CLIC Overview

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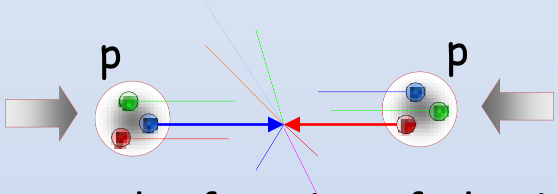
CERN BE/BI

For the CLIC / CTF3 Collaboration

Outline

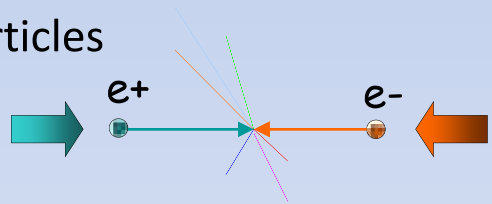
- Motivation and Introduction to the CLIC study
- A selection of progress in 2009/2010
    - ✓ CLIC Test Facility (CTF3)
    - ✓ Decelerating structures (PETs)
    - ✓ Accelerating Structure
    - ✓ Two Beam Acceleration
    - ✓ CLIC Detector R&D and machine detector interface
- Forward to 2011
    - ➢ CLIC Conceptual Design report 2011
- Outlook for CLIC

Introduction

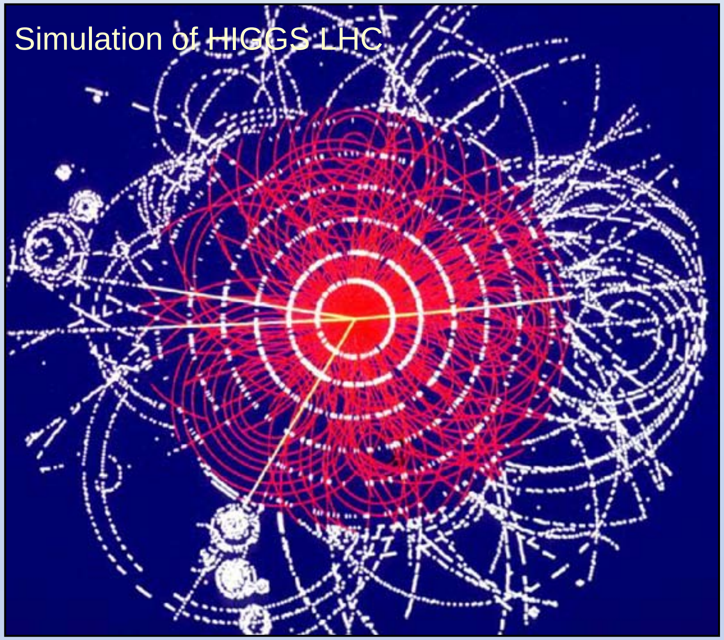


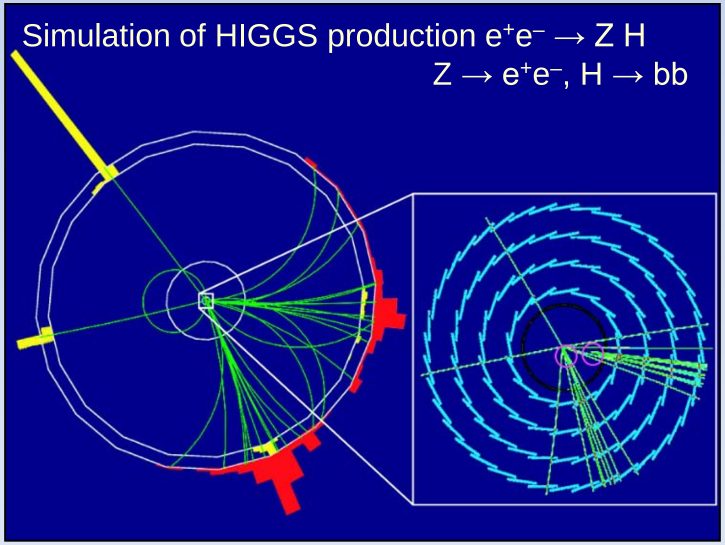
- hadron collider at the frontier of physics
  - huge QCD background
  - not all nucleon energy available in collision

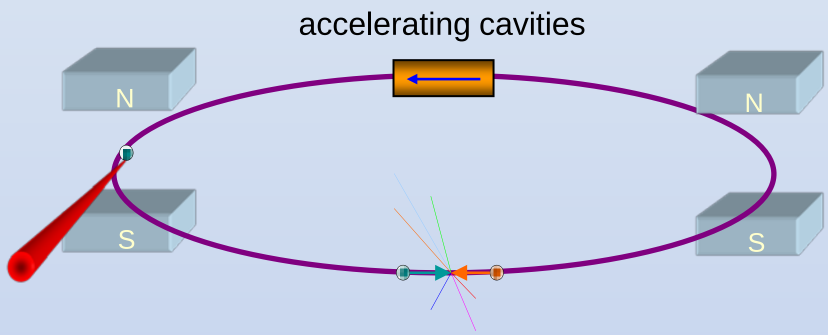
- lepton collider for precision physics
  - well defined initial energy for reaction
  - Colliding “point” like particles



- 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





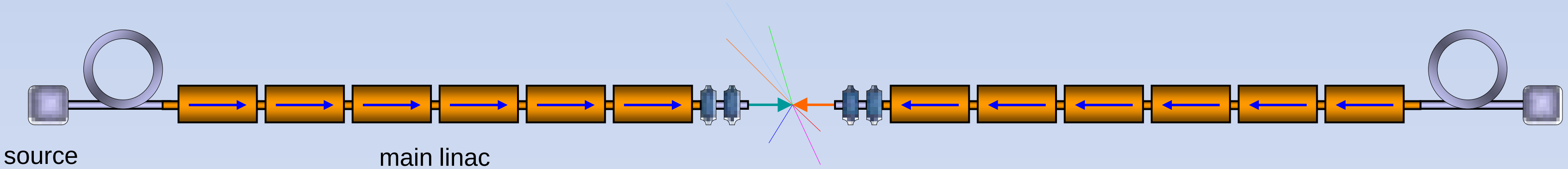


Circular Collider

many magnets, few cavities, stored beam

higher energy → stronger magnetic field

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



Linear Collider

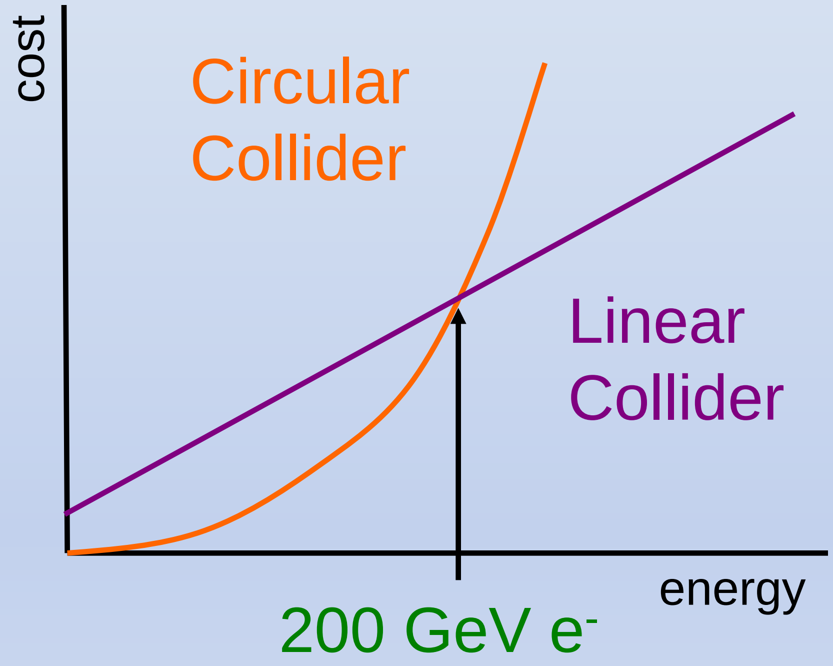
few magnets, many cavities, single pass beam

higher energy → higher accelerating gradient

higher luminosity → higher beam power (high bunch repetition)

Courtesy R. Ruber

Cost Linear versus Circular Collider



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

Aim of the CLIC study

Develop technology for e^-/e^+ linear collider with the requirements:

- ✓E_{CM} should cover **range** from ILC to LHC maximum reach and beyond
  - ⇒ ***E_{CM}* = 0.5-3 TeV**
- ✓L > few **10^{34} cm^{-2}** with acceptable background and energy spread
- ✓Design compatible with maximum length ~ **50 km**
- ✓Affordable
- ✓Total power consumption < **500 MW**

Physics motivation:

"Physics at the CLIC Multi-TeV Linear Collider: report of the CLIC Physics Working Group",
CERN report 2004-5

Present goal:

Demonstrate all key feasibility issues and document in a Conceptual Design Report (CDR) by mid-2011

Document in 3 Volumes

- Vol. 1 Executive summary: Target 20 pages
- Vol. 2 The CLIC accelerator and site facilities
- Vol. 3 The CLIC physics and detectors
  (L. Linssen PH-LCD team)

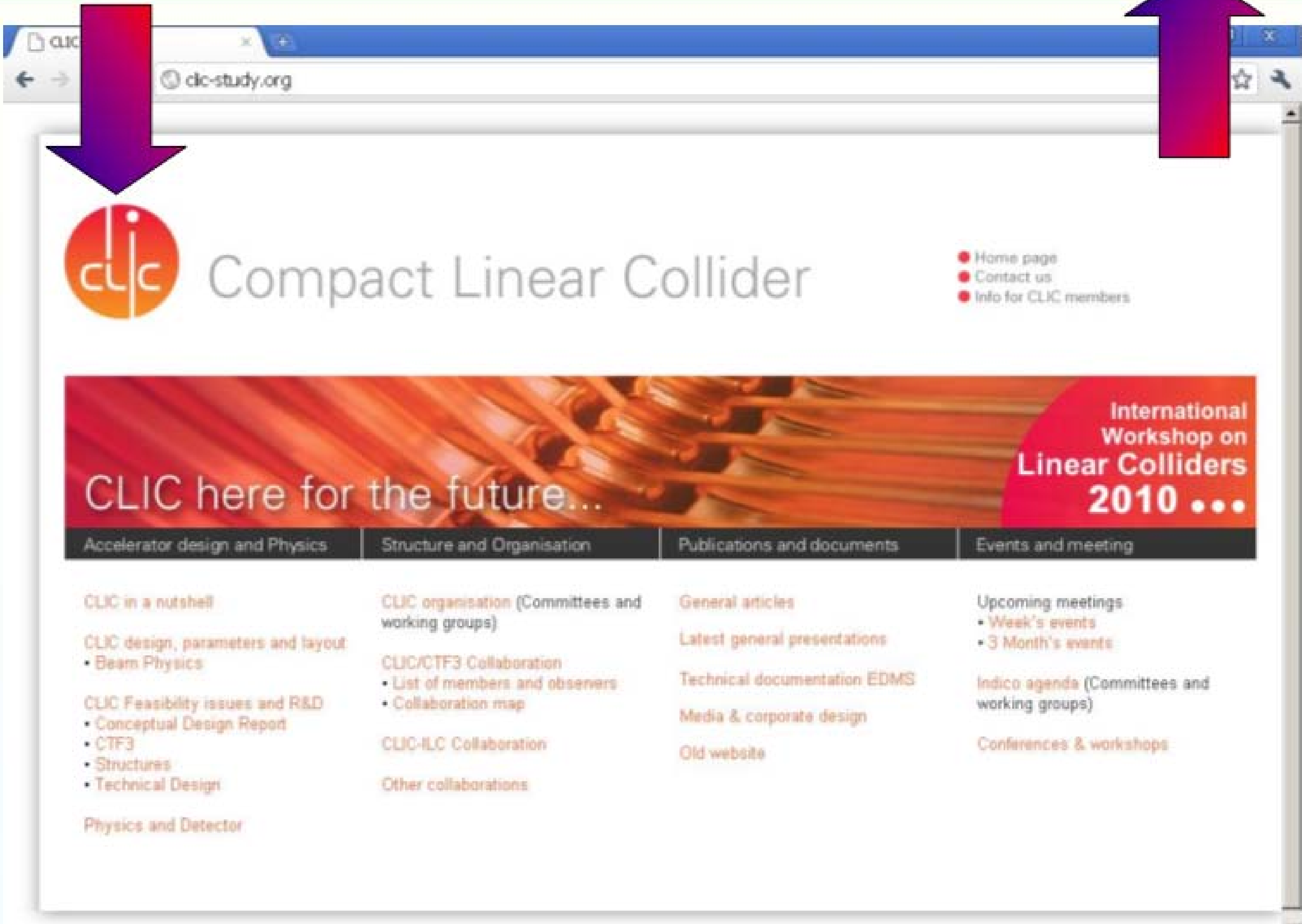
  - 3 TeV option for CLIC as baseline for the optimization
  - Describe construction staging, starting from the lowest demanded energy ➔ to the full 3 TeV machine.
  - Parameter changes and optimization for the “500 GeV” machine plus additional consequences for later energy upgrades in a separate chapter

Present goal:

Demonstrate all key feasibility issues and produce a CDR mid 2011

H. Schmickler

New CLIC website: http://clic-study.org/



CLIC /ILC Collaboration

- **Common working groups** on technical subjects with strong **synergy** between CLIC & ILC:

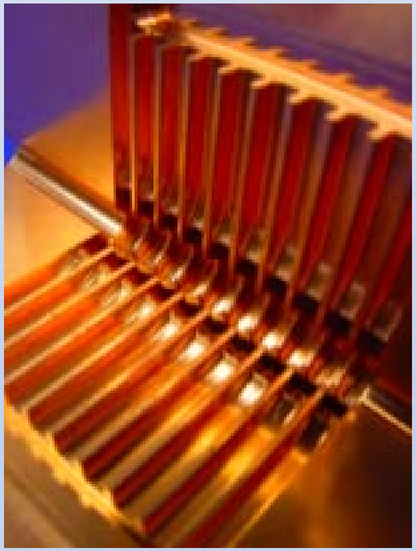
  - ✓ Physics & Detectors
  - ✓ Beam Delivery System (BDS) & Machine Detector Interface (MDI)
  - ✓ Civil Engineering & Conventional Facilities
  - ✓ Positron Generation
  - ✓ Damping Rings
  - ✓ Beam Dynamics
  - ✓ Cost & Schedule
  - ✓ Linear Collider General Issues

FRIENDLY RIVALRY

Nature 456,422, 27 Nov 08

“The spirit of collaboration in the race to define the LHC’s successor sets an example for large projects. The future for high energy physics is decidedly mixed …”

CLIC and ILC in a few words



- Based on 2-beam acceleration scheme
- Gradient 100 MV/m
- Energy: 3 TeV, though will probably start at lower energy (~0.5 TeV)
- Detector study focuses on 3 TeV

- Based on superconducting RF technology
- Gradient 32 MV/m
- Energy: 500 GeV, though upgradable to 1.0 TeV
- Detector study focuses on 500 GeV

Luminosities: few 10^{34} $cm^{-2}s^{-1}$

World-wide CLIC&CTF3 Collaboration

http://clic-meeting.web.cern.ch/clic-meeting/CTF3_Coordination_Mtg/Table_MoU.htm

Collaboration Board Chairman – K. Peach (JAI)
Spokesperson – R. Corsini (CERN)

CLIC multi-lateral collaboration
41 Institutes from 21 countries

- ACAS (Australia)
- Aarhus University (Denmark)
- Ankara University (Turkey)
- Argonne National Laboratory (USA)
- Athens University (Greece)
- BINP (Russia)
- CERN
- CIEMAT (Spain)
- Cockcroft Institute (UK)
- ETHZurich (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 (Netherland)
- 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)

CLIC physics up to 3 TeV

LHC will indicate what physics, and at which energy scale

Potential Physics in 0.5-3 TeV range?

Higgs physics:

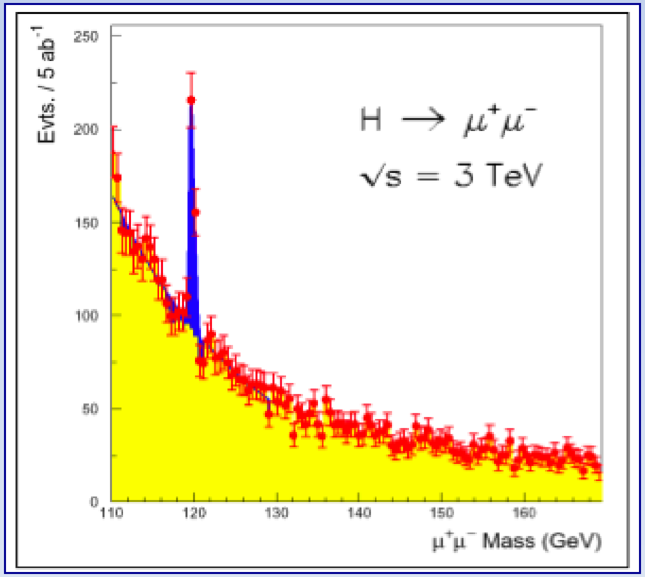
- Complete study of the light standard-model Higgs boson, including rare decay modes (rates factor ~5 higher at 3 TeV than at 500 GeV)
  - Higgs coupling to leptons
  - Study of triple Higgs coupling using double Higgs production
- Study of heavy Higgs bosons (supersymmetry models)

Supersymmetry:

- Extensive reach to measure SUSY particles

And in addition:

- Probe for theories of extra dimensions
- New heavy gauge bosons (e.g. Z')
- Excited quarks or leptons



http://www.cern.ch/lcd Lucie Linssen, CLIC'09 12/10/2009

(S) LHC, ILC, CLIC reach

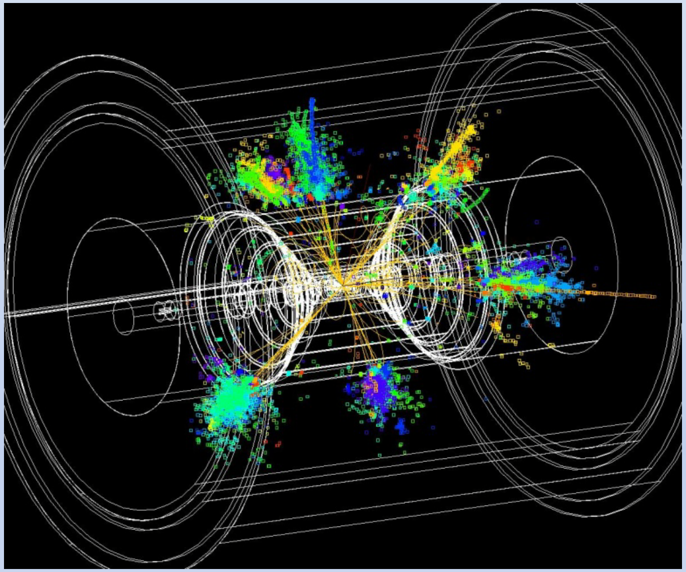
	LHC 100 fb^{-1}	ILC 800 GeV 500 fb^{-1}	SLHC 1000 fb^{-1}	CLIC 3 TeV 1000 fb^{-1}
Squarks (TeV)	2.5	0.4	3	1.5
Sleptons (TeV)	0.34	0.4		1.5
New gauge boson Z' (TeV)	5	8	6	22
Excited quark q* (TeV)	6.5	0.8	7.5	3
Excited lepton l* (TeV)	3.4	0.8		3
Two extra space dimensions (TeV)	9	5-8.5	12	20-35
Strong $W_L W_L$ scattering	2σ	-	4σ	70σ
Triple-gauge Coupling (95%)	.0014	0.0004	0.0006	0.00013

Gian Giudice CLIC09

ILC and CLIC detector concepts

In several aspects the CLIC detector will be more challenging than ILC case, due to:

- Energy 500 GeV → 3 TeV
- More severe background conditions
  - Due to higher energy
  - Due to smaller beam sizes
    - (40 nm in x ; 1 nm in y)
- Time structure of the accelerator
  0.5 ns between bunch crossing



Detector R&D currently carried out for the ILC → most relevant for CLIC.

Many years of investment in ILC e^+e^- physics/detector simulations, hardware R&D and detector concepts → No need to duplicate work.

The CLIC detector study (LCD) project @ CERN links to several ILC collaborations

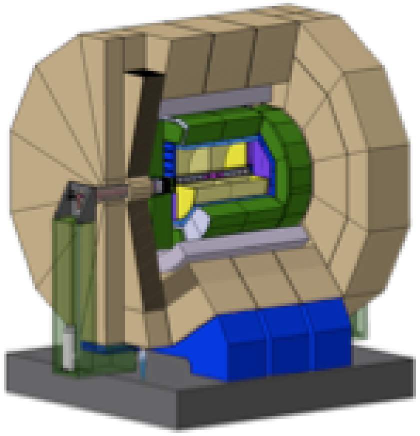
ILD concept, SID concept, CALICE, FCAL, LC-TPC,+ EU projects (EUDET / AIDA)

http://www.cern.ch/lcd Lucie Linssen, CLIC'09 12/10/2009

Detector based on validated ILC detector concepts

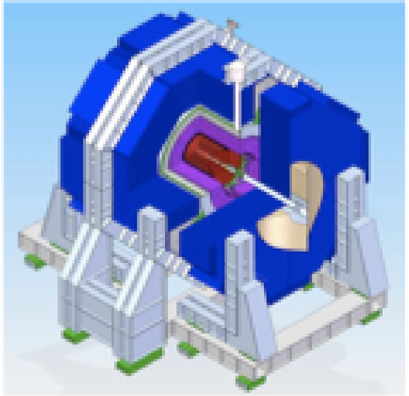
ILD: International Large Detector

"Large" : tracker radius 1.8m
B-field : 3.5 T
Tracker : TPC + Silicon
Calorimetry : high granularity particle flow
ECAL + HCAL inside large solenoid



SiD: Silicon Detector

"Small" : tracker radius 1.2m
B-field : 5 T
Tracker : Silicon
Calorimetry : high granularity particle flow
ECAL + HCAL inside large solenoid



- CLIC detector concepts will be based on SiD and ILD.
- Modified to meet CLIC requirements

http://www.cern.ch/lcd Lucie Linssen, CLIC'09 12/10/2009

CLIC detector requirements

Compared to ILC:

Energy 500 GeV => 3 TeV

- Need for deeper calorimetry
- Possible need for higher granularity, better intrinsic resolution (boosted jets)
- Forward region tracking / calorimetry becomes more important

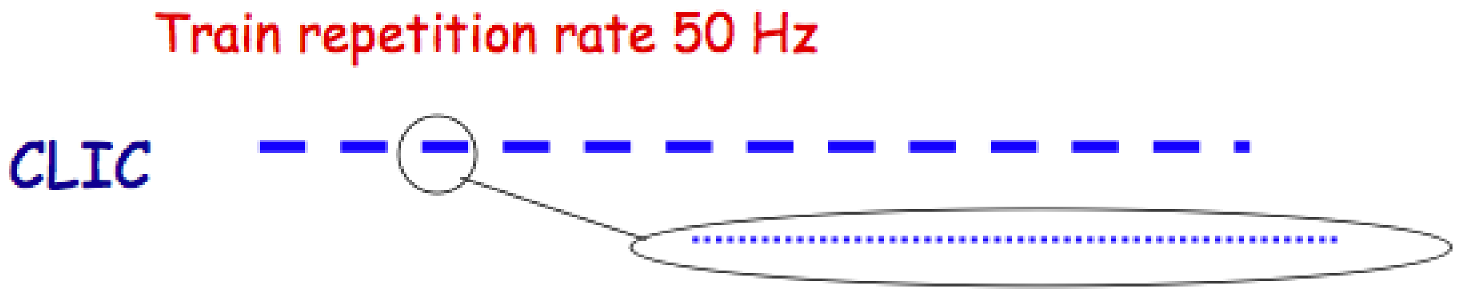
More severe beam-induced background conditions

Time structure of the accelerator (0.5 ns bunch separation)

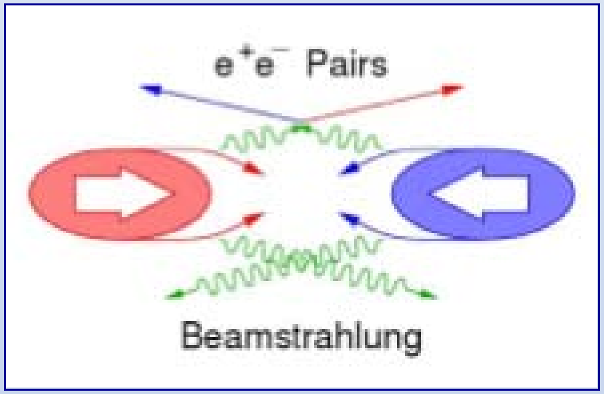
- Need larger crossing angle (20 mrad)
- Careful forward region design to avoid back-scattering
- Larger inner radius of vertex detector
- Possible need for smaller granularity in vertex/tracker (occupancy issue)
- Time-stamping of hits in all detectors

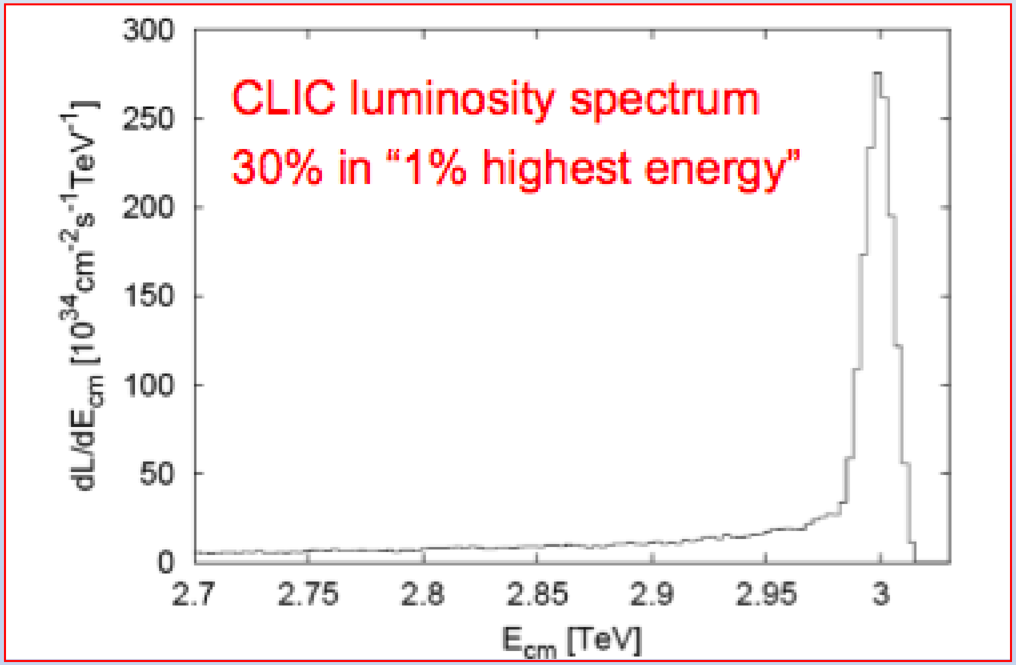
Mark Thomson, CLIC'09

http://www.cern.ch/lcd Lucie Linssen, CLIC'09 12/10/2009



CLIC:	1 train = 312 bunches	0.5 ns apart	50 Hz
ILC:	1 train = 2820 bunches	308 ns apart	5 Hz





Main backgrounds

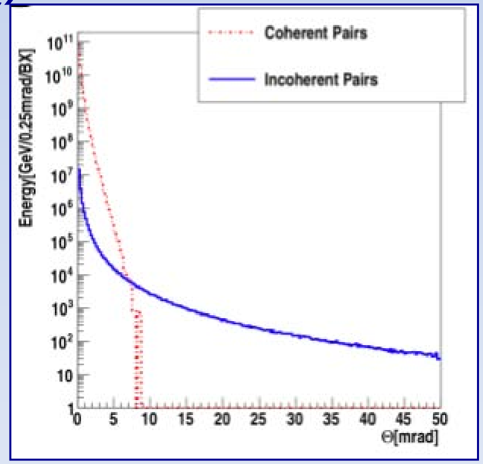
CLIC 3 TeV beamstrahlung ΔE/E = 29% (10 × ILC$_{value}$)

Coherent e+e- pairs

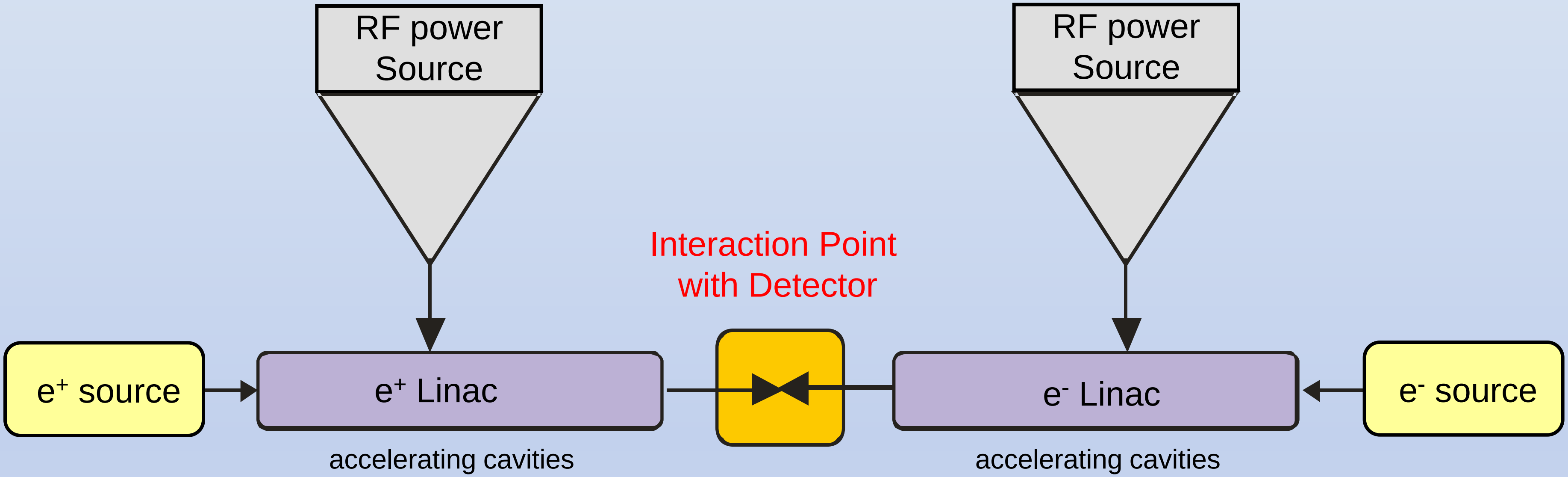
- Direct photons conversion in strong fields
- Cutoff at near 10 mrad
- Few 10^8 particles/ BX

Incoherent e+e- pairs

- Photons interacting with other electron/photon
- Peak at lowest Energies
- Few 10^5 particles/BX



Linear Collider Machine R&D in General



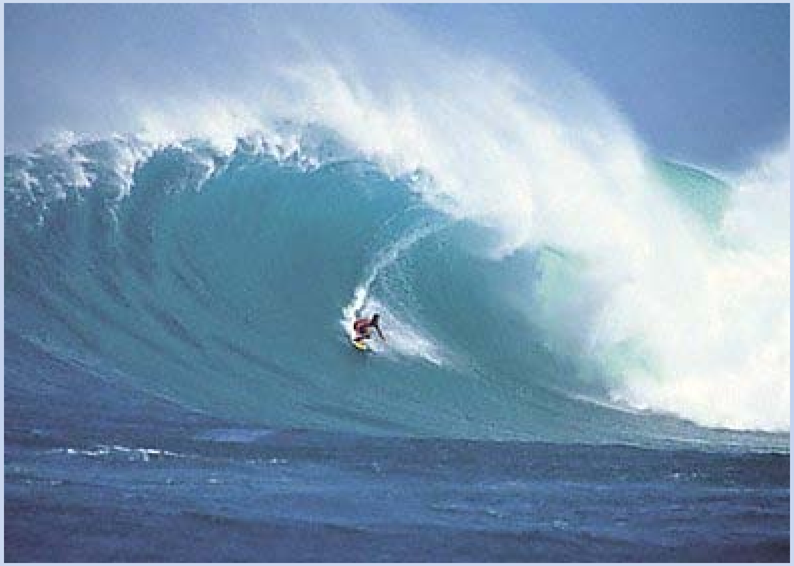
Challenges:

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

How to accelerate particles?

DC Accelerator

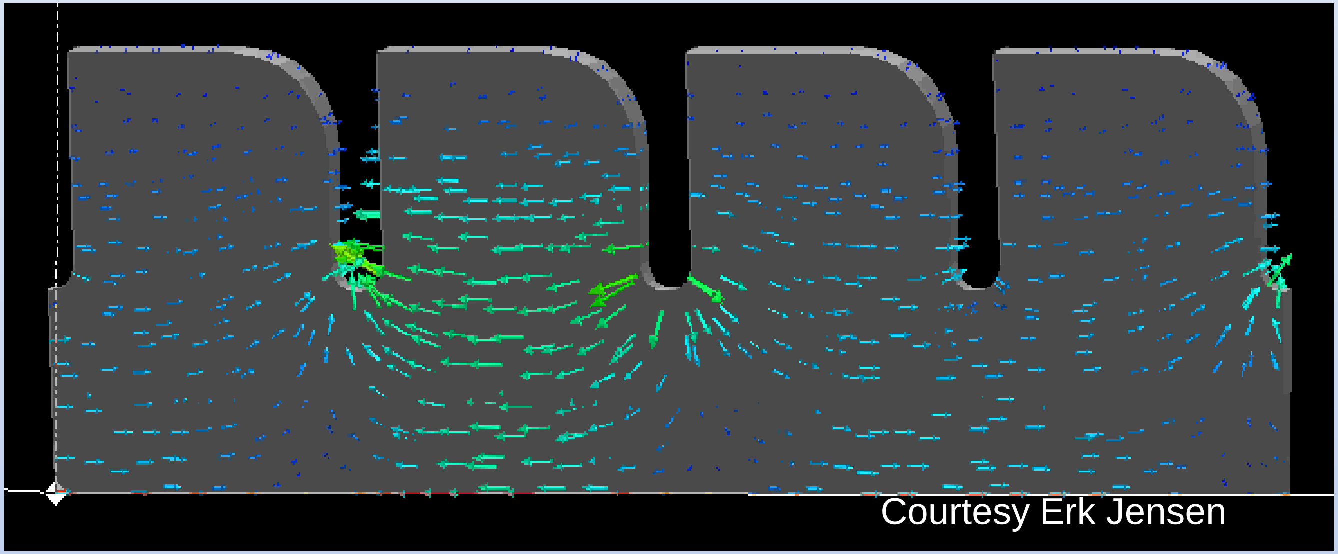
RF Accelerator

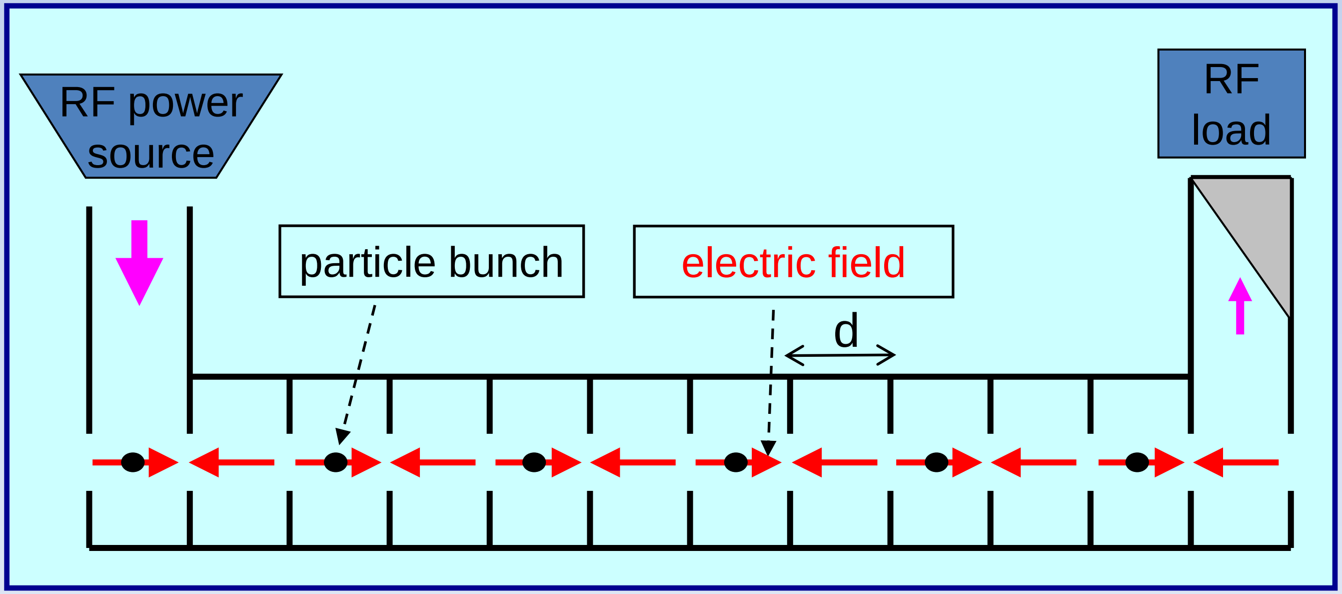


synchronize particle
with an
electromagnetic wave!

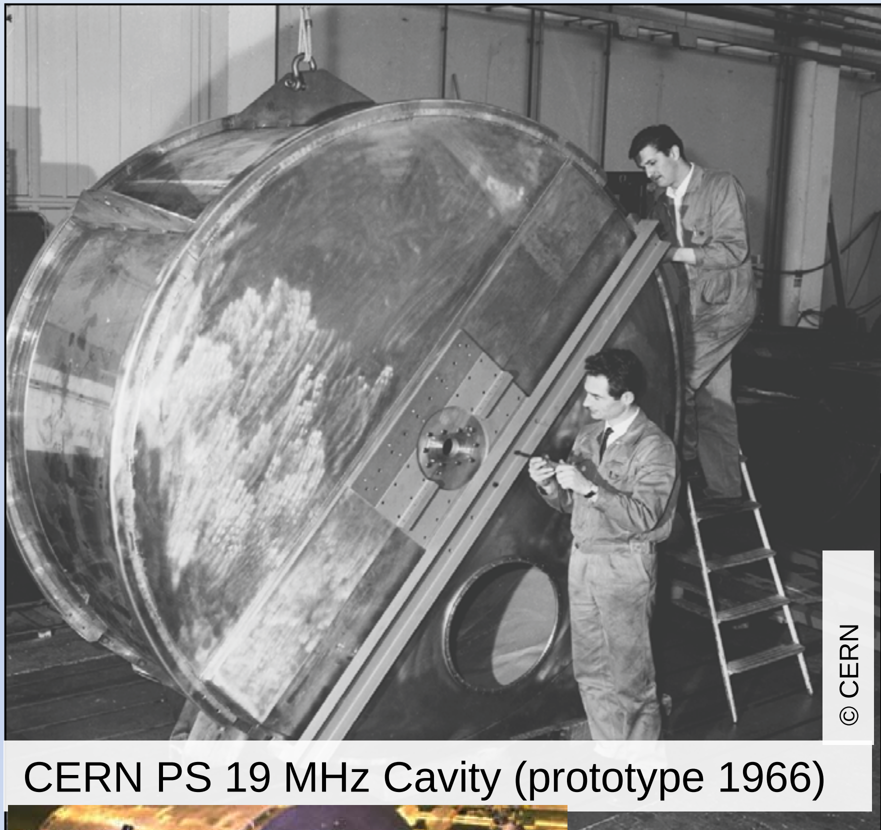
Travelling wave cavity : High RF to Beam Efficiency

- 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

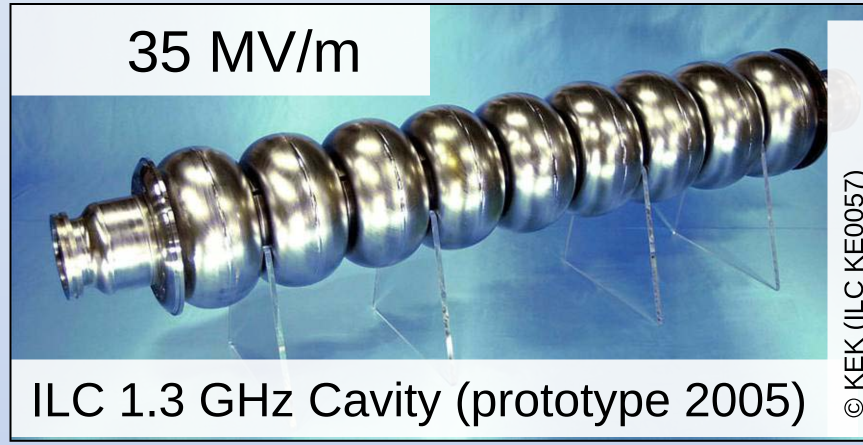




Accelerating Cavities

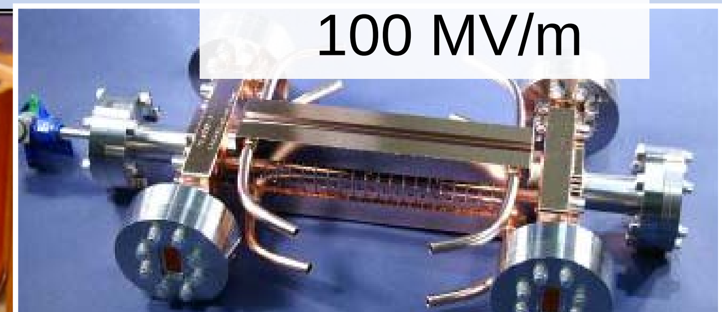


CERN PS 19 MHz Cavity (prototype 1966)



35 MV/m

ILC 1.3 GHz Cavity (prototype 2005)



100 MV/m

CLIC 12 GHz Cavity (prototype 2009)

CLIC 30 GHz Cavity (prototype 2006)

LHC Cavity

(shown inside the cryro-module)

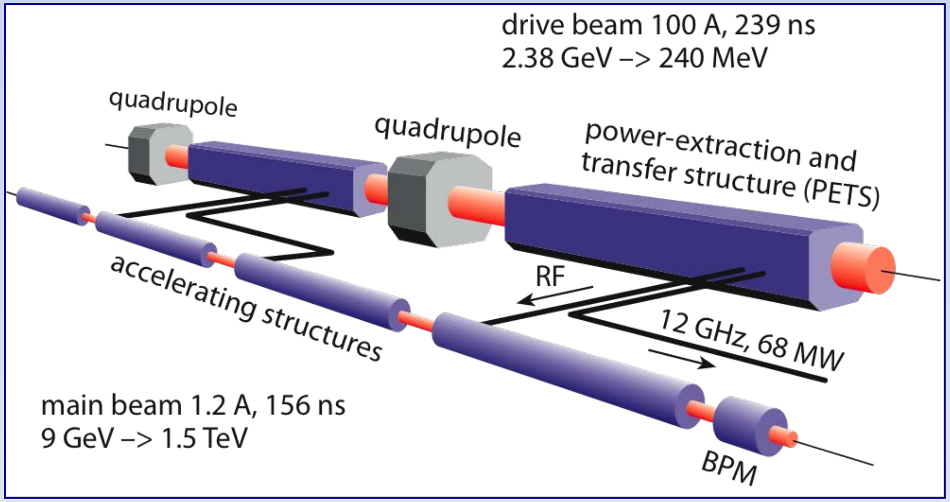
400 MHz 5 MV/m

A protoype cryomodule containing superconducting accelerating cavities for CERN's LHC proton collider.

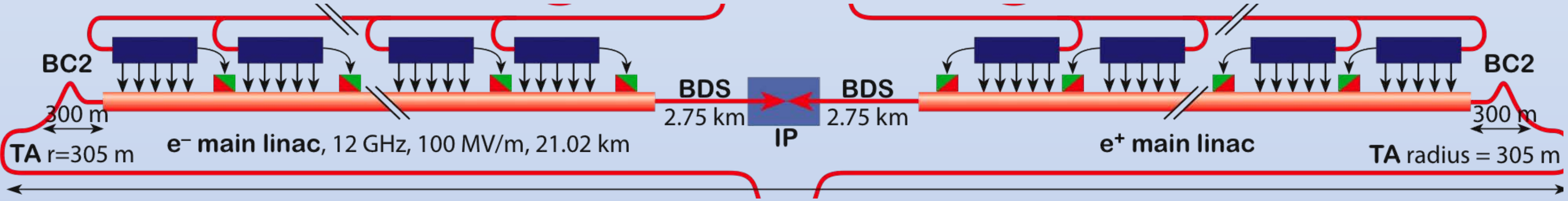
The CLIC way to a multi-TeV linear collider

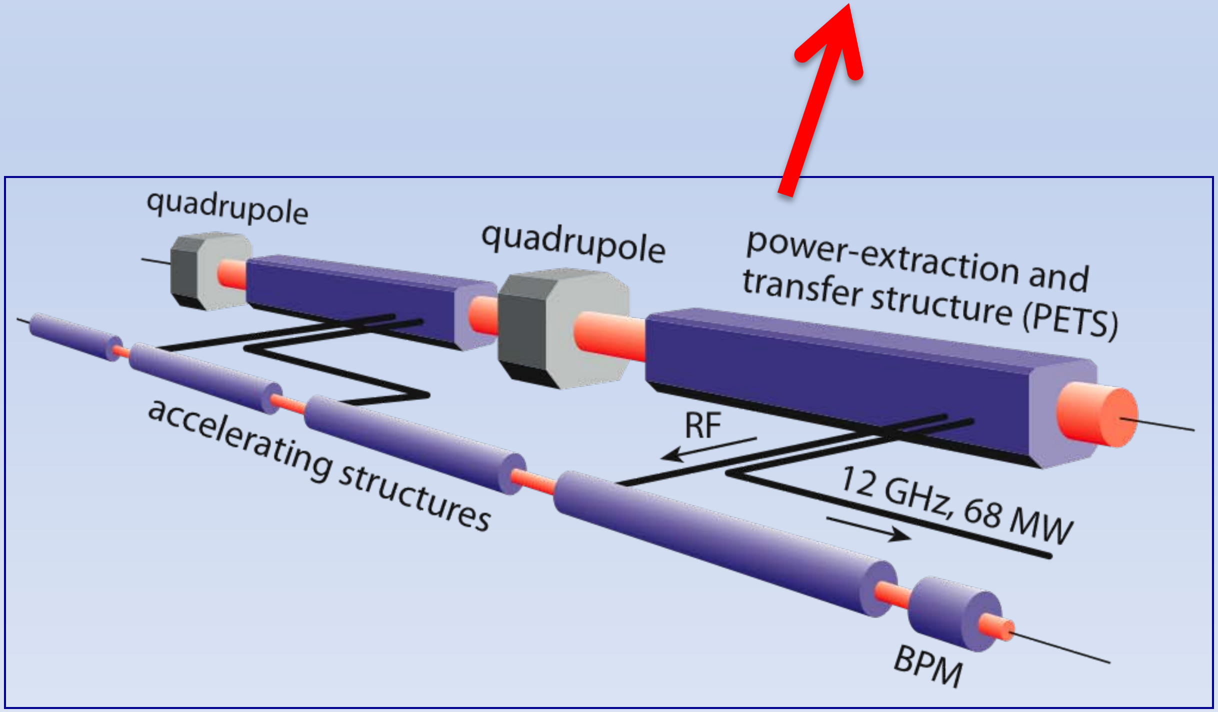
- High acceleration gradient (100 MV/m)
  - ✓ "Compact" collider - overall length @ 3 TeV < 50 km
  - ✓ Normal conducting accelerating structures
  - ✓ High acceleration frequency (12 GHz)

- Two-Beam Acceleration Scheme
  - ✓ Cost effective, reliable, efficient
  - ✓ Simple tunnel, no active elements
  - ✓ Modular, easy energy upgrade in stages



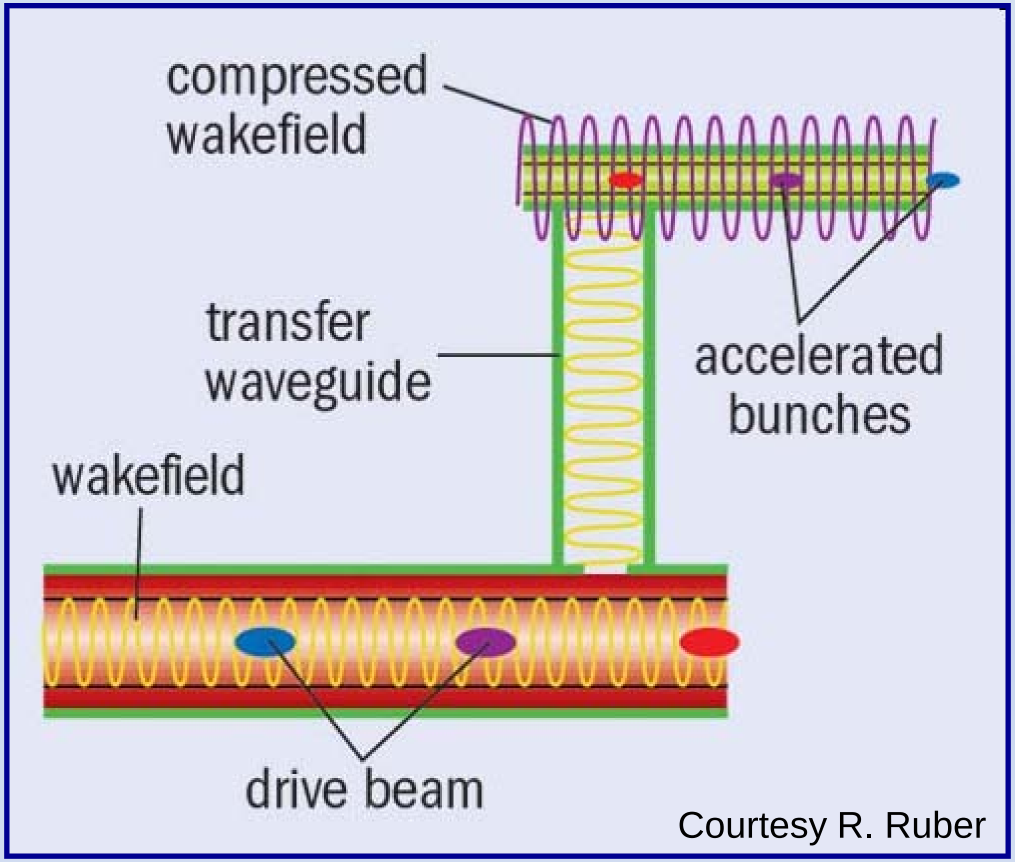
The CLIC Two-Beam Accelerator

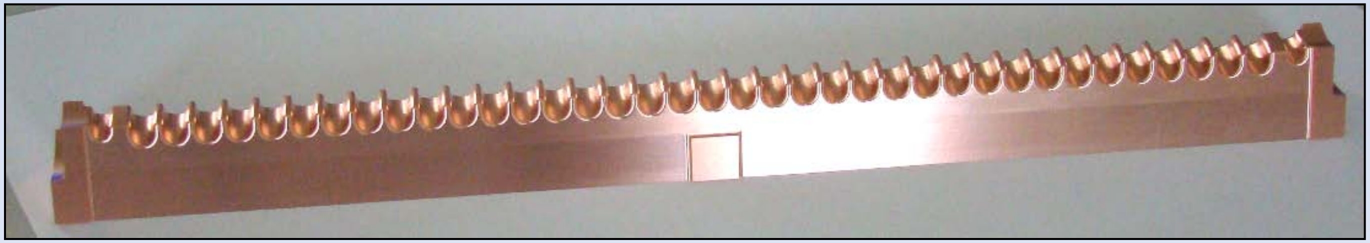


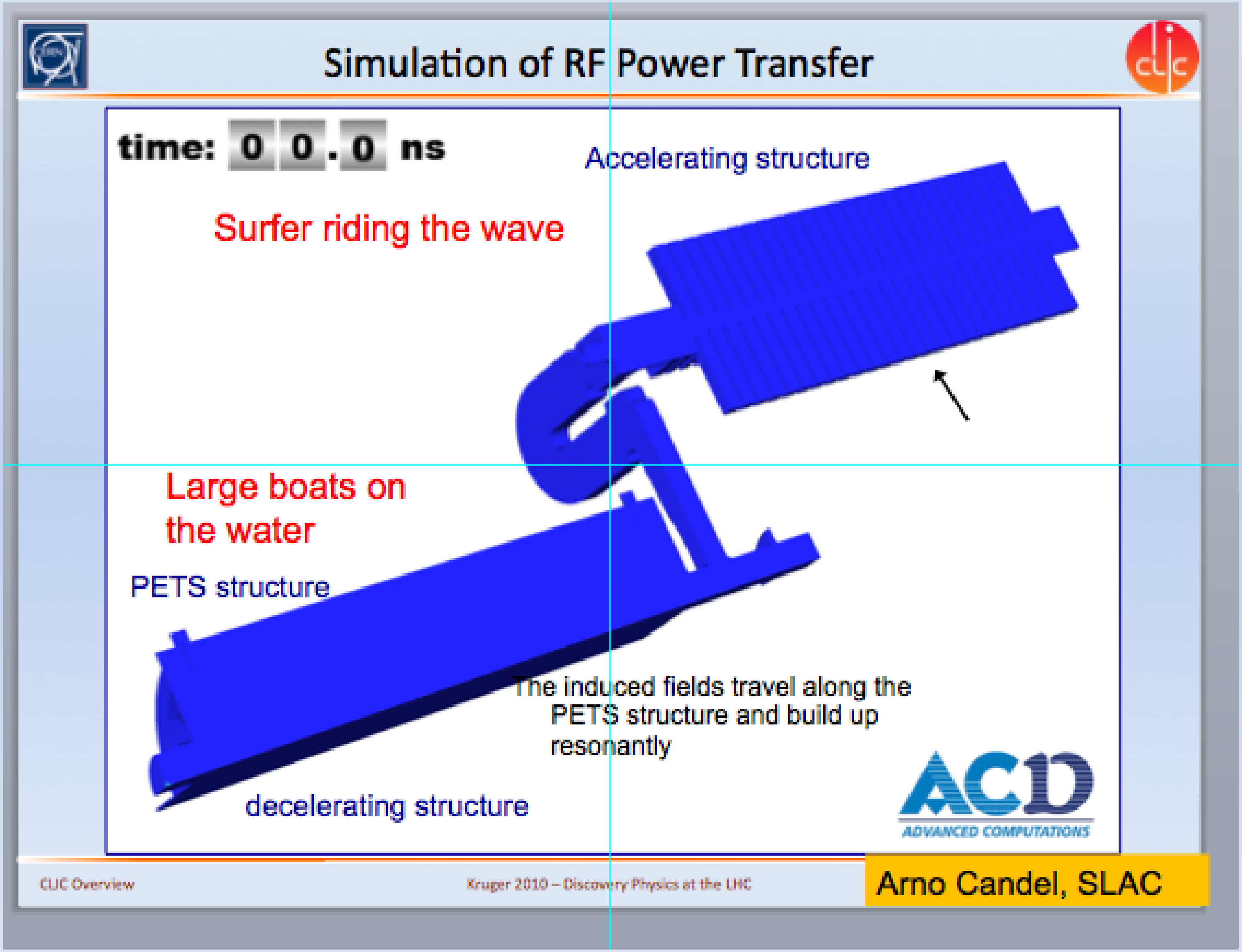


CLIC Two-beam Acceleration Concept

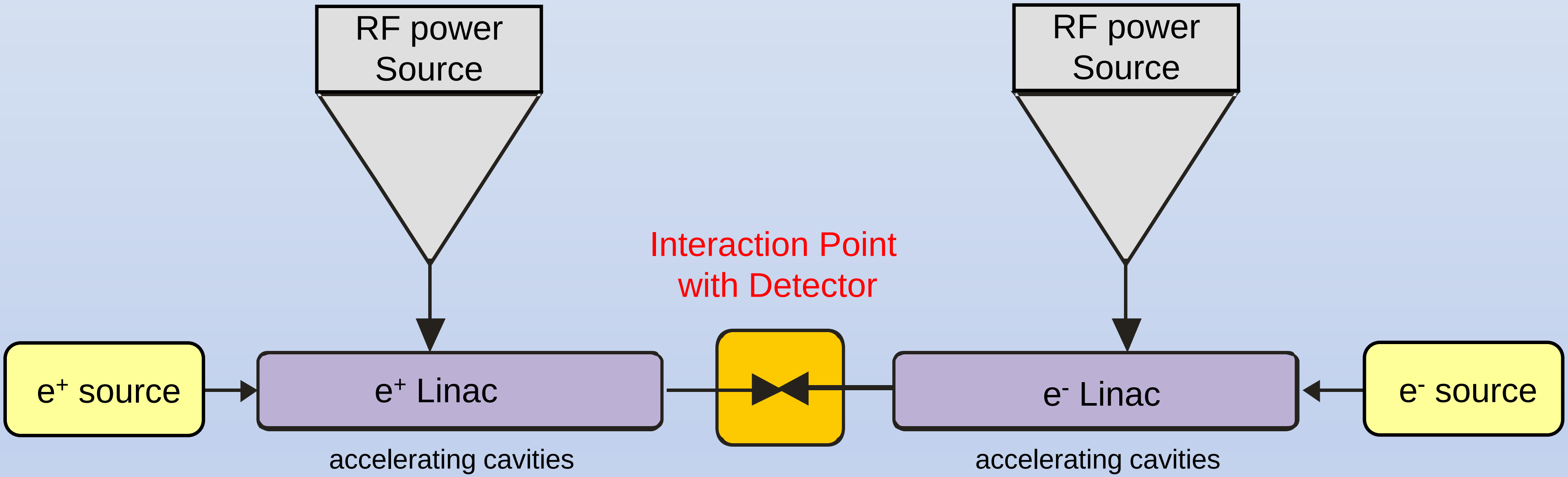
- 12 GHz modulated and high power drive beam
- RF power extraction in a special structure (PETS)
- use RF power to accelerate main beam






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
ACD
ADVANCED COMPUTATIONS
CLIC Overview
Kruger 2010 – Discovery Physics at the LHC
Arno Candel, SLAC

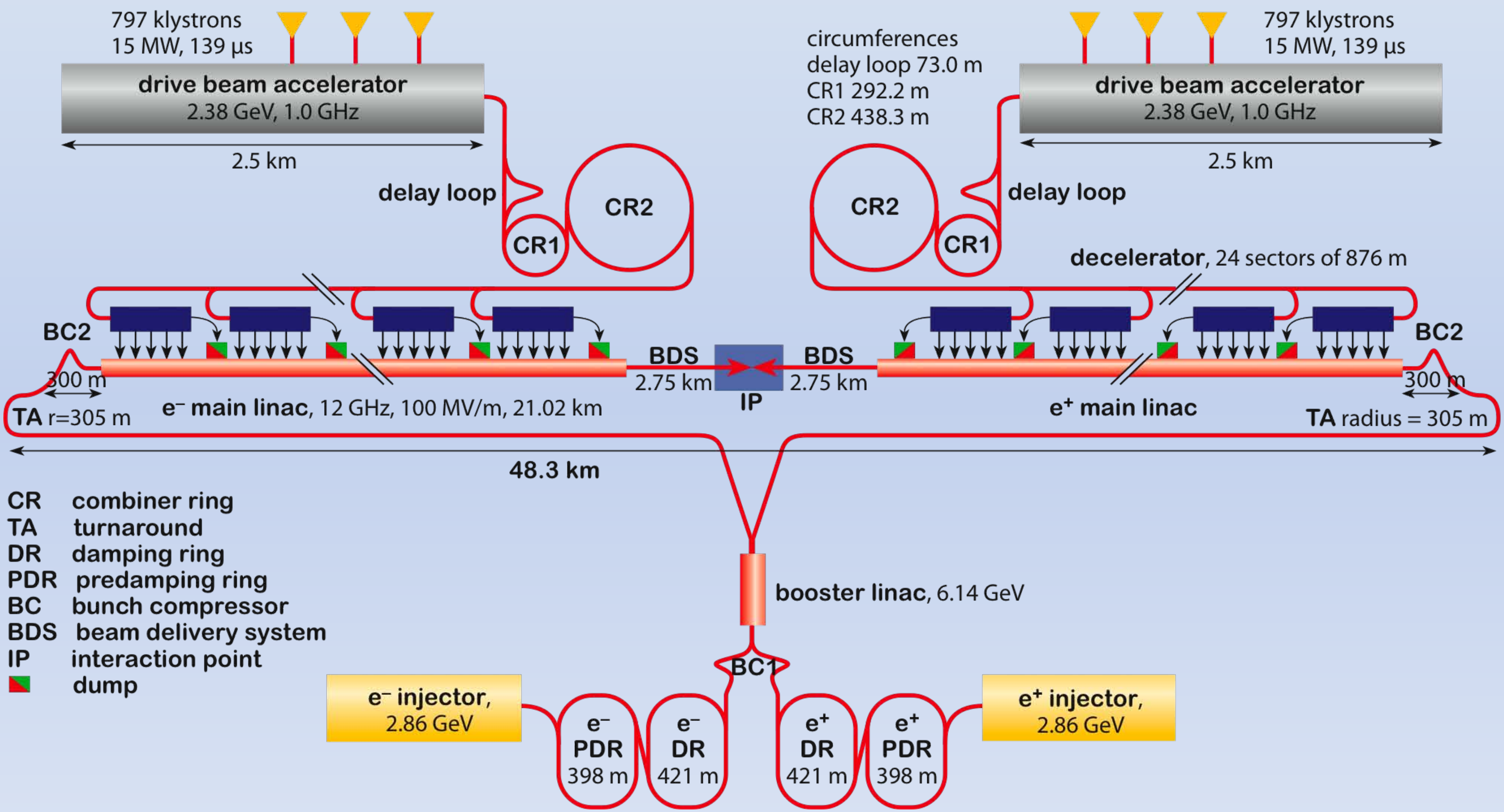
Linear Collider R&D in General



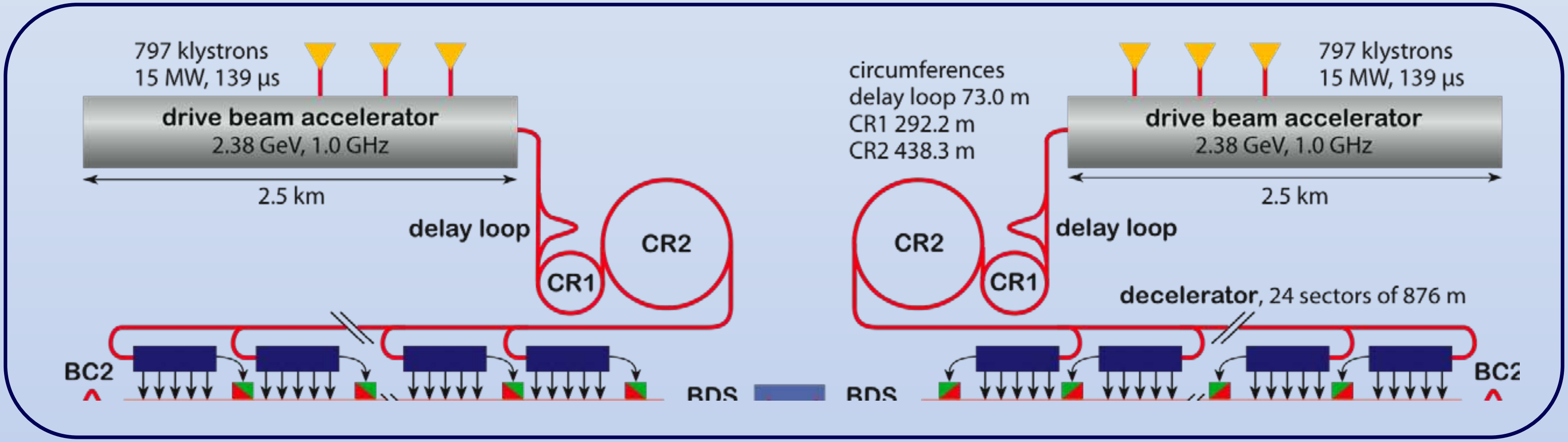
Challenges:

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

CLIC schematic layout @ 3 TeV

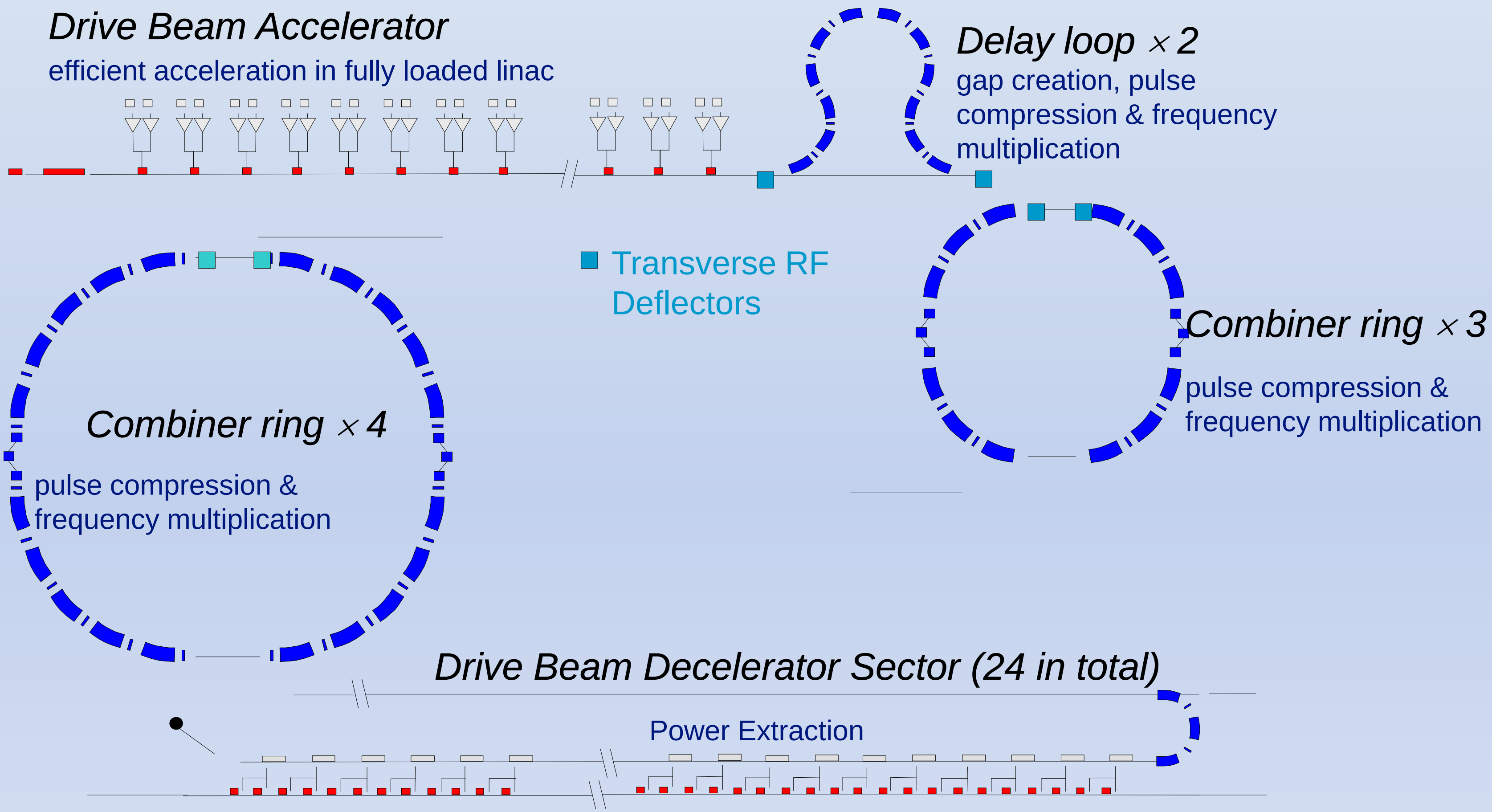


CLIC schematic layout @ 3 TeV

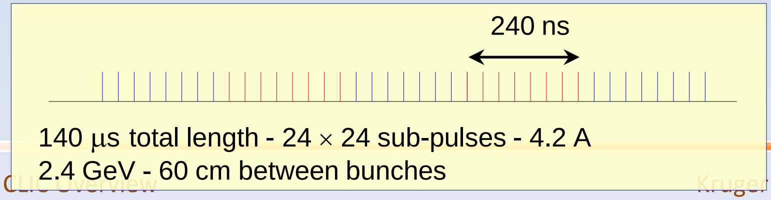


CLIC RF power source

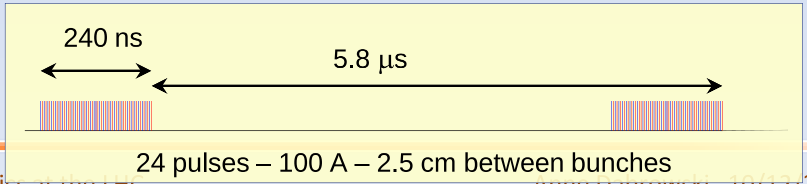
CLIC RF power source



Drive beam time structure - initial

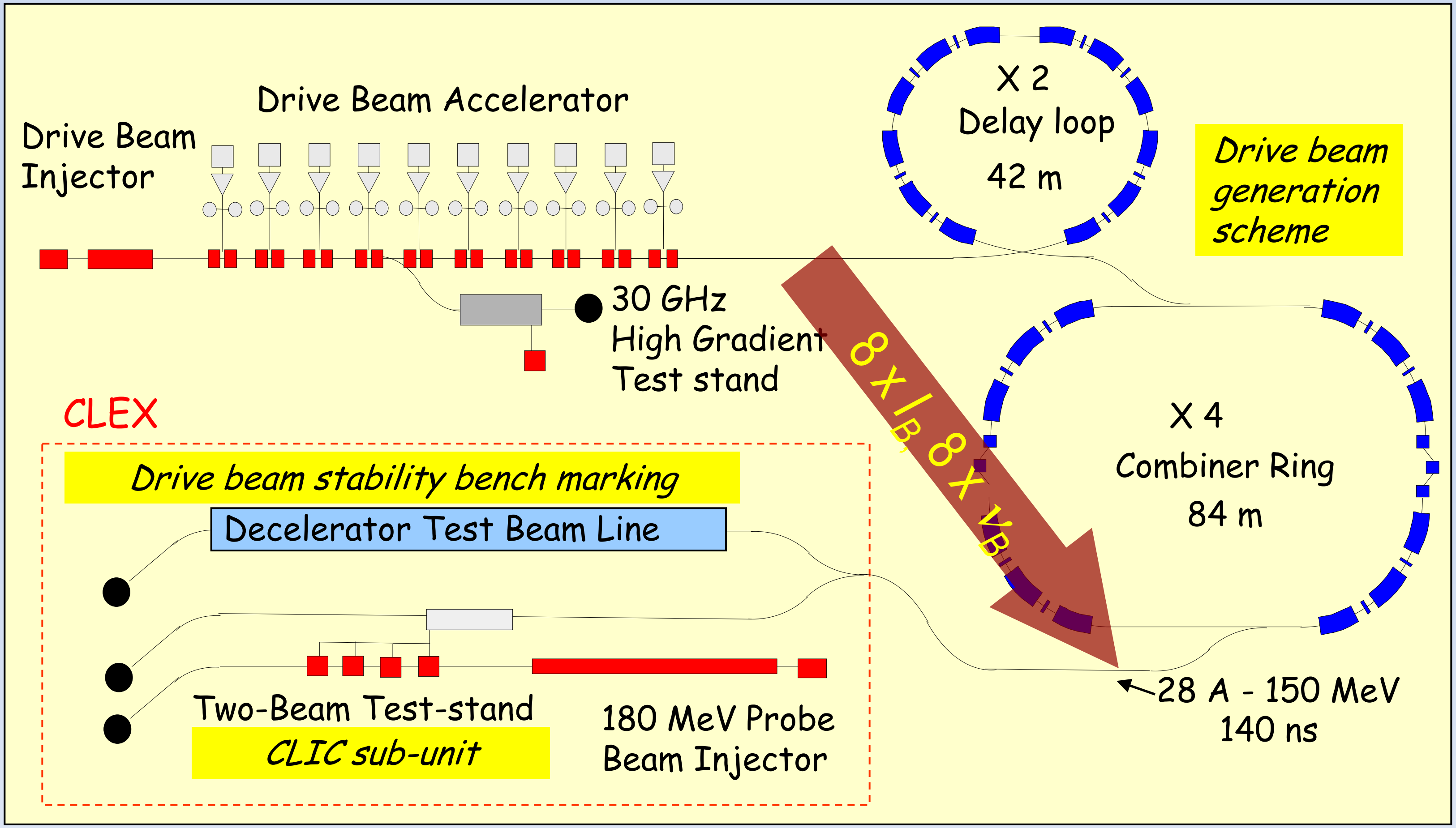


Drive beam time structure - final

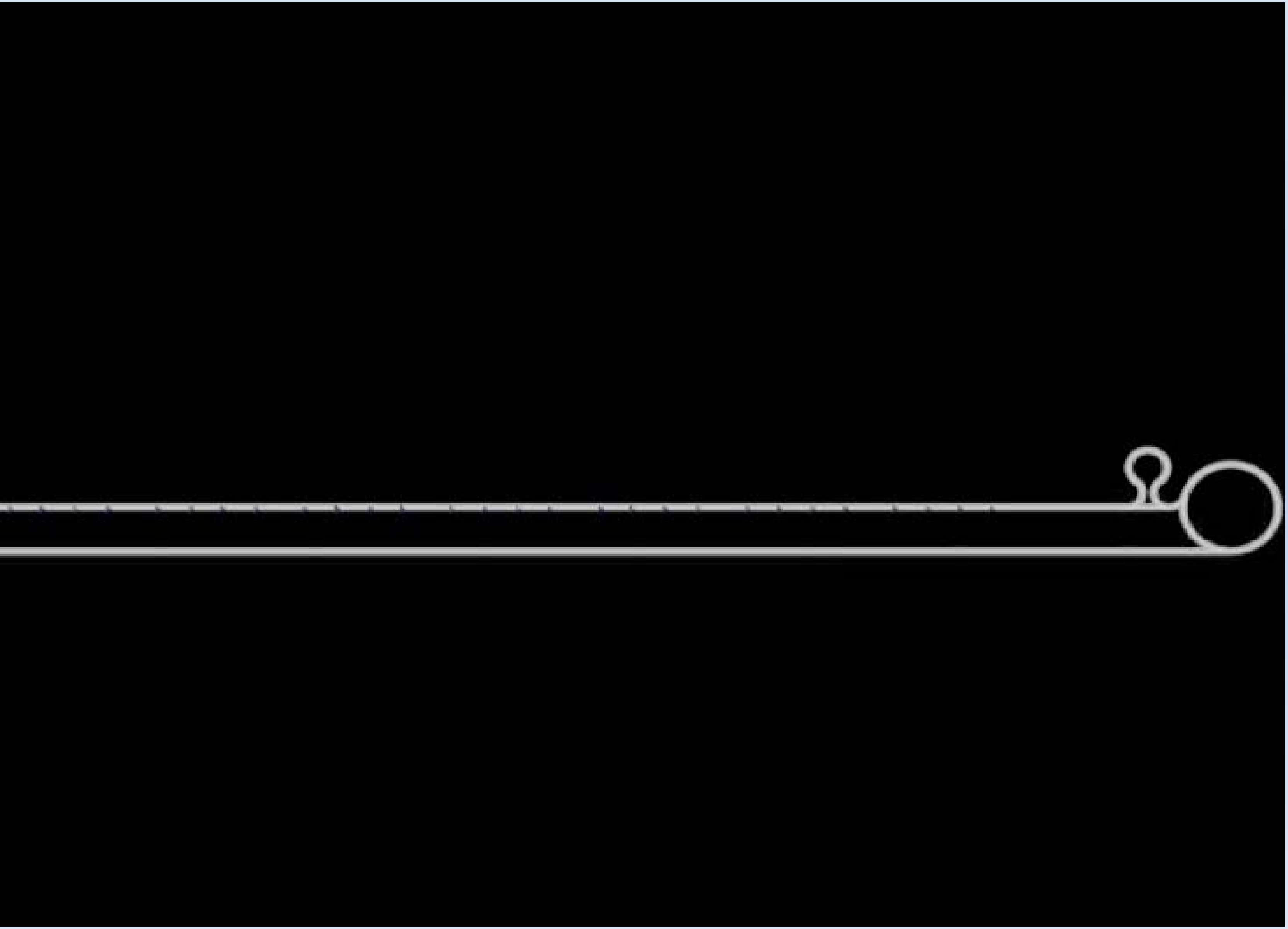


CTF3 Test Facility

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



Drive Beam Generation Scheme (boat factory)



Courtesy Alexandra Anderssen

Comparison CLIC - CTF3

	CTF3	CLIC
Energy	0.150 GeV	2.4 GeV
Pulse length	1.2 µs	140 µs
Multiplication factor	2 x 4 = 8 (DL + 1 CR)	2 x 3 x 4 = 24 (DL + 2 CR)
Linac current	3.5 A	4.2 A
Final current	28 A	100 A
RF frequency	3 GHz	1 GHz
Final bunch frequency	12 GHz	12 GHz
Deceleration	to ~60% energy	to 10% energy
Repetition rate	up to 5 Hz	50 Hz
Energy per beam pulse	0.7 kJ	1400 kJ
Average beam power	3.4 kW	70 MW

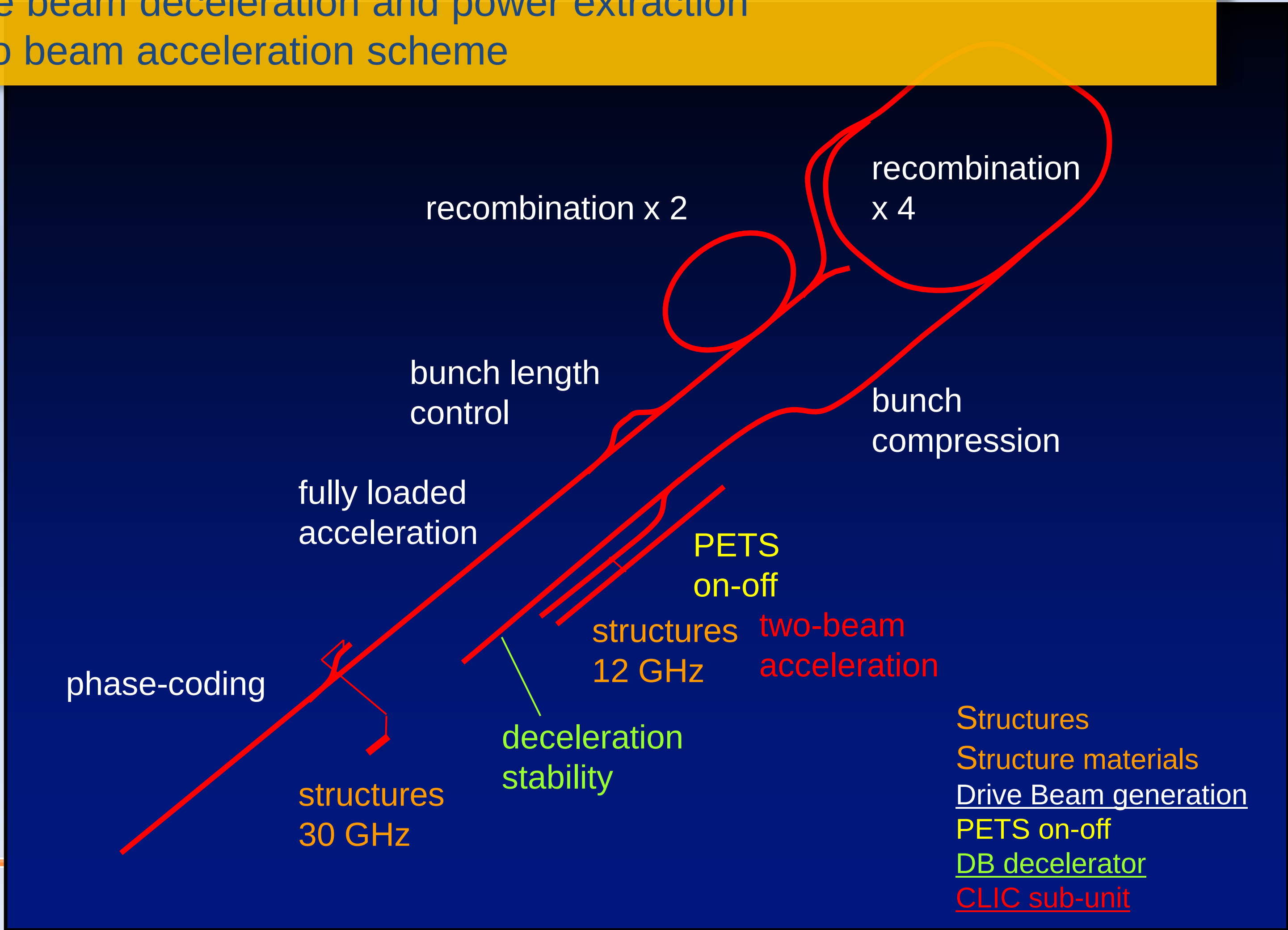
- CTF3 covers well the CLIC drive beam generation scheme
- Still considerable extrapolation to CLIC parameters

F. Tecker CLIC'09 Workshop

CTF3 for CLIC

CTF3 is a small scale version of the CLIC drive beam complex:

- ✓ Provide the RF power to test the CLIC accelerating structures and components
- ✓ Full beam-loading accelerator operation
- ✓ Electron beam pulse compression and frequency multiplication
- ✓ Safe and stable beam deceleration and power extraction
- ✓ High power two beam acceleration scheme



Bunch Combination in CTF3 Combiner Ring

Streak camera Measurement

666 ps initial bunch spacing

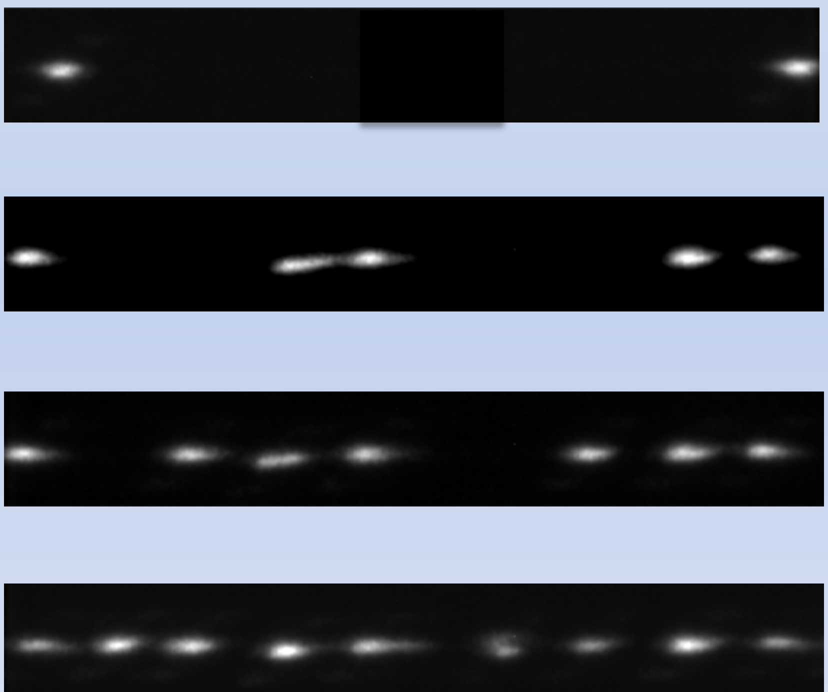
From DL

Turn 1

Turn 2

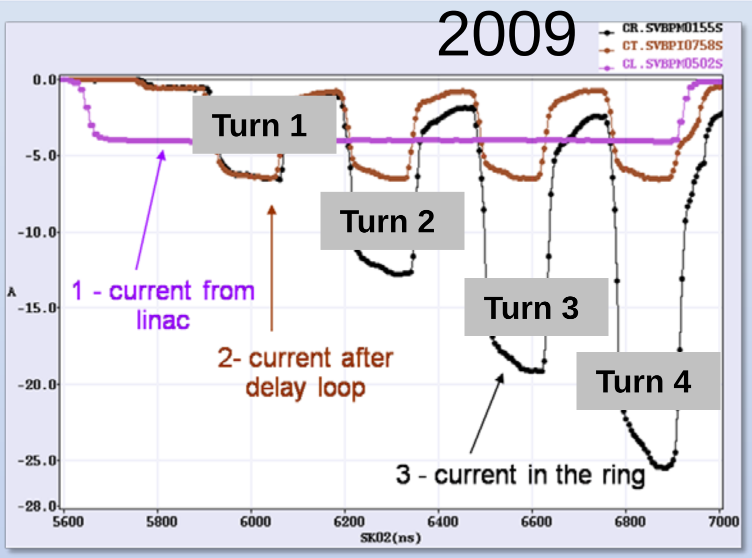
Turn 3

Turn 4

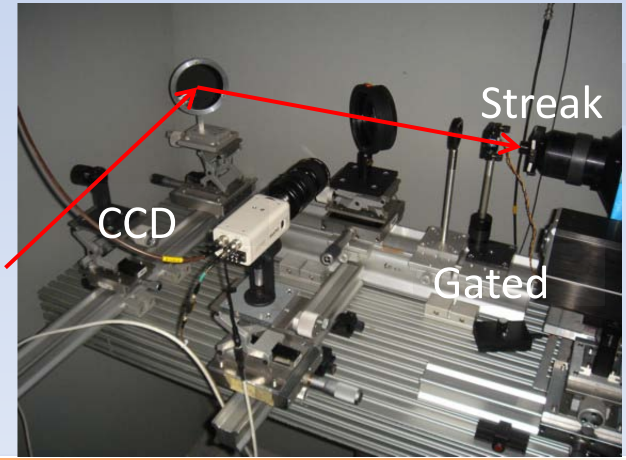


83 ps final bunch spacing

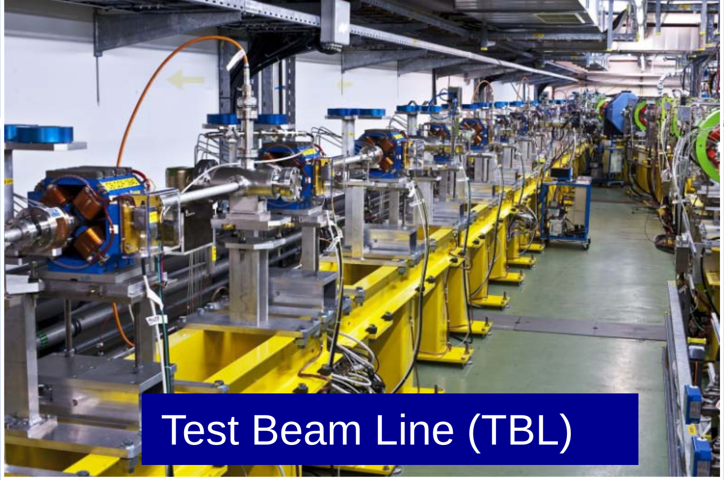
Time axis (ps)



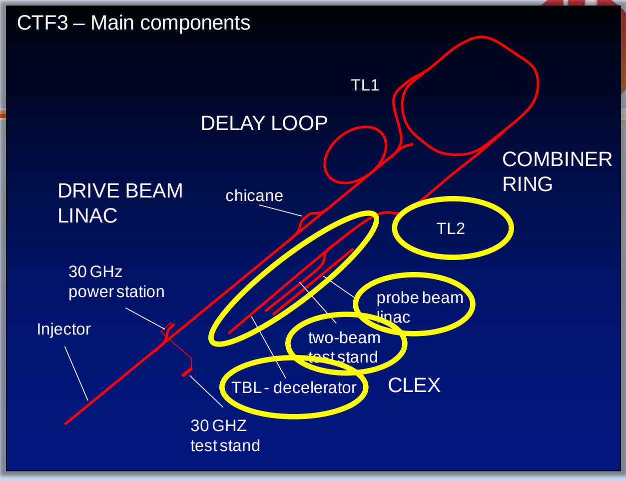
Current Multiplication Measured with BPMS



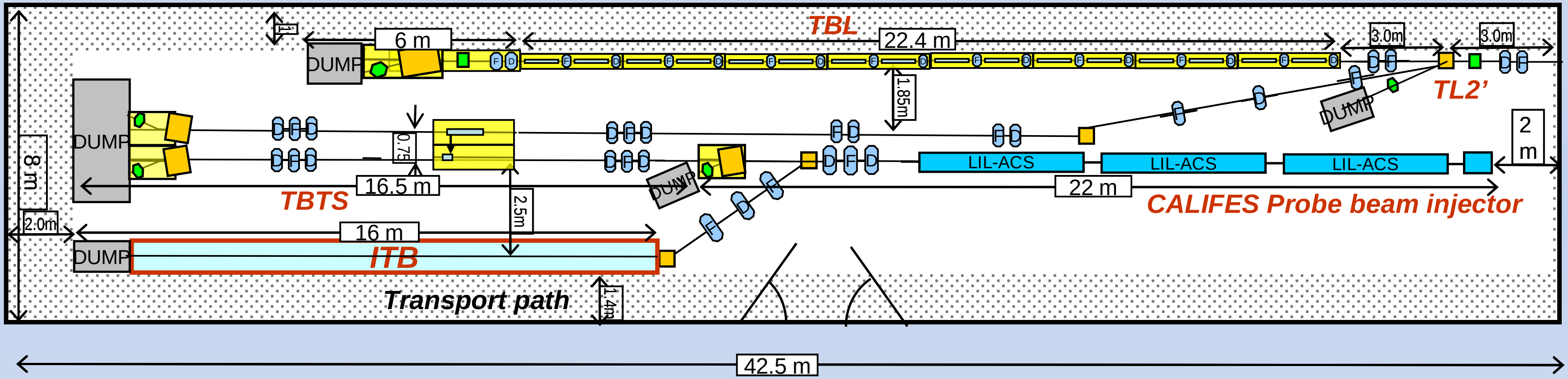
CLEX Area



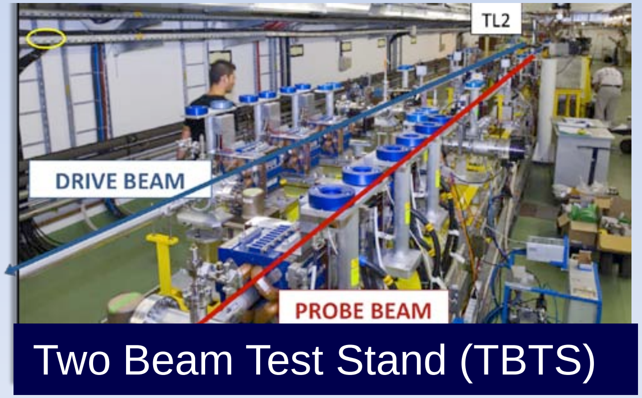
Test Beam Line (TBL)



CTF3 – Main components
TL1
DELAY LOOP
COMBINER RING
DRIVE BEAM LINAC
chicane
TL2
30 GHz power station
probe beam linac
Injector
two-beam test stand
TBL - decelerator
CLEX
30 GHZ test stand



TBL
6 m
22.4 m
3.0m
3.0m
DUMP
1.85m
TL2'
DUMP
DUMP
0.75
2 m
LIL-ACS
LIL-ACS
LIL-ACS
8 m
16.5 m
22 m
TBTS
DUMP
CALIFES Probe beam injector
2.0m
16 m
2.5m
DUMP
ITB
Transport path
1.4m
42.5 m

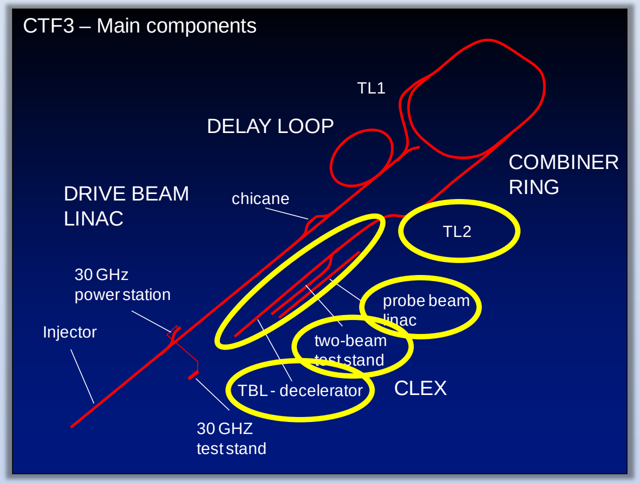


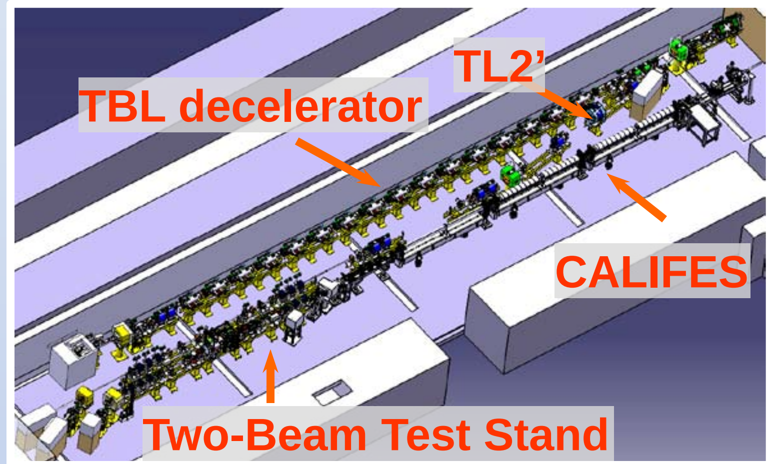
TL2
DRIVE BEAM
PROBE BEAM
Two Beam Test Stand (TBTS)

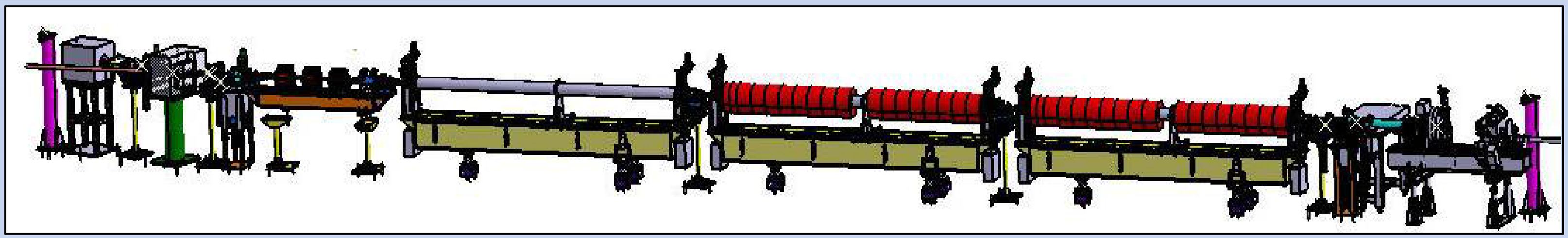
Califes Accelerating section

Califes Photo-injector

Califes Probe Beam Commissioned

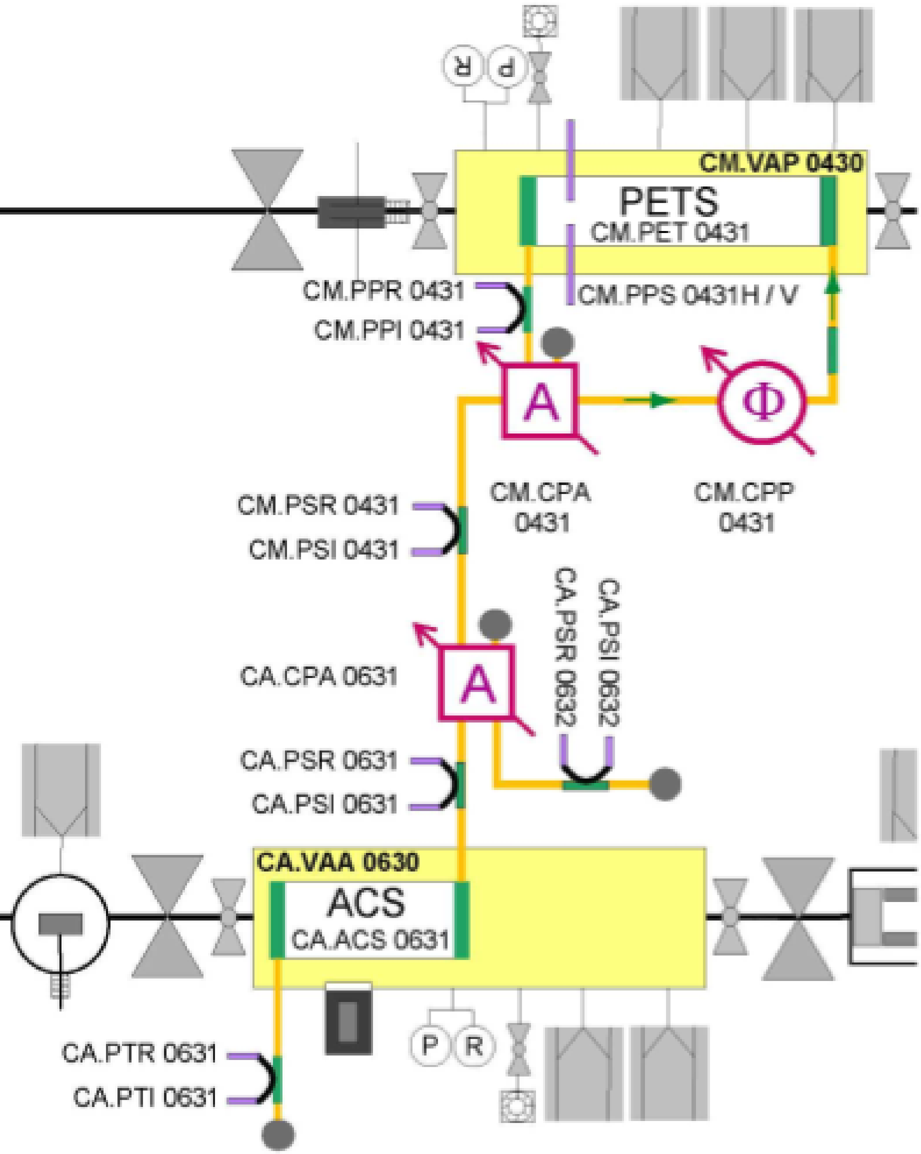




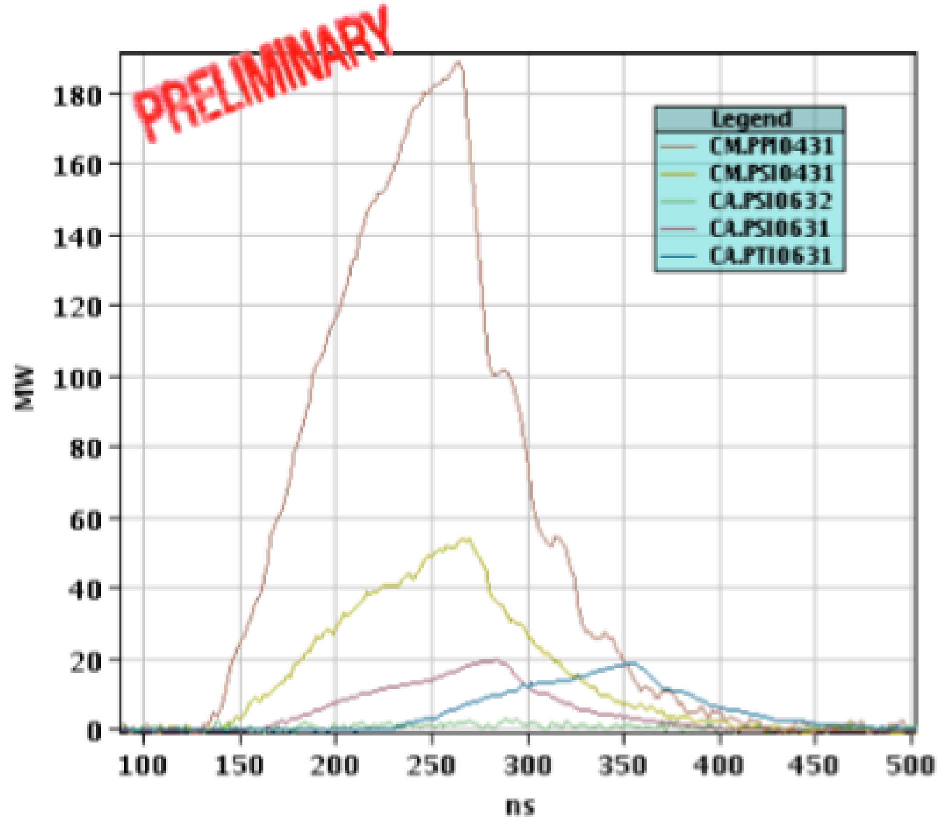


Parameters	Specified	Tested
Energy	200 MeV	185 MeV
Norm. rms emittance	< 20 p mm.mrad	8 p mm.mrad
Energy spread	< ± 2 %	± 0.5 %
Bunch charge	0.6 nC	0.65 nC
Bunch spacing	0.667 ns	0.667 ns
Number of bunches	1-32-226	from 1 to 300
rms. bunch length	< 0.75 ps	1.4 ps

PETS power



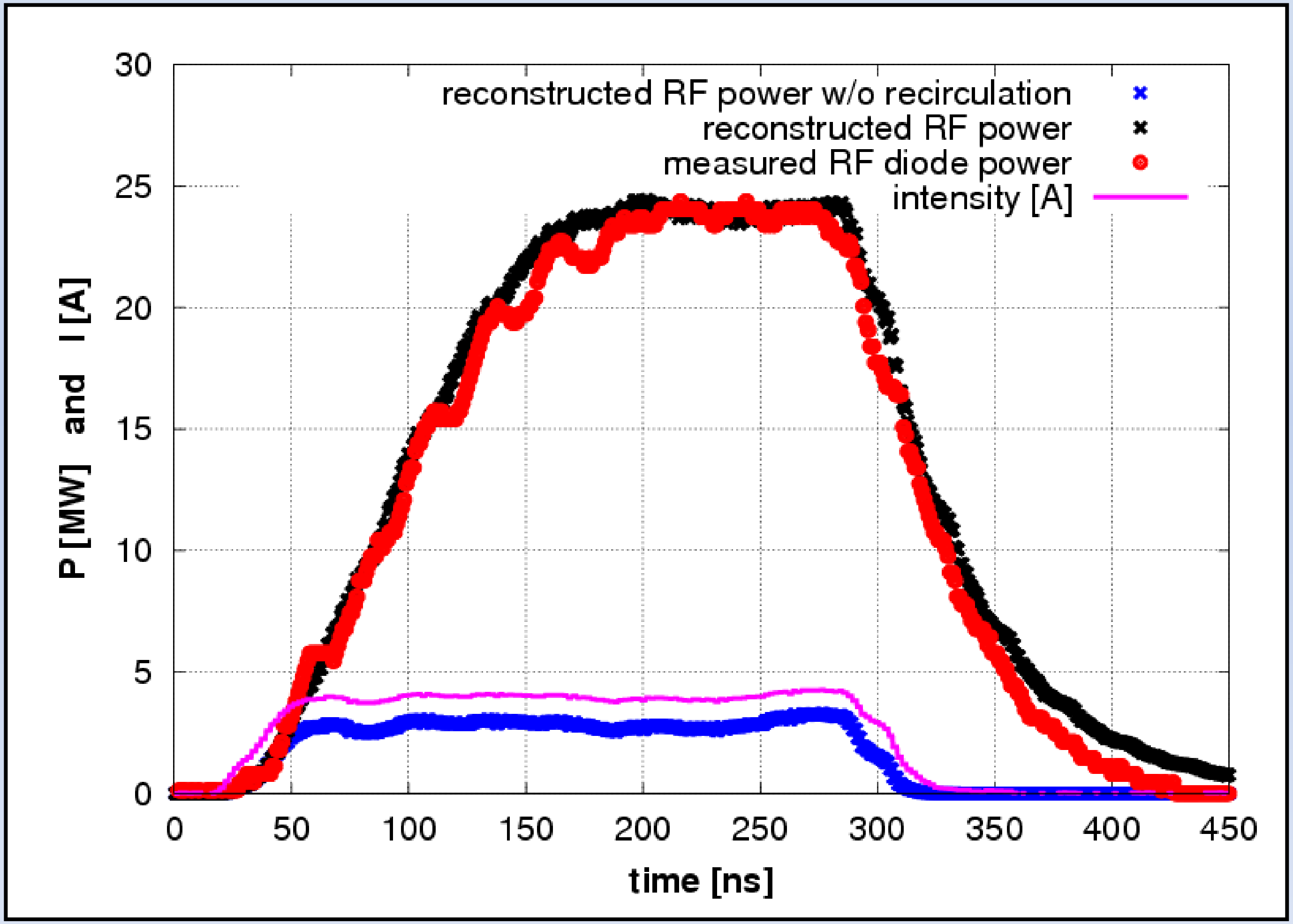
power amplification in the PETS: recirculation time is 26 ns



about 12 A, peak power is 190 MW

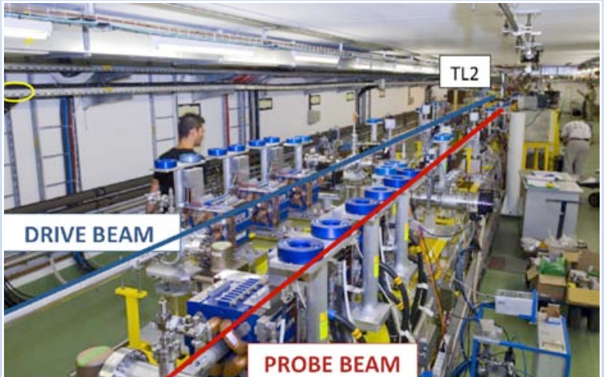
12 GHz PETS Conditioning

Total ~ 30 hours integrated conditioning time (15/11/2008 to 15/12/2008)



E. Adli, "Analysis of the first 12 GHz PETS tests with beam using a constant parameter recirculation model", CERN-CTF3 Note 096.

Two beam acceleration



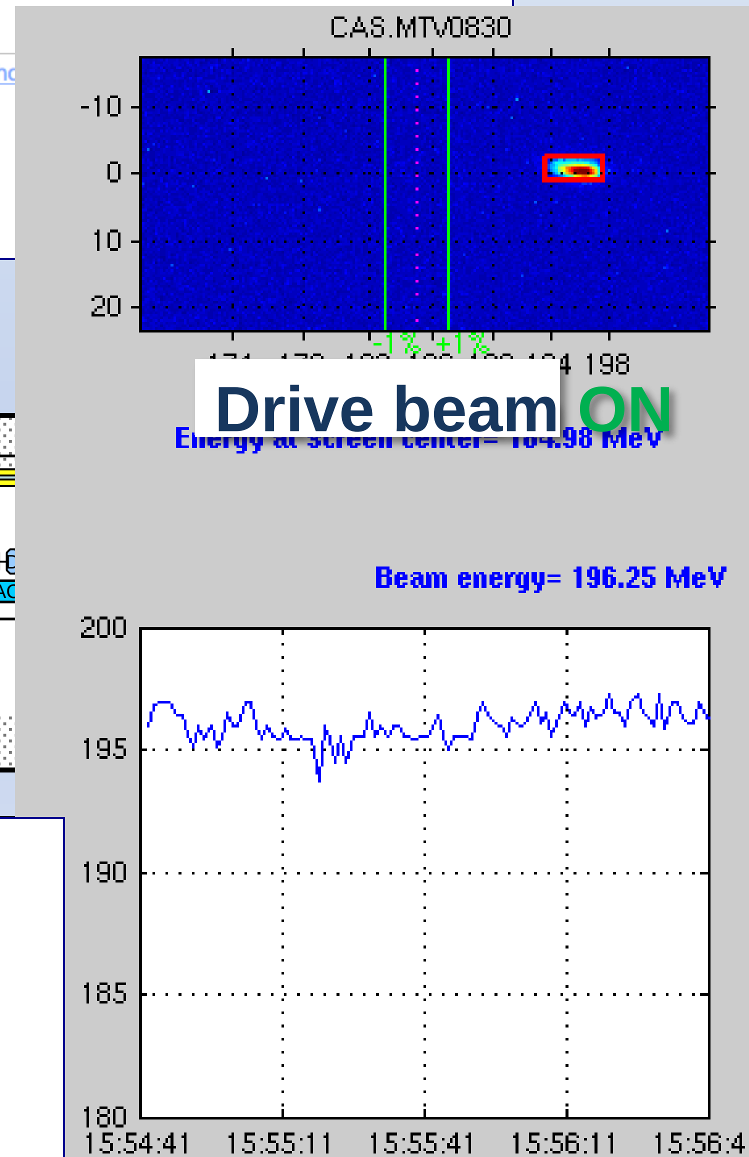
Two Beam Test Stand (TBTS)

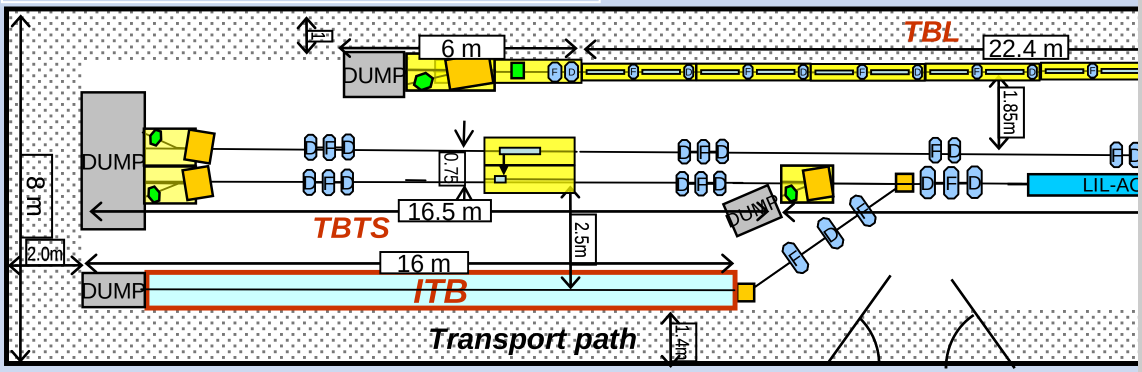
FW: Premiere acceleration du faisceau CALIFES dans une structure CLIC 12 GHz Inbox | X

Roger Ruber to Franck, Marta, Massi sho

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

Bonjour chers collegues,





Two beam acceleration optimized:

- Power
- Time
- Phase

up to 18 MeV gain so far gradient ~90 MV/m
(preliminary – calibrations being varified)

Summary of CTF3 Progress

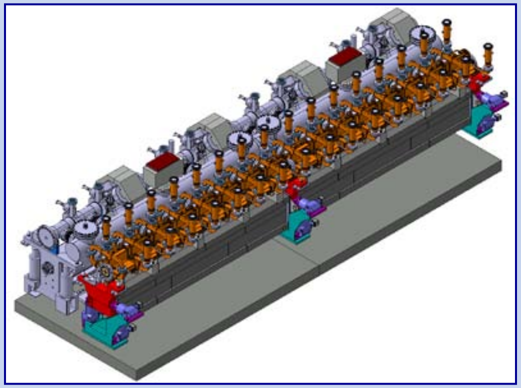
2009 / 2010 Achievements

- ✓ Successful drive beam generation ➔ 1,5 GHz to 12 GHz bunch spacing ➔ final beam of 28 Amps!
- ✓ Commissioning of CTF3 Probe Beam Califes
- ✓ Power production of 190 MW PETs structures
- ✓ 2-Beam acceleration demonstration 90 MV/m
- ✓ Installation of the first of 16 PETs in the TBL line and deceleration measurements

Next Steps for CTF3

- TBL drive beam deceleration studies (string of up to 16 PETS)
- Study of two-beam issues
  - RF breakdown kicks experiment
  - Beam loading compensation of probe beam

2010



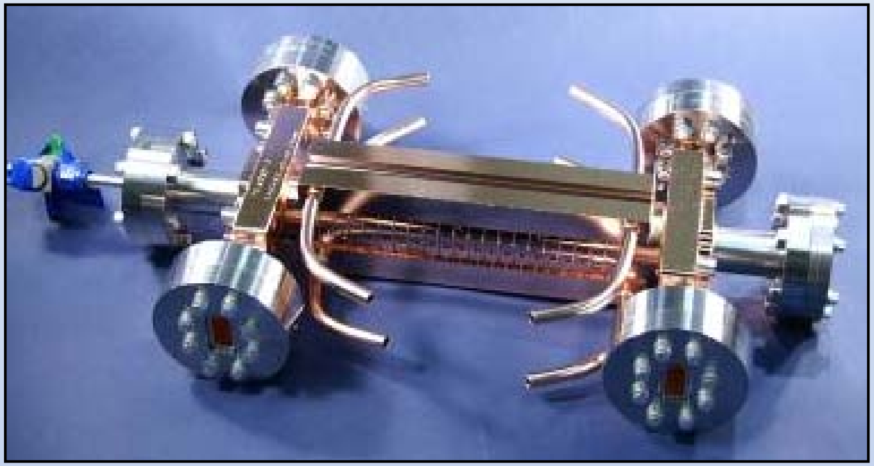
2012 +

- Photo-injector option full implementation
- Phase stability measurements & feed-forward tests
- CTF3 upgraded to X-band power production & testing facility
- Full-fledged CLIC modules beam tests in CLEX
- Instrumentation development for LC – Instrumentation Test Beamline

R. Corsini

Continued R&D on accelerating and decelerating structures

Accelerating structures – specifications

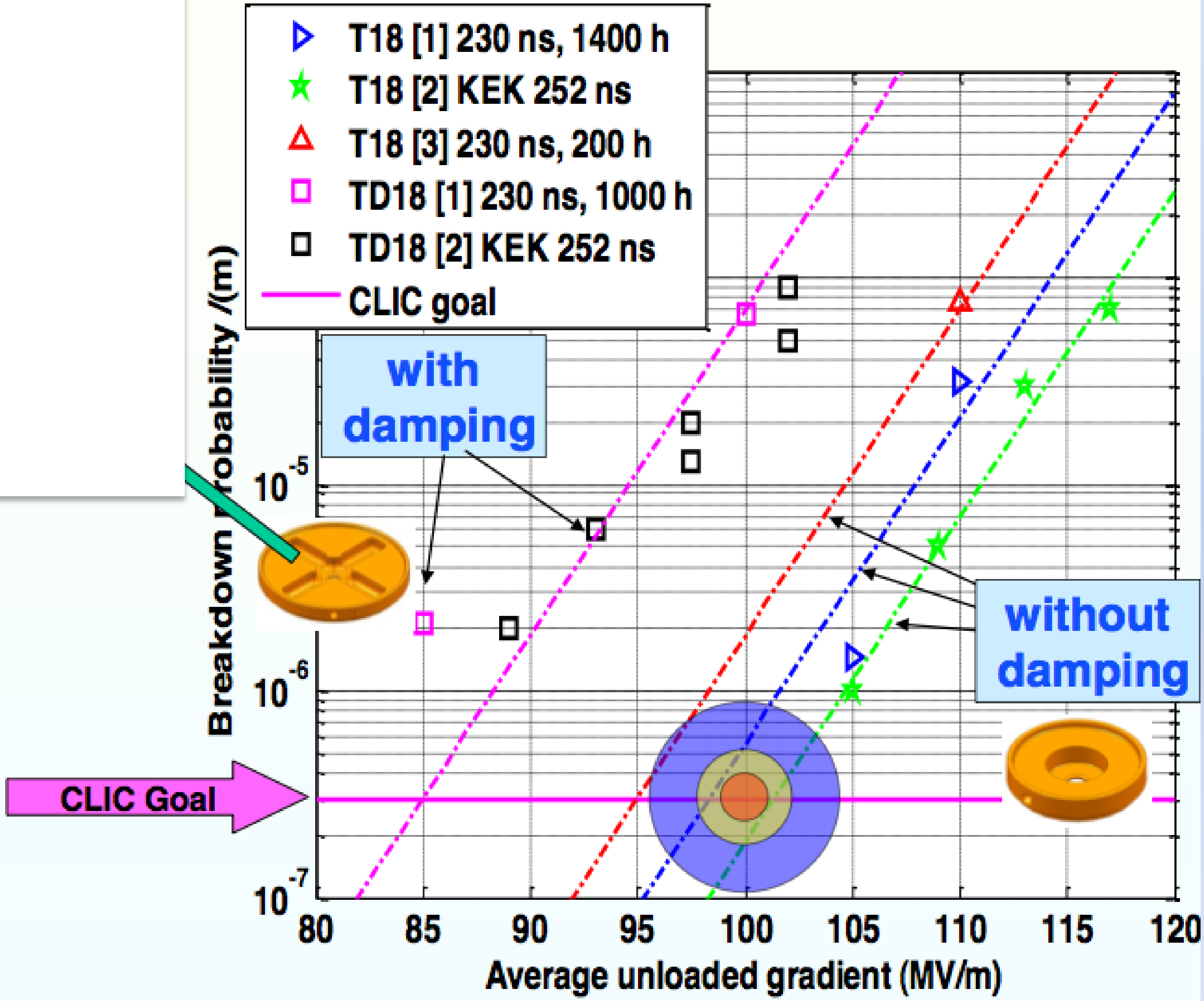


High-gradient:

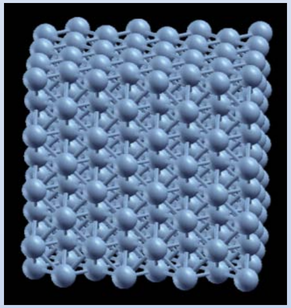
1. 100 MV/m loaded gradient
2. 170 (flat top)/240 (full) ns pulse length
3. <4x10^{-7} /pulse/m breakdown rate

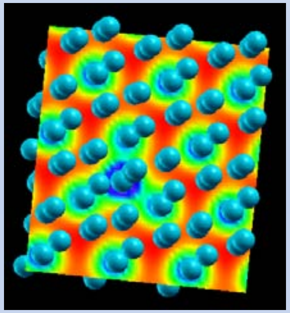
Beam dynamics:

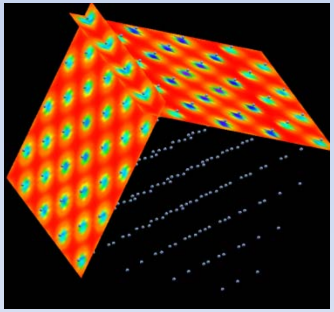
1. 5.8 mm diameter minimum average aperture (short range transverse wake)
2. < 1 V/pC/mm/m long-range transverse wakefield at second bunch (approximately x50 suppression).


T18 [1] 230 ns, 1400 h
T18 [2] KEK 252 ns
T18 [3] 230 ns, 200 h
TD18 [1] 230 ns, 1000 h
TD18 [2] KEK 252 ns
CLIC goal
with damping
without damping
CLIC Goal
Breakdown probability /(m)
10-5
10-6
10-7
80
85
90
95
100
105
110
115
120
Average unloaded gradient (MV/m)

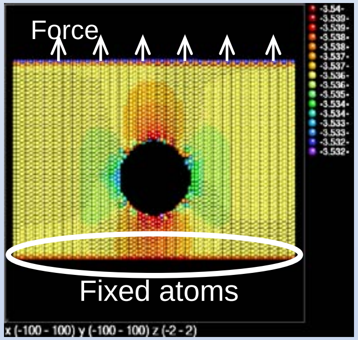
Multi-scale simulation of breakdown developed by the Helsinki Institute of Physics

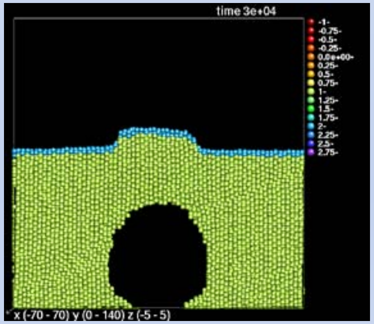


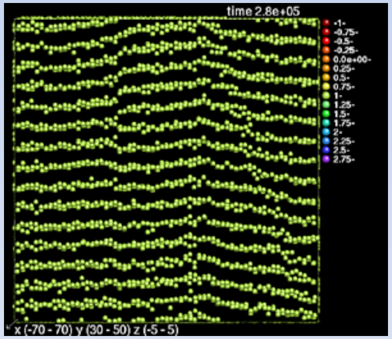




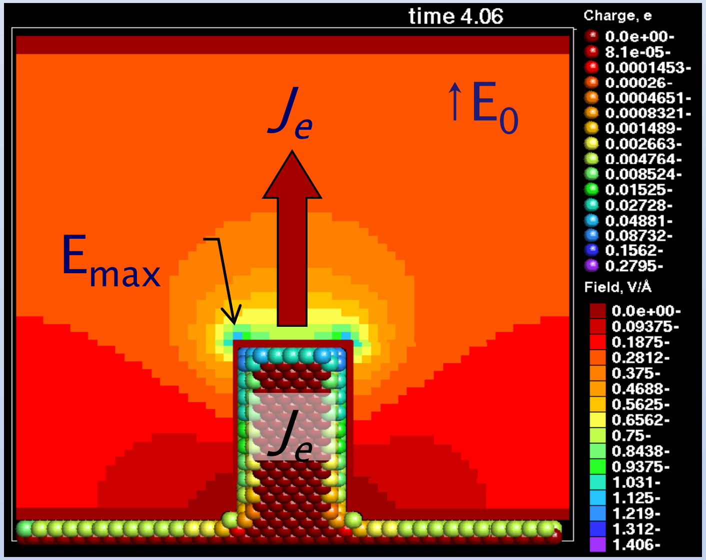
1. Calculation of charge distribution in crystal

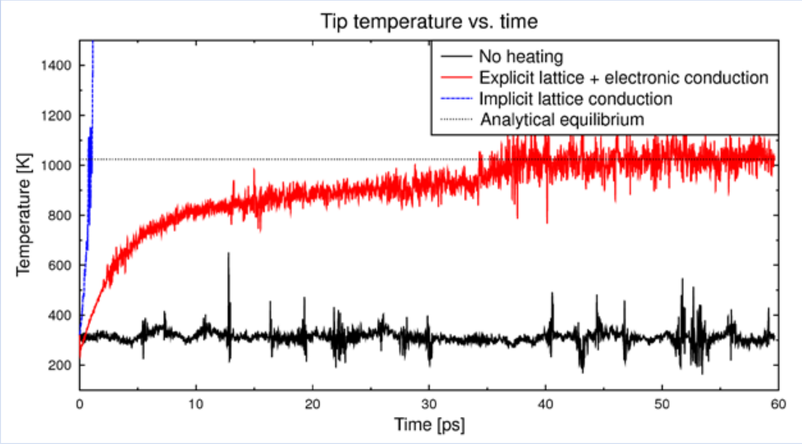






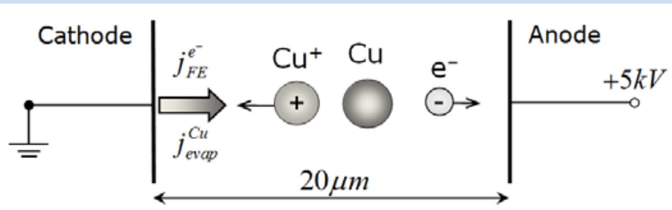
2. Emission site formation – breakdown rate

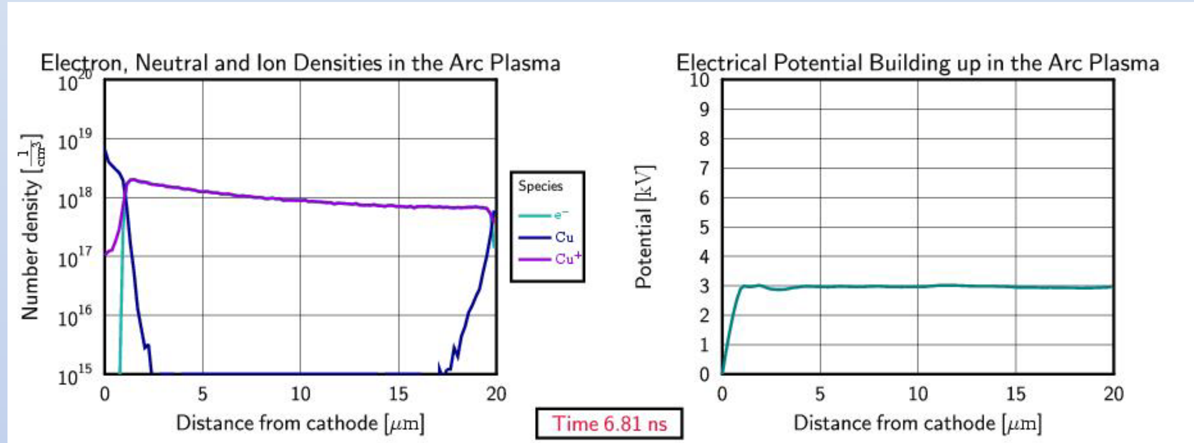




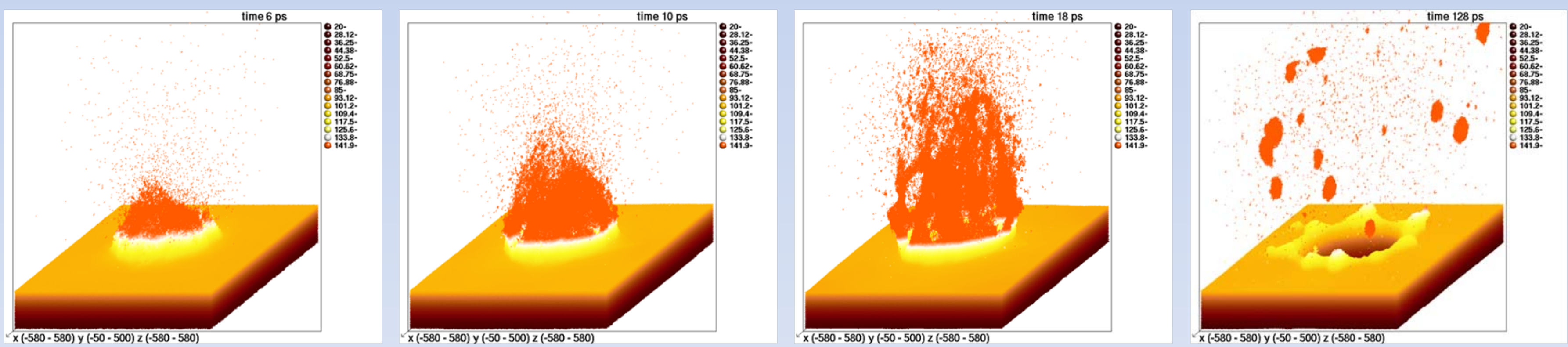
3. Field emission to breakdown trigger, including thermal effects

Multi-scale simulation of breakdown developed by the Helsinki Institute of Physics





4. Breakdown ignition and plasma formation

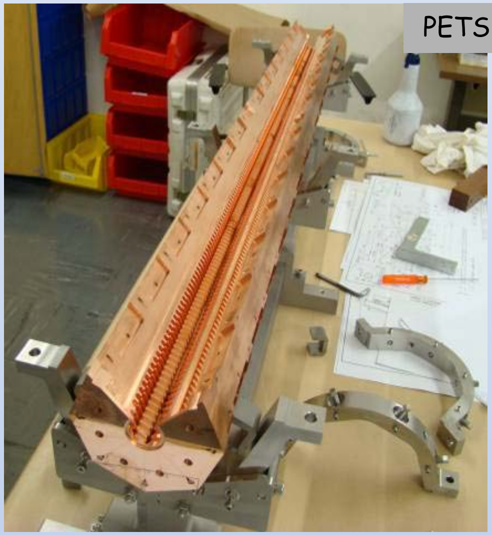


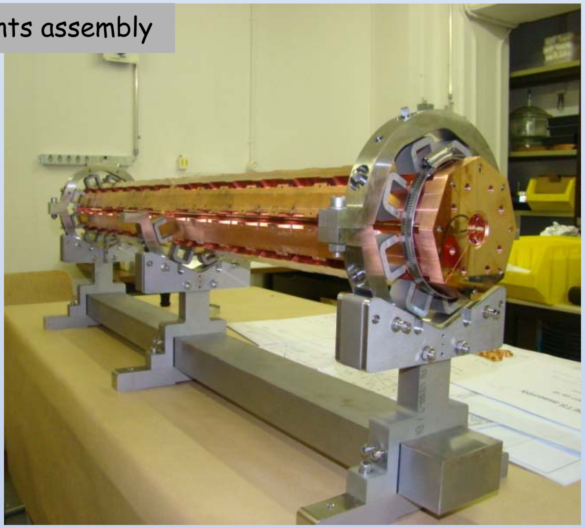
5. Surface damage mechanism

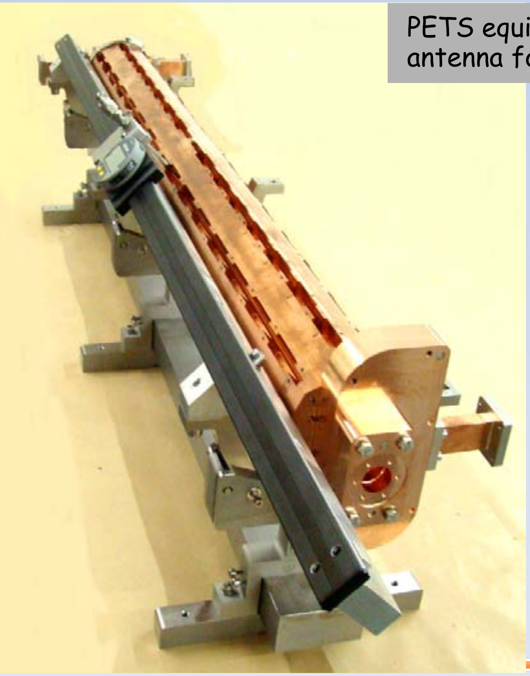
12 GHz PETS test assembly

8 bars, as received from VDL

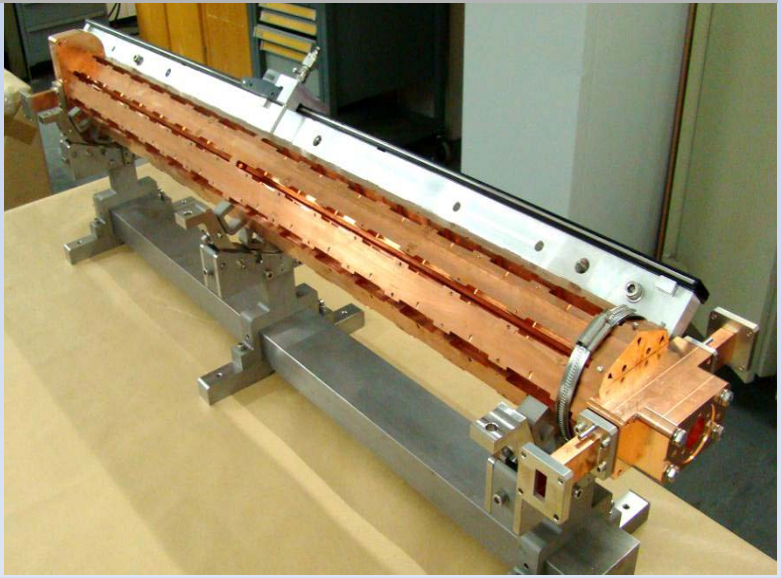
PETS octants assembly

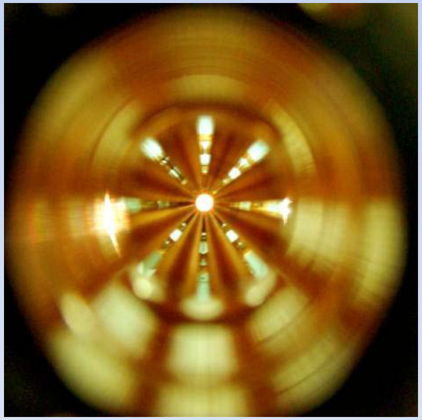






PETS equipped with the power couplers and electronic ruler with pick-up antenna for the phase advance measurements.





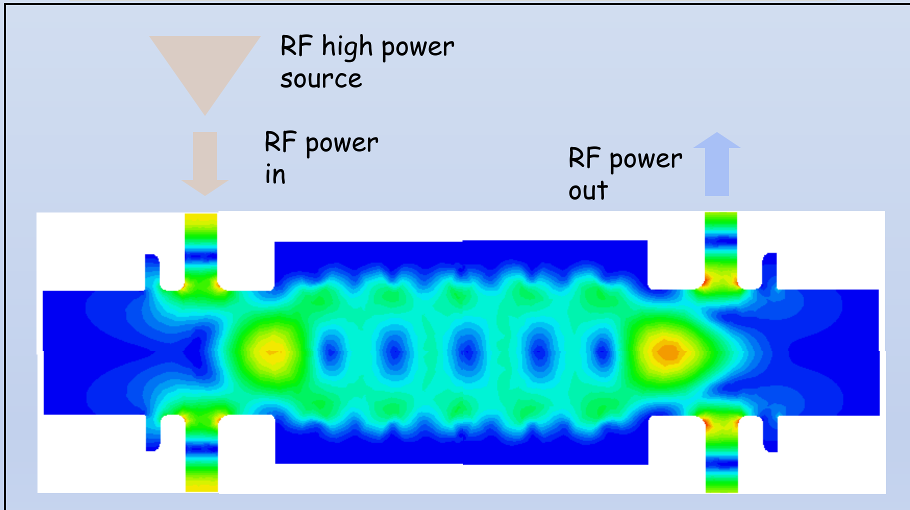
I. Syratchev

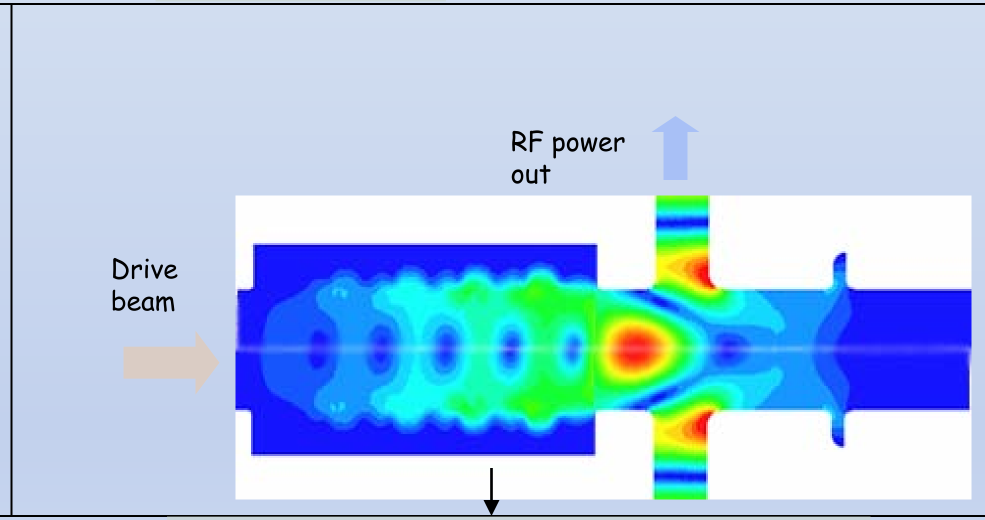
PETs testing program

RF power sources

External RF power source

Drive beam





CTF3 (CERN + Collaborations)

ASTA (SLAC)

Objective: to understand the limiting factors for the PETS ultimate performance.

• Access to the very high power levels (300 MW) and nominal CLIC pulse length.
• High repetition rate – 60 Hz.

Two beam test stand (CERN + Collaborations)

Objective: to demonstrate the reliable production of the nominal CLIC RF power level throughout the deceleration of the drive beam.

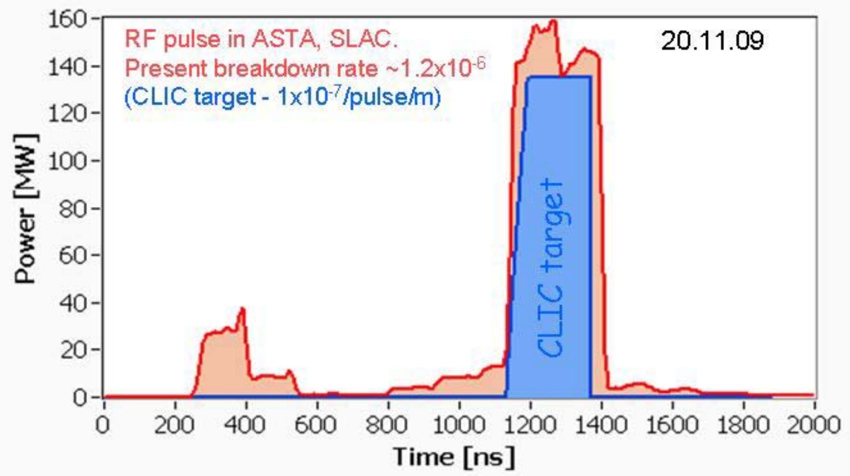
Test beam line (CERN + Collaborations)

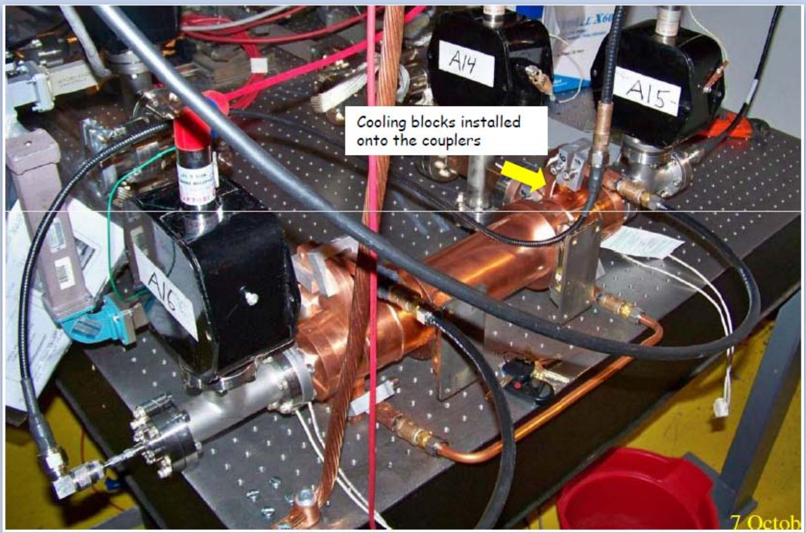
Objective: to demonstrate the stable, without losses, beam transportation in a presence of the strong (.50%) deceleration.

I. Syratchev CLIC'09

PETS Results

Klystron based testing:

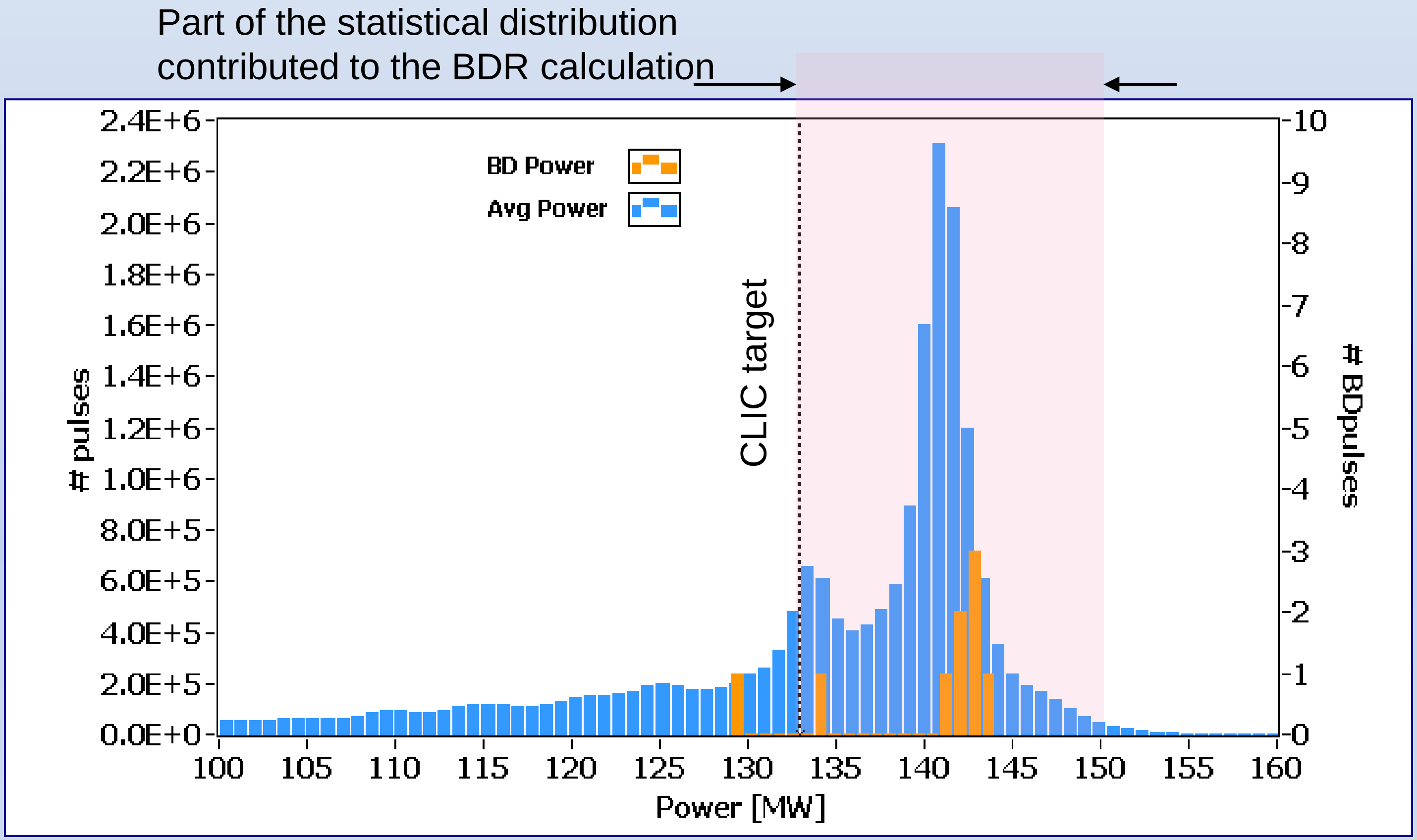




Beam based (with recirculation):

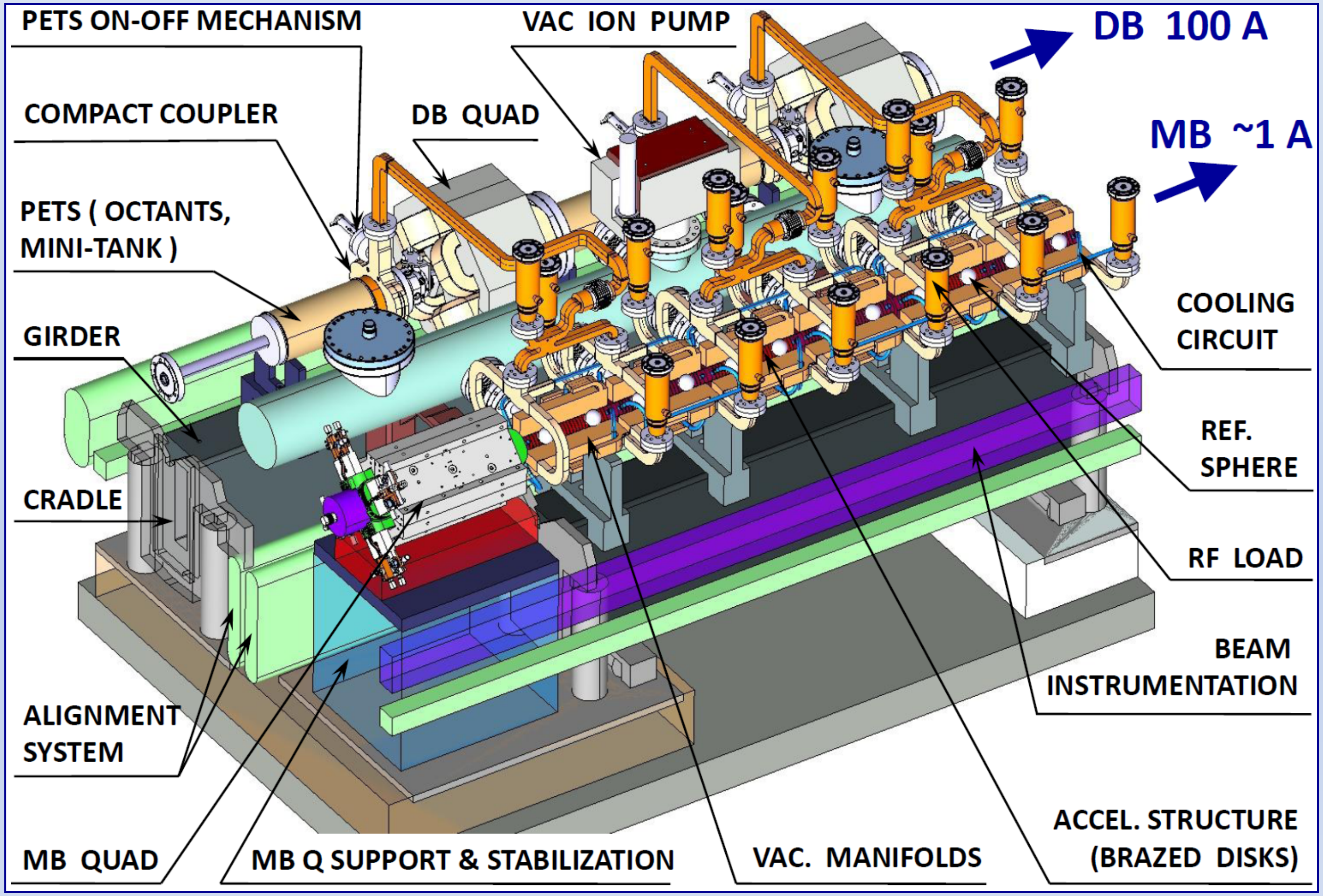
- Power
  - 130 MW peak at 150 ns
  - Limited by attenuator and phase shifter breakdowns
  - Power production according to predictions

Extraction of PETS breakdown trip rate



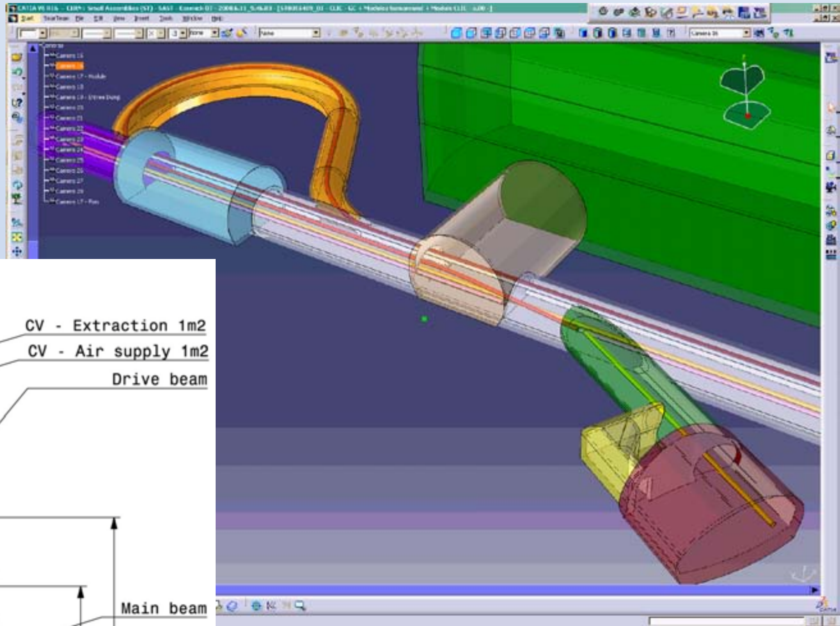
- 1.6×10^7 pulses were accumulated in a 110 hour run.
- 8 PETS breakdowns were identified giving a breakdown rate of **5×10^{-7}/pulse**.
- Most of the breakdowns were located in the upper tail of the distribution, which makes BDR estimate rather conservative.
- During the last 80 hours no breakdowns were registered giving a BDR **<1.2×10^{-7}/pulse**.

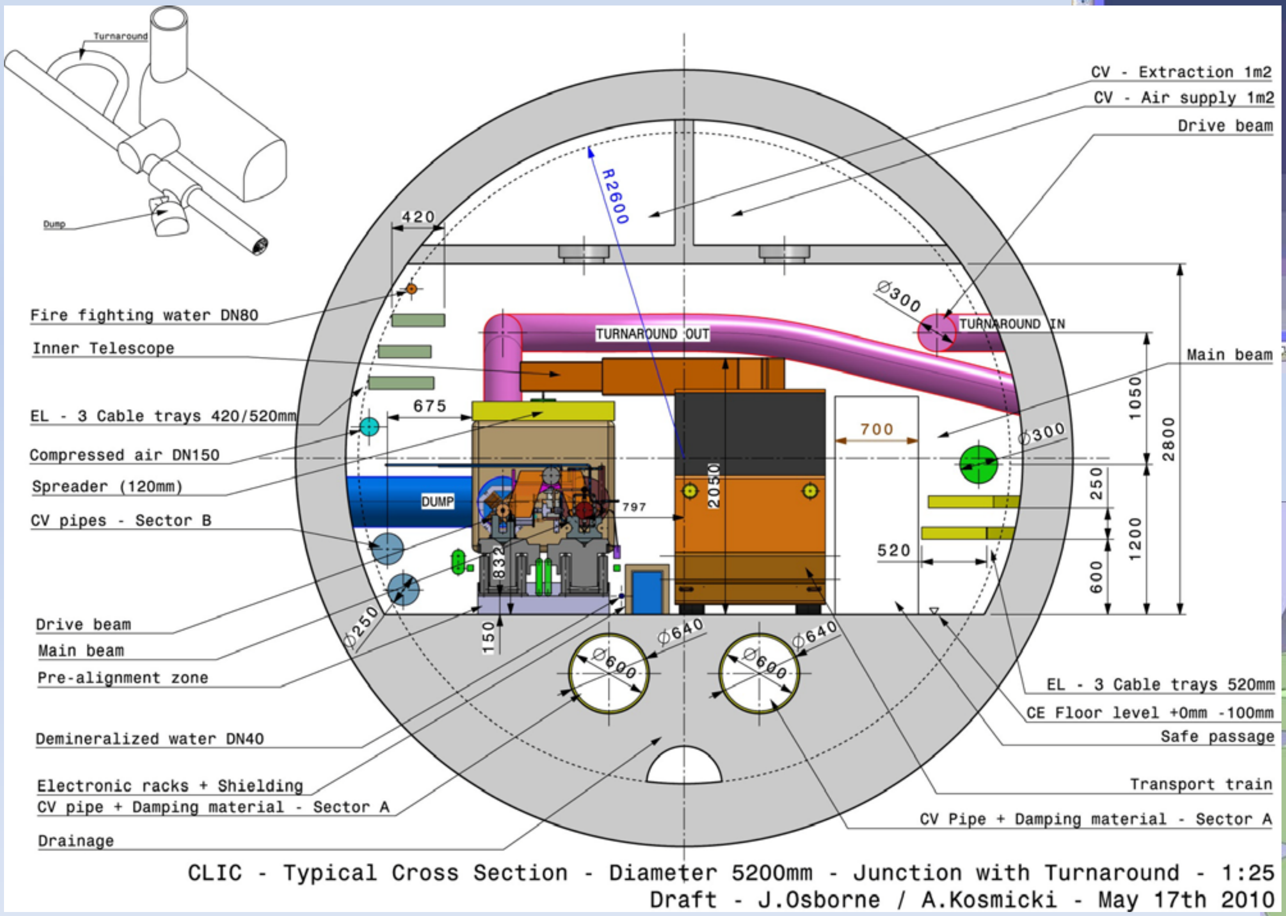
CLIC Module



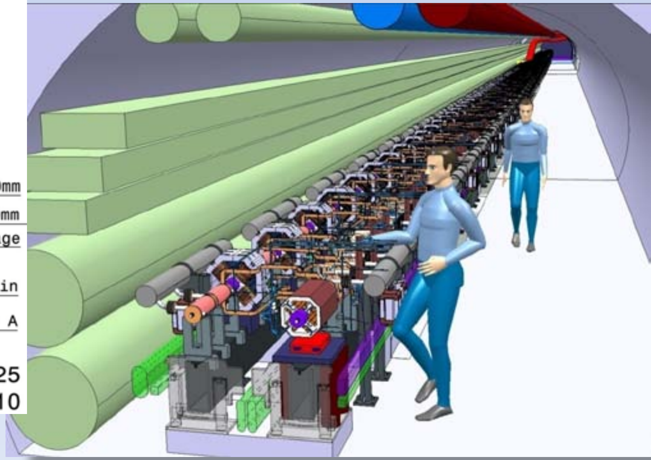
- Test module representative of all module types integrating all various components: RF structures, quadruples, instrumentation, alignment, stabilization, vacuum, etc.…
- Prototype CLIC-type module suitable for CTF3 will be install in CTF3 in Two Beam Test stand 2012

Tunnel Integration

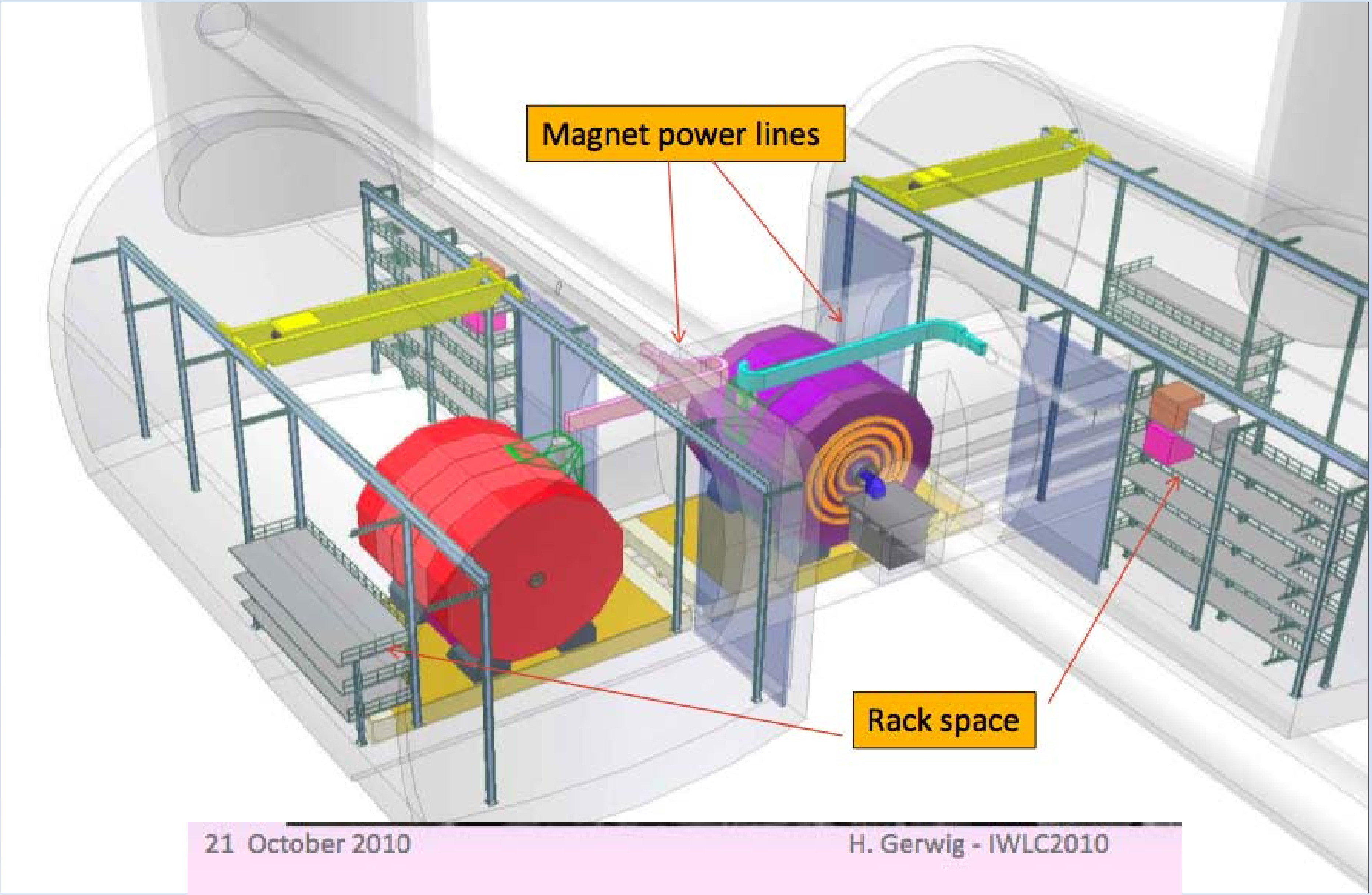




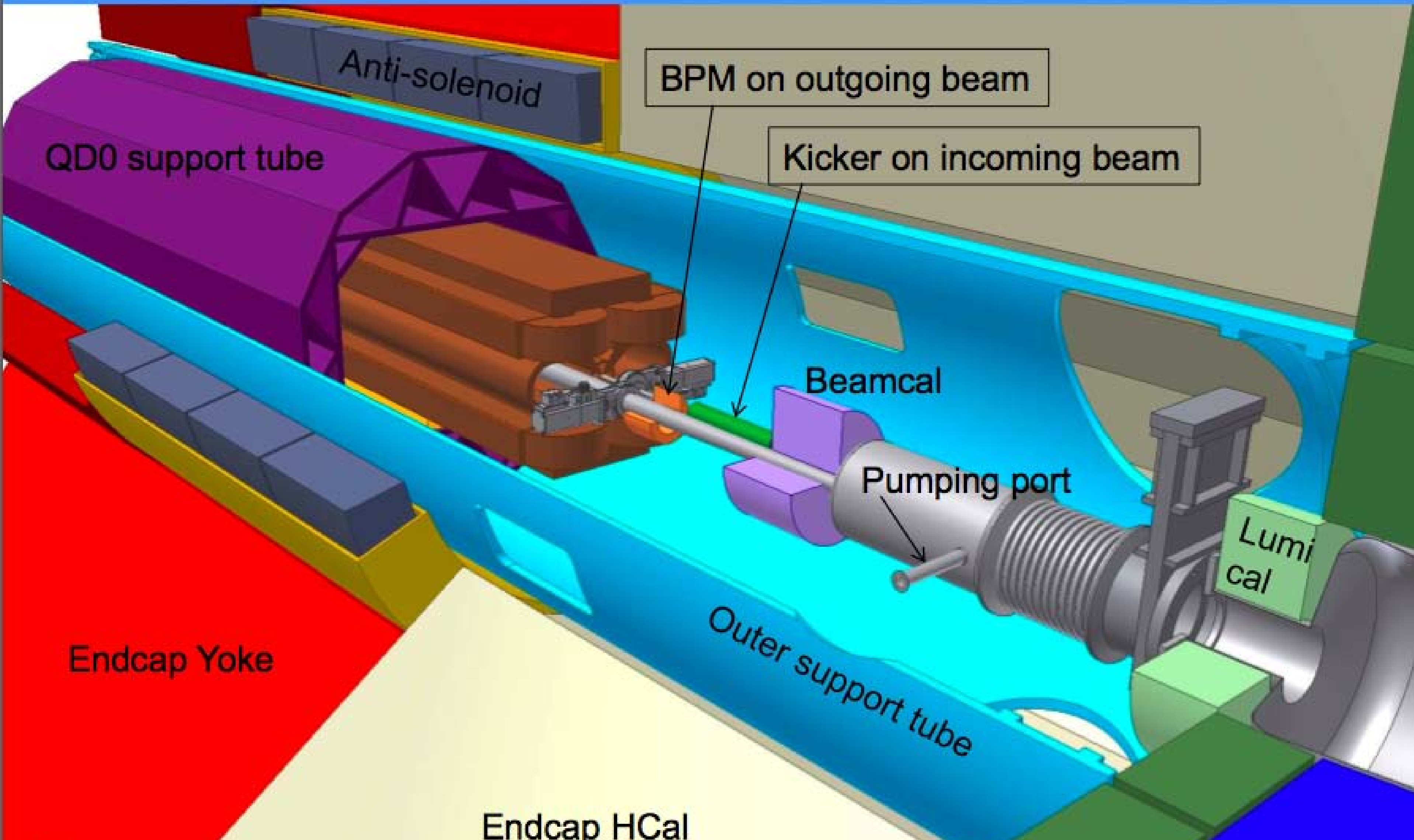
(Courtesy John Osborne)



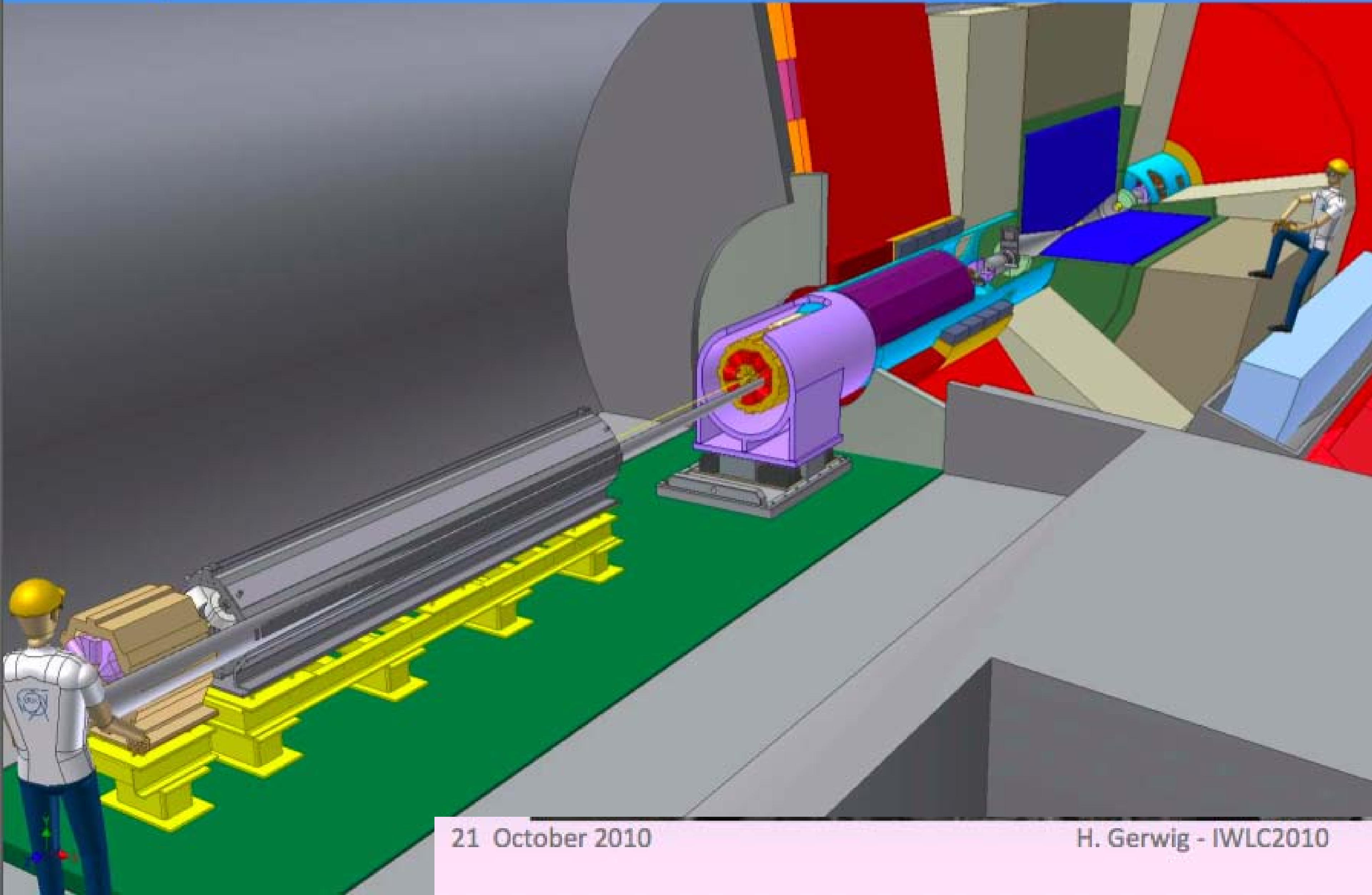
Detector push – pull system



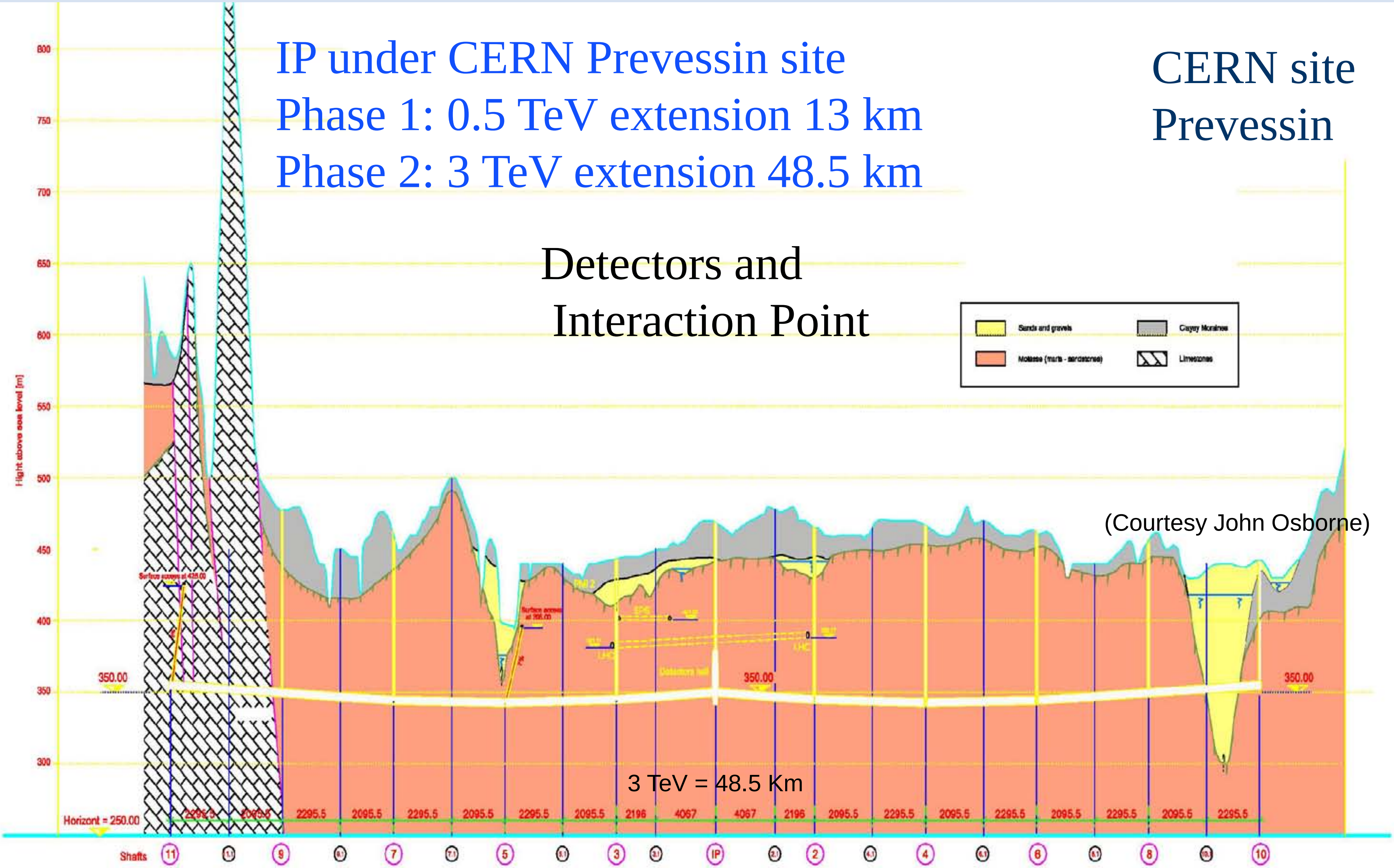
Layout Inner and Outer Support Tube



Detector on IP seen from tunnel

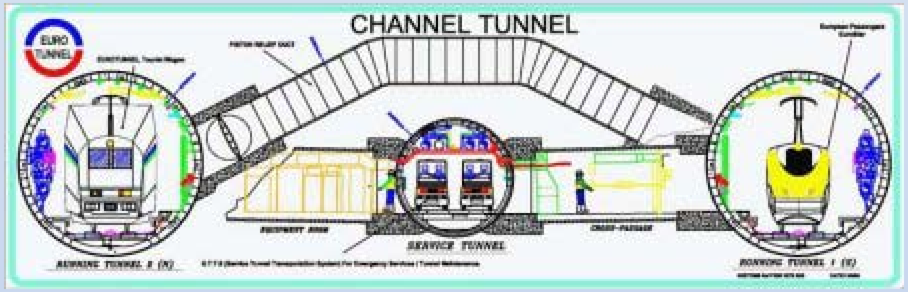


A Potential machine site



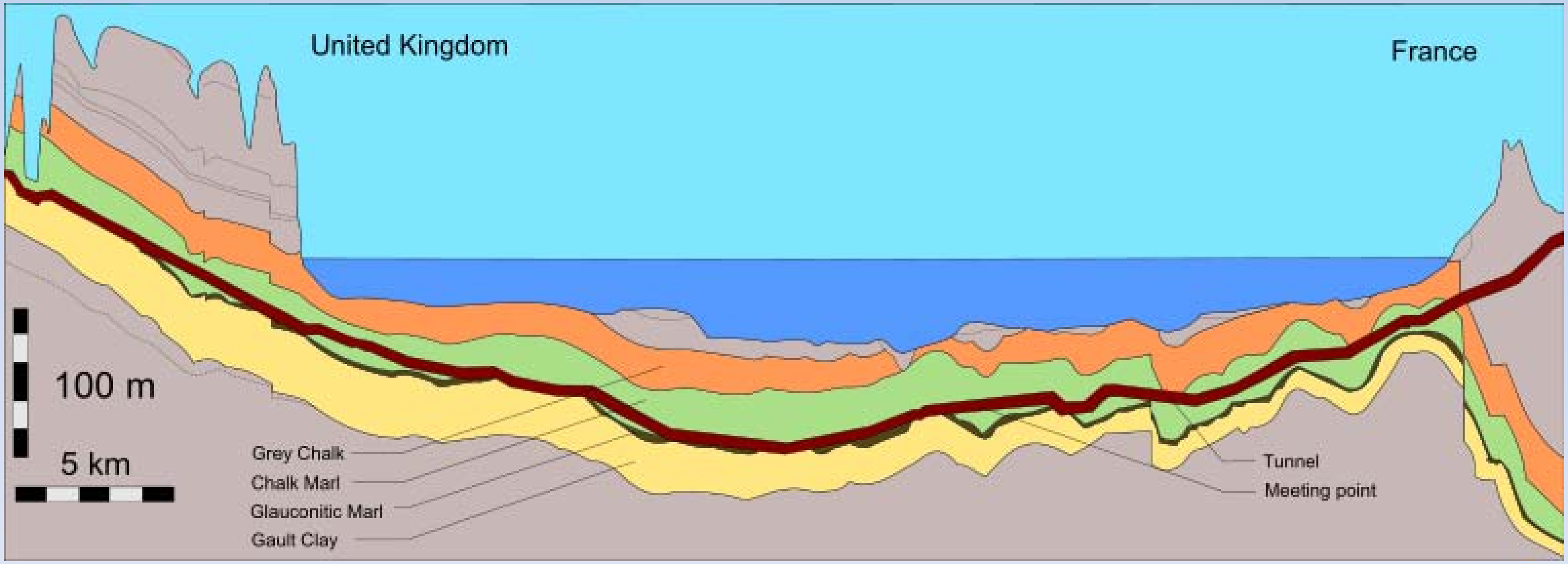
Longitudinal section of a laser straight Linear Collider on CERN site

For CLIC & ILC, similar World Projects: Channel Tunnel

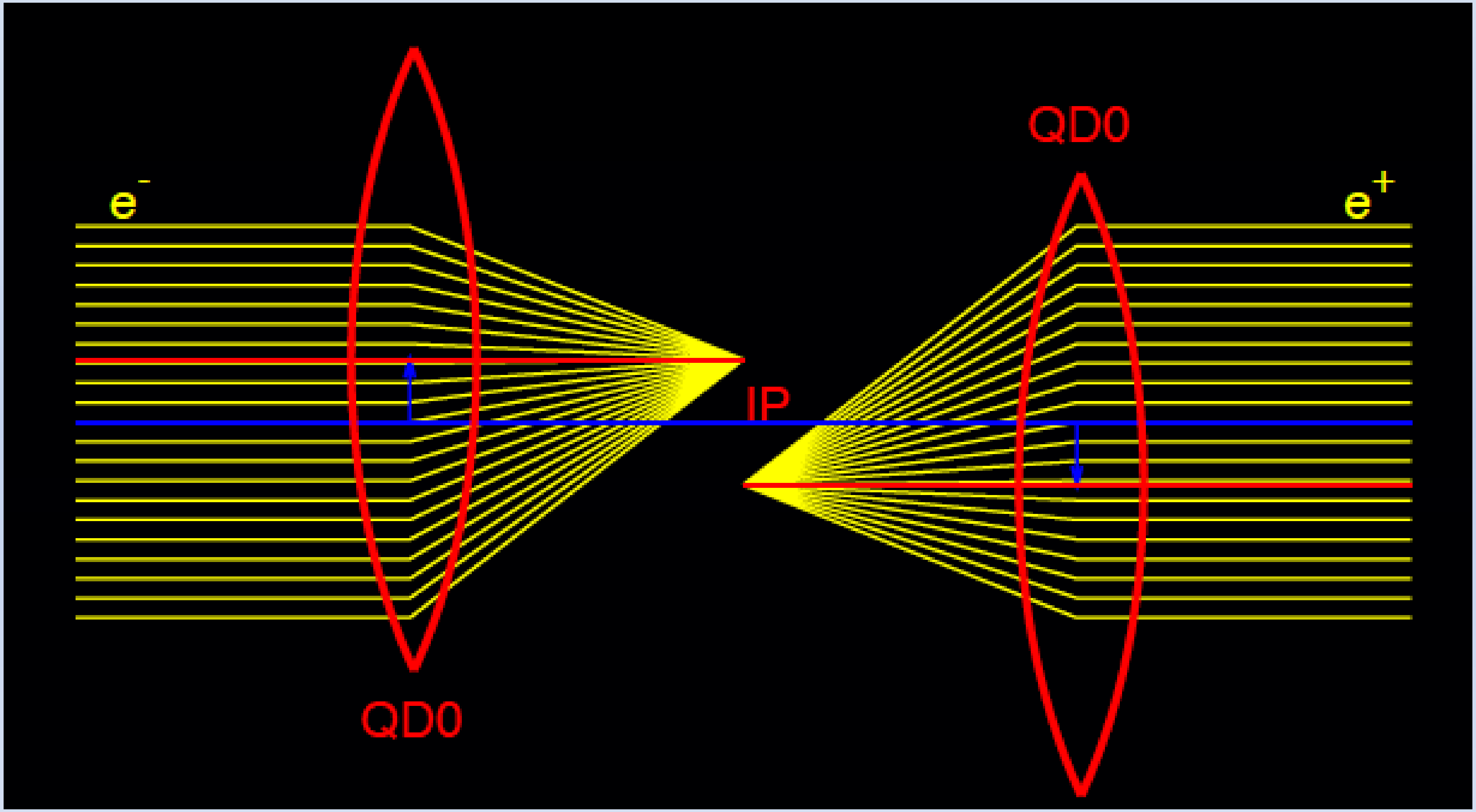


7.6mØ 4.8m Ø 7.6mØ

50Km

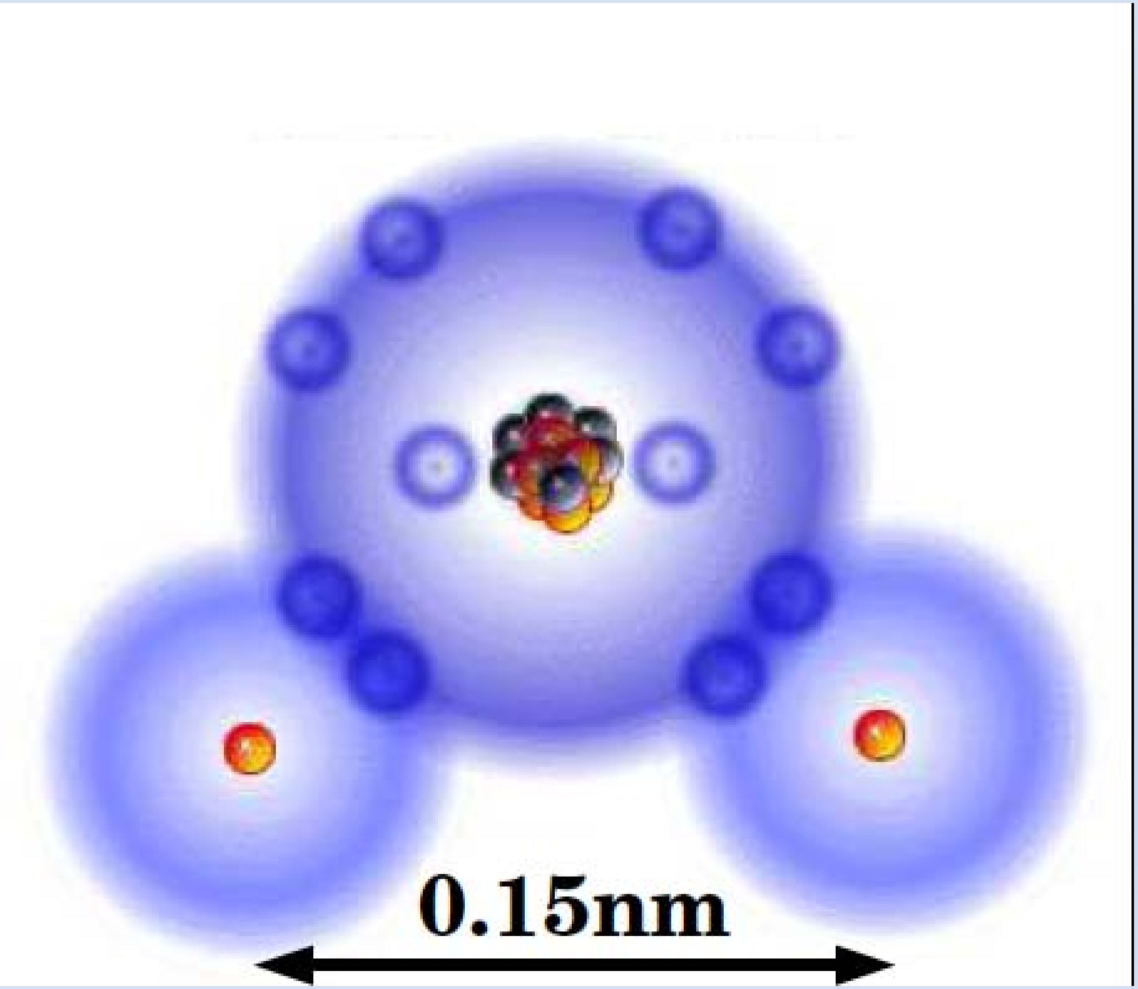


Other technological challenges

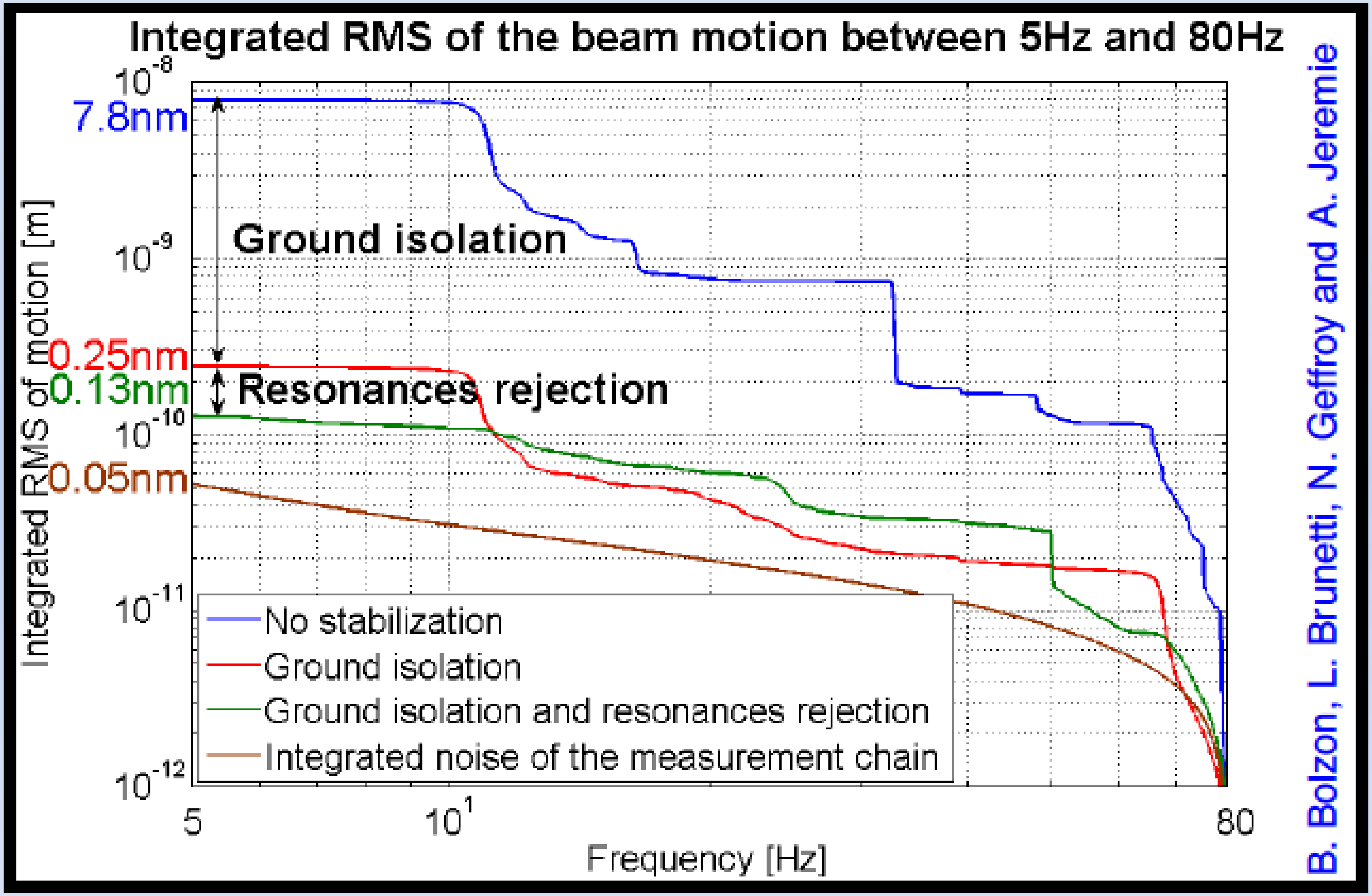


The final focusing quadruple should be stabilized to 0.15 nm for frequencies above 4 Hz

Other technological challenges

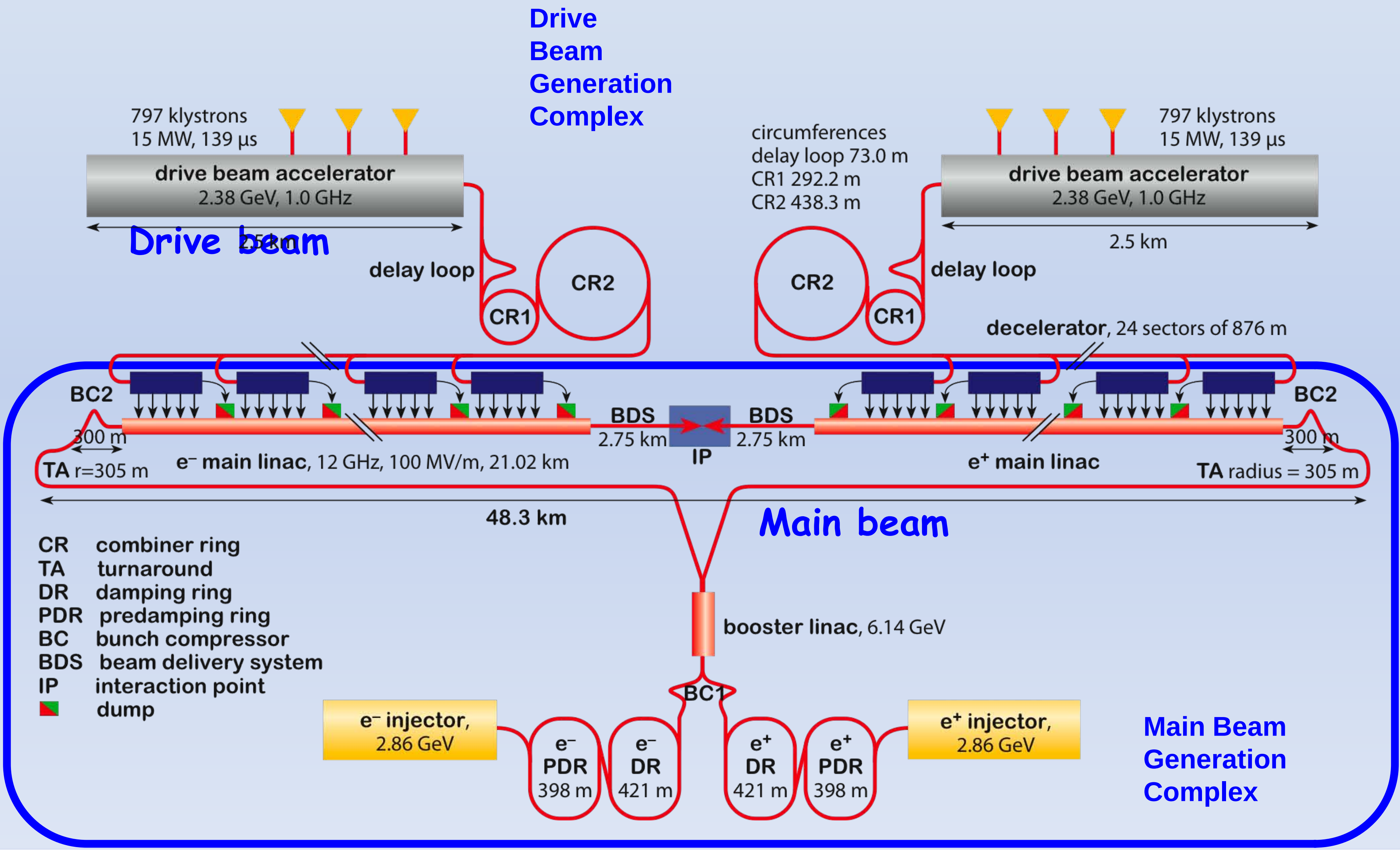


0.15 nm, small as a H_20 molecule !

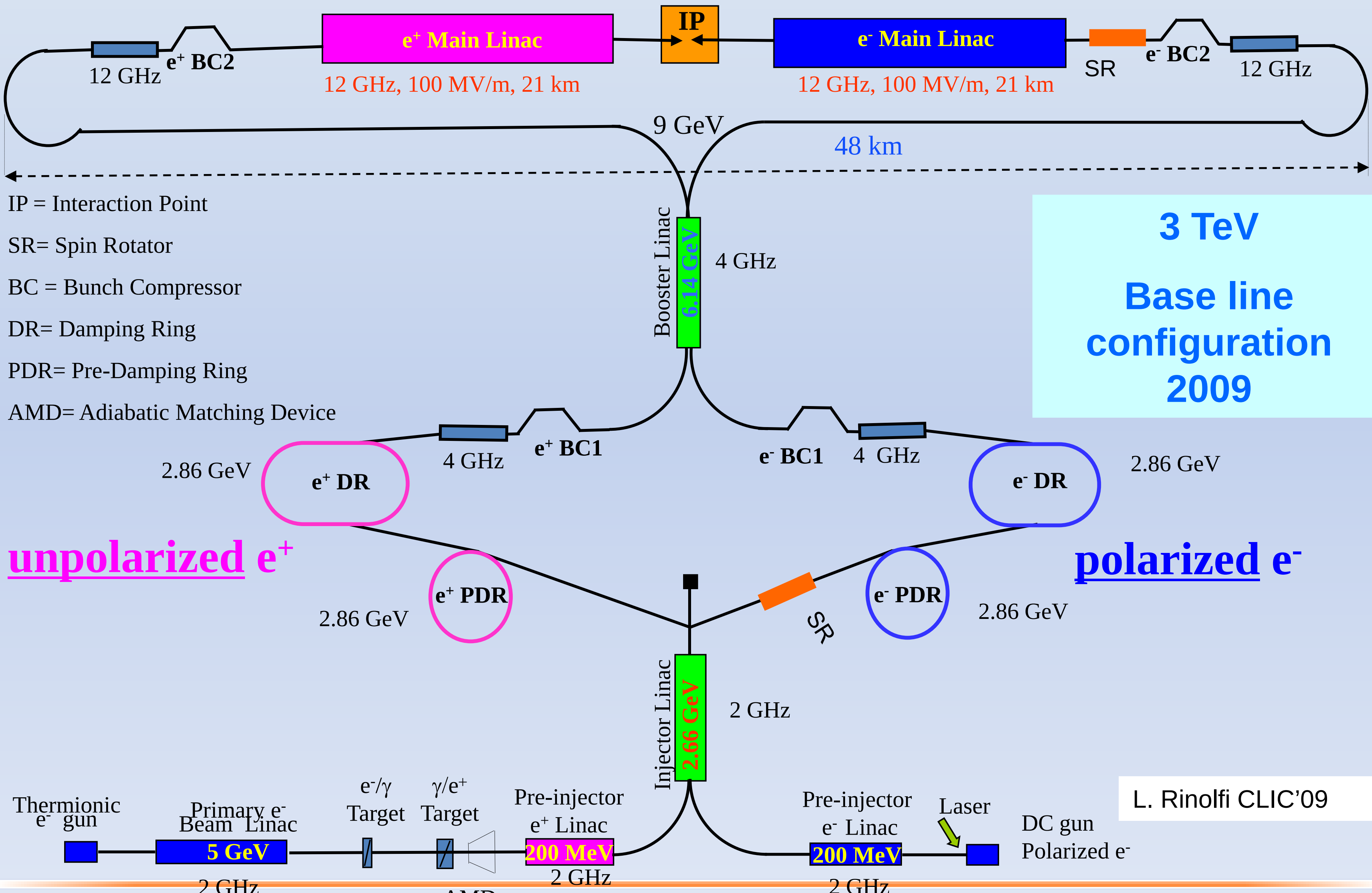


- ✓ 0.13 nm reached in the laboratory
  - ➢ challenge remains to prove 0.15 nm within the detector !

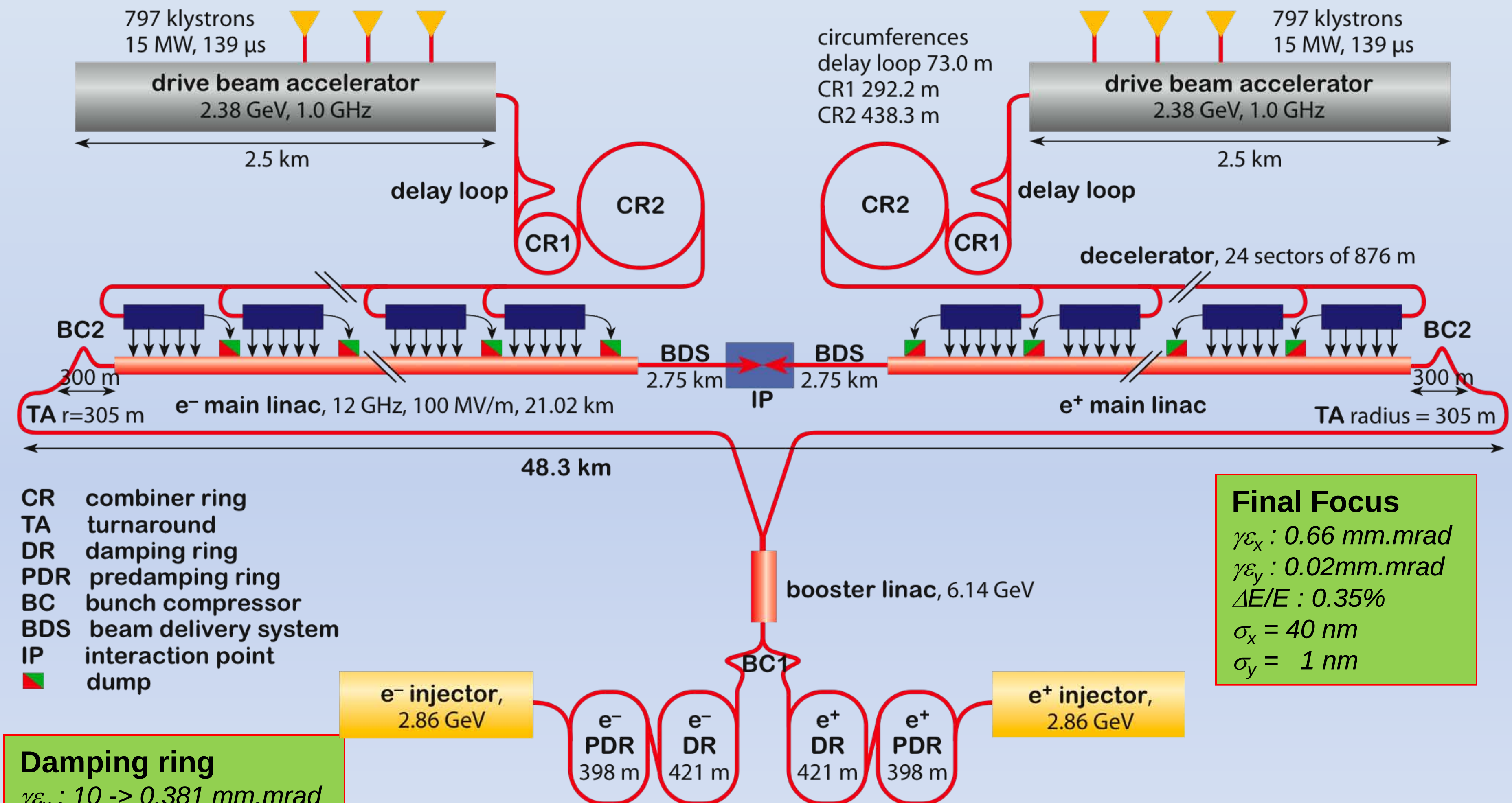
General Layout of Complex



CLIC Main Beam Injector Complex



Instrumentation for CLIC



Final Focus

$\gamma\varepsilon_x$: 0.66 mm.mrad
$\gamma\varepsilon_y$: 0.02mm.mrad
$\Delta E/E$: 0.35%
σ_x = 40 nm
σ_y = 1 nm

Damping ring

$\gamma\varepsilon_x$: 10 -> 0.381 mm.mrad
$\gamma\varepsilon_y$: 10 -> 0.004 mm.mrad
$\Delta E/E$: 0.134%
σ_z : 1.5mm (5ps)

More than 200kms of beamline requiring > **50 000 instruments**

Today’s Work Plan

- Demonstrate feasibility of CLIC technology (R&D on critical feasibility issues)
- Design of a linear collider based on CLIC technology
- Estimation of its cost (capital investment & operation)
- CLIC Physics study and detector development

Conceptual Design Report to be published in mid-2011 including:

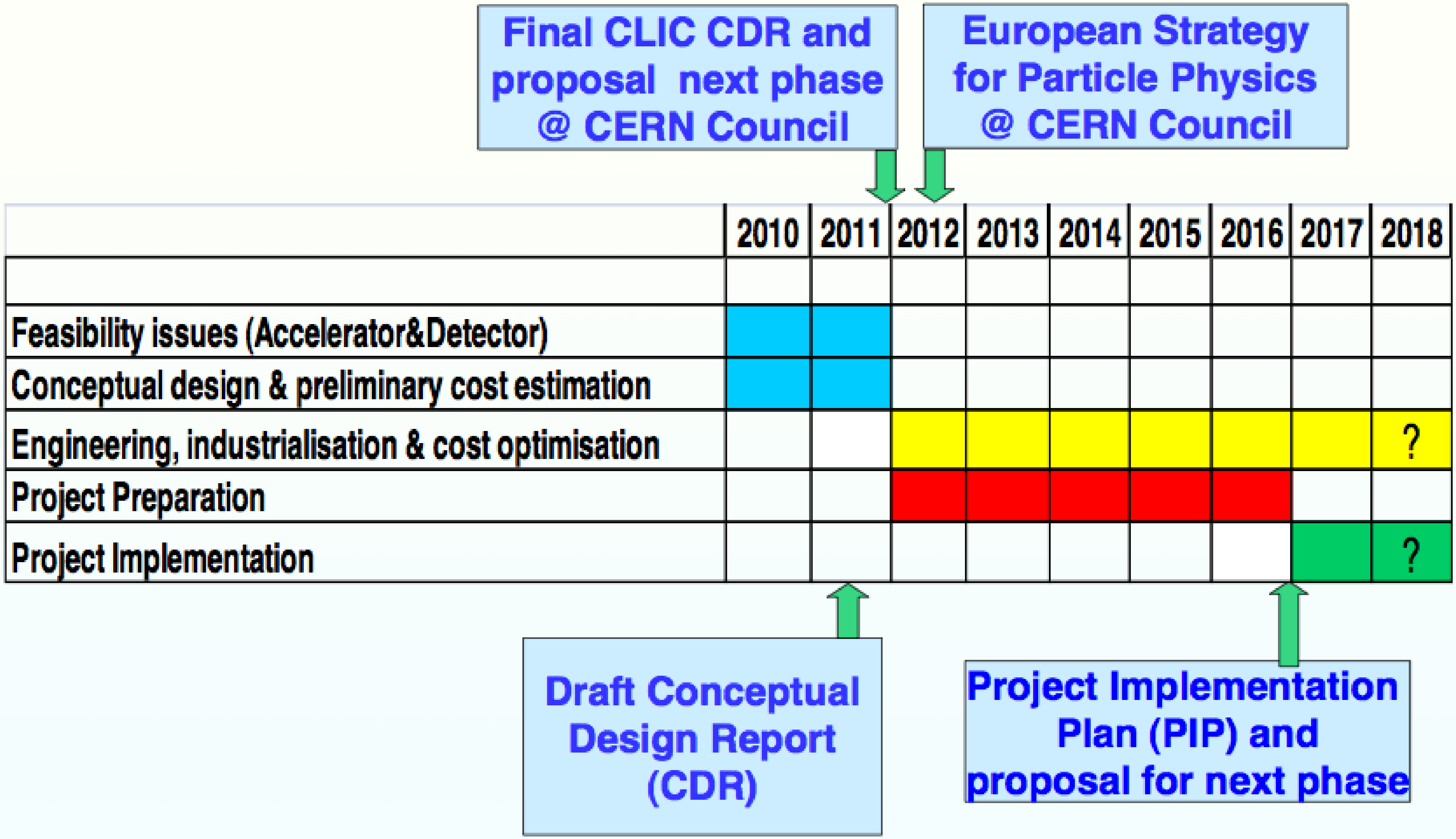
- Physics, Accelerator and Detectors
- Results of feasibility study
- Preliminary performance and cost estimation

R&D Issues classified in **three** categories:

- critical for feasibility → fully addressed by specific R&D to be completed before mid 2011 results in CDR
- critical for performance — being addressed now by specific R&D to be completed before 2016 first assessments in CDR [see R. Corsini IWC2010, TDR phase]
- critical for cost → results in Technical Design Report (TDR) with consolidated performance & cost

R. Corsini

CLIC Tentative Schedule



Acknowledgements

Thank you to my CLIC colleagues for use of their slides

Especially … R. Corsini, F. Tecker, S. Bettoni, L. Linssen, R. Tomás, J.P. Delahaye, I. Syratchev, H. Schmickler, T. Lefèvre, G. Riddone, W. Wuensch, S. Doebert, L. Rinolfe, D. Schulte, A. Andersson, R. Ruber, E. Adli,

A project plan is being developed

IWLC 2010

R. Corsini, CLIC TDR plans 10/20/2010

Work Plan for the next years:

- We need the help of present – and new – collaborators, in order to:
  - Revise, improve and better refine the technical plan
  - Provide additional resources

~50 FTE

~60 MCHF

Please send your expressions of interest to us at clic-tdr-contributions@cern.ch

Before 2011

CDR (2011), CLIC feasibility established

2011-2016 – Project Preparation phase

This is the current focus for planning in the collaboration, with main activities covering:
- review of the CLIC baseline design, taking into account CDR results and including:
  - cost & power consumption optimization
  - energy staging
  - technical risks and performance risks
- technical developments and test of critical component prototypes, using several facilities across the collaboration
- exploitation and upgrade of CTF3 to CTF3+, construction and commissioning of CLIC drive beam injector
- detector and physics studies
- site studies
- preparation of a Project Implementation Plan (PIP) for CLIC

This phase will culminate with a document, or several, covering the points above, with a detailed plan for the next phase

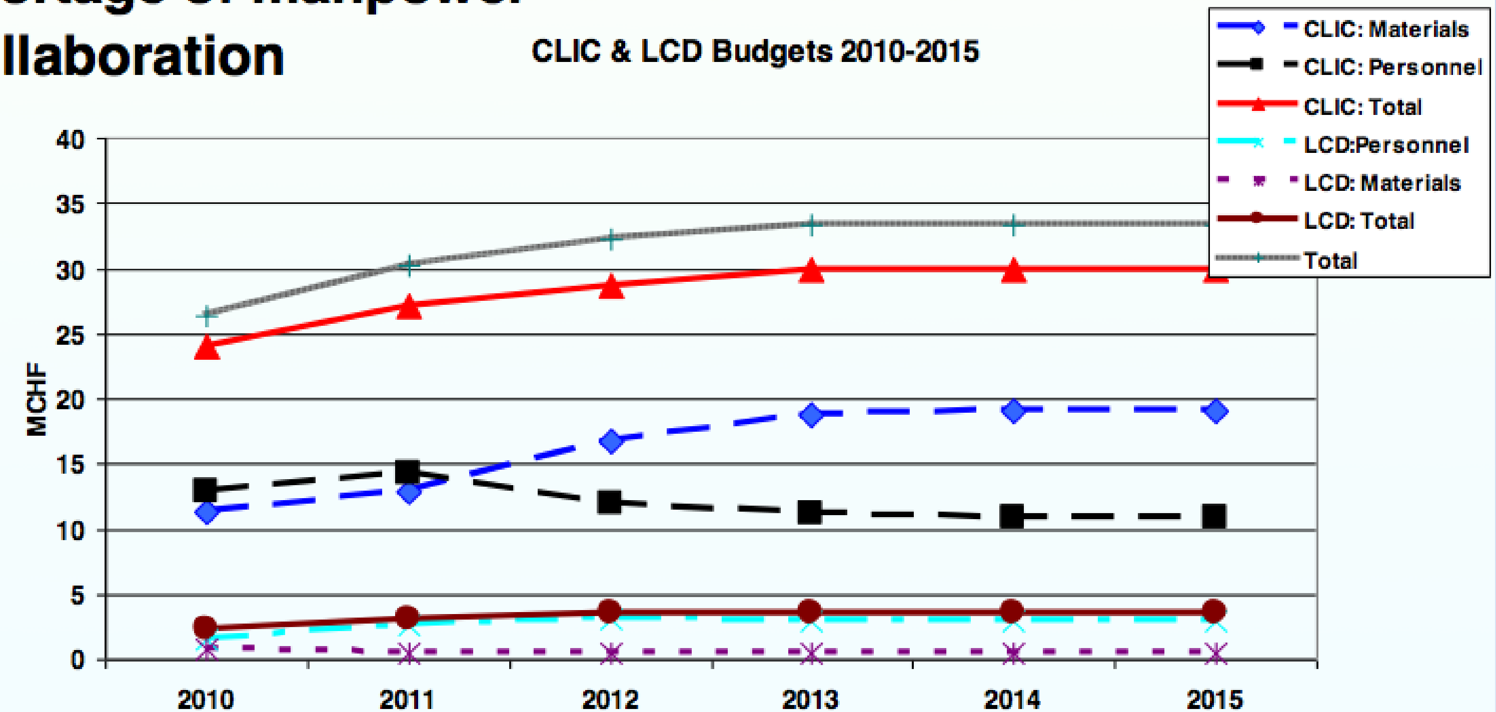
After 2016 – Project Implementation phase, including an initial period to lay the grounds for full approval

Considering the preparation steps foreseen and the resources situation it is clear that several key tasks will need further effort before the project can move into construction:
- finalization of the CLIC technical design, taking into account:
  - results of technical studies done in the previous phase
  - final energy staging scenario based on the LHC Physics results, which should be fully available by the time
- possible construction of CLIC Zero as first CLIC phase
- industrialization and pre-series production of large series components with validation facilities
- further detector and physics studies, with increased emphasis on technical coordination issues and integration
- revision of the Project Implementation Plan (PIP) of CLIC, following the energy staging strategy and detailed resource discussion with all partners – providing the basis for a staged or full approval, and subsequent construction start up

During this initial period we will need to produce the necessary documents to support a proposal for CLIC construction start-up

Resources from CERN midterm plan

- **Increase in resources for CLIC**
  - **Materials 11.9→19.0MCHF**
  - **Personnel 12.8→10.9MCHF**
    - **Overall increase ~60%**
  - **but**
    - **Shortage of manpower**
    - **Collaboration**



Extra slides

CLIC Main Parameters

High gradient to reduce cost

- Break down of structures at high fields and long pulses
  - Pushes to short pulses
  - and small iris radii (high wakefields)

High luminosity

- Improve wall plug to RF efficiency
- Push RF to beam efficiency
  - Push single bunch charge to beam dynamics limit
  - Reduce bunch distance to beam dynamics limit
- Push specific luminosity -> High beam quality
  - Beam-based alignment and tuning
  - Excellent pre-alignment
  - Component stabilisation

		CLIC	CLIC	ILC
E_{cms}	[TeV]	0.5	3.0	0.5
f_{rep}	[Hz]	50	50	5
f_{RF}	[GHz]	12	12	1.3
G_{RF}	[MV/m]	80	100	31.5
n_b		354	312	2625
Δt	[ns]	0.5	0.5	369
N	$[10^9]$	6.8	3.7	20
σ_x	[nm]	202	40	655
σ_y	[nm]	2.26	1	5.7
ϵ_x	[μm]	2.4	0.66	10
ϵ_y	[nm]	25	20	40
$\mathcal{L}_{total}$	$[10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$	2.3	5.9	2.0
$\mathcal{L}_{0.01}$	$[10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$	1.4	2.0	1.45

http://cdsweb.cern.ch/record/1132079?ln=fr
http://clic-meeting.web.cern.ch/clic-meeting/clictable2007.html

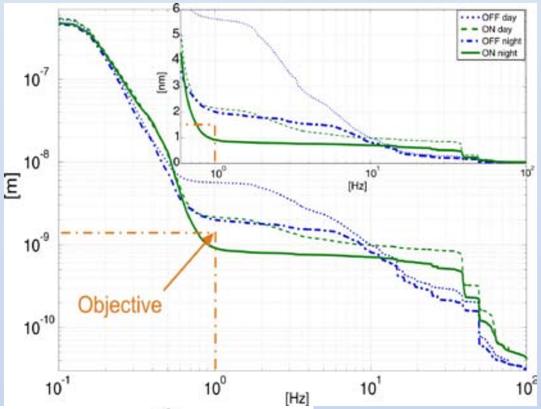
CLIC Project Planning Phase

Activity	Description	Deliverables (2016)	Total material budget
CTF3 +	CTF3 consolidation and upgrade	• Consolidation and upgrade (higher energy, stability, reliability) • Drive beam phase feed-forward experiments • Upgrade and operate TBL as 12 GHz power production facility • Operation with beam of a long string of CLIC two-beam modules	43 MCHF
CLIC Zero	Injector for the CLIC drive beam generation complex	• Build and commission 30 MeV Drive Beam injector with nominal CLIC parameters • Build and commission a few Drive Beam accelerator nominal modules • Participation to Technical Design of full CLIC Zero facility	42 MCHF
RF Structures	design and fabrication of 12 GHz accelerating structures & PETS and associated R&D	• Build and test about 120 accelerating structures • Build and test about 10 PETS prototype • Establish quality control, brazing and assembly procedures for structure fabrication at CERN • Precision machining center at CERN	29 MCHF
RF test infrastructure	Building, commissioning and operation of high-power RF test stands	• Four 12 GHz klystron-based RF high-power test stations, for about 8 slots, running before 2016 • Continue high-power testing at 11.4 GHz (KEK and SLAC) • Contribution to high-power testing in CTF3+ (TBL)	13 MCHF
Prototypes of critical components	Technical R&D – design, build and test prototypes of CLIC critical components	• R&D and prototypes of two-beam modules alignment and stabilization systems • Prototype of final focus QD) quadrupole and stabilization system • Several nominal CLIC two-beam modules, mechanically tested, possibly beam tested • R&D and prototyping of critical beam instrumentation • Design and studies of machine protection system • DR superconducting wiggler prototypes, test with beam • DR extraction kickers prototypes • Dynamic vacuum assessment • Contribution to the CLIC Zero TDR • …	29 MCHF
Cost studies, Civil engineering, Proj, Implementation	Update and improve CLIC cost model & civil engineering studies	• Technical Design (TD) and Project Implementation Plan (PIP) of CLIC Zero • Improved cost model, feedback to CLIC baseline review	4 MCHF
Beam physics studies	Beam physics and overall design	• Review of the CLIC baseline design • Contribution to the TDR of CLIC Zero	3 MCHF

Technical development, prototyping

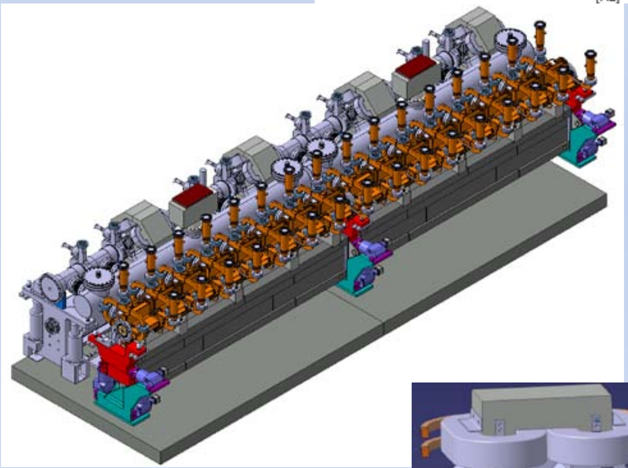
- Conceptual design of technical systems ⇨ **CDR** (including basic feasibility)

April 2010 – nm stabilization results

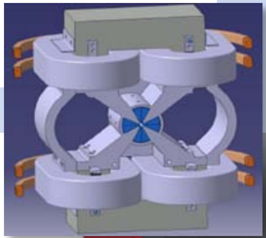


Still to be done (2011-2016):

- Technical design, prototypes and beginning of industrialization for all large-series items
  (critical for cost, performance and schedule)
  - Nominal two beam modules with all features this includes accelerating structures & PETS
  - Drive beam accelerator units (modulator, klystron, RF network, accelerating structure)
- Technical design and working prototypes for all items critical for performance and cost
- Ensure technical feasibility of all components

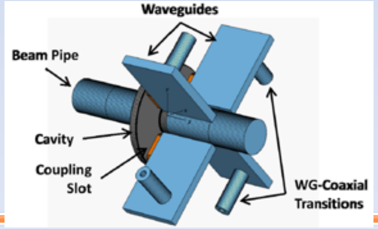


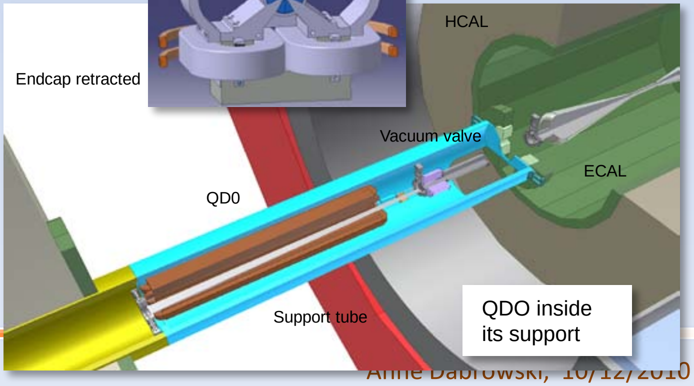
CLIC two-beam modules



CLIC FF QDO prototype

CLIC cavity BPM



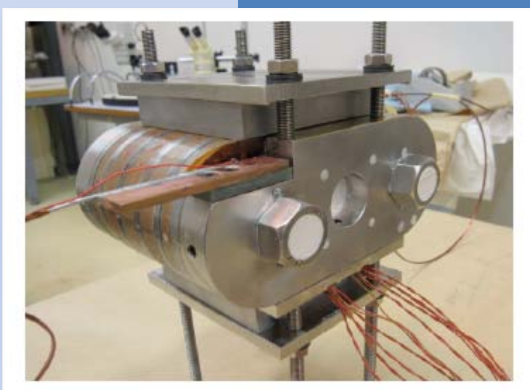


Technical development, prototyping

Technical R&D – design, build and test prototypes of CLIC critical components

Technical design and prototypes for all components critical for cost or performance and
and beginning of industrialization for large-series items

- Development of 15 MW 1 GHZ MBK and modulators
- R&D and prototypes of CLIC two-beam modules , including alignment and stabilization systems
- Prototypes of FF QDO quadrupole and stabilization system
- R&D and prototyping of critical beam instrumentation
- Prototypes and tests of critical equipment for DRs:
  - SC wiggler
  - Vacuum components
  - Fast extraction kickers
- Dynamic vacuum assessment
- Prototype installation of fs timing system
- Magnet prototypes, power supplies
- Design and studies of machine protection system
- …



DR superconducting wiggler prototype

nm active stabilization systems

Draft program for technical developments

domain	deliverable
development of 15 MW 1 GHZ MBK	1 working prototype/firm
development of modulators for above	3 prototypes
prototypes of stabilized MB quads	at least one T1, T2, T3, T4
alignment system	400m working demonstrator in TZ32
alternative alignment system	prototypes
prototype for FF quad (including stabilization)	Short and long prototype
Validation of quad stability through beam experiments	validation
Prototypes of critical beam instruments	experimental validation; BPMs, ODR
Prototype installation of fs timing system	24 km transport of 10 fs timing reference
prototypes of fast kickers	10-4 jitter kicker in lab; beam tests
various magnet prototypes with power supplies	preparation of industrial production
Critical equipment for DRs: vacuum, SC wiggler	prototypes, verification in light sources
dump, masks	studies, designs, material tests

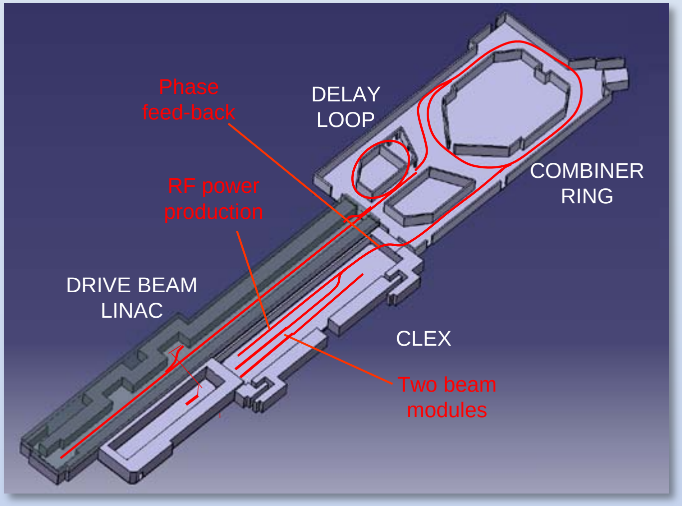
Test facilities

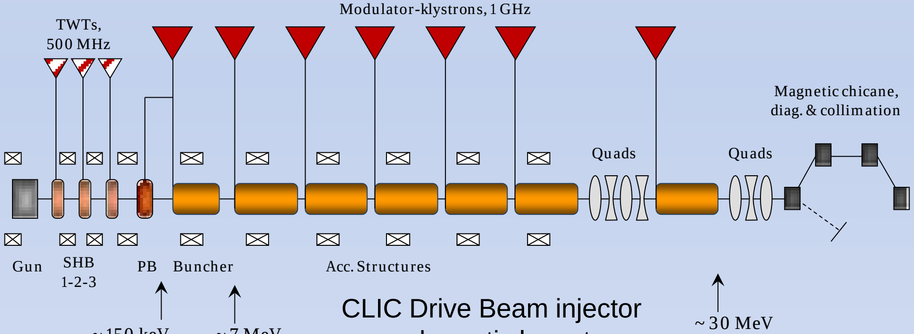
- Feasibility demonstration in CTF3 ⇨ **Mid 2011**
  (present experimental program of CTF3 completed by 2012)

Outlook for (2011-2016):

- Consolidation/upgrade of CTF3 to fully exploit its potential
  - Verify stability/reliability performance in view of CLIC requirements , improve operational experience
  - Contribute to high-power RF testing, demonstrate operation of a drive -beam driven power source
  - Test with beam CLIC two-beam modules
- New drive beam injector facility, at nominal CLIC parameters
  - Final proof of drive beam performances, long-pulse, high - power operation
  - provides a focus for development and pre-industrialization of drive beam components – all hardware reusable
- Pursue and intensify experimental program in other facilities
  - ATF II
  - CesR-TA, SLS, ATF I, ANKA…
  - Asset
  - …

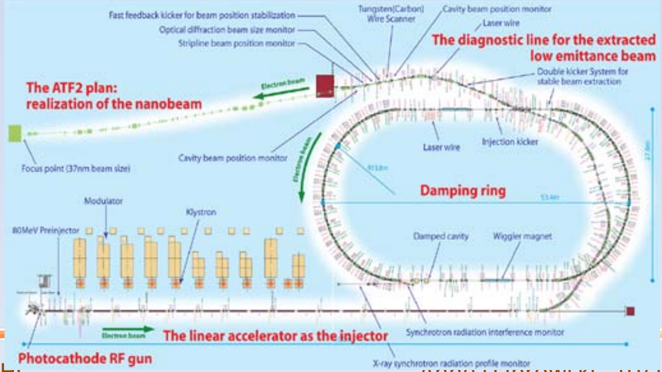
CTF3+





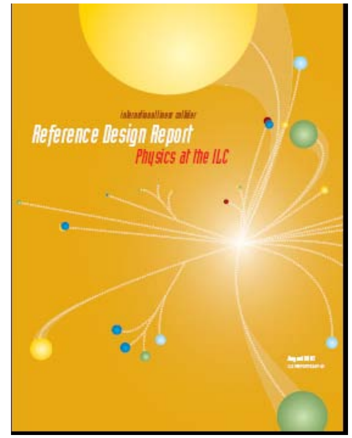
CLIC Drive Beam injector schematic layout

ATF - KEK



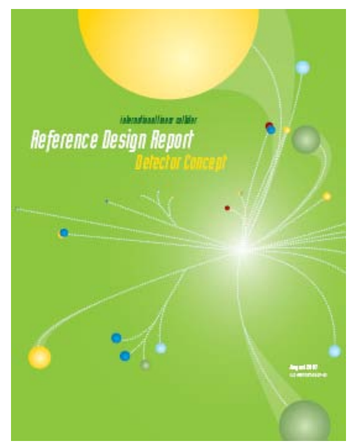
- **Reference Design Report (4 volumes)**

Executive Summary



Physics at the ILC

Accelerator



Detectors

Global Design Effort

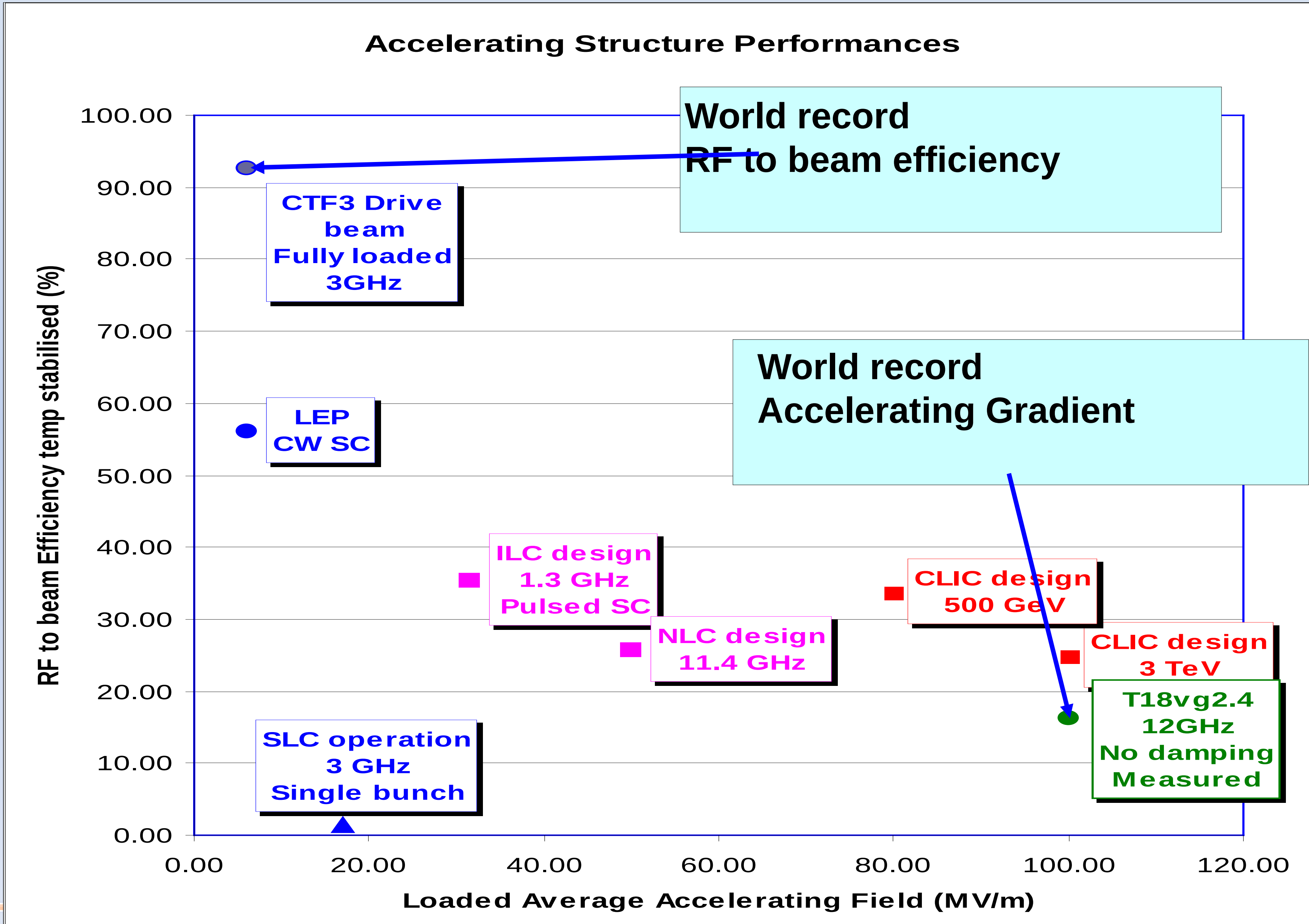
24-July-10
ICHEP-10 Paris

ILC RDR Design Parameters

Max. Center-of-mass energy	500	GeV
Peak Luminosity	~$2x10^{34}$	$1/cm^2s$
Beam Current	9.0	mA
Repetition rate	5	Hz
Average accelerating gradient	31.5	MV/m
Beam pulse length	0.95	ms
Total Site Length	31	km
Total AC Power Consumption	~230	MW

Global Design Effort 24-July-10 ICHEP-10 Paris

Accelerating Structure Performances



CLIC Feasibility Status

System	Item	Feasibility Issue	Unit	Nominal	Achieved	How	Feasibility
Two Beam Acceleration	Drive beam generation	Fully loaded accel effic	%	97	95	CTF3	✓
		Freq&Current multipl	-	2*3*4	2*4	CTF3	✓
		12 GHz beam current	A	4.5*24=100	3.5*8=28	CTF3	✓
		12 GHz pulse length	nsec	240	240	CTF3	✓
		Intensity stability	1.E-03	0.75	0.6	CTF3	✓
		Drive beam linac RF phase stability	Deg (1GHZ)	0.05	0.035	CTF3, XFEL	✓
	Beam Driven RF power generation	PETS RF Power	MW	130	130	TBTS/SLAC	✓
		PETS Pulse length	ns	170	>170	TBTS/SLAC	✓
		PETS Breakdown rate	/m	< 1·10-7	>1.2 10-6	TBTS/SLAC	✓
		PETS ON/OFF	-	@ 50Hz	-	CTF3/TBTS	2011
		Drive beam to RF efficiency	%	90%	-	CTF3/TBL	2010-11
		RF pulse shape control	%	< 0.1%	-	CTF3/TBTS	
	Accelerating Structures (CAS)	Structure Acc field	MV/m	100	100	CTF3 Test Stand, SLAC, KEK	✓
		Structure Flat Top Pulse length	ns	170	170		✓
		Structure Breakdown rate	/m MV/m.ns	< 3·10-7	5·10-5(D)		2010-11
		Rf to beam transfer efficiency	%	27	15		2010-11
	Two Beam Acceleration	Power producton and probe beam acceleration in Two beam module	MV/m - ns	100 - 170	55 - 170	TBTS	2011-12
		Drive to main beam timing stability	psec	0.05	-	CTF3	2012
		Main to main beam timing stability	psec	0.07	-	CTF3	2012
Ultra low beam emittance & sizes	Ultra low Emittances	Emitttance generation H/V	nm	500/5	3000/12	ATF, NSLS/SLS + simulation	✓
		Emittance preservation: Blow-up	nm	160/15	160/15		2010-12
	Alignment	Main Linac components	microns	15	10 (princ.)	Alignement & Mod.Test Bench	2010
		Final-Doublet	microns	2 to 8			2010
	Vertical stabilisation	Quad Main Linac	nm>1 Hz	1.5	0.13 (principle)	Stabilisation Test Bench	2010-12
		Final Doublet (assuming feedbacks)	nm>4 Hz	0.2			

CLIC feasibility issues

System	Item	Feasibility Issue	Unit	Nominal
Two Beam Acceleration	Drive beam generation	Fully loaded accel effic	%	97
		Freq&Current multipl	-	2*3*4
		12 GHz beam current	A	4.5*24=100
		12 GHz pulse length	nsec	240
		Intensity stability	1.E-03	0.75
		Drive beam linac RF phase stability	Deg (1GHZ)	0.05
	Beam Driven RF power generation	PETS RF Power	MW	130
		PETS Pulse length	ns	170
		PETS Breakdown rate	/m	< 1·10-7
		PETS ON/OFF	-	@ 50Hz
		Drive beam to RF efficiency	%	90%
		RF pulse shape control	%	< 0.1%
	Accelerating Structures (CAS)	Structure Acc field	MV/m	100
		Structure Pulse length	ns	240
		Structure Breakdown rate	/m MV/m.ns	< 3·10-7
	Two Beam Acceleration	Power producton and probe beam acceleration in Two beam module	MV/m - ns	100 - 240
		Drive to main beam timing stability	psec	0.05
		Main to main beam timing stability	psec	0.07
Ultra low beam emittance & sizes	Ultra low Emittances	Emitttance generation H/V	nm	500/5
		Emittance preservation: Blow-up	nm	160/15
	Alignment	Main Linac components	microns	15
		Final-Doublet	microns	2 to 8
	Vertical stabilisation	Quad Main Linac	nm>1 Hz	1.5
		Final Doublet (assuming feedbacks)	nm>4 Hz	0.2
Operation and Machine Protection System (MPS)		72MW@2.4GeV main beam power of 13MW@1.5TeV		

Heuer

From Rolf on Monday …

What can we expect from LHC and Tevatron

- LHC will have results on masses of SUSY particles (squarks, gluinos) up to/beyond around 800 GeV by end of 2011
- LHC and Tevatron together will have results on Higgs mass exclusion or even possible allowed mass range up to around 500 GeV by end 2011

→ 2012 could be a decisive year concerning LC (in time with update of European strategy)

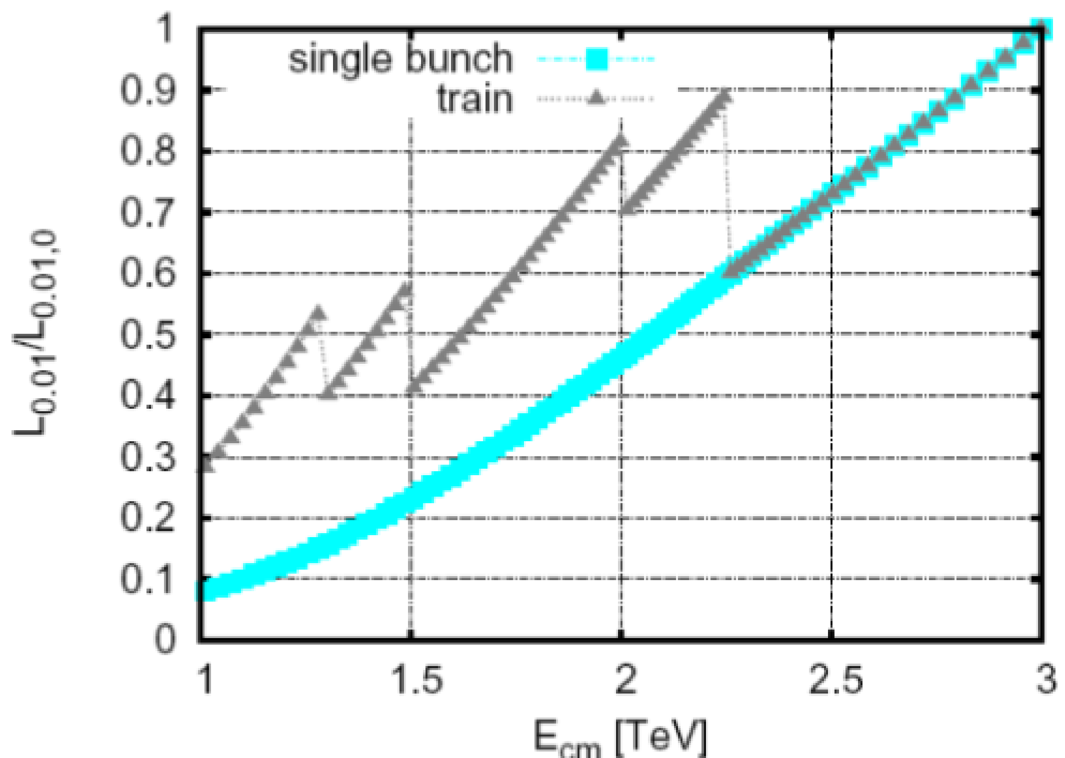
10

Progress-1: Energy scanning

- The issue
  - Small (10%) scans can always be done
    - Tune magnets, detune RF
  - Optimise the machine for one energy
    - Running at much lower (or higher) energy
      - Compromised luminosity
      - Needs a machine reconfiguration
      - Cannot be done quickly (within a few hours)
        - » Can it be done at all?

Progress-1: Energy scanning-2

- **Compensate partially for loss of (useful) luminosity from *decreasing* the RF gradient by *increasing* the pulse length**



E/E_0	n_b	$n_{\mathcal{L}}$	$Q_p/Q_{p,0}$
1.0	312	1.0	1.0
0.75	472	1.5	1.12
0.667	552	1.77	1.18
0.5	792	2.54	1.27
0.375	1112	3.56	1.34
(0.333)	(1272)	(4.08)	(1.36)

E maximum centre-of-mass energy for operation mode

CLIC/CTF3 Multi-Lateral Collaboration of Volunteer Institutes

41 Institutes from 21 countries

Organized as a Physics Detector Collaboration

Collab. Board: Chair: K.Peach/JAI; Spokesperson: R.Corsini/CERN

MoU with addenda describing specific contribution (& resources)

http://clic-meeting.web.cern.ch/clic-meeting/CTF3_Coordination_Mtg/Table_MoU.htm

Members (full responsibility of work packages and providing voluntary resources):

- **23 institutes from 12 countries CERN member states:**

CERN, Denmark (Aarhus), Finland (HIP), France (IRFU, LAL, LAPP), Germany (Karlsruhe), Greece (Athens, Patras, Thrace), Italy (LNF), Netherland (NIKHEF), Norway (Univ. Oslo), Spain (CIEMAT, UPC, IFIC), Sweden (Uppsala), Switzerland (ETHZ, PSI), UK (Cockcroft, JAI(OXFORD), JAI (RHUL), RAL)

- **17 institutes from 9 countries non CERN member states:**

Australia (ACAS), China (IHEP, Tsinghua Univ.) India (RRCAT), Japan (KEK), Pakistan (NCP), Russia (BINP, IAP, JINR), Turkey (Ankara U., Gazi U.), Ukraine (IAP), USA (ANL, FNAL, JLAB, NWU, SLAC, UCSC-SCIPP)

MoU under discussion:

Trieste (Elettra), Iran (IPM), Thailand (SLRI), TERA, European Space Agency (ESA)