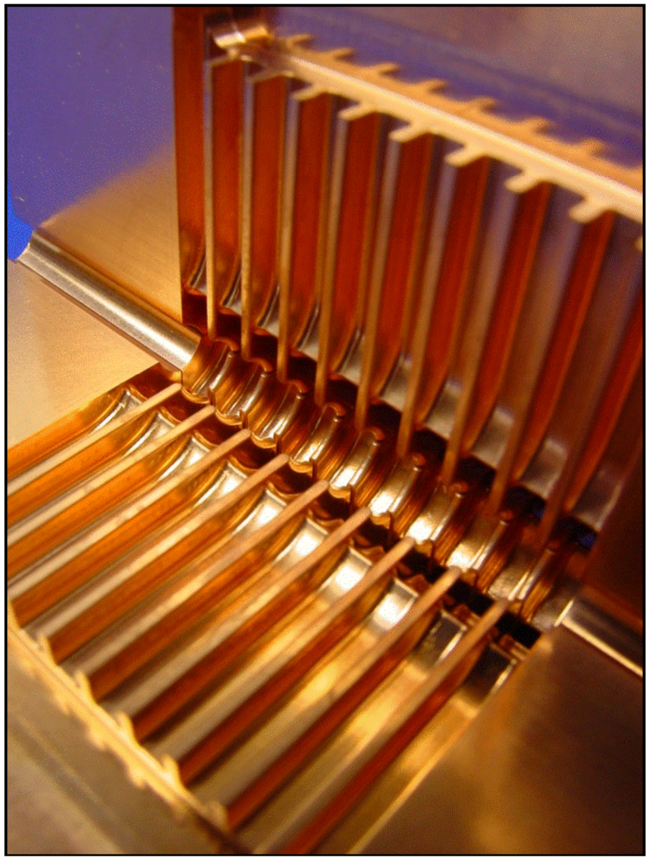
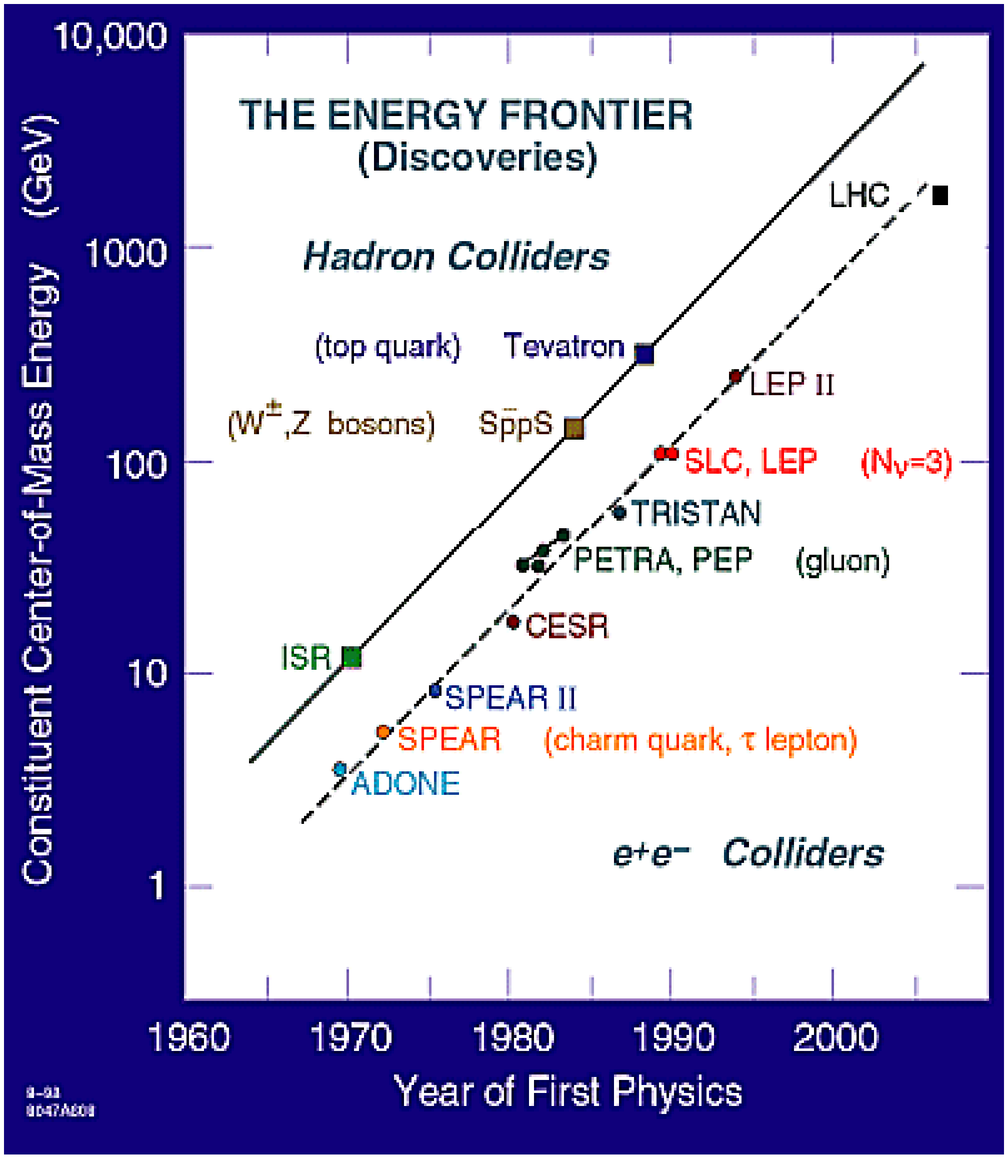
CLIC / CTF 3

Frank Tecker - AB/OP

- Introduction CLIC / CTF 3
- Visit of CTF3



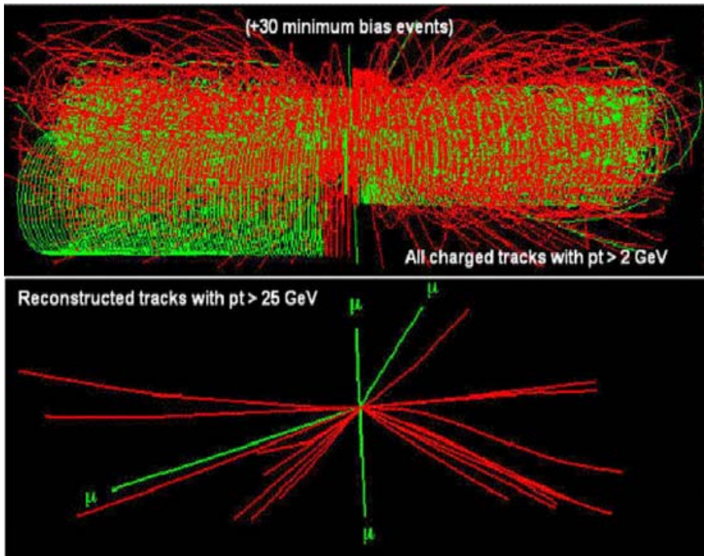
Path to higher energy

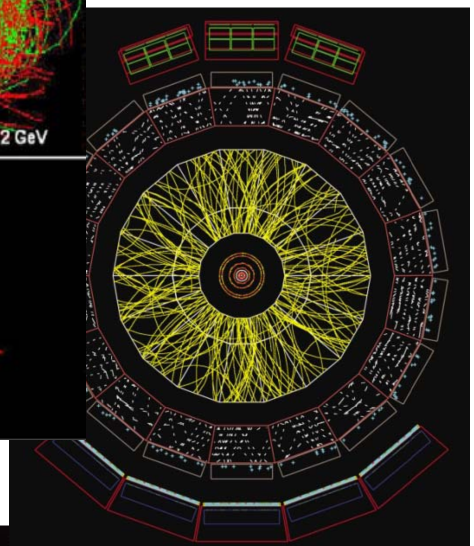


- History:
  - Energy constantly increasing with time
  - Hadron Collider at the energy frontier
  - Lepton Collider for precision physics
- LHC coming online soon
- Consensus to build Lin. Collider with E_{cm} > 500 GeV to complement LHC physics (*European strategy for particle physics* by CERN Council)

Lepton vs. Hadron Collisions

LHC: H $\rightarrow$ ZZ $\rightarrow$ 4μ

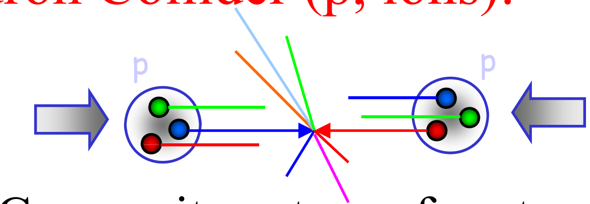




ALICE:
Ion event

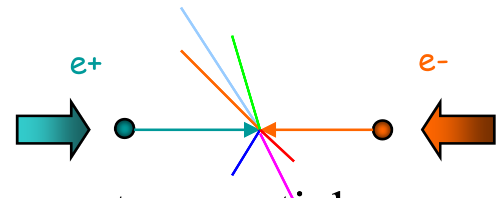
LEP event:
$Z^0 \rightarrow$ 3 jets

- Hadron Collider (p, ions):



  - Composite nature of protons
  - Can only use p_t conservation
  - Huge QCD background

- Lepton Collider:



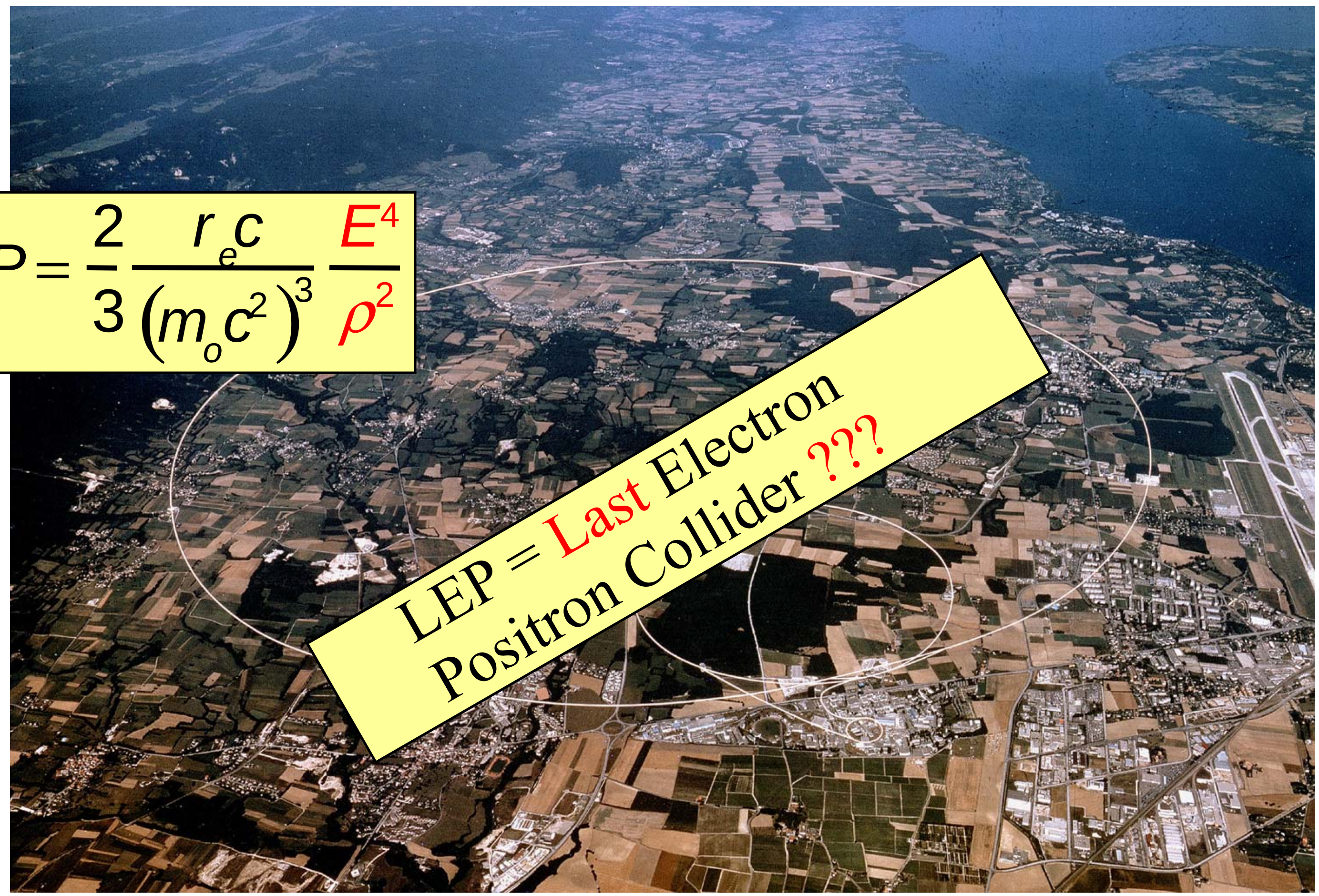
  - Elementary particles
  - Well defined initial state
  - Beam polarization
  - produces particles democratically
  - Momentum conservation eases decay product analysis

The LEP collider

- LEP (Large Electron Positron collider) was installed in LHC tunnel
- e+ e- circular collider (27 km) with E_{cm}=200 GeV

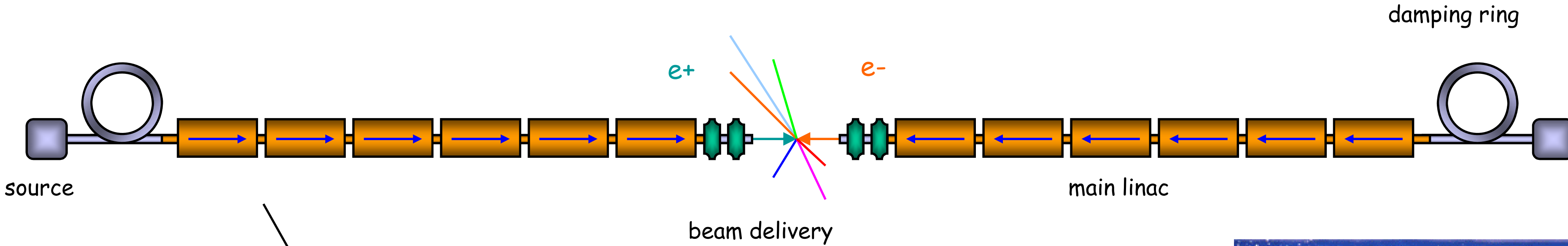
- Problem for any ring: Synchrotron radiation
- Emitted power: scales with E^4 !! and $1/m_0^3$ (much less for heavy particles)
- This energy loss must be replaced by the RF system !!
- particles lost 3% of their energy each turn!

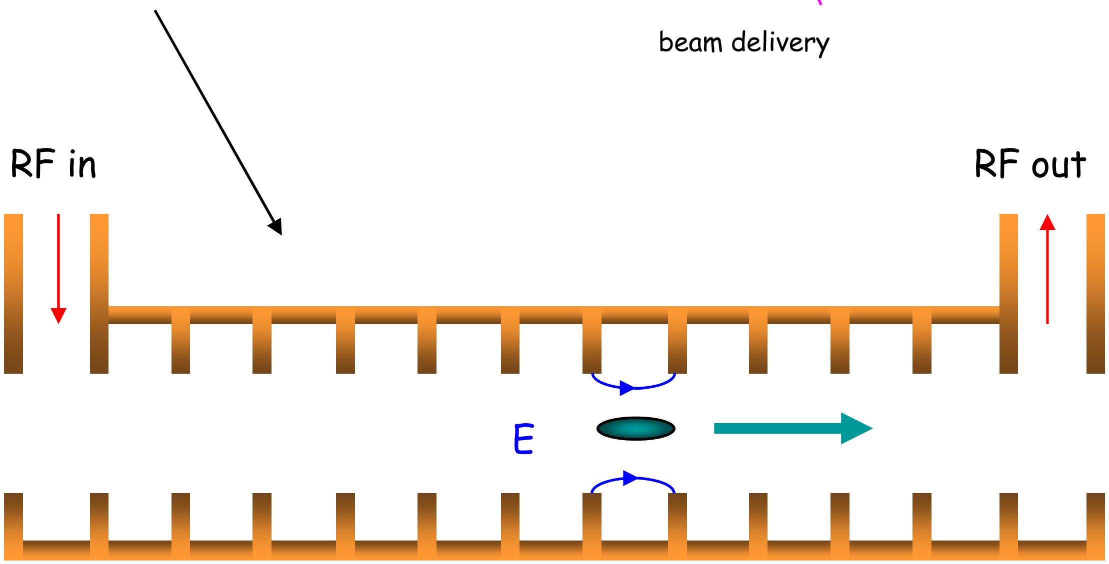
$$P = \frac{2}{3} \frac{r_e c}{(m_o c^2)^3} \frac{E^4}{\rho^2}$$

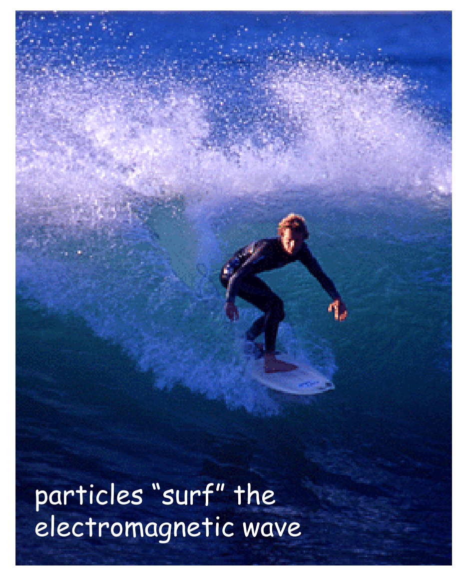


The next lepton collider

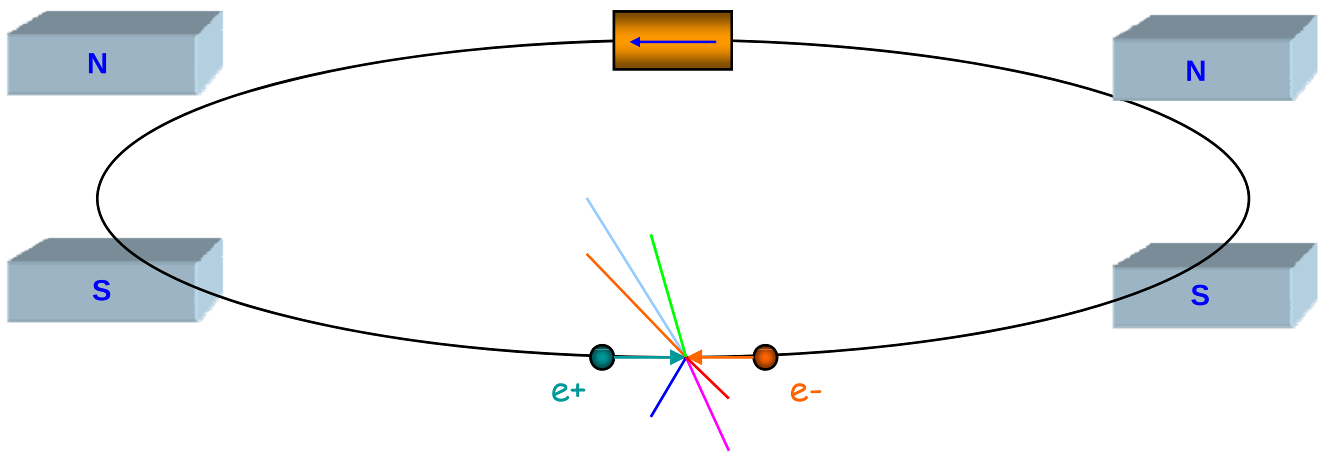
- Solution: LINEAR COLLIDER
- avoid synchrotron radiation
- no bending magnets, huge amount of cavities and RF







Linear Collider vs. Ring



- **Storage rings:**
  - accelerate + collide every turn
  - 're-use' RF + 're-use' particles
- ⇒ efficient

- **Linear Collider:**
  - one-pass acceleration + collision

  ⇒ need
  - high gradient (acceleration)
  - small beam size

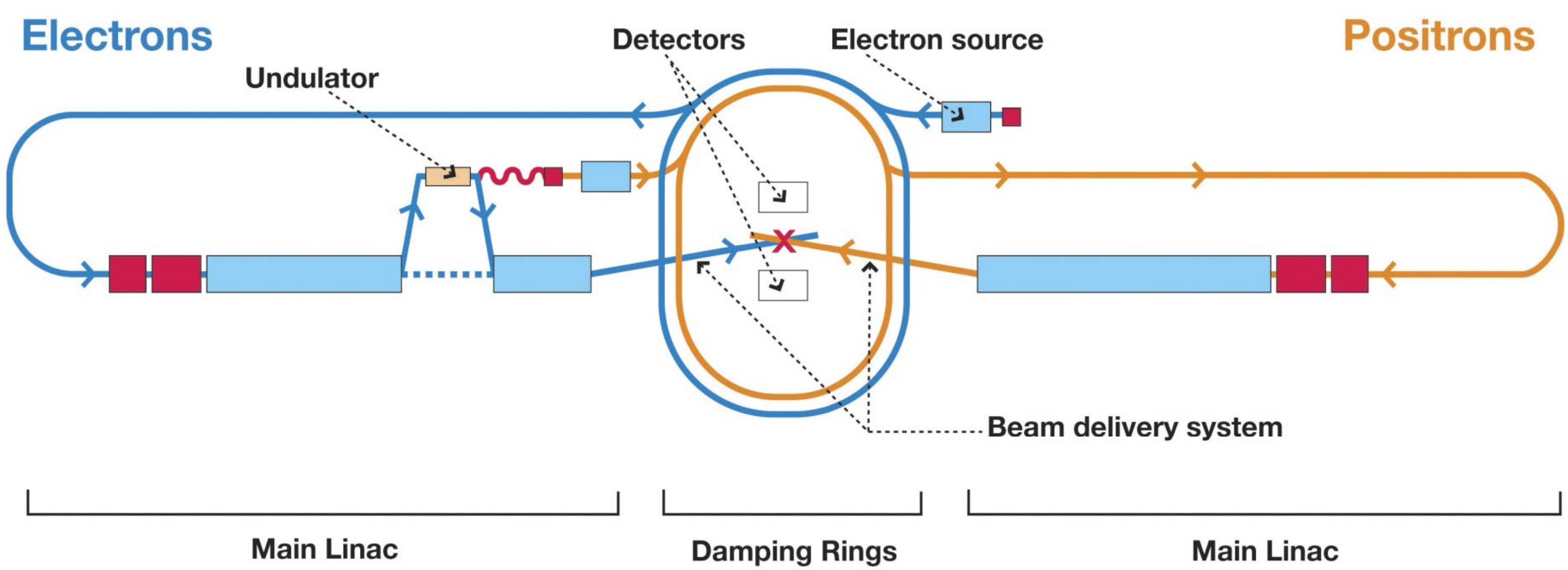
  to reach high event rate (Luminosity)

Linear Collider projects

- ILC (International Linear Collider)
  - Technology decision Aug 2004
  - Superconducting technology
  - 1.3 GHz RF frequency
  - ~31 MV/m accelerating gradient
  - 500 GeV centre-of-mass energy
  - upgrade to 1 TeV possible

- CLIC (Compact Linear Collider)
  - normalconducting technology
  - multi-TeV energy range (nom. 3 TeV)

~35 km total length



CLIC-CTF3 Collaboration

WORLD WIDE CLIC & CTF3 COLLABORATION

Ankara University (Turkey)
Berlin Tech. Univ. (Germany)
BINP (Russia)
CERN
CIEMAT (Spain)
DAPNIA/Saclay (France)

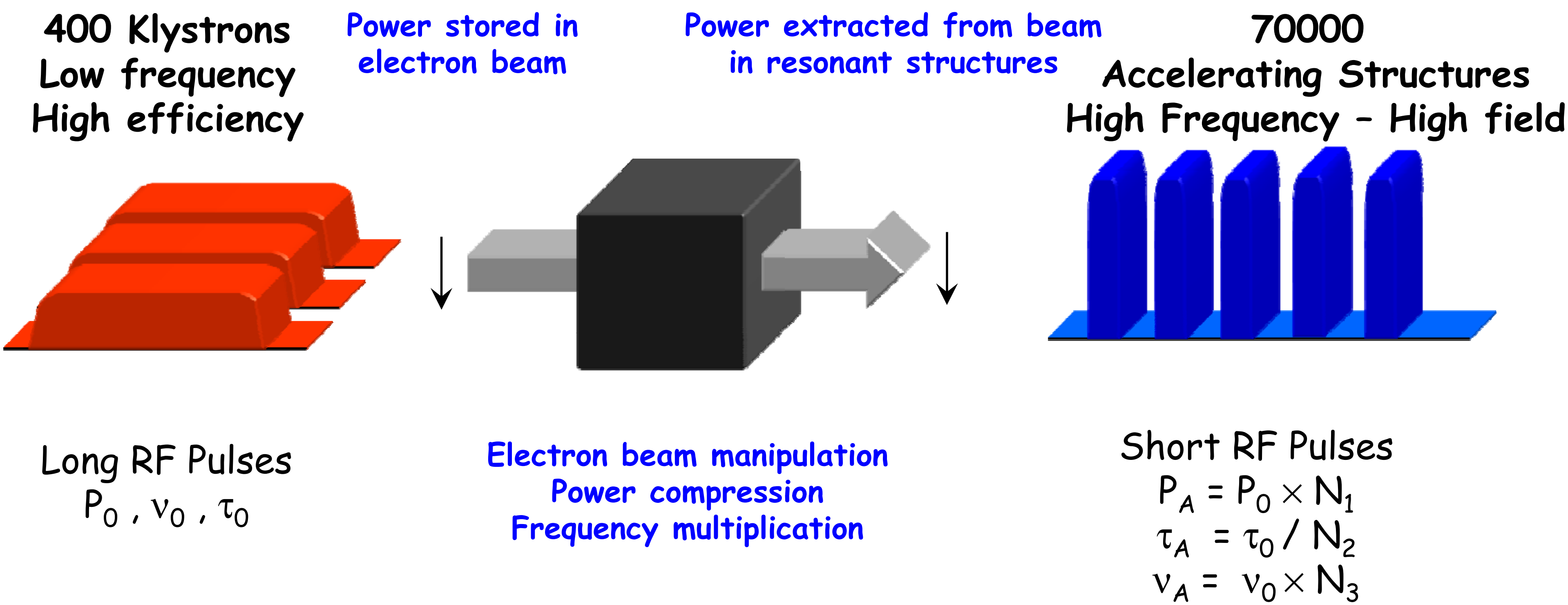
RRCAT-Indore (India)
Finnish Industry (Finland)
Gazi Universities (Turkey)
Helsinki Institute of Physics (Finland)
IAP (Russia)
Instituto de Fisica Corpuscular (Spain)
INFN / LNF (Italy)

JASRI (Japan)
JINR (Russia)
KEK (Japan)
LAL/Orsay (France)
LAPP/ESIA (France)
LLBL/LBL (USA)
NCP (Pakistan)

PSI (Switzerland),
North-West. Univ. Illinois (USA)
Polytech. University of Catalonia (Spain)
John Adams Institute (England)
SLAC (USA)
Svedberg Laboratory (Sweden)
Uppsala University (Sweden)

CLIC scheme

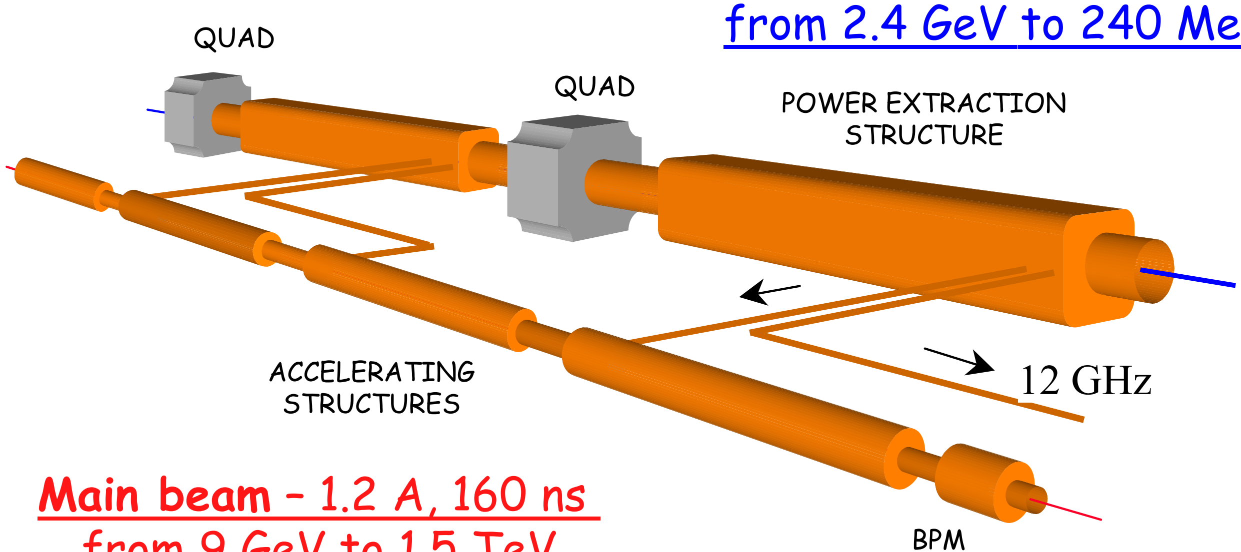
- Very high gradients possible with NC accelerating structures at high RF frequencies (12 → 30 GHz)
- Extract RF power from an intense electron “drive beam”
- Generate efficiently long pulse and compress it (in power + frequency)



CLIC two beam scheme

- Two beam acceleration scheme:
  - High charge Drive Beam (low energy)
  - Low charge Main Beam (high collision energy)
- High power for high gradient of >100 MV/m

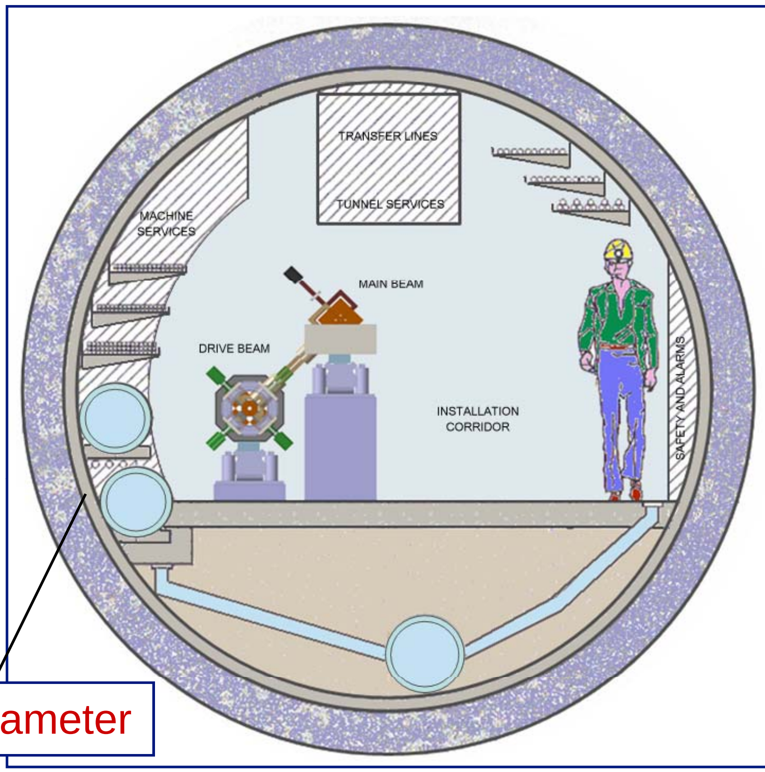
Drive beam - 100 A, 240 ns
from 2.4 GeV to 240 MeV



Main beam – 1.2 A, 160 ns
from 9 GeV to 1.5 TeV

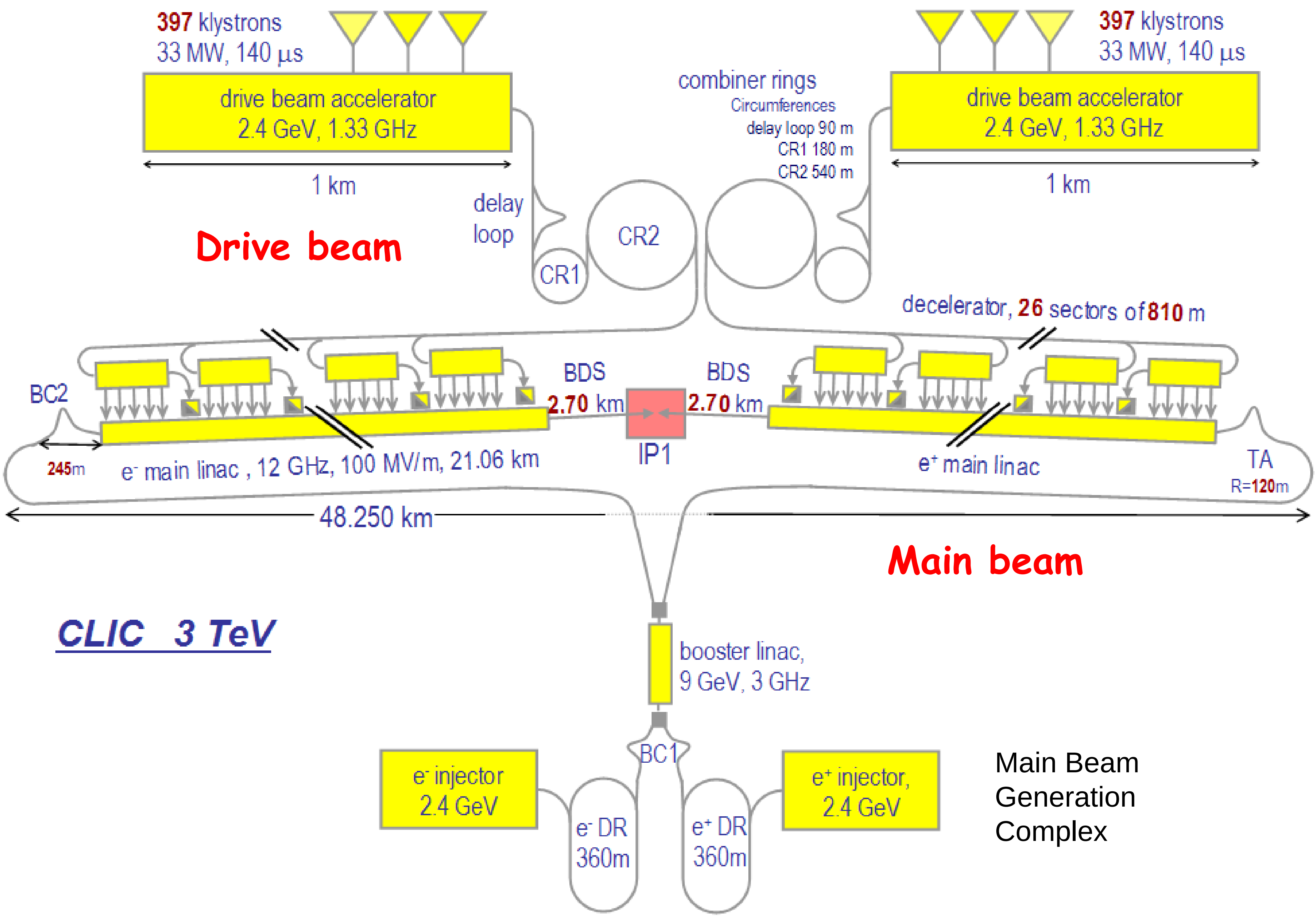
CLIC MODULE

CLIC TUNNEL
CROSS-SECTION



4.5 m diameter

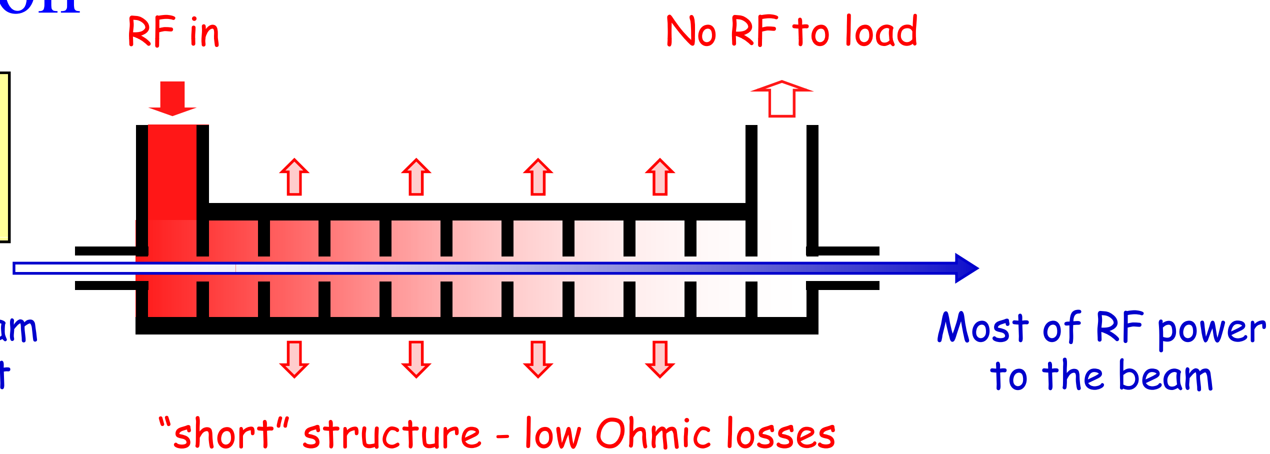
CLIC – overall layout



Drive beam generation basics

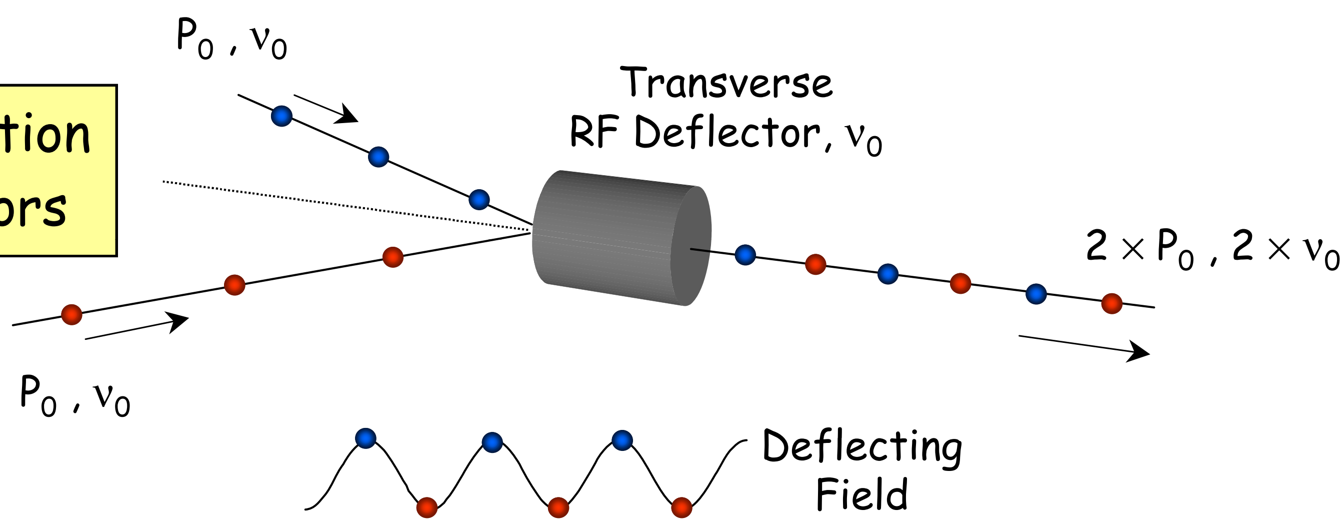
- Efficient acceleration

Full beam-loading acceleration in TW sections

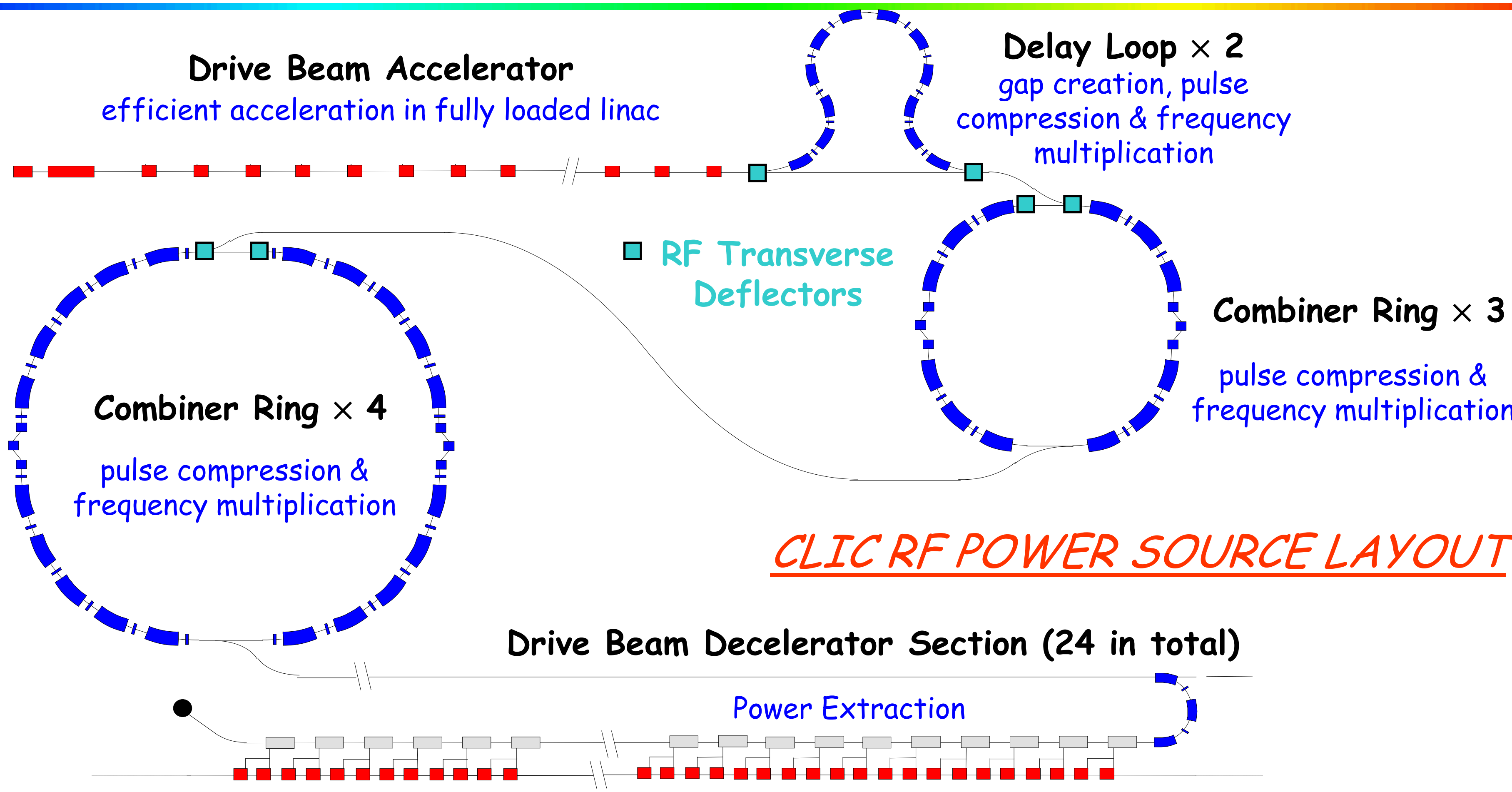


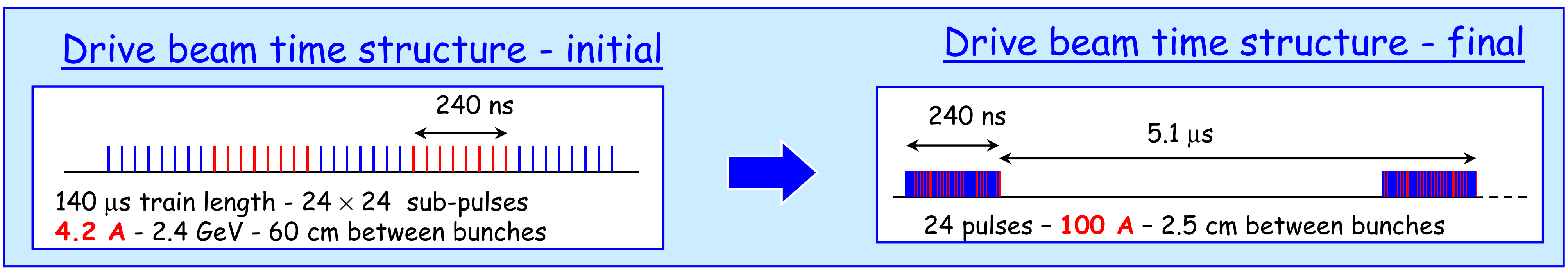
- Frequency multiplication

Beam combination/separation by transverse RF deflectors



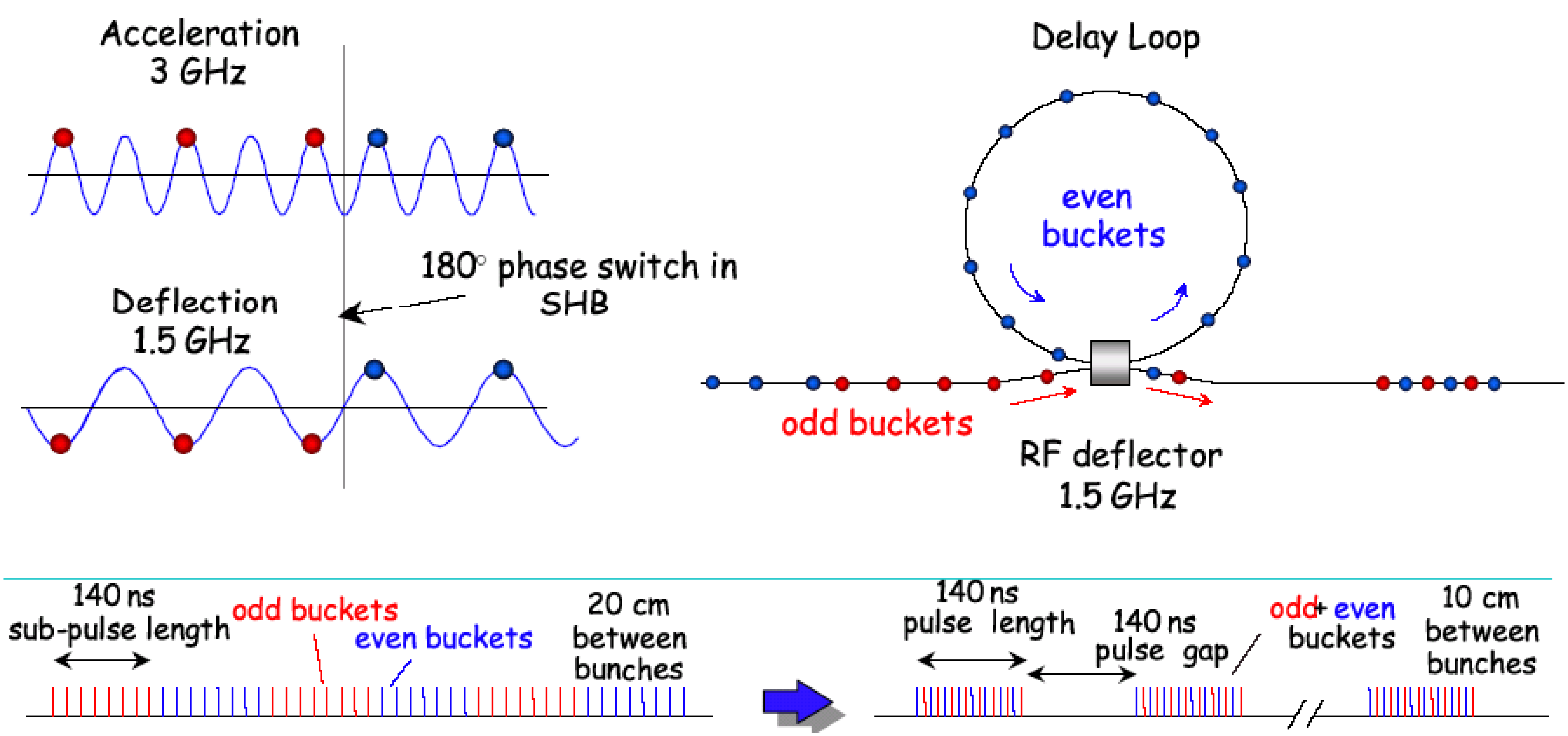
CLIC Drive Beam generation





Delay Loop Principle

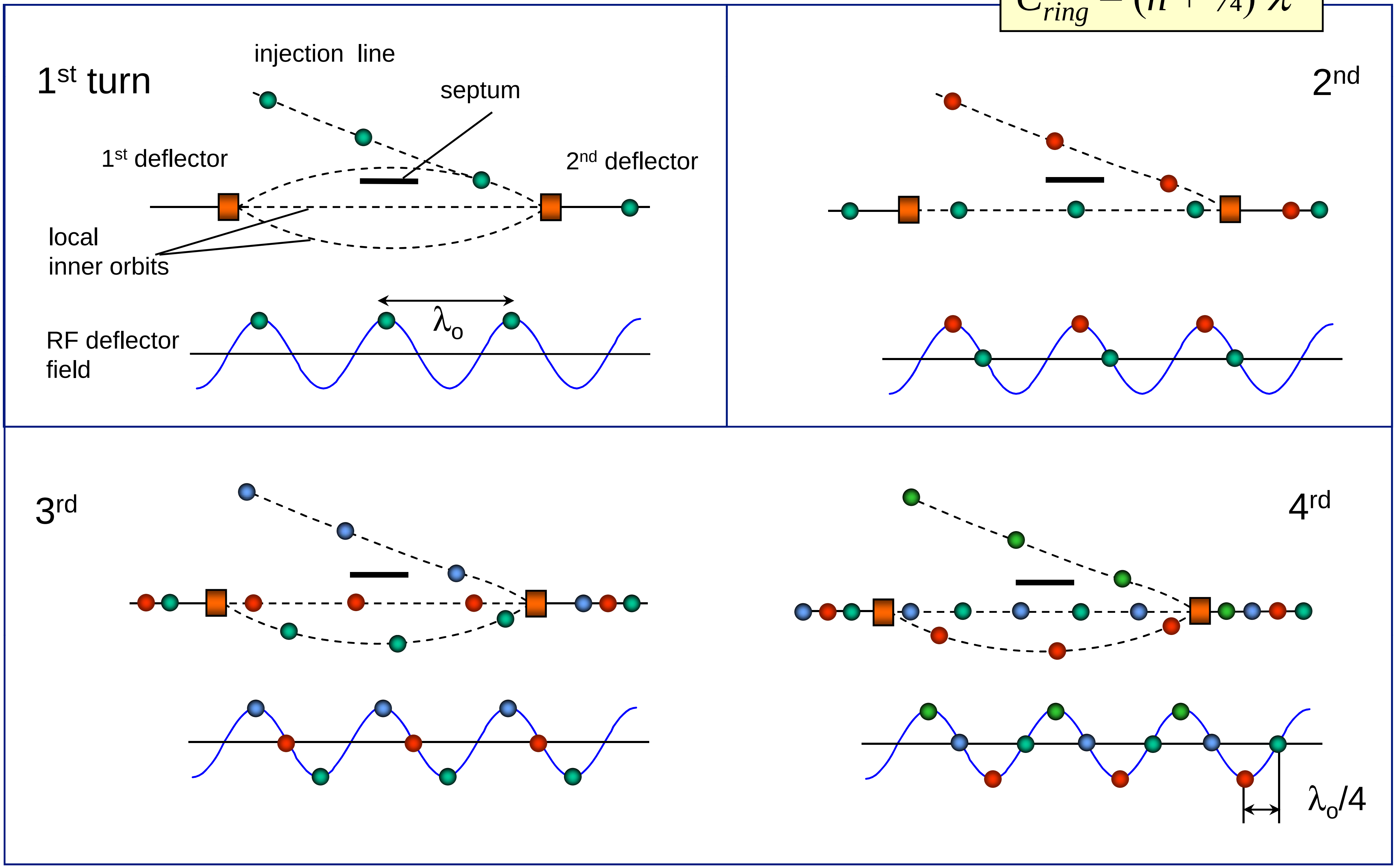
- **double repetition frequency and current**
- parts of bunch train delayed in loop
- RF deflector combines the bunches



RF injection in combiner ring

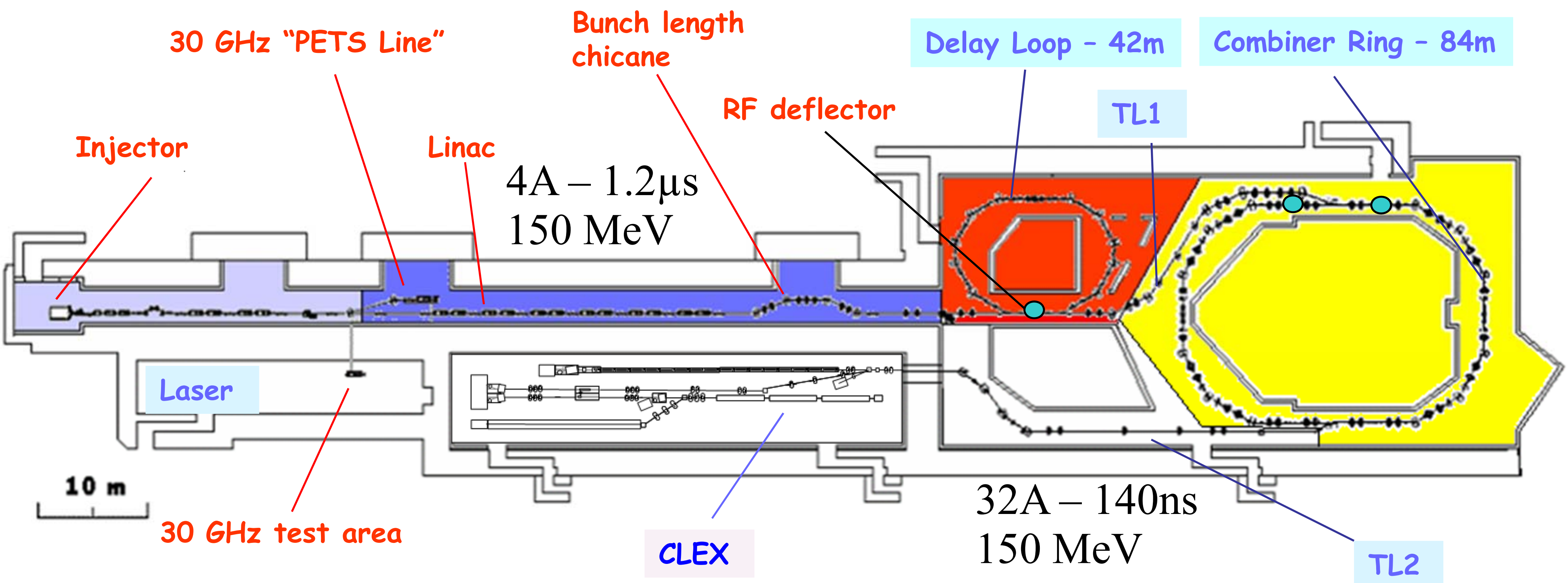
- combination factors up to 5 reachable in a ring

$$C_{ring} = (n + ¼)\ \lambda$$

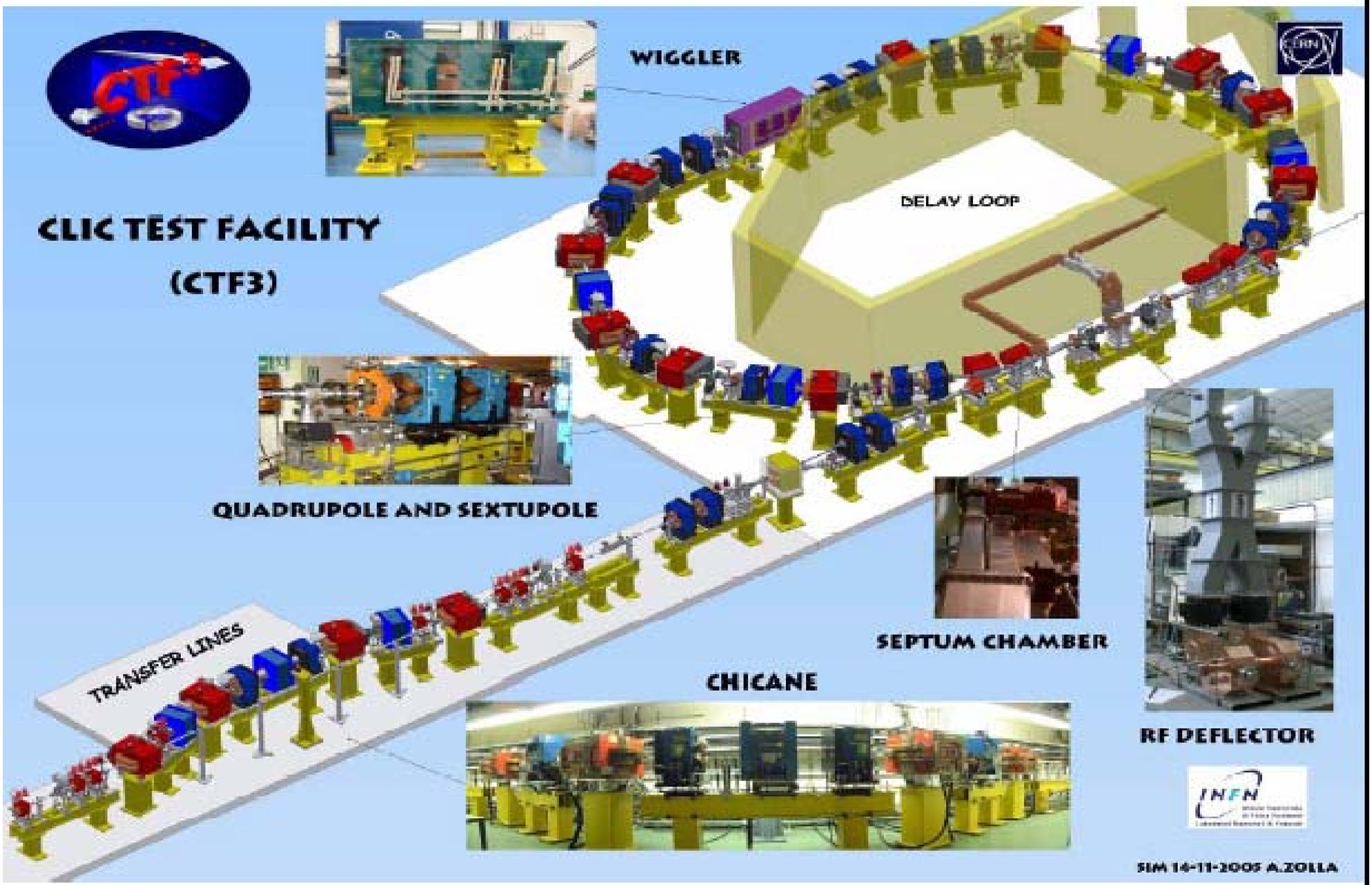


CTF 3

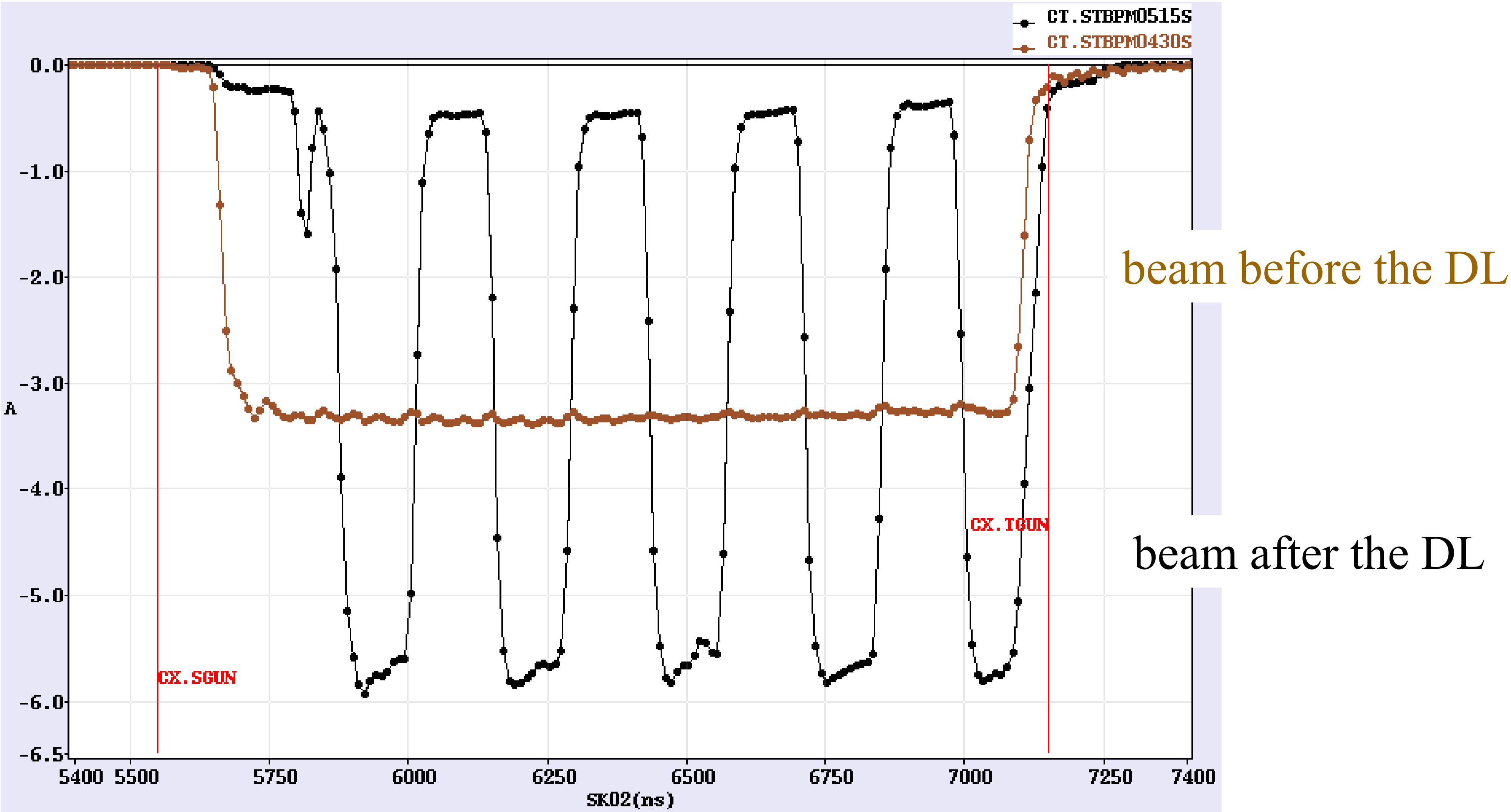
- demonstrate remaining CLIC feasibility issues, in particular:
  - Drive Beam generation (fully loaded acceleration, bunch frequency multiplication)
  - CLIC accelerating structures
  - CLIC power production structures (PETS)



CTF3 Delay Loop



Delay Loop – full recombination

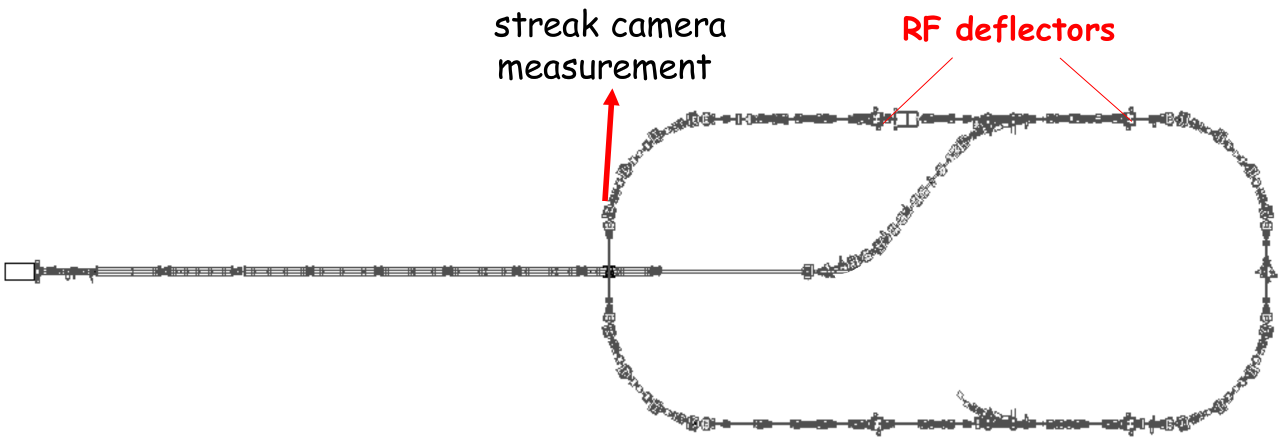


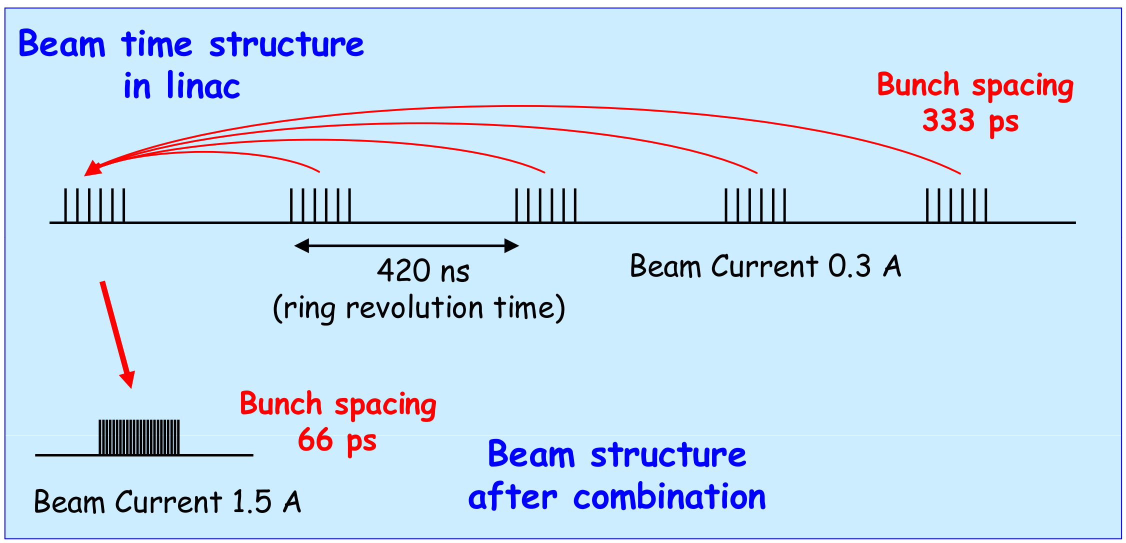
- 3.3 A after chicane => < 6 A after combination (satellites)

Demonstration of RF recombination

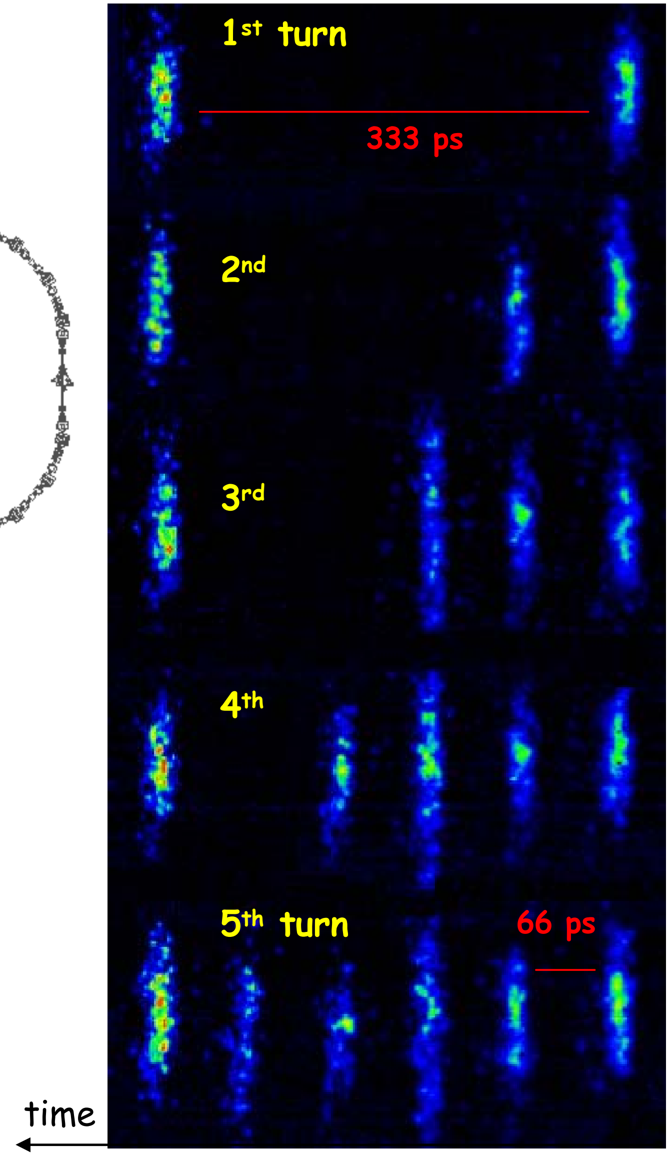
CTF3 - PRELIMINARY PHASE

Successful low-charge demonstration of electron pulse combination and bunch frequency multiplication by up to factor 5

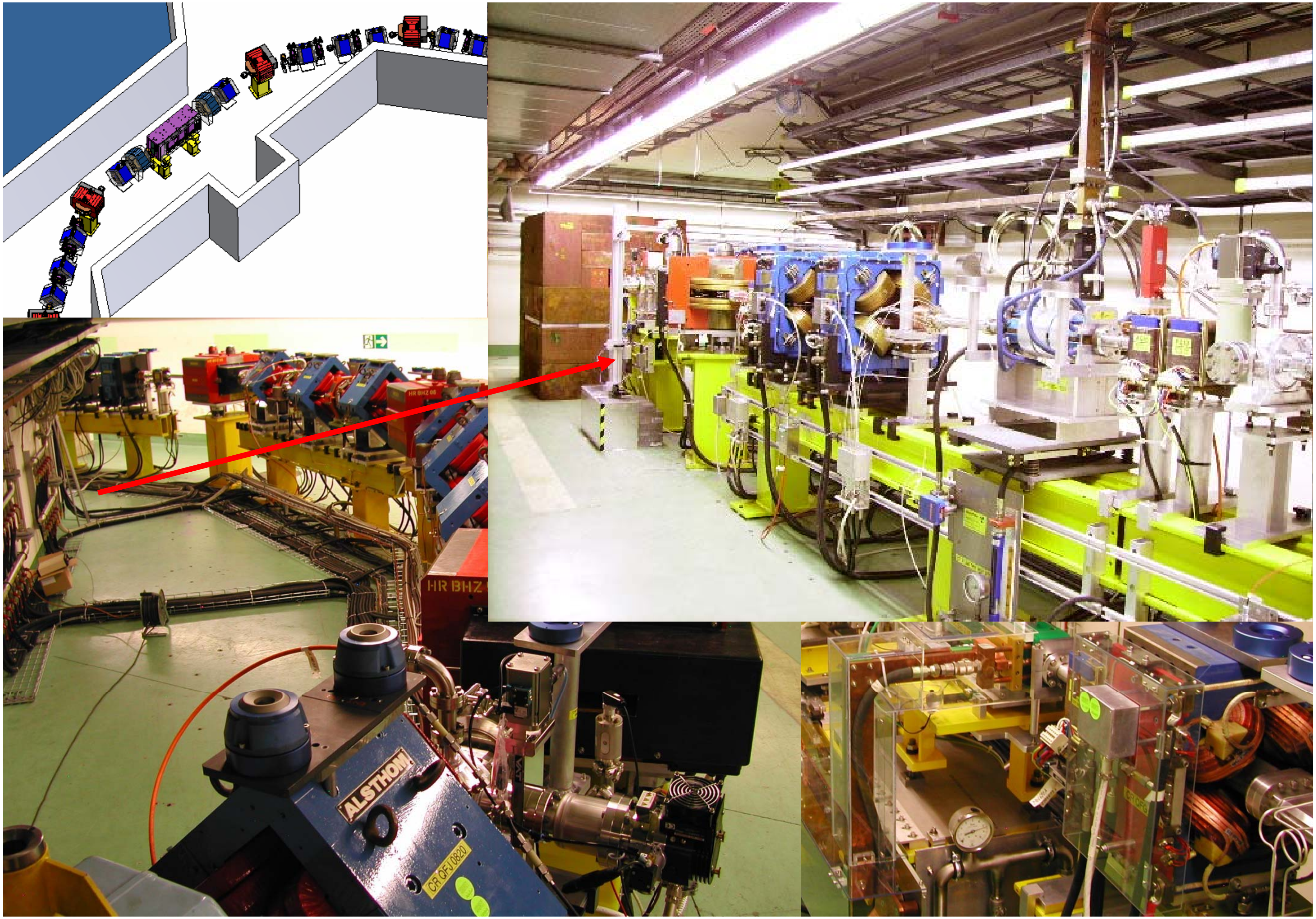




Streak camera image of
beam time structure evolution

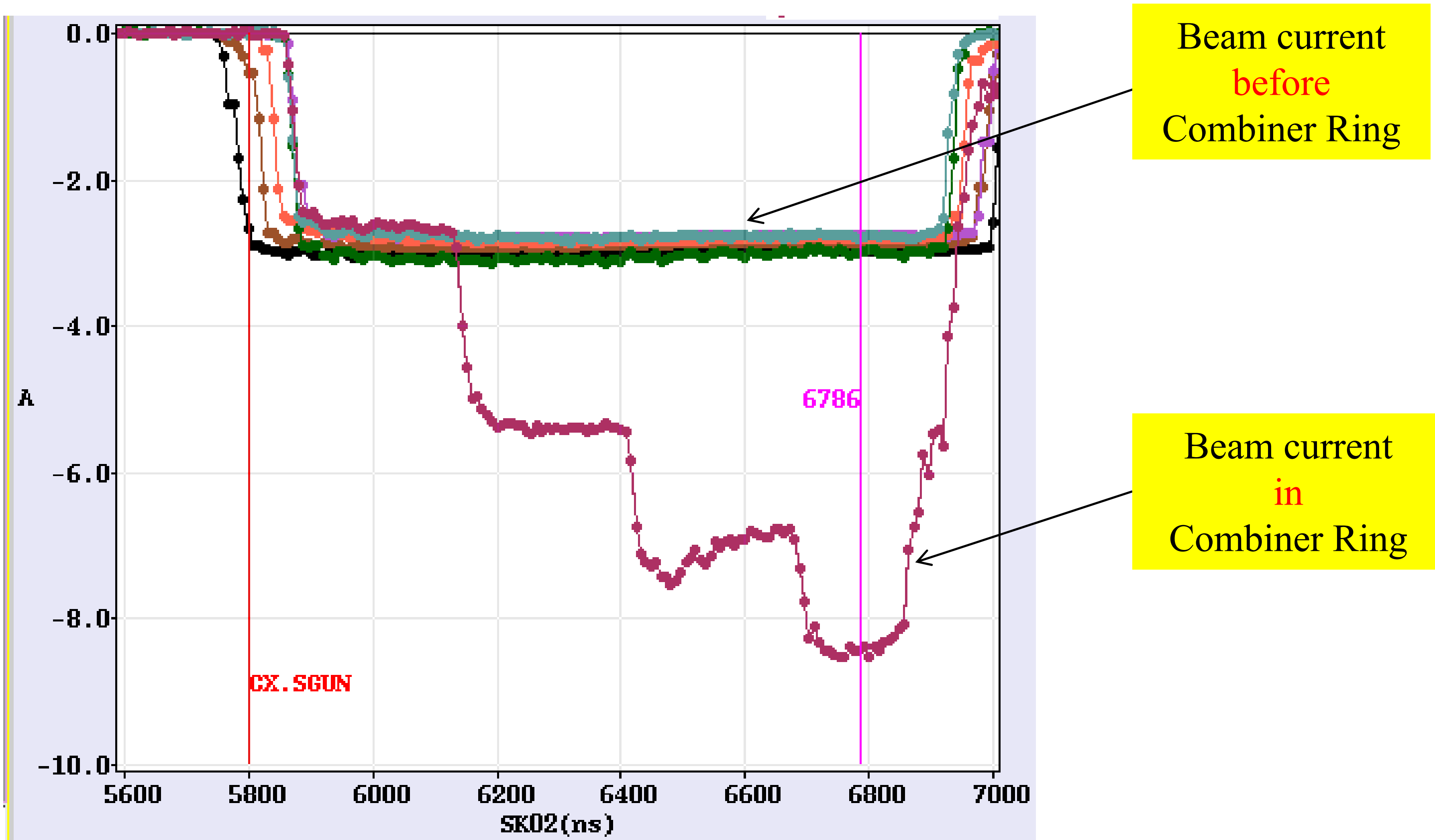


CTF3 combiner ring

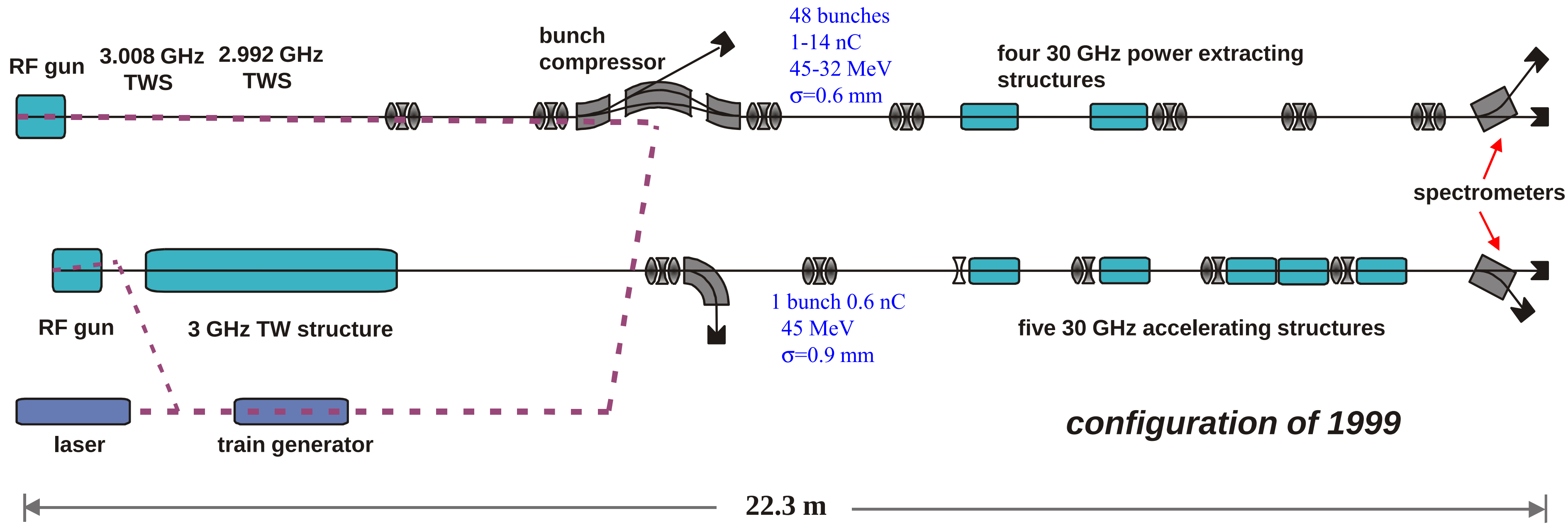


CTF3 Combiner Ring Status

- First recombination at higher current achieved



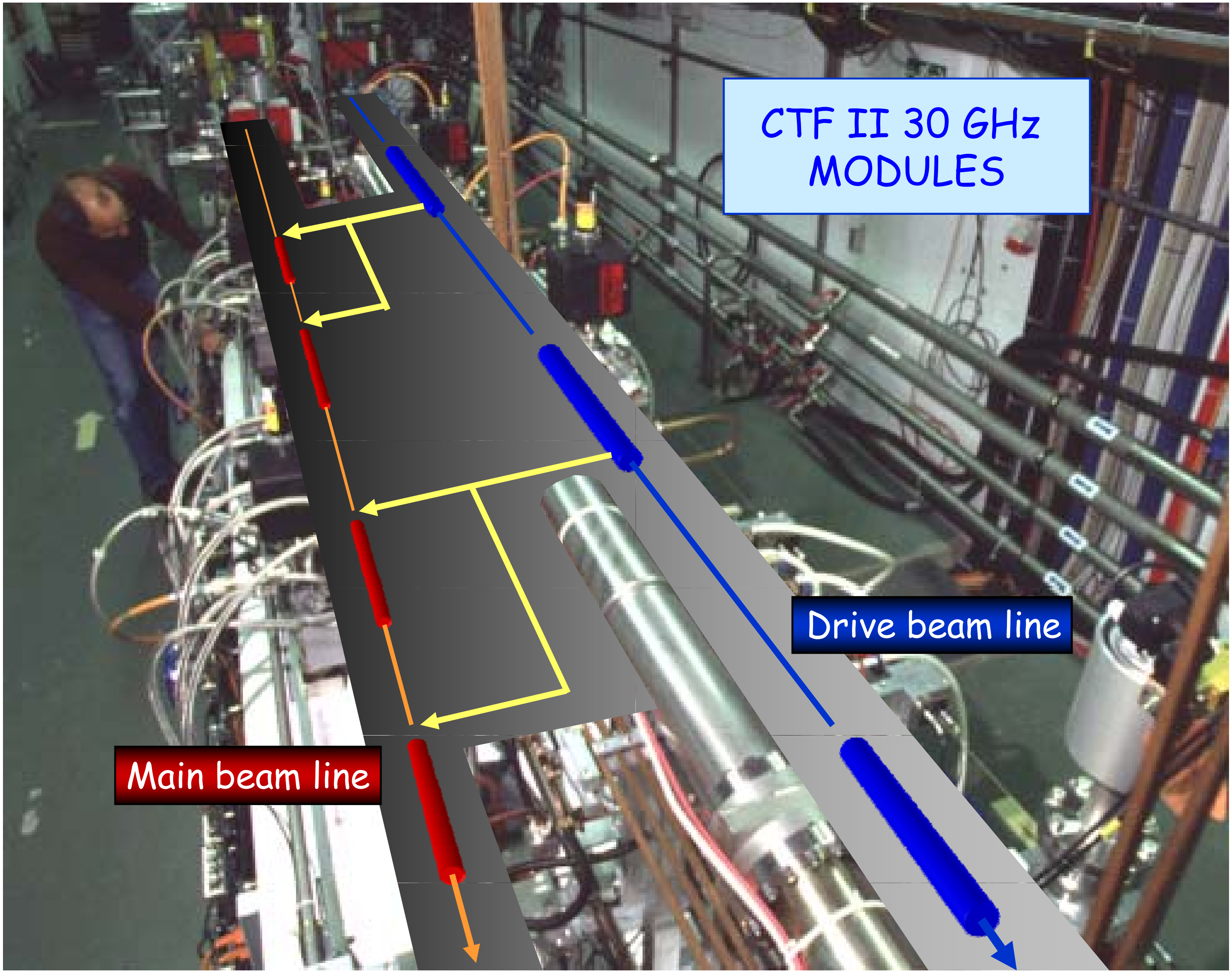
CLIC Test Facility CTF II



Dismantled in 2002, after having achieved its goals :

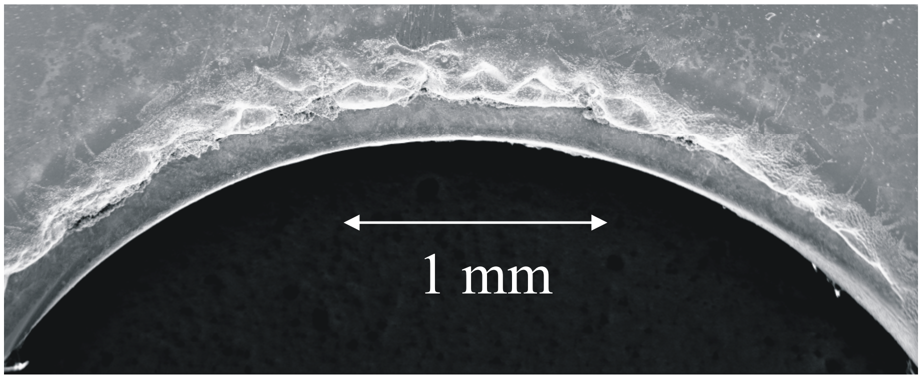
- Demonstrate feasibility of a two-beam acceleration scheme
- Provide high power 30 GHz RF source for high gradient testing (280 MW, 16 ns pulses)
- Study generation of short, intense e-bunches using photocathode RF guns
- Demonstrate operability of μ-precision active-alignment system in accelerator environment
- Provide a test bed to develop and test accelerator diagnostic equipment

CLIC Test Facility CTF II

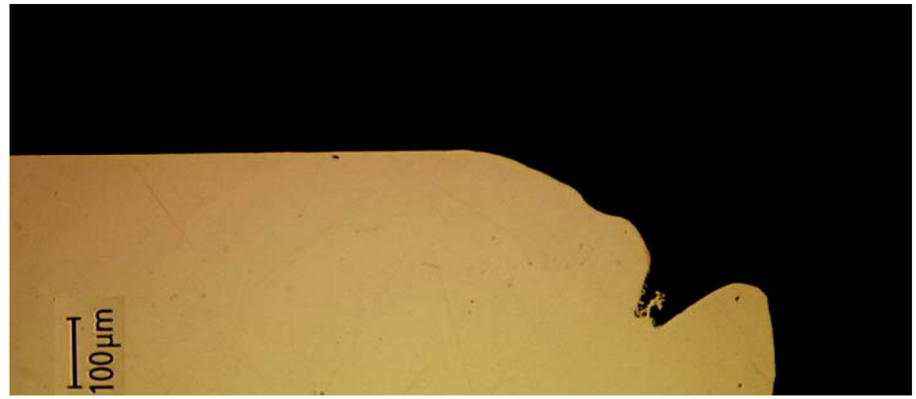


Structure breakdown and damages

- Cu structures limited to surface fields of 300-400 MV/m
- Severe surface damage noticed

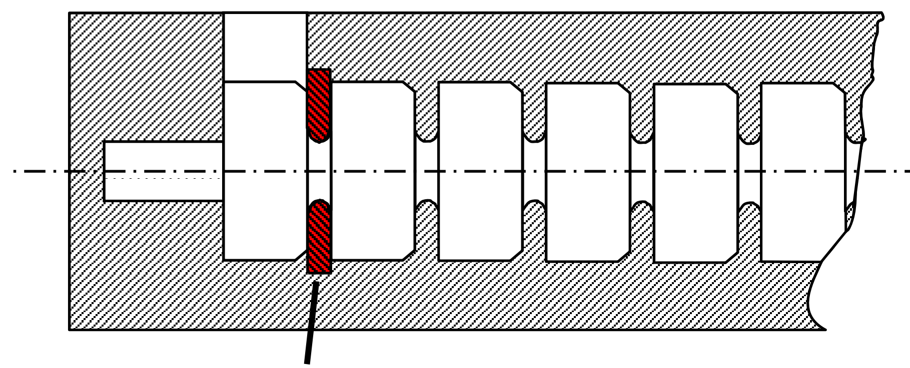


Microscopic image of damaged iris



Damaged iris – longitudinal cut

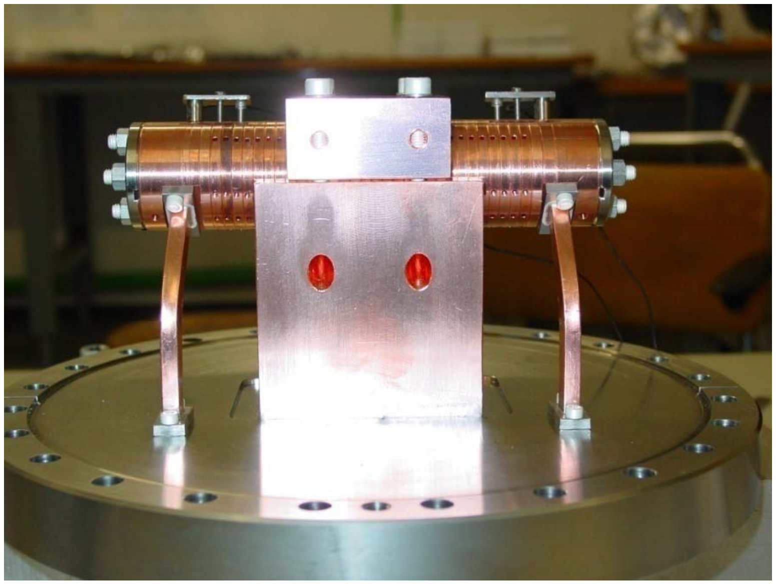
- Two-pronged approach:
  - modify RF design geometry => lower Es/Ea ~ 2
  - investigate new iris material



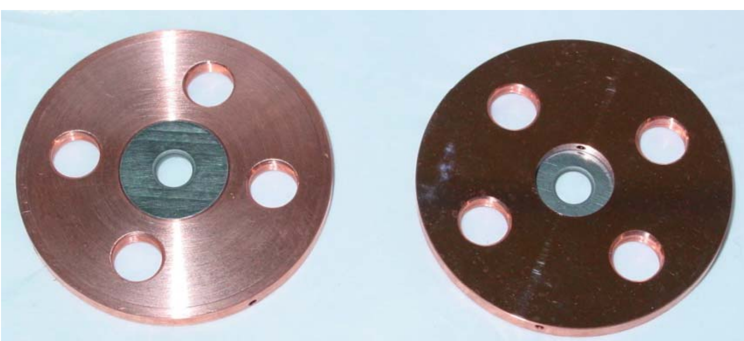
Copper iris replaced by Tungsten iris

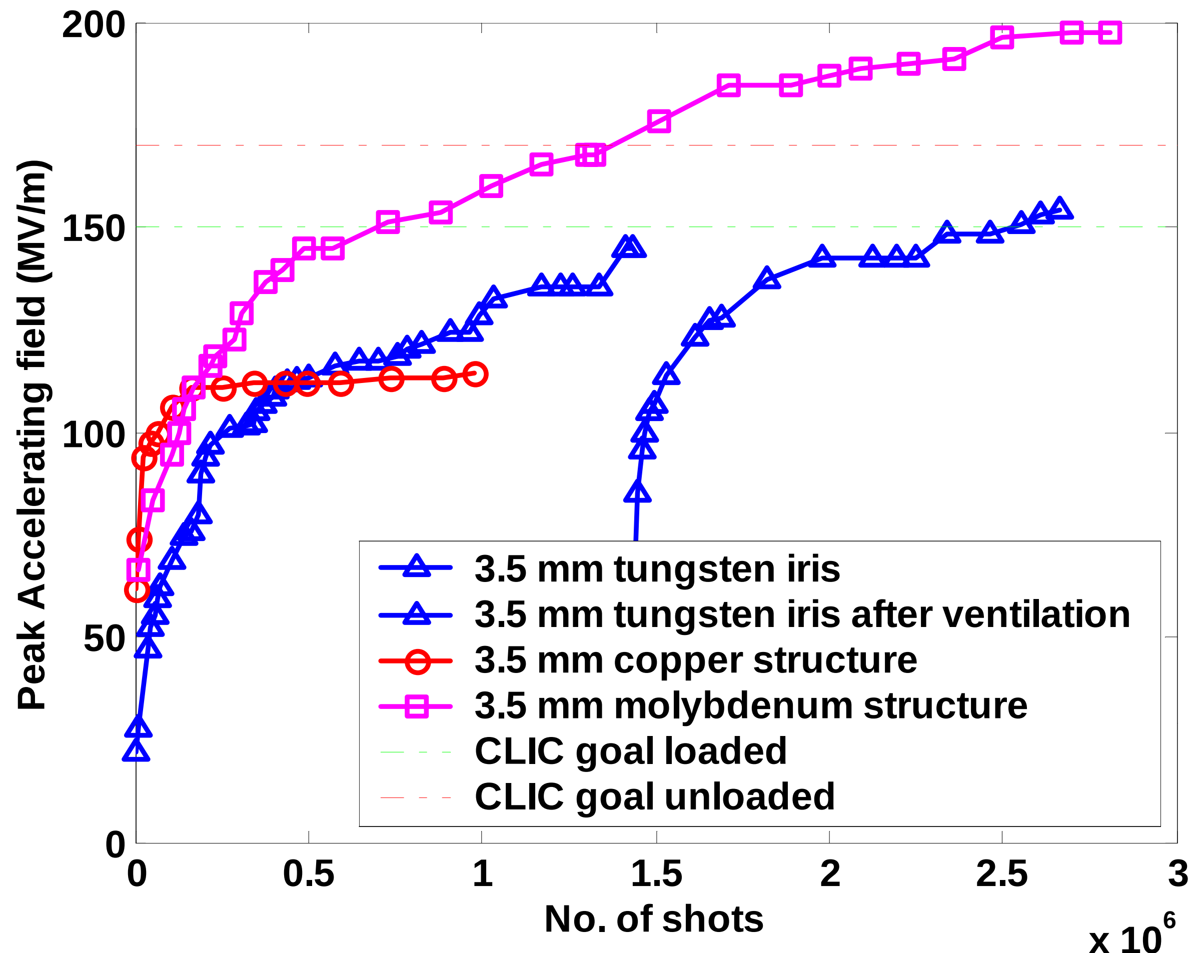
Achieved accelerating fields in CTF2

High gradient tests of 30 GHz structures with molybdenum irises reached 190 MV/m peak accelerating gradient without any damage well above the nominal CLIC accelerating field of 150 MV/m but with RF pulse length of 16 ns only (nominal 160 ns)



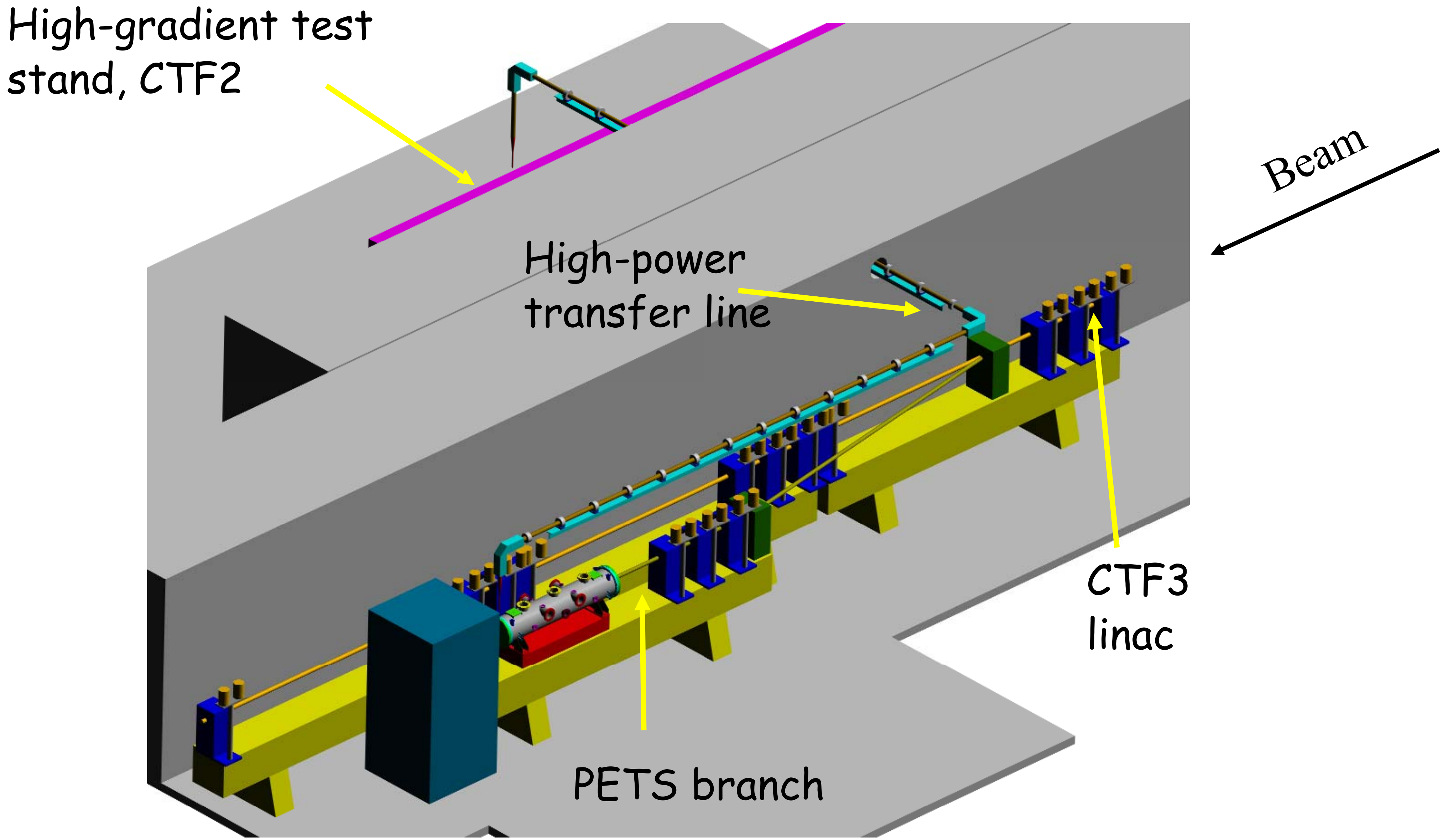
30 cell clamped tungsten-iris structure





A world record !!!

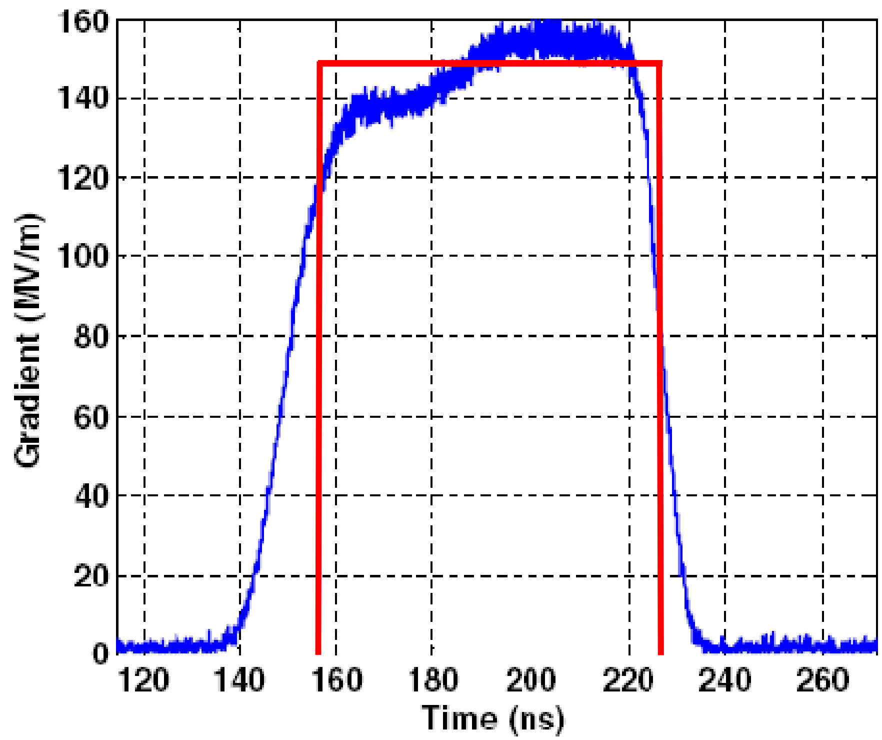
30 GHz test line in CTF3



30 GHz structure testing

- 150 MV/m peak for ~ 70 ns (but breakdown rate too high)

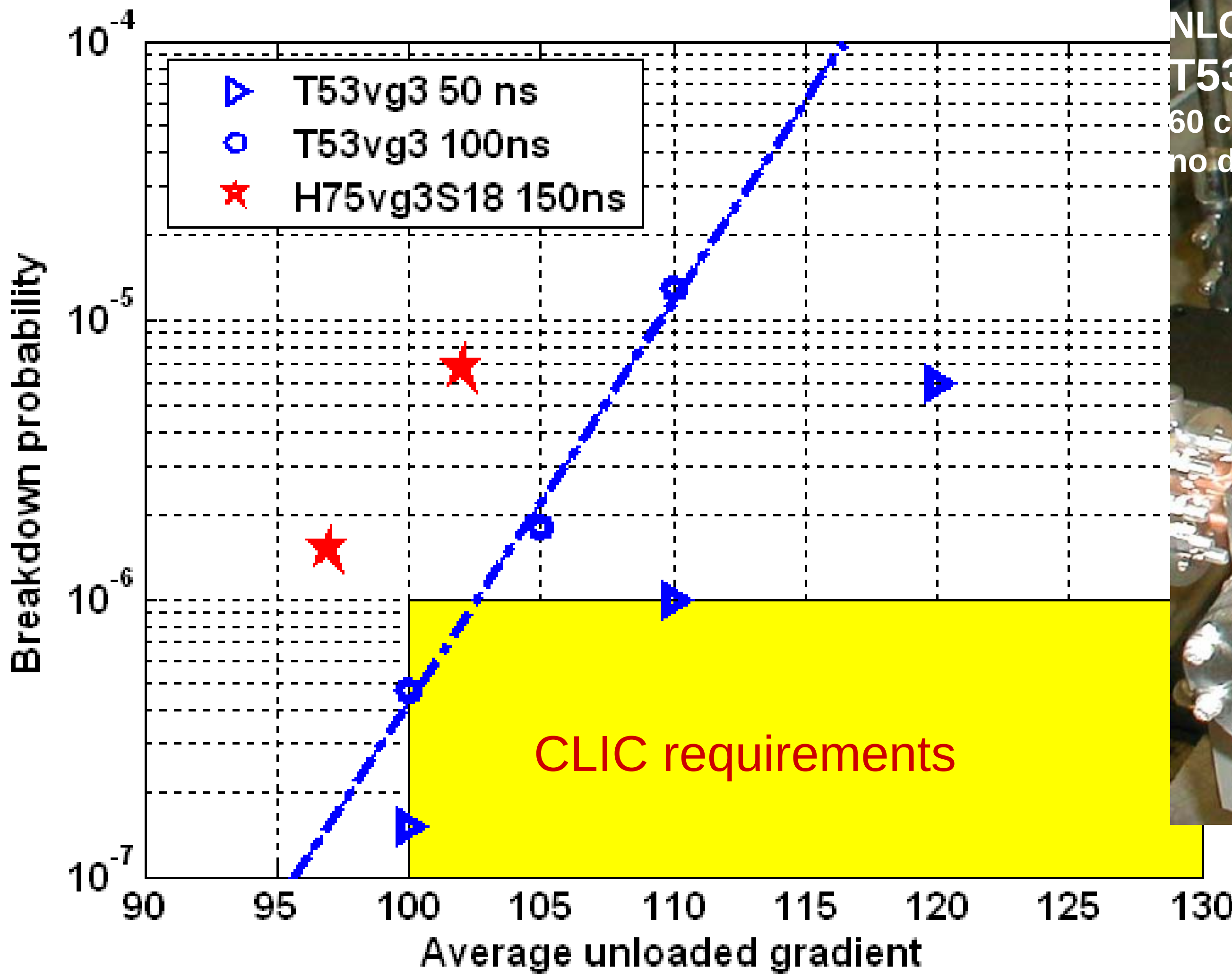
- breakdown behaviour not yet understood:
  - physics background
  - dependence on
    - field/power/energy
    - time
    - material

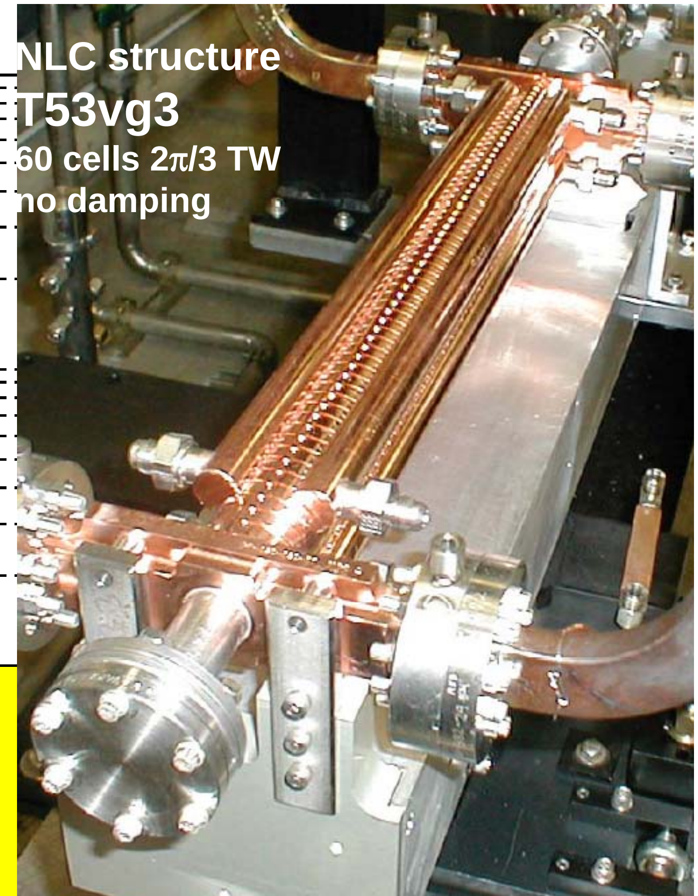


- intensive test program ongoing

11.4 GHz High-Power test results

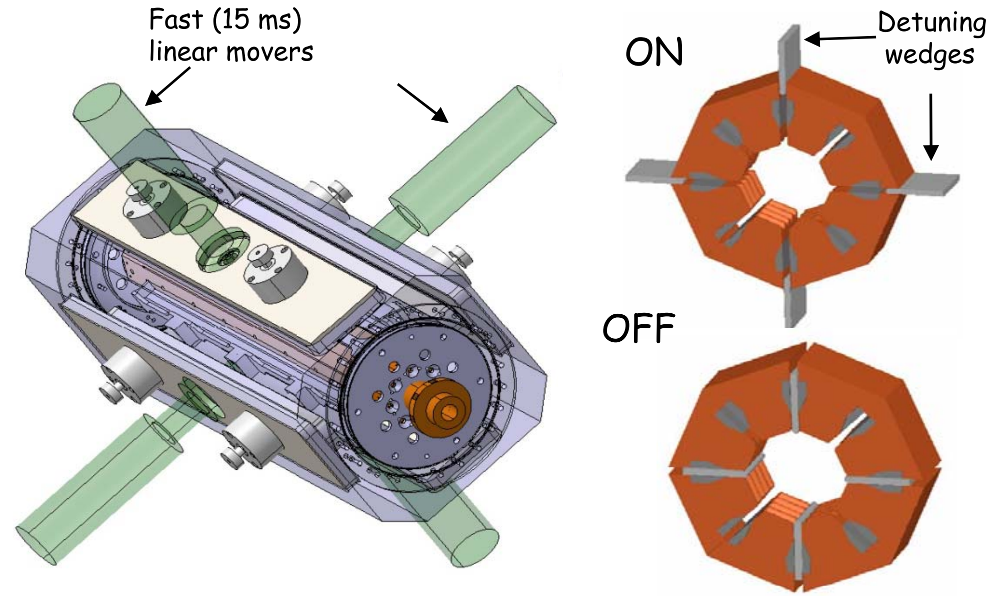
Recent SLAC High-Power test results – 11.4 GHz



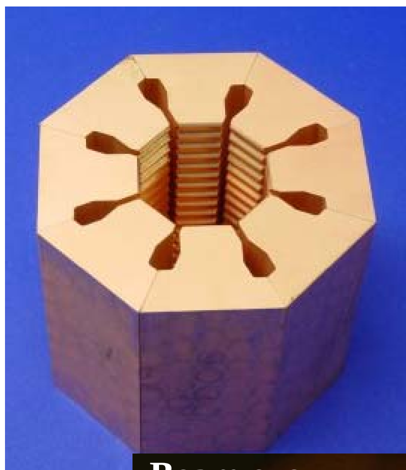


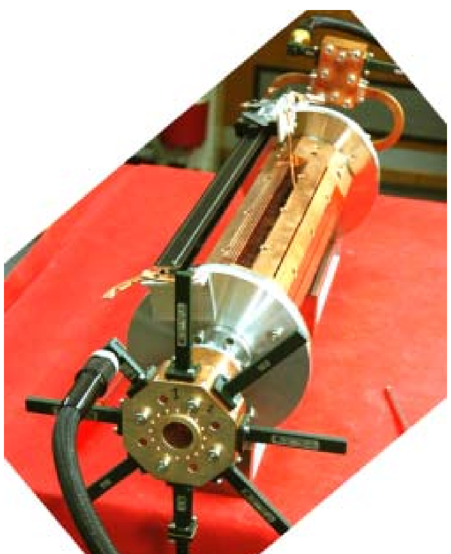
Power extraction structure PETS

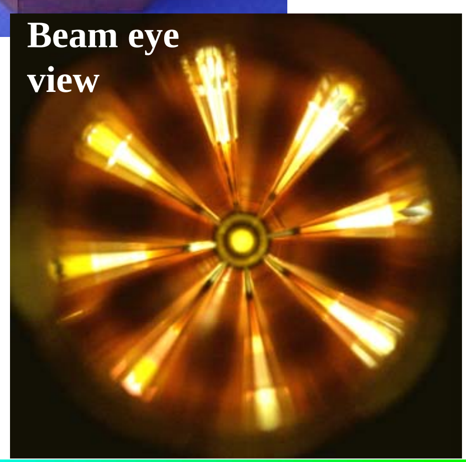
- must extract efficiently several 100 MW power from high current drive beam
- periodically corrugated structure with low impedance (big a/λ)
- ON/OFF mechanism

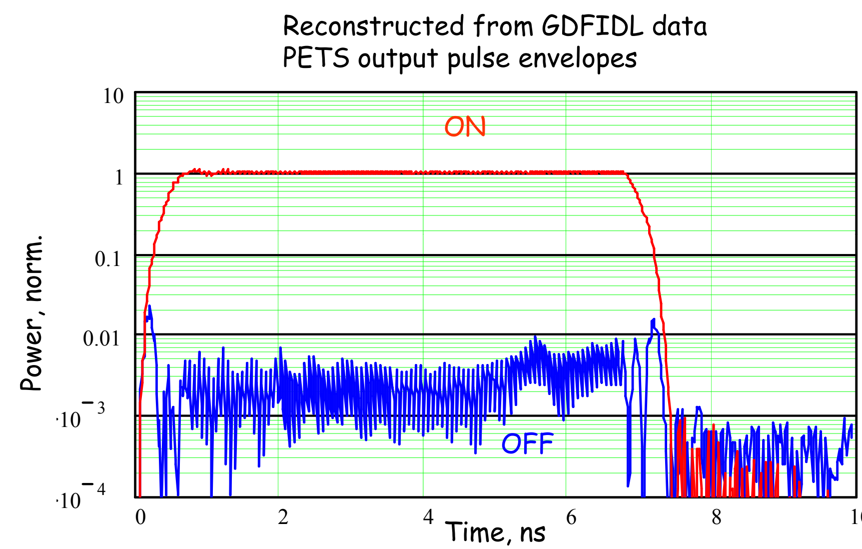


PETS ON/OFF mechanism



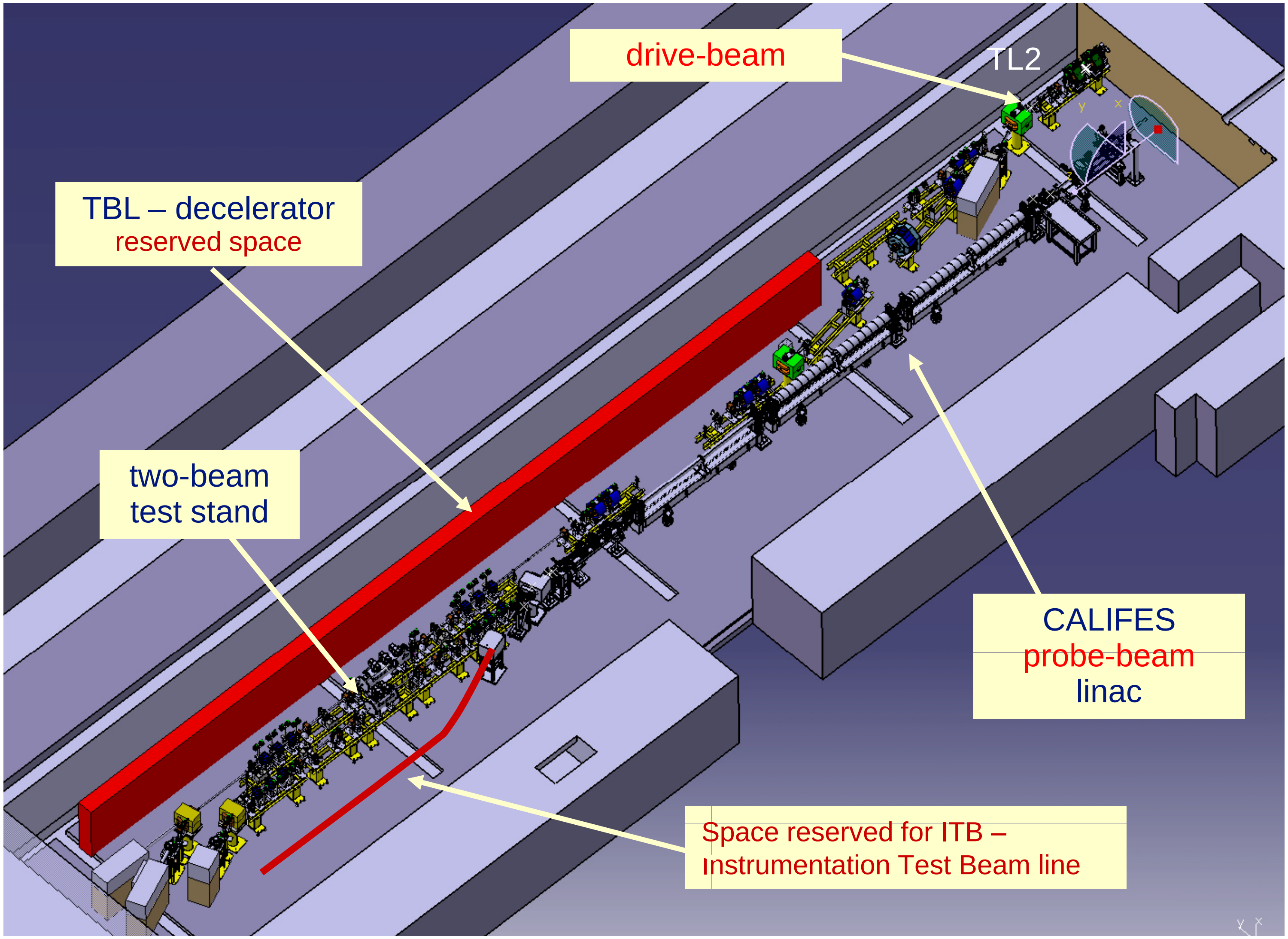






CLEX test area

- Deceleration and two-beam tests
- Test of PETS and accelerating structures at high power



Conclusions

- CTF3 is to show the CLIC feasibility until 2010
  - stable Drive Beam generation
  - high gradient RF performance
- many important results obtained so far
- key issues still to demonstrate
- challenging but very interesting

- next: Visit to CTF3