CLIC DR EXTRACTION KICKER DESIGN, MANUFACTURE AND EXPERIMENTAL PROGRAM

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On behalf of:

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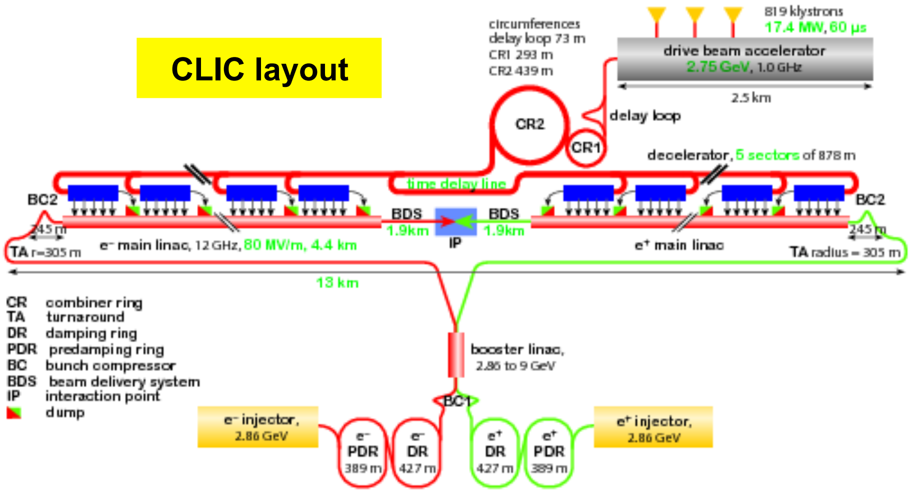
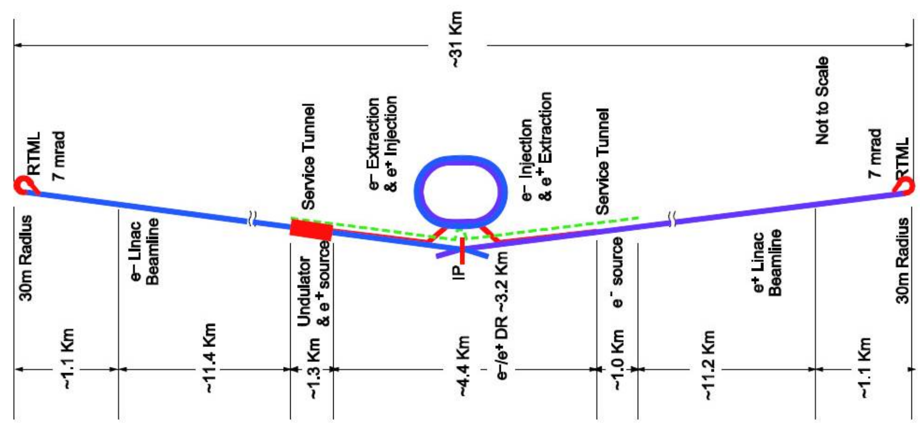
http://gap.ific.uv.es

CLIC DAMPING RINGS vs ILC DAMPING RINGS

CLIC layout



ILC layout



DRs parameters	ILC	CLIC
Energy (GeV)	5	2.86
Circumference (km)	3.2	0.427
RF frequency (GHz)	0.650	2
Normalized emittance (nm)	5500 (H) 20 (V)	500 (H) 5 (V)
Repetition rate (Hz)	5	50
Bunches/train	1	1
Number of bunches	1312	312
Bunch length (mm)	6	1.6
Bunch spacing (ns)	3.1	0.5
Bunch population [10^9]	20	4.1

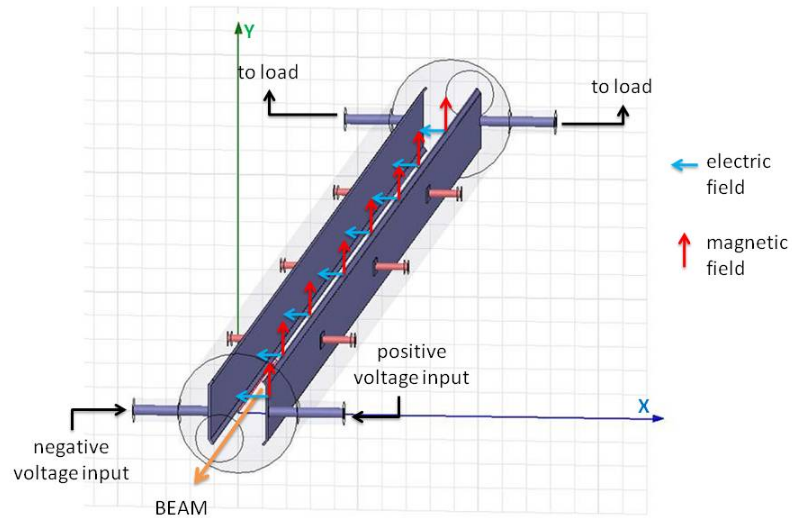
Kickers parameters	ILC	CLIC
Deflection angle (mrad)	0.7	1.5
Striplines aperture (mm)	24	20
Striplines length (cm)	32 (20 multi-units)	170
Field rise and fall times (ns)	< 3 for e^- ring < 6 for e^+ ring	900
Pulse rise and fall times (ns)	1.2	≈ 100
Pulse flat-top (ns)	2	160
Extraction field inhomogeneity (%)	± 0.07 (over 1.8 mm)	± 0.01 (over 1 mm)
Stripline voltage (kV)	± 5 (per multi-unit)	± 12.5

KICKERS FOR CLIC PRE-DAMPING AND DAMPING RINGS

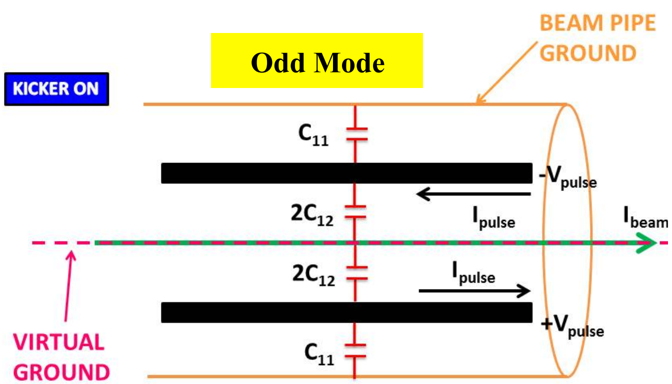
THE MOST CHALLENGING PARAMETERS FOR THE STRIPLINES OF THE EXTRACTION KICKER OF THE DAMPING RINGS

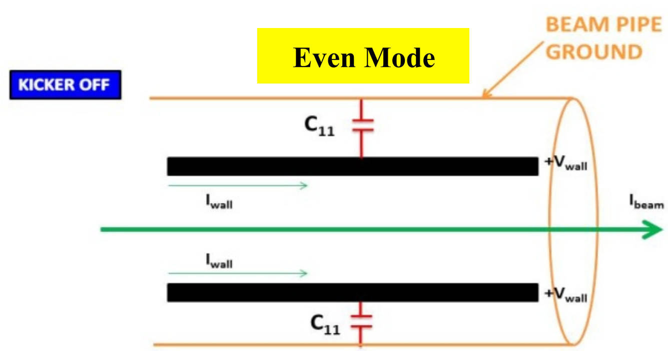
Field inhomogeneity (%) [CLIC: 1mm radius]	± 0.01
Longitudinal beam coupling impedance (Ω per turn)	< 0.05
Transverse beam coupling impedance (kΩ/m)	< 200

SCHEME OF THE STRIPLINE KICKER FOR CTF3



TWO OPERATION MODES



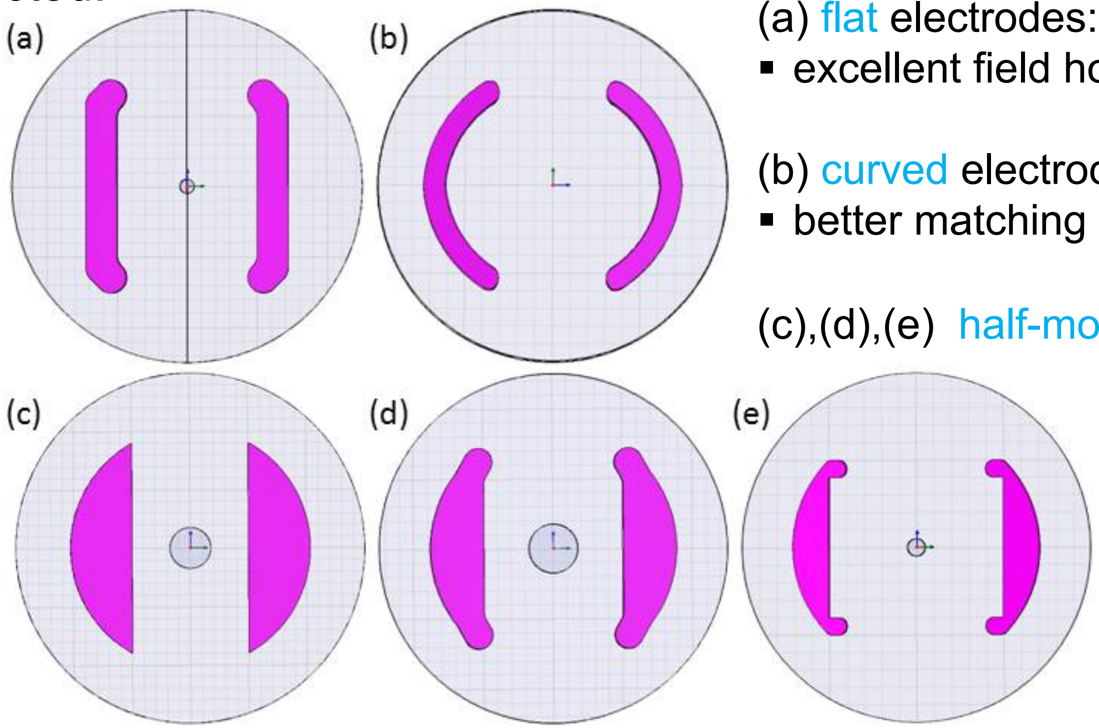


$$C_{odd} = C_{11} + 2C_{12}$$
$$C_{even} = C_{11}$$

$$C_{odd} > C_{even} \rightarrow Z_{odd} < Z_{even}$$

STRIPLINE KICKER DESIGN

- If **coupling (C_{12}) is zero** → **Z_{odd} = Z_{even} = 50 Ω**. This is the **ideal case**.
- If **coupling (C_{12}) is not equal to zero**:
  - → **Z_{odd} = 50 Ω** and **Z_{even} > 50 Ω**. Z_{even} and thus the **beam coupling impedance** increase in proportion to the even mode characteristic impedance.
  - → **Z_{even} = 50 Ω** and **Z_{odd} < 50 Ω**. Z_{odd}, the characteristic impedance of the striplines seen by the pulse generator, is mismatched. As a result of the impedance mismatch, **multiple reflections** from the inductive adder can be expected.



(a) flat electrodes:
- excellent field homogeneity

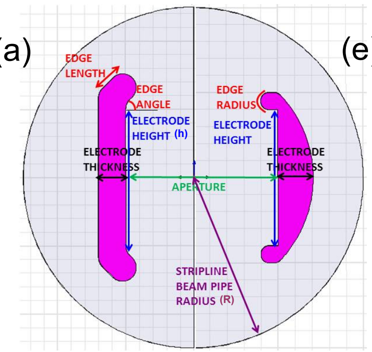
(b) curved electrodes:
- better matching between modes

(c),(d),(e) half-moon electrodes

STRIPLINE KICKER DESIGN

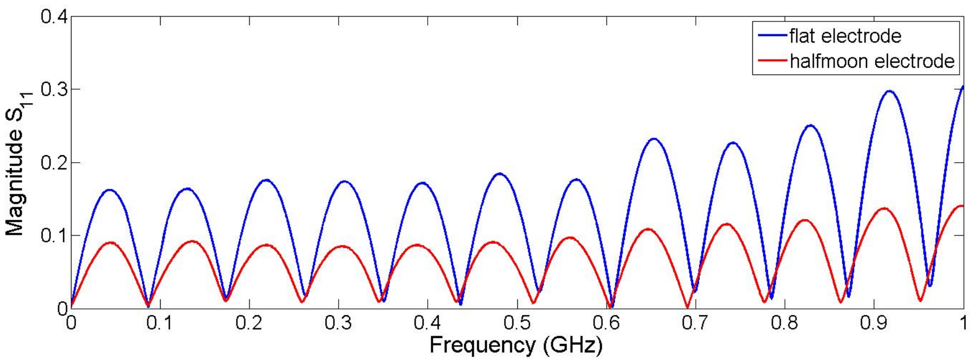
ELECTRODE CROSS SECTIONS

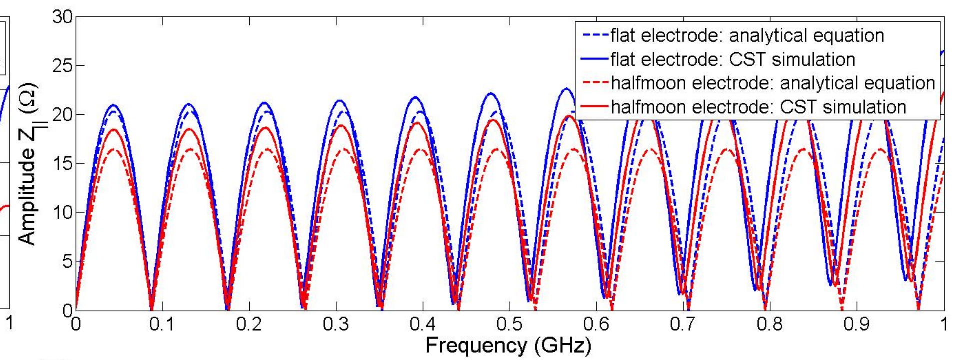
(a) (e)



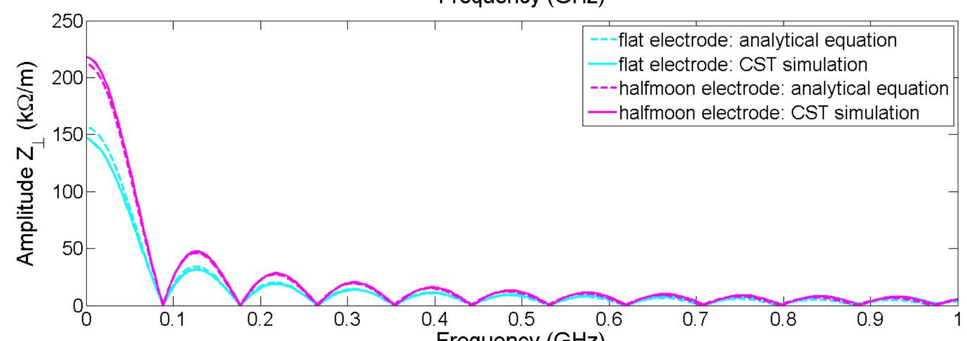
Electrode configuration		R (mm)	ϕ_0 (radians)	Z_{odd} (Ω)	Field inhomogeneity (%)
Flat	(a)	25	2.0	36.8	± 0.01
Half-moon	(e)	20	1.8	40.9	± 0.01

REFLECTION PARAMETER AND BEAM COUPLING IMPEDANCE



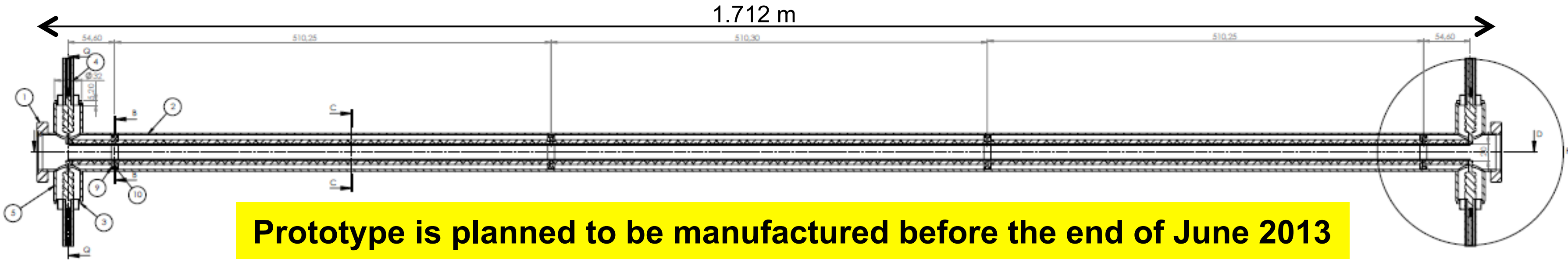


	FLAT ELECTRODE	HALF-MOON ELECTRODE
Odd characteristic impedance		✓
Signal transmission		✓
Longitudinal beam coupling impedance		✓
Transverse beam coupling impedance	✓	

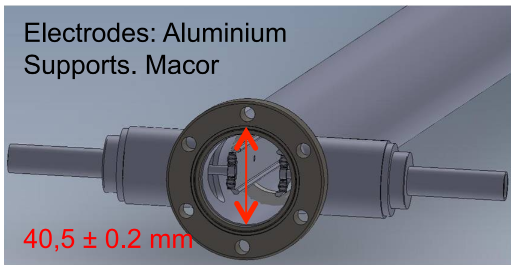


MANUFACTURING PROCESS

TRINOS VACUUM PROJECTS S.L.

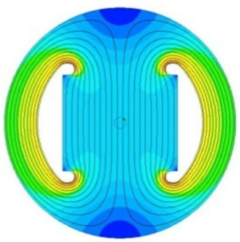


Prototype is planned to be manufactured before the end of June 2013



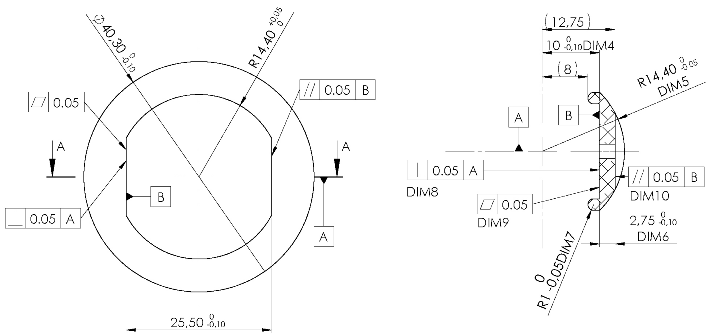
MECHANICAL TOLERANCES

QUICKFIELD SIMULATIONS:
effect of the fabrication tolerances, upon field homogeneity over 1 mm radius



Maximum field inhomogeneity specified over 1 mm radius: **± 0.01%** (achieved with nominal dimensions)

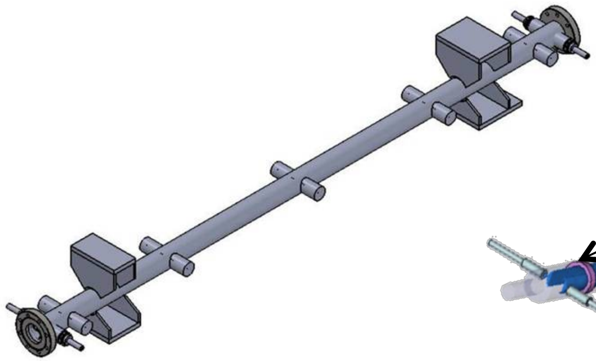
Tolerances of the electrode supports and the electrodes

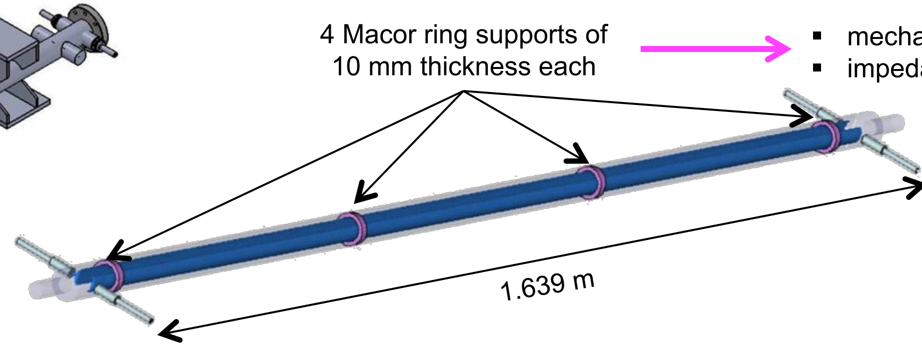


	Maximum error	Field inhomogeneity
Horizontal	± 0.2 mm	± 0.015%
Vertical	± 0.1 mm	± 0.02%
Inclination	0.06°	± 0.01%

The specificated parameters have to be revised: for a realistic tolerances, we need either a higher limit for field inhomogeneity or a smaller radius where the field inhomogeneity can be achieved. Furthermore, higher limits of beam coupling impedance are required.
➢The possibility of relaxing the field inhomogeneity requirements is being studied (R. Apsimon).

STUDY AND OPTIMIZATION OF ELECTRODE SUPPORTS

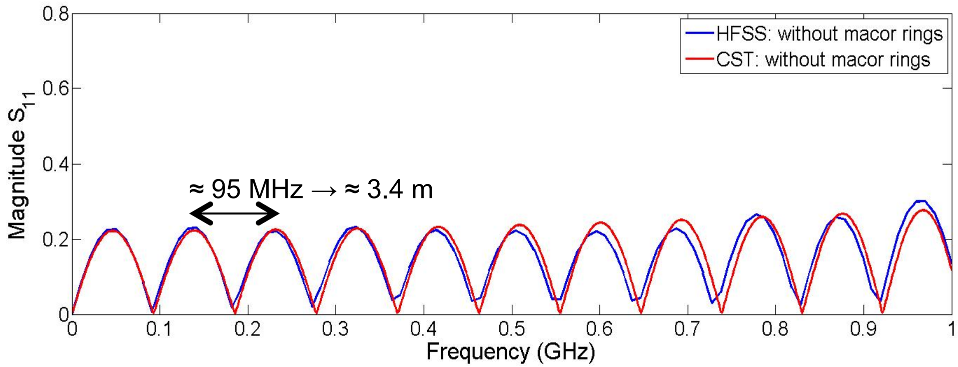


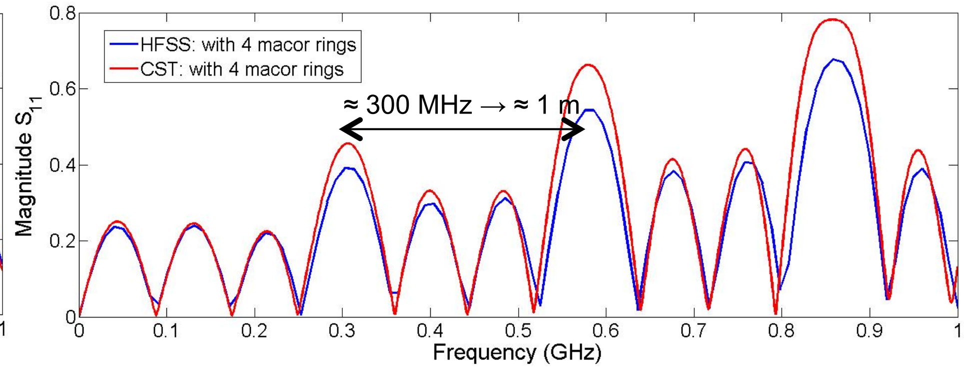


- mechanical requirements
- impedance mismatch

HFSS and CST MS SIMULATIONS

- The electrodes are fixed outside the beam aperture
- The angular position is guaranteed by two grub screws





Frequency content of the pulse (≈100 ns rise and fall time times) ≈ 10 MHz

Since the Macor rings mainly affect the S_{11} above 300 MHz, they are not expected to significantly influence the ripple of the driving pulse.

STUDY AND OPTIMIZATION OF ELECTRODE SUPPORTS

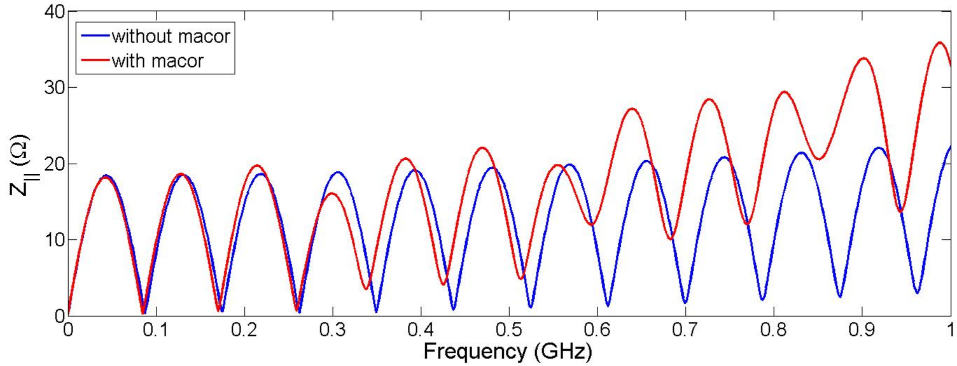
From beam dynamics, the allowable broad band impedance, per kicker system is:

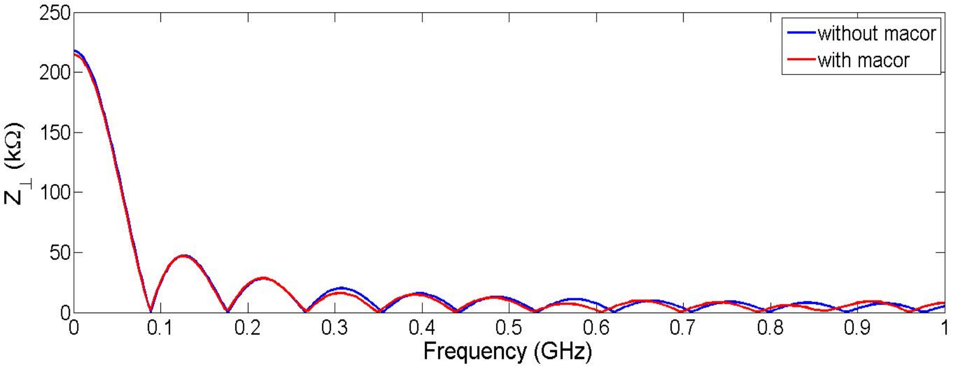
- 0.05 Ω per turn **longitudinal beam coupling impedance**,
- 200 kΩ/m **transverse beam coupling impedance**.

CST PS simulations

Half-moon electrode $\begin{cases} Z_{\parallel}/n = 0.06\ \Omega \\ Z_{\perp} \approx 220\ k\Omega/m \end{cases}$

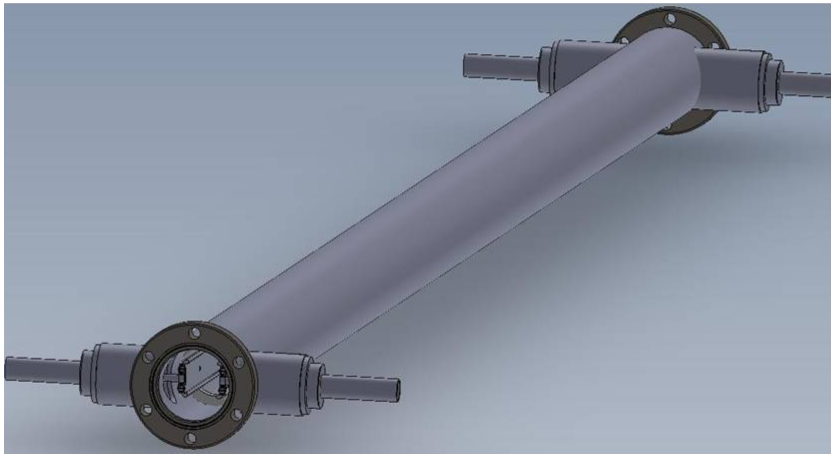
$\sigma_{z,simulated}$ = 50 mm



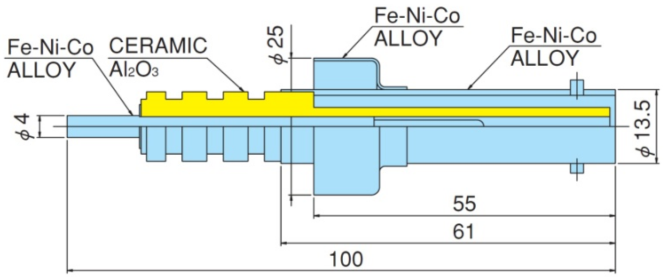


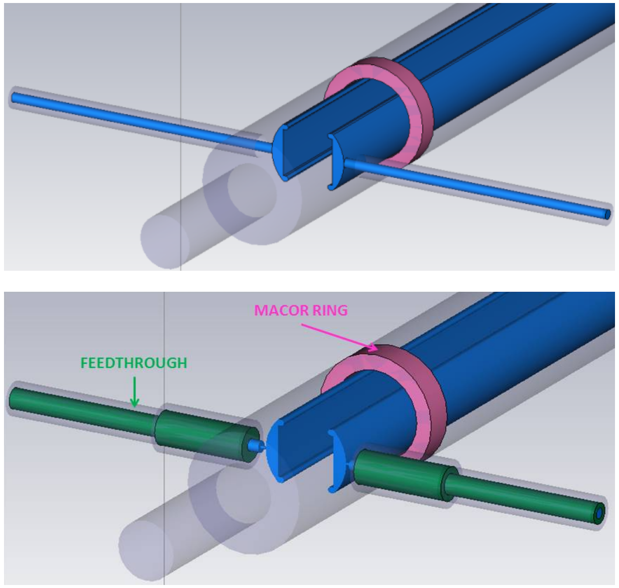
- **Increase of the longitudinal beam coupling impedance above ≈ 300 MHz**
- **The transverse beam coupling impedance is not significantly affected**

FEEDTHROUGHS STUDY AND OPTIMIZATION

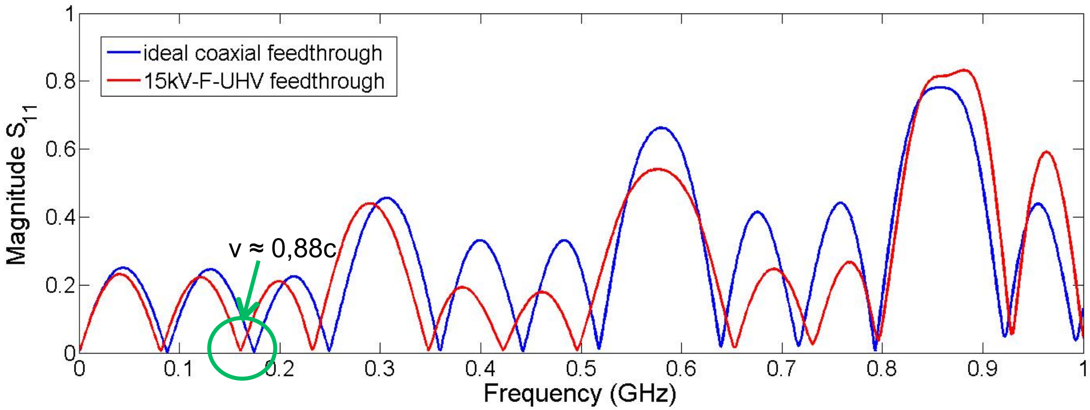


Kyocera 15kV-F-UHV coaxial feedthroughs



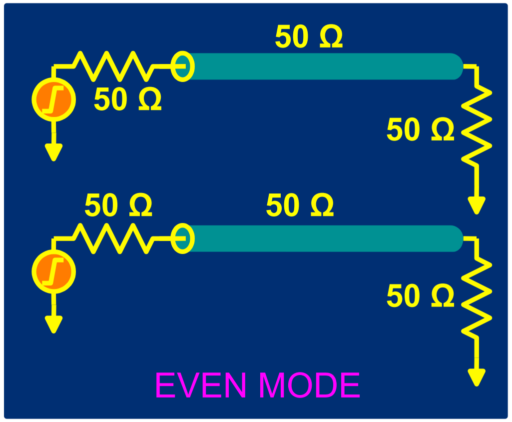


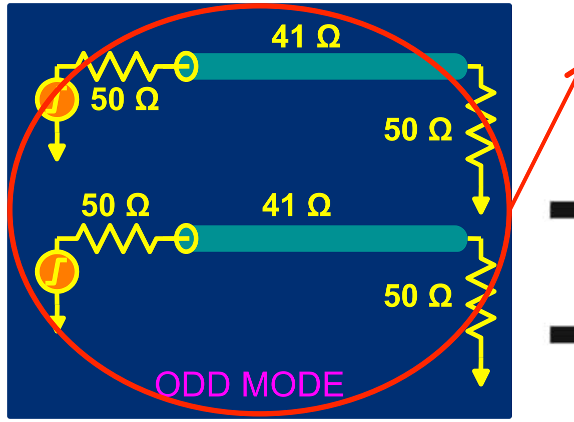
CST PS simulations



Up to ≈ 800 MHz, the magnitude of the S_{11} parameter is generally lower with the Kyocera feedthroughs than with the ideal coaxial feedthroughs.

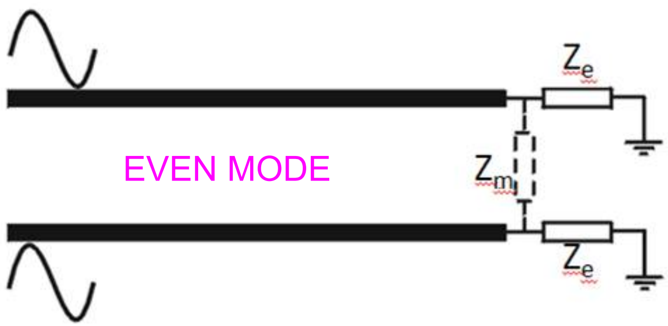
NEW IDEAS FOR MATCHING CHARACTERISTIC IMPEDANCES

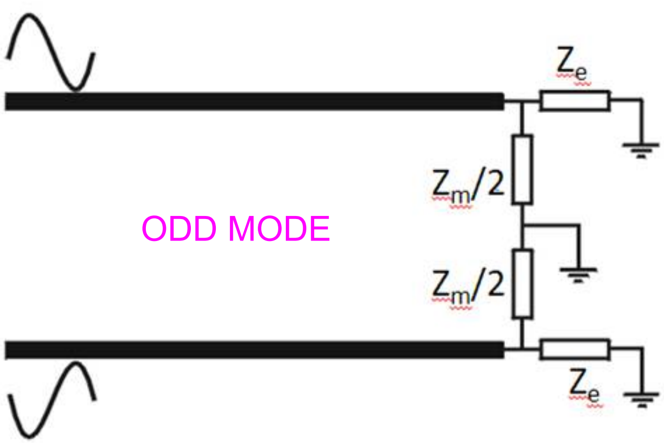




IMPEDANCE MISMATCH

PROPOSAL





EVEN MODE

- Matching resistor is invisible to pulse

ODD MODE

- The odd mode termination impedance is equal to:

$$Z_{odd} = \frac{Z_{even} Z_m}{2Z_{even} + Z_m}$$

$Z_m = 450\ \Omega$

- **The matching resistor will result in the odd mode impedance of each stripline being terminated in 41 Ω.**
- **The odd mode input impedance of the striplines is still mismatched to the transmission line impedance.**
- **The impedance matching resistor increases the pulse current which must be supplied by the inductive adder by approximately 20%.**

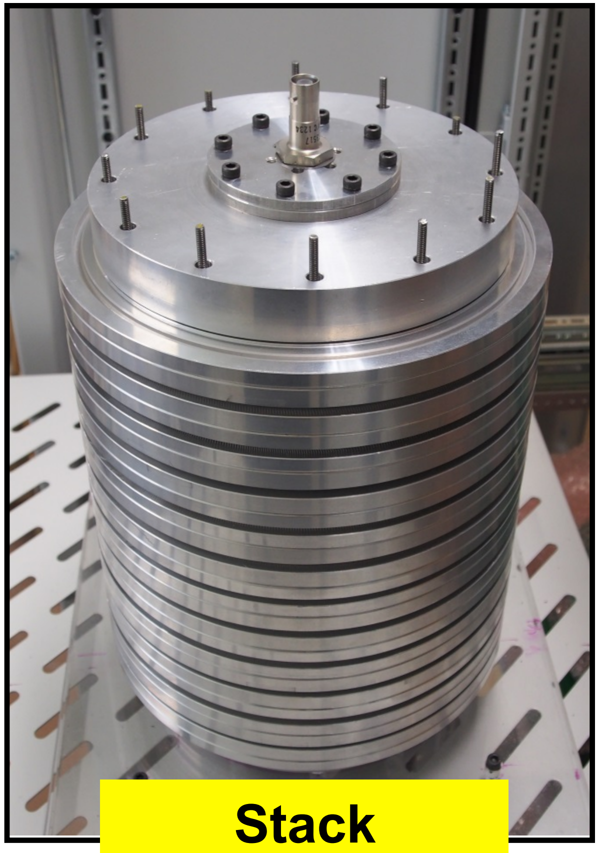
PLANS FOR THE STRIPLINES

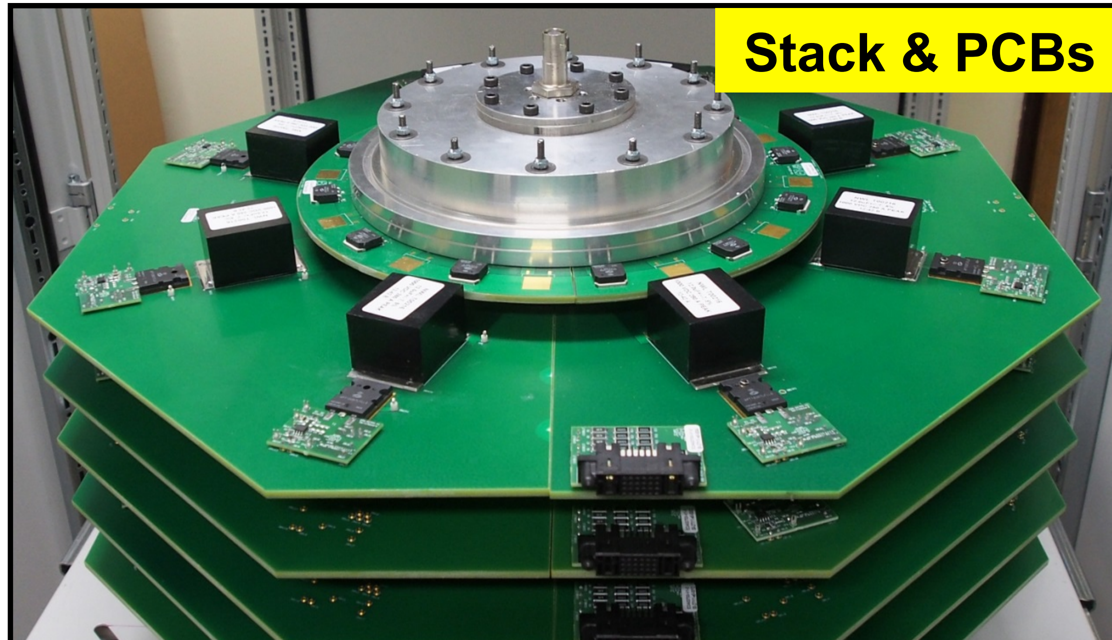
Starting September 2013:

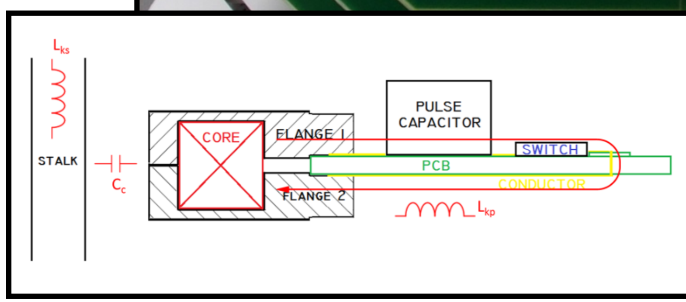
Tests **without beam** at IFIC, CIEMAT and CERN labs

- Verification of the stripline dimensions
- Vacuum compatibility
- High voltage performance
- Longitudinal and transverse beam coupling impedance measurements
- Others…

5-LAYER PROTOTYPE INDUCTIVE ADDER







- Good impedance matching between the inductive adder and the load is desirable in order to achieve short rise time for the output pulse and low ripple. Detailed 3D simulations have been carried out to predict the value of the primary leakage inductance.
- A **5-layer prototype inductive adder** has been assembled and is being tested at CERN. Power tests, at up to ~3 kV, are planned to verify the predictions for the inductive adder.

PLANS FOR THE INDUCTIVE ADDER

Starting September 2013:

A **second five layer prototype inductive adder** will be built. Power tests, at up to ±3 kV, with both prototypes, will be carried out.

➢The second prototype adder will allow detailed measurements of the pulse shape and permit confirmation that the flattop of the pulse can be controlled using a special analogue modulation layer in the inductive adder.

Both inductive adders will also be connected to the prototype striplines for power testing.

Starting December 2013:

A **full-size 20-layer prototype adder** will be built.

➢This prototype will be used to demonstrate the overall performance, including precision high voltage pulses at the required repetition rate, of the CLIC DR power modulator. The long-term reliability of the adder will also be demonstrated.

Adding additional layers to give a **28 layer prototype**, will allow investigation as to whether it is feasible to use the inductive adder as both the power modulator of a high precision extraction kicker and an emergency dump kicker system, without affecting pulse ripple.

Starting June 2014:

A **second full-size 20-layer prototype adder** will be built.

➢This prototype will be used to demonstrate the overall performance, of both striplines and inductive adders, in an Accelerator Test Facility.

PLANS FOR THE STRIPLINES AND THE INDUCTIVE ADDER

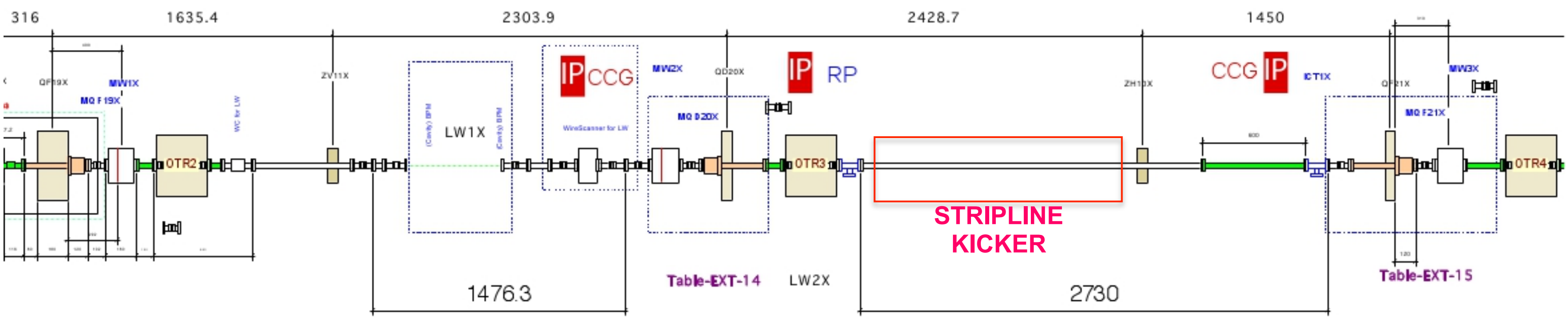
1) Striplines <u>**not**</u> used as a **extraction device** and <u>**without**</u> **inductive adder** (ALBA or ATF2)

- ❑ Longitudinal and transverse beam coupling impedance

2) Striplines <u>**not**</u> used as **extraction device** and <u>**with**</u> **inductive adder** (ATF2) **(after June 2014)**

- ❑ Field inhomogeneity
- ❑ Pulse shape and repeatability
- ❑ Long term reliability of the system

Possible location of the stripline kicker in ATF2 for being tested: Final Focus System



3) Possible use as **extraction device** (ATF2)

CONCLUSIONS

- The electromagnetic **design** of the striplines, including a detailed study of both the electrode supports and the feedthroughs, has been **completed**.
- The stripline design provides the **performance** specified for the extraction kicker of the CLIC DRs: excellent field homogeneity, good power transmission and low broadband beam coupling impedance.
- The effect of **manufacturing tolerances** has been studied. The possibility of relaxing the field inhomogeneity requirement is being studied.
- A **prototype** of the extraction stripline kicker for the CLIC DR is presently **being manufactured** by Trinos Vacuum Projects (Valencia, Spain).
- After the **striplines** manufacture, several **tests** will be carried out **without beam** at IFIC, CIEMAT and CERN labs.
- A **5-layer prototype inductive adder** has been assembled and is **being tested** at CERN.
- A **second 5-layer prototype**, and **two full-size 20-layer prototypes** are planned to be built in the next months.
- The **stripline** and the **inductive adder** will be tested separately (ALBA/ATF2) and jointly (ATF2) **with beam**.