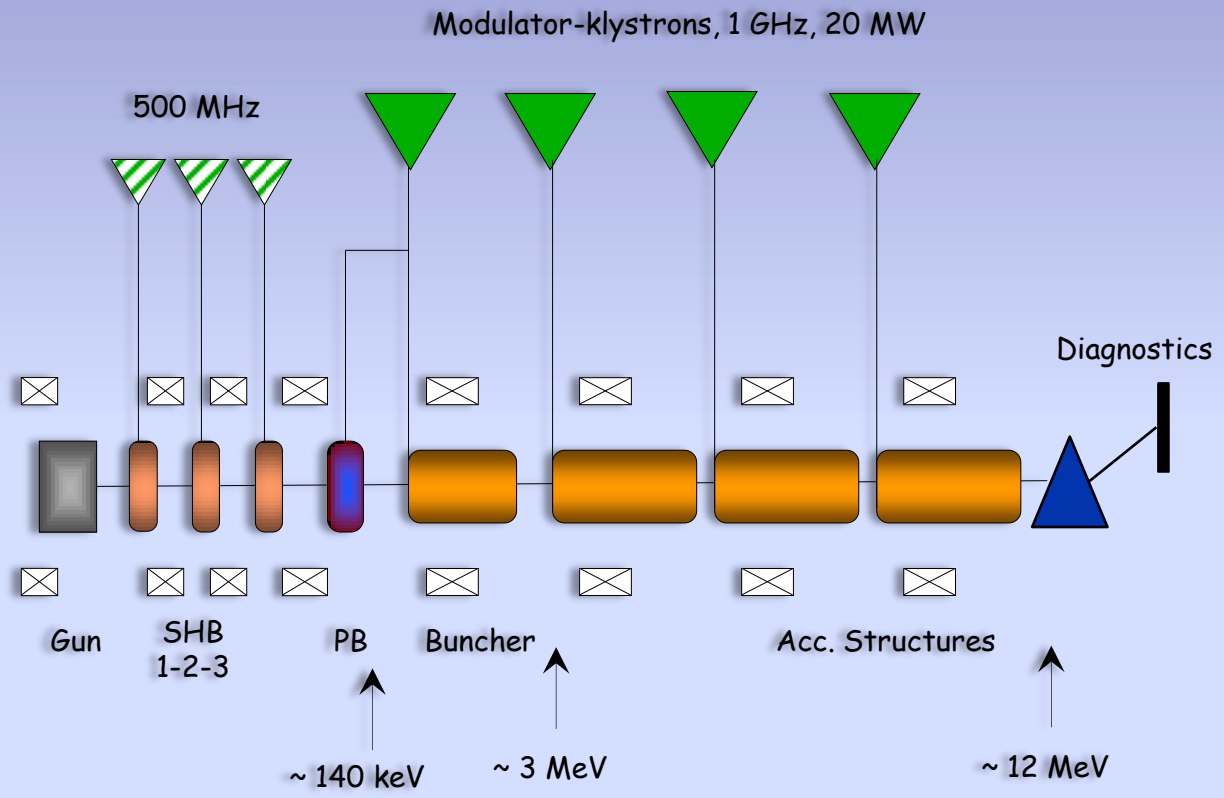
Update on the drive beam front end developments

- DB injector introduction
- Beam dynamics design
- Thermionic gun
- Klystron and Modulators
- Outlook

CLIC DB front end, Post CDR Project



For time being only major component development:
GUN, SHB, high bandwidth 500 MHz source, 1 GHZ MBK, modulator and fully loaded accelerating structure

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

Beam Dynamics design

- Longitudinal and transverse dynamics basically finished, some additional investigations with possible improvements ongoing
  All specified beam parameters reached, very low losses and satellite content.
  See Shahin's presentation

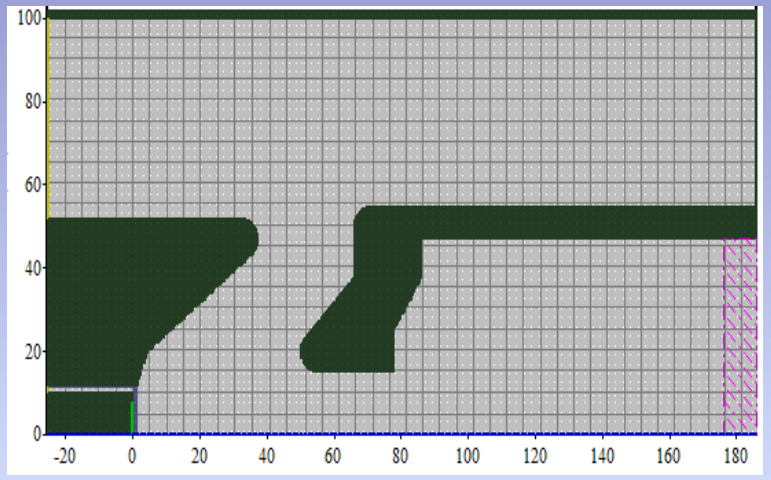
- Design of sub-harmonic bunchers and travelling wave buncher
  See Hamed's presentation

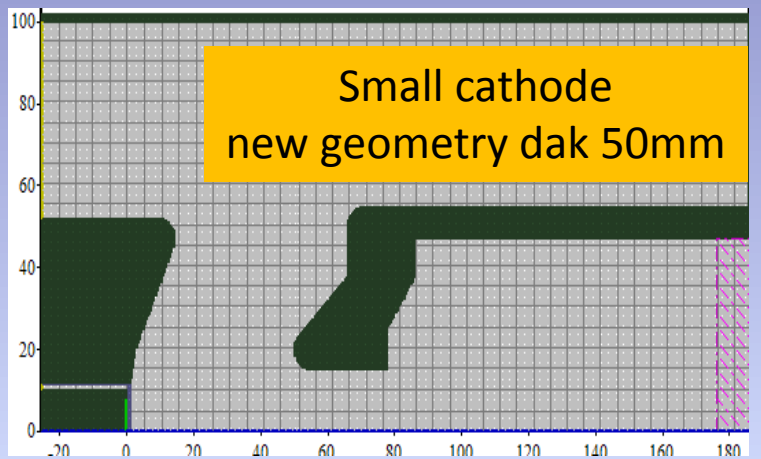
- Design of pre-buncher including beam loading study
  See for example LINAC 2013 by Mohsen

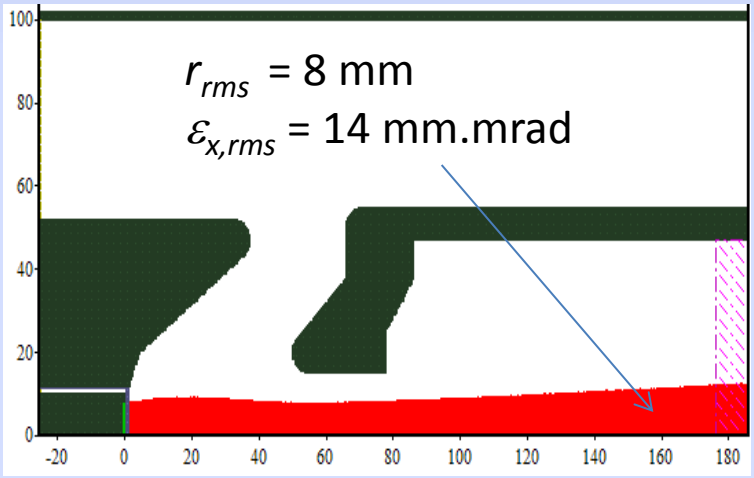
- First investigation on rf-gun beam dynamics and design
  See Mohsen's talk

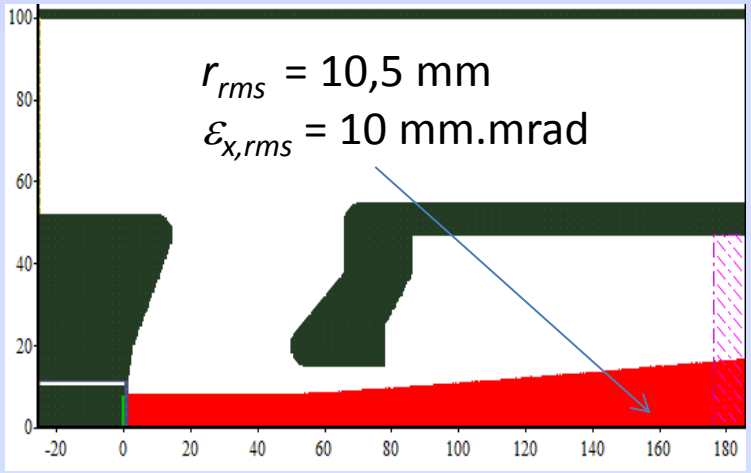
- Iterations with drive beam linac design needed, compromises in beam parameter choice possible.

DB gun simulations





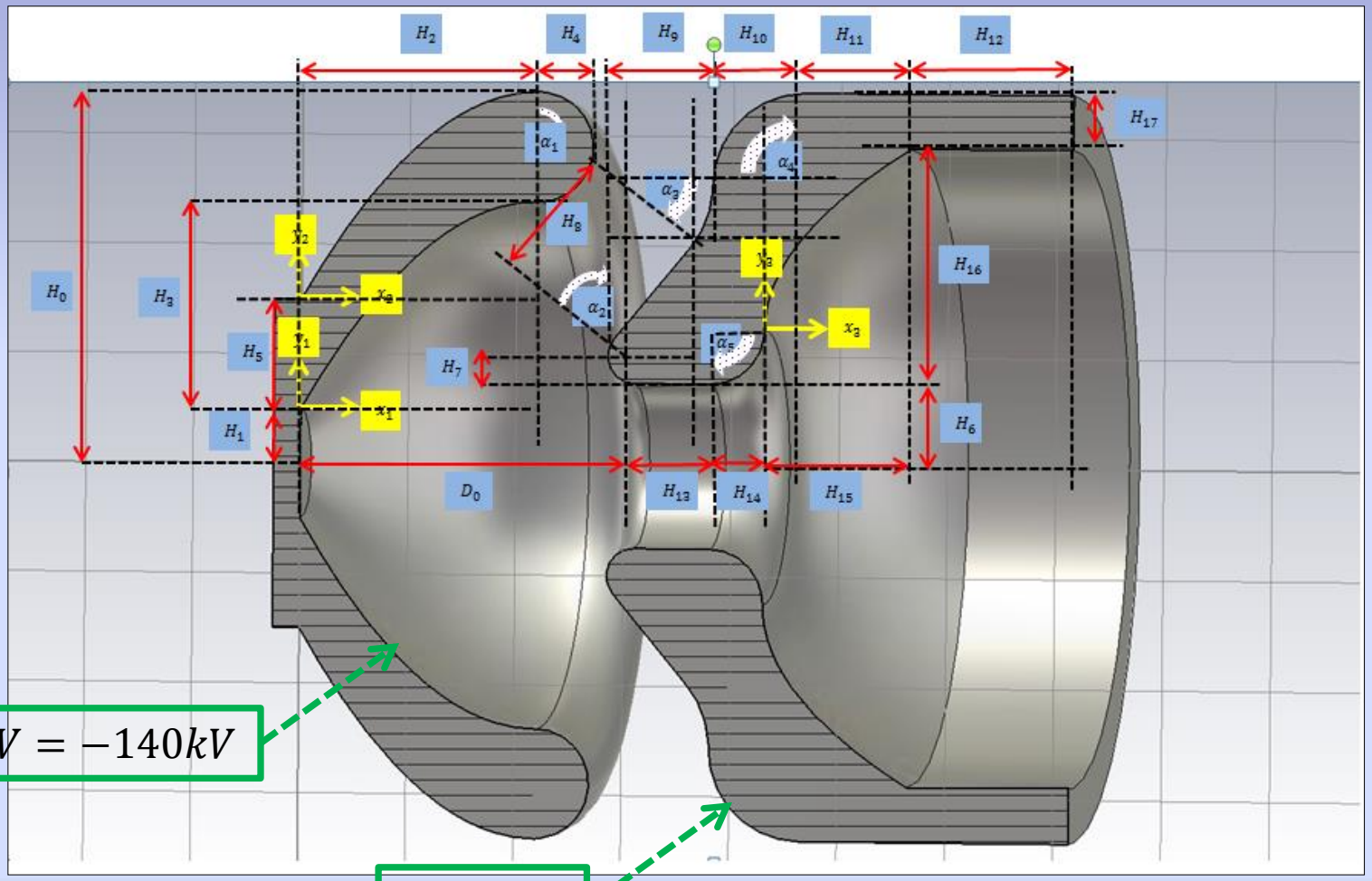




α_1 = 62,5 °
α_2 = 35°

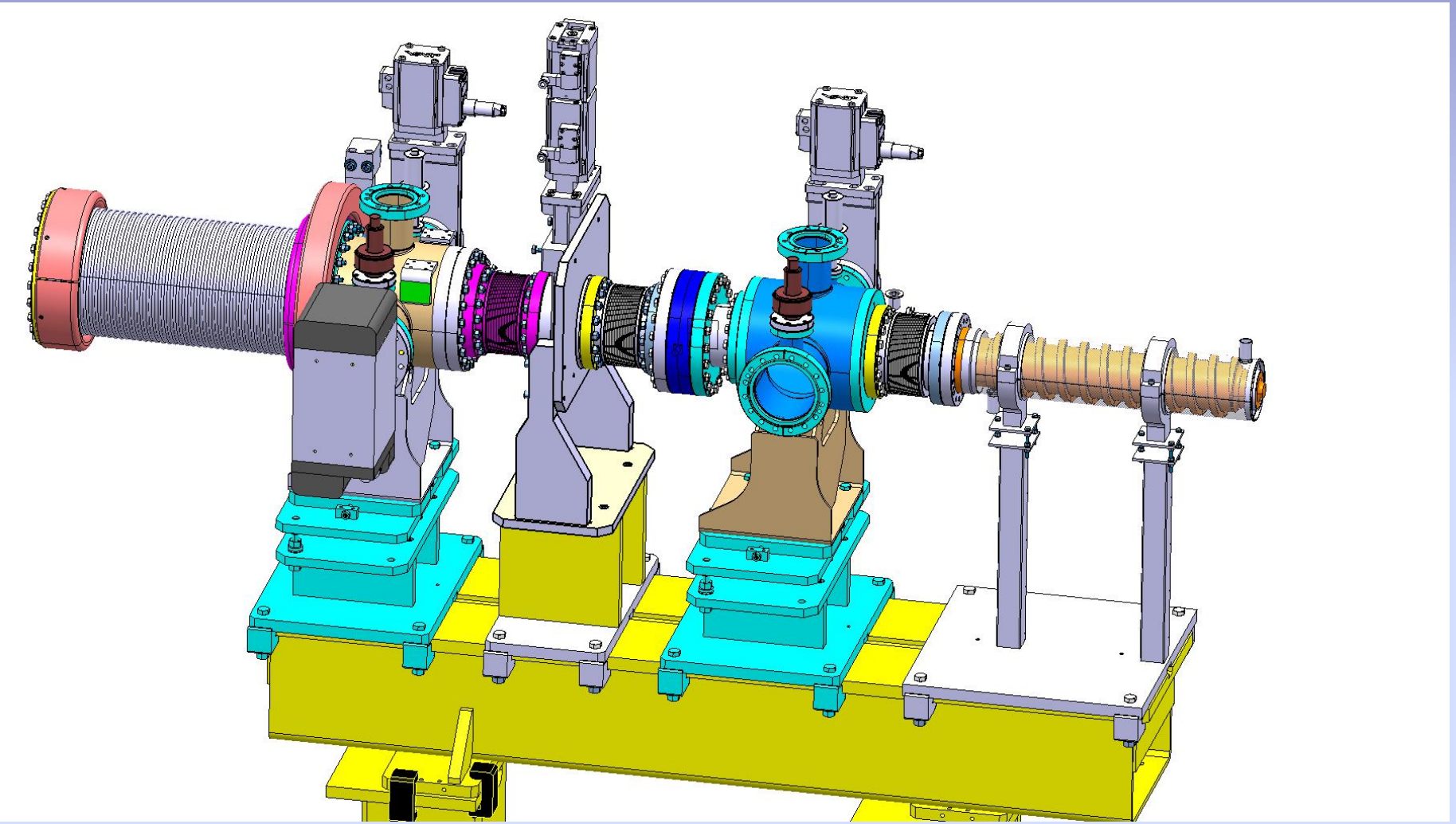
α_1 = 67,5 °
α_2 = 65°

DB gun simulations based on analytical approach

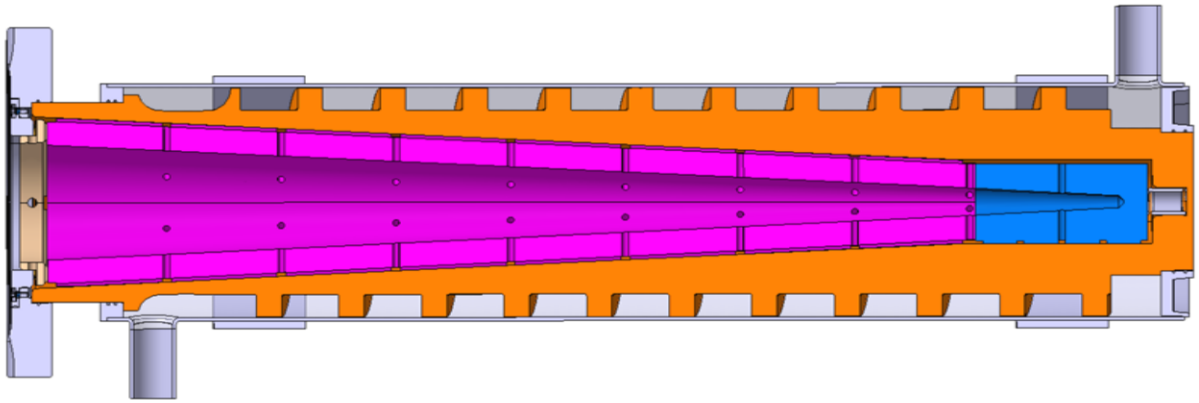


Mohsen Dayyani Kelisani

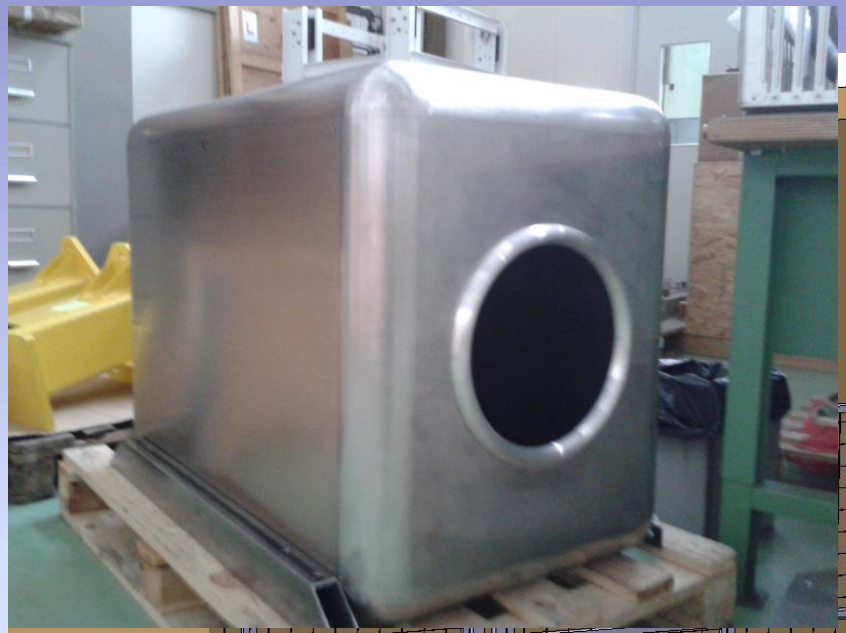
Thermionic Gun design



Beam Dump



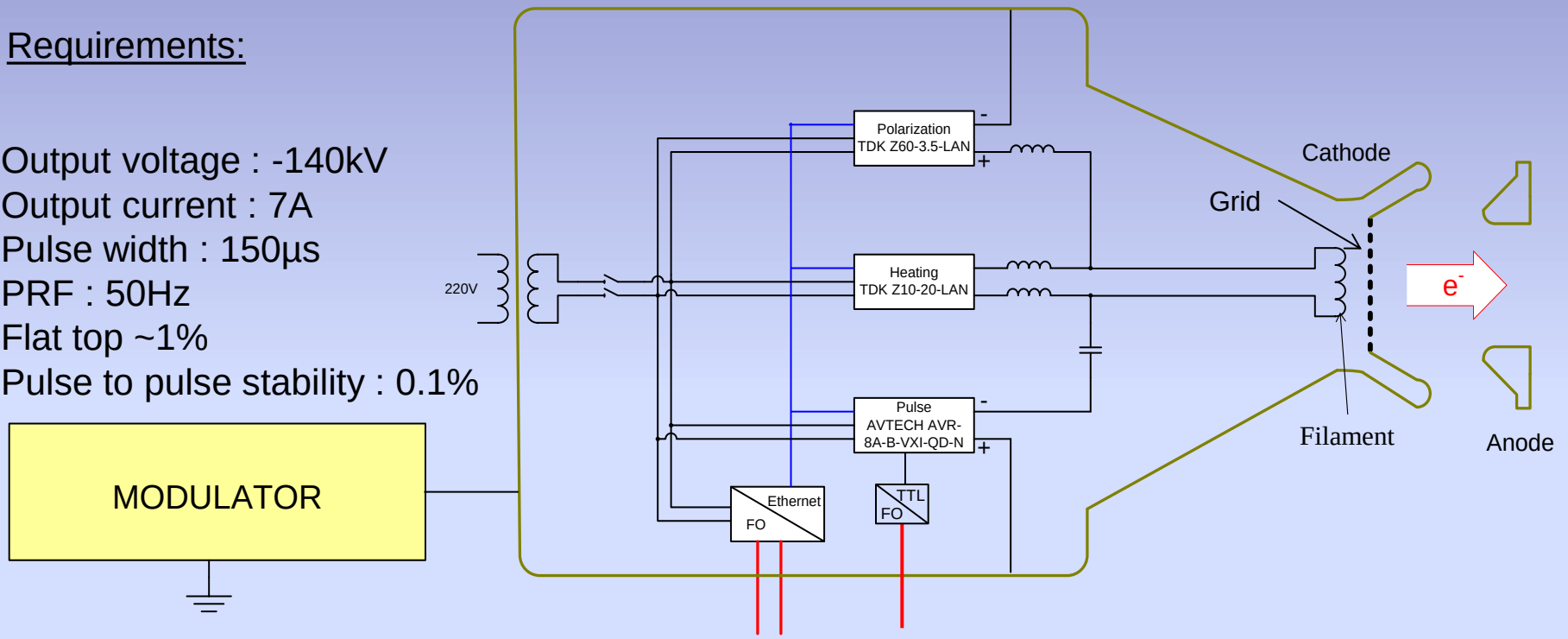
Gun Test Facility



Electron gun design

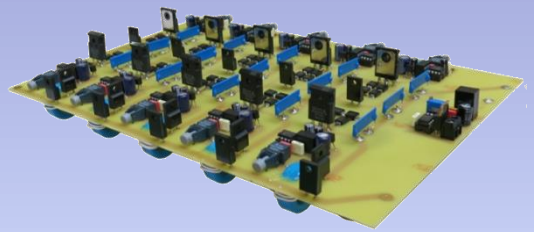
Requirements:

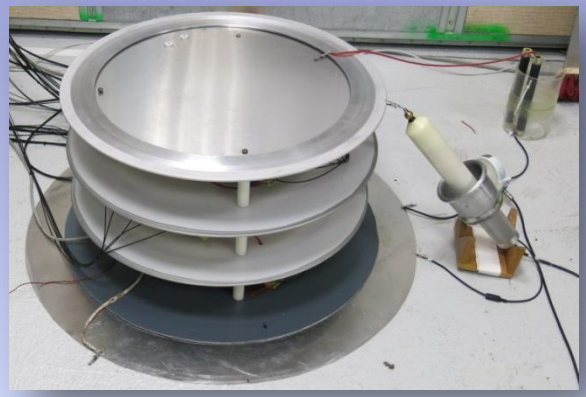
Output voltage : -140kV
Output current : 7A
Pulse width : 150µs
PRF : 50Hz
Flat top ~1%
Pulse to pulse stability : 0.1%



Filament polarization : ~60V DC
Pulse trigger : ~100V

- Prototype under development at CEA
- Based on Marx topology (capacitors charged in parallel, discharged in series)
- 100 solid state (IGBT) stages @ 1.5 kV
- Global short circuit detection & protection

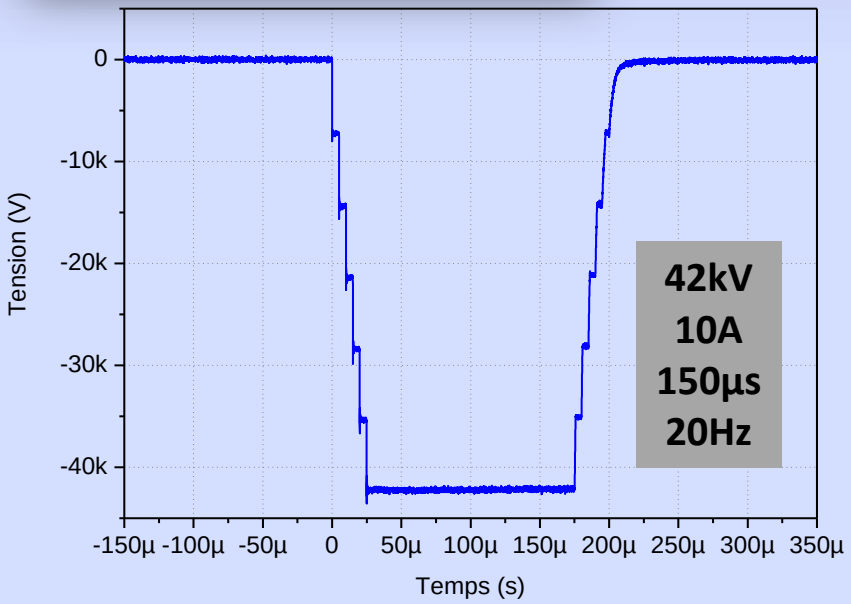
6 ×  =



Status

- Tested up to 42 kV, 20 Hz
- Flattop < 1%
- EMC issue on low level command @ 50 Hz

→ New active short circuit protection tested on 5 stages



Future

- Increase of frequency and voltage
- Implementation of SC protection on the whole modulator

Bruno Cassany

Sub-harmonic bunching system

Status:

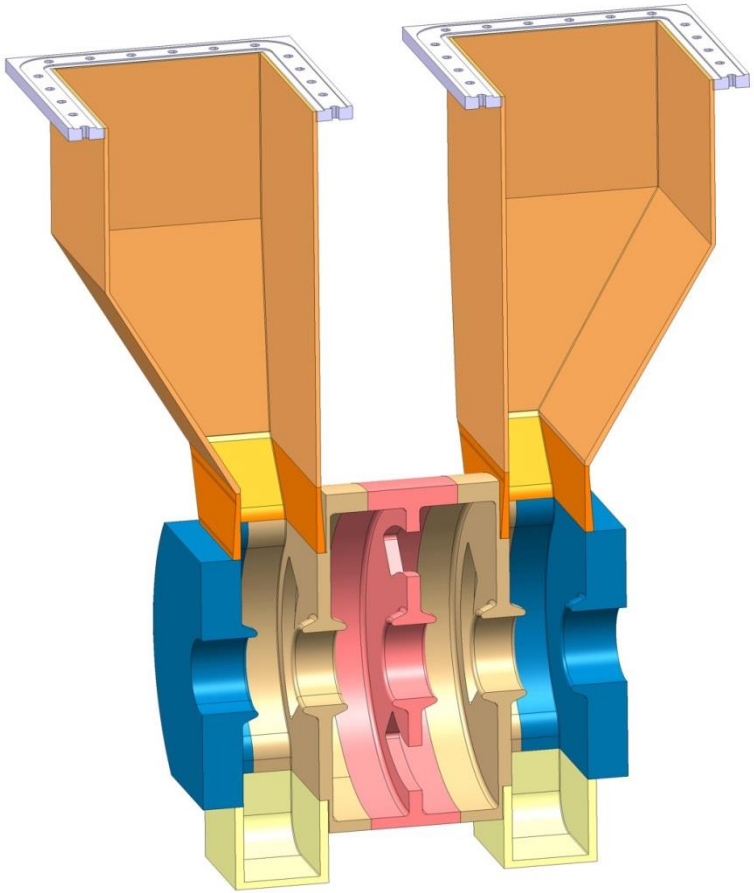
Under manufacturing in the CERN workshops

Power source:

500 MHz, 15-115 kW, wide band (60 MHz) sources needed for fast phase switching.

Solid state favored

Agreement with RRCAT (India) ready for signature



	SHB 1	SHB 2	SHB 3
Beam velocity	0.62 c	0.62 c	0.62 c
Current	5 A	5 A	5 A
Voltage	15 kV	30 kV	45 kV
Bunch form factor	0.058	0.57	0.73
Detuning	1.6 MHz	12.1 MHz	12.7 MHz

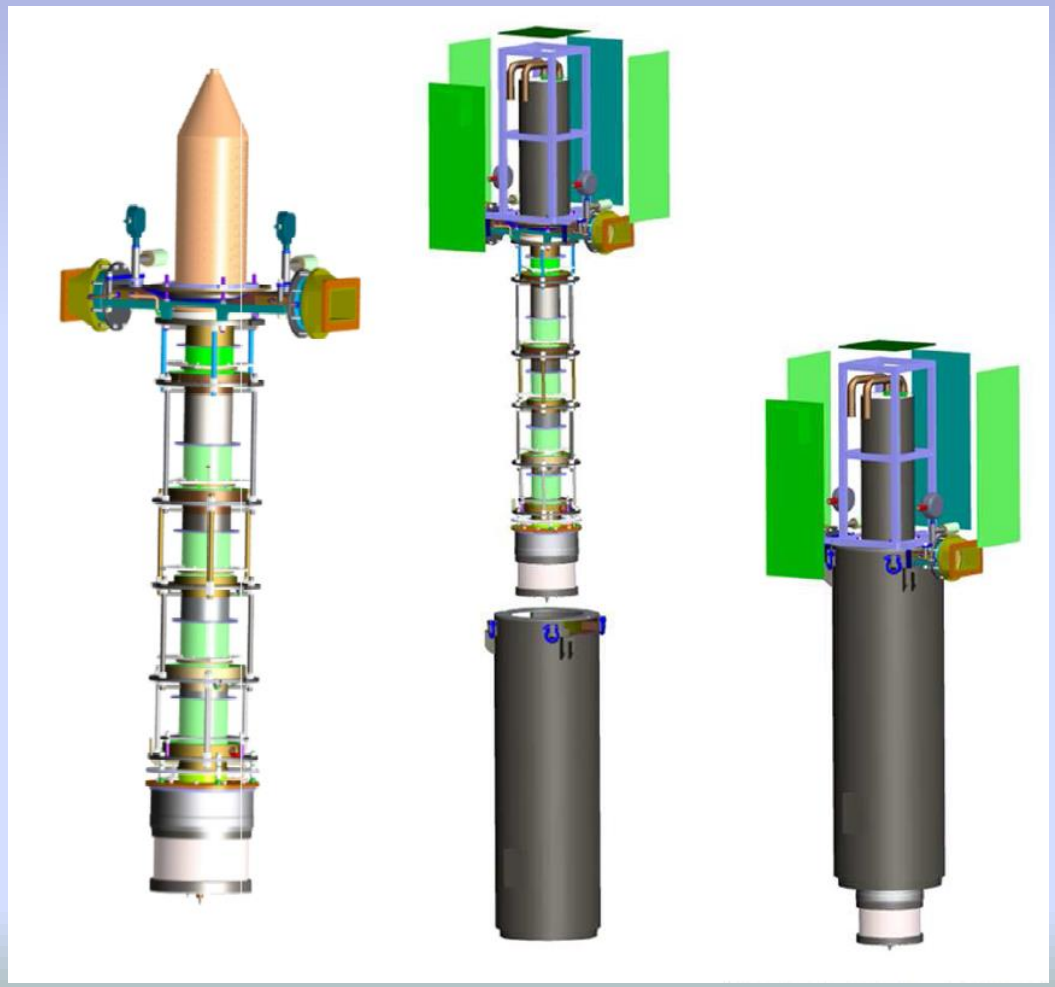
Multi-Beam Klystron Development

1 GHz, 20 MW, 150 μs, 50 Hz, > 70% efficiency

Thales Electron Devices TH1803:

10 beam multi beam klystrons, 153 kV, 77 % efficiency calculated

Design approved, delivery spring 2016

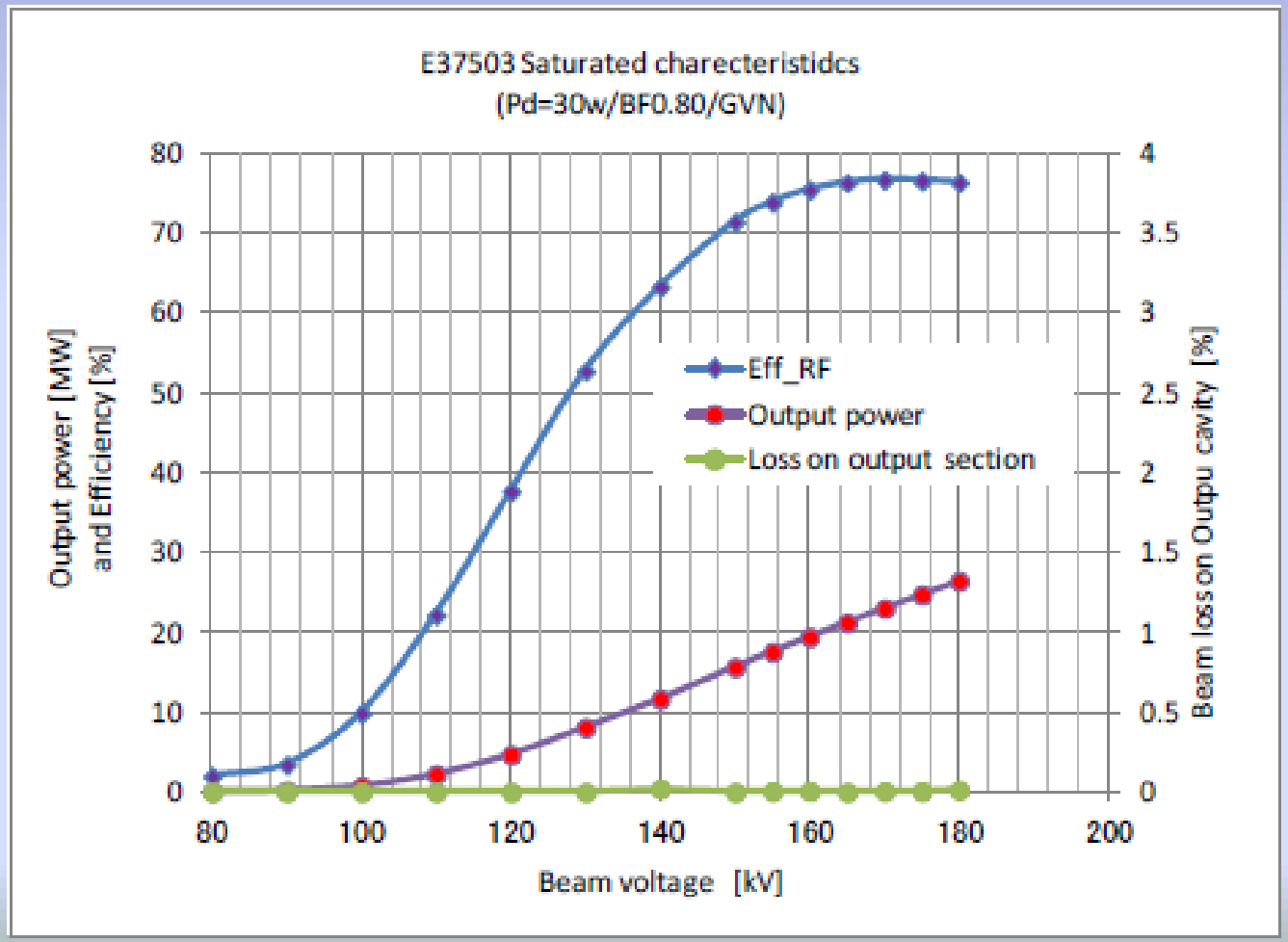


Multi-Beam Klystron Development

1 GHz, 20 MW, 150 μs, 50 Hz, > 70% efficiency

Toshiba E37503:

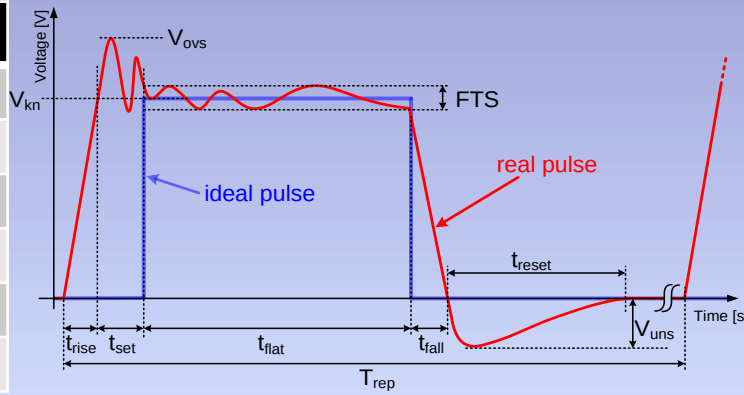
6 beam multi beam klystrons, 75 % efficiency calculated
Design approval in April 2015, Delivery summer 2016



CLIC klystron modulators (KM) R&D

- R&D challenges: voltage levels & rise time, repeatability, connection to grid.

CLIC Klystron modulators main specs			
Pulsed voltage	V_{kn}	180	kV
Peak nominal power	P_{out}	29	MW
Rise/fall times	t_{rise}	3	µs
Flat-top length	t_{flat}	140	µs
Rep. rate	Rep_r	50	Hz
Pulse repeatability	PPR	10-50	ppm



1300 modulators synchronously operated

29 MW x 1300 klystrons = ***38GW of pulsed power!***

- R&D (CERN + int'l collaborations)

Hot R&D topics:

Distribution grid layout optimization (re-think from 400kV to modulators)

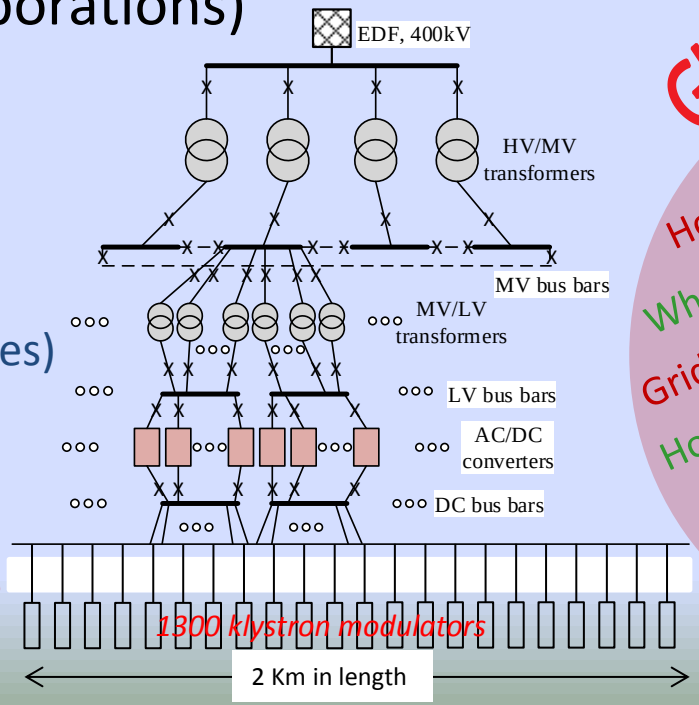
Active compensation of power fluctuation (new converters topologies)

High efficiency, high bandwidth, high repeatable power electronics

HV fast pulse transformers design

Highly repeatable HV measurements

Redundancy, modularity, availability

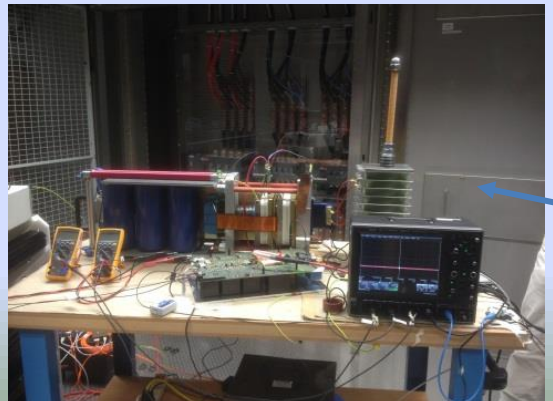


Global Optimization

How many transfo.?
What voltage levels?
Grid redundancy? N+1?
How many AC/DC (AFE)?
Modulator topology?
Modulator+klystron system repeatability?

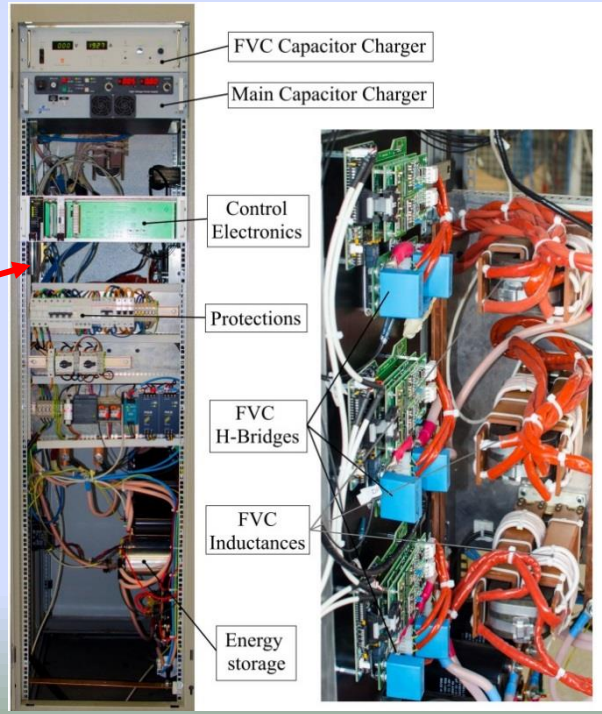
CLIC klystron modulators (KM) R&D

- Test stand: 2 modulators – 1 in early 2016 and in 2017
  - ETH Zurich (CH) collaboration: develop & deliver 1 modulator in 2016
  - LAVAL Uni. (CA) collaboration: develop & deliver design files for construction in industry, delivery to CERN in 2017
  - Nottingham Uni. (UK) collab.: deliver studies on grid layout optimisation and gives inputs to others collaborations
  - @ CERN: Study common issues to all collaborations, i.e. repeatability & high precision measurements
- Status
  - Topologies selected (Nottingham & CERN inputs)
  - Reduced scale prototypes tests at LAVAL/CERN
  - Full power modules under test at ETHZ



Full system test at reduced scale at LAVAL and CERN

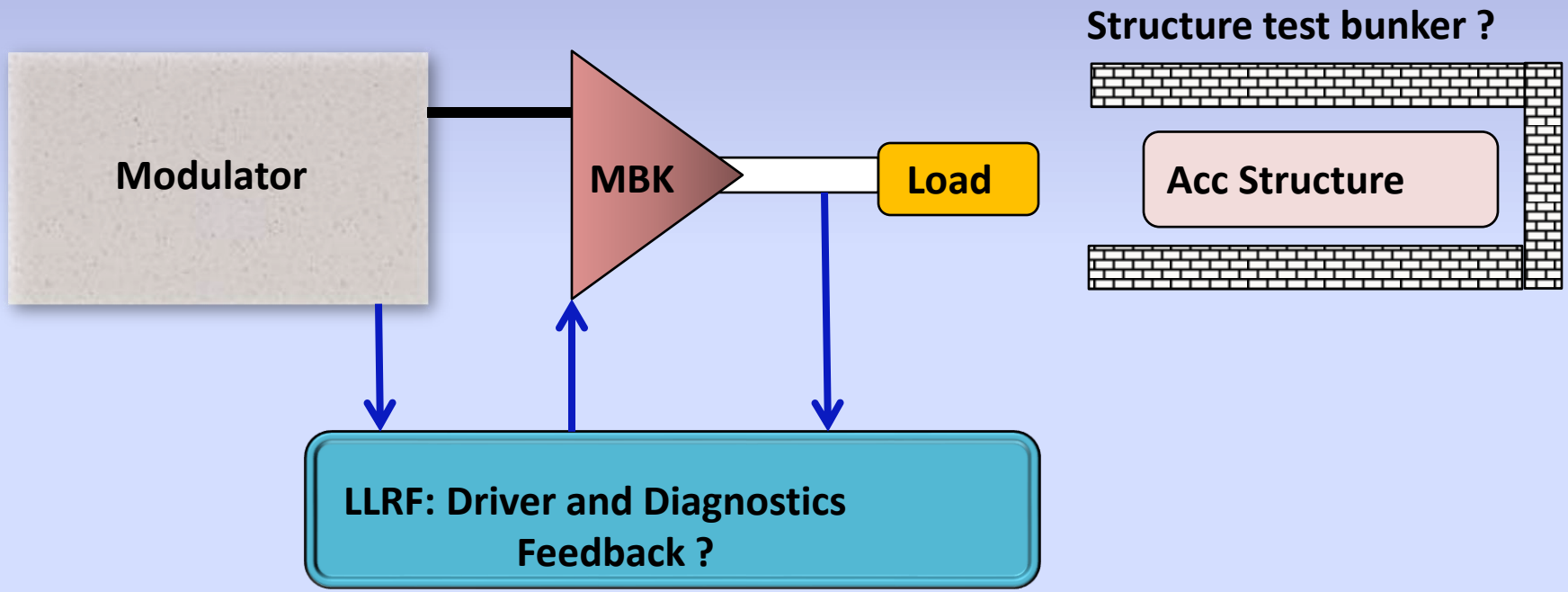
Full power modules tests at ETH



Davide Agulia

Klystron Test Stand

Together with the Modulator team a test stand will be created to test the rf unit in detail with special emphasis on the stability measurements



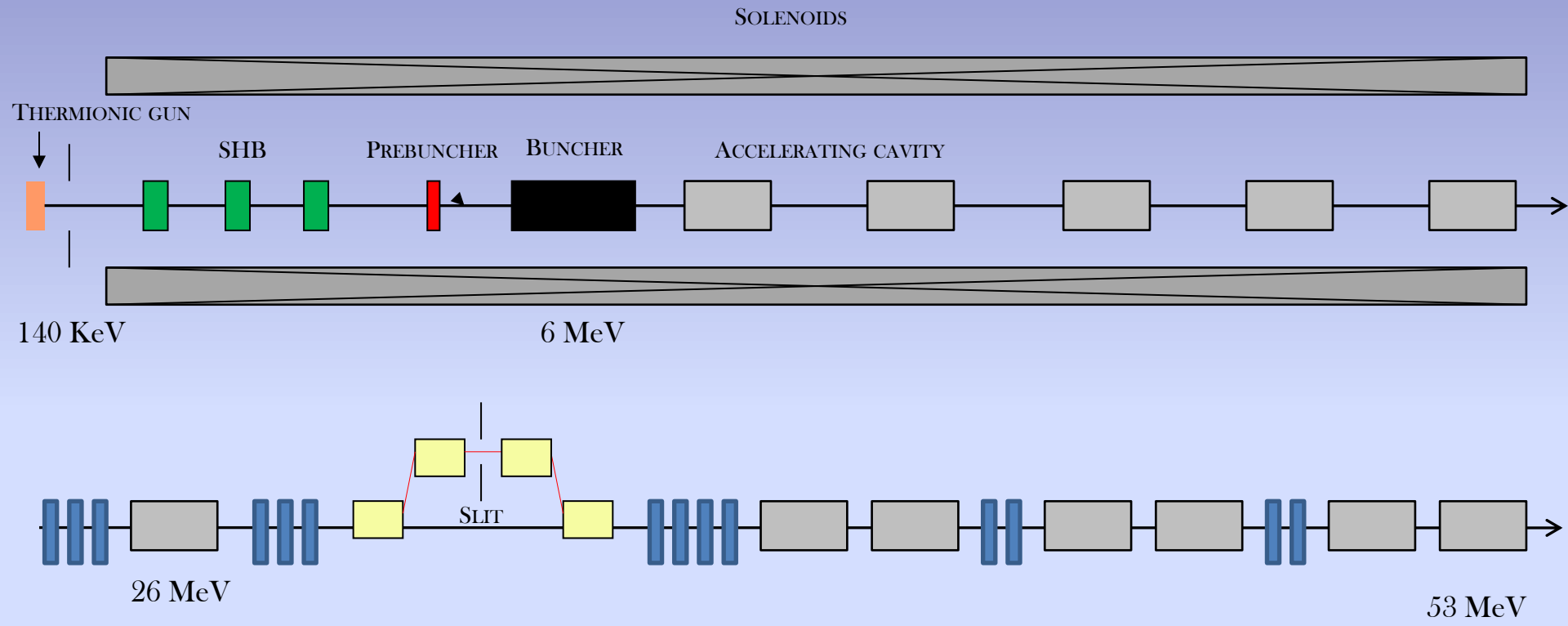
Chosen Location: Bldg: 112

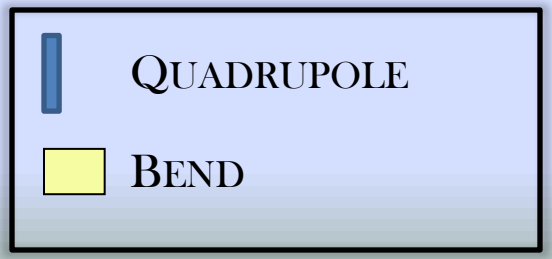
Outlook

- Klystron and Modulator developments progressing well need to advance on the test stand now
- Thermionic gun mostly manufactured, assembly and test to be pushed in the next few month. Beam dump still a tricky development
- Nice collaborations on Marx-generator for the gun (CEA) and the wideband 500 MHz source for the buncher (RRCAT)

End

CLIC drive beam injector layout



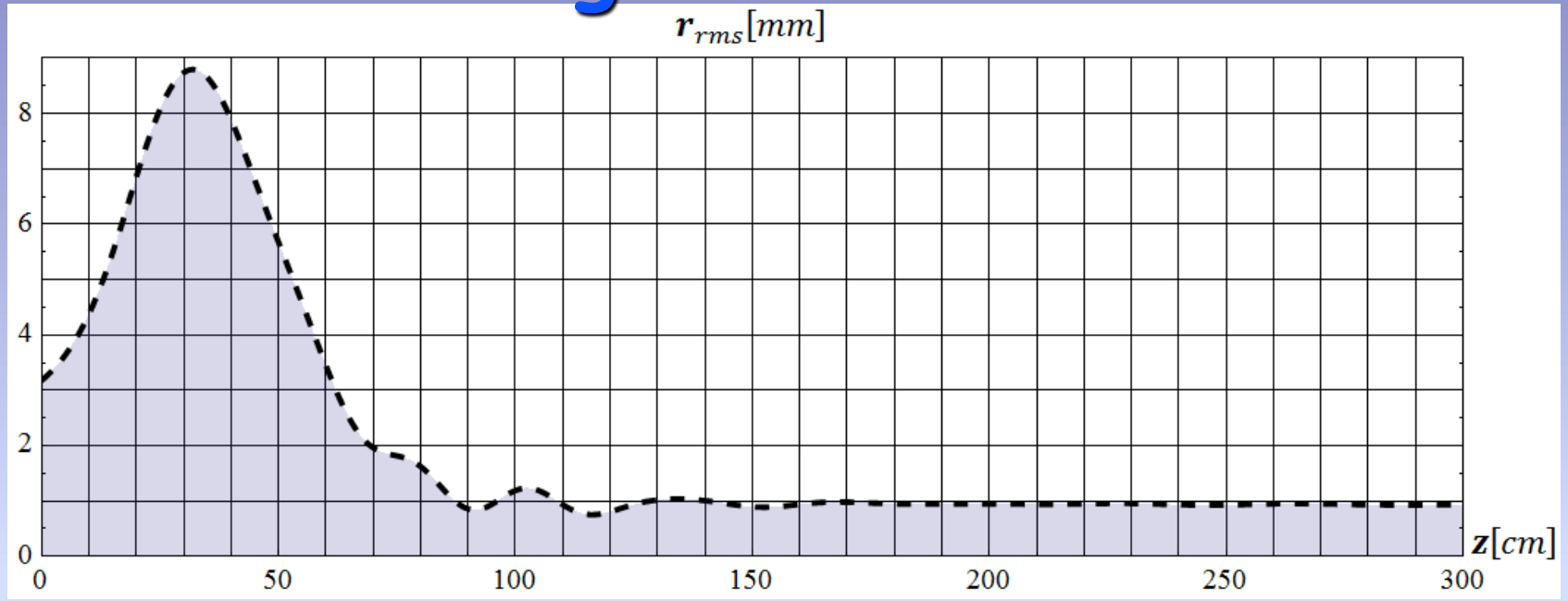


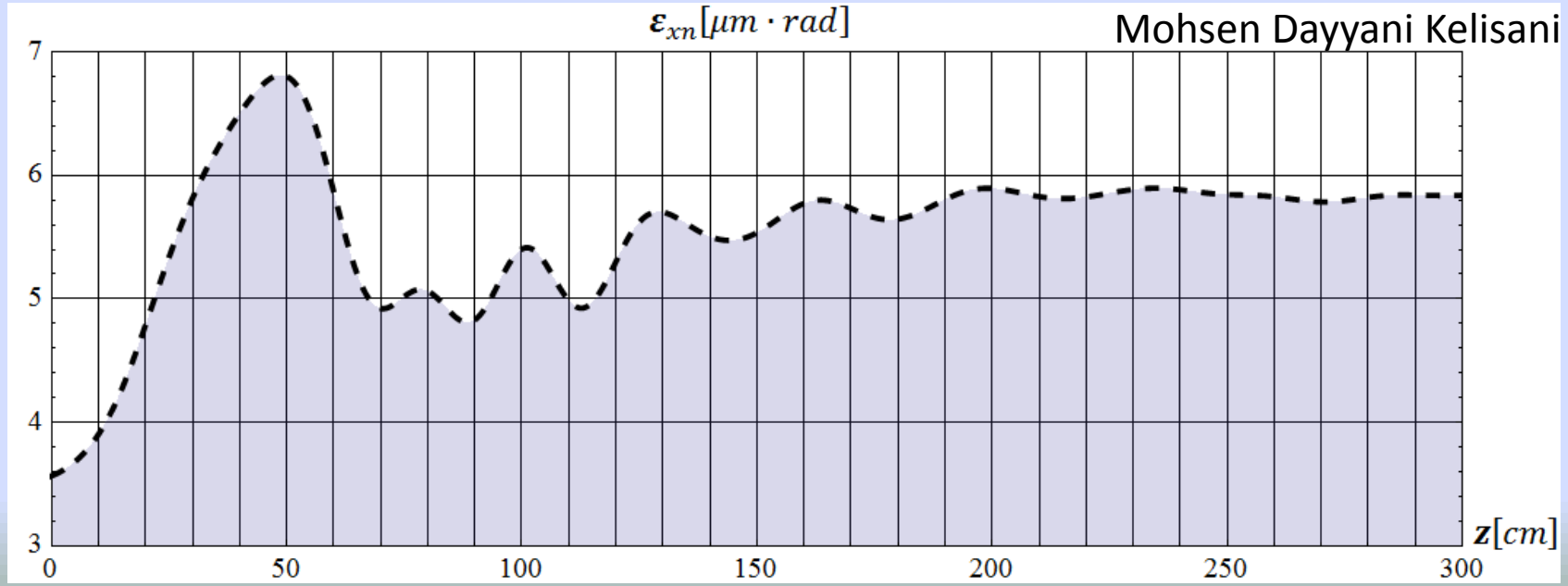
Tentative klystron parameters

PARAMETER	VALUE	UNITS
RF Frequency	999.516	MHz
Bandwidth at -1dB	≥ 1	MHz
RF Power:		
Peak Power	≥ 20	MW
Average Power	150	kW
RF Pulse width (at -3dB)	150	µs
HV pulse width (at full width half height)	165	µs
Repetition Rate	50	Hz
High Voltage applied to the cathode	tbd, ≤ 180	kV
Tolerable peak reverse voltage	tbd	kV
Efficiency at peak power	67 ≤ 70	%
RF gain at peak power	tbd, > 48	dB
Perveance	tbd	$\mu A/V^{1.5}$
Stability of RF output signal at nominal working point		
RF phase ripple [*]	±1 (max)	RF deg
RF amplitude ripple	±1 (max)	%
Pulse failures (arcs etc.) during 14 hour continuous test period	≤ 1-2	
Matching load, fundamental and 2nd harmonic	tbd	VSWR
Average radiation at 0.1m distance from klystron	≤ 1	µSv/h
Output waveguide type,	WR975 pressurised	2-3 bar

Status: Two prototypes ordered in industry

DB gun simulations





Mohsen Dayyani Kelisani