HIE-ISOLDE Diagnostics

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*on behalf of the HIE-ISOLDE BI team

BI Day, Archamps

16 October 2014

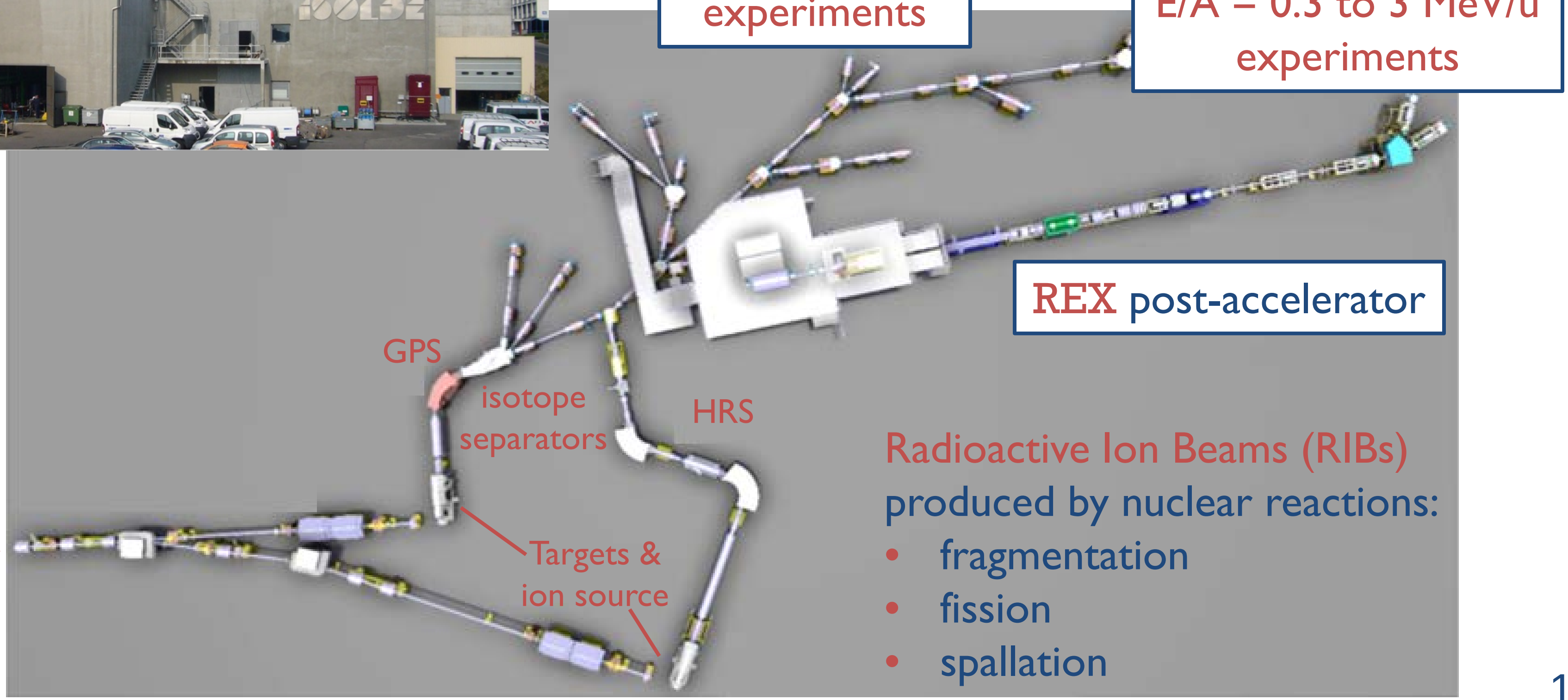
Outline

- Introduction to the HIE-ISOLDE project.
- Diagnostic requirements.
- Short and long Diagnostic Boxes, locations and devices.
- Validation tests with prototypes:
  - Beam intensity: Faraday cup.
  - Transverse beam profile: scanning slit + FC.
  - Transverse emittance: slit + grid or 2 slits + FC.
  - Longitudinal beam profile: silicon detectors.
- Electronics, controls and software.
- Status and outlook.

ISOLDE and REX

- **ISOLDE** is the CERN radioactive beam facility.
- Provides low energy or post-accelerated beams.
- Physics at the femtometer scale (1 fm = 10^{-15} m).

[1]



Radioactive Ion Beams (RIBs)
produced by nuclear reactions:

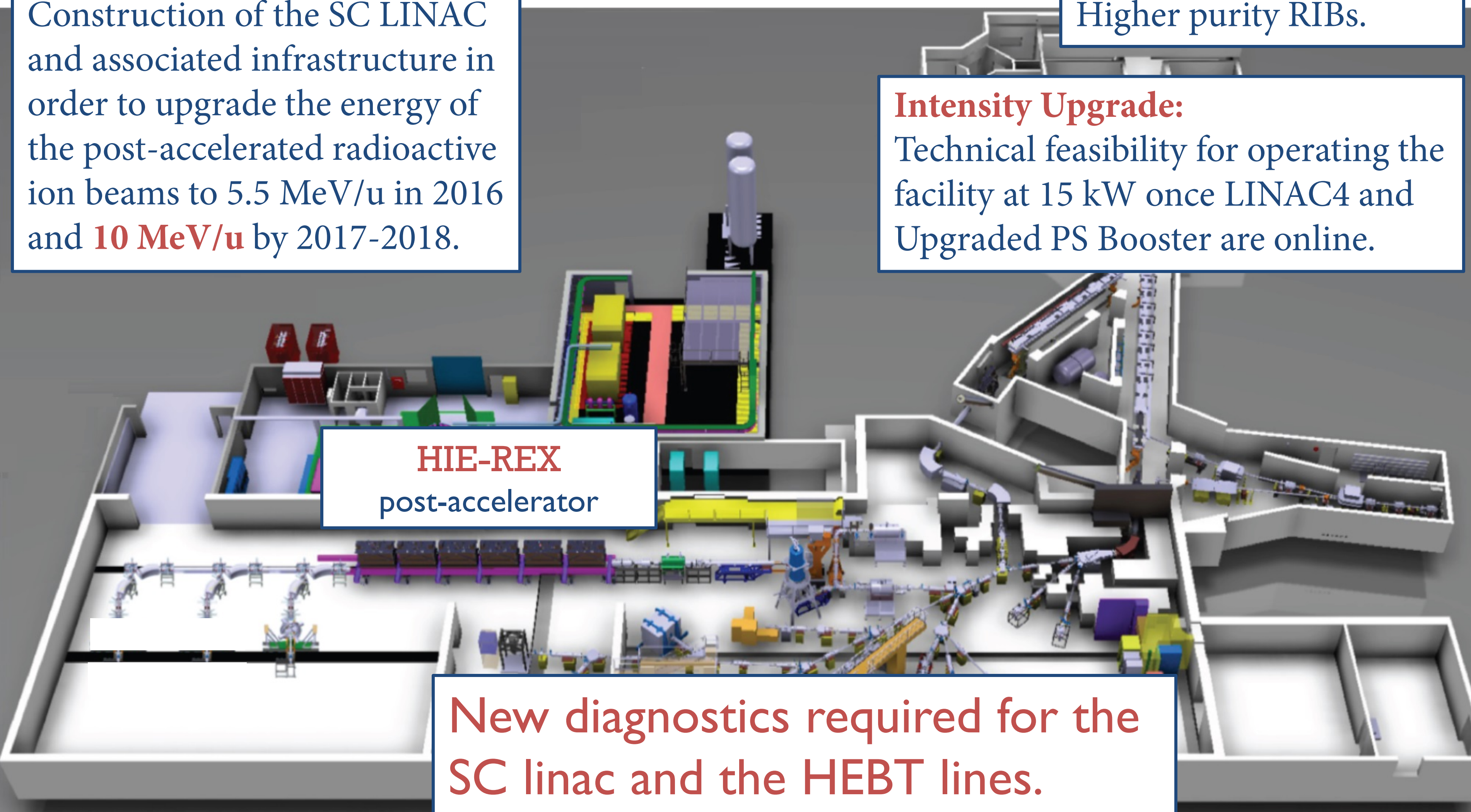
- fragmentation
- fission
- spallation

The HIE-ISOLDE project

Energy Upgrade:
Construction of the SC LINAC and associated infrastructure in order to upgrade the energy of the post-accelerated radioactive ion beams to 5.5 MeV/u in 2016 and **10 MeV/u** by 2017-2018.

Beam Quality Upgrade:
Higher purity RIBs.

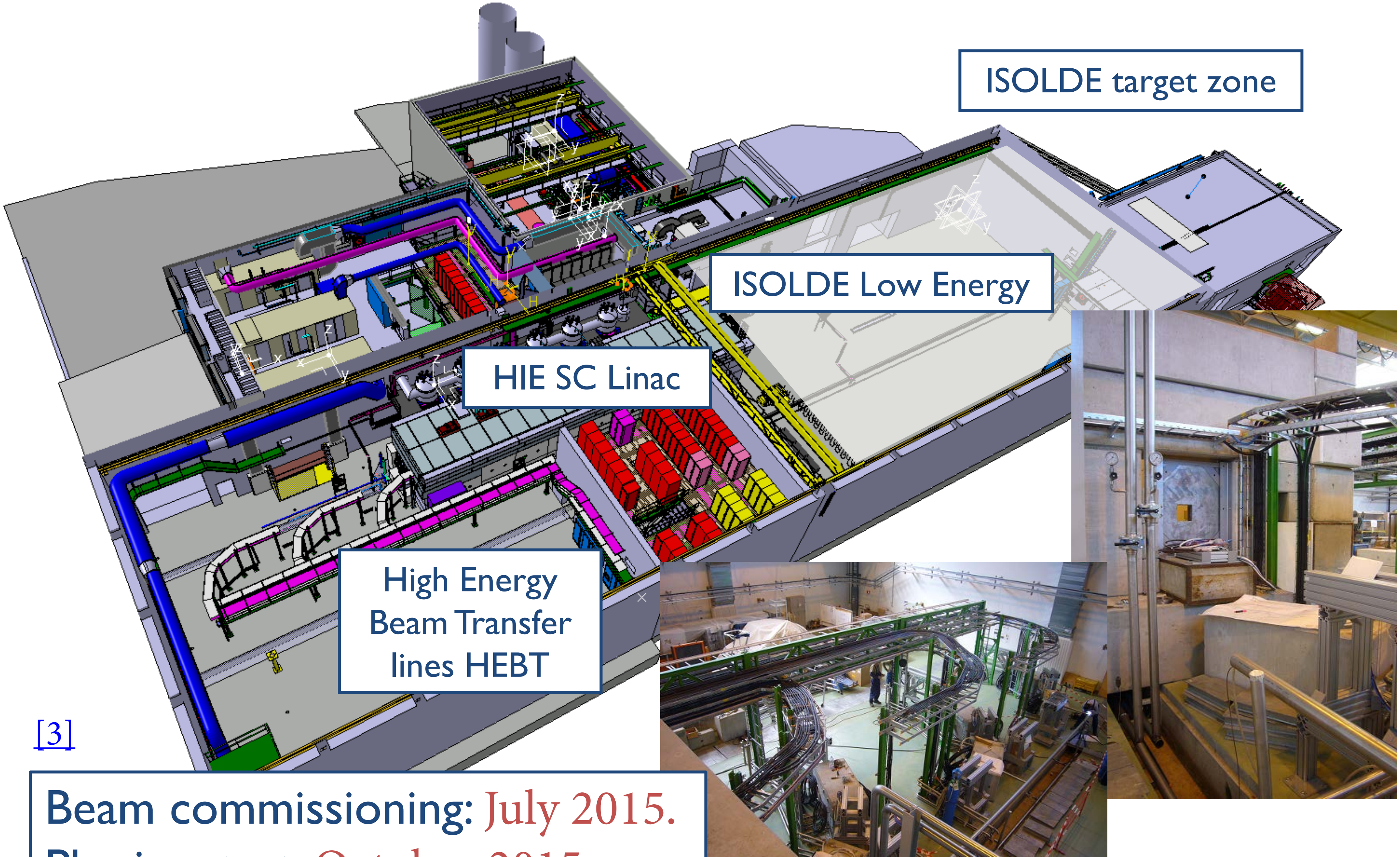
Intensity Upgrade:
Technical feasibility for operating the facility at 15 kW once LINAC4 and Upgraded PS Booster are online.



New diagnostics required for the SC linac and the HEBT lines. Stable beams ($^{16}O^{4+}$, $^{20}Ne^{5+}$).

[2]

HIE-ISOLDE: actual status



[3]

Beam commissioning: July 2015.
Physics start: October 2015.

Diagnostic requirements, typical beam parameters and implementation

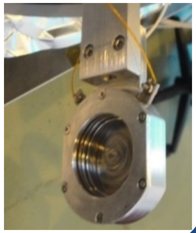
[4] EDMS **1213401**
[5] Proc. IBIC 2014 **WEPF13**

Beam Intensity

Stable (pilot) beams: 1 pA to 1 nA

FARADAY CUP

[6] EDMS **1370597**
[7] Proc. IBIC 2014 **WEPF07**

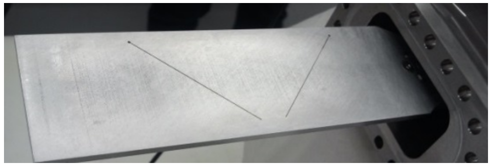


Transverse profile

Beam sizes: 1 to 5 mm (1 σ_{RMS})

SCANNING SLIT + FC

[8] EDMS **1370586**
[9] EDMS **1370583**



Transverse emittance

$\varepsilon^{rms}_{x,\,norm}$: 0.09 π mm mrad

SLIT + GRID
or 2 SLITS + FC

[10] EDMS **127963**

Longitudinal profile

Energy: 0.3 < E/A < 10 MeV/u
T_{RF} ~ 10 ns

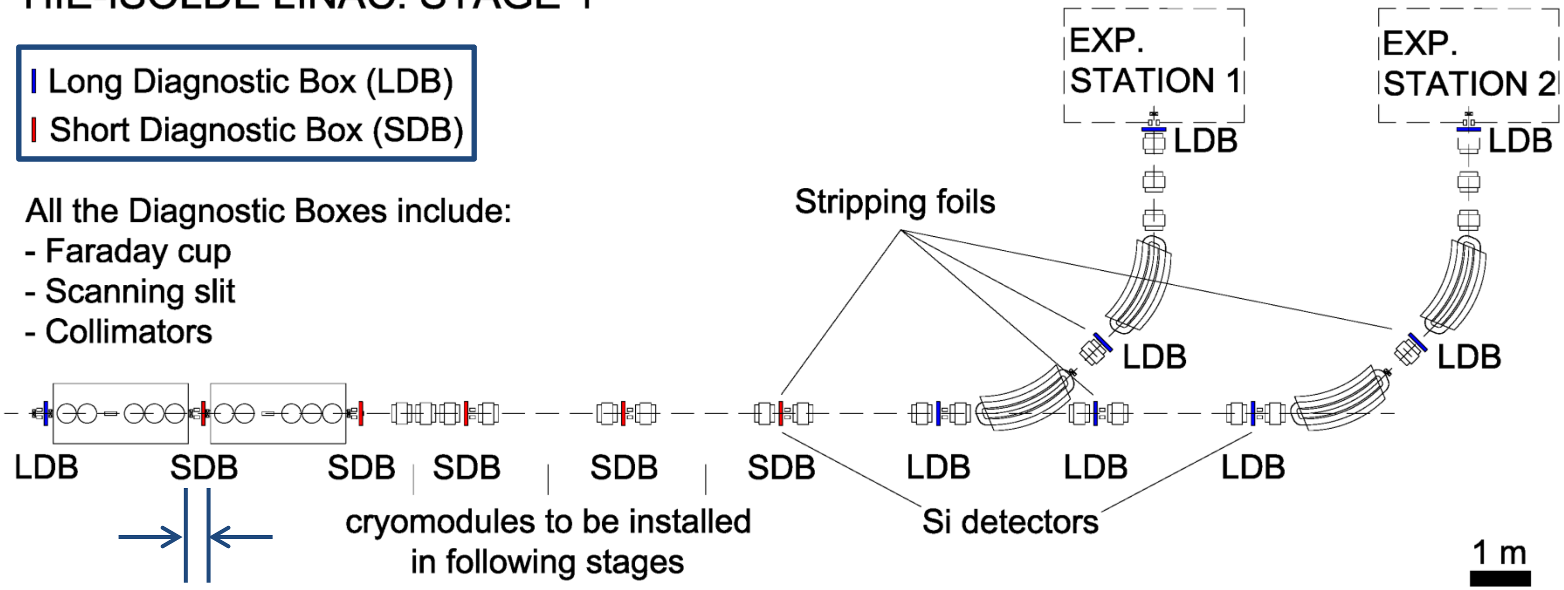
SILICON DETECTOR

[11] NIM A **672**, 21 (2012)
[12] EDMS **1370591**

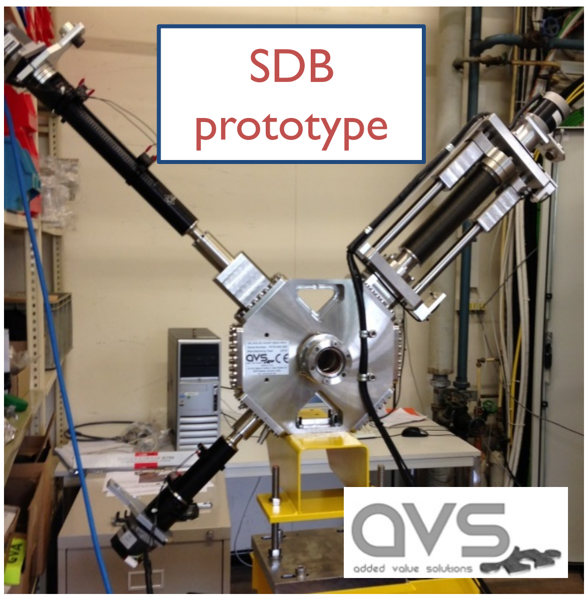
Diagnostic boxes: 8 x long, 5 x short

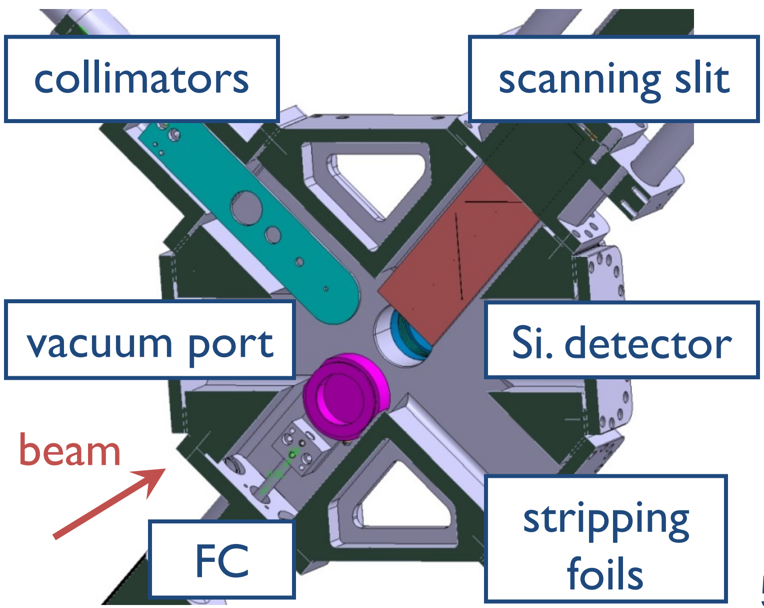
HIE-ISOLDE LINAC: STAGE 1

All the Diagnostic Boxes include:
- Faraday cup
- Scanning slit
- Collimators



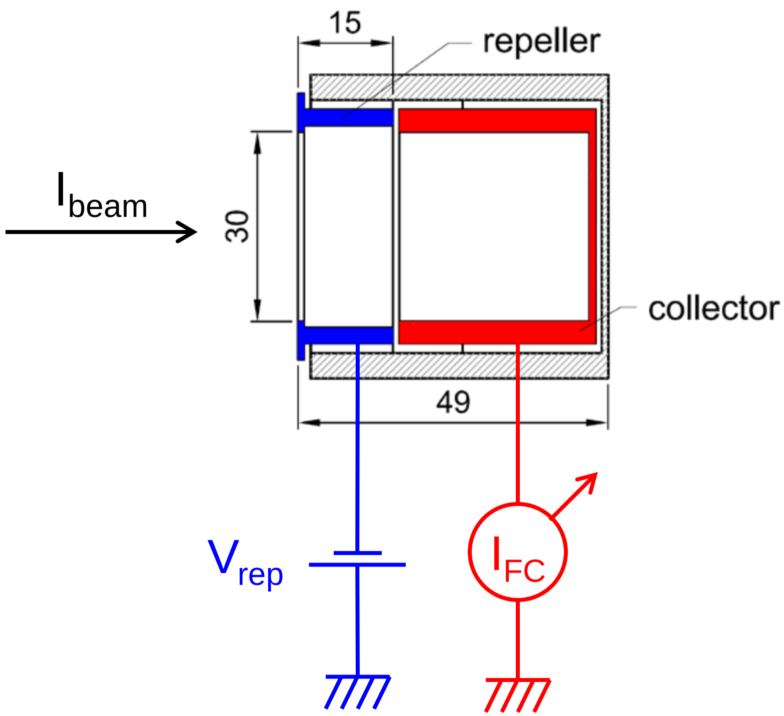
LINAC
tight long. space,
compact design!

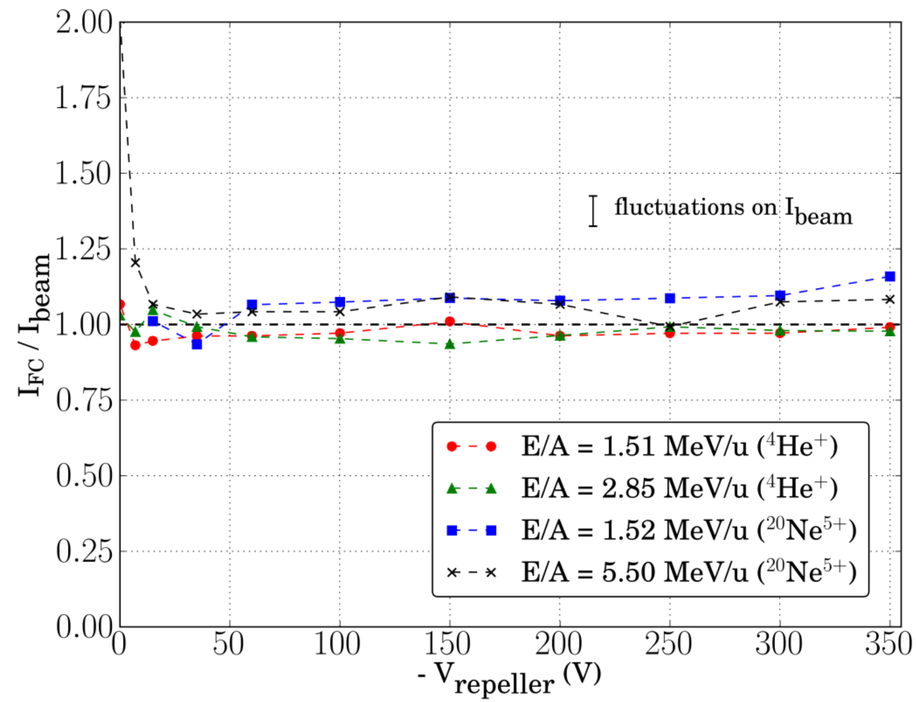


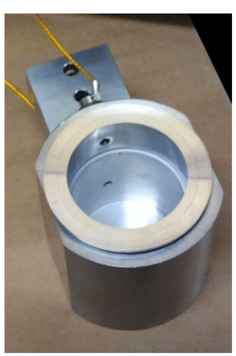


Beam intensity: long Faraday cup

Final design







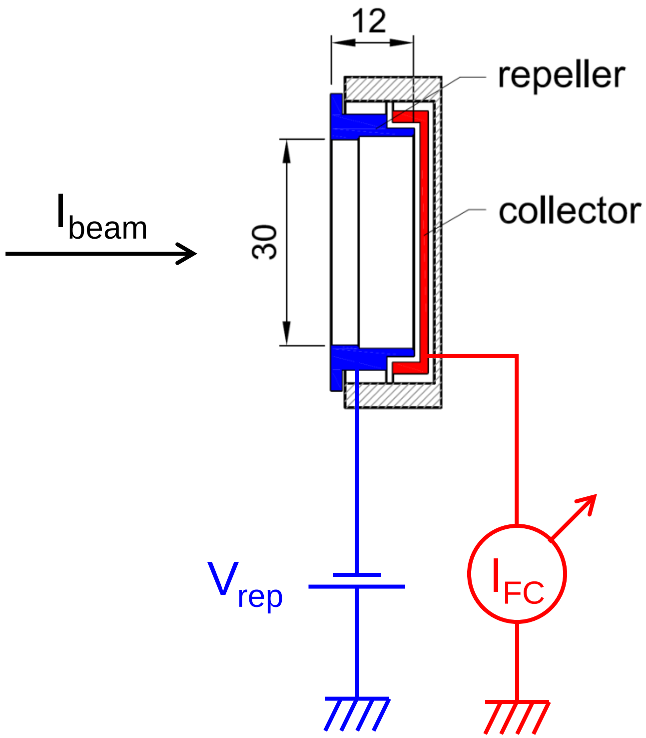
Validation tests
during 2012 & 2013.

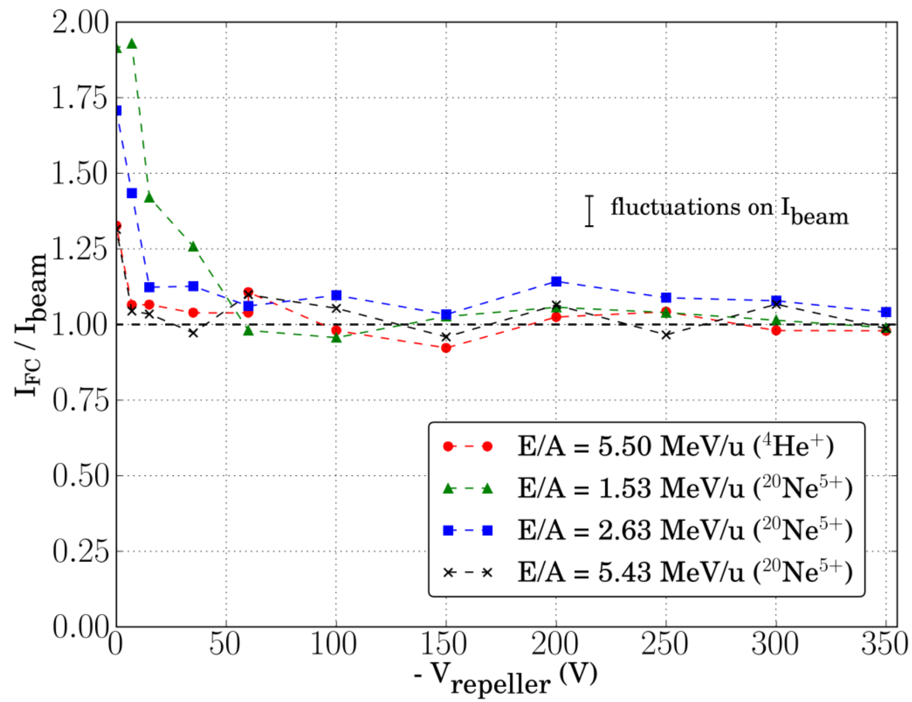
ISOLDE

TRIUMF

Beam intensity: short Faraday cup

Final design





Validation tests
during 2012 & 2013.

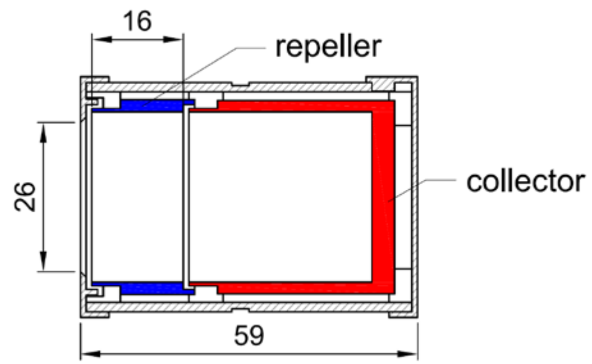
ISOLDE

TRIUMF

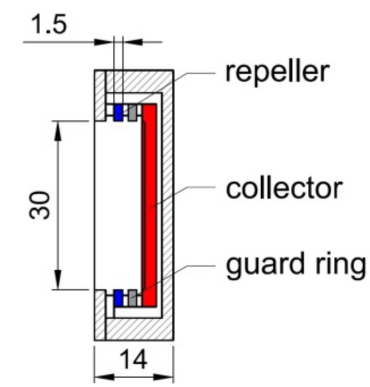
Beam intensity: short Faraday cup

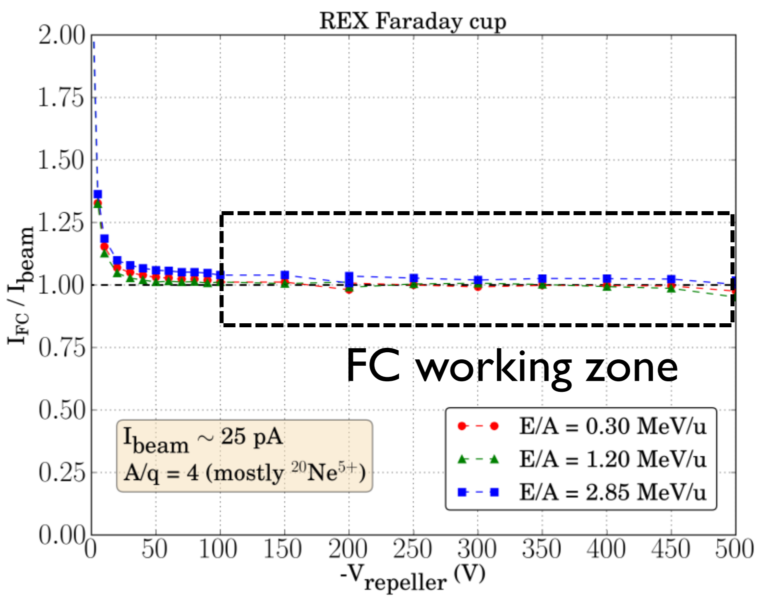
Back in 2012…

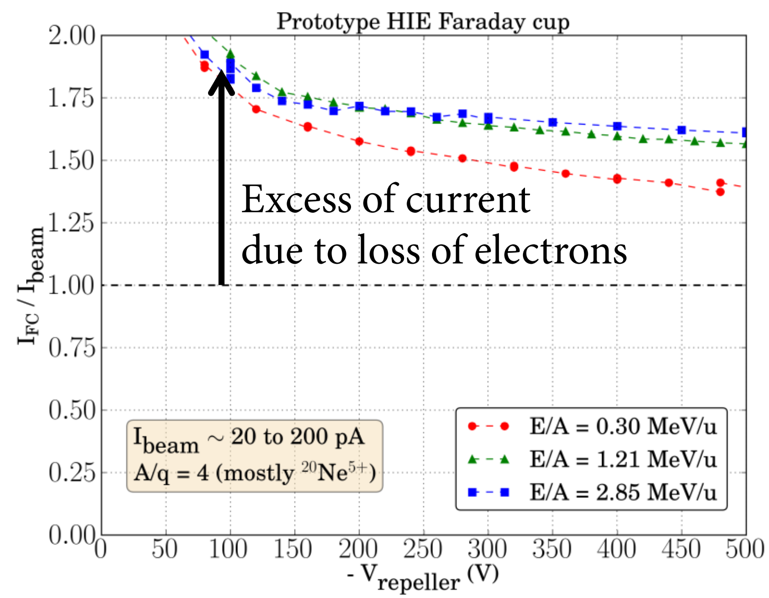
REX Faraday cup



Prototype short FC

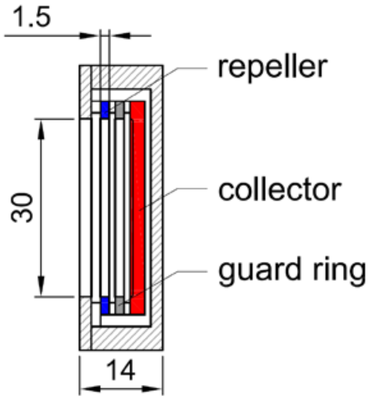






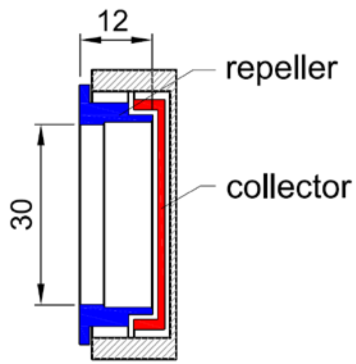
Beam intensity: short Faraday cup

Prototype short FC

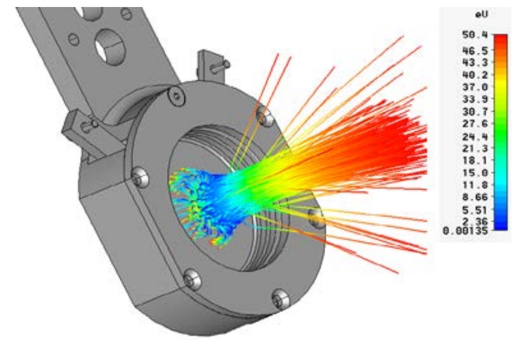


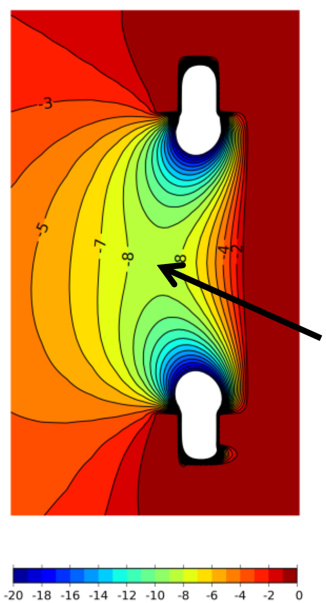
July 2012 to August 2013

Final design short FC



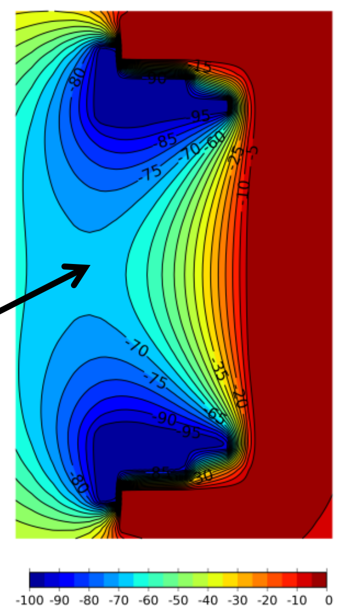
Simulations of electrostatic fields and particle tracking used for optimization of the design.

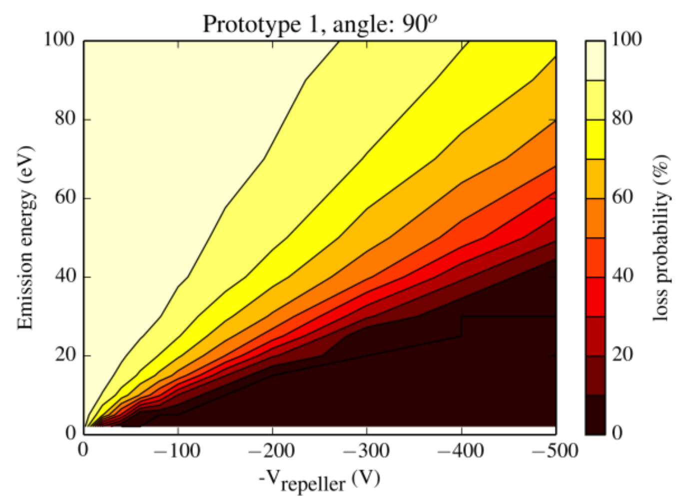




Electrostatic potential (V) for V_{rep} = -100 V

-8.5 V -67 V





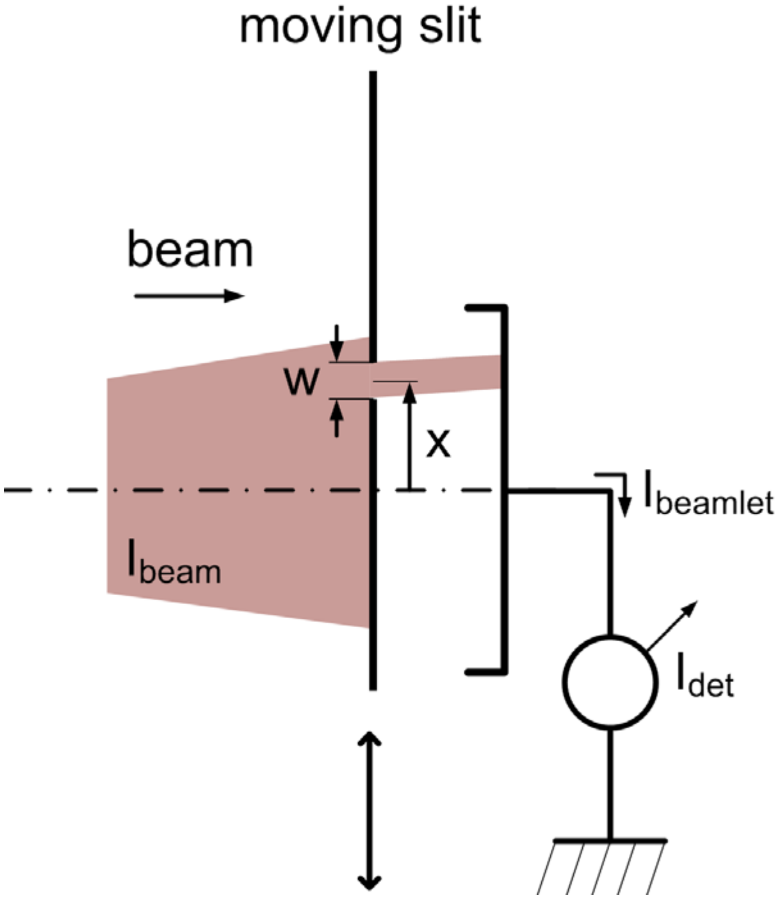
CST

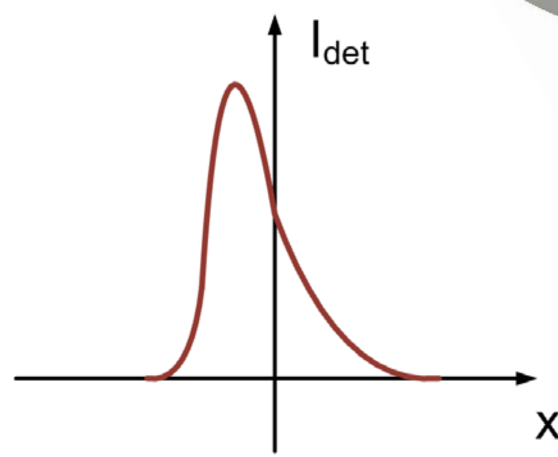
CST PARTICLE STUDIO®

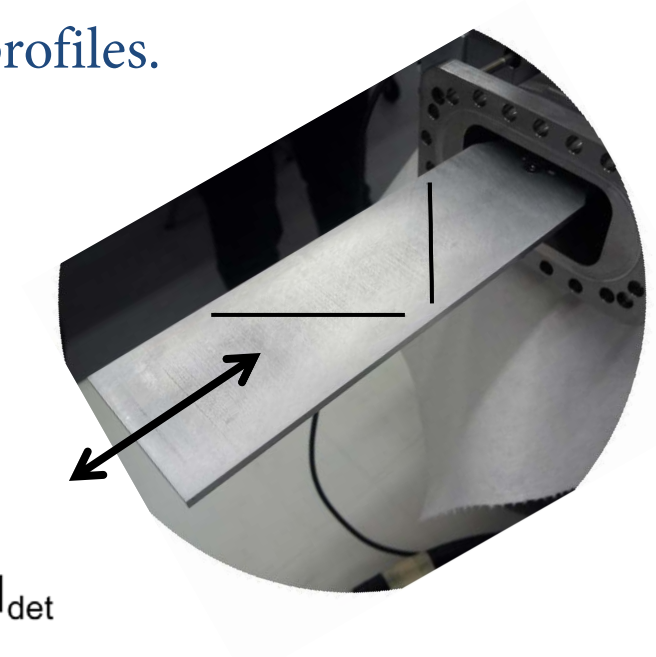
Transverse profile: scanning slit + FC

Horizontal and vertical profiles.

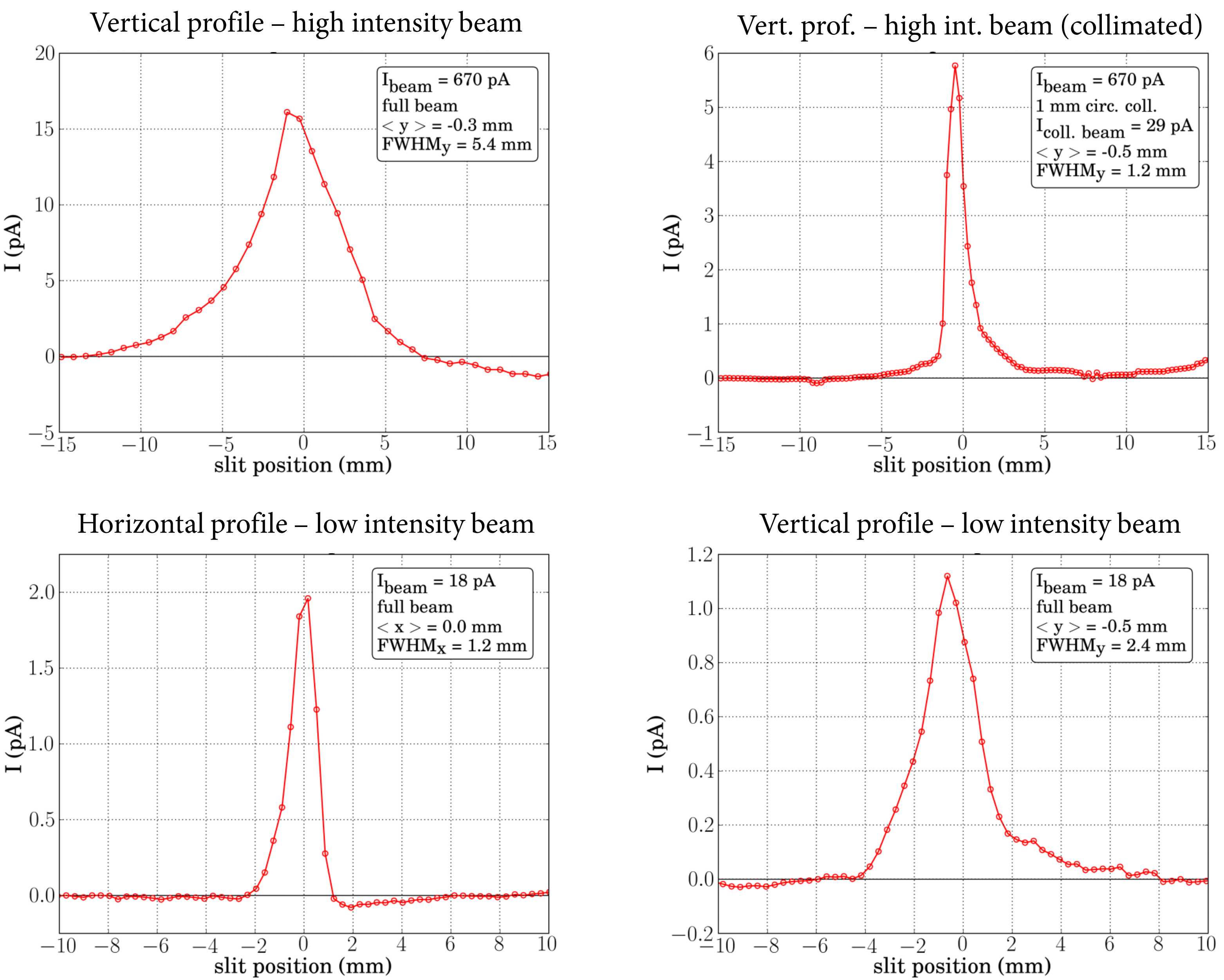
Beam size and position.



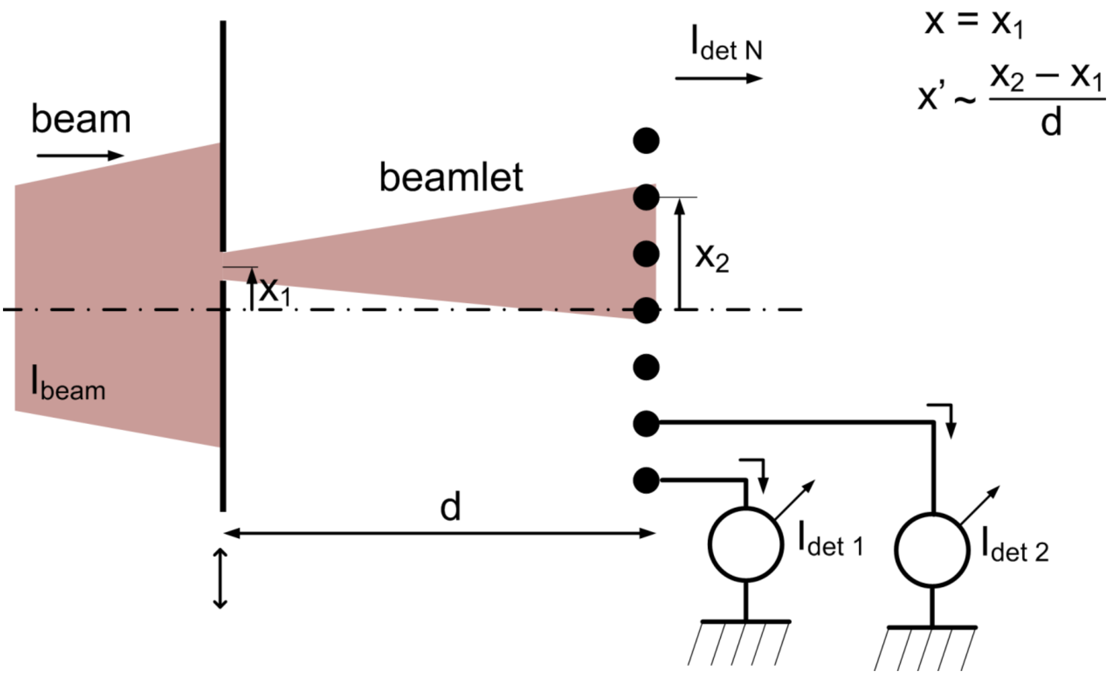


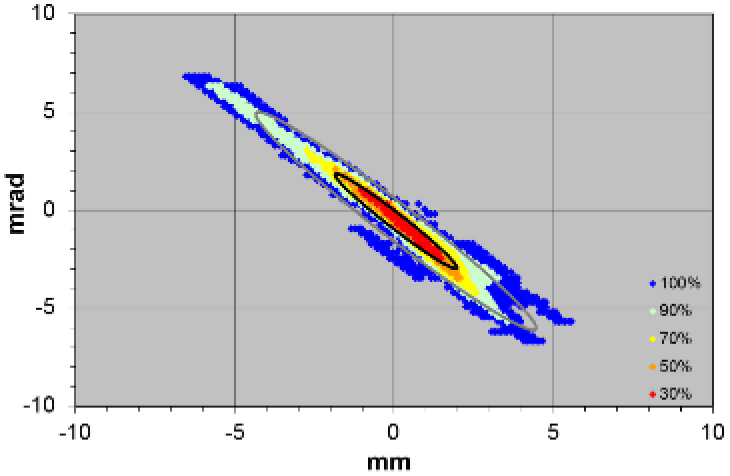


Transverse profile: scanning slit + FC



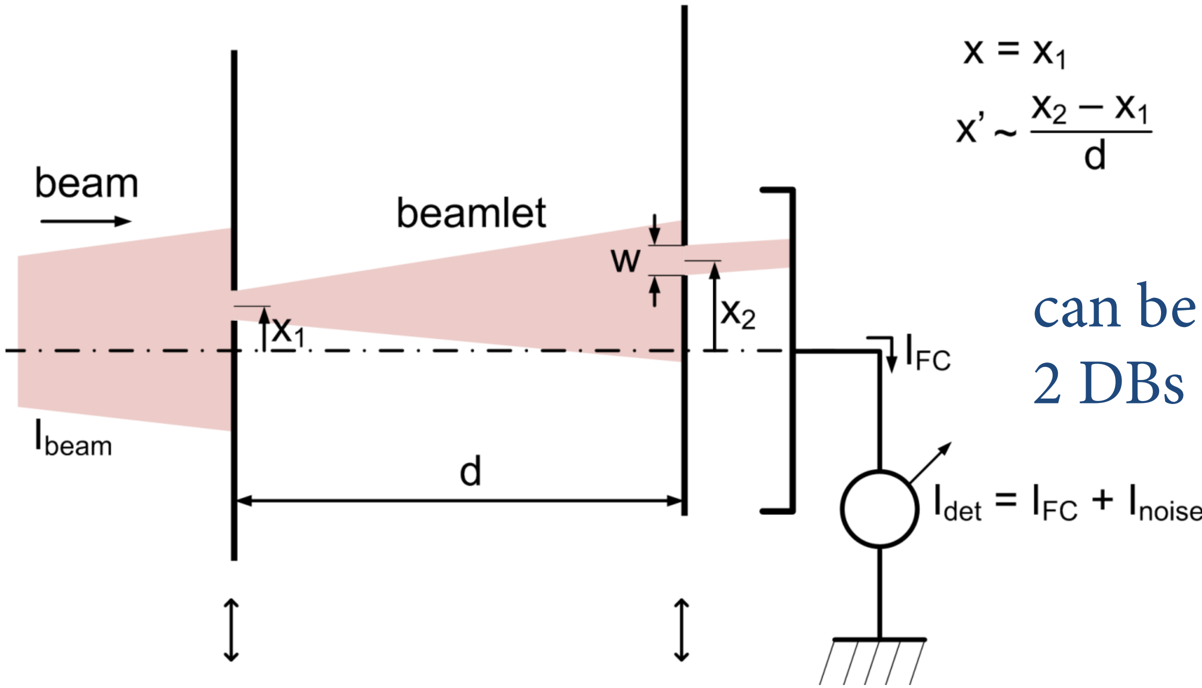
Transverse emittance: slit + grid





Already implemented and working in **REX-ISOLDE** [10].

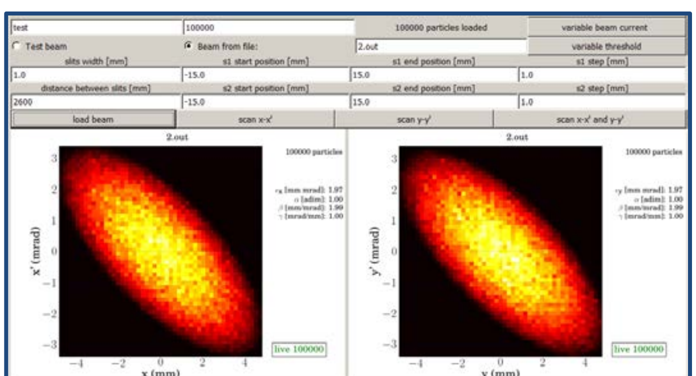
Transverse emittance: 2 slits + FC

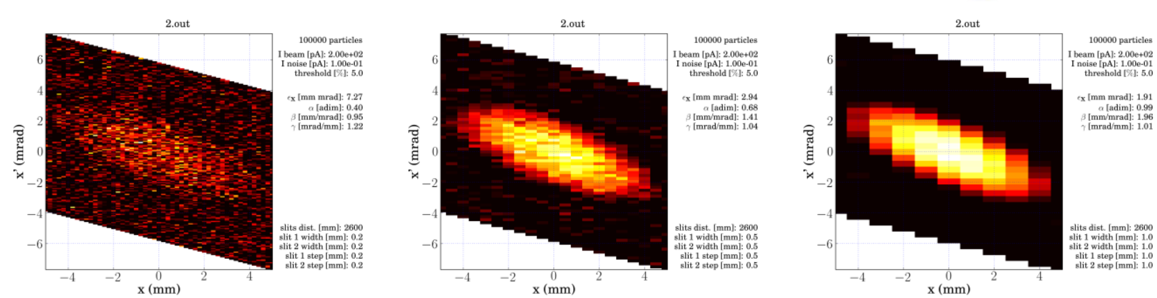


can be implemented with
2 DBs at the HEBT (d = 2.6 m)

MonteCarlo simulation of particles transport

python





optimal slit width w = 1 mm

Longitudinal profile: silicon detector

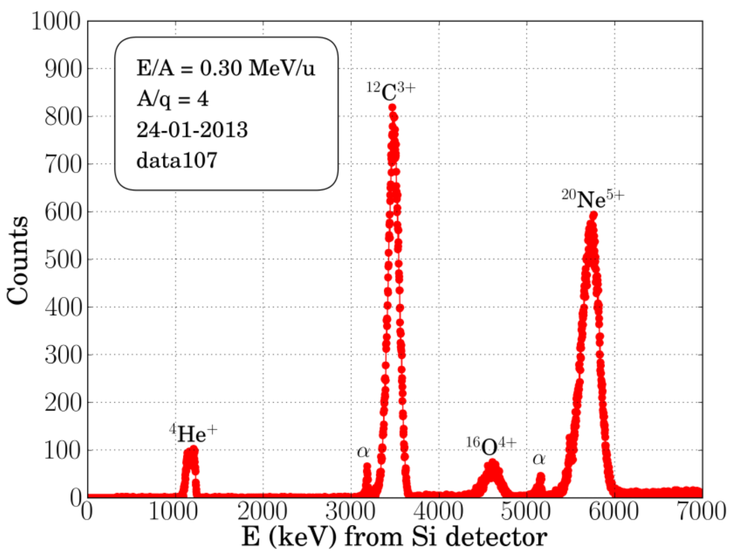
Canberra PIPS
TMPD50-16-300RM

preamplifier

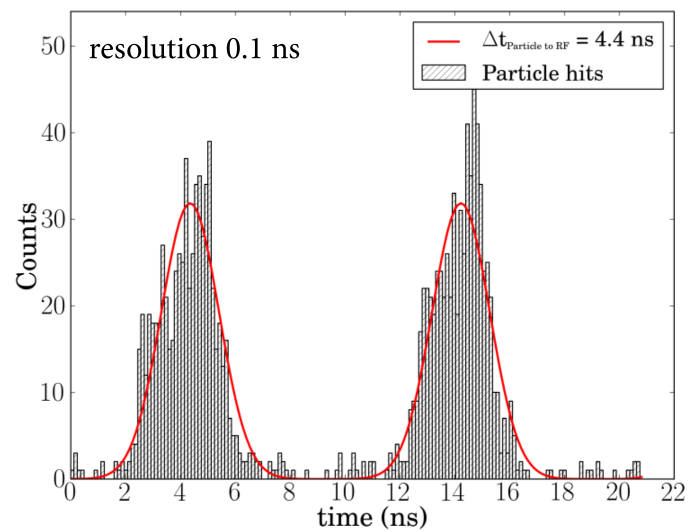
energy chain → charged particles spectroscopy
- total particle energy
- mass composition

timing chain → time of flight
- particle speed
- bunch length

energy spectrum



TOF spectrum



More details: [11] [12]

Important tool for fast tuning of SC cavities.

Electronics and controls

- New VME cards for controlling stepper motors and FC acquisition.
- New charge integrating preamplifier for the FCs.
- Commercial electronics for the Si. Detector.

  - CANBERRA Preamplifier.

  - CAEN Fast ADC + firmware for energy chain.

  - Agilent TDC for timing chain.

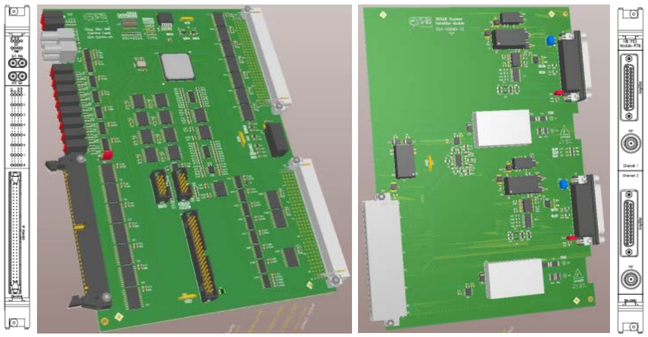
Software

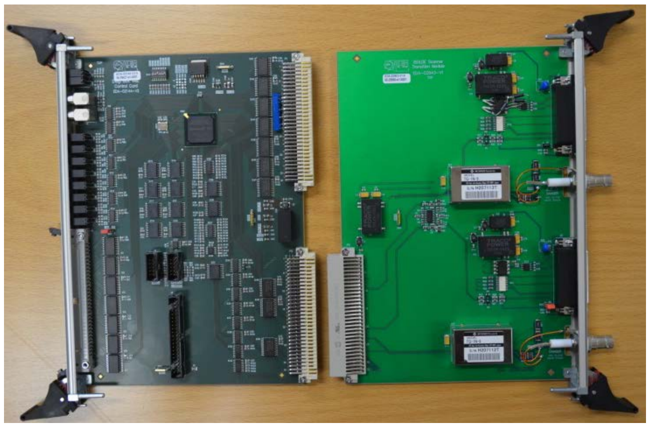
- 2 new main FESA servers, 1 for the DBs and 1 for the Si. detector.

Electronics and controls

VME REX DB Board (EDA-02144-V3-0)

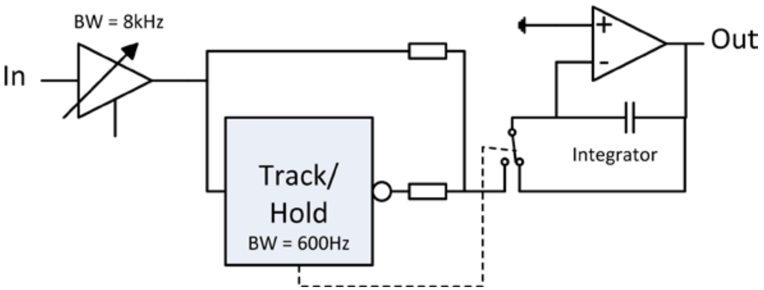
REX Rear Board (EDA-02943-V2-0)

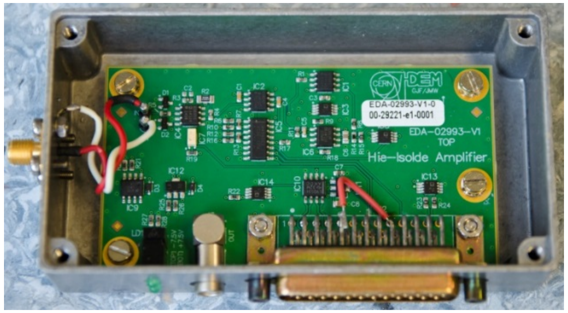




	Available	HIE ISOLDE
Stepping Motor	8	5
ADC	8	1
DAC	12	1
Gain	4	4
IT / Gate	2	2
HV	2	1

HIE-Isolde amplifier (EDA-02993-V1-0)





Development finished.
2x25 VME cards at CERN 'now'.
Test bench & tests before end of 2014.

Status

Short DBs: already at CERN, undergoing final acceptance tests.

Long DBs: will arrive in November.

Commercial electronics: already at CERN.

VME electronic cards: final production is arriving 'now'.

FC preamplifier: design finished, 2nd prototype to be tested soon.

Software: 1st version to be released.

Outlook

Installation of DBs and related equipment is scheduled between November 2014 and May 2015.

Commissioning with beam will start in July 2015.

Physics starts by October 2015, with 1 cryomodule and 2 beam lines for experiments.

Acknowledgements

This presentation includes work and input from many CERN colleagues, in particular William Andreazza, Stephane Bart Pedersen, Enrico Bravin, Stephane Burger, Michel Duraffourg, Martino Ferrari, Gerrit Jan Focker, Matthew Fraser, Davide Lanaia, Alex Sosa, Jean Tassan-Viol, Didier Voulot and Francesca Zocca.

The mechanical design of the short diagnostic box was done in a collaboration between CERN and the Spanish company Added Value Solutions.

Funding from the European Commission under the FP7-PEOPLE-2010-ITN project CATHI (Marie Curie Actions - ITN), grant agreement No. PITN-GA-2010-264330 is acknowledged.

References

[1] **'Exploring the nuclear landscape with HIE-ISOLDE',** *M.J. García Borge*, Indico Event **316392**, (2014).

[2] **'The CATHI project and HIE-ISOLDE',** *Y. Kadi*, Indico Event **316392**, (2014).

[3] **'HIE-ISOLDE installation progress',** *E. Siesling*, Indico Event **316392**, (2014).

[4] **"Functional Specification of the Beam Diagnostic Boxes for HIE-ISOLDE"**, *M. A. Fraser et al*, EDMS **1213401**.

[5] "**The Status of Beam Diagnostics for the HIE-ISOLDE Linac at Cern**", *E. D. Cantero et al*, Proc. IBIC 2014 **WEPF13.**

[6] **"HIE-ISOLDE Faraday cups tested with ion beams at TRIUMF",** *E. D. Cantero et al*, EDMS **1370597**.

[7] **"Optimization of a short Faraday cup for low-energy ions using numerical simulations"**, *A. Sosa et al*, Proc. IBIC 2014 **WEPF07.**

[8] **"Transverse beam profile measurements with slit scanner and Faraday cup at REX-ISOLDE",** *E. D. Cantero et al*, EDMS **1370586**.

[9] **"Acceptance test of the linear motion actuator for the scanning slit of the HIE-ISOLDE short diagnostic boxes",** *E. D. Cantero et al*, EDMS **1370583**.

[10] **"Transverse Emittance Measurements at REX - ISOLDE",** *D. Lanaia et al*, EDMS **127963**.

[11] **"Development of a silicon detector monitor for the HIE-ISOLDE superconducting upgrade of the REX-ISOLDE heavy-ion linac",** *F. Zocca et al*, NIM A **672**, 21 (2012).

[12] **"Energy and time of flight measurements of REX-ISOLDE stable beams using Si detectors",** *E. D. Cantero et al*, EDMS **1370583**.

Backup slides

HIE ISOLDE beam parameters

Projectiles: He to U

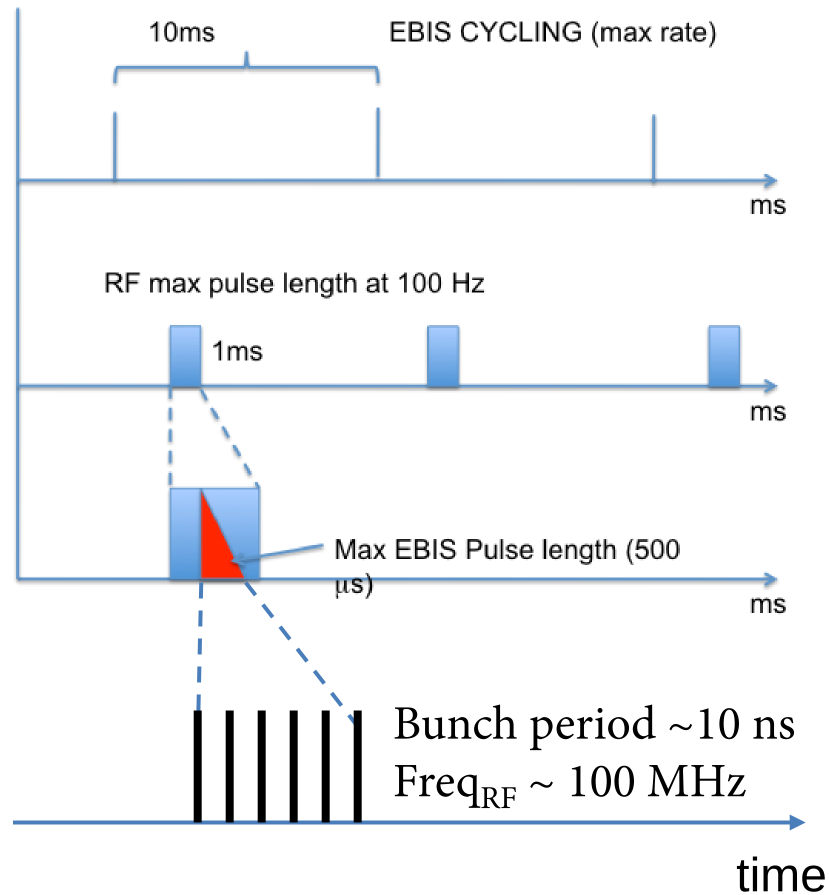
$2 < A / q < 4.5$

$0.3 < E/A < 10$ MeV/u

- RIBs (pps to few pA).
- Stable beam (1 pA to 1 nA).

Normal setup procedures use stable beams, and scale the accelerating and transport stages to the desired A/q.

Repetition rate: 2 to 100 Hz.
Macro pulse length: 50 to 500 μs.
Micro-bunches separated 9.87 ns.



Instruments and devices

Instrument	Qty	Inputs	Outputs	Plane *	Positions	Connected to
Faraday cup	18	V repeller	I signal plate	2	IN – OUT	FC preamplifier + VME board
Scanning slit	18			1	continuous stroke 135 mm	
Si detector	2	HV	particle energy and time of arrival	2	IN – OUT and continuous adjustment	preamplifier + VME-NIM modules
Collimators 1	12			1	4 setpoints and continuous adjustment	
Collimators 2	6			1	4 setpoints and continuous adjustment	
Stripping foils	6			1	3 setpoints and continuous adjustment	

* to avoid collisions, only one device at a time can be inserted on each plane of the DB.

Measurements: procedure

1) **Beam intensity:** Faraday cup (+ collimators).
   - Used every day for setting up the accelerator and aligning and transporting the beam.
2) **Beam transverse profiles (and position):** Scanning slit + FC.
   - Horizontal and vertical profiles.
   - Expected ~1000 scans per year for each box.
3) **Beam longitudinal profile:** Silicon detectors.
   - Energy and time spectra.
   - To obtain the time of flight, the spectra with the arrival time to both detectors needs to be combined (measurements might take place in parallel if we use an annular Si detector).
   - Energy spectra might be acquired during the cavities phasing (daily/weekly). TOF spectra will be used to provide a calibration point for E/A of the bending magnet (~twice a year).
4) **Transverse emittance:** 2 scanning slits + FC (or REX slit + grid emittancemeter).
   - Once a year.
5) **Beam cleaning:** collimators or stripping foils.