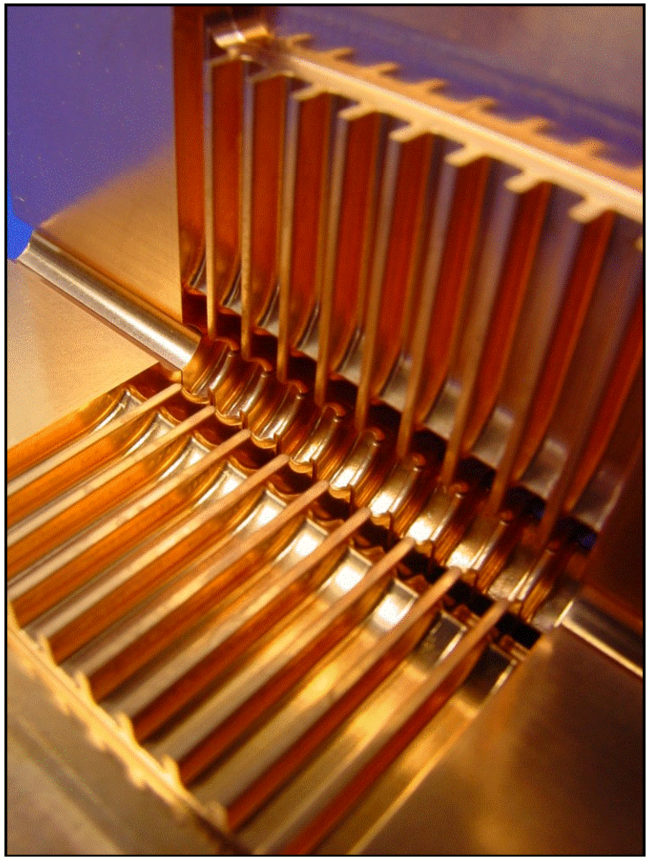
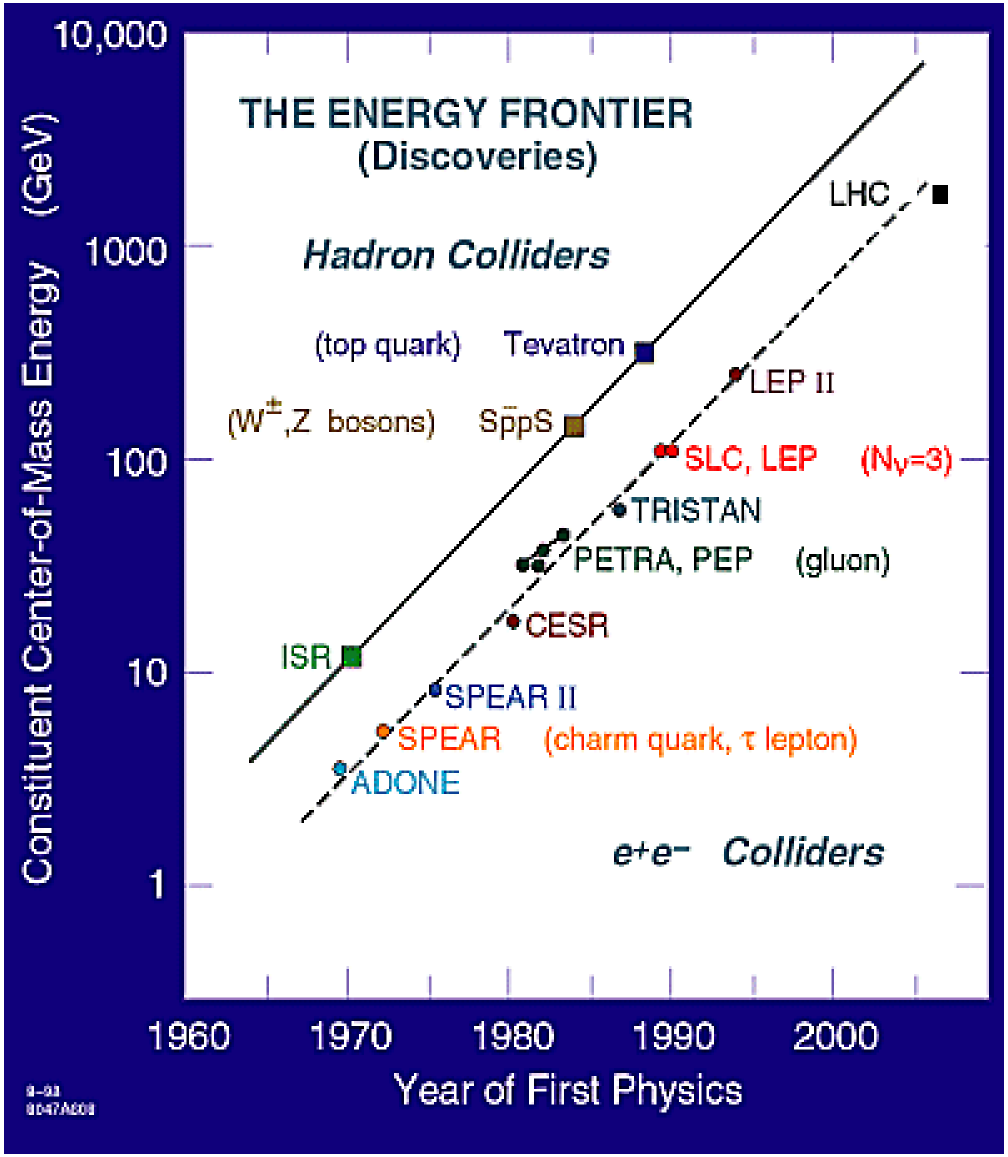
CLIC / CTF 3

Frank Tecker - BE/OP

- Introduction CLIC / CTF 3
- Visit of CTF3



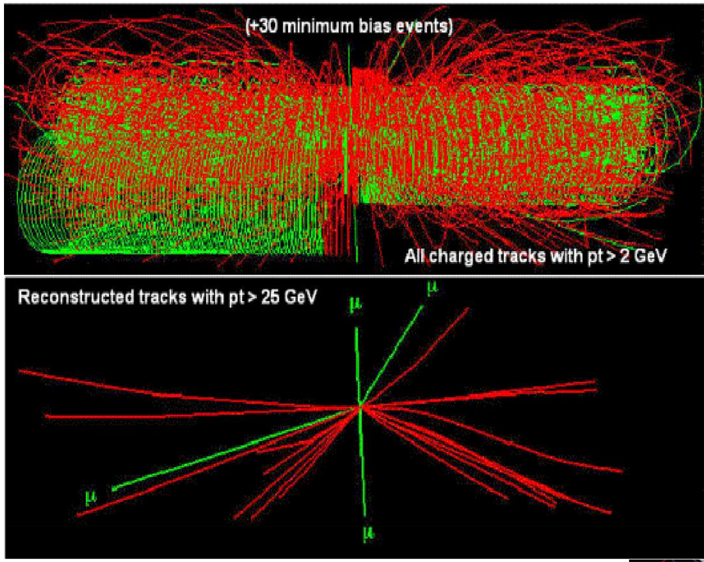
Path to higher energy

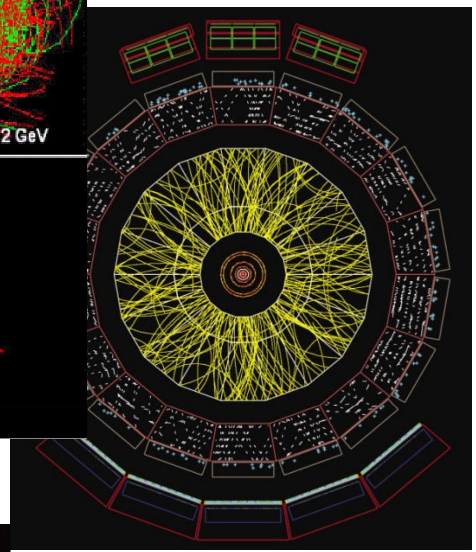


- History:
  - Energy constantly increasing with time
  - Hadron Collider at the energy frontier
  - Lepton Collider for precision physics
- LHC coming online soon
- Consensus to build Lin. Collider with $E_{cm} > 500$ GeV to complement LHC physics (*European strategy for particle physics* by CERN Council)

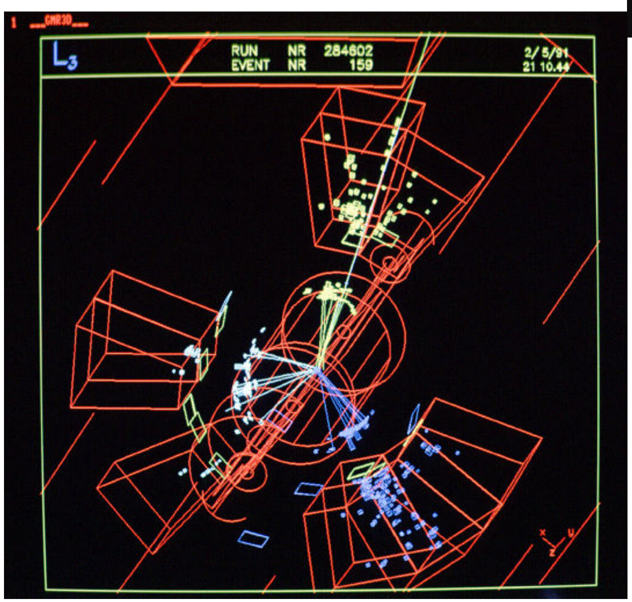
Lepton vs. Hadron Collisions

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



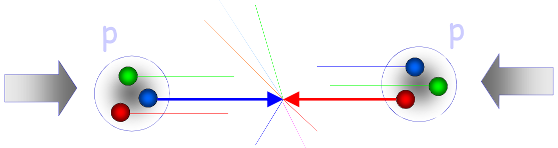


ALICE:
Ion event



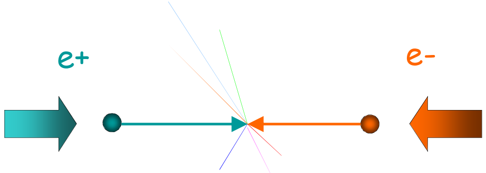
LEP event:
$Z^0 \rightarrow$ 3 jets

- Hadron Collider (p, ions):



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

- Lepton Collider:



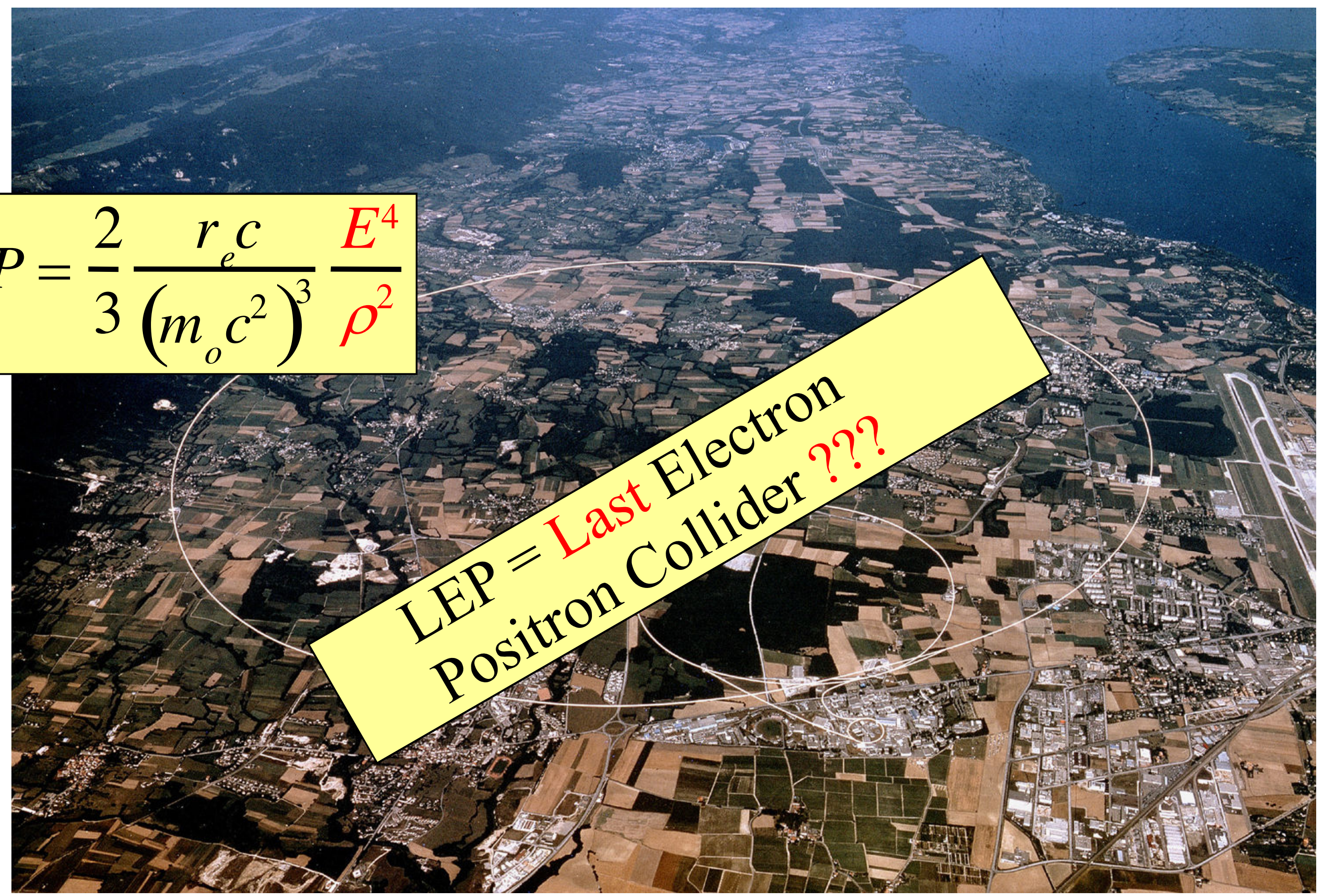
  - Elementary particles
  - Well defined initial state
  - Beam polarization
  - produces particles democratically
  - Momentum conservation eases decay product analysis

The LEP collider

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

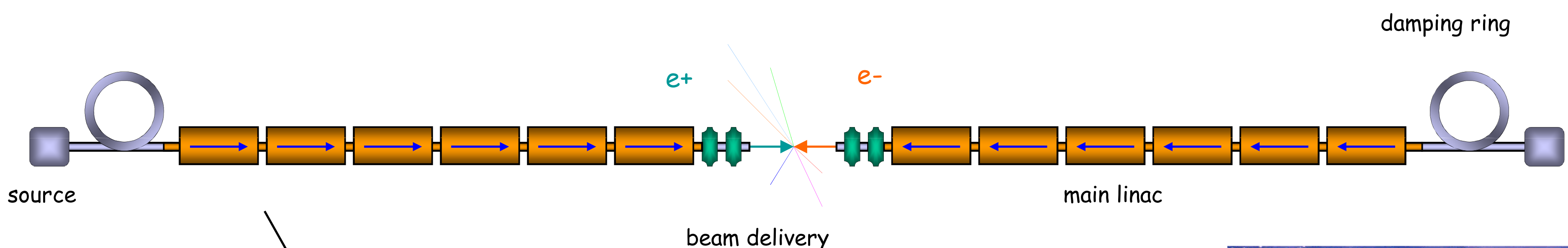
- Problem for any ring:
  Synchrotron radiation
- Emitted power:
  scales with E^4 !!
  and $1/m_0^3$ (much less for heavy particles)
- This energy loss must be replaced by the RF system !!
- particles lost 3% of their energy each turn!

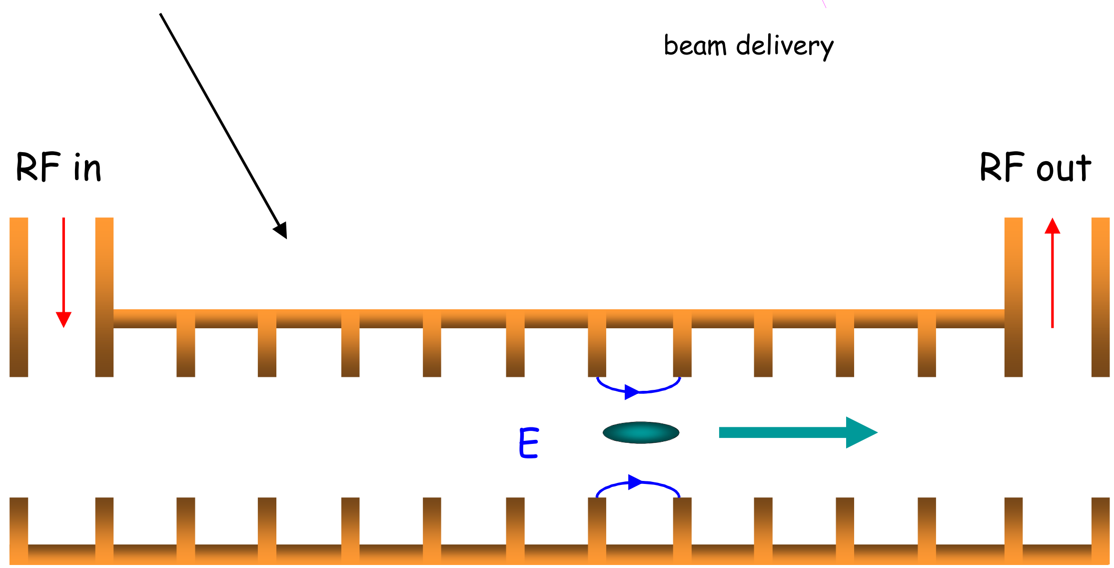
$$P = \frac{2}{3}\frac{r_e c}{\left(m_o c^2\right)^3}\frac{E^4}{\rho^2}$$



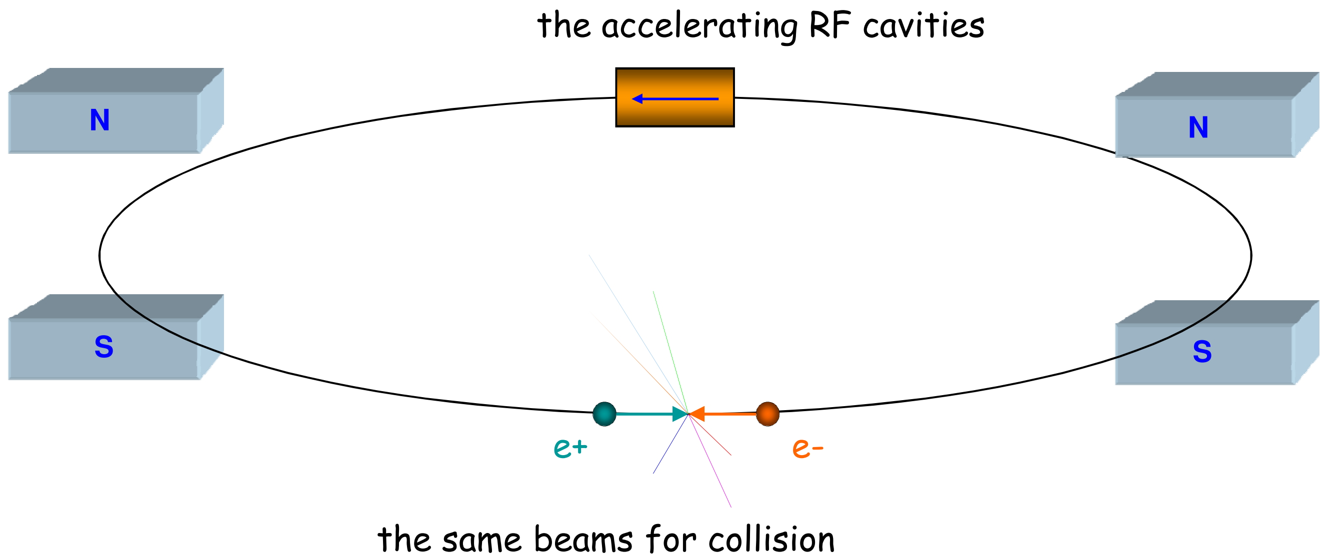
The next lepton collider

- 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

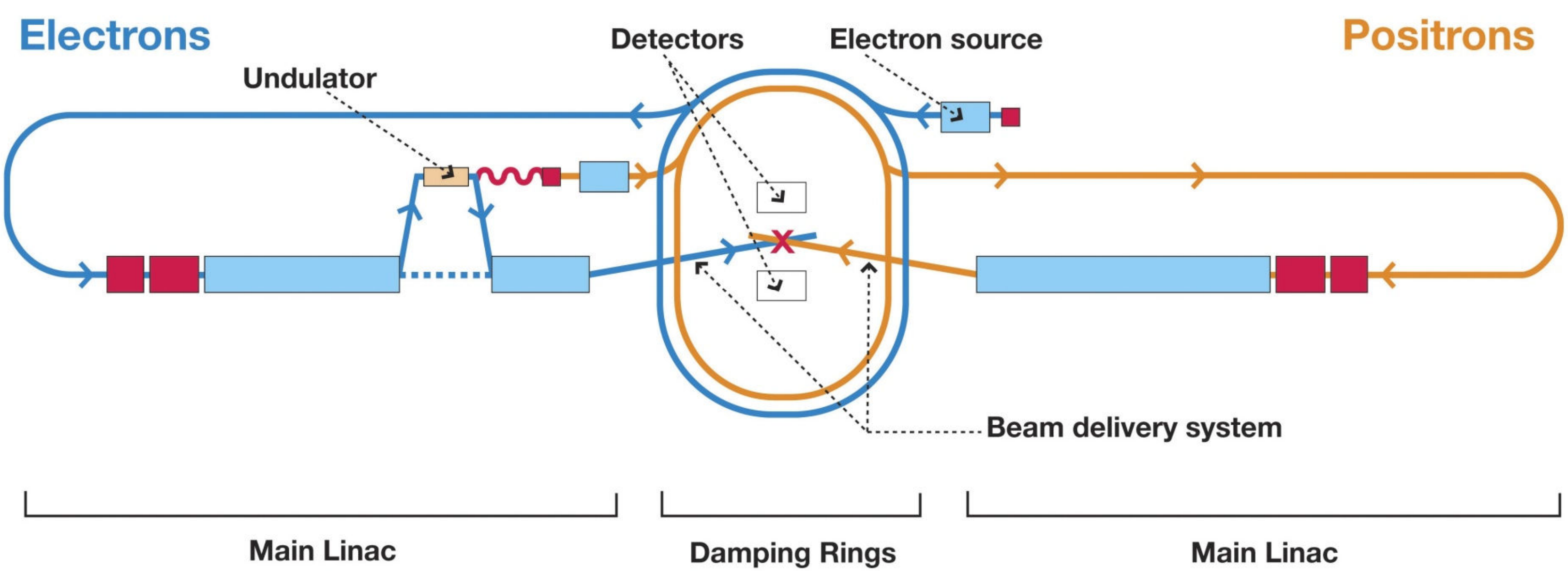
  to reach high event rate (Luminosity)

Linear Collider projects

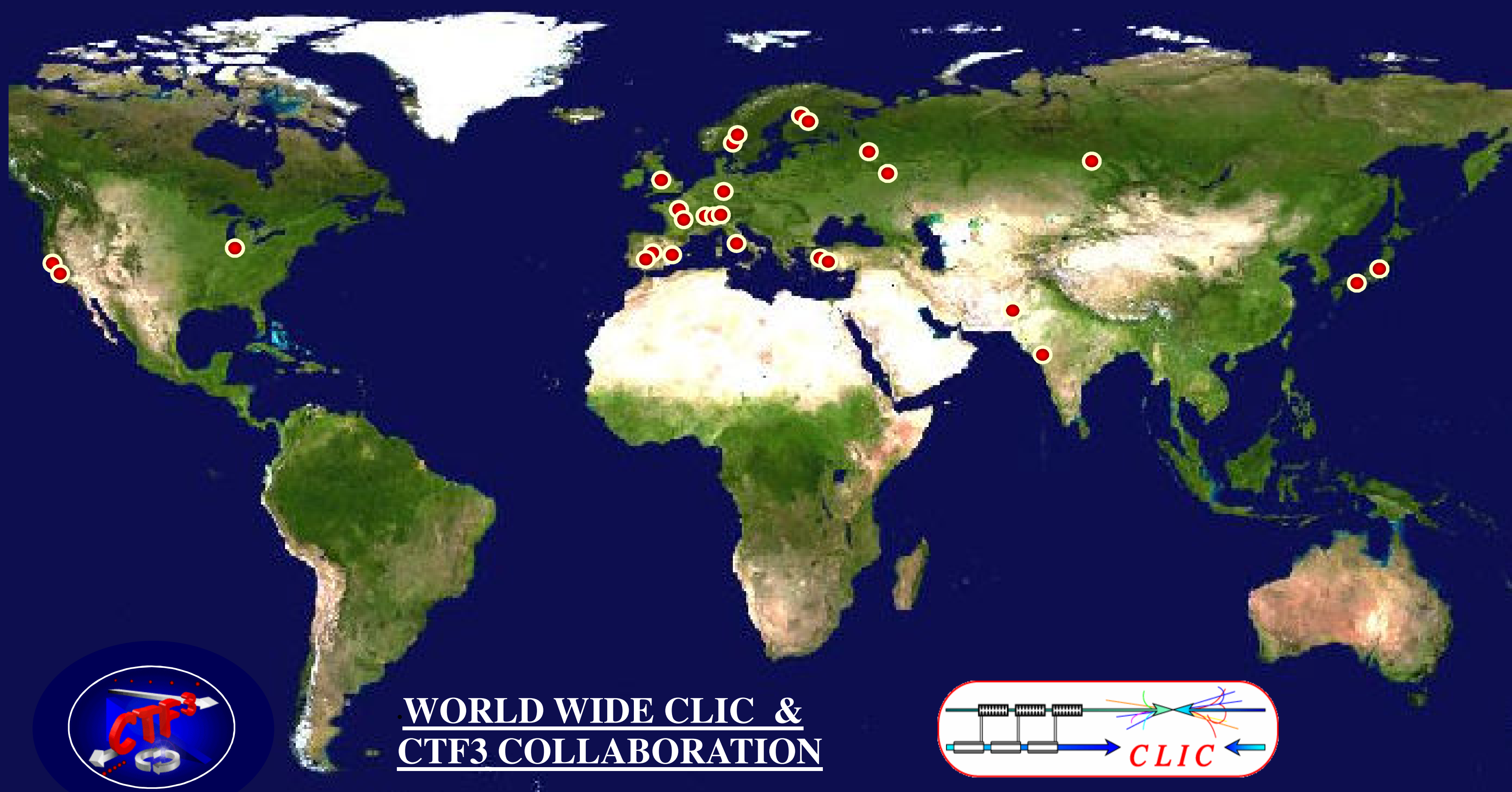
- ILC (International Linear Collider)
  - Technology decision Aug 2004
  - Superconducting technology
  - 1.3 GHz RF frequency
  - ~31 MV/m accelerating gradient
  - 500 GeV centre-of-mass energy
  - upgrade to 1 TeV possible

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

~35 km total length



CLIC-CTF3 Collaboration



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

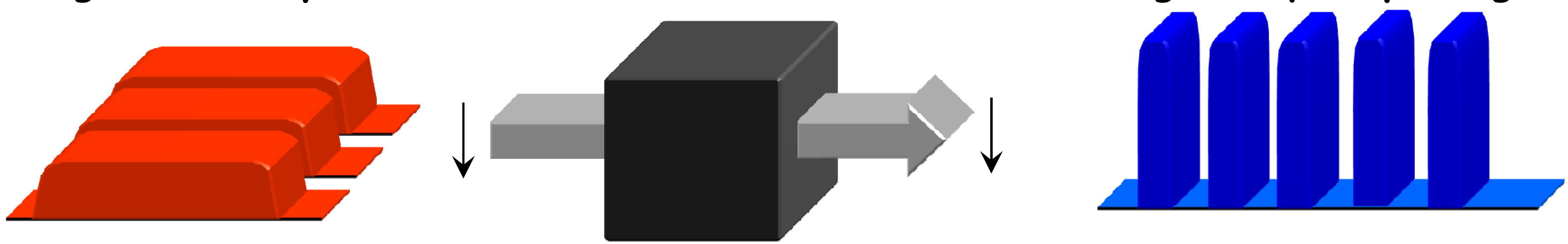
RRCAT-Indore (India)
Finnish Industry (Finland)
Gazi Universities (Turkey)
Helsinki Institute of Physics (Finland)
IAP (Russia)
Instituto de Fisica Corpuscular (Spain)
INFN / LNF (Italy)

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)

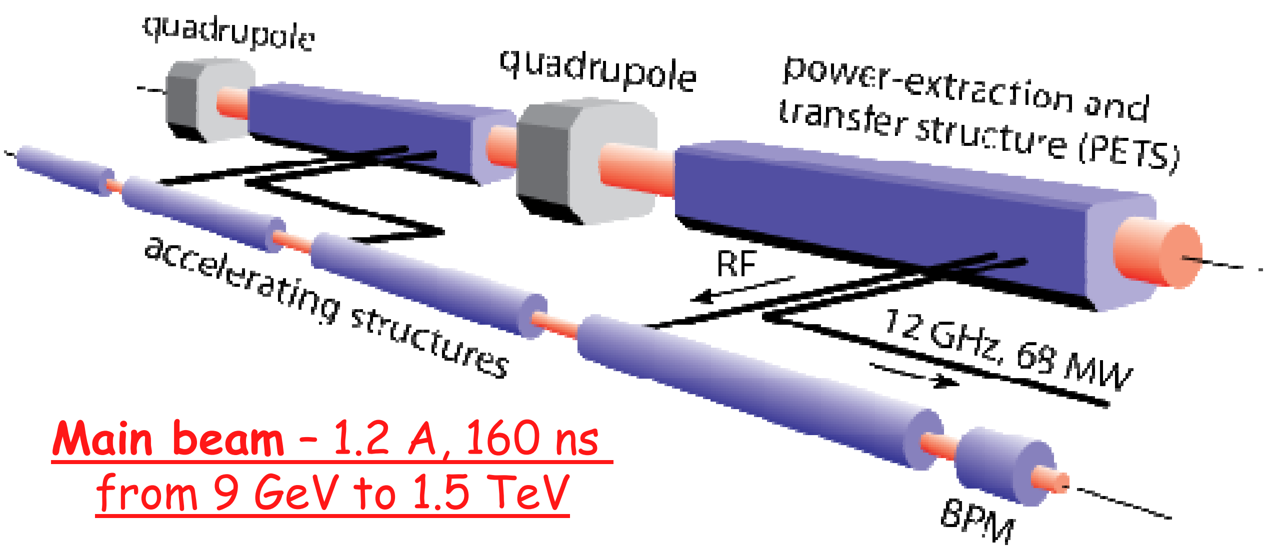


CLIC two beam scheme

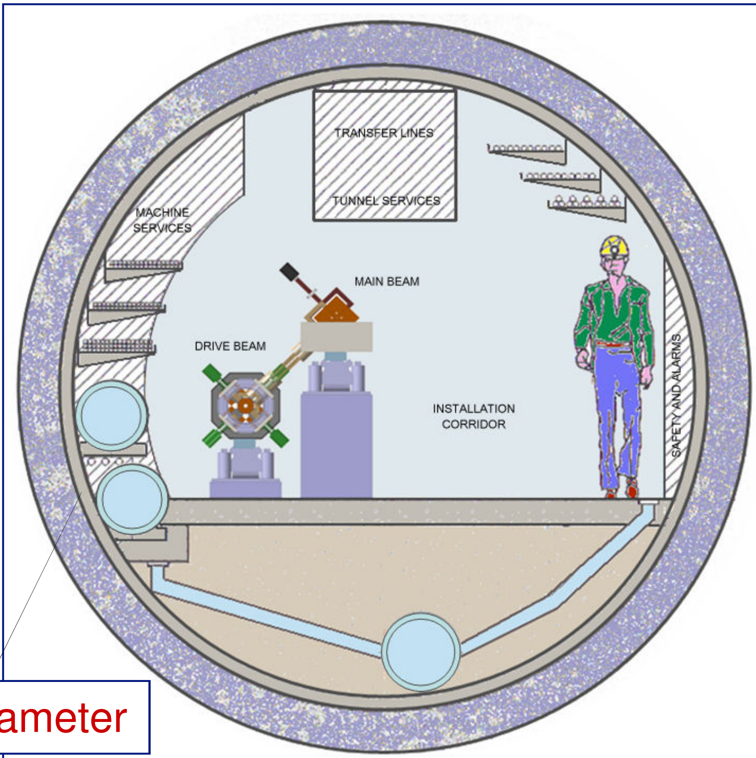
- Two beam acceleration scheme:
  - High charge Drive Beam (low energy)
  - Low charge Main Beam (high collision energy)
- High power for high gradient of >100 MV/m

CLIC TUNNEL CROSS-SECTION

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

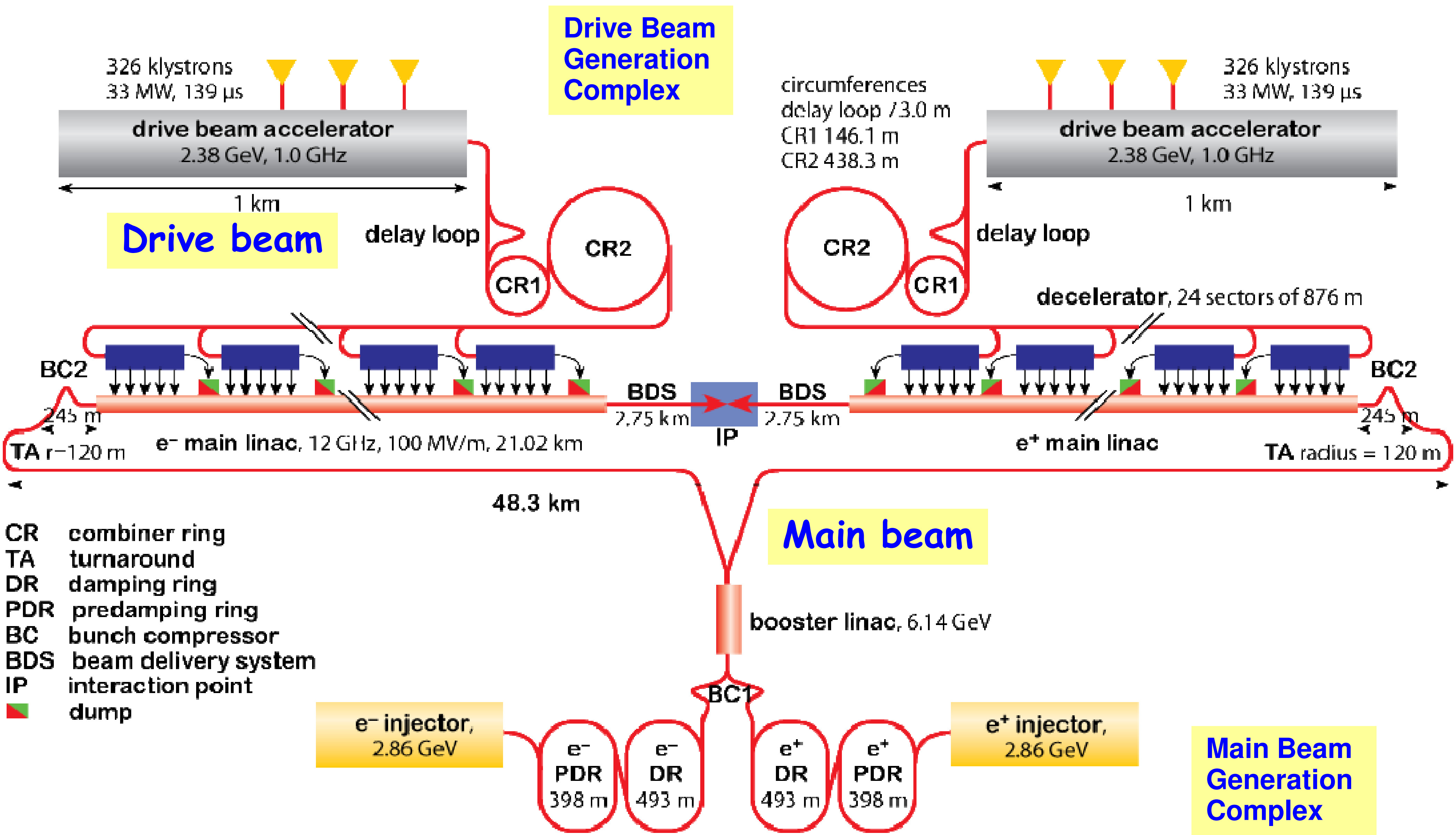


Main beam – 1.2 A, 160 ns
from 9 GeV to 1.5 TeV



4.5 m diameter

CLIC – overall layout – 3 TeV

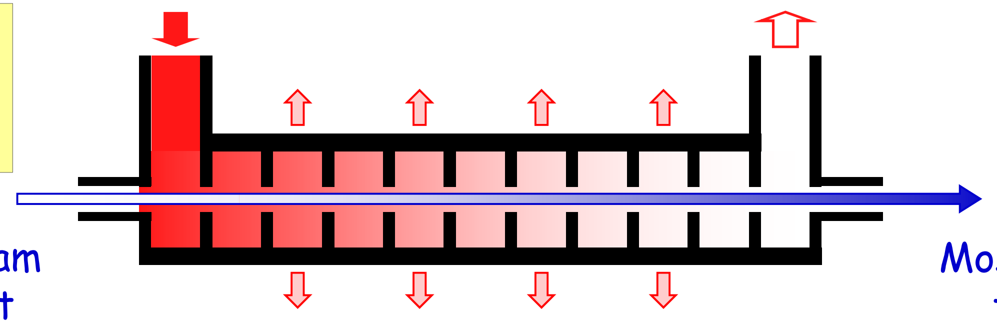


CR	combiner ring
TA	turnaround
DR	damping ring
PDR	predamping ring
BC	bunch compressor
BDS	beam delivery system
IP	interaction point
(red/green square)	dump

Drive beam generation basics

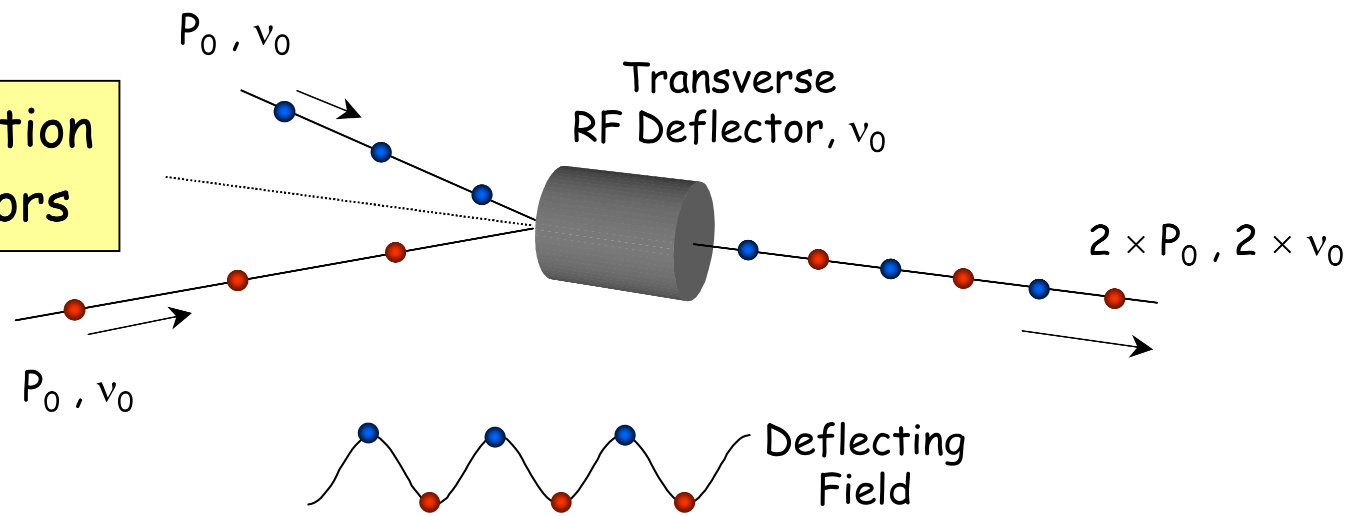
- Efficient acceleration

Full beam-loading acceleration in TW sections

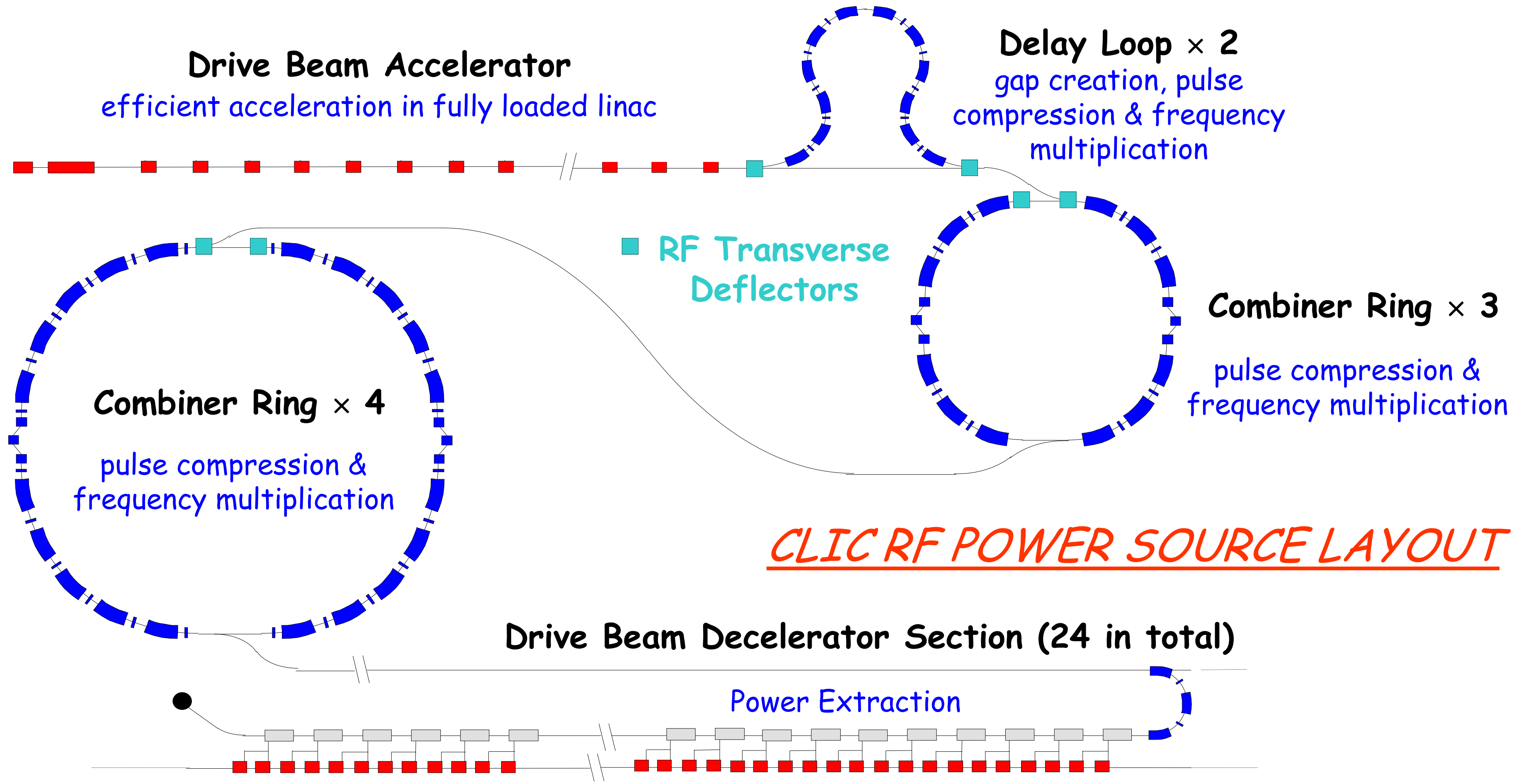


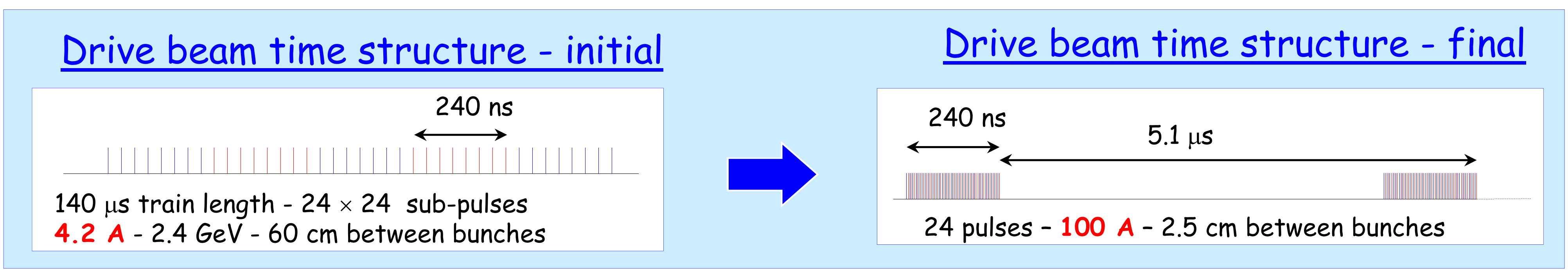
- Frequency multiplication

Beam combination/separation by transverse RF deflectors



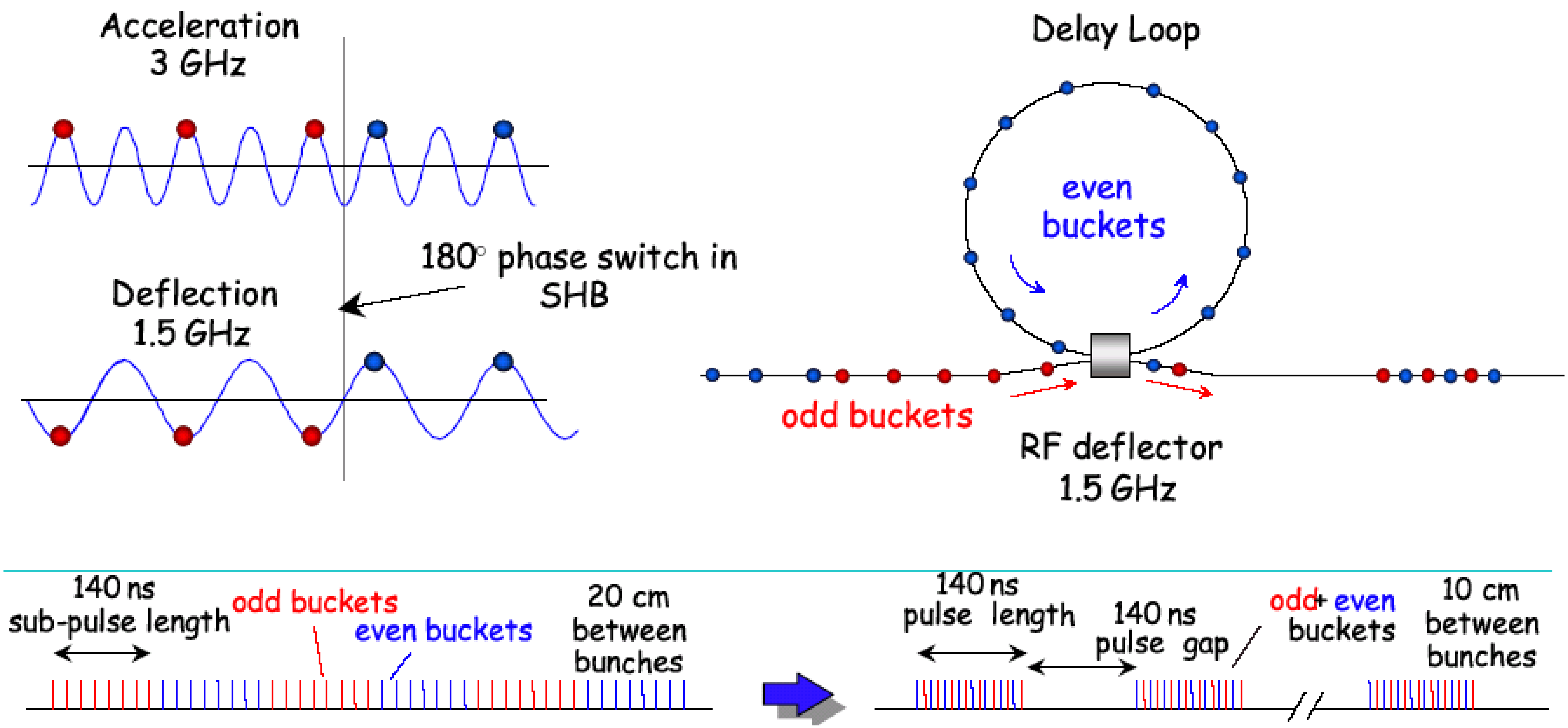
CLIC Drive Beam generation





Delay Loop Principle

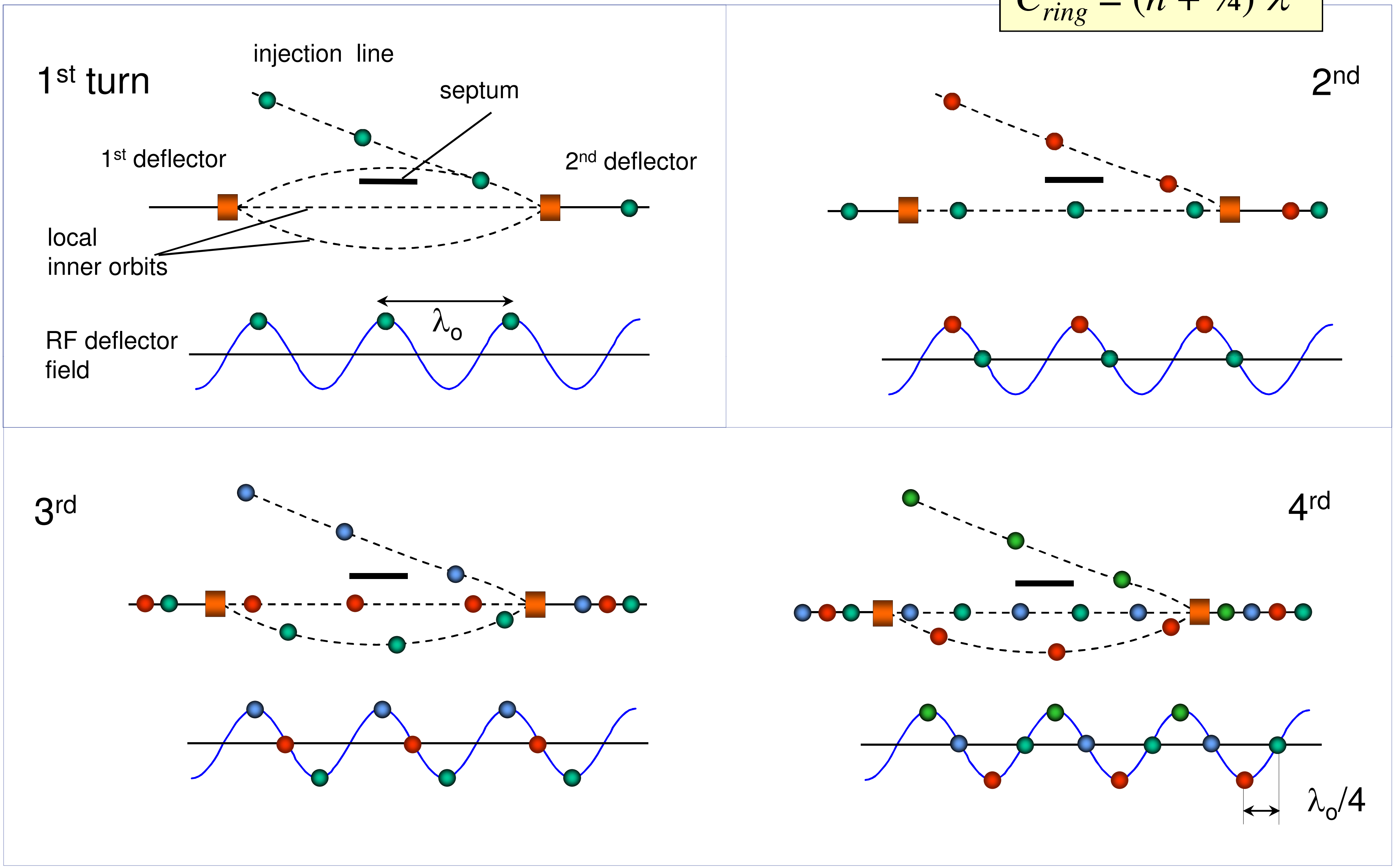
- **double repetition frequency and current**
- parts of bunch train delayed in loop
- RF deflector combines the bunches



RF injection in combiner ring

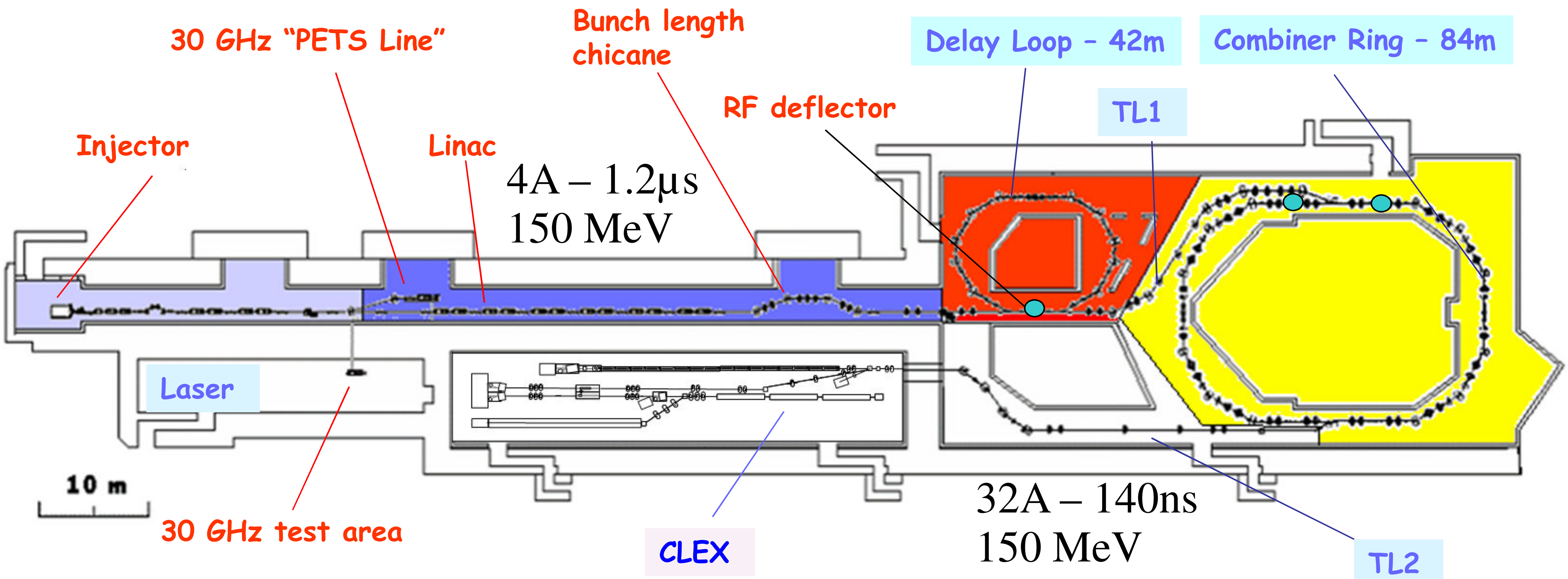
- combination factors up to 5 reachable in a ring

$$C_{ring} = (n + 1/4)\ \lambda$$

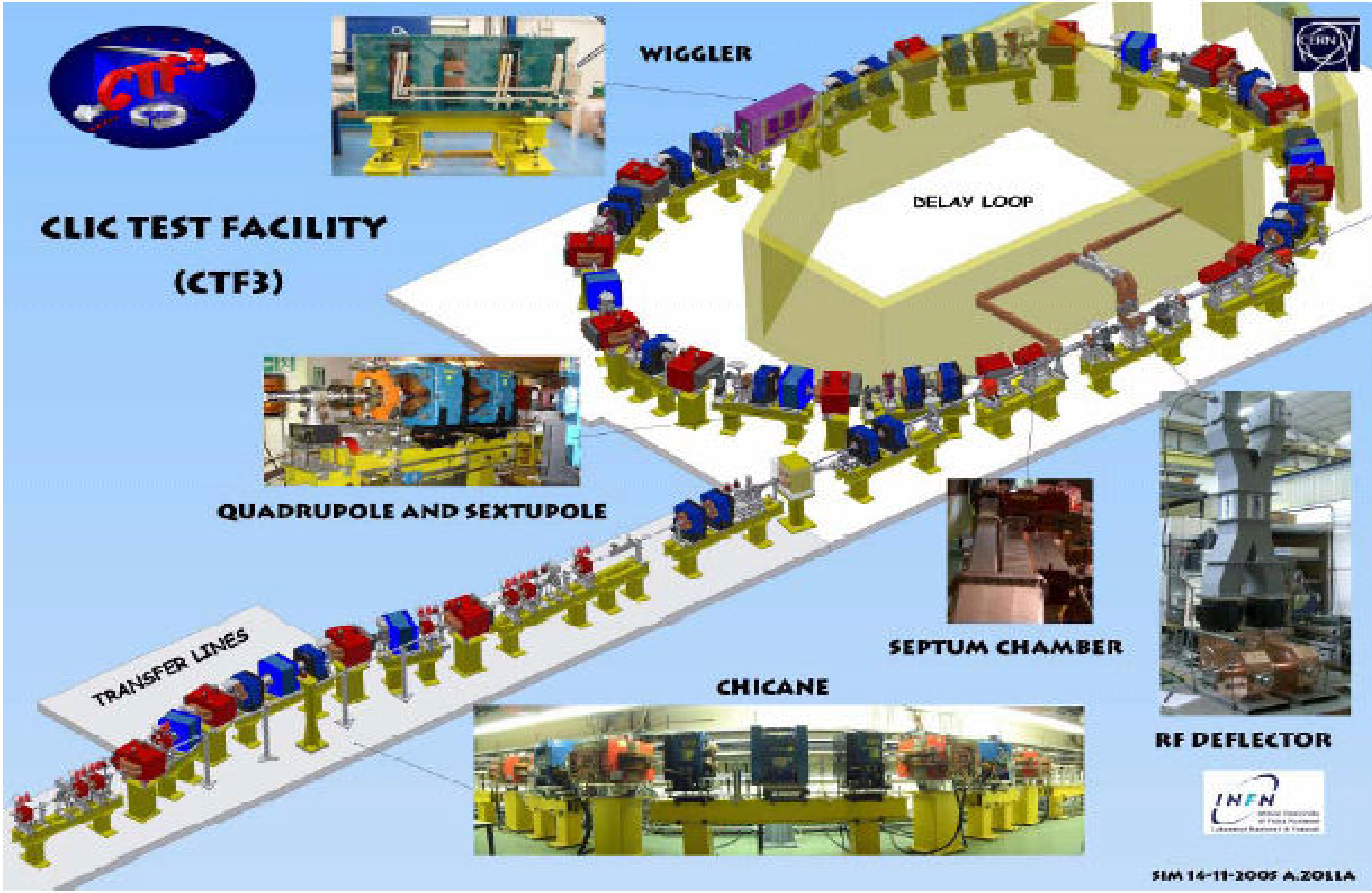


CTF 3

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

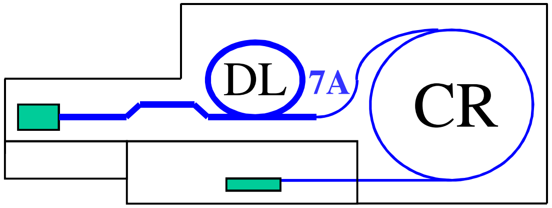


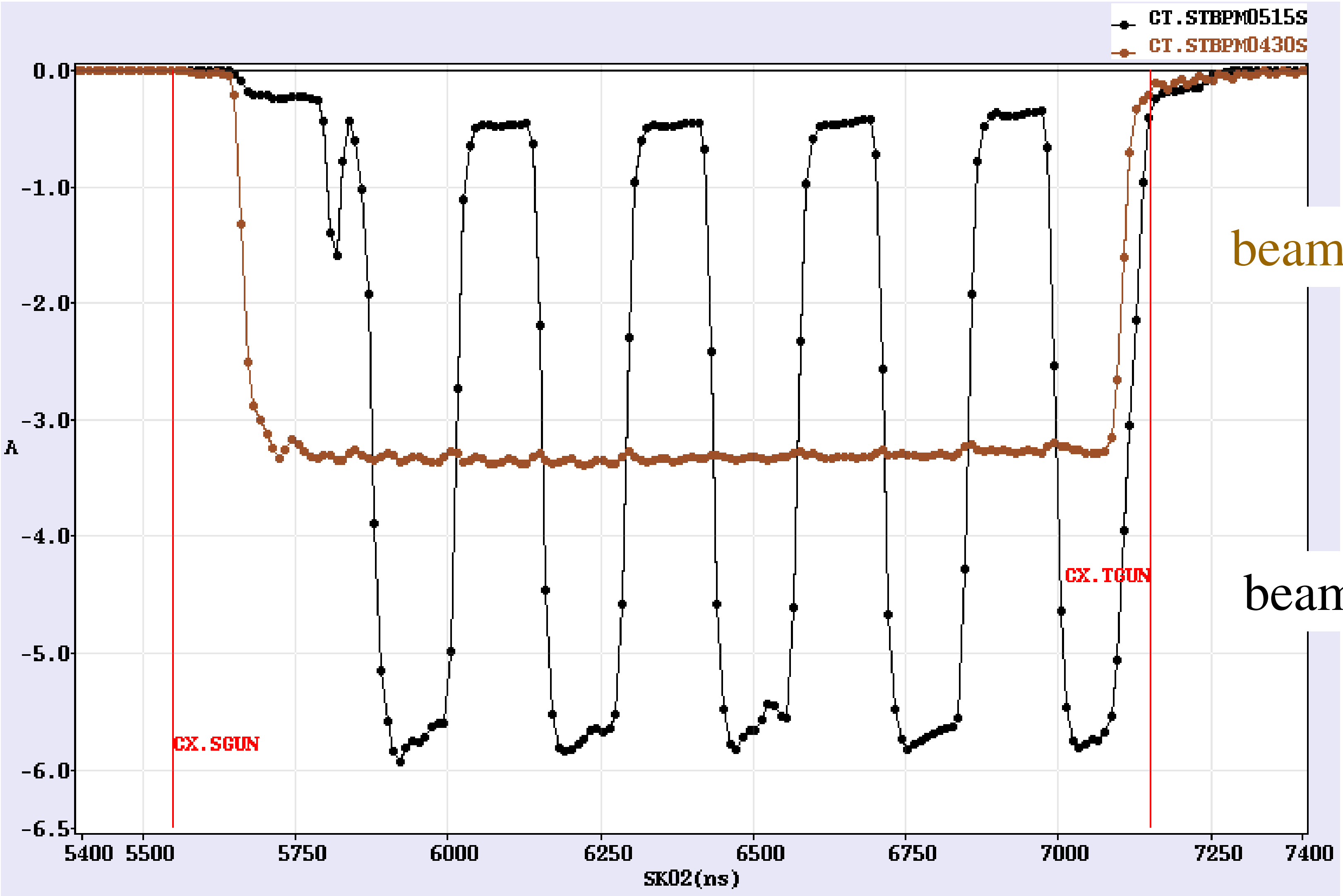
CTF3 Delay Loop



Delay Loop – full recombination

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





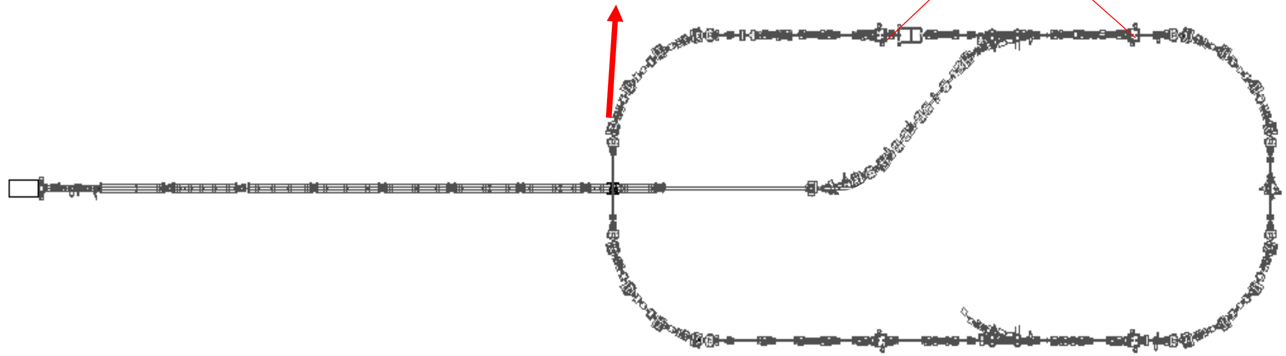
beam **before** the DL

beam **after** the DL

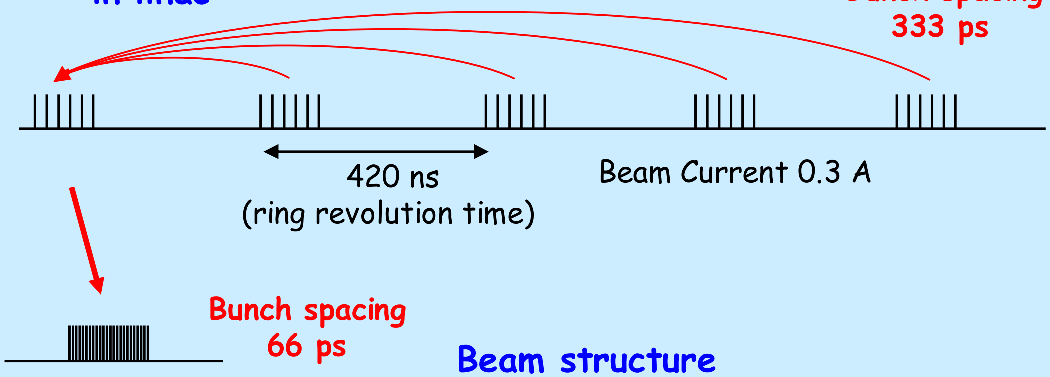
Demonstration of RF recombination

CTF3 - PRELIMINARY PHASE

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

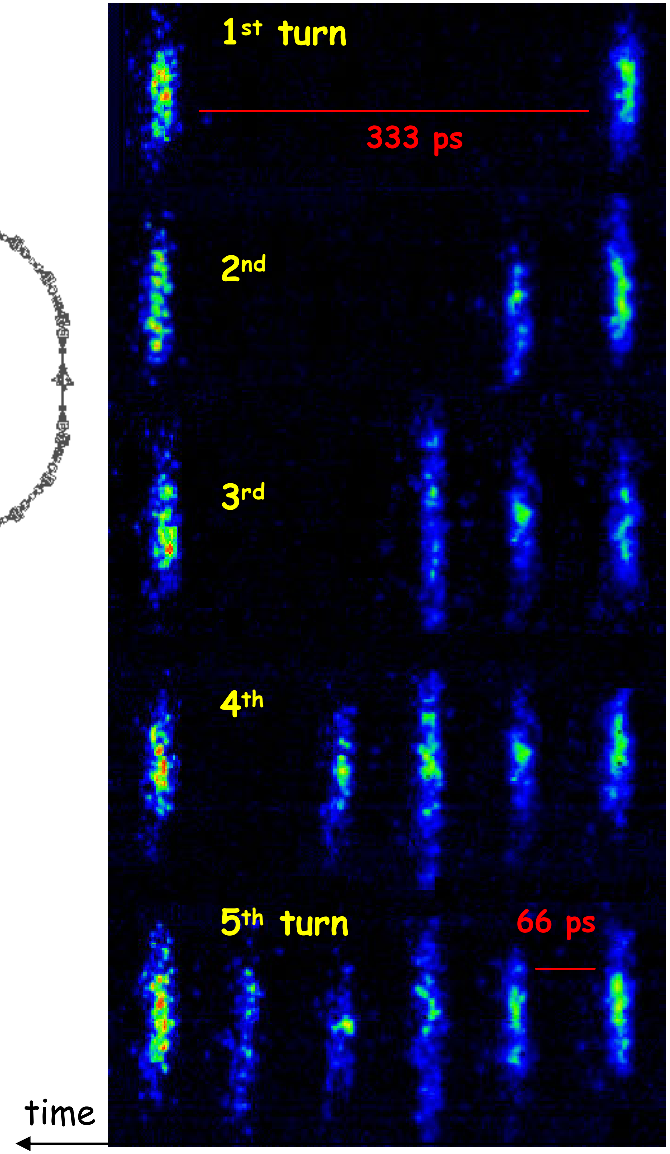


Beam time structure in linac

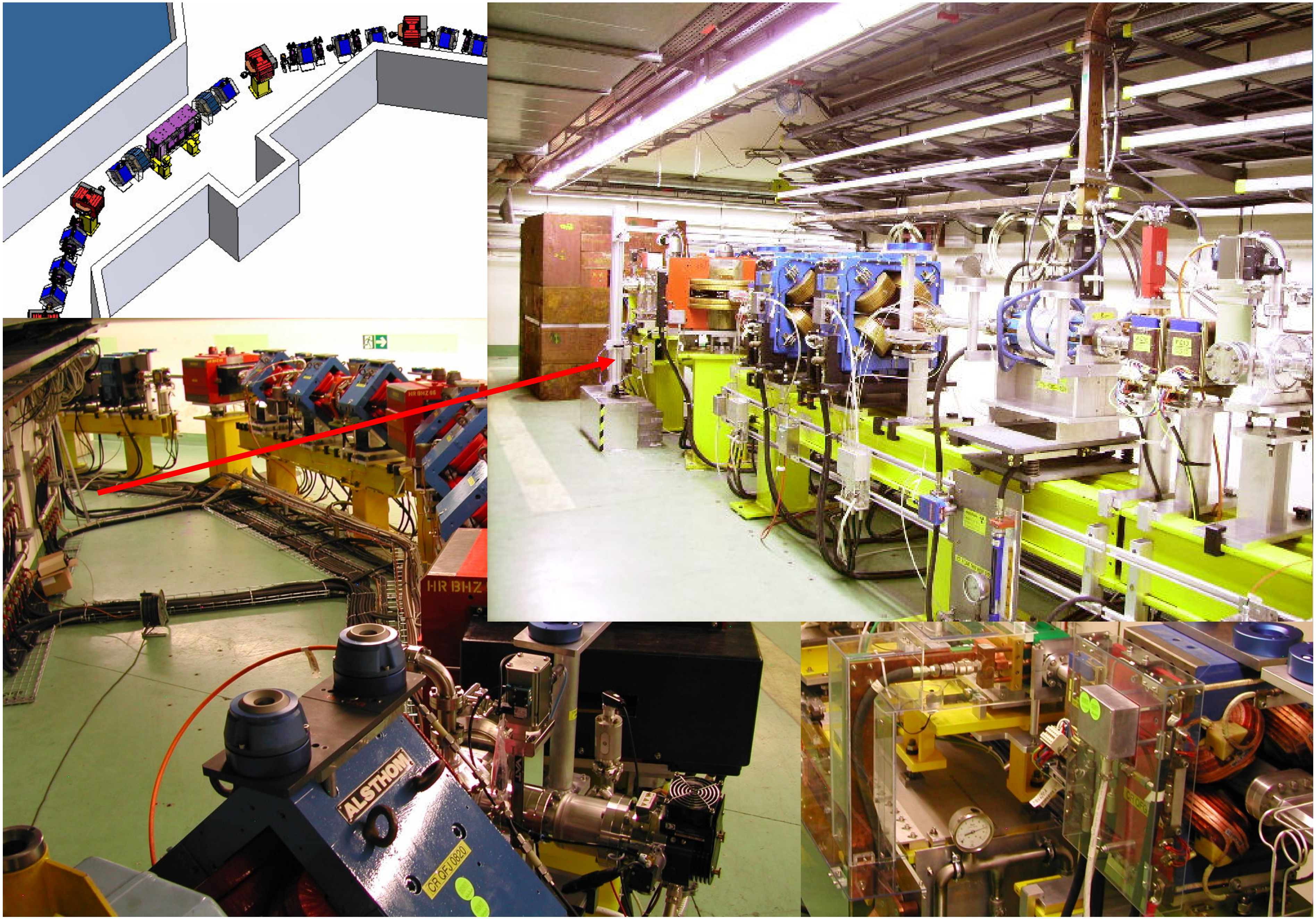


Beam structure after combination

Streak camera image of beam time structure evolution

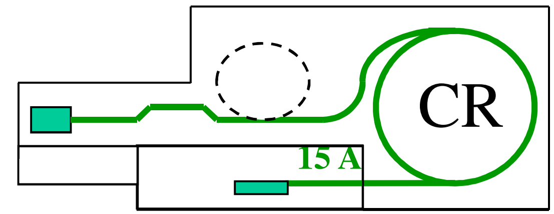


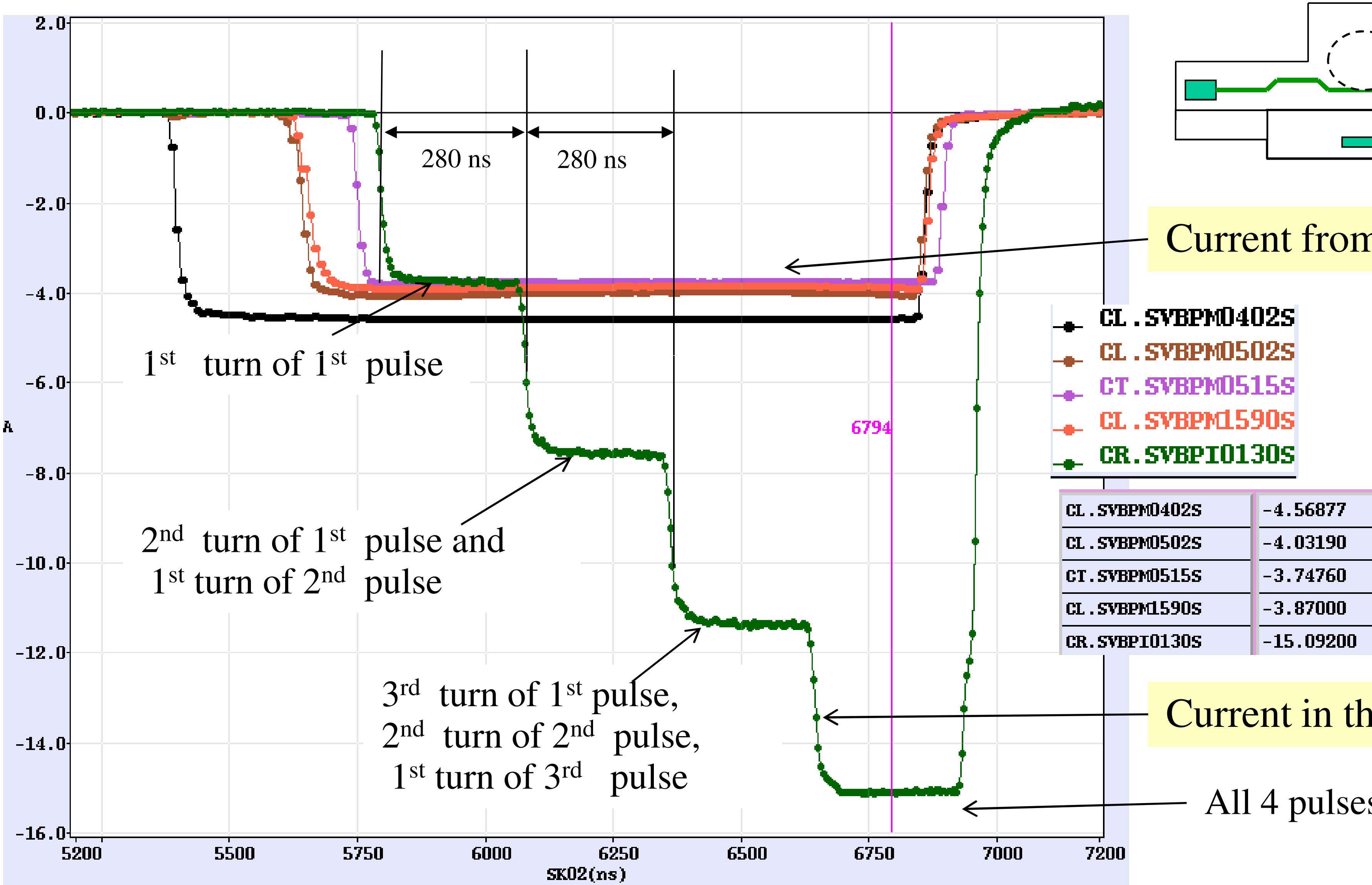
CTF3 combiner ring



Combiner ring status

- factor 4 combination achieved with 15 A, 280 ns (without Delay Loop)

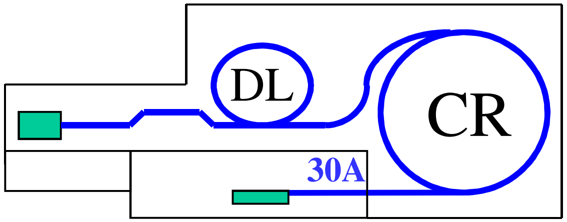


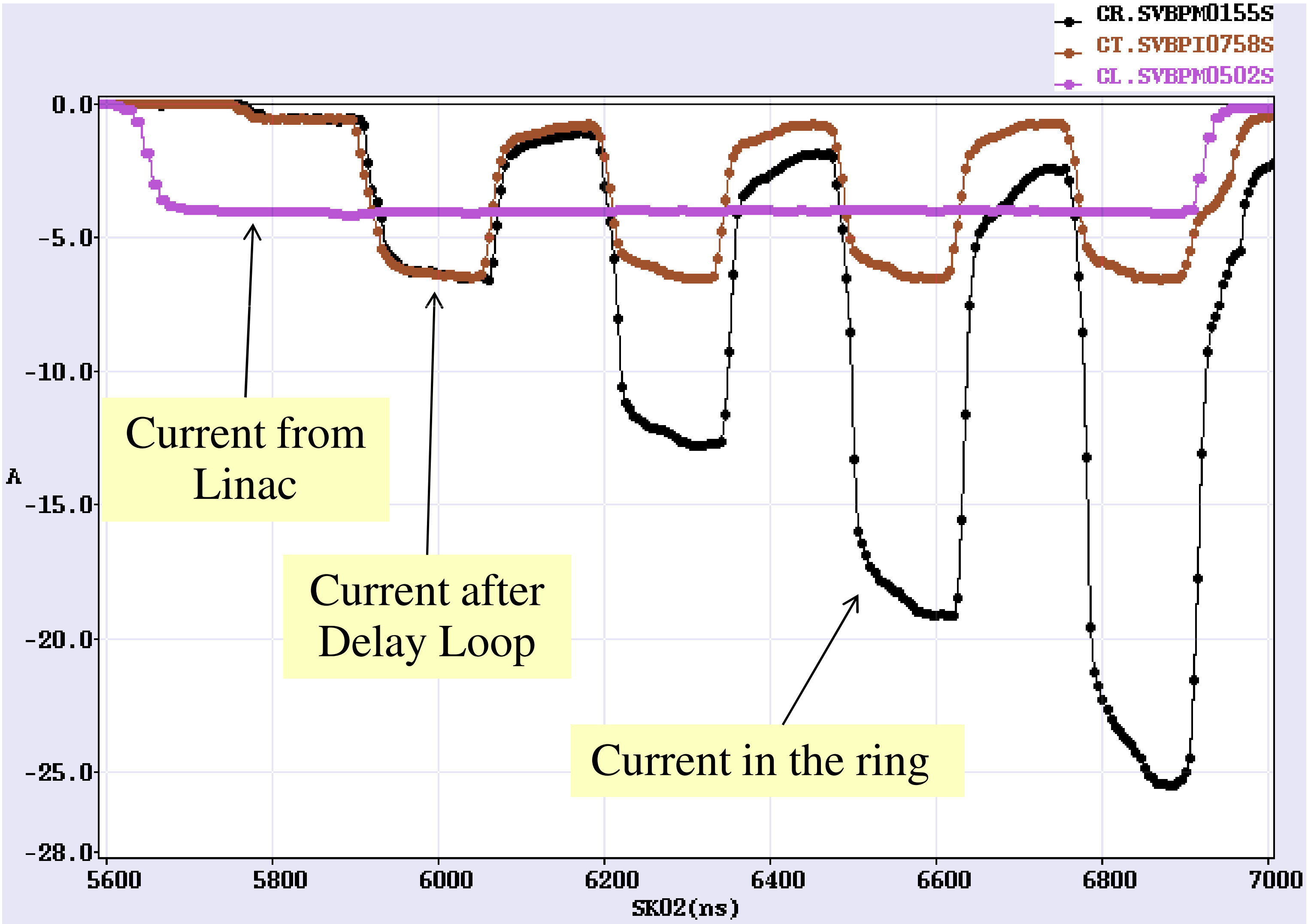


CL.SVBPM0402S	-4.56877
CL.SVBPM0502S	-4.03190
CT.SVBPM0515S	-3.74760
CL.SVBPM1590S	-3.87000
CR.SVBPI0130S	-15.09200

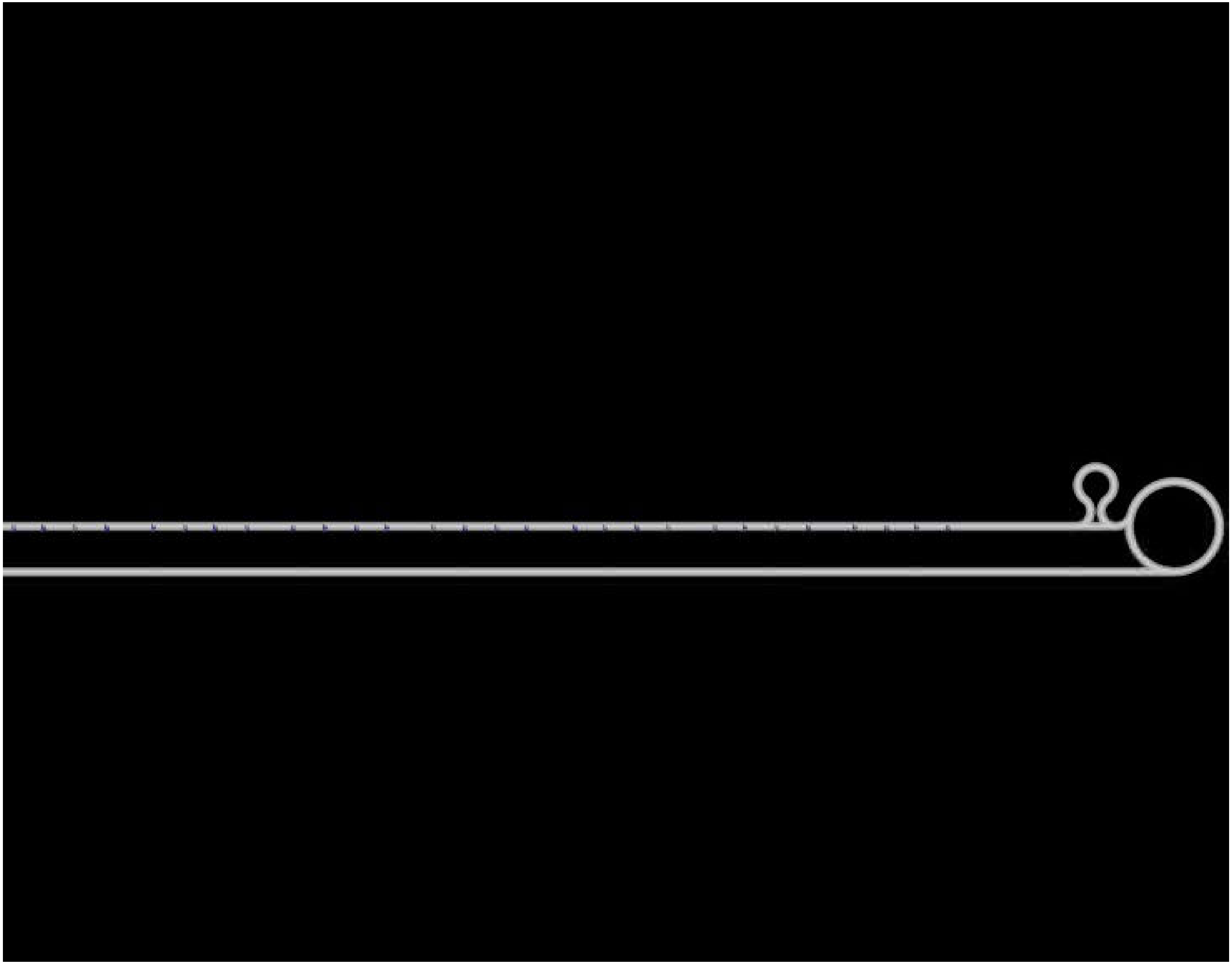
Factor 8 combination (DL+CR)

- ~26 A combination achieved, nominal 140 ns pulse length
- detailed studies still to be done





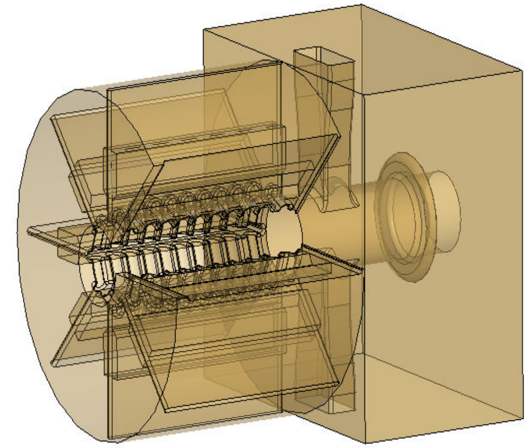
Lemmings Drive Beam

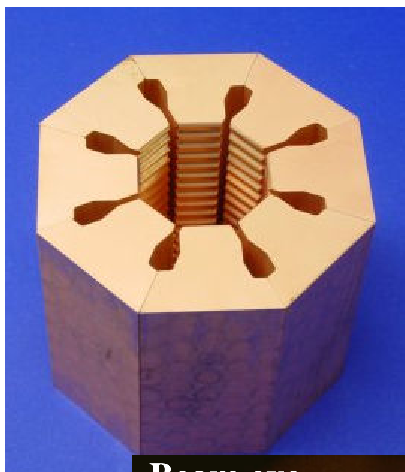


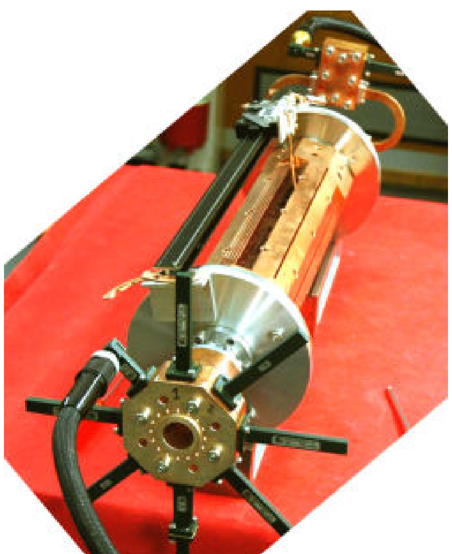
Alexandra Andersson

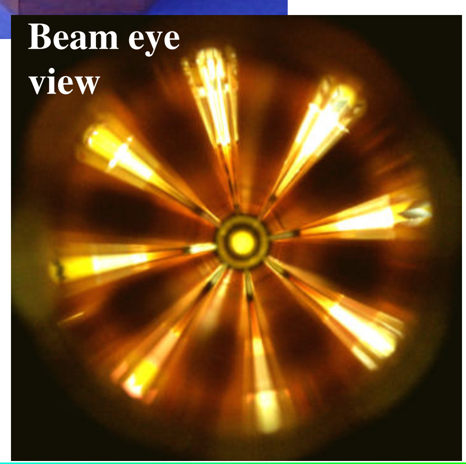
Power extraction structure PETS

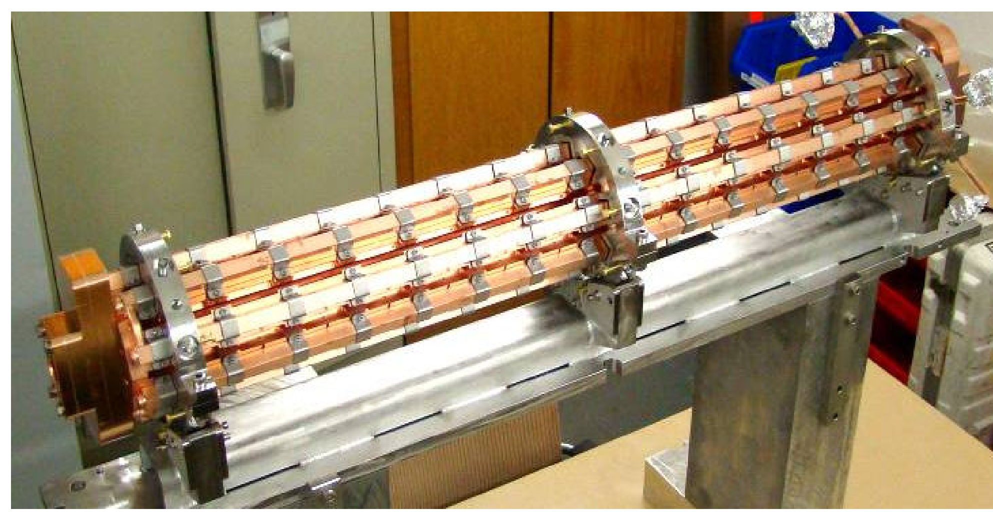
- must extract efficiently several 100 MW power from high current drive beam
- periodically corrugated structure with low impedance (big a/λ)
- ON/OFF mechanism



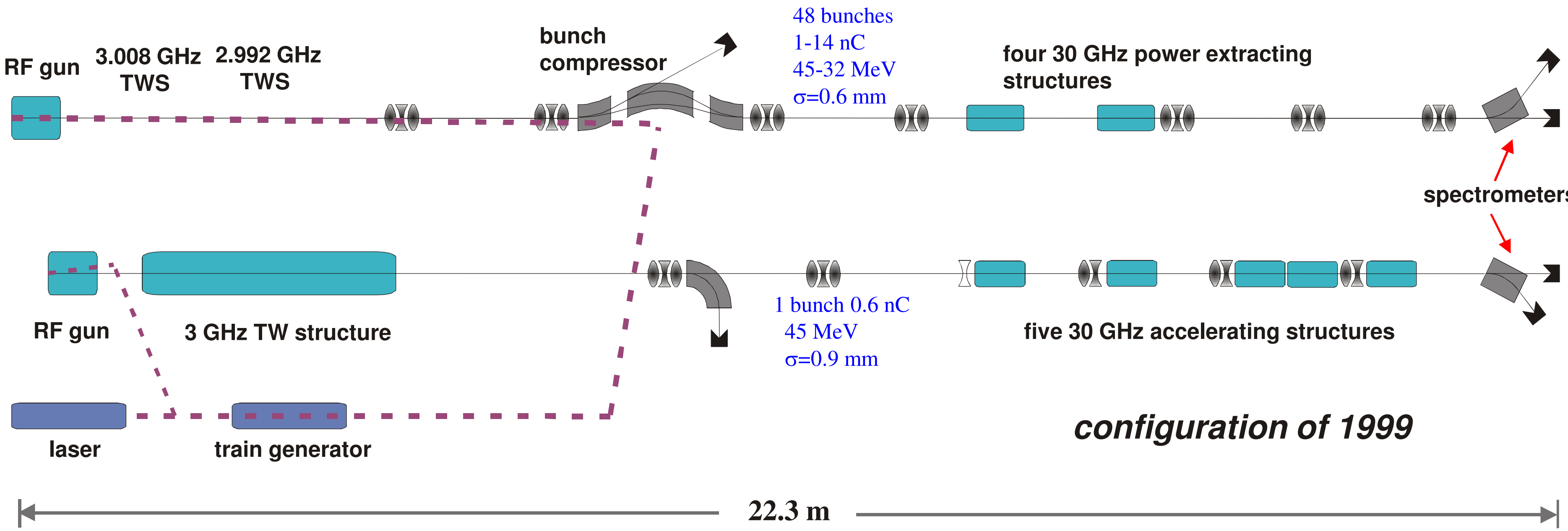








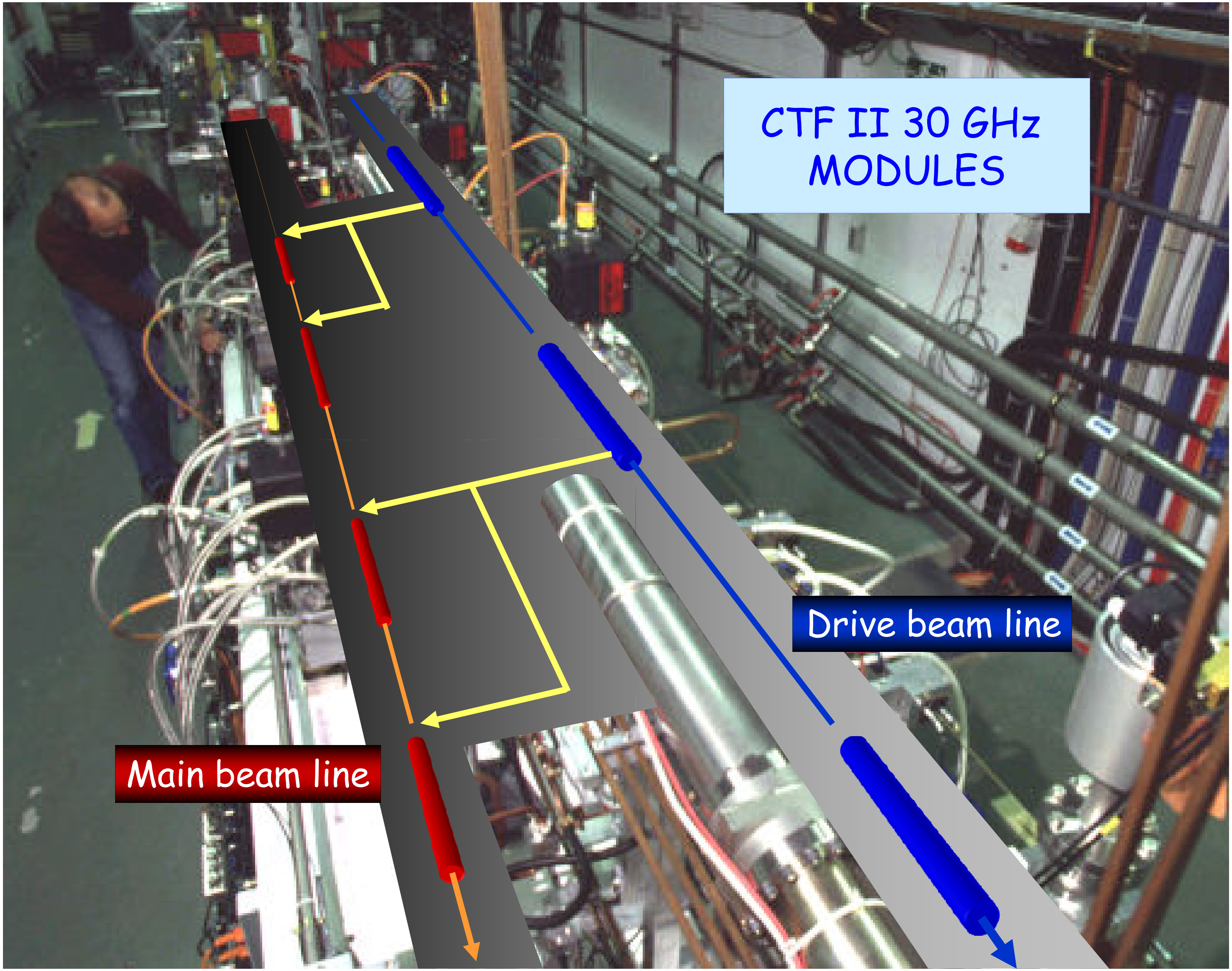
CLIC Test Facility CTF II



Dismantled in 2002, after having achieved its goals :

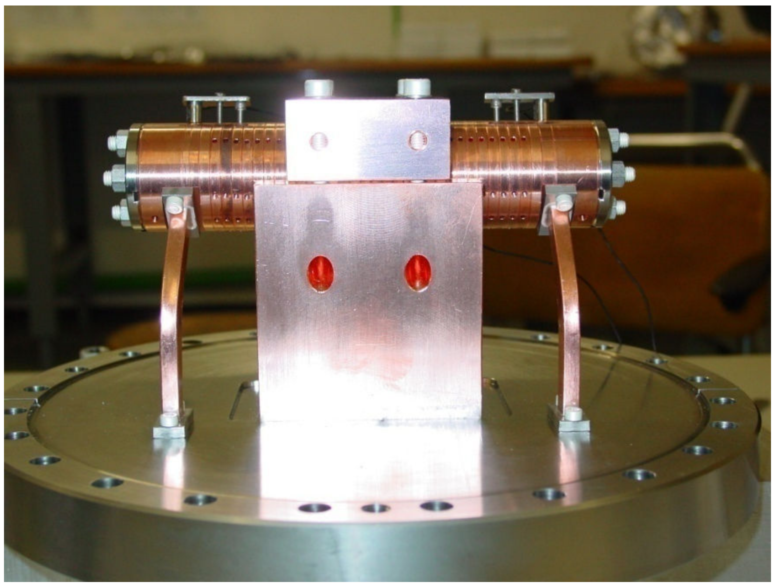
- Demonstrate feasibility of a two-beam acceleration scheme
- Provide high power 30 GHz RF source for high gradient testing (280 MW, 16 ns pulses)
- Study generation of short, intense e-bunches using photocathode RF guns
- Demonstrate operability of μ-precision active-alignment system in accelerator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

CLIC Test Facility CTF II

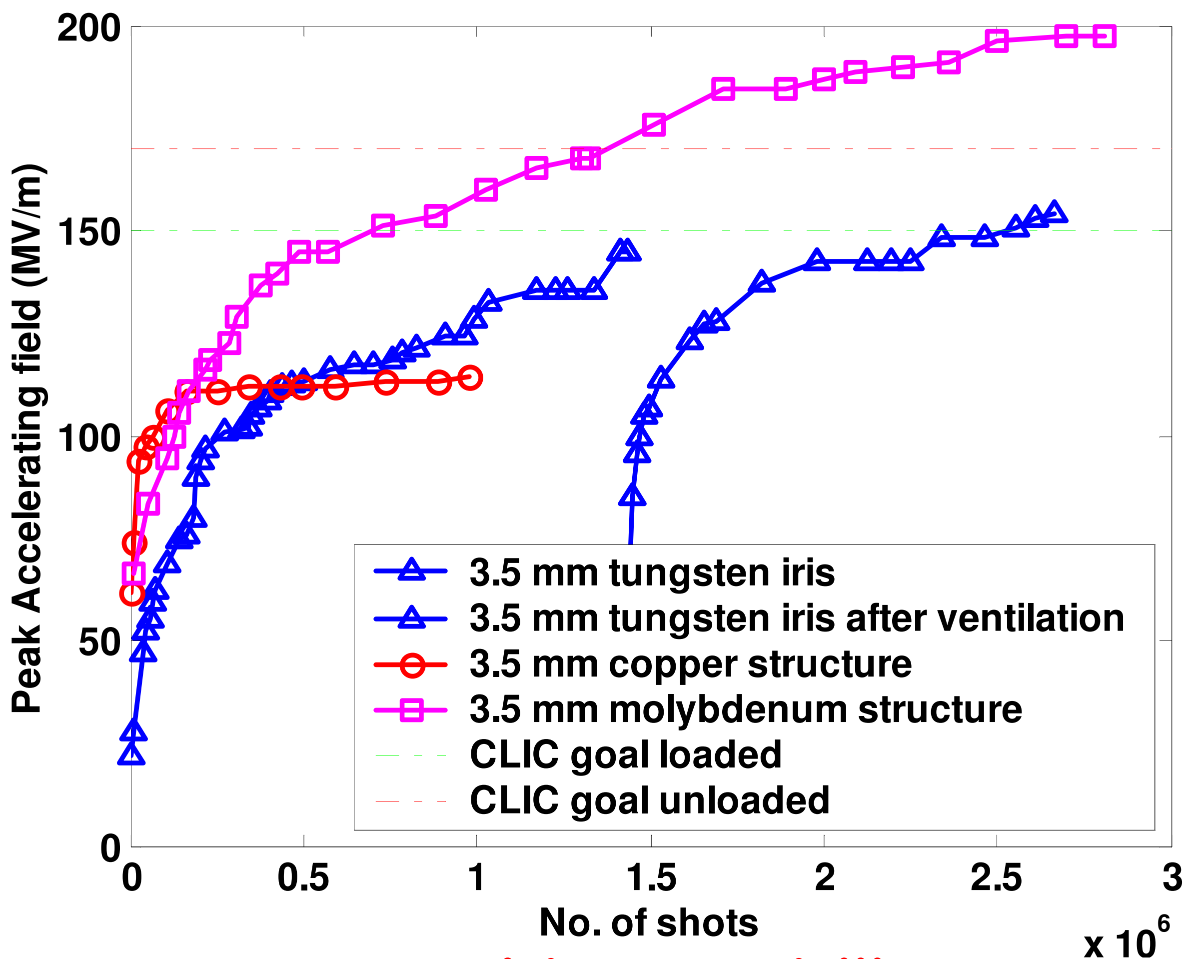


Achieved accelerating fields in CTF2

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)



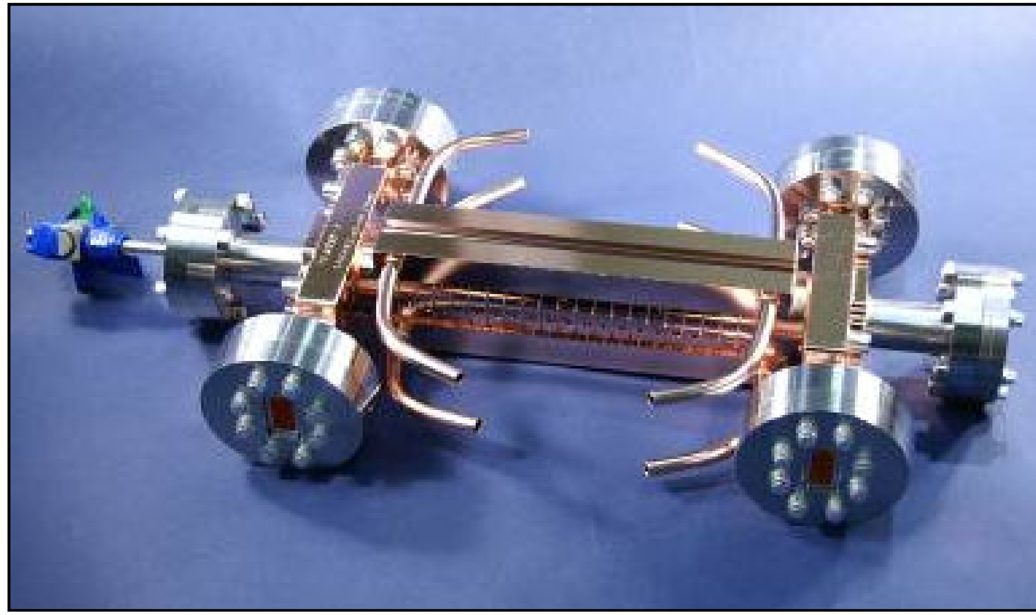
30 cell clamped tungsten-iris structure

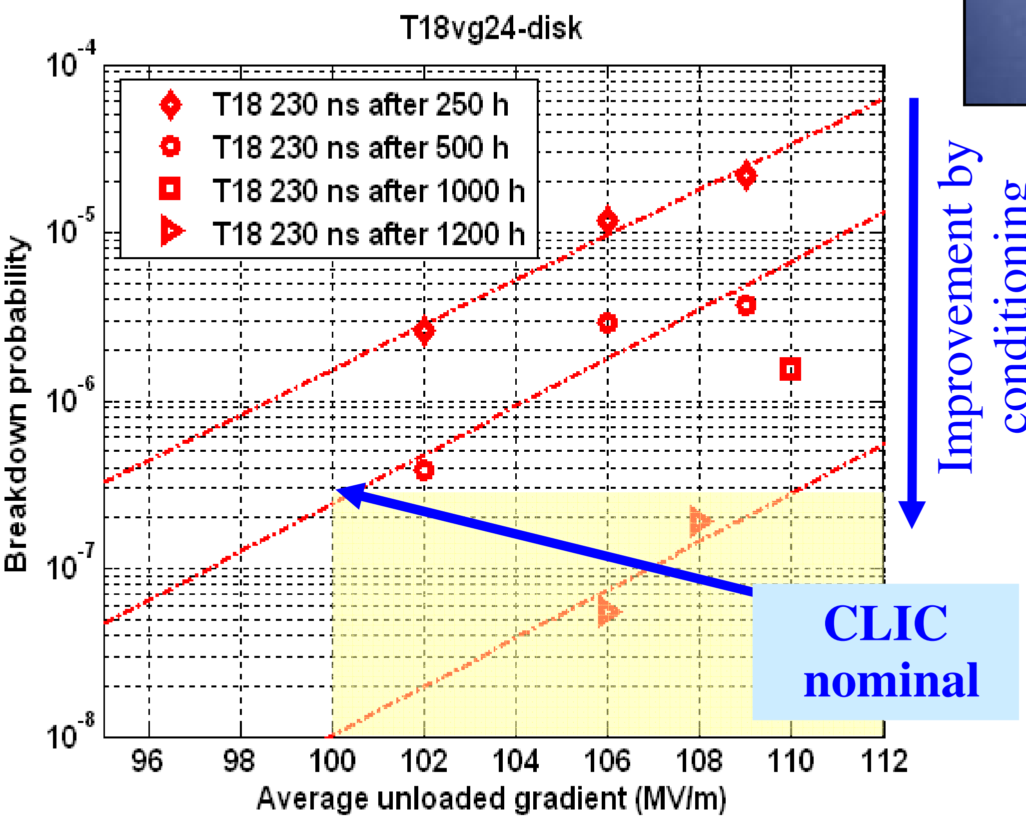


A world record !!!

Present best structure performance

- Exceeded 100 MV/m at nominal CLIC pulse length and breakdown rate

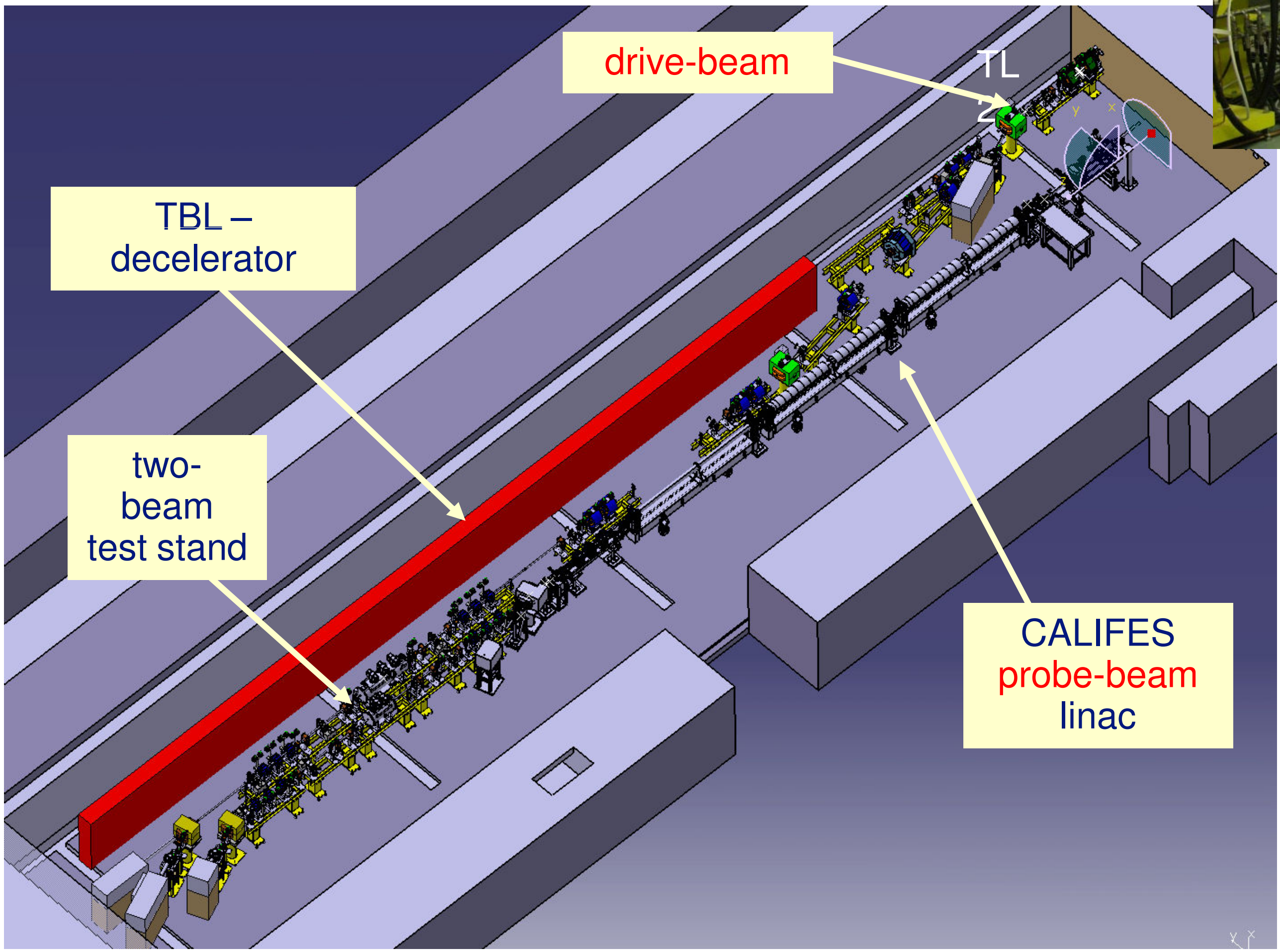


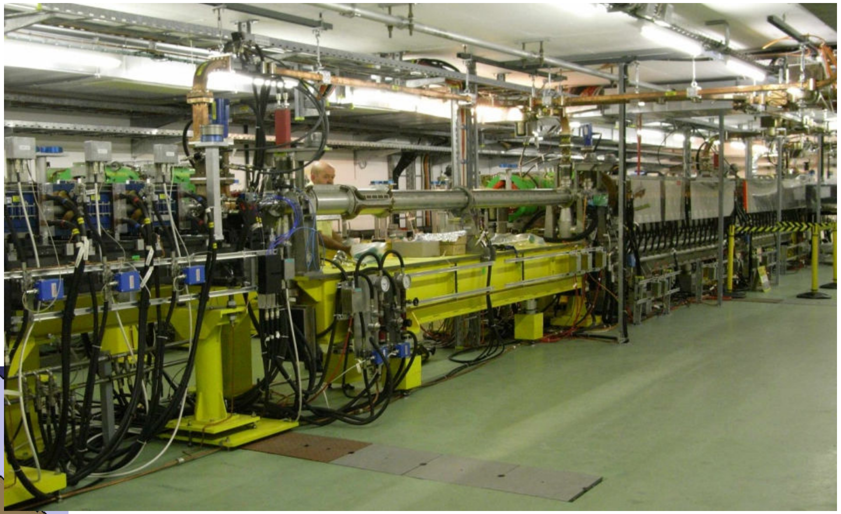


Frequency:	**11.424 GHz**
Cells:	**18+2 matching cells**
Filling Time:	**36 ns**
Length: active acceleration	**18 cm**
Iris Dia. a/λ	**0.155~0.10**
Group Velocity: vg/c	**2.6-1.0 %**
Phase Advace Per Cell	**2π/3**
Power for <Ea>=100MV/m	**55.5 MW**
Unloaded Ea(out)/Ea(in)	**1.55**
Es/Ea	**2**

CLEX test area

- Deceleration and two-beam tests
- High power tests of PETS and accelerating structures





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: the visit