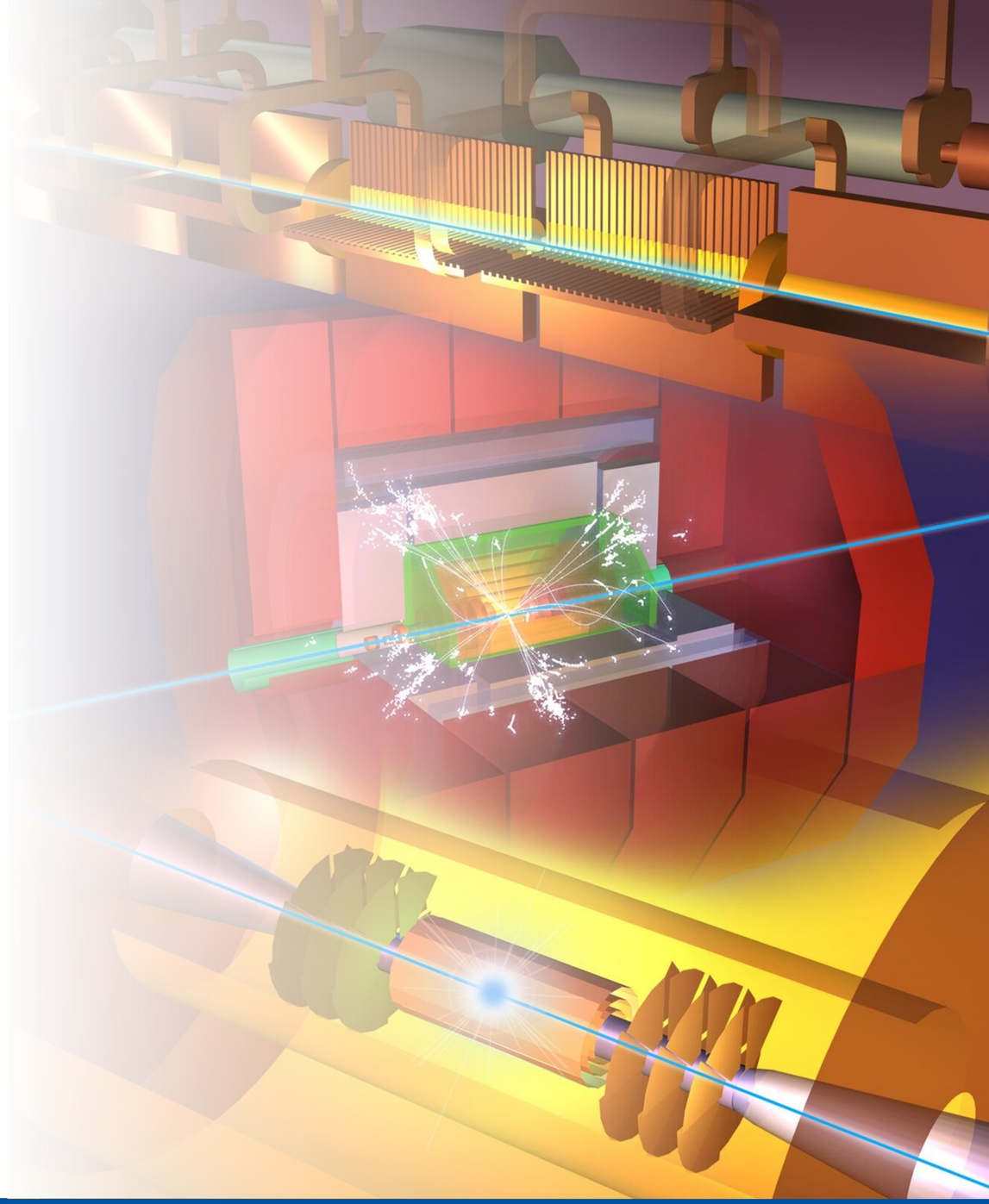
CLIC 2021-25

Outline

- Some updates
- Planning 2021-25 based on ESPP outcome
- Conclusion and next steps

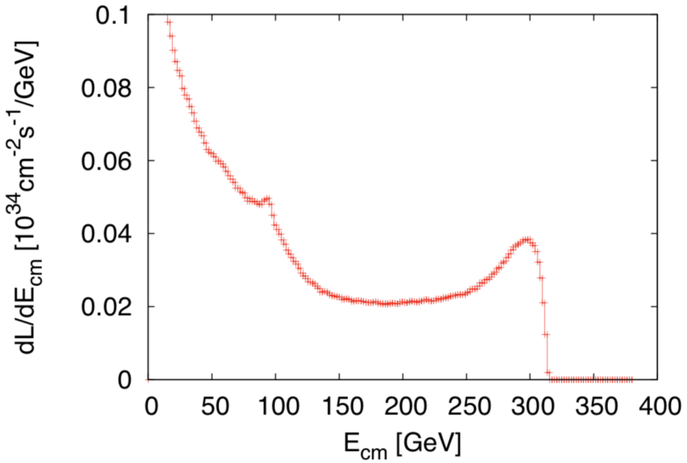


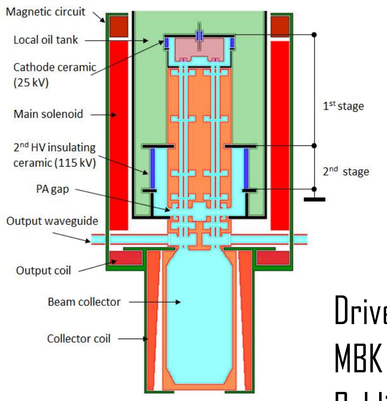
CLIC mini-week 2020

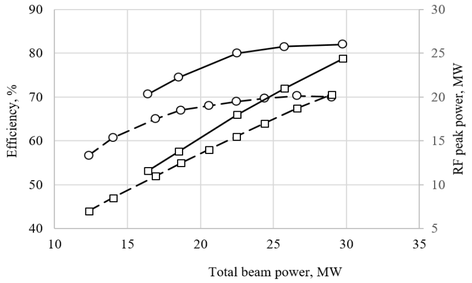
CLIC acc. studies 2019/20 – some examples

Further work on luminosity performance, possible improvements and margins, operation at the Z-pole and gamma-gamma

- Z pole performance, 2.3×10^{32} – 0.4×10^{34} cm^{-2} s^{-1}
  - The latter number when accelerator configured for Z running (e.g. early or end of first stage)
- Gamma – Gamma spectrum (example)
- Luminosity margins and increases
  - Baseline includes estimates static and dynamic degradations from damping ring to IP: 1.5 x 10^{34} cm^{-2} s^{-1}, a "perfect" machine will give : 4.3 x 10^{34} cm^{-2} s^{-1}, so significant upside
  - In addition: doubling the frequency (50 Hz to 100 Hz) would double the luminosity, at a cost of +50 MW and ~5% cost increase
- CLIC note at: http://cds.cern.ch/record/2687090 (being updated to a new version)

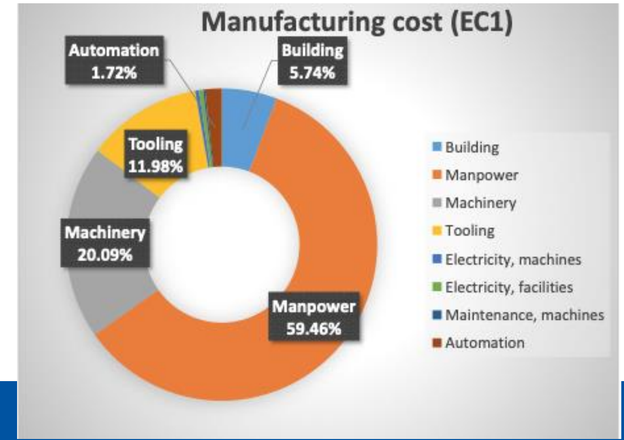






Drivebeam klystron: The klystron efficiency (circles) and the peak RF power (squares) simulated for the CLIC TS MBK (solid lines) and measured for the Canon MBK E37503 (dashed lines) vs total beam power. See more later.
Publication: https://ieeexplore.ieee.org/document/9115885

Industrial questionnaire:
Based on the companies feedback, the preparation phase to the mass production could take about five years. Capacity clearly available. Talk of of Anastasiya



Some recent overview papers

Several LoIs have been submitted on behalf of CLIC and CLICdp to the Snowmass process:

The CLIC accelerator study:
https://www.snowmass21.org/docs/files/summaries/AF/SNOWMASS21-AF4_AF3-EF0_EF0-177.pdf

https://www.snowmass21.org/docs/files/summaries/AF/SNOWMASS21-AF1_AF4-161.pdf (Beam-dynamics focused on very high energies)

The physics potential:
https://www.snowmass21.org/docs/files/summaries/EF/SNOWMASS21-EF0_EF0_CLICphysics-170.pdf
The detector:
https://www.snowmass21.org/docs/files/summaries/IF/SNOWMASS21-IF3_IF6_Mathieu_Benoit-188.pdf

Unrelated but significant:
The CDR for eSPS has been completed (still some edits for CERN yellow report to come): https://arxiv.org/abs/2009.06938

LC 2021-25 - ESPP

Three main conclusions in the ESPP for CLIC:

- A Higgs factory is a priority
- Not enough resources to move into extended prep. phase for CLIC -> maintain, development and improve capabilities and core technology (i.e. earliest project start moved 5-10 years back wrt to our ESPP input)
- Accelerator R&D is a priority including applications

Also: Timely ILC to be pursued - in many areas CLIC and ILC can work together, and also CERN specific expertise can be helpful

Implemented in CERN medium term plan (MTP) 2021-25 - three projects:

- LC (CLIC and ILC)
- CLEAR (LC are users)
- HiEff klystrons (LC are potential clients)

LC 2021-25, internal guidance

- Maintain CLIC as option for a Higgs/top machine for CERN – pursue High Gradient R&D
  - Concentrate on key technologies:
    - High gradient primarily (design, constr., tests) – also the key to all applications in research, medical and industrial accelerators (with high relevance for many coll. partners)
    - Nanobeams/luminosity and maintaining capabilities for start-to-end simulations
    - Drive-beam (in particular high eff klystrons – L band, some design work for structures)
  - Encourage collaboration activities where possible - fulfill commitments (collaboration agreements, EU projects – ARIES, CompactLight, I-FAST, KT agreements)
- Make sure CLIC technology investments are exploited in compact medical and industrial accelerators where possible, with (as before mostly) external funding – enabled by the High Gradient Technology
- Coordinate common CLIC/ILC activities, from LCC to ILC Development Phase activities, CERN LC/KEK common activities in next phase
- Additional: "Coordinate" with other CERN acc. R&D activities (Hi-Eff klystrons , injectors with AWAKE, normal temp acc. cavities with RFQ and muon cooling designs, CLEAR, possibly PBC) – transfer/combine knowledge and resources

MTP text

After the ESPP submissions and during the coming years the focus will remain on core technology development and spread making use of existing facilities (High Gradient Test Stand and the CLEAR beam facility), optimising X-band components, and efficient use of the abovementioned collaborations with laboratories and universities using the technology.

The use of the CLIC technology - primarily X-band RF, associated components and nano-beams - in compact medical, industrial and research accelerators in many of the CERN Member States has become increasingly important development and test grounds for CLIC, and is destined to grow further. An EC supported design study with 24 partners pursue the use of the technology in future FELs facilities (CompactLight).

On the design side the parameters for running at multi-TeV energies, with X-band or other RF technologies, will be studied further, in particular with energy efficiency guiding the designs.

International Linear Collider (ILC) studies are supported through combined working groups (beam-dynamics, positrons, etc.) and co-operation with KEK for specific technology developments and ATF2. The future of the ILC focused part of linear collider activities will depend on the progress of the ILC project in Japan, primarily exploiting the commonalities between CLIC and ILC, common R&D studies between CERN and KEK, and European capabilities related to ILC technologies, inside and outside CERN.

MTP goals 2021

- Optimise and develop the X-band core-technology by exploiting the existing experimental facilities, the High Gradient test stands, for testing and verifications of prototypes made within the collaboration;
- Maintain linear collider and linac design capabilities;
- Continue High Efficiency klystron optimisation in a coordinated effort with other studies and projects at CERN with similar needs;
- Continue high gradient studies, using the CLEAR facility, including among others wakefields, instrumentation for nano-beams, medical accelerators based on the technology;
- Follow up with collaborators the many smaller projects outside CERN where X-band technology is used – for medical, industrial and research linacs, providing very relevant effort/studies for CLIC, including industrial capability build up;
- Planning for European activities within ILC; in particular participate in defining the project's preparation phase activities, in case of further positive statements from Japan about hosting the project.

Our goals – more specifically

Three main goals for CLIC(++) by 2025:

- 380 GeV optimization: luminosity (beam-delivery/final focus (incl. ATF2-3), positrons, 100 Hz), RF power (DR, L-band klystrons), module/linac design, costs)
- Multi-TeV, 3 TeV and beyond (alternative parameters and beam-delivery/FF, same as above for power and incl. perm. magnets, module/linac design, costs)
- Applications - from FELs of all sizes to medical (need X-band and injector – both with RF, module construction)

Organize CERN's ILC efforts and provide help with/facilitate European coordination

Collaboration on all these topics

Core enabling “technologies” for CLIC:

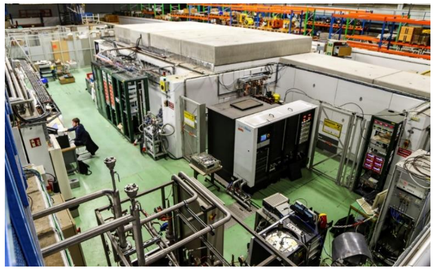
- X-band from fundamentals to structures, ultimately on modules, X-band RF power as needed for these studies
- Nanobeams with all it implies
- Drivebeam and positron prod.
- HEff RF
- Simulation and modeling
- For applications: Injector(s)

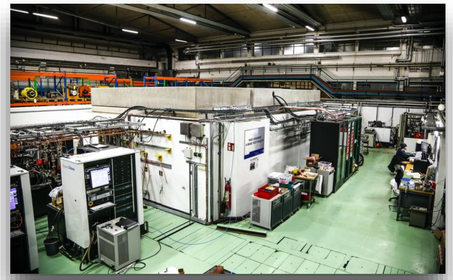
Facilities: CLEAR, ATF2, FACET, X-band users and installations around the world

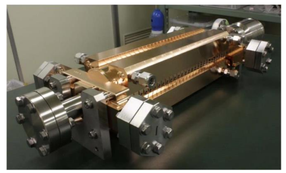
X-band and Xboxes

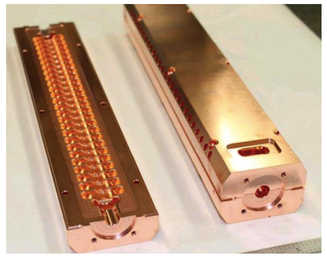
Studies, activities:

- Structures breakdown limits and optimization
- Operation and conditioning
- Baseline verification
- New ideas
- Assembly and industry qualification
- TNA Aries until 2022
- CompactLight structure in I-FAST
- Systems to Melbourne and Frascati
- Likely: Medical RT structures









Crab cavity	CLIC
TD26R1N2	CLIC
TD26R1N3	CLIC
DEFLECTOR	
T24OPEN (B)	CLIC
TD26R1N4	CLIC
TD26R1_CIEMAT	CLIC
TD31N1	CLIC
TD31N2	CLIC
CRAB CAVITY (D)	CLIC
DIELECTRIC	CLIC
TD31N3	CLIC
TD31N4	CLIC
TD26CC_HALVES	CLIC
COMPASS_1	CompactLight
COMPASS_1	CompactLight
FLASH_1	Flash
FLASH_2	Flash
T24Open (W)	CLIC
Components	
Spiral load 21	
Spiral Load 22	
Window 1	
Window 2	
Pulse compressor	

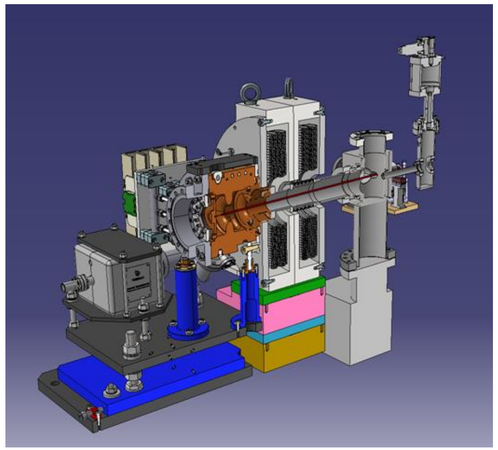
Collaborate for these topics and with “Xboxes” outside.
High Gradient yearly workshops

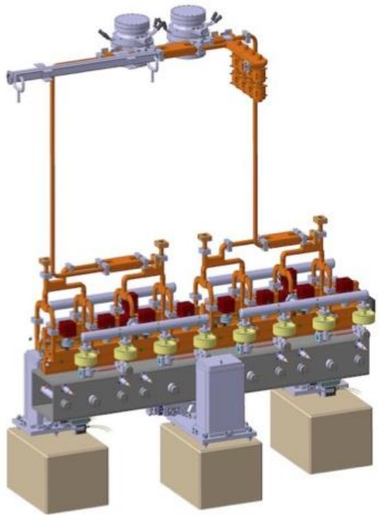
Applications – injector, X-band modules, RF

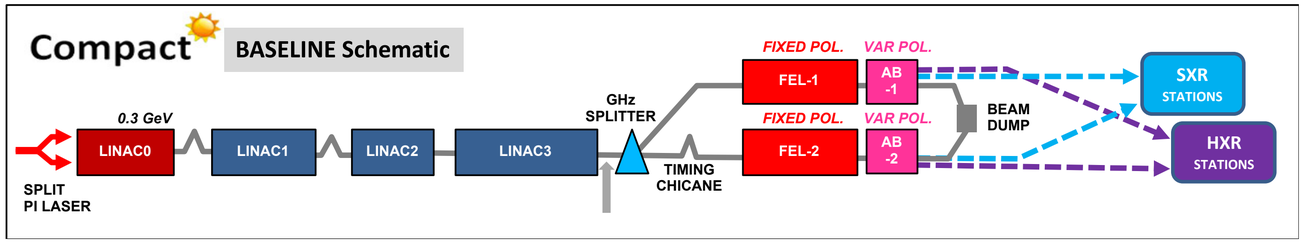
X-band enabler of CLIC and a variety of compact smaller machines , however recognized need for injector knowledge/expertise/studies: CLEAR, all applications (see right), AWAKE, CompactLight – all possible future e+e- machines

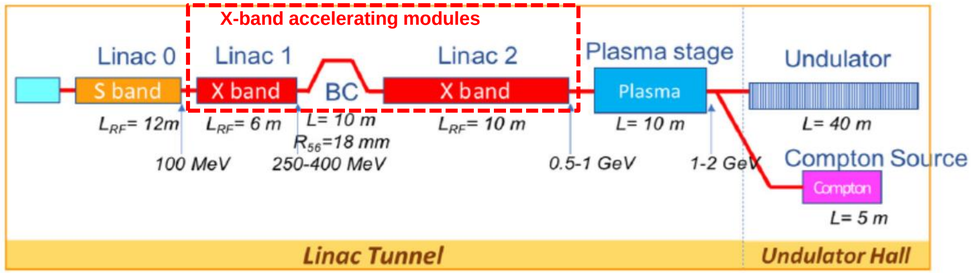
- Delivery of gun from Frascati this year (pre-Covid), install in CTF2 for tests and assembly of injector – use in CLEAR and/or AWAKE (a second copy or later)

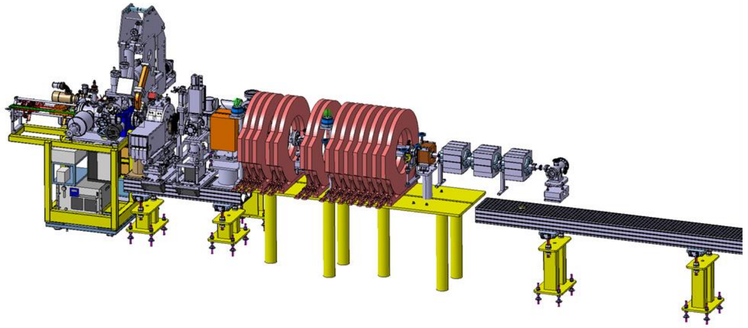
Module: We will do technical design studies of klystron driven module incl. RF power according to CLIC specs (see later if we can find resources to construct)

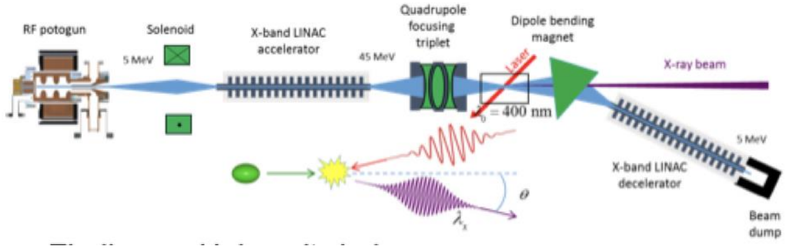


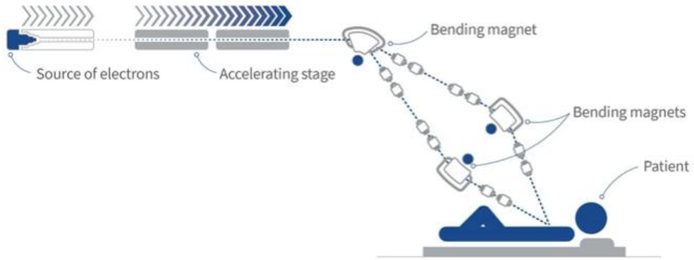












Funding also foreseen for

Beamdynamis and parameter studies: Nanobeams, start-to-end simulations (also for applications), pushing limits in multi TeV region (parameters, beam structure vs energy efficiency) – note also work done in 2019/20 (slide 2)

Propose: "Nanobeam Hardware Workshop"

"Project Office": Travels, admin – collaboration and CERN team, conferences, publications/reports, outreach, industrial/commercial studies, KT/EU seeds

Small technical activities – in many cases only partly funded: examples ATF2-3, instrumentation, positron studies, DR studies (you saw several presentations yesterday and this morning expanding on this work)

ILC: Common Fund for the Development Phase and CERN office at KEK (note: several of the activities above and on next page are also relevant for ILC and might be executed in collaboration with KEK).

Some very limited **collaborative contracts.**

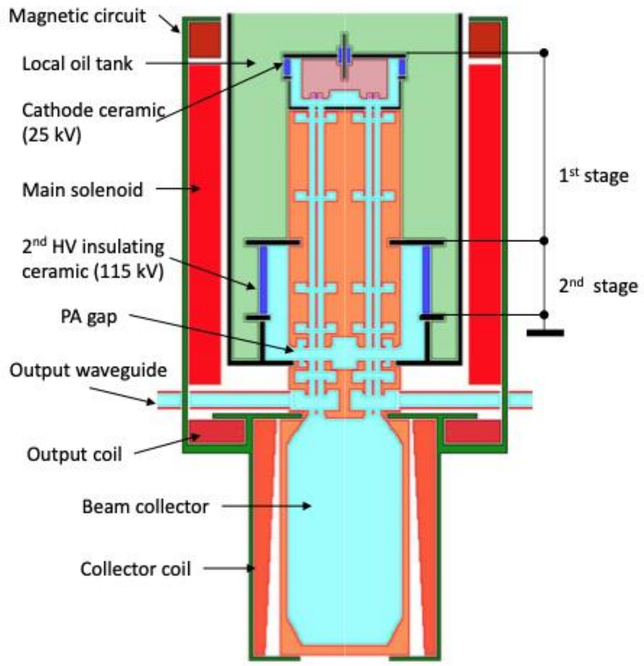
Drivebeam and High Eff. Klystrons (latter now in separate budget)

Tailored Technologies. High Efficiency (85%) 24 MW, 1 GHz, CLIC MBK/2S klystron.

Industrial CLIC MBK prototypes delivers **~70 %** RF power production efficiency

The new klystron bunching technologies cannot be directly adopted to the CLIC MBK:

- **COM** requires very long (5m) RF circuit.
- In **CMS**, the 3rd harmonic cavity is not compatible with MB-type cavities layout.

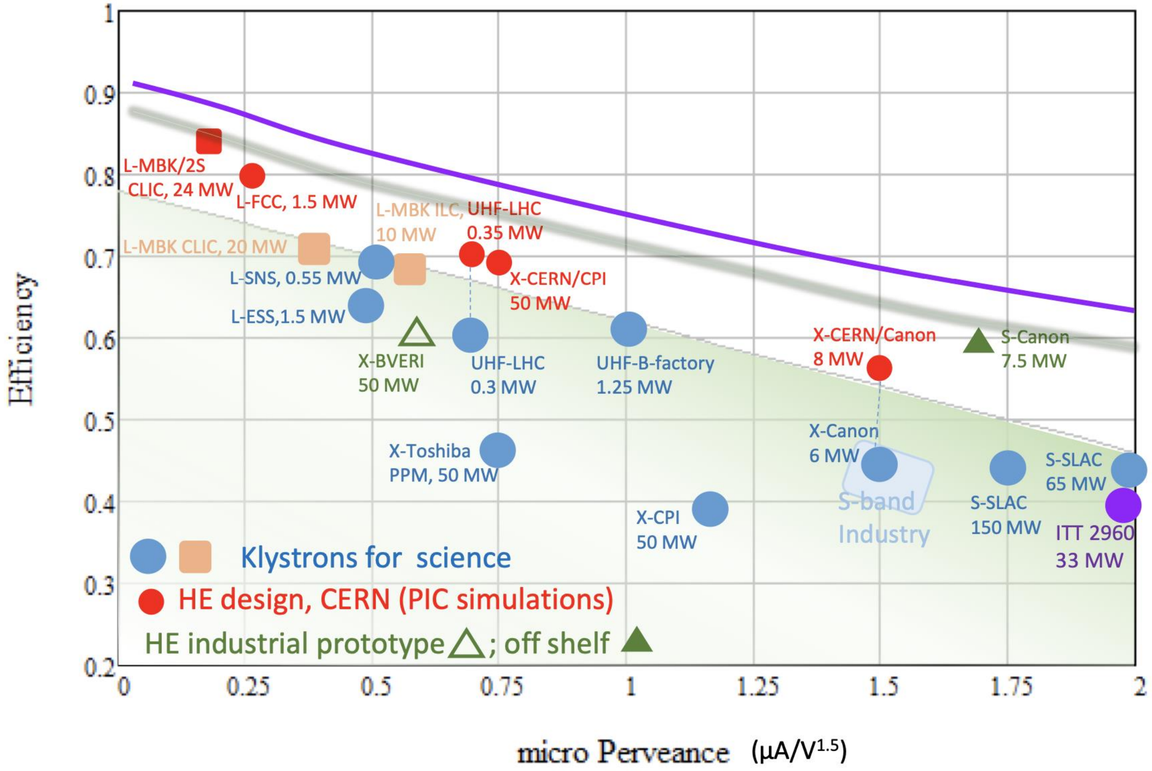


I. Syratchev, LCWS, Japan, Sendai, October 28 – November 1, 2019

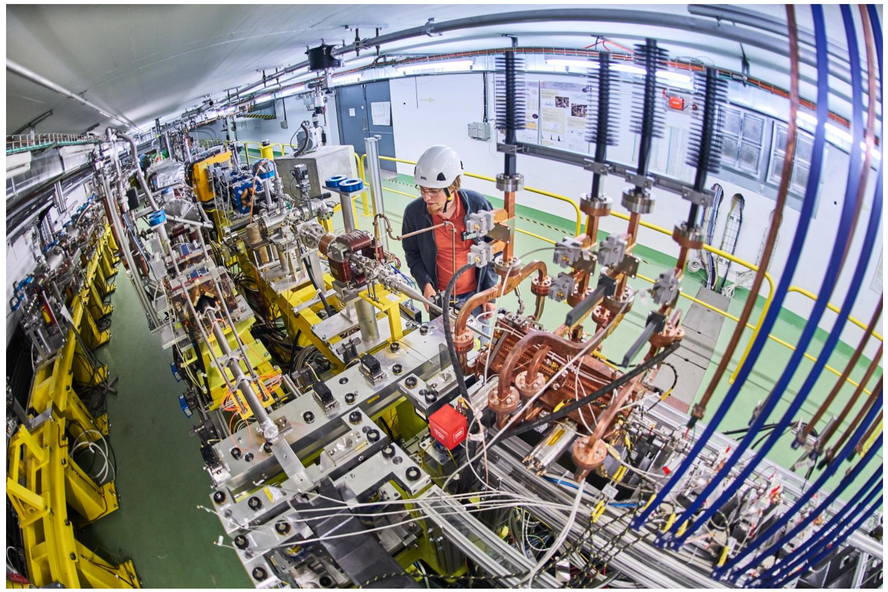
In LC budget line:
Ongoing activity in B112 of tests of delivered hardware (modulator and klystrons - left picture), will also do design of DB structure (manufacture to be decided later)

Prototyping of new L-band concept: for CLIC (and will also work for ILC), pushing efficiencies further (and reducing size/costs significantly) – only partly funded (see Igor's talk yesterday)

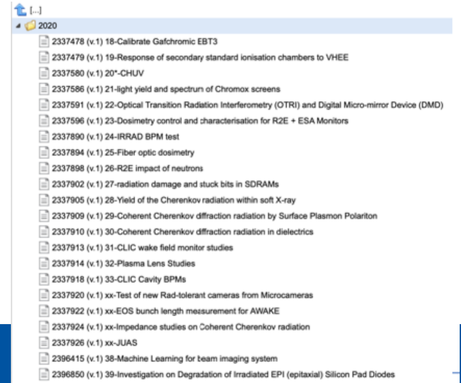
Further X-band RF developments to be seen in connection to X-boxes and applications (high efficiency and high rep rate) – again in Igor's and Gerry's talk



CLEAR – now separate budget



A small budget is foreseen for CLIC specific CLEAR studies



- Providing a test facility at CERN with high availability, easy access and high quality e- beams.
  - Performing R&D on accelerator components, including innovative beam instrumentation prototyping, high gradient RF technology realistic beam tests and beam-based impedance measurements.
  - Providing an irradiation facility with high-energy electrons, e.g. for testing electronic components in collaboration with ESA or for medical purposes(VHEE), possibly also for particle physic detectors.
  - Performing R&D on novel accelerating techniques – electron driven plasma and THz acceleration. In particular developing technology and solutions needed for future particle physics applications, e.g., beam emittance preservation for reaching high luminosities.
- Maintaining CERN and European expertise for electron linacs linked to future collider studies (e.g. CLIC and ILC, but also AWAKE and FCC-ee injectors), and providing a focus for strengthening collaboration in this area.
- Using CLEAR as a training infrastructure for the next generation of accelerator scientists and engineers.

Experiments/Activities in 2019 – 38 weeks

(Possibly not a complete list)

- JUAS Practical Work Days
- NPL – Irradiation/dosimetry
- CHUV – FLASH dosimetry
- AWAKE Cherenkov BPM
- CLIC Wake-Field Monitors
- EOS bunch length monitor
- Inductive BPMs
- CLIC Structure wake-field kicks
- THz Smith-Purcell radiation
- THz high power generation/bunch length monitoring
- Ionization chambers dosimetry (Oldenburg U. /PTW)
- R2E Irradiation studies SEU-SEE
- R2E – ESA monitor flash
- R2E – displacement damage
- Plasma Lens (Oslo, DESY, Oxford U.)
- VHEE radiobiology/plasmid irradiation (Manchester U.)
- AWAKE spectrometer calibration
- Cryogel radiation length evaluation (FCC detectors R&D)
- Cherenkov X-ray pre-tests (Belgorod)
- RP measurements/neutrons
- Double-bunch generation
- High Charge bunch compression
- Irradiation of DCDC converters for detectors (EP/ESE group)
- IRRAD Beam Profile Monitors prototype tests
- WSM-BPR diagnostics tests
- Cherenkov Plasmonic

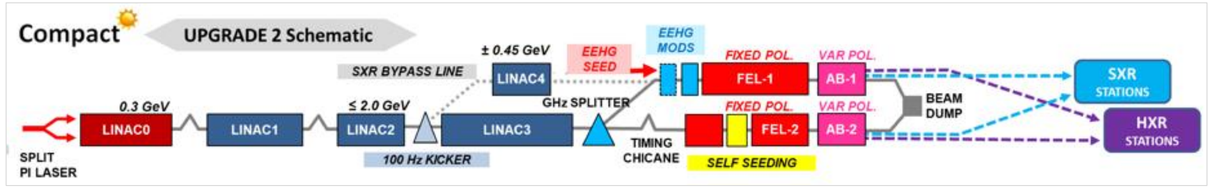
CLIC studies 2021-25 (Snow-mass slide)

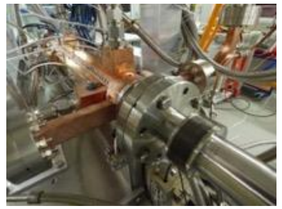
X-band technology:

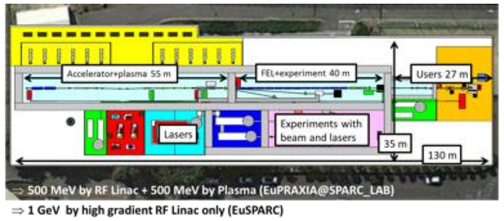
- Design and manufacturing of X-band structures and components
- Study structures breakdown limits and optimization, operation and conditioning
- Baseline verification and explore new ideas
- Assembly and industry qualification
- Structures for applications, FELs, medical, etc

Technical and experimental studies, design and parameters:

- Module studies (see some targets for development below)
- Beamdynamics and parameters: Nanobeams (focus on beam-delivery), pushing multi TeV region (parameters and beam structure vs energy efficiency)
- Tests in CLEAR (wakefields, instrumentation) and other facilities (e.g. ATF2)
- High efficiency klystrons
- Injector studies suitable for X-band linacs (coll. with Frascati)







Application of X-band technology (examples):

- A compact FEL (CompactLight: EU Design Study 2018-21)
- Compact Medical linacs (proton and electrons)
- Inverse Compton Scattering Source (SmartLight)
- Linearizers and deflectors in FELs (PSI, DESY, more)
- 1 GeV X-band linac at LNF
- eSPS for light dark matter searches (within the PBC-project)

Conclusions

The programme for 2021-25 is very technically R&D focused

It is also very collaborative (some of you will have larger X-band facilities than CERN so for CLIC this is extremely valuable)

We have very limited resources for R&D agreement were we transfer funds - need creative collaborations for many of the planned activities (sharing of costs)

Technical activities outside X-band also limited, but again we can do a significant amount with collaborative effort and linked to beam facilities

CLEAR is included in the plans for 2021-25, HiEff klystrons also – in addition to the LC budget

Next

Implementing what is described above ..

Worth noting the many applications presented today – from medical radiation therapy to ICS to FELs (soft/hard) ..

Collaboration agreements and MoU addenda for next period – reviewing, need your help

Meetings next year (tentative):

Nanobeam WS, LCWS (how strongly CLIC related?), High Gradient workshop, CLIC week in autumn

Project meeting in December