Theory acceptance systematics in neutral (B)SM Higgs tautau searches

Terascale annual workshop (DESY)
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Outline

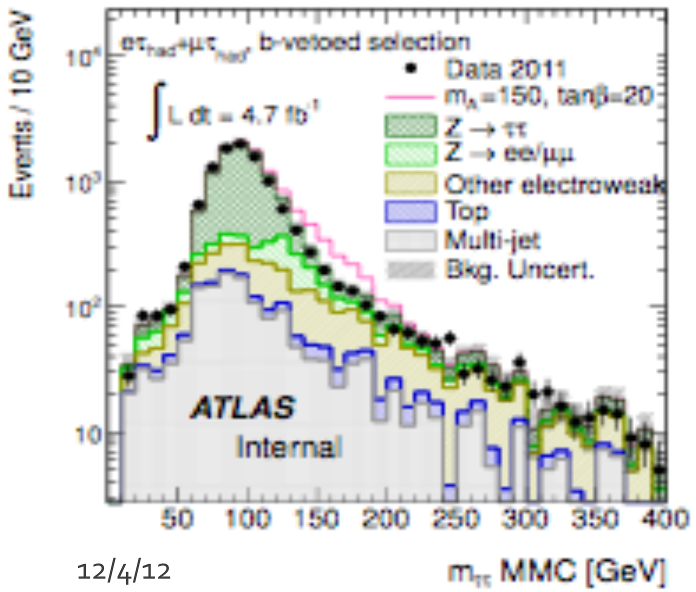
- Recap of 2011 MSSM neutral Higgs analysis
  - h/H/A -> $\tau\tau$
  - h/H/A -> $\mu\mu$
- Plans for 2012 analysis
  - SM H -> $\mu\mu$
  - MSSM h/H/A -> $\tau\tau$

H-> ττ (lh, hh)

- Split into b-tagged/b-veto category
- Mass reconstruction using MMC

Lephad channel

- Single lepton trigger
- 1 isolated lepton
- 1 identified hadronic tau



Hadhad channel

- Pass di-tau trigger
- No leptons
- At least 2 identified taus with p_T > 45 (30) GeV

process	generator
bb h/H/A ->ττ	Sherpa
gg h/H/A -> ττ	PowHeg
W+jets, Z+jets	Alpgen, (Embedding)
Diboson	MC@NLO, Herwig
Top	MC@NLO, AcerMC

Theory acceptance systematics

- Evaluated by changing generator parameters and re-run full production chain (try to change this in 2012)
- Parton shower matching is dominant theory acceptance systematic

	b-tag sample, muon						
	Signal	Embedding $Z\to\tau\tau$	W+jets	$Z\to ll$	$t\bar{t}$	Single Top	Diboson
Cross-section/Normalization	14	5	20	$12\oplus5$	16	13	7
Acceptance	21	14	-	14		2	2
Jet/Tau energy scale	15	1	14	48	12	30	15
b-jet identification	11	-	20	28	12	12	19
Embedding shape		3.6					
E_T^{miss} Pile-up & Cluster	8	-	9	2	3	14	22
Other (apart from Luminosity)	5	4	2	2	5	5	5
Luminosity	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Total Systematic	33	16	33	59	24	38	34

h/H/A -> $\tau\tau\to\mu\tau_{had}$

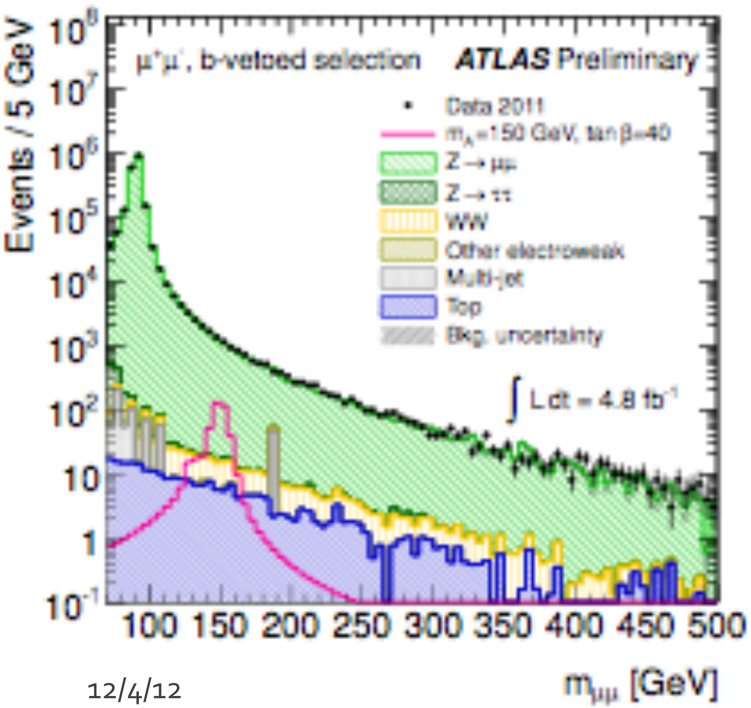
Sources	120 GeV		150 GeV		200 GeV		300 GeV	
	b jet	no b jet	b jet	no b jet	b jet	no b jet	b jet	no b jet
2 Parton	0.6 %	0.0 %	1.2 %	0.5%	2.5%	-0.4%	3.0%	-0.2%
CKKW15	-12.8 %	-9.4 %	-13.0 %	-0.5%	-10.5%	0.8%	-8.8%	1.1%
CKKW30	14.9 %	9.7 %	15.1 %	-0.5%	13.5%	-1.0%	13.0%	-1.7%
FacScale05	-3.0 %	-6.4 %	-4.4 %	-1.2%	-4.0%	0.1%	-2.9%	-0.2%
FacScale20	-9.9 %	-9.8 %	-9.1 %	-0.5%	-6.4%	0.9%	-6.8%	1.0%
RenScale09	2.7 %	2.3 %	-0.5 %	0.1%	1.7%	-0.1%	0.2%	0.0%
RenScale11	0.0 %	2.6 %	-0.7 %	0.0%	0.8%	0.3%	0.0%	-0.1%
UEDown	0.7 %	0.6 %	0.0 %	0.0%	0.0%	0.0%	0.3%	0.0%
UEUp	0.0 %	0.4 %	0.8 %	0.0%	0.0%	0.0%	0.3%	0.0%
MassiveBees	-2.0 %	-3.4 %	-4.5 %	-0.8%	-1.7%	0.4%	-1.3%	-0.1%
PDF	-5.2 %	-1.6 %	-6.4 %	-1.2%	-5.7%	-1.0%	-5.6%	-0.9%
+	15.2 %	10.1 %	15.2 %	0.5%	13.8%	1.3%	13.3%	1.5%
-	-17.1 %	-14.1 %	-17.7 %	-1.5%	-13.7%	-1.5%	-12.5%	-1.9%

h/H/A -> $\tau_{had}\tau_{had}$

h/H/A->μμ

Event selection

- Single muon trigger
- 2 isolated muons with p_T > 20 (15) GeV
- MET < 40 GeV
- Invariant di-muon mass > 70 GeV
- B-tagged/b-vetoed category
- Invariant mass fit



Dominant backgrounds

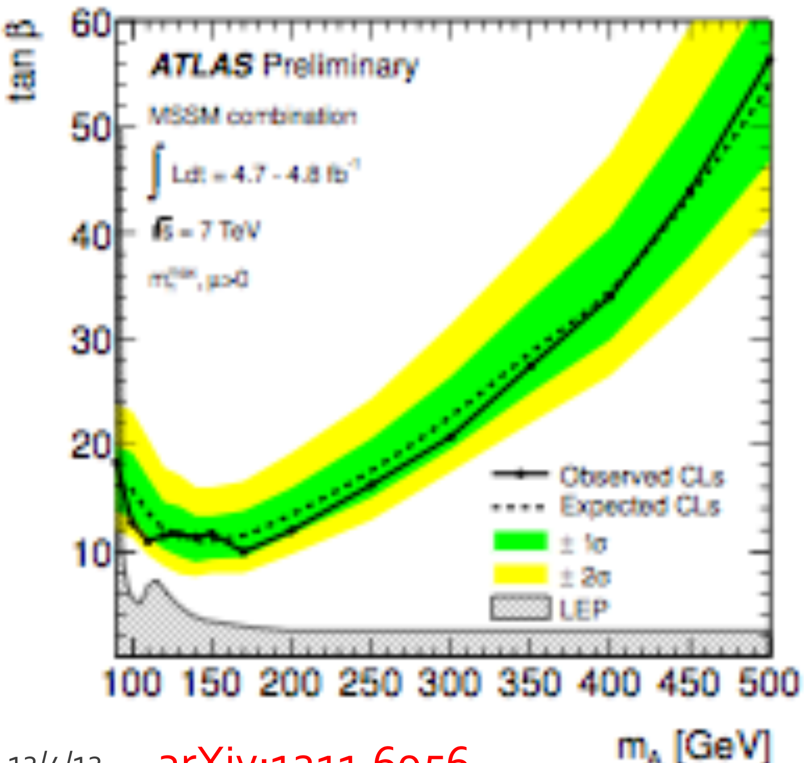
process	generator
Z/γ* ->μμ	Alpgen
Diboson	MC@NLO, Herwig
Top	MC@NLO, AcerMC

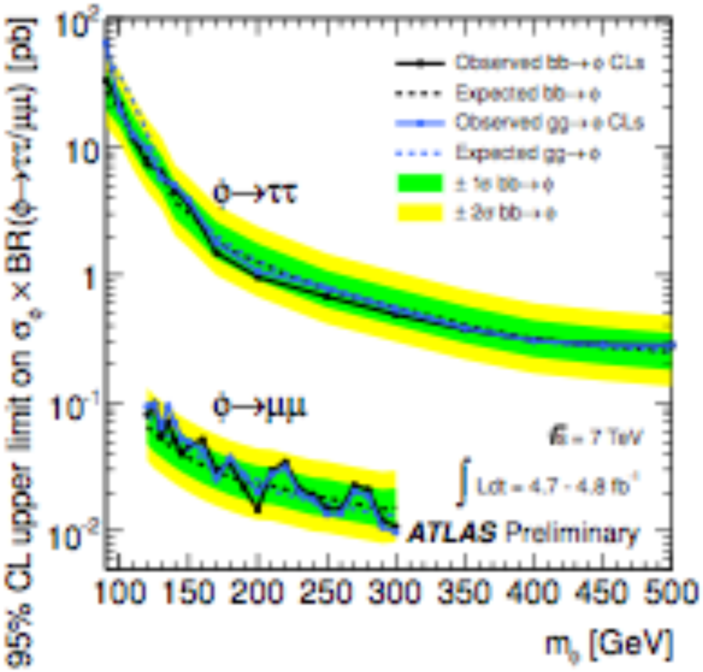
Theory uncertainties

- Studied for Z/γ* ->μμ
- Compared Alpgen to Pythia
- Different pdf sets used by the generators (Alpgen: CTEQ6.11, Pythia: MRST2007LO*)
  - Better modeling of additional jets by Alpgen, while Pythia models central eta region better
- Apply pdf reweighting to Alpgen
- Uncertainty:
  - 3.5% Z+light jets
  - 2.9% Z+b-jets

2011 analysis

- 4.7 fb^{-1} of pp collision data analysed
- Consider both $\tau\tau$ ($e\mu$, $e\tau_{had}$, $\mu\tau_{had}$, $\tau_{had}\tau_{had}$) and $\mu\mu$ final states



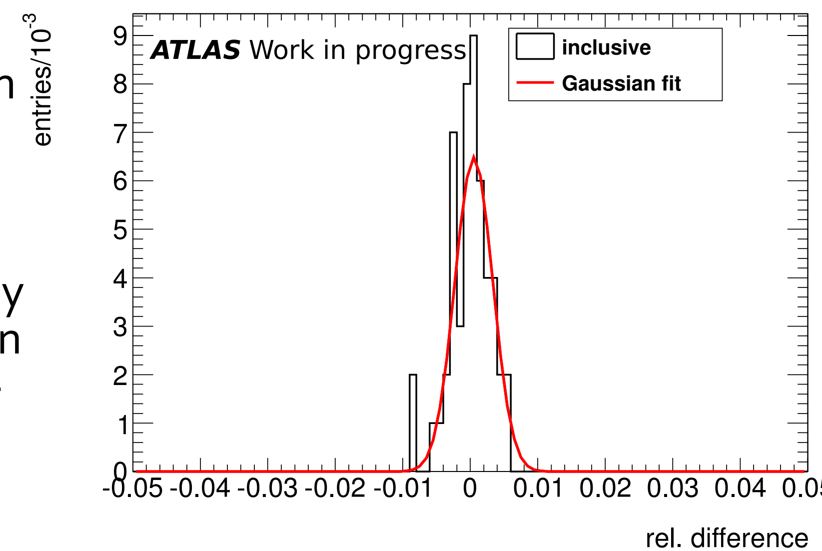


arXiv:1211.6956

SM H->μμ

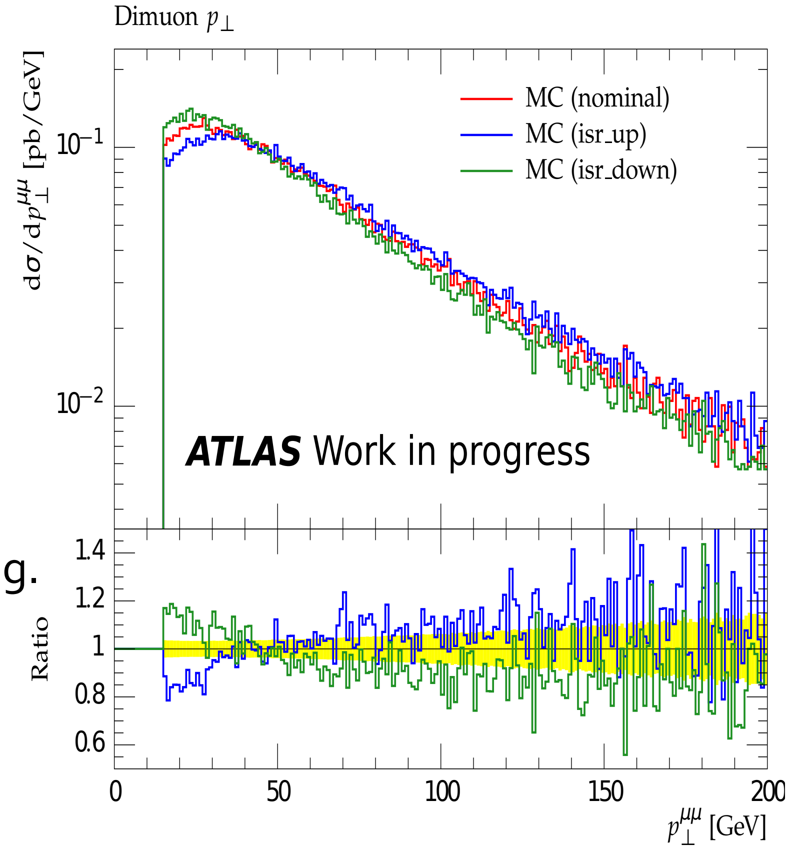
- Signal generated by PowHeg
- Similar analysis will be performed for MSSM h/A/H->μμ, but considering b-associated production using Sherpa generator
- Use RIVET framework to estimate relative difference @ generator level

- PDF uncertainties:
  - Nominal pdf set: CT10
  - Relative difference in event yield between nominal pdf set and each eigenvector variation fitted by Gaussian
  - Take width of Gaussian as uncertainty
  - Results in much smaller (~10x) uncertainty than reported on production cross-section
  - Does this procedure cover systematics or should one change the pdf set itself (e.g. compare to MSTW)
  - Total uncertainty: 0.3% … 0.75%



SM H->μμ

- **ISR/FSR**
  - Several shower evolution models available
    - pT ordering
    - Angular ordering
    - Catani-Seymor dipole factorisation
  - All models tuned to match data
    - Involves many parameters on shower modeling
    - Arbitrarily complex endeavour
  - "guesstimate": change $\alpha_s(M_Z)$ parameter by +- 20%
  - Can have huge effect on event kinematics, e.g. di-muon p_T
  - Leaves isolation unchanged (unexpected)
  - Total uncertainty: ~-2.8 %.. 1.6%



- Matrix element (ME) parton shower (PS) matching
  - Is there any theoretically motivated way to match NLO ME to LO PS, like CKKW, MLM do?

h/H/A->$\tau\tau$

- Using RIVET framework to evaluate acceptance systematics @ generator level
  - Hadronic tau final state much more sensitive to shower modeling which cannot be emulated at generator level
  - Need full simulation to prove RIVET results are reliable
  - Advantages:
    - Much less expensive in terms of CPU time
    - One is able to generate much higher statistics and more systematics (e.g. PDF variation)
- Strategy in lephad and hadhad final state very similar, but different categorisation

h/H/A->$\tau_{lep}\tau_{had}$

- Consider b-tagged/b-vetoed category for electron and muon channel separately
- Signal generators:
  - gg fusion: PowHeg
  - b-associated production: Sherpa
  - Dominant backgrounds:
    - W+jets: Alpgen
    - Top: MC@NLO/AcerMC
  - Need to evaluate acceptance systematics on each of them (RIVET analysis heavily preferred if reliable results can be obtained)

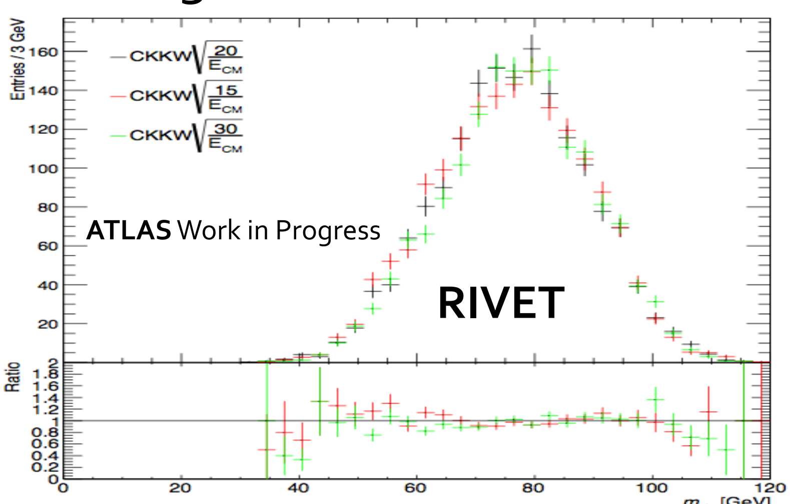
Parton shower matching

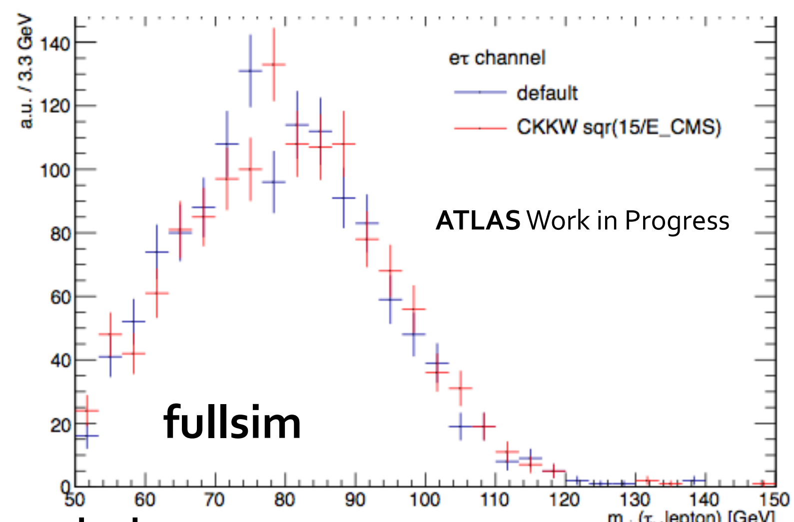
- Dominant acceptance systematic in 2011
- Change CKKW parameter to 0.5/2 x nominal
- Evaluated for M_A=120 GeV using Sherpa bb h/H/A samples

Channel	CKKW up/down RIVET	CKKW down fullsim
Electron	-2.5%/ 0.14%	0.45%
Muon	-2.3%/-3.7%	-1.9%
combined	-2.4%/-2.2%	-1.0%

Event yields	b-tag deviation [%]	b-veto deviation [%]
Default	0 ± 3.3	0 ± 0.9
CKKW down	-14.6 ± 3.2	1.1 ± 0.9
CKKW up	12.1 ± 3.4	-1.3 ± 0.9
Fac. scale up	-11.8 ± 3.2	0.6 ± 0.9
Fac. scale down	-3.2 ± 3.3	0.6 ± 0.9
Massive b-quarks	-2.8 ± 3.3	0.1 ± 0.9
PDF	-8.2 ± 3.3	-0.8 ± 0.9
Ren. scale down	0.4 ± 3.3	-0.1 ± 0.9
Ren. scale up	-2.6 ± 3.3	0.4 ± 0.9
Total (up)	12.1	1.4
Total (down)	−21.1	−1.5

- But huge statistical errors (~100%)



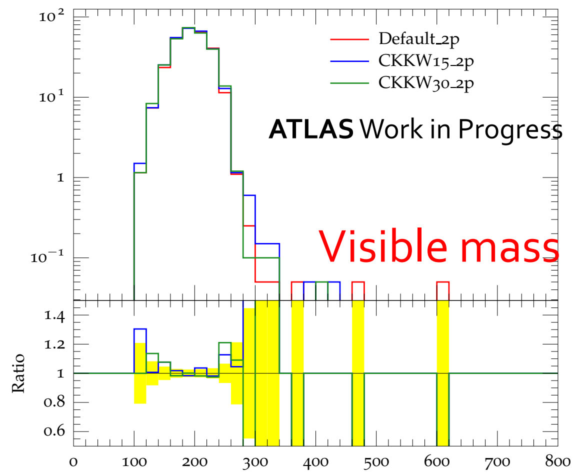


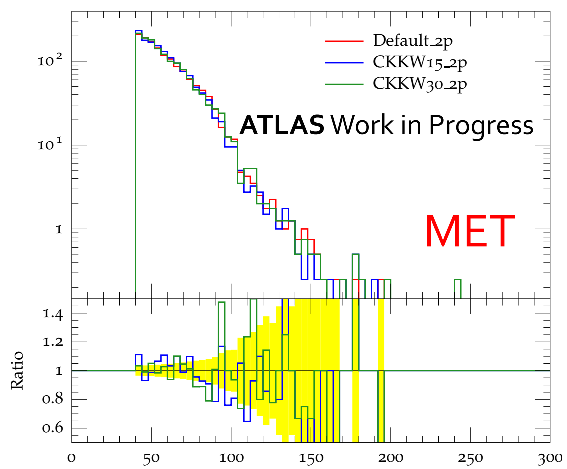
- No conclusion so far -> need more stats

h/H/A->$\tau_{had}\tau_{had}$

- Follow closely lephad theory acceptance estimation strategy
- Use same MC generators
- Currently no b-tag categorisation
- Focus on high mass (dominated by b-associated Higgs production)

- Measure uncertainty for parton shower matching by varying CKKW parameter by factor 0.5/2
- Consider bb h/H/A (M_A = 300 GeV, tanβ=20) Sherpa sample





2% CKKW down

0.8% CKKW up

Comparable to 2011 no b-tag systematics

- Complex mass reconstruction algorithms (MMC) cannot be rebuild at generator level
- Need to monitor shape effects on visible mass and MET to measure if absolute uncertainty is feasible
- Can only measure truth MET (no fake MET due to detector effects)

h/A/H->ττ (common)

- PDF uncertainties:
  - Follow H->μμ strategy by evaluating each eigenvector variation in case RIVET can be used
    - Not an option for full simulation analysis
  - If one needs to switch to full simulation estimate uncertainty by varying pdf set
    - Is there any recommended pdf set which should be used to compare with? (MSTW, HERA pdf, others?)
  - Using different pdf set requires to adapt UE tune
    - convoluted pdf + UE systematic
  - UE event tune can be varied within its uncertainties, but effect is expected to be negligible

h/A/H->$\tau\tau$ (common)

- ISR/FSR uncertainties:
  - Does one need to consider them correlated or uncorrelated (may be generator dependent)?
    - Uncorrelated should be the correct way to do
- μ_F, μ_R
  - Threated fully correlated
  - Scaling up/down by factor 2

Summary

- Theory acceptance systematics is evaluated by varying generator configuration parameters
- They are rather small in H->$\mu\mu$ (~few %)
- But can have rather large impact in $\tau\tau$ final states
- Estimation in $\tau\tau$ final states requires cross check with full simulation as these analyses depends strongly on the modeling of the shower profile

Discussion