CTF3 Programme, Status and Collaborations, Commissioning and Operation

G. Geschonke
CERN AB/RF

CTF3 collaboration

The first CLIC/CTF3 collaboration meeting at CERN in **1999** with INFN Frascati, LAL SLAC, CERN.

The most recent one (the **11th**) was held in **January 2007**.
The collaboration involves now 22 institutes

CTF3 is now an experiment.
1st meeting of Collaboration Board: November **2005**
3rd meeting **Friday 22.6.2007**

➔ Chairman of collaboration Board: Mario Calvetti / INFN/LNF
Spokesperson: G.Geschonke

CTF3 machine advisory Committee in October 2001
(B. Aune (Saclay), H. Henke (T. U. Berlin), R. Siemann (SLAC)

Collaborating institutes

Countries	*Funding Agencies*	*Laboratory*
	CERN	CERN
FINLAND		Helsinki Inst of Phys (HIP)
FRANCE	CEA	DAPNIA Saclay
	CNRS/IN2P3	LAL
		LAPP
		LURE
INDIA*	Indian DAE	RRCAT, Indore
ITALY	INFN	LNF
PAKISTAN *	PAEC	NCP
RUSSIA		Budker Inst (BINP)
		IAP
	Dubna	JINR
SPAIN	Ministry of Education & Science (MEC)	CIEMAT
		UPC
		IFIC
SWEDEN	Swedish Research Council	Uppsala University
	Wallenberg Foundation	TSL
SWITZERLAND		Paul Scherrer Inst (PSI)
TURKEY		Ankara Univ Group (2)
USA	DOE	Northwestern Univ Illinois (NWU)
		SLAC

17 members involving 22 Institutes

* India and Pakistan have not signed the CTF3 MoU, but have an agreement with CERN for the development of novel accelerator technologies

Draft MoU Addendum with J.Adams Institute London

Discussions with : Iran, UK (Cockcroft Institute), JLAB, EPFL, INFN Milan

Past collaboration with RAL within PHIN

CLIC Test Facilities CTF

CLIC two Beam scheme proposed in 1985

Drive Beam with SC cavities

CTF and CTF2

CTF from 1998 – 1995

Two-Beam acceleration demonstrated in CTF and CTF2

30 GHz power testing of CLIC accelerating structures

CTF2 1995-2001

two independent beams

CTF3:

Present RF power generation scheme proposed in 1998

After LEP end 2000: LEP Injector complex became available:

building with shielded accelerator tunnel and klystron gallery,

klystrons, modulators, magnets, e.t.c.

CTF 1988 - 1995

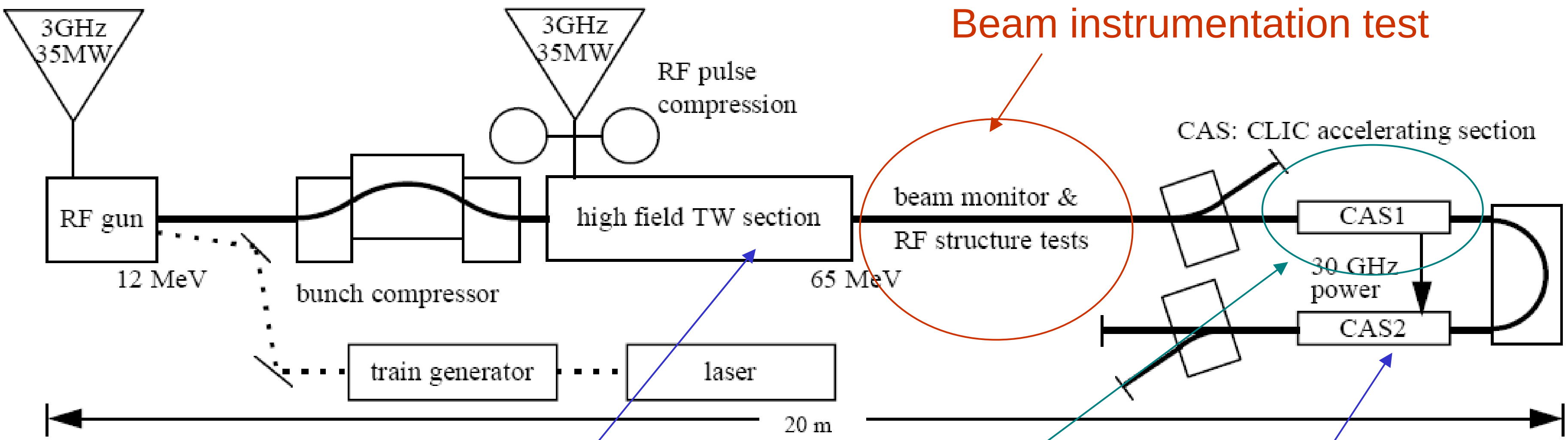


Figure 1. Schematic layout of CTF as it was in 1995

- generation of a high intensity drive beam with short bunches by a photo-injector
- production of 30 GHz RF power
- acceleration of a probe beam by 30 GHz structures

94 MV/m (CAS2) – 123MV/m (CAS1) 12 nsec, few nC x bunch

CTF2 1995 - 2001

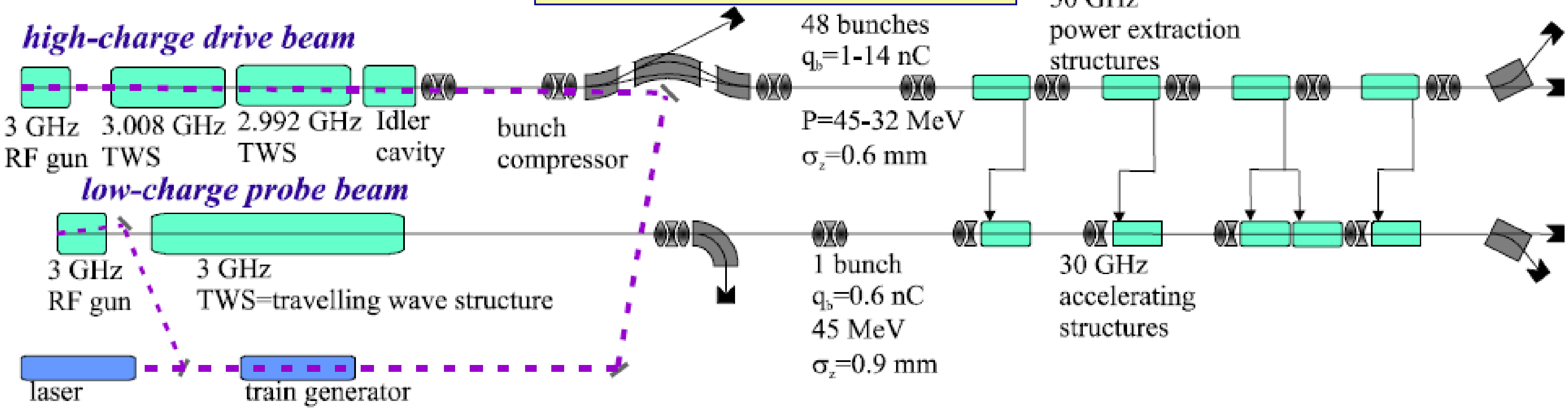


Figure 1: Configuration of CTF II during the 1999 run

Acceleration of drive beam with 3 GHz normal conducting linac
Deceleration with 30 GHz structure: 30 GHz RF power production
Acceleration of the low charge probe beam

- **measurements of csr effects in bunch compressor**
- **high-gradient tests in single-cell 30 GHz cavities**
- **high-power tests of a planar 30 GHz RFstructure**
- **tests of BPM prototypes**

CLIC parameters
From 80MV/m, 12 nsec, 10 bunches
To 150MV/m, 140 nsec, 154 bunches -> CTF3

CTF3 objectives

International Linear Collider Technical Review Committee (SLAC-R-606),2003 :

R1.1 CLIC accelerating structure, damped, at design gradient and pulse length

** CTF3 as 30 GHz RF power source as early as possible*

** 30 GHz test stand, well instrumented, extended exploitation*

** aggressive structure development*

R1.2 Drive beam scheme with a fully loaded linac

** CTF3: 150 MeV*	*CLIC: 2.4 GeV*
3.5 A	*5.2 A*
3 GHz	*1.33 GHz*

R1.3 Power-Extraction Structure (PETS) with on/off capability, damped

R2.1 Validation of beam stability and losses in the drive beam decelerator, and design of a machine protection system

** benchmark experiments 35 A @ 150 MeV => 150 A @ 2 GeV*

R2.2 Test of a relevant linac sub-unit with beam

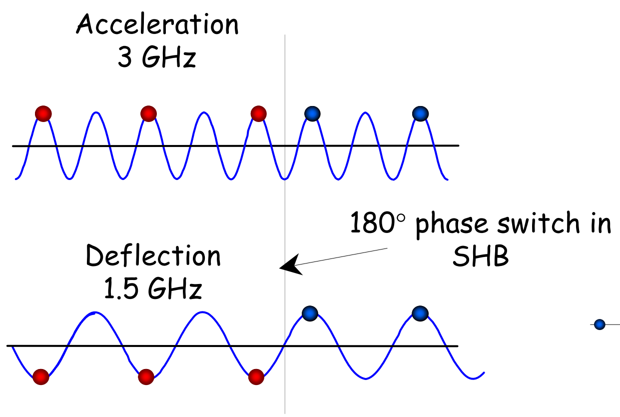
** second beam required (probe beam)*

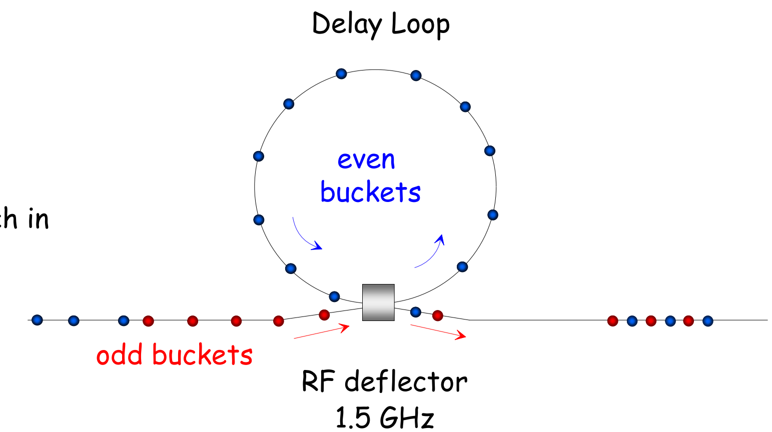
Drive Beam generation

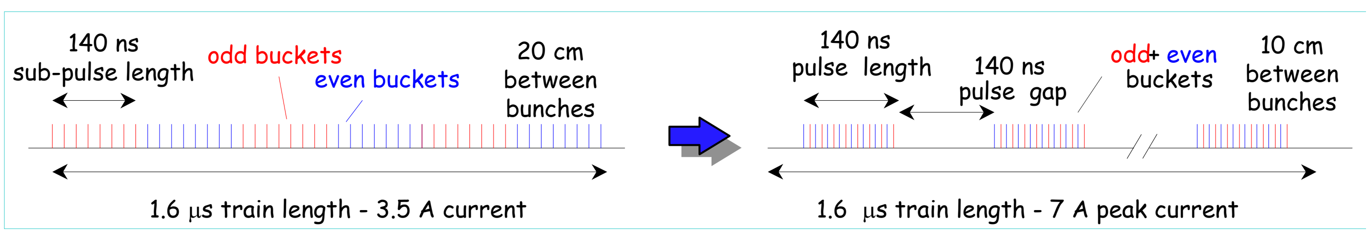
Principle: A long high intensity bunch train (1.4 μs) is accelerated with 3 GHz
Bunch manipulations increase bunch repetition frequency
and increase peak current

“Phase-coding” of bunches

bunch interleaving with **Delay Loop**

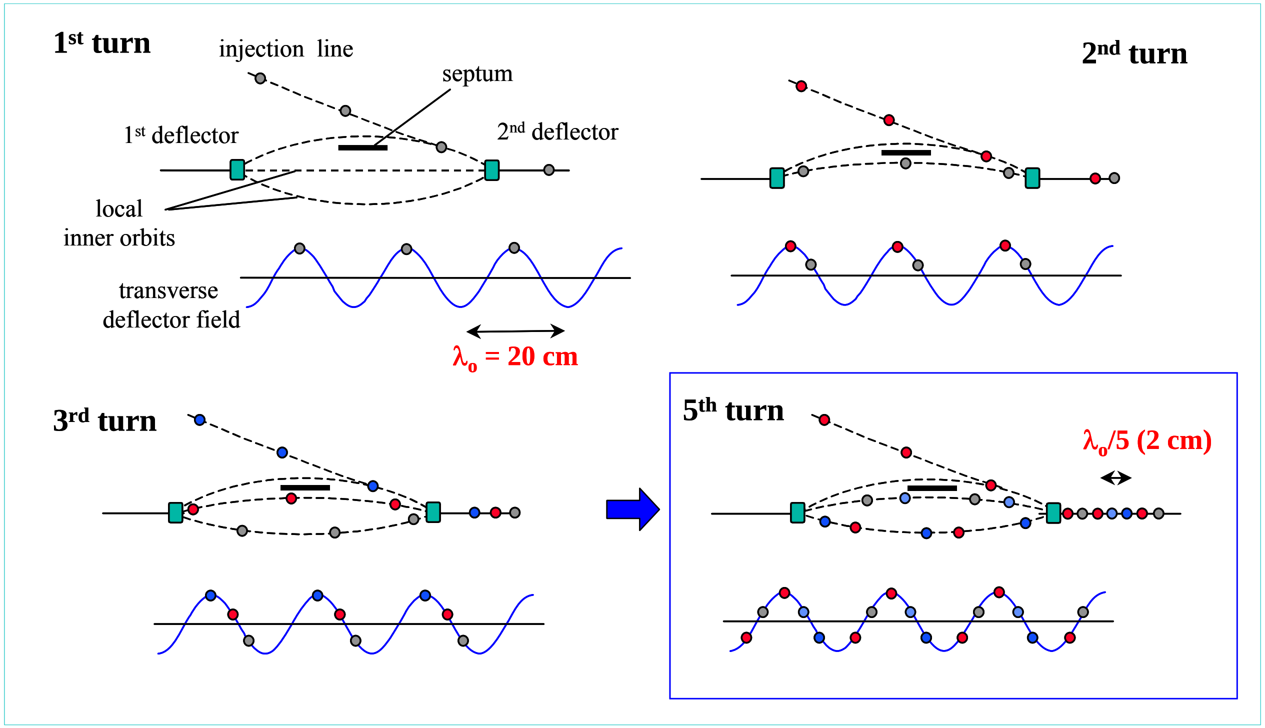


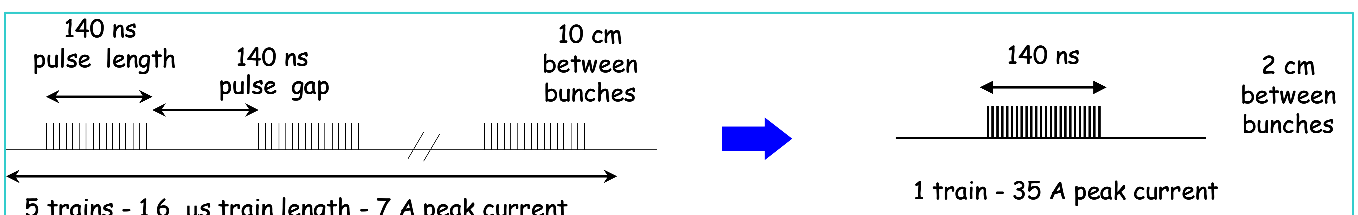




Drive Beam generation

successive injection of 5 bunch trains into **Combiner Ring**





CTF3 objectives

Provide answers for CLIC specific issues by 2009
➔ Write CDR in 2010

Two main missions:

Prove CLIC 30 GHz RF power source:

- bunch manipulations, beam stability,
- 30 GHz extraction

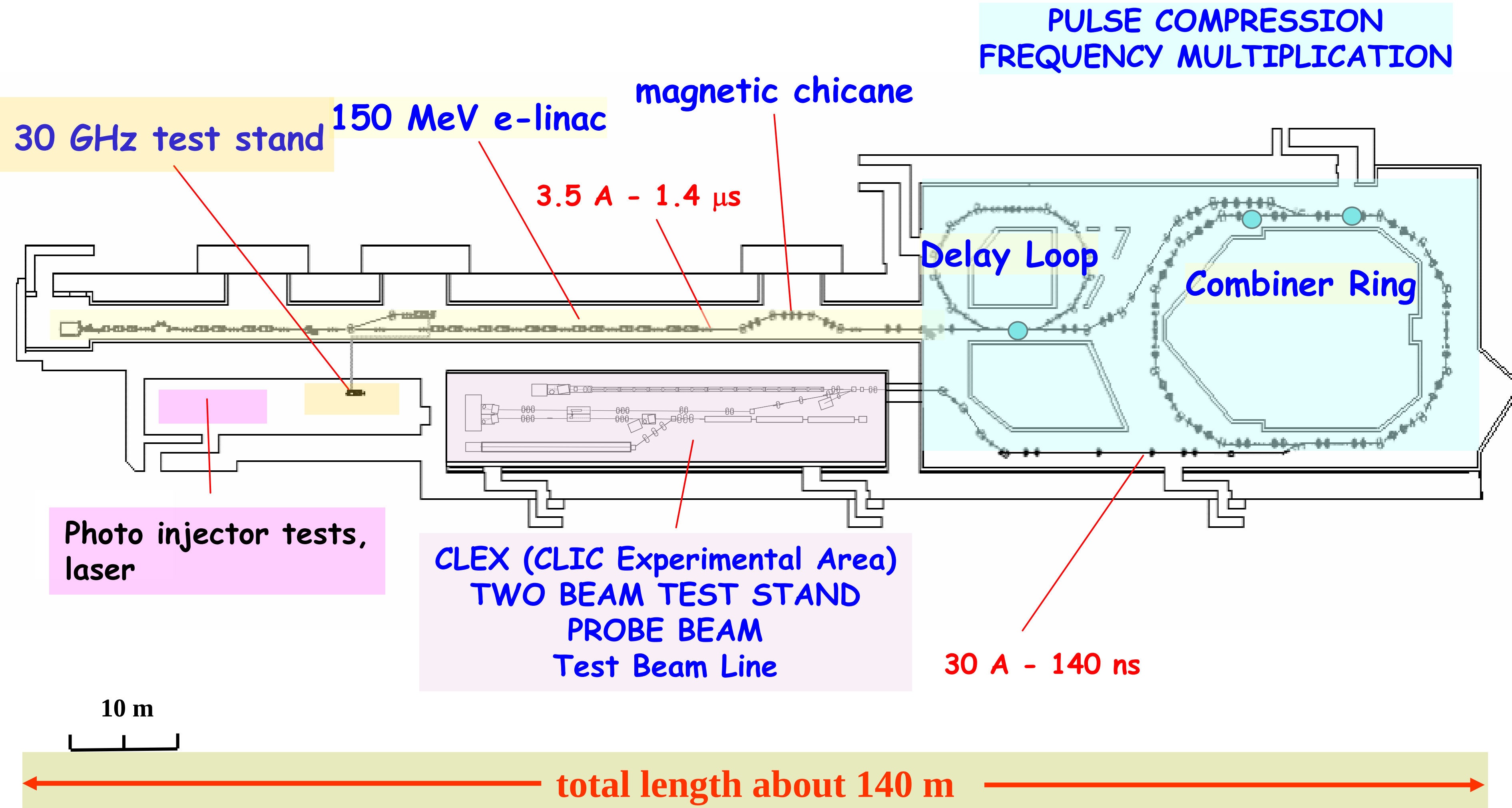
Demonstration of "relevant" linac sub-unit:

- 30 GHz generation
- acceleration of test beam

Provide 30 GHz RF power for validation of CLIC components:
accelerating structures,
RF distribution,
PETS (Power extraction and Transfer Structure)

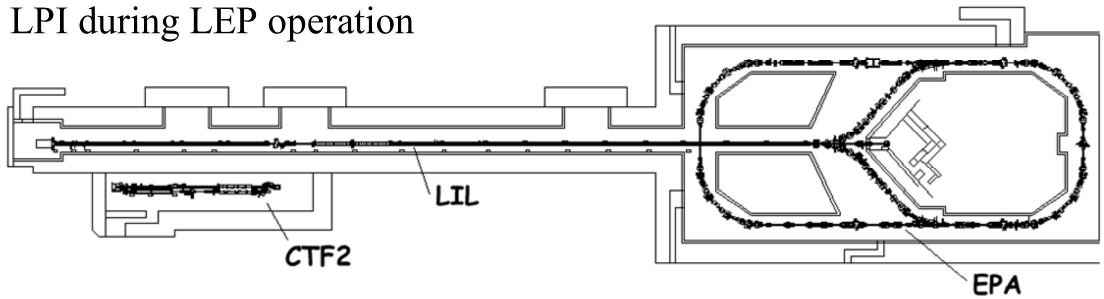
CTF3 building blocks

Infrastructure from LEP

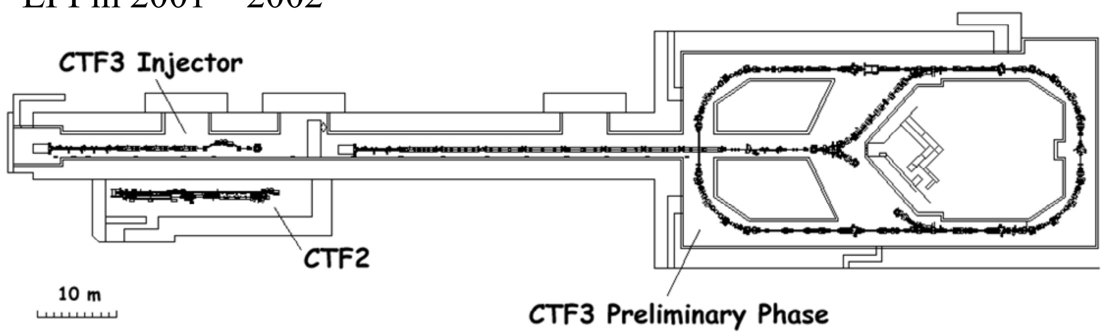


CTF3 Preliminary Phase

LPI during LEP operation



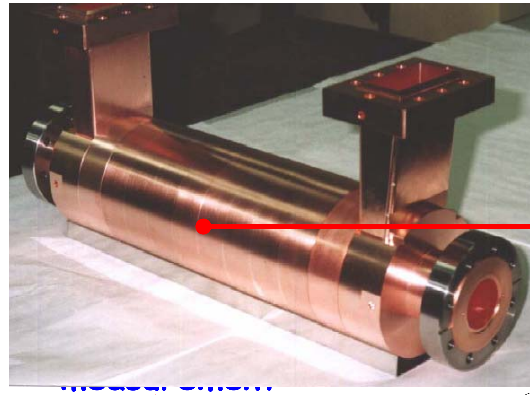
LPI in 2001 – 2002



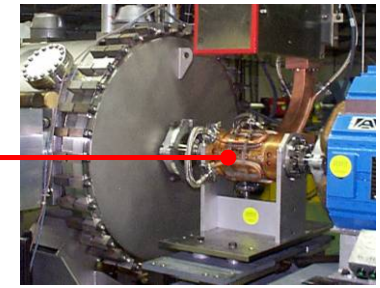
Objectives:
- Demonstrate Interleaving of 5 bunch trains using RF deflectors
- Operation of isochronous ring

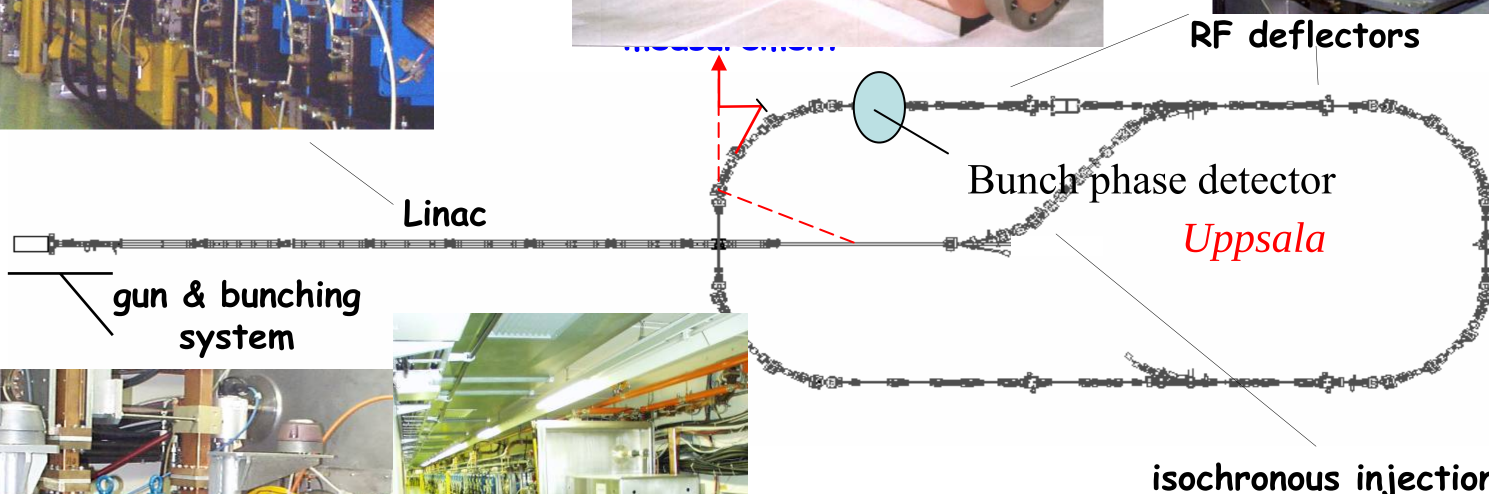
Preliminary phase

Modifications to the
LEP pre-injector complex



Provided by INFN





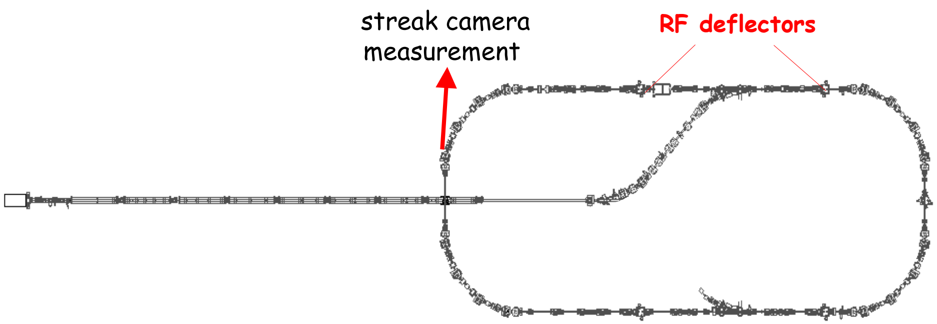
Provided by LAL

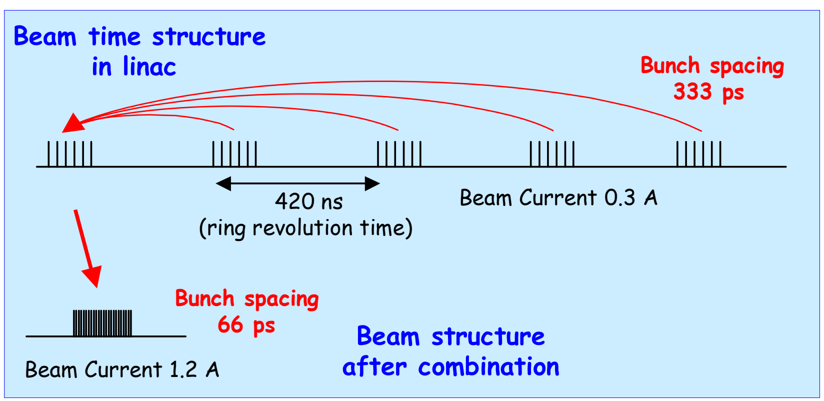
R.Corsimi

Results – Preliminary Phase → Frank Tecker

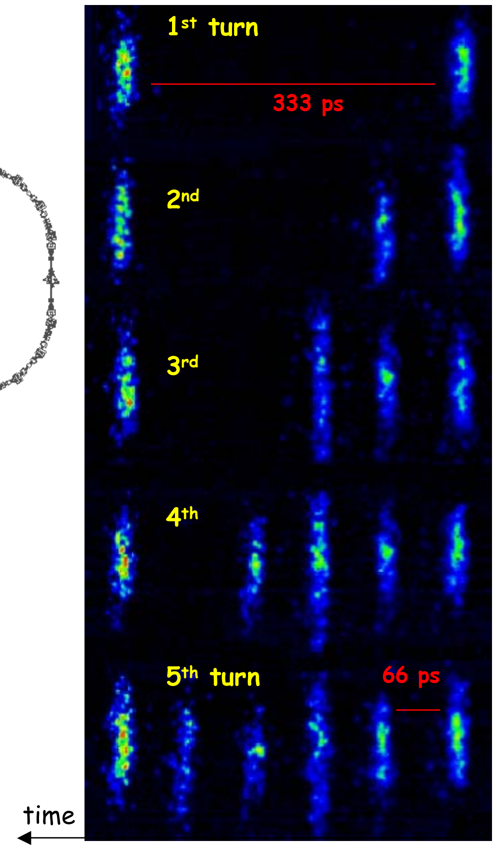
CTF3 - PRELIMINARY PHASE

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





Streak camera image of beam time structure evolution



CTF3 - CLIC

CTF3 is scaled down from CLIC:

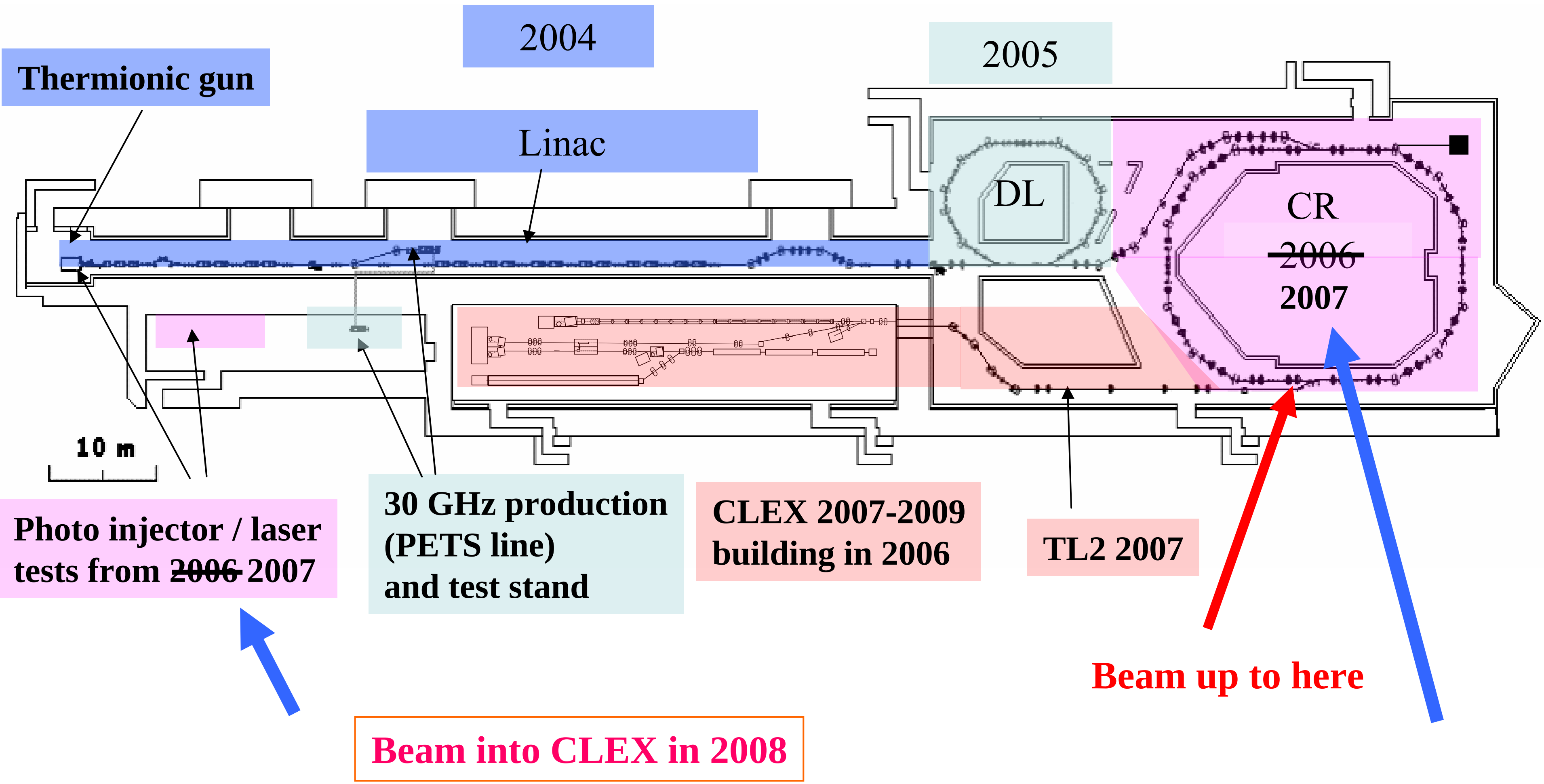
	CLIC	CTF3
Drive Beam energy	2.4 GeV	150 MeV (300 MeV @ 0-current)
compression / frequency multiplication	18 (Delay Loop + 2 Combiner Rings)	6,8, or 10 (Delay Loop + 1 Combiner Ring)
Drive Beam current	5.2 A*18 ➔93 A	3.5 A*10➔ 35 A max
RF Frequency	1.333 GHz	3 GHz
train length in linac	139 µs	1.5 µs
energy extraction	90 %	~ 50 %
Compressed train length	297 ns	140 ns

CTF3 uses existing infrastructure from LEP injector:

Building, infrastructure,

3 GHz RF power plant,

Present status



Collaborations for "Preliminary Phase"

INFN:

RF deflectors
Participation in operation

Uppsala:

Bunch phase monitor,
Operations support

University Lausanne:

PhD student

LAL:

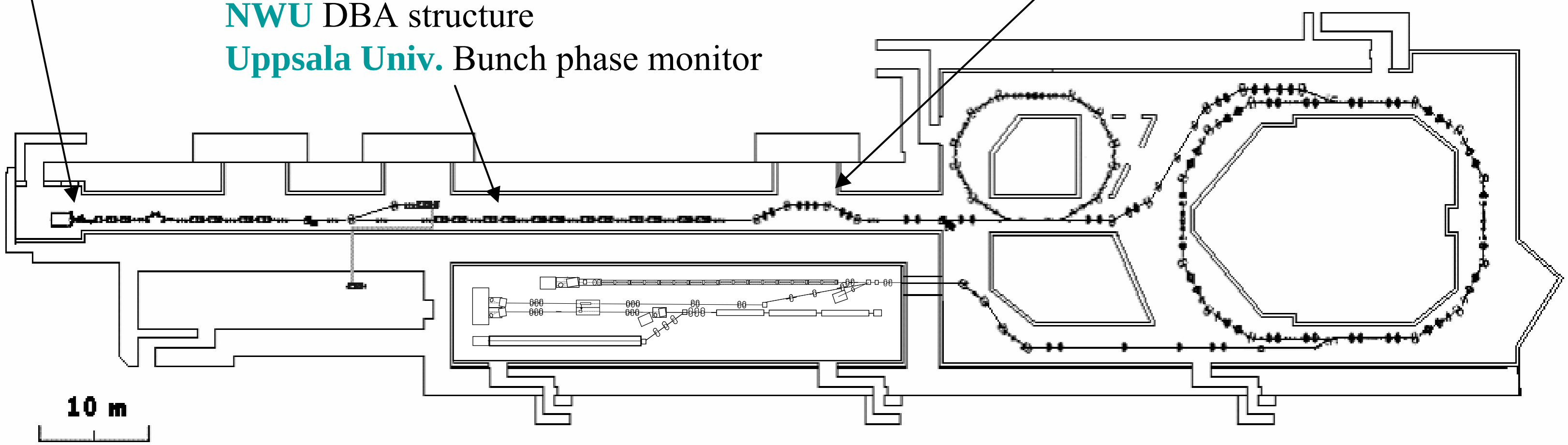
New thermionic gun

Collaborations

LAL HV deck and pulser for thermionic gun, pre-bunchers
CERN installation, infrastructure
SLAC electron gun, injector design

INFN Overall responsibility, optics, vac chambers, BPI, RF deflector, installation, commissioning
CERN magnets, BPM, infrastructure, installation

CERN Drive Beam accelerator
NWU DBA structure
Uppsala Univ. Bunch phase monitor



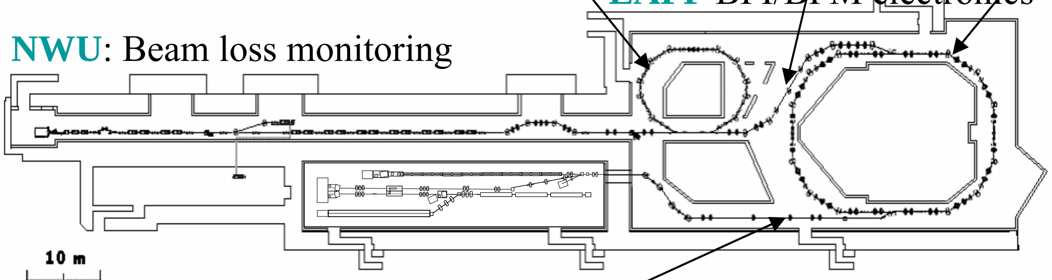
Collaborations

INFN Overall responsibility, optics, vac chambers, BPI, RF deflector, installation, commissioning
CERN magnets, BPM, infrastructure, installation

INFN vac chambers, BPI, installation, optics, operation
CIEMAT correctors,
BINP quadrupoles
LURE quadrupoles
CERN magnets, BPM, infrastructure, installation
NWU RF bunch length monitor
LAPP BPI/BPM electronics

INFN vac chambers, BPI, wiggler, installation, optics, RF deflectors
CIEMAT correctors, septa, kicker + pulser
BINP quadrupoles, sextupoles
LURE quadrupoles
CERN Infrastructure, RF power, installation, magnets, Beam diagnostics, vacuum
Uppsala Bunch phase monitor
LAPP BPI/BPM electronics

NWU: Beam loss monitoring

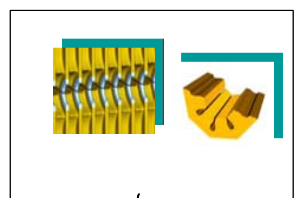


PSI additional modulator

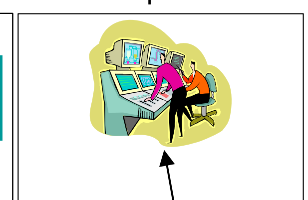
RRCAT optics, 5 bending magnets, Al vacuum chambers
TSL magnets
CERN Infrastructure, vacuum , magnets, installation

IAP

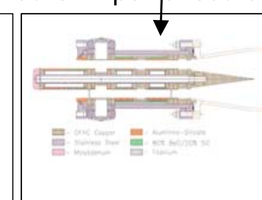
Structures



CTF3 Operation



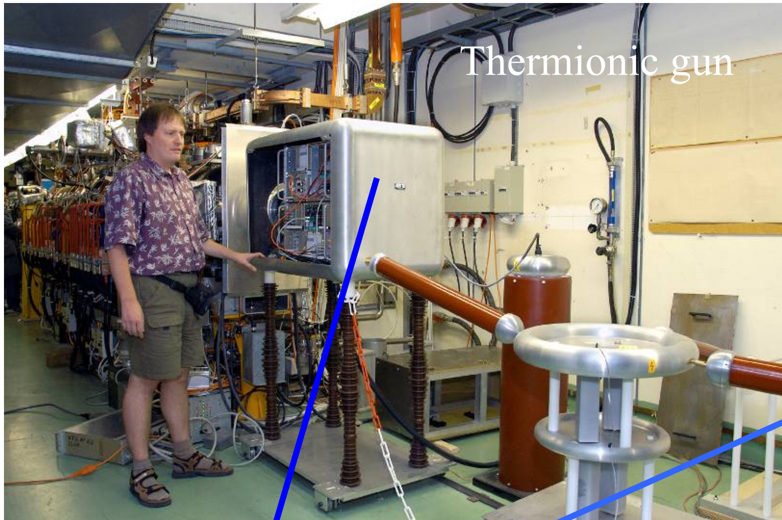
30 GHz power source

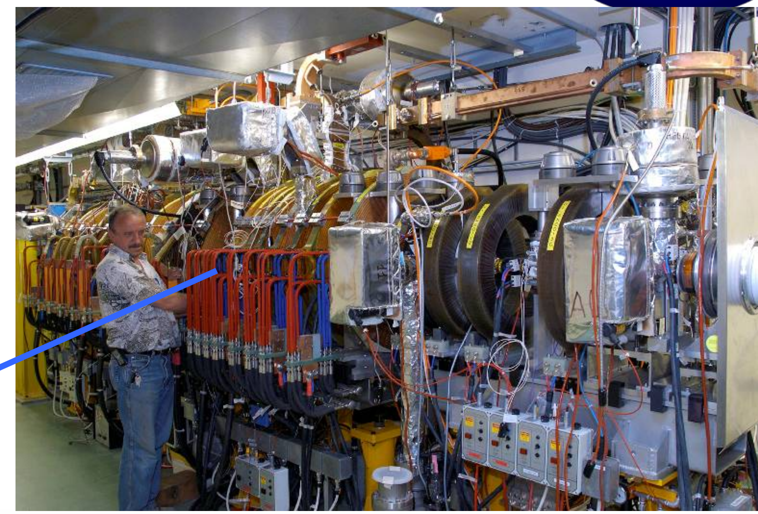


HIP Helsinki
CERN
CIEMAT
SLAC structure testing

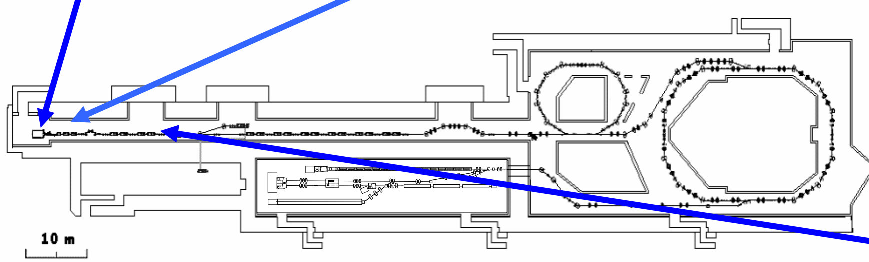
Ankara Universities,
INFN,
JINR Dubna automatic conditioning
RRCAT software
CERN

CTF3 Installation





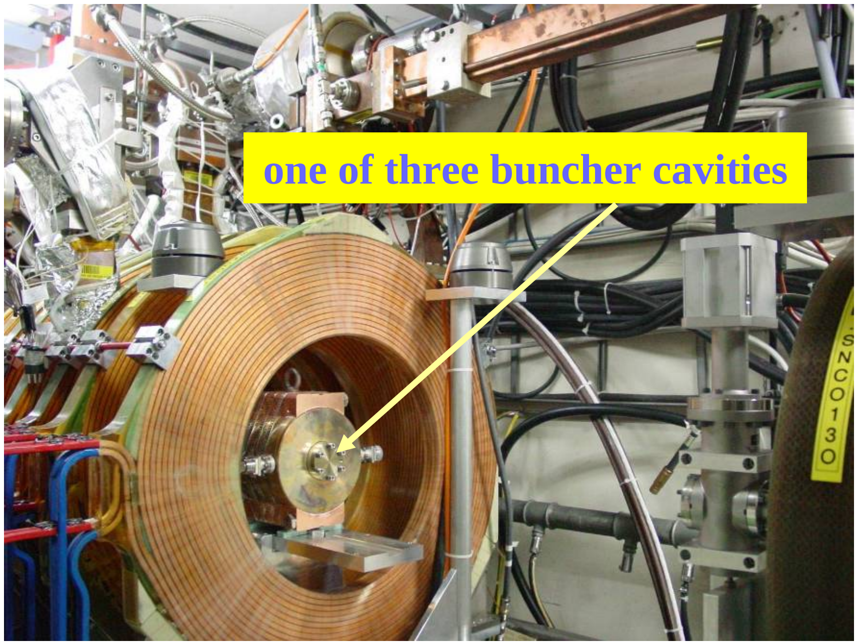
Injector solenoid

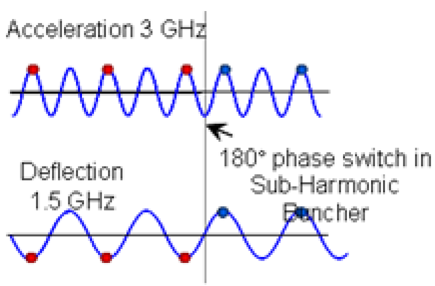


Magnetic chicane

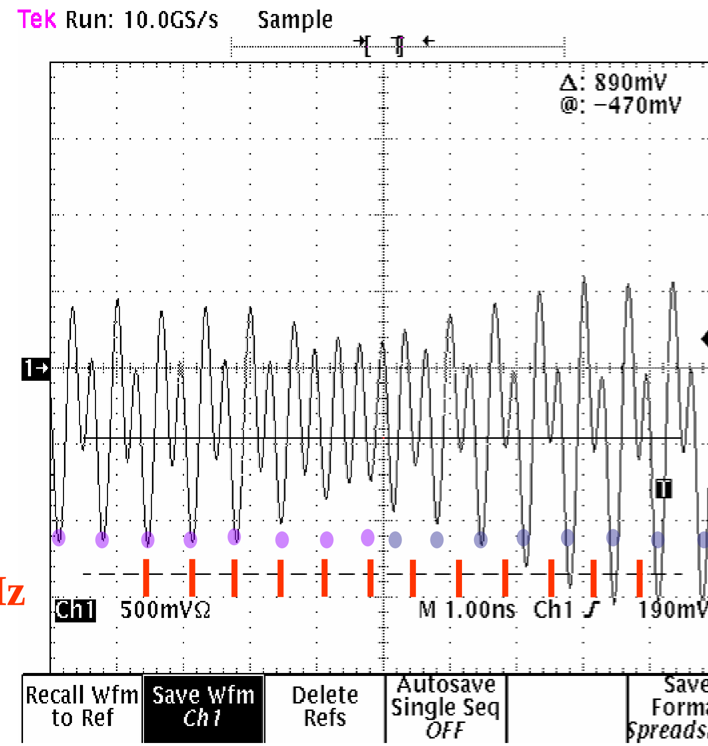
Thermionic gun
- 10 A max,
- after bunching
  - 3.5 A nominal, max. 7 A
- one sw and one tw buncher
- three 1.5 GHz bunchers

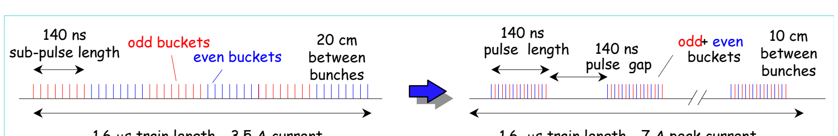
Sub-harmonic bunching / phase coding





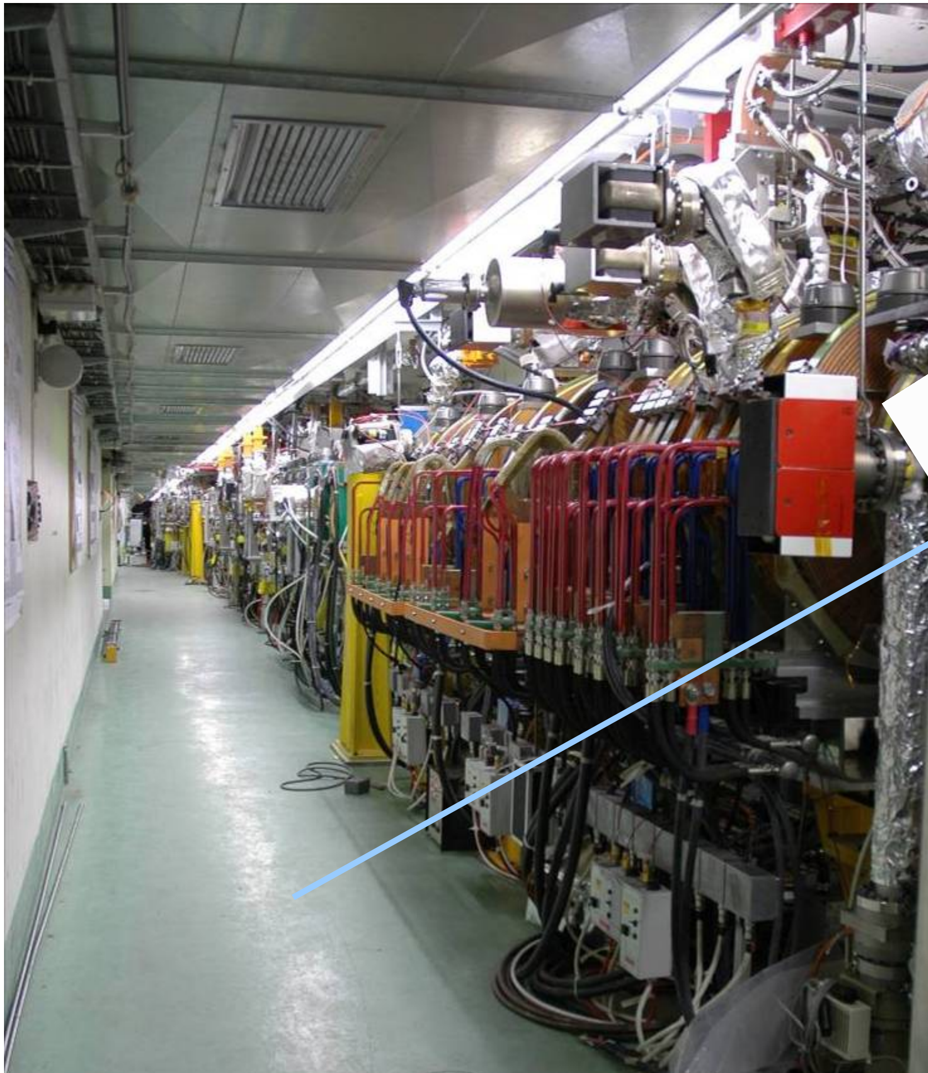
1.5 GHz

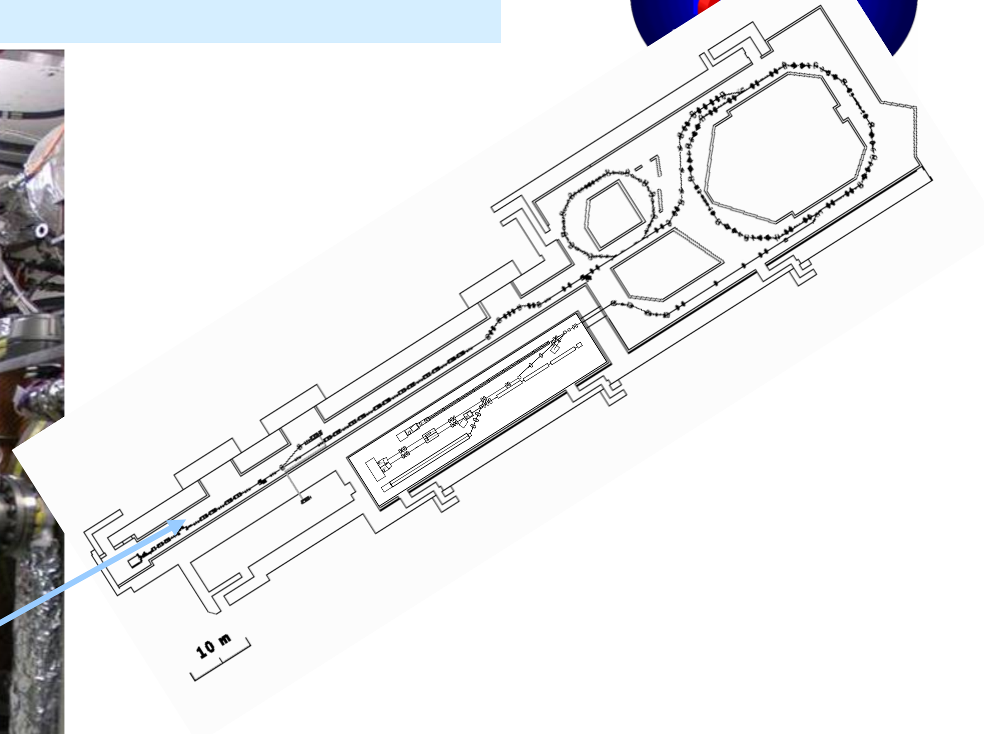




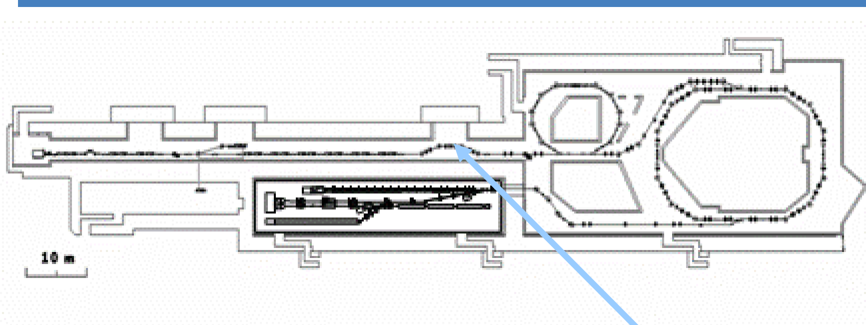
Switching transient about 7 bunches
➔ **Frank Tecker**

Injector and Linac



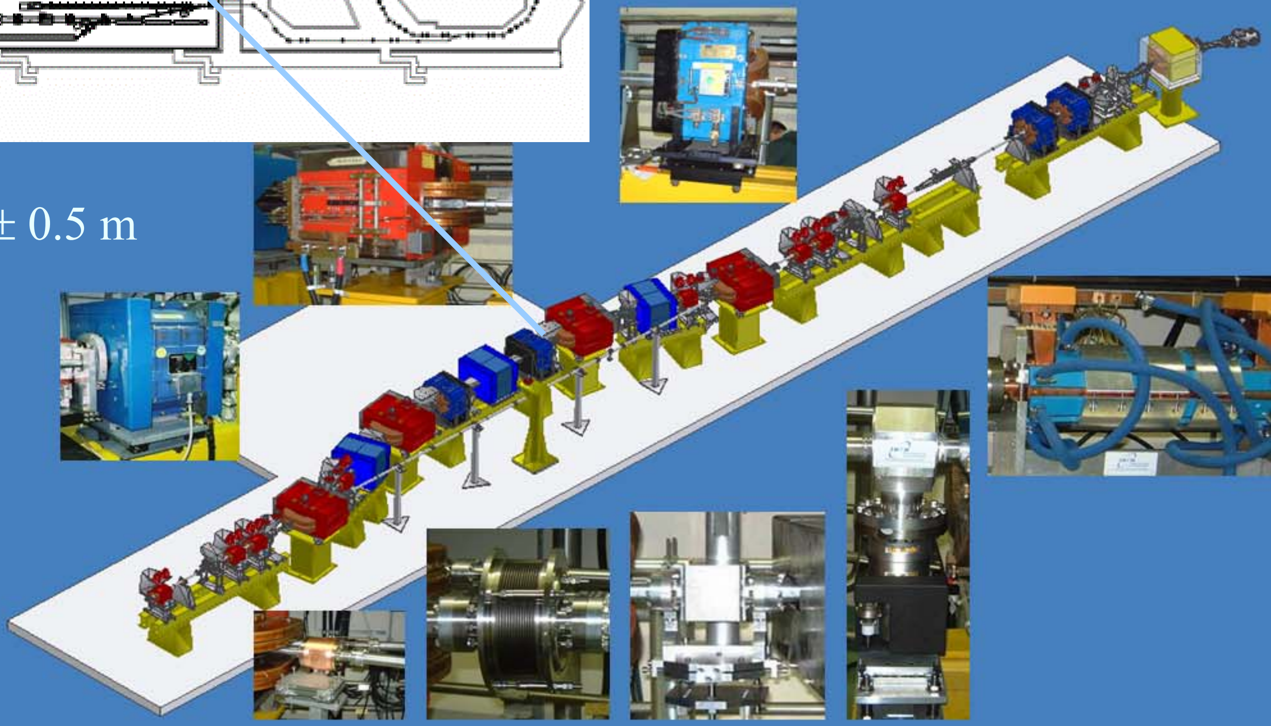


Bunch Stretcher – Compressor Chicane



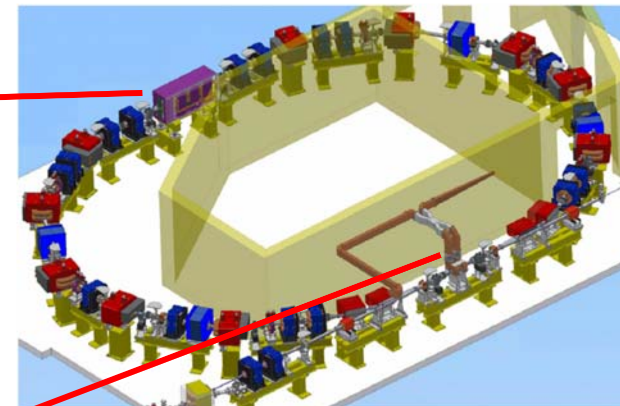
Built by INFN Frascati

R_{56} between ± 0.5 m

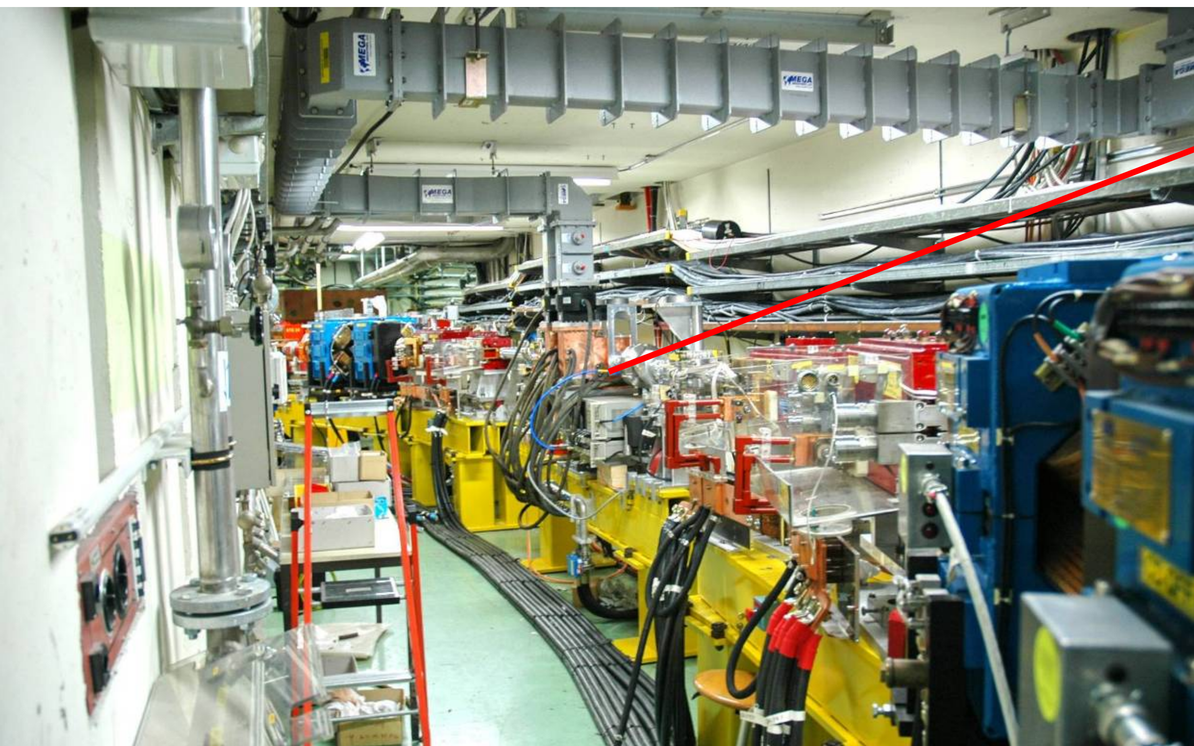


Delay Loop

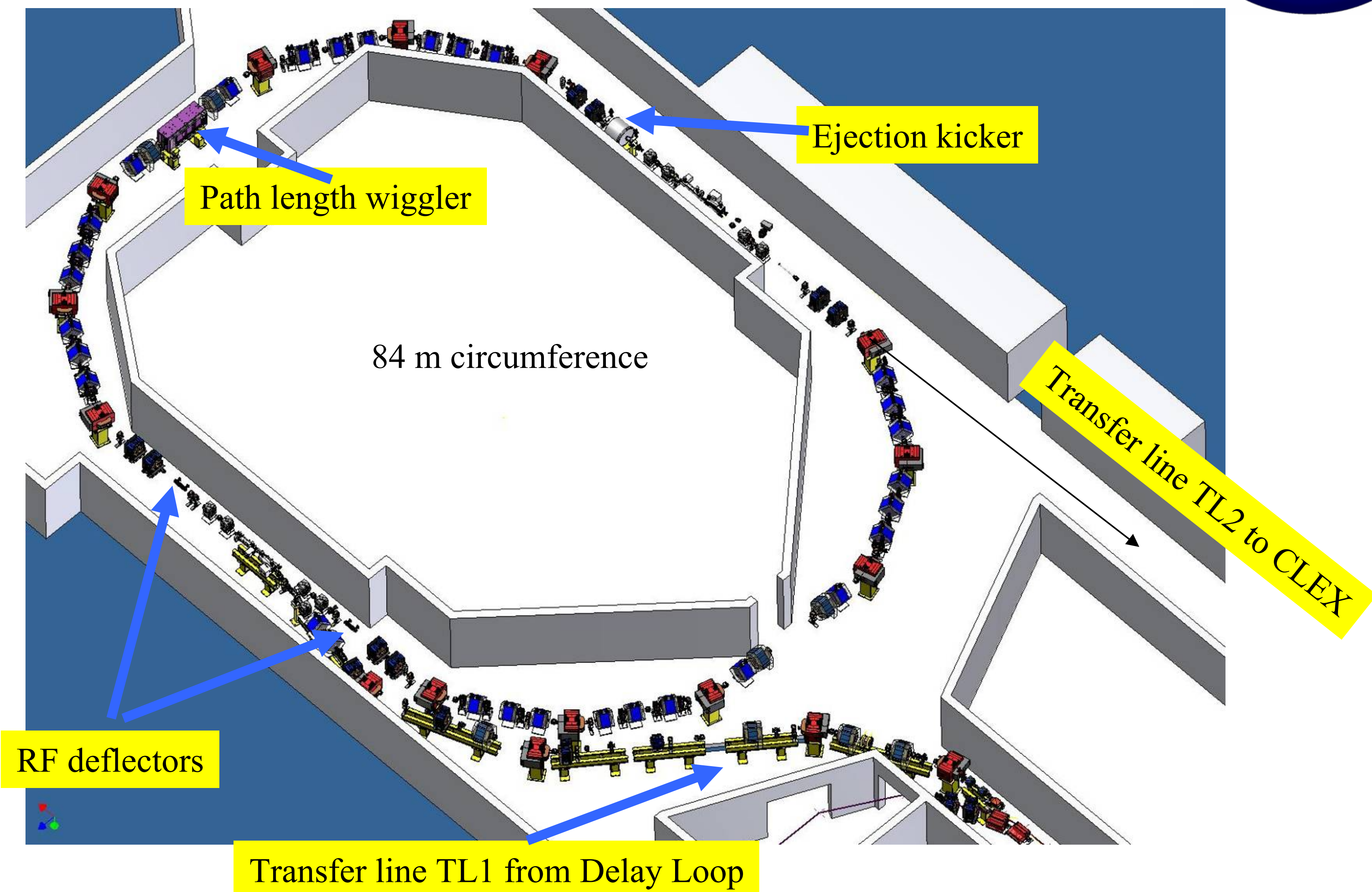
circumference 42 m (140 ns)
isochronous optics
wiggler to tune path length
(9 mm range)



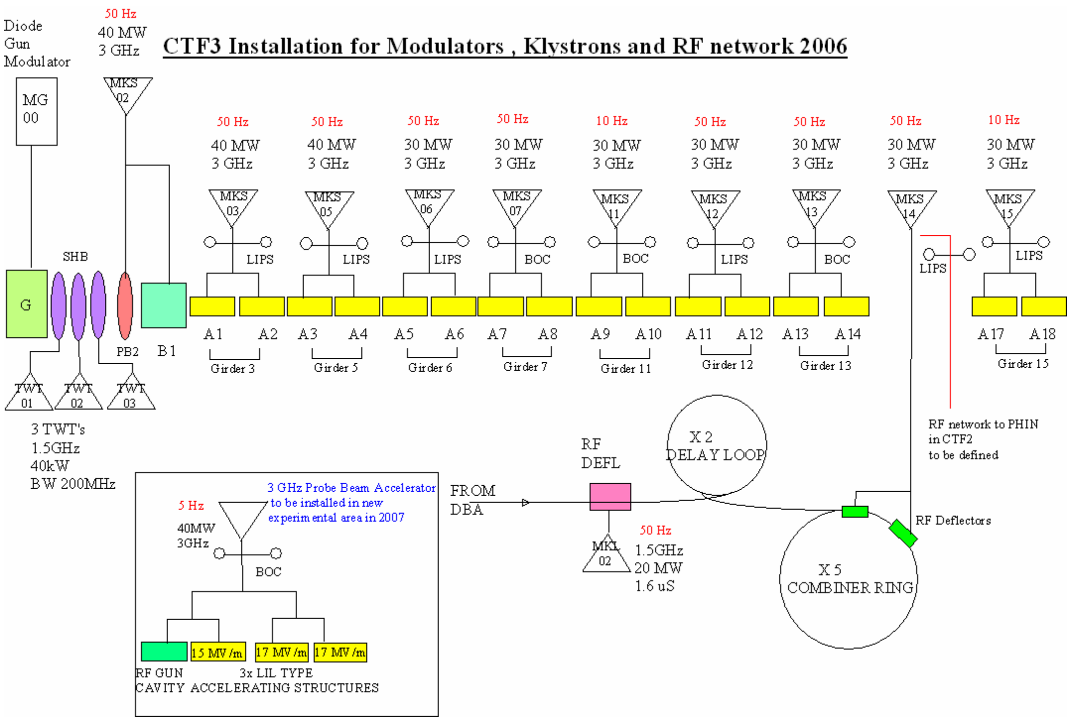
1.5 GHz RF deflector



Combiner Ring



RF power plant



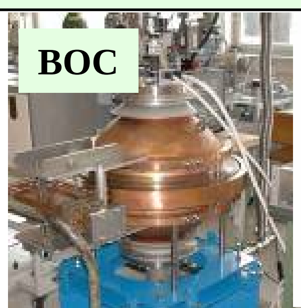
10 s-band klystrons 3 GHz
35 – 45 MW, 5.5 μs

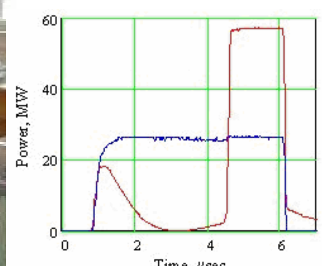
9 with pulse compressors:
factor 1.9 – 2 (1.6 μs)

3 L-band travelling wave tubes
40 kW, 3 μs
1.5 GHz BW >200 MHz

1 L-band klystron
22 MW, 5.5 μs

RF Pulse compression

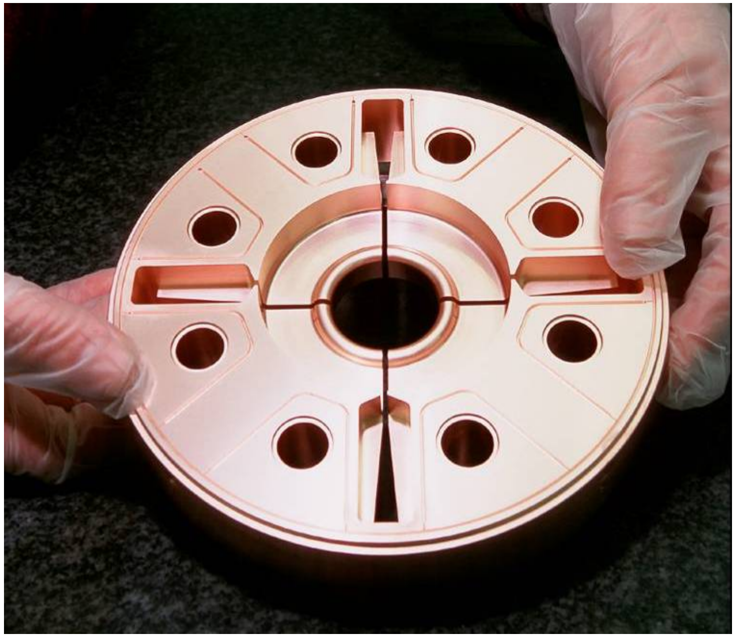


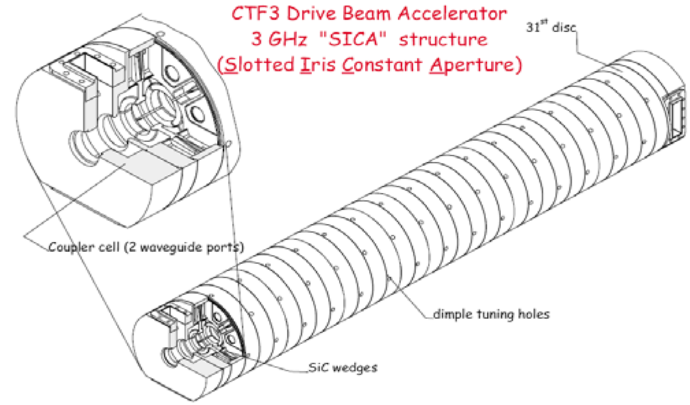


first 5 klystrons: ~ 5000 hours operation in 2006
2 klystrons replaced
3 thyratrons replaced
phase and amplitude stability under investigation

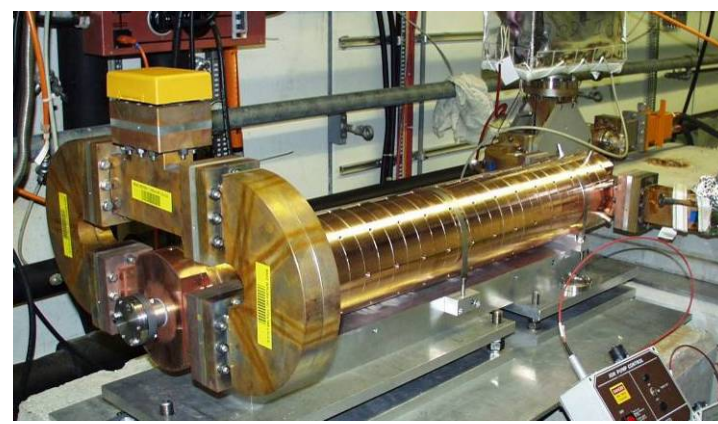
Linac accelerating structure

Developed for "full beam "loading"





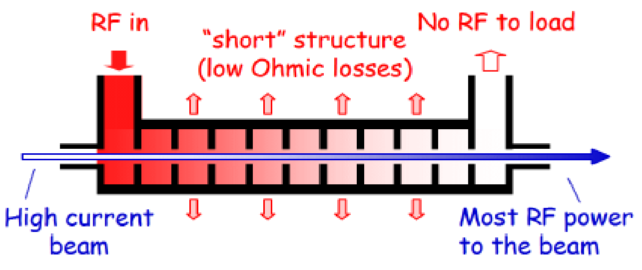
Travelling wave structure
32 cells + 2 coupler cells (1.22 m long)
2π/3 phase advance / cell
HOM detuning via nose cones / different cell diameter
HOM damping with radial slots and SiC absorbers
Q < 20 for lowest dipole modes
6.5 MV/m with nominal beam with 40 MW input



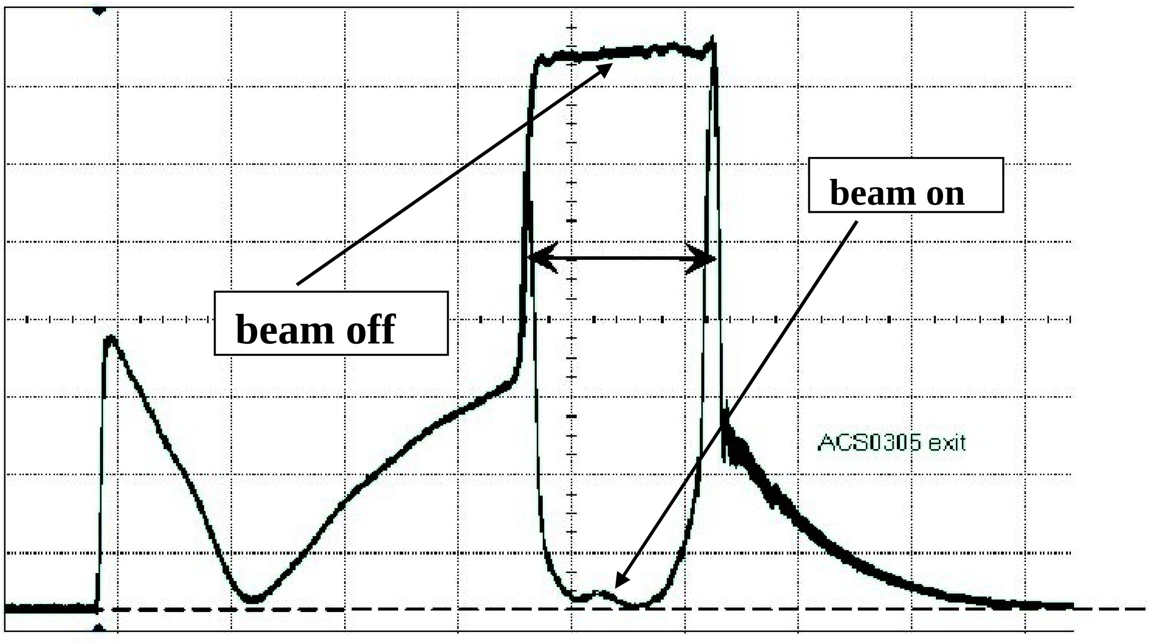
Full Beam loading

Proof of one of the major CLIC features: full beam loading

Results ➔ Frank Tecker



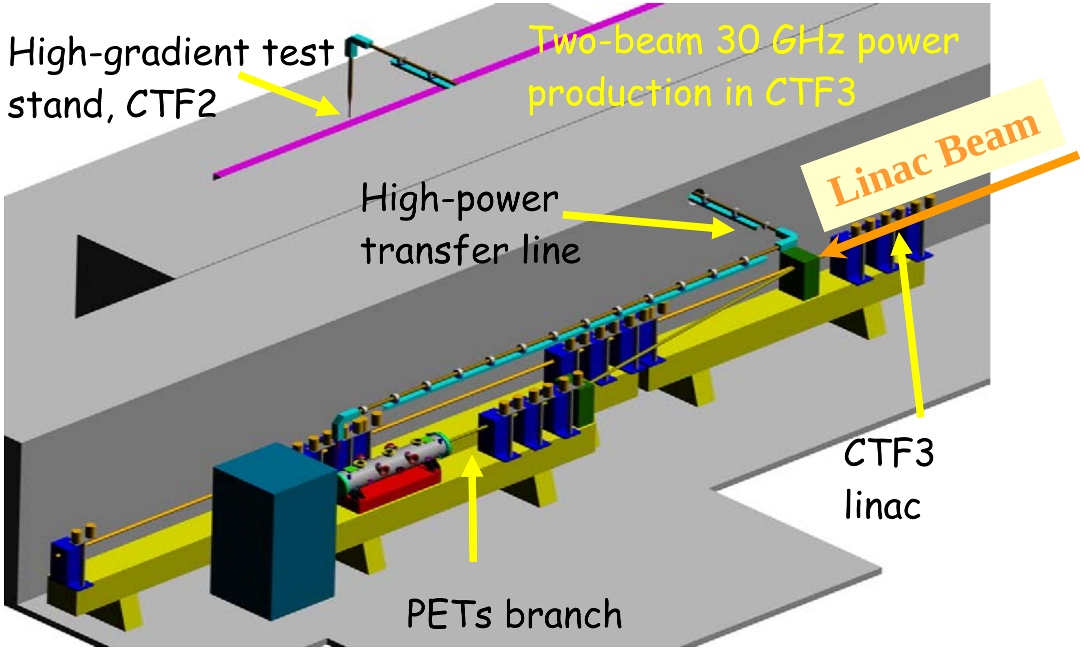
More details in paper MOP002



RF power at output of accelerating structure

Linac routinely operated now with full beam loading

30 GHz RF production



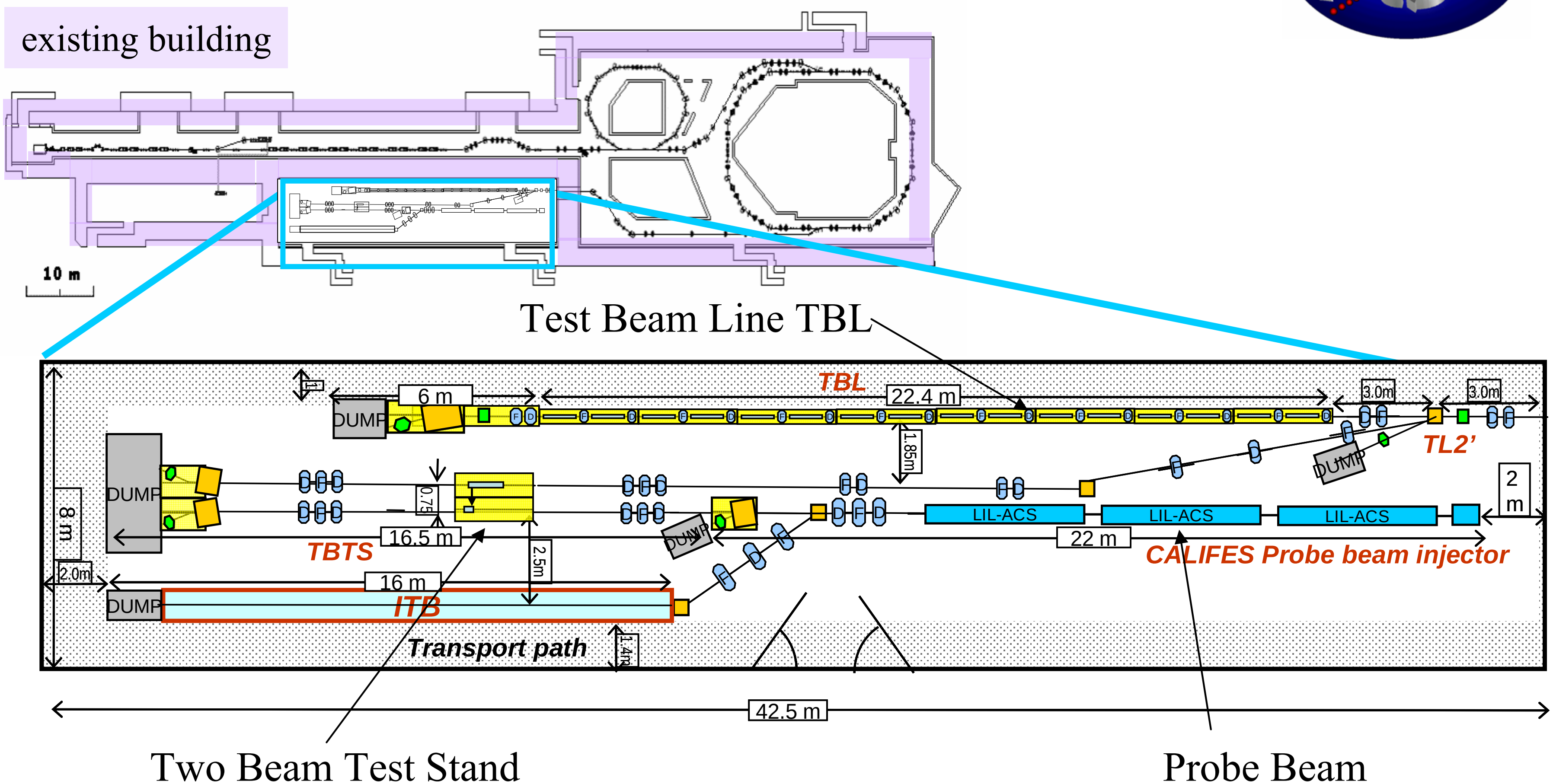
special operating conditions for 30 GHz operation:

- short bunches
- higher current (5A instead of 3.5)
- higher power (more compression)
  80 MW into structure

100 MW produced at 30 GHz, Transmission via circular TE_{01} line (17 m) with 65 % efficiency

operation for 30 GHz now routine,
largely automatic.
soon 24 hour operation

CLEX (CLIC Experimental Area)

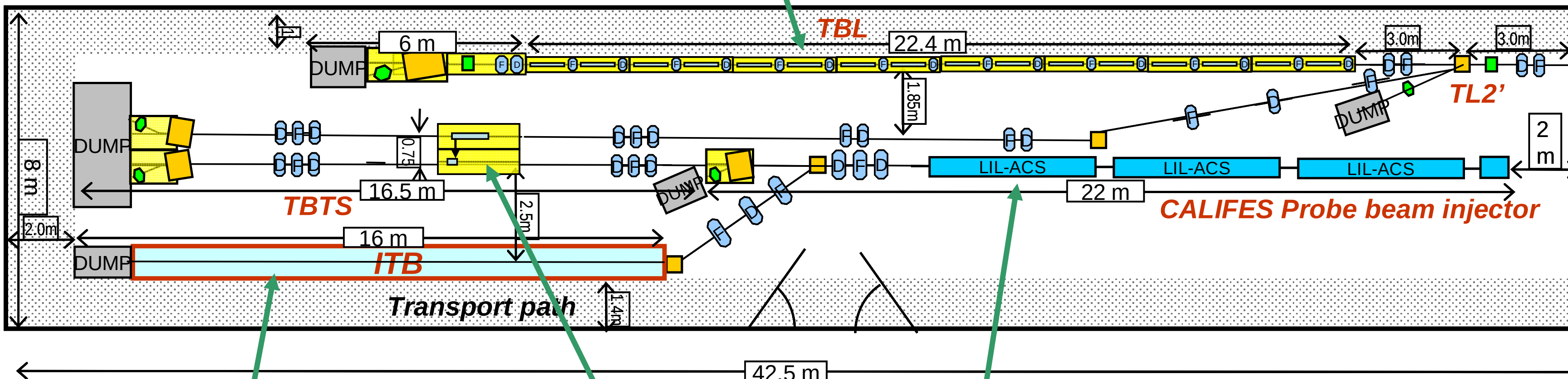


Construction during 2006/beg 2007
installation of equipment from
2007 - 2009

Beam in CLEX from 2008 onwards

Ongoing work in CLEX

CIEMAT magnet movers, PETS prototype,(+ series ????), PETS tank (series ???)
UPC & IFIC : BPM development + electronics (series ???)
CERN overall responsibility, optics, RF equipment, diagnostics, infrastructure, quadrupoles ???



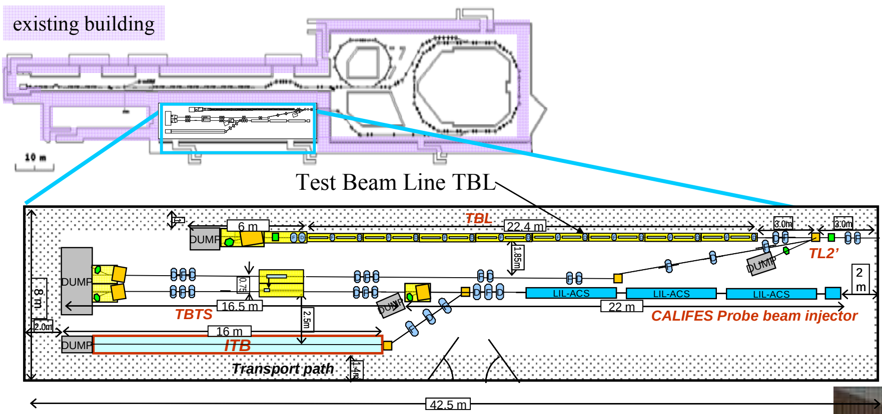
Instrumentation Test Beam Line
not presently funded
(FP7 GADGET proposal)

CEA Dapnia Saclay overall responsibility
CERN
CEA laser beam line, laser beam conditioning
LAL RF gun for photo injector

Uppsala University Two Beam Test Stand
CERN PETS and Accelerating structure

Pakistan: stainless steel vacuum components + ???
Iran: RF + Beam dynamics simulations

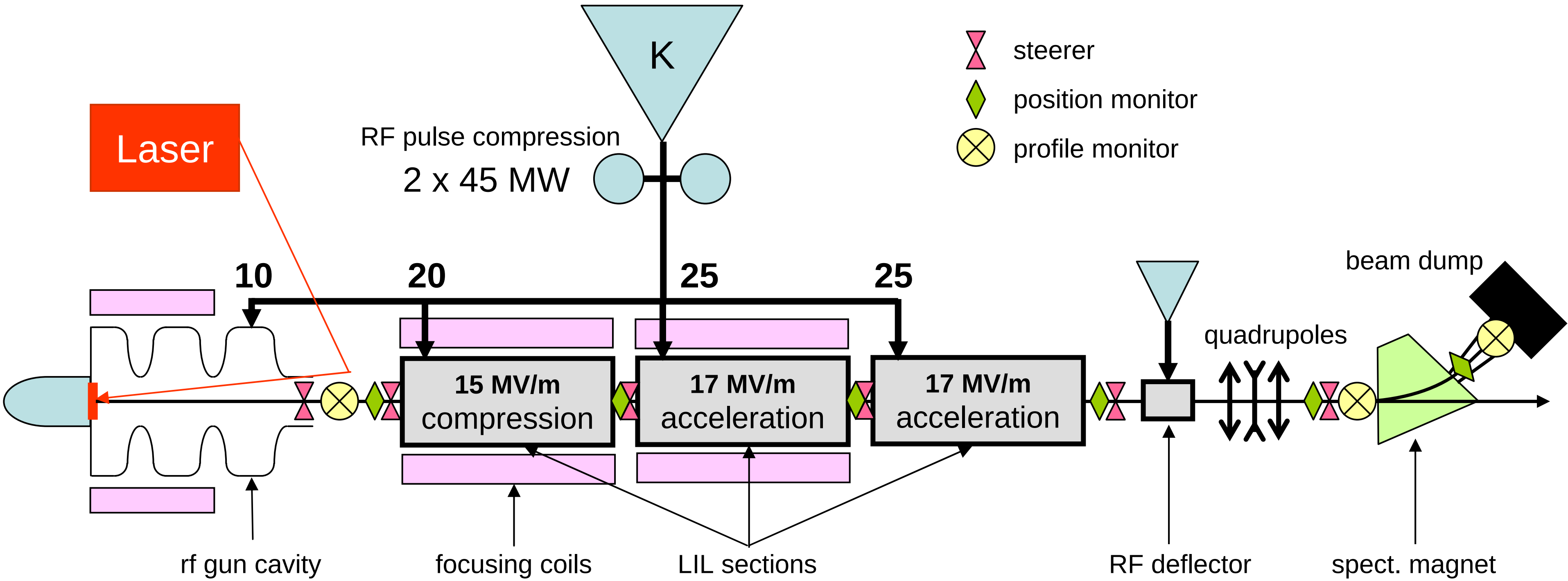
CLEX building



Construction on schedule
Equipment installation from May 2007,
Beam foreseen from March 2008

Probe Beam

200 MeV
bunch charge 0.5 nC
number of bunches 1 - 64

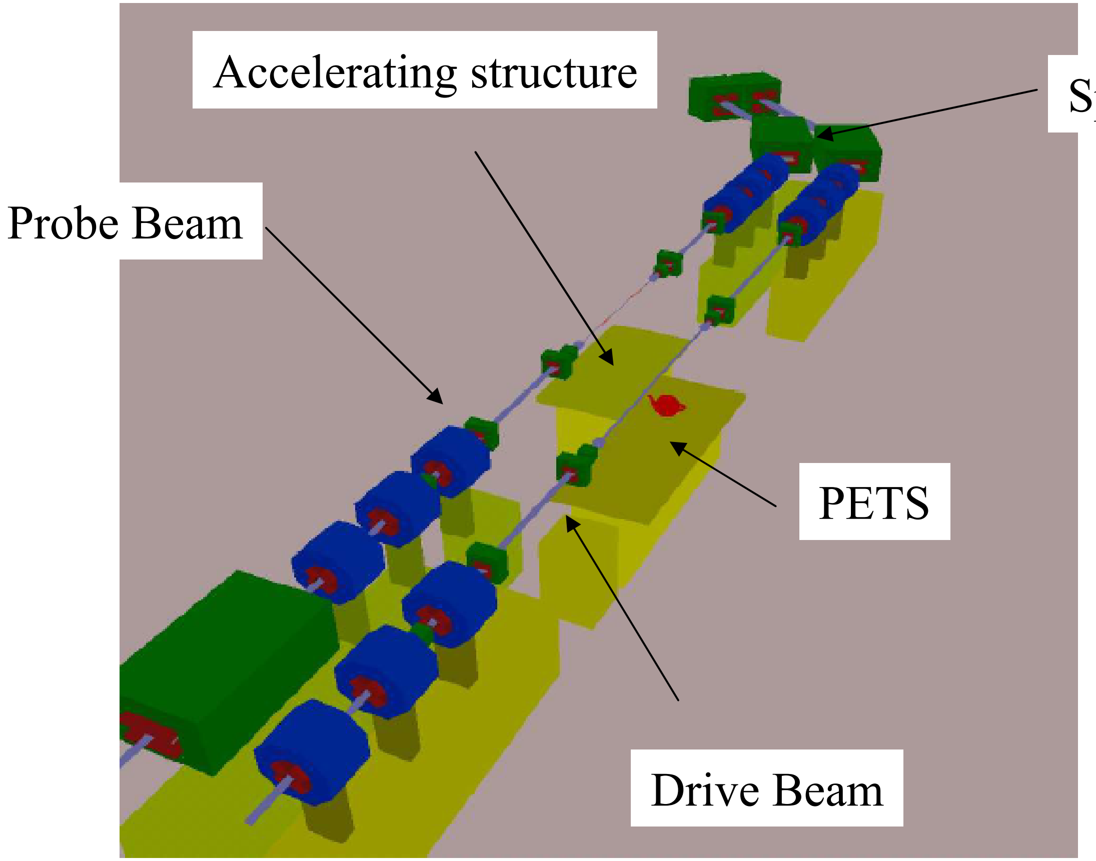


C A L I F E S

A. Mosnier, CEA Dapnia

Two Beam Test Stand

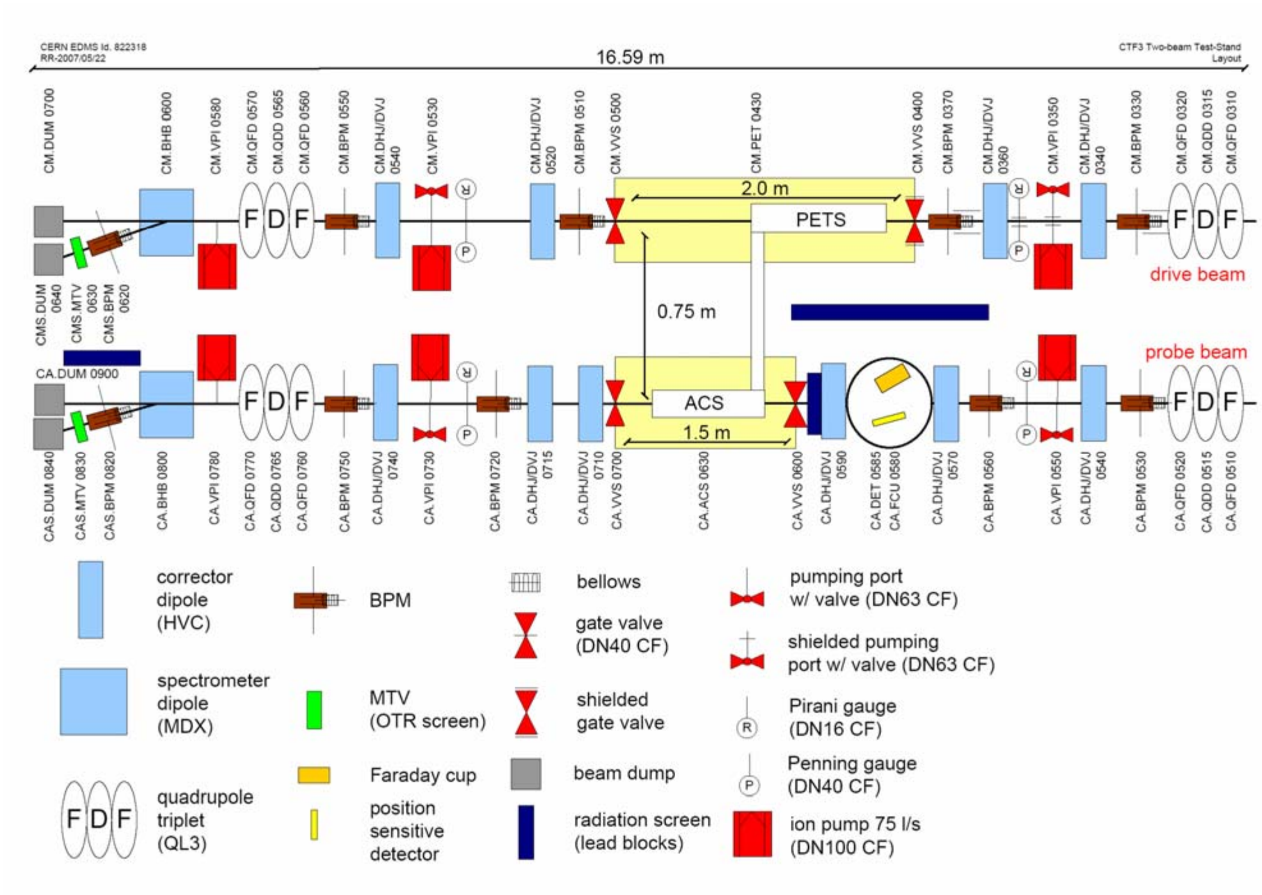
Accelerate Probe Beam with 30 GHz power from Drive Beam



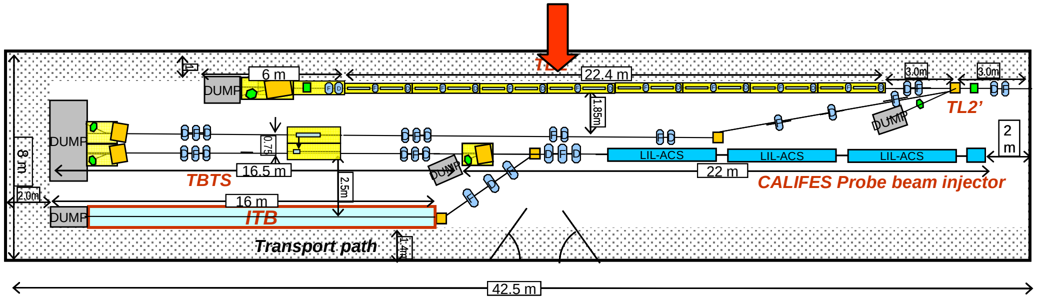
Diagnostics for energy, transverse kick due to RF breakdown

V.Ziemann, Uppsala University

Two Beam Test Stand

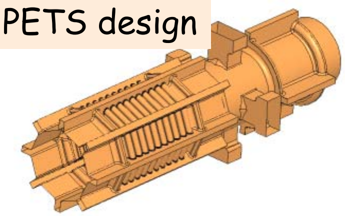


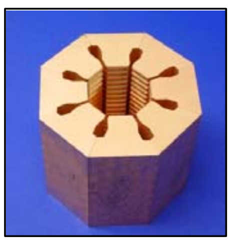
Test Beam Line TBL



Demonstrate beam stability under deceleration

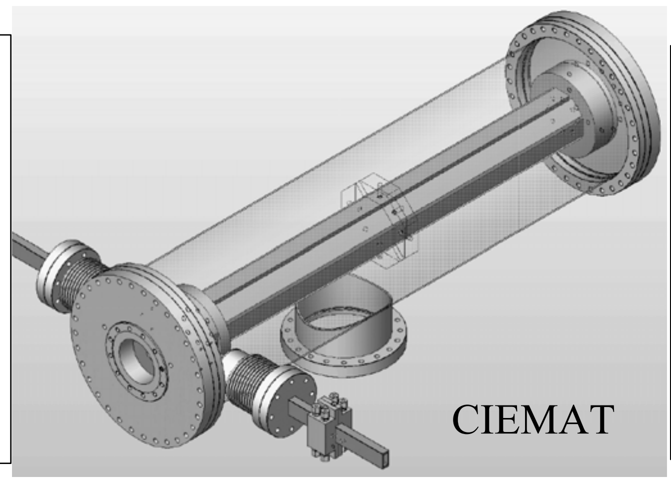
PETS design

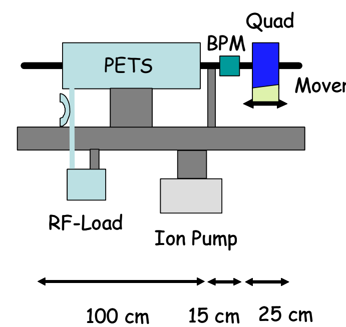




5 MV/m deceleration (35 A)

165 MV output Power





standard cell, 16 total

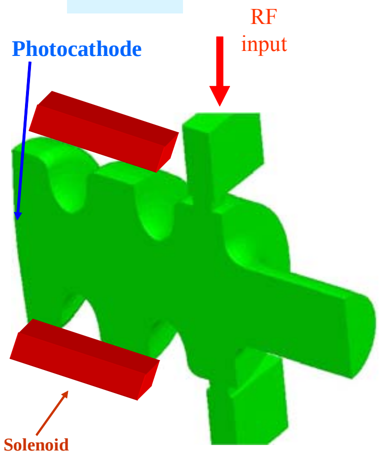
Decelerate to about 50 % beam energy
Total power produced in 16 PETS: 2.5 GW

S. Doebert, CERN

Photo Injector

smaller emittance, faster phase coding, no "satellite bunches"

LAL



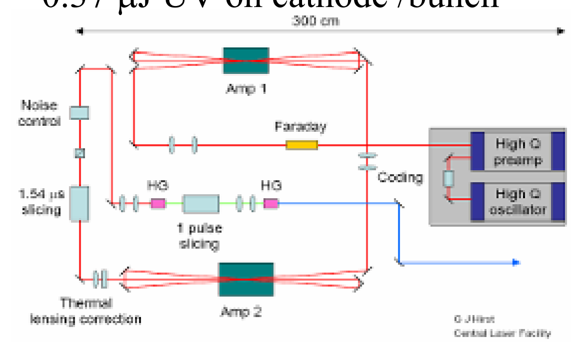
Phase 1:
off-line testing from 2007

CERN

Cs_2Te photo cathode
3% QE
40 hours life time
pulse train: 1.5 µs,
charge per bunch: 2.33 nC
bunch spacing 0.67 ns
number of bunches: 2332

RAL

diode pumped Nd:YLF laser
10 µJ IR / bunch
0.37 µJ UV on cathode /bunch



Phase 2:
Gun in CTF3: earliest spring 2008 ?????

Present status:
RF gun being built,
Laser at CERN, needs to be finished
with strong involvement from CERN, INFN Frascati and Milan

Laser is needed also for CALIFES injector !

12 GHz

Decision to change CLIC structure development from 30 GHz to 12 GHz

Effect on CTF3: For 30 GHz: bunch repetition frequency in Linac: 1.5 GHz
increase by x2 in DL
x5 in CR → 15 GHz
For 12 GHz: bunch repetition frequency in Linac: 1.5 GHz
increase by x2 in DL
x4 in CR → 12 GHz

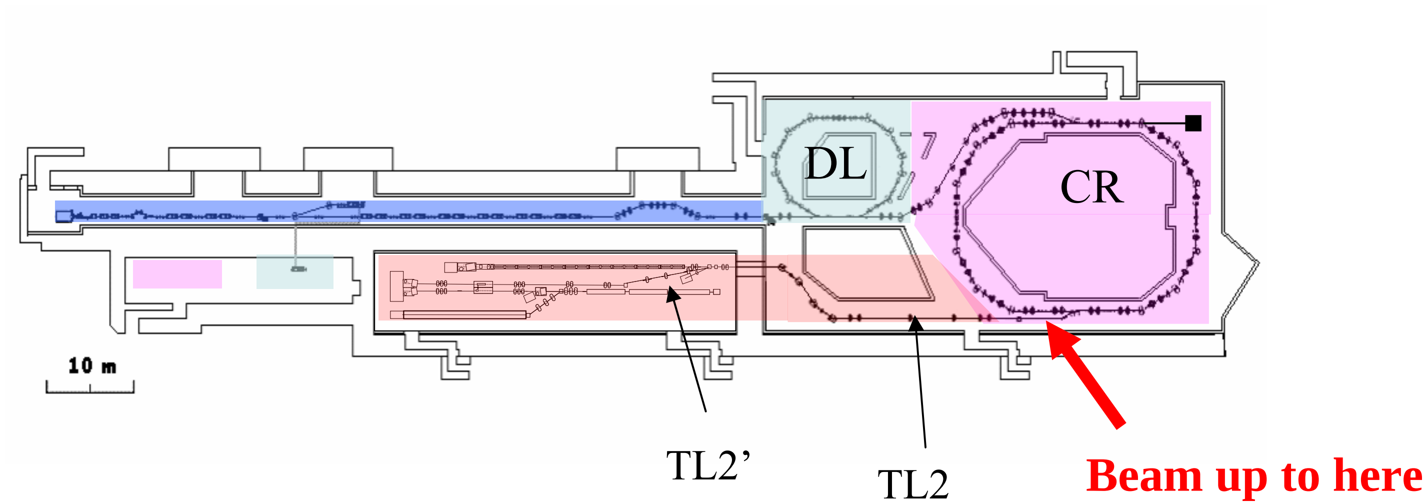
small circumference change in CR can be accomplished with wiggler

smaller nominal beam current: can be increased by higher current in linac and higher RF power (shorter pulse)

→ no effect on hardware

→ 30 GHz structure programme continues for the moment
→ 12 GHz PETS in TBL
→ 12 GHz PETS and accelerating structures in Two Beam Test Stand

Next steps

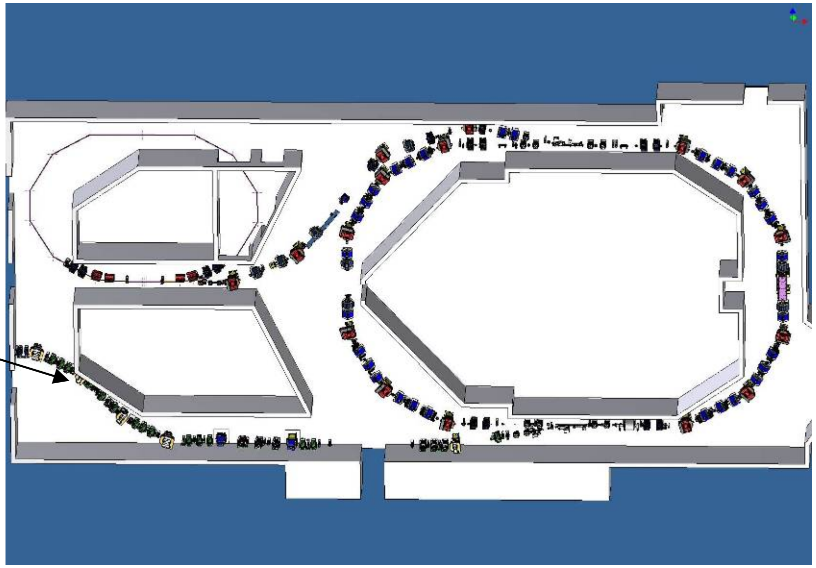


TL2 optics (RRCAT) finished, procurement of missing components has started

installation end 2007 / beginning 2008

beam into CLEX after winter shut-down.

TL2 : bunch compressor, vertical level change



TL2' optics done (CERN),

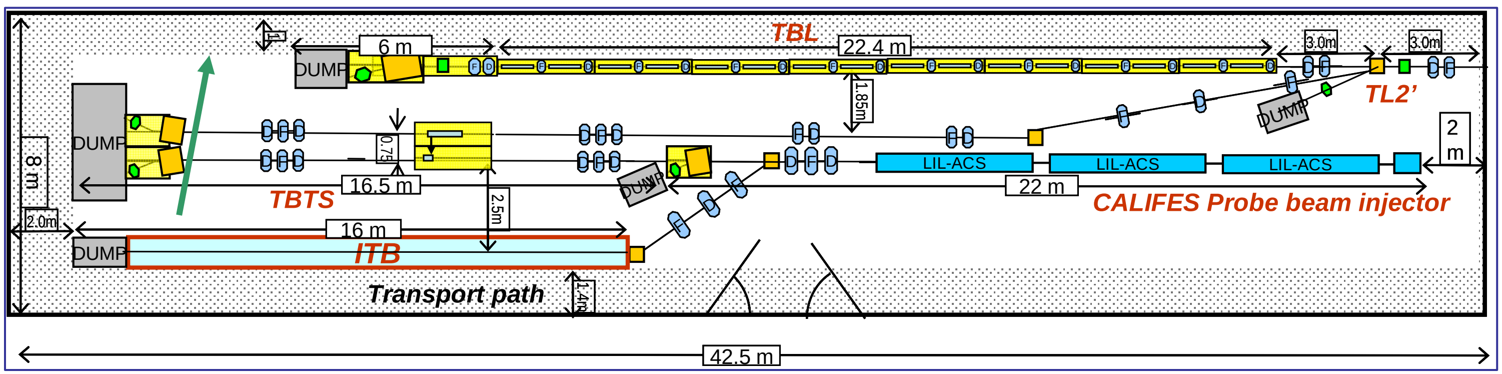
installation also end 2007 / beginning 2008

Beam into CLEX in 2008

Next steps CLEX

TBL: Layout progressing
PETS prototype incl. vac tank: CIEMAT. **Series ????**
Qadrupole movers : CIEMAT, **Quadrupoles to be designed and produced**
Installation of **one PETS in 2008, series in 2009**
BPM: Spain prototype. **Series ?**
total cost estimated to be 2.4 MCHF

Two Beam Test stand: All components under control
ready to receive beam April 2008 (PETS ? CLIC acc. structure ?)



Instrumentation Test Beam Line: not presently part of base-line programme
(FP7 GADGET proposal)

Califes covered, all major components on order or order being prepared.
new modulator ordered,
Commissioning planned for April 2008

Conclusion

Commissioned up to including TL1

- Combiner Ring installed, being commissioned,
- TL2 in 2007/2008, all components covered
- CLEX : everything covered except TBL series

Already demonstrated:

- full Beam Loading operation of linac
- Phase coding of bunches
- Bunch Interleaving in Delay Loop

Additional documents

CTF3 cost

		Status March 04		Status Nov 05	
		Budget	Manpower	Budget	Manpower
		MCHF	p-y	MCHF	p-y
TOTAL TO COMPLETION		95.4	393.3	101.1	395.8
CERN	Existing Equipments	40.0		40.0	
	Contrib. 2000-2003	16.0	100.0	16.0	100.0
	Pledged 2004-2009	17.4	150.0	14.9	125.0
	Contingency	0.0	0.0	5.5	25.0
COLLAB	Contrib. 2000-2003	4.8	48.3	4.8	48.3
	Pledged 2004-2009	0.0	0.0	9.4	59.0
Missing		17.2	95.0	10.5	38.5

15/12/2006		spent up to end 2004		pledged for 2005-2009		totals<2004+pledged		2005				2006			
		manpower my	cost kSFr	manpower my	cost kSFr	manpower	cost	m*y	m*y [kCHF]	material	total	m*y	m*y [CHF]	material	total
Addendum signed / Protocol with CERN*															
CERN	*totals*	*100.00*	*56,000*	*125.00*	*14,815*	*225.00*	*70,815*	*29*		*3,225*		*36.0*		4,314	
Helsinki Institute of Physics (HIP)	specialist in micro machining technologies for CLIC structure developments			3.00		*3.00*						*1.3*	45		
	establish dedicated project for development of technology with industrial and academic partners														
CEA	Probe Beam linac			30.00	1,950	*30.00*	*1,950*								
CNRS IN3P3						*23.00*	*450*								
	LURE 32 quadrupoles														
	LAL														
	MCHF)	15.00													
	probe beam photo gun			3.00	300										
	LAPP BPM read-out electronics			5.00	150							*4.8*		63	
India *	TL2 design,												6		
	Alu vac chambers for TL2														
	Dipole magnets for TL2														
INFN	Delay Loop	25.00	4,000			*33.00*	*4,900*	*7*		*568*		*7.0*		1,190	
	vacuum chamber TL1 and CR			4.00	900										
	CTF3 commissioning, operation			4.00											
Pakistan NCP *					800										
Budker institute of Nuclear Physics (BINP) Novosibirsk	11 quadrupoles, 26 sextupoles				270		*270*								
	future: more magnets as required according to the same conditions.														
IAP	30 GHz power source				1,024	*0.00*	*1,024*								
	Manpower and material , ISTC 227k$ included														
JINR Dubna	Manpower for automatic conditioning		114				*114*								
Spain Ciemat	15 qadrupoles for TBL + precision tables					*4.00*	*2,000*						272	840	
	2 Septa for CR														
	Extraction kicker for CR														
	HV pulser for kicker														
	32 corrector magnets for CR														
	PETS design														
UPC / IFIC	Contribution to BPM design for TBL			4.00	2,000										
Sweden Uppsala Univ.	Preliminary phase participation	1.50				*3.00*	*2,650*					*1.3*		107	
	Phase monitor	1.50	150												
	Phase monitor cont.				200										
	Two Beam Test Stand				2,300										
TSL	Celsius magnets				150									150	
PSI	Modulator components				200		*200*							200	
Ankara University	manpower for CTF3 operation	0.25		5.00		*5.25*		*0.5*				*1.0*			
Northwestern University Illinois	one accelerating structure		100			*3.00*	*350*								
	beam loss monitor		100		50										
	total manpower	2.00		1.00											
	RF pick-up for bunch length				100										
SLAC	electron gun triode (long term loan)		320			*3.00*	*320*								
	injector design and commissioning	3.00													
	sum:	48.25	4,784	59.00	10,394										
Under discussion															
UK	Beam Instrumentation line, Studies														
RAL	Laser for photo injector														
	total sum without CERN	-51.75	-51,216	-66.00	-4,421										

CLIC resources from CERN

		2008	2009	2010	Total
Material budget (kCHF)	Present MTP	3485	3485	3485	10455
	Additional LTP (CLIC-PLO/06-17 and White Paper)	4000	4000	4000	12000
	12 GHz power test stand and structure tests	1050	1850	600	3500
	Total additional (to present MTP plans) resources	5050	5850	4600	15500
	Total needed resources (to be included in future MTP)	8535	9335	8085	25955
Man-Power (FTE)	Present MTP	30.5	28	26.5	85
	Additional LTP (CLIC-PLO/06-17 and White Paper)	20	20	20	60
	12 GHz power test stand and structure tests	3	3	3	9
	Total additional (to present MTP plans) resources	23	23	23	69
	Total needed resources (to be included in future MTP)	53.5	51	49.5	154

Open work packages for CTF3

1. RF equipment for Probe Beam (Califes)

1.1 klystron for Califes

3 GHz, 45 MW, pulse length 5.5 ms

1.2 waveguide components for Califes:

WR 284, LIL-type flanges, peak power 100 MW, pulse length 5.5 ms

1.2.1. various line components: straight lines, bends, directional couplers, RF loads, operation under UH Vacuum

1.2.2. special waveguide components:

- one 4.5/1.9 dB splitter
- one variable waveguide attenuator, 0.5 to 20 dB attenuation, peak power 10 MW, operation under SF_6

2. RF equipment for CTF3 operation

The 3 GHz klystrons which reach the end of their lifetime have to be repaired or eventually replaced by new ones if they cannot be repaired any more. We estimate that on average 1.5 to two klystrons need to be replaced every year. The klystrons are rated at 45 MW peak power at an RF pulse length of 5.5 ms and a repetition rate of 100 Hz.

3. Vacuum equipment:

Vacuum pumping equipment, instrumentation and vacuum chambers have to be provided for Transfer Line TL2 and TL2’, TBL and Califes: :

3.1. 60 ion pumps (60 l/s)
30 HV pump power supplies (compatible with CERN vacuum control system),

3.2. 10 vacuum gauges

3.3. 3 mobile turbo pumps

3.4. 20 shielded pumping ports according to existing drawings

3.5. 3 vacuum valves with RF shielding

3.6. 20 Bellows with RF shielding according to existing drawings

Open work packages for CTF3

4. Material for Test Beam Line (TBL)

4.1. 16 quadrupoles for TBL

4.2. 16 CLIC power extraction and transfer structures (PETS) modules. *A prototype is being built by Spain. The series production is still open*

4.3. 16 vacuum tanks for PETS structures. *A prototype is being built by Spain, the series is still open.*

4.4. 16 beam position monitors (BPM). *A prototype is being developed and built by Spain, the series is still open.*

4.5. 16 front end analogue electronics for the BPMs(4.4). *A prototype is being developed and built by Spain. The series is still open.*

4.6. 16 BPM digital electronics. *Preferably use LAPP electronics*

4.7. analogue front electronics for 12 GHz signal acquisition in TBL

4.8. digital read-out electronics for 12 GHz RF signals (see 4.7 above) ***EPFL ?***

4.9. 32 power loads for 12 GHz RF and 16 directional couplers

5. Equipment for additional S-band RF power installation

Most of the component needed for a modulator has been provided by PSI. This could be used for an additional S-band power sources to power two additional RF accelerating structures in the CTF3 Drive Beal linac.

5.1 A 45 MW klystron is required

Open work packages for CTF3

6. Stand-alone X-band power source

For CLIC accelerating structure developments a stand-alone power source is required which allows to enhance the CLIC accelerating structure testing capacity considerably.

6.1. X-band klystron, peak power 50 MW, RF pulse length 1.5 ms.

6.2. Modulator for the klystron (6.1), 500 kV

7. 12 GHz RF components:

High-power X-band RF components including: flanges, bends, twists, directional couplers, hybrids, splitters, variable power dividers, windows, valves, loads etc. Some of these components will be adapted from SLAC and KEK designs and others will have to be designed from scratch. The components must be produced in quantities of approximately ten parts each for both the Two Beam Test Stand and

8. 12 GHz signal acquisition system

The 12 GHz RF pulses from both PETS and accelerating structures will need to be monitored by a fast acquisition system. The system will include: 12 GHz down-converter incorporating programmable attenuators, wideband IQ demodulators, data acquisition system sampling at 750MS/s. Around 50 channels will be required.

Open work packages for CTF3

9. Prototype PETS structure manufacture:

These structures require 10 micron precision, fully three dimensional milling in relatively large, 1 m long, parts. We expect that two or three generations of PETS will required for the testing program.

10. Ultrasonic fatigue testing:

This work package consists in measuring the fatigue behaviour of bulk materials which can be applied for the construction of accelerating cavities for CLIC by ultrasonic excitation or similar methods. Testing should be extended to the nominal lifetime of the machine (1011 pulses) and should give a base for the estimate of the surface fatigue provoked by the RF pulses. The focus is at present on precipitation hardened copper alloys which have high electrical conductivity and mechanical strength. The influence of the various surface treatments which could improve fatigue resistance and be compatible with the requirements of RF application, high precision machining and in a second priority with bi-metal joining techniques should be investigated. Other potential candidates beyond such alloys, as composites or other materials, having similar and superior properties should be selected and evaluated.

11. CTF3 commissioning and operation support by experienced machine physicists

October 3, 2001

CTF3 Review
B. Aune (Saclay), H. Henke (T. U. Berlin), R. Siemann (SLAC)

Introduction

CLIC is a multi-TeV linear collider that is a possible future CERN project. Distinctive CLIC features include

- A two-beam configuration to generate the RF power,
- High RF frequency, f_{RF} = 30 GHz,
- High accelerating gradient, G = 150 MeV/m.

CTF3 is a test facility that is part of the CLIC development and is collaboration between CERN, INFN Frascati, LAL Orsay, RAL Didcot, SLAC, Strathclyde UK, and Uppsala University. CTF3 would test the underlying concepts of the RF power generation by experimentally demonstrating several critical aspects including high efficiency energy transfer from low frequency RF to the Drive Beam and frequency multiplication using a delay loop and a combiner ring. Thirty GHz RF would be produced at the end of the Drive Beam linac in the Initial Phase and with the beam from the combiner ring in the Nominal Phase. This power can be used to test accelerating structures and RF components to establish the feasibility of the CLIC accelerating gradient.

Specific CTF3 goals are

- Fully beam-loaded operation of the Drive Beam Accelerator
- Phase coding of bunches and bunch interleaving
- Control of bunch length and energy spread
- Production of 30GHz RF power at nominal CLIC requirements
- Provide a test facility for CLIC RF components

Principal Findings and Recommendations

CTF3 or an equivalent facility is imperative for the development of CLIC. The actual technical choice of CTF3 is based on existing buildings and components. Under the given boundary conditions **collaborations are vital for the project**. INFN (Frascati) is taking responsibility for the transfer lines, delay loop and combiner ring, which are major, essential parts of CTF3.

The CTF3 concept is sound, and it takes advantage of existing buildings and hardware to realize substantial savings. **The project is staged intelligently** with three stages that explore the various CTF3 goals with increasing demands on performance.

The project is technically demanding, but there are no insurmountable problems. Resources and schedule look possible but tight. We believe that, because of the technical demands, several years of commissioning and operation will be required after the completion of the installation.

CLIC is critically dependent on developing the processes, materials, techniques, etc. that firmly establish the feasibility of the high acceleration gradient. The RF power from CTF3 will be available for testing major CLIC components, but high power RF experiments need at least one fully dedicated and continuously available test stand. **Either a dedicated power source** or new collaborations devoted to understanding gradient limits are necessary soon for a timely and systematic exploration of the many issues that must be resolved.

Comments on Technical Solutions

Injector: A thermionic gun and bunchers have been designed with **requirements on current magnitude and stability that are at the upper limit of what is possible**. If the stability is not achievable right away, a feedback solution is foreseen. In parallel an RF gun is under design. It would allow for a better bunch structure and lower emittance. The main challenge is the drive laser. There is encouraging progress on that, and planned experiments should allow a choice between these two injector options.

Linac: A slotted iris structure with higher order mode damping and detuning (SICA) was chosen, and the first high power tests were positive. The 3 GHz power generation relies on existing klystrons, modulators, and modified LIPS pulse compression. The RF system will require sophisticated temperature and phase control. The linac would be operated fully beam-loaded to demonstrate high efficiency, but full beam-loading is not necessary for high power RF generation. Comparison between FODO, doublet and triplet optics showed best emittance preservation and smallest jitter amplification in the case of triplets.

Transfer lines, delay loop and combiner ring: All of these devices are isochronous, and parameters have been chosen but they are not final. They make use of existing magnets and are being designed to fit within the footprint of the available building. Work on the RF deflectors is in progress, and no major problems have been encountered. A novelty is the use of wigglers in the rings for path length control. The requirement on the low frequency impedance in the combiner ring, **$Z/n = 0.4\Omega$, is low but possible** with a smooth vacuum chamber and a minimum number of vacuum chamber transitions.

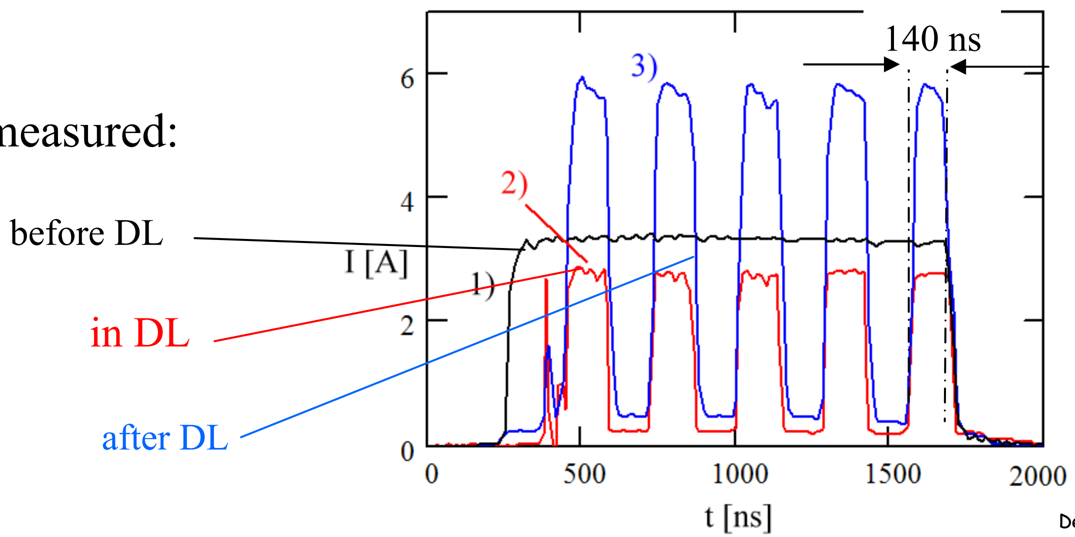
Longitudinal phase space manipulations: Very short bunches will create coherent synchrotron radiation in the rings and degrade the emittance. Bunches, which are compressed in the linac to reduce energy spread, must be lengthened before they are injected into the delay loop and compressed again after the combiner ring. **This will be demanding and requires sophisticated diagnostics.**

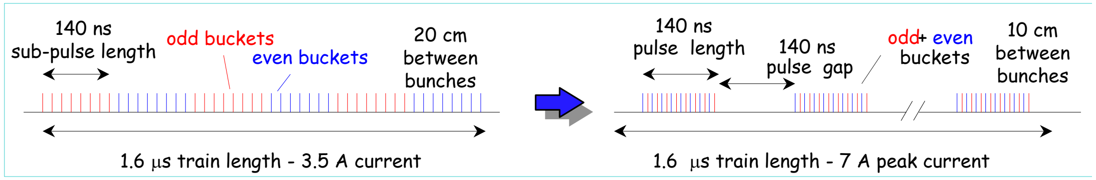
Staging of the project: A Prelimary Phase, which has already started, makes use of the existing linac, a new gun, and EPA ring with a modified lattice. It will allow the first demonstration of beam combining with factors of 3, 4 and 5 at low current. It will also allow first experiments on deflectors, on coherent synchrotron radiation effects, and bunch length and phase monitors. In a second stage, the Initial Stage, the new linac will be installed and will have a test stand for high power RF experiments. High power RF test stands will be invaluable for CLIC, and this test stand should remain operational during installation, commissioning and operation of the full CTF3 facility. The combiner ring, delay loop, CLEX experimental area and a probe beam will be added in the Nominal Phase, which is the third and final stage.

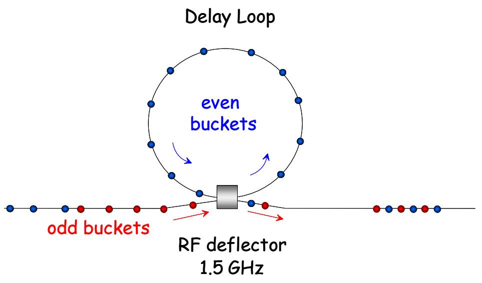
Probe beam and CLEX experimental area: CLIC needs 240 MW/m for 130 nsec at a repetition rate of 100 Hz. This would give 150 MeV/m accelerating gradient in the main linac. The CLEX test stand is intended for power generation, testing of waveguide components and accelerating structures, study of breakdown phenomena, and determining the ultimate possible gradient. A 200 MeV probe beam will serve for verification of RF parameters, measuring of wake effects, and the CLIC beam-loading compensation scheme.

Bunch interleaving in Delay Loop

Beam current measured:







Successful demonstration of Delay Loop operation !