Africans have talent

Support

Opportunity

Partnership

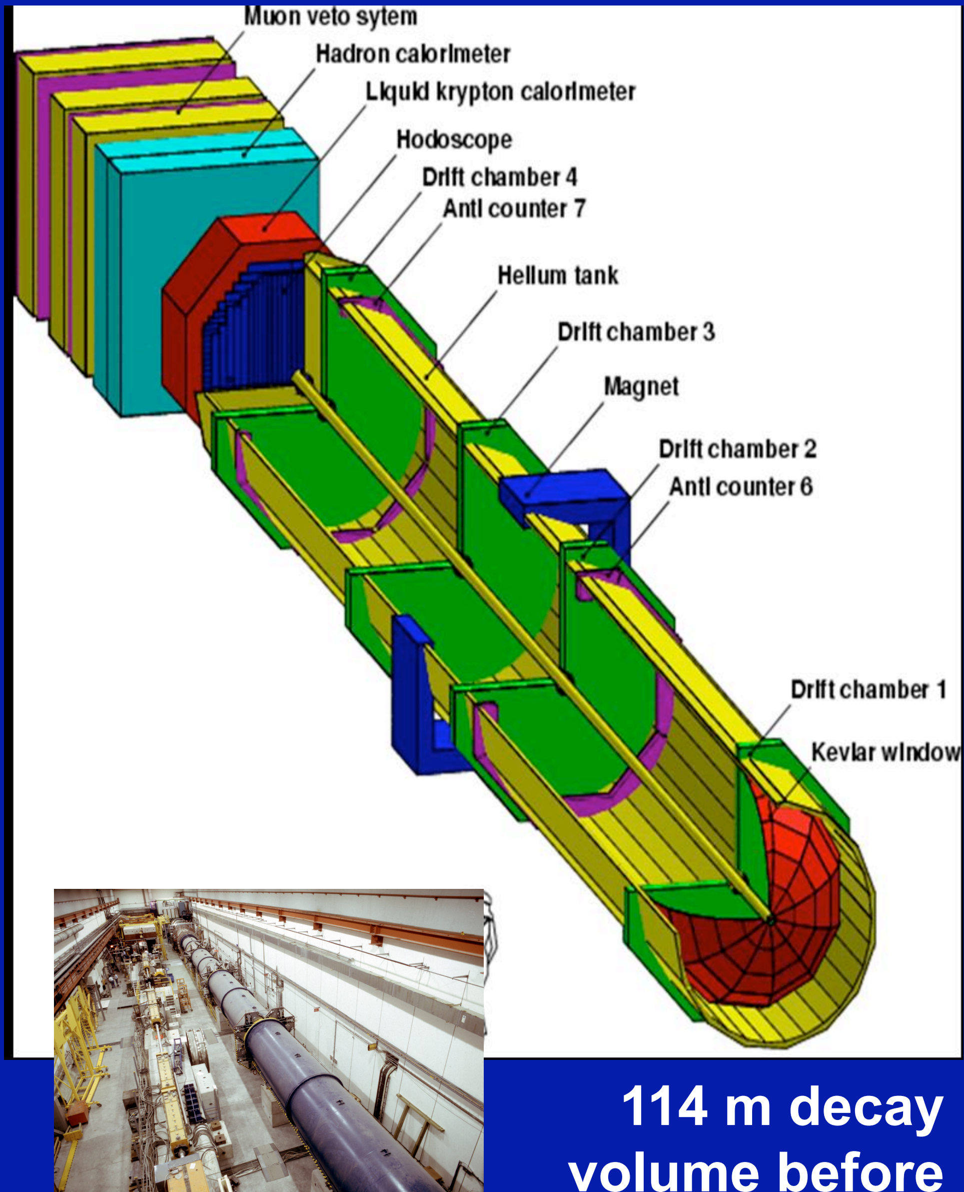
Anne Dabrowski
CERN Beams Department

African School of Fundamental Physics and its Applications,
Stellenbosch
20-08-2010

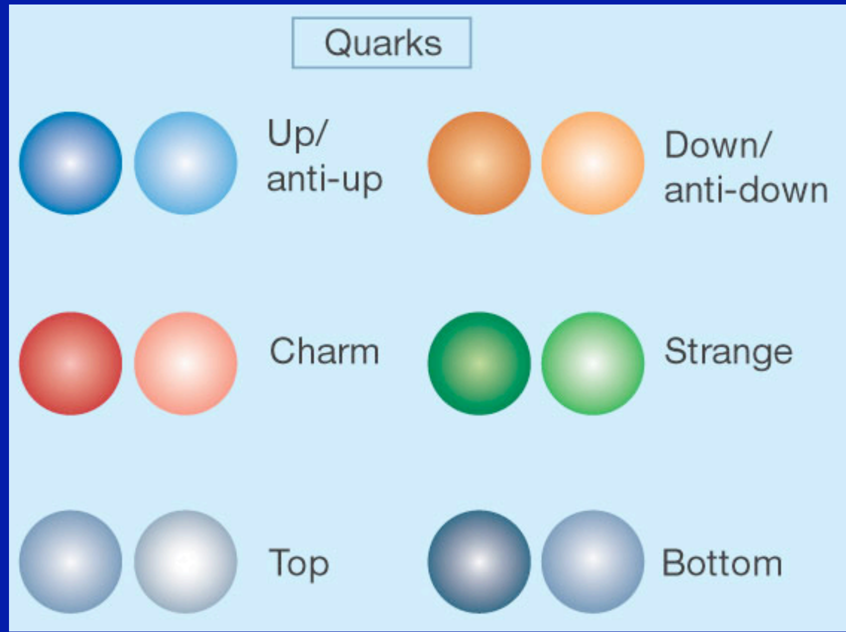
NORTHWESTERN UNIVERSITY

International Multi-disciplinary Scientific Collaboration

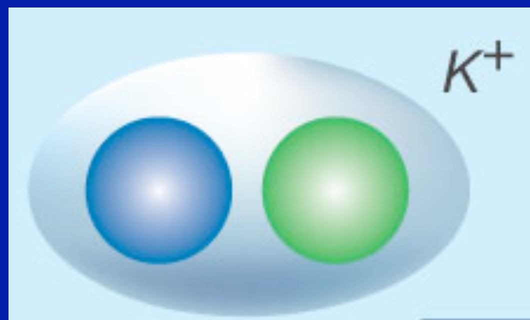
NA48/2 Experiment



114 m decay volume before detector



NA48/2 K+ beam
On quark level ➔ measured weak transition of strange quark to an up quark

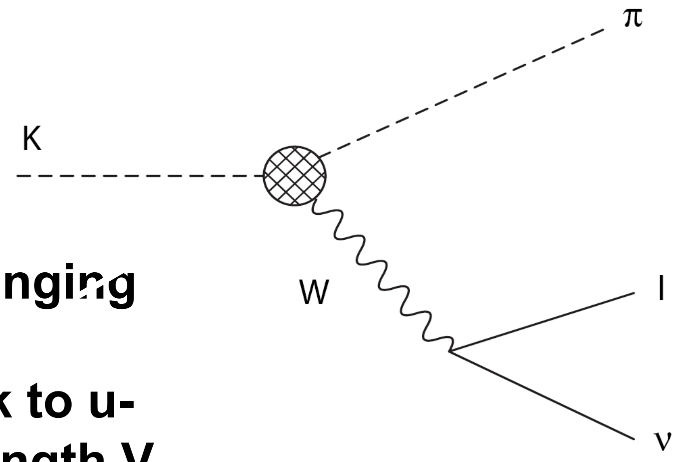


Kaon Semileptonic Branching Ratio's

Kaon semileptonic decays are pure vector transitions

Hadronic Vertex → described by form factors

$$\mathcal{M} = \frac{G_F}{\sqrt{2}} C\, V_{us} [f_+(t)\,(p_K + p_\pi)^\mu + f_-(t)\,(p_K - p_\pi)^\mu$$
$$\times\, \bar{u}_l \gamma_\mu (1+\gamma_5) u_\nu$$



Measure Br(K_{l3})

Quark level, flavor changing charge weak current transforming a s-quark to u-quark → coupling strength V_{us}

$$\frac{BR(K_{\ell 3})}{\tau_K} = \frac{C_K^2 G_F^2 m_K^5}{192\pi^3} S_{EW} |V_{us}|^2 |f_+(0)|^2 I_K^\ell(\lambda_{+0}) (1 + \delta^\ell_{SU(2)} + \delta^\ell_{EM})$$

Extract

Unitarity of CKM Matrix

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$$V_{\mathrm{CKM}} = \begin{pmatrix} 0.97383^{+0.00024}_{-0.00023} & 0.2272^{+0.0010}_{-0.0010} & (3.96^{+0.09}_{-0.09}) \times 10^{-3} \\ 0.2271^{+0.0010}_{-0.0010} & 0.97296^{+0.00024}_{-0.00024} & (42.21^{+0.10}_{-0.80}) \times 10^{-3} \\ (8.14^{+0.32}_{-0.64}) \times 10^{-3} & (41.61^{+0.12}_{-0.78}) \times 10^{-3} & 0.999100^{+0.000034}_{-0.000004} \end{pmatrix}$$

Status 2007

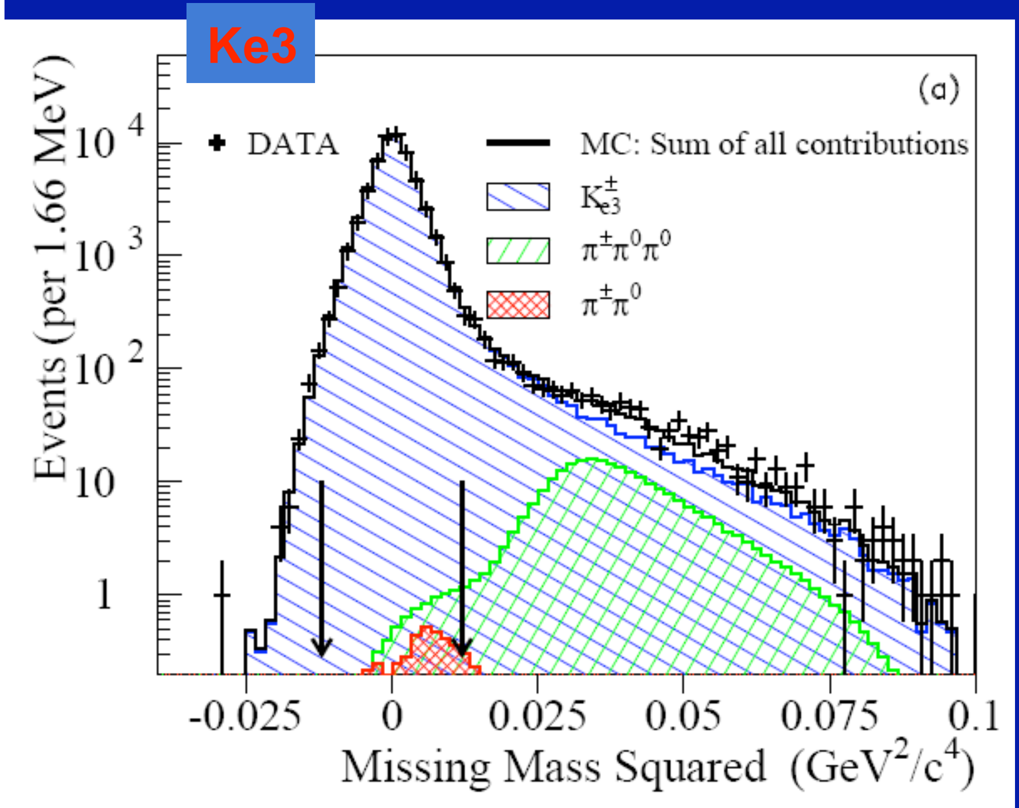
- **Entries not predicted ➔ need to be experimentally measured**
- **Deviation from unitarity would have to be attributed to by new physics**
- **V only source of quark mixing in the standard model**
- **3x3 matrix contains one imaginary phase**

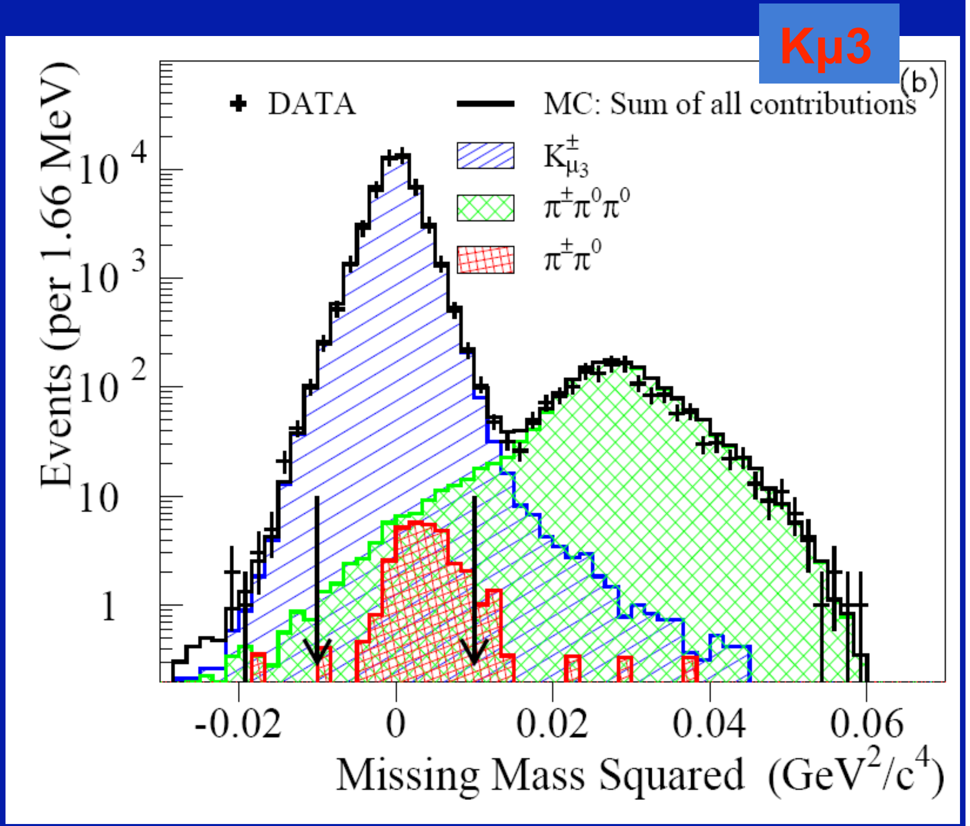
$$(V^{\dagger}V)_{11} = 1 \qquad |V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1$$

Most well measured unitarity constraint

Nobel prize for physics 2008 for Kobayashi and Maskawa

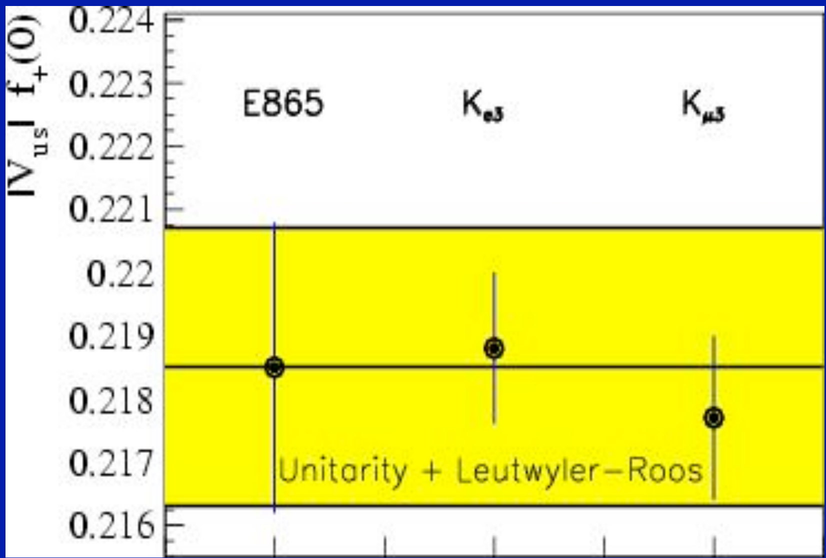
Measure data sample to extract Vus





Extraction of Vus

Decay Channel	Branching Fraction Br	Phase Space Integral I_K^ℓ	Radiative Correction[33, 50, 51] $\delta^\ell_{SU(2)}(\%)$	$\delta^\ell_{EM}(\%)$	$\lvert V_{us}\rvert f_+(0)$
K_{e3}	0.0517 ± 0.0004	0.1591 ± 0.0012	2.31 ± 0.22	0.03 ± 0.10	0.2193 ± 0.0012
$K_{\mu3}$	0.0343 ± 0.0002	0.1066 ± 0.0008	2.31 ± 0.22	0.20 ± 0.20	0.2177 ± 0.0013



$$|V_{us}|f_+(0) = 0.2193 \pm 0.0012 \qquad K_{e3}$$

$$|V_{us}|f_+(0) = 0.2177 \pm 0.0013 \qquad K_{\mu3}$$

$$|V_{us}|f_+(0) = 0.2188 \pm 0.0012 \qquad K_{l3}$$

$$|V_{us}|_{unitary}\, f_+(0) = 0.2185 \pm 0.0022$$

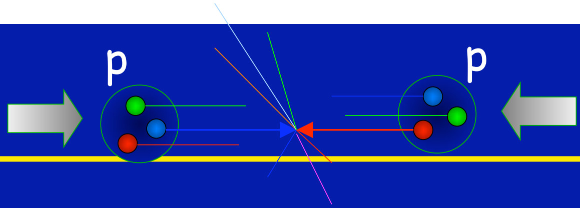
Measurement more precise than previous world average.
Agreement with theory

New Physics → waiting for the LHC

Physics at the high energy frontier *BEYOND* the LHC

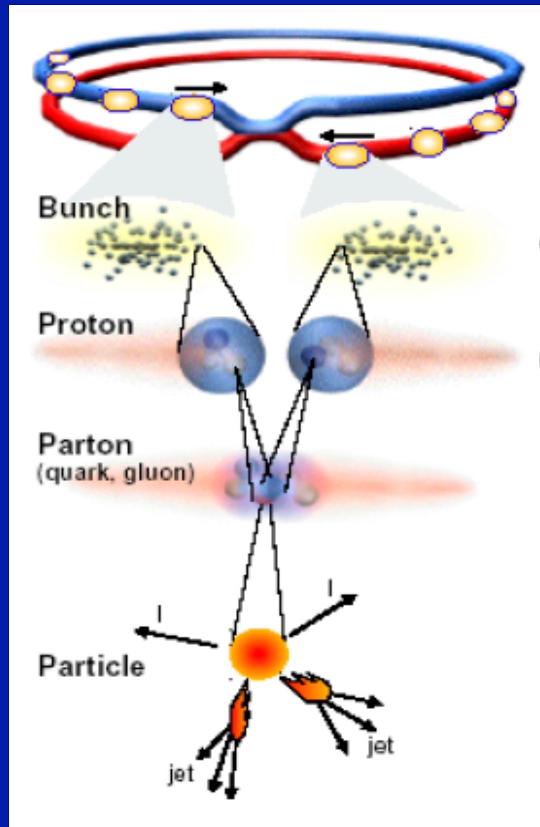
Technologies for Future Linear Colliders

LHC

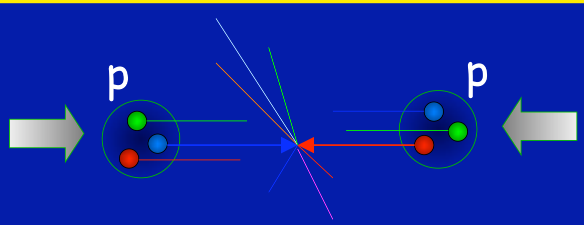


hadron collider at the **energy frontier of physics today**

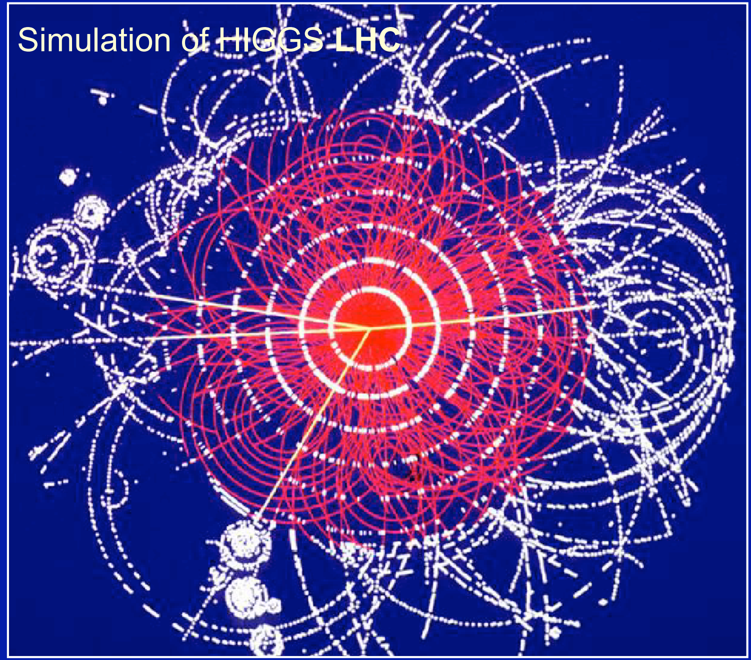
- Particle energies in the laboratory (7 TeV)
- Multipurpose facility
  - proton – proton collisions (ATLAS, CMS) Univ Johannesburg and Wits
  - Ion – ion collisions (ALICE) Univ. Cape Town and Ithemba Labs
- Open up the energy frontier for physics



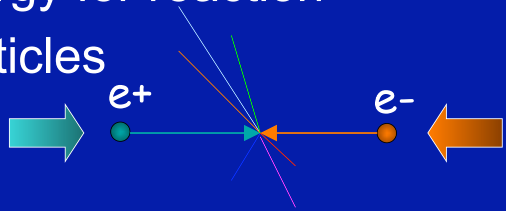
Collider History

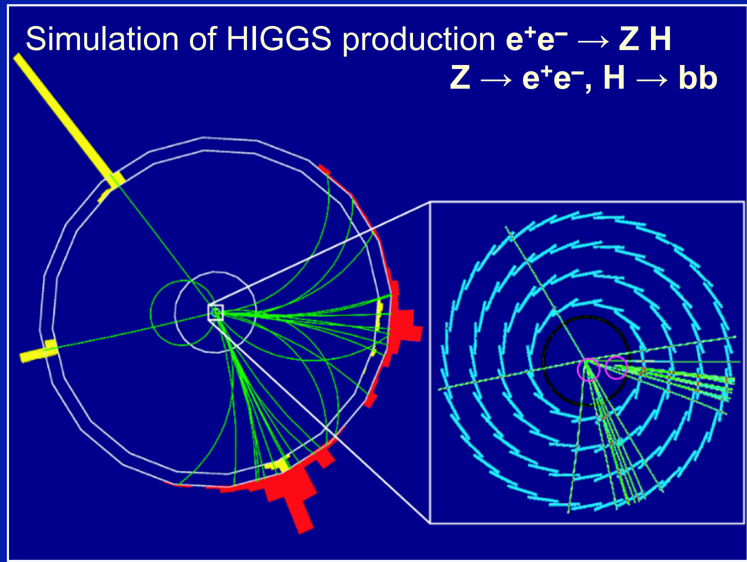


- hadron collider at the frontier of physics
  - huge QCD background
  - not all nucleon energy available in collision



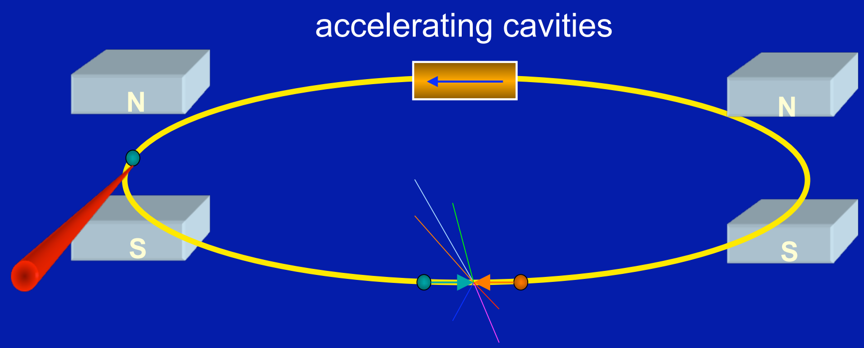
- lepton collider for precision physics
  - well defined initial energy for reaction
  - Colliding point like particles





- Candidate next machine after LHC
  - e^+e^- collider
  - energy determined by LHC discoveries
  - Study in detail the properties of the new physics that the LHC finds

Circular versus Linear Collider

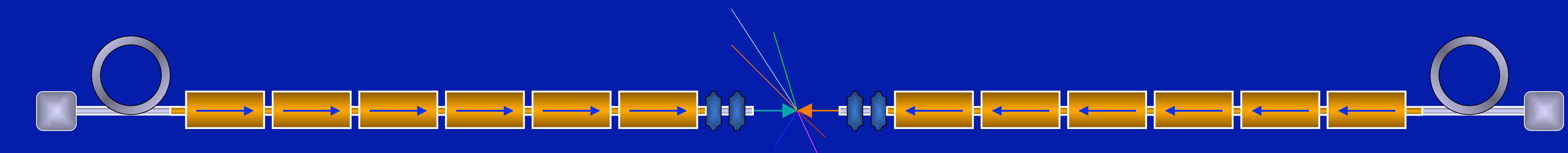


Circular Collider

many magnets, few cavities, stored beam

higher energy → stronger magnetic field

→ higher synchrotron radiation losses (E^4/m^4R)



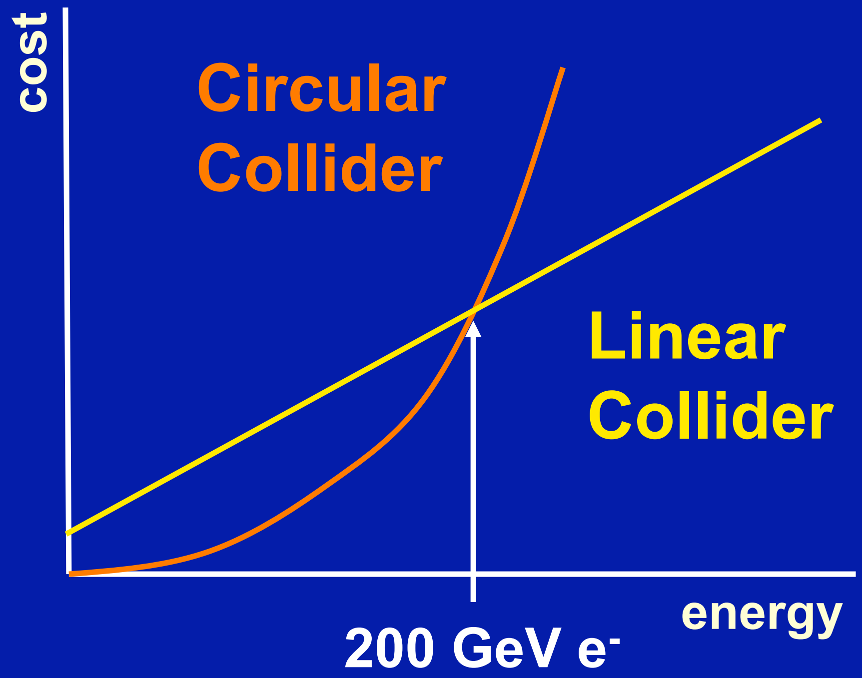
Linear Collider

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 ~ L
- cost ~ aL

World-wide CLIC & CTF3 Collaboration

38 Institutes from 19 countries

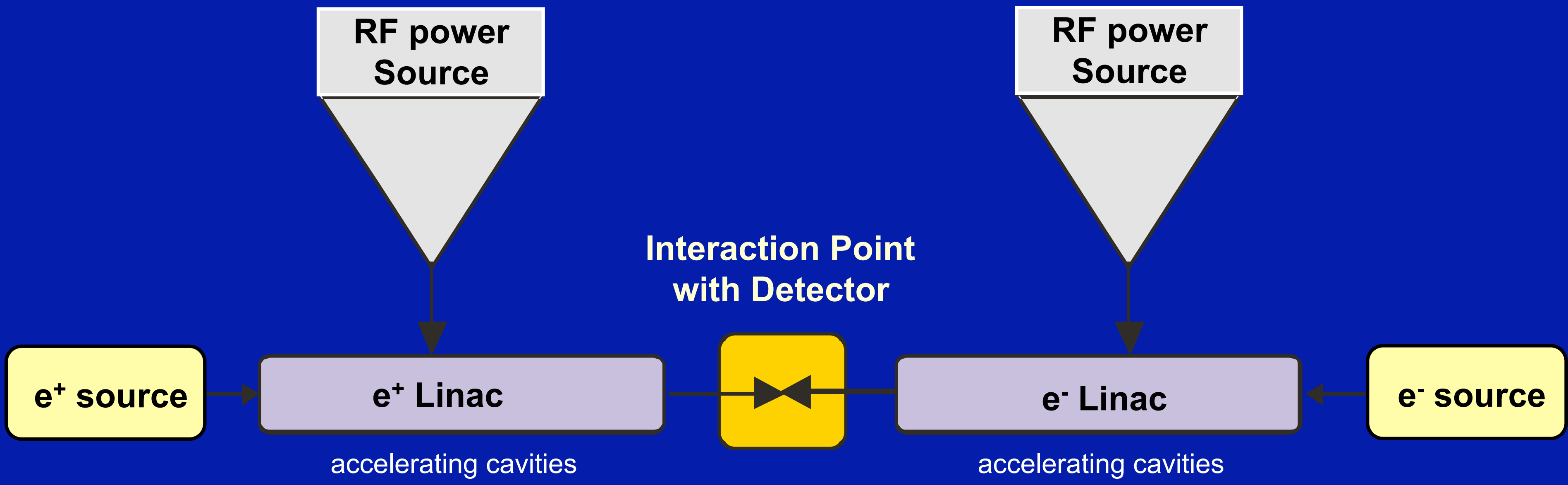
Aarhus University (Denmark)
Ankara University (Turkey)
Argonne National Laboratory (USA)
Athens University (Greece)
BINP (Russia)
CERN
CIEMAT (Spain)
Cockcroft Institute (UK)
ETHZurich (Switzerland)
Gazi Universities (Turkey)

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)
NCP (Pakistan)
Northwestern. 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)

Linear Collider R&D



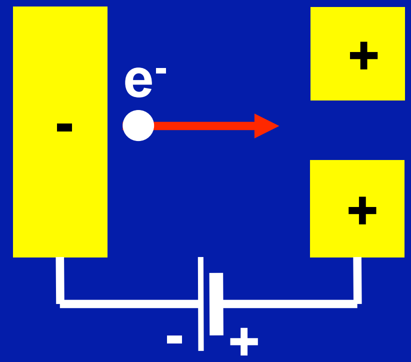
Challenges:

1. High accelerating gradient
2. Efficient power production and transfer to beam
3. Feasibility demonstration on small scale
   - ➔ before building larger machine
4. Small beam at the collision point

Acceleration of Charged Particles

- Lorenz (EM) force most practical

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



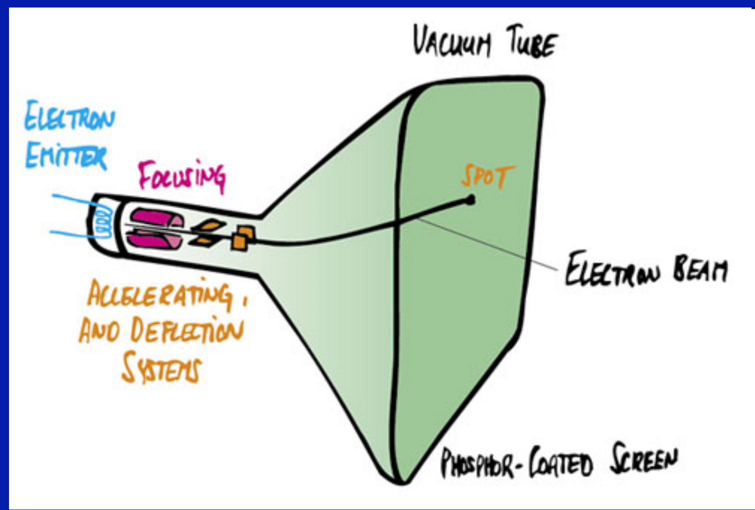
- increasing particle energy

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

- to gain 1 MeV energy requires a 1 MV field

Direct-voltage acceleration used in

- TV tube: 20~40 keV
- X-ray tube: ~100 keV



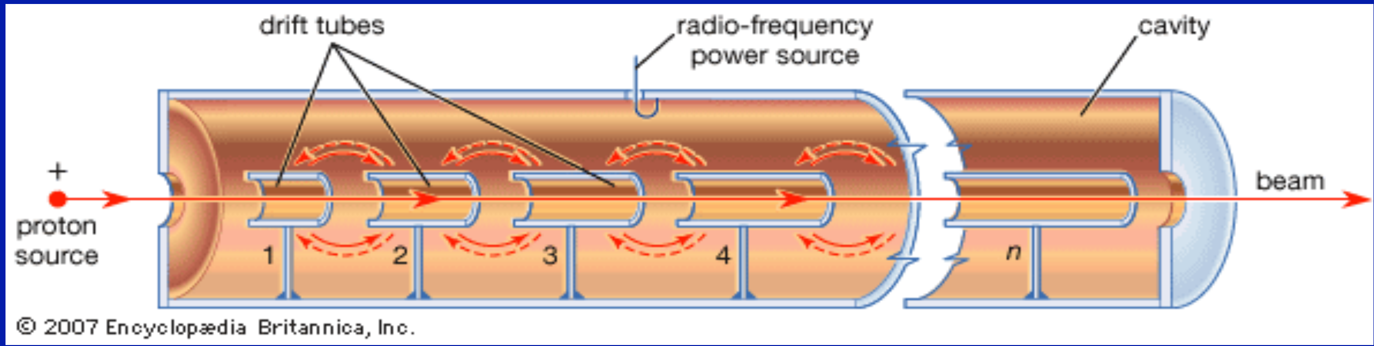
Surfing: or How to Accelerate Particles

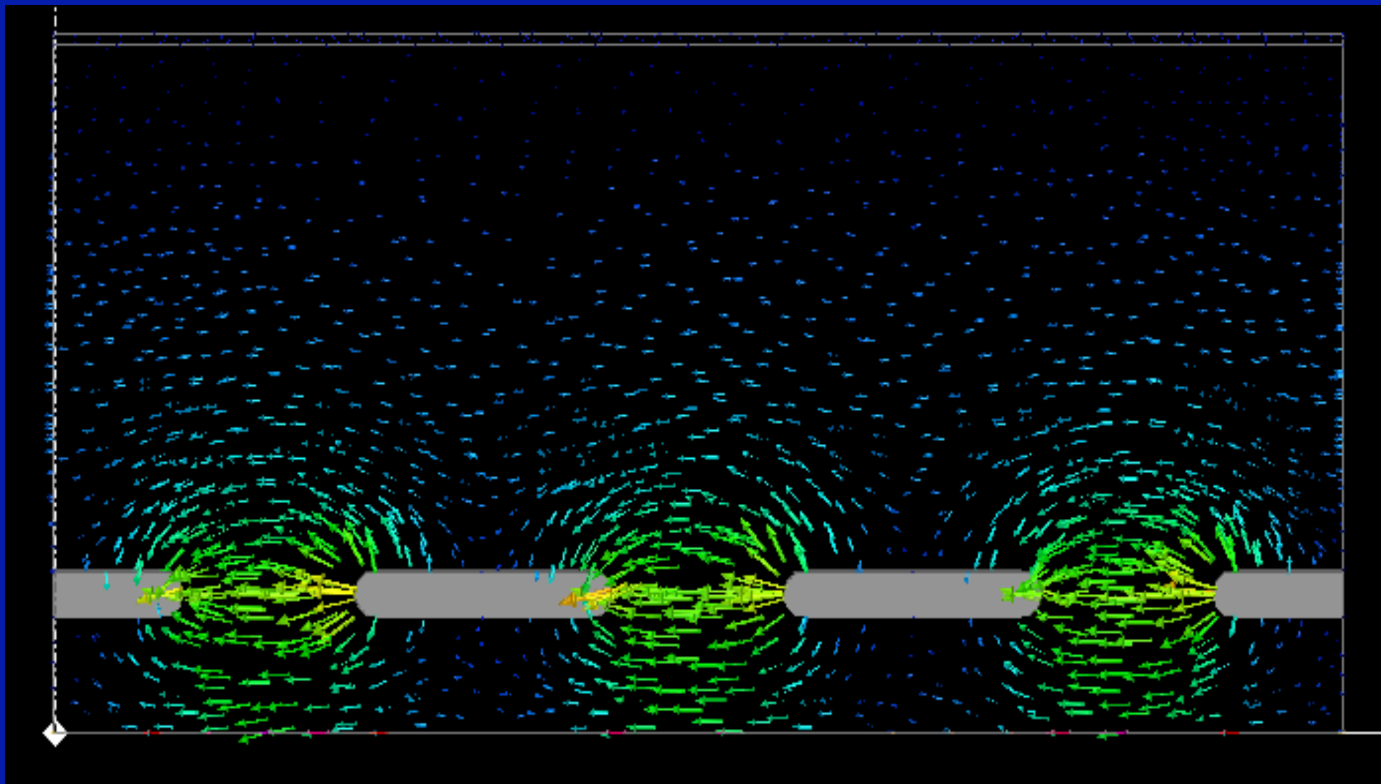
DC Accelerator

RF Accelerator

synchronize particle
with an
electromagnetic wave!

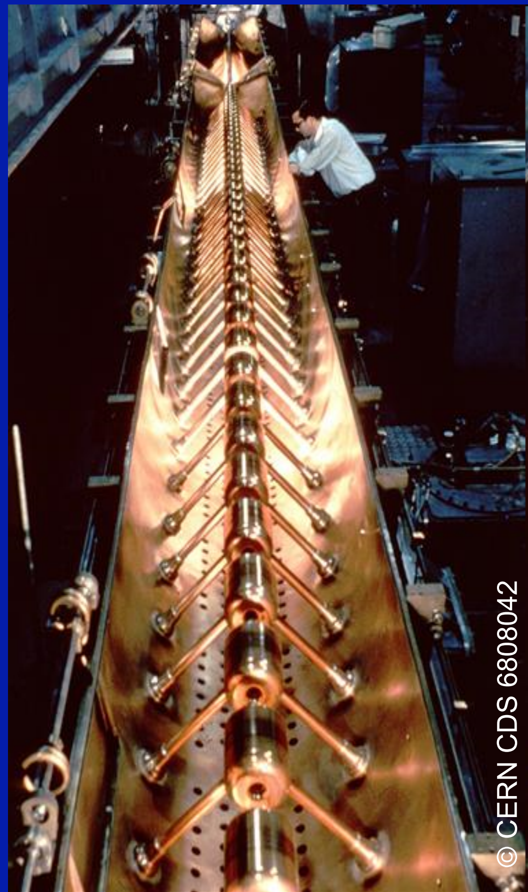
Drift Tube Linac: Higher Integrated Field





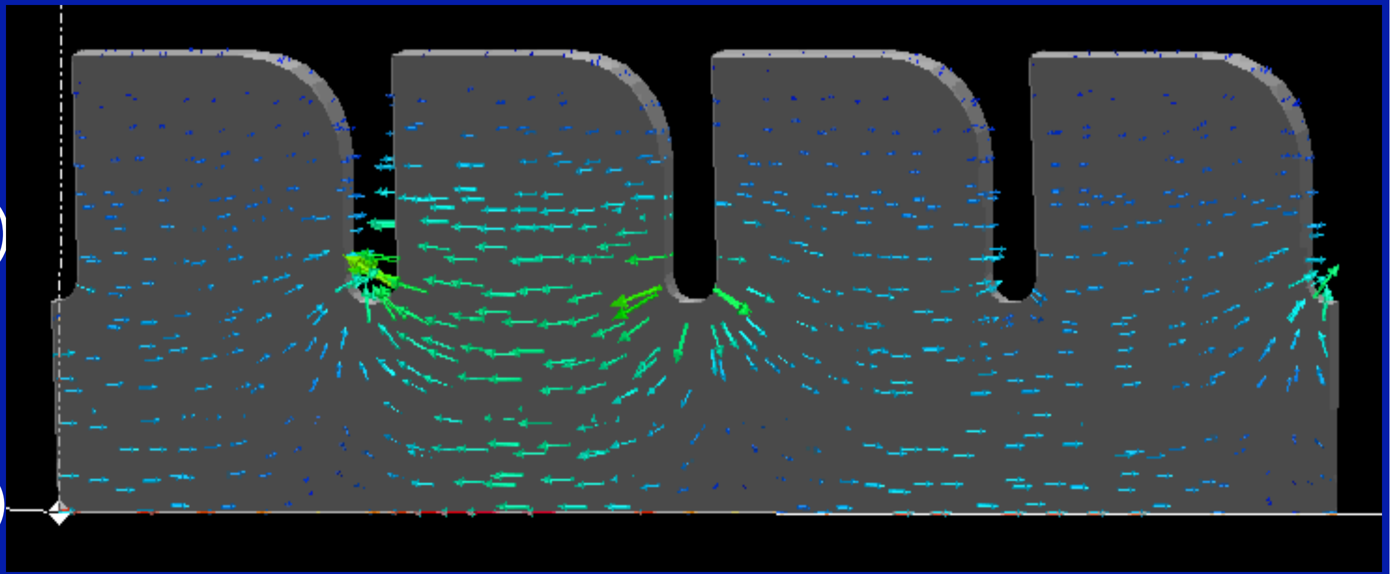
Courtesy E. Jensen

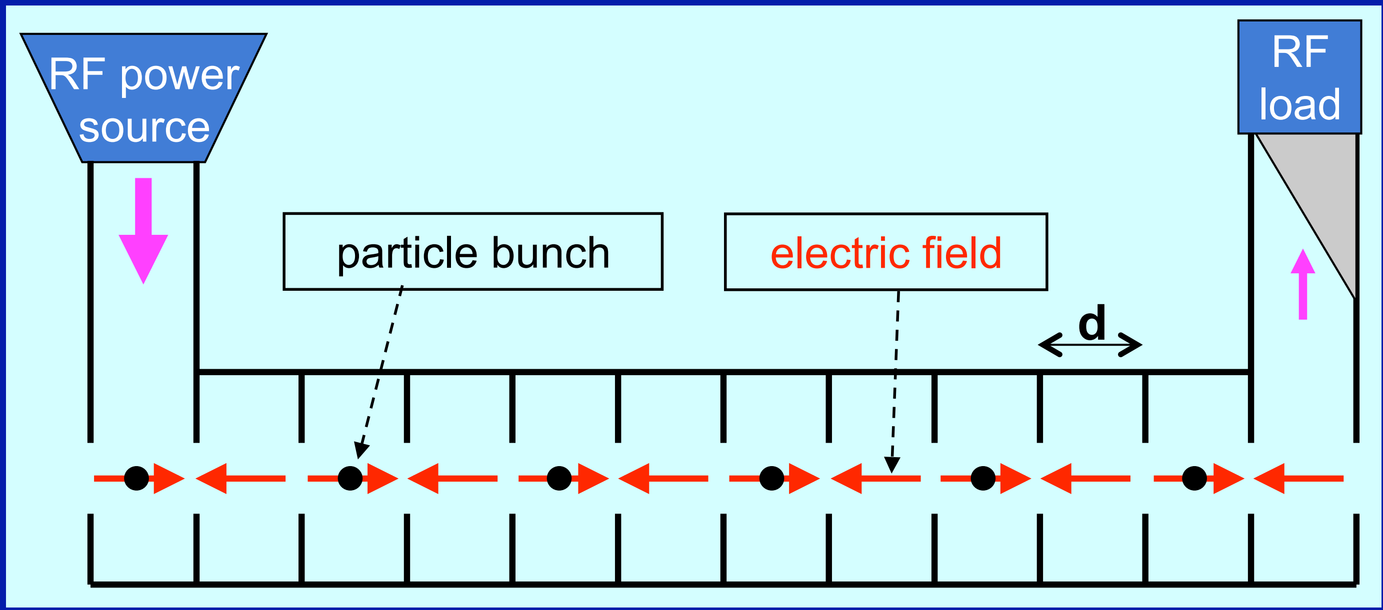
Linac 1 1982-1992



Travelling wave cavity

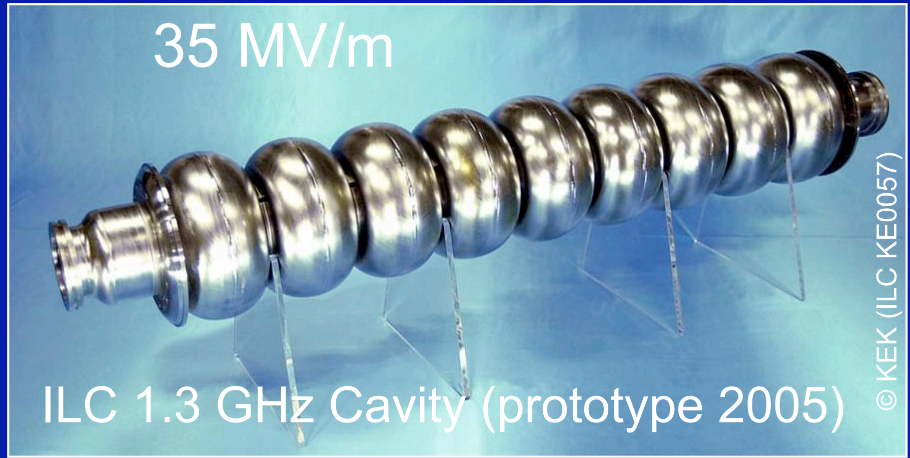
- Electrons v~c
- short pulses (mm)
- high frequency >3 GHz (< 10 cm)
- typical 10~20 MV/m
- CLIC:
  - 12 GHz
  - 240 ns
  - 100 MV/m



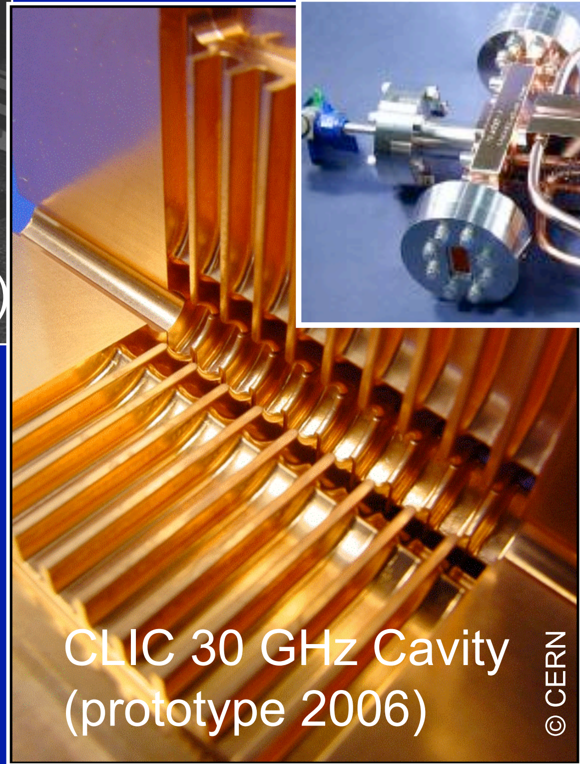


Accelerating Cavities

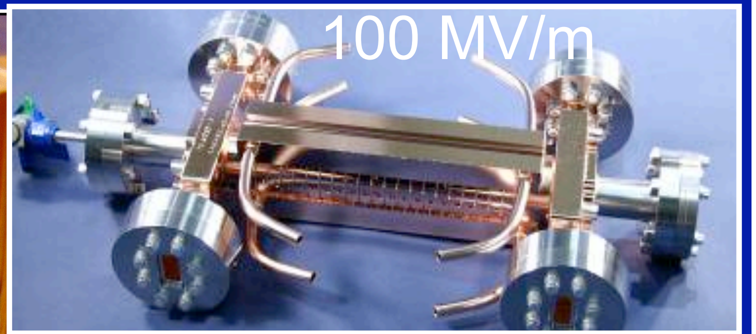
CERN PS 19 MHz Cavity (prototype 1966)



ILC 1.3 GHz Cavity (prototype 2005)

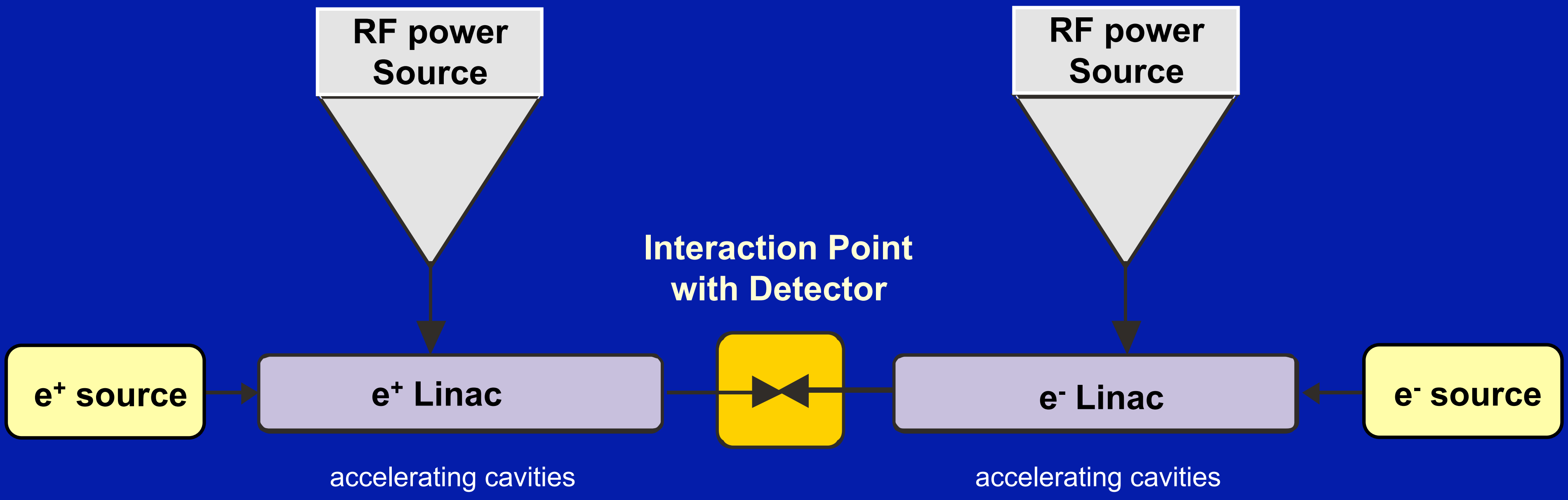


CLIC 30 GHz Cavity
(prototype 2006)



CLIC 12 GHz Cavity
(prototype 2009)

Linear Collider R&D

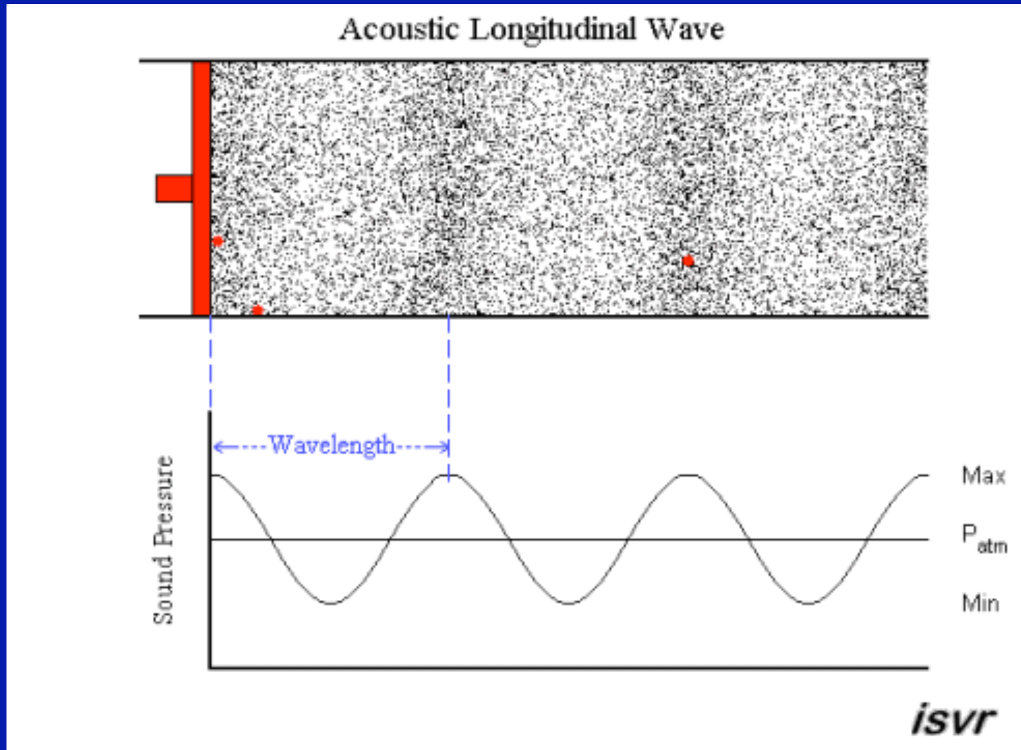


Challenges:

1. High accelerating gradient
2. Efficient power production and transfer to beam
3. Feasibility demonstration on small scale
   - ➔ before building larger machine
4. Small beam at the IP Luminosity

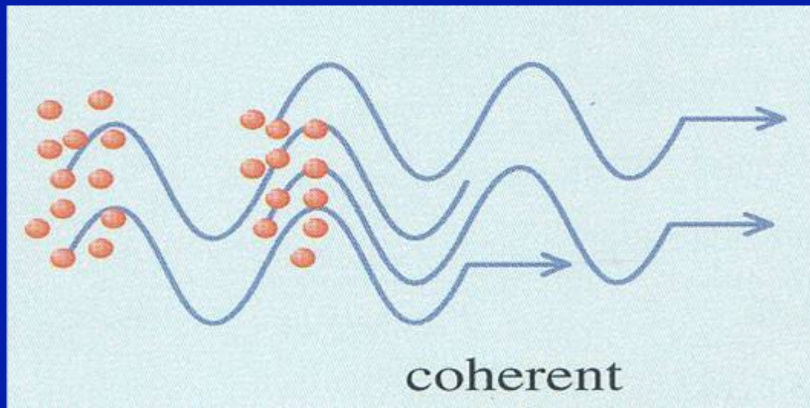
Electromagnetic Waves

- static electron
  → electric field



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

- bunched electron beam
  → electromagnetic wave

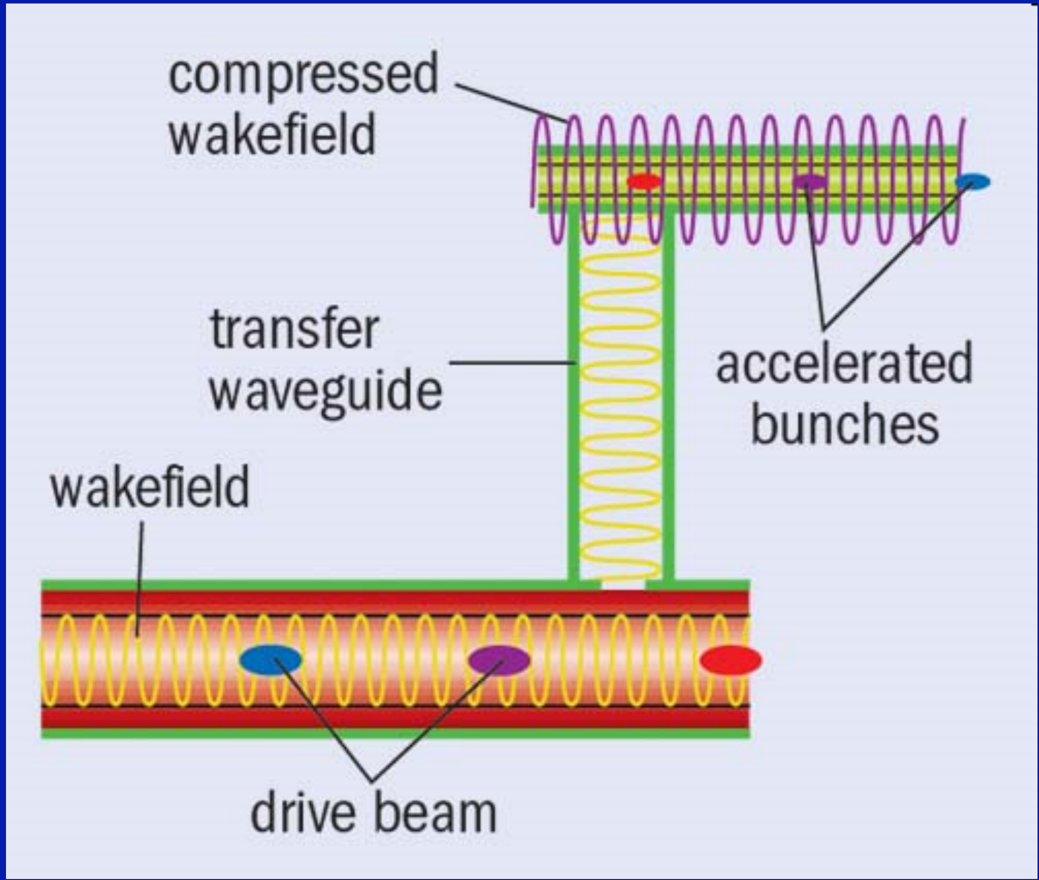


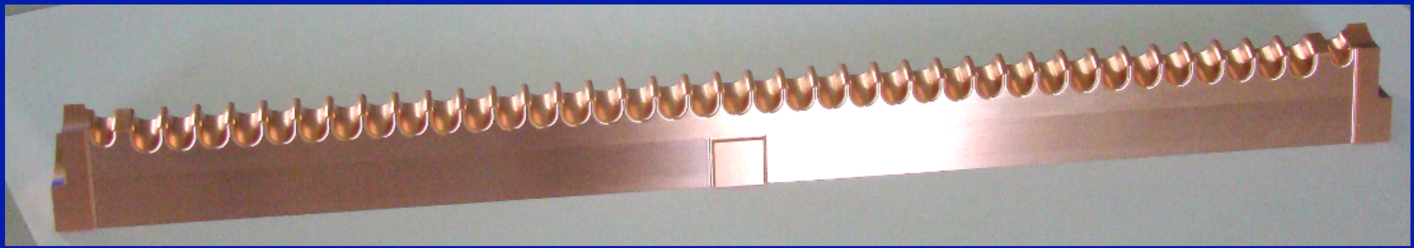
CLIC Two-beam Acceleration Concept

- 12 GHz modulated and high power drive beam

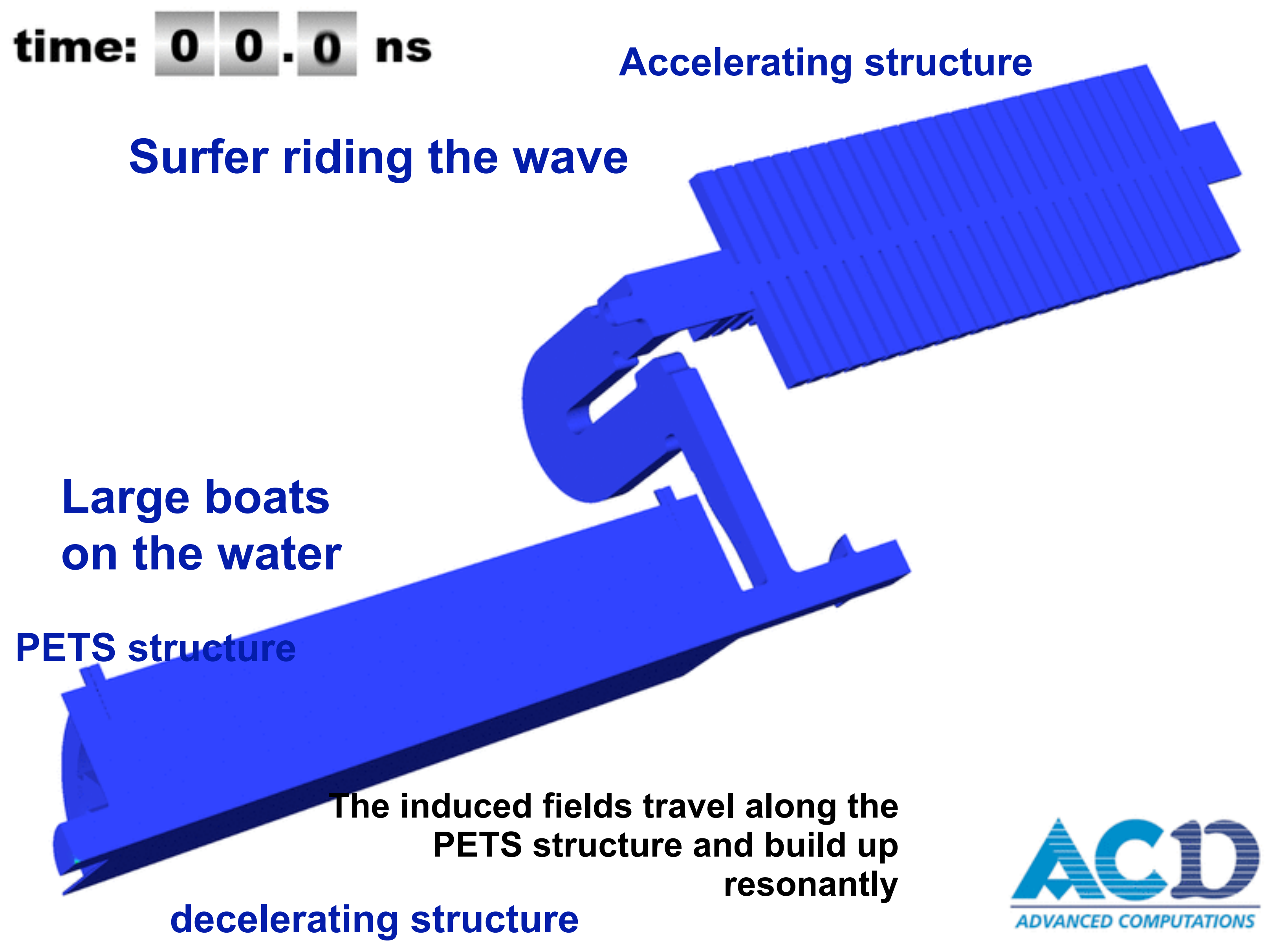
- RF power extraction in a special structure (PETS)

- use RF power to accelerate main beam



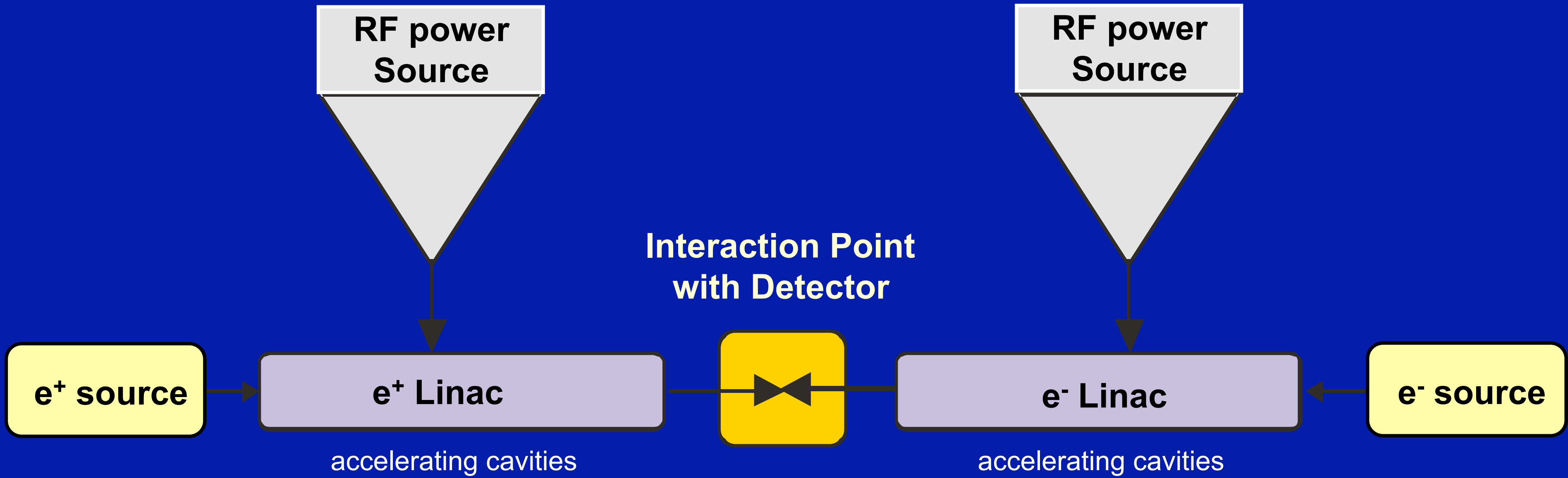


Simulation of RF Power Transfer



Arno Candel, SLAC

Linear Collider R&D

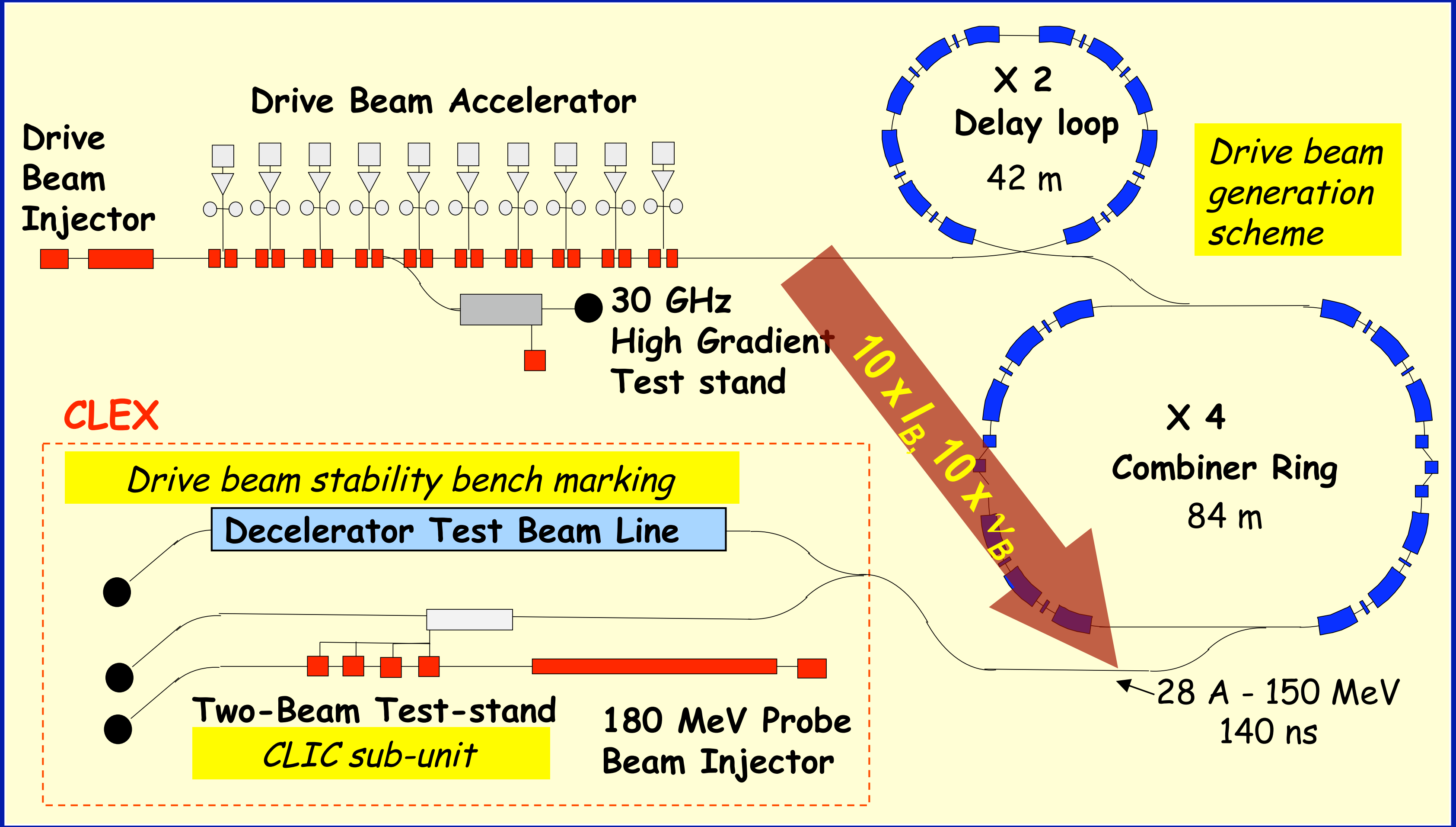


Challenges:

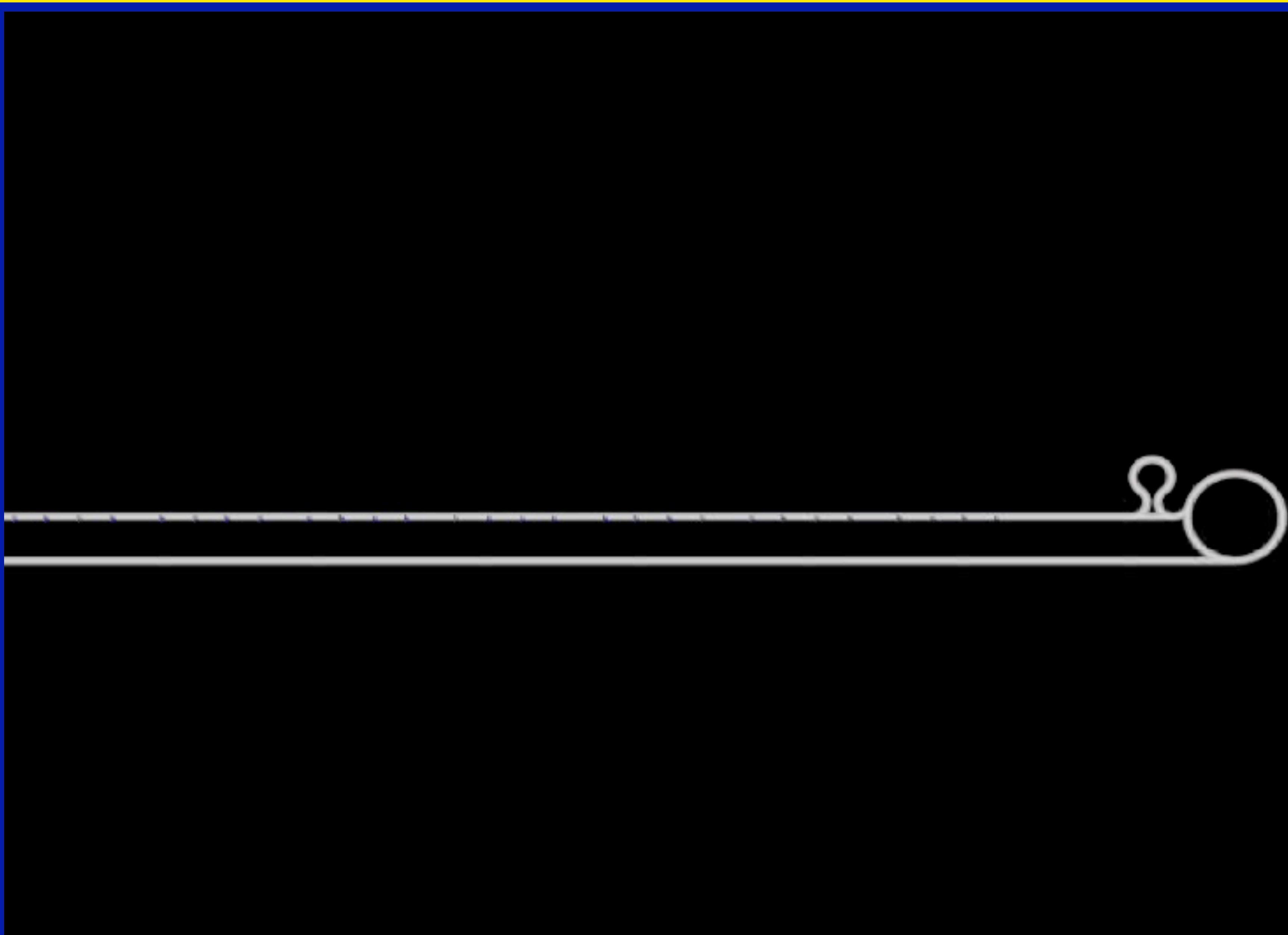
1. High accelerating gradient
2. Efficient power production and transfer to beam
3. Feasibility demonstration on small scale
   ➔ before building larger machine
4. Small beam at the IP Luminosity

CTF3 Test Facility

- demonstration drive beam generation (boat factory)
- evaluate beam stability & losses in deceleration
- Accelerate the main beam (surfer)

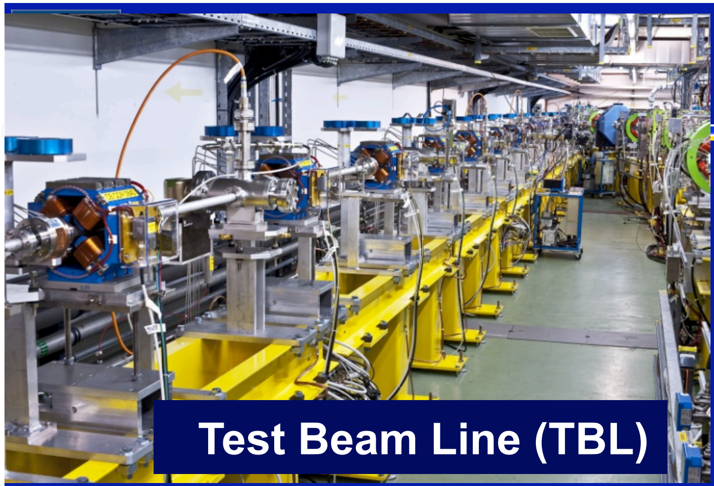


Drive Beam Generation Scheme (boat factory)

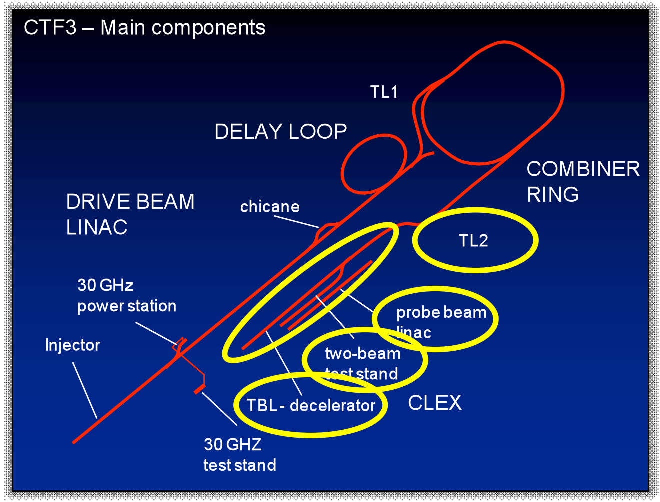


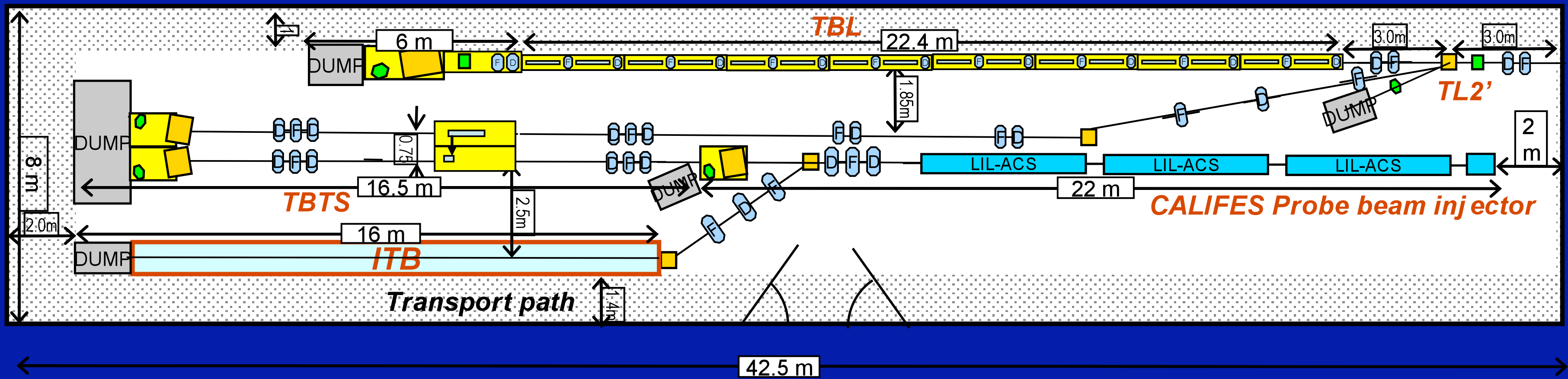
Courtesy Alex Anderssen

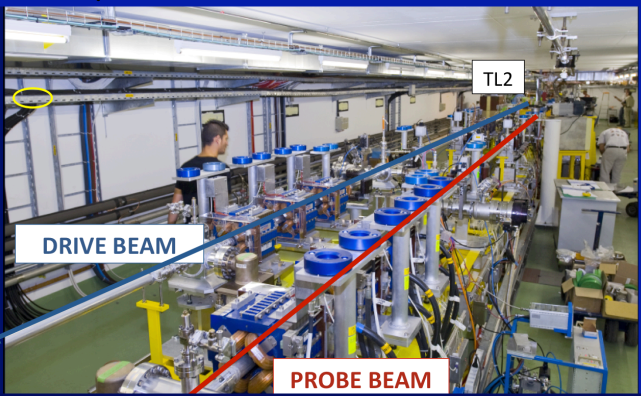
CLEX Area



Test Beam Line (TBL)

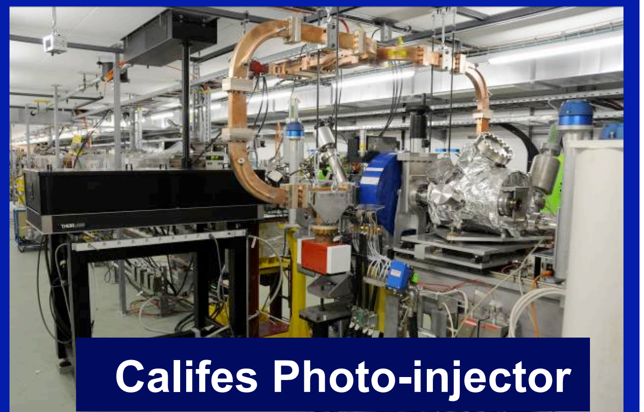






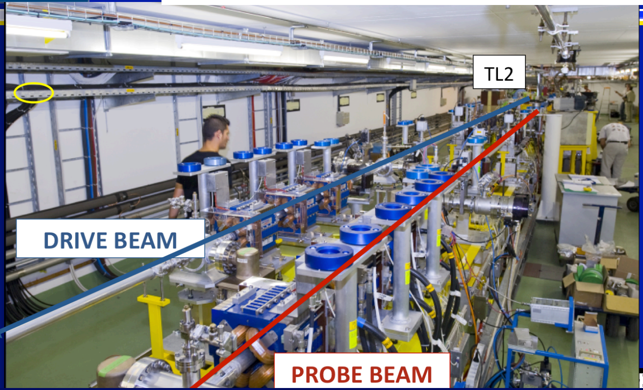
Two Beam Test Stand (TBTS)

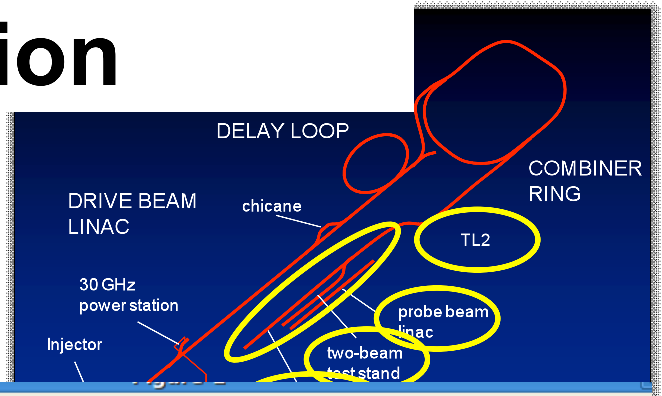
Accelerating sections



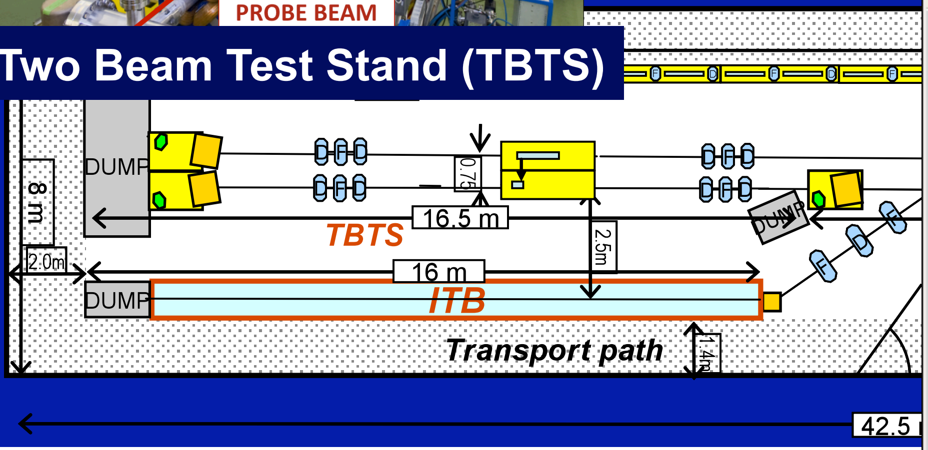
Califes Photo-injector

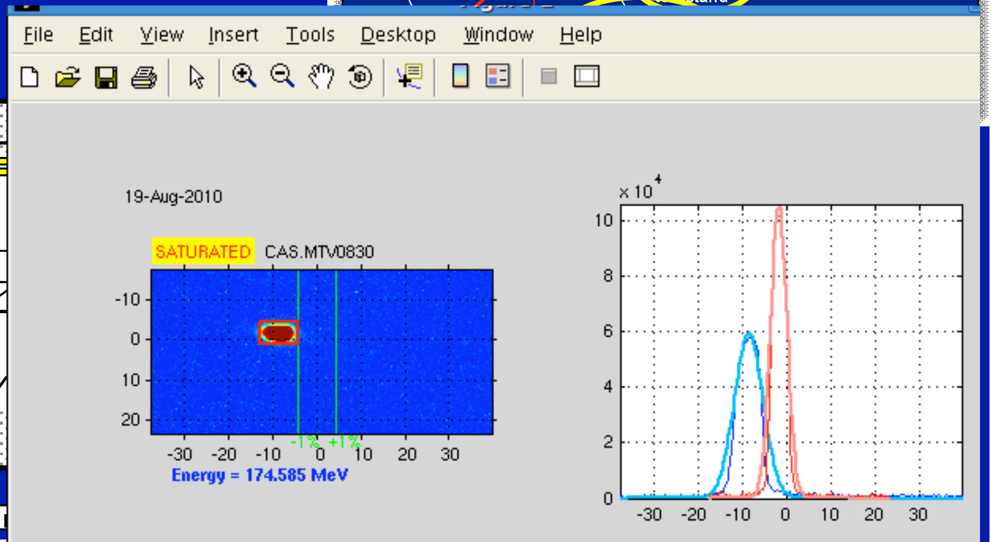
Two beam acceleration





Two Beam Test Stand (TBTS)



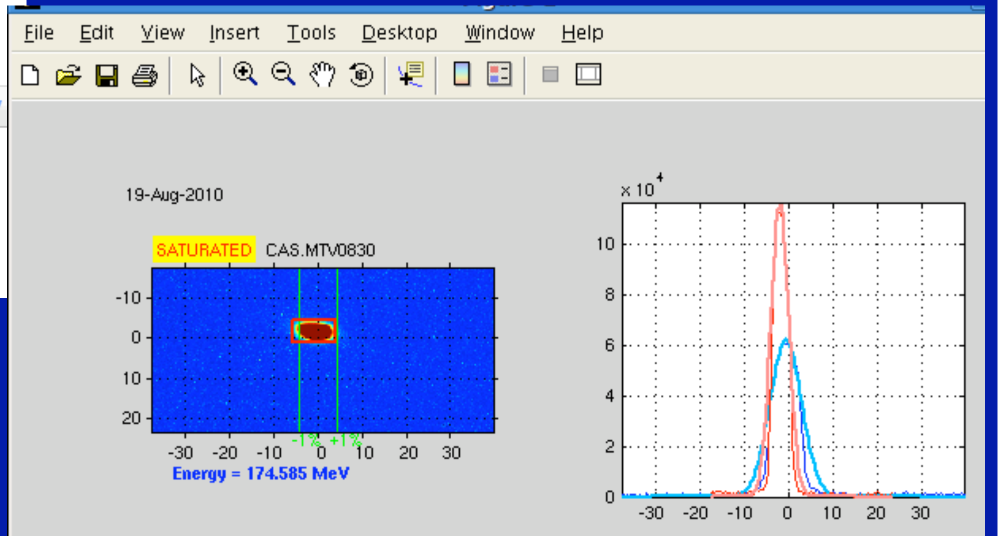


FW: Premiere acceleration du faisceau CALIFES dans une structure CLIC 12 GHz Inbox | X

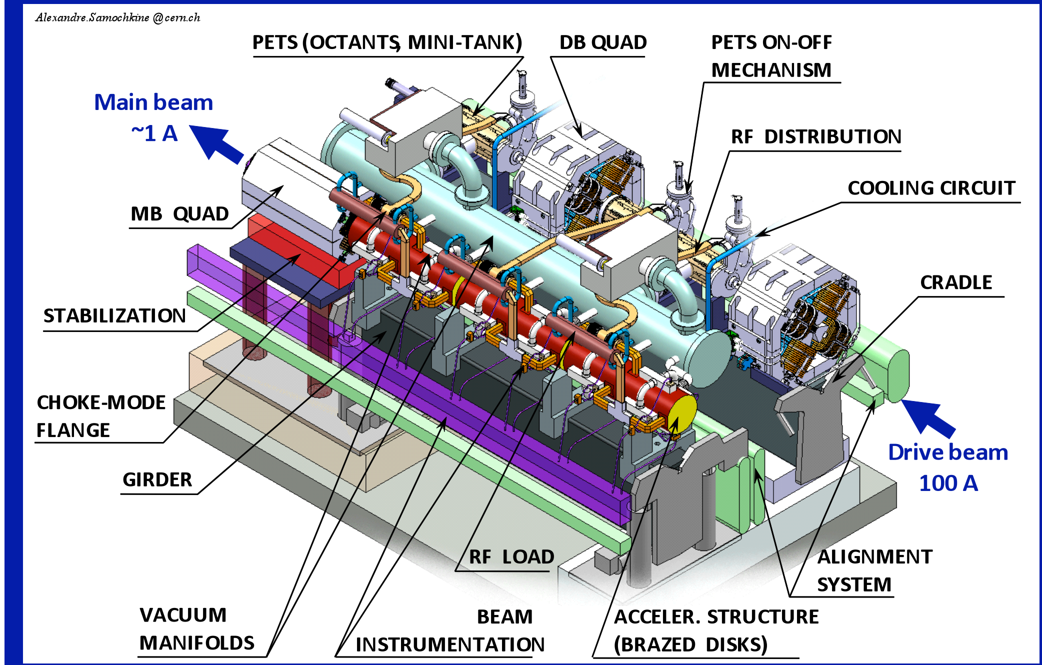
Roger Ruber to Franck, Marta, Massi show details 1:12 PM (1 hour ago) Reply

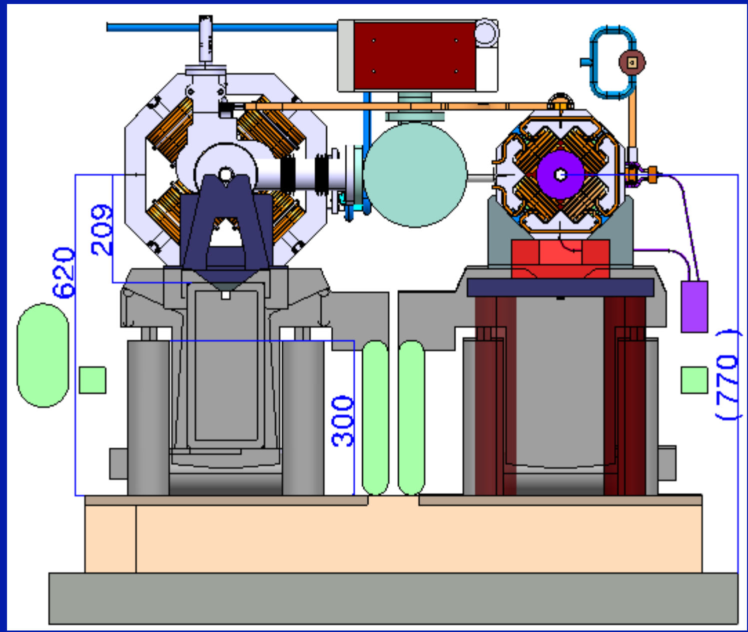
-----Original Message-----
From: Wilfrid Farabolini

Bonjour chers collegues,



CLIC module





(Courtecy A. Samoshkin)

20760 modules (2 meters long)

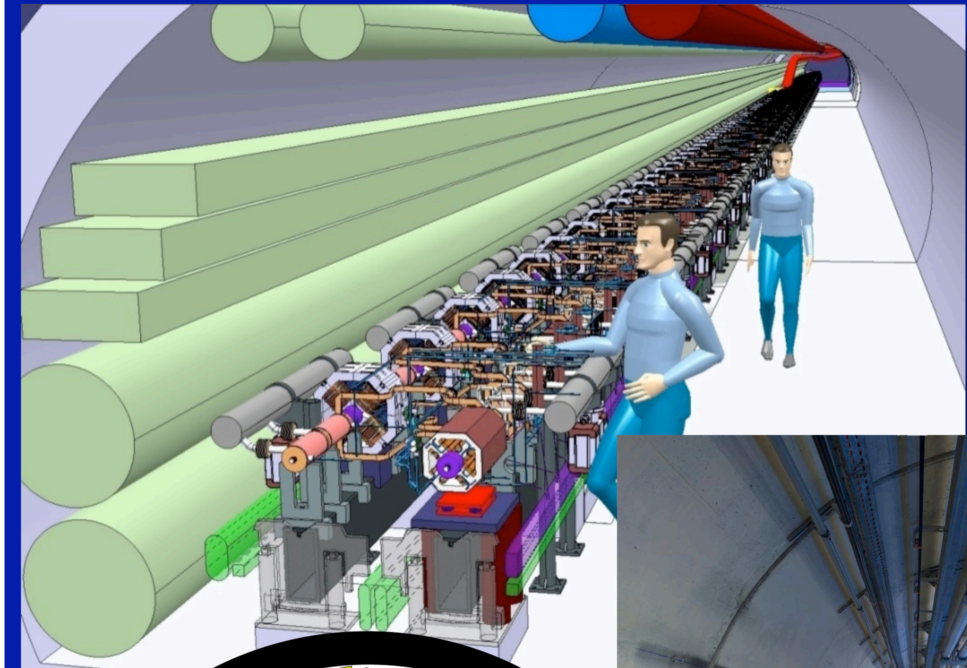
71460 power production structures PETS (drive beam)

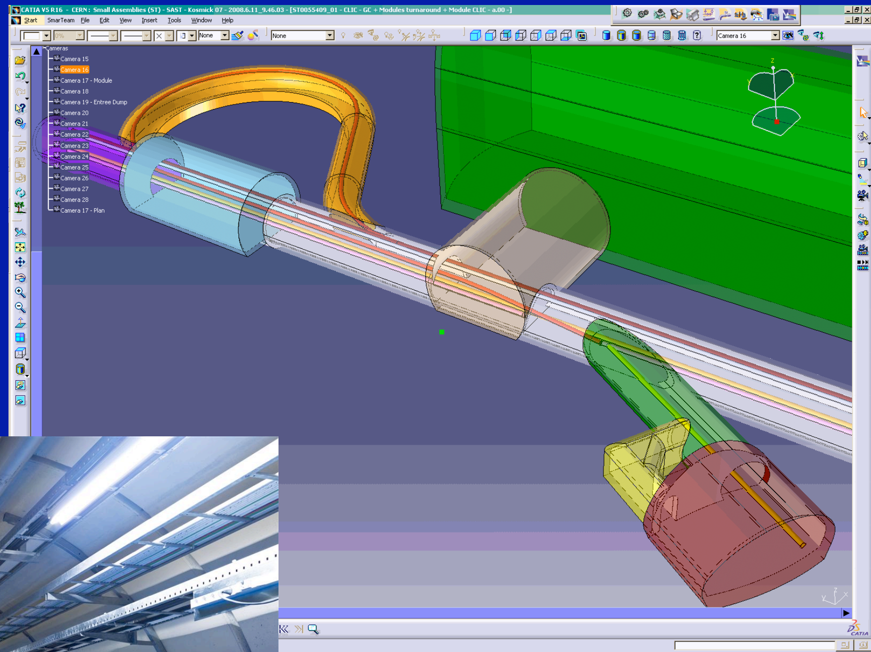
143010 accelerating structures

(main beam)

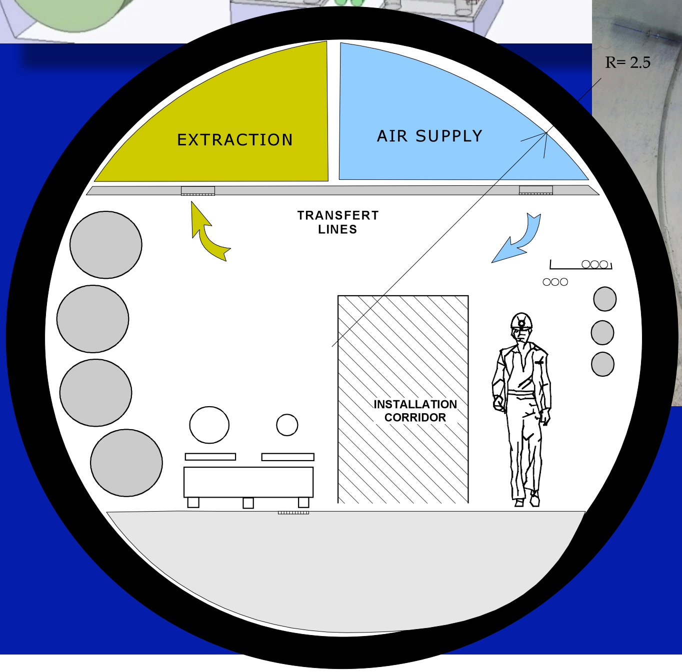
Huge engineering challenges to integrate all subsystems Stabilization, vacuum, beam instrumentation, etc..

Tunnel Integration



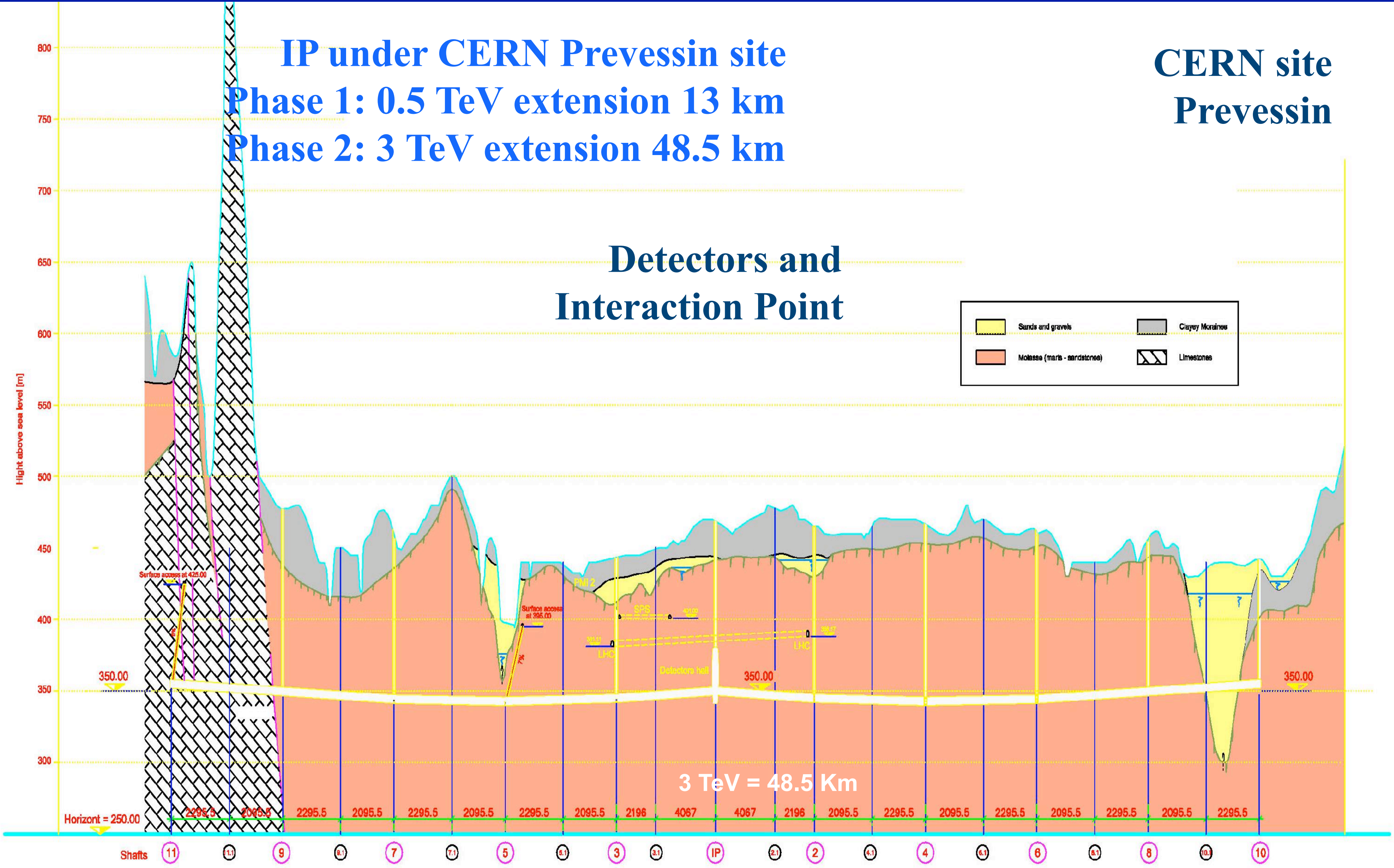


(Courtecy John Osborne)



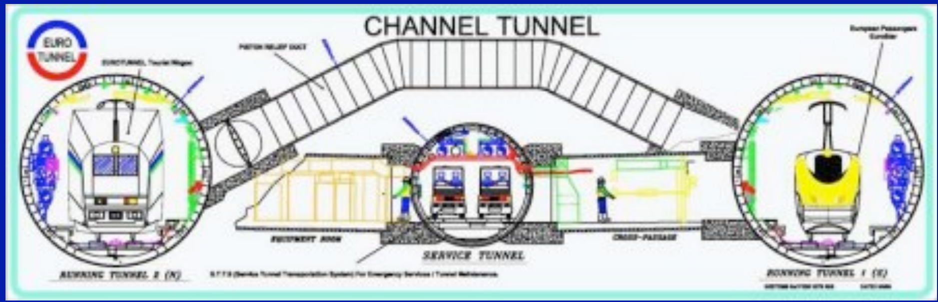
Standard tunnel with modules

Potential machine site



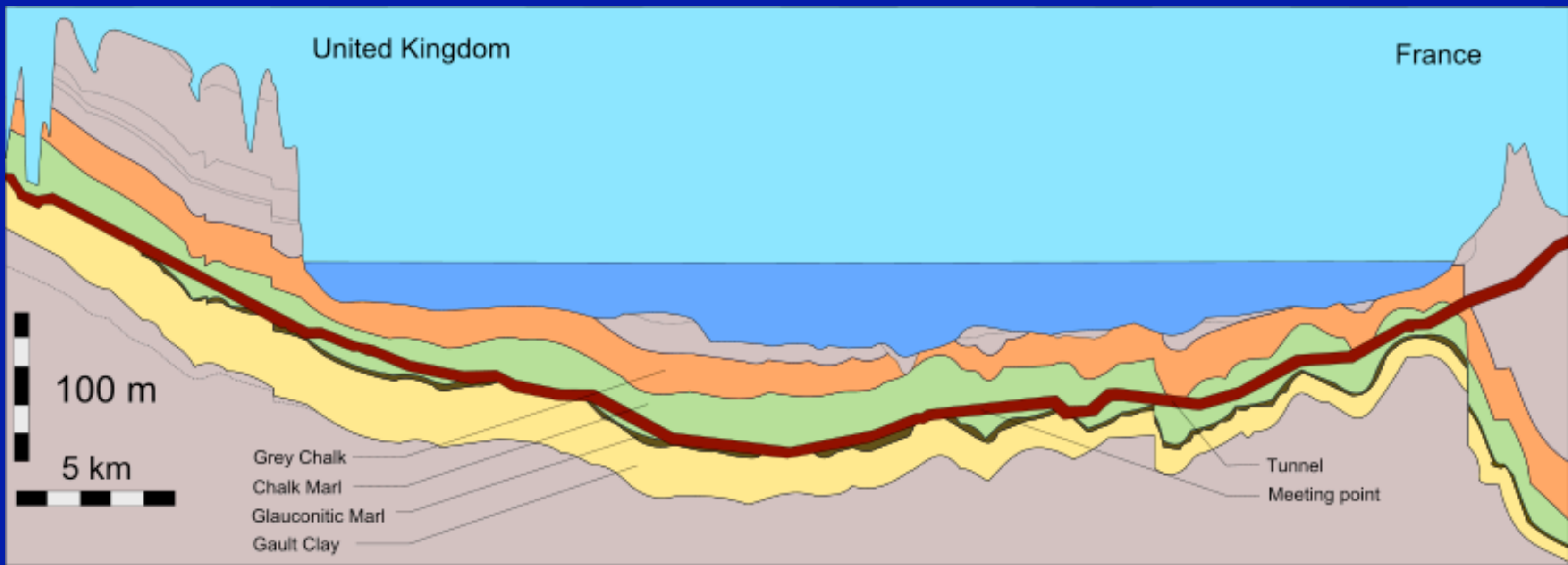
Longitudinal section of a laser straight Linear Collider on CERN site–

For CLIC & ILC, similar World Projects: Channel Tunnel

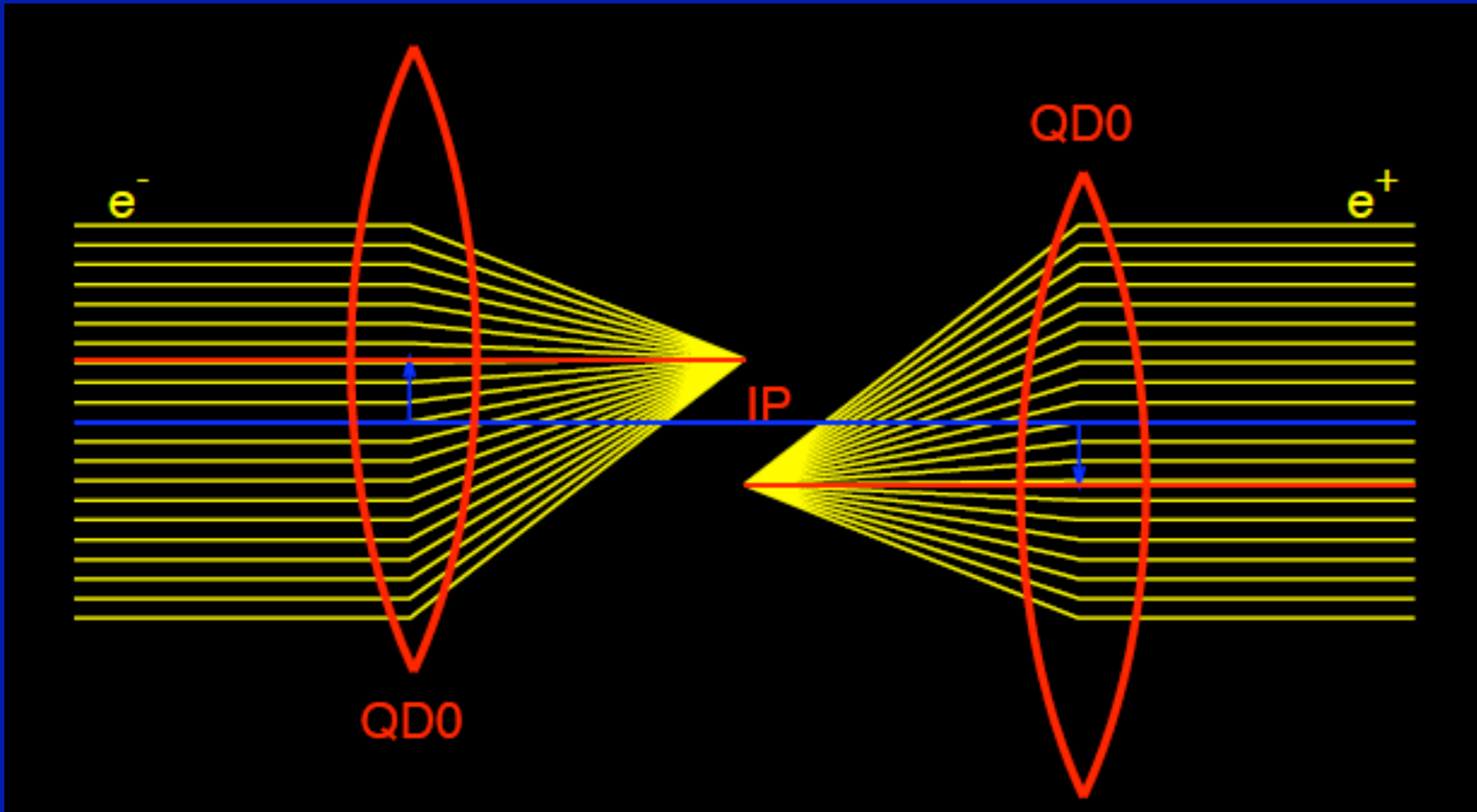


7.6mØ 4.8m Ø 7.6mØ

50Km

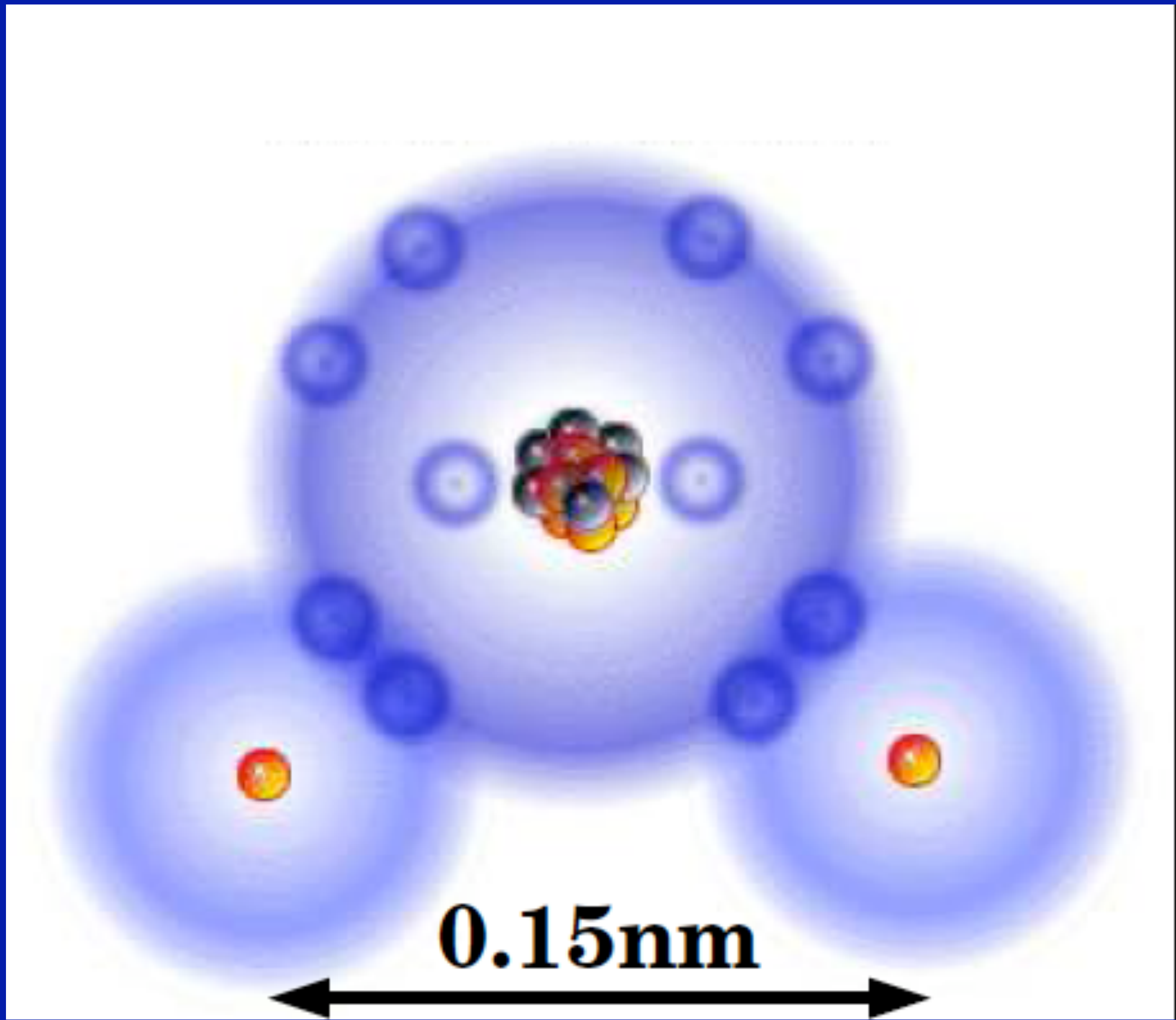


Other technological challenges



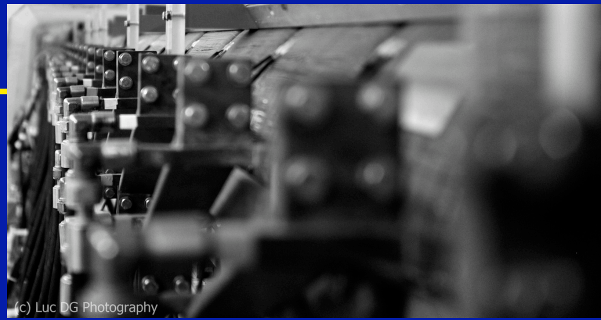
The final focusing quadruple should be stabilized to 0.15 nm for frequencies about 4 Hz

Other technological challenges



0.15 nm, small as a H_20 molecule !

Conclusion – linear technology



LHC should find new physics

Linear Collider will be able to study new physics with extreme precision

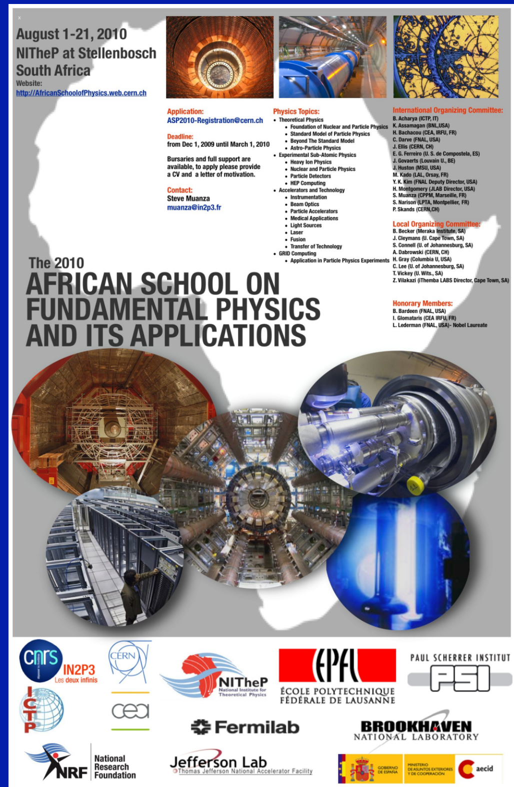
Collaboration of scientists and engineers from 19 countries

Optimization of costs and performance
- Accelerating gradient
- Efficient transfer of power from the “wall” to the beam

Many engineering challenges
- Material science – micron precision machining
- Mechanics – sub – nm beam stabilization
- Cooling, Vacuum, Integration, Civil engineering, alignment
- Diagnostics, Femto-second timing synchronization and feedback

You

- Attitude
- Your scientific interest (and late night studies)
- Ideas, knowledge and expertise
- Partnership, sustainability and Ubunthu
- Your government
- Your university
- You have choices
- Feedback

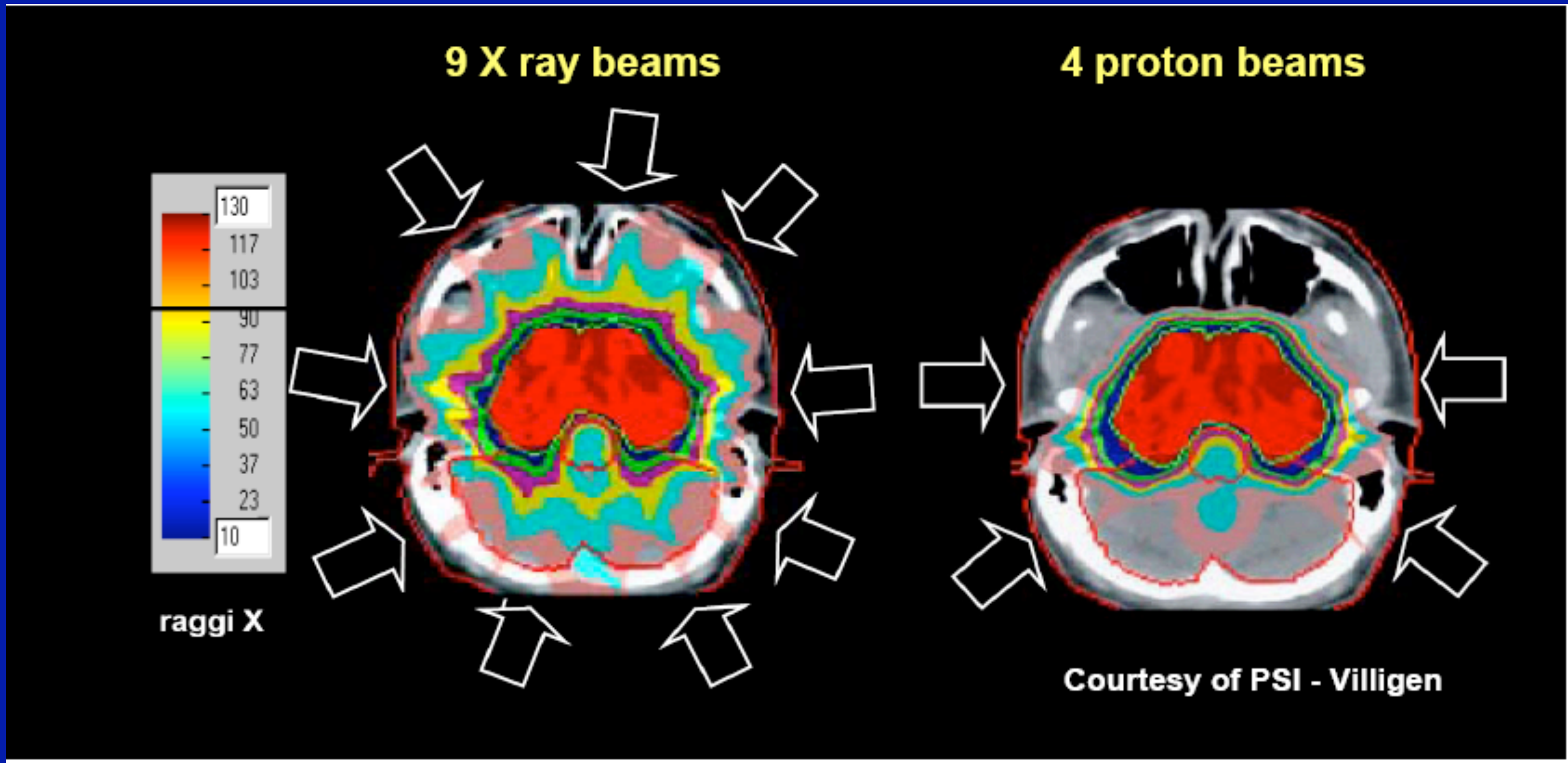


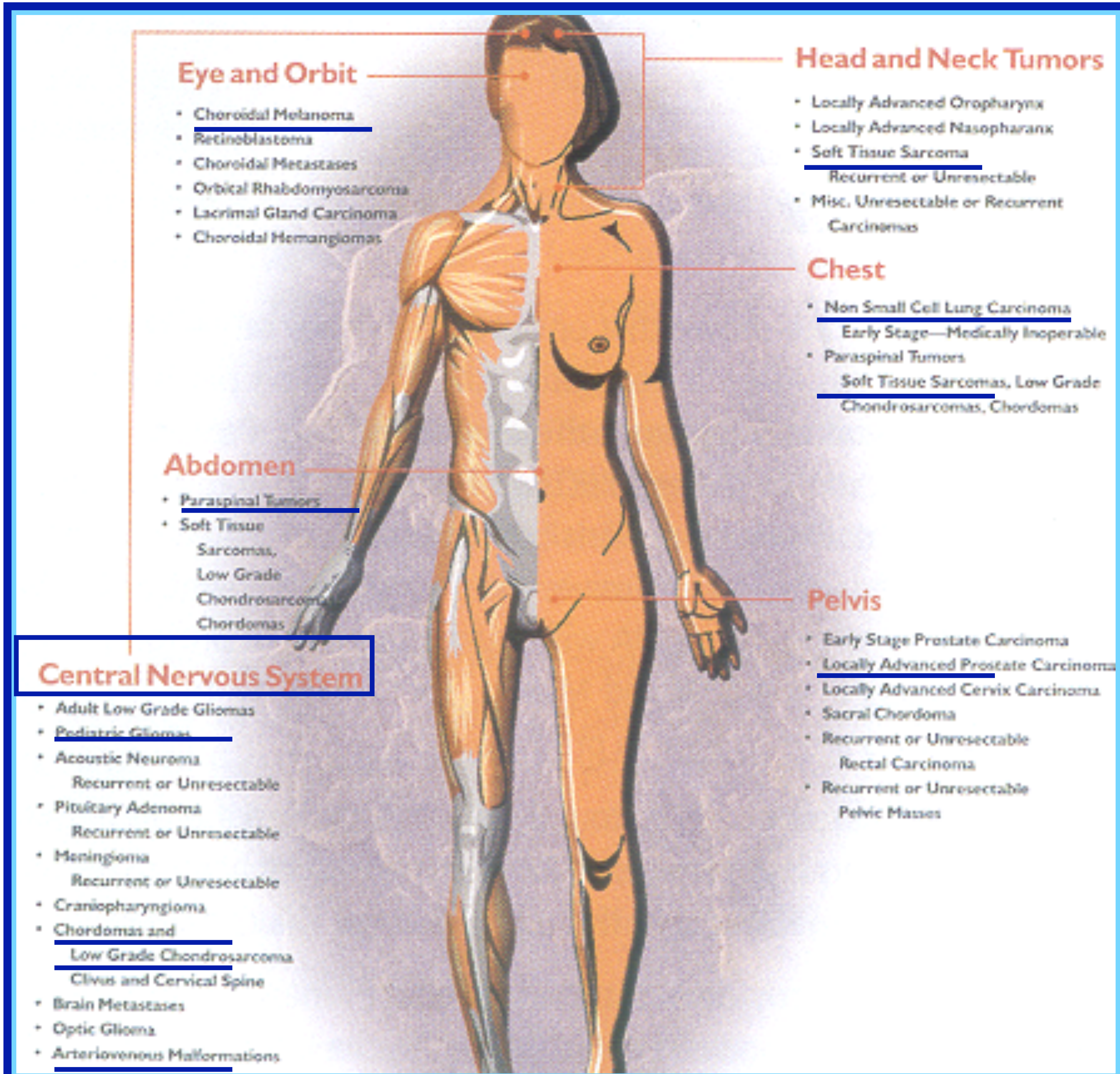
Acknowledgement

Thank you to Roger Ruber, Erk Jensen, Alex Anderssen and all my CLIC/CTF3 colleagues for material for this talk.

Collaboration with TERA foundation

CLIC / CTF3 accelerating cavity research being applied to medical physics industry





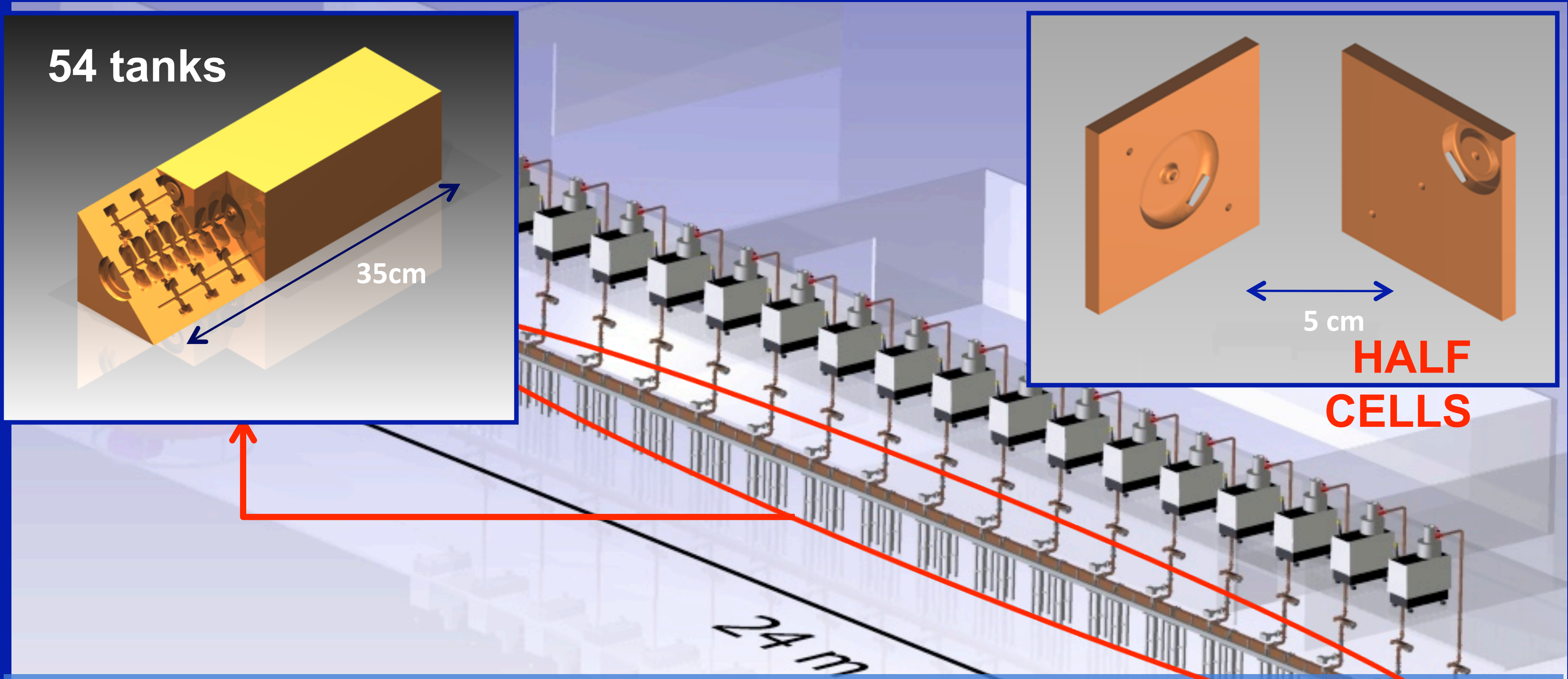
In the world
protontherapy: 60'000 patients

carbon ion therapy 5500 patients

BUT

About 1% with 'active' dose distribution systems at PSI and GSI with spot/raster scanning

First application: Carbon Booster for Therapy in Oncology



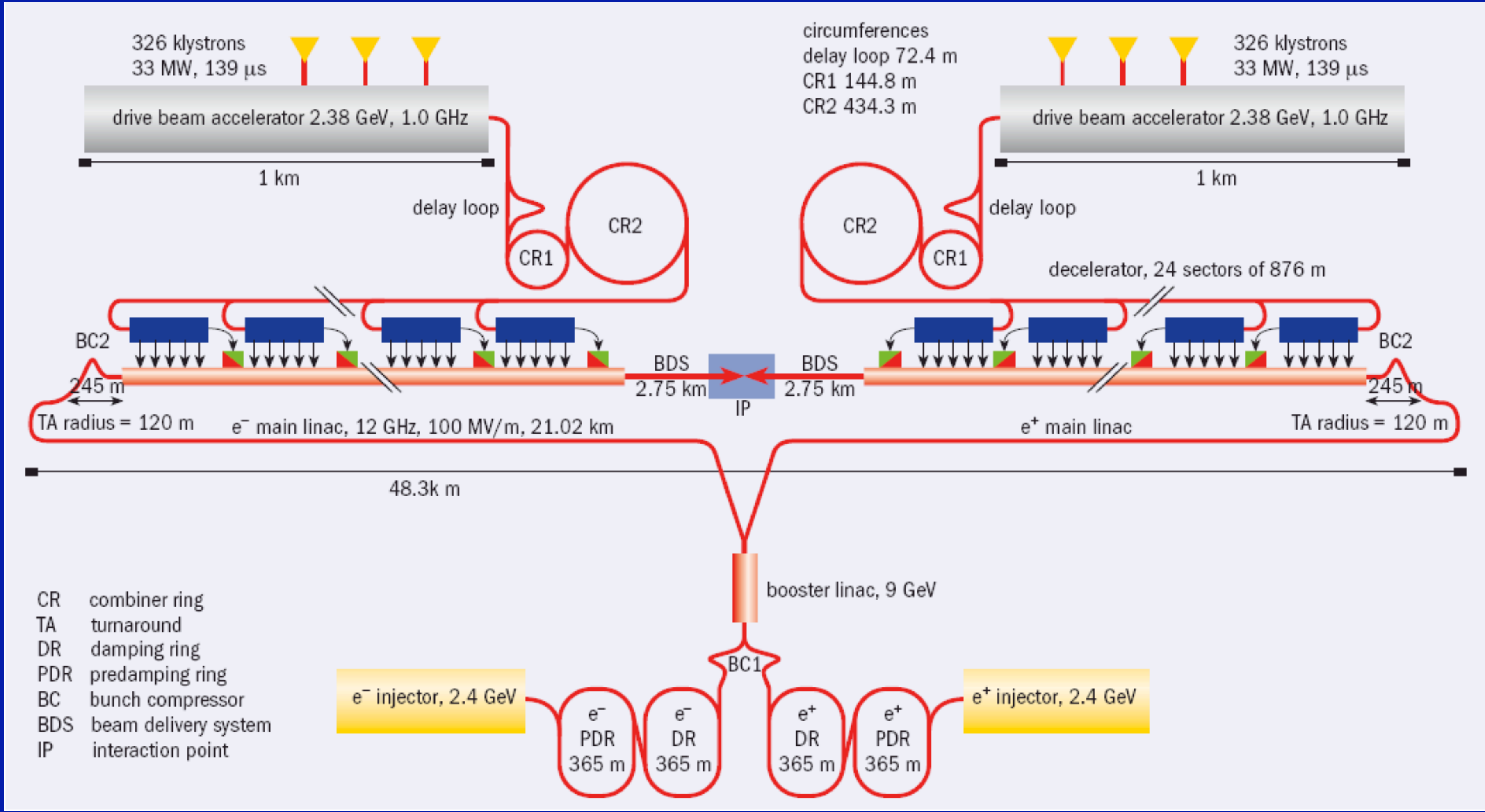
- Cell Coupled Linac at 5.7 GHz
- 18 accelerating modules
- Length of each module ~ 1.3 m

High gradient : 40 MV/m (TERA+CLIC collaboration)

Linear Collider Designs – Competing Technologies

CLIC – compact Linear accelerator

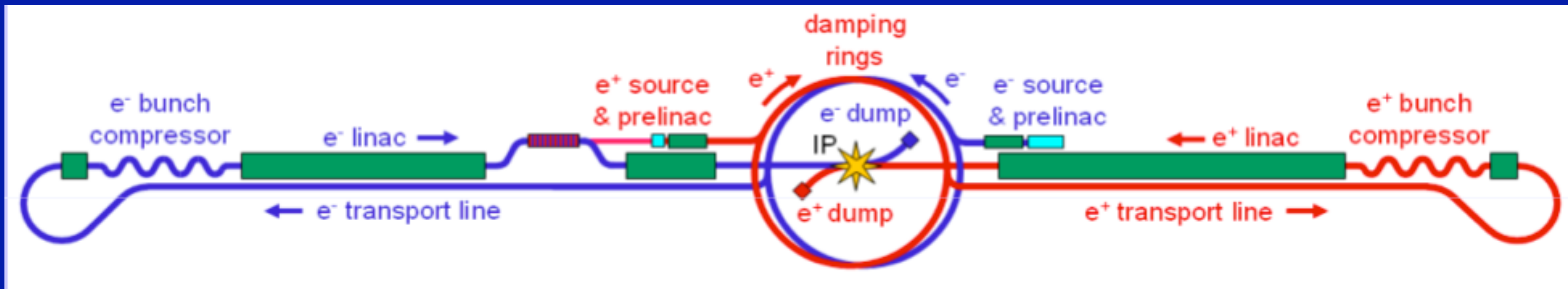
- Using copper travelling wave accelerating cavities
- 100 MV/m
- 48 km linac for a 3 TeV machine



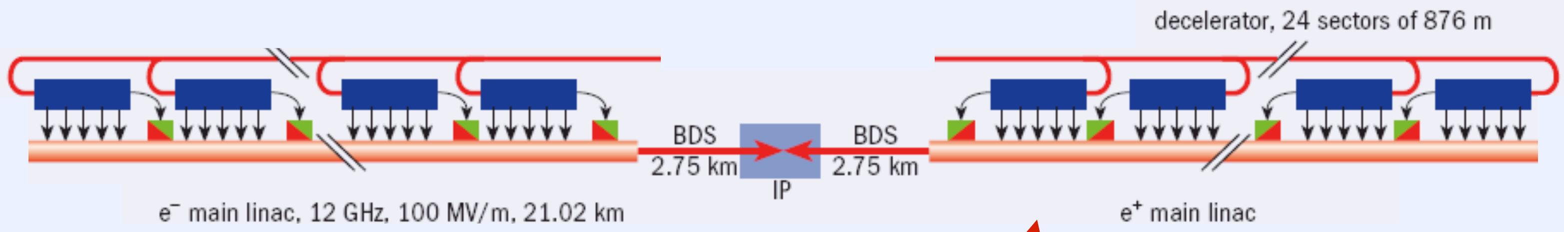
Linear Collider Designs – Competing Technologies

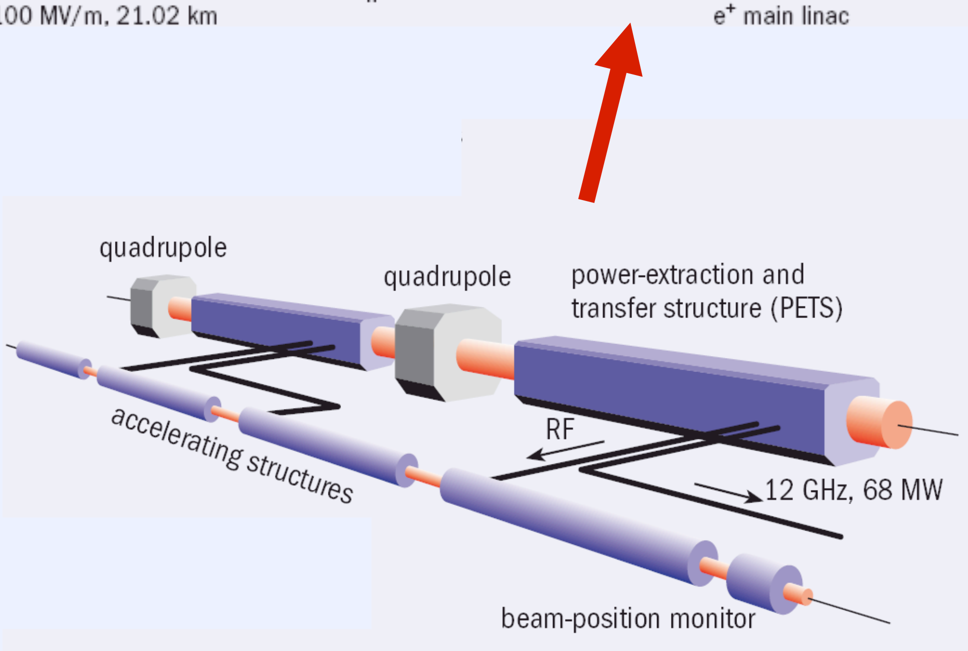
International Linear Collider

- using superconducting accelerating cavities
  - ☺ Negligible energy lost to the cavity walls as heat
  - ☹ Need energy to cool the cavities down to -271° C
- 35 MV/m
- 40 km linac for 500 GeV machine

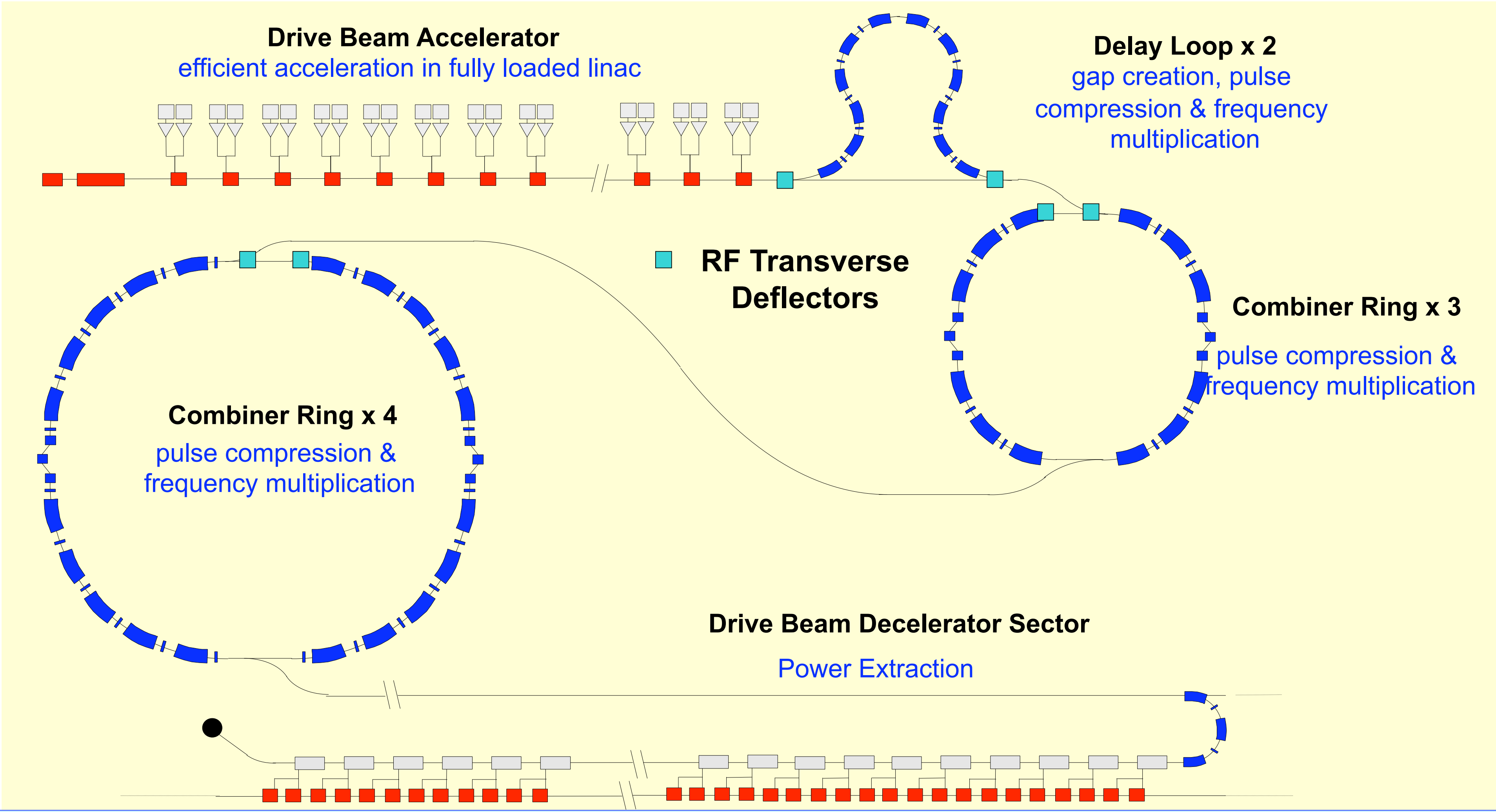


CLIC Two-beam Acceleration Concept

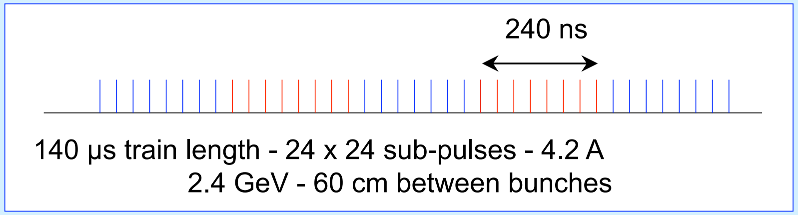




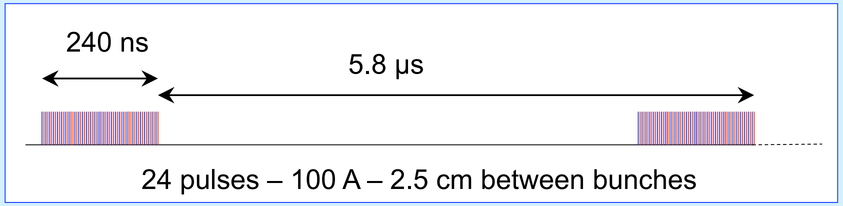
Recombination to Increase Peak Power & Frequency



Drive beam time structure - initial

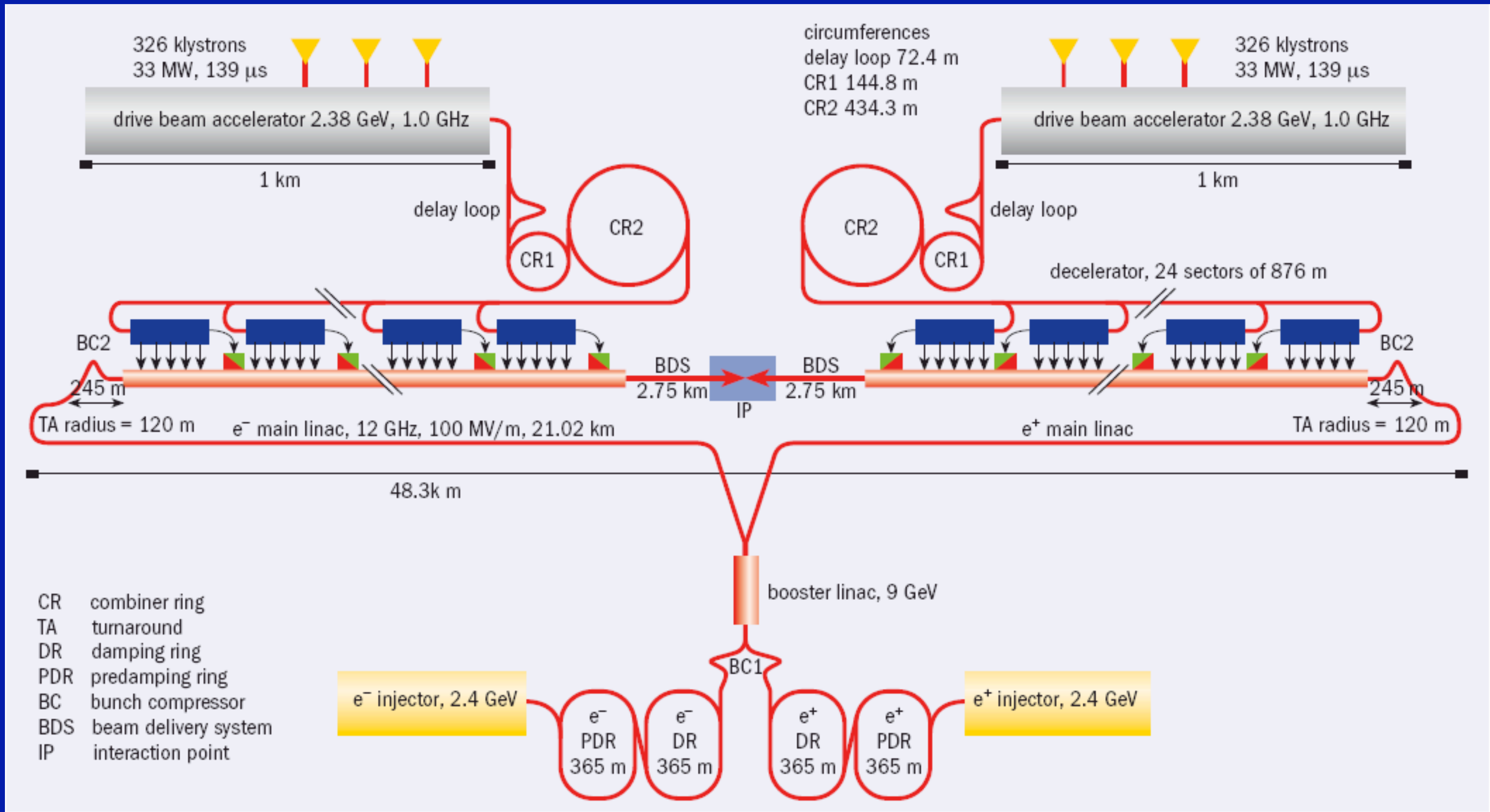


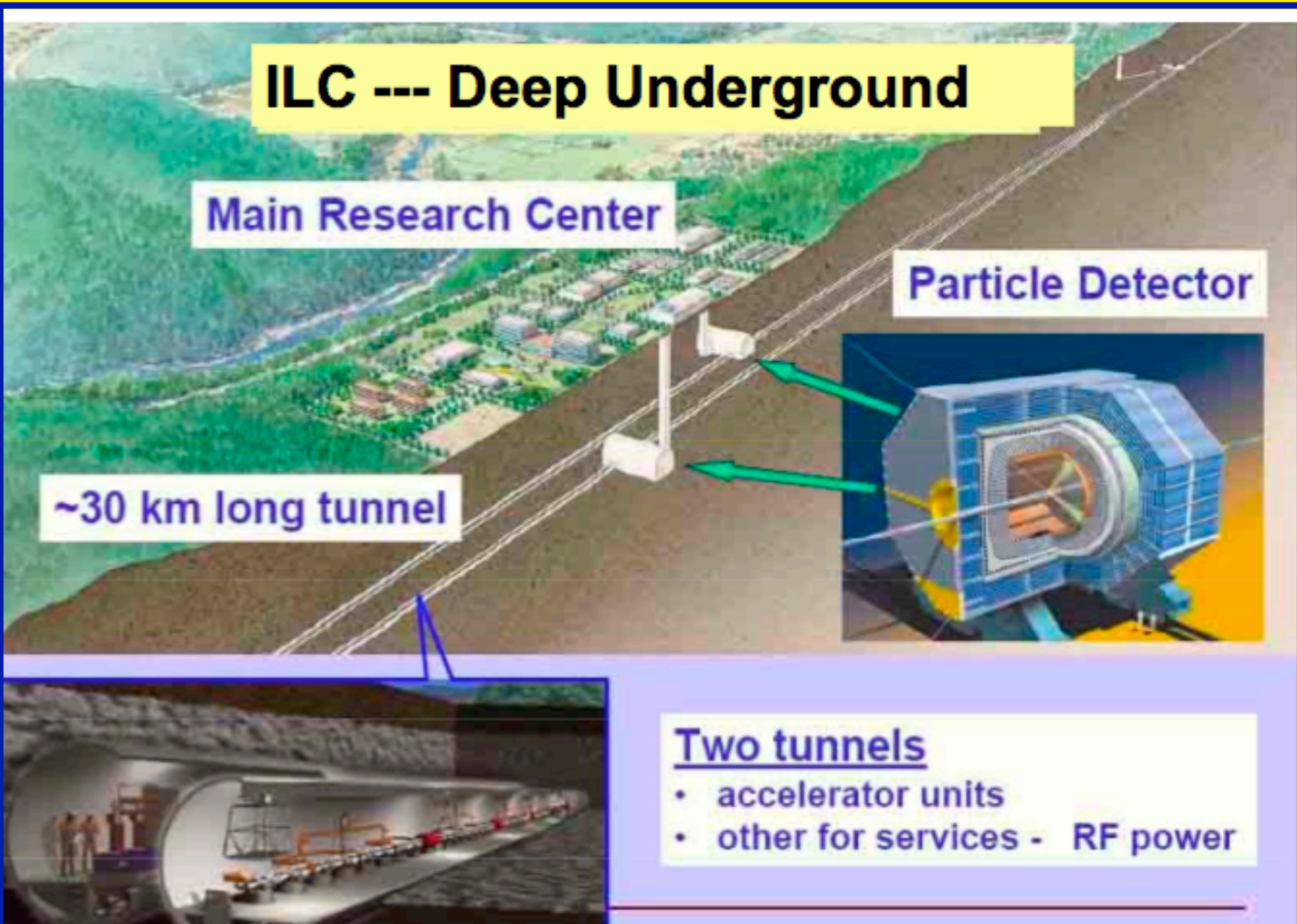
Drive beam time structure - final



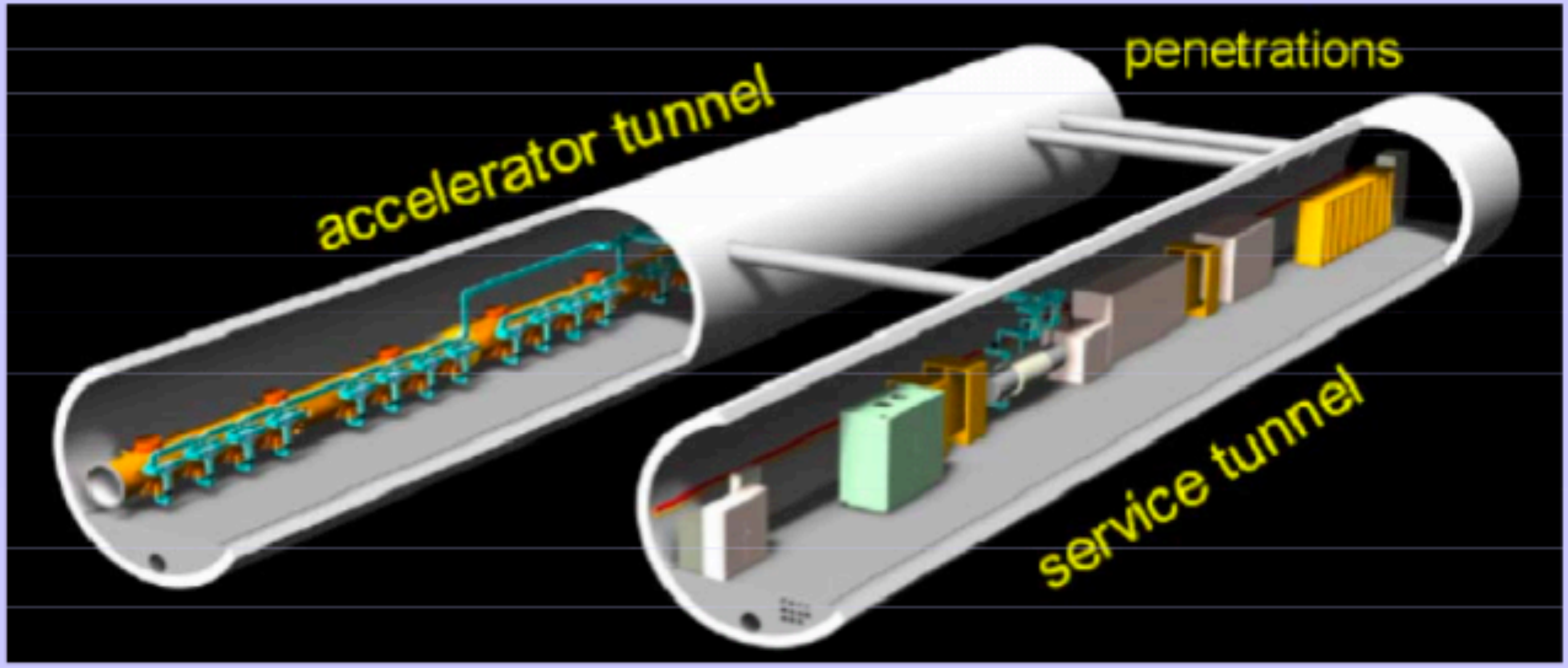
Compact Linear Collider Layout

- Using copper travelling wave accelerating cavities
- 100 MV/m
- 48 km linac for a 3 TeV machine




ILC --- Deep Underground
Main Research Center
Particle Detector
~30 km long tunnel
Two tunnels
• accelerator units
• other for services - RF power

Main Linac Double Tunnel



- Three RF/cable penetrations every rf unit
- Safety crossovers every 500 m
- 34 kV power distribution