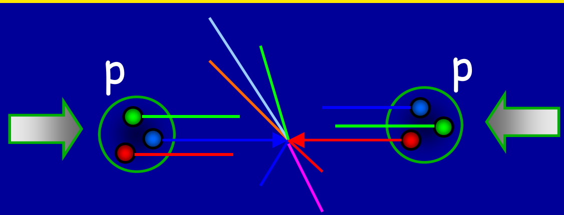
Short Introduction to CLIC and CTF3, Technologies for Future Linear Colliders

Explanation of the Basic Principles and Goals

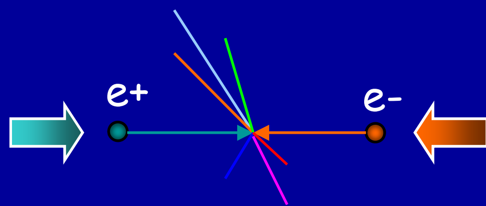
Visit to the CTF3 Installation

Roger Ruber

Collider History

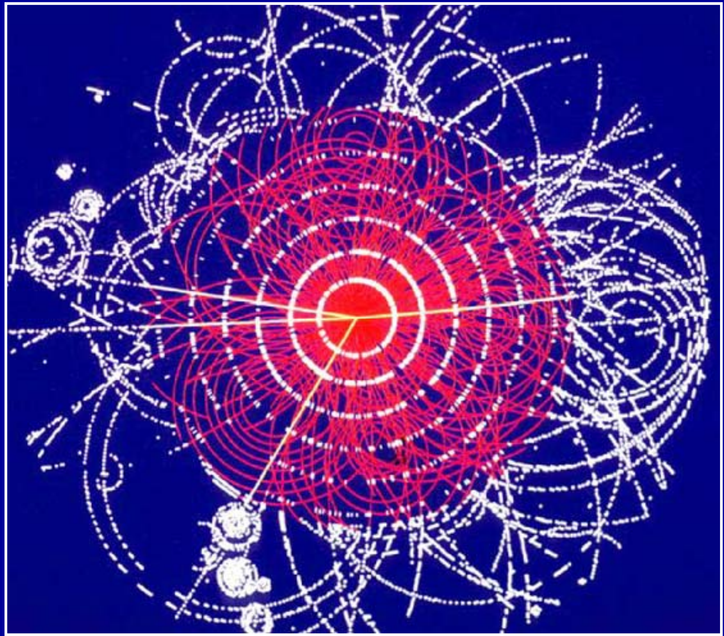


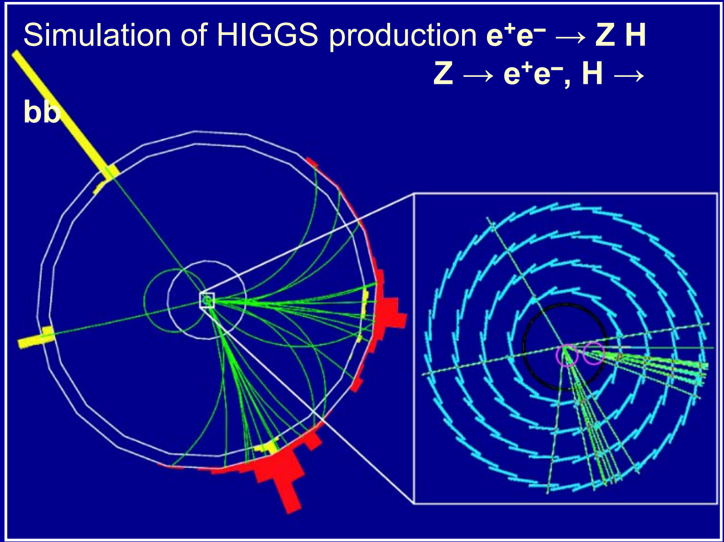
- hadron collider at the frontier of physics
  - huge QCD background
  - not all nucleon energy available in collision



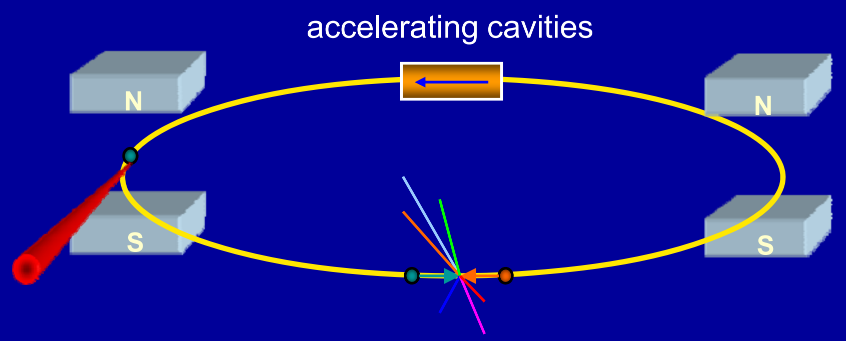
- lepton collider for precision physics
  - well defined CM energy
  - polarization possible

- next machine after LHC
  - e^+e^- collider
  - energy determined by LHC discoveries consensus $E_{cm} \geq 0.5$ TeV





Circular versus Linear Collider

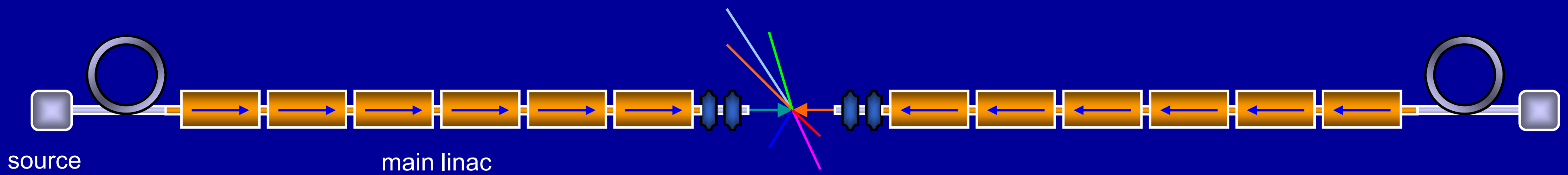


Circular Collider

many magnets, few cavities, stored beam

higher energy → stronger magnetic field

→ higher synchrotron radiation losses ($\propto E^4/R$)



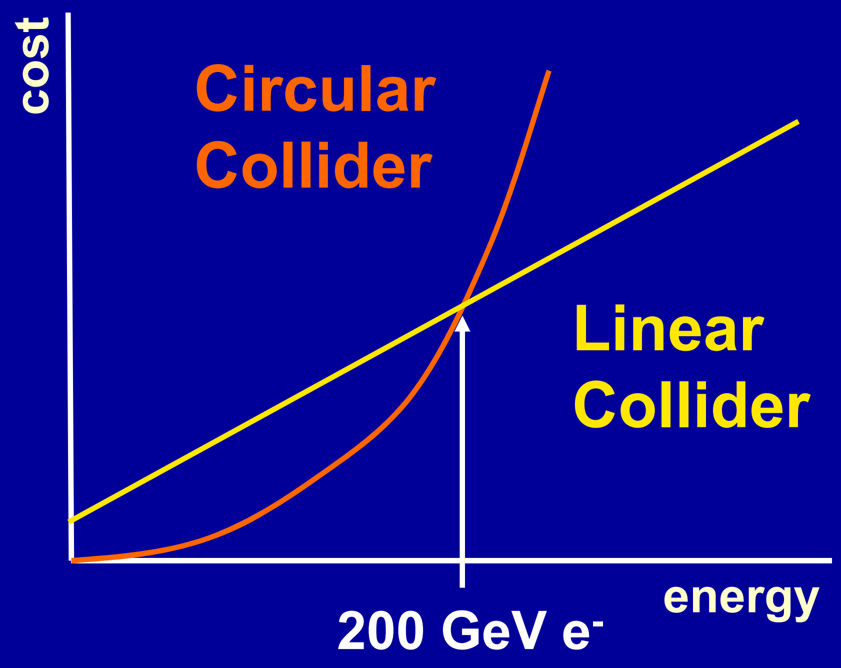
Linear Collider

few magnets, many cavities, single pass beam

higher energy → higher accelerating gradient

higher luminosity → higher beam power (high bunch repetition)

Cost of Circular & Linear Accelerators



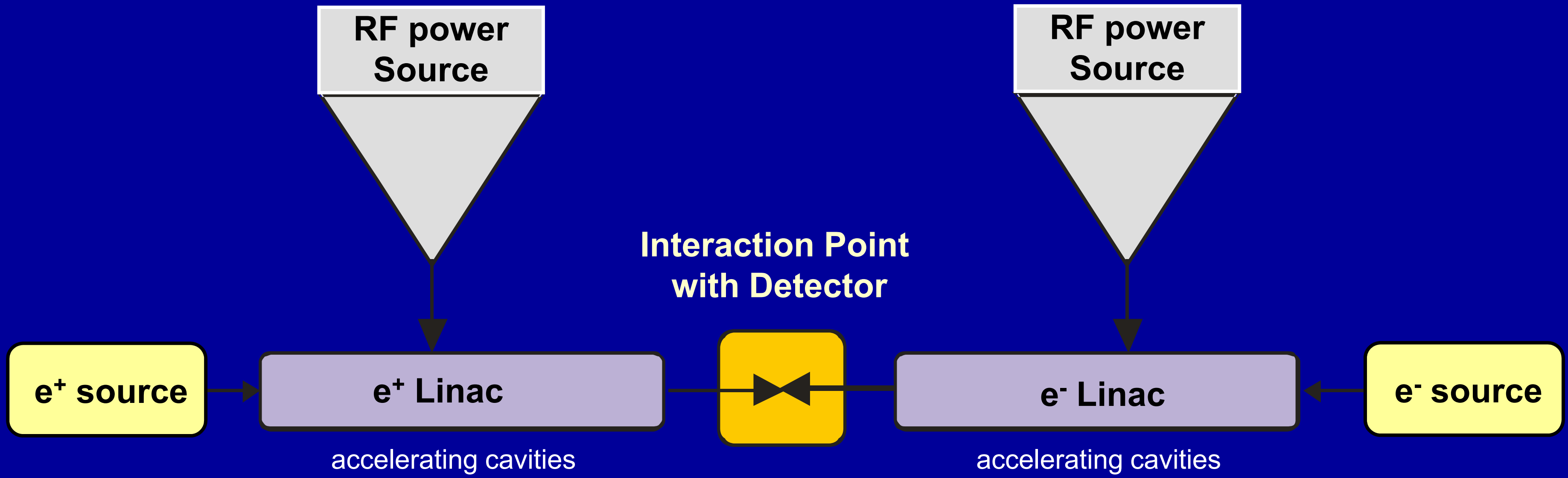
Circular Collider

- $\Delta E \sim (E^4/m^4 R)$
- cost ~ aR + b ΔE
- optimization: $R \sim E^2 \rightarrow$ cost ~ cE^2

Linear Collider

- $E \sim L$
- cost ~ aL

Linear Collider R&D



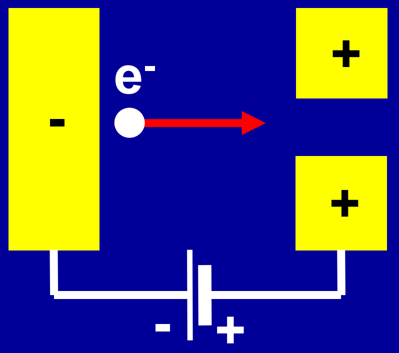
CTF3 goals:

1. **high accelerating gradient**
2. efficient power production
3. feasibility demonstration

Acceleration of Charged Particles

- Lorenz (EM) force most practical

$$\mathbf{F} = e(\mathbf{v} \times \mathbf{B} + \mathbf{E})$$



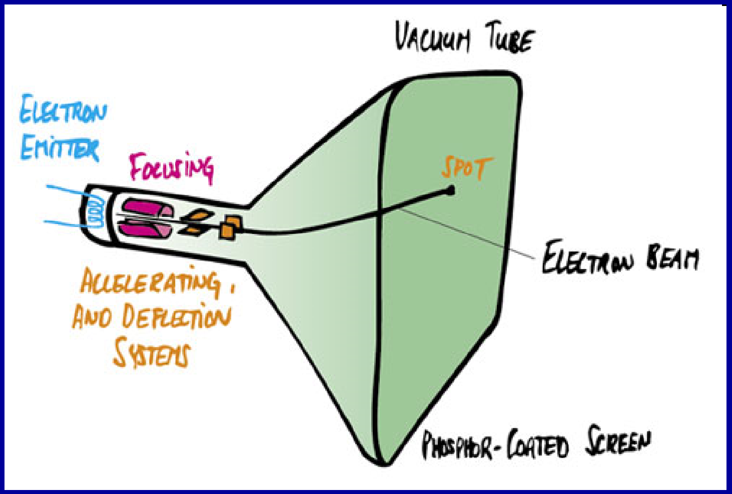
- increasing particle energy

$$\Delta E = e\int \mathbf{E} \cdot d\mathbf{r} = eU$$

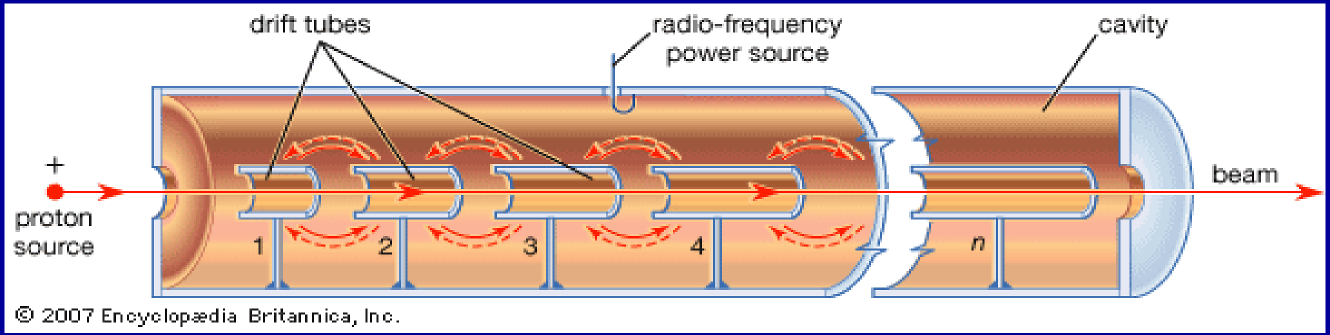
- to gain 1 MeV energy requires a 1 MV field

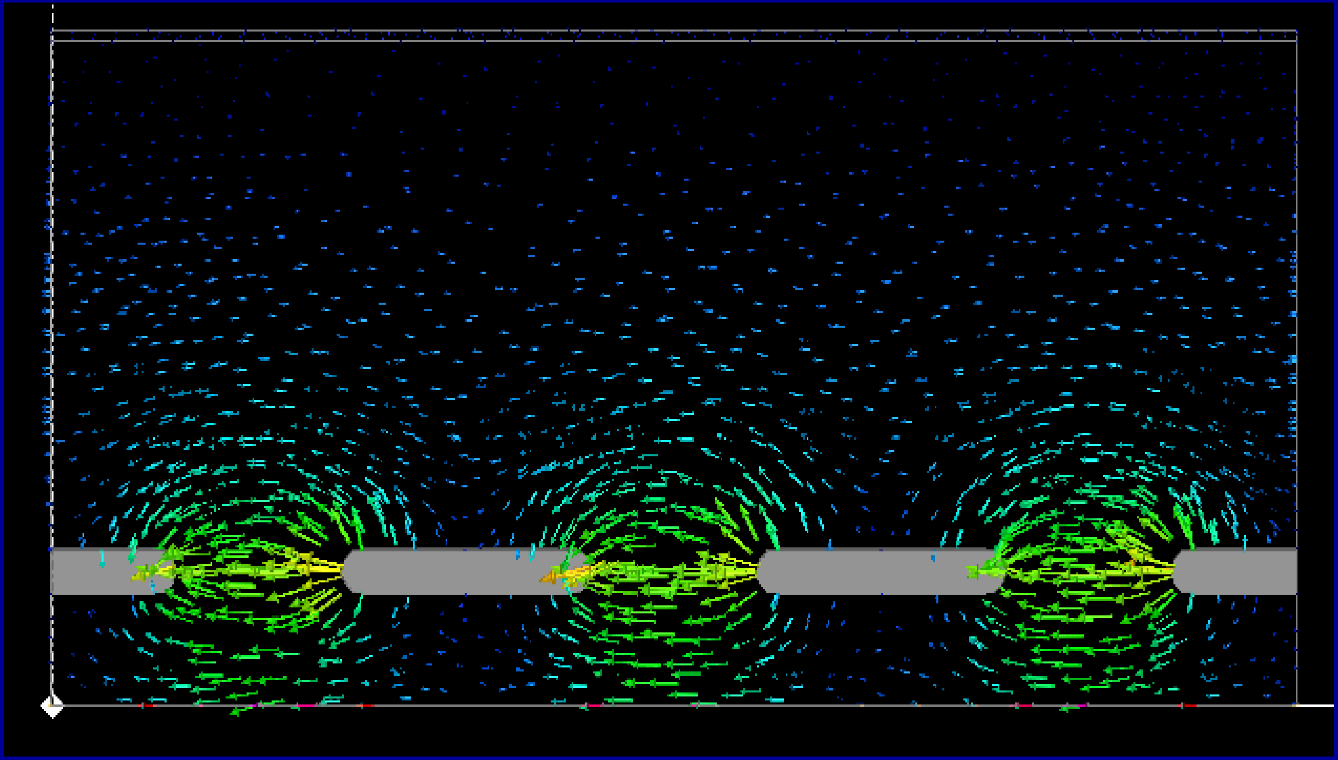
Direct-voltage acceleration used in

- TV tube: 20~40 kV
- X-ray tube: ~100 kV
- tandem van de Graaff: up to ~25 MV

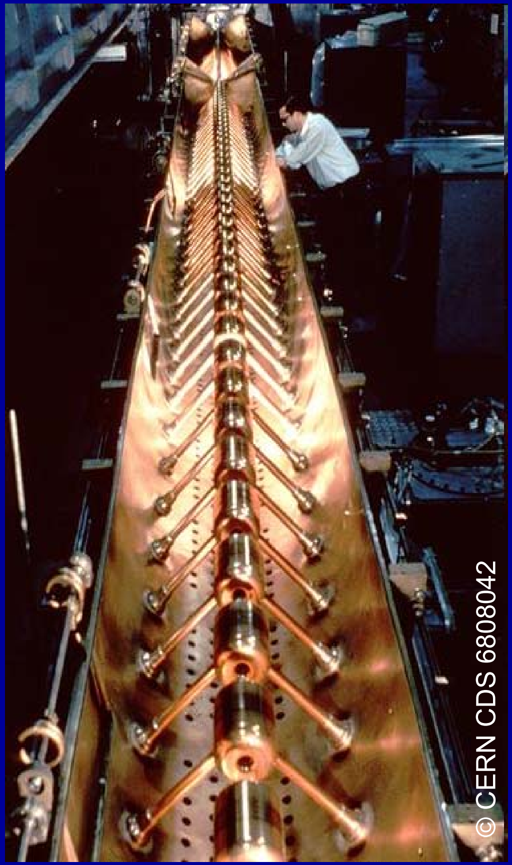


Drift Tube Linac: Higher Integrated Field



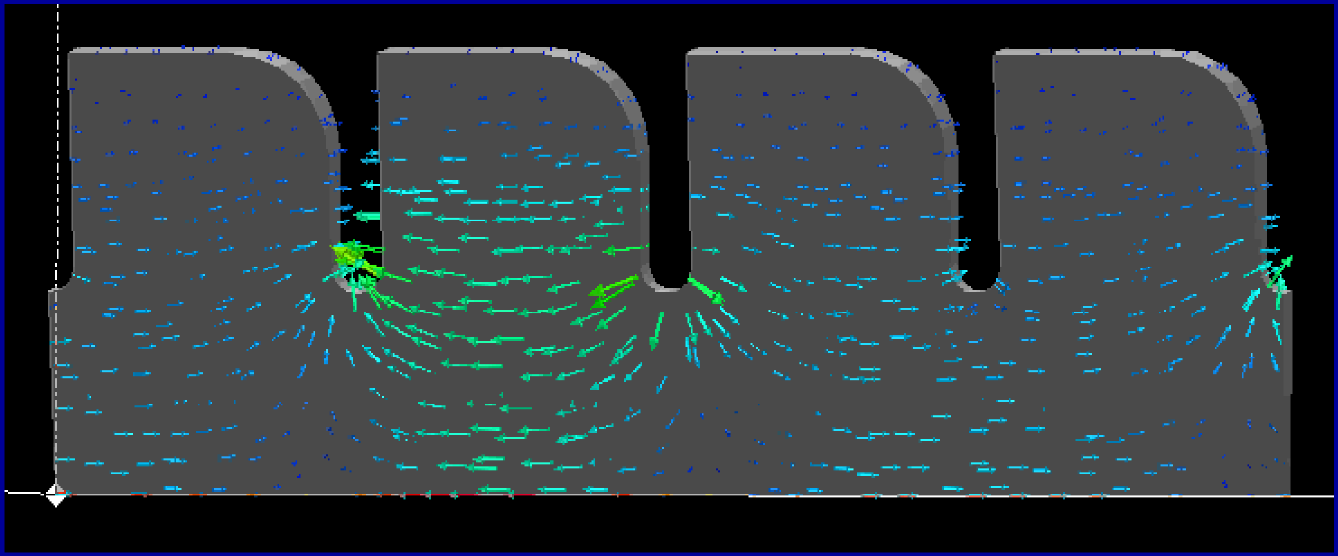


Courtesy E. Jensen

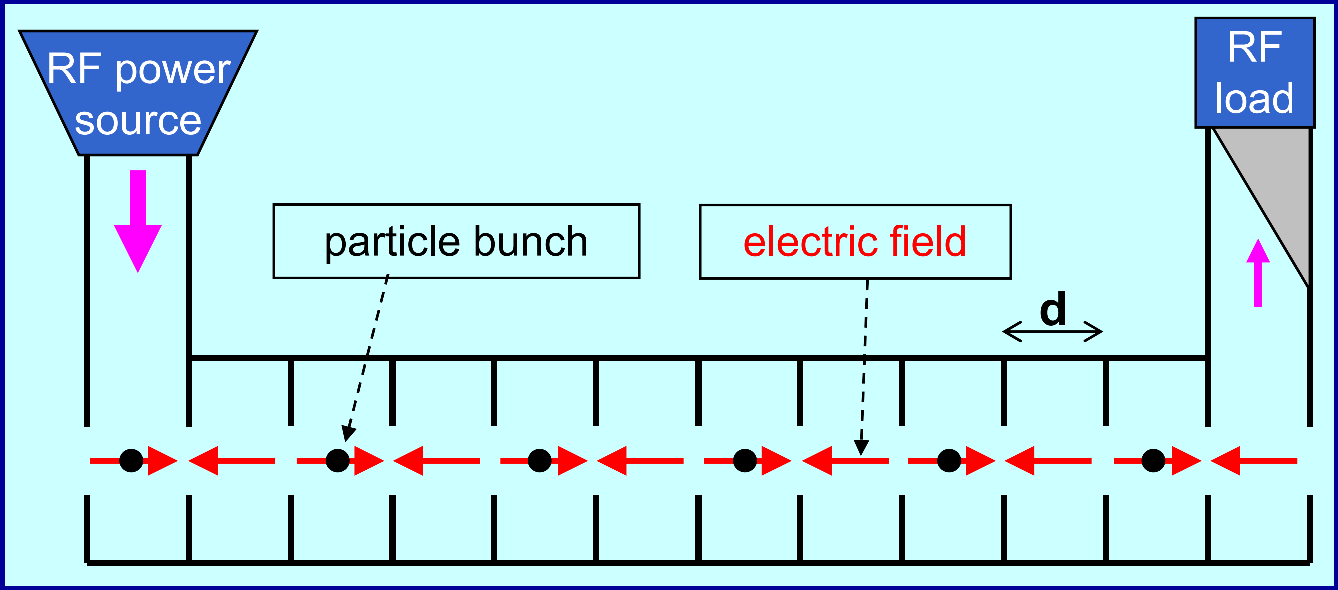


Travelling Wave Structure

- electrons β~1 (v~c)

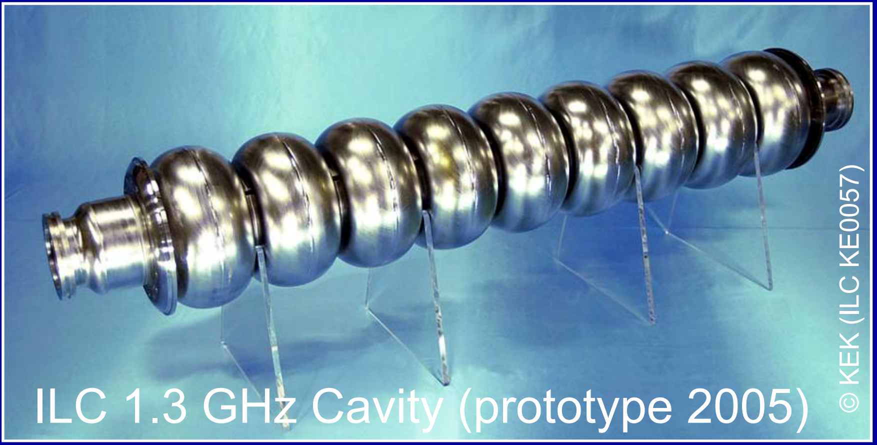


- short pulses
- high frequency >3 GHz
- typical 10~20 MV/m
- CLIC:
  - 12 GHz
  - 240 ns
  - 100 MV/m

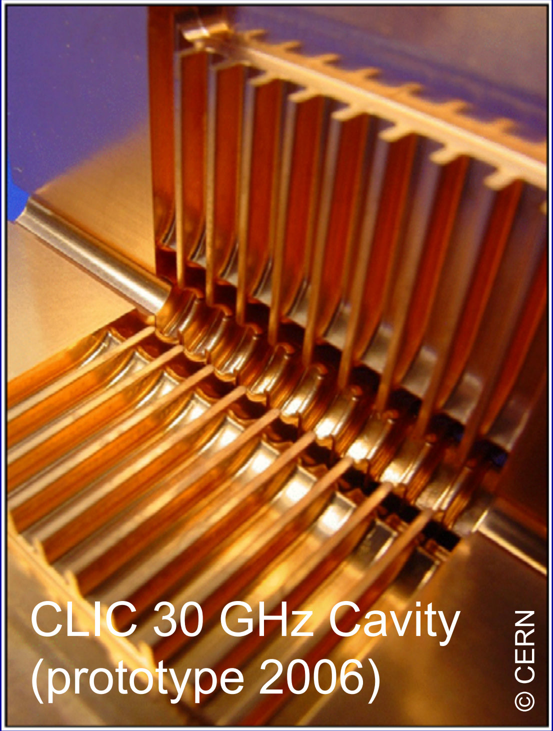


Accelerating Cavities

CERN PS 19 MHz Cavity (prototype 1966)



ILC 1.3 GHz Cavity (prototype 2005)



CLIC 30 GHz Cavity (prototype 2006)

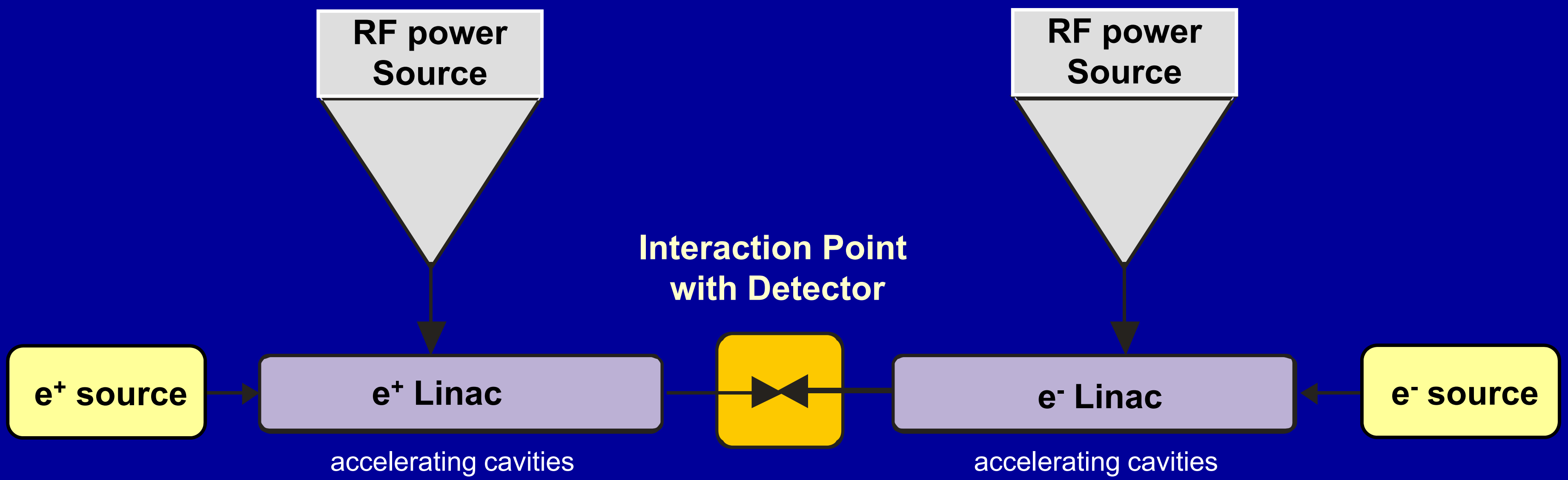
Surfing: or How to Accelerate Particles

DC Accelerator

RF Accelerator

synchronize particle
with an
electromagnetic wave!

Linear Collider R&D



Challenges:

1. high accelerating gradient
2. **efficient power production**
3. feasibility demonstration

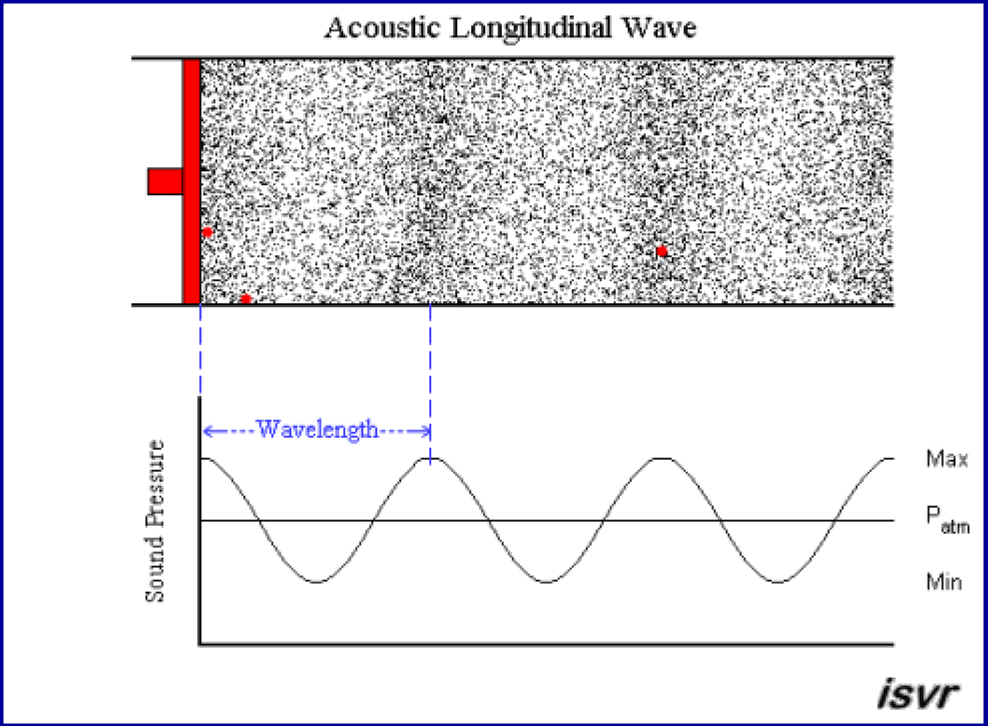
Electromagnetic Waves

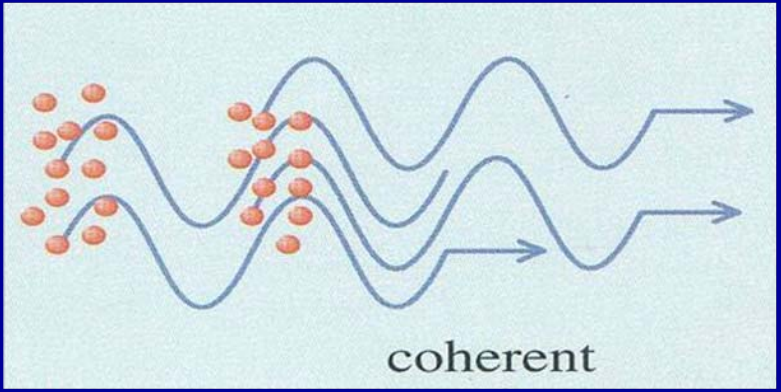
- static electron
  → electric field

- moving electron
  → electromagnetic wave

- constant electron beam
  → static electric field
  + static magnetic field

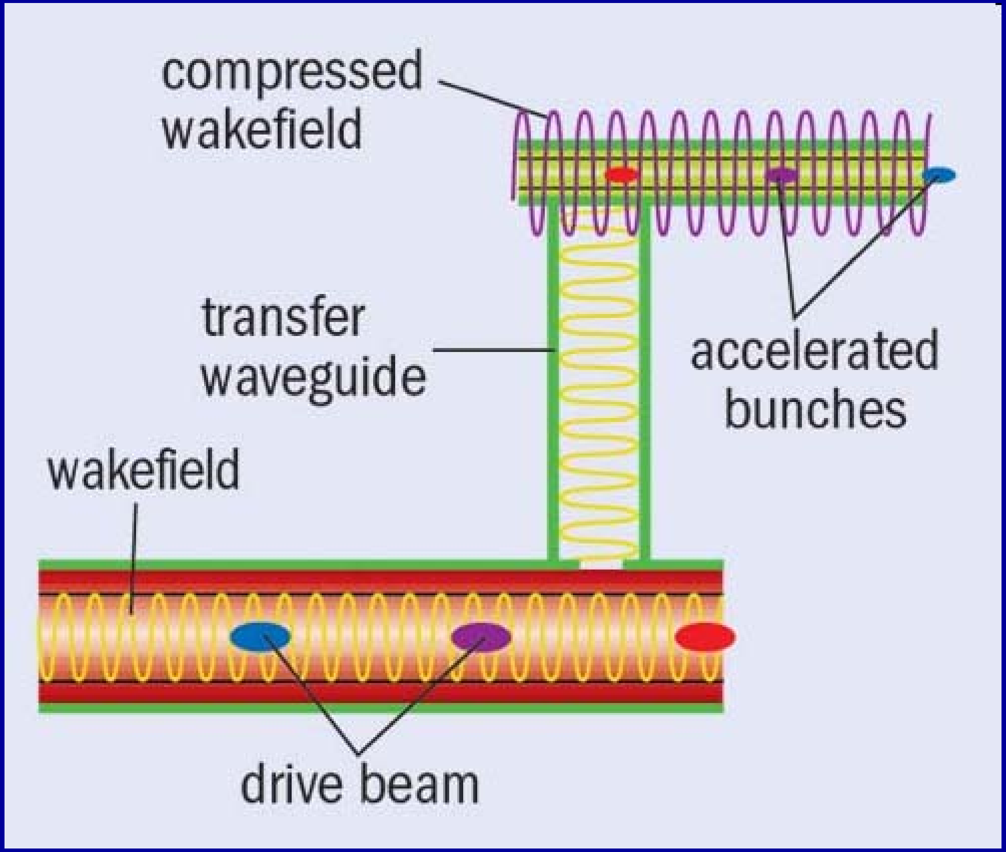
- bunched electron beam
  → electromagnetic wave

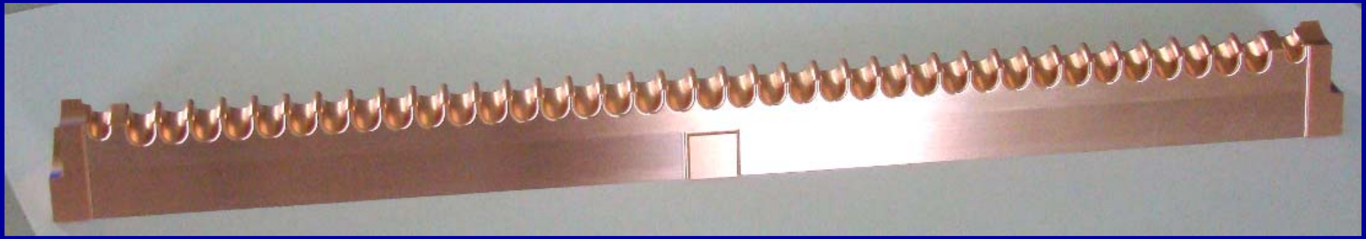




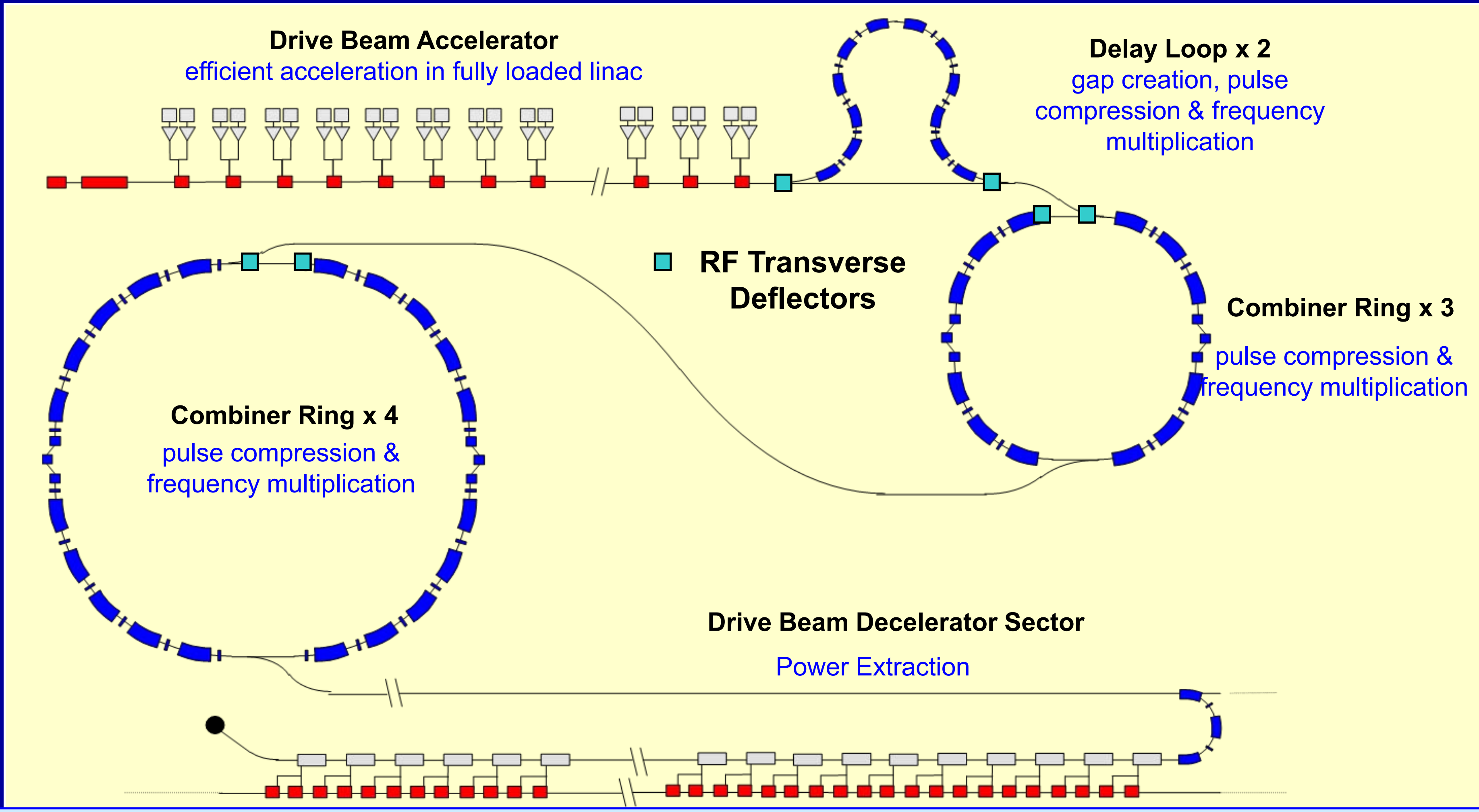
CLIC Two-beam Acceleration Concept

- 12 GHz modulated and high power drive beam
- RF power extraction in a special structure (PETS)
- use RF power to accelerate main beam

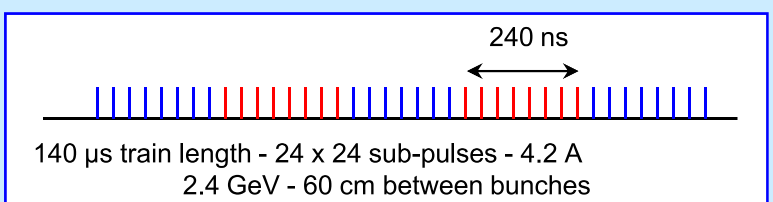




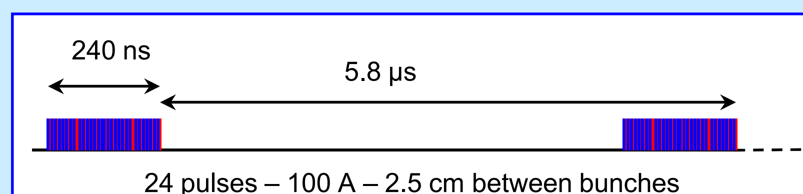
Recombination to Increase Peak Power & Frequency



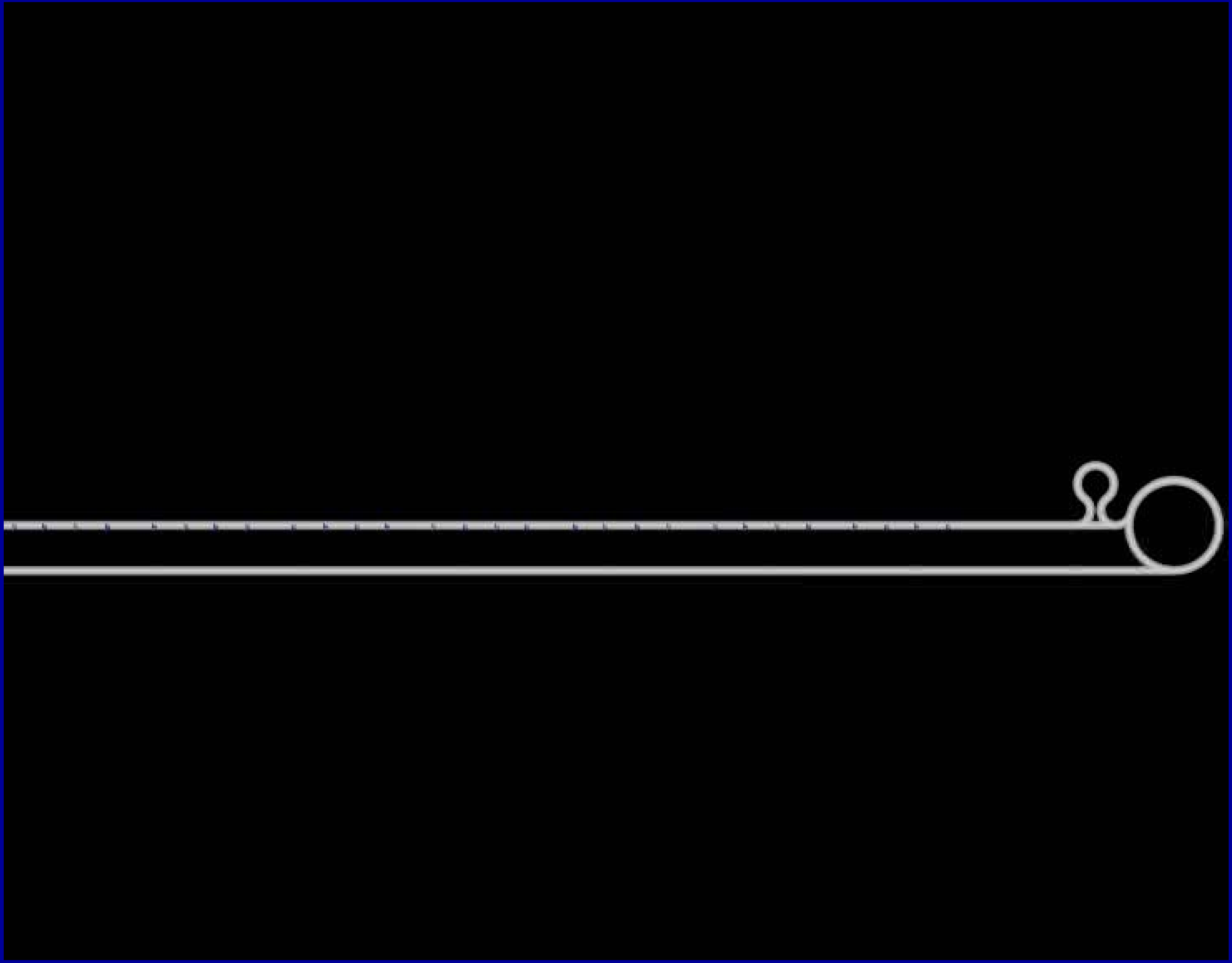
Drive beam time structure - initial



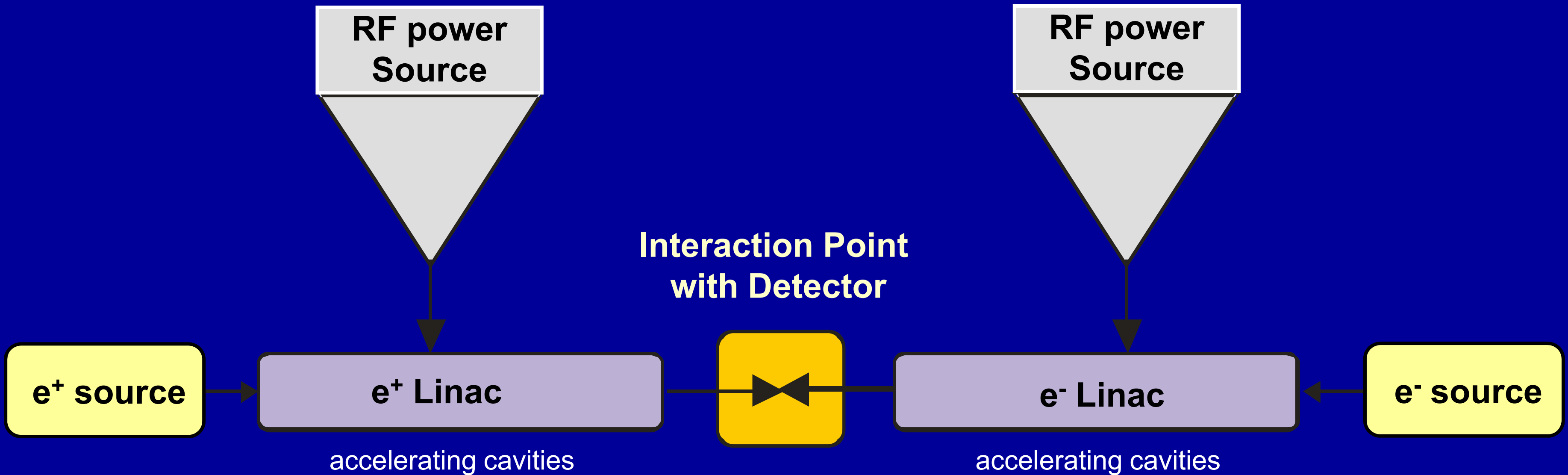
Drive beam time structure - final



Drive Beam Generation Scheme



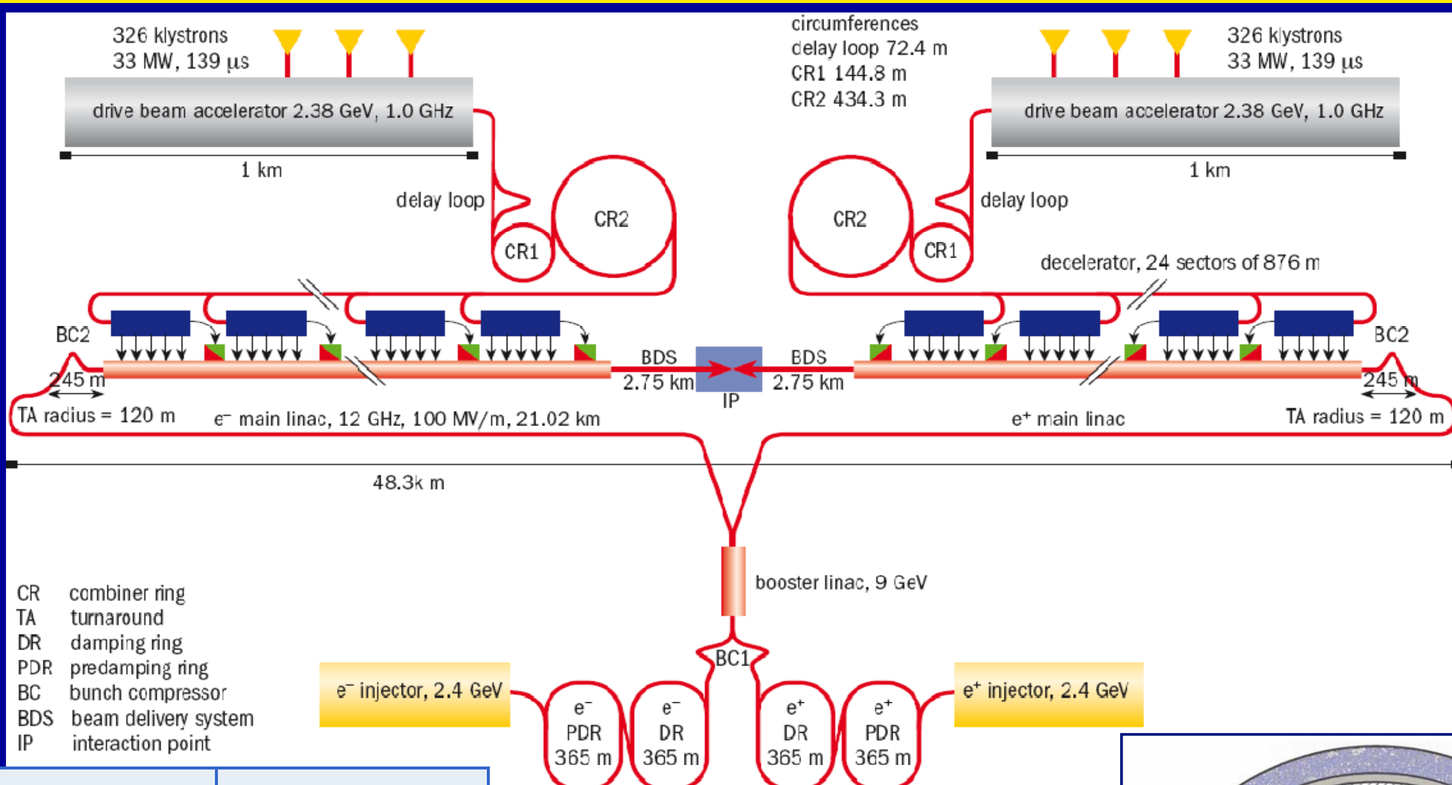
Linear Collider R&D



Challenges:

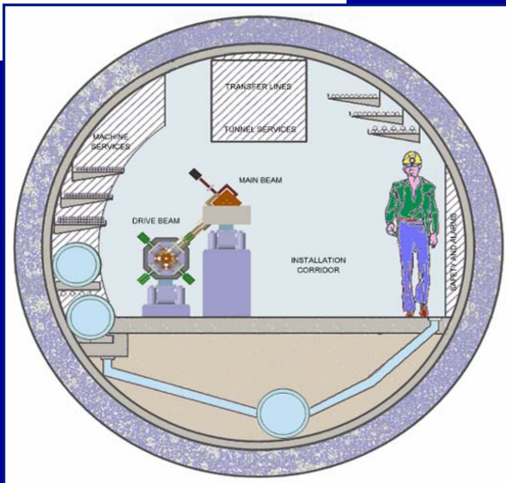
1. high accelerating gradient
2. efficient power production
3. **feasibility demonstration**

CLIC: Compact Linear Collider



Main Linac	
C.M. Energy	3 TeV
Peak luminosity	$2x10^{34}$ $cm^{-2}s^{-1}$
Beam Rep. rate	50 Hz
Pulse time duration	156 ns
Average field gradient	100 MV/m
# accelerating cavities	2 x 71,548

Φ4.5m tunnel



CTF3 Test Facility

- demonstration drive beam generation
- evaluate beam stability & losses in deceleration
- develop power production & accelerating structures