Patrizia Azzi – Lecture 1 Questions

Questions marked in green were answered during the Q&A session. I haven't tried to correct grammar/spelling. Where a slide number was given it is shown.

Thanks a lot for the opportunity of giving more precise answer in written form. Do not hesitate to share my email with the students in case they have further enquiries.

Q1 (slide 11): why polarisation for positron less than that of electron?

A1:

Polarized electrons are produced from Compton scattering of electrons (easy to produce) with a polarized high-power laser beam. Polarisation is 100% transferred from the photon to the electron, and can be preserved upon acceleration. This technique has been used by SLC (30 years ago).

Polarized positron production is much more involved, as they are produced via pair production from energetic circularly-polarized photons (which come from the high-energy electron beam). Polarisation is not as efficient as with the Compton scattering above.

I suggest the reading of Chapter 5 of https://arxiv.org/abs/hep-ph/0507011 for a deeper understanding.

Q2 (slide 27): why does e-L e+R has greater impact from polarization than e-R e+L?

A2:

The answer to this question (which I had troubles to understand!) was already given in slide 30: the HZ cross section is multiplied by $1 - P_- P_+ - A_e \times (P_- - P_+)$.

Exercise: calculate the factor for LR and RL configurations !

Q3 (slide 31): Cross section vs energy for H-e-e (and to a lesser extent for H-nu-nu) has a spike near threshold. What physics is driving this feature?

A3:

I am not absolutely sure (as I am not the one who did the plot), but it may well be due to the fact that the interference term with the ZH graph (with Z -> ee and Z -> nu nu) is included in the Hee and Hnunu cross section.

Q4 (slide 21): Why do the CLIC and ILC increase luminosity as energy increases while FCCee and CEPC reduce luminosity as energy increases?

A4:
Synchrotron radiation energy loss at circular colliders is proportional to E^4 / R. At high energy, the RF power is used to compensate for this energy loss.
At lower energy, it is used to accelerate many more bunches, leading to a much higher luminosity (10^5 times LEP at the Z pole!).
The luminosity increase with energy at linear colliders (~prop. to E) is due to a kinematically increased "focussing" (p_perp constant, p// larger).

Q5 (slide 36): The figure on the left seems to say that we need to know sqrt(s) to ~ MeV. How plausible is this?

A5:

The energy at circular colliders can be known (up to the WW threshold) to 100 - 300 keV than to the natural transverse polarisation (with the resonant depolarisation method, which I did not have the time to describe in detail). It is plausible only at circular colliders. Together with the high luminosity, these are two ingredients compulsory to (maybe) do ee -> H. There are many other hurdles on the way, this is a very very challenging measurement.

Q6 (slide 44): In the case of running at 1 TeV, the blue curve says that measurement precision is order 100%for Lambda = 1.5 times SM. Am I interpreting this figure correctly? If so, what is the reason for the poor performance at this combination of energy and value of Lambda?

A6:

The graph that involves the triple Higgs coupling in WW fusion (nu nu HH) interferes destructively with the other SM graphs. This causes the cross section (see the plot) to decrease while increasing lambda all the way to 1.5, where it is minimal. After that the HHH graph starts to dominate. Since the cross section has a minimum, the sensitivity to lambda vanishes at this value.

Q7 (slide 48): How does polarization help? Naively think that the detector still has to deal with high multiplicity. Is it in statistics?

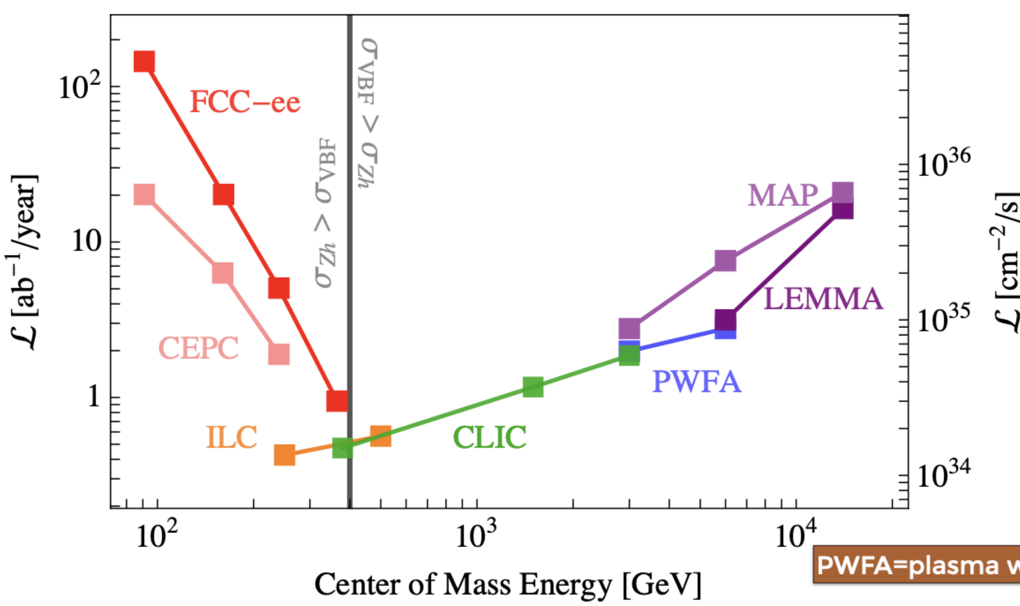
A7:
As mentioned already in slide 27, longitudinal polarisation helps linear colliders to partially compensate for the smaller luminosity than circular colliders.
There is nothing that cannot be done without longitudinal polarisation.
On the other hand, transverse polarisation (using the resonant depolarization method) is the only way to measure the beam energy with enough precision to improve the Z mass and width (and the W mass) by more than one order of magnitude, and is unique to circular collider. Sadly this was one specific topic I had to remove for sake of time, but I will add it back for future presetnations.

Q8 (slide ?): Would other type of lepton colliders eg muon colliders give better bounds than e+e- colliders on higgs couplings to the SM particles?

A8:
The answers needs to be articulated as, in the case of a muon collider, there are several possible center of mass energies considered. Lots of studies currently in progress though. Let's go from low to high √s.
-- A muon collider could be used at √s = mH (mu mu -> H), but here again, the luminosity is too small to be really useful + no absolute coupling measurement.
-- For a Higgs factory at 240-380 GeV, the key element at the end of the day is the luminosity. FCCee > CEPC >> ILC > CLIC > muon collider.
-- For higher energires the dominant production process is VBF.
The performance around 3TeV can be compared quite well with those of CLIC for the same luminosity
-For higher energies, from https://journals.aps.org/prd/abstract/10.1103/PhysRevD.103.013002: we can find the following estimate: 10(30)TeV, Lint=10(90)1/ab, 0.073% (0.023%) for HWW coupling, 0.61% (0.21%) for ZZH coupling, and 5.6% (2.0%) for HHH coupling (which now becomes comparable to the FCC-hh estimate, recently reviewed see M. Selvaggi lecture).
Preliminary estimate for potential measurement of the quartic coupling to 50% at a 14 TeV muon collider, can be found here: https://arxiv.org/pdf/2003.13628.pdf
For more information about the muon collider I invite you to check the links on their official site: https://muoncollider.web.cern.ch/ and https://arxiv.org/pdf/2103.14043.pdf

Fit Result [%]

	10 TeV Muon Collider	with HL-LHC	with HL-LHC + 250 GeV e^+e^-
κ_W	0.06	0.06	0.06
κ_Z	0.23	0.22	0.10
κ_g	0.15	0.15	0.15
κ_γ	0.64	0.57	0.57
$\kappa_{Z\gamma}$	1.0	1.0	0.97
κ_c	0.89	0.89	0.79
κ_t	6.0	2.8	2.8
κ_b	0.16	0.16	0.15
κ_μ	2.0	1.8	1.8
κ_τ	0.31	0.30	0.27



PWFA=plasma wake field Acc.