ISOLDE in the EPPS

The Future of (HIE-)ISOLDE

The EPIC project:

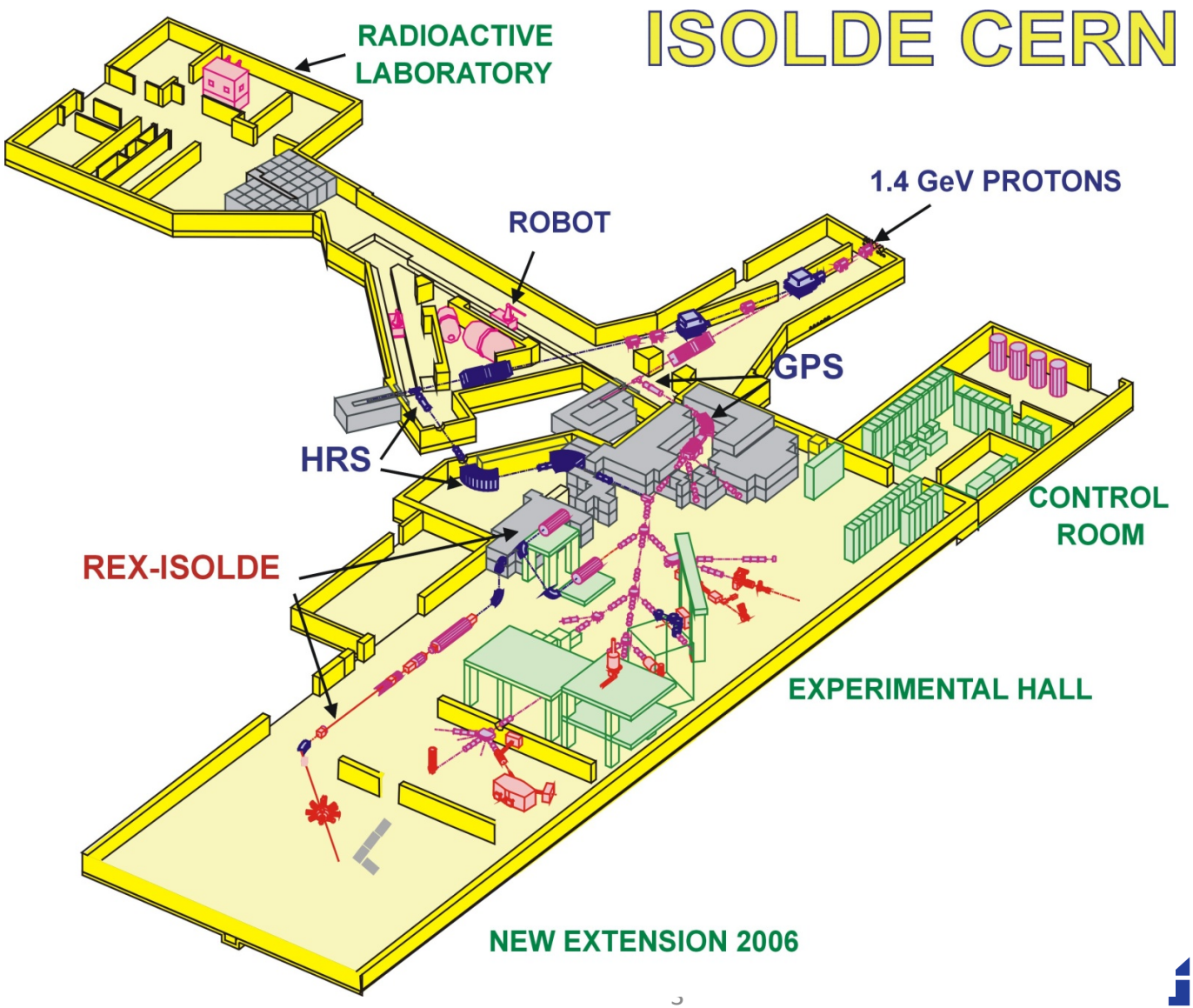
Exploiting the Potential of ISOLDE at CERN

the ISOLDE Collaboration input to the European Particle Physics Strategy update

Gerda Neyens, ISOLDE Collaboration Spokesperson
Richard Catherall, ISOLDE Technical Coordinator
Bertram Blank, Chair of the ISOLDE Collaboration
Karsten Riisager, Chair of the ISOLDE and n-TOF (INTC) program committee

With thanks to Klaus Blaum, Yuri Litvinov, Ronald Garcia Ruiz, Kieran Flanagan, Manfred Grieser, Erwin Siesling, Tim Giles and many others…

SOLDE @ CERN


ISOLDE CERN
RADIOACTIVE LABORATORY
1.4 GeV PROTONS
ROBOT
GPS
HRS
CONTROL ROOM
REX-ISOLDE
EXPERIMENTAL HALL
NEW EXTENSION 2006

ISOLDE 50 Years

OPEN ACCESS
IOP Publishing
Journal of Physics G: Nuclear and Particle Physics
J. Phys. G: Nucl. Part. Phys. **45** (2018) 010301 (3pp)
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Preface

Focus on Exotic Beams at ISOLDE: A Laboratory Portrait

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CrossMark

Present ISOLDE

HIE-ISOLDE's Phase 2 reaches completion

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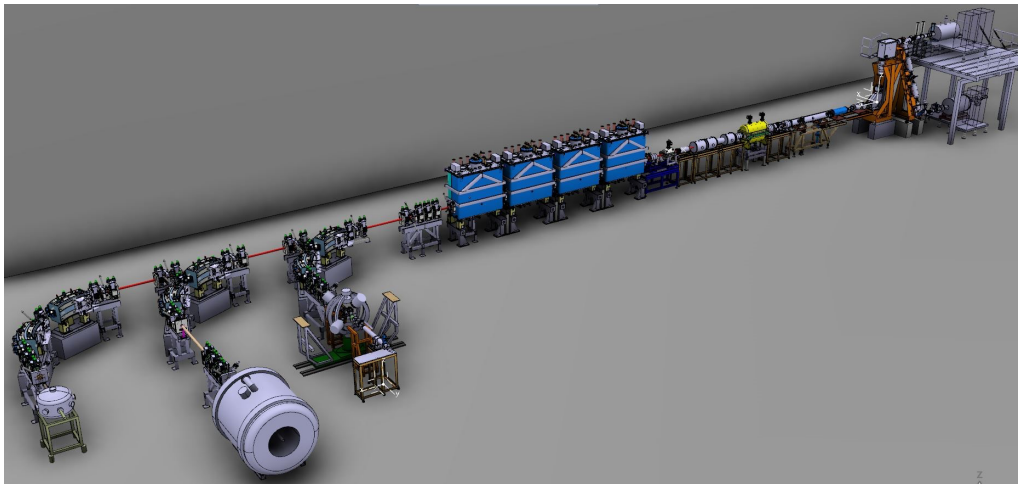
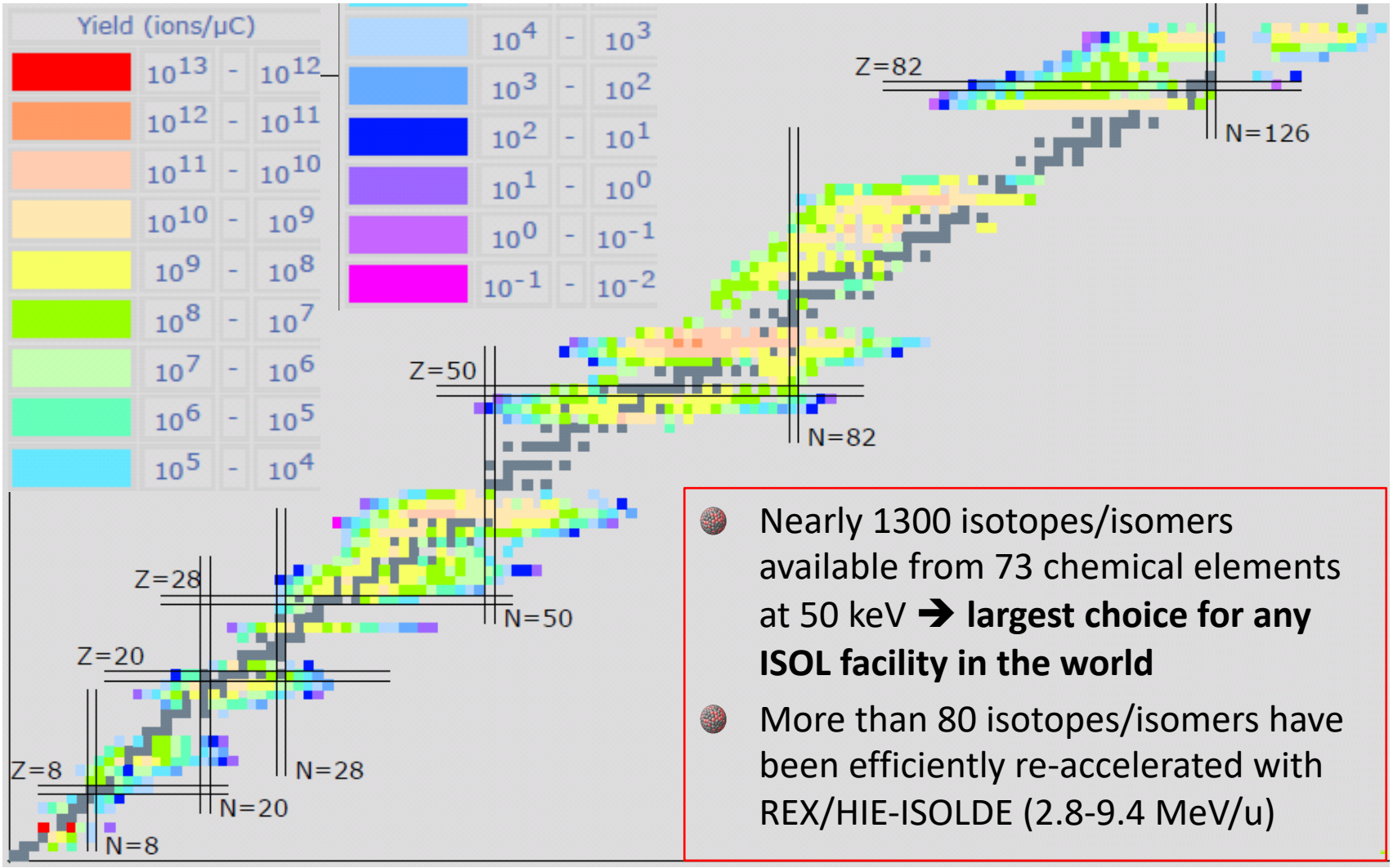
CERN's ISOLDE facility has been in operation for more than 50 years. It produces radioactive isotopes for studies of the structure of atomic nuclei and a variety of other purposes including medical applications. Now, Phase 2 of its HIE-ISOLDE upgrade has reached completion.

This will allow ISOLDE to accelerate radioactive beams to energies up to 10 MeV per nucleon ("nucleon" is the collective term for protons and neutrons in the nucleus); the pre-upgrade maximum energy was 2.8 MeV per nucleon. The increase in energy will help study a variety of nuclear reactions with radioactive isotopes, opening up new possibilities for nuclear-structure research.

The HIE prefix stands for "High Intensity and Energy". With the end of Phase 2, the facility has completed an important part of its "Energy" upgrade. The "Intensity" upgrade is foreseen for Phase 3, and will allow ISOLDE to remain at the forefront of nuclear and astrophysics research for another ten to fifteen years.



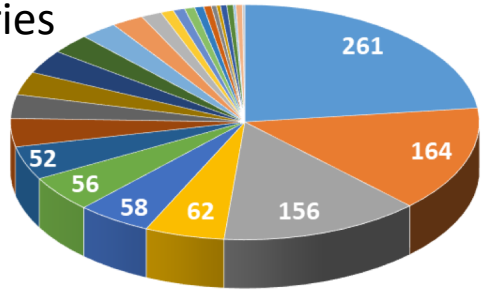
Present ISOLDE beams



- Nearly 1300 isotopes/isomers available from 73 chemical elements at 50 keV ➔ **largest choice for any ISOL facility in the world**
- More than 80 isotopes/isomers have been efficiently re-accelerated with REX/HIE-ISOLDE (2.8-9.4 MeV/u)

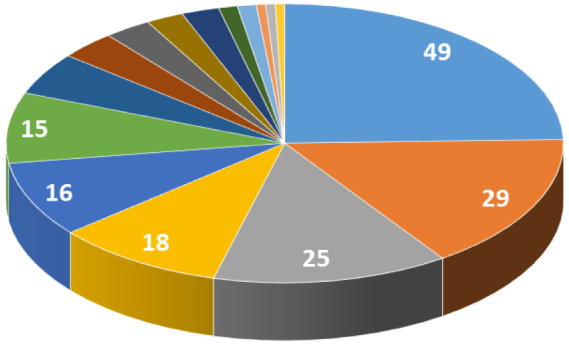
The ISOLDE users community

European Countries



Germany, UK, France, spain, Belgium, Portugal, Poland, Italy, Finland, Romania, Switserland, Denmark, Sweden, Norway, Slovakia, Czech Republiek, Greece, Hungary, Ireland, Austia, Turkey, Croatia, Bulgaria, Iceland, slovenia, Serbia, Netherlands

Non-European



United States, South Africa, Russia, Canada, Japan, India, Brazil, china, Chile, Australia, Israel, Bangladesh, Algeria, Iran, South Korea, Costa Rica

Since post-accelerated beams became available: continuous growing users community !

ISOLDE USERS:

- **In pre-HIE-ISOLDE era: 500-600**
- **Today: 1314 !**
  - ✓ **From 43 countries**
  - ✓ **From > 200 institutions**
  - ✓ **From all around the world**

ISOLDE in the EPPS

3 objectives

- Profit from increased driver beam energy and intensity (2 GeV, 4 μA), thanks to the LIU at CERN and improve the exploitation of the existing infrastructure
- Have multiple simultaneous beams for users
- A new storage ring for short-lived, light and heavy ions

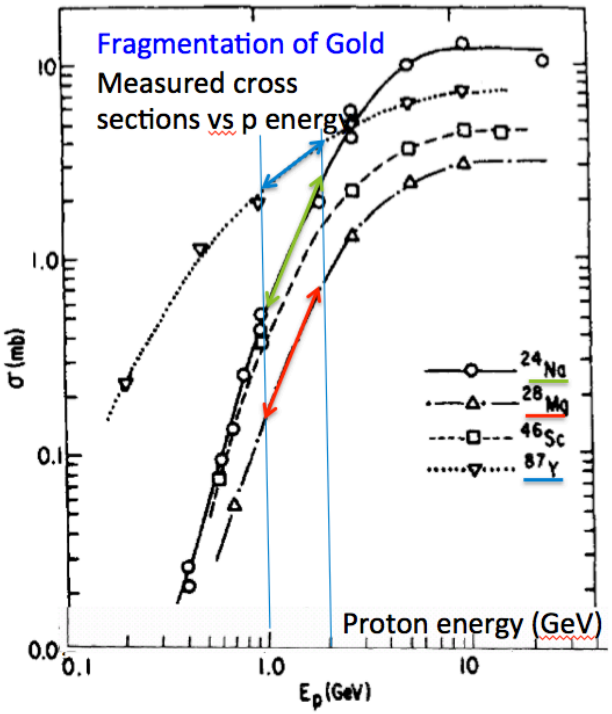
Objective 1

Profit from increased driver beam energy (2 GeV) and intensity (4 μA)

- Take advantage of CERN's LHC Injector Upgrade (LIU): higher proton intensities from LINAC4 and Booster energy increase from 1.4 GeV to 2 GeV

- GAIN FOR ISOLDE: **Higher radioactive beam intensities** for fragmentation and spallation products (gain between factor of 2 and more than 10 in intensity)

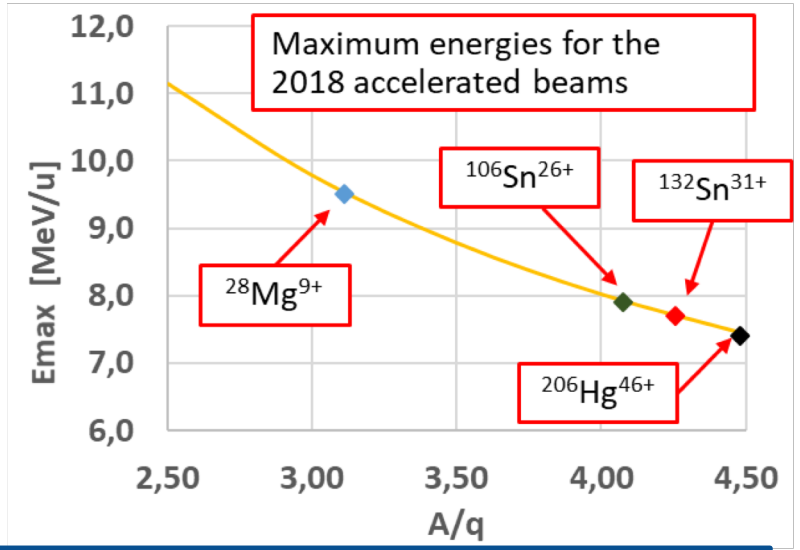
- **NEEDED CERN INVESTMENTS, in order for ISOLDE TO RECEIVE THESE BEAMS:**
  - ✓ New beam dumps to cope with higher power
  - ✓ New transfer line from booster to ISOLDE



Objective 1

And improve the exploitation of the existing infrastructure

- HIE-ISOLDE post-accelerator design goal:
  beams up to 10 MeV/u, for light and heavy beams
  NOW: max 9.4 MeV/u for light beams
  max 7.4 MeV/u for heavy beams



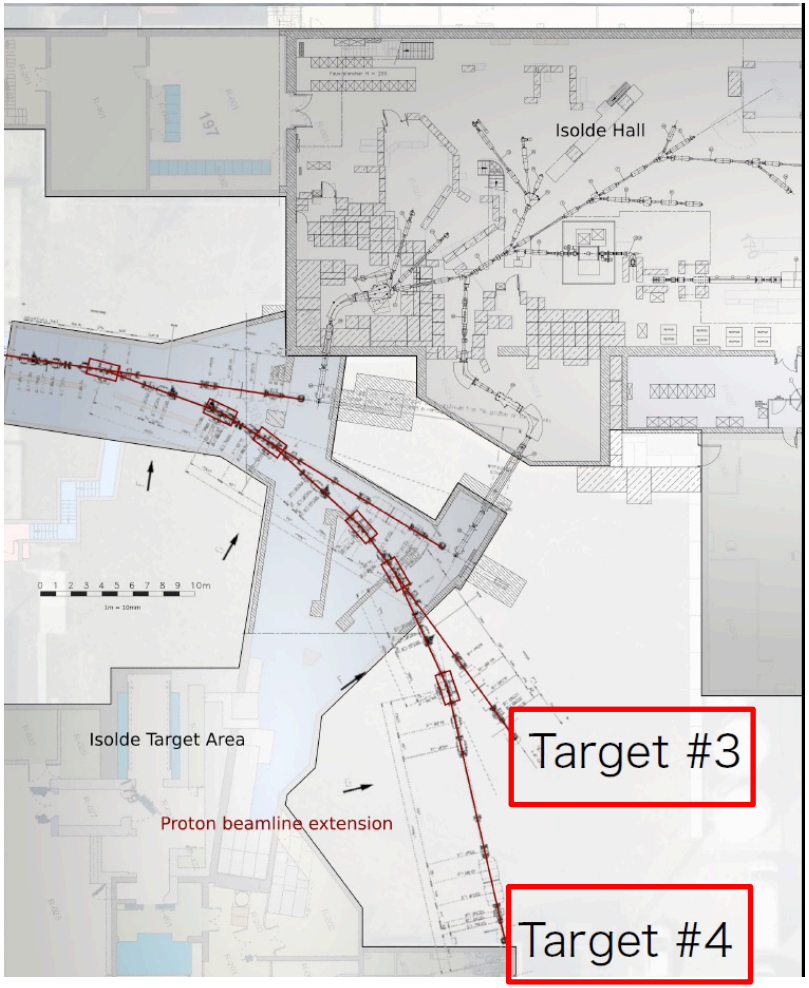
SOLUTIONS TO REACH FULL ENERGY POTENTIAL:

- ✓ **Have all cavities working after LS2 !**
- ✓ **FINALIZE the HIE-ISOLDE energy upgrade:**
  post-accelerated beams in the full (low) energy range from 0.3 and 2.8 MeV/u (most important for astrophysics experiments) and up to 10 MeV/u
  METHOD: upgrade of the (20 years old!) REX-part of the HIE-ISOLDE LINAC

Objective 2

Have multiple simultaneous and better quality beams

- GOAL: serve the ever growing ISOLDE users community, who pursues very diverse research program
  - in nuclear physics,
  - fundamental interaction studies,
  - atomic physics
  - nuclear astrophysics
  - material sciences
  - biochemical/ medical research



- **METHOD:**

1. **Two new additional target stations**

Preliminary design: Tim Giles, presented at the EMIS 2018 Conference, CERN

Objective 2

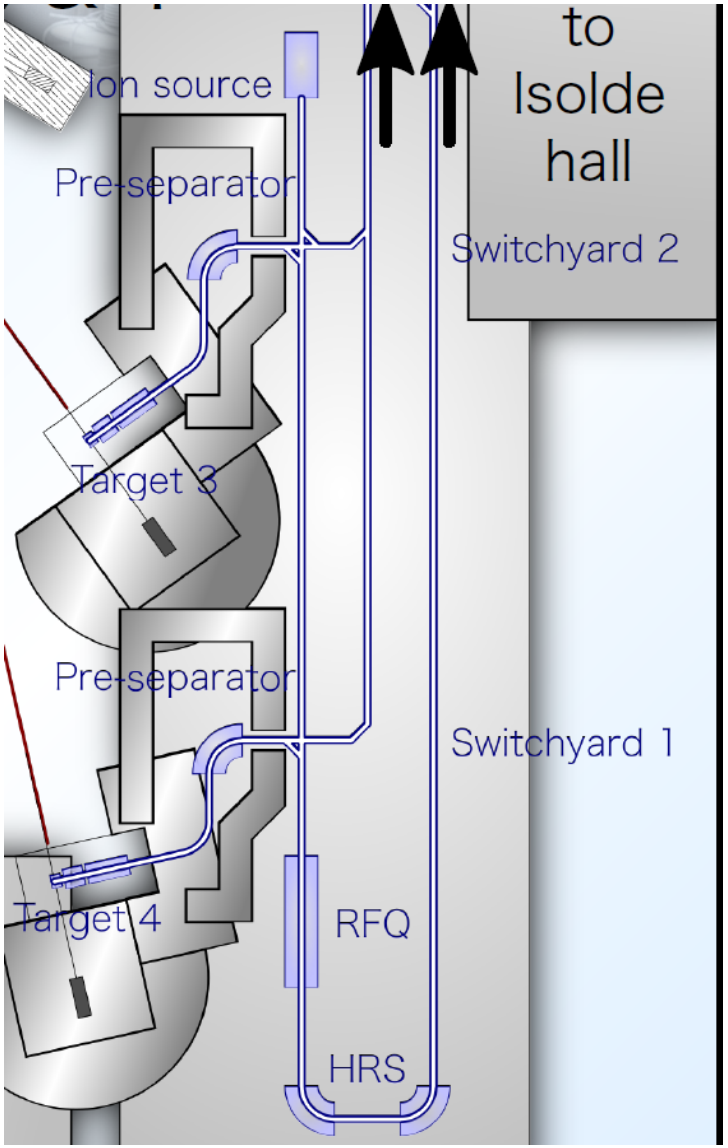
Have multiple simultaneous better quality beams

➢ **METHOD:**

1. Two new additional target stations

2. A new high-resolution mass separator (state-of-the-art) to deliver purer beams (very important for HIE-ISOLDE operations)

➔ currently, some RIB's beams cannot be efficiently accelerated due to contaminations that are too high



Preliminary design: Tim Giles, presented at the EMIS 2018 Conference, CERN

Objective 3

A new compact storage ring for light and heavy ions

- Stored radioactive beams have many advantageous:

  - Can be used multiple times in an in-ring detector (luminosity increase)

  - Can be cooled to deliver excellent quality beams to external experiments for high-precision studies

- **Research areas:**

nuclear ground-state properties,
reaction studies of astrophysical relevance,
investigations with highly-charged ions
studies with pure isomeric beams
(e.g. fundamental constants)

Eur. Phys. J. Special Topics 207, 1-117 (2012)

Physics Case For a Low-Energy Storage Ring

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

Storage ring facility at HIE-ISOLDE

evaluated at INTC meeting on 2nd February 2011

CERN-INTC-2011-019, INTC-I-133, *Storage ring facility at HIE-ISOLDE*

The LOI for HIE-ISOLDE was found very interesting and, if successful, it would lead to the first storage ring at an ISOL-type facility. The planned experimental programme is diverse and offers unique opportunities for studies in nuclear structure and nuclear astrophysics. The feasibility of some of the proposed studies needs to be further investigated, as well as the space, cost and manpower required for installing and running the device. The committee **endorsed** the scientific case presented in the LOI and encouraged the proponents to submit a Technical Design Report for the move and installation of the TSR at ISOLDE at their earliest convenience.

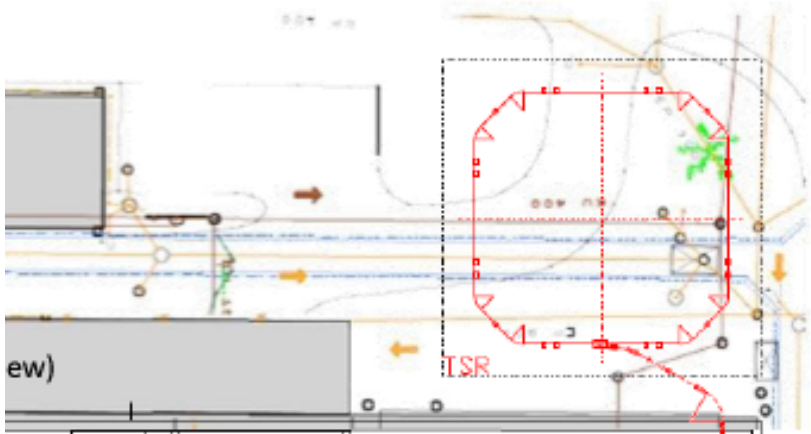
we intend to submit the Technical Design Proposal
for the evaluation to the coming INTC meeting

First time a storage ring would be connected to an ISOL-based facility!

Physics Case For a Low-Energy Storage Ring

- Half-life measurements of ^{7}Be in different atomic charge states
- Capture reactions for astrophysical p-process
- Nuclear structure through transfer reactions
- Long-lived isomeric states
- Atomic effects on nuclear half-lives
- Nuclear effects on atomic decay rates
- Di-electronic recombination on exotic nuclei
- Neutrino physics; Tests for the neutrino beam project
- Purification of secondary beams from contaminants
- .....

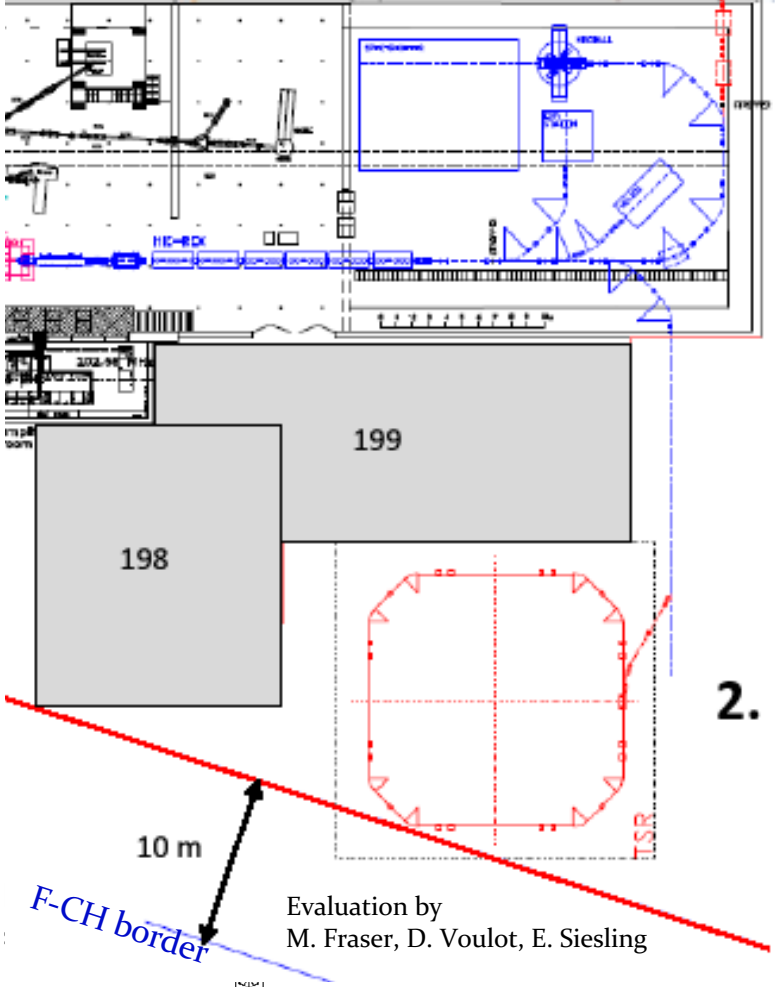
TSR location at ISOLDE



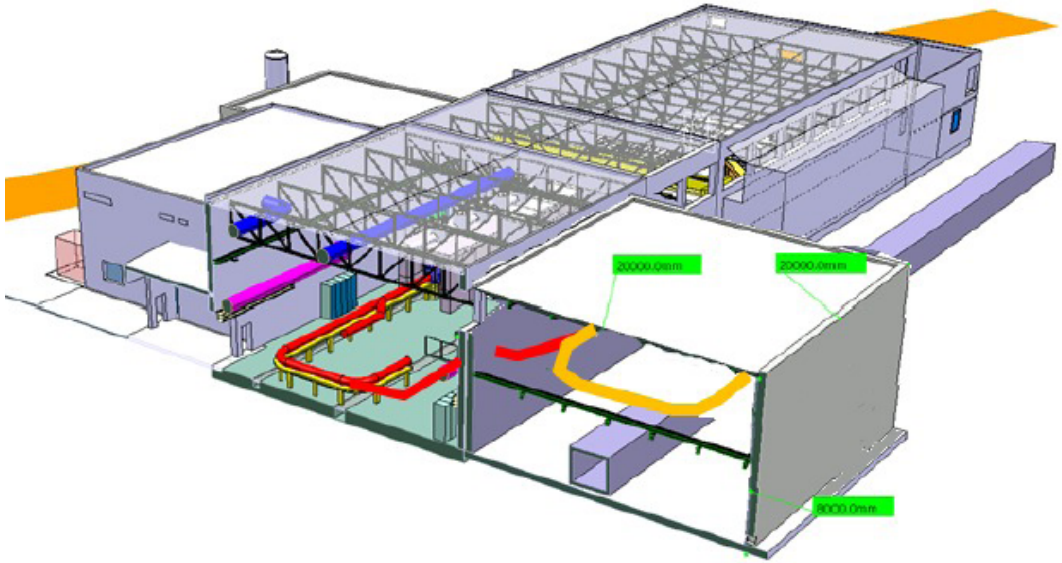
1.

1. - On top of CERN service tunnel
   - Close to road behind
   - Beam level 2.8 m up from HIE-ISOLDE

2. - Cryo coldbox and compressor building
   - 10 m distance limit to border
   + Excavate a basement for power supplies



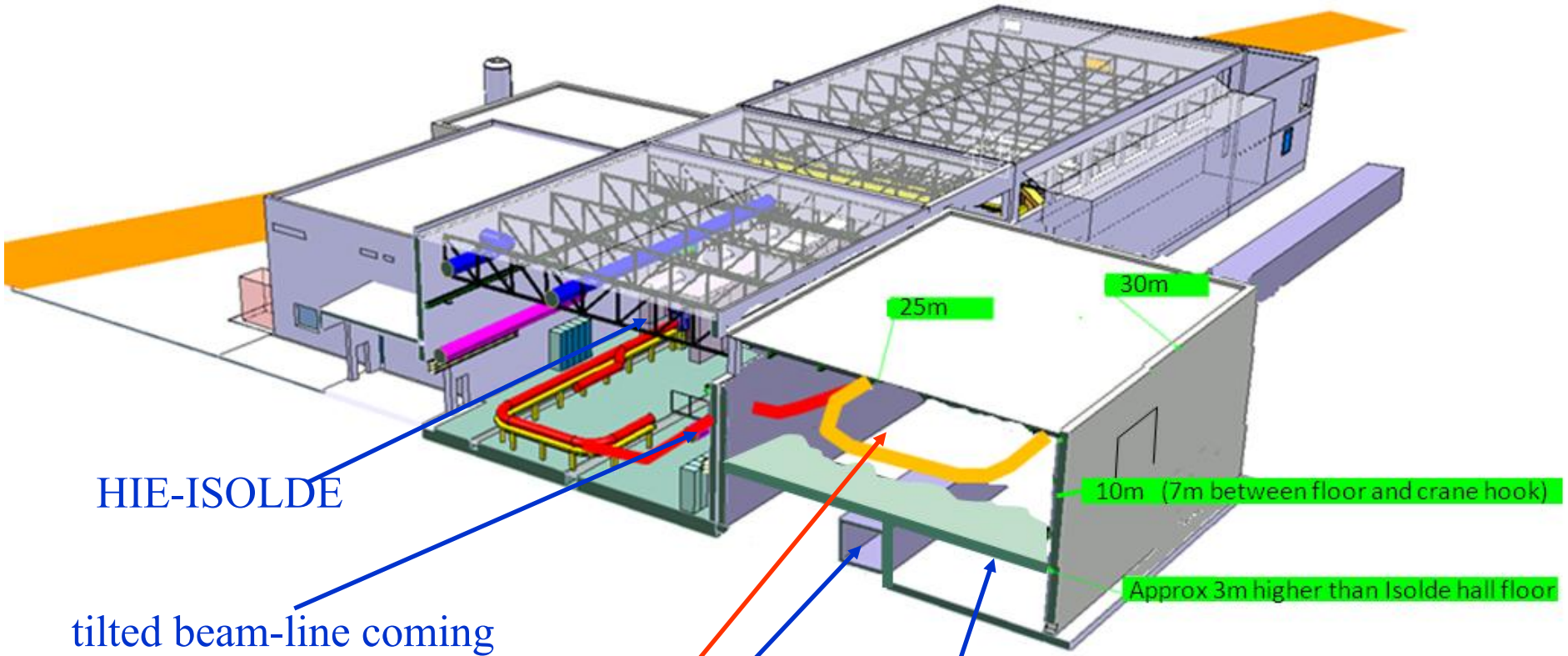
2.



Evaluation by
M. Fraser, D. Voulot, E. Siesling

Courtesy E. Siesling

TSR @ HIE-ISOLDE



HIE-ISOLDE

tilted beam-line coming
from the HIE-ISOLDE machine.

possible TSR installation
above the CERN cable-tunnel.
(E. Siesling)

TSR@HIE-ISOLDE building

TSR@HIE-ISOLDE Collaboration

more than 120 participants from more than 40 institutions from 17 countries

M. Aliotta, A. Andreyev, A. Artemyev, D. Atanasov, T. Aumann, J. Äystö, D. Balabanski, A. Barzakh, L. Batist, A.-P. Bernardes, D. Bernhardt, J. Billowes, S. Bishop, K. Blaum, Y. Blumenfeld, M. Borge, I. Borzov, F. Bosch, A. Boston, C. Brandau, P. Butler, W. Catford, R. Catherall, J. Cederkäll, D. Cullen, T. Davinson, I. Dillmann, C. Dimopoulou, G. Dracoulis, C. Düllmann, P. Egelhof, A. Estrade, D. Fischer, K. Flanagan, M. Fraser, S. Freeman, H. Geissel, J. Gerl, M. Grieser, R.E. Grisenti, R. von Hahn, M. Hausmann, J. J. He, M. Heil, M. Huyse, D. Jenkins, A. Jokinen, J. Jolie, B. Jonson, D. Joss, Y. Kadi, N. Kalantar-Nayestanaki, B. Kay, H.-J. Kluge, M. Kowalska, C. Kozhuharov, S. Kreim, T. Kröll, R. Krücken, J. Kurcewicz, M. Labiche, R.C. Lemmon, M. Lestinsky, Yu.A. Litvinov, G. Lotay, X.W. Ma, D. Mücher, I. Mukha, A. Müller, A. Murphy, G. Neyens, T. Nilsson, C. Nociforo, W. Nörtershäuser, R. Page, M. Pasini, N. Petridis, N. Pietralla, Zs. Podolyak, R. Raabe, P. Reagan, M.W. Reed, R. Reifarth, P. Reiter, R. Repnow, K. Riisager, B. Rubio, M.S. Sanjari, D.W. Savin, C. Scheidenberger, S. Schippers, D. Schneider, R. Schuch, D. Schwalm, D. Shubina, E. Siesling, H. Simon, J. Simpson, J. Smith, K. Sonnabend, M. Steck, T. Stora, T. Stöhlker, A. Surzhykov, F. Suzaki, O. Tarasov, X.L. Tu, P. VanDuppen, C. Volpe, D. Voulot, P.M. Walker, F. Wenander, E. Wildner, N. Winckler, D.F.A. Winters, A. Wolf, P. Woods, H.S. Xu, A. Yakushev, T. Yamaguchi, Y.J. Yuan, K. Zuber

GSI

HELMHOLTZ GEMEINSCHAFT

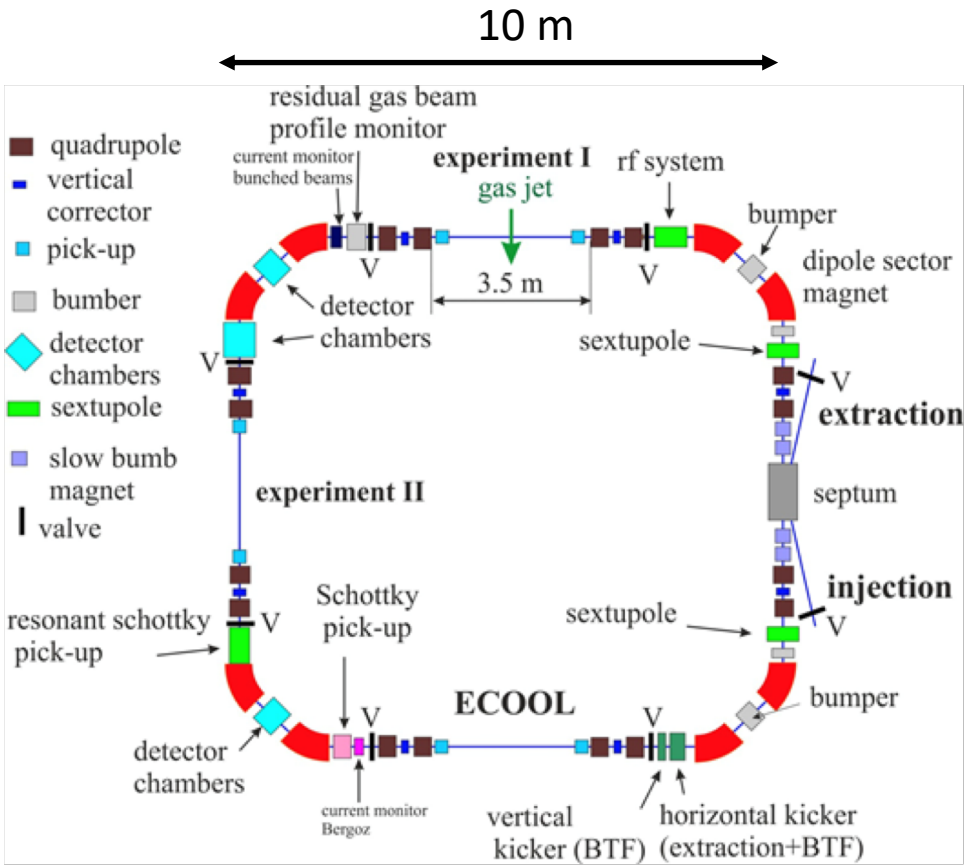
ISOLDE Workshop and Users meeting 2011

05-07 December 2011, CERN

Max-Planck-Institut für Kernphysik

Objective 3

A new compact storage ring for light and heavy ions

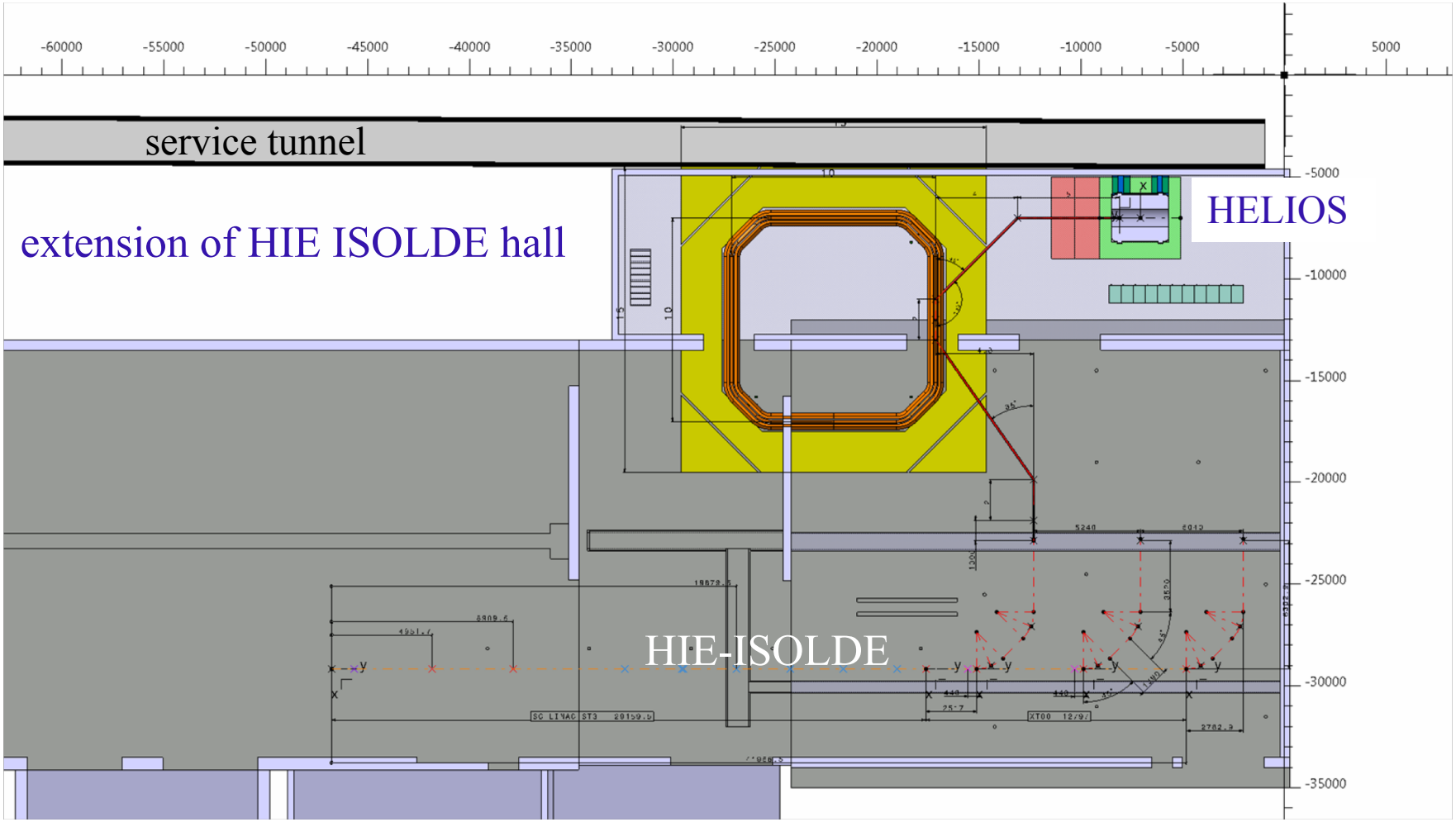


Preliminary design:
Manfred Grieser, MPI-K Heidelberg

Preliminary integration in ISOLDE:
Erwin Siesling

Possible location of the new storage at HIE-ISOLDE

transparency from Erwin Siesling and Stephane Maridor, CERN



Objective 3

Only one example:

Charge particle induced reaction for p-process nucleosynthesis studies

g/p-process:
explosive scenarios like type-II/Ia supernovae at temperatures of 1-3 GK

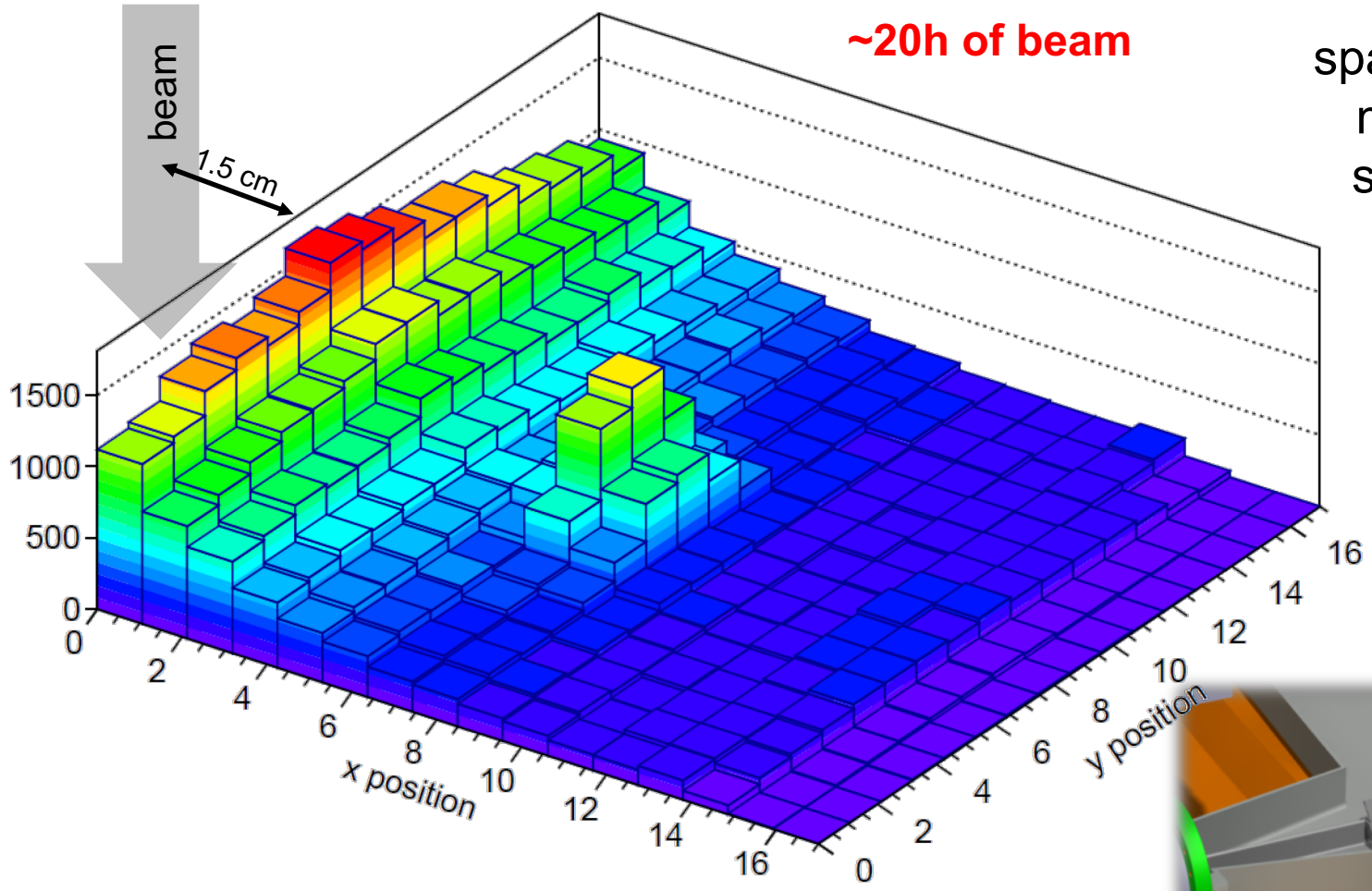
~35 neutron-deficient isotopes between ^{74}Se and ^{196}Hg that cannot be produced by rp-, s- or r-processes

several thousand reactions involving hundreds of isotopes (mostly radioactive)

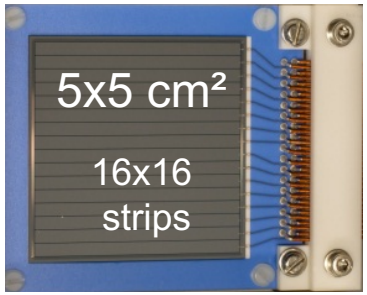
of interest are (p,g), (p,a), (p,n), (n,g), (a,g), etc. reactions

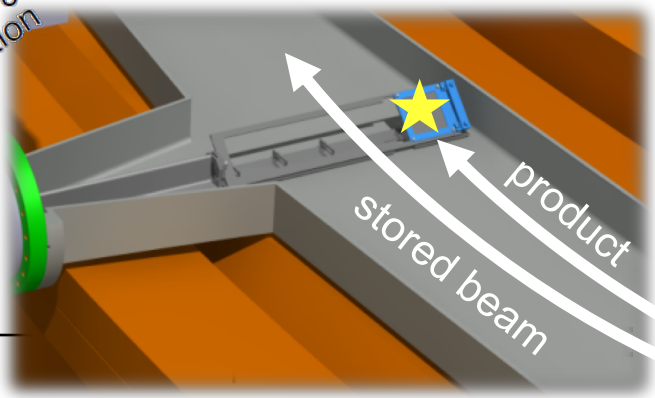
nearly no experimental data – modelling is based on Hauser-Feshbach calculations

The first (p,g) Measurement on 124Xe



spacial distribution measured with silicon detector

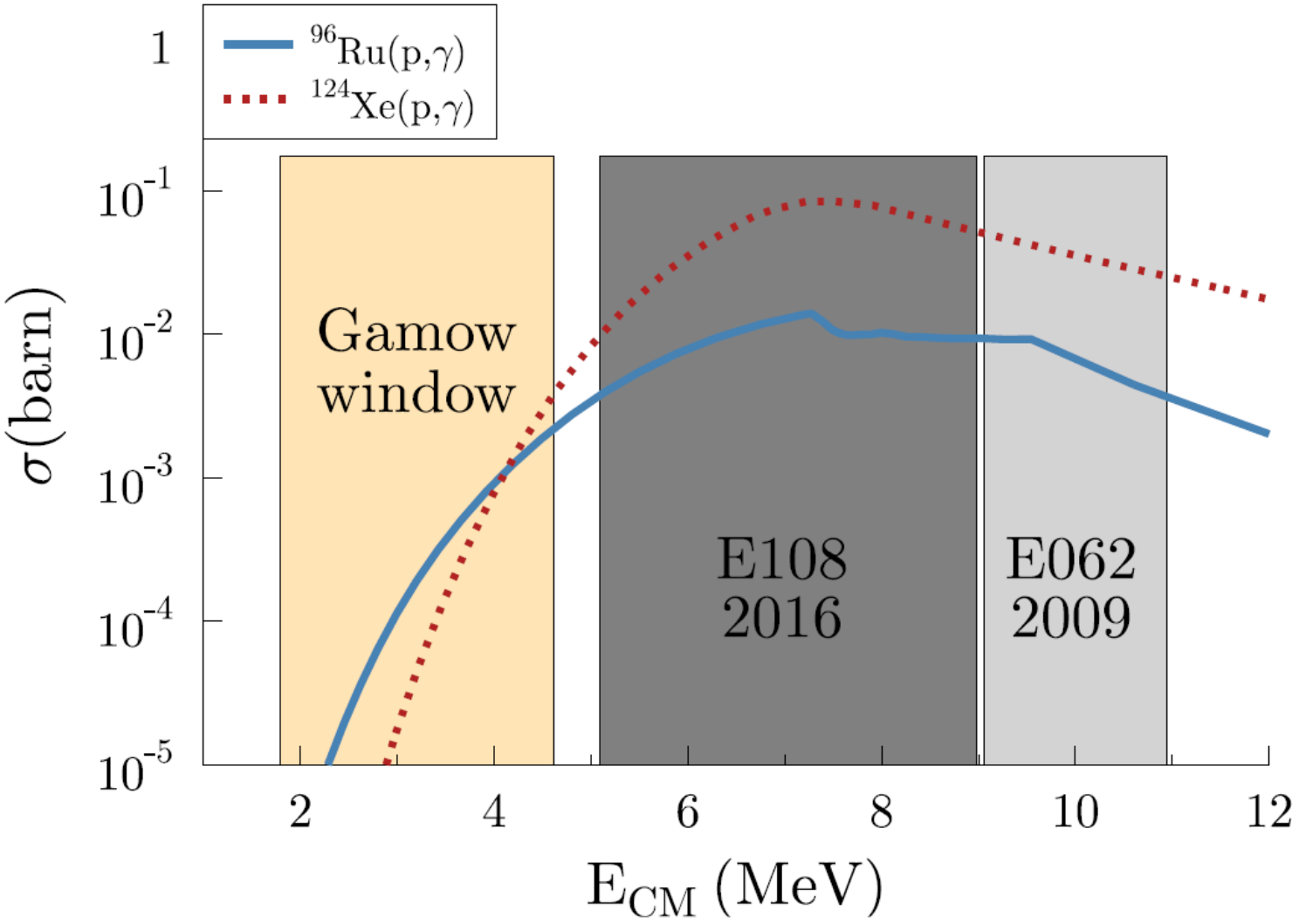




erc ASTRUm

Courtesy Jan Glorius

(p,g) studies at the ESR for p-process



Courtesy Rene Reifarth

Impact on Physics

- Most of HIE-ISOLDE and many ISOLDE proposals suffer from low intensity ➔ **unnecessary prolongation of beam times.**
- **New and more exotic species will be available** with the increase of intensities: **from x2-x5** for fragmentation, x1 – x2 for fission, **x6-x10** for spallation.
- Several HIE-ISOLDE experiments cannot reach full intensity due to contamination in the ISOLDE beam ➔ **need better beam purification (new HRS mass separator, …)**
- New target stations will allow **operation of low-energy and high-energy experiments**, thus doubling the available beam time.
- A low-energy storage ring will **enable a broad range of new physics experiments**

ISOLDE in the EPPS