Beam Instrumentation for the HIE-ISOLDE linac

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on behalf of BE-BI group and HIE-ISOLDE collaboration

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Outline

- Beam instrumentation overview for the HIE-ISOLDE super-conducting linac
- Inter-tank diagnostic boxes for beam intensity, position and transverse profile measurements: design status
- Silicon detector monitor for cavity phase-up and longitudinal profile measurements: test results of the first prototype
- Conclusions & outlook

Beam diagnostics tasks

Main beam parameters to be measured:

- intensity
- position
- transverse profile

diagnostic box ("short-box") in each inter-cryomodule region → Faraday cup, slit and current-sensitive device (for low intensity beams)

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  - absolute → *ToF system*

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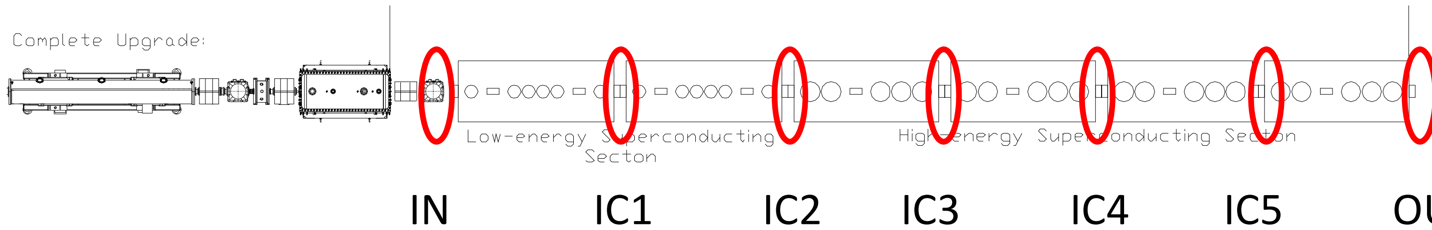
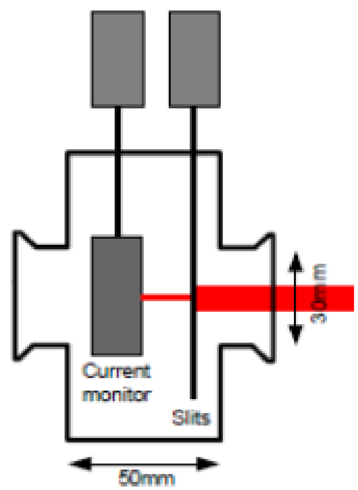
  - absolute → *ToF system*
- longitudinal profile and emittance (energy and time spread)

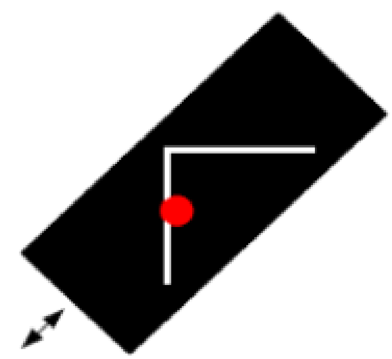
Spectrometer and/or solid state detectors (↑ silicon monitor)

HIE-linac inter-tank diagnostic boxes

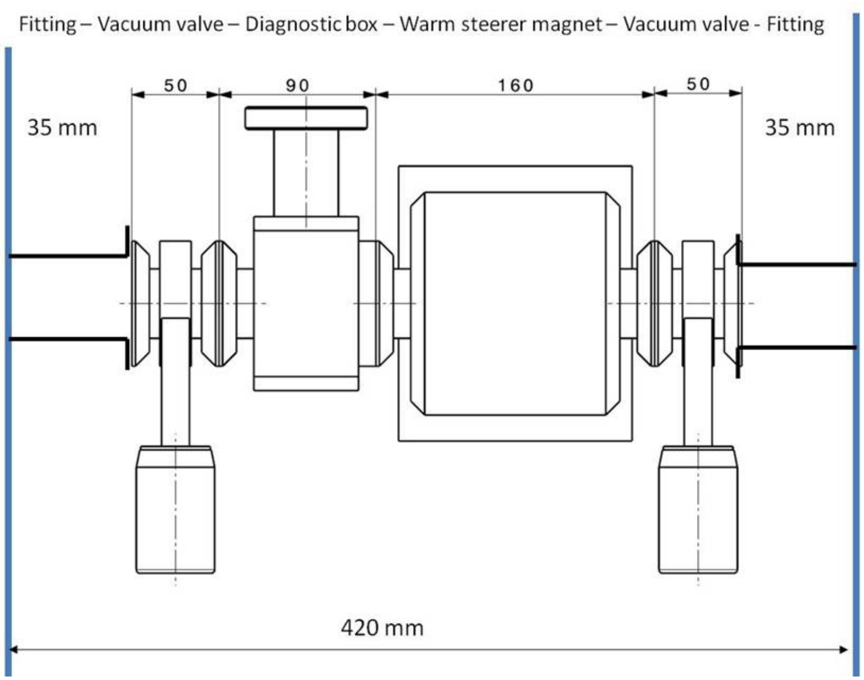


beam intensity, position and transverse profile measurements





Inter-tank region preliminary scheme



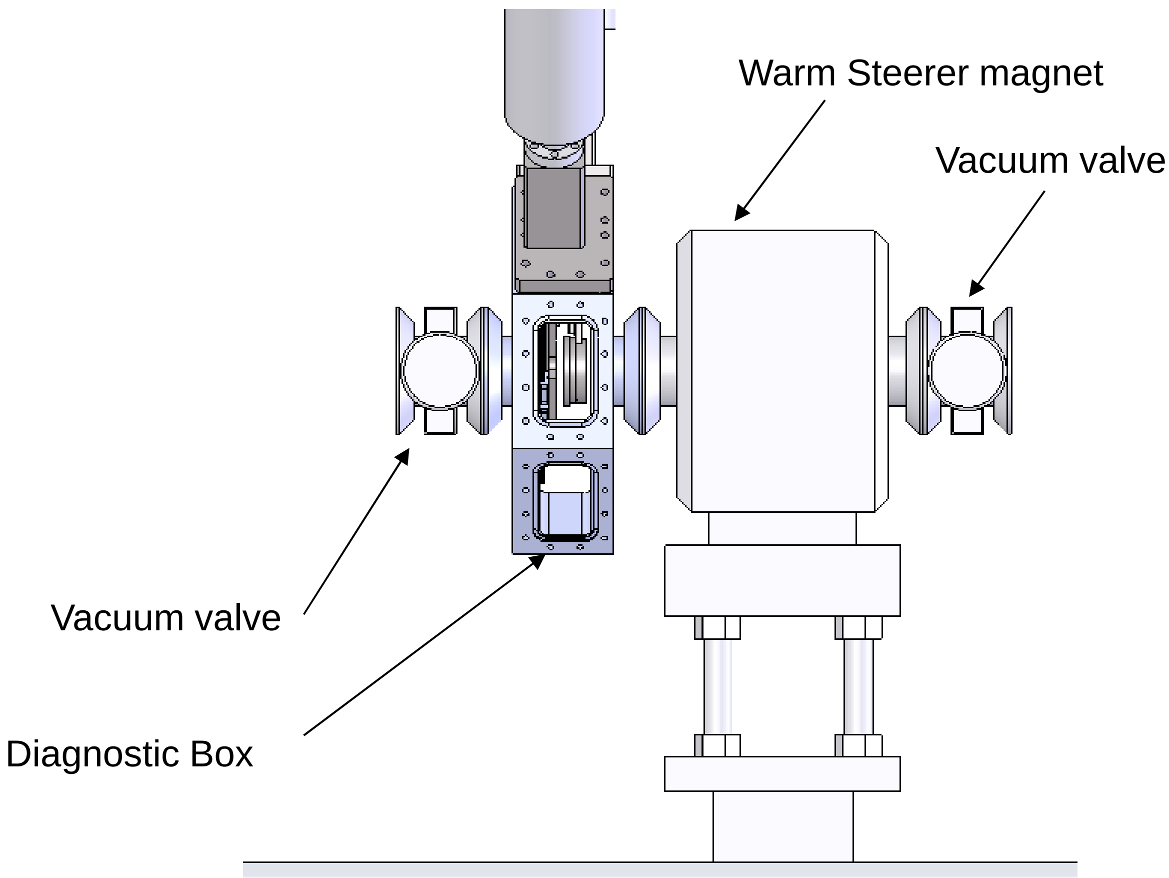
CURRENT/INTENSITY MONITOR:

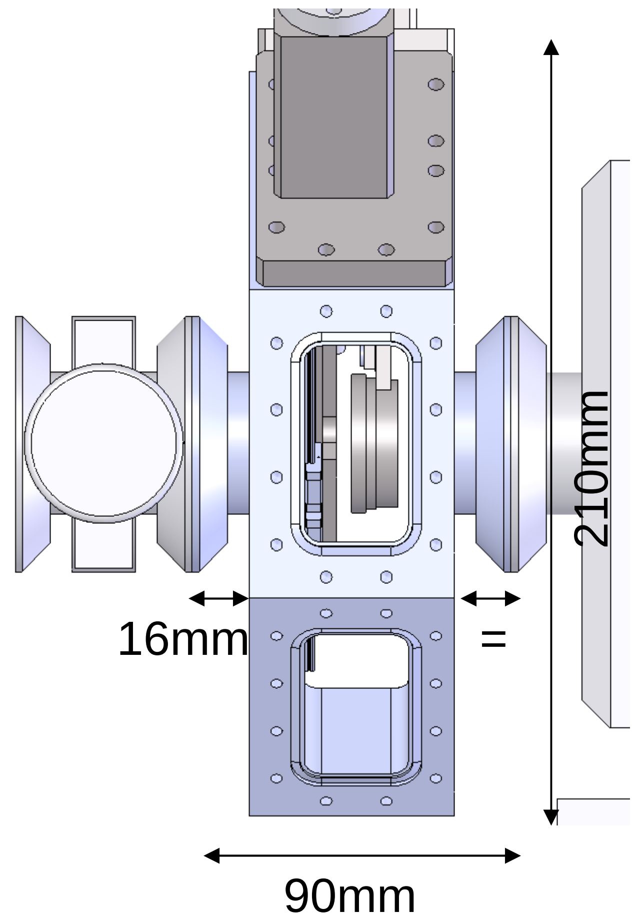
Faraday cup for stable pilot beams (down to 0.5 pA)

NEW device to be developed for lower currents (from 10^7 pps to a few pps)

Short-box preliminary design

Provided by : Julio Galipienzo – AVS company (Added Value Solutions) – Gipuzkoa, Spain





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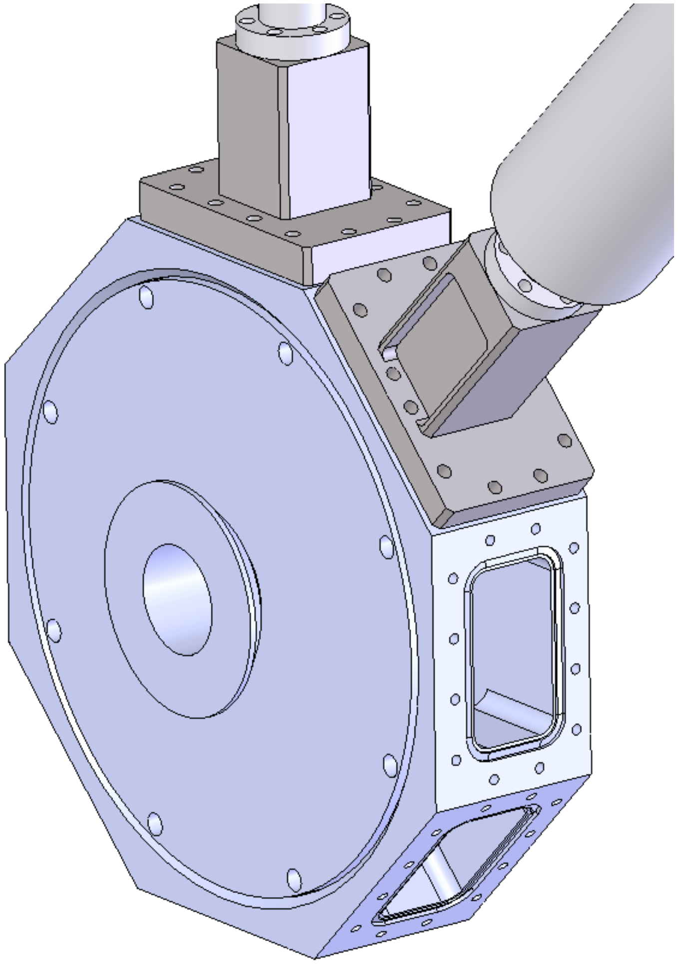
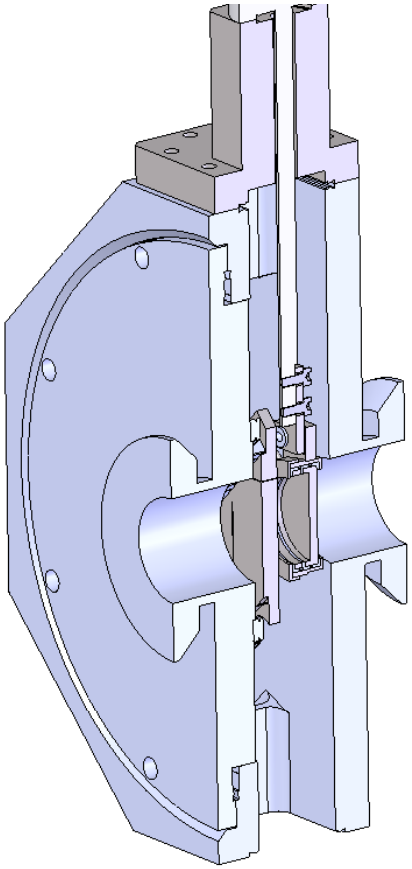
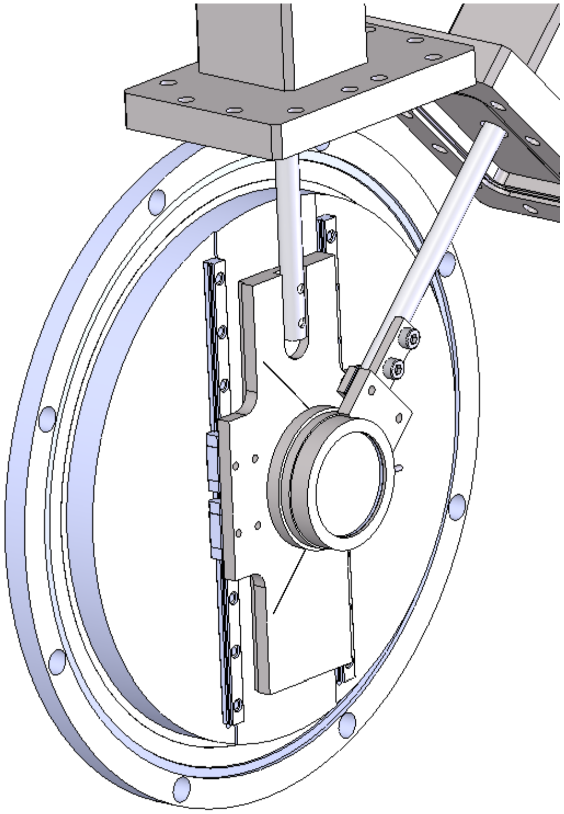


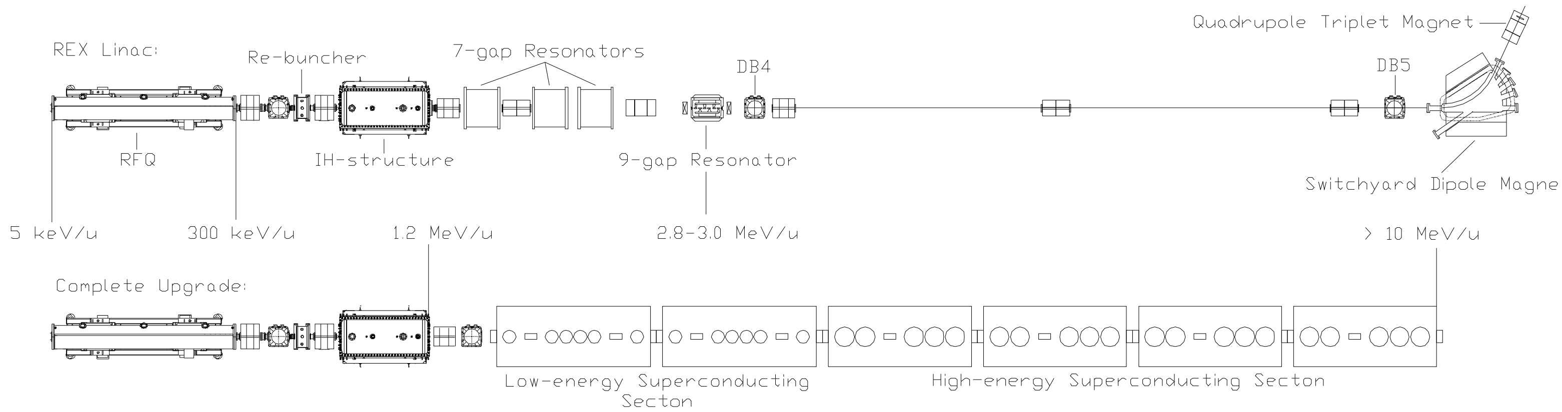




HIE-ISOLDE linac & cavity phase-up

REX

HIE-REX

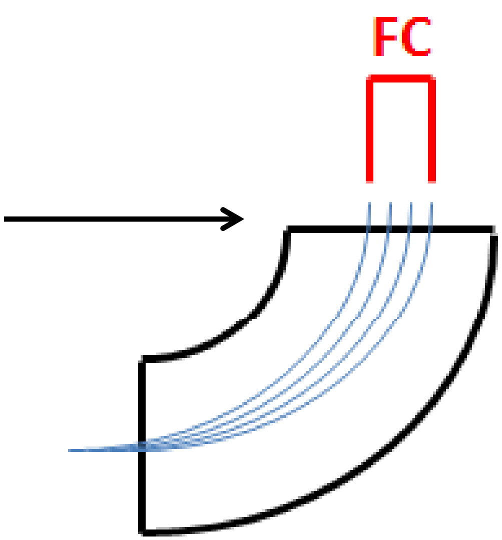


6 cryomodules with 32 superconducting cavities

- Increase in the number of cavities:
  from 5 (REX) → to 34 (HIE-REX)

- REX phase-up procedure: relative measurement of the beam average energy vs. the RF phase downstream the cavity by means of the switchyard dipole magnet

  → robust and reliable procedure but time consuming and difficult to automate

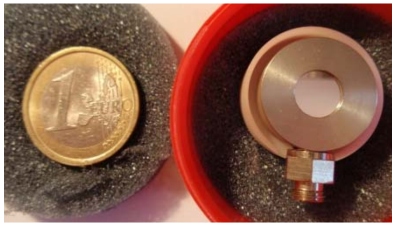


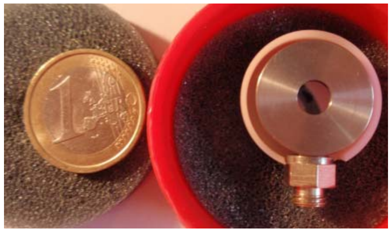
Need for a quick and eventually automated phase-up

Silicon detector monitor

- Longitudinal profile monitor to be placed downstream the cryomodules aimed at the phase tuning of the superconducting cavities
- High sensitivity required by the low intensity beams at REX (100-500pA pilot beams)
- PIPS (Passivated Implanted Planar Silicon) detector, suited for charged particle spectroscopy → beam particles stopped → measure of energy and time of arrival

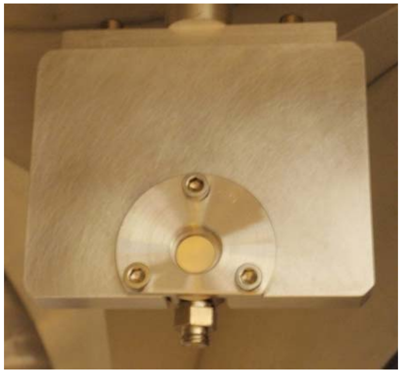
Canberra PIPS det



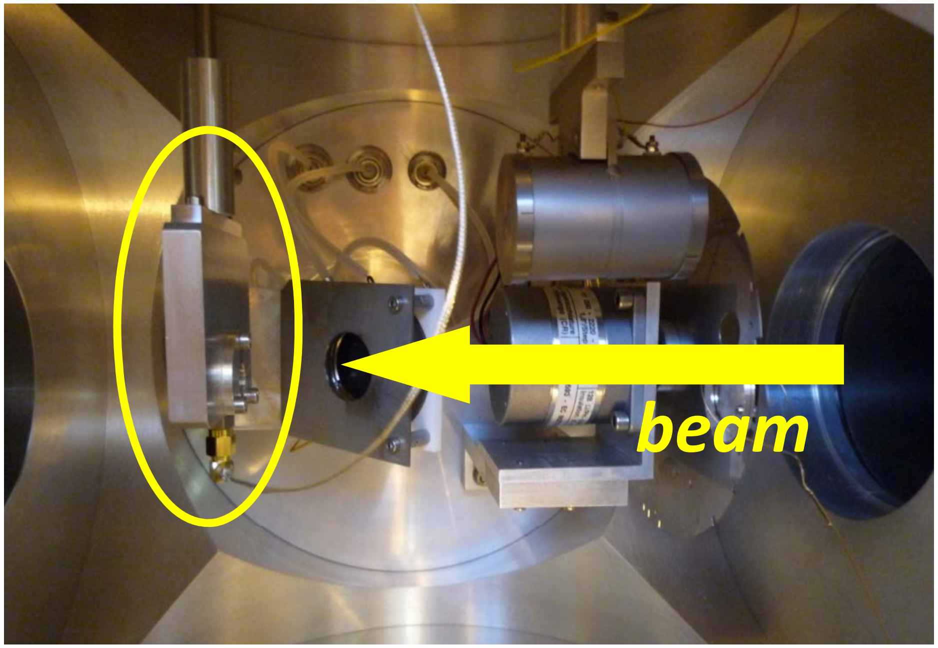


Area= 50mm² / 25 mm²
Thickness = 300 μm / 500 μm
Bias voltage = +60 V / +100 V
Capacitance = 30 pF / 11 pF

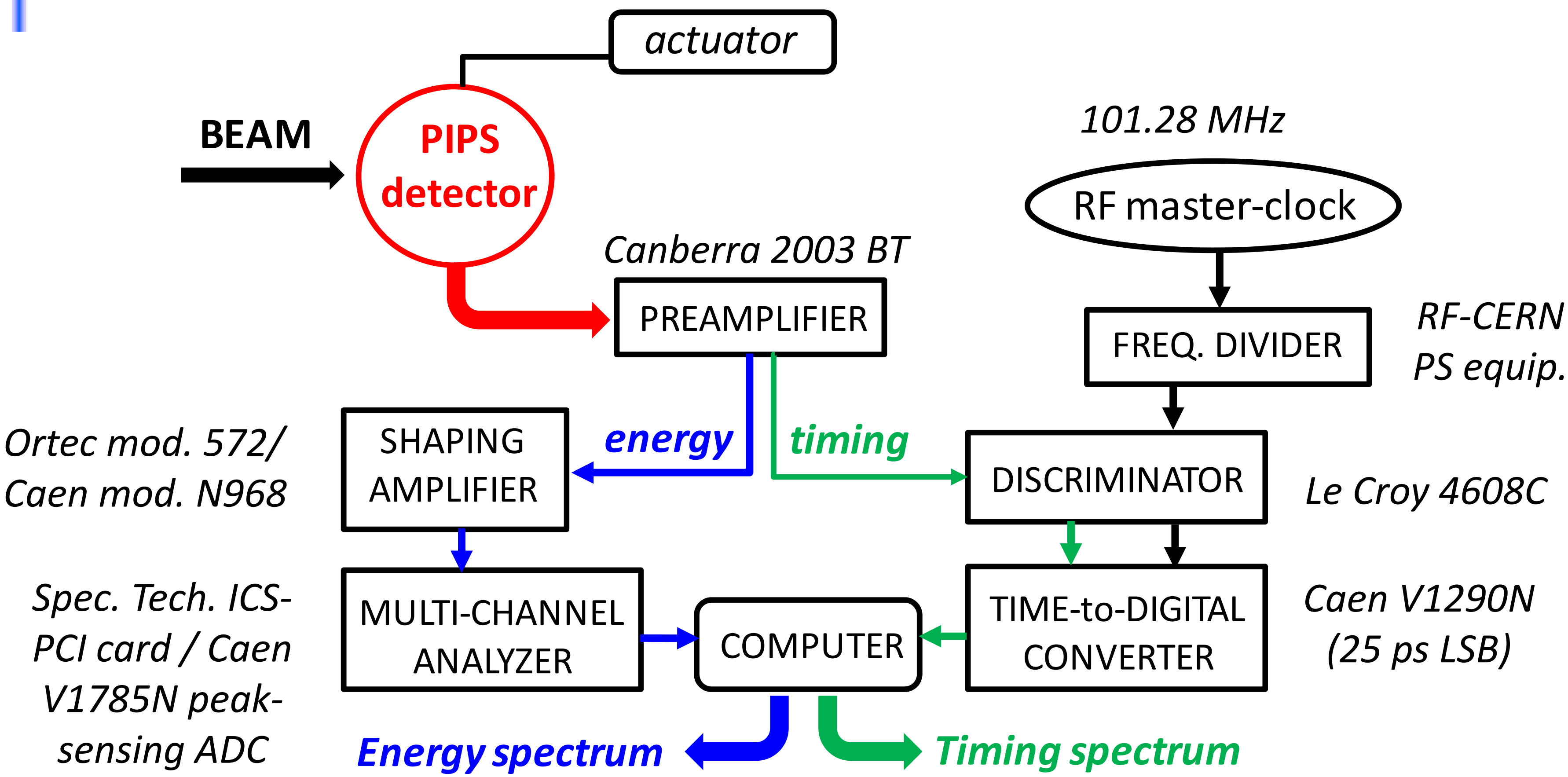
Mechanical support



Test setup inside one REX diagnostic box



Monitor structure and DAQ setup

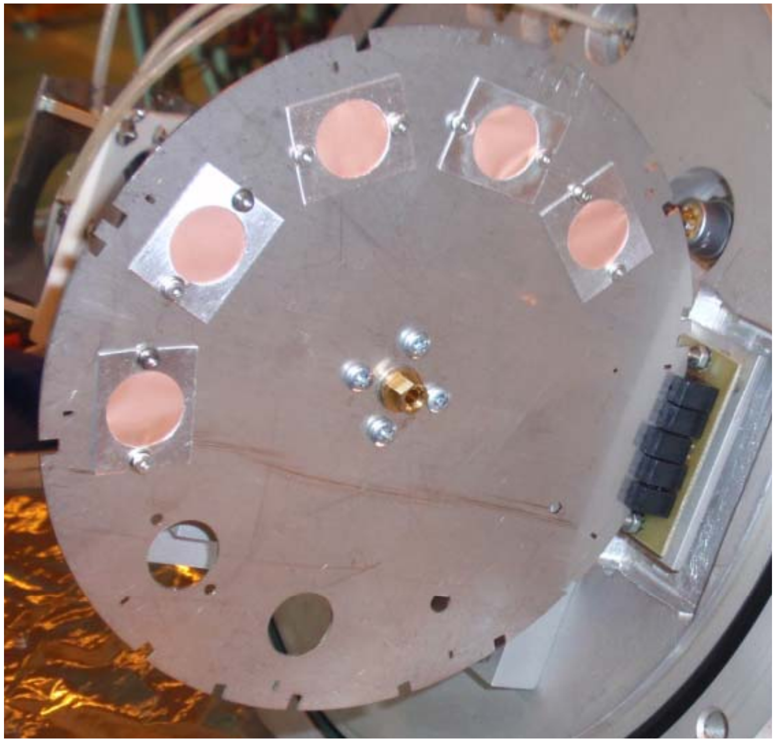


Beam attenuation methods

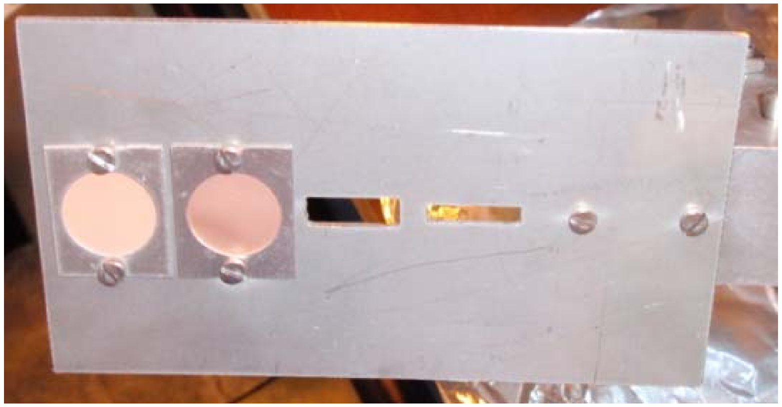
→ manipulation of REXEBIS parameters + collimators along the linac:

removing the time structure of the pulse extracted from the EBIS (Electron Beam Ion Source) resulted in a strongly reduced beam intensity

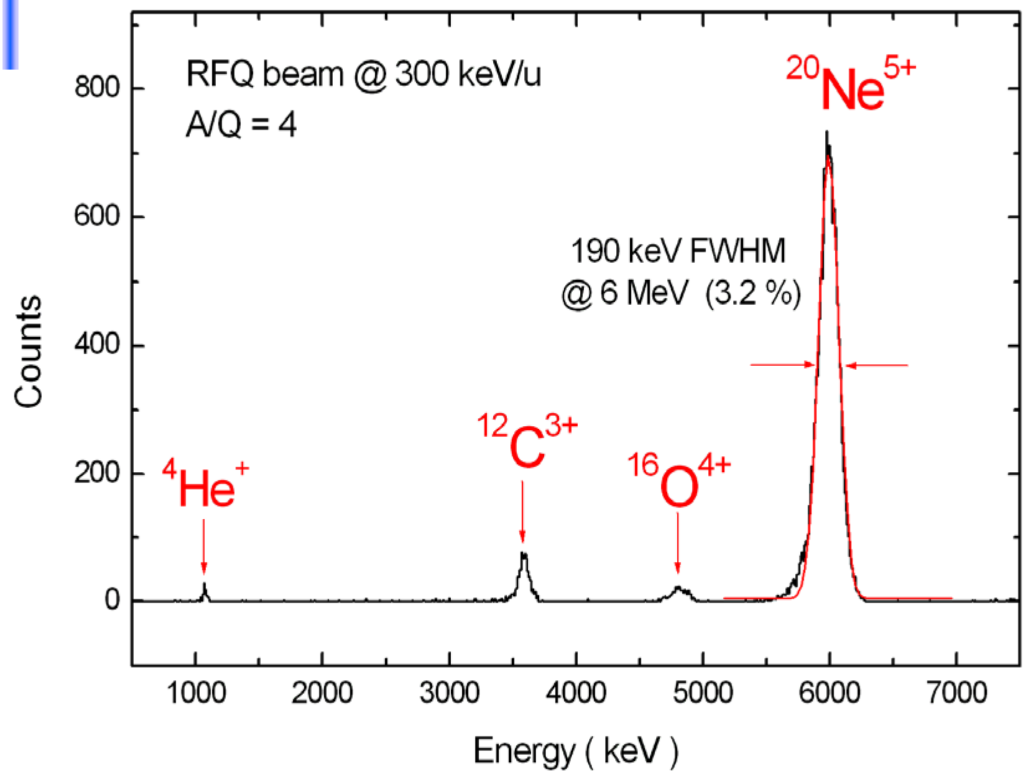
→ perforated copper foils placed upstream and downstream the RFQ:



- thickness=15 μm (particle energy 5keV-300keV)
- holes diameters = 50 μm and 35 μm
- holes spacing = 0.2-5 mm
- transmission factors per foil = 5% - 0.01%



Beam energy spectrum



REX BEAM SPECTRUM at 300 keV/u and A/Q=4

Average particle count rate = 100 Hz (count rate of 6.7 kHz in the RF pulse window)

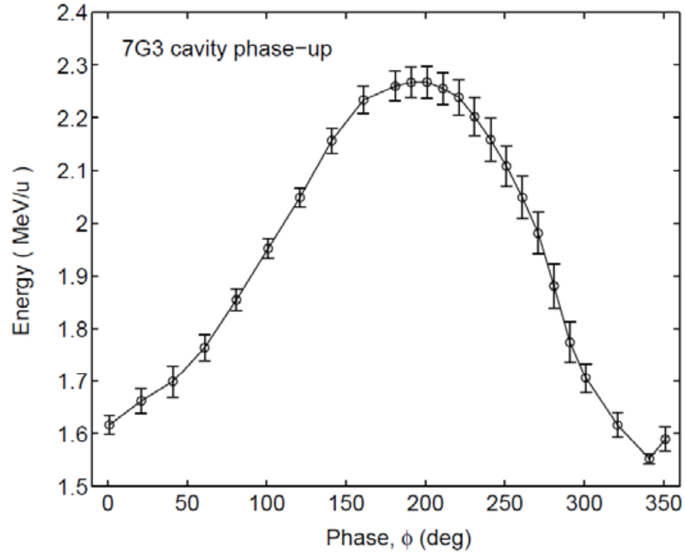
→ **Helium, carbon, oxygen** and **neon peaks** well identified

Measured **monitor energy resolution**:

in the range from **1.3 to 0.4 % rms** (3 to 1 % FWHM)

while varying REX beam energy from **300 keV/u to 3 MeV/u**

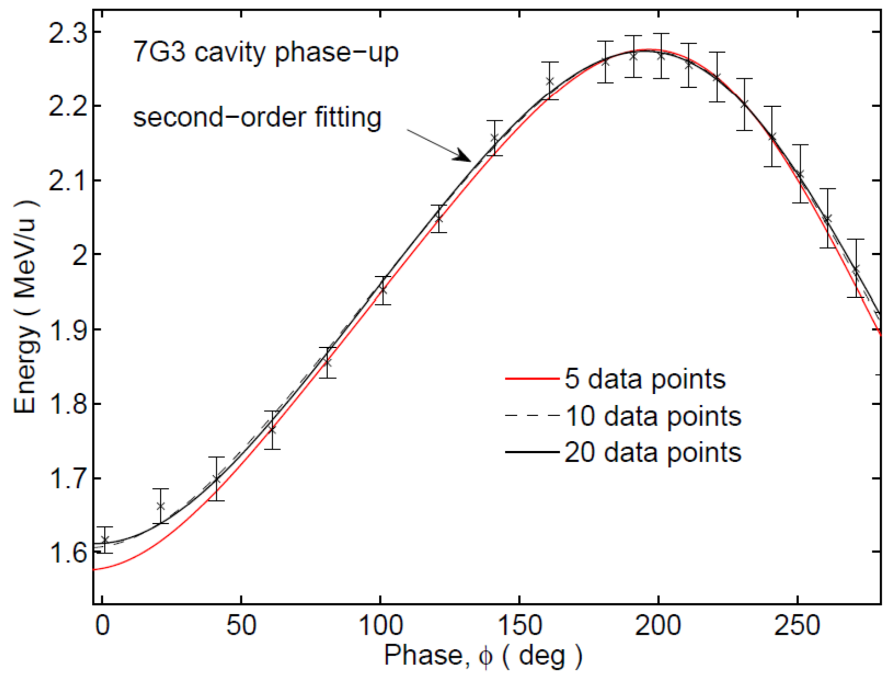
Cavity phase-up demonstration



Fast and accurate phase-up procedure of REX 7-gap resonator @ 1.95 MeV/u

Peak channel number of the energy signal quickly recorded as a function of the RF phase

$$\Delta W_0 = a(\beta)\cos\phi + b(\beta)\sin 2\phi + c(\beta)$$



synchronous phase determined with the required accuracy of ± 2.5 degrees even with a minimized number of points in the phase-up curve

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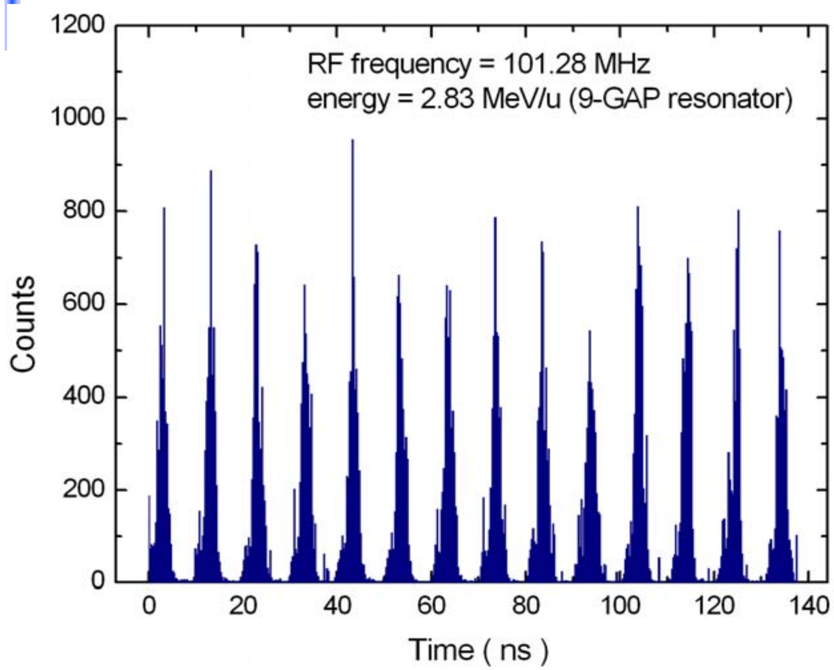
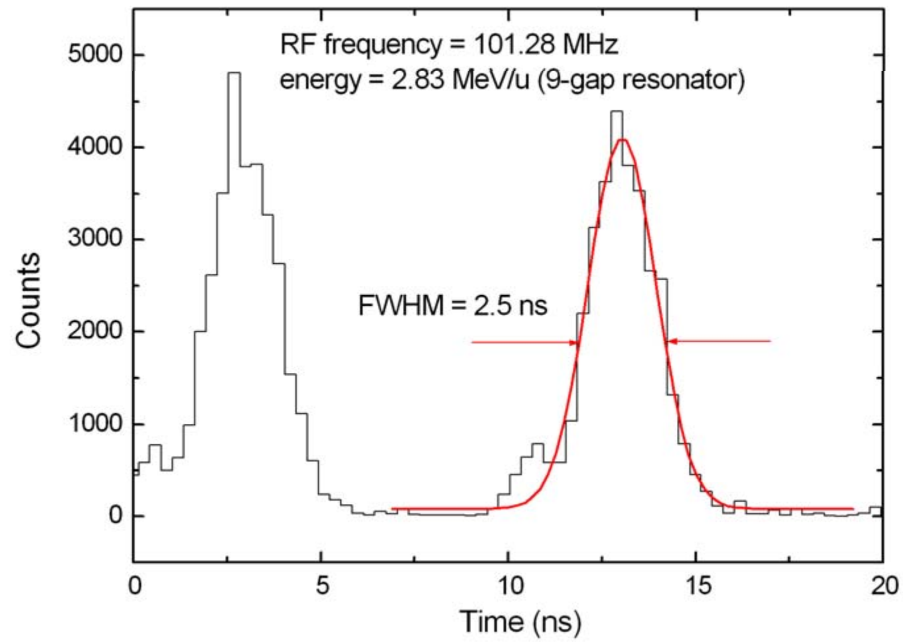
reasonable **measurement time** of a few minutes per cavity (@ 100Hz count rate)

Beam time profile

Estimated system timing resolution better than 200 ps rms

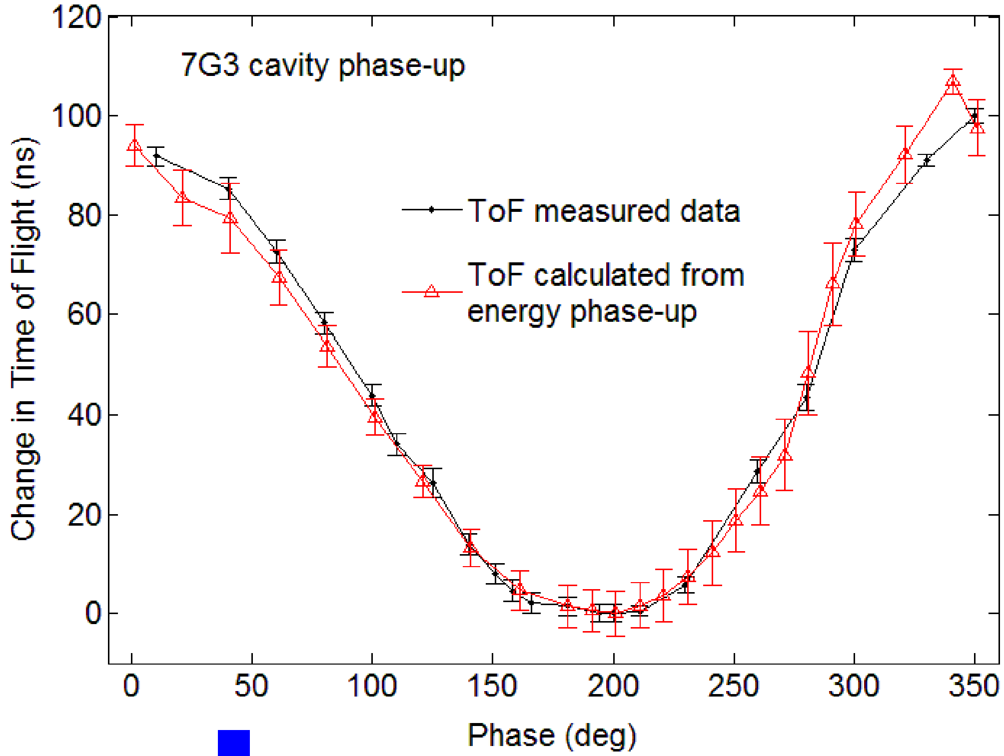


Acquired beam time structure with the **expected bunch period of 9.87 ns (RF=101.28MHz)** @ energy = 2.83 MeV (output energy of the 9-gap resonator)



Measured bunch length of 2.5 ns FWHM → compatible with the time spread expected at the output of the 9-gap resonator and after a drift of approximately 9 m to the silicon detector

Time-of-Flight cavity phase-up



The bunches arrival time vary up to 90 ns over the 10.6 m drift distance between the cavity and the silicon detector monitor

Bunch spacing of 9.87 ns :

→ phase must be varied slowly to be able to identify the bunch

→ too much time-consuming

Principle demonstrated → viable option for cavity phasing should a chopper be incorporated in the HIE-ISOLDE upgrade and the bunch spacing increased

Conclusions & outlook

- Almost complete design of the inter-tank short boxes aimed at intensity, position and transverse profile measurements
- Successful test of a prototype Si-detector monitor for longitudinal profile measurements aimed at cavity phase-up

Future developments:

- Inter-tank short boxes: electronic read-out chain, test of a first prototype either at CERN or on other beam lines outside CERN
- R&D of a detection system to measure the faint currents of radioactive beams, to be integrated in the short-boxes
- Si detector: automated system control, optimization of the intensity attenuation factors to achieve the fastest possible phase-up
- Emittance-meter design (slit + profiler→ based on short-box design)