Okay.
Good afternoon.
Today we finished the nuclear imaging part.
So lecture 17, spiked and applied.
So before I explain the content for this lecture, let's review a little bit and what we learned some confusing point last lecture.
And have you reviewed the slides and the book chapter and have you reconsidered why you have dynamic curve was shown on this slide.
And then we use the generator to produce TC 99, 99 I'm and we show the dynamic range.
And also I underlined the result between parents and the daughter.
It's constant.
The decay rate of daughter is pretty much governed by the half level of parent.
And you show three different equations.
You solve equations and you plot using math live.
You could reproduce the curves and some things.
So here usually you just do milking operation and at peak.
So you got curve like this.
So from the moly coals.
So you keep guiding 99 I'm TC for spiked imaging purpose.
And any of you could tell me why the rate the decay rate of daughter which is TC 99 I'm is governed by the time constant or decay rate of the parent.
Any idea how you check the equation any confusing feeling.
So why you have this kind of rate.
And actually you can consider this way.
And I think for learning medical imaging some complicated relationships and so on always try to understand try to simplify complicated picture into simple things.
Then you get better understanding.
Like the curve and the old statement say the daughter is governed by mother in terms of decay rate.
Why is that? You can actually think some daily life example.
The parents very nicely gave money to to kids to daughter like her to spend.
And the parents have a certain amount of fortune keep giving daughter at a certain rate.
Okay.
The daughter is very active and the now we're see guys money.
She wants to spend immediately the iPhone and the movie theater party traveling everything.
So very quickly.
So in that case you see the parents money will decay.
So parents decay rate is slow.
But the daughter spend so fast whenever she got money and she she just the spend them.
So in this way the spending rate pretty governed by the rate parents is giving the daughter the money or what so I work.
So this is some heuristic and the standing make some simple picture otherwise you see all kinds of different so you don't know what's going on simple like this.
And also the time.
And if you just look at your equation two point seventeen and they may not be immediately clear to you.
But if you write it this way then you know and the end capital N is two countries and the lower case N is the opposite of the country rate.
It's a country rate.
So receipt protocol of country rate is our is time taken.
So for you to our zero country rate.
So our average is spend this much time.
But once going on the real rate the time period is one over capital N.
Capital N is true country rate.
So the difference is and it's called time.
And you hope that time is zero.
Whenever you have a true count then you have zero data very count.
But in reality you do slower than what's happening when the rate is very high.

So always try to guide the heuristic understanding.
Don't confuse yourself.
If you feel something you are buried under mathematical details a lot of formulas.
Once some of my students show me the program he or she wrote several thousand lines say the result not right where is the problem.
In this case you really need to divide into module.
These modules small block maybe twenty thirty lines.
Then you know the input and you know what the output should be any problem.
You limit it yourself to the small block.
Then you do debug.
So divide and conquer try to simplify your understanding.
And guide some very heuristic picture in your mind.
It's a key to guide good understanding.
So now we talk about all our outline.
What we will cover today.
We will talk about single photon IMAZEN computing the tomography.
And the positive electron IMAZEN tomography.
These are two major nuclear imaging modalities for tomographic imaging reconstruction.
And we learned a single photon IMAZEN.
We also talked about poditron IMAZEN.
The poditron wouldn't stay for a long time.
We will capture nearby electron.
Then I use a big word called a narration.
Then the poditron plus electron becomes part of gamma ray photons.
They move in opposite direction as speed of light.
So you have two kinds of IMAZEN.
The single photon IMAZEN tomography, the computer tomography, utilize single photon IMAZEN of course by name.
And the poditron IMAZEN is part of the photon IMAZEN.
So both IMAZEN precisely govern the by statistics.
So the first part of introductory of background information, I really would like to review with you about statistical distribution.
And we are not explaining statistics to you.
So my review is brief, which I try to follow me in terms of rapid idea.
If you want to look at details, you will come to do so later on.
And after statistical discussion, we will talk about data model.
So you know either single photon IMAZEN or poditron IMAZEN, how do you mathematically model the data acquisition process.
And last last lecture, I explained the physical sense, physical, chemical mechanism, and even talked about the colemation.
But if you write down the formula based on which you can do myelot programming to IMAZEN recond<|tr|> So the second part of data modeling is pretty much about formulation.
So given a distribution, what kind of measurement you ask back to see.
So after that, you know the forward modeling, you want to inward the process.
And the in-version would give you the underlying distribution, which is what I also call tomographic images in this case.
The images are not anatomical details, not structural features, but rather the images are underlying the distribution of radio features, you introduce them into a patient.
And to do so, you need to do a translation compensation, and you can perform easy deterministic or statistical reconstruction.
And we will come to that later on.
And finally, I will talk about scanner architecture.
Like CT scanner, you know CT scanner consists of X-3 cells and X-3 detectors, some high voltage and high voltage transformer and cooling system, SLEP ring system, so you have all these key elements inside CT GANCHRIC.
But for nuclear scanner, if you just look at the appearance, it looks not so much different from CT scanner, but inside there are quite different, and I will explain.
And particularly, I will mention how do you do some correction, particularly scatter correction, also some random count, how you detect it, it's made and

remove random counts.
And these things are different from X-3 computer tomography.
And finally, we will mention a little bit about the calming, fully-ready prime of international conference on medical imaging reconstruction, with emphasized on X-3 CT and the spaghine pattern.
We are organizing the meeting, so just to give you some interesting information.
And if time permits, I will show you homework questions.
Today, I also give you some comments.
It's pretty much my plan.
Just let you know the big picture that we follow each individual part.
And the statistical distributions are very important, and you know noise, you know random variable over interval, and the basic uniform distribution.
So uniform distribution is kind of simple.
And the more interesting, and we have Gaussian and the Poisson distribution.
And if you ask me, just tell me a little bit about statistical distribution, maybe first I will say uniform distribution.
So, within over interval 0, 1, 0, 5, what is I, so any point, you have equal possibility, so you have random numbers.
So this is one simple case.
And after that, I would say Gaussian.
After Gaussian, I would say Poisson noise.
Gaussian model, Gaussian shape is a bell shape distribution.
And normally you have half mean, mu, and standard deviation sigma.
And if mu is 0, sigma is 1, you have the standard form like this.
So I surprised mathematically as a scaling factor, then you have exponential factor mu and sigma.
So this is mostly used in engineering, in iron measurement estimation, and so on.
So if you have many individual independent random variables, and the uniform itself which contributes a little bit, but many of them put together.
And they are independent.
You basically convert all the individual distributions over or to form the final outcome, which by statistical theory will give you Gaussian shape like this.
And in reality, many times, under the precise, all the outcome is effected by many independent random factors.
That's why you see Gaussian distribution so often.
And Poisson distribution is related, but look quite different.
Basically, you have random variable.
You can give you number 1, 2, 3, and any number, by the way, different possibility.
And you use lambda to represent the mean.
The hour is number.
So when hour is number is small, say from 1, 10, something.
So you have this asymmetric distribution.
But when lambda is really big, the curve will look more and more like Gaussian.
So Poisson distribution when the mean lambda is big, it looks very similar to Gaussian distribution.
And for Poisson distribution, the standard deviation is also not standard deviation, the variance is also lambda.
So here you have mu and sigma, but for Gaussian, for Poisson distribution, you have mean and the variance, they noted by same variable lambda.
And how you can derive the Gaussian distribution and mention that you use many individual probability distributions.
And you do convolution and you prove it is Gaussian and it's a bell shape distribution.
And Poisson noise, Poisson distribution, you would need some high school staff, you learned permutations and combinations.
And this permutation, you just see the different arrangement, roughly speaking, a combination, you need to just remove those, those essentially the same arrangement like ABC and ACB.
In terms of combination, you think it's same thing because this is same three individuals involved in this activity.
So you need just the distinctness between permutation and combination.
So you can review this slide, you will recall what you learned.

And by nominal formula, basically you have a series of events.
And for easy event, it's a probability stake.
And say you're toaster coin, and it's a certain probability P and you see one result.
And the other possibility will be Q, Q equal to 1 minus P.
So you keep doing multiple experiment.
And you how many times you see high, how many times you see tails, this is a good model.
And like the example shown here, and you purchase 10 computers.
And individually you know the defective rate is 2%.
If you buy 10 computers in a row, what's the chance you got to buy the computer, then you can use by nominal formula.
Basically something like a toast coin.
And the probability for you to see one side may not be exactly half.
And in general you can call it P and Q, Q equal to 1 minus P.
And the personal distribution is derived from this binomial distribution.
One, the number n is very big.
So you just go through the maximatic, I put a green button here.
So if you want to know, so this says go back, the Gaussian Poisson, Poisson you need to know the binomial formula.
And to understand the binomial formula, and you need to review permutation and the combination formulas.
And when you have a lot of events linked together, when it's very big, then you use some analytic scale, you can show the distribution will be Poisson distribution.
And the gamma-ray-am<|hu|> emission, the single gamma-ray emission, or power gamma-ray emission, they follow Poisson models.
They find Poisson models characterized by lambda.
So what it says? It says you keep a guiding gamma-ray photons, but the whole of the recent period, you cut into small pieces, like you all have zero, you say 10 minutes, and you have many small time interval.
Really easy small time interval, the radio-trisher, I made gamma-ray or not, with the possibility for individual time unit, with the possibility P, small possibility, it will I made gamma-ray.
And with the probability Q, one minus P, it will not decay.
No gamma-ray photon will be given out over that period of time.
So this is purely random sim.
So you look into the mechanism, you know the physics fundamentally is not deterministic, it's not deterministic, it's a probability sim.
And the old argument, you may heard Albert Einstein thinks God will not play dice.
Okay, then he's opponent say, argue against Albert Einstein, say God doesn't need a ureth wise, what God would like to do.
So in this case, we see fundamentally, and the gamma-ray emission really follows purely by chance, this is by Poisson's distribution.
Poisson's distribution really has a mechanism, you look at it, you look at it, you infinitely small interval, then you have purely chance, you have gamma-ray photon or not, P or Q, something like this.
So this is, let you know, this is statistical model, Poisson model, so you know little bit, and this is something also applies to x-3 emission.
x-3 emission when you have electron beam interact with tungsten material, you have certain number of x-3 photon coming out, and the x-3 emission also follows Poisson's distribution.
And the bottom one, you detect x-3 photons, you can actually detect, photon counting detect is the latest technology, but popular x-3 detector still current or energy integrating, and for the traditional x-3 detection, and on top of Poisson noise, you also have electron noise, and due to semiconductor x-3 detector design, so the model for electron noise, and it's a Gaussian model, so for x-3 CT data acquisition, statistically model will be a mix model, Poisson plus Gaussian, so this is the side note for you to know.
The data model, now we look at single photon and the pilot photon emission.
So look at this slide, you see diamond, so pay attention.
For nuclear emission, the gamma-re photon energy will be in roughly in this range, and mostly importantly, I say 90% is a application, use the isotope TC-

99IM, this is the isotope, and the energy range, and now let's try to remember this, and I try to remember oftentimes I forgot, but it's a 140 KV, it's a little over, little bit higher than x-3 energy, and x-3 energy usually between 80 KV to 130 something, but now you have this radio-treature energy range, and I would say quite comparable to x-3 photon energy range, okay.
For poditron emission, and in the homework questions, and we have one of the questions about the gamma-re energy from a poditron emission, and the data is 511 KV, okay.
And for single photon emission, how do you model that? They support at location x equal to a, and you have the radio-treature, stress, concentration, or number of radio-active elements, what do you call it, it's sols, and this location is nA, okay.
Then you see, you're collimated the gamma-re flux at this location, you try to look along this line, you see, and up towards the galing factor, you think, and the sols distribution along this line, in this case, is nA, the nA can be just the sols concentration, but it will emit any direction, so you need to have a scaling factor proportional to the aperture of this mechanical collimator, so you have the detector here, and you watch how many gamma-re photons you can receive, okay.
So if you put the gamma-re source in vacuum, then you just have 0 nA, certainly you need the putest galing factor, depending on how large is the opening of the collimator here, but in reality, the radio-treature is inside the human body, so from this location A, and the gamma-re photons will be propagated until reaching upon the gamma-re-camera element or detector at the location, I see equal to D, so along this way, and you have a tiny wave and a big wave, the gamma-re photons, I see the energy slightly higher than high-end of x-ray CT energy range, but still kind of x-rays, okay.
So x-ray will be a tiny wave, so will gamma-re photons of 140 kV, so this factor, e to the power minus integral from A to D, so from A to D, is a partial integral, and the tiny linear tiny wave, all the way from the emission source to the detector into a count, and we think the tiny wave is a function of location denoted as mu of i's, so integral mu i's d i's, so overall, so this is a tiny wave factor, okay.
So what you might see is not the source distribution per se, is a modified weighted source distribution, and the weighting factor is line integral, but it's not line integral we show in x-ray CT, this is a partial line integral, so this makes the spiked reconstructions a little different from x-ray CT reconstructions, so this is the ratio to no, this is data model, it's straightforward, but it is very important, okay.
Now let's look at the part of the photon emission, so shown here, so you have a event, the event by event I mean, you have a emitted positron, which captures a nearby electron, so positive and negative particles gathered together, so we have a event called an annihilation, and the result is part of the gamma-re photon moving in opposite direction, I shown here, then we have applied similar argument, so this is gamma-re photon, I need to switch to gamma, so this is the way I copy this picture from all the slides, so this change, this g should be gamma, I will refine before upload, okay.
So one gamma-re photon moving from x equal to a to detector d1, the other the part of the gamma-re photon moved to detector d2, so both gamma-re photon will subtract to a titanulation, the titanulation factor is really interpreted as a probability, so like in the first case here, so you have a gamma-re photon, and the titanulation means by what chance the gamma-re photon will reach the detector, in this case for a part photon emission be detected, you need to two-even happen simultaneously, that means you live the detector and write detector, curvature, part photon, simultaneously then you really have individual probability, two individual probability, multiply the together, so that will be the overload probability for this part emission be reported to your computer system, and the nice thing is that although you look just the partial titanulation, you do have a location dependent variable in this case, a is a, so one is from the integral, line integral is from d1 to a, the other is from a to d2, and now you're talking about drawing the probability, two individual probability factors, multiply the together, then the x potential part and the indexes should be added together, so look at the line integral from d1 to a from a to d2, so these two things added together, it will result in a traditional

line integral from d1 to d2, so this line integral is nice, that's not depends on source location, so it does not depend on a, i is equal to a here, really eliminated, the result is just purely traditional line integral, so this is give you two data model, the data weighs in the result constant weight, so this is a constant weight, doesn't matter, why are you you position the gamma resources, and this is not a constant weight, the weight depends on location of the radio threshold, this is elemental distribution, if it is at a here, you have the threshold integral from a to d, a could be 1, then you have a weighting factor, for that location, if you change a to 2, the weighting factor will be changed, okay, any question? Okay, and some further this constant here, I may put some green button here, but just let me say, you see this way you eliminate the location dependent, location is a, this way you have two factors, probability, multiply it together, this location got cancelled out, and you can apply this idea to the sparkly imaging, you can do something similar, so the support for sparkly imaging also single photon emission, single okay, I put the detector on one side, and the other side, you got two measurement like this, okay, then I multiply the two measurement together, multiply the measurement here, so the treasure intensity, the treasure concentration got the square root here, but by the way, when I do this multiplication, so this is two partial factors for single photon emission, so from a to d1, from a to d2, they multiply together, now I got a constant weight, doesn't depend, doesn't depend, depend on a, so you got this one, so looks okay, so sparkly imaging and got also a constant weighting factor, so this is, this is for sparkly imaging, this is for party imaging, party imaging, I already explained that you got this constant weighting factor, and the real life is not that simple, there's only about one treasure concentration, but whatever you have two, two, two gamma resources, two gamma resources, and in the big risk of actually delay, if you do multiplication as I explained in the previous slides, and you multiply this part and this part, okay, so you have these two terms, you just expand the product, you have this nice term, so you have a constant weighting factor, but the real treasure distribution kind of different, you got squirt, then I did the together, so the line integral become squirt concentration, you do line integral, let's not divide, as long as this weighting factor is constant, but the problem happens with the cross product, so you got this two terms, in the first factor, and the two terms in the other factor, so when you expand, you got a four factors, this is a nice part, take considerate of two of the four resultant terms, and the other two terms are cross terms, so you have d1 to a, and b2, d2, so a, b are not the same, and you have this cross terms, so this will make the model quite messy, that wouldn't work, so again, we have to stay, this is partial attenuation, corrects in model, but for pattern, that's easier, okay, just, I will put green pattern there, so for pattern imaging, and then we use a ring detector, so we try to do the synchrony, co-eased in the detection, so you can determine line integral along this green line, along this blue line, you'll ring a little bit, so you can got a projection along this angle, and you can guide the projection for different angles, and you put them together, you got a synogram pretty much like what you have from CT data, which is in precise, and here, as long as you know, as long as you know the tenuous and corrects in factor, then you can accumulate the data into this kind of line integral, so this is the essential idea of spiked and the pattern data acquisition, and earlier, the pattern scanner, you use planar imaging mode, so you have collimators, mechanical collimators, that define imaging plane, so you have a collimator, so all the radio-active treasure distribution within this slide, or within this slide, will be detected by this ring, so you have a left part, right part ring, but really you have a hole ring surrounding the patient, and the modern pattern scanner, you remove the mechanical collimator, so you do the coincident detection, so from 3D orientation, so anyway, you can do, so picture wise, you see something like this, and the 3D pattern, enjoy as the benefit, you do not have mechanical collimators, so this will increase the number of gamma photons, you can capture, so this will increase sensitivity of imaging system, downside, because you have wide opening, and the scattered and random event will be also captured, and later pattern will be played, what are the scattered and random event, how we will remove them, but anyway, so you have a larger opening, some unwantated signal, we also have an opportunity to interfere the data quality, and while you do 2D based imaging, so the noise, or random scattered

gamma photons will not be able to release a given plane from all the plane structures, so we are talking about model, and the key idea, the part of the emission can be modeled and the waste of the source concentration times the weighting factor, the weighting factor is constant, so when you do integral with all the source distributions, the tiny waste factor can be taken out, and you will see that in the next slide, so here, so we talk about image reconstruction, and we need to see what is the data model, so for spark the reconstruction, first let's think the number photons is a larger enough, so we can use probability things, and we can use mean, the measurement will pretty much reflect the mean, so we can have a deterministic model, so the target number photons for a given line pass, or the line of response, so we will be the redo-treature concentration at a given location, and then in previous slide I call it a, but here I call it ice, okay, so lambda ice, okay, so this is a tiny waste factor from ice to D, D is a detector location, so you have a detector here, and we don't know you have one line, you have one element that is radioactive, or you have many elements, so we just mathematically consider, each pixel or box along the given line is radioactive, with a redo-treature concentration lambda of ice, and if it is not radioactive, then lambda ice at that point will be 0, okay, so you do this a decional line integral, you see this a tiny waste factor, it depends on ice, if not the depend on ice, you can factor this whole thing out, then you have a line integral, then you can use CT algorithm, but the trouble I have been explaining to you, recall the earlier model, and it depends on the location, clear is ice, earlier slides I call it a, so you cannot factor rise, you cannot factor rise, this out, so what you measure, clear is not a line integral, but it is rather x peninsula a tiny way to the line integral, or x peninsula a tiny way to the redone transform, which is different from conventional redone transform, and in CT data precision, and we do little bit data prep processing, and we show that we will have this line integral, which relates back to linear tiny way to coefficient, we don't have this trouble something, but we know we have this problem, the redone transform talking about line integral, so the p projection as a function of the detector location and the projection angle, and it is a function of linear tiny way to coefficient, mu xy linear tiny way to coefficient, but here we are talking about the radio treasure distribution lambda xy, and for given line, and we use parameter ice lambda line, okay, this is redone transformation, you understand, and this redone transformation in the CT slice, okay, so because of this annoying vector, and the filter of the bike projection cannot be directly applied to find the underlying radio treasure distribution lambda xy, okay, you cannot do this, but how we can get more of this x peninsula tiny way to the redone transform, so we have some easy ways, or proximate method, so first we will assume what about we assume no tiny way to make a proximate, we are engineers, we just make a proximate, another way we can assume this mu is dependent on location, another linear tiny way to coefficient, mu also depends on location, so to simplify our life little bit, we say okay, how about we assume there is a tiny way to background, but this tiny way to background is uniform, so this is second way, so we assume it is uniform, then we try to solve the problem, and if you assume it is constant, you

still cannot factorize this out, why? Because see, this is lower limit depends on location, even this does not depend on location, the mu does not depend on location, you still cannot factorize that out, and yet another way, and we can do independent CT type of scan, transmission scan, so we can find all the mu's, and we plug these mu's into the data model, so we know the mu, mu is no longer unknown, and we can model the data more precisely, and even you know mu, you still cannot factorize it out, so you cannot apply filter to background projection, so this is the data model, and the data model, once you know, you know mu, and this model integral can be converted into a linear system, so once you know this, so that means this unknown, lambda is point wise, and depending on the location, okay, we have this VTN factor, the integral weighted by a kernel can always be converted into a linear equation, so each measurement in CT case, the linear equation is resum, but in the spiked case, in the spiked case, so the unknown is real unknown is weighted, but this is still linear equation, so if you use CT, it will algebraic measure, in this case, once you know mu, then you can solve the system of linear equation, so that is still deterministic way to do image reconstruction, okay, and there are a lot of research going on,

I should put a green button here, so we can analytically solve deterministic problem, when you assume mu is constant, so you can derive, you use Fourier analysis, and so on, for example, this paper, and just for those of you really curious, you can solve this problem using the algebraic measure, solve system of linear equation, and you can also use some analytic technique, and to solve the reconstruction problem, you don't need to use it really measure, you can use closed form solution, look something more complicated than CT, Fourier slices theorem, and so on, but anyway, there are ways to do that, so now let's talk about deterministic pattern reconstruction, so see the pattern model, pattern model has a constant factor, times the concentration at location, previous, previous slices, I say, hey, now I say, is, okay, because the longer line, I have to be location, I have to be is, may have a lambda is, okay, so we do the total measurement, all the coincident detections, you will recall everything, so you add all these individual lambda is together, so you do resum, or you do integral, in this case it's nice, because there is a tiny reason factor, that's not depends on is, so you can factor right this out, and you have this, you have this line integral measurement, let me just put here, so you have this line integral measurement, up to this uniform weighting factor, so I will be you don't know mu, this is a known, but we have to make a mu known, so this becomes a known factor, then you have measurement normalize by this known factor, what you measure is a line integral, in this case, if the number of gamma refotons, the part of gamma refotons is high enough, then you think the measurement reflect the mean, then you can use deterministic measure, you can use filter by projection measure directly, to do tightly reconstructing, so you can assume the patient is just water, because we have a lot of water in our body, maybe over 70% is, assume mu is as mu water, so if you think mu water, this is known, so you know this factor, and also you can do individual scan, so you got this mu precisely, and you also know mu, so once you know mu, this becomes known, and interesting twist is that if you do time of flight is the measurement, that means you have two detectors, capture the gamma refotons arrival and individual times, based on time difference, you know, if the event is closer to one detector, or further away from one detector relative to the other, so that way, this is very sophisticated scheme, to estimate mu from gamma data directly, and we don't have time to cover that, and I would like to explain this, Taneuism correction, I keep saying the individual scan, and the individual scan to guide the mu distribution can be done using x3CT, but there is an important caution, we have to know, so the gamma-photon energy for path imaging, again is 511kV, but for x3CT scan, and the highest KVP, properly 140, and if you use 140kV, that's x3 tuber voltage, and the x3 spectrum will be from something like 30KV all the way up to 140KVP, and all these distributed energy spectrum can be converted to a single effective x3 energy, which is 70KV, roughly, so with CT transmission you measure linear Taneuism coefficient, but the coefficient is effective at 70KV, but to do path Taneuism correction, because gamma-photon is more energetic, gamma-photons are at 511kV, so it will interact with biological tissue, and we need linear Taneuism coefficient at 511kV to compensate for Taneuism for path imaging, so in this case we have to do this piece of our linear myping, so given CT linear Taneuism coefficient measurement, effective energy 70KV, we do this myping, and we estimate linear Taneuism coefficient for path imaging at 511kV, so you do this myping, and normally you have very good piece of a linear relationship.

So if you have low CT, a tiny reason coefficient, at lower KV, and most likely you have high, you have relatively low, a tiny reason coefficient, at five, eleven KV.

So you follow this monotonic relationship, then you can do a tiny reason correction.

So we talk about the pilot CT imaging previously.

We say why you put the pilot CT together.

We say CT gave you an atomic structure, pilot gave you functional information.

So you have two kinds of complementary information, in a core register framework, that's good.

So that's the argument.

And now, as we explained more, I would add another benefit, you have a pilot CT together, because CT information, provide critical information for pilot imaging, so that you can make this scaling factor known, then you can convert

pilot data into line integrals.
Once you convert pilot data into line integrals, you can remove a tiny reason, and then we will make a pilot imaging and more accurate, quantitative information can be extracted.
And like I said here, the pilot result of tiny reason coefficient, you see very dark side here, but the ways a tiny reason coefficient, you have more uniform looking, and the result will be more accurate for concertrhythmic for example.
So much for this part, you can have a rise to the full eight minutes, then come back, we finish the rise of the lecture.
I forgot my water bottle, I need a drink of water for my canyonsidone, we will be back in a minute, okay? Okay, so we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one, and then we will start with the first one.
Sorry again...
It's all right, the first lecture is I am Your Eye, I think we have a second exam, right? It's an all-interioral thesis.
I think it's all right.
I need this kind of thesis, the other instructor.
See, if we see the ink load I might or not, I guess we should have the first lecture.
I might include it in a second exam.
I guess.
I'm going to do a second lecture.
I'm going to do a second lecture.
Yeah.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
Okay.
What is that? That means this...
How did this object, or phantom here? Then you take one projection.
It was second projection.
So number of projections.
Also called the number of views.
How many? 1 view, 2 view.
So that means it really means the number of projections.
Okay, so if we just have an example of that.
And if you have a lot of projections, you will get a good reconstruction.

If you use say five real five projections, the image wouldn't look good.
You just see that you're five.
Done.
Okay.
Thank you.
You're welcome.
Thank you.
Thank you.
Thank you.
Thank you.
Thank you.
Thank you.
Thank you.
Thank you.
So far, we have discussed how do you do image reconstruction for both spiked and the pattern.
Assuming the data you modeled are good enough, meaning you have a large number of gamma-refortance captured.
So the quantity you measured pretty much reflected the true statistical parameters, the mean number of photons, and the measured is really statistical mean.
So in that case, you have formula, the data model.
The data model is tricky pattern for single photon emission, and the full pattern for photon emission.
The data model is a little different in terms of waiting factor.
So for single photon emission, the waiting factor depends on, I would say fundamentally depends on, the active source element takes a walk, so location.
So the waiting factor depends on location.
And I explained to you a little bit that the location dependence cannot be easily removed.
And I tried to show you how to get a pilot measurement multiply.
Then you have cross terms, and you cannot easily remove the spatial dependence.
But for pilot photon emission, you get to simultaneously for single source distribution, and you have the probability to factor, multiply the factor, you have a location dependent formula.
And if you have multiple redirected with source point along same line, you just do line integral, I did together.
And that the teneous factor for any radio active element, any location along the line, the waiting for the teneous factor is the same.
So you can factor right that out.
So as long as you know mu, you know the teneous factor, and you can have a very neat line integral obtained.
Then you can use filter back projection.
So this is very nice in terms of image reconstructing.
Okay.
If you haven't got the point, review the slides.
And I was very busy for past several days.
I didn't upload this side of the slides, but I will refine little bit, we will upload this afternoon.
So review the slides, follow the argument.
So you understand the data model for spiked in the pipe.
That's a key.
And once you know that, for pipe in particular, you can use filter back projection.
That's why nuclear tomography comes after CT, because you need some CT knowledge there.
But for spiked imaging, you have a specifically dependent teneous factor.
But if you know mu, if you have the mu measure, like this individual transmission scan, then you can still convert explanately a teneous rate of the read-down data, the governing model.
You can still convert that into each measurement, carries bounds to a line integral, a resum.
Then you can have a system of linear equation.
So that's the same thing as CT.

The linear system of linear equation.
Then you can solve linear system equation.
It retable a real half super computer, big computer.
You can just use linear algebraic, measure the multiple measure to solve linear equations.
We know how to solve linear equations.
And numerically or analytically.
But what if you don't have enough flux? That's a very problem.
I mentioned the other day.
And the x-ray flux is high.
But the nuclear imaging, the flux is relatively much lower, because you introduce the radio-tripsure.
The i-made gamma-ray photons.
You don't want to introduce two-cyl-drone radio-sauce-digit-bucin inside the human body.
You need the minimum amount of guided information.
On the other hand, the radio-tripsure-digit-bucin is very sensitive.
Any signal you detect this from a radio-tripsure.
So you have very sensitive, high sensitivity there.
It comes to statistical pros.
That's why I covered the first product, how the deterministic reconstruction pros.
Now I gave you the high-level idea about statistical reconstruction.
So if you have this lambda, this big capital lambda, is the image to be estimated.
So we from statistical point of view.
And we want to give this noisy measurement.
We want to estimate what is the image.
And the measurement called q.
So that's actually measured.
Use mechanical columnite or co-incident detegison circuit.
Very noisy, because the gamma-ray-tripsure concentration is not very good.
You don't want to drink too much.
And the decay rate is reasonable.
You got a gamma-ray photon, but the mass noise is no longer normal.
It's no longer normal.
It's not normal.
It's a CT reconstruction.
So you have underlying source distribution.
This is fundamental statistical.
We can model the image.
The image is source distribution.
You disagree to small pixels.
You treat as a small life bob.
It says I'm meeting gamma rays.
And the model is not bad.
It's a plasma model.
And also, this is the image.
This is the pixel.
And the neighboring pixel.
And this pixel, they all do the same.
They do not depend on each other.
Parts from this distribution.
And total 10 minutes, for example, of the recent period.
And you cut into small time intervals.
It's interval 10 milliseconds.
This 10 milliseconds, next 10 milliseconds, and far away.
Another 10 milliseconds.
They all do independent things.
And the independence is very important.
So the probability for this measurement will be product of many, many small probabilities.
This is individual detector.
Individual pixel.

Individual time constant.
You have all since multiplied together.
So you have the probability.
You can estimate.
You can formulate the probability easily.
And the base rule is very known.
And you learn in high school, but it's so important.
It says, OK, you do data measurement.
The patient comes in.
Use the camera, the camera, or use the pet scanner.
I got the measurement.
You just sorted it into Synogram 2D3D.
What's the error? And the mathematical notation is so powerful.
It's just cute.
OK.
So given cute, cute studies, it will seem.
Comes from underlying Poisson distribution.
OK.
Intimidance base.
So given cute, water would be the image.
So given cute, you want to find the image lambda.
Capital lambda.
So this probability really depends on three things.
First, say, given the image.
Given the image, the image is known.
Assuming the tiny green background is also known.
So the image is known.
The source distribution is known.
The tiny green background is known.
I know your imaging geometry.
Then I can't predict.
So given this image, this detector says the gamma red detector.
What's the probability? This gamma red detector will receive, say, 3,000 gamma red photons.
It will be the first 5 minutes of sky.
OK.
So you can predict this.
Given this image.
The problem you don't know the image.
But you know the data.
OK.
And also you need to know the probability of the image.
So this is our total population.
And the sum are very young.
Some are old.
And the image is capital lambda.
And maybe for younger patients, there are no radio-treature distribution in major organs.
Because there are not cancer patients.
So you have certain probability of X-backation.
And for senior patients, you may think it's maybe 5 or 10 probability.
The colon may have some radioactivity.
Because they have a colon tumor or even cancer, depending on the disease.
So you really have a distribution.
You can estimate the distribution.
And also, if you don't have the strong big data based knowledge, particularly earlier years, and you don't want to assume anything, just say anything is possible.
It's equal possible.
So this is a constant.
This constant doesn't affect statistical estimation.
And the statistical estimation oftentimes you want to maximize this probability.
If you have a constant factor, it doesn't matter.
The qpq is the probability of the data actually measured.

You measured it.
So that's what happened.
So you know this.
OK.
So we have two key concepts.
The map and the i-mile.
So what is the map? The map is to find a maximum of posterior probability.
So this is the probability called the map estimation.
So if you just have the data, you suppose you have this patient image distribution probability.
It's the metadata.
You know this.
And you know the measurement.
And you can, you can, this is the protabituary image there.
Or a reasonable estimate, a measure there.
You can predict what is probability q.
So this part, you can use numerical computation to find.
You keep changing images until you're lucky enough you happen to get a good one closer to the truth.
This gives you higher probability.
And you say, OK, this is what I want to report.
OK.
You have this model.
You keep changing different candidate images.
And one of them gives you higher probability.
Give you high probability.
Then you say, OK, this is my results.
So this is a very, very reasonable way.
This W will be, will bring the highest probability.
OK.
And as I mentioned, if you don't want to assume the probability distribution of underlying image or radio-trigger distribution, you treat as constant, the pq is constant anyway.
So this my place is the emission.
And this my place is the emission.
And this my estimation will be the same.
Because of the network, this is the q is maximum value.
The map is the highest value as well.
And as I mentioned, pq is no pq lambda.
already assume the constant.
So this part becomes the same under this condition.
So this is called the maximum likelihood problem.
The map problem becomes i-m-i-l problem.
So the i-m-i-l problem basically shows you want to find the image.
Find the image.
So this image will generate, generate, you measure the data with the highest probability.
So you keep changing the image.
Once you put the image, this image, same-related data, looks like what you measure.
And this part, the i-m-i-l oftentimes used, and really have the statistical knowledge built in.
And the simple way, like the CT-reconstraxin, let me ask you for a little bit.
CT-reconstraxin, so you got a different view.
The one view looks like this.
The other view looks like this.
You keep putting your underlying image.
I say, underlying image is a star.
And the tree's the star does not look like this.
The tree's the star vertically does not look like this.
And now I put a different side here.
I put a elliptical ellipse here.
The ellipse, you trace it horizontally, you got this profile.
What exactly you got this one? I think these are x-plane.

The elliptical model x-plane data is the best.
Then I say, okay, this is the image.
This is the image I want to report.
And this maximum likelihood is the missing problem to keep putting underlying image.
Then you generate your measurement.
And once the measurement probability is maximized, then you report that is your underlying image.
So this is different from that deterministic CT data fading.
This is in statistical framework.
And we do use the Poisson distribution, plug-in Poisson distribution, because the independence of the measurement and the likelihood can be x-prize as product.
Then you use natural log, you convert the production, the multiplication into summation.
So the formulation isn't that complicated.
But I wouldn't x-plane.
Just let you know.
And we have a statistical perspective to deal with Poisson noise, Poisson distribution.
So the power of this iterative measurement, based in Poisson, is to utilize the specific statistical knowledge.
And you can do better job.
And I show you here.
So you have a phantom.
And you can introduce radio-active tricers into the phantom.
If you assume the measurement, just to reflect the statistical means, and you can use filter the back projection method.
And you do filter the back projection method.
Filter the back projection assumes no noise.
Every measurement is true from line integral.
But in reality, the measurement network is as faithful as true line integral, and has statistical fluctuation.
So the noise is not consistent.
So you have all these artifacts, stripping artifacts, and random noise appearance.
But if you use maximum likelihood, the reconsur-dragson, so those fluctuation will be better explained.
So you will have a little bit better reconsur-dragson results.
So showing here.
And this is a phantom example.
And this is a patient reconsur-dragson results.
So from the patient, if you just do filter the back projection, you have the stripping artifacts, and the noise appearance filter the back projection, give you coronal transsexual and sagittal views.
Very noisy.
And if you do maximum likelihood, the iterative reconsur-dragson, and you build the reconsur-dragson, build the statistical knowledge in the reconsur-dragson process, you see the image quality visually and the quantitatively better.
Okay, this is the example.
And the pilot CT, and we mentioned several times.
So you have CT image, structural and anatomical information, higher spatial resolution.
And therefore, pilot image, you have a radio-trisher distribution, and there's a lot of accumulation in this organ.
That means the basculature is rich, and trying to take a lot of nutrition since it's too grow.
And the pilot trisher, and we explained earlier, the inter-sugar glucose.
So this is the like nutrition components.
So all accumulated here, and that's just the by-the-sign tumor growth in this area.
So if you superimpose pilot image or CT image, so you see the contacts very well, and by the way, the CT image, CT linear-tiny-resistant coefficient, is used to correct the tiny-resistant background.

And if you do not do, if you do the uniform tiny-resistant correction, the lung usually is kind of an iron-feeling organ.
So you assume our reason, a tiny-resistant background.
But therefore lung, that's an over-cal.
So if you do uniform tiny-resistant correction, the activity in lung will show higher, because you correct them all.
You tend to think this measurement due to a lot of tiny-resistant in the lung.
So you correct it for that.
You add more value.
But actually, through lung reason, the tiny-resistant is much weaker.
So if you use uniform correction, you may report higher activity.
So that's the problem.
If you assume uniform tiny-resistant background.
So the type CT, the CT, gives you specific individualized tomographic details.
So the lung CT number is low.
So you report low CT number in the lung reason.
Then you use the piece of ice linear mapping.
You get relatively low tiny-resistant coefficient at 511 kV.
So you will get better results.
So this is an activity.
So all these activities, and I think indicated tumor just bright out.
It's not good to see.
But after treatment, you do paticity again.
You see this little bit of core amazement.
And the mass reduced activity, that shows the treatment is effective, has been effective.
So this is paticity.
And the CT is not very sensitive to soft tissue contrast.
CT is good.
Remember the CT amazement is good for life, so you have gold ring.
So the amazement shows CT good.
I mentioned to you, tissue IR interface, bone, bone tissue interface.
But soft tissue contrast is not very good.
So the part is, I'm an I, it drives that problem.
So the I'm an I, has very good soft tissue contrast.
You see better sitting here.
But I'm an I, not good for bone-easter structure, and the IR imaging, or long imaging can also see much.
And also, I'm an I, we will start I'm an I, from next lecture.
And I already play recorded because I will be out of time.
And I do suggest you to preview IMI, it's different modality.
IMI take a longer time, special resolution agent that I go and the maximum expanse of.
But if you combine, pilot and IMI, you do have unique organosis, information, and for brain, and for soft tissue, tumor, and so on.
So this is very, very cutting-edge technology.
Okay? The IMI moved to the fourth part, talking about system architecture and the scatter correction.
Okay? So this part kind of, kind of easy.
Okay? So look beautiful picture.
So this is a spiked scatter.
So you have a spiked camera here, a gong trie, just hold the things together, and you can rotate it.
So you can collect data from different orientations.
And this is like CT.
You rotate, I actually shot in the detector around the patient, the same idea.
Okay? The spiked can be standard long-sown here.
And also, like the pilot CT idea, you can talk about a spiked CT.
Okay? So this is spiked, two spiked camera, even you can use three spiked camera to acquire data simultaneously.
So in this case, if you only use one, one plane gamma detector, or gamma camera, and the data into this direction and downwards, will be wasted.
So if you have triple detector, you can utilize gamma photons, more effectively.
Okay? So this is CT, and again CT is used to give you an atomic complex, and

also information for a tiny way is correct, the same idea.
And for pilot imaging, you have a detector ring.
Okay? And you can do human, also you can do small animals, because pharmaceutical companies use small animals to test the drugs.
So you have different faces when they develop a new drug.
You need to know how hundreds new drugs, potentially useful.
They do cellular cell cultures, that small animals, that they may take a progeny, a trial, a clinical trial, many stages.
And only small, small fragments of drug-candidates will eventually intermarket.
That's why it's so expensive.
So the pilot rings, you really have gamma detectors and associated circuitry.
So you can have the signal and also timing.
And you make sure in the same time window report a pile of gamma photons then you can report a even along line of response.
So you have a line of response.
So radio-treature distributions along the line I did together and it's a line integral.
And the tiny wave coefficient is basically independent, can be factorized out.
So this is a big picture.
If you look at components details and you have multiple figures and the power of the unit chapter.
So you have a Sintelesian crystal in front of the module.
So this Sintelesian crystal will convert gamma photons into visible light.
Visible light will be captured by little bit bigger components called photo-multiply-chew-visit.
So the crystal can work a gamma-multiply-chew-visit.
And the photo-multiply-chew-visit takes a photo-visible light.
That multiply means I'm play-five.
So I'm play-five the photo-optical signal into electrical current.
The output electrical current.
So after this chube you have some circuit.
And this is a report the electrical impulse.
And it depends on the amplitude of impulse.
You can infer the energy of interacting gamma-refortance.
And this is called one block.
And the multiple block put together called a back-head.
And the multiple back-head make a ring.
So you collect data together.
And there are some engineering details.
And the digital property of the crystal material.
And I will go quickly with you.
So it will be high density.
So you have larger effective cross-section.
And you want to have a larger effective atomic number.
Again, that will give you high gamma-re-detection efficiency.
And the soft decay time.
And the temperature will be very fast.
Otherwise, one photon coming in to keep emitting visible light.
For a long time, the time rate is loosen would then be good.
So you want to have a high light yield.
So the light signal is one of the states.
So you want to have a high efficiency.
And every state.
The wave lines of light signal prefer at 400, about 400 nanometer.
This is for engineering reasons.
Because the photon multi-plier tube works best for these wave lines.
And also the reference index should be near 1.5 for optical coupling.
And also the crystal should not absorb the moisture.
It's very strongly done.
The nanometer will compromise.
It will just be...
Maybe just the crystal will become a poders.
It just becomes not workable anymore.
So all these are desirable properties.

And mainly candidate materials.
And I couldn't remember.
I don't want you to remember easily.
This is no...
Engineering details.
And mainly detectives people working in this area.
So key components for part detectives.
It is harder about this.
The crystal make into block.
And this background you have multi-plier tube.
And you make a ring.
So you have a ring.
The signal will be precise by co-easier than the precise unit or co-easier than the detectives in the circuit.
So you have this power-like processing capability.
You basically monitor the electrical signal.
Which means the gamma photons detect the capture in the crystal.
So you want to know when, why they happen at water energy.
Because the generic primary gamma photon has energy 500 11 kV.
If you have multiple scattering, the energy will be lost in constant scattering.
Okay, you have all these things.
Finally, integrated in data side.
So you have to do the computer.
And you do reconstructing.
The database takes reconstructing a simple filter of the background for the Jackson.
It will give you cross-sectional image.
So this is just a rough idea.
The technical advancement for part-image in pretty much in detector technology.
Again, it is a long-laced, different technology.
And the miles-done years and the image quality.
So just for your information, I don't want to spend too much time.
So outside promise for a system to work at the base.
The noise and the scatter and the random events should be estimated and removed.
So this is a nice summary.
So true event means you have single annihilation.
Then you have two photons emitted and detected by opposite detectors and the capture by the circuit.
So this is true.
So you really want to have this.
And the scattered photon and the half-different mechanisms.
So this shows the scattered photon.
So you have the event.
And this goes this way, that's scattered away.
So you report, you report coincident along this way.
But it's not true.
So it's not the real signal you want to utilize.
This scattered pretty much like CTs scattered.
You want to remove the random thing, just too many possibility.
Like in this case, you have two gamma-refortant generated.
One, this is this way.
The other gamma-refortant inside the body.
So you got it tiny weighted and you got it lost.
And in the same time window, you got another event.
And this goes this way.
And the other photon got it tiny weighted.
So the system will report coincident along this line.
This is not true.
So we want to avoid.
So when you use 3D, you can see the image in the scattered and the random event will be more.
So you want to keep the sensitivity due to wider aperture, 3D data acquisition.
And you want to minimize scattered event and random event.
How can you estimate the scattered background, so this simple street forward.

So you set the energy window around the peak.
You got this part.
And also, you have live and right window.
You collect things because you know the primary gamma-refortance.
Our energy is 511.
So it should be in this range.
And if you got scattered, the energy will be lower or some other thing.
And we will be higher, multiple random things.
We recorded them in these windows.
Then we know in the lower and the higher window, the scattered is not what we want.
And we kind of do weighted our reason of the data in lower and higher energy window.
We think that gave you this scattering background.
Then we remove that.
So you remove the scattered components.
You estimate the scattered.
Then you measure the scattered components in the main window and remove it.
So this shows you the result.
So this is the real measurement.
And you have the scattered background is they made it.
You remove scattered background.
So you have these corrected measurement or corrected reconstructing.
Result, scattering problem.
So this scatter correction is a key point.
And the random correction, this is a very, very cute idea I think.
Okay.
If you have the random event recorded this way, this is a probability thing.
So if you do your usual data precision and this kind of random event will introduce noise.
And we can purposely.
So for each part of the detector, we introduce a delay.
So if it is a random coincidence, we would say the probability of the random event, race and result delay will be the same.
This is a key statement.
Oh, this is key line.
So if you introduce the delay, introduce the delay, or the coincident, you report.
It's not true.
This is coincident probability for this kind of incident.
Race the delay and result delay is the same.
Because this random thing, you are assuming the gamma rate delay is, this is the mean, the gamma rate, redirectivity level is more or less constant.
This is the delay, doesn't make any change.
Okay.
You can, as they made the random event, remove that from your data.
So this will make your data higher quality.
So you result more quantitative.
So this is the idea.
There are multiple high-order effects, like the water I show here, and the EU figure.
So you try to get coincident detects, but definition, at a given time window, you have only two gamma rate photons captured.
If the time window is short enough, so you count of 100,000, that's a principle.
But the chances are that given you, you small time interval, you may get three gamma rate photons reported simultaneously.
How that could be happened? For example, this is the event.
Okay.
Closer to detect the two.
So the gamma rate photons, first, the risk detect the two.
Okay.
Remember, it recorded this.
You have an event.
And within that time window, we happen to have another event here.

Closer to detect the 13.
And the temperature by that detect.
Then this sister photon, travel the long way, finally reach the detect, before the sister photon, for second event reaching detect five.
So within this time interval, three photons reported.
And whenever you got three coincident detects, the detects photons, and we think this is the confusing.
And you just discard the data.
Okay.
So you have this by the time loss, you have triple photon, you just discard this.
And you say you just possibly may see the two coincident.
But you also have a wide confusing confusion.
You don't know which way to assign the event to reach line of response.
So you can use the crack-synfactor.
And those truly double the mean pilot photon detects.
And the blast water you discarded for this triple event.
Okay.
You can consider other high-order components.
So you probably will be small, but you could really solve the time window.
You'll detect it, say, ten-igumery photons, or together.
This is a higher order, highly unlikely.
But all these things you discard.
And all the read of the data loss times the total time of data acquisition.
That is, they may take how much you lost.
And you have the true measurement.
So this is a lot of estimated loss, plus two measurement, the divided by true measurement.
It's a crack-synfactor.
So you can bring back the measurement to the real level.
This is the estimation.
So graphically, so you see this.
So the total count, the total measurement, the signal one or image contains two components.
Two components.
You have a scatter by ground.
Random counts, and the whole different weird things.
And you can, as they made, random count by delay, and the triple coincident, you correct.
And there may be a dozen ways, but the most important thing, and the curve order in this lecture, for you to have a rough idea.
These are all these corrections.
The tiny ways of corrections, scatter, and random corrections, and the divided time corrections.
And you make your line integral data, reflect the true line integral.
So you reconstruct the image, really reflect the concentration of the radio-trisher in the organ of interest.
And you can do so for each organ, and the follow, each time instant, instant during the pattern imaging size.
So you can plot the time curve.
You can check the profusion.
So you guide more physiologically correct parameters, and the more diagonals, the information.
So this is about the essential idea of a quantitative table pattern.
I want to summarize, pattern and the spiked imaging, and this slice.
I particularly say the data model different, and this is a lower energy, and again the technology should be gamma.
So this is the, this is needed to refine little bit.
So the spiked imaging level 140, little bit lower energy.
So you can use mechanical collimator.
So the x-ray type of, x-ray level energy can be blocked by highly metal.
But for pattern, the energy too high, 500, 11 KV.
And we don't use mechanical collimation.
We use, we use electrical collimation.

So whenever you use mechanical collimation, you rejected a lot of gamma ray photons.
But if you use electric, electronic collimation, in principle, you do not block any useful gamma ray photons.
So the path sensitivity is fundamentally higher than spiked sensitivity.
And this is part of the emission, really provided in here and the clock.
These two things happen simultaneously.
So the time information becomes available.
But for spiked imaging, and you don't know when the radio-treature emitted gamma ray photons inside the body, you don't have a time scale.
Like x-ray imaging, we want to do, why was the PIGT student? And I consider how about using time information to do x-ray imaging.
Again, you don't have a timing standard.
For x-ray imaging, and you can now control precisely when the x-ray photon is emitted.
So then even you can time when the x-ray photon arrives at the detector.
You don't have the reference.
But this part of the emission gives you the timing possibility.
You can do time-resolved imaging very sensitively.
And the show is fancy idea.
The leading researcher in the field considered to make a pattern detector very large, called the whole body pattern.
The high sensitivity will be even higher.
So you will have a much more sensitive and global picture.
The interesting idea you can consider.
And you do whole body pattern, you do whole body CT.
Whole body CT uses a lot of radiation.
But the whole body pattern you see you don't have place to put x-ray components around the patient.
But I think, we actually want students working on the possibility to do this part of the CT simultaneously even for whole body.
Whether we use some different idea, out of box idea, involving the MRI technique, we could talk about that later on.
Another point need to put a green button here.
So the sparkly camera, and you use a pinhole camera to take one picture.
But here, there is all the papers.
You put a silent pinhole.
So you can form a small pinhole, you can form one image.
The double cone image is geometry.
You put a silent pinhole, you have seven images.
And the easy images is really review-labeled heart.
So one time, one accuracy, you got seven views simultaneously.
So they tried to make kind of street immational reconstructions of the heart from seven views to results.
It wasn't very impressive.
But one possibility you make seven views from one direction.
Then another seven views from orthogonal direction.
And the most modern signal processing technology, we may have opportunity to do image reconstructions that are way better.
Anyway, so this is just for your information.
And we will have a fully 3D meeting in China.
So this is the website.
If you are interested, you can take a look.
And we will do the meeting in Xi'an, it is an ancient capital of China for 13 dynasty states.
And in the center of the city, they have this built tower.
So every morning, it just knocked the bell.
So you get up, so you use the bell tower to synchronize live over all the dynasty states.
This is the city.
We very much look forward to half the meeting.
Having the meeting and enjoying the tour and the so on.
So interesting thing, they designed a logo of fully 3D meeting.
The pretty much like the bell tower, the city bell tower.

Why build a logo like this? Because we see the reason, so the meeting is full.
CT, spiked, and the pattern reconstructions.
So you have saws, 2D detectors, combing, geometry.
And this part, remember, you have, this is a collimator.
You have a crystal layer, a photo multiply tube.
So this is really do spiked the image.
And this base is the pattern ring.
So you have this to put the together.
So you have this to the animation, that's the order.
But anyway.
And also we are building a fully 3D community.
So the people and the students in the area can just do learning and some job.
Other world testament and the south of the world.
So this is a hardening being up yet.
And anyway, so much for today.
And today is a homework and I'll list five here.
You could do more.
And about these things, this is also sensitive imaging.
Really, I already mentioned a little bit.
So you have two views.
But these two views, you compensate in the way you kind of I mentioned earlier.
They assume a long binary, you only have a one source distribution.
So you can just do the multiplication.
Some how you can compensate.
But it's not general solution.
And also for the second question, how many total counter necessary for 1% is uniformity.
Given 100 by 100 data matrix for example.
And these things are not that complicated.
Use the power zone distribution and some signal sensitivity things.
So the answer is kind of straight forward.
And also when you compute the energy of the gamma refotom for positive and emission, is 500, 11kV, you use E equal to Mc square.
And just the exercise.
So you can check Google find the rest of the mass of electron, positive and you have this number.
And other things kind of straight forward.
If you have questions, we will ask a TA to pause the answer later on.
But you should do your own exercise.
And this is just so much for today.
And the next lecture TA will work with you show my prerecorded lecture.
And I will be back next Sunday.
So I think I only gave one lecture.
So much for today.
Any questions? And those of you who I received to email, I hope all of you are today.
Okay.
Thank you very much.
Thank you.