Overview of ATLAS Physics Performance and Analysis

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and
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ATLAS Induction Day
CERN
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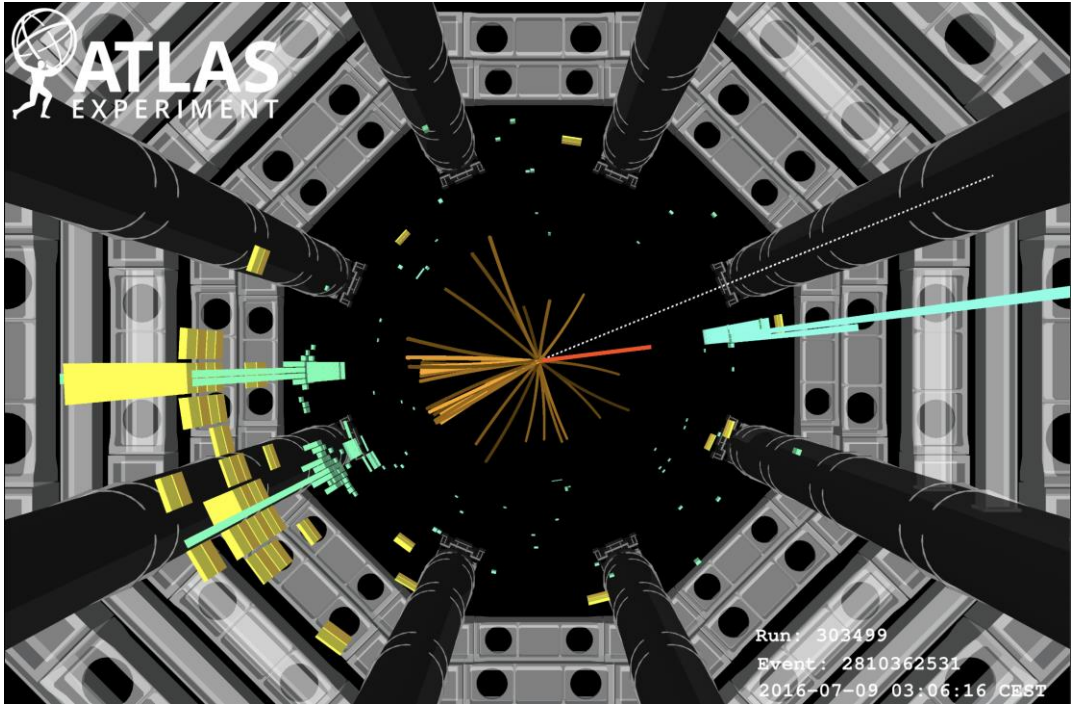
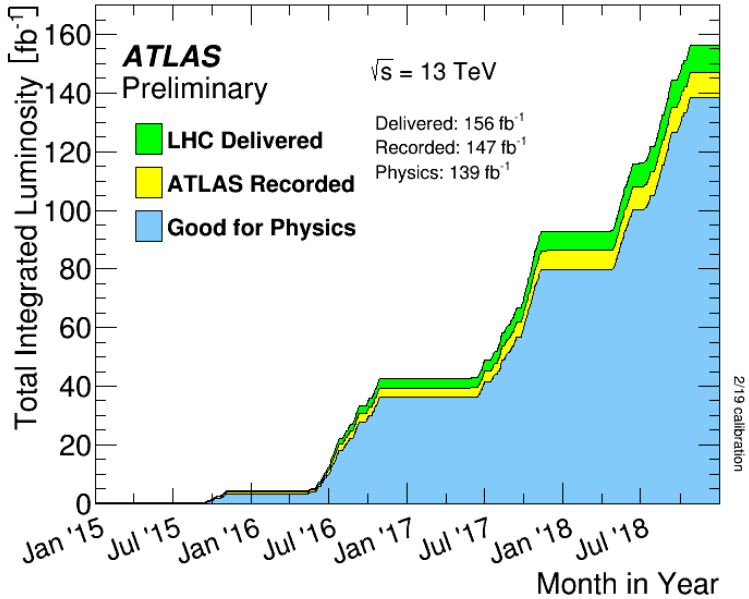


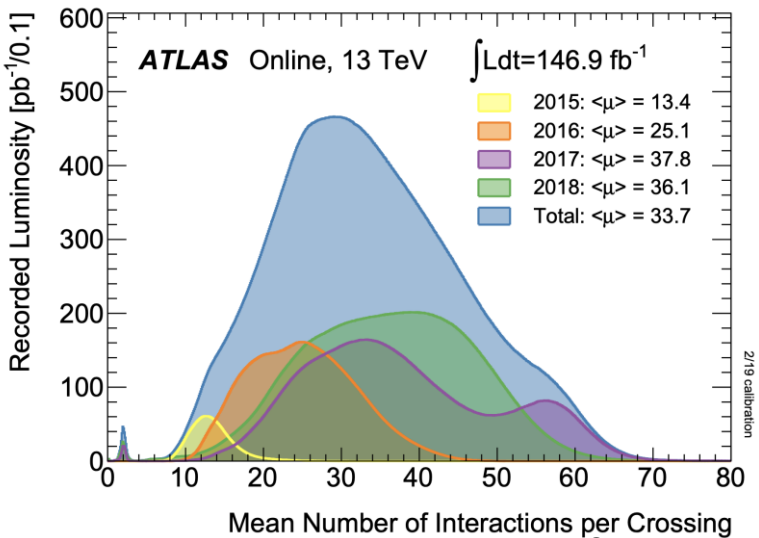
DESY.

UMass Amherst

Run 2 data taking

- 147 fb^{-1} recorded at $\sqrt{s}$ = 13 TeV
- Excellent data taking efficiency and data quality (139 fb^{-1} usable for physics)
- However high pileup in 2017 & 2018 ($\langle\mu\rangle$=37, design was 20)
- Many analyses already published with 2015 & 2016 data (36 fb^{-1}) in release 20.7
- First results (mainly searches) with full dataset and release 21 have come out





Run 2 dataset: a gold mine

- This is a great time to be joining ATLAS!
- You can help fulfil the fantastic physics potential of Run 2
- You will have access to the largest dataset ever recorded at a hadron collider, at the highest collision energy ever achieved
- An enormous amount of work has already gone into
  - collecting and calibrating the data
  - understanding the detectors
  - understanding the physics objects (electron, muons, jets, b-tagging...)
  - developing advanced algorithms for physics performance & analysis
- You can (and should!) play a role in improving all of the above

ATLAS: a multi-purpose experiment

ATLAS is a multi-purpose hadron collider experiment. It can address many interesting questions in various subfields of particle and nuclear physics:

- Standard Model Measurements
  - QCD and Top physics
  - Electroweak and Higgs physics
  - Flavor (mostly B) physics
- Searches for beyond the Standard Model (BSM) physics from very heavy particles, to very rare processes, to long-lived particles
- Heavy ion physics

Expect >200 publications on the full Run 2 dataset

Many opportunities and often not enough people to do everything we'd like to do

Many analyses need additional people! (see talks from ATLAS Week in Berlin)

Structure of Performance & Physics Groups

Combined Performance groups:

Electrons / Photons

Muon

Tau leptons

Jet / Etmiss

Tracking

Flavour tagging

Physics groups:

Standard Model physics

Top physics

Higgs physics

B-physics & light states

Heavy ion physics

Searches for Supersymmetry

Searches for exotic phenomena

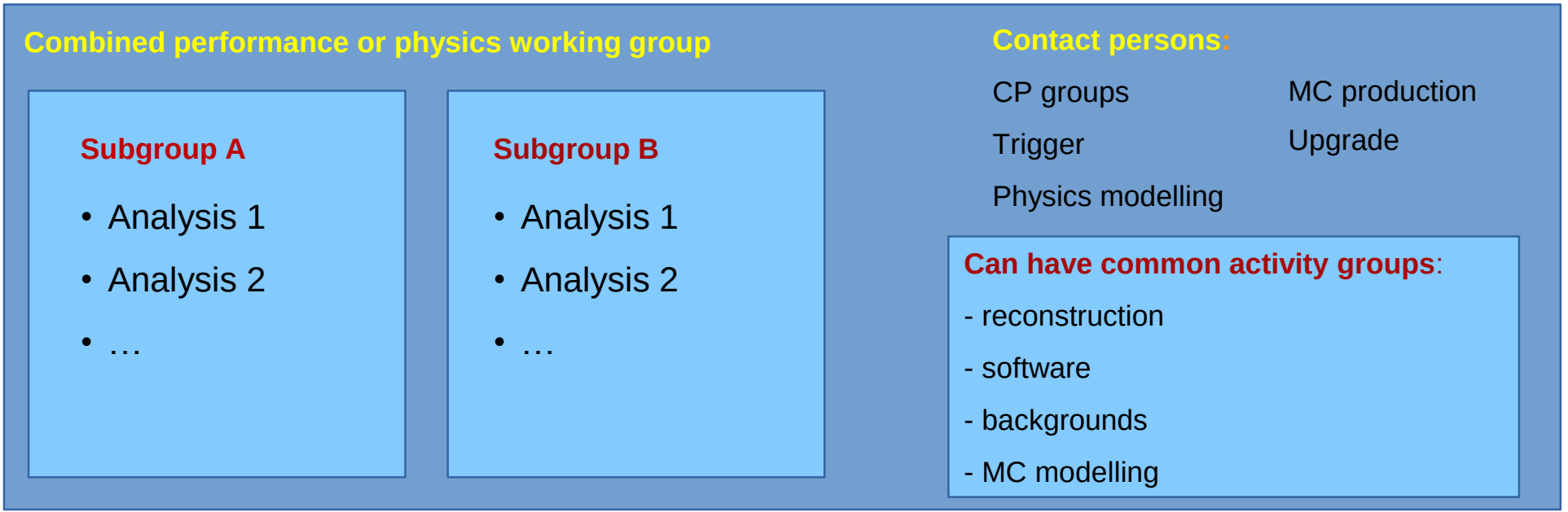
BSM Higgs and di-bosons

Upgrade physics

Physics modelling

- Fora and other groups: Statistics, machine learning, long-lived particles
- Joint subgroups: Isolation and fake leptons, common dark matter
- Important tools and support groups: Analysis software, MC production, simulation, derivation coordination, physics validation, physics office

Structure of Performance & Physics Groups



- Engage in discussions in analysis, subgroup, and group meetings
- Contribute to common tasks within working group
- Organize your work in well connected, reasonably sized analysis groups
- Do not embark on isolated analysis projects: stay connected

Combined Performance Groups

- Many important results are the fruit of years of investment in understanding and improving of detectors + optimization of reconstruction, identification, and calibration
- Three examples:
  - Higgs mass: precision calibration of photons and electrons/muons
  - High-mass resonance decaying to dibosons or top-quarks: boosted jets
  - Observation of H→bb decays: b-tagging, charm- and light-jet rejection
- This work is coordinated in the Combined Performance (CP) groups:
  - Forum where analyzers discuss performance needs for each analysis → cross-fertilization
  - Work is often very challenging and interesting
  - Place to bring in new ideas and commission resulting techniques
  - Opportunity to get additional publications and show broader interest
- Systematics limitation of some analyses can be improved with Run 2 data, new techniques
- → Investment is key to success of ATLAS Run-2 physics program

Physics Modelling Group

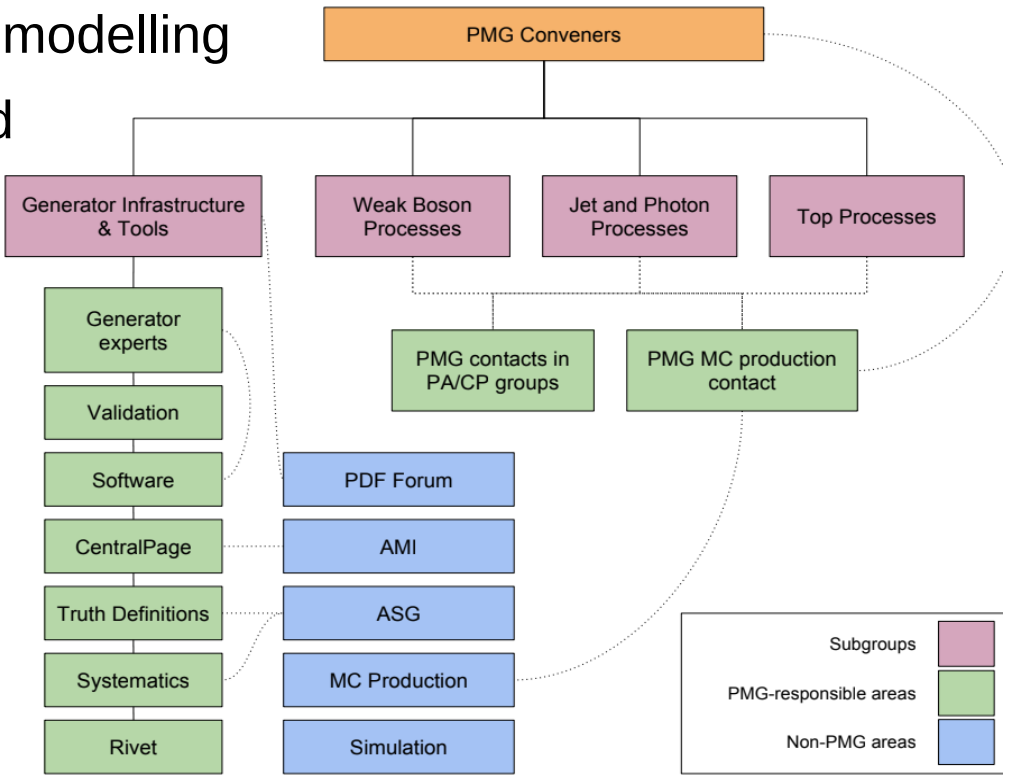
Responsible for:

- Development and validation of Monte Carlo event generators
- Setting common recipes for theory systematics and re-weighting procedures to correct modelling
- Planning of Monte Carlo production and approval of requests

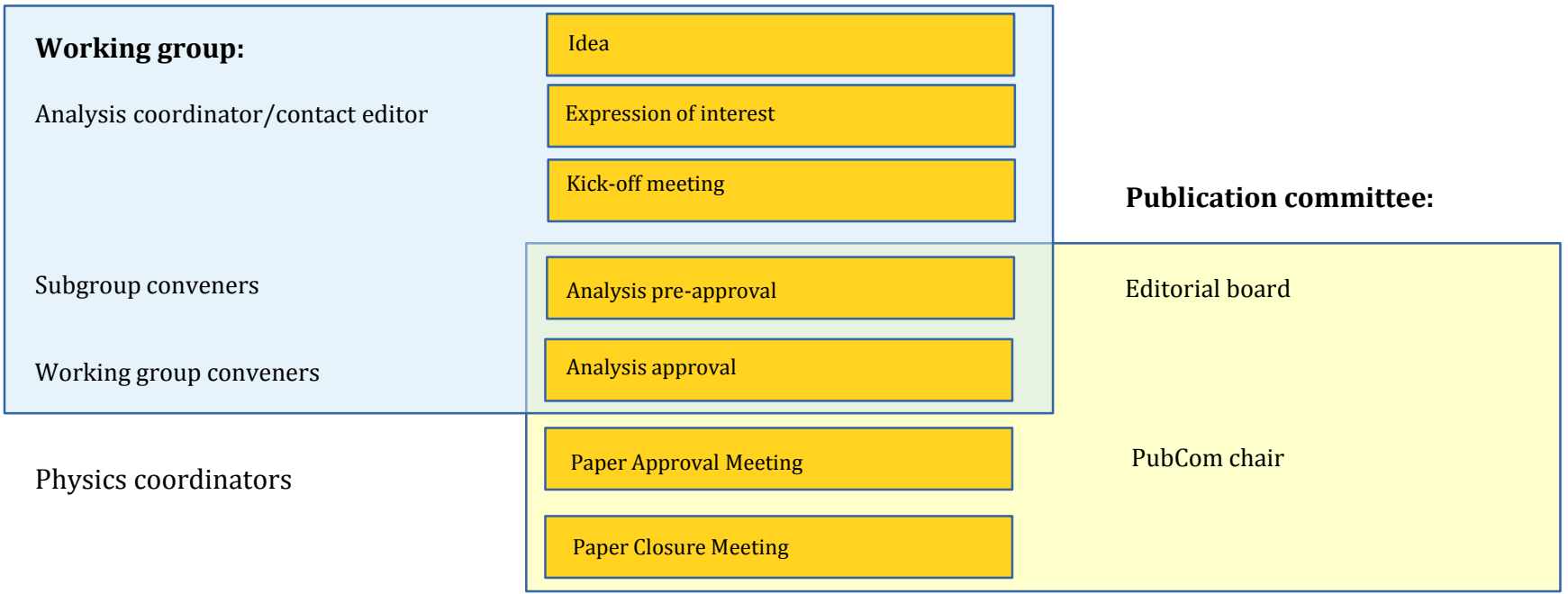
Coordinated work via:

- MC production contacts
- Physics contacts following needs of each group

PMG processes subgroups define the MC setup for the main SM processes (mainly based on ATLAS measurements)



Analysis and Paper Approval (in a nutshell)



- Regular presentations and discussion in working group are key to success
- Do not embark on isolated paper projects
- Nobody “owns” an analysis, you are allowed to join, where you like

Planning for Run 2: General Considerations

The Run 2 dataset will have a long lifetime:

- Long shutdown in 2019 and 2020
- Commissioning year in 2021 for LHC
- Production years in 2022 and 2023 (expect ~ 200 fb^{-1})
- Probably need both production years to surpass the Run 2 dataset
- Some high pT and high mass searches will profit from higher LHC energy earlier (if higher energy is available)
- Will take time to understand the Run 3 dataset as well as the Run 2 dataset will be understood, with precision CP recommendations etc.
- We are developing a plan where interesting results are produced throughout that 5-year period

New analysis ideas & improvements needed for papers over that period

Current Run 2 Publication Plan

- Early/medium-term Run-2 papers (2019/2020)
  - Many searches and statistics-limited measurements
- Comprehensive search papers (2020)
  - Merging signal regions, sensitivity optimization, detailed background understanding, coherent interpretation papers
- Systematically limited measurements (2020+)
  - Profits from precision CP work, improved physics modelling, MC statistics extensions, sophisticated analysis techniques and background estimates
- High precision measurements (2020++) e.g. W mass, $\sin^2\theta_w$
  - Profits from ultimate performance of Run 2, improved event generators, etc.

Staggering of papers makes it possible to publish updates of already published analysis, e.g. show improved analysis in a combination paper

Plans for Combined Performance Papers

- Write first set of CP papers to support early physics papers (based on 2015-2017 data initially, now using full Run 2)
- Challenging given limited number of people but papers can be concise
- Many advantages to CP contributors and to the collaboration
- Acknowledges CP work, needed to support physics results
- Write detailed CP papers later to support higher precision measurements
- Ideally the CP papers are early enough that they can be cited by the physics papers

Opportunities for the next Runs

- Preparations for release 22, the software release to be used at the beginning of Run 3
- Trigger opportunities for Run 3: what we do not trigger on is lost forever! We will have new trigger hardware for Run 3 and now is the time to work on improved triggers!
- Preparations for ATLAS detector Phase-II upgrade

In many of these areas only small analysis teams are working
You can have a large impact !

Run 2 physics workshop

- Physics workshop on the finalization of the Run 2 results during the P&P week in December: https://indico.cern.ch/event/822577/
- This will give you a detailed overview of what is going on in physics analysis
- Will help you choose a performance and/or physics analysis if you are still looking for one

A Few Recommendations

ATLAS needs people everywhere!

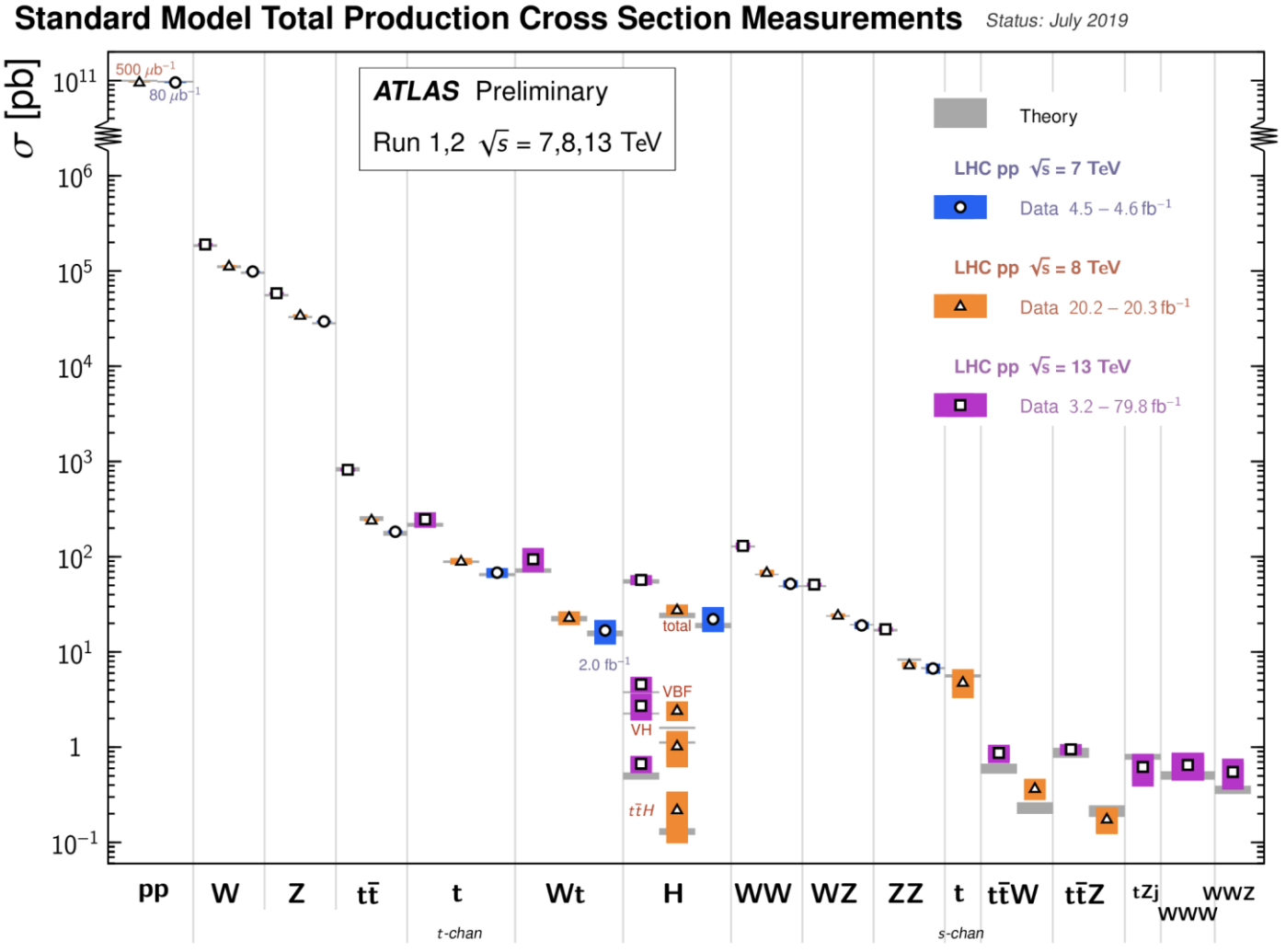
- There is usually room for committed individuals even in activities that seem well staffed; If you do good work, your contributions will be valuable *and valued*
- Analysis work in ATLAS is complex
  - Do not try to work everything out on your own
  - Don’t get discouraged, ask for help or guidance (meetings, e-groups, JIRA), stay connected: work in reasonably-sized, well-connected groups

Learn something(s) new and **have fun!**

- More important to contribute broadly (e.g. Performance, Physics, Trigger, Software & Computing, Detector, Upgrade) than produce many physics papers
- But don’t stretch yourself too thin
  → strike a balance to contribute to a few areas significantly
- *You will learn a lot and develop valuable skills in the process*

Backup

Standard Model Measurements



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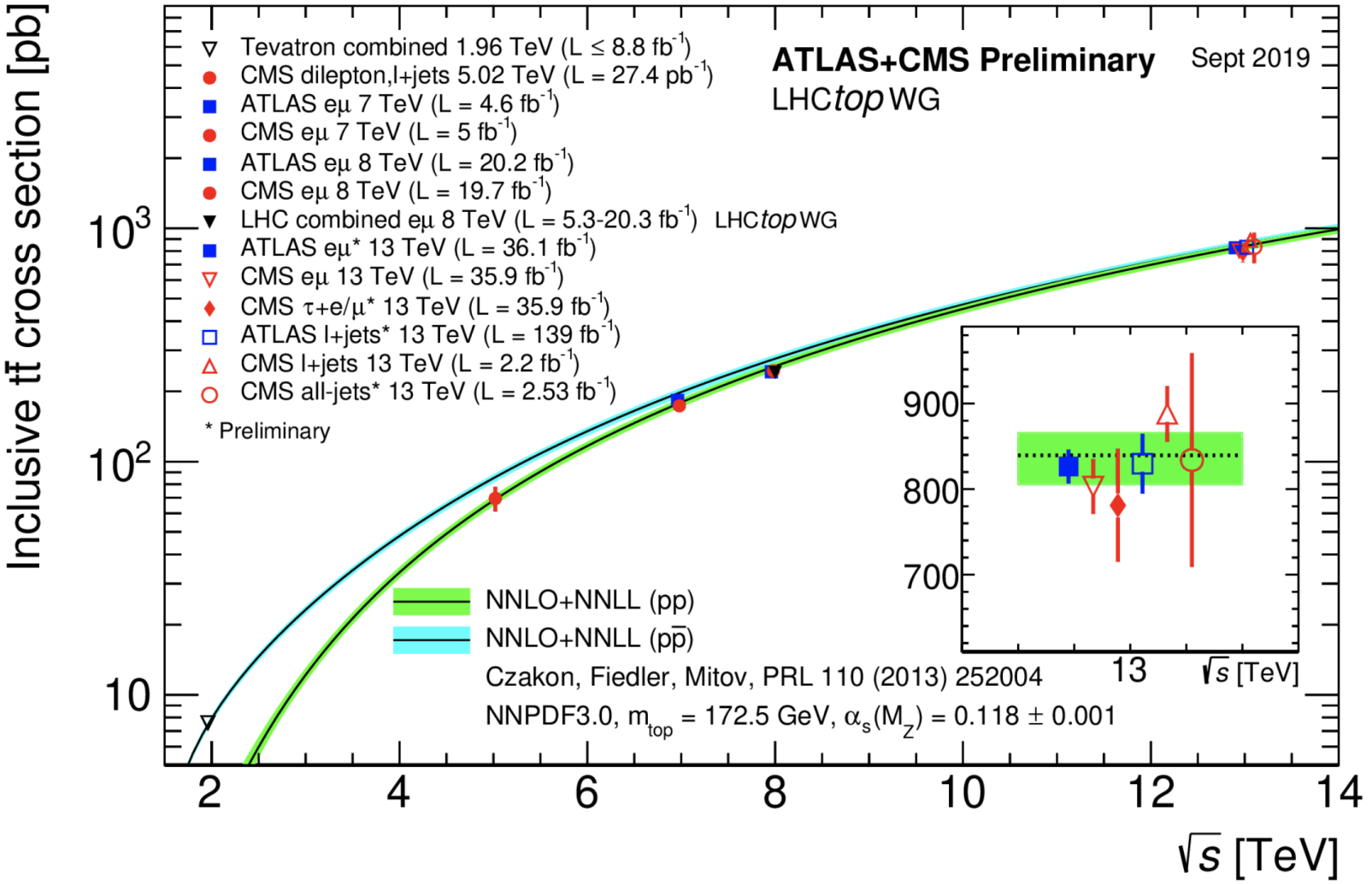
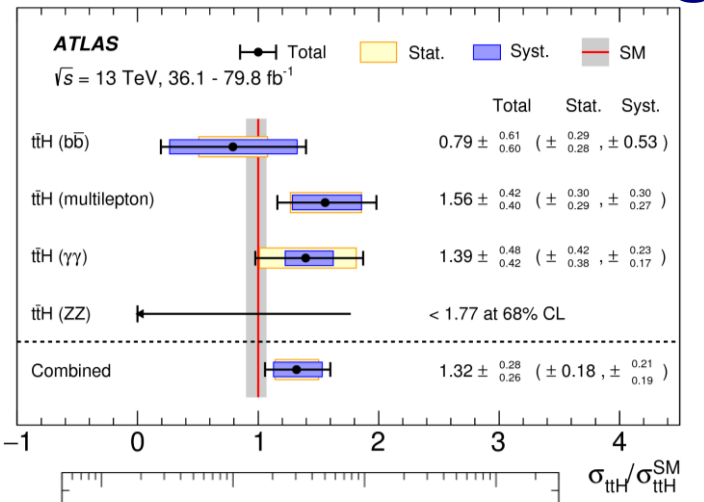
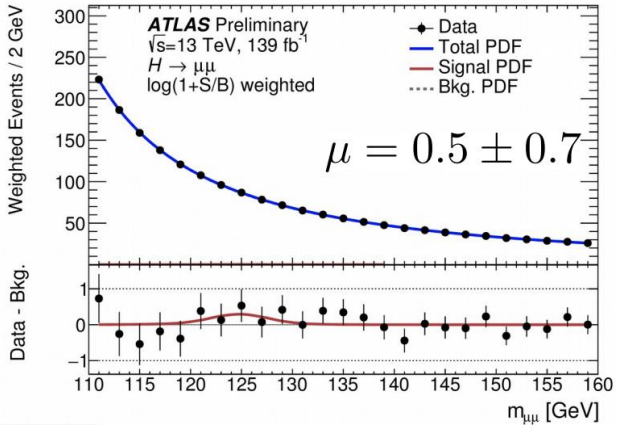
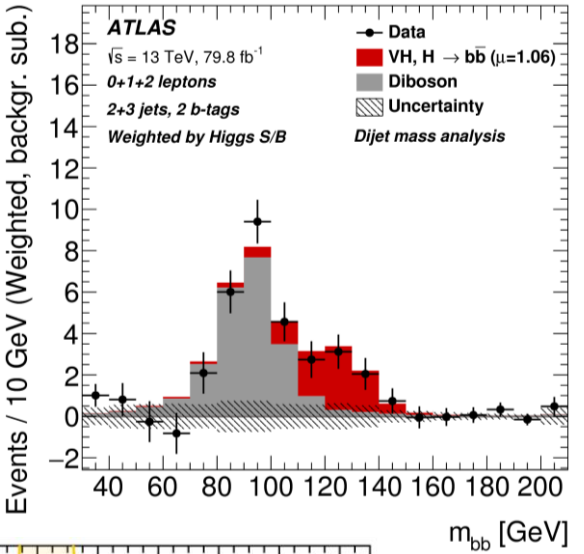
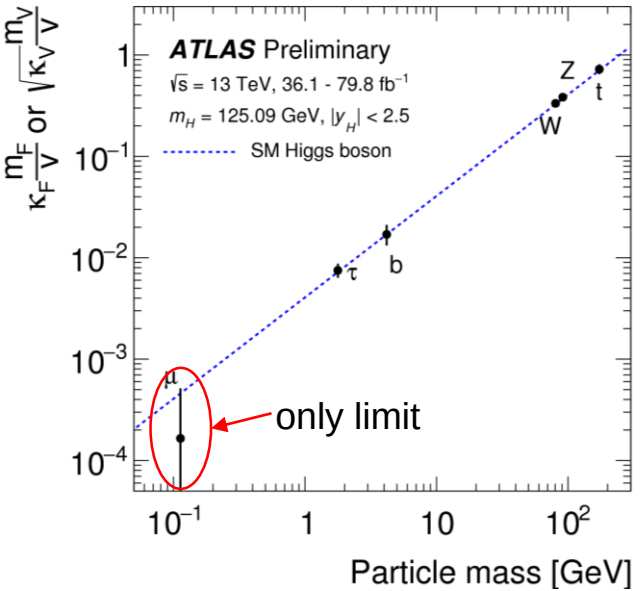


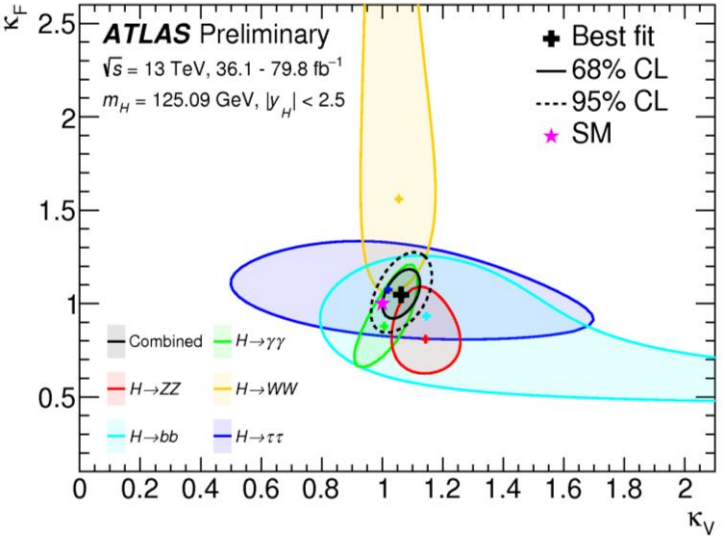
Higgs highlights



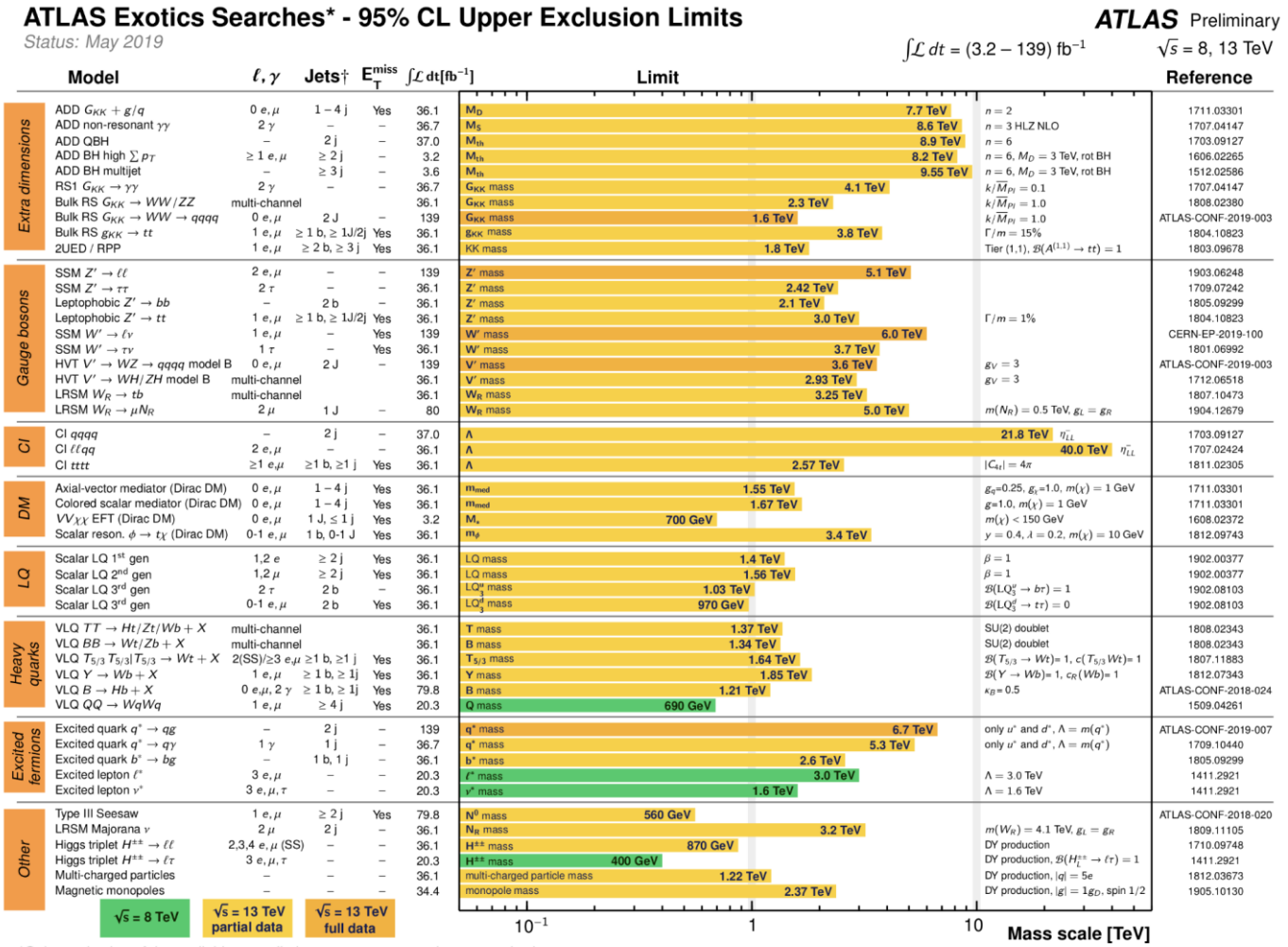








Searches for new particles



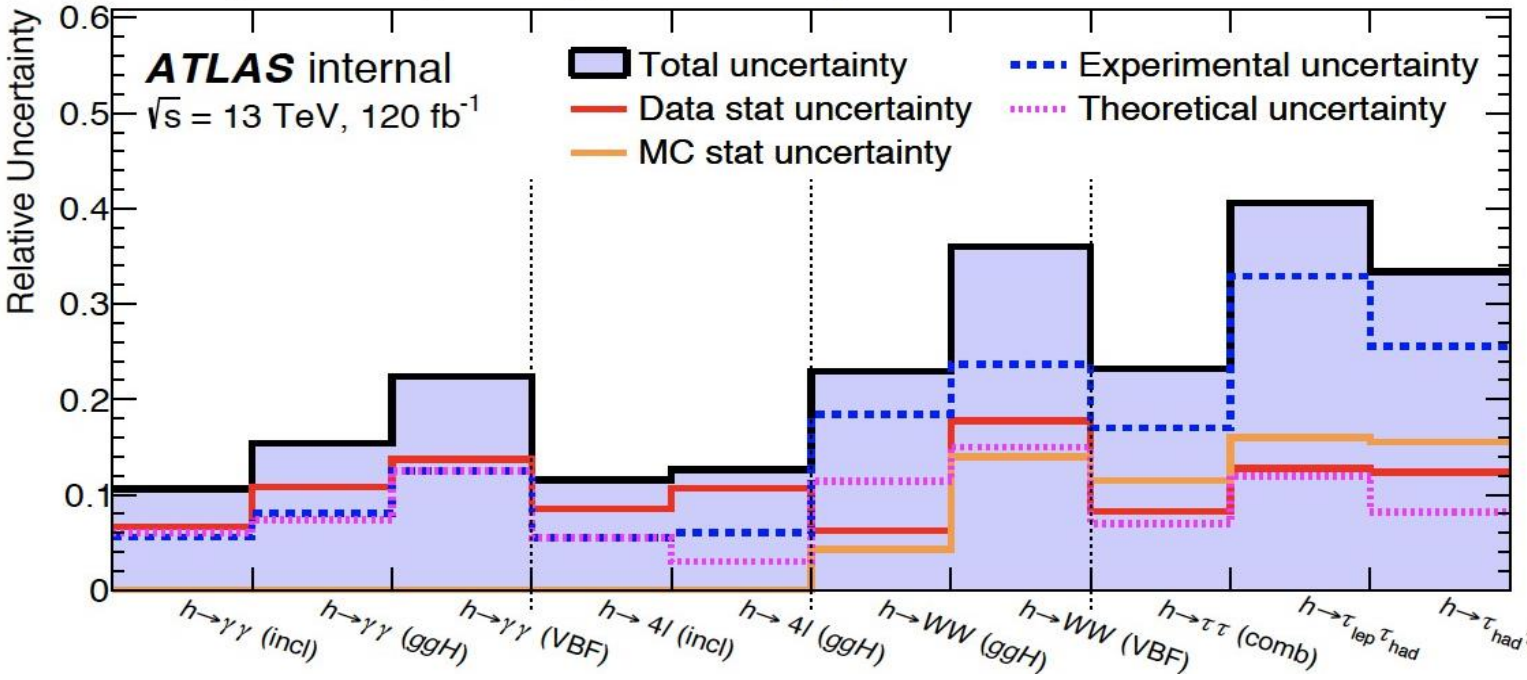
*Only a selection of the available mass limits on new states or phenomena is shown.

†Small-radius (large-radius) jets are denoted by the letter j (J).

Limiting factors in recent ATLAS analyses

Example from Higgs group

- ***h*(125) coupling extrapolation to 120 fb^{-1}**

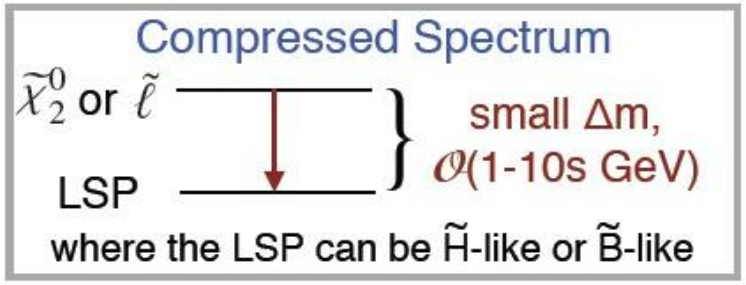


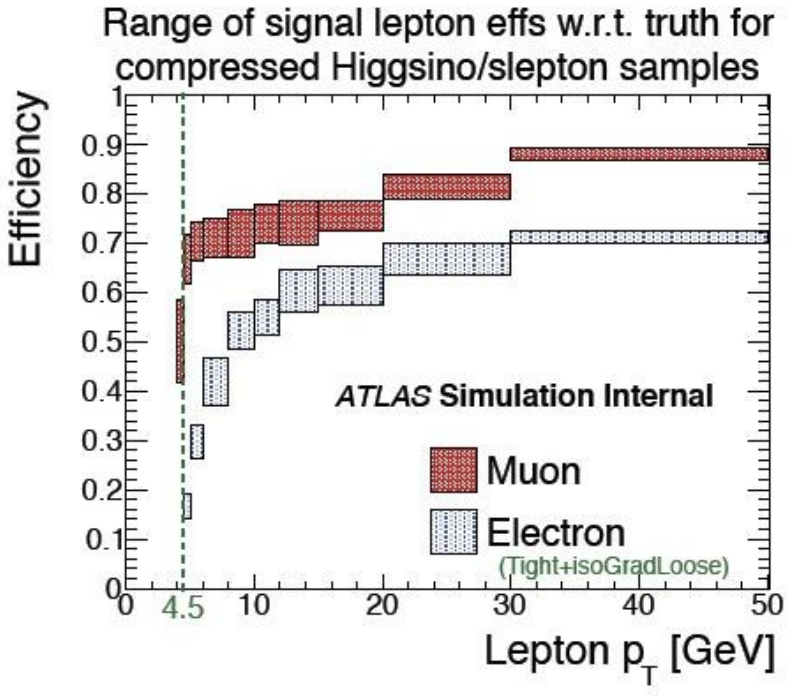
- Note: ttH(bb,ML),VH(bb) syst.-limited with 36 fb^{-1}, need large MC samples

R&D in object reconstruction

Low-p_T leptons

- Example of physics motivation: SUSY EWK searches, compressed scenarios
- New low-p_t muon selection recovers efficiency for 3 < p_t < 5 GeV
- Foreseen improvements with dedicated triggers
- Electrons now supported down to 4.5 GeV
- Soft electrons (a la Run 1) could be revived but need people
- Improvements on calibrations (“E-p) and efficiency meas. (Z->eey) underway
- CP work can open new opportunities for searches and measurements, e.g. for searches the increased mass/pt reach is now rather limited while with more work, new signatures open up





R&D in object reconstruction

- In some cases large improvements are possible, e.g.:
- b-tagging using VR- track jets
- t-tagging using DNN
- tau-tagging using RNN