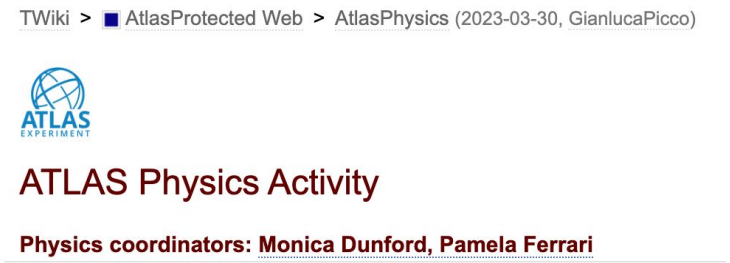
Experimental HEP Analyses

ATLAS Working Groups

- ATLAS consists of numerous working groups
  - Detector operations
  - Trigger
  - Computing
  - Detector upgrades
  - etc.
- We will focus on the Physics working group
- Contains all work on Physics Analysis (PA) and Combined Performance (CP)
- https://twiki.cern.ch/twiki/bin/view/AtlasProtected/AtlasPhysics
- Directed by Physics Coordinators (PC)
  - Rotating 2 year appointment
  - High-level decisions
  - Decisions on analysis approval



PA and CP group structures

- PA and CP groups each focus on one area of physics or performance
  - CP groups provide recommendations for using objects in physics analysis
- Each PA and CP group is directed by 2 conveners
  - Rotating 2 year appointment
  - Coordinate all work within realm of group focus
- Each group is made from subgroups with a more narrow focus
  - 2 year appointment for subgroup conveners
- PA subgroups contain multiple analysis teams
  - 2 analysis contacts direct all work related to performing the analysis until publication
  - Sometimes one analysis team works on multiple analyses/publications simultaneously
- CP subgroups may contain analyses, but often work is directed by conveners

CP groups

Combined Performance (CP) Groups

E/gamma	R. Turra, L. Aperio Bella
Flavour Tagging	B.X. Liu, F.A. Di Bello
Inner Tracking	G. Facini, C. Grefe
Jet/EtMiss	R. Camacho Toro, M. Leblanc
Muon	M. Vanadia, R. Nikolaidou
Tau	D. Ta, S.M. Farrington

Jet/EtMiss subgroups

Subgroups	Conveners
Etmiss and pileup jet tagging	Michael Holzbock, Aaron O'Neill
Jet definitions and MC calibration	Hannsjoerg Weber, Margherita Spalla
Software and Validation	Jana Schaarschmidt, Max Swiatlowski
Jet tagging and scale factors	Josu Cantero, Brian Le
Jet in situ calibration and resolution	Jona Bossio, Daniel Camarero

PA groups

Physics Analysis (PA) Groups

B Physics & Light States	P.U.E. Onyisi, A. Cerri
Exotics	F.A. De Almeida Dias, T. Vazquez Schroeder
Heavy Ions	M. Rybar, A. Angerami
Higgs	T. Masubuchi, N. Berger
Higgs & Diboson Searches	A. Ferrari, E. Brost
Physics Modelling	M. Gignac, D. Hirschbuehl
Standard Model	O. Kepka, P. Sommer
Supersymmetry	B.H. Hooberman, J. Montejo Berlingen
Top	M. Vos, A. Knue
Upgrade Physics	T. Strebler, A. Schwartzman

HDBS subgroups

Subgroup information

Subgroups	Conveners
DBL DBL is a Boson Lab	Joany Manjarres, Antonio Giannini
HBSM Higgs Beyond-the-SM	Imma Riu, Tatjana Lenz
HLRS Higgs and Light Resonance Searches	Rafael Coelho Lopes De Sa, Elliot Reynolds
DiHiggs SM and BSM Higgs Pair Production	Valentina Cairo, Alessandra Betti
CDM Common Dark Matter	Zirui Wang, Spyros Argyropoulos

DiHiggs analyses

Full Run 2 published analyses

Channel	Mailing List	Contacts	Combination Liaison	TWiki	Meeting Time	Agenda Archive	Glance Record
bbγγ		Valentina Cairo, Elisabeth Petit (ggF-optimized)	Alex Wang	DiHiggsTobbyy	Wednesdays 17:00	bbγγ Indicomb	ggF-optimized bbyy, full Run 2 HL-LHC HH->bbyy prospects
bbττ		Tatjana Lenz, Allison McCarn Deiana (resonant and non-resonant xsec)	Alessandra Betti (resolved) Bowen Zhang (boosted)	DiHiggsTobbtautau	Wednesdays 15:00	bbττ Indicomb	Resonant and non-resonant bbtautau, full Run 2 Boosted bbtautau, full Run2 HL-LHC HH->bbττ prospects
bbbb		Max Swiatlowski, Rafael Teixeira De Lima (ggF resonant and resolved non-resonant)	Jana Schaarschmidt	DiHiggsTobbbb	Thursdays 17:00 (HH)	bbbb Indicomb	Resolved VBF, full Run 2 Resonant bbbb, full Run 2 Non-resonant bbbb, full Run 2 HL-LHC HH->4b and combination projections
bbll		Bing Li, Julian Wollrath	Stefano Manzoni	DiHiggsTobbll	Tuesdays 15:00	bbll Indicomb	bbWW2l
Combination		Alessandra Betti, Stefano Manzoni, Rui Zhang	atlas-phys-hdbs-dihiggs-combination-liaisons@cern.ch	DiHiggsCombination	Thursdays 15:00	Combination Indicomb	HHComb, full Run 2 September 2021 CONF HL-LHC combination prospects HEFT PUB Note HH+H combination full Run 2 for Higgs Symposium HL-LHC HH->4b and combination projections
Summary plots	-	-	-	-	-	-	July 2021 September 2022

Glance

- Glance is used to centrally track collaboration matters
- https://atlas-glance.cern.ch/atlas/
- Every ATLAS member has an entry:
  - https://atlas-glance.cern.ch/atlas/membership/members/profile
- Each analysis has an entry:
  - https://atlas-glance.cern.ch/atlas/analysis/analyses/details?id=1367
- Each public result has an entry:
  - https://atlas-glance.cern.ch/atlas/analysis/papers/details.php?id=13428

Internal documentation

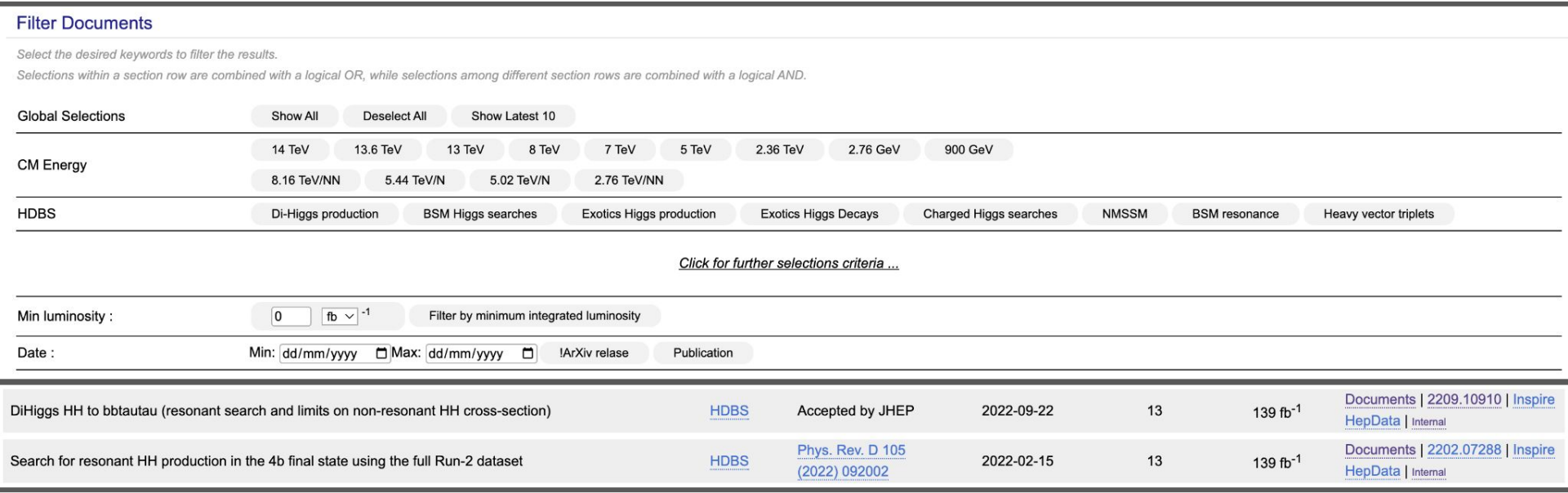
- Every analysis is documented internally in an INT note
  - Sometimes multiple INT notes are part of the same analysis
- Available exclusively to anyone in the collaboration
- Contains a complete description of all details of the analysis
  - Filenames, software versions, etc.
  - Should be sufficient to replicate the analysis
- Generally filled with excruciating detail about every study and cross-check
- Serves as the main resource while analysis is being reviewed

Public documents

- Ultimate goal is make analysis results public
- PUB note:
  - Low level of internal review
  - Generally for CP results, analysis techniques or interpretations of published results
  - Cannot be based directly on detector data
  - https://twiki.cern.ch/twiki/bin/view/AtlasPublic/PUBnotes
- CONF note:
  - Medium level of internal review
  - Usually preliminary results that will be published as a paper
  - Released early to make a conference deadline
  - https://twiki.cern.ch/twiki/bin/view/AtlasPublic/CONFnotes
- Paper:
  - High level of internal review
  - Polished results submitted for publication in a journal
  - https://twiki.cern.ch/twiki/bin/view/AtlasPublic/Publications

ATLAS Public Results

- All public results are available online
  - Physics analyses, CP, and detector documents
- https://twiki.cern.ch/twiki/bin/view/AtlasPublic
- Sorted by group and searchable by various criteria



Author list

- There are currently ~3000 individuals on the ATLAS author list
  - All PA and CP publications use the complete author list
  - Detector publications can have a limited author list
- ATLAS is too complicated to disentangle indirect contributions
- Qualification task is required to become an author
  - Service work that benefits the collaboration but do not result in publication
  - Typically maintaining software or re-deriving calibrations
- After qualification period, you are on the author list until leaving ATLAS

CDS

- Cern Document Server is a repository for any CERN documents
- https://cds.cern.ch/
- Public documents as well as internal documentation
- Relatively easy search interface
- Documents organized by type
- Ability to track versions and facilitate discussions

Open access

- Public ATLAS results are all available for free
  - Journal publications are often behind a paywall
- PUB notes, CONF notes, and papers are available on CDS
- Papers are available on https://arxiv.org/
  - When accessing papers on arxiv, it is possible to download all figures
- Publications are all searchable on https://inspirehep.net/
  - Also a great resource for tracking personal publications and searching for jobs

Searches vs measurements

- ATLAS physics analyses can broadly be split into two categories
- Searches:
  - Seeking evidence of new physics
    - New particles or new couplings/decay modes
  - Often systematic uncertainties can be overestimated for simplicity
    - Statistical uncertainties often dominate
  - Benchmark models are used to guide analysis design
  - Typically faster turnaround time than measurements
- Measurements:
  - Precise analysis of known processes to measure various parameters
    - Masses, cross-sections (differential or fiducial), couplings, etc.
  - Requires very thorough validation of methodologies and careful evaluation of systematics
  - Generally takes much longer a search

Overview of analyses

- Signal and background simulation
- Object definition/selection
- Event preselection
- Selection optimization
- Background estimation and validation
- Systematic uncertainty evaluation
- Statistical analysis
  - Fitting, bump hunting or setting limits
- Interpreting results

Blinded analysis

- Looking at data when designing analysis can introduce bias
  - Conscious or unconscious
- Various effects can result in artificial shapes in data distributions
  - Observing such shapes can lead to enhancing them to appear like a discovery
- Analyses are blinded while being designed
  - Rely primarily on signal and background simulated samples
  - Make use of signal-depleted control regions and validation regions to check modeling
- During approval procedure, permission is given to unblind and look at data
  - Analysis strategy should not be changed after unblinding without strong reason (e.g. bug fixes)
- Not perfect, but has a significant effect reducing effects of human bias

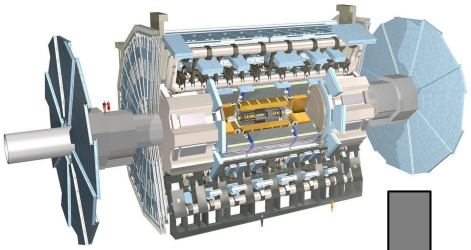
Monte Carlo

- Most analyses involve comparing collision data to simulated data
  - Monte Carlo (MC) method used
- Significant tuning is applied to MC sample parameters to match data
- MC generation is done in discrete steps:
  - Event generation - exact calculations of interactions and decays given initial conditions
  - Parton showering/hadronization - parton fragmentation and formation of hadronic showers
  - Detector simulation - parameterized or stepwise simulation of particles interacting with detector material and depositing energy
  - Pileup overlay - superimpose pileup events on single collision simulation
  - Digitization - conversion of deposited energy to digital signals
- Many third party tools used for first 2 steps (Pythia, Herwig, MadGraph, etc.)
- Analysis teams design and test commands to simulate signal processes
  - Request sent to central production to ensure correct settings for full sample
- Common Standard Model processes managed centrally

Data flow

Data

Collision

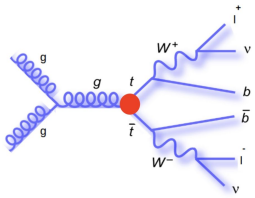


Detection

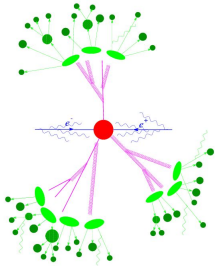
Reconstruction

Analysis inputs

MC



Matrix element calculation



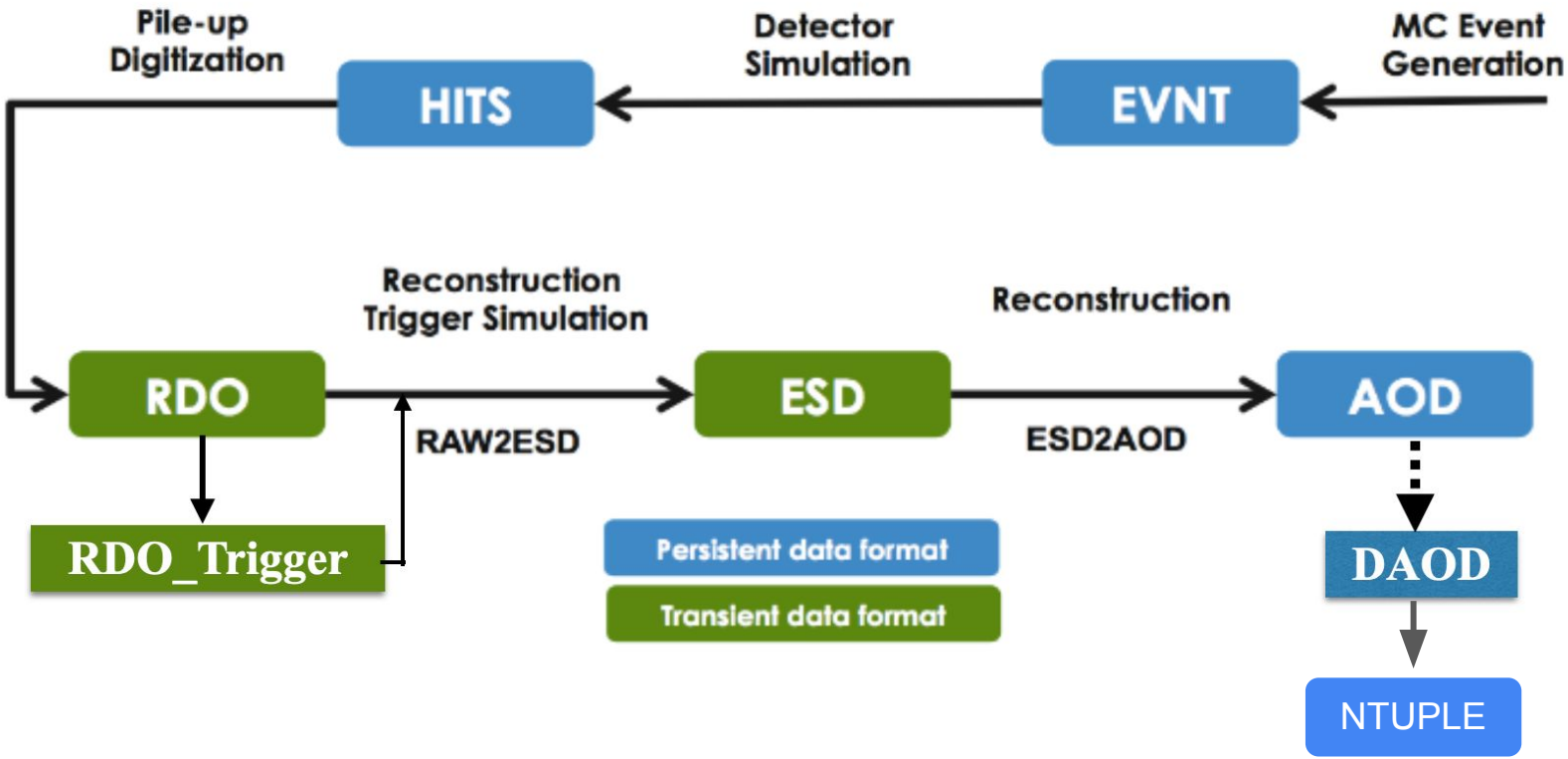
Parton shower/ hadronization

Pileup overlay

Detector simulation

Digitization

Data formats



Applying corrections

- It is critical that MC describes data well
  - Disagreements between MC and data can result in false observations
- Modeling is corrected/validated in phase space where no signal is expected
- Pileup reweighting:
  - Pileup condition profile of collisions is assumed for MC production
    - Allows MC to be produced before collision data is collected
  - MC events are reweighted to match the data pileup distribution
- Scale factors:
  - Detector response is not perfectly modeled
  - Object calibrations and characteristics can differ from data to MC
  - Per-object scale factors applied to reweight MC to match data response