Discussion on proposed ILD benchmark reactions

J.List

ILD Optimisation Meeting

November 12, 2014

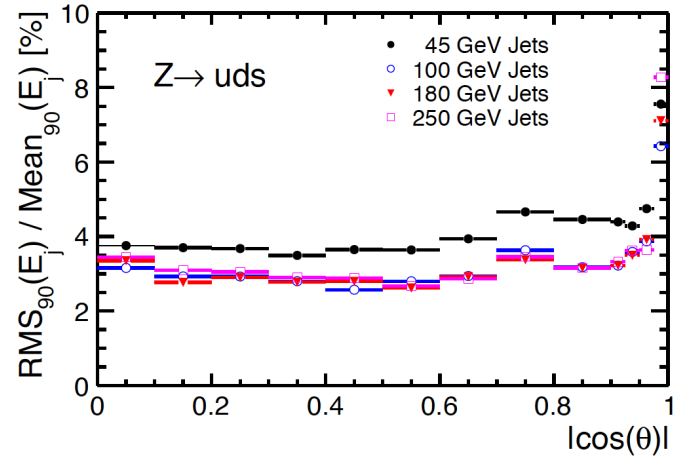
Outline

1. Bottom-Up:
   - The canonical set: Which detector performance aspects did we look at in the past?
   - Complementing the canonical set:
     Which others are relevant and should be added?
2. Top-Down:
   - What are the key physics observables?
   - Which detector properties are they sensitive to?
   - What is their status / coverage within ILD?
3. Discussion: YOU ;-)

1. Bottom-Up: The Canonical Set

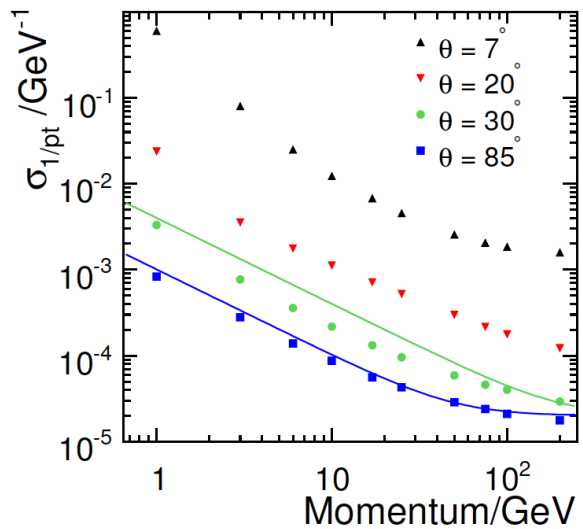
- Jet Energy Resolution

  RMS_{90}/E_{jet},
  E_{jet} = 45, 100, 180, 250, (500) GeV
  (ee->Z/gamma->uds w/o ISR)



- Tracking Resolutions

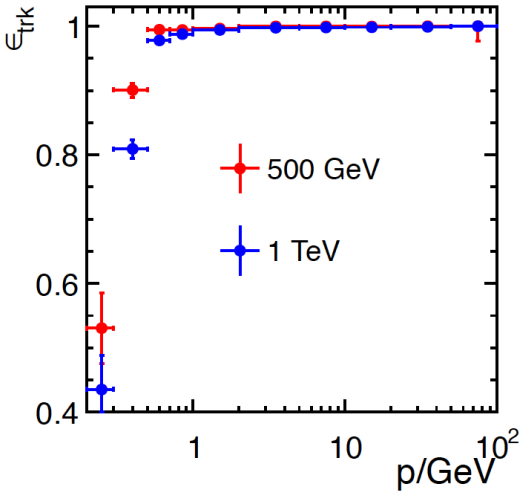
  $\sigma_{1/pT}$ and $\sigma_{r\phi}$
  p_T = 1, ..., 100 (400) GeV
  θ=85°,40°,20°,7°



1. Bottom-Up: The Canonical Set

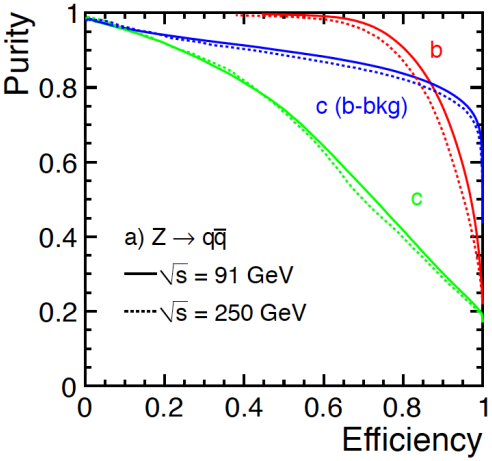
- Tracking Efficiency

  tt -> 6 jets & pair background,
  excluding decays in flight (!)
  p_T = 0.2, ..., 100 GeV
  $|\cos\theta| < 0.99$



- Flavour Tag

  efficiency vs purity for
  b, c & c (b-bkg)
  Z->qq (91, 250 GeV)
  Z->qqqqqq (500, 1000 GeV)



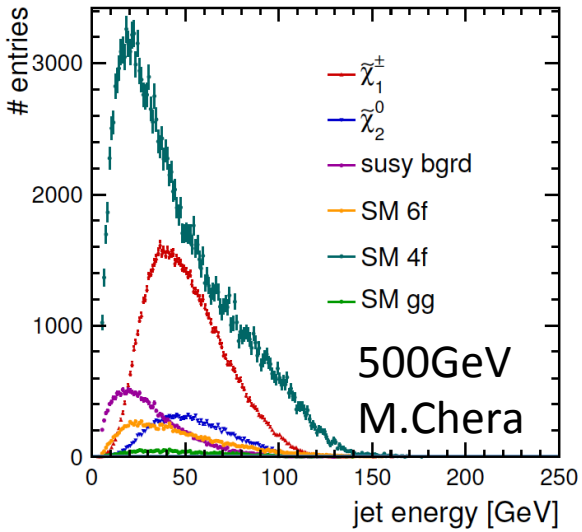
1. Bottom-Up: Complementing the Canonical Set

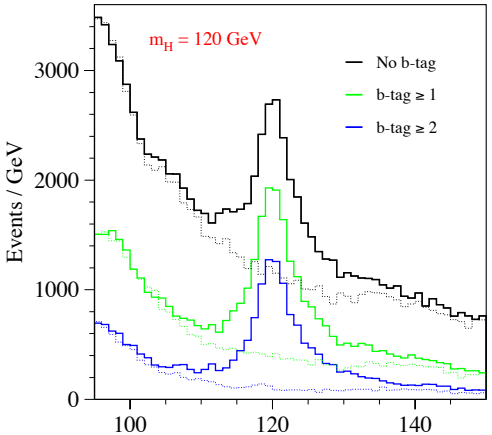
Jet Energy Resolution:

- add E_{jet} = 5, 10, 15, 25, 35 GeV:
  a lot of physics is HERE!
- add JER for b and c jets ?

not only calorimetry, but also capability to identify semi-leptonic b/c decays and correct for neutrinos based on lepton momentum, exclusive decay modes, etc

-> non-trivial!!!
but important: eg m_H from H->bb
competitive to recoil mass,
in particular incl WW fusion





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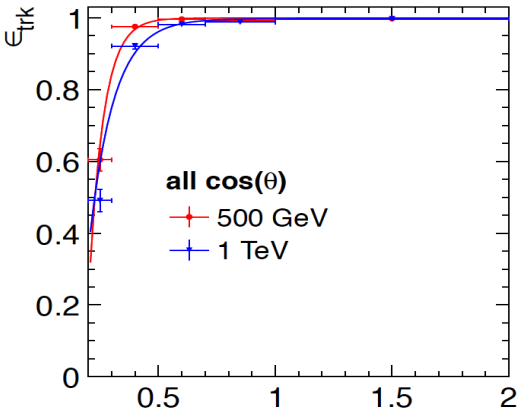
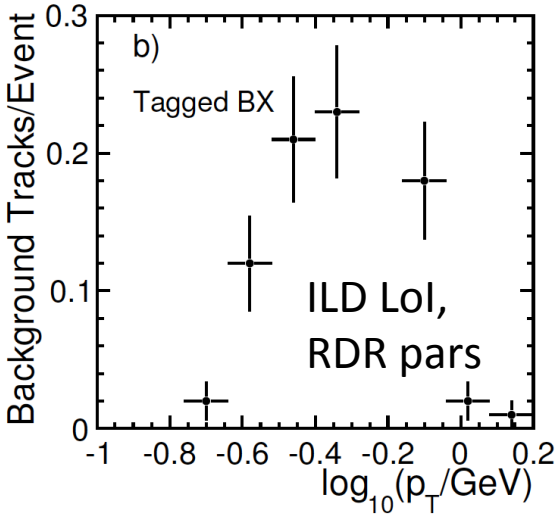
1. Bottom-Up: Complementing the Canonical Set

Tracking Resolutions & Efficiency

- add p_T = 0.1, ... , 2 GeV in linear scale
- add efficiency for tracks *not* originating from primary vertex
- add fake tracks vs pt, vs cosθ
- add dE/dx resolution
  sofar only "goal" 5%





1. Bottom-Up: Complementing the Canonical Set

Hermeticity (BSM, DM, missing mass for ZH <-> nunuH)

- detection efficiency for e, μ, γ, π, n vs cosθ from 0.1 GeV to 250 GeV

Vertex charge (eg A_FB (top) in tt->6jets)

- probability to get correct vs jet momentum?

Particle Identification (SM and BSM (?) precision)

- e / μ / π^{+-} / p / K / n / π^0/ γ ID-Efficiencies and fake rates vs momentum/energy (0.1 to 250 GeV) and vs cosθ
- isolated and in jets

Photon reconstruction (eg WIMPs, gen. BSM)

- E, θ, ϕ resolutions, from 0.1 to 250 GeV and vs cosθ

1. Bottom-Up: One step further

τ reconstruction (Higgs, BSM)

- ID efficiency & mis-ID vs momentum and vs $\cos\theta$
- separation (efficiency/purity) of individual τ decay modes
- τ polarisation

B and D hadrons

- eg Λ_b (CP test in polarisation of Λ_b from Z decays)
- eg $D^{(*)}$ (important for charm tag, soft tracks)

Bhabhas (BSM, Lumi)

- rejection efficiency of (radiative) Bhabha events

2. Top-Down: The big physics sellers

Searching for new physics ***indirectly***:

- Higgs precision measurements
- top precision measurements
- gauge boson precision measurements

Searching for new physics ***directly***:

- Dark Matter
- small mass differences
- eventually: precision measurements of BSM

So far: benchmarks focus HERE

need to expand HERE

2. Top-Down: Physics Benchmarks

Keep all existing studies, eg:

- Higgs coupling sizes
- top mass and couplings

however: so far seem to sit on performance plateau

But is a cliff hiding in dimensions we didn't look at?

Are the candidates to add/study in more detail?

2. Top-Down: Physics with "cliff potential"

Suggestion of a *minimal* set of analyses to be compared for different ILD flavours:

- H -> cc
- H -> ττ
- H -> μμ
- m_H from H->bb
- m_W from eνW->eνqq
- A_{FB}(top) in tt -> 6jets
- near degenerate Higgsinos
- WIMPs

Disclaimer

We have many more analyses going in ILD than listed here or in the following.

See .pptx on agenda page for the full collection

They are all extremely important for the physics case and should be continued!

2. Top-Down: H -> cc

Physics

- flagship measurement
- complementary to LHC

Detector Performance

- charm tagging: D mesons!
- tracks from D decays rather soft
- $\sigma_{1/pt}$ and $\sigma_{r\phi}$ for low momentum tracks
- fake tracks from pairs
- timing vs point res. in VTX

Status:

- several FullSim studies ongoing at 250, 350 and 500 GeV, all Z decay modes / WW fusion
- Hiroaki Ono, Felix Müller, Benjamin Boitrelle (upcoming), Yorgos Voutsinas (Si tracking)

2. Top-Down: H ->ττ

Physics

- BR
- CP properties of Higgs-fermion coupling

Detector Performance

- τ reconstruction
- Particle ID
- Exclusive τ decay modes
- $\sigma_{1/pT}$ and $\sigma_{r\phi}$

Status:

- BR: Shin-Ichi Kawada (250/500 GeV)
- CP properties:
  - LoI time study @ 250 GeV by Marcel Reinhardt
  - needs update, study of other ECM, more advanced interpretation

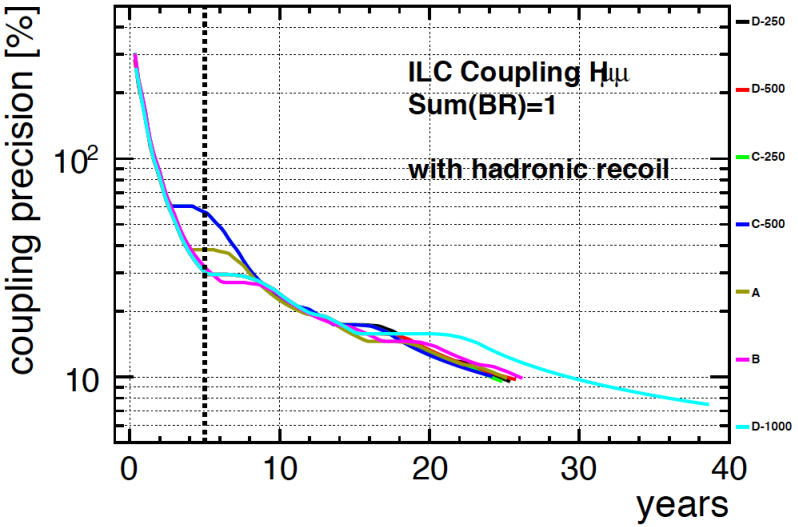
2. Top-Down: H ->μμ

Physics

- BR
- starts to get feasible already at 500 GeV!

Detector Performance

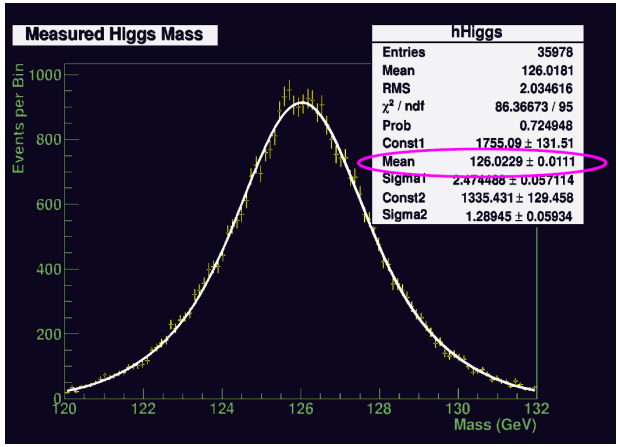
- ultimate momentum resolution for isolated tracks



Status

- FullSim ongoing by Tino Calancha

2. Top-Down: m_H from H->bb



- Physics
  - competitive to leptonic recoil at 250 GeV
  - could reduce data set size needed at 250 GeV
- Detector Performance
  - Jet energy resolution & scale for b-jets
  - π^0 reconstruction: $\sigma(M_H)$ naively 11 MeV -> 7 MeV
  - b-tag, l in jet, excl. B decays
  - neutral hadron fraction

- feasibility study & π0 fitting:
  Graham Wilson & Brian van Doren

2. Top-Down: m_W from evW->evqq

- Physics
  - potential: 3-4 MeV
  - competitive to threshold scan!
- Detector Performance
  - Jet energy resolution & scale for uds and c jets
  - neutral hadron fraction
  - jet energy scale
  - tagging of forward electron

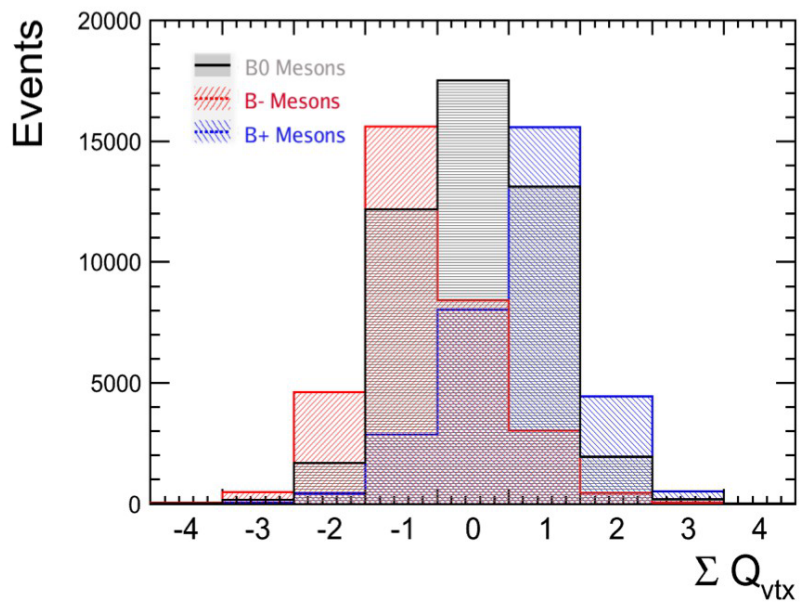
ΔM_W [MeV]	ILC	ILC	ILC	ILC
$\sqrt{s}$ [GeV]	250	350	500	1000
$\mathcal{L}$ [fb^{-1}]	500	350	1000	2000
$P(e^-)$ [%]	80	80	80	80
$P(e^+)$ [%]	30	30	30	30
jet energy scale	3.0	3.0	3.0	3.0
hadronization	1.5	1.5	1.5	1.5
pileup	0.5	0.7	1.0	2.0
total systematics	3.4	3.4	3.5	3.9
statistical	1.5	1.5	1.0	0.5
total	3.7	3.7	3.6	3.9

- feasibility study: Graham Wilson

2. Top-Down: A_{FB}(top) in tt -> 6jets

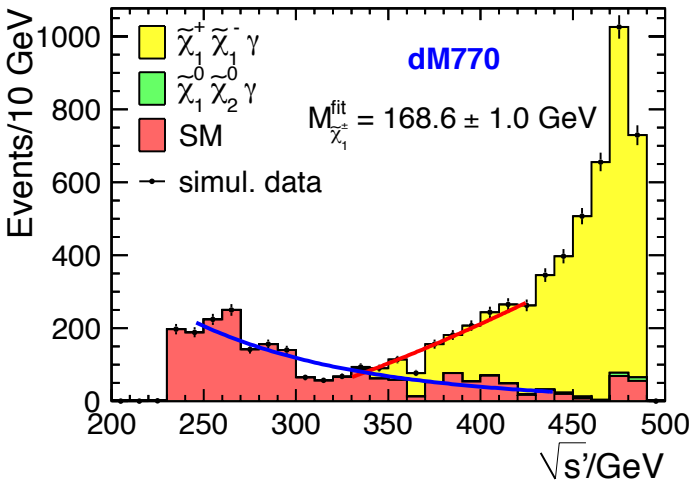
- Physics
  - anomalous top couplings
  - probing for extra-dimension / compositeness models
  - CP violating couplings?
- Detector Performance
  - Jet energy resolution for light and b-jets
  - b-tag
  - ***Jet charge***
  - *exclusive B/C decays*
  - *tertiary vertices*

- Status:
  - being worked on in groups of Roman Poeschl, Marcel Vos, Frank Simon



2. Top-Down: near degenerate Higgsinos

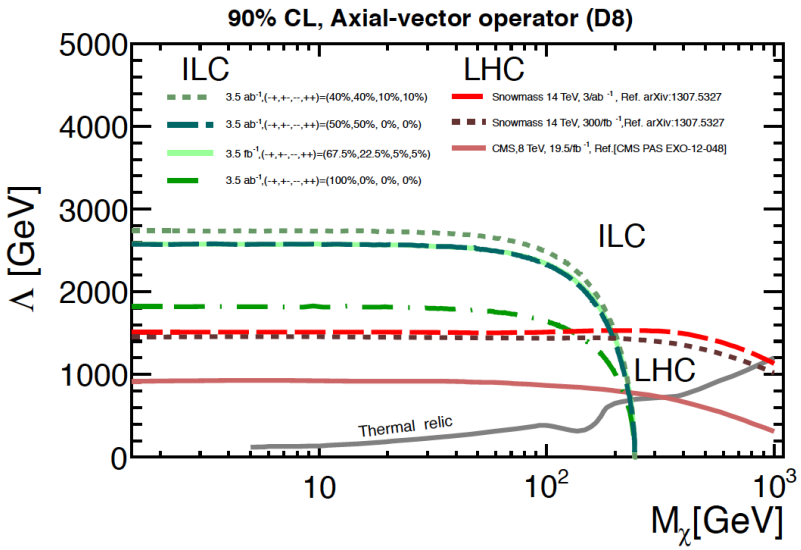
- Physics
  - core of "natural SUSY"
  - complementary to LHC
  - small ΔM => low momentum decay products
- Detector Performance
  - **Reconstruction of low momentum particles**
  - **Fake tracks**
  - **Particle ID**
  - Hermeticity
  - Low and high-energy photon energy & angle resolution



- Status
  - feasibility & potential shown in SGV study
  - identified critical items
  - started to realize in FullSim
  - ½ postdoc (Yorgos Voutsinas) taking over from Hale Sert

2. Top-Down: Mono-photon WIMPs

- Physics:
  - ee -> XXγ
  - complementary to LHC/DD
  - observation / exclusion
  - characterisation & model discrimination
- Detector performance:
  - Photon energy resolution
  - Photon energy scale
  - hermeticity
  - *suppression of Bhabhas*
  - dL/dE_{CM}
- last FullSim:
  - LDCPrime (!), 500 GeV



- 1 PhD student at DESY (Moritz Habermehl):
  - extrapolation to other ECM
  - new Whizard
  - beam spectrum

3. Discussion

YOU!

BACKUP

Additional Optimisation benchmarks - Physics Level -

m_H from ee->ννH->ννbb

- 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->eνW->eνqq

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}*

Goals of further Simulation Studies

Open physics case questions

- High-level perspective
- Ultimate luminosity requirements
- Polarisation sharing
- Not yet (fully) demonstrated key measurements

=> interplay with running strategy & accelerator & detectors

Detector issues not yet studied (sufficiently)

- Calibration & alignment
  => need for Z pole running?
  => machine implications!
- Systematic uncertainties
- PID, low momentum particles…

Detector cost justification (reduction?)

- shrink overall size?
- Ecal technology?
- **Why a TPC?**
- …

Change requests from machine

- L* = 4.4 m -> 4.0 m ?
- Crossing angle
  14mrad -> 10mrad ?

=> cf Yokoya-San's presentation & MDI session

Strategy for Factorisation

Detector-level performance

- Efficiencies, resolutions etc
- Study for O(3-4) detector models in full simulation

Example: Particle ID

- Determine actual capabilities in FullSim
- Study impact on analyses by varying PID efficiencies & fake rates in SGV

Physics performance

- ILD_o1 full simulation: reference analysis
- Where ever possible: determine *relative impact* of
  - efficiencies
  - resolutions
  - systematic uncertainties

  in SGV or cheated full sim

Optimisation benchmarks
- Detector Level -

- Hermeticity:
  - for high E (>90%E_{beam}?) e^{+-}/ γ
  - for "normal" e, μ, γ, π, n
- Calorimetry:
  - Jet energy resolution, including $5 < E_{jet} < 50$ GeV
  - Photon energy & angle resolution
  - Bhabha reconstruction
- Tracking system:
  - Efficiency, fake rate
  - $\sigma(1/p_t)$, σ_{IP}
  - Vertex efficiency, resolution
  - Jet charge
  - Flavour tag
- Low momentum particles (p_t = 0.1….2 GeV):
  - Tracking efficiency, $\sigma(1/p_t)$, σ_{IP}
  - Calorimeter detection efficiency
- Particle ID (dE/dx & calo)
  - e / μ / π^{+-} / p / K / n / π^0/ γ
  - Low p_t and "normal"
  - Particle ID in jets
- Exclusive decay mode reconstruction:
  - τ leptons
  - B, D hadrons

Strategy for Detector & Physics Benchmarking

- 1-1 relation between physics measurement and one specific detector performance aspect is *rare*

$\Rightarrow$can we factorize 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

First Testcase: Hermeticity

- Two changes in the pipeline
  - L*: we have been asked to evaluate how far can reduce L*
  - Smaller crossing angle 14 -> 10 mrad: this is an **offer** from the machine side – but will only come if **we quantify the benefits**
- In both cases:
  - Study hermeticity for e, y, mu, hadrons in various configurations
  - Quantify impact of loss / gain of hermeticity for physics analyses

=> Understand "parameter space" around the optimum, take informed decision

News from the ILD Analysis WG

- Started to collect an up to date list of ongoing activities – will help to channel newcomers to places where they're most urgently needed
  - please check http://agenda.linearcollider.org/getFile.py/access?contribId=6&resId=0&materialId=slides&confId=6526
  - Email comments / additions to jenny.list@desy.de
- Started a subgroup on systematic uncertainties led by M. Vos, G. Wilson + NN (Higgs/flavour tag)

Your comments?