

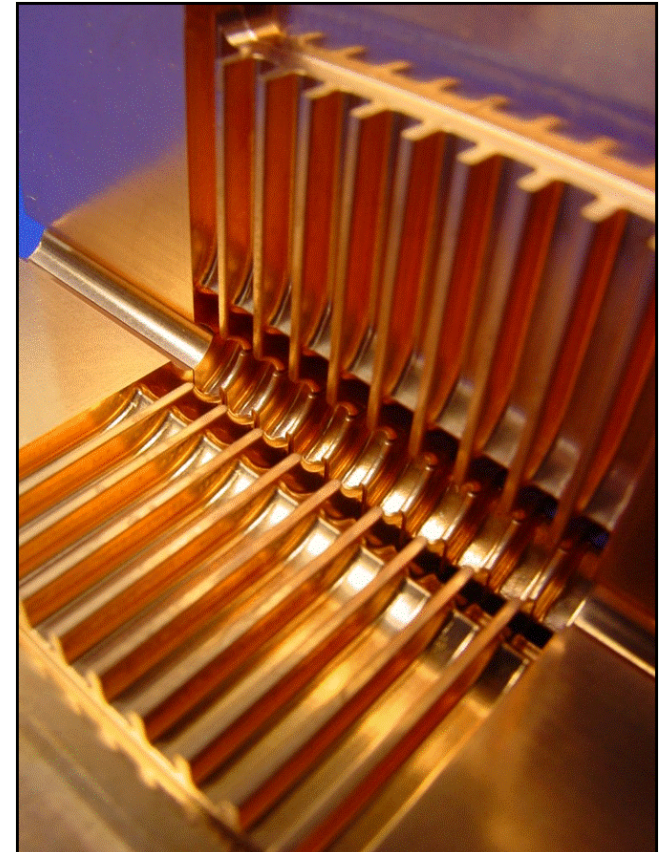


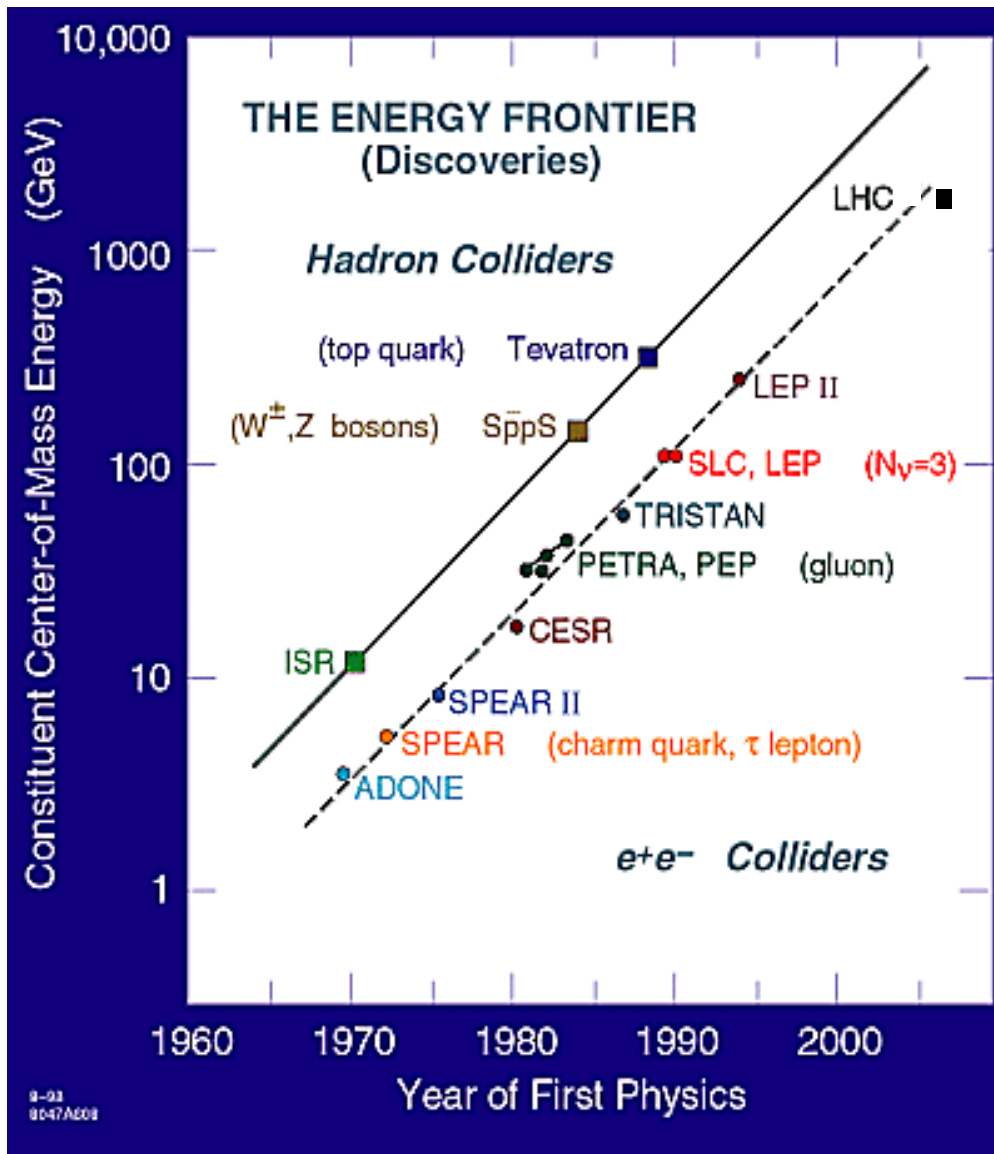
CLIC / CTF 3



Frank Tecker - BE/OP

- Introduction CLIC / CTF 3
- Visit of CTF3

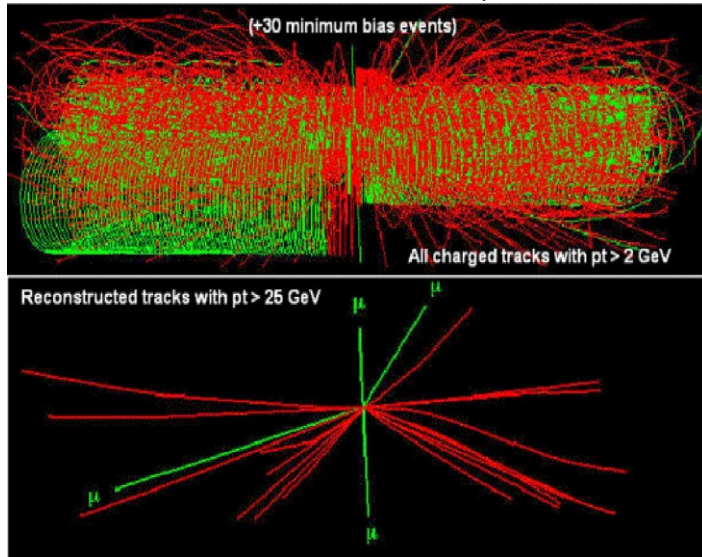




History:

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

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

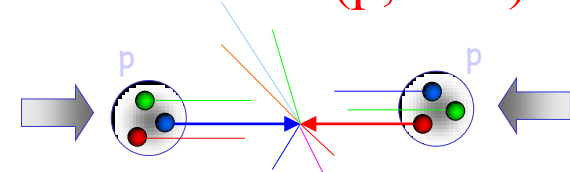


ALICE: Ion event



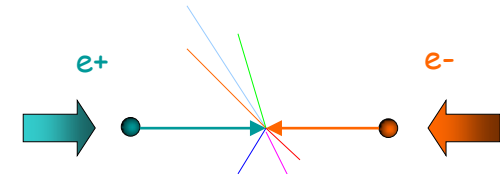
LEP event: $Z^0 \rightarrow 3 \text{ jets}$

● Hadron Collider (p, ions):



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

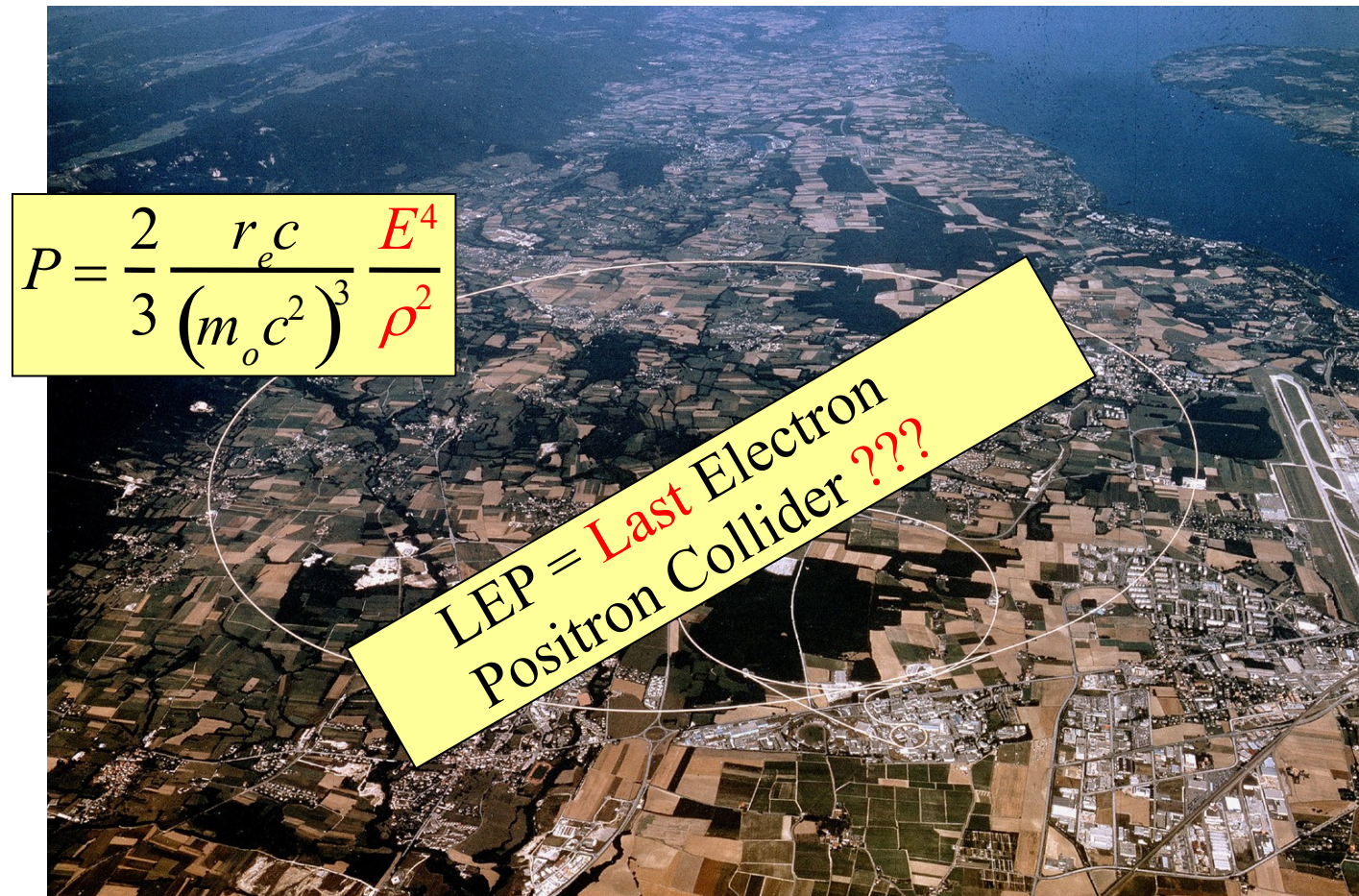
● Lepton Collider:



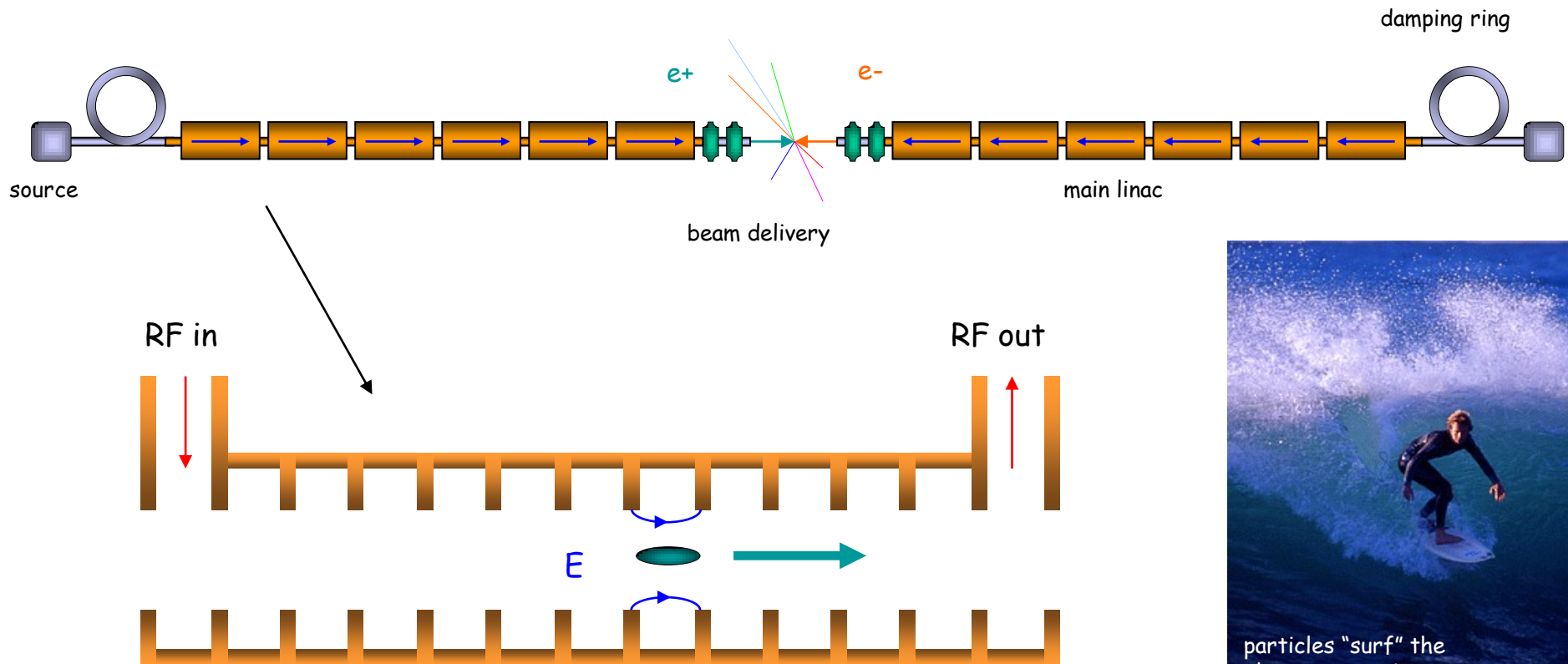
- Elementary particles
- Well defined initial state
- Beam polarization
- produces particles democratically
- Momentum conservation eases decay product analysis

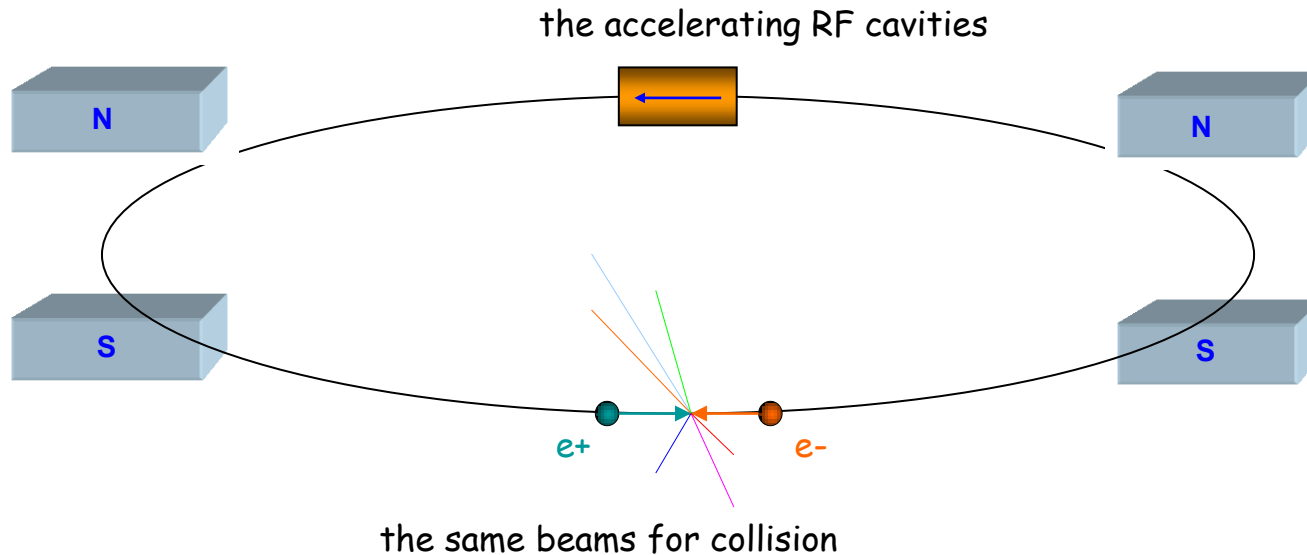
Much more **precise analysis** with **leptons**
 \Rightarrow **precision measurements** of particle properties

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



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





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)

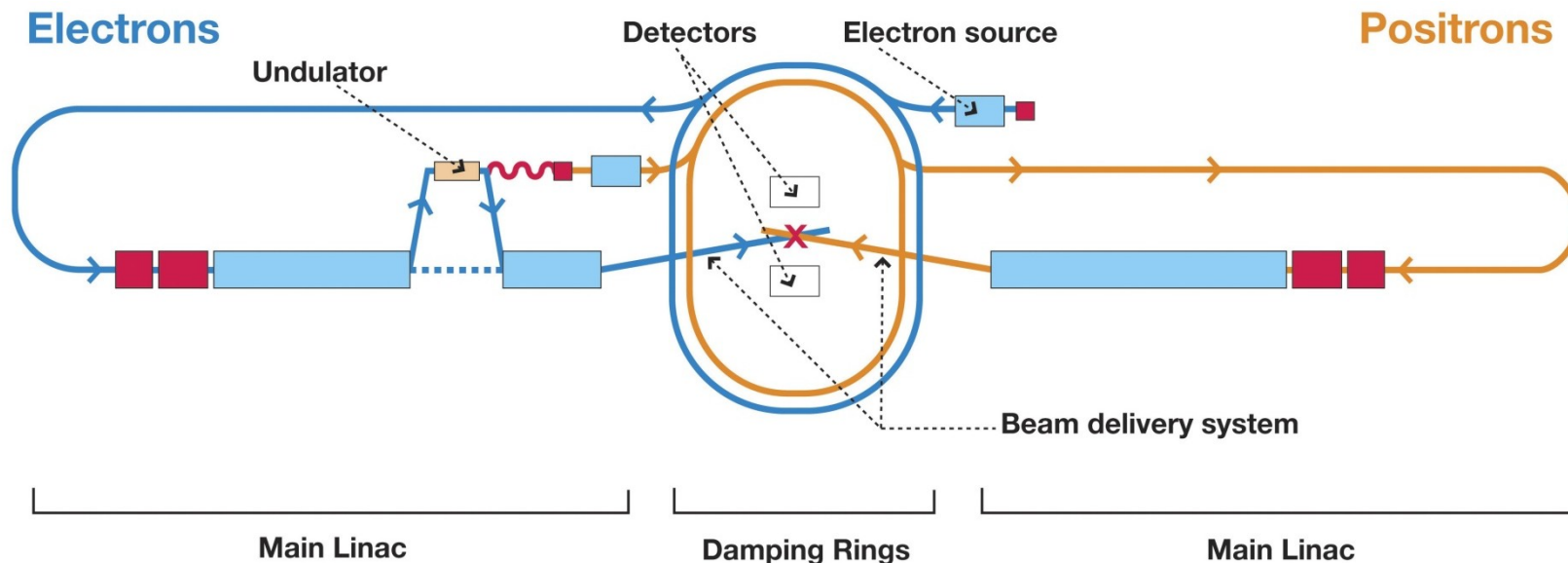
• ILC (International Linear Collider)

- 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





World-wide CLIC&CTF3 Collaboration



New member
in 2010

**CLIC multi-lateral collaboration
41 Institutes from 21 countries**

ACAS (Australia)

- Aarnus University (Denmark)
- Ankara University (Turkey)
- Argonne National Laboratory (USA)
- Athens University (Greece)
- BINP (Russia)
- CERN
- CIEMAT (Spain)
- Cockcroft Institute (UK)
- **ETH Zurich (Switzerland)**
- **FNAL (USA)**
- Gazi Universities (Turkey)

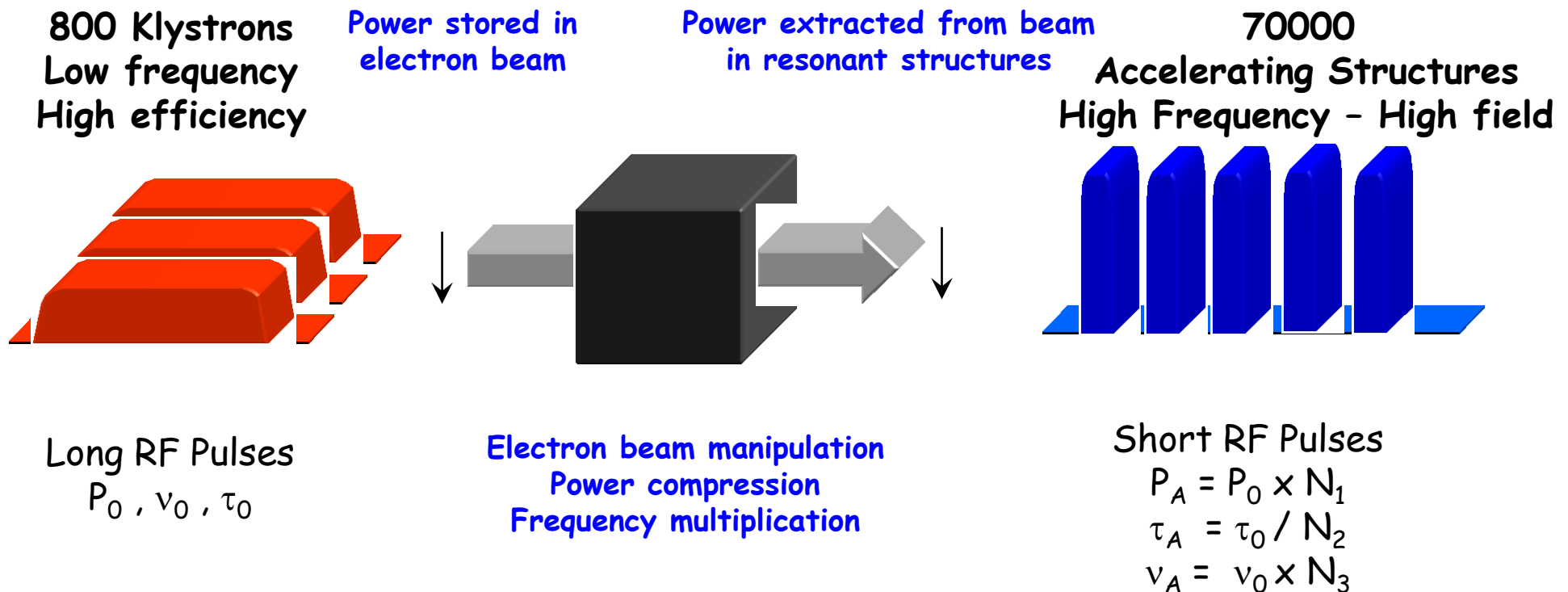
- Helsinki Institute of Physics (Finland)
- IAP (Russia)
- IAP NASU (Ukraine)
- **IHEP (China)**
- INFN / LNF (Italy)

- Instituto de Fisica Corpuscular (Spain)
- IRFU / Saclay (France)
- Jefferson Lab (USA)
- **John Adams Institute/Oxford (UK)**

- John Adams Institute/RHUL (UK)
- JINR (Russia)
- Karlsruhe University (Germany)
- KEK (Japan)
- LAL / Orsay (France)
- LAPP / ESIA (France)
- **NIKHEF/Amsterdam (Netherlands)**
- NCP (Pakistan)
- North-West. Univ. Illinois (USA)
- Patras University (Greece)

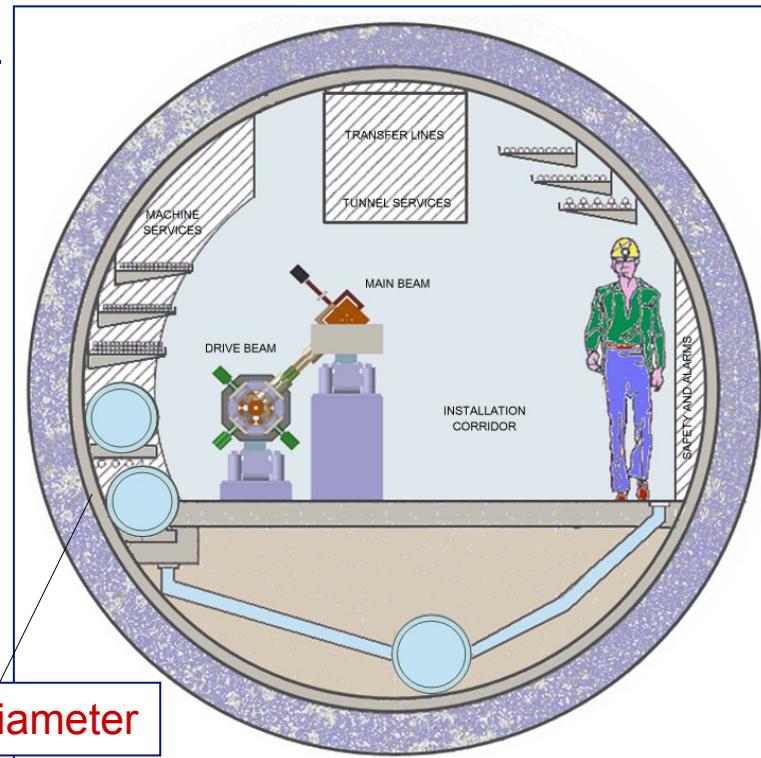
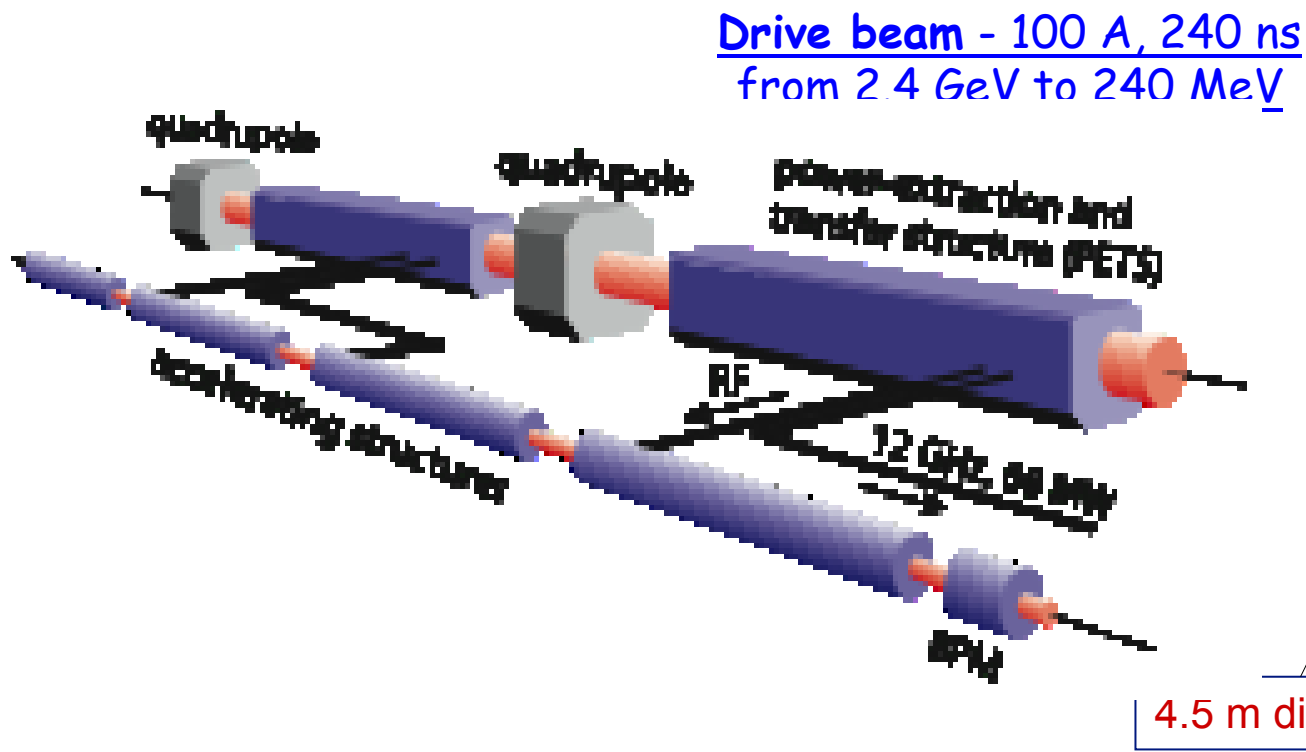
- Polytech. University of Catalonia (Spain)
- PSI (Switzerland)
- RAL (UK)
- RRCAT / Indore (India)
- SLAC (USA)
- Thrace University (Greece)
- Tsinghua University (China)
- University of Oslo (Norway)
- Uppsala University (Sweden)
- **UCSC SCIPP (USA)**

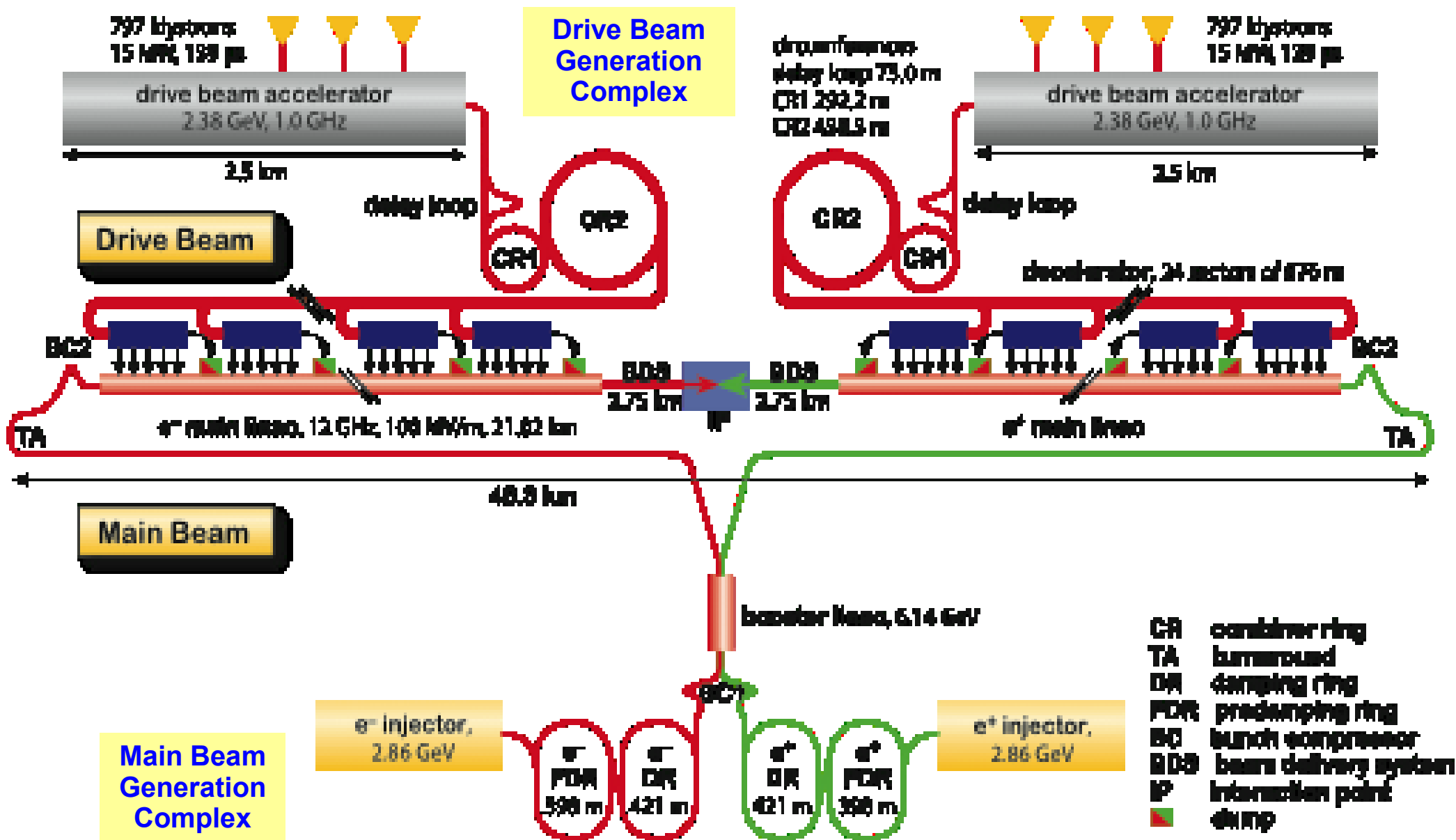
- **Very high gradients** possible with NC accelerating structures at high RF frequencies (**12 → 30 GHz**) for **short RF pulses**
- Extract RF power from an **intense** electron “**drive beam**”
- Generate **efficiently** long pulse and compress it (in power + frequency)



- 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**

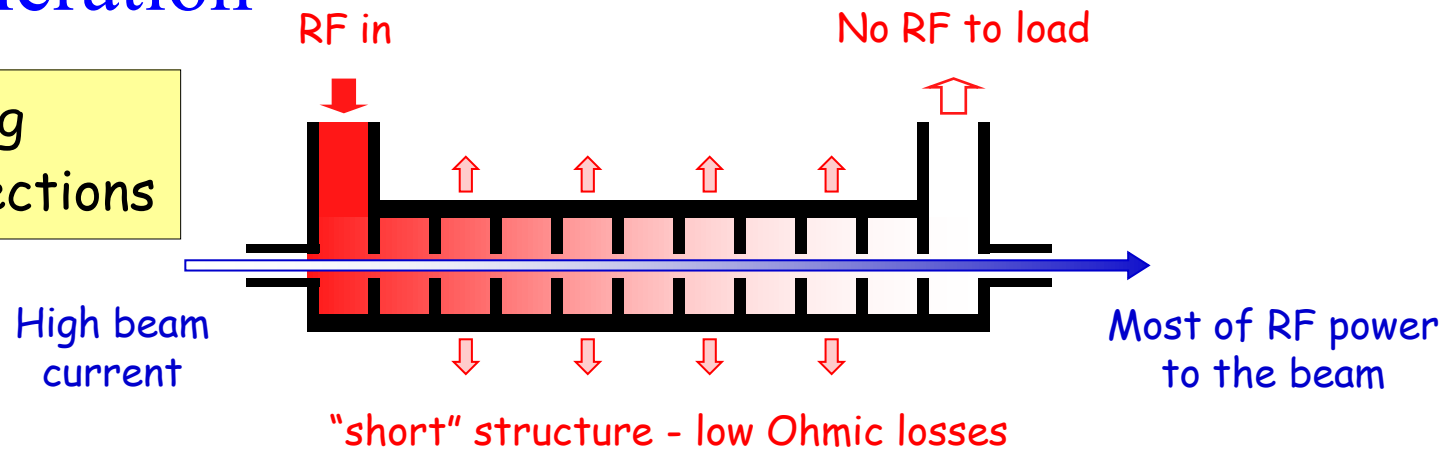
CLIC TUNNEL CROSS-SECTION





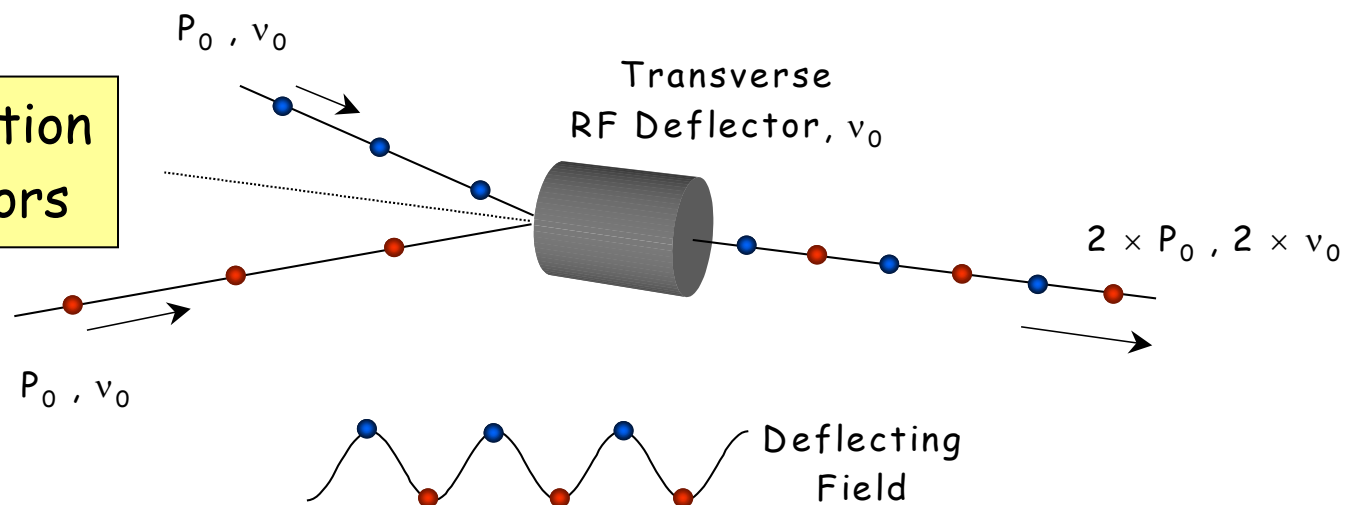
Efficient acceleration

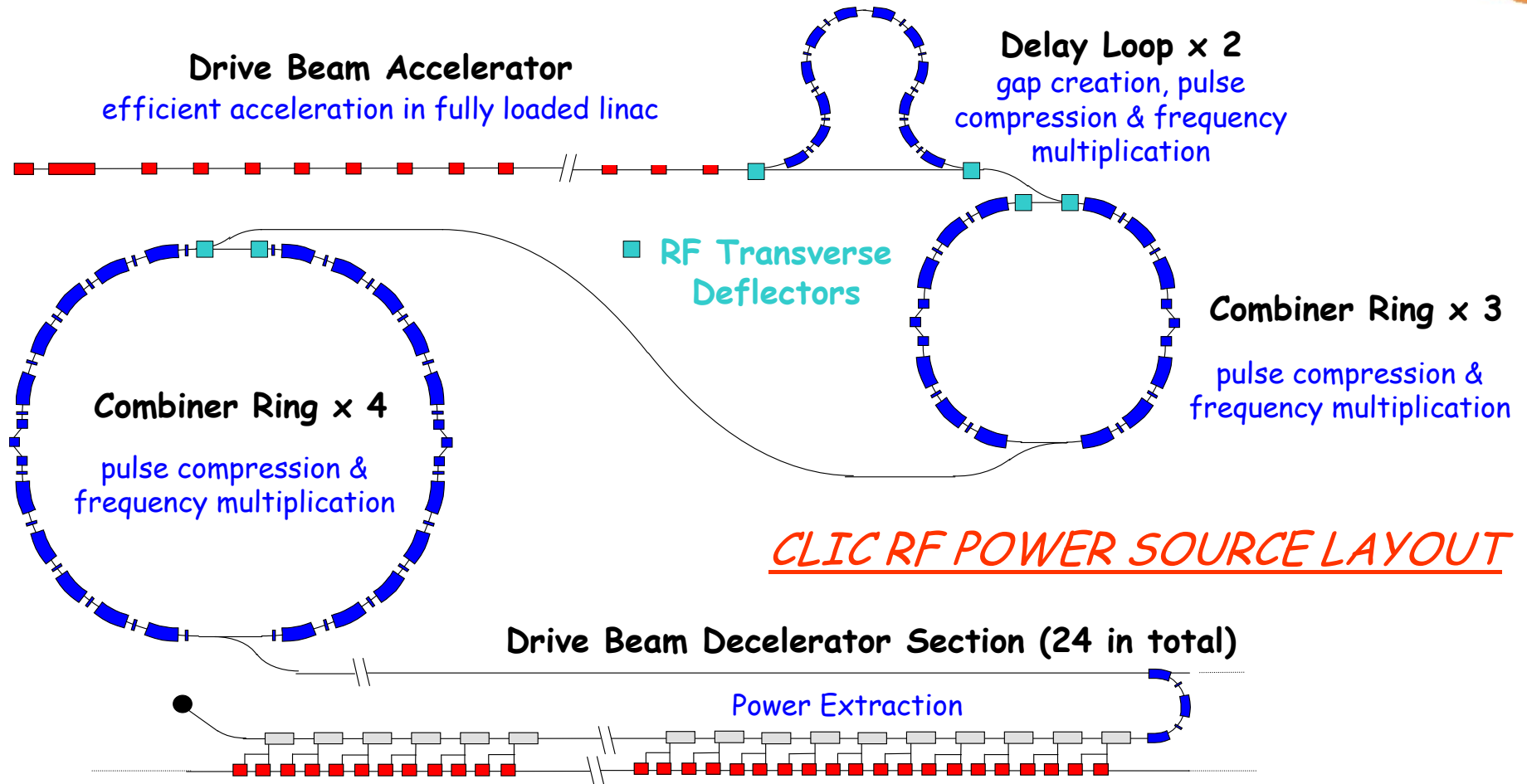
Full beam-loading
acceleration in TW sections



Frequency multiplication

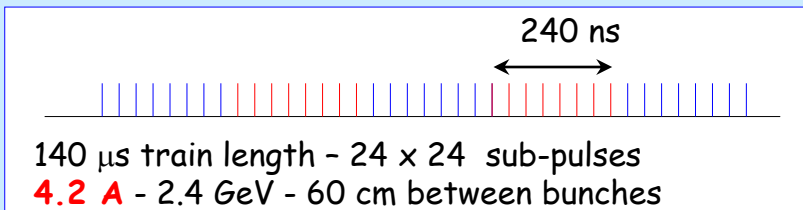
Beam combination/separation
by transverse RF deflectors



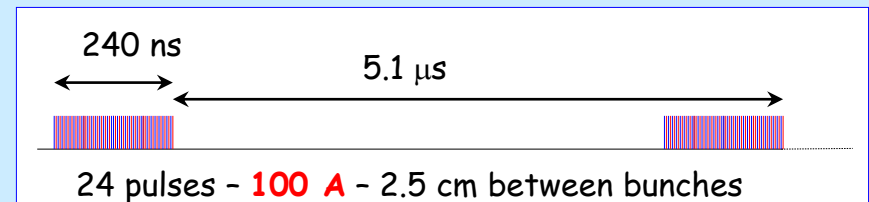


CLIC RF POWER SOURCE LAYOUT

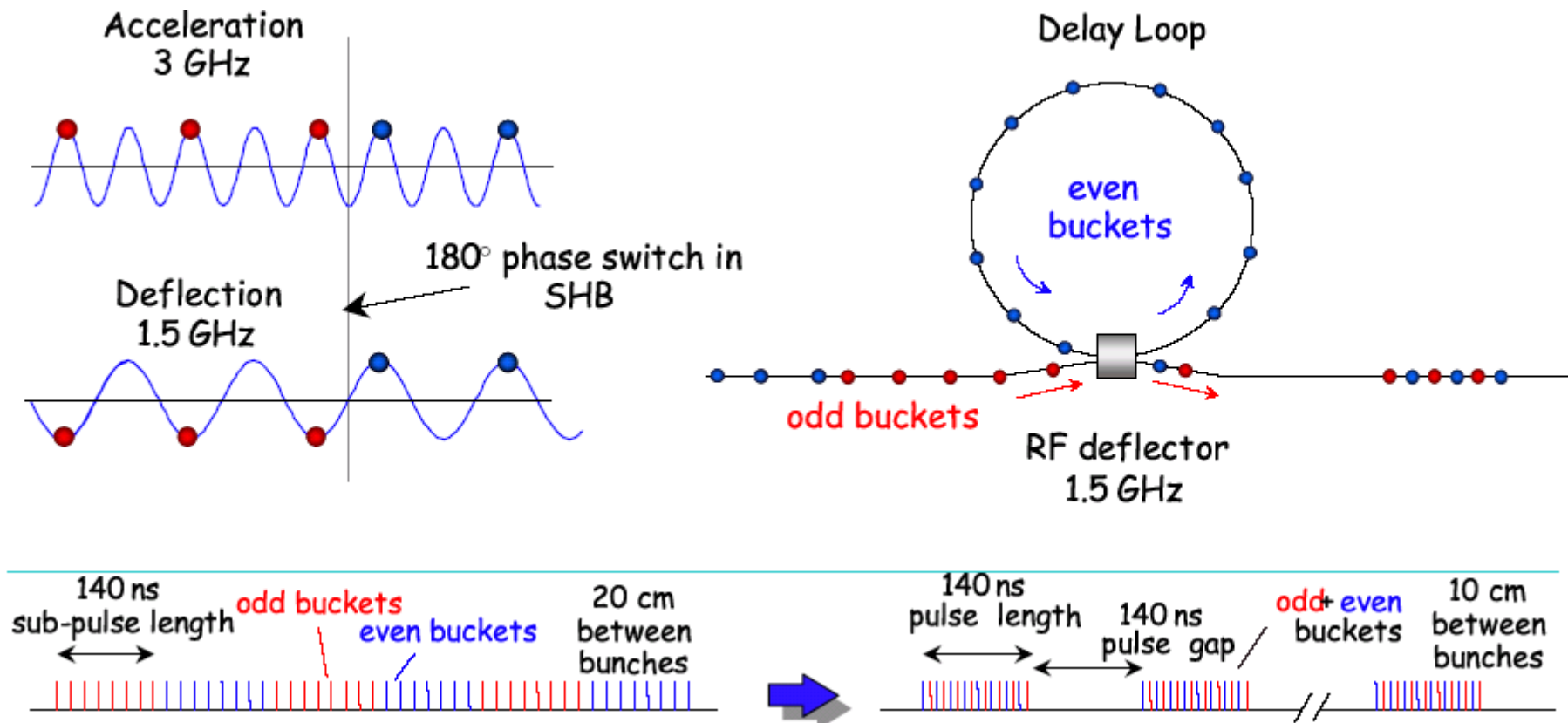
Drive beam time structure - initial



Drive beam time structure - final



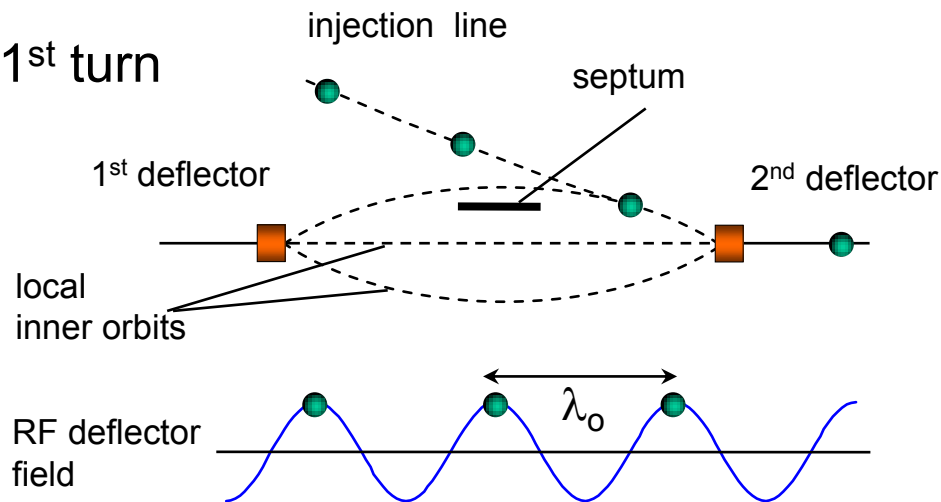
- double repetition frequency and current
- parts of bunch train delayed in loop
- RF deflector combines the bunches



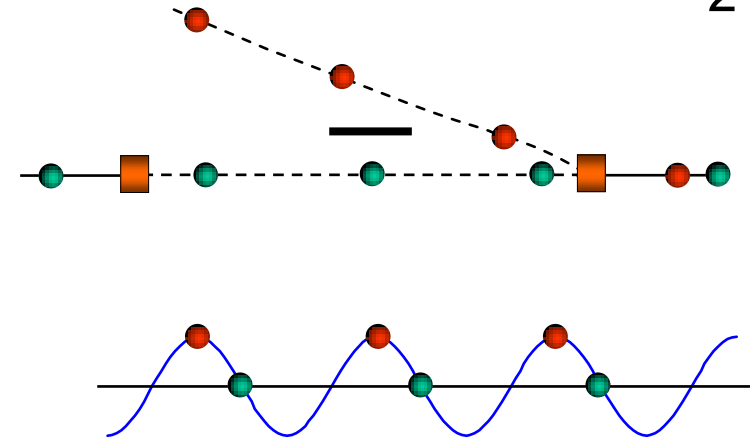
- combination factors up to 5 reachable in a ring

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

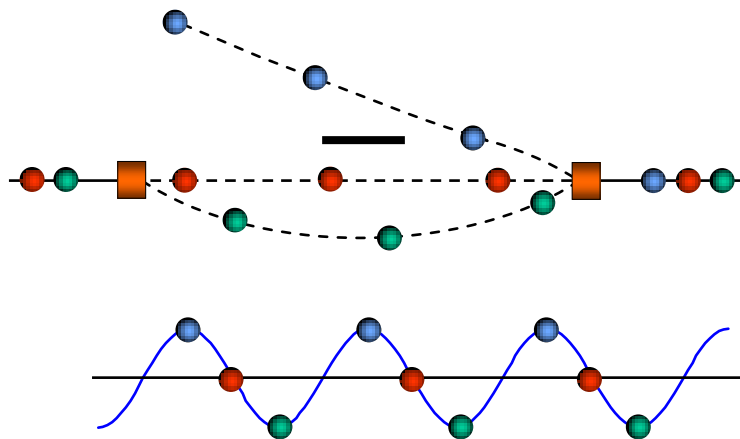
1st turn



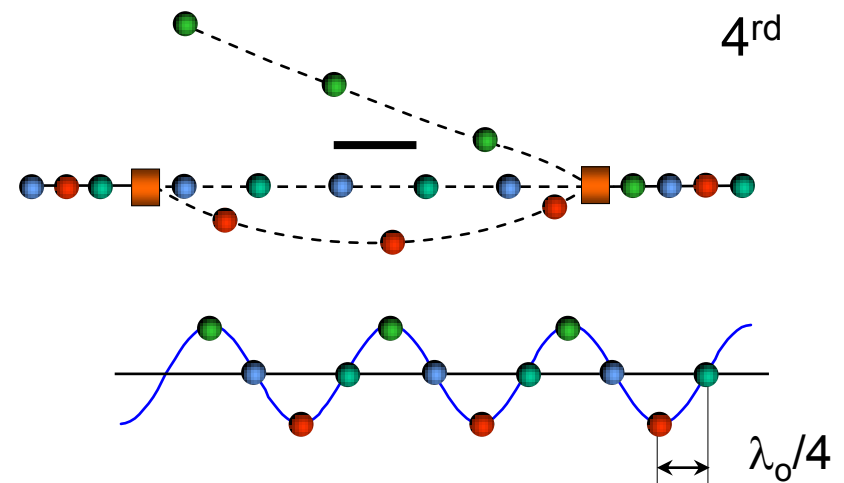
2nd



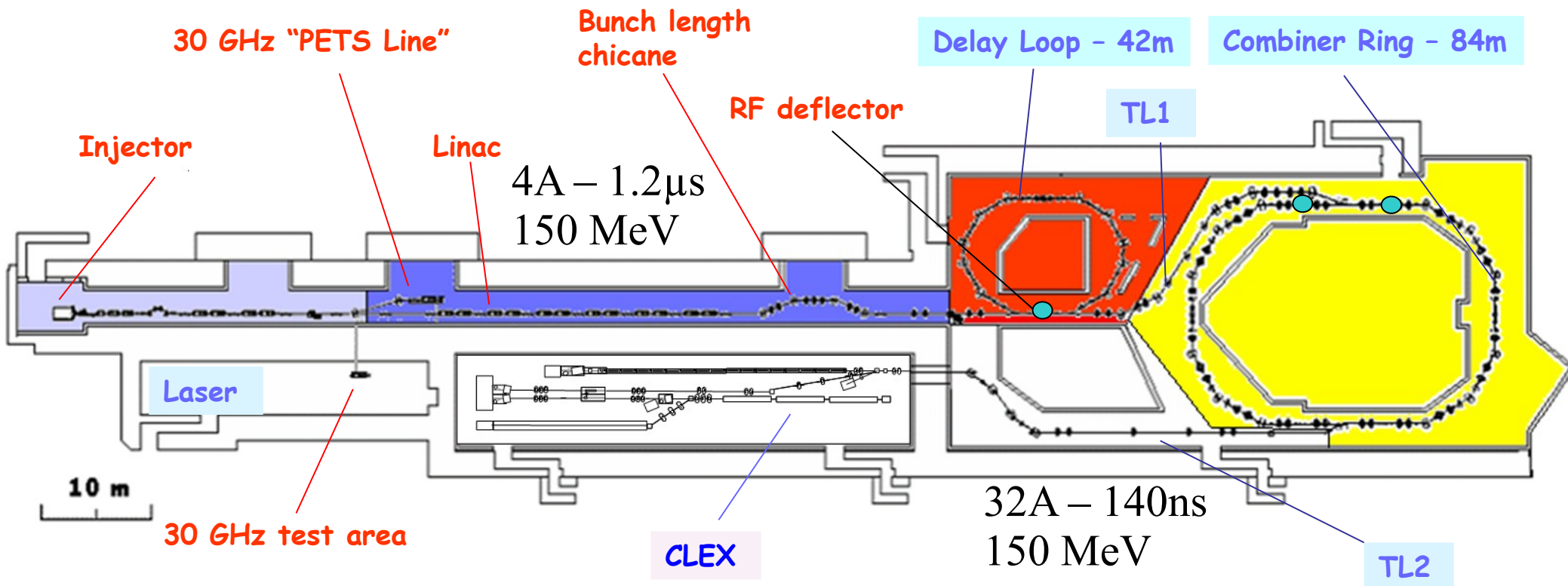
3rd

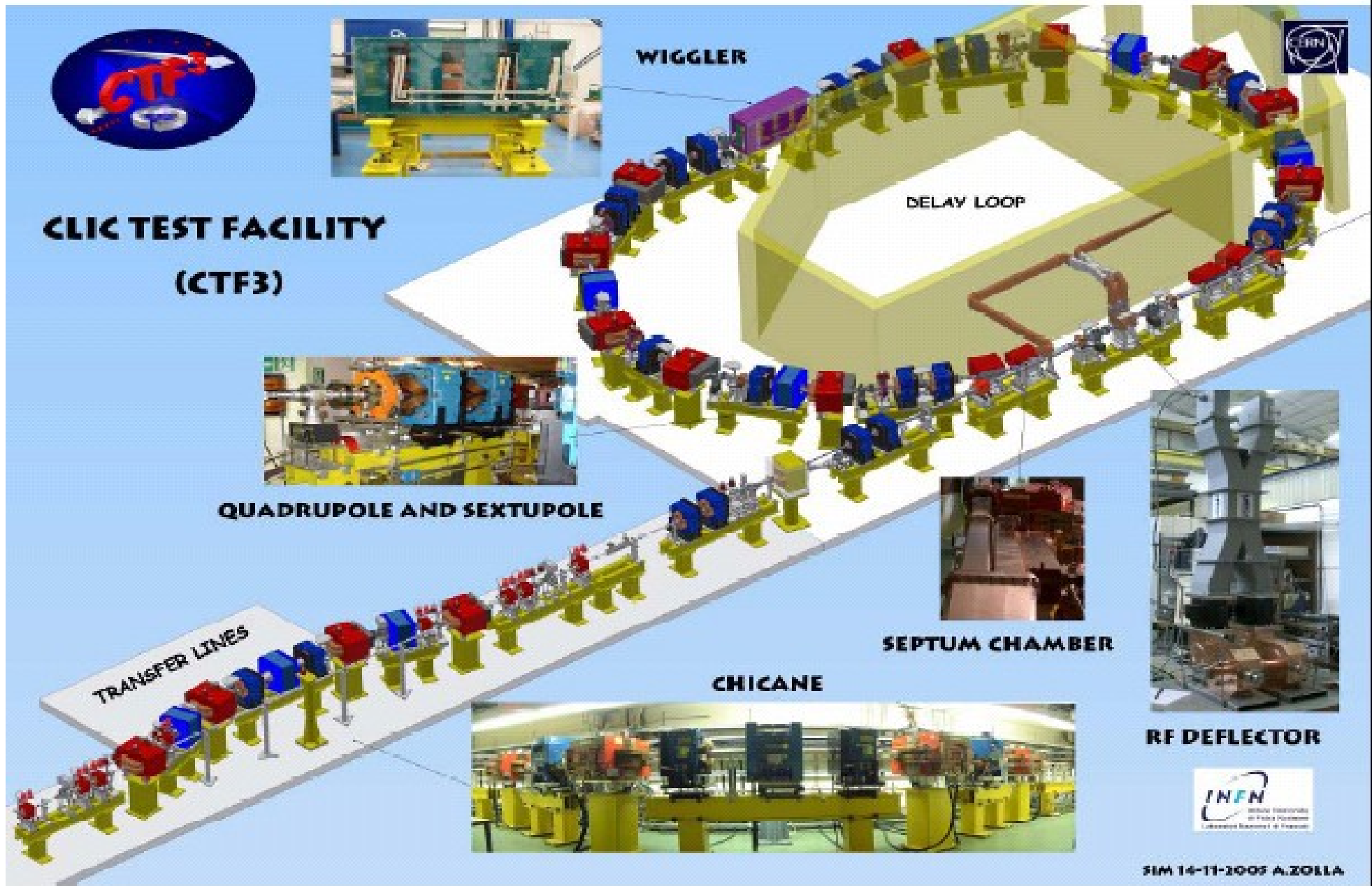


4rd



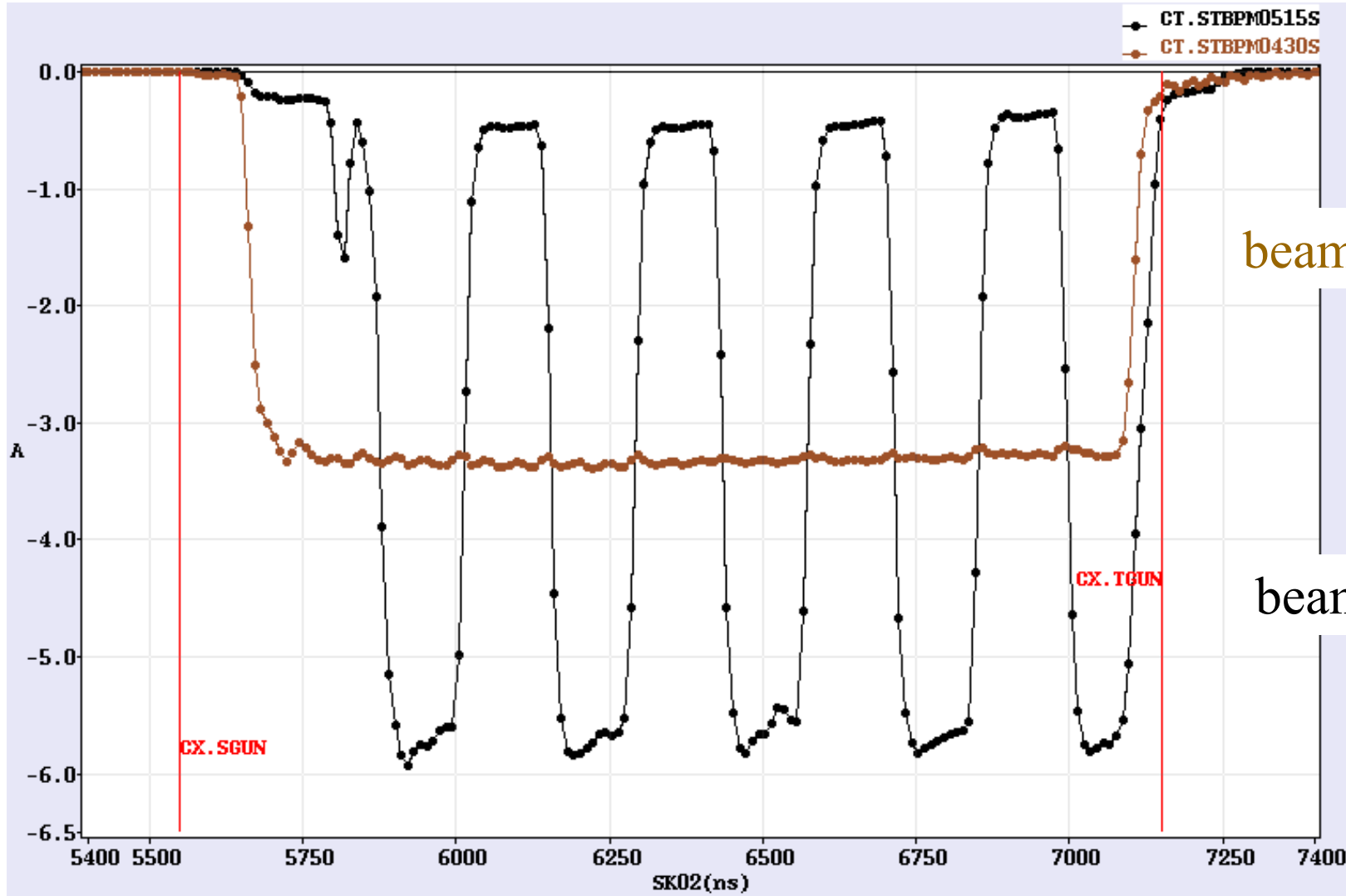
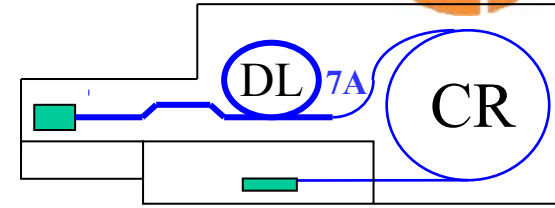
- demonstrate remaining CLIC feasibility issues, in particular:
 - Drive Beam generation (fully loaded acceleration, bunch frequency multiplication)
 - CLIC accelerating structures
 - CLIC power production structures (PETS)





Delay Loop – full recombination

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

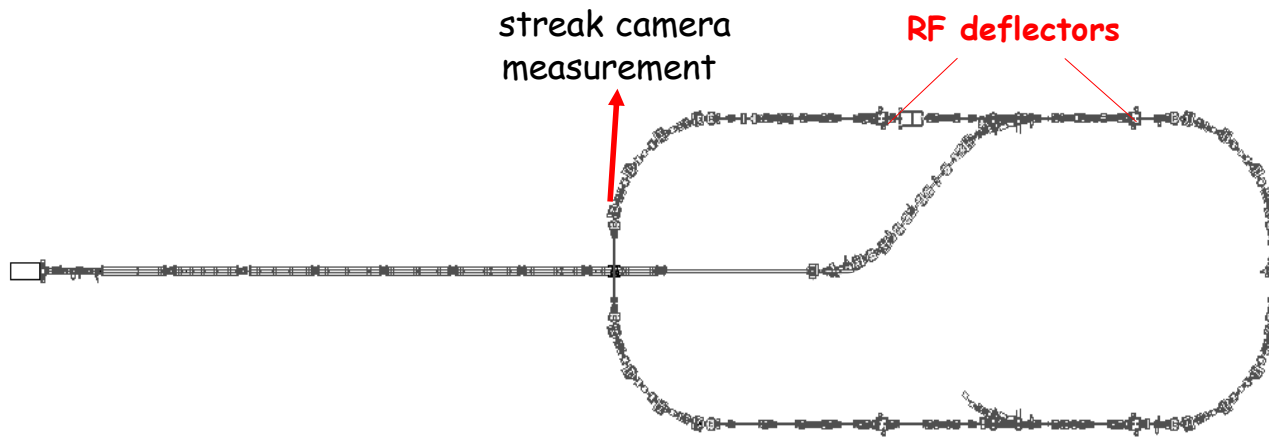


beam **before** the DL

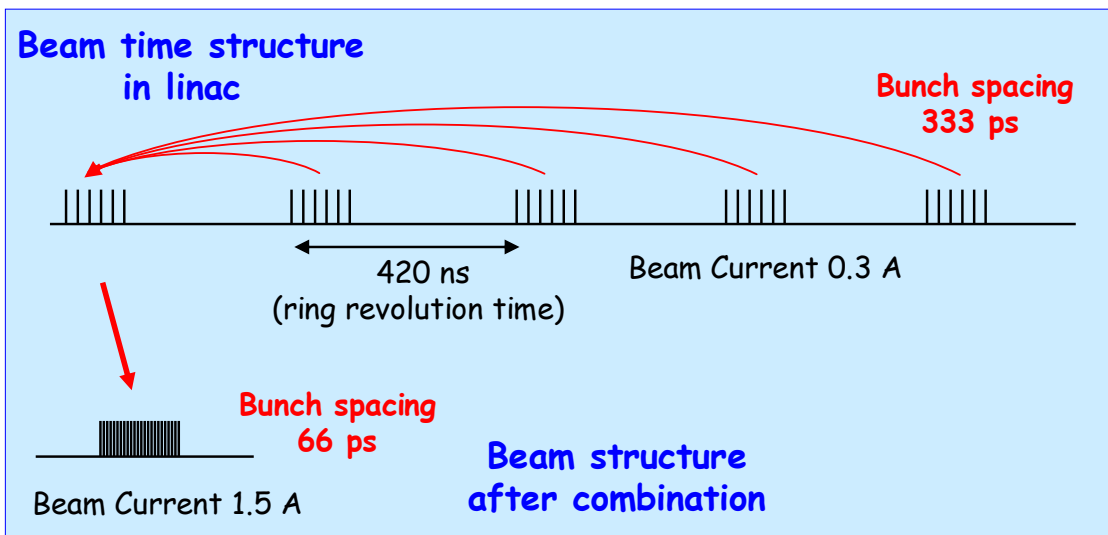
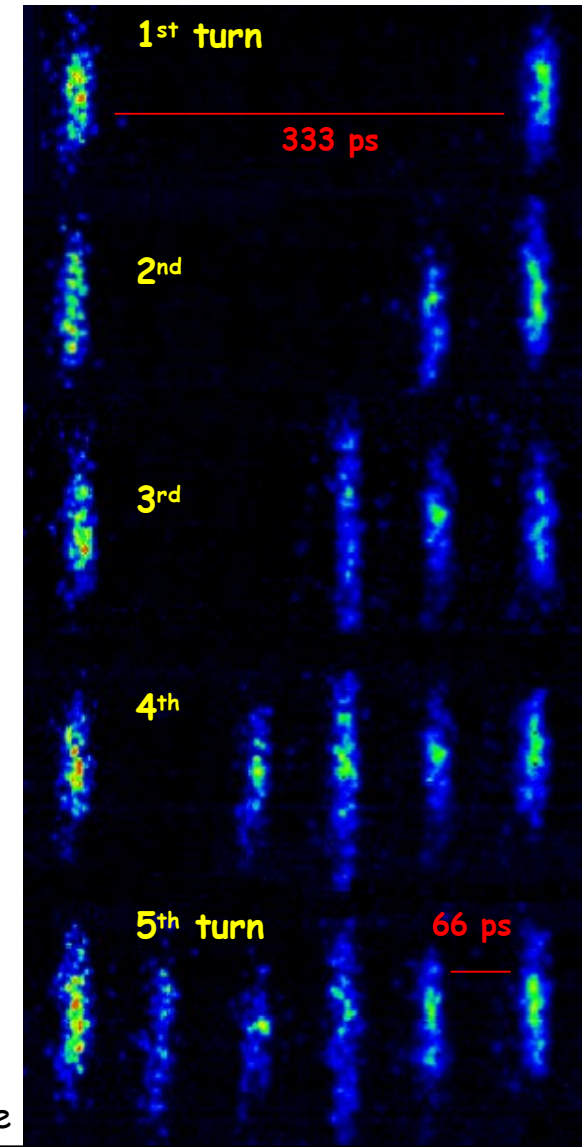
beam **after** the DL

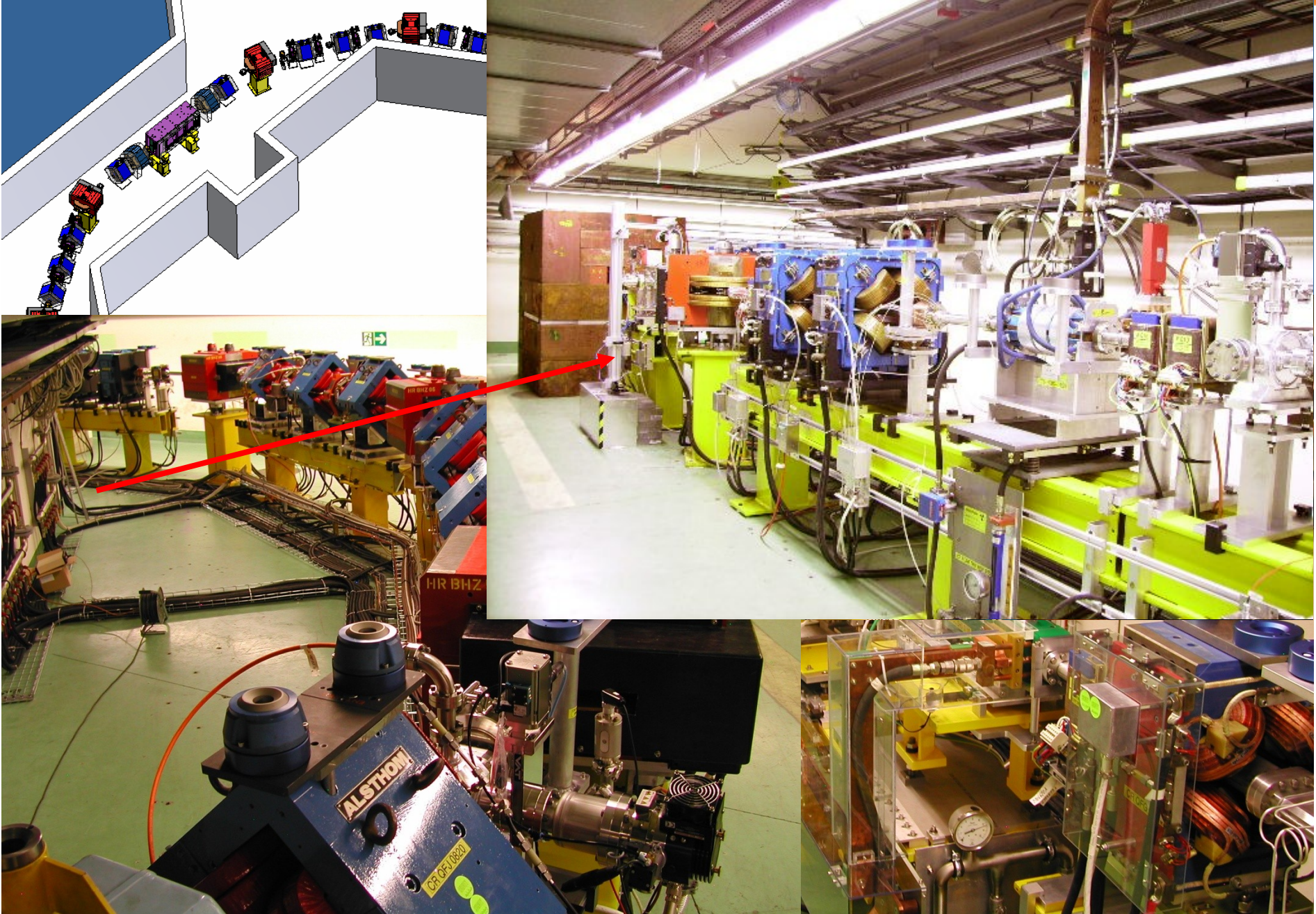
CTF3 - PRELIMINARY PHASE

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

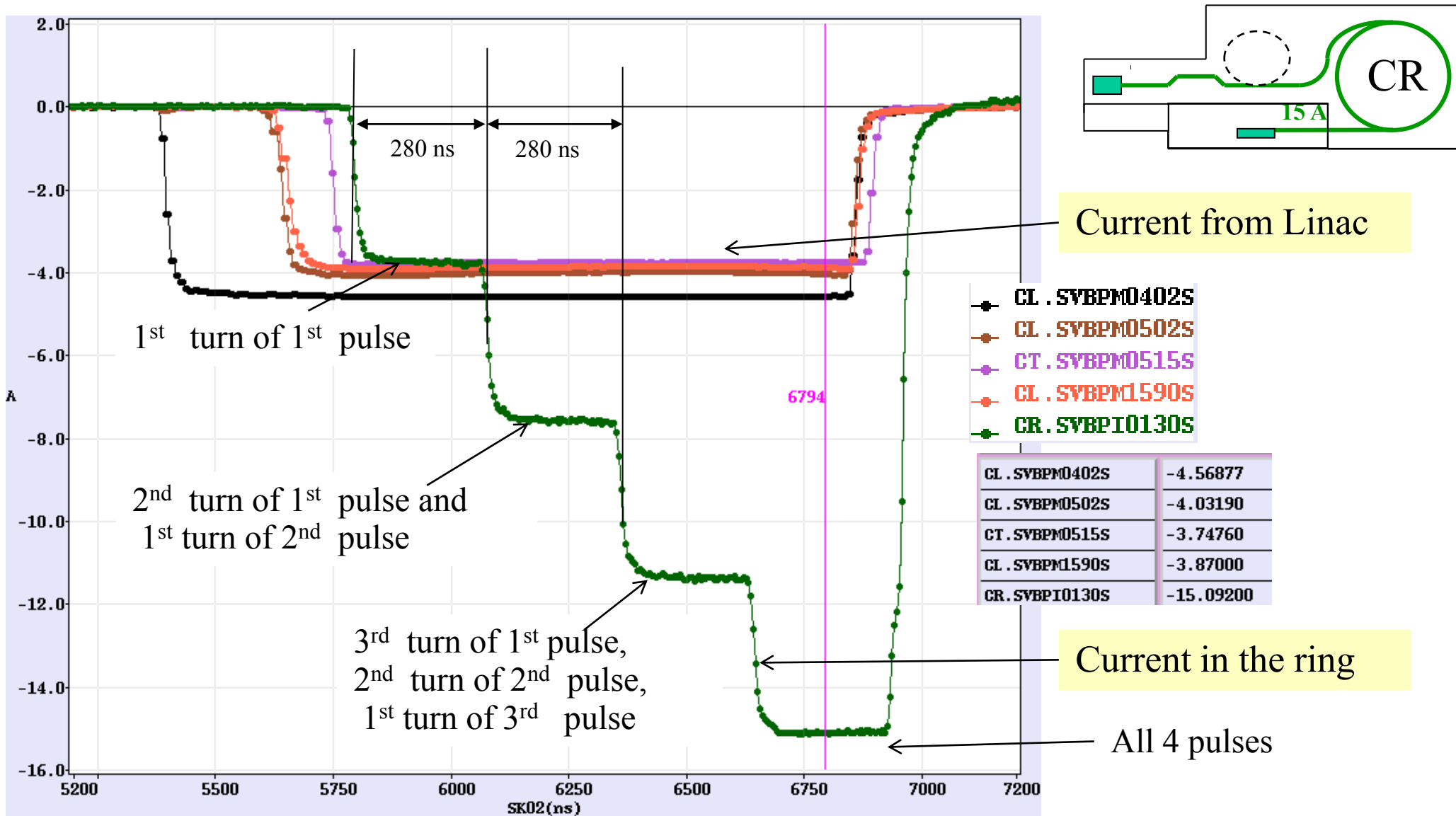


Streak camera image of
beam time structure evolution



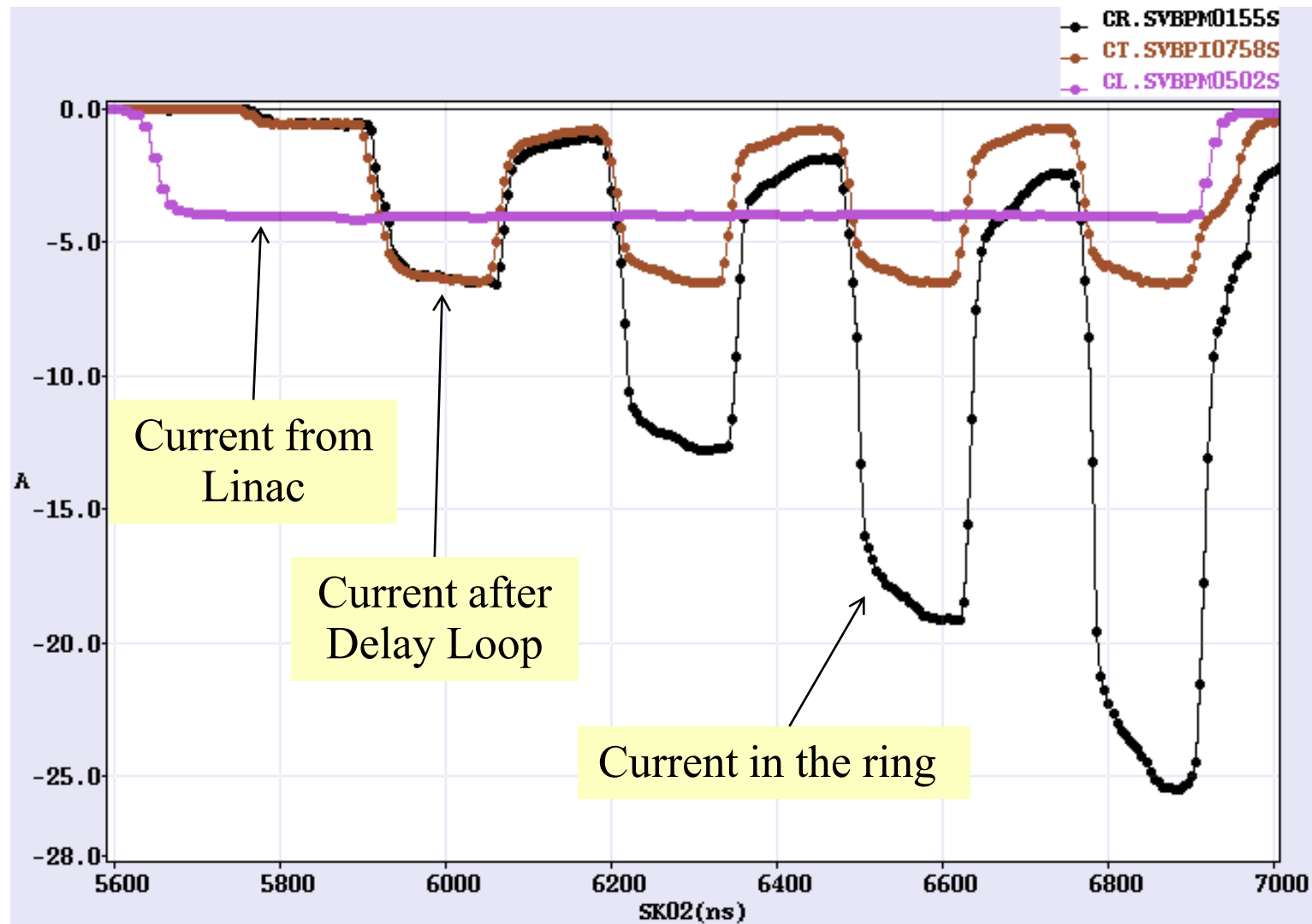
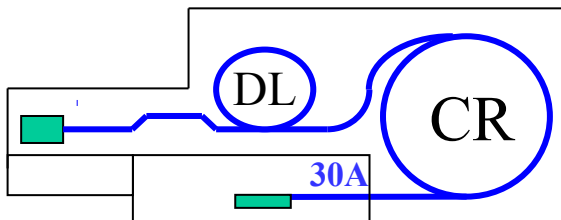


- factor 4 combination achieved with 15 A, 280 ns (without Delay Loop)

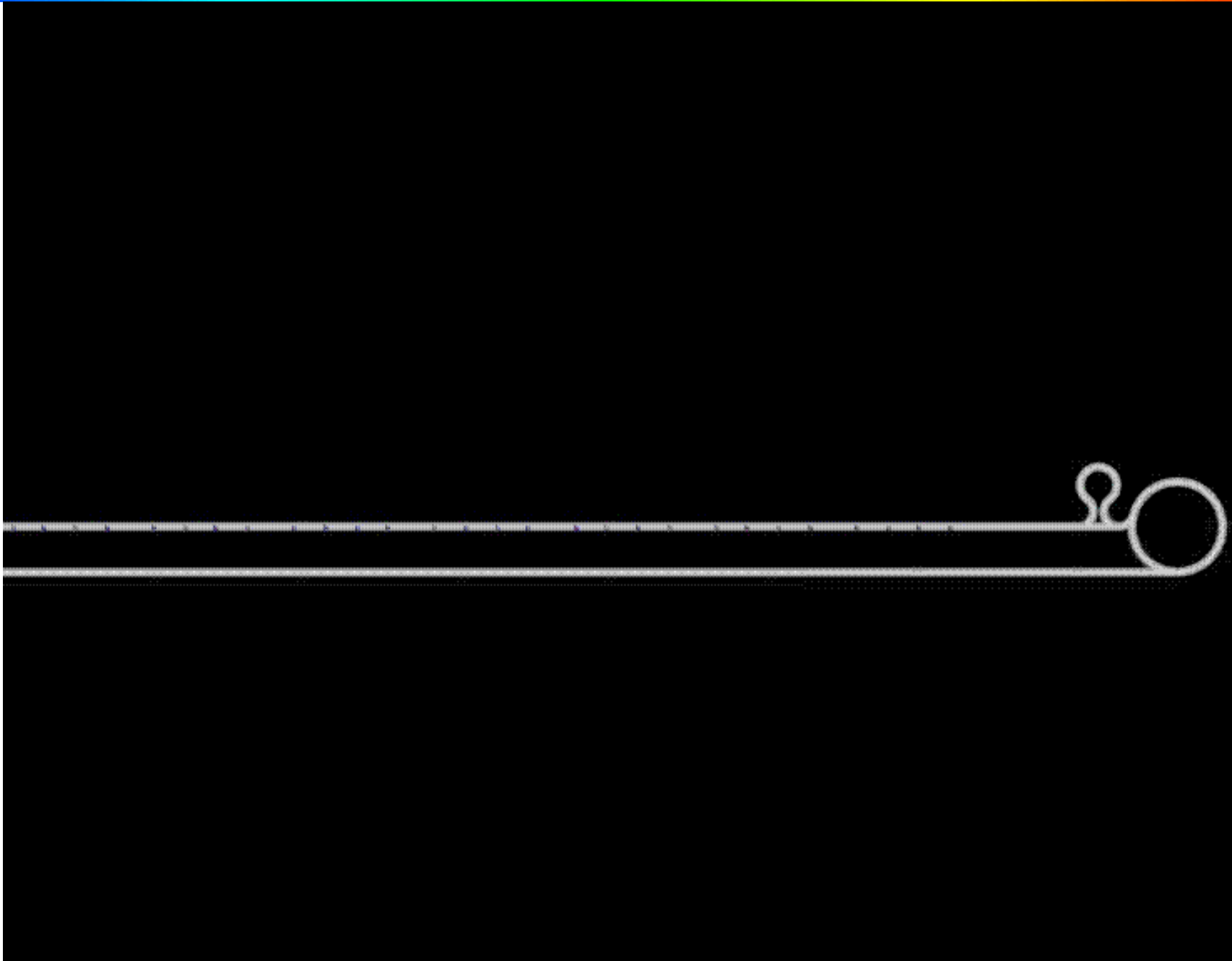


Factor 8 combination (DL+CR)

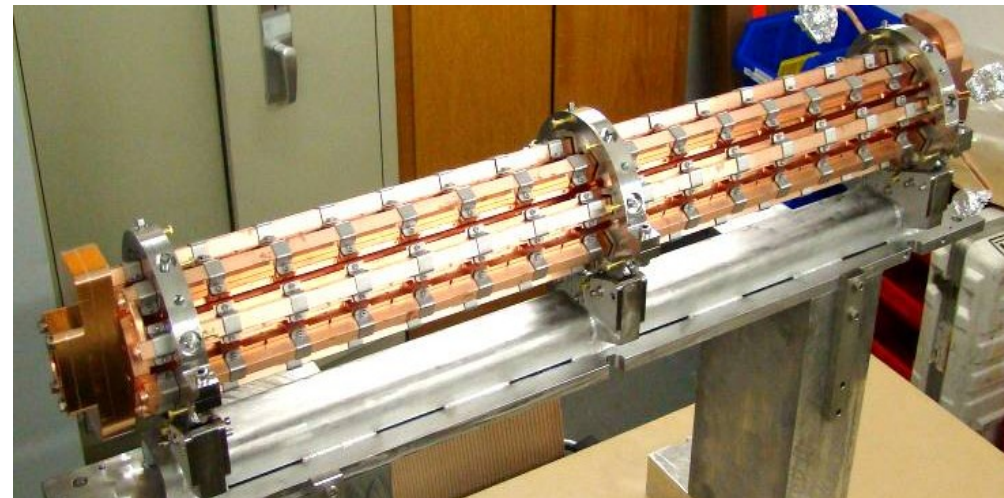
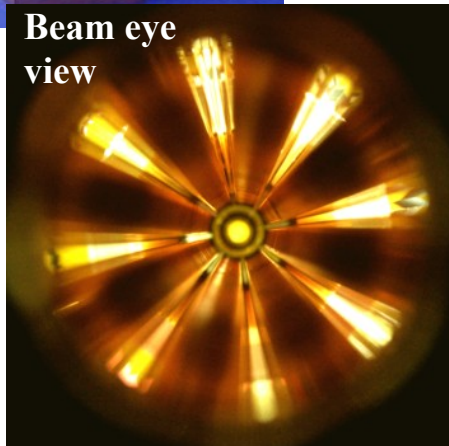
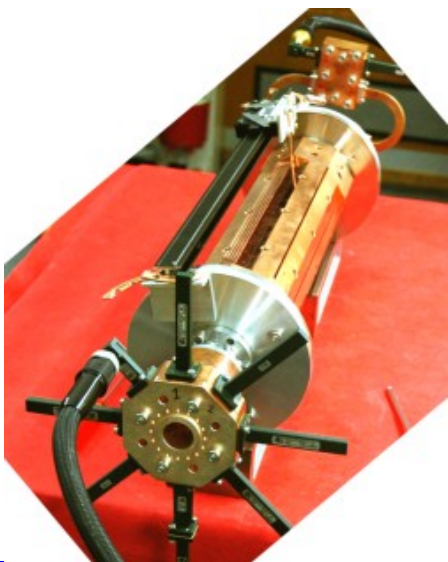
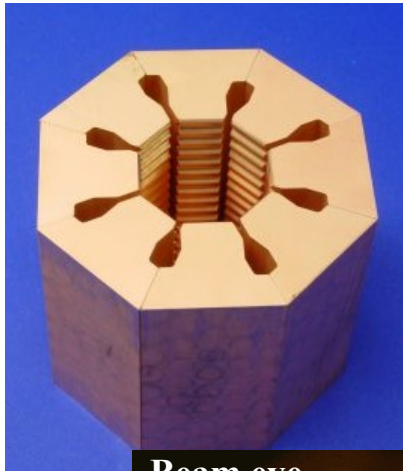
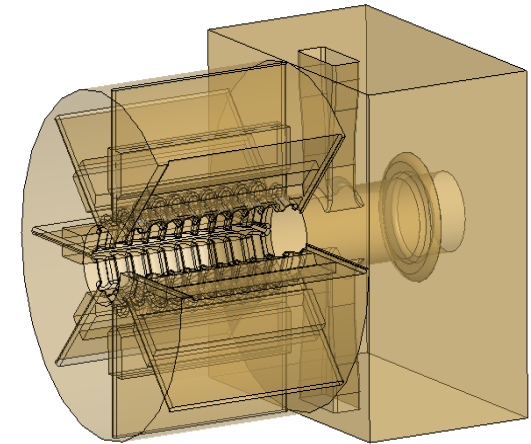
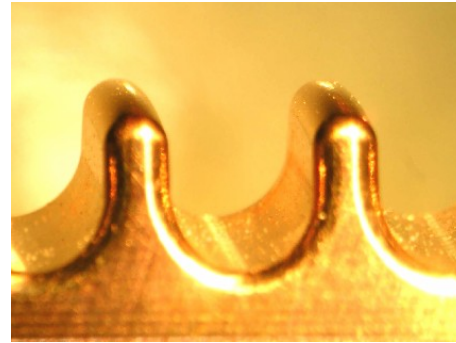
- ~26 A combination achieved, nominal 140 ns pulse length
- detailed studies still to be done

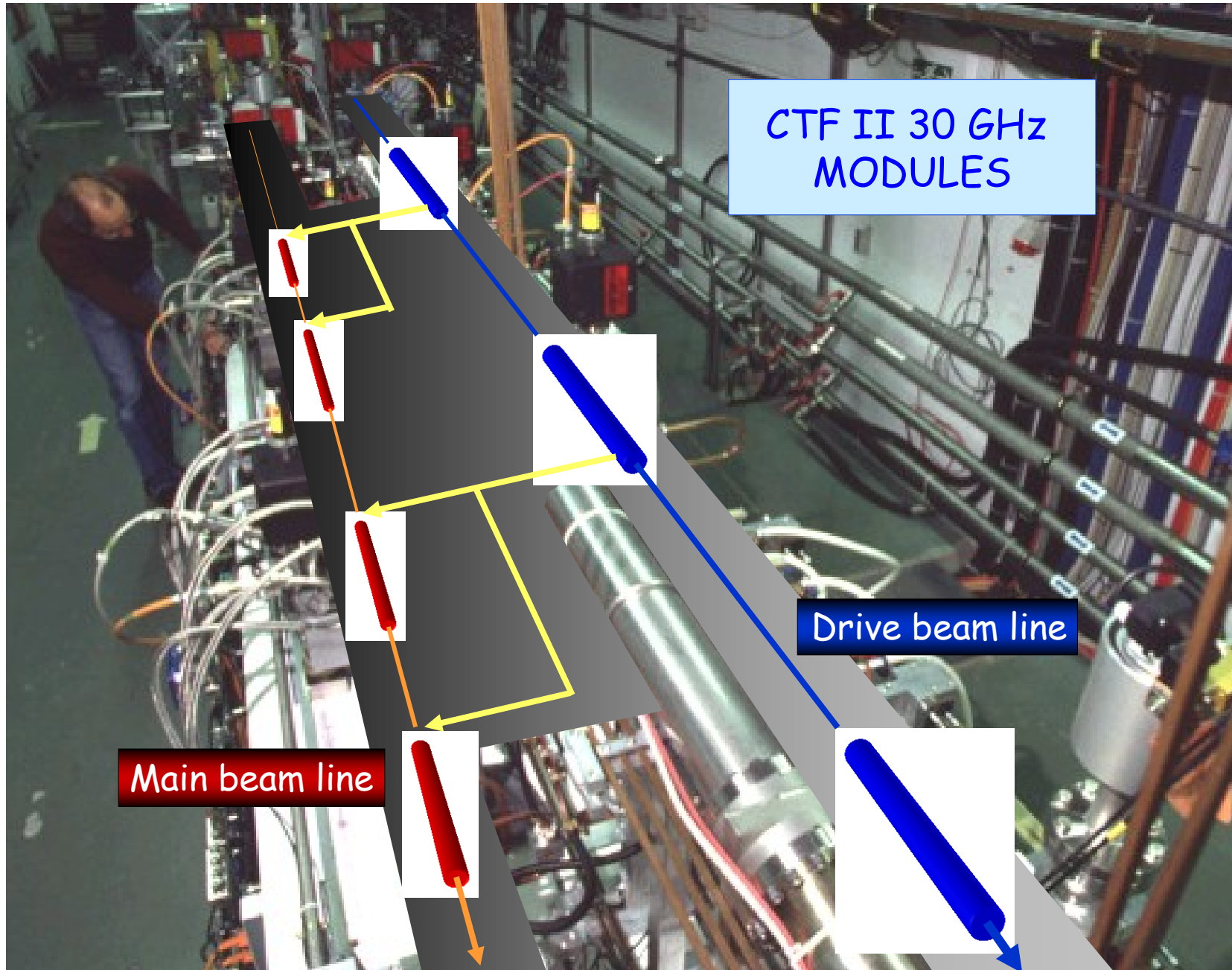


Lemmings Drive Beam

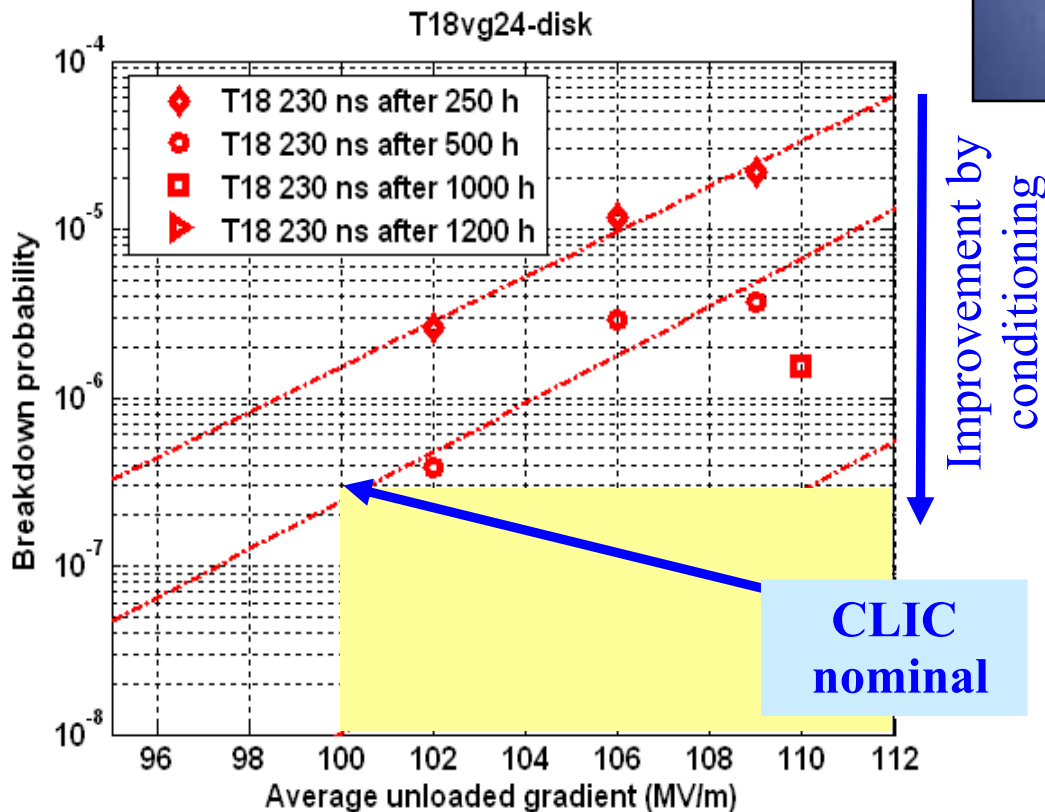


- must extract efficiently several 100 MW power from high current drive beam
- periodically corrugated structure with low impedance (big a/λ)
- ON/OFF mechanism



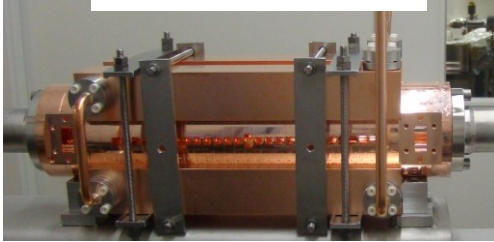


- Exceeded 100 MV/m at nominal CLIC pulse length and breakdown rate



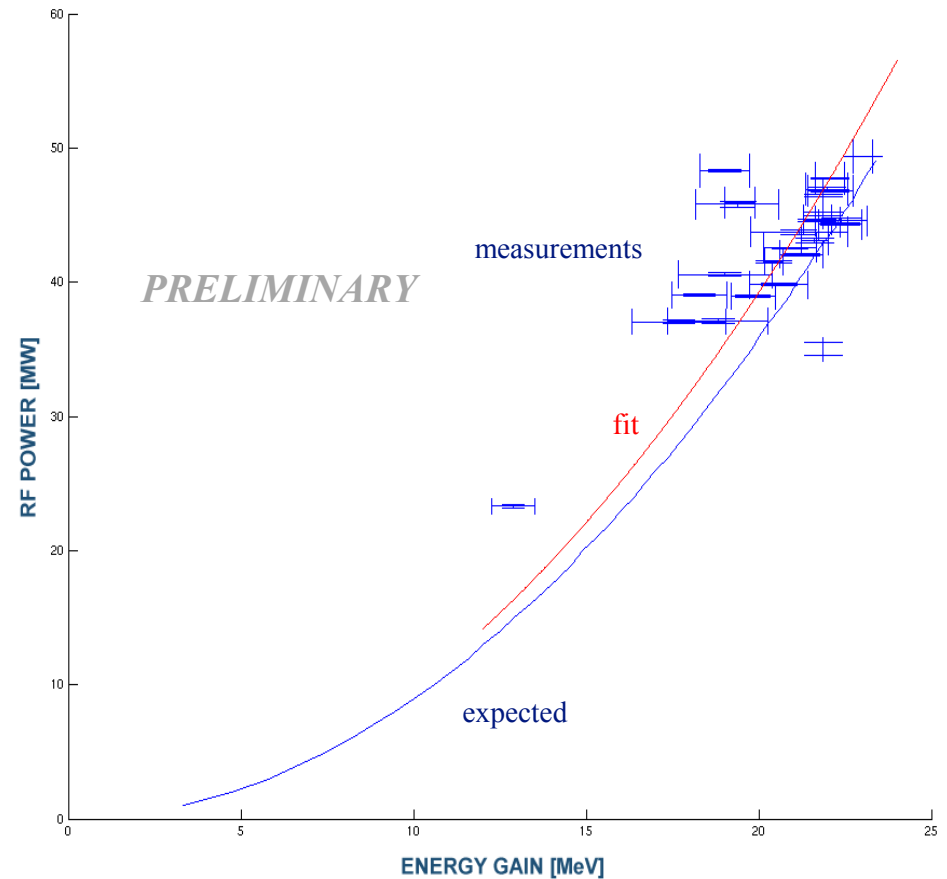
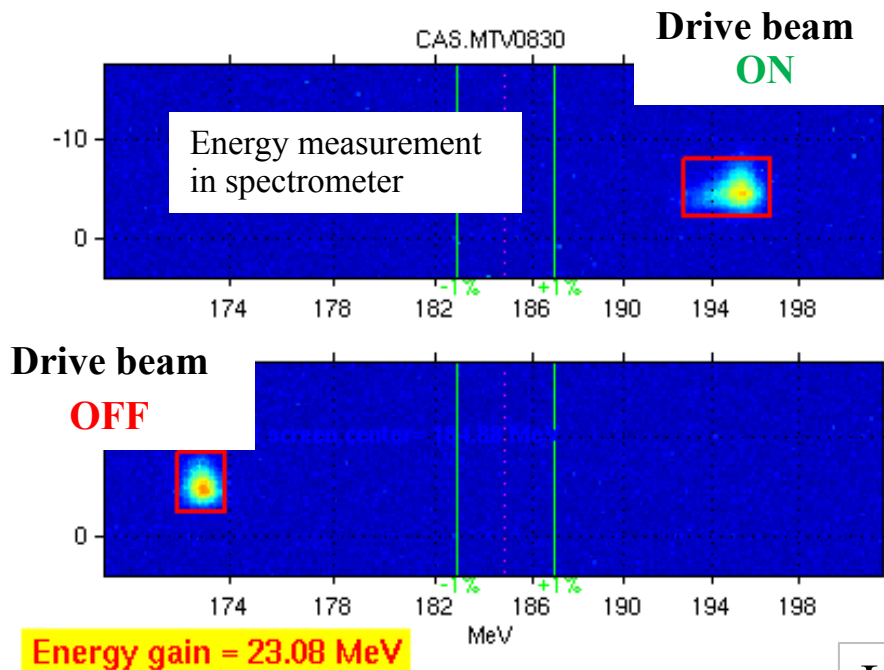
Frequency:	11.424 GHz
Cells:	18+2 matching cells
Filling Time:	36 ns
Length: active acceleration	18 cm
Iris Dia. a/λ	0.155~0.10
Group Velocity: vg/c	2.6-1.0 %
Phase Advance Per Cell	$2\pi/3$
Power for $\langle Ea \rangle = 100 \text{ MV/m}$	55.5 MW
Unloaded $Ea(\text{out})/Ea(\text{in})$	1.55
Es/Ea	2

TD24 accelerating structure



Maximum probe beam acceleration of **23 MeV**
measured (with structure heated to 60°C)

=> Corresponding to a **gradient of 106 MV/m**



Lots of work still to be done, but on-time to complete feasibility benchmarks by mid-2011

- CTF3 is to show the CLIC feasibility until 2011
 - stable Drive Beam generation
 - high gradient RF performance
 - many **important results** obtained **so far**
 - some key issues still to demonstrate
 - challenging but very interesting
-
- next: the visit