Preparation of CLIC zero, Drive Beam injector planning 2012-2016

- Introduction to CLIC zero
- Motivation for CLIC zero
- What has to be done to get ready,

relation to the work packages 2012-2016

- CLIC DB injector front end
- Conclusions

Introduction to Czero

Motivation for $CLIC_{zero}$

- Demonstrate nominal drive beam parameters (except the energy)
  Full combination scheme to 100 A, full pulse length in injector

- Demonstrate two beam acceleration with nominal hardware for a significant length (~100 m)

- Drives industrialization, needed to be ready for CLIC
  Significant size series production of cost and performance driving hardware (46 two beam modules, 276 x-band structures, 138 PETS, 140 L-band klystrons, modulators and structures)

- Most hardware reusable for CLIC

- Could be a beam driven processing facility for the x-band structures

<u>Drawbacks:</u>

- Expensive
- Beam dynamics for combination might be more difficult due to lower energy
- Does not address sufficiently emittance preservation and luminosity issues

Features of $CLIC_{zero}$

- ❑ Nominal CLIC DB injector
- ❑ Nominal DB rf system (Klystron, Modulator, accelerating structure)
- ❑ Nominal 100 A drive beam (6 μs)
- ❑ 20 % drive beam energy

- ❑ Nominal Delay Loop and Combiner Rings (1/5 of the energy)
- ❑ Drive beam pulse shaping can be studied
- ❑ DB turn around to study phase feed forward

- ❑ 46 nominal two beam modules (type 1; ~ 100 m)
- ❑ 10% of a decelerator (last 10 % most difficult)
- ❑ 6.25 GeV electron beam, 1.2 A
- ❑ Nominal beam loading

$CLIC_{zero}$ Parameters

Parameter	Nominal value	Unit
Drive Beam Energy	480	MeV
Pulse Length	**6-140**/ 243.7	µs / ns
Drive Beam Current (linac)	4.2	A
Decelerator Current	**101**	A
Combination Factor	24	
Bunch Spacing	1.992	ns
Drive Beam Emittance	~100	mm mrad
Decelerator Bunch Length	1	mm
Repetition Rate	50	Hz
Main Beam Energy	6.5	GeV
Main Beam Current	1.2	A
Main Beam Pulse Length	156	ns
Main Beam Bunch Length	~0.5	mm
Main Beam Emittance	~30	mm mrad

What is needed to get ready for $CLIC_{zero}$

- Prototyping and small series production of major hardware
  DB-klystron, DB acc-structure, Modulator,
  Diagnostics, two beam modules
- DB injector design and demonstration (Source, phase coding, stability)
  includes prototyping of DB rf system
- Technical design of the DB linac
- Technical design of the beam combination complex
  (delay loop, combiner rings)
- Technical design of the turn around loop
- Technical design of the probe beam injector
- Technical design and prototyping of the two beam modules
  (acc-structure, PETS, diagnostics, Quads, stabilization and alignment)
- Study and prepare location and implementation (tunnel, building)
- .....

Working packages related to $CLIC_{zero}$ preparation

- Experimental verification

CLIC DB injector front end and photo injector option, Drive beam phase forward

- Technical Developments

Two-beam modules and production facility, Magnets, Instrumentation, Controls, Powering, Survey, Stabilization, Vacuum

- X-band technology

x-band structure fabrication and testing

- Parameters and design

Drive Beam Complex, Feedback Design, Main Linac

- Civil Engineering

Critical preparation items

- L-band Klystrons: 150 needed, typical production rate 12/year
- Modulators: 150 needed
- L-band structures: 150 needed
- x-band structure: 280 needed, current rate ~10/year,
  900/month for CLIC
- PETS: 140 needed
- Civil engineering: ~ 400 m needed
- Cost: ~ 400 MCHF

This shows how important CLIC zero would be to be ready for CLIC !

Clearly more discussion needed on these items and the scope of the project

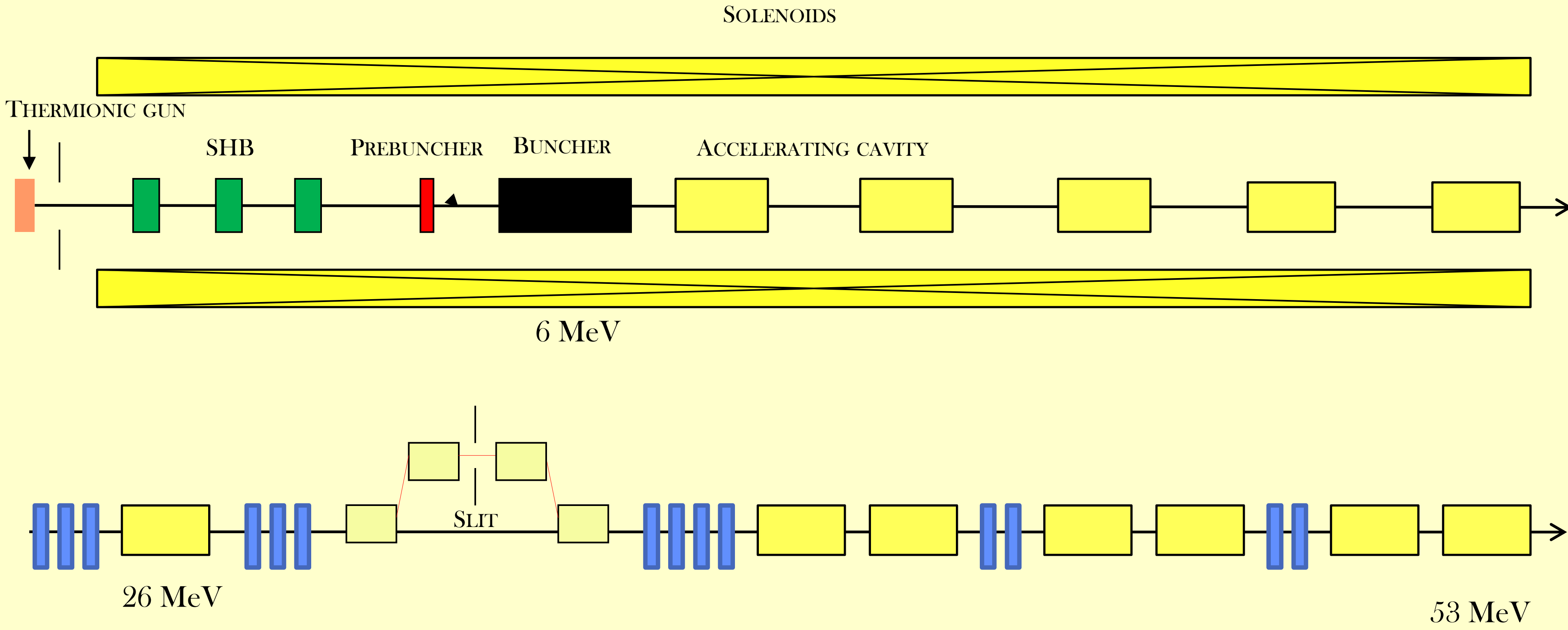
Can $CLIC_{zero}$ be useful for physics experiments ?

For time being designed as a CLIC technology demonstrator and to study accelerator physics related to CLIC

Possible use of the high power drive beam and medium energy main beam for experiments in nuclear physics, photon science, advanced accelerator R&D,….

Topic of tomorrows working group session !

CLIC DB injector schematics

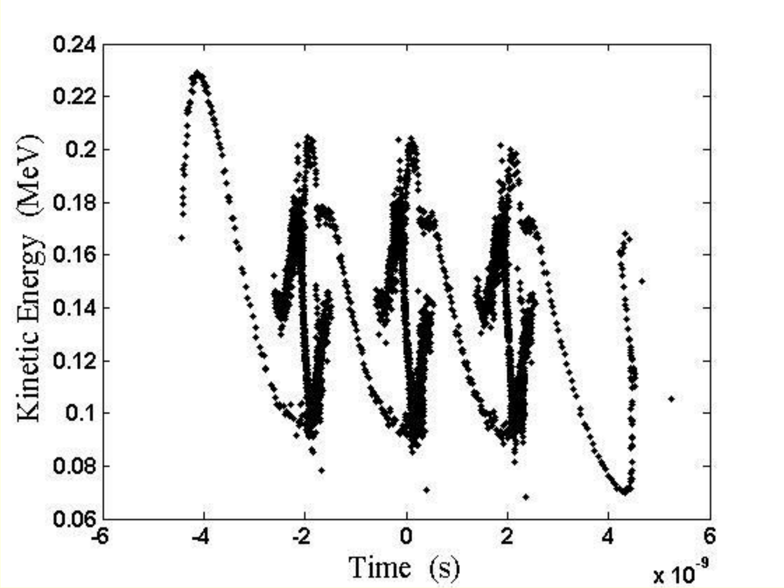


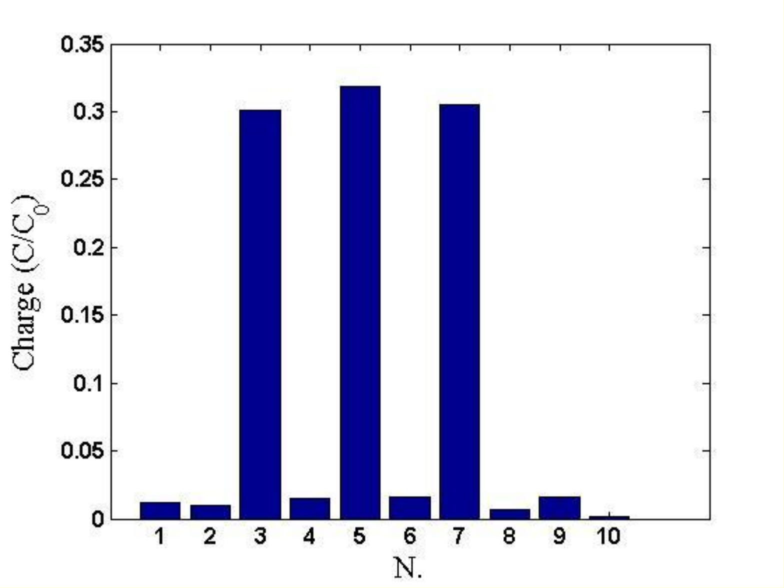
Documented in the CDR; a scaled version of CTF3
Simona Bettoni, Alessandro Vivoli

CLIC DB injector specifications

Parameter	Nominal value	Unit
Beam Energy	50	MeV
Pulse Length	**140.3** / 243.7	μs / ns
Beam current	4.2	A
Bunch charge	**8.4**	nC
Number of bunches	70128	
Total charge per pulse	**590**	μC
Bunch spacing	**1.992**	ns
Emittance at 50 MeV	100	mm mrad
Repetition rate	100	Hz
Energy spread at 50 MeV	1	% FWHM
Bunch length at 50 MeV	3	mm rms
Charge variation shot to shot	**0.1**	%
Charge flatness on flat top	**0.1**	%
Allowed satellite charge	< 7	%
Allowed switching time	5	ns

Simulation results





Longitudinal phase space after sub-harmonic bunching
Same total gap-voltage but fewer cells (2 instead of 6)
35-39 KV needed

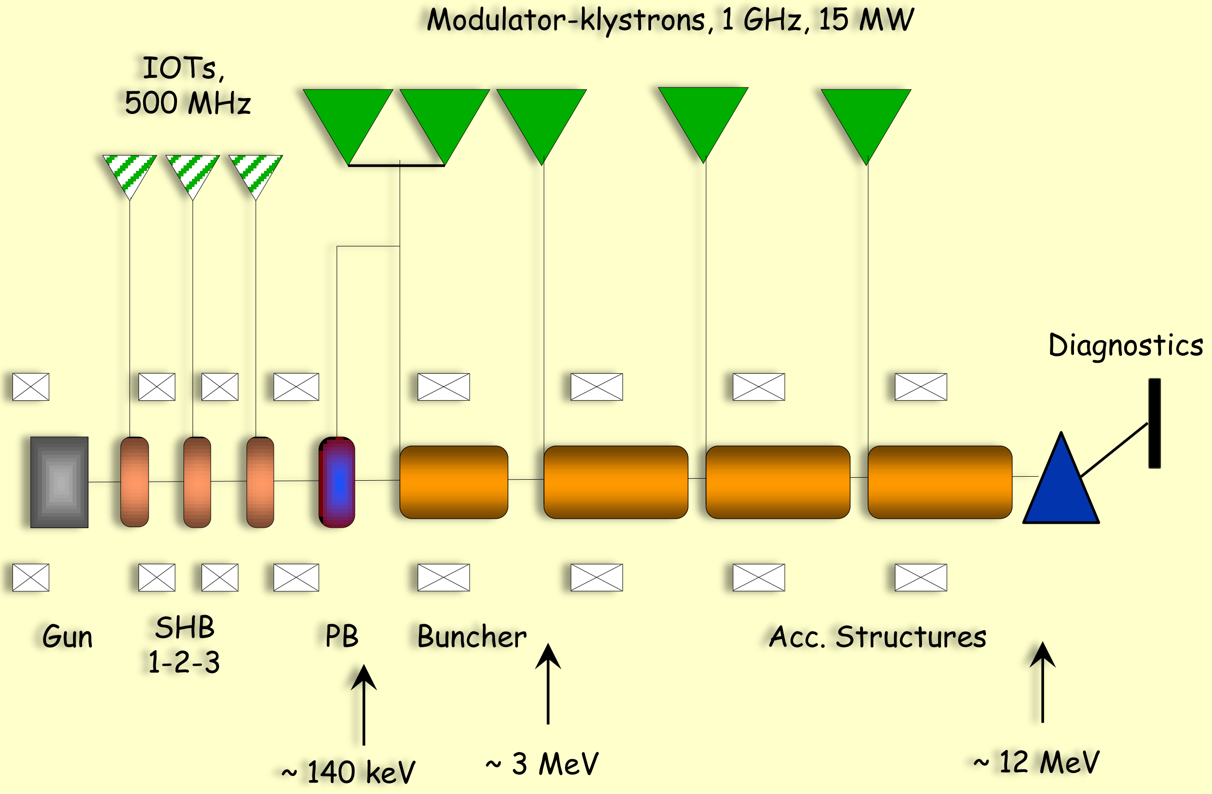
Simulation results

Parameter	Unit	Simulations	CLIC
Energy	MeV	53.2	
Bunch charge	nC	8.16	8.4
Bunch length (rms)	mm	2.83	3 (@ 50 MeV)
Energy spread (rms)	MeV	0.45 (@53 MeV)	< 0.50 (@ 50 MeV)
Horizontal normalized emittance (rms)	µm rad	32.9	≤ 100
Vertical normalized emittance (rms)	µm rad	28.7	≤ 100
Satellites population	%	4.9	As small as possible

- Specifications can be fulfilled but still high satellite population and high losses in cleaning chicane
- Some ideas to improve the satellites and total losses
- Beam loading and wake field effects to be studied

- Some inconsistencies due to a lack of realistic rf-parameters (simulations have to be redone with new parameters)

What do we plan to do until 2016, CLIC DB front end



Gun, sub-harmonic bunching, bunching, three accelerating structures, 5 long pulse klystrons and modulators, diagnostics

What do we plan to do until 2016

Optimistic and rough planning

Task	2012	2013	2014	2015	2016
Building	Identify and prepare building	ready for first installations			
Gun	specify gun and HV supply	Order and test	ready to use		
SHB Buncher	design	fabrication	installation		
500 MHz power source	purchase power source	testing	installation		
Buncher	design	fabrication	installation		
1 GHz structure	design	prototype+ fabrication	test prototype+series production	install first structure	install structure 2+3
Solenoids	design	fabrication	installation		
Vacuum system		design	fabrication	installation	
Diagnostis	specification	fabrication	installation		
Controls		preparation	installation		
LLRF	specification	Design, prototype	fabrication		
1 GHz klystrons	purchase prototype	fabrication	Klystron 1	Klystron 2	Klystron 3+4
1 GHz Modulator	purchase first MDK	fabrication	Receive first MD	MD 2	MD 3+4

Electron source options

Some simple considerations

CTF3: 1.6 μs, 9.6μC per pulse
1 % droop specs
→7 nF, ~70 J stored energy

CLIC: 140 μs, 700 μC per pulse
0.1 % droop specs
→ 5 μF, ~50 kJ stored energy
gridded cathode might not survive

CTF3 gun concept might be not scalable for CLIC

Some Options:

1. CTF3 type gridded gun with a HV modulator, tests needed
2. Modulated anode gun, needs new design and simulation
3. RF modulated grid, IOT-type gun, very attractive but needs tests and simulation

Sub-harmonic bunching system

Status:
RF design existing, ready to start mechanical design and launch prototype or cold model

Power source:
500 MHz, ~100 kW, wide band (70 MHz) sources needed for fast phase switching. Started to discuss with industry.

Candidates: IOT, frequency and power available, bandwidth to be seen
tests are planned with an 800 MHz IOT for SPS

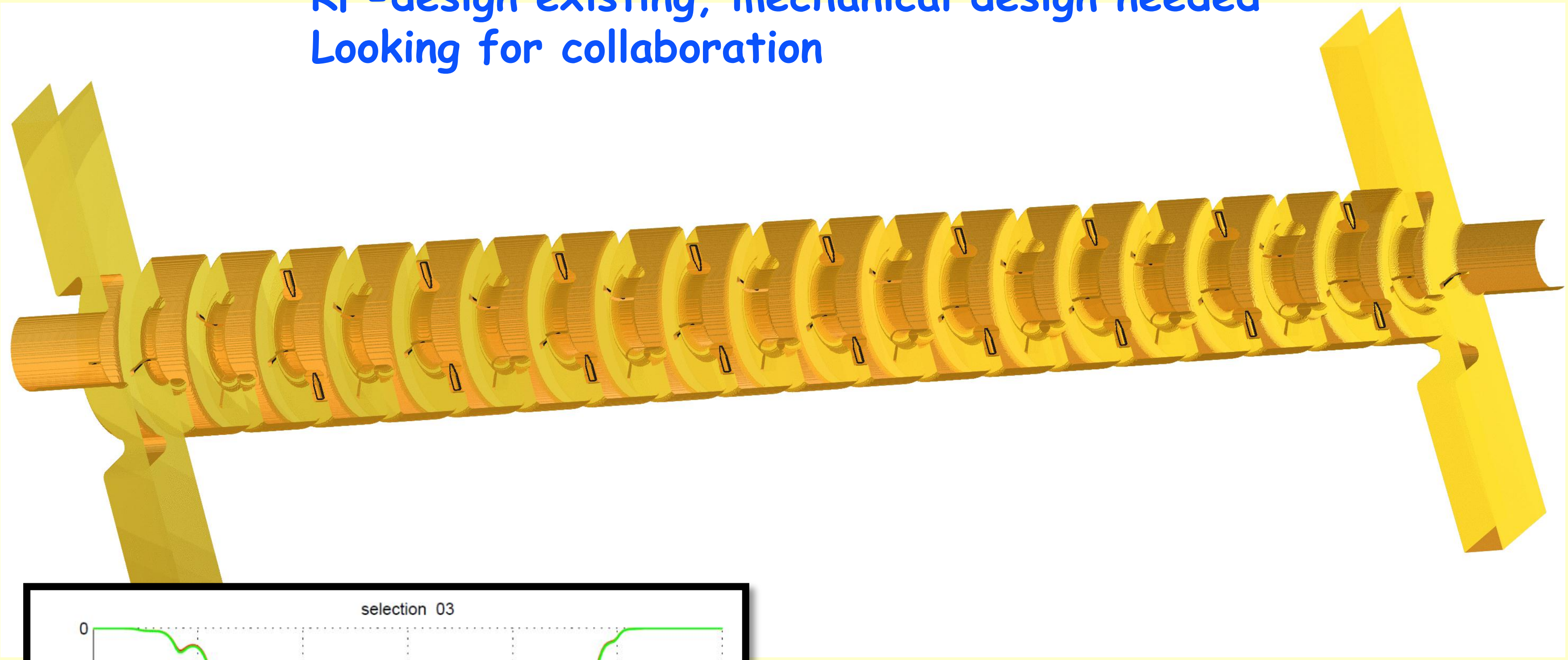
Solid state amplifier (Soleil, India), bandwidth, power ?

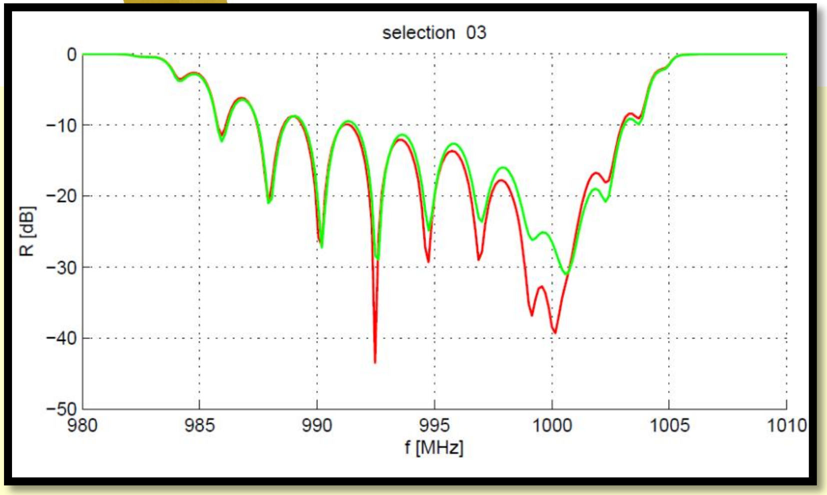
RF design of 1 GHz pre-buncher and travelling wave buncher existing

(see presentation by Hamed Shaker tomorrow)

DB-accelerator structure

RF-design existing, mechanical design needed
Looking for collaboration





Input and output coupler design finished
Correct match, input reflection < 30 dB.
(red and green: two different geometries; red is final)

Rolf Wegener

RF power sources
1 GHz klystron

Scenarios	2012	2013	2014	2015	2016	2017
Single beam klystron (40% efficiency)	Tender/ Order		Klystron 1	Klystron 2	Klystron 3	Klystron4/5
Multi beam klystron (ILC-based, 60% efficiency)	Tender/ Order			Klystron 1 ?	Klystron 2	Klystron 3
Ultimate efficiency (>70%) based on Chiara Marrelli's work	Study	Study	Single beam prototype ?	MBK Engineering	MBK Prototype	
Ultimate effiency based on EuCard2		Start of Progam	EuCard study	EuCard study	EuCard study	Transfer to Industry

<u>Development and Purchasing strategy:</u>

Start with single beam klystron now to get started with the injector (ready to launch call for tender)

Aim to get at least one multi beam klystron towards 2016 wit an efficiency approaching 70% (to be linked with modulator development)

Plan to hold a workshop on high efficiency klystrons and modulators before the end of the year. Seeking collaborations for this topic !

Modulators

Modulator development and purchasing in coordination with powering work package in CTC by David Nisbet (see presentation tomorrow)

CLIC DB front end:
Purchase Modulators needed for single beam klystron in industry with reduced specification for efficiency and stability. Try to explore different technologies / companies and use modulators to develop measurements and build up experience for the ultimate technology for CLIC

CLIC DB linac:
Develop and explore with collaboration partners technologies to meet the ultimate specification for CLIC with the goal to have to working prototypes in 2015-2016. At some point klystron specs are needed.

Diagnostics
needs and opportunities

Diagnostics for the DB injector front end:

- Current measurement, long pulse, good resolution to study beam stability
  CT-type could work
- Beam position monitors for beam steering, not very demanding for injector but can we test prototypes for CLIC (strip lines) to get experience
- Spectrometer to check energy and energy spread, slit or segmented dump
- Beam profile measurements, screen (restricted to short pulse),
  wire scanner ?
- Beam Loss Monitors, prepare for CLIC DB linac
- Machine Protection instrumentation (current, BLM),
  details to be determined

Demonstration goals for the injector front end

- Demonstrate rf system at full pulse length and beam loading
  High efficiency klystron
  High efficiency and stable modulator
  Full loaded accelerating structure (validate technology)

- Demonstrate beam quality and stability requirements for long pulse
  Current stability 0.1%
  Beam phase stability
  Emittance and energy and position jitter

- Demonstrate electron source and phase coding
  Life time, reliability, routine operation

- Demonstrate diagnostics suitable for long pulse and machine protection

- DB Injector suitable for CLIC zero and CLIC (special operation modes needed ?)

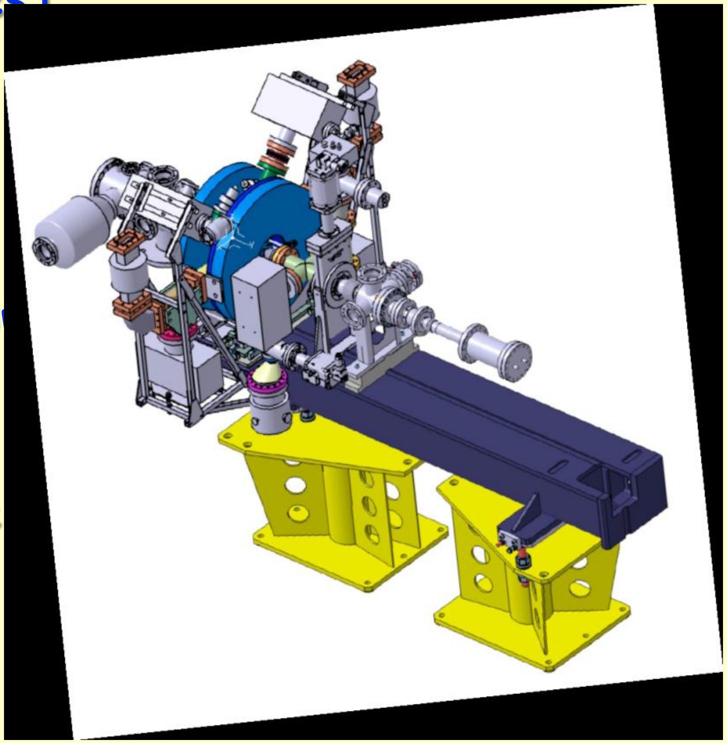
Photo injector option

Advantages

- No satellites or tails, phase coding on the laser side
- No or less bunching needed, possibly better emittance
- Flexible time structure (single bunches)

Concerns

- Cathode lifetime
- Challenging laser, peak and average po
- Intensity stability
- Maintenance and operation
- Very little resource available for time



Conclusions

- CLIC zero parameters and concept will have to be revived to come up with a coherent strategy
- Study physics potential for such a machine
- More on these topics tomorrow in the working group

- Rough conceptual design for the injector exists, now we have to get really started
- Will set up a working group to do technical design (everybody is welcome to join in)
- Plans for purchasing the key hardware items have been developed and need to be followed up now (discussion tomorrow in working group)
- We could need help for low energy simulations, gun design and construction, mechanical design and drawings, photo injector option

End

1GHz single bean klystron parameters

Test Condition	Limits		Unit
	min	max	
Operating mode :			
Peak beam voltage	-	215	kV
Peak cathode current	-	190	A
Beam perveance	1.75	2.15	$\mu A/V^{3/2}$
Peak drive power	-	200	W
Peak output power	15	-	MW
Average output power	105	-	kW
Focusing coil current	-	68	A
Efficiency	40	-	%
Average body power	-	10	kW
Bandwidth (-1 dB)	TBD	-	MHz
Ion pump current	-	10	μA

Klystron specifications

TH1802, ILC MBK klystron

FREQ	Vklystron	Iklystron	V pulse width	RF pulse width	Peak RF Power	Repetition rate	Average Power	Gain	Efficiency	Waveguide
MHz	kV	A	μs	μs	MW	Hz	kW	dB	%	
1300	115	132	1700	1500	10	10	150	47	65	WR 650

CLIC DB klystron design goal, ~ 150kV voltage was assumed for time being

FREQ	Vklystron	Iklystron	V pulse width	RF pulse width	Peak RF Power	Repetition rate	Average Power	Gain	Efficiency	Waveguide
MHz	kV	A	μs	μs	MW	Hz	kW	dB	%	
999.52				**150**	**15-20**	**50**	**113**		**70**	

More information about gun options

1. CTF3 type gridded gun with a HV modulator,
   Modulator stability, grid survival, several SHB needed, can be purchased

2. Modulated anode gun, needs new design and simulation, Can't be bought of the shelf, not sure if modulation fulfills requirements

3. RF modulated grid,
   IOT-type gun, very attractive but needs tests and simulation, dark current issue, emittance ?, reliability, can be purchased, no SHB, no satellites, likely R&D needed

   RF Modulate classical gun, typical pulse length 1 ns, less SHB needed, could have very low satellites, can this deliver enough current

→ We should create a gun test facility as a first step ! We have a place, a HV power supply, cathodes. We need some infra structure and a gun (isolated anode)