Follow up on SB2009

- physics impact, things to be studied ...

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Given the discussion we had yesterday, maybe I don't need to repeat this again, but it might be useful to reflect on what kind of lessons we have learned.

RD's SB2009 WG

M. Thomson, T.Markiewicz, K.Busser, A.Miyamoto, K.Fujii, J. Brau,
M.Berggren, T.Maruyama, G.Norman, D.Miller, S.Boogert

- Charge (my understanding)
  - Identify issues concerning the possible impact of the changes from physics & detector point of view.
  - Reevaluate and clarify the requirements from projected ILC physics to the machine performance.
  - Investigate the issues and validate/invalidate the SB2009 design.

Major Concern

Impact on ILC physics

- SB2009 optimized only at 500 GeV (tradition since RDR?)
- Afterall we need to know how
    - L(Ecm)
    - delta E(Ecm)
    - Pol(Ecm)
    - BG(Ecm)
    - and their stability

  differ from RDR and how they affect the ILC physics performance.
- Potential processes at Ecm < 500 GeV to be affected
    - Higgs studies
        - Recoil mass (mh and total ZH X-section)
        - BR measurements
    - Various threshold scans
        - ttbar threshold
        - New particles
    - WW, giga-Z, ...

What has been happening?

Interactions between GDE (Acc.) and SB2009 WG (Phys.)

- What has been happening
  - The first list of questions has been sent to the GDE
  - A note from the physics CTG, suggesting studies to be made by the physics & detector community
  - A couple of exchanges of messages between the WG and the GDE to clarify the issues addressed by the questions
  - Preliminary answers from the GDE to the first list of questions from the RD's SB2009 WG shown by B.Foster at AD&I Meeting
  - Work plan made and sent to the GDE.
  - AAP suggestions on SB2009
  - The discussion we had yesterday!

Q's & A's

Interactions between GDE (Acc.) and SB2009 WG (Phys.)

Question 1

Beam parameters at 250, 350, and 500 GeV?

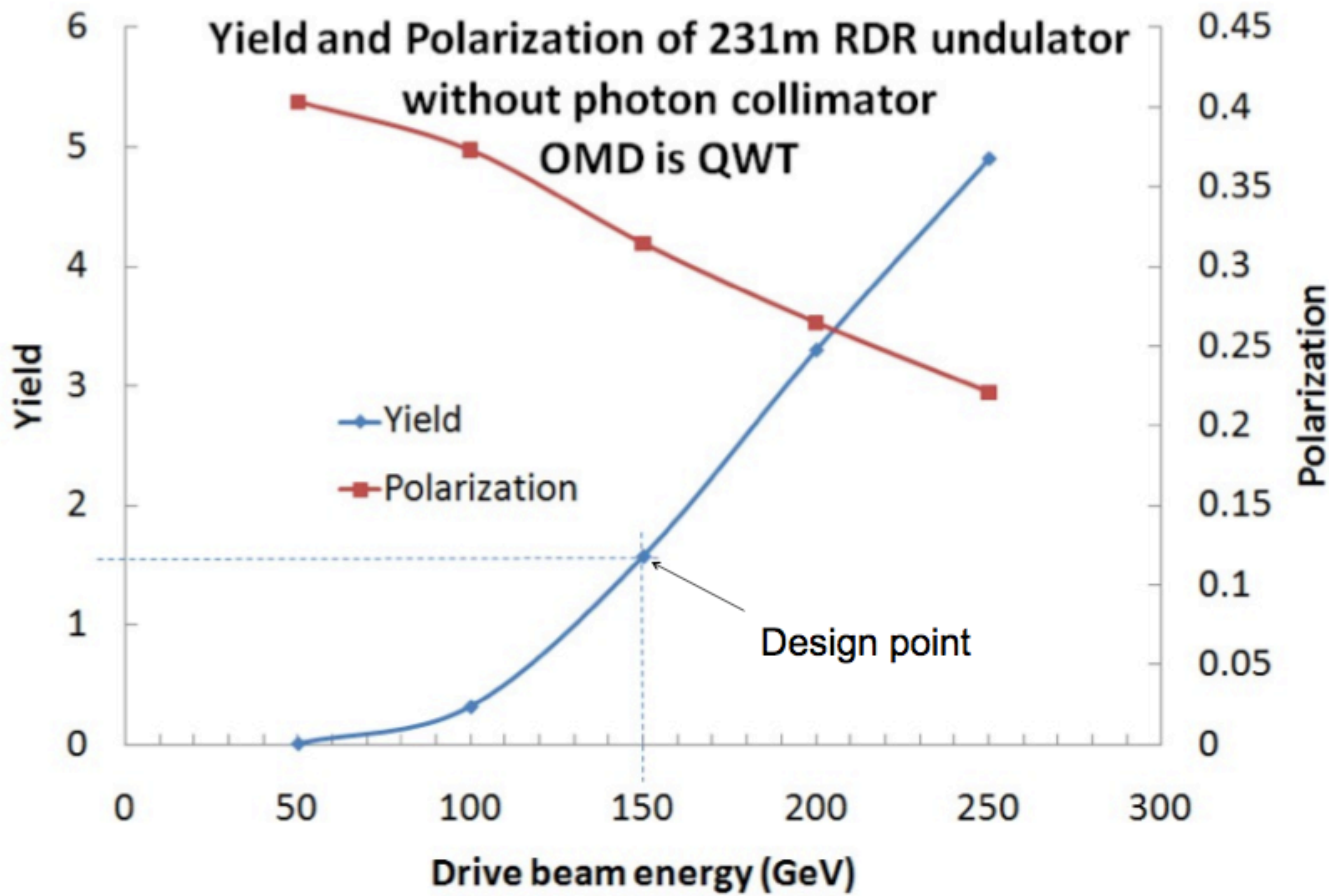
It turned out that

- The SB2009 value of L(250GeV) was about 1/4 of that of RDR!
  - This means about 1/8 of that at 500GeV.
- There was no official RDR design for Ecm=250GeV!
  - The machine has been optimized primarily/only at 500 GeV!

Important rules which we should know

- $L(E_{CM}) \propto E_{CM}$ since $\epsilon(E_{CM}) \propto 1/\gamma \propto 1/E_{CM}$ -> x 1/2
- $L \propto \#\ \mathrm{bunches/train}$ -> x 1/2 (Low Power)
- $L \propto \mathrm{positron\ yield}$ -> x 1/2 (see the fig. in the next page)
- Optimizing beta helps a little but limited by collimation depth.
- Maybe we had better consider TF as a bonus, not guaranteed.

Source Yield



Question 2

Electron/positron energy spread?

dE/E in %	250 GeV CM	350 GeV CM	Official 500 GeV CM
RDR, electrons	0.272	0.194	0.136
RDR, positrons	0.180	0.129	0.09
SB09, electrons	0.220	0.218	0.207
SB09, positrons	0.130	0.093	0.065

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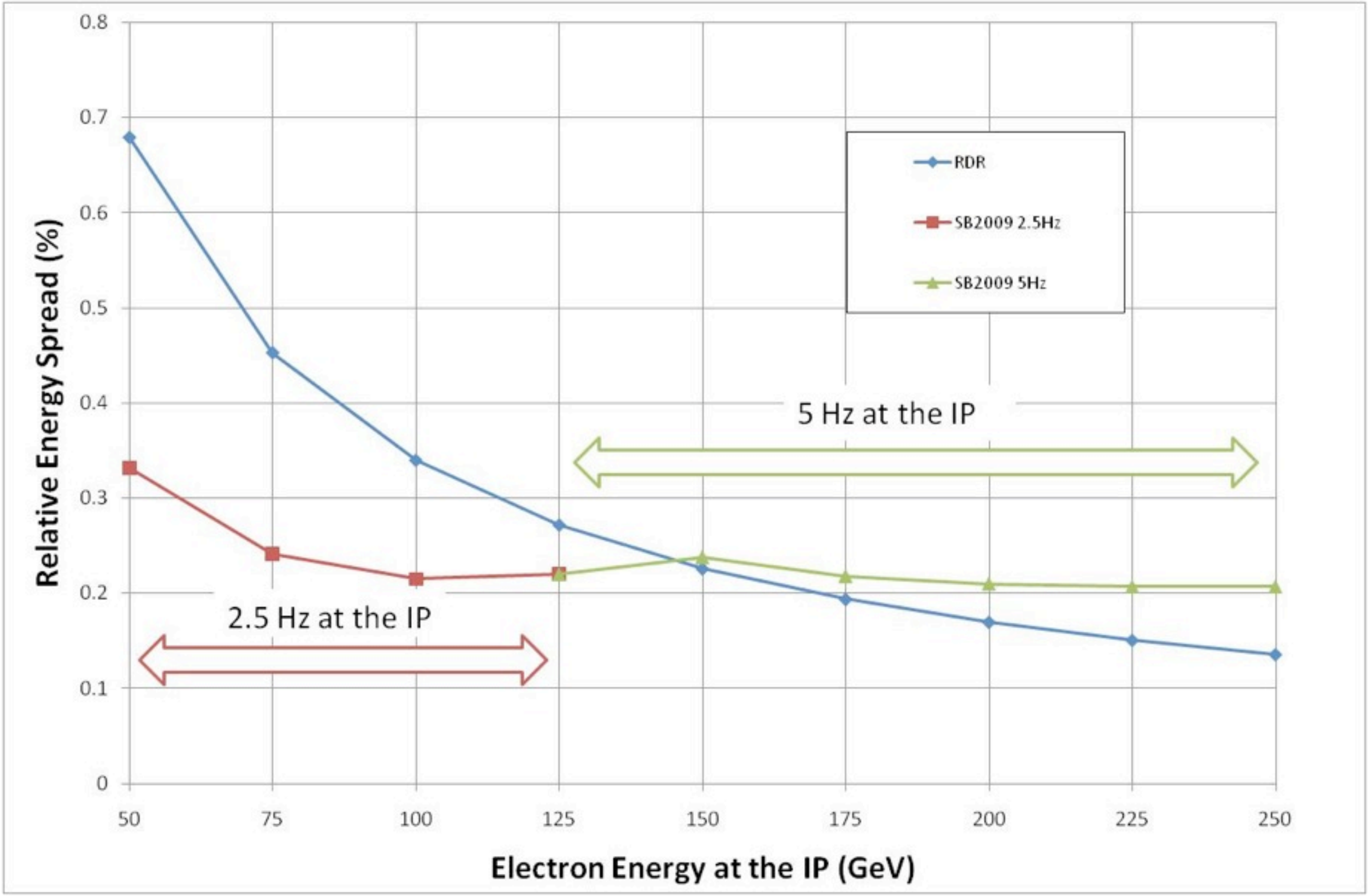
It turned out that

- The SB2009 values are not very much different from those of RDR.

Important rules which we should know

- Inherent energy spread in the main linac is E-independent
  - Determined mainly by how each bunch is on the RF crest.
- Electrons passing the undulator emit SR and have a larger spread
  - No additional spread in the 2.5Hz mode.

Questions



0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Relative Energy Spread (%)
50
75
100
125
150
175
200
225
250
Electron Energy at the IP (GeV)
RDR
SB2009 2.5Hz
SB2009 5Hz
5 Hz at the IP
2.5 Hz at the IP

Question 3

BG and luminosity spectrum?

	RDR			SB2009 w/o TF				SB2009 w TF			
Par/E	250	350	500	250.a	250.b	350	500	250.a	250.b	350	500
δE %	0.6	1.2	2.4	0.3	0.6	1.6	4.1	0.3	0.6	1.6	3.6
Npairs* 10^3	97	156	288	48.7	97.4	214	494	57.4	115	255	596
L	0.75	1.2	2.0	0.2	0.22	0.7	1.5	0.24	0.27	1.0	2.0
L (1%)/L	0.97	0.92	0.83	0.98	0.96	0.88	0.73	0.94	0.89	0.77	0.72

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It turned out that

- BG at 500GeV is about a factor of 2 larger.
- More beamstrahlung at 350GeV -> Effect on ttbar threshold scan?

Important rules which we should know

- Optimization of L means squeezing the beams at IP, leading to higher beamstrahlung and hence higher pair BG.

Question 4

Conventional positron source?

- I will skip this, since it does not matter how the positrons are created as long as there are enough from physics point of view, though technically it is a very important issue.

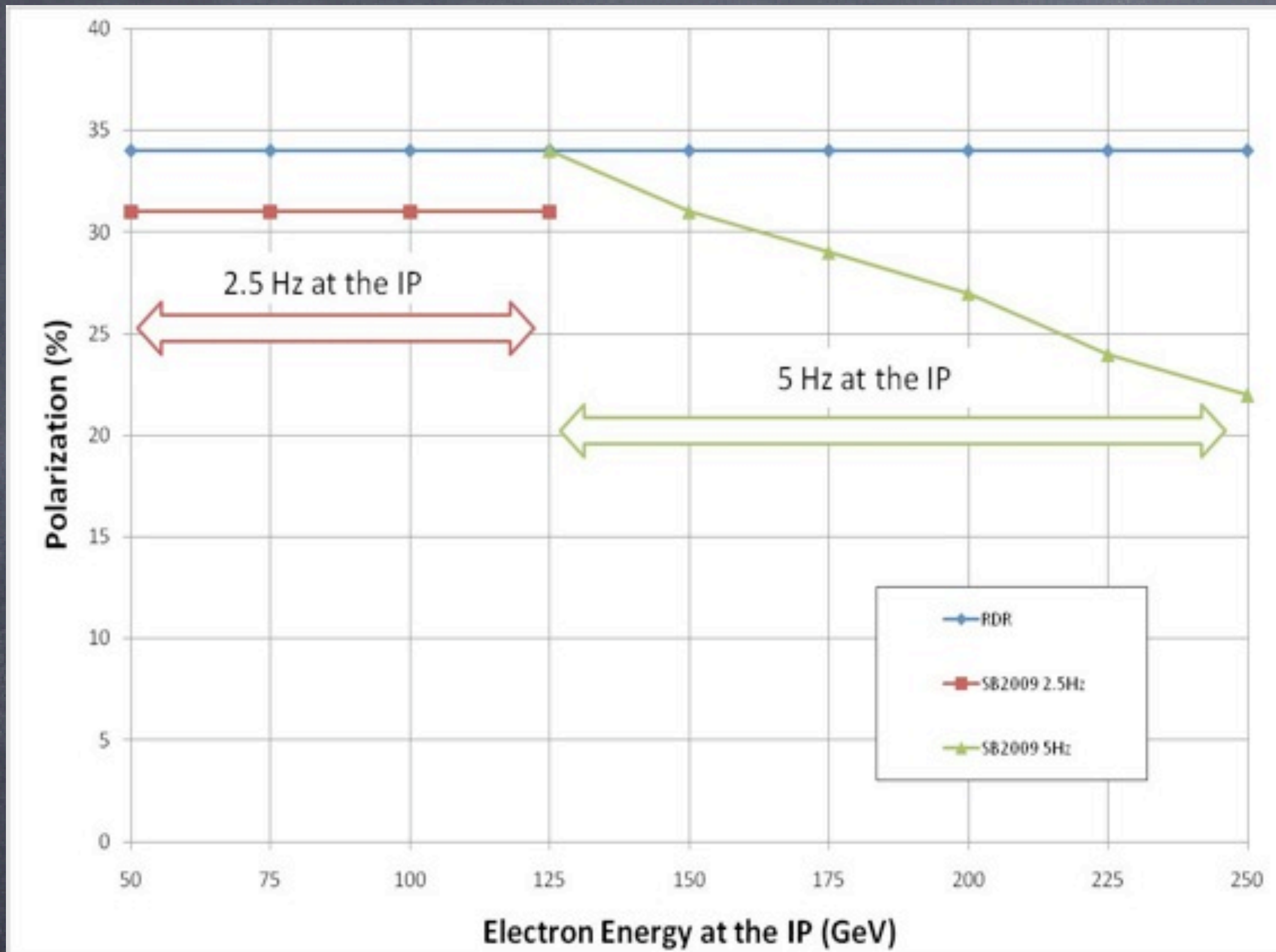
Question 5

L, delta E, and Pol(e+) stability during a threshold scan?

- GDE required us to be more specific about
  - energy range (energy points)
  - luminosity/point
  - timescales
- We should provide the answers to GDE

Question 6

Sketch of L(Ecm), delta E(Ecm), and Pol.e+(Ecm)?



e+ polarization

e- polarization
unchanged @~80%

L(Ecm) and delta E(Ecm) : next page

Beam Parameters

	RDR			SB2009 w/o TF				SB2009 w TF			
CM Energy (GeV)	250	350	500	250.a	250.b	350	500	250.a	250.b	350	500
Ne- ($*10^{10}$)	2.05	2.05	2.05	2	2	2	2.05	2	2	2	2.05
Ne+ ($*10^{10}$)	2.05	2.05	2.05	1	2	2	2.05	1	2	2	2.05
nb	2625	2625	2625	1312	1312	1312	1312	1312	1312	1312	1312
Tsep (nsecs)	370	370	370	740	740	740	740	740	740	740	740
F (Hz)	5	5	5	5	2.5	5	5	5	2.5	5	5
γex ($*10^{-6}$)	10	10	10	10	10	10	10	10	10	10	10
γey ($*10^{-6}$)	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
βx	22	22	20	21	21	15	11	21	21	15	11
βy	0.5	0.5	0.4	0.48	0.48	0.48	0.48	0.2	0.2	0.2	0.2
σz (mm)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
σx eff ($*10^{-9}$ m)	948	802	639	927	927	662	474	927	927	662	474
σy eff ($*10^{-9}$ m)	10	8.1	5.7	9.5	9.5	7.4	5.8	6.4	6.4	5.0	3.8
L (10^{34} cm^{-2}s^{-1})	0.75	1.2	2.0	0.2	0.22	0.7	1.5	0.25	0.27	1.0	2.0

Low Power

?

- Major difference between SB2009 and RDR is L @ 250 GeV. Naively this would be 1/4 RDR – optimisation saves a bit to make it ~1/3.

Suggestions from Physics Panel

Remarks on the SB2009 Machine Design

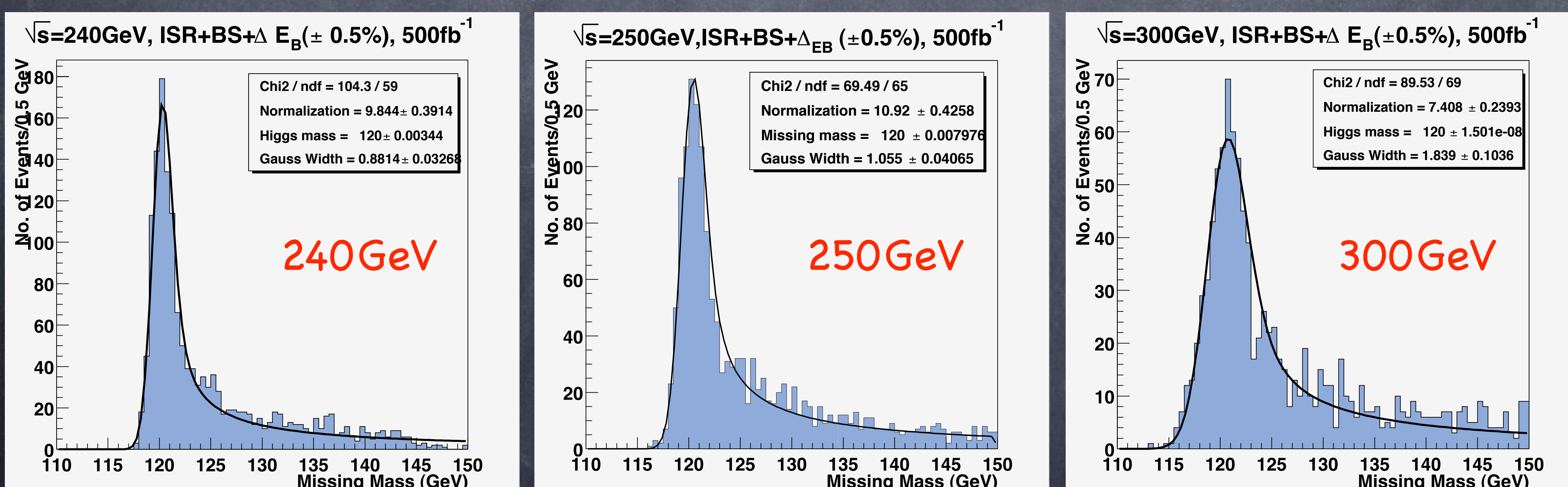
ILC LOI Common Task Groups Physics Panel

- A crucial question about SB2009 is the machine performance at center of mass energies lower than 500 GeV. In the ILC program it is very likely that there should be long periods of running at energies lower than 500 GeV to study the Higgs boson couplings with high statistics and to study the top quark threshold region. This is relevant to the SB2009 design because that design gives a lower luminosity than previously expected at energies below the peak energy.

  The $t\bar{t}$ threshold running must be done at the threshold energy, about 340 GeV. For the Higgs couplings, the optimal condition would be running at an energy of about $m_h + m_Z + 20$ GeV, which maximizes the cross section and minimizes background processes. This corresponds to 230 GeV for $m_h = 120$ GeV. However, ? we expect that the experimental conditions are not very sensitive to the energy, so that this program could be done at a higher energy as long as the statistics are adequate. (As we point out below, we recommend that this statement be evaluated by the LOI groups.) ? In that case, the optimal energy would be the one that optimizes the product of the luminosity and the cross section $\sigma(e^+e^- \to h^0 Z^0)$. To understand that optimization, we need to know the expected luminosity performance as a function of energy, as was already requested by the SB2009 Working Group.

It seems to us important to specify the amounts of running that would be needed at these lower energies. We estimate these as follows: To achieve the accuracy in Higgs couplings of a few percent, which should be a goal of the ILC, a luminosity sample of about 250 fb^{-1} at the Higgs cross section peak would be required. With this data sample, the measurements are still statistics-limited. They would profit from increased running up to 400 fb^{-1}. If the running is done at higher energy, these luminosity estimates should be increased to obtain the same total number of Higgs events. The main goals of the $t\bar{t}$ threshold program would achieve their theoretical systematics limits at about 100 fb^{-1}. We hope that the LOI groups will refine these estimates of needed luminosity in the light of more detailed studies.

Recoil mass measurements could be significantly deteriorated by the worse tracker resolution at higher energies



Old ACFA Study by Akiya

More from Roman

These studies can be performed as parametric analyses and do not require full detector simulation. Here are the studies that are, in our opinion, the most important:

1. Dependence of the Higgs coupling measurement accuracies on E_{CM} and $P(e^+)$ for an assumed fixed $\mathcal{L} \cdot \sigma(e^+e^- \to Zh)$
2. Dependence of the Higgs recoil mass on δE_{bm} and Ecm
3. Dependence of BR$(h \to c\bar{c})$ on R_{vtx}
4. Dependence of the top quark mass on the machine stability parameters

The ability of the ILC to measure b and c forward-backward asymmetries at 500 GeV, a study that is proposed in the new set of benchmark reactions, is also affected by R_{vtx}; and the dependence on this parameter should be evaluated as a part of this study.

SB2009 WG Work Plan

Response to the GDE's answers

PRECIS - The very low SB2009 luminosity at 250 GeV will have a negative impact on the physics strategy of the ILC. This is a major concern. Detailed studies are underway to quantitatively address this concern, and the implications of the other SB2009 parameters.

The ILC physics community is studying the impact of SB2009 parameters on the physics program of the ILC through a set of studies being carried out by members of both LOI detector groups. Important physics processes are being recomputed with the SB2009 parameters provided by the GDE Physics Questions Committee. It will take some time for these quantitative studies to be completed. The detector groups are making a best effort to deliver preliminary results by the end of January.

One qualitative conclusion is easily reached. The GDE Physics Questions Committee document provides semi-official estimates of luminosity at 250 GeV center of mass energy which are significantly lower than what has been assumed for the LOI studies. This low luminosity would make it difficult to perform the Higgs physics measurements with the prescribed precision, a major motivation for the ILC project. This is a serious concern for the physics community.

The following studies are being carried out:

- Effect of traveling focus on pair spatial distribution and hit density in vertex detector and forward calorimeter -> Mikael
- Study of impact of increased hit density in forward calorimeteron stau measurements Forward and small angle calorimeter studies
- Recoil mass resolution quantifying tradeoffs between ZH threshold running and higher energy -> Roman
- Physics requirements and implications for Higgs and top mass
- Reproduction of selected benchmark reactions (including recoil mass resolution mentioned above)

The optimal energy for Higgs studies which depend primarily on event count (such as branching ratio measurements) is a few tens of GeV above threshold (mZ + mHiggs), where the cross section is largest, with the largest yield of events. However, if the luminosity is very low at 250 GeV, as the semi-official parameters indicate, the optimal
energy for such measurements of the 120 GeV Higgs is higher. Other measurements, such as the Higgs recoil mass, are degraded by running at higher energy (see studies by A. Miyamoto, http://acfahep.kek.jp/acfareport/node41.html#5078, and Richard and Bambade, http://arxiv.org/abs/hep-ph/0703173v1). The ILC scope document specified that the machine should produce 500 fb-1 in four years in the center of mass energy range of 200 to 500 GeV. The low 250 GeV luminosity is inconsistent with this specification, and the strategy to react to this needs study.

mt and mh

Klaus's summary

The questions about desired/needed precisions on mt and mh are rather clear to be answered:

1. In general there is no lower limit on the desired precision on fundamental constants. But ok - Let´s be more specific.
2. If we go into SUSY models, the impact of mt in many observables, the prediction of mh in particular, is enormous, roughly 1 GeV on mt shifts the mh-prediction by 1 GeV --> the mt measurement should be at least as precise as that on mh. Since there is a theoretical limit on delta-mt of ~100 MeV, probably 100 MeV is and should remain the target.
3. Precision on mh: within SUSY models, the prediction of mh has currently (and probably also in the future) a larger error (1 GeV?) than its measurement --> apart from (1.), there is no apparent need to measure mh much better than 100-200 MeV or so.
4. IMPORTANT: (3.) is not the motivation to collect as many HZ-events in the recoil technique as possible. The true motivation is to pin down the HZZ coupling as precisely as possible, because this precision enters in ALL Higgs-coupling measurements (bb and WW in particular) as a normalization factor. As shown in Hengne Li´s analysis which went into the ILD RDR the best precision on the ZH-cross section is 2.2% for 250 fb-1 at sqrt(s)=230 GeV. With 1/4 Luminosity this will become this will probably become 4.4% and thus become a limiting factor in absolute measurement of the the bb and WW couplings as well. It has often been shown, that only percent-level precision is suitable to reveal non-decoupling effects in the MSSM Higgs sectors and e.g. pin the mass of the CP-odd Higgs (see e.g. hep-ph/0406322).

Comment : BR(h->X) = fun(mh)

What kind of lessons we have learned?

- SB2009 optimized only at 500 GeV (tradition since RDR?)
  - Why was this so? --> Lack of communication
- Low luminosity @ 250GeV must have been expected from the beginning. Why was this overlooked?
  - Delusion about a magical measure to recover Lumi. by optics?
  - Preference of the undulator at the end of the linac in terms of potentially higher Pol.e+?

    --> Lack of communication
- The amount of the cost saving with SB2009 must have been more or less predicted by the costing experts long before. Why was this not more openly discussed? --> Lack of communication
  - If it is only 10%, it can hardly affect the probability of ILC approval by the funding agencies.
- Nevertheless, SB2009 exercise will be useful
  - for re-clarifying the physics demands to the machine.
  - for possible staging scenarios: lower startup energy, say the ZH threshold, may require the undulator at the end of the linac, for the initial cost of such a machine, the 10% cost saving may be significant. We can, however, decide on this later.
  - for possible measures to increase Lumi. (TF, low beta optics...)