Tau Embedding with ATLAS
Reminder & Update

Jürgen Kroseberg

(Physikalisches Institut, Universität Bonn)

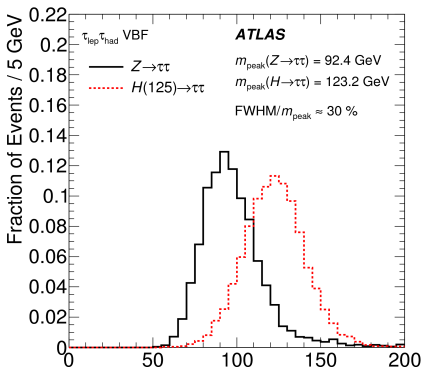
Motivation

- $Z \rightarrow \tau\tau$ decays result in same final state as $H \rightarrow \tau\tau$; $\sigma_Z/\sigma_H \approx 2000$
- Z/H mass difference not large compared to $m_{\tau\tau}$ resolution and spin effects are fairly subtle

$\Rightarrow$ $Z \rightarrow \tau\tau$ **large irreducible $H \rightarrow \tau\tau$ BG**; overlapping mass peaks

- $H \rightarrow \tau\tau$ analyses use complex signatures (VBF, boosted H, MVA)
- MC systematics (event topology, jets, MET) difficult to assess

$\Rightarrow$ **rely on simulation as little as possible**



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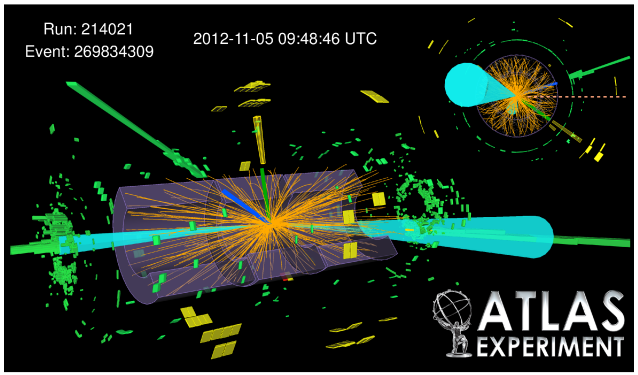

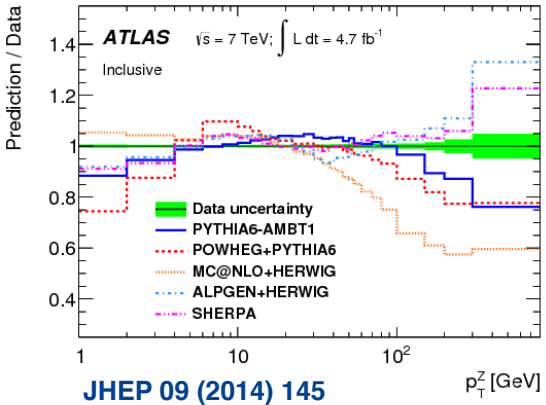

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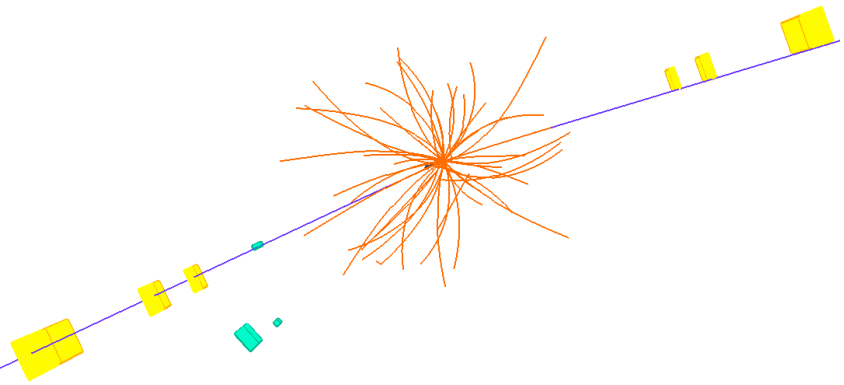
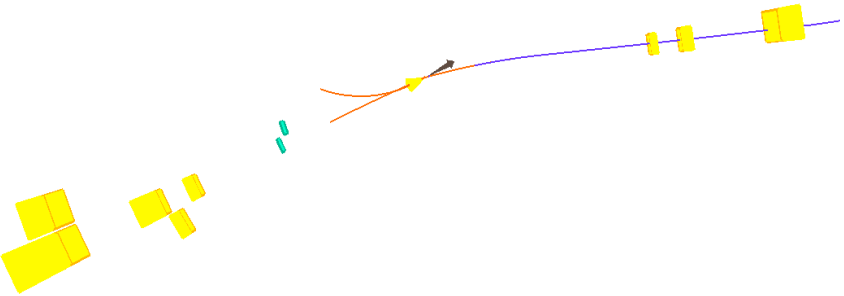
⇒ **rely on simulation as little as possible**

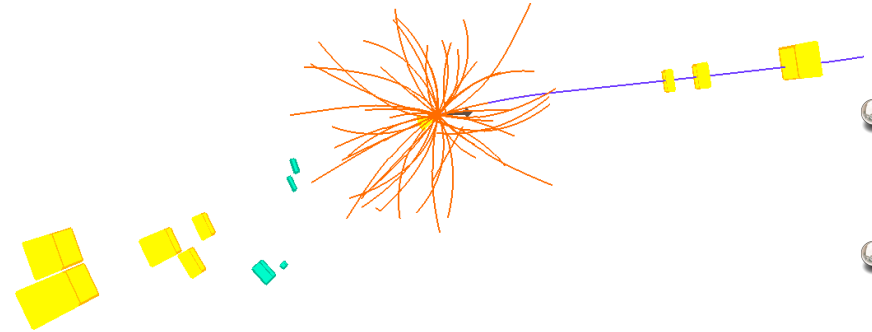
- cannot select signal-free $Z \rightarrow \tau\tau$ directly from data
- $Z \rightarrow \mu\mu$ events have ~same properties; H-μ coupling small; easy to select with hight purity and signal-free

⇒ **use $Z \rightarrow \mu\mu$ data as starting point**

Concept

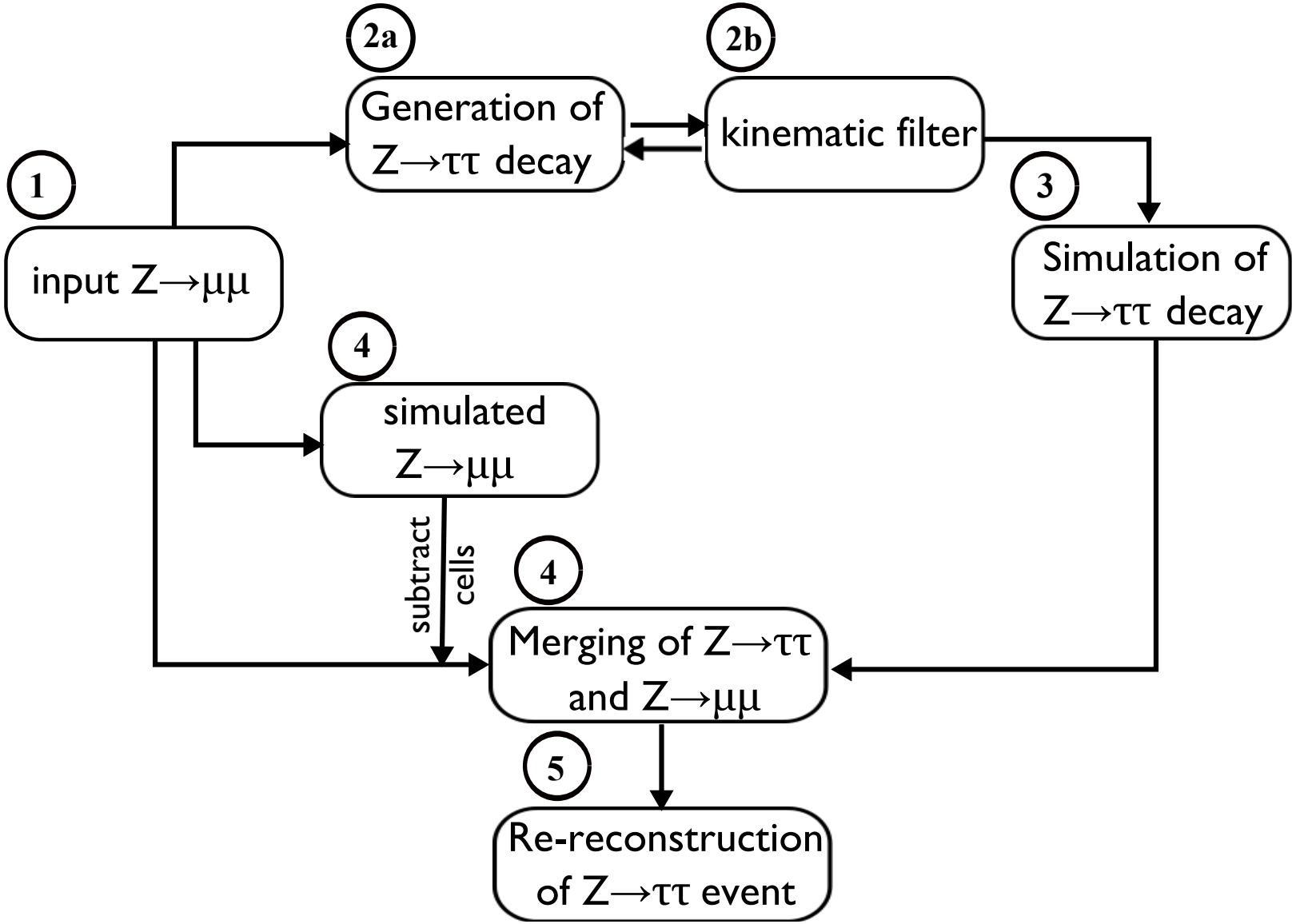






- **select $Z \rightarrow \mu\mu$ data**
- **remove muon tracks and cells** (removed calo energy estimated from stand-alone muon simulation with same kinematics)
- from reconstructed muons, **simulate** corresponding TAUOLA **$Z \rightarrow \tau\tau$ decays** at reconstructed vertex (disable calorimeter noise)
- **insert simulated tracks** and **cells**
- **re-reconstruct** objects and missing E_T

Concept


2a
2b
Generation of Z→ττ decay
kinematic filter
1
3
input Z→μμ
Simulation of Z→ττ decay
4
simulated Z→μμ
subtract
cells
4
Merging of Z→ττ and Z→μμ
5
Re-reconstruction of Z→ττ event

Validation

- don't embed anything, just re-run reconstruction on Z→μμ data("**re-reconstructed data**");
  compare to original Z→μμ input data
- embedding of simulated Z→μμ decays in Z→μμ data ("**muon-embedded data**");
  compare to original Z→μμ input data
- embedding of of simulated Z→μμ decays in simulated Z→μμ events ("**muon-embedded MC**");
  compare to original Z→μμ input MC
- embedding of of simulated Z→ττ decays in simulated Z→μμ events ("**tau-embedded MC**");
  compare to standard Z→ττ MC

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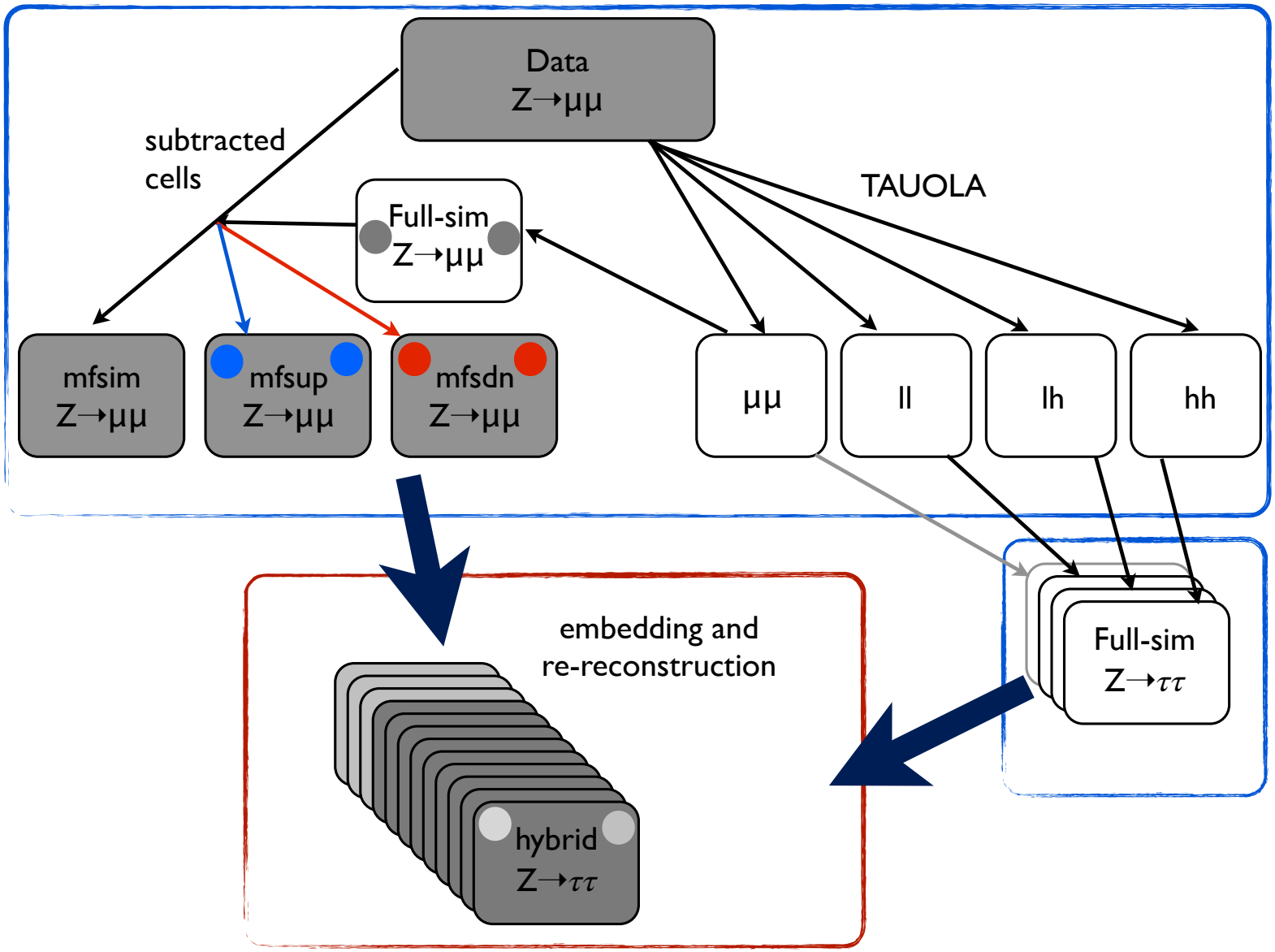
also, internal work (C. Schillo) on Z→ee embedding, see slide 14 of

https://indico.desy.de/getFile.py/access?contribId=12&resId=0&materialId=slides&confId=10937

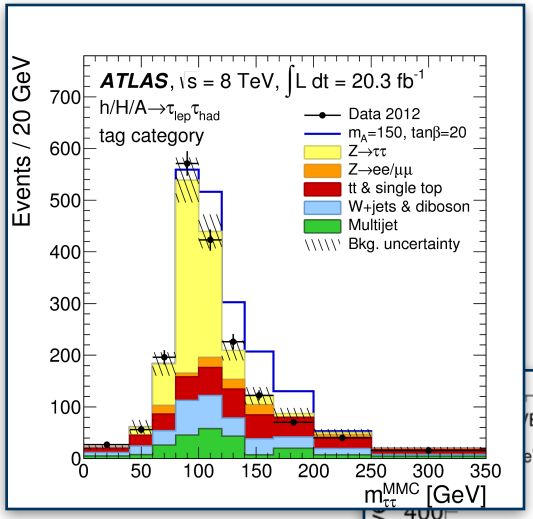
Actual Workflow



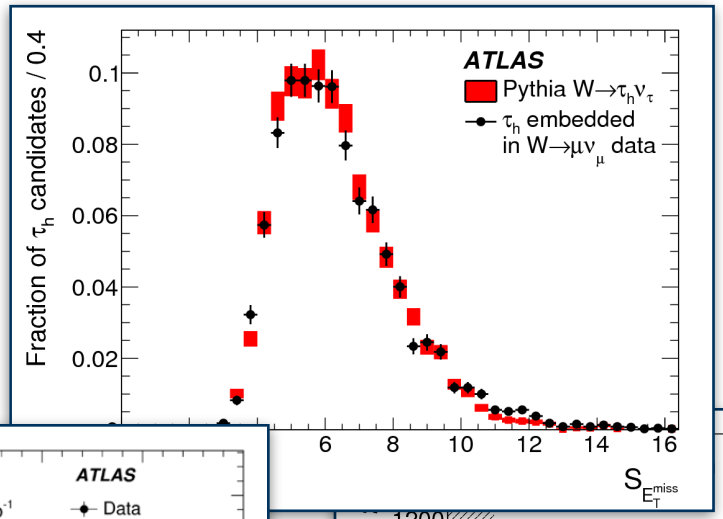
Physics Use Cases

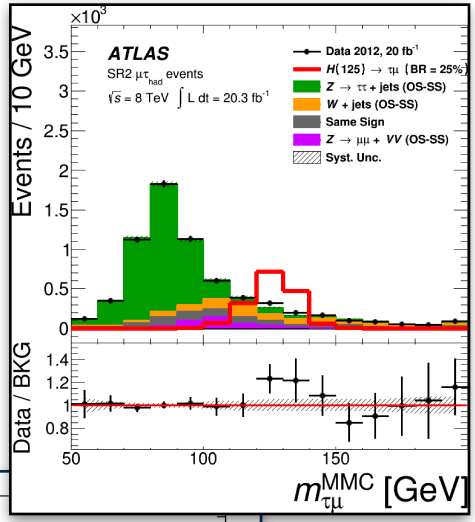
- used in **all** public Run1 ATLAS **Higgs→ττ analyses**
- also **adapted to single-τ final states** (W→τν, H⁺→τν)

MSSM H/h/A→ττ

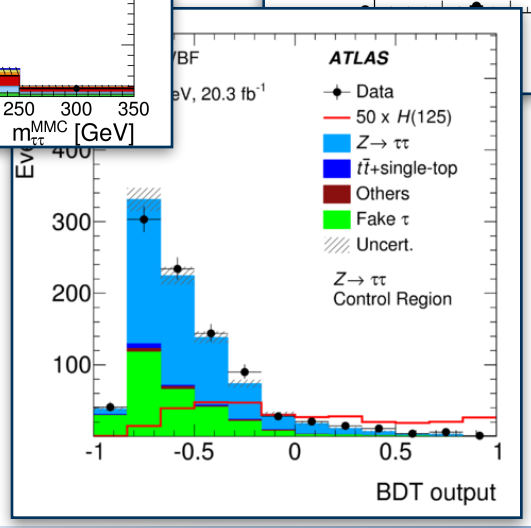


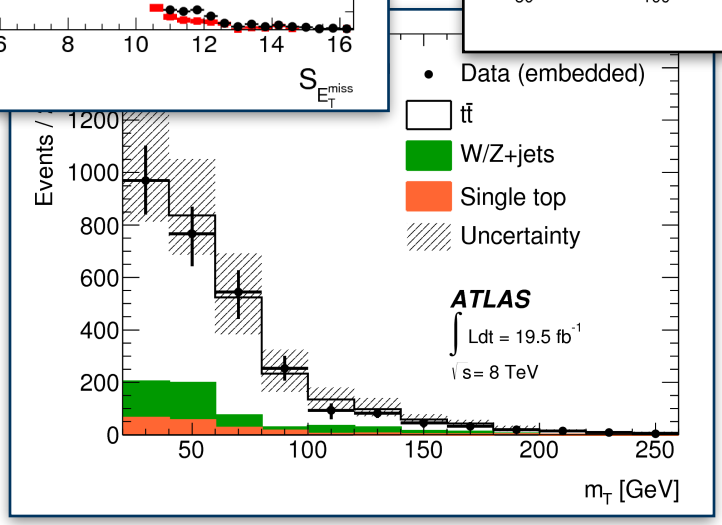
W→τν





LVF H→τμ





SM H→ττ

H⁺→τν

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

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28th September 2015

Modelling $Z \to \tau\tau$ processes in ATLAS with τ-embedded $Z \to \mu\mu$ data

The ATLAS Collaboration

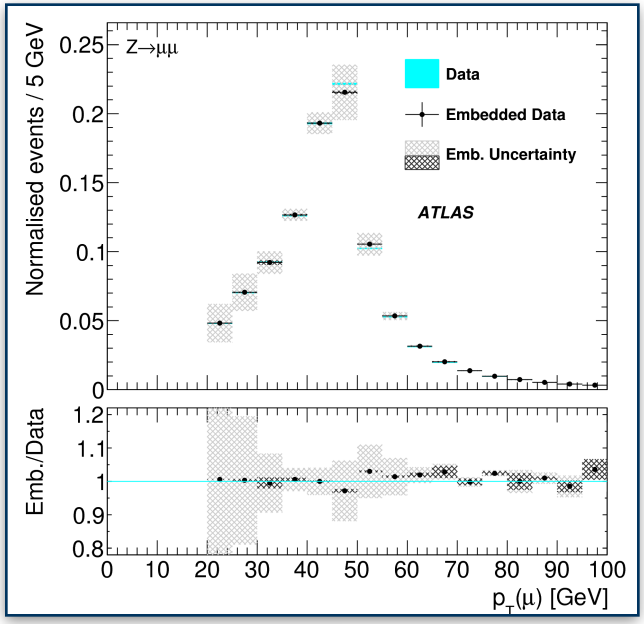
Abstract

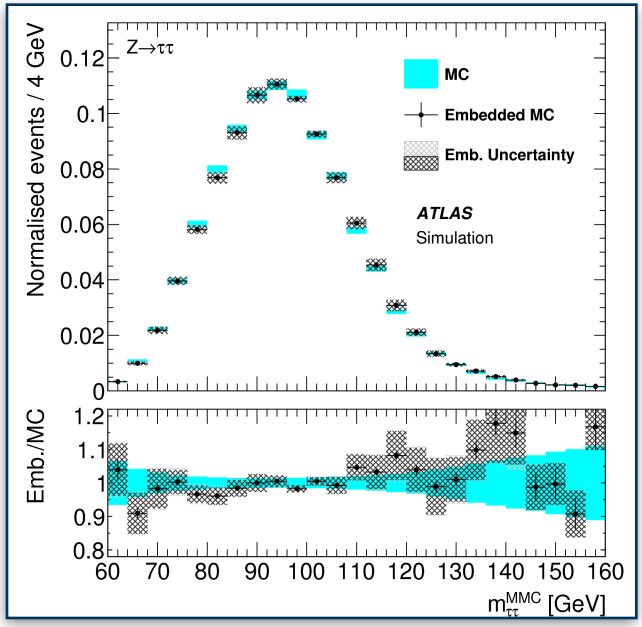
This paper describes the concept, technical realisation and validation of a largely data-driven method to model events with $Z \to \tau\tau$ decays. In $Z \to \mu\mu$ events selected from proton–proton collision data recorded at $\sqrt{s} = 8$ TeV with the ATLAS experiment at the LHC in 2012, the Z decay muons are replaced by τ leptons from simulated $Z \to \tau\tau$ decays at the level of reconstructed tracks and calorimeter cells. The τ lepton kinematics are derived from the kinematics of the original muons. Thus, only the well-understood decays of the Z boson and τ leptons as well as the detector response to the τ decay products are obtained from simulation. All other aspects of the event, such as the Z boson and jet kinematics as well as effects from multiple interactions, are given by the actual data. This so-called *τ-embedding* method is particularly relevant for Higgs boson searches and analyses in $\tau\tau$ final states, where $Z \to \tau\tau$ decays constitute a large irreducible background that cannot be obtained directly from data control samples. In this paper, the relevant concepts are discussed based on the implementation used in the ATLAS Standard Model $H \to \tau\tau$ analysis of the full datataset recorded during 2011 and 2012.

JINST 10 (2015) P09018 (arXiv:1506.05623)

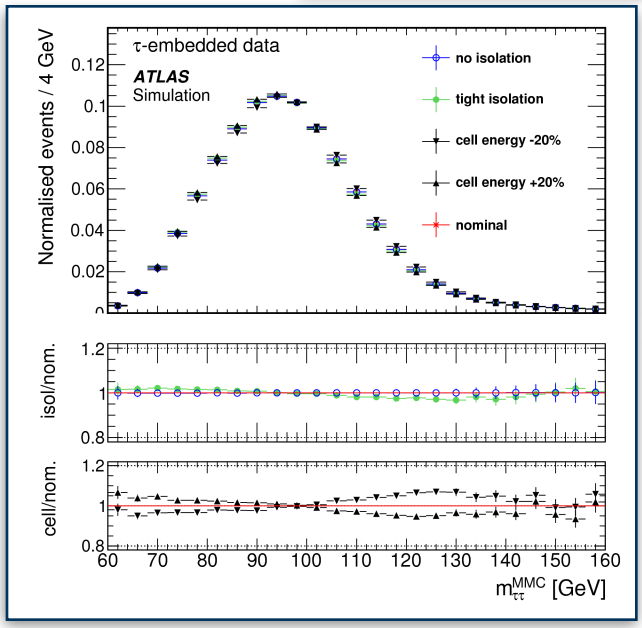
Contents

μ embedding

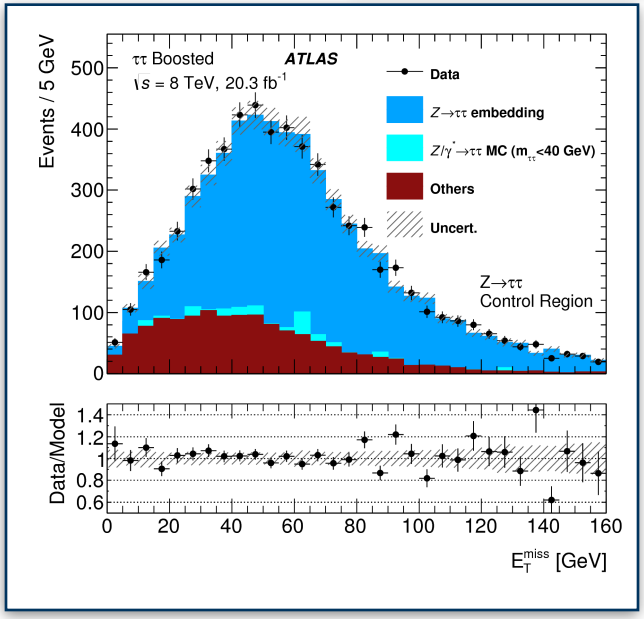




systematics



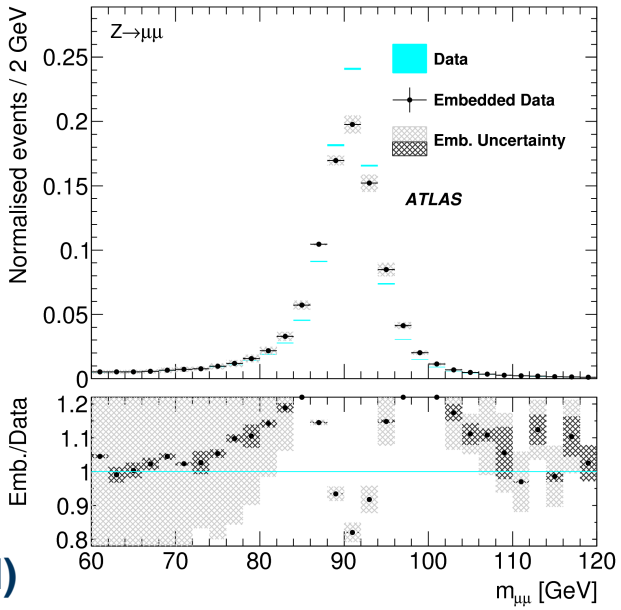
τ embedding



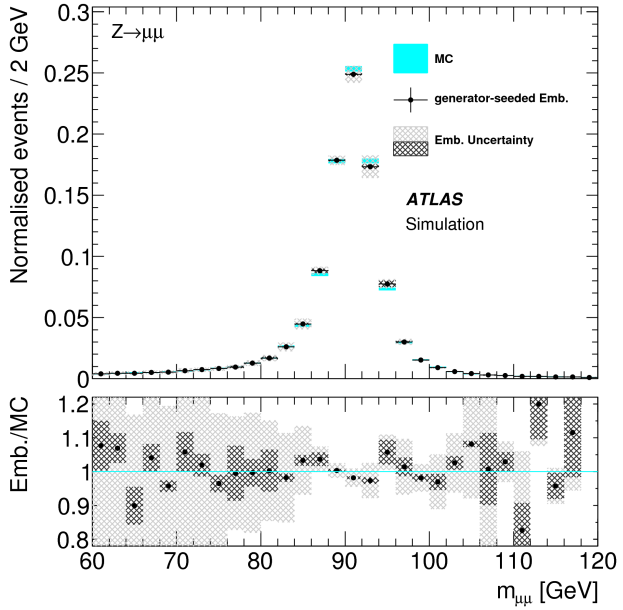
Z-enriched control region

Muon reconstruction and FSR effects

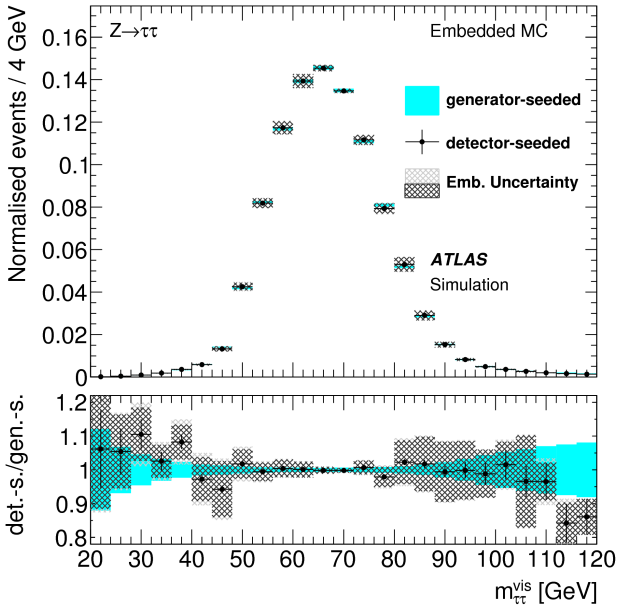
μ embedding (reco seed)



μ embedding (gen. seed)



τ embedding (reco/gen. seed)



- **effects of** input **muon reco and final state radiation covered by** (and difficult to separate from and) **procedure-based systematics** (isolation + associated energy)

Run2

- merits and challenges of continued use of τ-embedded samples was assessed by an ATLAS-**internal review** board
  ⇒ **proceed with τ embedding in Run2**
- at least **initially**, try to minimise changes w.r.t. **Run1 procedure**
- however, **significant changes in the environment** (data model, reconstruction/ID algorithms) pose conceptual and technical challenges
- **work is** still **on-going**; timeline for first physics analysis deployment under discussion

Summary

- τ-embedding was a **key component of** ATLAS **Run1 Higgs searches** / analyses in τ final states
- **limited** public **documentation** was available already **within** the corresponding **physics papers**
- have **now** followed up with a **dedicated publication** describing the procedure and its validation
- transfer to **Run2** setup is not at all trivial but **work** is **well underway**

- Bonn group has been passing the **technical responsibility** on **to Freiburg**