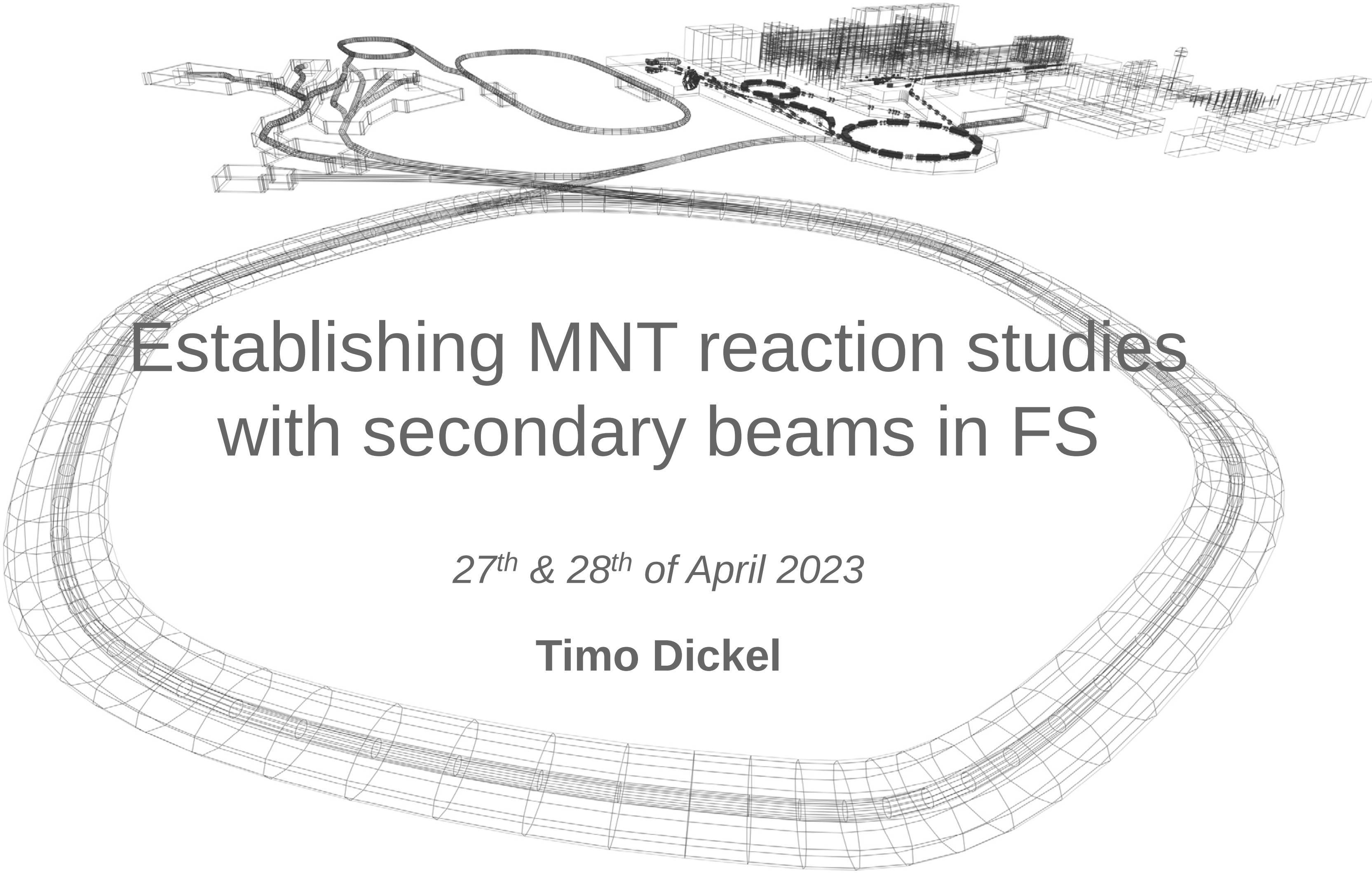


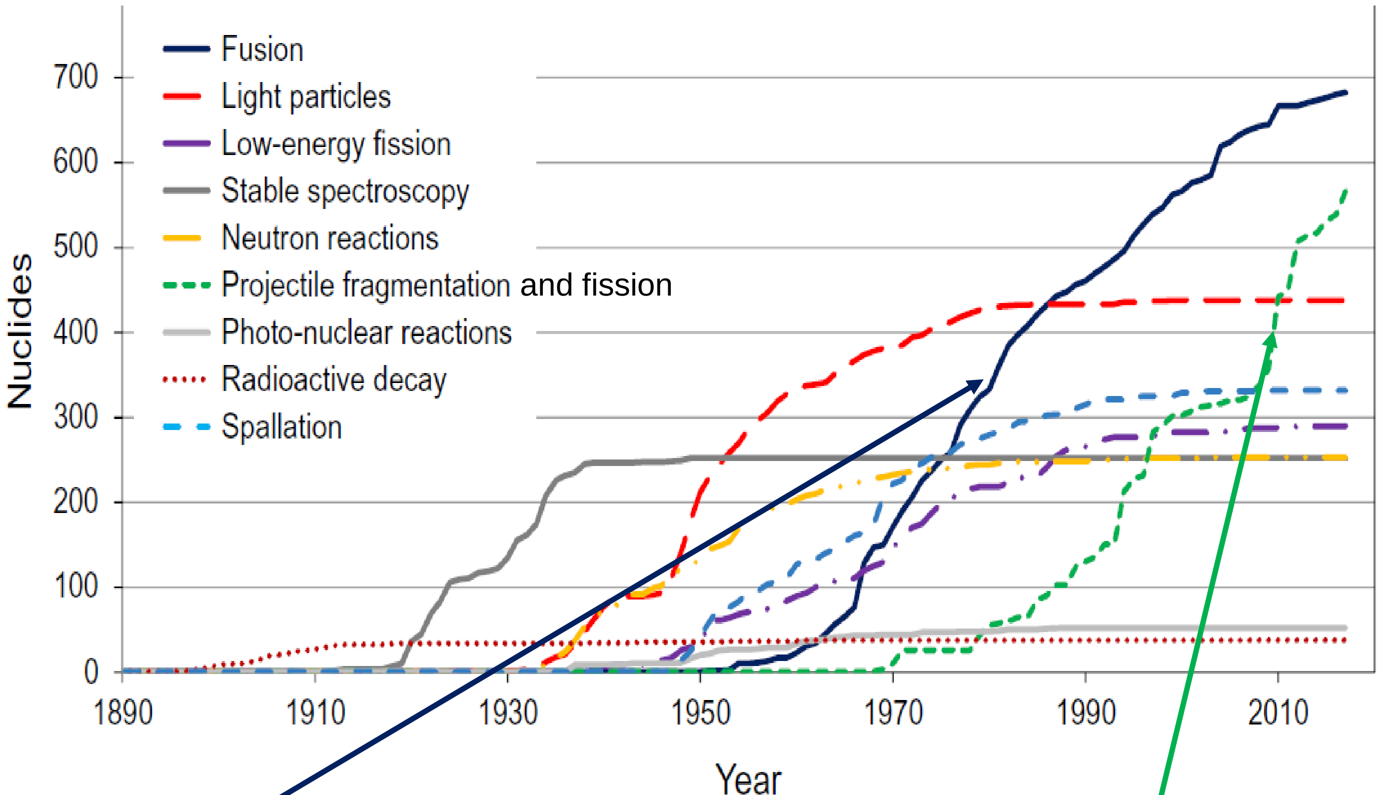
Establishing MNT reaction studies with secondary beams in FS

27th & 28th of April 2023

Timo Dickel

Do we need a “new” production method for exotic nuclei?

History of production methods for new isotopes

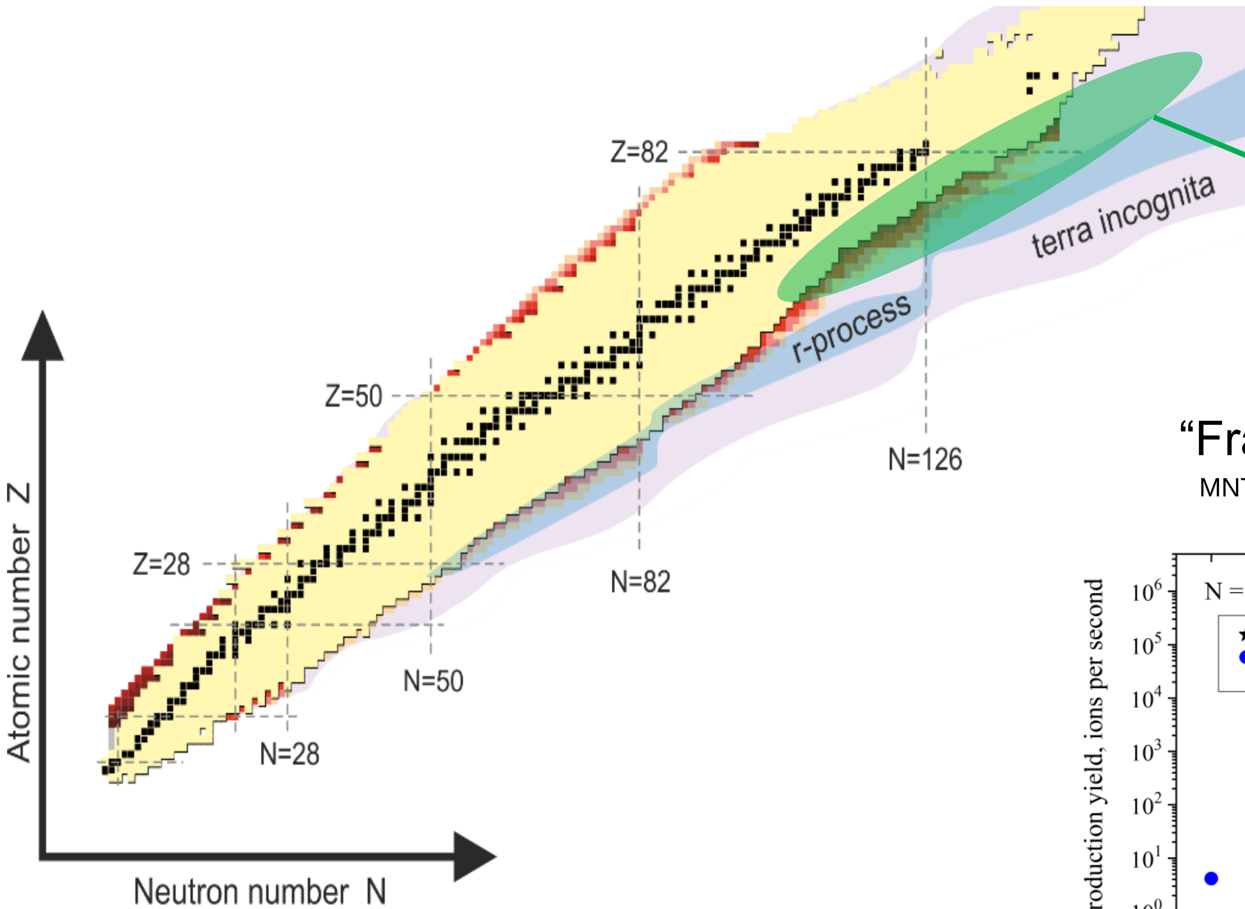


@GSI/FAIR

- Fusion still contributes (SHIP & TASCA)
- Current “work horse”: projectile fragmentation (FRS) and fission (Super-FRS)
- What is next?

M. Thoennessen, Int. J. Modern Phys. E, 27, 1830002, (2018).

Explore the optimal conditions to produce new nuclei in the Terra Incognita?

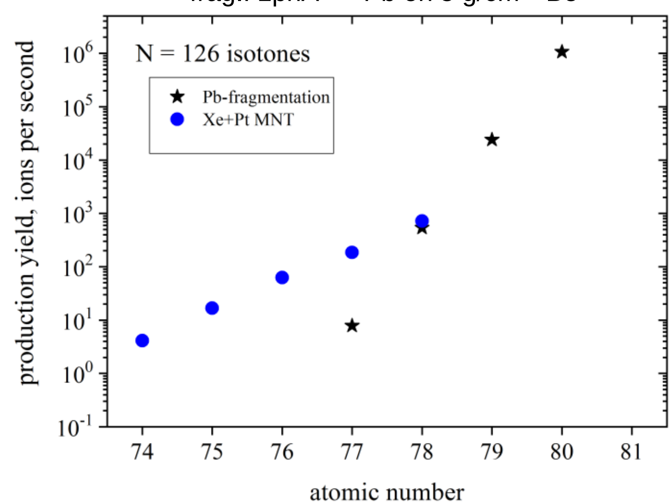


Hard or impossible to reach with fragmentation or fusion of stable beams

"Fragmentation vs. MNT"

MNT: 20pnA ^{136}Xe / ^{238}U on 2 mg/cm² ^{198}Pt

frag.: 1pnA ^{208}Pb on 5 g/cm² ^{9}Be



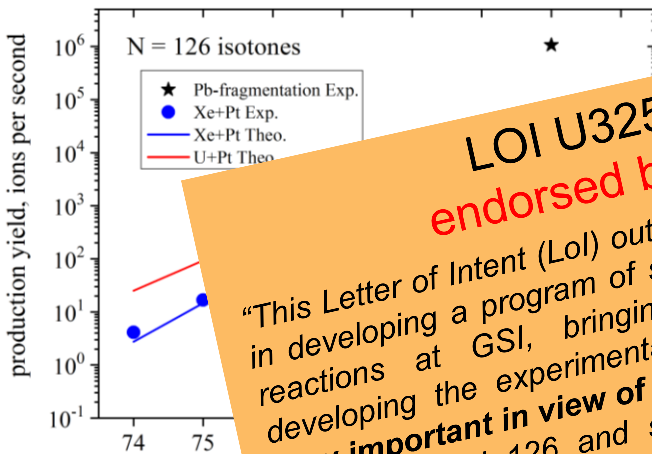
Y. X. Watanabe et al., PRL115, 1–5 (2015)

The most promising “new” production method for exotic nuclei and new isotopes

- Multinucleon Transfer Reactions (MNT)

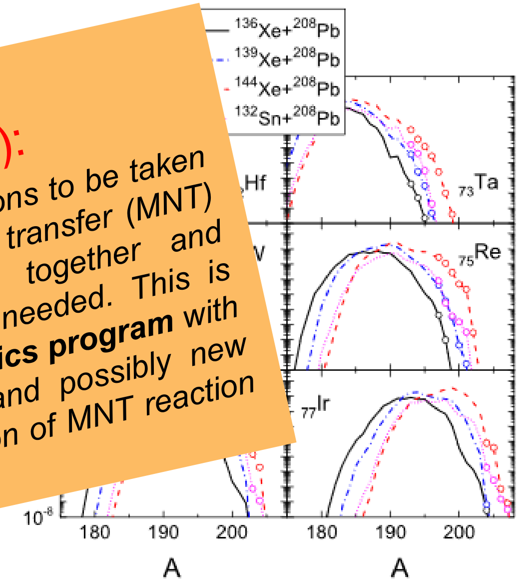
Stable beams: ^{136}Xe or ^{238}U

MNT: 20pnA ^{136}Xe on 2 mg/cm² ^{198}Pt | frag.: 1pnA ^{208}Pb on 5 g/cm² ^{9}Be *



Y. X. Watanabe e…
A. Karpov, Priva… (2020)
V. V. Saiko et al., …RC 99, 014613 (2019)

Secondary beams



L. Zhu et al., PLB 767 (2017) 437–44

LOI U325: Dickel et al.
endorsed by GPAC (2020):

“This Letter of Intent (LoI) outlines the future directions to be taken in developing a program of study of multi-nucleon transfer (MNT) reactions at GSI, bringing interested parties together and developing the experimental and theory forces needed. This is **very important in view of the future FAIR physics program** with a focus on N=126 and super heavy nuclei, and possibly new neutron-rich beams delivered following separation of MNT reaction products. **The committee supports this LoI.**”

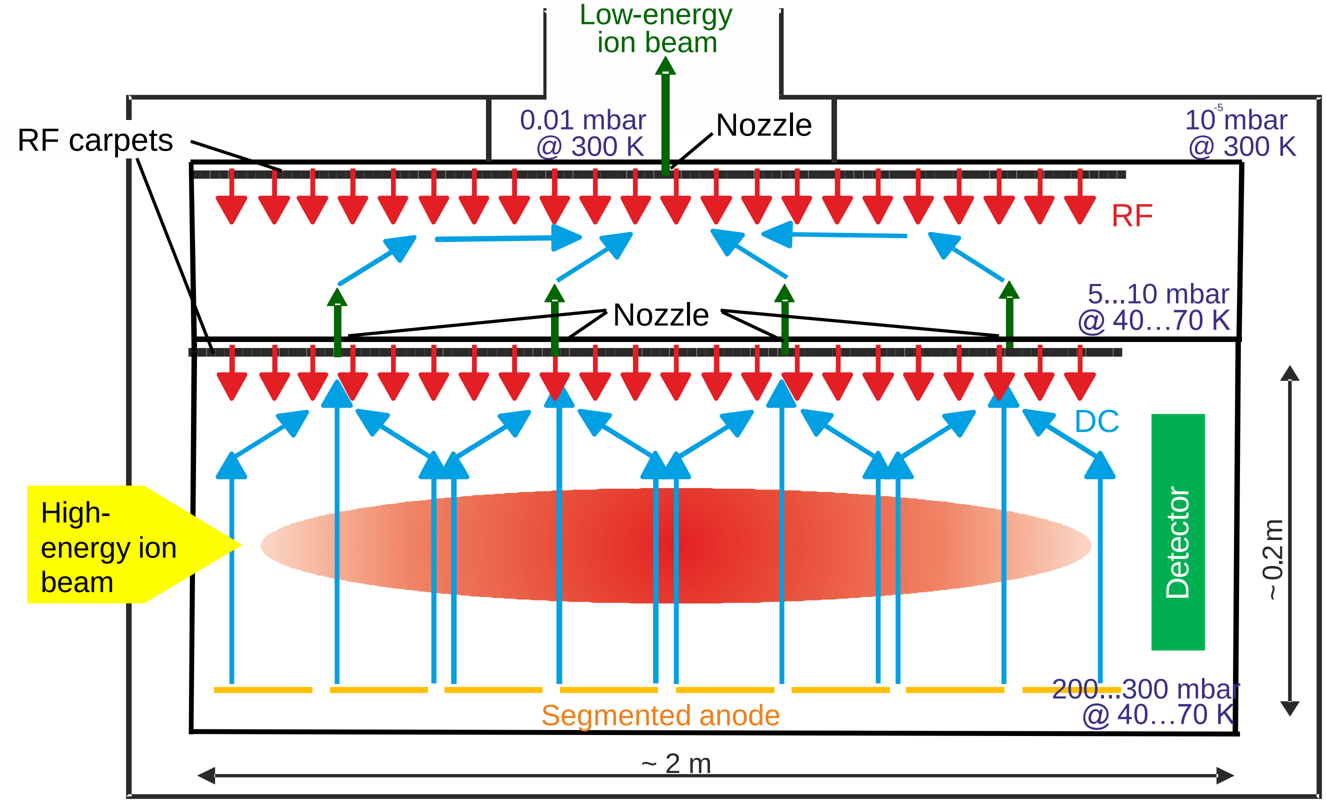
- Better understanding needed: systematic studies (cross sections,…) on the influence of isospin, shell effects, deformed nuclear shapes.
- Beams with large N/Z, e.g. ^{136}Xe, ^{238}U or secondary beams (fission fragments)
- Dedicated instrumentation needs to be build

Strategy for MNT experiments at GSI/FAIR

	today → (ES) / FS
UNILAC	**Investigation optimal stable beam, energy and target** Reaction Studies with **TOSCA** U323 + G174 **LINAC Ion Catcher (^{238}U, heavy products)** mass spectrometry · new isotopes · nuclear spectroscopy
FRS	**Pilot experiments** with slowed down beams (stable and near stable) @ **FRS Ion Catcher**, G117
HELIAC	**Precision experiments with stable beams** **LINAC Ion Catcher** new isotopes · mass spectrometry · nuclear spectroscopy
Super-FRS SIS100 & PSU	**Super-FRS Ion Catcher & Upgraded TOSCA** **new isotopes with secondary beams**

The Super-FRS CSC

	FRS CSC	Super-FRS CSC
Areal density (He)	6 mg/cm^2	28…40 mg/cm^2
Extraction time	25 ms	5…15 ms
Rate capability	10^4/s	10^7/s



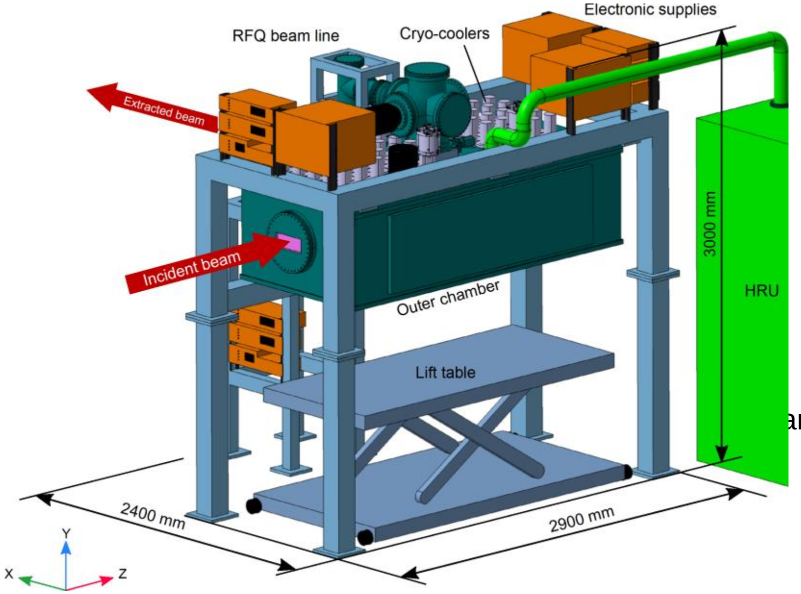
- Higher density
- Longer stopping volume
- Shorter Extraction path
- Higher Field strength

TDR approved

T. Dickel et al., NIMB 376 (2015) 216

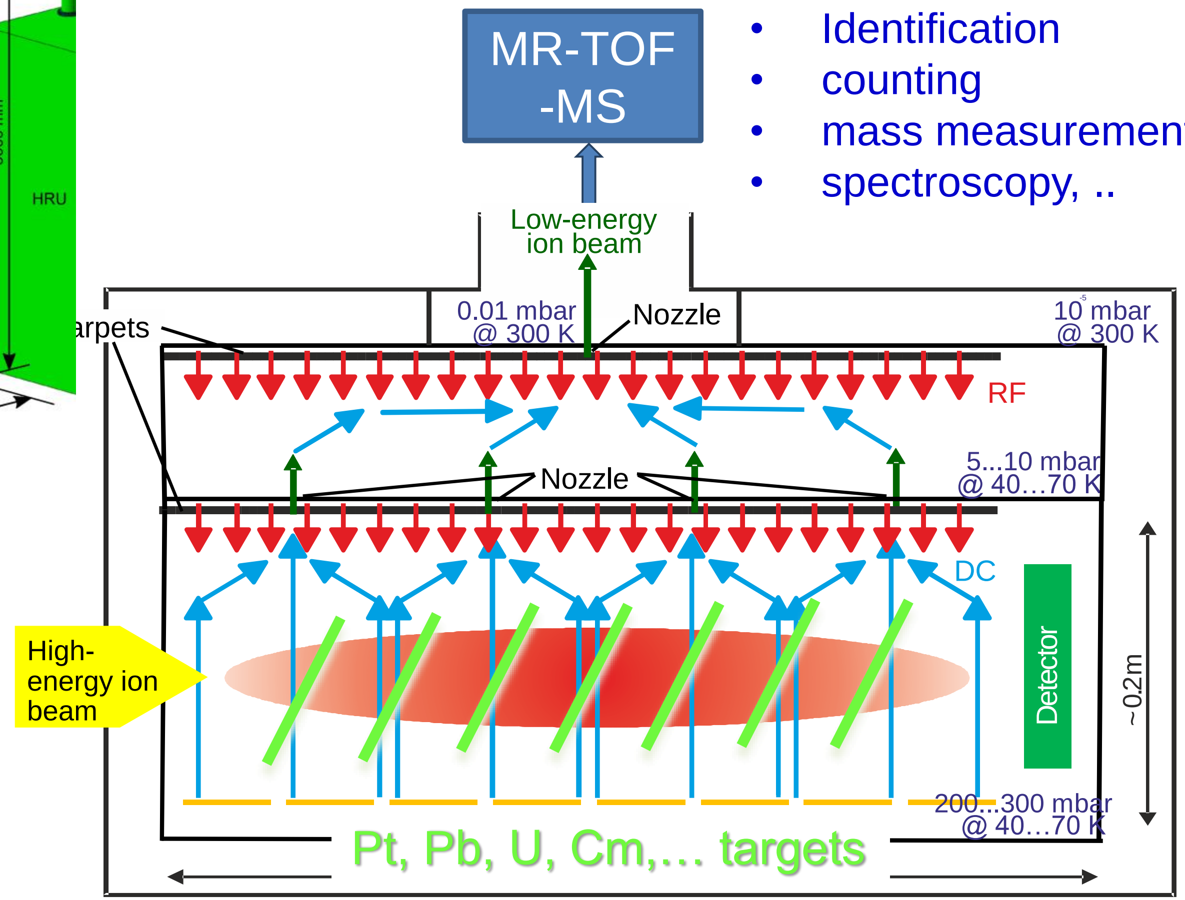
Secondary beams at the Super-FRS

Super-FRS Ion Catcher with reaction targets inside



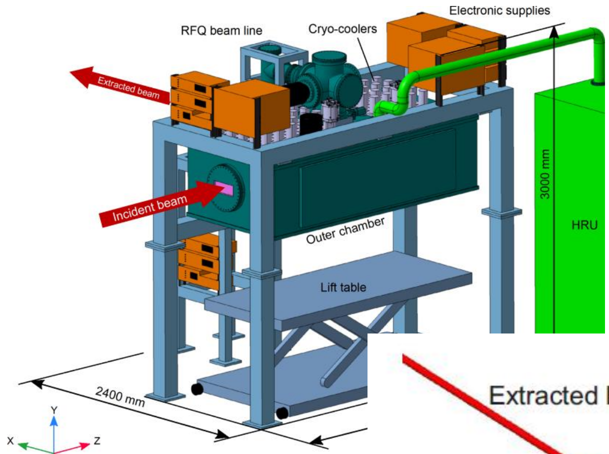
higher rates at the Super-FRS and full scale CSC → very exotic nuclei produced with secondary beams

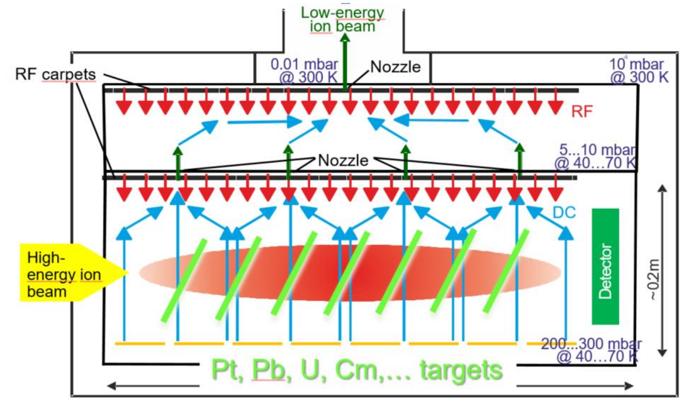
- Identification
- counting
- mass measurement
- spectroscopy, ..

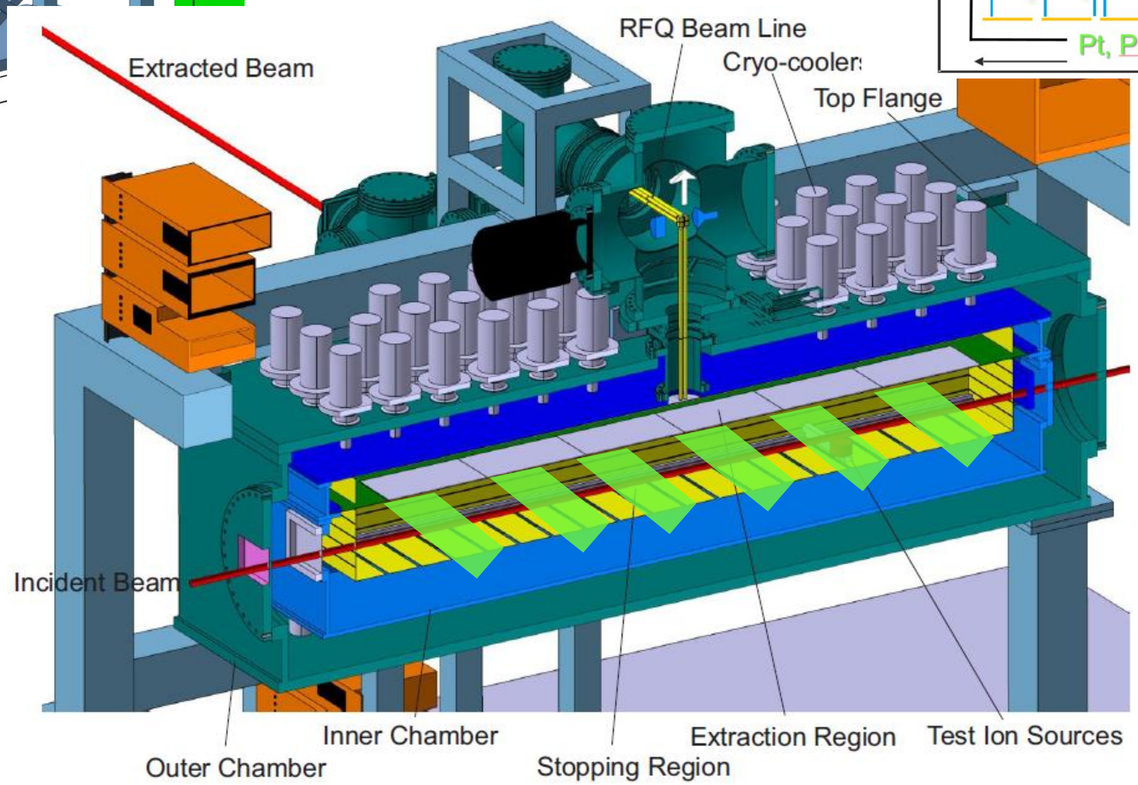


pure or "cocktail" beams

Super-FRS Ion Catcher with reaction targets







Target

Short, mid and long-term plans with MNT

short term:

Approved G-PAC Proposal:

- feasibility of secondary beam experiments
- systematic studies (cross-sections)
- mass measurements
- search for new isomeric states

mid term:

Experiments with primary beam at UNILAC/HELIAC

- systematic studies (cross-sections)
- mass measurements
- search for new isotopes and isomeric states
- separated beams for decay and laser spectroscopy

long term:

Most exotic Isotopes produced with secondary beams at the Super-FRS

- orders of mag. higher secondary beams than FRS
- Super-FRS CSC can work with target stack and therefore use full range of fragments

Start in ES or early FS with test of concept and secondary beams

Full potential of method with full FAIR intensities ($>10^{11}$)

Collaboration

Timo Dickel, Emanuele Vardaci, Paul Constantin, Daler Amanbayev, Samuel Ayet, Dimiter Balabanski, Sönke Beck, A. Bogachev, C. Borcea, R. Borcea, M. Boromiza, S. Calinescu, Olga Charviakova, Antonio Di Nitto, Alexander Eremin, Hans Geissel, Jürgen Gerl, Magdalena Gorska, Florian Greiner, Mohini Gupta, Emma Haettner, I. Harca, Yoshikazu Hirayama, Christine Hornung, J. Itkis, Alexander Karpov, Anu Kankainen, Birgit Kindler, S. Khlebnikov, G. Knyazheva, Eduard Kozulin, Gabriella Kripko-Koncz, G. La Rana, Bettina Lommel, Israel Mardor, Gottfried Münzenberg, A. Negret, Dragos Nichita, Kirill Novikov, A. Olacel, Concetta Parascandolo, Zygmund Patyk, I. Pchelinsev, C. Petrone, Dimitra Pierroutsakou, Stephane Pietri, Wolfgang Plaß, Zolt Podolyak, Alessandro Pulcini, Moritz Pascal Reiter, Adrian Rotaru, F. Rotaru, Vyacheslav Saiko, Christoph Scheidenberger, Anamaria Spataru, M. Stanoiu, W. Trzaska, I. Vorobev, Yutaka Watanabe, John Winfield, J. Zhao and the Super-FRS Experiment Collaboration

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