Perspectives for the CLIC Study and our X-band Activity

HG2013, 6 June 2013

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Beyond the CDR

In 2012 we finished our CDR.

We even managed to achieve our primary feasibility demonstration, the TD24 running at 106 MV/m in time for the report.
My sincere thanks and congratulations to those of you who made this possible!

So, what's next for CLIC?

Let me address this question first at the level of the

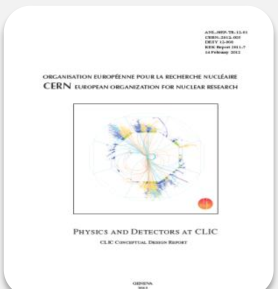
- European strategy exercise,
- followed by CERN,
- the CLIC study,
- and then the X-band activity.

Of course the fundamental unknown is what the LHC produces once it starts up again. Discovery, or not, of new TeV-range physics will change our whole game. But we won't find out until 2015, 2016 or beyond.

The physics and accelerator studies of CLIC have been documented in a CDR which was released last year:

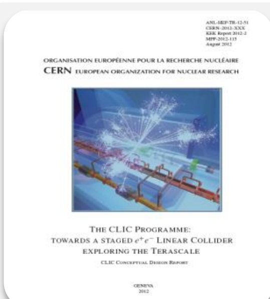
Vol 1: The CLIC accelerator and site facilities (H.Schmickler)

- CLIC concept with exploration over multi-TeV energy range up to 3 TeV
- Feasibility study of CLIC parameters optimized at 3 TeV (most demanding)
- Consider also 500 GeV, and intermediate energy range
- Complete, presented in SPC in March 2012 https://edms.cern.ch/document/1234244/



Vol 2: Physics and detectors at CLIC (L.Linssen)

- Physics at a multi-TeV CLIC machine can be measured with high precision, despite challenging background conditions
- External review procedure in October 2011
- Completed and printed, presented in SPC in December 2011 http://arxiv.org/pdf/1202.5940v1



Vol 3: "CLIC study summary" (S.Stapnes)

- Summary and available for the European Strategy process, including possible implementation stages for a CLIC machine as well as costing and cost-drives
- Proposing objectives and work plan of post CDR phase (2012-16)
- Completed and printed, submitted for the European Strategy Open Meeting in September http://arxiv.org/pdf/1209.2543v1

In addition a shorter overview document was submitted as input to the European Strategy update, available at: http://arxiv.org/pdf/1208.1402v1

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.

c) The discovery of the Higgs boson is the start of a major programme of work to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. The LHC is in a unique position to pursue this programme. *Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*

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.*

e) There is a strong scientific case for an electron-positron collider, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and whose energy can be upgraded. The Technical Design Report of the International Linear Collider (ILC) has been completed, with large European participation. The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate. *Europe looks forward to a proposal from Japan to discuss a possible participation.*

f) Rapid progress in neutrino oscillation physics, with significant European involvement, has established a strong scientific case for a long-baseline neutrino programme exploring CP violation and the mass hierarchy in the neutrino sector. *CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading neutrino projects in the US and Japan.*

CLIC physics potential

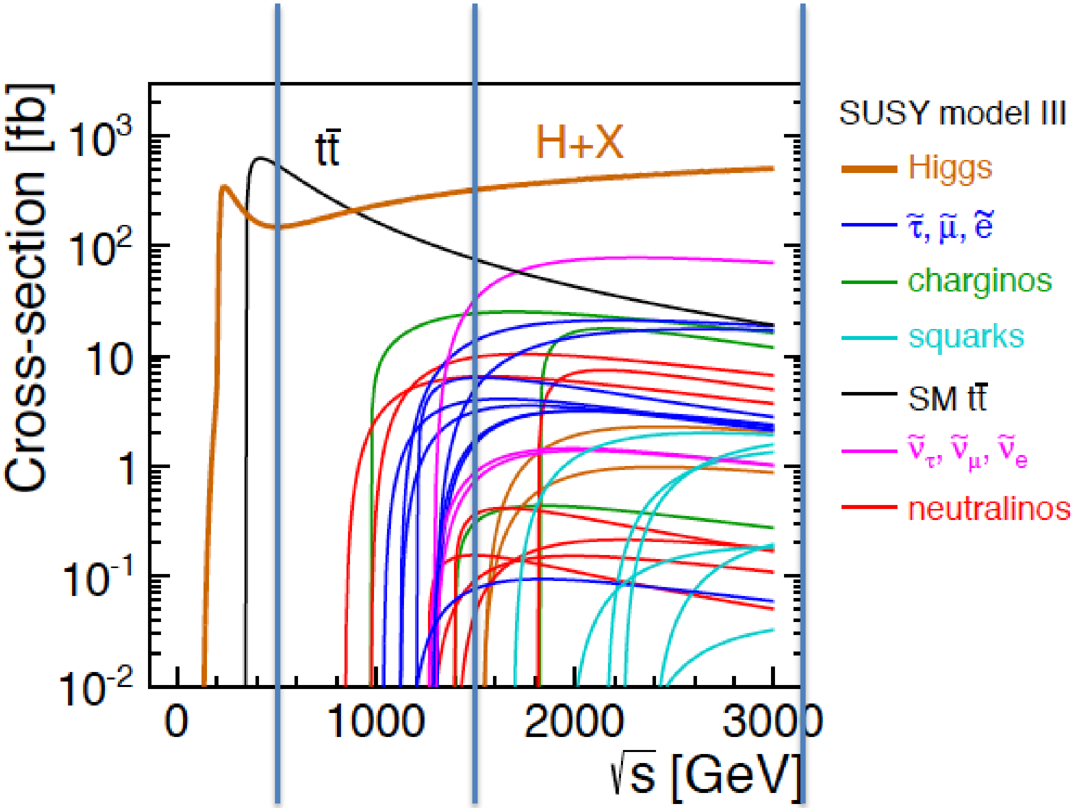
LHC complementarity at the energy frontier:

- How do we build the optimal machine given a physics scenario (partly seen at LHC ?)

Examples highlighted in the CDR:

- Higgs physics (SM and non-SM)
- Top
- SUSY
- Higgs strong interactions
- New Z' sector
- Contact interactions
- Extra dimensions

Detailed studies at 350, 500, 1400, 1500 and 3000 GeV for these processes



Stage 1: ~500 (350) GeV => Higgs and top physics
Stage 2: ~1.5 TeV => ttH, ννHH + New Physics (lower mass scale)
Stage 3: ~3 TeV => New Physics (higher mass scale)

CERN

This year's CLIC material budget is healthy at 16 MCHF, like the past few years and we have maintained levels.

For the future, we will get our first indication of funding level from this year's MTP (CERN five year plan) which is now in preparation.

We have reports that we will start to feel pressure on the CLIC budget in the coming years. The main reason is that the budget to study the VLHC will have to have to come from the same pot for R&D as CLIC.

In addition there will be pressure on CERN manpower as we are for example asked how we can help AWAKE, which is a proton driven plasma wakefield experiment using the SPS beam.

But despite all this, the CLIC budget should be OK for the next few years for us to move forward on the most important technical areas for the CLIC study.

CLIC

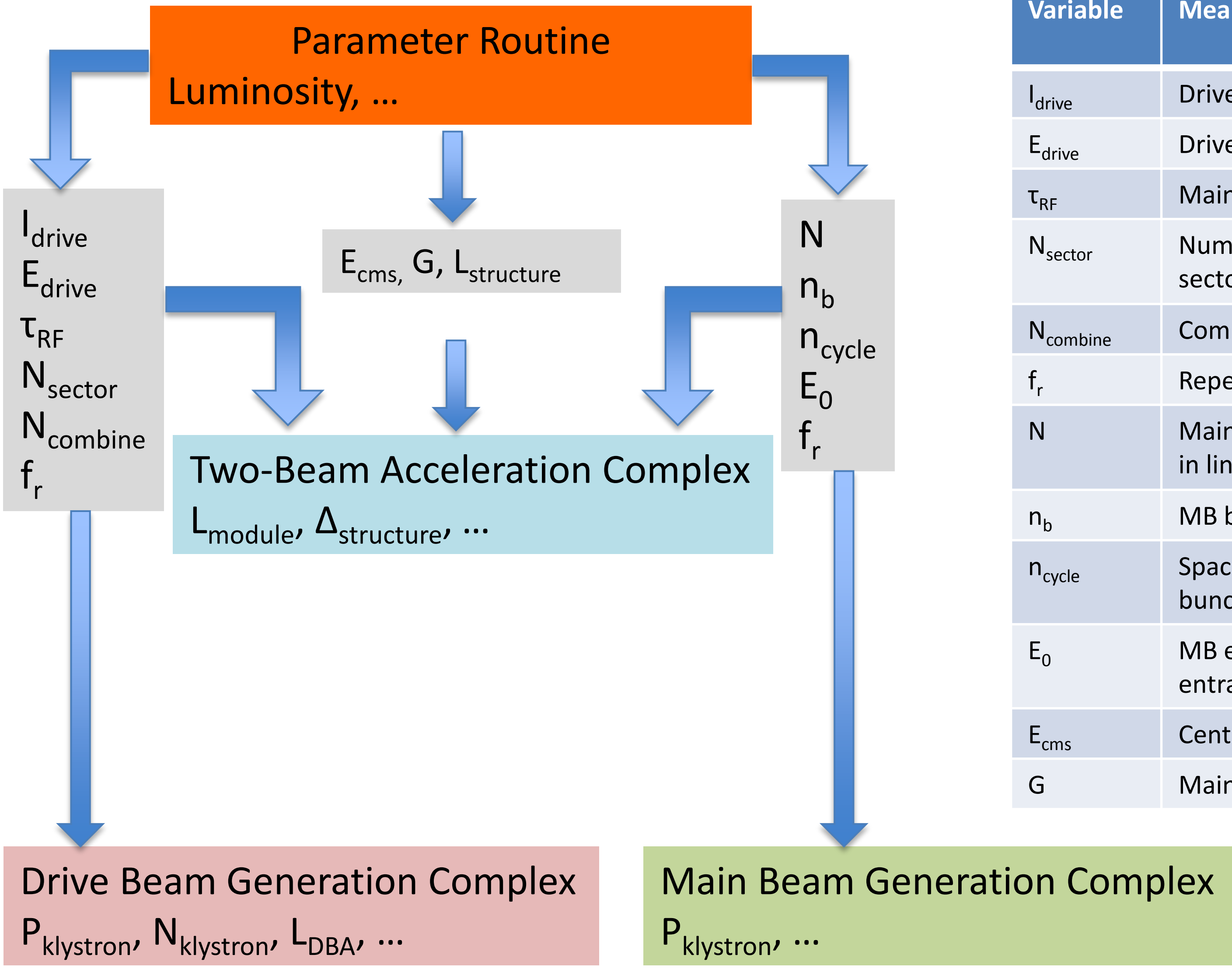
We have a rather ambitious post-CDR plan. We are now discussing readjusting our program in the coming months in light of new developments.

It is clear that the high-gradient accelerating structures will remain one of the highest priorities of the study. Consequently I am confident that we be able to basically maintain the level of our present resources.

We are re-base lining CLIC. We learned a lot during the feasibility exercise and are now re-doing the full optimization for cost and power consumption. In addition we are also doing the optimization for an entry level energy, 375 GeV. The first time around we got our 500 GeV parameters by scaling from the optimization which was done at 3 TeV.

An interesting aspect for us is a refreshed look at klystron based entry energy machines.

Simplified Parameter Diagram



Variable	Meaning	Current value
I_{drive}	Drive beam current	101A
E_{drive}	Drive beam energy	2.37GeV
τ_{RF}	Main linac RF pulse length	244ns
N_{sector}	Number of drive beam sectors per linac	4
$N_{combine}$	Combination number	24
f_r	Repetition rate	50Hz
N	Main beam bunch charge in linac	3.72e9
n_b	MB bunches per pulse	312
n_{cycle}	Spacing between MB bunches	6 cycles
E_0	MB energy at linac entrance	9GeV
E_{cms}	Centre-of-mass energy	500GeV
G	Main linac gradient	100MV/m

Power source scaling

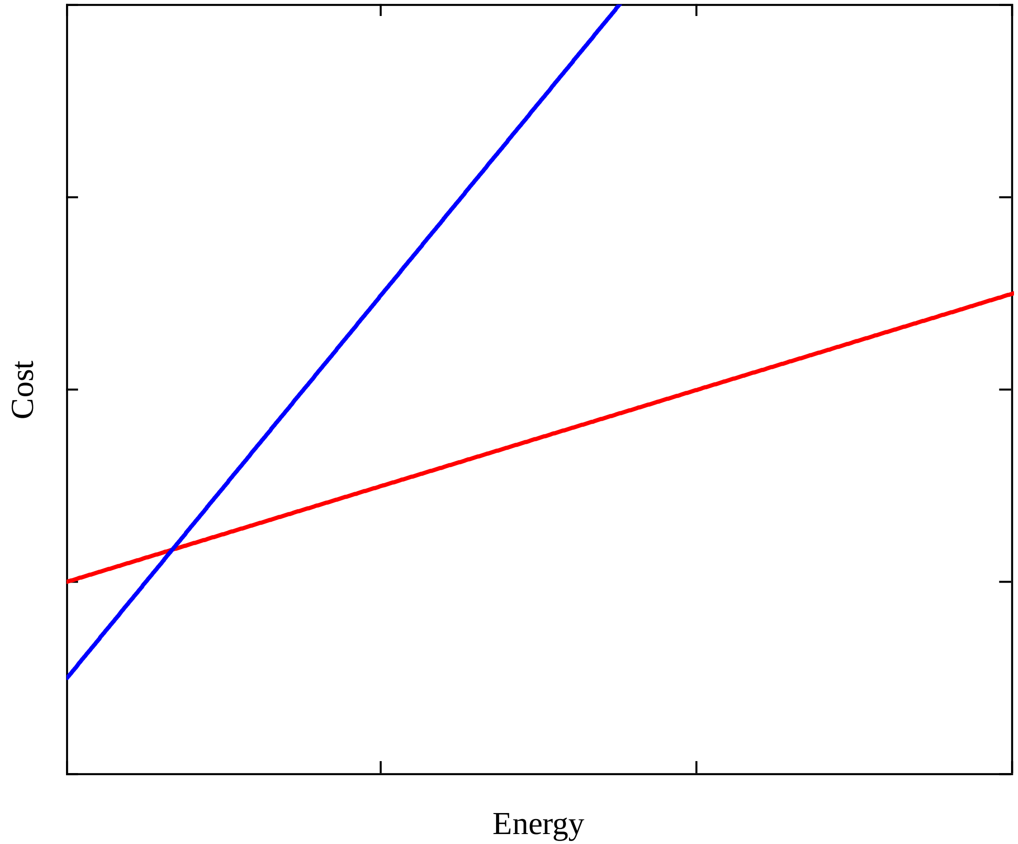
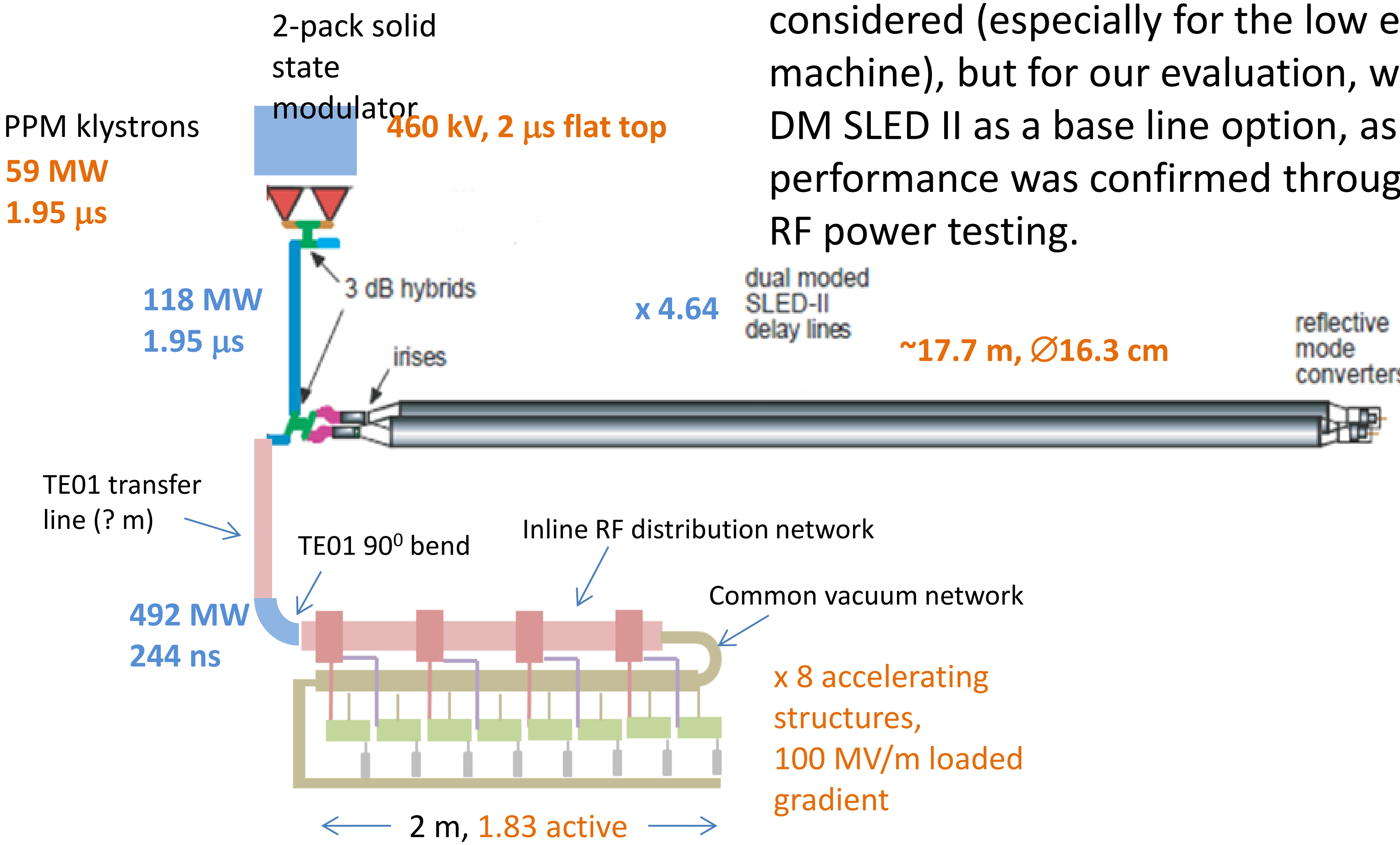


Figure 1: schematic representation of cost scaling of a klystron-based linear collider [blue] and a two-beam linear collider [red]. A klystron-based machine has a lower initial cost but higher marginal cost.

CLIC'k RF unit layout

The alternative PC schemes certainly must be considered (especially for the low energy machine), but for our evaluation, we will keep DM SLED II as a base line option, as its performance was confirmed through the high RF power testing.



Compared to NLC, the energy gain per unit in CLIC'k case is 26% lower (need more klystrons per meter), but the unit active length is ~ 2 time shorter.

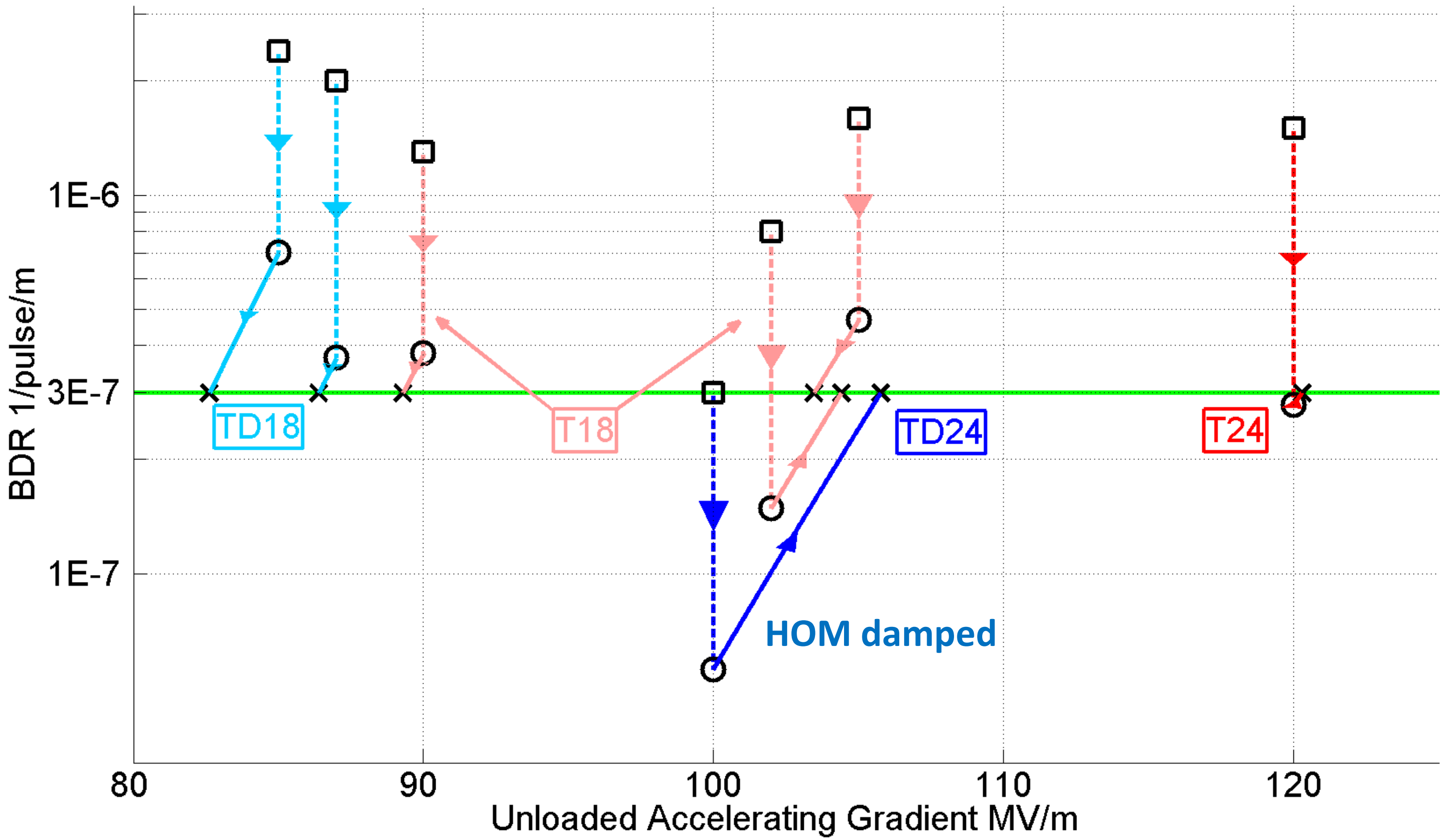
X-band activity, objectives

Our overall objective is to show that we can systematically make 100 MV/m range structures and that we have covered all major issues.

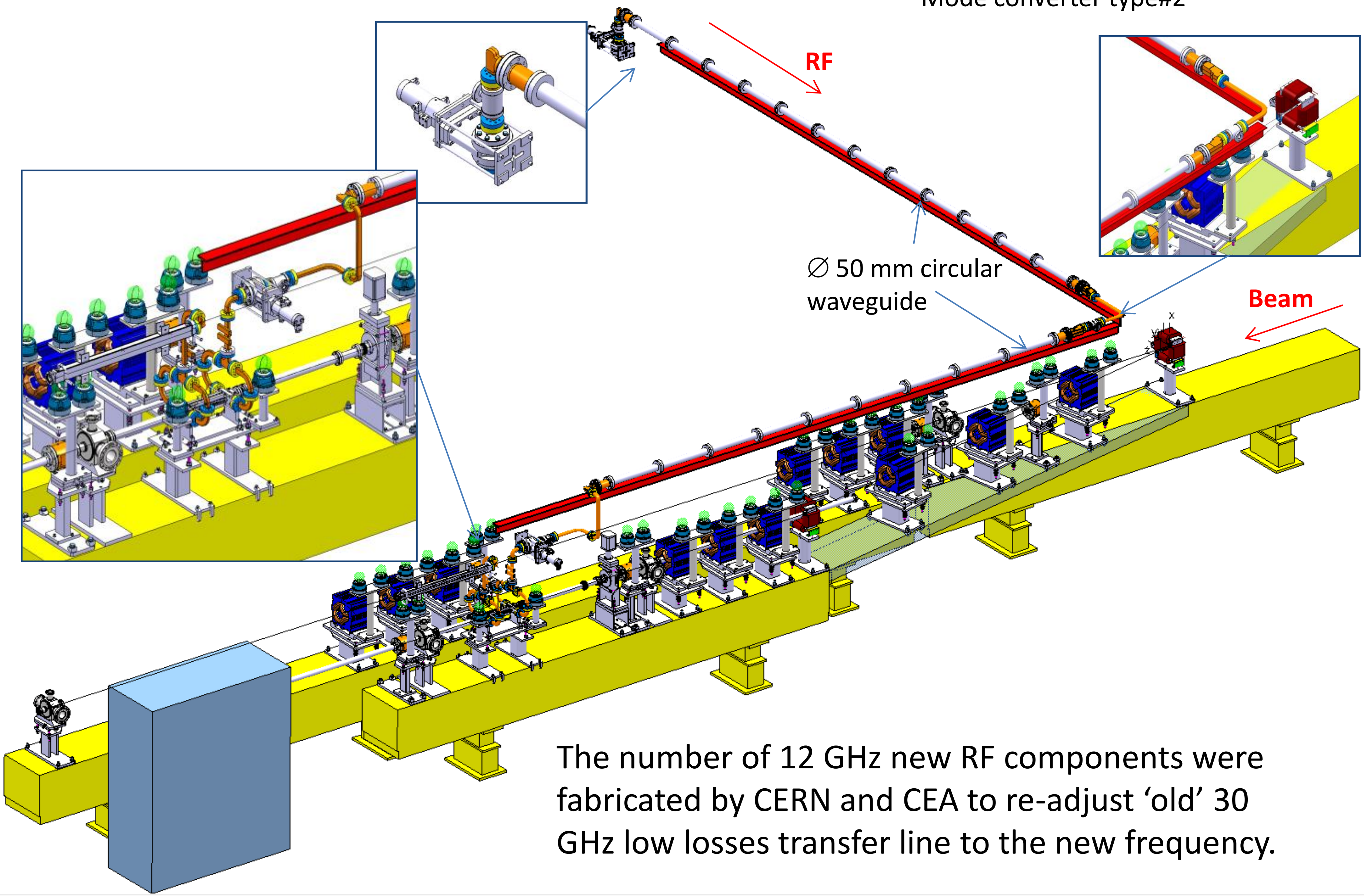
Showing one damped structure running at above 100 MV/m (unloaded) was crucial and necessary but not sufficient. Specifically we need to:

- Understand the effect of beam-loading on BDR (dog-leg experiment).
- Understand and resolve the loss of performance caused by damping waveguides.
- Test more structures to get better statistics.
- Run some structures much longer to make sure nothing awkward happens in the long term.
- Show the compact coupler works.
- Make sure SiC loads don’t give us any problems, resolve the associated engineering issues.
- Probably build and test a new baseline structure.

Accelerating gradients achieved in tests. Status: 4-9-2012



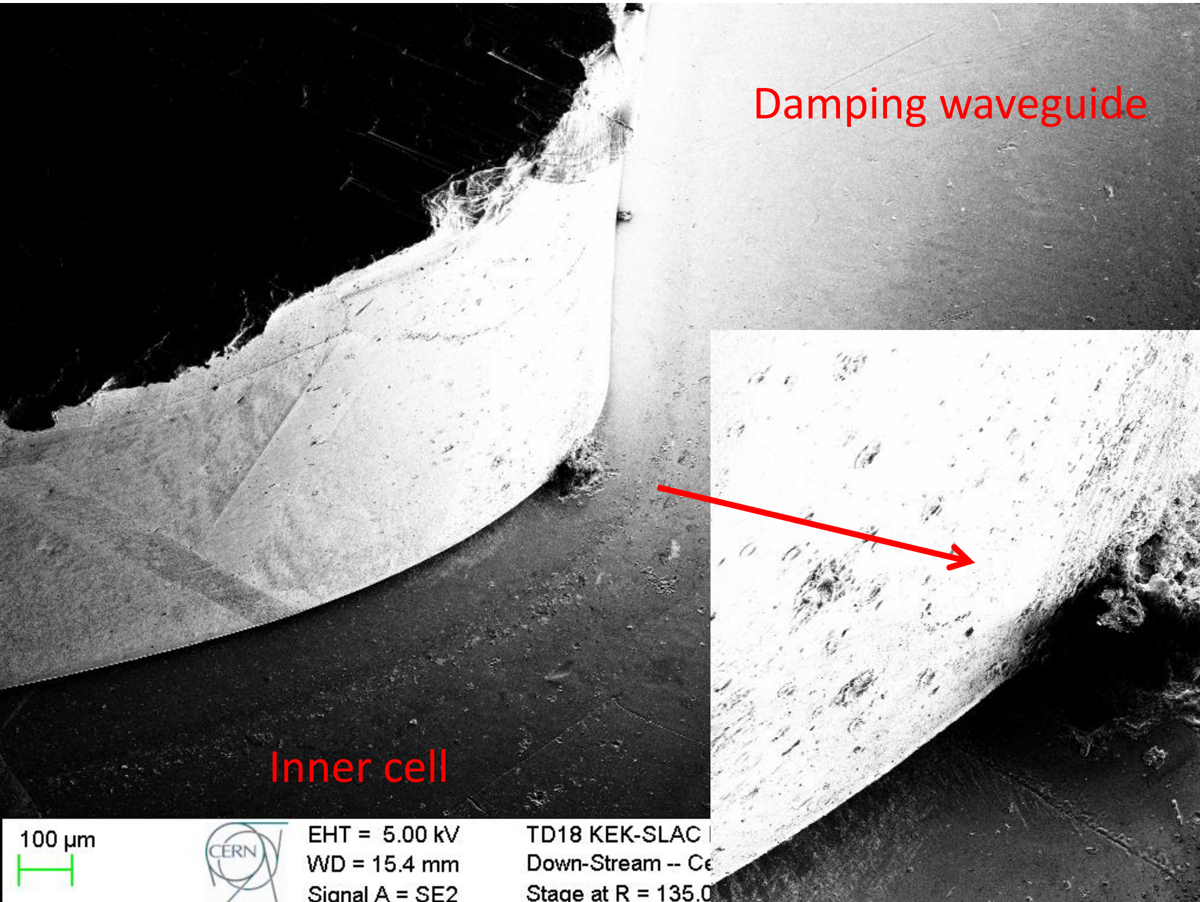
Complete Dog-leg test RF network layout (calculated RF transfer efficiency ~0.75)

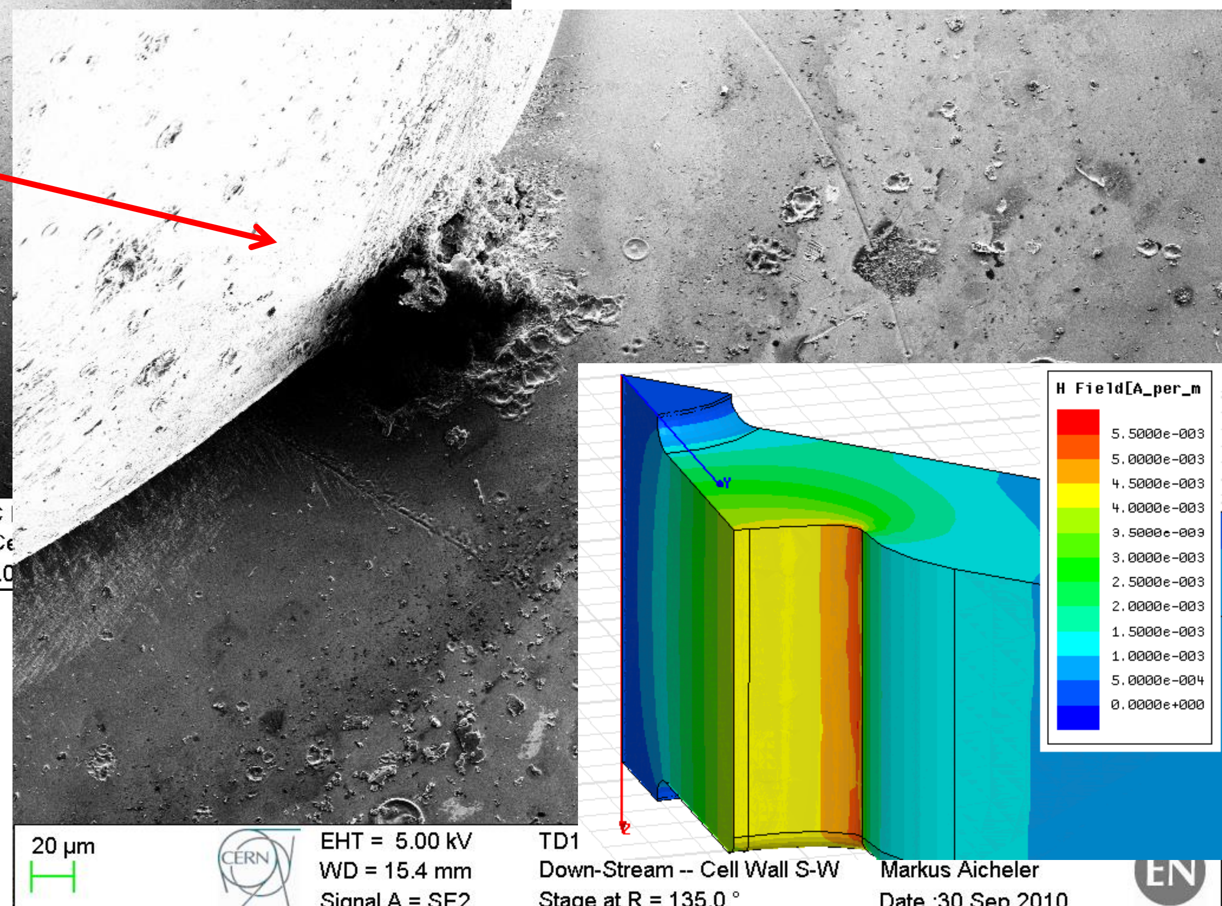


The number of 12 GHz new RF components were fabricated by CERN and CEA to re-adjust ‘old’ 30 GHz low losses transfer line to the new frequency.

Features in high current region of TD18

Current density around $2x10^{8}A/cm^{2}$ during test





X-band activity

Our activity is divided into the following work packages:

- RF design and new concepts
- Test structure fabrication
- Test areas
- Testing
- Basic high-gradient R&D

PRIORITES

In order to run more structures we need to build more test stands.

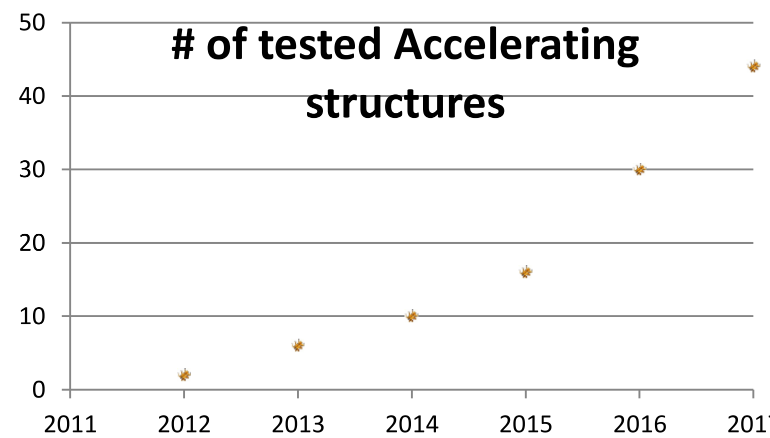
Xbox-1 running, Dog-leg almost ready, Xbox-2 under construction, Xbox-3 klystron/modulators are under order.

Our budget in the next few years will be dominated by klystron/modulator orders. This is essential investment for the medium term.

Integrated testing of X-band structures

		2013				2014				2015				2016				2017			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
NEXTEF		TD24_R05	TD24_R05_4																		
ASTA		TD24_R05_1																			
TBTS	Slot 1	TD24_WFM_1				CFT3 technical stop	Module			CFT3 technical stop	Module			CFT3 technical stop				CFT3 technical stop			
	Slot 2	TD24_WFM_2																			
Xbox1	Dogleg	Inst.		Comm.			T24_1														
	CTF2	TD24_R05_1				TD24_R05_1		TD26_CC_1		TD24_R05_SiC_1		DDSA									
Xbox2	Slot 1	Procurement		Installation		Comm.	TD24_R05_3			Crab Cavity											
	Slot 2					New power splitter			Comm.												
Xbox3	Slot 1	Contract placement		Klystrons/modulator procurement								Inst.	Comm.								
	Slot 2																				
	Slot 3																				
	Slot 4																				

- Xbox1 first production tests less than six months
- Conservative testing time (6 months) assumed for klystron based benches
- Double Xbox2 capacity thanks to a new power splitter. (see I. Syratchev)
- More than 40 accelerating structures tested by 2017



Some of our other main efforts:

- **High-power rf system design** – Driven now by klystron-based test stand needs, the results can be applied elsewhere, compact components for module, rotating joint for TERA etc.
- **Breakdown studies** – We have made significant progress in quantifying breakdown and addressing some of the major questions. Major pushes in material science and plasma simulation the main themes. Now beginning to apply the knowledge to high-gradient technology development.
- **Alternative designs** - Choke mode structures are being developed at Tsinghua University and quadrant at KEK. A DDS-A high-power test structure is almost done.
- **Wakefield monitor** – This a major diagnostic for the structures. Progress with current SACLAY structures in CTF3 two-beam test stand needs to be continued.
- **Industrialization** – Is partially covered by the CLIC module development program, partially by the CLIC cost study and also in collaboration with industry. All X-band/high gradient projects contribute to this.

New Directions

In an effort to build the technological base for the CLIC X-band system – including experts all the way through industrial suppliers - we are taking an active interest in other projects which could potentially benefit from high-gradient, high-frequency technology.

For example some of you in the audience have seen this workshop shift from almost exclusively focusing on CLIC rf structures to encompassing the broad scope of this year. This wasn't random.

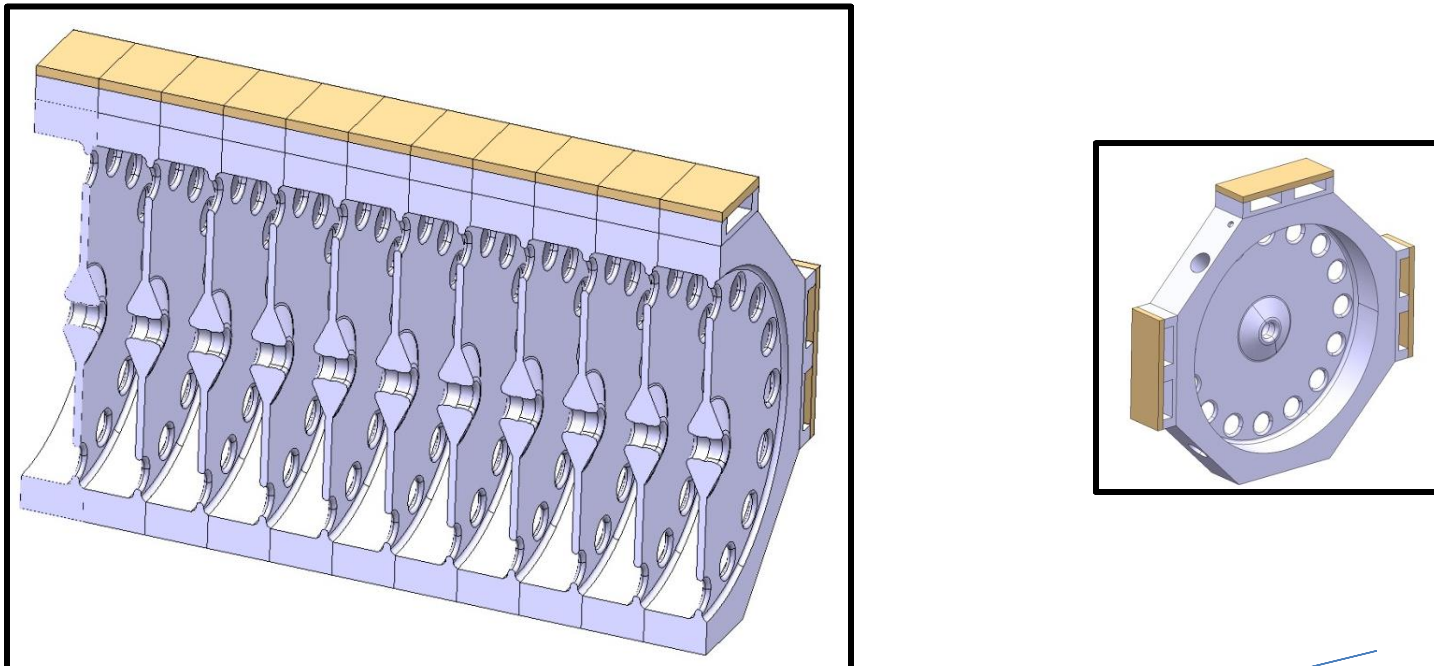
The kind of **projects** we have identified which potentially benefit from high-gradient technology include:

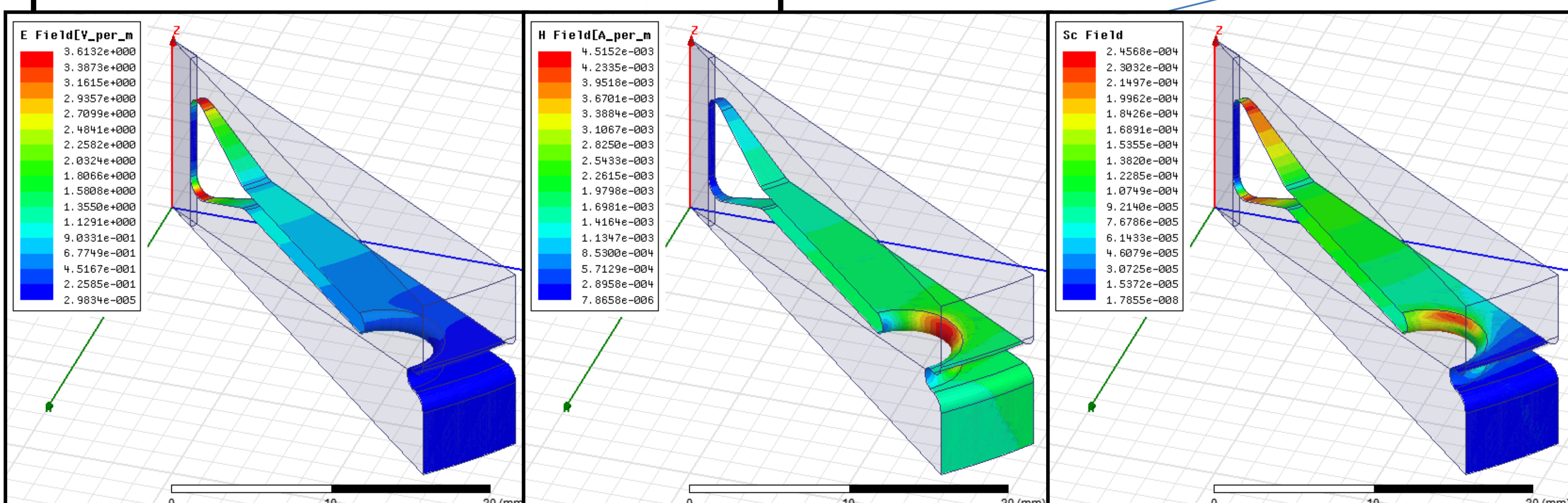
- FELs
- Compton sources
- Medical linacs

There are also **components** such as:

- Phase linearizing cavities
- Deflectors
- Rf guns

Backward wave high-gradient accelerating structure for proton acceleration based on CLIC technology





What the broader scope could mean in practice

- Participate (but not lead) in funding proposals for R&D for projects using high-gradient normal conducting technology,
- specific proposals such as CERN KT medical linac accelerating structure project,
- testing of prototype hardware for different projects in the Xboxes,
- perhaps even reconfiguring an Xbox into a prototype rf system for a project,
- and certainly giving rf and beam dynamics and design support and consultation.

I will end on with a purely personal statement – a number of us are very motivated to see the developments made for normal conducting linear colliders used as widely as possible. We'll do our best to try to help.