Data-Driven Methods for the Estimation of $t\bar{t}$ Backgrounds to Charged Higgs Searches

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On behalf of the ATLAS Collaboration

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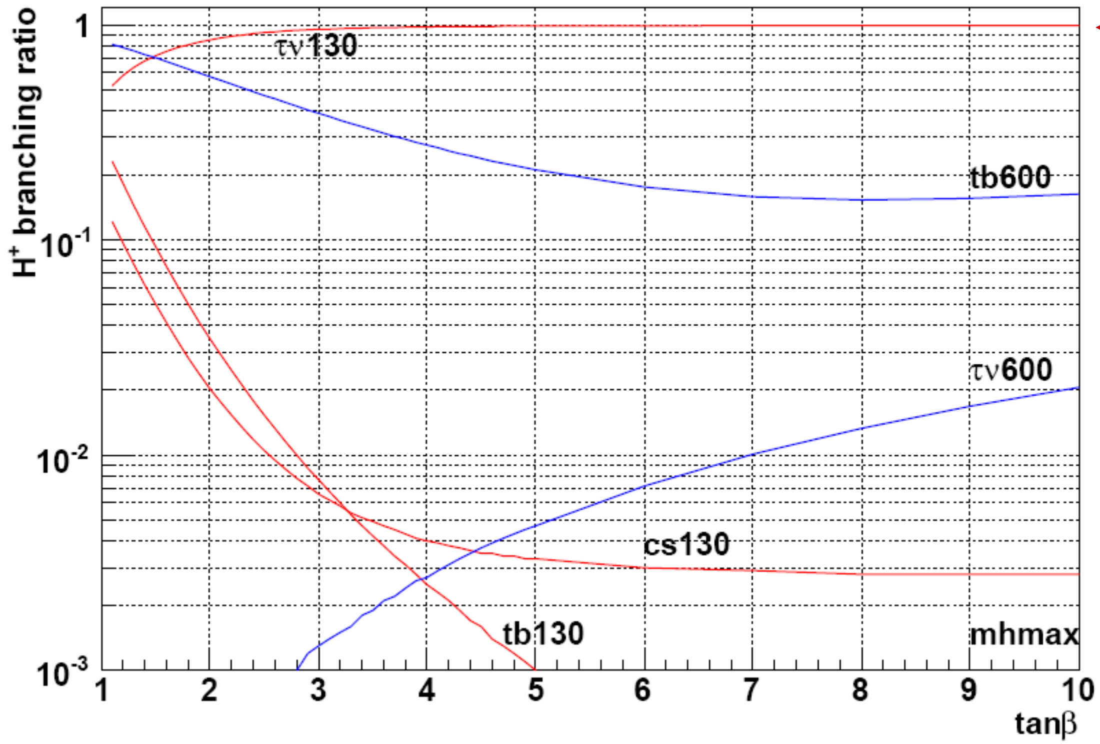
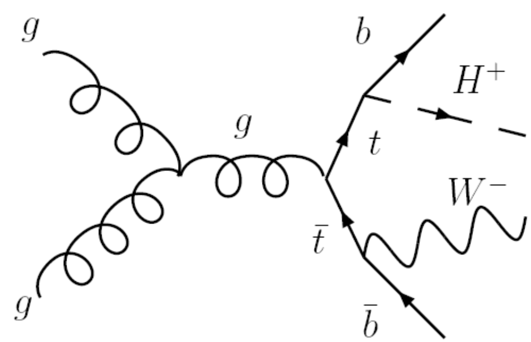
Introduction

Many talks have highlighted the importance of tau leptons in Charged Higgs Searches

- Consider the case of a light H^+ ($mH^+ < mt$)
- Production at the LHC via $gg \rightarrow ttbar \rightarrow H^+bWb$
- With the exception of small tanβ values, BR ($H+ \rightarrow$ tau nu) ~1



BR ~1

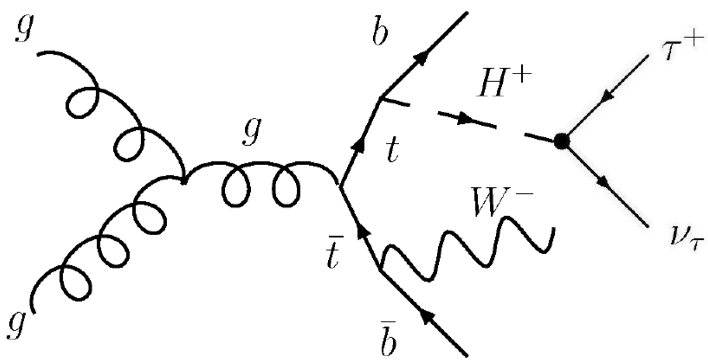


This talk will focus on a data-driven method for estimating ttbar backgrounds

- Study to appear in: ATLAS Collaboration, “Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics”, CERN-OPEN-2008-020, Geneva, 2008

Motivation

Signal Final State



$$H^+ \rightarrow \tau_H \nu;\ W \rightarrow qq$$

(Elias Coniavitis' Talk)

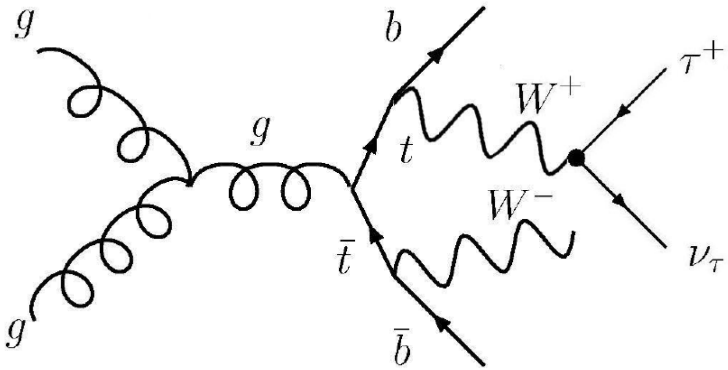
$$H^+ \rightarrow \tau_L \nu;\ W \rightarrow qq$$

(Ofer Vitells' Talk)

$$H^+ \rightarrow \tau_H \nu;\ W \rightarrow l\nu$$

(Thies Ehrich's Talk)

Dominant Background



$$W \rightarrow \tau_H \nu;\ W \rightarrow qq$$

$$W \rightarrow \tau_L \nu;\ W \rightarrow qq$$

$$W \rightarrow \tau_H \nu;\ W \rightarrow l\nu$$

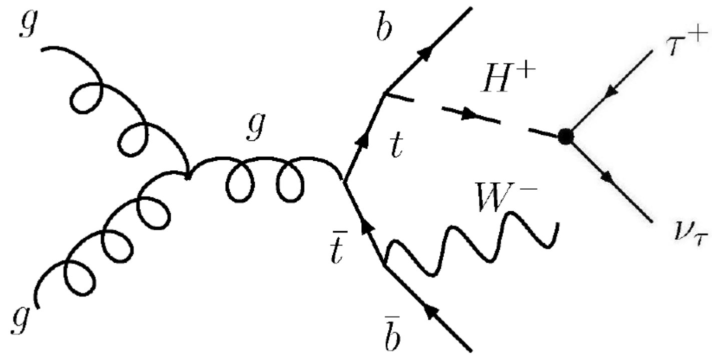
Do not trust Tevatron extrapolations

Difficult to obtain clean samples from data

Unknowns related to analysis-specific variables exist

Motivation

Signal Final State



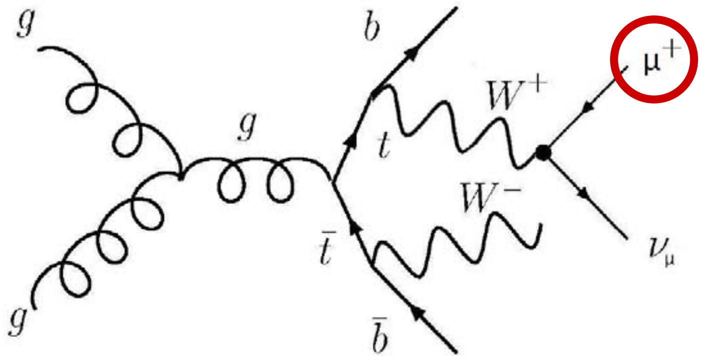
$$H^+ \to \tau_H \nu;\ W \to qq$$

$$H^+ \to \tau_L \nu;\ W \to qq$$

$$H^+ \to \tau_H \nu;\ W \to l\nu$$

Background Control Sample

Change muons into taus using the TAUOLA package



Leptonically- and hadronically-decaying taus can be emulated

Does not rely on the Tevatron

Clean samples can be obtained from data

Unknowns related to analysis-specific variables included

Obtaining μ Samples from Data

(selection criteria optimized for efficiency and purity)

The Di-Lepton Control Sample

Selection criteria:

- At least two isolated muons with pT > 20 GeV
- Z veto [70, 110 GeV]
- MET > 40 GeV

Process	cross section (pb)	events used	events passed	expected events in 1 fb^{-1}
$t\bar{t}$ signal	9.3	1265	359	2641.2
$t\bar{t}$ background	823.7	46500	23	407.4
W+1J	65.3	5000	1	13.1
W+2J	71.0	9450	1	7.7
W+3J	53.3	6500	0	$<$8.2
W+4J	28.0	7000	3	12.0
W+5J	15.3	5000	0	$<$3.1
Z+1J	172.7	3750	3	138.2
Z+2J	65.7	14500	17	77.0
Z+3J	20.7	2000	6	62.1
Z+4J	5.9	5250	18	20.1
Z+5J	2.1	2950	11	8.0
$b\bar{b}(mu20mu20)$	261	2435	3	321.6
Total BG	-	-	-	1066.8

Efficiency = 28%
Purity = 71%

The Lepton+Jets Control Sample

Selection criteria (designed to reject bbbar→1μ + X events):

- One isolated muon; two jets with pT > 40 GeV and within 20 GeV of the nominal W mass
- MET > 40 GeV; large event transverse energy (> 250 GeV)
- At least one jet must have been tagged as a b-jet

Process	cross section (pb)	events used	events passed	expected events in 1 fb^{-1}
$t\bar{t}$ signal	119.0	12864	1109	10262.5
$t\bar{t}$ background	714.0	42714	77	1287.1
W+1J	65.3	3000	0	<21.8
W+2J	71.0	6750	1	10.5
W+3J	53.25	5000	8	85.2
W+4J	28.0	6250	66	295.1
W+5J	15.3	3250	158	743.6
Z+1J	172.7	1750	0	<98.7
Z+2J	65.7	18000	0	<3.7
Z+3J	20.7	2000	0	<10.3
Z+4J	5.9	6150	20	19.0
Z+5J	2.1	2950	76	55.0
$b\bar{b}(mu20)$	87600	35576	3	1147
Total BG	-	-	-	3642.3

Efficiency = 8.6%
Purity = 74%

Turning Muons into Taus

The Method

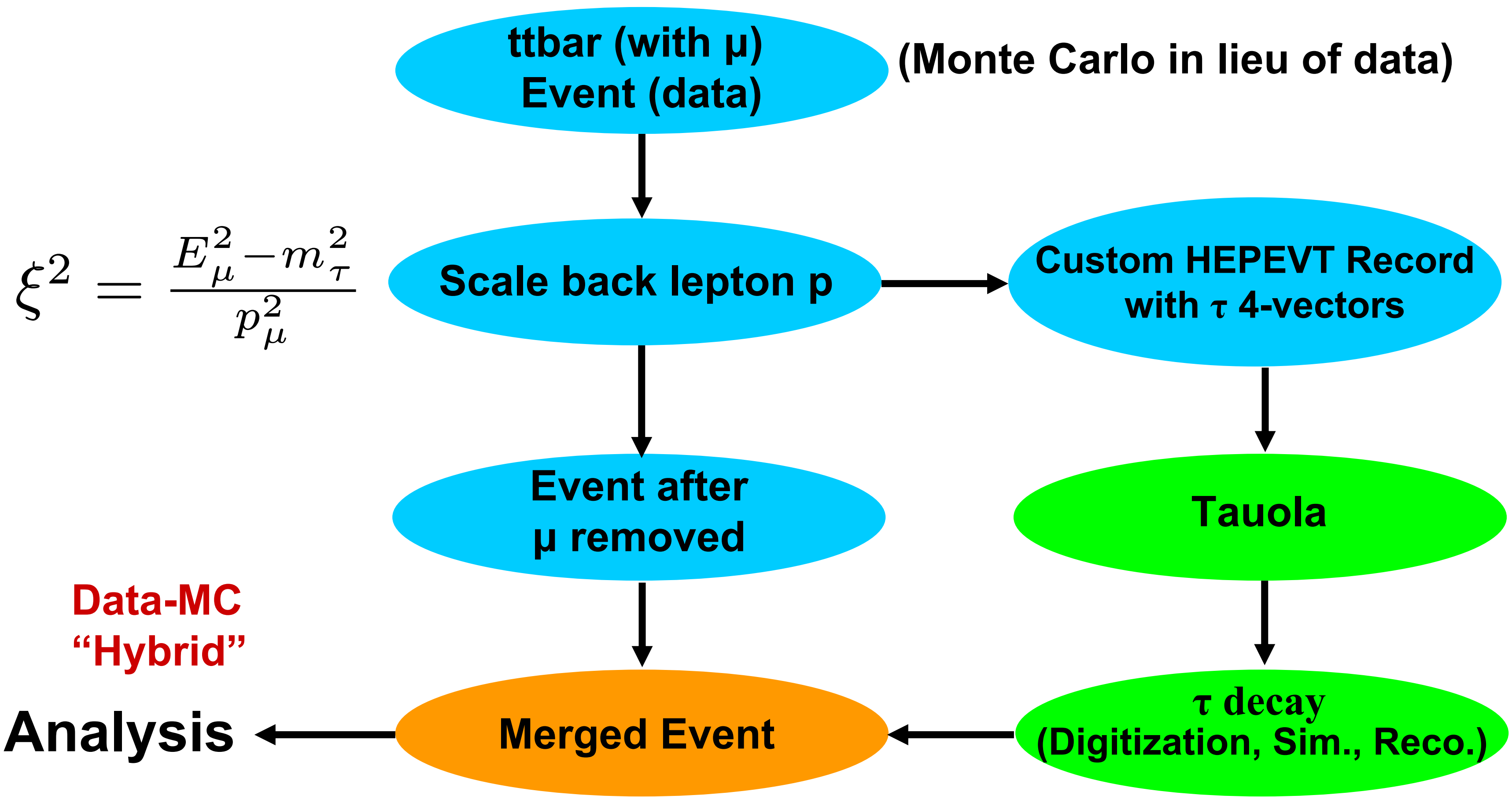
Based on a method used in ATLAS for SM and MSSM neutral Higgs searches

- Generate control samples for the Z+jets backgrounds

Original implementation (ATLAS CSC studies)

- Done at the ntuple-level and used the full ATLAS detector simulation
- These are the results presented in this talk

$$\xi^2 = \frac{E_\mu^2 - m_\tau^2}{p_\mu^2}$$



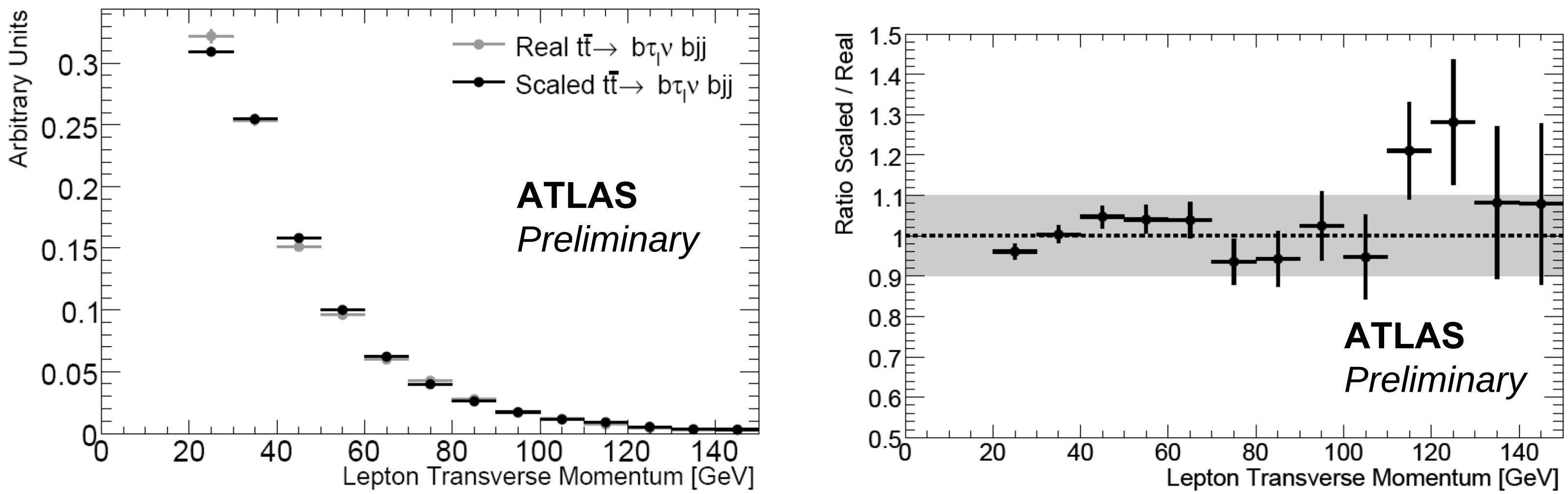
ATLAS Offline Software Framework (ATHENA)

Results

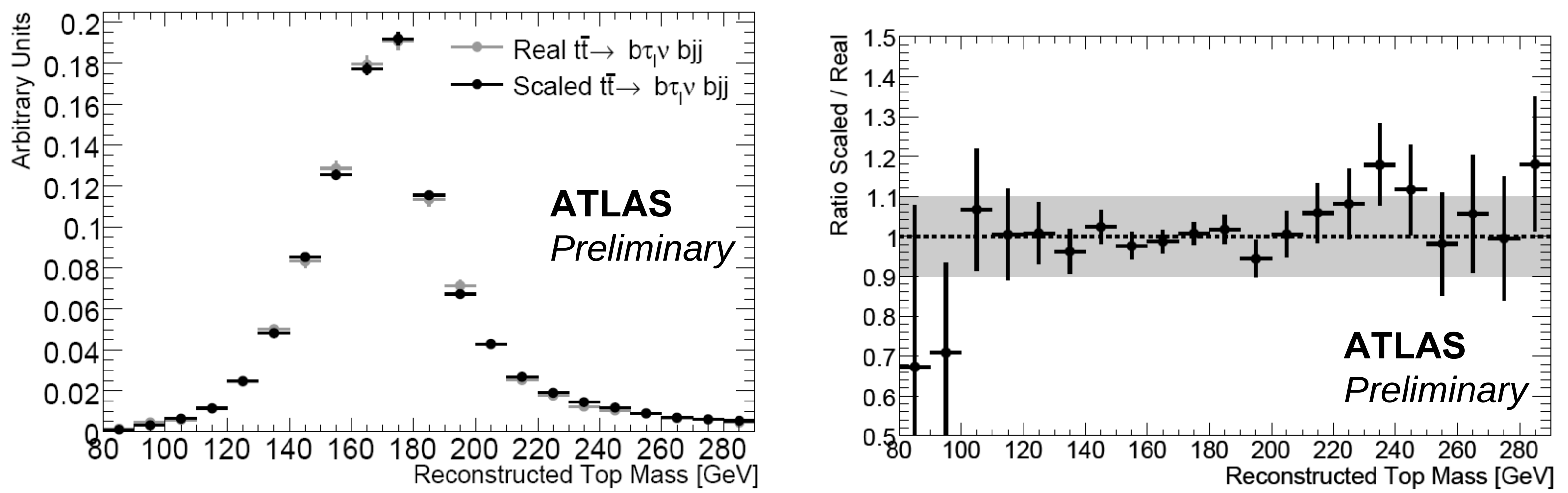
(a few simple and complex variables for each final-state)

$t\bar{t} \rightarrow b\tau_L\nu bqq$

Lepton Transverse Momentum (charged lepton from tau decay):

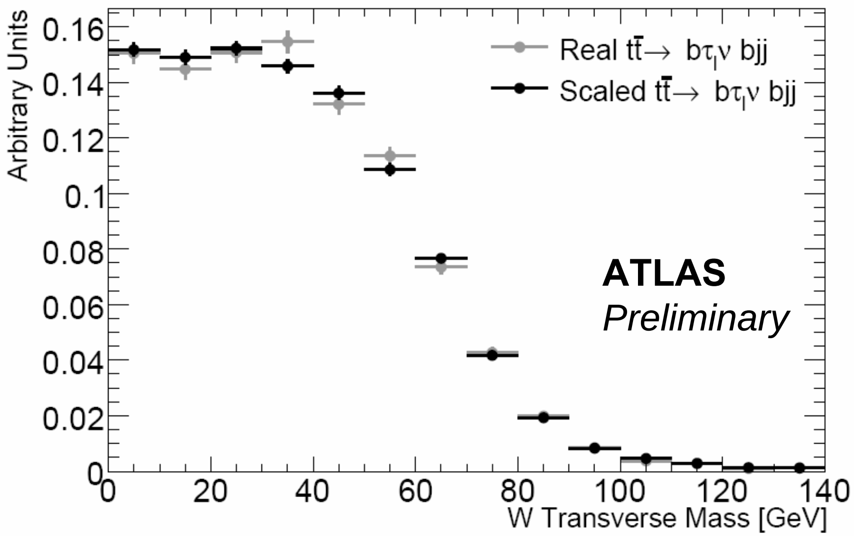


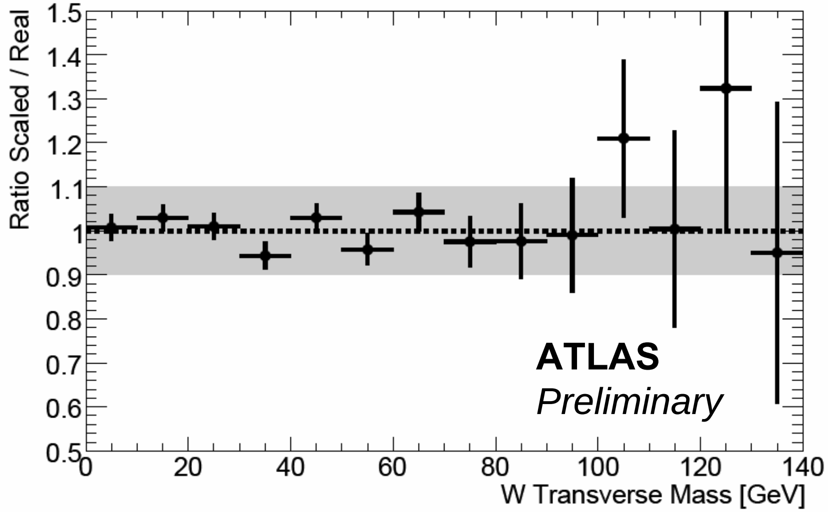
Reconstructed hadronic top quark mass (uninfluenced by replacement)



$t\bar{t} \rightarrow b\tau_L \nu bqq$

W Transverse Mass Distribution (complex quantity; relevant correlations preserved)

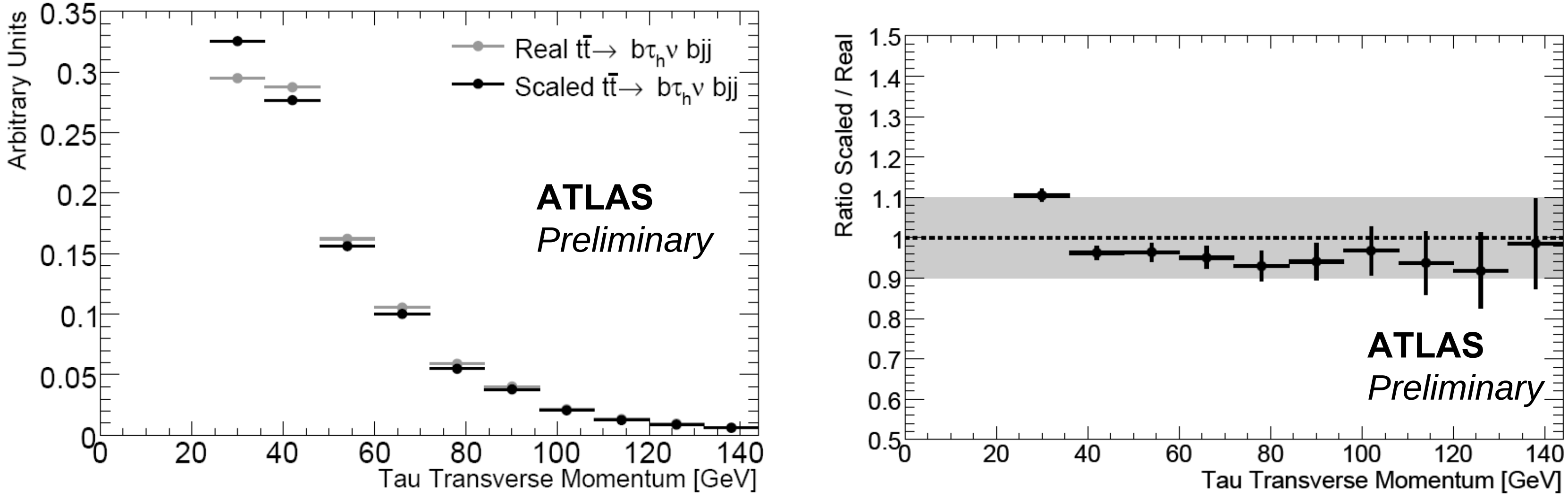




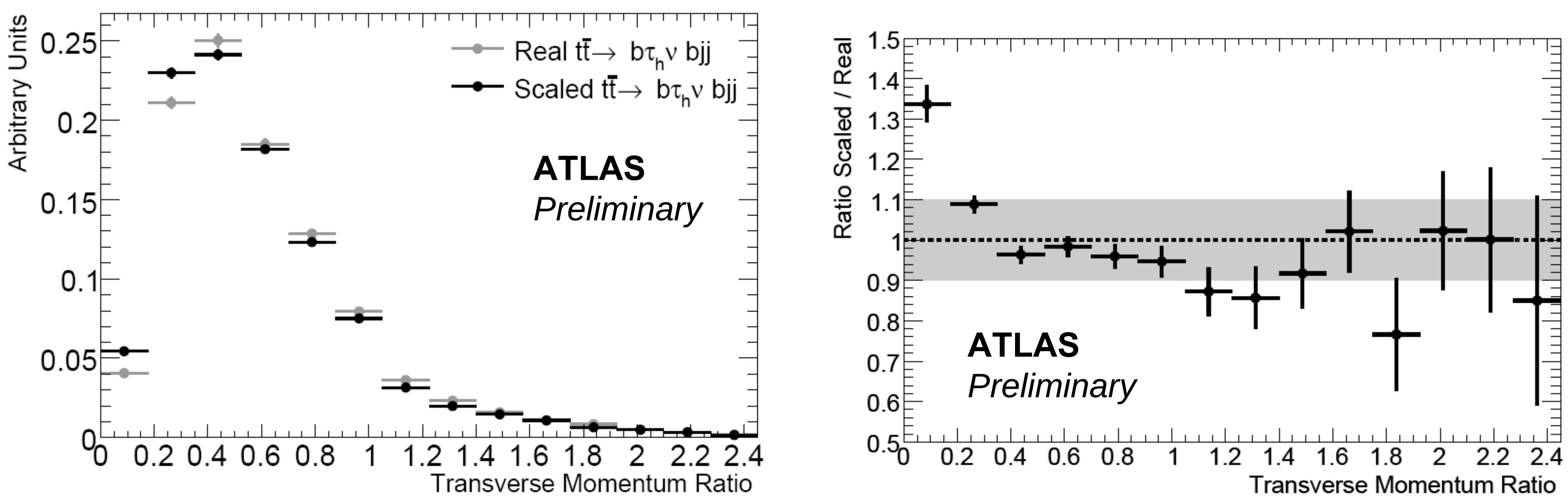
$$m_T = \sqrt{2p_T^l p_T^{miss}(1 - \cos(\Delta\phi))}$$

$$t\bar{t} \rightarrow b\tau_H \nu bqq$$

Tau Transverse Momentum (hadronic)

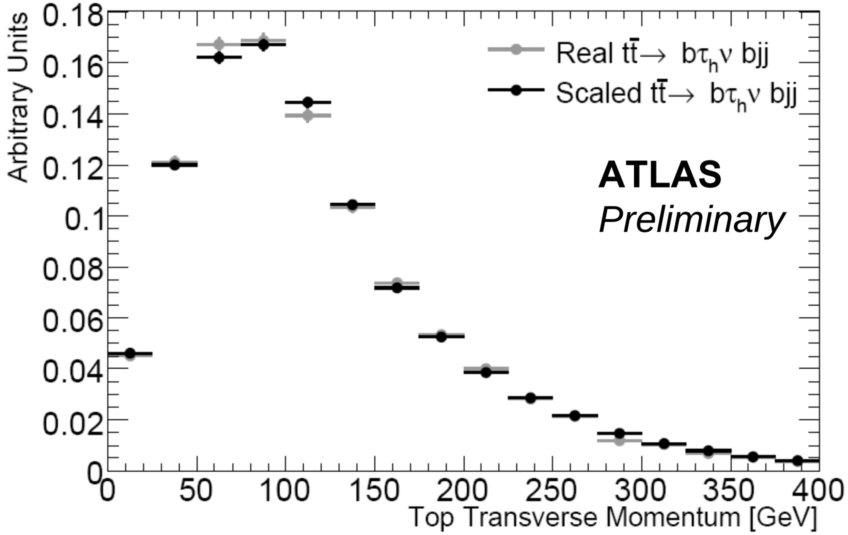


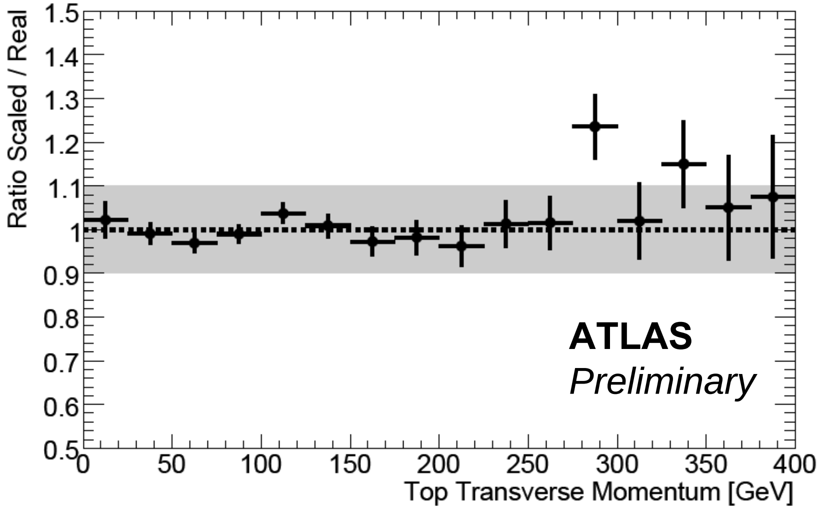
Transverse Momentum Ratio (tau pT / pT of hardest jet not used in top reco.)



$t\bar{t} \to b\tau_H \nu bqq$

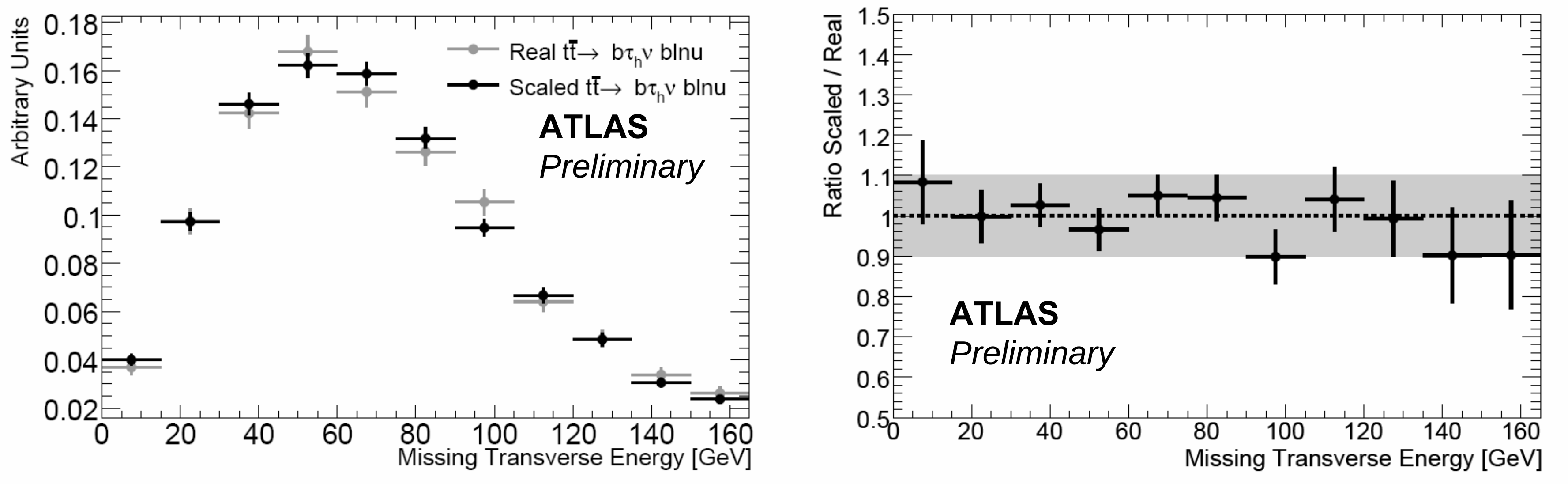
Top Quark Transverse Momentum (complex quantity)





$$t\bar{t} \rightarrow b\tau_H \nu b l \nu$$

Event Missing Transverse Energy (complex quantity; resulting from the combination of all objects in the event)

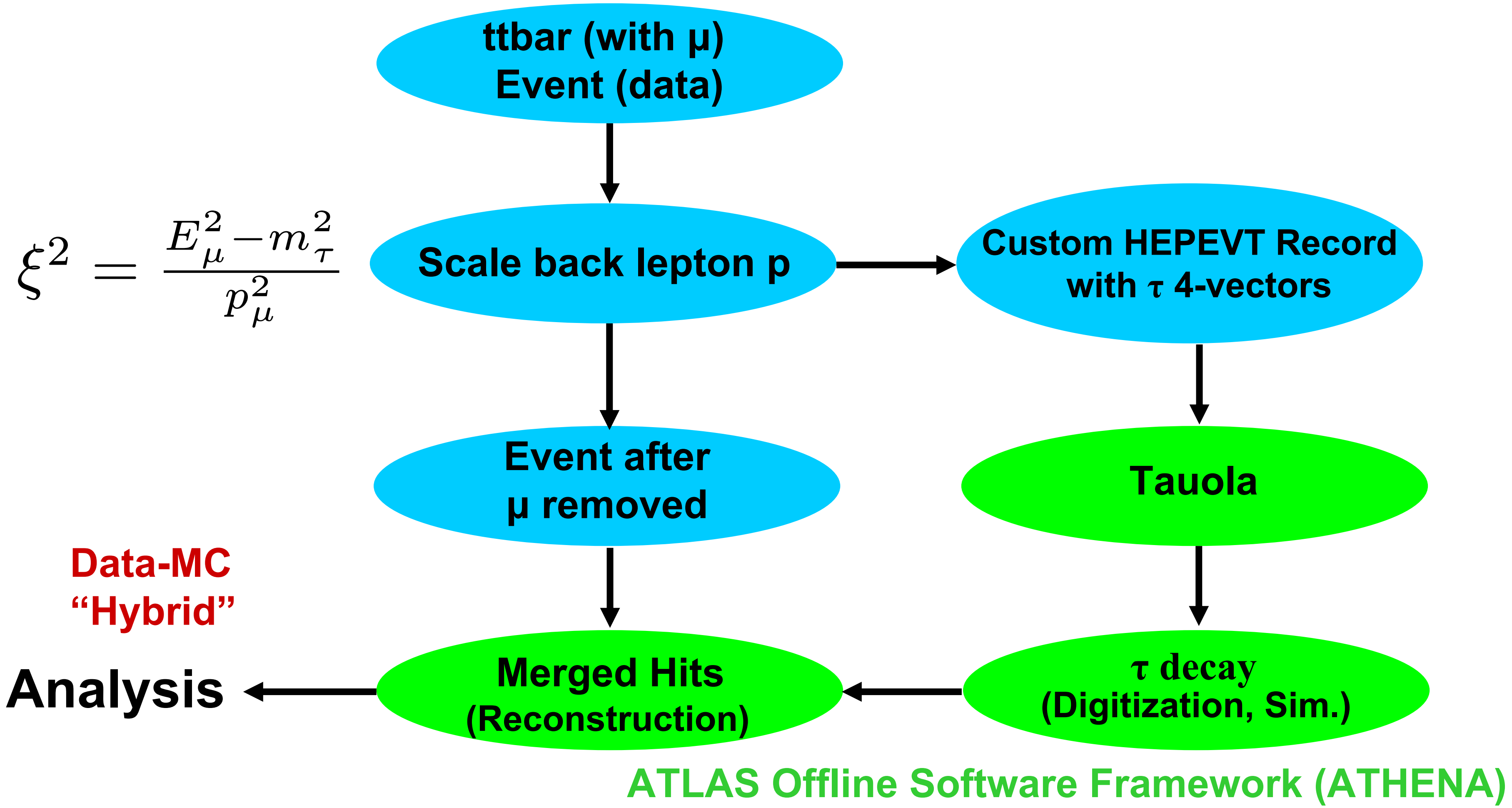


Current Efforts

Future implementations in ATLAS will merge the event at the hits level

- Subtract muon tracks and calorimeter depositions from the event
- Add tau tracks and calorimeter depositions
- Re-run the ATLAS reconstruction on the entire merged event, followed by the full Charged Higgs Analysis

$$\xi^2 = \frac{E_\mu^2 - m_\tau^2}{p_\mu^2}$$



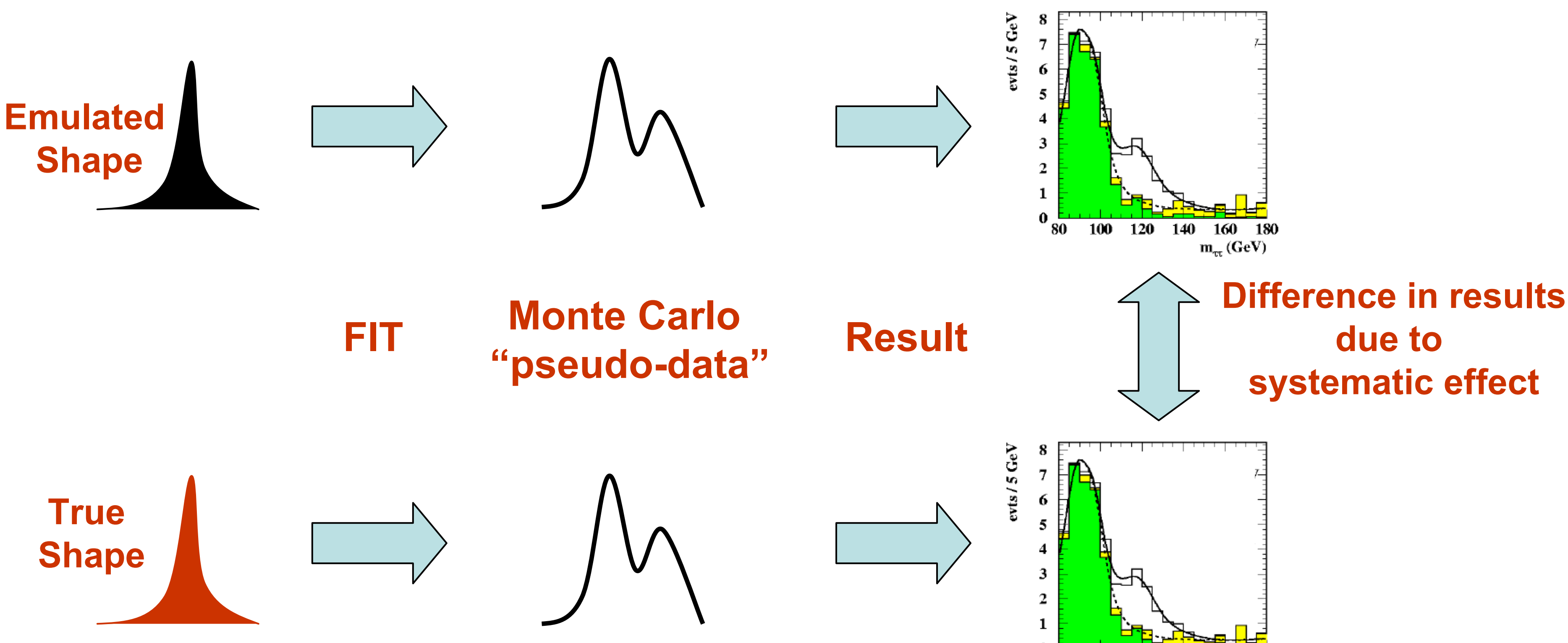
Systematics

In early running, uncertainties in the shape are predominantly statistical

- Error bars are mostly dependant on the size of these control samples (e.g., ttbar di-lepton and lepton+jets events with μ final-states)

Toy Monte Carlo “pseudo-experiments” can be used to evaluate systematics

- Contamination of the control sample is certainly one of the larger sources
- Particle identification efficiencies and resolutions will also come into play



Summary

Backgrounds to Charged Higgs searches from ttbar events can be estimated using data-driven control samples

- Final states containing leptonically- or hadronically-decaying taus can be emulated
- The shapes obtained from the control sample agree well (~10%) with those from Monte Carlo
- Normalization can also be estimated (through event counting / algebraic means, or using fits of the shapes to data)

Future

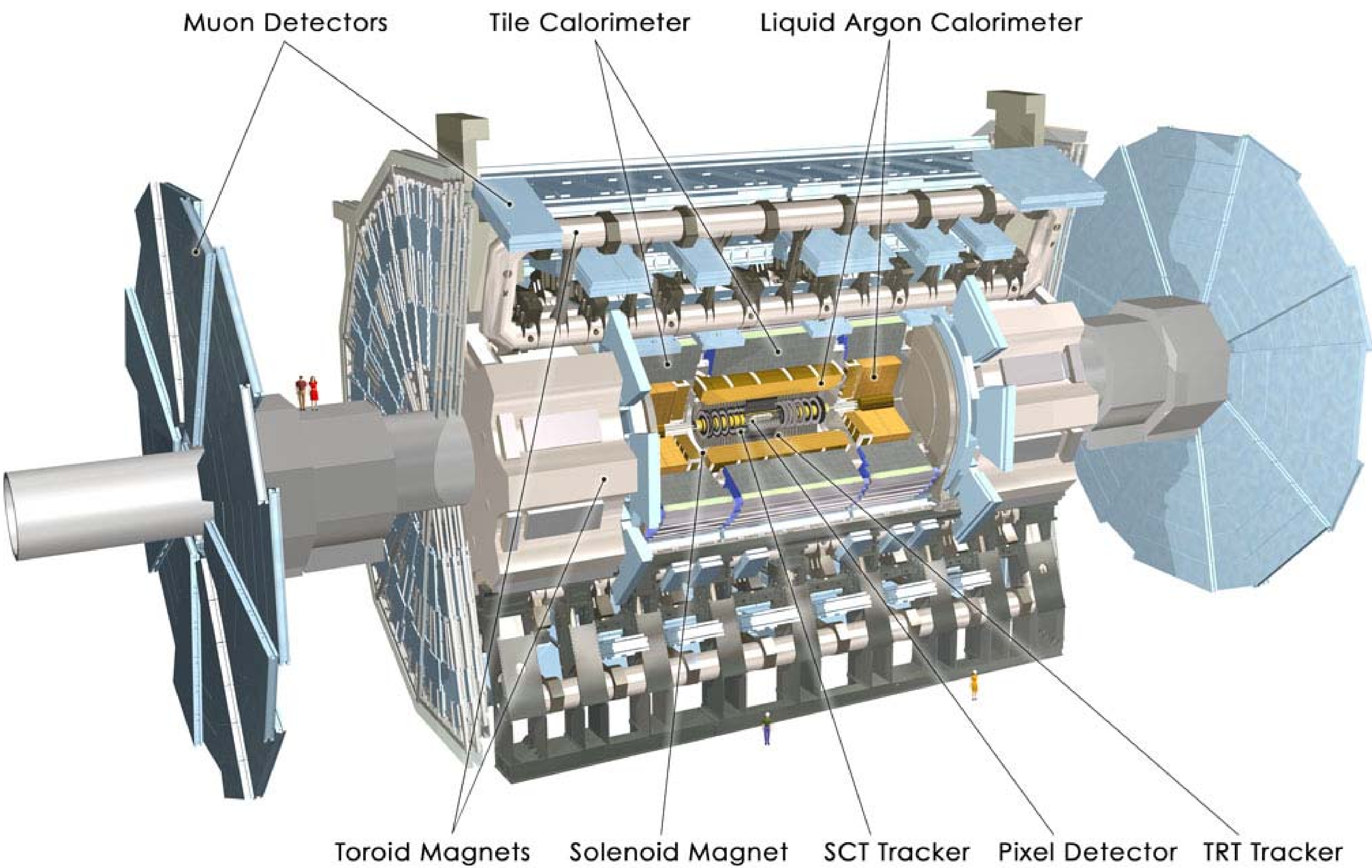
- Study to appear in: ATLAS Collaboration, “Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics”, CERN-OPEN-2008-020, Geneva, 2008
- Refinement of the method: on-going efforts to remove / replace at the detector hits level
- Investigate using events with electrons in the final state (roughly double the statistics available)

Many other uses for similar data-MC hybrid samples

- Minimum-bias (Data) + Single Particle (MC): Identification / Efficiency studies
- Minimum-bias (Data) + Minimum-bias (Data) + …+ Background (MC): Evaluate event selection criteria at high luminosity during the low-luminosity era
- Additional data-driven background control samples for other analyses: e.g., $Z \rightarrow$tau tau

Backup Slides

The ATLAS Experiment



Event Selection Criteria

Only muons were considered in this study:

- One (or two) isolated muons (in the case of two muons require opposite charge)
- Isolation requirement: Sum ET (EM) in cone of 0.2 / muon pT < 0.1
- Muon pT > 6 GeV
- Muon(s) must be central (i.e., $|\eta| < 2.5$)
- Specific to the ATLAS reconstruction software (STACO muons with a 0 < chi2 < 20)