Physics and ILD tracker optimisation

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Outline

1. Introduction
2. Basic optimisations
3. Optimisation and physics
   - Optimisation and physics: Tracking
   - Optimisation and physics: Other issues
4. Conclusions and recommendations

Introduction

Strategy for Detector & Physics Benchmarking:

- 1-to-1 relation between physics measurement and one specific detector performance aspect is rare ⇒
- can we factorise the two?
- Physics studies:
  - formulate requirements on various detector performance aspects, ideally "partial derivative"
  - this includes requirements on controlling systematics.
- Detector benchmarking:
  - Test a comprehensive list of performance aspects for various detector configurations.

(From J. List in the ILD concept meeting @LCWS)

Introduction

In This talk

- I will try to show how different detector issues that becomes important for different physics,
- It will not say (much) about detailed optimisation-work done for individual detector elements.
- It will try to point out the way forward, rather than to give answers

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Basic optimisations

A few observations on detector-component optimisation in ILD (post DBD):

- Presently
    - Mainly has been about ECal
    - Radius
    - Sensitive detector technology
    - Number of layers
- Aimed at cost-reduction.
- Only considers JER as metric - mainly for highest energy jets.

Other talks today have covered this !

Optimisation and physics

- Higgs, higgs, higgs ....
  - What does that require ?
  - Has anything changed ?
- But also: we have been asked to strengthen the BSM case.
  - What does that require ?
- ILC does precision physics ⇒ systematics control.
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- I will try to touch on aspects of these issues, looking specifically at the tracker, with a few comments on other issues.
- In no way a complete survey, Eg. nothing specific about impact-parameters.

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Optimisation and physics: Tracking

Reminder:

- $\Delta(1/p_T) \propto L^{-2.5}$ (2 purely geometric + ($\geq$) 0.5 because of less points in TPC).
- But only linear in σ_{point} and B-field $\Rightarrow$
- Technologically challenging to compensate lower radius by higher B-field and/or σ_{point}.
- But please note: Stored energy in B-field $\propto B^2 V$, so at equal stored energy, a smaller detector can have a higher field.
- Also: $\sigma^2_{point,TPC} = \sigma_0^2(\sin\phi) + \frac{C_d^2(B)}{N_{eff}(\sin\theta)} Z$, $C_d(B) \propto 1/B^2 \Rightarrow$ complicated relation, but gets better with shorter drift-length and higher B.
- Issues to be studied in the near future: please connect to the ILD optimisation phone meetings !

Optimisation and physics: Tracking

Recent developments in Higgs analysis: A game-changer?

- At 250 GeV, beam-spread dominating Higgs mass.
- Not so at 350: average p_μ approx 50% higher $\Rightarrow \Delta(p_t)$ is approx 2.5 times worse.
- Common wisdom up to now: No big deal, we'll get the mass at 250, then the rest at 350 and 500.
- True if only $Z \rightarrow$ leptons is used, which we want to do to remain model-independent, ie. with the Higgs decay making no difference.
- However, now methods and ideas are coming up to also use the hadronic decays ...
- See M. Thomson's talk in ILD@Oshu, T. Barklow @LCWS, Y. Haddad on Monday.

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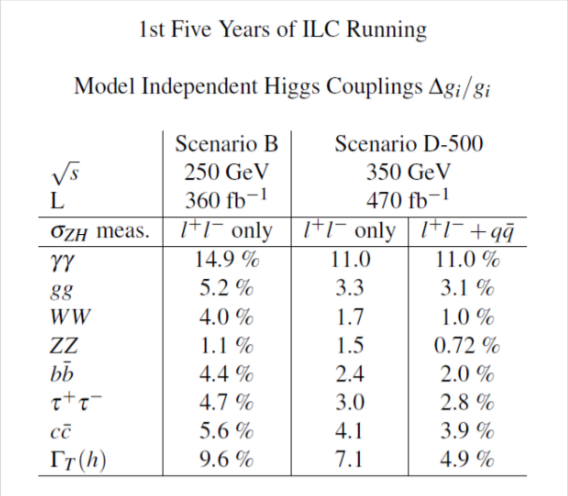
Optimisation and physics: Tracking

Error-breakdown from T. Barklow, propagating uncertainties in BSM.



1st Five Years of ILC Running

Model Independent Higgs Couplings $\Delta g_i/g_i$

	Scenario B	Scenario D-500	
$\sqrt{s}$	250 GeV	350 GeV	
L	360 fb^{-1}	470 fb^{-1}	
σ_{ZH} meas.	l^+l^- only	l^+l^- only	$l^+l^- + q\bar{q}$
$\gamma\gamma$	14.9 %	11.0	11.0 %
gg	5.2 %	3.3	3.1 %
WW	4.0 %	1.7	1.0 %
ZZ	1.1 %	1.5	0.72 %
$b\bar{b}$	4.4 %	2.4	2.0 %
$\tau^+\tau^-$	4.7 %	3.0	2.8 %
$c\bar{c}$	5.6 %	4.1	3.9 %
$\Gamma_T(h)$	9.6 %	7.1	4.9 %

- But, also in this case the $Z \to$ leptons gives a important contribution: they not so many, but they're much more precise.
- Higgs recoil @ 350 GeV $\Rightarrow$ the return of the detector ...

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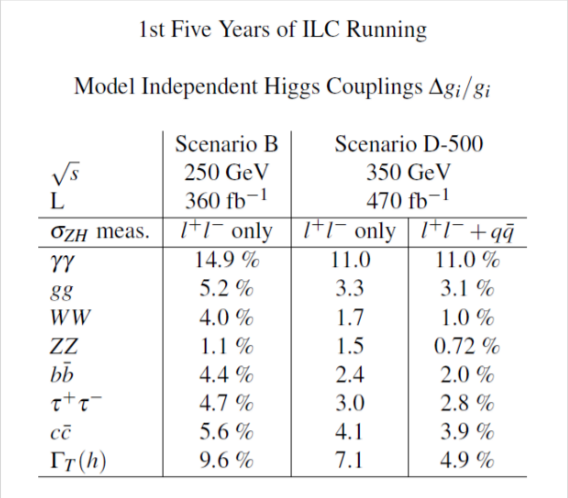

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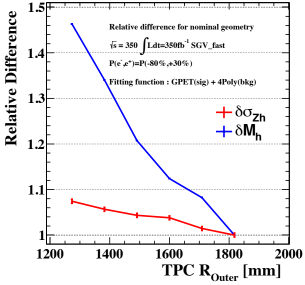
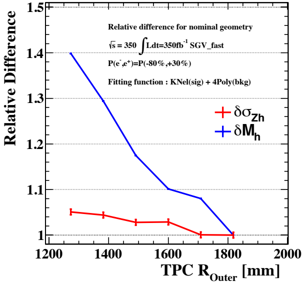
Relative Difference from the nominal geometry ($\sqrt{s}$=350GeV)

- GPET(sig) + 4th Poly(bkg).



- Kernel(sig) + 4th Poly(bkg).



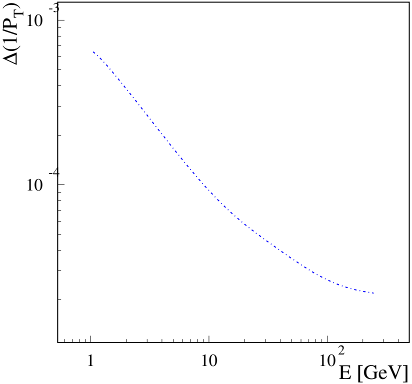
⇨ Kernel(sig) + 4th Poly(bkg).

- σzh precision degrades > 5 % (R: 1.8 m ⟹ 1.4 m)
- Mh precision degrades ~ 30 % (R: 1.8 m ⟹ 1.4 m)

- Impact of the Radius 25 -

Optimisation and physics: Tracking

- How to get the best $\Delta(1/p_T)$ in ILD at high momentum ?
- Answer: The SET.
- Almost a factor 2.
- In fact, the current SET has saturated what can be achieved by a very precise external measurement, so only B remains !



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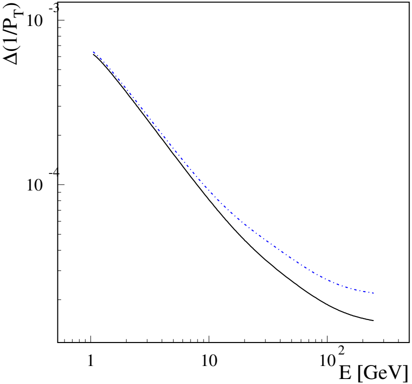

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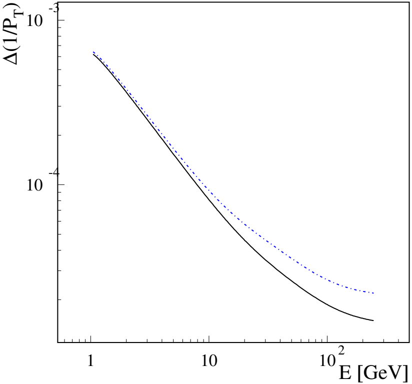

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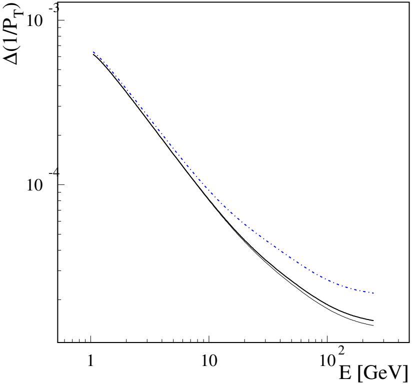

Optimisation and physics: Tracking

BSM case-study

Natural SUSY: Light, degenerate higgsinos.

- Natural SUSY:
  - $m_Z^2 = 2\frac{m_{H_u}^2 \tan^2\beta - m_{H_d}^2}{1-\tan^2\beta} - 2|\mu|^2$
  - $\Rightarrow$ Low fine-tuning $\Rightarrow$ $\mu = \mathcal{O}$(weak scale).
  - If multi-TeV gaugino masses:
    - $\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^\pm$ pure higgsino. Rest of SUSY at multi-TeV.
    - $M_{\tilde{\chi}_{1,2}^0}, M_{\tilde{\chi}_1^\pm} \approx \mu$
    - Degenerate (ΔM is 1 GeV or less)
    - Few, quite soft tracks.
    - $\Rightarrow \gamma\gamma$ background, effect of pairs background on pat. rec.

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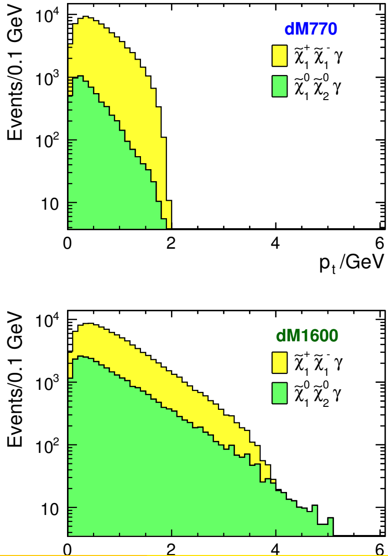
- The TPC has almost continuous tracking ⇒ low (sub 1 GeV) track-finding.



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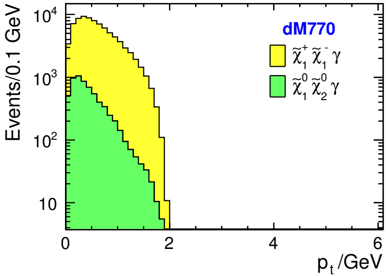
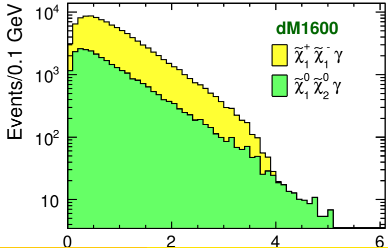
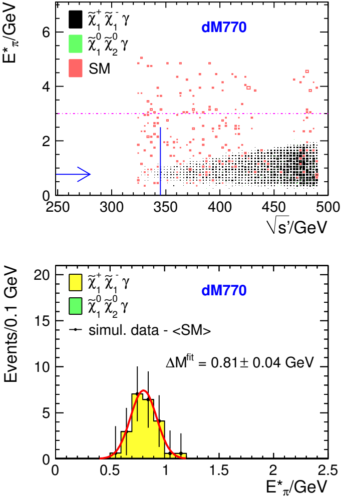




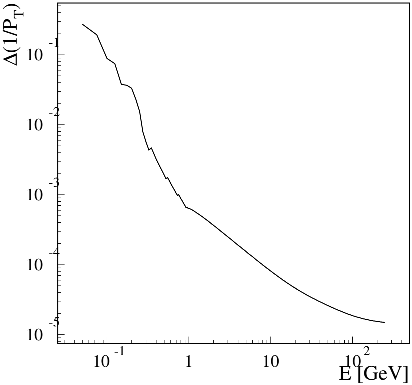
Optimisation and physics: Tracking

- Momentum resolution at low momentum: Higgsinos
- Close to end-point, E_π gives $\Delta(M_{\tilde{\chi}^0_1}, M_{\tilde{\chi}^\pm_1})$ to $\sim$ 100 MeV.



Optimisation and physics: Tracking

- Gaseous detector ⇒ less M.S. ⇒ better σ at lower p:
- ILD,
- ... and an all Si tracker (with properties like SiD tracker)
- Factor 2 better at 1 GeV.



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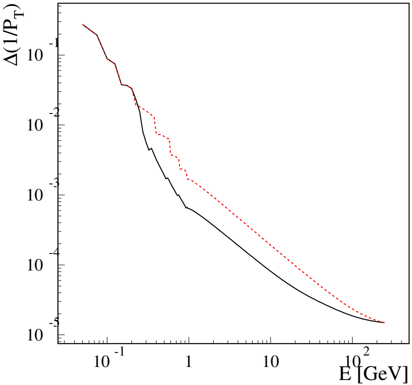

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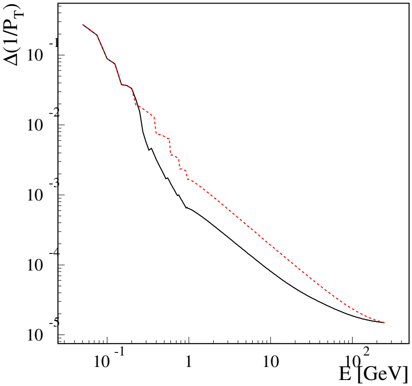

Optimisation and physics: Tracking

Systematics case-study

Uncertainty on jet energy due to neutral-hadron fraction.

- With the Particle-flow paradigm, error on jet-energy is highly influenced by the worst measured particle-class: Neutral hadrons.
- ⇒ Number of neutral hadrons needs to be tuned.
- e^+e^- is not *pp*: Need to tune to data on the market - now LEPII.
- Example numbers from current tune:

particle	Pythia tune	OPAL tune	LEP data
p	1.2190	0.9110	0.9750 ± 0.0870
n	1.1661	0.8664	
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- NB: Quite some dependence on tune ⇒
- We need to be able to do this with our data !
- Fraction of neutral hadrons: K_S^0 finding the key.
- $c\tau$ is 2,7 cm, meaning that the average flight of a $\sim$ 5 GeV K_S^0 is $\sim$ 30 : In TPC.

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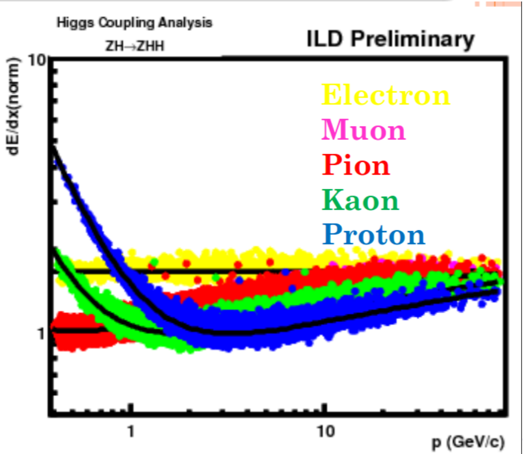
Optimisation and physics: Tracking

Flavour-tag case study:

Particle identification - secondary vertex reconstruction.

- Identify heavy flavour particles by secondary vertex reconstruction:
  - c → s ⇒
  - Which one is K, which is π ?
- Particle id ⇒ dE/dx in TPC.



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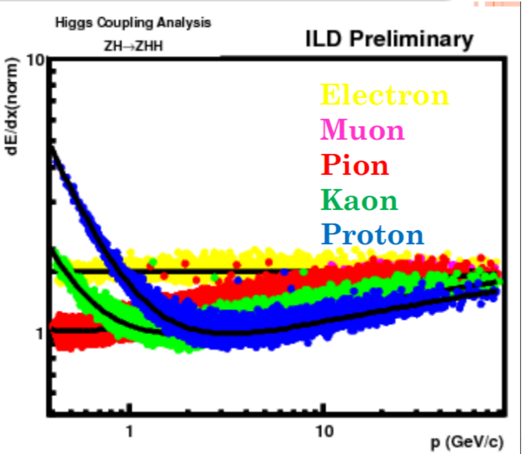

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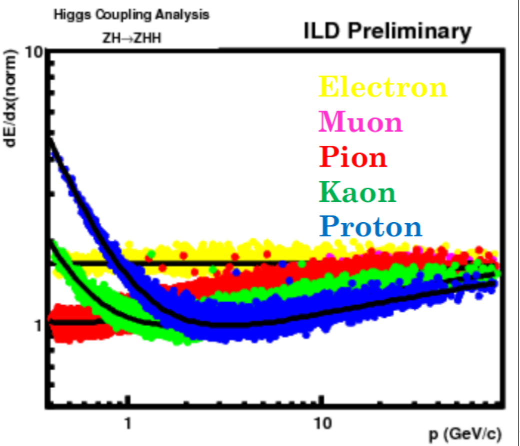

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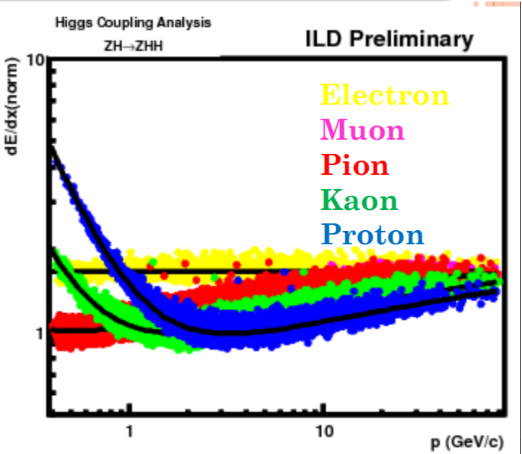
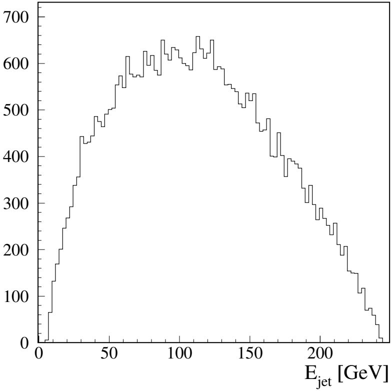


Optimisation and physics: Other issues

Remark on PFA and jet-energy:

- *WW* → hadrons at 500 Gev
- Average 112 GeV, 15 % below 50 GeV, 15 % above 175 GeV ⇒
- PFA performance well below 45 GeV matters !



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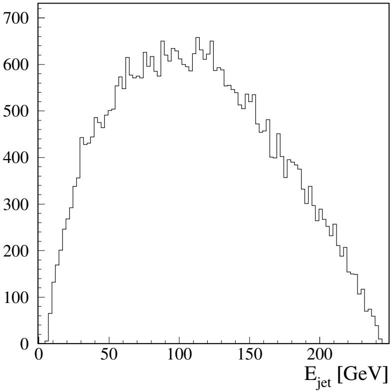

Optimisation and physics: Other issues

- For BSM: hermeticity !
- When s' matters: Ecal intrinsic resolution matters (eg. WIMPS, low $\Delta(M)$ SUSY, ...)
- For h.f. : Recent studies of π^0 reconstruction and their inclusion in secondary vertex finding → Ecal intrinsic E and direction resolution matters !
- Trigger-less operation: DAC, data storage
- PID: muons, too.

Summary

- Different physics signatures emphasise different detector properties.
- A coherent optimisation must keep this in mind.
- All physics is important, either by it's own right, or to help control systematics.
- The new ideas of doing most Higgs physics at 350 GeV means that the tracking-performance at high momentum becomes important, again.
- For BSM, hermeticity and triggerless operation is essential.
- Low momentum track-finding and measurement might be essential
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