Particle decay studies: Microscopic structure of isoscalar giant resonances

Notre Dame – 2005

Mátyás Hunyadi

- **ATOMKI** **Institute of Nuclear Research** ***Debrecen, Hungary***
- KVI Kerfysisch Versneller Instituut *Groningen, The Netherlands*
- NDU University of Notre Dame *Notre Dame, USA*
- RCNP Research Center for Nuclear Physics *Osaka, Japan*

Motivation

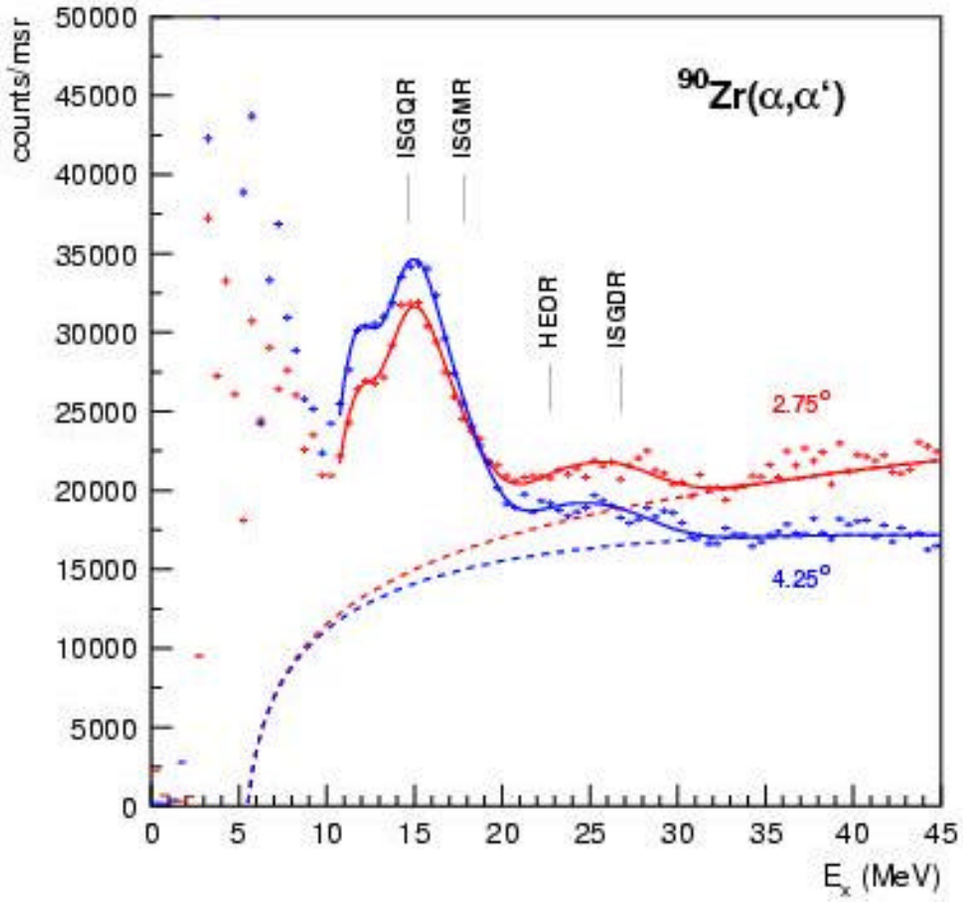
- Problems around the treatment of various background contributions:
  - instrumental background
  - quasi-free processes
  - nuclear continuum
- Microscopic structure, test for recent RPA calculations

? Coincidence measurements:
  - decay by proton and neutron emission

? Difference-of-spectra analysis

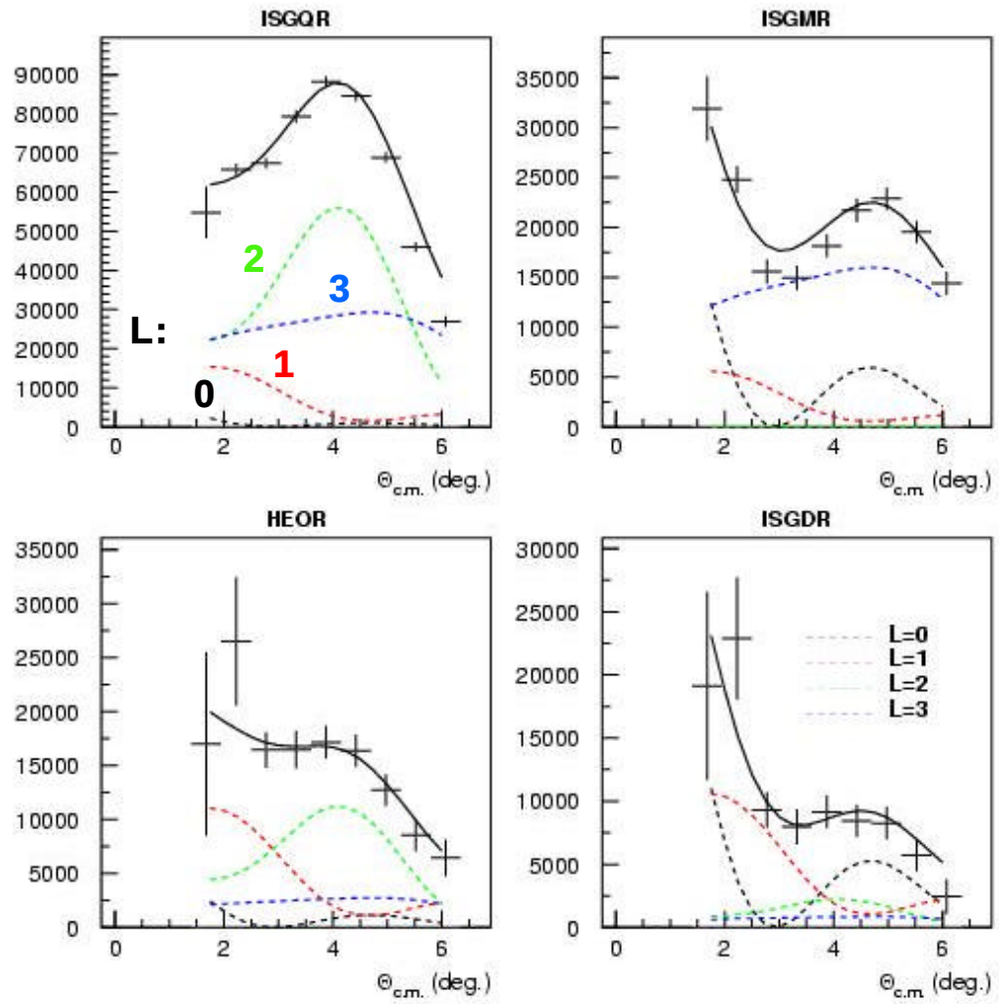
Singles data: ^{90}Zr

E*x*-spectra



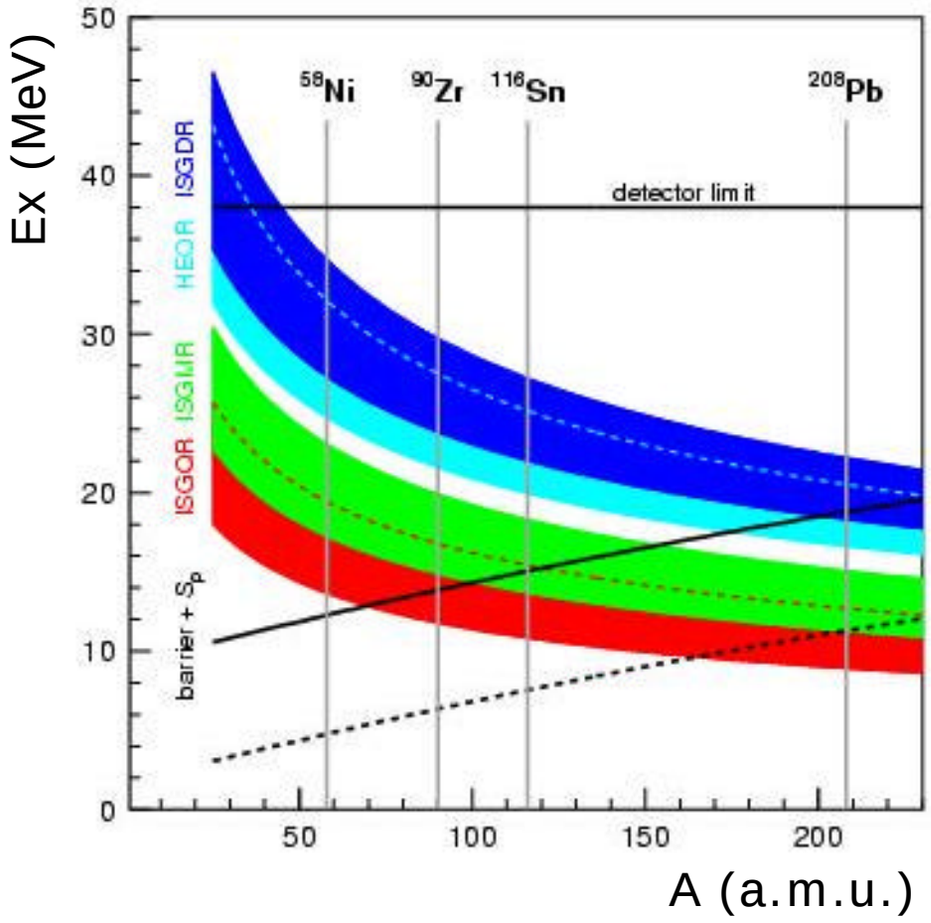
Singles data: ^{90}Zr

Angular distributions



Decay studies

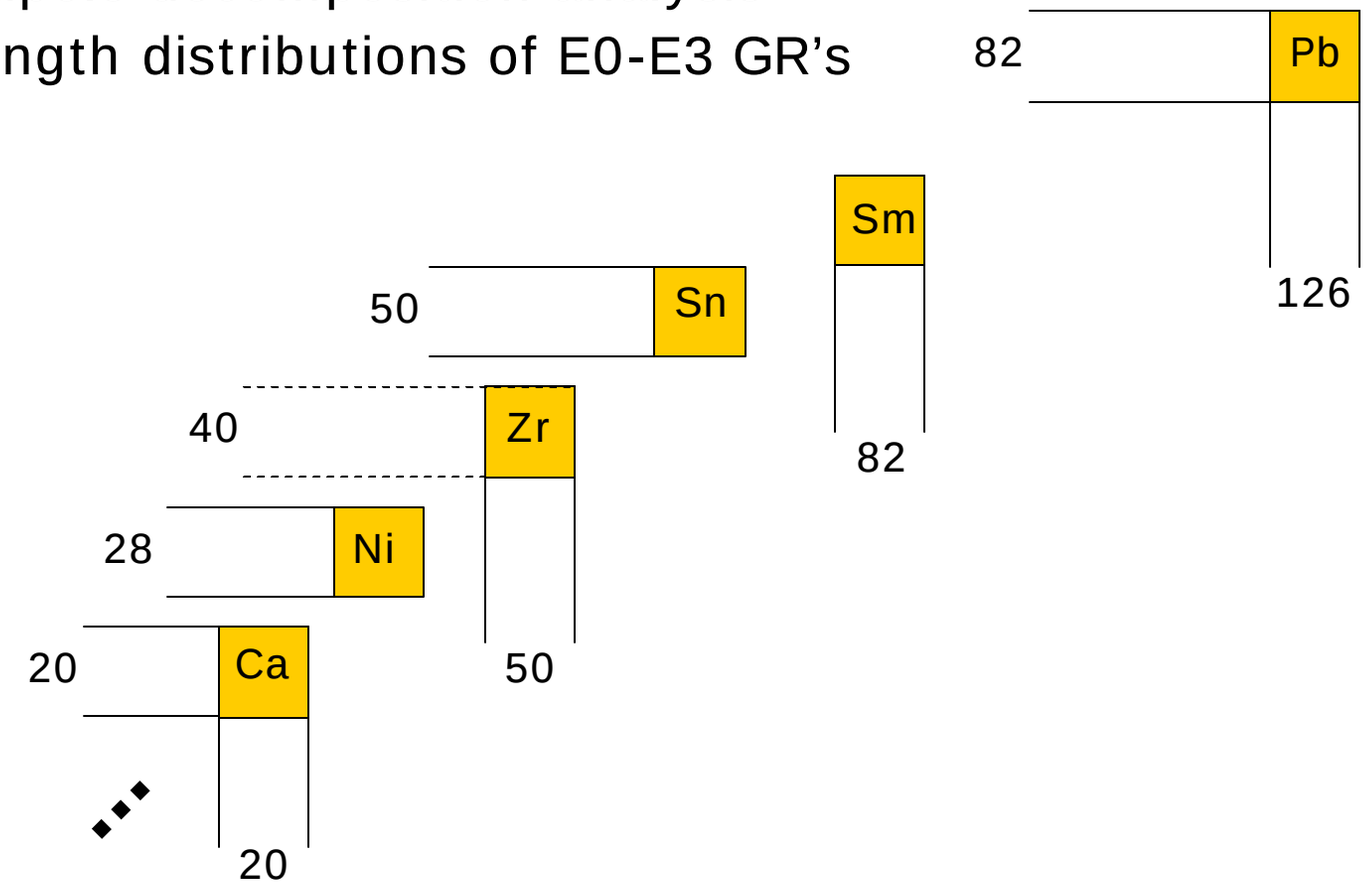
Optimal regions for proton decay studies of GR's



Historical overview

Singles measurements using (a,a') reaction

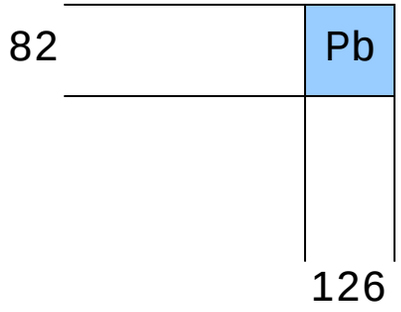
- Multipole decomposition analysis
- Strength distributions of E0-E3 GR's



Historical overview

Coincidence measurements using (a,a'n) reaction

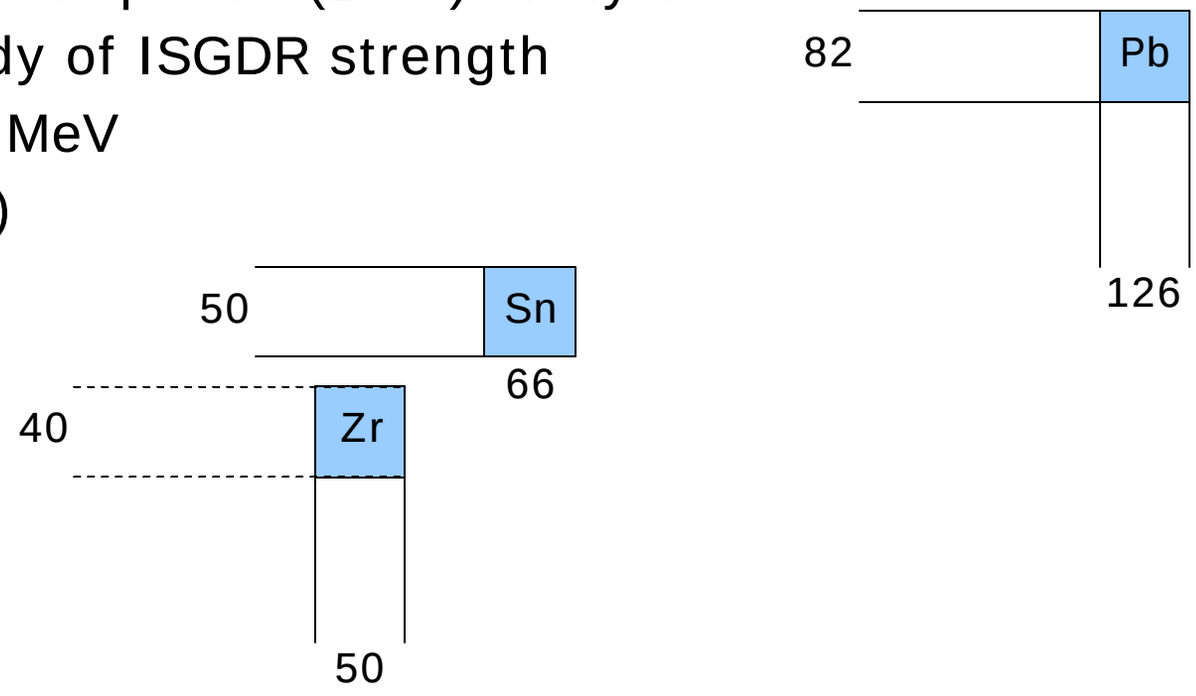
- Difference-of-spectra (DOS) analysis
- Decay study of ISGMR
  (S. Brandenburg – 1989)



Decay studies

Coincidence measurements using (a,a'n) reaction

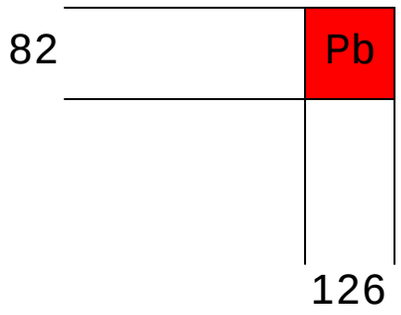
- Difference-of-spectra (DOS) analysis
- Decay study of ISGDR strength up to ~40 MeV (this work)

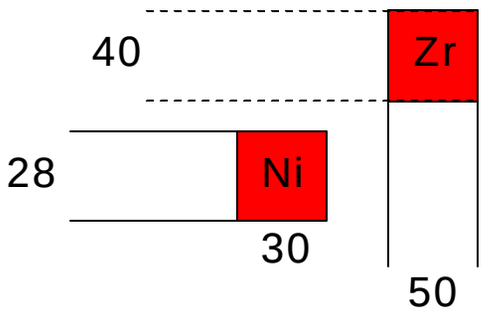


Decay studies

Coincidence measurements using (a,a'p) reaction

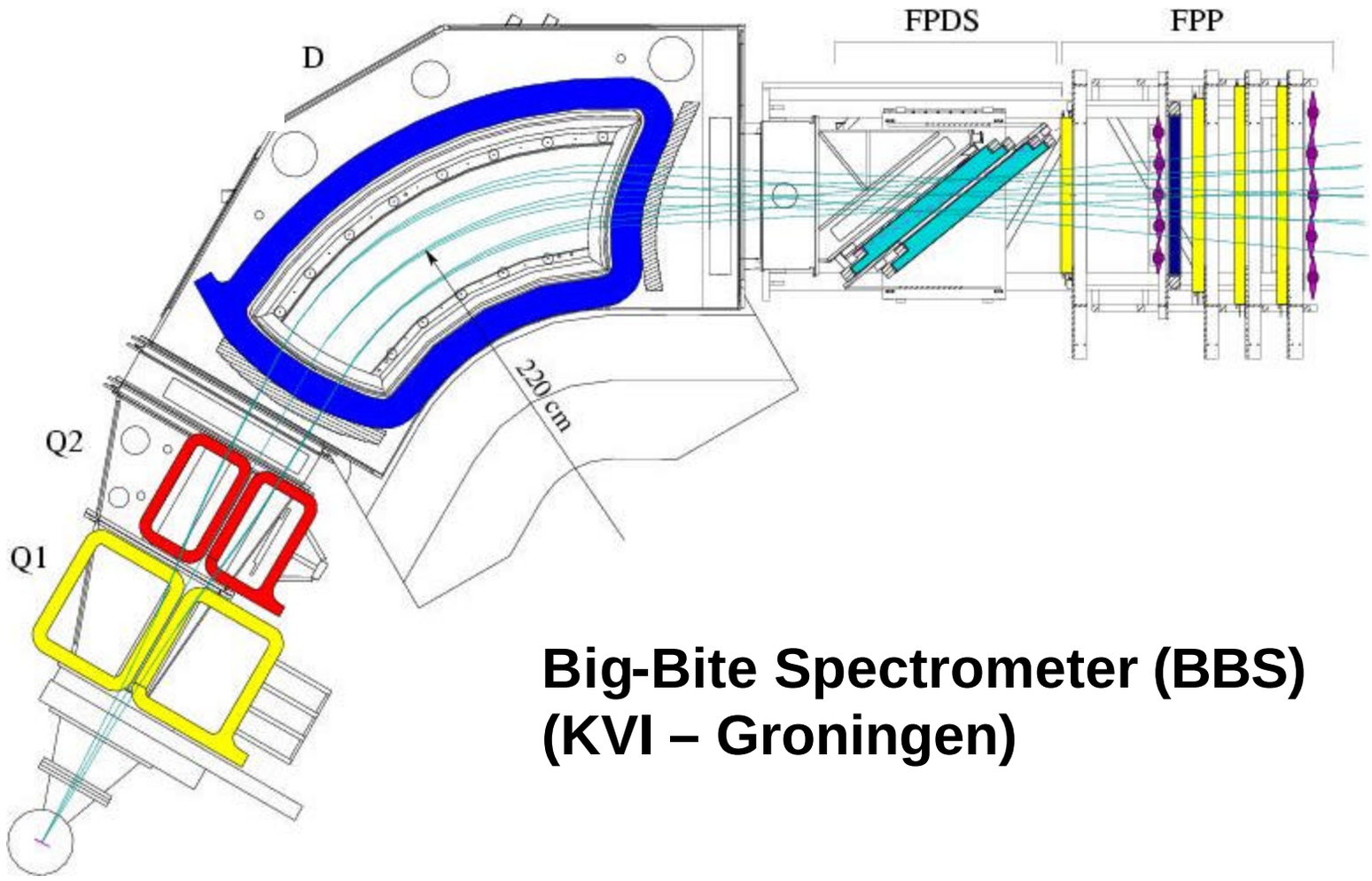
- Difference-of-spectra (DOS) analysis
- Decay study of isoscalar GR strength up to ~38 MeV (this work)





^{58}Ni	RCNP (390 MeV)
^{90}Zr	KVI (200 MeV)
^{208}Pb	KVI (200 MeV)

Experimental setup

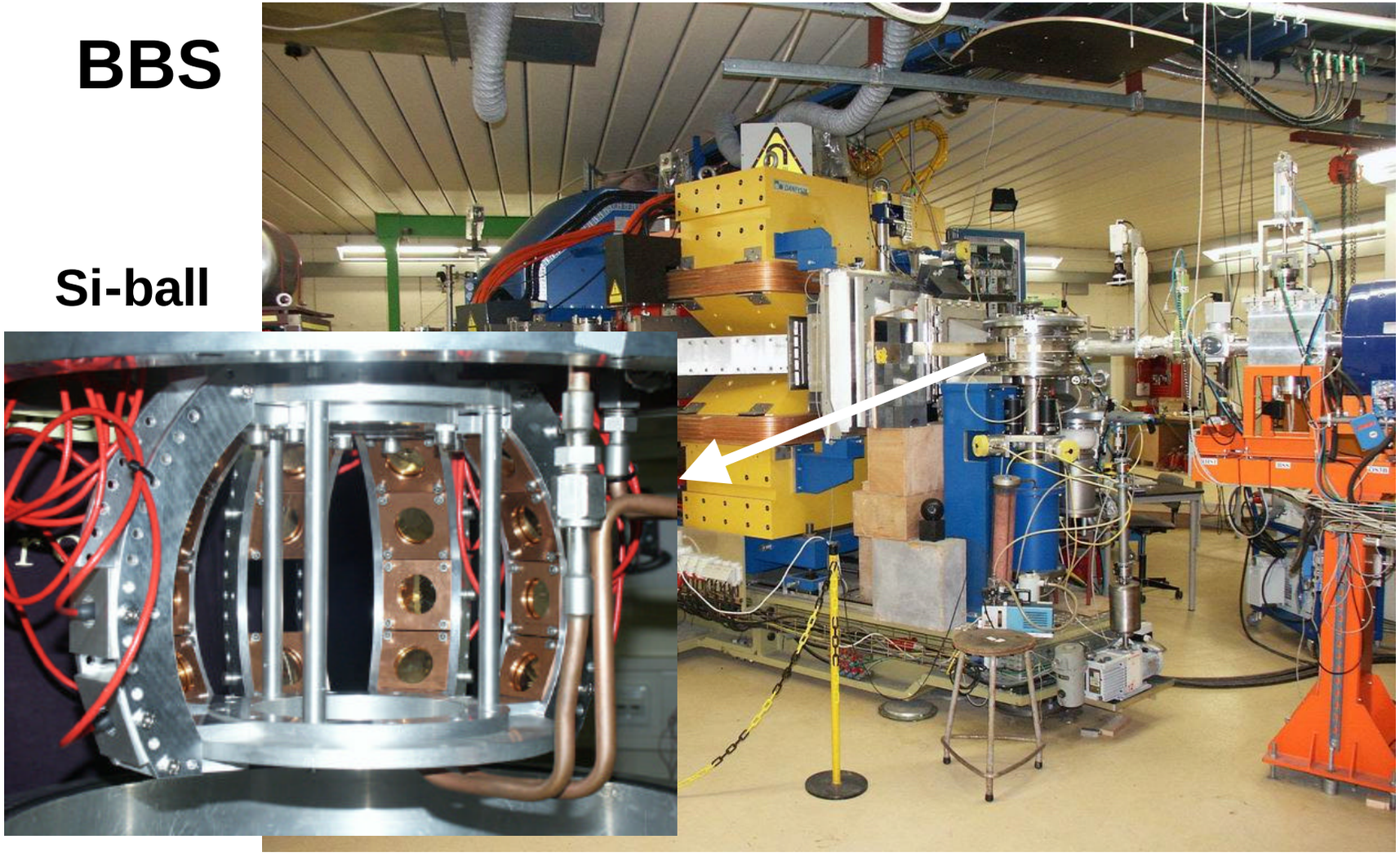


Big-Bite Spectrometer (BBS)
(KVI – Groningen)

Experimental setup

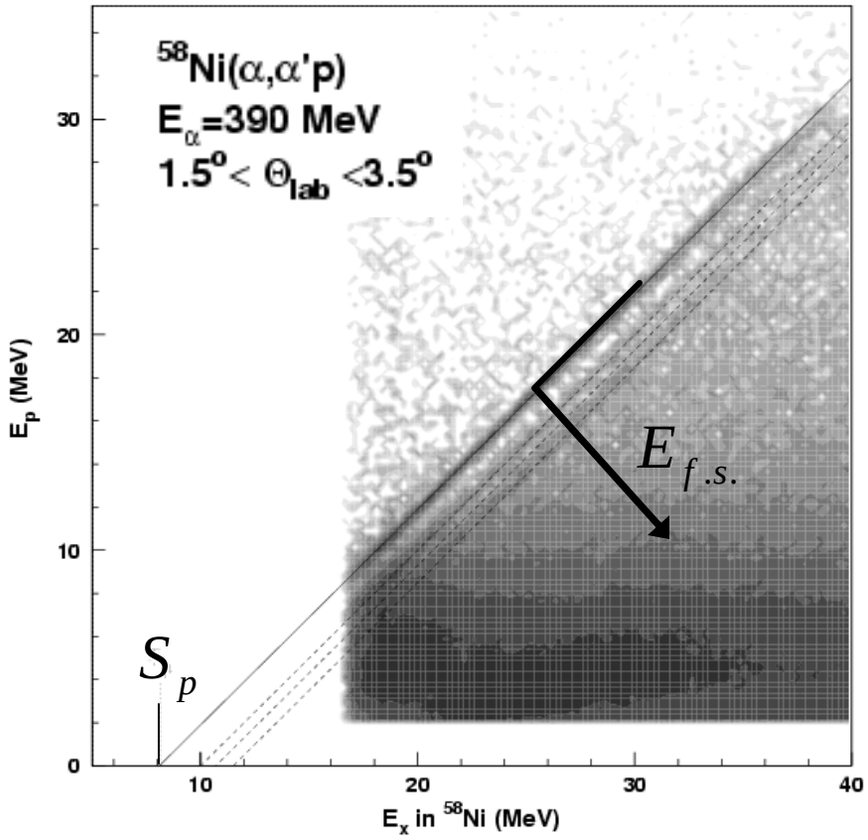
BBS

Si-ball

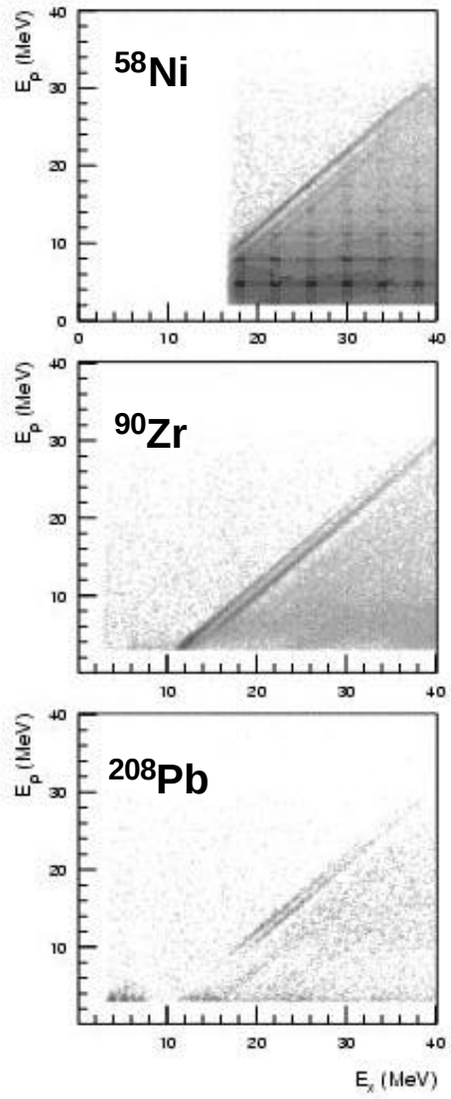


Decay data

Decay particle – ejectile correlation

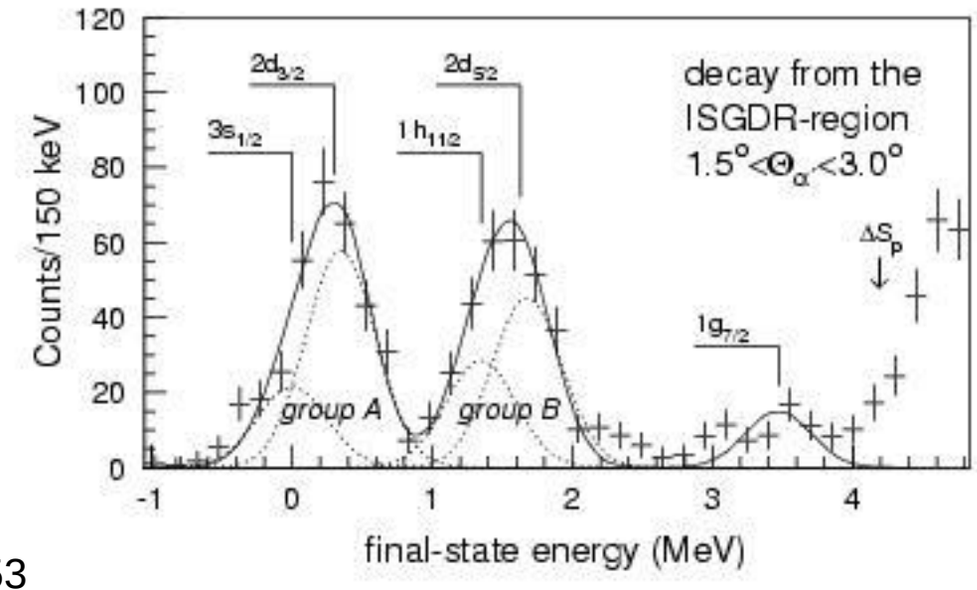


(a,a'p)



Decay data: ^{208}Pb

E*fs*-spectra gated on decay protons from the ISGDR region

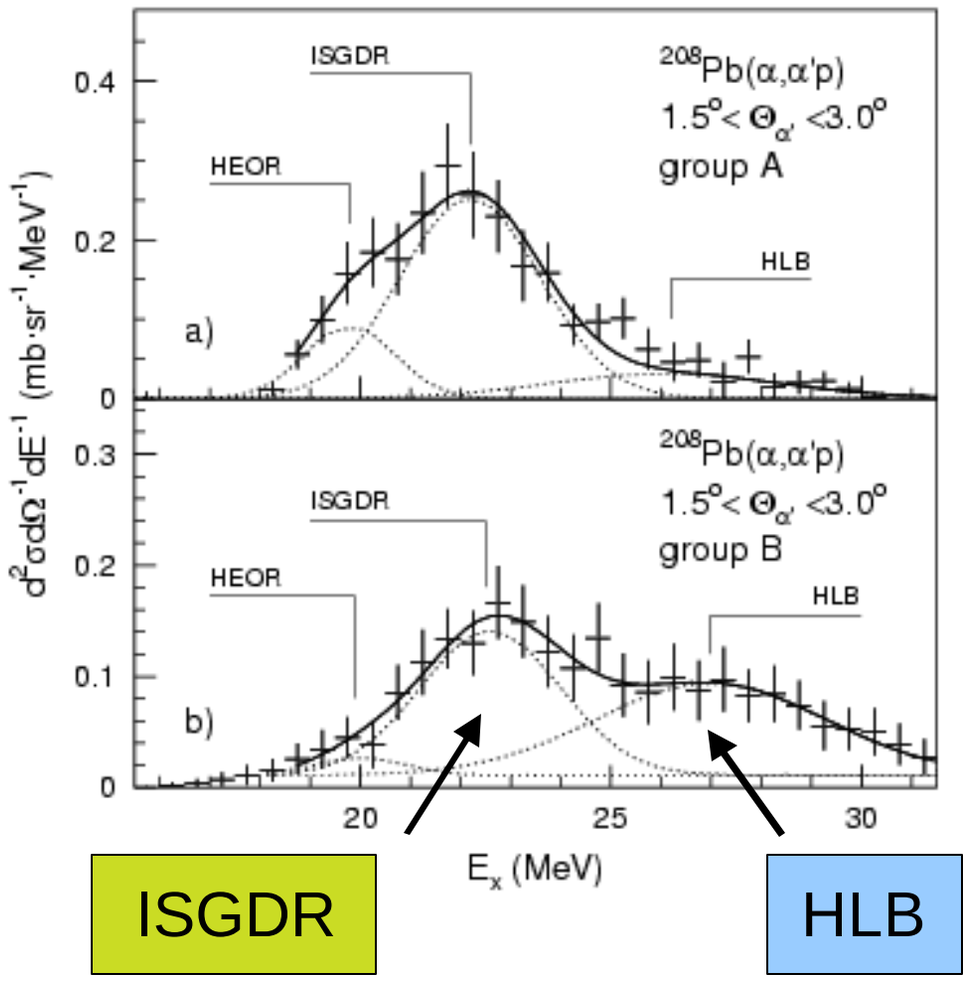


? M. Hunyadi et al., Phys. Lett. B 576 (2003) 253

? M. Hunyadi et al., Nucl. Phys. A731 (2004) 49c

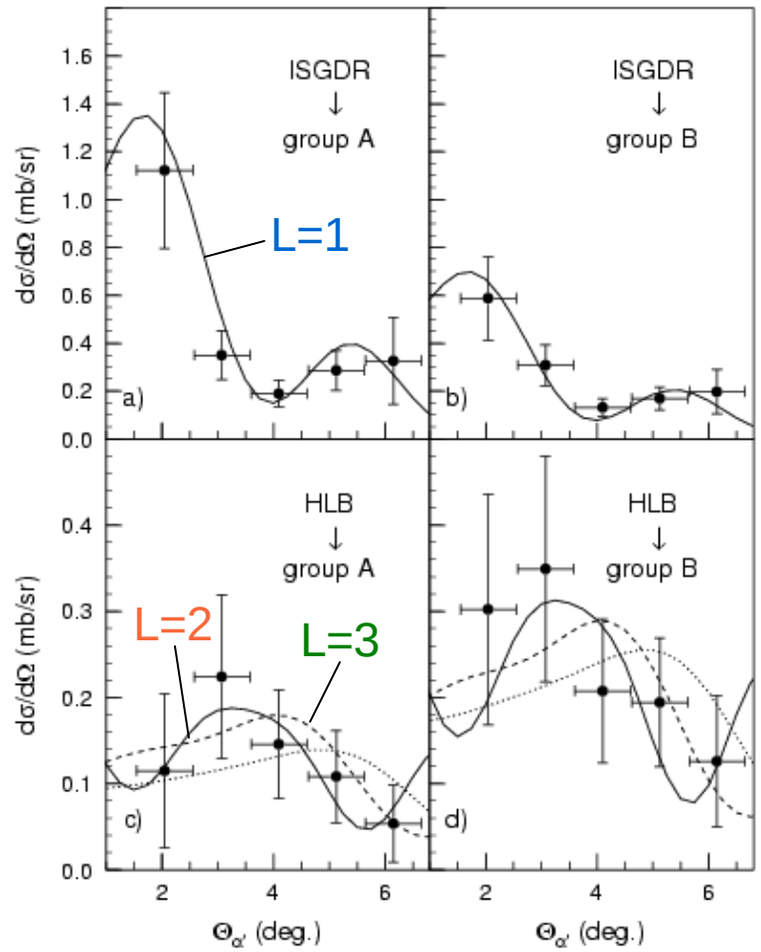
Decay data: ^{208}Pb

E_x-spectra gated on direct proton decay groups



Decay data: ^{208}Pb

Angular distributions gated on direct proton decay

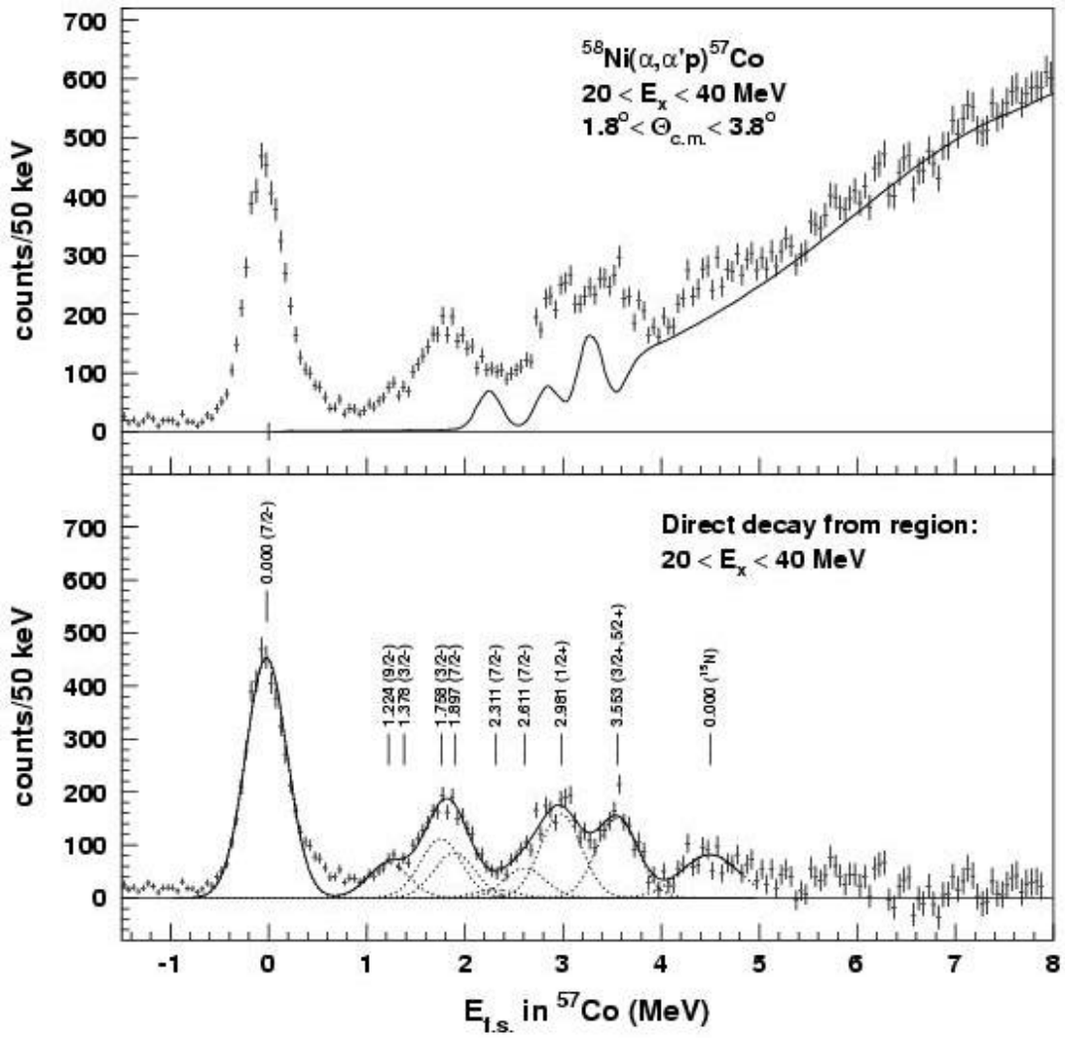


L=2 structure peaking at 26.9±0.7 MeV

4h? ISGQR2 ?

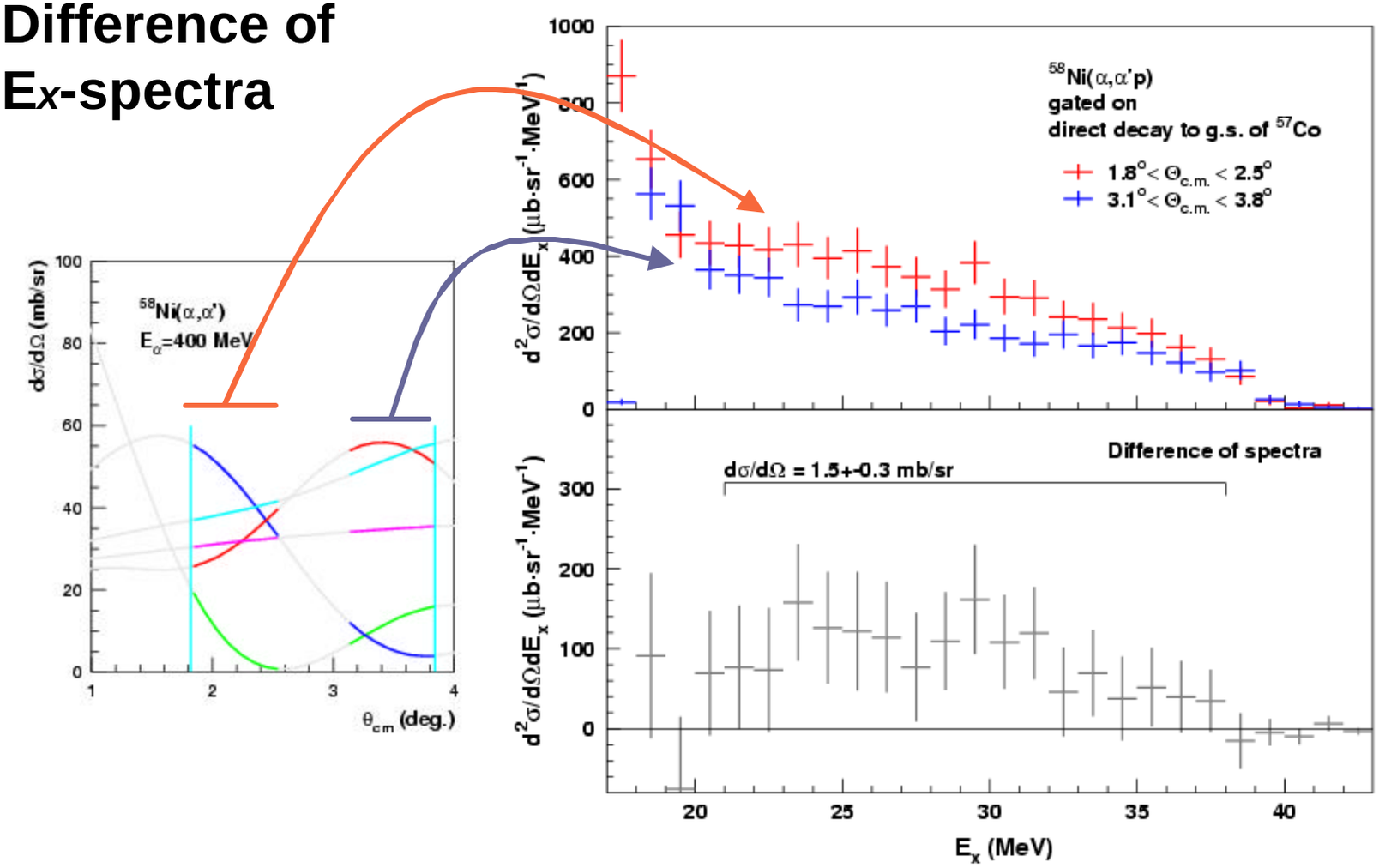
Decay data: ^{58}Ni

Final-state energy spectra



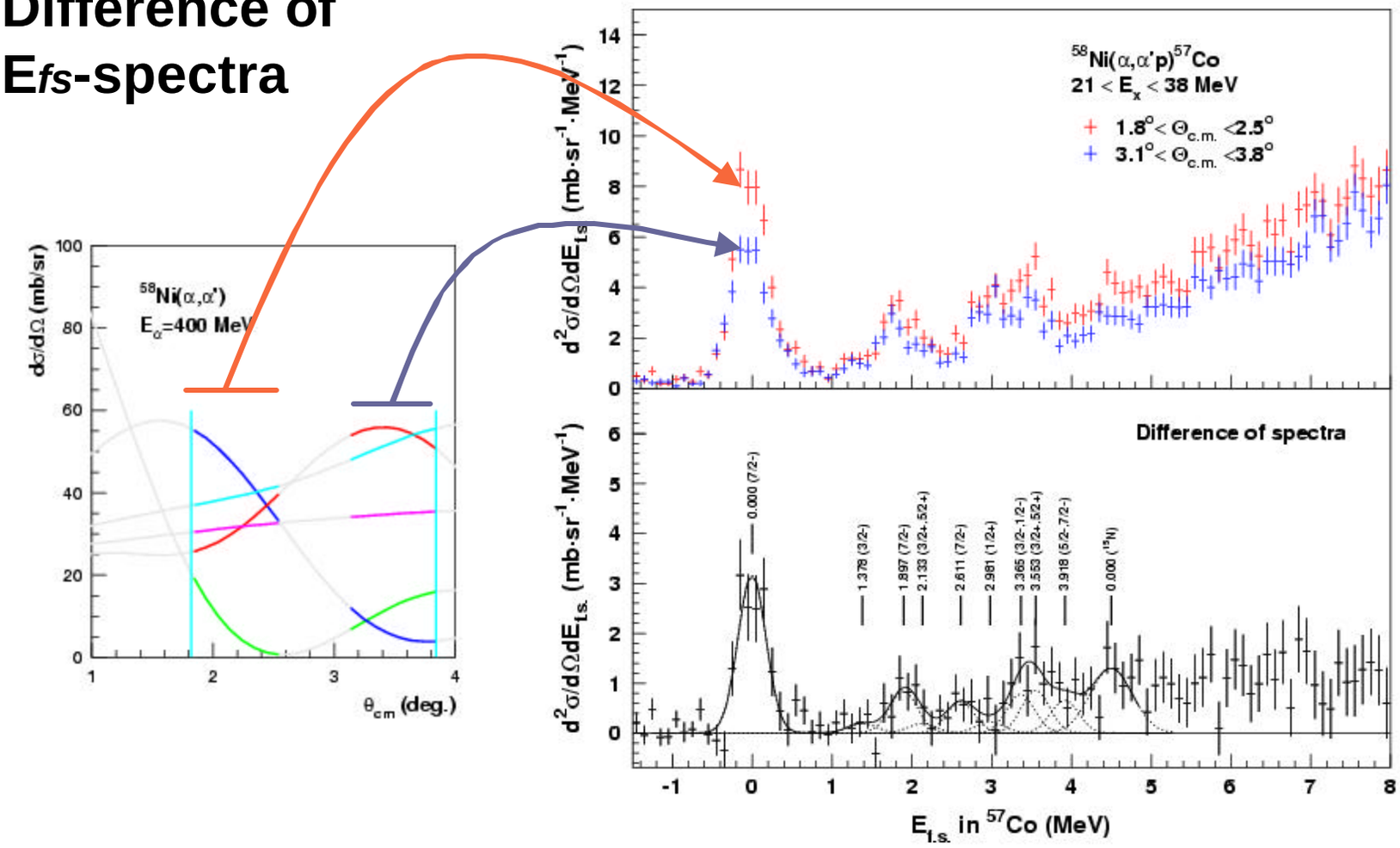
Decay data: ^{58}Ni

Difference of E_x-spectra



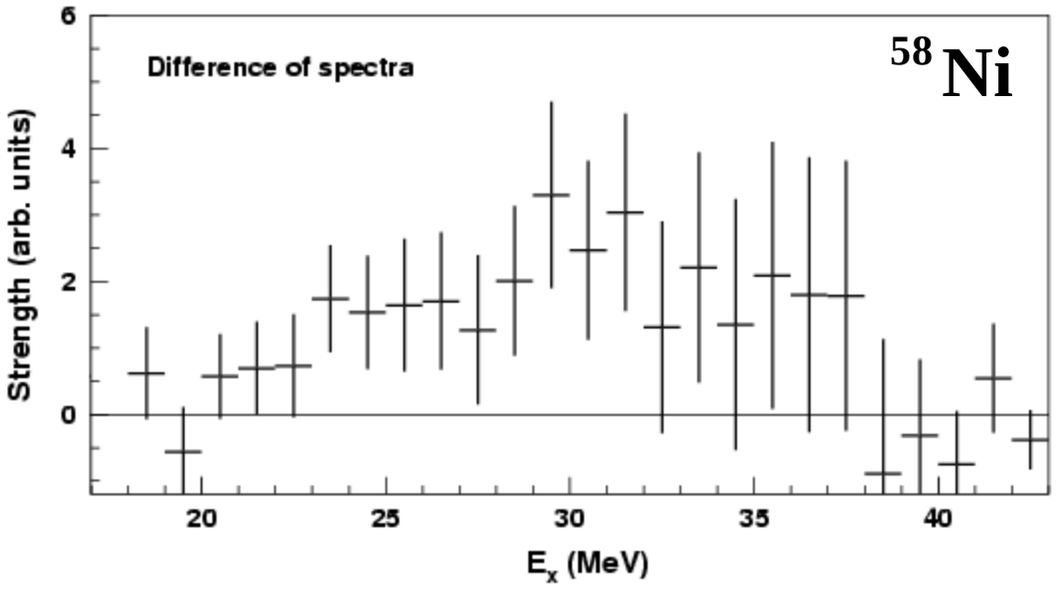
Decay data: ^{58}Ni

Difference of E*fs*-spectra



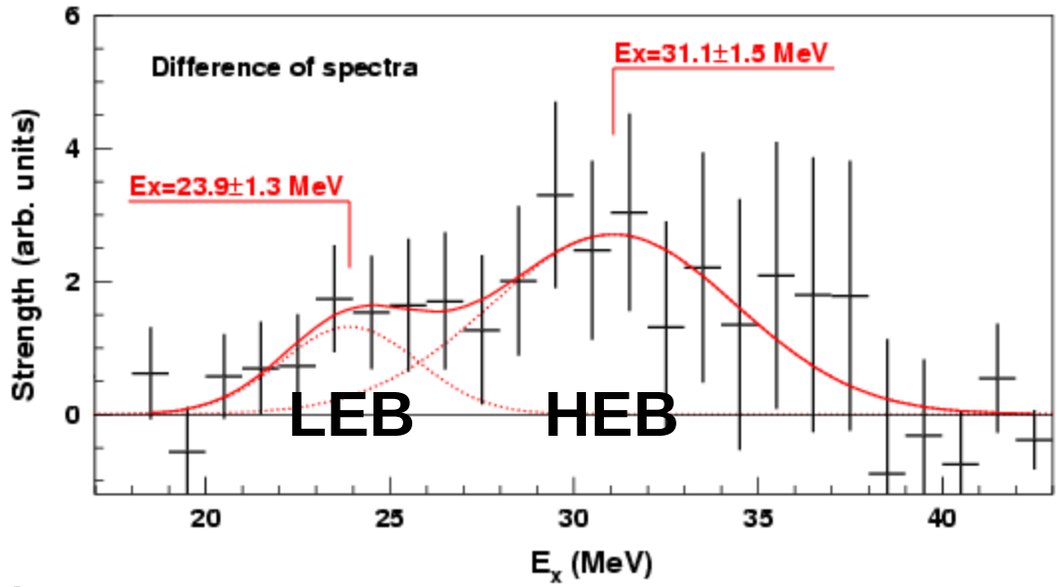
Decay data: ^{58}Ni

Strength distribution of ISGDR



Decay data: ^{58}Ni

Strength distribution of ISGDR



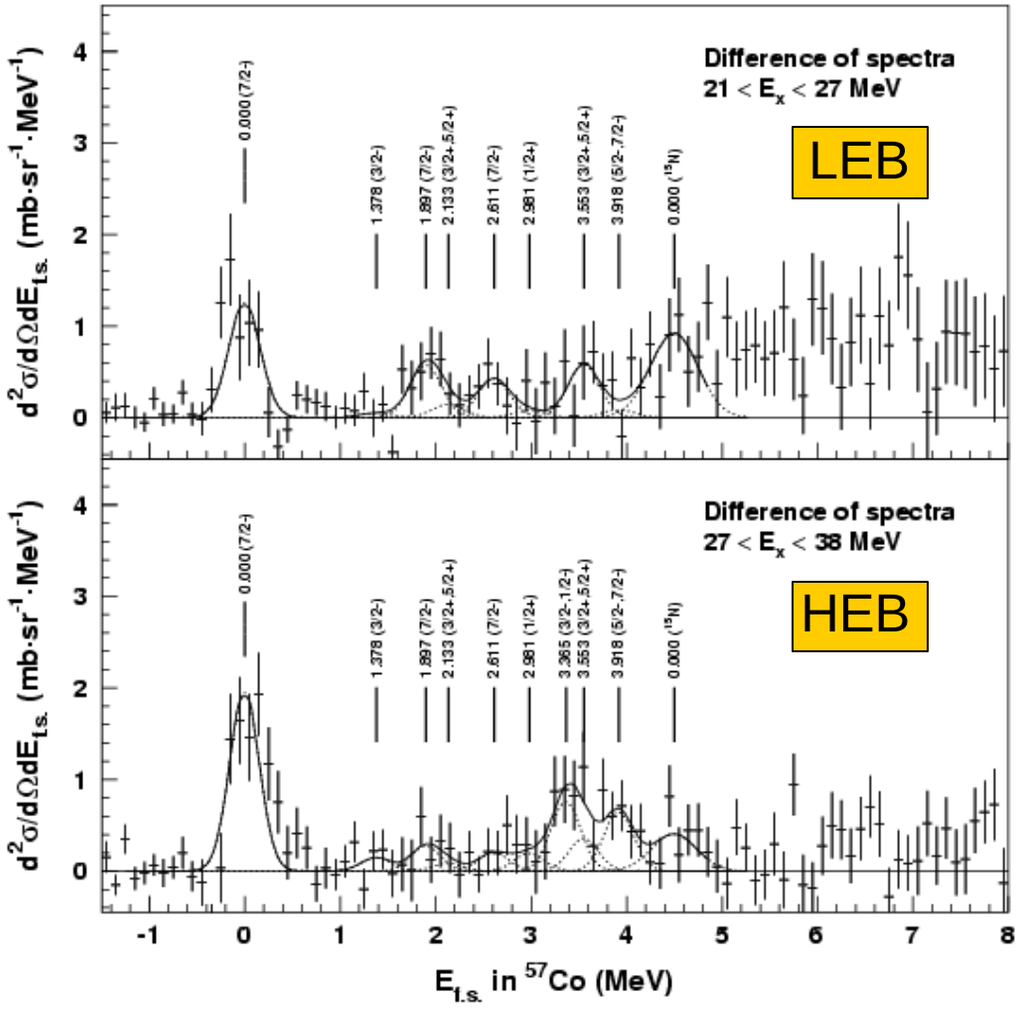
Centroid energies:

$$\langle E \rangle = 31.1 \pm 1.5\,\mathrm{MeV}$$ high-energy bump (HEB)

$$\langle E \rangle = 29.7 \pm 0.8\,\mathrm{MeV}$$ for 20<E$_x$<40 MeV

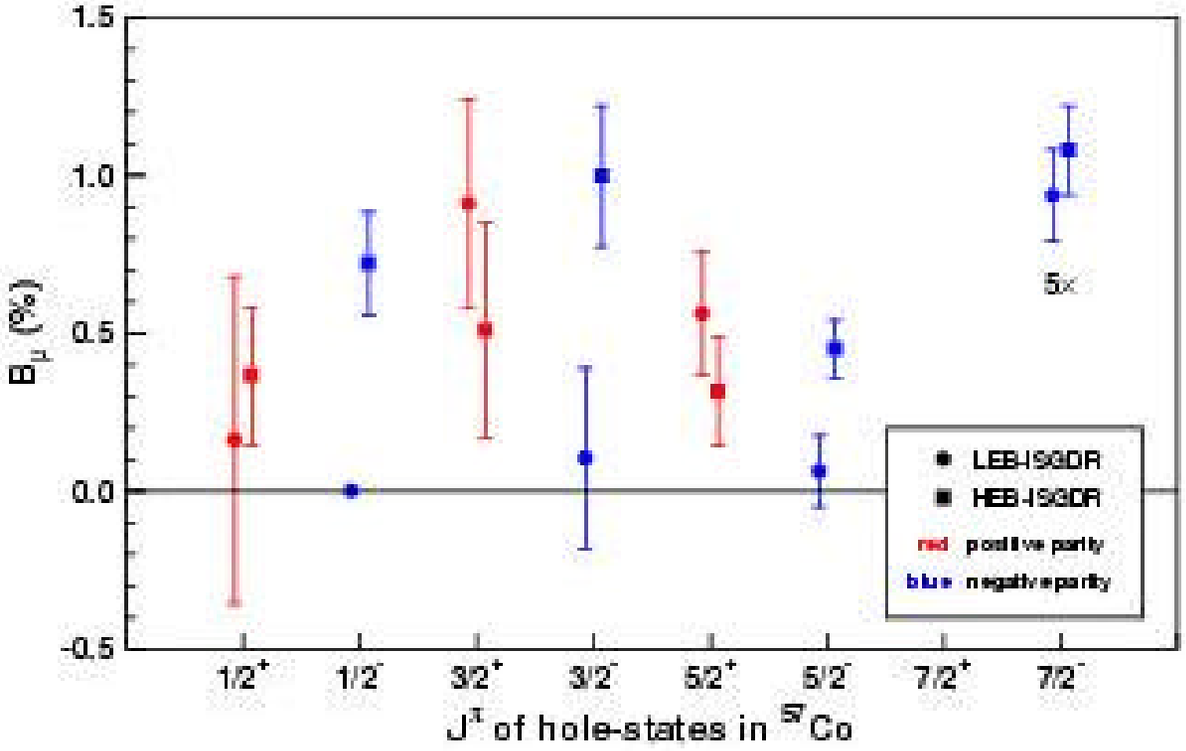
Decay data: ^{58}Ni

Population of hole-states



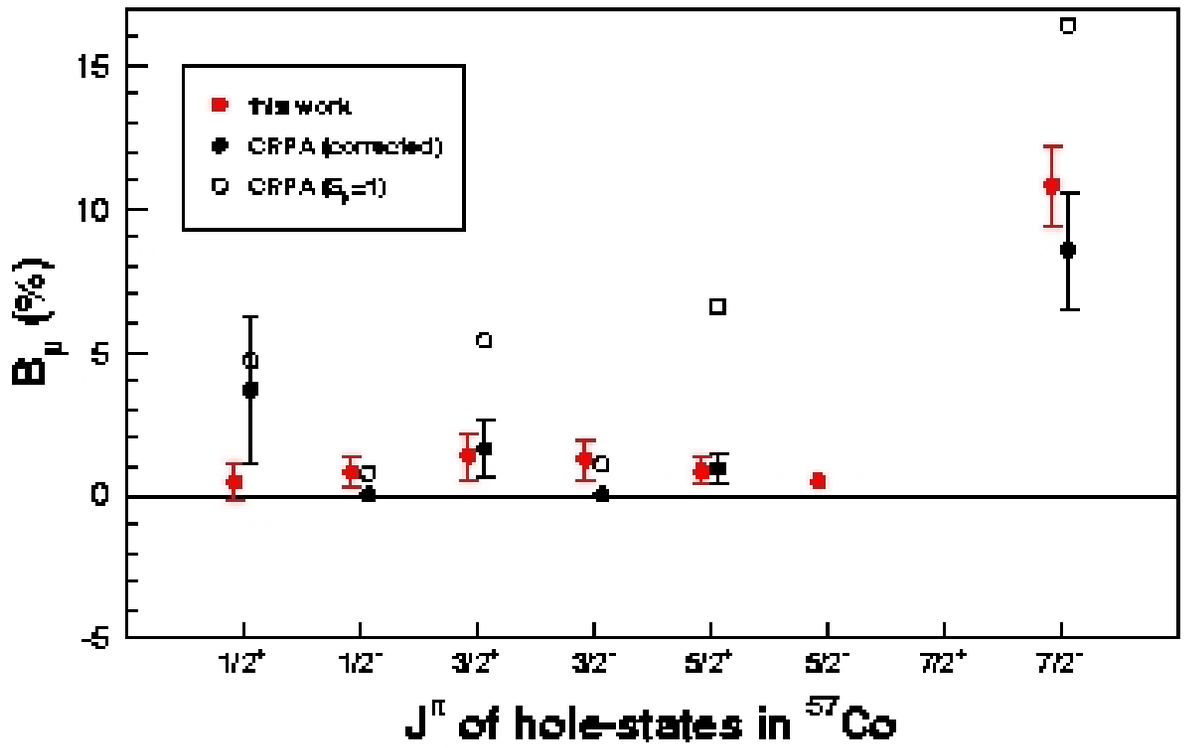
Decay data: ^{58}Ni

Population of hole-states



Decay data: ^{58}Ni

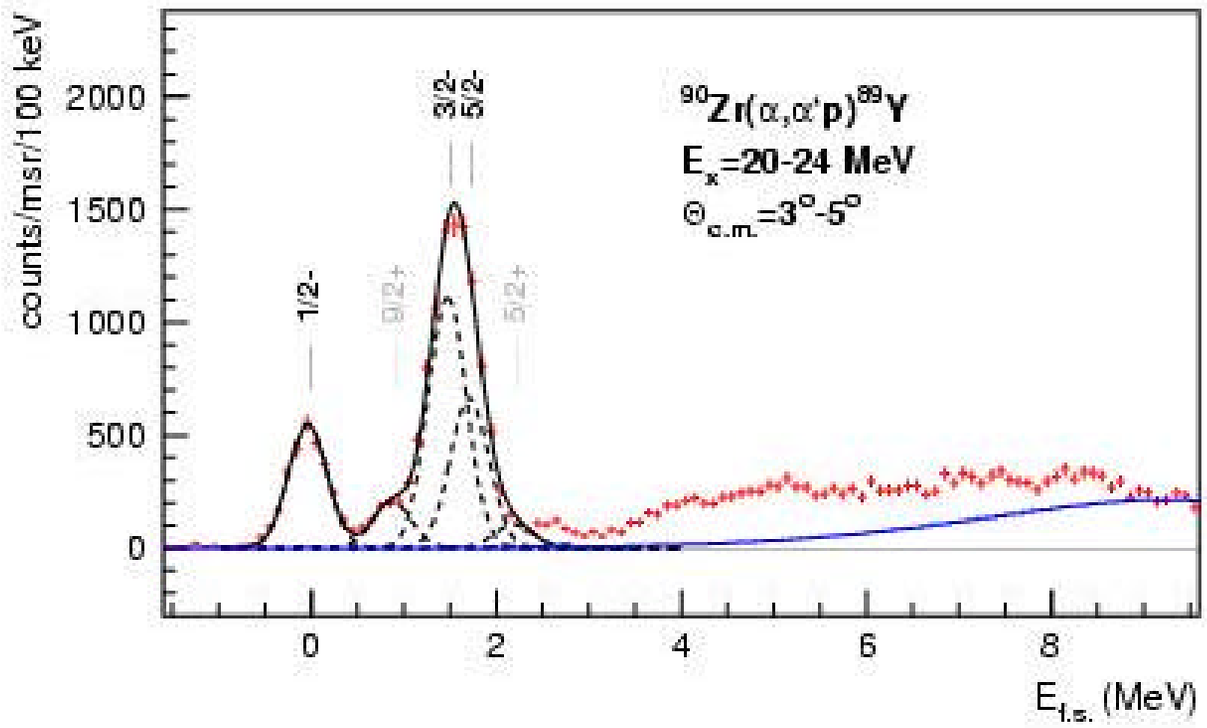
Population of hole-states



Comparison to theory: *M. Gorelik et al.*

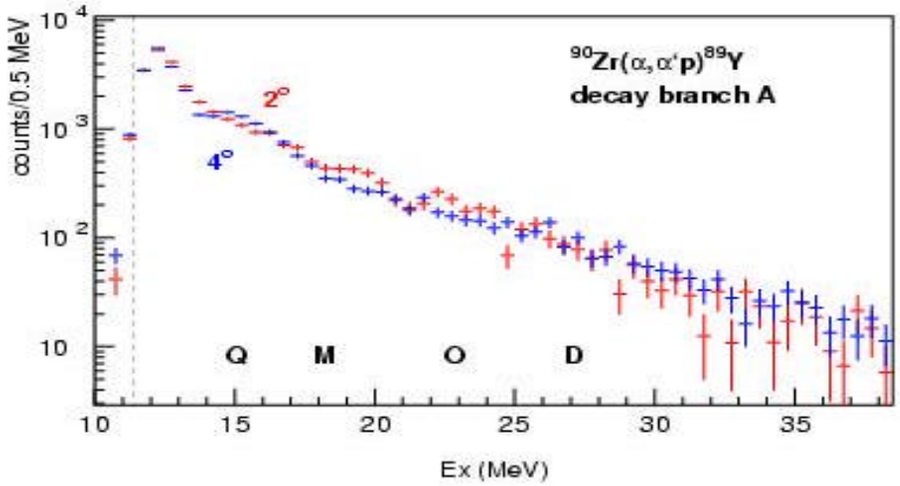
Decay data: ^{90}Zr

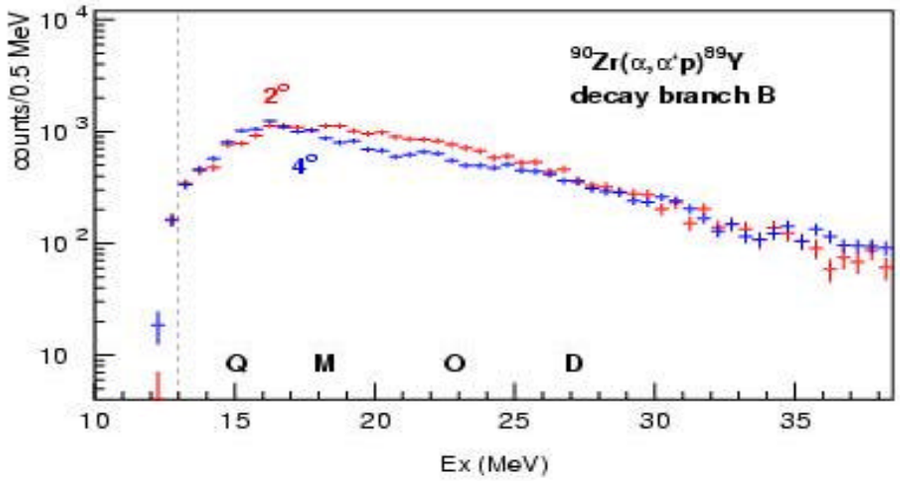
Final-state energy (E_{fs}) spectra



Decay data: ^{90}Zr

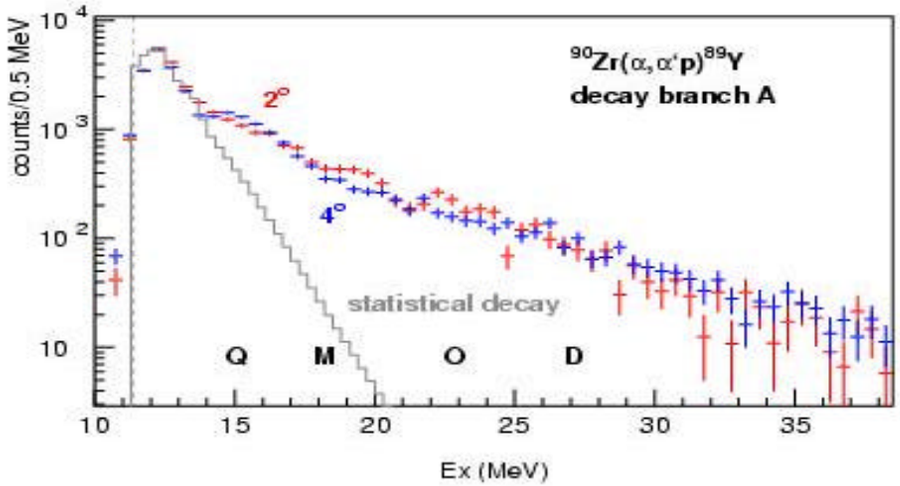
E*x*-spectra

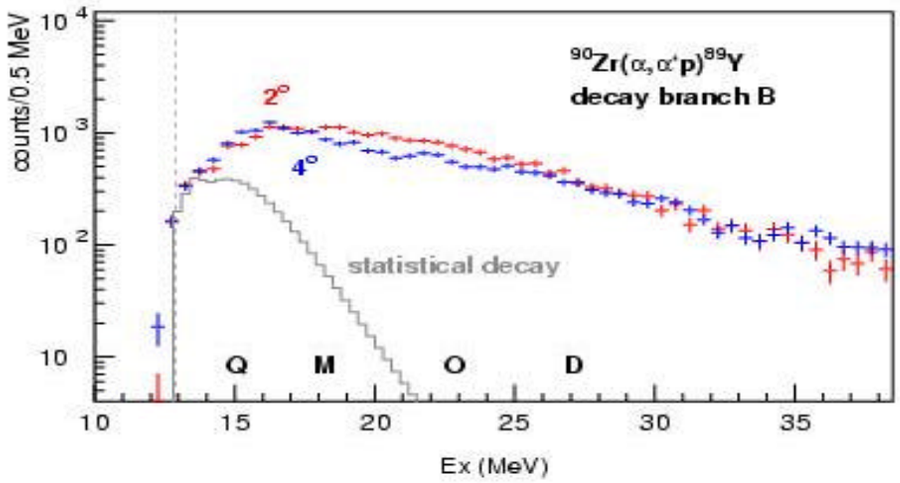




Decay data: ^{90}Zr

E*x*-spectra

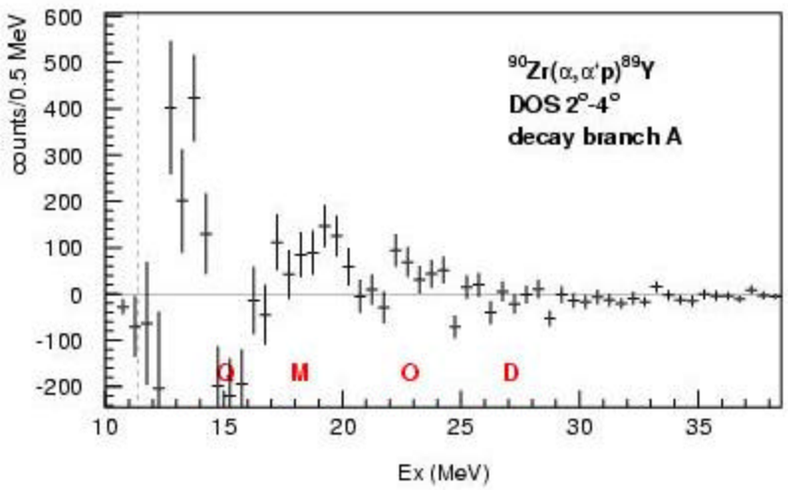


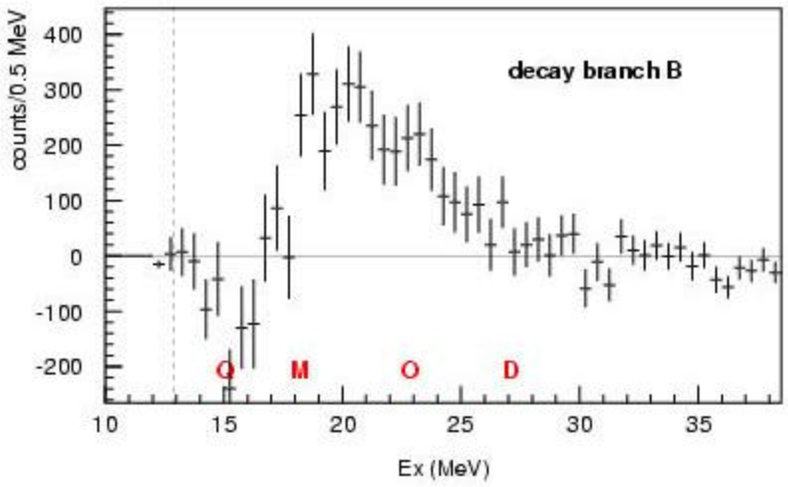


Decay data: ^{90}Zr

Difference of E*x*-spectra

L	
0	–
1	+ + +
2	- -
3	–

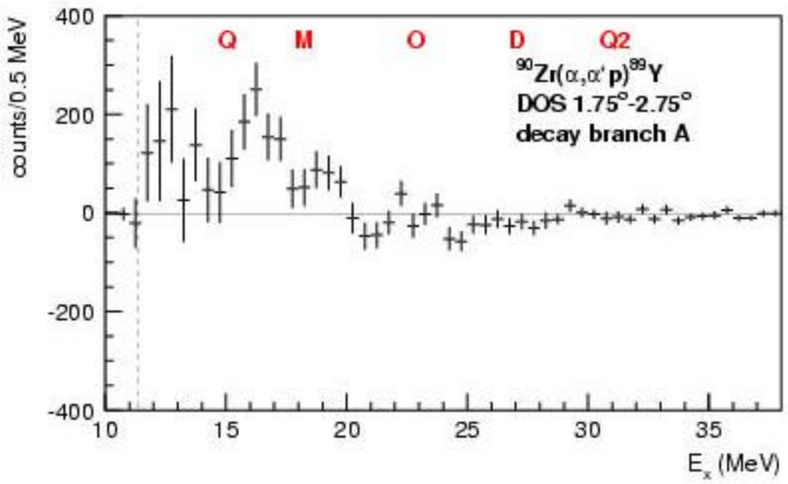


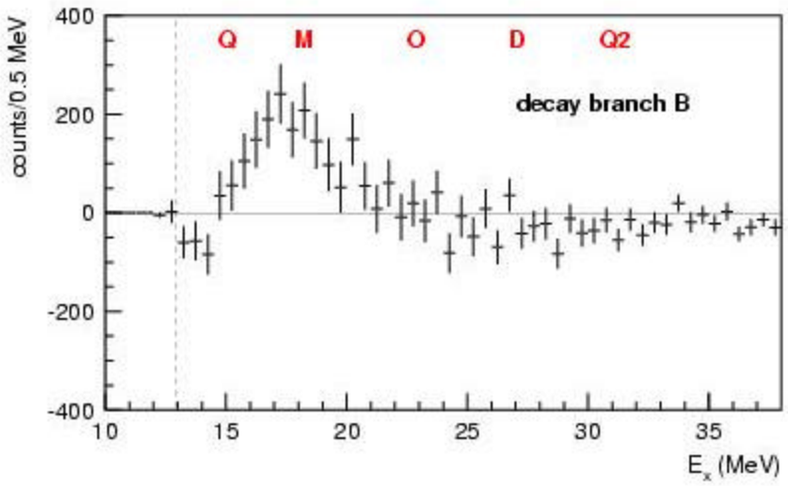


Decay data: ^{90}Zr

Difference of E*x*-spectra

L	
0	+ + +
1	+
2	
3	

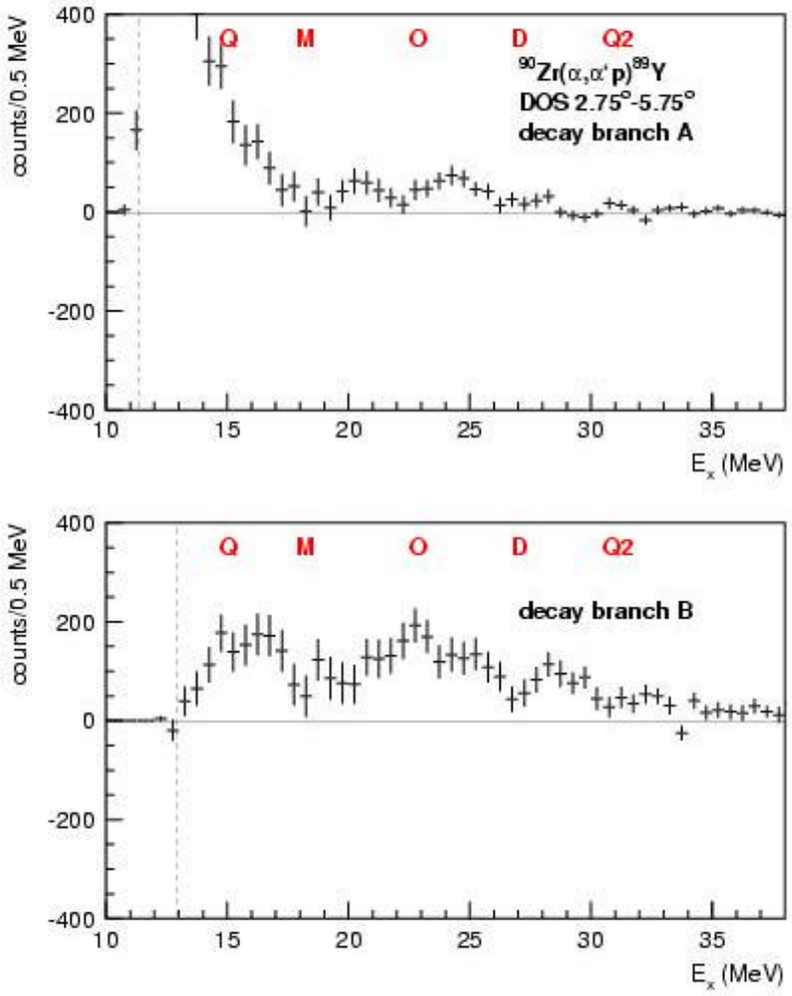




Decay data: ^{90}Zr

Difference of E*x*-spectra

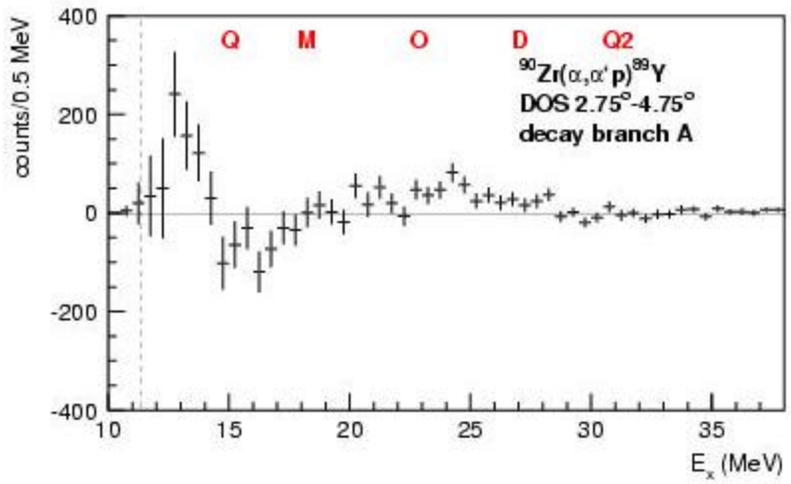
L	
0	–
1	+ + +
2	+
3	

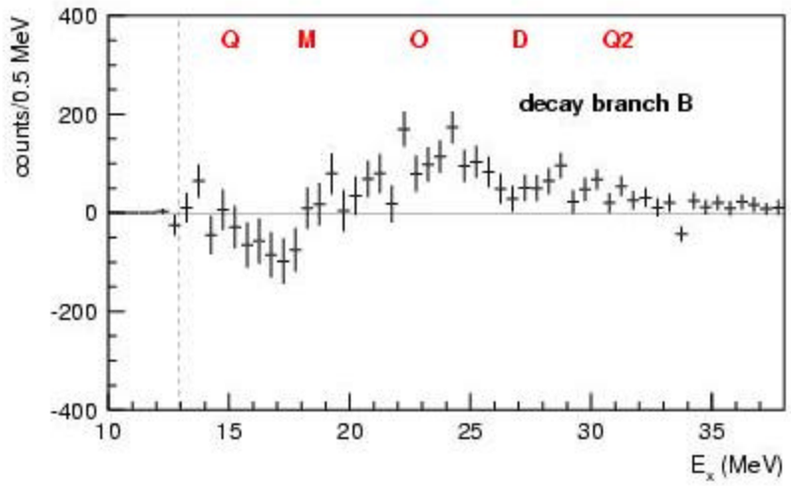


Decay data: ^{90}Zr

Difference of E*x*-spectra

L	
0	– –
1	+ + +
2	-
3	–

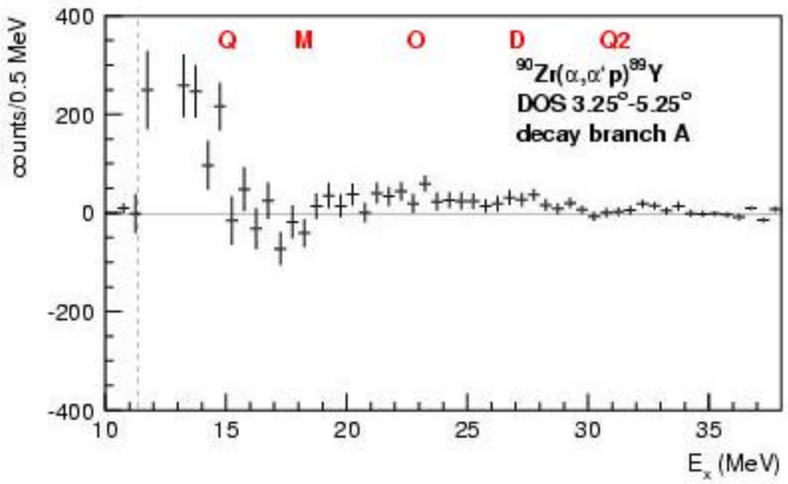


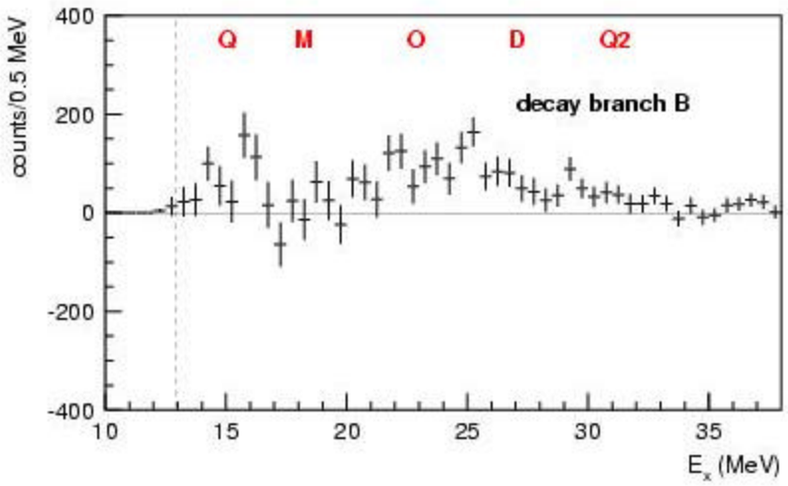


Decay data: ^{90}Zr

Difference of E*x*-spectra

L	
0	-
1	+ +
2	
3	

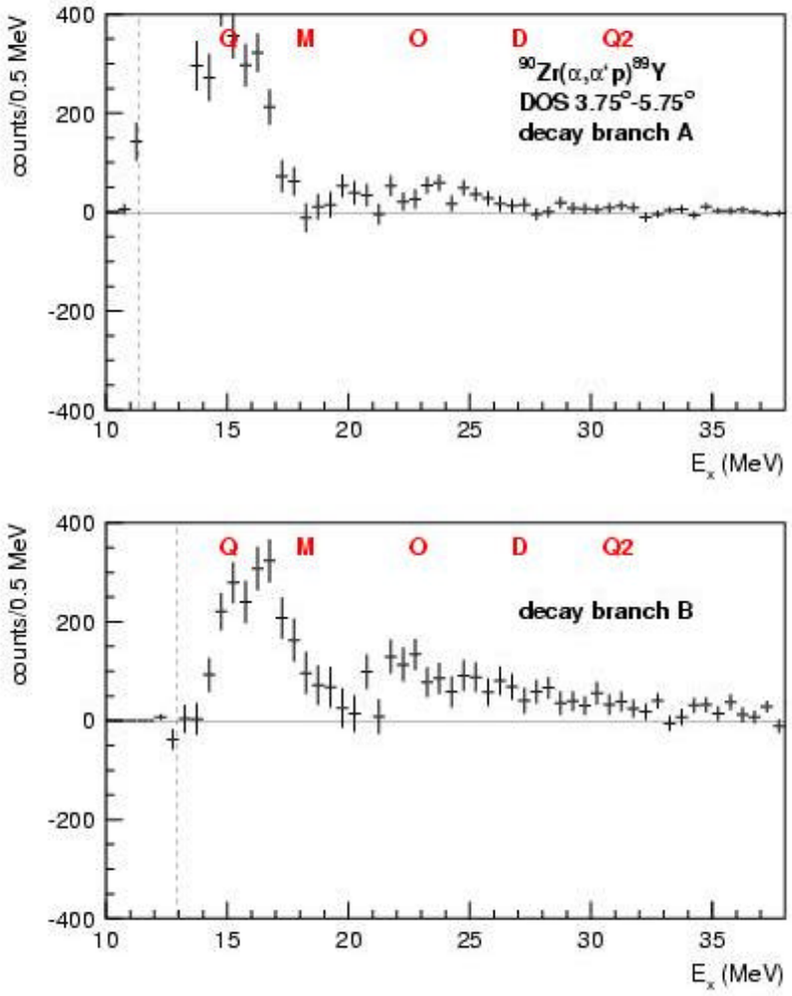




Decay data: ^{90}Zr

Difference of E*x*-spectra

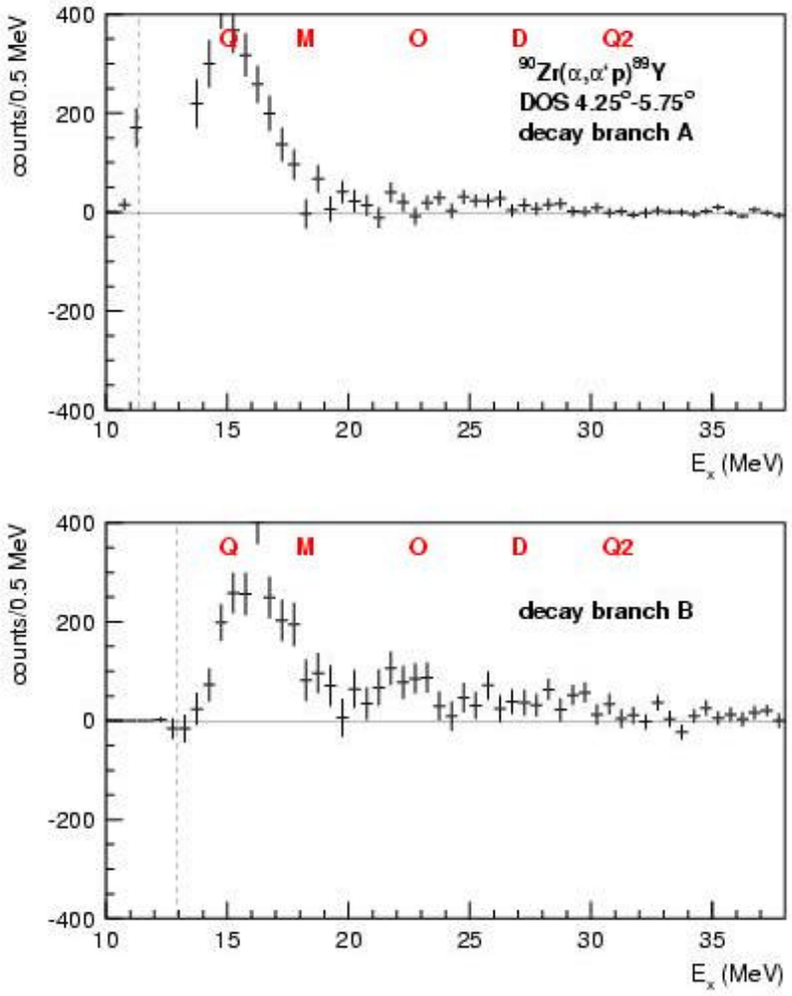
L	
0	
1	
2	+ + +
3	



Decay data: ^{90}Zr

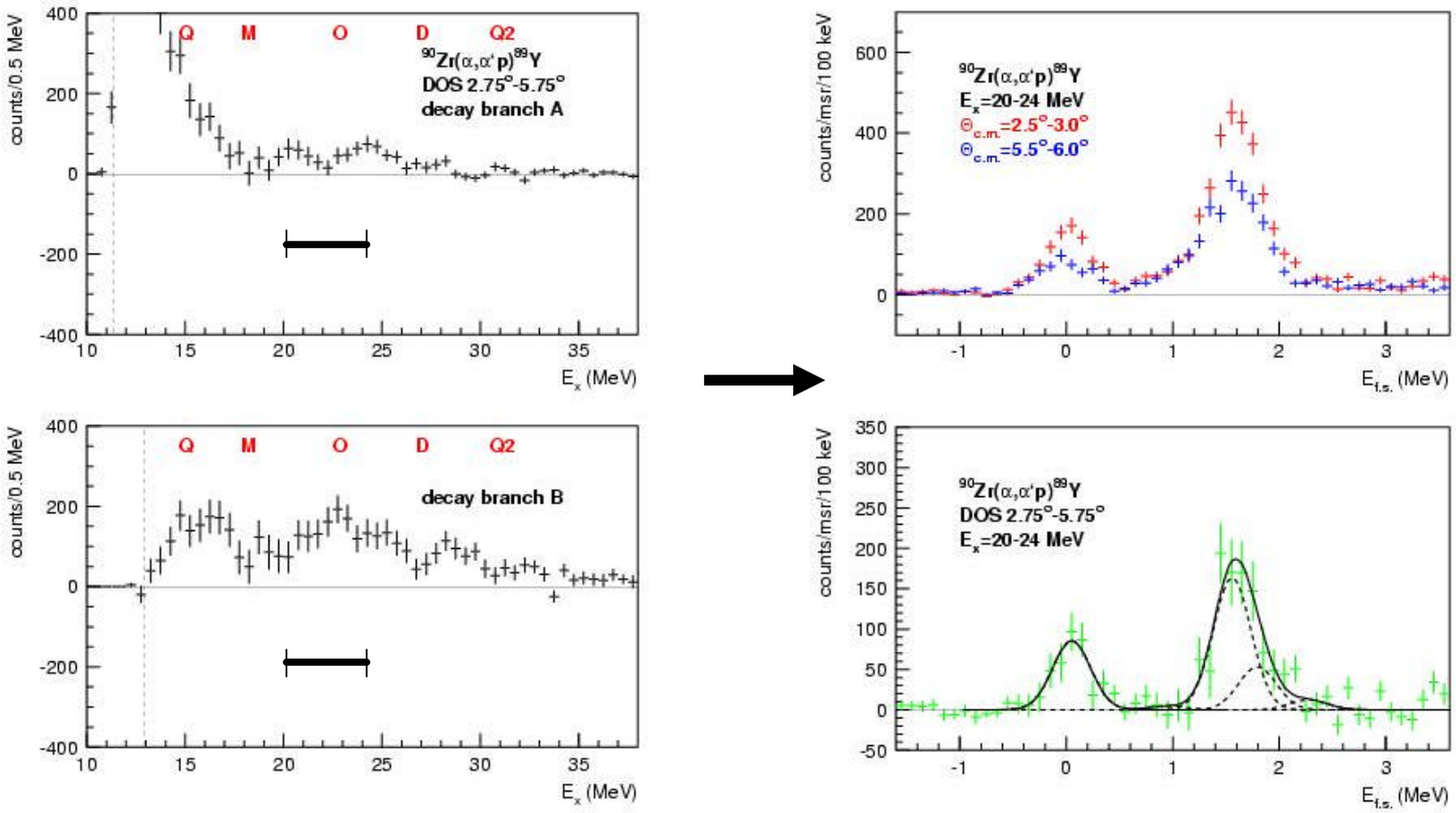
Difference of E*x*-spectra

L	
0	
1	
2	+ + +
3	



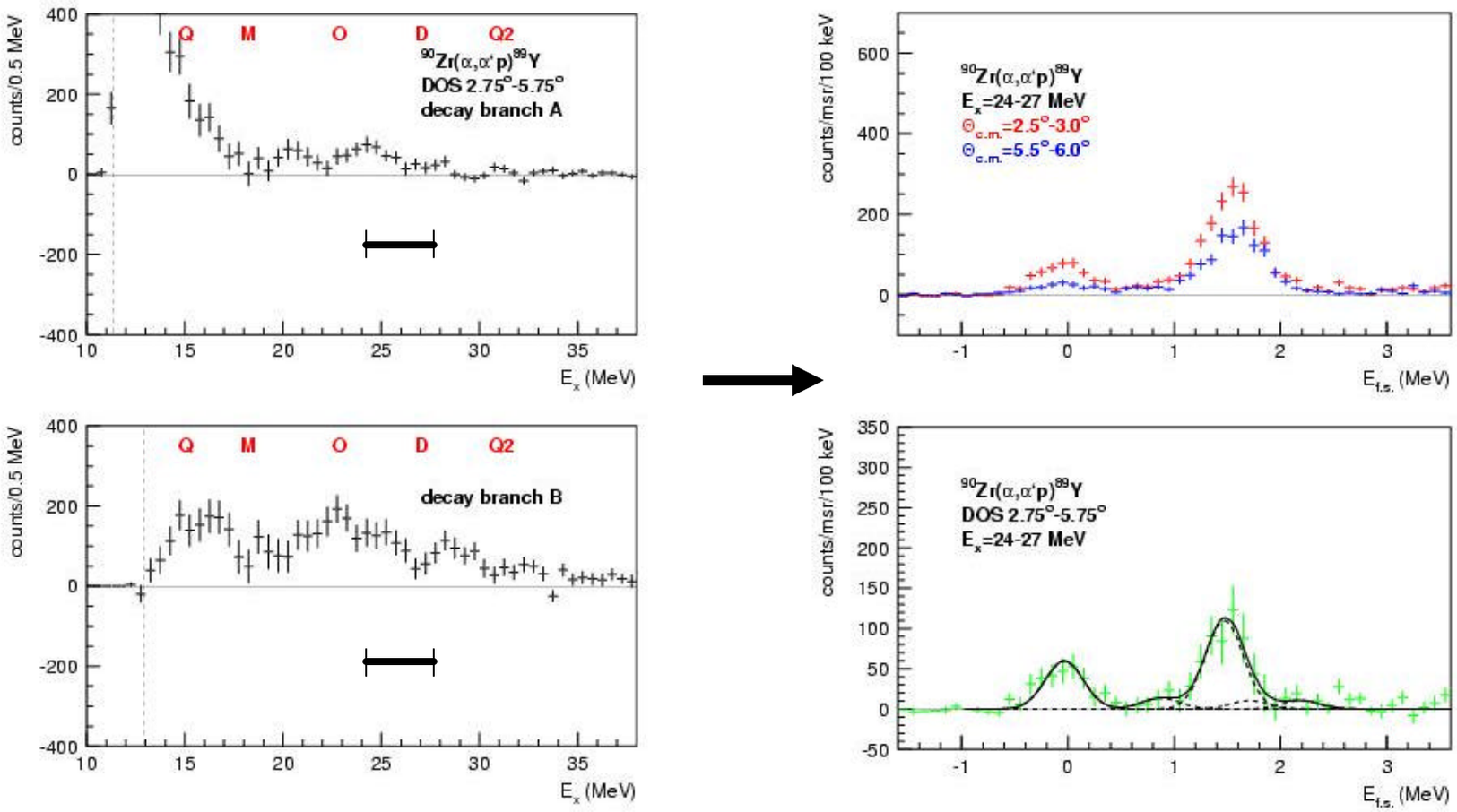
Decay data: ^{90}Zr

Fit of Difference of E_{fs}-spectra



Decay data: ^{90}Zr

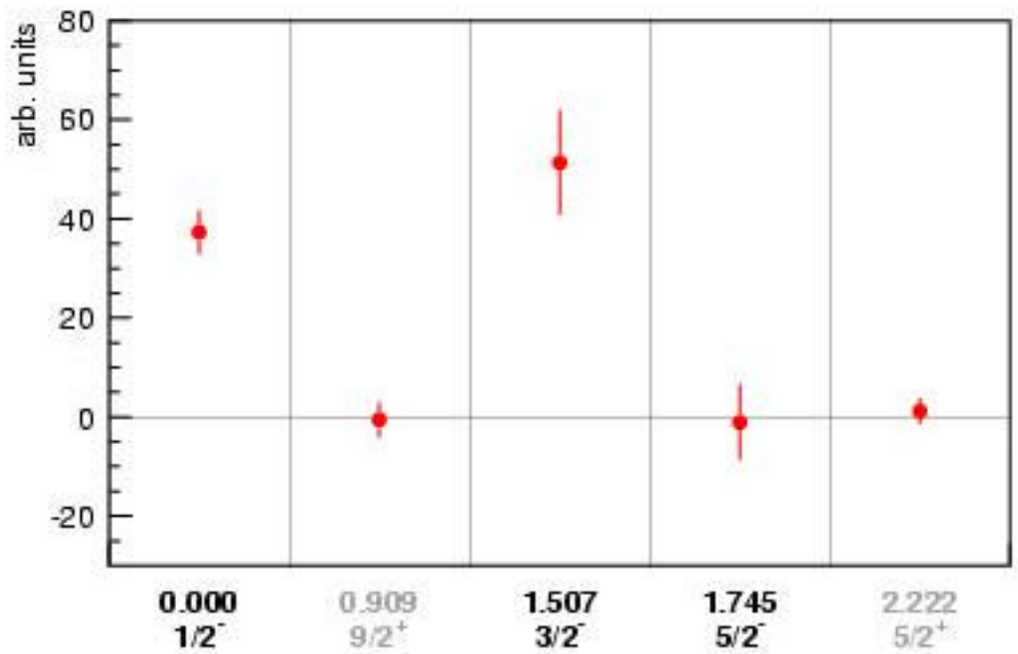
Fit of Difference of E_{fs}-spectra



Decay data: ^{90}Zr

Population of final states: direct decay of ISGMR

E_x:
15-19 MeV

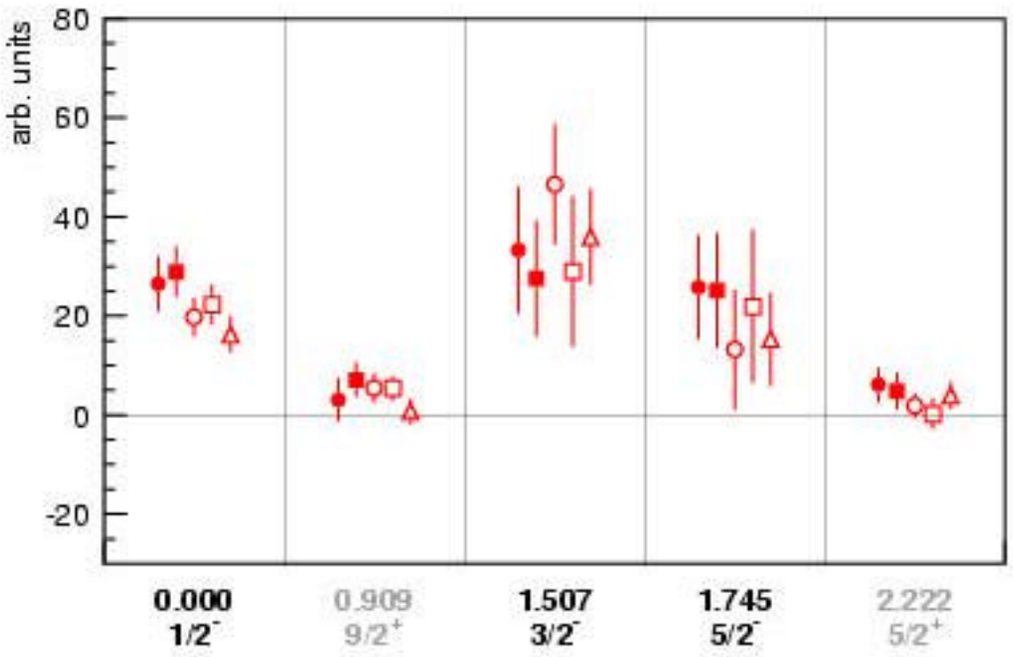


1h states: 2p1/2 2p3/2 1f5/2

Decay data: ^{90}Zr

Population of final states: direct decay of ISGDR

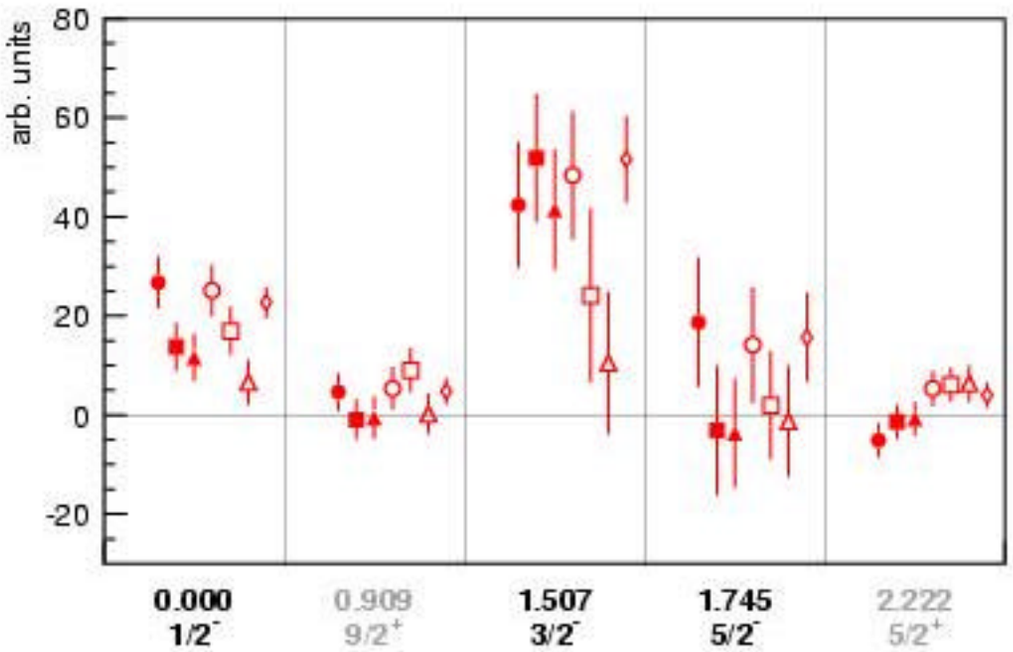
E_x:
20-24 MeV
24-27 MeV



Decay data: ^{90}Zr

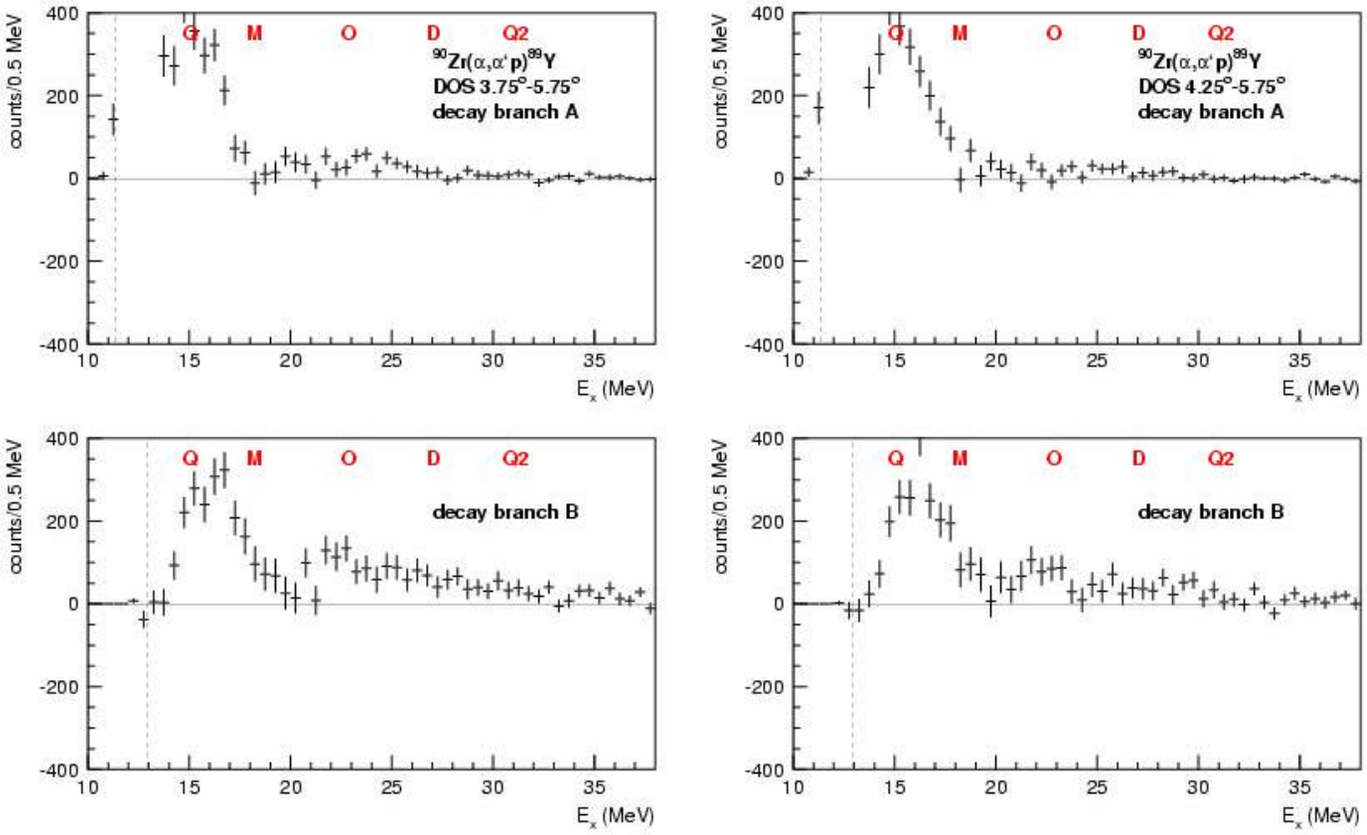
Population of final states: direct decay of L=2 strength

E_x:
20-24 MeV
24-27 MeV
21-35 MeV



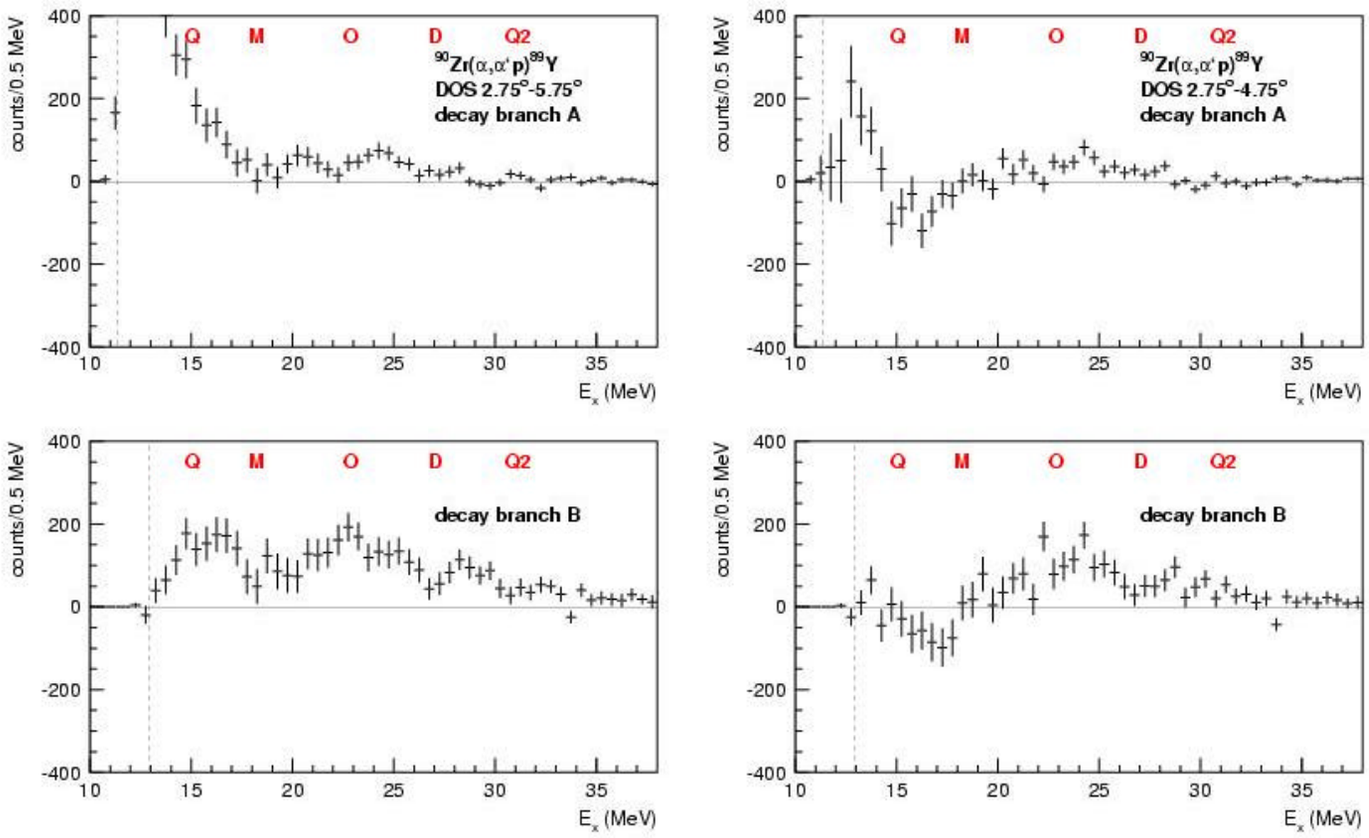
Decay data: ^{90}Zr

1h-strength in the decay channel of L=2 strength:



Decay data: ^{90}Zr

Fragmentation of 3h? ISGDR strength: p-h structures



Conclusion & outlook

? coincidence technique:
  elimination of instrumental background and contributions of quasi-free processes
? difference-of-spectra technique:
  elimination of nuclear continuum, which was supposed to decay by isotropic, statistical particle emission
? population of 1h-states in the daughter nuclei by decay of well-defined multipolarity:
  model-independent definition of GR strengths
  microscopic structure
? relative branching ratios:
  test for RPA calculations

Participants

ATOMKI (H)

M. Csatlós
L. Csige
J. Gulyás
M. Hunyadi
A. Krasznahorkay
D. Sohler
A. Vitéz

NDU (USA)

U. Garg
T. Li
B.K. Nayak
J. Hoffman

KVI (NL)

A.M. van den Berg
M.N. Harakeh
M.A. de Huu
H.J. Wörtche

RCNP (J)

H. Akimune
H. Fujimura
M. Fujiwara
K. Hara
M. Itoh
K. Nakanishi
H. Sakaguchi
H. Takeda
M. Uchida
Y. Yasuda
M. Yosoi