

The Norwegian ISOLDE program

Aka: Non-LHC Nuclear Physics
Experiments

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Post doc @ UiO

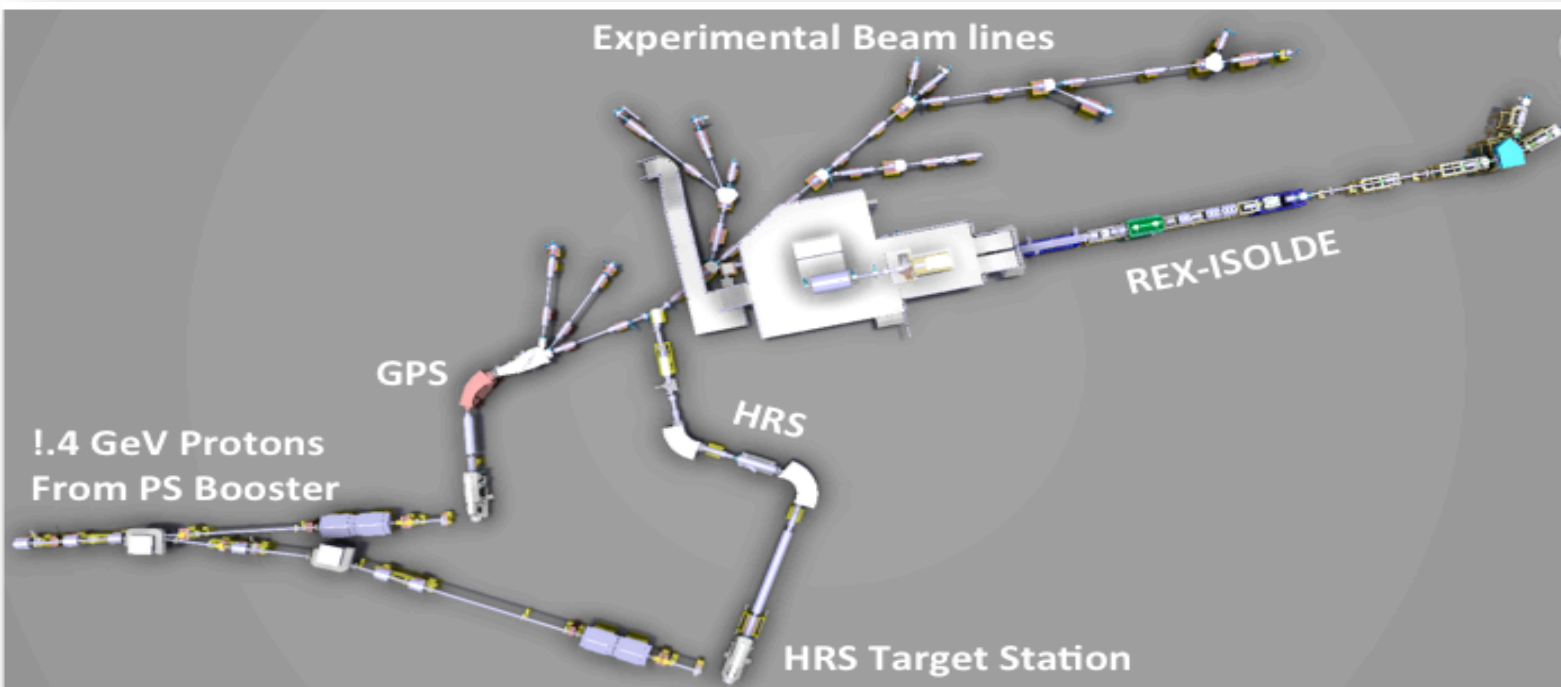


UiO : **Department of Physics**
University of Oslo



The ISOLDE facility and the Norwegian program

- ISOLDE is the CERN radioactive beam facility (approved 50 y ago!)
- The largest selection of isotopes of any ISOL facility worldwide
- Provides low energy or post-accelerated beams
- Norway is involved in experiments with post-accelerated beams
- We became members again in 2007 (10 publications since then ref. handout)
- I will present our main areas of research at ISOLDE



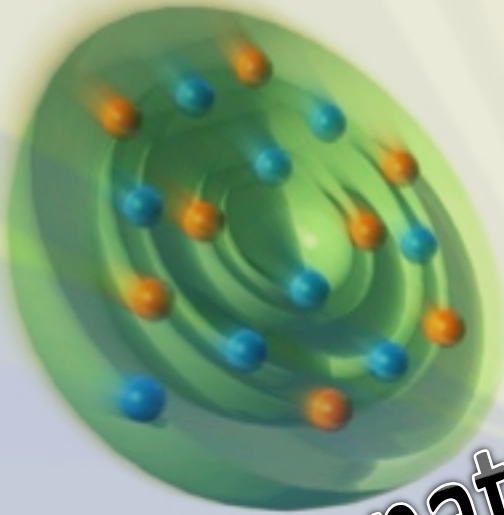
Ongoing projects to increase the experimental possibilities at ISOLDE:

- HIE-ISOLDE (2010-) (43 M€)
 - Energy upgrade of post accelerated beam (2015-)
 - Increased intensity from Injectors
 - ✓ Linac 4 (5×10^{13} – 1×10^{14})
 - ✓ PSBooster to 2 GeV
 - Beam purity and emittance: New target materials & LIST
 - ✓ ISCOOL: DS of new RFQ Cooler and Buncher
 - ✓ HRS: DS for higher mass resolving power
 - ✓ EBIS: DS for EBIS upgrade
- Test storage ring (TSR) @ ISOLDE (16 M€)



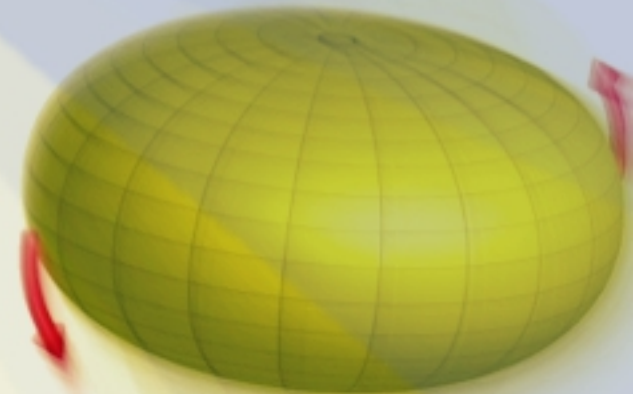
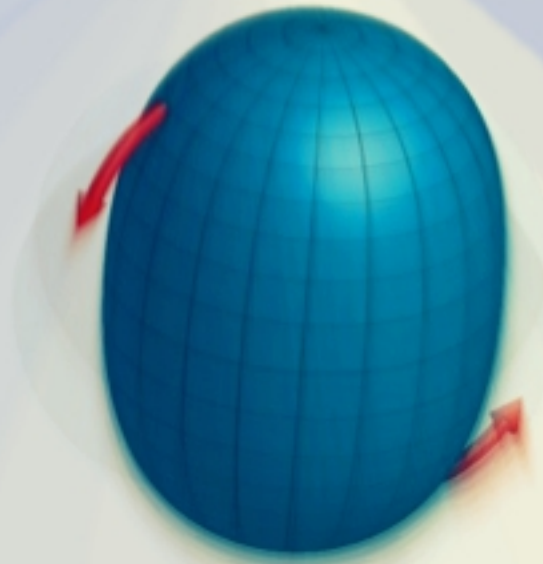
shell structure

pairing

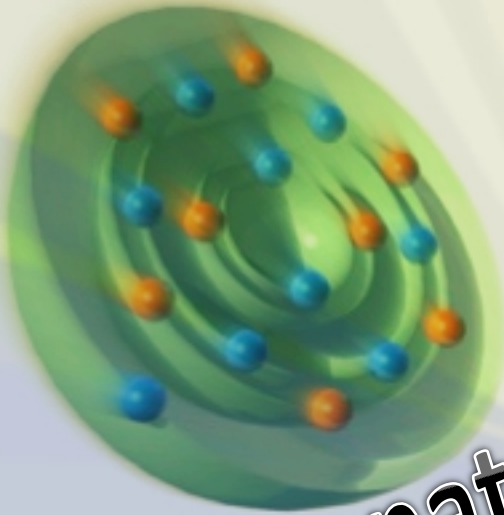


What is the nature of nuclear matter?

deformation



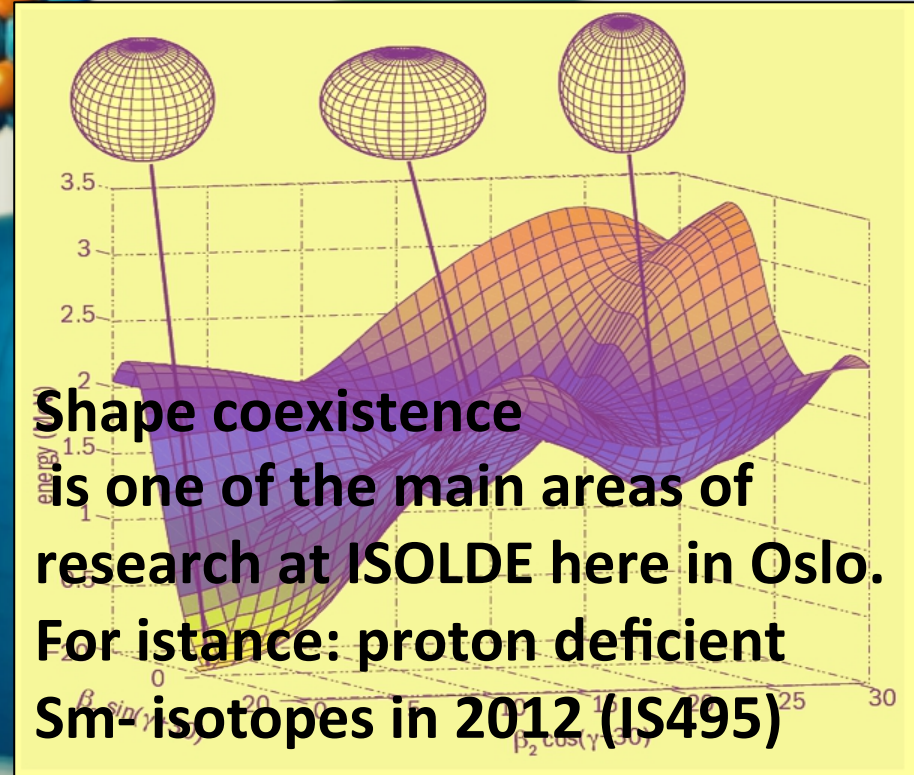
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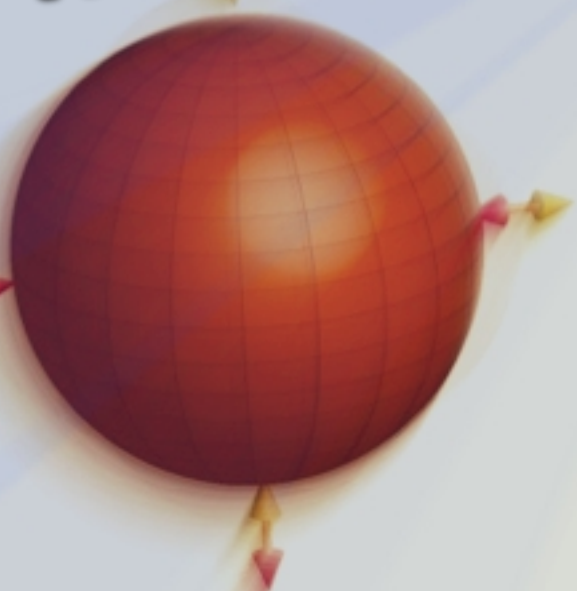
pairing



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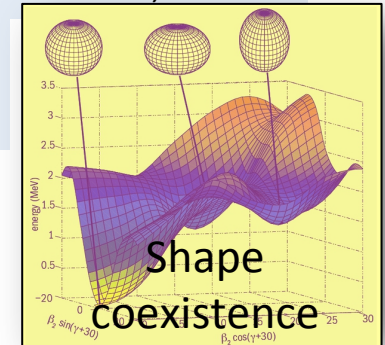
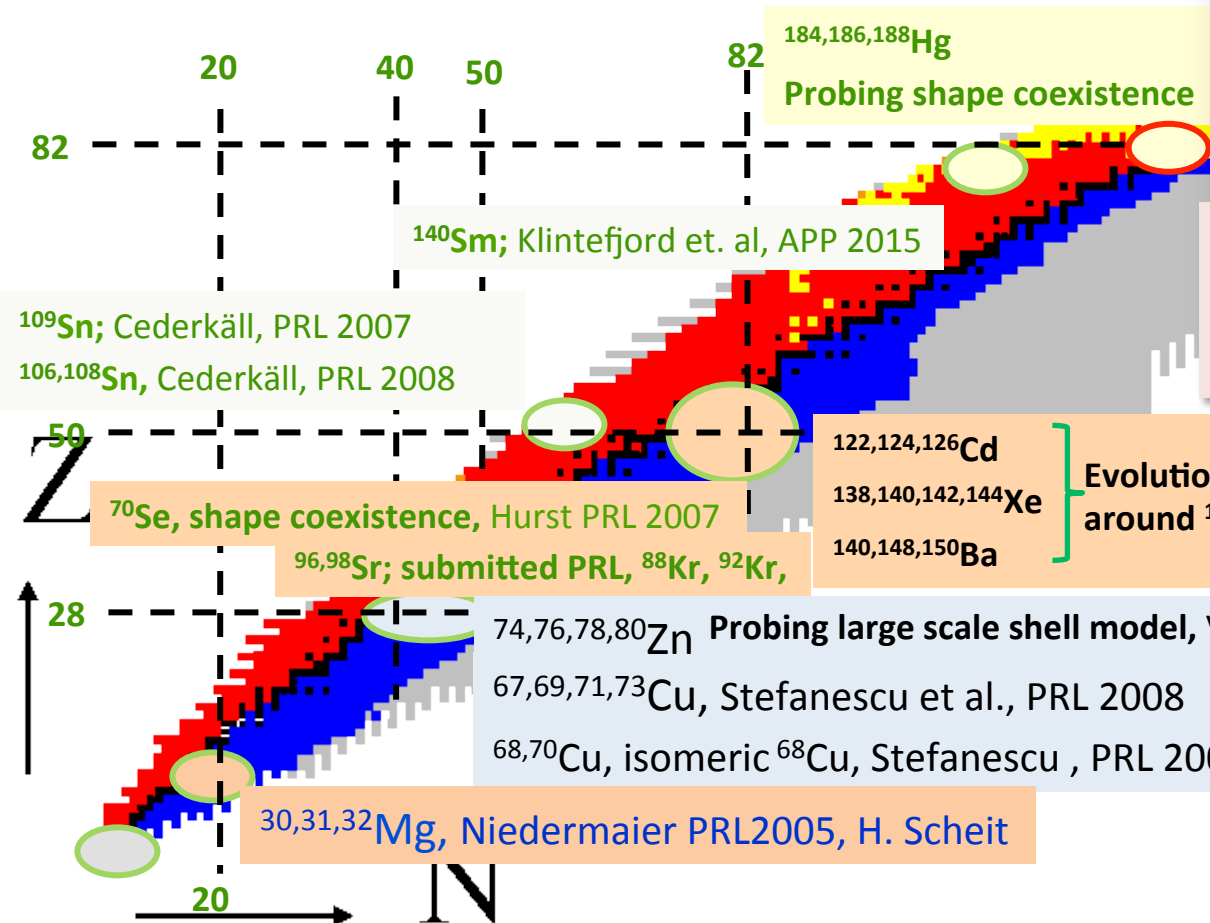
Physics program with post-accelerated beams @ REX => Newer results waiting for HIE-ISOLDE

Coulomb excitation with Miniball:
collectivity versus individual nucleon behaviour

Green: Publications with Oslo involvement



222,224Ra; 220,222Rn
Probing Pear Shape
Gaffney Nature 2013



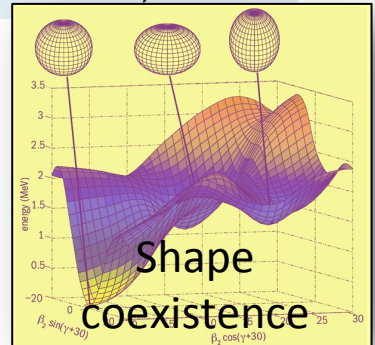
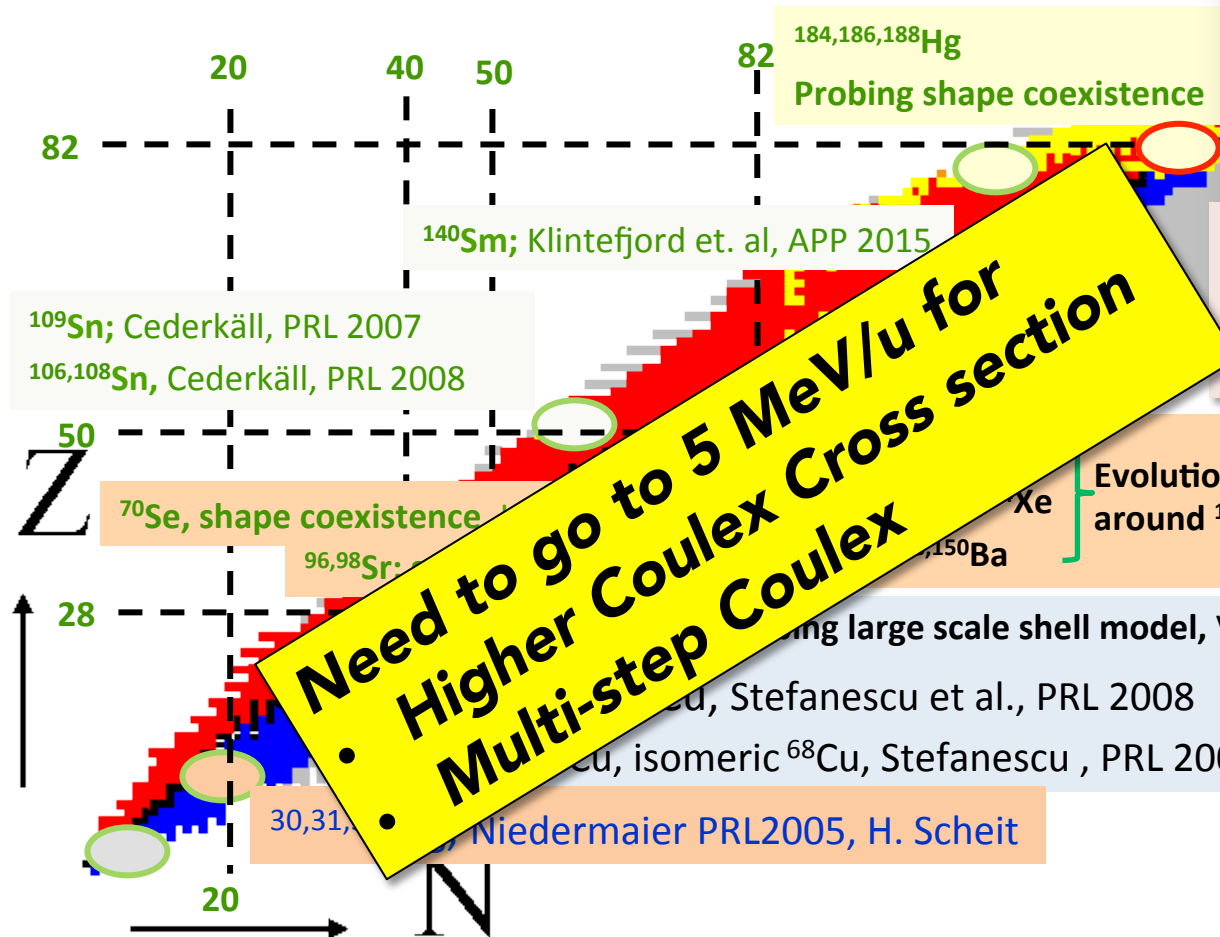
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Coulomb excitation with Miniball:
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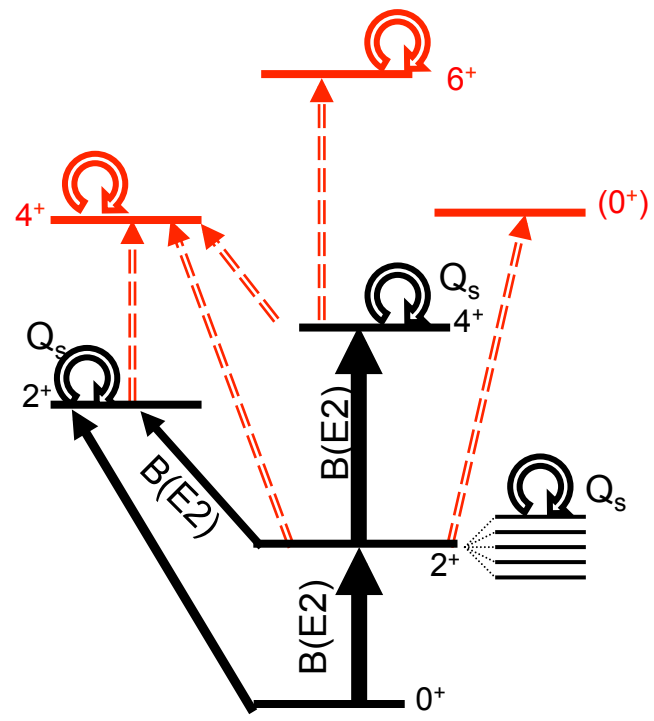
222,224Ra; 220,222Rn
 Probing Pear Shape
 Gaffney Nature 2013



Ex: With 5 MeV/u beams we can probe the shapes of individual levels at higher excitation energies

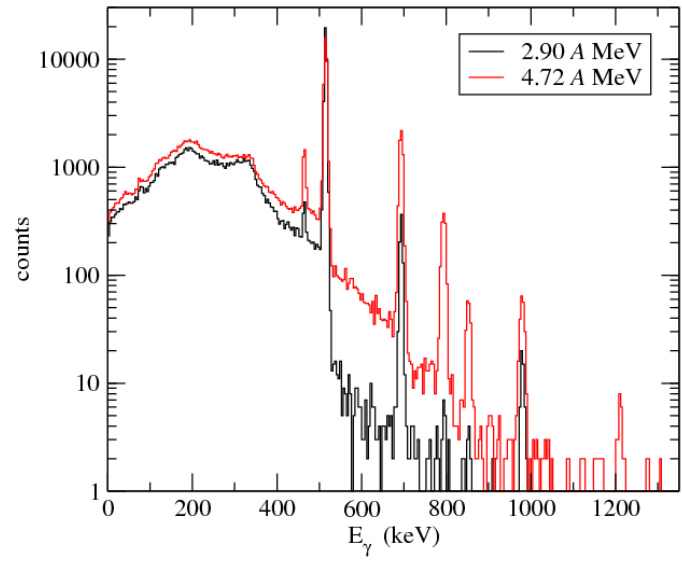
In red: 4.7 MeV/u

In black: 2.9 MeV/u



$^{142}\text{Gd} + ^{208}\text{Pb}$ at 4.7 MeV/u

2.5×10^4 pps
1 mg/cm² ^{208}Pb
12 shifts



GEANT4 simulation

Calculations presented for INTC regarding HIE-ISOLDE experiment IS558

Veil Nebula Supernova Remnant



What is the origin of the chemical elements?

Veil Nebula Supernova Remnant



Rich research function [MeV⁻³]

Guttormsen,
PRC 71, 044307
(2005).

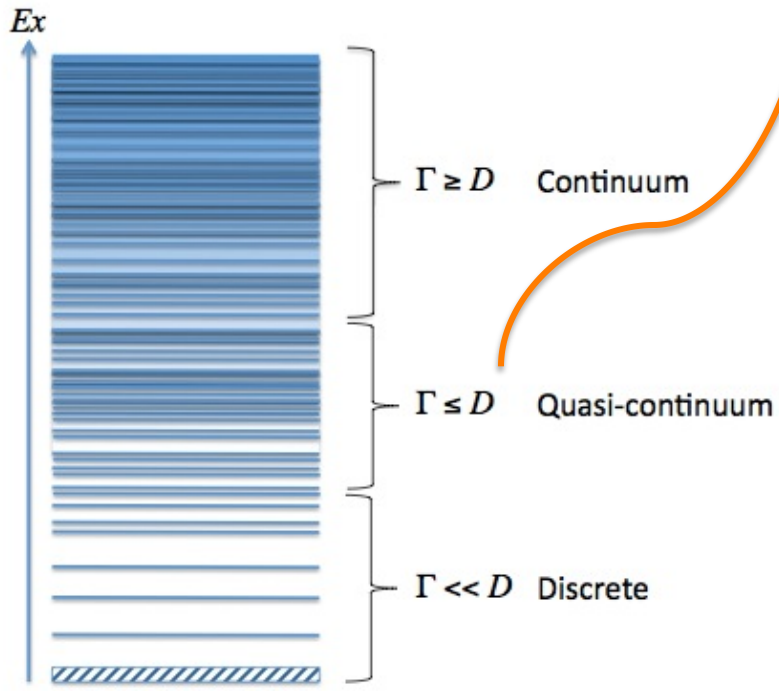
Understanding the statistical properties of neutron rich nuclei could improve our understanding of the r-process (HIE-ISOLDE IS559)

energy E_γ [MeV]

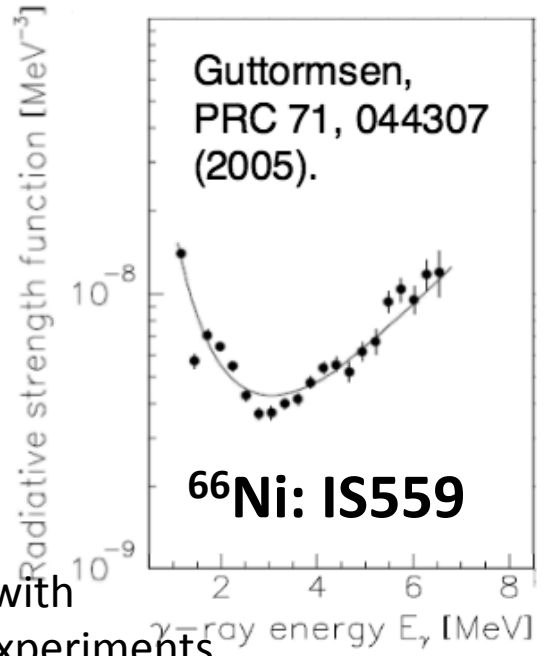


What is the origin of the chemical elements?

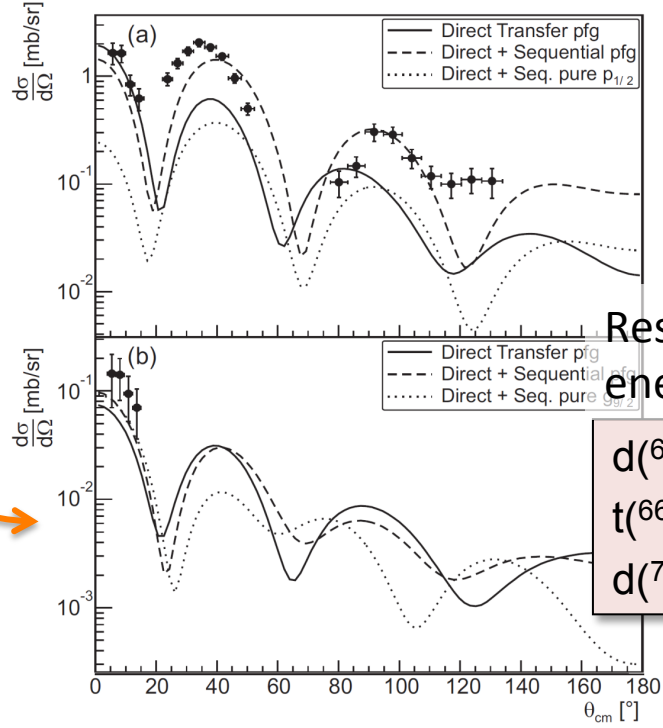
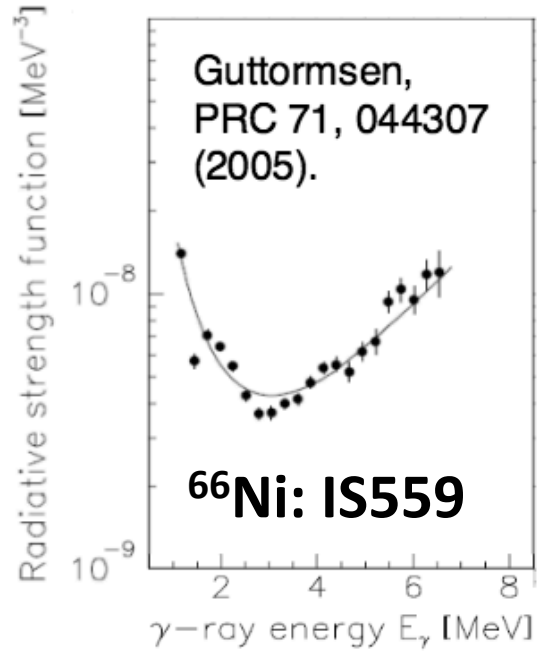
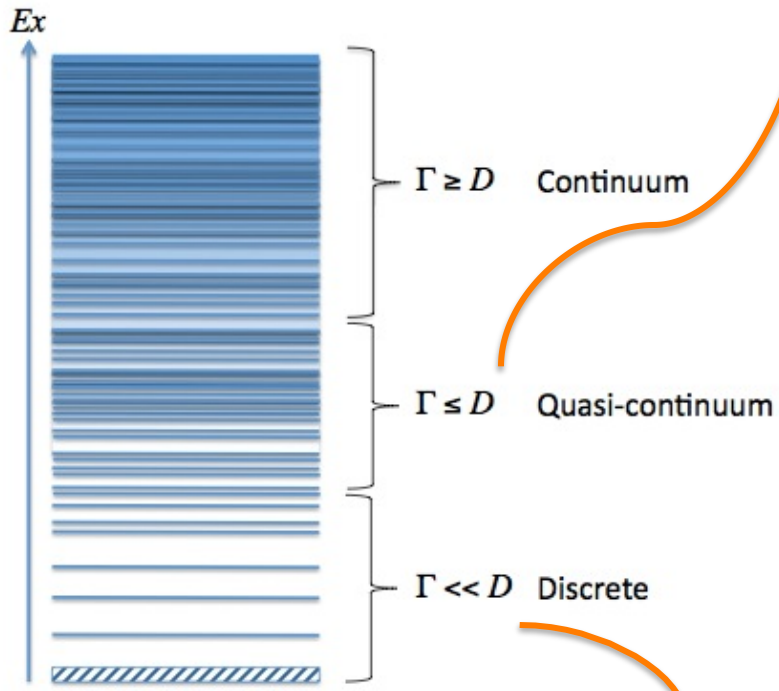
Transfer reactions and statistical properties of warm nuclei



Inverse kinematics with stable beams test experiments have been carried out



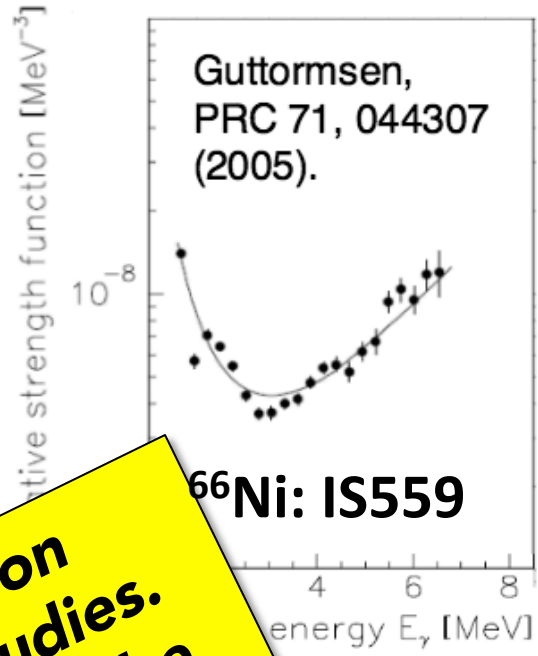
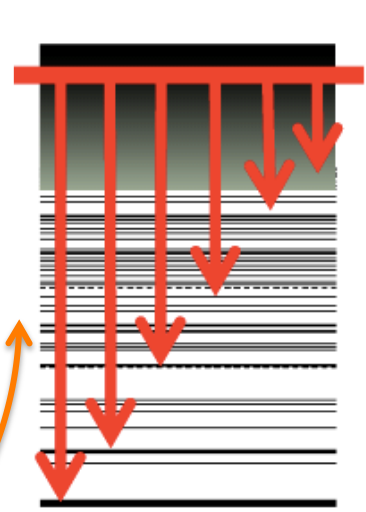
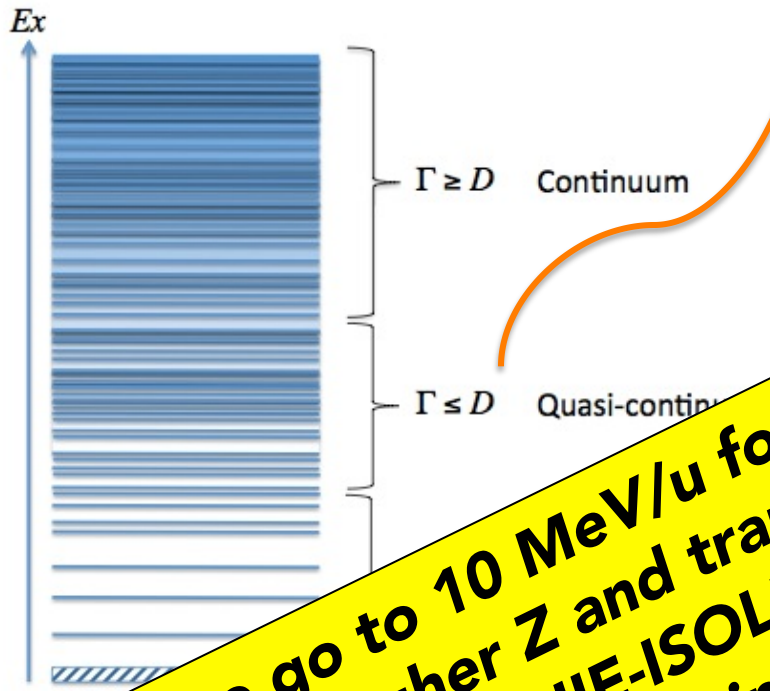
Transfer reactions and statistical properties of warm nuclei



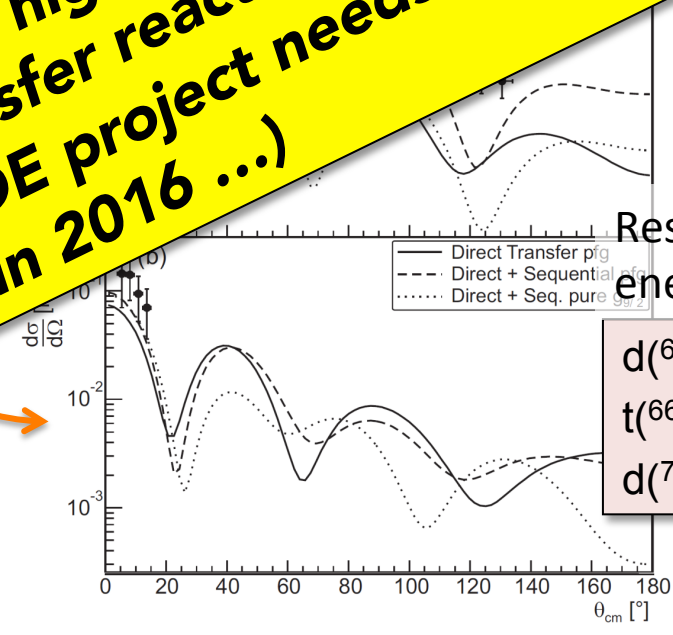
Results for lower beam energies:

- $d(^{66}\text{Ni},p)^{67}\text{Ni}$ Diriken
- $t(^{66}\text{Ni},p)^{68}\text{Ni}$ Elseviers
- $d(^{78}\text{Zn},p)^{79}\text{Zn}$ Orlandi

Transfer reactions and statistical properties of warm nuclei



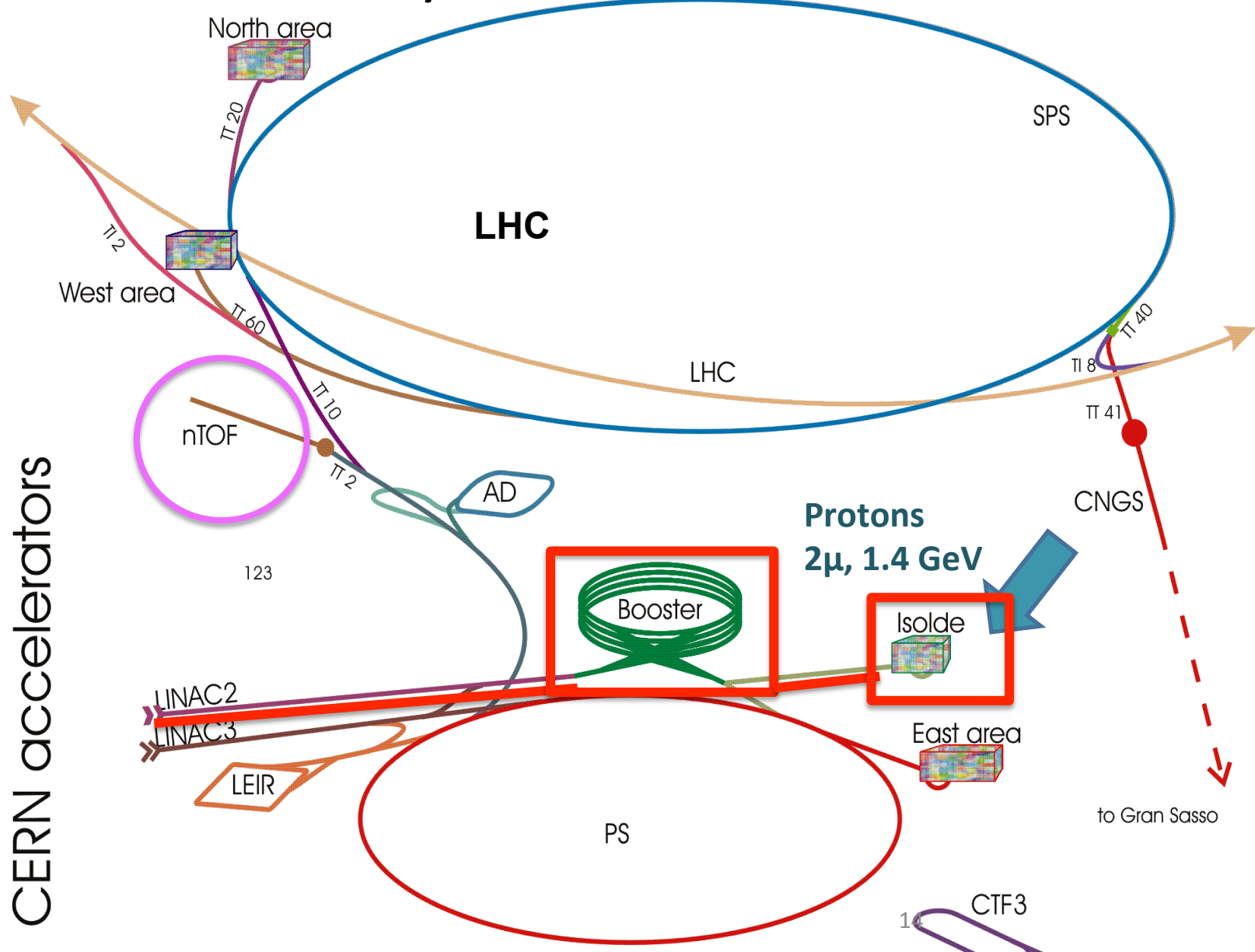
Need to go to 10 MeV/u for higher excitation energies, higher Z and transfer reaction studies. This part of the HIE-ISOLDE project needs to be financed (we'll try again in 2016 ...)



Results for lower beam energies:

- d(⁶⁶Ni,p)⁶⁷Ni Diriken
- t(⁶⁶Ni,p)⁶⁸Ni Elseviers
- d(⁷⁸Zn,p)⁷⁹Zn Orlandi

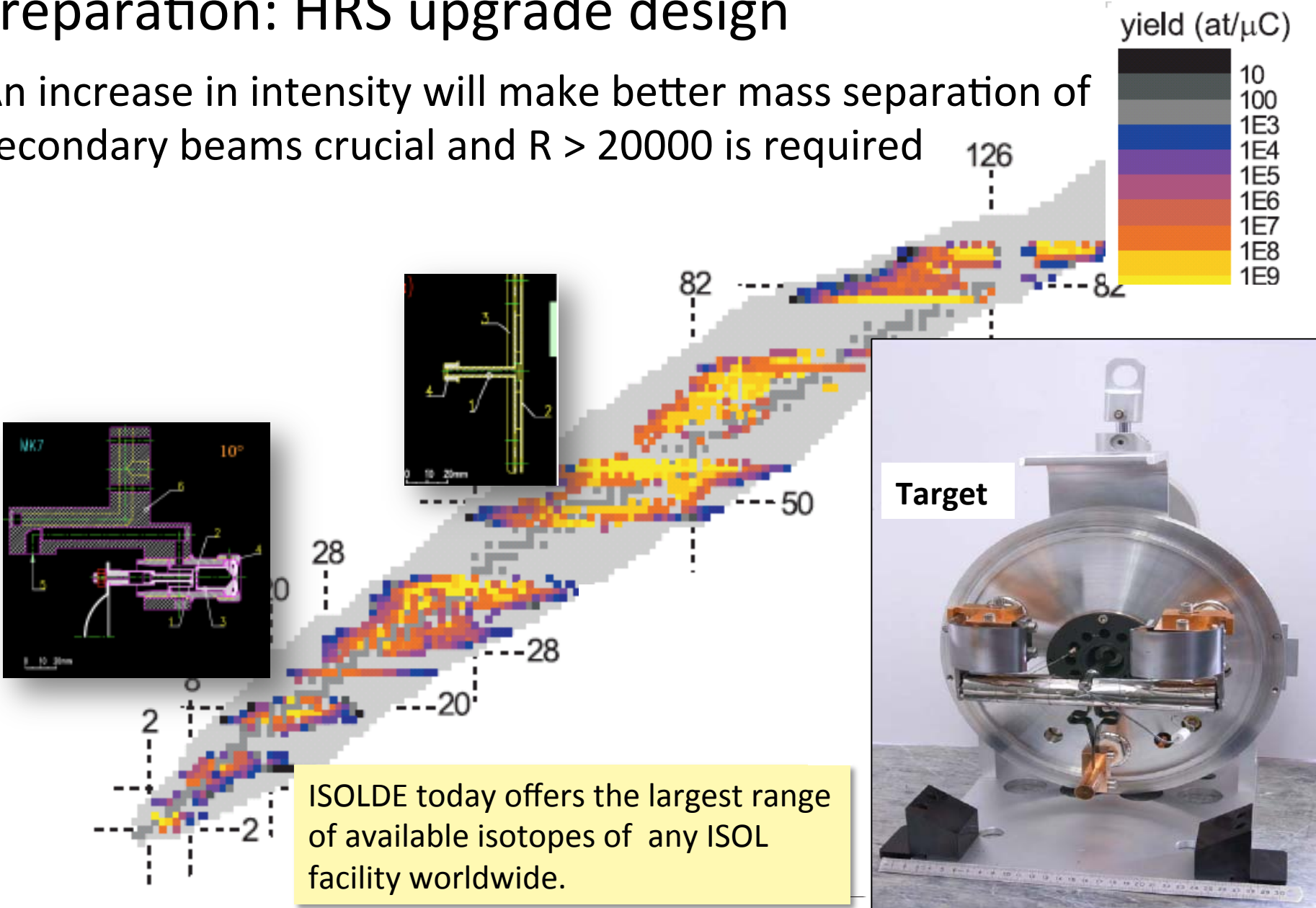
ISOLDE will benefit from the upgrade to LINAC4 and the PS Booster by x2 – x10 cross section increase



CERN accelerators

Developments in mass separation and beam preparation: HRS upgrade design

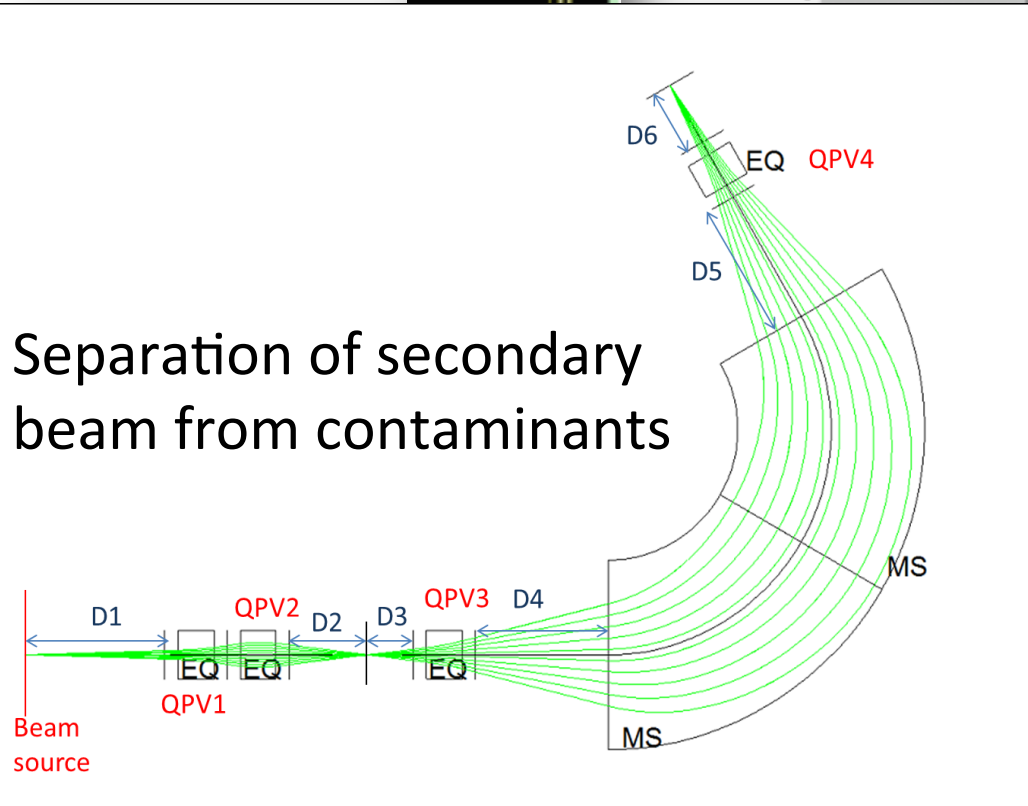
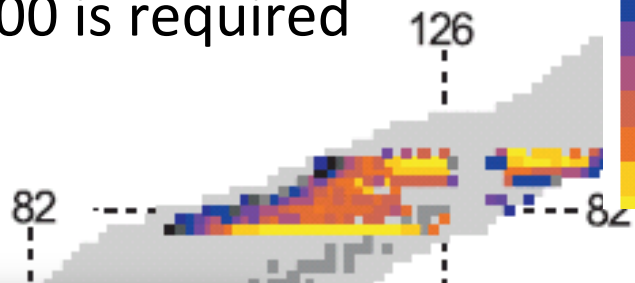
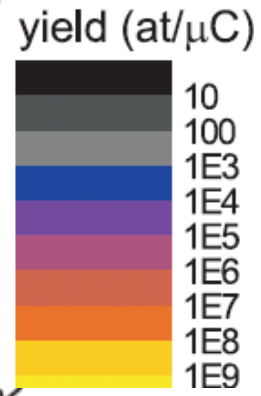
An increase in intensity will make better mass separation of secondary beams crucial and $R > 20000$ is required



ISOLDE today offers the largest range of available isotopes of any ISOL facility worldwide.

Developments in mass separation and beam preparation: HRS upgrade design

An increase in intensity will make better mass separation of secondary beams crucial and $R > 20000$ is required



Local group and national funding

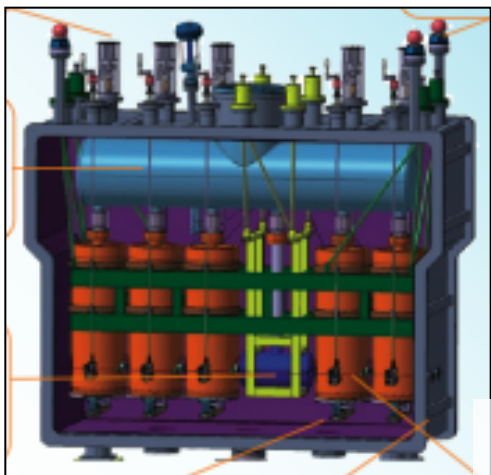
Current manpower situation:

- 3 full professors
(two hired in 2012: Andreas Gørgen and Sunniva Siem)
- 4 researchers/post docs
- 5 PhD students

Recent ISOLDE related funding (mostly from independent programs at The Research Council of Norway):

- 1.7 MNOK: membership fee for ISOLDE
Grantholder: Sunniva Siem
- 6.0 MNOK: Statistical properties of warm nuclei
Grantholder: Sunniva Siem
- 0.9 million NOK: Shapes and collectivity of exotic nuclei
(+ 2 PhDs and 2 Post docs 5.7 MNOK from Faculty of science)
Grantholder: Andreas Gørgen
- 3.6 MNOK Personal post doc from the FRINATEK program
Grantholder: Gry M. Tveten

Innovative funding strategies: CATE



HIE-ISOLDE: Replace REX by new superconducting LINAC

E_{max} at present: 3 MeV/u, HIE-ISOLDE: 10 MeV/u

- Coulomb excitation
- direct reactions (⇒ Oslo method)
- deep inelastic reactions / fusion evaporation

**EU regional grant total budget
1.8 M€ (about 50% from EU)**

- Lund (Fahlander, Cederkäll)
- Århus (Riisager)
- Göteborg (Nilsson)
- Oslo (Siem, Görger)

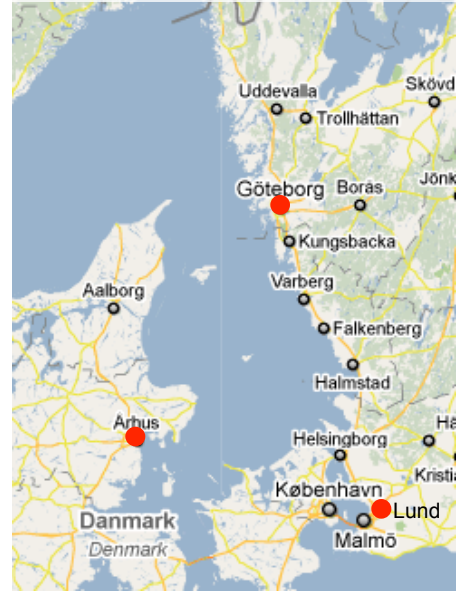
- develop accelerator competence the region (⇒ ESS)
- build a accelerator module for HIE-ISOLDE LINAC
- Prototype for ESS accelerator
- strengthen collaboration in the region
- increase skandinavian weight within ISOLDE collaboration



CLUSTER FOR ACCELERATOR TECHNOLOGY



Öresund-Kattegat-Skagerrak
European Regional Development Fund



Future challenges

- Funding for the ISOLDE membership fee (60 k€/yr)
- Funding for the final stages of HIE-ISOLDE
- Also: Post docs and PhDs (but we have good experience with applying to the independent funding programs)
- Far future: EURISOL to CERN?

Questions?

Thank you for your attention!



My personal wish for the future of radioactive ion experiments at CERN:
EURISOL

We need developments like:

- More intense proton beam
- New primary targets
- Faster charge breeding

