Institut für Kernphysik
S-DALINAC
Technische Universität Darmstadt

iThemba LABS

One- and Two-Phonon Mixed-Symmetry States in ^{94}Mo in High-Resolution Electron and Proton Scattering*

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Identification of Mixed-Symmetry States: Interacting Boson Model - 2

- Pairing of nucleons to s- / d-bosons

- F-Spin: π boson: $F_0 = 1/2$
  ν boson: $F_0 = -1/2$

$$\frac{|N_\pi - N_\nu|}{2} \leq F \leq F_{max} = \frac{N_\pi + N_\nu}{2}$$

$$F_0 = \frac{N_\pi - N_\nu}{2}$$

$\rightarrow F = F_{max}$: symmetric states

$\rightarrow F < F_{max}$: mixed-symmetry states (ms)

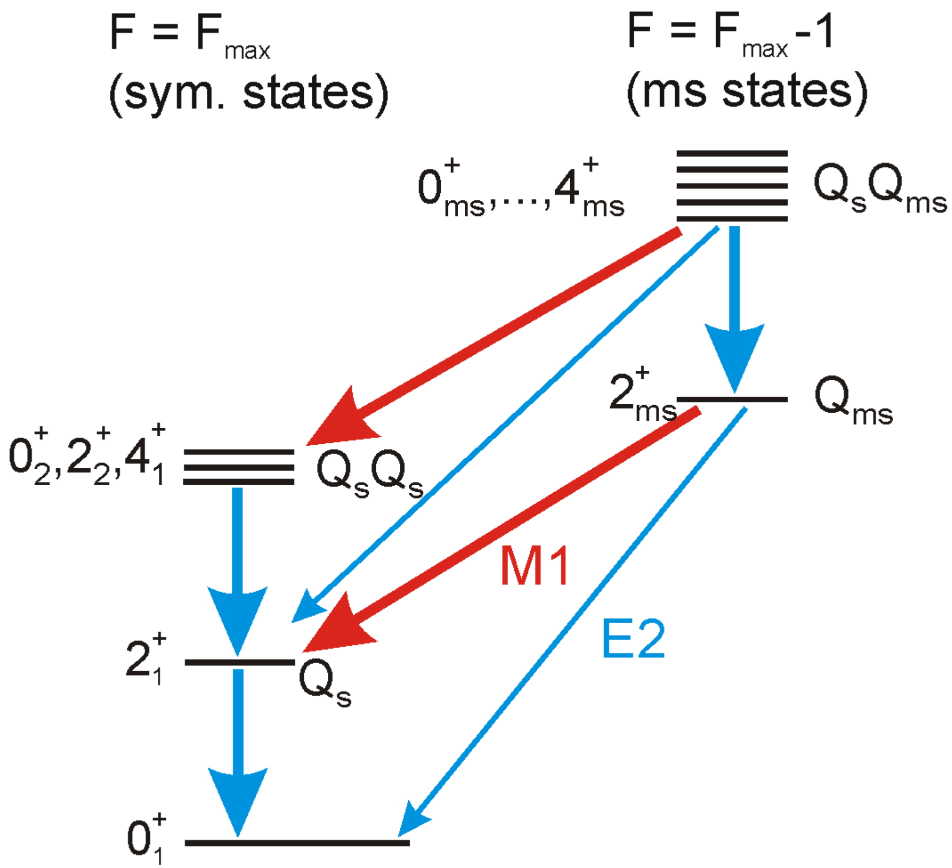
- Q-Phonon scheme: $Q_s = Q_\pi + Q_\nu$

$$|\,2^+_1\rangle \propto Q_s\,|\,0^+_1\rangle$$

$$Q_{ms} = \frac{N}{2}\left(\frac{Q_\pi}{N_\pi} - \frac{Q_\nu}{N_\nu}\right)$$

$$|\,2^+_{ms}\rangle \propto Q_{ms}\,|\,0^+_1\rangle$$

Identification of Mixed-Symmetry States: Q-Phonon Scheme



- Strong **E2** transitions for decay of sym. Q-phonon
- Weak E2 transitions for decay of ms Q-phonon
- Strong **M1** transitions for decay of ms states to sym. states

Experiments

- High resolution required to resolve all 2^+ states below 4 MeV
- Lateral dispersion matching technique

• (e,e´): S-DALINAC, TU Darmstadt	• (p,p´): SSC, iThemba LABS
$E_e = 70$ MeV	$E_p = 200$ MeV
$\Theta_e = 93°- 165°$	$\Theta_p = 4.5°- 26°$
$\Delta E = 30$ keV (FWHM)	$\Delta E = 35$ keV (FWHM)

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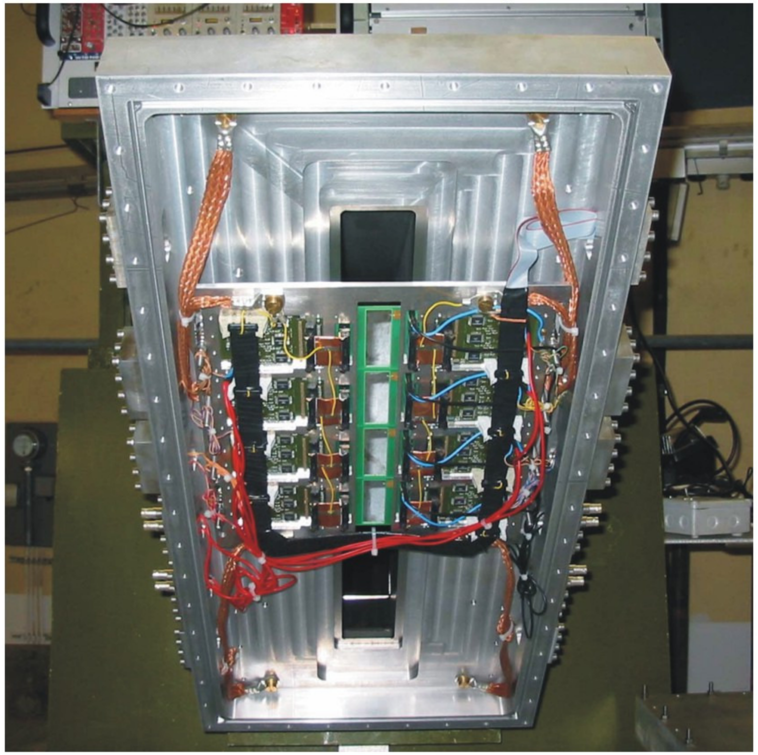
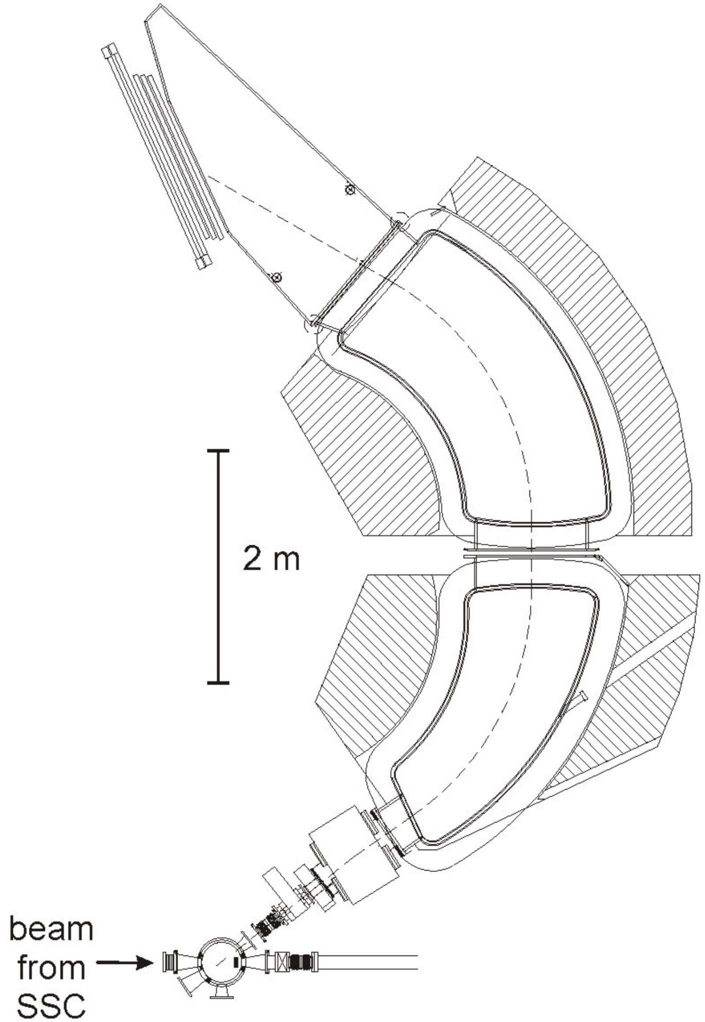
LINTOTT Spectrometer and Focal Plane Detector System

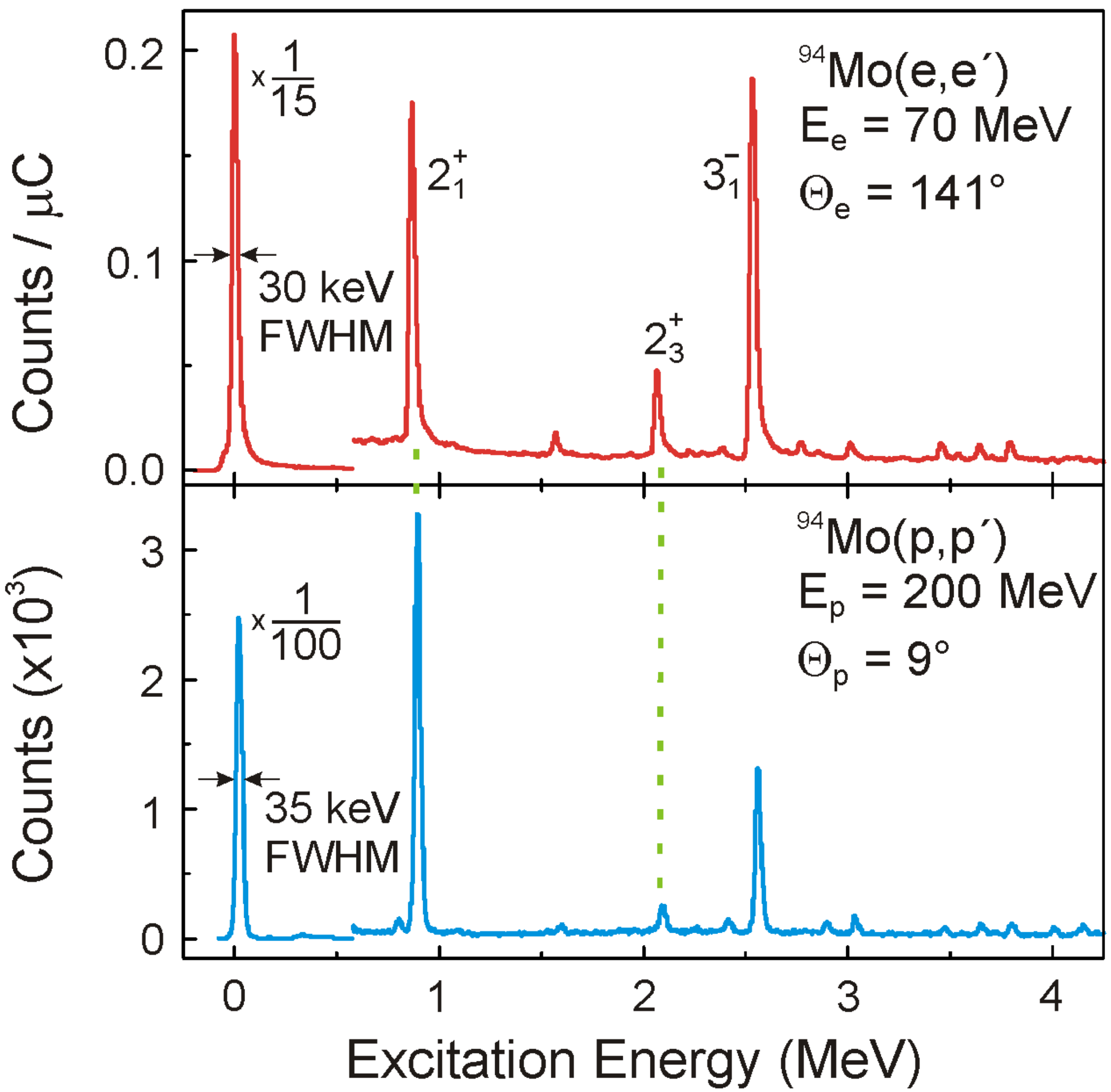


- New Si microstrip detector system: 4 modules, each contains 96 strips with active width of 500 μm
- Resolution: $\Delta E/E = 4 \times 10^{-4}$
- Data rates up to 100 kHz

K600 Magnetic Spectrometer and Detector System



Measured Spectra



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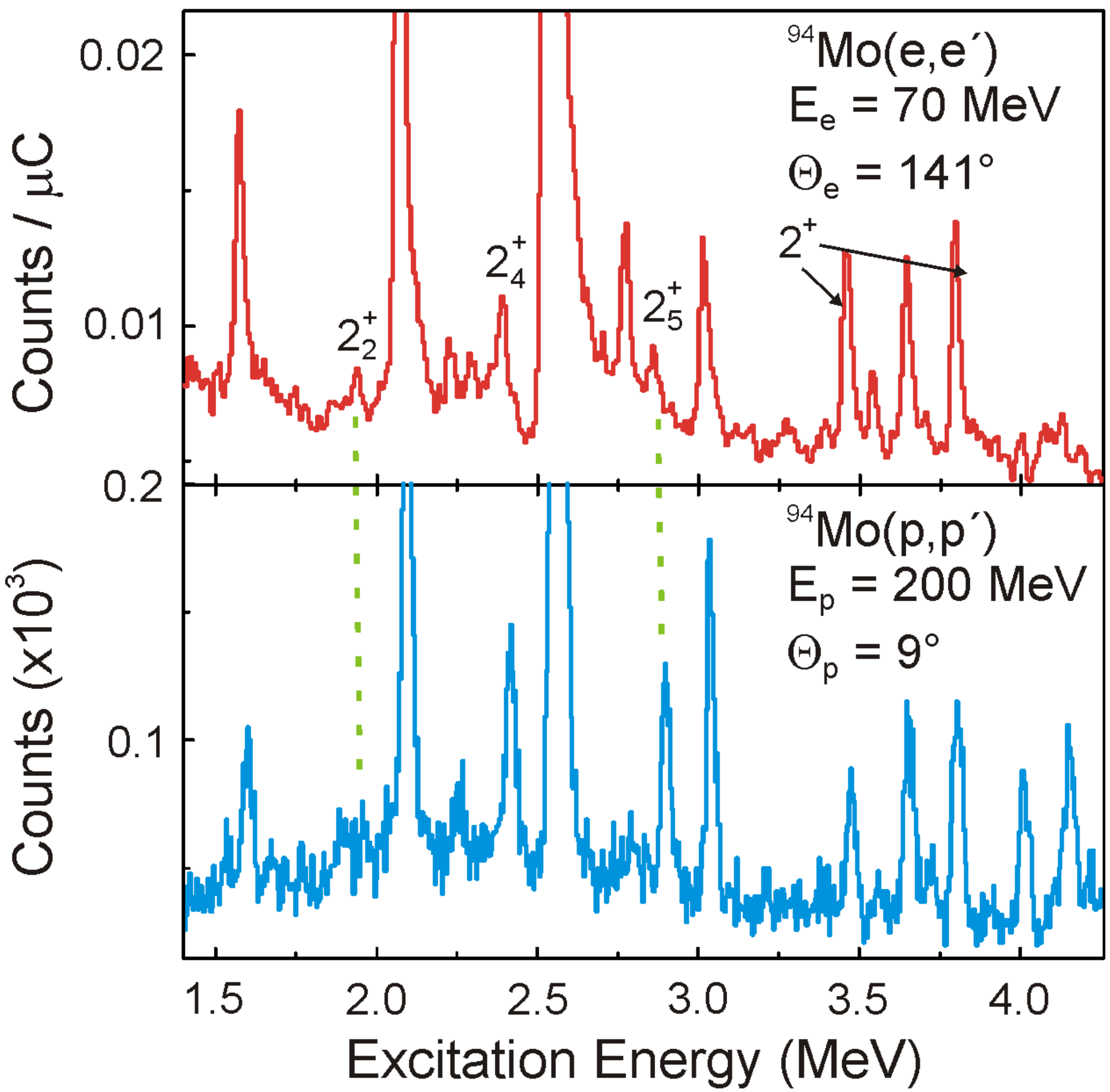
Measured Spectra



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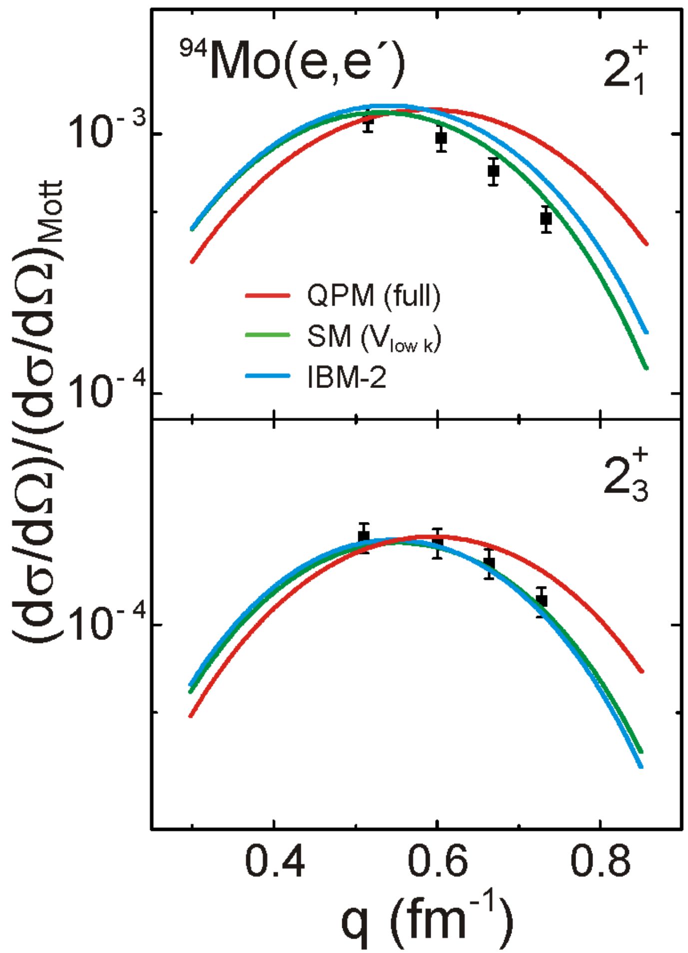
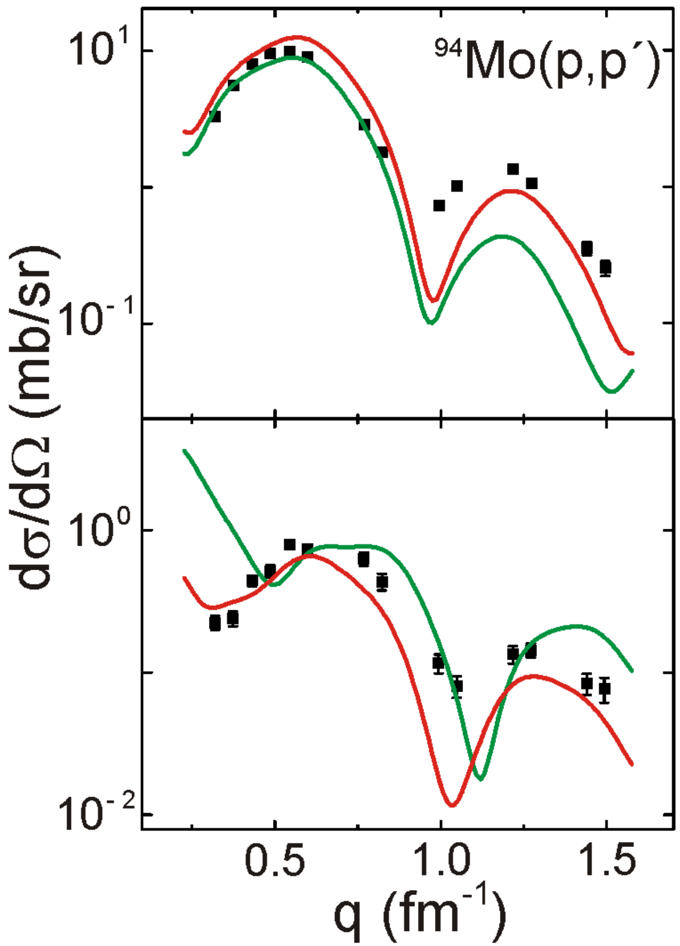
Theoretical Calculation

- Quasiparticle Phonon Model
  - $\Rightarrow$ coupling up to 3 phonons
- Shell Model
  - $\Rightarrow$ ^{88}Sr core / $V_{low\ k}$
- IBM-2
- Cross Sections
  - $\Rightarrow$ DWBA / Love-Franey effective nucleon-target interaction for (p,p´)

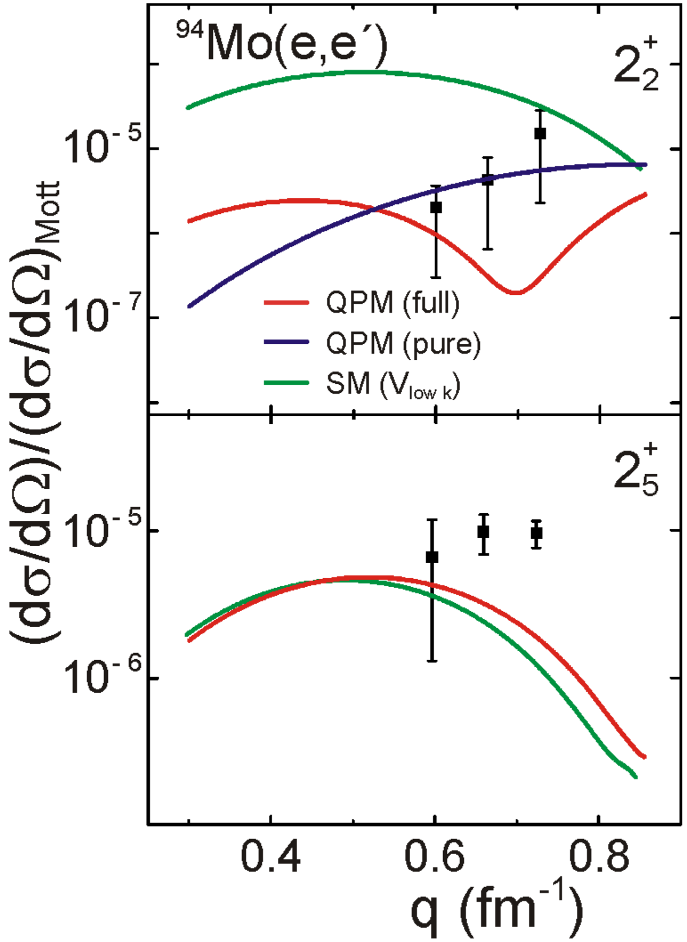
One-Phonon Symmetric and Mixed-Symmetry States

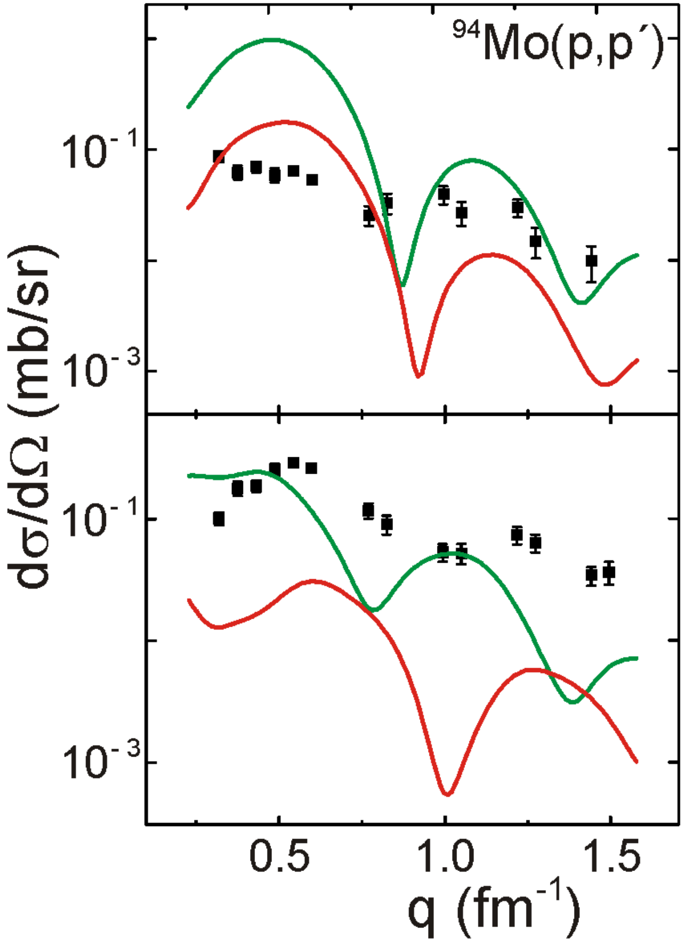




- one-phonon character confirmed

Two-Phonon Symmetric and Mixed-Symmetry State

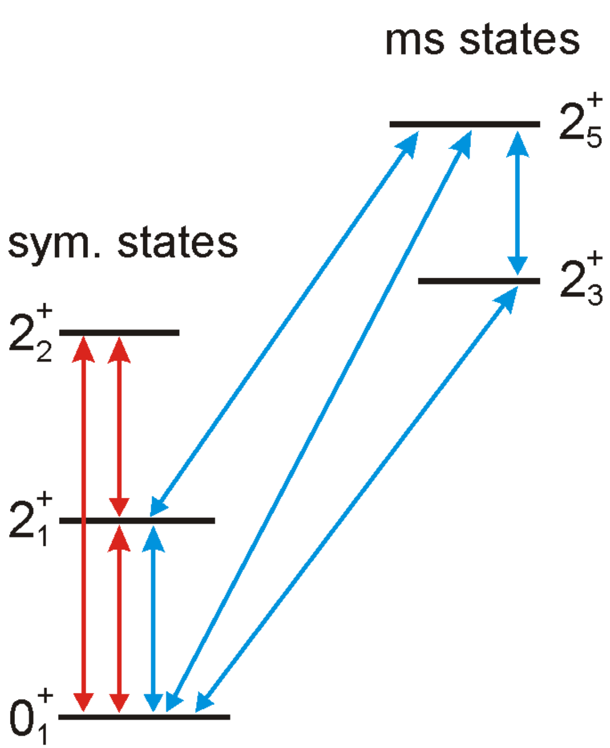


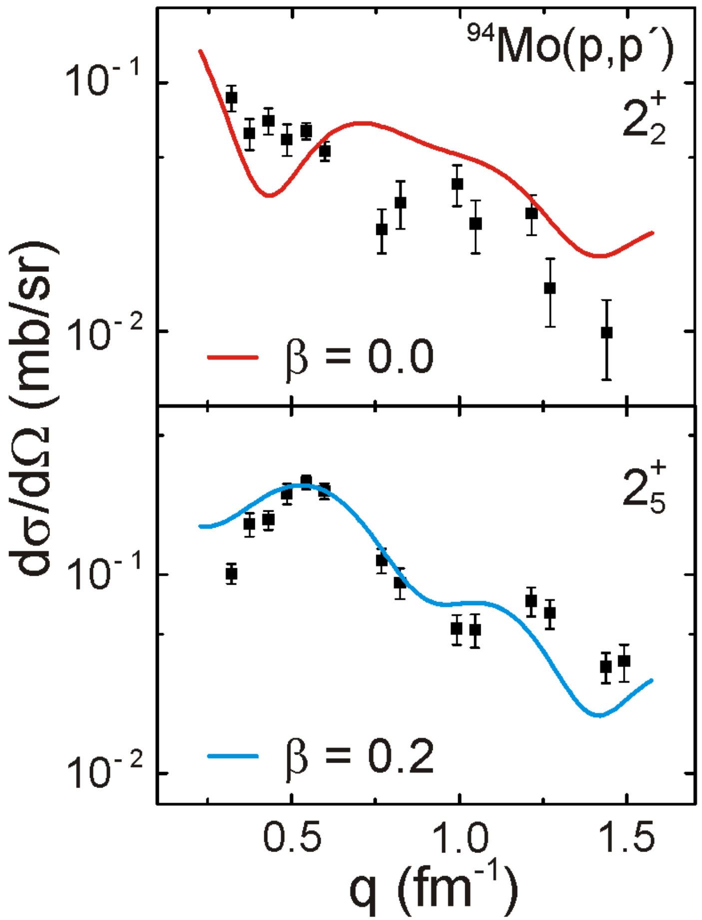


- pure two-phonon FSS
- about 15% one-phonon admixtures in MSS

- two-step contributions?

Coupled-Channel Analysis





- pure two-phonon symmetric state confirmed
- admixture to two-phonon ms state confirmed

Summary

- Study of one- and two-phonon 2^+ states in ^{94}Mo with high-resolution (e,e´) and (p,p´) experiments

- Combined analysis with microscopic models reveals:
  - dominant one-phonon character of the 2^+_1 and 2^+_3 states
  - quantitatively consistent results after inclusion of two-step processes in (p,p´) cross section
  - two-phonon symmetric state extremely pure
  - about 15% one-phonon and about 17% three-phonon admixtures in two-phonon ms state
    - but dominant two-phonon character

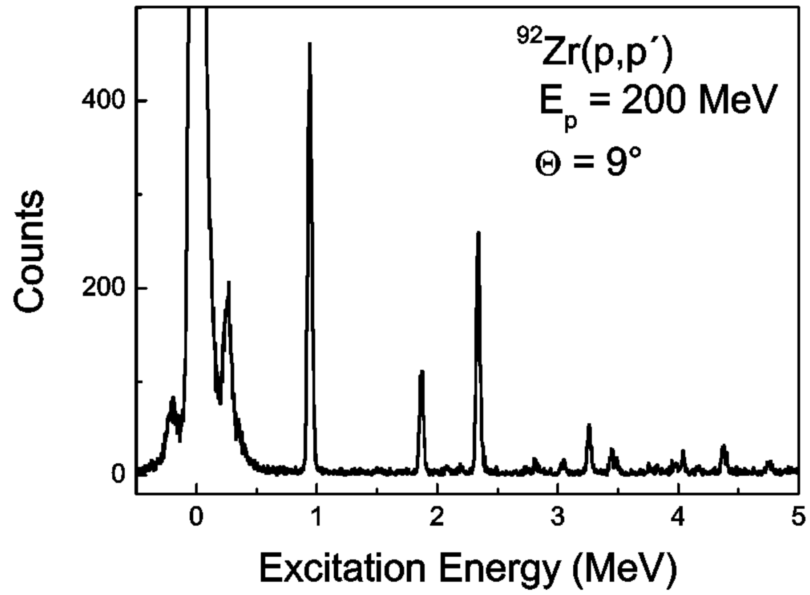
Outlook

- The case of ^{92}Zr: Mixed-symmetry concept seems to fail
  C.Fransen *et al.*, Phys. Rev. C 71 (2005) 054304

⇒ Experiments:

☑ (p,p´) at iThemba LABS

☐ (e,e´) at S-DALINAC



Why ^{94}Mo?

- The low-energy spectrum of ^{94}Mo is well studied and candidates for most one- and two-phonon states have been identified

N. Pietralla *et al.*, Phys. Rev. Lett. 83 (1999) 1303; Phys. Rev. Lett. 84 (2000) 3775
C. Fransen *et al.*, Phys. Lett. B 508 (2001) 219; Phys. Rev. C 67 (2003) 024307

- Study of 2^+ states with (e,e´) and (p,p´)

$\Rightarrow$ sensitive to one-phonon components of the wave function
$\Rightarrow$ test of fundamental phonon character
$\Rightarrow$ isoscalar / isovector decomposition
$\Rightarrow$ purity of two-phonon states

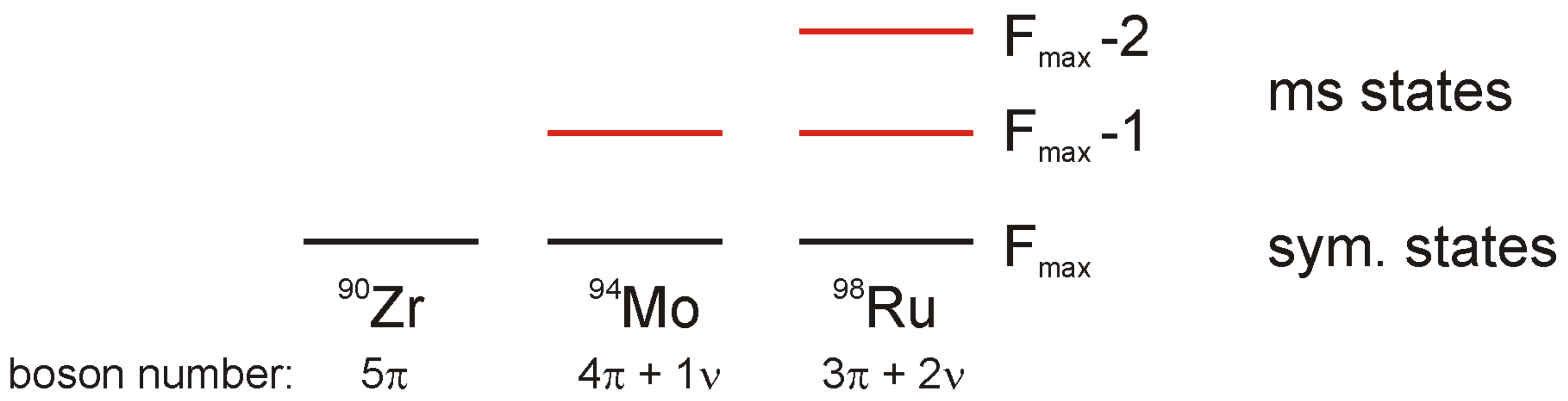
Coupled-Channel Analysis

- Collective model

$$\Rightarrow \quad U_{fi}(r) = -\frac{\beta_L R_0}{\sqrt{2L+1}} \frac{d}{dr} U(r), \qquad L \leq 2$$

$$\Rightarrow \quad \beta_L^2 = \left(\frac{d\sigma}{d\Omega}\right)_L^{exp} \Big/ \left(\frac{d\sigma}{d\Omega}\right)_L^{DWBA}$$

F-Spin Multiplet



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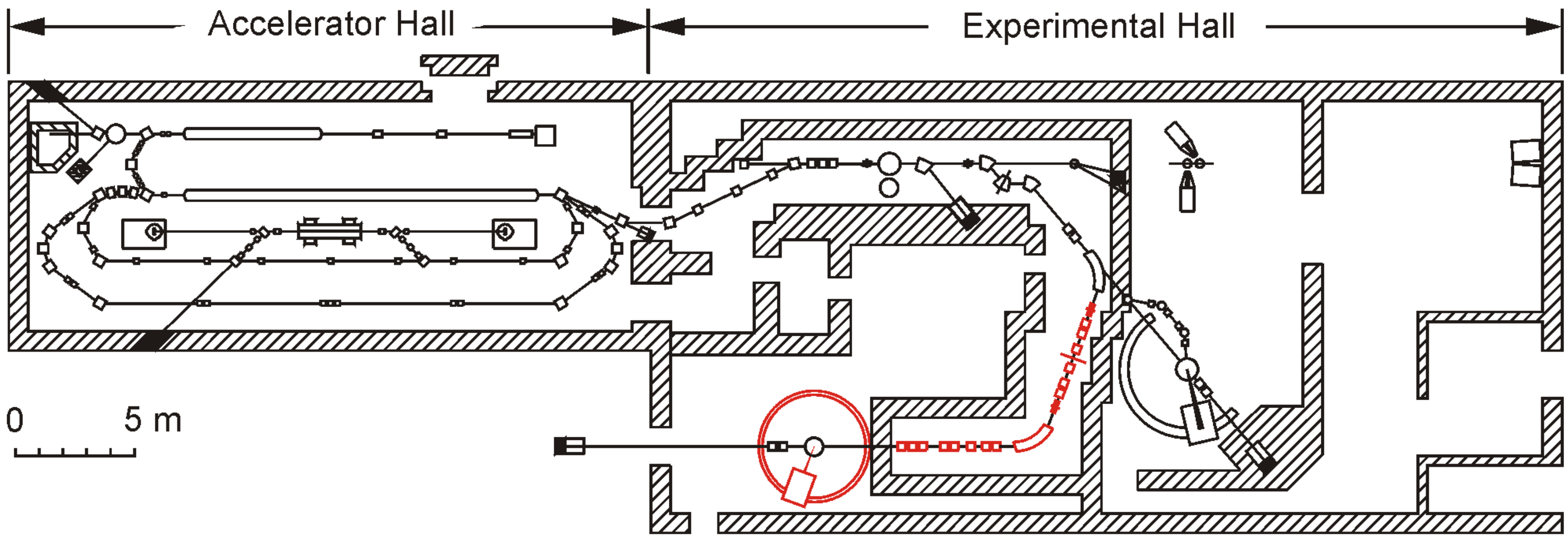

- High-resolution (e,e´) experiments

Separated-Sector Cyclotron Facility