Radioactive Ion Beams (RIBs) production at

Speaker: Dragos Nichita, ELI-NP

Physics Opportunities with the Gamma Factory – Nov 30th – Dec 4th, 2020

Overview

1. Introduction

2. ELISOL experimental setup

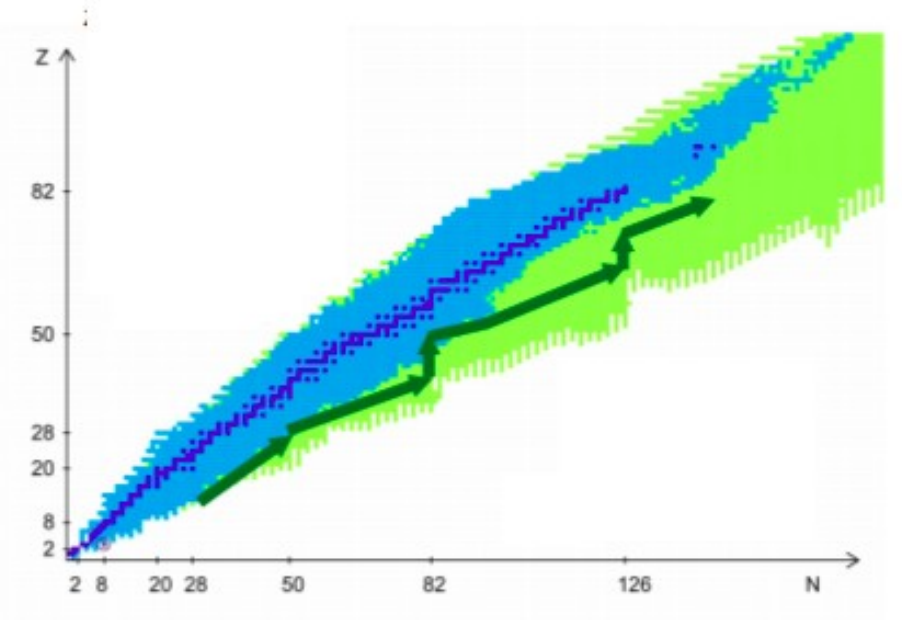
3. GEANT4 simulations for ion yield estimations of an ELISOL-Type setup @ GF

4. Challenges & Conclusions

1. Introduction - Exotic nuclei – RIBs

Thanks to the previous speakers for the nice introduction into RIBs and exotic nuclei.

Radioactive ion beam (RIB) facilities allowed the study of many exotic nuclei.



2. ELISOL setup

ELISOL concept: RIBs by γ irradiation of many thin targets inside a CSC

HADO-CSC also developed at LEB/FAIR (GSI).

CSC @ FRS Ion Catcher: prototype in operation

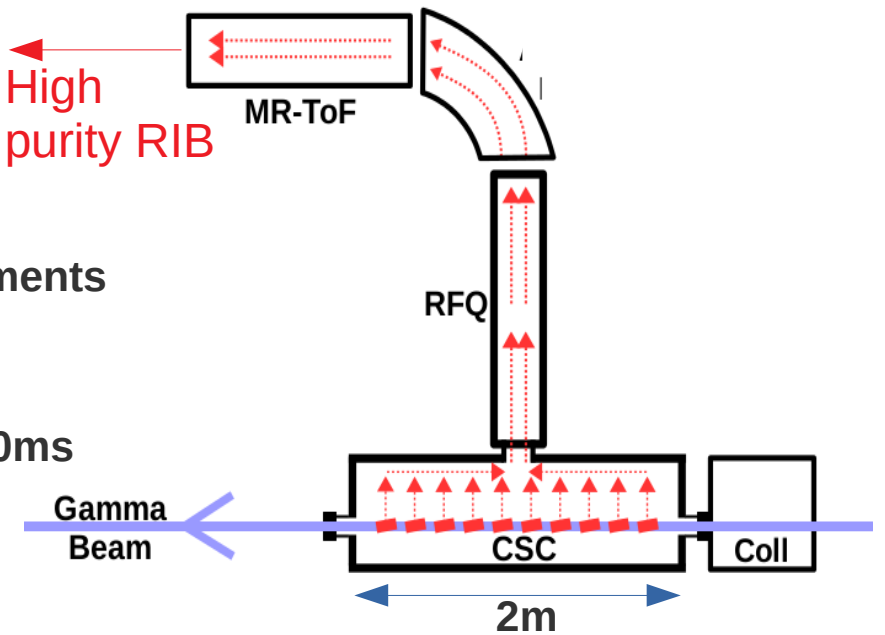
1. Photo-fission in actinide targets: E_γ= 10-20 MeV

2. Many thin targets to allow release of refractory elements

3. Fission fragments thermalized in the gas

4. Ions extracted fast with DC & RF fields: ε>60%, t≈10ms

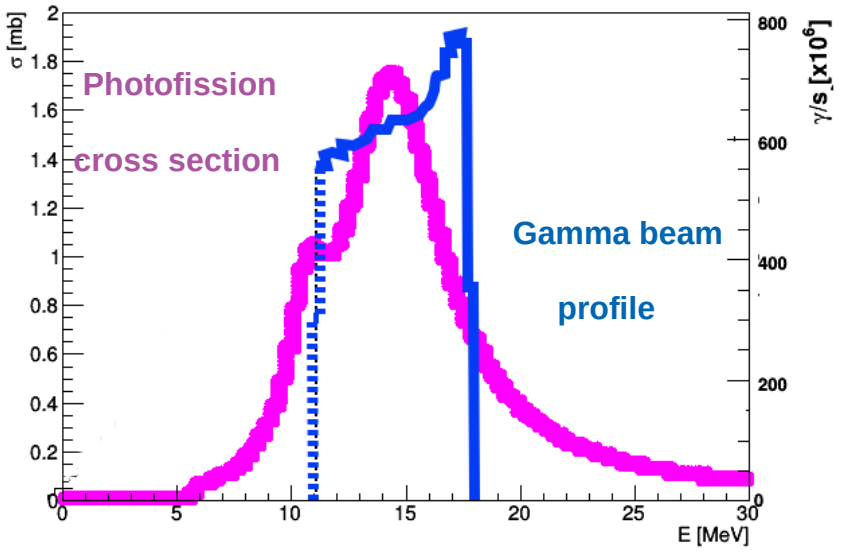
5. High purity beam formed with MR-TOF-MS.

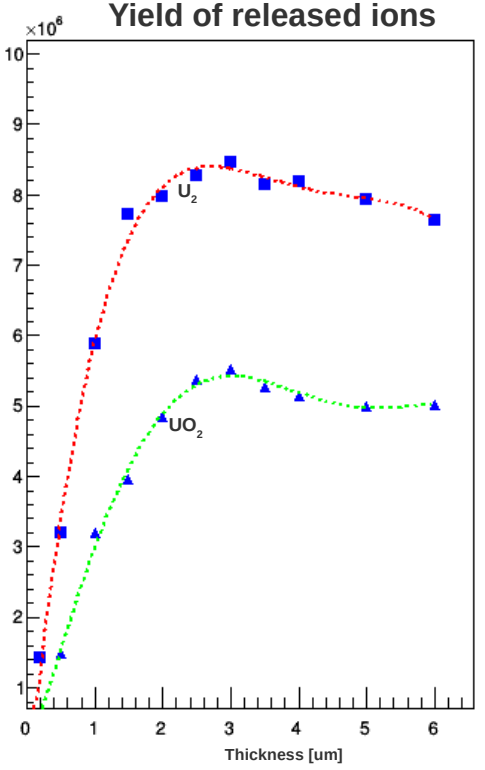


2. ELISOL setup

ELISOL - General optimization for achieving higher yields

Targets number, thickness, angle wrt. the beam, beam energy,...

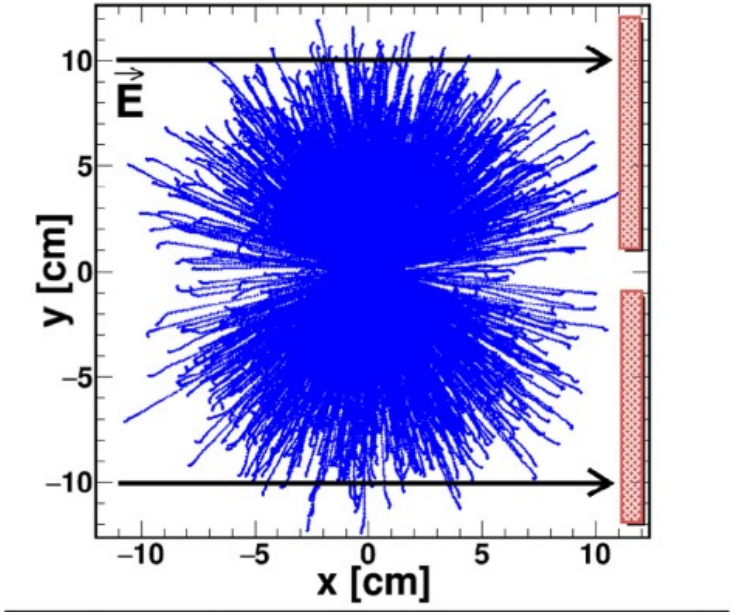




D.Nichita et al., U.P.B. Sci. Bull., Series A, Vol. 82, 2020

2. ELISOL setup

Range of ions → CSC transversal dimensions for stopping



Gamma beam along z axis.

P. Constantin et al., NIMB (2017)

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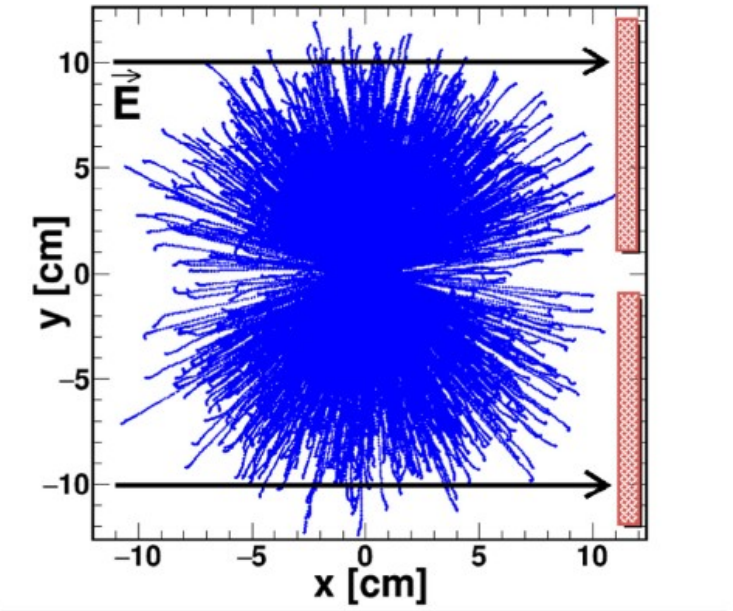
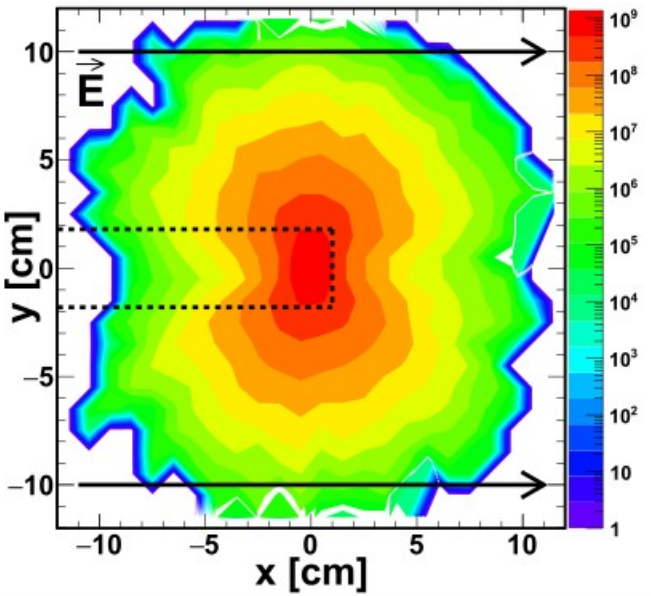


Gamma beam along z axis.

Energy deposit in gas → Space charge

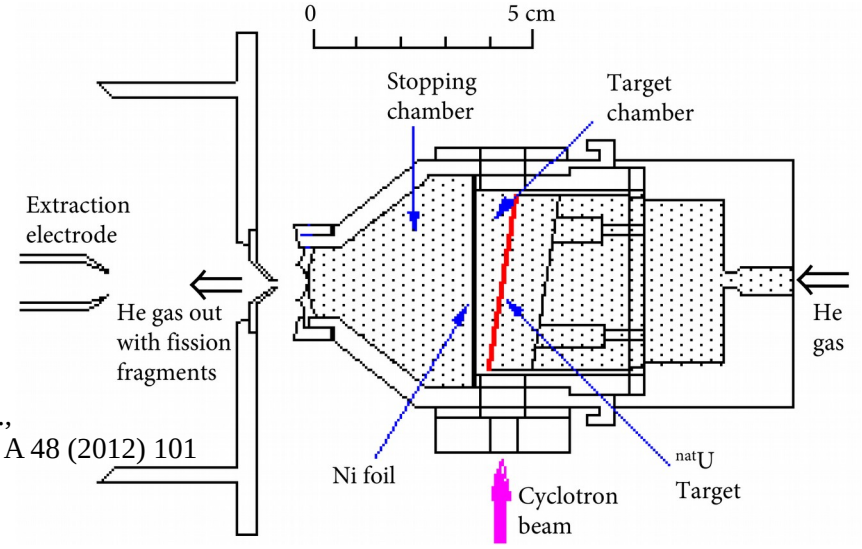
(cloud of He+ ions)



P. Constantin et al., NIMB (2017)

2. Alternative gas cells

– large space charge → flow extraction
– just one target: 10cm vs 200cm (HADO-CSC)
– small extraction efficiency ~0.1-1%
– large extraction time ~100ms
– ion neutralization → selective RIB formation (e.g. with laser)

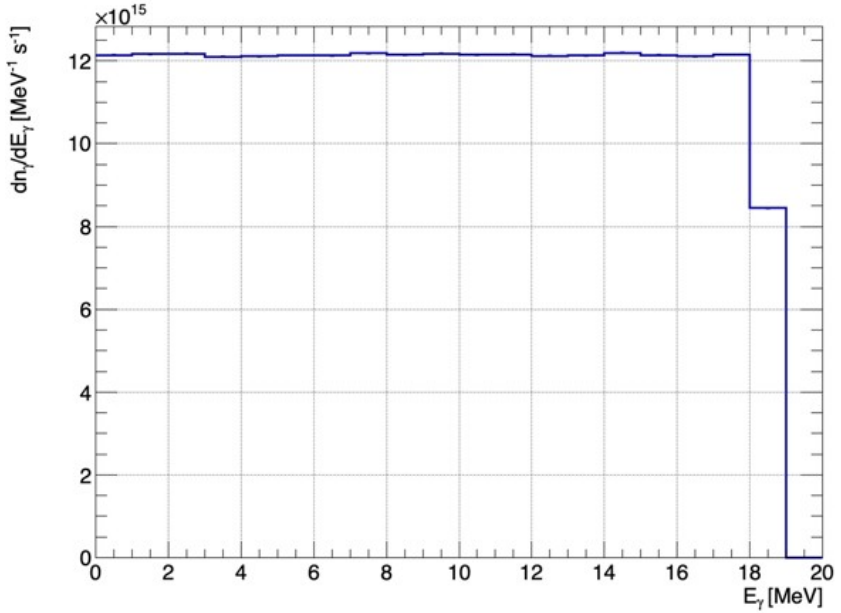


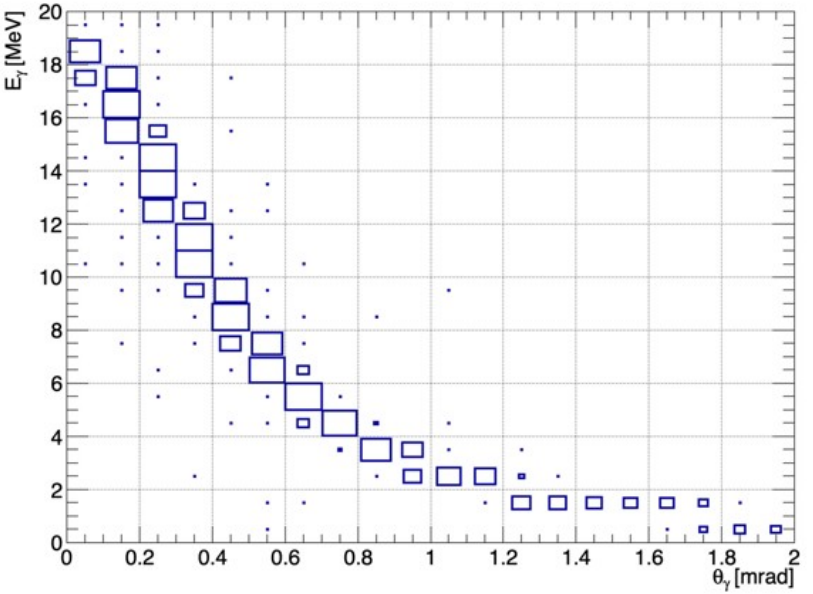
H. Penttilä et al.,
Eur. Phys. Jour. A 48 (2012) 101

IGISOL @ JYFL
^{nat}U target: 15mg/cm^2 (~8μm)
Ni foil: 1mg/cm^2 (~1μm)
He gas: 250mbar

3. GEANT4 simulations for yield estimations of ELISOL-Type setup @ GF

Gamma Factory energy distribution

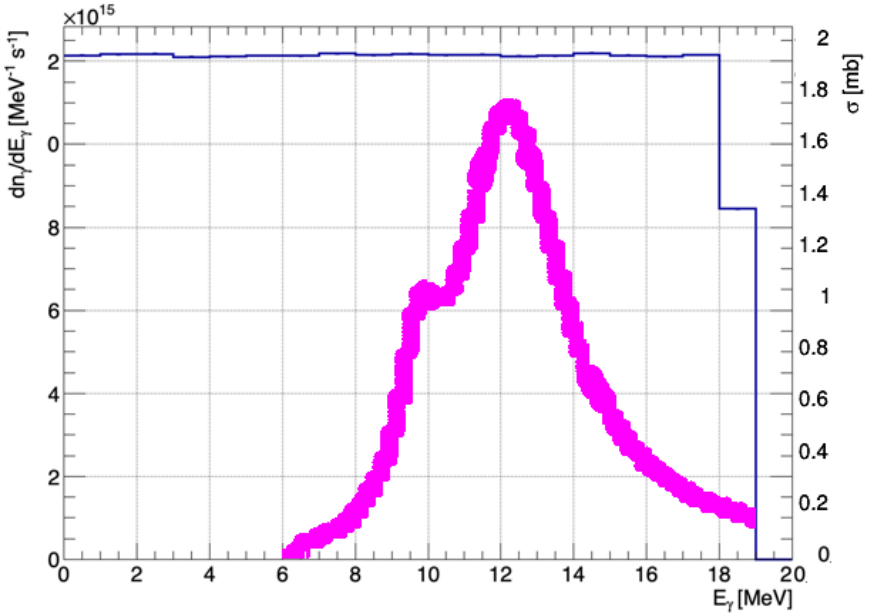


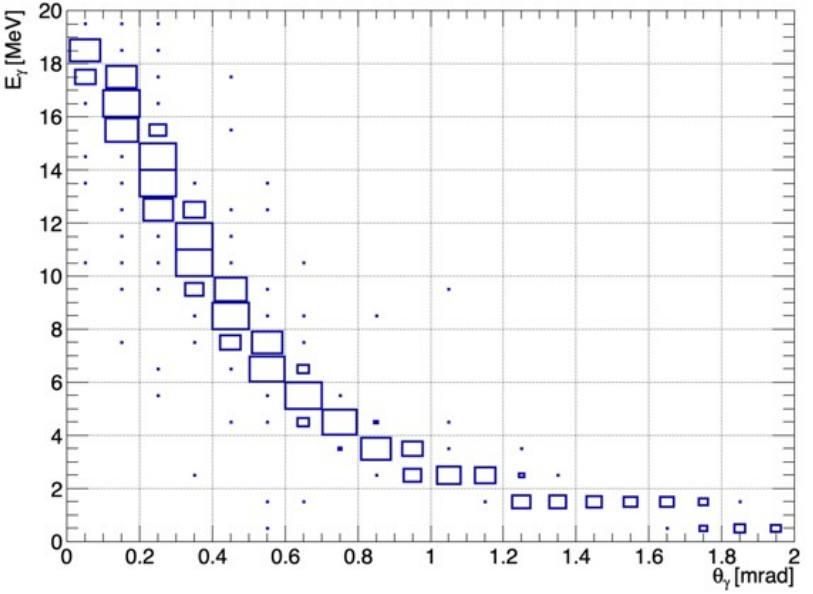


GF distributions provided by
Dr. M.W. Krasny & Dr. W. Placzek

3. GEANT4 simulations for yield estimations of ELISOL-Type setup @ GF

Gamma Factory energy distribution overlapping with the photo-fission cross section





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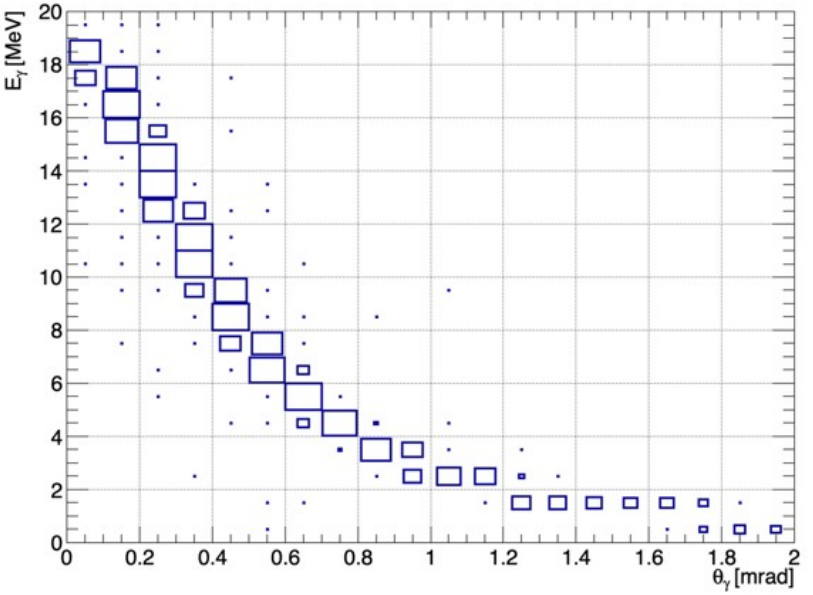
Dr. M.W. Krasny & Dr. W. Placzek

Gamma Factory energy distribution overlapping with the photo-fission cross section

2 positions of the setup have been simulated:

50 meters away from the interaction point

100 meters away from the interaction point



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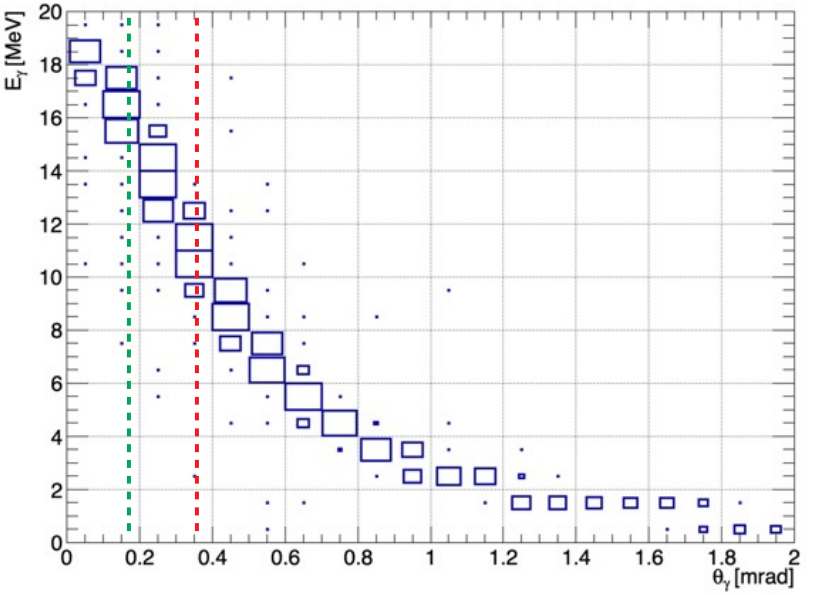

3. GEANT4 simulations for yield estimations of ELISOL-Type setup @ GF

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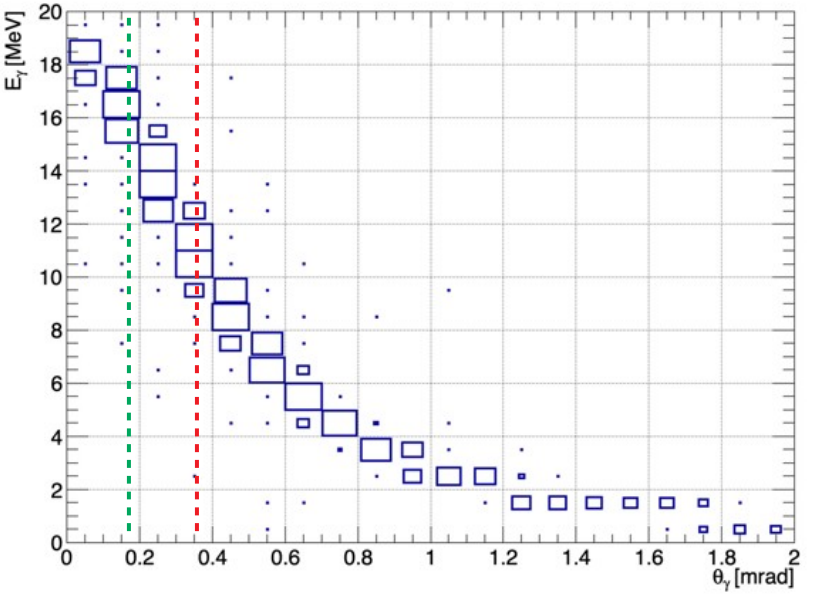


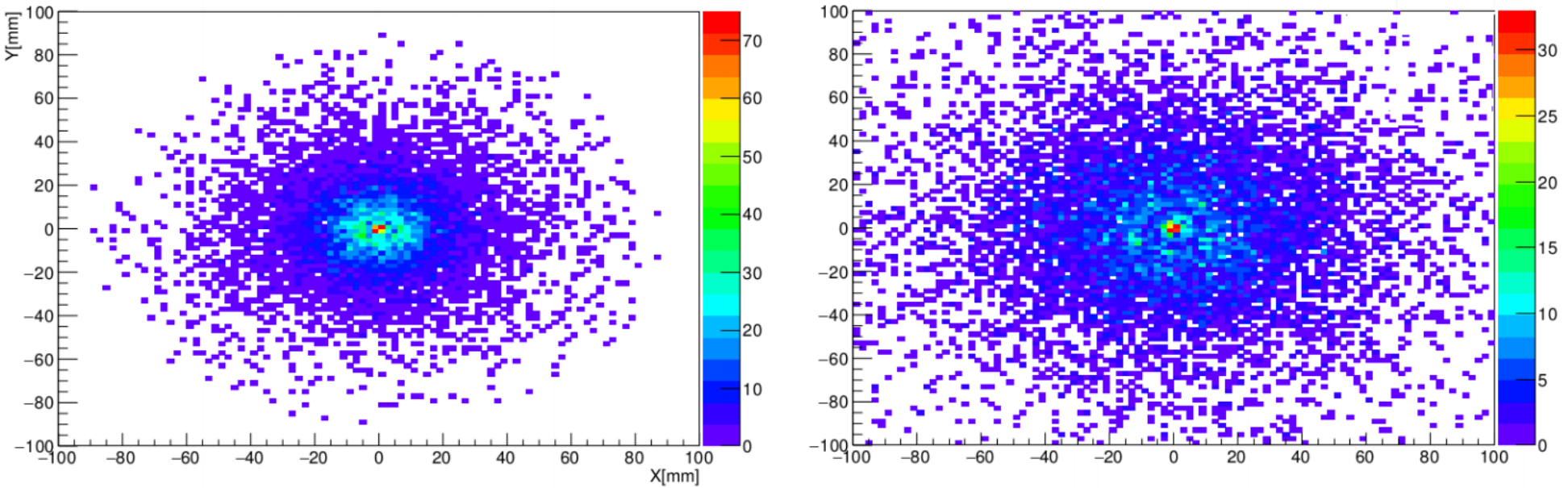
Nice beam features:

1. **Tunable E_{max} for optimal target overlap;**
2. **Tunable repetition rate (time structure) above t – 10ms (for space charge control)**

3. GEANT4 simulations for yield estimations of ELISOL-Type setup @ GF

GEANT4 Simulations showing beam profile for the two cases

(50m left and 100m right)



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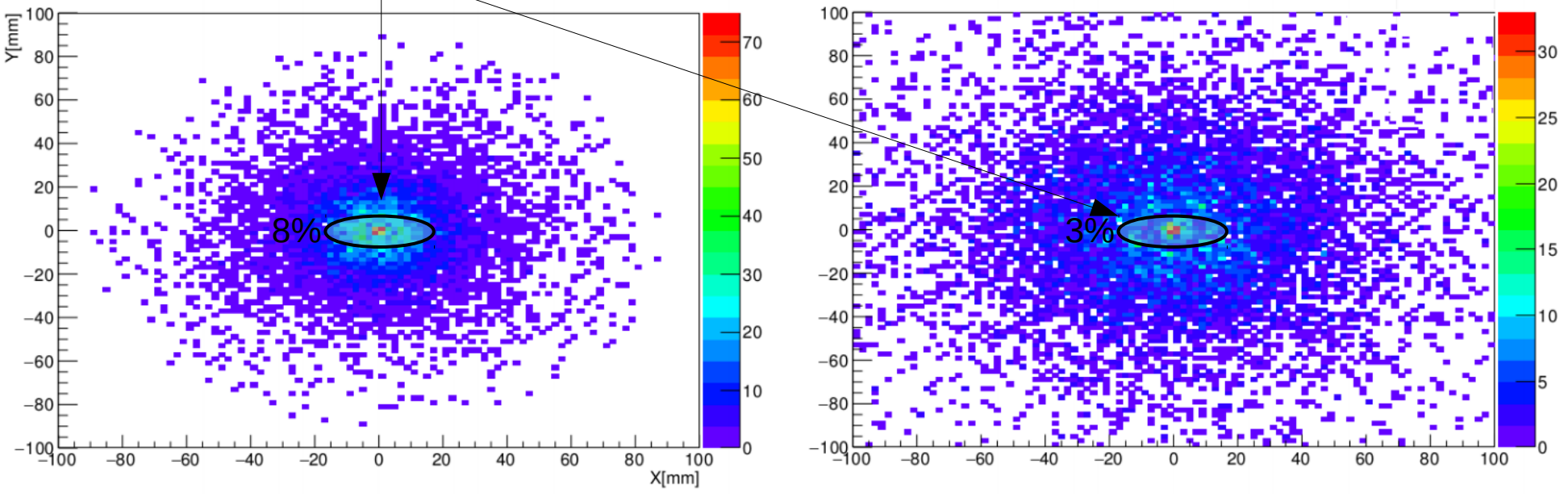
GEANT4 Simulations showing beam profile for the two cases

Intensity hitting the target system (50m left and 100m right)



GEANT4 Simulations Results:

ELISOL @ Gamma Factory (CERN)

50 meters

2.25 x 10^{12} ions / second (produced)

1.15 x 10^{12} ions / second (released from target)

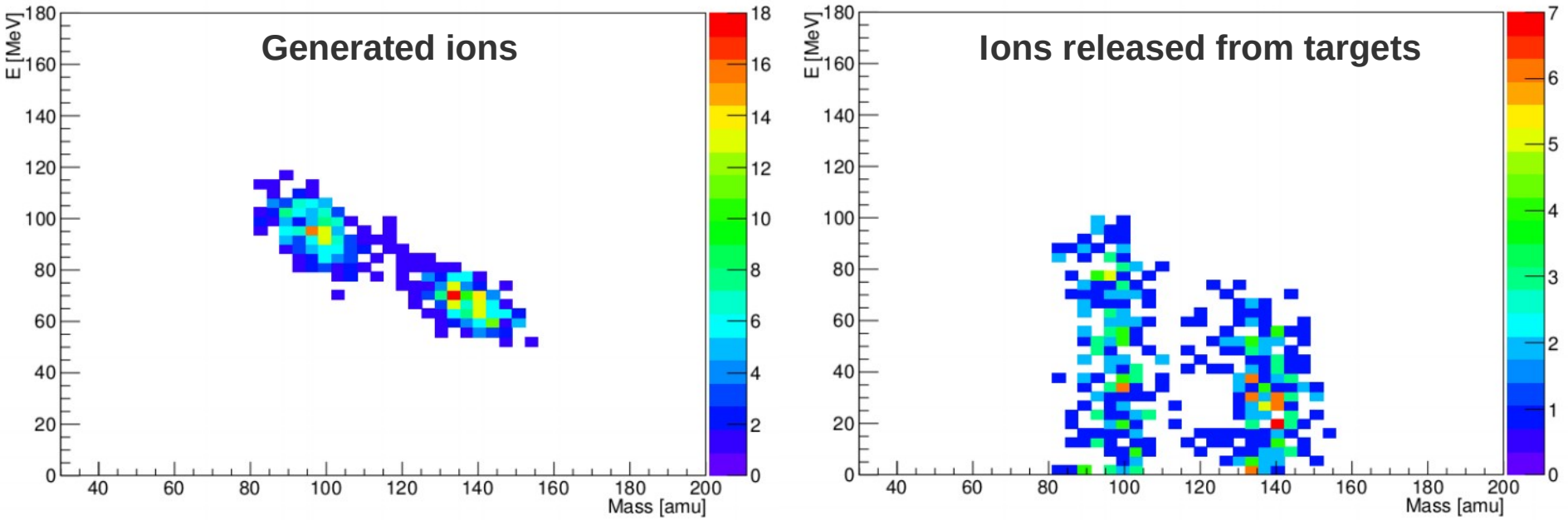
100 meters

0.9 x 10^{12} ions / second (produced)

0.49 x 10^{12} ions / second (released from target)

3. GEANT4 simulations for yield estimations of ELISOL-Type setup @ GF

Energy vs Mass distribution



Mean energy of released ions: 39.8 MeV

4. Challenges & Conclusions

0.49 x 10^{12} ions/second

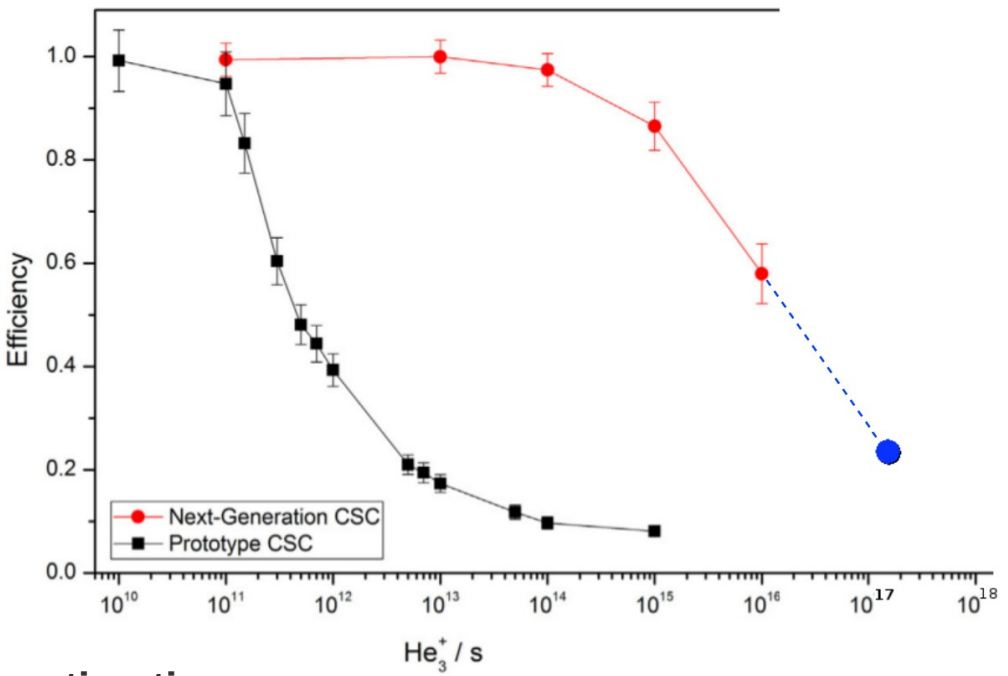
each depositing a mean energy of 39.8 MeV

the total deposited energy in the He

approx 1.95 x 10^{19} eV per second.

41 ev as effective ionization energy for one

He-e pair to → 4.75 x 10^{17} He+ / second



T. Dickel et al. NIM B, 376 (2016)

Interesting to know the GF time structure

Run full SIMION simulations for more accurate estimations

Conclusions

1. Next generation CSCs could solve at least partially the space charge challenge

Some concepts already emerged for elevating the extraction efficiency and extraction times.

Our proposal → Tackle refractory elements, rare isotopes (high yields) and short lived.

2. Even with less than 10% extraction efficiency we can produce RIB with flux of 10^{10} ions / second

which is still one of the best yields available worldwide.

Message: Huge opportunity to produce high yield RIB at the GF and touch hardly available nuclei as refractory elements

Totally complementary with big specialized facilities like ISOLDE, Ion Catcher, RIKEN, IGISOL, etc.

Group & collaboration acknowledgments - THANK YOU!

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Jagiellonian University (Poland): W. Placzek

EUROPEAN UNION

Competitiveness Operational Programme (COP)

Structural Instruments 2014-2020