Tau efficiency systematics in the Z → tautau measurement in ATLAS

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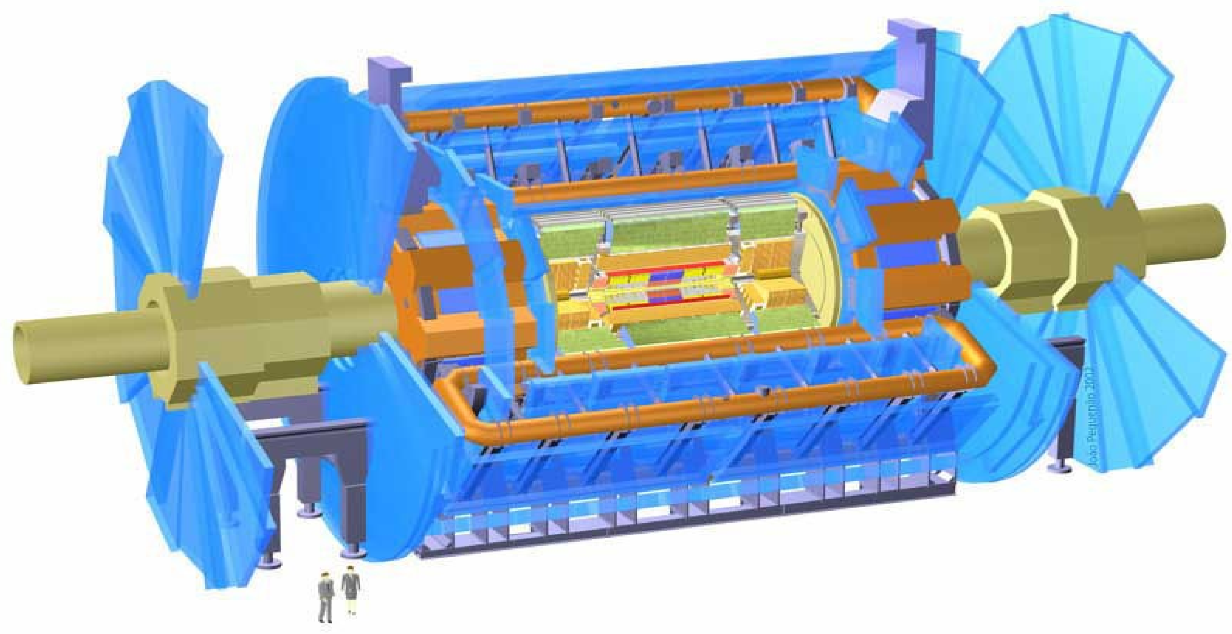


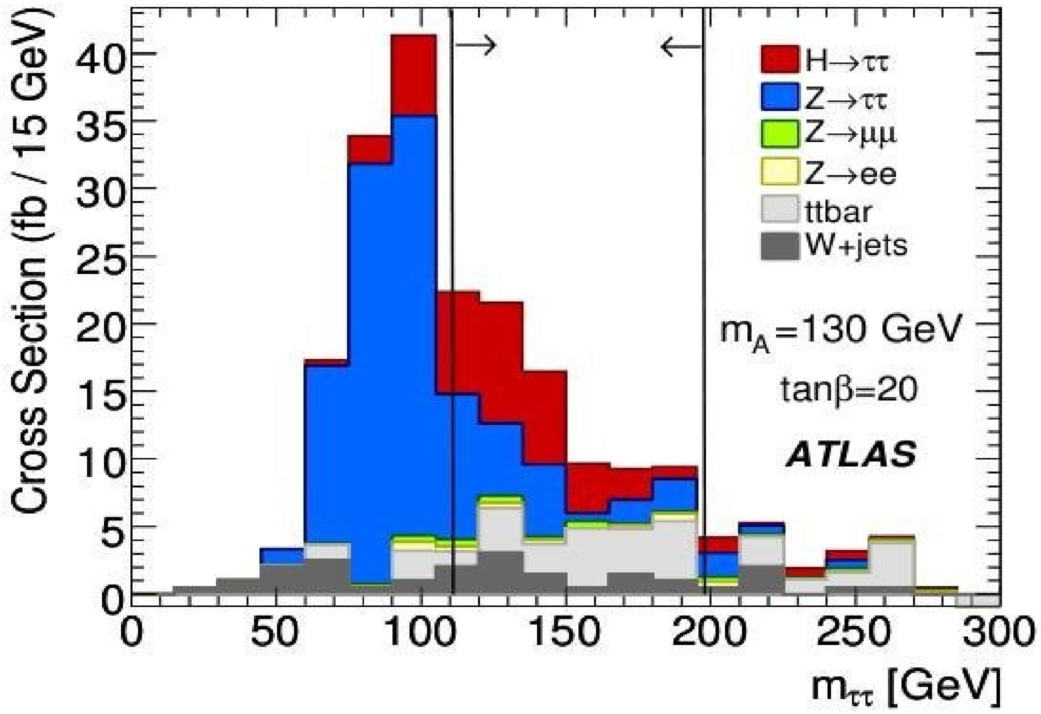
1. Motivation

Measurement of the Z → $\tau\tau$ cross section in ATLAS is an important issue to understand and measure this channel as relevant background for e.g.:

- **MSSM Higgs searches:** H/A/h → $\tau\tau$
- **SM Higgs searches:** H → ZZ → $\tau\tau$ll
- **Z' searches:** Z' → $\tau\tau$

Relevant for the precision of that measurement are:

- **Statistical uncertainties**
- **Systematical uncertainties**



ATLAS Collaboration, Expected Performance of the ATLAS Experiment Detector, Trigger and Physics, CERN-OPEN-2008-020

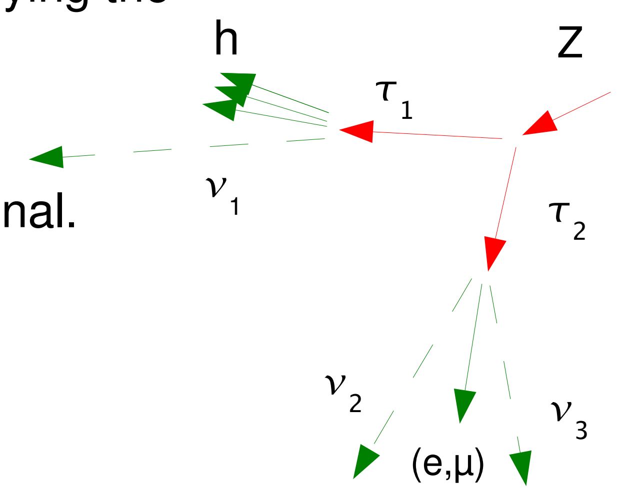
2. Method of cross-section measurement

$$\sigma(Z \rightarrow \tau\tau \rightarrow lh+3\nu) = \sigma(Z \rightarrow \tau\tau) \times BR(\tau\tau \rightarrow lh+3\nu) = \frac{N^{measured}_{Z \rightarrow \tau\tau \rightarrow lh+3\nu}}{L_{integrated}} \times \frac{1}{A_Z\, C_Z}$$

with: A_Z **=: kinematical/geometrical acceptance of the decay products**

C_Z **=: Efficiency of analysis cuts**

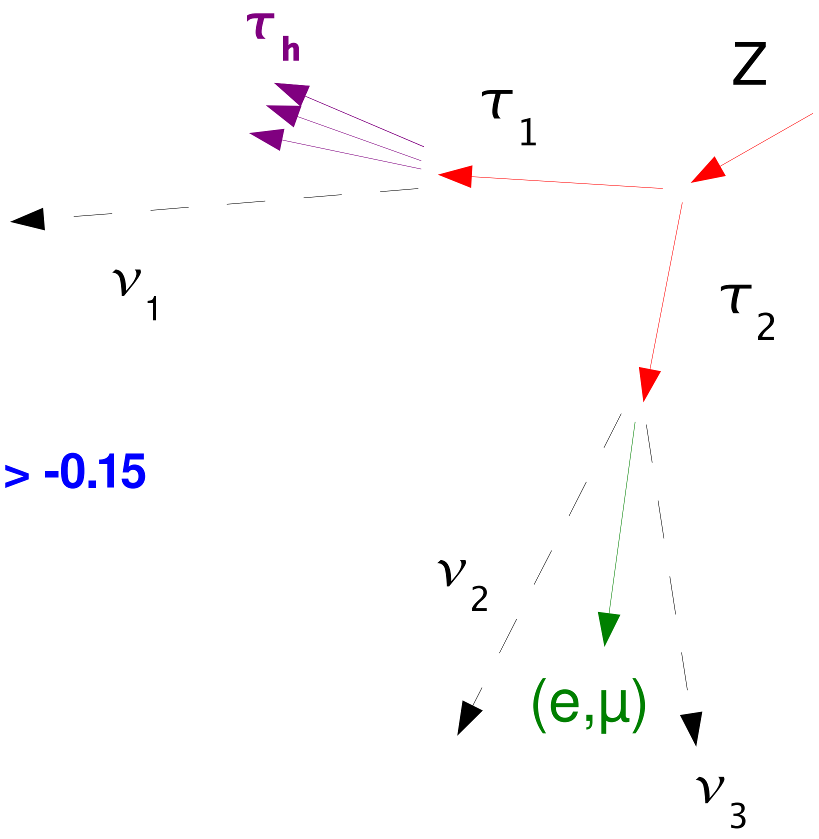
- Includes the efficiencies of reconstructing and identifying the electron/muon and the hadronical decaying tau.
- Includes efficiency of kinematic cuts to select the signal.



2. Method of cross-section measurement

Requirements considered for the selection:

- $\geq$1 reconstructed tau candidate, p_T > 15 GeV
- $\geq$1 electron or muon, p_T > 15 GeV
- Electron/Muon (lep) isolation
- Tau passed ID requirements
- Dilepton veto
- $\cos[\varphi(\mathrm{lep})-\varphi(E_T^{miss})] + \cos[\varphi(\tau_h)-\varphi(E_T^{miss})] > -0.15$
- Transverse mass $M_T(\mathrm{lep},E_T^{miss}) < 50$ GeV
- Opposite charge of lep and τ_h
- τ_h : N_{prong} = 1 or 3, |charge| = 1
- 35 GeV < $M_{vis}(\mathrm{lep},\tau_h)$ < 75 GeV



3. Tau ID and efficiencies

M_τ = 1.77 GeV

$c\tau$ = 87μm

Decay:

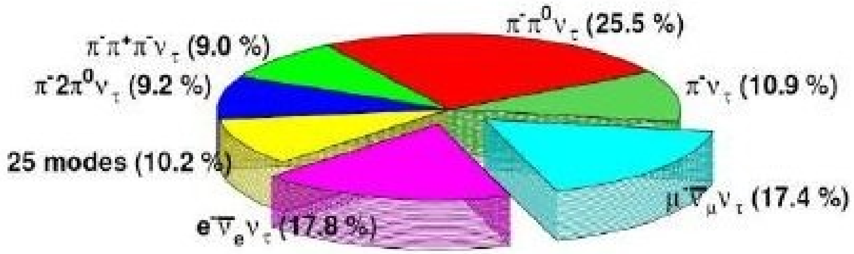
~35% leptonic

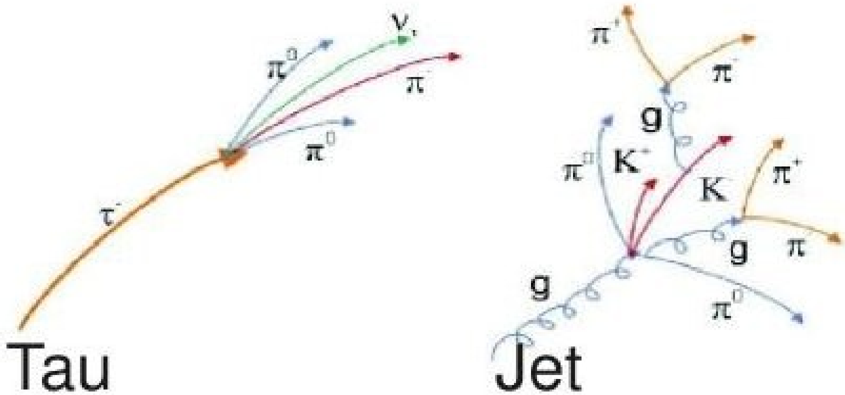
~65% hadronic

(~55% 1-prong or 3-prong
pion decay)

-> Mini-Jet like structure

Problem:
big QCD background

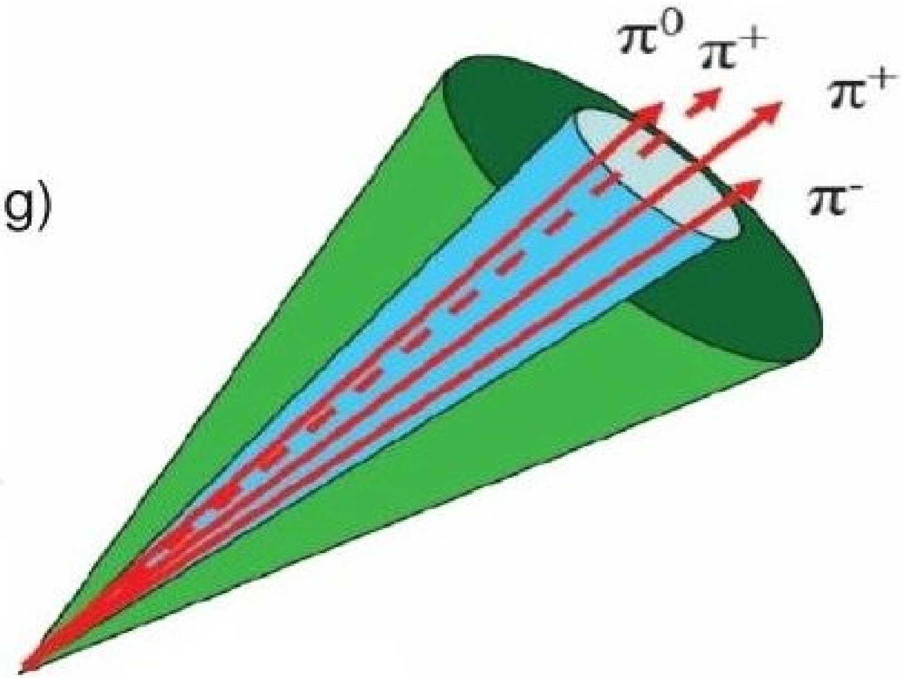




3. Tau ID and efficiencies

Tracking:
- Low track multiplicity
- Collimated tracks
- Secondary vertex reconstruction (3-prong)
- Isolation from other tracks (Cone)

Calorimetry:
- Collimated energy deposit in calorimeter
- Strong e.m. component (1-prong)
- Possible to identify pi0 clusters
- Use e.m. and had. component



3. Tau ID and efficiencies

- Several methods for Tau identification have been developed:
  - Cut based ID (Cuts) - uses 3 variables
  - Boosted decision tree (BDT) - uses 8 variables
  - Projective Likelihood (LLH) - uses 7 variables

- Evaluation of tau ID systematics based on Monte Carlo study.

- Tau Identification efficiency: $\varepsilon_{ID} = \frac{\#\ \tau\text{(truth \& ID-Matched)}}{\#\ \tau\text{(truth)}}$

→ in the kinematical and geometrical acceptance (p_T > 15GeV, $|\eta|$ < 2.5)

- Analysis of efficiencies and systematic uncertainties depending on:
  - 1-prong, 3-prong, multi-prong taus
  - High and low multiplicity of primary vertices in the event
  - p_T of the tau
  - For various IDs in combination with an electron veto

4. Evaluation of systematic uncertainties

Systematic uncertainties include the following contributions:

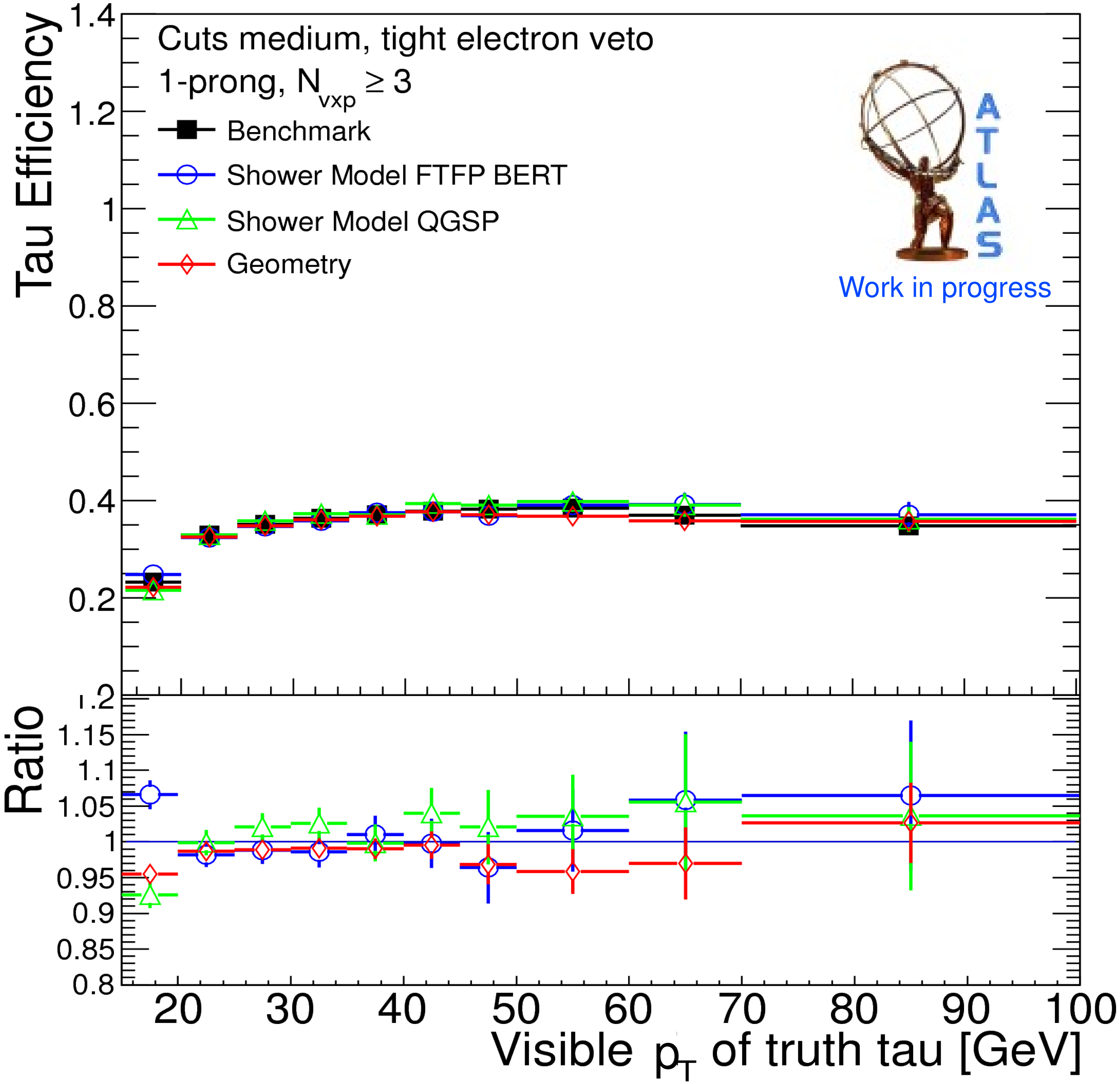
- **Different shower models**
- **Geometry of the Detector**
- **Different Monte-Carlo Generators and Underlying event models**
- **Different noise thresholds of calo cells for cluster reconstruction**

→ Variouse types have been studied, highest for each contribution has been taken

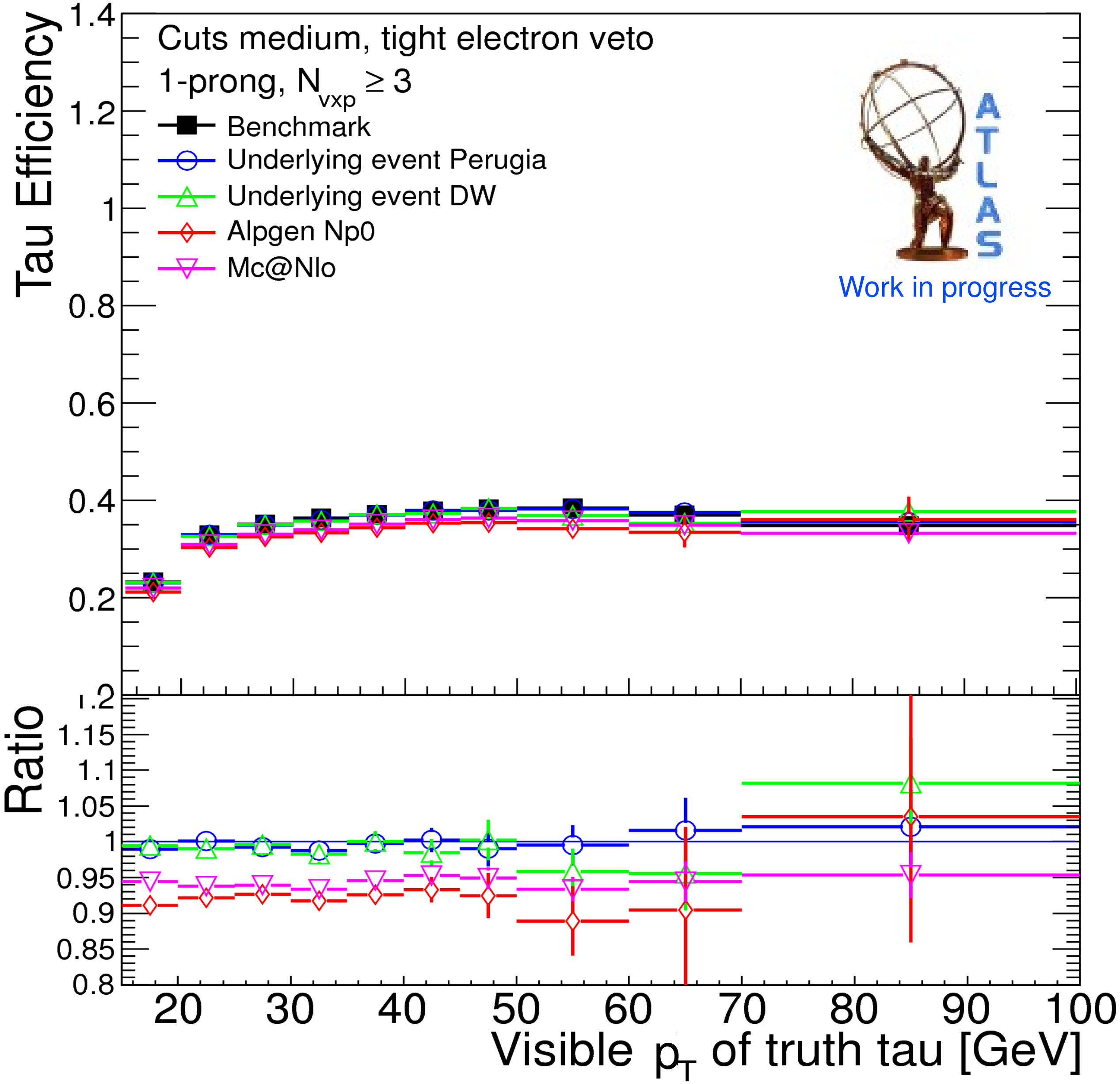
Relevant ID/veto – combination for $Z \rightarrow \tau\tau \rightarrow l\tau_h$ is expected to be:

- **Cuts medium (1-prong tau), Cuts tight (3-prong tau) and tight el. veto**

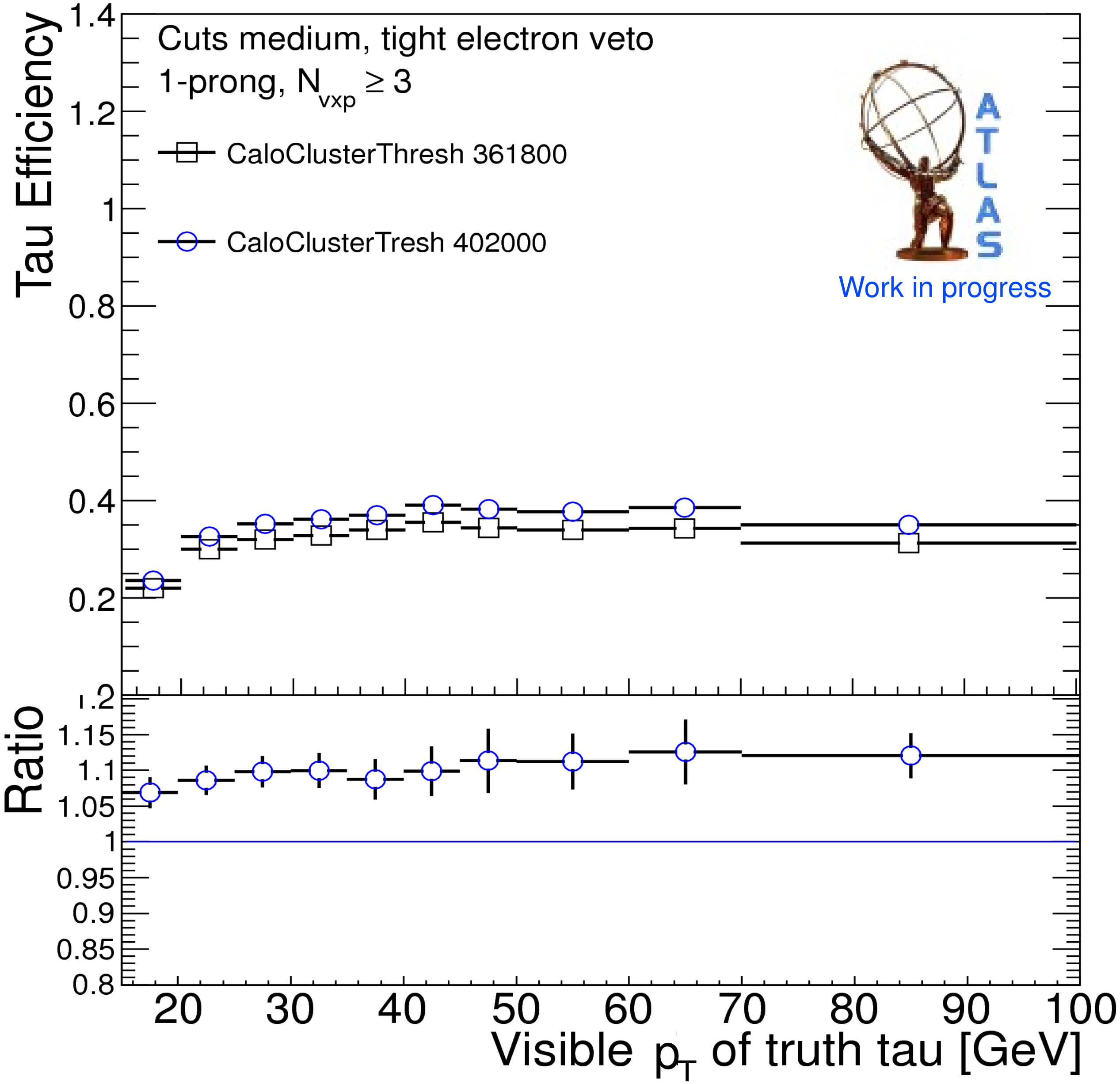
Different shower model and Geometry



Different Monte-Carlo Generators and Underlying event models



Different Monte-Carlo Generators and Underlying event models



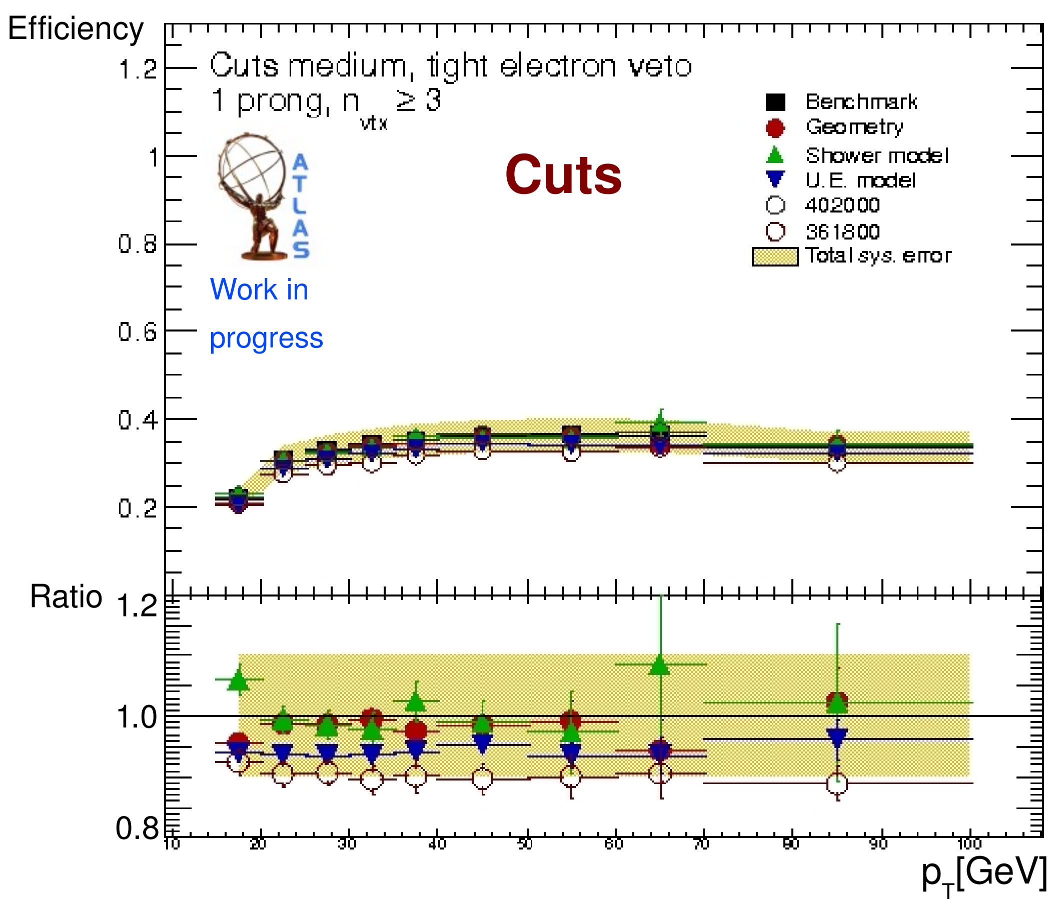
4. Evaluation of systematic uncertainties

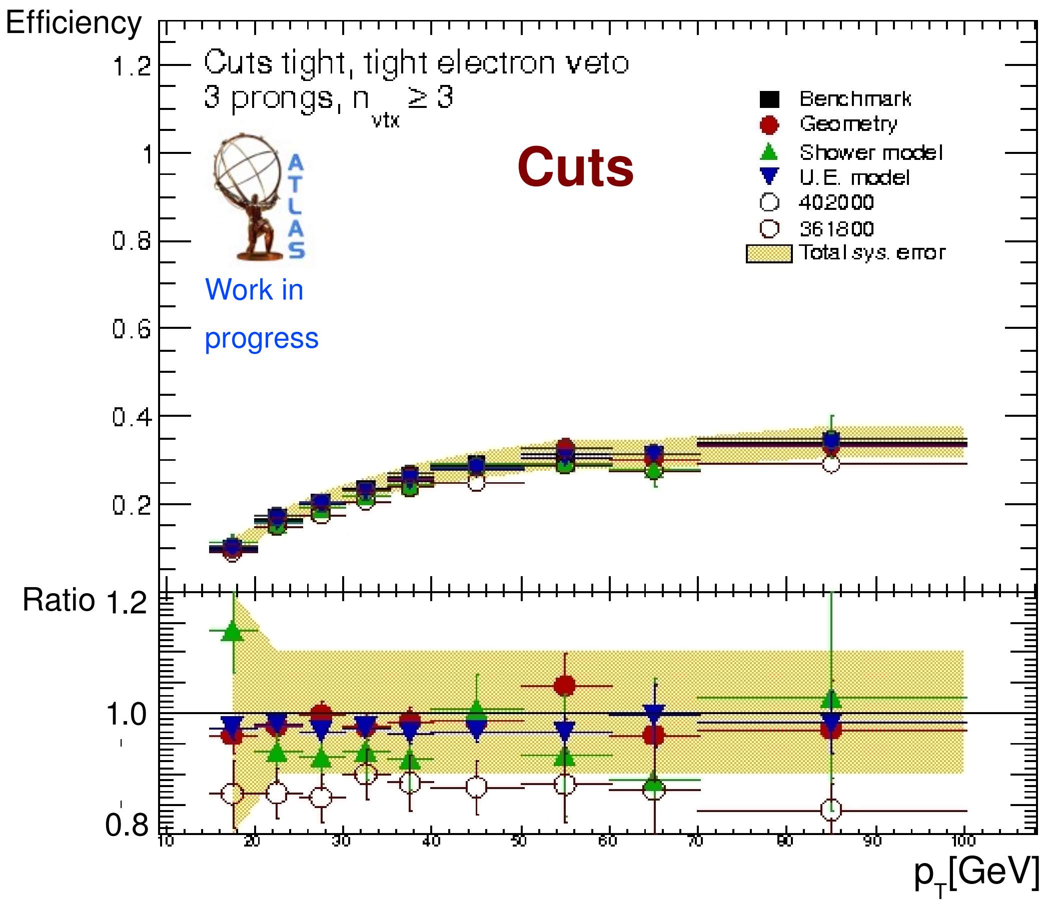
- **Relevant types of systematics for each contribution:**

  Highest types added in quadrature to obtain the total systematic uncertainty

  (for each ID-electron-veto-combination and bin in n-prong, N_{vxp}, $p_T(\tau)$)

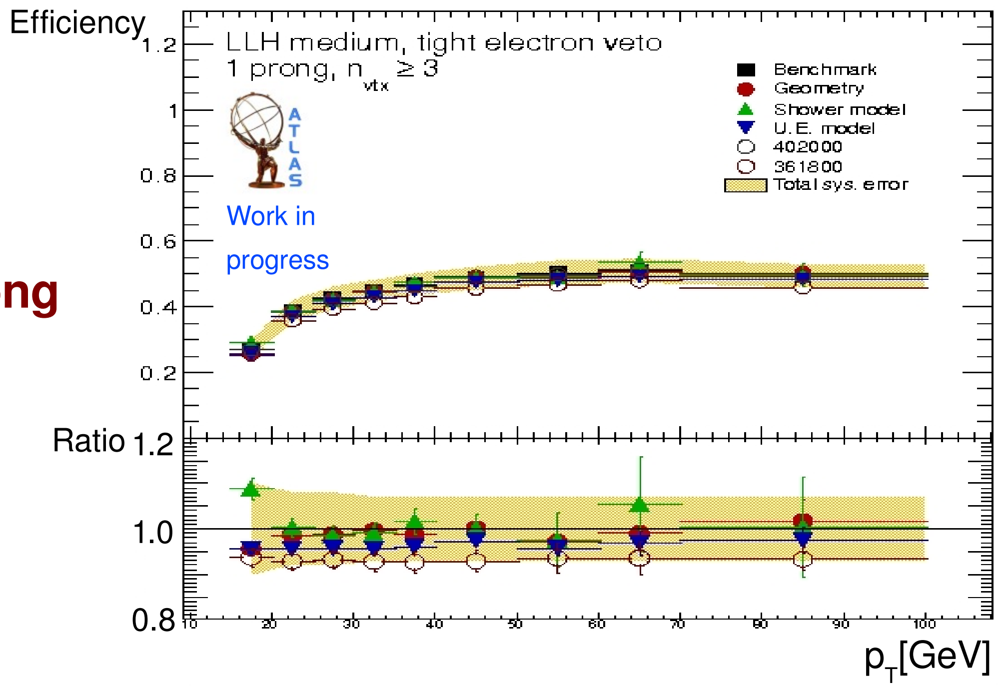
Example for Cuts medium (1-prong tau), Cuts tight (3-prong tau) and tight el. veto:

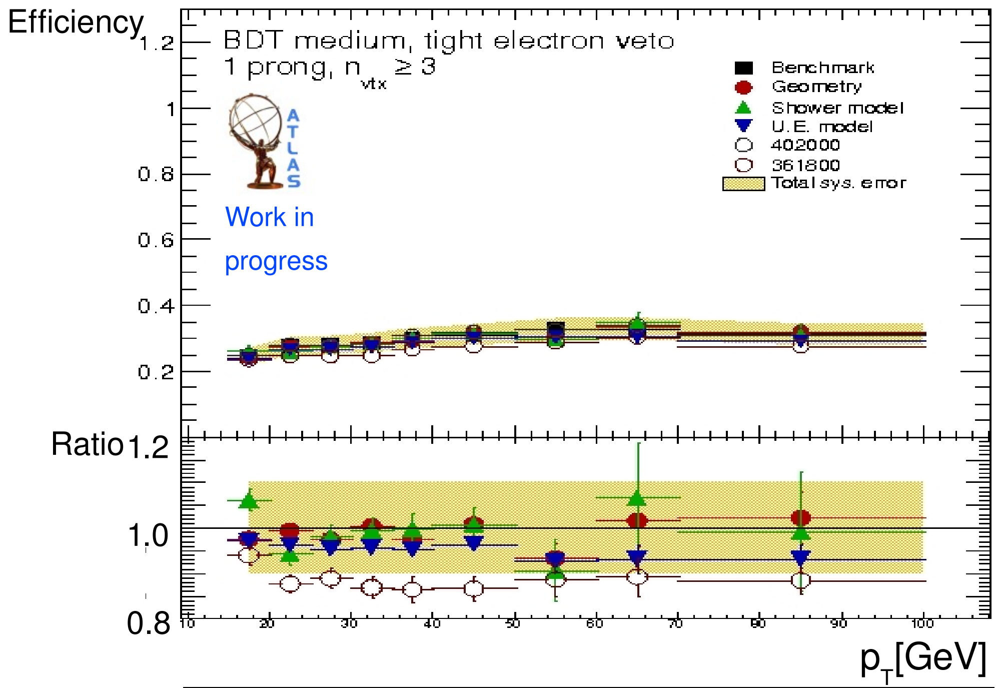




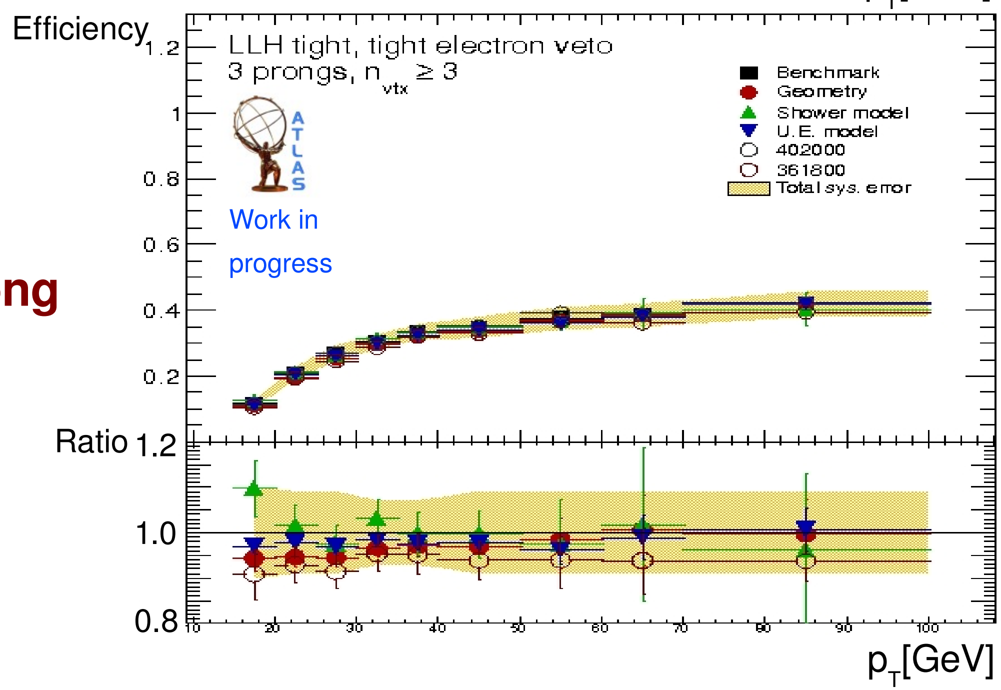
LLH **BDT**

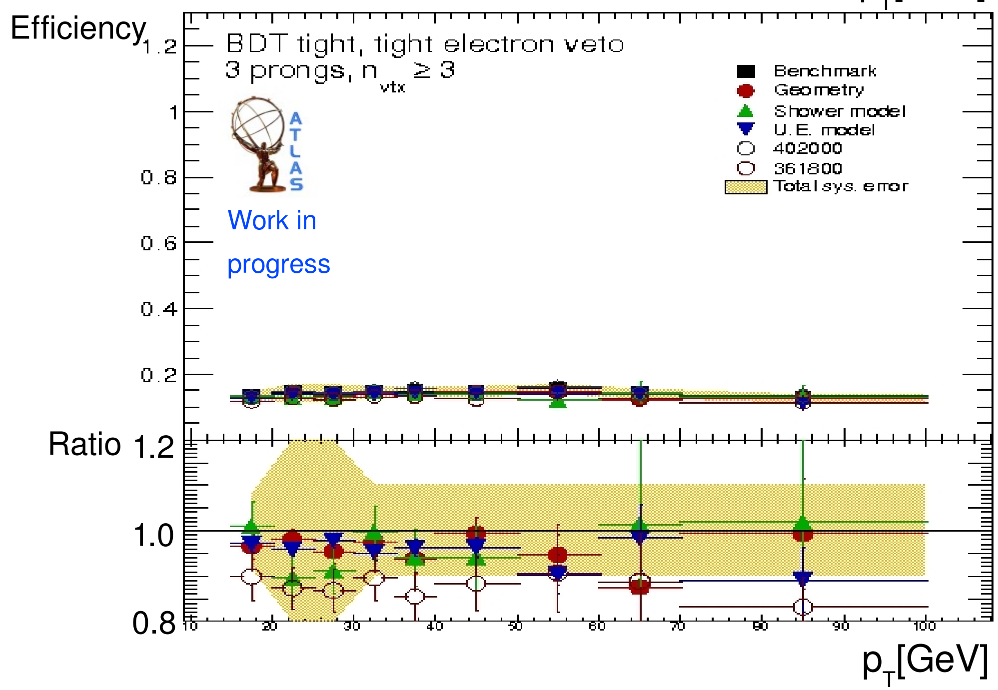
1-prong





3-prong





5. Conclusion

- **Biggest differences in the lowest p_T bin (15 – 20 GeV) → high p_T bins pretty stable.**
  - ➔ (due to high shower model contribution in low p_T range)

- **LLH shows higher efficiency than BDT and slightliy higher than cuts.**

- **Overall the systematic uncertainties of Cuts and LLH are quite comparable.**

- **With BDT one obtain on average higher systematic uncertainties.**

- **Concluding the systematics for tau ID efficiencies are in order ~8-12% relative to the efficiency itself (depending of the ID and bin).**

Backup

Comparison of Cuts, LLH and BDT for the ID-veto-combination:

Medium ID (1-track tau), tight ID (3-track tau) and tight el. Veto.

$p_T(\tau)$ [GeV]			[15, 20]		[20, 30]		[30, 40]		[40, 100]	
WP	N_{vxp}	N_{trk}	Effic. [%]	(Syst. [%])	Effic. [%]	(Syst. [%])	Effic. [%]	(Syst. [%])	Effic. [%]	(Syst. [%])
Cuts	≤ 2	1	27.0±0.1	(9.7±1.5)	40.0±0.1	(8.7±0.8)	42.1±0.1	(8.8±0.8)	42.1±0.2	(9.2±0.9)
		3	12.5±0.2	(8.0±3.4)	23.3±0.1	(12.3±2.9)	29.6±0.2	(8.9±1.7)	34.9±0.3	(11.9±2.6)
	≥ 3	1	21.8±0.1	(12.1±1.4)	31.7±0.1	(11.0±0.7)	34.6±0.1	(10.4±0.8)	35.7±0.1	(9.6±0.8)
		3	9.9±0.1	(15.3±4.3)	18.4±0.1	(11.5±2.0)	24.6±0.1	(11.1±2.0)	30.3±0.2	(10.5±1.5)
LLH	≤ 2	1	29.3±0.1	(10.1±1.5)	44.9±0.1	(7.3±0.7)	48.7±0.1	(7.0±0.8)	50.3±0.2	(7.5±1.0)
		3	12.2±0.2	(13.4±3.4)	25.0±0.1	(8.9±1.9)	33.1±0.2	(10.5±2.0)	37.6±0.3	(12.9±3.1)
	≥ 3	1	27.0±0.1	(12.6±1.3)	40.5±0.1	(7.9±0.6)	45.6±0.1	(6.8±0.7)	49.3±0.1	(6.7±0.7)
		3	11.7±0.1	(13.1±3.9)	23.8±0.1	(8.7±1.1)	31.6±0.2	(6.9±1.1)	36.7±0.2	(9.4±1.5)
BDT	≤ 2	1	32.4±0.1	(7.4±1.4)	39.8±0.1	(8.7±0.9)	38.3±0.1	(9.5±1.0)	36.7±0.2	(10.8±1.2)
		3	22.9±0.2	(9.2±2.7)	28.9±0.2	(10.3±2.1)	30.0±0.2	(11.7±1.6)	29.2±0.2	(14.6±3.9)
	≥ 3	1	24.6±0.1	(9.7±1.4)	27.7±0.1	(12.9±1.0)	29.2±0.1	(12.6±1.1)	31.6±0.1	(13.2±1.0)
		3	13.2±0.1	(7.9±2.1)	14.2±0.1	(15.8±2.6)	14.7±0.1	(13.8±1.6)	14.5±0.2	(14.4±3.1)

All ID/veto combinations considered in the study

Working point	ID 1-prong τ	ID 3-prong τ	Electron veto
WP1	LLH loose	LLH loose	medium
WP2	LLH medium	LLH medium	medium
WP3	LLH medium	LLH medium	tight
WP4	LLH loose	LLH medium	medium
WP5	LLH medium	LLH tight	medium
WP6	LLH medium	LLH tight	tight
WP7	BDT loose	BDT loose	medium
WP8	BDT medium	BDT medium	medium
WP9	BDT medium	BDT medium	tight
WP10	BDT loose	BDT medium	medium
WP11	BDT medium	BDT tight	medium
WP12	BDT medium	BDT tight	tight
WP13	Cuts loose	Cuts medium	medium
WP14	Cuts medium	Cuts tight	medium
WP15	Cuts medium	Cuts tight	tight
WP16	BDTj > 0.5	BDTj > 0.6	BDTe > 0.5
WP17	Cuts medium	Cuts tight	BDTe > 0.5