# Overview of the DB accelerator complex

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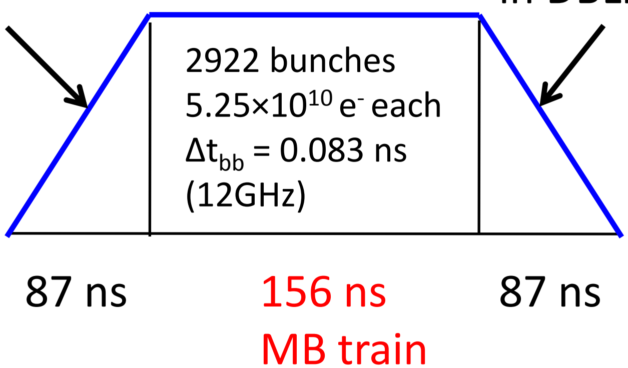
WG6 at IWLC_2010

# Beam as requested by Decelerators

AIM : produce a gradient of 100 MV/m at $f_0$=12 GHz for the Main Beam

This part to ensure flat filling of the PETS (talk O. Kononenko)

This part for constant beam loading in DBLinac

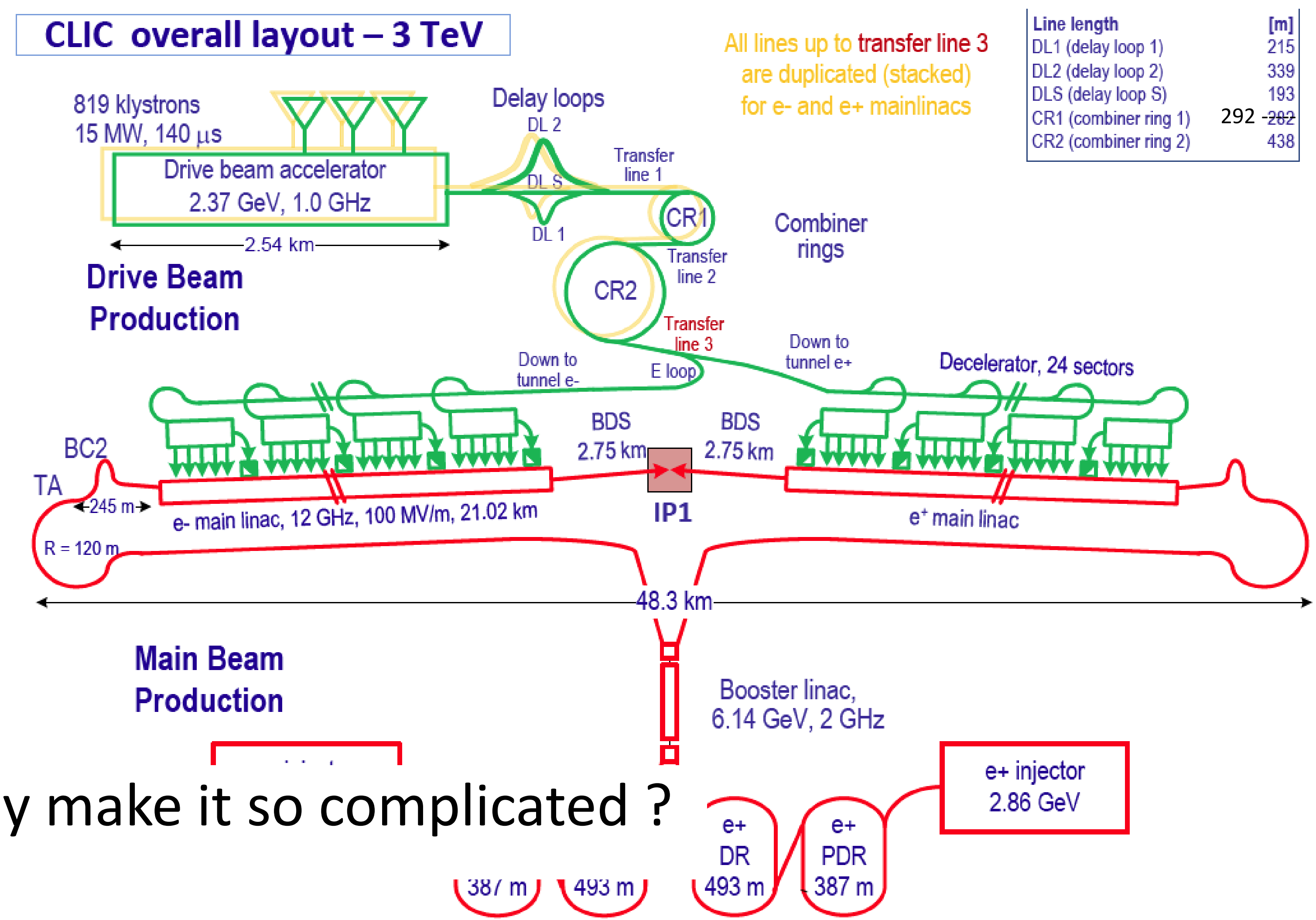



- Beam energy E=2.37 GeV
- Beam current I = 100 A
- 2×24 such trains for 3 TeV
- 2×5 0.5 TeV

Tolerances on Drive Beam for luminosity
$\Delta L/L$ = 1% (D. Schulte)

| Variable | | Coherent (24 trains) | Individual trains |
|---|---|---|---|
| Phase@12GHz | $\sigma(\phi)$ | 0.2° | 0.8° |
| Current | $\sigma(I)/I$ | $7.4\times10^{-4}$ | $2.2\times10^{-3}$ |
| Bunch length | $\sigma(\sigma_z)/\sigma_z$ | $1.1\times10^{-2}$ | $3.2\times10^{-2}$ |

# The way to produce these beams




- Why make it so complicated ?

# Frequency Multiplication

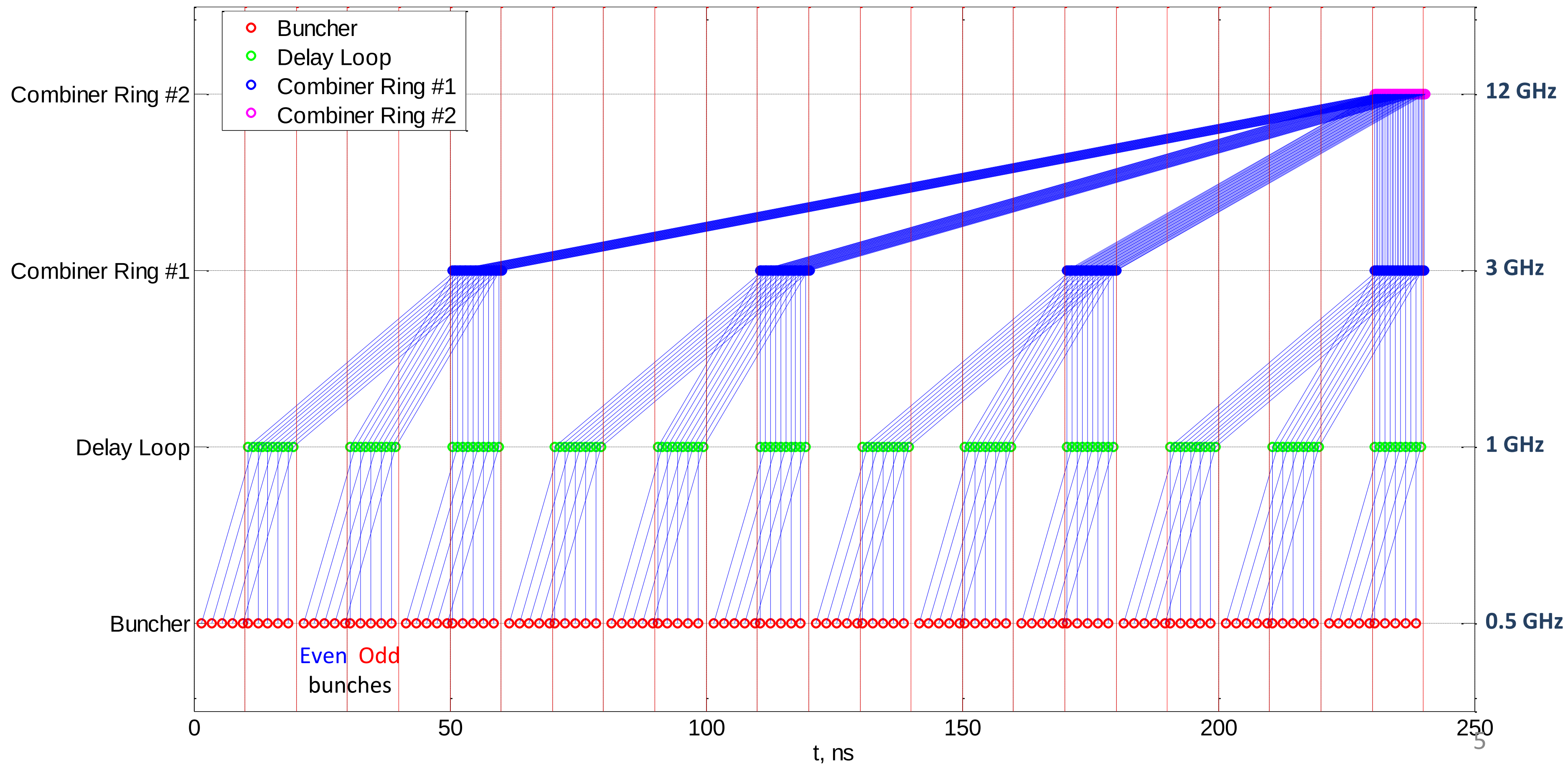
- Producing short pulses (243 ns) with klystrons is not efficient
- Lower fequency klystrons are more efficient
- No gun can produce a current $I = q_b \times f_0 = 100A$
- The CLIC way :
  - Drive Beam Linac : 1 GHz klystrons, 0.5 GHz bunch spacing
  - Use FM (DL, CR1,CR2) to interleave 24 pulses → 12 GHz
  - Produce 24 trains in continuous to feed each decelerator

  → Pulse length in DB Linac : Dt = $24 \times 24 \times 237$ns = 140 µs
  - Use full beam loading for maximum efficiency

# Drive Beam Combination Steps

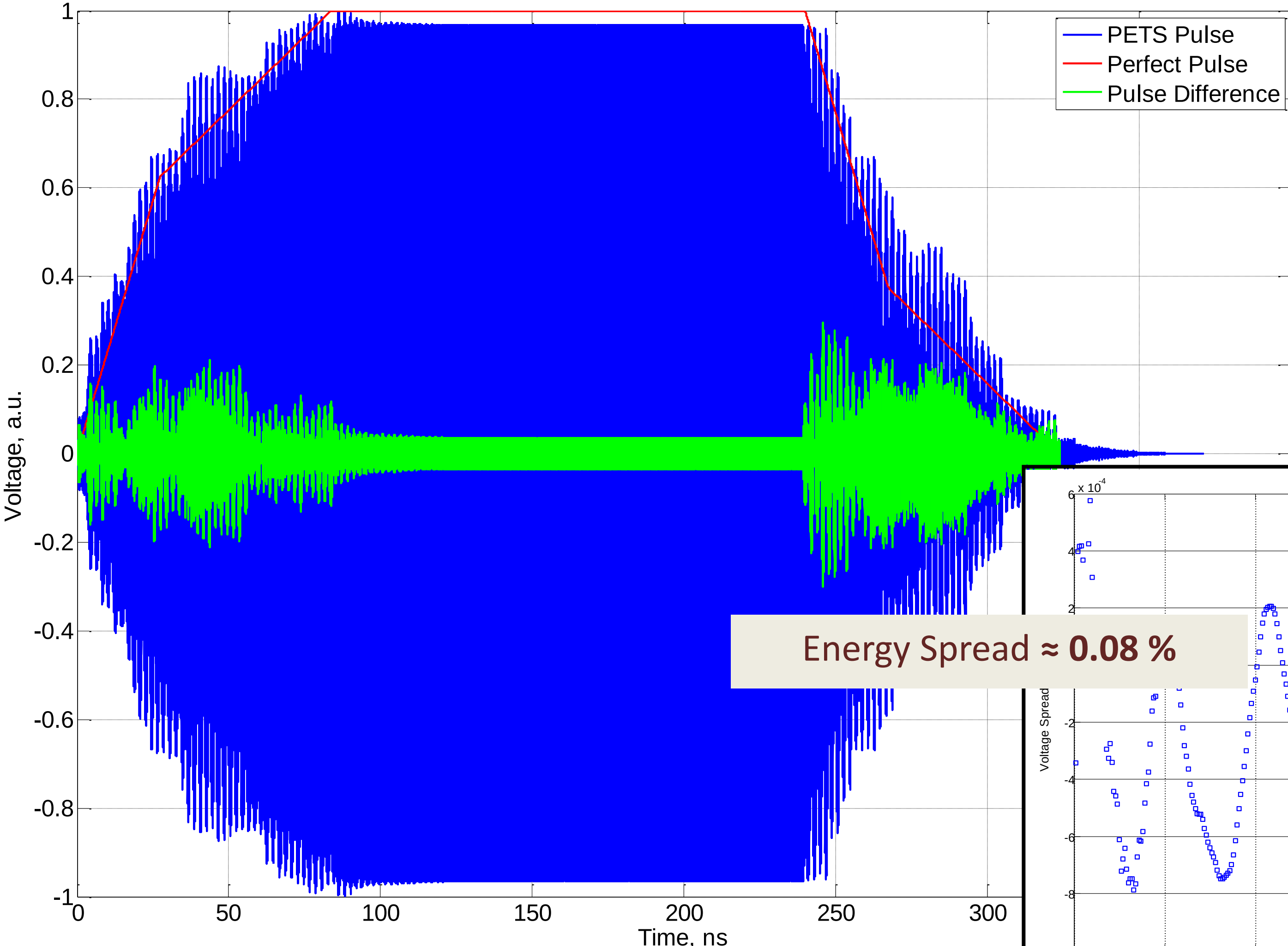
$f_{beam} = 4 * 3 * 2 * f_{buncher}$

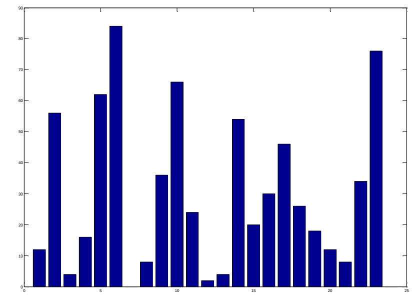
Picture borrowed from O. Kononenko

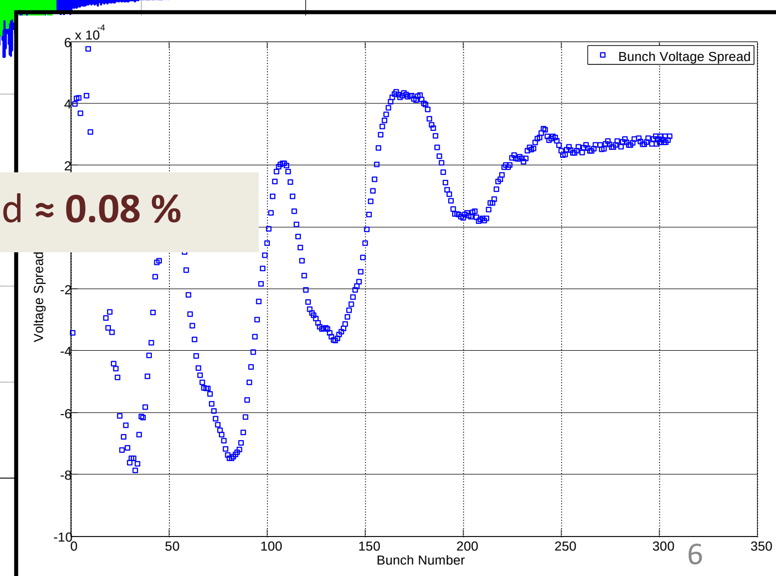


# Optimized Pulse Shape for the Full Bunch Response in PETS

Picture borrowed from O. Kononenko (see his talk)






Energy Spread ≈ **0.08 %**

# Beam production

- Gun must produce $n = 2922 \times 24 \times 50 = 3.5 \times 10^6$ bunches/s (current $I = 4A$)
- Must alternate trains with odd/even bunches
- Odd/even bunch structure must be programmable inside the rise-time period (recipe by Olexsiy, see former slide).
- Timing tolerance for the beam at the entrance of the DB Linac:
  - $\Delta\phi_1 = 0.1°$@1GHz ⇔ 85 μm ⇔ 0.3 ps
- Timing at 12 GHZ (synchonisation DB/MB & MB $e^+/e^-$) :
  - $\Delta\phi_2 = 0.2°$@12GHz ⇔ 14 μm ⇔ 46 fs ($46 \times 10^{-15}$ s)
  - Need active phase feed-back after each-turnaround to match $\Delta\phi_1$ and $\Delta\phi_2$
  - Need (most likely) a site-wide timing network offering this precision

→ Dedicated session in WG2+6+7+8 yesterday

*Can a thermo-ionic gun, followed by a bunching System, do this ?*

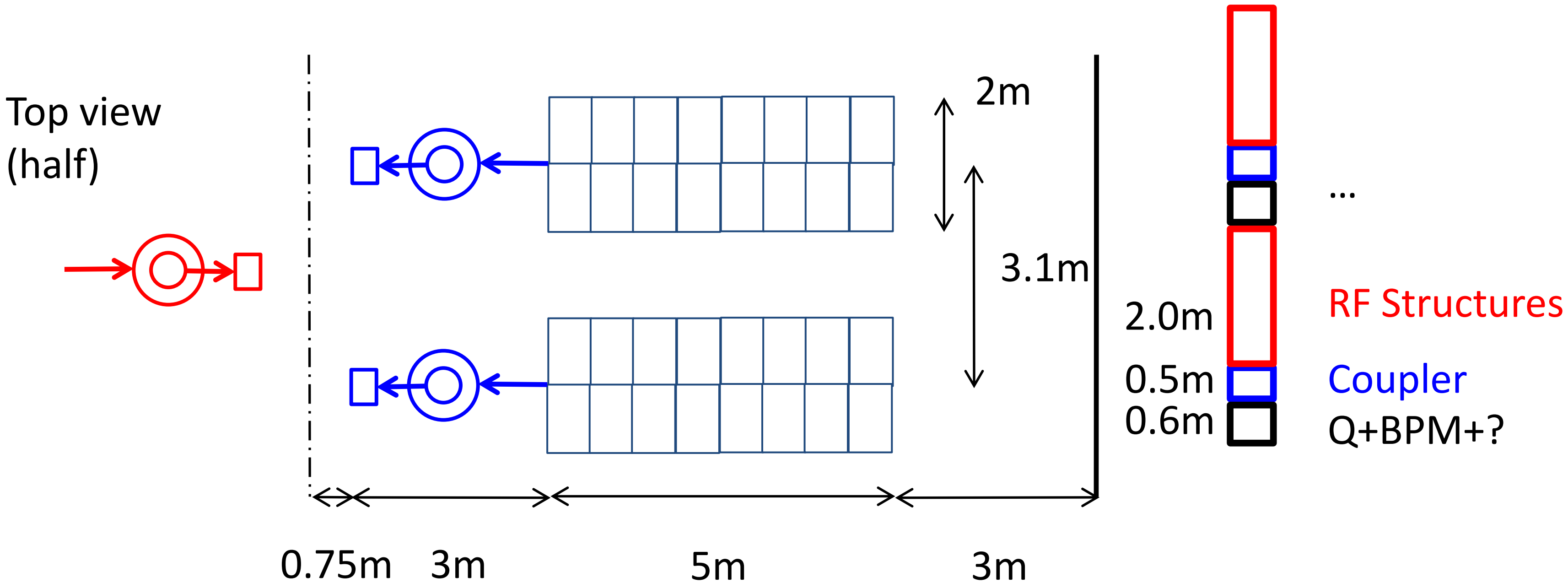
*Will a reliable laser gun exist ?*

See talks by Simona and Marta

# DB Linac

- Dedicated session after coffee with WG4 ←
- RF system : studied by E. Jensen and R. Wegner
- Modulators : pre-study by D. Nisbet and D. Siemaszko
- Optics and beam dynamics : A. Aksoy
- Overall dimensions and power needs at hand
- Still much work ahead

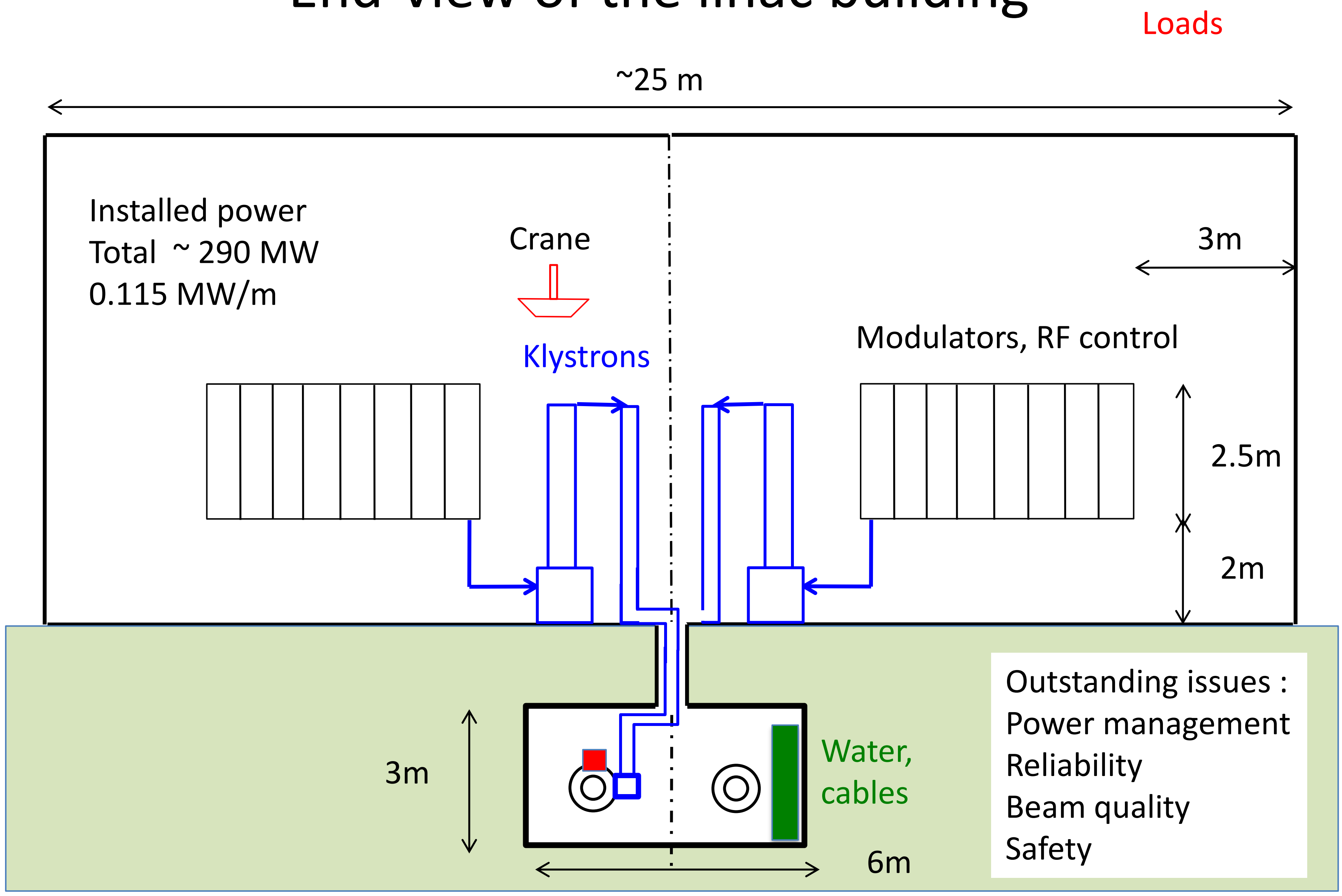
# Top view of the Linac building




Building :
Width: 2 × 12.5m ≈ 25 m
Length : 820×3.1m = 2540 m ←

Total for 2 Beams :
1640
Klystrons + modulators

# End-view of the linac building

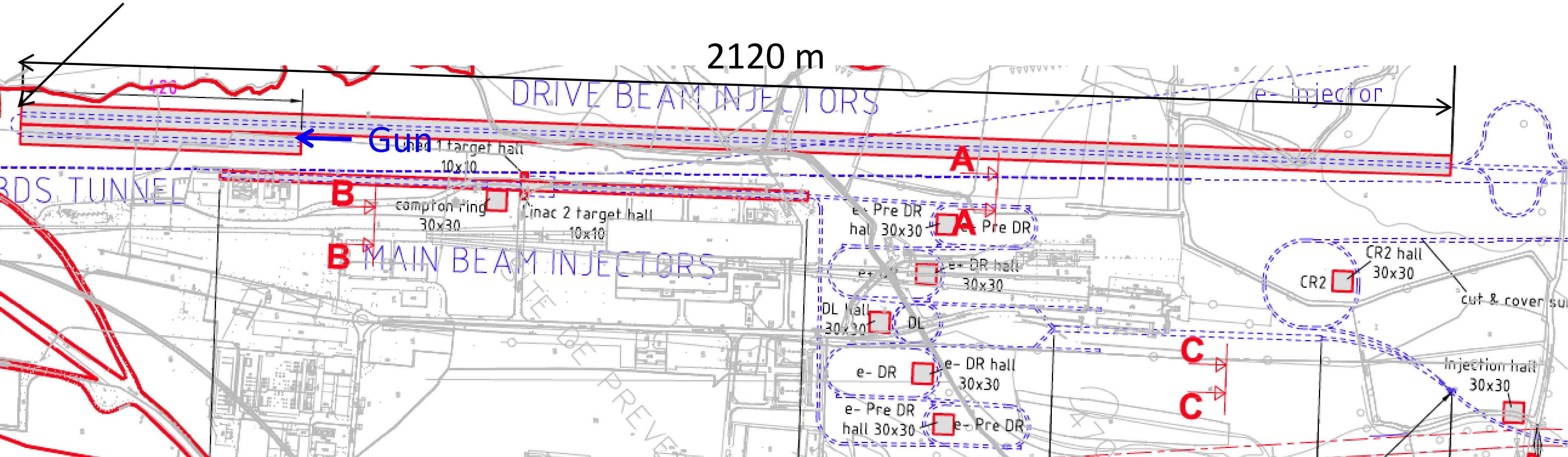


# More on tolerances for the DB LInac

- Timing tolerance at the entrance of the DB Linac :
  - $\Delta\phi = 0.1°$@1GHz ⇔ 85 μm ⇔ 0.3 ps
  - This to ensure $\Delta\phi_{DB/MB} = 0.2°$@12GHz in the Main Tunnel
  - The factor ~10 is must be granted by the active feed-back at each turn-around in the Main tunnel
- As for the DB Linac itself , in the segment before compression:
  - Gradient : $\Delta G/G < 2\times10^{-3}$ coherent over 100 klystrons, $< 2\times10^{-2}$ per klystron
  - Phase : $\Delta\phi = 0.05°$ to avoid undue bunch lenghtening (A. Aksoy, D. Schulte)
  - This in turn for modulator : $\Delta P/P < 10^{-5}$
- The last two values are certainly a nice challenge. They require much attention in the near future

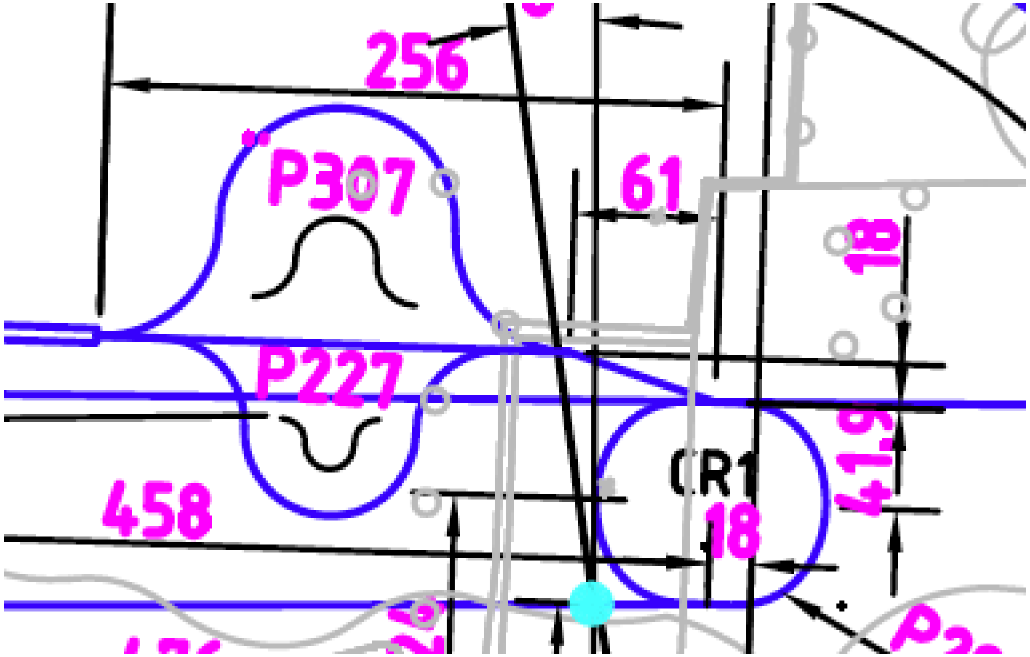
# The DB Linac complex in the landscape

Loop for phase- feed-back, compression




- The DB Linac is the power source of CLIC
- It shall receive more attention in the future
  - Structures (beam loading, ageing ,…)
  - Klystron studies & prototypes
  - Modulators studies
  - Power management
  - Beam management, collective effects
  - Phase and gradient tolerances

# Frequency Multiplication & transport to tunnel - I



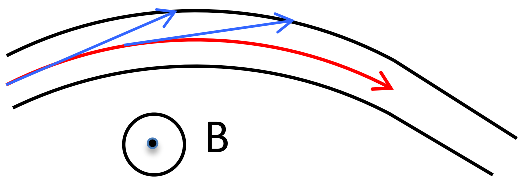

| Ring Or Line | Length Or Circum | Δ |
|---|---|---|
| DLS | 142 , 193 | |
| DL1 | 215 | 73 |
| DL2 | 339 | 146 |
| CR1 | 292 | |
| CR2 | 438 | |
| TA | 150 | |

- Changes 2010 :
  - Twice longer lines (DL1, CR1,TA) to allow for good isochronicity, achromaticity and flexibility
  - Addition of a second Delay Line for energy scan between 1 & 3TeV (longer trains at lower energies)
  - Endorsed by the Tech. Comm. and Civil Engineering

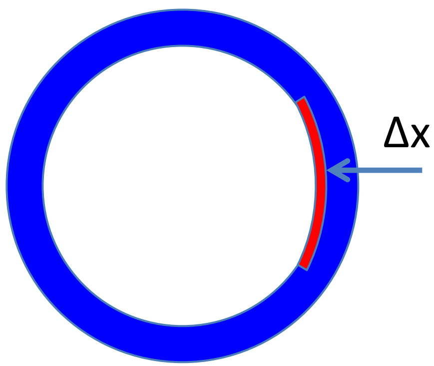
# Frequency Multiplication & transport to tunnel - II

- Strategy and work for CDR
  - Fully work-out optics of CR1 (see talk by Piotr)
  - With now larger radii in DL and TA's , good optics can be derived from CR1 to other rings/lines
  - A magnet catalogue is at hand , much detailed for all the lines (talk by Alexey Vorozhtsov wed.)
    - It was used for the power and cost estimate exercise (CDR)
    - It will be much useful for any variational work
  - Concentrate on still open issues
    - Vacuum, SR, CSR, collective effects
    - Options for power & cost reduction

# Synchrotron Radiation impact on hardware




- X-ray @ 6 keV : $L_{absorption}$ = 50 µm (Aluminium)
- Impact angle : $\alpha \approx 0.2$ rad
- $\Delta T$ = 80 K @ 50 Hz (CR2 & TA's)
- Compare to $\Delta T_{uts}$ = 180 K
- Risk of rapid ageing
- As of today : not solved



$\Delta x = L_{abs} \times \alpha \approx 10$ µm

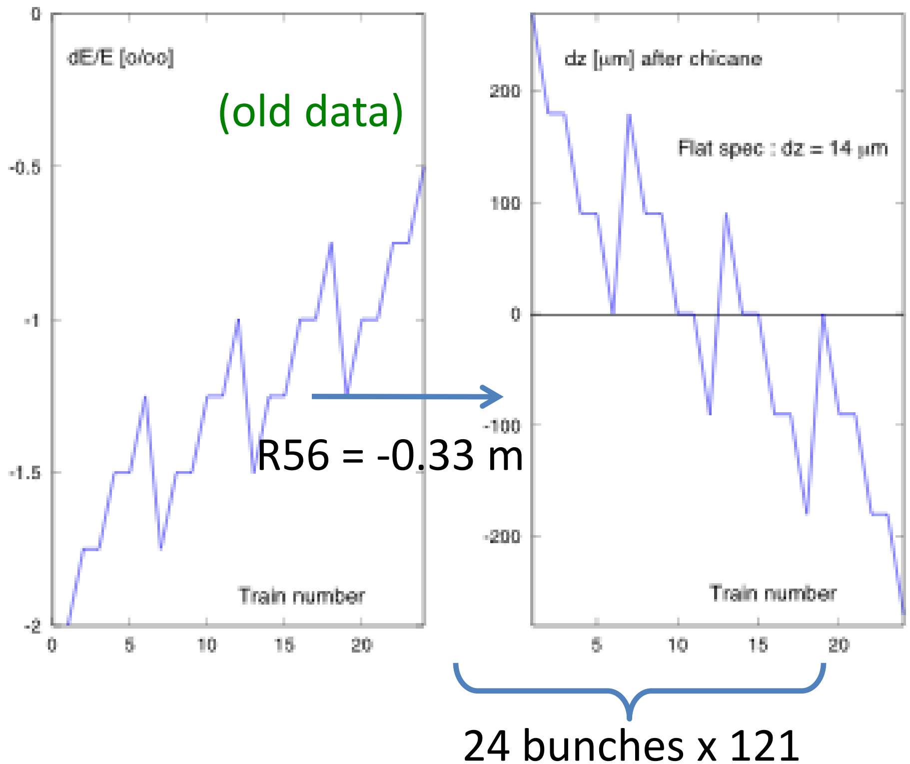
- Power / dipole ~ 1 KW
- Vacuum with this flux of photons ?
  - Spec for ion instabilities : $p = 10^{-10}$ Torr
- As of today : not studied

# Options for Dipoles & Vacuum vs. SR

- Super-conducting super-ferric magnets
  - s.c coils, but classical C-yoke for field shaping
    - More expensive, but power ÷5
    - Cost savings with time
  - Cold pipe (~20-30K) → Thermal expansion vanishes → *Ageing solved*
    - Another vacuum regime to study
- Classical resistive magnets
  - Berylium pipe at SR-impact
    - Transparent to 6 KeV X-rays
    - SR absorbed in water behind
  - Be disliked for safety reasons ⇔negotiable ?

# SR impact on beam

- $\Delta E_{turn}$ → different E inside trains through CR1 and CR2
- Converts to $\Delta z$ after final compression chicane




- Annoying for synchronisation with irregular time structure
- Beyond a certain spread , reduces PETS efficiency
- To be re-worked with new optics
- Consider s.c. super-ferric magnets in CR1, CR2 (minimise CSR, optimise SR)

# Collective effects

- Ion instabilities : hard constraints on vacuum
  - DB Linac : $p < 5 \times 10^{-11}$ Torr Not Studied
  - FM, transport : $p < 10^{-10}$ Torr Not Studied
- Multi-bunch resistive wall instabilities
  - The deformation of the trajectory of the rear bunches of a train goes like
  - Need large pipe radius

$$\Delta x \sim \sqrt{\frac{n_{\text{bunch}} < \beta >}{\sigma_{\text{elec}}} \frac{1}{r^3}}$$

- CSR
  - With large pipe radius, the energy loss is similar to SR loss
  - Small SR losses → low B, large L for constant BL
  - Small CSR losses → short L
  - So, screening CSR would help , i.e. allow to optimise SR
- But CSR & n-bunch instabilities are in conflicts
  - Another reason to look at super-ferric magnets
  - Better conductivity would allow for smaller radius → screening , …

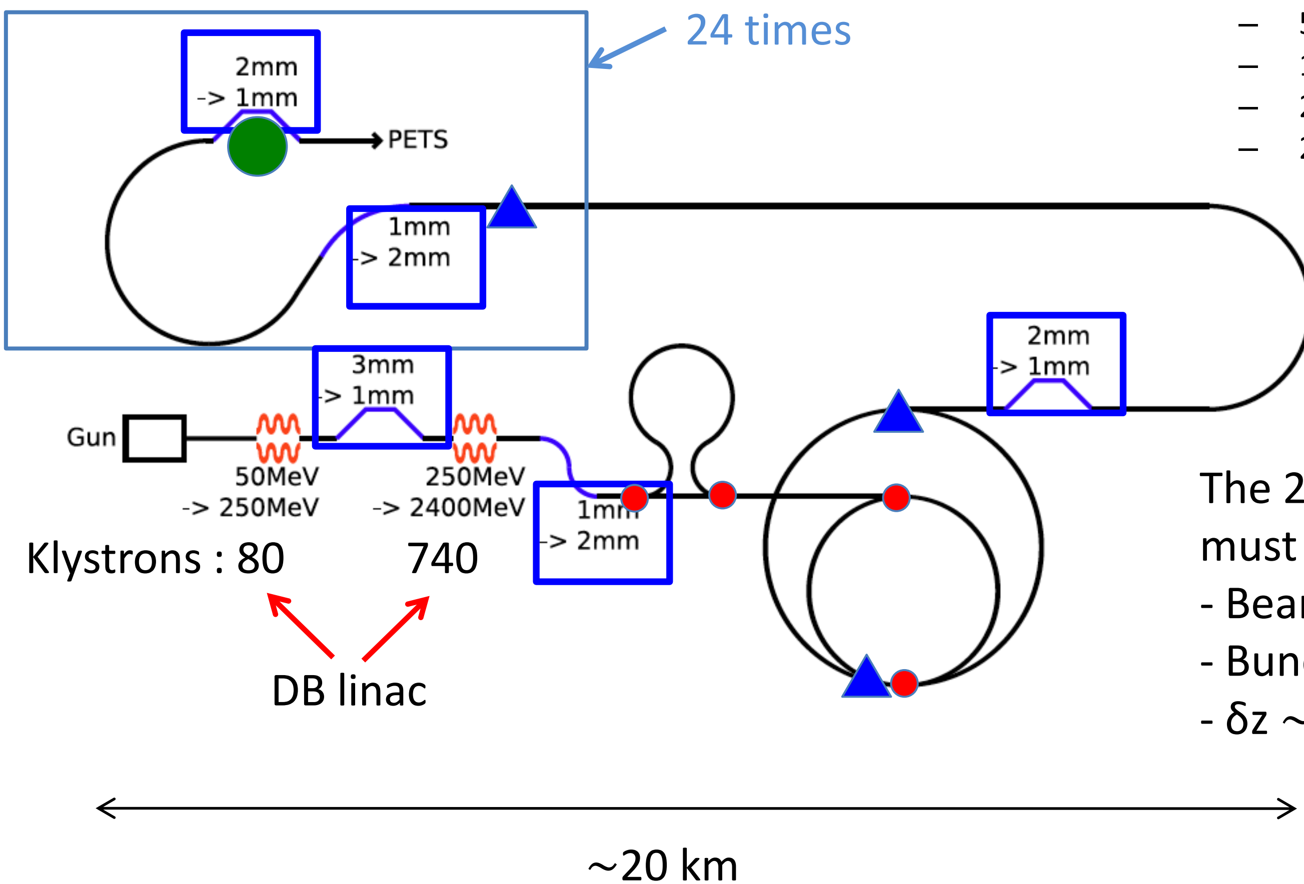
With copper chamber

| Line | R [mm] |
|---|---|
| DL,CR | 40 |
| LTL | 100 |
| TA | 20 |

# Operability

- RF deflector
- Kicker
- RF kicker (phase synchro)

- Total longest path for a train : 29 km
- Through :
  - 820 klystrons
  - 14 RF deflectors
  - 3 Kickers
  - 5 compression chicanes
  - 1 RF kicker
  - 2 loops
  - 2 rings, several turns




The 24 trains
must Survive with:
- Beam losses < $10^{-3}$
- Bunch lenghtening < few %
- $\delta z \sim 10$ µm

# Future (post-CDR)

- Many oustanding issues to be worked-out
- Can CTF3 validate the requirements for the CLIC Drive Beam ?
- If not, what do we need to do so ?
- See talks by Roberto and Frank this afternoon

My worries : Mismatch between work to do & manpower

- Activity scattered in too many 'sub-projects'

| | | | | |
|---|---|---|---|---|
| CTF3 | CTF3+ | CLIC-500GeV | KLIC | ILC |
| | CTF3++ | CLIC-3TeV | | |
| | CLIC0 | CLIC-var-E | | |

An item for the round-table this afternoon …