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Resonance states and branching ratios from a time-dependent perspective.

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The spectrum of a given Hermitian quantum mechanical system can be generally separated into a discrete part containing the bound states and a continuous part of scattering states above the threshold. These states are solutions to the time-independent Schrödinger equation (TISE) with the corresponding boundary conditions. The discrete nature of the bound spectrum enables the characterization of the stable part of the studied system along with its physical properties based on its energy levels. The continuum can be used to characterize the system by probing it through scattering experiments. In this context instead of discrete energy levels the discussion is usually shifted to resonances in the scattering profile of the studied system. These appear as sharp features in the energy profile of the interaction.

Wavepacket dynamics in the continuum of meta-stable open quantum systems reveals that in the interaction region the evolution resembles that of bound states. There is, however, one difference where a bound system preserves probability in a meta-stable one when we observe decay in time. When the decay from the interaction region tends to follow an exponential form then the energy content of the localized part of the wavepacket assumes a constant value. This value is complex where the real part represents the energy of a resonance of the system and the imaginary part is related to the width of this resonance. The dynamics outside the interaction region exhibit a spatial exponential increase which drops off at the edge of the escaping wavefront. The velocity of the escaping part of the wavepacket has the momentum corresponding to the average energy inside. Similar dynamics is observed when scattering a wavepacket off a potential at a resonant energy. Initially the arriving wavepacket populates a resonant bound-like state inside the interaction region and consequently the formed meta-stable state decays.

The time-dependent dynamics observed in meta-stable systems demonstrates the properties of both stationary bound and scattering states. This type of dynamics usually occurs due to either the shape of the potential of interaction where the variation can lead to confinement of finite time or due the coupling of a bound state in an closed channel with the continuum of an open channel. The first type of states is often termed shape-type resonance whereas the second type is usually called Feshbach-type resonances. The above discussion suggests that the essence of the dynamics can be captured by solving a time independent equation with appropriate boundary conditions. Such boundary conditions allow only outgoing flux. Solving the TISE with outgoing boundary conditions leads to solutions with complex momentum. This makes the energies of these states complex just as the portrayed dynamics and it also displays the asymptotic divergence which was observed.

In order to be able to calculate the energies of the resonance states one needs to be able to fix the asymptotic divergence. This can be achieved in various ways which all lead to a non-Hermitian Hamiltonian. Some of the techniques used are: (1) scaling of the coordinate by a complex factor (complex scaling); (2) addition of a complex absorbing potential at the asymptotes far from the interaction region; (3) Feshabch projection formalism which separates between the spaces of localized and scattering states; (4) Siegert pseudo states which satisfy the required boundary condition on a given surface but lead to a quadratic eiegnvalue problem.

The use of Non-Hermitian Hamiltonians readily yields the information regarding the lifetime of a given meta-stable state in addition to its energy. On the other hand, it leads to some complications due the non-Hermiticity. First of all, the resonance states are not orthogonal with respect to the conventional scalar Dirac product. Instead one needs to find and additional set of states which are orthogonal to them. These are the eigenstates of the Hermitian conjugate Hamiltonian which physically are their time-reversed counterparts. The two bi-orthogonal states form together the resolution of the identity. Another aspect is the loss of the probabilistic interpretation due to the non-Hermiticty. This can be amended by redefining the inner product based on the bi-orthogonal set of states. By doing so the probabilistic interpretation is retained along with the non-unitary evolution resulting from the decay of the system. This allows to describe very complicated dynamics in the continuum based on dynamics of several resonance states alone.

In decaying few-body systems there are often several channels open to decay. In such case the decay rate of the resonance contains contributions due to the flux in each of the open channels. When considering the above mentioned outgoing boundary conditions one finds that the momentum of the outgoing flux in each channel depends on the resonance energy and the threshold energy of the given channel. When following the wavepacket dynamics in such systems one observes that at every channel the wavepacket leaks at the velocity given by the momentum in that channel. Consequently all the information regarding the partial widths to the different channels and their branching ratios can be extracted from the stationary resonance wavefunction. All that is needed in order to evaluate the branching ratios is the complex amplitude of the resonance wavefunction at the asymptotes and the momentum at every given channel which is obtained from the difference between the resonance energy and the channel's threshold energy.

References

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Povzetki v slovenščini

Resonance in njihova razvejitvena razmerja iz perspektive časovnega razvoj

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Časovni razvoj metastabilnih stanj kaže značinosti vezanih stanj in sipanih stanj. Dinamiko teh stanj lahko opišemo s kompleksno energijo, ki ponazarja lego in širino resonance. Opisani in pojasneni so razni pristopi k temu problemu.

Lastnosti nukleona v snovi, v modelu z mezoni π, ρ in ω

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Poročamo o svežih raziskavah transverzalne gostote naboja in energije/gibalne količine pri nukleonu v jedrski snovi, osnovanih na solitonskem modelu $\pi-\rho-\omega$, prilagojenem za sistem v snovi. Rezultati nam pomagajo ugotoviti splošne lastosti takšne prilagoditve zgradbe nukleonov, vezanih v jedrsko snov. Na kratko predstavimo rezultate za transverzalno gostoto naboja in energije/gibalne količine.

ηMAID-2015: posodobitev z novimi podatki in novimi resonancami

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Predstavimo sveže podatke o fotoprodukciji η in η' na protonih, ki jih je izmerila Kolaboracija A2 na pospeševalniku MAMI. Celotni presek za fotoprodukcijo η kaže ost pri energiji praga za η'. Analizirali smo nove podatke in stare podatke (od kolaboracij GRAAL, CBELSA/TAPS in CLAS) z razvojem po pridruženih Legendreovih polinomih. Za reproduciranje novih podatkov smo uporabili izobarni model ηMAID, posodobljen s kanalom η' in novimi resonancami. Nova verzija, η MAID-2015, razmeroma dobro opiše podatke, pridobljene s fotonskimi žarki z energijami do 3.7 GeV.