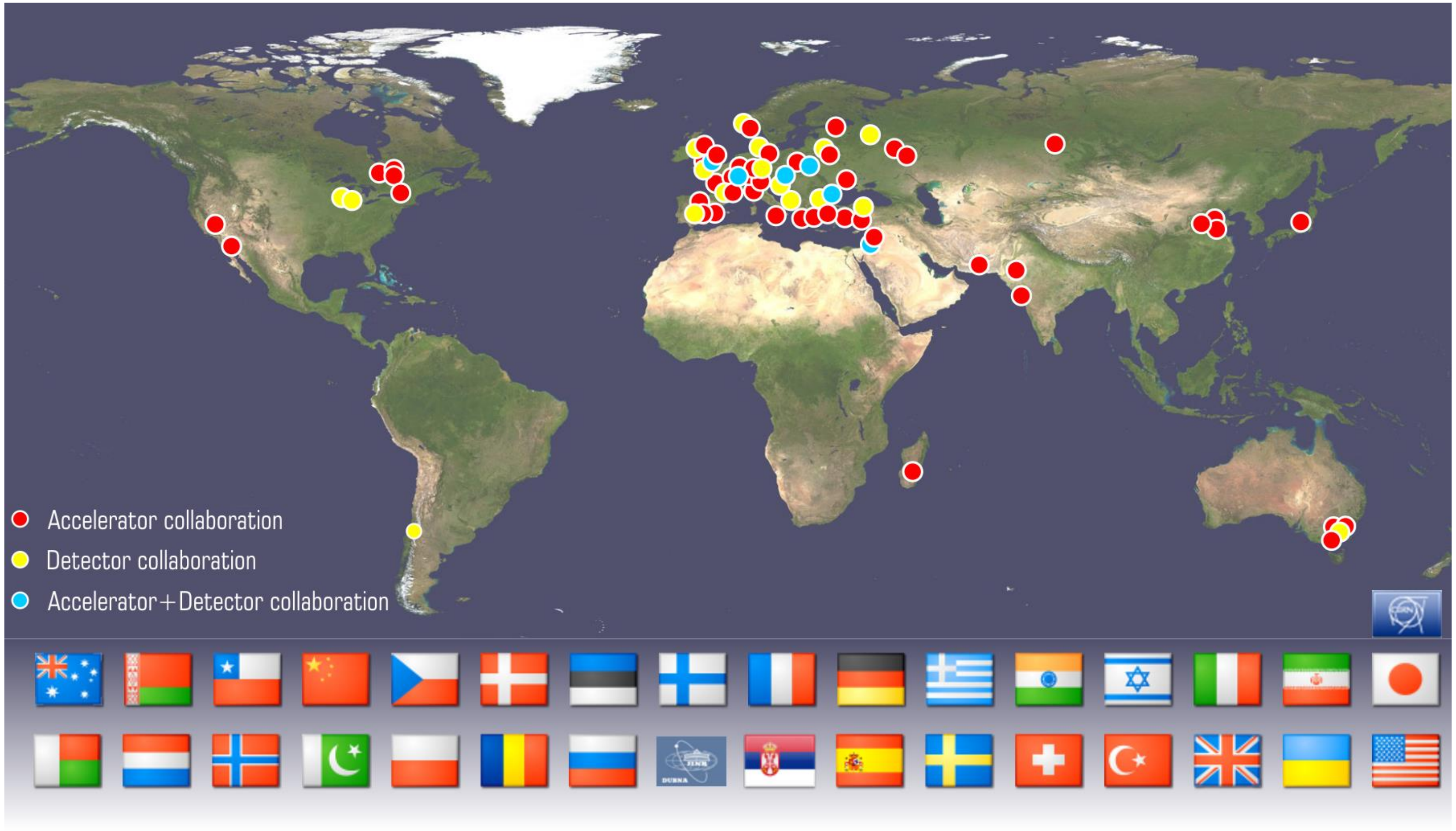
INDUSTRIAL TECHNOLOGIES IN CLIC

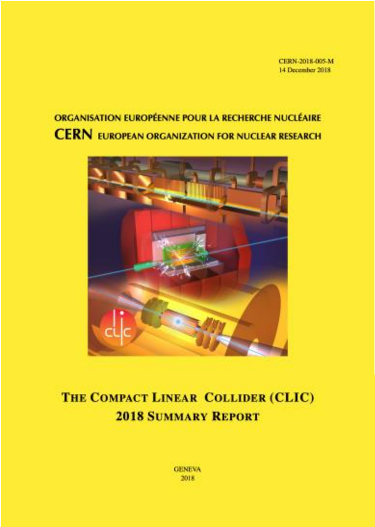
N. CATALAN LASHERAS.

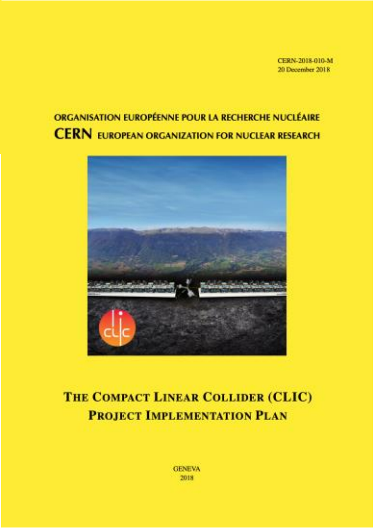
BRIEF INTRODUCTION TO CLIC

COLLABORATION



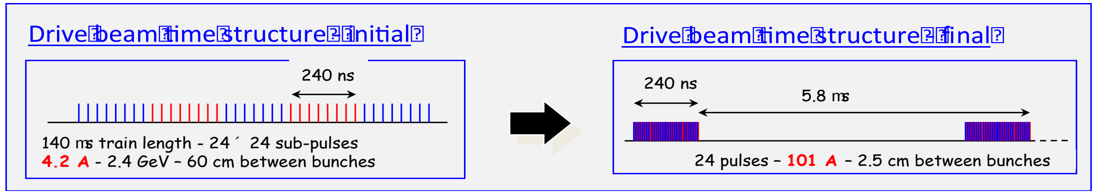
58 institutes from 28 countries

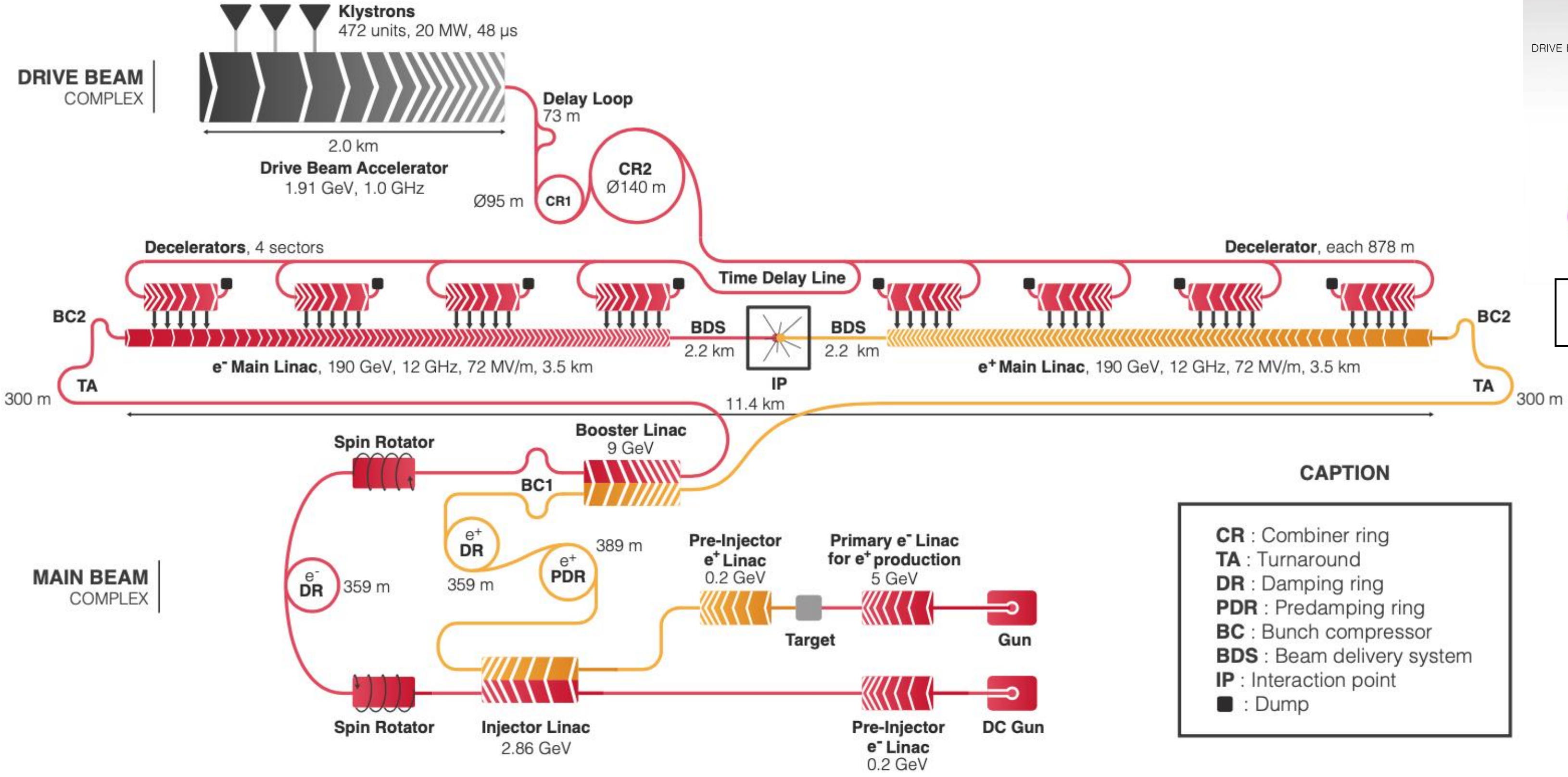


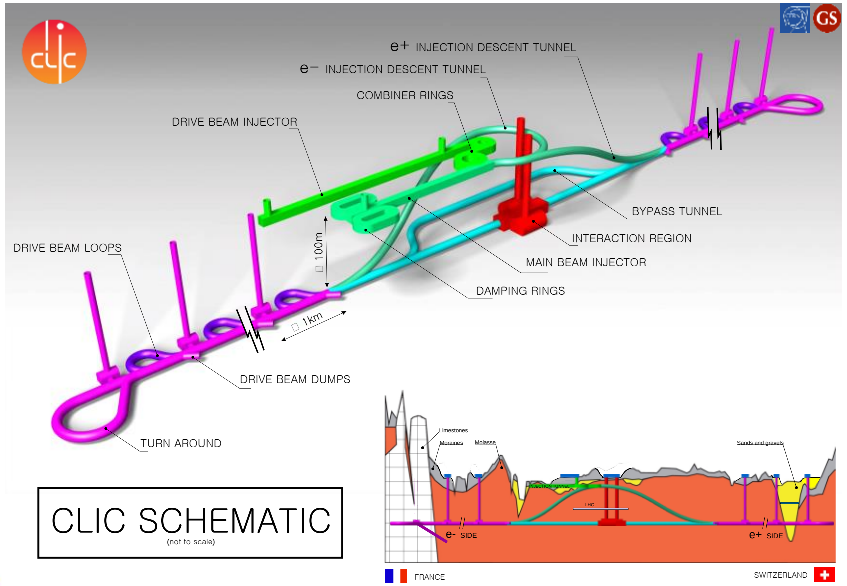


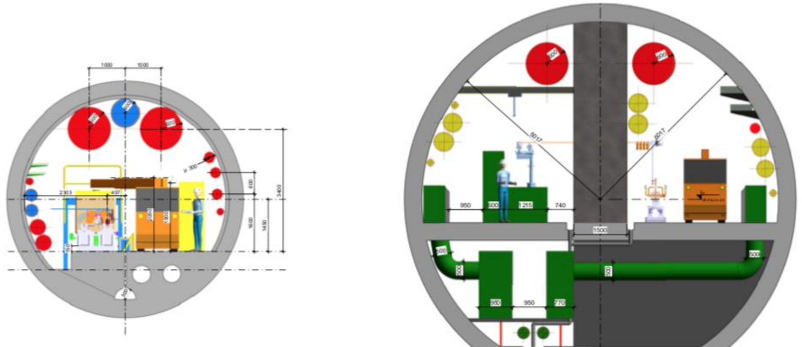
https://clic.cern/european-strategy

CLIC LAYOUT 380 GEV









(a)

(b)

2013 - 2019 Development Phase

Development of a Project Plan for a staged CLIC implementation in line with LHC results; technical developments with industry, performance studies for accelerator parts and systems, detector technology demonstrators

2020 - 2025 Preparation Phase

Finalisation of implementation parameters, preparation for industrial procurement, Drive Beam Facility and other system verifications, Technical Proposal of the experiment, site authorisation

2026 - 2034 Construction Phase

Construction of the first CLIC accelerator stage compatible with implementation of further stages; construction of the experiment; hardware commissioning

2019 - 2020 Decisions

Update of the European Strategy for Particle Physics; decision towards a next CERN project at the energy frontier (e.g. CLIC, FCC)

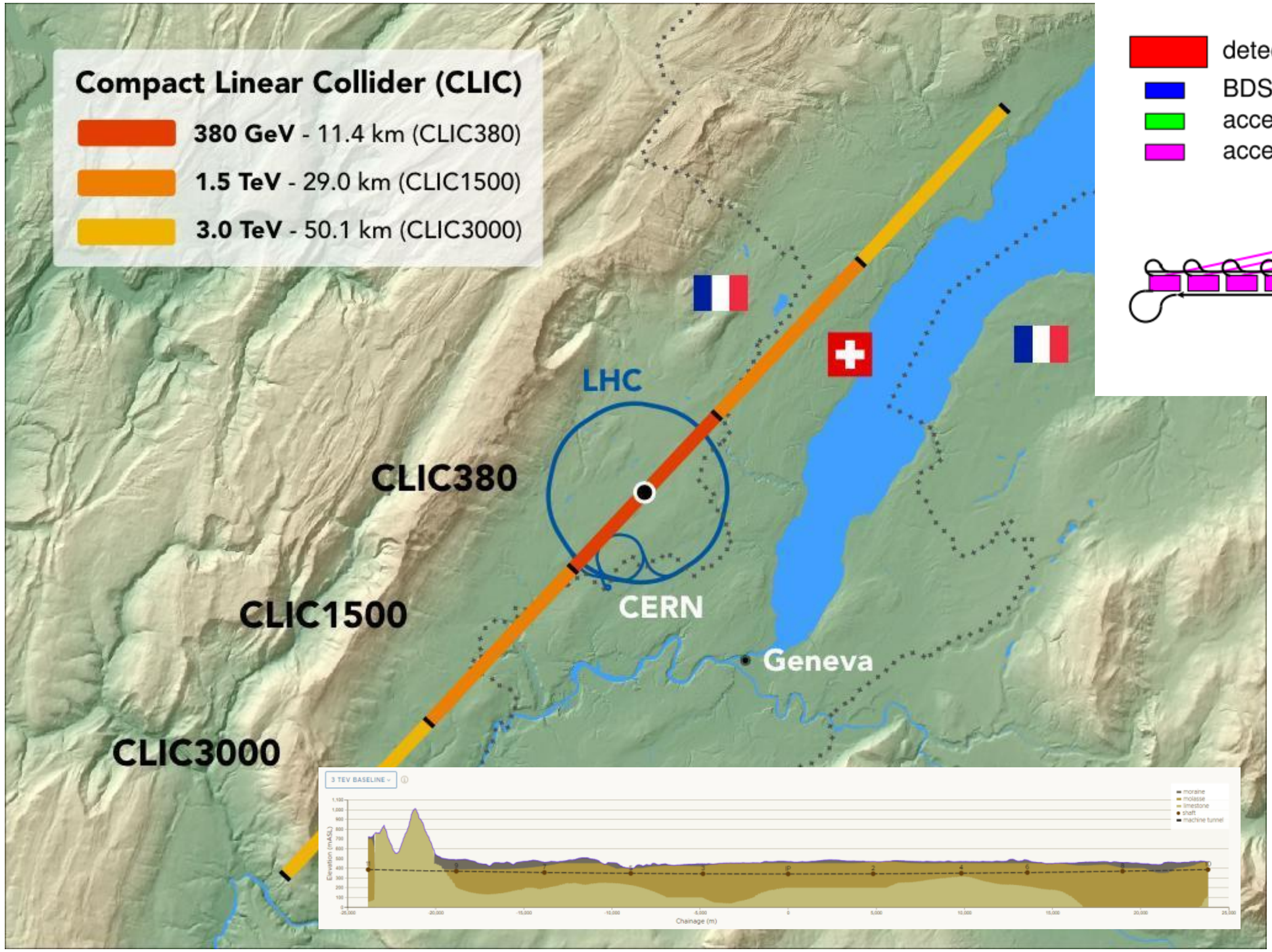
2025 Construction Start

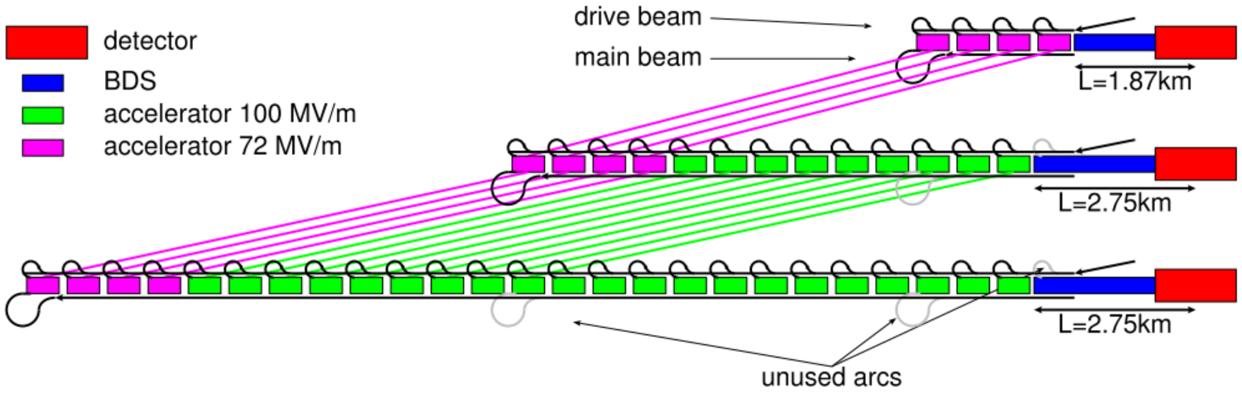
Ready for construction; start of excavations

2035 First Beams

Getting ready for data taking by the time the LHC programme reaches completion

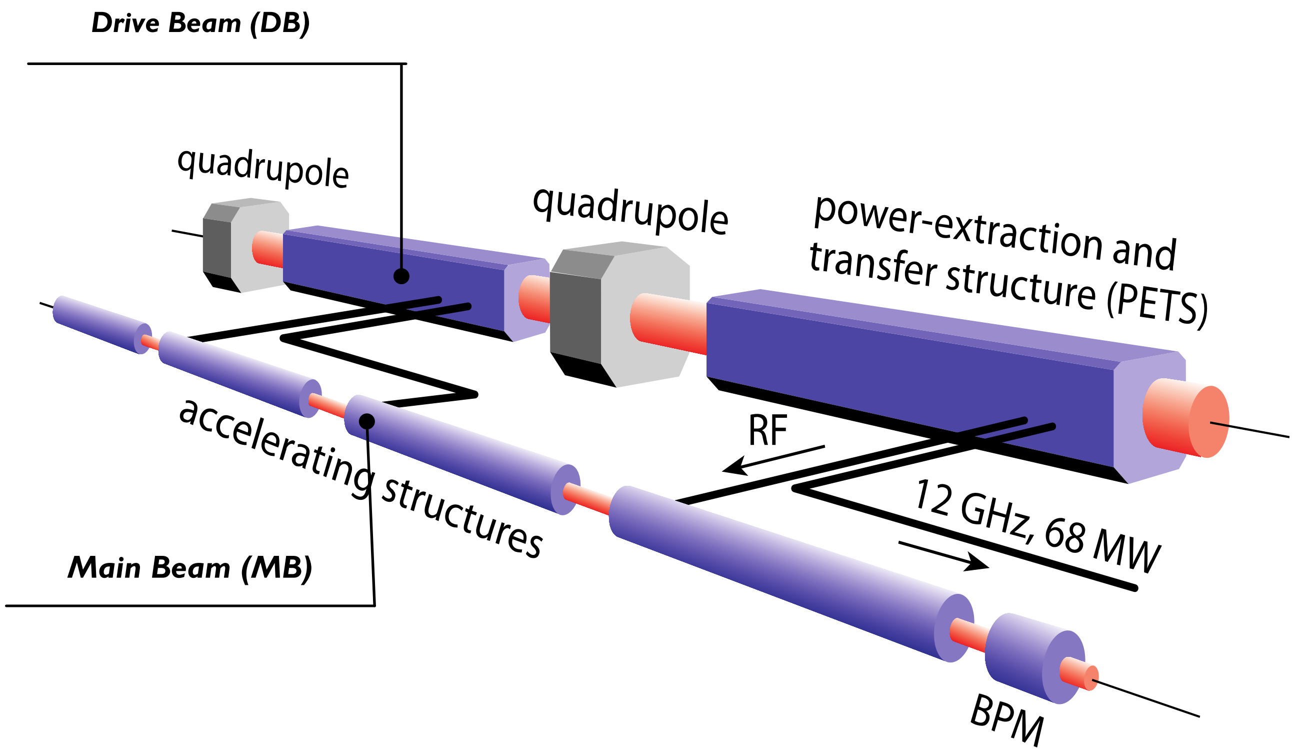
STAGED CLIC IMPLEMENTATION





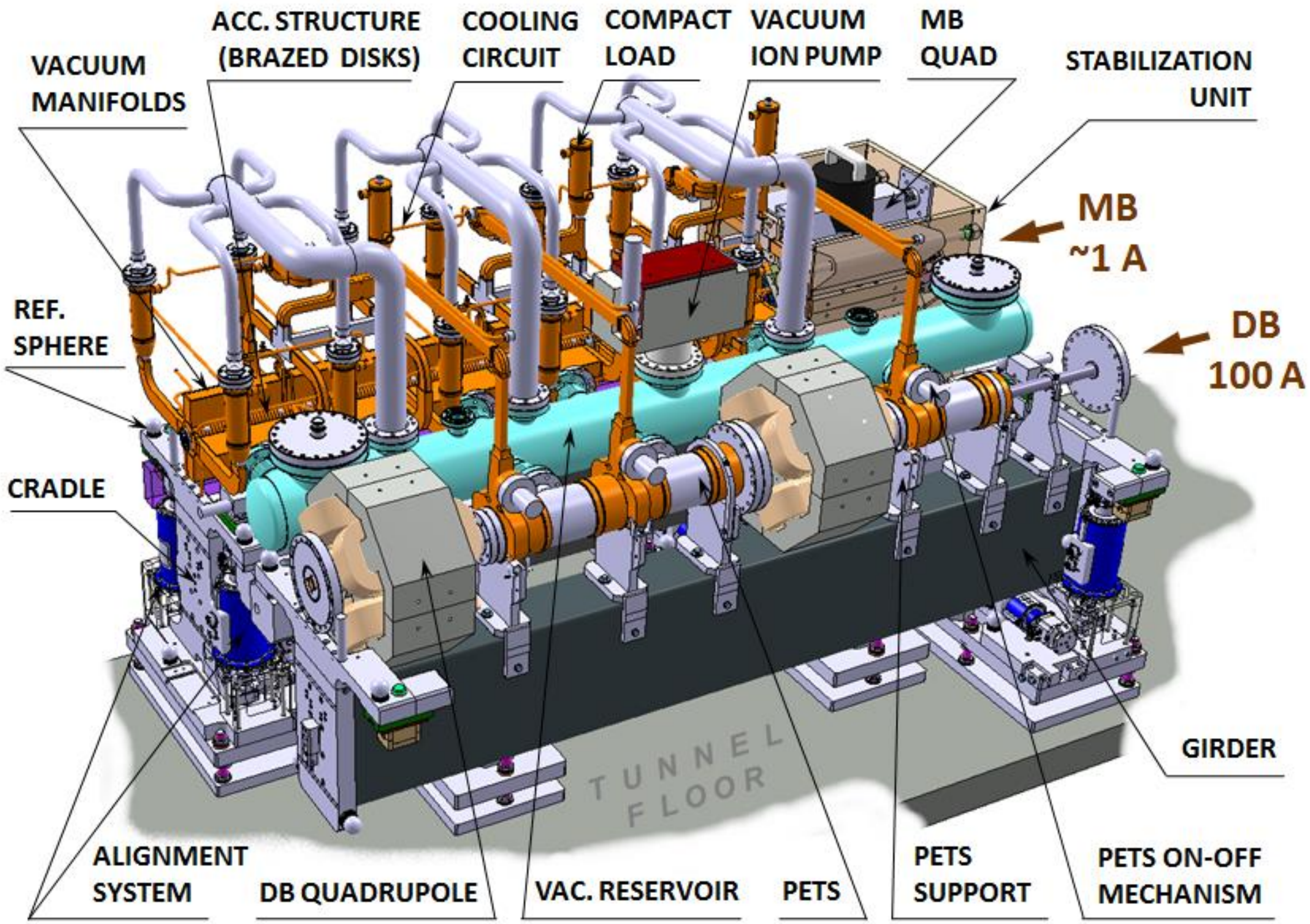
Parameter	Symbol	Unit	Stage 1	Stage 2	Stage 3
Centre-of-mass energy	$\sqrt{s}$	GeV	380	1500	3000
Repetition frequency	f_{rep}	Hz	50	50	50
Number of bunches per train	n_b		352	312	312
Bunch separation	Δt	ns	0.5	0.5	0.5
Pulse length	τ_{RF}	ns	244	244	244
Accelerating gradient	G	MV/m	72	72/100	72/100
Total luminosity	$\mathscr{L}$	10^{34} cm^{-2}s^{-1}	1.5	3.7	5.9
Luminosity above 99% of $\sqrt{s}$	$\mathscr{L}_{0.01}$	10^{34} cm^{-2}s^{-1}	0.9	1.4	2
Main tunnel length		km	11.4	29.0	50.1
Number of particles per bunch	N	10^9	5.2	3.7	3.7
Bunch length	σ_z	µm	70	44	44
IP beam size	σ_x/σ_y	nm	149/2.9	$\sim$ 60/1.5	$\sim$ 40/1
Normalised emittance (end of linac)	$\varepsilon_x/\varepsilon_y$	nm	920/20	660/20	660/20
Normalised emittance (at IP)	$\varepsilon_x/\varepsilon_y$	nm	950/30	—	—
Estimated power consumption	P_{wall}	MW	252	364	589

TWO-BEAM PRINCIPLE



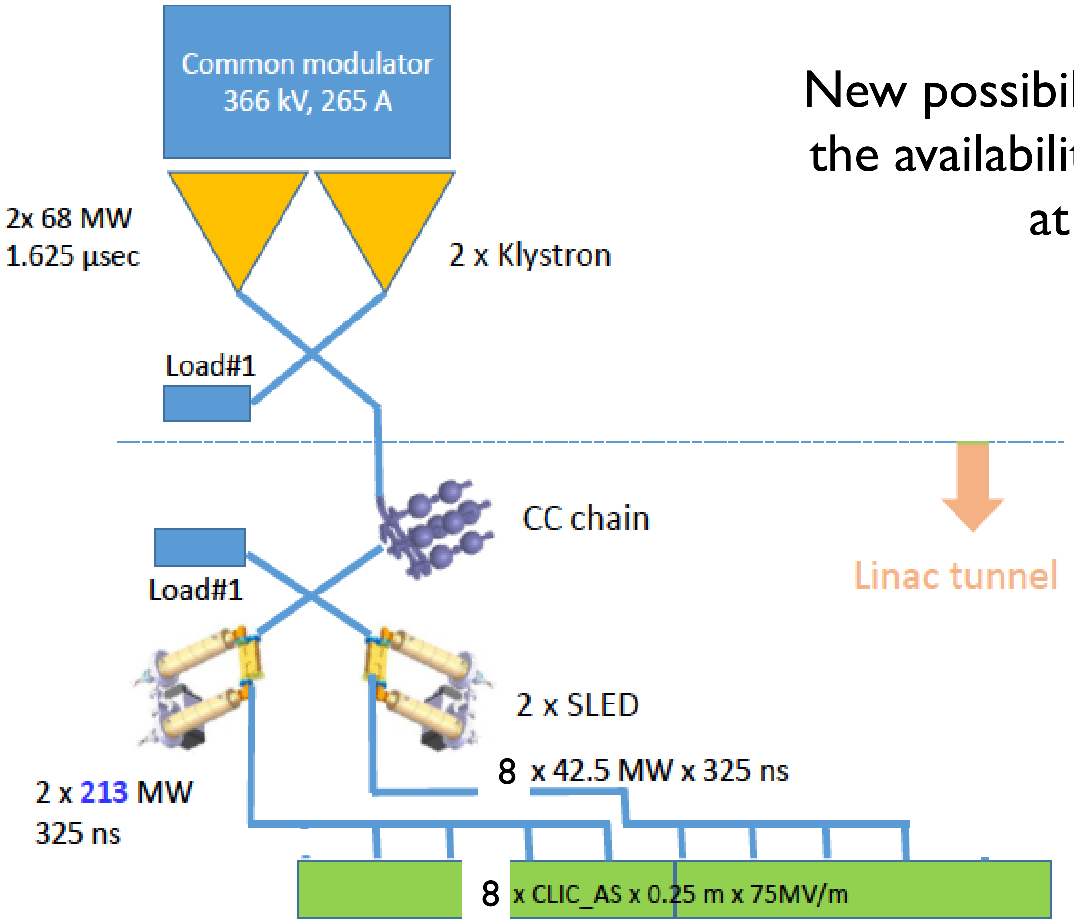
The RF power is extracted from a drive beam with low energy and high intensity to be injected in the main linac where a lower intensity, higher energy electron beam is accelerated and made to collide with a second positron beam equally generated

CLIC MODULE. MAIN PARAMETERS AND COMPONENTS

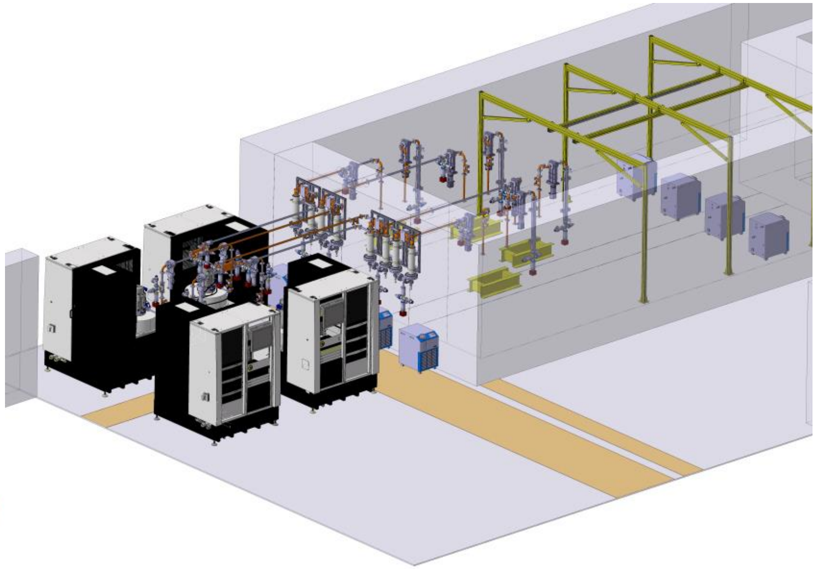


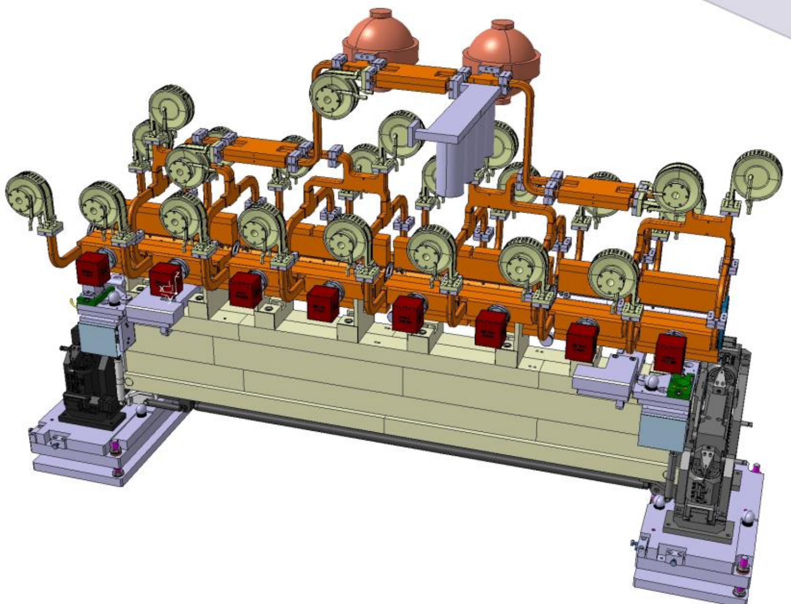
Main parameters of CLIC module		
Module length	2010	mm
PETS length	308	mm
PETS aperture	23	Mm
PETS gradient	6.5	MV/m
PETS power	136	MW
AS length	230	mm
AS aperture	5	Mm
AS gradient	100	MV/m
AS power	64	MW
Vacuum level	10^{-9}	mbar

KYSTRON-BASED CLIC AND X-BAND TEST FACILITY.



New possibilities open thanks to the availability of power sources at 12 GHz!!





CLIC TECHNOLOGIES IN INDUSTRY

THE NEED FOR QUALIFICATION

Proven technologies

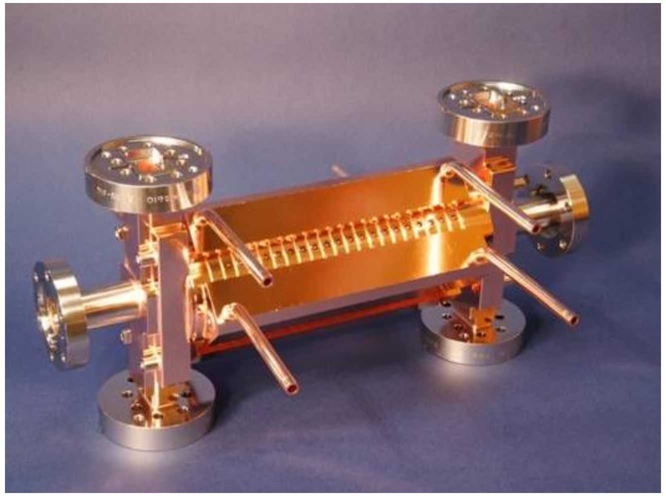
- There are either "off the shelf" products or technologies that have been proven by the manufacturer in previous products.
- The product exist on the company catalogue or can be adapted with a reasonable effort.
- Companies can be included in a call for tender with a technical specification.
- Typically, a first unit will be order and subject to a battery of tests to fulfil the tight requirements.
- Examples; High voltage modulators, klystrons, ceramics, electronic components, piezo movers, sensors, etc.

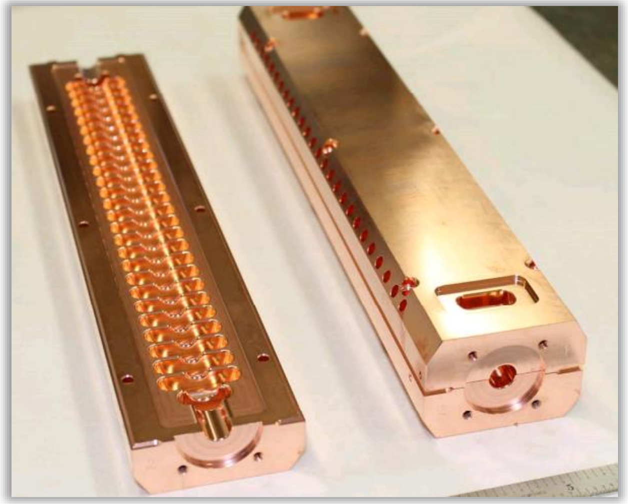
New technologies

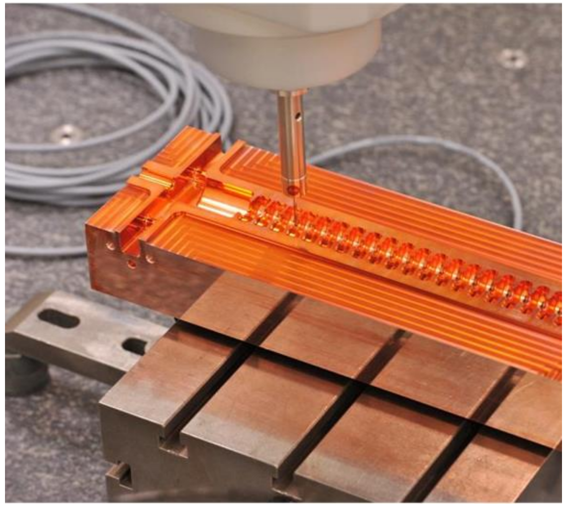
- New, tighter tolerances required.
- Stringent constrains on safety, cleanliness, etc.
- Done as prototypes at CERN. Technology transfer is generally required from CLIC side.
- **The firm capability to produce the parts needs to be proven through a qualification process.**
- **Qualification may consist on visits, the delivery of a test unit or a dedicated test. Qualification documents are available.**
- Examples: Ultra precision machining, hydrogen copper bonding, ultra-high-vacuum RF components.

COPPER ULTRA-PRECISION MACHINING I

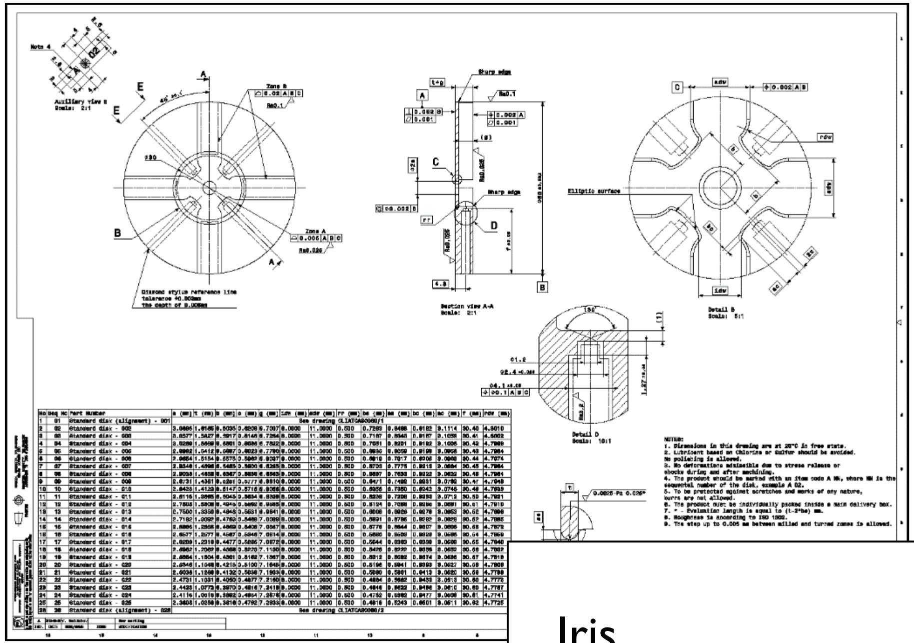
- Diamond-tool ultraprecision machining.
- Turning and milling.
- Very strict qualification based on visual inspection and CMM metrology.
- VDL (NL), LT-Ultra (DE), Yvon Boyer (FR), DMP (ES), Morikawa (JP), KERN (DE).







COPPER ULTRA PRESIDION MACHINING II



Cell shape accuracy:

zone A - 0.005 mm

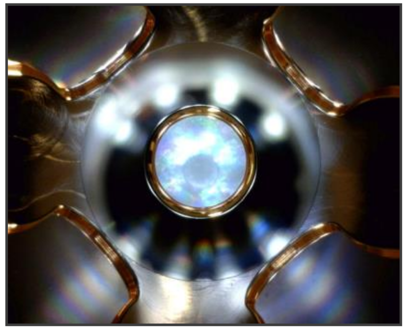
zone B - 0.02 mm

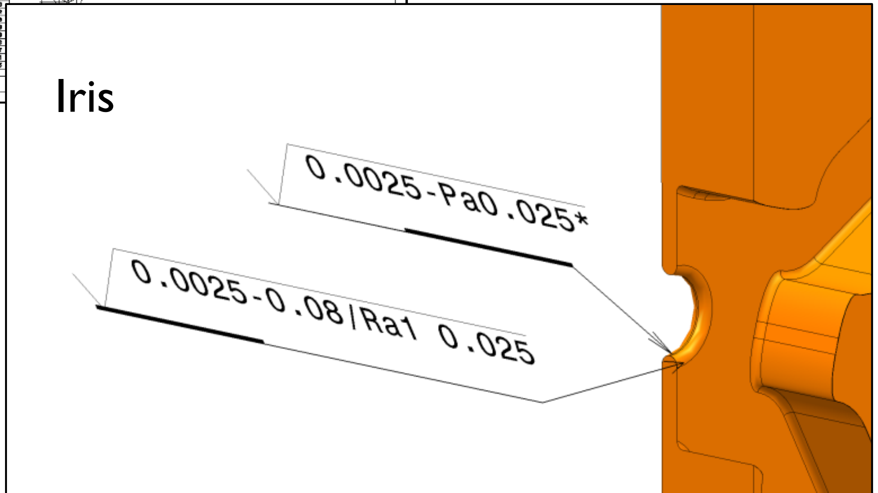
Flatness - 0.001 mm

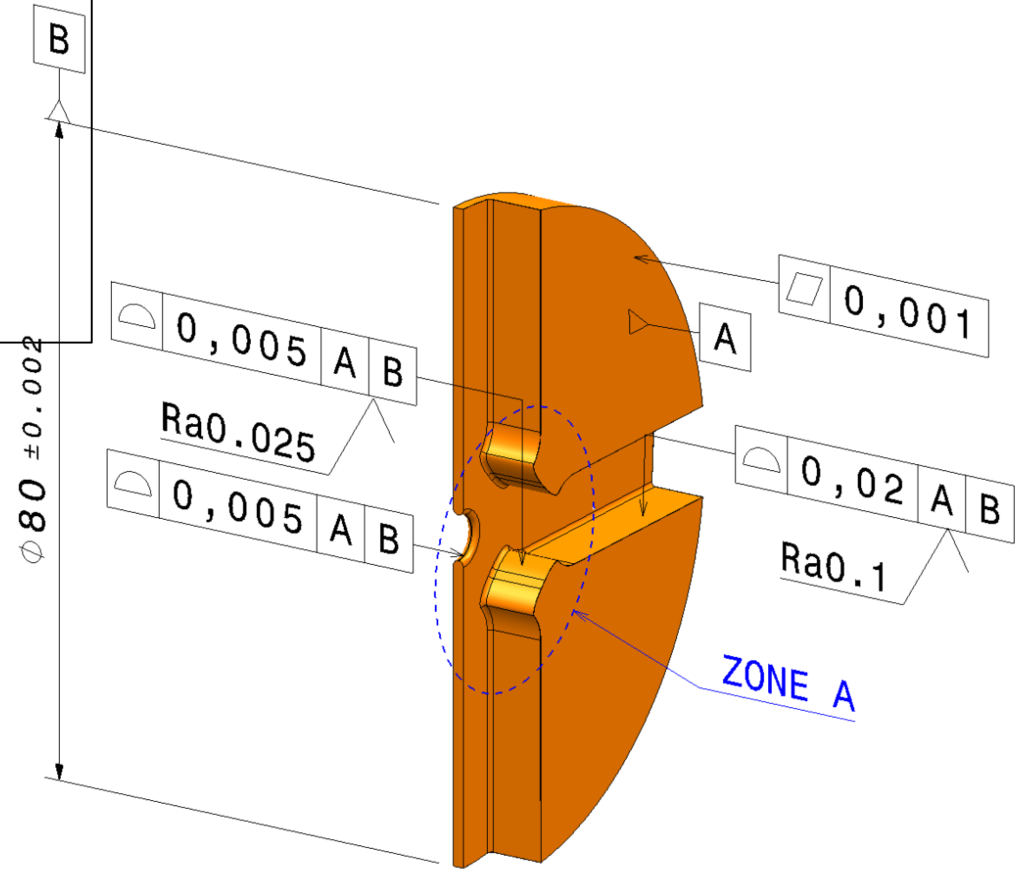
Surface roughness:

zone A Ra 0.025 µm

zone B Ra 0.1 µm



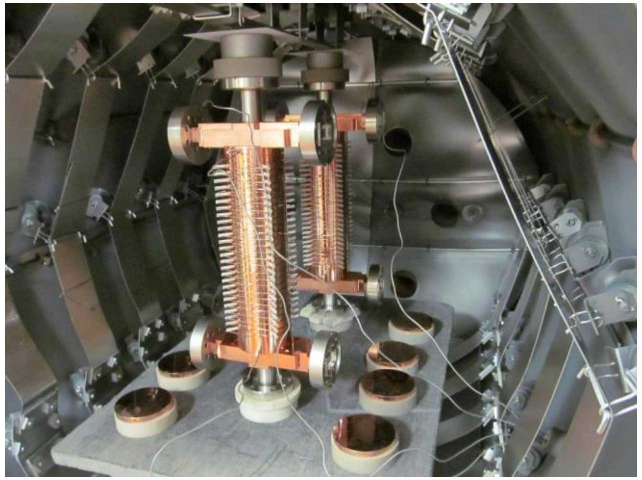




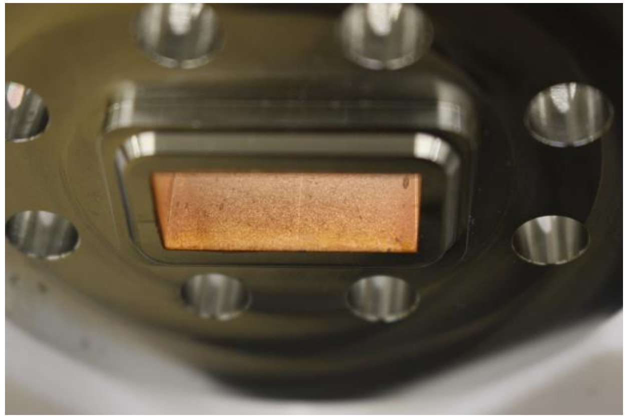
JOINING. COPPER DIFFUSION BONDING AND BRAZING

- Diffusion bonding and brazing with a protective H^2 atmosphere.
- High vacuum $<10^{-5}$ mbar; >15% H2; T > 1000 °C.
- Qualification of the oven involving pollution tests and an observation with scanning electron microscope.
- Bodycote (FR), Reuter (DE), TMD (UK), MHI (JP).
  - Potential extension to vacuum brazing following structure manufactured by PSI.
    - Electron-beam-welding of hard copper under development.



SURFACE TREATMENT

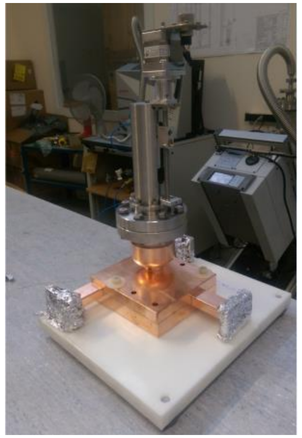
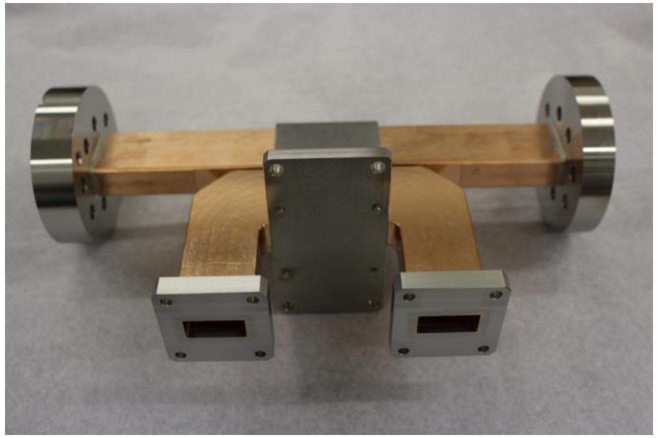
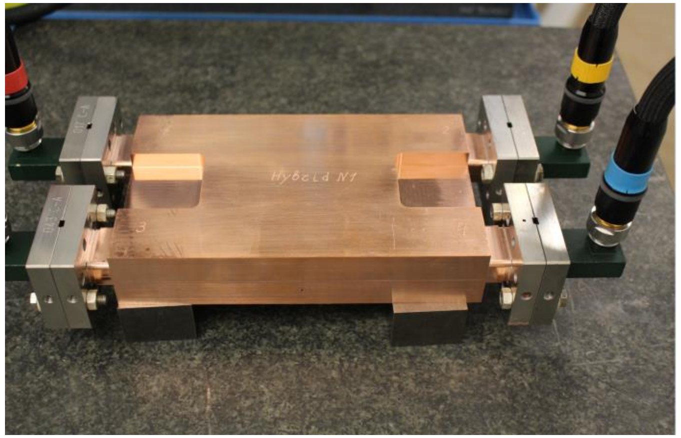
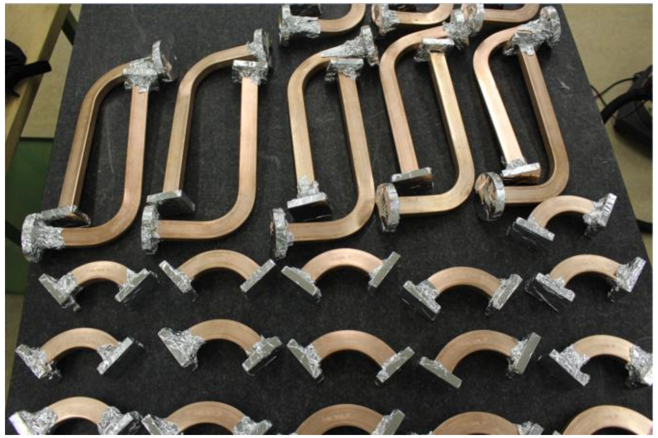


- Copper coating on stainless steel.
- Need to respect dimensioning.
- Technology transfer from CERN if needed.
- Thermocompact (FR), BACMI (FR).

- Vacuum baking at 10^{-8} Torr for 1-2 days.
- Big furnace.
- Bodycote (FR), COMEB (IT), MHI (JP).

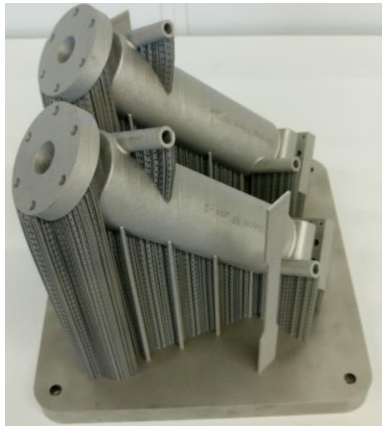
UHV, RF COMPONENTS

- Traditional precision machining of copper and stainless steel parts (20 - 40 μm).
- Brazing of copper to SS, copper to copper and copper to SiC.
- Copper sintering.
- Relative small series tested up to 60 MW peak power.
- CINEL (IT), VDL (NL), BACMI (FR), CECOM(IT) Reuter (DE), Nihon (JP), Viztrotech (KR), COMEB (IT, ongoing).

ADDITIVE MANUFACTURING

- 3D printing in Titanium for lossy parts like loads or low power components.
- Parallel development at CERN and in industry.
- SWISSto12 (CH), 3T RPD (UK), Concept Laser (DE), INITIAL (FR), Protoshop (DE).
- Successfully tested for high power operation. Currently being re-designed for manufacturability.

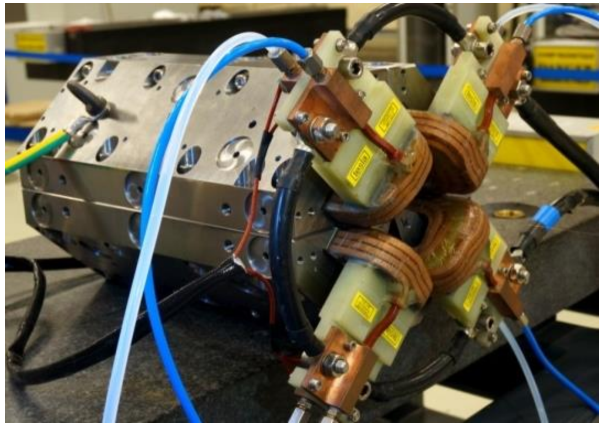
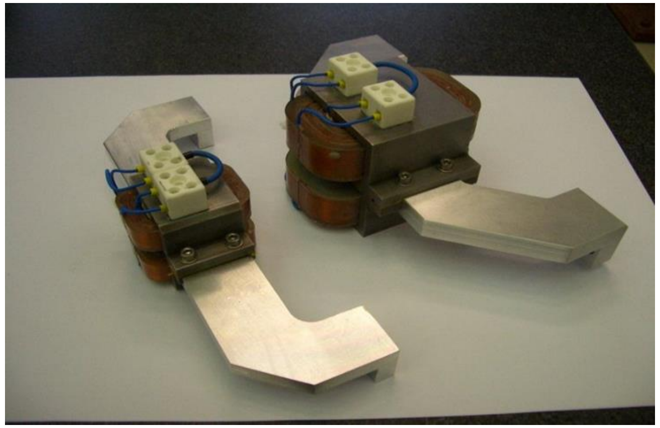





CONVENTIONAL MAGNETS

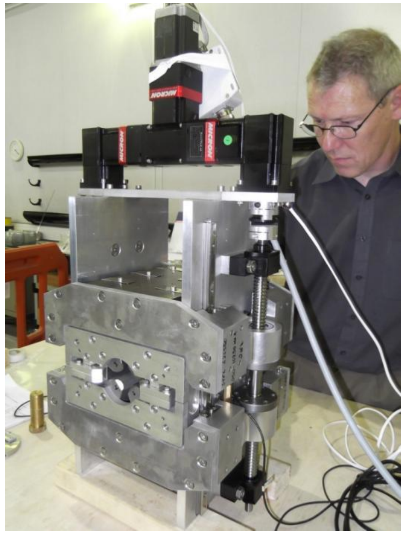
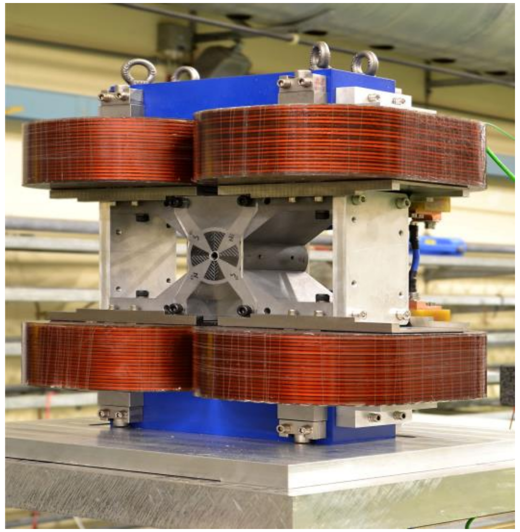
- Complete manufacturing Danfysik (DK).
- Procurement and winding of coils, TESLA (UK), S.E.F. (F).
- High Precision quadrants machining DMP (ES), OSTROJ (CZ).
- Iron-yokes lamination laser-cut and packing : LCD (CH).
- Iron Yokes EDM Machining: Röttgers Værktøj (DK).



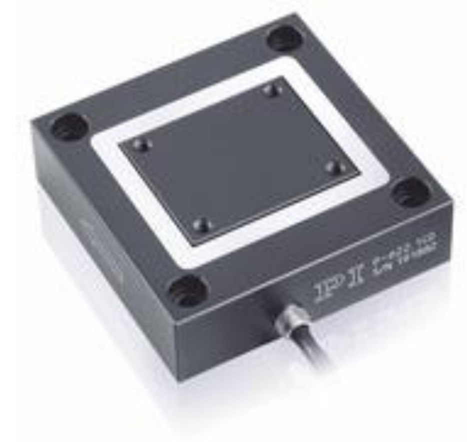
PERMANENT MAGNETS

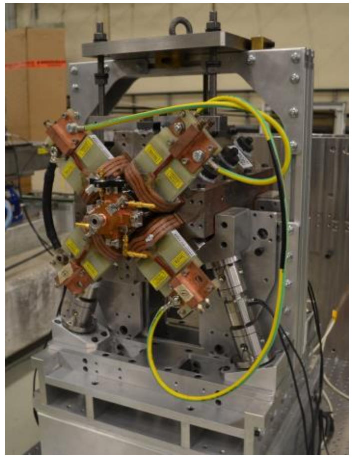
- Tuneable permanent magnets in collaboration with Daresbury Laboratory.
- PM blocks and Permendur: Vacuumschmelze GmbH & Co. (D), VDL (NL).
- High Precision mechanic components: SENAR (UK), TSW (UK), Group4 (UK), Mclennan (UK).

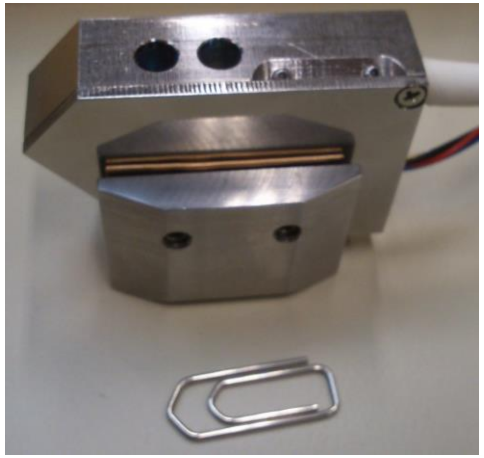





PRECISION ENGINEERING

- Nano-stabilization and nano-positioning coupled with very high stiffness systems and vibration sensors are necessary in CLIC to guarantee a high beam quality and thus high luminosity.
- Piezo actuators beyond the state of the art. Prototype qualification required: PI (DE), Heinmade (NL), NOLIAC (DK), Heidenhain (DE), Fagor automation (ES).
- Sensors, encoders, scales with nanometer resolution: Renishaw (UK),
- High precision assemblies: STTSL (NL), JPE (NL).
- Vibration sensors with bandwidth 0.1~200Hz, resolution <0.1nm rms @1Hz and resistant to magnetic fields and radiation: MI partners (NL), TNO (NL), Silicon audio (US).

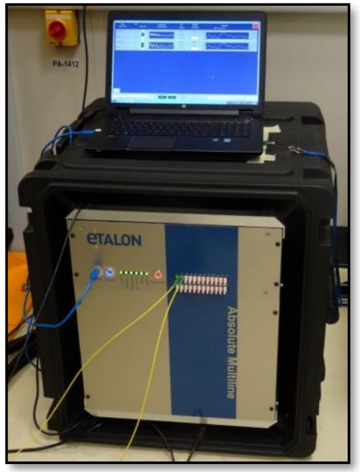




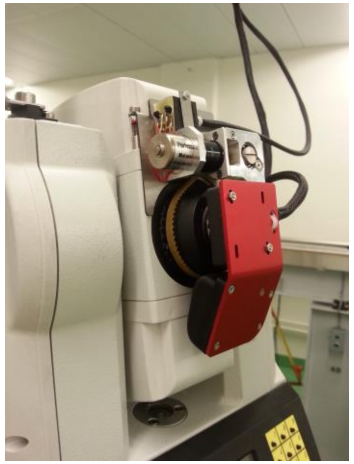


MEDIUM AND LARGE SCALE METROLOGY

- Coordinate Measuring Machines: Leitz (DE), Zeiss
- Laser trackers laser scanner, portable CMM, tacheometer: Hexagon Metrology/Leica-geosystems (DE, CH), Faro (US)
- Frequency scanning interferometry systems: Etalon (DE)
- Targets and reflectors: PLX (US), Etalon AG (DE), Leica-geosystems (CH), Thorlabs (US)
- Alignment systems: Fogale Nanotech (FR), Queensgate (UK), micro-epsilon (DE)
- Adjustment systems, linear actuators, cam movers : ZTS vvu Kosice (SK)
- Tables, stages: PI (DE), Dyneos (CH), Aerotech (UK), Newport (US)



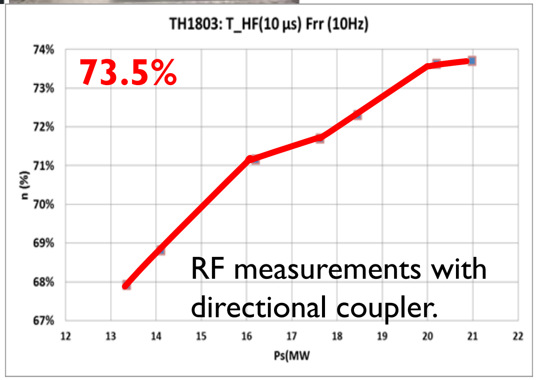





PULSED KLYSTRONS

CPI (US)VKX-8311A @ 11.9942 GHz
50 MW peak power, 1.5 μs pulse length
50 Hz rep. rate

Based on SLAC XL5 klystron
developed by SLAC from SLS XL4

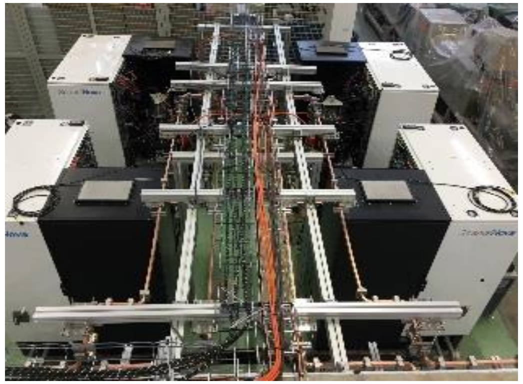


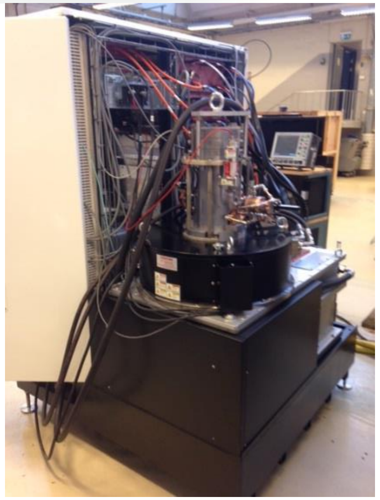
TOSHIBA (JP) E37113 @ 11.9942 GHz
6 MW peak power, 5 μs pulse length
400 Hz rep. rate
Developed by Toshiba on CERN contract

THALES (FR) MBKTH1803 @ 1.0 GHz
21 MW peak power, 10 μs pulse length
10 Hz rep. rate
Developed by THALES on CERN contract

MODULATORS

- High Voltage Pulsed modulators.
- Maximum pulse voltage ripple 0.25%
- Pulse to pulse stability 0.1%
- Scandinova (SE) modified K1 and K2 modulators for Xboxes
- ETH-Zurich development in collaboration with CERN for drive beam.
- Pulse transformer built by Pikatron (CH)

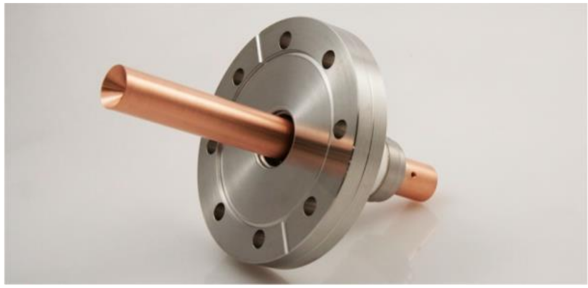




RF DRIVERS, DIAGNOSTICS AND LLRF

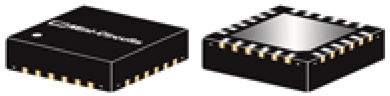
New Solid State Amplifier 400 W AM61-12S-60-56-PR SN001 by Microwave Amps (UK)

Radiabeam (US) faraday cups



High stability RF cables Megaphase (US), Rodan Technologies (DK).

Other LLRF components like filters, power splitters, isolators, attenators etc Mini-circuits (US), Techniwave (FR), Marki Microwave (US), Huber Shuner (CH),



Ceramics for RF and ultra high vacuum Ceratec (NL), Micropierre (FR), Andalo Giani (IT), Friatec (DE)

VACUUM TECHNOLOGY

- Vacuum pumps
- Vacuum valves and gauges
- UHV tubes, bellows and connections
- SAES (IT), VAT (CH), CECOM (IT)

Thanks!!