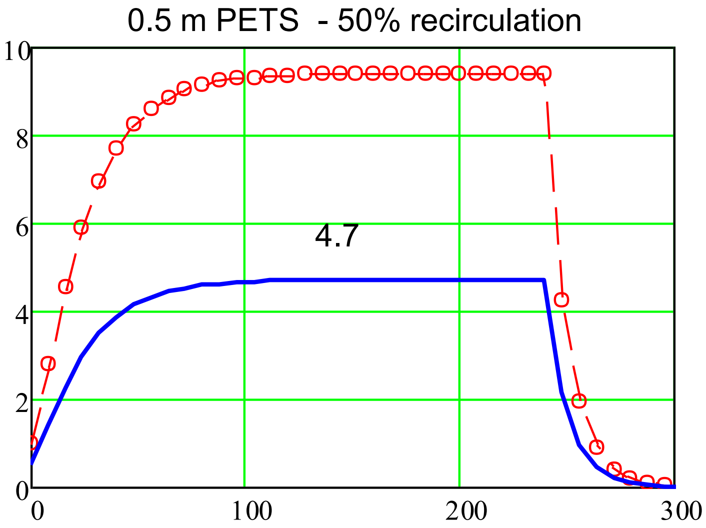
- PETS has twice the nominal length
- PETS have half of the nominal power
- Only one out of four structures fed in the TBA
- RF pulse has 140 ns pulse length instead of 240 ns
- Doubts on drive beam transport, can we decelerate from 200 MeV to 50 MeV ?
- Probe beam does not have nominal CLIC charge/time structure (or need upgrade of CALIFES)



Lower current, long pulse version

Use recirculation (~ 50%) to be able to use 14 A beam (mode #2)





- Gain a factor of 4.7 in delivered power, about 9 in power inside PETS
- 0.5 m long PETS can be run at full power, full pulse length
- 0.5 m long PETS will deliver full power to 1 structure

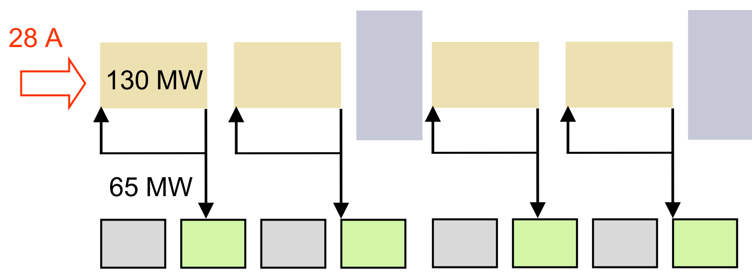
However: the 14 A beam will have only half of the peak power needed for 50 structures – can feed at most 25

➡ feed half of the modules, or only 1 structure every module

N.B.: can be used as in the previous case

Another option, 28 A + recirculation

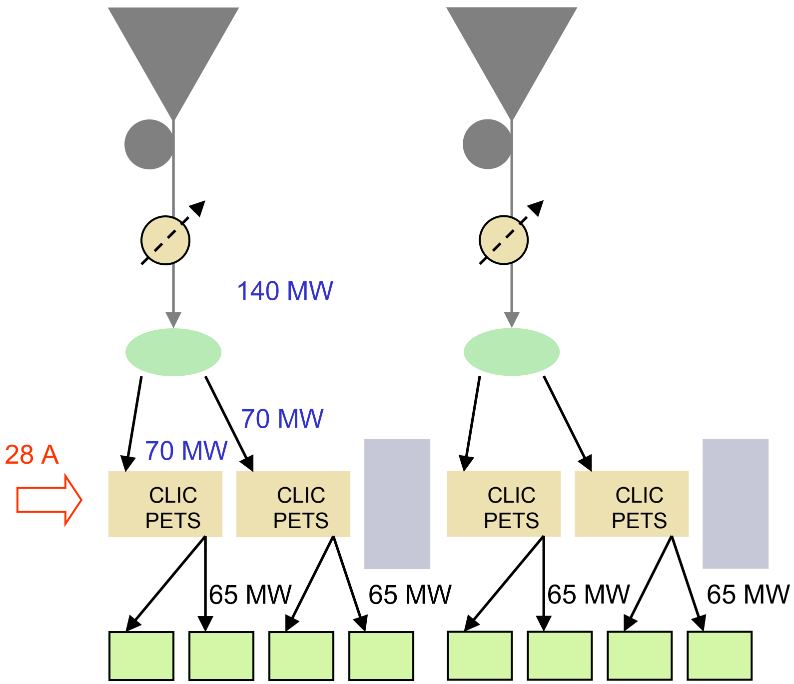
Use recirculation (~ 50%) to feed every second structure (mode #1)



- Could feed a total of ~12 modules this way
- Full power in PETS
- Pulse length only 140 ns

How to feed complete modules

Feed complete modules by using priming



- Use nominal PETS length, nominal PETS power (but not field profile)
- Need 2 klystrons + RF compressors / module
- Part of the power (a bit more than half) provided by klystrons
- Therefore can potentially feed all 25 modules this way, and bring main beam to 2.6 GeV (but would need 50 X-band klystrons!)

What can we learn with modules in CTF3?

- One
- A few
- Many

Module engineering, and assembly

Beam-based alignment

Transport, installation and maintenance

RF waveguide network

Vacuum system performance

Full system RF breakdown

Cooling system performance

What can we learn with modules in CTF3?

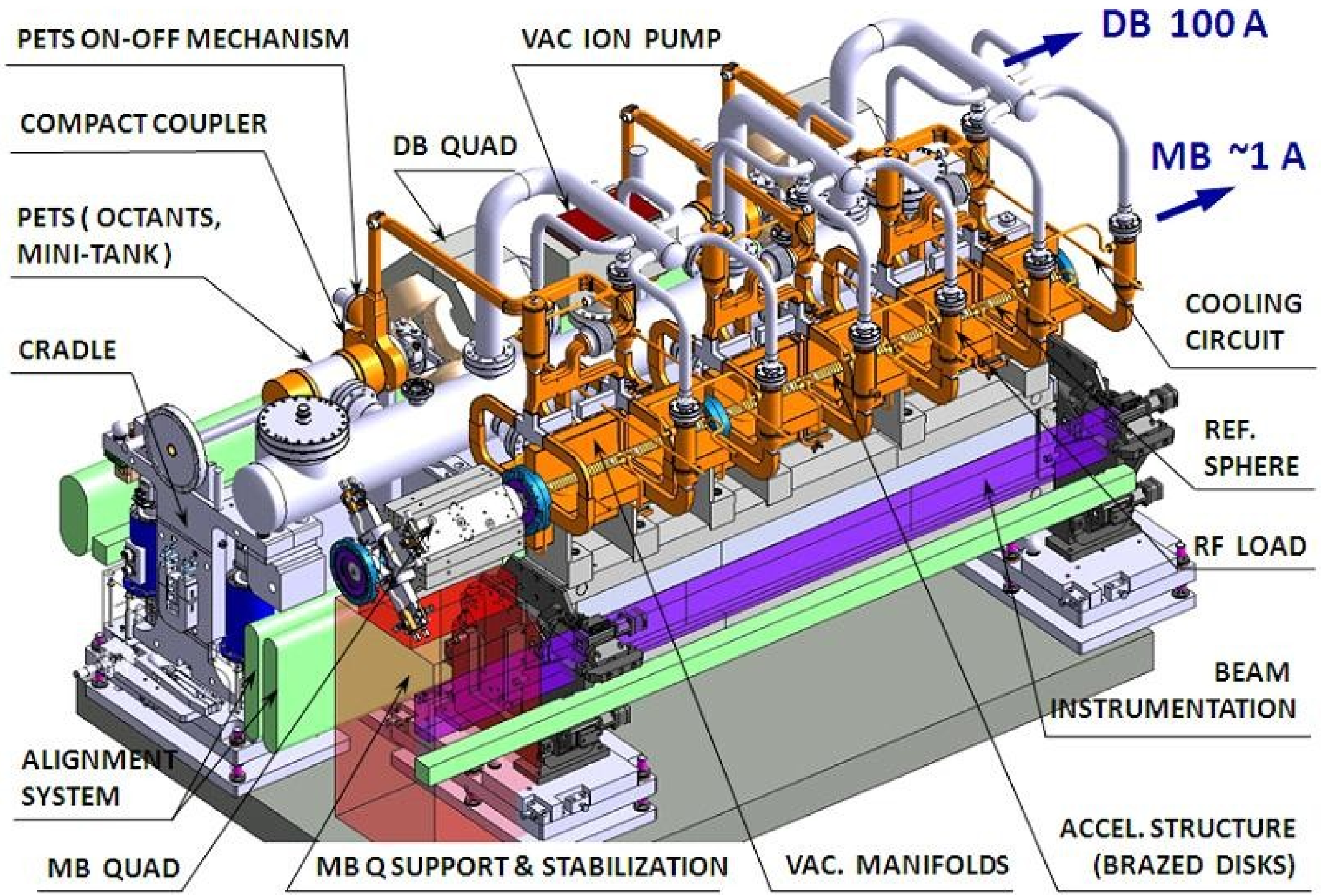
Stabilization of main beam quadrupole

Metrology

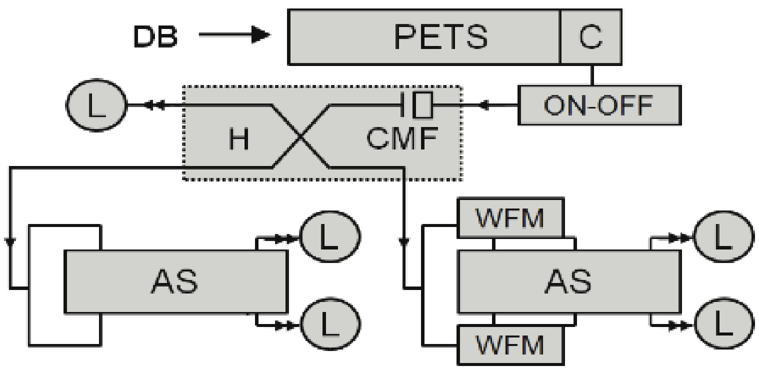
Measurement of resonant frequencies

Vibration study

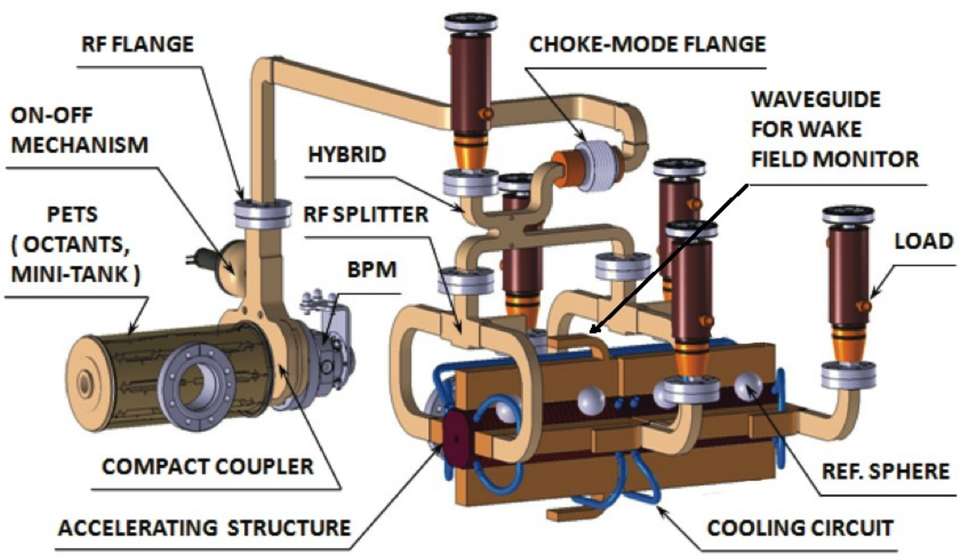
Two-Beam Module Type-I



Module RF Network



CMF - choke mode flange, H - compact E-hybrid,
C - compact coupler, L - rf load, WFM - wake field monitor



- The two-beam RF network includes the X-band rectangular wave-guides providing connection between PETS, AC and other supplementary devices.
- It's necessary to join the PETS outgoing waves by one channel. Because of the limited longitudinal space a compact coupler is needed.
- In case of a breakdown in a AS it is necessary to interrupt the power produced by the corresponding PETS within 20 ms. "On-Off" mechanism

  - Another requirement is to guarantee transverse alignment flexibility between the two beams and thus to allow for the power transmission without electrical contact
  - Another necessity is to have a split of power between two AS without any reflection to the feeding PETS in a broad frequency range
  - The power delivered from PETS to the two fed AS must be **synchronized in phase**

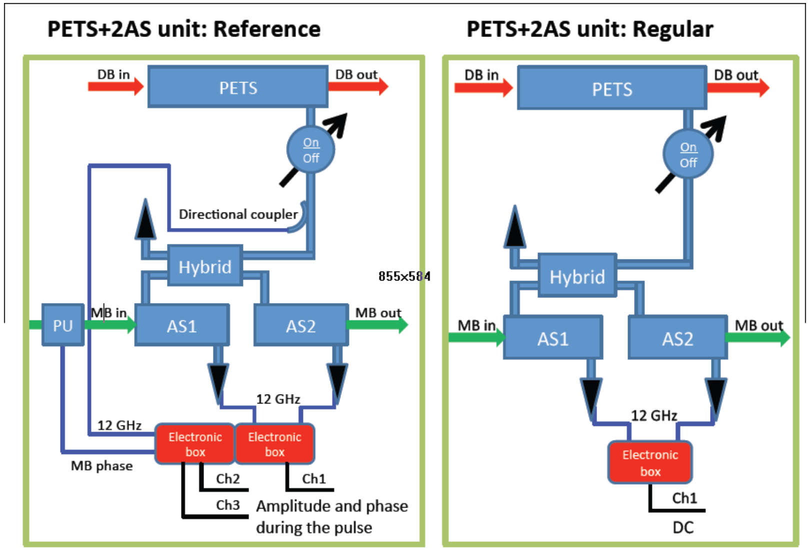
Components, integration of components

Main Beam RF Diagnostics

Use of diagnostics in operation

Two types of PETS+2AS units will be installed:

1. Reference **(black)** (2 units at the beginning and 2 units at the end of a DB sector)
   - It will have more signals and with higher resolution
   - The signals will be time resolved: dt ~ 0.5 ns (pulse shape)
2. Regular **(blue)** (all the rest)
   - It will have 1 or 2 signals
   - Integral over the pulse (1 or 2 numbers per pulse)



- RF diagnostic
  1. RF breakdown in PETS and AS
  2. PETS on/off failure
  3. Provide references for the regular PETS+2AS units
- Beam control
  1. RF power production
  2. Energy measurement and beam loading transient compensation

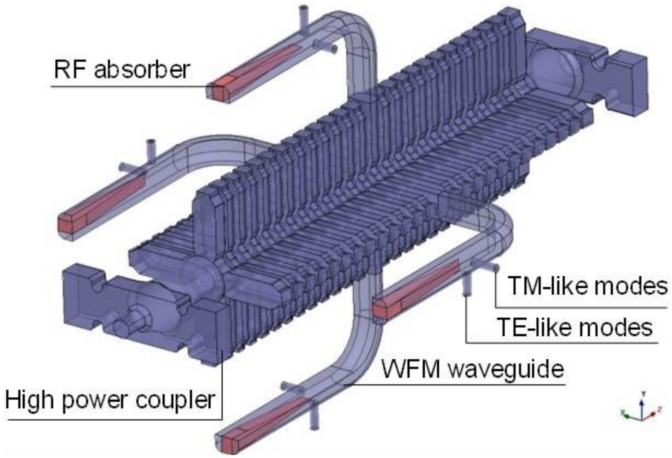
1. RF breakdown
2. PETS on/off failure

Courtesy of **A. Grudiev**

WakeField Monitors

Position monitors called Wakefield Monitors (WFM) are integrated to the structure for beam-based alignment (cost saving solution). There will be 1 WFM for each super-structure.

To achieve the target luminosity, the accelerating structures must be aligned to an accuracy of **3.5 μm** with respect to the beam trajectory.



TBTS WakeField Monitor Prototype

From single structure to string…?

Some additional points:

- How many module "generations" will we have?
  - It looks like we would need to test with beam at least a short string (~3) whenever they will undergo major changes. Keep existing modules in place or substitute them?
  - What is the right balance between "LAB" modules and "CLEX" modules in the future?
- CLIC will probably be "rebaselined" on the 2012-2013 time scale. Is it worth to insist too much on nominal parameters when they could well change? (Remember CTF3 pulse length…)

Reserve

Beyond CTF3

- In the TDR phase, it is planned to build one full-scale drive beam injector (up to ~ 30 MeV).
  - Thermionic + bunching system solution preferred w.r.t. photoinjector (possibly build both).
  - Time scale around 2013.
- Need as well at least a few drive beam accelerator modules (klystron/modulator/structure)
- Present plan – add modules to arrive gradually at about 200 MeV (first bunch compression stage/ 10% of average CLIC beam power))
- Total cost: ~ 100 MCHF (including manpower)
- (Very) recent alternative: CLIC 0- (reduced cost CLIC0)

CLIC0 Drive Beam Accelerator Scenarios with Lower Power

D. Schulte

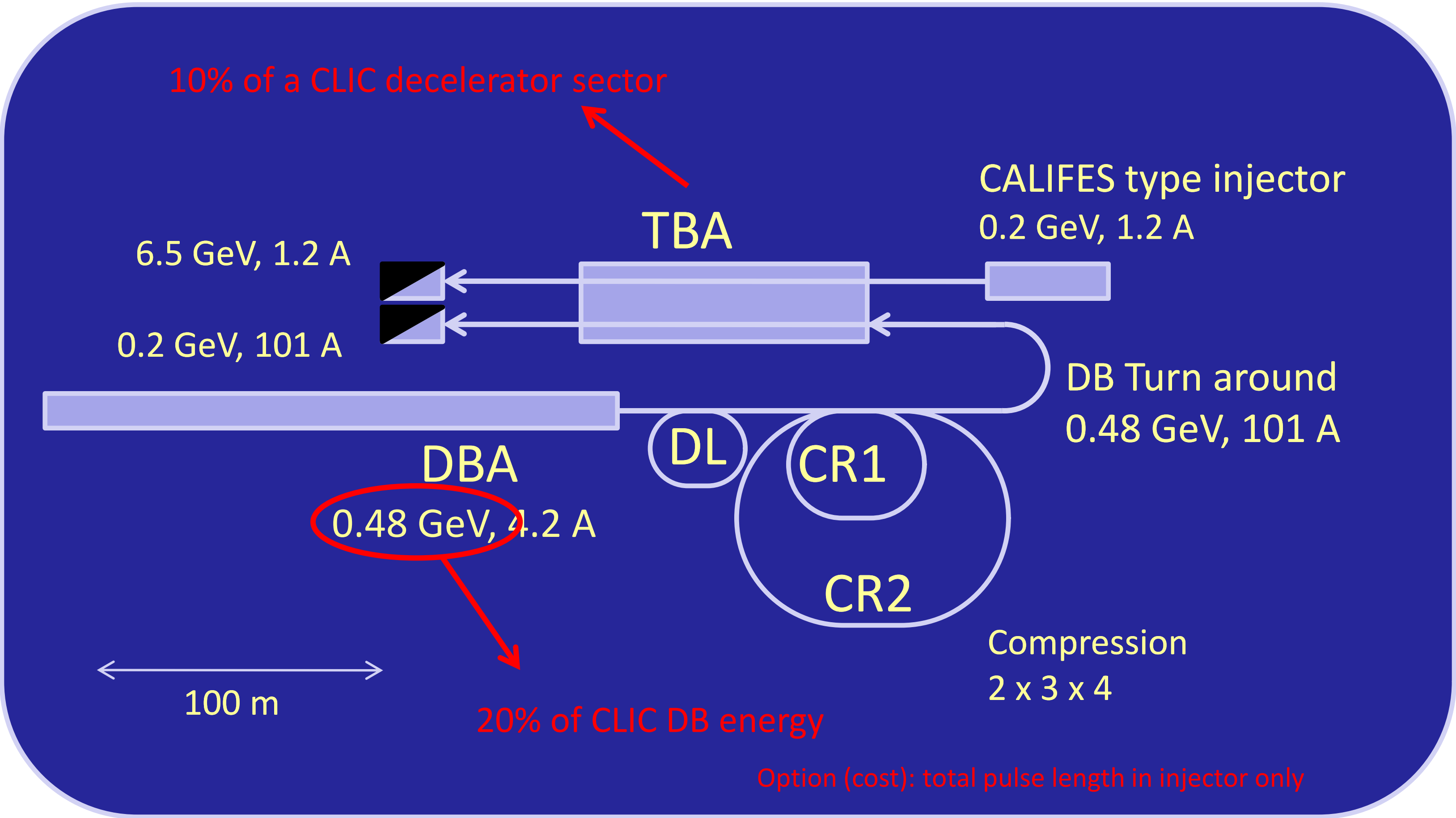
- Double bunch spacing, i.e. every fourth bucket (Alexej, D.S)
  - chain two structures
    - ⇒ use half as many klystrons and modulators
  - merge 6 times in second ring
    - ⇒ requires two RF deflector frequencies
  - ⇒ recovers full beam current with twice as long RF pulse
    - ⇒ still smaller pulse length than CLIC nominal
- Run at 70% current and 70% energy of CLIC0
  - energy scan proposal
  - can remove one klystron of each pair that is combined
- In both cases one can install klystrons later
- Both options could be combined
- Cost of system up to combiner rings very close to cost for 200 MeV injector proposal
- Note: could also reduce number of modules for 100 A at lower energies

Another factor 2 in klystrons/modulators (reduced performance)

Could cost (very preliminary) about 180 MCHF including rings, decelerator and probe beam injector

Halfway between Inj + 200MeV DBA and full CLIC0 (300 MCHF)

CLIC Zero



All other parameters nominal - all components nominal and re-usable for CLIC

CLIC Zero – Pros & cons

- Demonstrates nominal DBA injector with all parameters
- Creates nominal drive beam train apart from energy (0.48 GeV instead of 2.4 GeV)
- Demonstrates nominal DBA module with klystron and modulator with all parameters
- Demonstrates two beam acceleration over significant distance with fully nominal modules
- Forces pre-series production of all mass produced components → Industrialization
- Well suited to create confidence in CLIC technology
- All hardware investment is re-usable for real CLIC

- **Expensive** – will absorb most of planned budget
- **Schedule too long** – results with beam not before 2015
- No obvious use of 6.5 GeV main beam but for testing
- Drive beam dynamics more difficult than in real CLIC (like in CTF3)