Physics and ILD detector optimisation

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Outline

Introduction

- Strategy for Detector & Physics Benchmarking:
- 1-to-1 relation between physics measurement and one specific detector performance aspect is rare $\Rightarrow$
- 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 yesterday)

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 donre for individual detector elements.
- It will try to point out the way forward, rather than to give answers
- It has the ILD angle.

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Basic optimisations

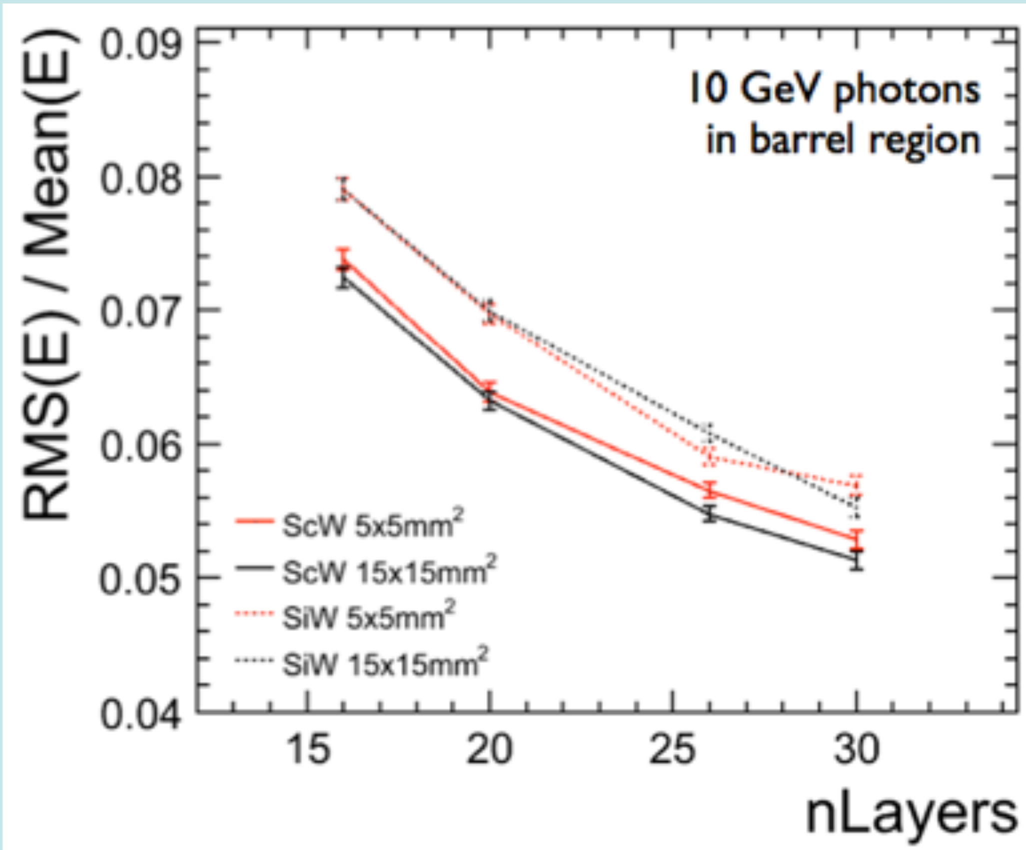
A few observations on detector-component optimisation in ILD (post DBD):

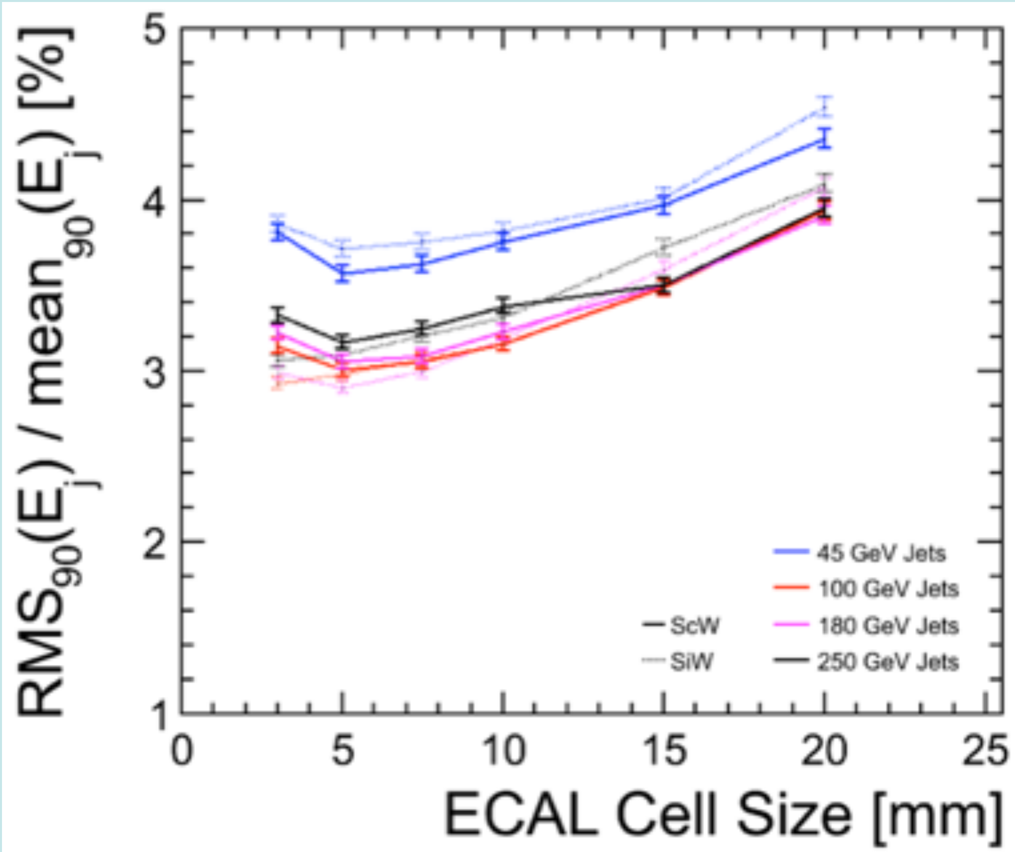
- Presently
  - Mainly has been about ECal
  - Radius
  - Sensitive detector technology
  - Number of layers
- Aimed at cost-reduction.
- Only considers JER as metric - mainly for highest energy jets.

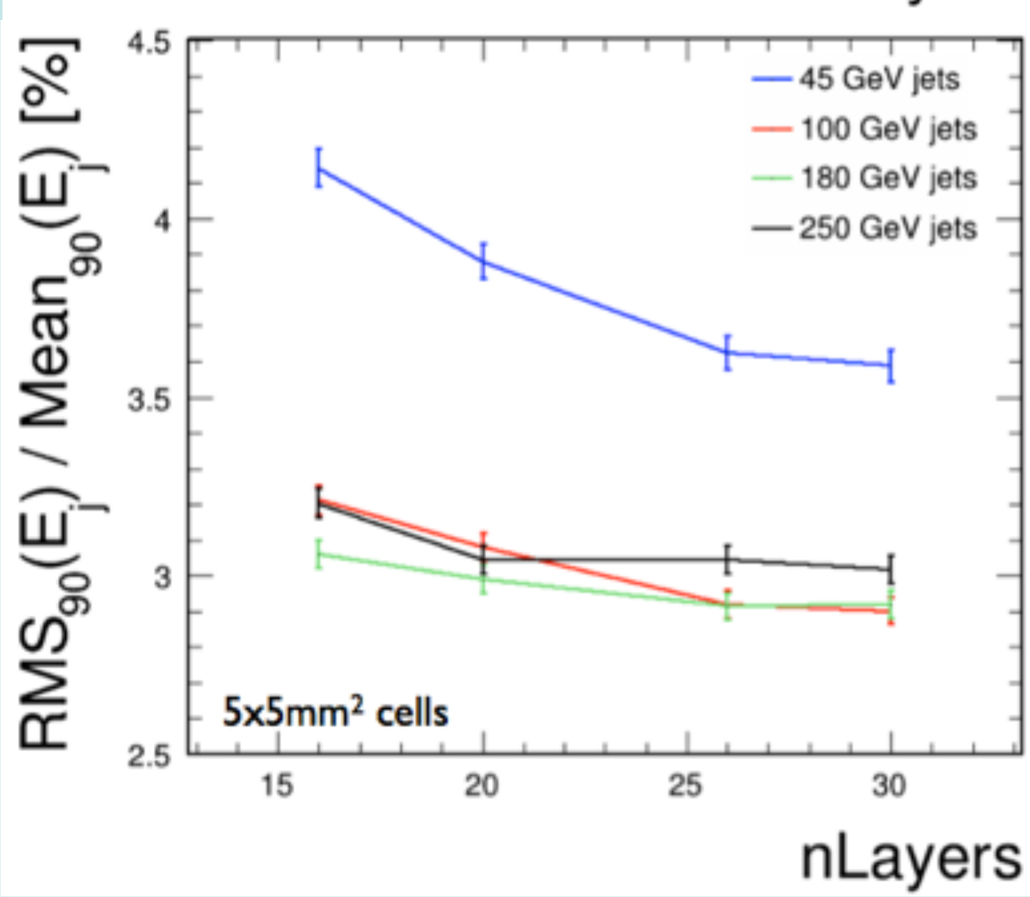
See slides of J. Tian's talk on Monday....

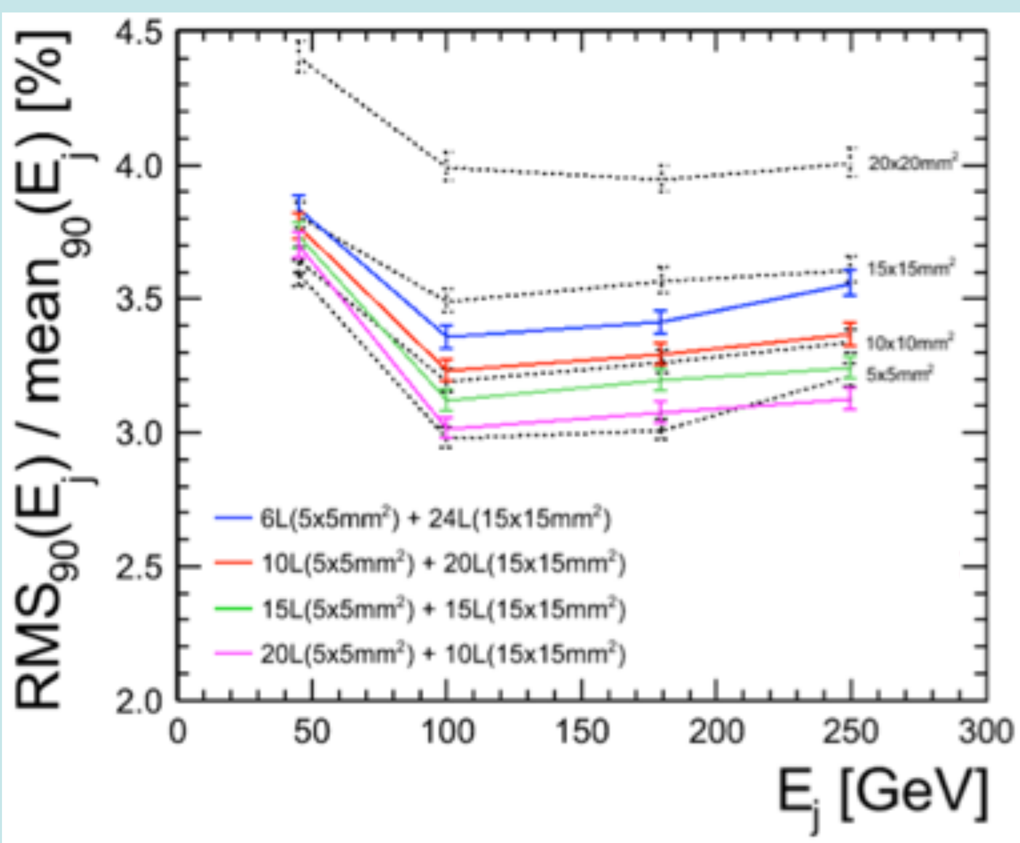
jet energy resolution: ECAL layers & granularity

J. Marshall









jet energy resolution: ECAL inner radius & B-Field

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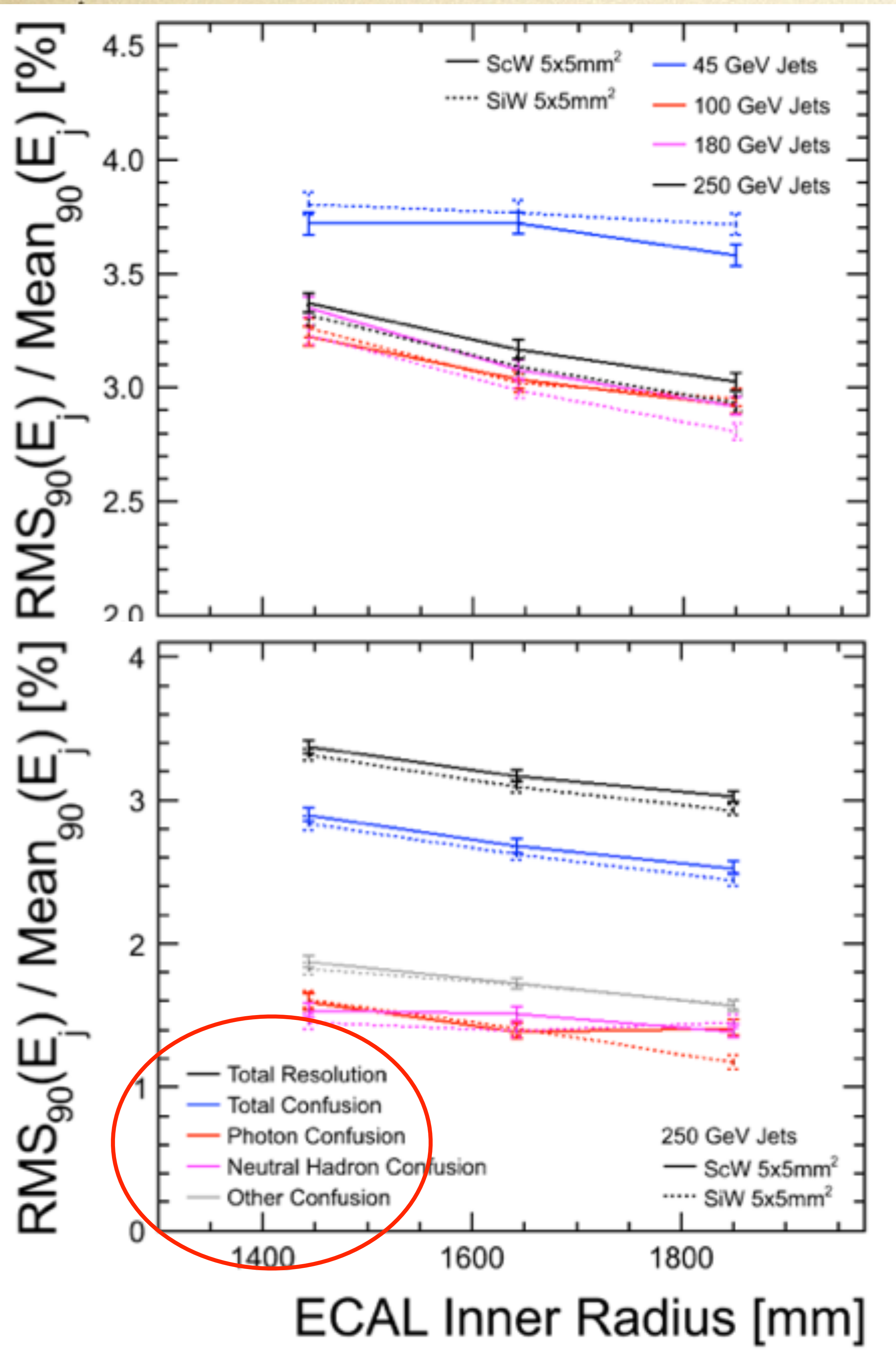
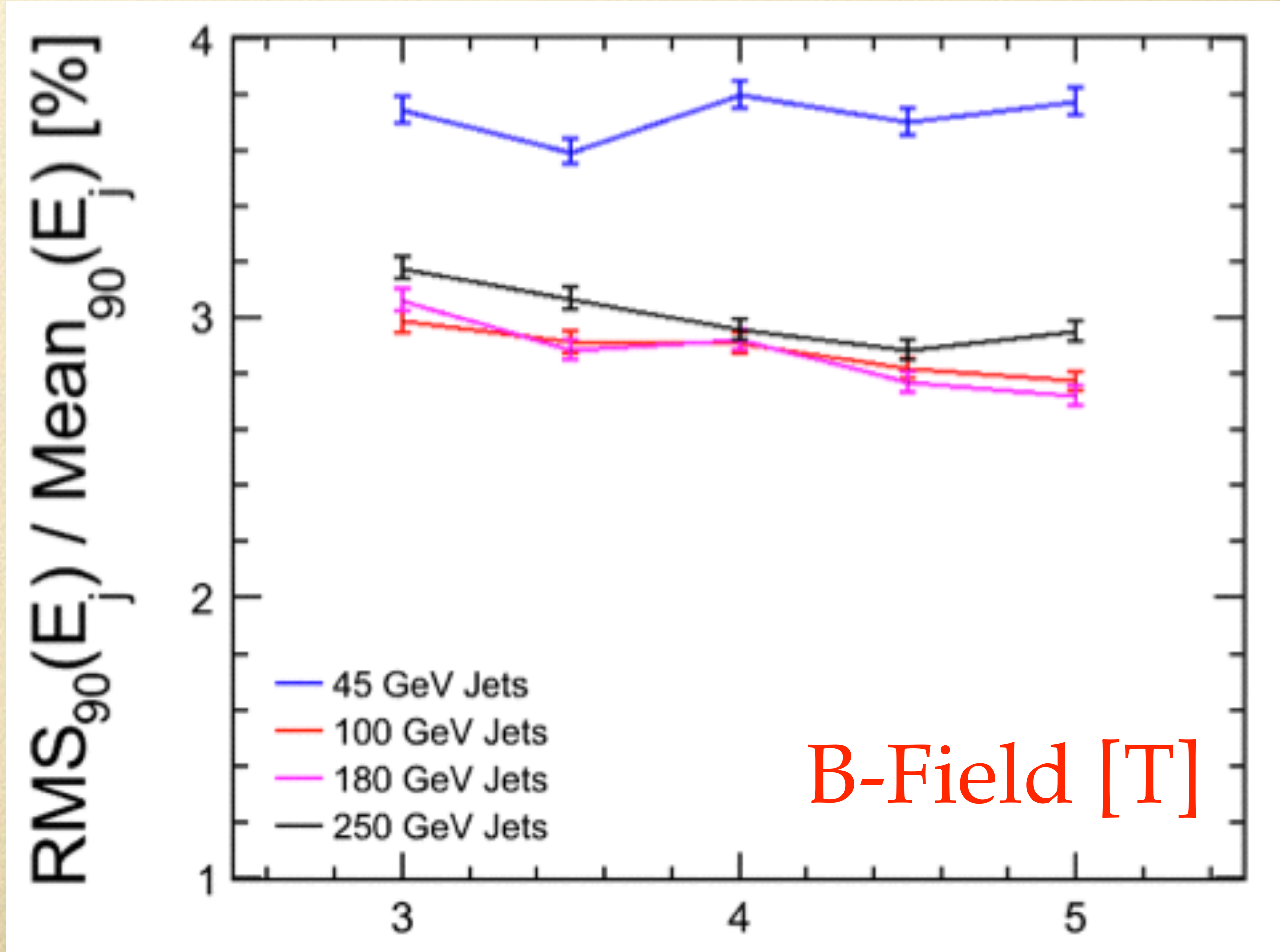


- single photon .vs. jet
- multi granularity ECAL
- smaller cell size, larger radius, high B-Field can help separate particles
- to understand PFA performance is most crucial here



Optimisation and physics

- Higgs, higgs, higgs ....
  - What does that require ?
  - Has anything changed ?
- But also: we have been asked to strenthen the BSM case.
  - What does that require ?
- ILC does precision physics $\Rightarrow$ sytematics control
  - What does that require ?
- I will try to touch on aspects of these issues, looking at tracker and calorimetry separately.
- 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}.

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Recent developments in Higgs analysis: |alertA 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 Oshu, T. Barklow in this conference.

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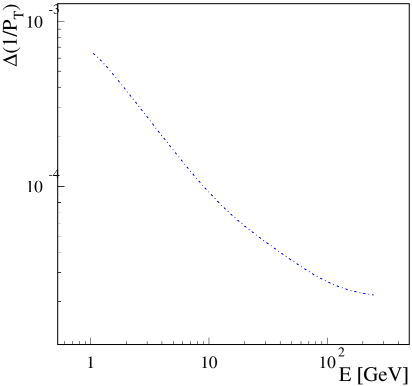
- How to get the best $\Delta(1/p_T)$ in ILD at high momentum ?
- Answer: The SET.
- Almost a factro 2.
- In fact, the current SET has saturated what can be achieved by a very precise external measurement, so only B remains !



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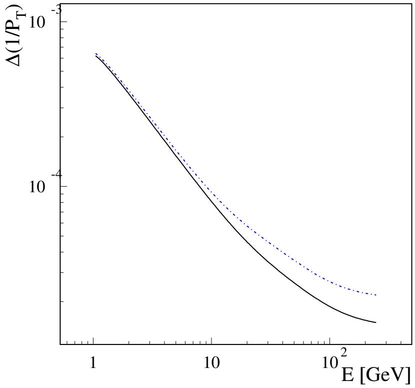

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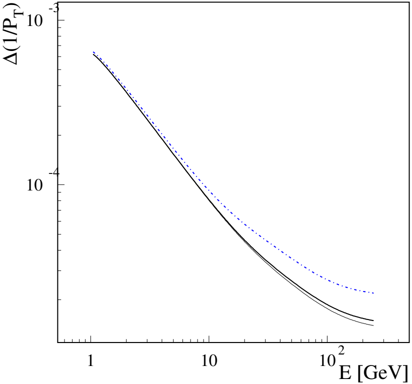

Optimisation and physics: Tracking

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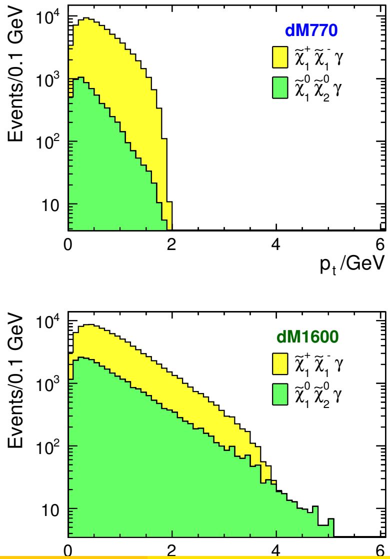
- The TPC has almost continuous ⇒ low (sub 1 GeV) track-finding.



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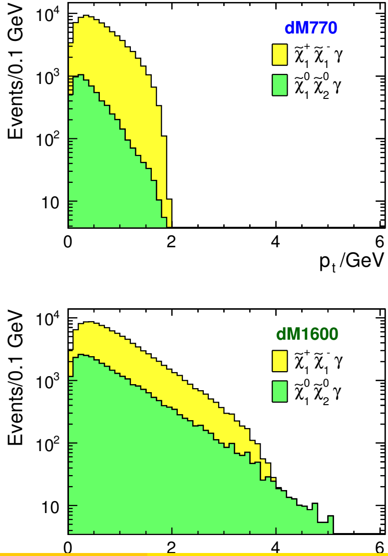

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- Momentum resolution at low momentum: Higgsions
- Close to end-point, E_π gives $\Delta(M_{\tilde{\chi}_1^0}, M_{\tilde{\chi}_1^\pm})$ to $\sim$ 100 MeV.

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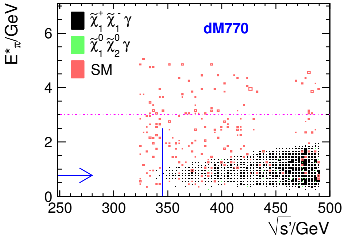

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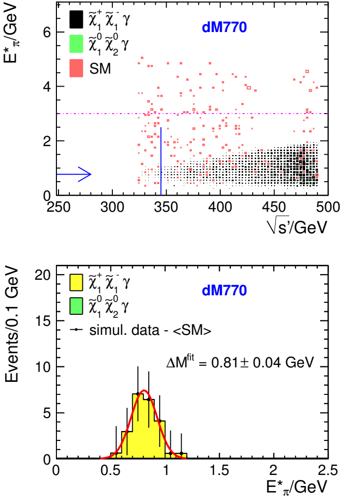

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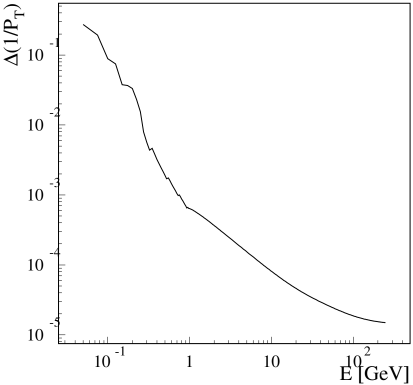
- Gaseous detector ⇒ less M.S. ⇒ better σ at lower p:
- ILD,
- ... and an all Si tracker (with properties like SiD tracker)
- Factor 2 better at 1 GeV.



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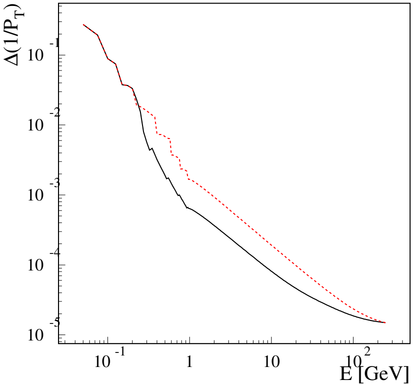

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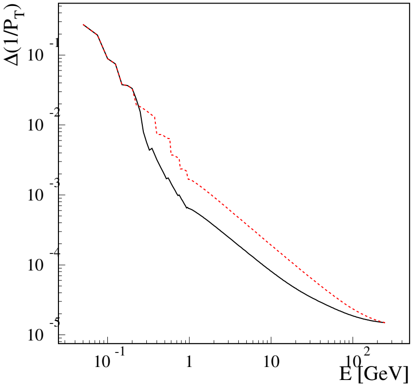

Optimisation and physics: Tracking

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
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- We need to be able to do this with our data !
- Fraction of neutral hadrons: K_S^0 finding the key.
- cτ 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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Flavour-tag case strudy:

Particle identification - secondary vertex reconstruction.

- Identify heavy flavour particles by secondary vertex reconstruction:
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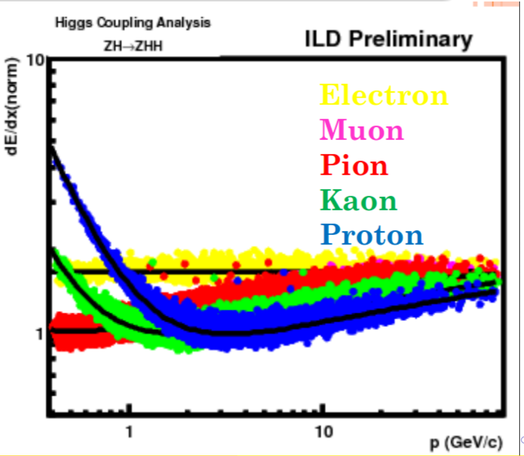

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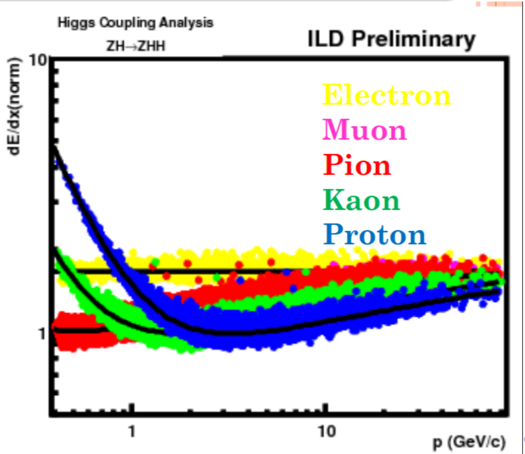

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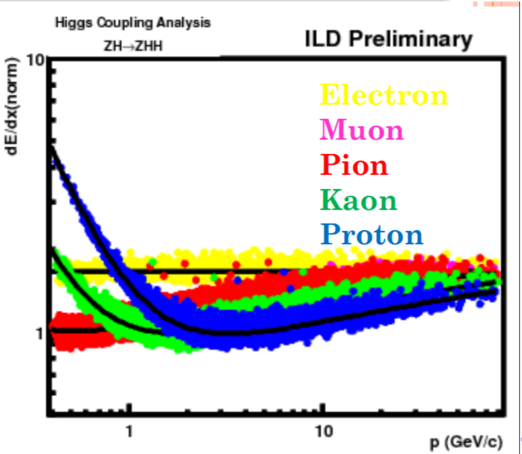

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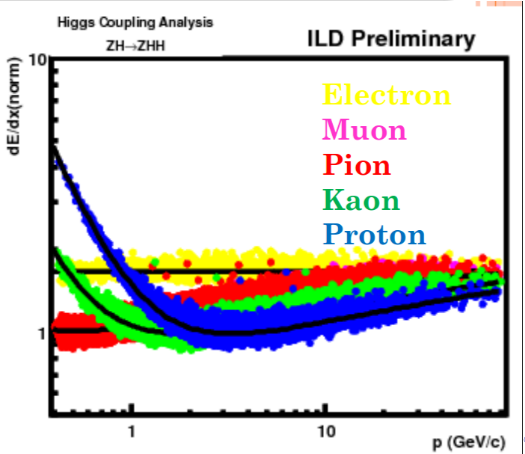

Optimisation and physics: Calorimeters

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Still Natural SUSY: Light, degenerate higgsinos.

- How to detect ?
- Tag using ISR photon, then look at rest of event !

SUSY signal and $\gamma\gamma$ background ... and with an ISR photon in addition

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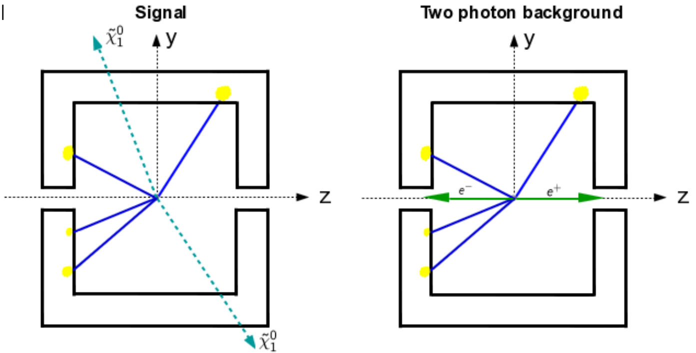

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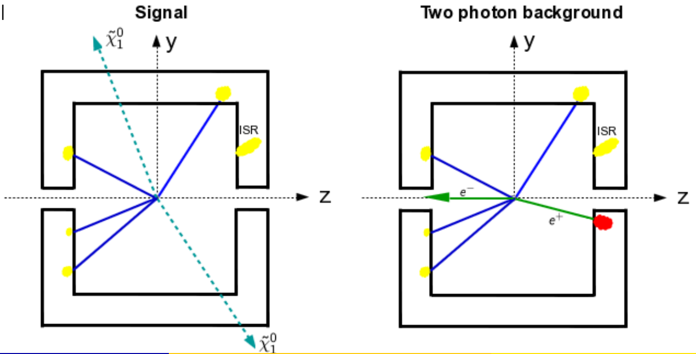

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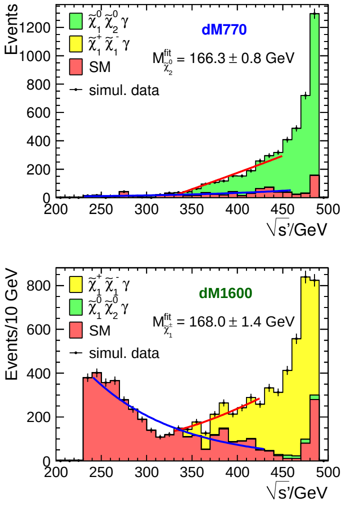
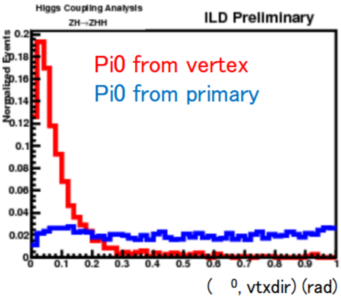
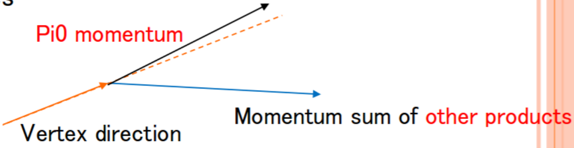


Optimisation and physics: Calorimeters

- Find π^0, attach to secondary vertex: Ecal intrinsic and direction matters (M. Kurata).

- Pi0s from (secondary, third) vertices are very collinear to vertex direction
  - due to their small masses





Optimisation and physics: Calorimeters

- Remark on PFA and jet-energy
- $WW \rightarrow$ hadrons at 500 Gev
- Average 112 GeV, 15 % below 50 GeV, 15 % above 175 GeV
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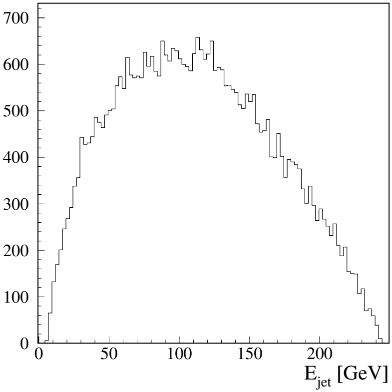

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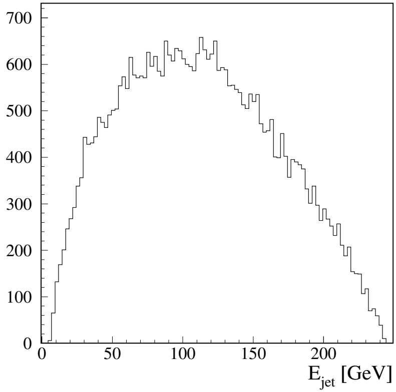

Optimisation and physics: Other issues

- Trigger-less operation: DAC, data storage
- PID: muons, too.

Summary

- Different physics signatures emphasize 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
- Single photon energy resolution

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Conclusions and recommendations (J. List)

m_H from ee->vvH->vvbb

- JER
- π^0 reconstruction
- b-tag, l in jet, excl. B decays
- JES, b-tag, had., frag, neutral hadrons fraction uncertainties

Similar, but for "light jets":
m_W from ee->evW->evqq

Higgs CP properties H->ττ

- τ reconstruction
- PID, Exclusive decay modes
- momentum & impact parameter

Near-degenerate Higgsinos

- Reco of low momentum particles
- Fake tracks
- PID, Exclusive decay modes
- Hermeticity
- Low and high-energy photon energy & angle resolution

A_{FB} (top)

- JER, lepton ID, b-tag
- *Jet charge*, excl. B-decays,

Mono-photon WIMPs

- Photon energy resolution & scale, hermeticity, *suppression of Bhabhas, dL/dE_{CM}*

Oct. 8, 2014 ILD Optimisation & Physics, J.List 6

Thank You !