Taus in Higgs searches

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on behalf of the HiggsWG

Tau Workshop Copenhagen, April 17th

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Background estimation from data by rescaling/embedding

- ttbar, $t\rightarrow Wb\rightarrow \mu\nu b \Rightarrow t\rightarrow Wb\rightarrow \tau\nu b$ (***C. Isaksson***)
- $Z\rightarrow ee \Rightarrow Z\rightarrow \tau\tau\rightarrow ee+4\nu$ (***K. Leonhardt***)
- $Z\rightarrow \mu\mu \Rightarrow Z\rightarrow \tau\tau$ (***M. Schmitz***, ***N. Möser***)

Estimation of fake-tau $t\bar{t}$ background for light H+ search (***T. Ehrich***)

Tau Triggers in Higgs-Analyses

- VBF $H\rightarrow \tau\tau\rightarrow lh$ (***N. Möser***)
- VBF $H\rightarrow \tau\tau\rightarrow hh$ (***Z. Czyczula***, ***O. Igonkina***, ***S. Xella***)
- $H^{+}\rightarrow \tau(had)\nu$ (***E. Coniavitis***, ***M. Flechl***)

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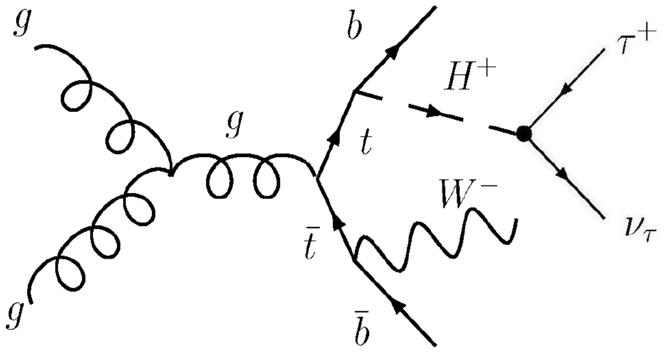
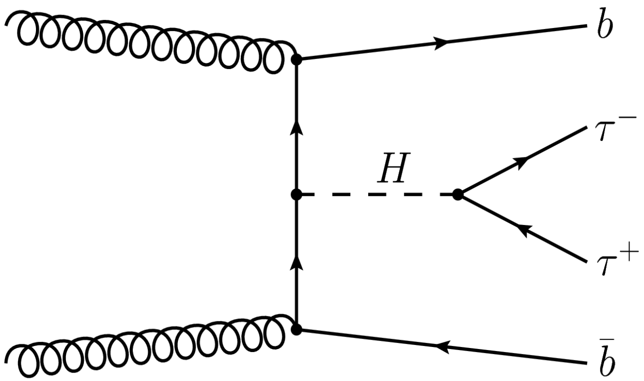
Signal Processes

***(very) short reminder: Higgs searches involving taus** (as covered in this talk)*



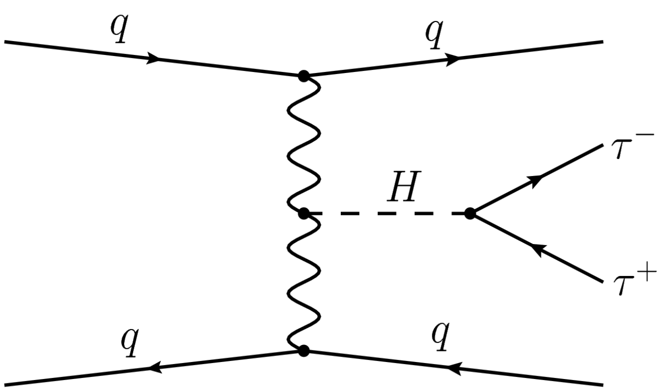
charged Higgs production in top quark decays:

- large cross section in some BSM models
- Higgs mass below top mass



b-quark associated production:

- MSSM: enhanced cross section for large tan beta
- higgs mass can be reconstructed w/ collinear approximation



vector boson fusion:

- 2 high-pt tagging jets
- no colour-flow between tagging jets
  ⇒ hadronic activity in central region suppressed
- higgs mass can be reconstructed w/ collinear approximation

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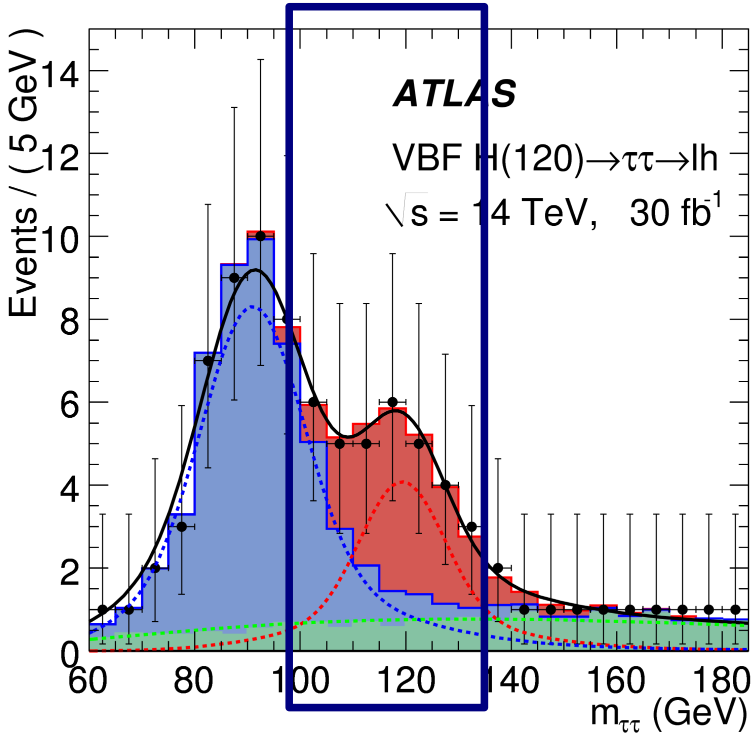
Background estimation from data by rescaling/embedding

Motivation

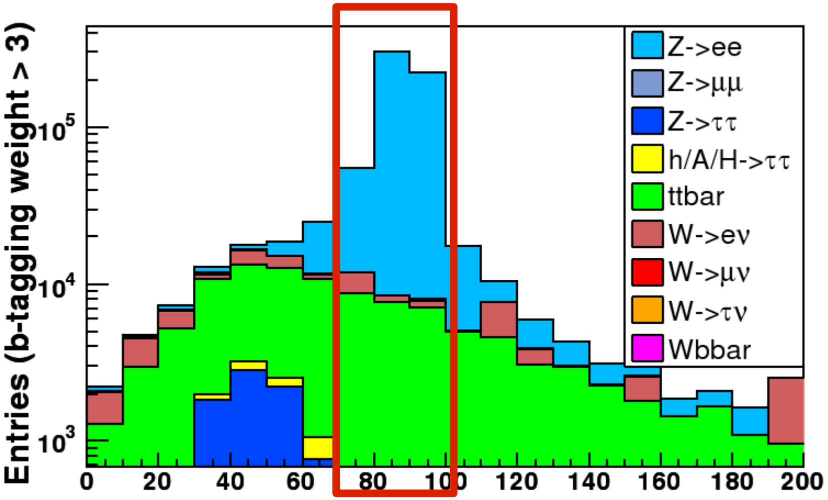
- Signal on top of non-flat background
- large theoretical uncertainties (MC)
- Need control sample from data
- Not always possible/easy to get signal free



→ select kinematically identical, but signal free sample

→ replace leptons with other simulated leptons

→ obtain control sample with minimal MC input



(after suitable cuts)

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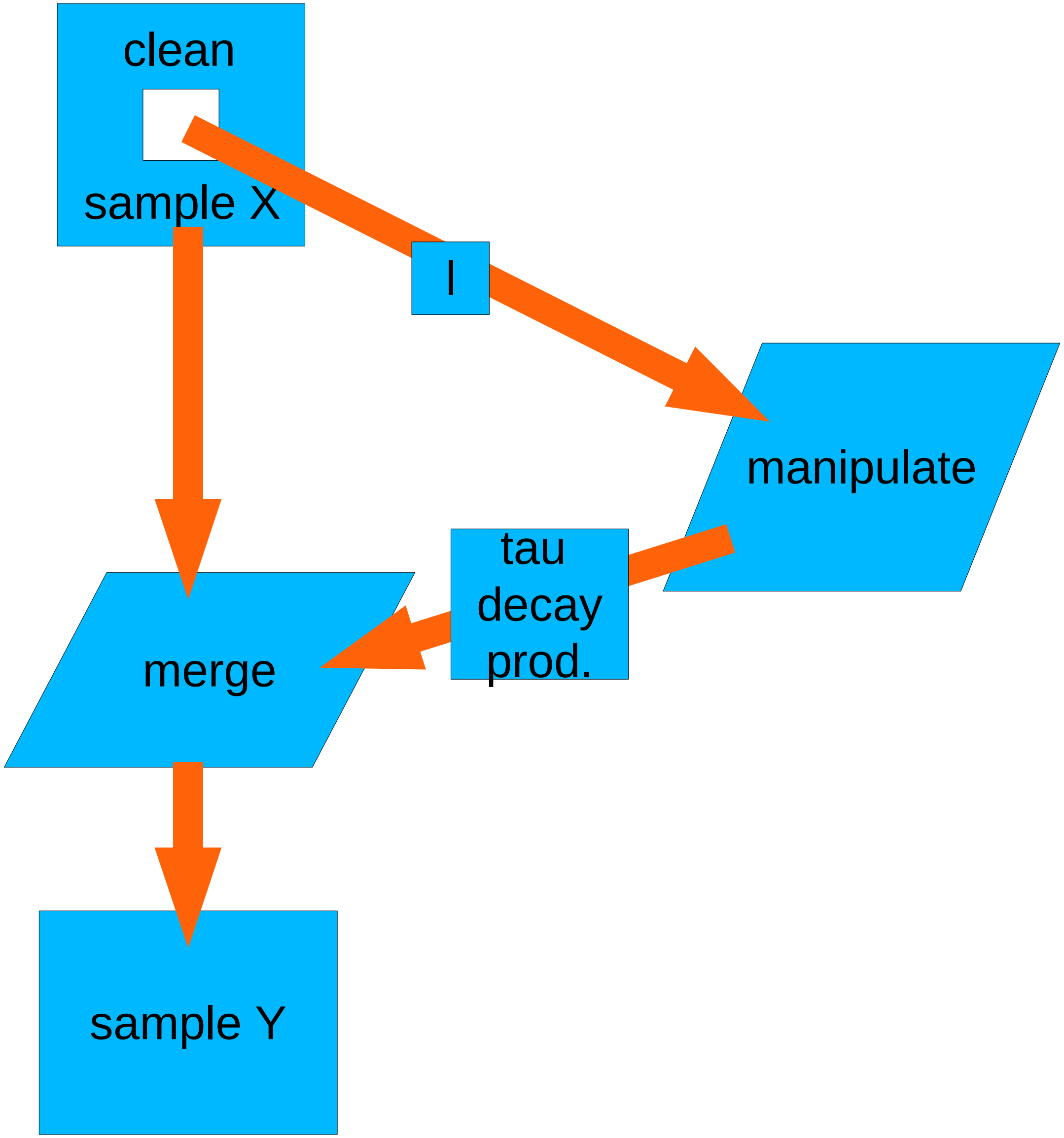
General ideas

general procedure
for ALL tools

- take clean sample X
- extract leptons (e/µ)
- manipulate leptons (l)
  ⇒ look like coming from tau decay
- merge tau decay products with remnant of original event
- obtain sample Y



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What's on the market

several tools available/under development (in chronological order):

M. Schmitz* (J. Schaarschmidt)	$Z\to\mu\mu \Rightarrow Z\to\tau\tau$ (app. to bbA, $A\to\tau\tau$)	rescale in Z rest frame w.r.t. ref. histograms
T. Vickey*	$Z\to\mu\mu \Rightarrow Z\to\tau\tau$, ttbar, $W\to\mu\nu \Rightarrow W\to\tau\nu$	decay μs w/ Tauola, run Det. simulation, replace objects
M. Schmitz, N.Möser	$Z\to\mu\mu \Rightarrow Z\to\tau\tau$	decay μs w/ Tauola, run Det. simulation, replace tracks/cells re-run reconstruction (ESD)
K. Leonhardt	$Z\to ee \Rightarrow Z\to\tau\tau\to ee+4\nu$	rescale cell energy of electrons w.r.t. ref. histograms, re-run reconstruction (RDO)
C. Isaksson	ttbar, $W\to\mu\nu \Rightarrow W\to\tau\nu$	replace cells/tracks in small cone, overlay rest, re-run reco.

**** already documented in CSC***

will concentrate on tools with recent results (light blue)

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Z→μμ ⇒ Z→ττ (I)

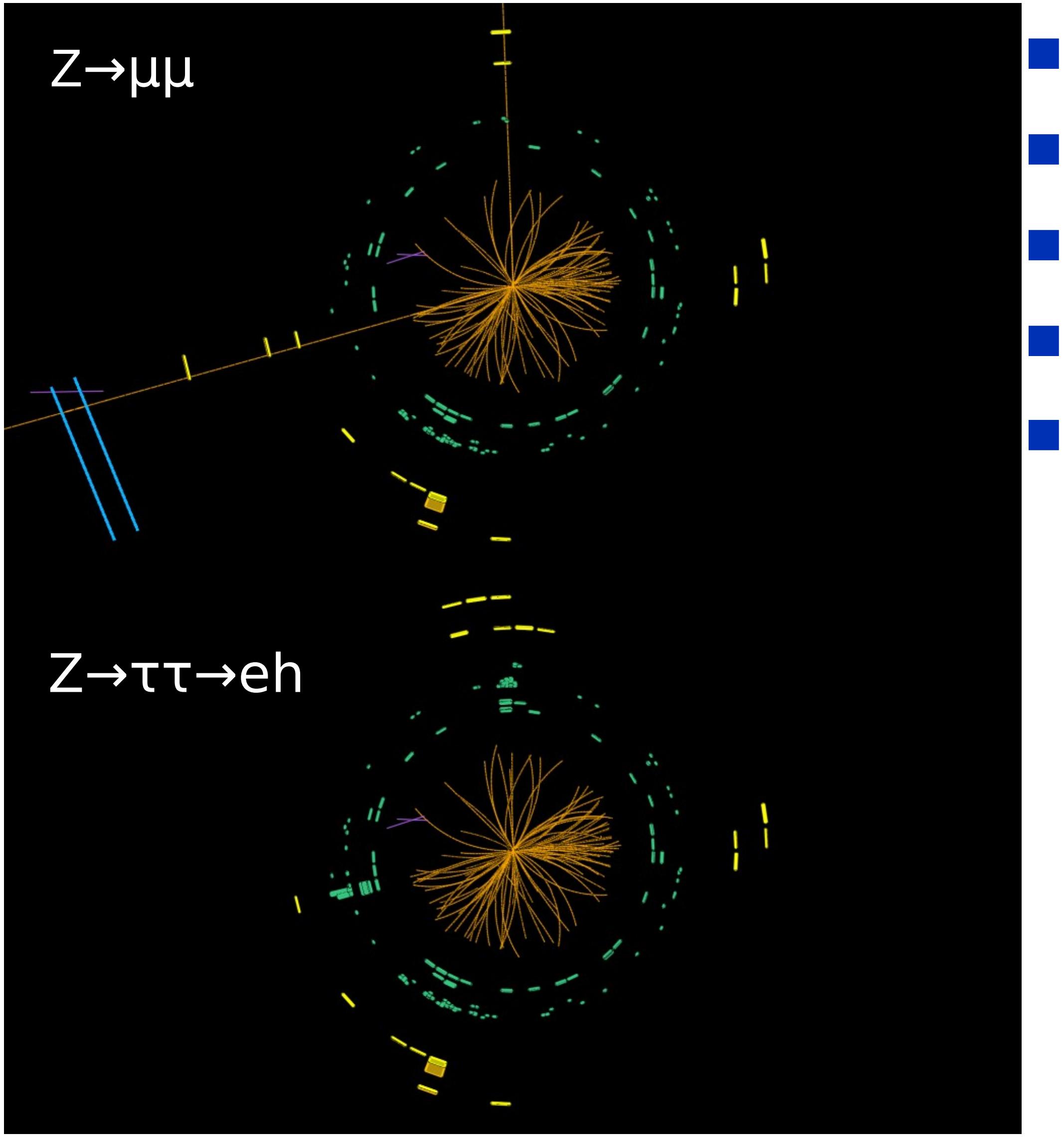
Z→ττ dominant background to VBF H→ττ select Z→μμ, obtain all ll, lh, (hh) final states

- let Tauola decay muon pair from Z→μμ
- simulate/digitize/reconstruct tau pair

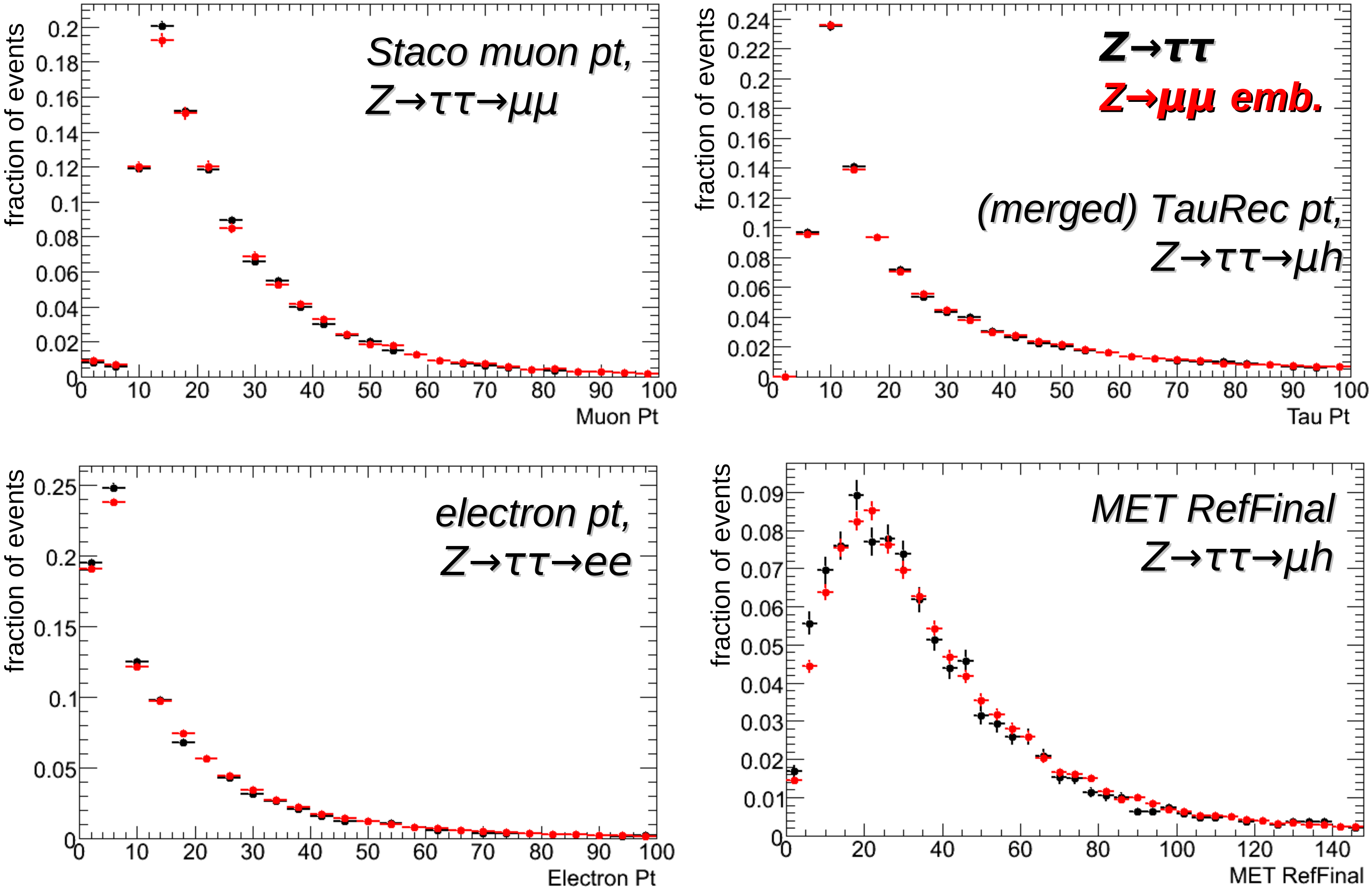
- ***in cone around orig. μ replace:*** calo-cells, MS track segments
- ***replace muon track*** with tracks associated to tau decay product

- ***re-reconstruct*** event (ESD)

- reproduce only shape; normalization: cp. studies by M. Schmitz, J. Schaarschmidt



$Z \to \mu\mu \Rightarrow Z \to \tau\tau$ (II)



basic ingredients for mass reconstruction

(lepton momenta, MET) in good agreement

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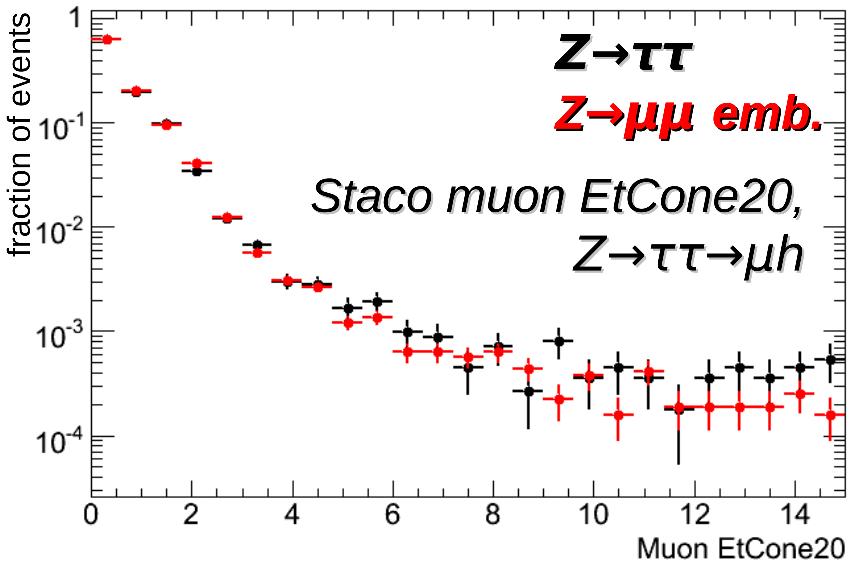
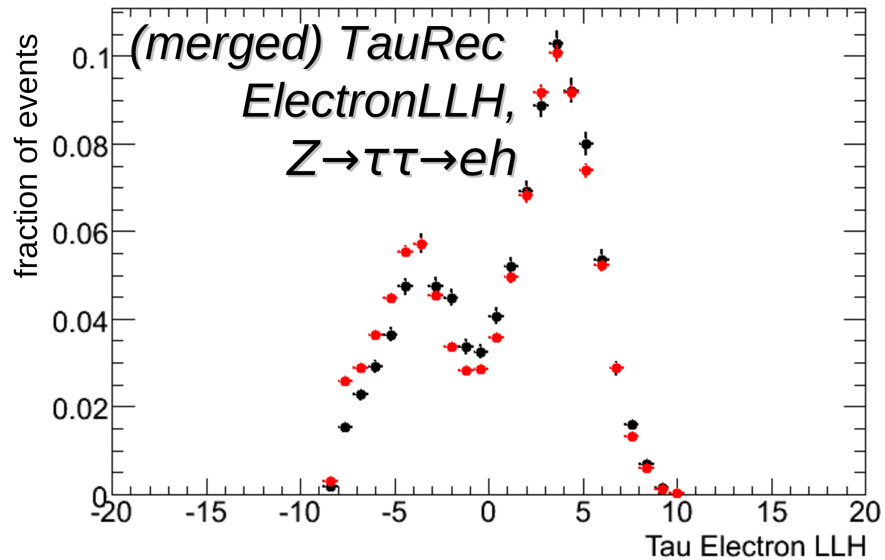
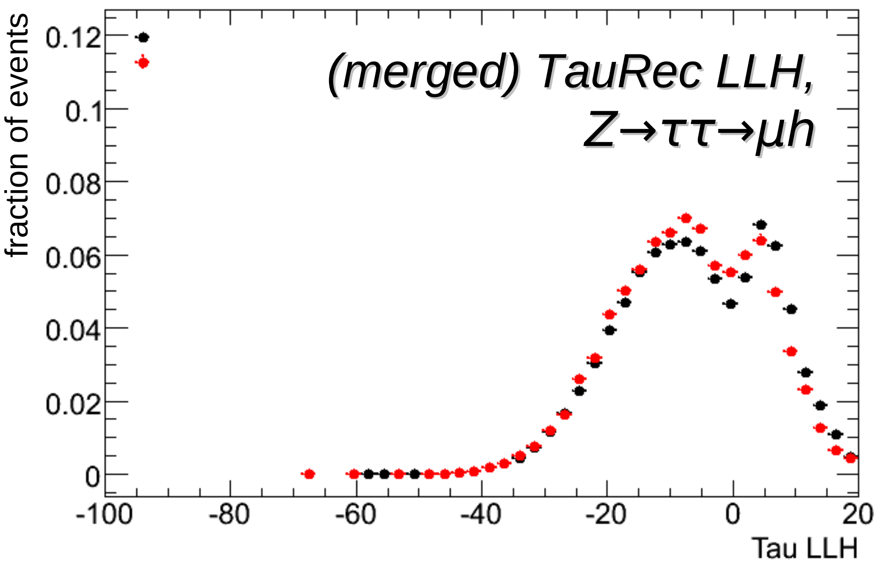
Z→μμ ⇒ Z→ττ (III)







analysis relevant variables (examples):

- some deviations but mostly in reasonable agreement

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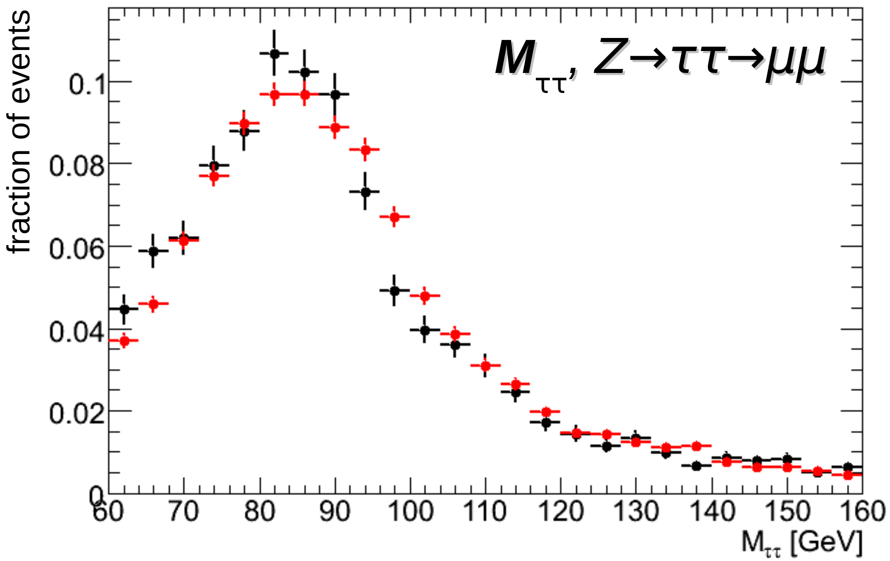
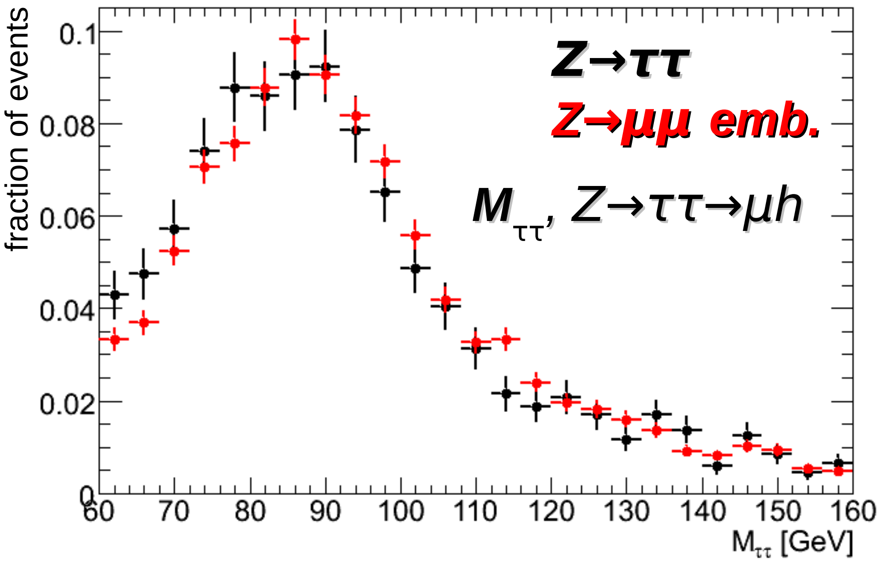
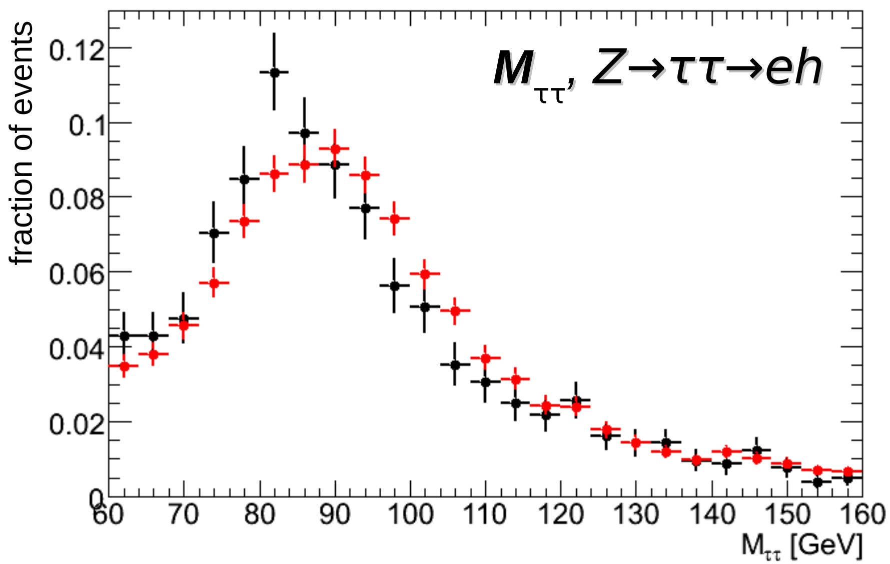
Z→μμ ⇒ Z→ττ (IV)







small shift in $M_{\tau\tau}$ distributions

- under investigation

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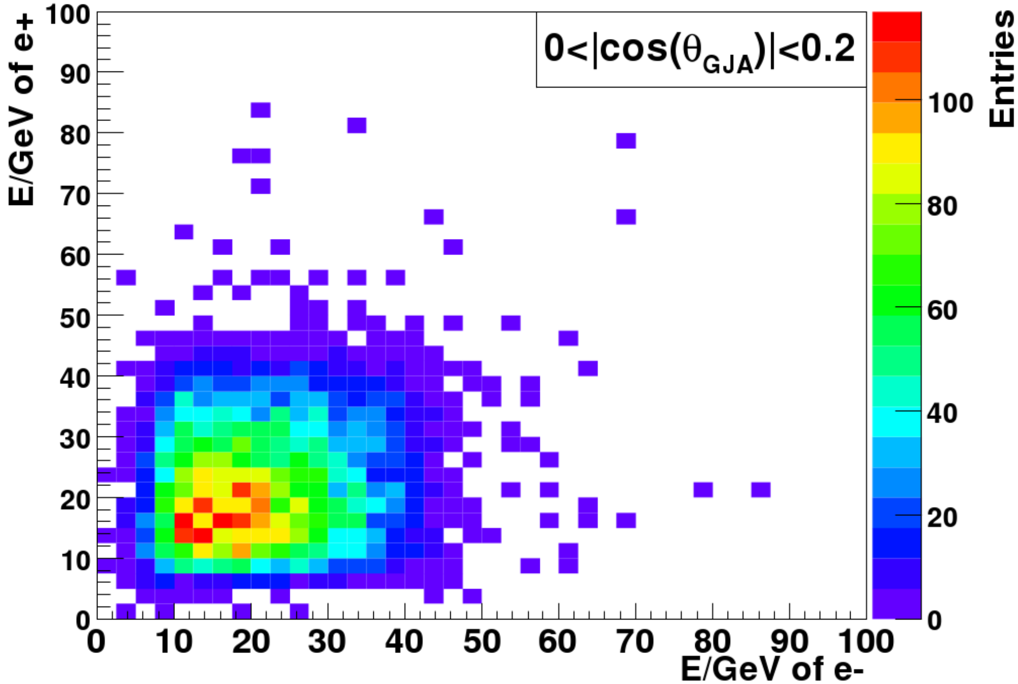
Z→ee ⇒ Z→ττ→ee+4ν (I)

Z→ττ→ee+4ν dominant
bg. to bbh/H/A, h→ττ→ee+4ν
estimate from Z→ee



select electrons from Z→ee

- ***match electrons with TauJets***
- boost back electrons to ***Z rest frame***

- ***rescale energy deposition*** of cells associated to tau-clusters
- ***obtain rescaling factor w.r.t. reference histograms***; function of gottfried-jackson angle (similar to M. Schmitz/J. Schaarschmidt)

- ***re-reconstruct*** event (RDO) (would also work on ESD-level)

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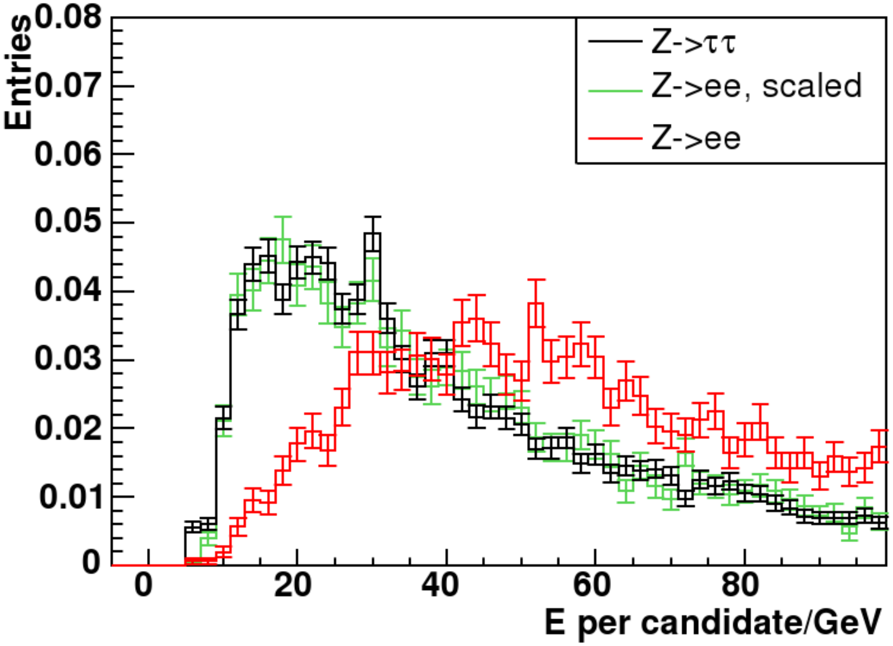
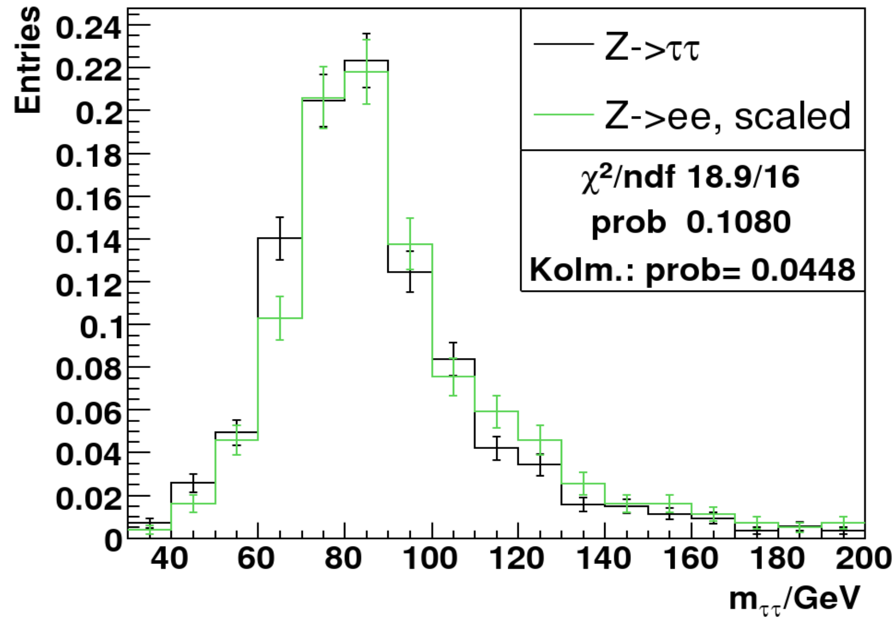
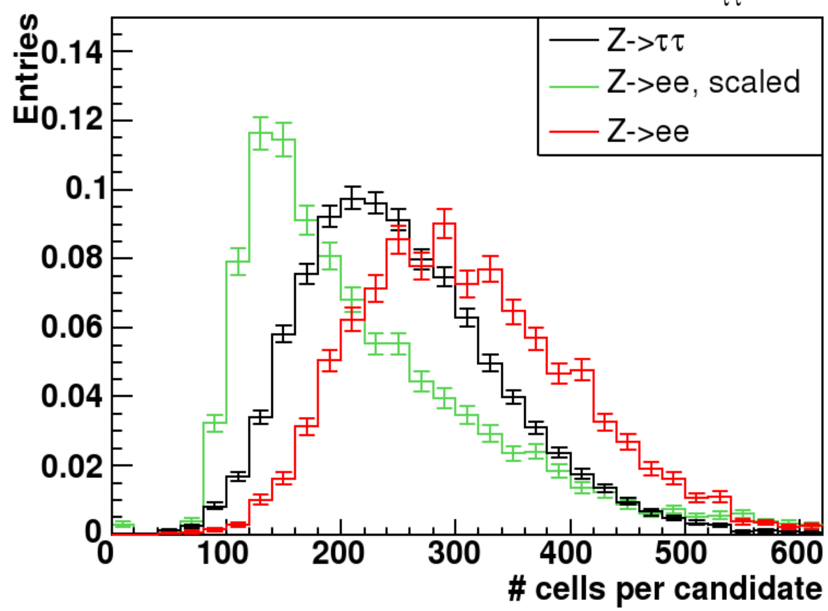
Z→ee ⇒ Z→ττ→ee+4ν (II)







Energy per candidate and $M_{\tau\tau}$ are reproduced well.

Global rescaling factor: cluster topology is not considered

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ttbar (I)

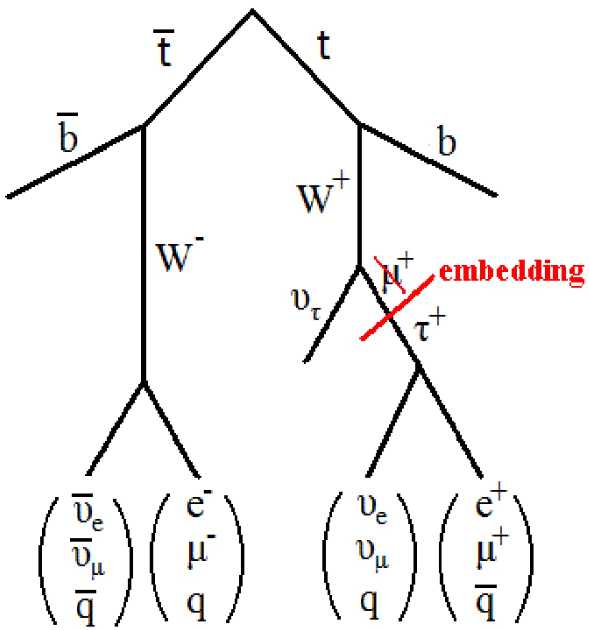
ttbar w/ one W decaying to a τ
main background to
$H^+\rightarrow\tau\nu$ production from top decays

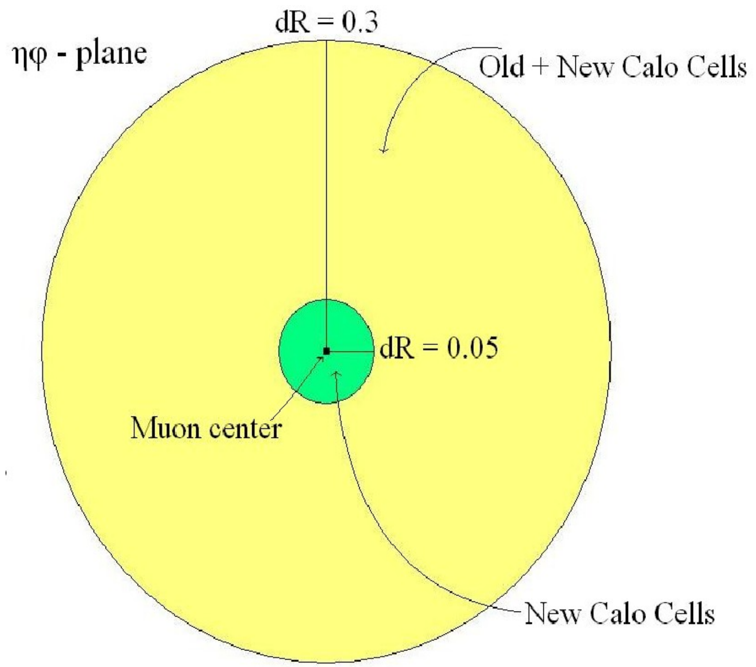
separate development of early
Bonn embedding-code

- select μ from W decay
- Tauola decays single muon as tau
- simulation/digitization/reconstruction of tau

- ***in small cone*** around orig. muon: replace energy deposition of cells
- ***in large cone*** around orig. muon: add energy deposition of simulated tau decay to original cell energy
- ***replace muon tracks*** with tracks of tau decay product

- ***re-reconstruct*** event (ESD)





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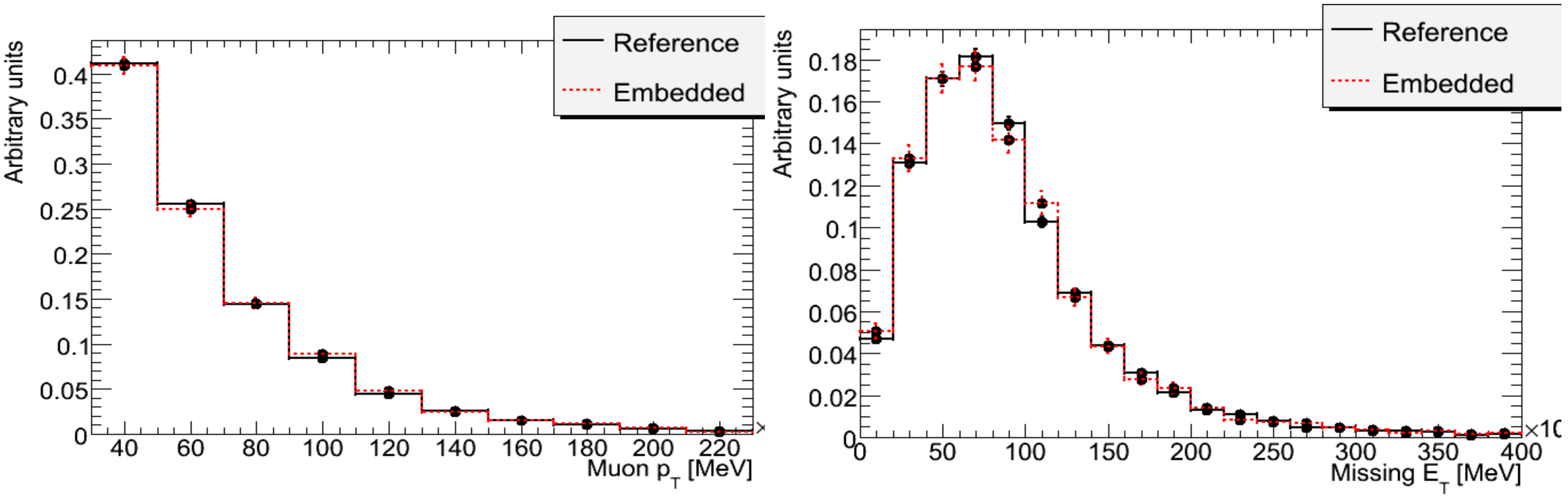
ttbar (II)



fully leptonic decay mode: ttbar→(τνb)(μνb)→(μννb)(μνb)

(muons w/ pt > 30 GeV) basic quantities, muon momenta,
MET in ***good agreement***

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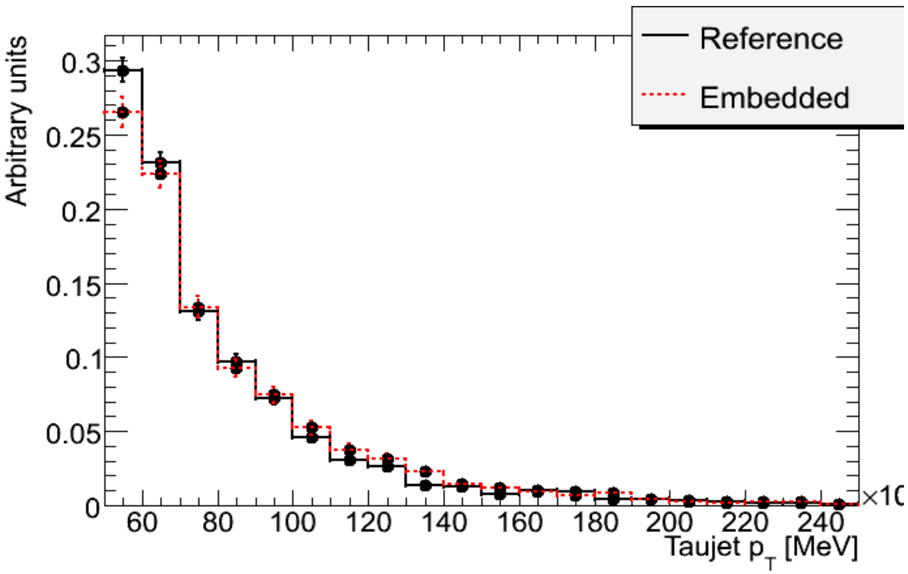
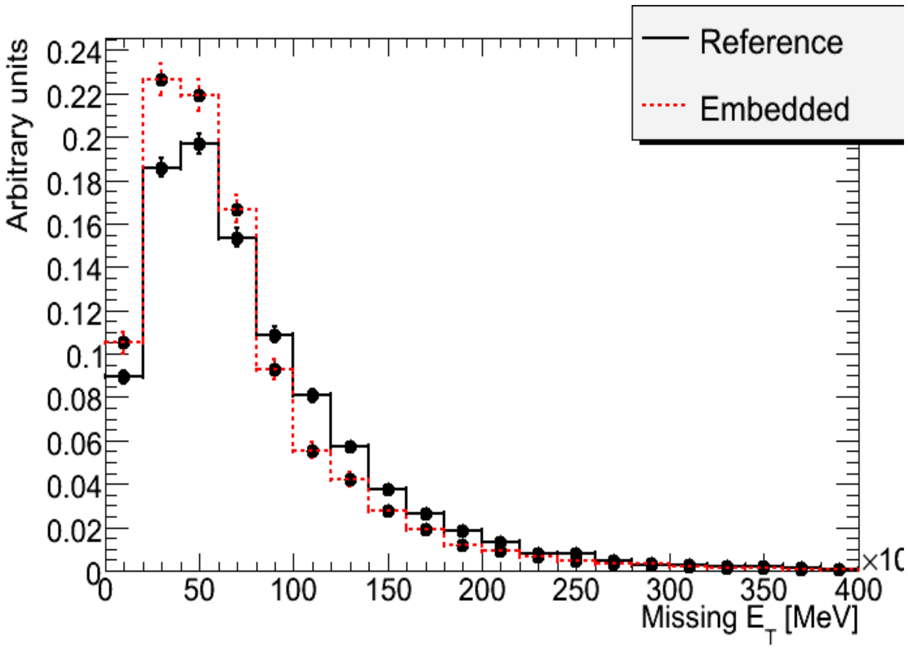
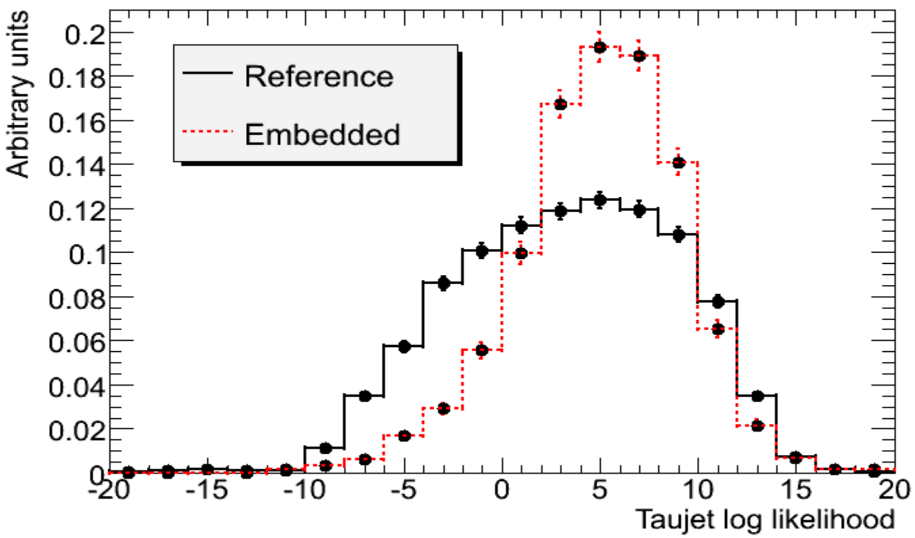
ttbar (III)







fully hadronic decay mode:

ttbar→(τνb)(qqb)→(hνb)(qqb)

- TauJets above Pt threshold in resonable agreement
- MET shifted to smaller values (effect already visible on truth level)
- deviation in Tau Likelihood: might be due to cleaner single tau environment

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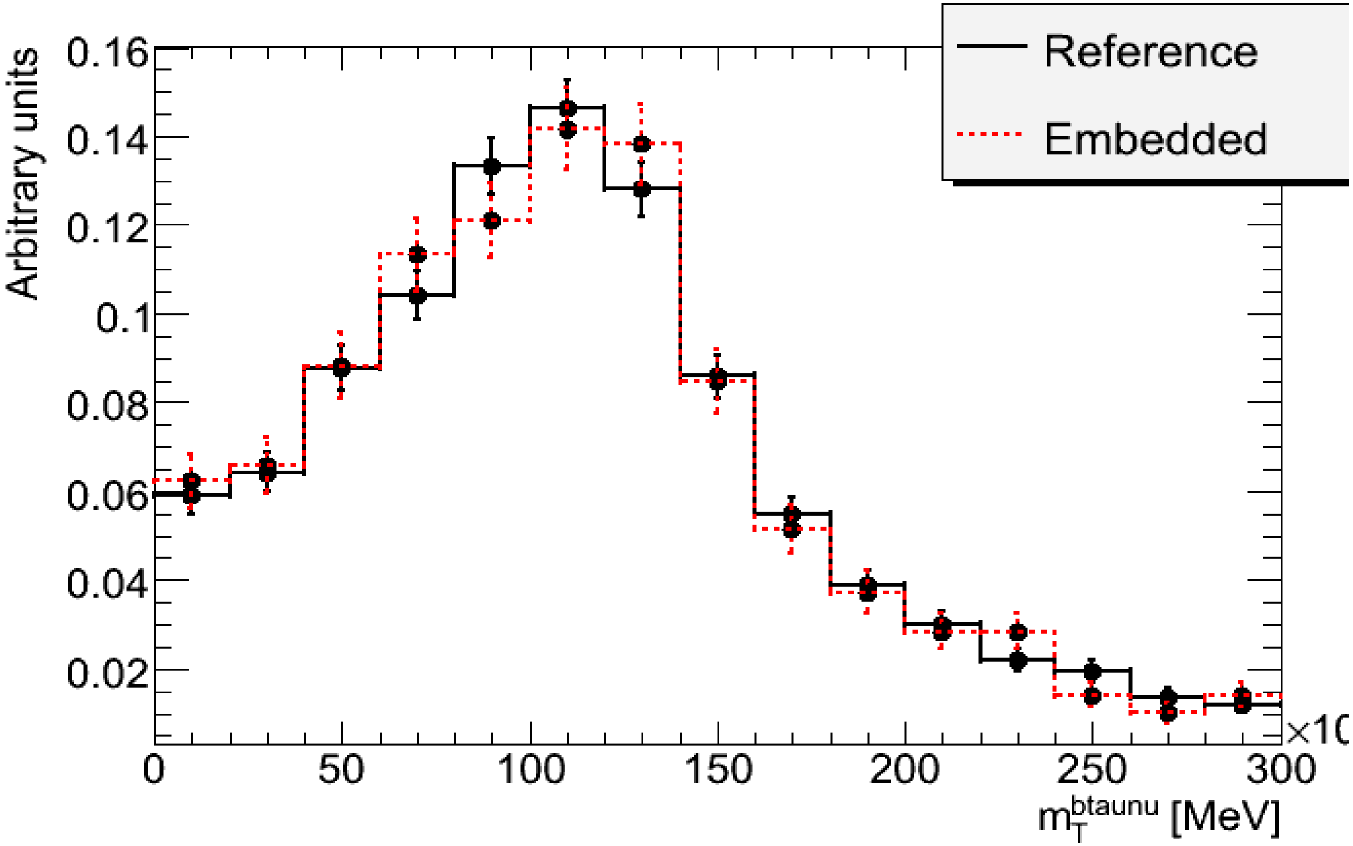
ttbar (IV)



despite deviations in input variables:

reconstructed transverse mass of the top quark
in ***good agreement***

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Summary Background Est.

tools to estimate background by rescaling/embedding are making good progress! general: need to study effects of pile-up

Z→μμ ⇒ Z→ττ:

- basic quantities (lepton momenta, MET) in good agreement
- most variables relevant for analysis are reproduced
- small shift in Mtautau distribution, a few other open issues
- future plans: make code available to collaboration, estimate sys. uncertainties

Z→ee ⇒ Z→ττ→ee+4ν:

- total energy per candidate in good agreement, small shift in Mtautau distribution
- global rescaling factor: shower shapes are not reproduced
- future work rescale cell energy while taking shower shapes into account

ttbar, t→Wb→μνb ⇒ t→Wb→τνb:

- good agreement for μμ channel
- deviations for had. tau decays
- Future: Embed already on track hits level and reconstruct the tracks after embedding.

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Estimation of fake-tau $t\bar{t}$ background for light H^+ search

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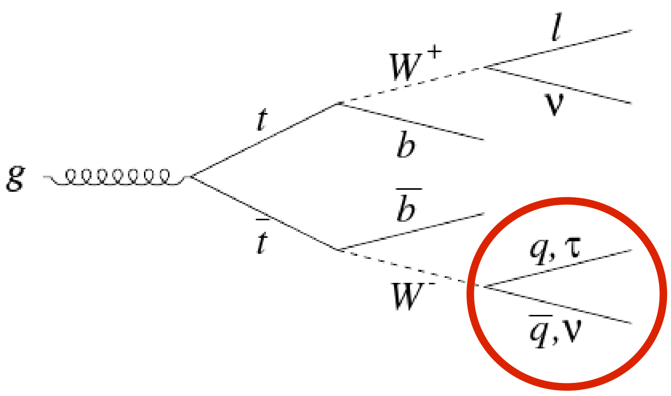
Fake-τ $t\bar{t}$ background (I)



from MC: ~25% of tau jets are faked by ***light jets***

measuring rejection from ttbar data ***not possible*** (origin of tau jet unknown)
⇒ estimate from ***other processes***

rec. tau candidates → $N_{reco} = N_{reco}^{real\ \tau} + N_{reco}^{l.jets}$

identified tau cand. LLH > 2 → $N_{ID} = N_{ID}^{real\ \tau} + N_{ID}^{l.jets}$

efficiency → $e = \frac{N_{ID}^{real\ \tau}}{N_{reco}^{real\ \tau}}$ *here:* from ttbar MC truth

fake rate → $f = \frac{N_{ID}^{l.jets}}{N_{reco}^{l.jets}}$ measure in data

number of fake tau jets: $N_{ID}^{l.jets} = \frac{f}{e-f}(eN_{reco} - N_{ID})$

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Fake-τ $t\bar{t}$ background (II)

define ***weights*** for tau candidates, function of pt

$$\omega = \frac{f}{e-f}(e-1) \ [\tau \text{ is identified}]$$
$$\omega = \frac{f}{e-f}(e-0) \ [\tau \text{ is not identified}]$$

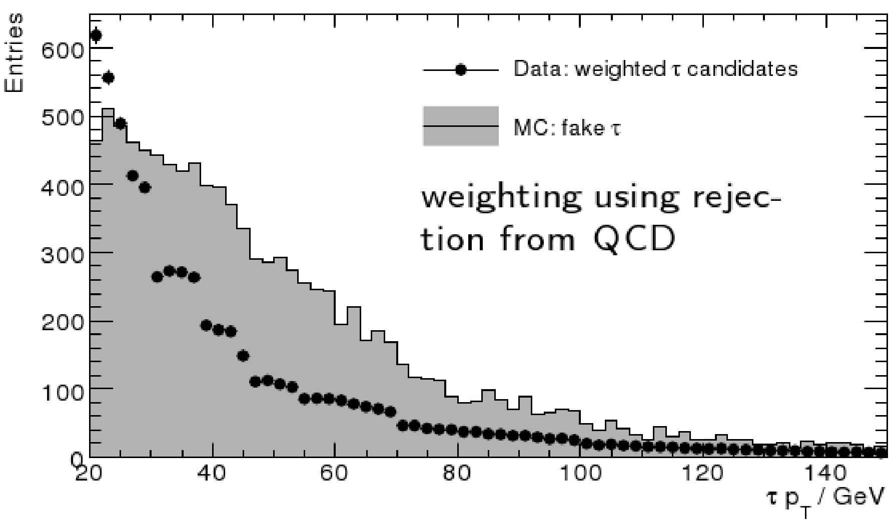
sum up weights, obtain number of fake tau jets:

$$N_{ID}^{l.jets} = \sum^{N_{reco}} \omega_i$$

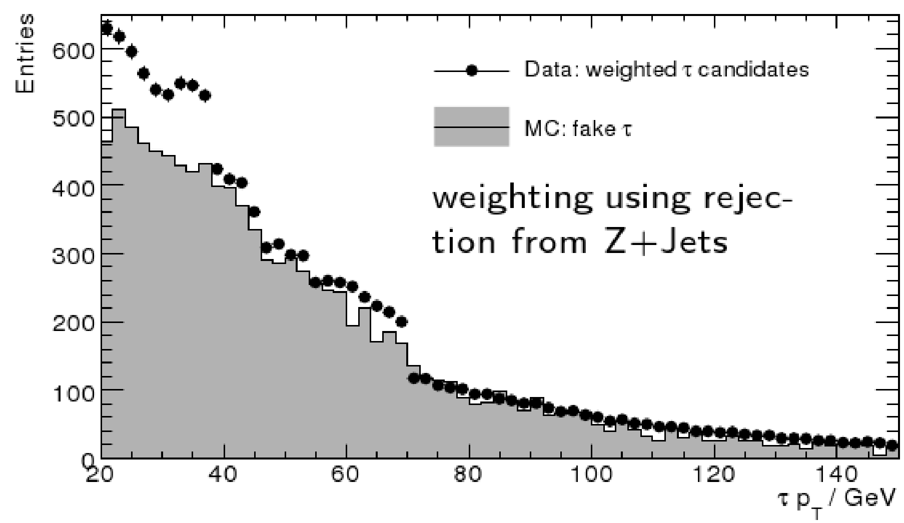
studied two processes:

- QCD di-jets (huge cross section)
- Z→ll + jets (smaller cross section, small background, higher quark content)

QCD di-jets



Z→ll + jets



large ***deviations*** for both processes ⇒ ***need additional binning***

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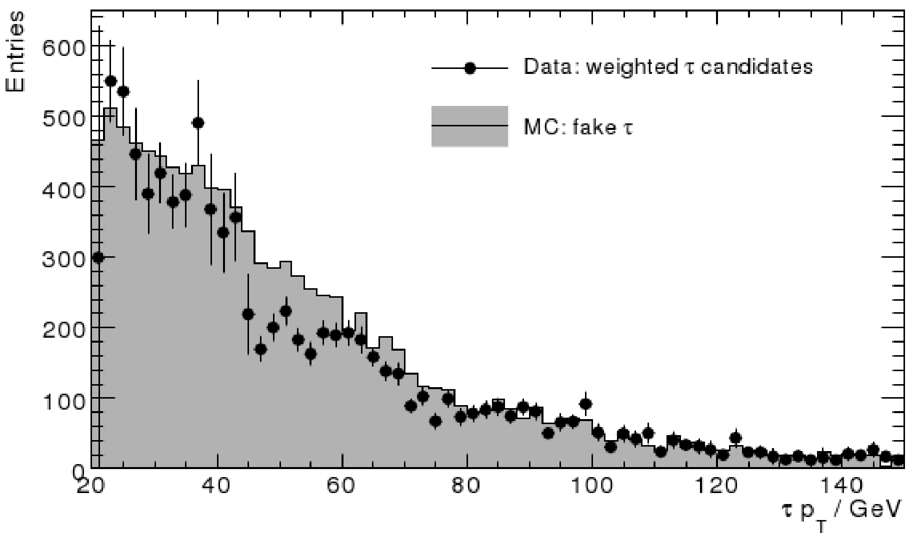
Fake-τ $t\bar{t}$ background (III)

look for other variables to improve estimation of rejection!

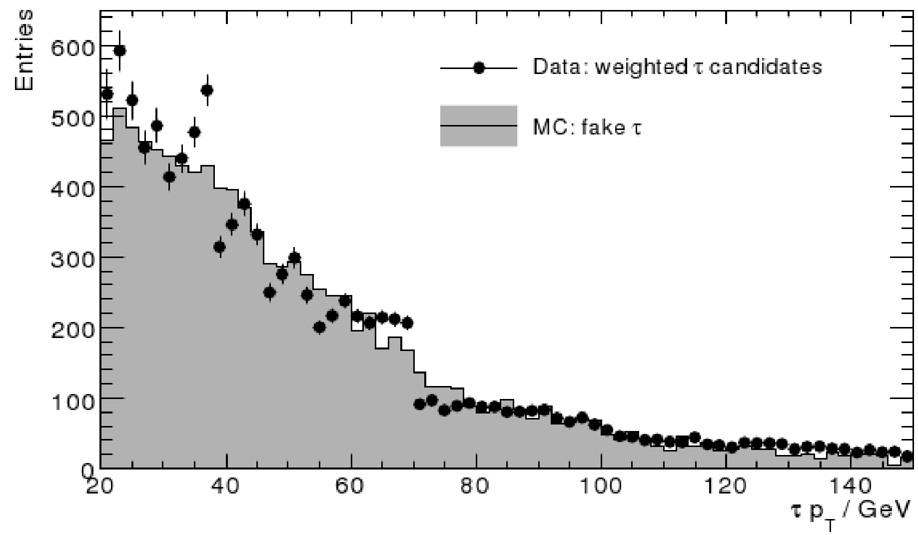
used variables with high discrimination power: (from tau-id)

- EM radius
- track pt / Et ratio

QCD di-jets; pt, Rem, track pt / Et



Z→ll + jets, pt, Rem



- prediction from ***QCD di-jets*** within ~20% (pt-, Rem-, track pt / Et – bins)
- from ***Z→ll + jet:*** ~10% (pt-, Rem-bins; no further improvement w/ track pt / Et)

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Higgs analyses & tau triggers

different issues:

- semi leptonic decay modes:
  can (and would like to) go with single lepton triggers
  ⇒ tau triggers to avoid prescaling or raising pt threshold of e/mu triggers

- fully hadronic decay modes:
  need primary trigger to obtain signal in the first place
  ⇒ need to keep rates low (QCD!)

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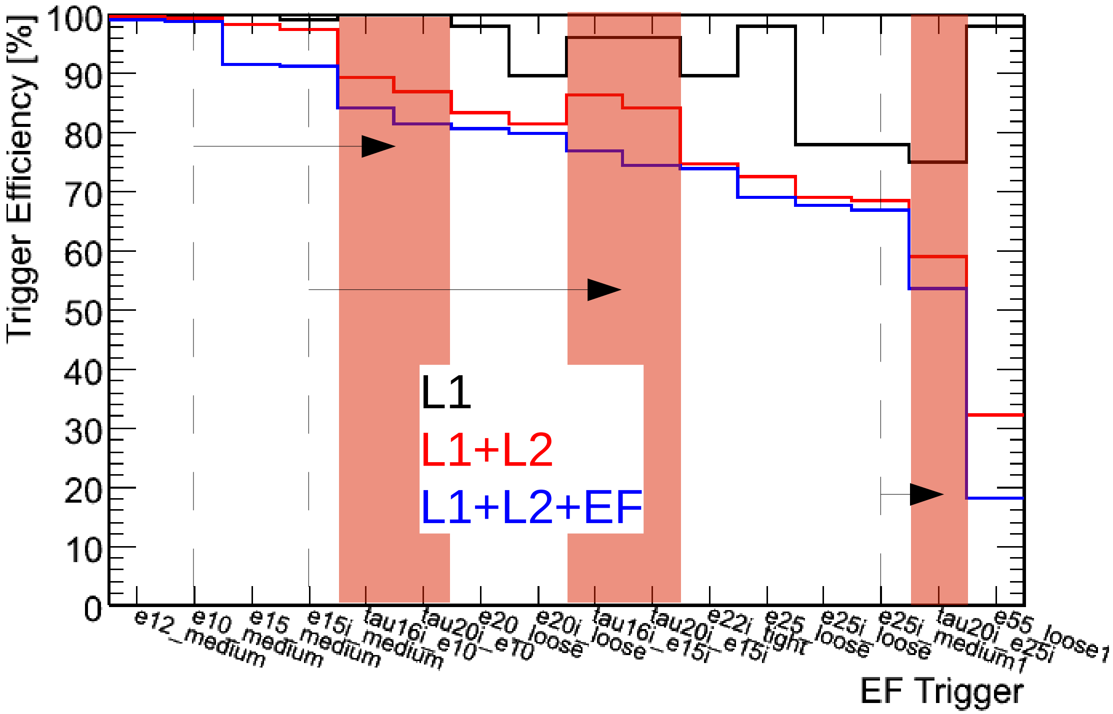
VBF H→ττ→lh (I)

10 TeV signal sample, r604, OFLCOND-00-00-03



efficiencies are calculated w.r.t. (CSC-like) offline analysis

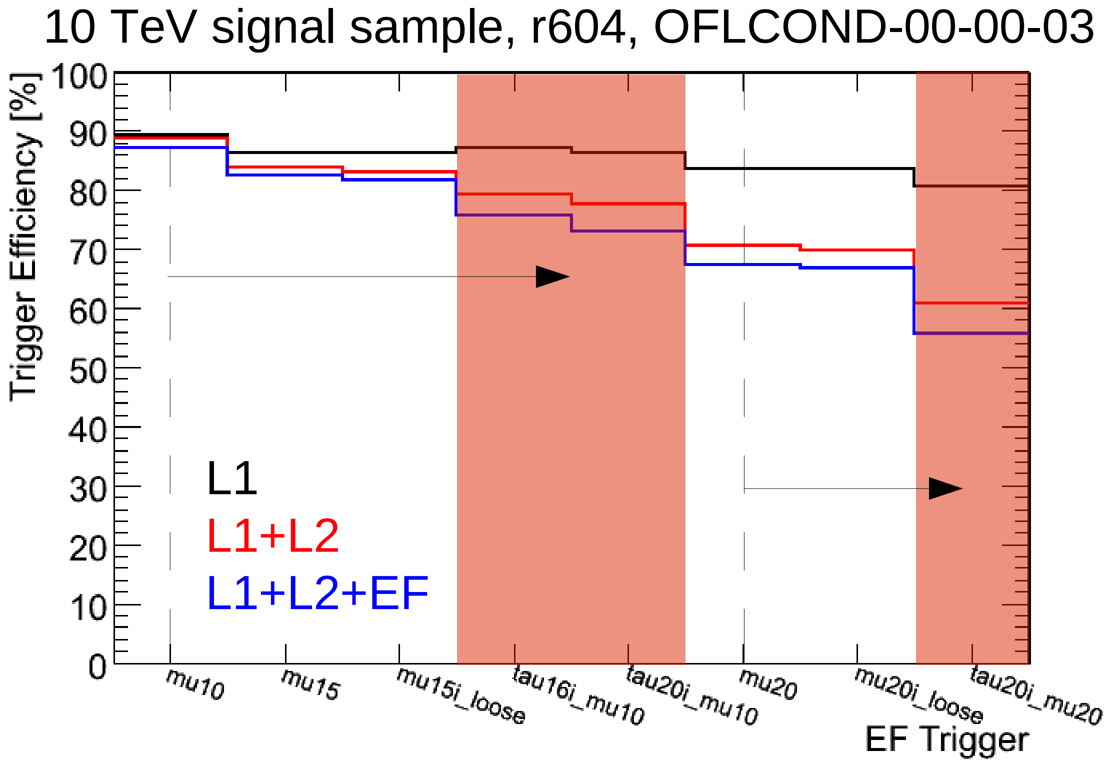
especially:

- medium electron or combined muon w/ pt > 15 GeV rel. isolation EtCone20/pt < 0.2
- had. tau w/ pt > 20 GeV, LLH > 0, EleLLH > 0

electron channel:

- roughly 15% decrease in signal efficiency with comb. el-tau trigger (w.r.t. corresponding single lepton trigger)
- often better efficiency than substantial increase of pt-threshold (e.g. e10→e20) ⇒ good alternative, need to study rates, though

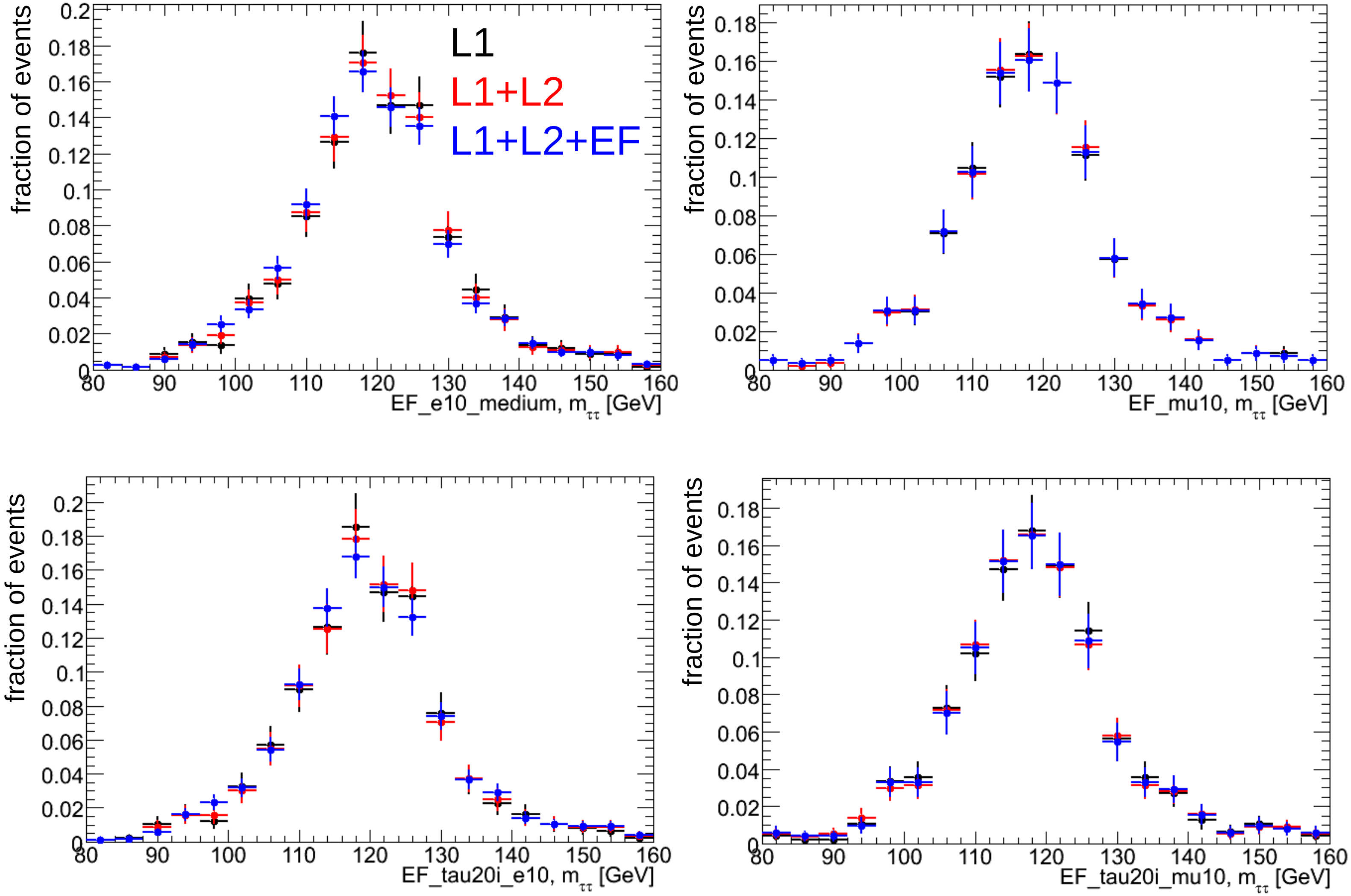
VBF H→ττ→lh (II)



muon channel:

- again roughly 15 percentage points decrease in signal efficiency (w.r.t. corresponding single lepton trigger)
- in terms of signal efficiency: better than or compatible with increased threshold
- for both channels: need to study actual rates and influence on background

VBF $H\to\tau\tau\to lh$ (III)



important check: do tau triggers distort the mass spectrum?

- seems not to be the case

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VBF H→ττ→hh (I)

In rel 14: much more mature triggers w.r.t. CSC exercise
⇒ evaluate again best trigger strategy for hh channel for 10^33 and 14 TeV

Tau analysis offline cuts: two taus with pt > 35 GeV, MET > 40 GeV

CSC: tau35i+met40, total efficiency ~4%

hh, 14 TeV , **medium** version for tau triggers, 10^33 (100* 10^31)

trigger	Rate EF (HZ)	Offline eff	Trigger eff	Total eff	N events 100pb-1 (10^31)
tau29i_tau38i	25.3	0.087	0.48	0.042	0.30
tau29i_tau38	30.7	0.087	0.51	0.044	0.32
tau29i_xe40	46.9	0.109	0.60	0.065	0.48
tau38i_xe40	13.4	0.109	0.59	0.064	0.37

rel 12 RDOs reconstructed in 14.2.23, 14 TeV

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VBF H→ττ→hh (II)

hh, 14 TeV , **tight** version for tau triggers, 10^33

trigger	Rate EF (HZ)	Offline eff	Trigger eff	Total eff	Nev 100pb^-1 (10^31)
2tau20i	45	0.177	0.54	0.095	0.70
2tau29i	8.7	0.094	0.50	0.047	0.34
tau16i_tau29i	19.9	0.207	0.43	0.089	0.65
tau29i_tau38i	6.6	0.087	0.39	0.034	0.25
tau29i_tau38	9.1	0.087	0.42	0.036	0.27
tau29i_xe40	14.7	0.085	0.58	0.049	0.47
tau38_xe40	33.9	0.085	0.58	0.049	0.37
tau38i_xe40	11.7	0.085	0.55	0.047	0.35
tau38i_efxe40	49	0.085	0.62	0.053	0.39

Safest with rate, and good efficiency seems 2tau29i
tau38i_xe40 might be kept as back up

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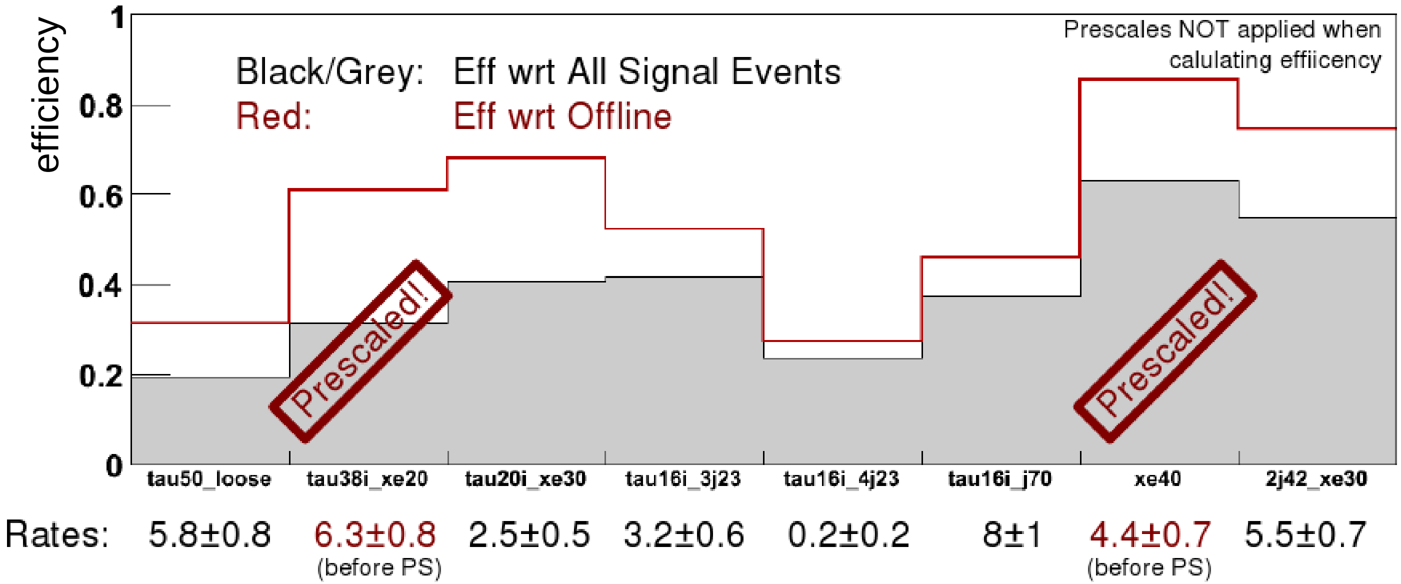
$H^+ \rightarrow \tau(had)\nu$ **(I)**

Triggers identified in CSC:

- 10E31: tau20i+xe30; tau15i+xe30+3jet20
- 10E33: tau35i+xe50; tau35i+xe40+3jet20

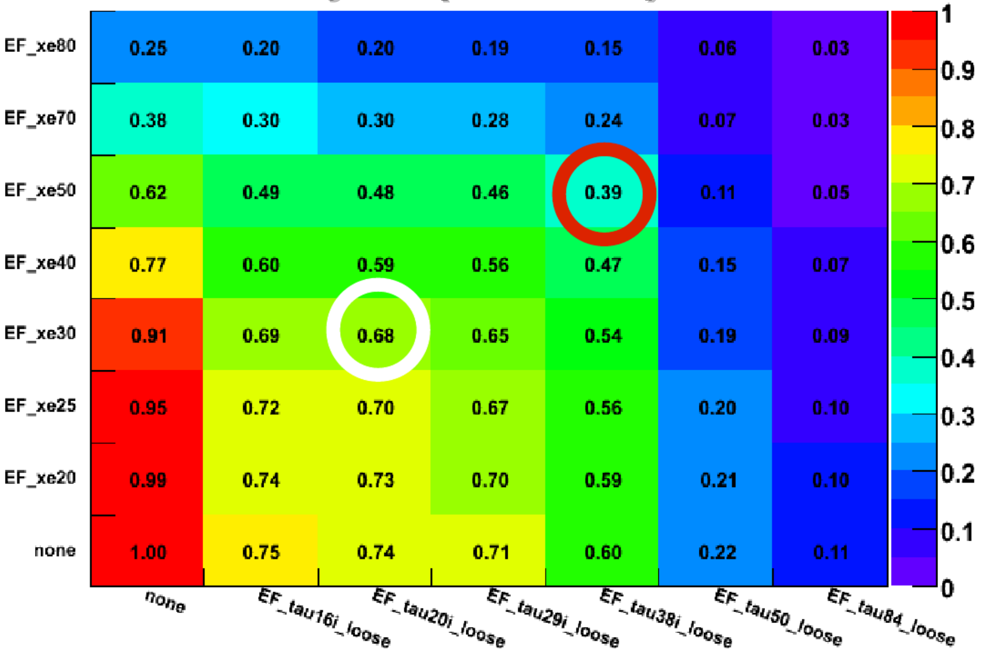


- tau20i_xe30, tau16i_3j23, xe40, 2j42_xe30 look decent, but:
  need to identify trigger which is similar to a feasible 10E33 trigger item (not necessarily the one with highest efficiency at 10E31)

- ***this study***: efficiency as function of threshold, multi-object triggers as as combination of single-object triggers (***e.g. EF_tau50 & EF_xe30***)

$H^+ \rightarrow \tau(had)\nu$ (II)

efficiency: EF tau & EF xe w.r.t. offline analysis (CSC-like)



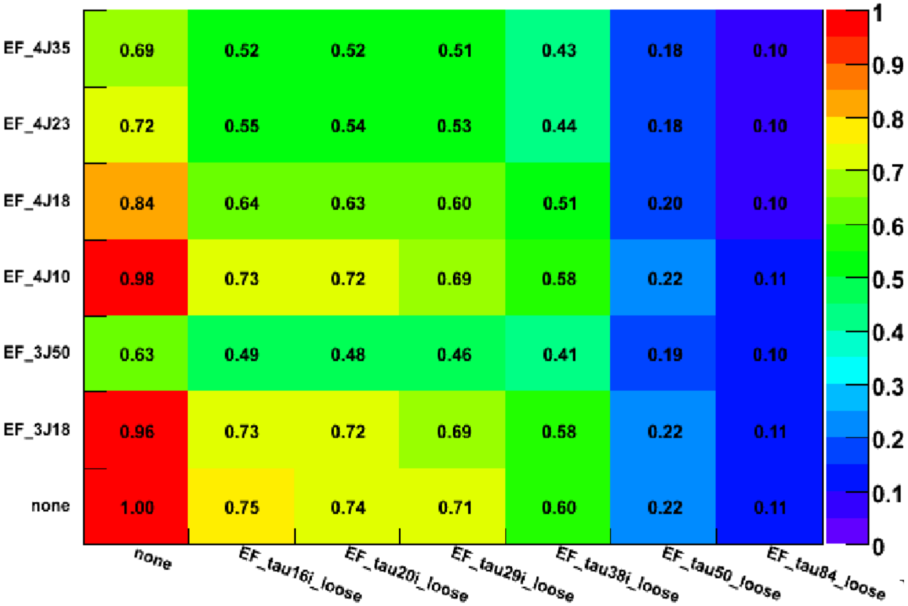
tau+xe: Has been studied extensively.
CSC: at 10E33 efficiencies will be low.

privately produced sample:
14 TeV, 14.2.5, full trigger menu

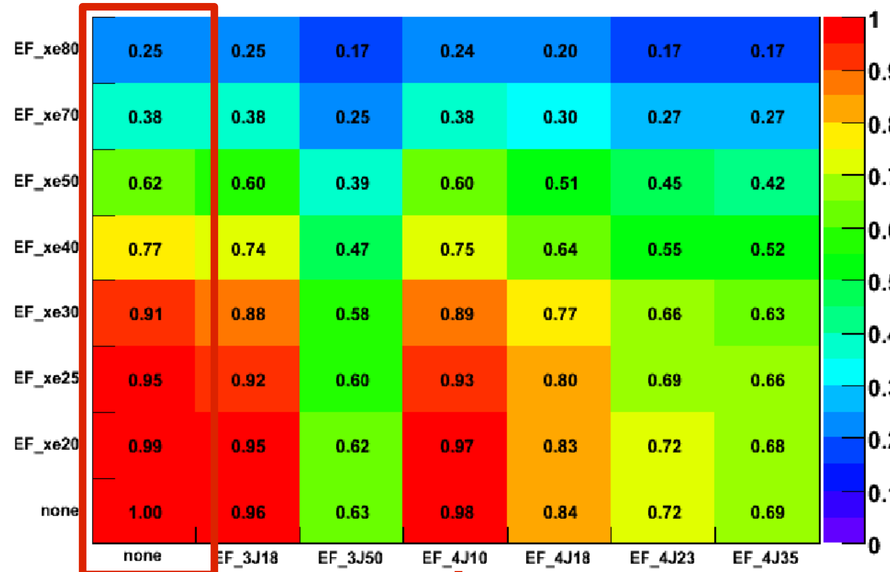
circles: approx CSC trigger
(white: 10E31, red: 10E33)

$H^+ \rightarrow \tau(had)\nu$ (III)

EF jets & EF tau



EF xe & EF jets



no overlap tau/jet taken into account

just xe: „cleanest“ solution (only one trigger object); can rates be kept low?

tau+(3)jets & xe+jets:
There seems to be some “room” for raising thresholds here.

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Summary Trigger

VBF $H \rightarrow \tau\tau \rightarrow lh$:

- some decrease (15 perc. points) in effinciency compared to single lepton triggers
- efficiency loss compatible with increase in pt-threshold
- Mtautau shape not influenced by tau trigger

VBF $H \rightarrow \tau\tau \rightarrow hh$:

- medium version of tau triggers still yield slightly high rates
- safest configuration 2tau29i (tight version)

$H^+ \rightarrow \tau(had)\nu$

- CSC configuration: well studied, but expect low efficiencies
- cleanest (and efficient) solution would be just MET trigger
  would have to be unprescaled at sufficiently low thresholds
- maybe some „room“ to raise thresholds for tau+(3)jets & xe+jets:

Thanks to all who contributed!!