High-Power RF Test Areas:
Design & Planning Progress of the CERN Klystron Test Area

CLIC WORKSHOP 2008

1. **Objectives**
2. **Layout**
3. **Modulator purchase status**
4. **SLED2 Pulse compressor**
5. **BOC Pulse compressor**
6. **Milestones and deliverables**

Objectives

Objectives:

1) Collaborate with CERN for the development and construction of a 12 GHz Klystron based Test Stand at CERN

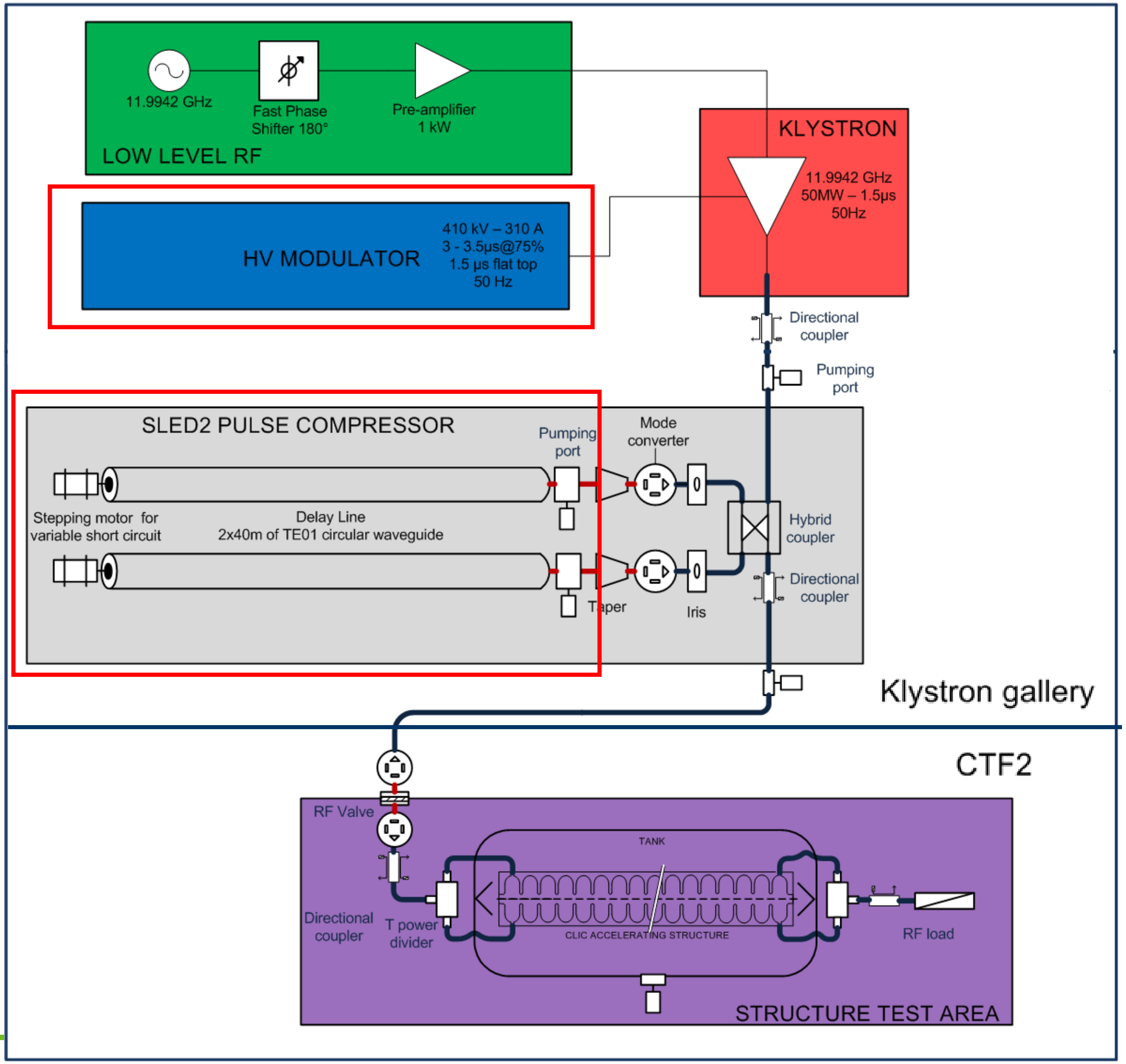
2) Get an experience on critical components for a future additional test stand at CEA Saclay in the SYNERGIUM accelerator test area (352 MHz, 704 MHz and 1.3 GHz power sources already exist)

CEA Participation to the CERN Test Stand:

1. High voltage modulator
   - Procurement, installation and tests with a 12 GHz klystron
2. RF Pulse Compressor
   - Design, fabrication and installation
3. RF Components
   - Procurements of loads or dir. couplers

In the framework of exceptional contribution of France to CERN

Layout with SLED2 pulse compressor (baseline)



HV Modulator: Call for tender

1) 1st Phase of Call for tender : Pre-selection of candidates

✓ **done in June 2008**

✓ **3 companies pre-selected**

2) 2nd phase of Call for tender :

o Technical specification and commercial documents submitted to the 3 candidates

o 45 days of delay for technical and commercial answer

3) Choice of the company

4) Adjudication of the contract

We miss now the 12 GHz klystron characteristics to finalize the modulator technical specification (perveance, gun mechanical configuration, nb of power supplies…)

HV Modulator: Pre-selection criteria

Preliminary specification:

- Pulse repetition rate = **50 Hz** but with an indication from the candidate if it is possible to provide a 100 Hz system
- Peak voltage = **460 kV,** Peak current = **310 A** Pulse length = **1.5 μs (flat top), 2.3 μs (at FWHM)**.
- Scope of the delivery:
  - High voltage pulsed power supply, auxiliary power supply (klystron focus magnet, filament, ion pump), high voltage oil tank, X-ray shielding, control-command system
- Scope of the services:
  - Fabrication of the system, acceptance tests at factory, installation and acceptance tests on-site with a 12 GHz klystron from SLAC (delivered by CERN).

Options:

Option 1 – realization of a second modulator with the same specification (for CEA Saclay Test Stand)

Option 2 – One additional year of maintenance

Delay : 12 months from the date of contract adjudication → **may become the critical path of the schedule**

Again, we need the 12 GHz klystron characteristics to be able to start the 2nd phase of modulator call for tender

Pulse compressor specifications

Preliminary specifications

Parameters	Values	units
Frequency	11.9942	GHz
Multiplication factor	2.5 min	-
Input power	50 min	MW
Output power	**150 min**	**MW**
Input pulse length	1.5	µs
Output pulse length	**300**	**ns**
Vacuum level	1.10^{-8} max	mbar

Complementary specifications to be discussed and defined

- Bandwidth
- Time to reach the nominal vacuum level
- RF pulse amplitude ripple
- RF pulse phase ripple
- Pulse to pulse stability (amplitude)
- Pulse to pulse stability (phase)
- Thermal stability
- Cooling circuit
- RF leakage
- X-ray radiation

- Ability to vary the pulse amplitude
- Ability to vary the pulse length
- Ability to vary the slope

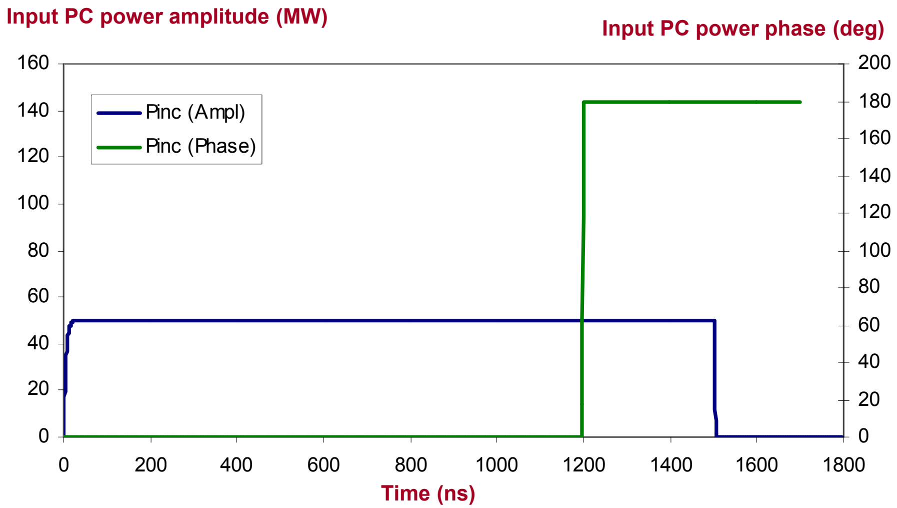
⇩

In order to study different philosophies of conditioning

SLED2: Pulse waveform after compression

- Propagation of the TE_{01} mode

$$L = \frac{T_d \cdot C^2}{2\omega}\sqrt{\omega^2 \mu\varepsilon - \frac{p'^2_{01}}{a^2}}$$



L : Length of the delay line

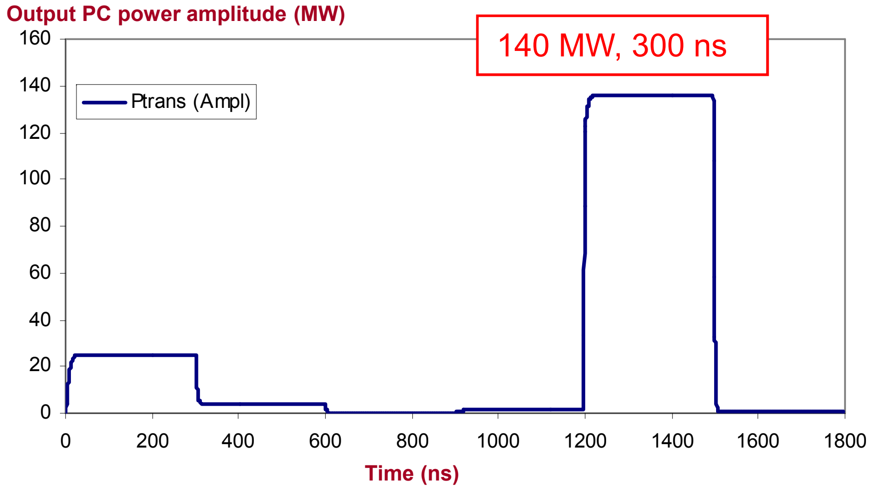
T_d :Time delay = $2L/v_g$ = length of output compressed pulse

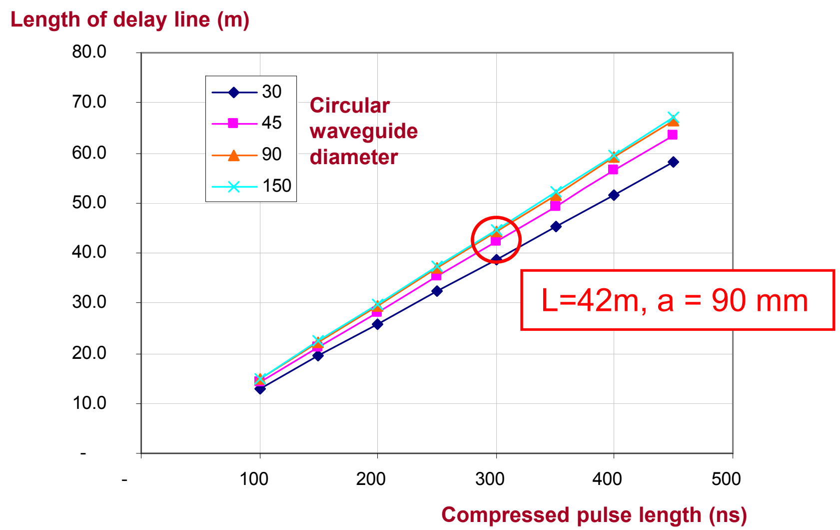
C : Light velocity

ω = 2πF with F operating frequency

p'_{01} : 1st root of J'_0 the derivative of J_0 the bessel function of kind
p'_{01} = 3.832

a : circular waveguide diameter

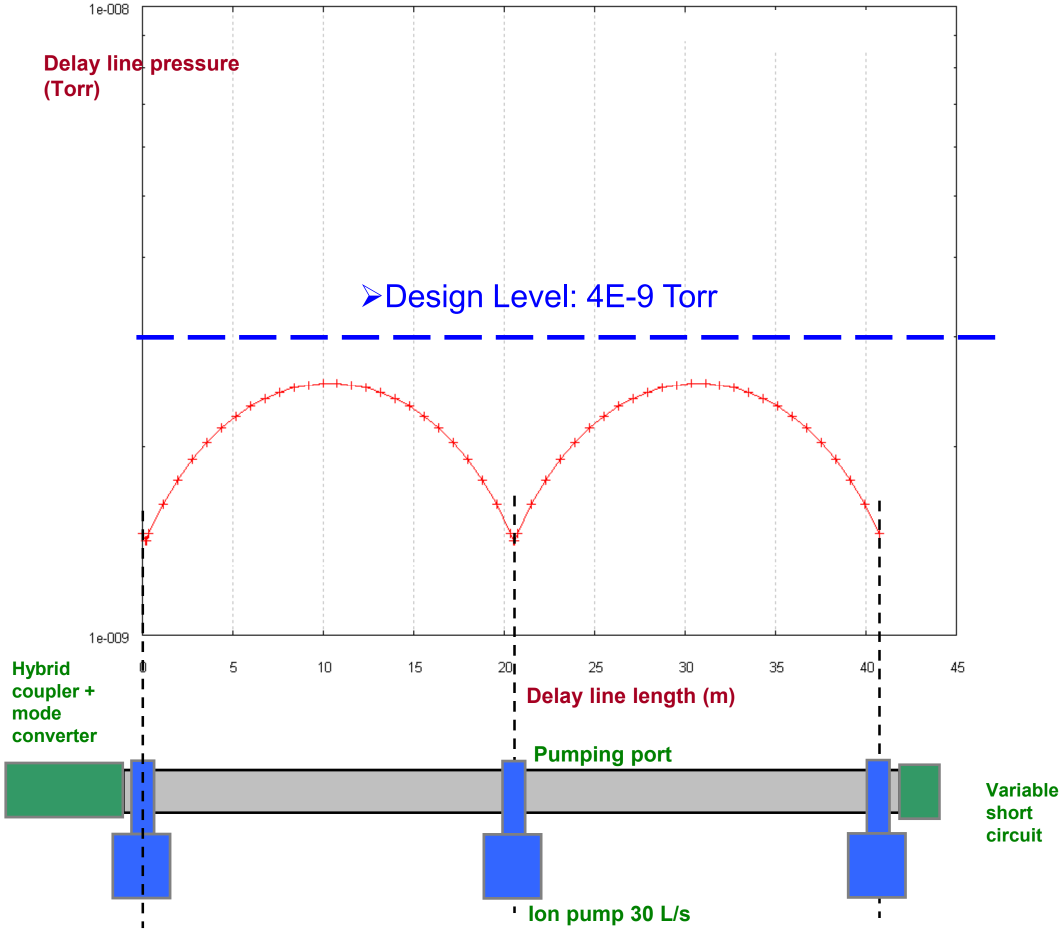




SLED2: Vacuum short study

- Cu OFHC
- Pre-heating at 950°C under vacuum during 10h
- bake out at 120°C

→ **q = 1.8 x 10^{-9} Torr.L.s-1.m-1**



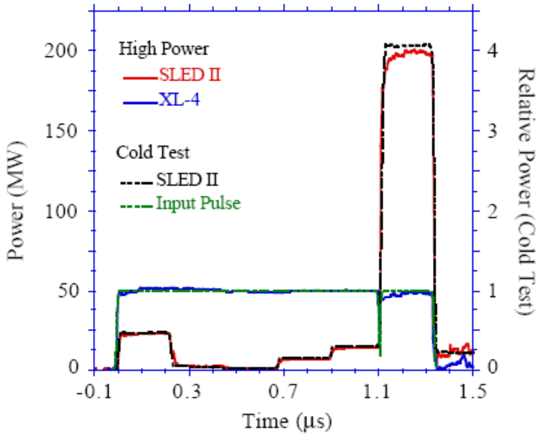
- Need at least 6 RF pumping ports, 3 ports on each delay line
- Sensitivity to the waveguide diameter?

SLED2 at SLAC

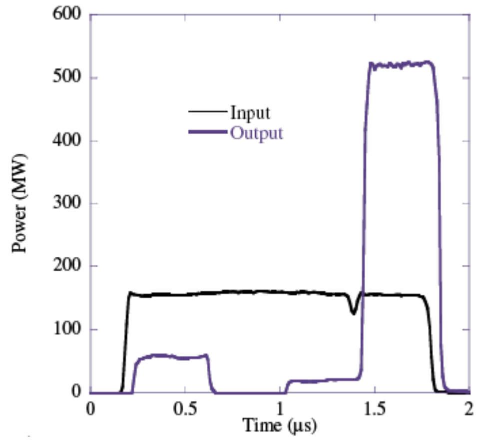
SLED-II concept was already demonstrated with NLCTA operation and runs routinely for high gradient research

S. Tantawi et al. Results:

With a single 50 MW klystron (1998)



With four 50 MW klystron and multimode PC (2005)

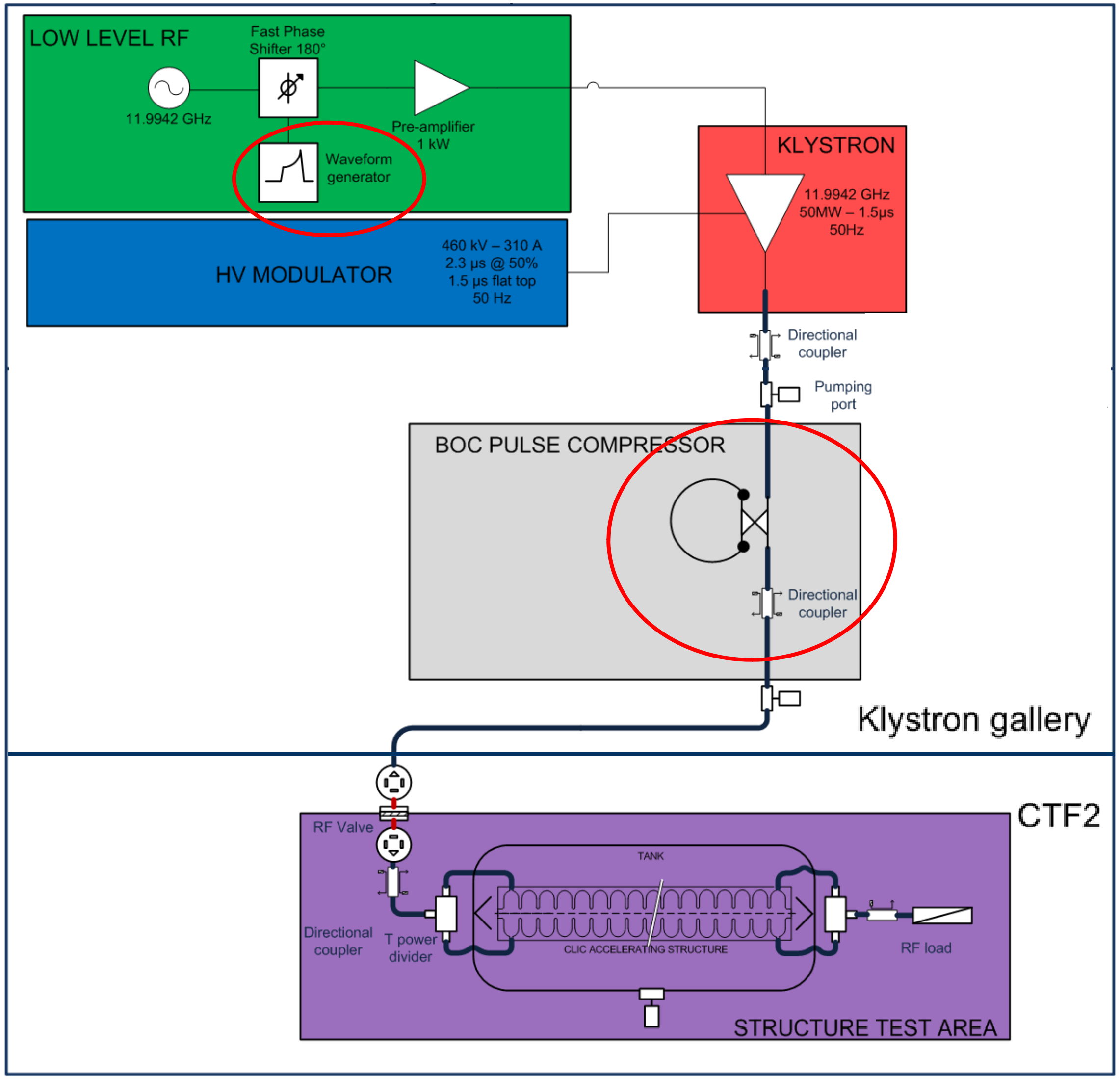


Recommendations from SLAC for our system are welcome (vacuum, tolerances for fabrication, mechanical support and alignment…)

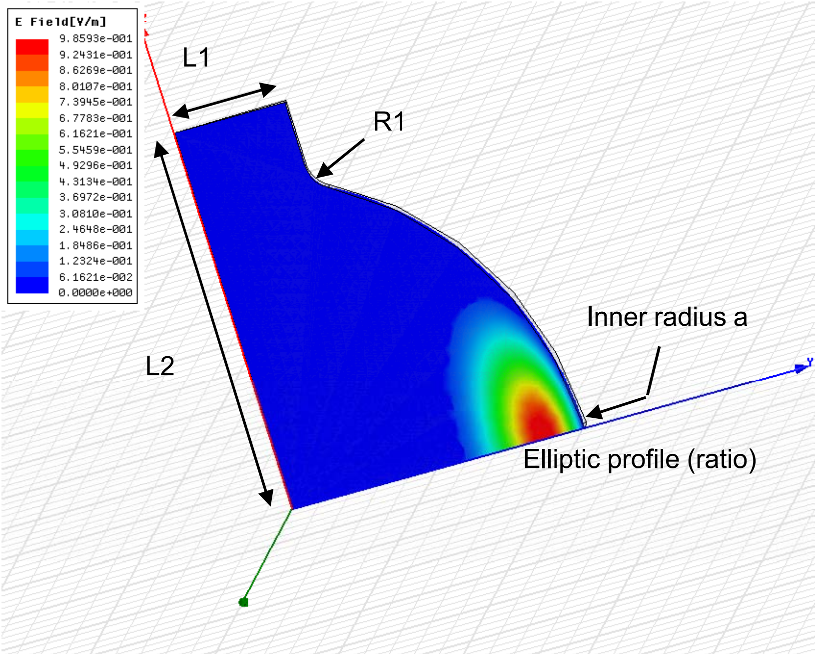
BUT: installation in CTF3 buildings may be problematic and cost could be high

→ Alternative solution: X-band Barrel Open Cavity (BOC)

Layout with BOC pulse compressor (option)



BOC: Preliminary RF design



$$Q_0 = \frac{a}{\delta}$$ With δ = skin depth

With a $TM_{20,1,1}$ mode:

a = 103.75 mm

L2 = 100 mm

R1 = 10 mm

L1 = 40 mm

ratio = 0.848

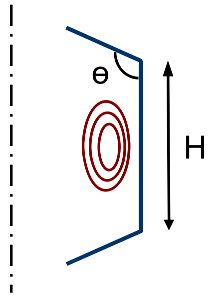
F_0 = 11.9968 GHz

Q_0 = 169465 with copper

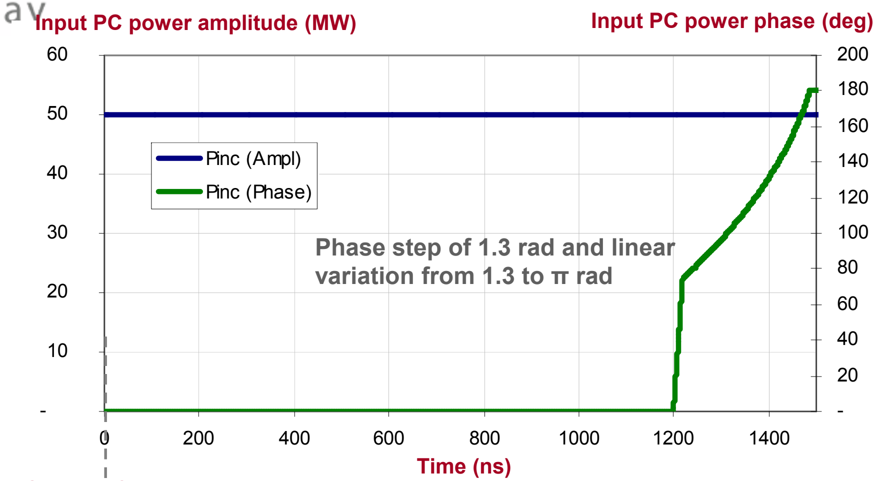
$\Delta F/\Delta a$ = -0.1182 GHz/mm

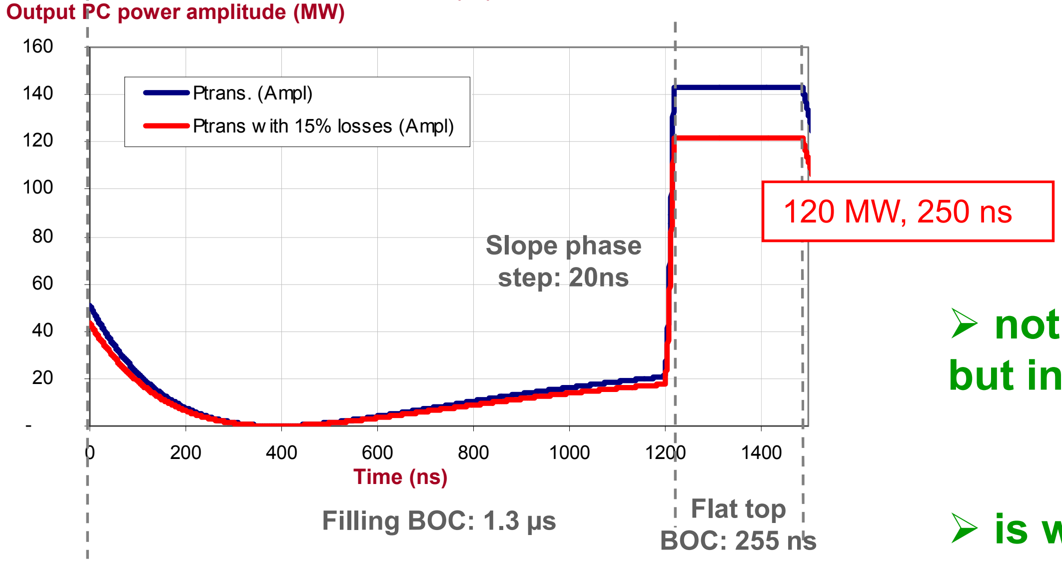
- Other modes will be studied: Q_0 = 200000 with a=130 mm, …

- Simplification of the cavity profil
  - Optimisation of H and ɵ for a given inner radius a…



BOC: Pulse waveform after compression





- Q0 = 160000
- β=Qx/Q0 = 8
- Reflexion coef = 0.777
- Filling time = 0.471 µs

- **not within spec (150MW - 300ns) but interesting first results**
- **is worth being more studied and optimized**

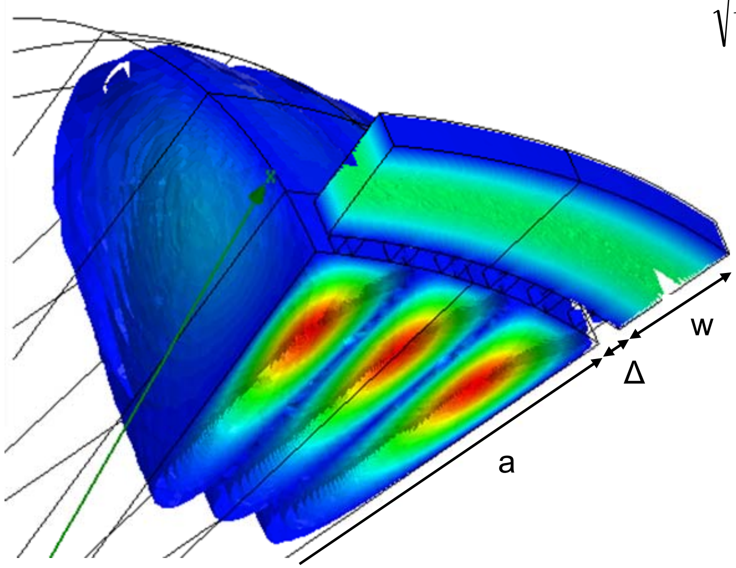
Irfu cea saclay

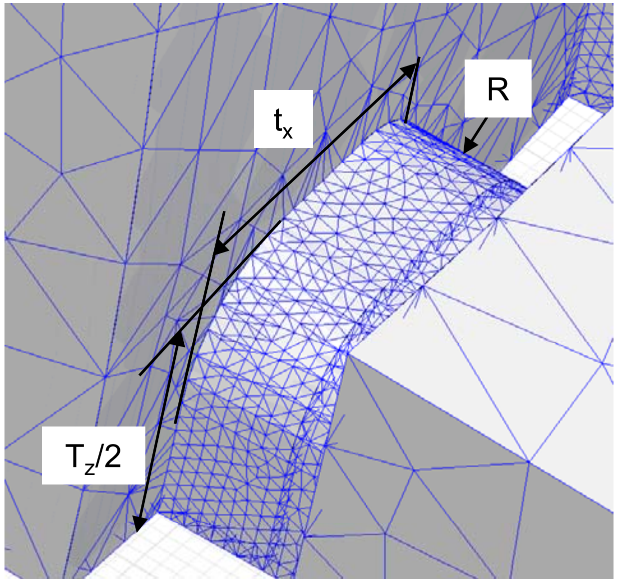
BOC: Coupling

- Quarter wavelength multi-hole coupler: $TM_{20,1,1}$ → 20 x 4 = 80 holes (m=20)
- Synchronism conditions between surrounding waveguide and cavity:

$$\frac{2\pi(a+\Delta+w)}{m}=\frac{\lambda_0}{\sqrt{1-\left(\frac{\lambda_0}{2w}\right)^2}}$$

With wavelength $\lambda_0=\frac{C}{F}$ = 24.995 mm





Parameters	Case 1	Case 2
Tx	2.95 mm	3.05 mm
Tz	3 mm	3 mm
R	1 mm	1 mm
β= Qx/Q0	8.45	6.43

Milestones and deliverables

1. High voltage modulator

• Participation in the klystron design review at SLAC	Oct. 2008
• Tender for modulator purchase	Nov. 2008
• Choice of the supplier in collaboration with CERN	Jan. 2009
• Modulator production follow-up	Feb 2009 to Feb 2010
• Delivery of the modulator to CERN, installation and high power tests with a SLAC klystron	Feb. 2010

2. Pulse compressor

• Preliminary Design Review : decision between SLED2 and BOC	July 2009
• Delivery of the Pulse Compressor to CERN, installation and high power tests with a SLAC klystron	Feb 2010

3. RF Components

• Participation in 12 GHz component review at CERN	Oct. 2008
• Participation in component testing at SLAC	Nov. 2009
• High-power testing at CERN	Feb. to June 2010

Conclusion

- *Interesting and challenging program with significant R&D effort*
- *We are waiting for the klystron characteristics in order to finalize the modulator technical specifications and continue the call for tender which is planed in Nov. 08 for the end phase*
- *Design studies have started for Pulse Compressor, with SLED2 as baseline and BOC as option → decision in July 2009*
- *Preliminary Design Study started with Thales ED (S. Sierra) for the study and realization of an additional test stand at CEA Saclay (except the klystron): delivery in Nov. 08*

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Thank you for your attention