Sarajevo Ion Accelerator project as a seed to build capacity for next generation Accelerator Physicists in Bosnia and Herzegovina via partnership with CERN

Amer Ajanovic

UNSA (Sarajevo, BiH) + CERN (Geneva, Swi)

18/10/2024, Thessaloniki, Greece

HITRI plus

Heavy Ion Therapy Research Integration

CERN

SARAI: Sarajevo Ion Accelerator

Partnership: UNSA-CERN-JSI-GSI-COSYLAB-PANTECHNIK

Supported by: The Three Physicists Foundation + Ministry of Science and Education BiH

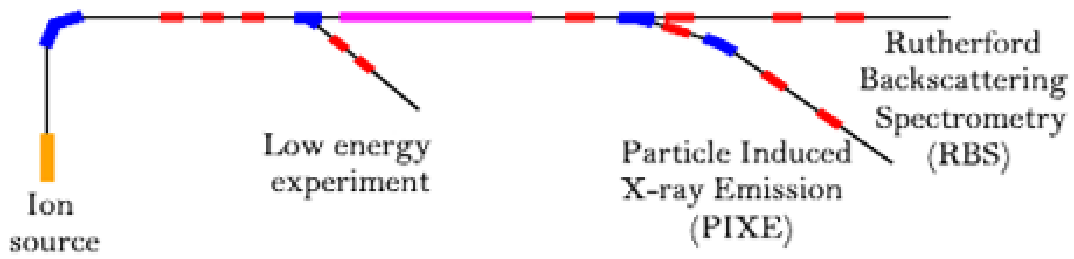
Journey so far: 2024

Jan-Mar: JUAS 1+2

Apr: Sarajevo Lab Shielding Prerequisites

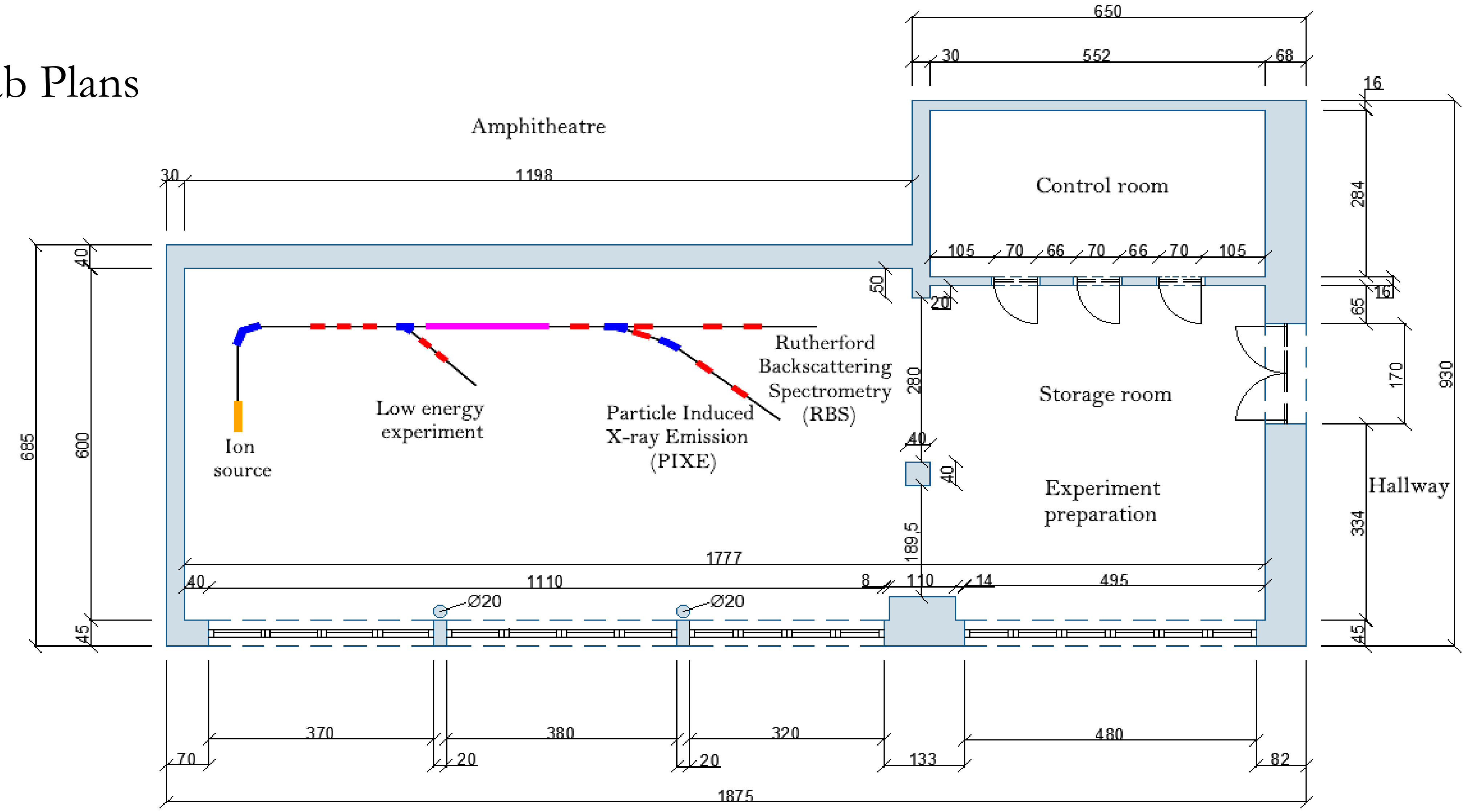
May-Jul: COSYLAB

Aug: CERN



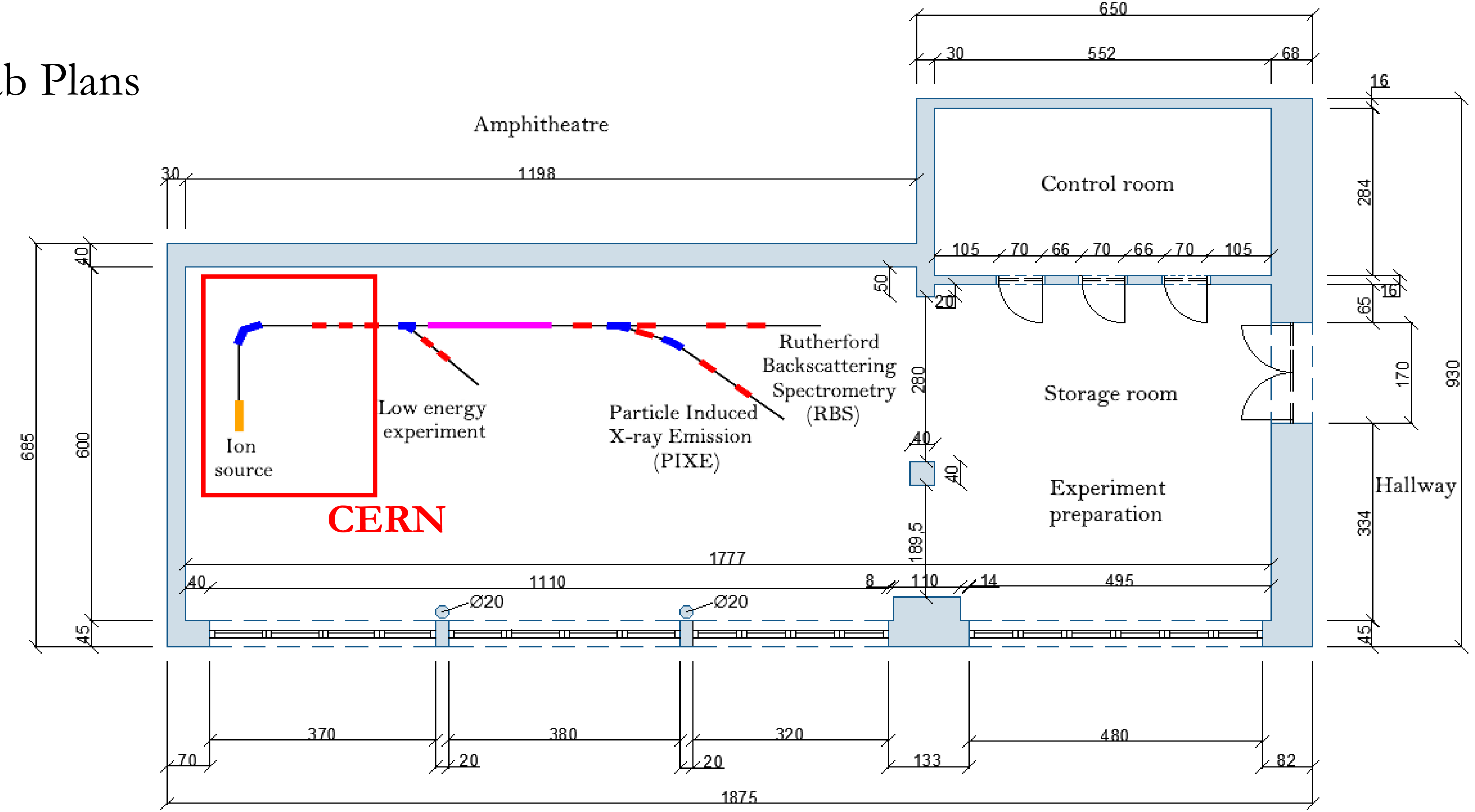
SARAI: Sarajevo Ion Accelerator

Lab Plans



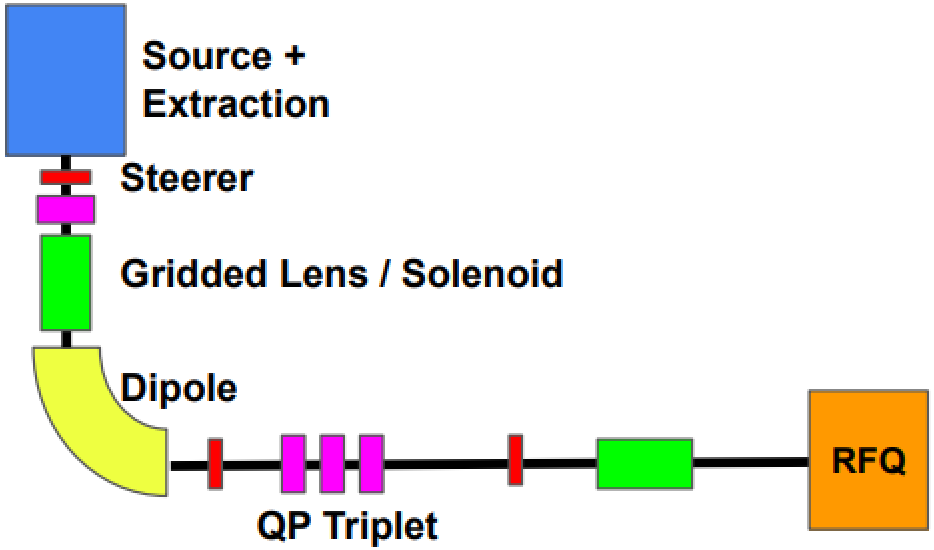
SARAI: Sarajevo Ion Accelerator

Lab Plans

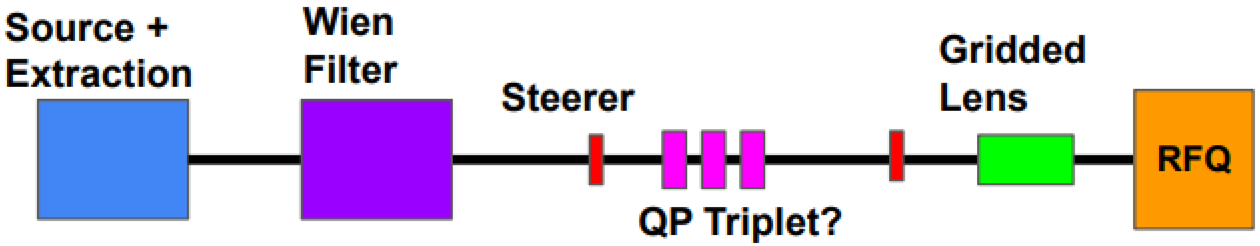


Pantechnik Source: He2+ with LEBT

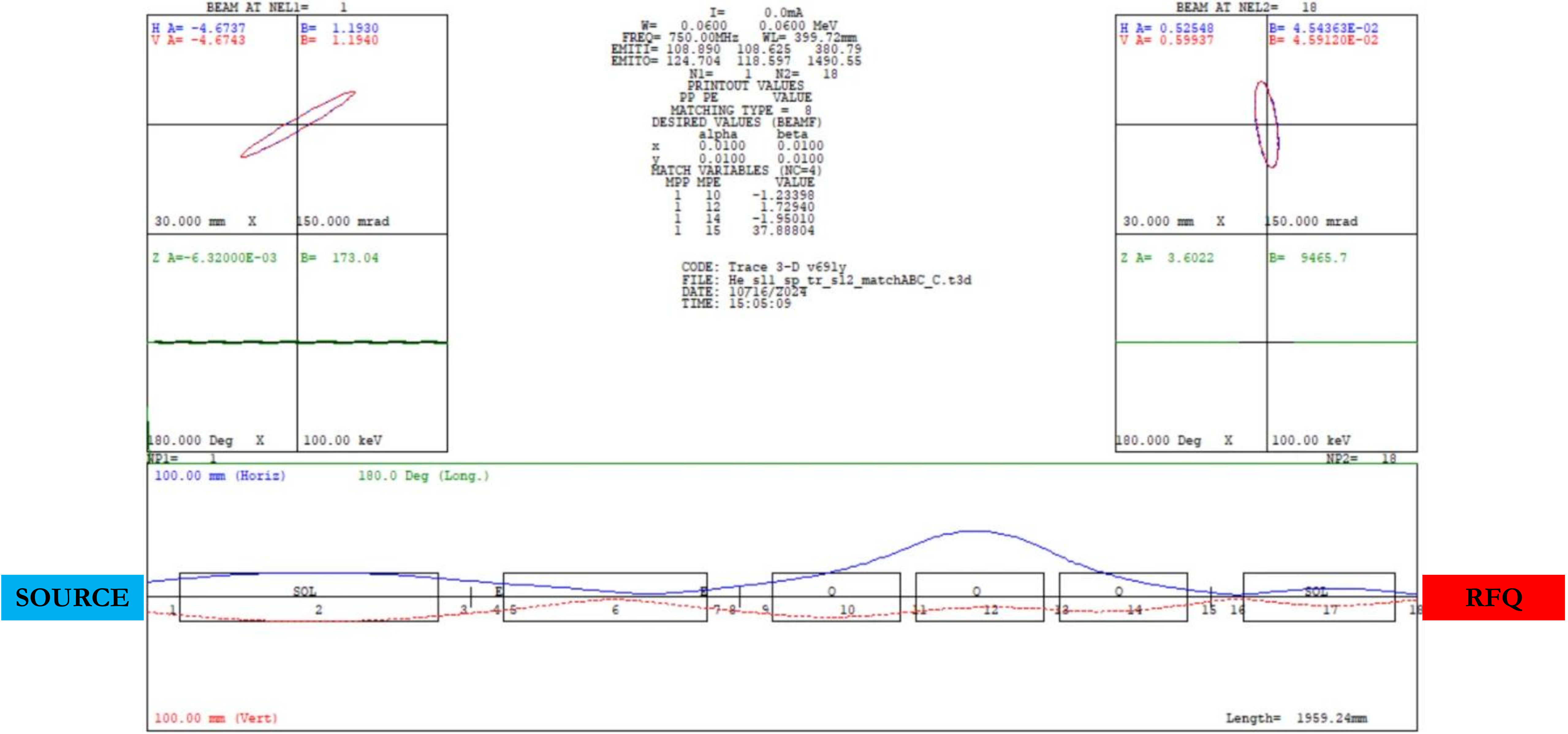
1. SPECTROMETER: BENDING DIPOLE



2. WIEN FILTER



Matching to the RFQ: Optimizing LEBT Configuration



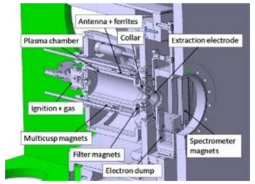
Example UNSA Student Projects at CERN: Summer 2024

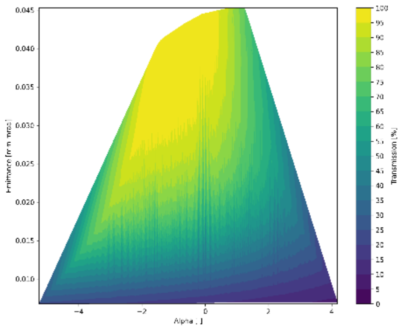
Danis Bradarić

Beam Dynamics Simulations of a Low-Energy Extraction System for LINAC4

Danis Bradarić

18.10.2024. Thessaloniki, Greece



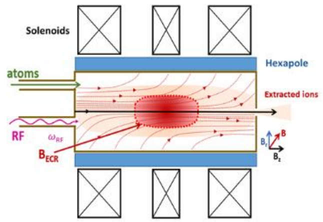


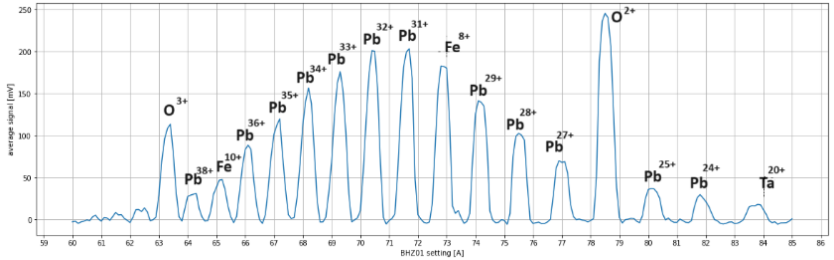
Naida Ustavdić

Experimental Ion Spectroscopy on LINAC3's Electron Cyclotron Resonance Source

Naida Ustavdić
Student at PMF UNSA

Thessaloniki, Greece 18/10/2024





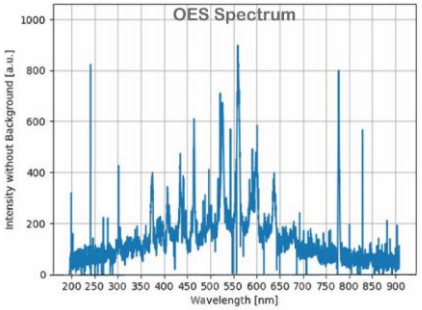
Medina Dugonjić

Automated Post-Analysis Data Transfer Implementation for LINAC3 ECR Source

Medina Dugonjić
Supervisor: Bichu Bhaskar

Faculty of Natural Sciences and Mathematics
University of Sarajevo, CERN
Sponsored by: Dr. Al Tawil Clinic, Sarajevo

October 16, 2024



Beam Dynamics Simulations of a Low-Energy Extraction System for LINAC4

Danis Bradarić

18.10.2024.

Thessaloniki, Greece

Introduction

The goal?

- The AM01 extraction system integrates beam extraction, acceleration, and matching to the LINAC4 RFQ matching plane into a single design

- As it is not possible to accurately simulate the beam extracted from the source, a range of different beam distributions was generated and passed through the AM01 extraction system

- This approach allowed for stress testing the system, and the results can serve as a reference point for comparison with future experimental outcomes

Tools and software

Travel

- For numerical simulations of the beam dynamics Travel was used, which is a multi-particle tracking code, developed at CERN, for the beam dynamics calculations of the linear accelerators

PyTravel

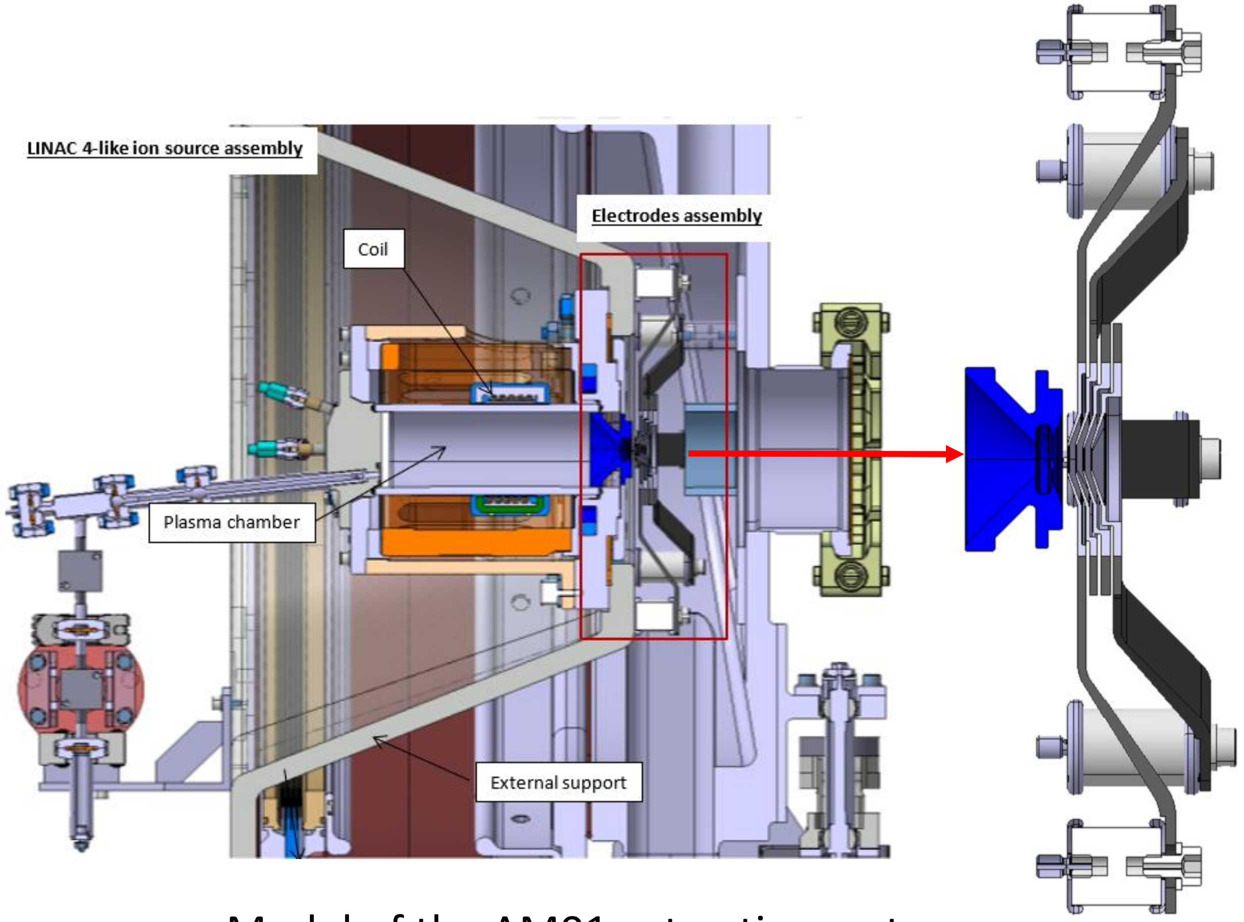
- Set of functions wrote in Python that can be used as a tool when working with Travel simulations
- The results and plots shown in this presentation were obtained using PyTravel

The AM01 extraction system

Design

- The system consists of 5 electrodes including the source electrode with cylindrical symmetry able to withstand and exploit high voltages to reach a 45 keV beam acceleration
- System's length: 2 cm (axially)
- Beam current: 40 mA (for protons)
- Voltage configuration: 45, 20, 12, 6, 0 kV

More information about the system presented by Aristeidis Mamaras



Model of the AM01 extraction system

AM01 Beam Dynamics: Rationale

Beamline

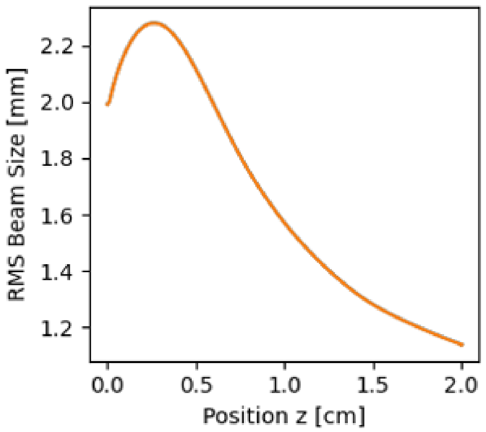
- The focus was on simulating the source extraction conditions
- Transmission of the beam through the system was analyzed in respect to different parameters

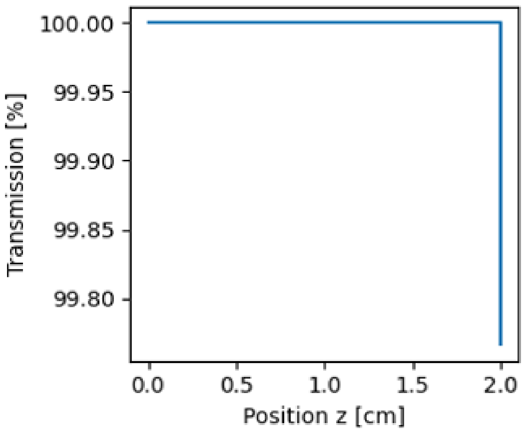
Schematics of the beamline used in simulations

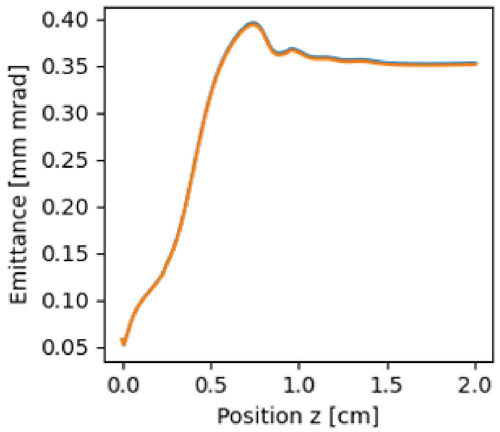
AM01 Beam Dynamics: Results

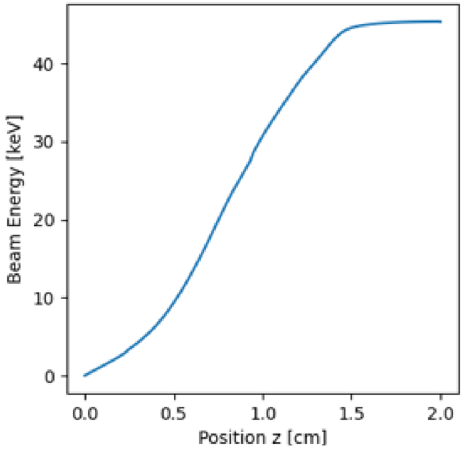
Characteristics of the system:

- The system demonstrated effective focusing capabilities for a wide range of beam distributions
- No particle loss is observed within the system for the current configuration, as shown in the „*Transmission-position z*" plot below. In other configurations, possible beam losses are primarily due to mismatches with the RFQ acceptance plane.
- Energy gain was as expected – 45keV



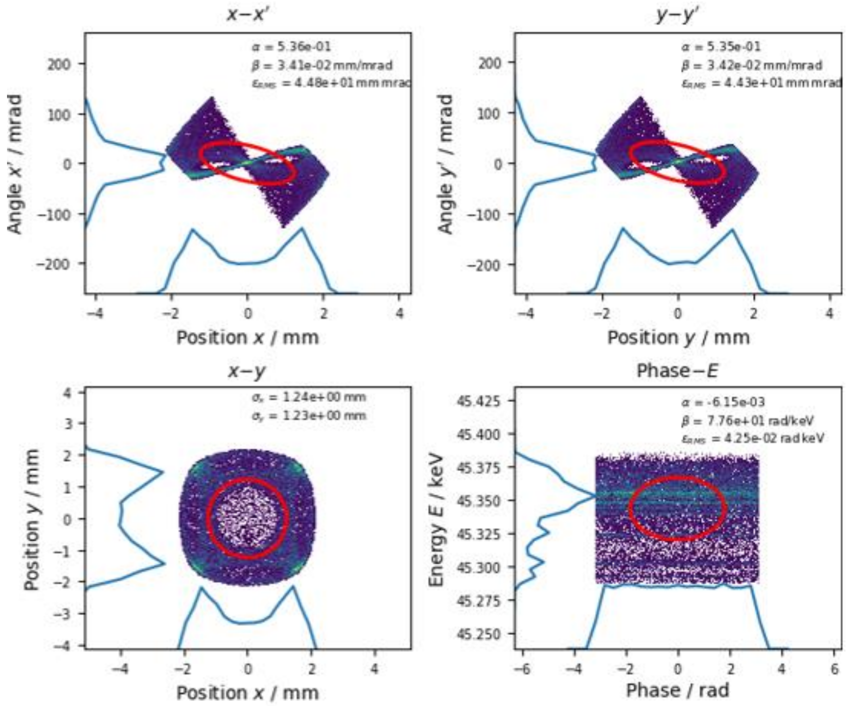




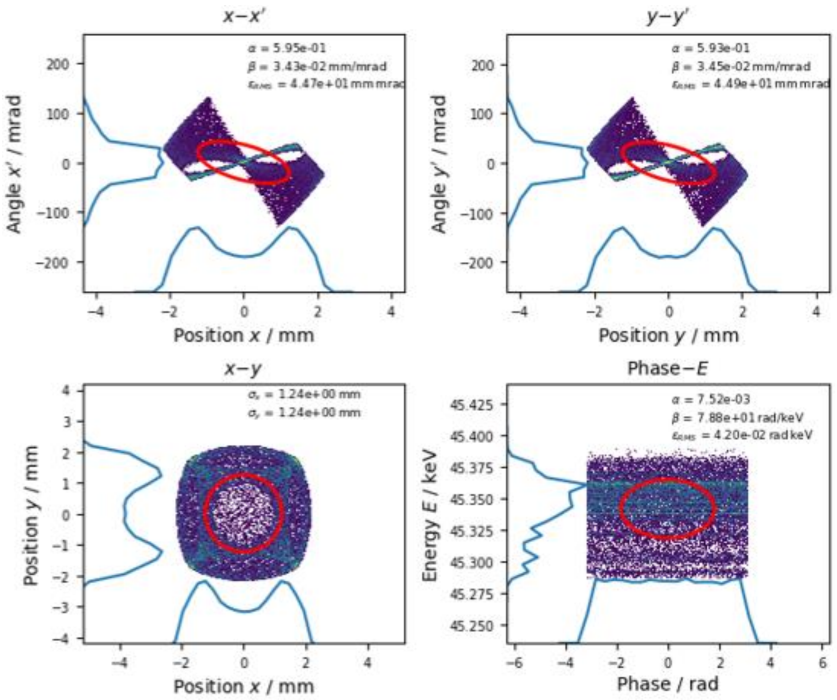


Beam Comparison

- When comparing beams with a Gaussian and Uniform distributions that have similar RMS normalized emittance values, the Uniform beam distributions generally achieve higher transmission rates in most instances



Unifrom beam – accepted to the RFQ



Gaussian beam – accepted to the RFQ

Optimal beam parameters

- Higher transmission values observed for lower energies of the initial plasma output beam – Figure 1

- Simulations done with a range of Emittance and alpha(Courant-Snyder) parameter values to see if there is an optimal set of parameters for the configuration – Figure 2

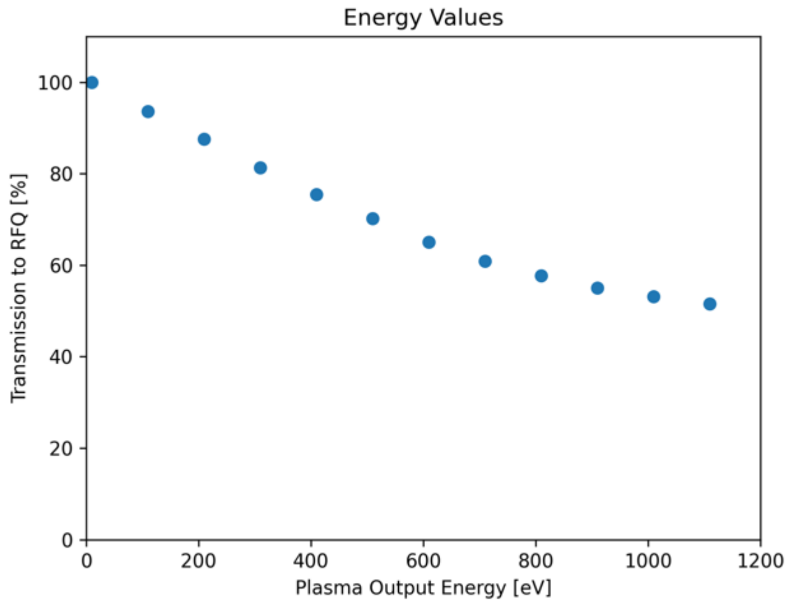


Figure 1

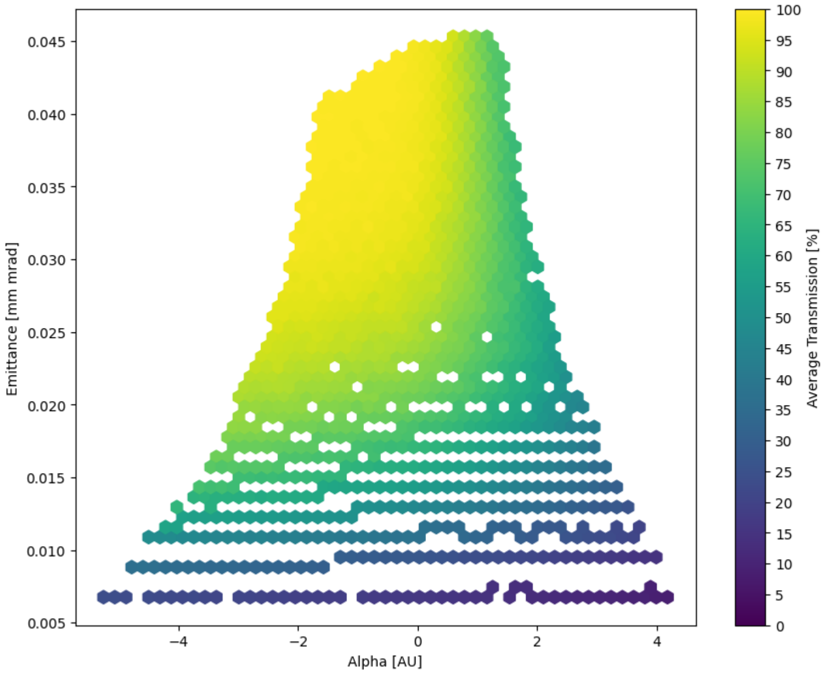


Figure 2

Conclusion

- The system effectively focuses the beam while accelerating it to the desired energies. It maintains high transmission of the beam to the RFQ (Radio Frequency Quadrupole)

- Uniformly distributed beams achieve higher transmission values in respect to beams with a Gaussian distribution

- Higher transmission is achieved with lower input energy distributions. An approach more compatible with the beam energy extracted from the source during the early stages

- Further investigation into beam current studies and various voltage configurations is essential to understand the system's behaviour and limitations, as well as to analyze the effects on beam evolution

Thank you for your attention!

Experimental Ion Spectroscopy on LINAC3's Electron Cyclotron Resonance Source

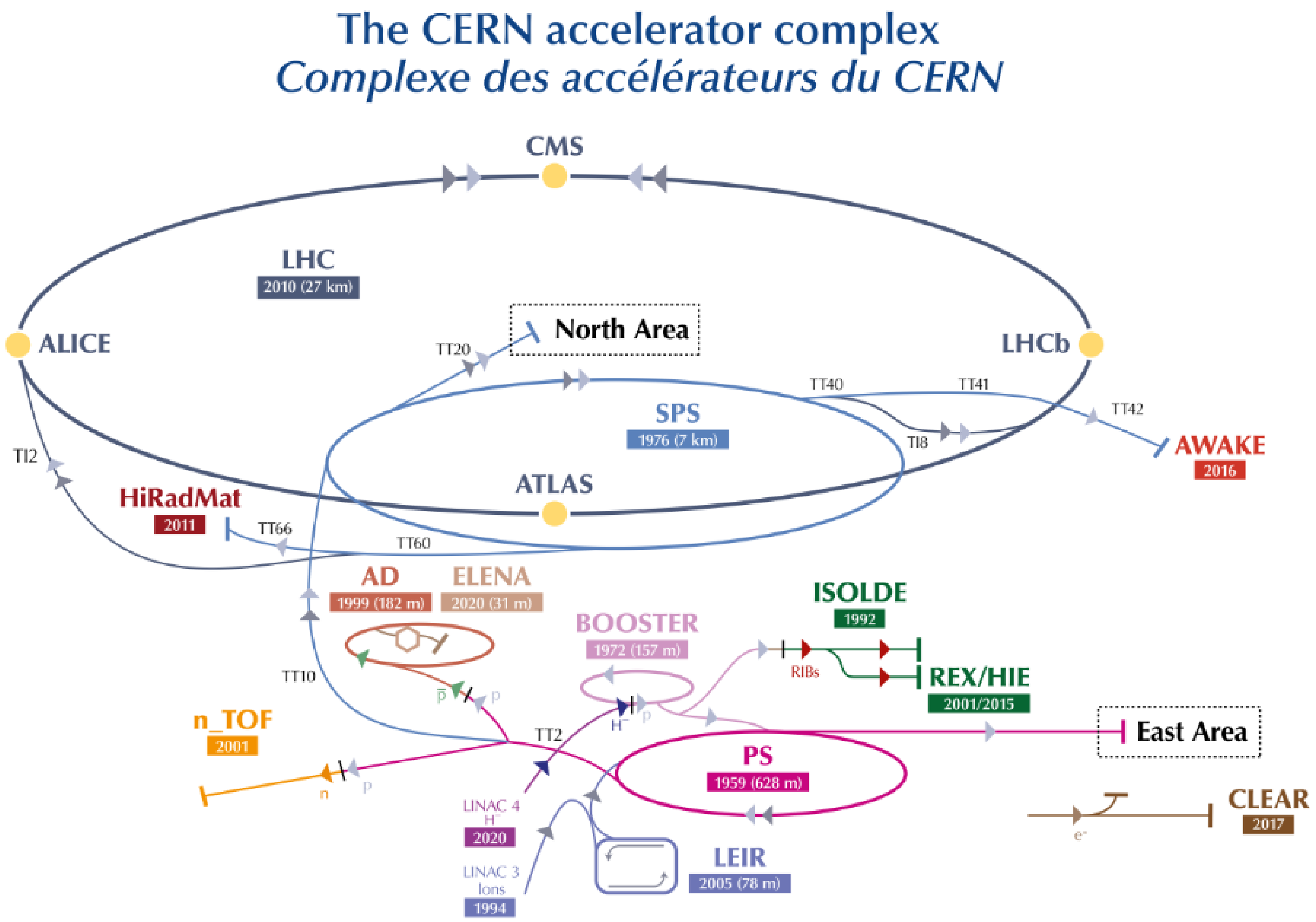
Naida Ustavdić

Student at PMF UNSA

Thessaloniki, Greece

18/10/2024

LINAC 3 in CERN accelerator complex



Working principle of ECR ion source

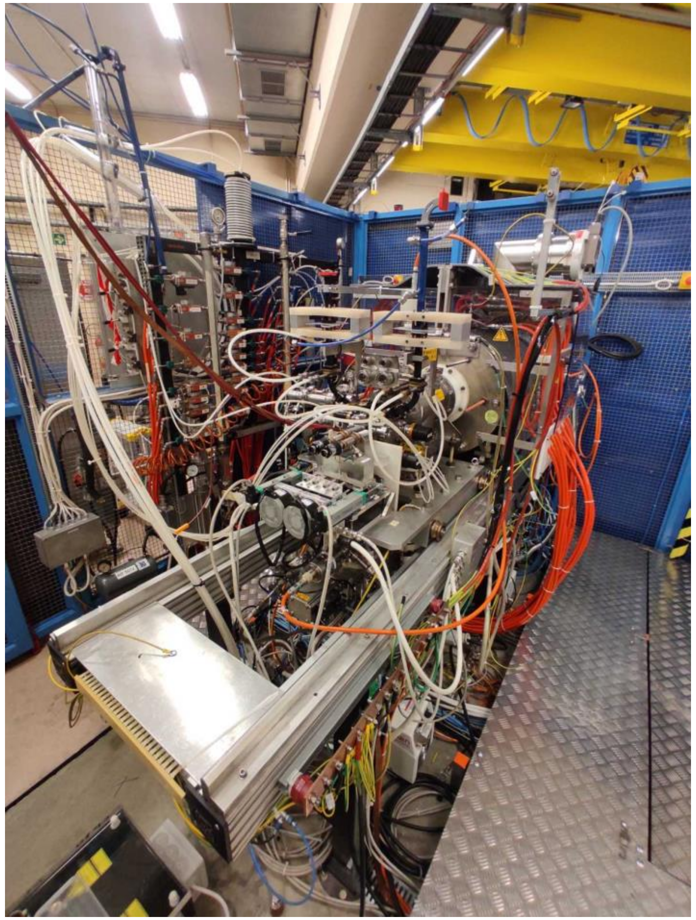


Figure: GTS-LHC ECR ion source
Picture taken by: Medina Dugonjić

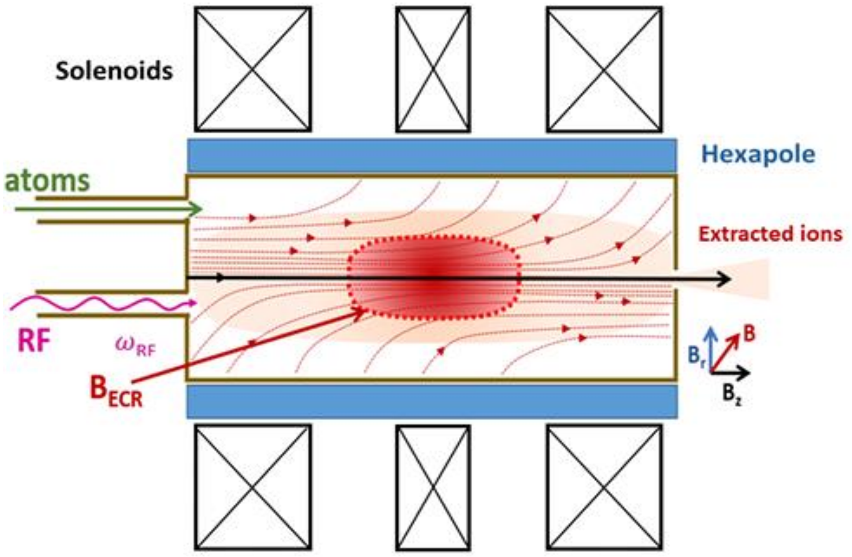


Figure: schematics of ECR ion source
Source: LINAC3 Source Mg test results-Bichu Bhaskar (ABP Group Information Meeting)

Plasma is ignited once we reach resonance meaning: $\omega_{RF} = \omega_e$.
where

$\omega_e = \frac{e \cdot B}{m}$ - frequency of electron in a magnetic field

ω_{RF} - is frequency of microwaves produced by RF generator

Working principle of ECR ion source

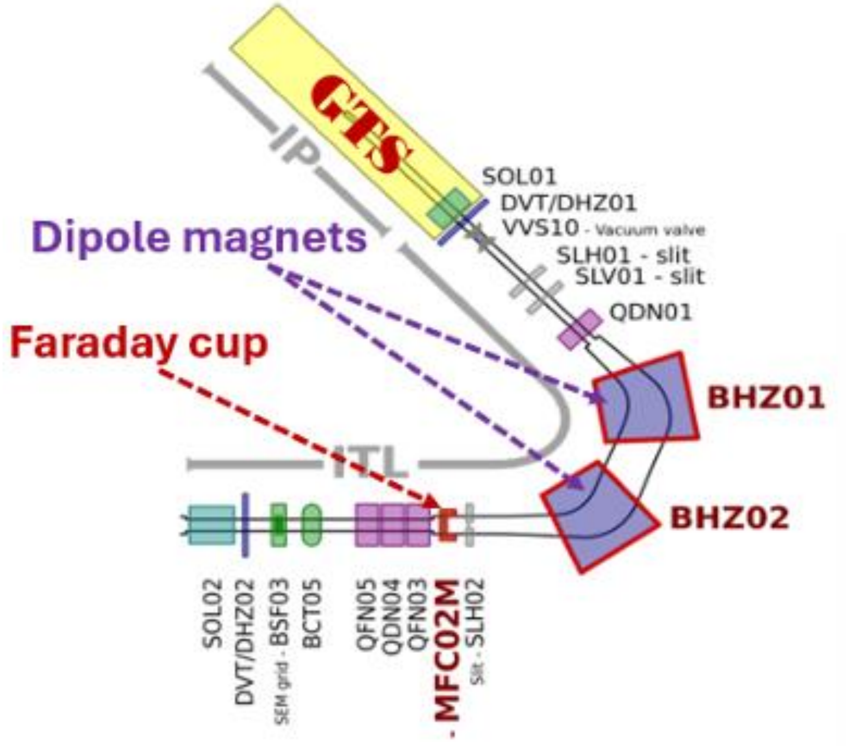


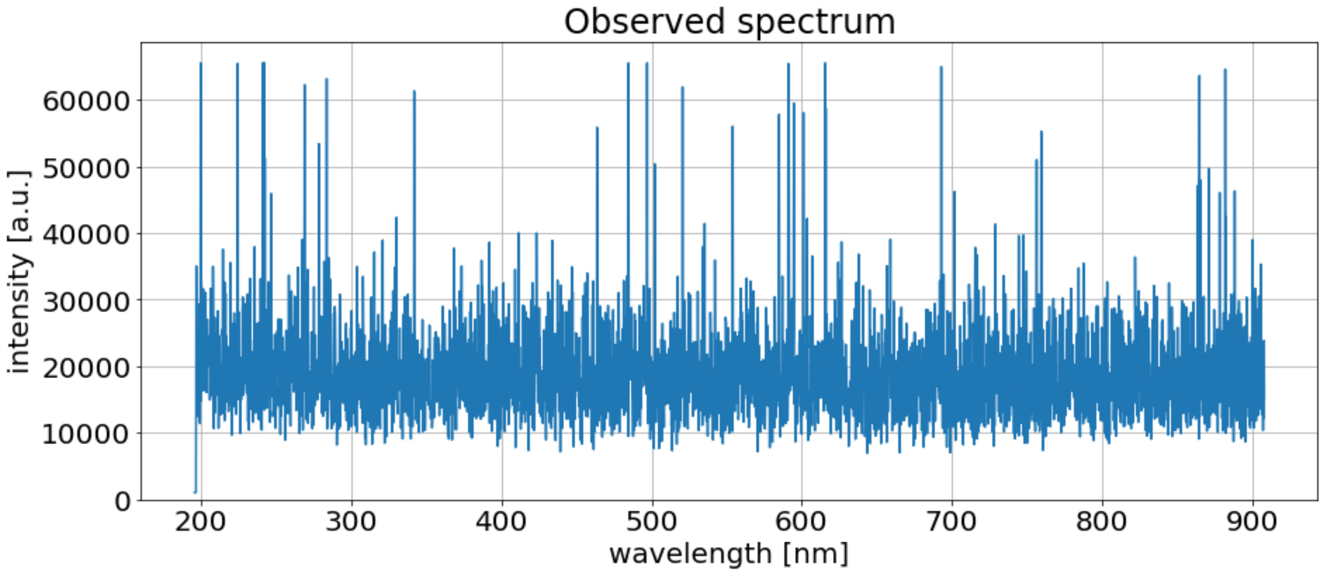
Figure: schematics of ECR ion source

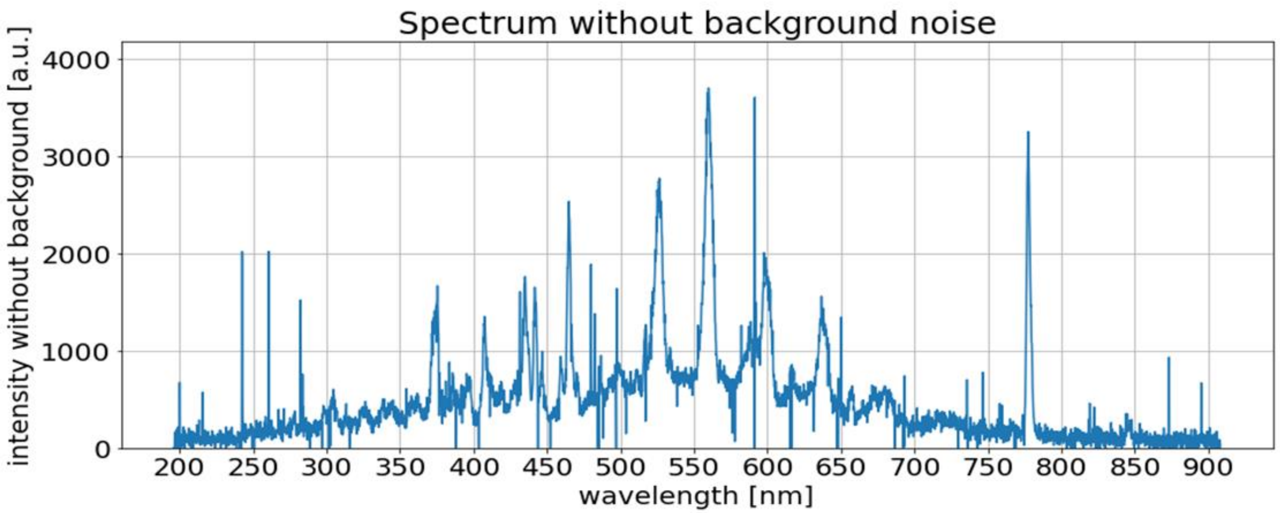
Source: LINAC3 Source Mg test results-Bichu Bhaskar (ABP Group Information Meeting)

- The beam passes through the dipole magnet, where ions are separated based on charge to mass ratio.
- Optical emission spectra is obtained using spectrometer.
- Charge State Distribution is recorded using Faraday cup, placed downstream from the dipole magnets.

Spectroscopy- obtaining spectra

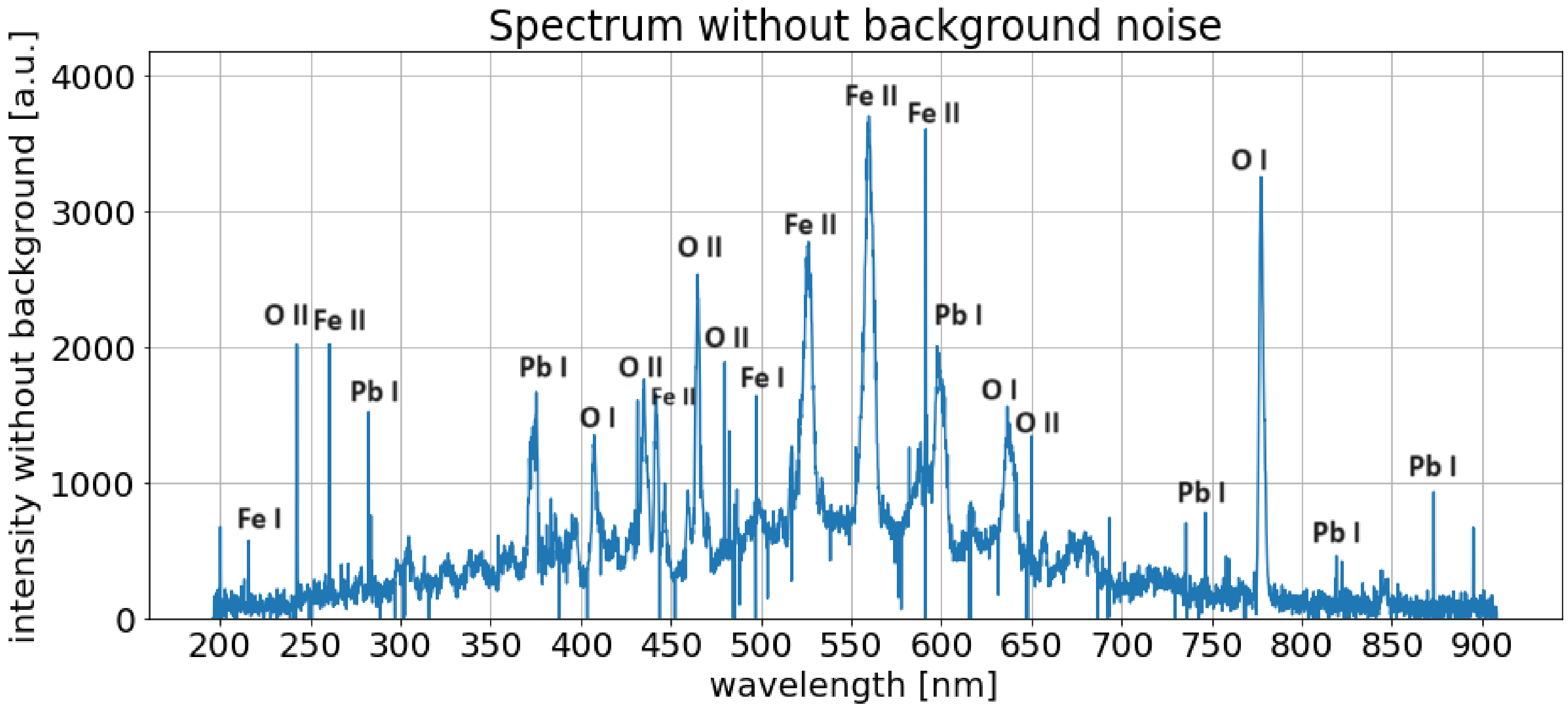
- Noninvasive diagnostic method
- Experimentally obtaining optical emission spectra (OES)
- Analyse the results using python (or any other coding tool)
- Note: different scales





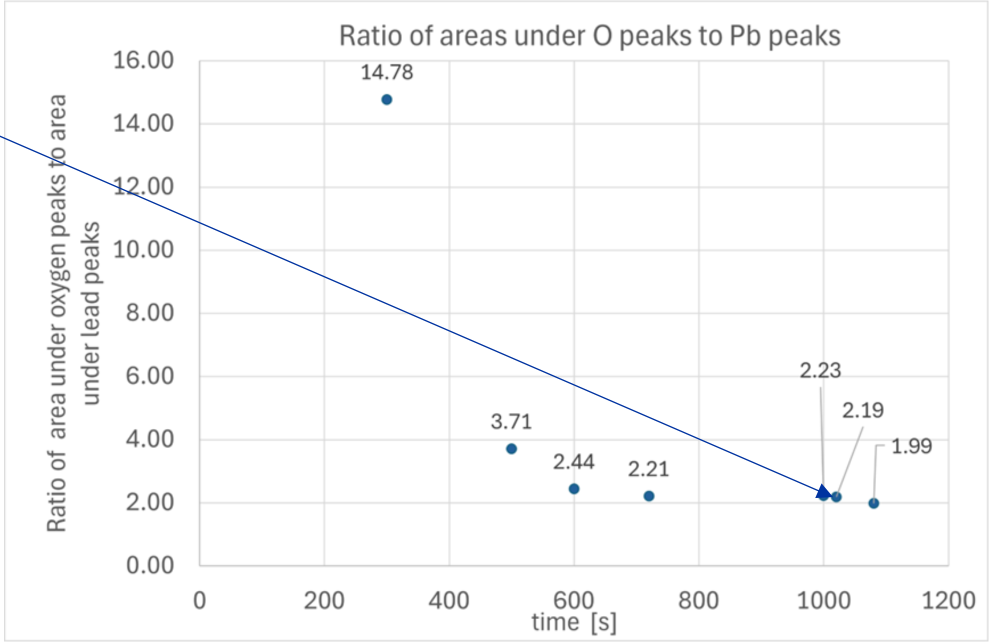
Spectroscopy-identifying elements

- Identification of elements was done using NIST database: https://physics.nist.gov/PhysRefData/ASD/lines_form.html
- Analysis of the spectrum performed by calculating area under every peak, and calculating ratios of area under each element
- All analysis done in Python
- PS:
- $O\ I \rightarrow neutral\ O$
- $O\ II \rightarrow O^{1+} ion\dots$



Spectroscopy – changing parameters for getting optimal results

Parameters	ratio of areas under O to areas under Pb	time [s]
spectra average: 15 | integration time 60s	2.19	1020
spectra average: 20 | integration time 50s	2.23	1000
spectra average: 60 | integration time 10s	2.21	720
spectra average: 50 | integration time 20s	1.99	1080
spectra average: 30 | integration time 10s	14.78	300
spectra average: 50 | integration time 10s	3.71	500
spectra average: 10 | integration time 60s	2.44	600



- Performed series of measurements changing integration time and spectra average
- Calculating ratios of area under each peak
- Finding optimal conditions to detect lead
- In this case optimal conditions are: integration time 60s and spectra averaged 15.

Charge state distribution (CSD)

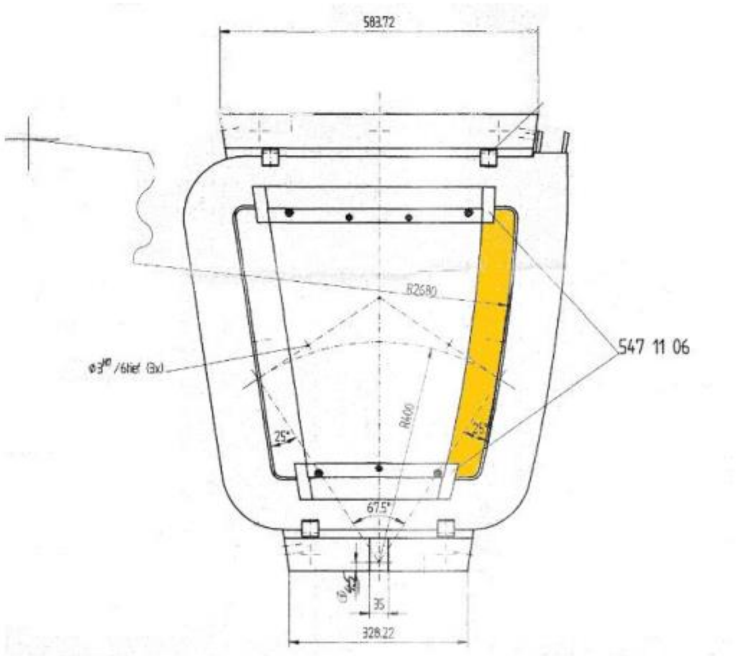
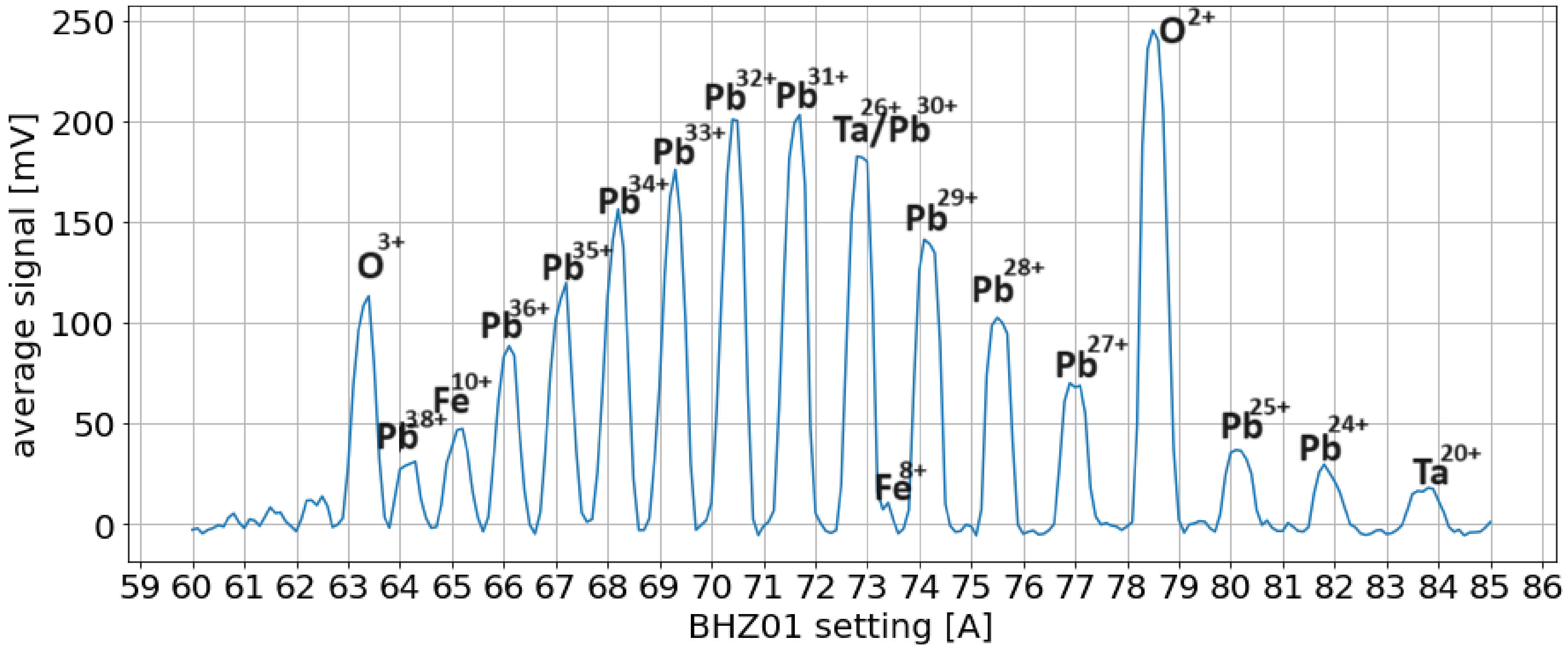


Figure: ITL_BHZ dipole magnet
Source: EDMS: 1727229

- Ions are separated based on difference in magnetic rigidity
- Magnetic rigidity is given by formula: $B\rho = \sqrt{\frac{2mV_{ext}}{q}}$

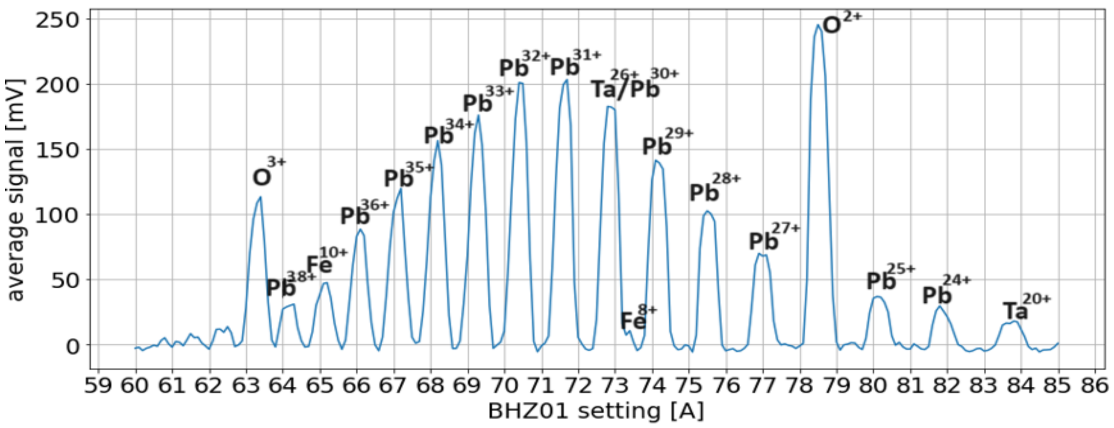
  where V_{ext} - extraction voltage, ρ-radius curvature of the ion path due to magnetic field
- At the time I was obtaining CSD : $V_{ext} = 19\text{kV}$
- ITL_BHZ Dipole magnet parameters: bending angle of 67.5° and ρ= 400mm
- On Monday 29/7/2024 2 CSD scans were obtained. The source parameters were not changed in between 2 scans. Due to problems with source during my stay no more scans were obtained.

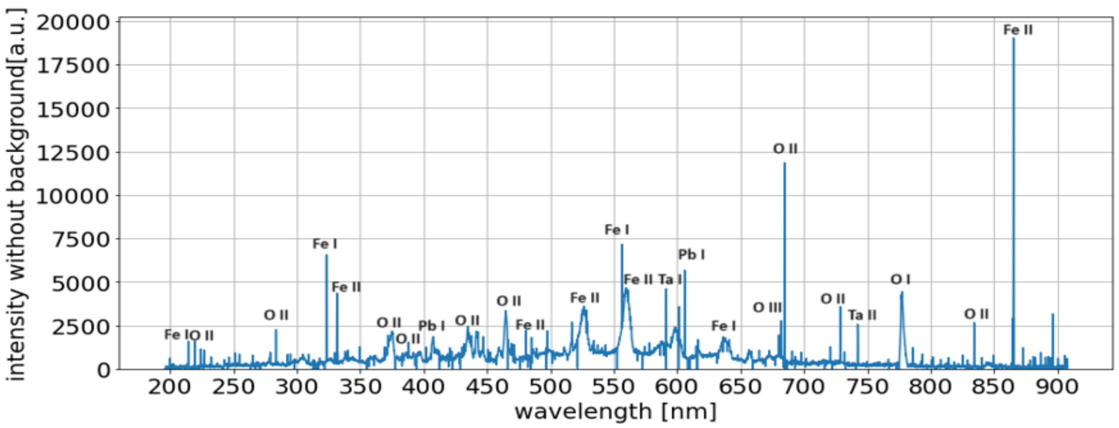
Charge state distribution

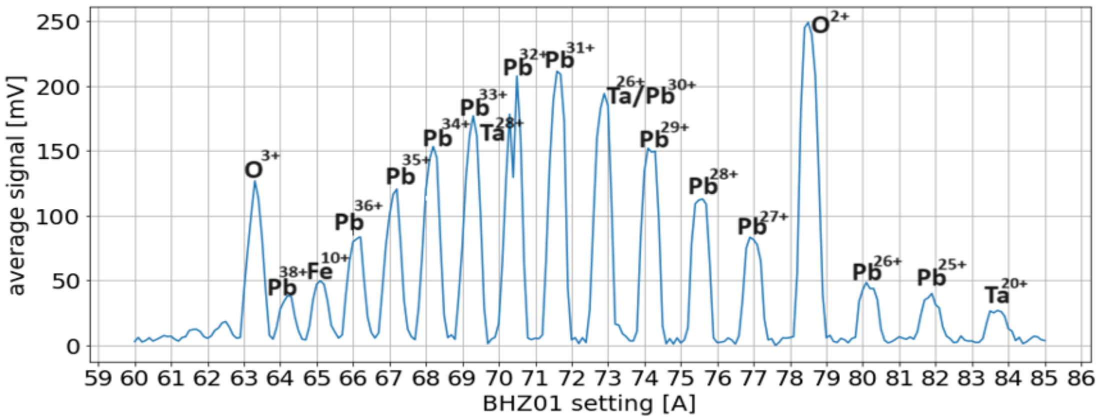


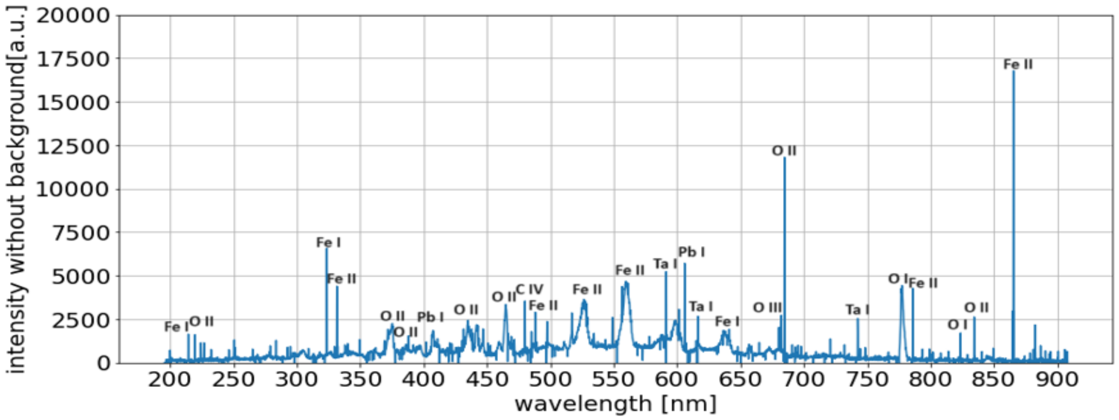
Charge state distribution with elements identified

Finding correlation









Thank you for your attention!

Automated Post-Analysis Data Transfer Implementation for LINAC3 ECR Source

Medina Dugonjić
Supervisor: Bichu Bhaskar

Faculty of Natural Sciences and Mathematics
University of Sarajevo, CERN
Sponsored by: Dr. Al Tawil Clinic, Sarajevo

October 16, 2024

Table of Contents

Motivation

- Idea: Convert already existing code in MATLAB to Python for analysing optical spectrums and integrate it with the CERN server via NXCALS/Timber
- *Why?*
  To be able to **track the data in real time**
- Real time tracking of OES analysis helps in source tuning and understanding plasma dynamics
- The only diagnostics for studying ECR plasma of GTS-LHC

Objectives of the Project

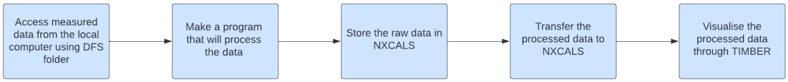


Figure: Intended workflow

Raw Data

File Edit View

```
SpectraSuite Data File
++++++++++++++++++++++++++++++++++++
Date: Mon Jul 08 10:30:21 CEST 2024
User: linac2
Dark Spectrum Present: No
Reference Spectrum Present: No
Number of Sampled Component Spectra: 1
Spectrometers: USB4F09588
Integration Time (usec): 10000000 (USB4F09588)
Spectra Averaged: 60 (USB4F09588)
Boxcar Smoothing: 0 (USB4F09588)
Correct for Electrical Dark: No (USB4F09588)
Strobe/Lamp Enabled: No (USB4F09588)
Correct for Detector Non-linearity: No (USB4F09588)
Correct for Stray Light: No (USB4F09588)
Number of Pixels in Processed Spectrum: 3648
>>>>>Begin Processed Spectral Data<<<<<
195.68  1066.96
195.91  1066.96
196.13  1066.96
196.35  1047.80
196.57  1054.10
196.79  7392.64
197.02  5325.80
197.24  5254.45
197.46  4930.45
197.68  4016.70
197.90  5643.80
198.13  3897.47
198.35  3783.69
198.57  5576.50
198.79  6307.99
199.01  6451.96
199.24  3559.27
199.46  4406.96
199.68  19529.78
199.90  4127.90
200.12  4488.07
200.34  6901.43
200.57  4819.87
```

Ln 1, Col 1 | 55,387 characters | 100% | Windows (CRLF) | UTF-8

Figure: Raw data .txt file

Make a program that will process the data

Code language:

- Python

Purpose of the code:

- Access the data
- Iterate through all files
- Extract timestamps
- Substract background and find peaks
- Find area of the peak for lead (Pb) at 600.2 nm[1]
- Make a .txt file that stores file names, timestamps, wavelengths of peaks and area of peaks
- Loop through the folder every 15 min and look for new files
- Report if new files are found and append the processed results in the already existing .txt file

[1] This wavelength was the most common one; courtesy of Naida Ustavdić

Make a program that will process the data

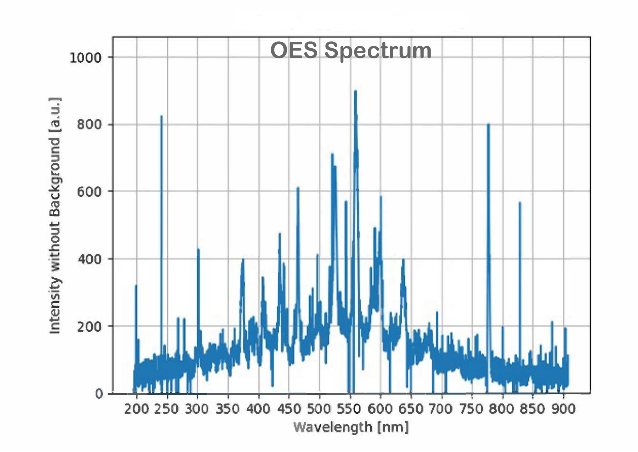


Figure: Peaks visualized

Make a program that will process the data

File Edit View

Filename	Timestamp	Peak Wavelength (nm)	Area Under Peak
background0000.txt	Wed Aug 07 11:51:04 CEST 2024	600.20	53047.7959
background0001.txt	Wed Aug 07 12:06:04 CEST 2024	600.20	51374.0838
background0002.txt	Wed Aug 07 12:21:03 CEST 2024	600.20	50454.2872
background0003.txt	Wed Aug 07 12:36:03 CEST 2024	600.20	50624.4292
background0004.txt	Wed Aug 07 12:51:03 CEST 2024	600.20	50071.4672
background0005.txt	Wed Aug 07 13:06:03 CEST 2024	600.20	50086.4294
background0006.txt	Wed Aug 07 13:21:03 CEST 2024	600.20	50094.5967
background0007.txt	Wed Aug 07 13:36:03 CEST 2024	600.20	49138.4418
background0008.txt	Wed Aug 07 13:51:03 CEST 2024	600.20	49259.6615
background0009.txt	Wed Aug 07 14:06:03 CEST 2024	600.20	50057.7781
background0010.txt	Wed Aug 07 14:21:03 CEST 2024	600.20	50132.5880
Data0000.txt	Wed Aug 07 14:36:03 CEST 2024	600.20	49971.5282
Data0001.txt	Wed Aug 07 14:51:03 CEST 2024	600.20	50360.6936
Data0002.txt	Wed Aug 07 15:06:02 CEST 2024	600.20	50445.0397
Data0003.txt	Wed Aug 07 15:21:02 CEST 2024	600.20	50494.6613
Data0004.txt	Wed Aug 07 15:36:02 CEST 2024	600.20	49740.9168
Data0005.txt	Wed Aug 07 15:51:02 CEST 2024	600.20	50255.4573
Data0006.txt	Wed Aug 07 16:06:02 CEST 2024	600.20	50555.8750
Data0007.txt	Wed Aug 07 16:21:02 CEST 2024	600.20	50426.6210
Data0008.txt	Wed Aug 07 16:36:02 CEST 2024	600.20	50144.7186
Data0009.txt	Wed Aug 07 16:51:02 CEST 2024	600.20	49679.1560
Data0010.txt	Wed Aug 07 17:06:02 CEST 2024	600.20	48791.0432
Data0011.txt	Wed Aug 07 17:21:02 CEST 2024	600.20	49000.1763
Data0012.txt	Wed Aug 07 17:36:01 CEST 2024	600.20	49908.6759
Data0013.txt	Wed Aug 07 17:51:01 CEST 2024	600.20	50525.3036
Data0014.txt	Wed Aug 07 18:06:01 CEST 2024	600.20	50294.0472
Data0015.txt	Wed Aug 07 18:21:01 CEST 2024	600.20	50286.7684
Data0016.txt	Wed Aug 07 18:36:01 CEST 2024	600.20	50216.8698
Data0017.txt	Wed Aug 07 18:51:01 CEST 2024	600.20	50196.2085
Data0018.txt	Wed Aug 07 19:06:01 CEST 2024	600.20	49359.1495
Data0019.txt	Wed Aug 07 19:21:01 CEST 2024	600.20	49489.3161
Data0020.txt	Wed Aug 07 19:36:01 CEST 2024	600.20	49806.5023
Data0021.txt	Wed Aug 07 19:51:01 CEST 2024	600.20	49327.9879
Data0022.txt	Wed Aug 07 20:06:01 CEST 2024	600.20	50013.3427
Data0023.txt	Wed Aug 07 20:21:00 CEST 2024	600.20	50017.5182
Data0024.txt	Wed Aug 07 20:36:00 CEST 2024	600.20	50187.3485
Data0025.txt	Wed Aug 07 20:51:00 CEST 2024	600.20	49656.7290
Data0026.txt	Wed Aug 07 21:06:00 CEST 2024	600.20	50124.8306
Data0027.txt	Wed Aug 07 21:21:00 CEST 2024	600.20	49455.7126

Ln 4, Col 57 | 37,421 characters | 100% | Windows (CRLF) | UTF-8

Figure: Look of the output file

Transfer the processed data

The second part of the project consisted of identifying all techincal aspects of data transfer.

Conclusion

The goal of the project was to make a program that will process the obtained data and integrate it with the CERN server via NXCALS/Timber.

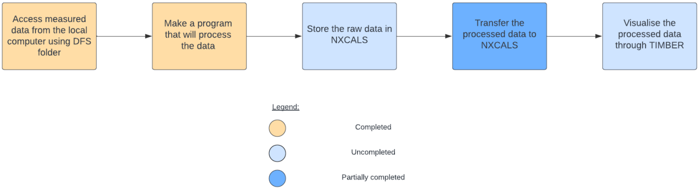


Figure: Conclusion

Thank you for your attention.