A New Setup for Transfer Reactions at REX-ISOLDE

Riccardo Raabe

IKS, K.U.Leuven

DREB 2007 Direct Reaction with Exotic Beams

Riken, 30 May – 2 June, 2007

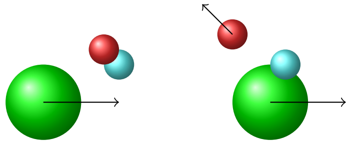
Collaboration

- Instituut voor Kern-en Stralingsfysica, K.U.Leuven, Belgium
  BriX Belgian Research Initiative on eXotic nuclei
- Physik-Department E12, T.U. München, Germany
- The Miniball Collaboration
- Manchester, York, Edinburgh
- V. Bildstein (T.U. München), N. Patronis (IKS, K.U.Leuven)

Outline

1. **Transfer reactions with RIBs**
2. **REX-ISOLDE at CERN**
   - Ion Sources
   - The REX post-accelerator
   - Miniball γ-array
3. **New setup for charged particles: T-REX**
   - Detector
   - Electronics
4. **First physics cases**
   - $d(^{30}\text{Mg},^{31}\text{Mg})p$
   - $d(^{66}\text{Ni},^{67}\text{Ni})p$
5. **Summary**

Transfer as spectroscopic tool



- Q-values ⇒ position of levels
- Angular distribution ⇒ spin and parities
- Cross sections ⇒ (relative) spectroscopic factors, ANCs

Measuring with RIBs

- Inverse kinematics
- Low intensity beams ("thick" targets)
- Detection of
  beam-like ejectile ⇒ spectrometer
  target-like ejectile ⇒ Si array
  γ-rays ⇒ Ge array

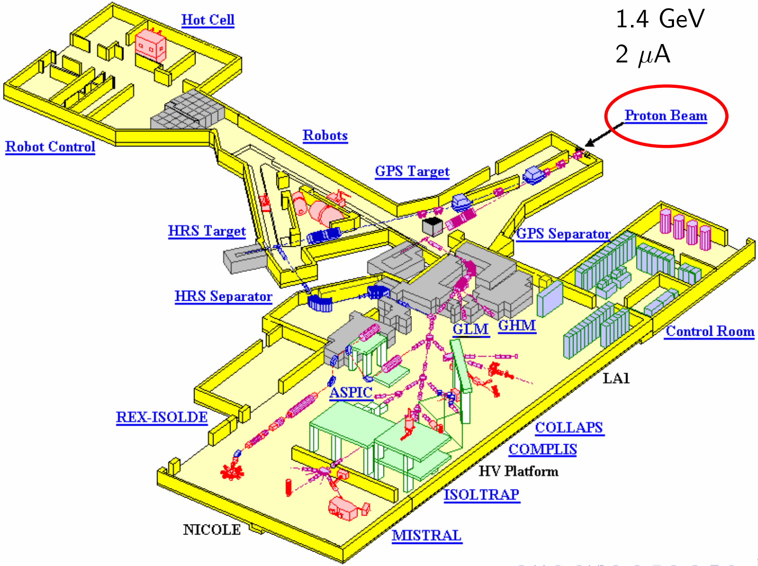
Problems

- Energy (angular) resolution
- Efficiency
- Background

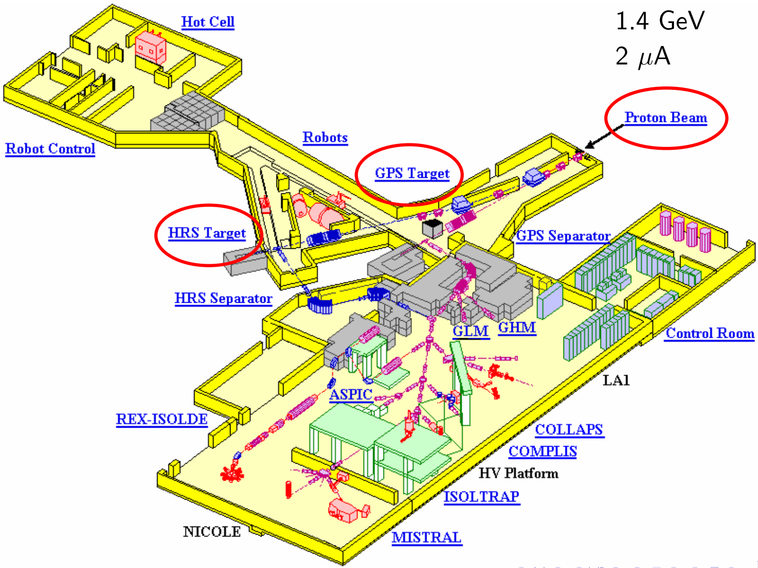
REX-ISOLDE @ CERN

1.4 GeV

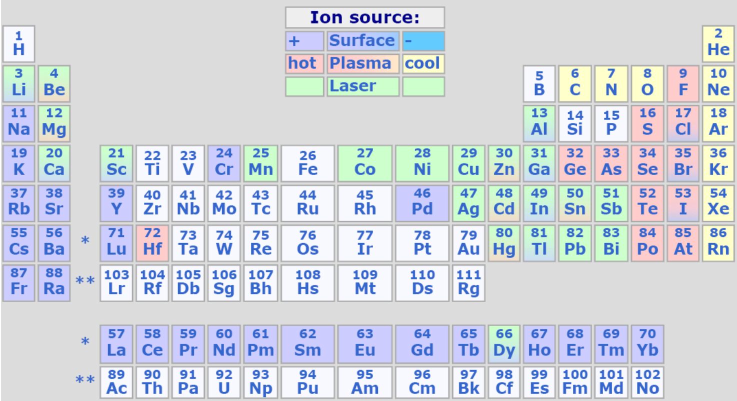
2 μA



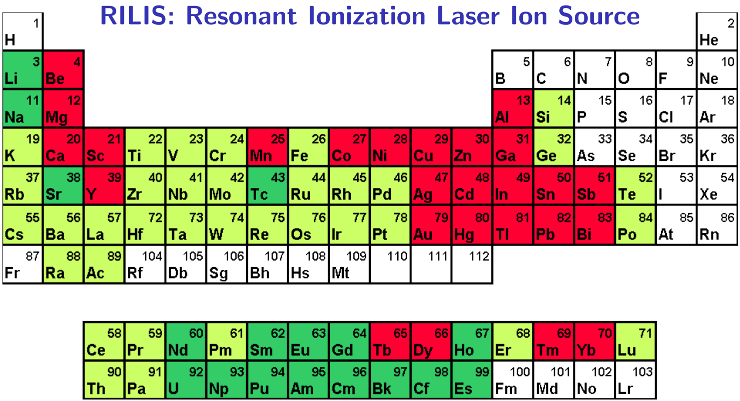
REX-ISOLDE @ CERN



ISOLDE Ion Sources



ISOLDE Ion Sources



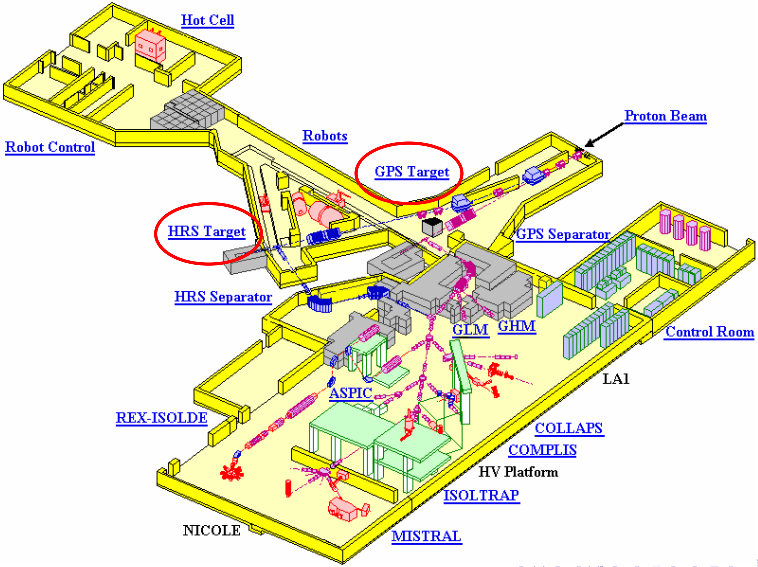
- Currently available
- Tested
- Feasible

Isomeric Beams

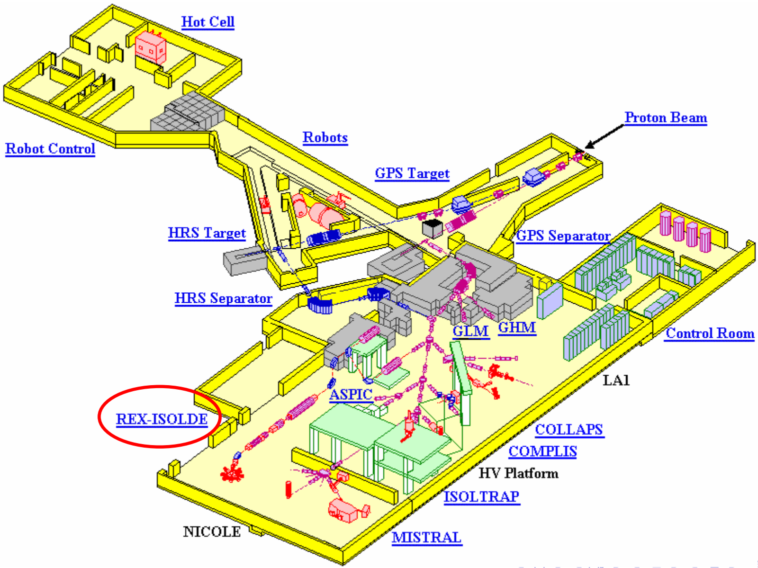
I. Stefanescu, PRL 98 (2007) 122701

COULEX with ^{68m,70g}Cu

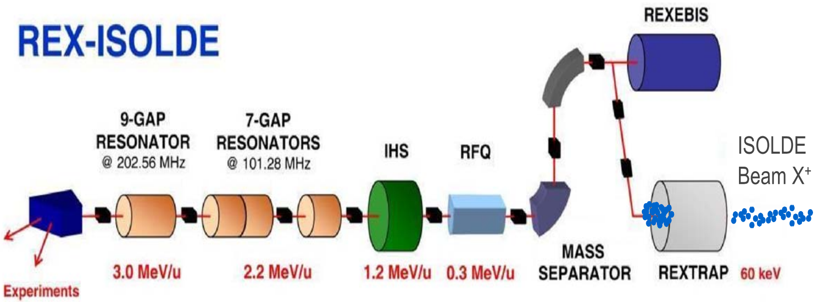
REX-ISOLDE @ CERN



REX-ISOLDE @ CERN

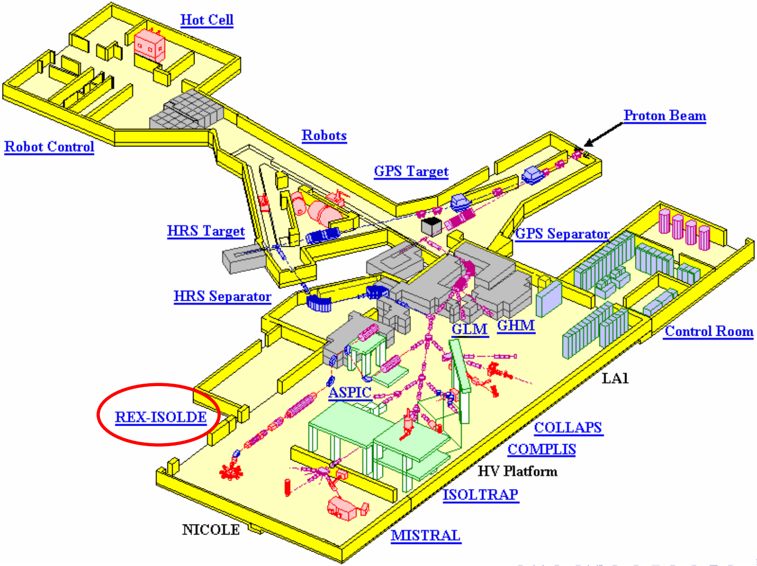


REX: Radioactive Beam EXperiment



- REXTRAP: Penning trap at 60 kV
- REXEBIS: Efficiency $\lesssim$ 30%
  $\tau =$ 10-100 ms
  $A/q < 4.5$, pulse width $< 100\mu$s
- Separator: q/A resolution ≈ 150
- LINAC: $L = 10$ m
  $0.8 < E < 3.0$ MeV/u
- Total efficiency: 1-5%

REX-ISOLDE @ CERN



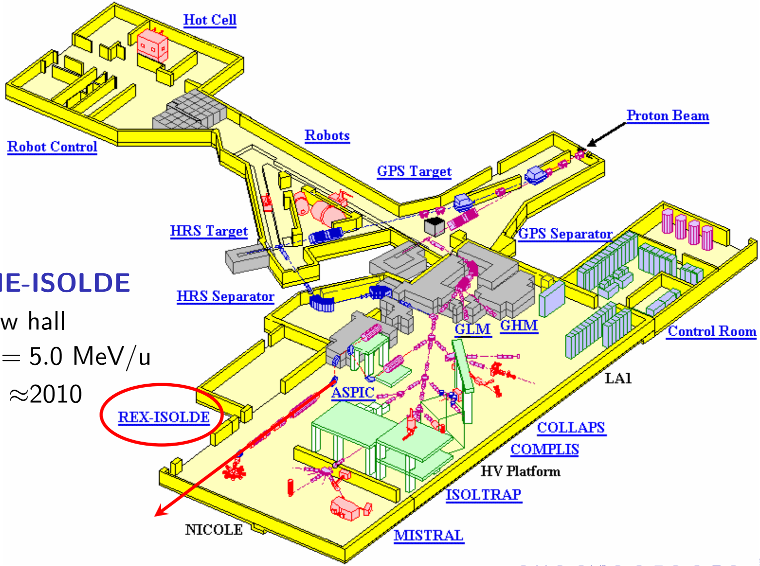
REX-ISOLDE @ CERN

HIE-ISOLDE

new hall

$E = 5.0$ MeV/u

by ≈2010



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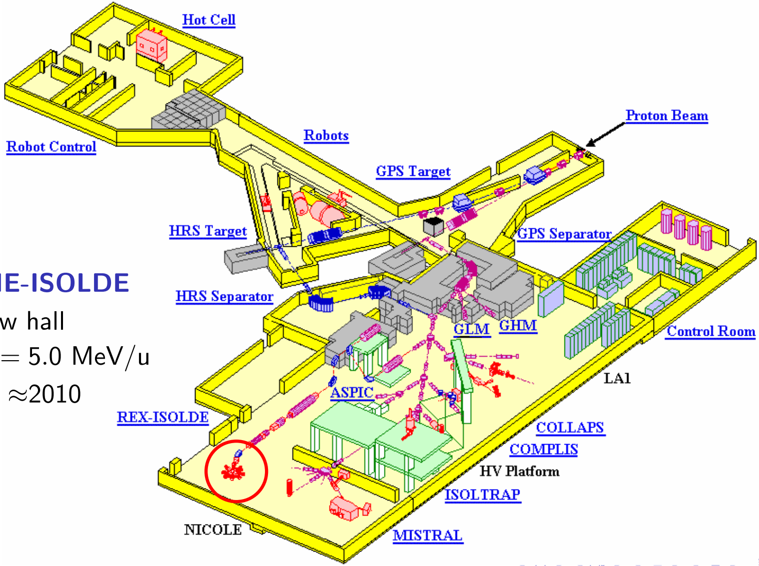
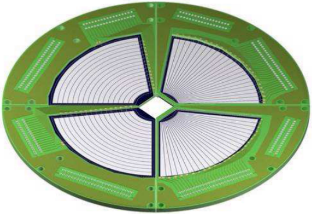


Miniball Ge-array

- Emphasis on efficiency: 20% @ 1.3 MeV photopeak
- High granularity: 8 clusters × 3 detectors × 6 segments + pulse-shape analysis
- Rate 10 kHz per detector
- Resolution 2-3 keV

The charged-particle detector array (T-REX)



Detector	Angles (deg)	Thickness (μm)	Segmentation
CD Front ΔE	8-27	300-500	$4 \times 16 \times 24$
CD Front E	8-27	1500	4

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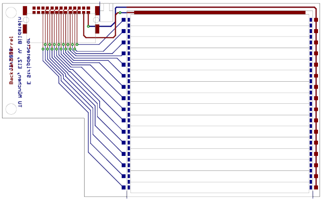

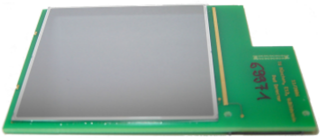

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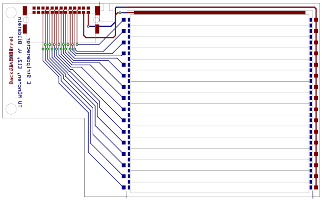

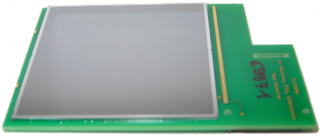

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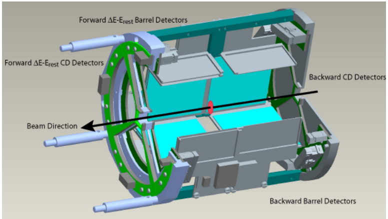

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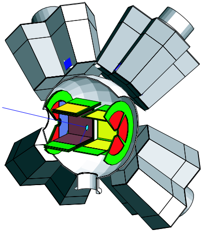

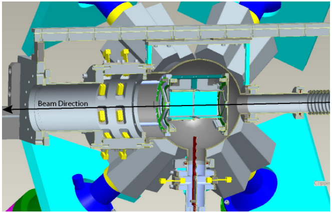

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Electronics for T-REX

- Miniball: triggerless acquisition (DGF modules, 3200 $/channel)
- T-REX: ≈ 450 channels

⇒ Limit the number of channels

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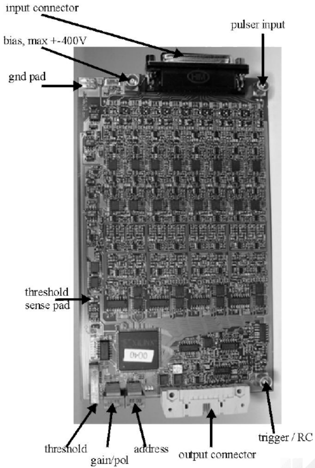
Mesytec MUX-16

- 16-into-2 channels (4 outputs)
- Low noise, high rate (500 MHz)
- One NIM trigger / LE timing
- Multiplicity (veto) output
- Replaceable preamp stage ⇒ different ranges possible
- Eight modules on the same bus ⇒ 128 channels into 4

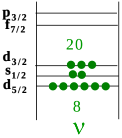


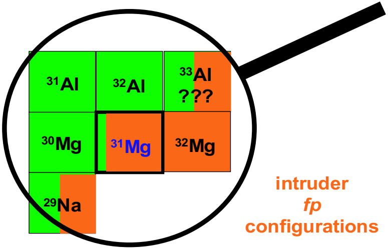
Electronics scheme

First case: d(^{30}Mg,^{31}Mg)p

Single-particle states in ^{31}Mg

- Border of the "island of inversion"
  Niedermeier PRL 94 (2005) 172501





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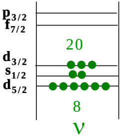

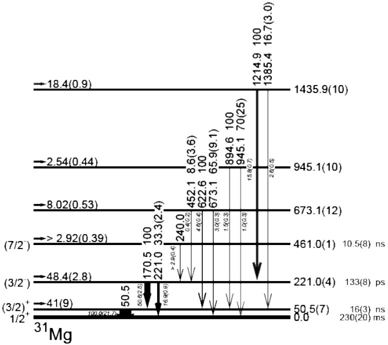

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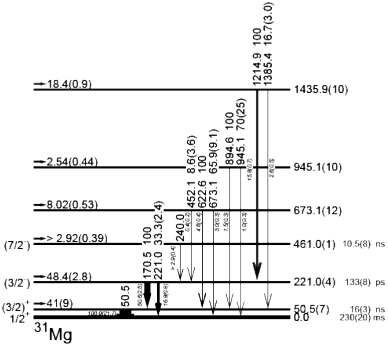
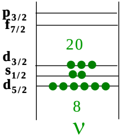
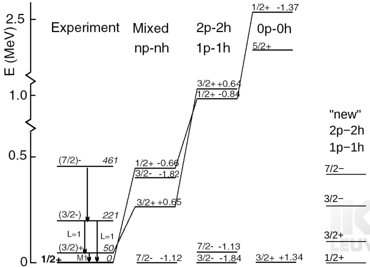




- Ground state,
  first excited state:
  $>$ 95% 2p-2h intruder

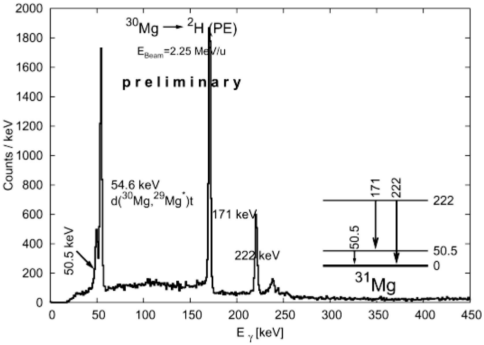


d(^{30}Mg,^{31}Mg)p with T-REX + Miniball

- ^{30}Mg at 3.0 MeV/u, 5×10^4 pps

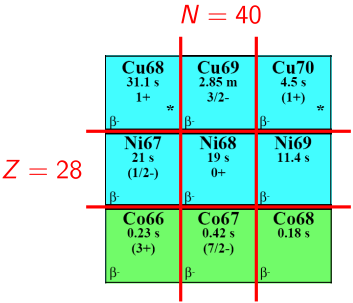
d(^{30}Mg,^{31}Mg)p with T-REX + Miniball

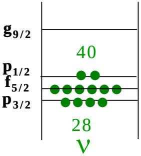
- ^{30}Mg at 3.0 MeV/u, 5×10^4 pps
- Coincidence with γ's to identify the states
- p, d, bgr identified in telescopes



d(^{66}Ni,^{67}Ni)p

The N = 40 subshell closure



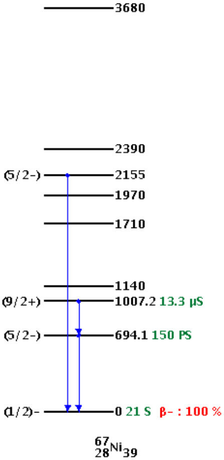


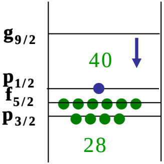
- Neighbours of ^{68}Ni probed by β-decay (and Coulex on ^{69}Cu)
- $N = 40$ strongly weakened by adding/removing a nucleon

$\Rightarrow$ Measure *structure* of states

Details

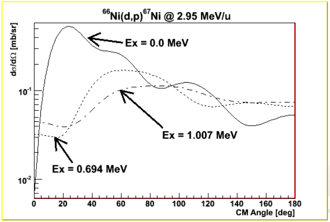
d(^{66}Ni,^{67}Ni)p with T-REX + Miniball





- ^{66}Ni at 3 MeV/u, 10^6 pps
- Prompt and delayed γ-coincidence

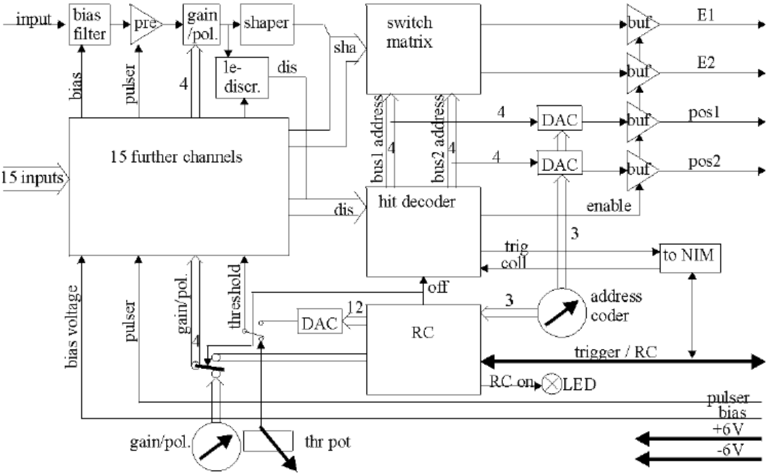
$\nu(g_{9/2})$ => $9/2^+$; l=4
$\nu(p_{1/2})$ => $1/2^-$; l=1
$\nu(f_{5/2})$ => $5/2^-$; l=3
$\nu(p_{3/2})$ => $3/2^-$; l=1



Summary

- New charged particle detection setup at REX-ISOLDE to measure transfer reactions
- Coupling with Miniball
- First measurement: $d(^{30}\mathrm{Mg},^{31}\mathrm{Mg})p$ in 2007
- First test of the setup at Munich with $d(^{64}\mathrm{Ni},^{65}\mathrm{Ni})p$

MUX-16 electronic scheme



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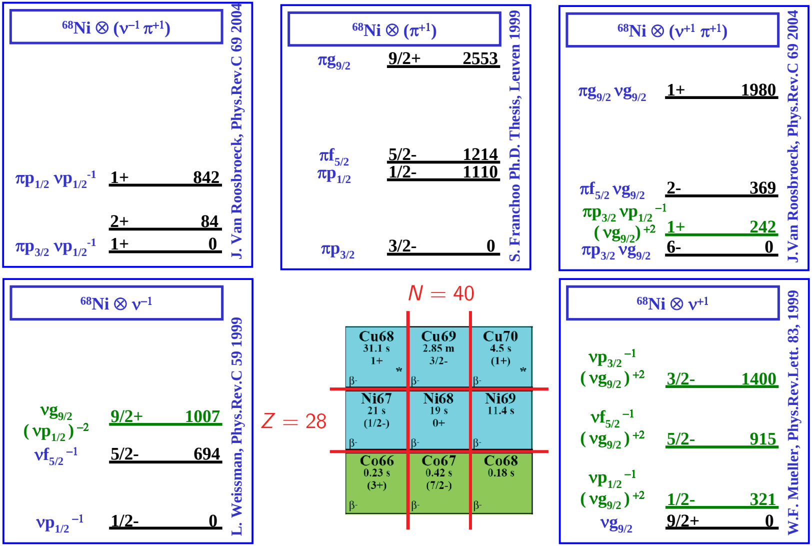
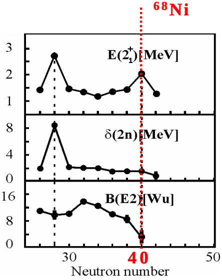
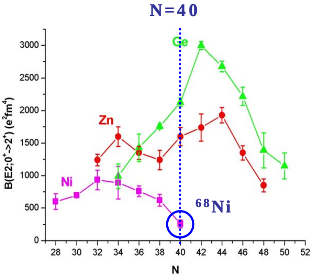
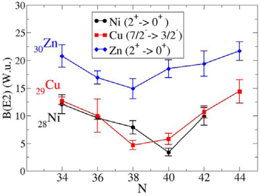
Around ^{68}Ni


^{68}Ni ⊗ (ν^{-1} π^{+1})
$\pi p_{1/2}$ $\nu p_{1/2}^{-1}$ 1+ 842
2+ 84
$\pi p_{3/2}$ $\nu p_{1/2}^{-1}$ 1+ 0
J. Van Roosbroeck, Phys.Rev.C 69 2004
^{68}Ni ⊗ (π^{+1})
$\pi g_{9/2}$ 9/2+ 2553
$\pi f_{5/2}$ 5/2- 1214
$\pi p_{1/2}$ 1/2- 1110
$\pi p_{3/2}$ 3/2- 0
S. Franchoo Ph.D. Thesis, Leuven 1999
^{68}Ni ⊗ (ν^{+1} π^{+1})
$\pi g_{9/2}$ $\nu g_{9/2}$ 1+ 1980
$\pi f_{5/2}$ $\nu g_{9/2}$ 2- 369
$\pi p_{3/2}$ $\nu p_{1/2}^{-1}$ $(\nu g_{9/2})^{+2}$ 1+ 242
$\pi p_{3/2}$ $\nu g_{9/2}$ 6- 0
J.Van Roosbroeck, Phys.Rev.C 69 2004
^{68}Ni ⊗ ν^{-1}
$\nu g_{9/2}$ $(\nu p_{1/2})^{-2}$ 9/2+ 1007
$\nu f_{5/2}^{-1}$ 5/2- 694
$\nu p_{1/2}^{-1}$ 1/2- 0
L. Weissman, Phys.Rev.C 59 1999
$N = 40$
$Z = 28$
Cu68 31.1 s 1+ β-
Cu69 2.85 m 3/2- β-
Cu70 4.5 s (1+) β-
Ni67 21 s (1/2-) β-
Ni68 19 s 0+ β-
Ni69 11.4 s β-
Co66 0.23 s (3+) β-
Co67 0.42 s (7/2-) β-
Co68 0.18 s β-
^{68}Ni ⊗ ν^{+1}
$\nu p_{3/2}^{-1}$ $(\nu g_{9/2})^{+2}$ 3/2- 1400
$\nu f_{5/2}^{-1}$ $(\nu g_{9/2})^{+2}$ 5/2- 915
$\nu p_{1/2}^{-1}$ $(\nu g_{9/2})^{+2}$ 1/2- 321
$\nu g_{9/2}$ 9/2+ 0
W.F. Mueller, Phys.Rev.Lett. 83, 1999

Around ^{68}Ni







Courtesy of I. Stefanescu

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