SPIRAL2 Bunch Extension Monitor

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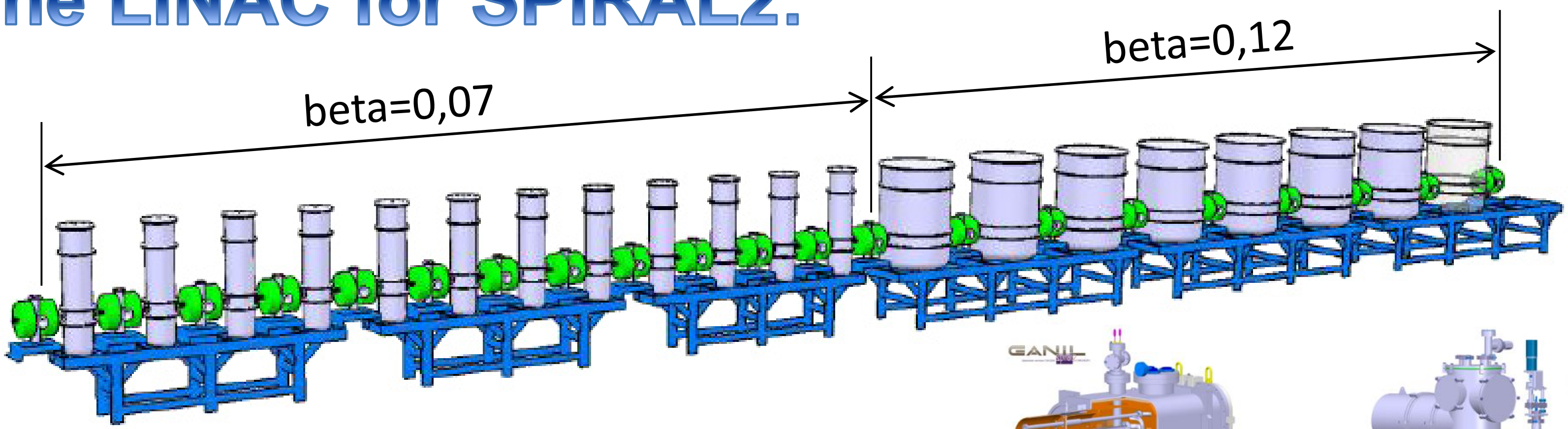
Outlines:
- Introduction to SPIRAL2 LINAC
- Principles of operation and design of BEM
- Tests of BEM with beam and at vicinity of cryomodule

The LINAC for SPIRAL2:



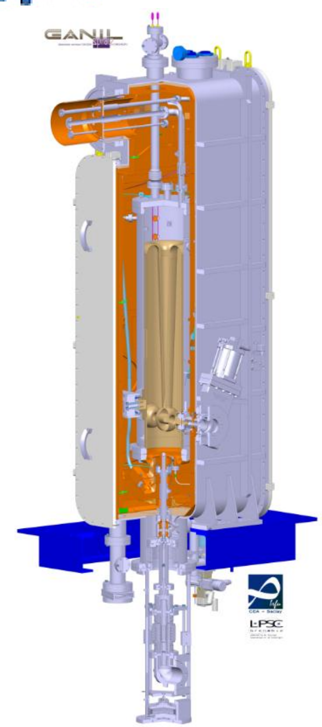
CW accelerator driver of SPIRAL2

26 superconducting QWR cavities

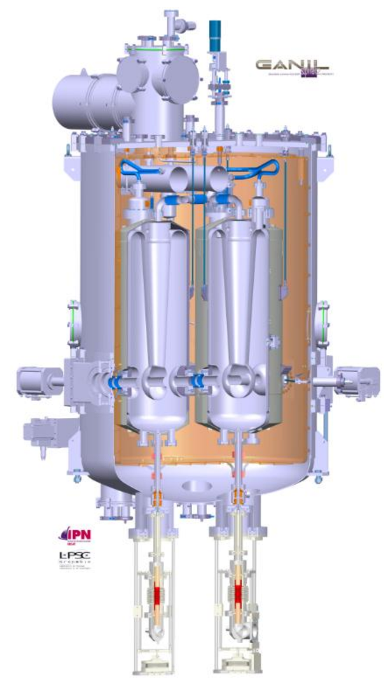
2 families of cavities/cryomodules

Beam parameters of LINAC

Particles	p^+	D^+	Ions	
Q/A	1	1/2	1/3	1/6
I (mA) max.	5	5	1	1
W_0 min. (Mev/A)	2	2	2	2
W_0 max. (Mev/A)	33	20	14.5	8.5
CW max. beam power (KW)	165	200	44	48

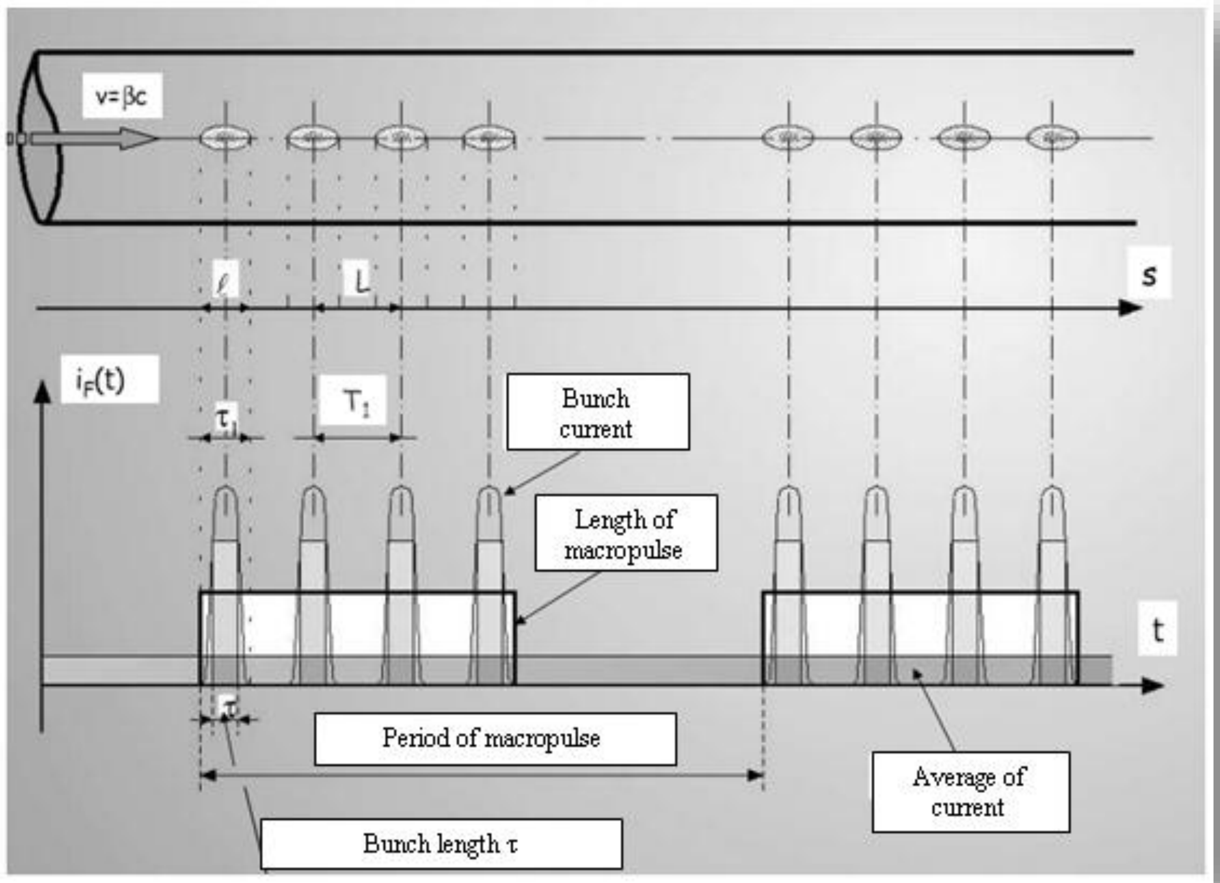


Type A



Type B

Time structure of LINAC beam:



- Frequency of the pulses: 88.0525 MHz (period of bunches: T~11.36 ns)
- Phase extension of the bunch (±2 σ): 60 ° or ~1.9 ns for bunch length τ
- Period of macropulse: can vary between 100 μs and 1s
- The form factor $\eta = \dfrac{\text{macropulce length}}{\text{period of macropulce}}$ is lay at range $1 < \eta < 10^4$

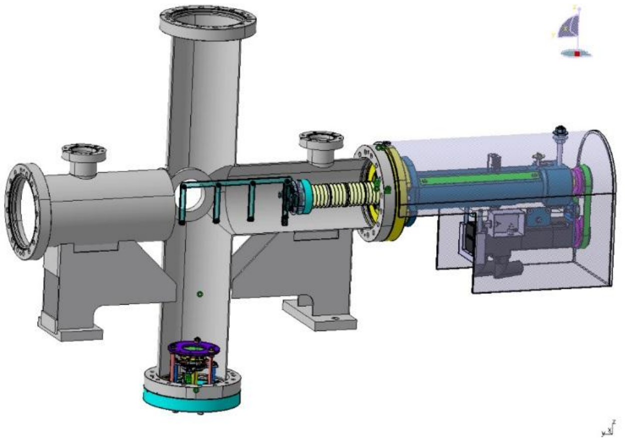
What is BEM for:

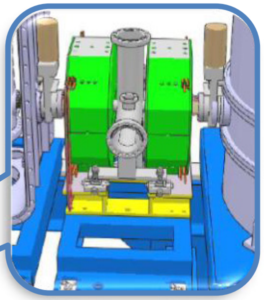
Proper beam adaption of LINAC requires measurement of phase extension

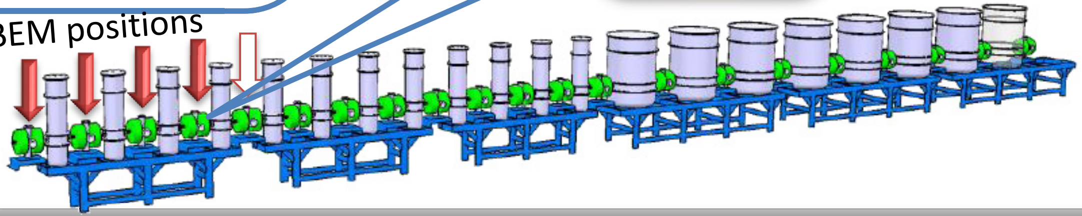
Requirements of BEM diagnostics:

- Provide measurements without beam perturbation
- Compact sized for installation at diagnostic box of LINAC
- Measurement time as short as possible
- Phase resolution 1°
- Operation at cryomodule vicinity (vacuum and cleanness conditions for BEM components)

Diagnostic box of LINAC equipped with BEM

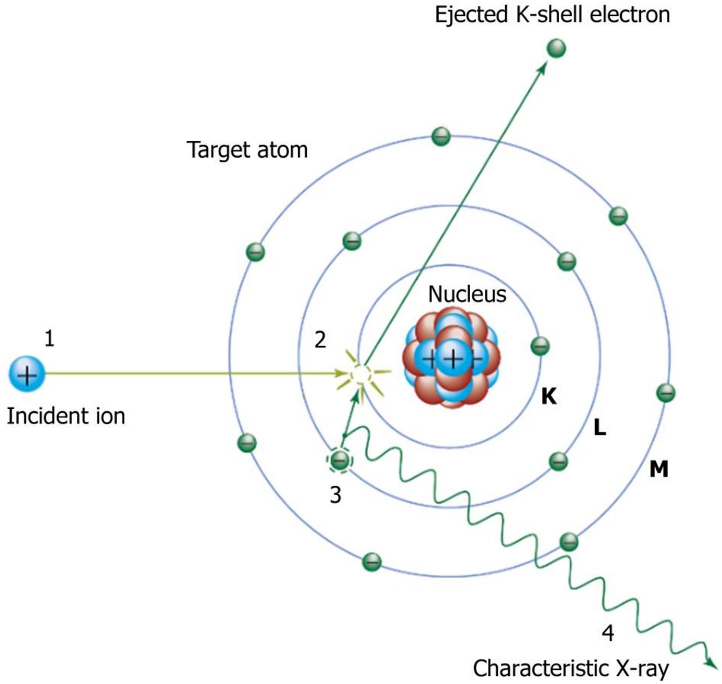


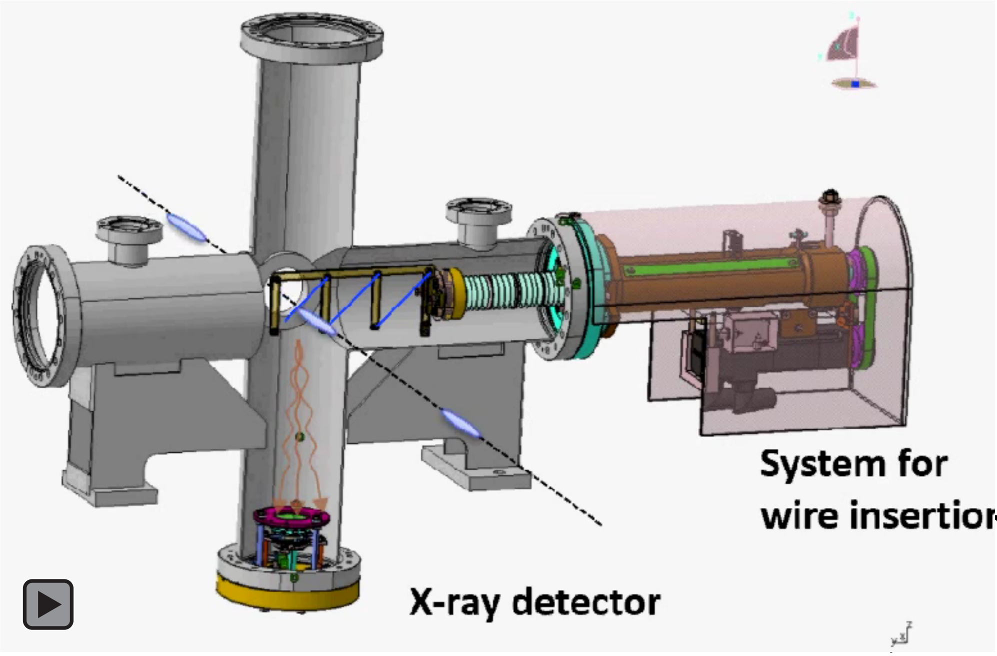




How it works

X-ray emission due to ionization of the wire by impinging beam ions





Principal Characteristic X-Rays Energies for Tungsten

	K Series			L Series				
Lines	**Kα1**	**Kα2**	**Kβ1**	**Lα1**	**Lα2**	**Lβ1**	**Lβ2**	**Lγ1**
Energy, keV	*59,32*	*57,98*	*67,24*	*8,40*	*8,34*	*9,67*	*9,96*	*11,29*

Values are from J. A. Bearden, "X-Ray Wavelengths", Review of Modern Physics, (January 1967) pp. 86-99

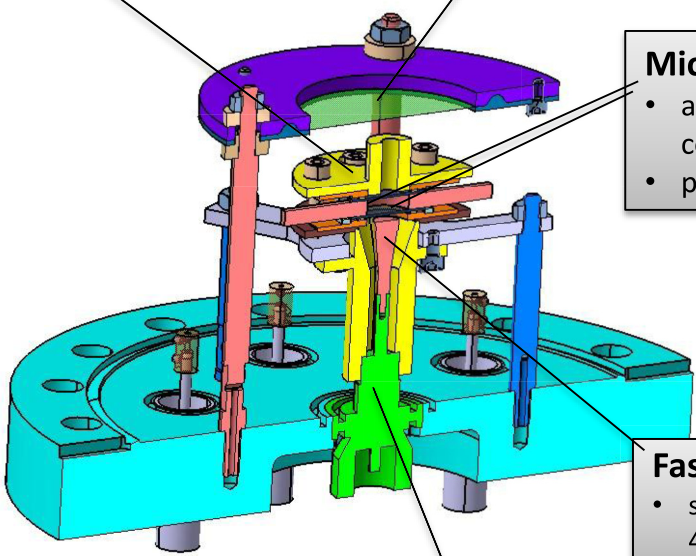
Precise time measurements similar to Time-Correlated Single Photon Counting (TCSPC) technique

How it looks like: X-ray detector

Copper collimator
Registration X-rays coming from the wire

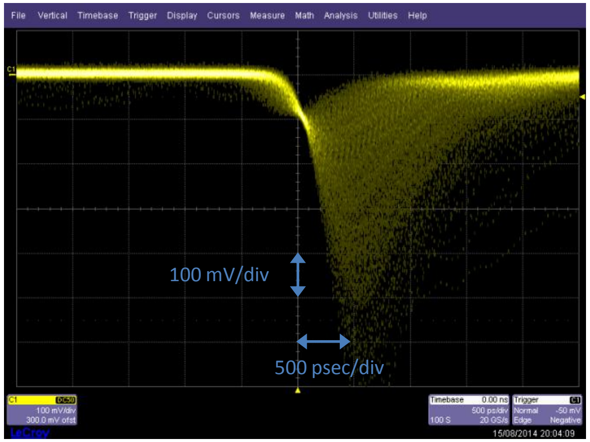
Deflecting foil
- suppression of residual gas ions
- transparent for x-rays

Microchannel plates
- assembled at chevron configuration
- provide 10^7-10^8 gain

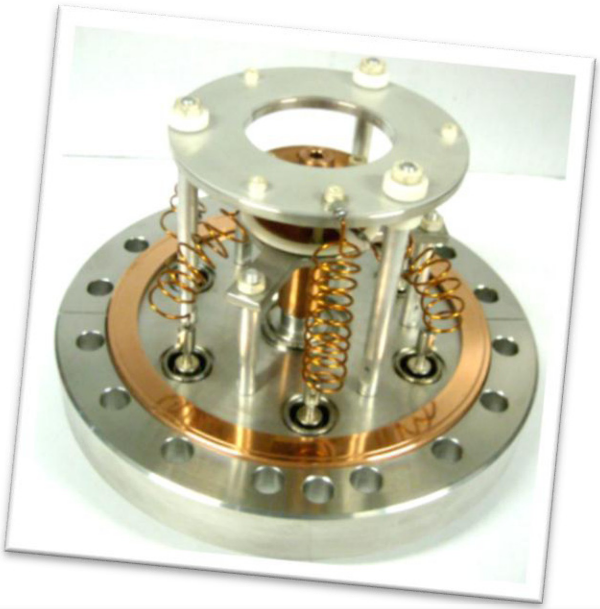


Fast readout anode
- short output signal with 400 psec risetime

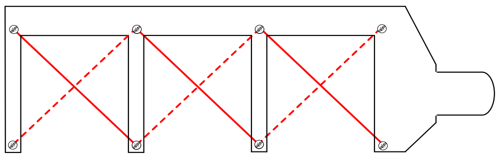
N-type connector
matched on 50Ω impedance for fast output pulse



Detector output signals for 5,9 keV x-ray source of 55Fe

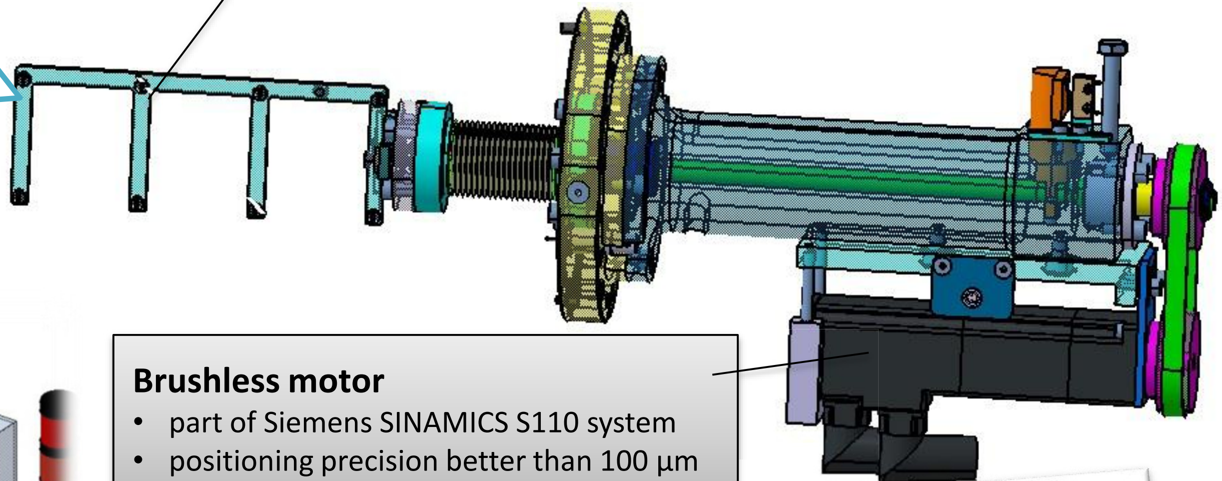


How it looks like: System for wire insertion

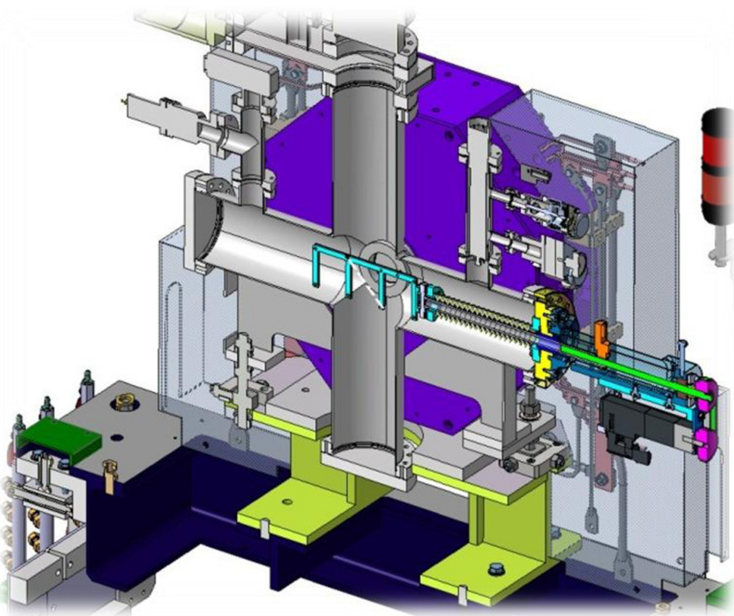


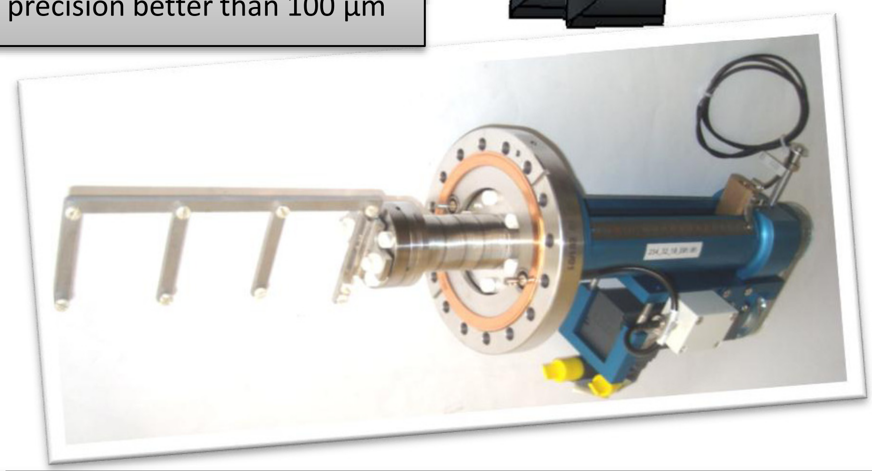
Alternate orientation of wires
to minimize influence of neighboring BEMs to their measurements

Conducting frame with tungsten wires
- three holders with ∅150 µm wires for quick replacement of damaged wire
- electrically insulated for current pick-up measurements from the wire

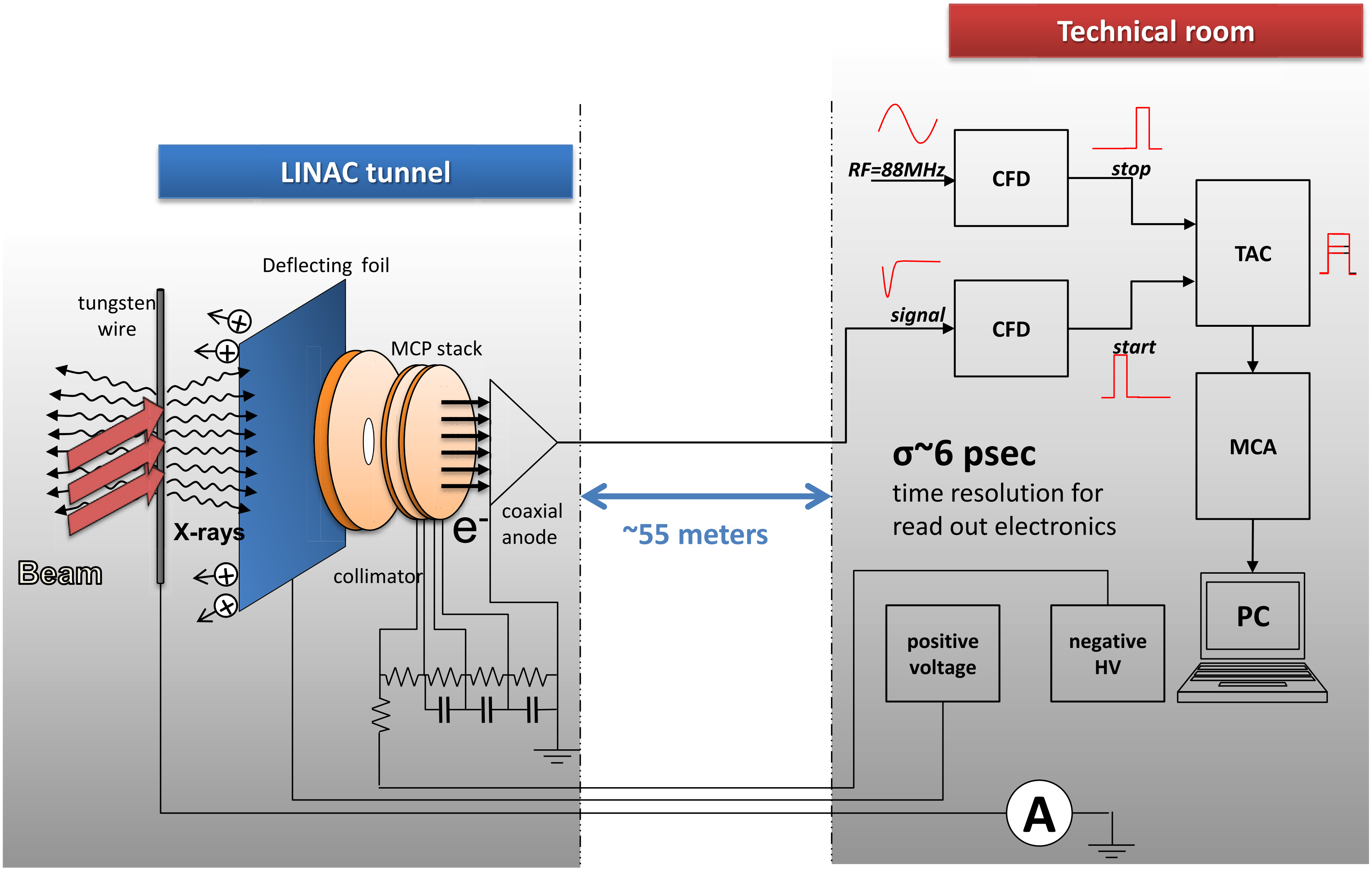


Brushless motor
- part of Siemens SINAMICS S110 system
- positioning precision better than 100 µm



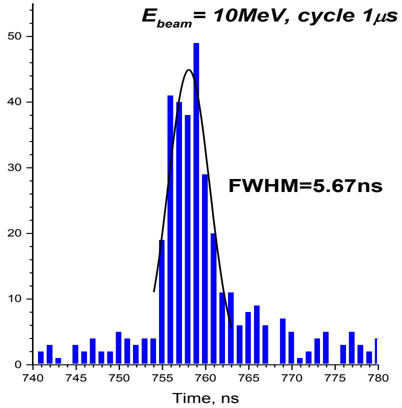


How it is measured



The BEM tests with ions beams

Test of prototype with proton beam (10 MeV, 1.75 nA)

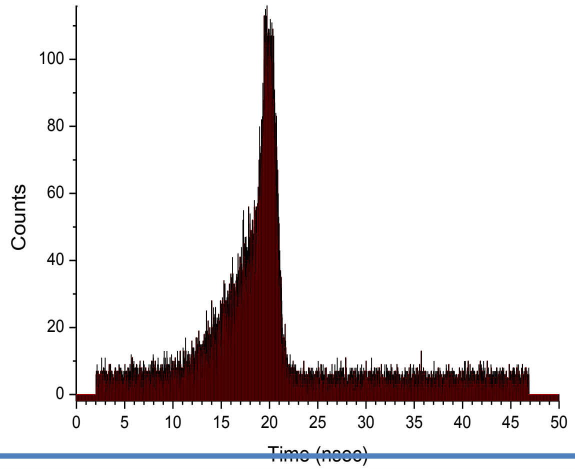


The first test shown high background related to residual gas ions

Test of BEM prototype with beam of ^{18}O ions (1.26 MeV/A, 10 μA)

Al foil of 10 μm thickness was placed before MCP entrance with applied positive voltage +30 Volts

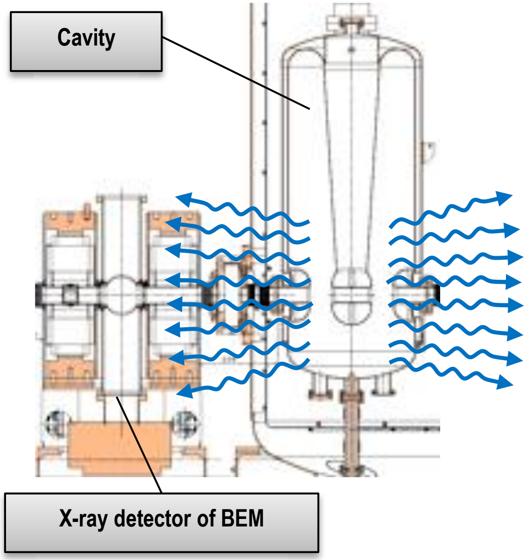
Signal to noise ratio is 10



X-ray background for BEM

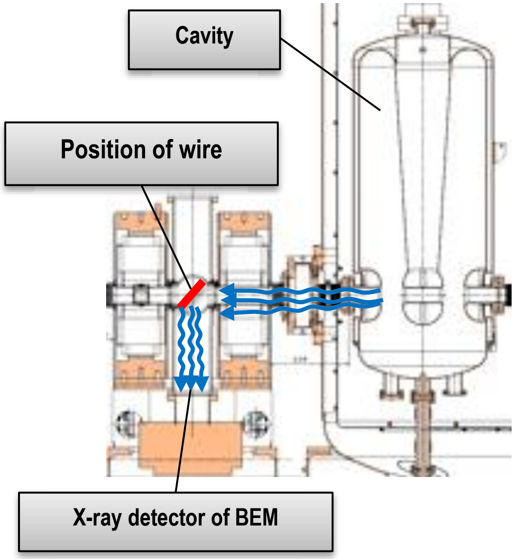
One of the most important questions for BEM operation is **X-ray emission** from cavity

Registration of X–rays due to field emission from cavity



X-rays have broad range of energies up to value of maximal energy of dark currents electrons

Registration of secondary x-rays emitted from the wire due to x-ray fluorescence

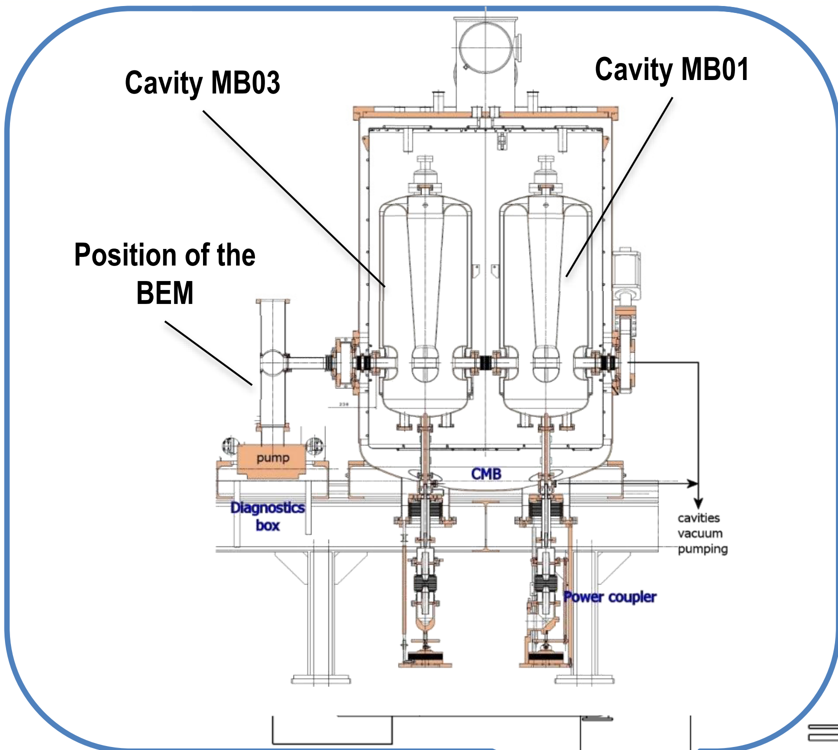


Finite spectrum of characteristic x-rays for tungsten

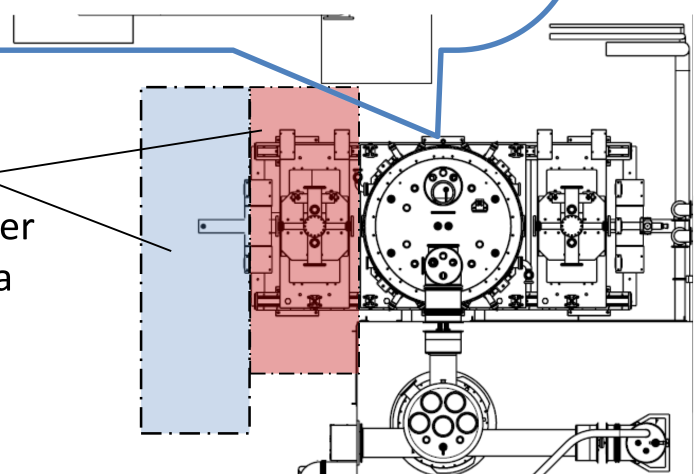
It is very complicated to assess in advance for x-ray emission (strongly different from one cavity to another)

The direct measurements are more preferable and can give clear results

Test-bench with cryomodule type B



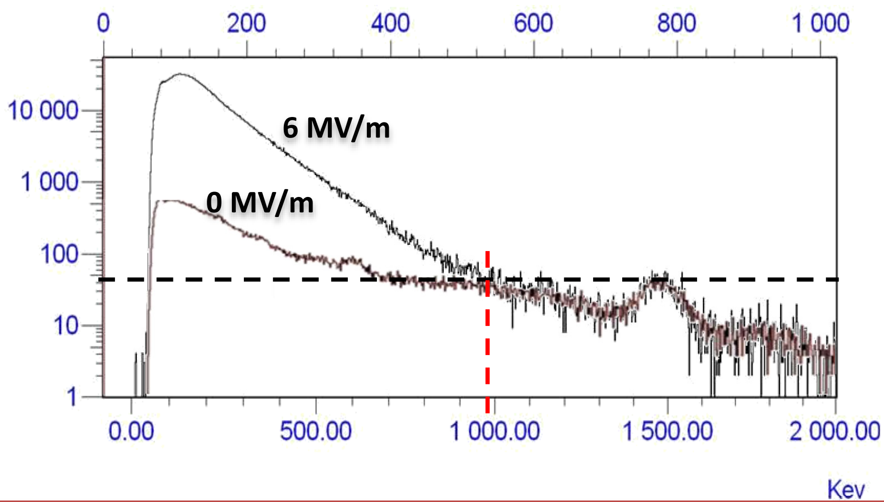
Two portable clean rooms over installation area



- Cleaning and preparation of BEM in ISO4 clean room
- Insertion in warm section under portable ISO5 clean room

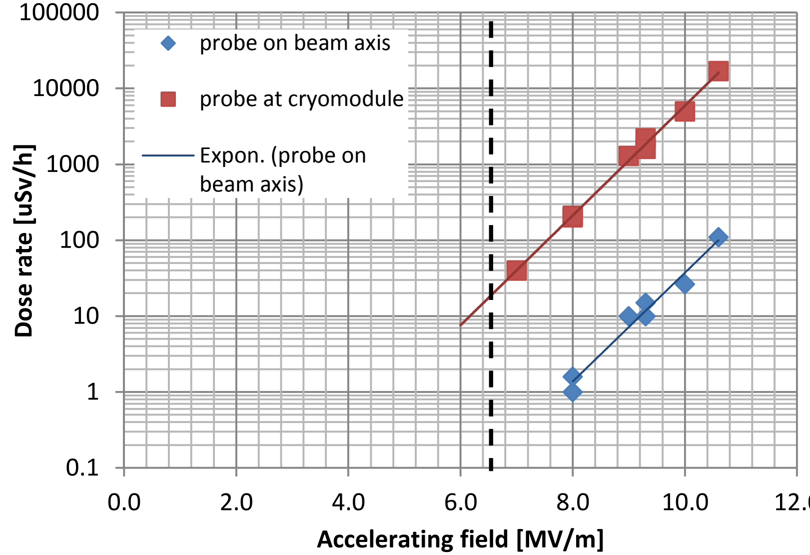
Monitoring of X-ray flux during the test

Spectrum of x-ray emission from cavity

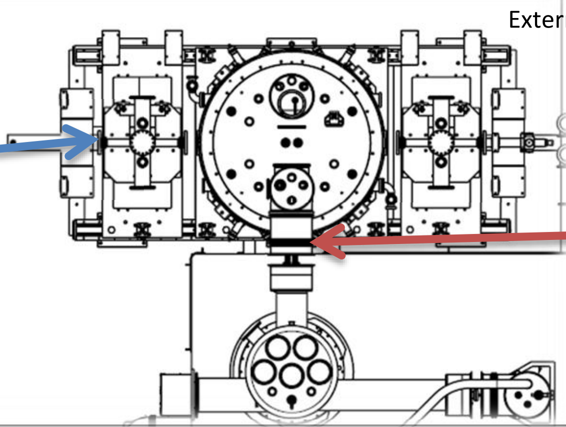


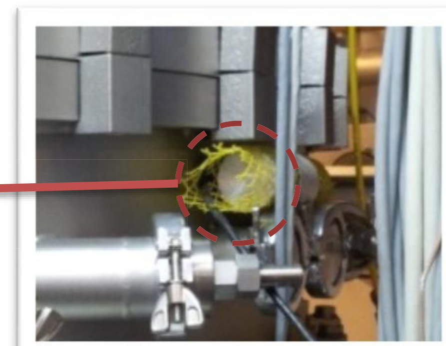
E_max ~ 1000 keV at nominal value 6,5 MV/m of field gradient

Dose rate measurements for cavity MB03



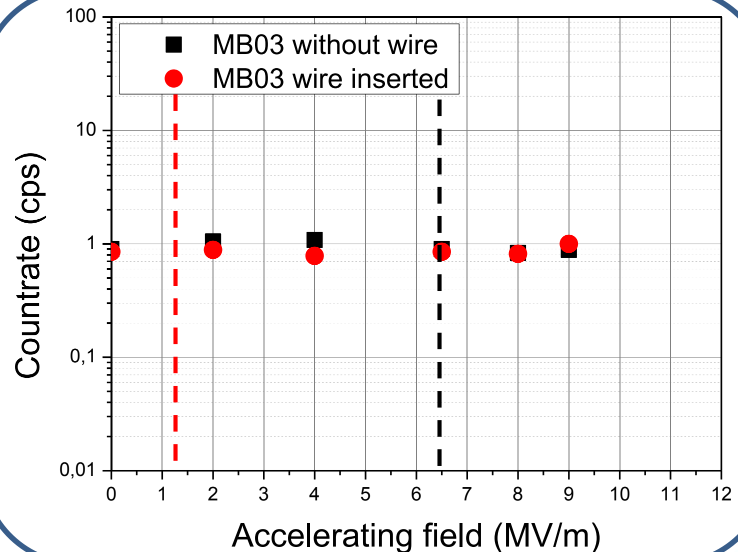
Detector:
Geiger Müller, energy compensated from 40 keV to 1.25 MeV
Measurement range:
External low dose rate probe: 3 µSv/h to 100 mSv/h



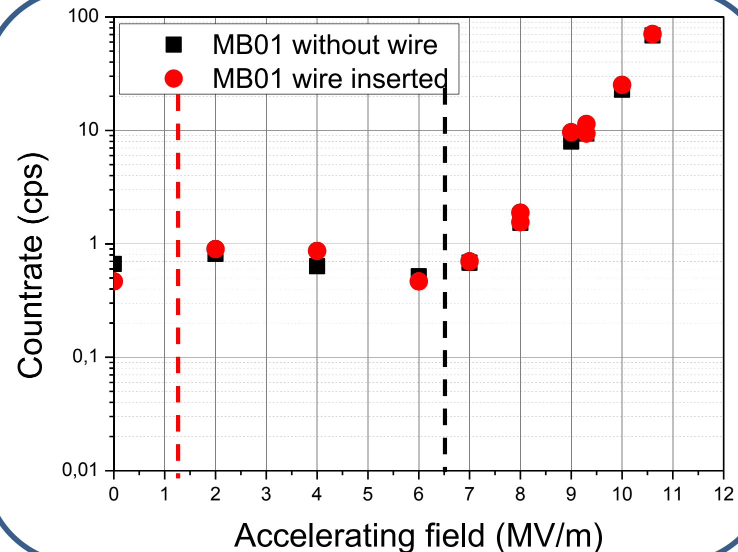


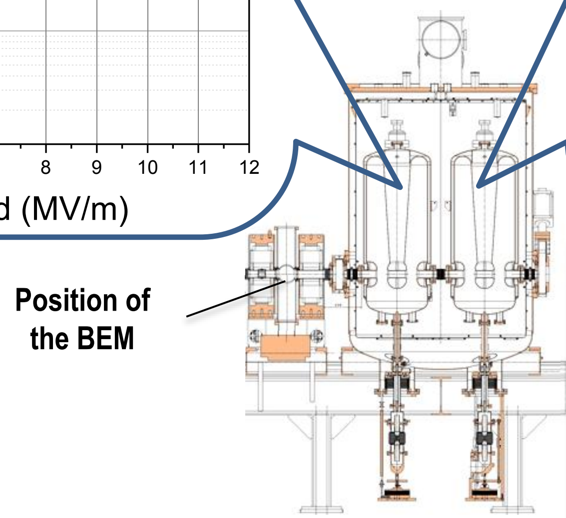
Results of the test

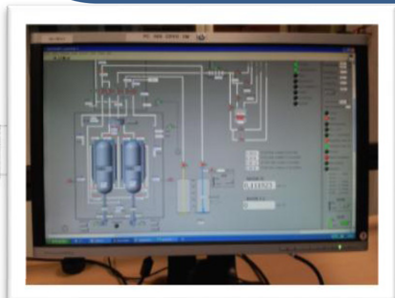
Cavity MB03

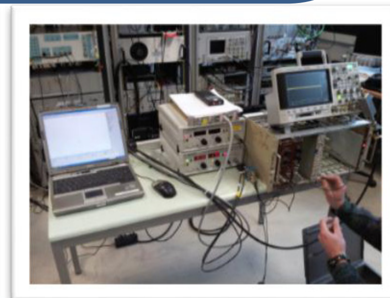


Cavity MB01









This test has proven the possibility of operation of a BEM close to a cryomodule working at nominal gradient

The first industrially produced BEM has been commissioned with a X-rays source during last month and its characterization is in progress

Next steps

- Tests with the industrial commissioned BEM on SARAF linac (cavities similar to SPIRAL2 ones)
- Development of Command/Control interface for BEM and integration of BEM architecture into the LINAC
- Procurement, control and commissioning of the whole series of BEMs
- Installation of the five BEMs into the LINAC warm sections, adjustment of parameters of associated electronics, bunch length measurements

Summary

- New design of a bunch extension monitor has been developed
- Prototype of this detector has been successfully tested with ions beams
- Possibility of operation close to a cryomodule has been demonstrated
- Full characterization of the first series BEM is in progress

Thank you for your attention