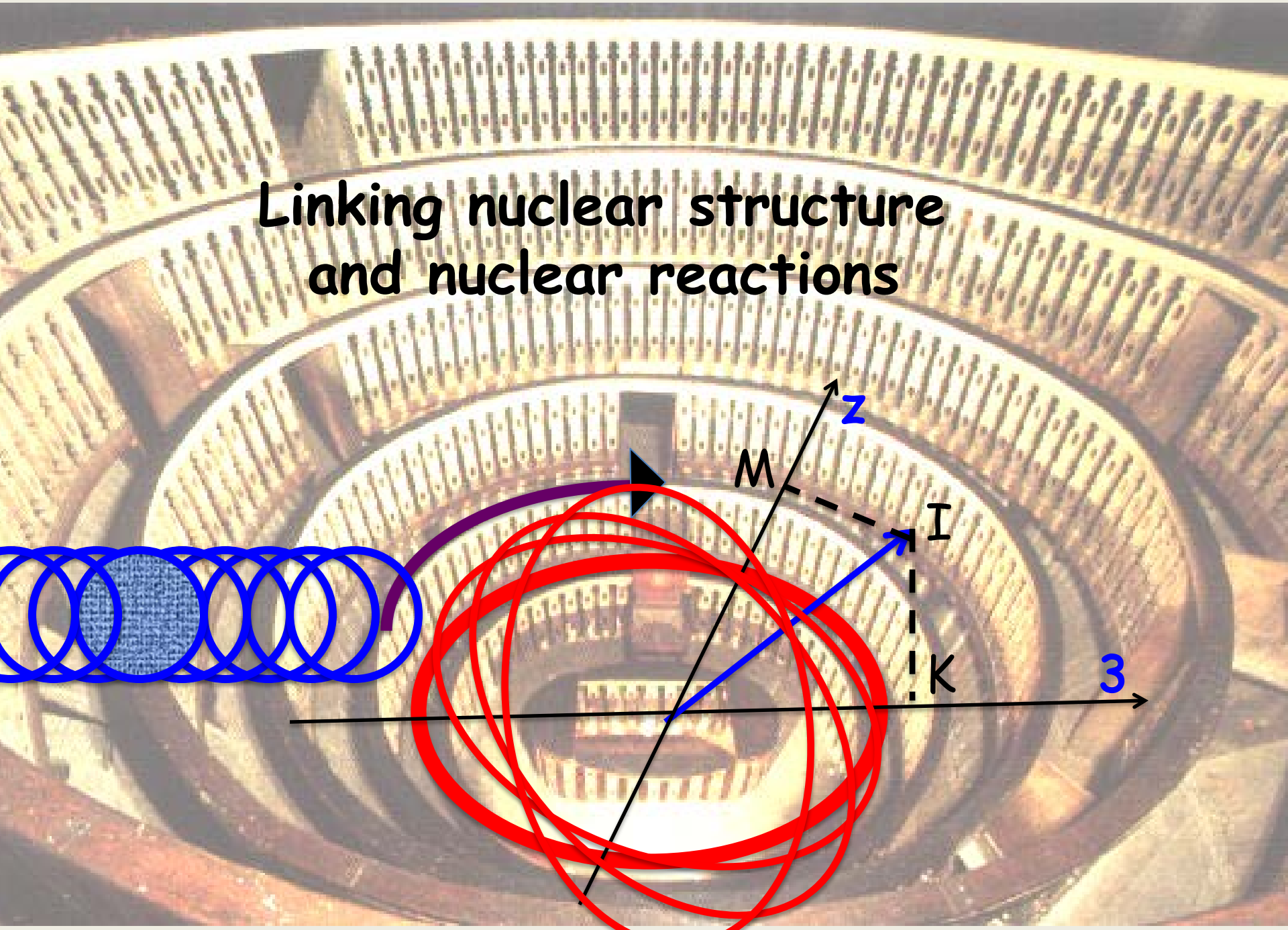
Linking nuclear structure and nuclear reactions



Nuclear structure (in my view):
static and dynamical properties of nuclear many-body systems (medium and heavy nuclei) in the low-energy sector (till some dozens of MeV)

Obs: the constituents bodies are the nucleons (the sub-nucleon structure entering only via effective two-body or higher order interactions among the nucleons) and the
key point is to describe properly the effect of the many-body correlations

Due to the large (but not infinite) number of nucleons (and degrees of freedom) a large variety of models (or approximations) have been advanced to reduce the complexity of the many-body problem to a more tractable form, each selecting a number of relevant degrees of freedom.

Popular models are:
large-scale shell models
mean-field models (e.g. EDF) and beyond
algebraic/geometrical models
cluster models

OBS: Need to smoothly merge into the ab-initio approaches

Although they may look (or really be) rather different (and somewhat orthogonal) they all attempt to describe the same physics (with larger or smaller success), focusing on definite degrees of freedom:

✓ interplay of single-particle and residual many-body aspects
✓ collective features (from long-range and short-range residual interactions) in different channels
✓ high-lying collective states (giant resonances)
✓ clustering phenomena
✓ shape-coexistence
✓ phase transitions

and outside the stability valley
✓ halo and skin effects
✓ shell evolution
✓ islands of inversion
✓ new collective states

The large variety of nuclear models is partly a consequence of the large variety of facets (and corresponding observables) characterizing the nuclear many-body wave functions, often changing wildly state by state within the same nucleus. The list of observables is rather long: masses, excitation energies, spins, EM transitions and moments, one-, two- and many-particle spectroscopic factors etc. Each nuclear model necessarily is particularly sensitive to specific observables.

OBS As a trivial example, two-particle spectroscopic factors are very sensitive to the level of sophistication in which the pairing interaction is implemented in each specific model

And here comes the essential and fundamental role of nuclear reactions.
Each specific feature of the nuclear wave functions is better (or sometimes exclusively) tested by a specific process.
Direct reactions, in particular, offer a large variety of projectiles and bombarding energies and the scattering conditions can be tuned to probe selected parts of the ion-ion interactions and of the nuclear wave functions. They are therefore able to investigate the response of the system to different operators and so to single out specific aspects of the many-body scenario (e.g. one-particle transfer for the mean-field, two-particle transfer for pairing correlations, Coulomb excitation for collective states and giant resonances, charge-exchange for spin-isospin modes, etc),
In particular direct nuclear reactions have been fundamental to discover and investigate novel features (haloes, skins, shell evolutions, new collective modes, etc) in exotic nuclei

OBS The large variety of reactions and the need for exclusive measurements implies
the development of different beams and different detectors (charge-particle spectrometers, neutron detectors, gamma detectors, etc)

However, to make efficient the link between the reactions and the structure, it is essential that the reaction mechanism is rather simple (as it is in fact in the direct reactions) but, in addition and more important, well understood. And here becomes important the role of the theoretical description of the reactions and the development of proper reaction models. Also for the reactions it is the domain not of exact solutions but of models, since it is necessary to introduce a number of simplifying assumptions to reduce the scattering many-body problem to a tractable form. Need for consistent treatment of both reaction and structure.

The talks in this section are therefore only apparently belonging to either nuclear structure or nuclear reactions. They may look with a favorite eye to one or another aspect, but they in fact all aim to the same target, the relevant properties of the nuclear many-body systems.