Search for the Standard Model Higgs at LHC (Part II)

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Taller de Altas Energías

Experimental Analyses

Final States

- $H \to WW$:
  - $H \to WW \to \ell\nu\ell\nu$
  - $qqH,\ H \to WW \to \ell\nu\ell\nu/qq'\ell\nu$
  - $WH \to WWW \to 3\ell 3\nu$
- $H \to ZZ$:
  - $H \to ZZ \to 4\ell$
  - $(qq)H \to ZZ \to 2q2\ell$
  - $qqH,\ H \to ZZ \to 2\ell 2\nu$
- $H \to \gamma\gamma$:
  - $gg \to H$
  - qqH
  - $W/Z/\mathrm{t\bar{t}}H$
- $H \to \tau\tau$:
  - $qqH,\ H \to \tau\tau \to \ell h\nu's$
  - $qqH,\ H \to \tau\tau \to \ell\ell\nu's$
- $H \to b\bar{b}$:
  - $\mathrm{t\bar{t}}H$
  - W/ZH

Key Points

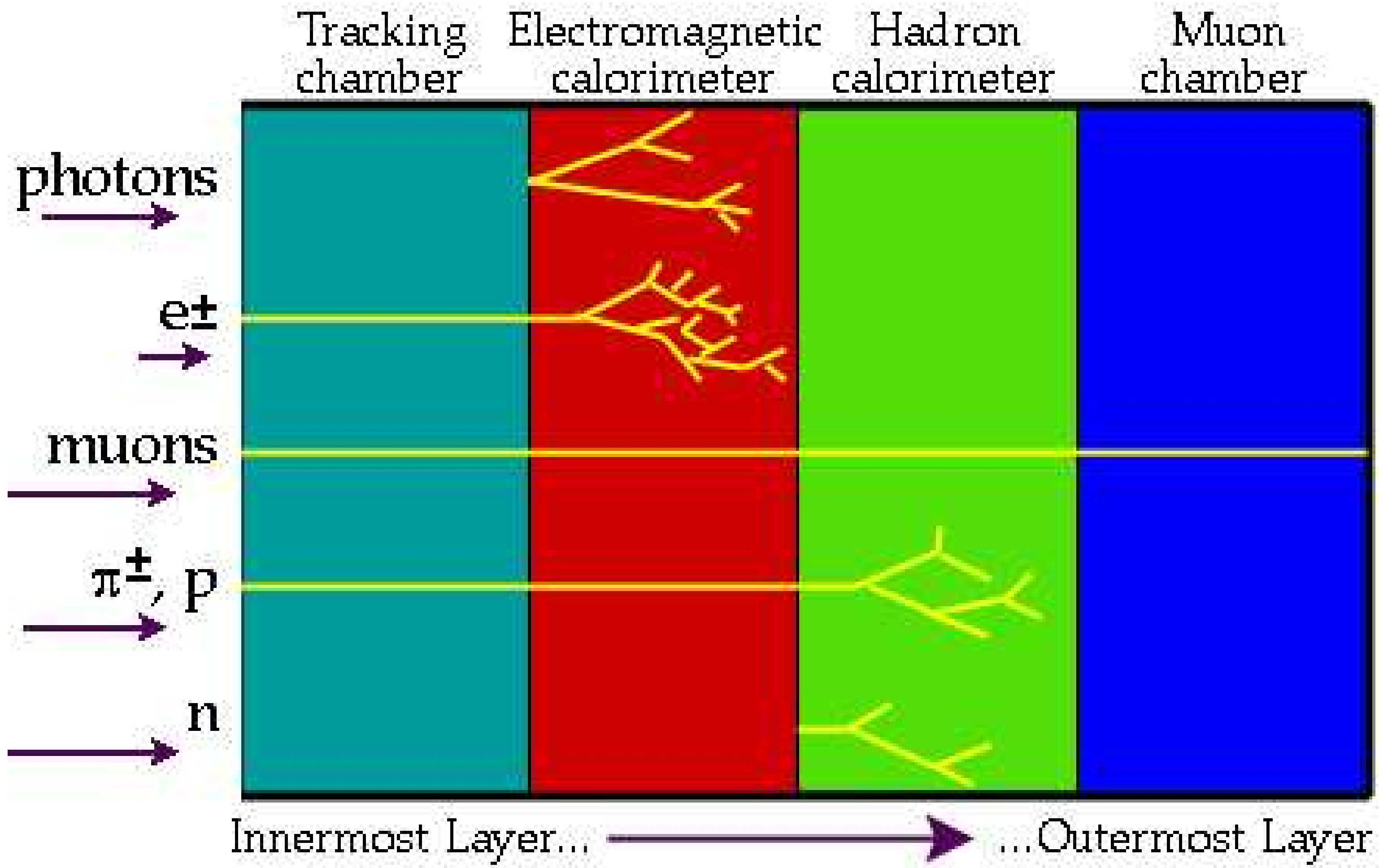
- Trigger
- μ, *e*, γ, τ identification:
  - high p_T isolated objects
- Jet reconstruction:
  - reject backgrounds
  - select WBF events
- *b*-tagging:
  - reject backgrounds, apply anti *b*-tagging
  - select *b*-jets
- E_T^{miss}:
  - select events with neutrinos in the final state
  - reject backgrounds
- Systematics, data-driven methods

Backgrounds

- WW
- WZ
- ZZ
- $t\bar{t}$
- $W(\rightarrow \ell\nu) + jets$
- $Z(\rightarrow \ell\ell)(+jets)$
- Single top: Wt, t-channel, s-channel
- Generic QCD

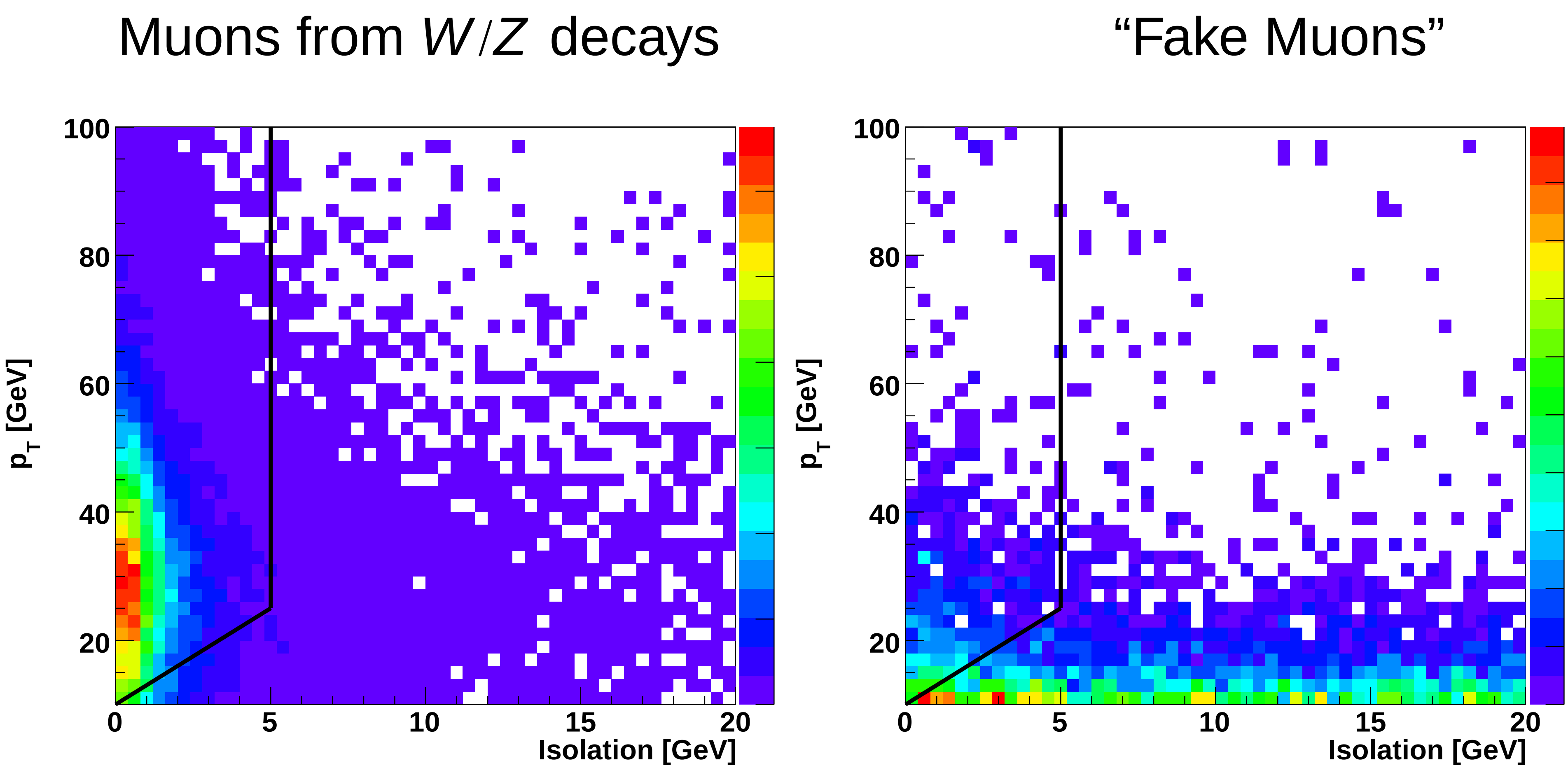
Object Identifi cation & Trigger Selection

Particle Detection



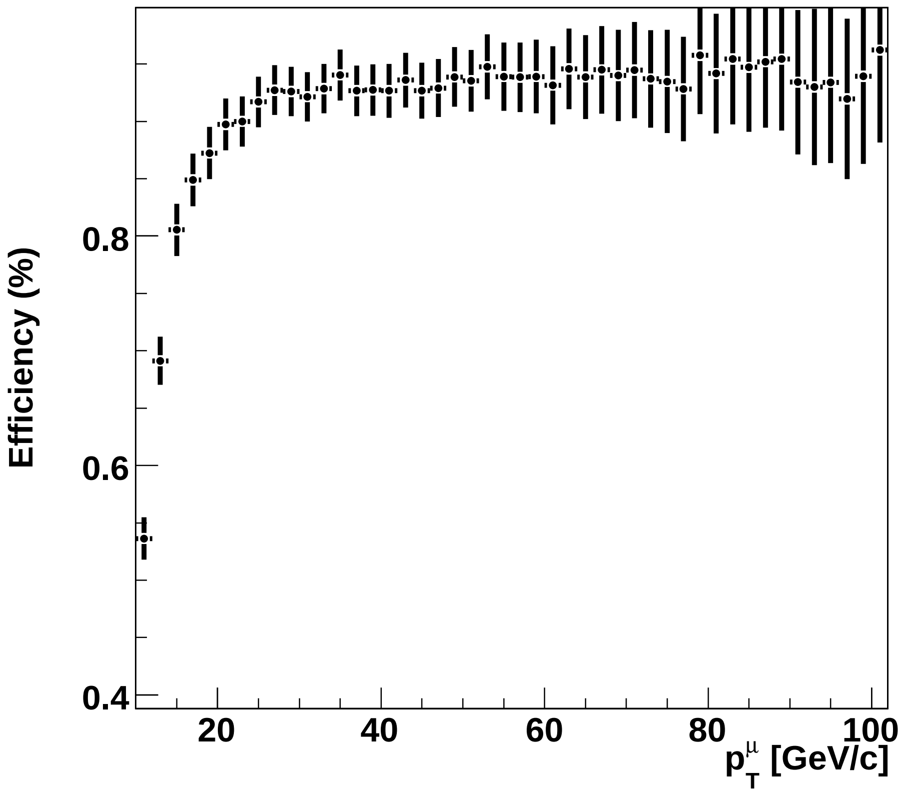
Keep in mind: specific identification results depend on detector, performance, cuts, analysis...

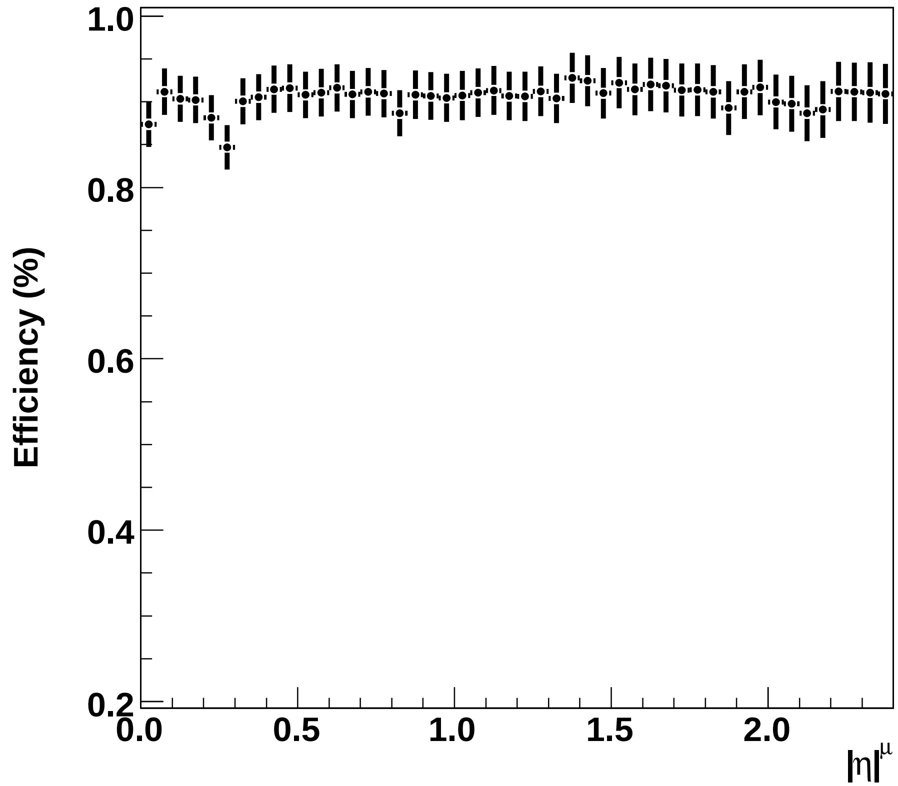
Isolation



- Isolation: sum p_T of objects around the lepton
- $Iso^{\mu}_{Total} = Iso^{\mu}_{Track} + Iso^{\mu}_{ECAL} + Iso^{\mu}_{HCAL}$
- Black line: cut position (mainly for illustration purposes)

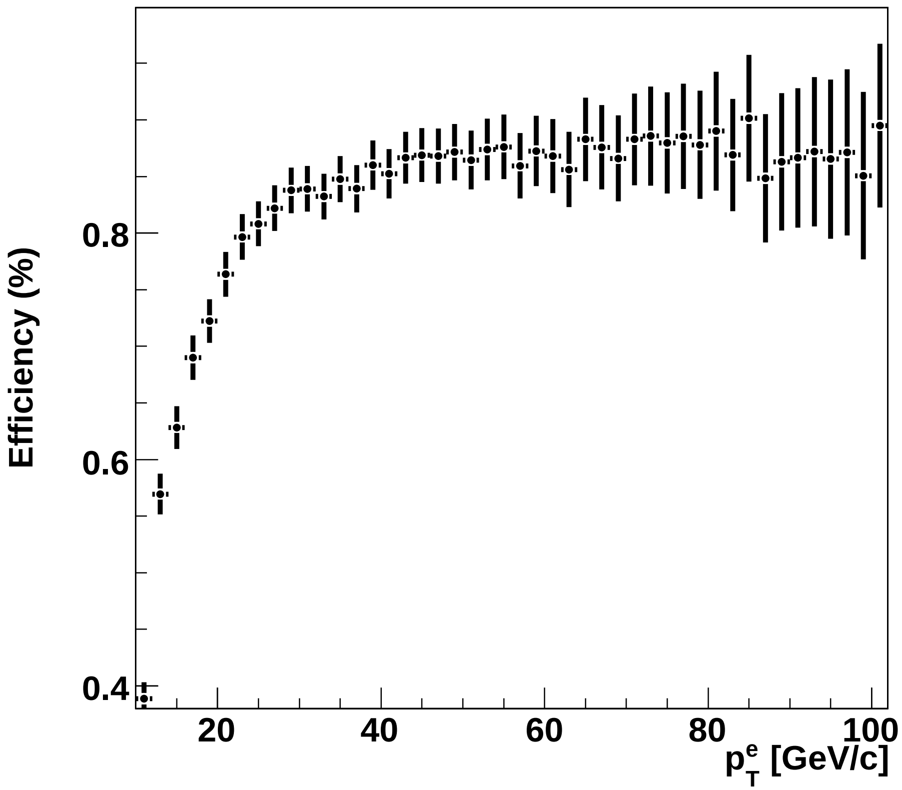
Muon Effi ciency

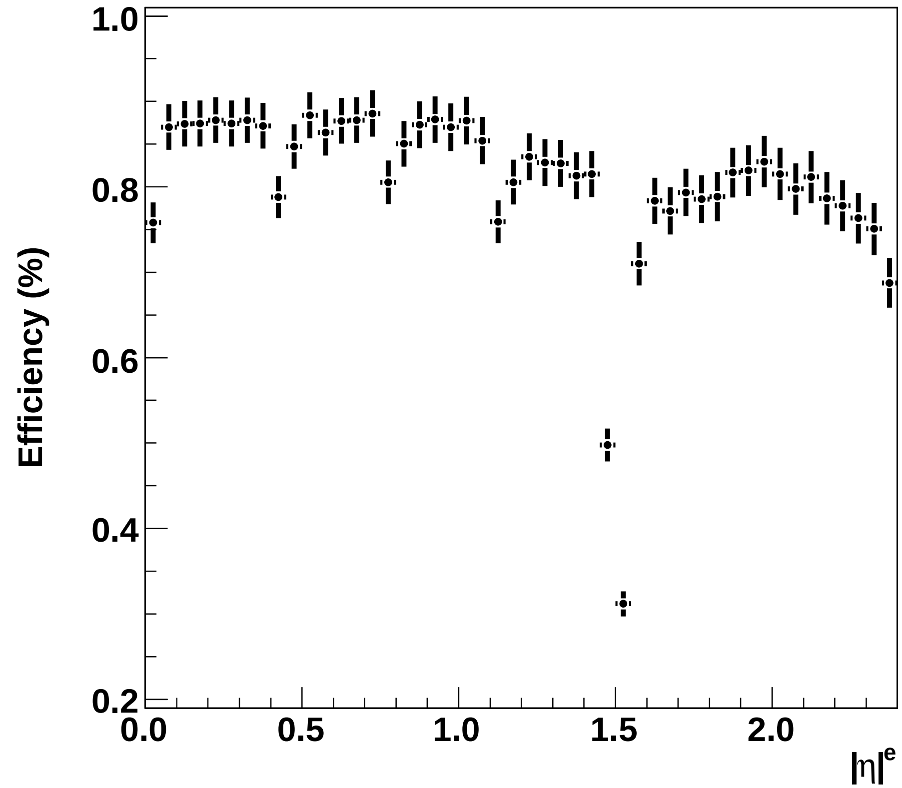




- ☞ Typical total efficiency ~90%
- ☞ Lower efficiency at low p_T due to tighter isolation requirements

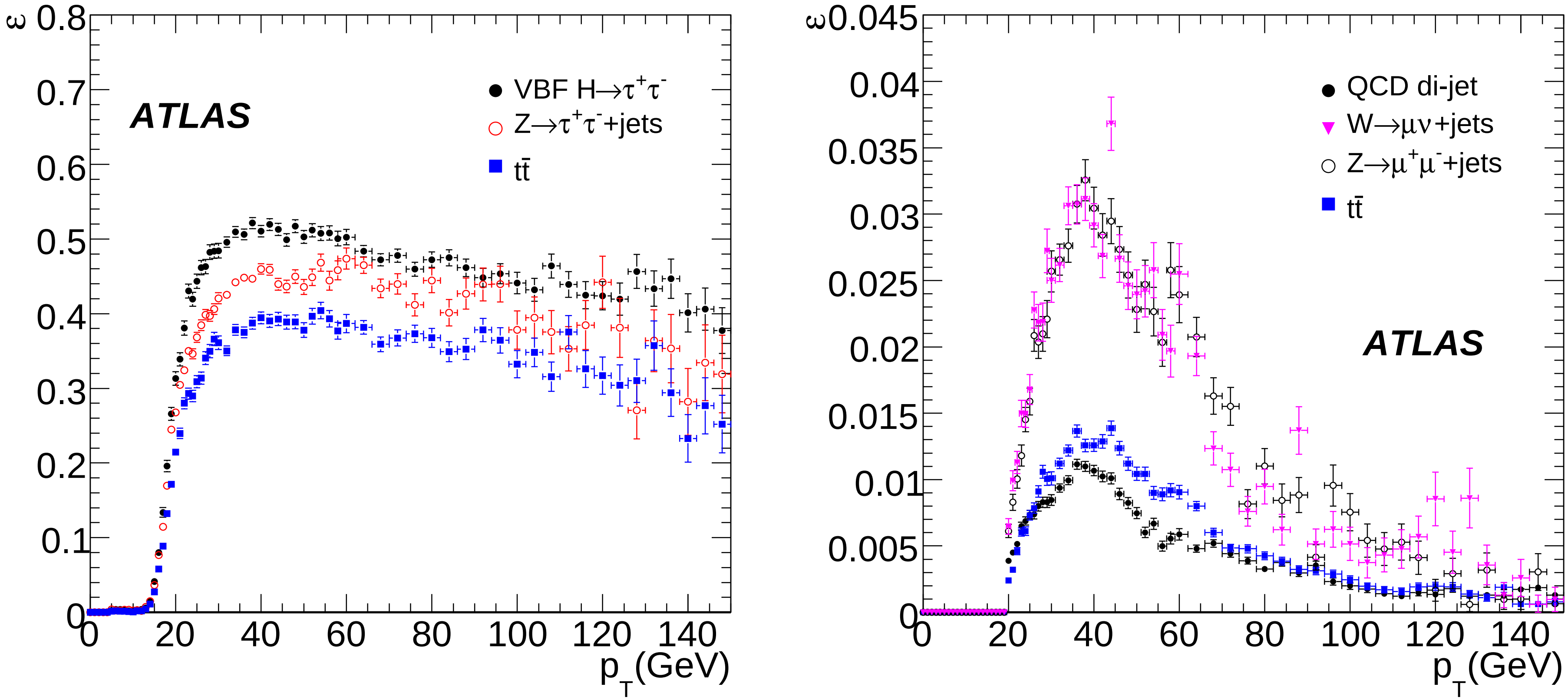
Electron Effi ciency





- ☞ Typical total efficiency ~80%
- ☞ Lower efficiency at low p_T due to tighter isolation requirements

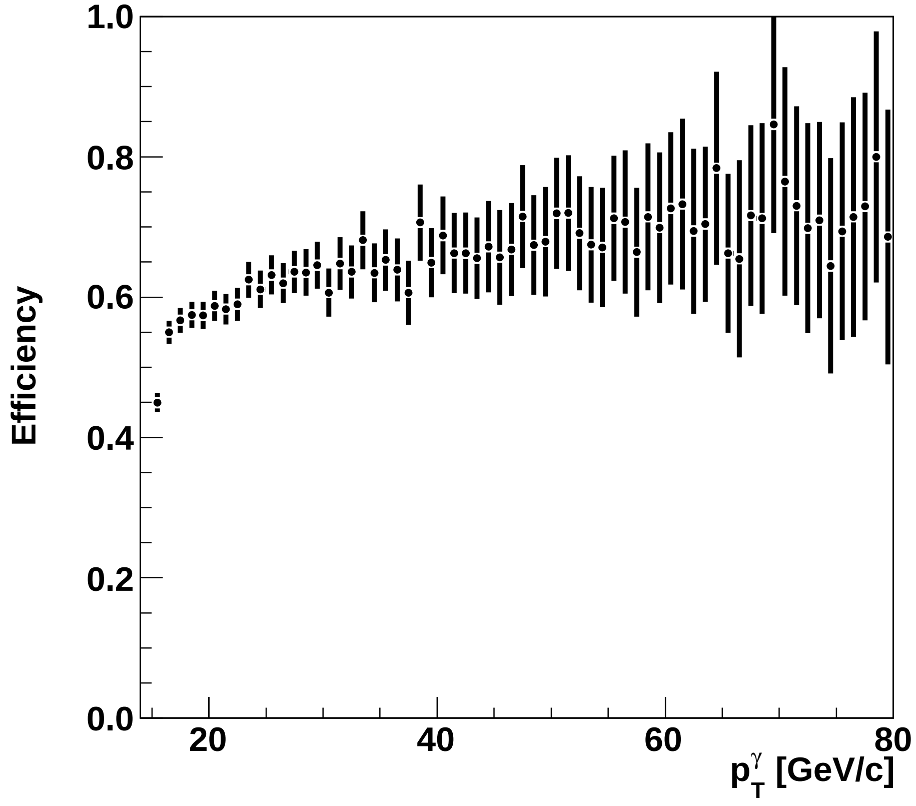
$\tau \to hX$ Efficiency

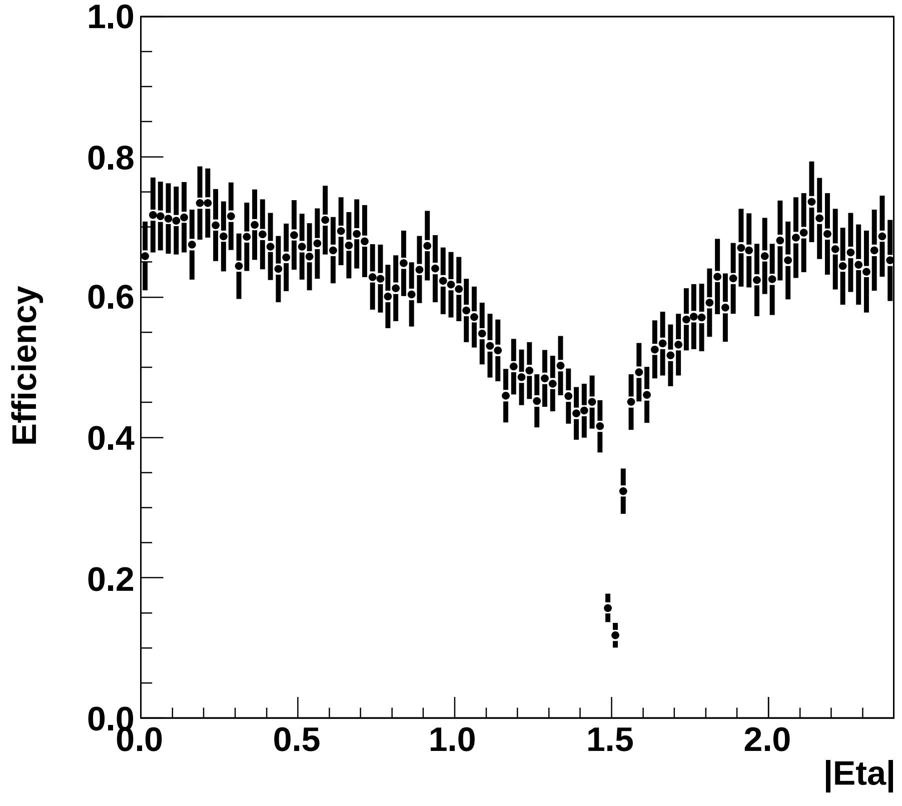


- ☞ Heavily analysis dependent
- ☞ Detector performance very important

γ Efficiency

CMS results...



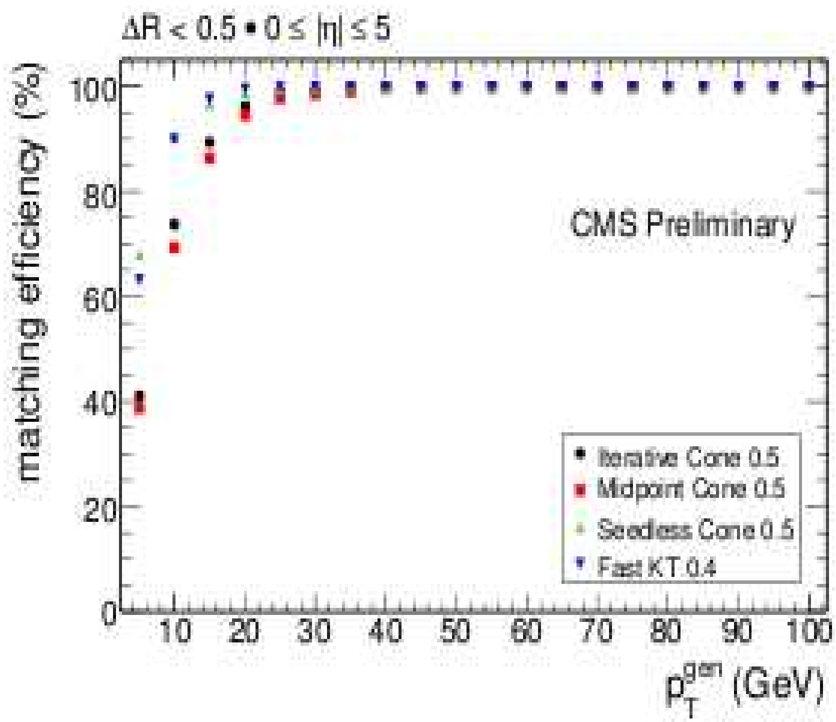


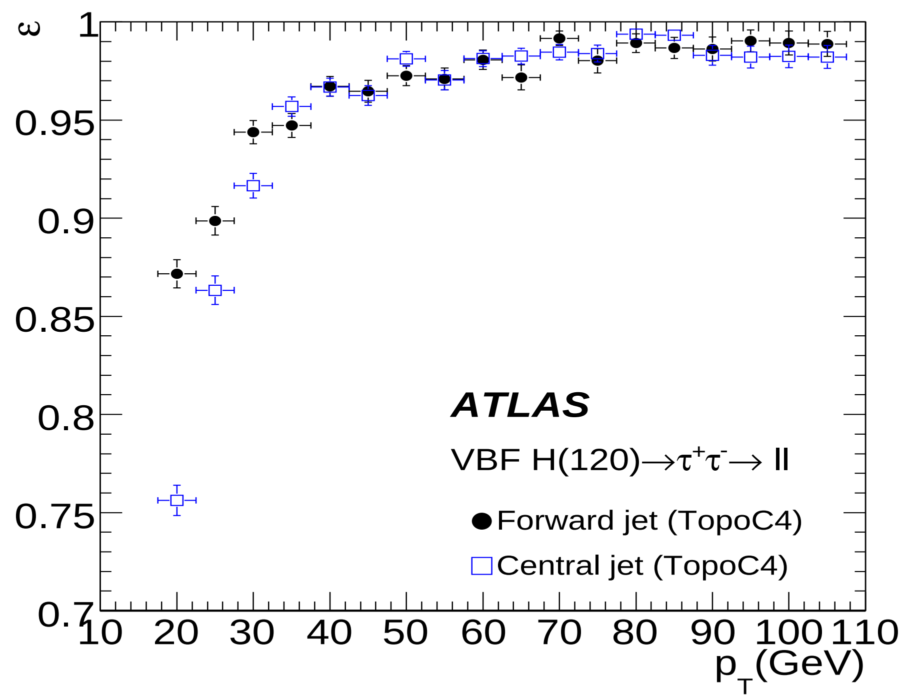
☞ Gap in $|\eta|$ ~ 1.5 due to an ECAL gap between Barrel and End-Cap

Jet Efficiency

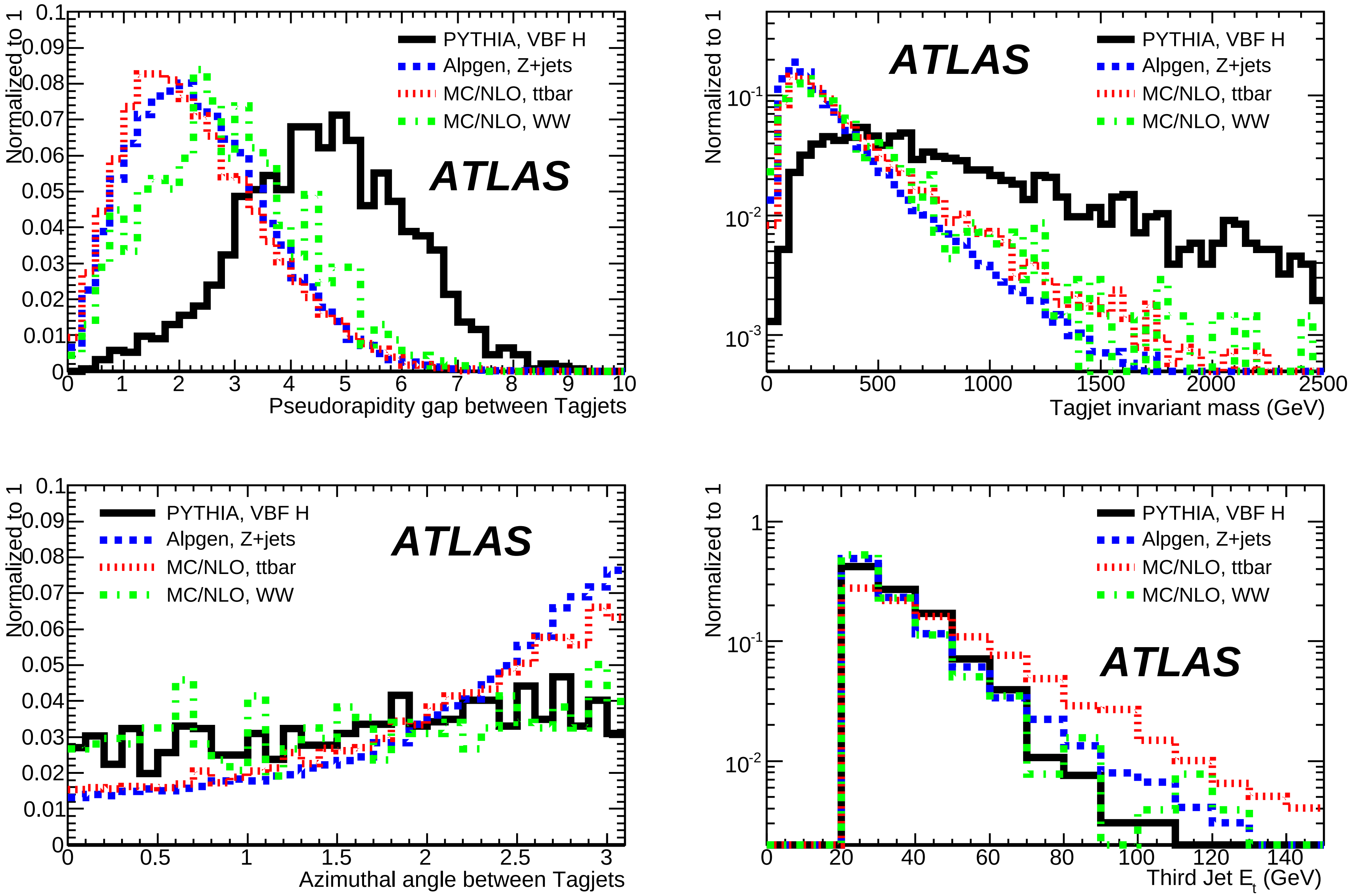
ε^{jet} > 95% for p_T^{jet} > 30 GeV

Dependence on jet algorithm





WBF Jets



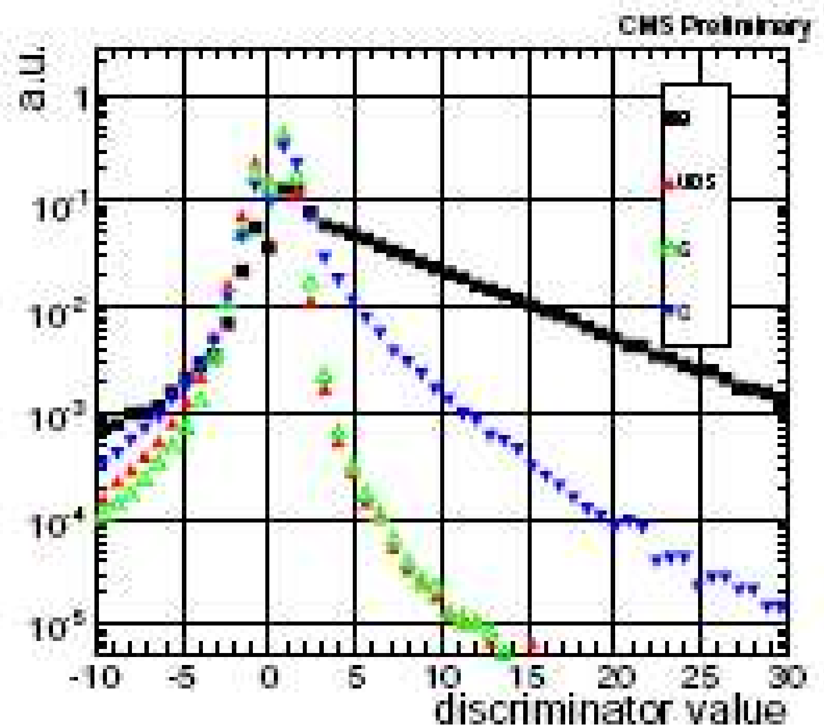
ATLAS
PYTHIA, VBF H
Alpgen, Z+jets
MC/NLO, ttbar
MC/NLO, WW
Normalized to 1
Pseudorapidity gap between Tagjets
Tagjet invariant mass (GeV)
Azimuthal angle between Tagjets
Third Jet E_t (GeV)

b-tagging Efficiency

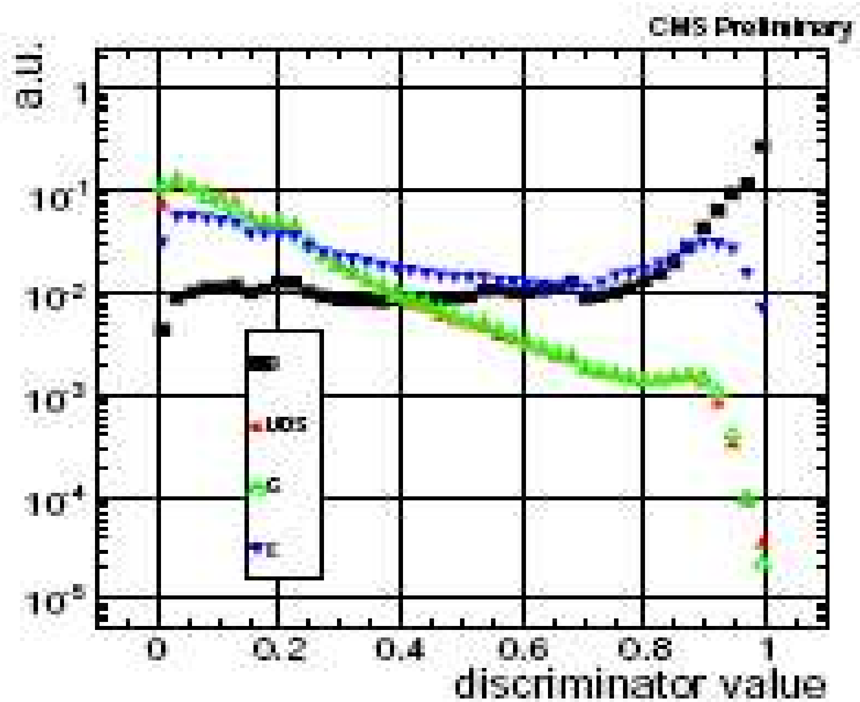
Observables to discriminate heavy and light flavor quark jets:

- ☞ soft-lepton tagging: leptons from $B \to \ell X$ decays
- ☞ track-counting: tracks with large impact parameter
- ☞ secondary vertex mass: group of tracks with relatively large mass

Track-counting

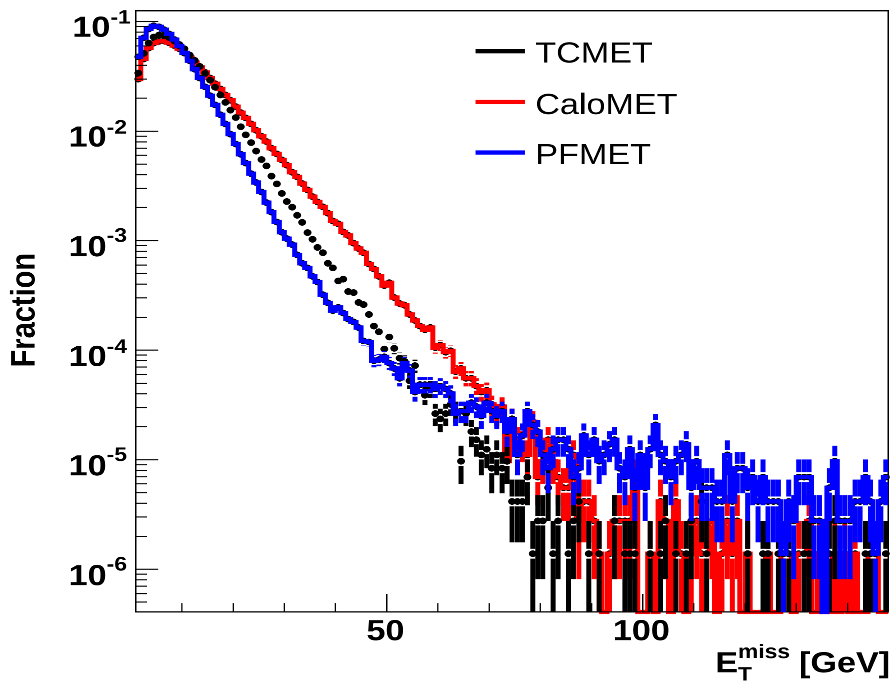


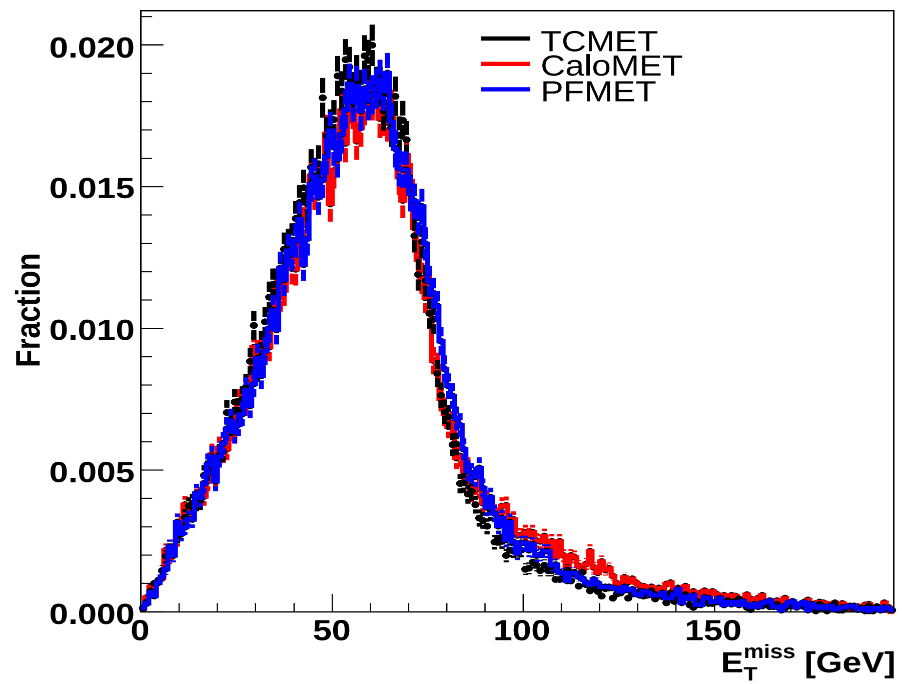
Combined b-tag



E_T^{miss} Reconstruction

$Z \to \ell\ell$ (no real E_T^{miss}) $\qquad$ $H(160) \to WW \to 2\ell 2\nu$ (real E_T^{miss})



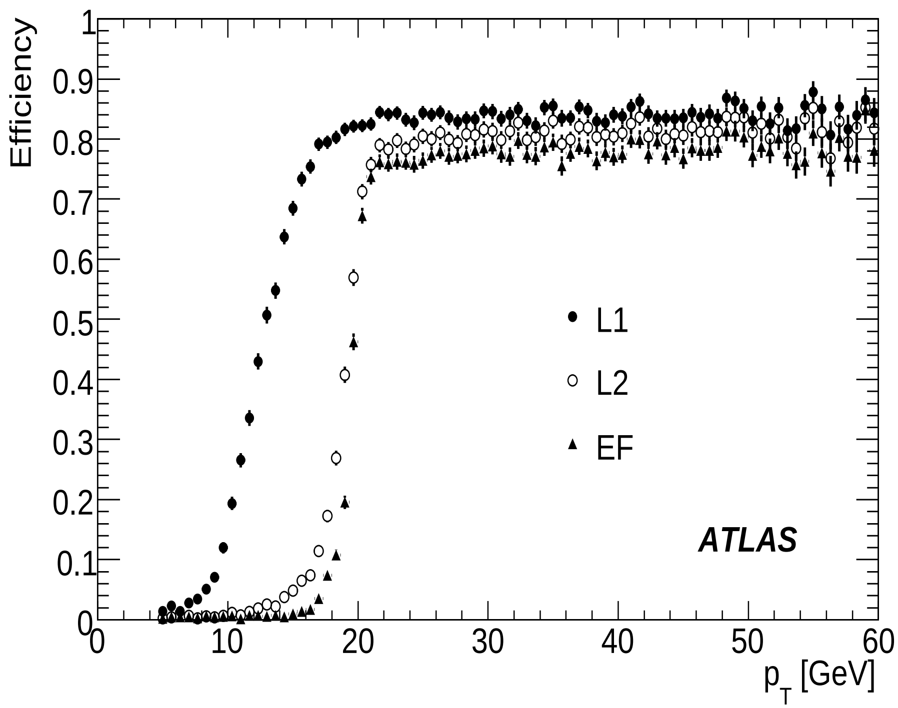


- ☞ CaloMET: reconstructed by the vector sum of ECAL and HCAL towers energy and subtracting the muons energy
- ☞ TCMET: precise measurement of charged particles is exploited to correct the calorimeter-based measurement
- ☞ PFMET: full Particle Flow algorithm is exploited

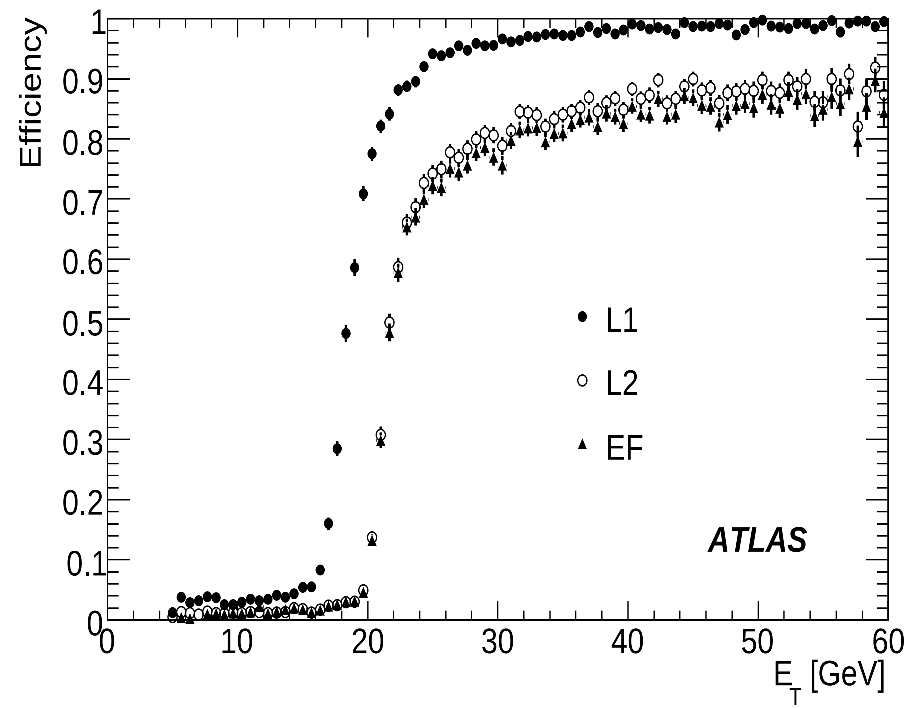
Triggers

Not going to enter in detail here...

Single muon trigger



Single Electron trigger



- ☞ Lepton final states less problematic than $\tau/\gamma/jet$ final states
- ☞ Offline requirements should be tighter than trigger requiments

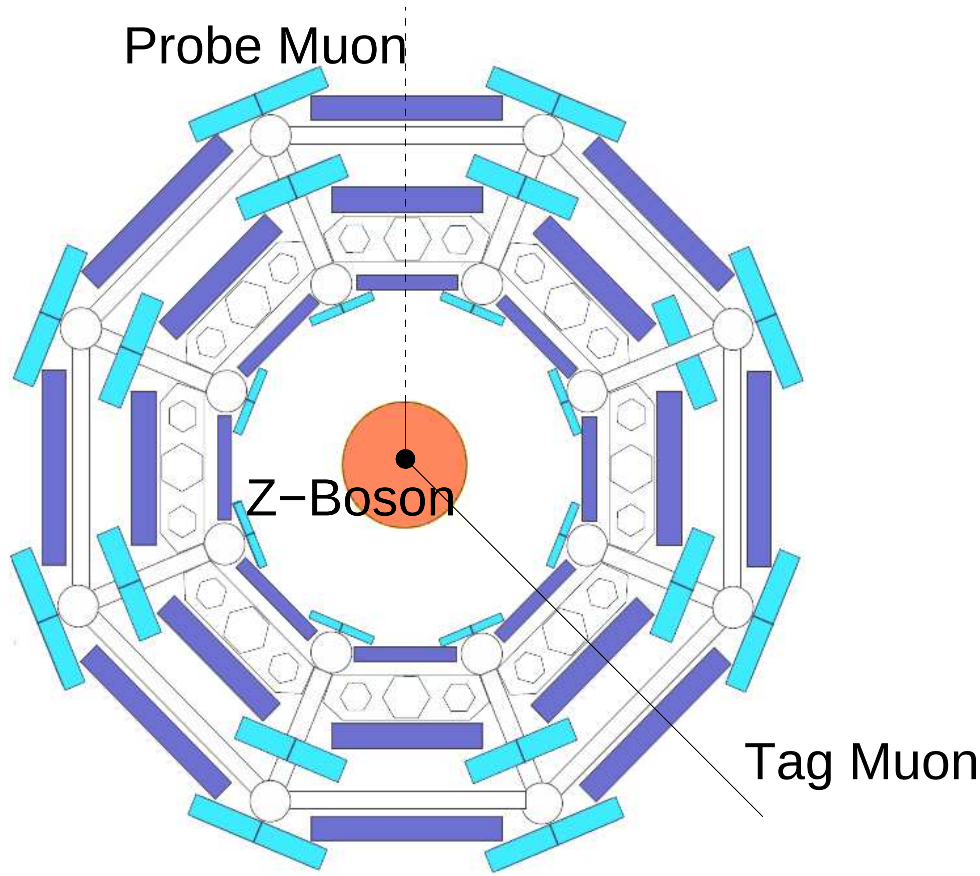
Systematics

The Name of the Game

- ☞ Very important to establish data-driven methods to understand backgrounds and efficiencies
- ☞ Should rely in Monte Carlo simulation as less as possible
- ☞ Critical component for analyses with no mass peak

Source	Normalization	Shape (per background type)
Luminosity	yes	no
ℓ/γ & trigger effi ciencies	yes	small
ℓ/γ isolation	yes	small
Miscalibration and misalignment	yes	small
Jet reconstruction	yes	yes
E_T^{miss} modeling	yes	yes
b-tagging	yes	small
PDF uncertainties	yes	yes
Background normalizations	yes	no
Conversion fi nding effi ciency	yes	no
Fake objects	yes	no
MC statistics	yes	no

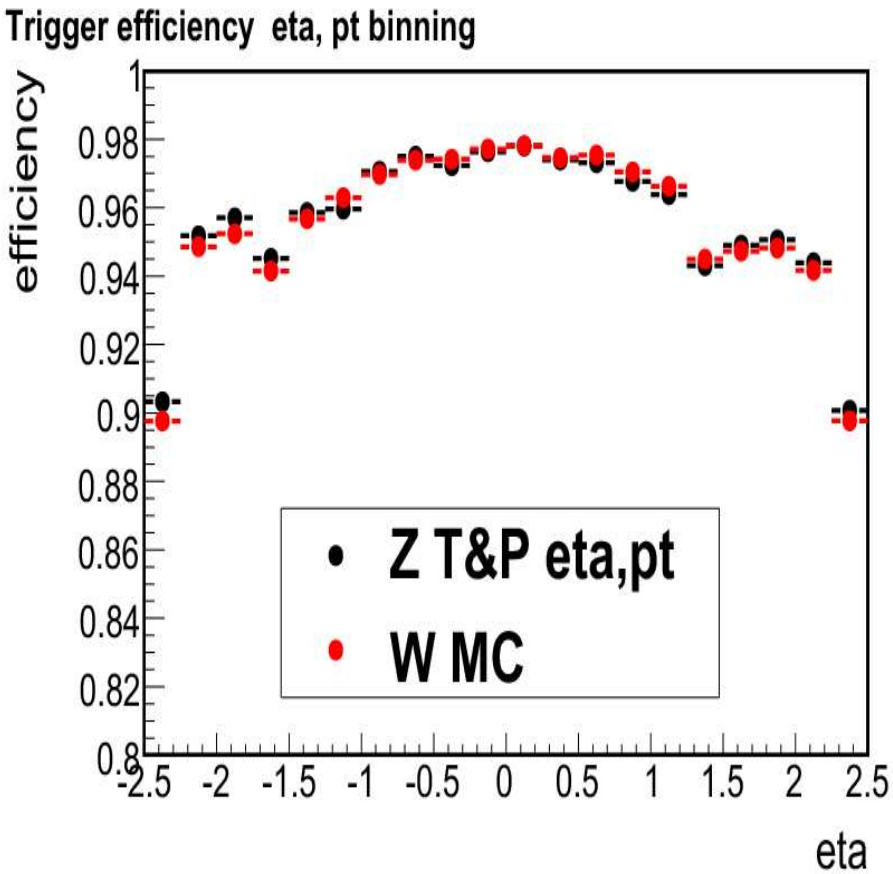
Tag & Probe Method (I)

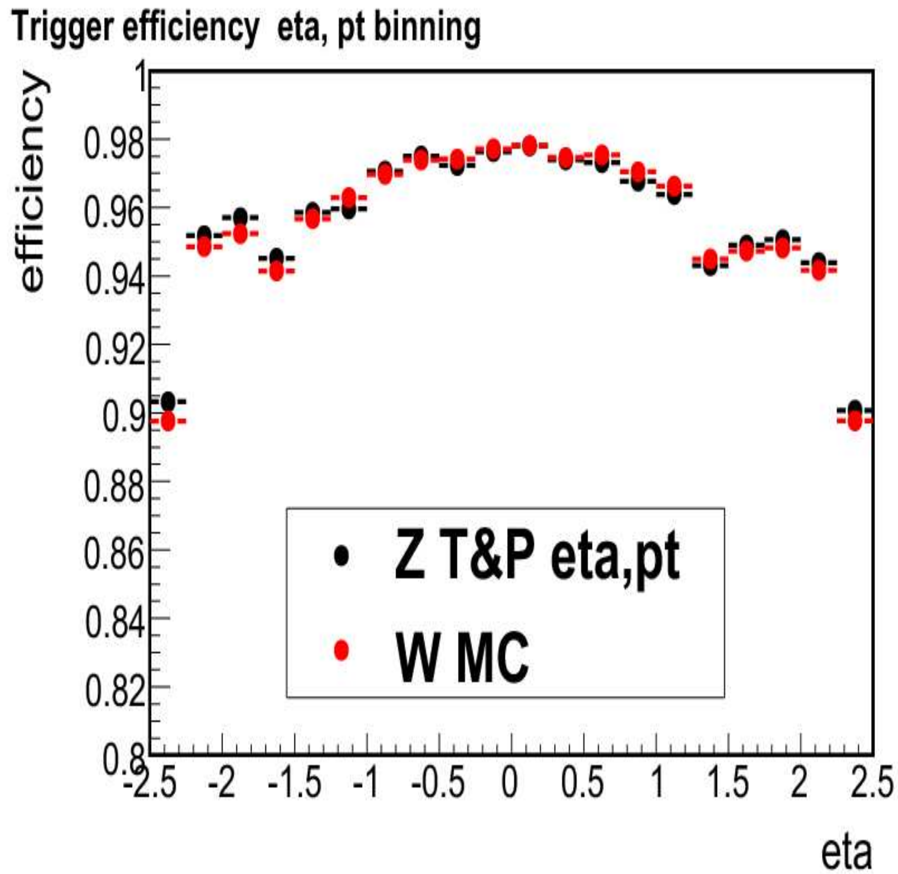


☞ Select one good identified lepton (tag)

☞ Look at the properties of the other side (probe), making use of well-known resonances: $J/\psi \to \ell\ell$, *Upsilon* $\to \ell\ell$ & $Z \to \ell\ell$

Tag & Probe Method (II)



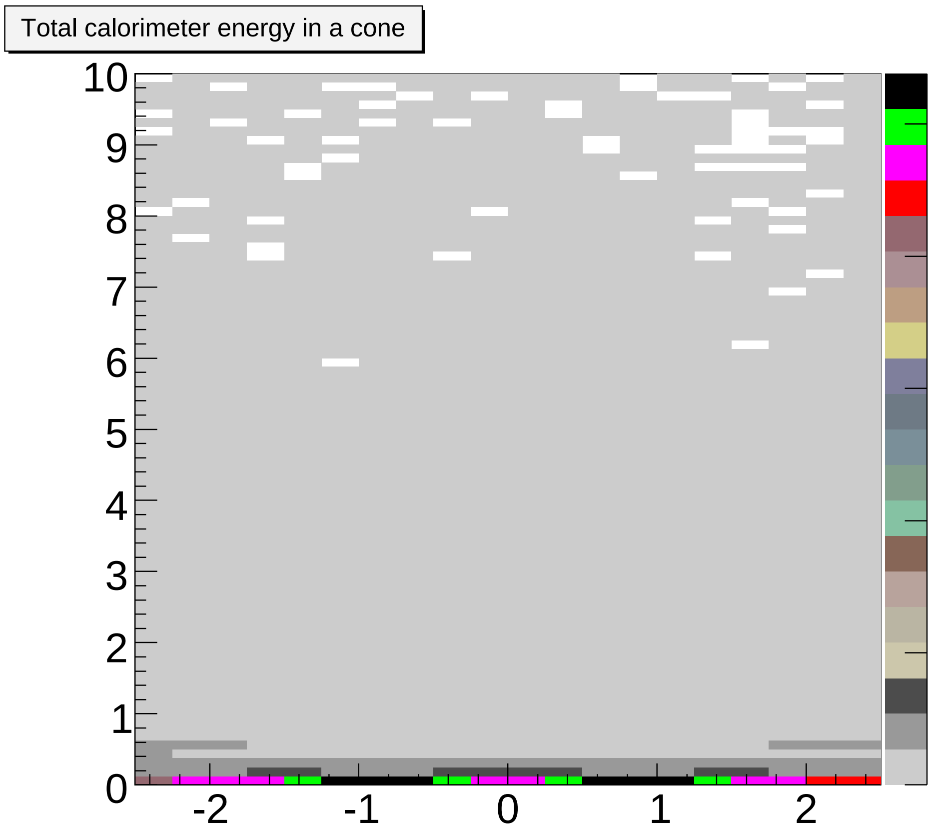


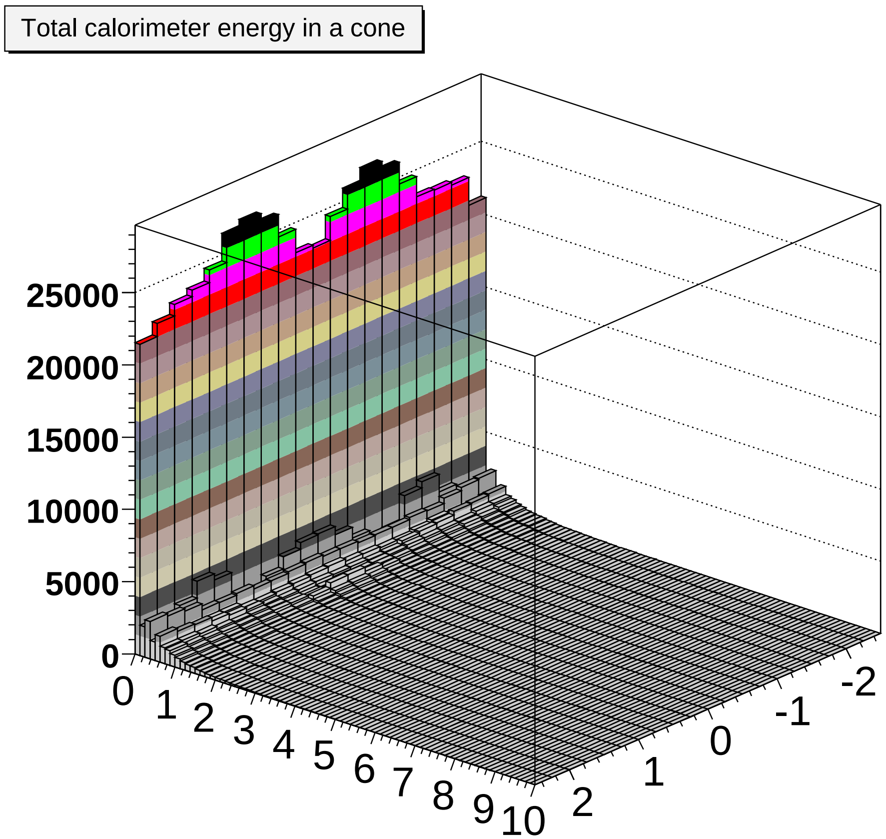
- ☞ Agreement between generation level information and the method is an important sanity check
- ☞ Can estimate lepton and trigger efficiencies with this method

Isolation Studies (I)

- Isolation requirements are important to reject fake leptons
- Random isolation cone for systematic studies:
  - selecting $Z \to \ell\ell$
  - look at random isolation cones removing both lepton legs
- Making sure MC reproduces data:
  - check underlying-event
  - check pile-up
  - check detector effects
- Comparing $Z \to \mu\mu$ MC with $Z \to ee$ MC for now

Isolation Studies (II)





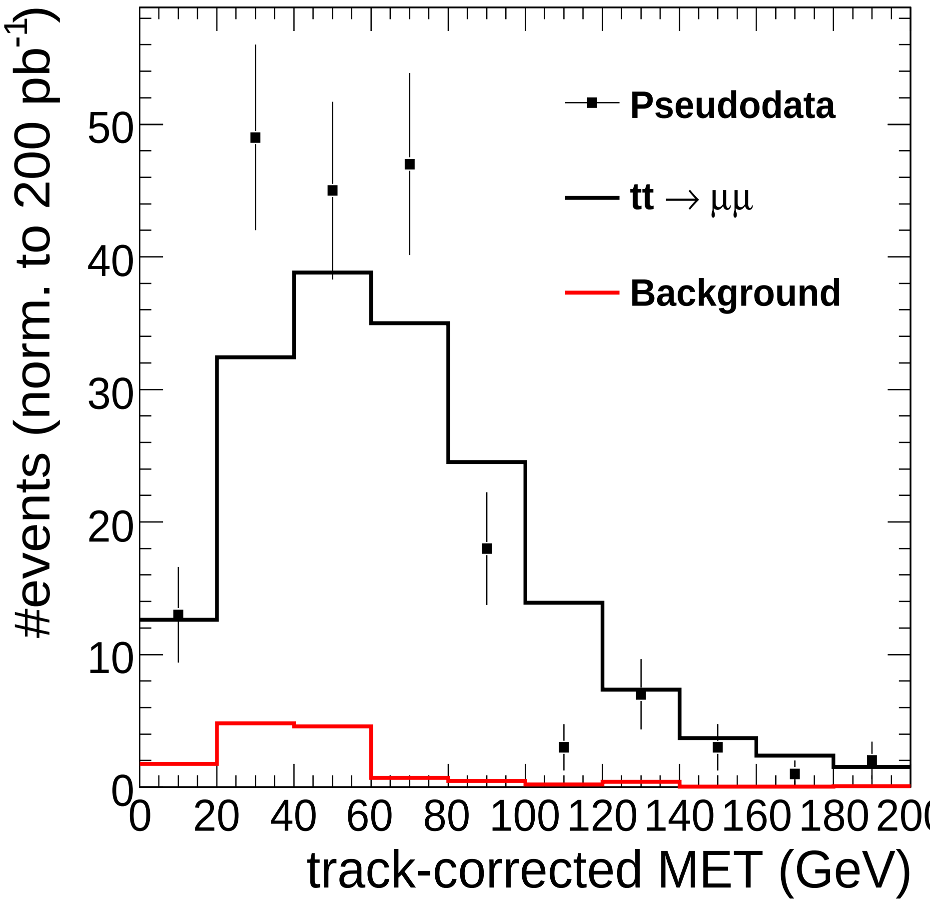
Studies in data should include dependences in η and ϕ

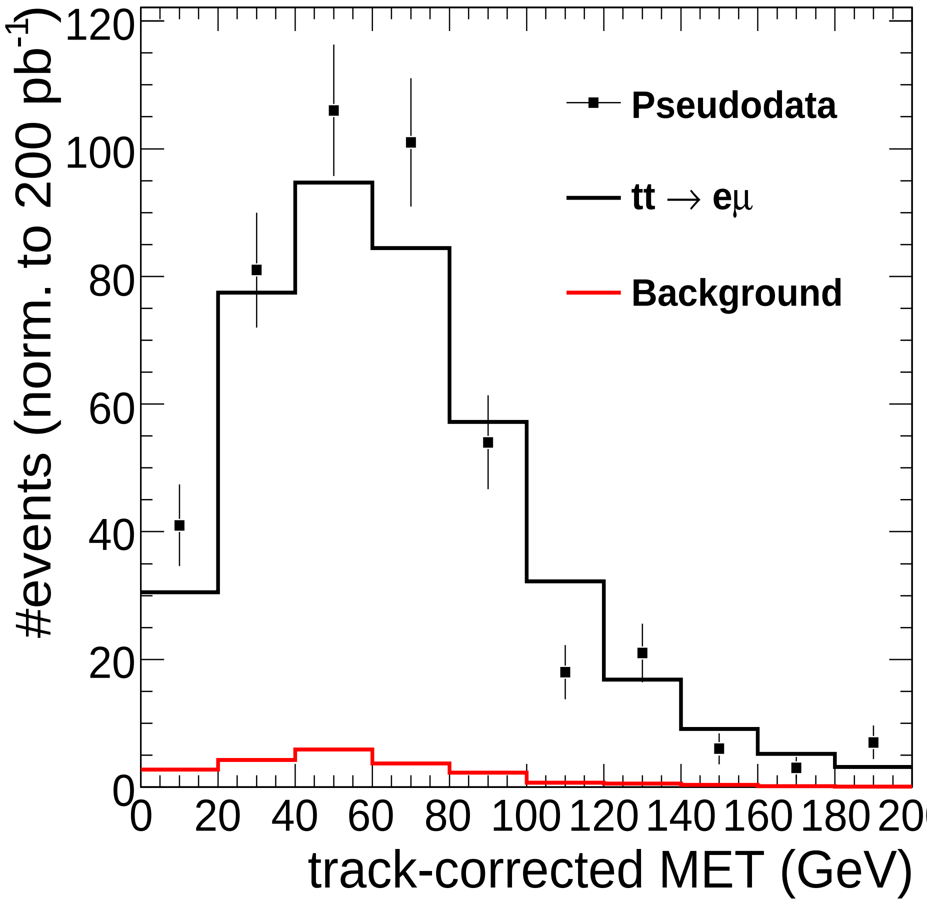
E_T^{miss} Modeling (I)

- ☞ Jet energy scale gives the larger error contribution
- ☞ Studies using $Z \to \ell\ell$ data events vs. $W \to \ell\nu$ MC events:
  - ☞ want to check the behavior of MC events with real E_T^{miss}
  - ☞ compare $W \to \ell\nu$ MC events with real data $Z \to \ell\ell$ events
  - ☞ one lepton is substracted (as if it was a neutrino)
  - ☞ small considerations:
    - ☞ need to rescale MC energies by m_Z/m_W ratio
    - ☞ need to impose same kinematical requirements to the neutrino in MC as the (substracted) muon in data
- ☞ Studies $t\bar{t} \to 2l2\nu 2b$:
  - ☞ selecting $t\bar{t} \to 2l2\nu 2b$ events with -no- E_T^{miss} requirements
  - ☞ making use of b-tagging and tighter Z veto requirement
  - ☞ able to study E_T^{miss} on a clean data sample
- ☞ Studies to check E_T^{miss} resolution:
  - ☞ QCD, $\gamma + jets$ and $Z \to \ell\ell$ events

E_T^{miss} Modeling (II)

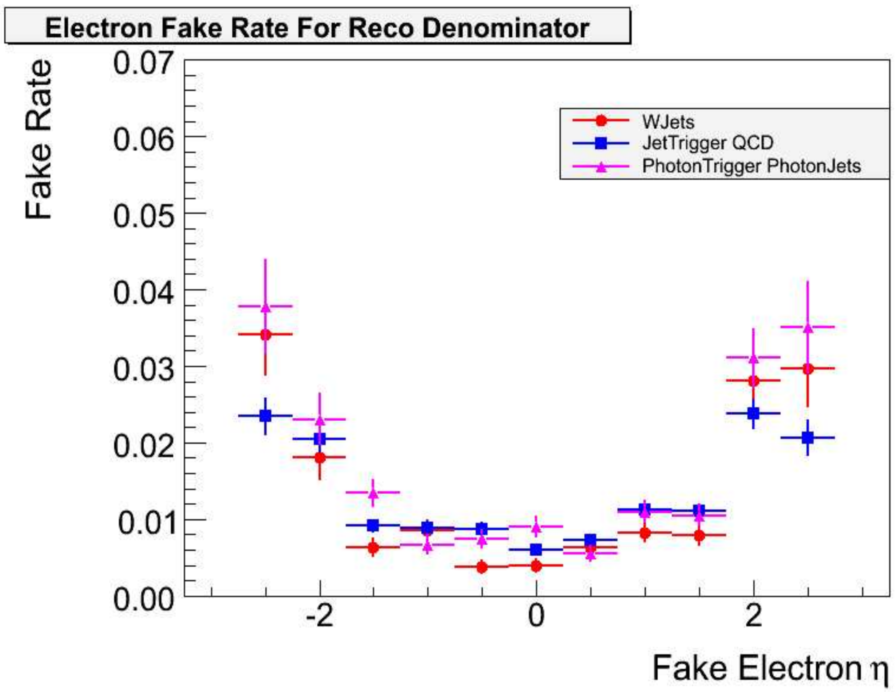
E_T^{miss} on $t\bar{t} \to 2\mu 2\nu 2b$ & $t\bar{t} \to e\mu 2\nu 2b$ events

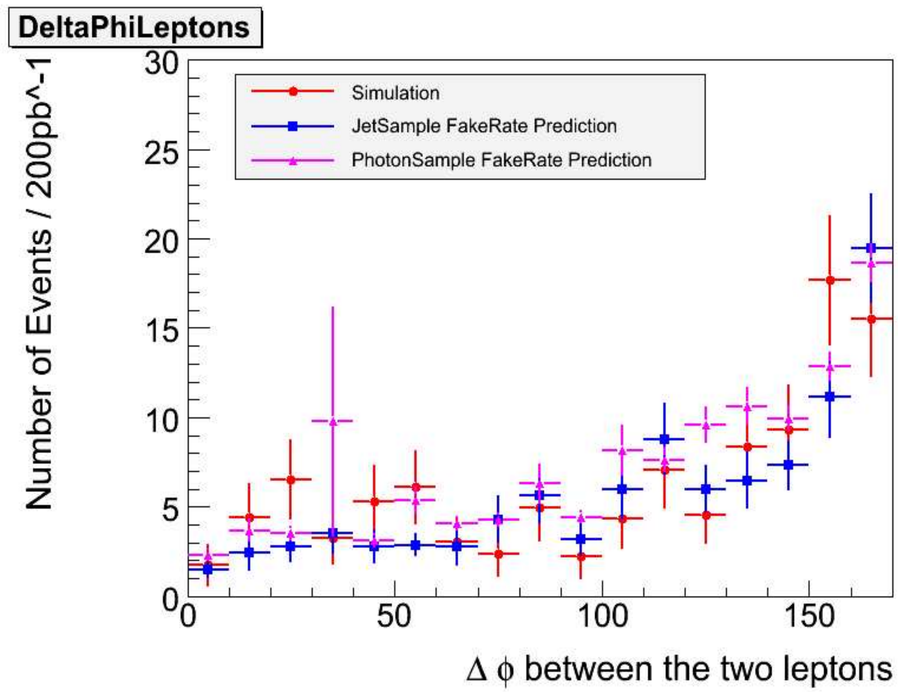




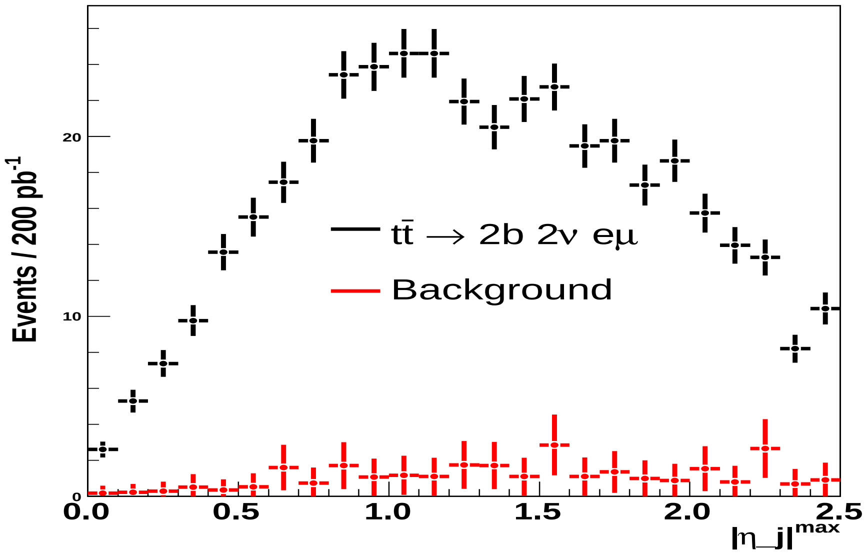
Lepton Fake Rate Method

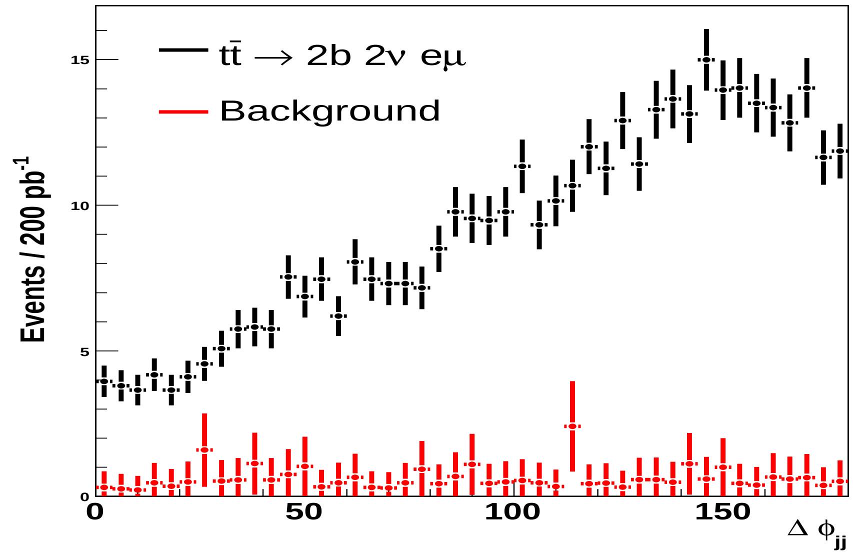
- ☞ In an orthogonal fake dominated sample, measure probability that a loose lepton-like denominator object passes tight lepton cuts
- ☞ For 2 ℓ final states: apply probability as a function of p_T, η in events with 1 lepton + any number of denominators to obtain the prediction for 1ℓ+fake events

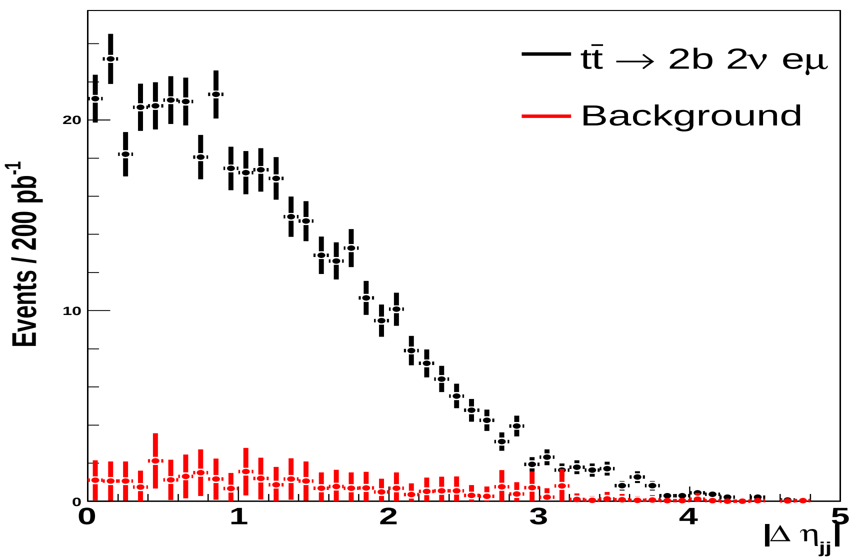


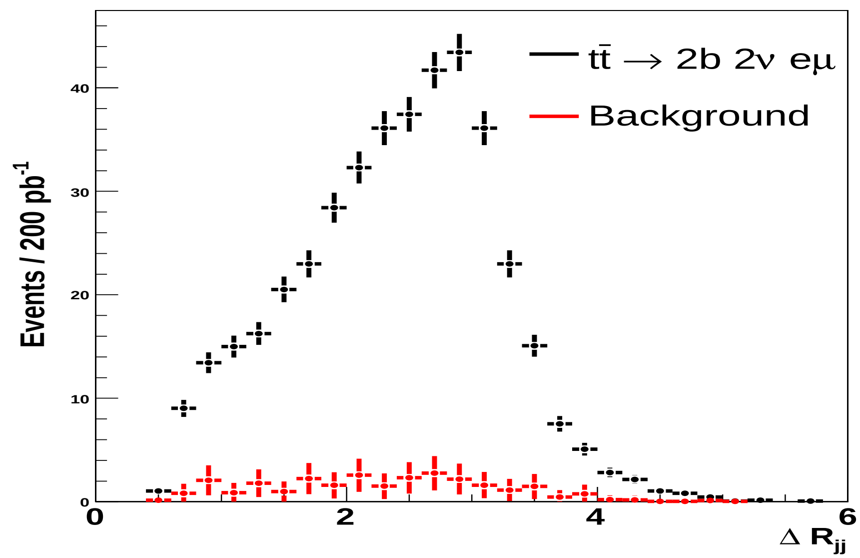


Jet Angular Distributions for $t\bar{t} \to 2l2\nu2b$ Events









Etc…