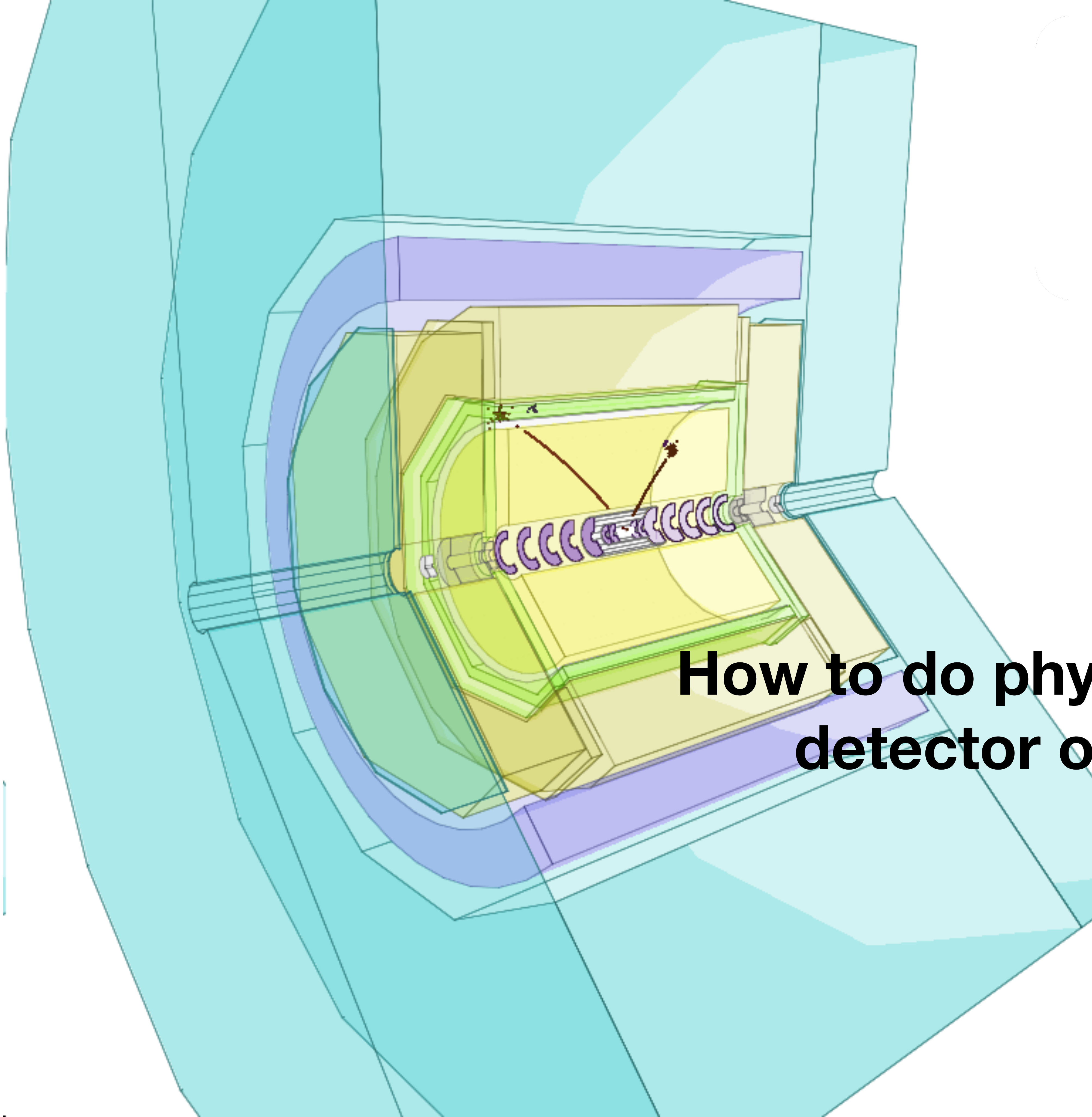

How to do physics-driven detector optimisation

J. List

ILD Meeting 2018
Ichinoseki
Feb 22 2018

Detector Design & Optimisation Questions

What is the benefit of a TPC-based tracking system?

- dE/dx: quantify benefit
- in-flight decays (V0, exotics): quantify impact
- material budget and distribution
  => demonstrate physics-level benefit?

How would we profit from timing? With which resolution?

- TOF for PID
- TOF for background rejection
- 4D (5D) particle flow

- **Is our Si system geometry optimal?**
  - gap VTX / FTD
  - pixelated SIT / FTD / (SET)
    => advantage in pattern recognition / resolution?
- **Is our missing 4-momentum resolution optimal?**
- **Is our photon energy resolution good enough?**

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c.f. talks on Tuesday by Marcel, Felix & Roman!

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Lessons from previous benchmarking

DBD / LoI benchmarking in a nutshell:

- take signal & background DSTs
- fish the signal out of the background such that statistic uncertainty on single observable is minimised
- be better than SiD ;-)

not talking about physics case studies today!

Conclusions?

- often no difference in final ILD vs SiD result - even if detector-level performance different (JER, c-tag, …)
- in case of significant differences: mostly traced back to different approaches in analyses (SUSY Point5, H->cc / gg, …)
- apart from a few simple cases (eg Higgs recoil), weak correlation between final physics result and detector performance - or obscured?

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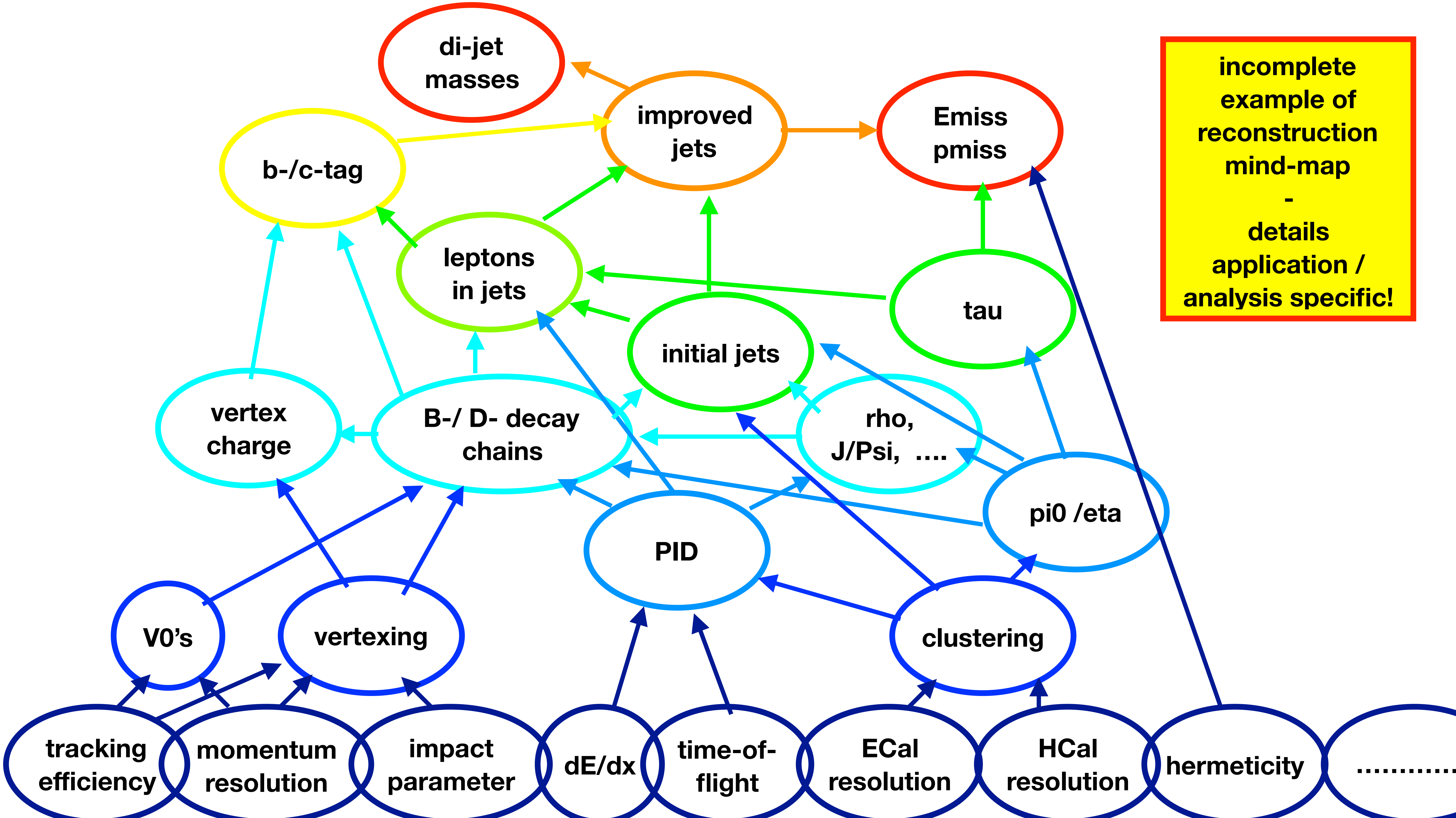
So why do it *again*?

Why is physics-driven optimisation non-trivial?



incomplete example of reconstruction mind-map
-
details application / analysis specific!

What do we expect to learn *now*?

Establish better connection between physics reach and detector performance:

1. **What is the theoretical limit and how far are we away?**
2. **Which performance aspects are important for**
   A. **statistical precision**
   B. **control of systematics**
3. **For each of these:**
   A. **obtain a well-defined performance plot for ILD Report**
   B. **limited by detector or by reconstruction?**
   C. **what can be gained if improved / what would be lost if worse performance? can a requirement be derived?**
4. **Finally, result of full analyses for new detector models**

How to - part I

1. **compare existing full sim results to theoretical limit(s)**
   A. **“ultimate theory limit”: 100% signal efficiency, 0 background, perfect resolution**
   B. **generator-level analysis of signal and irreducible backgrounds (same parton-content)**

=> this can be done NOW!

2. **Identify N most important performance aspects**
   - **think :-)   (…to identify candidates)**
   - **pick a candidate and cheat it in full sim (replace reconstructed value by truth)**
     A. **smear resolution / worsen efficiency by hand => impact on *statistical* uncertainty**
     B. **introduce a bias / shift => impact on *systematic* uncertainty**

=> this can be started anytime using existing DBD samples!

How to - part II

3. **For the N most important performance aspects**
    A. **define relevant performance plot(s) and deliver in ILDPerformance**
    B. **classify limitations / improvements:**
        - **reconstruction:**
            - **cheat / cheat & smear in order to show potential gain**
            - **investigate possible improvements**
        - **detector:**
            - **cheat / cheat & smear in order to show potential gain**
            - **define requirement**
    C. **quantify gain / loss in physics performance for better / worse detector performance - or in presence / absence of specific information (e.g. timing, dE/dx)**
4. **perform full analyses on various ILD models**

What do we need for this?

Intensive use of cheating & truth tools

- MCParticles
- RecoMCTruthLink
- TrueJet

=> c.f. talk by Mikael

Already now can start optimisation

- on generator level
- partially on DBD samples

=> c.f. talks by Shin-ichi & Yu

Already now can use test samples to

- evaluate "physics-object level" performance
- improve and stress test high-level reconstruction

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- **A lot can be prepared and done *before* new samples are available**
- ***Can* and *should* invest time to profit from imminent reconstruction improvements**
- **Can start by simulation only first, and reconstruct once ready**

Optimisation Plan

- **list of benchmark reactions** defined - see next slide
  - a short description of each benchmark will be prepared on ILD confluence pages by conveners
  - at least 2 persons per benchmark
    - eg 1 new student + 1 experienced person / experts from different detector technologies
  - **many volunteers needed - everybody is welcome !**
- first target **500 GeV** (1 TeV)
  - other ECM can be added later if time / interest / need
- **all analyses should start immediately** by
  - evaluating theoretical expectation on generator-level / set-up analyses on DBD samples
  - identifying key performance aspect(s)
  - test this aspect on test samples, contribute to high-level reconstruction where needed
  - implement standard performance plot(s) in `ILDPerformance`

=> can afford to take imminent reconstruction improvements into account (especially if separate simulation run first, then reconstruction)

- **plan to have at least internal analysis note to support ILD Document (can undergo review process and become public note / paper later)**

Physics Benchmarks

WG	Process	Physics	Detector	ECM	Who
Higgs & EW	**H->bb/cc/gg**	**BR**	**c-tag, b-tag, JER**	**500 GeV**	**NN + NN**
	H->bb	mass	JER, JES	500 GeV	Ali Ebrahimi (10%) + Junping Tian
	ee->tautau	A_FB, tau-pol, A_LR	tau-reco	500 GeV	Daniel Jeans **+ NN**
	H->mumu	BR	momentum resolution	500 GeV	Shin-ichi Kawada **+ NN**
	H->invisible	BR limit	JER, hermeticity	500 GeV	Yu Kato **+ NN**
	WW->qqlv	MW, TGCs, beam pol.	JES, JER, electron, mu	500 GeV	Kostiantyn Shpak **+ NN**
	vvqqqq	**QGCs**	**JES / JER**	**1 TeV**	**Jakob Beyer + NN**
	gamma Z	**A_LR, sigma_tot, JES**	**photon, JER/JES, e, mu**	**500 GeV**	**NN + NN**
Top, Bottom & QCD	tt->bbqqqq	x-section, AFB	b-tag, vertex charge, PID	500 GeV	Amjad **+ NN**
BSM	low deltaM Higgsinos	natural SUSY	low-p tracking, PID, hermeticity	500 GeV	Swathi Sasikumar **+ NN**
	mono-photons	**WIMPs / WISPs**	**photon reco, BeamCal**	**500 GeV**	**NN + NN**
	Zh, mh < 125 GeV	limit on ZZh coupling	p res, e reco, JER, hermeticity	500 GeV	Yan Wang **+ NN**

Conclusions

- many interesting optimisation questions
- make targeted use of MC truth / cheating in order to isolate effects
  => this can start already now
- (high-level) reconstruction often limiting performance thus obscuring impact of detector design
  => should invest time to include imminent improvements / fix holes / finish tuning:
  - BeamCal reco
  - silicon tracking
  - TOF / hit timing
  - V0Finding
  - Vertexing
- if needed, run separate simulation first
- need many volunteers to adopt a benchmark!
- from all detector technologies!!!

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THE chance to develop & test improvements before new physics productions coming up as next step!

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