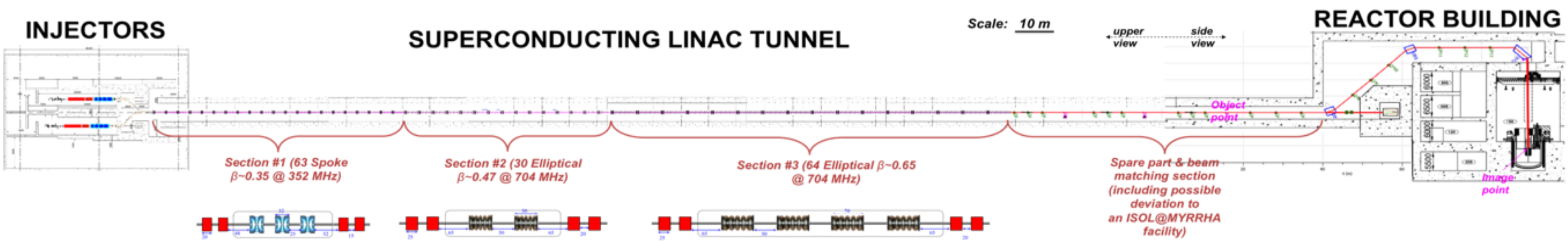
MYRRHA

Multipurpose h**Y**brid **R**esearch **R**eactor for **H**igh-tech **A**pplications



The MYRRHA LEBT test stand

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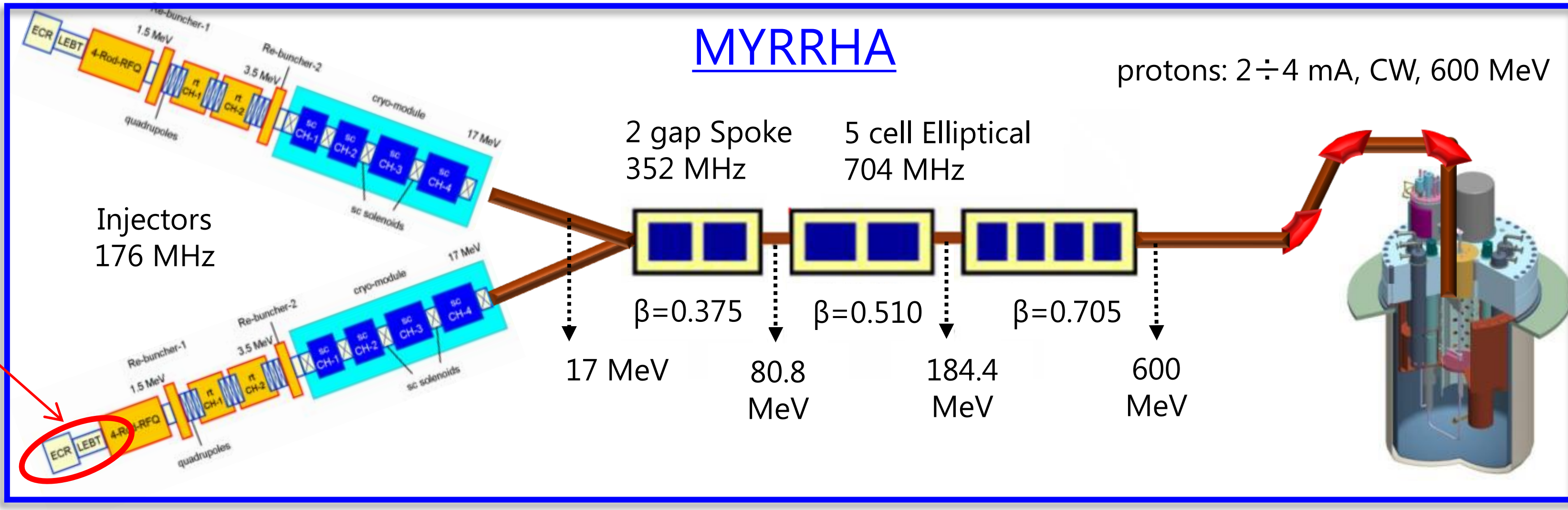
ADT - SCK•CEN

STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

MYRRHA Linear Accelerator



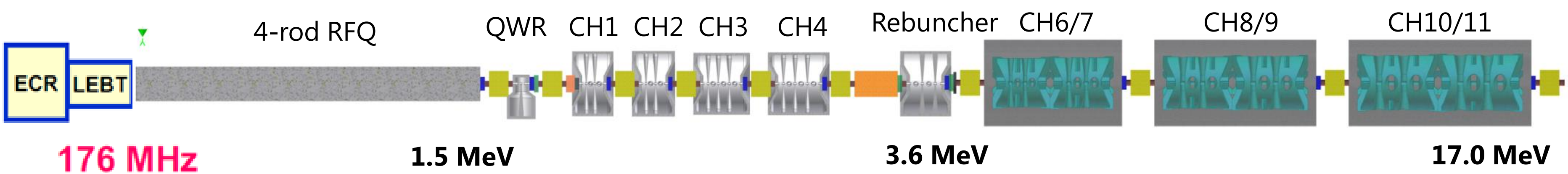
- Doubled Injector, multicell structures, up to 17 MeV @ 176.1 MHz:
  - ECR ion source, 30 keV
  - LEBT
  - 4-rod RFQ, 1.5 MeV
  - RT-CH, 3.5 MeV
  - SC-CH, 17 MeV

- Superconducting LINAC, modular, individually controlled cavities, warm quadrupoles doublets and diagnostics:

E_{in} [MeV]	*Cavity*	f_{RF} [MHz]	β	$\frac{cav.}{CM}$	*n. CM*	E_{out} [MeV]
17.0	spoke	352.2	0.375	2	24	80.8
80.8	elliptical	704.4	0.510	2	17	184.4
184.4	elliptical	704.4	0.705	4	15	600.0

CM: Cryomodule; $\beta = v/c$: cavity geom. value

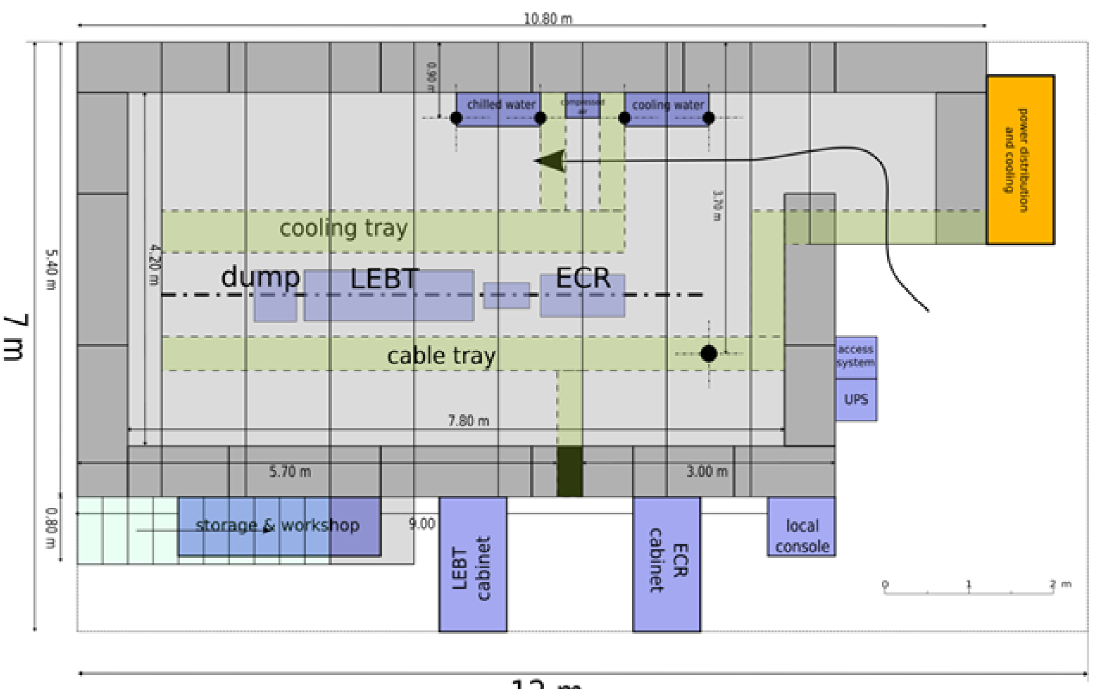
INJECTOR@UCL	
led by SCK•CEN	
Goals:	• Test platform: experimentally address the injector design though prototyping • tool for relevant reliability minded experience
Main topics:	• Beam characterization • CW operation of the 4-rod RFQ • SS RF amplifier @ 176.1 MHz – 160kW • Diagnostics for high current beams • 3-tier Control System • Long reliability runs
Principal partners:	• MAX Collaboration (especially WP1 and WP2) • research institutes: IPNO, LPSC, IAP, UCL/CRC, • industries: Pantechnik, Cosylab

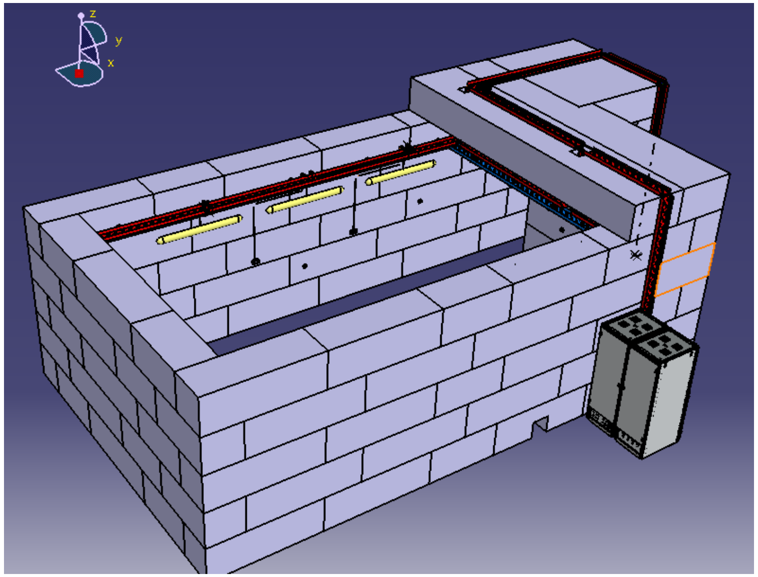


R&D@UCL/CRC : general layout

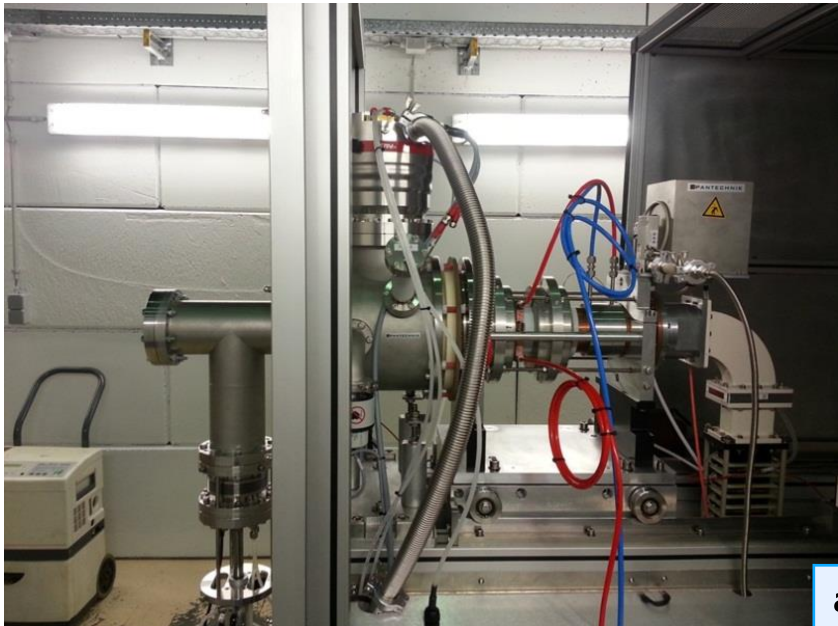
General layout of the experimental test stand in UCL/Centre de Ressources du Cyclotron (CRC) at Louvain-la-Neuve, Belgium:

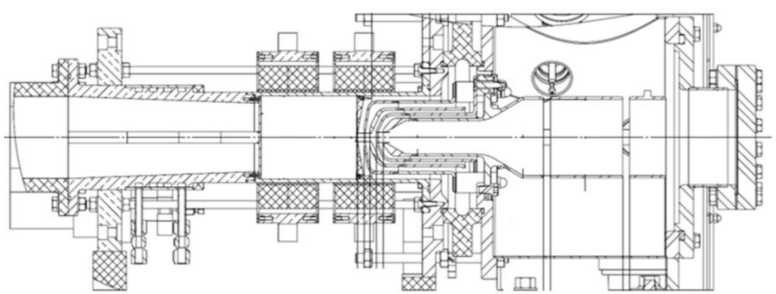
LEBT@UCL





The ECR proton source





courtesy of Pantechnik SA

PANTECHNIK

Monogan 1000

ECR Ion souce – 30keV, 20mA

- Electron Cyclotron Resonance, 2.45 GHz
- multi-electrodes extraction system
- flat magnetic profile configuration by PMs
- tapered axial RF injection
- Einzel electrostatic focusing lens

accelerating voltage	**30 kV** (40 kV capable)
beam current	20 mA DC
RF	2.45 GHz, 1200 W
transverse emittance @ 5 mA	**0.1 π·mm·mrad RMS norm.**
magnetic system	Permanent Magnets
autonomous control system	NI CompactRIO
provisions for reliability/repairability	
beam diagnostics devices incl.: Faraday Cup, Allison scanner	

Acceptance Tests

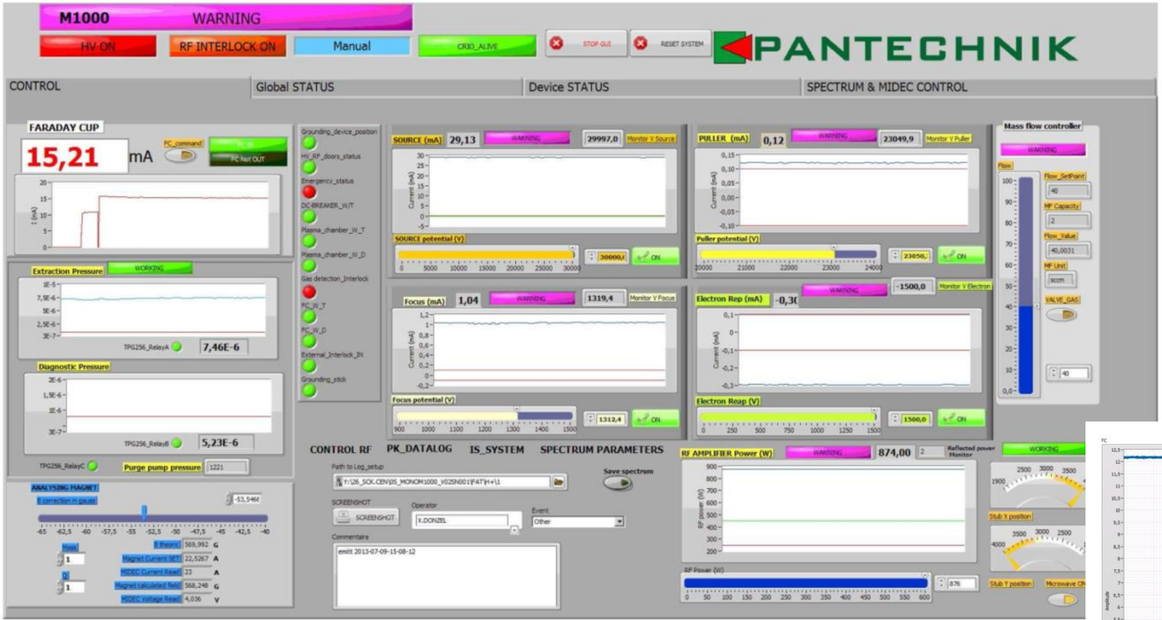
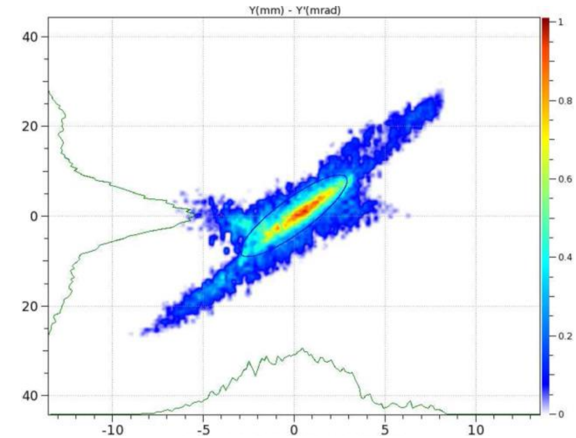


Figure 22: Source parameters at 15 mA@30keV



- Beam characterization in a short test line (source, dipole, FC, Allison scanner, dump)
- Max p beam current achieved: 16mA
- Long stability run (24hrs), standalone system, up to 12 mA
- Excellent stability shown with brief recovery time in case of electrical discharges

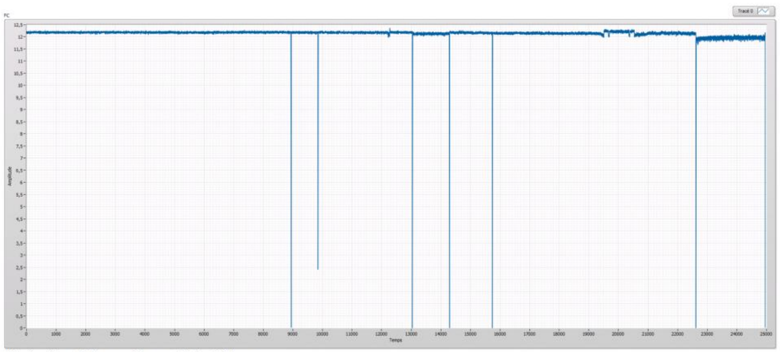


Illustration 4: Beam Current 8 to 14 hours

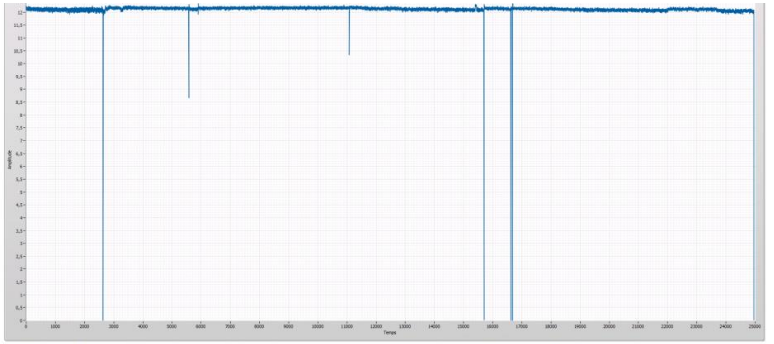
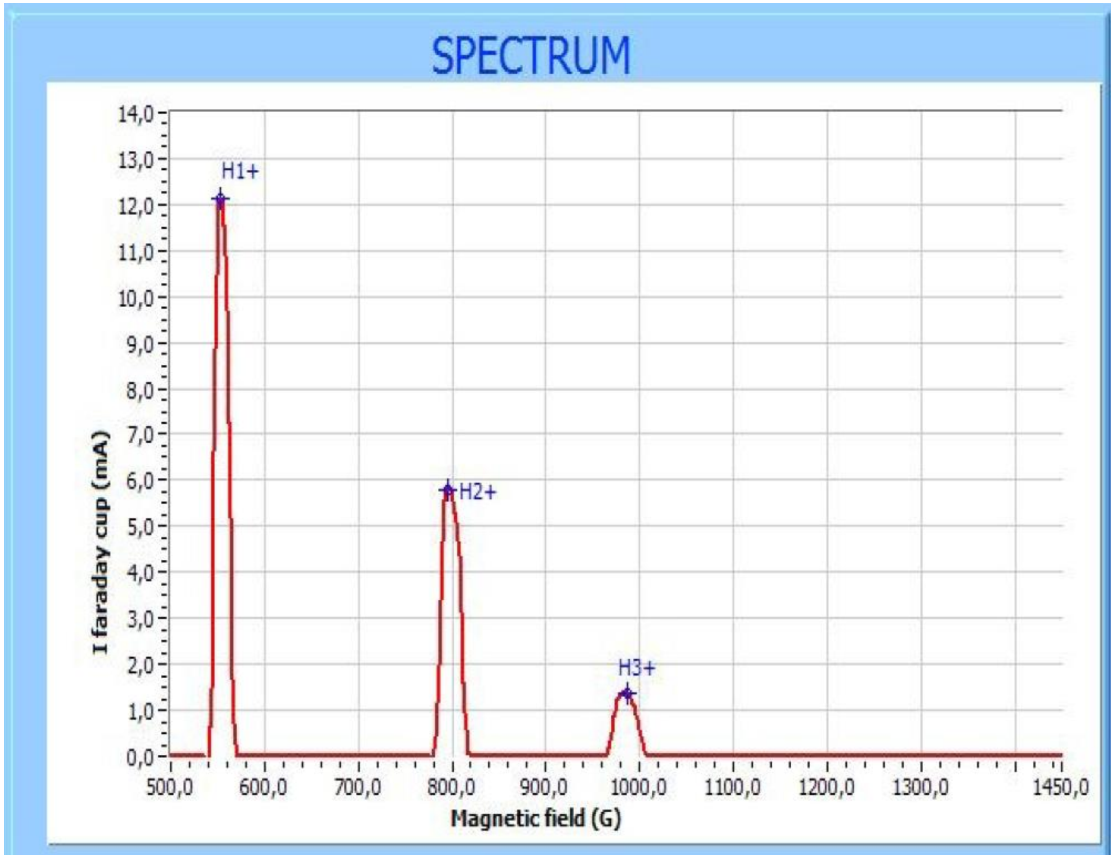


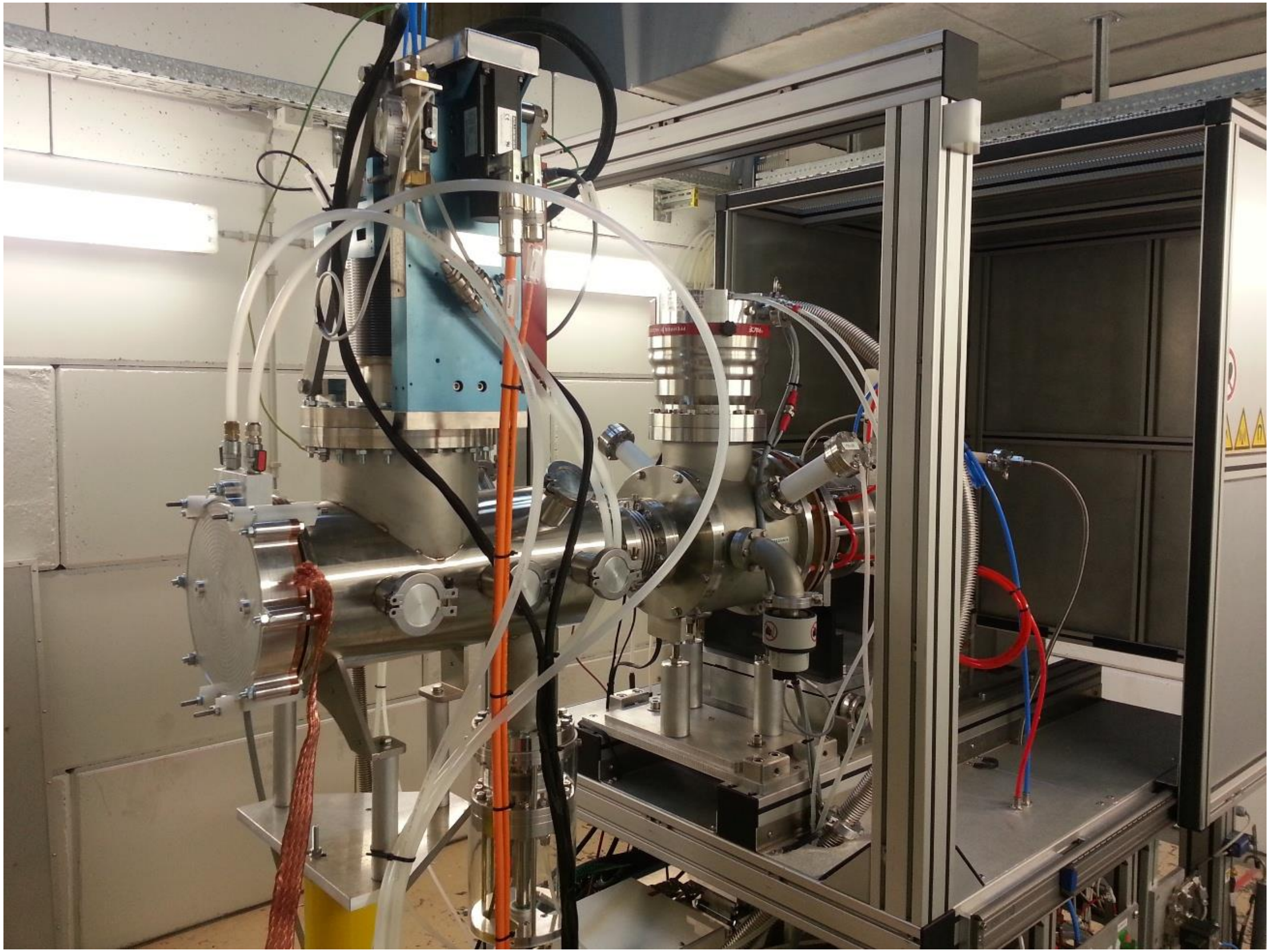
Illustration 3: Beam Current 14 to 21 hours (axis Horizontal in second and axis Vertical in mA)

Acceptance Tests



- Total efficiency : 84%
  - Includes beam transport efficiency (total current from power supply divided by the sum of measured intensity)
  - and HV losses (bleeder)
- Ionisation efficiency (ion intensity divided by total measured intensity)
  - H+ =63%
  - H2+=30%
  - H3+=7%

Current setup (UCL/CRC, LLN, Belgium)

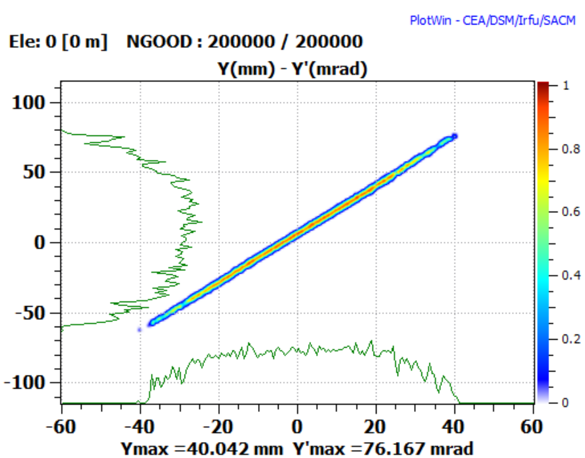


Current investigations

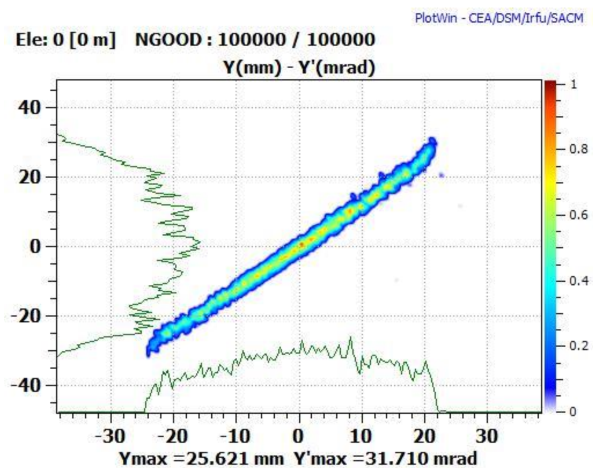
- Beam characterization at the exit of the Ion Source
- Measurements on total beam current (H+, H2+, H3+ species)
- Investigations on: → beam emittance
  → influence of the Einzel lens
  → back-tracking and validation of multiparticle simulations (Tracewin)

Vertical transverse phase space, tot. beam current ~9 mA, z = 0.765 m

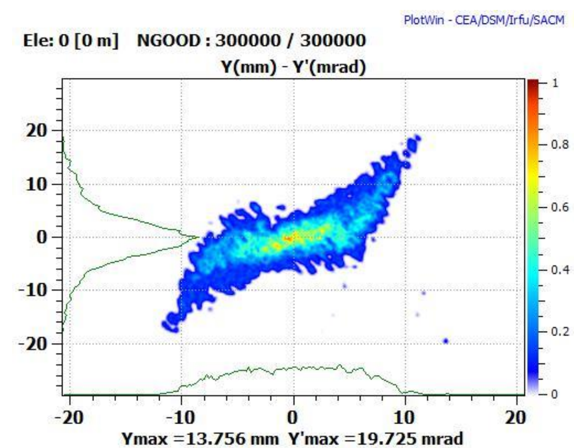
Einzel foc.= 0 kV



Einzel foc.= 22.3 kV

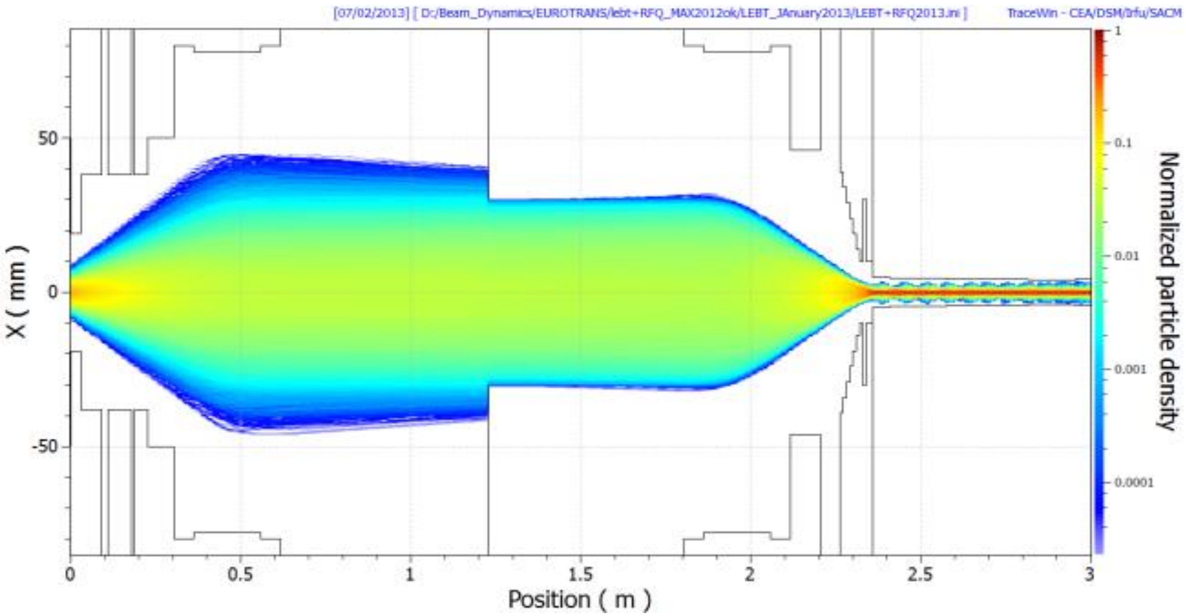


Einzel foc.= 25.5 kV

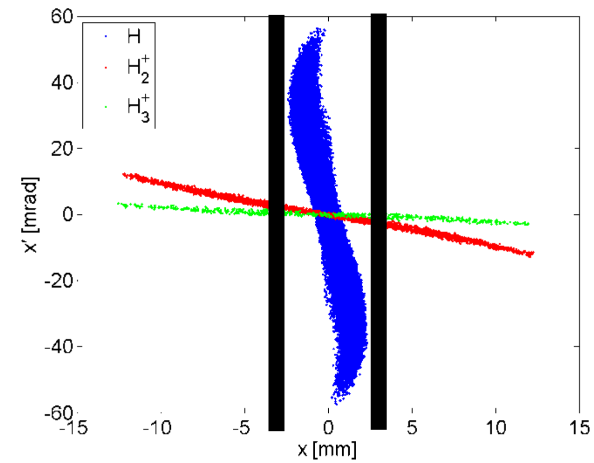


courtesy of F Bouly

Low Energy Beam Transport (LEBT) line



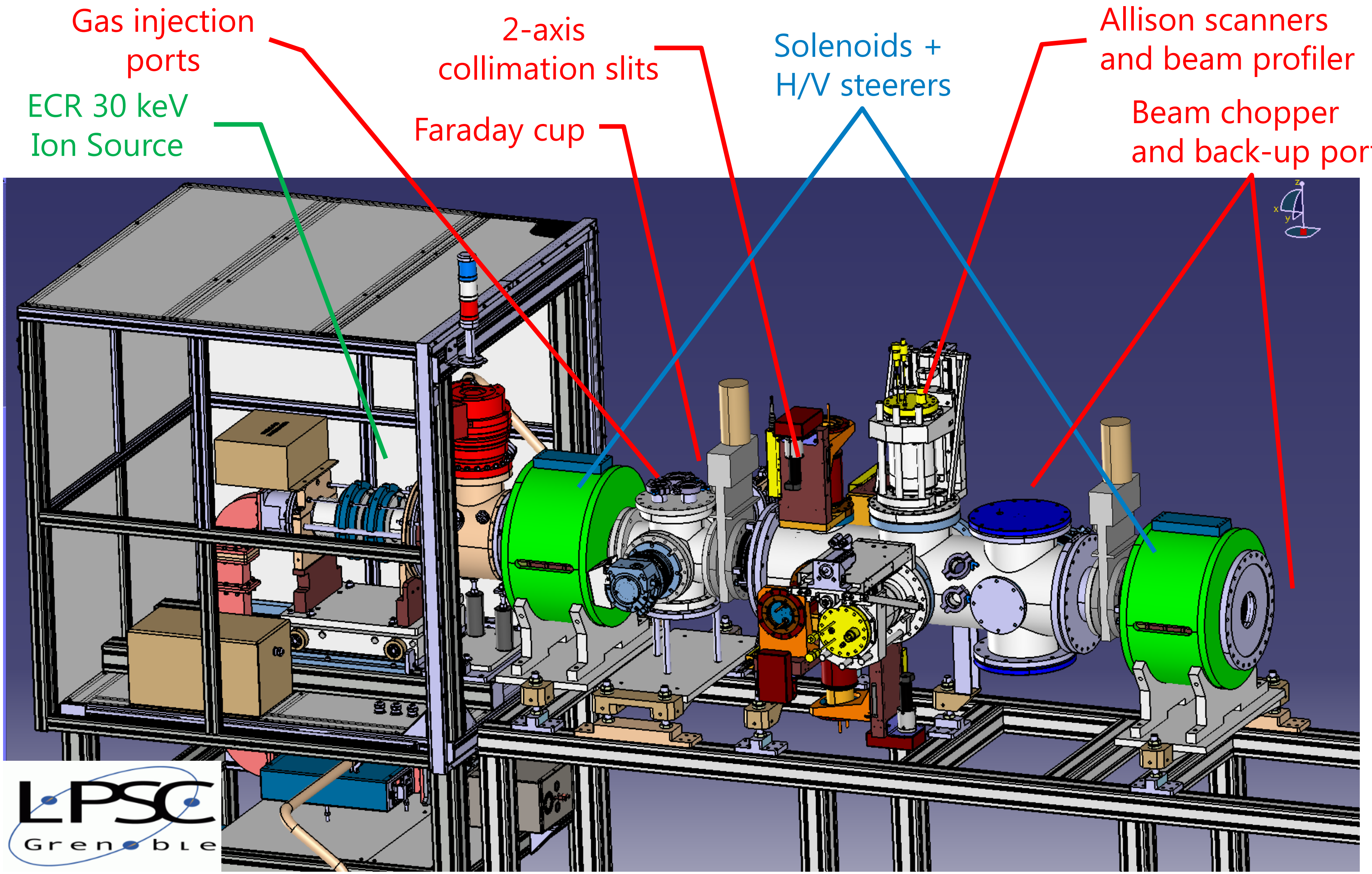
Multiparticle tracking through LEBT and first RFQ cell, with slits (vertical is similar), courtesy of JL Biarotte



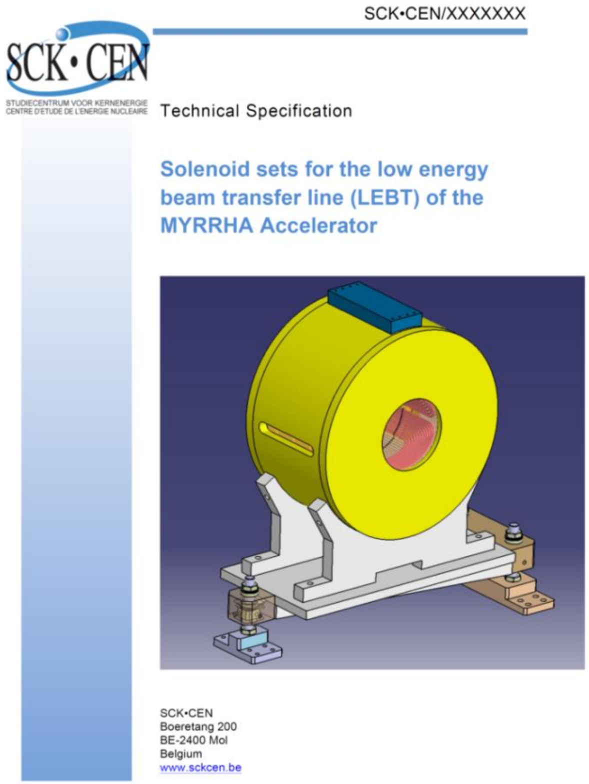
Horizontal Phase Space at the RFQ entrance (vertical is similar), courtesy of JP Carneiro

- Conceptual design by IPNO and SCK•CEN, engineering design LPSC
- Magnetic concept, optimized self space charge compensation, beam species separation, allows for diagnostics insertions
- Goal: provide a centred matched beam at the RFQ entrance, $\varepsilon_{trans} < 0.2\ \pi \cdot mm \cdot mrad$ norm. RMS (RFQ design value), $\alpha = 0.88$, $\beta = 0.04\ mm/(\pi \cdot mrad)$

Low Energy Beam Transport (LEBT) line



LEBT – Solenoid magnets and dipole steerers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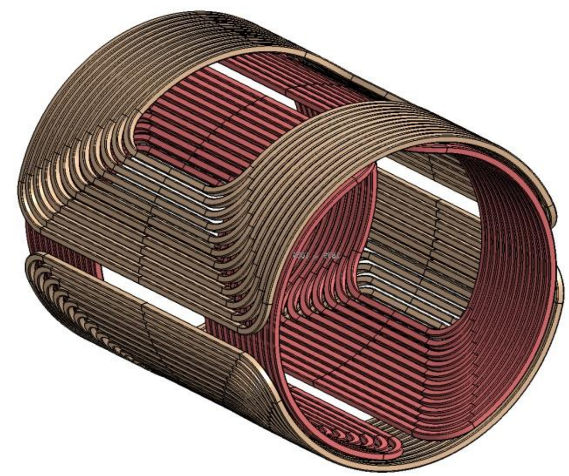
Technical Specification

Solenoid sets for the low energy beam transfer line (LEBT) of the MYRRHA Accelerator

SCK•CEN
Boeretang 200
BE-2400 Mol
Belgium
www.sckcen.be

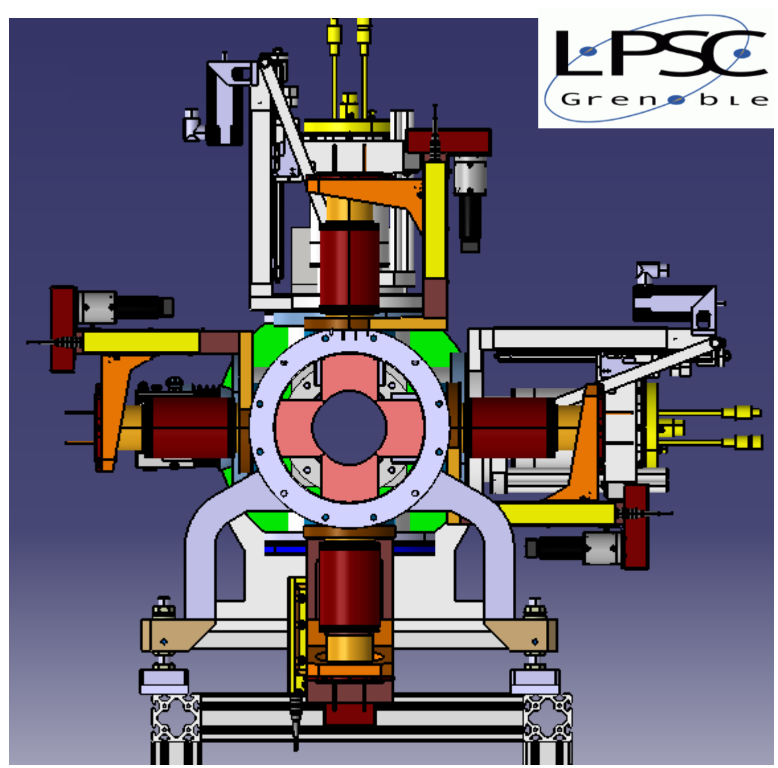
Full length	=	260	mm
Outer diameter	~	450	mm
Central field Bz(r=0,z=0)	>	0.25	T
Inner diameter with steerer coils	=	158	mm
End plate central hole diameter	=	157	mm
Solenoidal field integral	>	0.06	T.m
H,V steerer dipole field integral	>	$3.1\cdot10^{-4}$	T.m
Stray field ||B|| at (r=0,z=300)	<	3.3	mT
Stray field ||B|| at (r=100,z=270)	<	3.3	mT

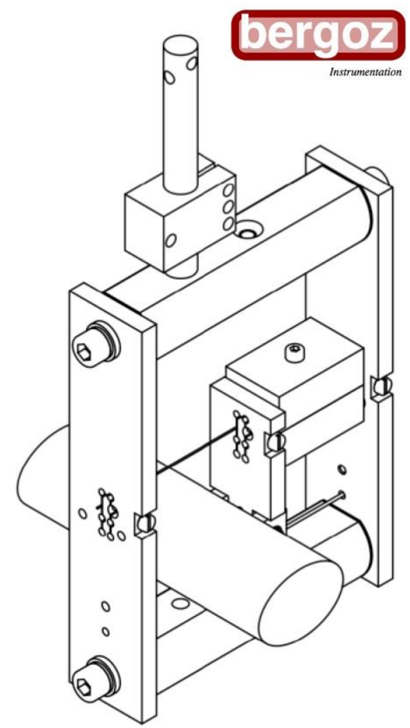


- Specification based on LPSC, IPNO and SCK•CEN pre-design study
- Released to a limited number of suppliers
- Under procurement from Sigma Phi, France

LEBT – diagnostics

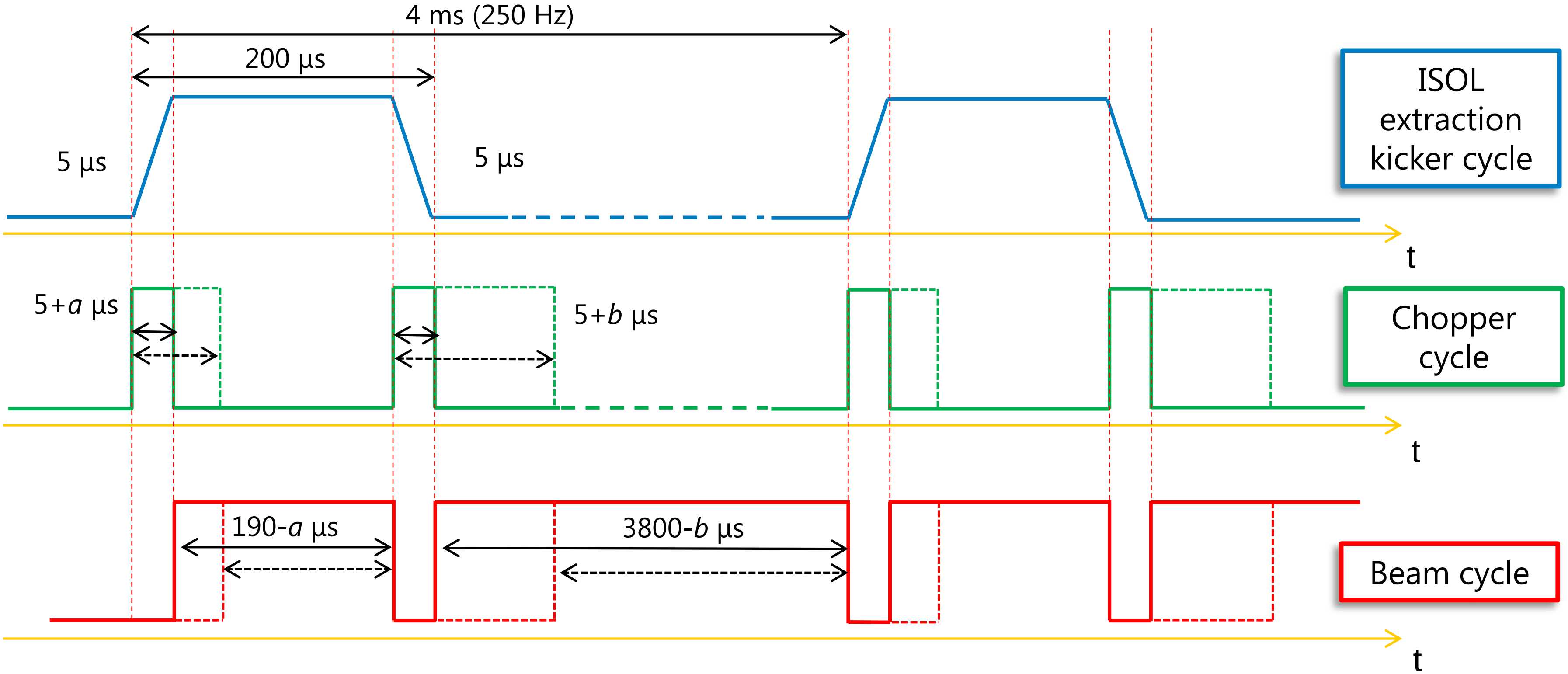
- Suitable FC found in SPIRAL2 cup, design reproducible from IPN Lyon
- Two Allison scanners for both H/V axes transverse emittance measurement
- Collimating slits (2-axes, 4 slits) designed by LPSC
- Evaluation of new additional diagnostic equipment: a Vibrating Wire profilemeter



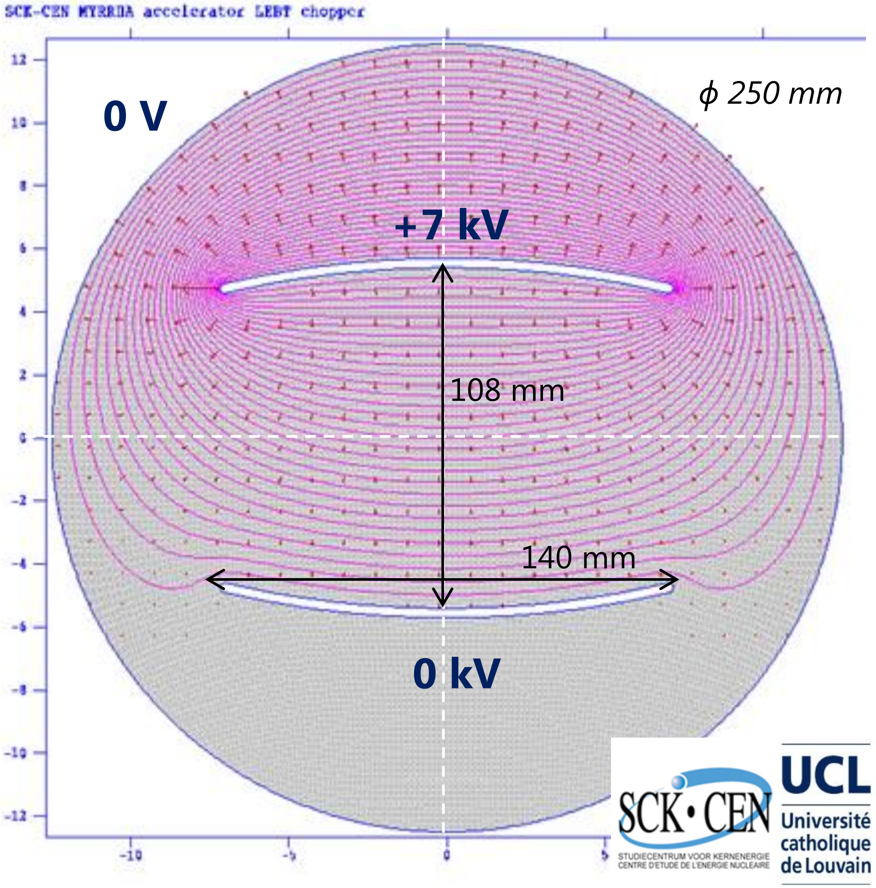


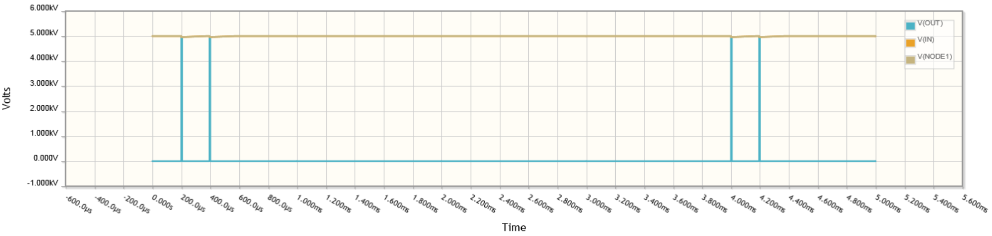
Beam delivery: reactor + ISOL@MYRRHA

- Beam delivery:
  - for reactor subcritical monitoring 200 µs/250 Hz beam interruptions are required
  - using an extraction kicker, 600 MeV, 190 µs/250 Hz beam pulses become available for an ISOL@MYRRHA facility
- 250 Hz macro cycle
- 5 to 190 µs pulses @ 5 kHz repetition time

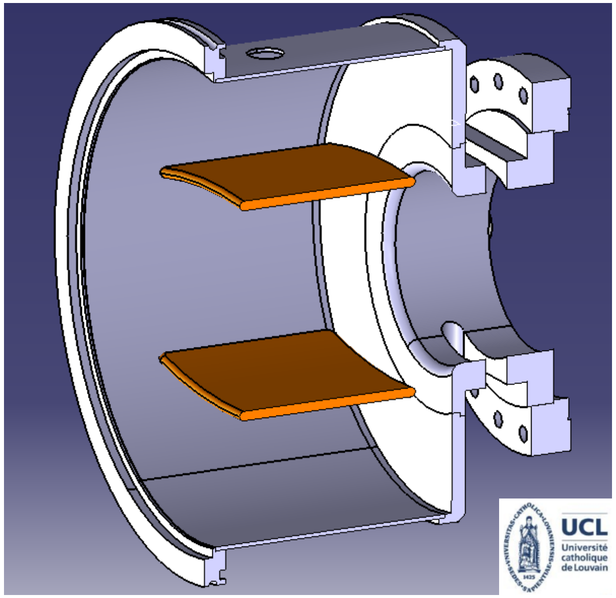


LEBT – RFQ interface





- Slow electrostatic beam chopper to create macro-pulsed beam structures on DC LEBT beam
- Beam dumped before RFQ injection onto RFQ collimator
- ACCT to monitor produced beam structure and RFQ transmission efficiency



LEBT – Control System

- Scope: LEBT integration
  - Magnetic elements PSs (solenoids, steerers)
  - Faraday cup, slits (motion controllers), profiler, beam chopper, beam dump
  - Ancillaries: vacuum system, cooling, gas injection system
  - Timing system
  - MP and safety interlocks
  - Nomenclature, archiving, GUI
- Pillars:
  - EPICS 3-tier architecture, Linux, cPCI
  - Industry-based field bus (Profibus) and automation (PLC) solutions
  - Micro Research Finland (MRF) timing transport layer based on FPGA

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Belgian Nuclear Research Centre

Stichting van Openbaar Nut
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