Discussions Before the Research Paper

Example 1 - How to improve 'Finding Higgs particles at LHC' ?

Question: I would like to discuss the prospects of finding Higgs particles in my final paper and presentation.

Reply:

1. what is H mass region you propose to improve?
2. what is the source?
3. what is your Method?
4. what is your Detector?

Question:

Prof. Chen,

1. I will look for H mass < 2 Mz ~ 180 GeV
2. I think it makes most sense to discuss this in the context of the LHC, so the source will be p-pbar
3. The method will be looking at invariant mass yields of the dominant b-bbar decay mode (possibly some others e.g. 2 photon events)
4. Again I would probably like to talk about this in the context of a detector at LHC. Should I pretend I am designing my own detector, or would it be more useful to work in the context of an existing detector and design an analysis method?

Any questions? Advice?

Reply:

By LHC, You mean the source will be p-p collisions

It is most useful to design your own detector, by modifying an existing LHC detector and design an analysis method. For example:

How well can the existing LHC detectors measure the directions and energy of the photons?

How well can the existing LHC detectors distinquish an isolated photon from a high energy neutral pion?

What are the expected signals?

What are the expected background?

How do you propose to improve?

What are the expected S/N ratio with your improvements?

Min

Example 2 - How to improve Higgs search at Linear Colliders, many years after the LHC have operated:

Question:

Dear Prof. Chen,

I remember you told me that I should explain in my paper why LC would be better than LHC at discovering the Higgs and measuring its properties. I'm now starting this effort and I would like to ask you to what level I am expected to rely on previous analyses.

What I mean is that there are several analyses which predict the performance of LHC and LC. They are complicated and lengthy, using software to make numerical calculations, simulation of the detector, events production etc. I think it is obvious that I can not repeat those analyses by myself, neither are there any analytical calculations I could make. So, I would like to know please if I can just refer to such analyses, present diagrams of their conclusions and briefly describe how they proceed if necessary.

I'm afraid my work will mostly be bibliographical, since this topic (SM Higgs at the LC) is well studied already. How "bad" would that be?

Reply:

It is ok to refer to such LC designs, LC limitations (e.g. luminosity, power comsumption, etc), analyses, present diagrams of their conclusions and briefly describe how they proceed.

Think hard about

Is there anything which we can improve from their analysis?

How to improve their detectors?

How to improve their S/N?"

How do we know the Higgs are longitudially polarized?

What should we do if the Higgs is still not found?

Min

Question:

Dear Prof. Chen,

I would like to ask you for some guidance. I've finished describing my accelerator (the LC), the source of electrons and positrons, some beam issues etc. I have not described the detector yet, but I think I should first get sure what analysis I want to do and then adjust the detector to the requirements of this analysis.

At the moment I'm thinking of measuring the Higgs mass through higgstrahlung (ee - Z - ZH). If the Higgs mass is big enough, then WW fusion will be the dominant production process. Would that be sufficient to consider those two cases and explain how I would measure the Higgs mass and how my detector should be?

Reply:

The higgstrahlung (ee - Z - ZH) and the (if Higgs mass is big enough) WW fusion are both very clean. So your tasks are:

1. How well can the Higgs mass be determined?

2. How to determine the (longitudinal or transverse) polarizations of the W's and explain why and how the polarization may reveal new physics?

Min

Question:

Dear Prof. Chen,

I'm having difficulty and I would like to ask you what to do. I'm reading the TDR for TESLA and I see that I could increase the luminosity of my beam by increasing some parameters: One way would be to double the repetition rate from 5Hz to 10 Hz and also increase the # of bunches and the charge per bunch. But if I write those suggestions, then I will need to justify whether this is technologically possible. For example, increasing the charge per bunch would require greater currents coming from the particle sources, as well as stronger magnets to control the beams, I guess. Increasing the repetition rate would require faster electronics (?) maybe (by the way, would that be true? 10 Hz don't look hard for the electronics to handle).

But I'm afraid that there will be more issues that will be affected by jiggling those parameters. I probably can not think of all of them, and even if you tell me, for example, that I would need to upgrade my Data Acquisition System, it would be very hard to get into so much detail and finish in 2 weeks.

So, how detailed should my suggestion be? Is it OK to write the luminosity formula, and then express some ideas as I did in this e-mail, and simply say, "faster electronics and stronger magnets should be used"?

Reply:

increasing the charge per bunch certainly requires greater currents coming from the particle sources, as well as stronger magnets to control the beams, but to increase the luminosity; you must keep the same phase space since particles of the same charge push each others apart!

Increasing the repetition rate would NOT require faster electronics from 5Hz to 10 Hz, but the acceleration time from source to linac to booster to cooling ring to LA from 5Hz to 10 Hz.

to upgrade Data Acquisition System: it means to design a trigger logic to select the events of interest. For example, if you want to select 4 isolated muon events, first define experimentally how to make sure it is a muon; next define 'isolated muons' by defining their energies, pt, and the maximum hadronic energy allowed around each muon; finally you require a 4-fold coincidence. You estimated the random trigger rate from background to conclude that the trigger rate is NOT too big. It is the logic required, not the program codes.

So, write the luminosity formula, and express some ideas, and then discuss the phase space limitation, trigger logic, event rate, etc.

Min

Question:

Dear Prof. Chen,

I have a question regarding the design of my detector.

I need it to be big in order to have better angular resolution. If the calorimeter shells are far from the interaction point then I will be able to distinguish particles that would otherwise hit the same cell. On the other hand, I want to fill the interior, before the calorimeters, with a tracker, and since I'm not worrying about money, I would like to fill it with finely granular silicon microchips, like those that will be used in the CMS inner tracker.

I wonder how big my detector can be, because if the particles have to cross too much tracker material then they will have lost too much energy before reaching the calorimeters. I would find it very helpful if you could tell me how you would choose the radius of your detector for 500 GeV e+e- collisions. I had the idea to do some calculations using the radiation length of electrons and muons in silicon, but then I realized that it would be naive, because I want also to detect positrons, hadronic jets etc, which interact in more complicated ways with the silicon of the tracker.

Could I do something else, like the following?

I imagine around the interaction point the tracker, equipped with a magnetic field. Then, after the tracker, a few meters of vacuum, without magnetic field. After this layer of vacuum, at a big enough distance, my calorimeters. In this way, I hope I would be able to know the momentum and the charge of the particles from what the tracker would tell me, then I would extrapolate their trajectories as straight lines in the vacuum layer, since there is no B-field there, and then I would read their energies with my calorimeters.

In this way I would combine a not too thick tracker together with a high angular resolution for my calorimeters.

Reply:

• The size needs to be reasonable.

• Separately define the required angular resolutions of the gammas, e's, hadrons, and the muons.

• Separate the EM calorimeters from the hadron calorimeters.

• Mass resolution depends not only on the angular resolution.

• Angular resolution depends not only on the calorimeter angular resolution, but also on multiple scattering, magnetic field, etc.

• For EM calorimeters, the total material of the trackers and of the beam pipes must not exceed a small fraction of a rad length.

• For hadron calorimeters, how good angular resolution is required?

• B-field is continuous. A certain boundary conditions must be satisfied. How to make a magnetic field inside and then, after the tracker, a few meters of vacuum, without magnetic field?

Min

Question:

Dear Prof. Chen,

I would like to ask you something about the analysis of ee - Z* - ZH
please.

I understand that I need the tracker to recognize particles (for example to be able to distinguish photons from electrons). In this way, combining information from the tracker and from the calorimeters (ECal and HCal) I will be able to determine the energy of the Z. Then, the mass of the Higgs is automatically known:

(m_H)^2 = (m_Z)^2 + E^2 - 2 E E_Z

Where E = CMS energy (like 500 GeV).

So, I don't need to know the momenta of the products of the Z too well, because I only need it to reconstruct the invariant mass and get sure that 2 particles are coming from the Z (if I find m_invariant about = m_Z). I'm not trying to measure the mass of the Z, so I don't need to reconstruct the invariant mass extremely accurately. I only need it for identification.

Then, in the above formula, I will use the m_Z that has been measured in so many other experiments with very good precision.

Please, tell me if my logic is right, or if I should try to independently measure m_Z and use _my_ number to determine m_H.

Reply:

Your logic is wrong for the following reasons:

1. There is background due to ee--4 jets and ff+2jets, which can distinguished from ZH by the mass of the Z!

2. Also how do we get E_Z? By measuring the momenta of the products of the Z well!

3. The invariant mass of the Z is broad, so you can not assume it is at the central value!

So, you should measure m_Z and use it to determine m_H.

Min

Question:

Dear Prof. Chen,

Could you please tell me the differences between a silicon tracker, a gas tracker and a CCD tracker? Which one is more accurate and what are the disadvantages of each kind?

Reply:

Silicon tracker: ~100micro-m resolution in one direction per layer, fast readout in parallel;

A gas tracker: ~1000micro-m resolution in one direction per layer, fast readout in parallel, with amplification; and

A CCD tracker: ~10micro-m resolution in two directions per layer, usually slow (20MHz per channel) readout in series, no amplification (i.e. large noise) except EBCCD (electron bombarded CCD, developed by collaborators, and me which has gain ~5000).

Min

Question:

Dear Prof. Chen,

I'm a little confused, about the z-size my detector should have. I would like to have coverage up do angles with cos (\theta)=0.98.

In the LC, the tube at the interaction point will be very fine, only 10mm radius. So, I calculated that to have acceptance up to cos (\theta)=0.98 I need to have my tracker expanding in the z-direction only 4.9cm. It means that the total thickness of my tracker does not need to be greater than 2x4.9 cm. Is it reasonable? It looks too thin to me. Of course, the detector in total will be longer, because I'll also have the endocarp calorimeters, but still, can the tracker
be so thin?

Reply:

No, the tracker can NOT be so SHORT AS 2x4.9 cm.

Let the total thickness of THE tracker be L and you want to cover up to cos (\theta)~0.98.

The length of the tracker is 2 * (10mm + L) / tan (\theta) + beam bunch length.

Define beam bunch length.

L needs to be sufficiently large in order to measure the angles and momenta of particles well.

Also, how serious is the radiation from the beam to the trackers at r=10mm?

Min

Question:

Dear Prof. Chen,

Could you please tell me if I can improve the TESLA Muon System (MS) by replacing the Resistive Plate Chambers (RPC) with silicon? I've put silicon everywhere, in the ECal, HCal and now I would like to put it in the MS as well, since I've "infinite money".

In the TESLA TDR they plan to make 12 layers of RPCs, separated by 10 cm of radiator (iron).

By putting silicon instead of RPCs I will have small tiles of active material. So I will have very good spatial resolution to distinguish muon trajectories from pion showers. Is that right?

How can I estimate the energy resolution of my silicon MS? The RPCs MS is simulated and will have
$ \DeltaE / E \simeq 135%/\sqrt{E} + 20% GeV $

Reply:

To put silicon in the HCal is a waste of money and effort, without improving resolution.

Not much better for mu detectors, nor for ECal.

The vast # of cables alone, required for read-out, would kill you and the resolution.

Min

Question:

Dear Prof. Chen,

I checked it again and you were right about the ECal of TESLA. It is mostly designed to be good at jet energy resolution. I think I should keep the sandwich type of ECal, because Z mostly goes into qqbar.

However, the calibration is done for electrons-photons. The 11%/\sqrt{E} and the 14%/\sqrt{E} refer to photons energy resolution. If I need it later for the analysis, should

I use that energy resolution for jets too? I can not find anywhere the calibration for hadronic jets...

Reply:

The calibration for hadronic jets has to be done in combination with the HCal.

The resolution will be much worse than 11%/\sqrt{E}.

Min

Question:

Dear Prof. Chen,

Please, read this email in HTML mode (not plain text) if you can.

I'm stuck in something computational, and it's very long to explain, please excuse me for that.

My purpose is to get an e+ e- pair and measure its invariant mass (mInv) to compare it to the mass of the Z (mZ). This is easy:

mInv^2 = (E1 + E2)^2 - (**p** 1+ **p** 2)^2 ==

mInv^2 = (E1 + E2)^2 - p1^2 - p2^2 -2 p1 p2 cos(Du)

where Du := The angle that separates the two leptons.

Given the mass of the Z (mZ), the mass of the electron (me), the energy of the Z (EZ = mZ), and the angle U at which the Z decays in its rest frame, I can calculate the Du in the above relationship, as well as the momenta p1 and p2. All I have as free parameters is the EZ and the angle U (from 0 to 180). Of course, in the experiment I will not know those parameters, but now I'm exploring my model... I can express all observables in terms of EZ and U and see how they are expected to vary, so as to know what range of values I will observe in the real experiment.

For example I calculated Du and I saw that it will be greater than 45 degrees for EZ<240 GeV and for all U's.

Back to the point now:

delta(mInv^2) --- write it as dmInv2 to make the notation shorter

From the relationship which gives me mInv^2 I calculate:

dmInv2 = 2 Sqrt[(EZ*dEe1)^2 + (EZ*dEe2)^2 +

((p1 + p2*Cos[Du])*dp1)^2 +

((p2 + p1*Cos[Du])*dp2)^2 +

(p1*p2*Sin[Du]*dDu)^2]

where:

dEe1 is the uncertainty in the energy of electron 1 (Ee1)

dEe2 is the uncertainty in the energy of electron 2 (Ee2)

p1 and p2 are the amplitudes of the 3-momenta of the leptons 1 and 2 respectively.

Du is the angle that separates the two leptons.

dp1 and dp2 are the uncertainties of p1 and p2.

dDu is the error in the measurement of Du.

Knowing the masses (mZ) and (me) I can *analytically* calculate:

Ee1, Ee2, p1, p2, Du, WITH (EZ) AND (U) as free parameters

Then, in order to calculate dmInv2 I need to determine-calculate the errors with which the above quantities

will be measured. I'll explain how I do that, analyzing the terms one by one:

I have proved that with an ideal tracker of resolution delta(p_transverse) = K * (p_transverse)^2, and of 10 micrometers spatial resolution, the resolution in the FULL 3-momentum of a track will be smaller or equal to:

delta(p)_max=K * p^2 (delta(p)=delta(p)_max when p=p_transverse).

For my specifications, it will be bigger than about

delta(p)_min ~ 2/5 * delta(p)_max = 2/5 * K * p^2.

The exact value of delta(p) depends on the orientation of the track in the tracker, but those are the extreme values it

takes, approximately.

dDu I regard to be (for my ideal high granularity tracker) about 10^(-6) rad. I'll let it vary later to see the impact it has on dmInv2.

So, I have found a formula for dp1 and dp2, I also can assign a number to dDu, and here comes the harder part, which is the dEe1 and dEe2. There are two approaches:

(1) to use only the calorimetric information. Then dEe = 0.11*Sqrt[Ee] (I neglect the constant term).

(2) to use the tracker's measurement of pe to find Ee (since I know me). Then dEe depends on dpe and has to do with how good my tracker is.

dEe := dEe_tracker = (pe^2 / Ee) * dpe = (analytic _expression of EZ and U) * K * pe^2 = analytically calculable, given the specification of K.

I tested both those methods. The best results come from method (2):

Sqrt[dmInv2] is very slightly dependent on dDu, is more dependent on K. As a function of EZ and U,

it oscillates cosinusoidally with U around a central value (*meandmInv*) which is determined mostly by EZ.

For K=3*10^-5 GeV^-1 and dDu=10^-5 rad, in the region of EZ from mZ to 240 GeV, I found:

(1) Using the ECal with the 0.11 factor:

meandmInv about 13.84 + 0.1127*(EZ-mZ) (GeV)

(2) Using the Tracker to find the energy of the leptons:

meandmInv about 4.01 + 0.145*(EZ-mZ) (GeV)

In the range EZ from mZ to 240 GeV, method (2) gives smaller meandmInv

Close to EZ=240 GeV they both give me approximately meandminv ~ 27 GeV.

Now, after this long analysis (which will be an appendix of my term paper, I guess), I would like to ask

you how well Z will be identifiable, given this uncertainty of about 25 GeV in the invariant mass of the e+ e- pair. Is the experiment still functional?

How can I make the precision higher? I obviously can not make a simulation so I try to do "phenomenology" to estimate my errors. This computational effort has taken me too long already, so I would like to ask you if I should change "strategy" to be in time, or if it would be possible to omit the discussion on the H-WW polarization identification.

Reply:

There are serious mistakes in your computation of errors!

1. Show the detailed computation on:

a) delta(p)_min ~ 2/5 * delta(p)_max = 2/5 * K * p^2.

b) dDu ~ about 10^(-6) rad.

c) K?

2. Wrong (!) are the following: dEe := dEe_tracker = (pe^2 / Ee) * dpe = (analytic _expression of EZ and U) * K * pe^2 = analytically calculable, given the specification of K.

3. Some errors are correlated while others are independent. Treat errors rigorously as we did in Calculus and Functional Analysis!

4. Reminder to all in 8811: Every research paper must include sections on error computation as well as statistical analysis.

Min

Questions:

Dear Prof. Chen,

I am now working on writing down my calculations. I used Mathematica extensively, and I have some chaotic multiline equations that I plot... It will not be possible to write everything in my appendix, but I'll certainly include the results.

Today I made a critical step which makes me think that what I'm doing is not wrong. I had dmInv2 (using the same notation as in my previous email), but I erroneously thought that the uncertainty in mInv would be dmInv=Sqrt[dmInv2].

Actually, it will be dmInv = dmInv2 / (2 Sqrt[mInv2])

I just made those calculations and I found the error in mInv to be below 10 GeV, which is pretty good I think, given the Gamma(Z) which is about 2.5 GeV.

So, I think I'm on the right track and I'm having good results, I just need to write down as much of it as I can and show you the plots I see here. The, the things you wrote me to be wrong appear as rigorous results in my appendices.

Thank you very much,

Reply:

2. Dimensionally Wrong (!) are the following: dEe := dEe_tracker = (pe^2 / Ee) * dpe.

dEe ~ dpe when me ~0.

The error in mInv needs to be much less than 10 GeV, and also much less than the Gamma(Z) which is about 2.5 GeV.

Your computation is incorrect for the following reasons:

1. The effect of multiple scattering

del theta = 15mrad * sqrt(material in rad length) /p in GeV

must be included in p and mass computation! This will make resolution worse!

2. As I pointed out earlier, but apparently you have not appreciated the importance, E and p of the same particle are correlated and this will make the mass resolution much much better!

Min

Question:

Dear Prof. Chen,

Thank you for that formula. I was unaware of it. I will try to use it in my computations.

Excuse me, I do appreciate every hint I can get, but I must have not understood. You must be referring to what you wrote me: "dEe ~ dpe when me ~0".

In the appendix D.2 (2nd approach using the Tracker) I use E=Sqrt[p^2 + m^2]. The Tracker approach makes my resolution better indeed. Is it what you mean?

Reply:

1. After you include the effect of multiple scattering

del theta = 15mrad * sqrt(material in rad length) /p in GeV, the Tracker resolution will not be much better than the ECal resolution for high energy e.

2. "As I pointed out earlier, but apparently you have not appreciated the importance, E and p of the same particle are correlated and this will make the mass resolution much much better!"

No, using "dEe ~ dpe when me ~0" or E=Sqrt[p^2 + m^2] makes no big difference in mass resolution.

3. "Some errors are correlated while others are independent. Treat errors rigorously as we did in Calculus and Functional Analysis!", i.e.

2 M dM ~ ... dE - ... dp ---- sqrt(...... dE^2 + ... dp^2) after statistically averaging, only if E and p are 100% uncorrelated. There are cross terms!!!!!!!!!!!!!!!

4. Reminder to all in 8811: Every research paper must include sections on error computation as well as statistical analysis. These two sections are on information processing. Information processing are the MOST IMPORTANT part not only in your research paper, but also in almost every project, not limited to Physics, which you need to find the best way to use in your life.

Min

Question:

Dear Prof. Chen,

In the measurement of m_H using the Z recoil mass, what is the (main) systematic error? Let's say, the 0.1% error in the beam energy is systematic? I think it is not, because the beam energy varies randomly + or - 0.1%, it is not something steadily off. But, let's say the uncertainty in the mass of the Z is a systematic error (correct me if I'm wrong), because I use m_Z in my calculations assuming a value, while there is a probability that this value is a few MeV off *all the times that I use it*.

Could you please give me an example of a systematic error?

Reply:

The (main) systematic error:

Let's say, the 0.1% error in the mean value of the beam energy (not the spread, because the beam energy varies randomly + or - 0.1%, it is not something steadily off!) is systematic.

The mass of the Z is measured from the E and p of the Z decay products, NOT from assuming a value. E and p have systematic errors due to magnetic field mis-calibration and tracker mis-alignment, also drift velocity maybe temperature, pressure and electric or magnetic field (which maybe systematically off!) dependent.

Jet energy is measured by ECal and HCal and is uncertain due to fluctuation of the fraction of neutral (pi0) energy in the jet. 2 jets are not completely separable (particles between 2 jets belong to which jet?).

Biased due to human scanning? Selection?

Min

Question:

Dear Prof. Chen,

I would like to ask you about the main background to my channel, which is ee -- Z* -- ZH -- lepton lepton + things I do not do anything with.

You said that Z gamma production is the main background. However I can not find any reference to this background in the literature.

e+e- -- Z gamma has a cross section, which is 20 times greater than the higgstrahlung cross section.

If the gamma is produced as initial state radiation, then I expect the energy of the Z to be 500 GeV minus the energy of the emitted gamma. But can the gamma have energy greater than 100 GeV, to be taken for a Higgs? And even more, how probable is it that the photon will give jets? I found papers about the Zgamma production, but they all refer to the gamma as a hard gamma that they detect (it does not transform to anything else).

Reply:

There are also background

e+e- -- Z gamma
e+e- -- Z Z

e+e- -- W W

e+e- -- e+e-+ 2 jets (mainly from gamma + gamma--jets).

Min

Example 3 - How to improve Neutrino Oscillations

Question:

Dear Prof Chen:

I think I have in mind what I want to write about: Neutrino Oscillations. Could you please spare me some time and give me some guidelines?

Reply:

1. What is your Neutrino sources:

a) solar Neutrino Oscillations,

b) atomsphere Neutrino Oscillations,

c) reactor Neutrino Oscillations.

2. which channel: e, mu , or tau Neutrino?

3. how to improve detectors in order to get a much bigger sample?

4. how to reduce systematical errors?

and here is a grand review paper: http://arxiv.org/PS_cache/hep-ph/pdf/0405/0405172.pdf

Min

Question:

Dear Prof. Chen:

I have a naive idea. Can we change Super-K water into Heavy water? In this way, although it does not distinguish between Muon-neutrino and Tau-neutrino, it can get the total flux of them. Compared with the Muon-neutrino flux in the beginning, we will be able to get to know whether the Muon-neutrino oscillates into Tau-neutrino or Electron-neutrino. Well of course, we suppose there are only 3 types of neutrinos, i.e., no sterile neutrino.

Reply:

Is your purpose to change Super-K water into Heavy water is to increase the index of refraction to detect lower energy particles?

Is it not better to

1. increase the incoming nu energy?

2. use glass instead of water? How about salty water?

Min

Question:

My purpose is to detect Tau-neutrinos. I want to ask how they tell a muon-neutrino from an electron neutrino right now, using pure water?

Reply:

To detect Tau-neutrinos, one need to see the secondary vertices of the tau and the multiple-particle decay products of the tau.
To tell a muon-neutrino<--------produce a mu (using the Cherenkov ring size and shape)

from an electron neutrino <----------produce an e, now, using pure water.

Min

Question:

Dear Prof. Chen,

One way to check for cosmic neutrino oscillations is to vary the distance that the neutrinos travel. Would it be possible to improve on the accuracy of the Super K data by building two additional detectors: one much deeper underground, and one at the surface of the Earth but underneath Mount Everest for shielding?

Reply:

Building two similar detectors at different distances is a good idea.

Is it really necessary to be underneath Mount Everest? How many collision lengths are needed for shielding against (what?) backgrounds?

It is easier to vary the distance that the neutrinos travel from reactors or accelerators, where you can also vary the energy of the neutrinos.

Min

Question:

Dear Prof. Chen:

I wanted to get my detector to see Tau-neutrinos. But I do not really know which material to use. I know DONUT experiment once use emulsion to see Tau-neutrino. What else can I choose?

Reply:

I. Before one designs a detector, one should 1st list the properties (energy, decay particles, cross sections, track length, beta, ... of

1. Signal: Tau-neutrinos,

2. Background: mu-neutrinos, neutrons, gammas, ...

Make such a table first.

II. Next make a table of detector properties (size, energy resolution, position resolution, angular resolution, beta resolution, etc......:

Emulsion, Ge, LXe, CCD, ...

Min

Question:

Dear Prof Chen:

I made a table. And I found that the way to detect tau-neutrino is to make use of its track length, which is fairly short, 2um. The material which we can use have to have a spatial resolution smaller than that: Emulsions can do as good as 1um. Ge could get down to 2um. LXe's response time is excellent, but its spatial resolution is not good enough to see tau.

I want ask where I can find a table listing all the properties of the detectors. Right now what I did is to search on the web, finding a bit info here and there, not systematic at all.

Reply:

For summary, see Particle Data Book.

Tau track length is 2um at what tau-neutrino energy?

How about increase the energy to get larger track length?

Can we not detect the decay products (3 or 5 pions) to ID tau?

Min

Question:

Dear Prof Chen:

I think I need to use "one prong" tau decay to identify tau.

One of the channel I am looking at is tau-lepton+lepton neutrino+tau neutrino.

Another one If we choose tau - pion + pion0 + tau-neutrino. We can reconstruct pion0 from pion-2gamma and pion - muon + anti-muon-neutrino. This channel has quite a big branching fraction. But is it hard to detect gamma at high energy?

Reply:

You have not answered my questions on the determination of the 2ndary vertices.

Why should you use only "one prong" tau decay to identify tau?

tau - 3 or 5 pions + tau-neutrino is perfect to ID taus. In addition, the determination of the 2ndary vertices is more precise with multiple-prong events.

Yes, we can reconstruct pion0 from pion-2gamma and pion - muon + anti-muon-neutrino.

gammas at high energy can be detected by E-Cal or converter + trackers.

Min

Question:

Dear Prof. Chen,

You have mentioned that having more than one detector is a good way to reduce systematic errors from the detector. If the detectors are built the same, what kind of errors would be reduced this way and why?

I don't understand how having two detectors eliminates systematic errors.

Reply:

Rate = flux * sigma * target * efficiency * oscillation for detector 1 or 2, So

rate2/rate1 = oscillation2_1

Min

Question:

Dear Prof Chen:

I have some difficulty in how big my target should be to get enough events I need. For high-energy neutrinos, when it passes through the material, I do not know how to get the cross section for the DIS events.

Reply:

The cross section for neutrino quark scattering is given in 12.8 in the textbook Q&L.

Min

Ps a recent paper: Title: Status of global fits to neutrino oscillations
Authors: M. Maltoni, T. Schwetz, M.A. Tortola and J.W.F. Valle
Comments: 41 pages, 22 figures, 2 tables. Updated version of two, three and four-neutrino oscillation analyses including new K2K and solar neutrino data as well as detailed analysis of the KamLAND results and their impact on constraining theta_13. Accepted review for publication in the Focus Issue on Neutrino Physics of New Journal of Physics" edited by F. Halzen, M. Lindner, and A. Suzuki; v4: short appendix added providing updated results which take into account a new background source in Kamland data Report-no: IFIC/04-19, TUM-HEP-548/04, YITP-SB-04-29
Journal-ref: New J.Phys. 6 (2004) 122
\\ (http://arXiv.org/abs/hep-ph/0405172 , 284kb)

Example 4 - Search for SUSY as dark matter by nuclear recoil

Question:

Hi,

Last class I asked you about detecting lightest supersymmetric particles as dark matter by nuclear recoil, and you asked me how model dependent it would be, and how one would tell the difference between high-energy neutrinos and heavy neutralinos. First, I'm looking at a neutralino interacting with a nucleus through Z exchange, which I don't see as violating R-parity. So the models I would be able to set limits on would be the ones which have the lightest supersymmetric particle be fairly heavy, above 100 GeV or so, and be the principle component of cold dark matter, so they drift around at around 3% the speed of light. Secondly, the detector design has a very small cross section for light neutrinos. I'm considering making a modification of the detector used in the Edelweiss experiment, which was basically a big hunk of germanium crystal kept quite cold. For each impact, they measured the ionization in the detector and the heat added to the detector, and could use the ratio of the two to separate charged particles from neutral ones, so as to get rid of muon and electron backgrounds. The trick is that slow moving neutralinos interact coherently with the entire nucleus, thus having a much higher cross section than neutrinos, leaving the only neutrons to contribute a significant background. For the project, starting with this detector, I'd like to examine how to change it to improve limits on the ratio of neutralino cross section to density (assuming they are the principle component of dark matter), or possibly modify it to look for something slightly more exotic, such as heavy neutrinos mentioned in one of the papers you suggested. Does this sound like a reasonable project? Is there anything you think I should focus on specifically in the paper?

Reply:

It is a good project.

Answer the following questions first:

0.3 c moving neutralinos is not so slow. What is its wavelength ~1/E?
Why does it interact coherently with the entire nucleus, which is bigger than its wavelength?

If indeed coherent, find the ratio of neutralino cross section not only to density but to the atomic # A!

Plot the crosssections for high-energy neutrinos and heavy neutralinos as function of energy for given neutralino masses.

What are the final state particles produced and how best to detect?

What directional dependence of the reactions is expected?

Min

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5. Searches for Extra Dimensions at the Tevatron

Questions:

Authors: Muge Karagoz Unel
Comments: 10 Pages. Proceedings, Hadron Collider Physics (HCP 2004), E. Lansing, Michigan, USA
\\
Models in which gravity and/or Standard Model gauge bosons propagate in more than three spatial dimensions have implications that can be tested at current colliders. In this paper, we report on the results from searches for extra dimensions at the two Tevatron experiments, CDF and D0, which utilize up to 200 pb^-1 of proton-antiproton collision data from Run II taken at 1.96 TeV CoM energy, between spring 2002 and fall 2003. \\ (http://arXiv.org/abs/hep-ex/0411067 , 160kb)

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6. Looking for dark matter (WIMP) by detecting gamma rays

Questions:

Dear Prof. Chen,

I would like to discuss about my project with you.

(I) Physics of my project
My project is looking for dark matter (WIMP) by detecting gamma rays. I think the signal and background I am trying to look at is

signal: monochromatic gamma rays with an energy equal or close to the WIMP mass produced by WIMP annihilation into gamma gamma and Z gamma.

Background: gamma rays produced in neutralino annihilations through pi0 decays + the cosmic ray induced gamma rays, which also mostly come by pi0 decays. They give a continuum spectrum and can be described by a power law.

The difficulty is most gamma rays generated in WIMP annihilations are through pi0 decay. The branching ratio for XX-2 gamma can be very small, maybe no larger than 1%. However, the good thing is it has been suggested in some papers that if the gamma lines pop up in the region around 100GeV, it may be large enough for discovery. An even promising thing is some papers point out in very high mass range above 1 TeV, pure higgsino can have the 2 gamma channel as one of the dominant annihilation modes. If so, I only need to have a powerful enough gamma ray detector, which can cover TeV energy range. My difficulty to understand the physics of this is:

1. it says that the "light" neutralino is likely to reside in the region 30-100GeV. How to estimate the mass of neutralino?

2. in order to know whether it is possible to see the gamma line signal poping up in a certain energy range, say 100GeV, I should estimate the BR of XX-2gamma and XX-Z gamma. How to do this? I found a paper about the calculation of this (http://arxiv.org/abs/hep-ph/9706232), but I don't quite understand and need your guidance. And also I don't see how to estimate the BR in it.

3. The method is quite sensitive to the dark matter density distribution. I found a paper that suggests a way which they claim less model dependent.
Phys. Rev. Lett. 87, 251301 (2001)
Spectral Gamma-Ray Signatures of Cosmological Dark Matter Annihilations
http://scitation.aip.org/getabs/servlet/GetabsServlet?prog=normal&id=PRLTAO0000870 00025251301000001&idtype=cvips&gifs=yes

Would you please give some comments on this? Should I put big effort on the DM density distribution model in my project?

II) Detector
One of the upcoming big gamma ray projects is GLAST, which can cover up to 100GeV. I want to make my detector referring to this one, which is basically made of precision tracker, calorimeter and anticoincidence detector. In order to see gamma line signal, my detector need to cover high energy, up to TeV if possible, and have large collection area. The energy resolution is not necessarily very high, 10%-20% may be OK. As for the angular resolution, I am not quite clear what does this do with my purpose. Should I need high angular resolution? Would you please give me some clues? I think the major difficulty is to make a detector that can cover such high energy. Would you please give me some guidance on this? I am not familiar with detectors. Would you please point out some references from which I can study these detectors?

Sorry for bothering you during the holiday weekend and listing so many questions. Actually I am quite willing to open the discussion with you. The problem is I think I know too little and I am not ready for discussion. So I always prefer to reading some papers and learning first. But it seems that sometimes it is not the most productive way, I will be stuck by tons of questions. I will modify my way to study in the future. Thanks for your patience and happy holiday weekend!

Reply:

I. Rates:

1. the "light" neutralino is unlikely to reside in the region ~30GeV. You should search it assuming the mass of neutralino is 100, 200,... GeV.

2. We obtain the cross sections for XX-2gamma and XX-Z gamma by dividing the v*sigma of the above reactions given in the paper by v and then integrating over density function of x as function of v.

3. The searches should be done for different models of the dark matter density distribution.

II) Detector
To detect high-energy gamma rays, precision tracker is not important, while precision EM calorimeter with rough directional capability to point back to the vertex will be very useful. So is anticoincidence detector.

TeV gamma rays can be detected similar to, not much harder than, 100GeV gamma rays since the shower length is only 1-2 r.l. longer for TeV gamma rays than the 100 GeV gamma rays.

Min

Question:

Dear Prof.Chen,

I've got some questions.
I Rates:

In order to know whether the XX-2gamma and XX-Zgamma induced gamma line signal is large enough for discovery (distinguished from the background), I think I am also interested in the BR of these two reaction. It says in some paper that the BR of XX-2gamma is typically no larger than 1% with the largest values of V*sigma, for neutralinos with a cosmologically significant relic abundance in the range 10e-29 to 10e-28 (cm3 s-1), but it didn't say how to get it. Would you please give me some clue on this?

2. detector

To estimate how many r.l I need to detect TeV gamma, can I use n=ln(E/Ec)/ln2, Ec is the critical energy, I assume it 100MeV approximately.

Reply:

I Rates:
In the paper Phys. Rev. Lett. 87, 251301 (2001)
Spectral Gamma-Ray Signatures of Cosmological Dark Matter Annihilations,

v*sigma for XX-2gamma and XX-Zgamma, etc were separately given, so br of XX-2gamma is simply v* sigma(XX-2gamma)/total v*sigma.

2.detector

To estimate how many r.l needed to detect TeV gamma, one needs first to decide how accurate the E measurement needs to be. E resolution is determined by the fluctuation in the shower leakage beyond the active detector as well as the intrinsic resolution of the ECal. For example, 24 r.l. is sufficient to get 1% E resolution for TeV gamma.

However, what determines the detector size is not just how thick the ECal is! It is ....

Min

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7. the determination of T_critical for QCD

Question:

Hello professor,

I'm considering writing a paper on the determination of T_critical for QCD, the point on the phase diagram where hadrons undergo a change from 2nd-order to 1st order phase transition. I don't fully understand all the theory -- not surprisingly -- but it seems like the heavy ion program at LHC + some changes to the current detectors would be good candidates for detecting a signal that would yield an answer to questions about the existence/location of T_crit.

Does this seem like a reasonable topic?

Reply:

Yes, it is.

1. Understand the physics and current limits,

2. Define your signal,

3. How to detect the signal?

4. Estimate the background.

Question:

We want to determine the position of the critical point for phase transition on the T-mu QCD phase diagram. To do so, we need to examine different collisions that can end up with a hadronic system at freeze out time near the critical point. To understand the physics, I use studies mostly by rajagopal et al to estimate the position of this point using lattice qcd. I motivate it by discussing the qualitatively new states of matter than can be understood and also by relating it to physics of the early universe.

once we know where in the diagram we want to probe, we choose our control parameter: collision energy and nucleus size. Then we choose our observables; the primary ones are pion multiplicities and mean transverse momentum. the way we detect a signal is that near the critical point, we expect nonmonotonic variations in the chosen observables. However, we have a background, primarily from bose-einstein effects that yield non-critical fluctuations. We need to detect fluctuations higher than these to claim to have found the critical point.

A good detector design emphasizes momentum resolution and particle identification in 4pi. A good accelerator needs to be able to run at several chosen energies to accommodate investigation in the vicinity of the critical point.

That takes care of the questions. I will send you more and more detail about the paper from now on so you can see if it's going ok, and I hope you understand that my carelessness did not stem from bad intentions, just many mistakes.

Reply:

Why and how much do pions multiplicities and mean transverse momentum, near the critical point, show nonmonotonic variations? What is the expected fluctuation at critical point?

What is the expected fluctuation (mean and standard error) below critical point?

Any other better signals, like charmonia and bottonia suppressions?

Here is a paper on an alternative approach to the pion multiplicity to search for phase transition in heavy ion collisions.

Min

Question:

Title: A new measurement of J/psi suppression in Pb-Pb collisions at 158 GeV per nucleon
Authors: NA50 Collaboration
Comments: 19 pages, 10 figures. Submitted to Eur. Phys. J. C
Report-no: CERN-PH-EP/2004-052
\\
We present a new measurement of J/psi production in Pb-Pb collisions at 158 GeV/nucleon, from the data sample collected in year 2000 by the NA50 Collaboration, under improved experimental conditions with respect to previous years. With the target system placed in vacuum, the setup was better adapted to study, in particular, the most peripheral nuclear collisions with unprecedented accuracy. The analysis of this data sample shows that the (J/psi)/Drell-Yan cross-sections ratio measured in the most peripheral Pb-Pb interactions is in good agreement with the nuclear absorption pattern

extrapolated from the studies of proton-nucleus collisions. Furthermore, this new measurement confirms our previous observation that the (J/psi)/Drell-Yan cross-sections ratio departs from the normal nuclear absorption pattern for semi-central Pb-Pb collisions and that this ratio persistently decreases up to the most central collisions.
\\ (http://arXiv.org/abs/hep-ex/0412036 , 261kb)