Detector Benchmarking

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From Physics Studies to Benchmarking

- We believe that the physics case for a TeV-scale linear $e^+ e^-$ collider has been made.
- The emphasis of analyses now shifts towards
  - Optimization, evaluation and comparison of detector choices
  - Realities required by engineering: e.g. amount and distribution of readout and support material, …
  - Realities required by realistic detector response simulations: e.g. electronics digitization, noise, …
  - Realities required by reconstruction algorithms: e.g. track finding & fitting, PFA, jetfinding, …

Motivation for Common Benchmarks

- Detector concepts will naturally seek to optimize their designs using physics processes.
- The wider community would like to see demonstrated physics capabilities from mature detectors, e.g. with a reasonable level of engineering, costing, etc.
- Natural, then, especially with limited resources, to agree upon a common set of analyses to be used by all the concepts in the LOI process.

Common LOI Benchmarks

- *…The evaluation of the detector performance should be based on physics benchmarks, some of which will be the same for all LOIs based upon an agreed upon list and some which may be chosen to emphasize the particular strengths of the proposed detector…*

"Guideline for the definition of a Letter of Intent …", 3 October '07

Benchmark Selection Process

- WWS Software panel (Akiya Miyamoto, KEK, Ties Behnke, DESY, Norman Graf, SLAC,) in consultation with the detector concepts and the WWS Roadmap Panel and starting from the Benchmark Panel Report has drafted a short list of processes which are:
  - consistent with the ILC baseline
  - sensitive to detector performance
  - not overly dependent on sophisticated analysis techniques.
    - i.e. emphasis is on demonstrating detector performance
- Expect, and welcome, input from IDAG

Benchmark Processes

$e^+e^- \longrightarrow ZH,\ H \longrightarrow e^+e^-X,\ \mu^+\mu^-X$ $(M_H=120\ \text{GeV},\ E_{cms}=250\ \text{GeV})$

- tracking efficiency and momentum resolution
- material distribution in the tracking detectors
- EM shower ID, kink reconstruction (bremsstrahlung)
- Higgs Mass and cross section

$e^+e^- \longrightarrow ZH,\ H \longrightarrow c\bar{c},\ Z \longrightarrow \nu\ \bar{\nu}$ $(M_H=120\ \text{GeV},\ E_{cms}=250\ \text{GeV})$

- heavy flavour tagging, secondary vertex reconstruction
- multi jet final state, c-tagging in jets, uds anti-tagging
- test anti-tagging by studying the $H \rightarrow gg$
- $BR(H \rightarrow c\bar{c})$

Benchmark Processes

$e^+e^- \longrightarrow ZH,\ H \longrightarrow c\bar{c},\ \ Z \longrightarrow q\bar{q}$ $(M_H = 120 GeV,\ E_{cms} = 250 GeV)$

- in addition to the charm tagging, this final state tests the confusion resolution capability
- BR($H \rightarrow c\bar{c}$)

$e^+e^- \longrightarrow Z \longrightarrow \tau^+ \tau^-$ $(E_{cms} = 500\ GeV)$

- tau reconstruction, aspects of particle flow
- π^0 reconstruction
- tracking of very close-by tracks
- σ, A_{FB}, and τ polarization

Benchmark Processes

$e^+e^- \rightarrow t\bar{t}$, $t \rightarrow bW$, $W \rightarrow qq'$ (M_{top}=175GeV, E_{cms}=500 GeV)

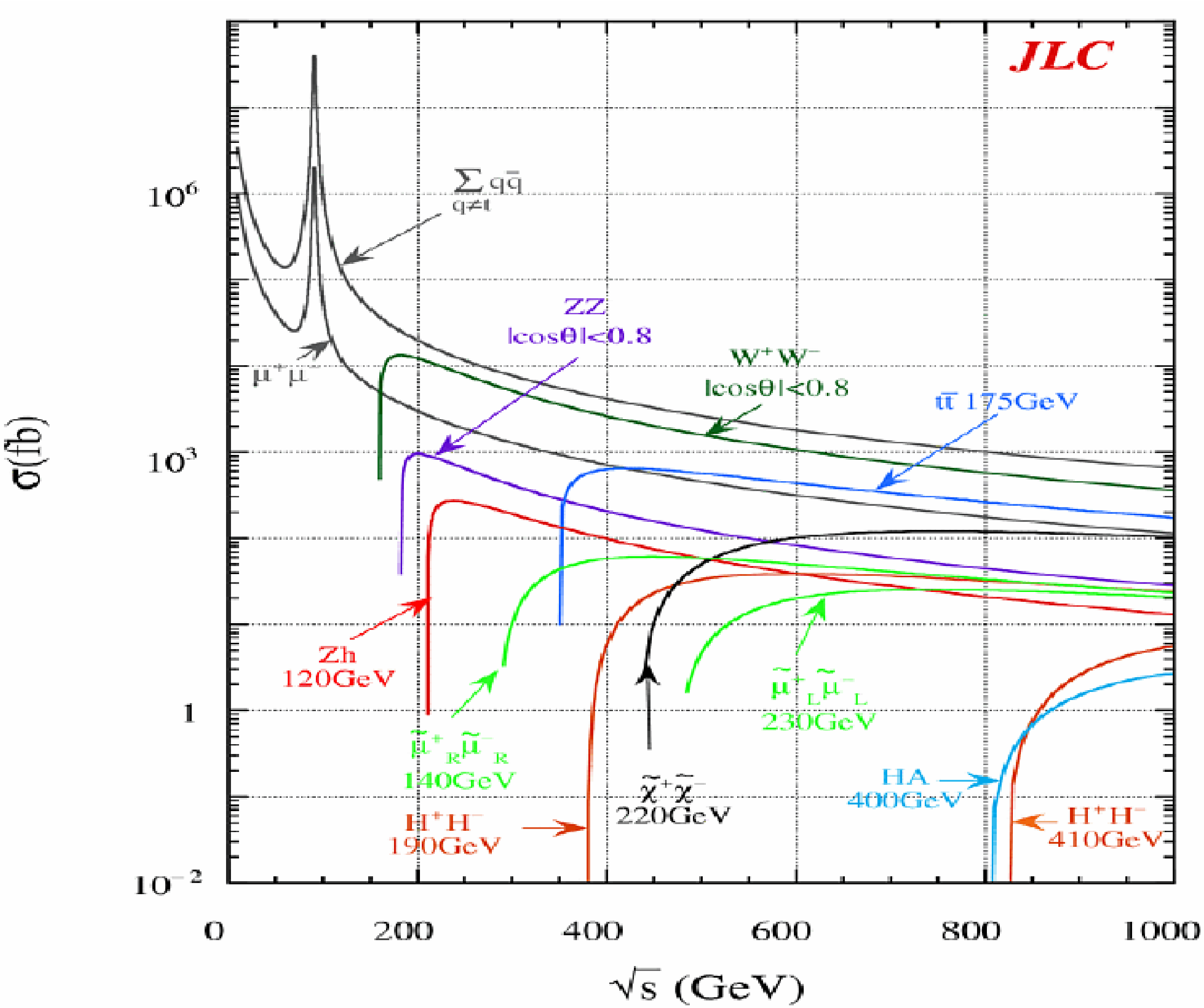
- multi jet final states, dense jet environment
- particle flow
- b-tagging inside a jet
- maybe lepton tagging in hadronic events (b-ID)
- tracking in a high multiplicity environment
- σ, A_{FB}, and m_{top}

$e^+e^- \rightarrow \chi^+ \chi^- / \chi_2^0 \chi_2^0$ (E_{cms}=500 GeV)

- particle flow (WW, ZZ separation)
- multi-jet final states
- SUSY parameter is point 5 of Table 1 of hep-ex/0603010
- σ, and masses

Standard Model Backgrounds

- All analyses used in the context of the detector optimization and LOI process will need an inclusive sample of the Standard Model Background.
- Will provide the SM sample centrally in stdhep format, for all concepts to use.
- Provide all information and tools necessary to produce specific signal samples individually with exactly the same setup as this SM sample.


JLC
σ(fb)
10^6
10^3
1
10^{-2}
0
200
400
600
800
1000
√s (GeV)
$\sum_{q \neq t} q\bar{q}$
$\mu^+\mu^-$
ZZ
|cosθ|<0.8
W⁺W⁻
|cosθ|<0.8
tt̄ 175GeV
Zh
120GeV
$\tilde{\mu}^+_R \tilde{\mu}^-_R$
140GeV
H⁺H⁻
190GeV
$\tilde{\chi}^+\tilde{\chi}^-$
220GeV
$\tilde{\mu}^+_L \tilde{\mu}^-_L$
230GeV
HA
400GeV
H⁺H⁻
410GeV

Event Generators

- No single MC generator is optimal for everything.
- However, Whizard is a multi-purpose Matrix Element generator.
  - Signals and backgrounds of all types (SM + MSSM) can be produced with the same settings
  - It contains all interferences, hence it is more accurate than generators like Pythia, especially for complex final states (6f and more)
  - Some inaccuracies remain, but benefits outweigh these minor issues.

Whizard SM Sample

- Generate an inclusive set of MC events with all SM processes
- WHIZARD Monte Carlo used to generate all 0,2,4,6-fermion and t quark dominated 8-fermion processes.
- 100% e^- and e^+ polarization used in generation. Arbitrary electron, positron polarization simulated by properly combining data sets.
- Fully fragmented MC data sets are produced. PYTHIA is used for final state QED & QCD parton showering, fragmentation, particle decay.
- Events are weighted!

Standard Model Sample

- Full 2ab^{-1} SM sample available via ftp from SLAC.
- Each file corresponds to a particular initial e-/e+ polarization and final state

  ftp://ftp-lcd.slac.stanford.edu/ilc/whizdata/ILC500/

  - cumbersome to work with for end user
    - Have to mix polarizations by hand
    - Each file contains only processes of one type, so need to run over complete data set (thousands of files) to get faithful subset.
- 500 fb^{-1} sample of these events generated with 80% e$^-$, 30% e$^+$ polarizations, randomly mixed events from all processes
  - ftp://ftp-lcd.slac.stanford.edu/ilc/ILC500/StandardModel/

Next Steps for SM Data Sample

- Remove 120 Higgs from n fermion final states at 500 GeV, and add explicit ffH, ffHH, etc. final states.
- Regenerate states with τ in final state using TAUOLA.
  - Coding done at DESY, to be incorporated soon.
- Produce full SM data set at 250 GeV
  - Need agreed-upon machine parameters.

Additional Signal Processes

- Detector concepts are free (and encouraged) to add additional processes to this list in order to optimize their designs or demonstrate the capabilities of the detectors.
- These should, however, be generated using conditions as close as possible to those used for the canonical samples.
- It is more important for this process that we use a common, well-understood set of events than it is to pick the “best” generator for each final state.
- We are comparing detector response, not making physics case for the machine.

Producing Signal Samples

- All necessary files to set up Whizard in exactly the same way as done for the SM sample:
  - http://confluence.slac.stanford.edu/display/ilc/Standard+Model+Data+Samples
- Beam Parameters can be set up using information at:
  - ftp://ftp-lcd.slac.stanford.edu/ilc/ILC500/StandardModel/whizard-src/user.f90
  - ftp://ftp-lcd.slac.stanford.edu/ilc/ILC500/StandardModel/guinea-pig/ilc_0500_may05_run05_seed06/
- Fragmentation can be set up using information at:
  - ftp://ftp-lcd.slac.stanford.edu/ilc/ILC500/StandardModel/a6f/include/ilc_fragment_call.f90
  - ftp://ftp-lcd.slac.stanford.edu/ilc/ILC500/StandardModel/a6f/include/calc_a1sq_a2sq.f90

Additional Backgrounds

- GuineaPig pairs and photons (Cain too?)
  - Added crossing angle, converted to stdhep, available here.
- Muons and other backgrounds from upstream collimators & converted to stdhep.
  - Need to validate and understand normalizations.
- $\gamma\gamma\rightarrow$ hadrons generated as part of the “2ab^{-1} SM sample.”
- All events then capable of being processed through full detector simulation.
- Additive at the detector hit level, with time offsets, using LCIO utilities.
  - i.e. simulate response separately for signals and backgrounds, then add at digitization/reconstruction level.

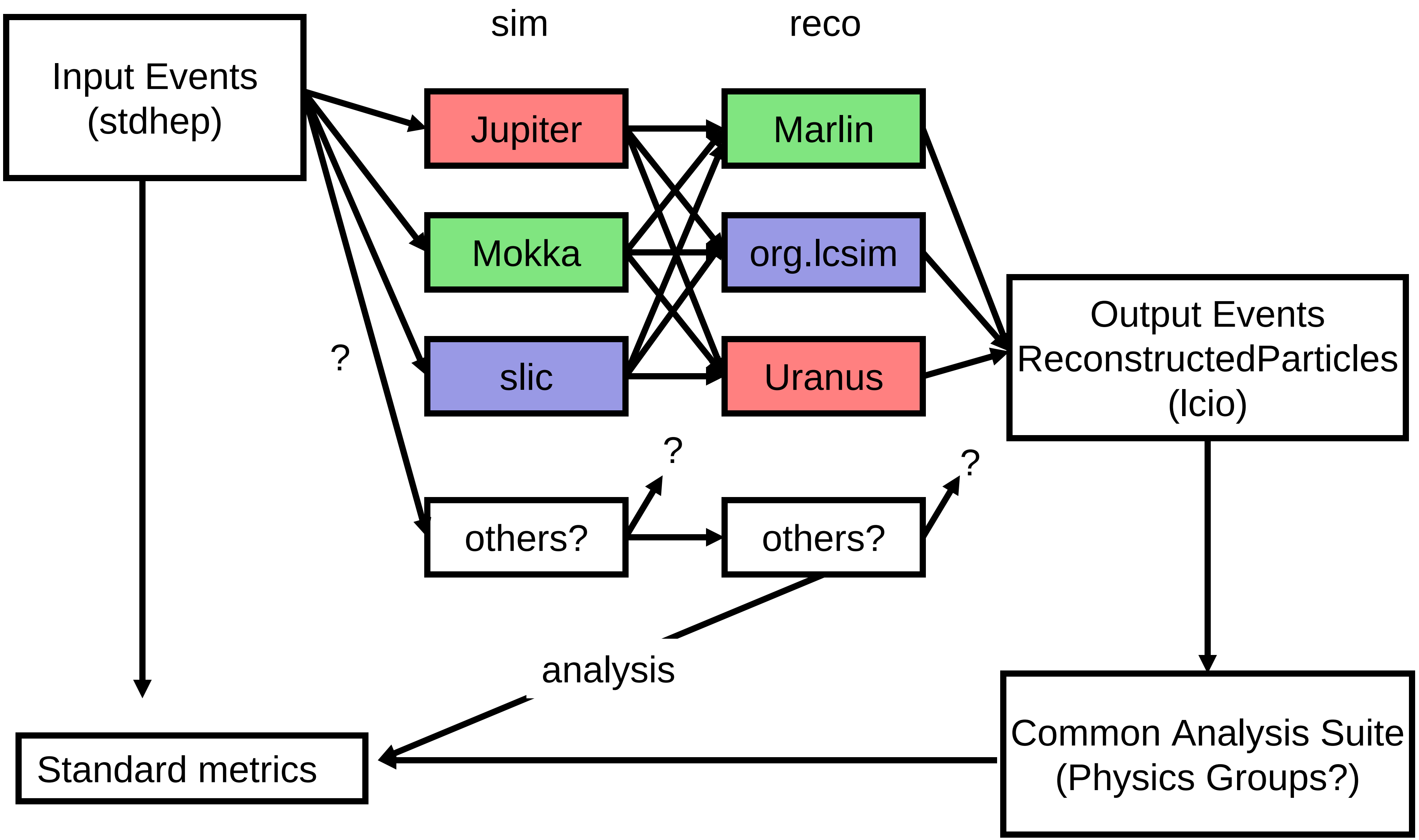
Additional Simulation Issues

- Crossing Angle
  - Agree that events will be generated with 0° and the 14mr crossing angle will be accounted for at the time of simulation.
- Detector Magnetic Fields
  - Implementing full field maps in Geant is very CPU consuming. Propose to generate signals using simplified fields, full fields for far-forward backgrounds.
- Essential to fully document and maintain a provenance for all files (and analyses?)

“Validation” Process

- Transparency in the analysis comparisons would be ensured if input and output were strictly controlled.
- Generating and providing a canonical data sample ensures common input.
- As I understand the LOI process, this benchmarking is primarily a detector concept exercise.
- Can we more fully involve the physics working groups?
- Could we develop and release “canned” physics analyses to reduce systematic uncertainties in e.g. jet-finding, combinatorics, constrained fits, …
  - Create library of analysis drivers which target LCIO lists of ReconstructedParticle.
  - Write out standard set of histograms or analysis metrics.
- Strengthens the “horizontal” nature of the physics working groups, does not disenfranchise them from LOI.

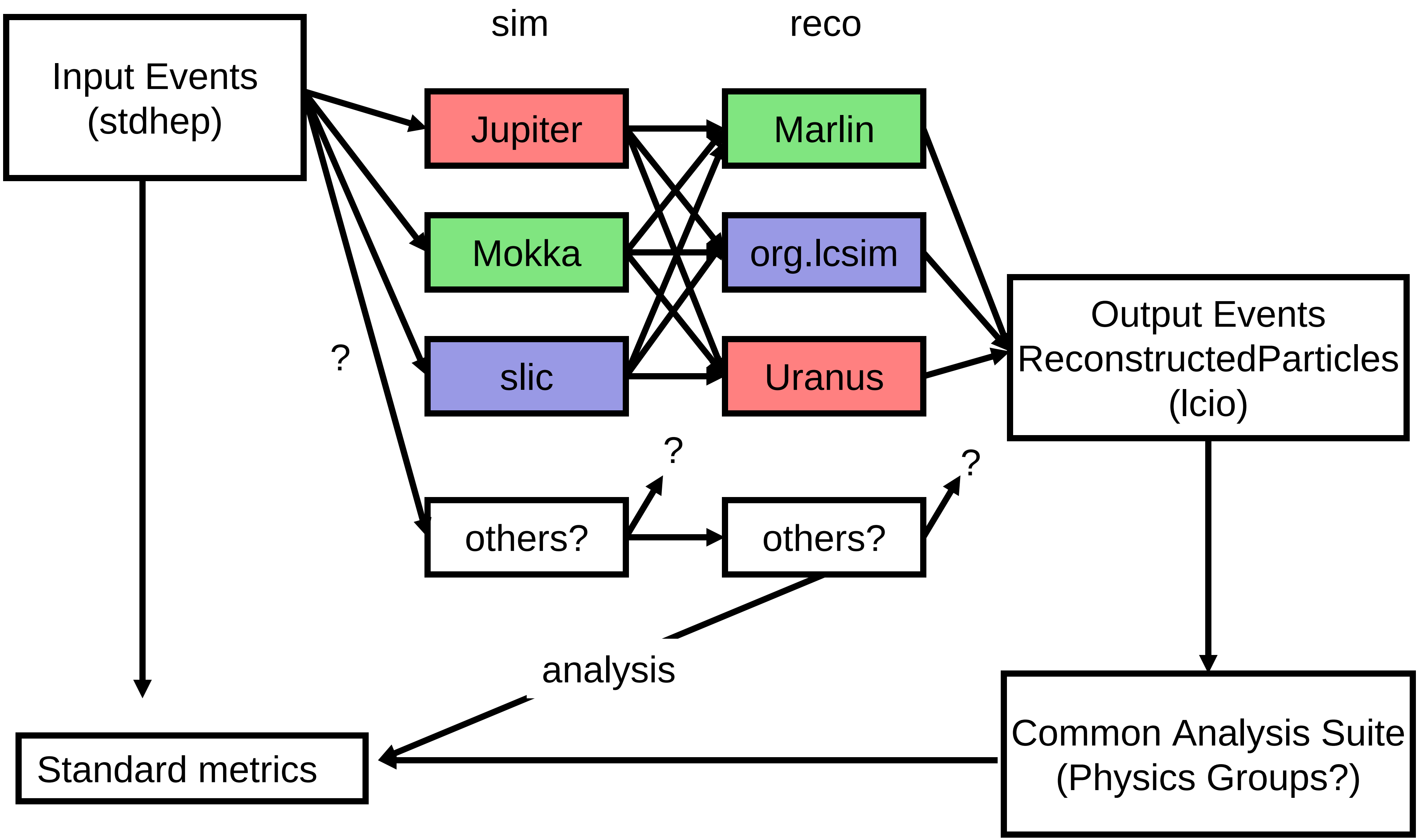
Analysis Flow



personal thoughts

Analysis Flow

Three regional efforts, ACFA-LC, ALCPG, ECFA-LC all support the LCIO event data model, making interoperability possible.



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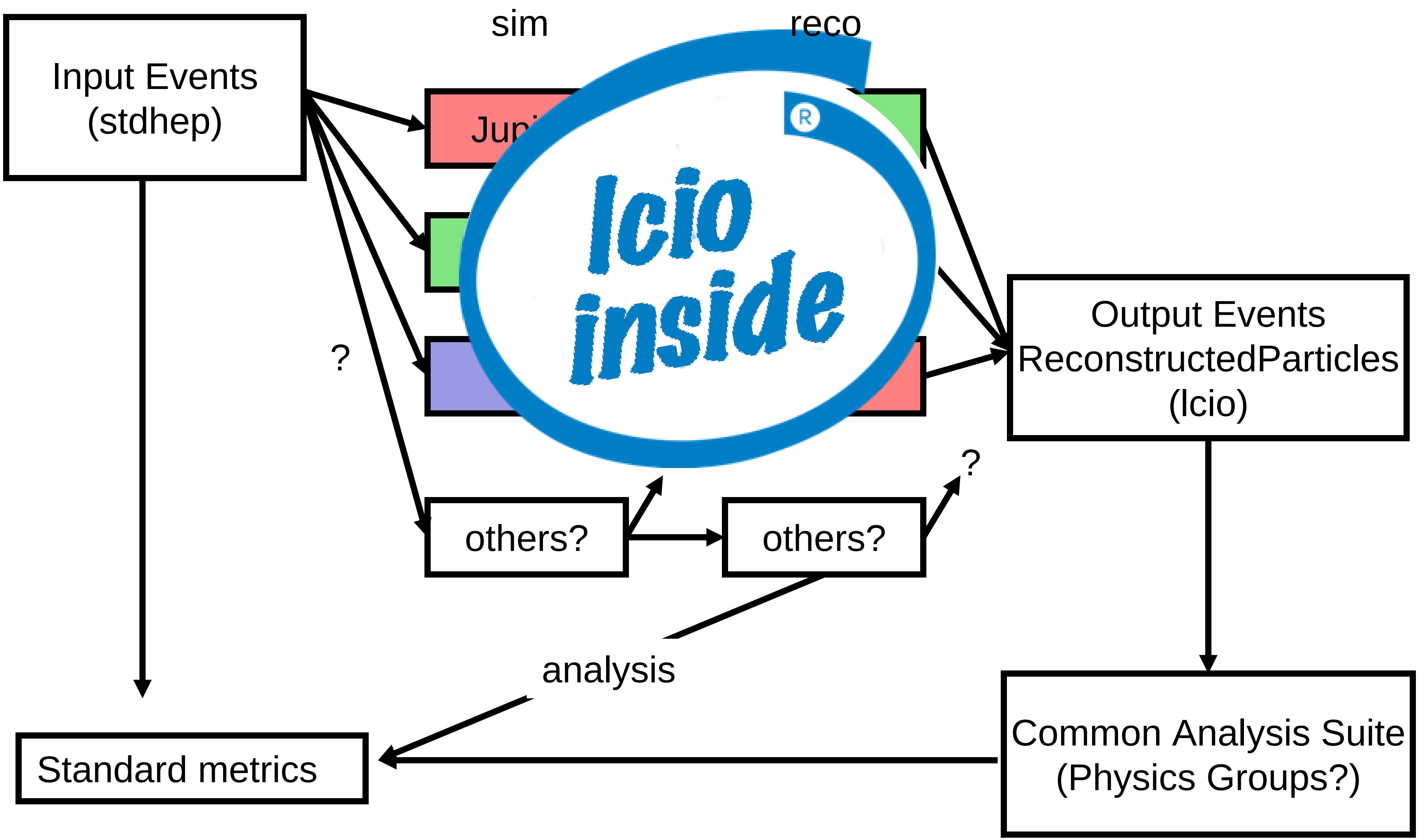

personal thoughts

Summary

- The WWS Software Panel has produced a short list of physics processes to be studied by each of the concepts for the LOI.
- Individual concepts will also analyze additional reactions in the process of optimizing their detector designs.
- A common set of Standard Model physics and machine backgrounds is being / has been generated.
- Events will be provided in stdhep format.
- Performance metrics have been identified.
- Details still to be resolved, and changes may still be made, but the benchmarking process is well underway.