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COMMISSIONING OF THE ECR ION SOURCE OF THE HIGH INTENSITY PROTON INJECTOR OF THE FACILITY FOR ANTI PROTON AND ION RESEARCH (FAIR) AT CEA-SACLAY

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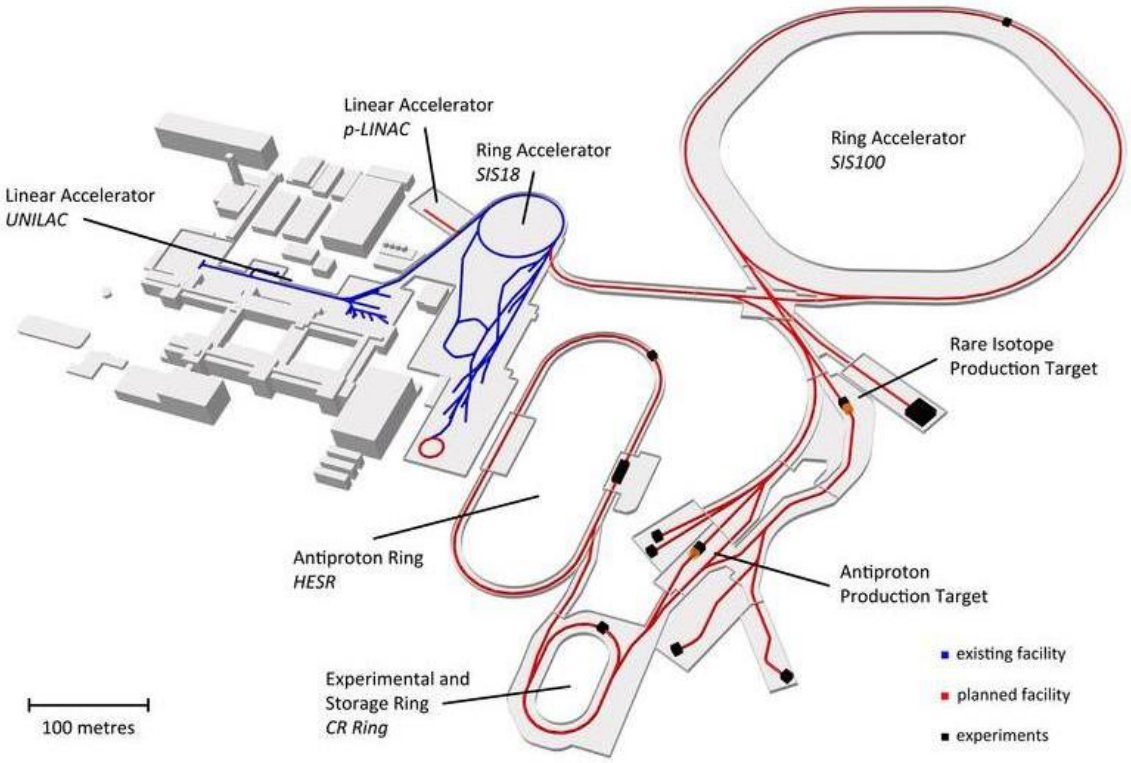
FAIR Facility for Antiproton and Ion Research in Europe GmbH

SUMMARY

- Introduction of the FAIR project
  - Project requirements
  - Beam simulations and Ion Source design
  - Planned commissioning steps
- Diagnostics for Beam characterization at Saclay
  - ACCT
  - Wien Filter and Doppler Shift measurements
  - Allison Scanner
- Some very preliminary Results
- Conclusions

FAIR AT GSI

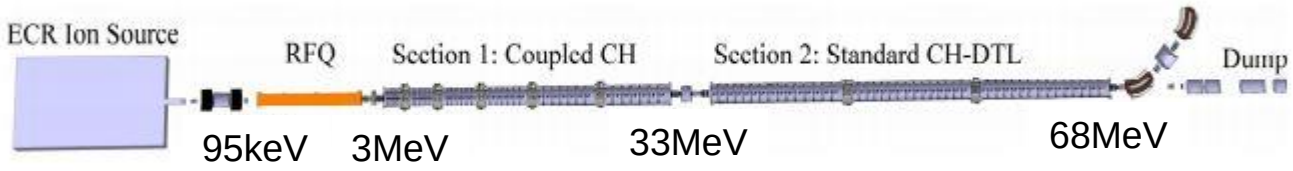
Facility for Antiproton and Ion Research in Europe GmbH



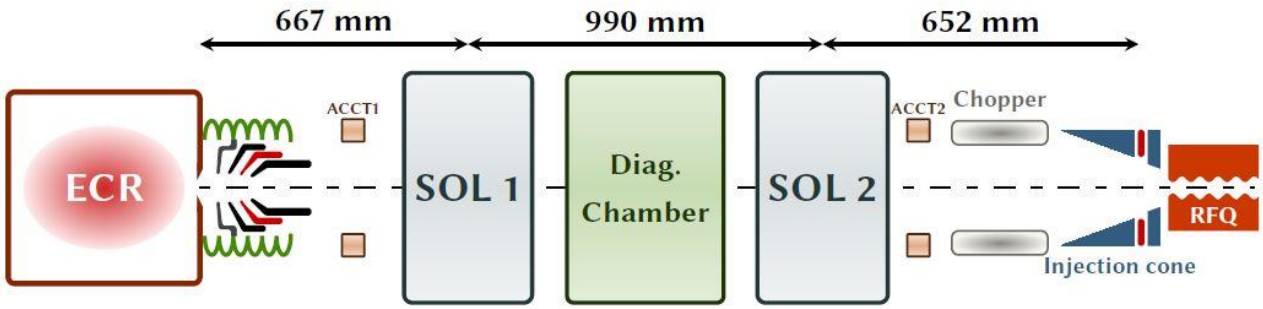
The FAIR complex

Facility for
Antiproton and
Ion
Research

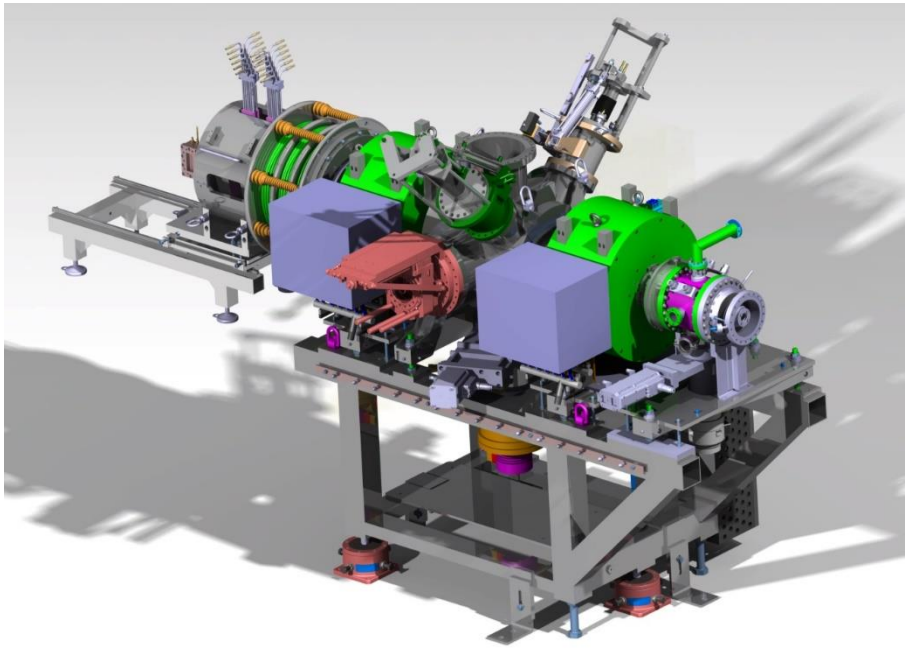
RFQ	3 MeV, 90 mA, ε_{norm}=2 µm
DTL	3 CCH+ 3 CH-DTL, 70 MeV
Frequency [MHz]	325.224
Current [mA]	70 (design), ≥ 35 (operation)
Emittance (µm]	≤ 2.8
Mom. Spread [‰]	≤ 1
RF Pulse [µs]	70
Max Beam Pulse[µs]	36
Repetition Rate [Hz]	4
Duty Factor [%]	0.1
Total Length [m]	~ 30



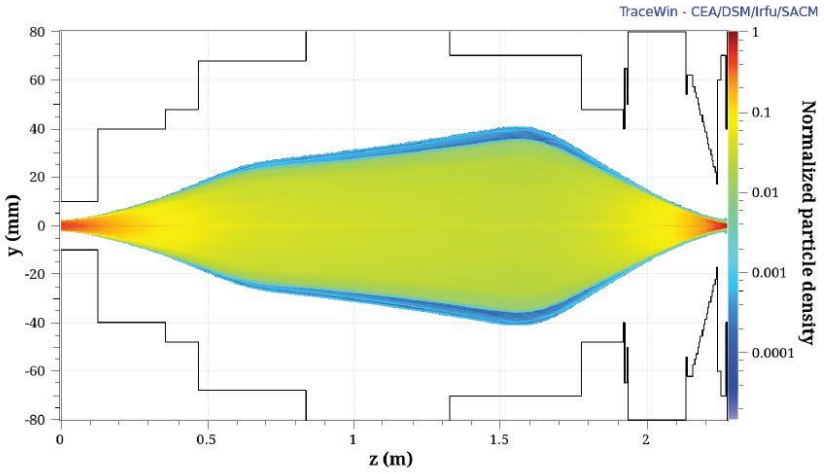
PLANNED P-LINAC AT GSI / INJECTOR AT SACLAY

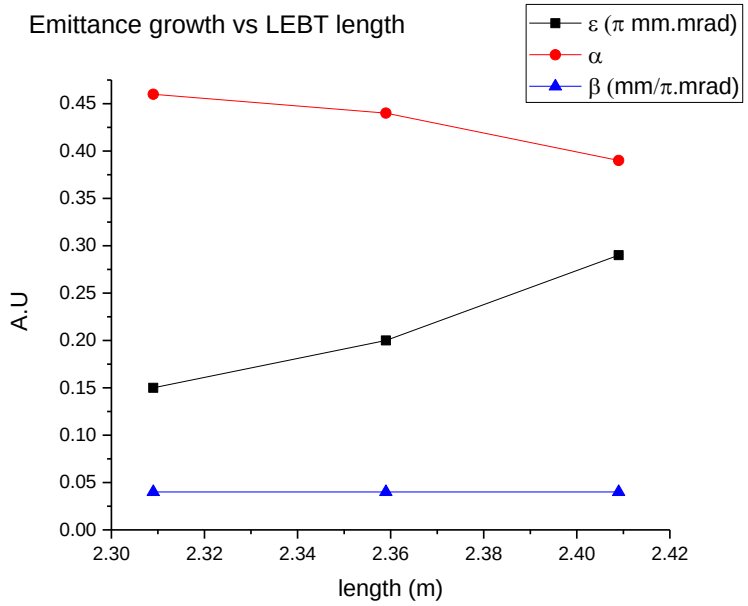


Parameter	Value
Particule	H^+
Mode	Pulsed mode (frequency: 4Hz)
Beam Intensity	100 mA
Energy Spread	60 eV
Emittance	$\leqslant 0.33\ \pi$ mm.mrad
Twiss Parameters	
	$0.27 \leqslant \alpha \leqslant 0.59$
	$0.037 \leqslant \beta \leqslant 0.046$ mm/π.mrad



BEAM SIMULATION



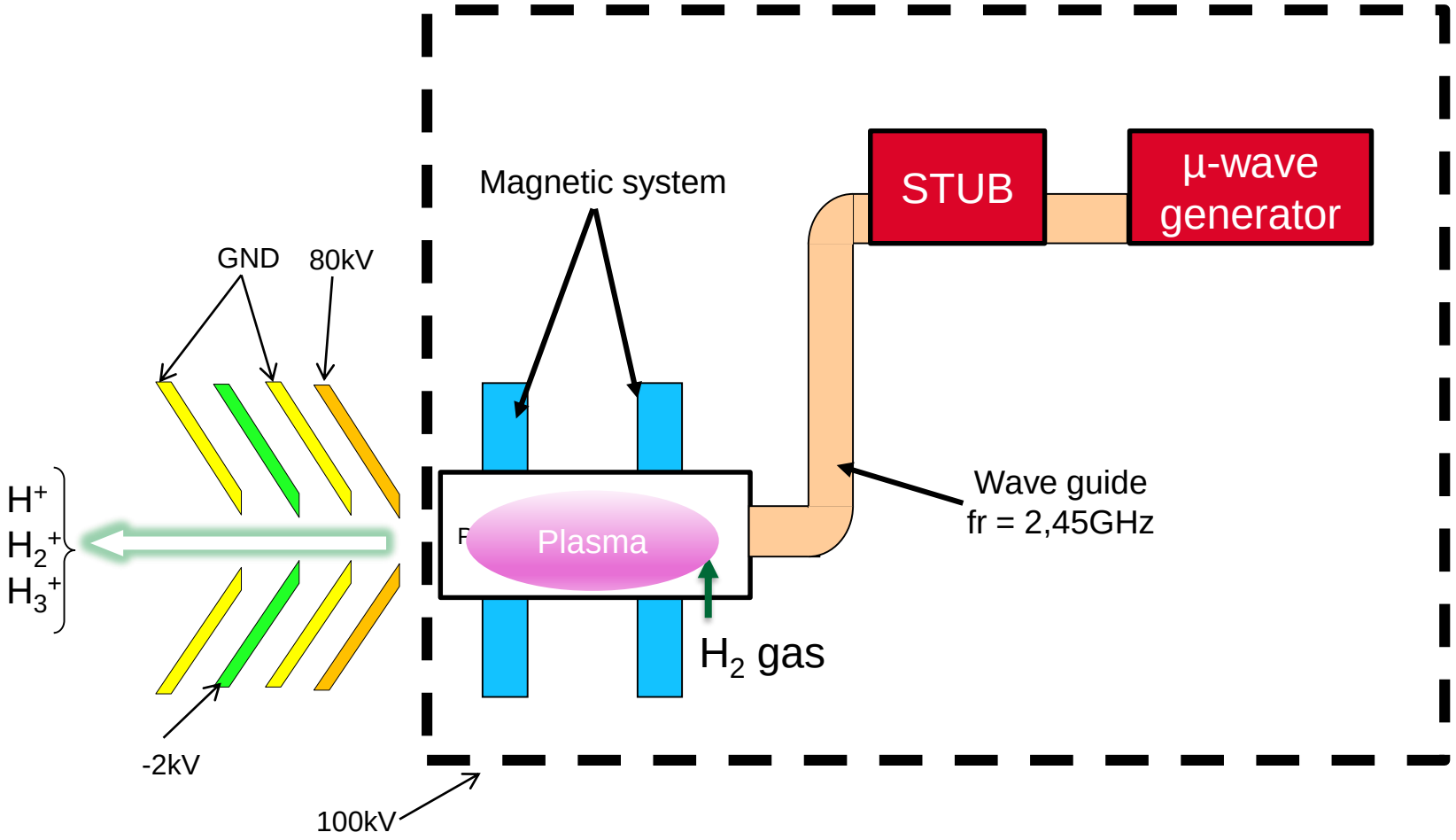


Early days
Beam Simulations :

- The beam dynamics simulations have been performed with TraceWin,
- the Space Charge Compensation degree is considered constant in all the beam line
- SCC value has been set to 80%.

- the emittance value is reduced as the LEBT is shorter

ECR ION SOURCE
FOR HIGH INTENSITY PROTON PRODUCTION



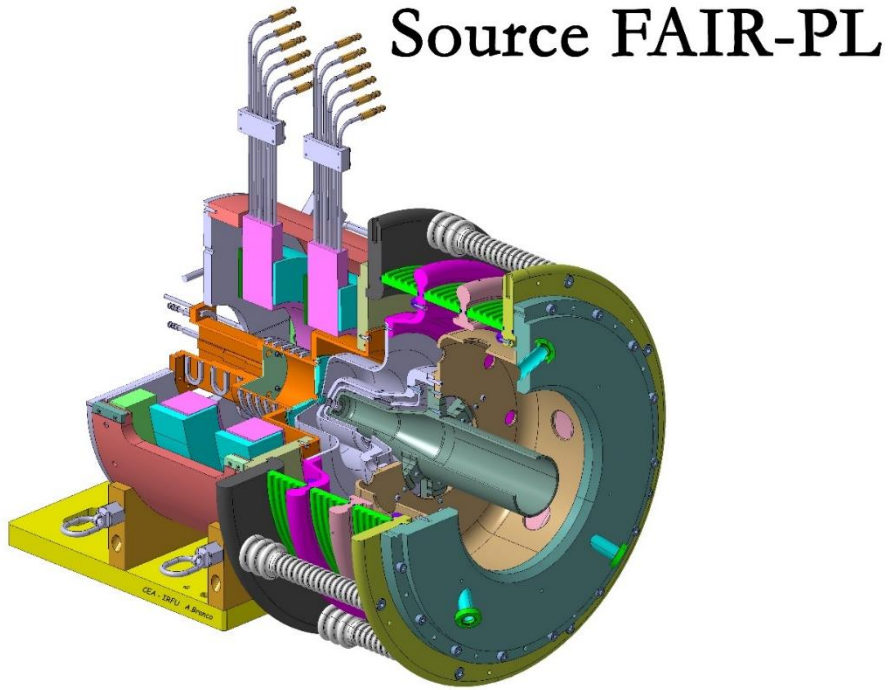
Electron in a magnetic flield

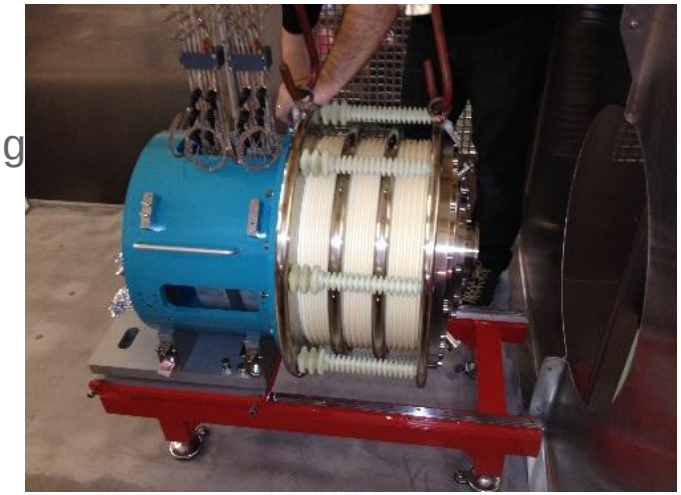
$\omega(\text{electron}) = e\,B / m = \omega(\mu\text{-wave})$ ➔ Brez = 87,5 mT @ 2,45GHz

ION SOURCE FAIR

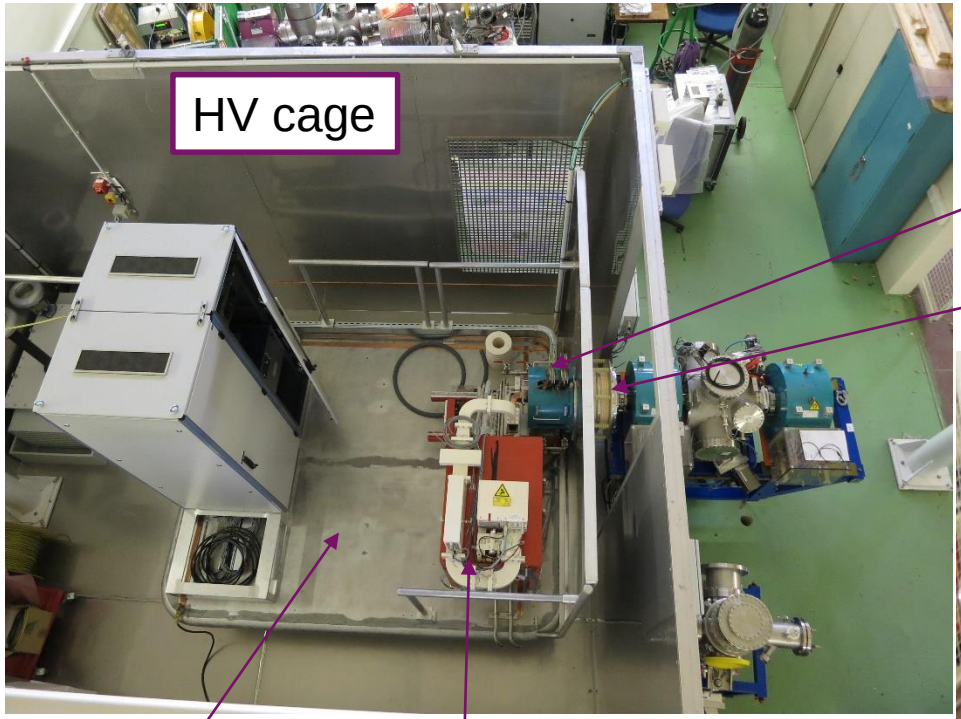
Based on the SILHI source design

- Pentode electrode extraction system
- 2 magnetic Coils
- Plasma Chamber : 100mm long, ∅90mm
- ∅9mm extraction hole
- Mass flow injection system
- SAIREM Pulsed Magnetron 2,45GHz, optical fiber timing control
- SAIREM 4 stub µ-wave Tunning System





INJECTOR @ SACLAY

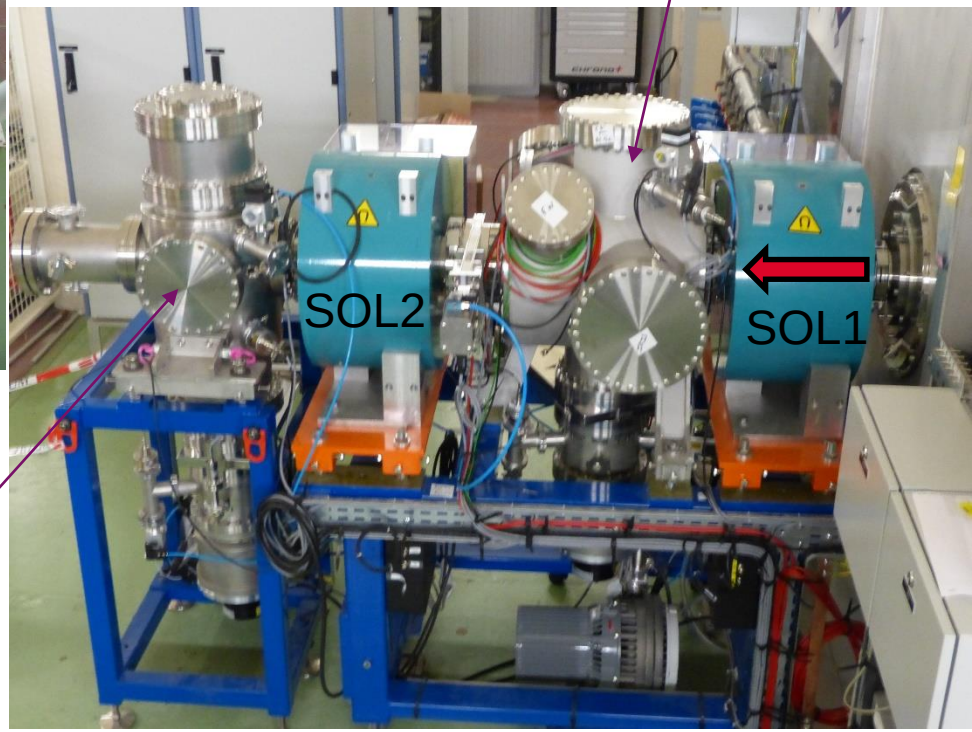


Ion Source

Accelerating column

Diagnostic chamber #1

Diagnostic chamber #2

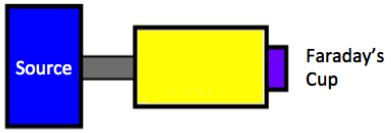


COMMISSIONING STEPS FOR THE IONS SOURCE AND LEBT

Commissioning in 3 steps

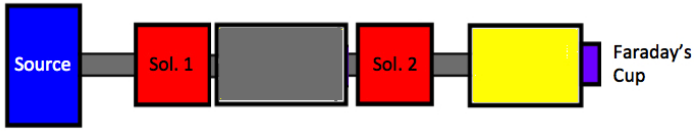
1 : Installation and commissioning of the source :

- Measure of the source total output current of the source with the Faraday cup and ACCT
- Ions species fraction measurement with Wien Filter.
- Emittance measurement at the exit of the source with Allison Scanner



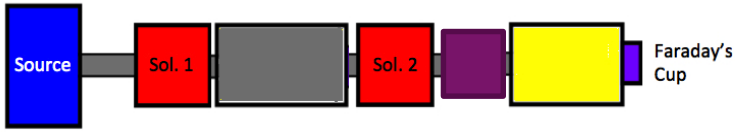
2 : Installation of the LEBT and diag BOX 2:

- Current and transmission measurements in the LEBT with the Faraday cup and ACCT as function of the solenoid setting.
- Twiss parameters measurement at the RFQ entrance as function of the solenoid setting and the iris aperture.



3 : Installation of the iris and the LEBT chopper :

- Installation of the GSI diagnostics : IRIS, Beam Profiler
- Test of the chopper.
- Ions species fraction measurement at the RFQ entrance.
- Twiss parameters measurement at the RFQ entrance as function of the solenoid setting and the iris aperture.
- Effect of the chopper rise time on the space charge compensation



Part II

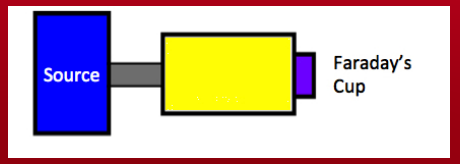
DIAGNOSTICS

ACCT :
CURRENT MEASUREMENT

FDW :
WIEN FILTER, VELOCITY FILTER

EMU :
EMITTANCE MEASUREMENT UNIT

DIAGNOSTICS FOR PRELIMINARY RESULTS IN PHASE #1 WITH APERTURE HOLE ∅6MM

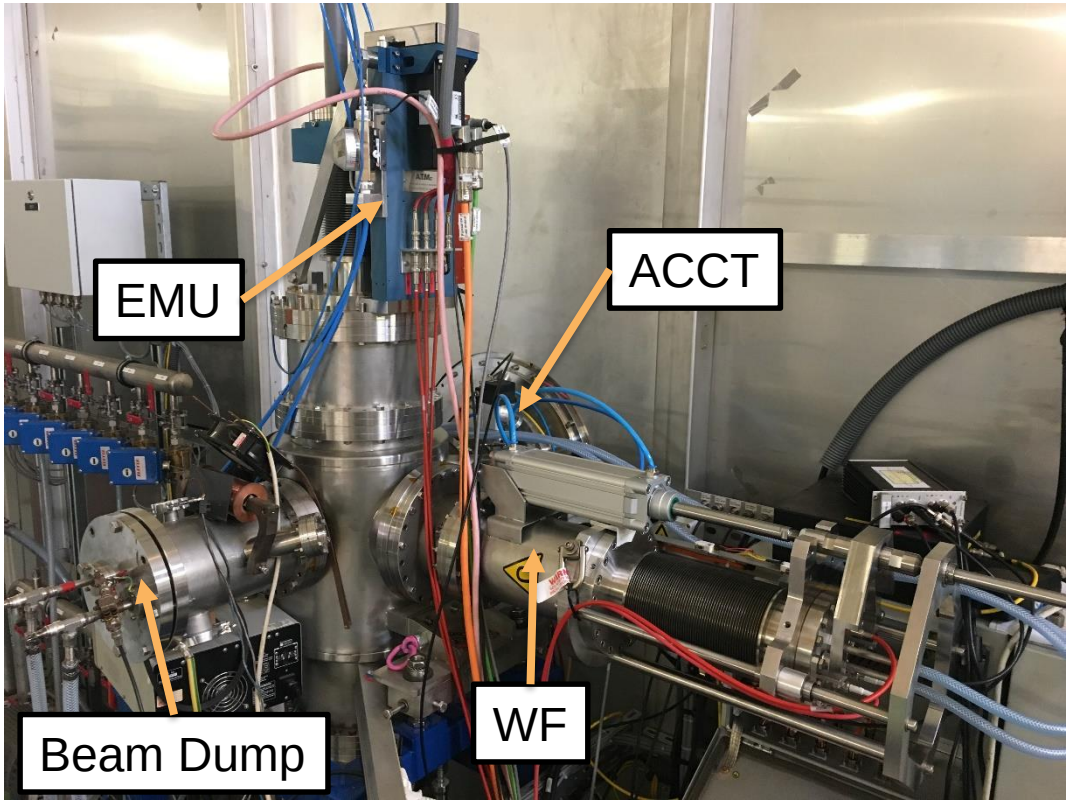


Beam characteristic at source exit

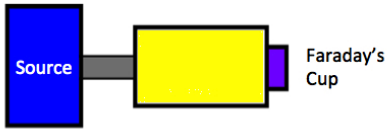
- Total Current
- Proportion measurement
- Emittance value

Beam Parameters to adjust

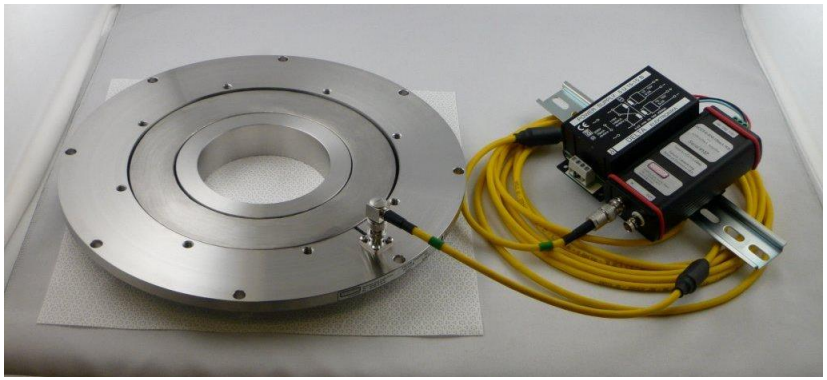
- Source Magnetic field
- H_2 Gas flux injection
- Microwave power & stub tuning
- Pulse length and repetition rate



DIAGNOSTIC #1/3 : BERGOZ CURRENT TRANSFORMER



bergoz INSTRUMENTATION



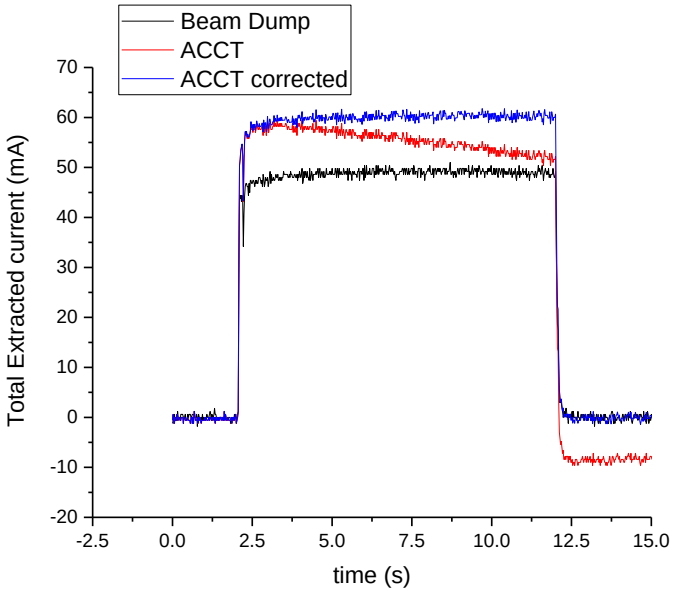
Localization

- One is installed after the Accelerating Column
- Second one will be after 2nd Solenoid
- Specific Magnetic shielding

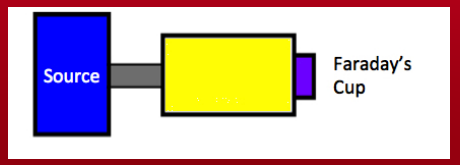
First Test on SILHI LEBT (IPHI Accelerator)

- ACCT was tested on the SILHI LEBT,
- We removed the iron shielding of solenoid to increase fringe field

Voltage drop software-corrected ➔

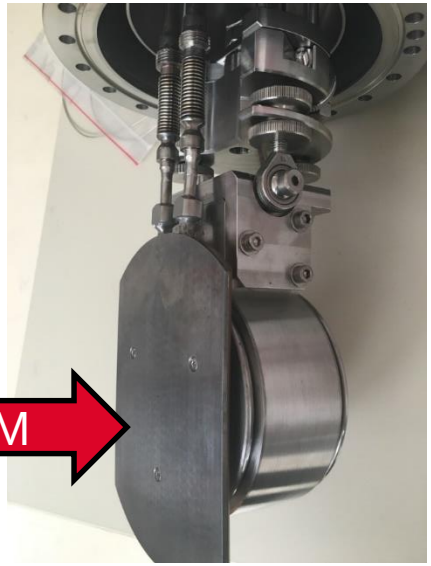


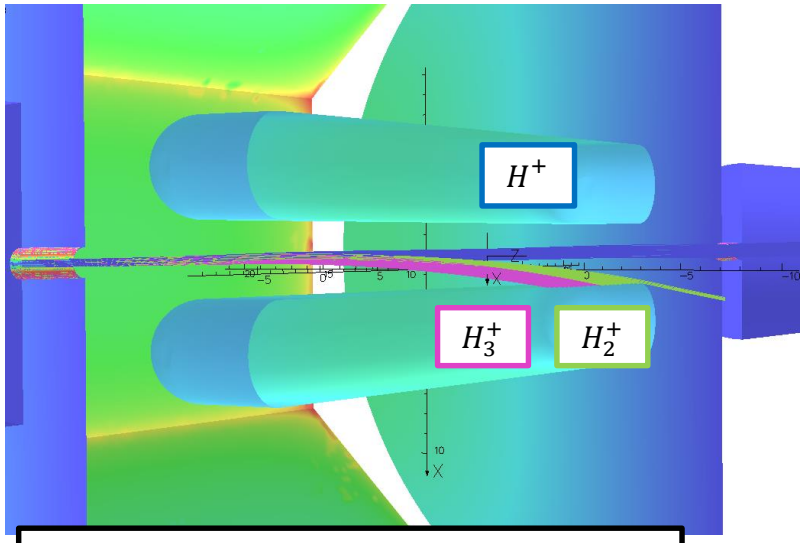
DIAGNOSTIC #2/3 : PROPORTION MEASUREMENTS



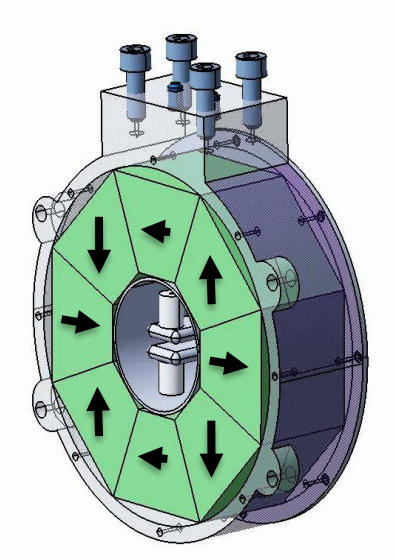
Wien Filter : velocity filter

- $\overrightarrow{Ex} \perp \overrightarrow{By}$
- $\overrightarrow{B}$: 8 magnets in Halbach configuration
- $\overrightarrow{E}$: Electric deviation with biased parallel plates
- Aperture hole ∅200µm in the water cooled W-Cu Beam stopper
- Front end acquisition with low noise and variable gain
- Time-resolved acquisition under Labview Real Time

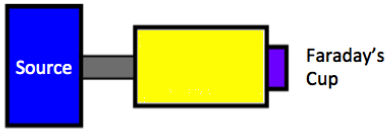




Opera simultation for proton selection

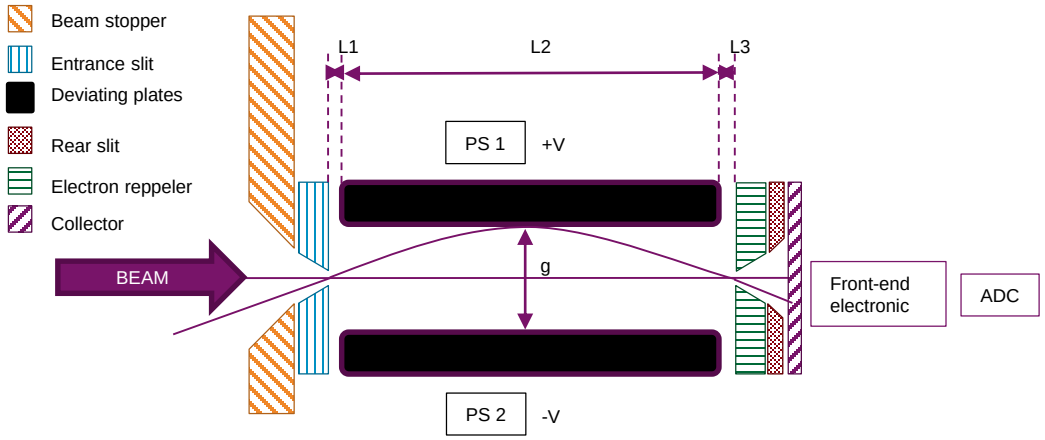


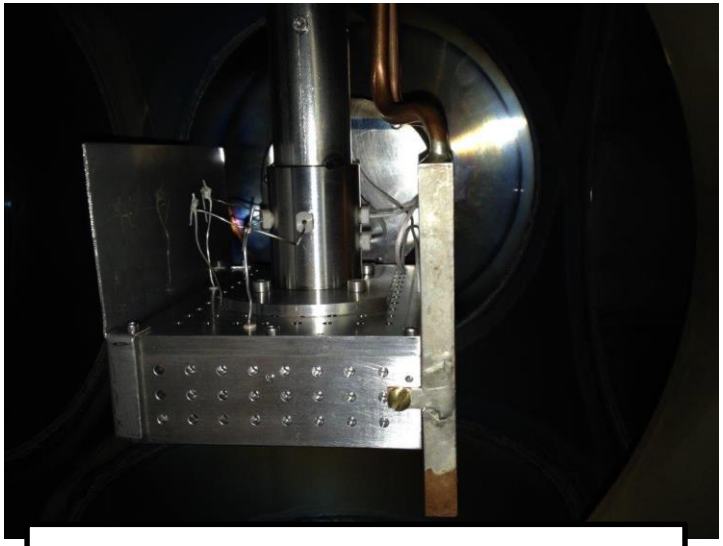
DIAGNOSTIC #3/3 : EMITTANCE MEASUREMENT UNIT



Allison Scanner

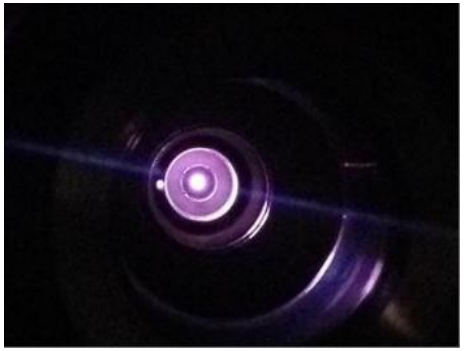
- Collaboration with IPHC Strasbourg
- Copper beam-stopper for 400W CW equivalent beam
- Entrance slit 110µm
- Electric deviation with 2 biased parallel plates
- Front end acquisition with low noise and variable gain
- Not time-resolved, acquisition time fixed at 2ms
- Labview FPGA control system





Shielding was added in 2017

Part III
Preliminary results, a short history



FIRST PLASMA NOV 2015

FIRST BEAM 2016

ONLY ACCT WAS AVAILABLE

CONTROL SYSTEM WAS NOT READY

LOCAL C&C WAS DEVELOPED IN LABVIEW

2016 : EMU DELIVERED AND INSTALLED

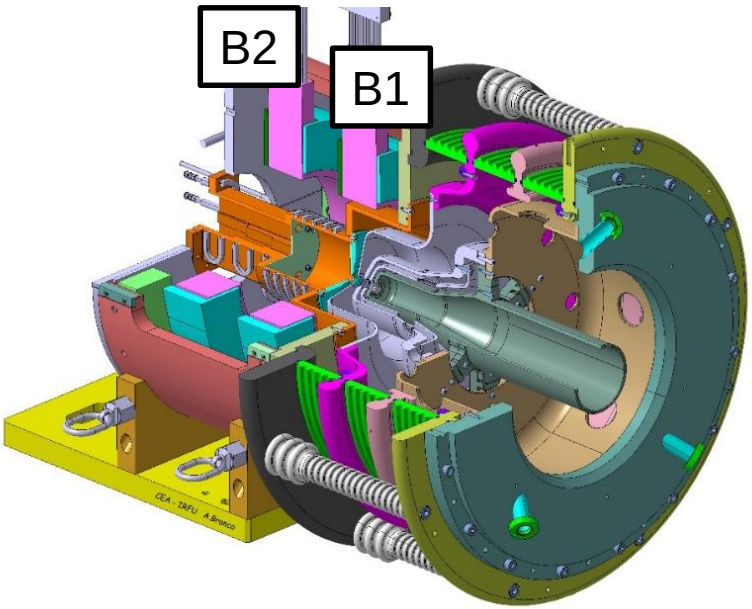
BUT NEED TO BE SHIELDED, …

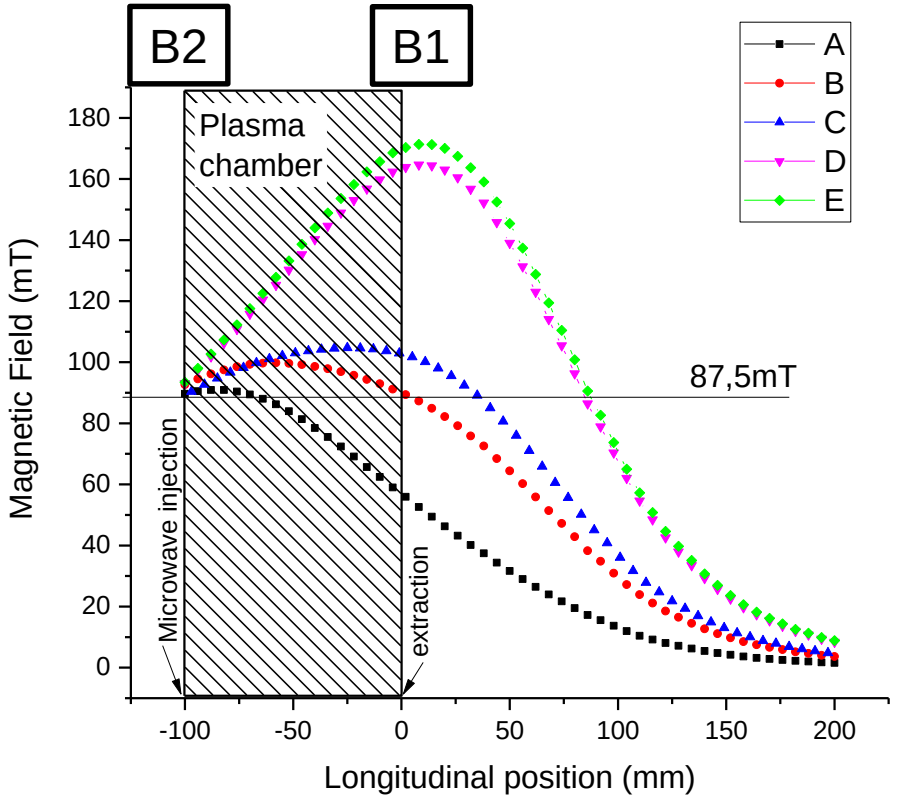
… AND REPAIRED ➔ 2017

2017 : WIEN FILTER AVAILABLE, STILL UNDER DEBBUGGING

MAGNETIC CONFIGURATIONS

Magnetic Configuration	B1 (A)	B2 (A)
A : Single coil magnetic configuration	0	113
B : Intermediate	50	91
C : SILHI source type of configuration	76	74
D : ALISES ion source type	170	38
E : ALISES ion source type	180	30

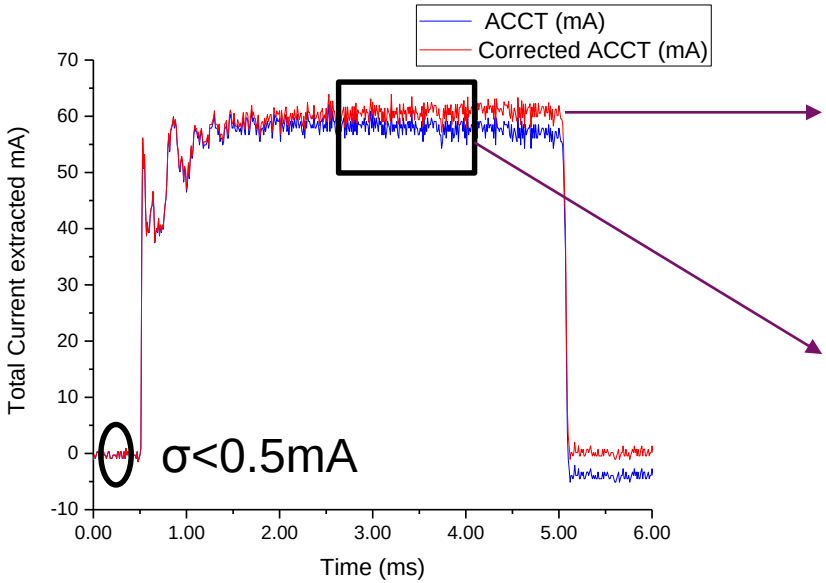


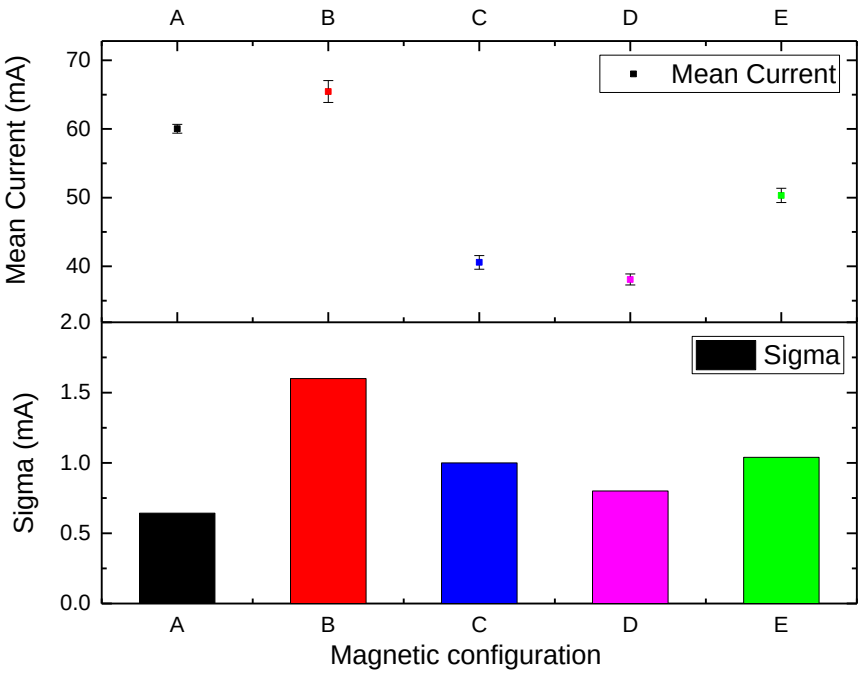


1/3 : ACCT RESULTS

What defines a “GOOD” source tuning point ?

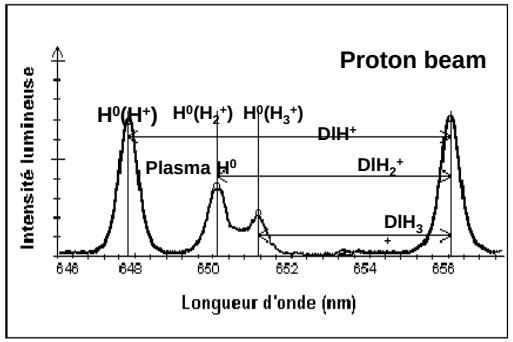
- Repeatable pulse shape in time
- Plateau reached before 2 ms
- Low ripple amplitude on the plateau
- Best total extracted current





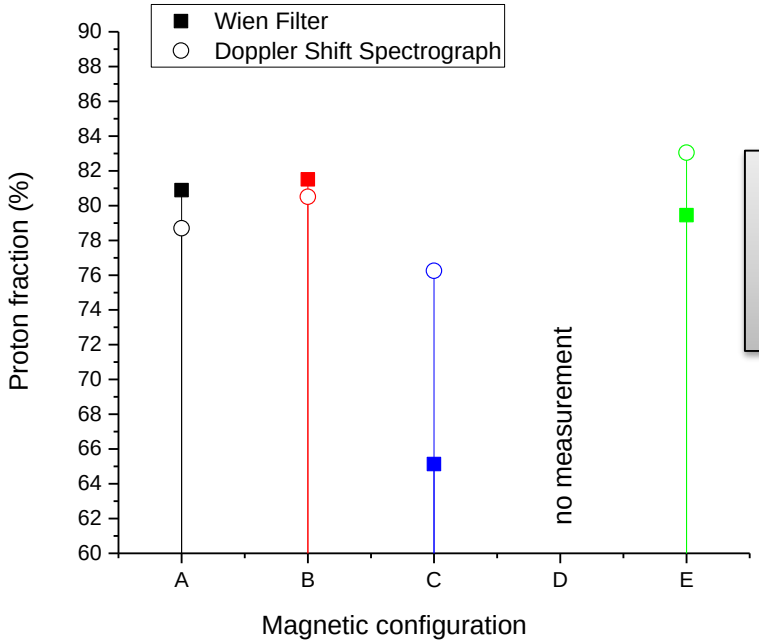
☺ Ripple amplitude is a good parameter to check the quality of the source tuning
☹ For some magnetic configurations, the mean extracted current is low for a good tuning!

2/3 : WIEN FILTER
COMPARISON WITH DOPPLER SHIFT MEASUREMENT



Doppler Shift Spectrometer

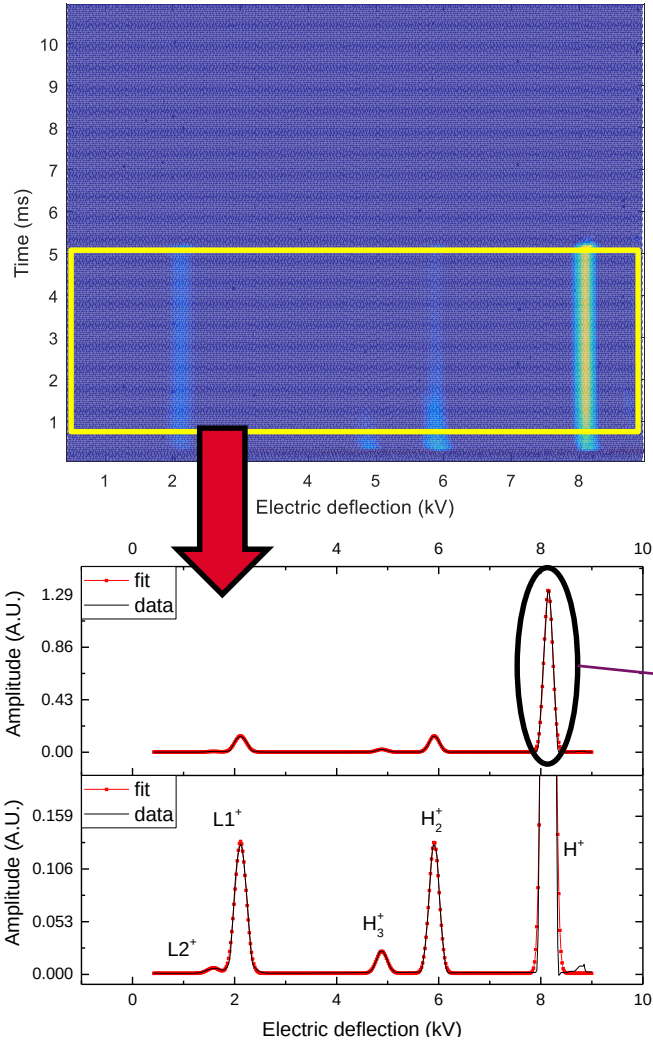
- Doppler Shift Spectrograph sensible to the Hα line of Hydrogen
- Shift due to velocity and angle of measurement θ=21°
- Light is collected and transported by a optical fiber to spectrometer
- Cooled camera to lower noise
- Same Source tuning for DDS and WF



☺ Good agreement for some magnetic configuration

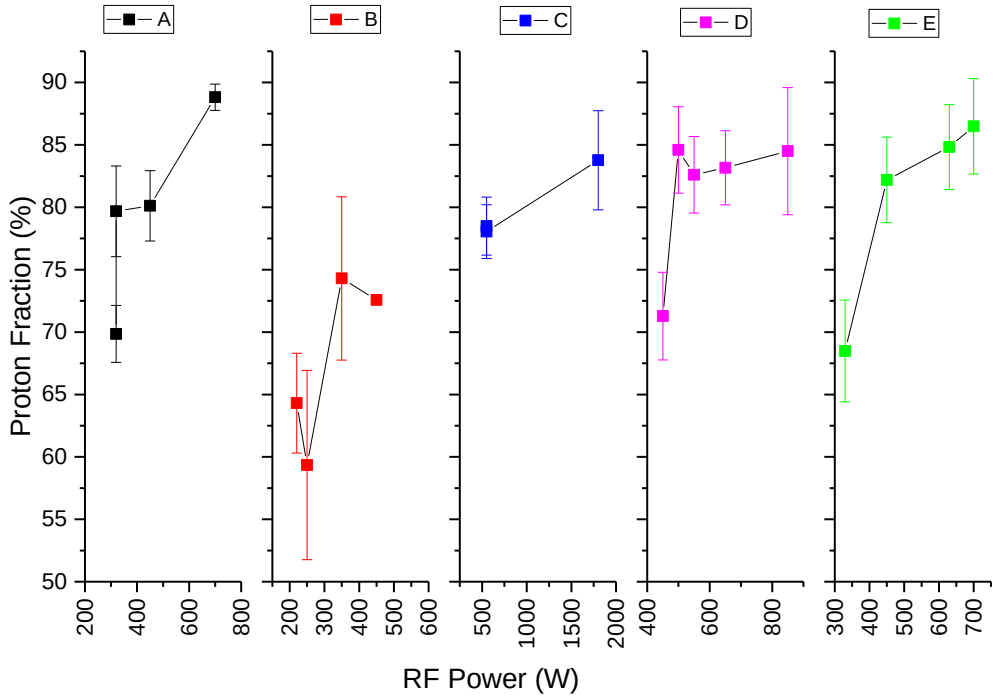
☹ Some unexplained results…

2/3 : WIEN FILTER PROTON FRACTION



FDW Analysis

- Timed resolved
- Keep same analysis than with the DSS
- Time ∈ [0,25;5] / Mean(0,25:5)
- 5 species analyzed



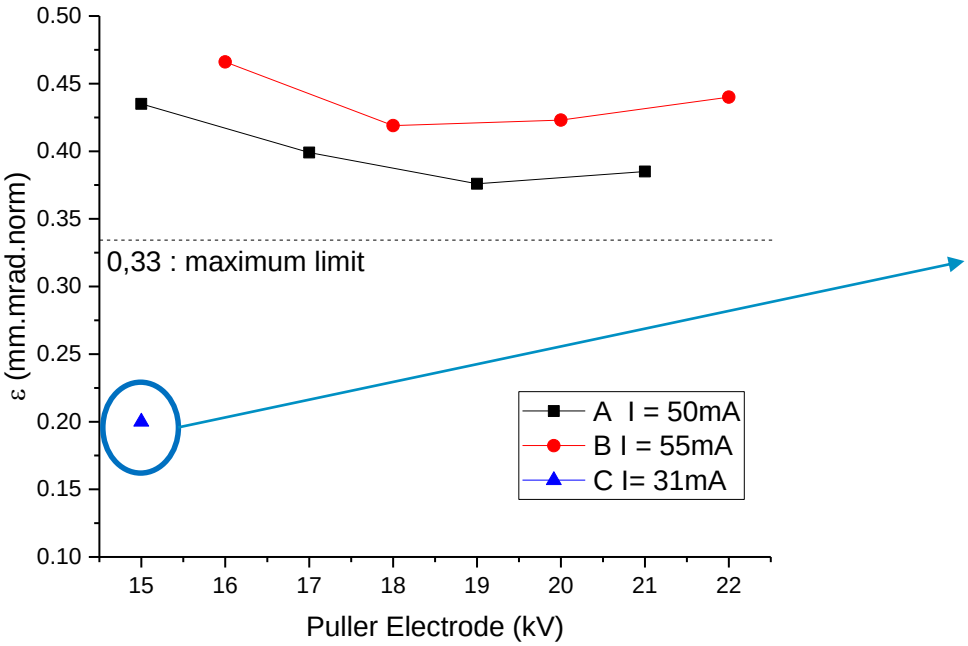
☺ Very high values of proton fraction 82-85%

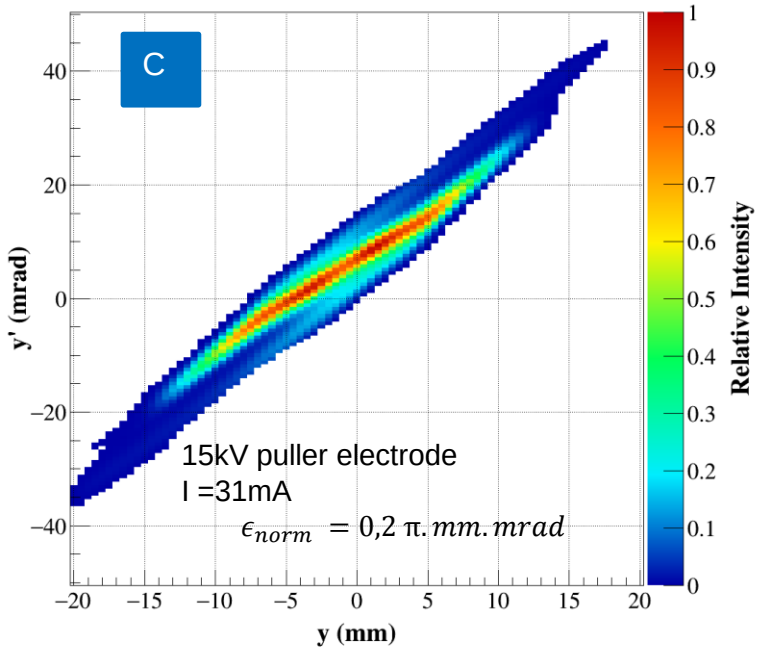
☹ Need more data to well understand the differences between results

3/3 : EMITTANCE MEASUREMENT

EMU Analysis at source exit

- Time ∈ [2 ; 5] ms / Mean(2 : 5)
- Background signal correction
- Series with Puller electrode bias voltage





☹ More measurements needed for the strong focusing magnetic configuration
☹ Emittance values are really too high !
➔ Accelerating column adapted for 120mA
➔ should be better with aperture Ø9mm

CONCLUSIONS

ION source

- The ion source is operational since 2016, with a local C&C which is not an “industrial” but it does the work for now
- The GSI 100kV high voltage and coil power supplies arrived in mid September 2017
- Beam qualification just started : presented results were done in early September 2017
- Aperture hole from Ø6 to Ø9mm will soon be changed

Diagnostics

- ACCT, FDW and EMU have just been installed and used all together
- Up to now only CEA staff can use them
- Analyze of data are “not online” and not “user friendly” yet !
- Proton fraction are around 82-85% but not for all magnetic configurations
- Emittance value are above limit mainly due to low extracted current

Schedule

- Commissionning PHASE #1 with GSI member will start probably end of the year with nominal source parameter
- PHASE #2 will start early 2018
- LEBT chopper will be ready around mid 2018

Thank you for your attention