$Z \rightarrow \tau\tau$ Embedding - systematics and validation in ATLAS

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$m_{\tau\tau}$ workshop Würzburg

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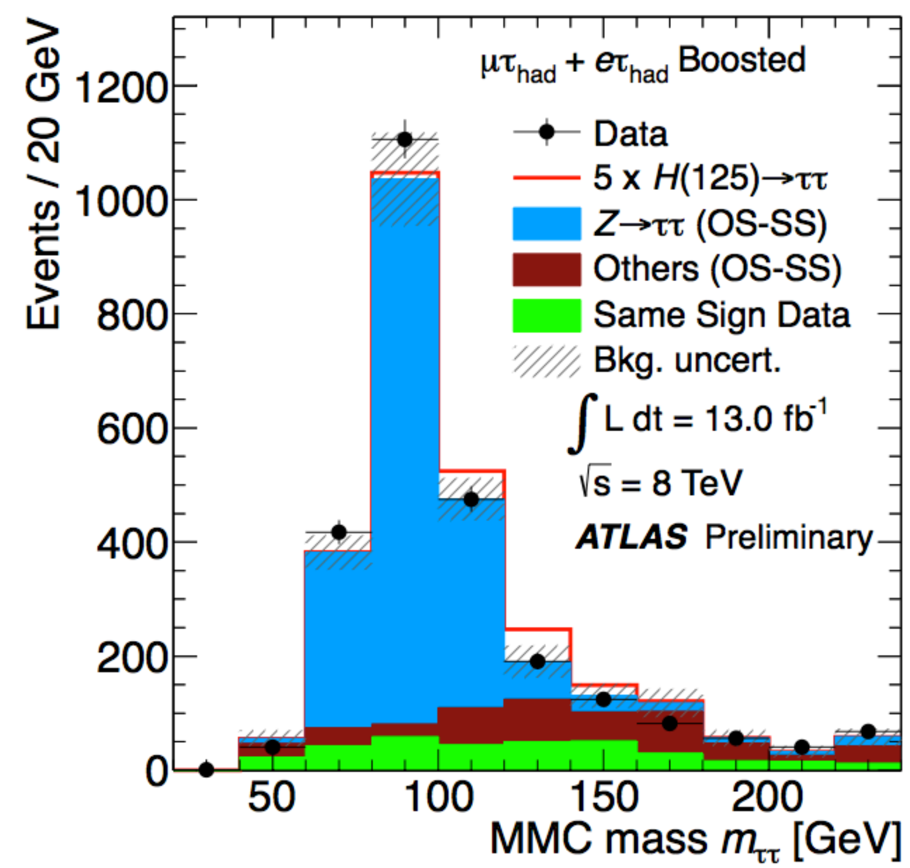
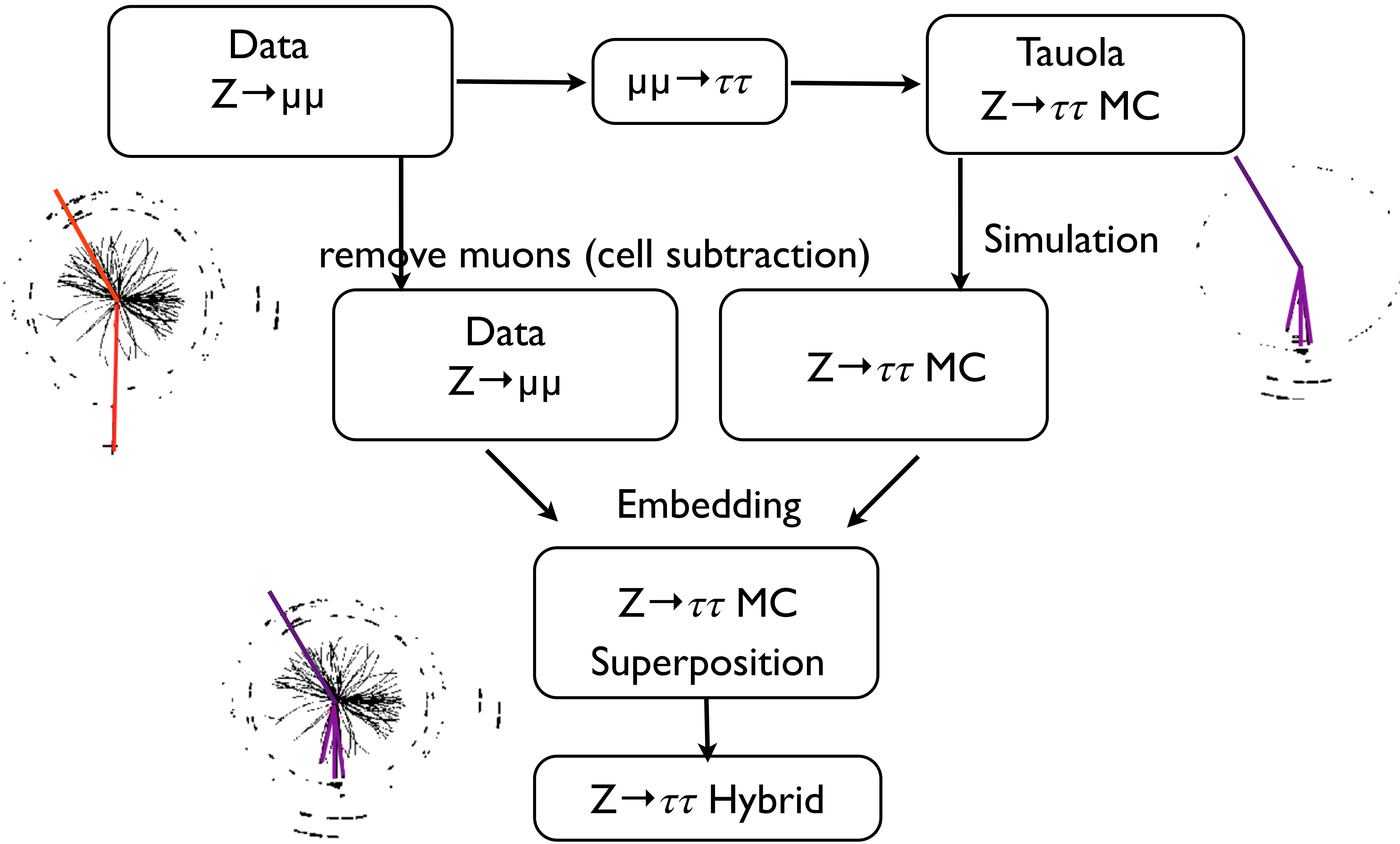
Motivation

- $Z \rightarrow \tau\tau$ most important background for $H \rightarrow \tau\tau$ searches
- No signal-free $Z \rightarrow \tau\tau$ samples avaiable from data
  - overlap with $H \rightarrow \tau\tau$ signal
- Large systematic errors if derived from MC (modelling of MET, jets)
- $Z \rightarrow \tau\tau$ background estimated using embedded samples
  - Advantage: no pile-up modelling necessary
  - Exploit that $Z \rightarrow \mu\mu$ has same decay kinematic
    - Very pure selection possible
    - Weak Higgs-to-muon coupling $\rightarrow$ signal free selection

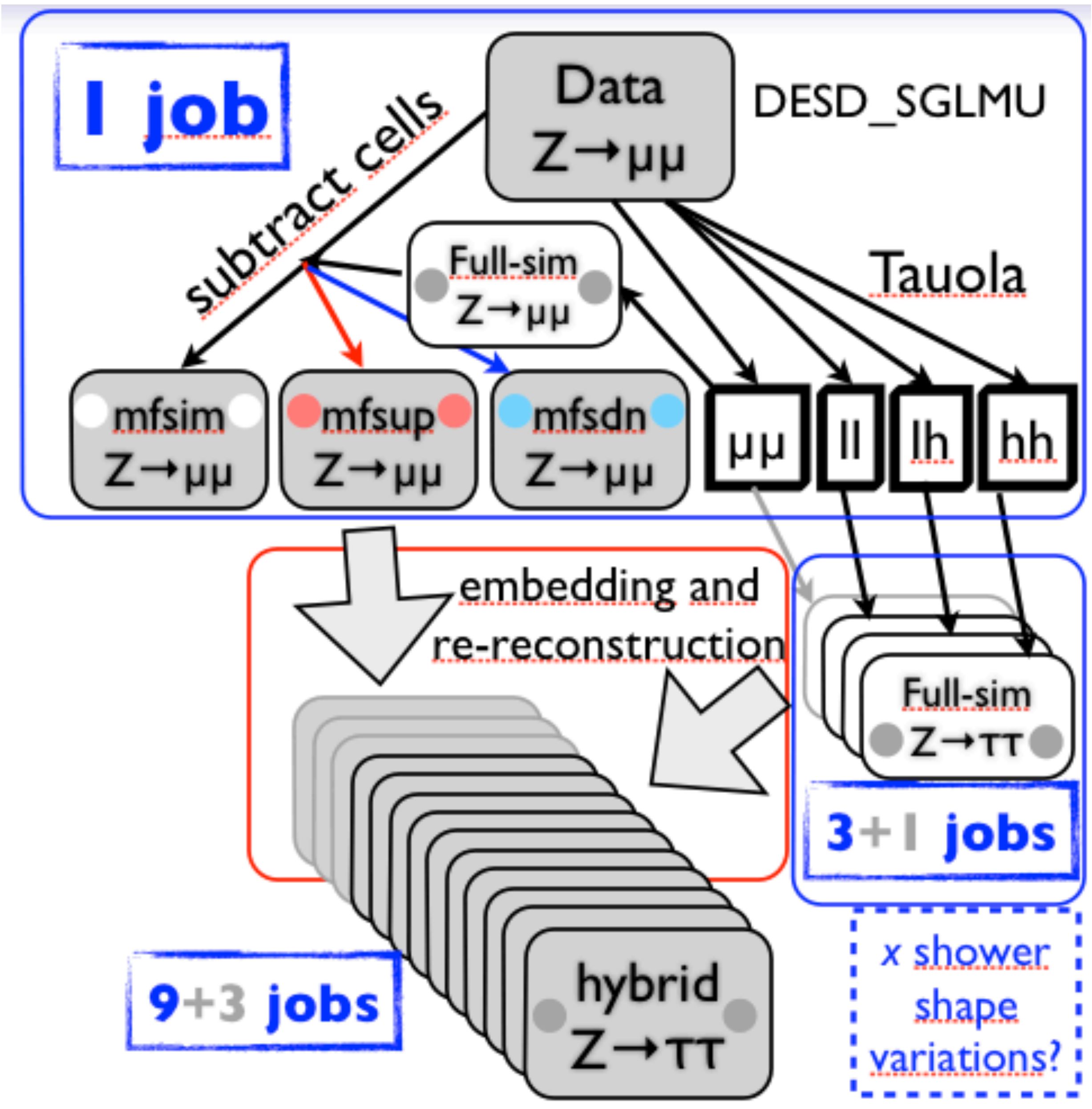
ATLAS-CONF-2012-160



The embedding method



Reminder: new workflow



- Successfully tested in last production round
- Transforms allow simultaneous production of outputs (nominal/systematics+veldiation)
  - Reusing intermediate files (more effcient)
  - Only necessary files produced depending on requested output

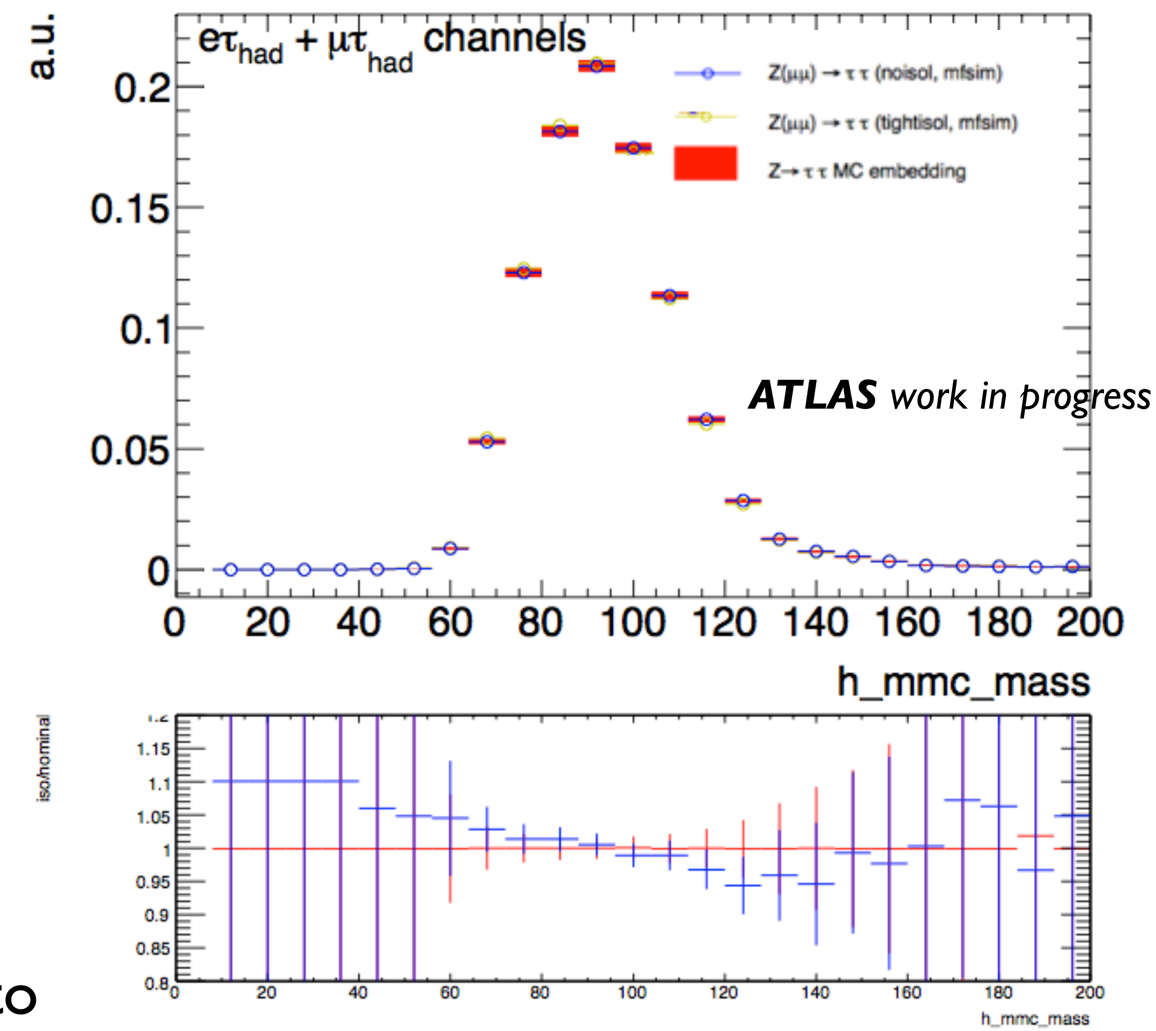
Isolation Systematics

- Refers to Z→μμ selection and muon objects to embed

- Isolation systematic covers
  - background contermination (ttbar) in Z→μμ selection
  - effect of isolation on embedded muon objects

- Vary isolation requirement for muon preselection

- Information stored in truth container
  - Just need to run embedding once
  - Can modify isolation criteria also after productions



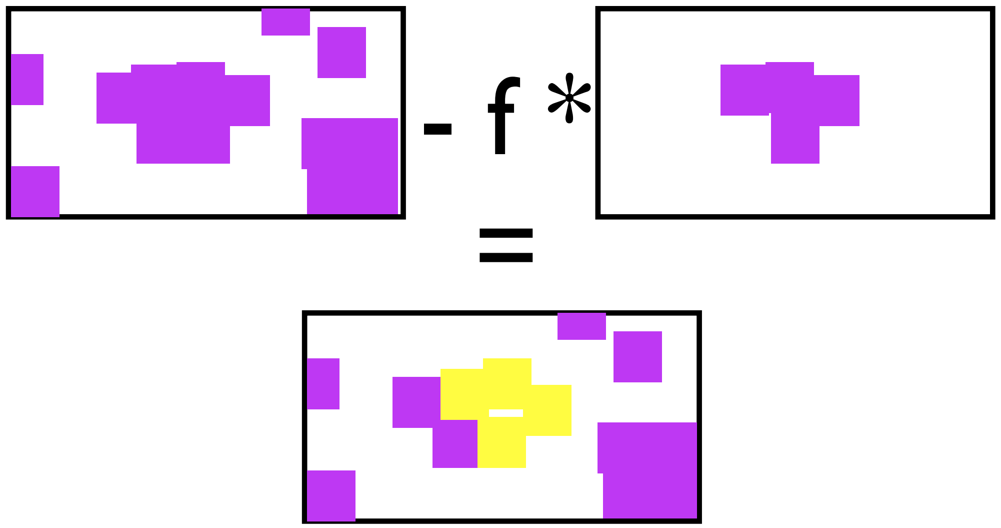
- Almost no difference between dn/nominal (0.1%) due to
  - SLT for Z→μμ selection (includes isolation requirement)
  - Analysis preselection (events surving presel. end up in nominal/up)

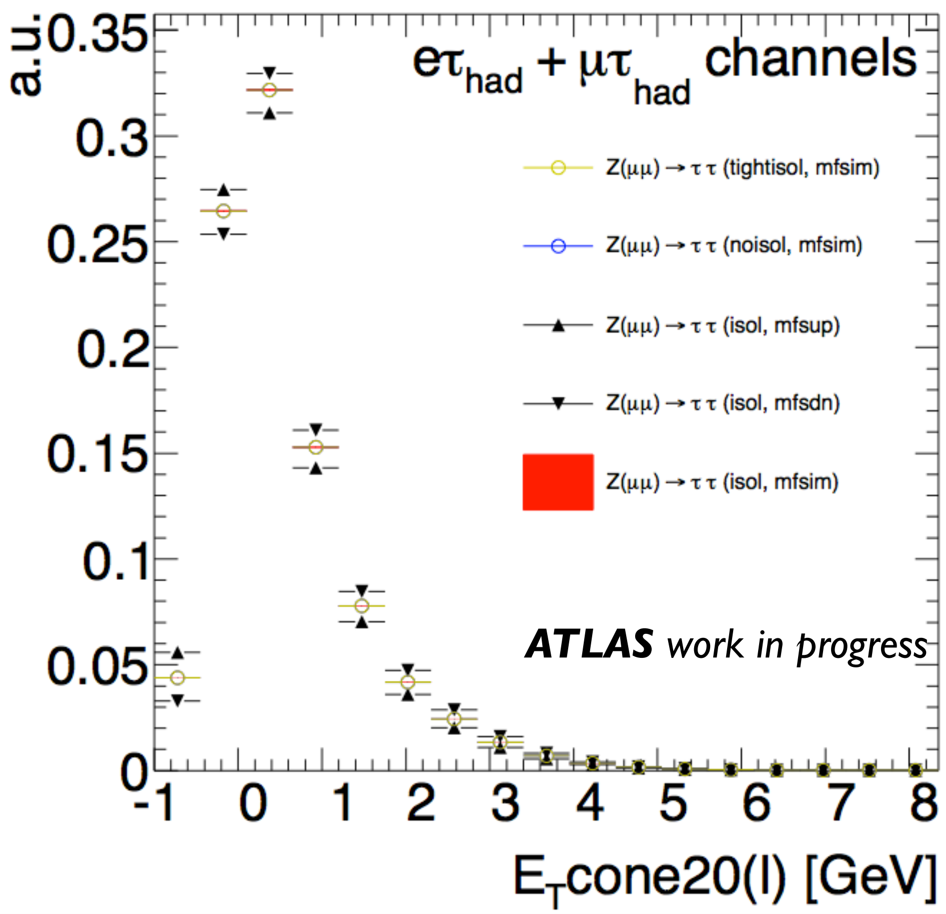
DN	nominal	UP
no iso	ptcone20/pt<0.2	ptcone40/pt<0.06 && etcone20/pt>0.04

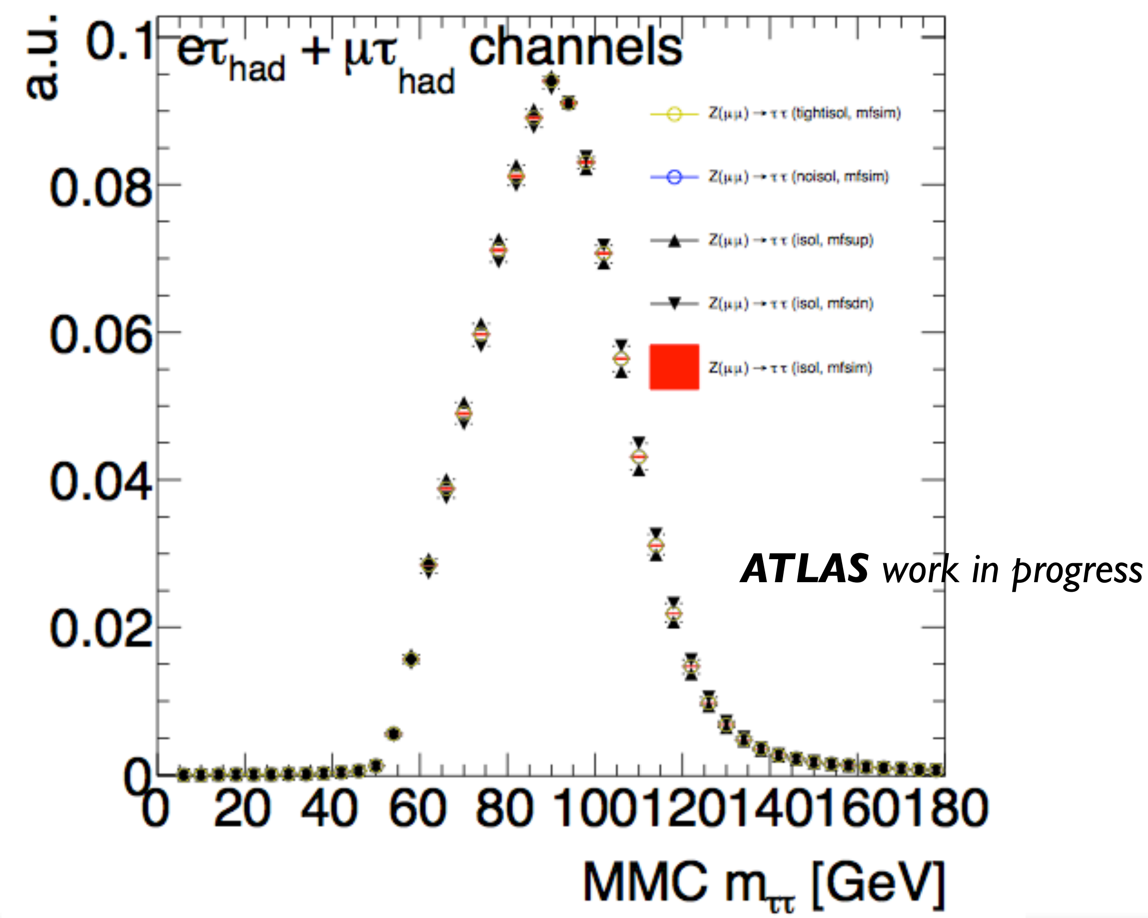
Cell Subtraction Systematic

- Remove cell energy of original muons by subtracting cell energy of simulated $Z \rightarrow \mu\mu$ event (same kinematic) from original $Z \rightarrow \mu\mu$ data event

- Vary subtracted cell energy up/down by 20%
  - Effect seen best in lepton isolation variables
    - Up variation: subtracting 1.2 of cell energy
      → less energy around embedded lepton (from tau decay)
    - Down variation: subtracting 0.8 of cell energy
      → more energy around embedded lepton

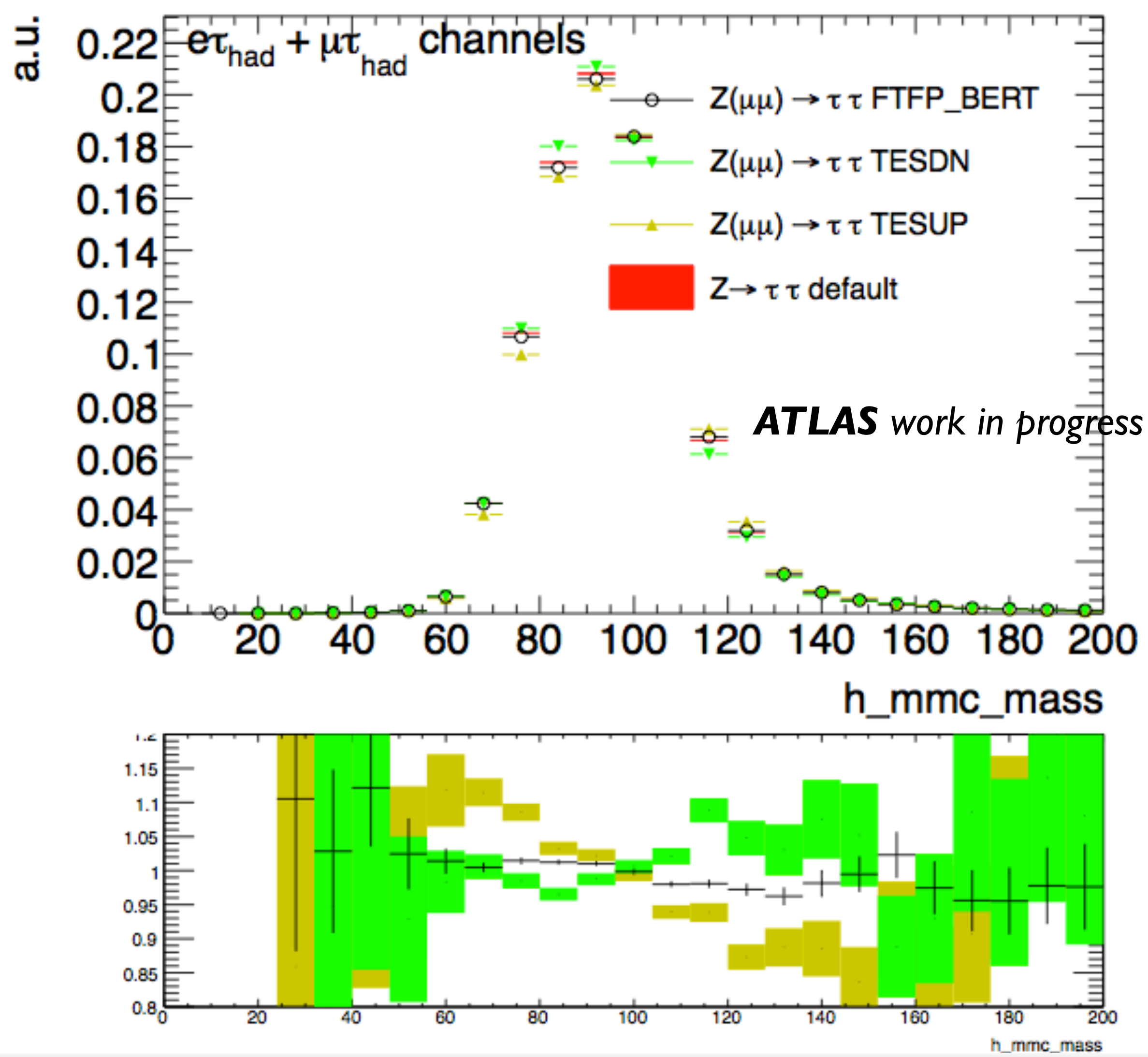


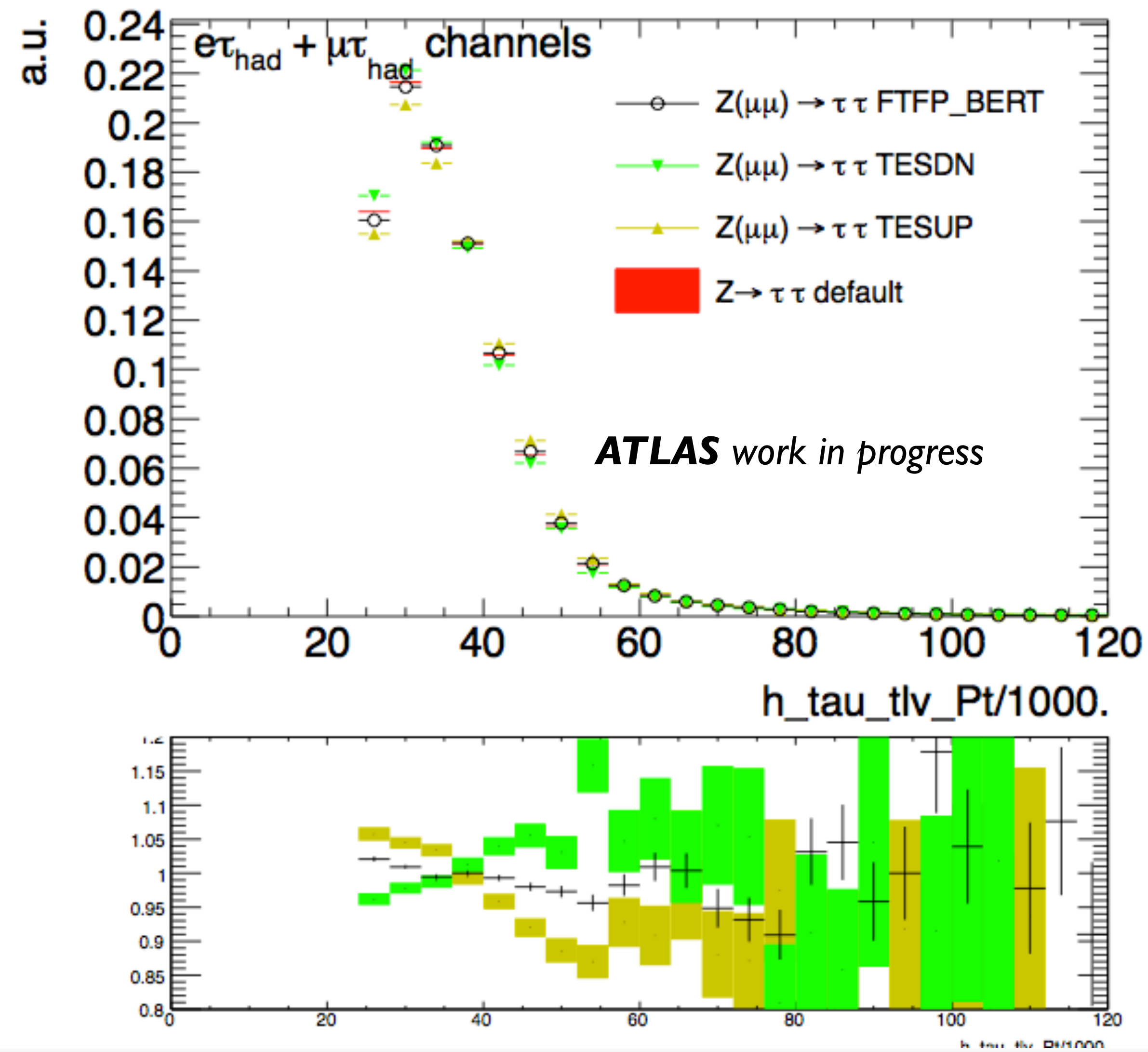




Test of alternative shower model

- Additional systematic necessary due to shower model?
- Alternative physicsList (FTFP) tested
- Observe shift in MMC mass
- But effect covered by TES → no additional systematic introduced





Validation methods

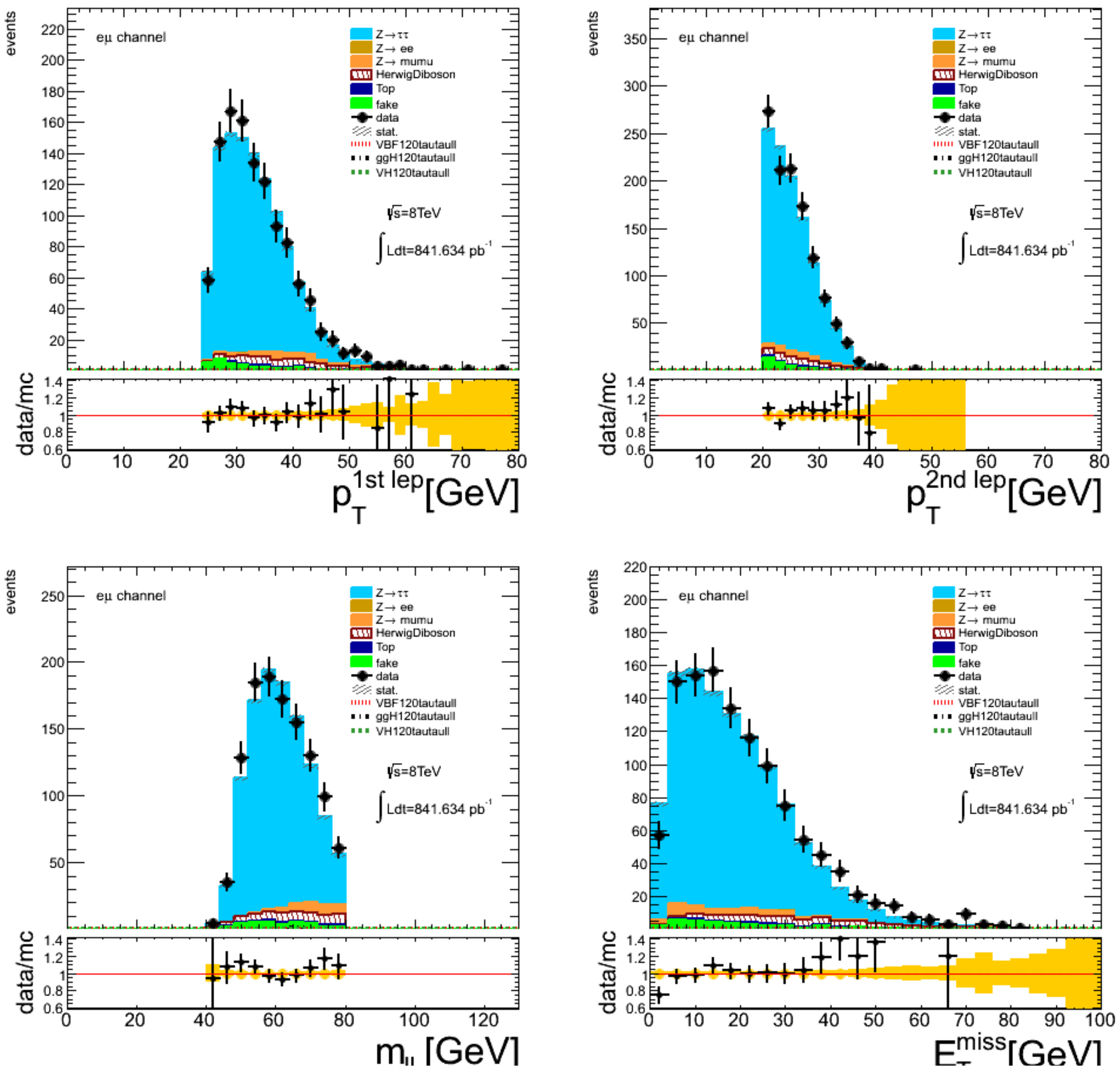
- **Data Background comparisons within analysis**
  - Overlays MC/embedding or embedding tag_XY/tag_Z
  - CR plots with Alpgen MC vs embedding

- **Technical validation methods**
  - $Z \rightarrow \mu\mu$ embedding in $Z \rightarrow \mu\mu$ data
  - Re-Reconstruction of $Z \rightarrow \mu\mu$ data
  - MC Embedding (run embedding on $Z \rightarrow \mu\mu$ MC)
  - MC Embedding with truth seeds (run embedding on $Z \rightarrow \mu\mu$ MC, use kinematic of truth muons to simulate tau decays)

Alpgen vs. embedding in Z CR

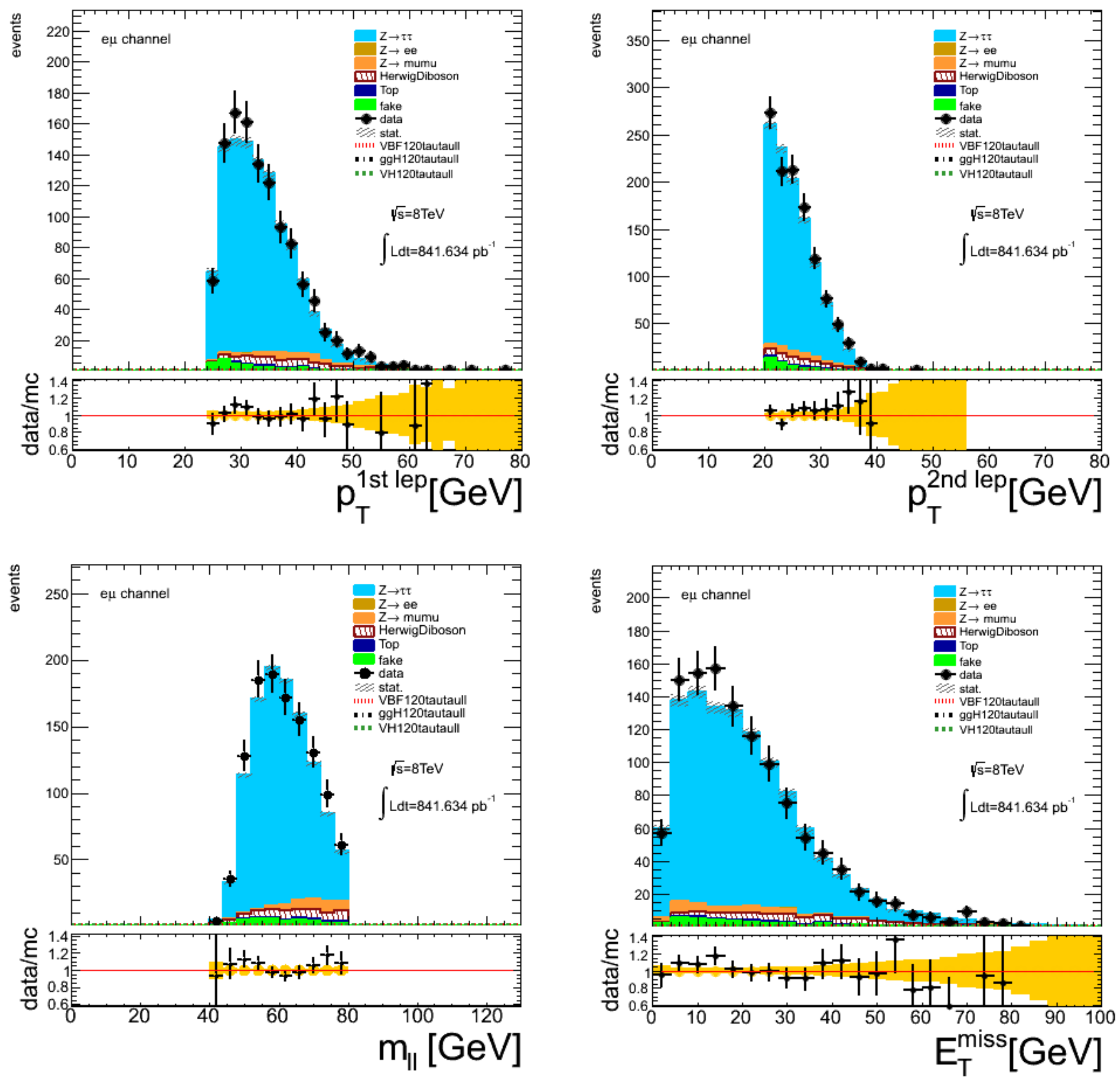
Alpgen

ATLAS *work in progress*



Embedding

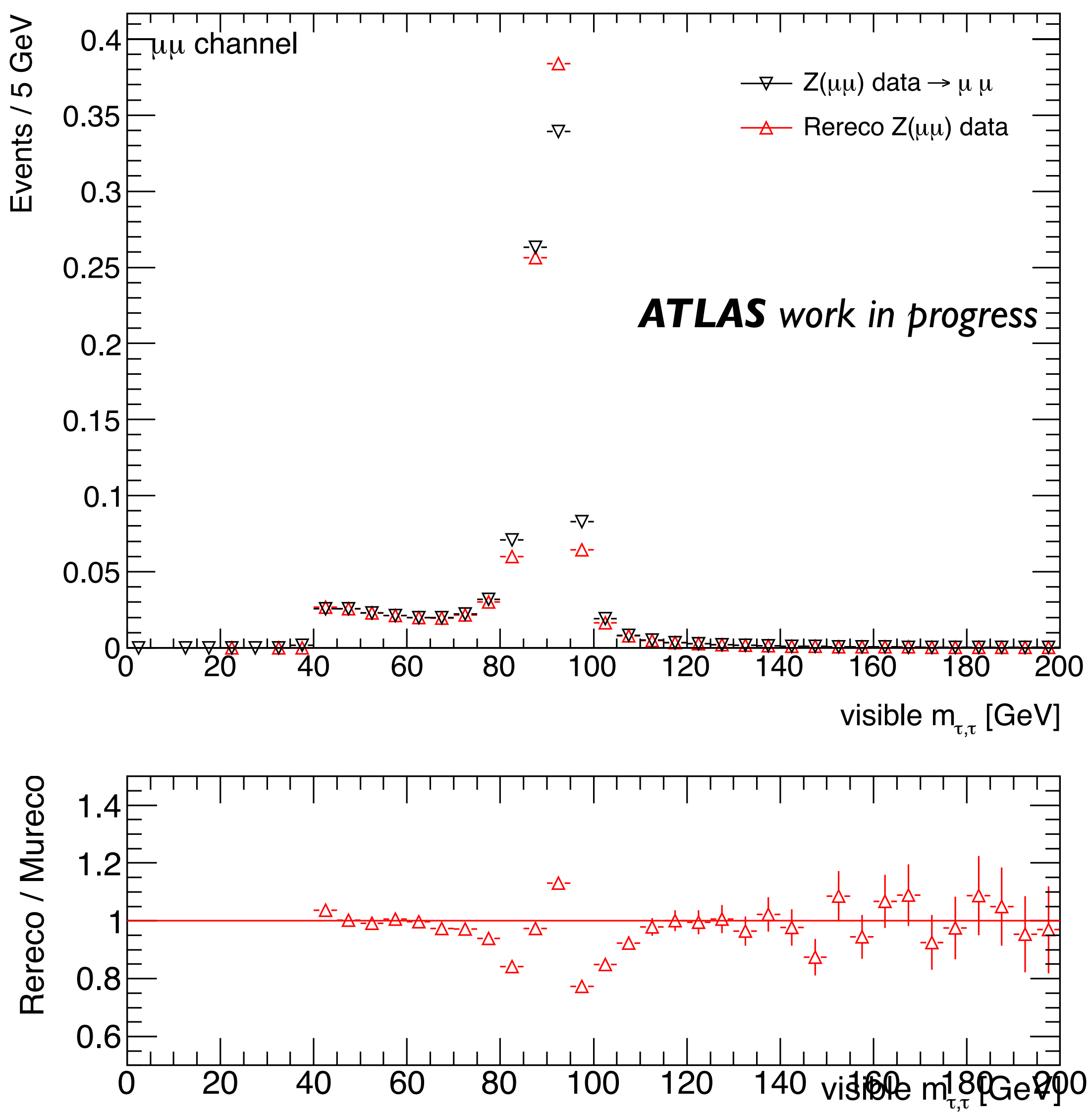
ATLAS *work in progress*

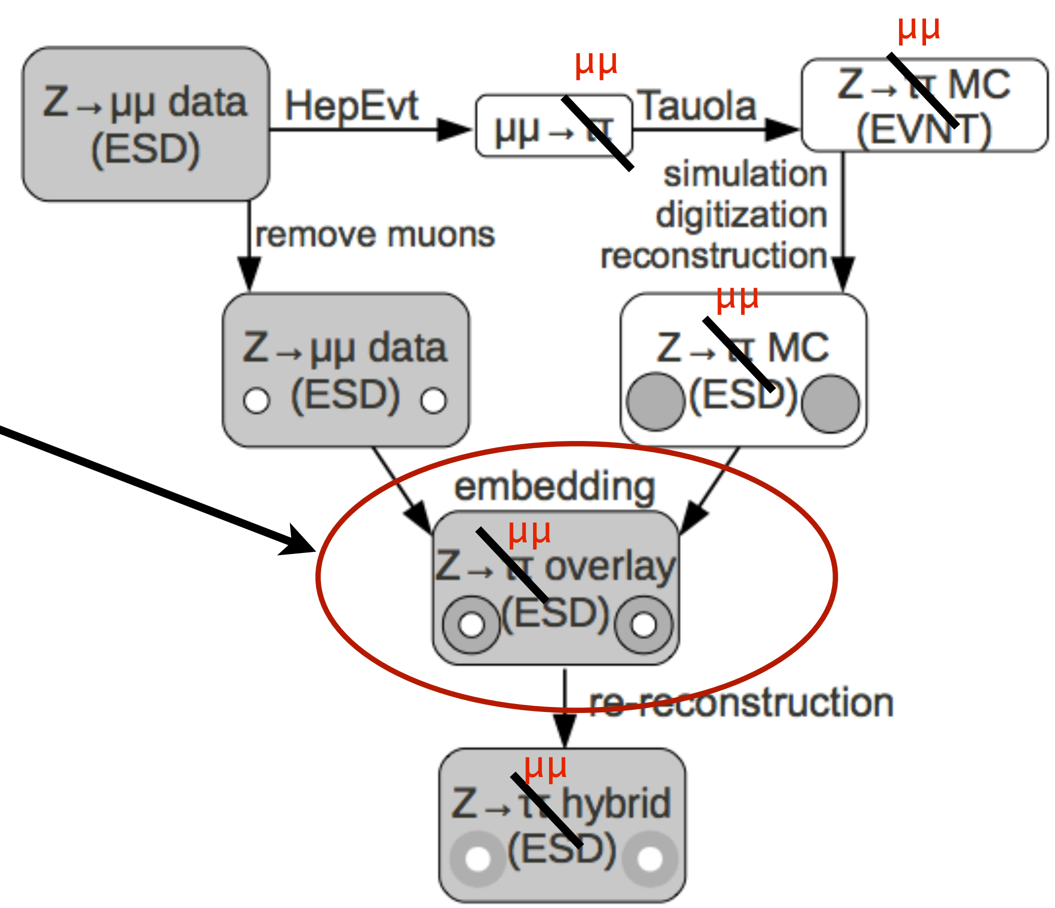


see Christian's talk

Embedding of Z→μμ in Z→μμ data

- Embed simulated Z→μμ event in Z→μμ data event
- Compared to skimmed Z→μμ data
  - Identify bugs in embedding procedure
  - Cell/container copying.....

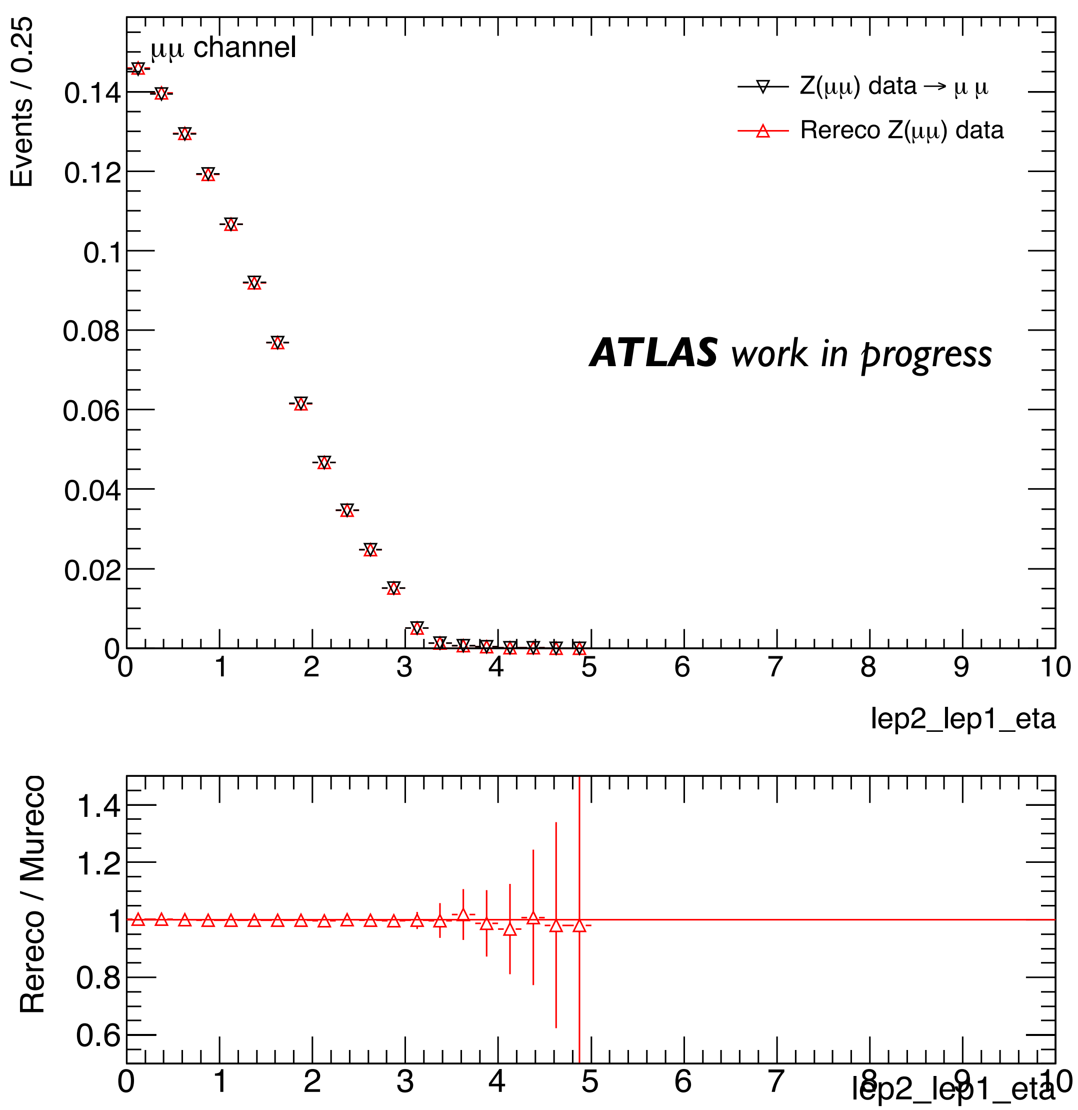


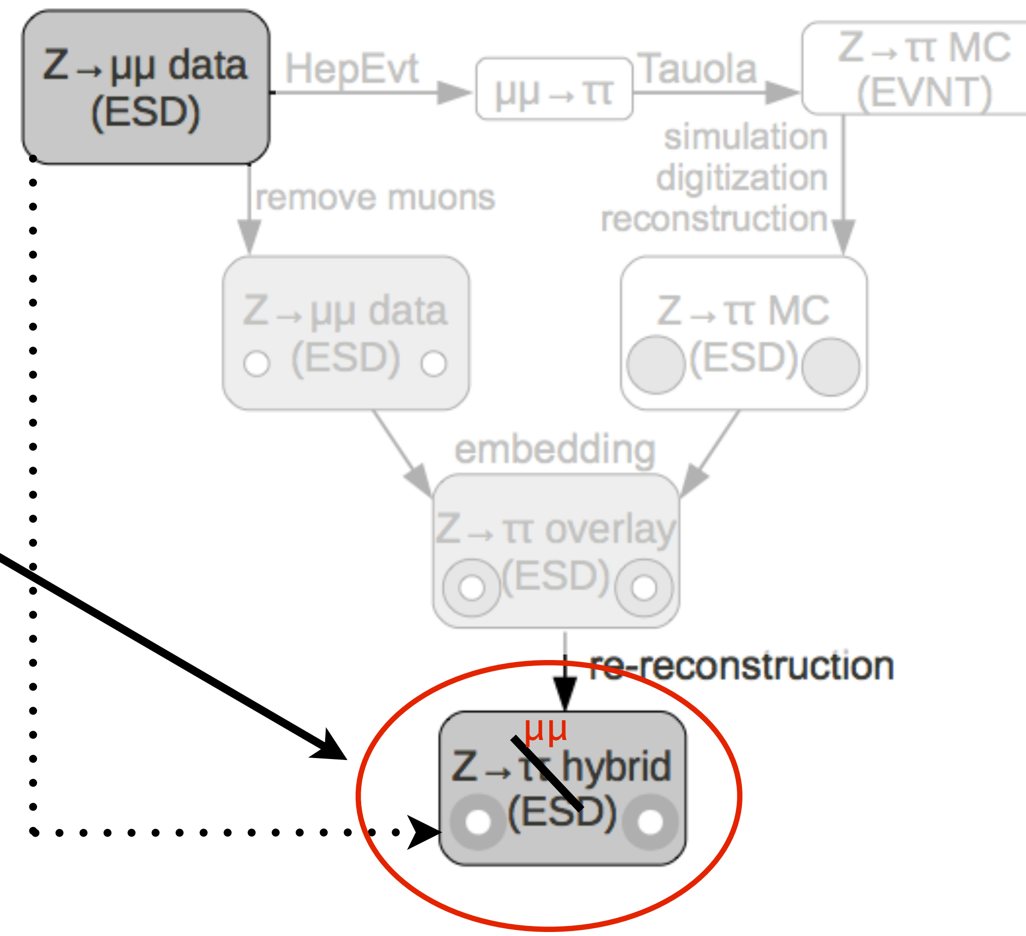


- But observed broader Z peak after embedding
- Originates from resolution effects of simulated muons
- Proofed via MC Embedding (later)

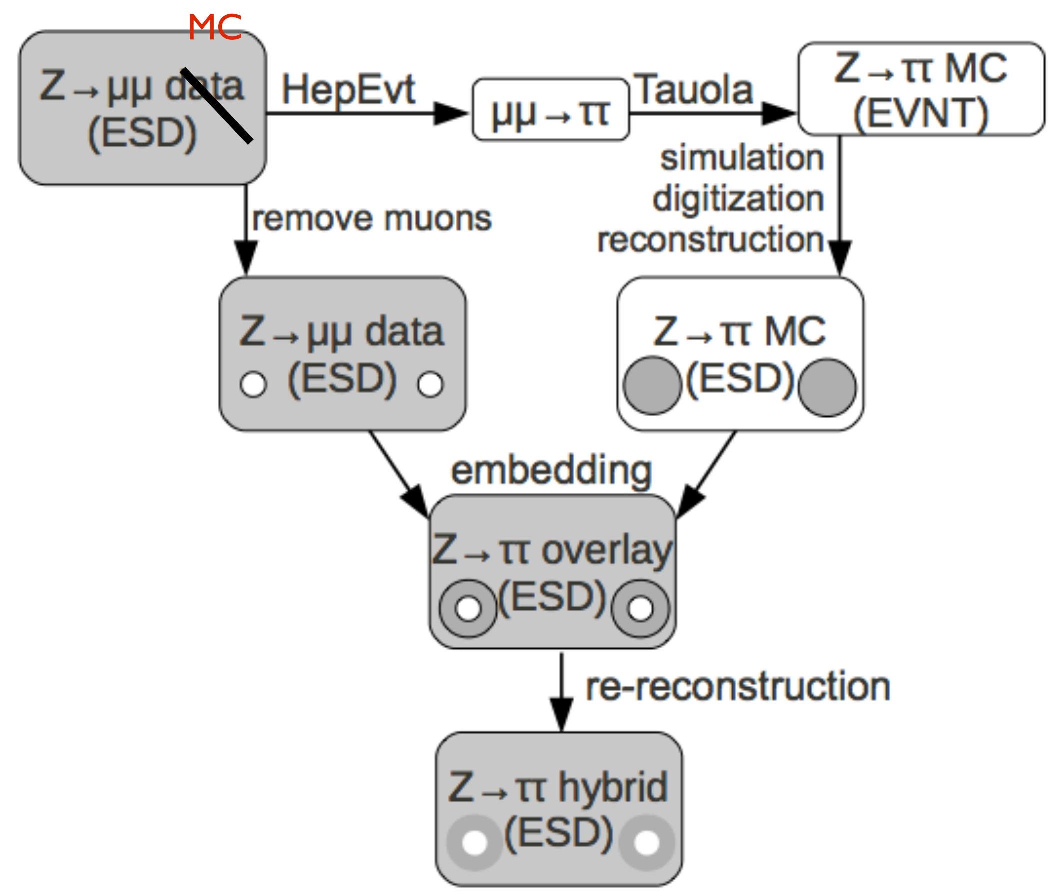
Re-reconstruction of Z→μμ data

- Re-Reconstruct Z→μμ events from skimmed Z→μμ data event
- Identify bugs in our reconstruction setup
  - E.g MET reconstruction

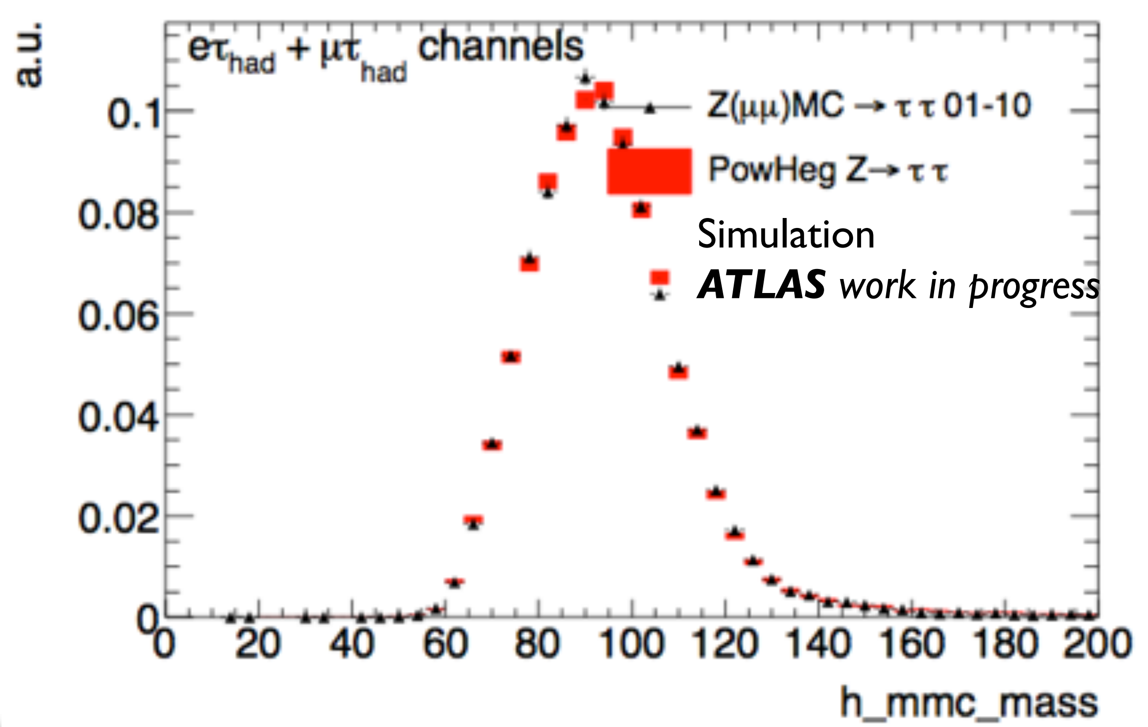


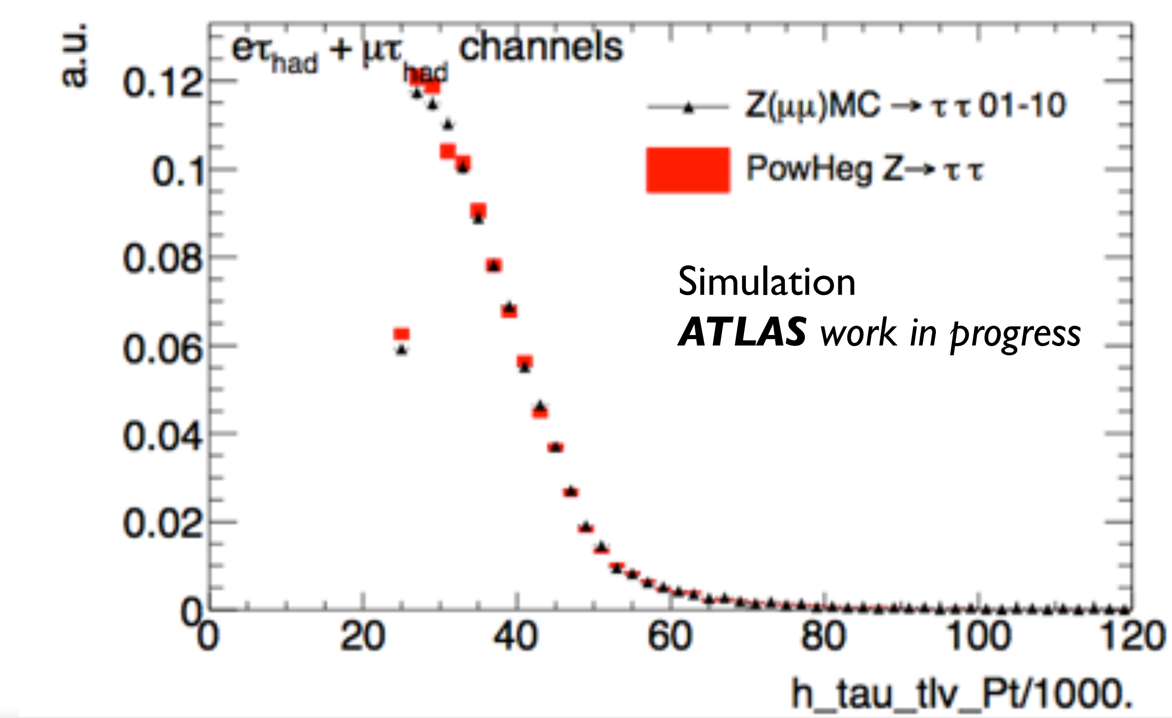


MC embedding



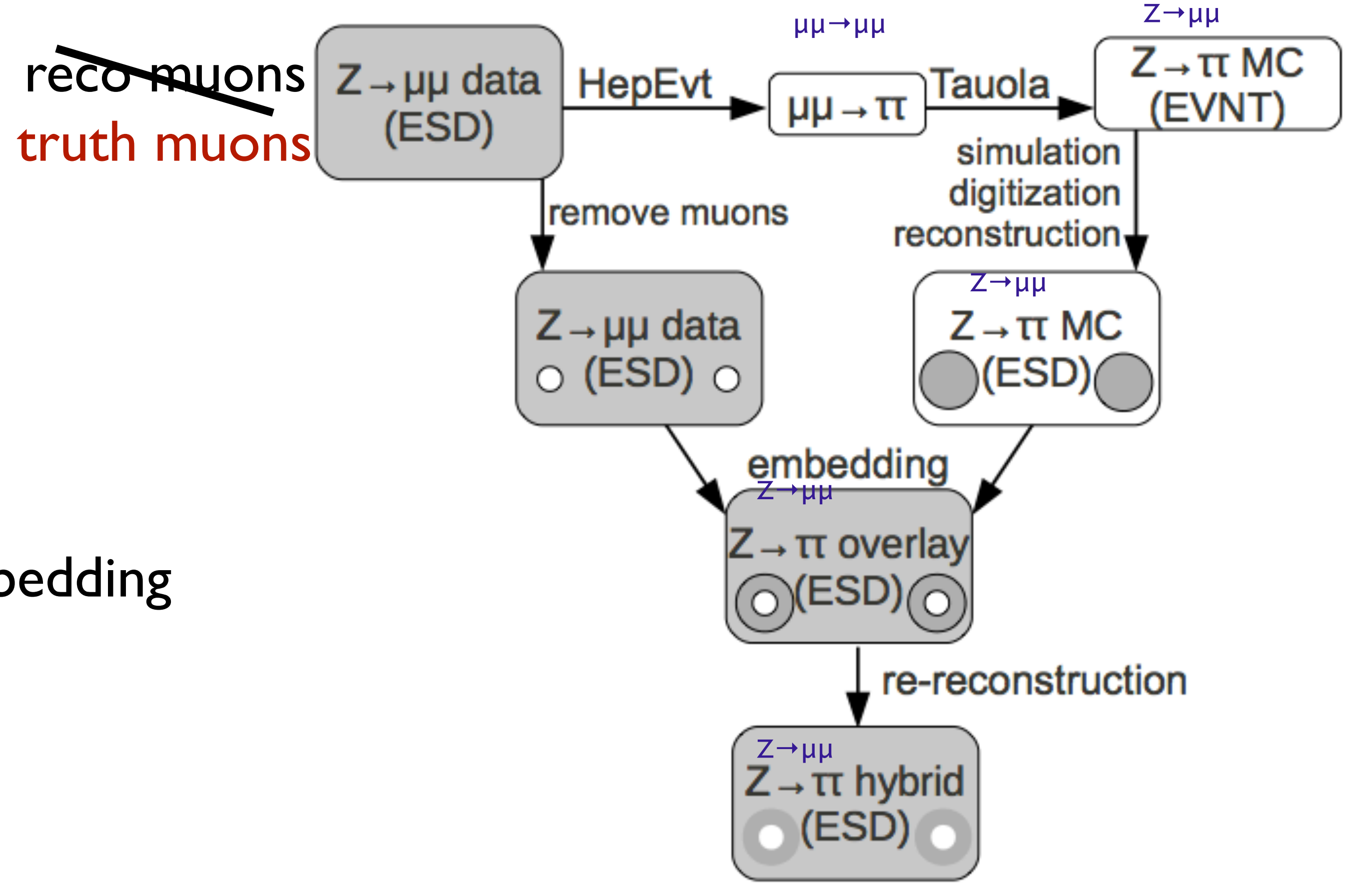
- Use Z→μμ MC instead of data as input
  - Apple to apple comparisons between MC embedding/Alpgen MC
    - Provided that same simulation conditions
- So far onle preliminary results



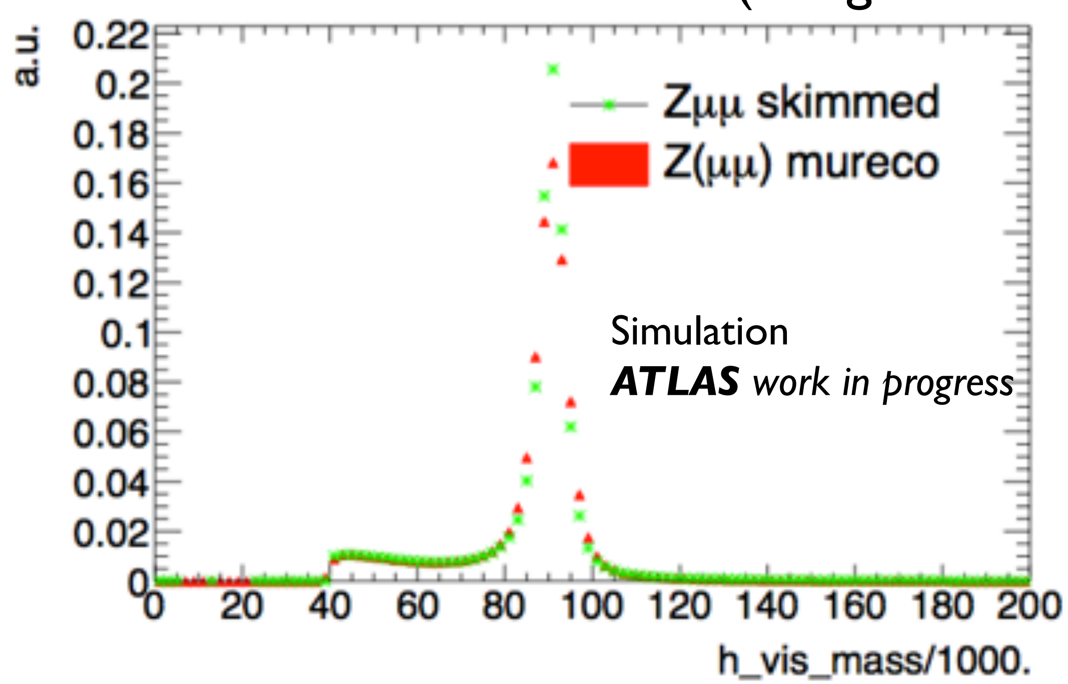


MC embedding with truth seeds

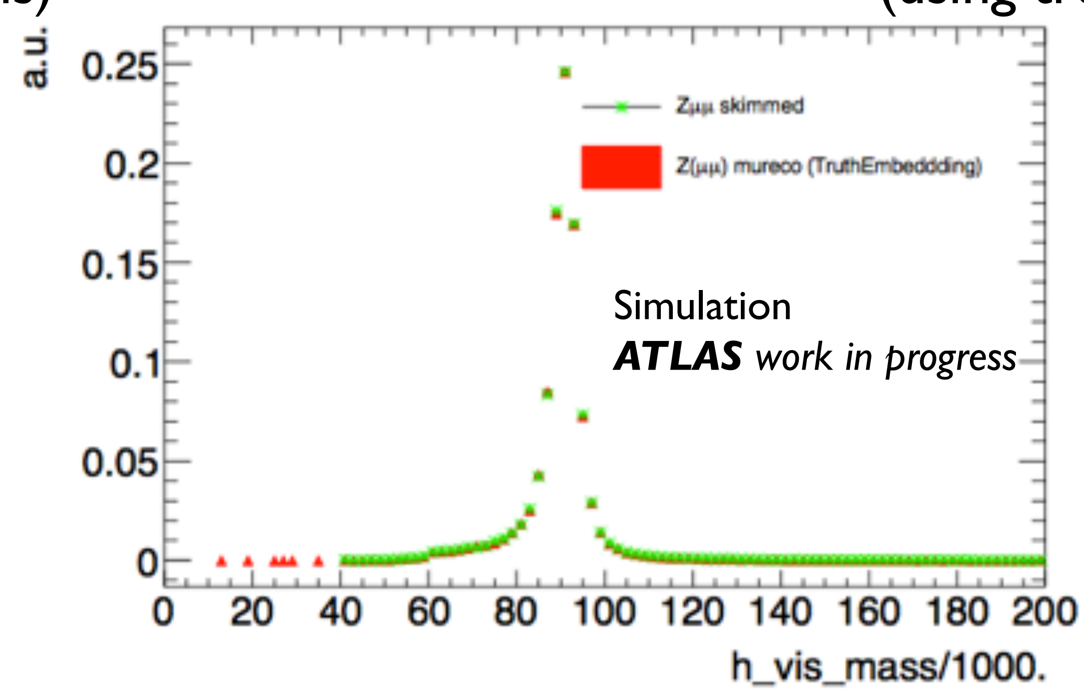
- Data embedding
  - Use reconstructed muons → truth taus
- MC embedding with truth seeds
  - Truth muons → truth taus
- No broadening of Z peak after Z→μμ embedding when using truth muon



(using reco muons)

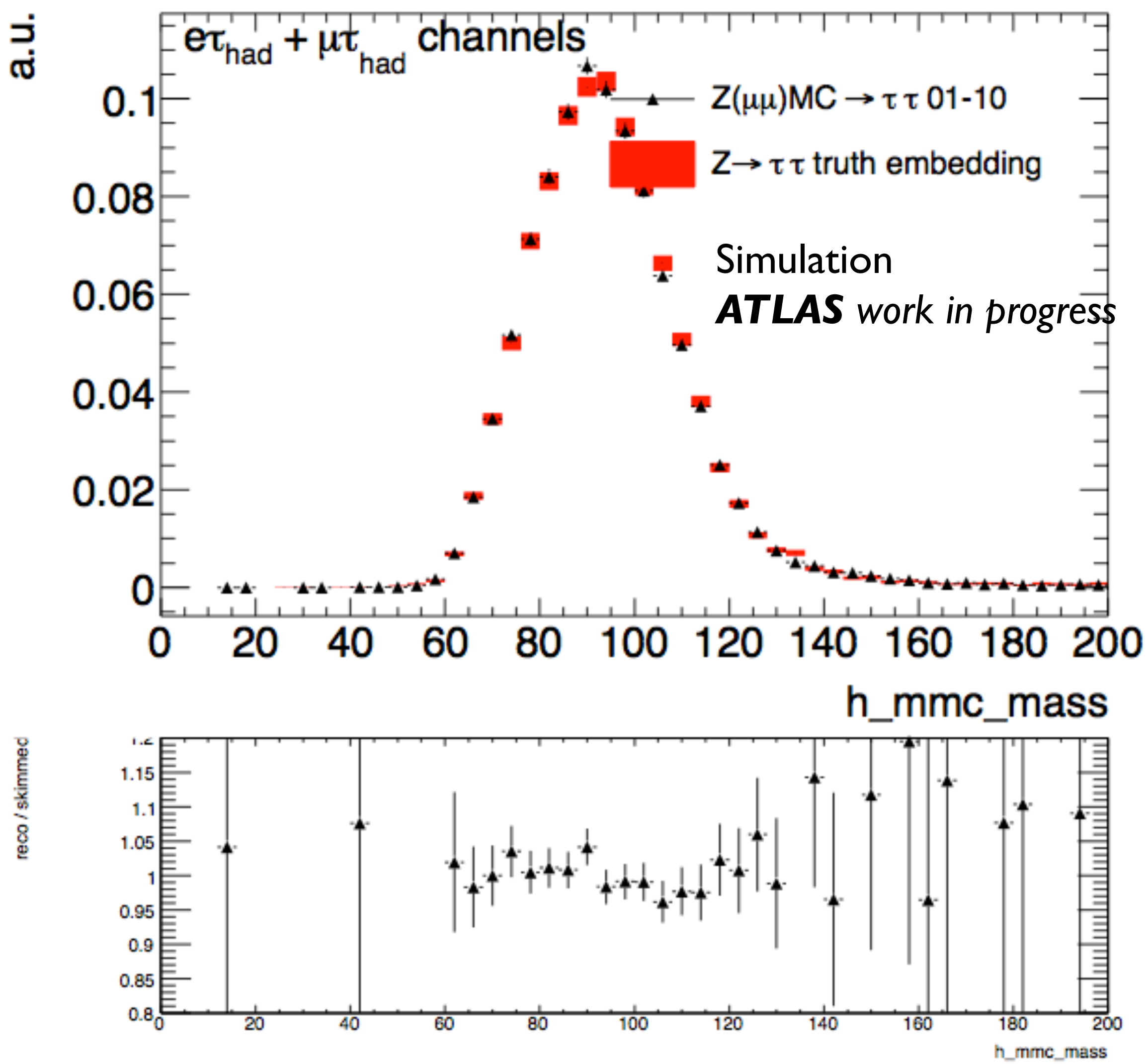


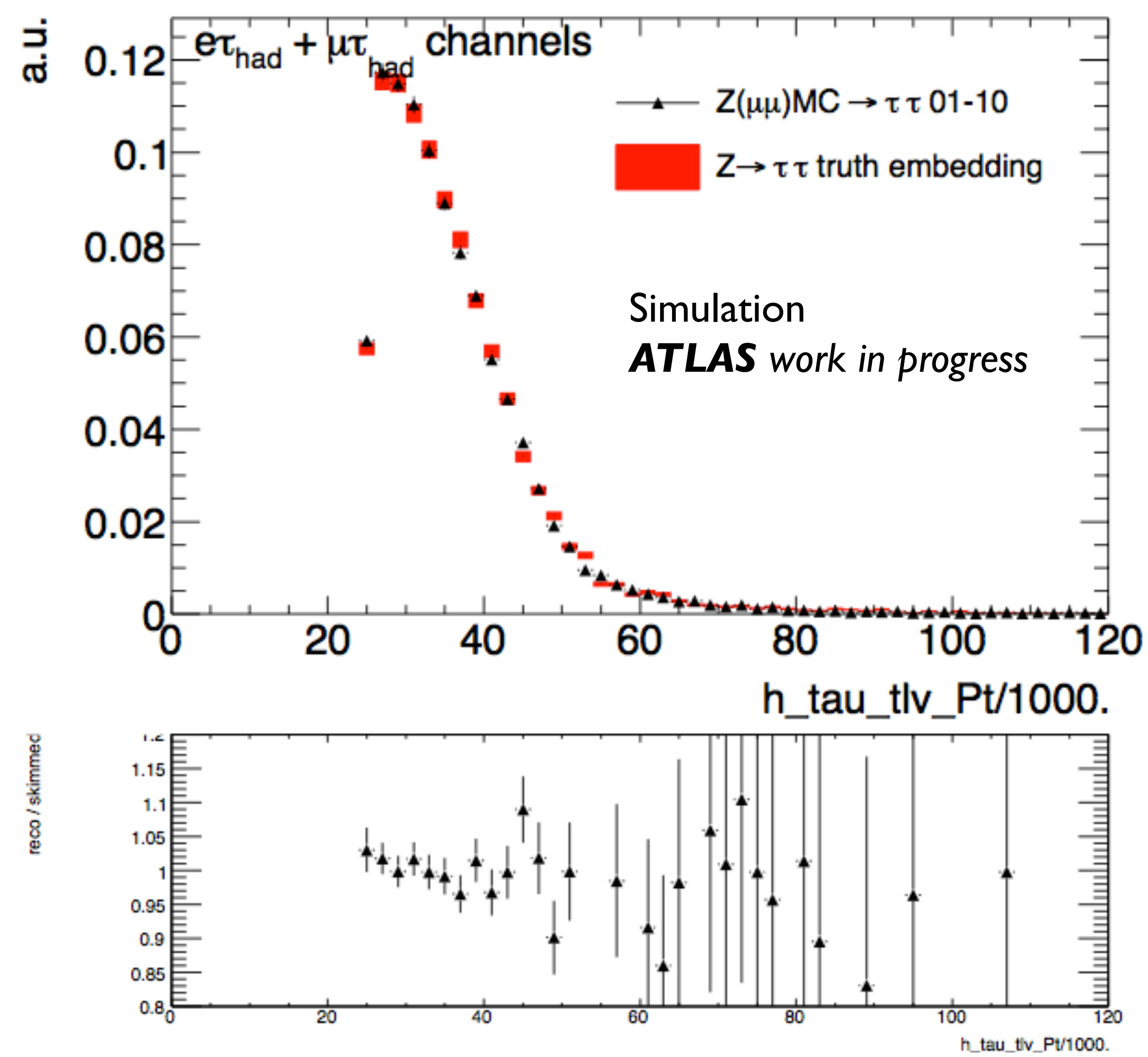
(using truth muons)



MC embedding (TruthMuons→Taus)

- Use again Z→μμ MC
  - a) Take reconstructed muons to embed taus (default)
  - b) Take truth muons to embed taus (MC Embedding with truth seeds)
- Comparisons between a) & b) is senstive to smearing due to muon reconstruction resolution
- Test can be used to derive additional systmatic for reconstruction resolution effects





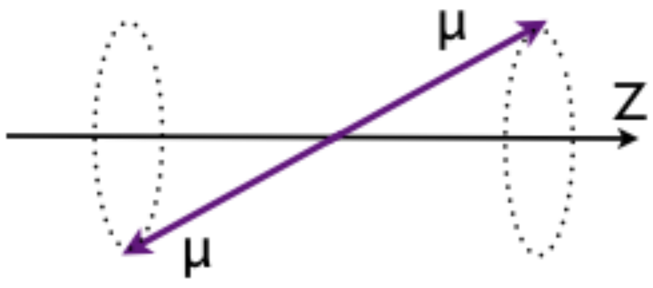
- Statement possible as soon as work on MC embedding finalized

Summary

- **New workflow implemented**
  - Allows efficient usage of ressources
- **Investigation of systematic uncertainities**
  - Isolation systematic
  - Cell substraction systematics
- **Validation methods strongly extended**
  - Technical validation methods applied/introduced
    - (Truth seeded) MC embedding

Outlook

- **Future improvements of method**
    - rotate muons in data event around Z-axis (as done in CMS)
        - get rid of cell subtraction systematic
    - embed MC background samples
        - closer investigation of isolation systematic



- **Further tuning of method to run in production system**
    - test efficiency of worklflow

Backup

Z→$\tau\tau$ controlregion in lep lep

$e\mu$ final state

$40 < m_{e\mu} < 80$ GeV

$p_T^{l1} > 25$ GeV and $p_T^{l2} > 20$ GeV

$p_T^e + p_T^\mu + \sum p_T^j + E_T^{miss} < 150$ GeV

$\cos\Delta\phi(E_T^{miss}, e) + \cos\Delta\phi(E_T^{miss}, \mu) > -0.7$