Proposal for impedance measurements at CLEAR Facility

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Overview

- Introduction
- Recap: Impedance Measurements at CLEAR Facility
- LIU Wirescanners – Overview and Measurement Plans

Introduction

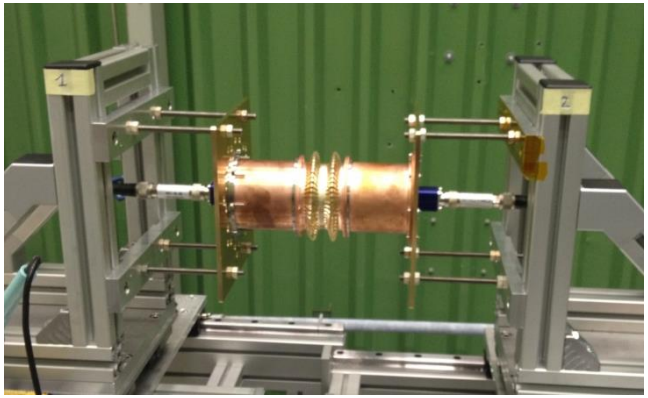
- Impedance working group (IWG) are involved in the design, optimisation and approval of components for all CERN circular machines.

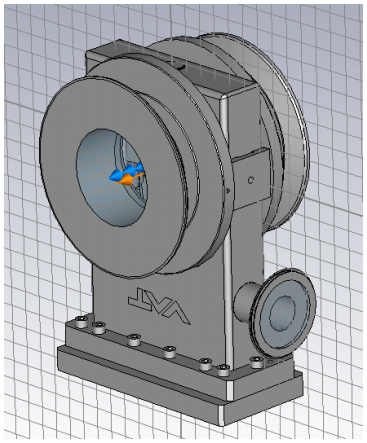
- **Various tools available for this endeavour.**

- **Bench measurement with wires and probes with 4 port network analyser.**
  - However, not a direct measurement of impedance or wakefield, and in some cases the wire can strongly perturb the EM fields which may skew the measurement.

- **Numerical simulation tools**
  - Difficult to accurately reproduce reality with a model due to fabrication errors, coating, matching errors, and the simulated exciting bunch is not a delta function.

- **Measurement with electron bunches would be complementary to these tools.**





Possibility for Impedance Measurements at CLEAR

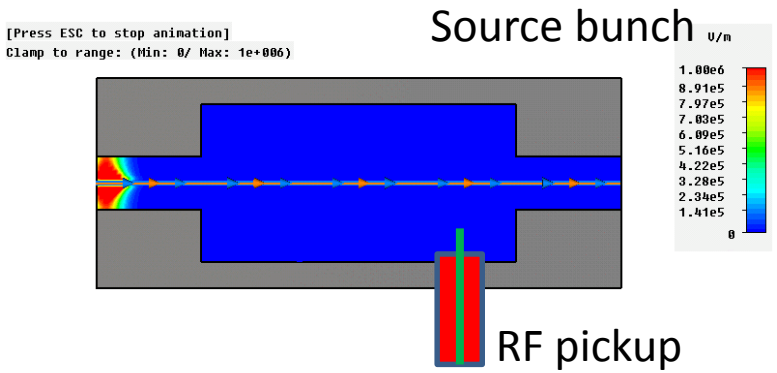
What we would like to measure

Direct measurement of electromagnetic fields.

- Can excite large frequency range with electron beam and **measure the field extracted** by the couplers / strip-lines / buttons / wires.

- Output can be compared with results from time domain solvers (i.e. CST Particle Studio).

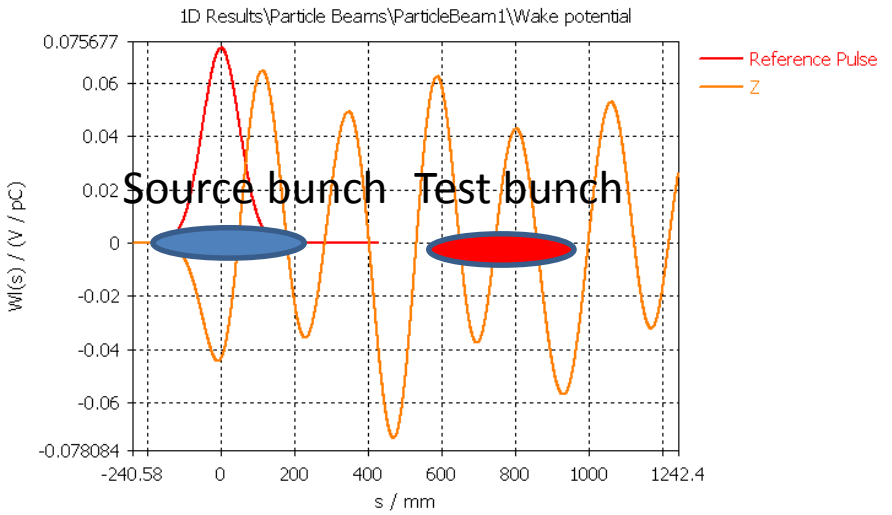
- Issues with current measurement techniques:
  - Probe measurements only verify transmission or eigenmode simulations.
  - Wire measurements can perturb the fields.

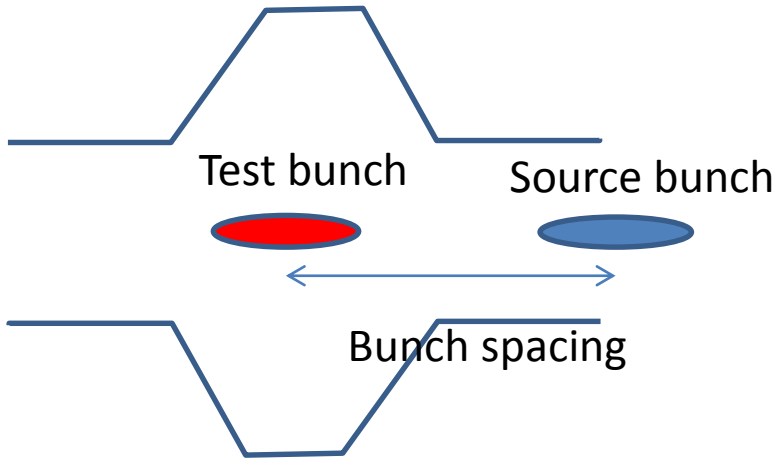


What we would like to measure

Direct measurement of 'wake function'

- Measurement of energy loss as a function of source/test bunch spacing can give the longitudinal wake function.
- Measurement of kick as a function of bunch spacing between source & test bunch can give the transverse wake function.
- For CLEAR parameters, it is **difficult to measure the short range wakefield due to there being only one beam species**. Cannot get close enough to source bunch to separate them out afterwards.
- If separation can be achieved, results similar to the measurements by A. Latina at FACET [1] could be achieved.
- **Very small bunch length** achievable (1 to 4 ps) means high frequency ranges (greater than can be achieved in simulations) can be probed.





What we would like to measure

Example of hardware to be measured

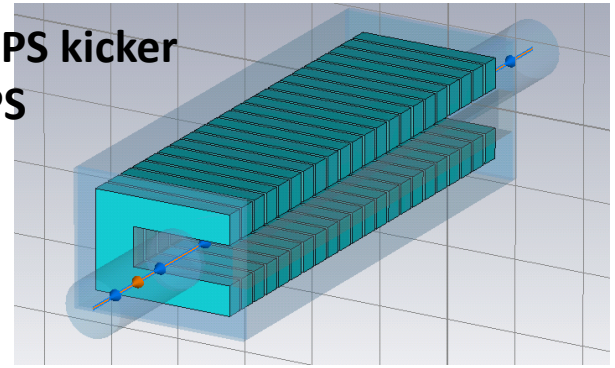
- Consolidation:
  - TDI beam screen consolidation
  - TCP replacement with spare
  - BSRT mirror design change
  - RF fingers consolidation, carousel
- Upgrade:
  - Tertiary collimators with BPMs (TCTP and TCSP)
  - ATLAS-ALFA
  - “TOTEM consolidation” of existing Roman pots
  - MKI screen conductor upgrade
  - New experimental beam pipe in CMS and ATLAS
  - Schottky
- New equipment:
  - New TCL4 and TCL6
  - 3rd TCDQ module
  - BGV on B2
  - New “TOTEM upgrade” pots
  - New UA9 goniometer
- Non conformities:
  - Contacts in triplets

What we would like to measure

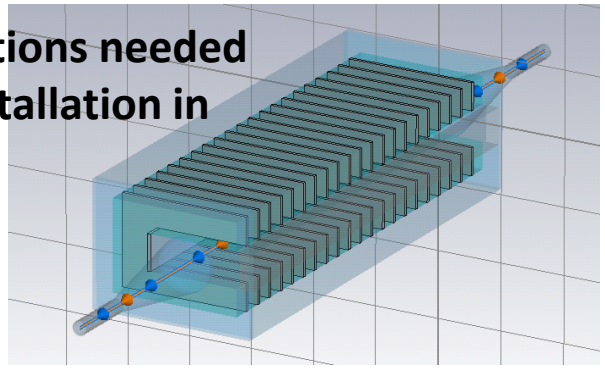
Example of hardware to be measured

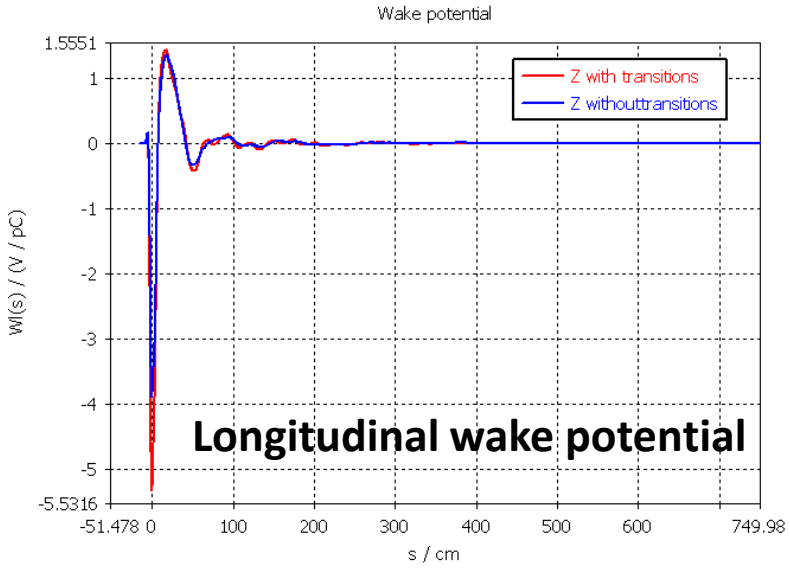
- Tapers would be required to connect components with different apertures.
- Need to ensure tapers do not contribute to the impedance.

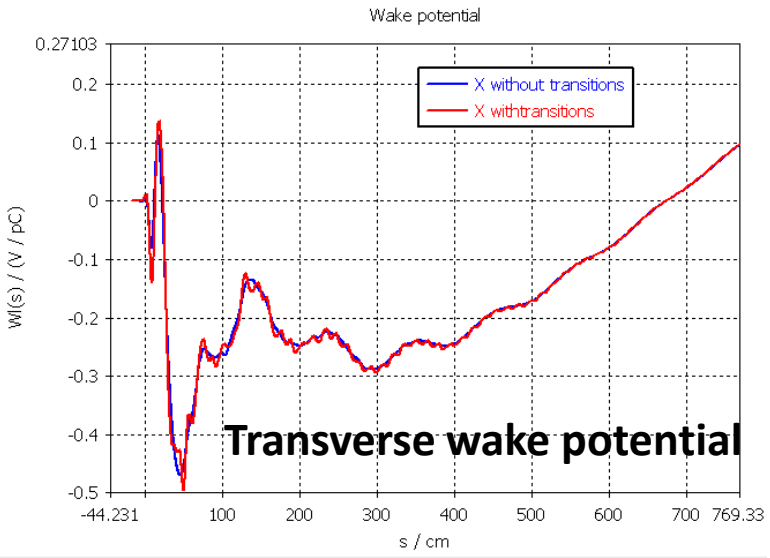
Typical SPS kicker in the SPS



Transitions needed for installation in CLEAR







Lots of tapers would be required for measurements on each component.

What we would need

Direct measurement of electromagnetic fields:

- Device under test
- Tapers out of and into the CLEAR beam pipes
- A probe to catch the electromagnetic fields
- An instrument to record the signals

Direct measurement of ‘wake function’

- Device under test
- Tapers out of and into the CLEAR beam pipes
- A system to measure the deflection to probe bunches

What we would need

Direct measurement of electromagnetic fields:

- Device under test
- Tapers out of and into the CLEAR beam pipes
- A probe to catch the electromagnetic fields
- An instrument to record the signals

Could be obtained if money and manpower is allocated

Direct measurement of 'wake function'

- Device under test
- Tapers out of and into the CLEAR beam pipes
- A system to measure the deflection to probe bunches

What we would need

Direct measurement of electromagnetic fields:

- Device under test
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- An instrument to record the signals

Need to choose the device wisely

Direct measurement of 'wake function'

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What we would need

Direct measurement of electromagnetic fields:

- Device under test
- Tapers out of and into the CLEAR beam pipes
- A probe to catch the electromagnetic fields
- An instrument to record the signals

Not trivial but can be attempted

Direct measurement of 'wake function'

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Direct measurement of 'wake function'

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- Tapers out of and into the CLEAR beam pipes
- A system to measure the deflection to probe bunches

Not envisaged for 2017 as requires a lot of additional hardware (BPMs, spectrometers, etc.)

Proposal for wirescanner measurements in CLEAR

Overview

Introduction

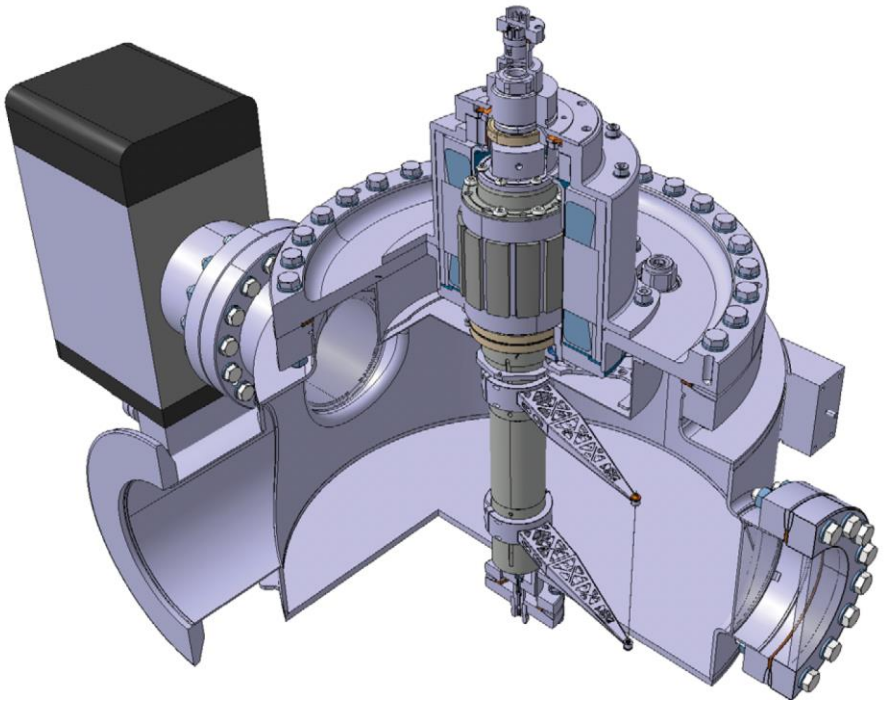
- SPS wirescanners have history of issues with **excessive heating of the wire**, even when in parking position.
- Heat delivered to wire has a bunch length dependence -> **rf issue**[2].
- Difficult to simulate as cannot be appropriately meshed (aspect ratio and losses of the wire and modelling both cabling and connections for the temperature measurement of the wire [3,4]).
- Bench measurements are dubious as the measurement wire **could not be used in conjunction with the stretched wire method** (probe measurements were done but difficult to conclude from these alone [3]).
- Need to clearly understand the problem and possible mitigations in **advance of LIU beams in the SPS** (and PSB and PS).

CLEAR Measurements

- Can use the CLEAR facility to perform tests and measurements to try and better understand the issue, **and as a first test to see the potential and the issues of the facility.**

Geometry

- Rotating wire in tank can intercept beam for transverse profile measurements.
- Full vacuum tank ~0.5m in length. Beam pipe diameter is maximum ~150mm
- CLEAR experimental area ~16m. Smaller beam pipe than wirescanner. Plenty of available space either side of tank for tapers.
- Tapers needed to match beam pipes from scanner to CLEAR beam line. -> for these direct EM measurements, should not perturb the signals up to the cutoff of the Wirescanner pipe.



Plan

- There are currently 2 variants of the new LIU wirescanners
  - A first prototype installed in the SPS and for which there is a spare tank and mechanism available for tests
  - A second (the final) version installed in the PSB for which a spare tank and mechanism will not be available for testing in CLEAR before 2018
- Several studies need to be performed prior to installation and testing to try and answer the following questions:
  - SPS beam is very different from CLEAR beam. Is the CLEAR beam adequate for testing wirescanners?
  - What modifications to the tank might be required to better improve diagnostics and measurements?
  - What sensitivity range can be achieved for the sensors?

- Could gain experience with CLEAR beam and impedance measurements in general by **testing a wirescanner mechanism in a relevant vacuum tank equipped with a coupler.**

Plan

What we would like to do:

- Measure the **frequency spectrum** of the signal coming out of the measurement cables for the temperature (DC resistance) of the wire.

What we need:

- A vacuum tank and a wire scanner mechanism with a carbon wire connected to a realistic DC resistance system.
- With an instrument connected to the cables, can see what frequencies are excited by CLEAR beam.

What we would measure

- Install coupler and **measure direct resonant signals** from CLEAR beam with and without scanner.
- Scan different wire angles and perform measurements.
- Exchange wire for tungsten, copper or copper loaded with resistors.
- Check effects of mitigation measures.

Open Questions

Some open questions still to be addressed:

- How much work is required to prepare the existing vacuum tank and mechanism for testing?
- Tapers need to be designed and constructed to transition into and out of DUT.

- What instruments could be used to record the signals with low repetition rate (spectrum analyser with time domain gating and adequate synchronisation? Fast digitiser)?
- **Can a spectrum analyser or fast digitiser be left near the DUT** or does it need to be in the control room? If it needs to stay in the control room, need to care about cable length and attenuation.
- Will there be enough signal with the CLEAR beam in the frequency range of interest?

- What can be done to **maximise duty cycle**?

- **Many of these issues will be followed up by the impedance working group.**

Thanks for listening.

Bibliography

[1] A. Latina *et al*, Beam-based measurements of long-range transverse wakefields in Compact Linear Collider main-linac accelerating structure, PRAB (16) 011001, 2016

[2] F. Roncarolo *et al*, Cavity Mode Related Wire Breaking of the SPS Wire Scanners and Loss Measurements of Wire Materials, DIPAC 2003

[3] A. Valimaa *et al,* Status of SPS wirescanner prototype measurements, Impedance Working Group Meeting, 18-06-15

[4] T. Kroyer, Simulation of Wire Scanner Heating by the Electromagnetic Field of a Particle Beam, CERN-AB-Note-2008-018.