



CERN-INTC-2017-011 / INTC-P-494

Spectroscopy of ^{81}Zn via one-neutron transfer $^{80}\text{Zn}(\text{d},\text{p})$ using ACTAR TPC

Spokesperson: M. Babo, R. Raabe
on behalf of the ACTAR-TPC collaboration

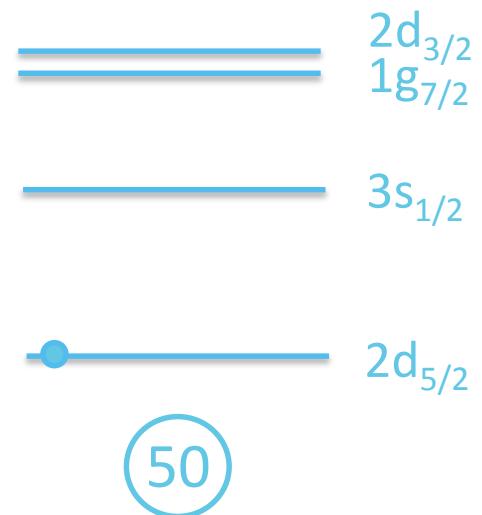
Local contact: L. Gaffney



Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Physics case

- $N = 51$ isotones : only one neutron above $N = 50$ shell closure
- Even Z : ground states are $5/2^+$ and the first excited states are $1/2^+$
- Excitation energies reflect the ESPE
- Tensor force drives the evolution of the ESPE

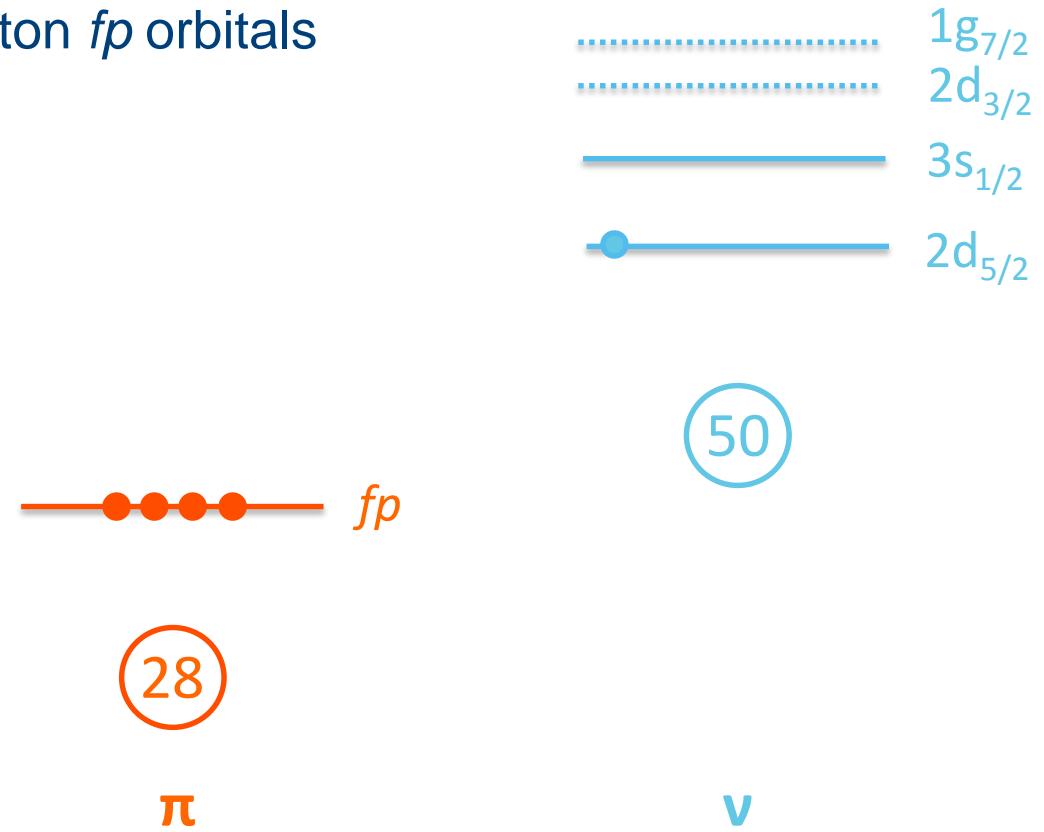
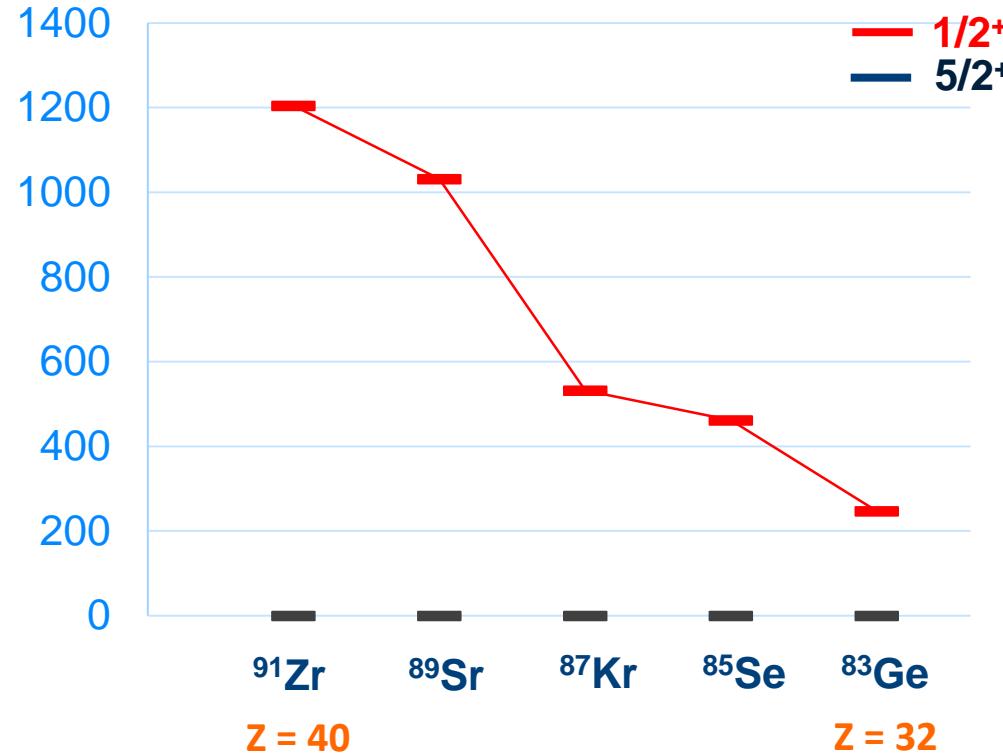


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Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Physics case

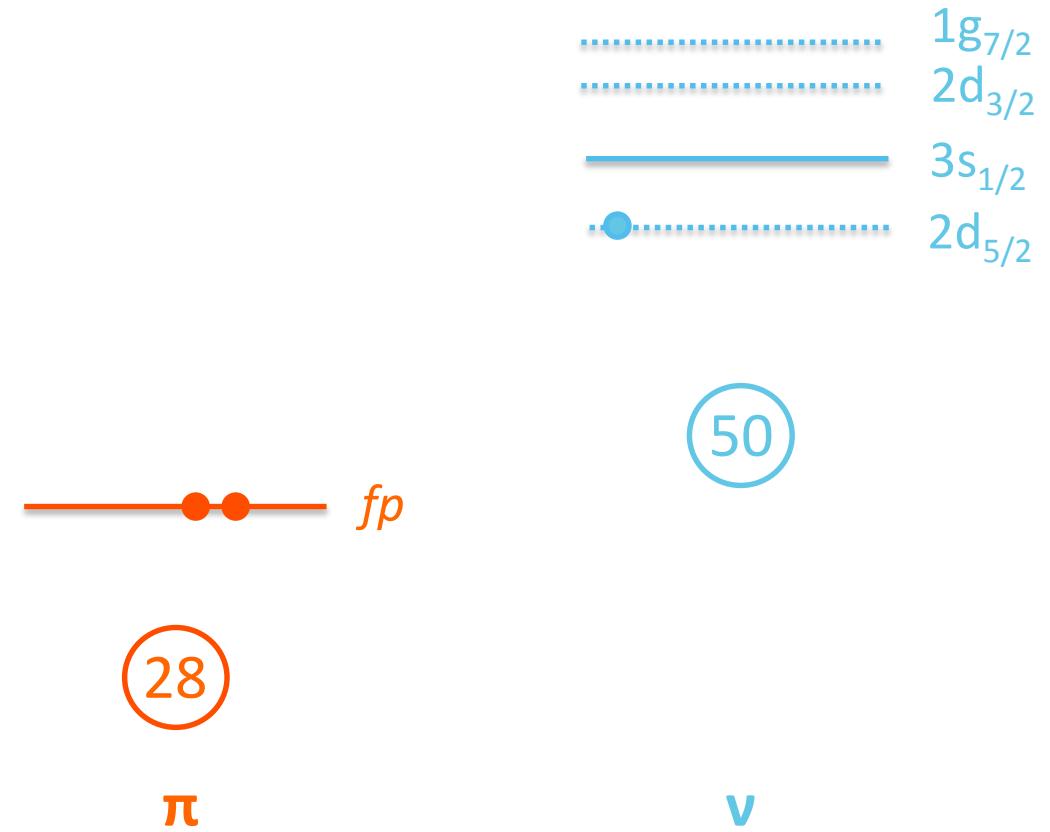
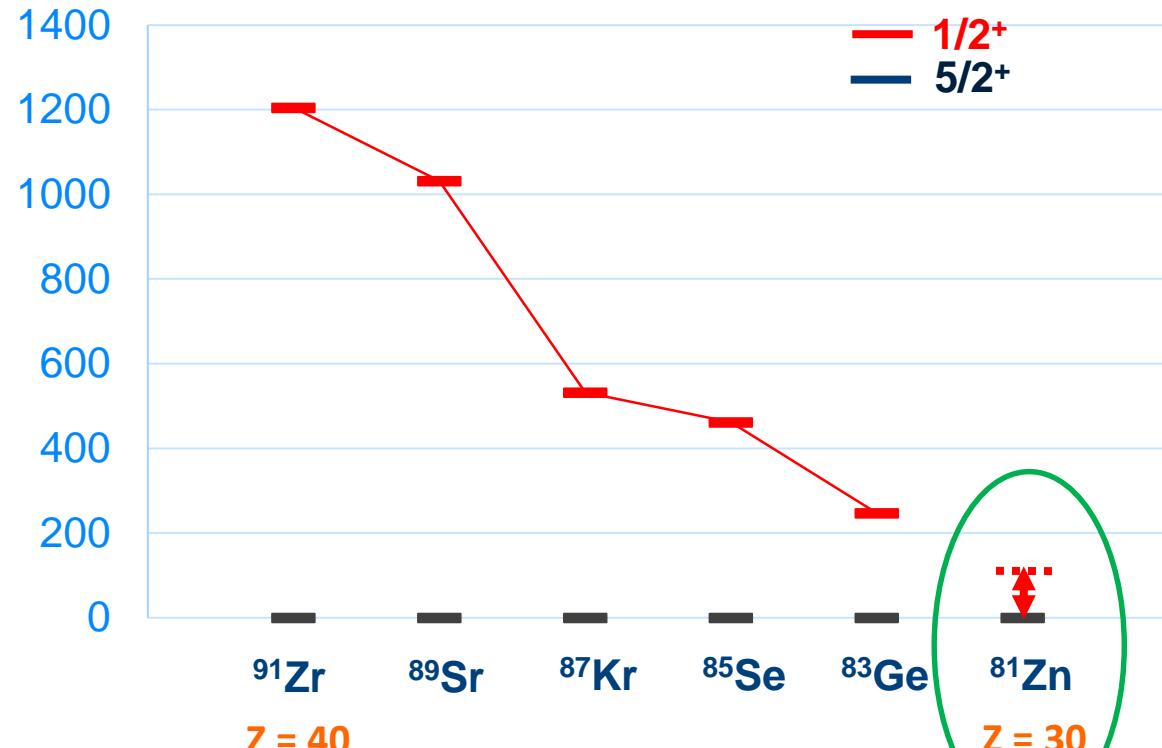
- Systematics on N=51 isotones: emptying of the proton *fp* orbitals



Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Physics case

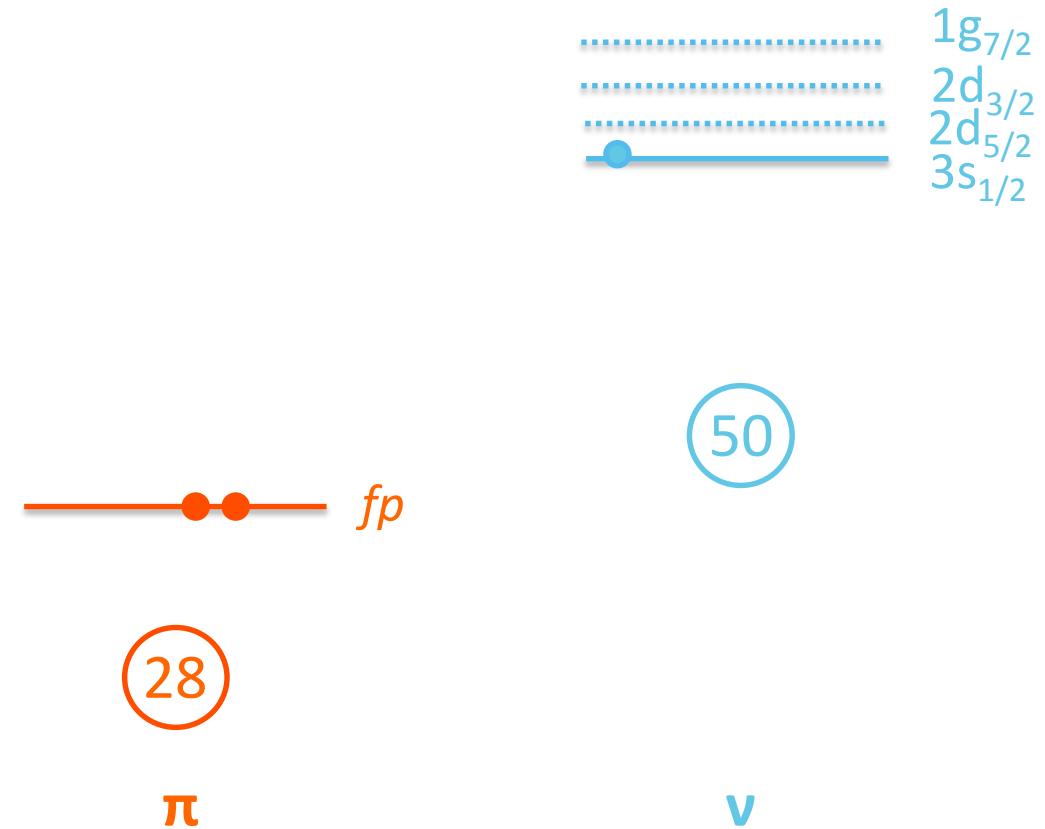
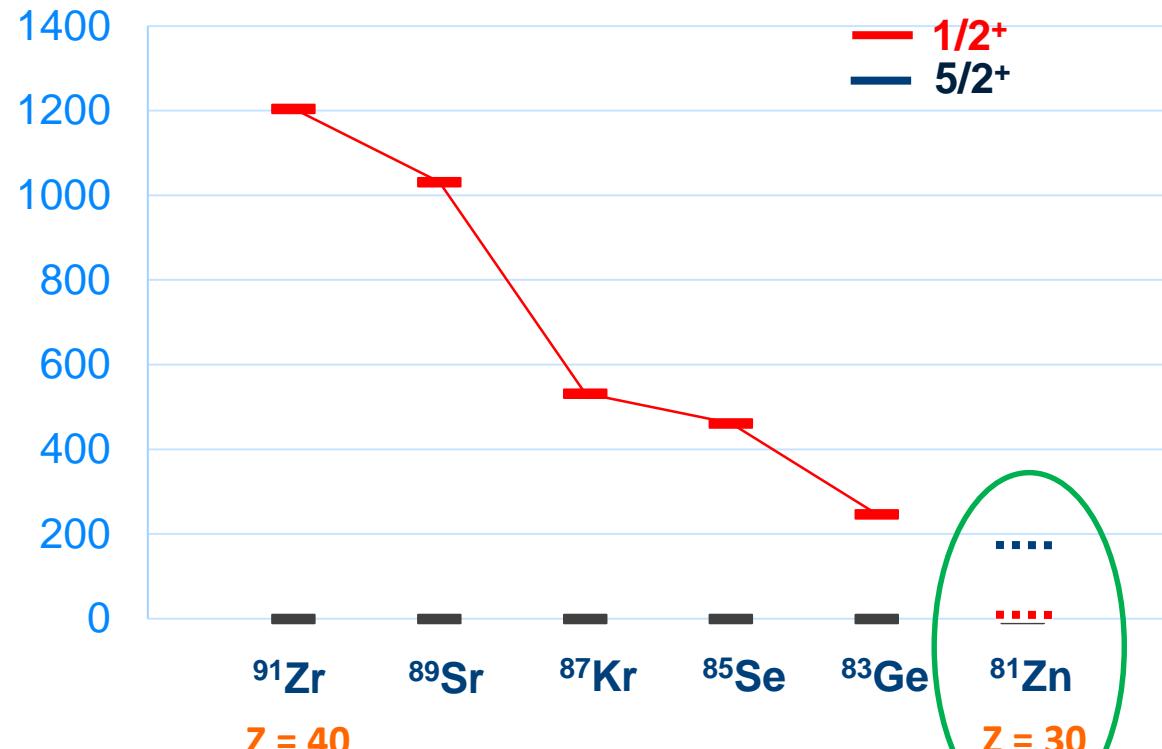
- What is the energy of the $1/2^+_1$?



Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

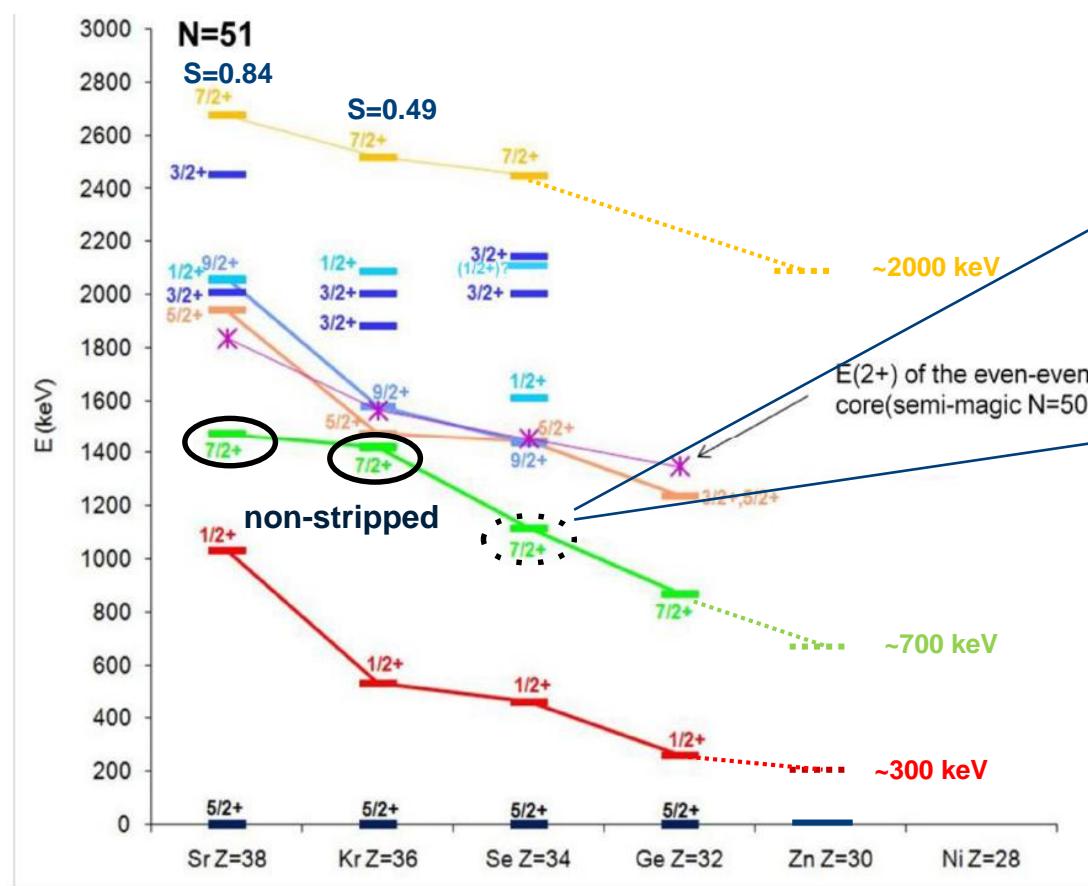
Physics case

- Does the trend lead to an inversion ?



Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Physics case



Single-particle state according to (d,p) reaction
J.S. Thomas, PRC 71, 021302 (2005) and PRC 76, 044302 (2007)

Core-coupling $2^+ \otimes v2d_{5/2}$ according to life-time meas.
(F. Didierjean – to be published in PRC)

- Which $7/2^+$ is single-particle ($g_{7/2}$)?

Courtesy of D. Verney

Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Experimental method

- Accepted experiment (INTC-P-352)
 - T-REX Si detectors
 - Angular distribution of the protons
 - Between **400-keV and 1-MeV resolution**
 - MINIBALL Ge array
 - Detection of the γ -rays with high resolution (~ 10 keV)
 - Limited by **low efficiency** for high-energy states ($7/2^+$ @ 2 MeV)
 - **E2 transition might be not observed ($T_{1/2} > 10$ ns)**

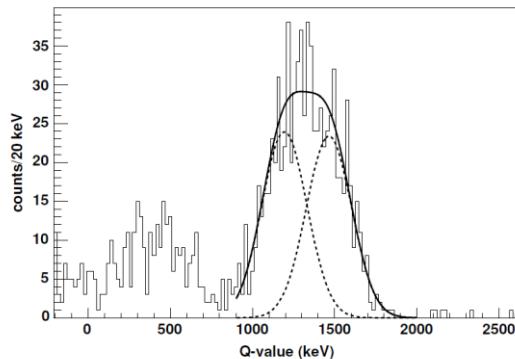
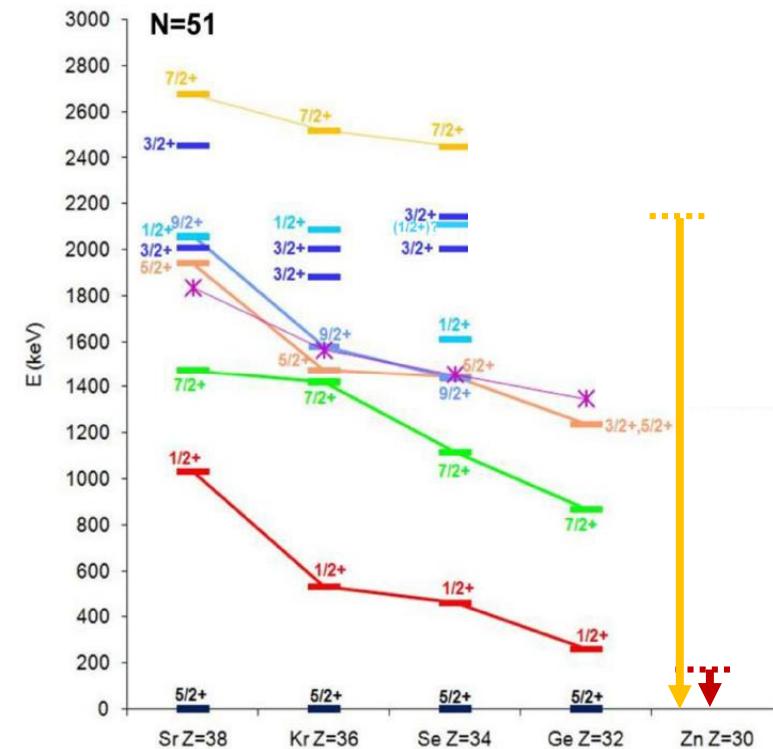


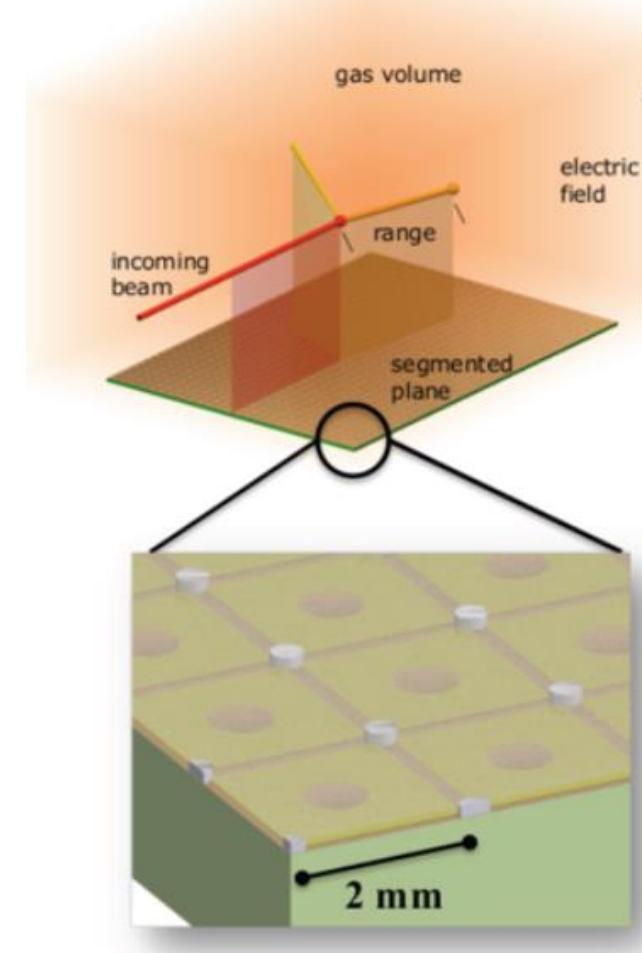
FIG. 3. $^{2}\text{H}(^{82}\text{Ge}, p)^{83}\text{Ge}$ Q-value spectrum (all angles). The solid line is the two-state fit for the ground and first-excited states of ^{83}Ge .



Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Experimental set-up

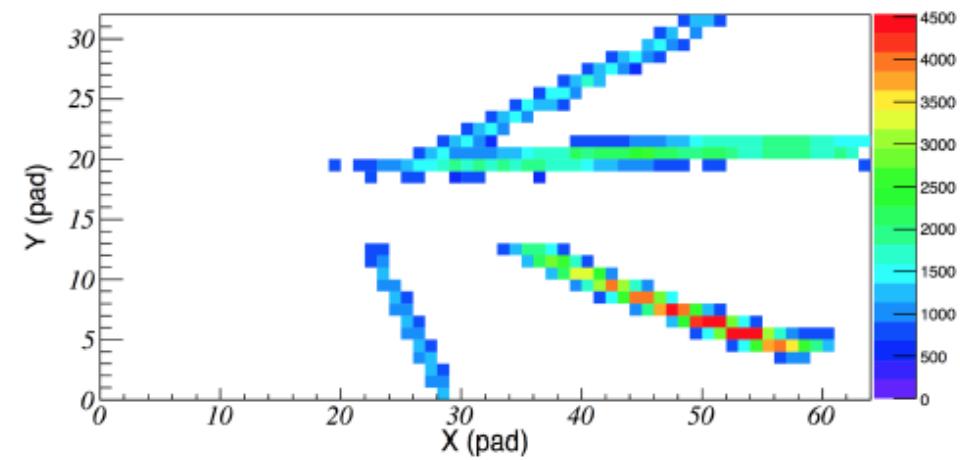
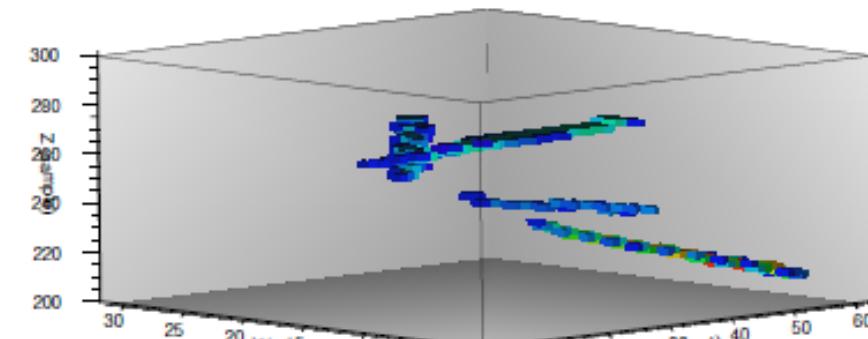
- ACTAR = ACtive TARget
 - Gas is used as a target ...
 - ... and to detect the reaction products.



Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Experimental set-up

- ACTAR = ACtive TARget
 - Gas is used as a target ...
 - ... and to detect the reaction products.
- TPC = Time Projection Chamber
 - 2D projection on the pads
 - 3rd dimension with e^- drift time

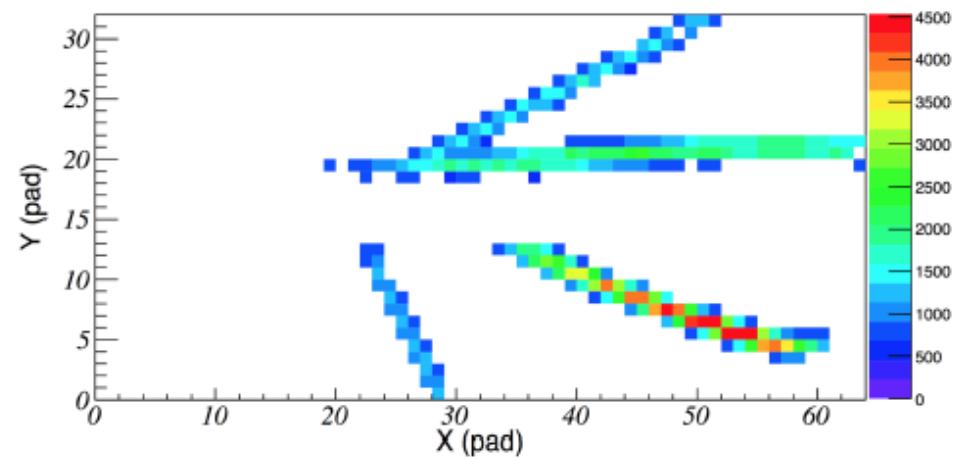
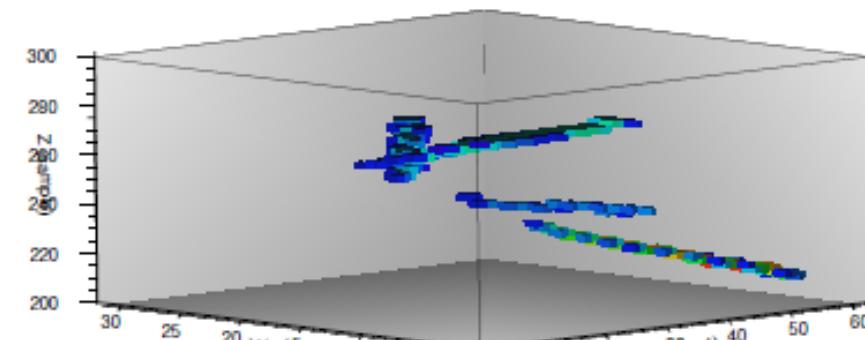


Courtesy of B. Mauss and A. L. Laffoley

Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Experimental set-up

- ACTAR = ACtive TARget
 - Gas is used as a target ...
 - ... and to detect the reaction products.
- TPC = Time Projection Chamber
 - 2D projection on the pads
 - 3rd dimension with e⁻ drift time
- **High luminosity and angular coverage (4π)**
- **Effective thickness** ~ 10 times higher than solid target
but still a good resolution on the vertex.

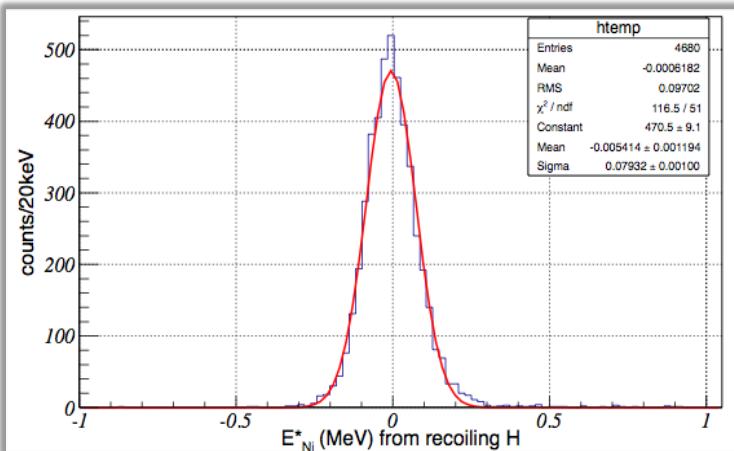


Courtesy of B. Mauss and A. L. Laffoley

Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

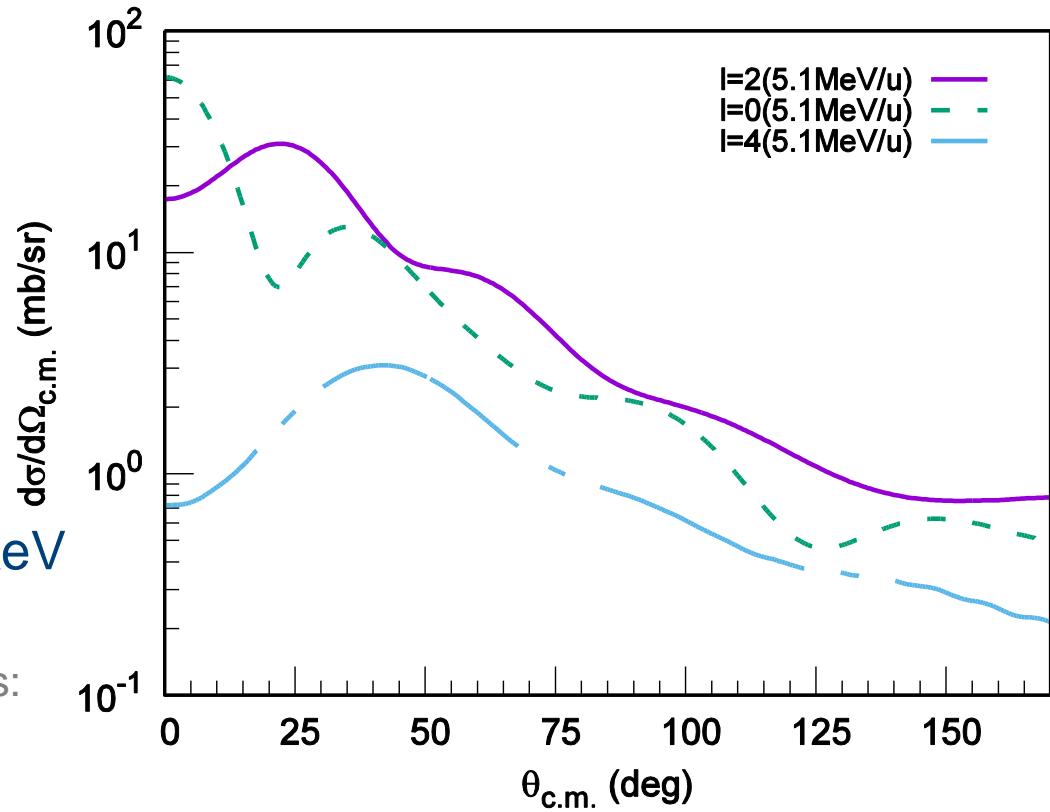
This experiment

- (d,p) transfer reaction in inverse kinematic
 - Protons mostly emitted at backward angles
- **Angular distribution of the protons**
 - $\text{FWHM}_\theta \sim 1^\circ$
 - Reconstruction of the vertex: $\text{FWHM}_{\text{Q-value}} \sim 200 \text{ keV}$



Inelastic scattering experiments:
 $^{58}\text{Ni}(p,p')^{58}\text{Ni}$

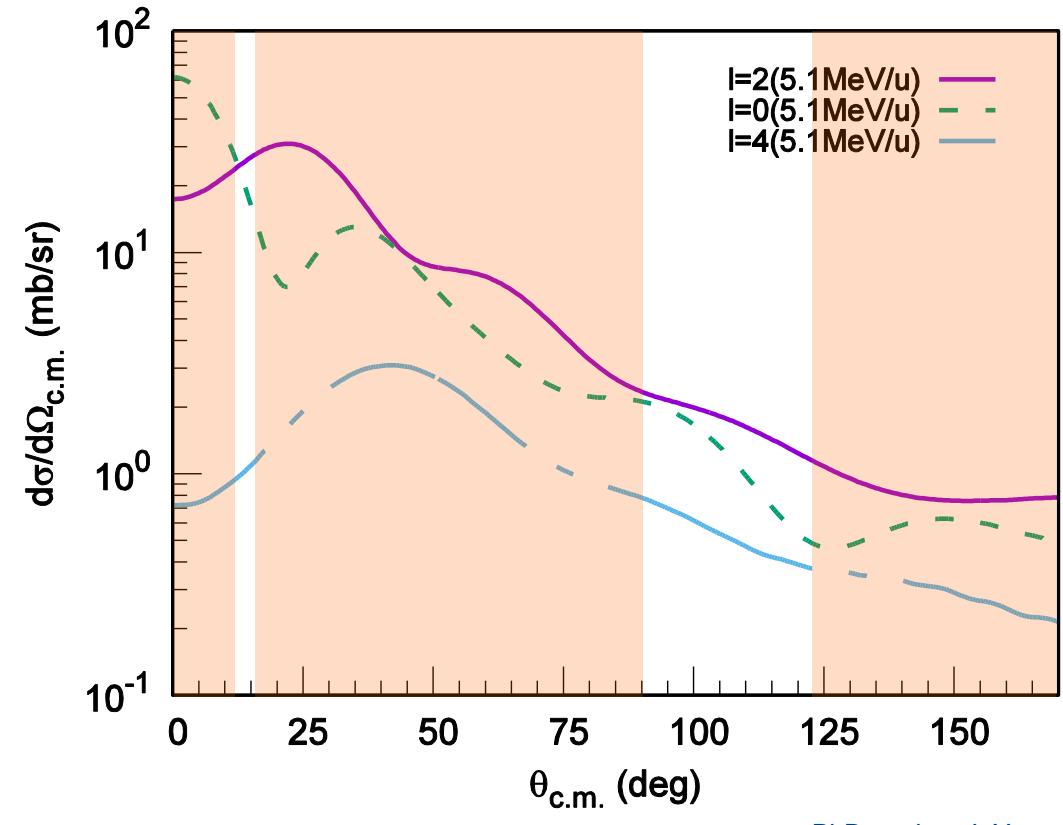
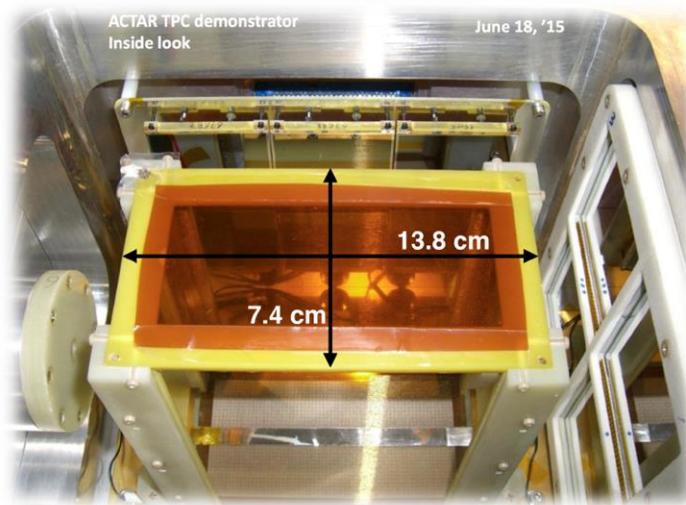
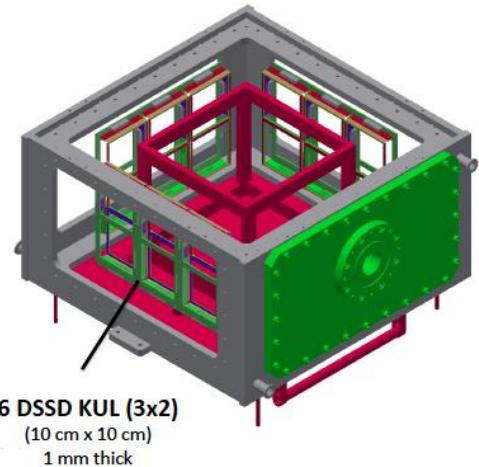
Courtesy of B. Mauss and A. L. Laffoley



Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

This experiment

- (d,p) transfer reaction in inverse kinematic
 - Energy resolution of Si: $\sigma_E \sim 75$ keV
 - 37% of angular coverage

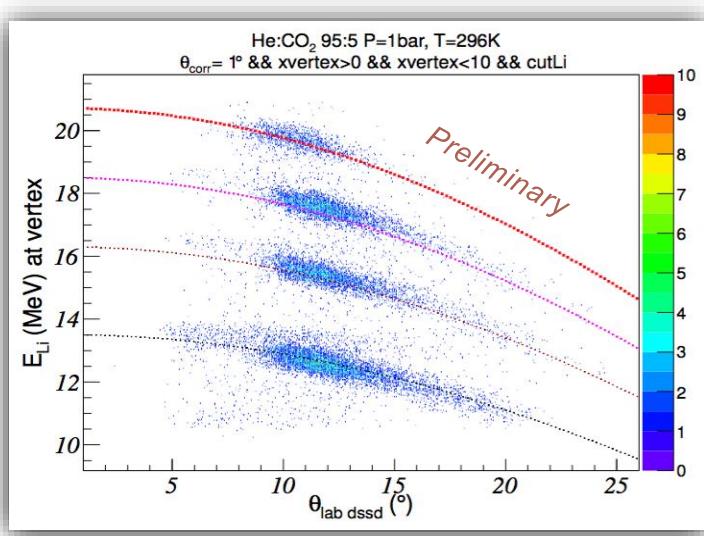


PhD student J. Yang

Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

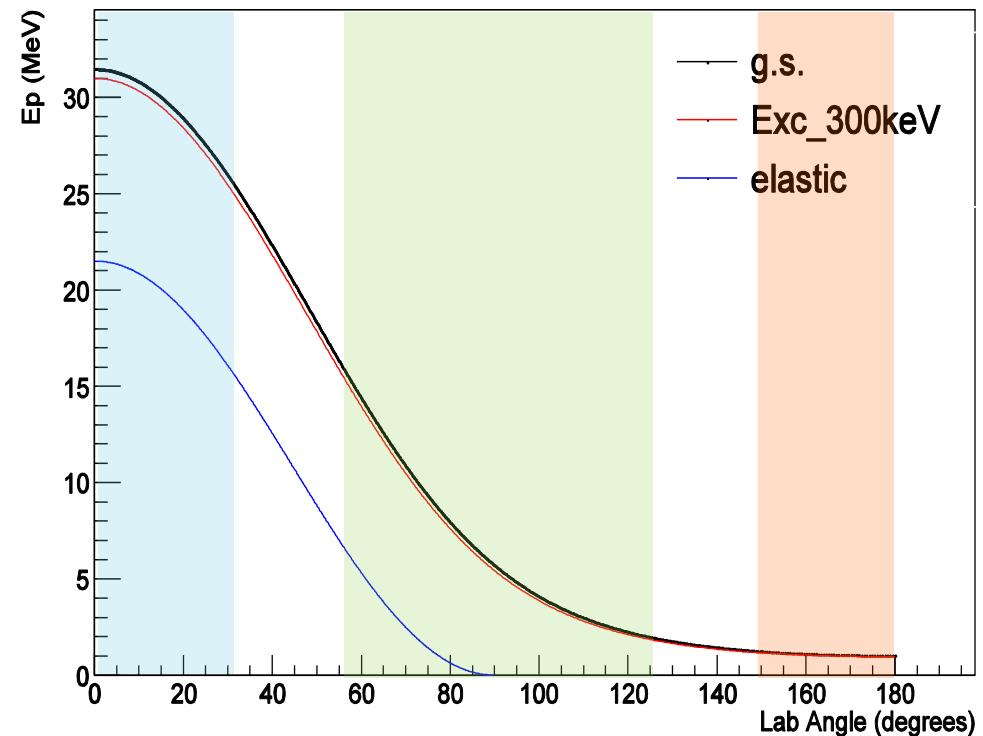
This experiment

- **Excitation energies**
 - Using the E_{Si} (75 keV)
 - Wide angular coverage
 - Separation even if $E^* \sim 100$ keV



Inelastic scattering experiments:
 ${}^6\text{Li}(\alpha, \alpha'){}^6\text{Li}$

Courtesy of B. Mauss and A. L. Laffoley



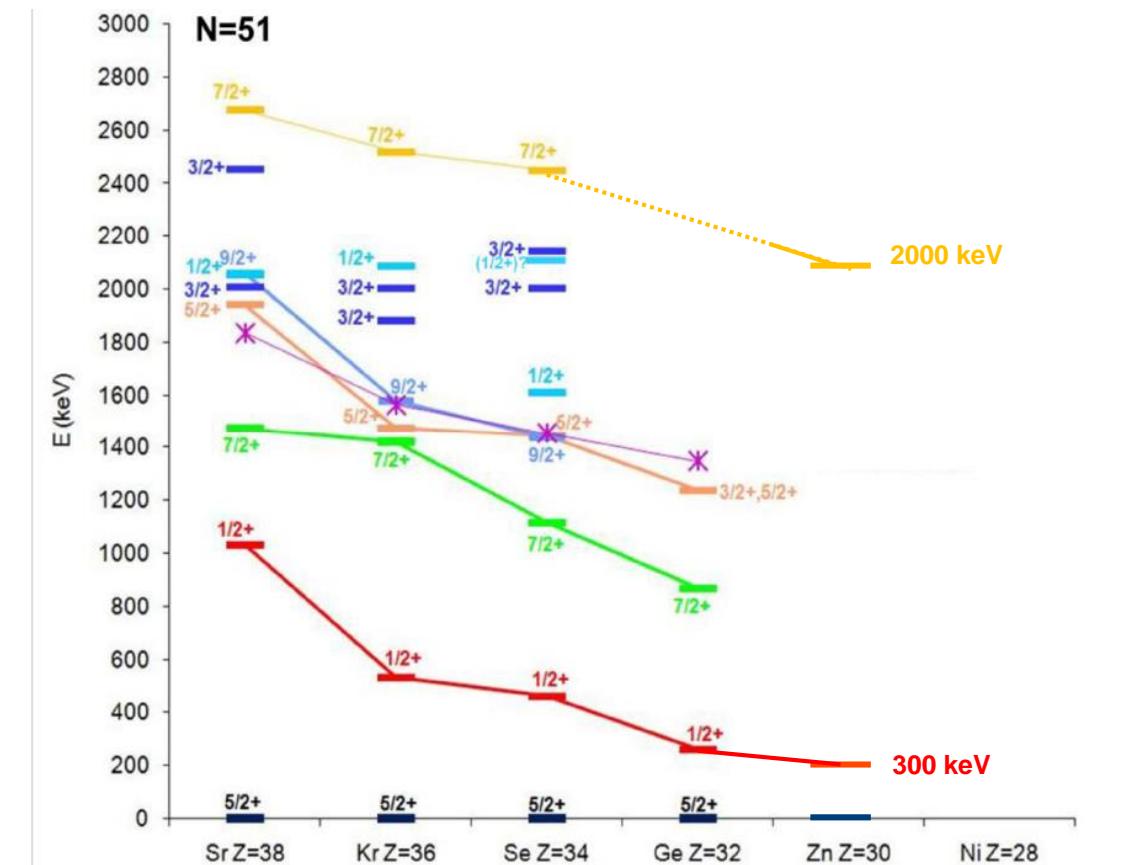
(d,p) with T-REX and solid target:
resolution of ~ 400 -1000 keV

Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Beam request

- Secondary beam (TAC)
 - ^{80}Zn : 1.10^4 pps
 - 5% of transmission, 16% of β decay
- Target : D_2 (95%) + CF_4 (5%) @ 1 bar
- Reaction rate (Spec. factor = 0.6)

	Cross Section (mb)	Reaction rate (pph)
s-wave	37.6	400
d-wave	64.7	690
g-wave	21.8	230



Courtesy of D. Verney

Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Beam request

- Efficiency
 - Reconstruction: ~ 90%
 - Si detectors: $\Omega \sim 37\%$
- Reaction rate (Spec. factor = 0.6)

	Cross Section (mb)	Reaction rate (pph)	Part. detected (pph)
s-wave	37.6	400	130
d-wave	64.7	690	230
g-wave	21.8	230	75

Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Beam request

- **10 shifts** for $^{80}\text{Zn}(\text{d},\text{p})^{81}\text{Zn}$ with LASER ON

	Cross Section (mb)	Reaction rate (pph)	Part. detected (pph)	Counts
s-wave	37.6	400	130	11 K
d-wave	64.7	690	230	18 K
g-wave	21.8	230	75	6 K

- ~~^{80}Ga will represent ~ 20% of the beam~~
 - ~~5 shifts with LASER OFF~~ **No contaminants**
 - **2 shifts** for the beam and detector tuning
- We require a total of **12 shifts**

Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

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Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Back up slides

Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Beam request – TAC feedback

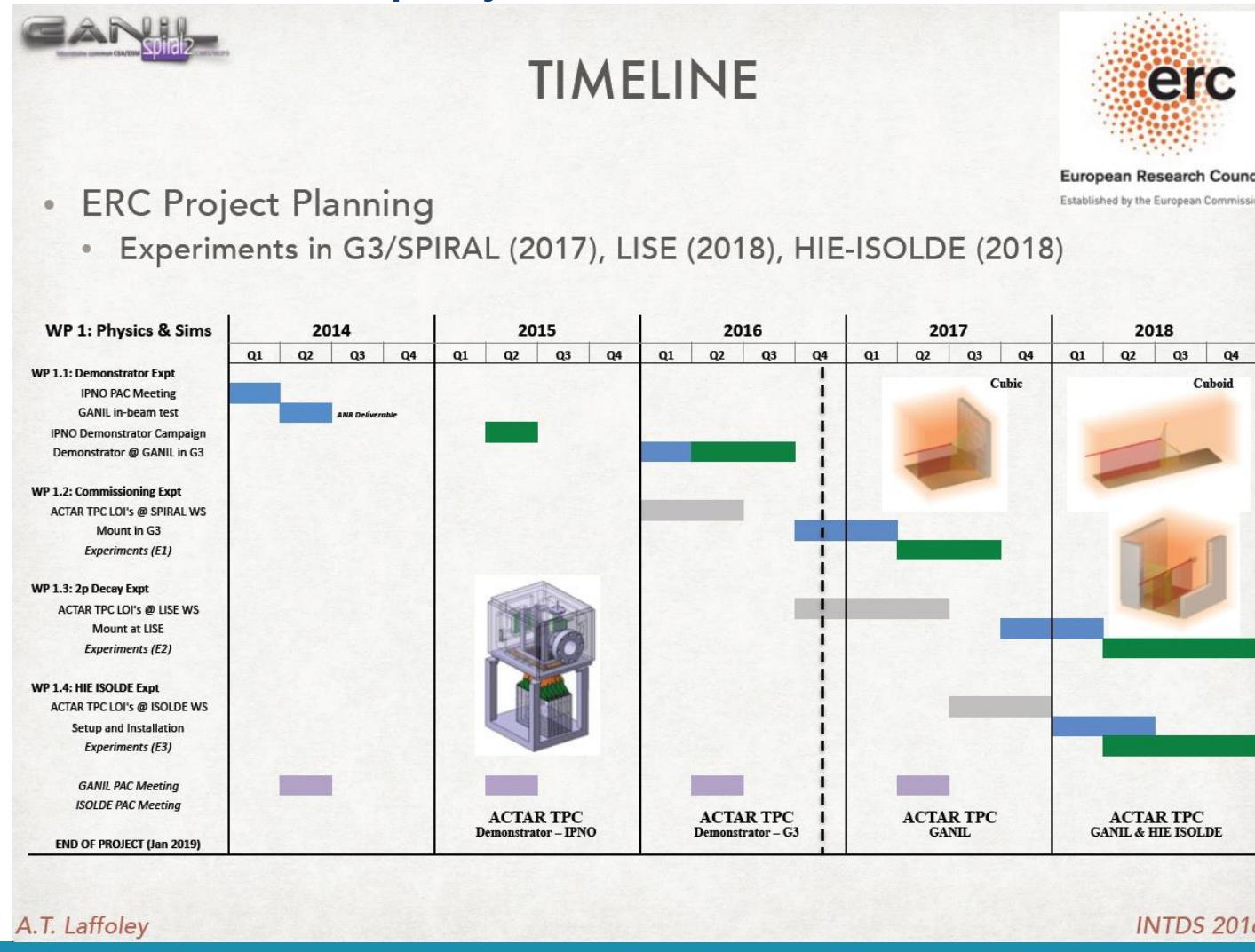
INTC-P-494		Actar	21	^{80}Zn	ACTAR	N/A	UCx-quartz v1.0-Ta n conv 3e4 n conv 1.4e5 targ in DB 1e5/uC requested 2006: UC329, 45%Ga, 20%Rb, 1 10^4 $^{80}\text{Zn}/\mu\text{C}$ UC542 (2015) ^{80}Zn – 1.2E3 /uC (lower estimate Laser on/off beta activity ratio: 1.2) 2016 UC584 ca 5e4/uC ^{80}Zn : no impurities. A yield of 5e4 can be delivered/guaranteed (lower than quoted in the proposal): physics still feasible?	ACTAR needs clearance	^{80}Zn done before A/q=80/21 Rb and Zn mass markers If 3 CMS are ok, then 7MeV/u ok.	N/A
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- Two times less intensity
- But no contaminants

- Still feasible with 10 shifts
- No shift with LASER OFF ?

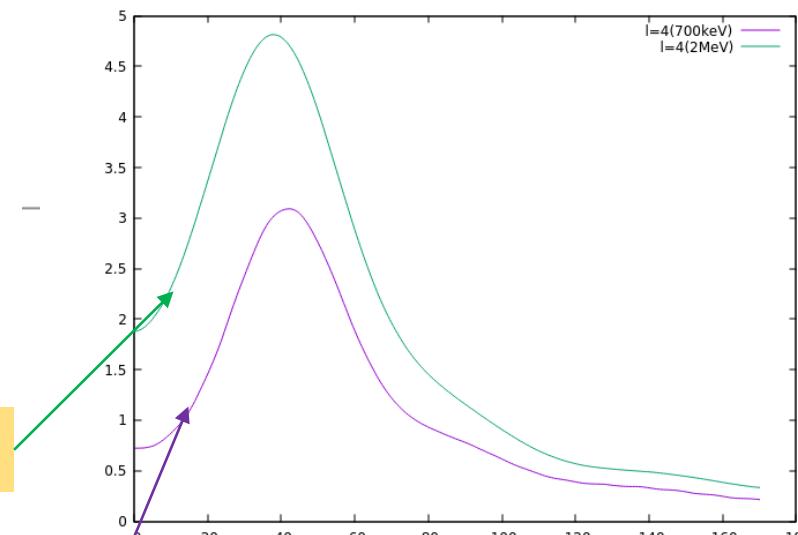
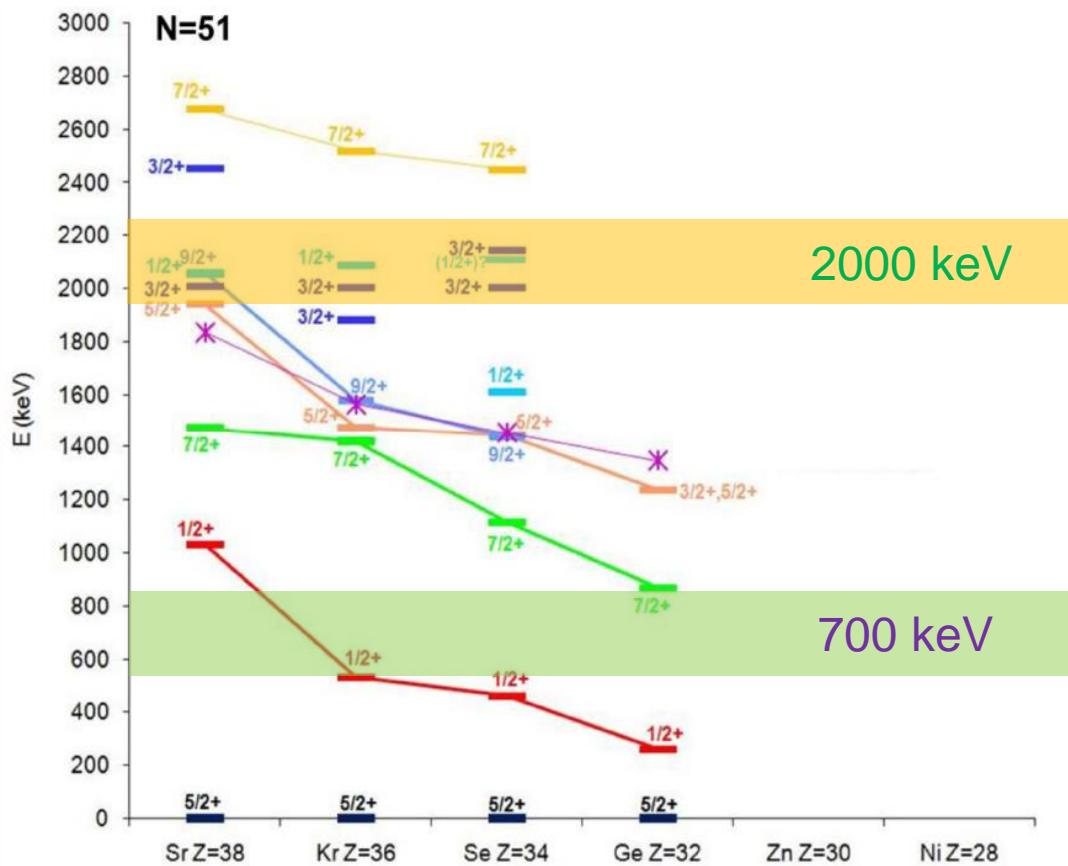
Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Time line of ACTAR TPC project



Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

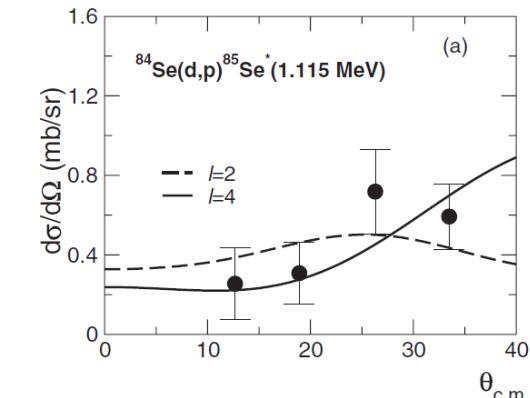
Beam request for $I=4$



	Cross Section (mb)	Reaction rate (pph)
s-wave	37.6	400
d-wave	64.7	690
g-wave	13.4 / 21.8	140 / 230

$7/2^+_2$ @ 2 MeV is most probable to be a single-part. state, according to F. Didierjean

$I=4$ identified in the case of ^{85}Se



Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Additional setup

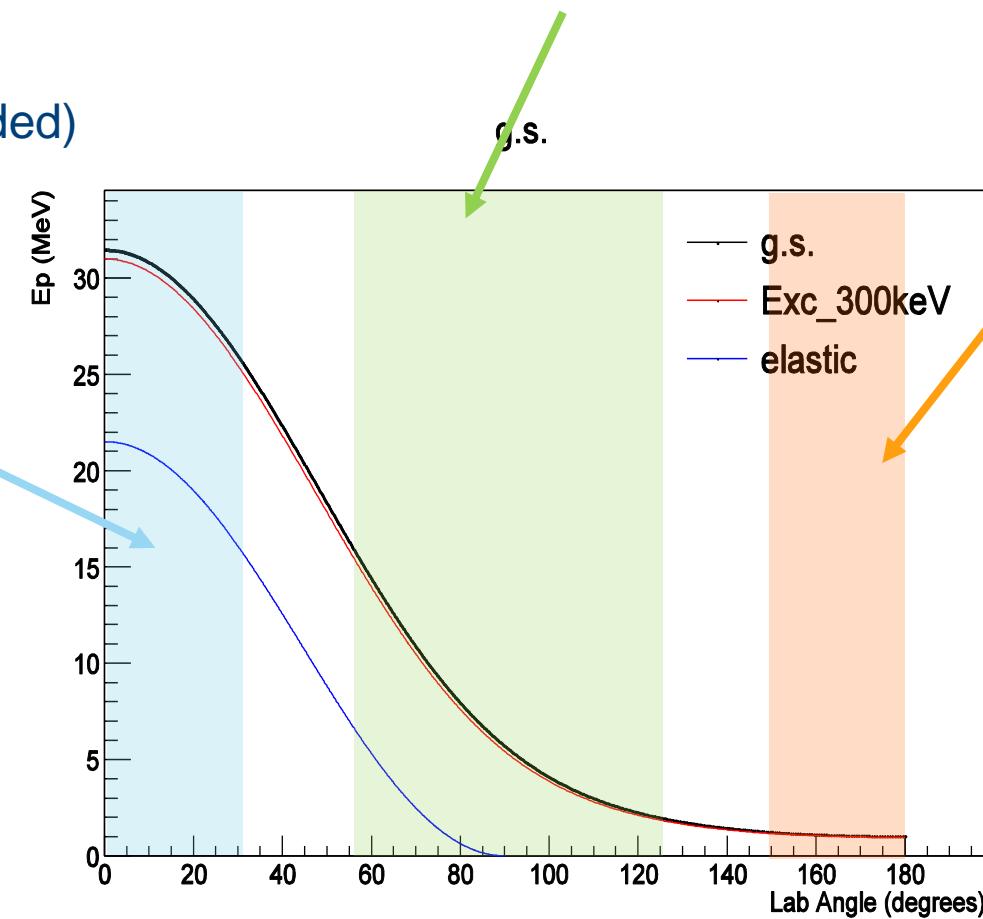
- Si thicknesses ...

(12cm of gas mixture included)

We need about 5 mm of Si
... or Si + Nal (2cm)
(all available)

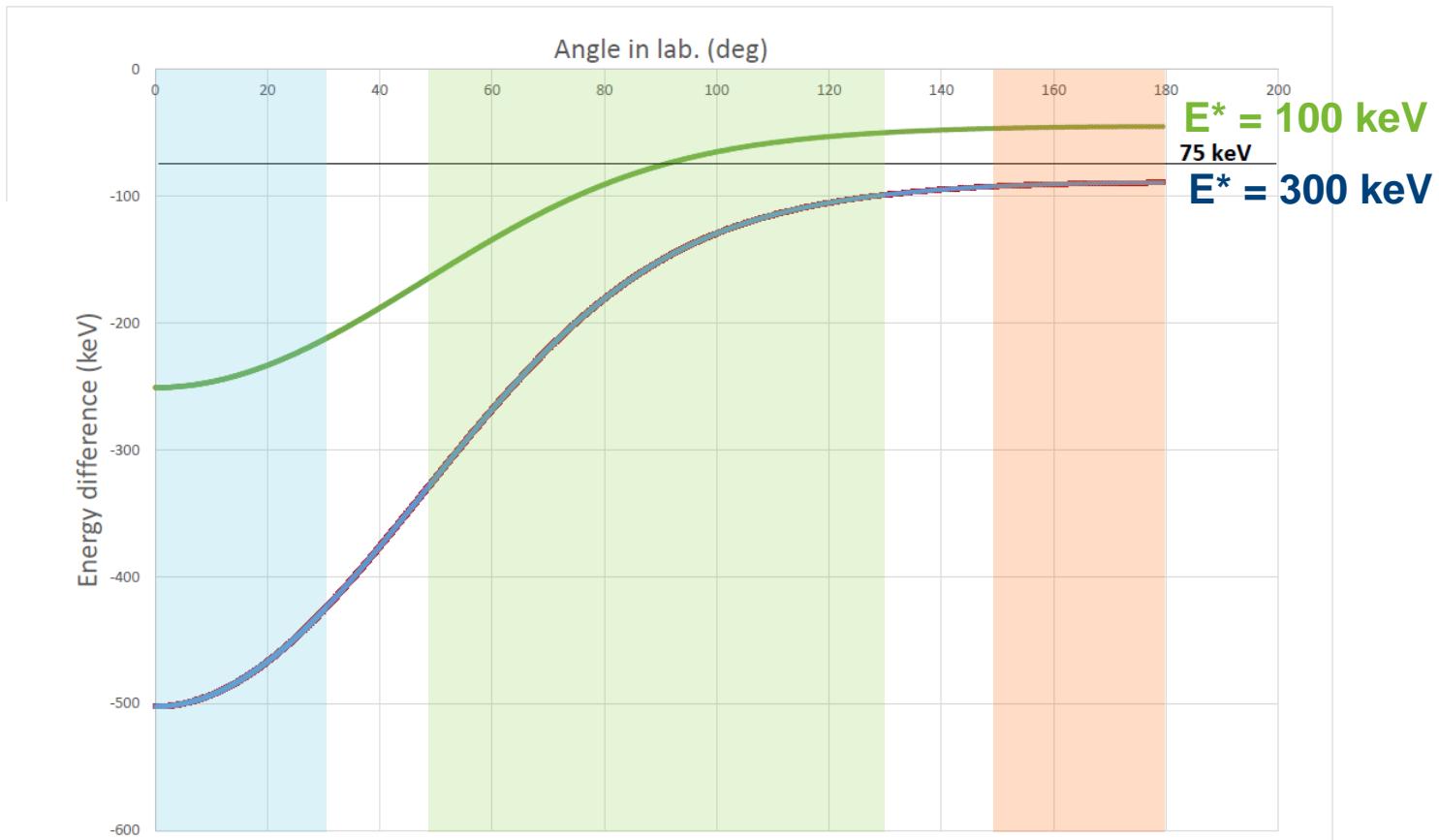
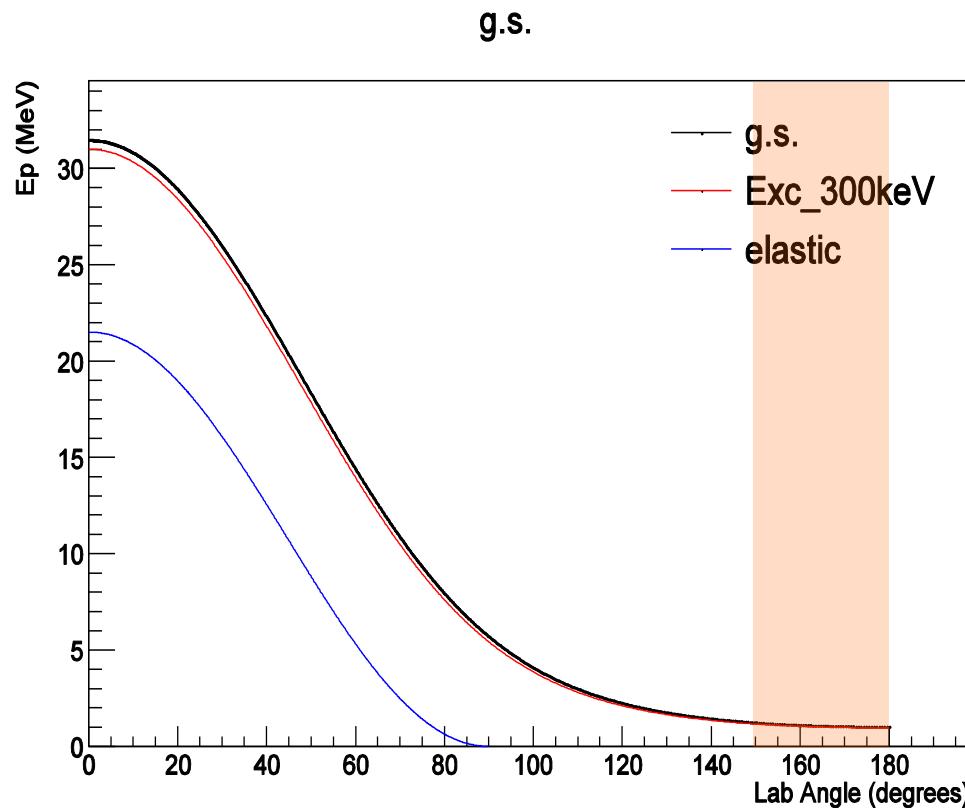
$E_p > 15.7 \text{ MeV}$ escapes 1.5 mm of Si
(DSSD of Leuven available soon)

$E_p < 6 \text{ MeV}$ don't escape 0.6 mm of Si
(20 detectors of 0.7 mm available)



Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Kinematic lines



Spectroscopy of ^{81}Zn via (d,p) reaction using ACTAR TPC

Kinematic lines

- Wide range of angles allows to determine the excitation energy
 - If $E^* \sim 100 \text{ keV}$: forward θ_{lab}
 - If $E^* > 250 \text{ keV}$: difference above the Si resolution

