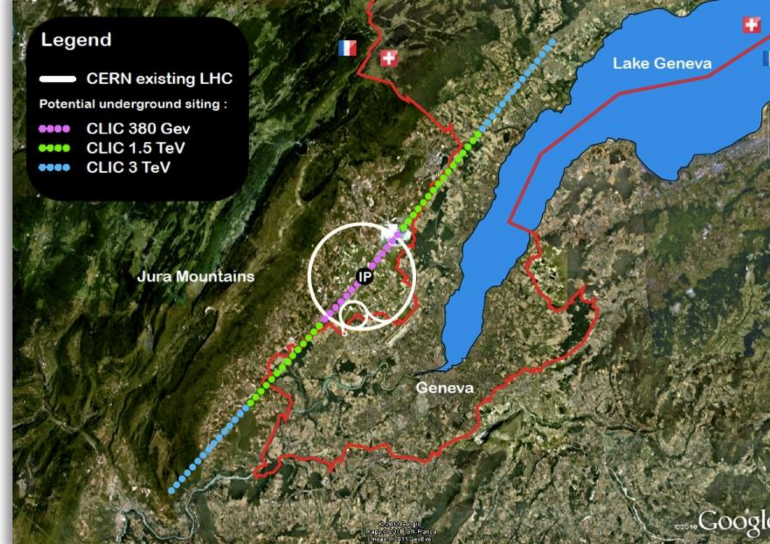
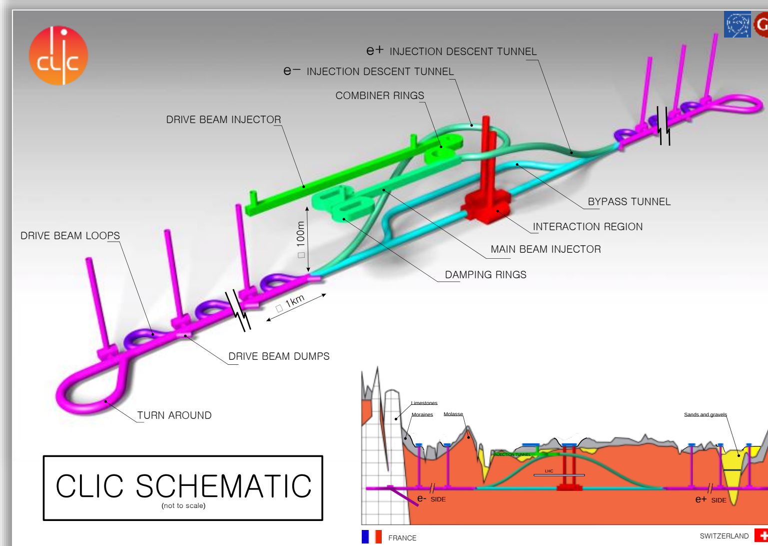
# CLIC status and plans

Outline:

- Project overview and background, resources
- Main technical activities
- Implementation issues
- Summary




| Parameter | Unit | 380 GeV | 3 TeV |
|---|---|---|---|
| Centre-of-mass energy | TeV | 0.38 | 3 |
| Total luminosity | $10^{34}cm^{-2}s^{-1}$ | 1.5 | 5.9 |
| Luminosity above 99% of √s | $10^{34}cm^{-2}s^{-1}$ | 0.9 | 2.0 |
| Repetition frequency | Hz | 50 | 50 |
| Number of bunches per train | | 352 | 312 |
| Bunch separation | ns | 0.5 | 0.5 |
| Acceleration gradient | MV/m | 72 | 100 |
| Site length | km | 11 | 50 |




Key features:

- High gradient (energy/length)
- Small beams (luminosity)
- Repetition rates and bunch spacing (experimental conditions)

# Strategy: Post-LHC high energy frontier machines

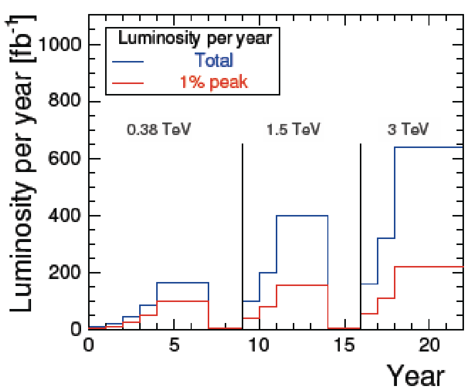
**European Strategy for Particle Physics**

**High-priority large-scale scientific activities**
After careful analysis of many possible large-scale scientific activities requiring significant resources, sizeable collaborations and sustained commitment, the following four activities have been identified as carrying the highest priority (the point below is the one relating to very high energy machines)

d) To stay at the forefront of particle physics, Europe needs to be in a position to propose an ambitious post-LHC accelerator project at CERN by the time of the next Strategy update, when physics results from the LHC running at 14 TeV will be available. ***CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high energy frontier machines. These design studies should be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide.***

**Goal for next strategy update (~2019): Present a CLIC project that is a "credible" option for CERN beyond LHC, a Project Implementation Plan. Guidelines used internally:**

- Adapt to physics results – LHC mostly - taking into account LHC at 13-14 TeV as results become available (be flexible)
- Physics no later than 2035, solid luminosities from Higgs/top at 380 GeV to 3 TeV (staging)
- Initial costs compatible with current CERN budget level (order LHC+50%) (staging)
- Upgradable in 2-3 stages over a 20-30y period, without major (max 3-4 years) operational breaks, and with upgrade costs also in reasonable agreement with current budget level.
- Cover accelerator, detector, physics



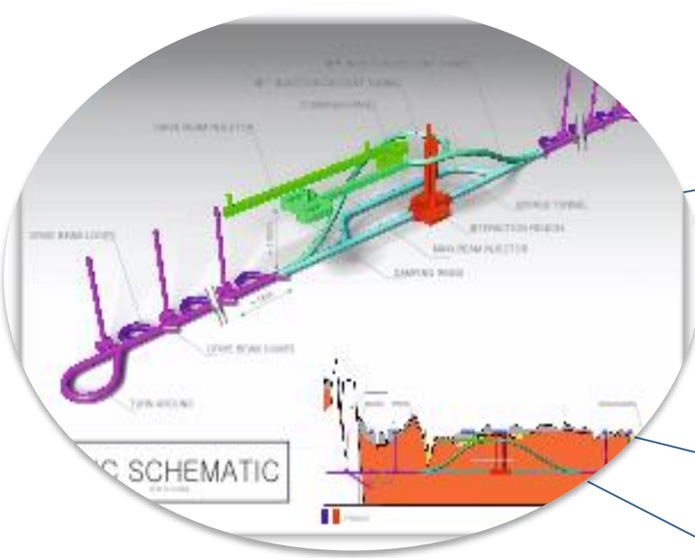
# Resources

Accelerator collaboration with ~50 institutes
Detector collaboration operative with ~27 institutes


MTP 2016:

- 27/29 MCHF Material/Personnel 2017-19 for Linear Colliders
- Covering accelerator (~80%)
- Detector & physics (~20%)

# Organisation of work, agreements




Many commitments related to Xband structure and testing, various technical developments, plus the CTF3 programme in the years 2015-2017

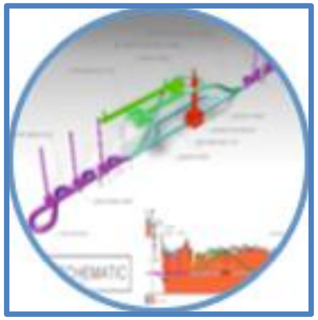
Covers personnel and hardware, exchange/test of equipment being built in the collaboration – at CERN or locally, and around 80 ph.d student (estimate in 2014)

- R&D contracts, UK (4), Oslo, Helsinki, Spain (3), Karlsruhe, Zurich
- MoU annexes (with MS and NMS collaborators)
- Annex to Int. Coll. Agreements (KEK, India, Pakistan, etc.)
- Techn. Transfer agreements, “Work for Others”, EU projects (Tulip, SLAC, Fermilab, EUCARD, AERIS, etc.

# Main activities

http://clic-study.web.cern.ch/content/clic-accelerator-activities

Project wide studies:
- Overall project planning
- Cost, power, schedule, staging
- Civil engineering, conventional systems



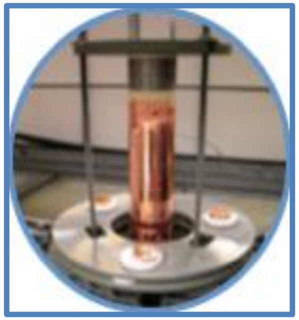
### Parameters and Design

Integrated Baseline Design and Parameters

- Integrated Modeling and Performance Studies
- Feedback Design, Background, Polarization
- Machine Protection & Operational Scenarios
- Electron and positron sources, Damping Rings, Ring-To-Main-Linac, Main Linac - two-Beam Acceleration, Beam Delivery System
- Machine-Detector Interface (MDI) activities
- Drive Beam Complex

### Experimental verification

- CTF3 Consolidation & Upgrades
- Drive Beam phase feed-forward and feedbacks
- Two-Beam module string, test with beam
- Drive-beam front end including modulator development and injector
- Modulator development, magnet converters
- Drive Beam Photo Injector
- Low emittance ring tests
- Accelerator Beam System Tests (ATF and FACET, others)

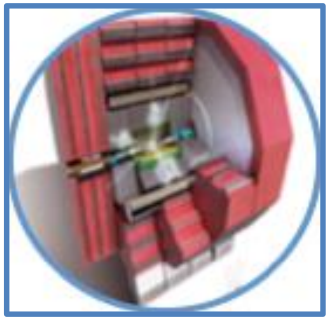


### X-band Technologies

- X-band Rf structure Design
- X-band Rf structure Production
- X band collaborations
- Novel RF unit developments (high efficiency)
- Installation and Operation of High power Testing Facilities
- Basic High Gradient R&D

### Technical Developments

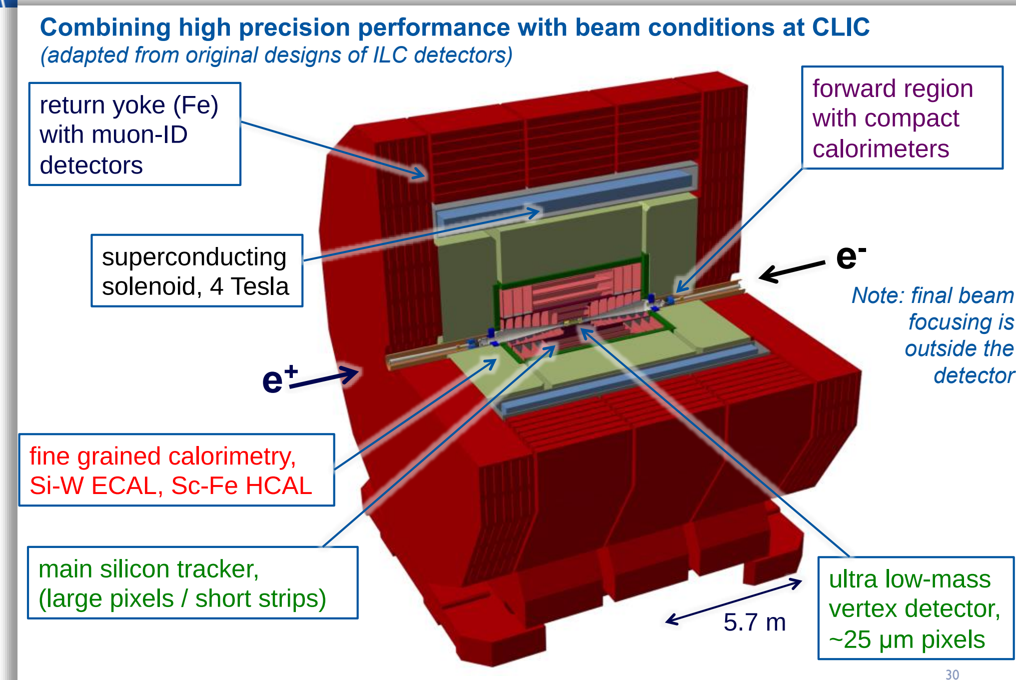
- Damping Rings Superconducting Wiggler
- Survey & Alignment
- Quadrupole Stability
- Warm Magnet Prototypes
- Beam Instrumentation and Control
- Two-Beam module development
- Beam Intercepting Devices
- Controls
- Vacuum Systems
- Beam Transport Equipment

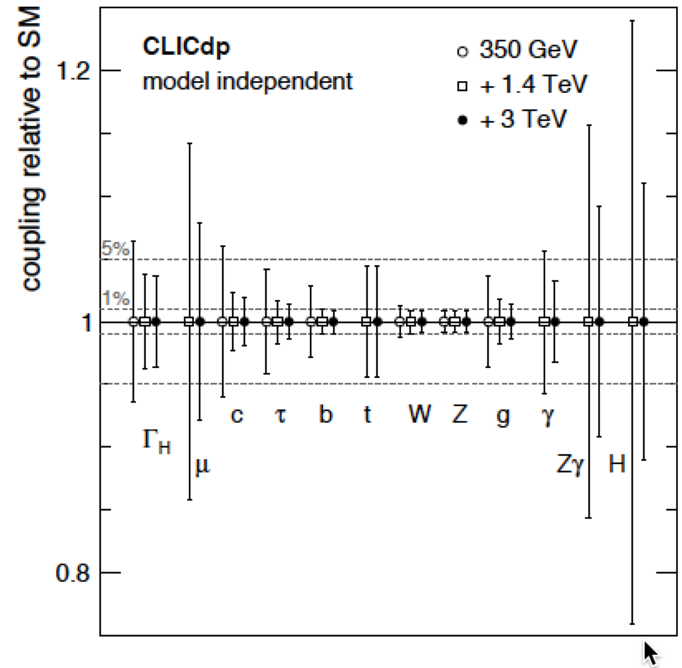


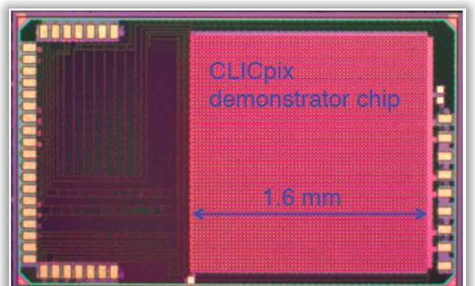
### Detector and Physics

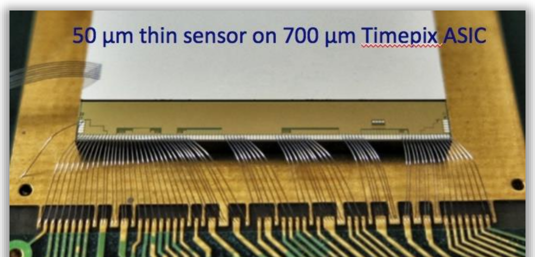
- Physics studies and benchmarking
- Detector Optimisation
- Techncial developments

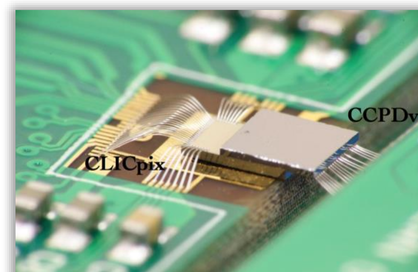
# CLIC physics and detectors



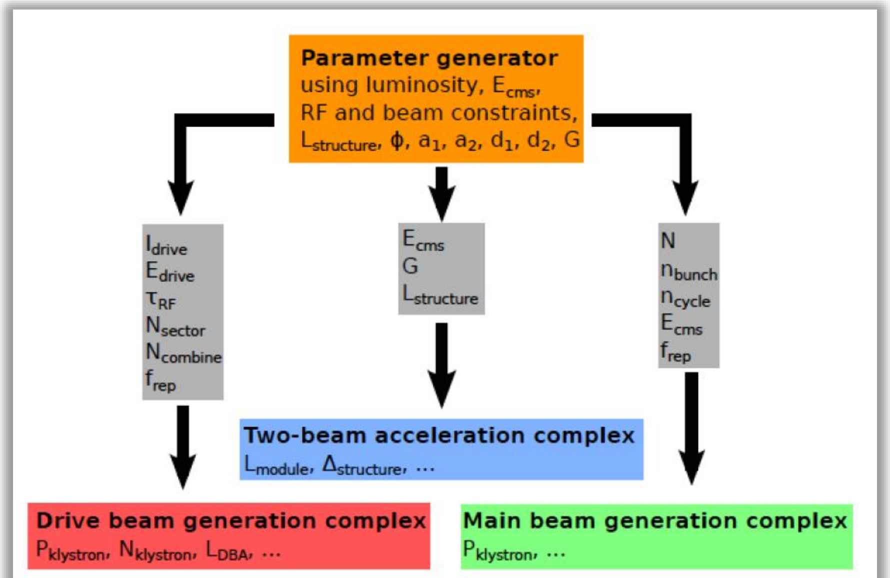



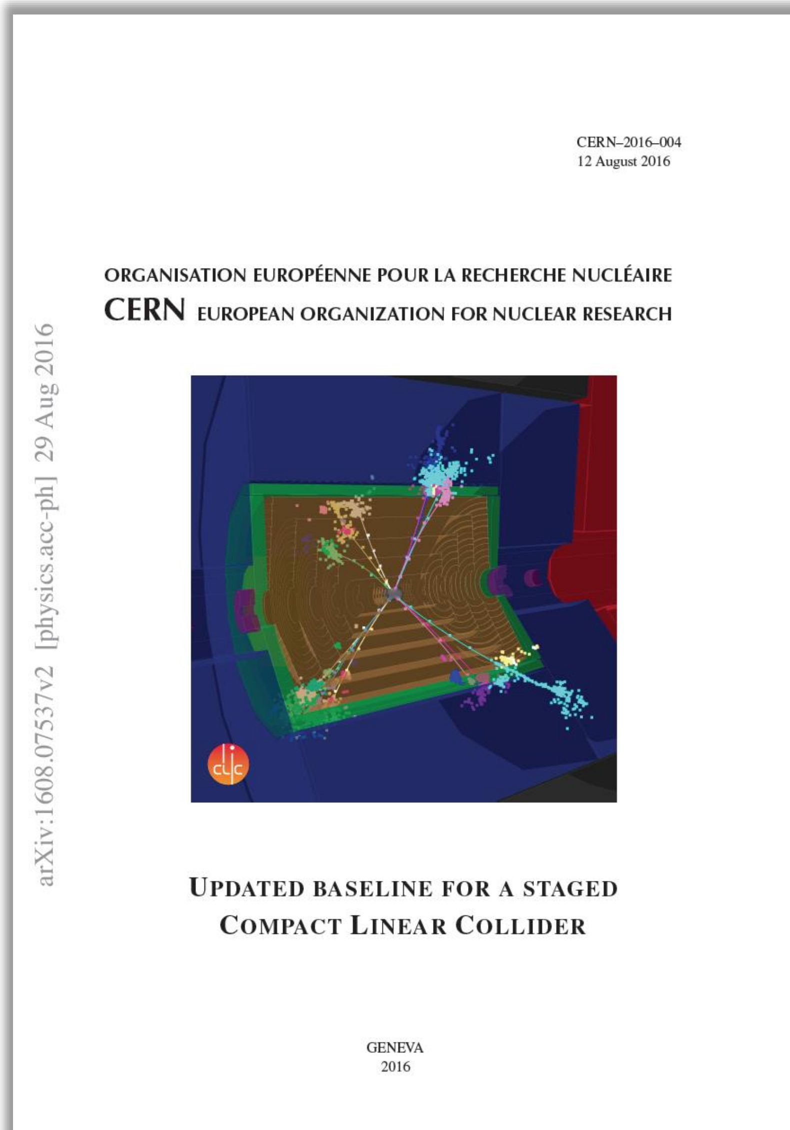




# Optimize initial stage (380 GeV)

- Contain updated general information similar to CLIC CDR volume 3 (2012)
- New reference plots for power, costs, luminosities, physics, etc
- Yellow report



CERN–2016–004
12 August 2016

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

arXiv:1608.07537v2 [physics.acc-ph] 29 Aug 2016

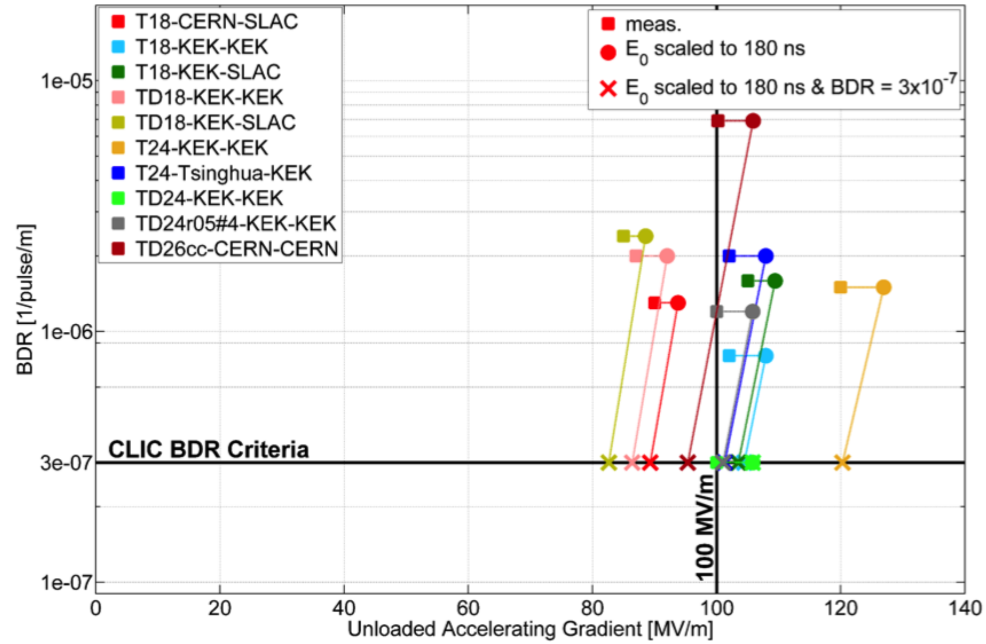
UPDATED BASELINE FOR A STAGED COMPACT LINEAR COLLIDER

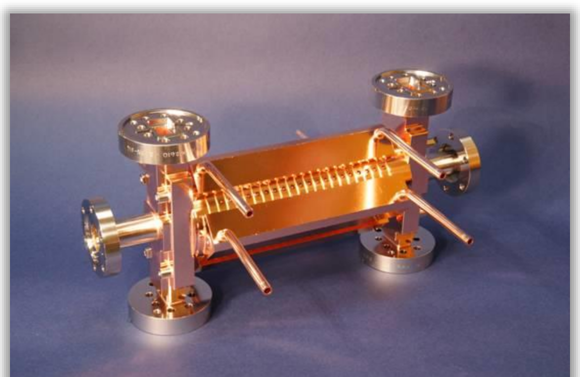
GENEVA
2016

# Xband and klystrons

Structure production and test programme:

- Point to address: Baseline structure statistics, 380 GeV and FEL structures, “simplified” structures (halves and brazing vs bonding, other R&D), industry qualification, conditioning studies, etc
- Can tests ~30-40 structures over next 3 years, currently 7 ready for tests and 6 in production



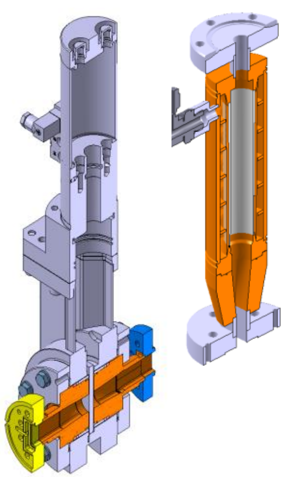
# X-band structures

**Ultra precision machining**
VDL, NL
Yvon Boyer, FR
LT-Ultra, DE
DMP, ES
Mecachrome, FR

**Ceramics**
Andalo Gianni, IT
Macropierre, FR
Ceratec, Friatec,DE
ESK Ceramincs, DE

**Surface treatment**
Multivalent,NL
Thermocompact, FR
Covimag, FR

**Additive manufacturing**
3T RPD, GB
Concept Laser, Protoshape DE
Initial, FR

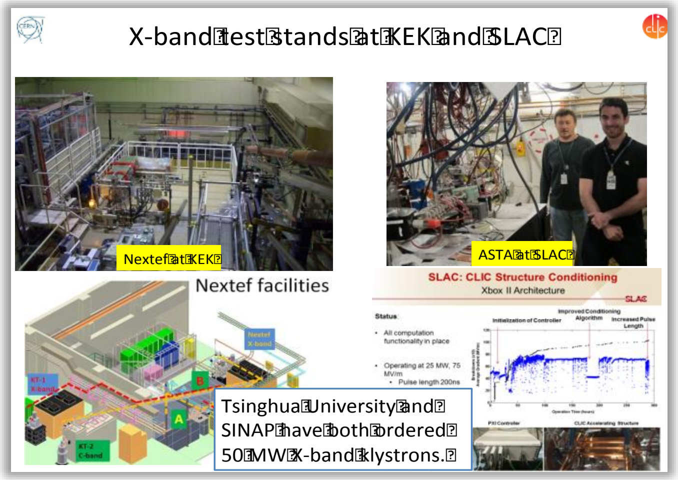


**Waveguides and components**
CINEL, IT
CECOM, IT
VDL, CH
KERN, DE
Radiabeam, US

**Brazing and bonding**
Bodycote, FR
Reuter, DE
TMD, GB

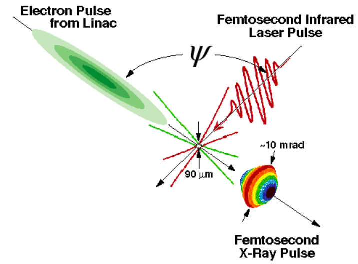
# Existing and planned Xband infrastructures

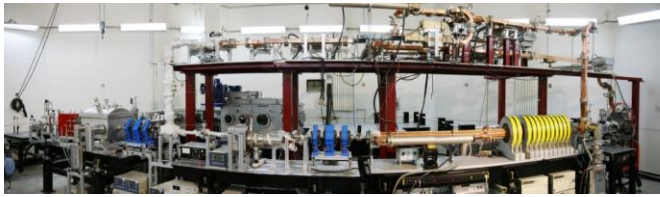
| | | | |
|---|---|---|---|
| CERN | XBox-1 test stand | 50 MW | Operational |
| | Xbox-2 test stand | 50 MW | Operational |
| | XBox-3 test stand | 4x6 MW | Commissioning |
| KEK | NEXTEF | 2x50 MW | Operational, supported in part by CERN |
| SLAC | ASTA | 50 MW | Operational, one structure test supported by CERN |
| | Design of high-efficiency X-band klystron | 30 MW | Under discussion |
| Trieste | Linearizer for Fermi | 50 MW | Operational |
| PSI | Linearizer for SwissFEL | 50 MW | Operational |
| | Deflector for SwissFEL | 50 MW | Planning |
| DESY | Deflector for FLASHforward | 50 MW | Planning (note first two may share power unit) |
| | Deflector for FLASH2 | 50 MW | Planning |
| | Deflector for Sinbad | 50 MW | Planning |

# Existing and planned Xband infrastructures

| | | | |
|---|---|---|---|
| Australia | Test stand | 2x6 MW | Proposal, loan agreement from CERN |
| Eindhoven | Compact Compton source | 6 MW | Proposal, request for loan from CERN |
| Uppsala | Test stand | 50 MW | Proposal, request for loan of spare klystron from CERN |
| Tsinghua | Deflector for Compton source | 50 MW | Ordered |
| | Linearizer for Compton source | 6 MW | Planning |
| SINAP | Linearizer for soft X-ray FEL | 6 MW | Ordered |
| | Deflectors for soft X-ray FEL | 3x50 MW | Planning |
| Valencia | S-band test stand | 2x10 MW | Under construction |
| STFC | Linearizer | 6 MW | Under discussion |
| | Deflector | 10 MW | Under discussion |
| | Accelerator | tbd | Under discussion |



# X-band test facilities

**Klystron**
CPI, US
Toshiba, JP

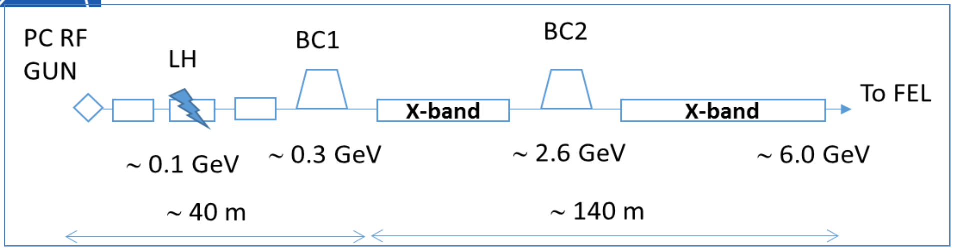
**Solid State Modulator**
Scandinova, SE

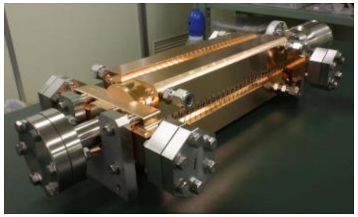
**Pulse compressor**
DMP, ES
Thermo Fisher, FR

**Vacuum components**
SAES, IT
VACOM, DE
VAT, CH

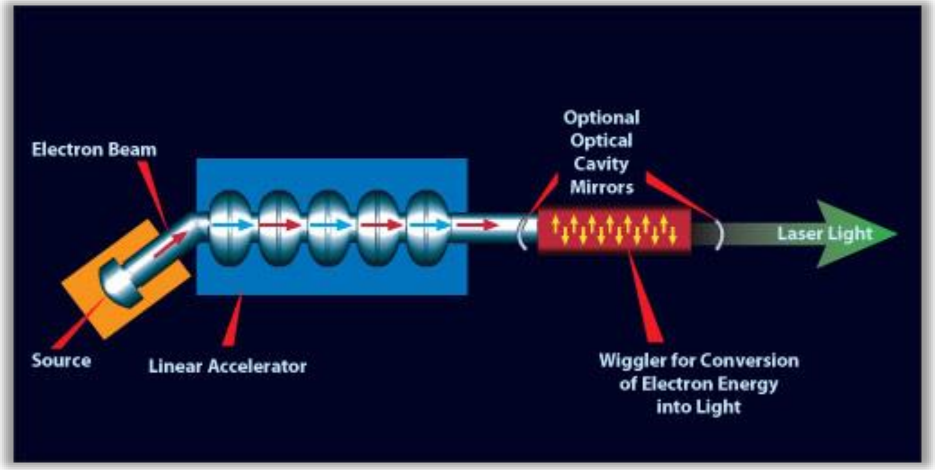
**RF instrumentation**
Rohde & Schwarz, DE
ETL Systems, GB
MegaPhase, US
Pentair, DE,FR

# Xband facilities - FELs



- X-band technology appears interesting for compact, relatively low cost FELs – new or extensions
  - Logical step after S-band and C-band
- Use of X-band in other projects will support industrialisation
  - They will be klystron-based, additional synergy with klystron-based first energy stage
- Use of X-band in FELs (FEL collaboration)
  - Australian Light Source, Turkish Accelerator Centre, Elettra, SINAP, Cockcroft Institute, TU Athens, U. Oslo, Uppsala University, CERN, TU Eindhoven … more

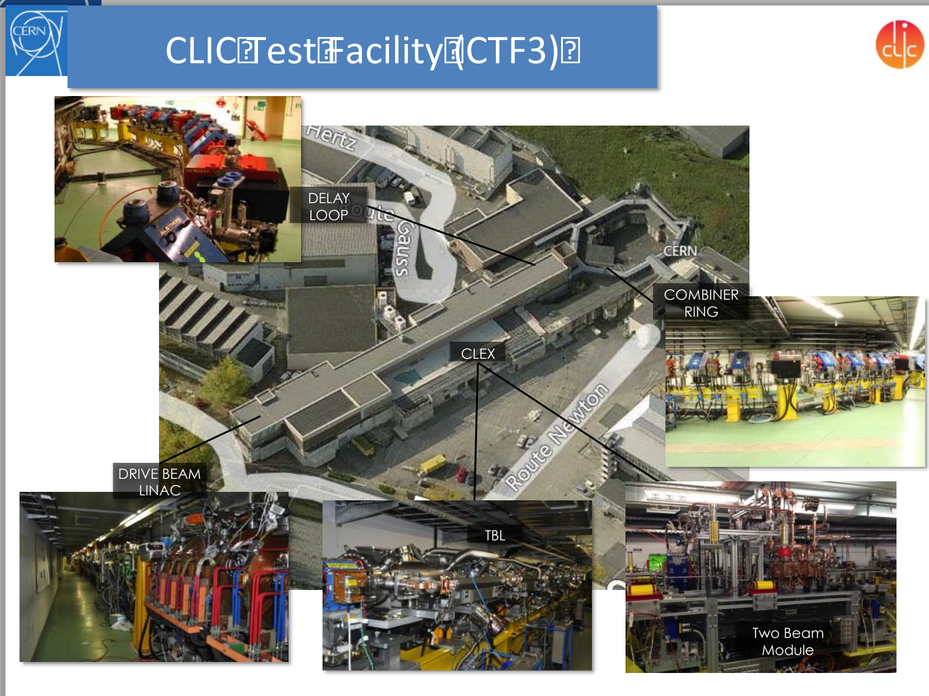


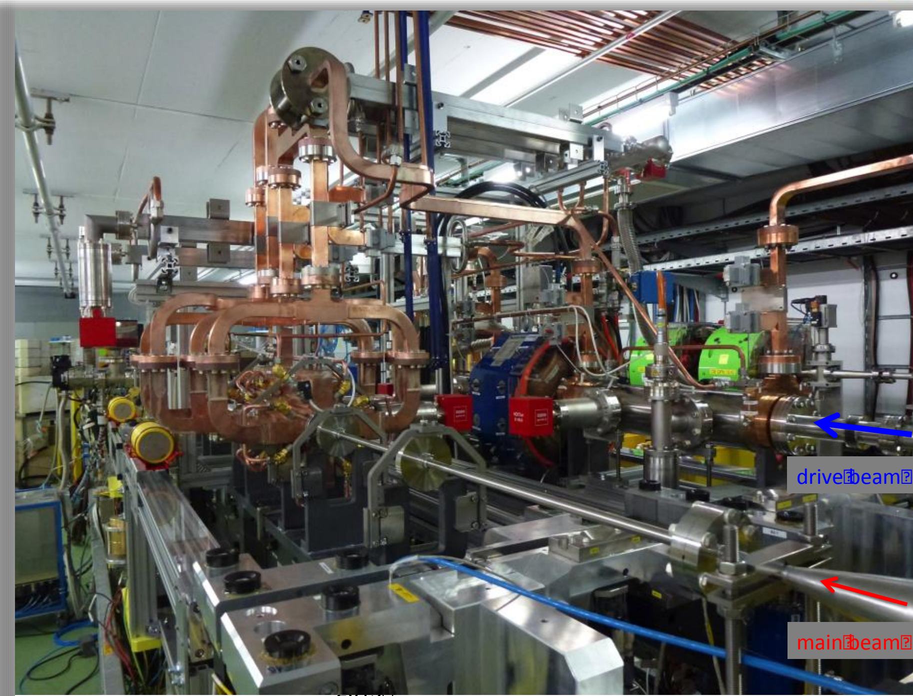

**FEL collaboration** dedicated to the development of inexpensive and compact X-ray sources, Compton scattering and XFEL, for national, university and industrial scale facilities.
**Exploit** recent developments of X-band and high-gradient technology to:

- increase short pulse and high repetition rate performance
- decrease size and cost of photon-science infrastructure.

**Submit** a design study in INFRADEV-01-2017.

# Experimental verifications

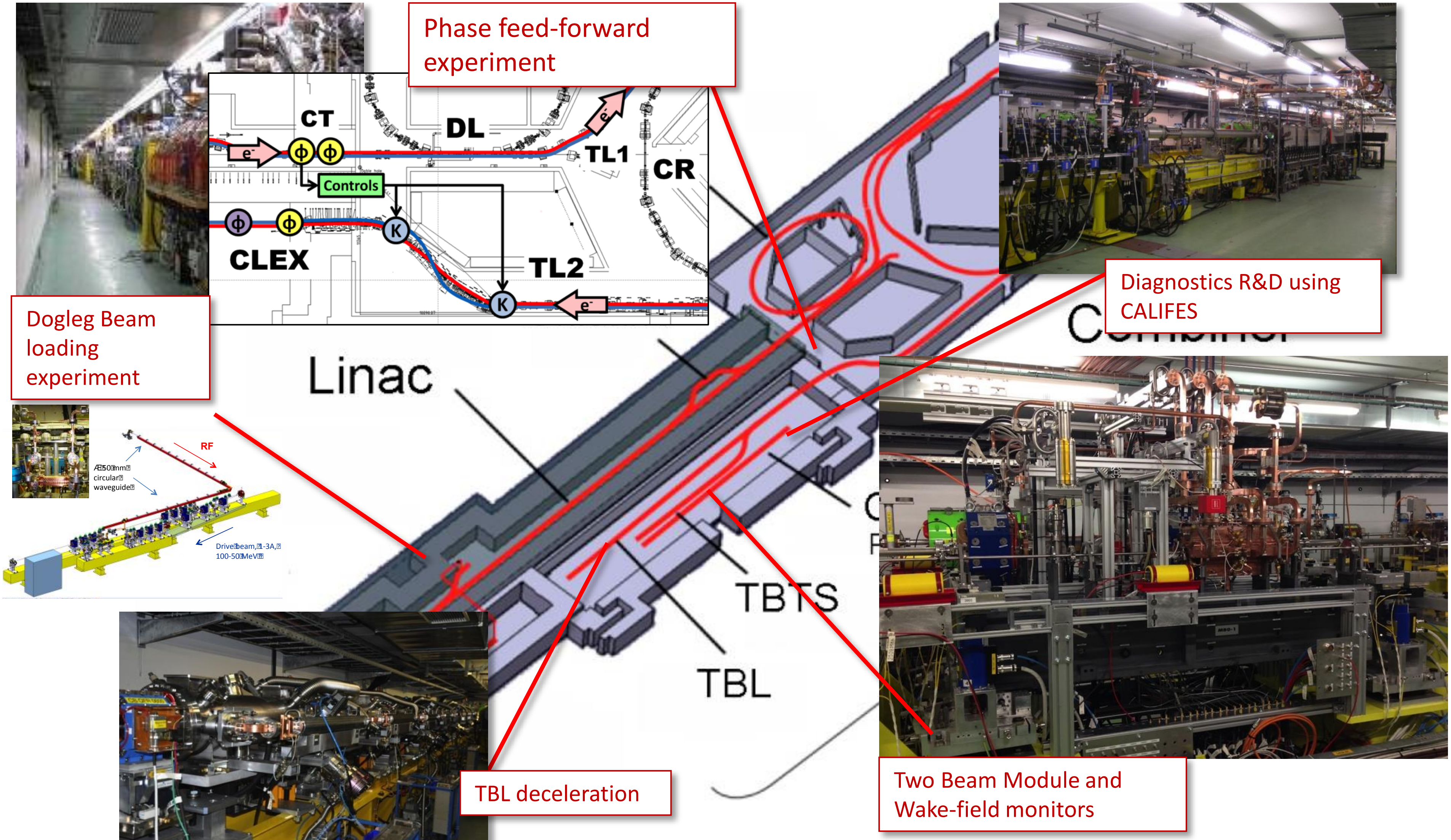



CTF3 remains the most crucial facility, but to be closed at the end of 2016

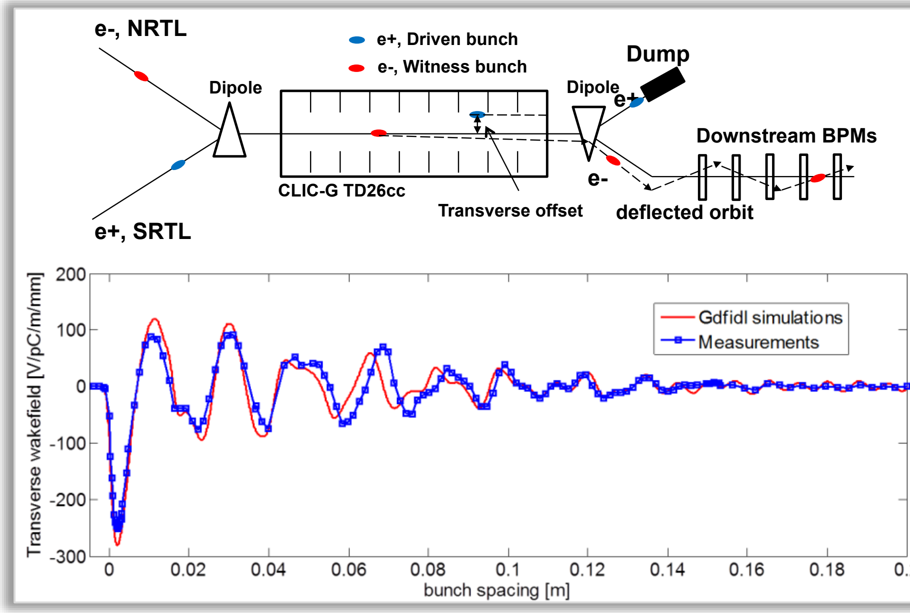
Installed 2-beam acceleration module in CTF3 (according to latest CLIC design)
First 2-beam tests stand reached 145 MV/m (2012)

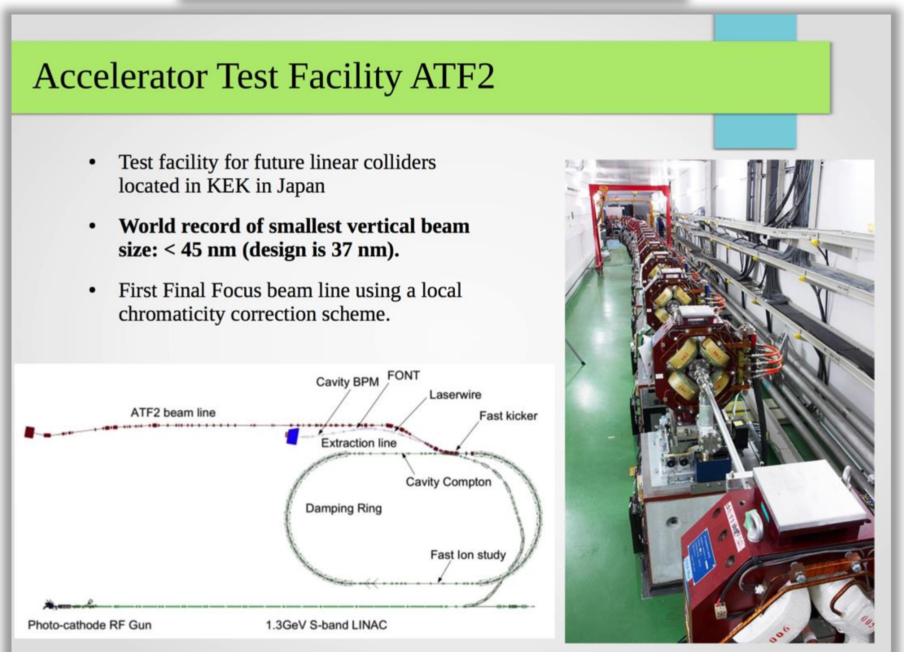
# CTF3



Phase feed-forward experiment
CT
DL
TL1
CR
Controls
CLEX
TL2
K
K
e-
e-
e-
Dogleg Beam loading experiment
RF
Drive beam, 1-3A, 100-500MeV
Linac
Diagnostics R&D using CALIFES
TBTS
TBL
TBL deceleration
Two Beam Module and Wake-field monitors

# Performance verifications DRs, FACET, ATF




Damping ring studies (example ALBA) incl. extraction

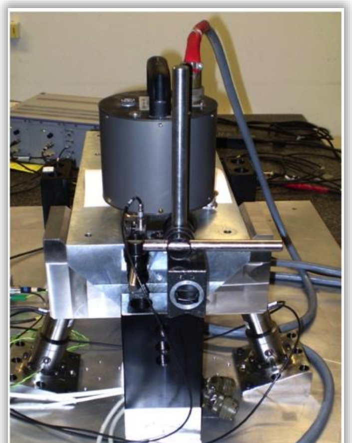
FACET at SLAC: beam based alignment and emittance studies

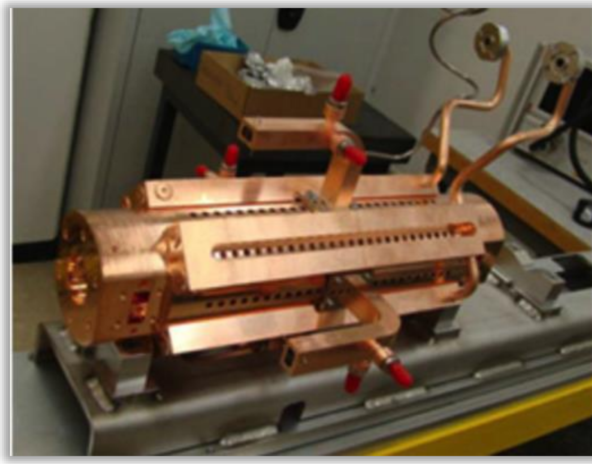
ATF2 at KEK: final focus studies

# Technical activities – examples

Technical Developments are motivated by several possible reasons – and are now quite mature:

- Key components for system-tests (example magnets, instrumentation, modules)
- Critical for machine performance (example alignment, stabilization, damping ring studies)
- Aimed at cost or power reduction (example magnets, klystrons, modules)

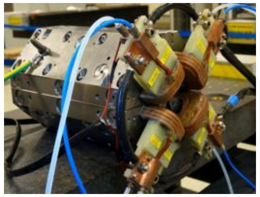




*Information about some relevant suppliers and subcontractors participating to prototypes procurement for the CLIC Magnets R&D phase*

*Note: majority of coils and of other components manufacturing, magnet assembly, was done by CERN apart for the DBQ magnets (EM and PM versions).*

1) **Main Beam Quadrupoles. 4 prototypes** procured: 3 Type1 (the shorter), 1 Type4 (the longer)



***Relevant procurements:***

- *Coils:* **TESLA** Engineering LTD, Storrington, West Sussex - UK
- *High Precision quadrants machining:*
- **DMP** 20850 Mendaro, Gipuzkoa - ES

2) **Drive Beam Quadrupoles** (EM version): **8 prototypes** procured:

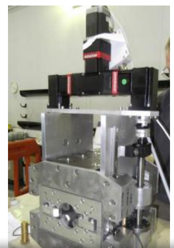
***Relevant manufacturers:***

- *Complete manufacturing:*

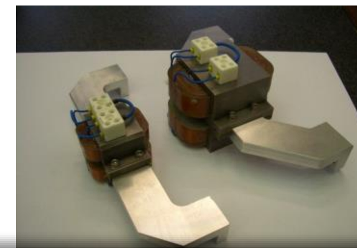
**Danfysik** A/S 2630 Taastrup, DK

***Rele***
-*Des*
-*PM*
Hana
-*Hig*
-**SEN**
-**TSV**
-**Mc**

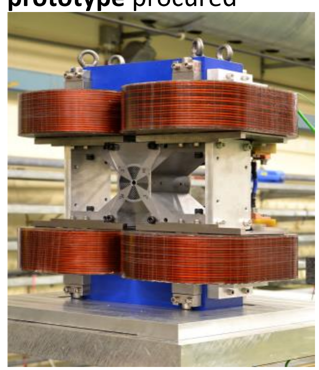
3) **Drive Beam Quadrupoles** (PM version): **2 prototypes** procured by Daresbury Laboratory



4) **Main Beam Steering Dipoles**: **2 prototypes** procured



5) **Final Focus Quadrupole QD0**: **1 prototype** procured



***Relevant manufacturers:***

- *PM blocks, Permendur EDM machining:* **Vacuumschmelze** GmbH & Co. KG, Hanau - D

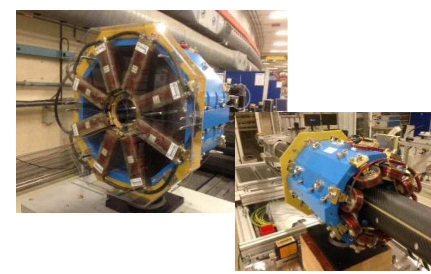
6) **Final Focus Sextupoles SD0:** *(**1 prototype** procurement **on-going**)*

***Relevant manufacturers:***

- *Permendur and PM blocks procurement:*

**VDL** Groep BV, Eindhoven - NL

7) **Octupoles for ATF** facility at KEK, Japan: **2 magnets** procured



***Relevant manufacturers:***

- *Coils:* **S.E.F.** Sarl, Labège - F
- *Iron Yokes EDM Machining:*

**Röttgers Værktøj** A/S Odense - DK

# Timeline

**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

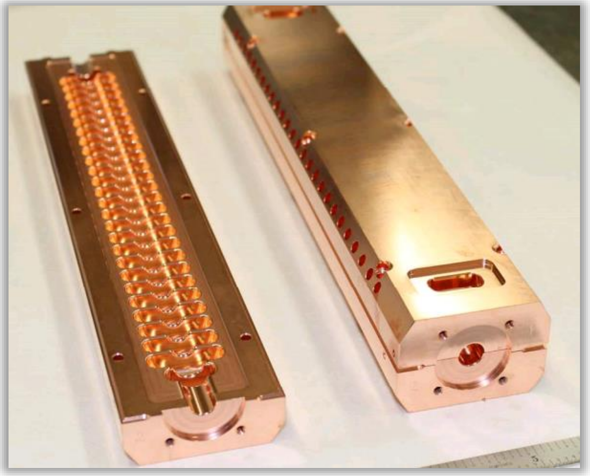
**2035 First Beams**

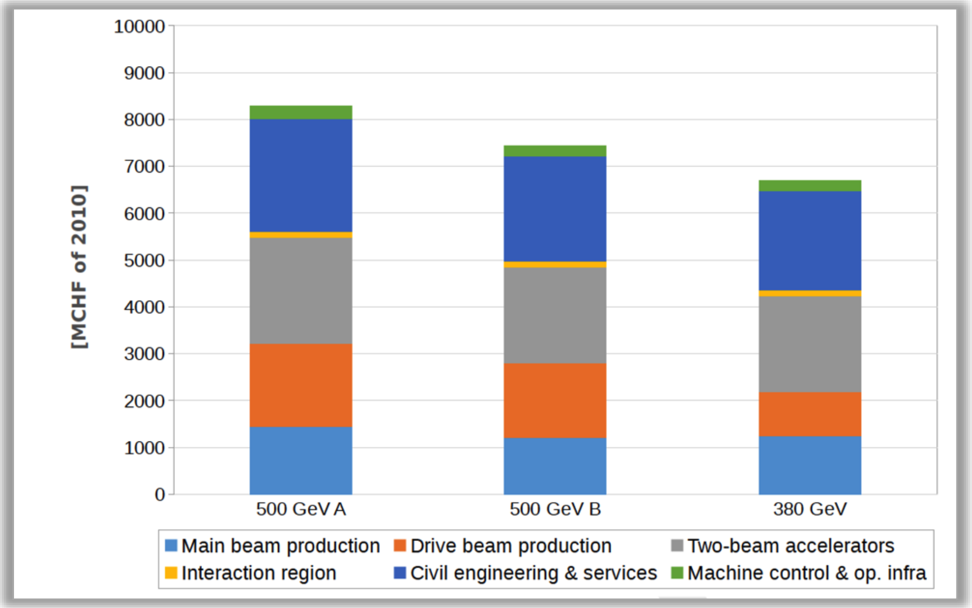
Getting ready for data taking by the time the LHC programme reaches completion

# Cost optimisation

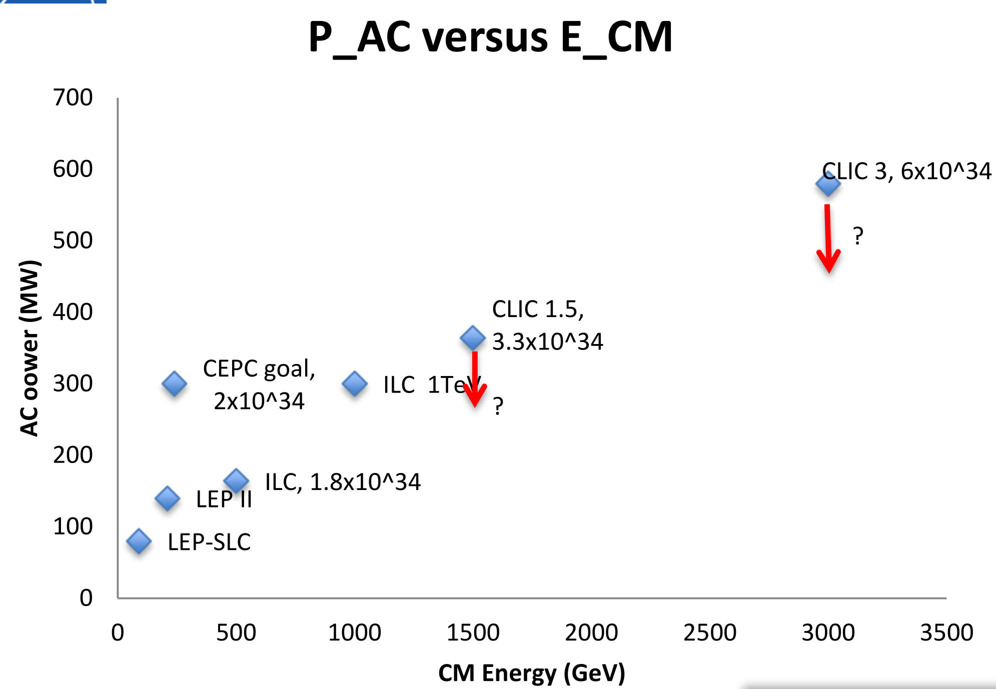
Beyond the parameter optimization there are other on-going developments (design/technical developments):

- Optimize drive beam accelerator klystron system (Syratchev) – also for power
- Electron pre-damping ring can be removed with good electron injector
- Dimension drive beam accelerator building and infrastructure are for 3 TeV, dimension to 1.5 TeV results in large saving
- Systematic optimization of injector complex linacs in preparation
- Module optimisation studies



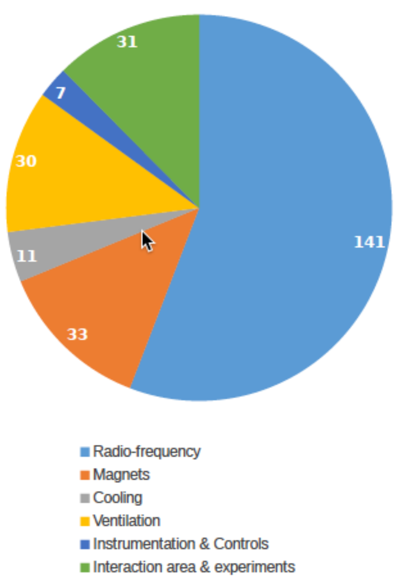


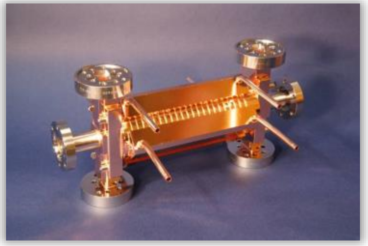

# Power and energy



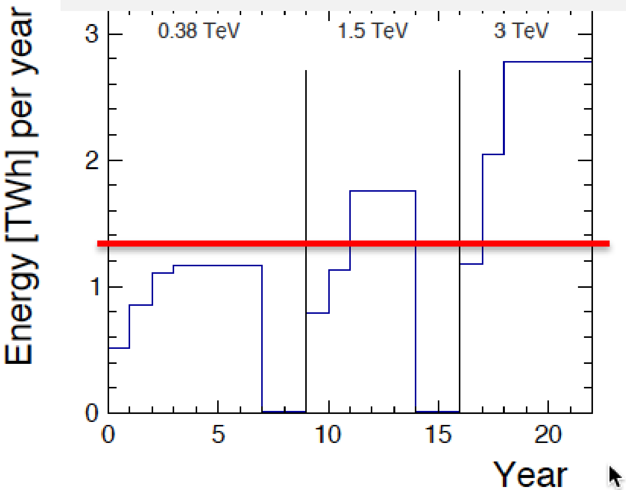

Power/energy reductions are being looked at:

- Machine parameters and technical developments (structures, RF systems and magnets)
- Consider where the power is dissipated (distributed or central)
- Look at daily and yearly fluctuation – can one run in “low general demand” periods
- Understand and minimize the energy (consider also standby, MD, down periods, running

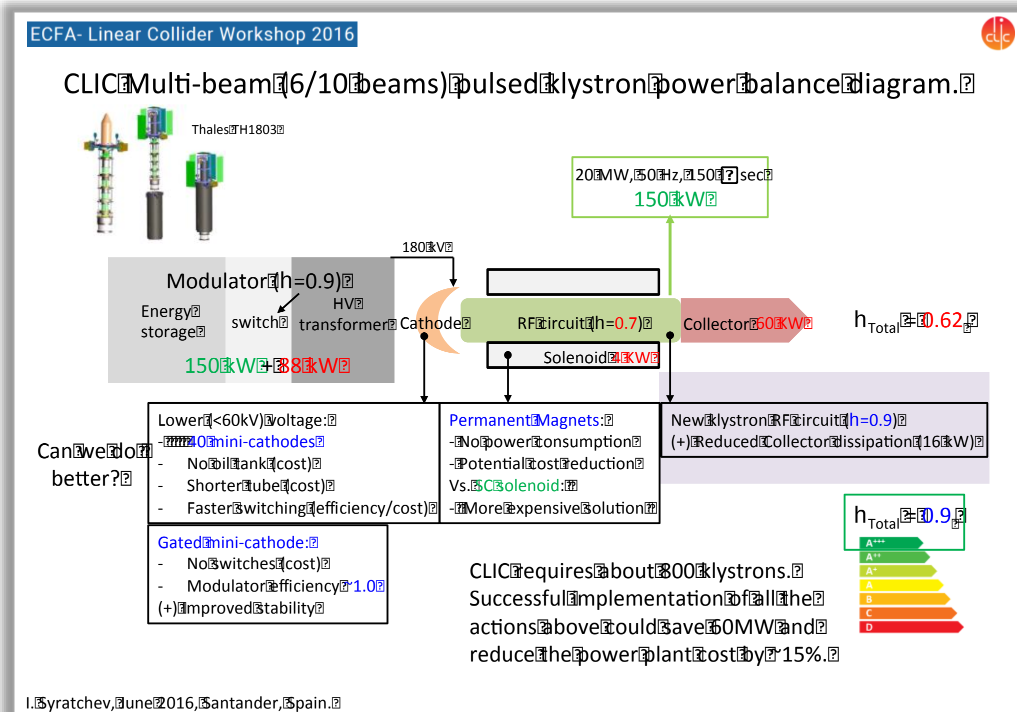


CERN energy consumption 2012: 1.35 TWh



# Klystron/modulator efficiencies




For the modulators:
ScandiNova, Sweden:
430 kV, 300 A solid state modulator (2 units in operation)
150 kV, 190 A solid state modulator (4 units in operation)
Specific contracts with Univ. Groups for drivebeam modulator development (Zurich, Laval)

For the RF power sources:

Toshiba, Japan:
6 MW, 5 usec pulsed X-band klystron (4 units in operation)
20 MW 150 usek pulsed L-band MBK (successfully tested at factory).

CPI, USA:
50 MW, 1.5 usek pulsed X-band klystron (2 unit s in operation)

Thales, France
20 MW 150 usek pulsed L-band MBK (under test at factory).
*Development of new high efficiency RF power sources for accelerators. CERN/Thales NDA to be signed soon.*

Microwave Amplifiers Ltd, UK:
New solid state X-band 300 W pre-amplifies (4 units in operation).
New solid state X-band 1200 W pre-amplifies (2 units ordered).

VDBT, Russia:
6 MW, 5 usec pulsed low (50 kV) voltage S-band MBK with PPM focusing. The first demonstrator of new klystron technology for the high efficiency (in operation).

# Summary

The goals and plans for 2016-19 are well defined for CLIC, focusing on the high energy frontier capabilities – well aligned with current strategies – also preparing to align with LHC physics as it progresses in the coming years.

Collaboration agreements in place:

- Many commitments related to Xband structure and testing, technical developments, plus the CTF3 programme. These commitments are covered by numerous R&D contracts and MoU annexes covering personnel and hardware, exchange/test of equipment being built in the collaboration, including many Ph.D students

The use of X-band structures and RF-sources in smaller projects of significant help to develop industrial and technical momentum

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