THE CLIC PETS ON/OFF OPERATION. PRINCIPLES AND DESIGN

4th X-band Structure Collaboration Meeting – 4th May 2010

Alessandro Cappelletti for CLIC collaboration

INTRODUCTION

International Linear Collider. Technical Review Committee
Second Report (2003)

CLIC feasibility issues, Ranking 1.

Reliability

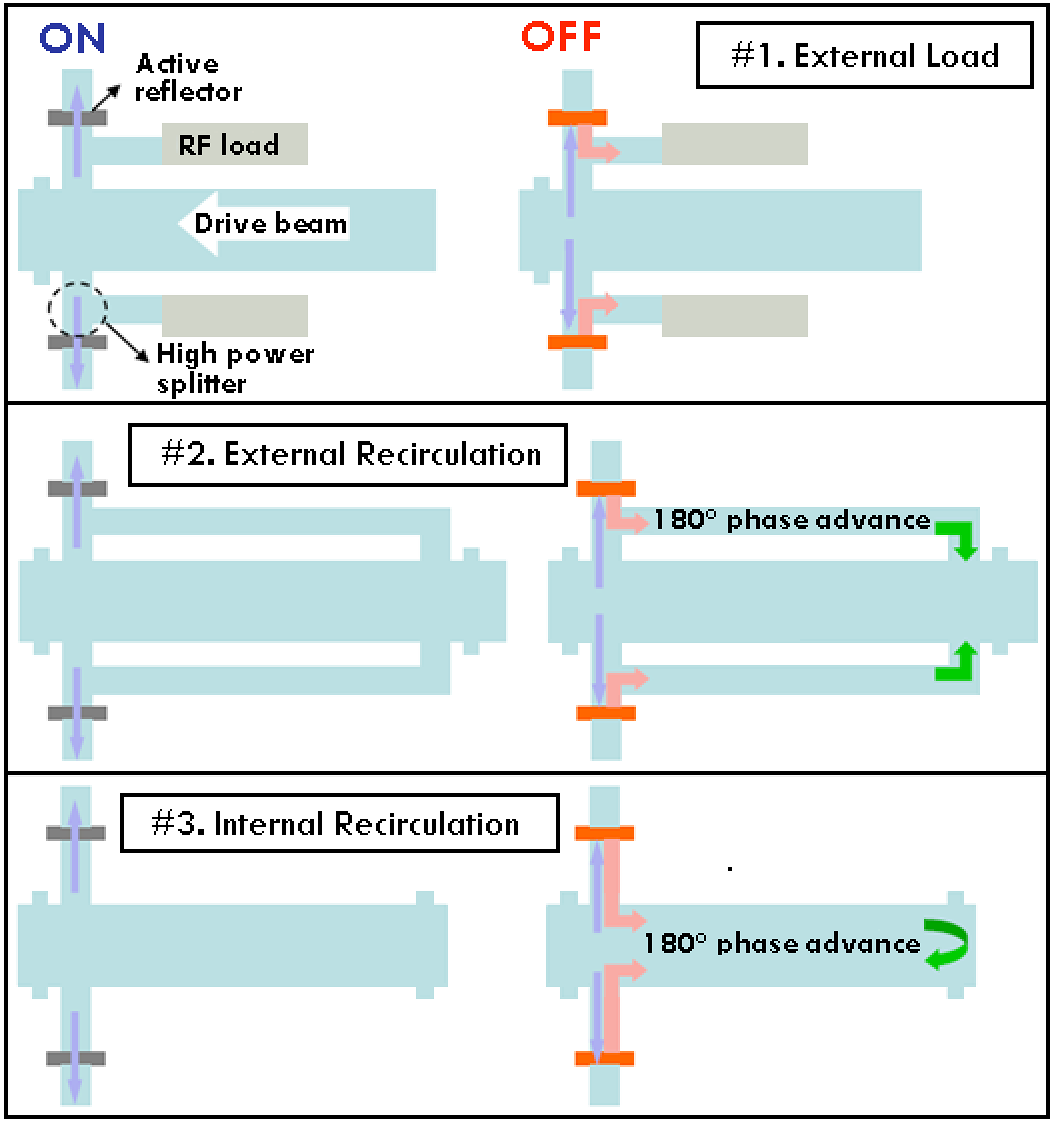
- In the present CLIC design, an entire drive beam section must be turned off on any fault (in particular on any cavity fault). CLIC needs to develop a mechanism to turn off only a few structures in the event of a fault

- During the machine operation, the accelerating structure and/or PETS will suffer from a number of RF breakdowns.

- Currently we have little information about the actual behavior of the structures at a very low (by design: $<3x10^{-7}$ /pulse/meter) breakdown trip rate, thus it might be necessary to switch off the single structure/PETS and re-process it.

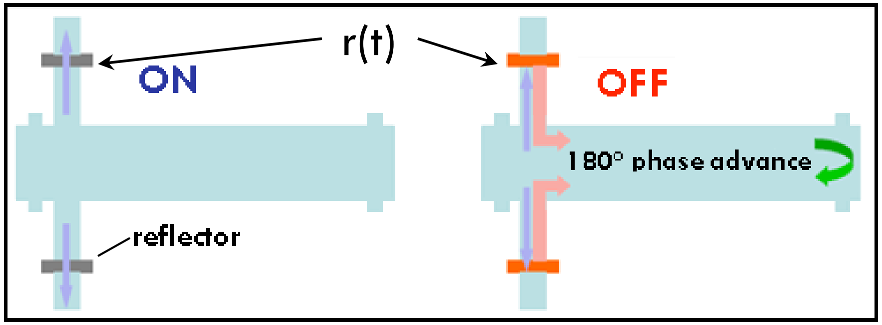
- In order to maintain the operation efficiency, we want to perform the off switching very fast between the pulses (20 msec).

BASELINE ON/OFF CONCEPT WITH EXTERNAL COMMUTATION AND INTERNAL RECIRCULATION

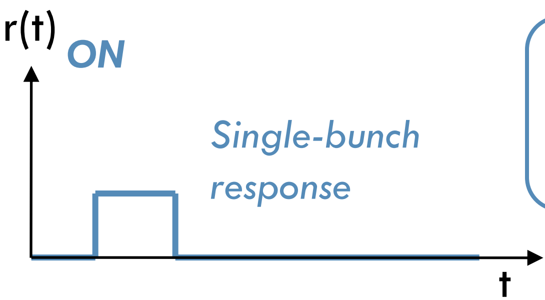


- With the proposed method the complete suppression of the RF delivery to the accelerating structure can be achieved.
- The RF power produced in the PETS itself will be significantly reduced for the cases #2 and #3.
- The case #3 was chosen as a base line due to the best efficiency and lowest cost.
- The method requires the development of a special RF high power switch.

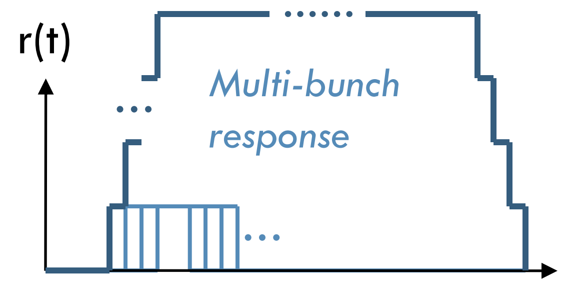
PRINCIPLE ILLUSTRATION

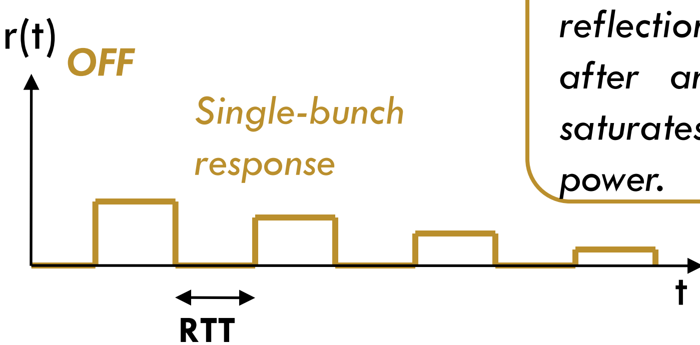


We consider the signals envelopes at the reflector section, in a **dispersion-free approximation.**

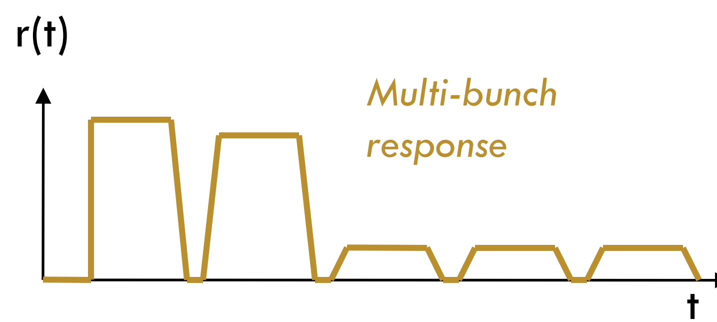


Every $t_0=\Delta_b/c$, a new signal reaches the output section and adds up to the previous ones.

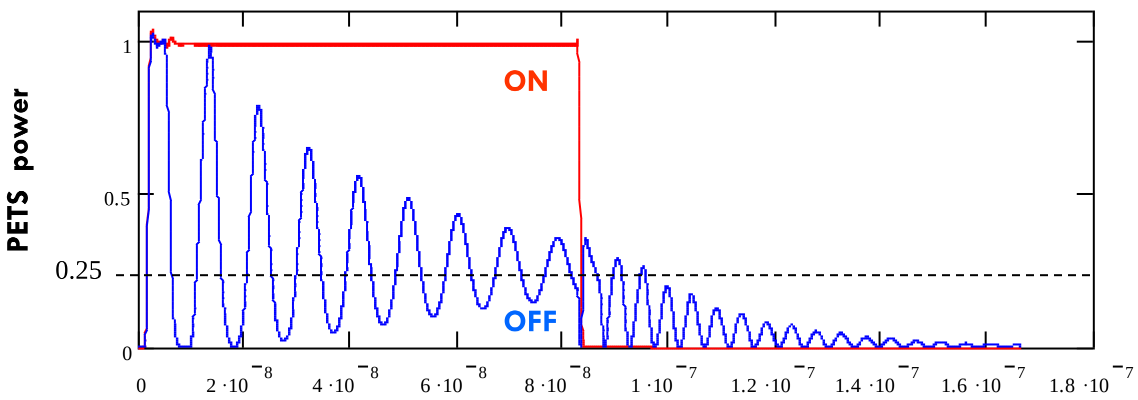


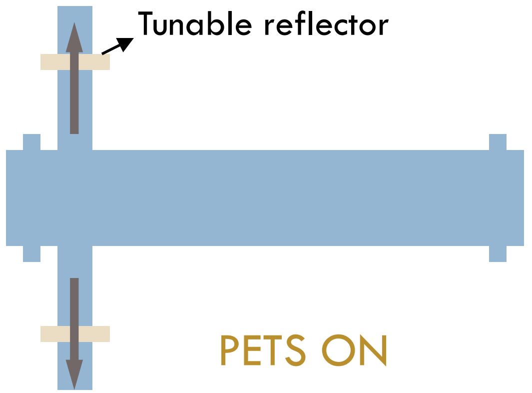


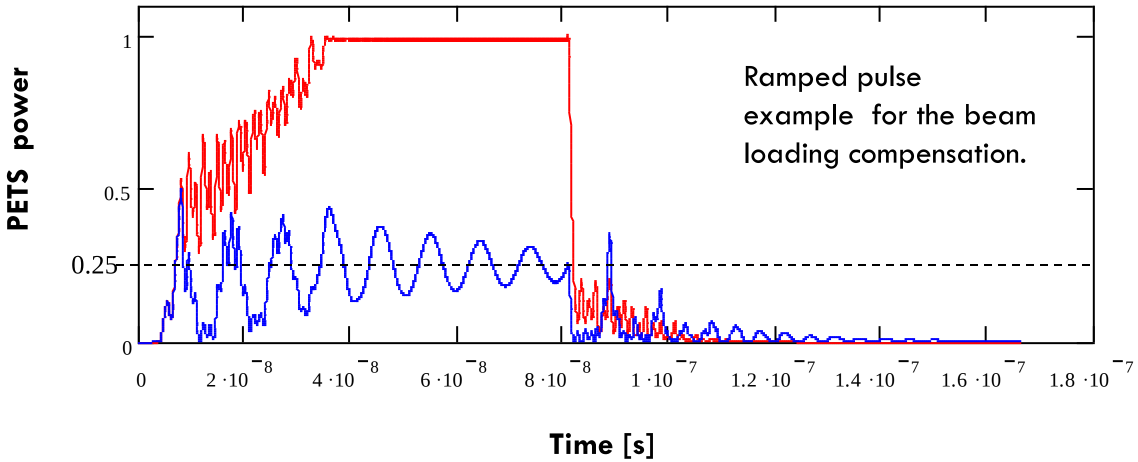
The s.b. response is made of signal reflections. The m.b. response, after an initial power build-up, saturates to a fractionof the "ON" power.

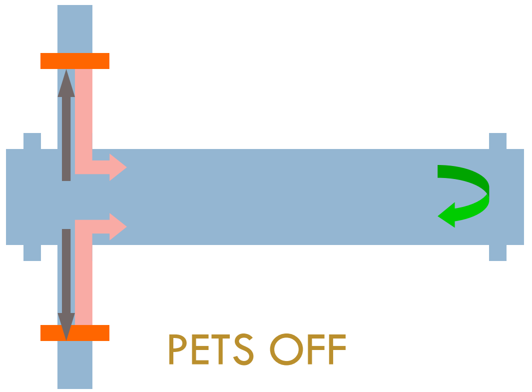


INTERNAL RECIRCULATION



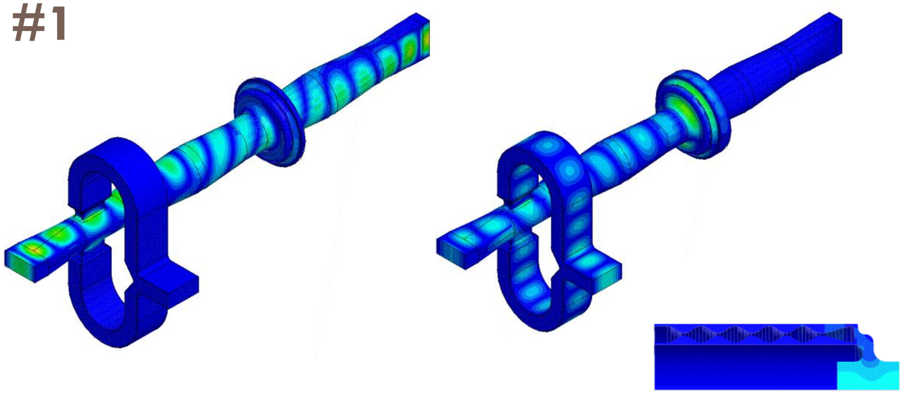


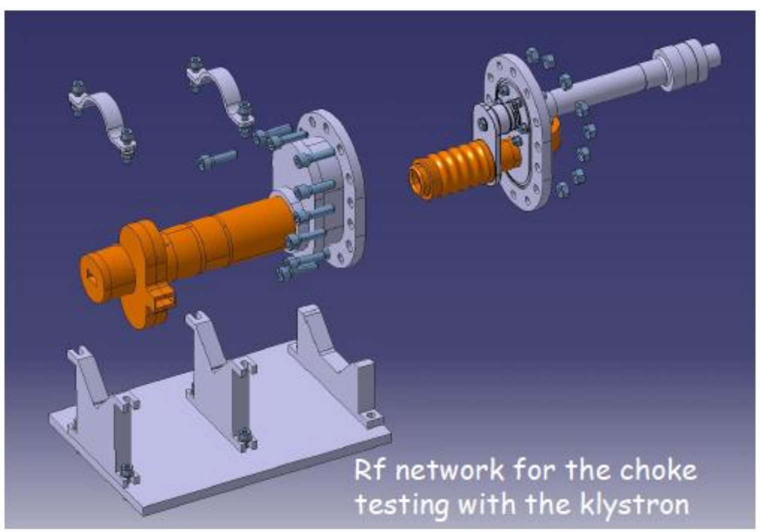




REFLECTOR DESIGNS

#1

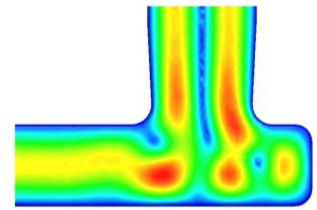


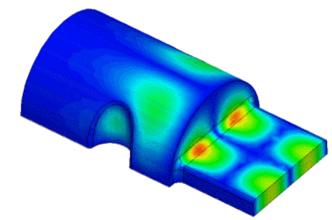


Bulky, expensive; high field concentration; testing needed, success not guaranteed.

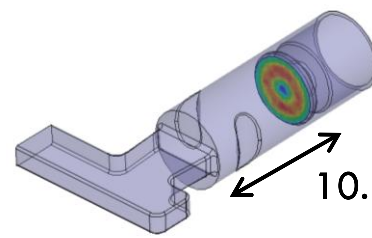
#2

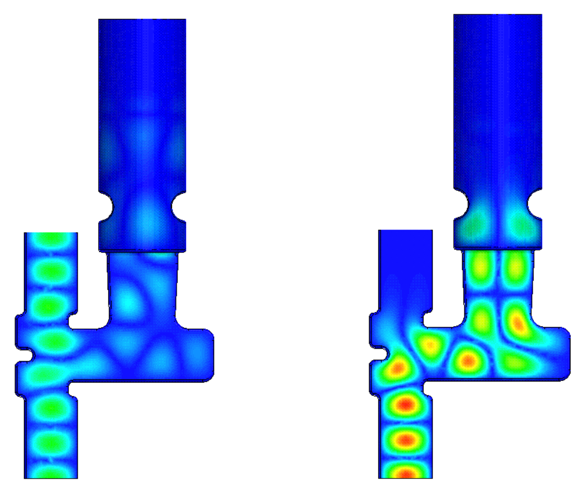
Original idea by S. Kazakov (KEK)



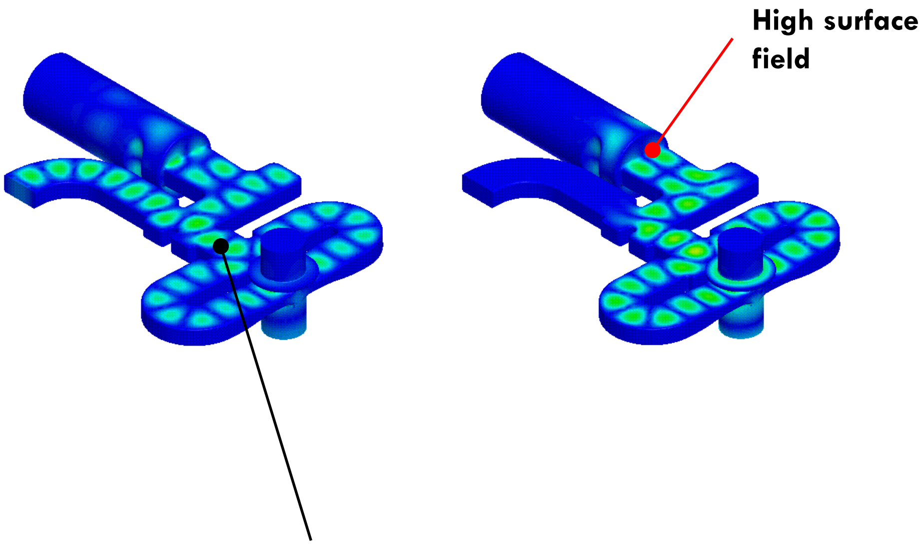


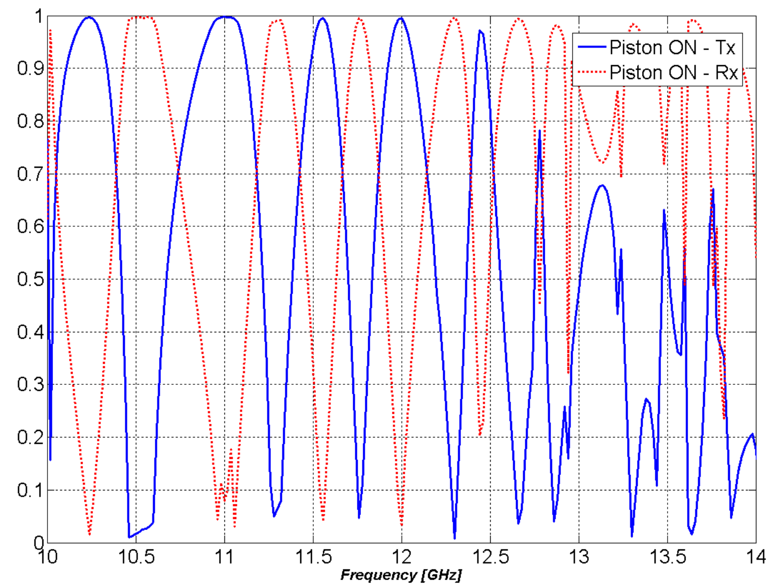
$TE_{10} \rightarrow TE_{20} \rightarrow TH_{01}$

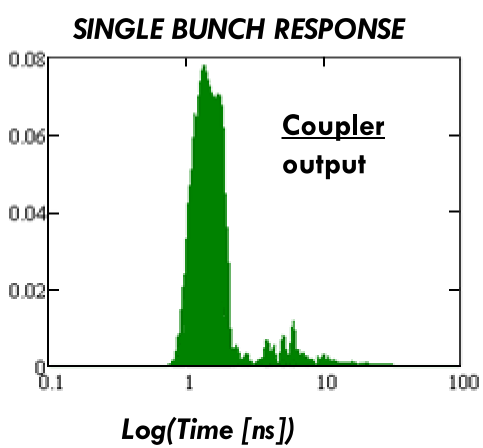


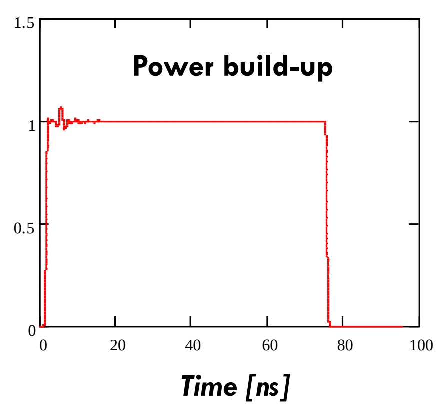


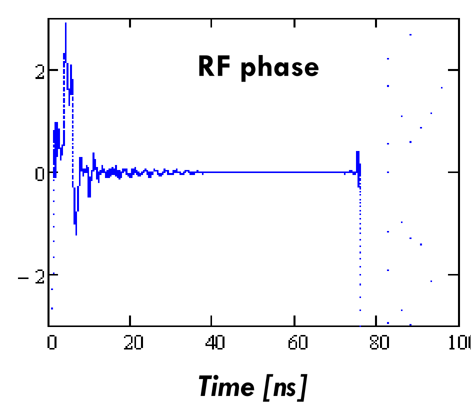
LIMITS OF DESIGN #2



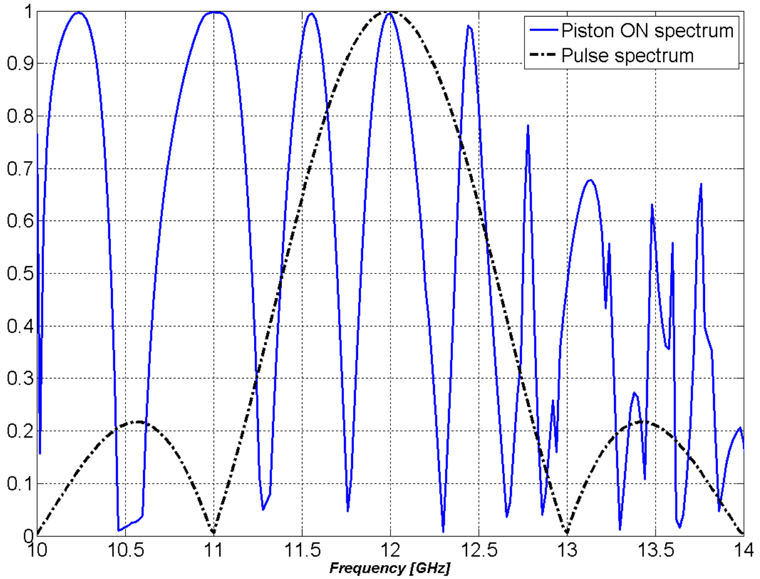


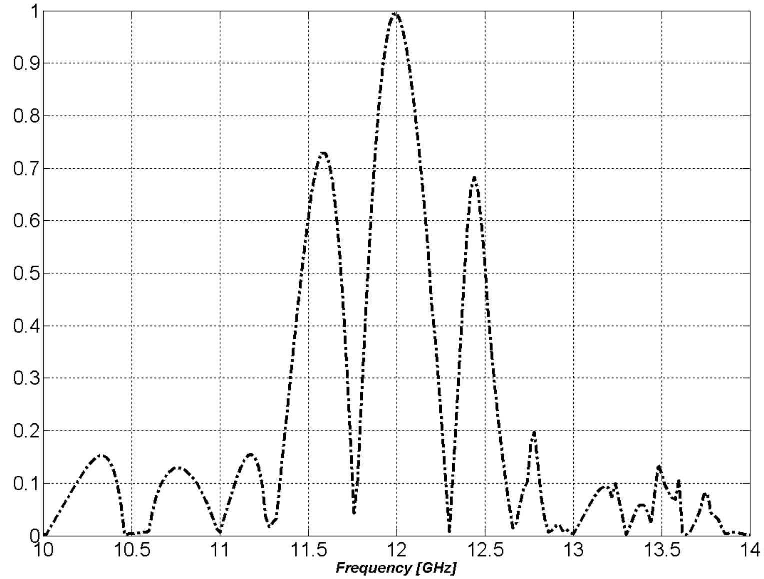


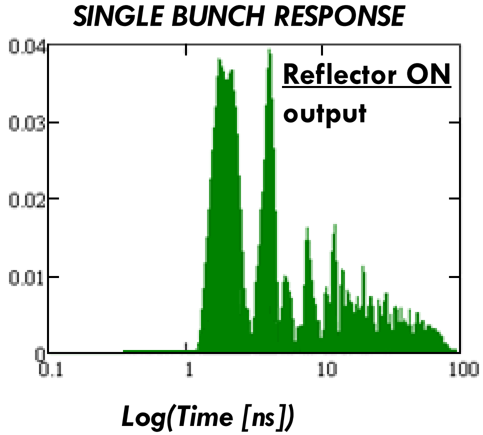


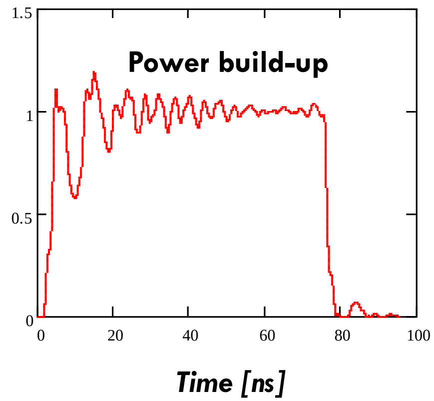


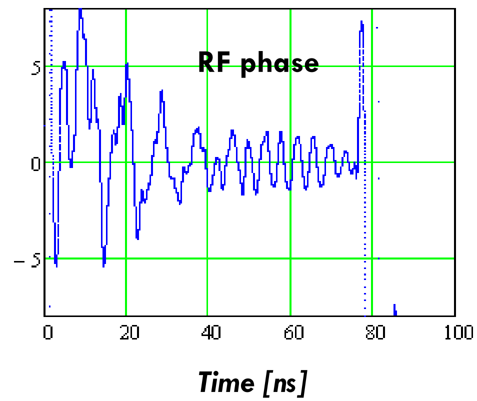
LIMITS OF DESIGN #2



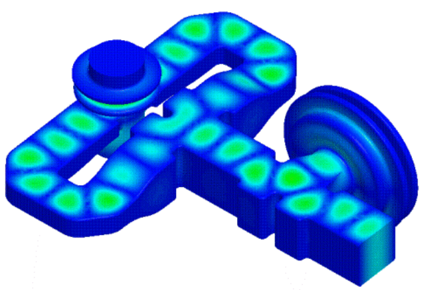


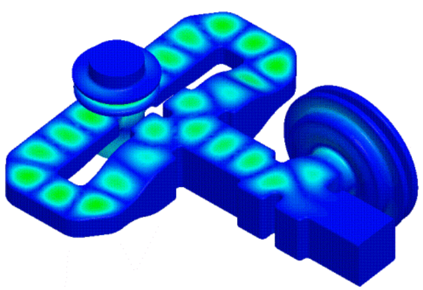


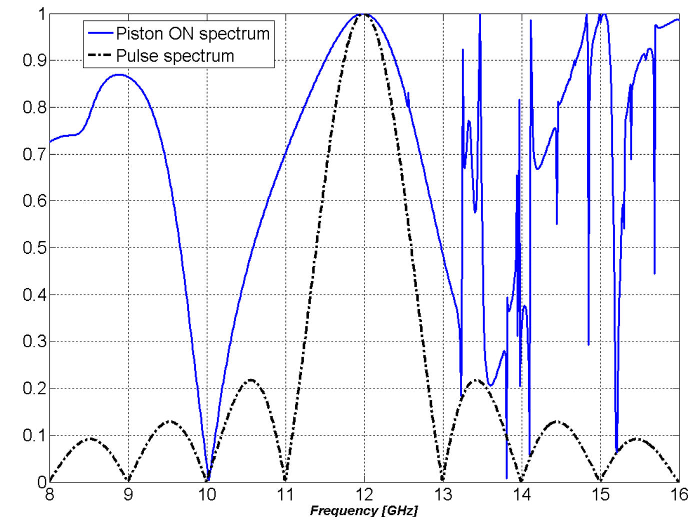




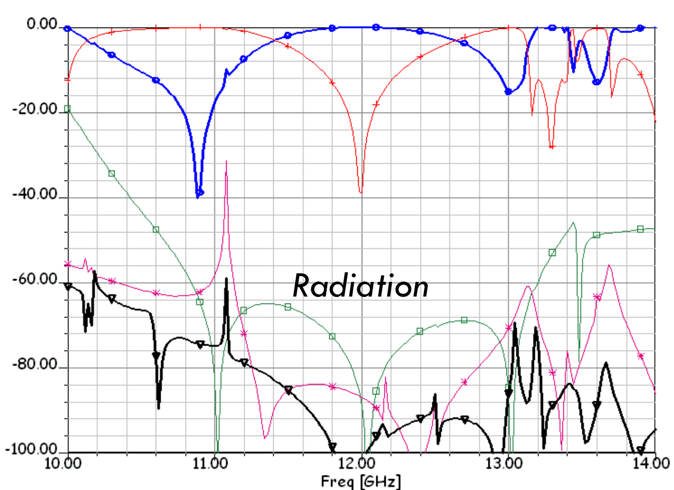
REFLECTOR: DESIGN #3

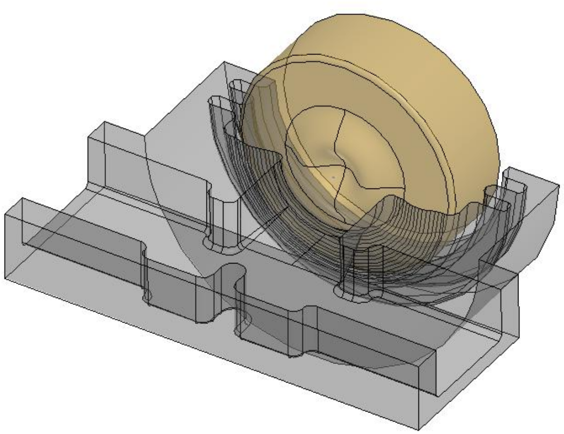




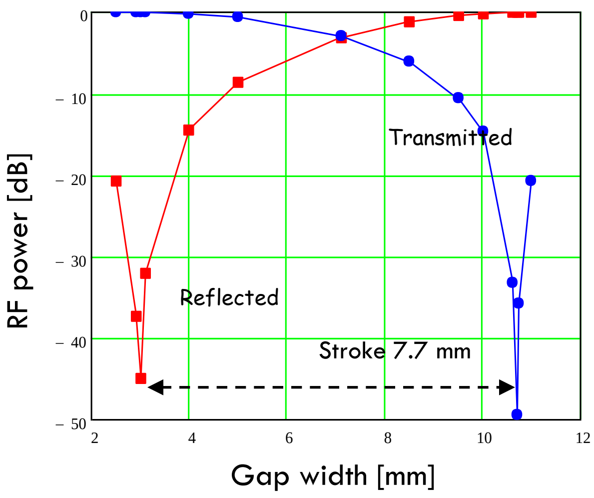


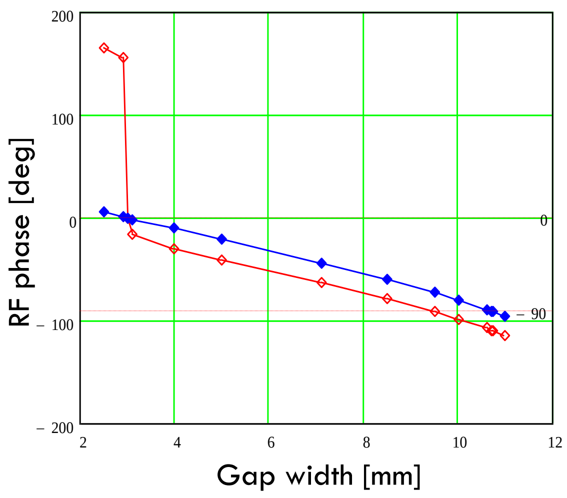
- extremely broad band (~4 GHz)
- low surface electric field (< 45 MV/m)
- reduced actuators stroke (~λ/4)
- contact-free

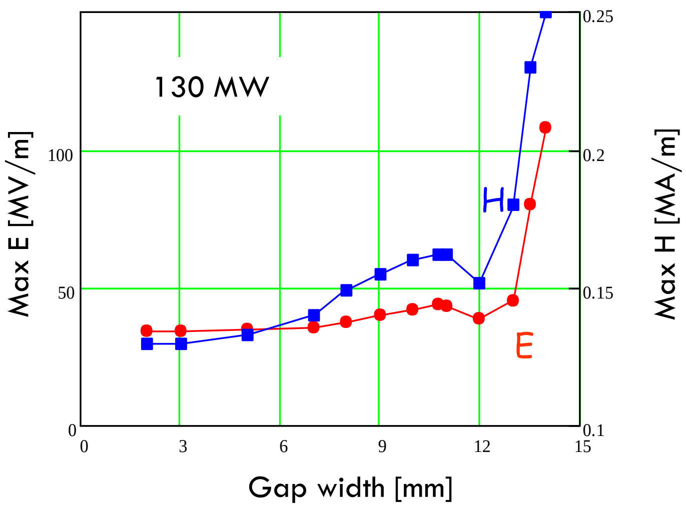




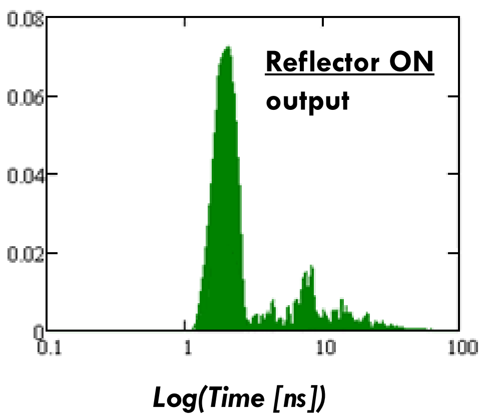
REFLECTOR: DESIGN #3

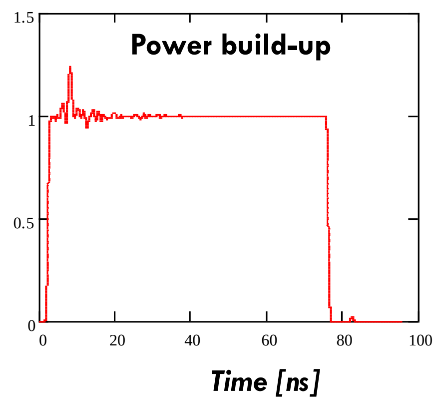


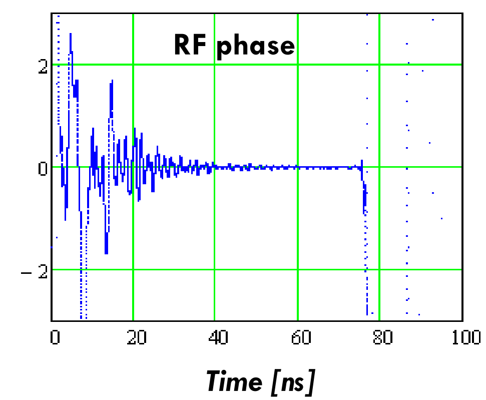




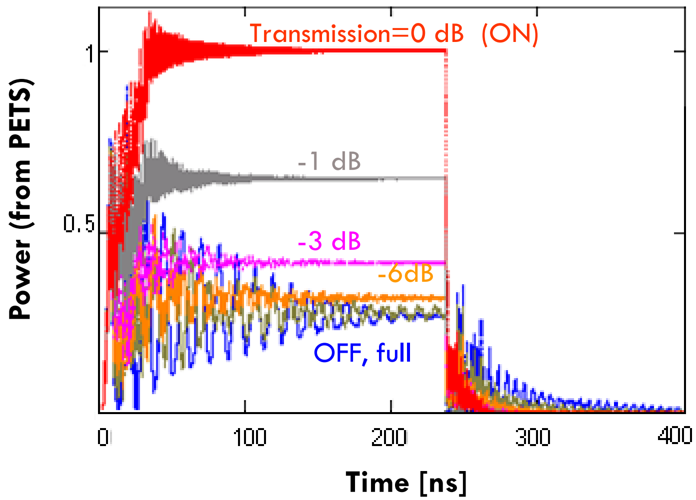
SINGLE BUNCH RESPONSE

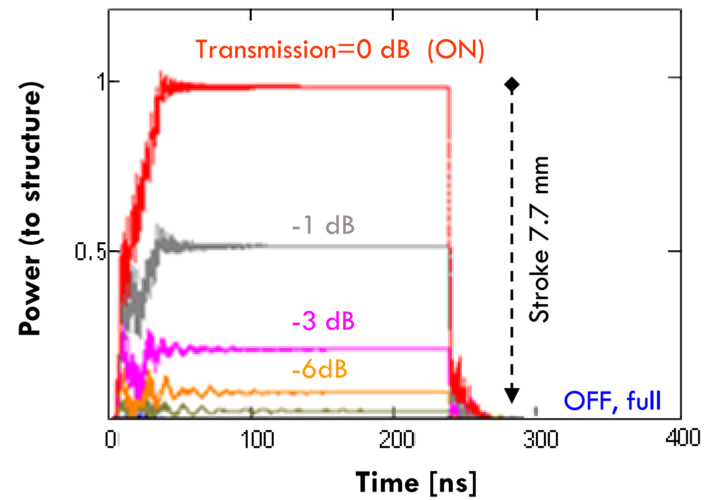


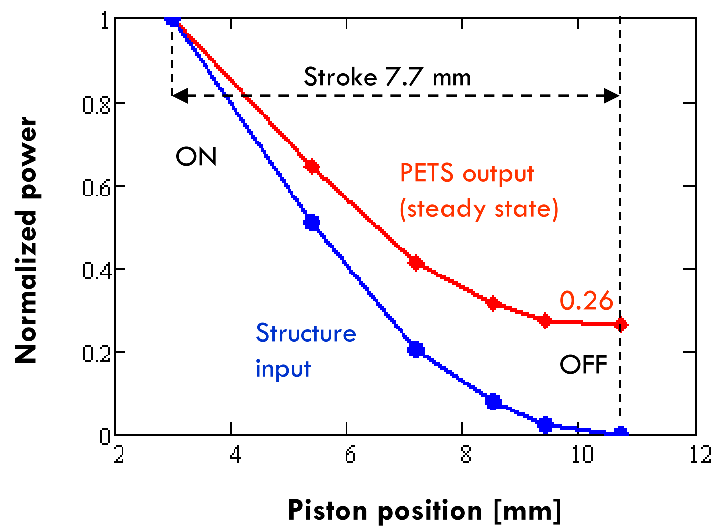




SIMULATED SIGNALS





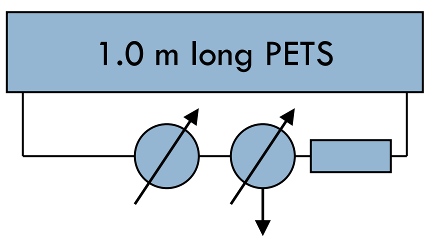


THE ON/OFF FEASIBILITY DEMONSTRATION

TBTS:

- PETS current configuration (recirculation)

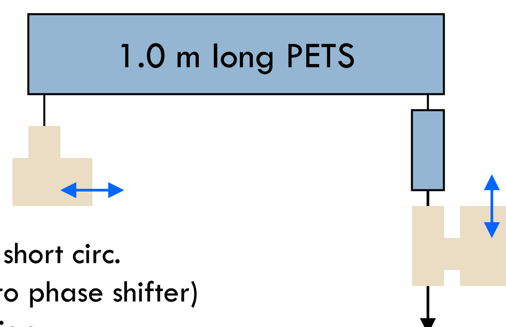
3-10A



End 2009/10

- PETS RF network modification
  (internal recirculation – ON/OFF option)

23 A

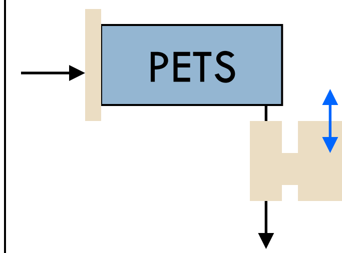


variable short circ.
(analog to phase shifter)
CLIC design

variable reflector
(analog to attenuator)
CLIC design

Integrated
Short circuit

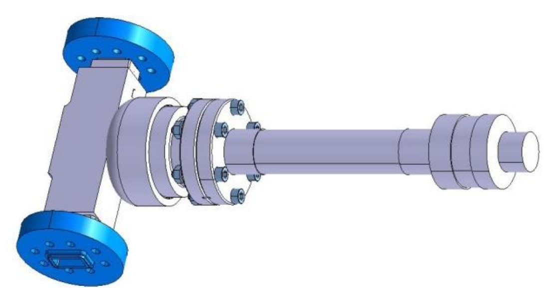
CLIC reference



variable reflector
CLIC design

-The ON/FF feasibility demonstration will require full (22.8 A) current.

Variable reflector

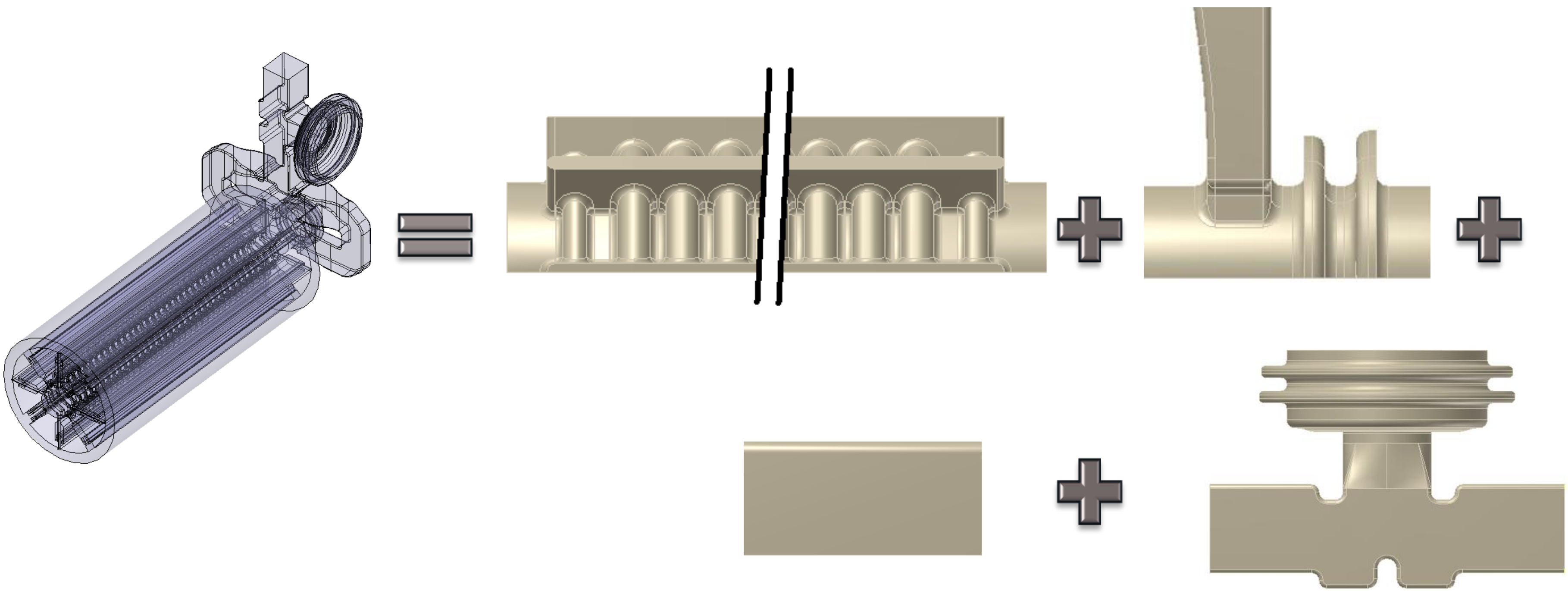


BUILDING IN PROGRESS!

PULSE PROPAGATION MODEL. INTRODUCTION

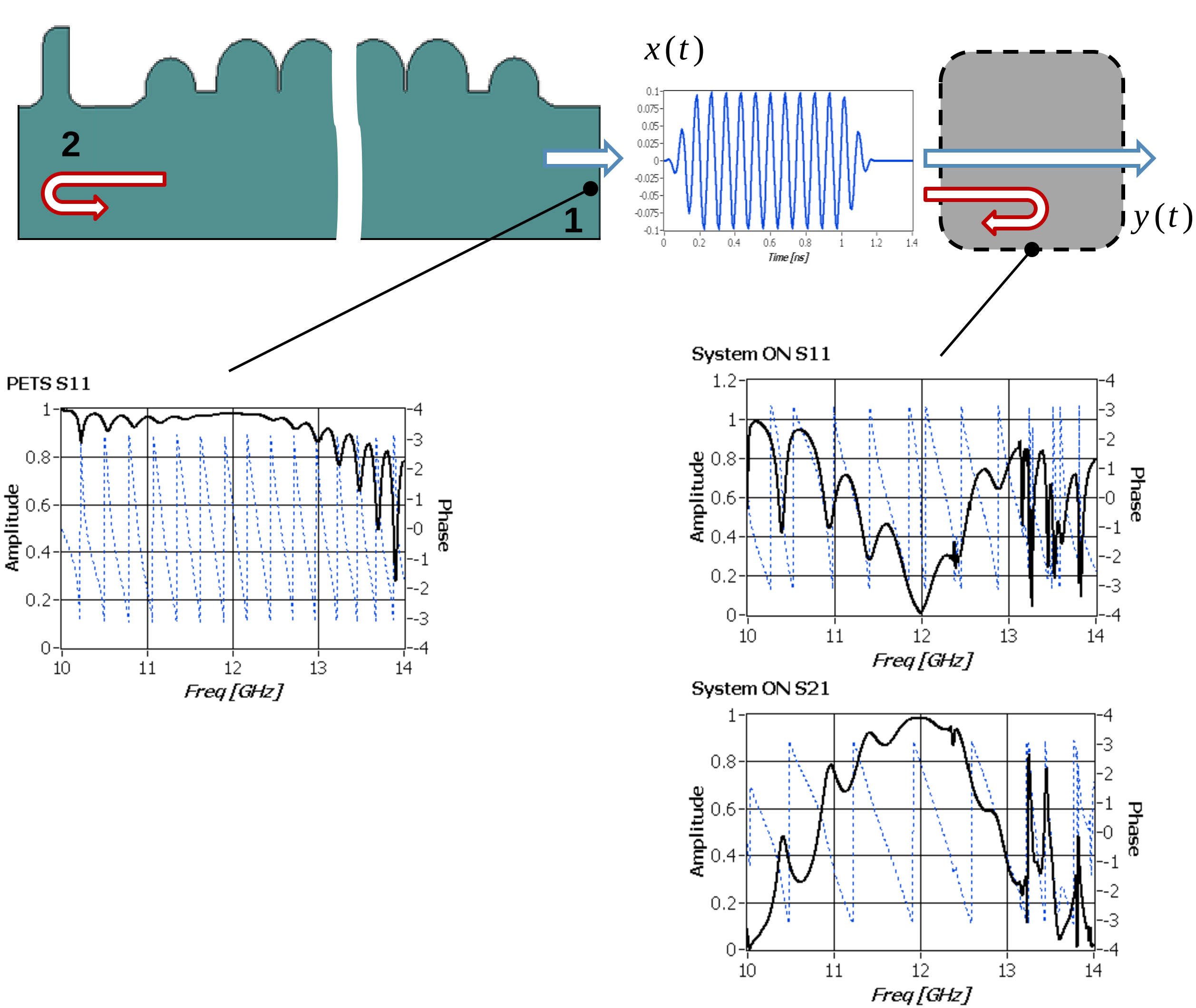
- The PETS ON/OFF mechanism design was firstly based on HFSS simulations.
- However, that approach alone is unfit to deal with the flexibility of the entire system and the computational load it would generate.
- A mathematical model of the whole device has been developed. It allows:
  - to get a numerical/analytical representation of any component we need to include into the RF network;
  - to perform an in-depth signal analysis to investigate the transmission and reflection issues and the resulting power production;
  - to tune up some parts of the system without resorting to time-consuming simulations;
  - to quickly adapt the model to any configuration we may want to test.

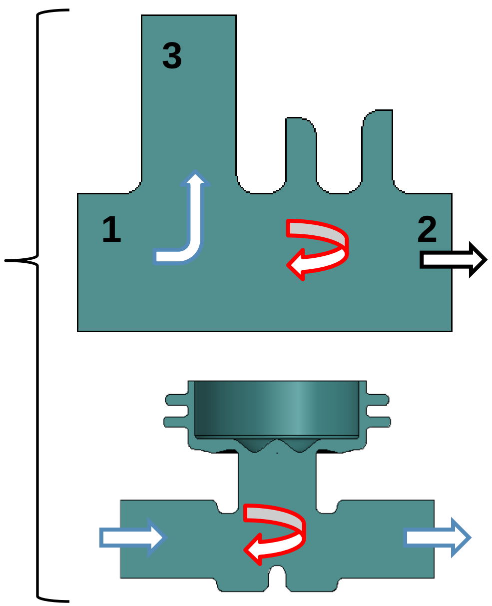
THE RF COMPONENTS



- Each device is characterized by its transfer function.
- A cascade of two-port devices is still equivalent to a two-port device (e.g.: inserting waveguide chunks).
- The signals can be analyzed at chosen sections (PETS, reflector).

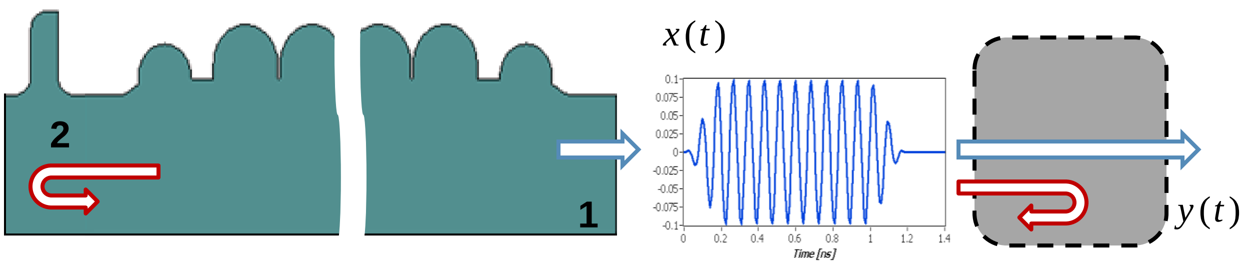
THEORETICAL APPROACH

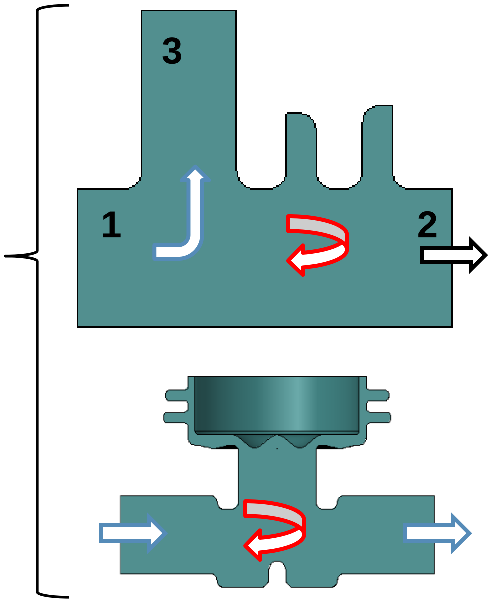




- x(t) is constructed analytically
- An input/output equation is needed to model the system

MATHEMATICAL MODEL





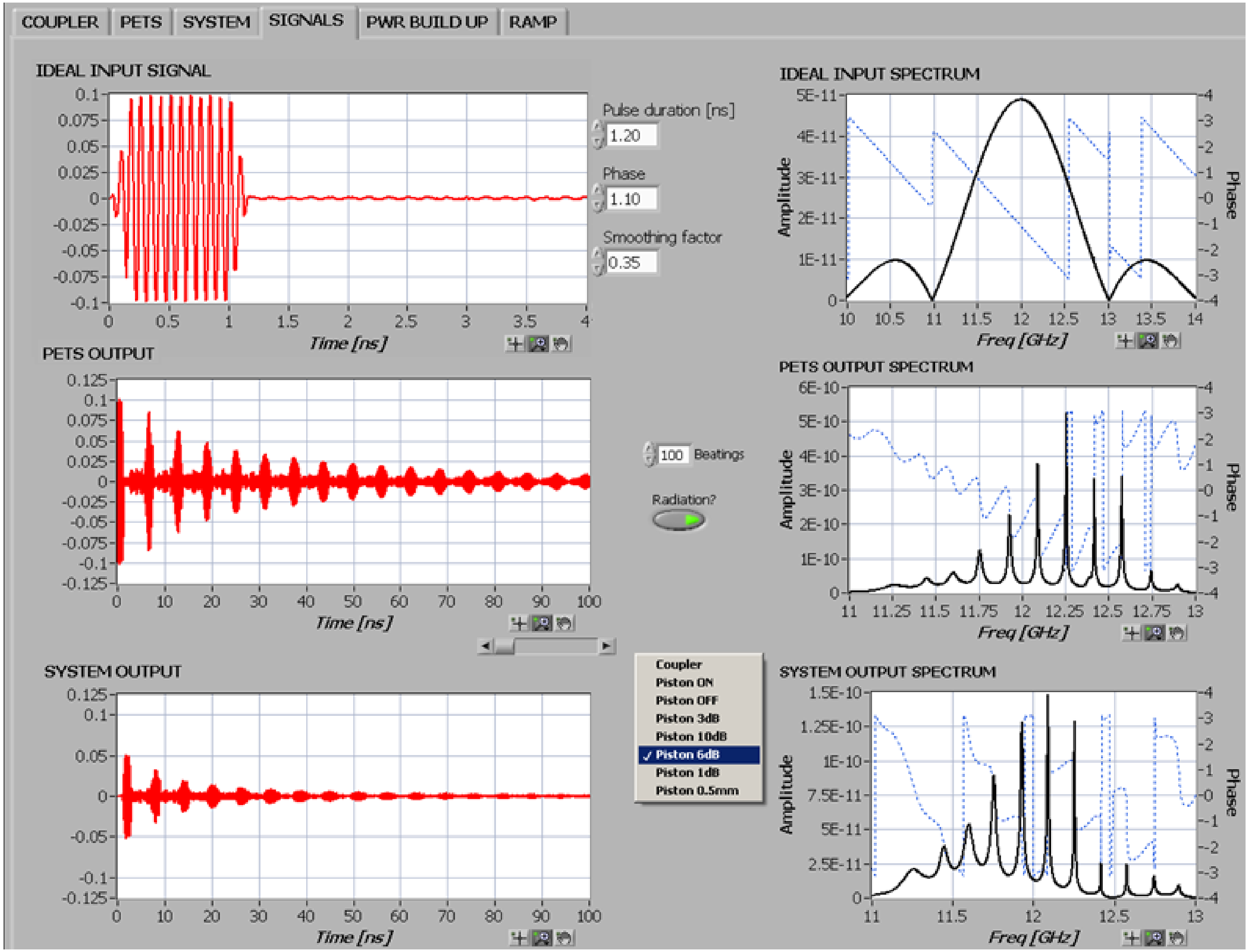
$$Y(f) = X(f)(1 + S_{21,c} S_{12,pnc} D) \sum_{k=0}^{N} (S_{11,s} S_{11,p})^{k} S_{31,s}$$

PETS output

System output

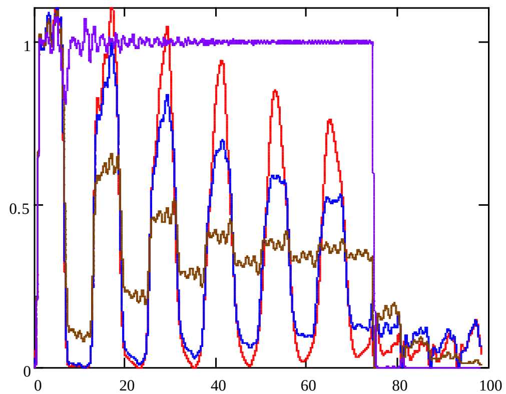
- c: coupler
- *pnc*: PETS with no choke
- *s*: system
- *p*: PETS

SOFTWARE IMPLEMENTATION

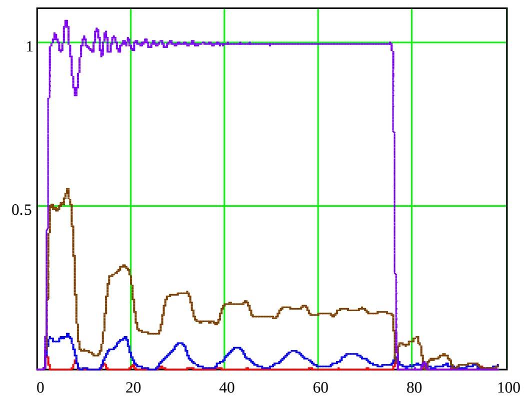


POWER BUILD-UP

Power (from PETS)



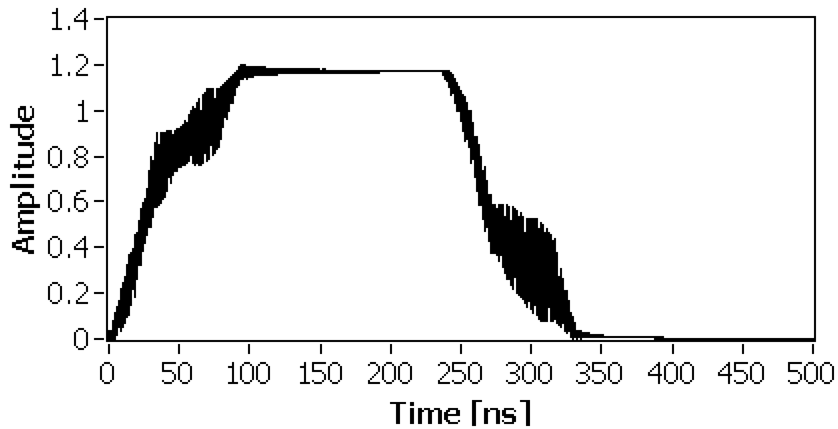
Power (to structure)



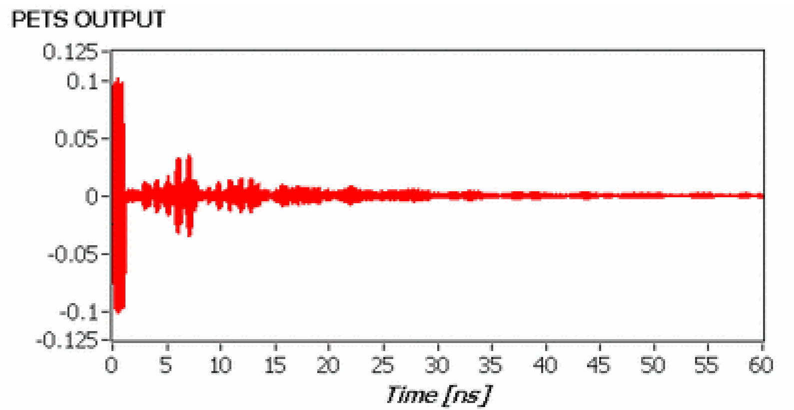
Note: for each reflector configuration, a waveguide of optimized length should be introduced

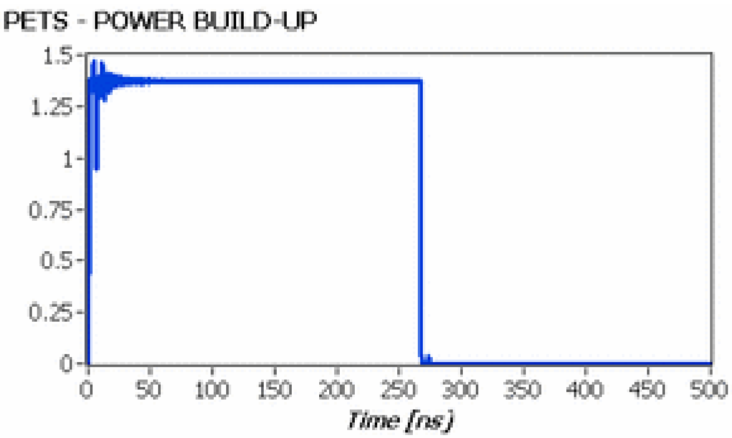
It is possible to test and verify the phase modulation schemes used in the bunch recombination concept.

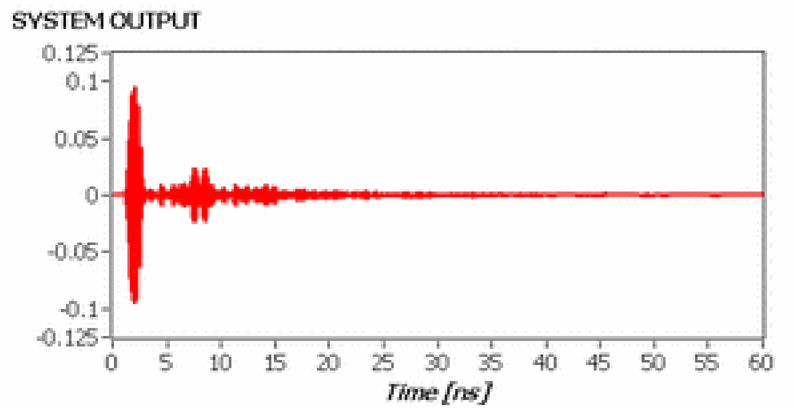
RAMPED PULSE

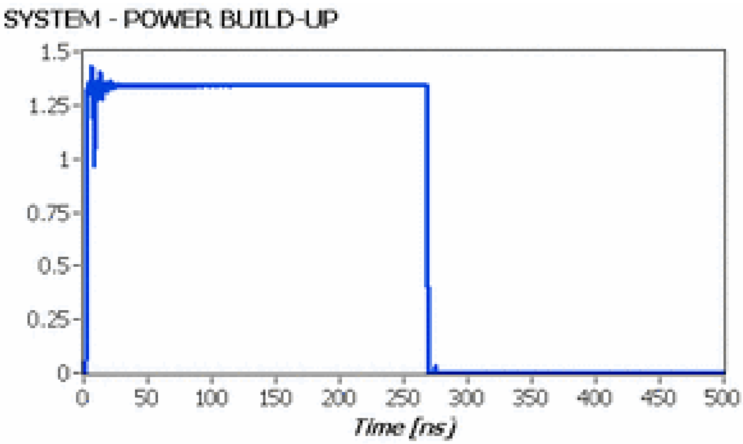


THE SIMULATED SIGNALS









0 dB

CONCLUSIONS

- The whole PETS ON/OFF study is overall at a well advanced stage.
- The proposed model provides a relatively easy-to-implement algorithm for simulating the pulse propagation in the ON/OFF system.
- Alternative configurations can easily be tested and the results can be discussed with the beam dynamics section.
- An improved design of the coupler will result into signals affected by lower reflection levels.
- … questions?