South East European
International Institute
for Sustainable Technologies

Options for the Sarajevo ion source programme

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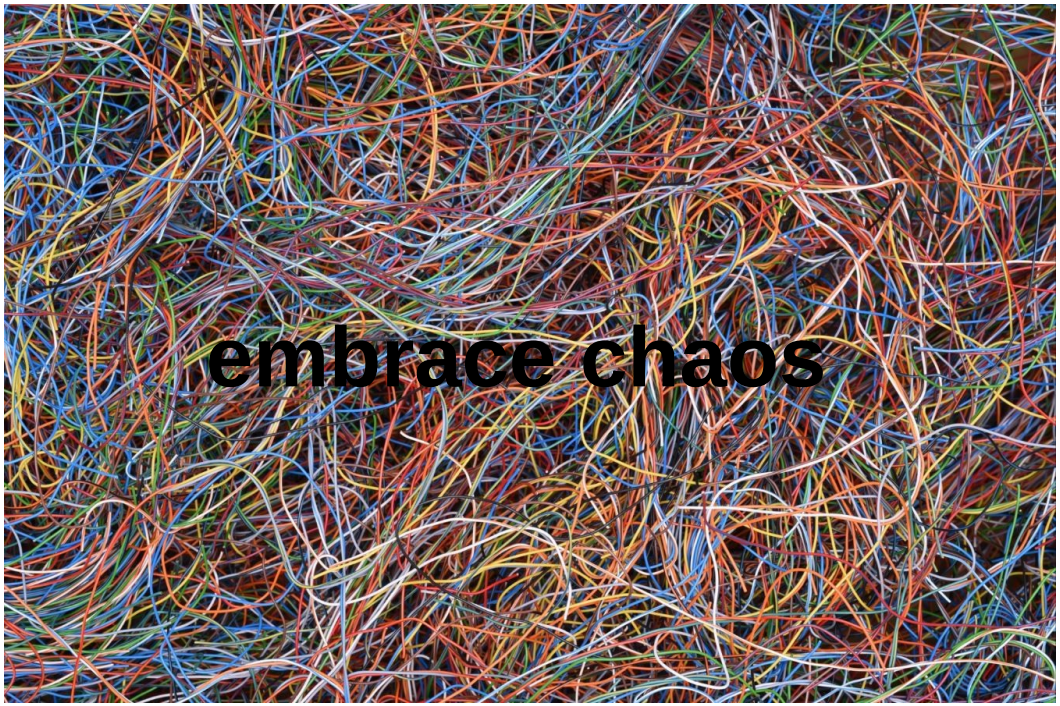
CERN, Dec 18, 2020

How to prepare decision about optimal equipment for Sarajevo Linac project?



- **Understand objectives – they are very vague, not driven by technical requirements**
- **Consider possible long-term scenarios - several possibilities**
- **Take into account needs, interests and potential resources at UNSA**
- **Collect the input information (publications, discussions, meetings)**
- **Organize the information in a way, which helps to make a decision**
- **Draw conclusions**

Main Objectives

- **Setup of an accelerator laboratory at UNSA:**
  - capable of some accelerator R&D,
  - useful for NIMMS/SEEIIST project,
  - useful for other research at UNSA:
    - low energy highly charged ions for graphene research (S. Gutic)
    - microPIXE for biological research (E. Karalija)
  - education
  - sustainable, but don't be afraid of risk
- Start international collaborations (eg. UNSA-CERN, UNSA-RBI etc)

Other opportunities:

- Maybe develop IBA and participate in Central European Research Infrastructure Consortium: https://www.ceric-eric.eu

Input

Meetings with companies:

- High Voltage Engineering Europe (HVEE): Jan Groot
- D.I.S.Germany (sister company of Dreebit): Guenter Zschornack (main expert)
- Pantechnik: Matthieu Cavellier
- Cosylab: Janko Burgar and others
- i-tech: Katarina Roskar and others

Other meetings:

- University of Sarajevo (UNSA): prof. Elvedin Hasović,
  prof. Azra Gazibegović – Busuladžić, prof. Adnan Beganović (UNSA Clinic)
- A number of other interesting inputs from researchers working at UNSA (other departments) or related to UNSA
- Ruđer Bošković Institute, Zagreb: Milko Jaksic, Zdravko Siketic and Natko Skukan (currently IBA expert at IAEA)
- Eddy Offerman

Task distribution and documentation

- **Benjamin:**
  - investigate ion sources available on the market focusing on duoplasmotron, ECR and EBIS,
  - investigate their specifications and technical requirements,
  - organize documentation of the investigations (google drive)
- **Fehima:**
  - investigate applications of low energy ion beams for research and industry
  - calculation of power consumption, investigation of instrumentation
  - characteristics of the room for laboratory
- **Aris:**
  - help Fehima focusing on ion implantation applications
- **Yiota:**
  - overall organization, communication, lead and follow up of the meetings (especially those with UNSA)

Baseline proposal

IMPLEMENTATION OF A SUPERCONDUCTING ELECTRON BEAM ION SOURCE INTO THE HIT ION SOURCE TESTBENCH

E. Ritter*, A. Silze, DREEBIT GmbH, Großröhrsdorf, Germany
G. Zschornack, TU Dresden and Helmholtz-Zentrum Dresden-Rossendorf e.V., Dresden, Germany
R. Cee, T. Haberer, A. Peters, T. Winkelmann, HIT, Heidelberg, Germany

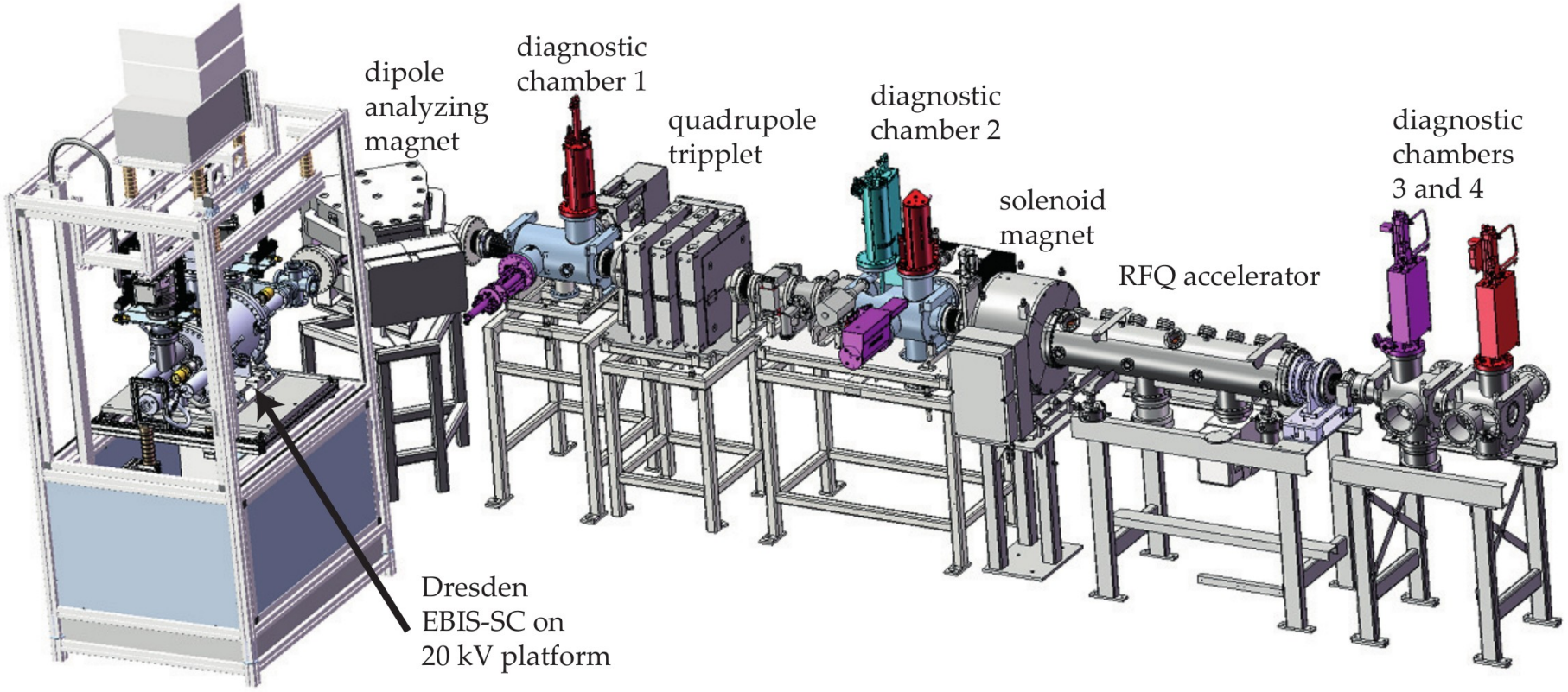
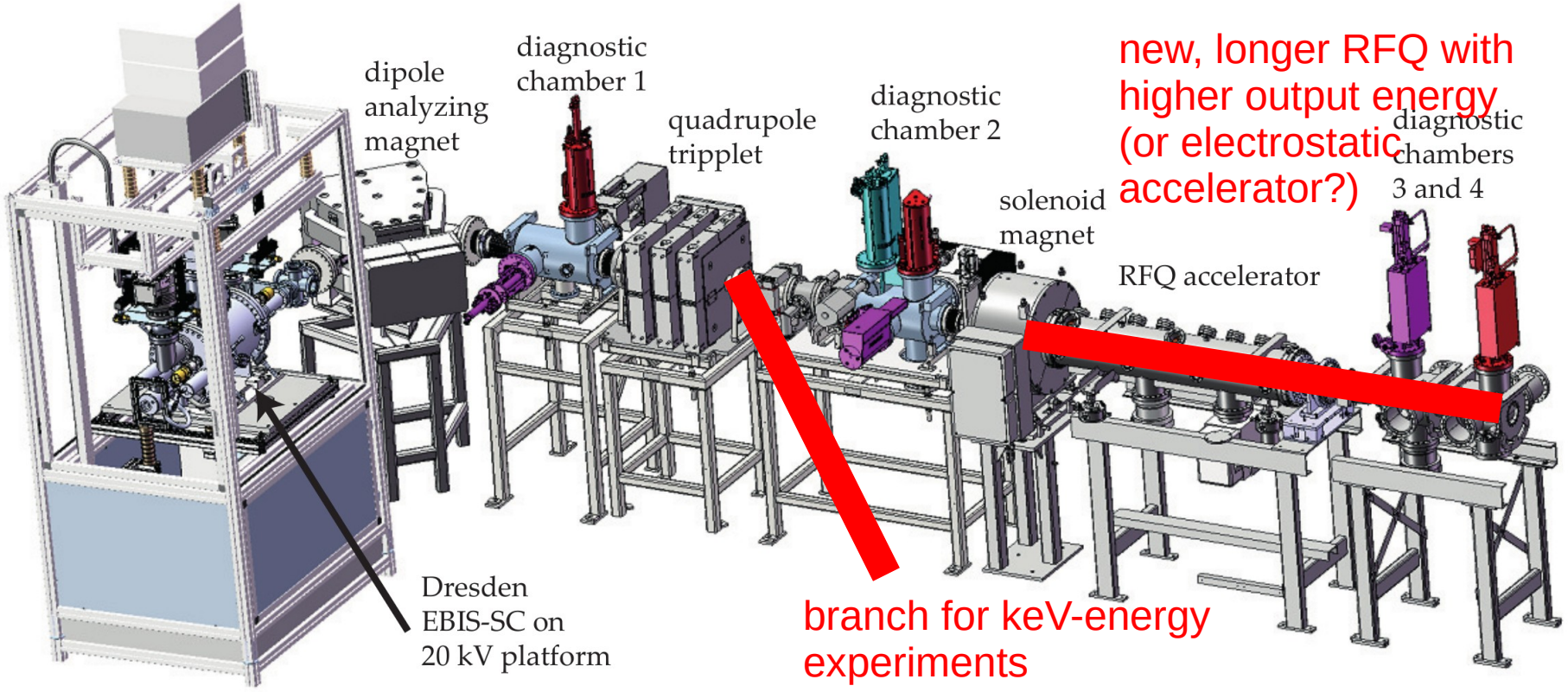


Figure 1: 3D CAD model of the testbench with the Dresden EBIS-SC (from left: EBIS-SC with 20 kV-platform, dipole analyzing magnet, diagnostic chamber one with profile grid 1, analyzing slits, and Faraday cup 1, quadrupole tripplet, diagnostic chamber two with pepper pot, profile grid 2, and Faraday cup 2, solenoid magnet, RFQ accelerator, diagnostic chambers three, and four with a set of 3 phase probes, profile grid 3, and Faraday cup 3). The Faraday cups are colored in red, the grid profile monitors are colored in purple, and the pepper pot is colored in blue.

Baseline proposal



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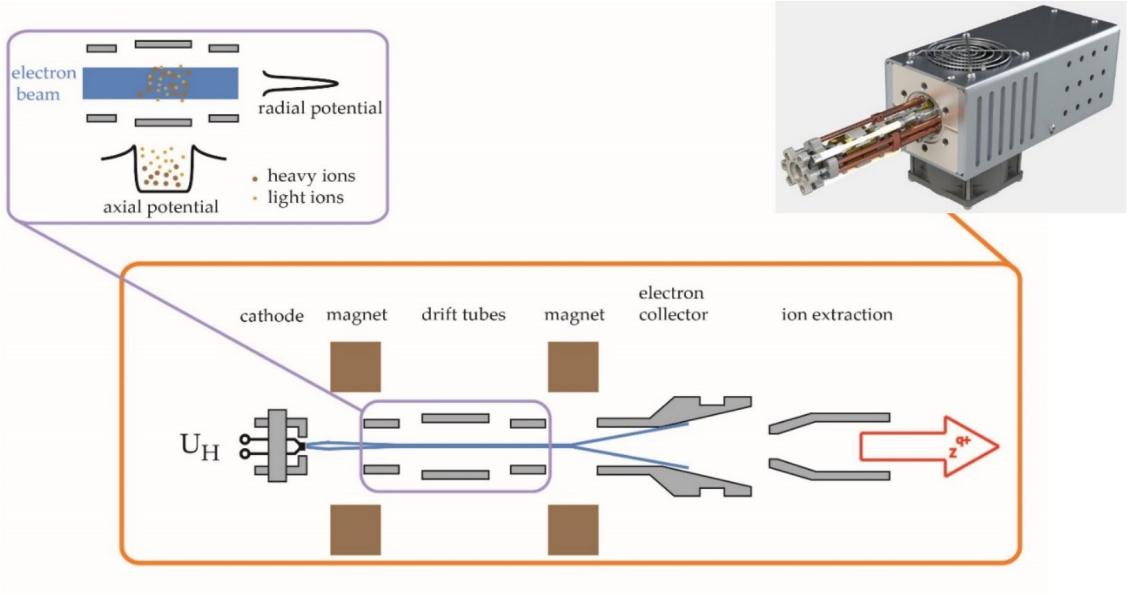
ECRIS vs EBIS (slide from G. Zschornack, DIS)

Parameter	ECRIS	EBIS
Ion beam current	µA … hundreds of µA	fA … nA
Vacuum	10^{-5} … 10^{-7} mbar	10^{-8} … 10^{-10} mbar (cleaner beam)
Ion charge states	$Ar^{(1-12+)}$ (for f > 2.45 GHz)	almost all, e.g. $Ar^{(1-18+)}$
Elements	almost all	almost all
Beam emittance	> 100 mm mrad	< 5 mm mrad
Ion extraction	DC AC in afterglow-mode	DC pulsed (ns … µs)
Electron energy Ion energy spread	wide distribution some tens of eV/u	monoenergetic, ΔE < 1eV 1 … 5 eV/u
Beam diameter	up to cm	mm
Distance detector-ionization zone for X-ray, EUV … spectrometry	> 30 cm	5 … 10 cm
RF (monitoring if necessary)	yes	no
Required radiation protection (from electron bremsstrahlung)	strong (but manageable)	low

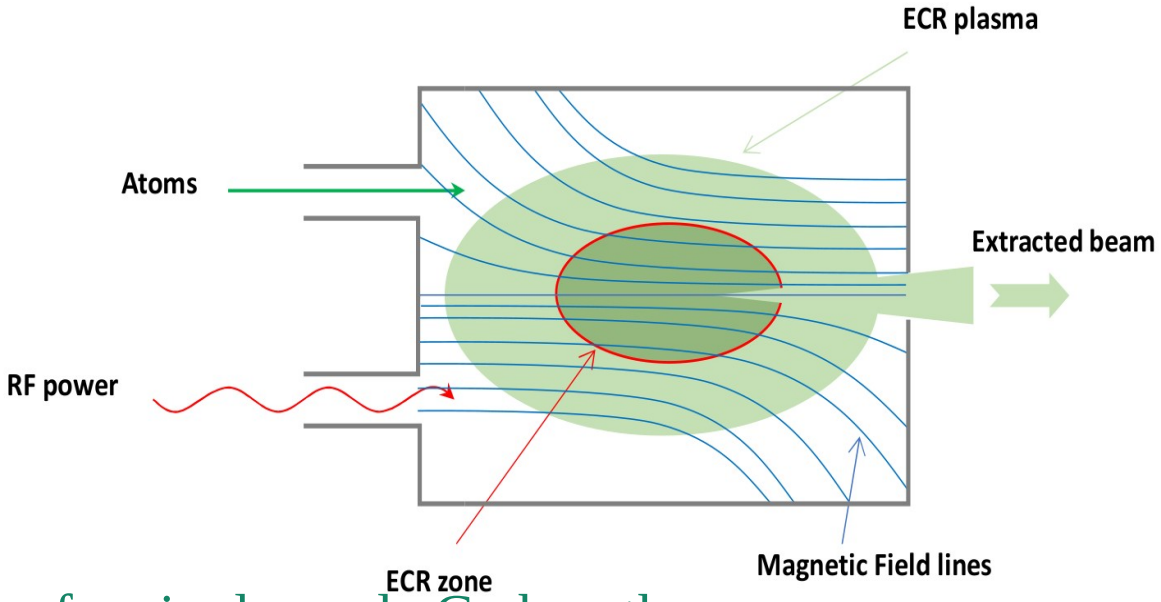
EBIS option



- No facility with highly charged ions in SEE – new research opportunities pointed out by M. Jaksic (IRB) and G. Zschornack (D.I.S.)
  - nanostructuring, materials with new properties, magnetic nanowires, quantum dots, but interest in SEE is unknown
- Could be a starting point of EBIS for therapy development
- In theory PIXE could be done with EBIS (assuming low losses in the rest of machine) but in practice it is more difficult than ECRIS (need to collimate the beam to get enough intensity in small beamlet)
- Intensities way too small for ion therapy (10^8 C^{6+}/s)
- Need HV platform to match to RFQ
- Other companies providing EBIS: Dreeebit, …?

ECRIS option

- Microgan provides enough He^{2+} intensity for single-cycle therapy
- Supernanogan provides base C^{4+} therapy intensities

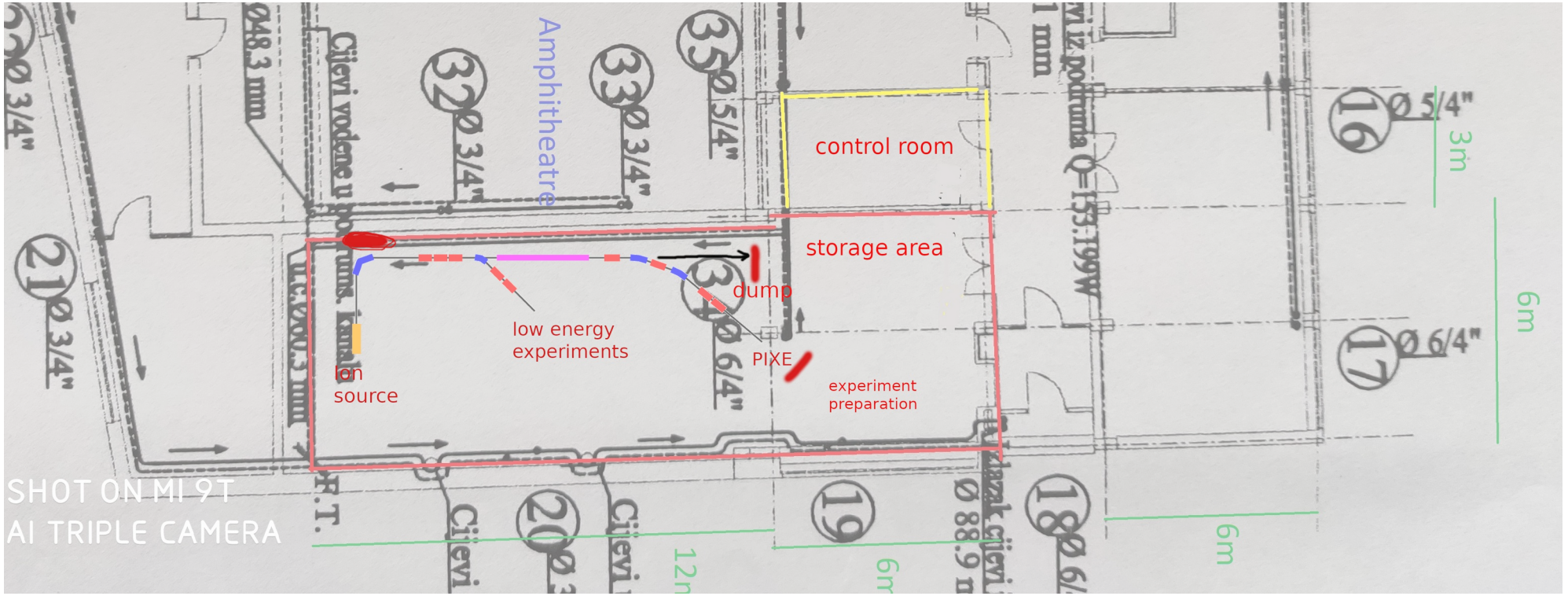


- PK-ISIS could provide intensities for single-cycle Carbon therapy
- Could be used for PIXE (there are PIXE facilities using microgan)
- Experience with RF is useful for RFQ (and DTL)
- ECRIS additional R&D: ion implantation (eg. metallurgy, semiconductors), nanotubes, etc.
- Both, Pantechnik and D.I.S., provide ECR sources, but D.I.S. provides only 2.45 GHz sources, which are not able to produce C^{4+}, while Pantechnik provides 10 and 14.5 GHz devices; other companies specialized in ECR: Sumitomo,…?
- Slightly more demanding with radiation shielding and power supply

Fulfilling the objectives – comparison table

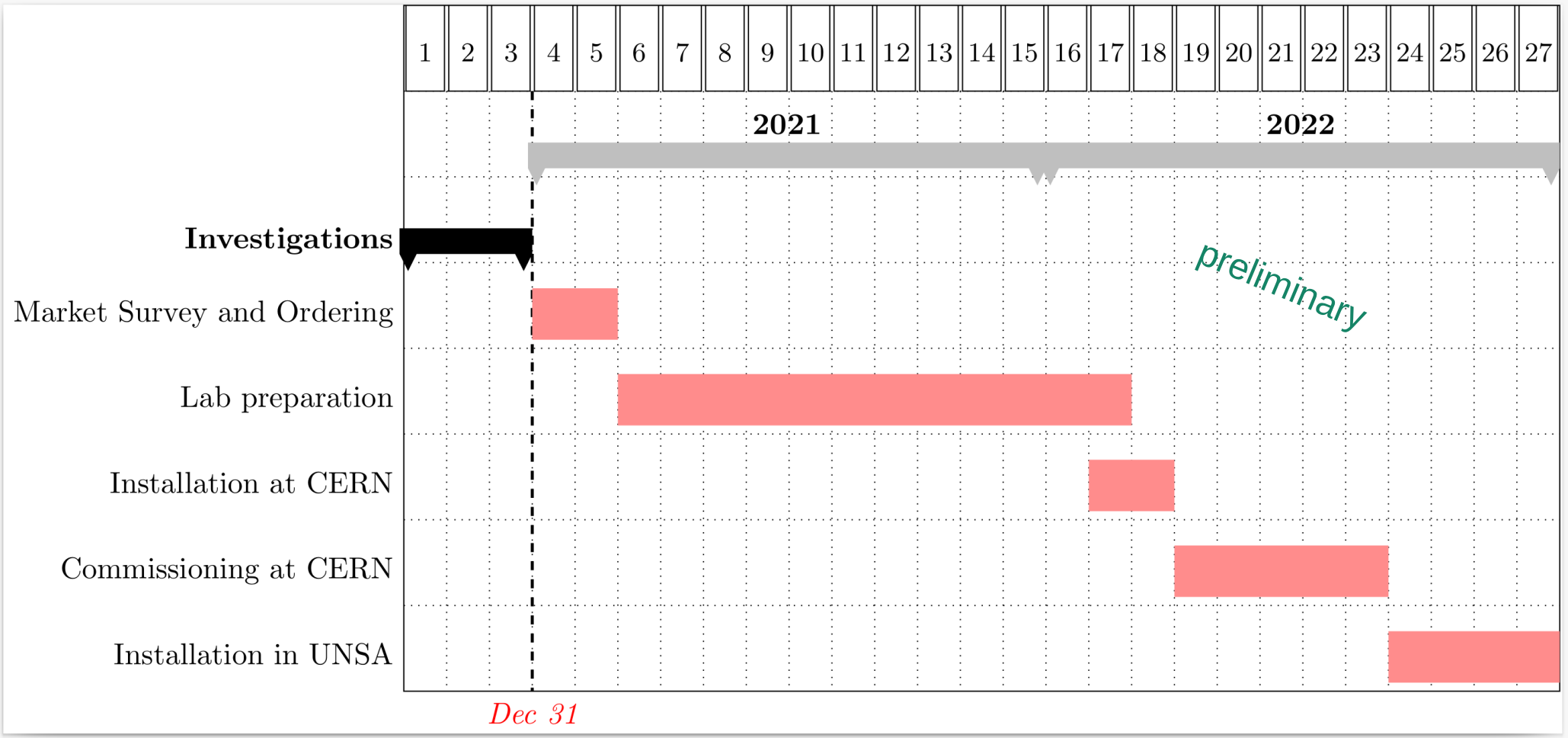
objective	ECRIS	EBIS
accelerator R&D	• HI ECR with Catania • beam cleaning • 750 MHz,q/m=1/2 or 1/3 RFQ	• EBIS as radiotherapy source • 750 MHz,q/m=1/2 RFQ
usefulness for NIMMS/SEEIIST	source can be directly used in SEEIIST	maybe in the future
other research at UNSA: graphene	less (but still)	yes
other research at UNSA: microPIXE	yes, but years of expertise building	rather not
education	yes	yes
international collaborations	CERN, RBI, CNAO, Catania	CERN, RBI, to be investigated

First idea about laboratory layout



Radiation shielding (red blocks) and sound insulation.

More realistic time schedule



Conclusions

- A lot of work has been done, discussions with world-class experts, collection of information
- Fantastic business meetings with D.I.S. Germany and Pantechnik, great support from Ruđer Bošković Institute and Cosylab
- Having IBA facility opens possibilities to apply for IAEA funding
- The proposed room at UNSA is enough for small accelerator lab
- Both source options are interesting, however:
  - ECRIS/Pantechnik offers directly link to SEEIIST
- There is interest in developing and testing of 750 MHz RFQ for Q/M=1/2 (or 1/3) – opportunity to join cutting-edge R&D
- We are less familiar with EBIS (low energy, high charge state) and its uses - we maybe biased – January review will be very helpful

Acknowledgments

- Many thanks to Fehima, Benjamin – great work, please continue
- Aris – thanks for joining
- Yiota
- Elena
- Maurizio
- Partners from D.I.S Germany, Pantechnik, HVEE, Cosylab, i-tech, RBI
- UNSA, especially prof. Elvedin Hasović and prof. Azra Gazibegović-Busuladzić
- Eddy Offerman, the source of the whole “trouble”