




August 1-21, 2010
NITheP at Stellenbosch
South Africa
Website:
<http://AfricanSchoolPhysics.web.cern.ch>



Application:
ASP2010-Registration@cern.ch

Deadline:
From Dec 1, 2009 until March 1, 2010

Bursaries and full support are available. To apply please provide a CV and a letter of motivation.

Contact:
Steve Maurice
maurice@aq3.fr



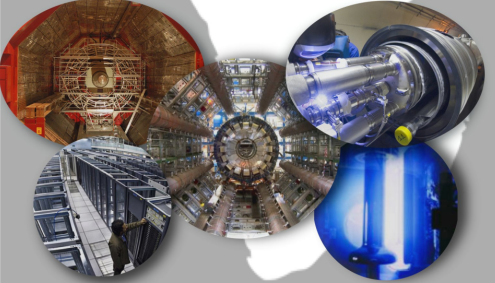
Physics Topics:

- Theoretical Physics
 - Interaction of Nuclear and Particle Physics
 - Structure of Matter
 - Beyond The Standard Model
 - Other Special Topics
- Experimental Sub-Atomic Physics
 - Nuclear and Particle Physics
 - Particle Detectors
- NPD Core Topics
 - Accelerator and Technology
 - Beam Optics
 - Particle Accelerators
 - Medical Applications
 - Light Sources
- Local Organizing Committee
 - Local Organizing Committee
 - Local Organizing Committee
 - Local Organizing Committee

Honorary Members:

- Honorary Members
- Honorary Members
- Honorary Members

The 2010 AFRICAN SCHOOL ON FUNDAMENTAL PHYSICS AND ITS APPLICATIONS



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



25 000 km / year



DE BEERS
A DIAMOND IS FOREVER

elementsix™



CERN-Latin American Summer School

Northwestern University | Weinberg College of Arts & Sciences

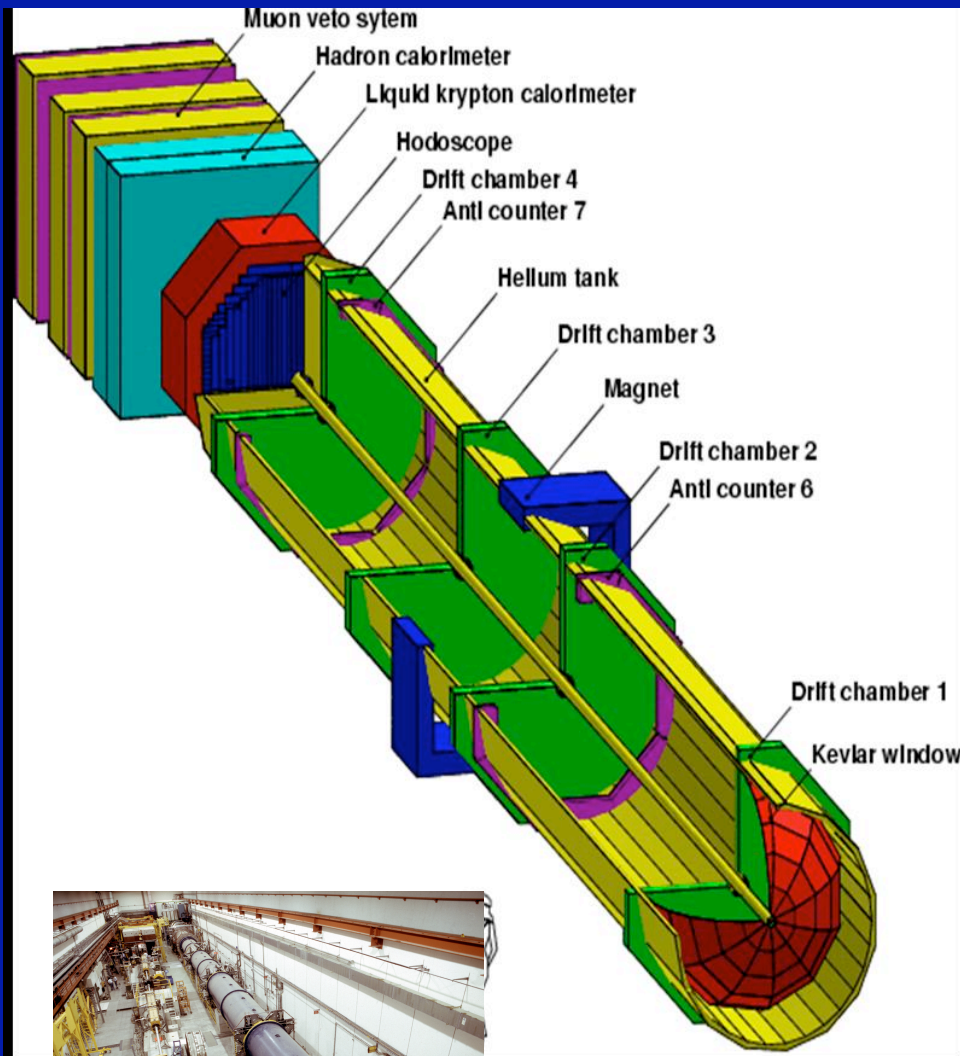


Lüderitz
2000

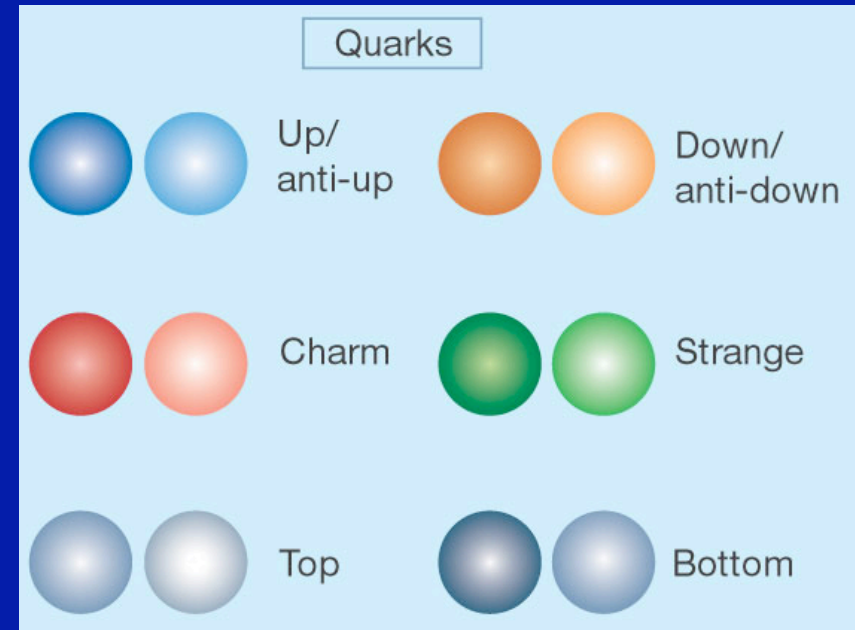


Physics & Astronomy

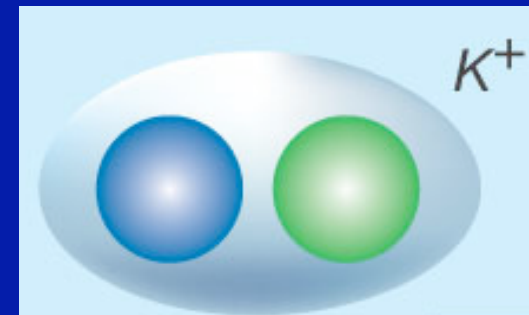
NA48/2 Experiment



114 m decay volume before detector



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

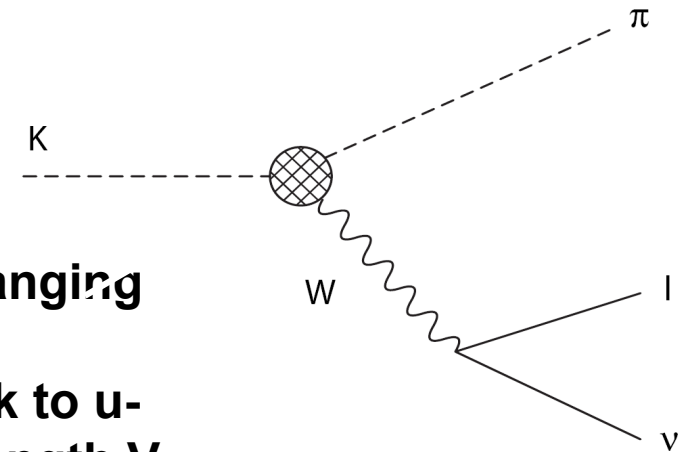


Kaon Semileptonic Branching Ratio's

Kaon semileptonic decays are pure vector transitions

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

Hadronic Vertex →
described by form factors



Measure $BR(K_{l3})$

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

$$\frac{BR(K_{l3})}{\tau_K} = \frac{C_K^2 G_F^2 m_K^5}{192\pi^3} S_{EW} |V_{us}|^2 |f_+(0)|^2 I_K^l(\lambda_{+0}) (1 + \delta_{SU(2)}^l + \delta_{EM}^l)$$

Extract

Unitarity of CKM Matrix

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} V_{\text{CKM}} = \begin{pmatrix} 0.97383^{+0.00024}_{-0.00023} & 0.2272^{+0.0010}_{-0.0010} & (3.96^{+0.09}_{-0.09}) \times 10^{-3} \\ 0.2271^{+0.0010}_{-0.0010} & 0.97296^{+0.00024}_{-0.00024} & (42.21^{+0.10}_{-0.80}) \times 10^{-3} \\ (8.14^{+0.32}_{-0.64}) \times 10^{-3} & (41.61^{+0.12}_{-0.78}) \times 10^{-3} & 0.999100^{+0.000034}_{-0.000004} \end{pmatrix}$$

Status 2007

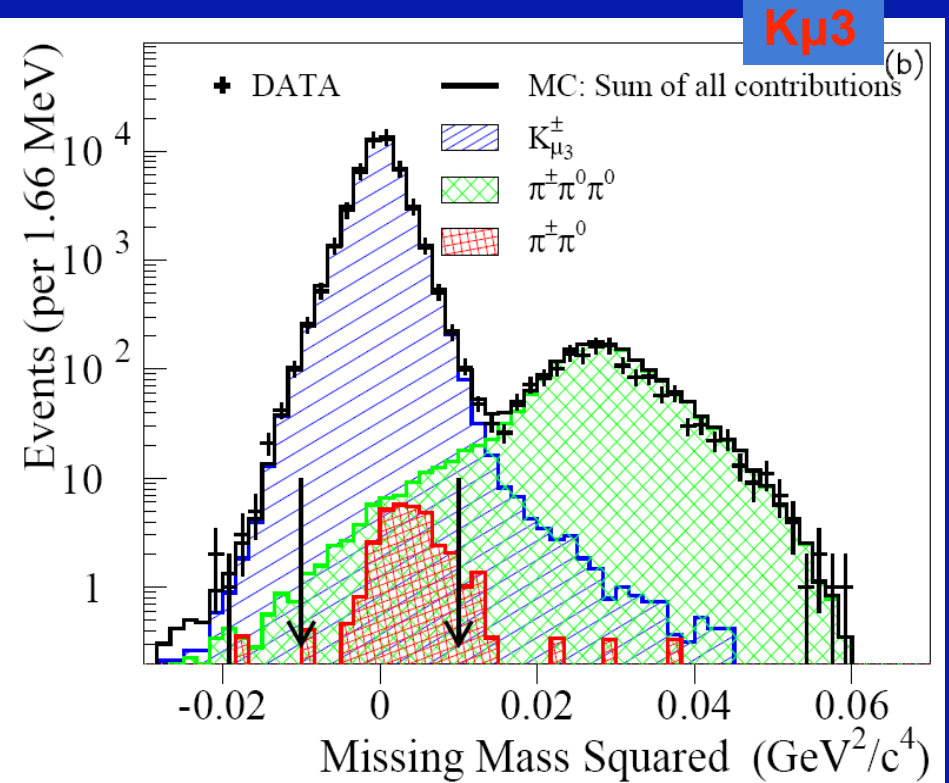
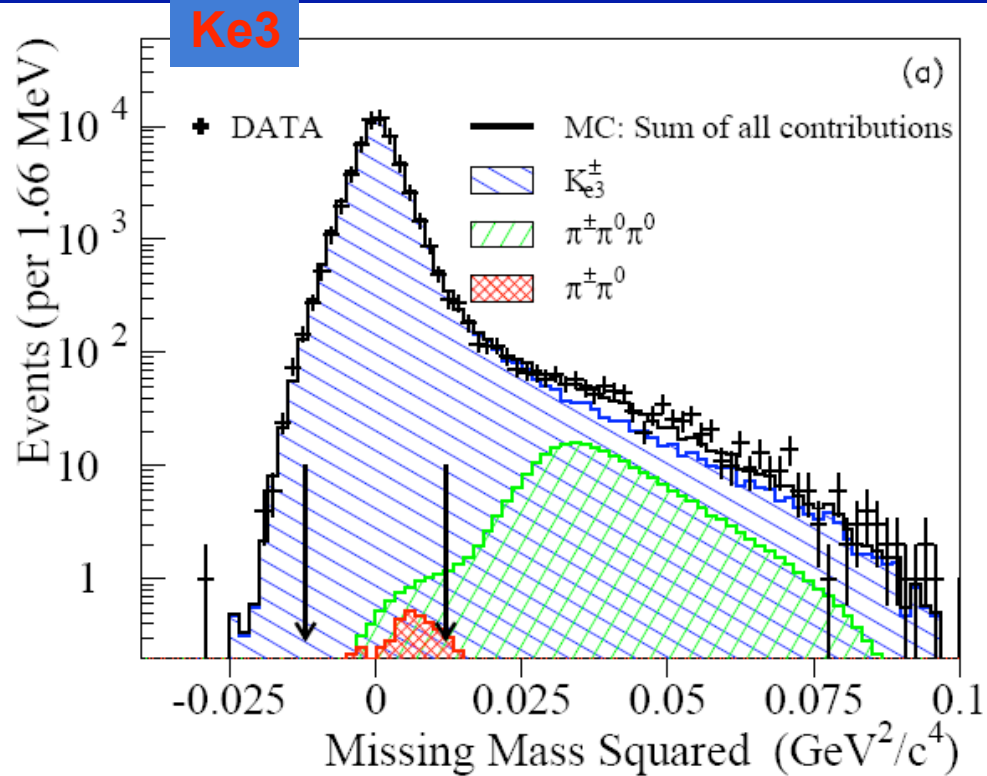
- **Entries not predicted → need to be experimentally measured**
- **Deviation from unitarity would have to be attributed to by new physics**
- **V only source of quark mixing in the standard model**
- **3x3 matrix contains one imaginary phase**

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

**Most well measured
unitarity constraint**

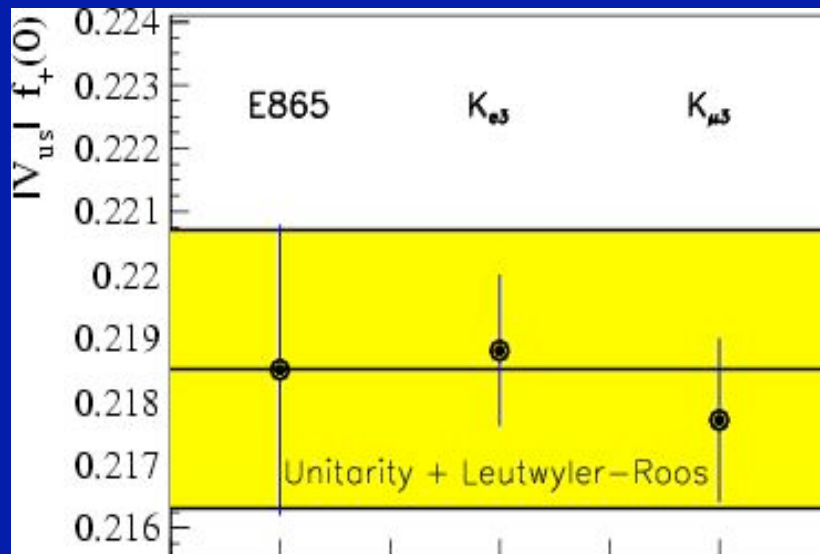
Nobel prize for physics 2008 for Kobayashi and Maskawa

Measure data sample to extract V_{us}



Extraction of V_{us}

| Decay Channel | Branching Fraction Br | Phase Space Integral I_K^ℓ | Radiative Correction[33, 50, 51] | | $ V_{us} f_+(0)$ |
|---------------|-------------------------|---------------------------------|----------------------------------|------------------------|---------------------|
| | | | $\delta_{SU(2)}^\ell(\%)$ | $\delta_{EM}^\ell(\%)$ | |
| K_{e3} | 0.0517 ± 0.0004 | 0.1591 ± 0.0012 | 2.31 ± 0.22 | 0.03 ± 0.10 | 0.2193 ± 0.0012 |
| $K_{\mu 3}$ | 0.0343 ± 0.0002 | 0.1066 ± 0.0008 | 2.31 ± 0.22 | 0.20 ± 0.20 | 0.2177 ± 0.0013 |



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

$$|V_{us}|f_+(0) = 0.2177 \pm 0.0013 \quad K_{\mu 3}$$

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

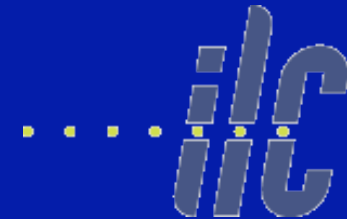
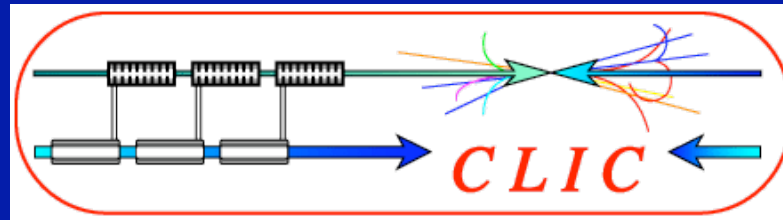
$$|V_{us}|_{unitary} f_+(0) = 0.2185 \pm 0.0022$$

**Measurement more precise than previous world average.
Agreement with theory**



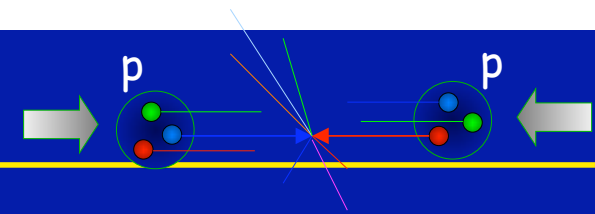
New Physics → waiting for the LHC





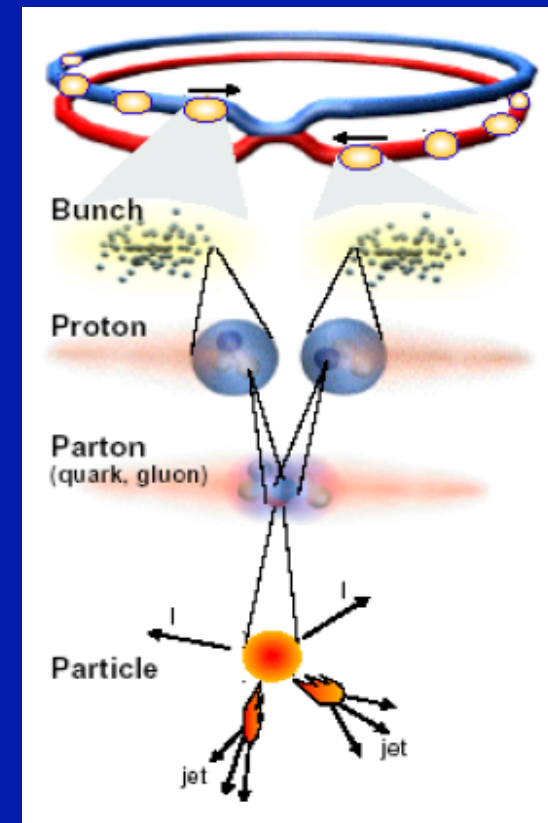
**Physics at the high energy frontier *BEYOND*
the LHC**

Technologies for Future Linear Colliders

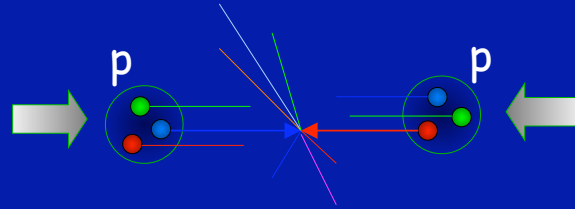


hadron collider at the energy frontier of physics today

- 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

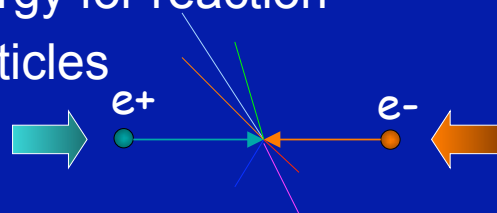


Collider History

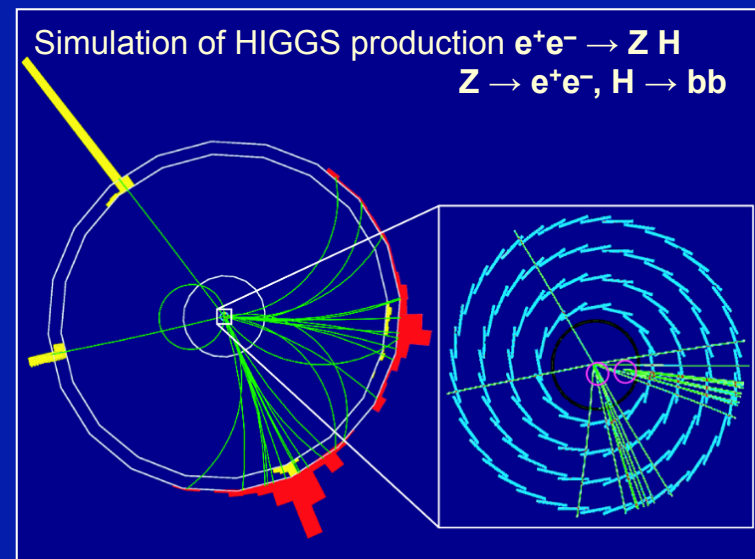
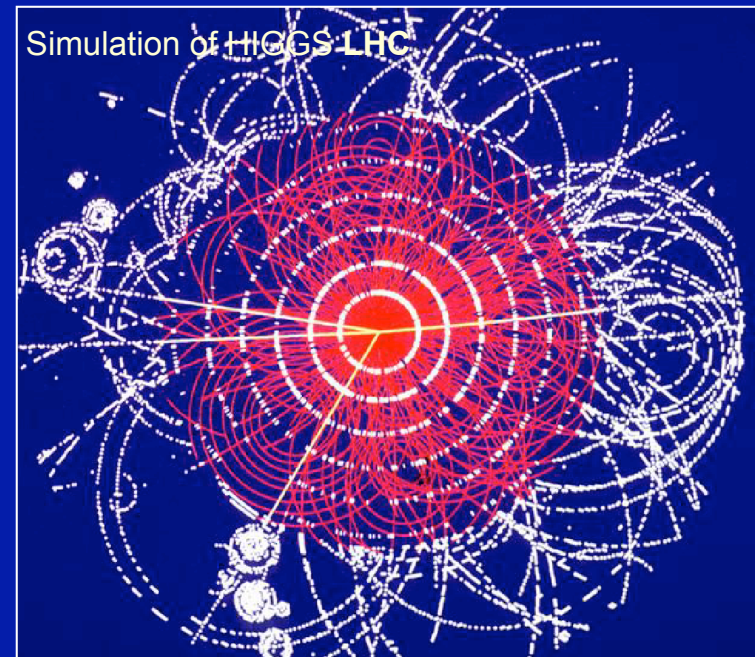


- **hadron collider** at the frontier of physics
 - huge QCD background
 - not all nucleon energy available in collision

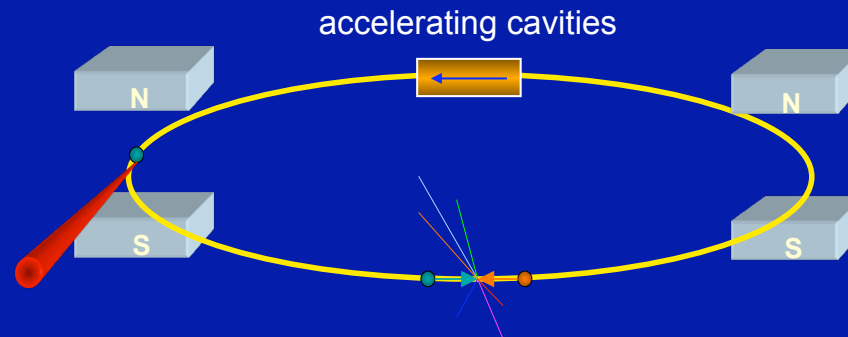
- **lepton collider** for precision physics
 - well defined initial energy for reaction
 - Colliding point like particles



- **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

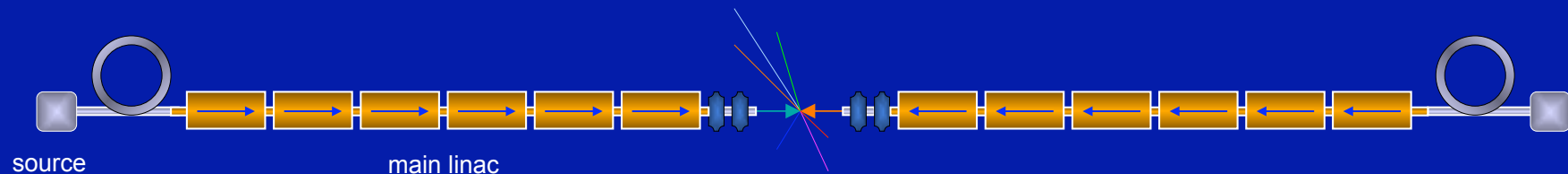


Circular versus Linear Collider



Circular Collider

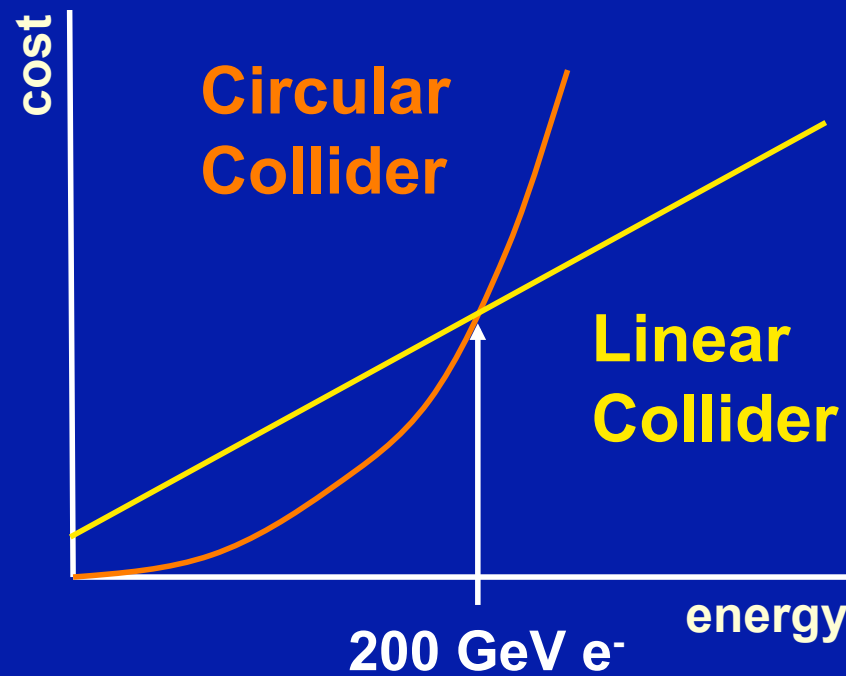
many magnets, few cavities, stored beam
higher energy → stronger magnetic field
→ higher synchrotron radiation losses (E^4/m^4R)



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



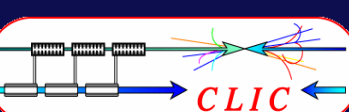
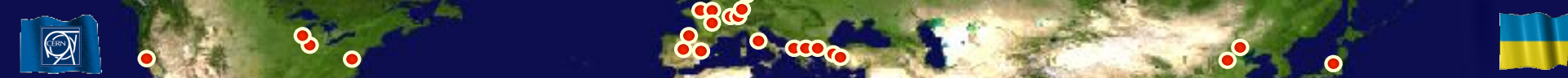
Circular Collider

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

Linear Collider

- $E \sim L$
- $\text{cost} \sim aL$

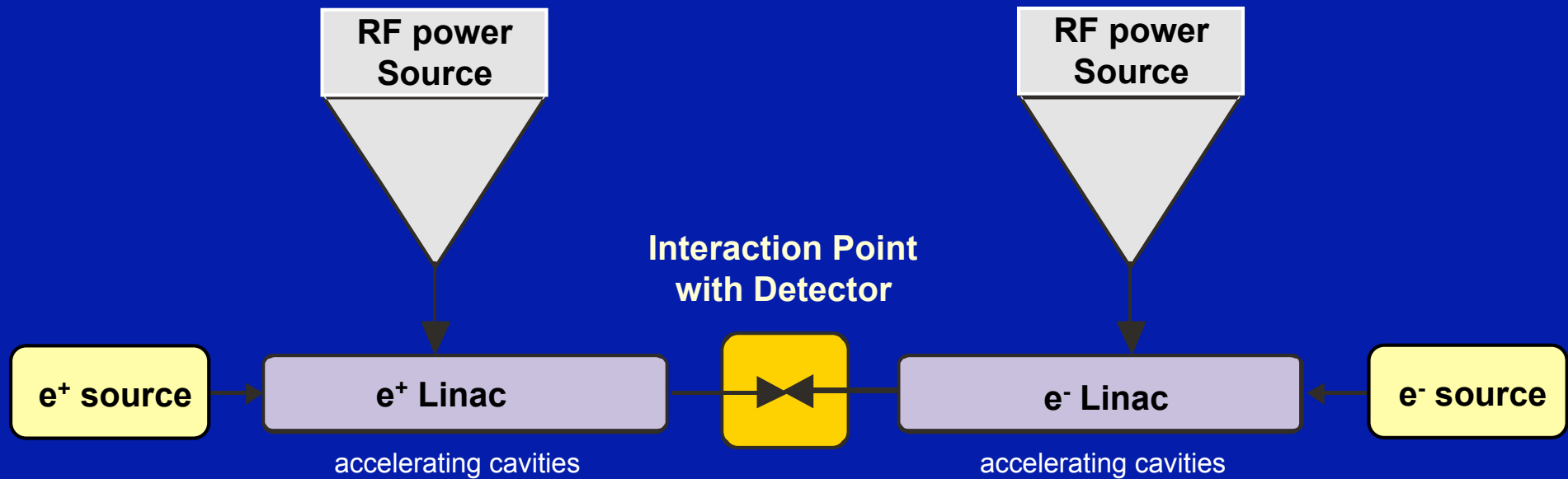
World-wide CLIC & CTF3 Collaboration



38 Institutes from 19 countries

- | | | | |
|-----------------------------------|---|------------------------------------|---|
| Aarhus University (Denmark) | Helsinki Institute of Physics (Finland) | John Adams Institute/RHUL (UK) | Polytech. University of Catalonia (Spain) |
| Ankara University (Turkey) | IAP (Russia) | JINR (Russia) | PSI (Switzerland) |
| Argonne National Laboratory (USA) | IAP NASU (Ukraine) | Karlsruhe University (Germany) | RAL (UK) |
| Athens University (Greece) | IHEP (China) | KEK (Japan) | RRCAT / Indore (India) |
| BINP (Russia) | INFN / LNF (Italy) | LAL / Orsay (France) | SLAC (USA) |
| CERN | Instituto de Fisica Corpuscular (Spain) | LAPP / ESIA (France) | Thrace University (Greece) |
| CIEMAT (Spain) | IRFU / Saclay (France) | NCP (Pakistan) | Tsinghua University (China) |
| Cockcroft Institute (UK) | Jefferson Lab (USA) | Northwestern. Univ. Illinois (USA) | University of Oslo (Norway) |
| ETHZurich (Switzerland) | John Adams Institute/Oxford (UK) | Patras University (Greece) | Uppsala University (Sweden) |
| Gazi Universities (Turkey) | | | UCSC SCIIPP (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

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

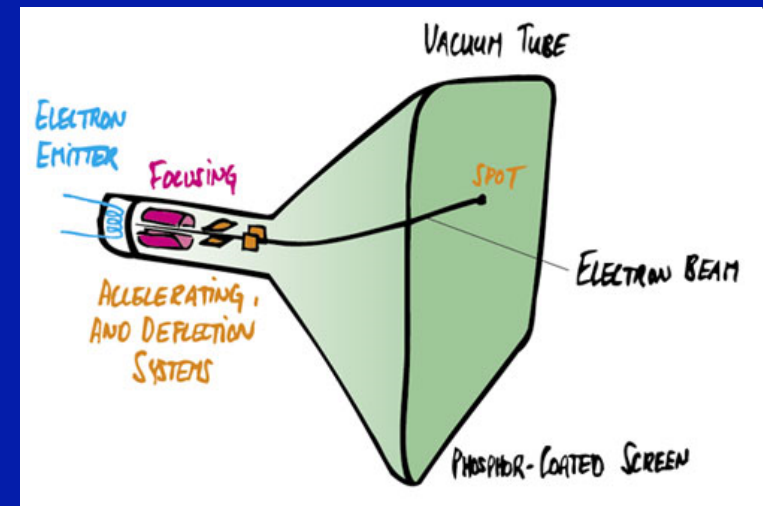
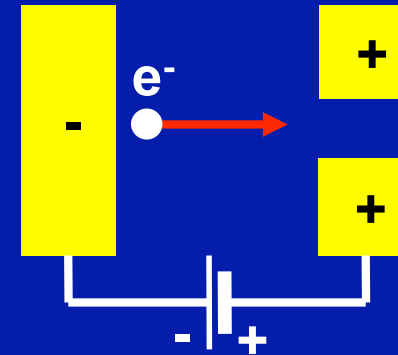
- increasing particle energy

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

- 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

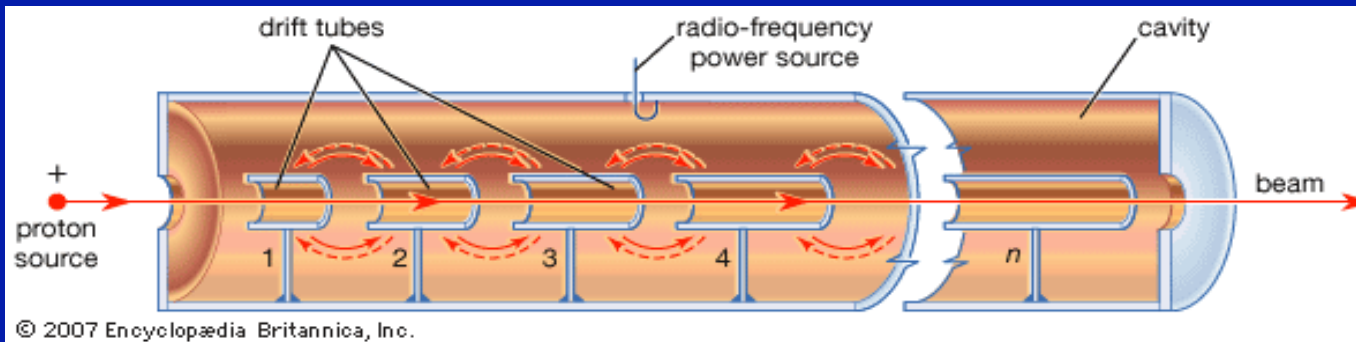


RF Accelerator

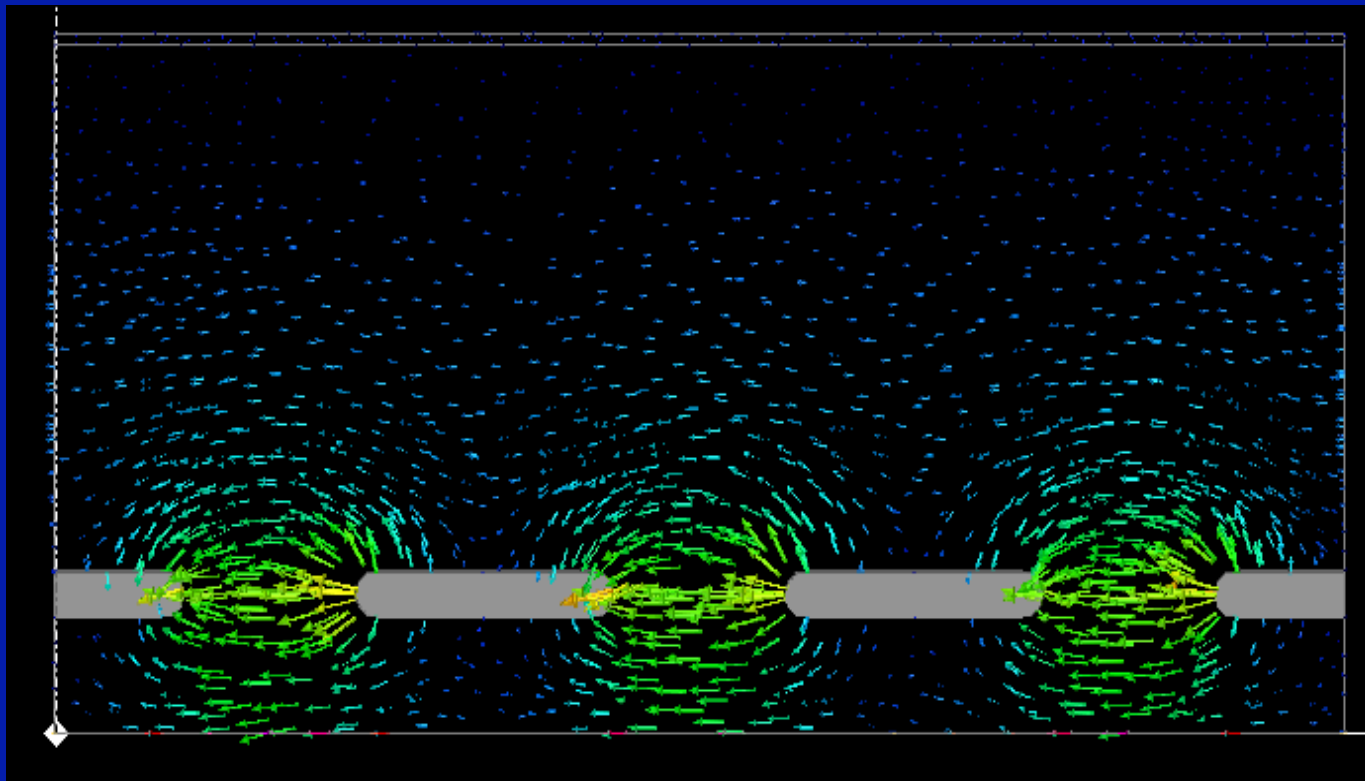


synchronize particle
with an
electromagnetic wave!

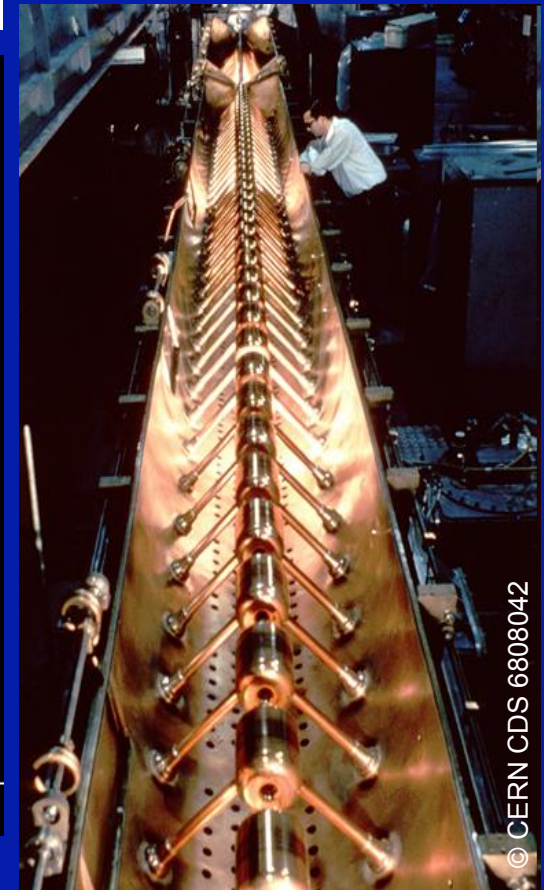
Drift Tube Linac: Higher Integrated Field



Linac 1 1982-1992

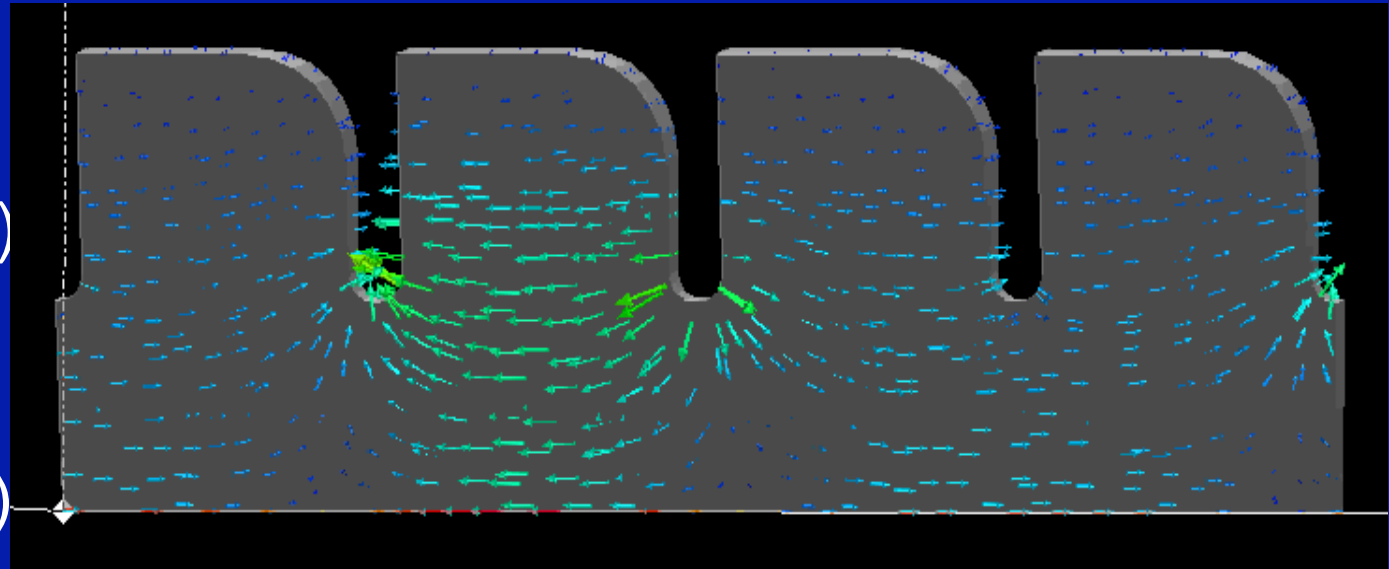


Courtesy E. Jensen



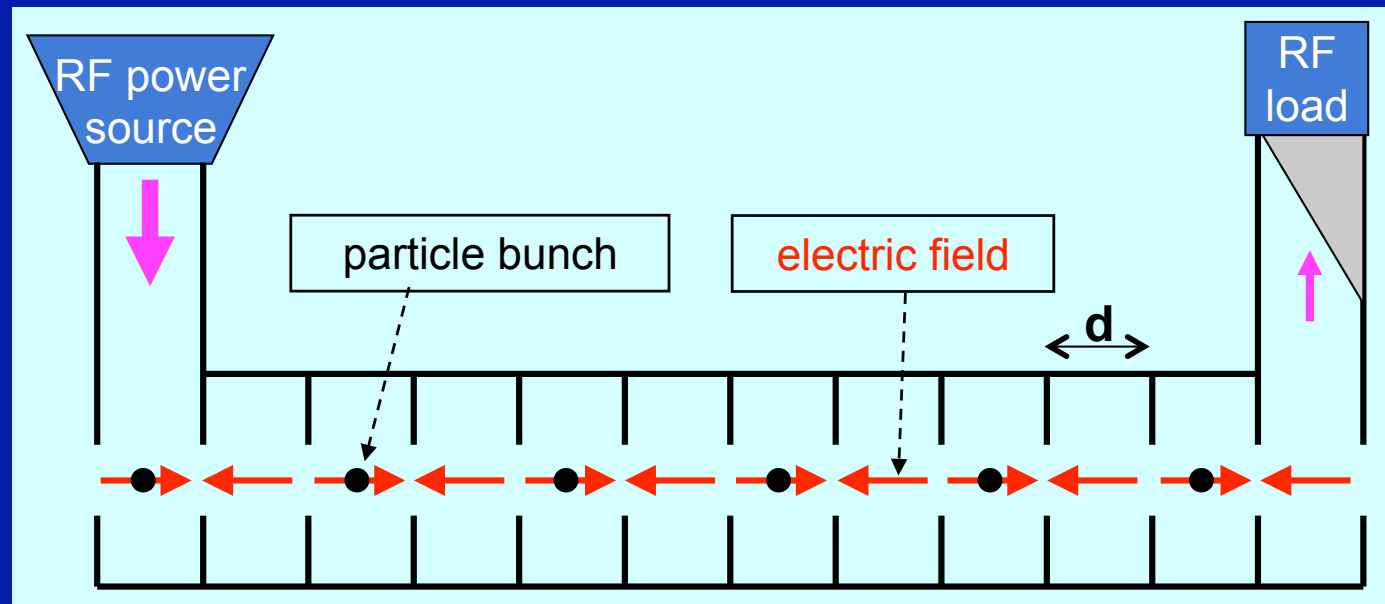
Travelling wave cavity

- Electrons $v \sim c$
- short pulses (mm)
- high frequency
>3 GHz (< 10 cm)



- typical
10~20 MV/m

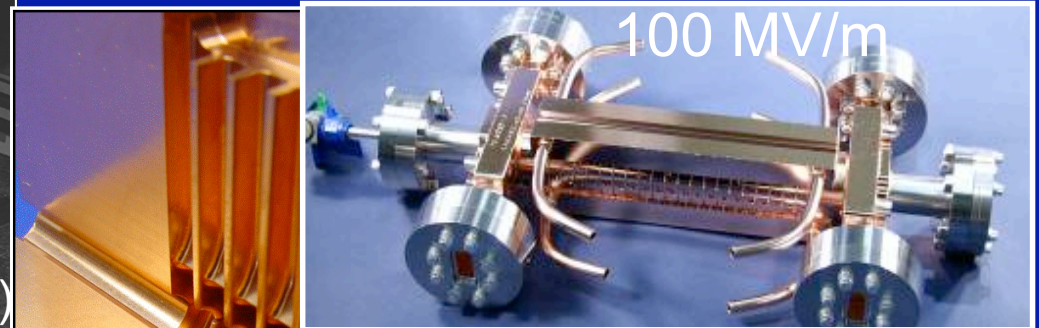
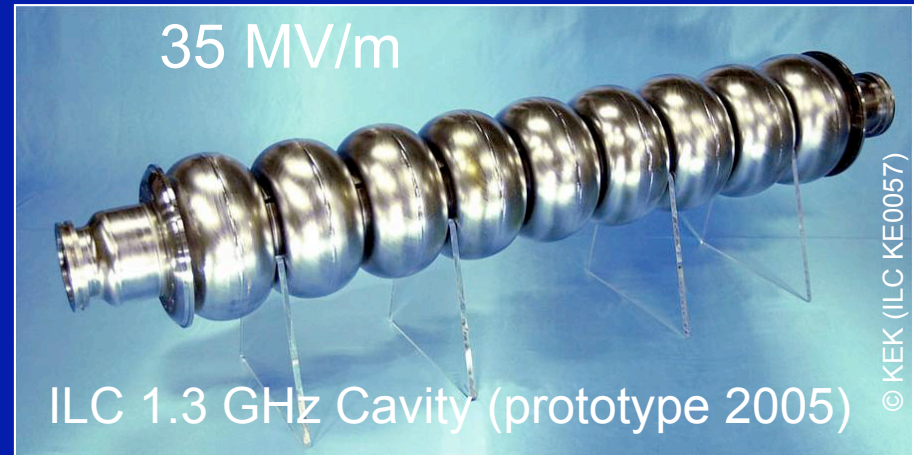
- CLIC:
 - 12 GHz
 - 240 ns
 - 100 MV/m



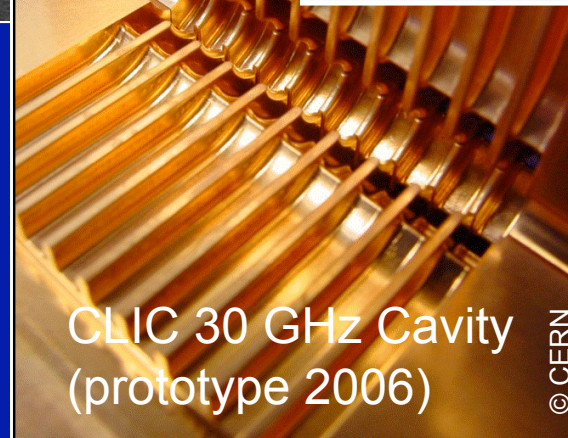
Accelerating Cavities



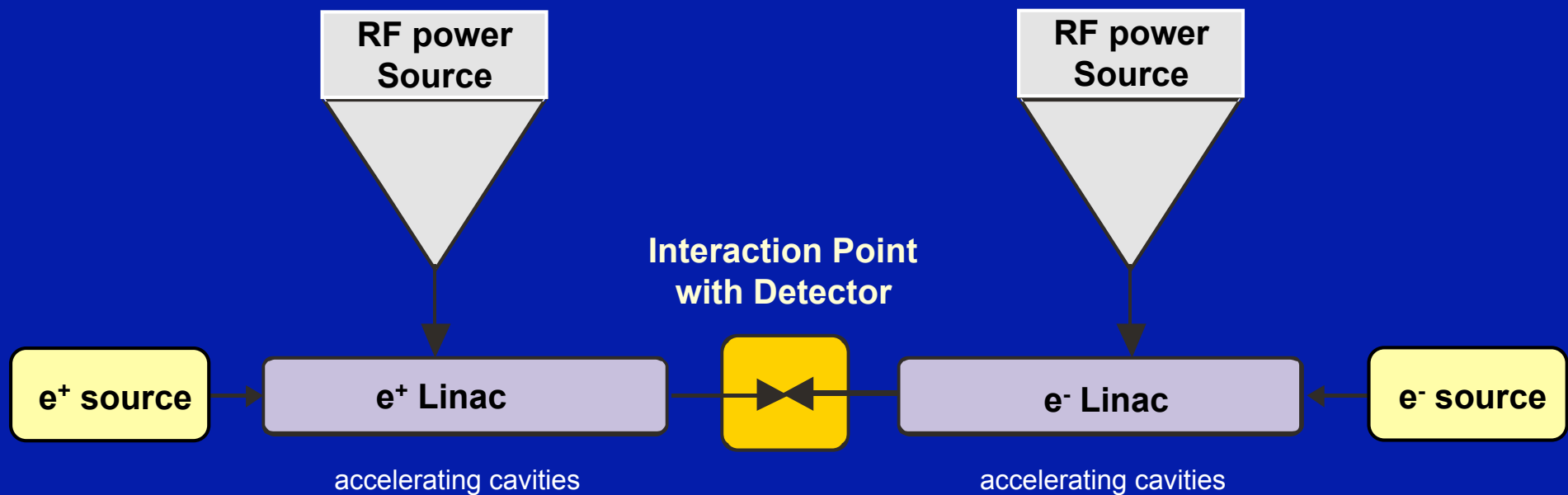
CERN PS 19 MHz Cavity (prototype 1966)



CLIC 12 GHz Cavity (prototype 2009)



Linear Collider R&D

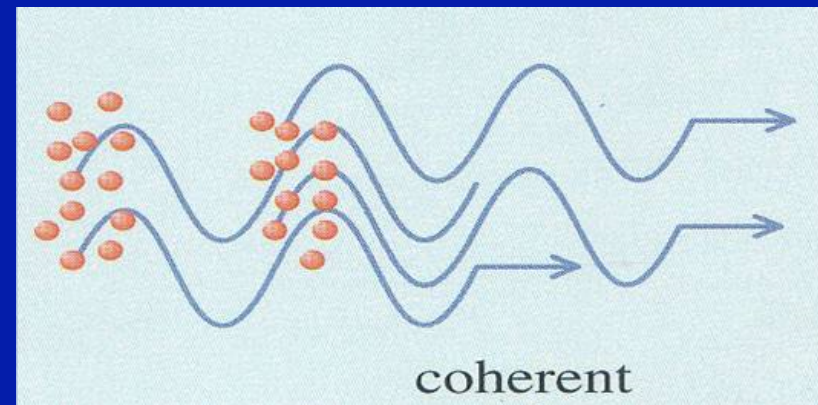
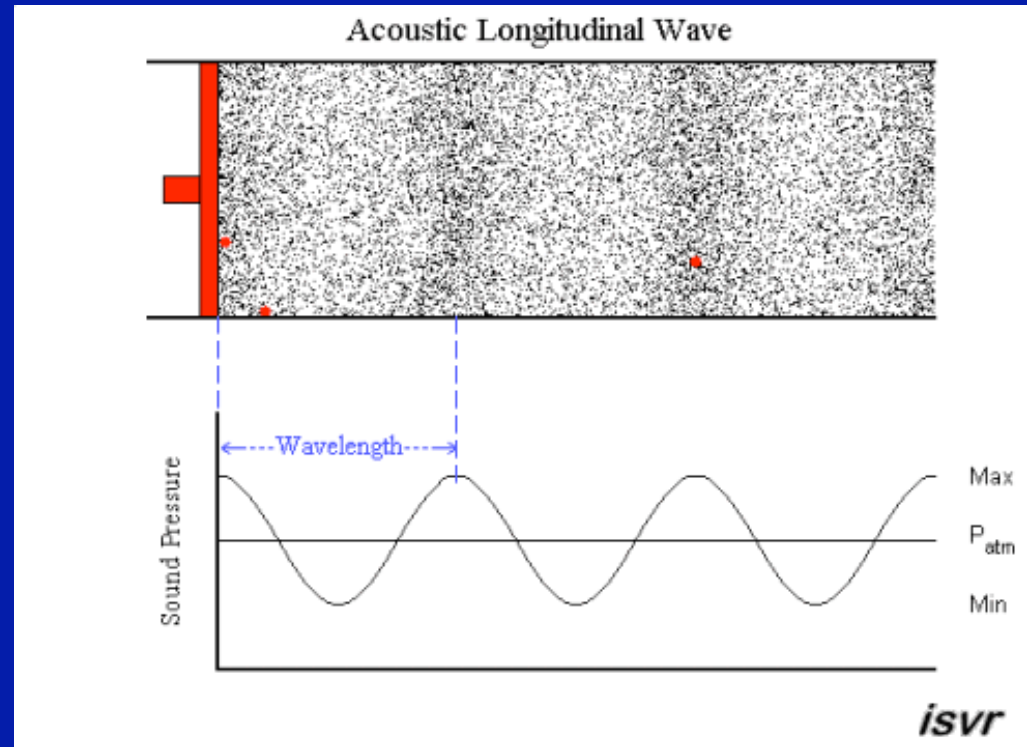


Challenges:

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

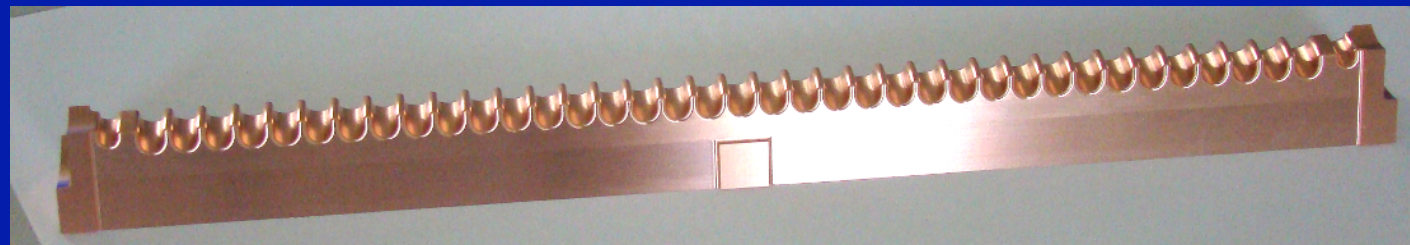
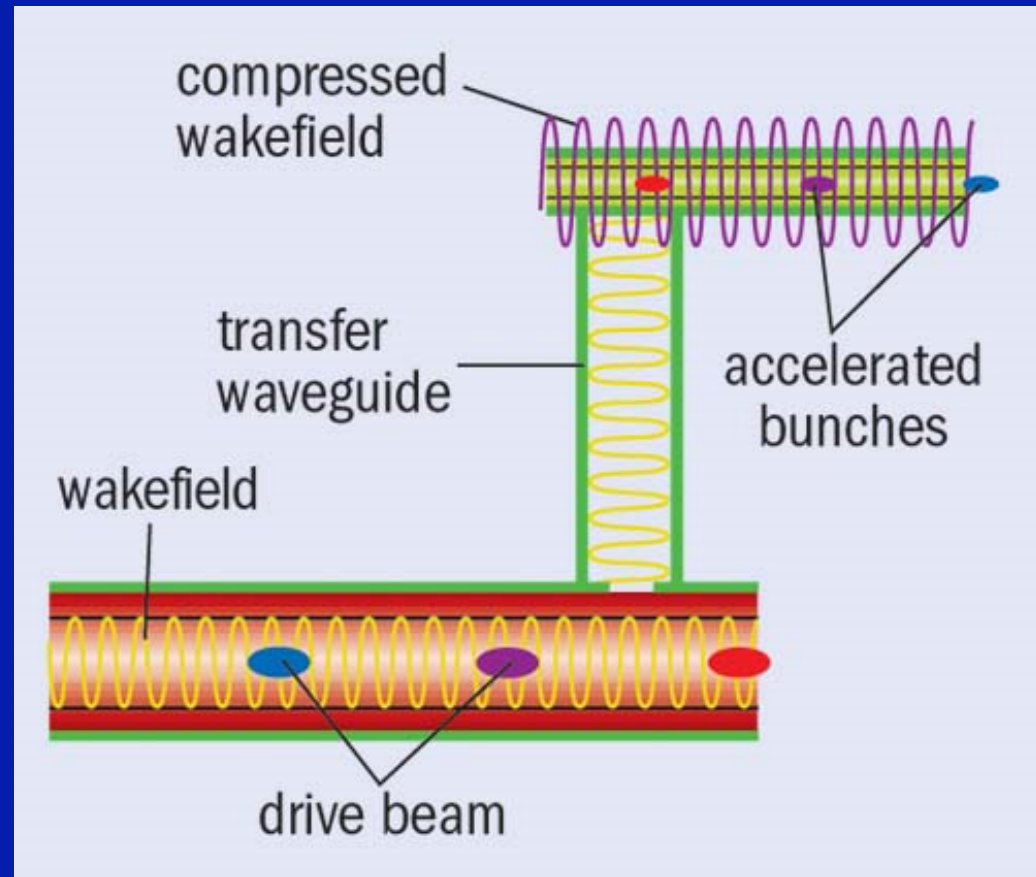
Electromagnetic Waves

- 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

time: 0 0 . 0 ns

Accelerating structure

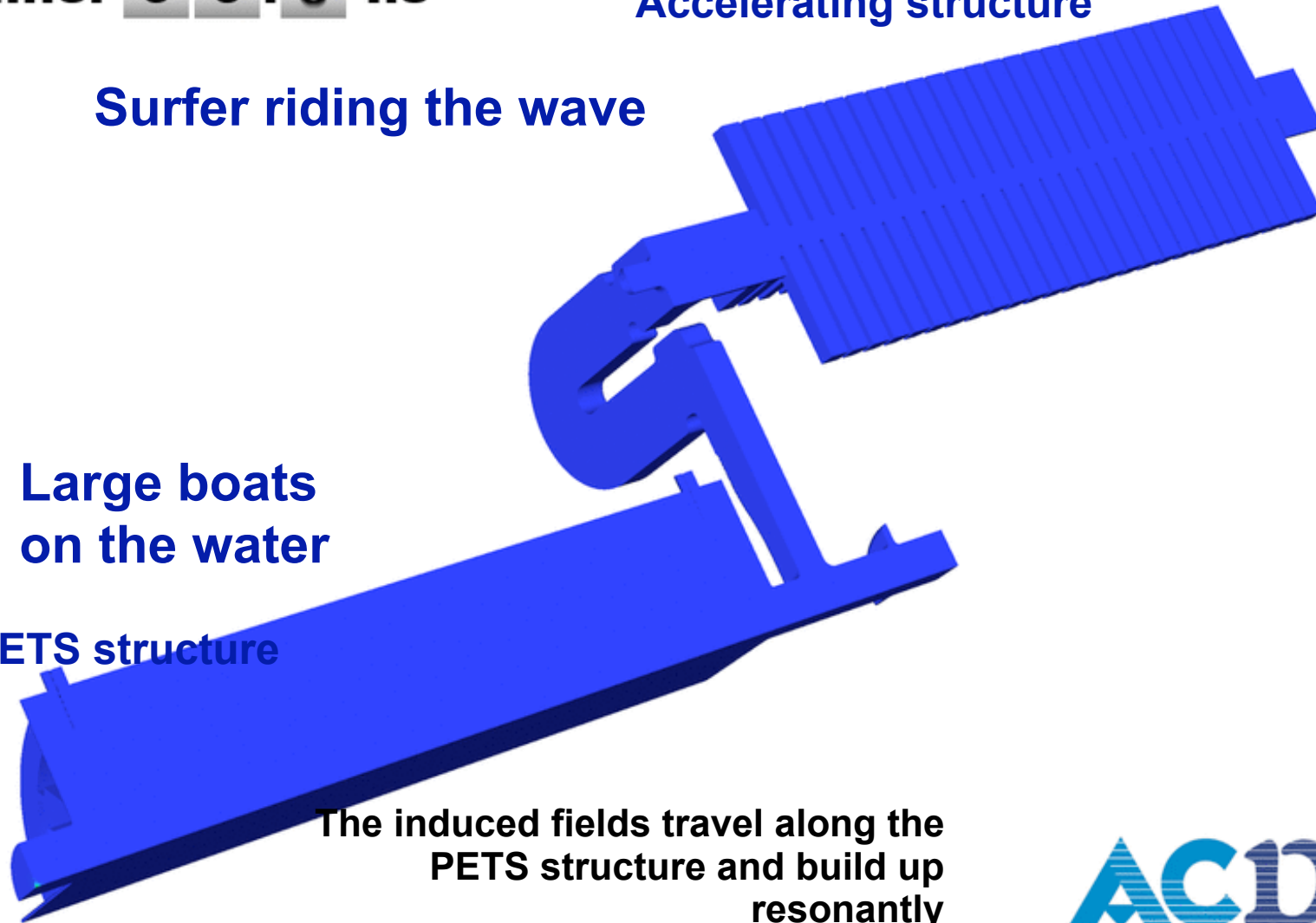
Surfer riding the wave

Large boats
on the water

PETS structure

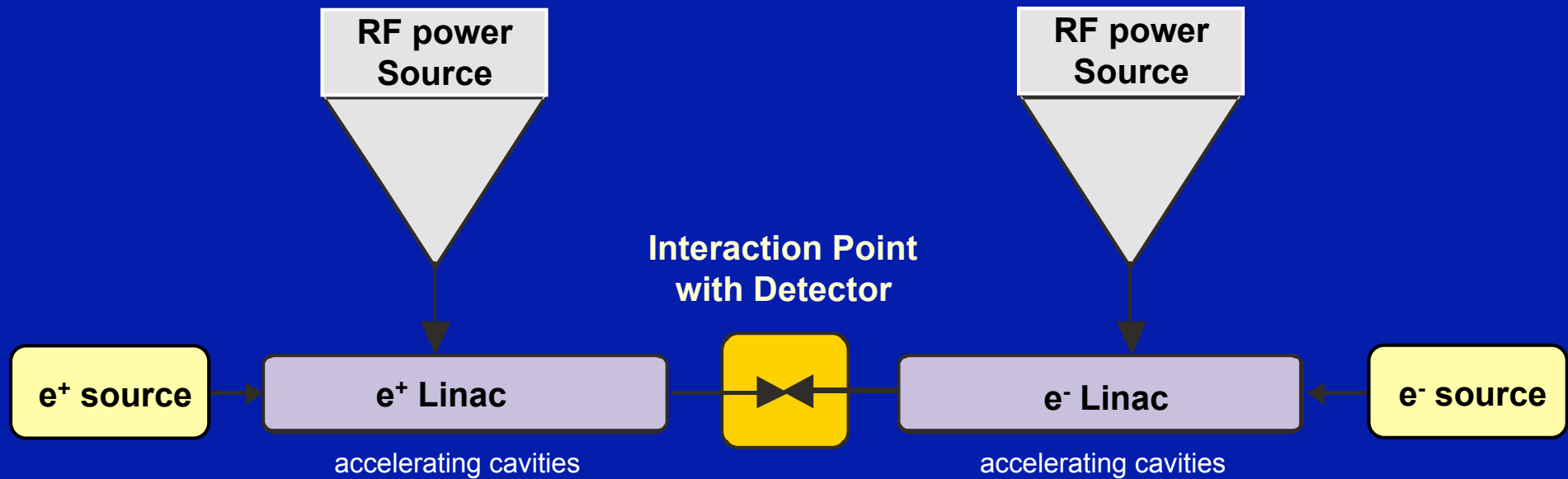
The induced fields travel along the
PETS structure and build up
resonantly

decelerating structure



Arno Candel, SLAC

Linear Collider R&D

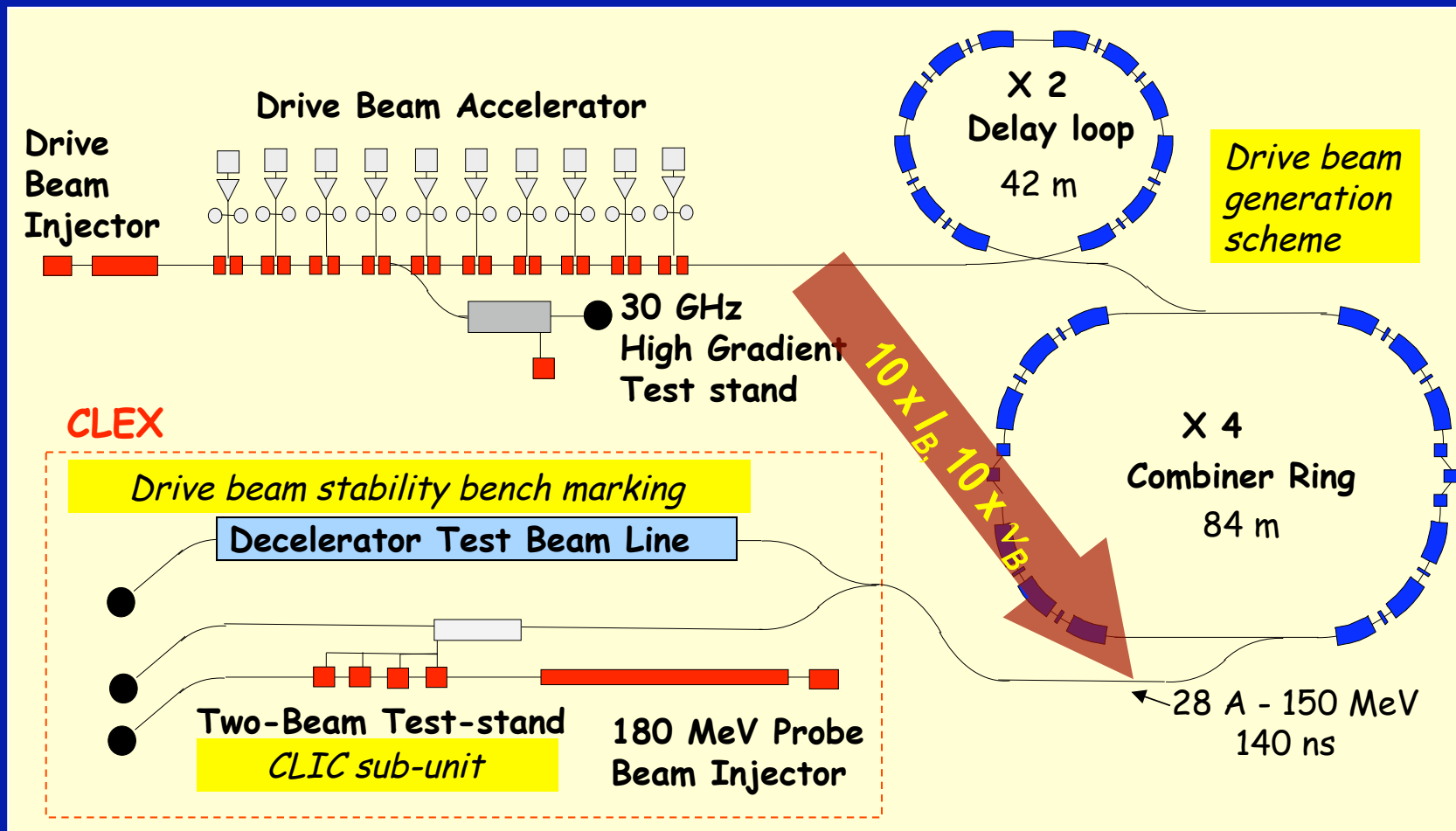


Challenges:

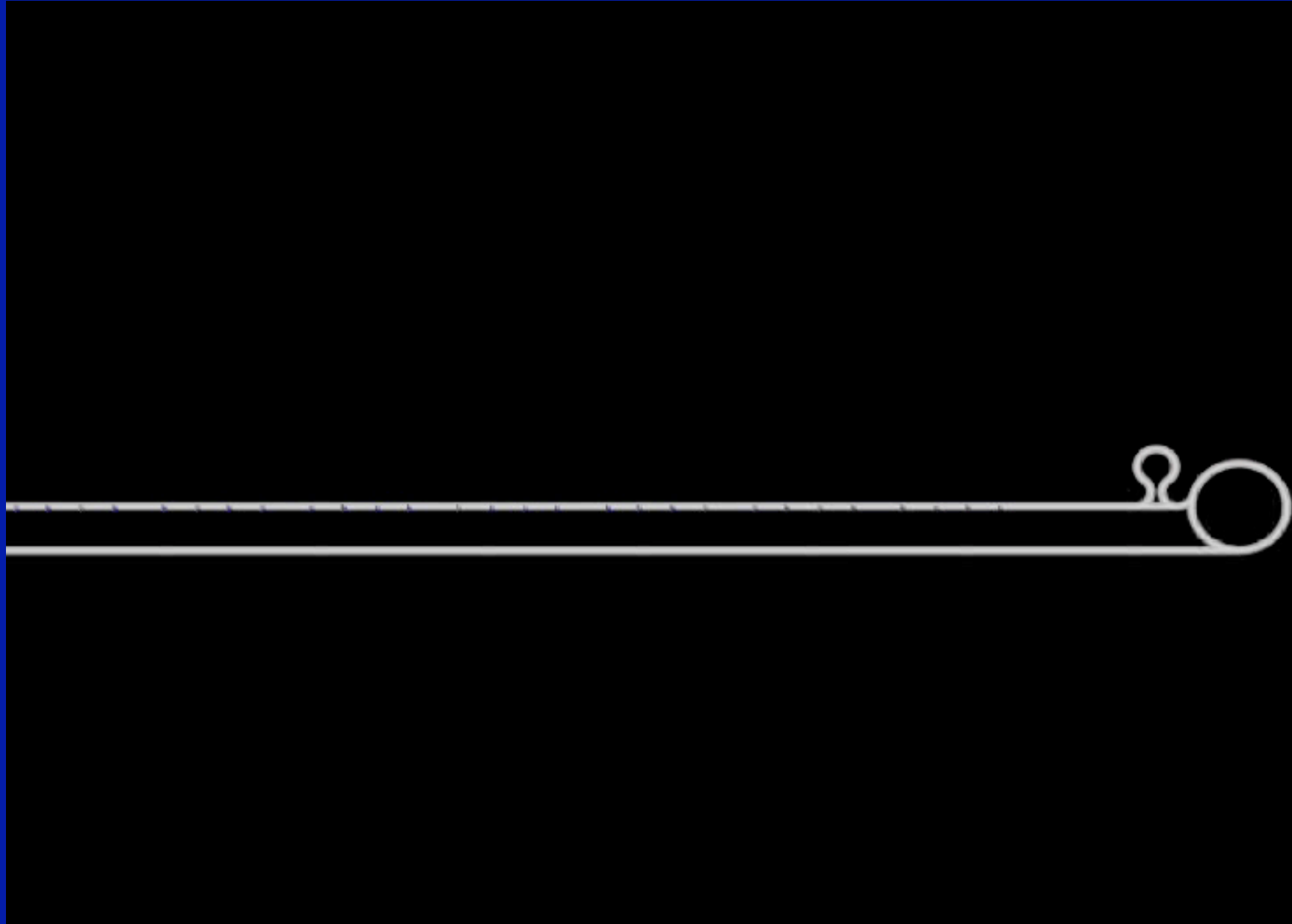
1. High accelerating gradient
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3. **Feasibility demonstration on small scale**
→ before building larger machine
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CTF3 Test Facility

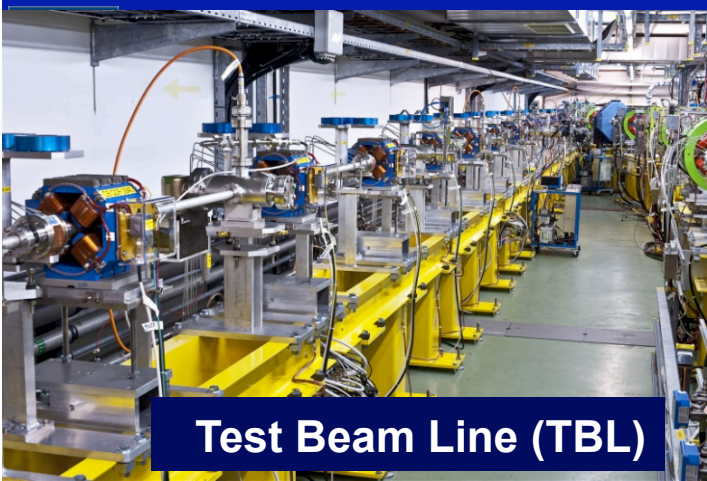
- demonstration drive beam generation (boat factory)
- evaluate beam stability & losses in deceleration
- Accelerate the main beam (surfer)



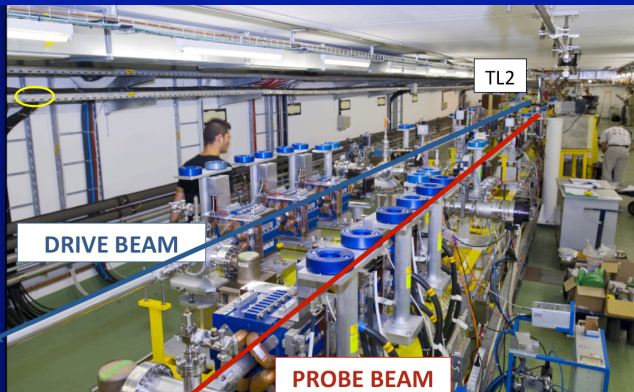
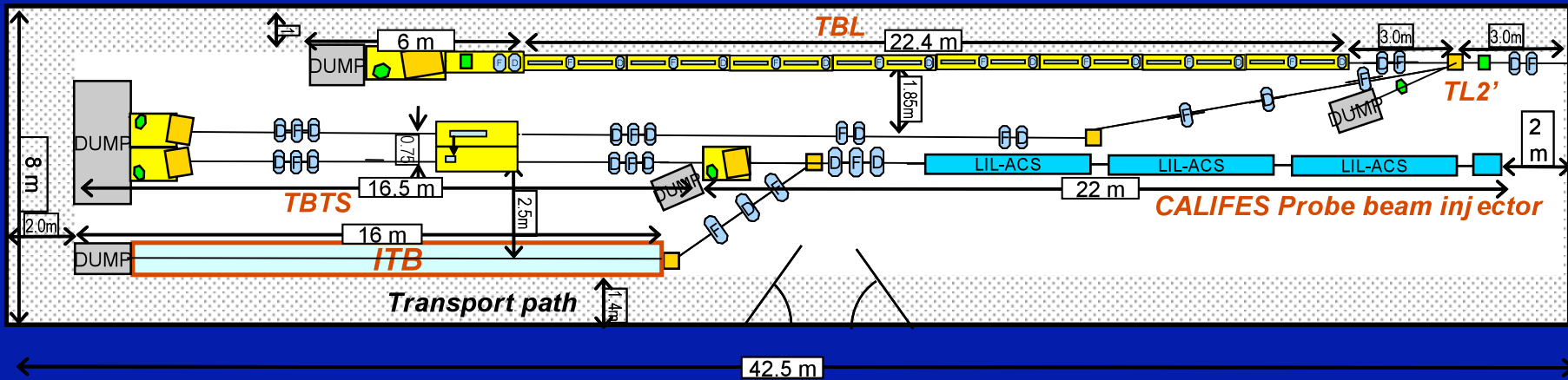
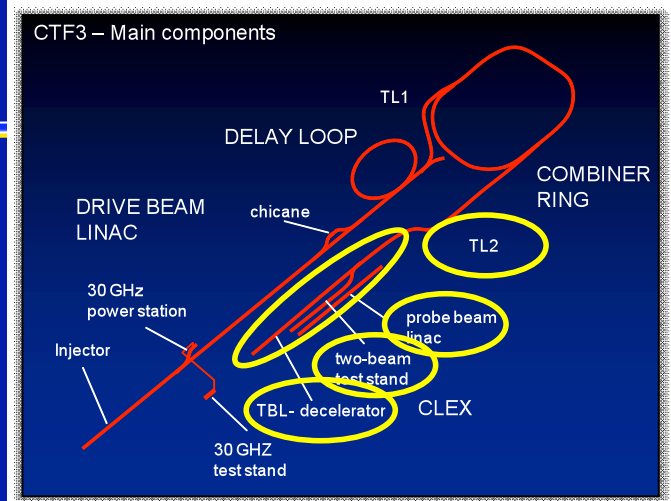
Drive Beam Generation Scheme (boat factory)



CLEX Area



Test Beam Line (TBL)



Two Beam Test Stand (TBTS)



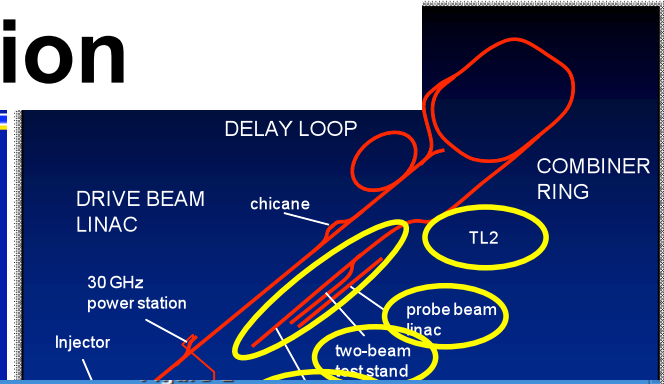
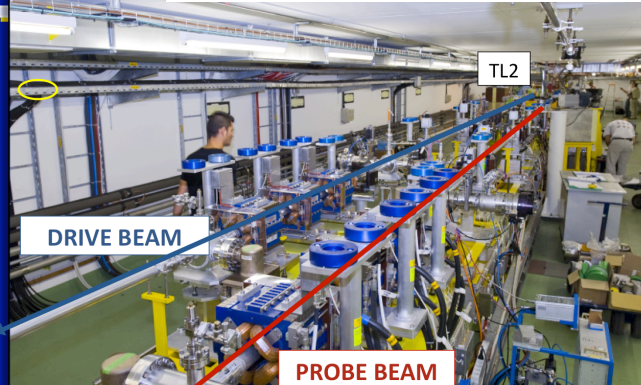
Accelerating sections



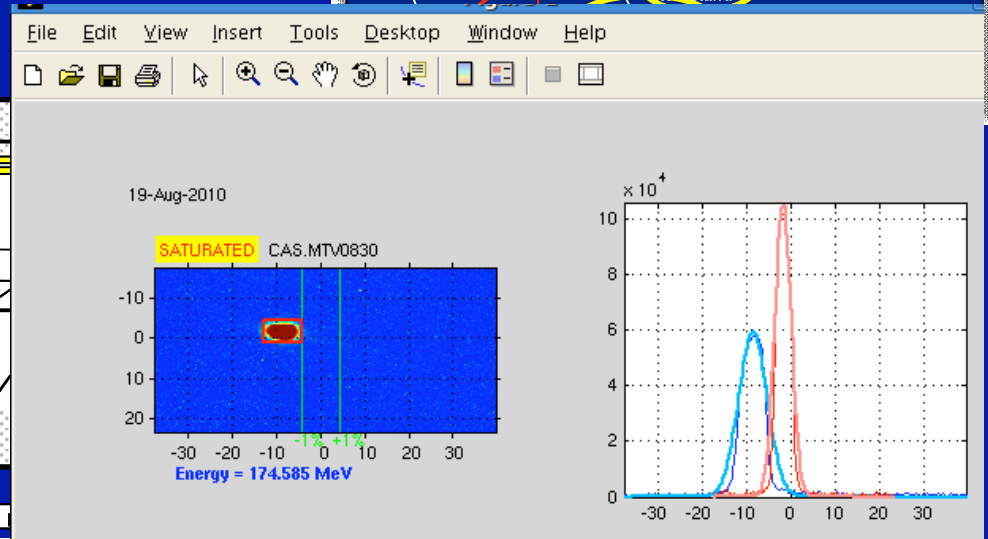
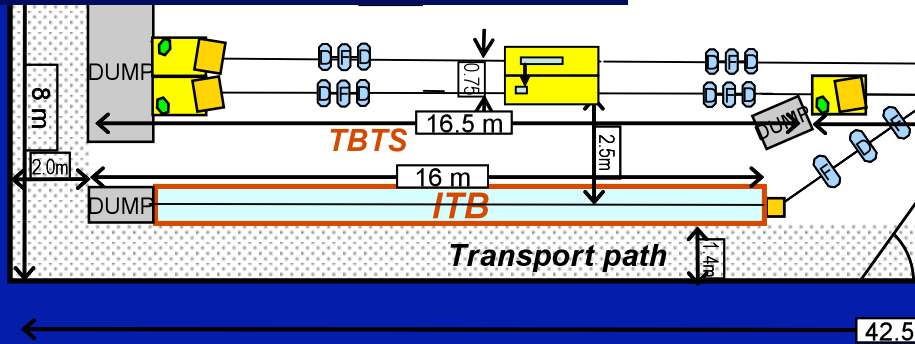
Califes Photo-injector



Two beam acceleration



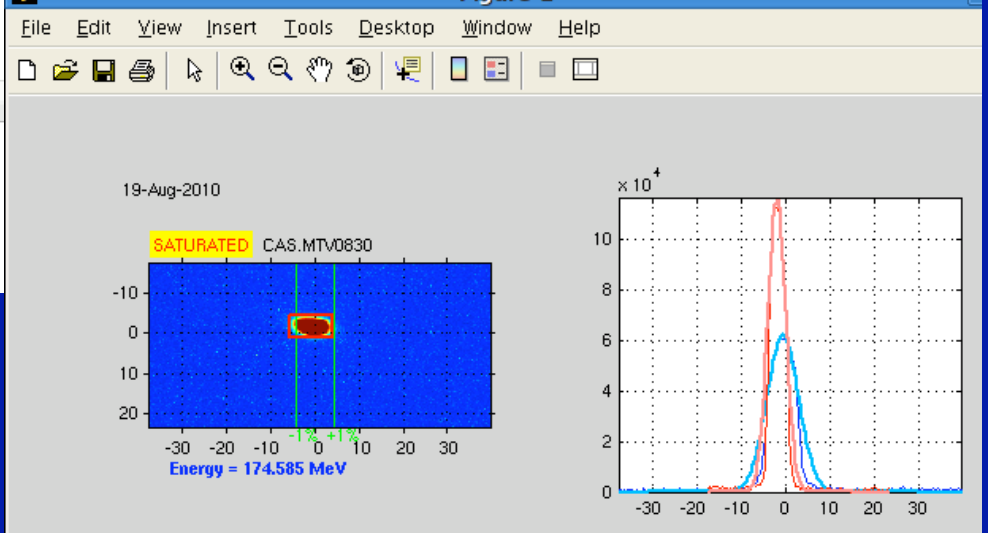
Two Beam Test Stand (TBTS)



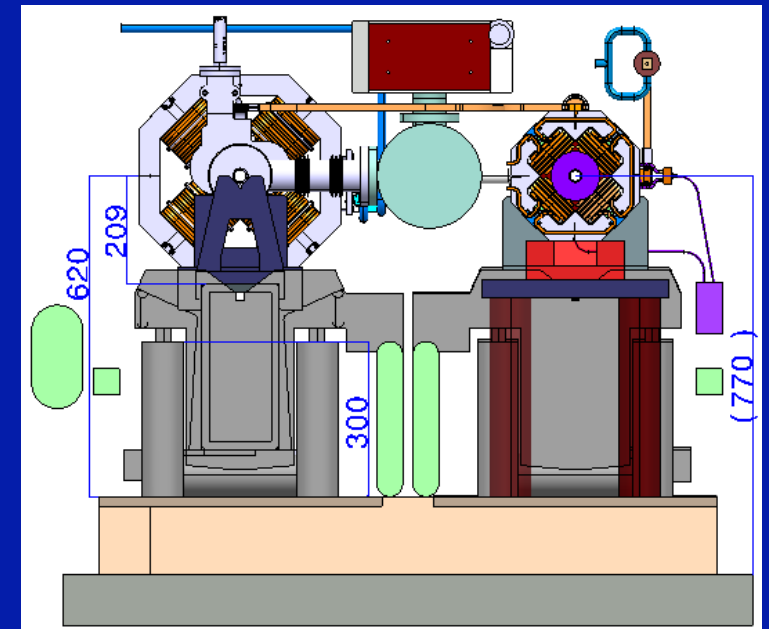
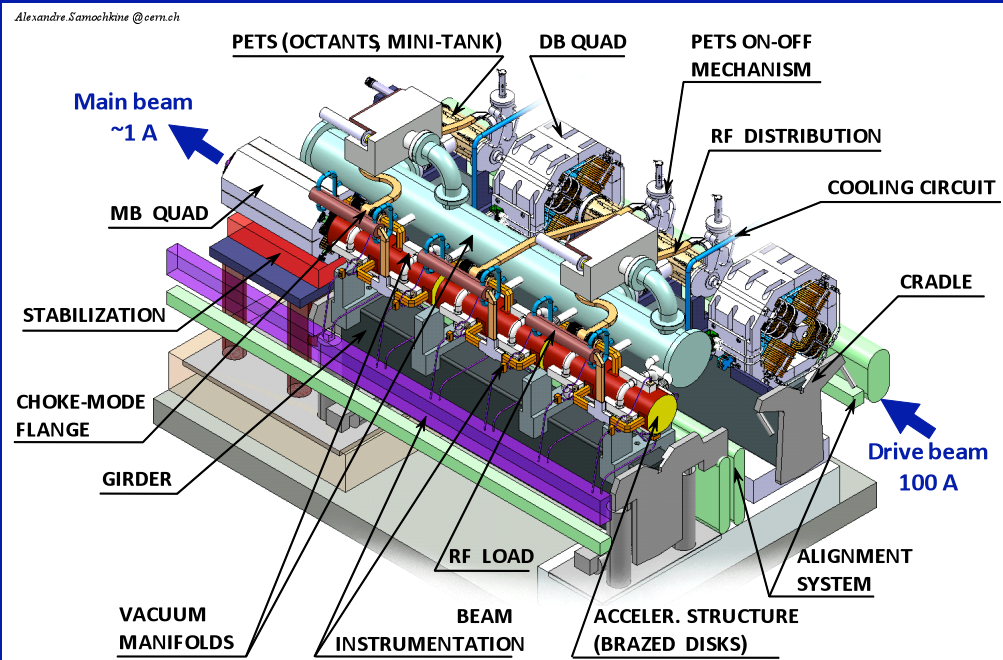
FW: Premiere acceleration du faisceau CALIFES dans une structure CLIC 12 GHz

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

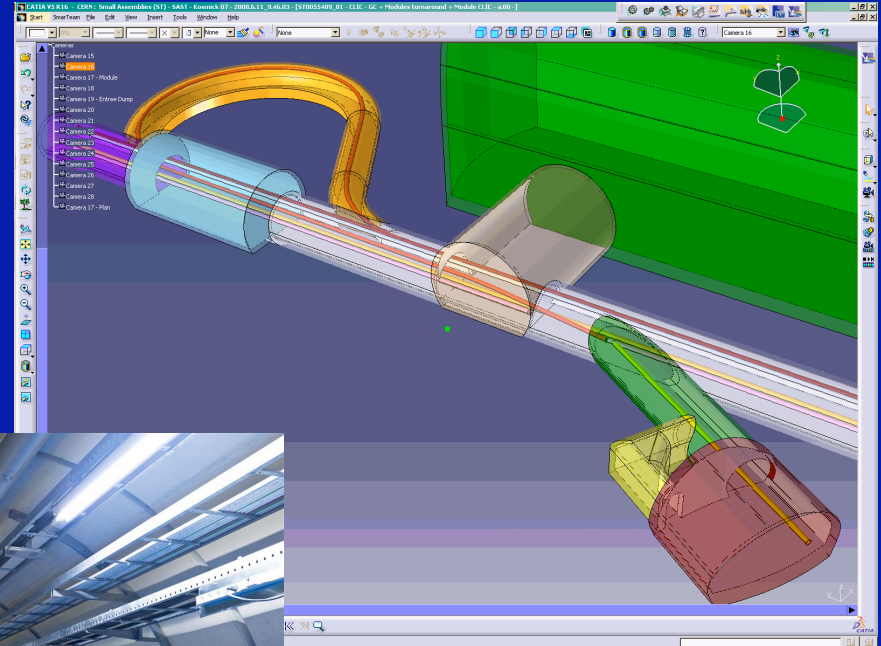
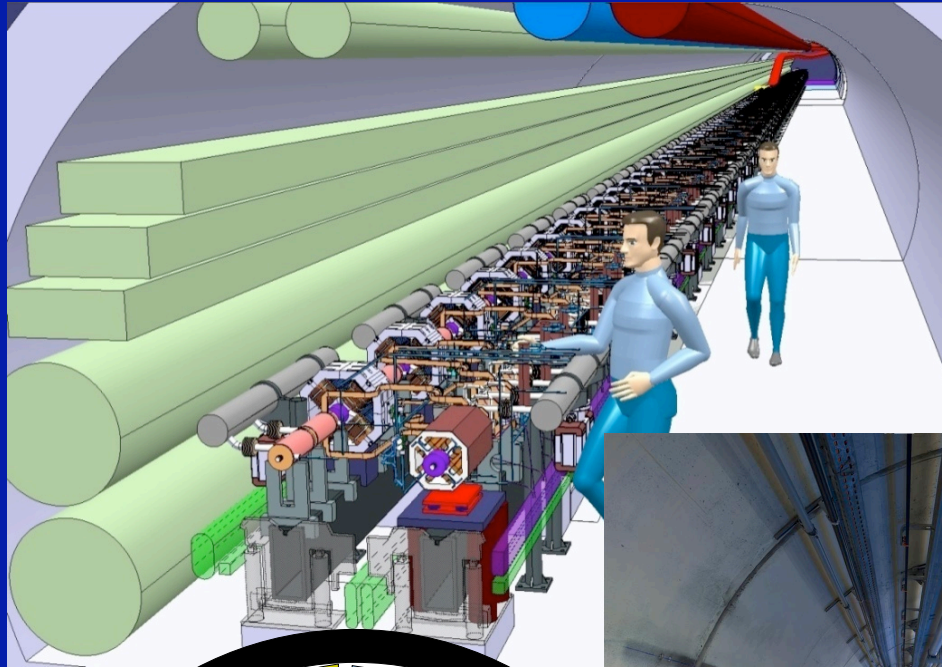


(Courtesy A. Samoshkin)

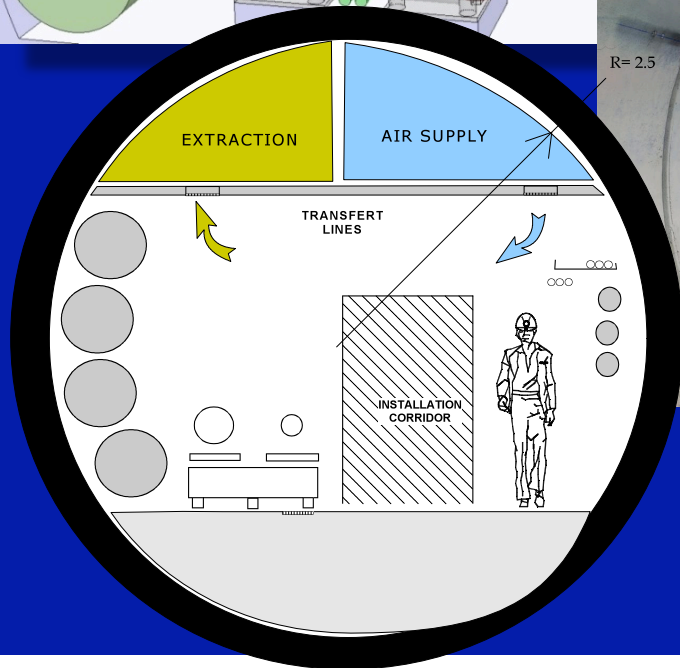
20760 modules (2 meters long)
71460 power production structures
PETS (drive beam)
143010 accelerating structures
(main beam)

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

Tunnel Integration

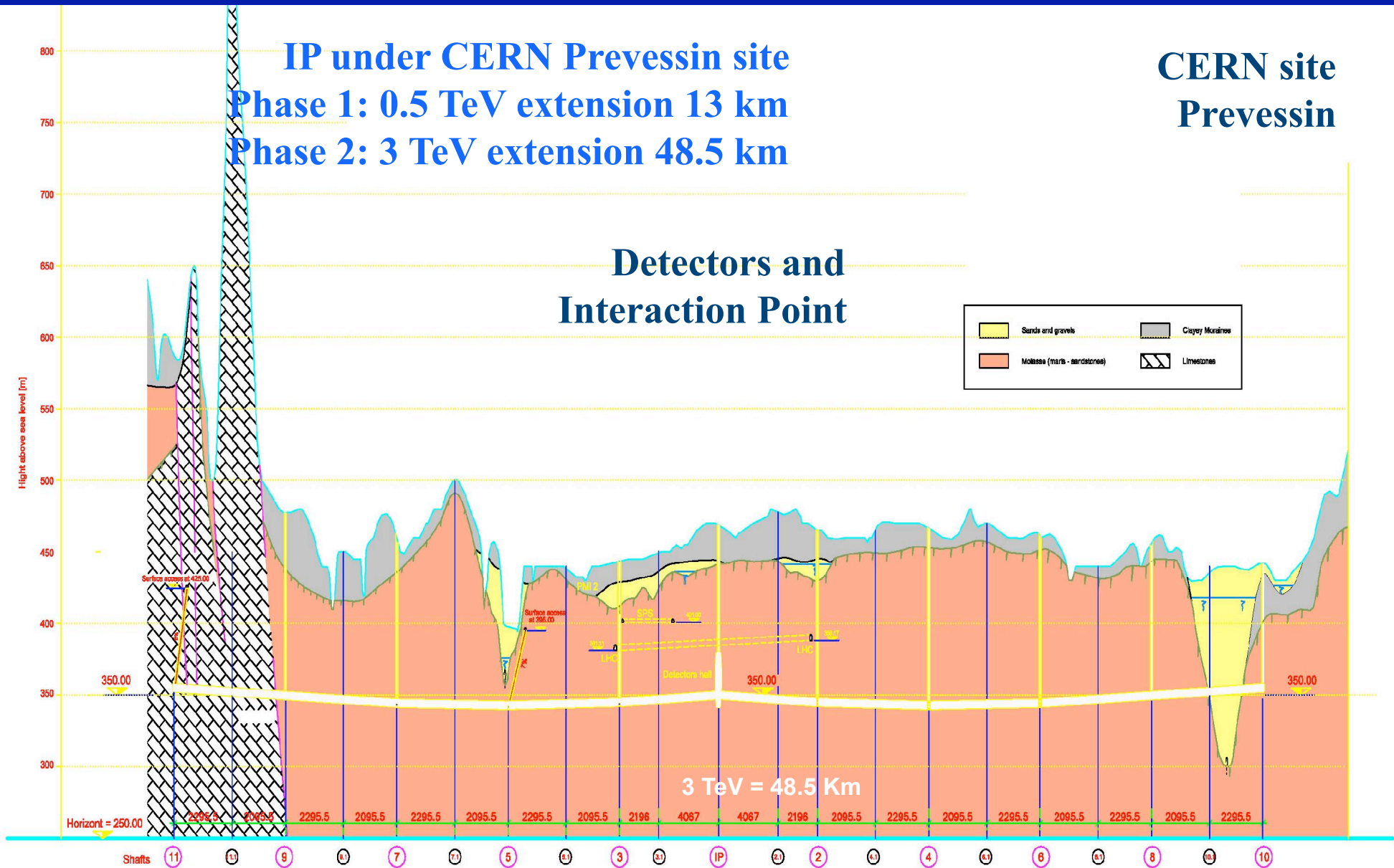


(Courtesy John Osborne)



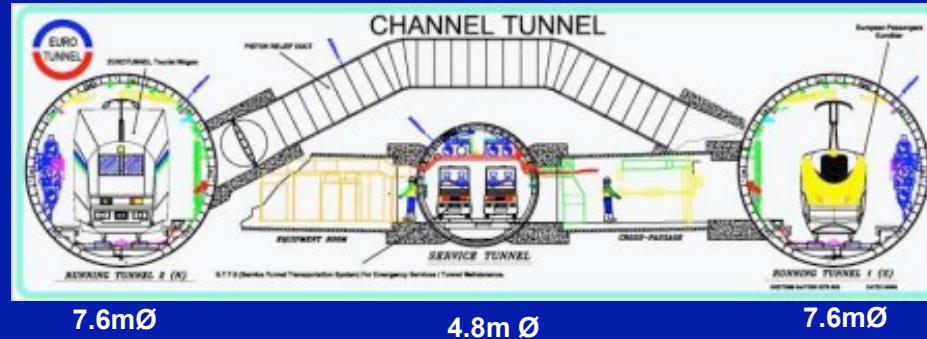
**Standard tunnel
with modules**

Potential machine site

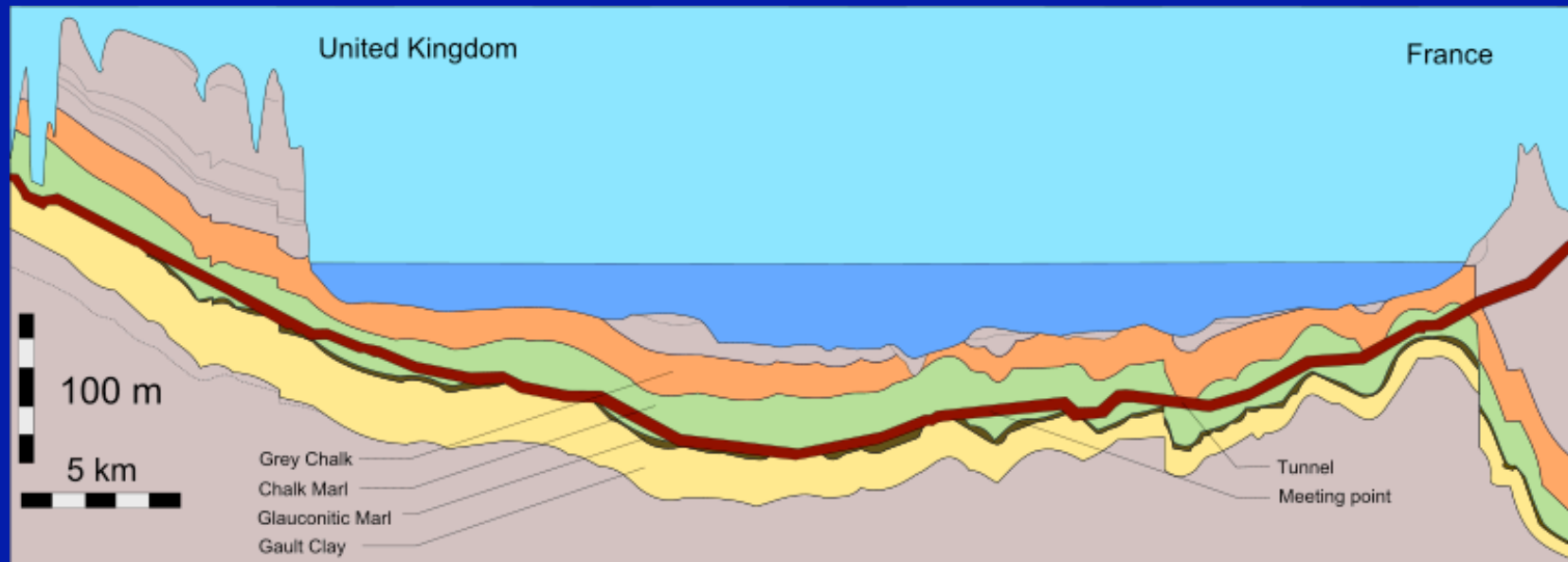


Longitudinal section of a laser straight Linear Collider on CERN site—

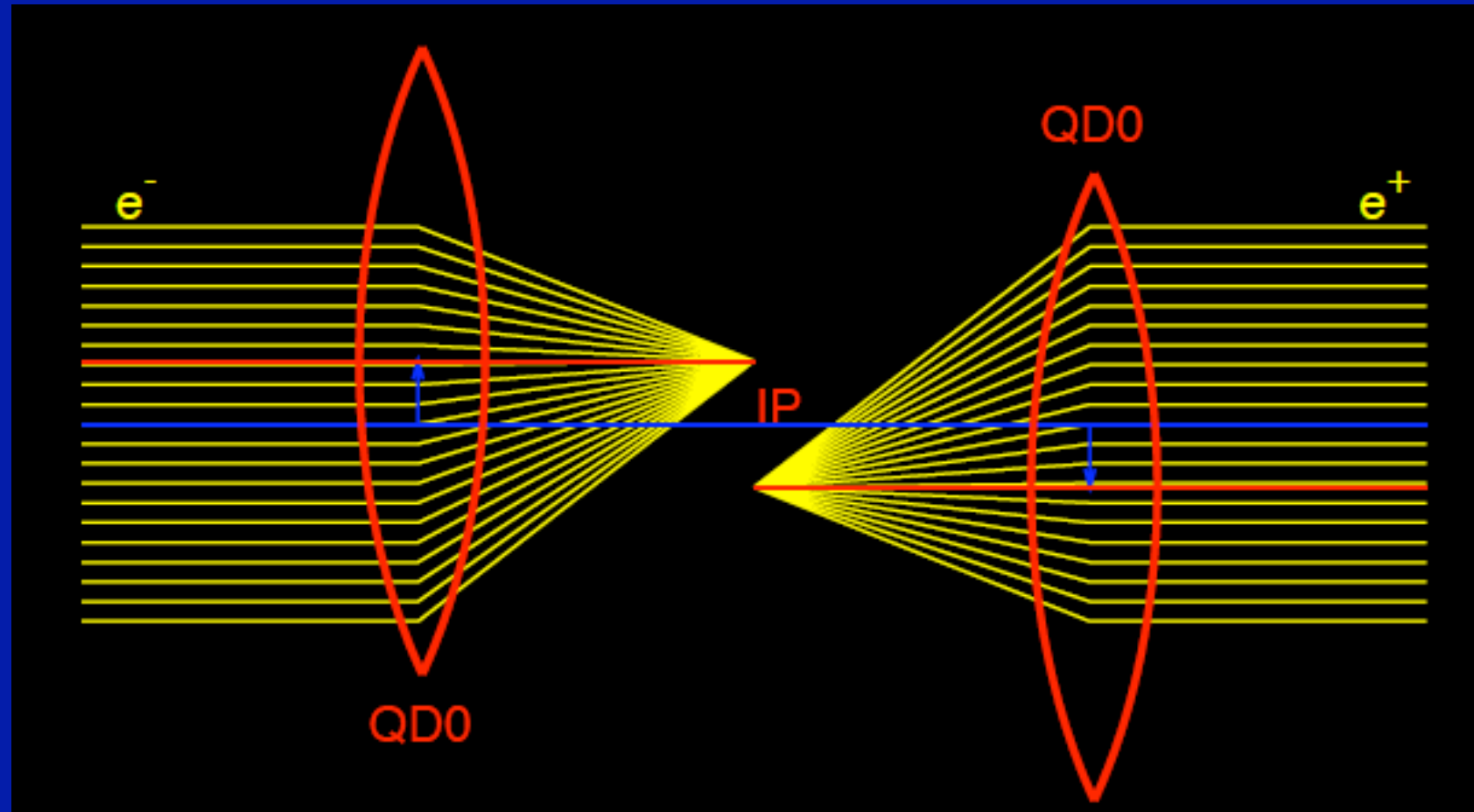
For CLIC & ILC, similar World Projects: Channel Tunnel



50Km

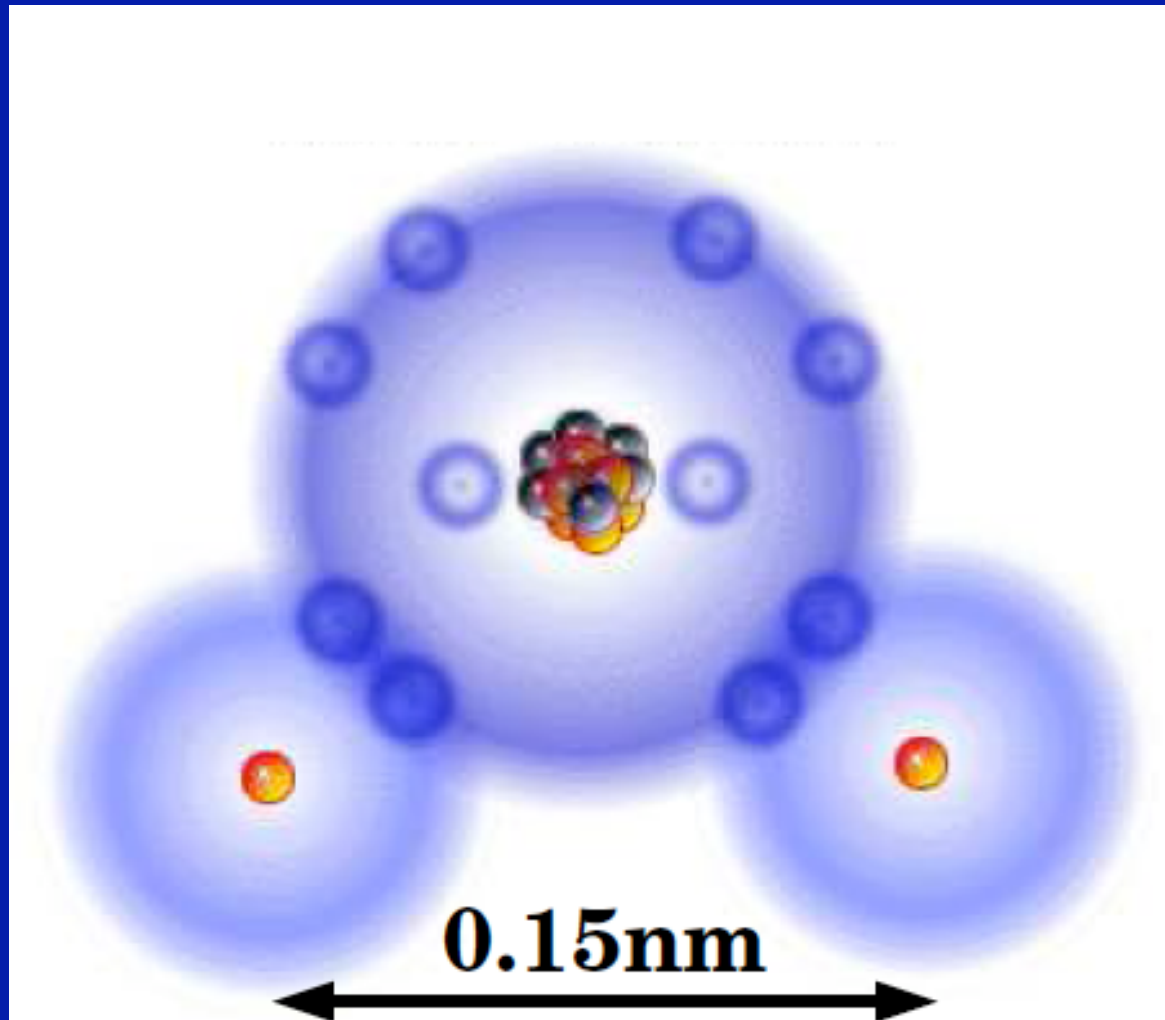


Other technological challenges



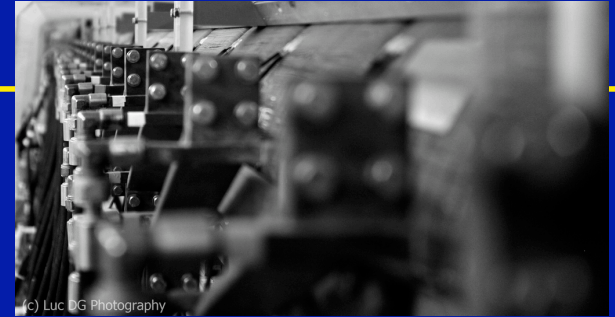
The final focusing quadrupole should be stabilized to 0.15 nm for frequencies about 4 Hz

Other technological challenges



0.15 nm, small as a H₂O 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 Ubuntu
- Your government
- Your university
- You have choices
- Feedback

August 1-21, 2010
NITheP at Stellenbosch
South Africa
Website: <http://AfricanSchoolPhysics.web.com.ch>

Application: ASP2010-Registration@cern.ch

Deadline: From Dec 1, 2009 until March 1, 2010

Remarks and full support are available. To apply please provide a CV and a letter of motivation.

Contact: Steve Muzica muzica@inp3.it

Physics Topics:

- Theoretical Physics
- Experimental Nuclear and Particle Physics
- Standard Model of Particle Physics
- Beyond The Standard Model
- Atomic Particle Physics
- Experimental Gas-Atom Physics
- Heavy Ion Physics
- Nonlinear and Quantum Physics
- Particle Detectors
- ASP Computing
- Accelerators and Technology
- Particle Accelerators
- Medical Applications
- Light Sources
- Lasers
- History of Technology
- CERN Computing
- Application in Particle Physics Experiments

Local Organizing Committee:

- B. Acharya (ICSI, IT)
- K. Anagnostopoulos (INFN, Italy)
- R. Barlow (SLAC, USA)
- C. Bebek (FNL, USA)
- J. Ellis (CERN, CH)
- C. Ferrel (Ecole Polytechnique, FR)
- J. G. Thompson (Fermilab, USA)
- Y. G. Kim (KIAS, Korea)
- Y. K. Kim (FNL, Fermilab Director, USA)
- R. Klumperman (SLAC Director, USA)
- S. Muzica (EPFL, Switzerland, FI)
- P. Shanley (CERN, CH)

International Organizing Committee:

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- T. Winkler (EPFL, CH)
- Z. Zhang (EPFL, CH)

History Members:

- B. Barlow (SLAC, USA)
- I. Chouinard (EPFL, Switzerland, FI)
- L. Lederman (FNL, USA)
- Nobel Laureate

The 2010
**AFRICAN SCHOOL ON
FUNDAMENTAL PHYSICS
AND ITS APPLICATIONS**

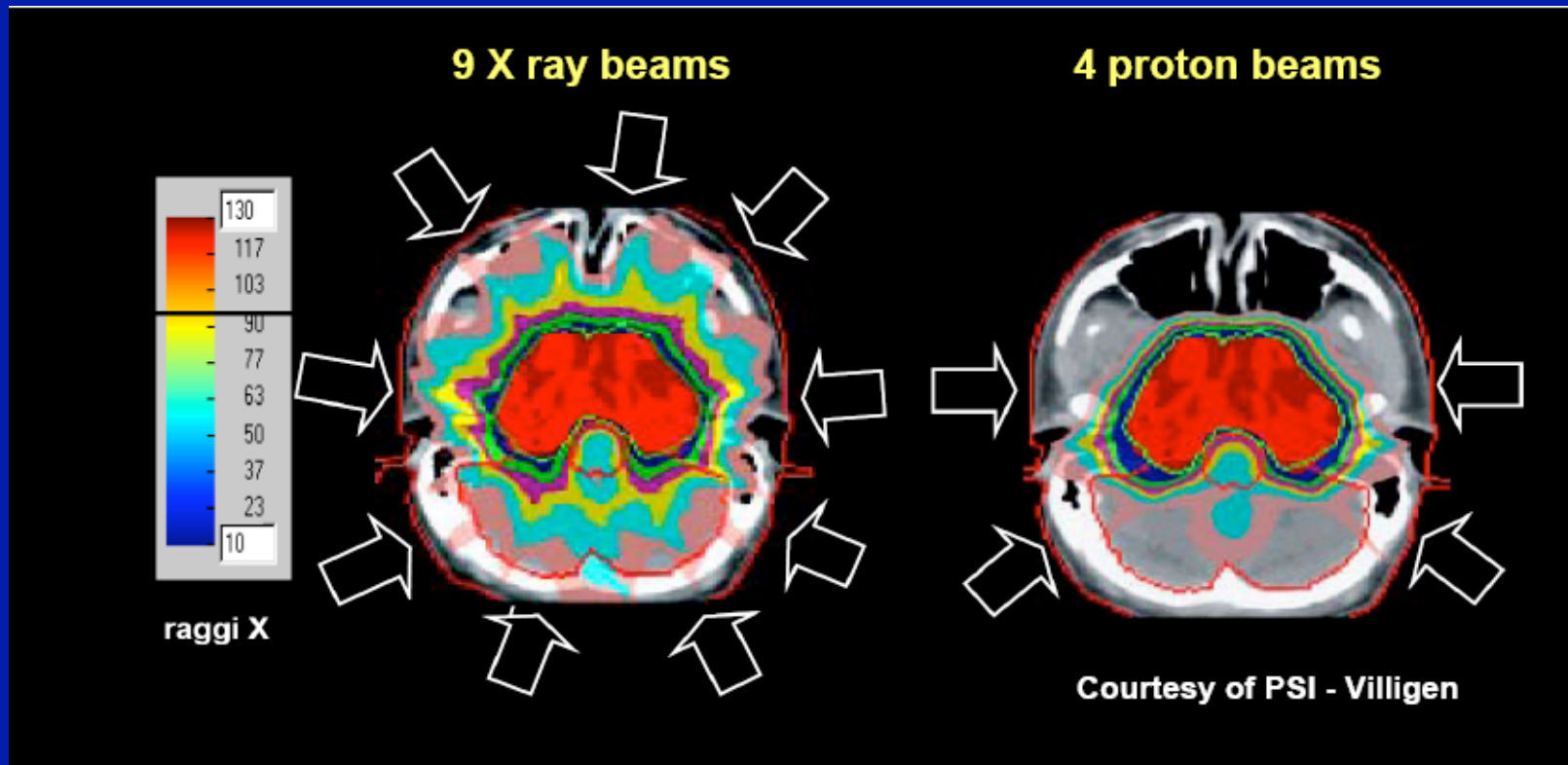


Acknowledgement

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



Eye and Orbit

- Choroidal Melanoma
- Retinoblastoma
- Choroidal Metastases
- Orbital Rhabdomyosarcoma
- Lacrimal Gland Carcinoma
- Choroidal Hemangiomas

Head and Neck Tumors

- Locally Advanced Oropharynx
- Locally Advanced Nasopharynx
- Soft Tissue Sarcoma
Recurrent or Unresectable
- Misc. Unresectable or Recurrent Carcinomas

Chest

- Non Small Cell Lung Carcinoma
Early Stage—Medically Inoperable
- Paraspinal Tumors
Soft Tissue Sarcomas, Low Grade Chondrosarcomas, Chordomas

Abdomen

- Paraspinal Tumors
- Soft Tissue Sarcomas, Low Grade Chondrosarcomas, Chordomas

Pelvis

- Early Stage Prostate Carcinoma
- Locally Advanced Prostate Carcinoma
- Locally Advanced Cervix Carcinoma
- Sacral Chordoma
- Recurrent or Unresectable Rectal Carcinoma
- Recurrent or Unresectable Pelvic Masses

Central Nervous System

- Adult Low Grade Gliomas
- Pediatric Gliomas
- Acoustic Neuroma
Recurrent or Unresectable
- Pituitary Adenoma
Recurrent or Unresectable
- Meningioma
Recurrent or Unresectable
- Craniopharyngioma
- Chordomas and Low Grade Chondrosarcoma
Clivus and Cervical Spine
- Brain Metastases
- Optic Glioma
- Arteriovenous Malformations

In the world
protontherapy:
60'000 patients

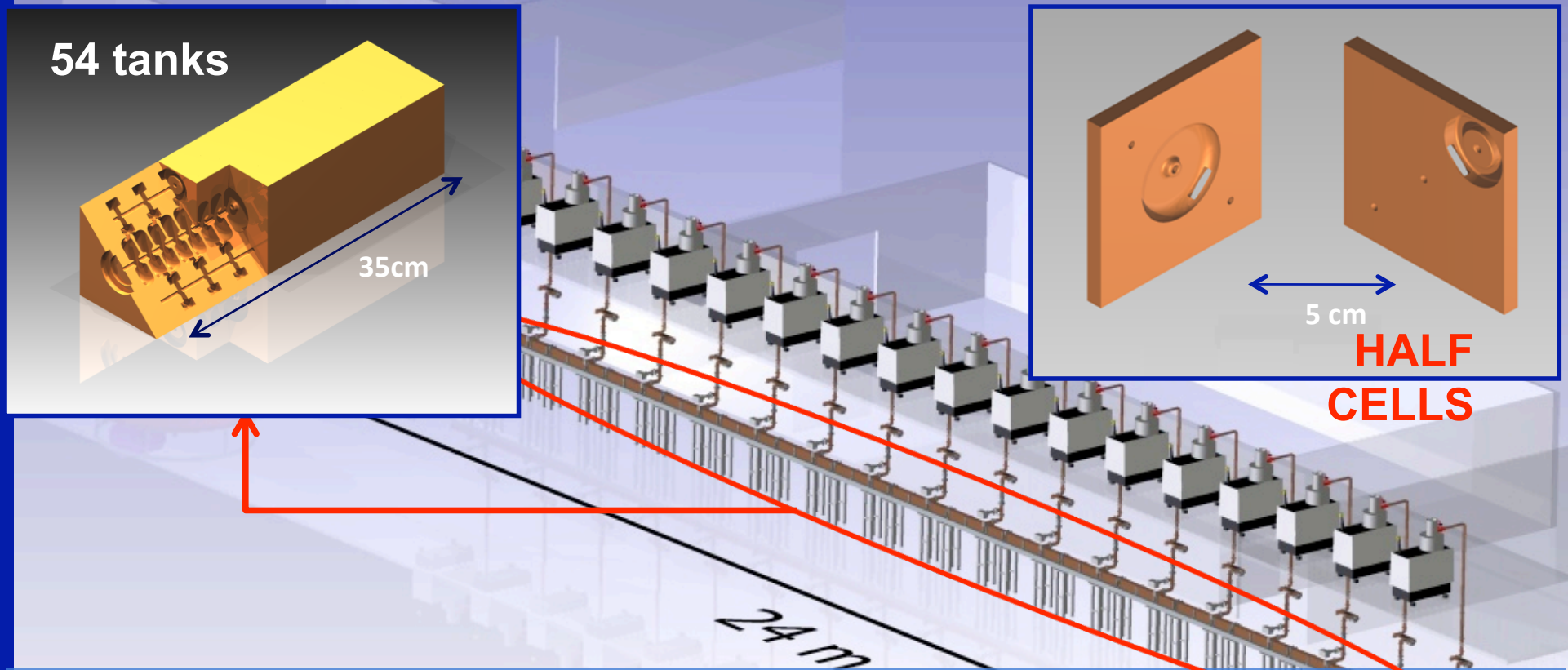
carbon ion
therapy
5500 patients

BUT

About 1% with
'active' dose
distribution

systems
at PSI and GSI
with spot/raster
scanning

First application: Carbon Booster for Therapy in Oncology



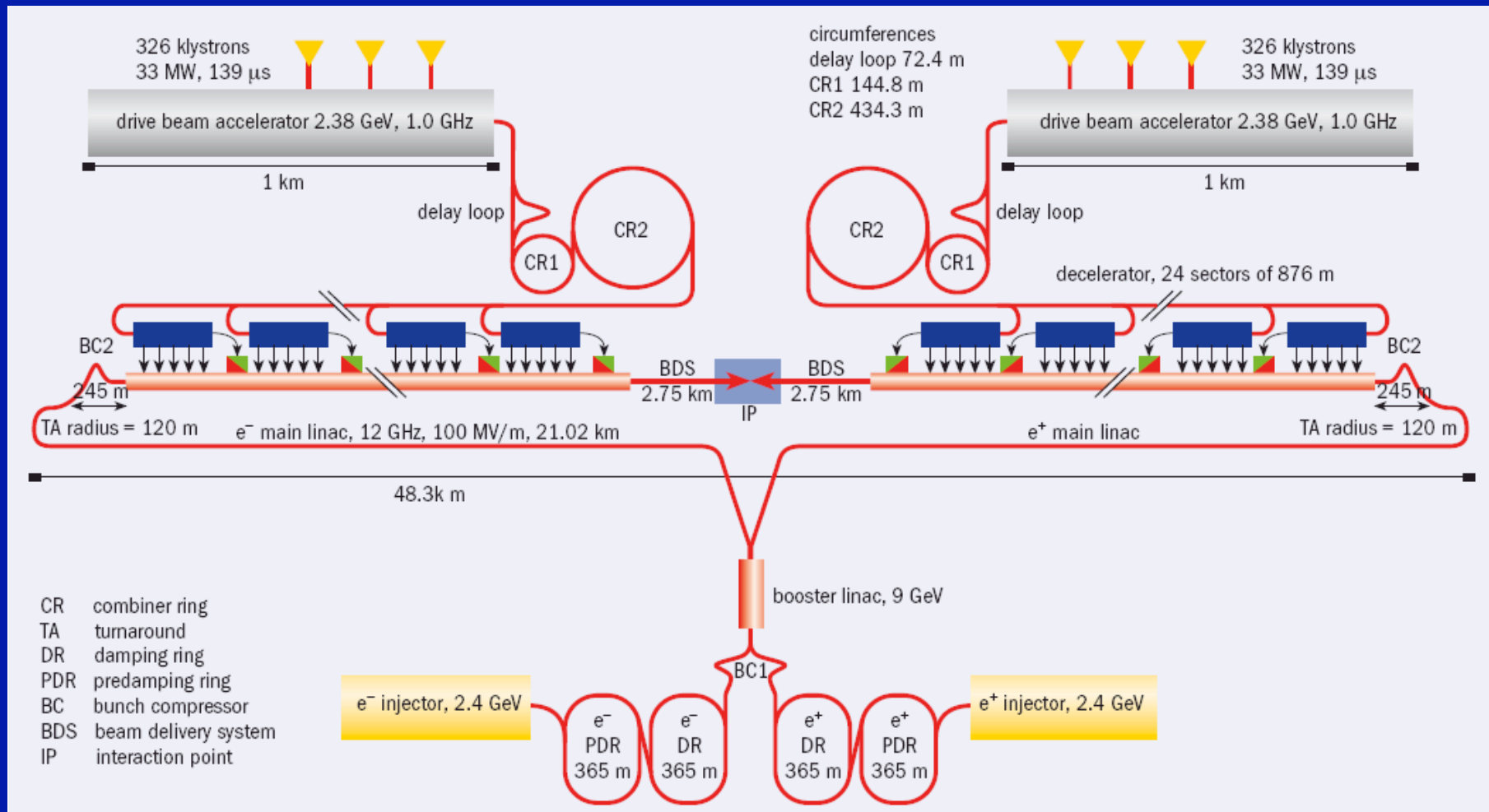
- Cell Coupled Linac at 5.7 GHz
- 18 accelerating modules
- Length of each module ~ 1.3 m

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

Linear Collider Designs – Competing Technologies

CLIC – compact Linear accelerator

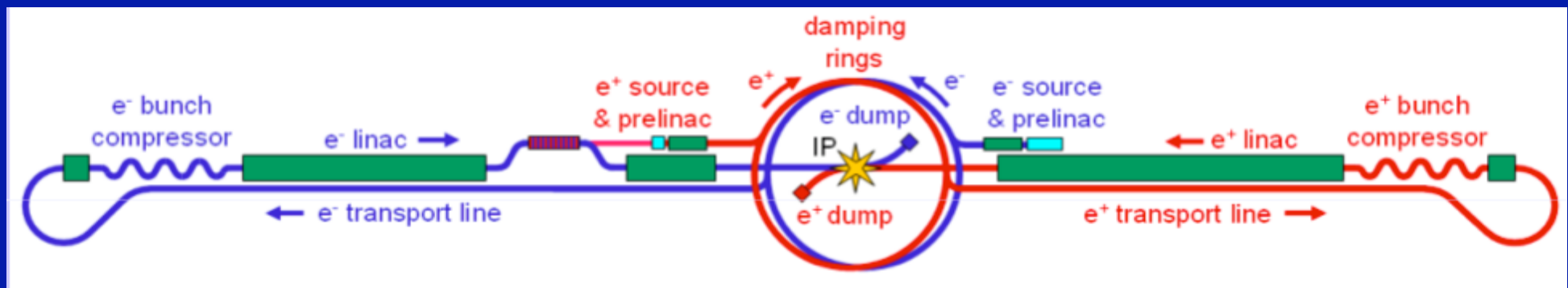
- Using copper travelling wave accelerating cavities
- 100 MV/m
- 48 km linac for a 3 TeV machine



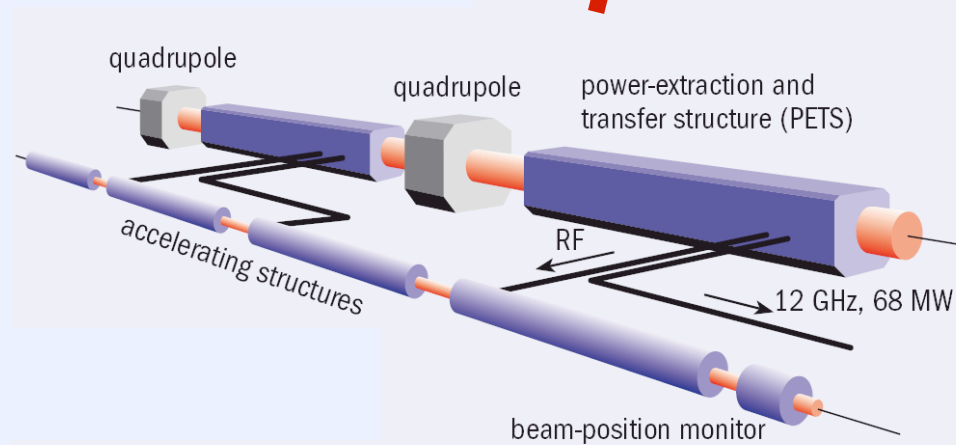
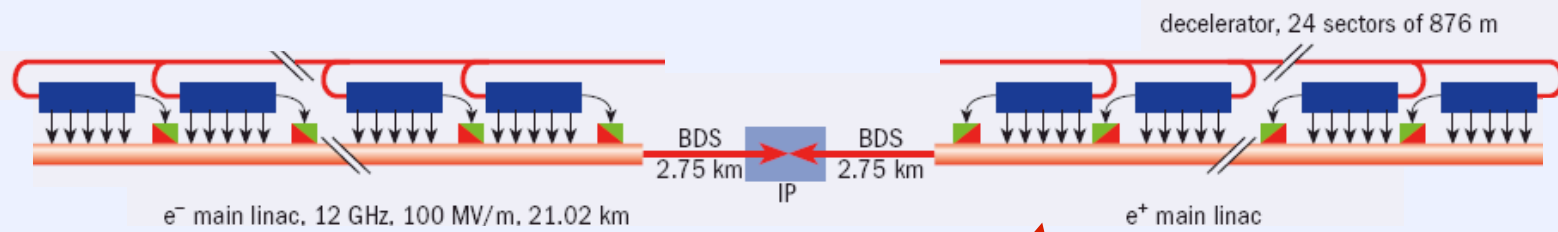
Linear Collider Designs – Competing Technologies

International Linear Collider

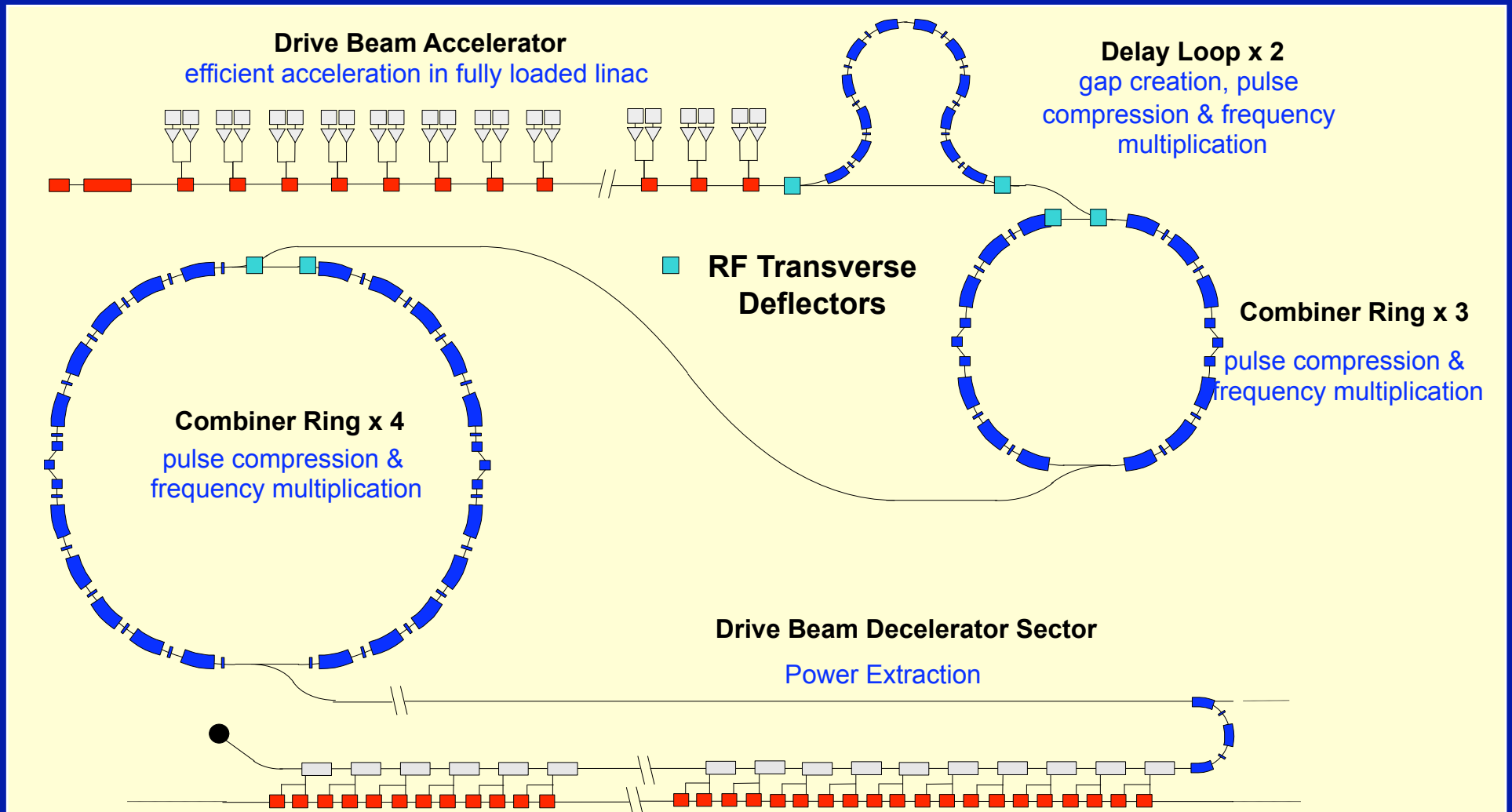
- using superconducting accelerating cavities
 - ☺ Negligible energy lost to the cavity walls as heat
 - ☹ Need energy to cool the cavities down to -271°C
- 35 MV/m
- 40 km linac for 500 GeV machine



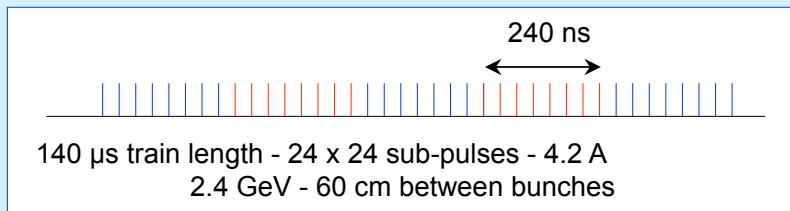
CLIC Two-beam Acceleration Concept



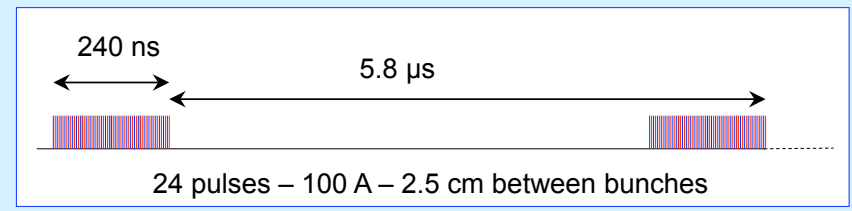
Recombination to Increase Peak Power & Frequency



Drive beam time structure - initial

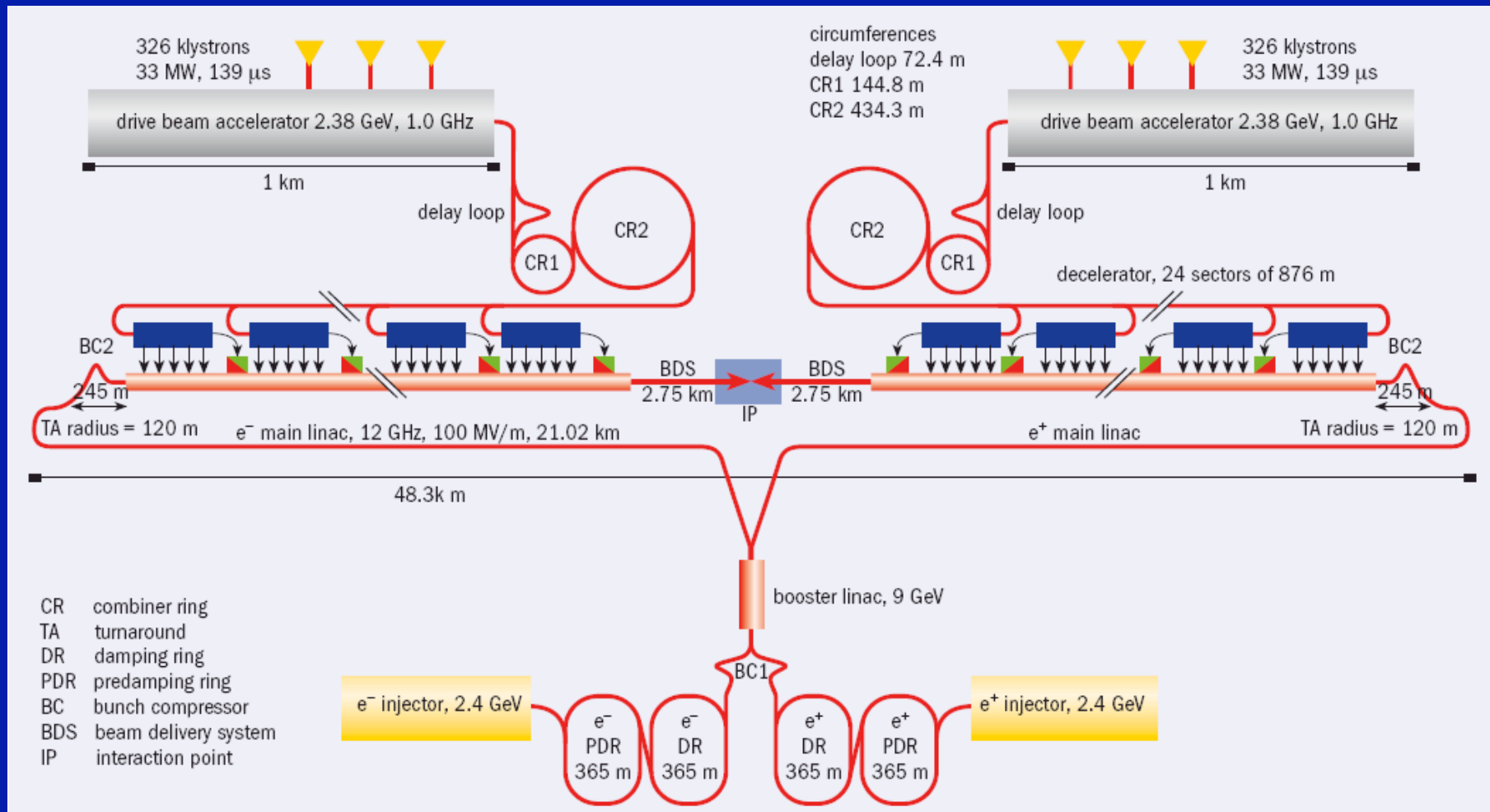


Drive beam time structure - final



Compact Linear Collider Layout

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

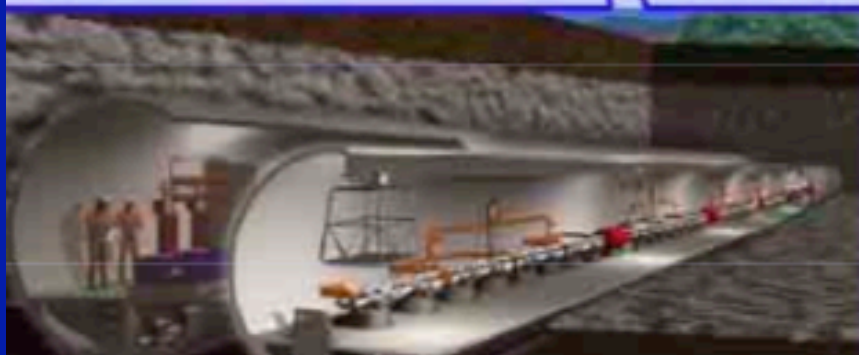
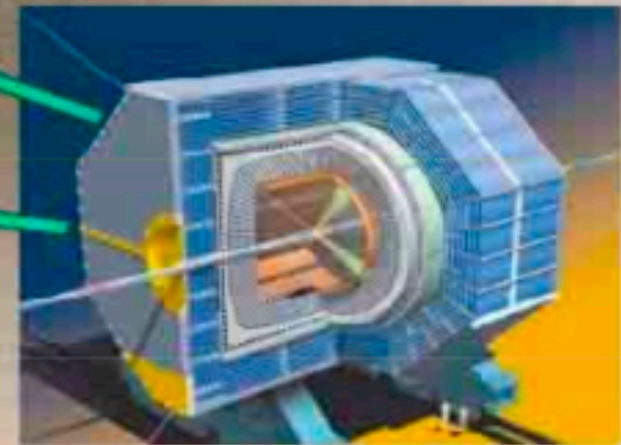


ILC --- Deep Underground

Main Research Center

Particle Detector

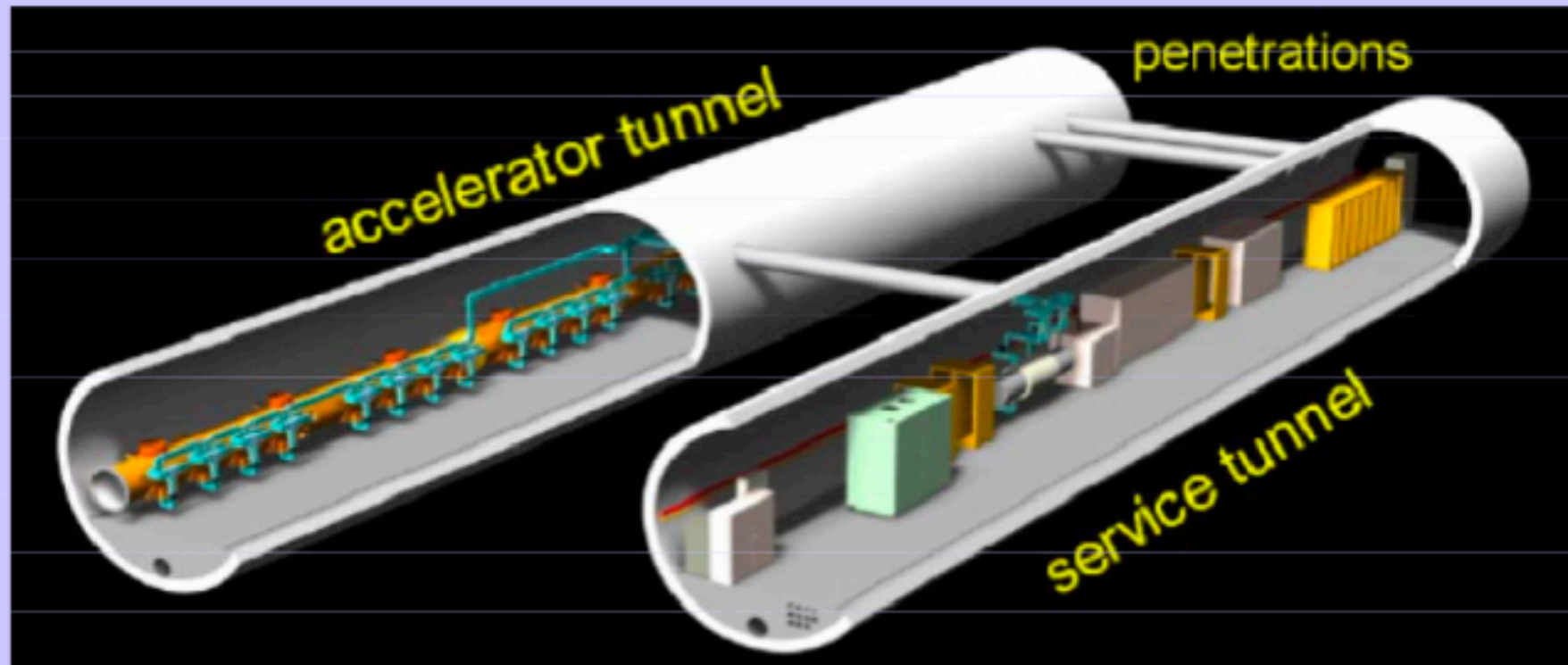
~30 km long tunnel



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

