Single particle states in ^{67}Ni

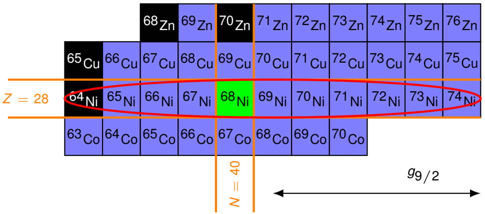
First results of ^{66}Ni(d,p)^{67}Ni using MINIBALL @ REX-ISOLDE

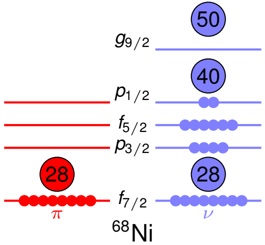
J. Diriken for the IS469 Collaboration

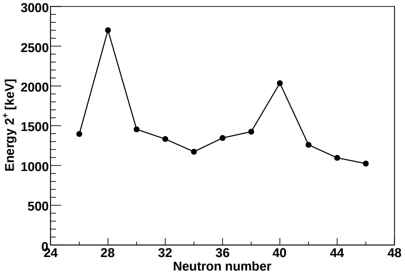
Instituut voor Kern- & Stralingsfysica - Katholieke Universiteit Leuven

EGAN Workshop 2011 - Padova
June 28, 2011

The $Z = 28$, $N = 40$-region







- Local maximum in $E_{ex}(2^+_1)$
- Minimum in $B(E2; 0^+ \to 2^+)$
- No irregularity in S_{2n}
- Shell effects to be expected, importance of $N = 40, 50$ shell gaps

R. Broda *et al.* PRL **74**:868 (1995), N. Bree *et al.* PRC **78**:041307 (2008), O. Sorlin *et al.* PRL **88**:092501 (2002), S. Rahaman *et al.* EPJA **34**:5 (2007), O. Perru *et al.* PRL**96**:232501 (2006), E. Caurier *et al.* EPJA **15**:145 (2002)

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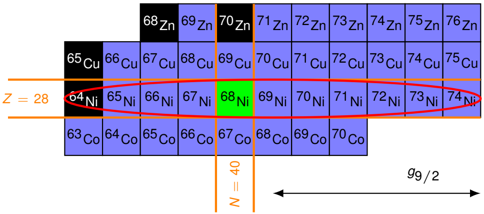

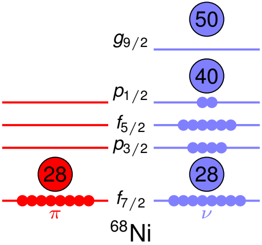

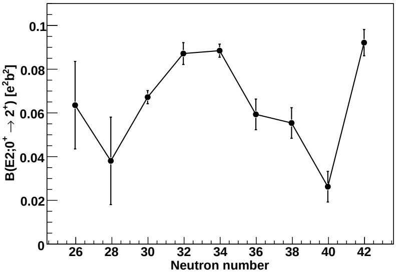

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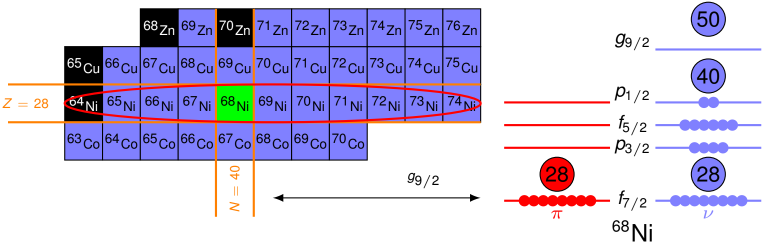

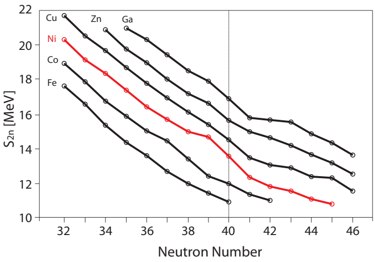

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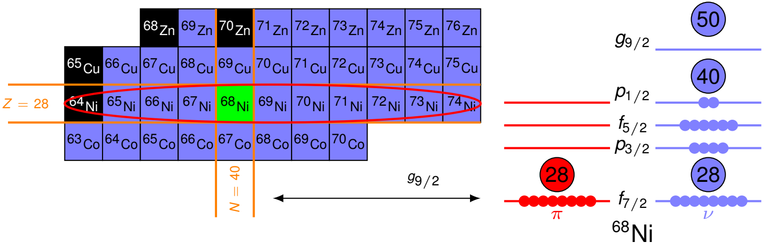

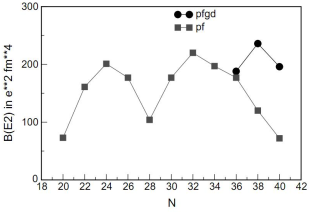

Fig. 9. $B(E2)\ 0^+ \to 2^+$ in $e^2\ fm^4$: Fe isotopes.

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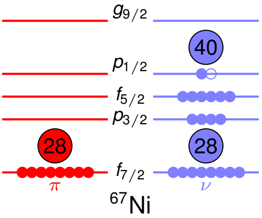
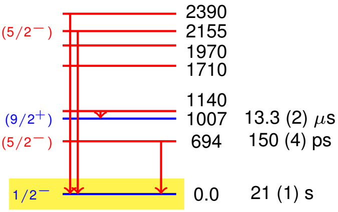
$^{2}H(^{66}Ni,^{1}H)^{67}Ni$





Questions

- Study the ground state structure (^{68}Ni $\otimes \nu^{-1}$)
- g-factor of the $9/2^+$-state is smaller by a factor of 2 than expected for a $1g_{9/2}$-state
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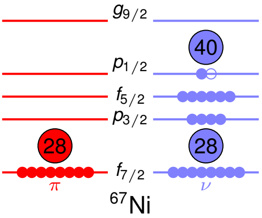

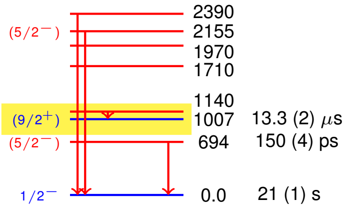

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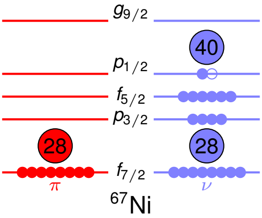

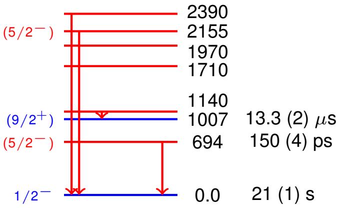

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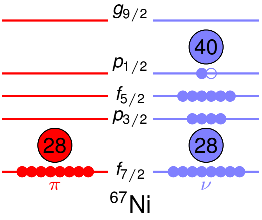

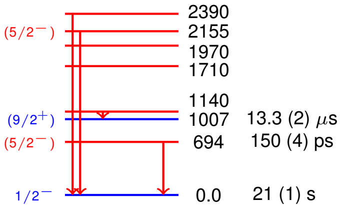

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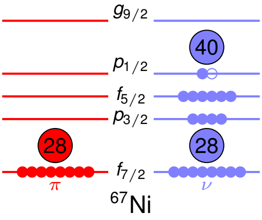

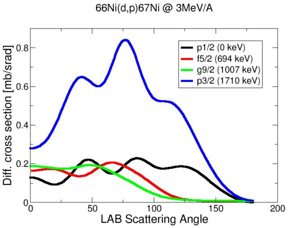

A.J. Koning *et al.*, NPA 713, 231 (2003)

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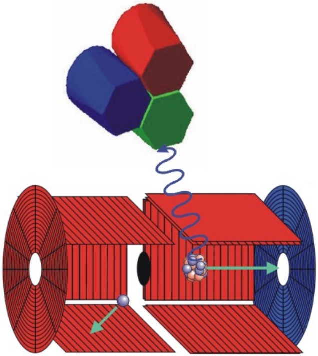
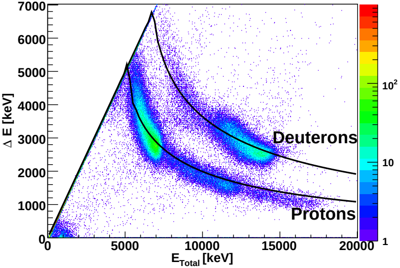
T-REX @ MINIBALL





V. Bildstein Prog.Part.Nucl.Phys **59**:386 (2007)

Detector	Angles	Thickness	Segmentation
Forw. Barrel (ΔE)	30-75	140 μm	16 resistive strips
Forw. Barrel (E)	30-75	1000 μm	-
Back. Barrel (ΔE)	104-152	140 μm	16 resistive strips
Back. Barrel (E)	104-152	1000 μm	-
Back. CD	152-172	500 μm	16 annular x 24 radial

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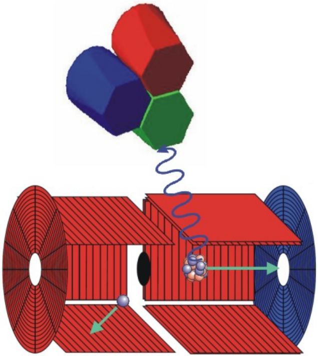

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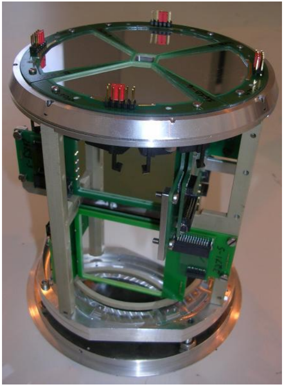

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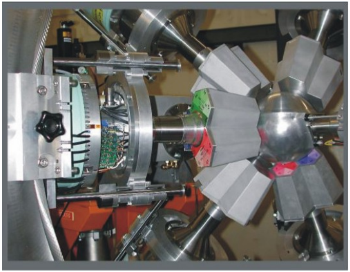
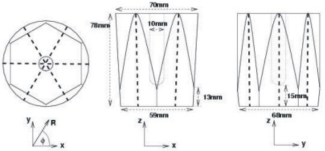
MINIBALL γ-array

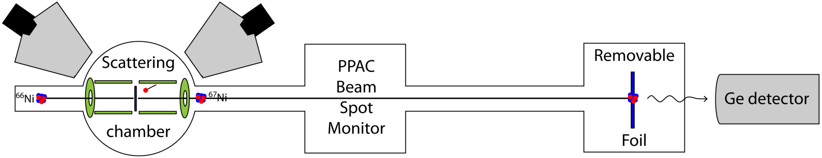




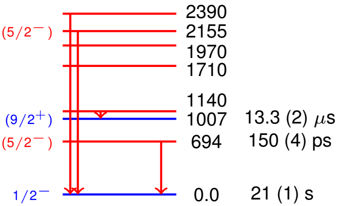
Main characteristics

- 8 Miniball clusters
- Each cluster: 3 HPGe crystals
- Each crystal: 6-fold segmented
- 8% efficiency @ 1 MeV

Slow coincidence technique



- Identify population of $(9/2^+)$ isomeric state and/or states decaying via this isomere
- Implant beam on removable foil (cycletime: $\sim$ 8 hours)
- Make correlation on longer time scale (120 μs vs. 2 μs (MINIBALL)) with protons detected in particle array



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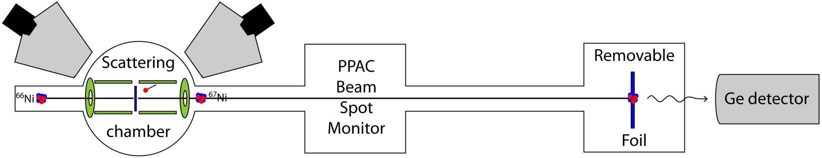

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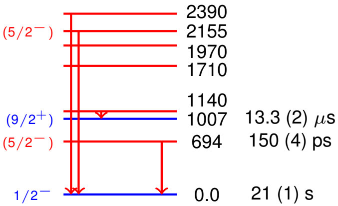

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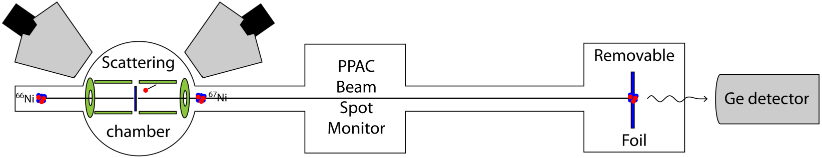

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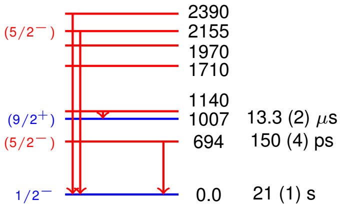
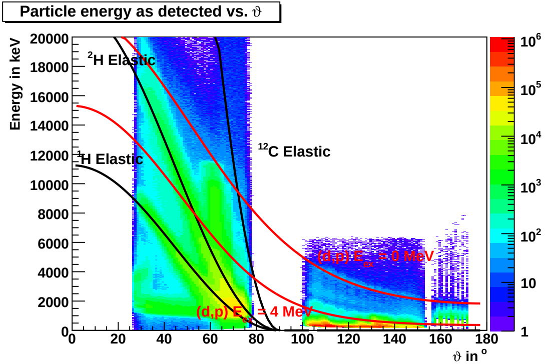


Measured proton energy spectrum



Conditions

- 100 μgr/cm^2 CD_2 target
- 3 10^6 pps
- > 99 % ^{66}Ni
- Laser ionisation by RILIS
- 9 days of beamtime

- Population of levels up to 6 MeV, strong feeding around 3.6 MeV
- ^{67}Ni excitation energy can be deduced from measured proton energy
- Use as trigger for γ-rays detected by MINIBALL

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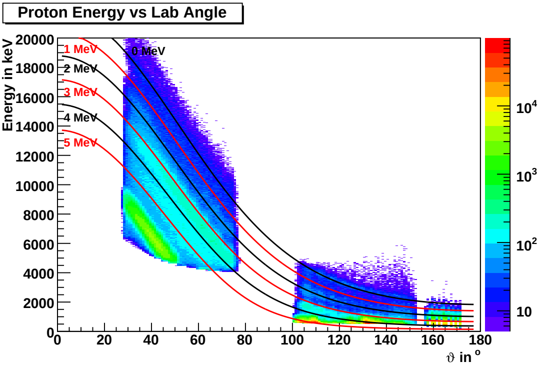

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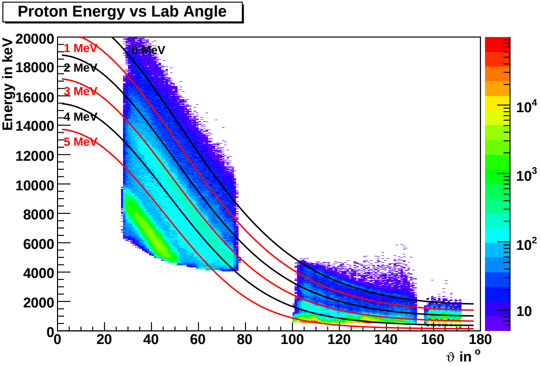

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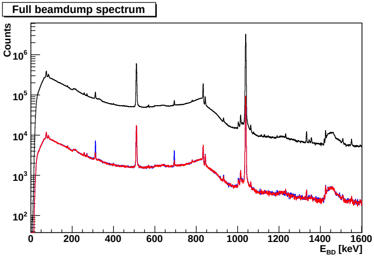

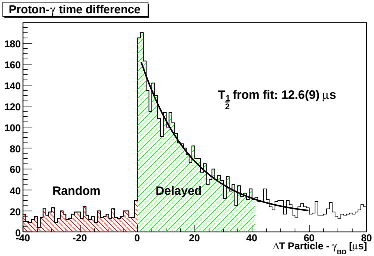

- Fitted half-life in agreement with previous measurement of 13.3(2) μs
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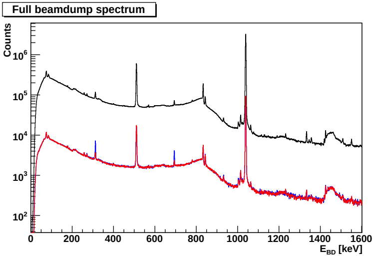

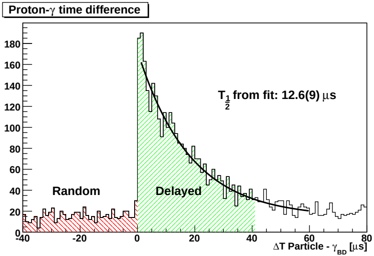

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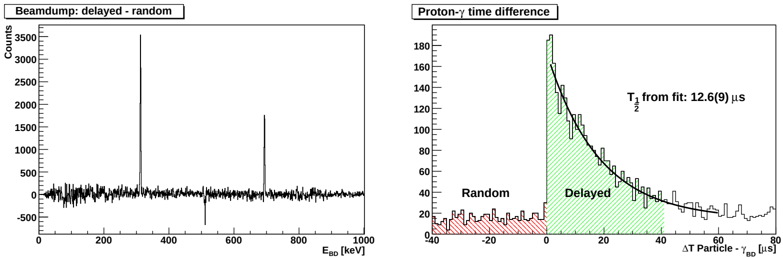

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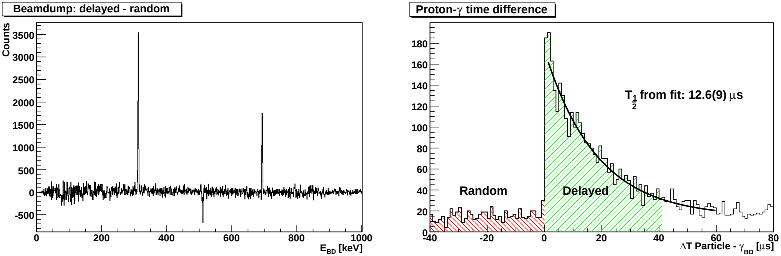

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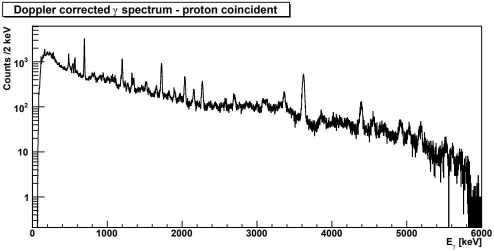
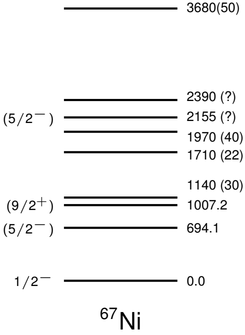


- Very rich proton-gated γ spectrum
- γ-transitions up to 5800 keV are observed
- Possibilities for p-γ-γ coincidences
- Additional information from p-γ-Beamdump coincidences and excitation energy deduced from proton energy



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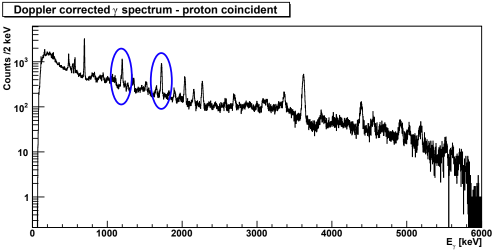

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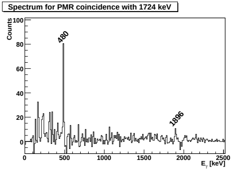
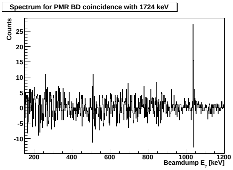
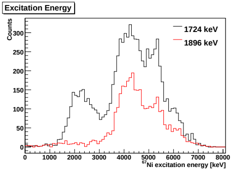
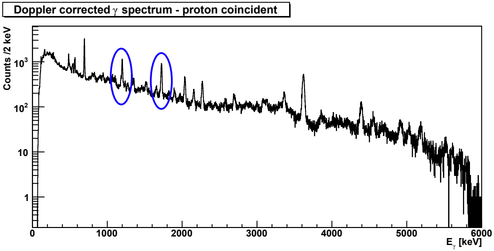
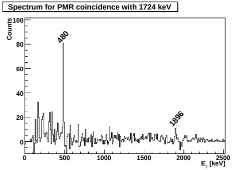


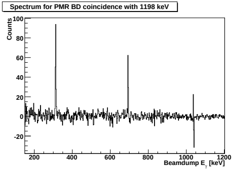


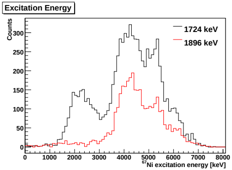


γ spectra









- Very rich proton-gated γ spectrum
- γ-transitions up to 5800 keV are observed
- Possibilities for p-γ-γ coincidences
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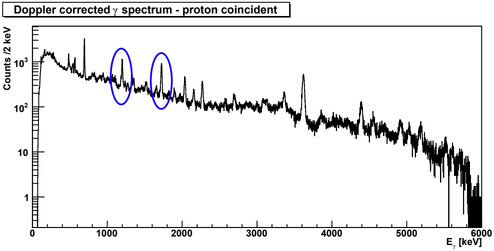

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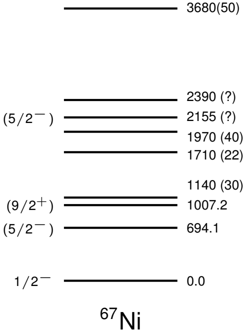

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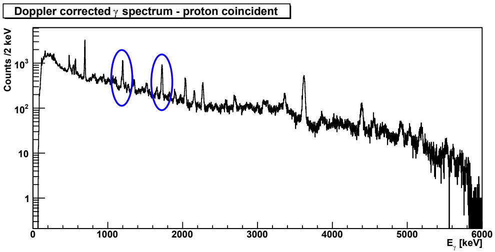

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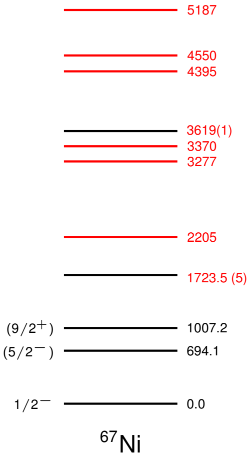

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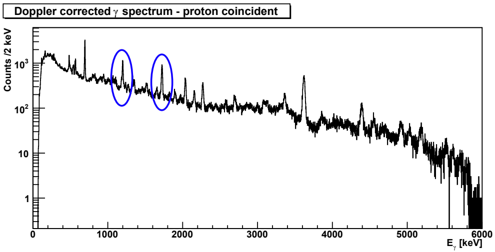

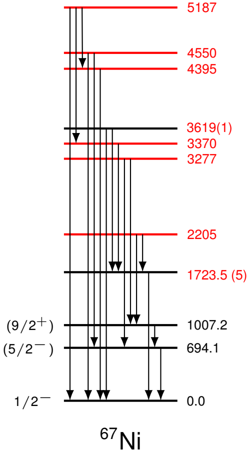

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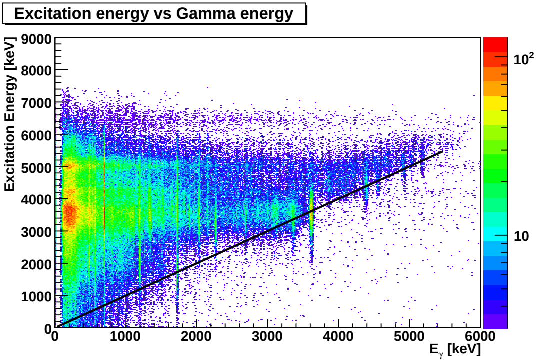
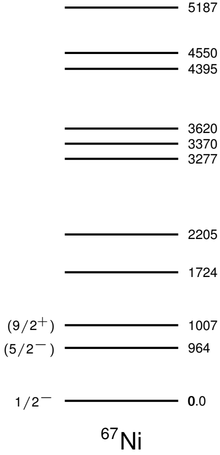
^{67}Ni excitation energy versus E_γ





- Indications of a populated level around 2.5 MeV which does not decay directly to the ground state $\Rightarrow$ good candidate for $\nu 2d_{5/2}$-state (N=50)
- Extensively new spectroscopic information on ^{67}Ni
- Extraction of angular distributions

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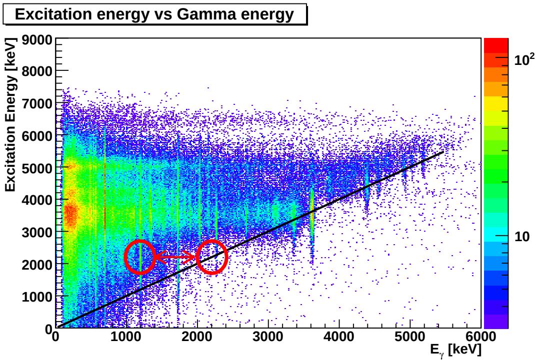

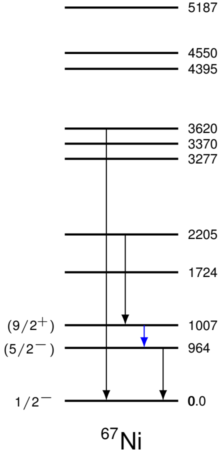

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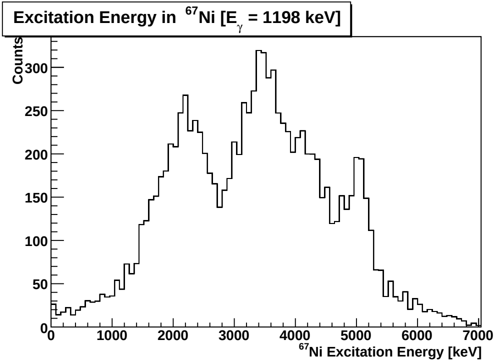

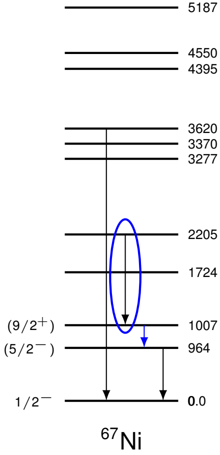

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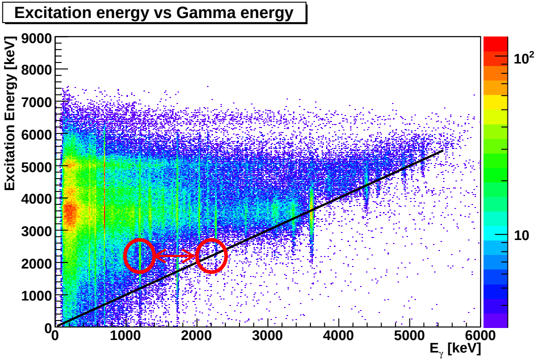

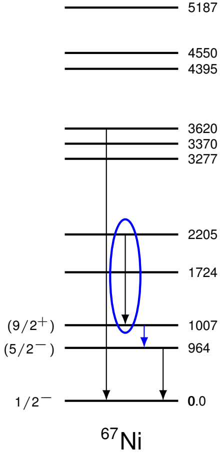

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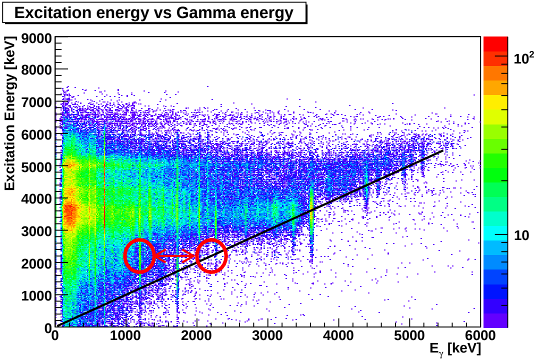

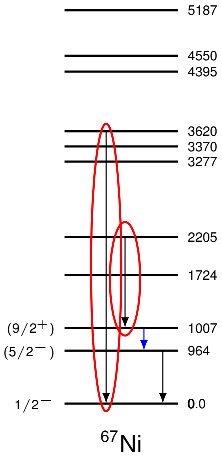

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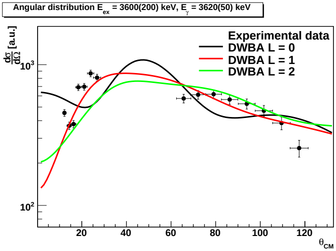
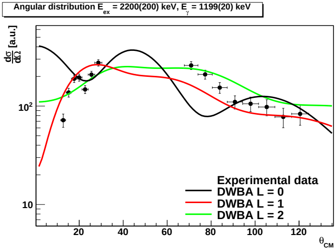
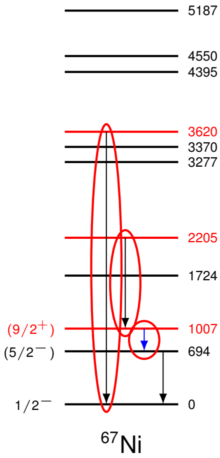
Proton angular distributions







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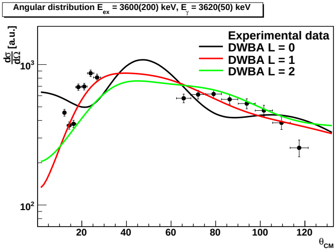

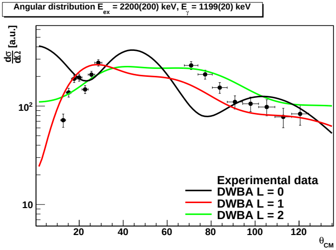

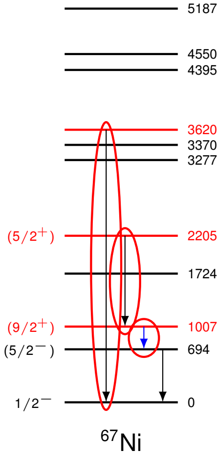

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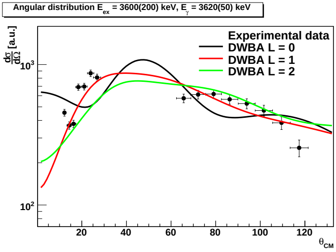
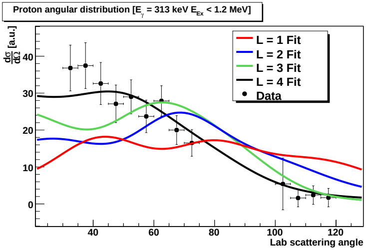
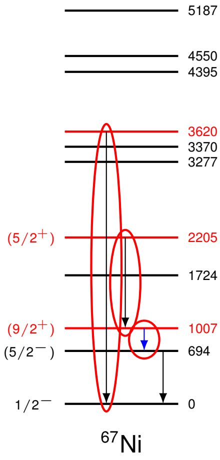
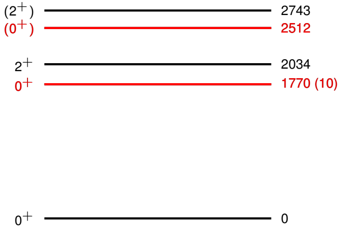


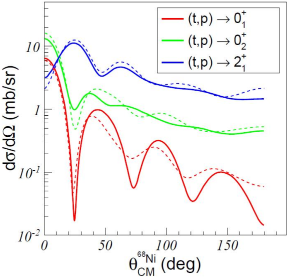


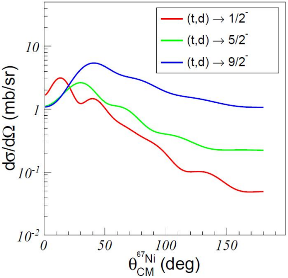


A look into the future...

- Accepted proposal: ^{66}Ni(t,p)^{68}Ni reaction
- Characterisation of the excited 0^+ states
  - 0_2^+: pure $\nu(p_{1/2})^{-2}$ or mixture of many different 2p-2h states?
  - 0_3^+: $\nu(f_{5/2})^{-2}$ or proton intruder?
  - 2_2^+: Spin confirmation required
- Complementary information from ^{66}Ni(t,d)^{67}Ni reaction







Conclusion & Outlook

- Conclusions
  - Succesfull first one neutron transfer experiment around ^{68}Ni using T-REX and MINIBALL @ REX-ISOLDE
  - Population of excited states up to 6 MeV are observed, most probably above $N = 50$
  - New and extensive spectroscopic information on ^{67}Ni to serve as benchmarks for new Shell Model calculations using different interactions
- Outlook
  - Recent experiment: ^{78}Zn(d,p)^{79}Zn (october 2010) and proposed continuation (^{80}Zn(d,p))
  - Accepted proposal: ^{66}Ni(t,p)^{68}Ni (september 2011) and ^{72}Zn(t,p)^{74}Zn (TUM - october 2011)
  - Approval of HIE-ISOLDE (beam energy up to 10 MeV/u) $\Rightarrow$ increased ΔL sensitivity

Collaboration

- **IKS, K.U. Leuven**: J. Diriken, I.G. Darby, H. De Witte, J. Elseviers, M. Huyse, R. Raabe, T. Roger, P. Van Duppen
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- **UWS, Paisley**: A. Andreyev, R. Orlandi
- **Comenius University Bratislava**: A. Antalic