Nuclear Physics Fundamentals and Application
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Lecture - 15
Low Energy n-p Scattering

This Scattering of neutron and proton and this scattering experiment geometry I had told scattering cross section I have told, scattering cross section, which have units of area that contains the information about the interaction between those particles, which are inter active. And in central forces scattering you generally describe things in terms of phase shifts in partial waves and this, phase shifts are related to this scattering cross section.

So, scattering cross sections are measured experimentally and then from the model that you develop theory that you develop, you also calculate it and test whether it is very is correct or not or it needs modification. So, we were looking at the same potential, that produced right kind of biding energy of neutron that is 36 MeV deep square will potential 2.1 centimetre wide to this potential, if we think that this is the inter action potential what kind of scattering cross section it should give.

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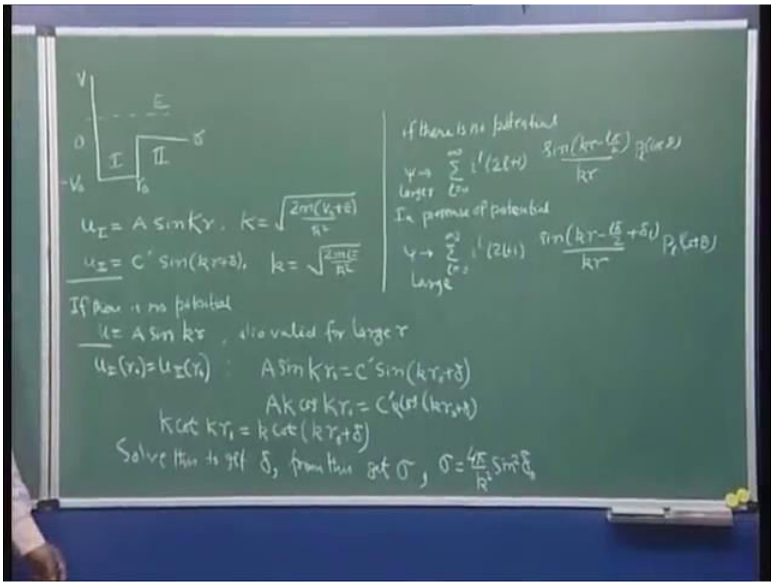

So, we were the writing the equations, scudding equations for that potential we have 2 region, region 1 and region 2 and energy some were here, this is v is here and r here this is r naught this point is r naught and then this is v equal to 0 and this v equally to minis v naught and from there we do not have an equation. And we found that in the first part the u function should be of this kind A sin capital K r were, capital K was square root of 2 m v nought plus e over x crosses h square. And this second reason, it was the type some c prim and then sin k r plus delta, were this is small k were square root of 2 m e over x crosses h square.

So, both are oscillating functions because in region 1 as well as reason 2 energy is more than this potential. So, u have in classical language, you have positive kinetic energy here as well as positive kinetic energy here. So, then the uni function is sin cosine the oscillating functions. If the energy less than the potential energy, that mean classical kinetic energy that were will become negative then you have exponential decay function it will because minis gamma, so on.

Now, this delta is same as the phase shift we were talking of was this were written as just 2 constants in this region the r equal to 0 is not contain. So, you can have both sin in cosine terms and that c sin k r plus 3 cross k r we just rotate like this, this are 2 constants, 2 are between constant is this delta same as the phase shift. So, how did we defined the phase shift if you remember. If there is no potential then we note that way function and the way function which just was e to the power of i k z was summation our what was that l 0 to infinite i l 2 l plus 1 sign k r minis l pi by 2 divided by k r and p l cos theta.

And when the potential was there in presence of potential, there are we introduced that phase shift. So, in the sign term you have an extra delta plus delta l and this is for large r this is for large r and this is for large r. So, at large value of r you compare the way function that would originate if there is no potential and when there is potential and then you find in each of this sign terms you have is delta l coming here. In our case we are only dealing with l equal to 0 to low energy in phase scattering. So, that only l equal to 0 is affective.

So, one phase shift is here, So, here if I see if there is no potential this potential is not there, then you do not have region 1 and region 2 we have only one region, why there is no boundary. So, this all v equal to 0 h from begging to end it is v equal to 0. So, in that case this is energy in that case this function u will be some constant times sign of which are capital K r or small k r, in that it become of the same whether you could call it capital

K r or small k r if there is no potential v nought is 0 this line is flat starting from 0. So, there is no v nought.

And therefore, this capital K will be same as this small k, but am using small k symbols because I am interested in large r and it large r I have use small k here. If there is no potential then u is A sin k r the real part is of off course u r divided by A r. So, that divided by r term will come this is way function, and way function pi and a function of r if we write it is u divided by r. So, this divided by r is also coming when you write the way function this is u function only, and of course p l cos theta l is because l equal to 0 and all those things.

So, if there is no potential this A sin k r and this is valid for all r therefore, also valid for right were as one if you put an potential for large r this u 2 is effective not u 1, u 1 is for r less than r nought. So, for large values of r, I have to look at this the way function becomes, some constant times sign here plus delta. So, you can see this delta is same as that delta, compare the situation when there is no potential and when there is potential.

When there is no potential and when there is an potential and then look at this sign term here that extra is this the phase shift at that exactly is the case here for large r when these is no potential it is this and when there is potential it is this and yes there is an extra delta there is this extra delta is the phase shift, see if we calculate this delta we can get the cross section using the equation between delta l and cross section. So, that is it. So, to get that delta you match the way functions and the slopes.

So, u 1 at r nought should be equal to u to at r nought the function as to be continues everywhere and therefore, A sin capital K r nought should be equal to c prim sign small k r nought plus delta. And slopes are continues d u d r is continues. So, A capital K cos capital K r nought should be equal to c prim cos this k will come out, small k here then cos k r nought plus delta. And when you divided you get capital K cot capital K r nought is equal to small k cot small k r nought plus delta.

Now, in this equation what is the unknown quantities and what are the unknown quantities is look at the capital K, capital K is here mass reduce to mass of protons, neutrons system known at crosses square known v nought known 63 m v e known the energy I am sending this particle. So, that is under our control the particles are that begin with sent. So, we have to look at that with kinetic energy you have given. So, from there you get this e this capital K is known r nought 2.1 centimetre small k once again 2 m e x crosses that. So, known r nought known, so this is single unknown delta here solve this equation to get delta.

Solve this to get delta and once you get delta from that get cross section sigma at 1 by k square, remember that for l equal to 0 it simple 4 pi over k square sin square delta nought. If only l equal to 0 is contributing you do not have an summation over different l than the equation is very simple 4 pi by k square and m square delta nought, once you get delta from this equation with it same as delta nought phase shift now, you gets sigma.

Similarly, if you have any given potential attractive potential here you can make proper calculations and get that cross sections.

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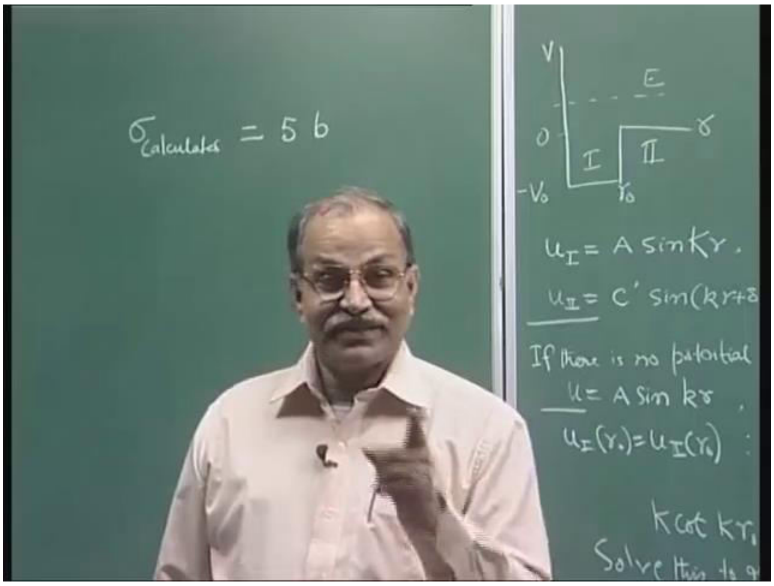

For this particular potential then we do the calculation what you find is that the sigma calculated using this potential remember depends if change the potential sigma will be different. Using this potential which gives me the right kind of binding energy for neutron using this potential, this is distances is to be around 5 bands alright 5 around 5 bands, even if you change this potential, because the different binding energy can also be gotten it not unique potential which will give the binding energy.

This potential gives that binding energy, but then you can always play with widths and depth and shape also I have taken square will shape, you can take some other shape attractive potential. So, you can play with it. So, you can change the potential and still get that minis 2.225 m v v, but the value of sigma will not change much, if we will see some were around 5 band, 4 band, 2 bands, 3 bands depends on what potential we have taken it.

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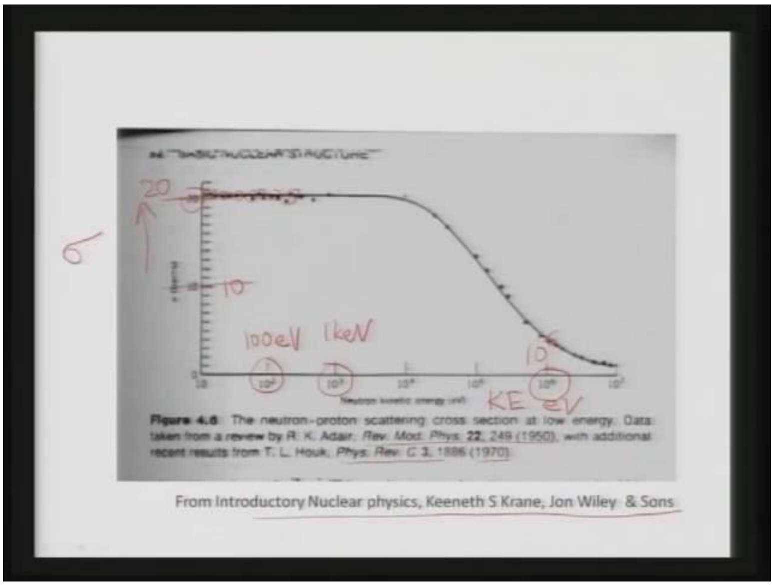

Now I will show the experimental results, nothing it is from that to book of this kind crane and look at your screens and I will show you this y axis's here it is sigma, this y axis's is sigma in bands and this point is 10, this point if you can read on this screen and this point here is 20, this is written here 20, this is written here 20, this is 20 band, this is 10 band and this is 0.

And this is neutron kinetic energy. This side is kinetic energy in electron works, this is 10 to the power 6, this point is 10 to the power of 6. So, 1 m v e here, this is 10 to the power of 3. So, 1 k e v here this is 100 e v here. So, this are the scales and then you can see the points are here, low energy look at low energy we are interested in low energy. So, that only in delta this l equal to 0 is operator at low energy the experimentally measured value is around 20 bands.

This is the data I have taken it from this book introductory to nuclear physics kenneth k s krane and they have taken this data from this papers the view of modern physics 22 1950 and additional results physics rev c 1970. So, let us discuss why the experimental value it. So, different from the calculated values, what is your guess why it is, so different we know that this potential is not the accurate you have other contribution the essential potential, the initial part of the potential all those things are there, but still is not that bad the potential is not that bad the variation could be say 10 percent, 20 percent, 50 percent, but there here is 400 percent.

So, what gross thing we are missing, we are missing something very big in our calculations and in our treatment. And that gross thing is that this potential that we have taken from deuteron bound state studies and deuteron bound states corresponds to capital S equal to 1, why in deuteron bound state capital S is always 1 is not 0.

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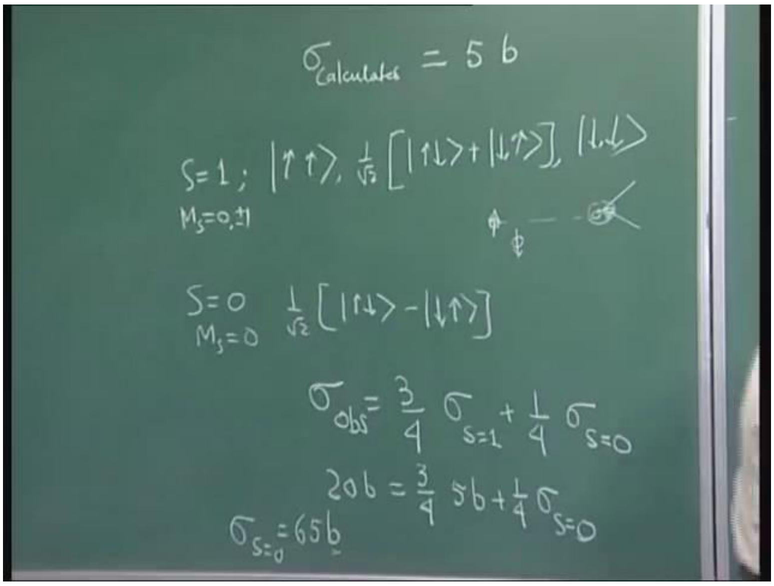

Were as, in our scattering geometry were is not bound the 2 particles are coming close and then here, there are not bound to each other they are getting scattered. So, the bound state is not formed, scattering is state is found were there are scattering from each other. So, if the bound state is not found then depending on with what spin orientation it is coming 1 neutron is coming with this spin orientation another will come with this spin orientation and so on you are sending a bean of neutrons.

So, different neutrons are having different orientations, than in this target we have protons, this protons will also have you do not have just 1 proton in this target we have protons on this which proton bean is coming. So, these protons will also have different spin orientations. So, in that bean some neutron is going close to this proton to some other neutron is going to close this proton and so on.

So, you have different kinds of spin orientations and therefore, when the spins couples they can couple to the s equal to 0, why is only the bound state that the conform that s deuteron capital S has to be 1 because the angular measure and angular moment term is capital equal to capital I equal to 1 and all to those things directive positive from there. But, in this scattering geometry were the neutrons, protons are inter acting through this nuclear forces but not producing the bounding state.

Then depending on initial spin orientation of the 2 particles they can combined s equal to 1, they can combined to s equal to 0. And that statistical probability factor will be operated capital S equal to 1 as 3 states remember, were capital S equal to 0 as only one in state capital S is equal to 1 as 3 states this M s equal to 0 and plus minis 1. So, spin up spin up then you have 1 by square root of 2 up down plus down up and then down, down.

Here, 3 possible orientations possible, 3 possible combinations are there were as if s equal to 0 we have only 1 possible combination this is 0 and that is 1 by root 2 up down minis down up. So, everything is random then 75 percent times you will end up with capital S equal to 1 and 25 percent times we will end up with capital S equal to 0. So, our calculation gives us cross section from only those events in which capital S is equal to 1 was formed. And the events in which capital S equal to 0 was formed that is not covered here.

So, the observe cross sections that I have observed in experiment that is taking contribution from both s equal to 0 and s equal to 1, that should be the sigma observed should be 3 is 2 1. So, 3 by 4 times sigma which should come from capital S equal to 1 and 1 4'th it become 75 percent 25 percent sigma s equal to 0. Now, I can estimate how much is sigma s equal to 0, the sigma observing is 20 bands and sigma for s equal to 1 lets believe this 10 20 percent this side that side, but use of this type.

So, 5 bands and plus 1 by 4 sigma s equal to 0. So, how much is sigma s equal to 0 from this 65 bands very, very different with capital S equal to 1 were are getting something like 5 bands with capital S equal to 0 65 bands. So, the nuclear forces are highly spine dependent, this is scattering of this particles neutron protons is very different if it is governed by that s equal to 0 potential, then when it is governed by s equal to 1 potential s equal to 1 potential is different and s equal to 0 potential is different and widely different.

So, that the cross sections are much different. So, now let me do something else this was for low energy scattering when you go for little bit higher energy scattering you see some different results. Let me show you another figure from kranes works and then we will discuss that, look at your screens.

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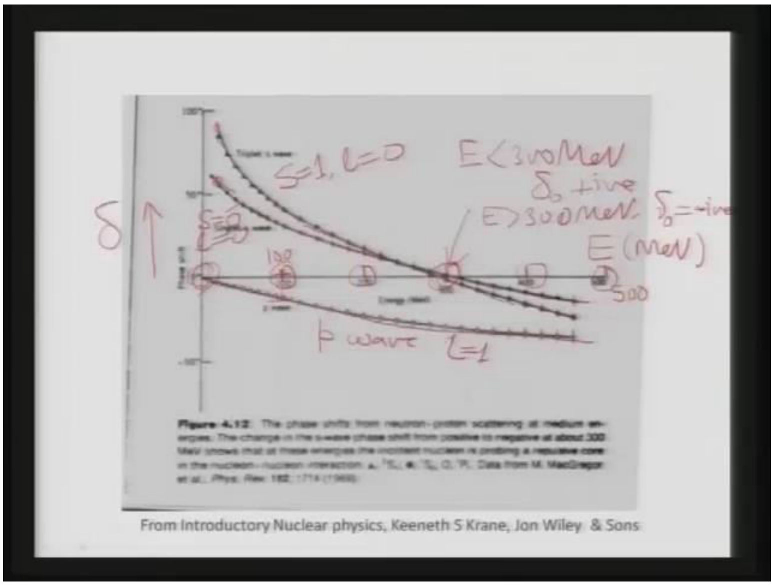

Now, this diagram that your seeing here, the experiments are then at different energy and higher energies, few 100 MeV is up to few 100 MeV is scattering experiments. And the phase shifts are plotted here. So, on the y axis's here, phase shifts delta and on the x axis's you have energy in MeV is and this point is 100 MeV, this point is 100 MeV, this point is 200, this point is 300, this point is 400, and this point is 500 MeV. So, this is scale if you are not able to see it clearly and this the scale.

Now, phase shifts there are 3 diagrams given, 1 is this and this is for singlet s wave it is called singlet s wave; that means, capital S equal to 0. And the other one here is triplet s wave. So, s equal to 1 and s wave means l equal to 0, and this 1 that we are seeing here, this is p wave; that means, l is equal to 1. So, at low energies that l is equal to 1 contribution neigh able here, remember the scale this is 100 mega electron volt. So, this scale is of that kind.

So, some were here if we look which will be x close to less than 1 MeV are, so less than 1 MeV that l equal to 1 contribution is neigh able your only getting contribution from l equal to 0, s equal to 0 and s equal to 1. So, let say here it is s is equal to 0 and here it is s equal to 1 at this energy, but as you increase the energy, so 100 MeV then p wave as started giving to contribution now, this much is coming from p waves l equal to 1 l equal to 1 as started coming here and that is increasing as you increase the energy more and more contribution is coming from there.

The important point that I want to focus attention is that this delta is positive at low energies and as you increase energy around 300 MeV here, this is 300 MeV around this 300 MeV some were here delta change it is sign, delta becomes negative. So, energy less than this 300 MeV, delta is positive and energy greater than 300 MeV delta is negative. This is delta 0 l equal to 0 am talking not l equal to 1. So, l equal to 0, so delta 0 that changes it sign at around 300 MeV.

So, let us discuss that first how this they come out separately how much the delta 1 and how much is delta 0 because when you do the experiment then the neutrons are coming and the neutrons are scattered. So, how do you know whether it is l equal to 0 neutrons or l equal to 1 neutron from here nuclear are coming to the angle. So, detector is detecting. So, how the angular movement is separating done. So, angular movement separation is done from angular distribution of the particles.

You saw when you think of l is equal to 0 scattering then there was theta dependence in the wave function. So, it is isototropic, but if you bring l equal to 1 you will have that y 1 spherical harmonics which have a particular kind of theta distributions, if it is l equal to 2 the theta defined will be different 3 crosses square theta minis 1, so on. So, once you have this data number of neutrons scattered of different angles you can separate them out this much is isotopic part.

And this is like cos theta variation, this is like 3 crosses minis 1 variation. So, from that angular distribution of the particles, they can separated it out. Now, what is the significant that this delta 0 is changes it sign.

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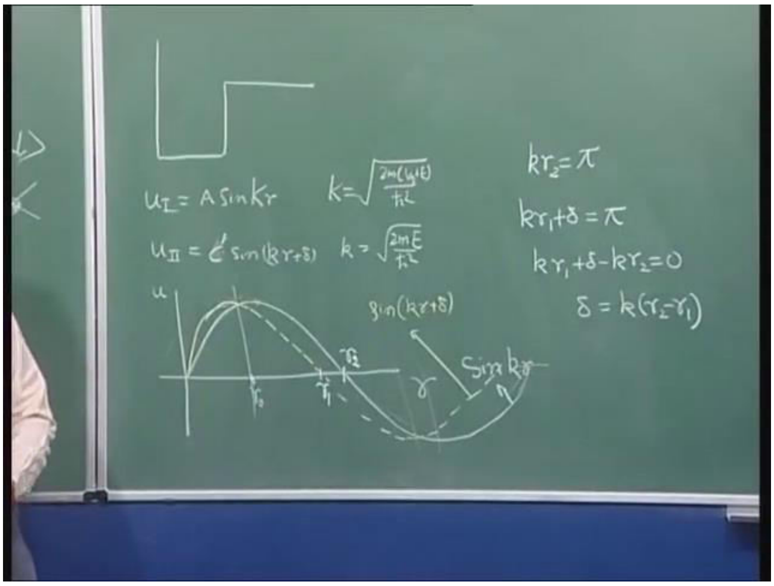

So, let us look at the diagram once again, this potential look at this potential. So, here u 1 was some sign capital K r or capital K was square root of 2 m v nought plus e over x crosses square and u 2 was a sign small k r plus delta, here k was 2 m e over x crosses square. So, if I plot the sign function just this sign function u this constant may be different c prim we wrote. Now, suppose here you have r nought, now if the potential was not there then you will have just sign of k r.

So, let us say this is sign of k r. Now, what happens in this region r less than r nought what happens now, the wave it is again sign function, but this k is different capital K small k this is also small k I have plotted. Now, it becomes capital K here and capital K is greater than small k, capital K is greater than small k and therefore, that periodicity in the sign function this period, this 1 period correct. So, this is if capital K is larger than periodicity become smaller.

Because, this k into r as change into 2 pi to complete 1 period. So, r will change to pi divided by capital K than 1 period. So, 2 pi angle will change for 2 pi. So, angle will change by 2 pi; that means, r will change by 2 pi divided by k. So, if k is large your period is sinking. So, this part of the this sign function to sink because of this greater k. So, it is sinking; that means, if this wave function is going like this here than it should be drawn to this side and possible it is like this at r equal to 0 that r equal to 0.

But, the maximum which was acquiring here, now perhaps acquiring some were here or are may be here, let us say from here it was acquiring and now, it is acquiring some were here and it is turning, here it is turning at this point when it is small k when it is capital K it as to sink that periodicity as to be slinked therefore, it has turned here. So, it is like this outside it is the same k. So, outside the periodicity is not going to change the separation between this 0 and this 0 while this shape as not going sink, but this whole shape has to shift because it is continuous at r nought.

This wave function and this wave function as to match it as to be continuous this slope as to be continuous, so this part will be drawn in this is sinking, but this is shifting towards left to make that matching. Now, this function this whole thing is slinked and you will perhaps matches this portion. So, this as to be shift this way. So, that it is now, it as to go this way and this will shift here, so alright it will cross some were and then if it is crossing the axis's here it we crosses the axis's here and so on.

This solid line, solid curved that I have drawn earlier outside all though the time period is not changing, not time period r period we say the periodicity in along this r axis's that is not changing, but the whole thing as to come left. So, that can be matched here, the value of u region 1 and value of u in region 2 should be equal at r equal to 0 r nought at r equal to r nought they 2 match slope should also be matched and therefore, this should drawn in right.

So, let me call this point r 1 and this point r 2 this I had drawn initially sign k r and this yellow 1 is sign k r plus delta. Now, after that potential is applied the second region u it sign of k r plus delta. So, that k remains the same, but because of the delta the whole thing is shifting. So, when it becomes 0 it was 0 here, originally it was 0 here and now, it has become 0 here this will be 0 when that small k into r 2 is pi. This white curve these whole white curve is sign curve sign of k r.

So, this will become 0 when k r is pi. So, k into r 2 is pi and now, look at this yellow curve, the yellow curve sign k r plus delta off course it will shift some were here. So, now this will be 0 when this k r plus delta is pi sign of pi is 0. So, this is becoming 0 here, at r 1 than sign of k r 1 plus delta, this is becoming 0 this should be equal to pi. And therefore, we subtract. So, k r 1 plus delta and minis k r 2 is 0 and therefore, delta is k r 2 r minis 1.

Positive or negative r 2 minis r 1, r 2 is here r 1 is here. So, r 2 r minis r 1 is positive. So, delta is positive greater than 0. Now, suppose the potential is not attractive, but ripples this is well square well. So, it trappers the particle it attracts the particle, classically if you think if some particle is here and going in this direction the kinetic energy is this much and when it reaches this r kinetic energy is only this much. So, it is slowing down attracting the r is increasing means the particle is going away and this potential inter action it is slowing a down.

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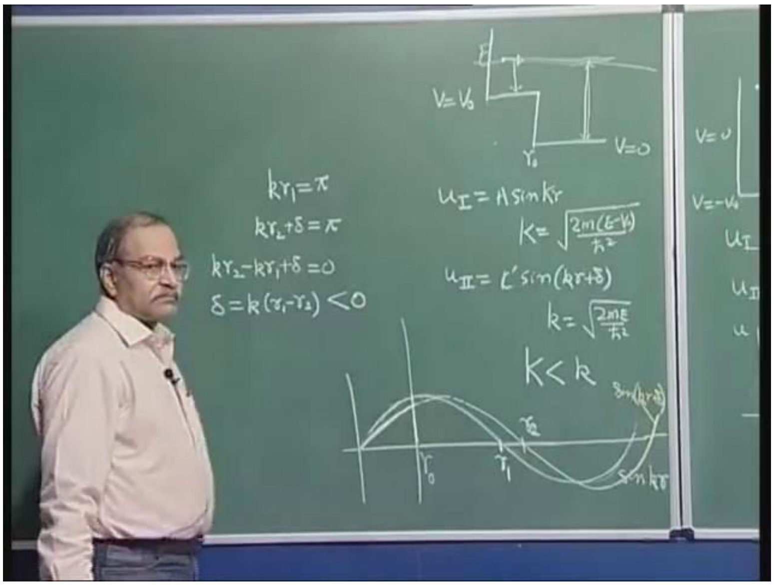

So, the kinetic energy is decreasing it is attracting it is attractive potential if you have repulsive potential I can draw something like this 0 here, and then as you reach that range of potential, this potential energy increases and off course at r equal to 0 it is infinity. So, v is 0 here, this is r equal to r nought and then here v is equal to plus v nought. Here it was v equal to minis v nought this was v equal to 0 for large distances we always take v equal to 0, but when you come into that inter action range suppose, if you have repulsive potential it will be like this.

Again you can think in terms of kinetic energy suppose, this is the separation and the separation is increasing. So, the particle is going to try it is going away at certain distance, suppose this is the separation and then the separation is increasing. So, the part wave is going away from the other particle. And then this much is the kinetic energy this total energy am telling. So, this is total energy, this is potential energy, this is kinetic energy.

And when it reaches here, what happens this becomes kinetic energy. So, the kinetic energy as increased the particle was going away and kinetic energy was increased. So, that means, this practical is repenting that other practical. So, the force is not attractive it is repulsive. So, if you have repulsive force the potential can be something of this slot, once again we can write the time independent of repulsing equation we can solve and the and we still write in this format.

But, now u 1 will be equal to A sign capital K r we can write and that is that capital K will be now, how much e minis v nought. So, 2 m e minis v nought capital K will be square root 2 m e minis v nought divided by h crosses square. It is this difference which comes in, this is e and v nought e minis v nought, here again this difference energy and potential energy. So, this is e and plus v nought, here it is v minis v nought and the second part you can write as u 2 equal to some other constant sign small k r plus delta were small k is 2 m e over x crosses square.

So, when you are here it is this difference. So, this is 0 and this is e 2 m e over h crosses h square. So, similar situation, but now this capital K is smaller than small k and than for the periodicity that period in this first region is larger, than the period in the second region. So, I can draw a similar diagram, here initially plot this is the sign of small k r and then probably some were here we have this r nought, and now in the first region that period as increased. So, it is expanding, this portion I have expand period is increasing.

So, this point will go this point will come some were here, as I have expand it. So, it will be like this. So, it is this slop, the slop is this here the same slope and the same point is here and if I have to match this portion should come here because it as to match with the value and it as to match with the slope. So, if I have to match this white curve with this yellow curve, I have to shift towards right. So, that this point comes here, then it will match to the slope and this thing.

And the whole thing is now, shifted this curve is this white curve is now, shifted and this point comes here, this point comes here, this point comes here. So, everything is shifted towards right this point will go some were here, this point will come here, maximum here, the maximum will be here. Then you will be able to match the value and the slope here. So, once again do the same analysis all this point r 1 and this point r 2. So, this white curve is sign k r and the yellow curve is sign yellow curve is sign of k r plus delta.

After this matching in enforced the new equation is sign small k r plus delta. So, white 1 where which is sign of k r here, it is becoming 0 and therefore, k into r 1 is pi and yellow curve here it is becoming 0 and this equation is yellow curve is some sign k r plus delta. So, k into r 2 plus delta that is becoming pi. So, k r 2 minis k r 1 plus delta this is 0. So, delta is k r 1 minis r 2 and that is negative.

So, sign of delta tells you weather this inter action was attractive of the repulsive l equal to 0, l equal to 0 contribution in this scattering from there you find that to phase shift corresponding l is equal to 0 and that phase shift if it is positive than you know that the this inter action was attractive and if that phase shift is negative then you know that the inter action was repulsive. Now, the experiment shows the data which was there on your screens which is still there on your screen.

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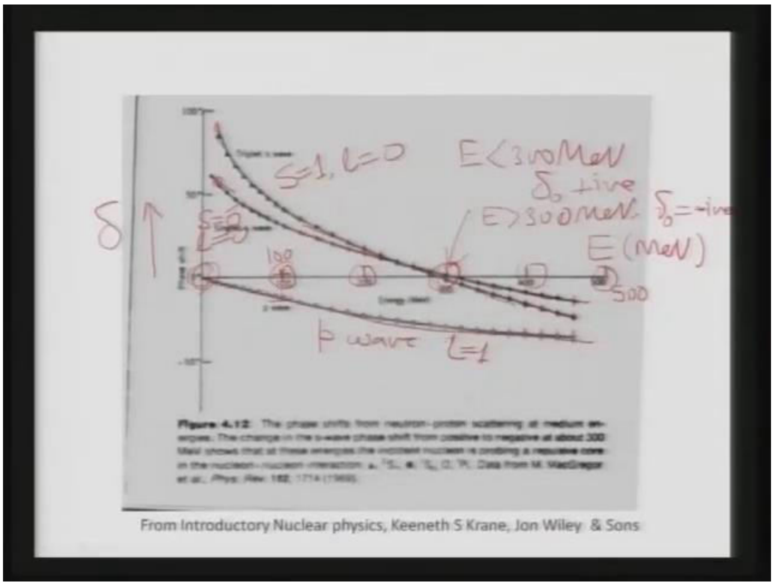

The data experimental data shows that this l equal to 0 with phase shift that changes it is sign some were around here 300 mega electron volt, for lower energy delta is positive, higher energy delta is negative. Now, the higher energy means the particles are getting closer to each other, if you are sending 2 particles towards each other, with the very high kinetic energy, then they are getting much closer and they are if you are sending them lower energy then they are some distance apart.

So, higher energy means they separation your probing a much lower separations, your getting into much closer distances. So, this change of sign as the energy signifies, that if you go to close the 2 nucleons go to close to each other very close to each other they nuclear force will become repulsive. And normally, we understand that nuclear force is that attractive and much stronger than the coulomb force therefore, in a nucleus of this protons do not fly apart the coulomb force is weaker and the nuclear force is much stronger.

But, if you go very close distances, for very close distances the nuclear force between the nucleons that itself will become repulsive. And then the calculation shows that separation is around 0.5 centimetres. So, if you try to push nucleons closer than 0.5 centimetres then you will find that nucleolus will start repelling each other through nuclear forces. So, some were between 0.5 centimetre and 2 centimetre the forces attractive beyond 2 centimetres that forces comes weak it significant goes down and below 0.5 centimetres it is repulsive.

And that is why and there is some kind of saturation density the nucleon are not becoming very dens at the centre like that because after 0.5 centimetres their departure. Similar, thing happens in molecular bands also if you remember the molecular physics your potential comes from positive sides and goes through a minimum and then becomes 0. So, some were it is crossing the origin. So, if the items are pushed to close to each other then it will give the repulsion. And beyond that attraction of the molecules bound.

So, the nuclear force is as a hard core you can say. So, the potential that we generally draw should be modified this is the attractive potential that we have drawn.

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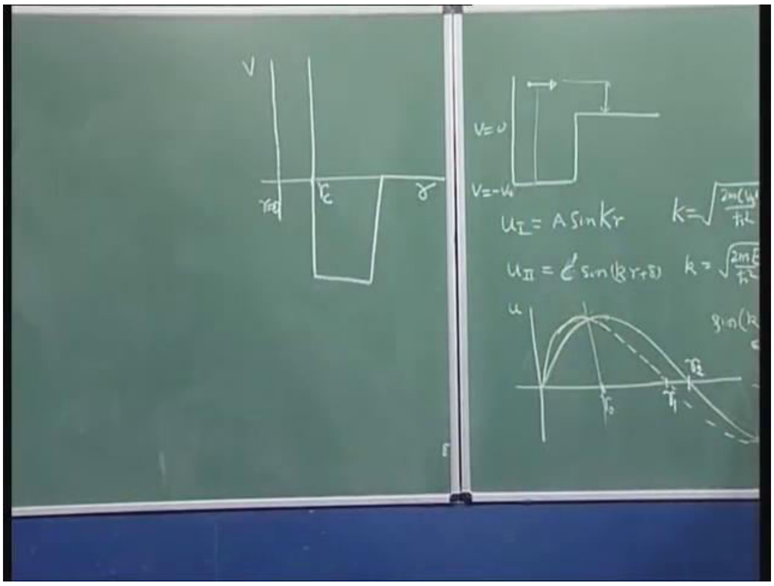

You should be little bit modified, if this is r equal to 0 and this side is r and this side is potential and this is that point let us say this is that 0.5 around 0.5 f m centimetres. So, before that it is all repulsive after that it is attractive. So, it should be something like this, assuming that 0.5 f m centimetres whatever is that value cut off value it just does not go closer than that of course a is not hard wall. So, that you will have some slope here and so on.

But, this is 1 presentation just like here we took a squirrel potential. Similarly, here you can take as a first approximation that separation cannot go up to 0 in this figure am allowing separation to go up to 0. But, here we are seeing that no separation between the 2 nucleus cannot be less than this point. So, infinite potential right here, here we say that r equal to 0 it will become infinite potential, here we say that no at r equal to this value are cut off you can call it r c. Here itself potential as gone to infinite and no further compression.

So, this is scattering data gives us the value r c were the nuclear potential changes it is character from attractive to repulsive. Now, the next the figure am going to show you on the screen is even more interesting.

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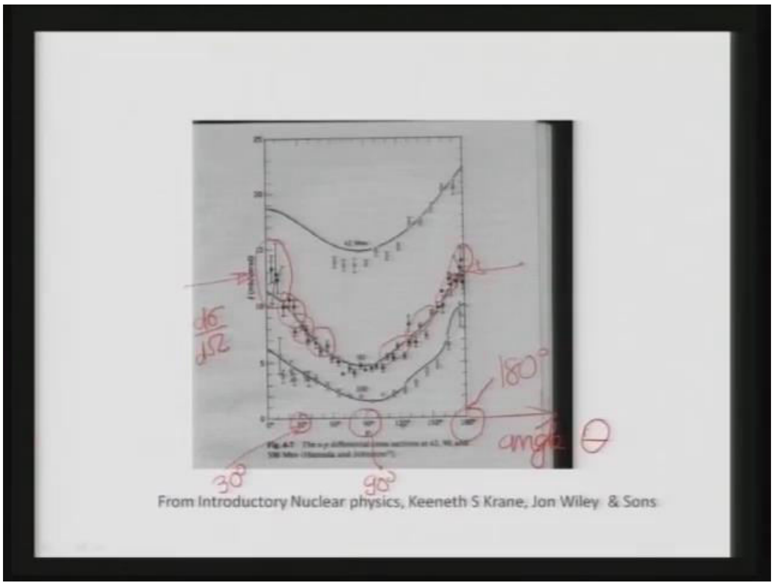

Now, this is neutron potential cross section the 3 figures given, 3 figures corresponds to 3 different kinetic energies and on the x axis's side it is angle which is plotted. This side is angle theta this is theta plotted. So, you can see that this point is 30 degrees and this is 90 degrees and then 120 150 and this 180. So, 0 to 180 is the scale here angles scattering angles. And this side is differential cross section d sigma, d omega not total cross section not integral over all theta pi at a particular theta what is the cross section then at some other at theta what is that cross section.

So, this is cross section as an function of theta. And this top curve here is 42 MeV the kinetic energies is 42 MeV, and the second one is 90 MeV and the third one is 300 MeV. So, what you see from here take any one, say an 90 MeV the middle one you see that the cross section is large near theta equal to 0 of small values of theta. And then cross section is decreases as you increase theta decreases, but then again the 90 degrees it starts increasing and it keeps on increasing, very close to theta is equal to 0 is it as highest value and then very close to 180 degrees again it as highest values.

So, 0 to 90 is decreasing and 90 to 180 it is increasing at this 90 MeV similar, it the characters of other energies 300 MeV also you can also see 42 MeV you can also see this same thing you do not have much data on the lower theta side, but whatever data is available is on that type. Now, let see what does this mean, in general theta dependence in general is that if you increase the theta the cross sections decreases, another 4 scattering cross sections you remember 1 sign 4 to the power theta by 2 in general that happens.

Now, whatever interaction it is from theta 0 to 90 you have seen that the cross section increases, decreases.

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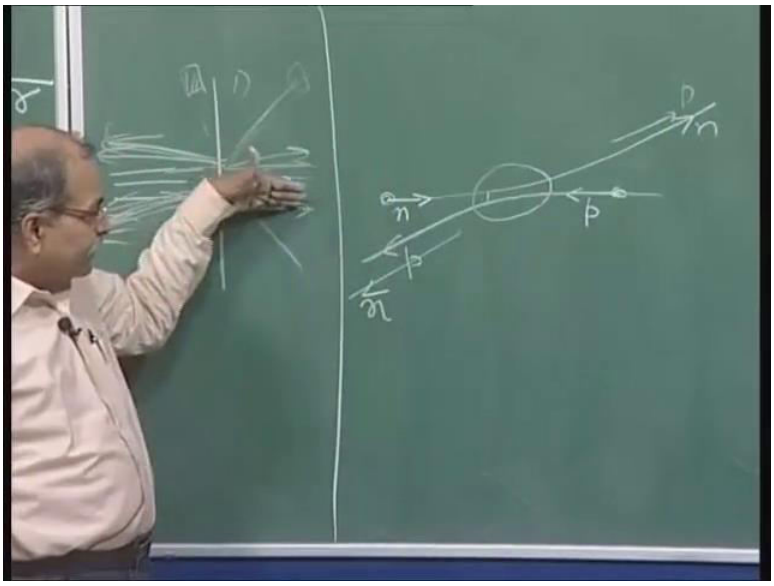

So; that means, if you are sending the particles here, you have many particles in this side going close to theta many particles and if you are putting an particle detective here then you find that the less number particles are scattered in this direction, that is quite understand able. Then you put theta detective here, and back scattering right particles coming here and you find that is here back scattered number is again very large. This number is again very large.

Why, now the kind of energy is that of used here 90 MeV and 100 MeV, this large angle of scattering it surely not expected, most of the particles should go at a very small the fractions. And as theta increases it as to go down and as theta further increases it should have gone further down. Now, the generally have to are explain this understand this data that why it is having a back ward peak, forward peak as well as back ward peak and nearly cemetery about the 90 degree direction.

An extremely, nice, good and very rich explanation comes out that if you are lets calling in talking of centre of mass co-ordinate suppose, you are sending a neutron from this side and you are sending a protons from this side. And then inter actions are going through a small deflection only. So, this neutron will go this way and this proton will go this way, small deflections, small scattering angles, if you look for a larger dimension the number is going to big to small.

But, then if it, so happens the during the inter actions the protons becomes neutrons and neutrons becomes protons, think of this situation when they are close to each other and the nuclear inter action taking place during that time if it is, so happens that proton becomes neutron and neutron becomes proton then the small angle is scattering itself will say that the neutron is coming this way, this proton as become neutron, and this neutron become a proton. So, if you have sent an neutron practical you find that an neutron is as come back.

So, even though this scattering is not large this scattering is small, the this scattering angle is small most of the particles are still going only slightly deviated from the original part, this proton is coming this way and the proton is only slightly deviated, but then what you will find in your detected, your detecting a neutron because this proton had converted itself into neutron. And this neutron had become proton.

So, this backward peak the increased cross section at theta close to 180 degrees in the case or can be understood if I take this as the mechanism of this inter action, the during the inter action this proton is becoming neutron and this neutron is becoming proton. Then if there is a peak around theta equal to 0 in your detector you will also have a peak around theta equal to 180 degrees. We will talk little bit more on this is called exchange model of nuclear inter action.

The proton and neutron are execrating nuclear forces on each other because they are exchanging some particles, which are creating this nuclear force and this particular case you the exchange it such that a proton and neutron inter change their character, proton becoming neutron and neutron becoming proton. We will talk little bit more about this model in next lecture and then we will go for next chapter of Nuclear Cell Model.