XIth Meeting of the Spanish Network for Future Linear Accelerators
UB, Barcelona
15-16 January 2015

Accelerator R&D activities at IFIC

Group members:

- **Dr. Angeles Faus-Golfe** (CSIC researcher)
- **Dr. Daniel Esperante** (Electronic engineer, nowadays at CERN-LHC consolidation)
- **César Blanch Gutiérrez** (Mechanical engineer, nowadays at CERN-LHC consolidation)
- **Carolina Belver Aguilar** (PhD FPI)
- **Alfonso Benot Morell (**PhD Infraestructuras Científicas y Organismos Internacionales)
- **Núria Fuster Martínez** (PhD Student UV)
- **Natalia Galindo Muñoz** (PhD Student PACMAN)

http://gap.ific.uv.es/

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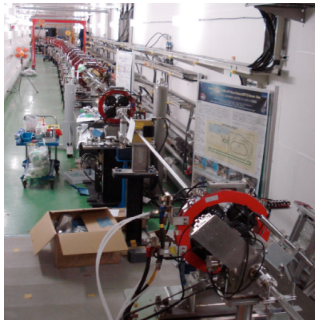
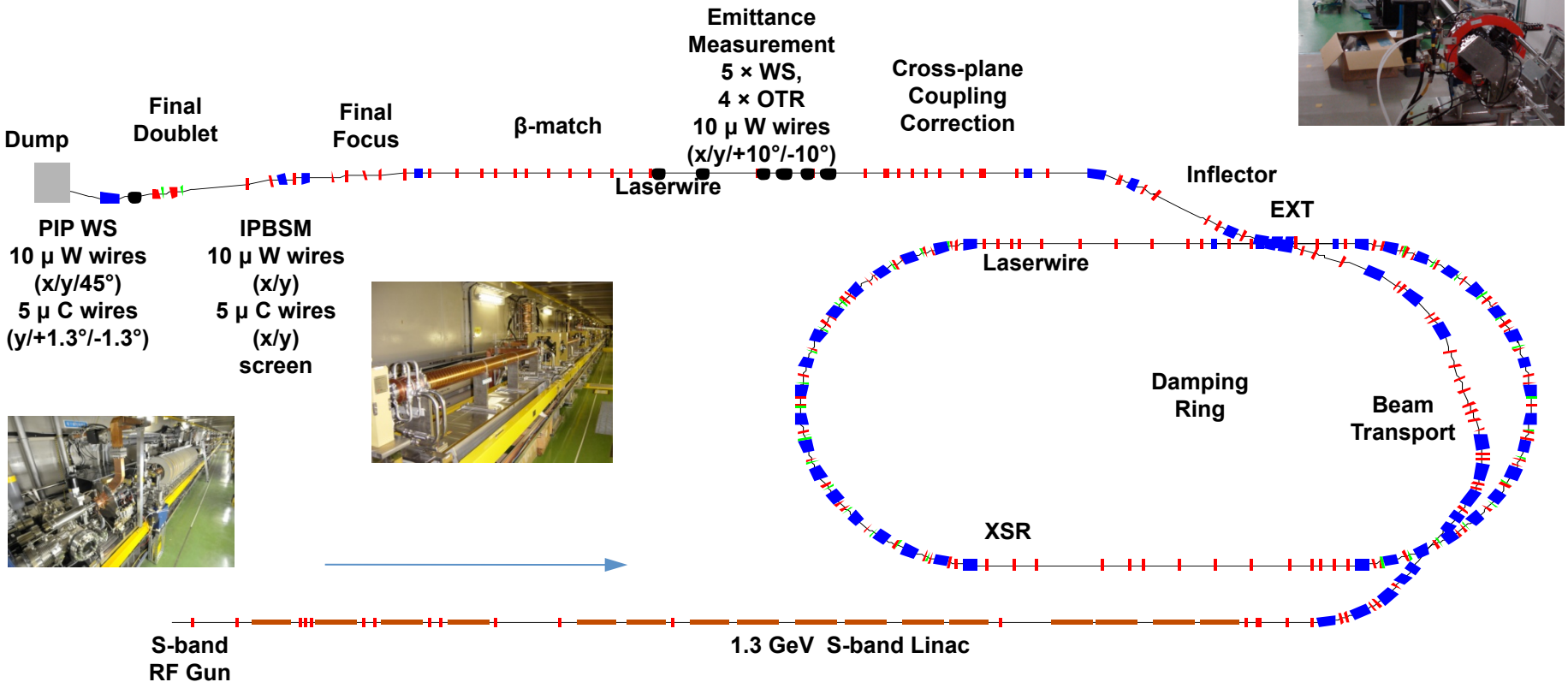
  - High-gradient RF structure studies for medical accelerators

R&D activities at ATF-ATF2

ATF-ATF2 OVERVIEW

- The Accelerator Test Facility (**ATF**) was built in KEK (Japan) to create small emittance beams. The Damping Ring (DR) of ATF has a world record of the emittance: 12 pm rad
- **ATF2** studies the feasibility of focusing the beam into a nanometer spot in a future linear collider (σ_y=37nm with nm level stability)

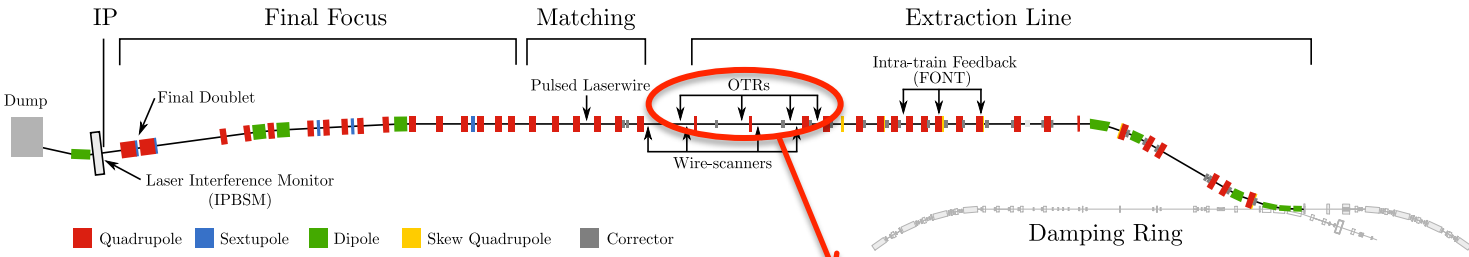




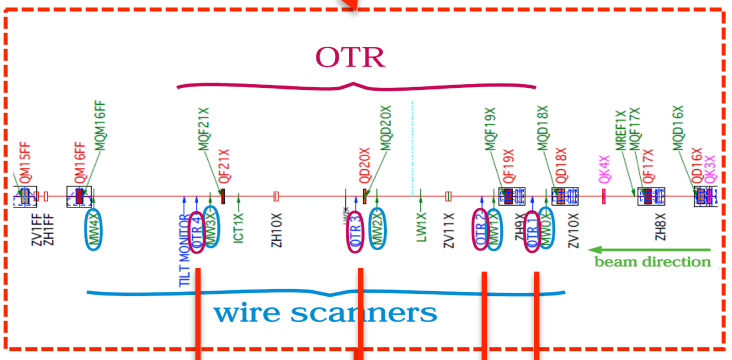
R&D activities at ATF-ATF2

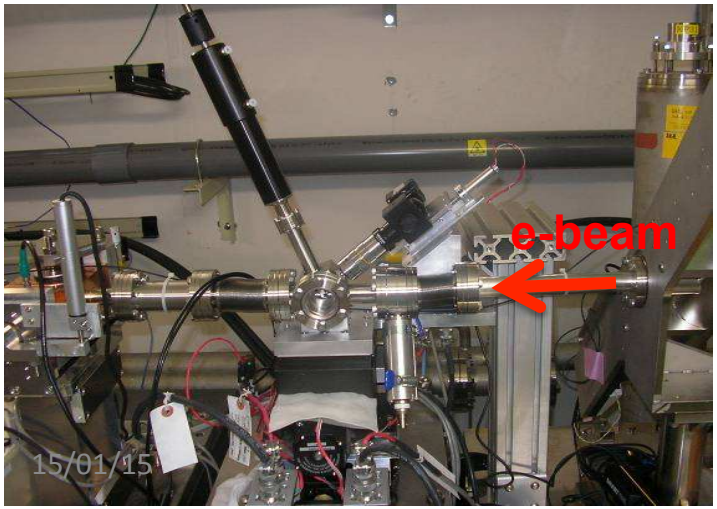
OPTICAL TRANSITION RADIATION MONITORS FOR ATF-ATF2

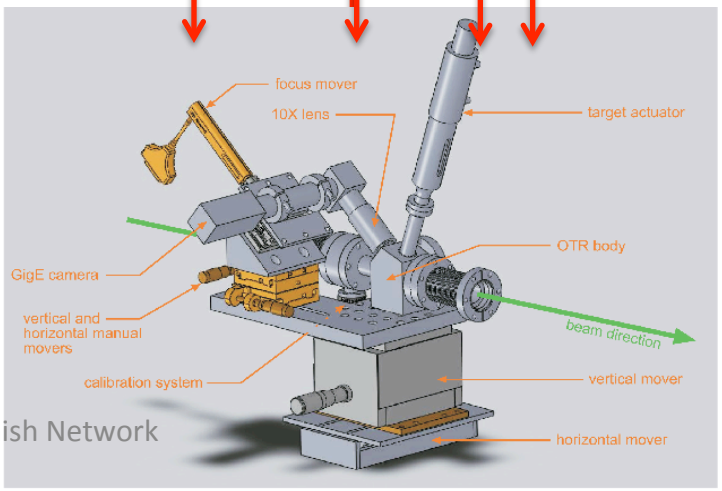
ATF2 layout



4-OTR system





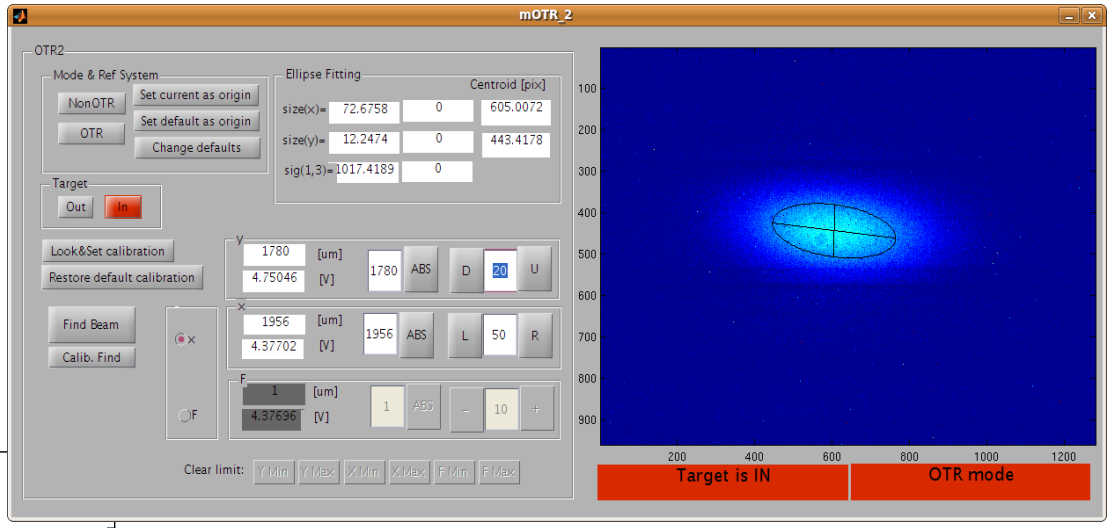


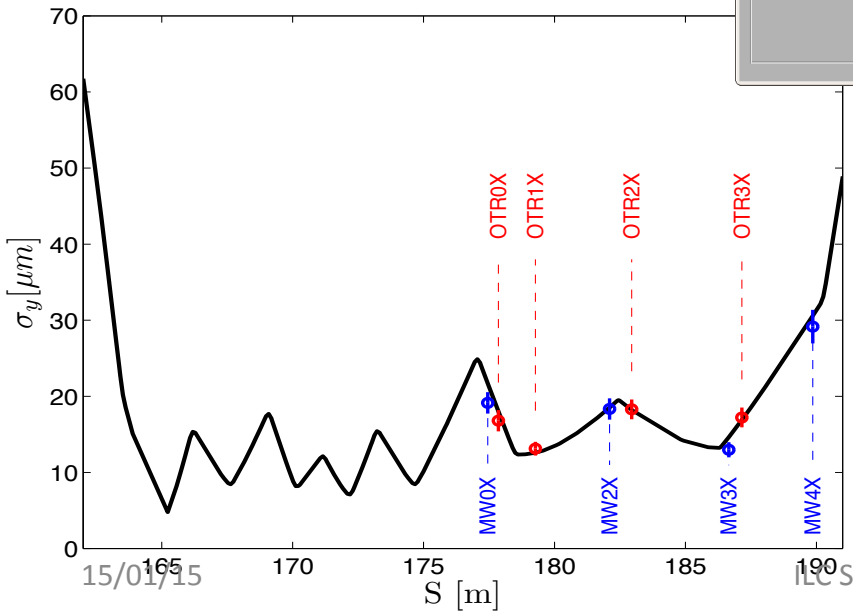
R&D activities at ATF-ATF2

OPTICAL TRANSITION RADIATION MONITORS FOR ATF-ATF2

Beam size measurements and emittance reconstrcution

- The ATF2 multi-OTR system has demonstrated to be very reliable
- Fast beam size measurement and emittance reconstruction
- Diagnostic tool very helpful for the tuning of the machine





Example of vertical beam size measurements by the 4 OTRs and the wire scanners compared with the ATF2 model

R&D activities at ATF-ATF2

OPTICAL TRANSITION RADIATION MONITORS FOR ATF-ATF2

- The **multi-OTR system** of the ATF2 EXT has demonstrated its performances as a **fast** (~1 min) and **reliable** system for measuring the beam size and the emittance.

- **Totally integrated** in the **online model** and **crucial** for beam **tuning procedures**: coupling correction, beta matching, energy spread measurements

- We have **studied analytically** the **conditions of solvability** of the systems of equations involved in the process of emittance reconstruction and we have obtained some rules about the **locations** of the **measurement stations** to avoid unphysical results.

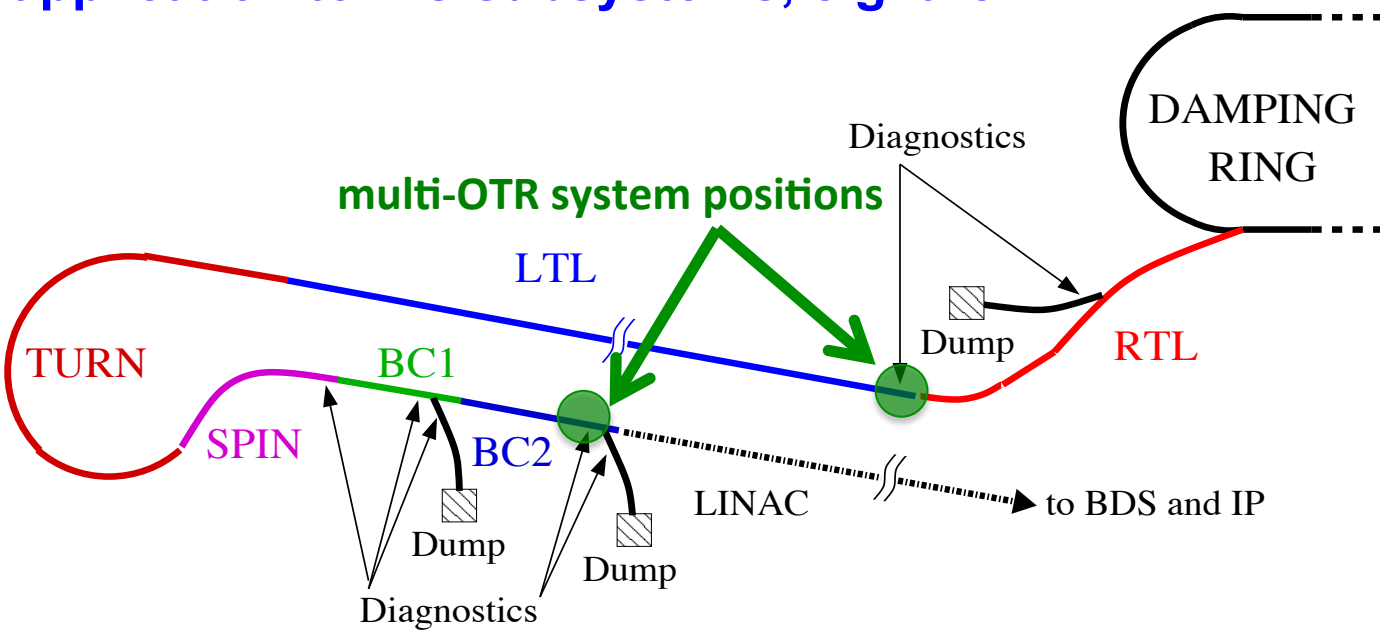
- **Simulations** has been made to test the robustness with high coupling scenarios and measurement errors. The results of these studies will be very **useful** to better determine the location of the emittance measurement stations in the **diagnostic sections** of **FLCs**.

- OTR monitors are **mature** and **reliable** diagnostic tools that could be **very suitable** for the setup and tuning of the machine in single-bunch mode. It can be very useful during **start up** and **commissioning** phases of the **RTML**. The **feasibility study** of using a m-OTR system in **transfer lines** of the **ILC RTML** has been made.

R&D activities at ATF-ATF2

OPTICAL TRANSITION RADIATION MONITORS FOR ATF-ATF2

Potential application to ILC subsystems, e.g. the RTML



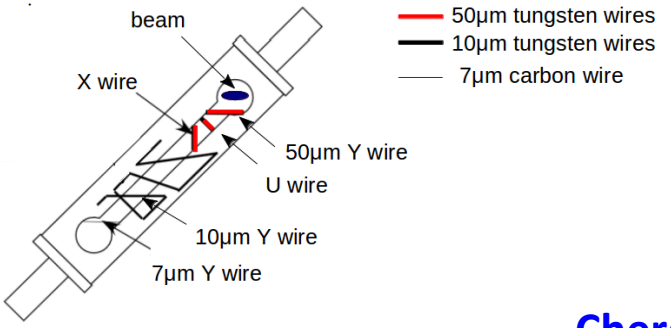
- OTR monitors are mature and reliable diagnostic tools that could be very suitable for the setup and tuning of the machine in single-bunch mode
- It can be very useful during startup and commissioning phases of the RTML
- When operating with high charge and multi-bunch train the OTRs would be in non-measurement mode, i.e. they would be retracted from the beam path

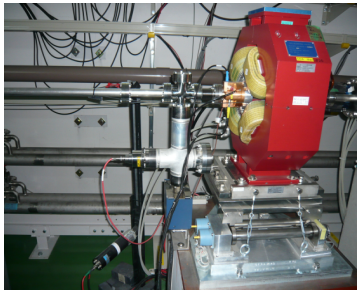
R&D activities at ATF-ATF2

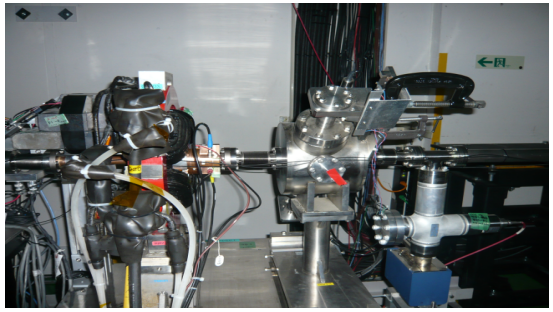
BEAM HALO MEASUREMENTS IN ATF2

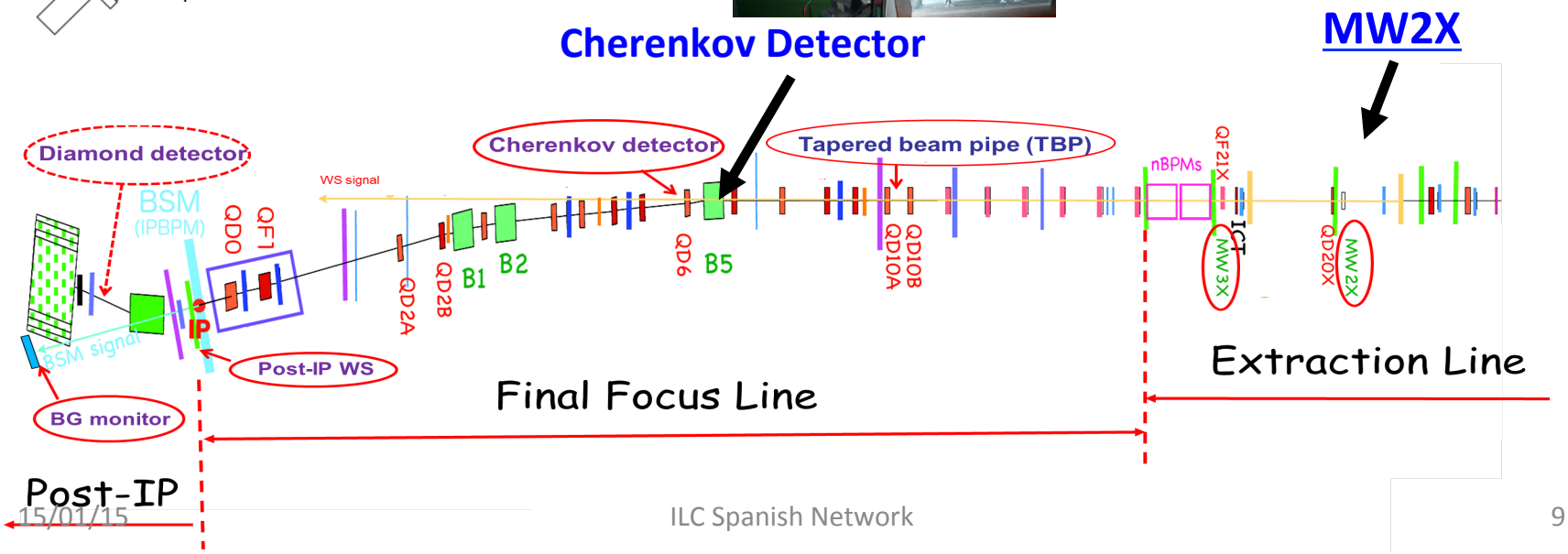
Investigation of **beam halo transverse distribution** is an important issue for **beam loss and background control** in **ATF2** and in **Future Linear Colliders (FLC)**

First beam halo measurements were done in **2005** using the **wire scanners in the ATF EXT** line -> these experiments has been updated for **ATF2 beam line in 2013 – 2014 runs**





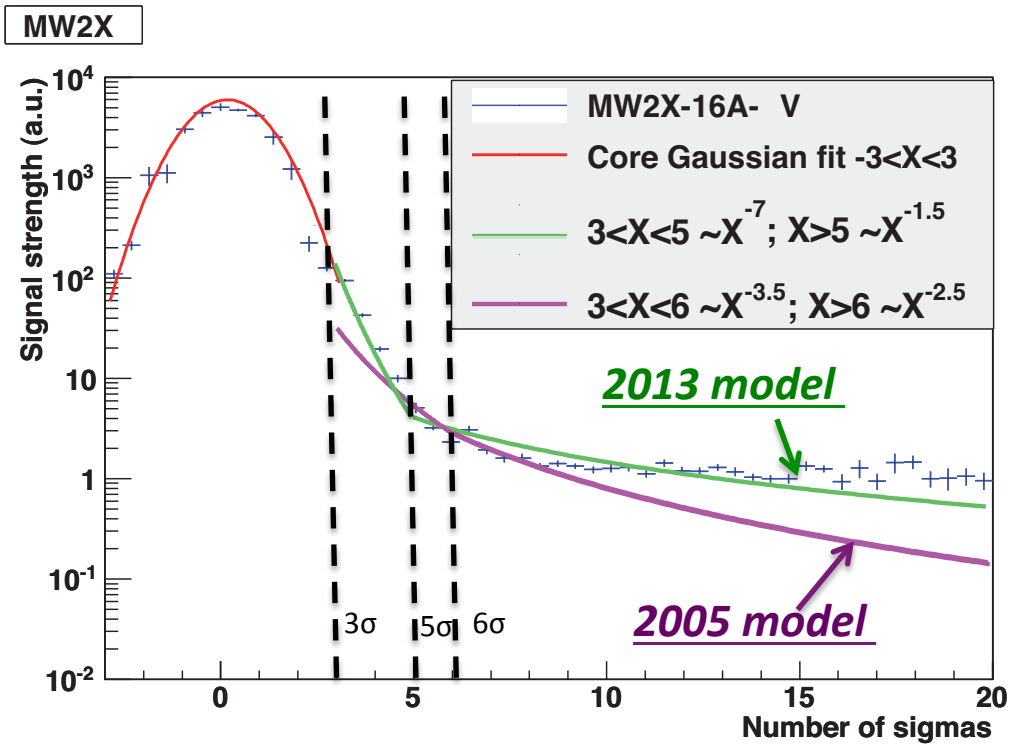


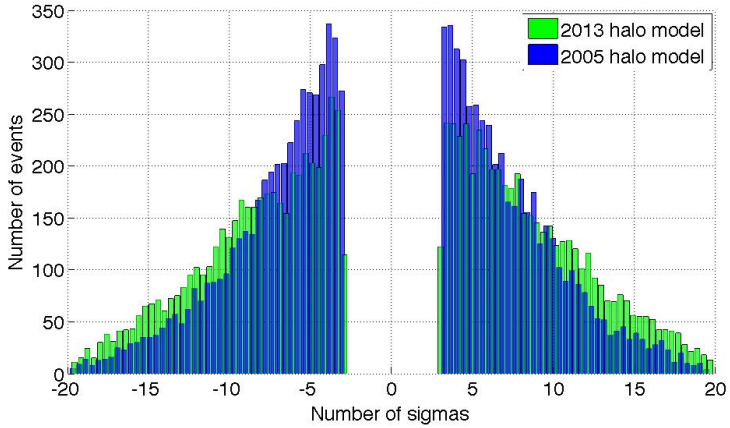


R&D Actvities at ATF-ATF2

BEAM HALO MEASUREMENTS IN ATF2

Vertical and horizontal beam halo measurements were done in the **EXT line** with **MW2X wire scanner** in **April 2013**





On going work

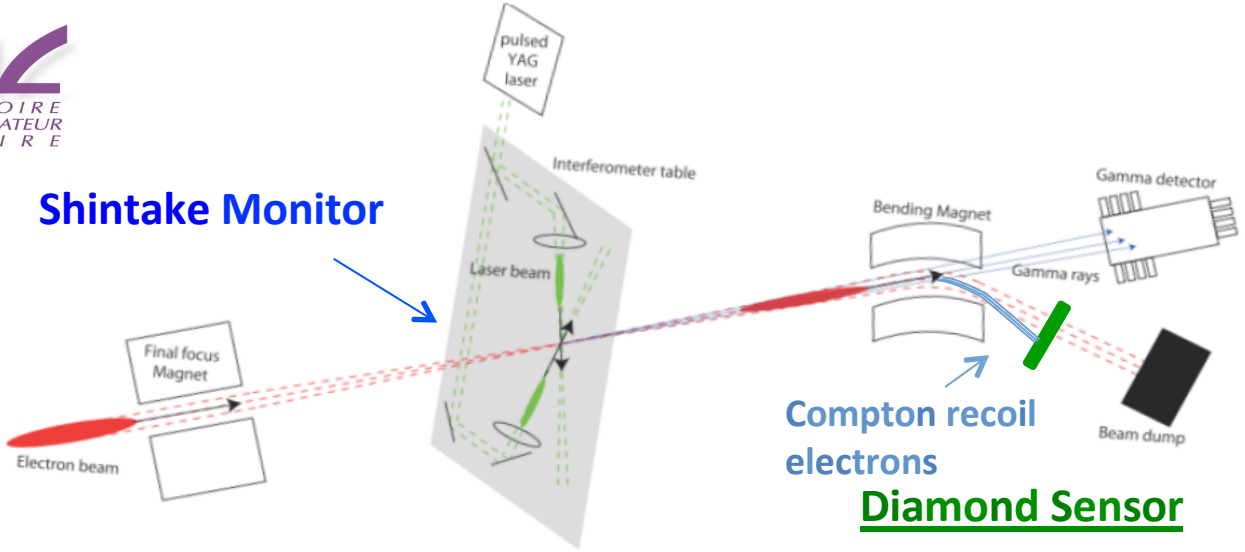
- In **December 2014** measurements of the beam halo distribution have been done in the EXT line of the ATF2 beamline with the **OTRs system** . The data is being analysed and will be compared with the wire scanner measurements done in 2013

R&D activities at ATF-ATF2

BEAM HALO COLLIMATION AND WAKEFIELDS

Motivation of the study

- **Reduction of the background** noise at the Shintake Monitor (IPBSM) at the IP
- Reduce halo extension, mainly in the **horizontal** plane, to **improve the detecion efficiency of the Diamond Sensors (DS)** located between the BDUMP bending magnet and the DUMP to measure the beam halo distribu7on and the Compton electrons coming from the interac7on between the laser and the electron beam



R&D activities at ATF-ATF2

BEAM HALO COLLIMATION AND WAKEFIELDS

1. **Beam dynamics simulation and realistic tracking studies** in ATF2 to evaluate the efficiency of a retractable halo collimation system (IFIC-LAL-KEK)

2. **Design** of a retractable halo collimation device: mechanical and material study (IFIC-LAL)

3. **Construction and calibration** of the halo collimation device (IFIC-LAL)

4. **Software design** of the halo collimation device control system (IFIC-LAL)

5. **Installation and commissioning** of the halo collimation device in ATF2 (IFIC-KEK-LAL)

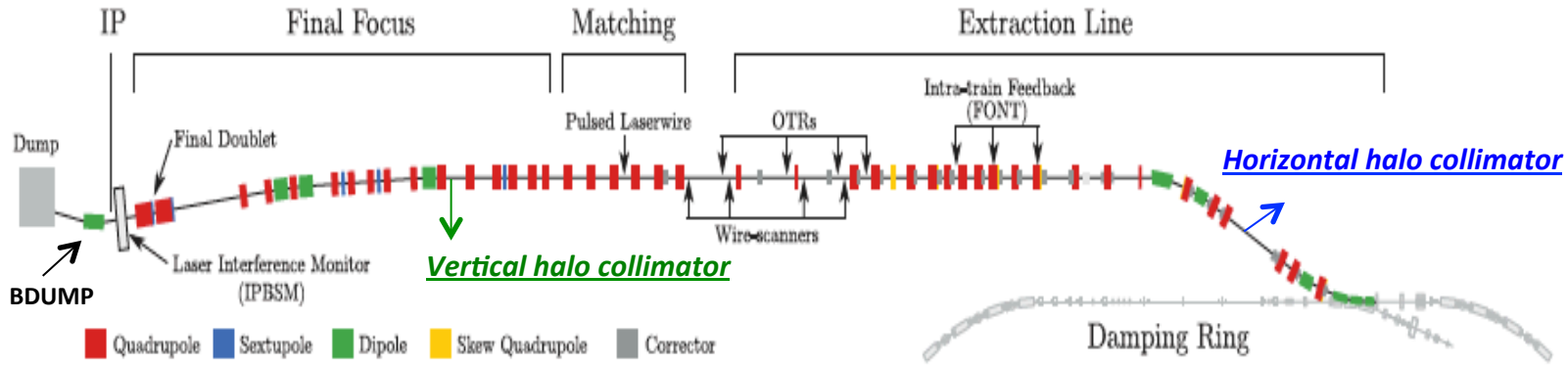
6. **Halo control, background reduction and collimator wakefield studies** using the ATF2 halo collimator (IFIC-KEK-LAL)

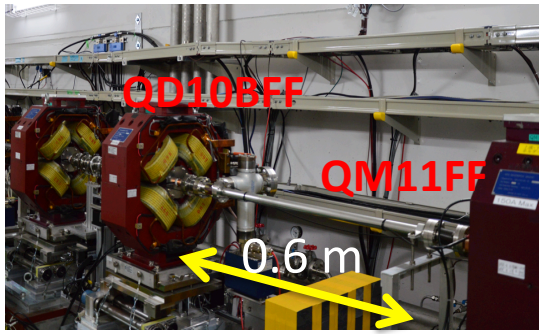
R&D activities at ATF-ATF2

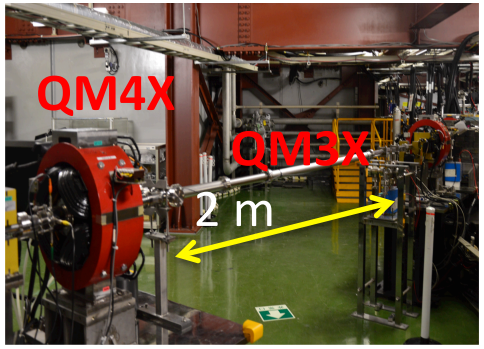
BEAM HALO COLLIMATION AND WAKEFIELDS

Beam dynamics simulation and realistic tracking studies:

- Optimized location for a betatron beam halo collimation system (vertical and horizontal)







Vertical halo collimator

- Between **QD10BFF-QM11FF**
- β_y=7126.51 m
- 0.6 m available free space length

Horizontal halo collimator

- Between **QD4FX-QD3FX**
- β_x=157.02 m
- 2 m available free space length

R&D Actvities at ATF-ATF2

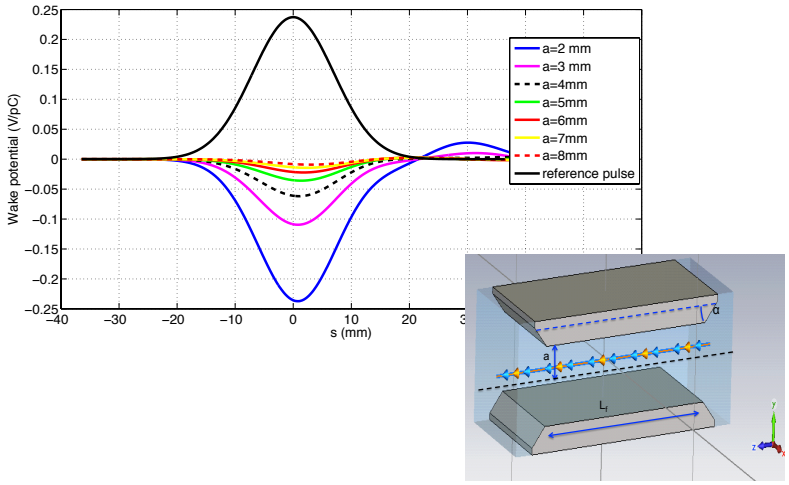
BEAM HALO COLLIMATION AND WAKEFIELDS

Design of a retractable halo collimation device: mechanical and material study:

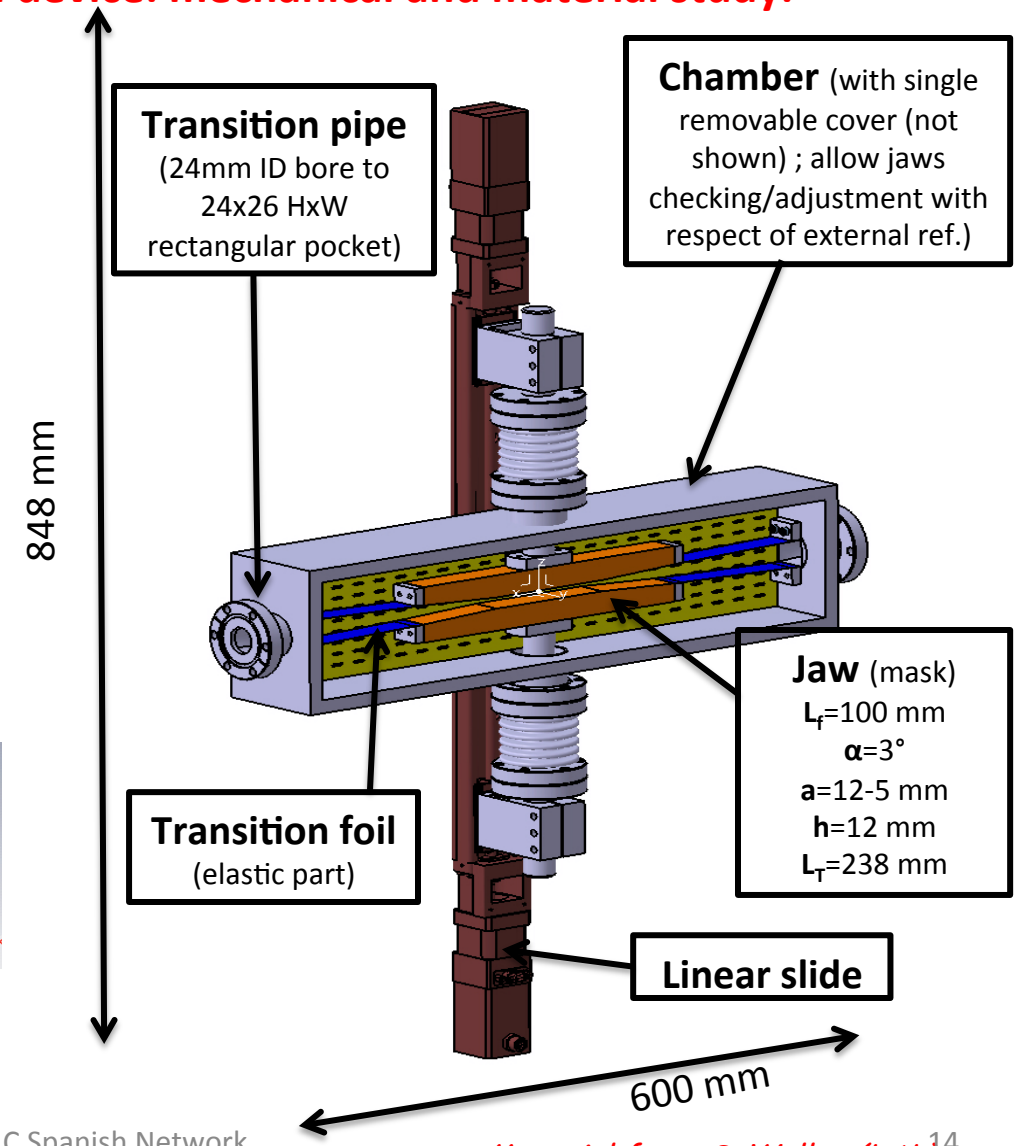
A retractable halo collimation type has been considered because of its flexibility in terms of operational aspects

Collimator wakefield study

Analytical and **Numerical simulations** using **CST PS**



This study has given the geometrical parameters to do a first 3D design



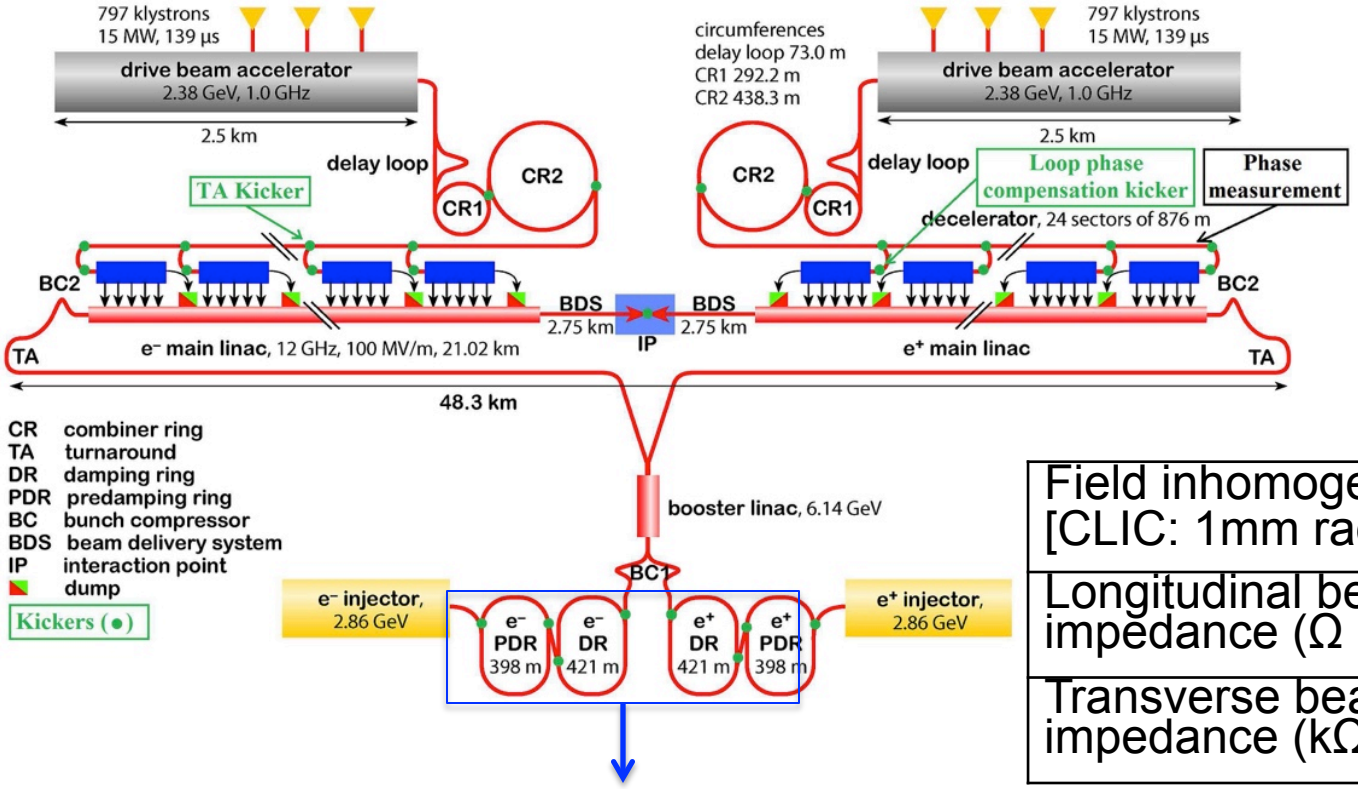
Material from S. Wallon (LAL)

R&D activities at CLIC

STRIPLINE KICKERS FOR BEAM INJECTION AND EXTRACTION IN FUTURE LINEAR COLLIDERS

IFIC INSTITUT DE FÍSICA CORPUSCULAR · GAP · CERN · GOBIERNO DE ESPAÑA · MINISTERIO DE CIENCIA E INNOVACIÓN · Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Striplines design for the extraction kicker of CLIC Damping Rings

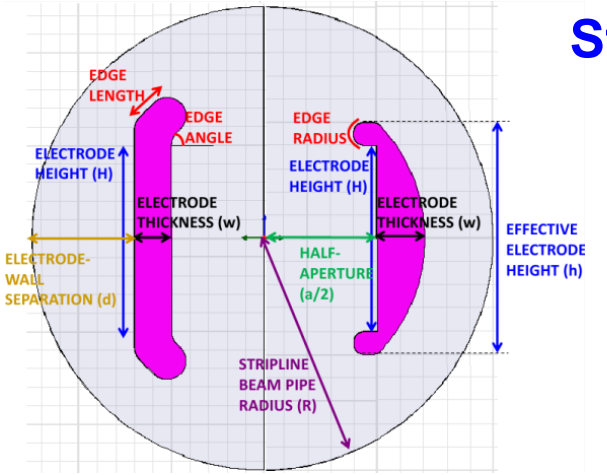


Field inhomogeneity (%) [CLIC: 1mm radius]	± 0.01
Longitudinal beam coupling impedance (Ω per turn)	< 0.05
Transverse beam coupling impedance (kΩ/m)	< 200

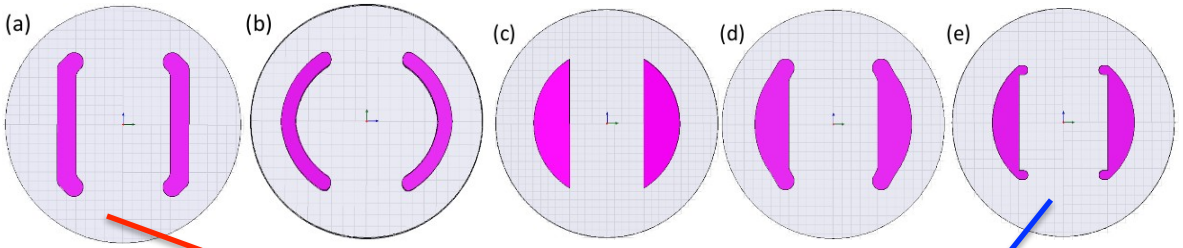
8 challenging kicker systems for beam injection and extraction from CLIC PDRs and DRs

R&D activities at CLIC

STRIPLINE KICKERS FOR BEAM INJECTION AND EXTRACTION IN FUTURE LINEAR COLLIDERS



Striplines geometry choices

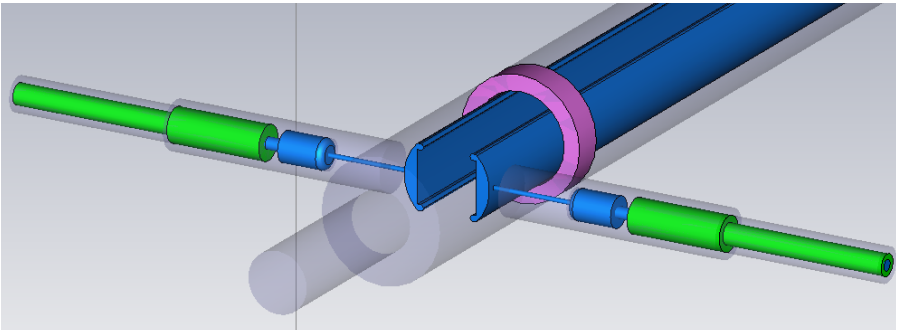


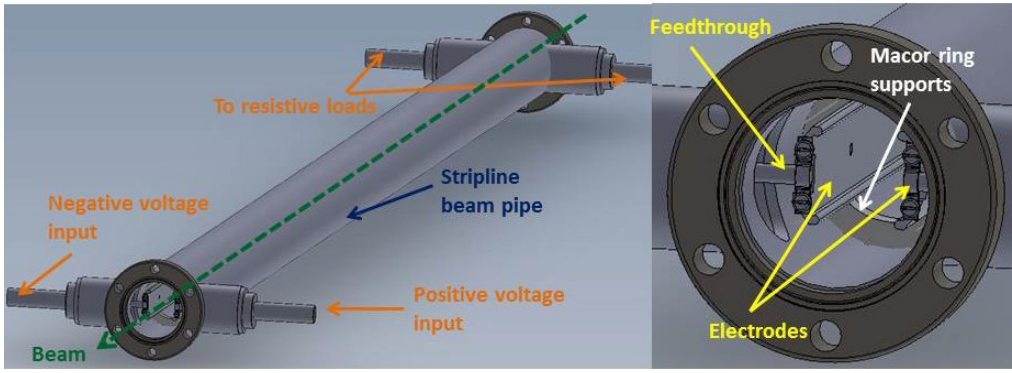
	FLAT ELECTRODE	HALFMOON ELECTRODE
Matching characteristic impedances		✓
Field homogeneity	✓	✓
Signal transmission		✓
Settling time		✓
Untapered longitudinal beam coupling impedance		✓
Untapered transverse beam coupling impedance	✓	

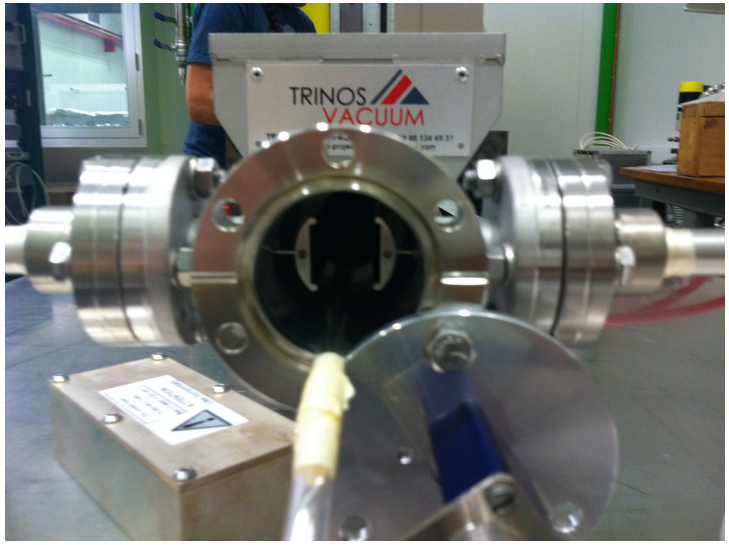
R&D activities at CLIC

STRIPLINE KICKERS FOR BEAM INJECTION AND EXTRACTION IN FUTURE LINEAR COLLIDERS

Fabrication of the striplines and their components







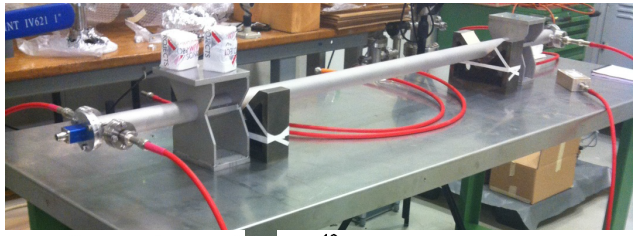
- The design of the striplines and their components, such as feedthroughs and electrode suports, has been published in the PRSTAB 17, 071003 (July 2014).
- The fabrication of the striplines has been carried out by the Spanish company Trinos Vacuum Projects, under the Spanish program "Science for Industry".

R&D activities at CLIC

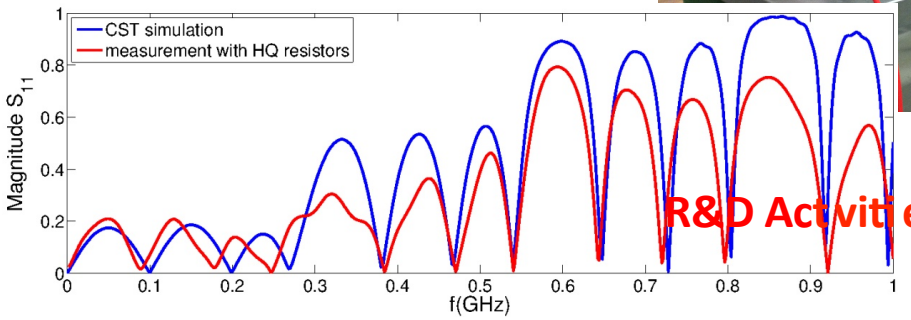
STRIPLINE KICKERS FOR BEAM INJECTION AND EXTRACTION IN FUTURE LINEAR COLLIDERS

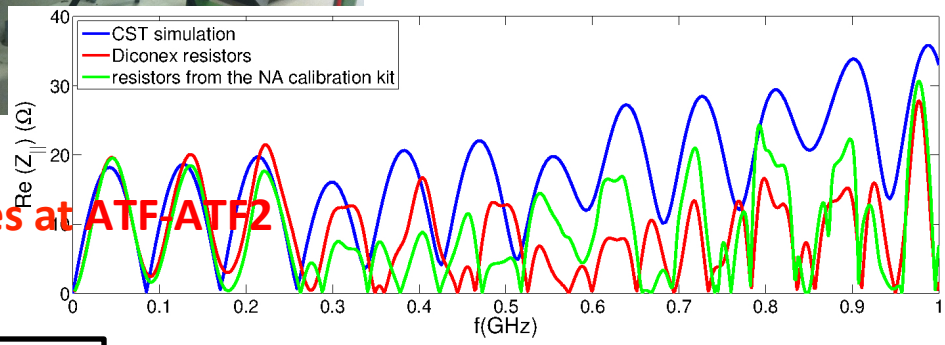
Laboratory tests at CERN:

S_{11} parameter



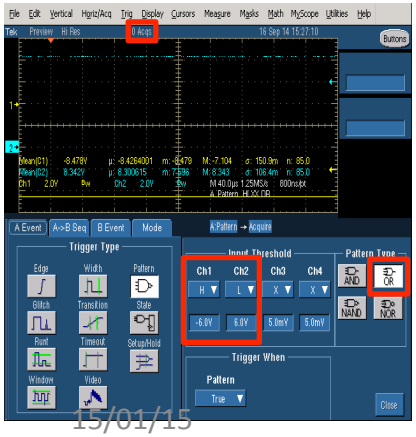
Longitudinal beam impedance

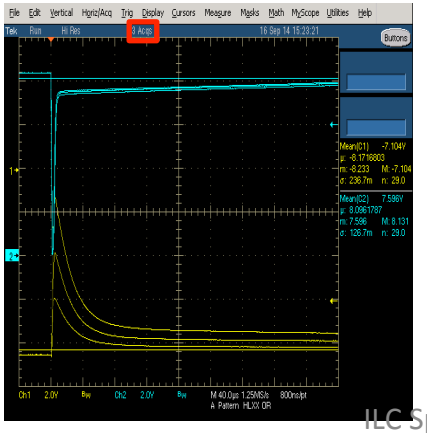


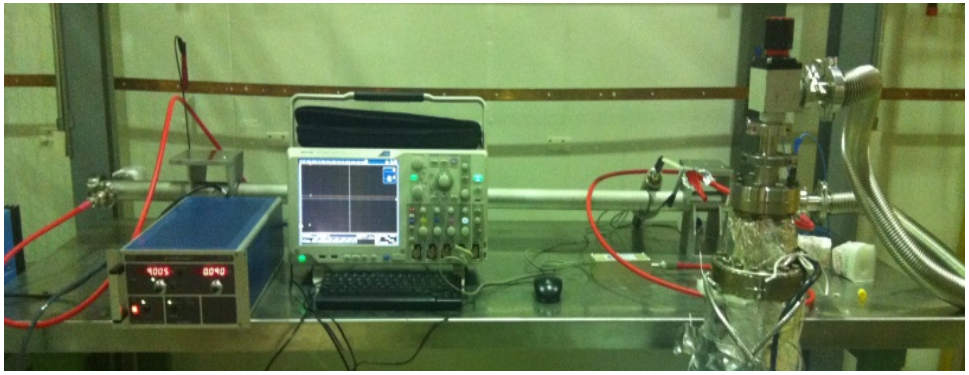


R&D Activities at ATF-ATF2

HV tests



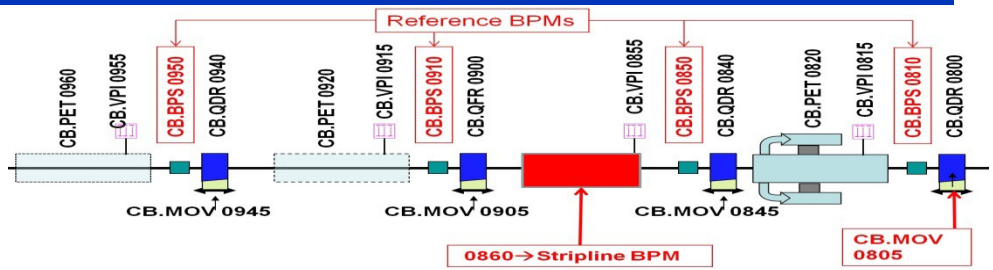


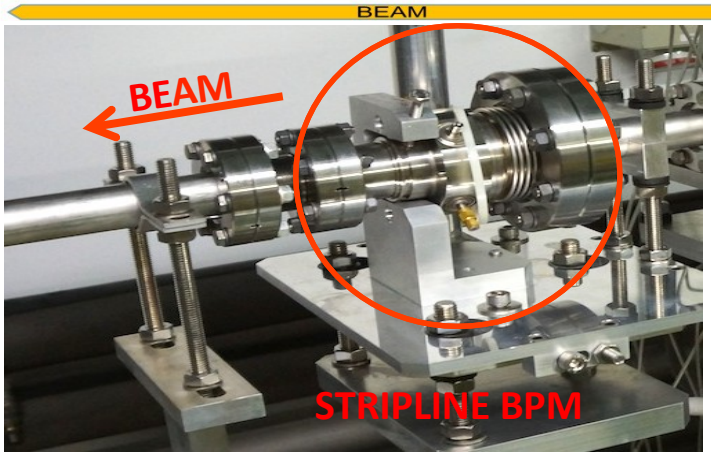


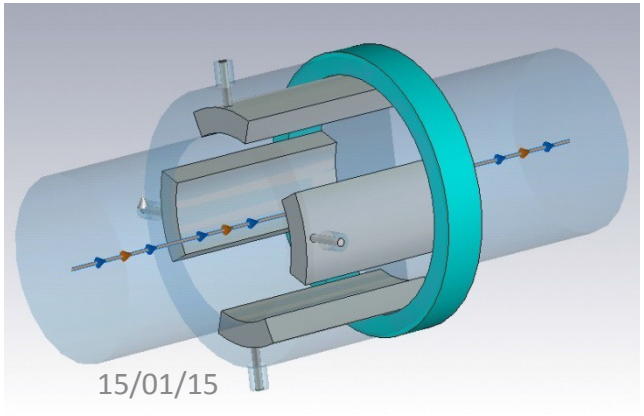
R&D activities at CLIC

STRIPLINE BPM DEVELOPMENT FOR THE CLIC DRIVE BEAM

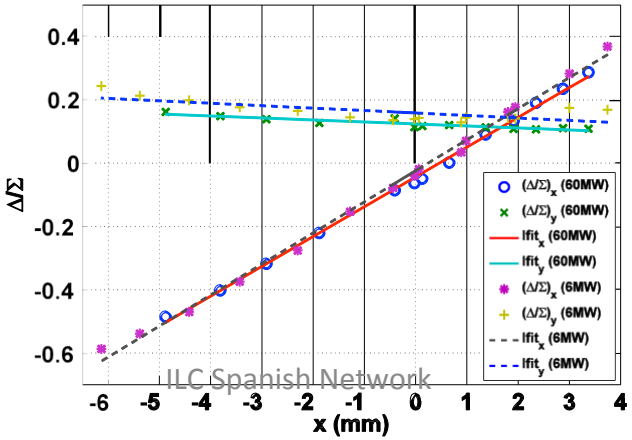
- Stripline prototype with short circuited electrodes installed in TBL at CTF3 and successfully tested with beam.
- FESA class developed for synchronous data acquisition with the rest of TBL BPMs
- Resolution tests performed using MIA/SVD analysis: **10 µm** (H and V planes) for a 3A beam current.

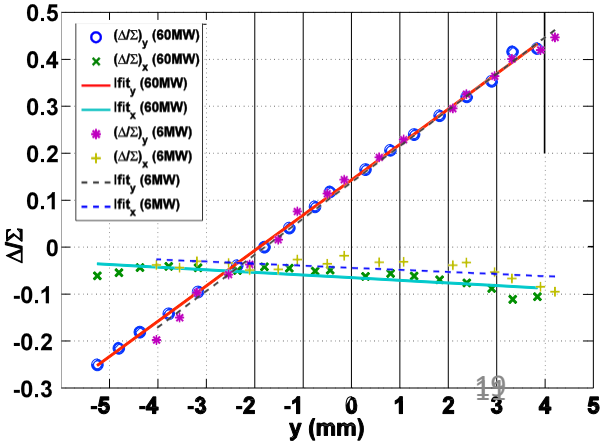






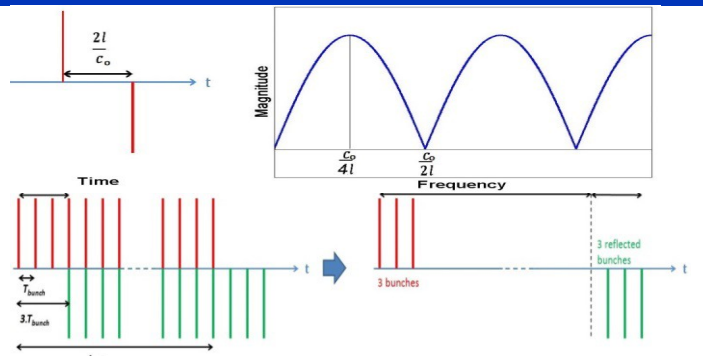
TBL Beam sweep in horizontal and vertical planes



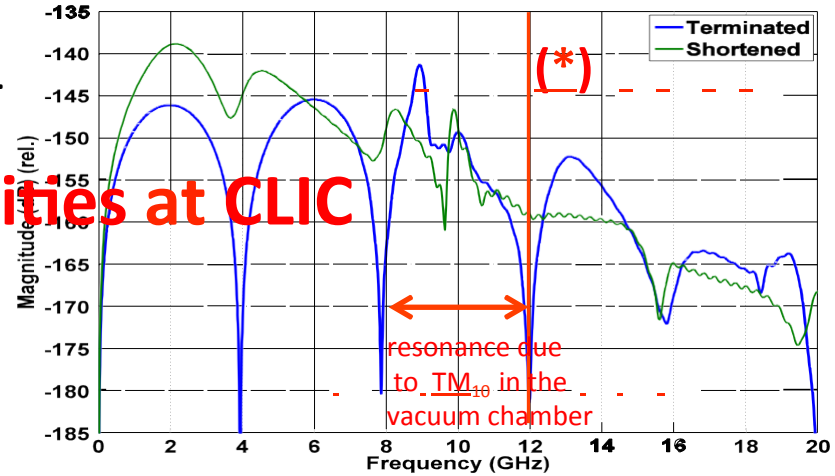


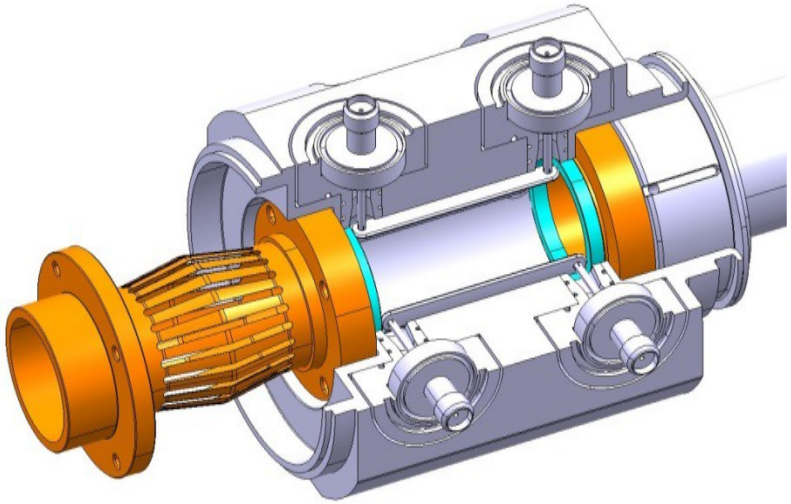
STRIPLINE BPM DEVELOPMENT FOR THE CLIC DRIVE BEAM

- 2 Stripline prototypes with 50Ω-terminated electrodes developed for CLIC Module and installed in summer/autumn 2014.
- 8-port design for increased notch tunability and loop-through calibration.
- Enhanced PETS interference suppression at 12 GHz (*).



R&D activities at CLIC





D. Gudkov BE-RF

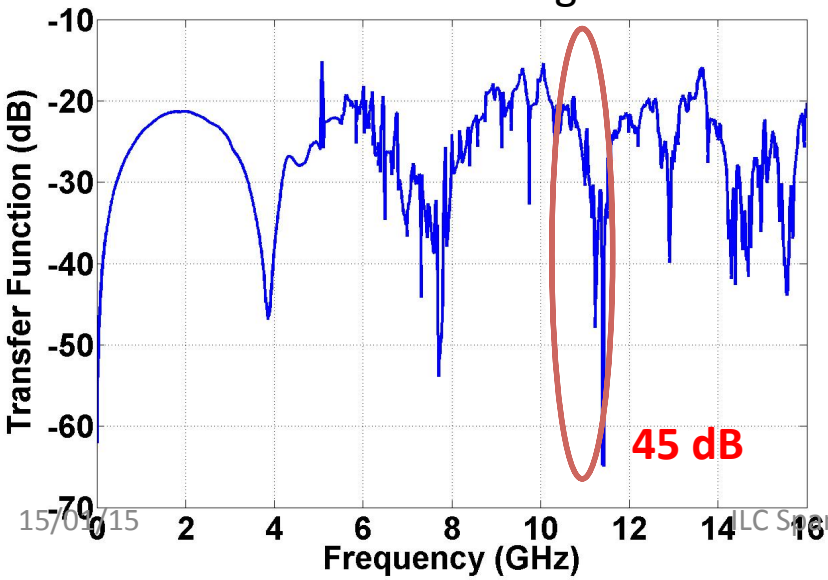
Parameter	Shortened BPM	Terminated BPM
Stripline length	25 mm	37.5 mm
Angular coverage	12.5% (45°)	5.55% (20°)
Electrode thickness	3.1 mm	1 mm
Outer radius	17 mm	13.54 mm
Ch. Impedance	37 Ω	50 Ω
Duct aperture	23 mm	23 mm
Resolu4on	2 µm	2 µm
Accuracy	20 µm	20 µm
Time Resolu4on	10 ns	10 ns

R&D activities at CLIC

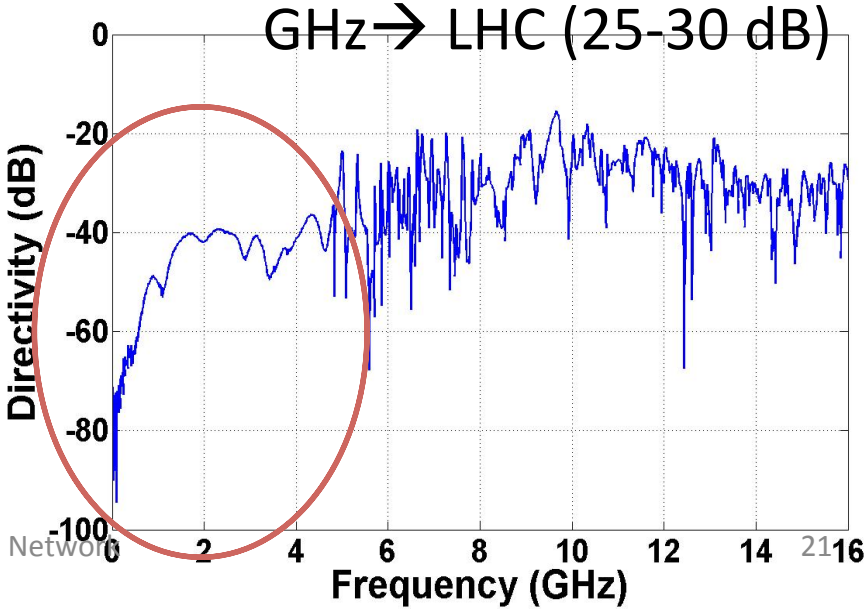
STRIPLINE BPM DEVELOPMENT FOR THE CLIC DRIVE BEAM

Frequency Response Measurement

45 dB-deep 3rd notch, moves between 11.4-12 GHz → Non-ideal HF measurement flange.

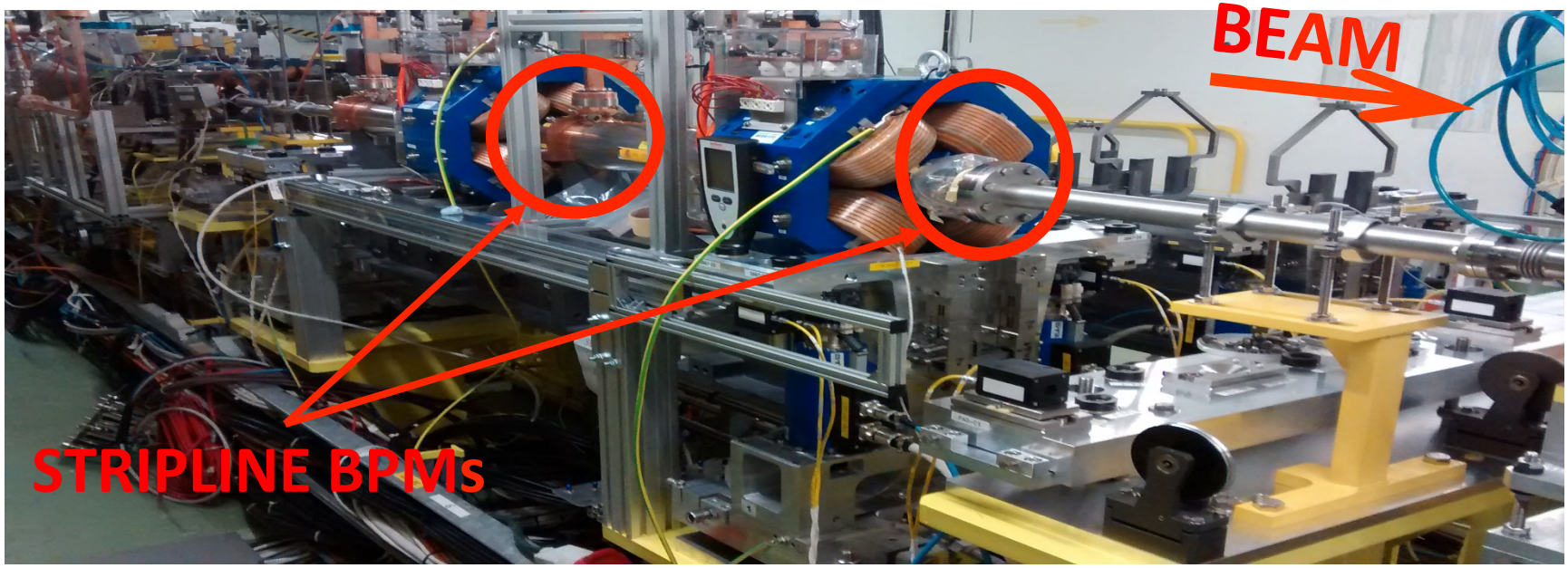


- Directivity: ~40dB up to 4 GHz→ LHC (25-30 dB)



R&D activities at CLIC

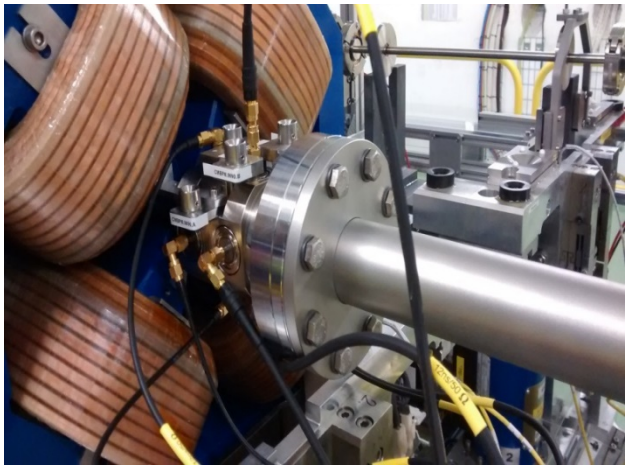
STRIPLINE BPM DEVELOPMENT FOR THE CLIC DRIVE BEAM



CLIC Two-Beam-Module Installation

- Two installed units:
  - CM.BPL0645
  - CM.BPL0685

- Beam tests planned for spring 2015

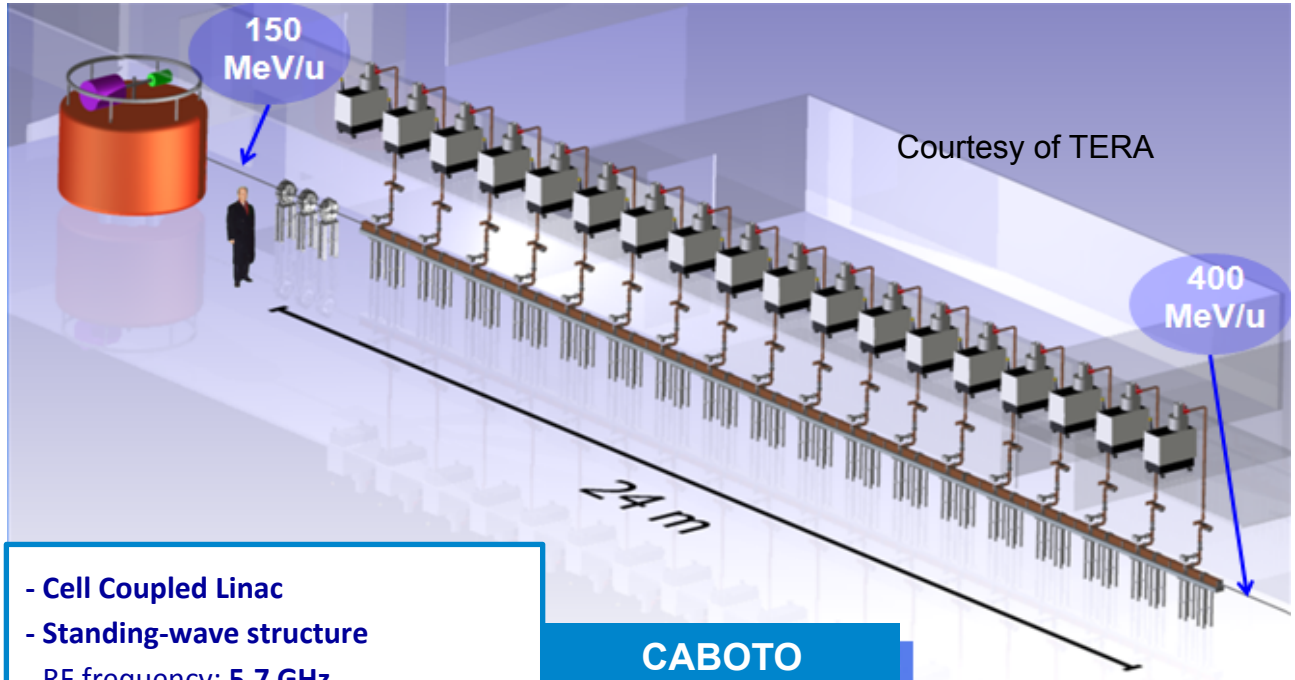


R&D activities at CLIC

HIGH-GRADIENT RF STRUCTURE STUDIES FOR MEDICAL ACCELERATORS

Motivation

Compact, energy-efficient accelerators for tumour treatment with hadrons (**hadrontherapy**)



- **Cell Coupled Linac**
- **Standing-wave structure**
- RF frequency: **5.7 GHz**
- **2.5 μs**-long pulse at **300 Hz**

CABOTO

(CArbon BOoster for Therapy in Oncology)

Compactness *(about 24-m long)* ⟷ **high-gradient RF technology** *(E_s ~ 200 MV/m)* **but** **RF breakdowns?**

•R&D activities at CLIC

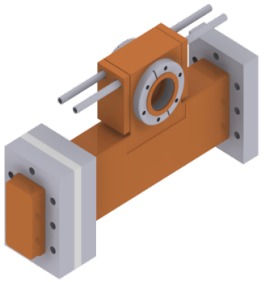
HIGH-GRADIENT RF STRUCTURE STUDIES FOR MEDICAL ACCELERATORS

- Determine the operation limits of high-gradient RF structures
- Evaluate the scaling laws that relate breakdown rate BDR, pulse length t_{pulse}, peak surface electric field E_S and modified Poynting vector S_C
- Use the results in the design of future RF structures

S-band: 3 GHz

❖One 3 GHz TERA **Single-Cell** Cavity

❖Low-power at CERN and high-power (CTF3) **tested**

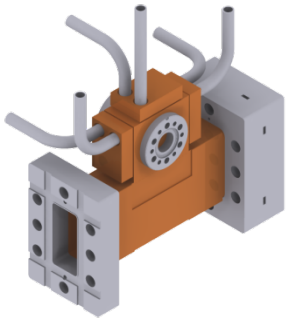


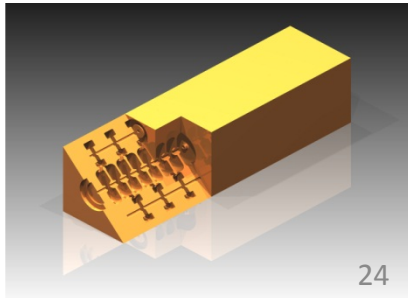
C-band: 5.7 GHz

❖Three 5.7 GHz TERA **Single-Cell** Cavities

- 2 conventional machining (Ring0s) → final production
- 1 diamond machining (Audrey) → final production

❖Low-power at CERN and high-power (ADAM S.A.)



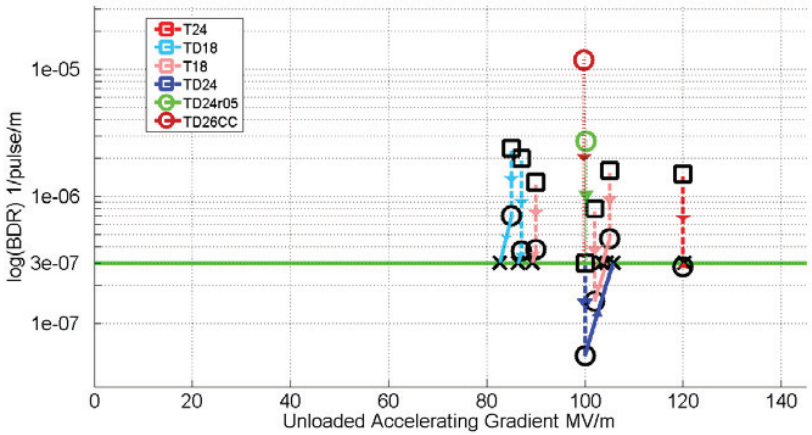


❖**Multi-Cell** Structure (either S-band **or** C-band)

R&D activities at CLIC

XBOX: X-BAND HIGH-POWER TEST STAND AT CERN

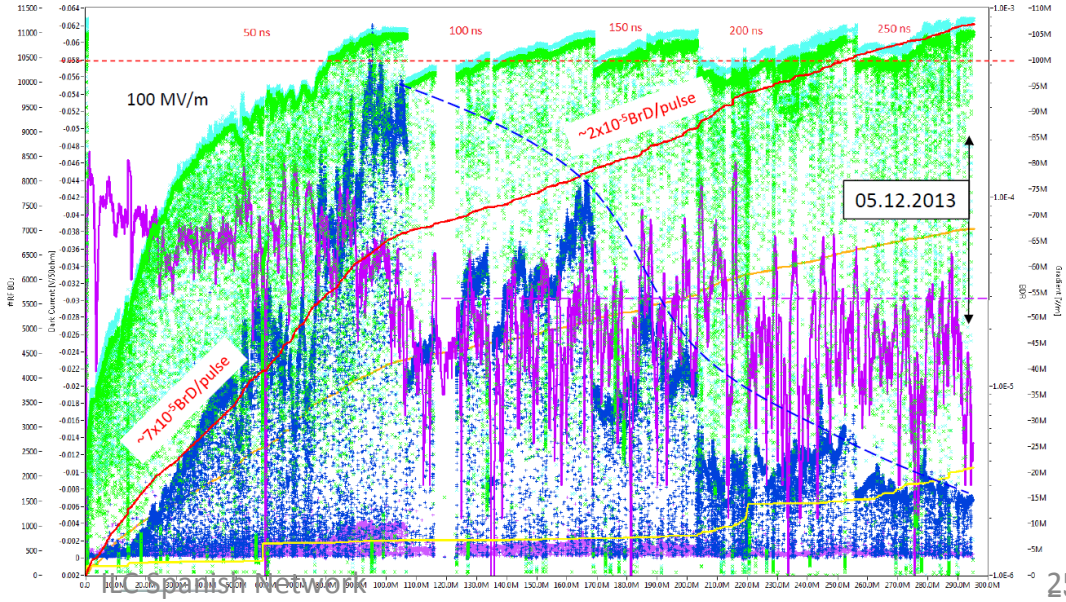
High-gradient in CLIC (Compact Linear Collider)



The performance of new designs of accelerating structures have been tested, based on the CLIC main requirements of 100 MV/m gradient and breakdown rate below 3e-7 bpp/m.

New X-band (12 GHz) test stands are operative at CERN: Xbox-1 and Xbox-2 (a third generation Xbox-3 is on design phase)

Conditioning and test of the TD26CC structure from July to December 2013 at Xbox-1



R&D activities at CLIC

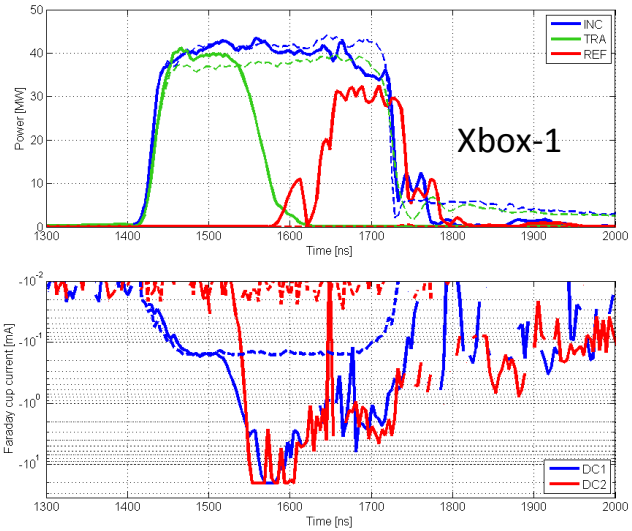
XBOX: X-BAND HIGH-POWER TEST STAND AT CERN

Breakdown studies in high gradient accelerating structures

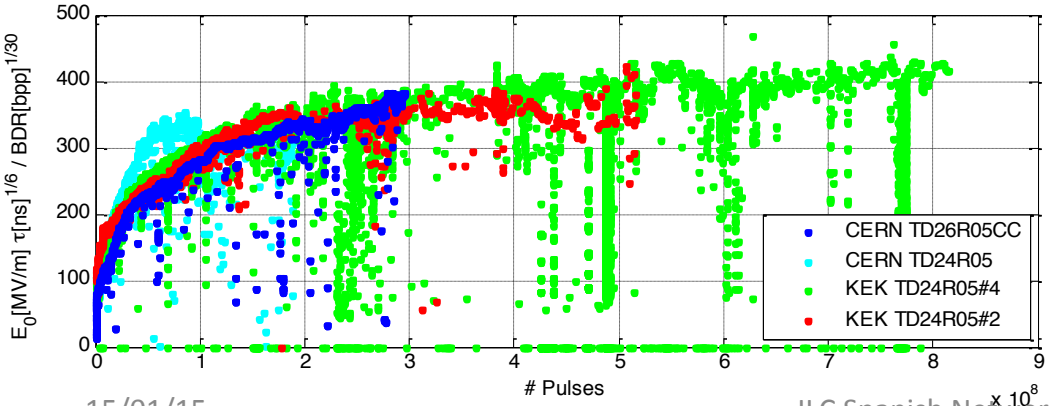
Data acquired in Xbox test stands is analysed to understand the nature of breakdown phenomena.

- Breakdown location
- Dark current and field emission measurements
- Breakdown statistics and measurement of the BDR-gradient dependence
- Conditioning process and test optimisation

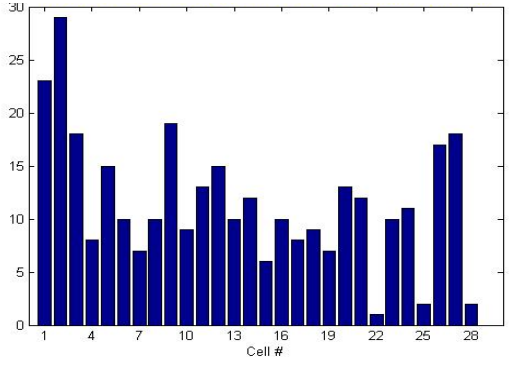
RF power and Dark Current signal analysis



Comparative analysis of RF conditioning with the cumulative pulses



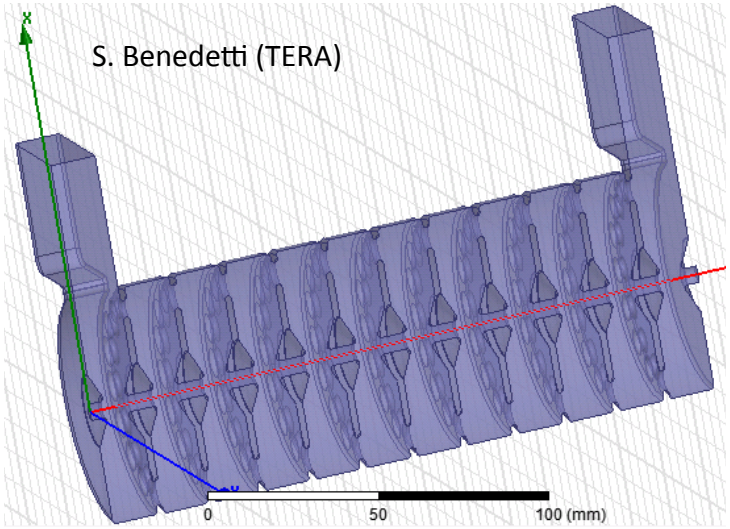
Cell location of breakdowns during TD26CC test



R&D activities at CLIC

HIGH GRADIENT RF STRUCTURE STUDIES FOR MEDICAL ACCELERATORS

Test of an S-band high gradient proton accelerating structure



A prototype of a high gradient 3 GHz proton accelerator operating in backward TW mode has been designed in the framework of the TULIP project.

It fulfils the requirements of compactness (gradient >50 MV/m) and acceptable low breakdown rate.

The prototype is being manufactured and a high-power test is planned at the end of 2015 in CTF3 (CLIC Test Facility, CERN), based on the experience of the operative X-band test stands at CERN.

R&D activities at CLIC

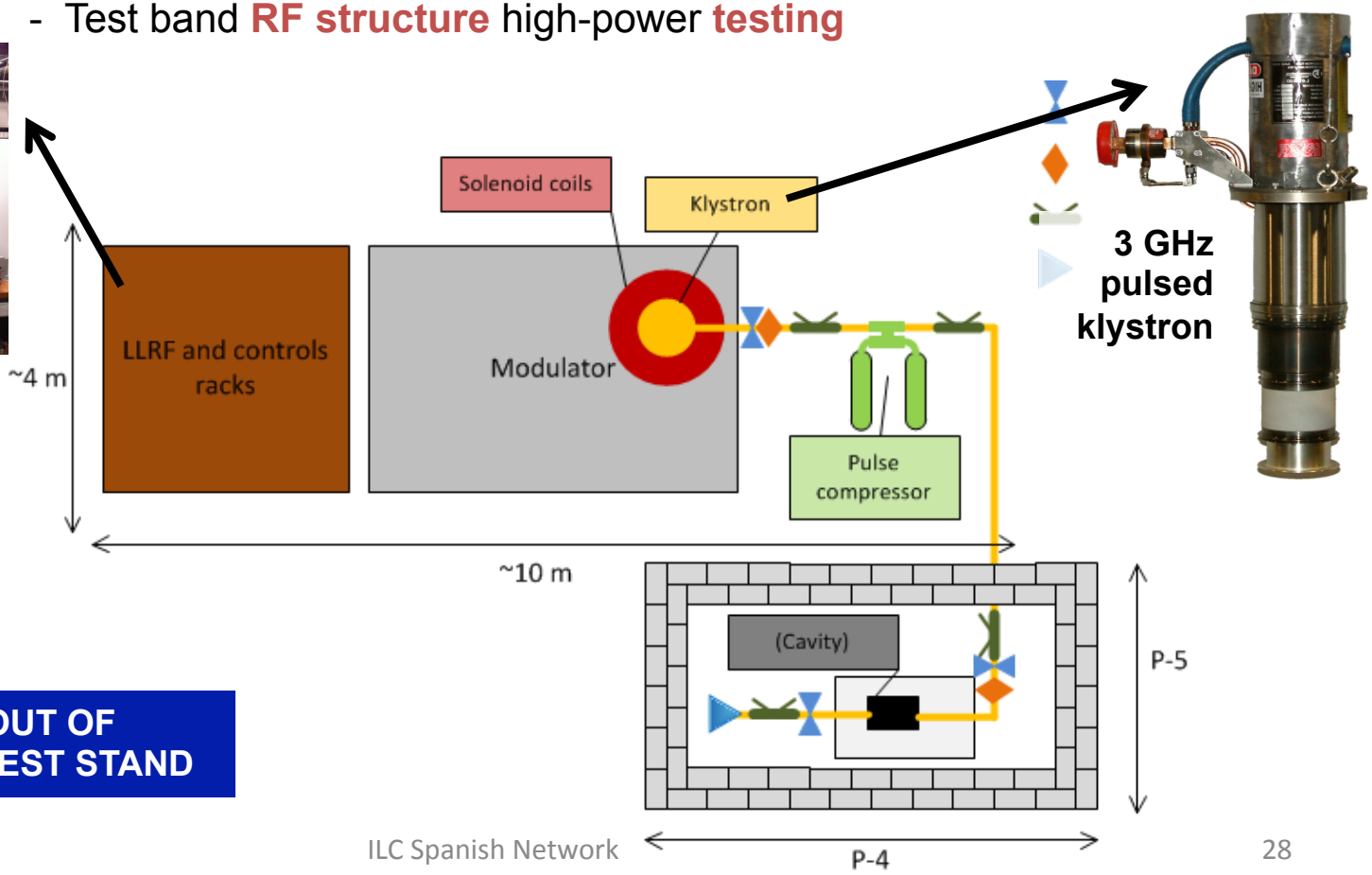
HIGH-GRADIENT RF STRUCTURE STUDIES FOR MEDICAL ACCELERATORS

IFIMED RF Test Infrastructure

- Creation and operation of **Test band high-power testing facility**

(high-gradient test stand in S-band (3.0 GHz))

- Test band **RF structure** high-power **testing**



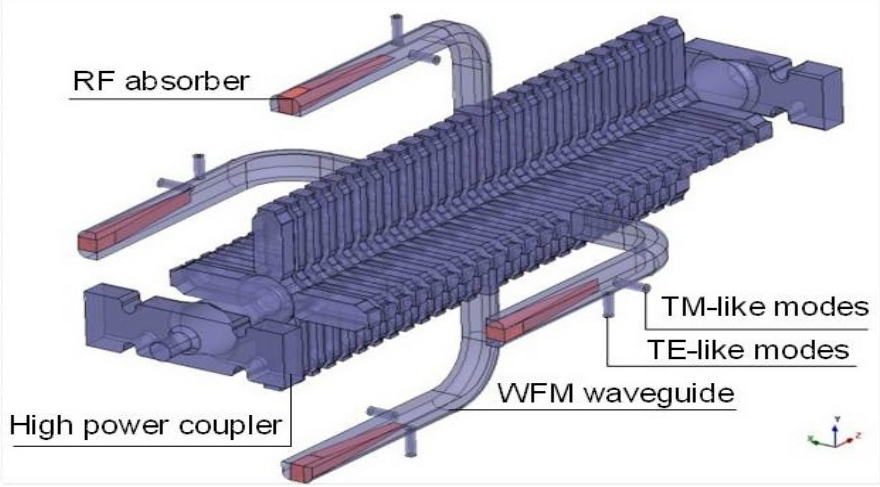
TYPICAL LAYOUT OF HIGH RF POWER TEST STAND

R&D activities at CLIC

DIRECT ALIGNEMENT OF ACCELERATING STRUCTURES

PACMAN is a Marie-Curie project consisting of 10 ESR PhD students for a development of a single test bench for the alignment of the CLIC components with a nanometer precision.

The objective involves the alignment of an accelerating structure (AS) with 5.5 mm of mean aperture and working at the acceleration frequency of 12 GHz.



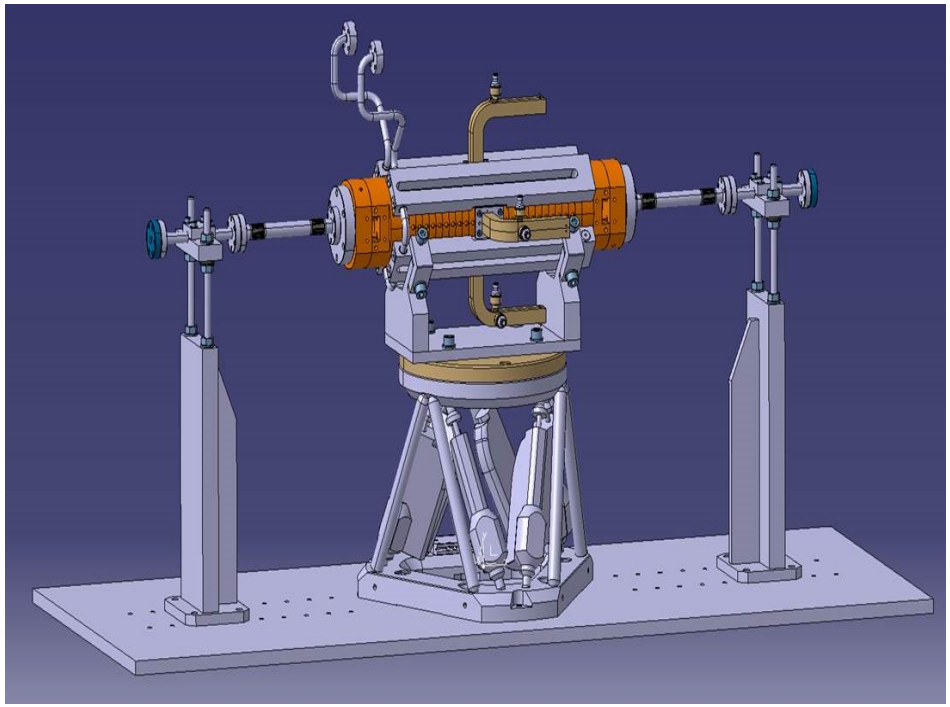
- The center of the outer diameter of the accelerating structure is going to be measured using a Coordinate Measuring Machine (CMM) at CERN with a precision of 0.3 um.
- The electrical center of the AS can be found using a network analyzer (VNA) and a test bench that has been designed for this purpose.

R&D activities at CLIC

DIRECT ALIGNEMENT OF ACCELERATING STRUCTURES

- The center of the wakefield monitors (WFM) should be aligned with respect to the center of the AS with an accuracy of 3.5 um. The performance of this measurement is still under study.

- Several AS will be placed in a girder with the help of fiducials. The electric center of each AS with respect to the girder axis should be less than 7 um.



The test bench consist of:

- Optical table.
- Hexapod.
- AS's support.
- Stretched wire tools.
- Comparators and metrology instrumentation.


Thanks for you attention
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