Experimental nuclear level densities and γ-ray strength functions in Sc and V isotopes

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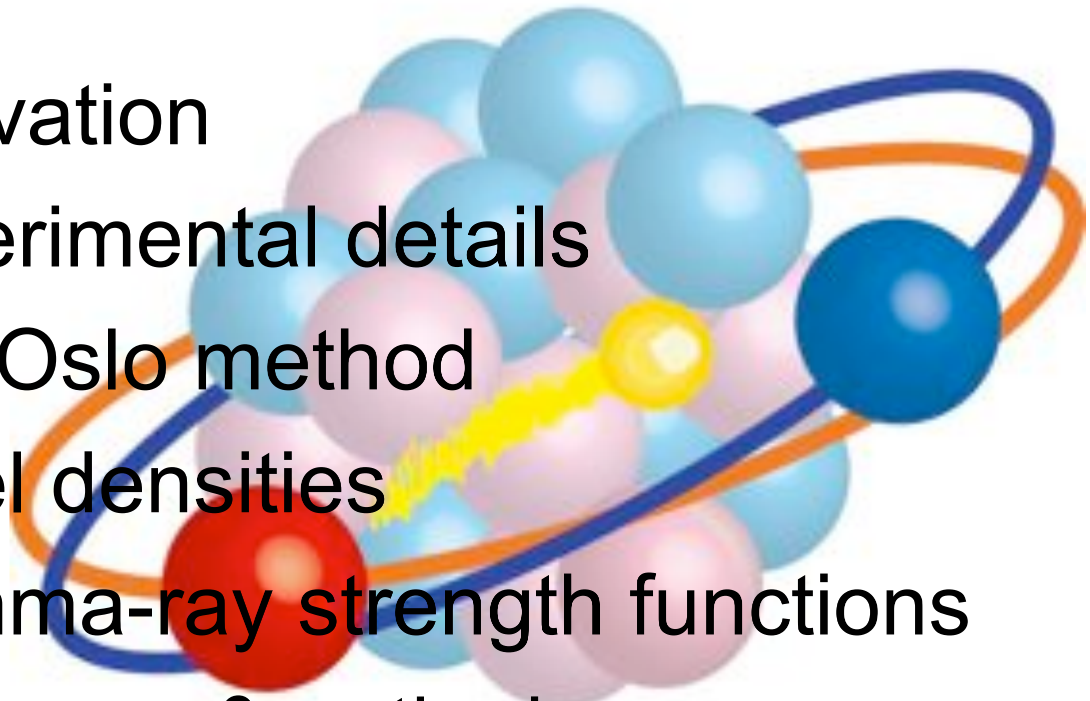
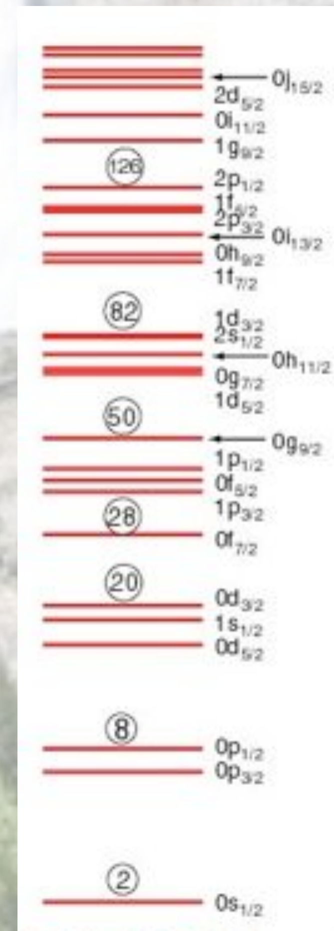
Outline



- Motivation
- Experimental details
- The Oslo method
- Level densities
- Gamma-ray strength functions
- Summary & outlook

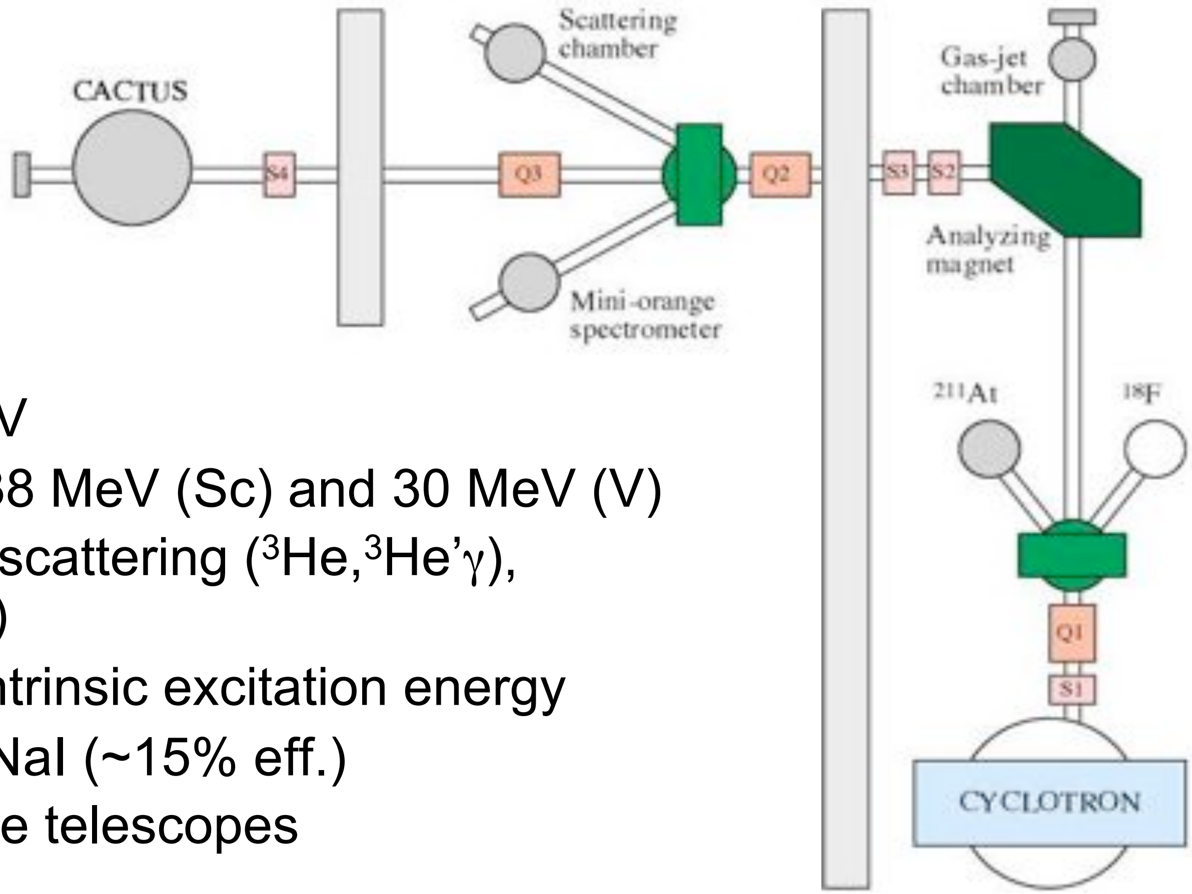
Why ^{44,45}Sc and ^{50,51}V?

- Nuclei with relatively few nucleons - “late” onset of statistical properties
- Possible shell effects (close to *Z*=20 & *N*=28)
- Large enhancement of decay probability for low-energy gammas? (Fe & Mo)



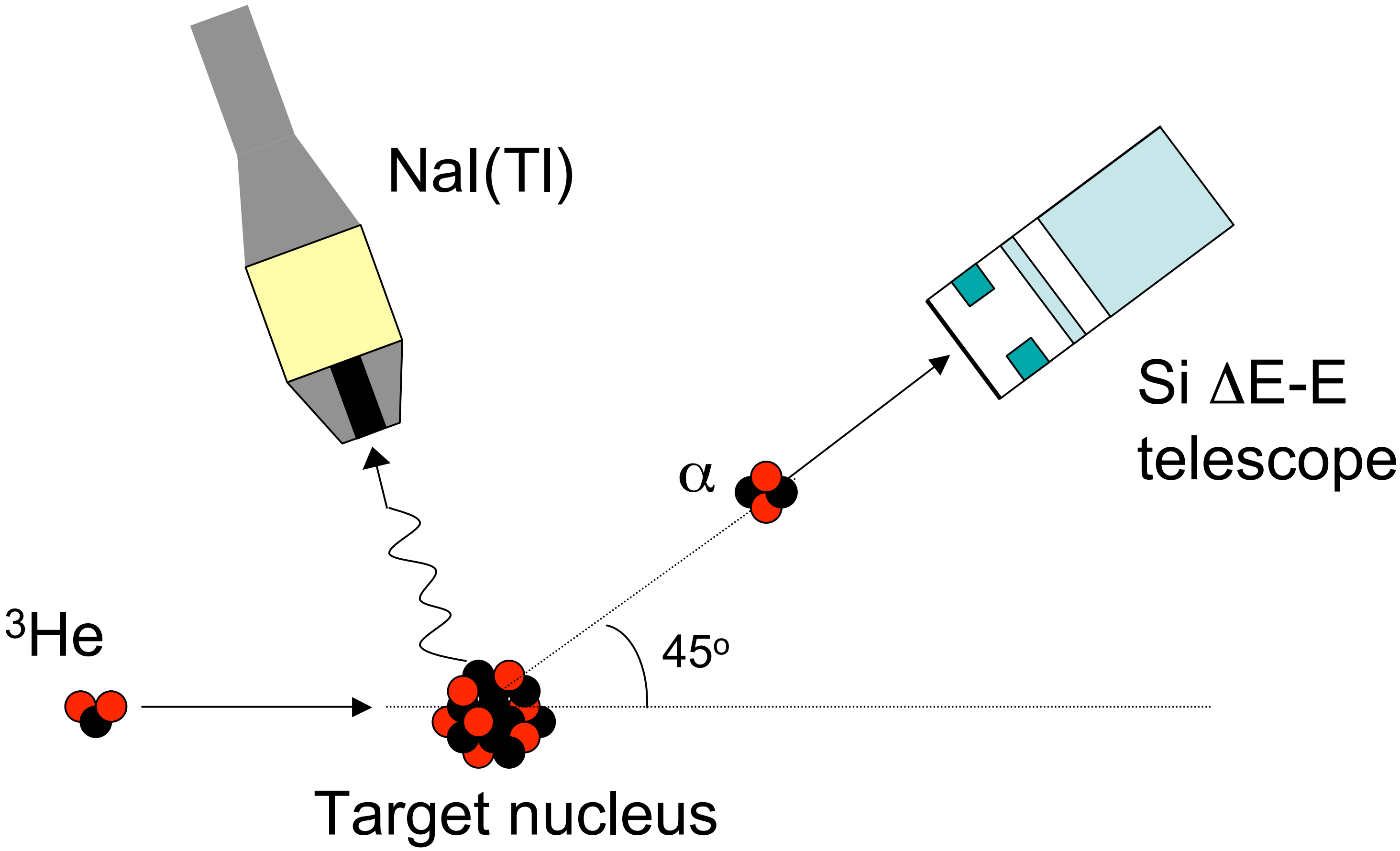
Shell Model of Nuclei

The Oslo Cyclotron Laboratory



- Targets: ^{45}Sc and ^{51}V
- Beam: ^{3}He ions @ 38 MeV (Sc) and 30 MeV (V)
- Reactions: inelastic scattering (^{3}He,^{3}He'γ), and pick-up (^{3}He,$\alpha\gamma$)
- Low spin and high intrinsic excitation energy
- CACTUS: 28 5"x5" NaI (~15% eff.)
- Eight ΔE-E Si particle telescopes

Particle-γ coincidences

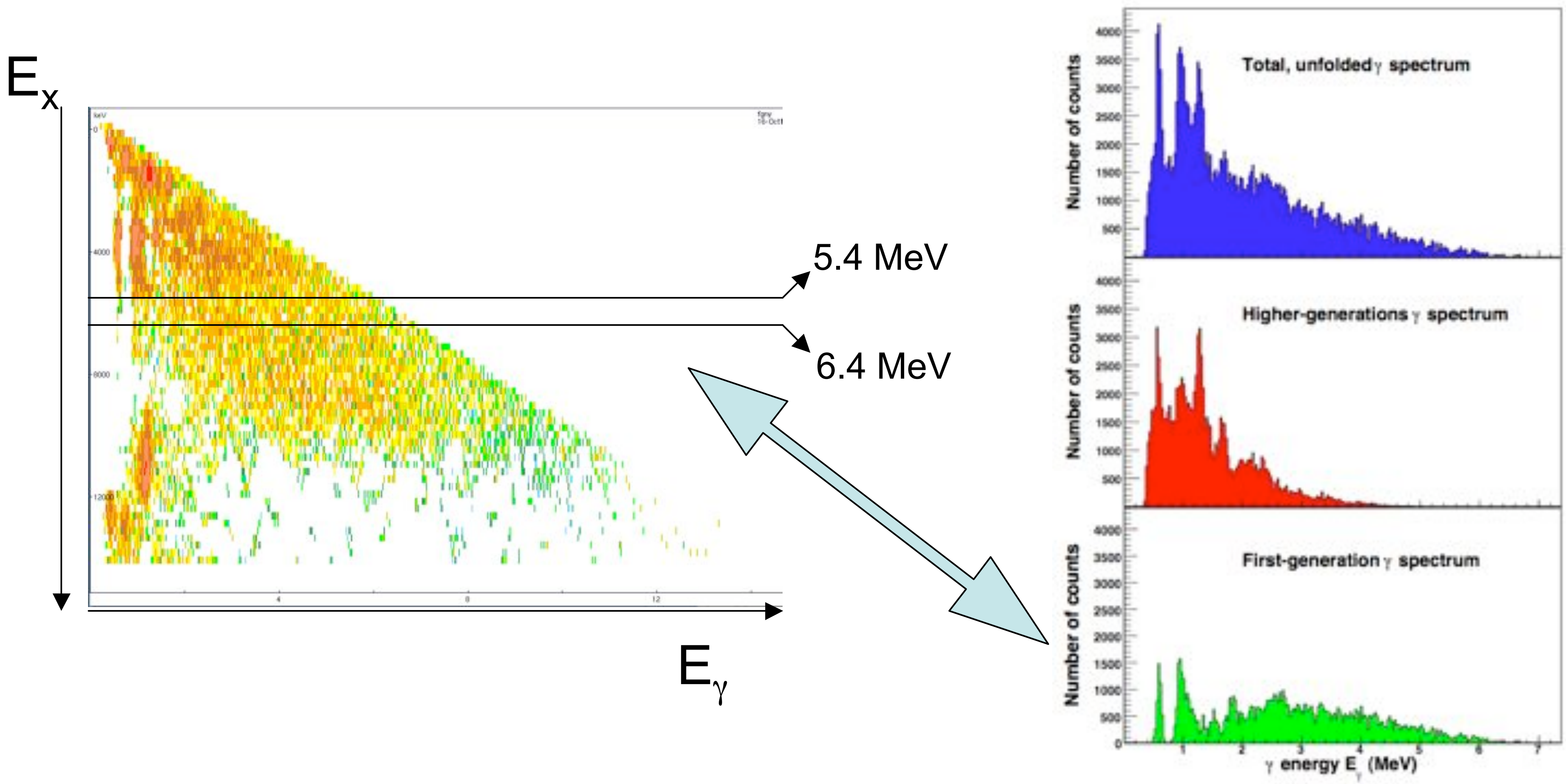


The Oslo method in a 

- Unfold γ spectra[1]
- Apply first-generation method[2]
- Ansatz[3]: f.g. matrix $\propto \rho(E_x - E_\gamma) \cdot \mathcal{T}(E_\gamma)$

[1] : M. Guttormsen et al., NIM A374 (1996) 371
[2] : M. Guttormsen et al., NIM A255 (1987) 518
[3] : A. Schiller et al., NIM A447 (2000) 498

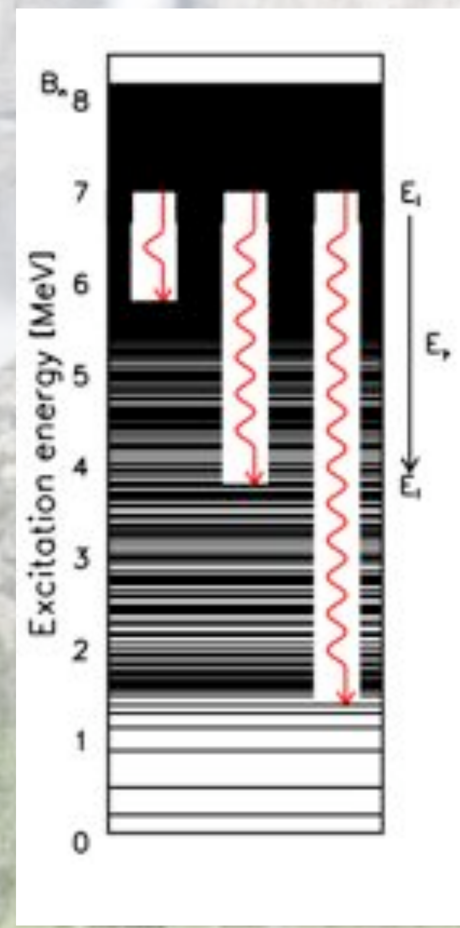
First-generation γ-ray spectrum, ^{45}Sc



Extraction of level density and γ-ray transmission coefficient

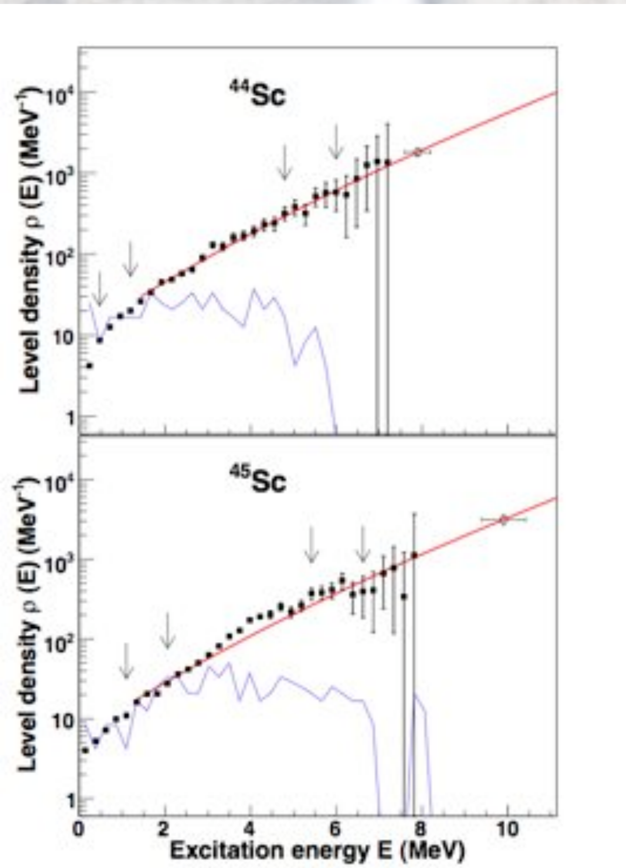
The primary γ-ray matrix $P(E_x,E_\gamma)$ is factorized according to

$$P(E_x,E_\gamma) \propto \rho(E_x-E_\gamma)\cdot\mathcal{T}(E_\gamma)$$



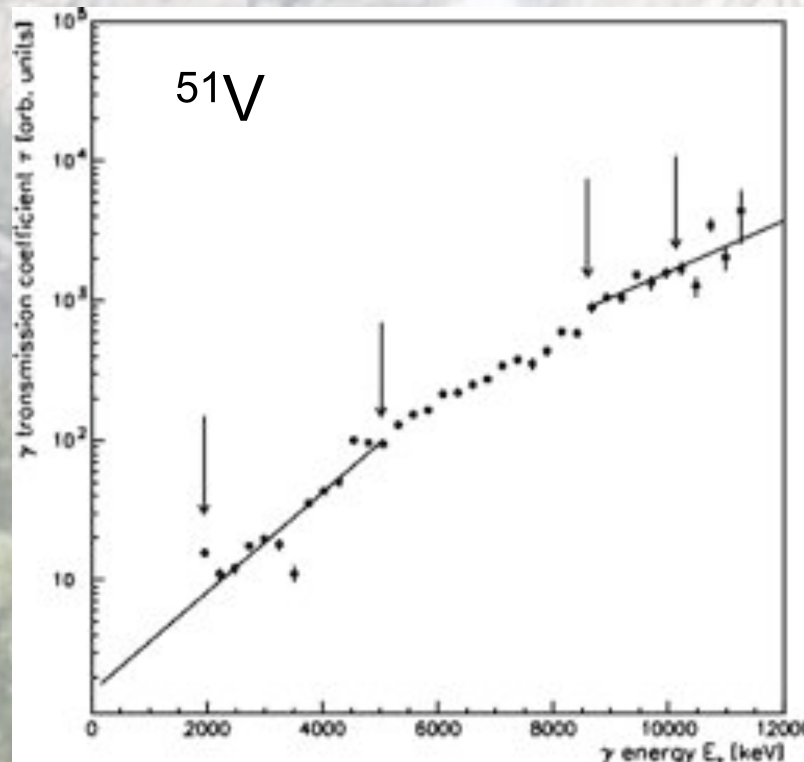
Normalization of level density

- At low E_x: known, discrete levels (blue line)
- At high E_x: data from neutron (proton) resonance experiments (open data point)
- Extrapolating with back-shifted Fermi gas level density

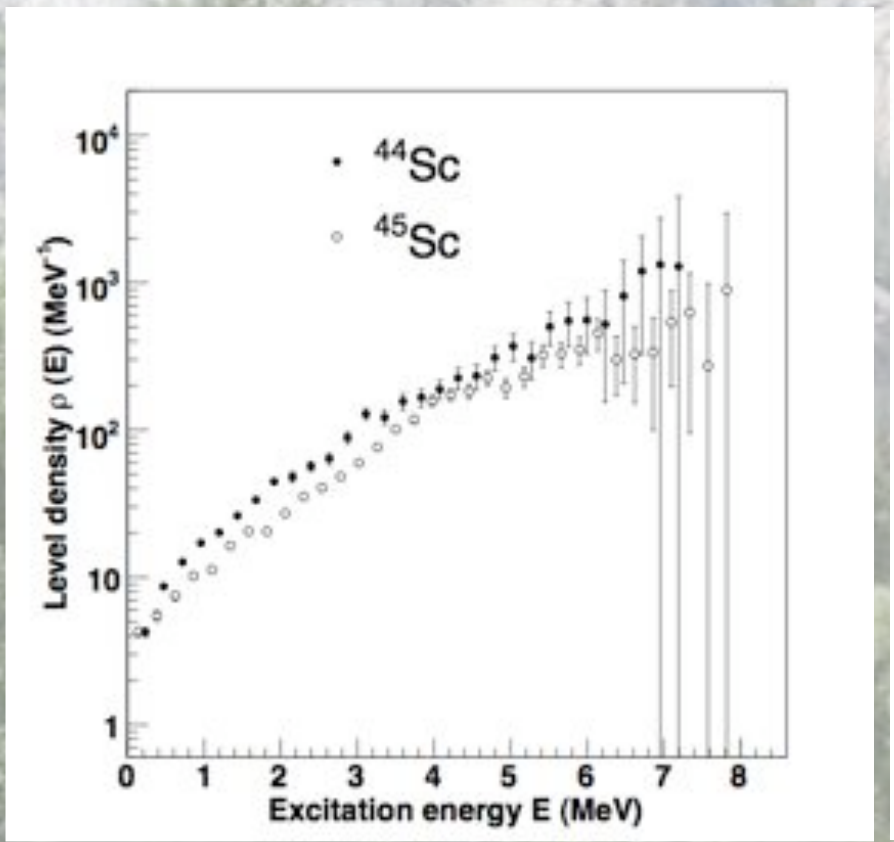


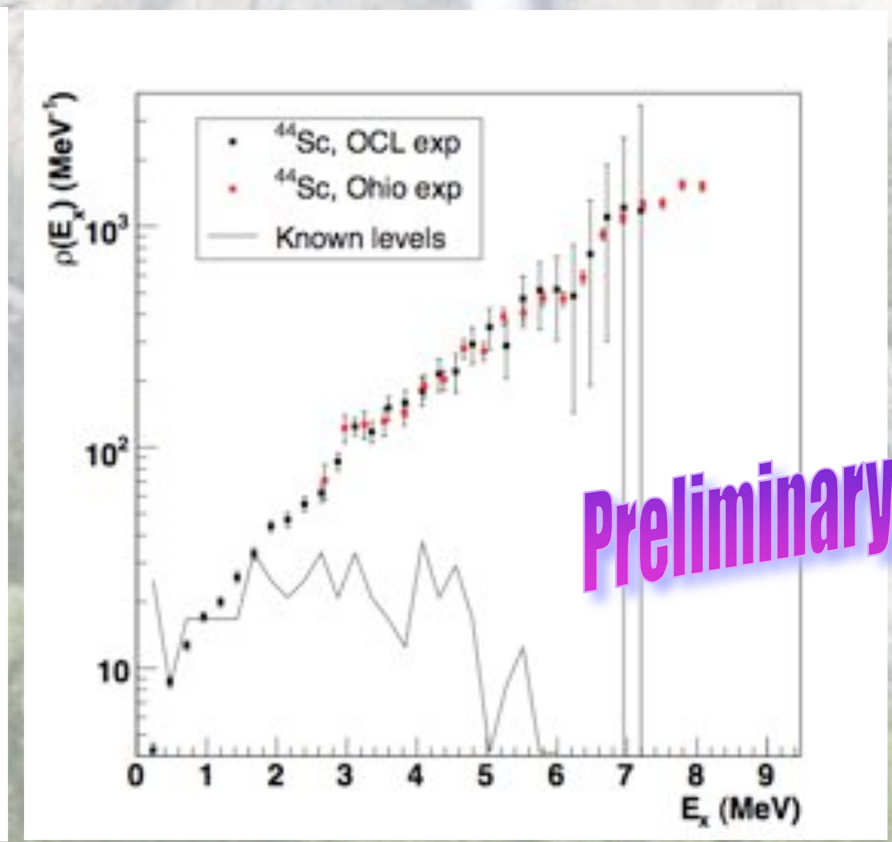
Normalizing the γ-ray transmission coefficient

- Utilizing data on the total, average radiative width at S_n
- Experimental γ-ray strengths for E1 and M1 radiation (RIPL-2, Kopecky)

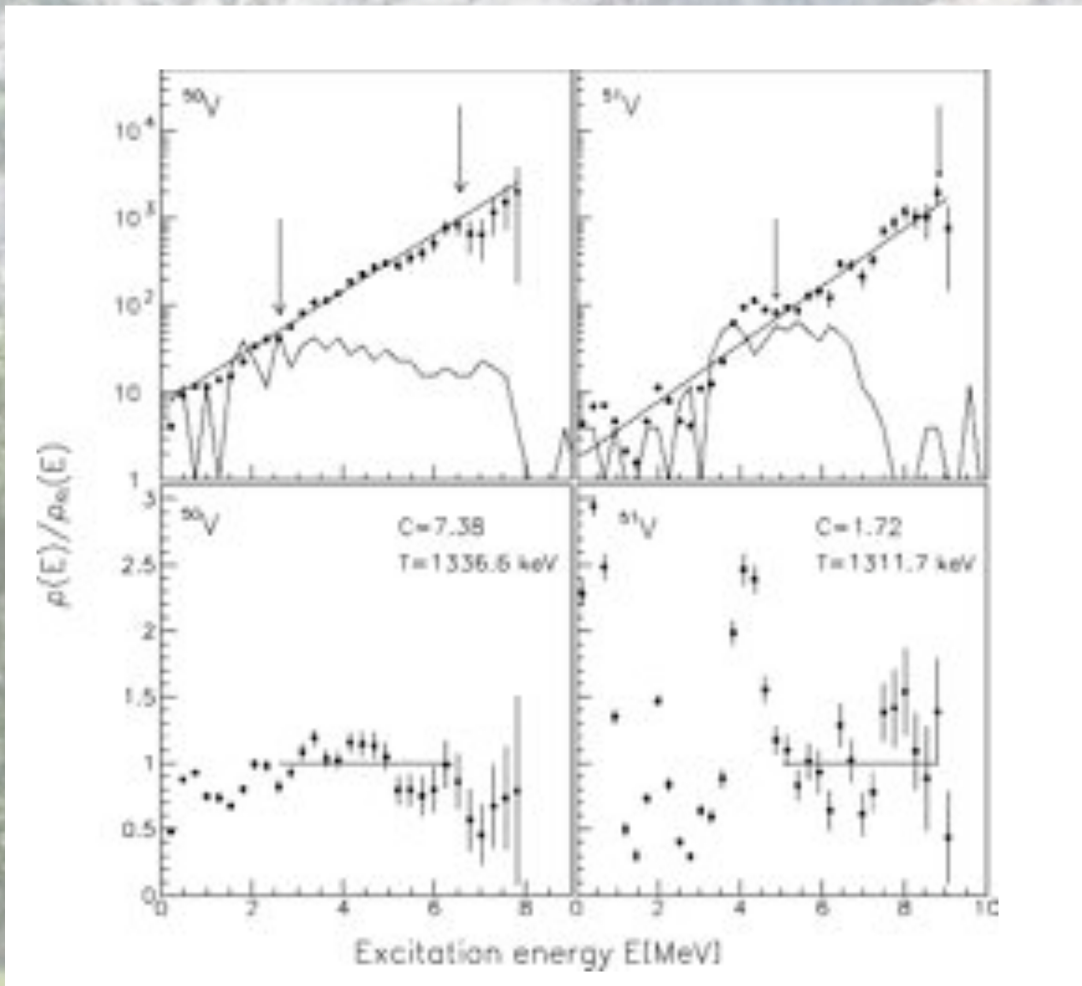


Level densities, $^{44,45}Sc$





Level densities, $^{50,51}V$

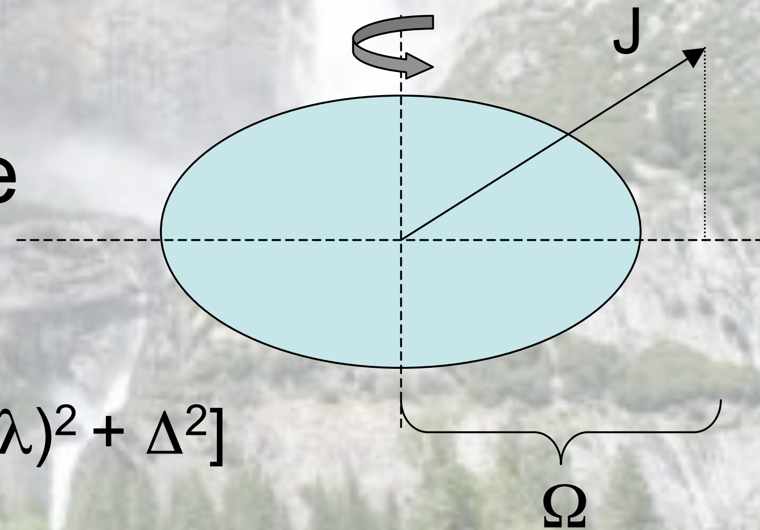


Constant temperature model:

$\rho_{fit} = C \cdot \exp(E_x/T)$

Combinatorial model to calculate level density

- Combining all possible proton and neutron configurations
- Nilsson energy scheme
- BCS quasiparticles



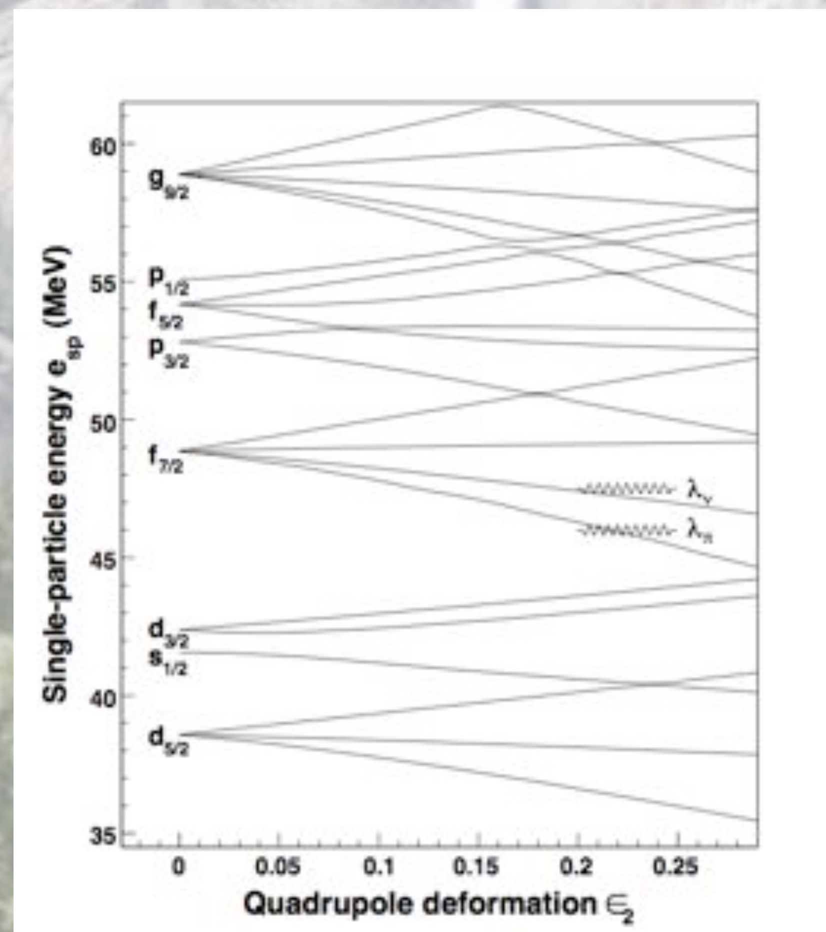
Single q.p energy: $e_{qp} = \sqrt{[(e_{sp} - \lambda)^2 + \Delta^2]}$

Total energy due to q.p. excitations:
$E_{qp}(\Omega_\pi,\Omega_\nu) = \sum[e_{qp}(\Omega_\pi') + e_{qp}(\Omega_\nu') + V(\Omega_\pi',\Omega_\nu')]$

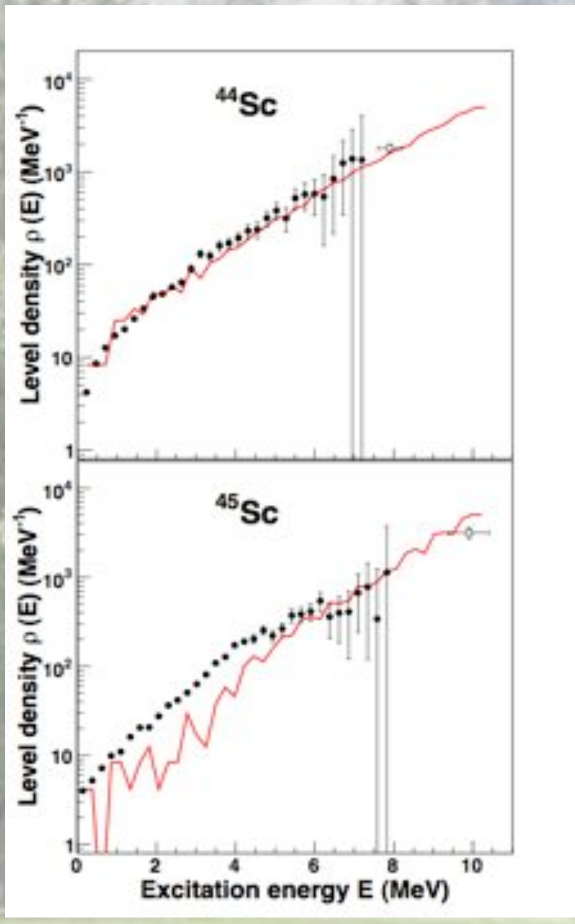
Nilsson levels, ^{45}Sc

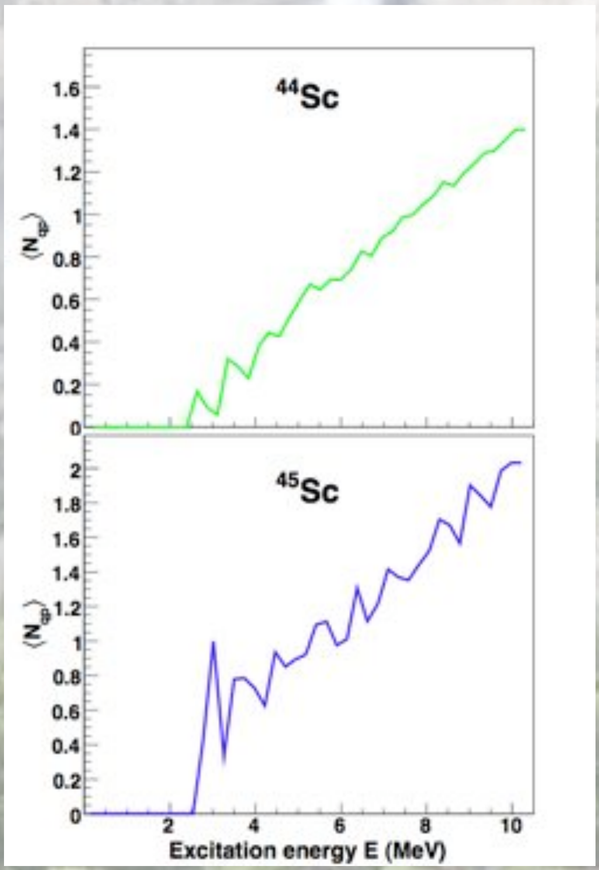
Model parameters:
κ = 0.066
μ = 0.32
[D.C.S. White *et al.*,
Nucl. Phys. A 260, 189 (1976)]

β= 0.23
[In agreement with
P. Bednarczyk *et al.*,
Phys. Lett. B 393, 285 (1997)]



Calculated level densities, average number of broken pairs





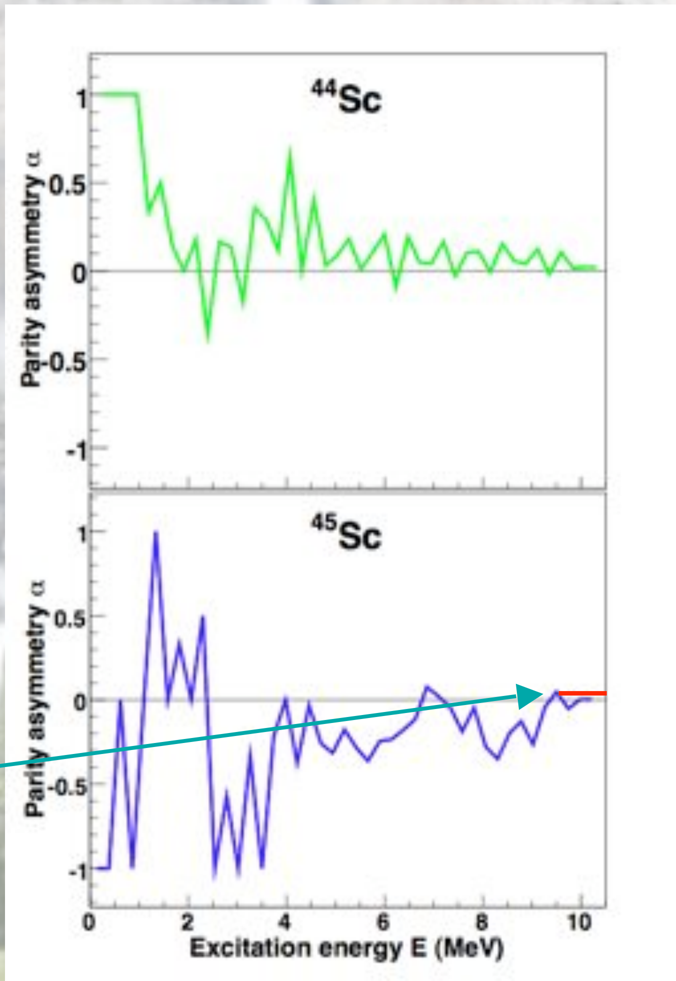
Parity asymmetry

Defining the parity asymmetry as

$$\alpha = (\rho_+ - \rho_-)/(\rho_+ + \rho_-)$$

[U. Agvaanluvsan, G.E. Mitchell, J.F. Shriner Jr., Phys. Rev. C 67, 064608 (2003)]

α~0.02
for ρ(J=1/2, J=3/2)
E_x=9.77-10.53 MeV



Gamma-ray strength functions

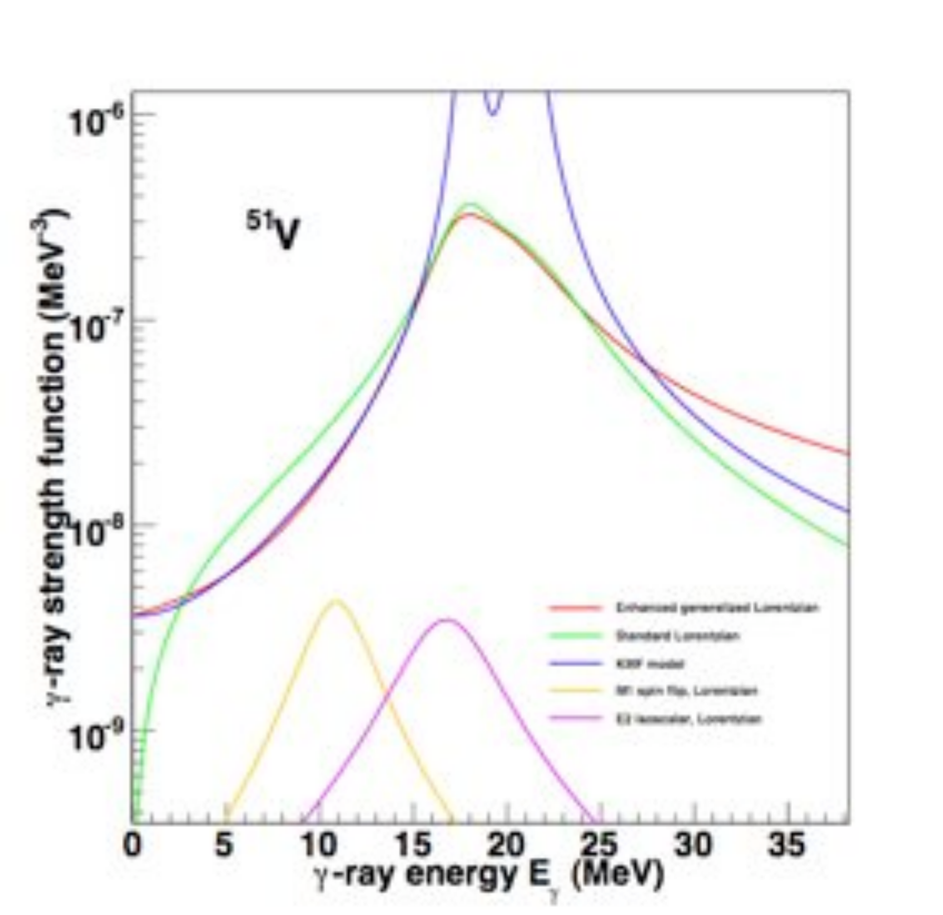
- Probability of decay
- Oslo measurements: below neutron threshold

$\mathcal{T}_{XL}(E_\gamma) = 2\pi\, E_\gamma^{2L+1} f_{XL}$

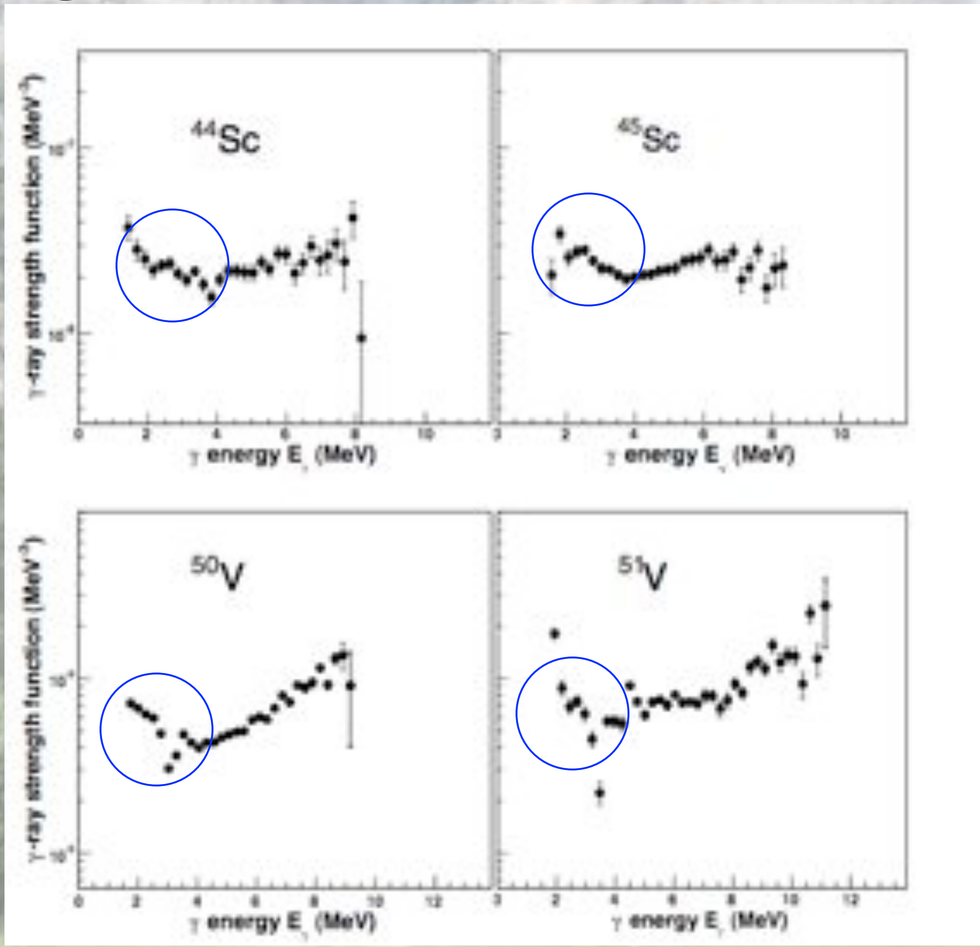
$f_{XL}(E_\gamma) = E_\gamma^{-(2L+1)} \langle \Gamma_{XL}(E_\gamma) \rangle / D$

Assuming only dipole radiation:

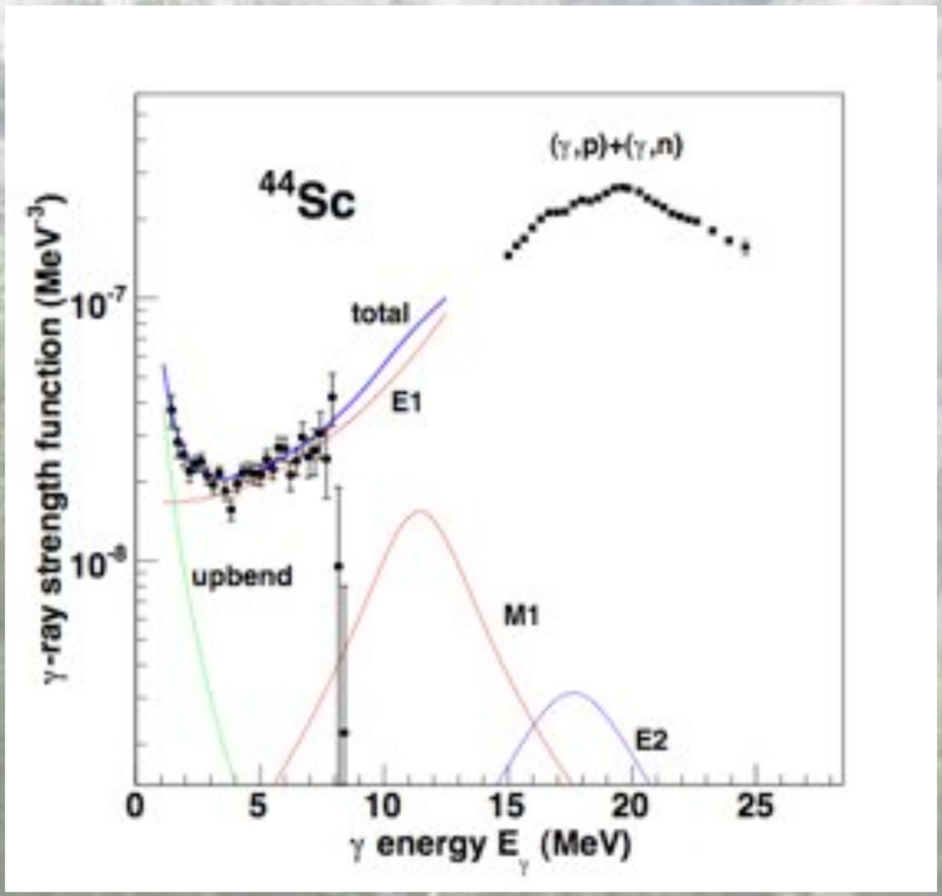
$f(E_\gamma) \approx \mathcal{T}(E_\gamma) / 2\pi E_\gamma^3$

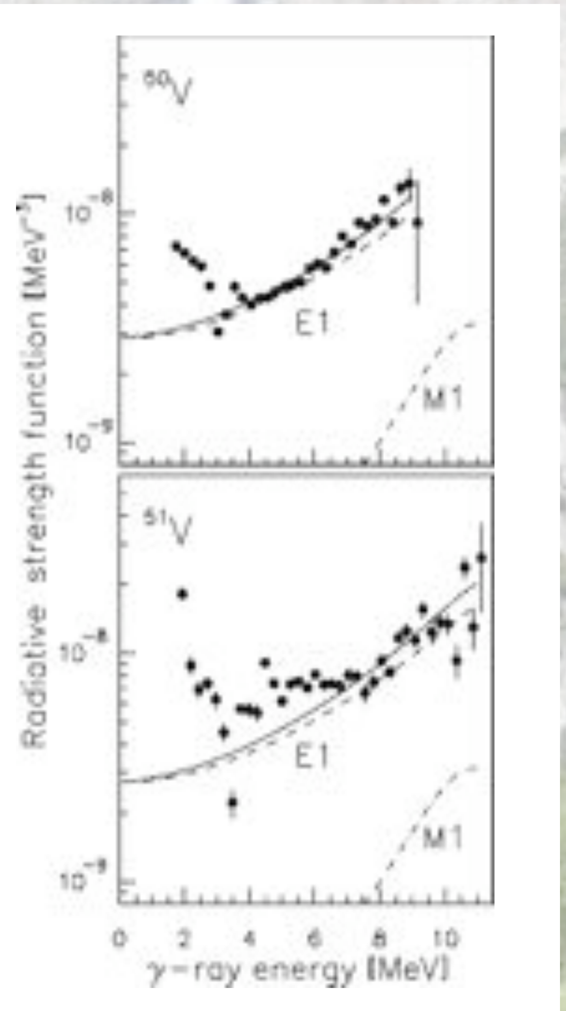


Experimental γ-ray strength functions, Sc and V



Compared with theory and (γ,n/p)





Summary & outlook

- Extraction of ρ and $\mathcal{T}$ from first-generation γ spectra
- Level densities of Sc and V
- New model to calculate ρ, $\langle N_{qp} \rangle$, α
- Gamma-ray strength functions of Sc and V: enhancement ~2-3 times KMF
- Future projects - new detectors

Collaborators

- Oslo: M. Guttormsen, F. Ingebretsen, S. Messelt, J. Rekstad, S. Siem and N.U.H. Syed
- North Carolina State University: R. Chankova
- Åbo Akademi: T. Lönnroth
- Ohio University: A. Schiller and A. Voinov

THANK YOU!