CLIC accelerator development and now technology transfer

CABOTO meeting, 24 September 2014

Walter Wuensch, CERN

Overview

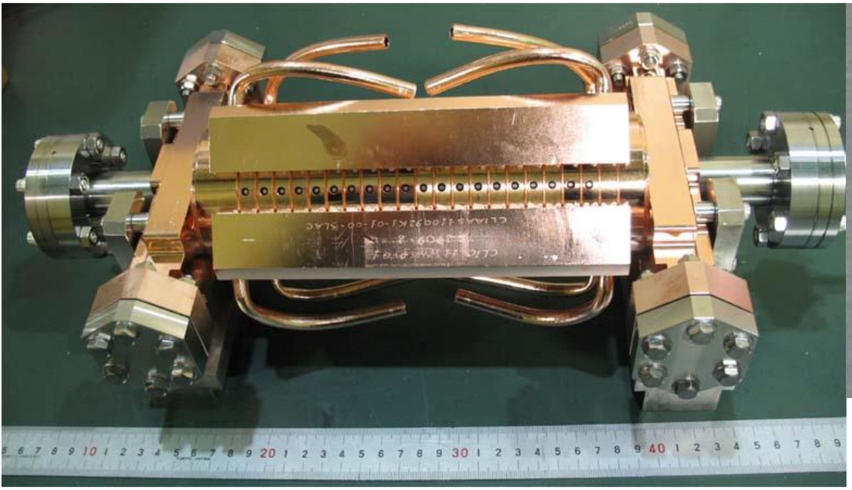
The CLIC project is developing the technology to make possible a TeV-range electron-positron linear collider.

One of the key objectives of the CLIC study has been to develop 100 MV/m accelerating structures along with the corresponding high-power, around 50 MW, rf systems.

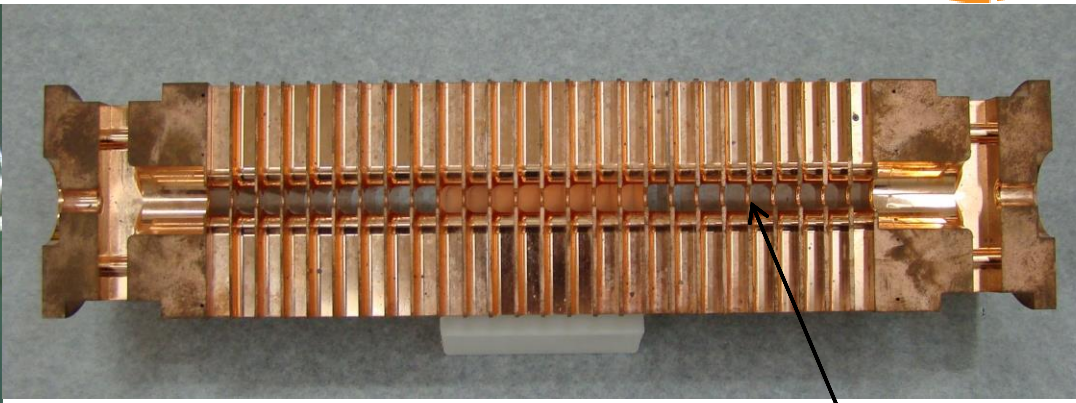
Gradients in excess of 100 MV/m, are now routinely achieved.

We are actively seeking to apply our advances to other applications.

CLIC accelerating structure



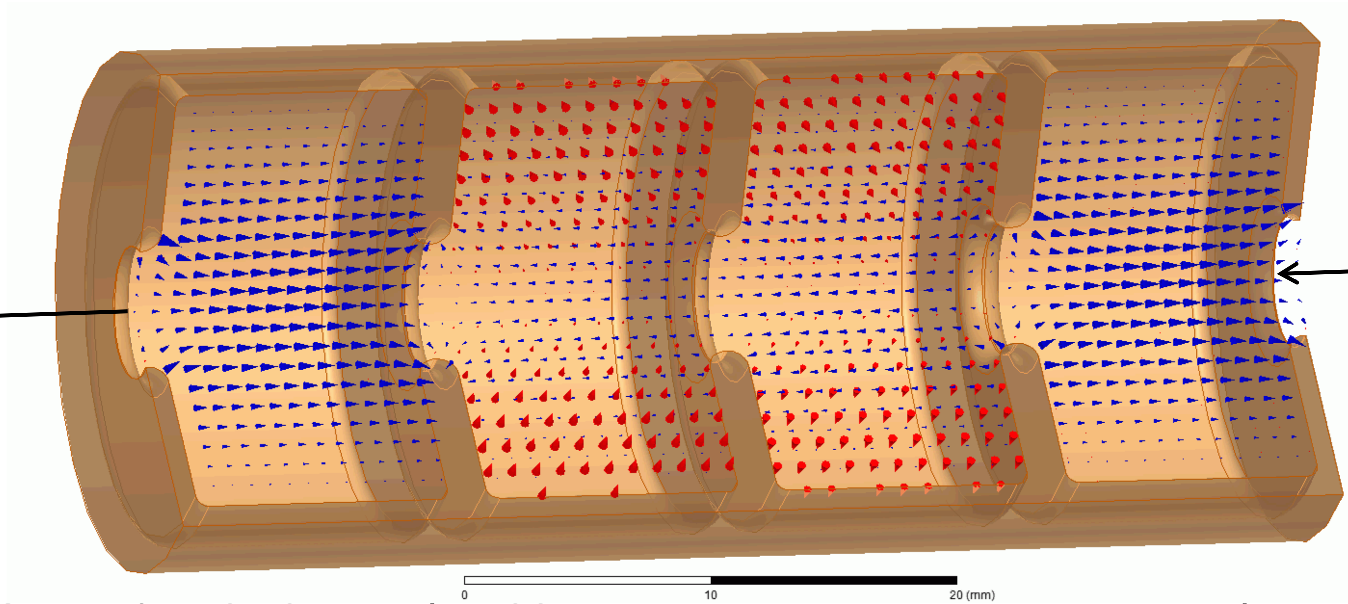
Outside



Inside

11.994 GHz X-band

6 mm diameter
beam aperture

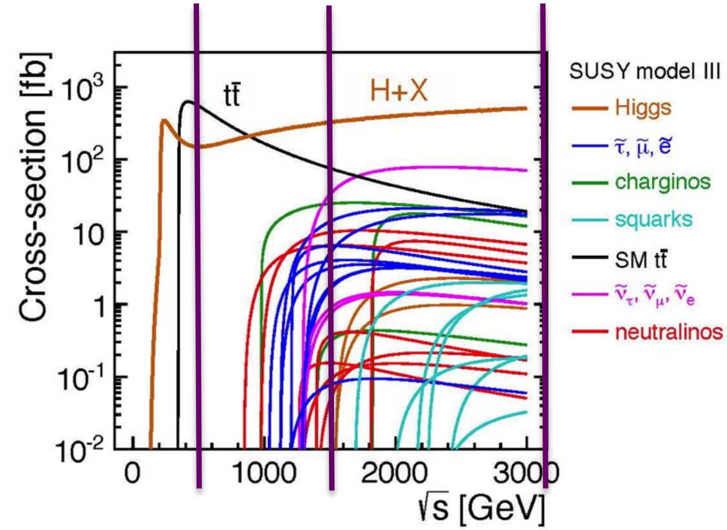


beam
propagation
direction

Concept

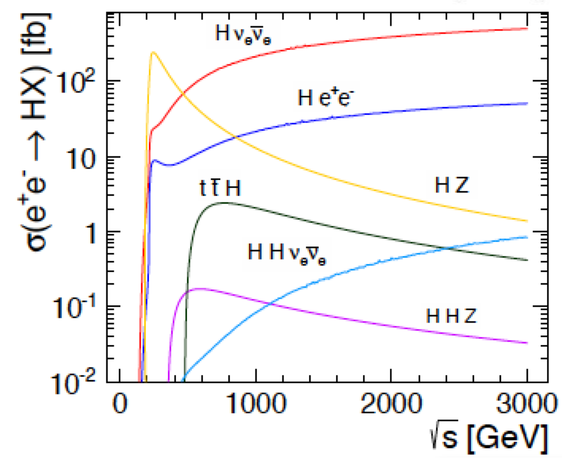
Physics at LC from 250 GeV to 3000 GeV

- Physics case for the Linear Collider:
  - Higgs physics (SM and non-SM)
  - Top
  - SUSY
  - Higgs strong interactions
  - New Z' sector
  - Contact interactions
  - Extra dimensions
  - …. AOP (any other physics) …



Specific challenges for CLIC studies:

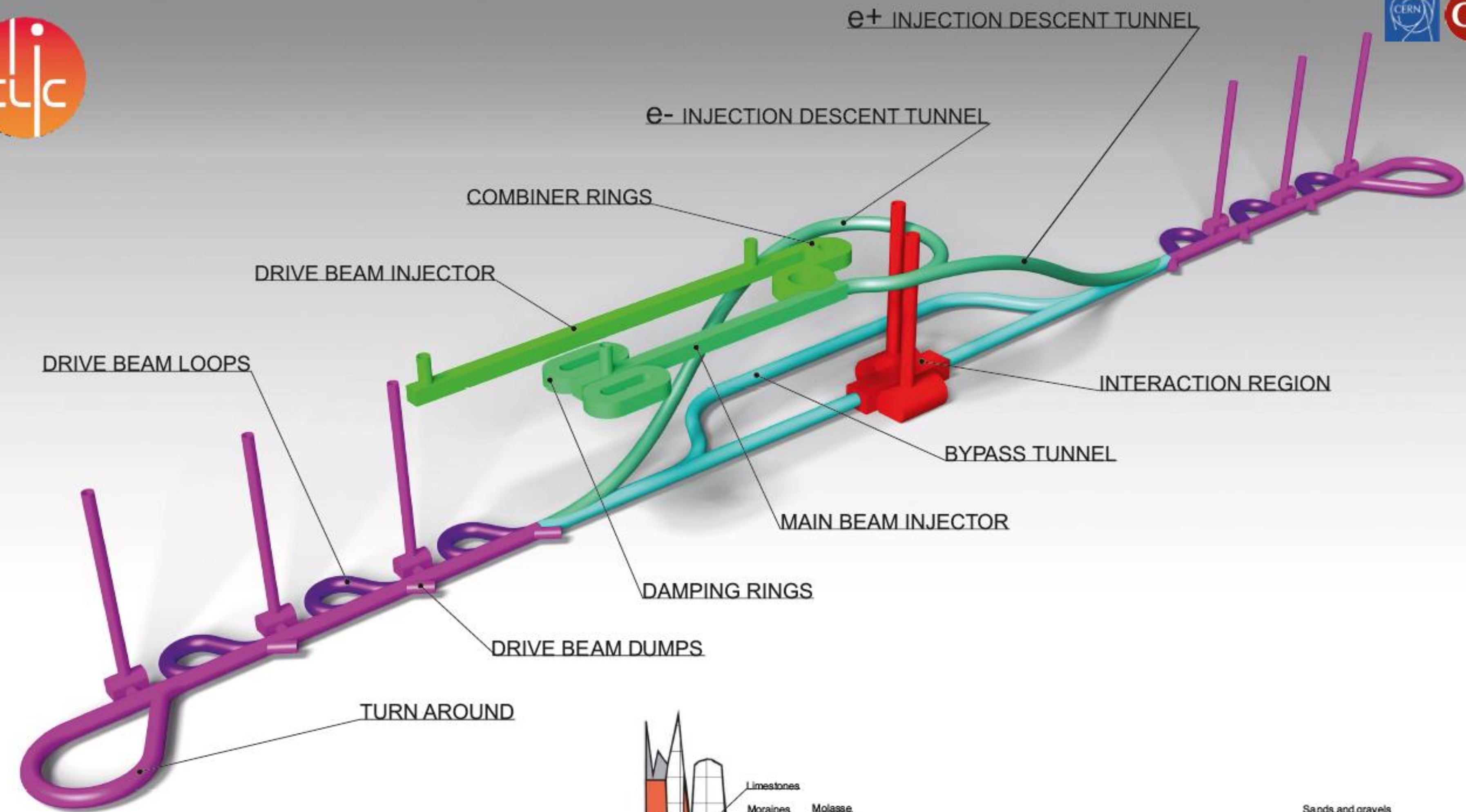
- Need to address Higgs-studies, including gains for measurements at higher energies
- Reach for various "new physics" (list above) options; comparative studies with HiLumi LHC and proton-proton at higher energies (FCC).



New particle	LHC (14 TeV)	HL-LHC	CLIC3
squarks [TeV]	2.5	3	$\lesssim$1.5
sleptons [TeV]	0.3	-	$\lesssim$1.5
Z' (SM couplings) [TeV]	5	7	20
2 extra dims M_D [TeV]	9	12	20–30
TGC (95%) (λ_γ coupling)	0.001	0.0006	0.0001
μ contact scale [TeV]	15	-	60
Higgs composite scale [TeV]	5–7	9–12	70

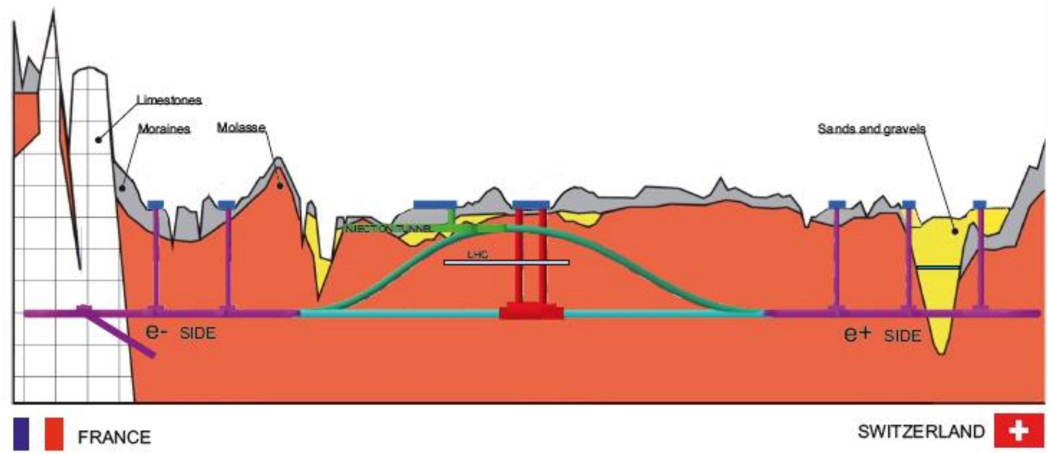
Process	VLHC	CLIC	
	200 TeV	3 TeV	5 TeV
squarks	15	1.5	2.5
sleptons		1.5	2.5
Z'	30	20	30
q^*	70	3	5
l^*		3	5
Extra two dimensions	65	20 – 33	30 – 55
$W_L W_L$	30σ	70σ	90σ
TGC (95%)	0.0003	0.00013	0.00008
Λ compos.	130	300	400

References:
CLIC CDR and
http://arxiv.org/pdf/hep-ex/0112004.pdf

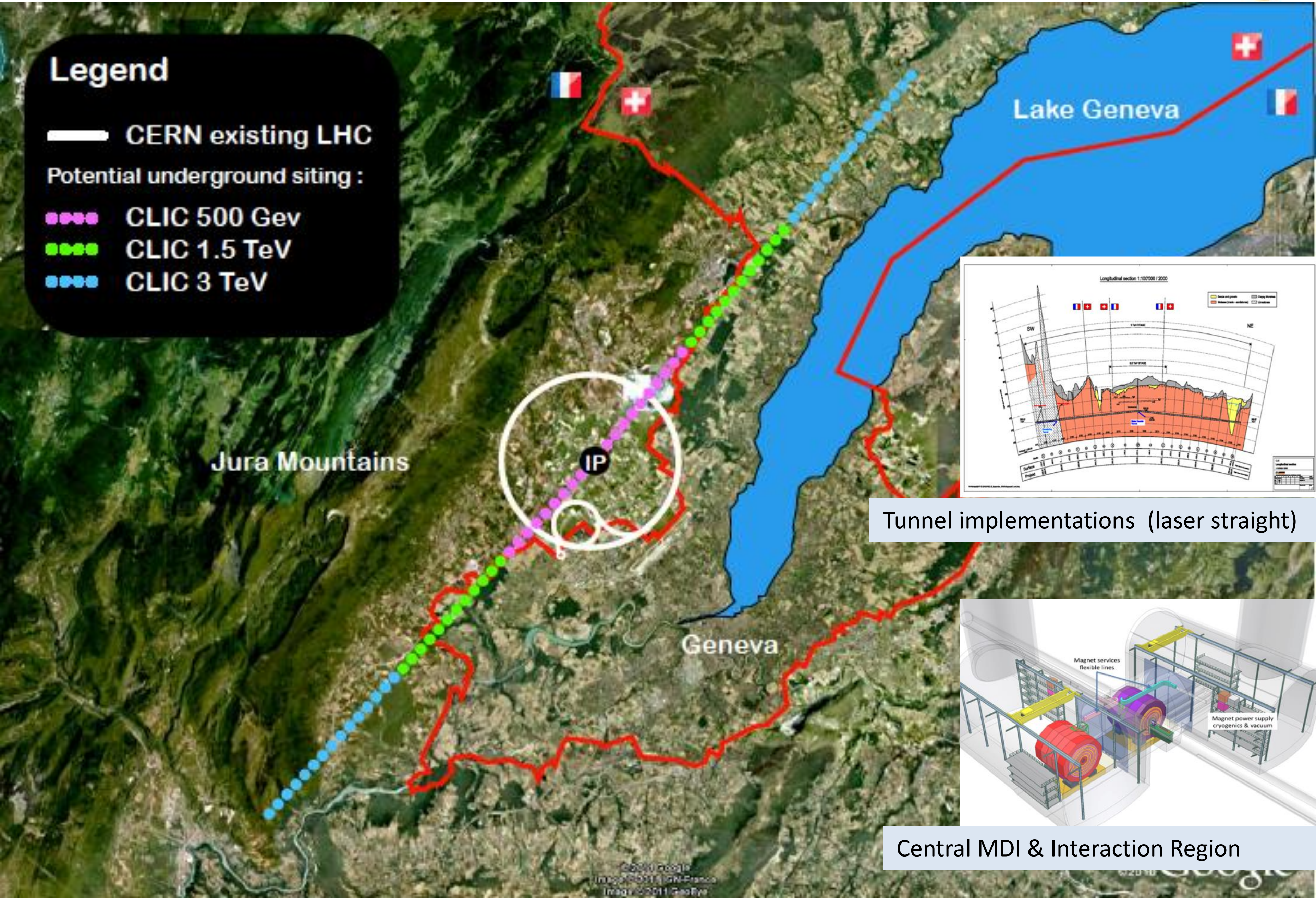


CLIC SCHEMATIC

(not to scale)



CLIC near CERN



High gradient – compact and potentially cheaper

State-of-the acceleration:

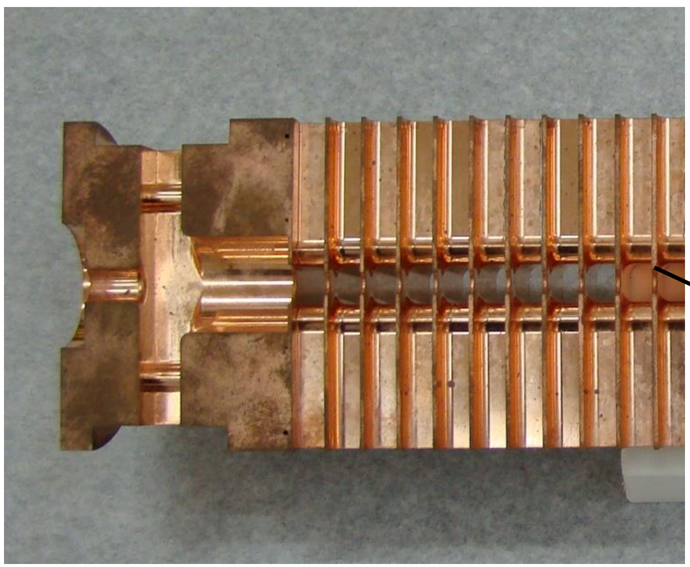
Normal conducting:
28 MV/m SwissFEL
35 MV/m SACLA
Superconducting:
24 MV/m European XFEL
31.5 MV/m ILC

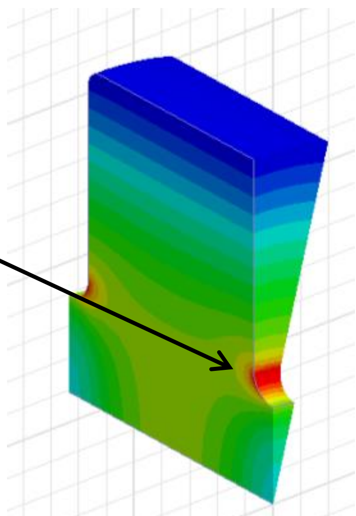
Our goals:

100 MV/m CLIC
60-80 MV/m compact XFELs
50 MV/m low-β proton therapy linacs

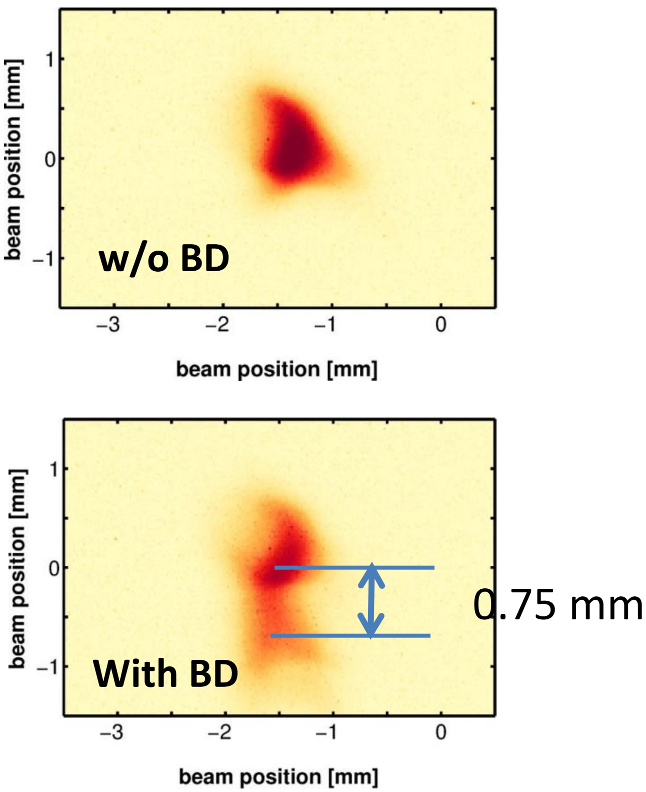
What is the main physical limitation?
Vacuum breakdown

- An accelerating gradient of 100 MV/m corresponds to around 250 MV/m peak surface electric field.
- The high field leads to ‘classic’ vacuum breakdown. Field emission, neutral copper emission, plasma formation, kA currents, collapse of fields. Beam is kicked, luminosity or brightness lost.





Surface electric field concentration on the beam-aperture irises

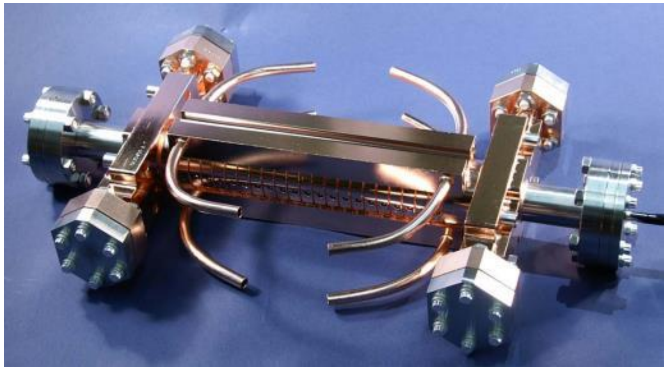


Some (round) numbers for CLIC

Operating frequency	12 GHz
Accelerating gradient	100 MV/m
Peak surface electric field	250 MV/m
Pulse length	200 ns
Repetition rate	50 Hz
Input power	50 MW
Breakdown rate	<10^{-7} BD/pulse/m

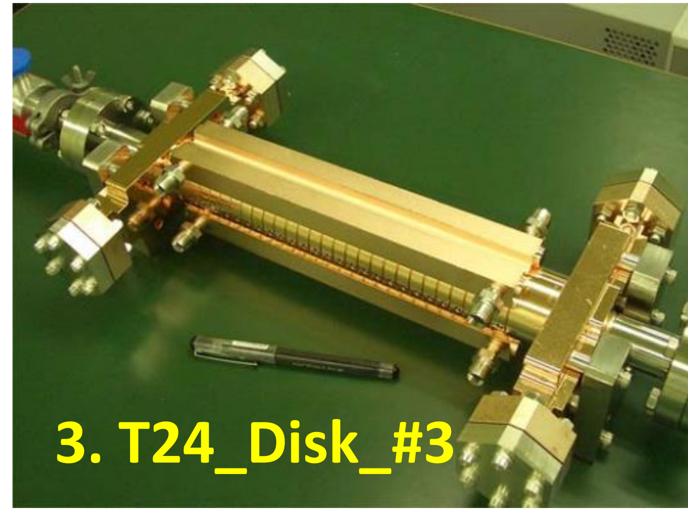
CLIC test structures; fabrication and test

T18 →TD18→T24→TD24→TD24R05



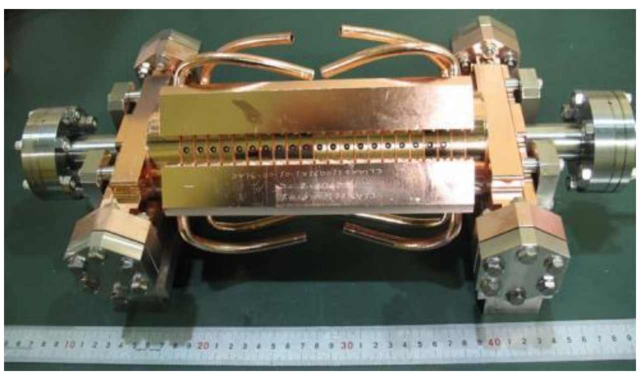
1. T18_Disk_#2

undamped



3. T24_Disk_#3

damped

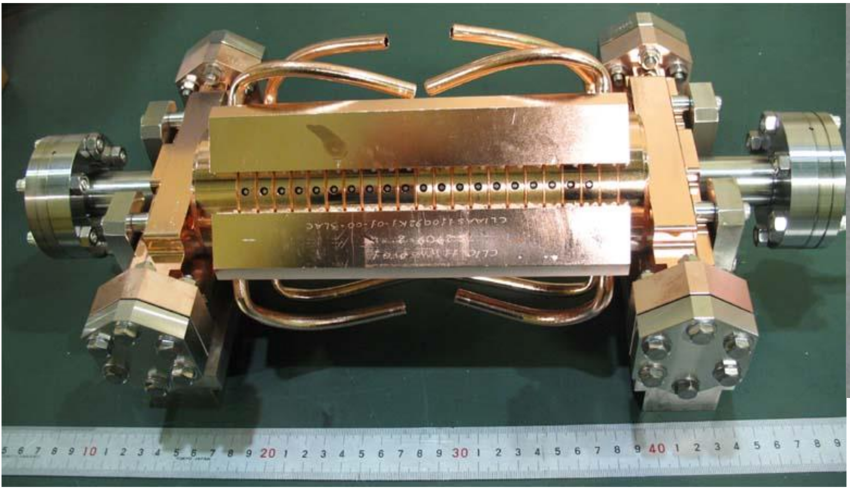


2. TD18_Disk_#2

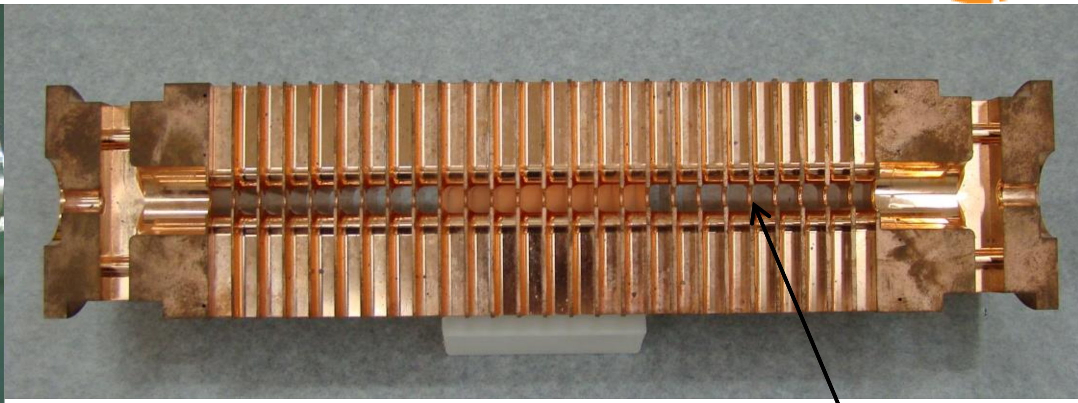
4. TD24_Disk_#4

5. TD24R05 under test now

CLIC accelerating structure

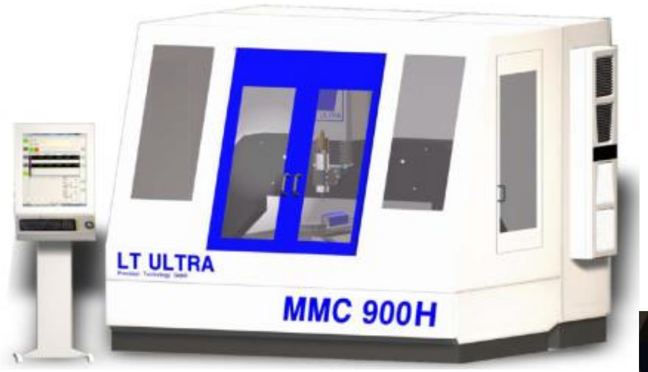


Outside

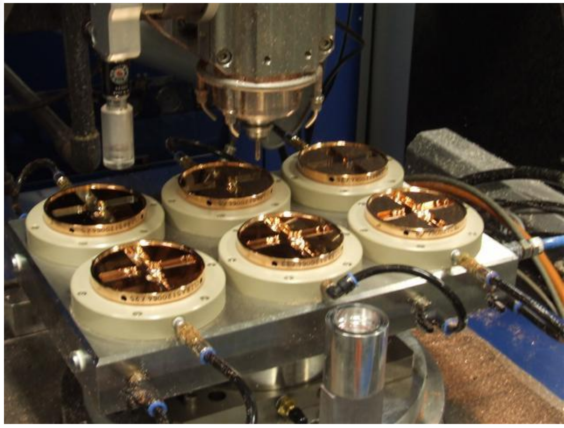


Inside (cut)

6 mm diameter beam aperture, 25 cm long



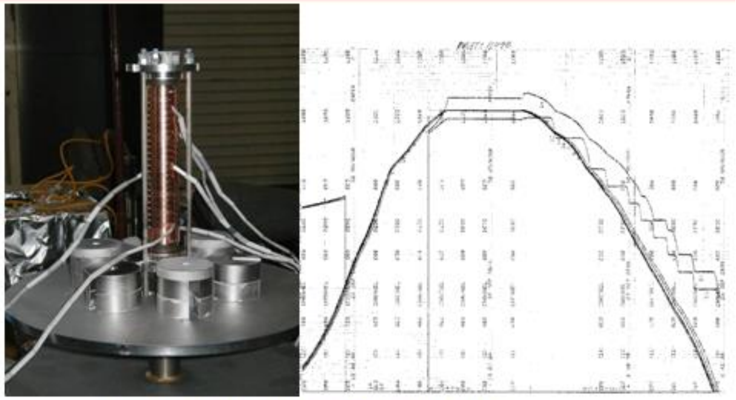
Micron-precision turning and milling.



Heat treatment and material structure

Stacking disks

Diffusion Bonding of T18_vg2.4_DISC



Pressure: 60 PSI (60 LB for this structure disks)

Holding for 1 hour at 1020° C

Vacuum Baking of T18_vg2.4_DISC

650° C

10 days

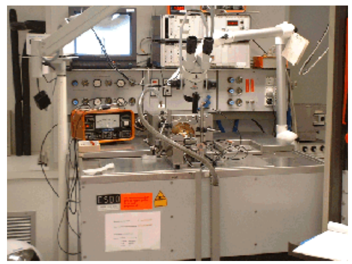
Temperature treatment for high-gradient developed by NLC/JLC

Find the bonding plane!

Evolution of machining capability

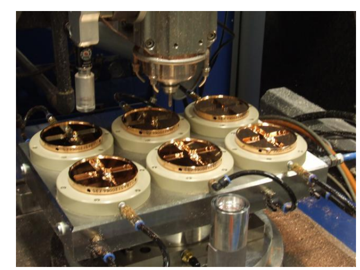
Single point diamond turning

Up to the 1980's	1980's - 1990's	2000's - 2010's	Future ?
First machines at research institutes and universities	Start of industrialization • *Optical recording* • *contact lenses*	• *Larger machines* • *Multiple axis (X/Y/Z and C)*	• *Intelligent machines ?* • *Robotisation ?*



Ultra precision diamond milling *(lagging more than a decade behind on turning)*

Up to the 1990's	1990's - 2000's	2010's	Future ?
Limited to fly cutting • *mirror optics* • *Laser scanner mirrors*	Milling as add-on on lathes • *Lens arrays* • *Intra ocular lenses*	First proto type machines • *Micro fluidics* • *Accelerator parts*	• *Pallet machining?* • *Robotisation ?*



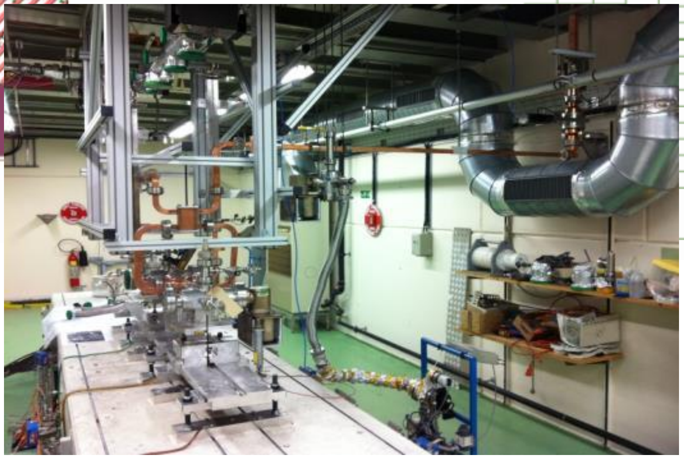
High – gradient testing infrastructure, klystrons

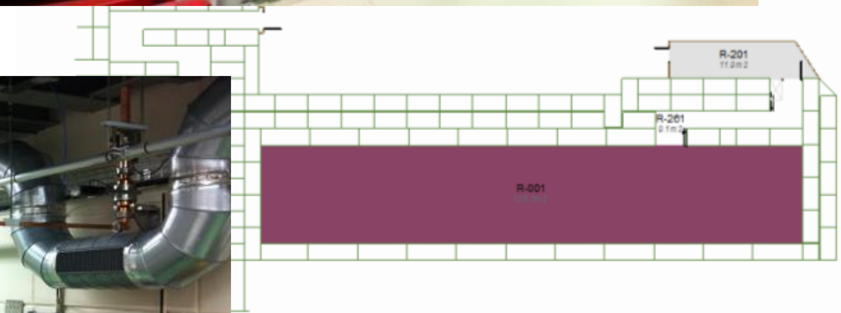
50 MW
1.5 μs

Toshiba 6 MW, 5 μs

Xbox1

CTF3 klystron gallery





CTF2

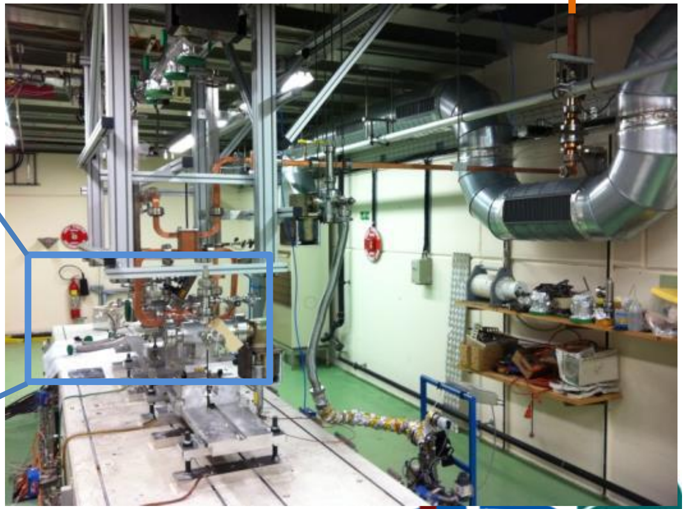
Xbox-1 Layout

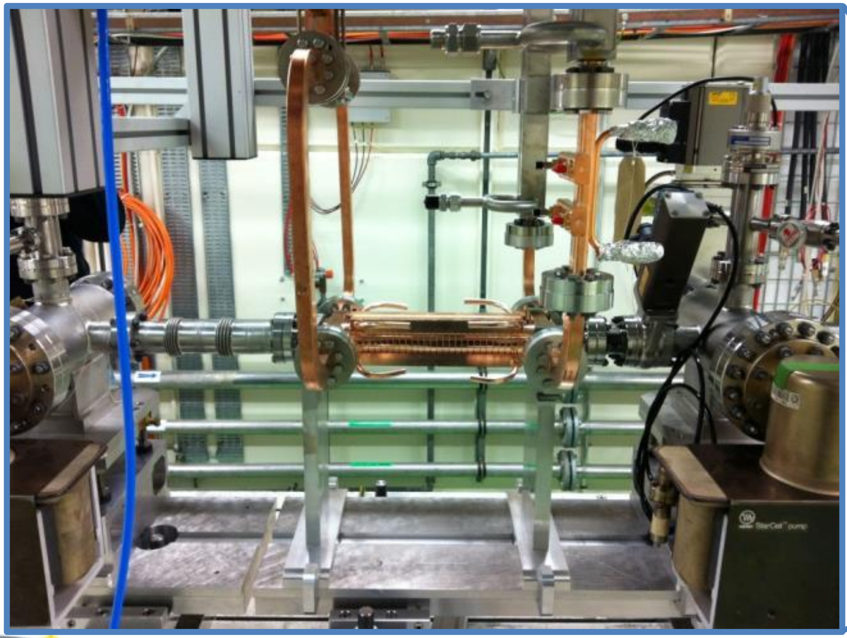
Clockwise from top-left:

- Modulator/klystron (50MW, 1.5us pulse)
- Pulse compressor (250ns, ratio 2.8)
- DUT + connections
- Acc. structure (TD26CC)

Gallery

Bunker



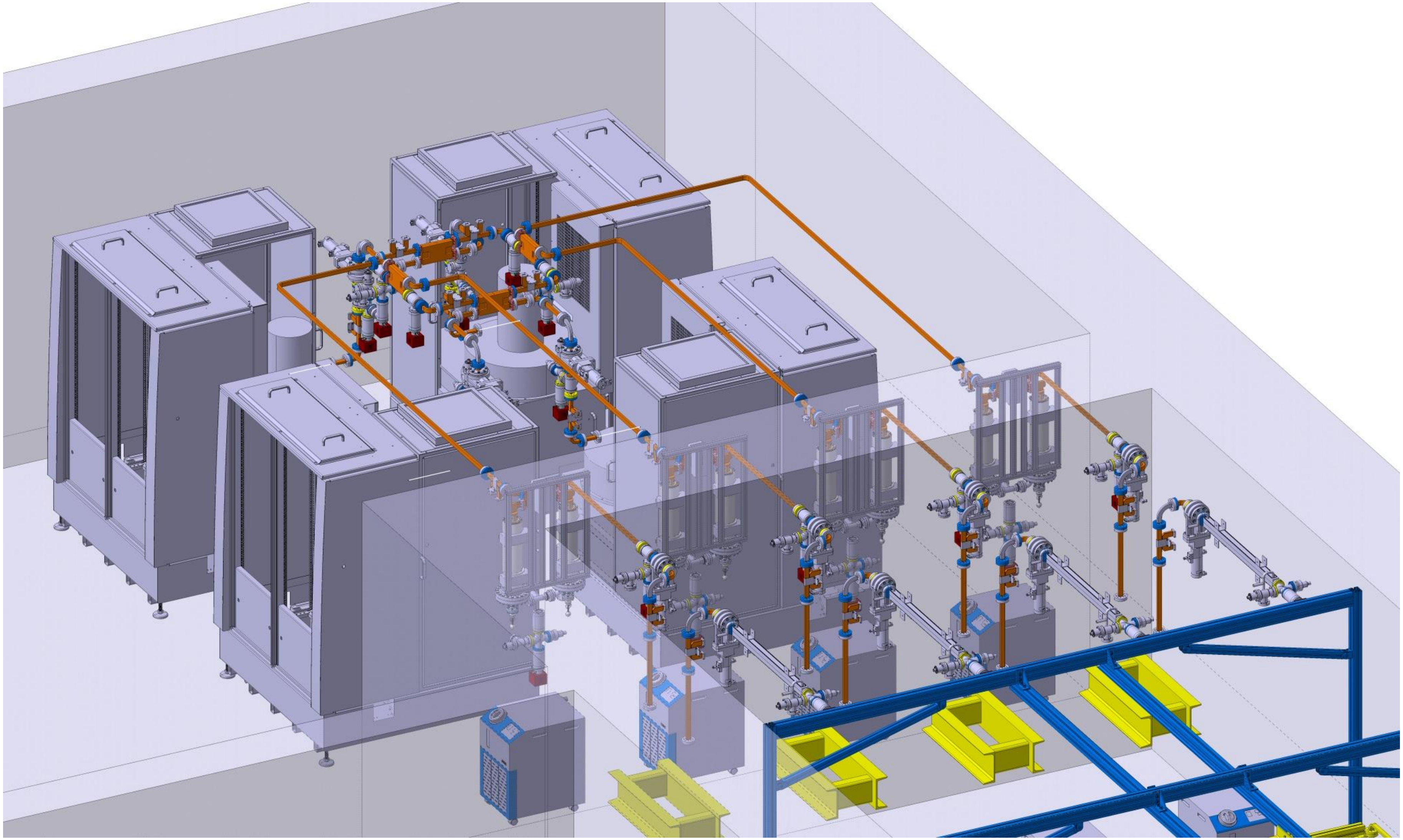


Xbox2

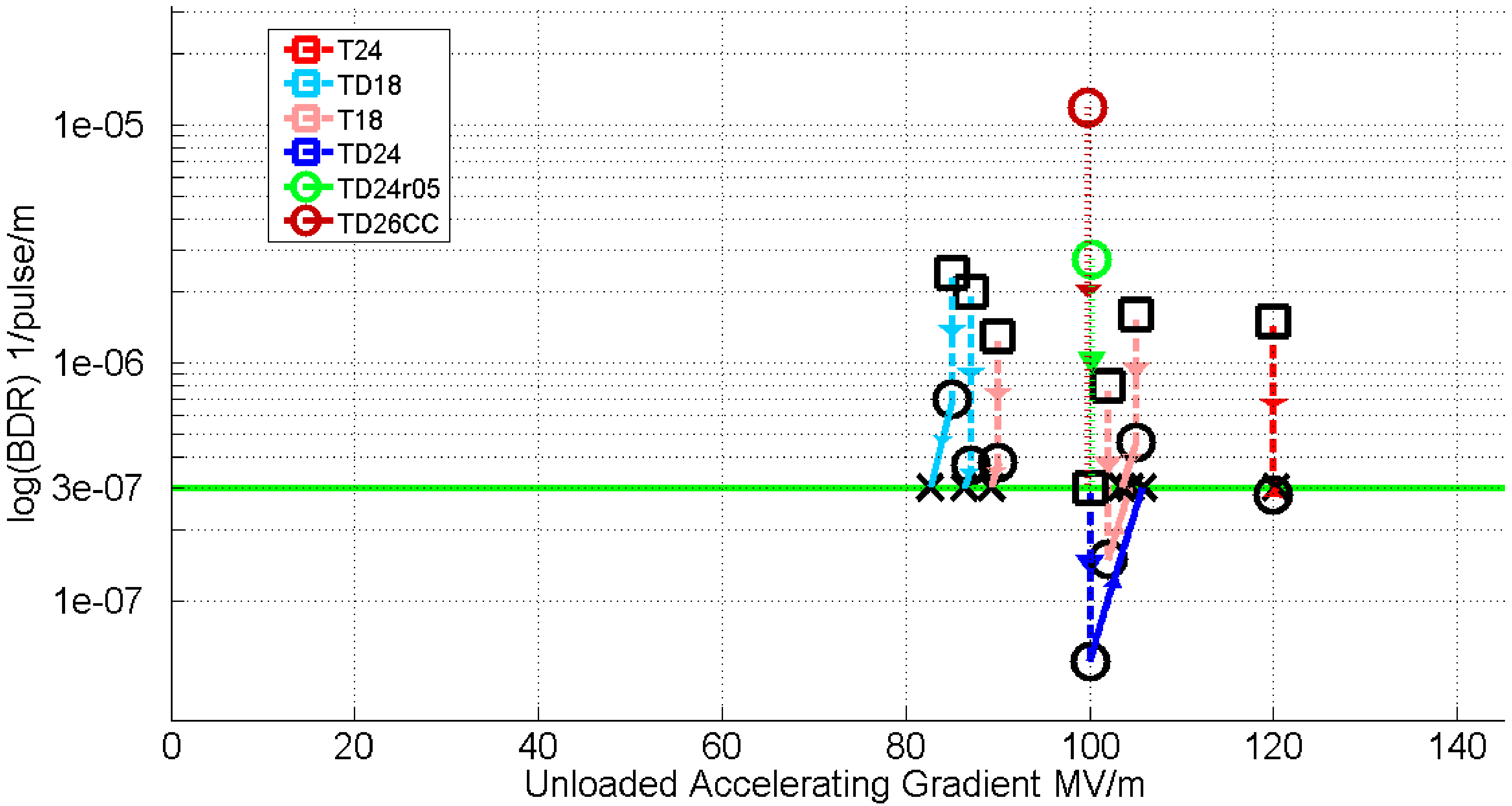
- Diode testing has started to commission modulator

N. Catalan Lasheras

Xbox3. 3D layout/integration almost finished



Accelerating structure performance summary



CLIC Collaboration

29 Countries – over 70 Institutes

- Accelerator collaboration (red)
- Detector collaboration (cyan)
- Accelerator + Detector collaboration (yellow)

Outreach

Our development goals have basically been achieved – we now need to consolidate them, reduce cost, increase industrial supplier base etc. – while we wait for the LHC to clarify the physics case for our facility.

One of the most productive ways of achieving those goals is through promoting the use of our technology in other projects.

We have identified some potential applications:

The kind of **projects** we have identified which potentially benefit from high-gradient technology include:

- FELs
- Compton sources
- Medical linacs
- Imaging scanners
- Pulsed neutron sources

There are also accelerator **components** such as:

- Phase linearizing cavities
- Deflectors
- Rf guns

High-gradient medical accelerator

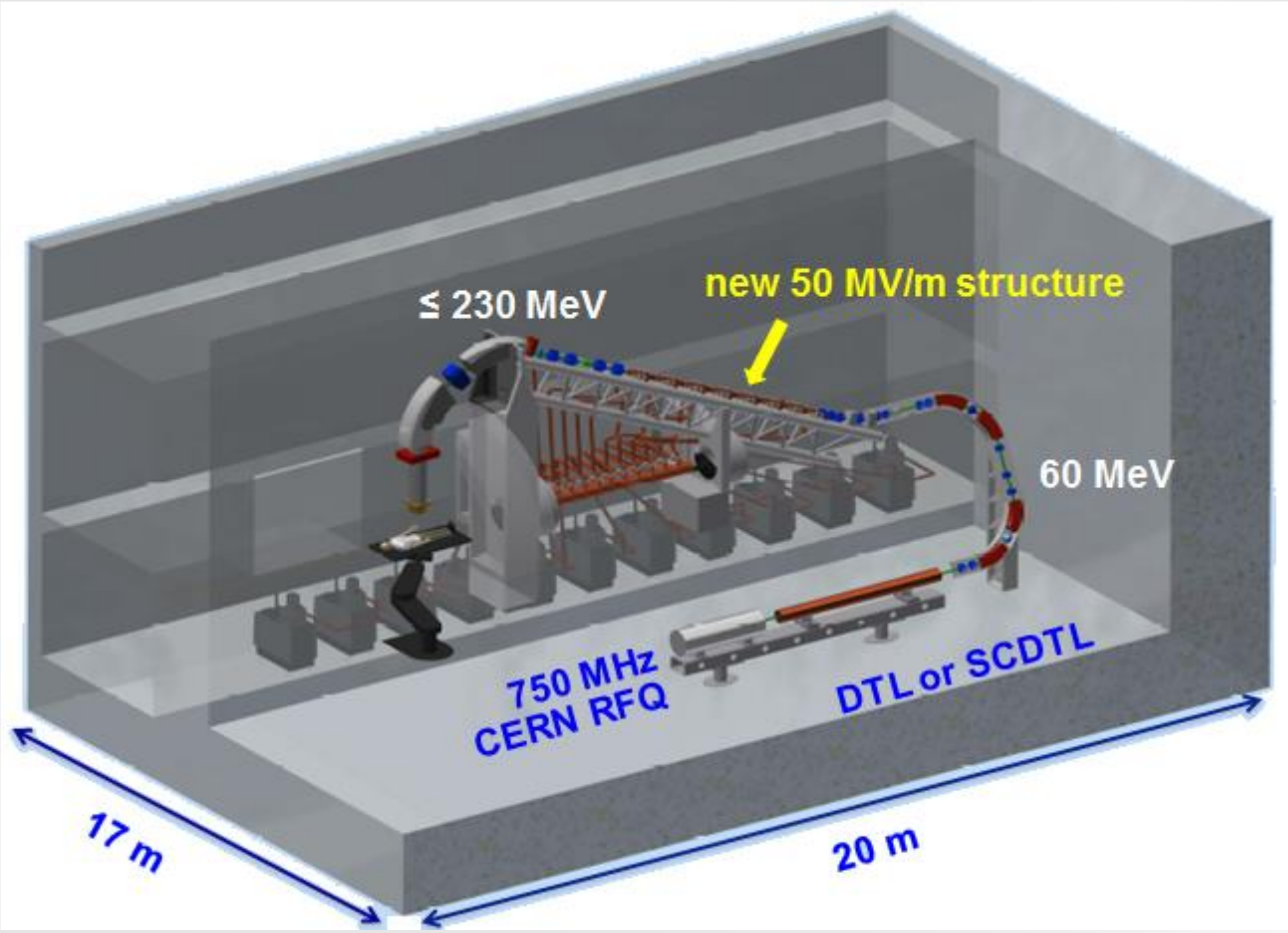
Objective – highest possible accelerating gradient for proton and ion acceleration by applying CLIC technology.

Target application is TERA's TULIP project.

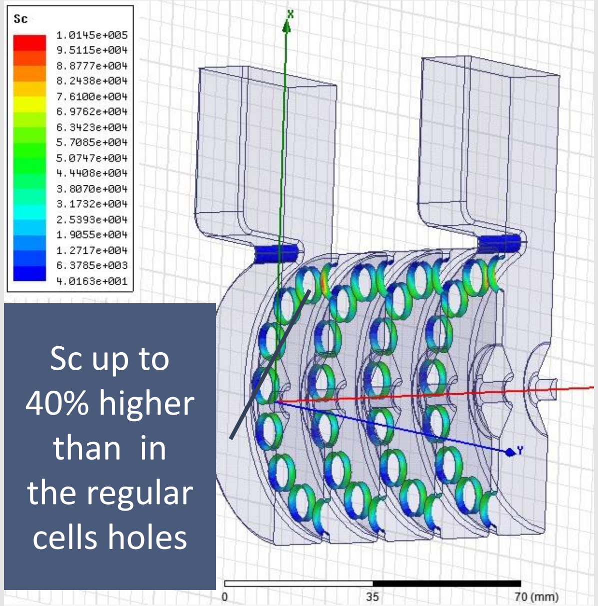
Collaboration between CLIC and TERA.

Prototype structure and experimental electronics funded by CERN KT. knowledge transfer fund (and also the office for CERN medical applications).

A single room protontherapy facility has been designed by TERA Foundation at CERN in collaboration with the CLIC group.



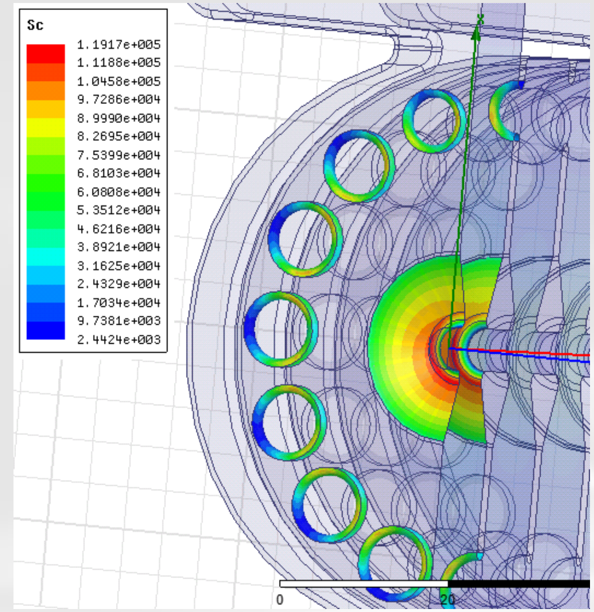
A linac based proton therapy facility



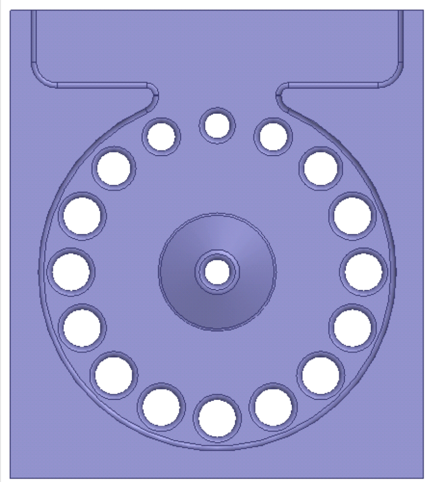
Sc up to 40% higher than in the regular cells holes

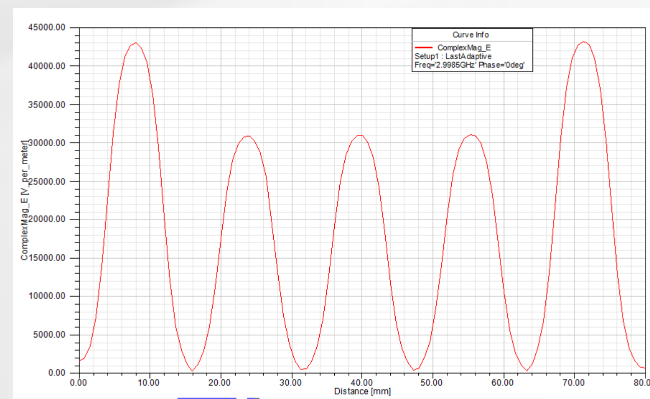
By reducing the coupling holes radius closer to the coupling slot the problem is solved

But we affect the vg, so the Ez



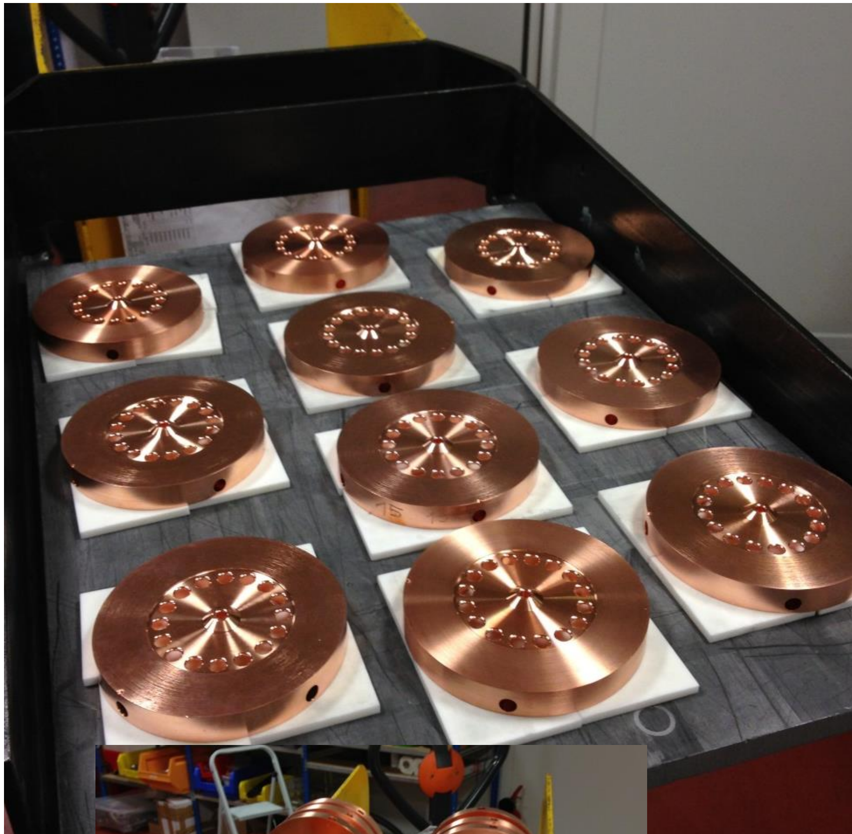
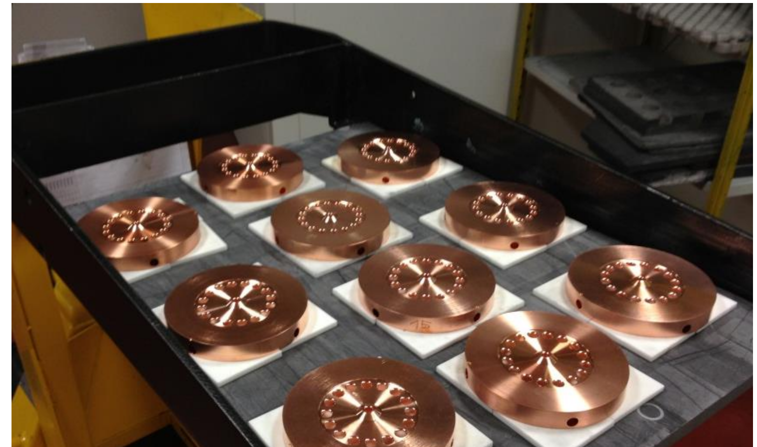
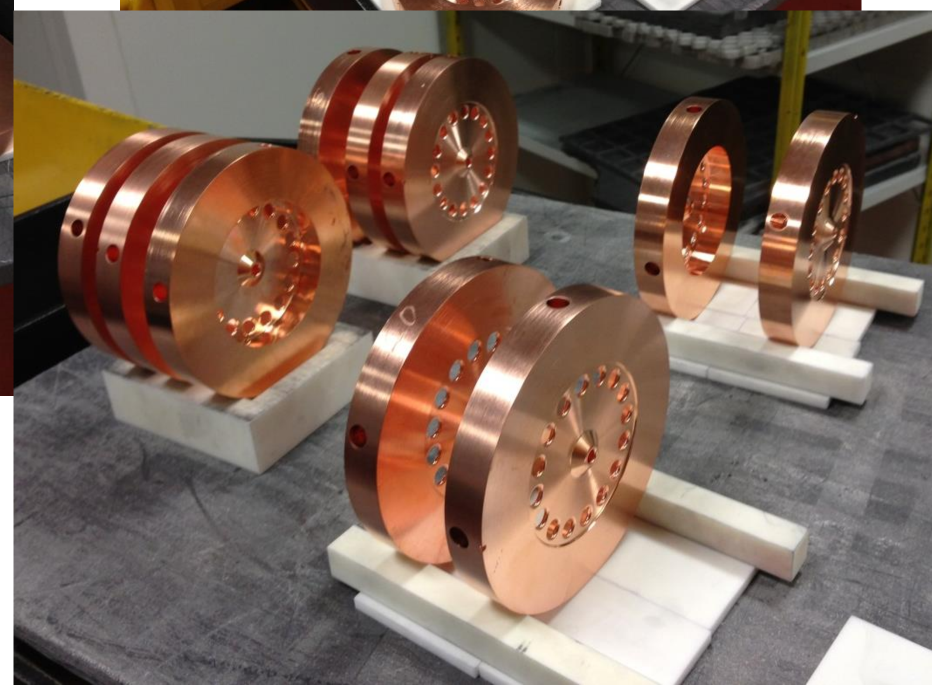
- **Particular effort dedicated to the input coupler design**
- **Asymmetric design of the coupling hole radii to compensate for local enhancement of Sc**





Couplers design

Thermal Test at Bodycote

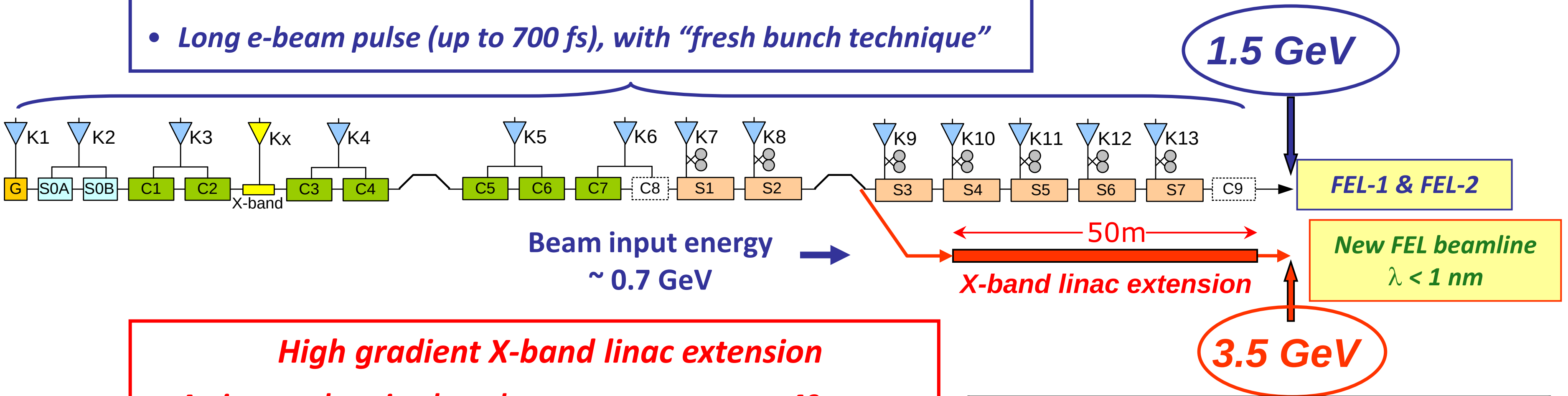

FERMI@Elettra: present layout and energy upgrade

FERMI@Elettra: present layout and energy upgrade

More details in MOPP023

FERMI current layout and performance

- E_{beam} up to 1.5 GeV
- FEL-1 at 80-10 nm and FEL-2 at 10-4 nm
- Long e-beam pulse (up to 700 fs), with "fresh bunch technique"



High gradient X-band linac extension

- Active accelerating length — 40 m
- Accelerating gradient — 70 MV/m
- Beam energy gain — 2.8 GeV
- Injection energy — 0.7 GeV

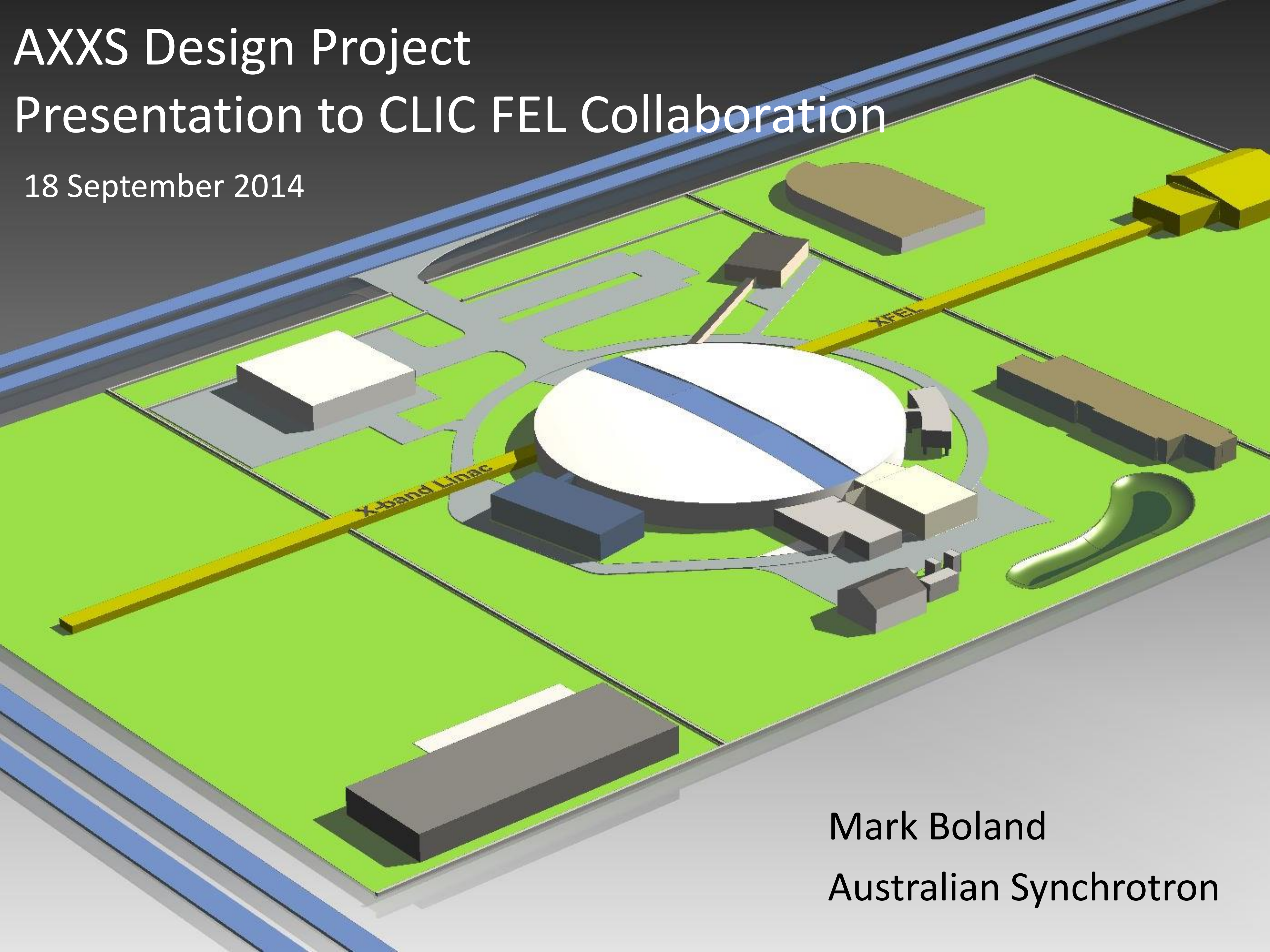
New FEL beamline expected performance	
Undulator period	30 mm
Undulator parameter	1
Fundamental wavelength	**0.5 nm**
Peak power at saturation	5.6 GW

N.B. The new layout could also provide two electron beams at the same time (@25 Hz) with different energies

Shanghai Photon Science Center at SINAP

AXXS Design Project
Presentation to CLIC FEL Collaboration

18 September 2014



Mark Boland
Australian Synchrotron

Horizon2020 application for X-band XFEL

Research and Innovation actions
Innovation actions

proposal full title	**X-band technology for FELs**
proposal acronym	**XbFEL**
type of funding scheme	**H2020**; Funding scheme **RIA**: **Research and Innovation actions – innovation actions**; proposal ID: **SEP-210171536**
work programme topic addressed	Topic: **INFRADEV-1-2014**: CALL IDENTIFIER **H2020-INFRADEV-1-2014-1**
name of the coordinating person	Gerardo d'Auria Project leader X-band systems for FERMI@Elettra project, at Elettra - Sincrotrone Trieste S.C.p.A.

LIST OF PARTICIPANTS

Participant No	Participant organisation name	Short name	Country
1 (Coordinator)	**Elettra – Sincrotrone Trieste S.C.p.A.**	ST	Italy
2	**CERN - European Organization for Nuclear Research**	CERN	Switzerland
3	**Uniwersytet Jagiellonski**	UJ	Poland
4	**Science and Technology Facilities Council**	STFC	United Kingdom
5	**Shanghai Institute of Applied Physics, Chinese Academy of Sciences**	SINAP	China
6	**VDL ETG Technology & Development B.V.**	VDL	Netherlands
7	**Universitetet i Oslo**	OSLO	Norway
8	**Institute of Accelerating Systems and Applications**	IASA	Greece
9	**Uppsala Universitet**	UU	Sweden
10	**Australian Synchrotron**	ASLS	Australia
11	**Ankara University Institute of Accelerator Technology**	AU-IAT	Turkey
12	**Lancaster University**	ULANC	United Kingdom

Conclusions

CLIC-developed X-band and high-gradient technology have enabled significant increases in accelerator performance.

There is the real possibility of seeing the technology implemented in projects in the near future, which we hope will launch a virtuous circle of further development, lower cost and further use.