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Holland@CERN 2010

Industrial Challenges & Possibilities

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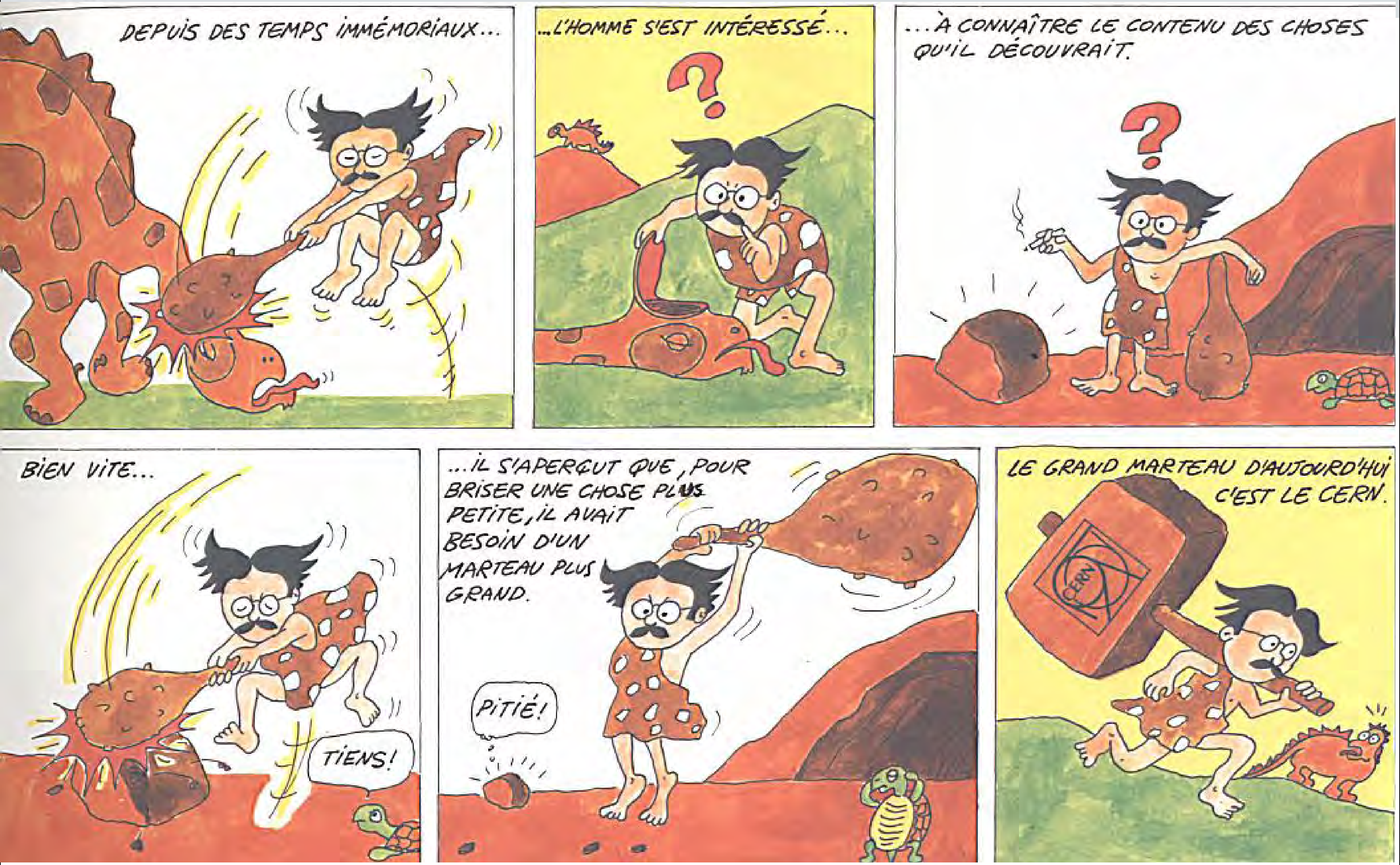
Large Science ...



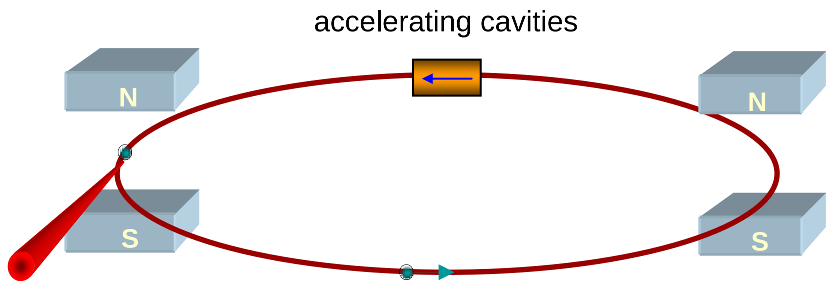
CERN is central,

- LHC (injector) upgrade
- CLIC study

but there is more:

- DESY – XFEL
- GSI – FAIR
- ESS – neutron spallation source
- KVI – ZFEL, and other small univeristy FELs
- medical & industrial accelerators
- Americas, Asia, …

Circular versus Linear Accelerator

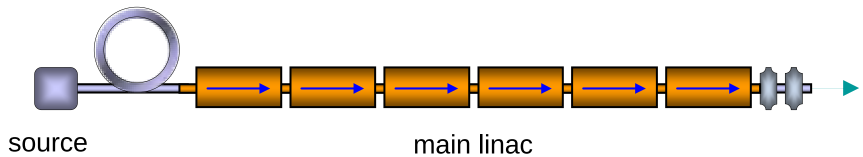


Circular Accelerator

many magnets, few cavities → need strong field for smaller ring

high energy → high synchrotron radiation losses ($\propto E^4/R$)

high bunch repetition rate → high luminosity



Linear Accelerator

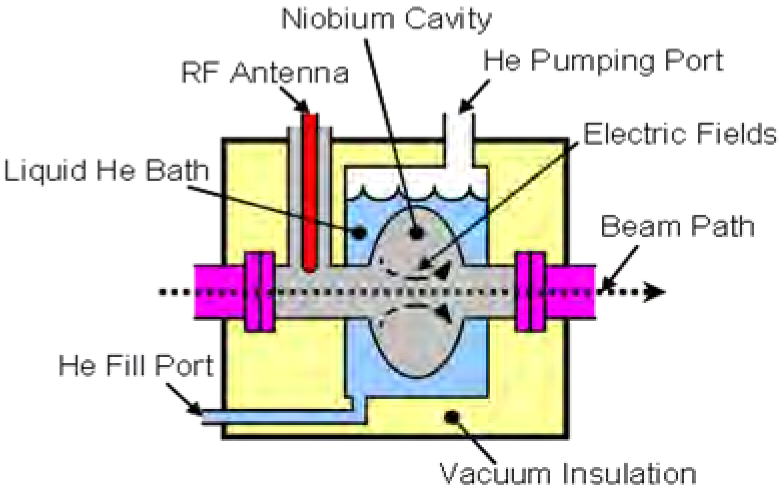
few magnets, many cavities → need efficient RF power production

higher gradient → shorter linac

single pass → need small cross-section for high luminosity:

(exceptional beam quality, alignment and stabilization)

- We need:
  - knowledge
  - experience
  - quality
  - reliability



- You will be dealing with a university culture
- Sometimes one-off pieces, sometimes series
- State-of-the-art requirements can help you enter or create new markets:
  - touch-pad screens (1970s), PET (1970s), WWW (1990s)
  - … (today)

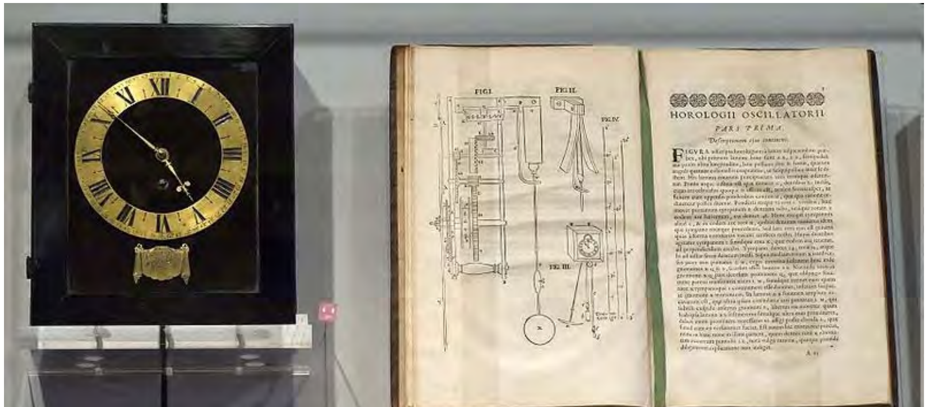
Similar challenges for PET and HEP detectors

- New scintillating crystals and detection materials
- Compact photo-detectors
- Highly integrated and low noise electronics
- High level of parallelism and event filtering algorithms in DAQ
- Modern and modular simulation software using worldwide recognized standards (GATE)

courtesy Manjit Dosanjh

Industrial Opportunities

- Mechanical
  - high precision machining (cavities, vacuum)
  - clean assembly, ultra-high vacuum (cavities, beam lines)
  - high quality welding (vacuum, cryogenics)
  - cryostats and cryo-lines
  - supports (few kg to many tons)
  - alignment and stabilization (µm level and below)
  - ceramics (insulation, measurement)
- Electro-mechanical
  - electro-magnets
  - 3D modelling (static, time and frequency domains)
- Others
  - Optics: mirrors, lenses, cameras
  - Energy efficiency
    - to control the operation costs
  - Thermo-dynamics & acoustics
    - to minimize vibrations
- Electrical & electronics
  - controls, data acquisition (slow, fast)
  - cables, connectors, feed-throughs
  - timing and synchronization (ns scale and below)
  - power converters
  - high power pulse modulators
  - RF power amplifiers (klystron, IOT, ...)
  - semi-conductors (detectors, MediPIX)
- Software
  - controls and supervision (FPGA, PLC, high level, GUI)



C. Huygens clock © Museum Boerhaave

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Projects for Future Accelerators

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The ILC and CLIC

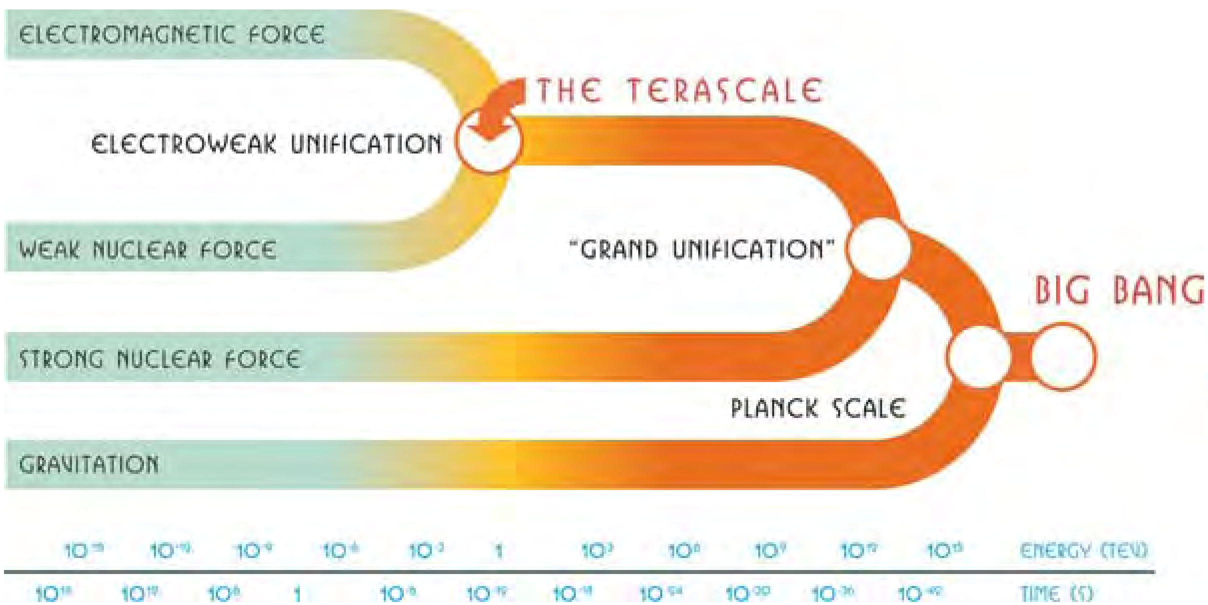
LHC should indicate which energy level is needed

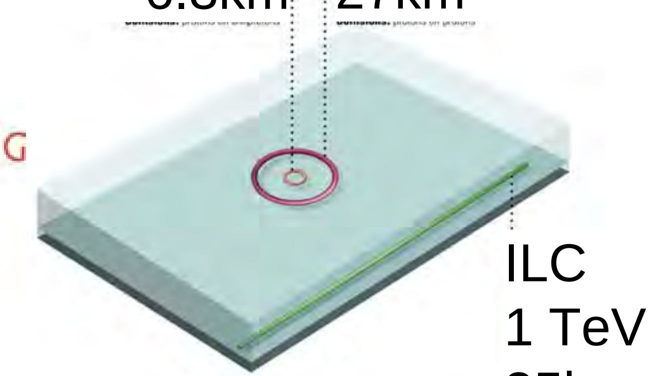
ILC International Linear Collider

- superconducting technology
- RF frequency 1.3 GHz
- acceleration gradient ~31 MV/m
- centre of mass energy 500 GeV
- upgrade to 1 TeV

CLIC Compact Linear Collider

- normal conducting technology
- 12 GHz
- ~100 MV/m
- multi-TeV, nominal 3 TeV





Courtesy Sandbox Studio / interactions.org

Source: New Scientist

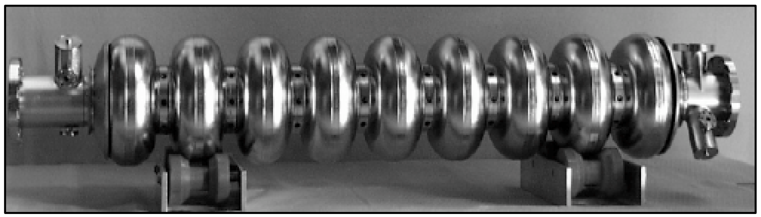
ILC: International Linear Collider

SC linacs: 2x11 km, 2x250 GeV

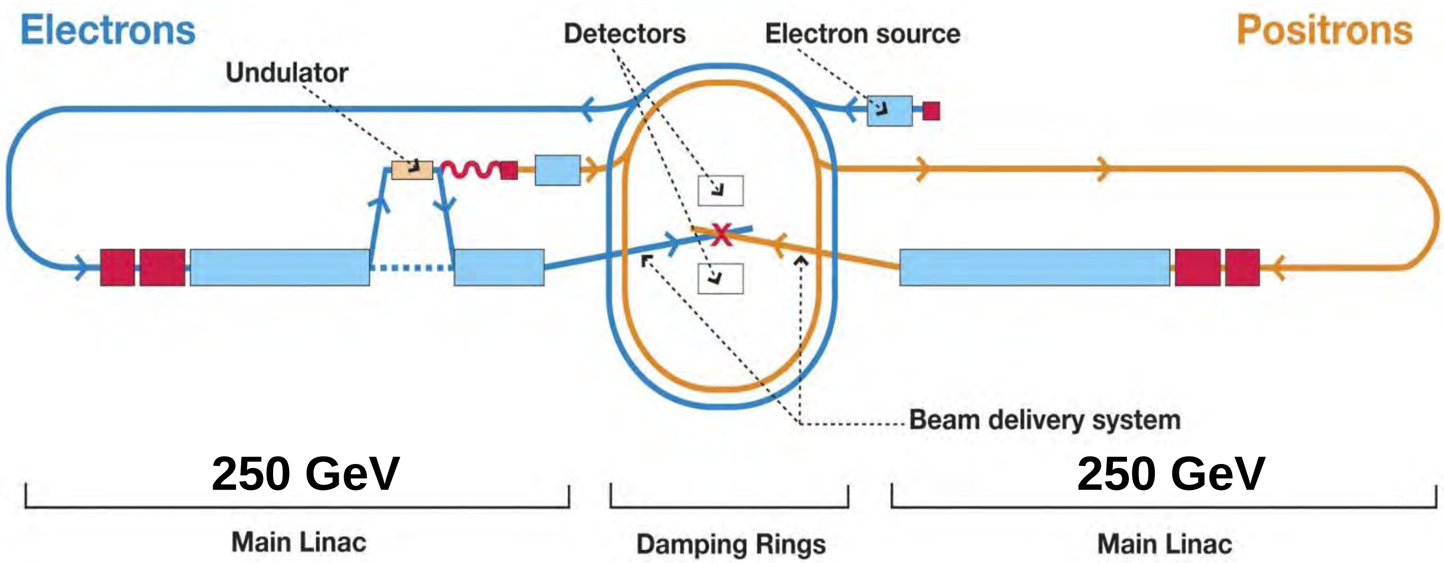
Central injector

circular damping rings

IR with 14 mrad crossing angle

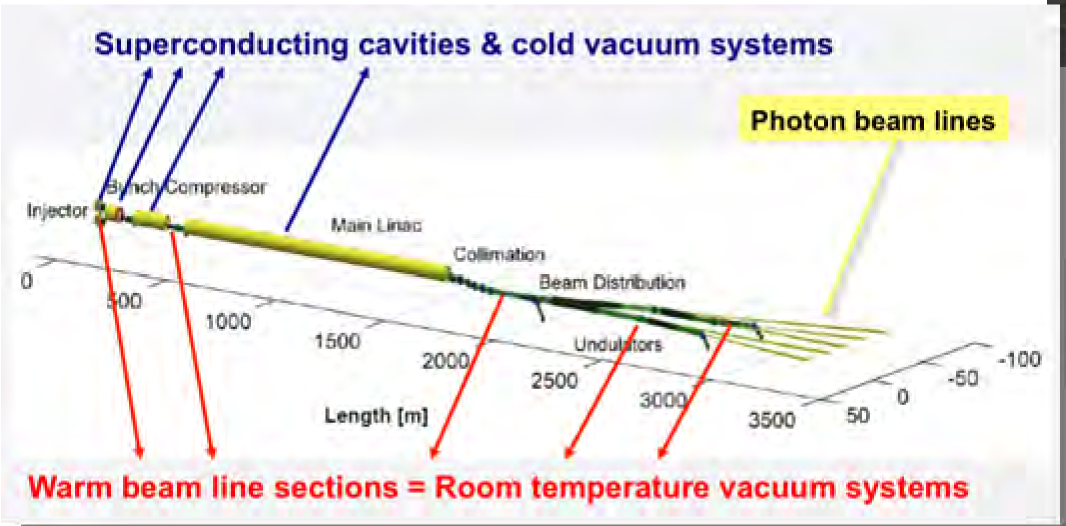


Parameter	Value
C.M. Energy	500 GeV
Peak luminosity	$2x10^{34}$ $cm^{-2}s^{-1}$
Beam Rep. rate	5 Hz
Pulse time duration	1 ms
Average beam current	9 mA (in pulse)
Average field gradient	**31.5 MV/m**
# 9-cell cavity	14,560
# cryomodule	1,680
# RF units	560

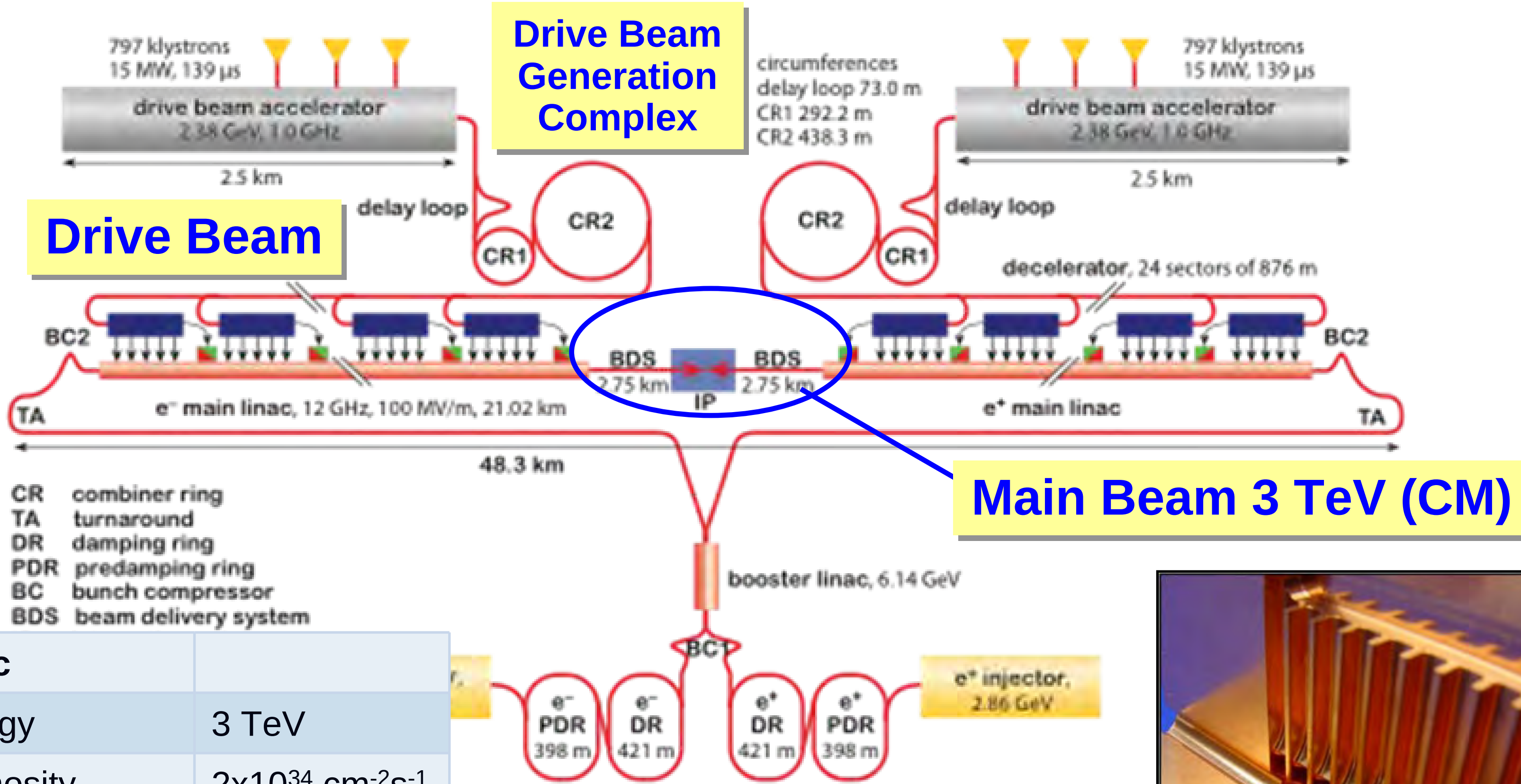


European XFEL

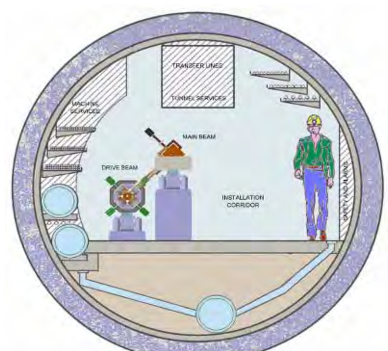
- X-ray FEL in Hamburg (Germany) for material & life science
  - 10% ILC prototype
- Construction started
  - First beam ~2014
- World's largest SCRF linac
  - ~800 cavities, ~100 cryostats

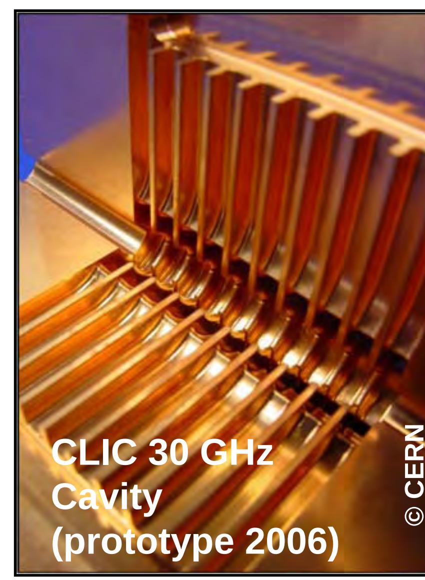


CLIC Compact Linear Collider



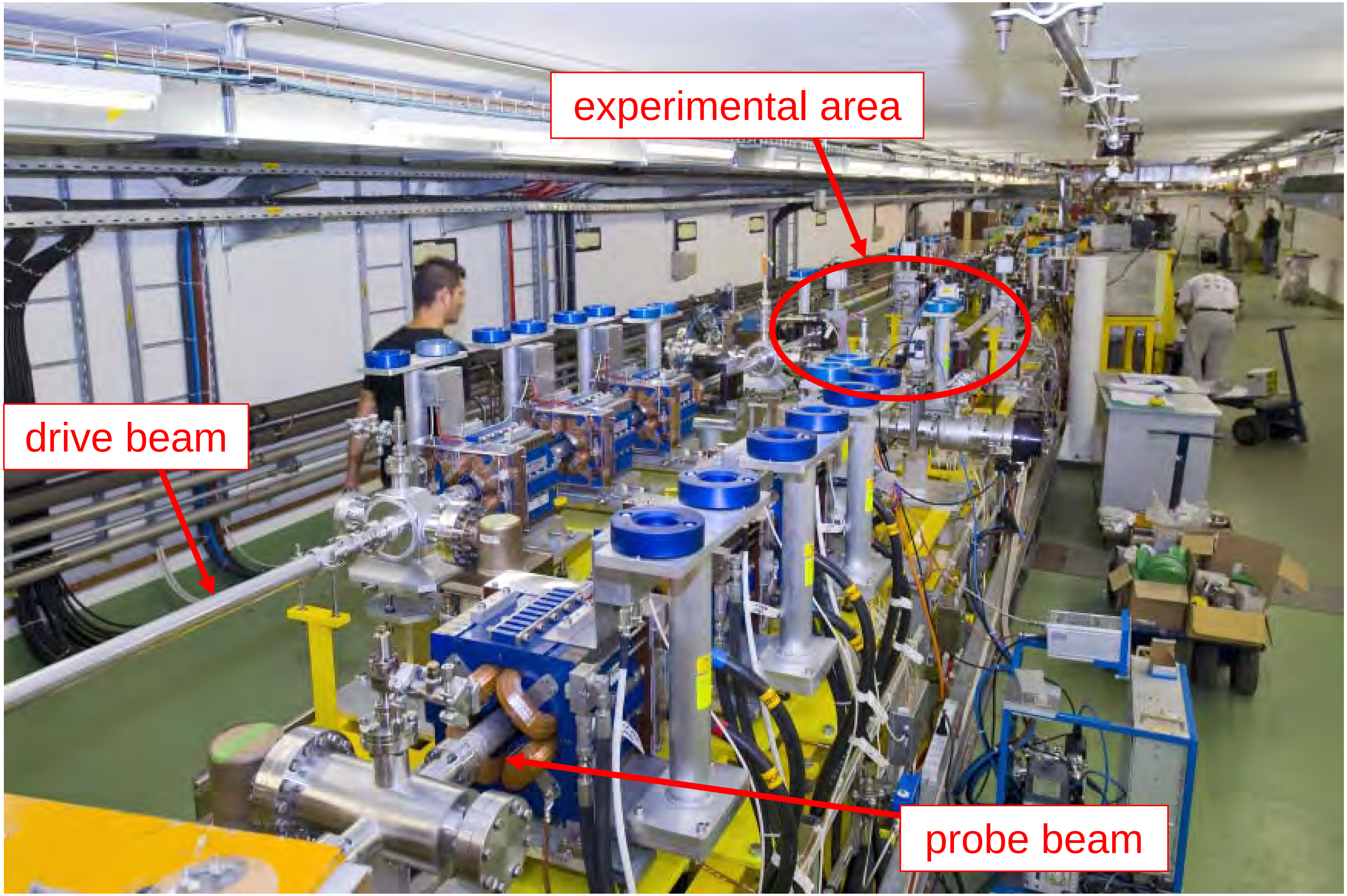
Main Linac	
C.M. Energy	3 TeV
Peak luminosity	$2x10^{34}$ $cm^{-2}s^{-1}$
Beam Rep. rate	50 Hz
Pulse time duration	156 ns
Average field gradient	100 MV/m
# accelerating cavities	2 x 71,548





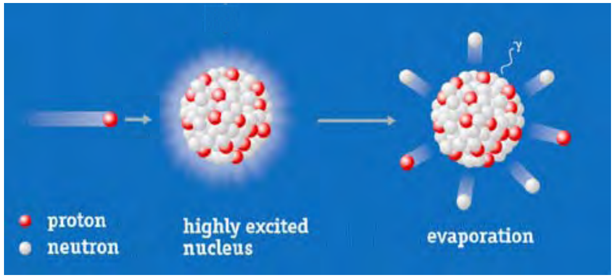
CLIC 30 GHz Cavity (prototype 2006)

CTF3 Two-beam Test Stand

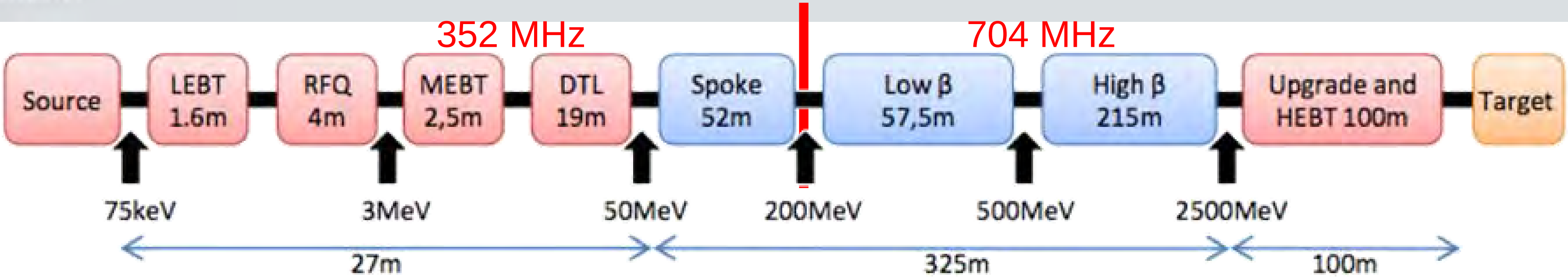


European Spallation Source

- Pulsed neutron source for material & life science
  - 5 MW p^+ to target
  - Multiple instruments (up to 22)
- Cost estimate ~1.5 G€ / 10 years
  - to be build in Lund (Sweden)
- First beam ~2019
  - 3 years design update
  - 5 years construction
- High intensity proton accelerator
  - based on CERN Linac 4 + SPL project

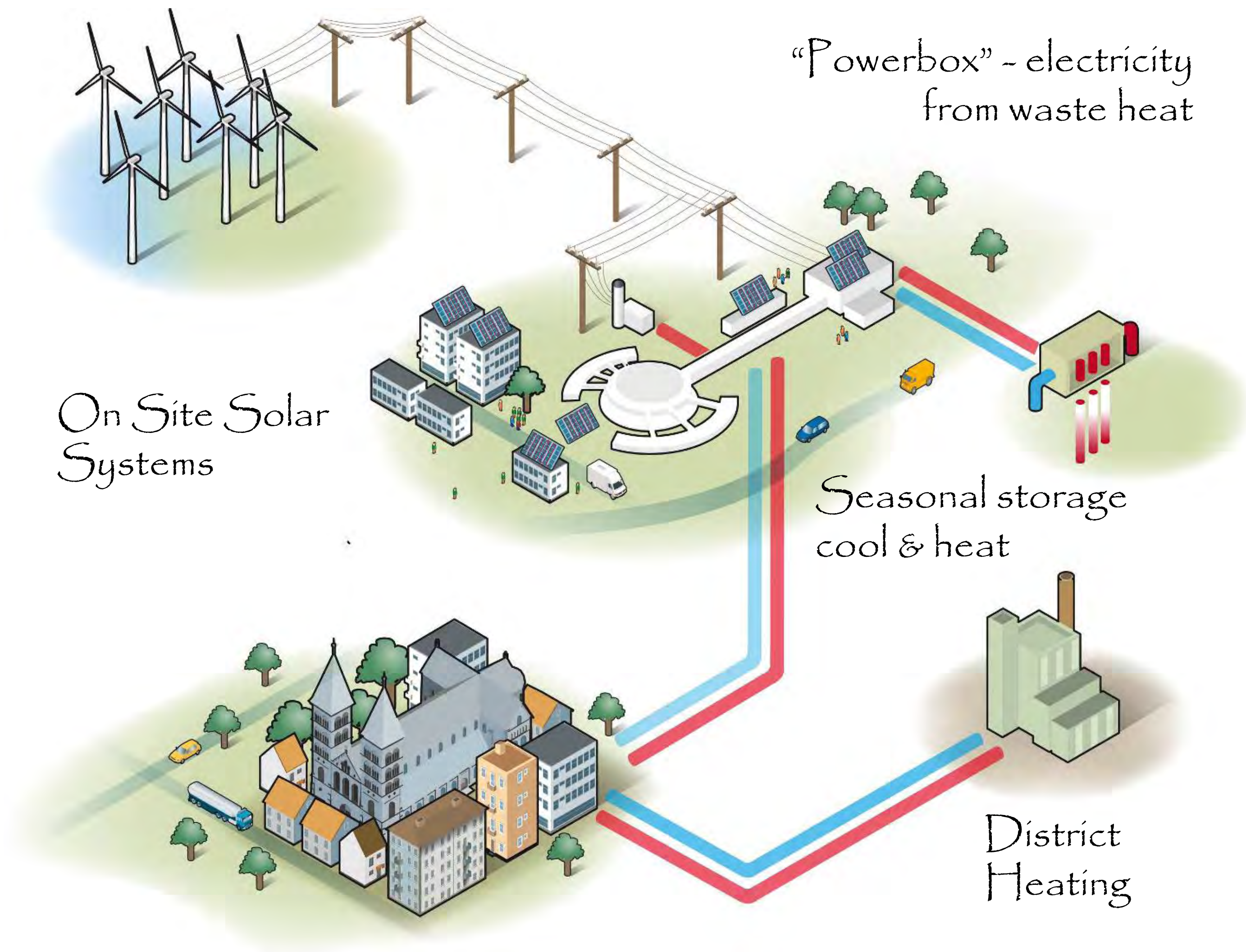


ESS Accelerator Base Line



- 5 MW p^+: 50 mA, 2.5 GeV, 2 ms, 20 Hz repetition rate
  - < 1 W/m losses
  - high up-time reliability for users (> 95%)
- ~200 accelerating cavities (352 + 704 MHz)
  - plus magnets, instrumentation, cryostats, power sources, controls, …
- design questions
  - how to reach the reliability
  - how to reach energy efficiency (to reduce operation costs)
  - technical design of NC and SC linac, RF systems, infrastructure, …
  - upgrade options to 7.5 or 15 MW

ESS Energy Management

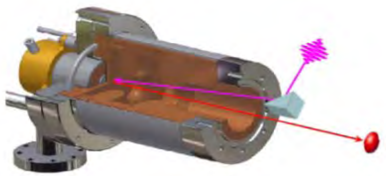


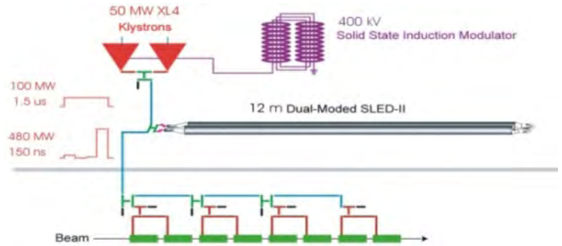
Include research, development & demonstration of emerging energy technologies.

Goal: carbon neutrality.

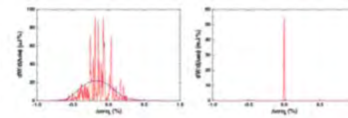
Eg options on wind turbine farms

ZFEL: Compact X-ray FEL at KVI/RUG

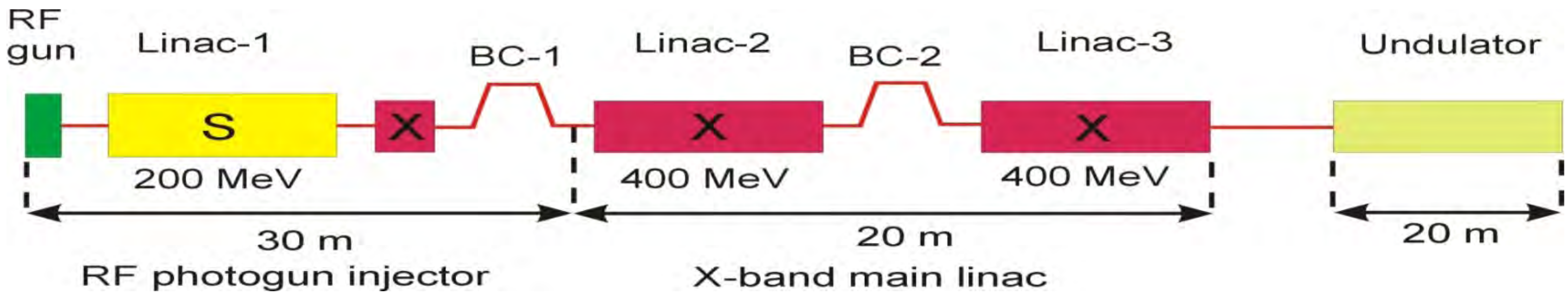


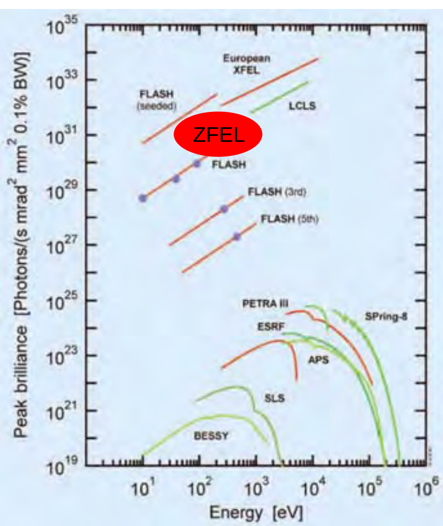


SASE vs seeded FEL



use of a seeding laser (high-harmonic generation from a fs-pulsed laser) allows also longitudinal coherence, shorter pulses and pulse-to-pulse reproducibility

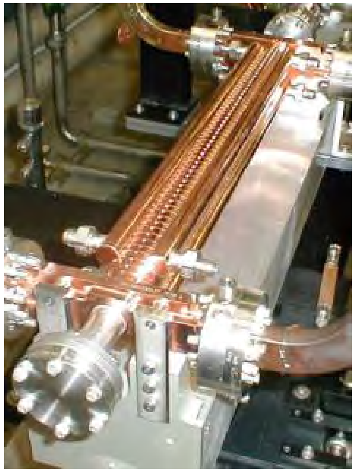




	Stage 1	Stage 2
Beam energy (GeV)	1.0	2.1
Bunch charge (pC)	10 - 100	10 - 100
Norm. emittance (mm-mrad)	1.0	1.0
Peak current (kA)	1.5	1.5
Energy spread (MeV)	0.3	0.4
Repetition frequency (Hz)	10 - 1000	10 - 1000
Photon wavelength (nm)	3.4	0.8

ZFEL: Opportunities for Industry

- High-power modulators for driving X-band klystrons
- State-of-the-art fine-mechanical manufacturing of high-gradient acceleration structures
- Magnet power supplies
- Power, control and feedback electronics
- Timing and synchronization on fs timescale
- Positioning and alignment with μm accuracy
- Soft X-ray optica, multilaag spiegels etc.



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Summary

- Many broad possibilities for industry
  - at CERN, in Europe and world wide
- There is a large synergy between projects
  - industry can use competences gained in one project towards the next project
  - but sometimes it can take years to develop something
- Important to understand your customer,
  - treat the institutes/universities as your friend
  - good quality and trust
- Research can be a business,
  - but researcher is not a businessperson!