Physics Simulation for Hadron and Lepton Colliders

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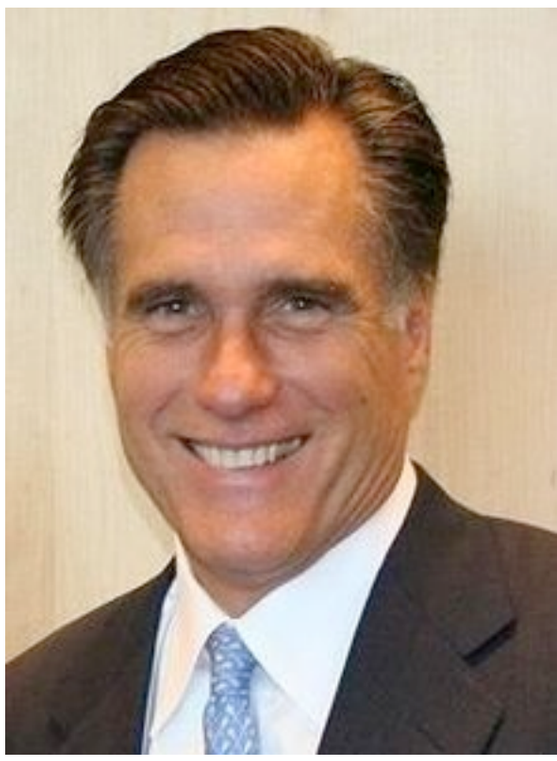
CPM2012
FNAL

A couple of notes…

Nobody has approved this message!

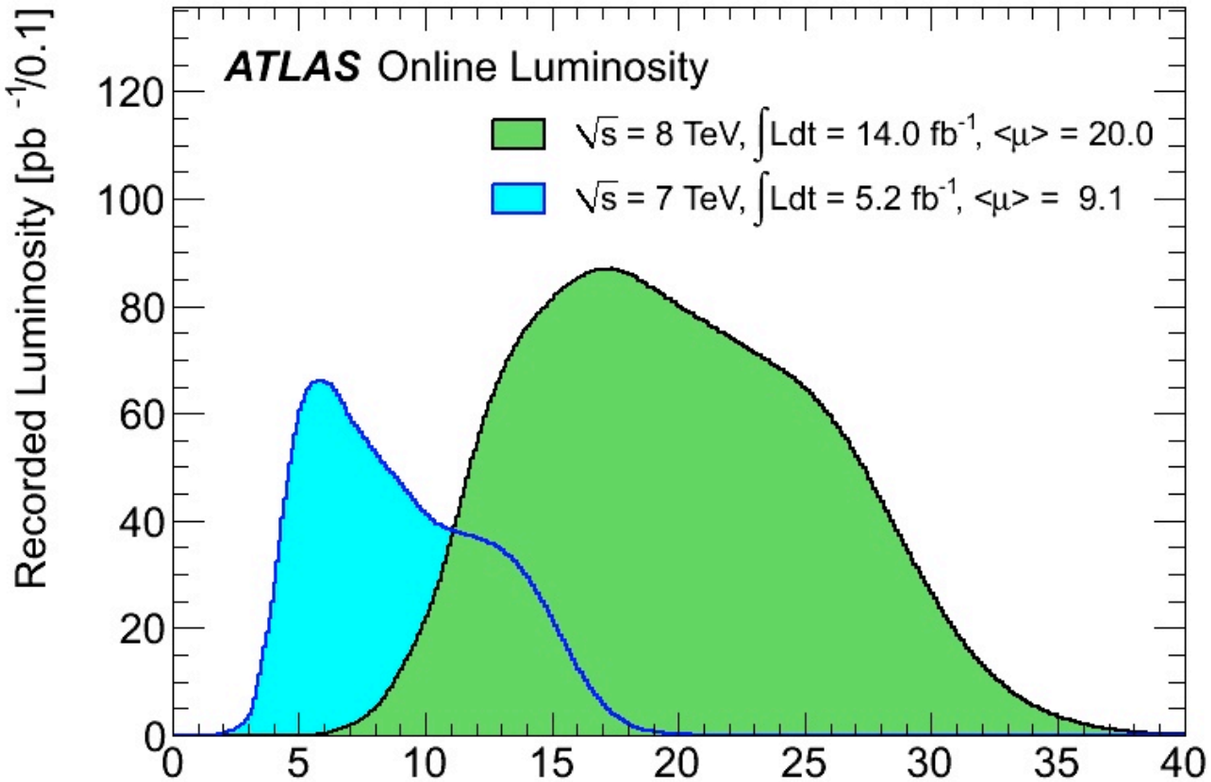


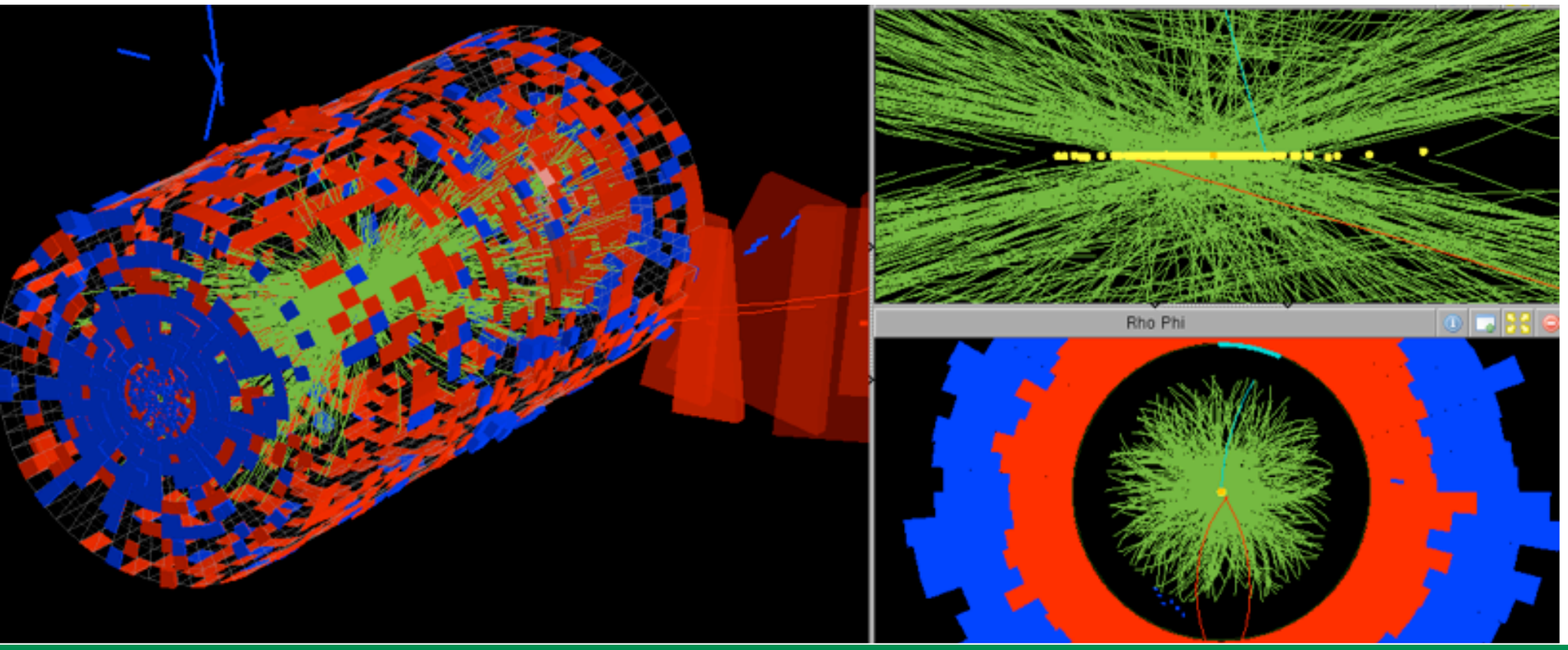
- I am not what I would call a ‘simulation expert’
- These are my thoughts, motivated by conversations with some real experts
- This is intended to start a discussion in the physics groups about what will work for them

LHC and Upgrades

Pileup at LHC

- ~35 pp interactions per crossing at 50 ns, $L_{peak} = 0.7 \times 10^{34}$
- HL-LHC would increase this to ~140/BX at 25 ns, $L = 5 \times 10^{34}$
- Challenge for any simulation...





78 verticies in CMS (special high-pileup fill)

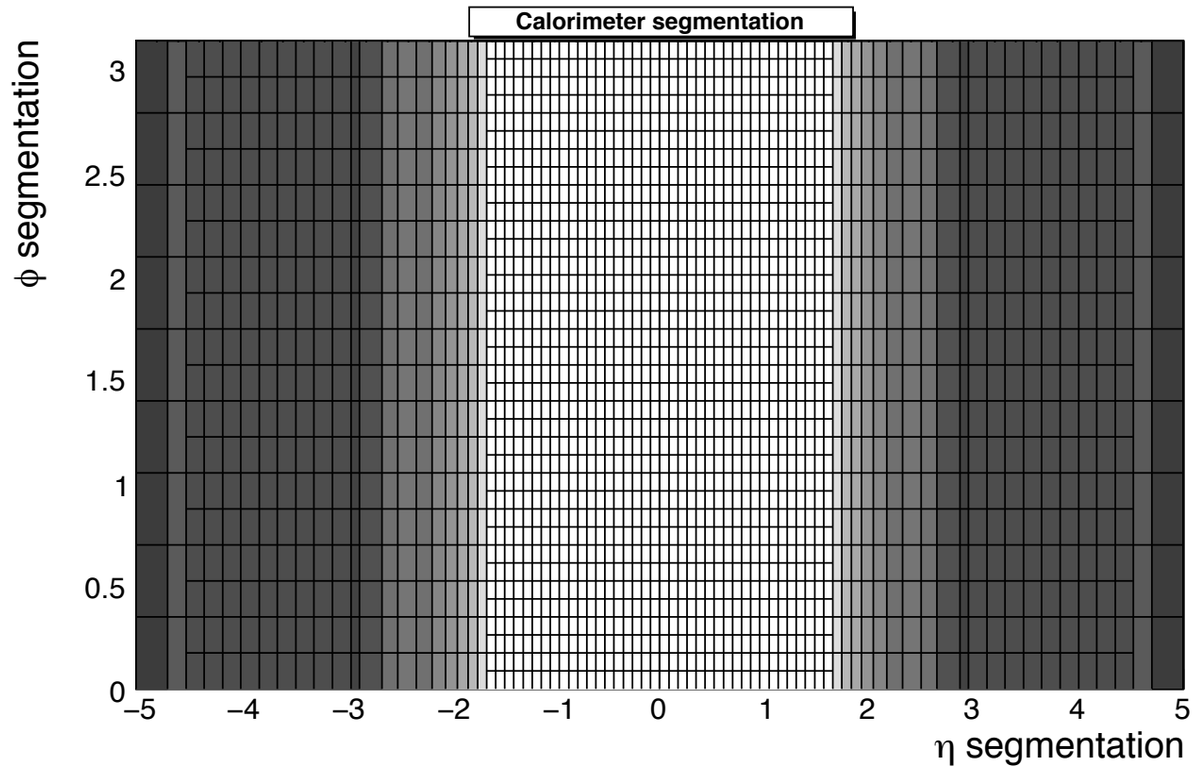
HL-LHC, HE-LHC simulations

- ATLAS and CMS contributions to European Strategy Symposium
  - Largely assume detector upgrades mitigate increased pileup
  - Physics analyses based mostly on 2012 detector performance
  - Justified? Probably as good a guess as any...
- Collaboration-driven studies must continue for justifying Phase II (HL-LHC) upgrades → synergy with Snowmass process
  - Krakow results will be more fully developed
  - Good questions from physics groups may inspire further work
- ATLAS/CMS simulation/analysis code is proprietary, official collaboration results will need collaboration approval
  - Not impossible, but doesn't lend itself to quick turnaround

Clearly want certified ATLAS/CMS results, but also need to be realistic about how long this might take, or how flexible this can be

Parameterized (fast) simulation

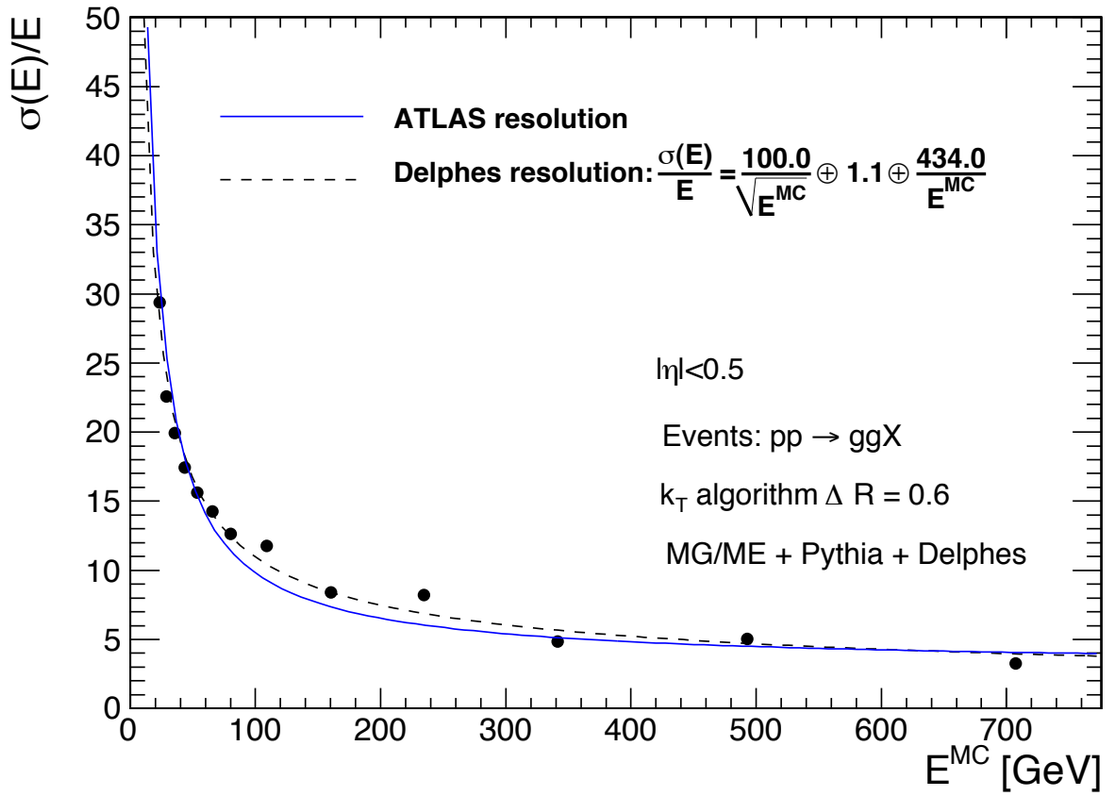
- Major exercise at LHC olympics (2006) with PGS (Pretty Good Sim)
- Current favorite seems to be Delphes (https://cp3.irmp.ucl.ac.be/projects/delphes)
- Stresses the calorimeter
  - Realistic segmentation (multiple η ranges)
  - Parameterized response (based on published perf.)
- Emulates useful analysis features
  - Jet finding, MET
  - Lepton ID + isolation
  - Trigger menus



- Detector parameters files available for ATLAS/CMS (need to verify)
- Simulation only (will read Les Houches format, or many others)

Example Delphes Performance

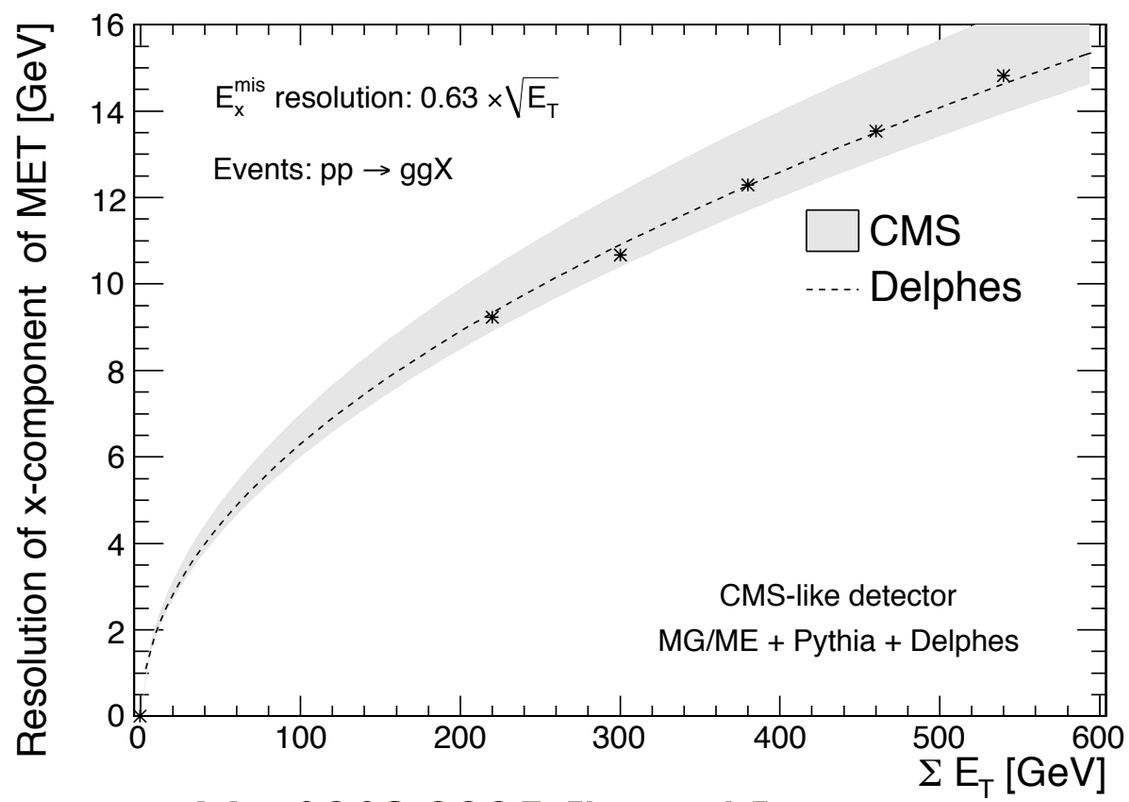
- Atlas Jet resolution



- CMS MET resolution

As was also shown by PGS,
can get pretty reasonable results
from parameterized calorimeter simulation

Will likely never match collaboration
analysis tools, always an approximation



arXiv:0903.2225 [hep-ph]

Beware!

- Can't apply this blindly to all analyses
- Pileup can't be (easily) simulated
  - Although random noise could be added to calorimeter...
- Also 'strongly-produced' backgrounds (di-jets, W+jets, ...)
  - Selecting signal usually isn't the problem → rejecting backgrounds is
  - Hard to believe any simulation when you are rejecting backgrounds by many orders of magnitude (sensitive to tails)
  - Point of HL-LHC is to be sensitive to even lower cross-sections...
- General danger zones
  - Low P_T leptons, weak isolation, small non-zero MET, taus, soft jets, ...
  - Studies still useful, but must avoid drawing strong conclusions
  - Working groups best places to evaluate reliability of individual simulation/analyses

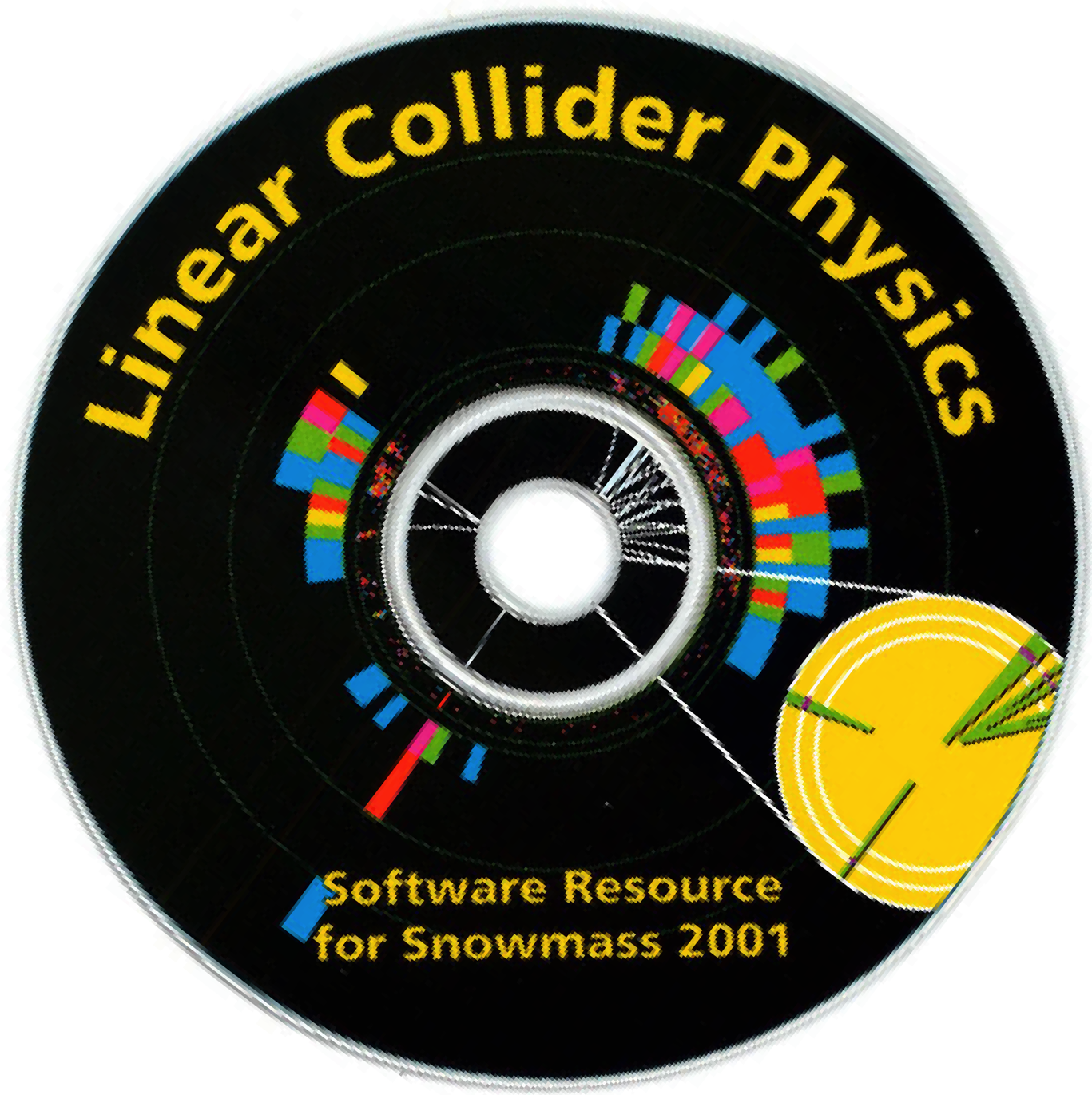
LHC Simulation Proposal

My opinion, for discussion...

- Certify two fast-sim parameter sets (ATLAS/CMS) for all LHC
  - Similar to Krakow strategy
  - Could try to agree on one 'average' detector, but probably not worth political effort
  - Differences may provoke official followup from ATLAS/CMS
- Provide common straw-man trigger menus for HL-LHC, HE-LHC
  - Must be educated guess, hopefully only need one for both detectors
  - Feedback from studies can help develop trigger strategies
- Working groups should promote official ATLAS/CMS studies in addition (not clear how these will be done either)
- Working groups must be responsible to avoid drawing strong conclusions from dubious simulation results and improper tools (including official ATLAS/CMS studies)

Lepton Colliders

ILC Simulations

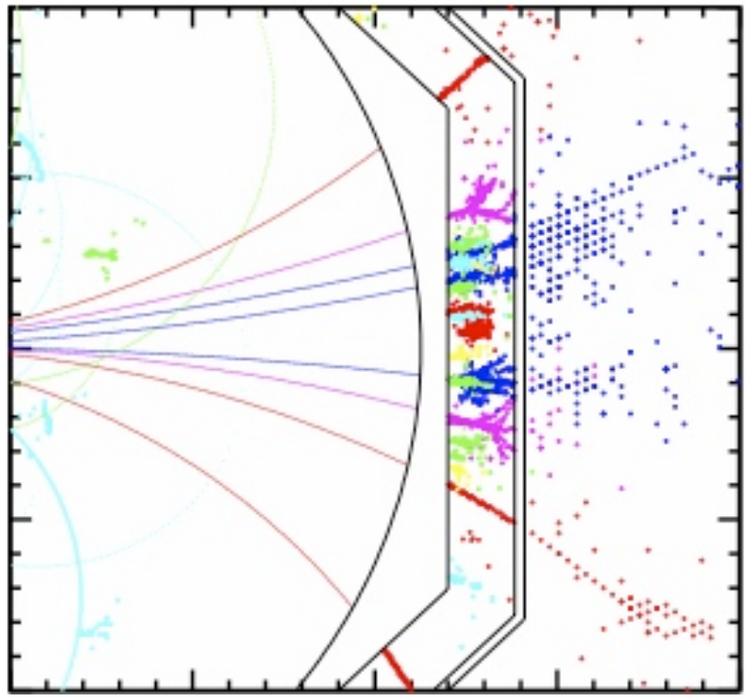


Long and fruitful history of Snowmass LC physics studies
This CD included generators, analysis code, even data samples

ILC Status

- ILC is probably the ideal machine for fast simulation physics studies
  - Democratic cross sections (background rejection easier)
  - Small (but not zero) pile-up and machine backgrounds
  - LHC-style (Delphes) probably won't work out of the box, as really need jet resolution, not calo resolution (Particle Flow)

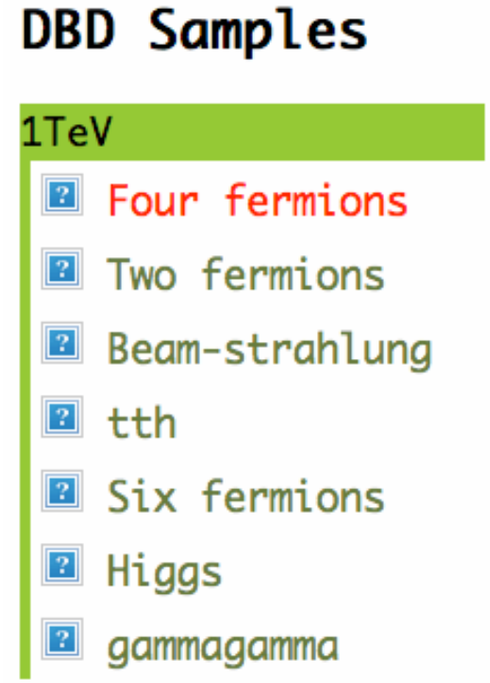
ILD



- Already has highly developed full sim frameworks
  - Driven by needs of detector studies
  - Common generators
  - SiD and ILD detector simulations
  - Some common reconstruction tools (e.g.: particle flow, vertexing)
  - Much more integration between detector concepts than in the past (although differences do remain)

DBD MC Production

- Currently in midst of the Detailed Baseline Design process
- As part of that, a full-blown 'professional' MC simulation has begun
  - Common sample generation (samples available)
  - Full G4 detector simulation (including bgd. overlay)
  - 'Data-ready' reconstruction package
  - Reco physics objects written to output DST
  - All under automated Grid production system
- All of this is (or will be) available for anybody to analyze

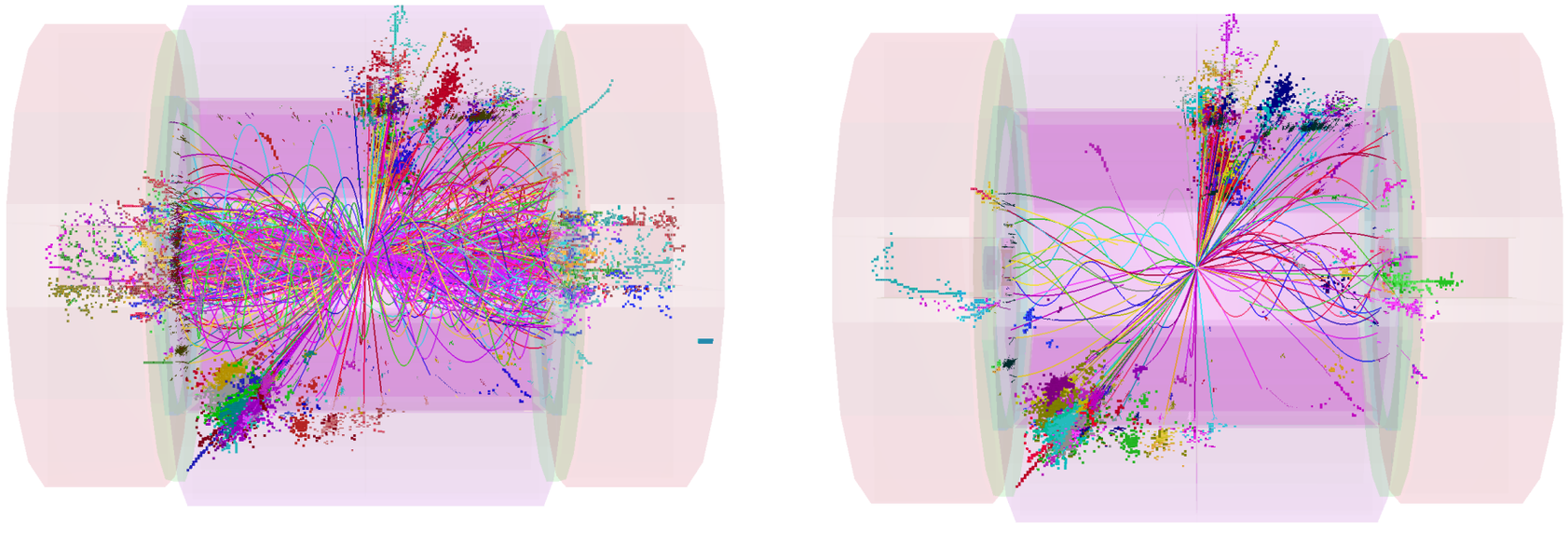


http://ilcsoft.desy.de/dbd/generated/

Can do real physics analyses on fully simulated and reconstructed samples without joining a collaboration!

- Also FastSim options
  - SGV3 for ILD (replacement for simdet, tuned to full simulation)
  - org.lcsim for SiD (still perfectly functional)

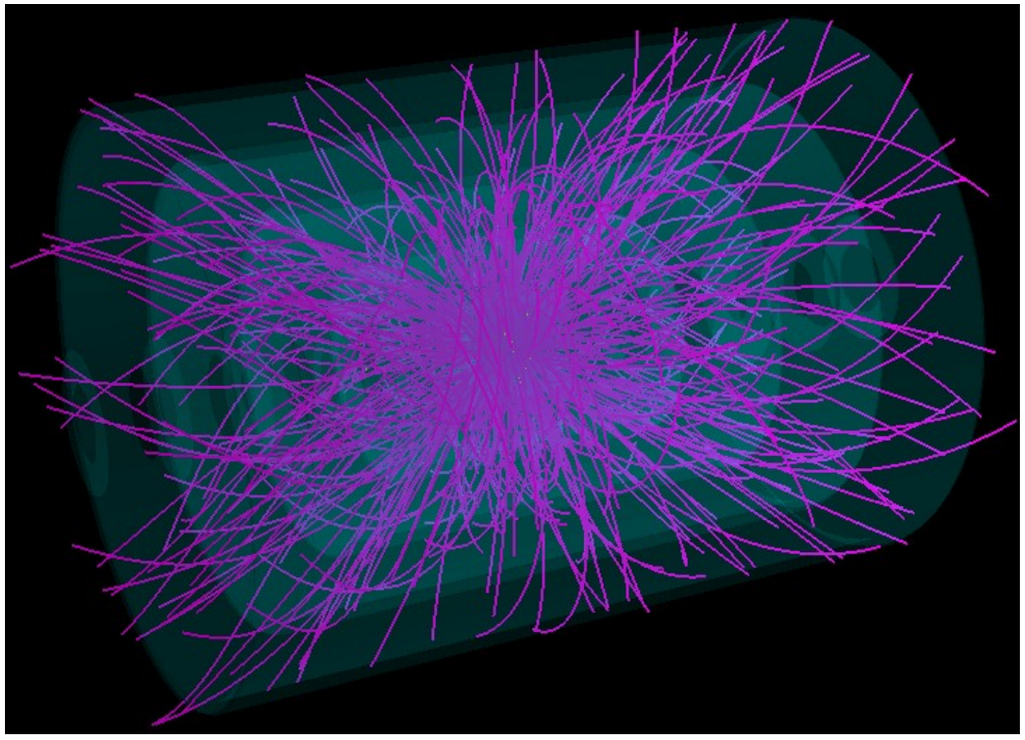
CLIC



HH→tbtb
CLIC CDR

- Beam backgrounds/pileup relatively more important at higher $\sqrt{s}$
  - Challenge for detector design (10 ns readout)
  - Fast simulations should be used with more caution here
- CLIC studies have adopted the ILC framework
  - Used for CLIC CDR
  - Versions of SiD and ILD detectors, adjusted for CLIC
  - Background/pileup overlay integrated into samples
  - Similar reconstruction as ILC

Muon Collider Studies



A. Mazzacane
Telluride WS

- Even more challenging environment (muon decay backgrounds)
  - Solution again is timing → large detector design challenge
  - Detectors a hybrid between ILC and LHC
- Physics case largely identical to ILC/CLIC (aside from μμ→H)
- Telluride studies use ILCroot*, now moving to ILC framework as well
  - Full simulation
  - Machine background overlays

* unrelated to ILC

Lepton Collider Simulation Proposal

My opinion, for discussion...

- Use fully simulated/reconstructed DST samples where possible
  - Samples are (or will soon be) available
  - Frustrated theorists can do a real analysis!
  - Probably easiest for ILC (production ongoing now)
  - Likely needs a bit better documentation, but warm bodies help...
- Exercise production chain for new signal samples
  - Submit 4-vectors in favorite format
  - Runs on grid, little human intervention needed
- Fast simulation can still be useful, but anything promising should be followed up with a full analysis, since the samples are there
- Stunning consolidation across the lepton collider community, Snowmass should profit from this development

Outliers

Other facilities

VLHC-style hadron collider

- Probably just an extension of HE-LHC studies
  - Can only guess at the physics
  - Can only guess at the detectors
- Using something like Delphes probably most reasonable approach
- No idea how to determine detector parameters

Circular Higgs Factory

- More driven by detector assumptions/location
  - In LHC tunnel: ATLAS/CMS - Delphes simulation probably best, or get answers from ATLAS/CMS
  - In new tunnel w/ ILC-style detector, use ILC studies/tools
  - Cheaper detectors: probably want detailed detector study on how degraded detectors effect Higgs properties

Summary

- Agree on ATLAS/CMS parameters, promote fast simulation studies
- Prod ATLAS/CMS to do more realistic studies on important points
- ATLAS/CMS needs this to sell detector upgrades anyways, make sure interesting questions are being answered

ATLAS/CMS have their own problems here

- Striking consolidation of effort in lepton colliders
- No reason not to use fully simulated and reconstructed samples
- Push to make it easy to turn a good idea into a fully simulated/ reconstructed sample which can be analyzed by a wide audience

Working groups should think about this,
best if some common solutions can be found

Thanks for useful information from Beate H., Graham W., Norman G., Mark T., Ron L., and dinner last night