Tau+MET Trigger Efficiencies in H+-> τ+jets Analysis with ATLAS

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Outline

- Motivation
- Overview of the analysis
- Trigger measurement
- Results of the publication
- Conclusions

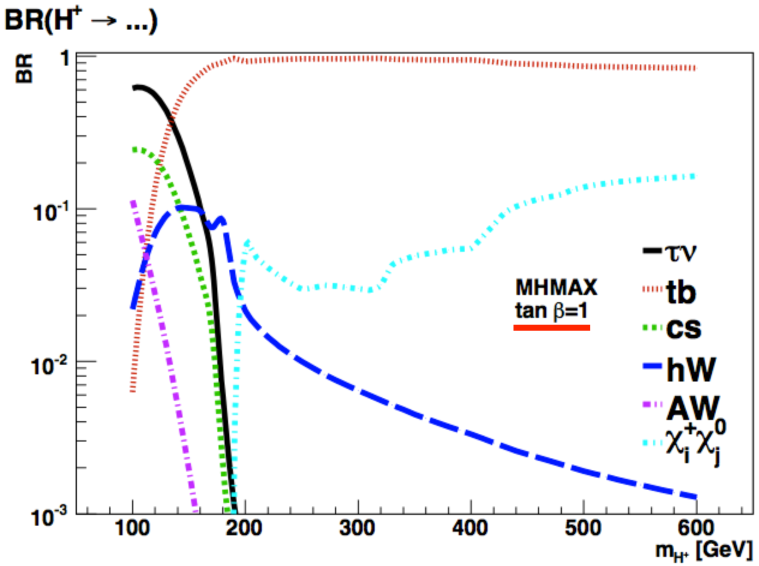
Analysis motivation/Overview

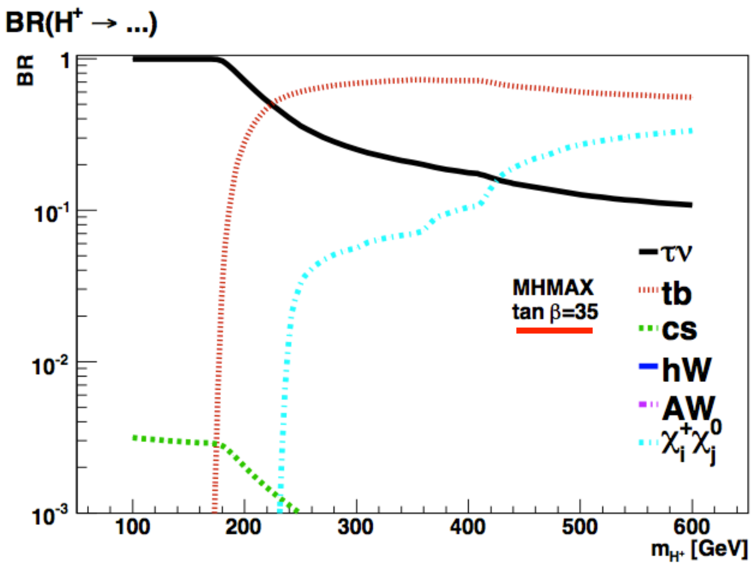
- Many BSM scenarios, Supersymmetry among others, include one additional scalar doublet leading to five physical states: 2 charged ($H^{+/-}$), 2 neutral (h^0,H^0) + 1 pseudoscalar.
- The branching ratios of the $H^{+/-}$ decay depend on the parameters of the model (below for MHMAX model which maximizes corrections at tree level value of m_{h0}, arXiv:hep-ph/0202167 (M.S. Carena et al.))

MHMAX parameters

$$m_t = 174.3 \text{ GeV}, \quad M_{SUSY} = 1 \text{ TeV}, \quad \mu = 200 \text{ GeV}, \quad M_2 = 200 \text{ GeV},$$
$$X_t^{\rm OS} = 2\, M_{SUSY} \text{ (FD calculation)}, \quad X_t^{\overline{\rm MS}} = \sqrt{6}\, M_{SUSY} \text{ (RG calculation)}$$
$$A_b = A_t, \quad m_{\tilde{g}} = 0.8\, M_{SUSY} \; .$$

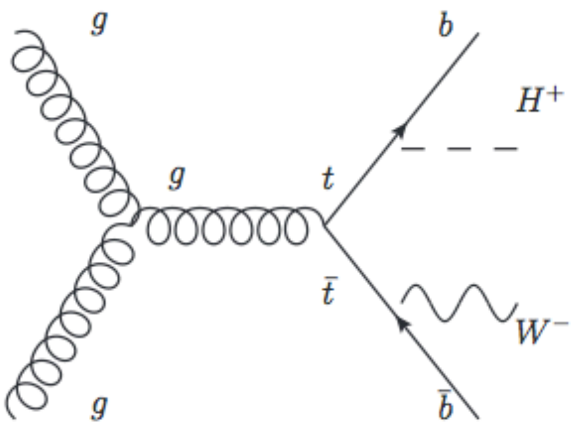
- We concentrate on the decay $H^{\pm} \to \tau\nu$, relevant in a large parameter range, specially for low mass H^+ (below top decay threshold), as can be seen below for MHMAX scenario of the MSSM.



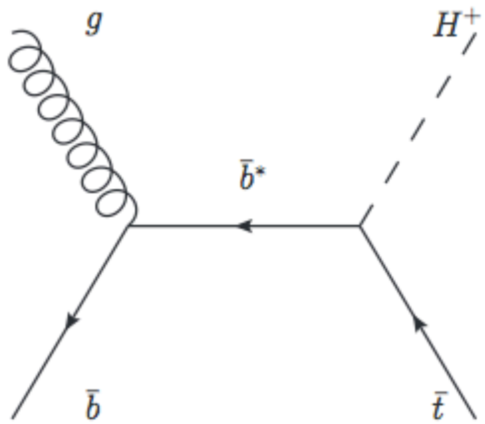


$\tan\beta$ = ratio of vacuum expectation values of the two Higgs doublets

Feynman diagrams for H+ production in the MSSM



Low H+ mass



High H+ mass

- Leading-order Feynman diagrams for the production of charged Higgs bosons at mass below (left) and above (right) the top quark mass.

Analysis overview

- The channels included in this search are:

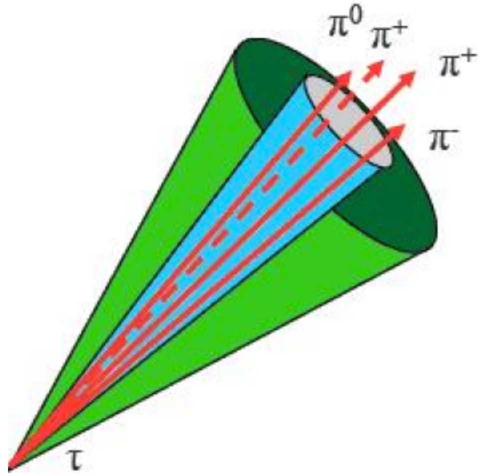
$m_{H+} < m_t$ $t\bar{t} \to [H^+b]\,[W^-\bar{b}] \to [(\tau^+_{\text{had-vis}} + \nu_\tau)b]\,[q\bar{q}\bar{b}]$

$m_{H+} > m_t$ $g\bar{b} \to [\bar{t}]\,[H^+] \to [q\bar{q}\bar{b}]\,[\tau^+_{\text{had-vis}} + \nu_\tau]$

$gg \to [\bar{t}b]\,[H^+] \to [(q\bar{q}\bar{b})b]\,[\tau^+_{\text{had-vis}} + \nu_\tau]$

One or two b-quarks in the final state.

- Experimental signatures:
  - 1 or 2 b-jets (identified with inner detector and calorimeters)
  - 3 – 4 jets coming from quarks
  - 1 τ-particle, reconstructed as a collimated jet of particles with very low charged hadron multiplicity (1 π or 3 π). Branching ratio for hadronic tau decays is 64.80%.
  - Neutrinos are detected as an imbalance of energy in the detector.



Event selection

- τ + E_T^{miss} trigger (IFAE contribution, described later)
- exactly one τ with p_T > 40 GeV
- at least 3 (4) jets for heavy (light) H^+ with p_T > 25 GeV
- no electron or muon with p_T above 25 GeV

- E_T^{miss} > 80 (65) GeV for heavy (light) H^+
- $\frac{E_T^{miss}}{0.5 \cdot \sqrt{\sum p_T^{PV\ trk}}}$ > 12 (13) $GeV^{1/2}$ for heavy (light) H^+ (MET Significance).
- at least one b-tagged jet

Composition of this sample

- Discriminating variable:

$$m_{\mathrm{T}} = \sqrt{2p_{\mathrm{T}}^{\tau}E_{\mathrm{T}}^{\mathrm{miss}}(1-\cos\Delta\phi_{\tau_{\mathrm{had-vis}},\mathrm{miss}})}$$

is related to transverse mass of W boson for background events (with W->τν), and H^+ boson for signal events.

- Definition m_T in hadron colliders:

$$M_T^2 = (E_{T,1}+E_{T,2})^2 - (\vec{p}_{T,1}+\vec{p}_{T,2})^2$$

with $$E_T^2 = m^2 + (\vec{p}_T)^2$$

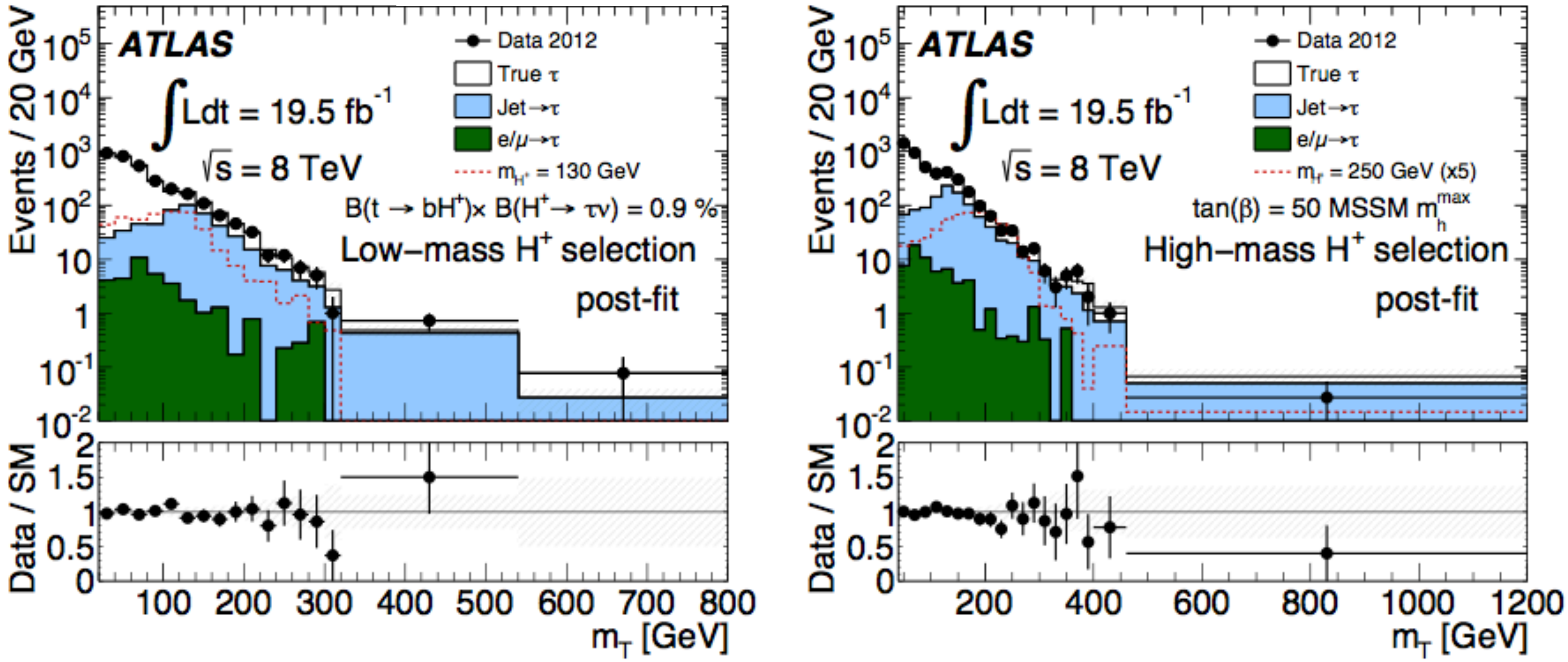
- If $m_1=m_2=0$:

$$M_T^2 \to 2E_{T,1}E_{T,2}\,(1-\cos\phi)$$

- Tevatron used that $M_T \leq M$.

Low H+ mass

High H+ mass



Determine true τ background (data-driven)

– An embedding method is used to estimate this background.

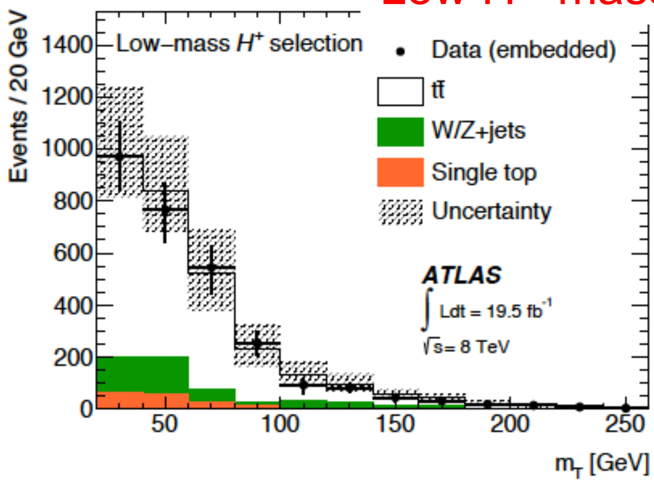
– A sample of μ+jets events is selected.

- Muon trigger (threshold 24 or 36 GeV)
- 1 muon with pT > 25 GeV
- 0 electrons
- At least 4 (3) jets for low (high) mass.
- MET > 25 (40) for low (high) mass.

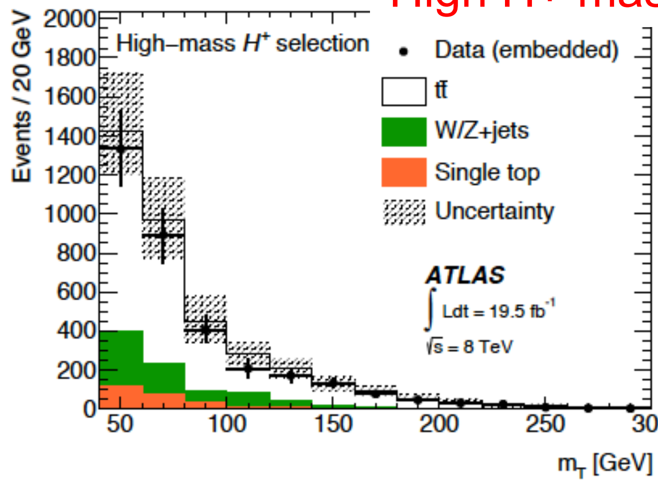
– The muon is replaced by a hadronic tau.

– Underlying event, pile-up and all sources of missing E_T except for the neutrino from the τ decay are correctely included.

Low H+ mass



High H+ mass



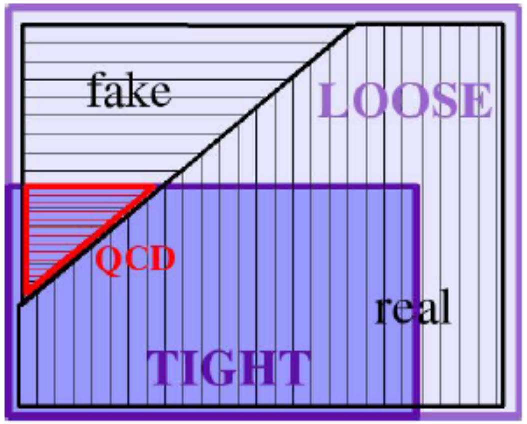
- Comparison of m_T distributions for events with a a true τ for (a) low-mass and (b) high-mass charged Higgs sarch, as predicted by the data-driven method (embedding) and the simulation.

Determine jet-> τ fake (data-driven)

- Matrix Method used already in previous analysis.

Basic principle:

- Select two regions in the event space defined by “tight” and “loose” requirements on the objects, and evaluate from the measured “real” and “fake” events the QCD



$$\begin{cases} N_r & = \text{\# events with real leptons} \\ N_f & = \text{\# events with fake leptons} \end{cases} \quad (1)$$

$$\begin{cases} N^L & = N_f^L + N_r^L \\ N^T & = N_f^T + N_r^T = \epsilon_f N_f^L + \epsilon_r N_r^L \end{cases} \quad (2)$$

Where

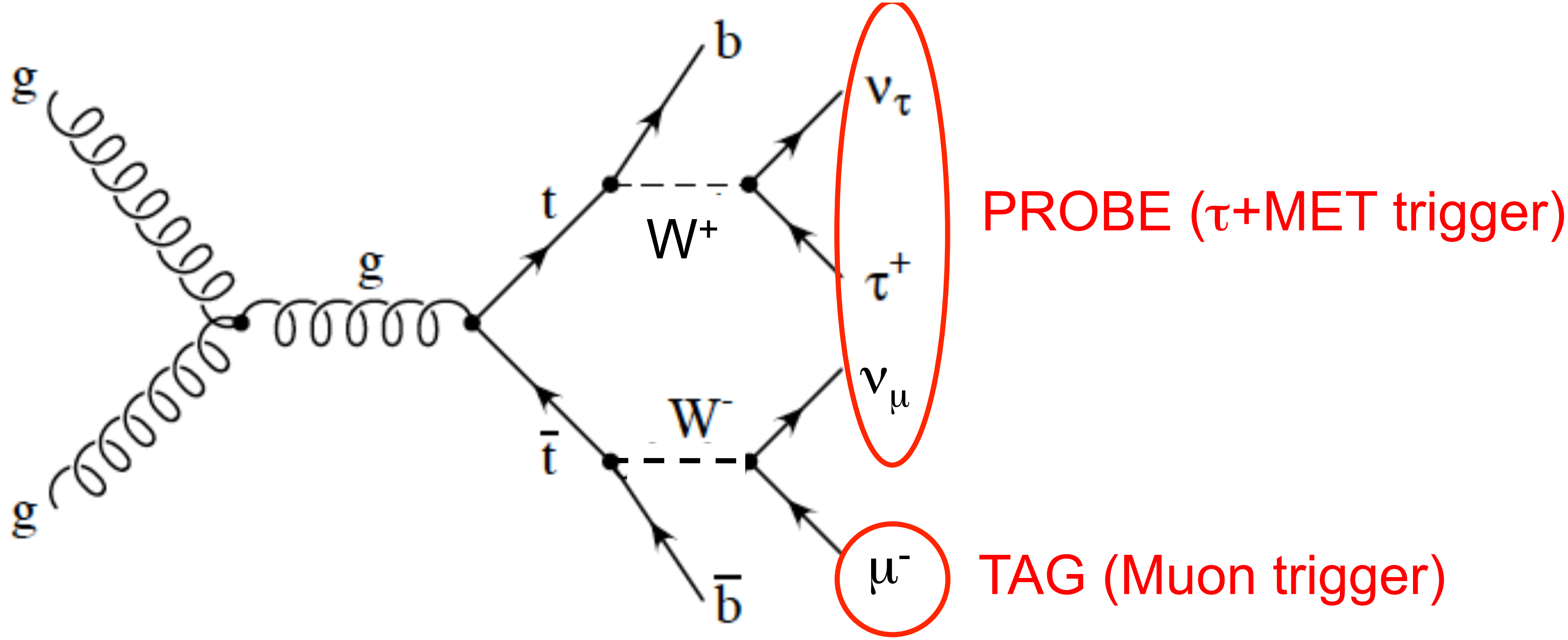
$$N_f^T = \epsilon_f \frac{\epsilon_r N_L - N_T}{\epsilon_r - \epsilon_f}$$

is our estimation of the QCD contamination in the signal region

- ε_r (ε_f): efficiencies for real (fake) loose τ leptons satisfying the tight criteria.
- ε_r from MC, ε_f measured in W+jets control sample.

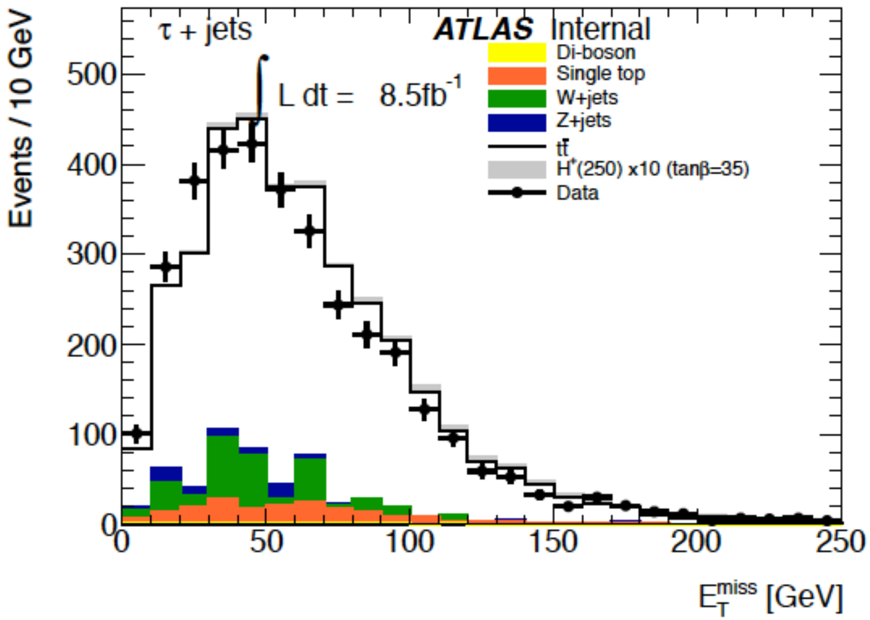
tau+MET trigger efficiencies

- Method for measurement: tag-and-probe in ttbar -> $\tau\ \mu\ \nu_\tau\ \nu_\mu$ + jets events
- tag: muon trigger
- probe: τ+MET trigger



Selection for trigger measurement (mutau selection)

- select ttbar -> $\tau\ \mu\ \nu_\tau\ \nu_\mu$ + jets events with the following requirements
  - Muon trigger
  - at least 2 jets
  - exactly 1 τ with p_T > 20 GeV
  - exactly 1 muon with p_T > 25 GeV
  - at least one b-tagged jet

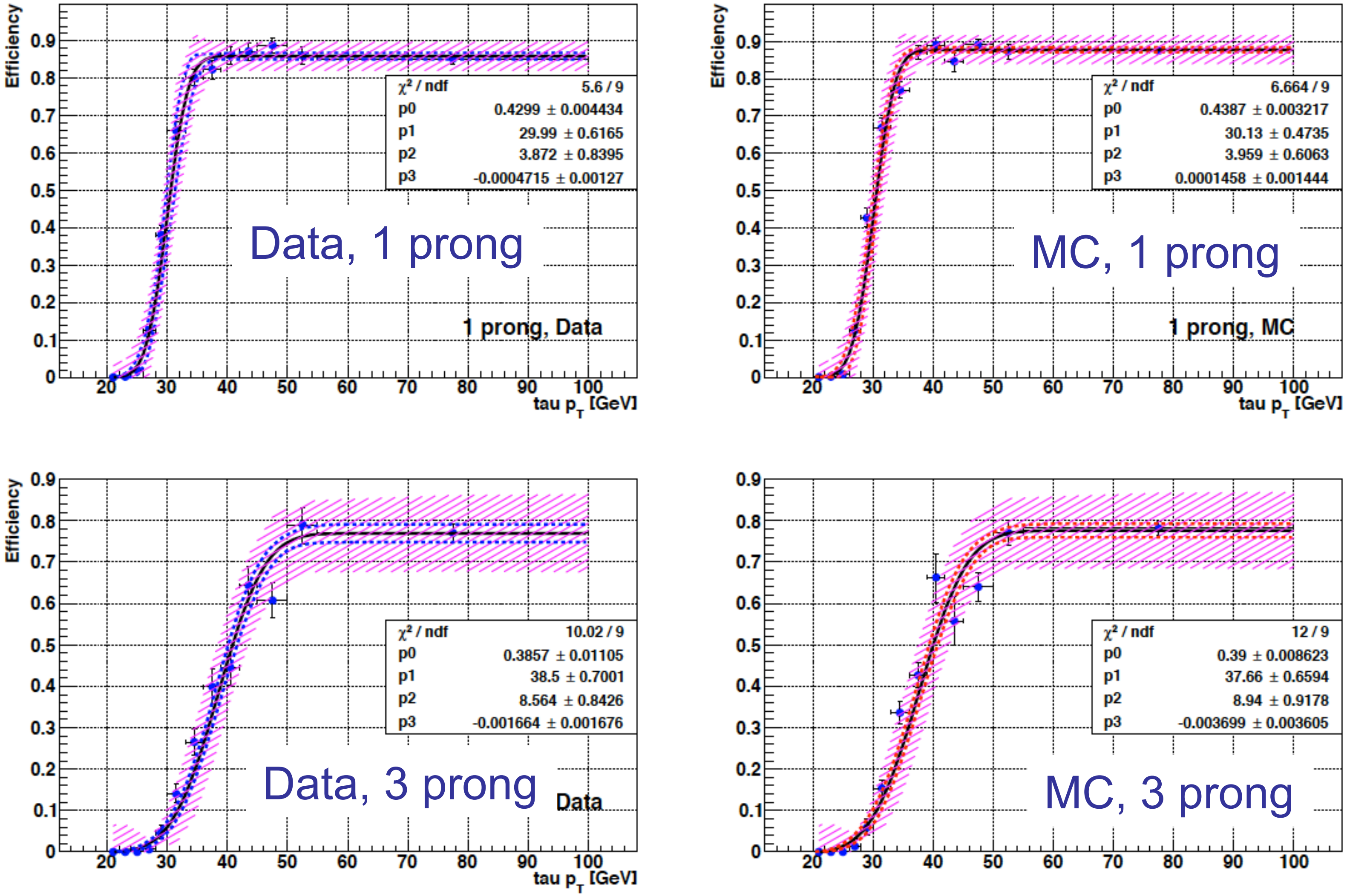


- MET distribution for mutau sample after mutau selection for a sample of 2012 data.
- The sample is dominated by ttbar.

- We measure in the following
  eff(τ+MET) = eff(τ) x eff(MET)

Trigger efficiency curves for τ trigger inclusive

- Select previous type of events with muons

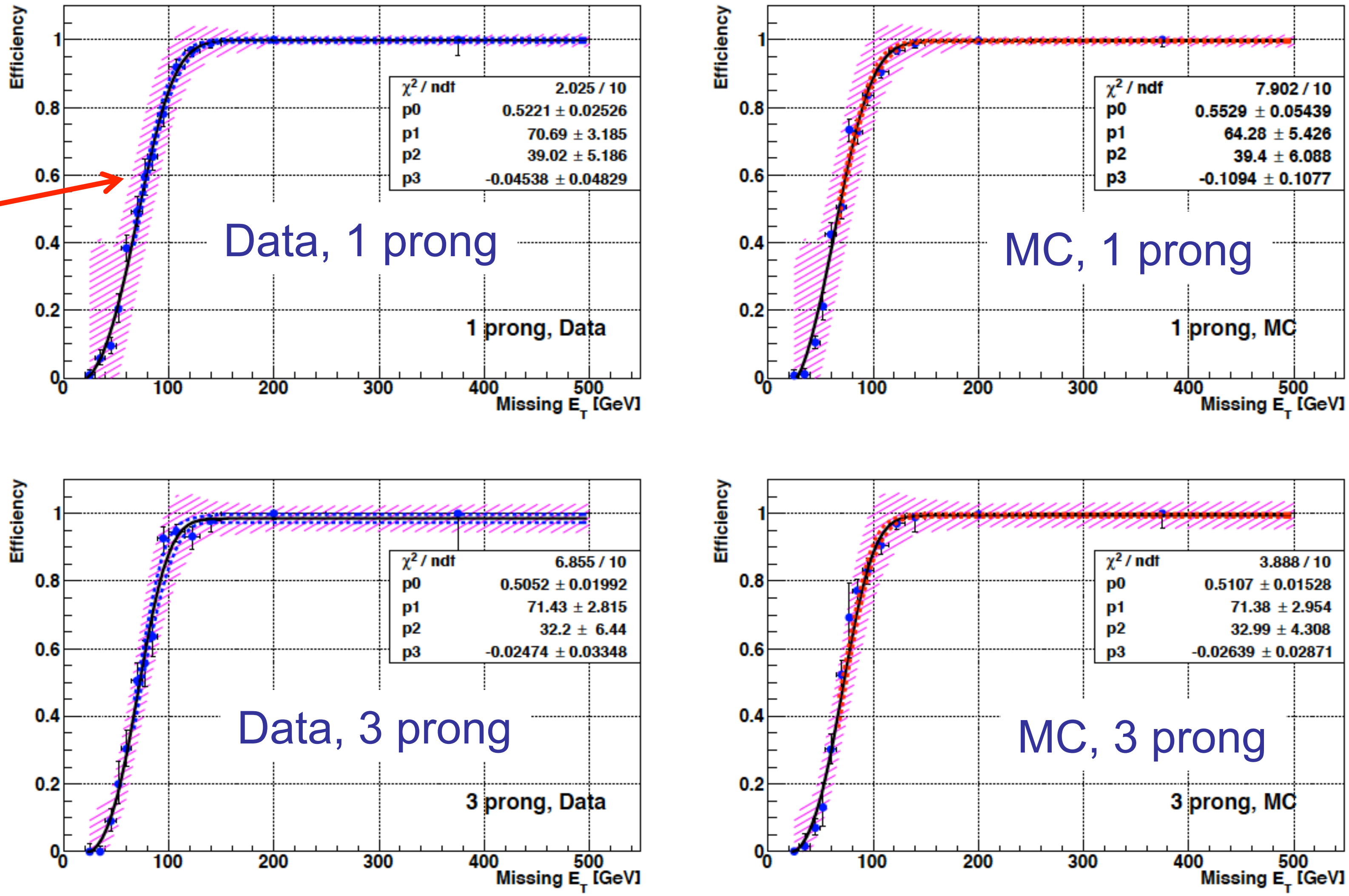


fits with function: $f(x) = C_0 * \left[1 + erf\left(\frac{x - C_1}{C_2}\right)\right] + C_3$, with $erf(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt.$

Trigger efficiency curves for MET trigger inclusive

- Select previous type of events with muons

Resolution effect, depends on hadronic activity of the event.



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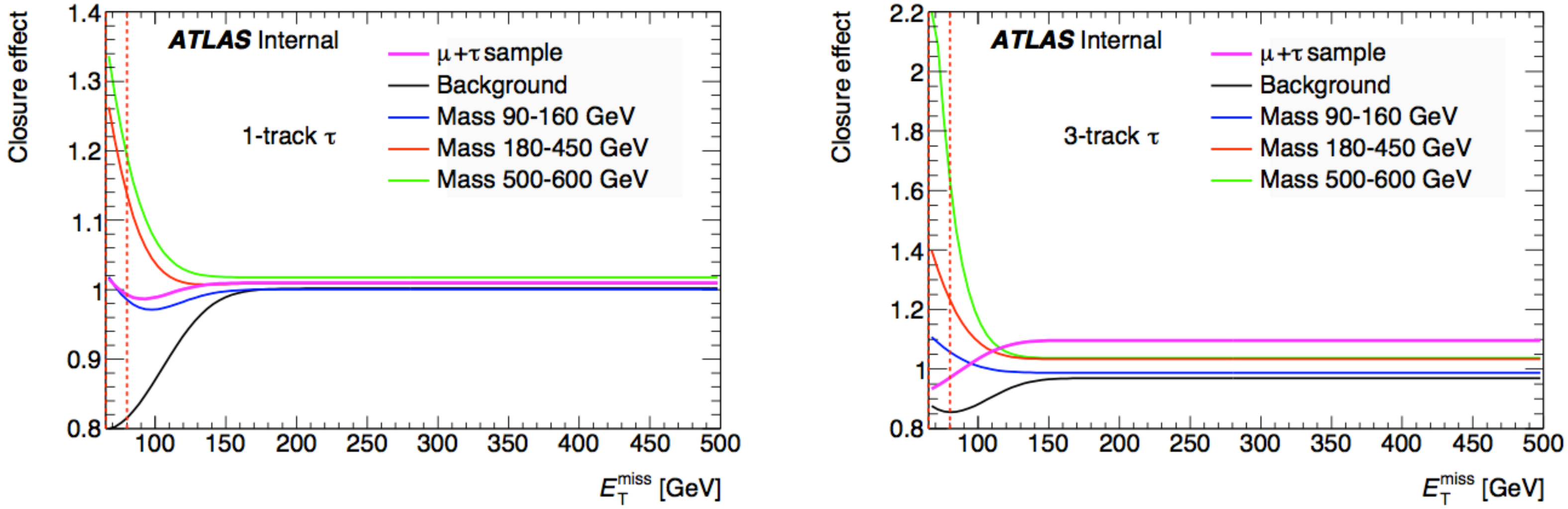
Systematics

- We perform a detailed evaluation.
- Most important: "correlation" systematic (~7-8%) and fake τ's (4-11%) – fake fraction in signal and control sample are quite different and have taken conservative estimate.
- The figure at the bottom shows the plots used to estimate the "correlation" systematic, the ratio of efficiencies obtained from the τ+MET trigger bit over the efficiencies obtained with the product of efficiencies. Before doing the ratio the τ p_T dependence is integrated.



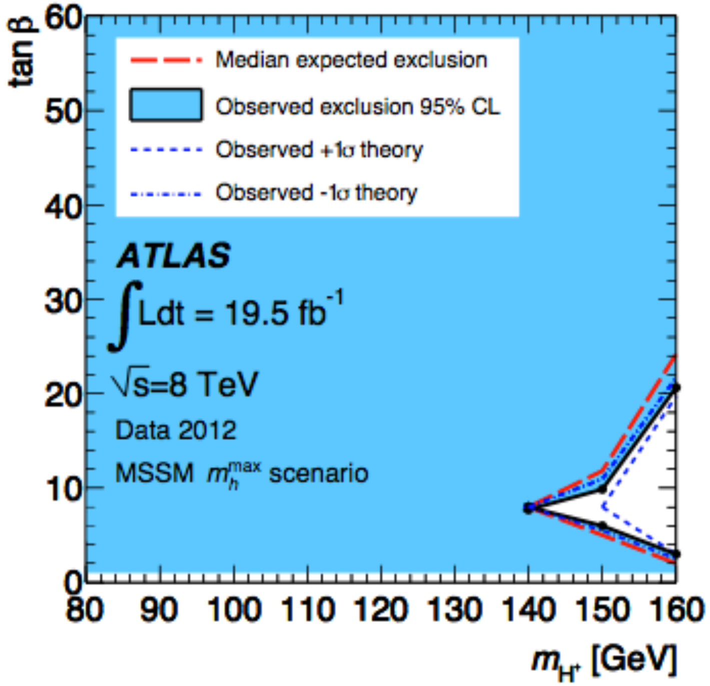
Main effect in MET

- slow turn-on due to poor resolution
- resolution depends on hadronic activity in the event and fraction of true MET from ν. This is different for different samples.

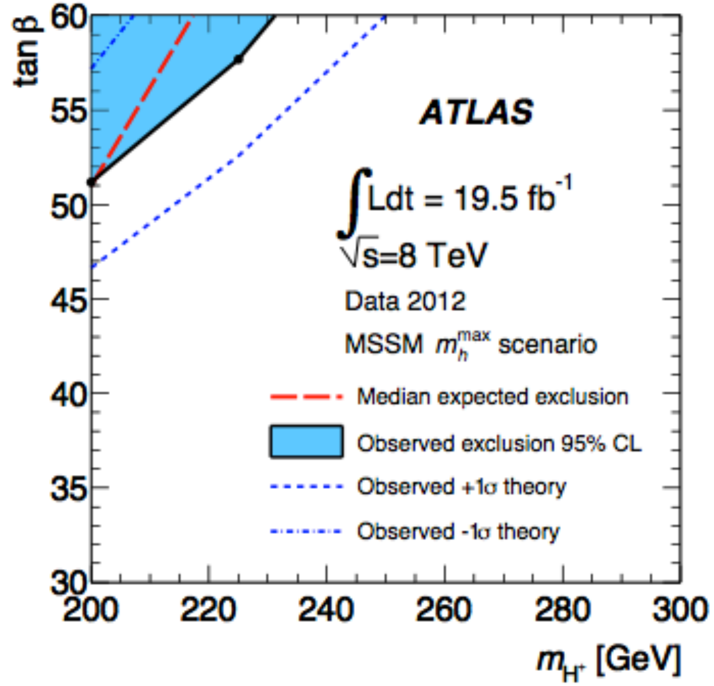
Results from Run-1 8 TeV data (1)

- Published in JHEP. "Search for charged Higgs boson decaying via $H^{+/-} \rightarrow \tau^{+/-} \nu$ in fully hadronic final states using pp collision data at $\sqrt{s}$ = 8 TeV with the ATLAS detector", JHEP03 (2015) 088.

Low H+ mass



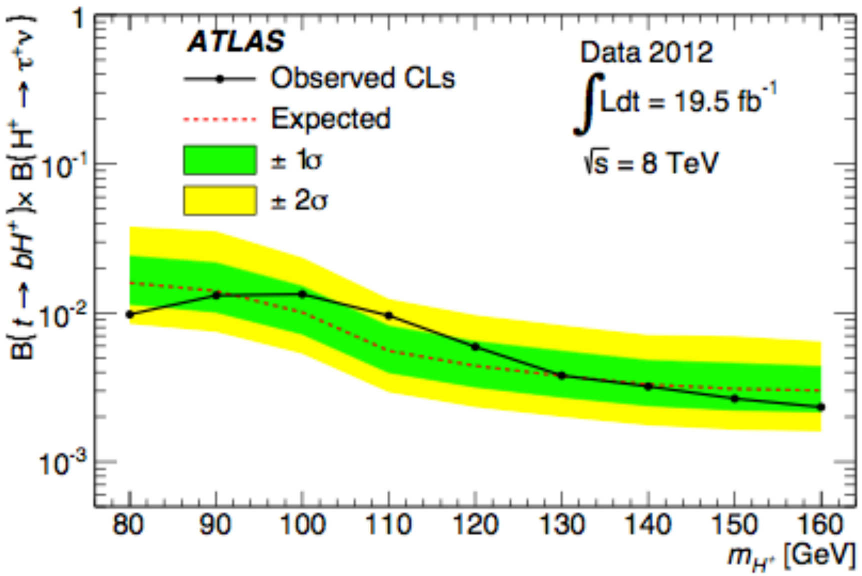
High H+ mass



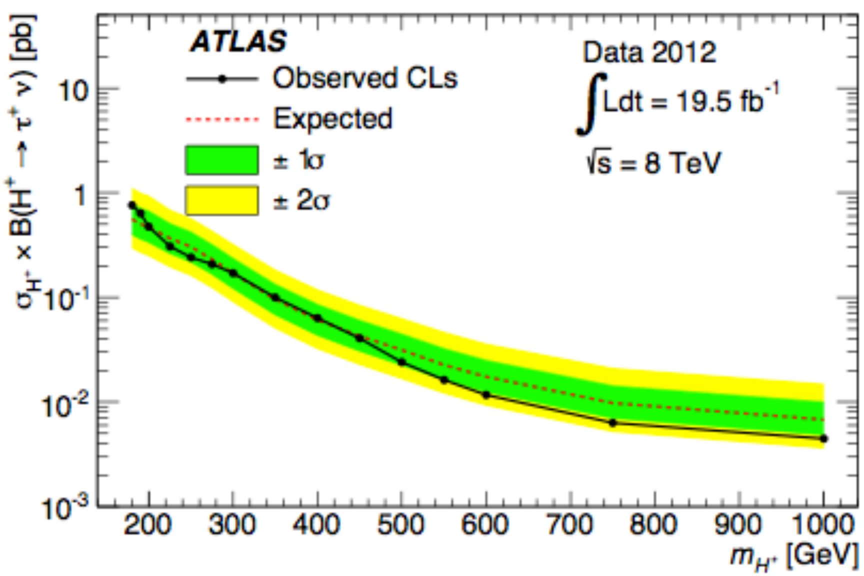
- 95% exclusion limits on $\tan\beta$ as a function of the m_{H+}, for the m_h^{max} scenario.
- Low mass: whole exclusion is reached.
- High mass: little sensitivity so far, only at high $\tan\beta$ $Br(H+ \rightarrow \tau\nu)$ is large.

Results from Run-1 8 TeV data (2)

Low H+ mass



High H+ mass

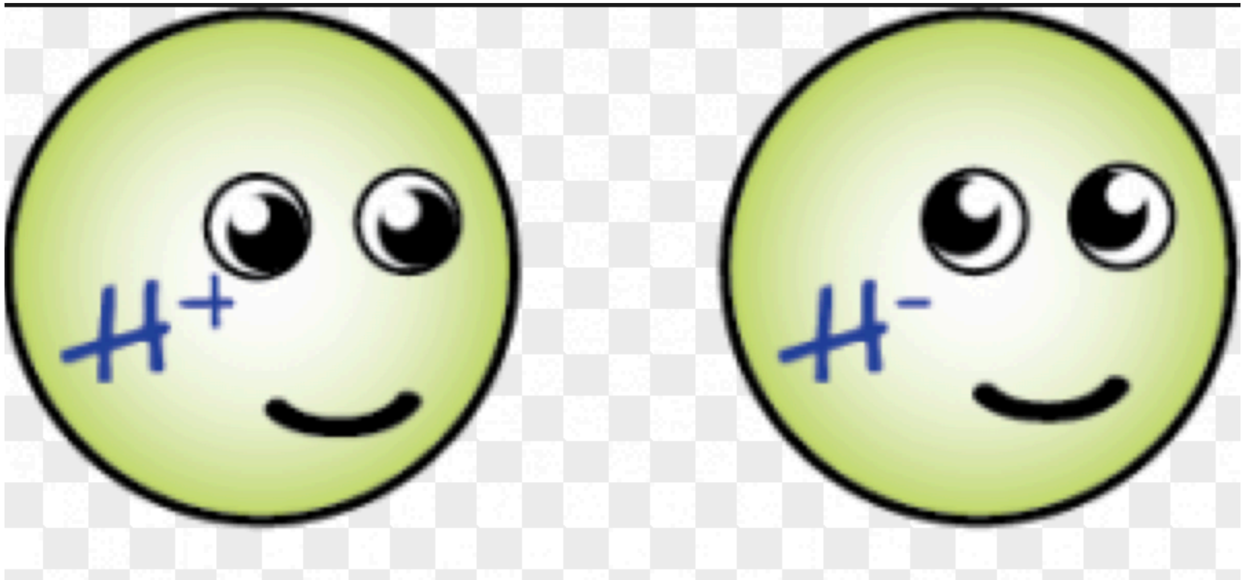


- Observed and expected 95% CL exclusion limits on the production and decay of (left) low-mass and (right) high-mass Higgs boson. The limits are computed for $\mathcal{B}(t \to bH^+) \times \mathcal{B}(H^+ \to \tau^+\nu)$ (left) and $\sigma(pp \to \bar{t}H^+ + X) \times \mathcal{B}(H^+ \to \tau^+\nu)$ (right).

Conclusion

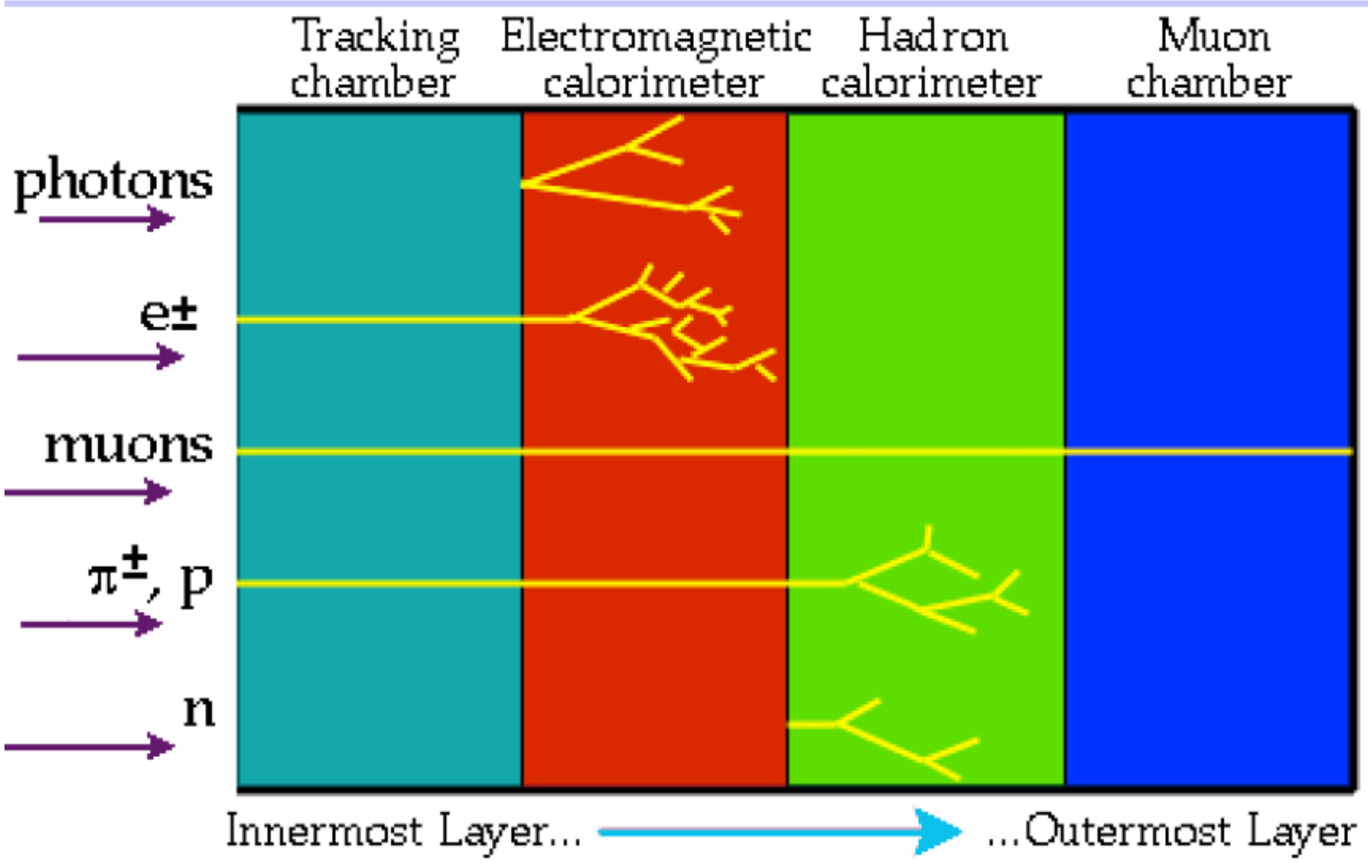
- Have performed a measurement of the τ+MET trigger efficiencies for the H+-> τ + jets analysis (2012 data).
- Main characteristics of the analysis:
  - obtain trigger efficiency of the “double trigger object” from the product of individual inclusive trigger efficiencies taking residual correlations as a systematic
  - individual efficiencies fitted with analytical functions
  - measured separately for 1 and 3 prong
- The method has served as a reference in combined trigger measurements for Run 2.
- Next focus to heavier H^+, in which the largest Br. fraction is H+->tb. Final state tt b(b), similar to ttH(bb) performed in the group.

Thank you

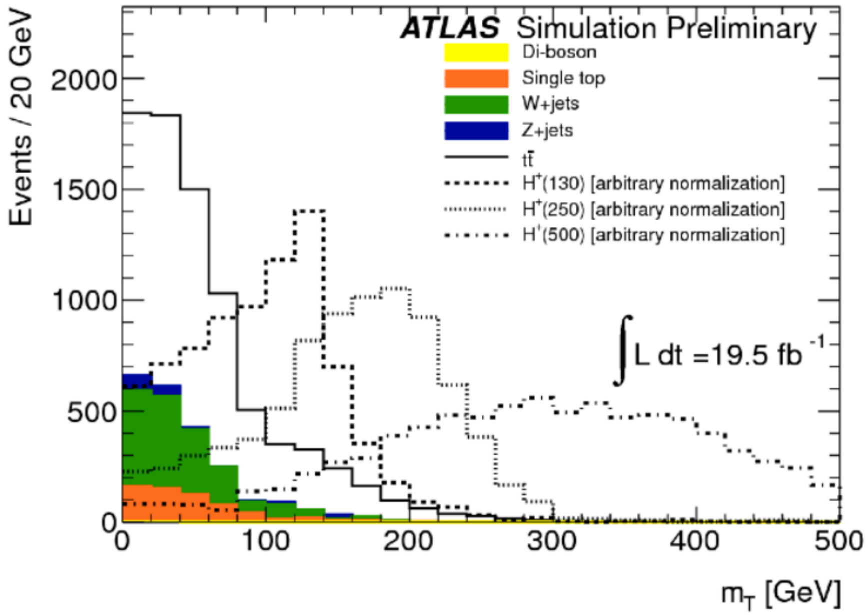


Backup

Particles in the detector



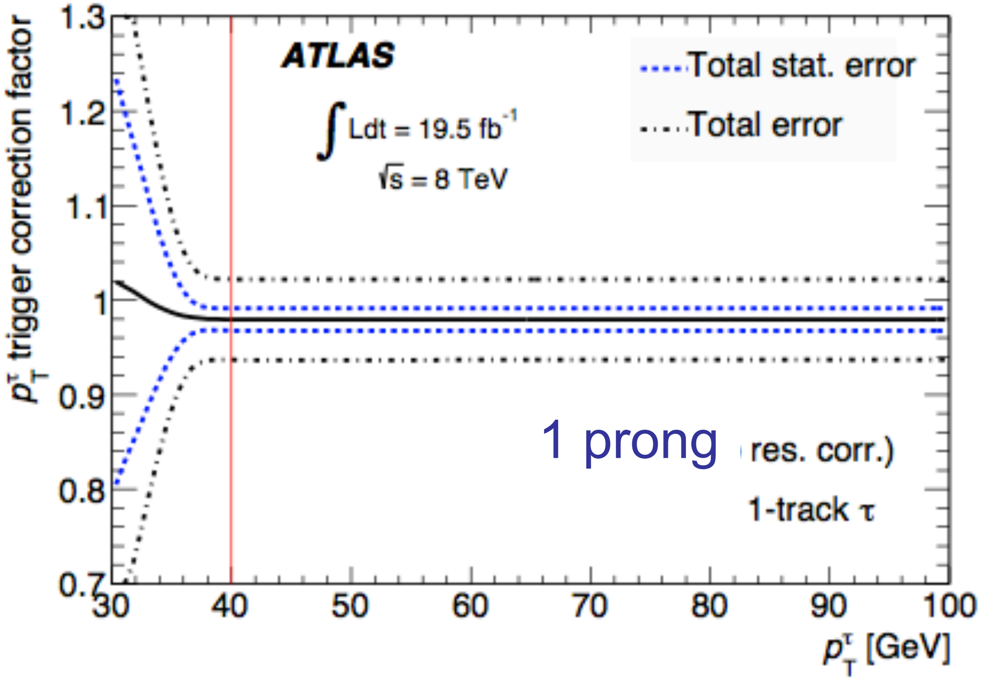
How a possible signal would show

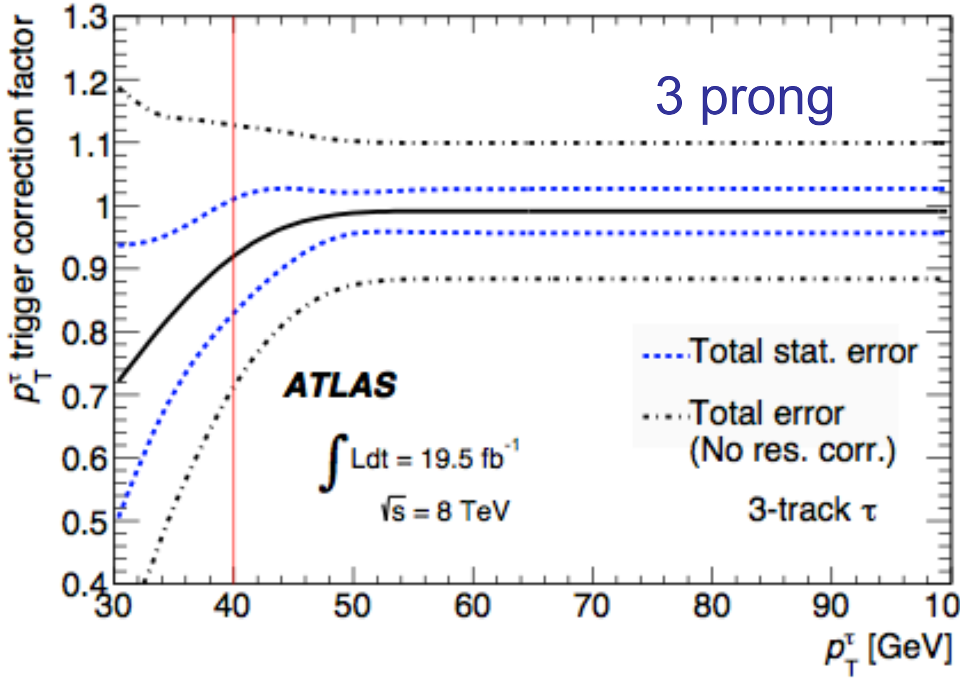


- m_T distributions for SM Monte Carlos and for possible different H+ mass signals.

Tau trigger SFs

- On bottom τ trigger scale factors obtained with the ratio of the fitted functions from the efficiency curves.
- The vertical red line indicates the lowest τ p_T threshold used in the baseline analysis.
- The total statistical uncertainty is indicated with the blue dotted line and sum in quadrature of the statistical and systematic uncertainties is presented with the black dotted line.
- The τ SFs in the 1p/3p samples are compatible with 1 within stat. errors.





MET trigger SFs

- On bottom MET trigger scale factors obtained with the ratio of the fitted functions from the efficiency curves.
- The vertical red line indicates the MET threshold used in the high H^+ search.
- The total statistical uncertainty is indicated with the blue dotted line and sum in quadrature of the statistical and systematic uncertainties is presented with the black dotted line. The main systematic in the MET trigger SF is not included in this plot (slide 17).
- MET SFs compatible with 1 within stat. errors above 100 GeV.