# Development of BPMs for the Linac4

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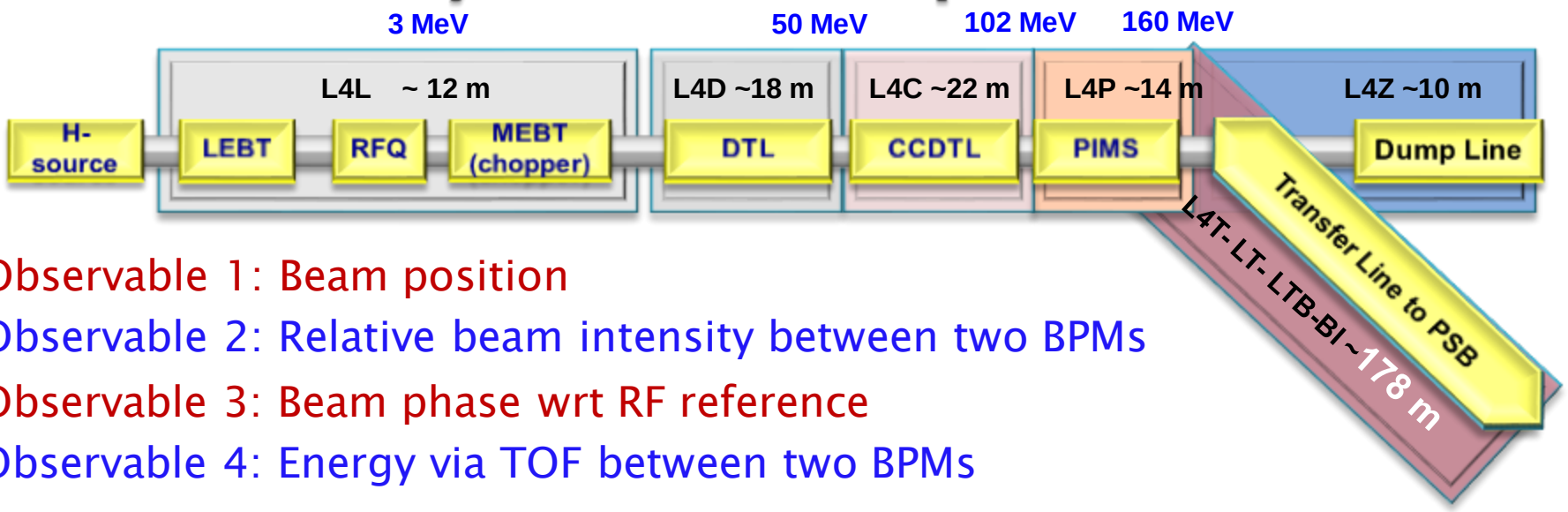
BE/BI

Linac4 Instrumentation Review
18th October 2011

# Outline

- BPM
  - Layout
  - Functional specs
  - The monitor and low beta beams
- STATUS
  - Drawings and prototyping
  - BPM test bench and Acquisition chain
  - First BPM characteristics
  - Todo list
- Spare policy
- Planning
- Summary

# BPMs layout and specs




Observable 1: Beam position

Observable 2: Relative beam intensity between two BPMs

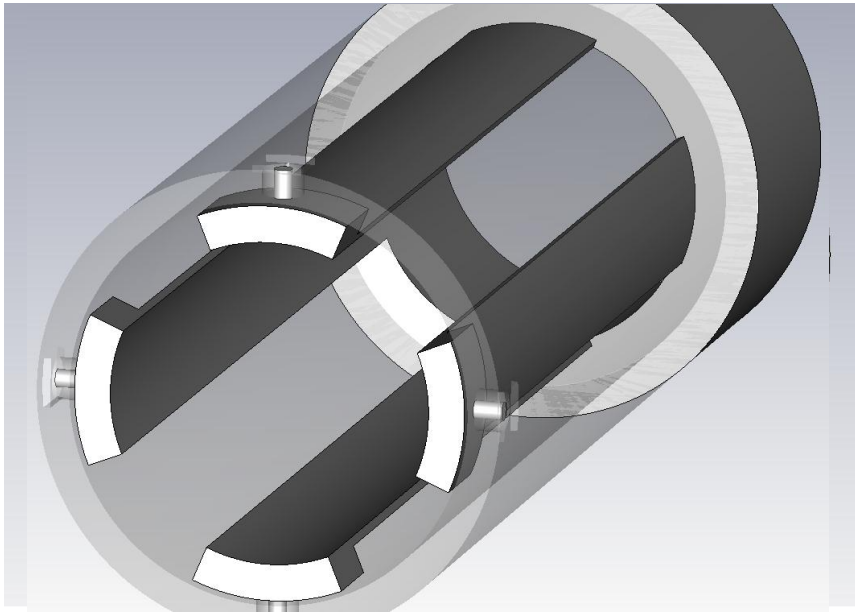
Observable 3: Beam phase wrt RF reference

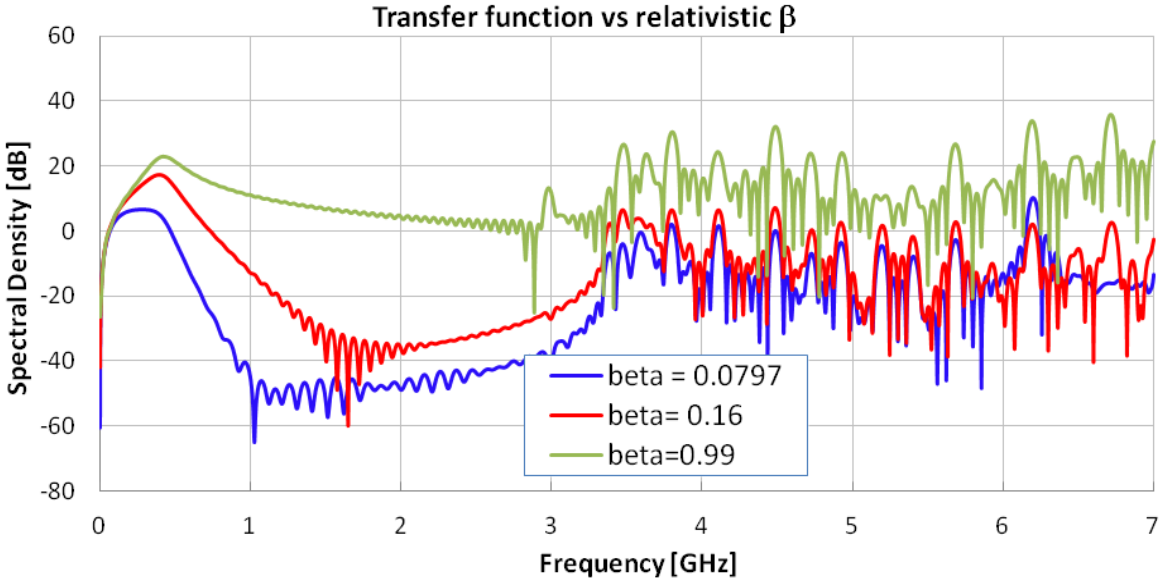
Observable 4: Energy via TOF between two BPMs

| Line | # of Monitors | Beam position | | Rel. Beam Int. | Beam phase | TOF | Comments |
|---|---|---|---|---|---|---|---|
| | | Resolution | Accuracy | | | | |
| L4D | 2 | 0.1mm | 0.3mm | 1% wrt to peak current | 0.5° | 1 per mille | |
| L4C | 7 | | | | | | |
| L4P | 6 | | | | | | |
| L4T to PSB | 27 | | | | | | |

# Linac4 BPM (1)

- Shorted Stripline
- Linear
- Fair sensitivity
- Compact
- Reasonable price
- Resonating
- β-dependent





# Dealing with low-β beams

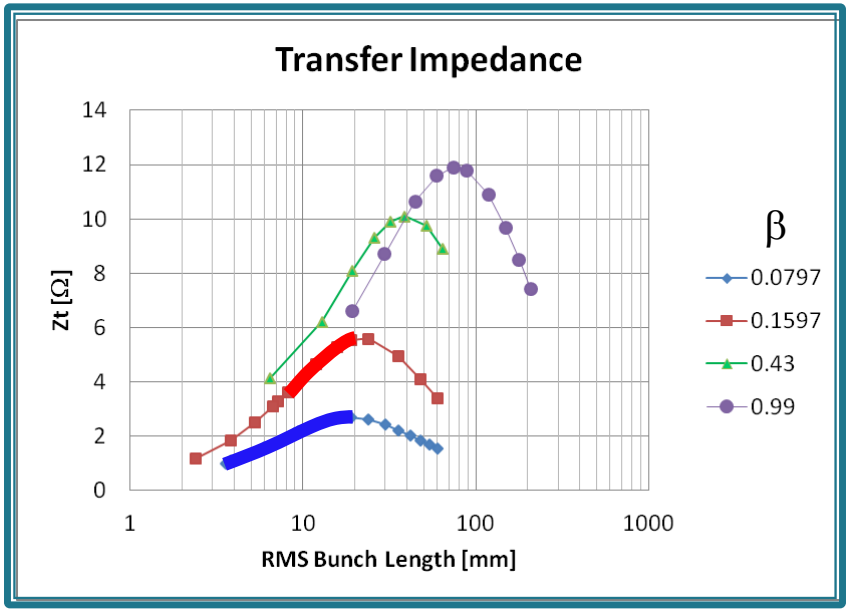
Movable test bench BPM

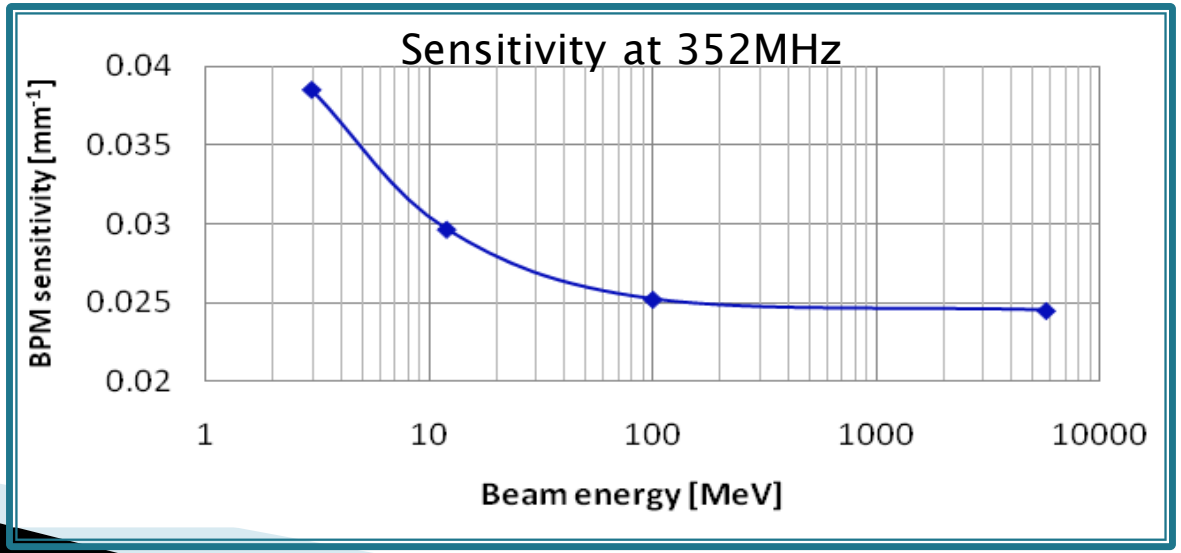
Transfer impedance changes with β and bunch length

PU sensitivity changes with β

These simulations confirm Shafer's theorem (1994)

The values obtained from the simulations will be implemented in the software



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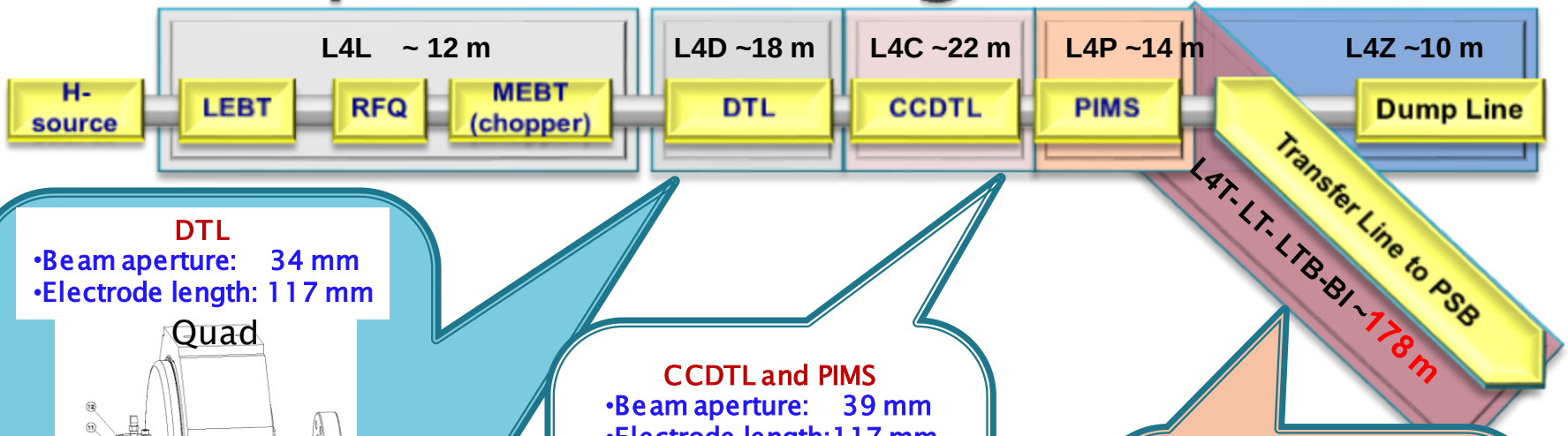
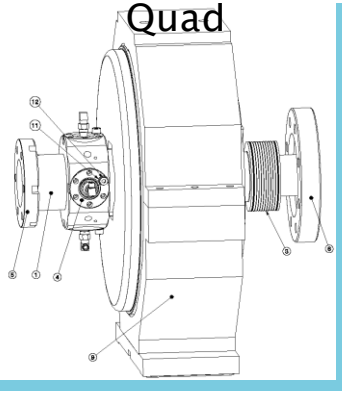
# Multiple BPM designs

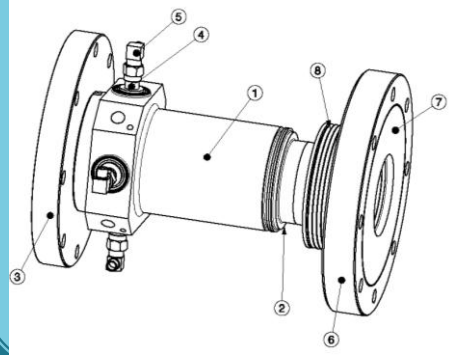



**DTL**
- Beam aperture: 34 mm
- Electrode length: 117 mm

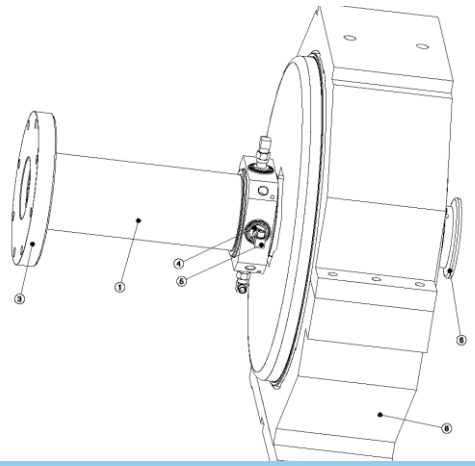
Quad



- Beam aperture: 34 mm
- Electrode length: 72 mm



**CCDTL and PIMS**
- Beam aperture: 39 mm
- Electrode length: 117 mm



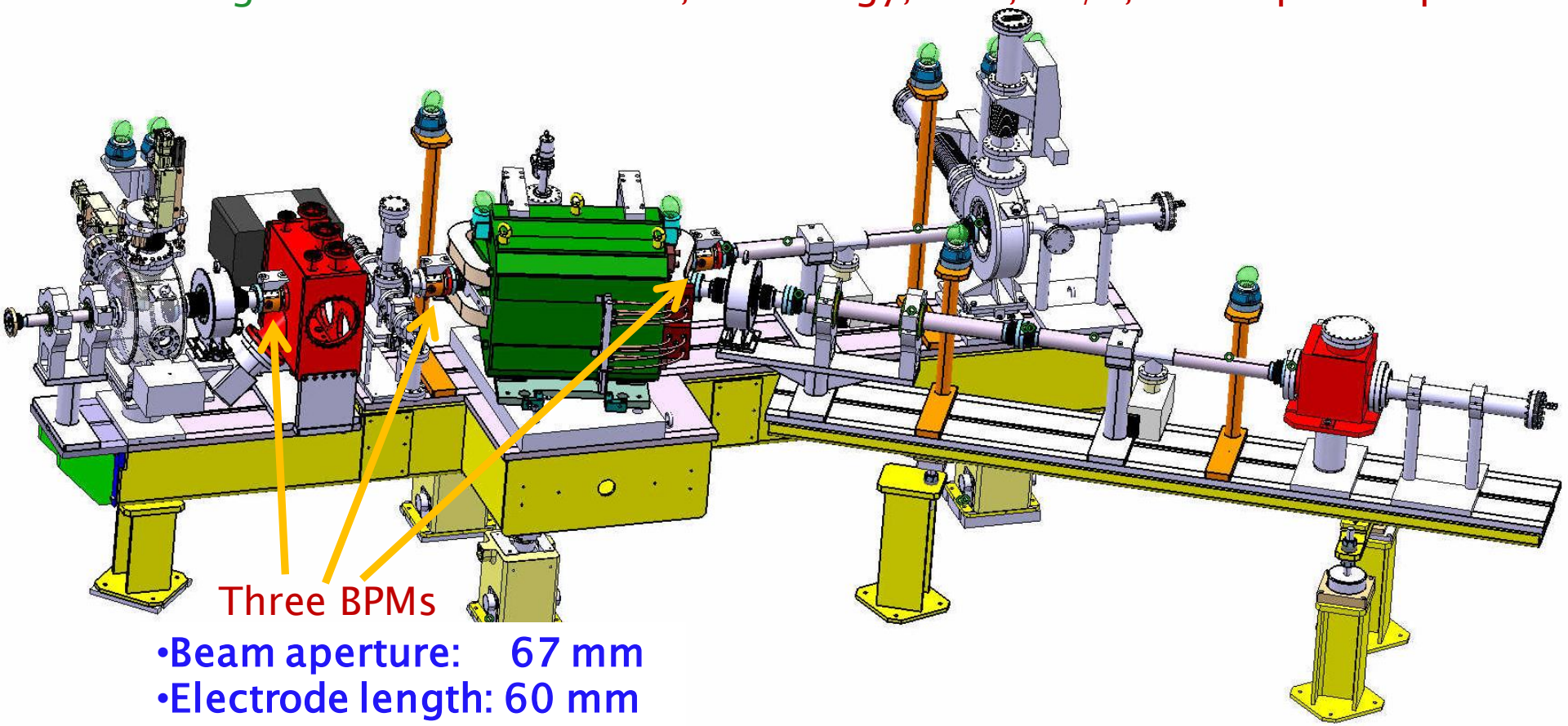
**TRANSFER LINE**
- Beam aperture: 100 mm
- Electrode length: 140 mm

3 BPMs with welded feedthroughs onto the body
39 BPMs with feedthroughs mounted on CF flanges

# Movable Test Bench BPMs

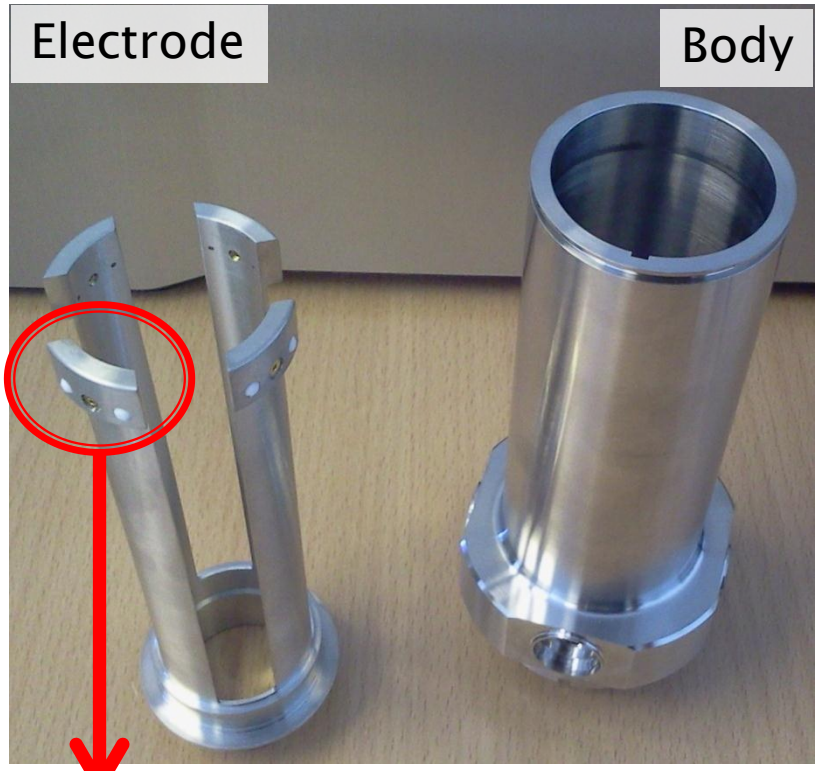
Modular commissioning of RFQ, MEBT and DTL tank1

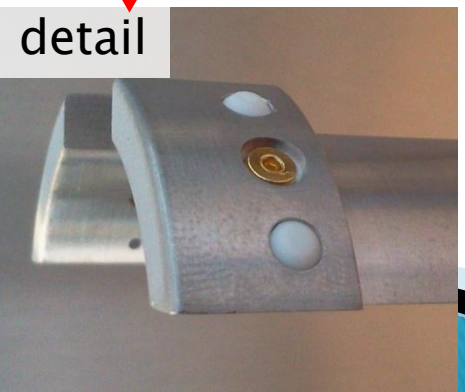
- Transverse : profiles, emittances, halo, position
- Longitudinal : transmission, av. energy, halo, $\Delta E/E$, bunch phase spread




- **Beam aperture: 67 mm**
- **Electrode length: 60 mm**

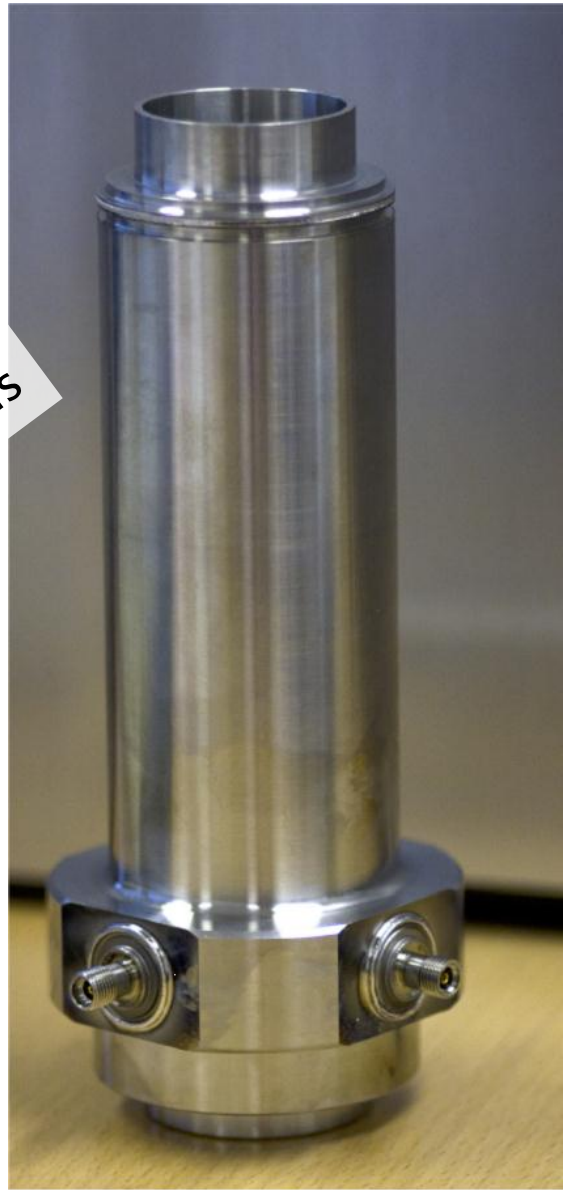
# Prototype of a DTL BPM (1)





Mounted unit with
Welded feedthroughs



# Prototype of a DTL BPM (2)

***Issues***

During $e^-$ bombardment welding

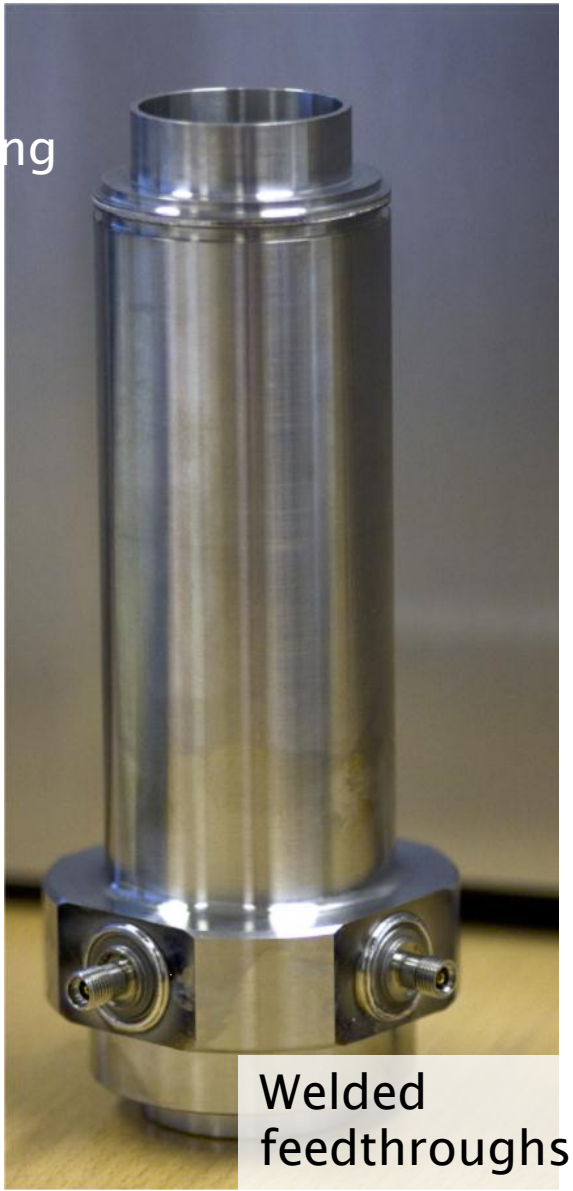
•Three feedthroughs affected by :

Manufacturer's procedure:

⇒glass-ceramic seal

⇒No sand blasting

⇒Ultrasonic cleaning +acetone rinsing before

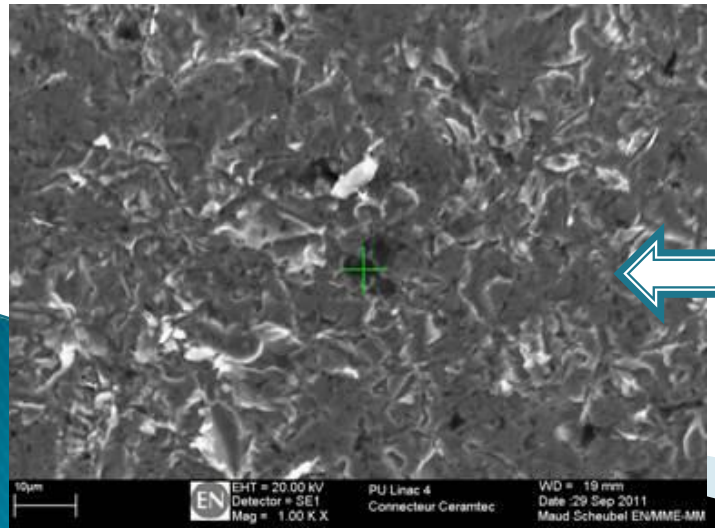



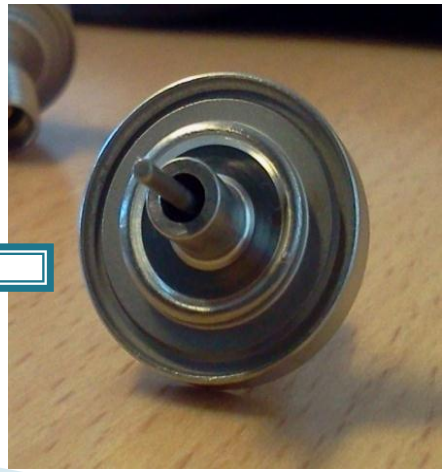

***Scanning electron microscopy***

•Standard 304 grade stainless steel

•Surface not inlayed with dust particles

•Traces of Si, Na, Mg, Ca



# BPM test bench

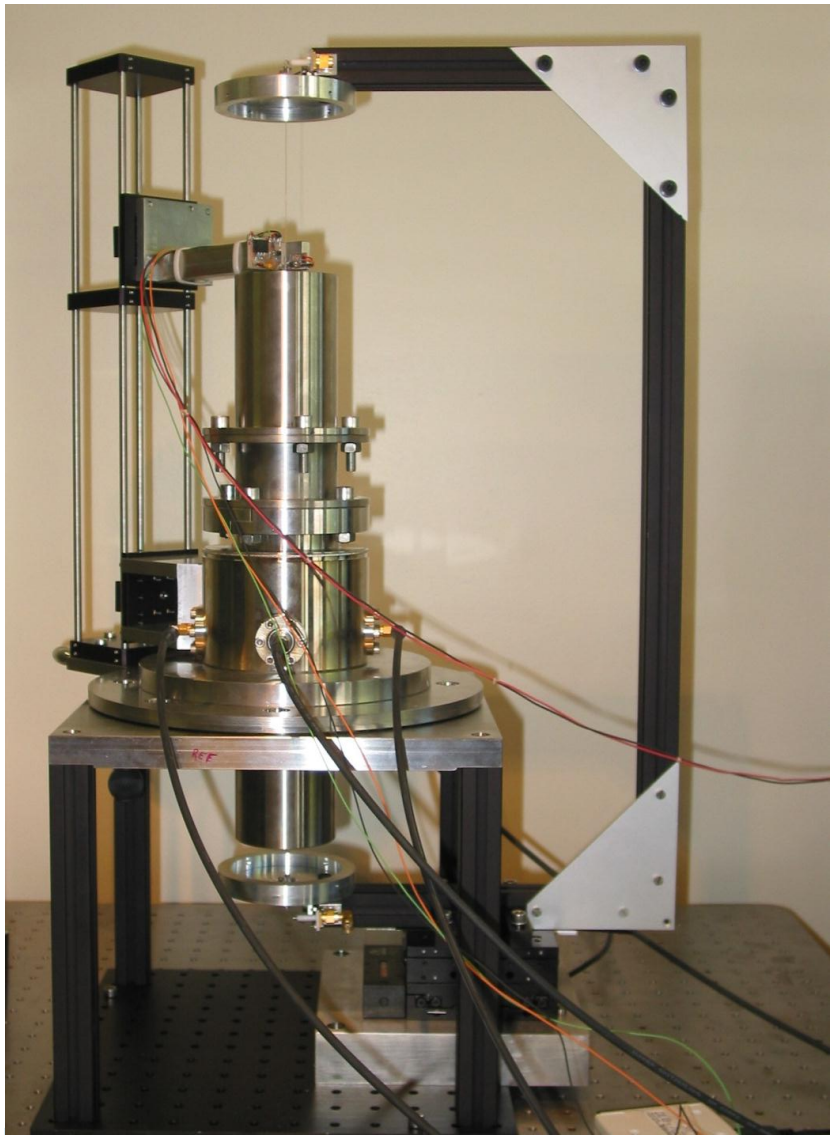
- Wire technique w/ standing waves
- Optical sensor for mechanical centering : ±0.01mm
- 352MHz sine wave with a N.A.
- Data acq by steps of 0.1mm

**Commissioning issues**

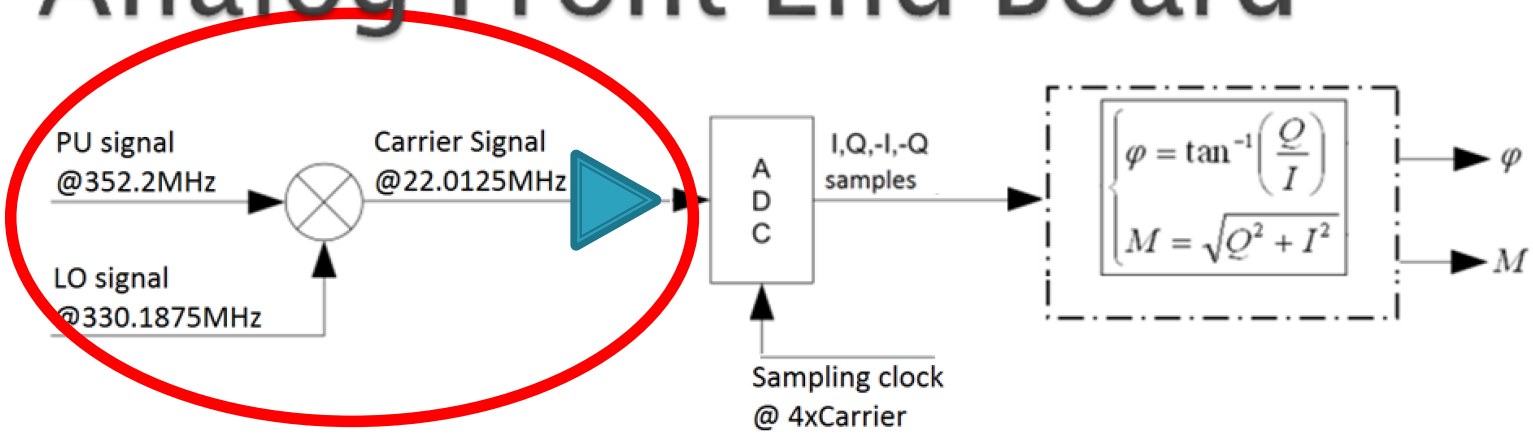
- Black anodized coating =poor grounding.
- *Solution*: Improve grounding. Done

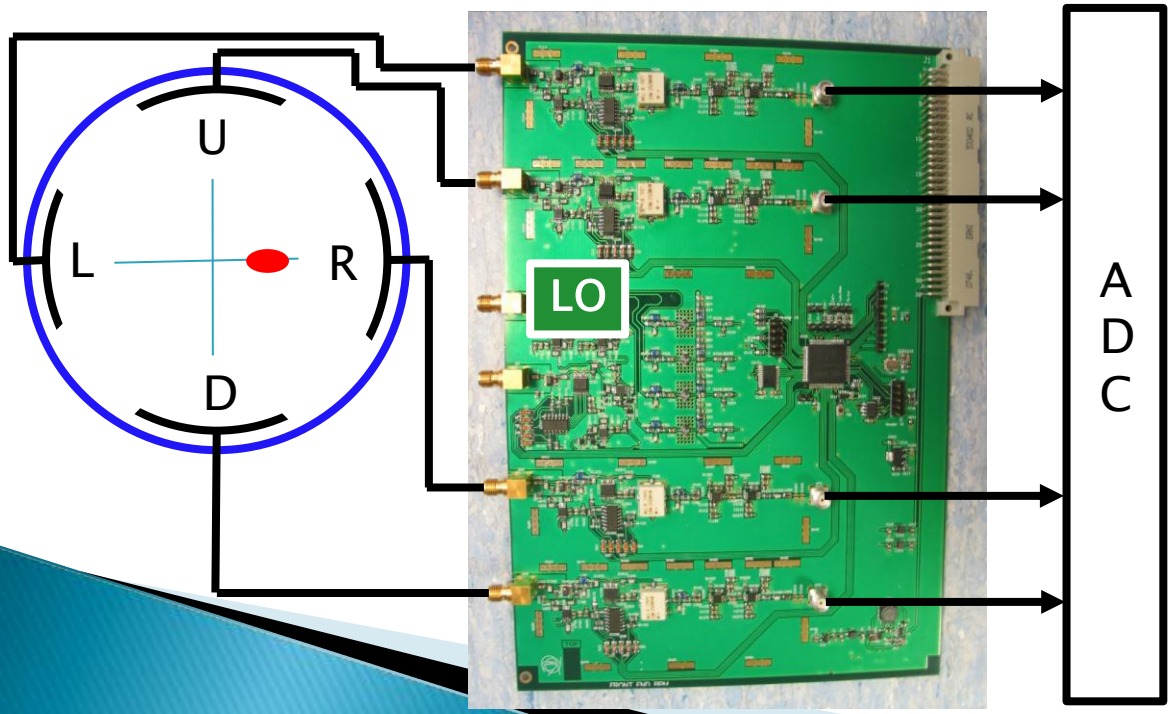
- Wire not terminated = Antenna
- *Solution*: terminate the wire by a short circuit. Done

- Optical rail : C-shape & 25mm cross section yield a lack of stiffness and 1mm electrical offset
- *Solution*: Swap to a full frame of 34mm cross section. Pending action.



# Analog Front End Board

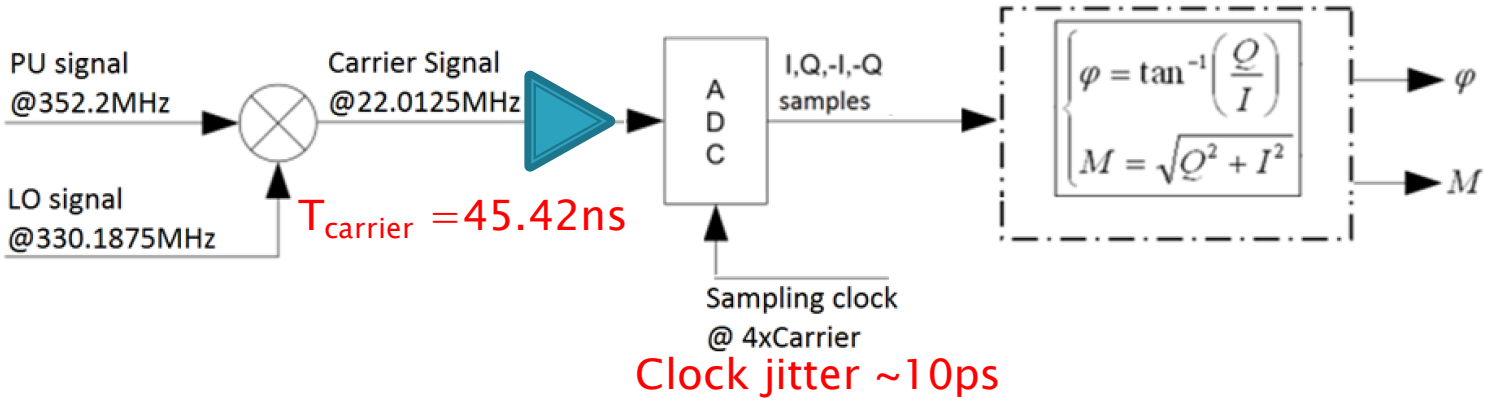


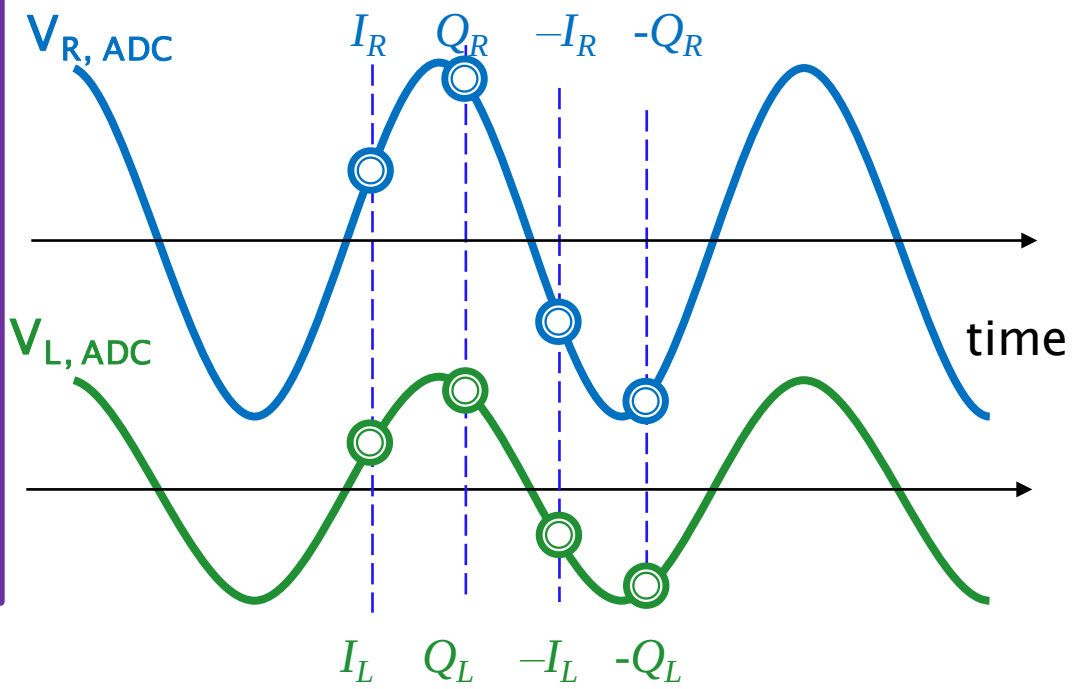

*FEATURES*

- Input Low pass filtering @1GHz
- Down-mixing with LO
- Variable gain with switchable attenuators
- Band-pass filtering @22MHz
- BPM Calibration

# Signal Processing




22.0125MHz Carrier Signal



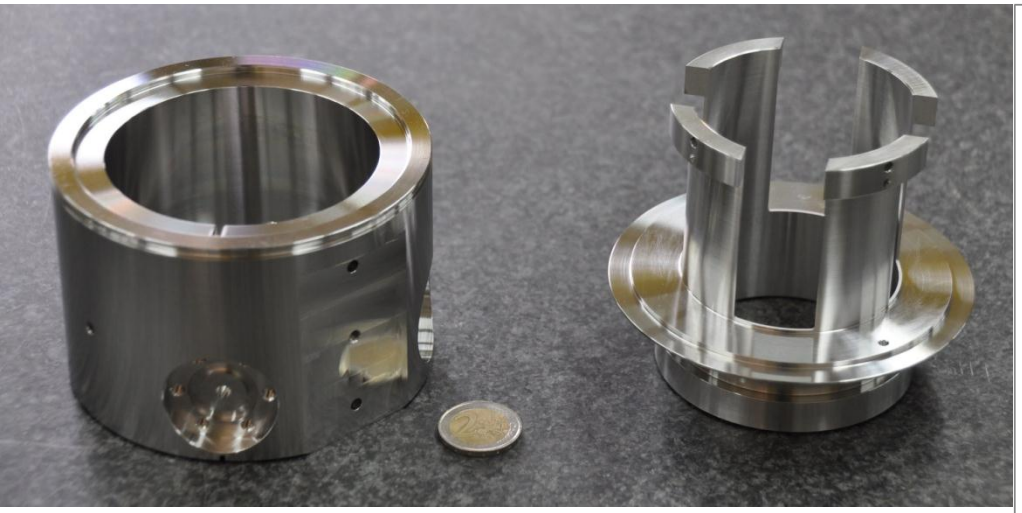

$$\Delta X = \frac{M_R - M_L}{M_R + M_L + M_U + M_D}$$

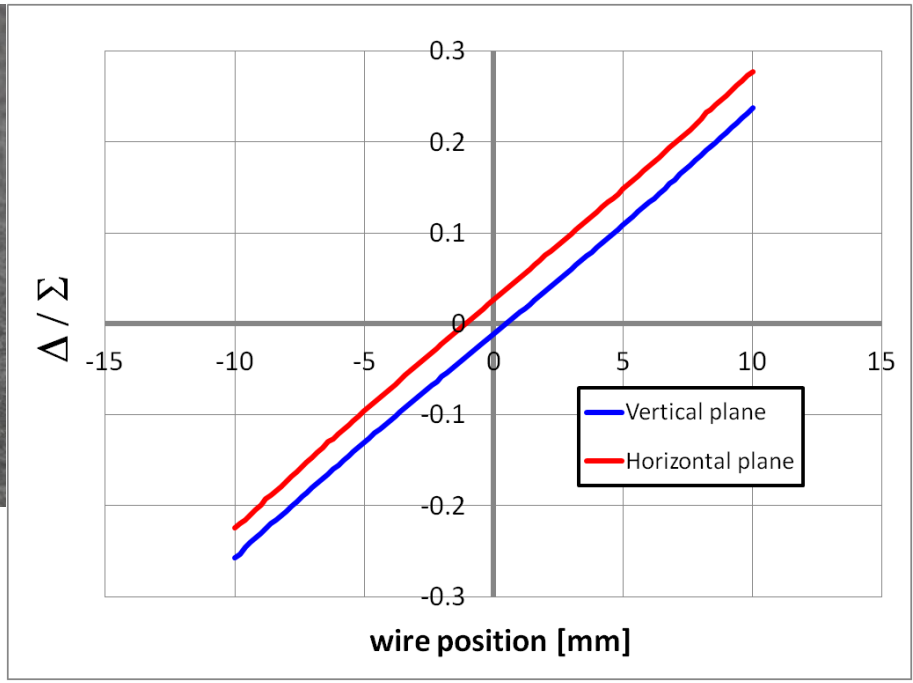
$$\varphi = \varphi_{beam} - \varphi_{LO}$$

$$I = M_R + M_L + M_U + M_D$$

$$TOF = \varphi_{PU2} - \varphi_{PU1}$$

# Stripline Characteristics






- Beam aperture= 67mm
- Electrode length = 60mm

| | THEORY | H plane | V plane |
|---|---|---|---|
| Slope [mm] | 40.32 | 41.79<br>σ=0.42 | 41.02<br>σ=0.56 |
| Elec. Offset [mm] | - | -0.77<br>σ=0.18 | -0.19<br>σ=0.13 |
| Coupling w/ adjacent electrodes | 7.3% | 6.56 | 6.6 |

# First Measured characteristics

352MHz signal injected via the wire
Measured voltages amplitudes from electrodes : ~65mV

From the simulations, this is equivalent to a signal induced by a
- nominal beam of $1.14 \times 10^9$ $H^-$
- 98° longitudinal phase (nearly debunched beam)

Position (averaged over pulse length 740μs ⇔ ~32k positions)
- Precision= 0.1mm
- Resolution = 0.1mm
- Resolution with few samples : to be done

RF phase wrt LO
- Precision = ±1° (room for improvement)

# Todo List

- Understand welding issues
- Improve stiffness of lab test bench
- Transfer impedance and characteristic impedance
- Resolution with short pulses
- Improve ADC clock jitter : the goal is ~200fs
- Commissioning of BPM calibration procedure
- Software : algorithm for I, Q, -I-Q determination
- Measurement with a pair of BPMs
  - TOF
  - Relative beam intensity
- Signal processing : Choose between
  - SIS3302 (16bits – 13.4ENOB) : 6400CHF per board x25
  - FMC (14bits – 11.7ENOB) : Status ? 25 boards. Unknown final price

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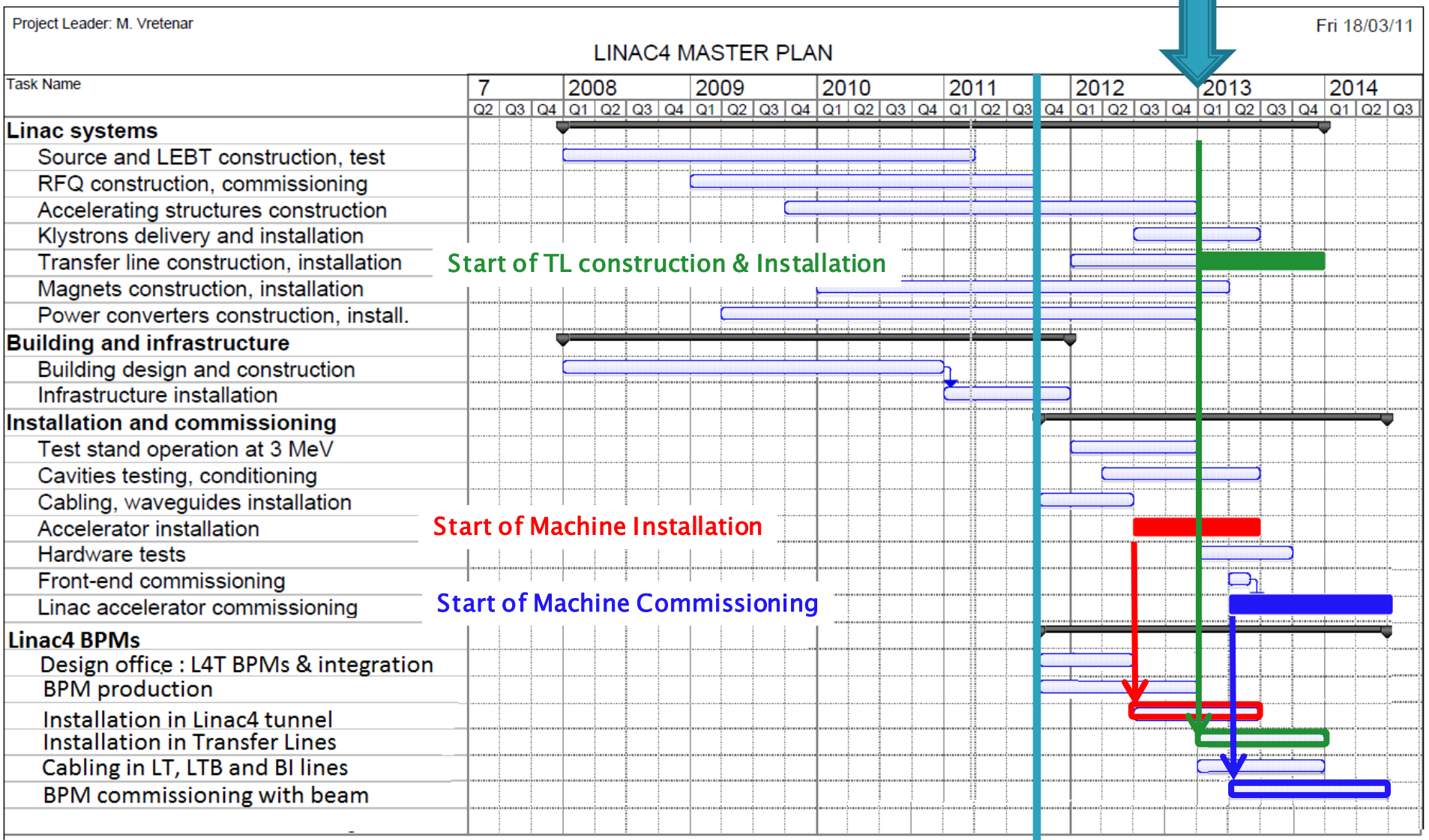
# Spare policy

- Monitors
  - Movable Test Bench : 3 +2 spares for lab commissioning
  - Linac : 15 + 11 spares (one per version)
  - Transfer line : 27 + 2 spares
  - TOTAL : 55 BPMs
- Acquisition chain
  - Front end board : 45 + 15 spares
  - ADC or FMC : 23 + 4 spares

# Planning


LS1
Project Leader: M. Vretenar
Fri 18/03/11
LINAC4 MASTER PLAN
Task Name
7
2008
2009
2010
2011
2012
2013
2014
Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3
Linac systems
Source and LEBT construction, test
RFQ construction, commissioning
Accelerating structures construction
Klystrons delivery and installation
Transfer line construction, installation
Magnets construction, installation
Power converters construction, install.
Building and infrastructure
Building design and construction
Infrastructure installation
Installation and commissioning
Test stand operation at 3 MeV
Cavities testing, conditioning
Cabling, waveguides installation
Accelerator installation
Hardware tests
Front-end commissioning
Linac accelerator commissioning
Linac4 BPMs
Design office : L4T BPMs & integration
BPM production
Installation in Linac4 tunnel
Installation in Transfer Lines
Cabling in LT, LTB and BI lines
BPM commissioning with beam
Start of TL construction & Installation
Start of Machine Installation
Start of Machine Commissioning

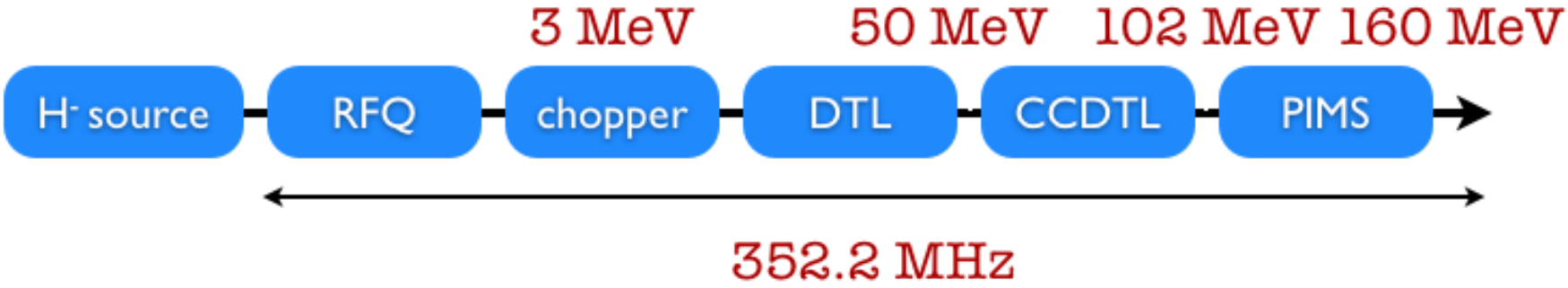
# Summary

- Very encouraging results yet still a lot of work ahead of us.
- Ready for the Movable Test Bench commissioning
- Planning in phase with Linac4 installation and LS1
- Budget sligthly underestimated : overrun by ~200kCHF

# Thank you for your attention

- …Questions ?

# Linac 4 – Basic architecture




| | Movable test bench 3–12MeV | DTL 50MeV | CCDTL 102MeV | PIMS 160MeV | New TL -> LT.BHZ20 160MeV | Old TL -> PSB 160MeV |
|---|---|---|---|---|---|---|
| Number of BPMs | 3 | 2 | 7 | 6 | 10 | 17 |
| Beam Ap. [mm] | 67 | 34 / 39 | 39 | 39 | 100 | 100 |
| Long. Phase [° rms] | 6.4 /98 | 3 | 3 | 2.5 | 25 | 55 |
| RMS length [ps] | 50 / 777 | 24 | 24 | 20 | 200 | 433 |

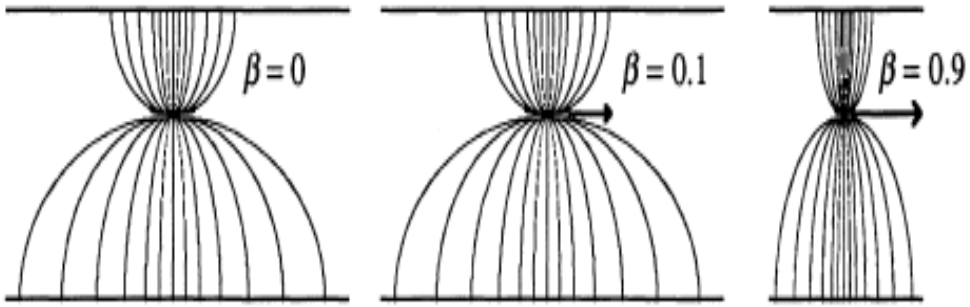
Bunch spacing : **2.84 ns**

# Simulation of non-relativistic beams

- Nominal beam phase width evolution (1RMS)

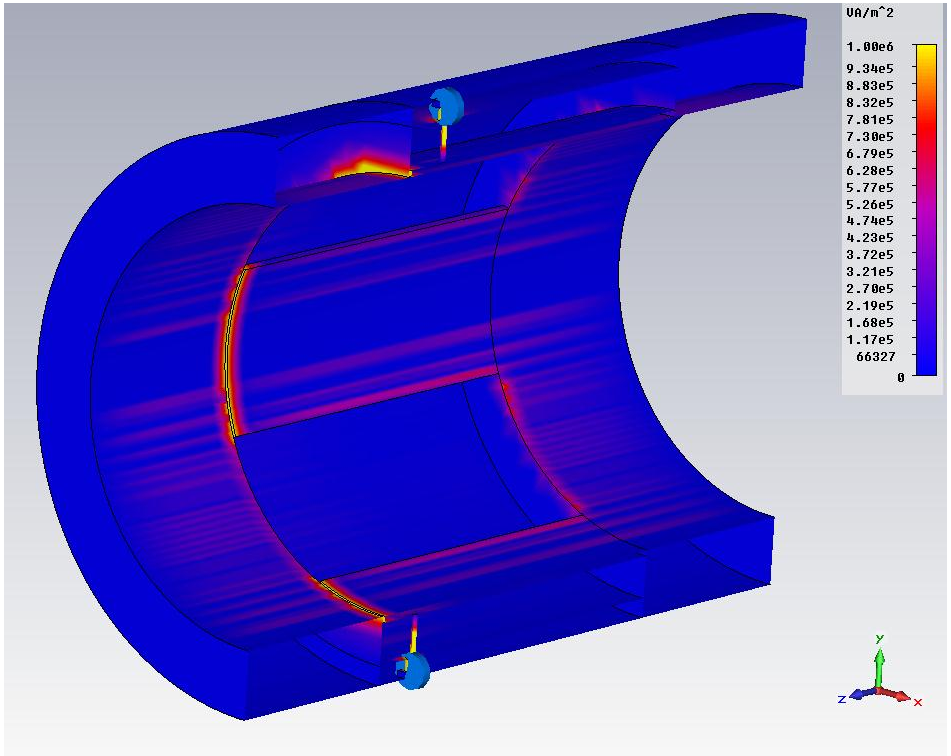
| | MEBT | Linac4 | PSB strip. foil |
|---|---|---|---|
| Sigma [ps] | 200 | 20 | 433 |
| Rel. beta | 0.0798 | 0.52 | 0.52 |

- Simulations with CST Particle Studio
  - Multi-bunch
  - Space charge effect
  - Low β

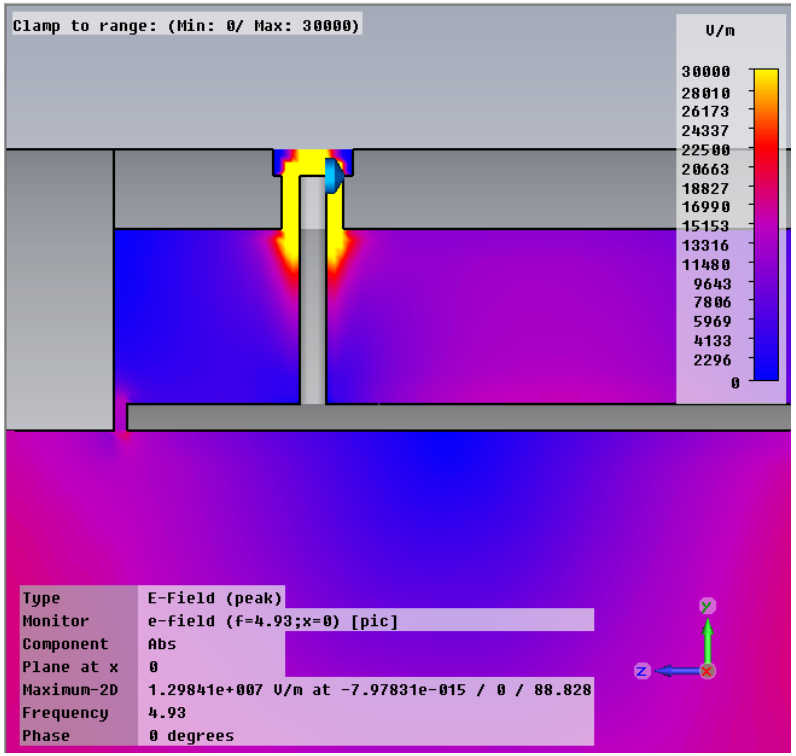


# High Frequency Losses

Power flow module

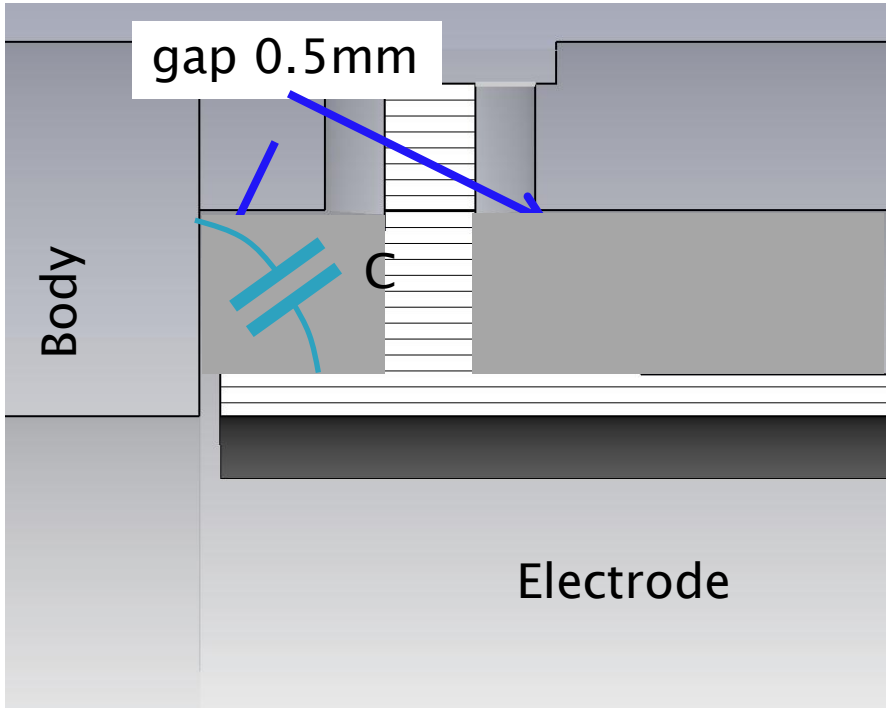


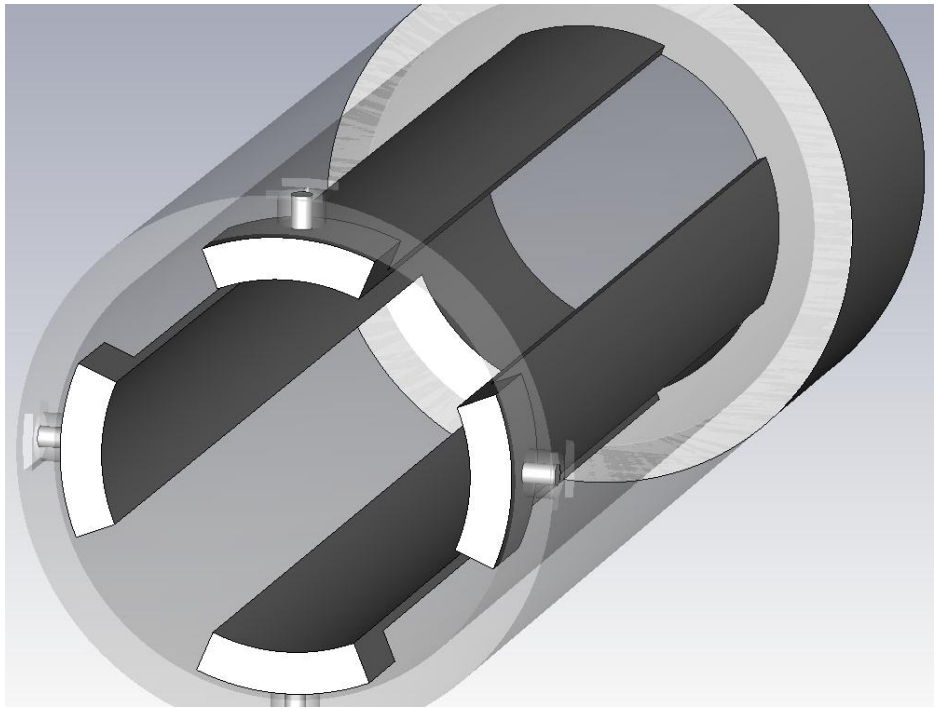

Electric field module




External diameter of the
RF feedthrough is important

# High Frequency Filter



Capacitive effect : 9pF