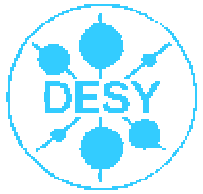



τ-efficiency using Z→ττ-events

DESY-ATLAS-Meeting

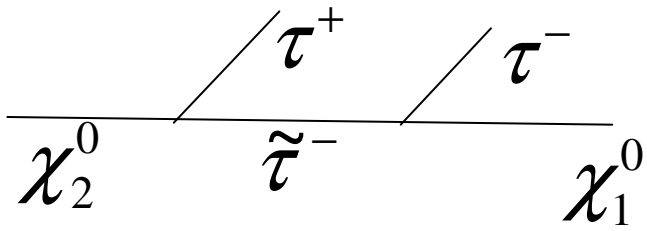
Philip Bechtle, Sylvie Brunet,

Sebastian Johnert

Zeuthen, 22.05.2008

motivation

- search for new particles and new physics (e.g. SM-Higgs ($H \rightarrow \tau\tau$), SUSY)
- τ-leptons: important final state
- high tan β: production of more τ's than other leptons



- $Z \rightarrow \tau\tau$: SM control sample
- check τ-identification algorithms (also to compare with $Z \rightarrow ee$, $Z \rightarrow \mu\mu$)
- results as prestudy for measurement of systematic uncertainties in first data

datasets

Datensatz	Events	WQ [pb]
$Z \rightarrow \tau\tau$	175250	1640
$Z \rightarrow ee$	11750	1670
$Z \rightarrow \mu\mu$	10000	1680
$W \rightarrow e\nu$	176150	17300
$W \rightarrow \mu\nu$	410300	17200
$W \rightarrow \tau\nu$	158600	17300
ttbar	111050	833
J0	366300	$17{,}6 \cdot 10^9$
J1	289850	$1{,}38 \cdot 10^9$
J2	305550	$93{,}3 \cdot 10^6$
J3	355550	$5{,}88 \cdot 10^6$
J4	278900	308000
J5	121550	12500
GamJet1	121550	261000
GamJet2	121550	27600
GamJet3	121550	2590

- **version 3 of SUSYView production release 12.0.6**
- **only ttbar Version 2**
- **all plots preliminary, normalized to 100 pb^{-1}**

Technical details

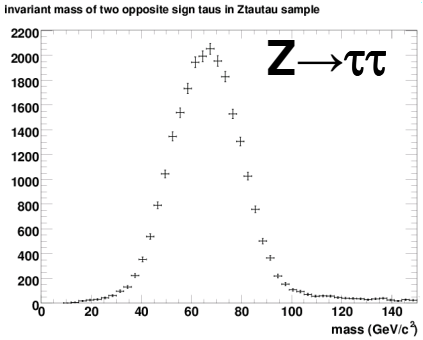
- ntuples of SUSYView production (https://twiki.cern.ch/twiki/bin/view/Atlas/CoordinatedSusyviewFiles)
- Staco-Algorithm for μ identification
- TauRec-Algorithm for τ identification

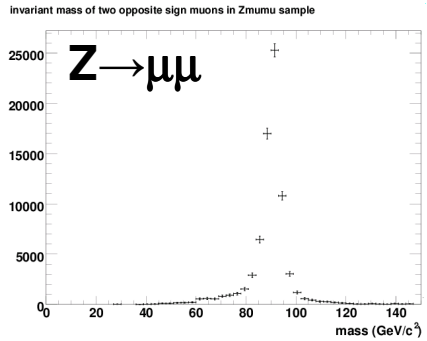
analysis goals

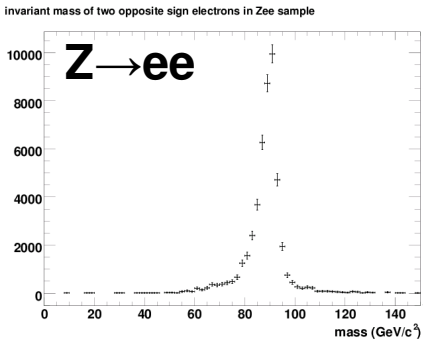
- separate measurement of same sign and opposite sign Z-mass peaks
- separate measurements of $Z \rightarrow \tau\tau$, $Z \rightarrow \mu\mu$ and $Z \rightarrow ee$ yields
- extraction of global τ-reconstruction and τ-identification efficiency relative to e- or μ-efficiency
- efficiency in different bins of p_T and η
- later combine with measurement of trigger efficiencies

expectation from signal

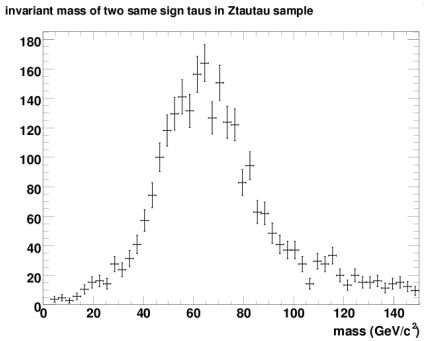
opposite sign (os)

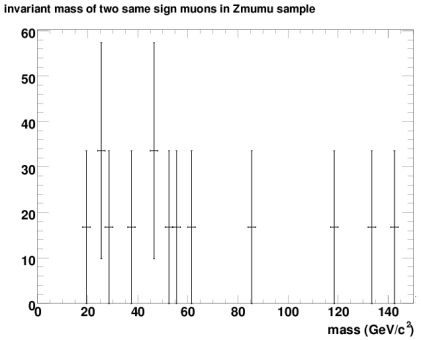


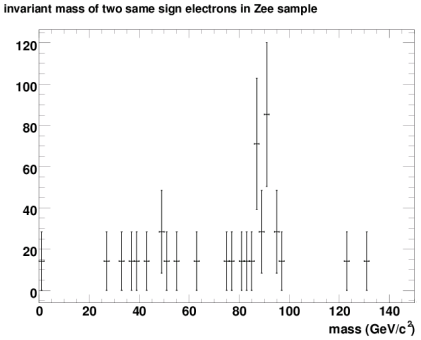




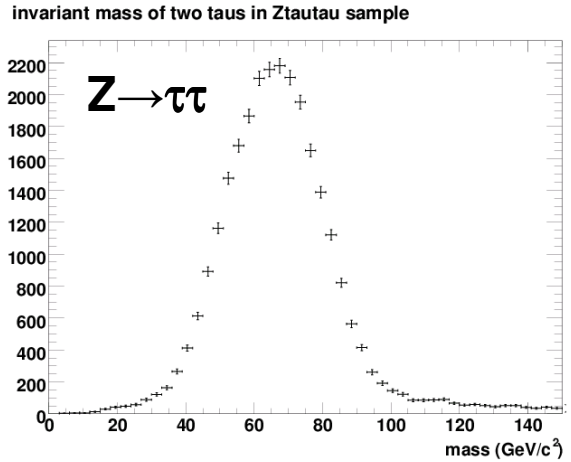
same sign (ss)

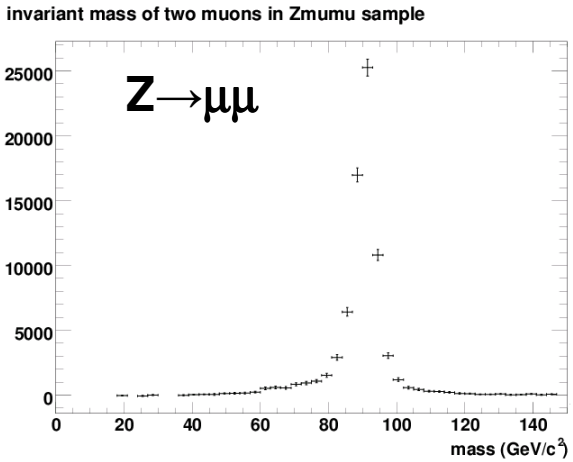


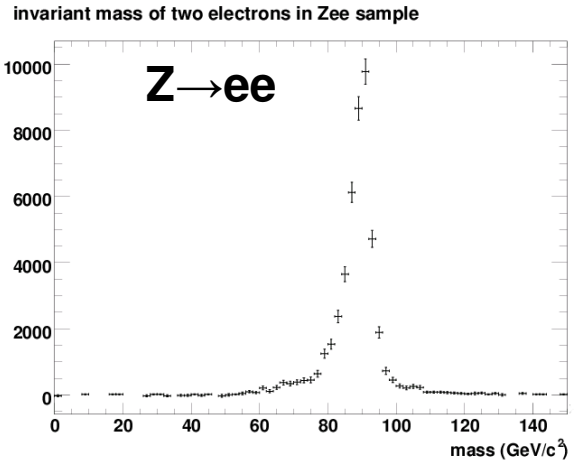




expectation from signal







- no positive effect from using collinear approximation, therefore not used here
- for τ: Z-Peak shifted and wider
- missing transverse energy due to neutrino of τ-decay
- for e and μ: resolution and mass reconstruction of Z more precisely

selection

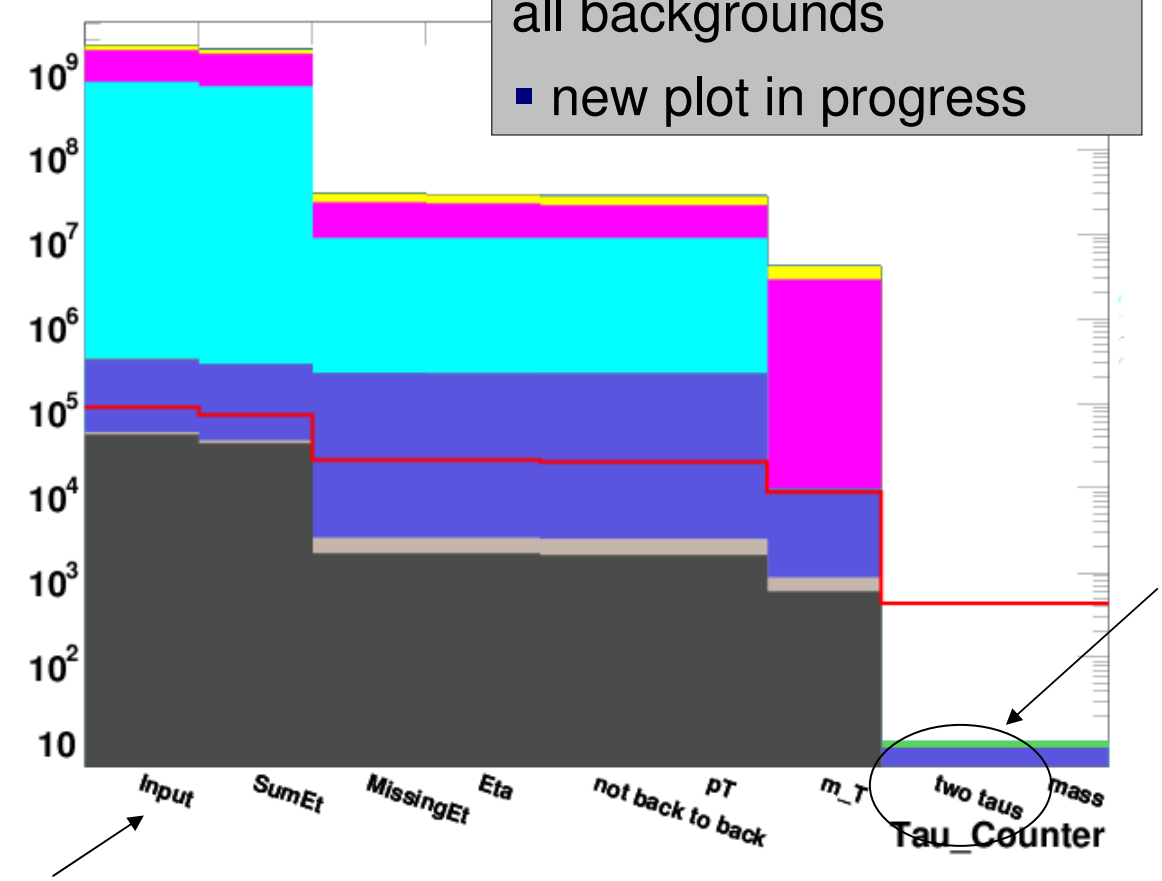
$Z \rightarrow \tau\tau$	$Z \rightarrow ee$	$Z \rightarrow \mu\mu$
SumEt < 260 GeV		
$\|\eta\| < 2.5$		
$p_T > 15$ GeV		
pairs of back to back jets $\rightarrow$ veto ($\Delta\phi_l^j < 2.94 \vee > 3.34$)		
$m_T < 40$ GeV		
MET > 20GeV	-	-
2 τ's	2 μ's	2 e's
20 GeV < $M_{\tau\tau}$ < 100 GeV	60 GeV < M_{ee} < 120 GeV	60 GeV < $M_{\mu\mu}$ < 120 GeV

- collective kinematic cuts (partly to „Tidy up“)
- some specific cuts
- only hadronic decaying τ's

$$m_T = \sqrt{2 \cdot pT_l \cdot MET \cdot (1 - \cos(\theta))}$$

transversal mass

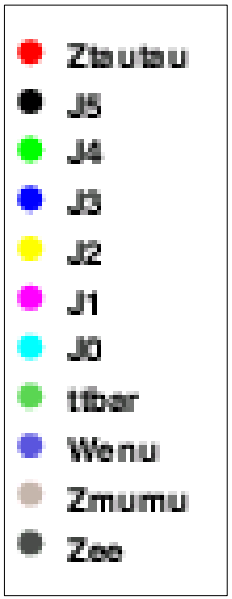
$Z \rightarrow \tau\tau$ -selection



- old plot , not including all backgrounds
- new plot in progress

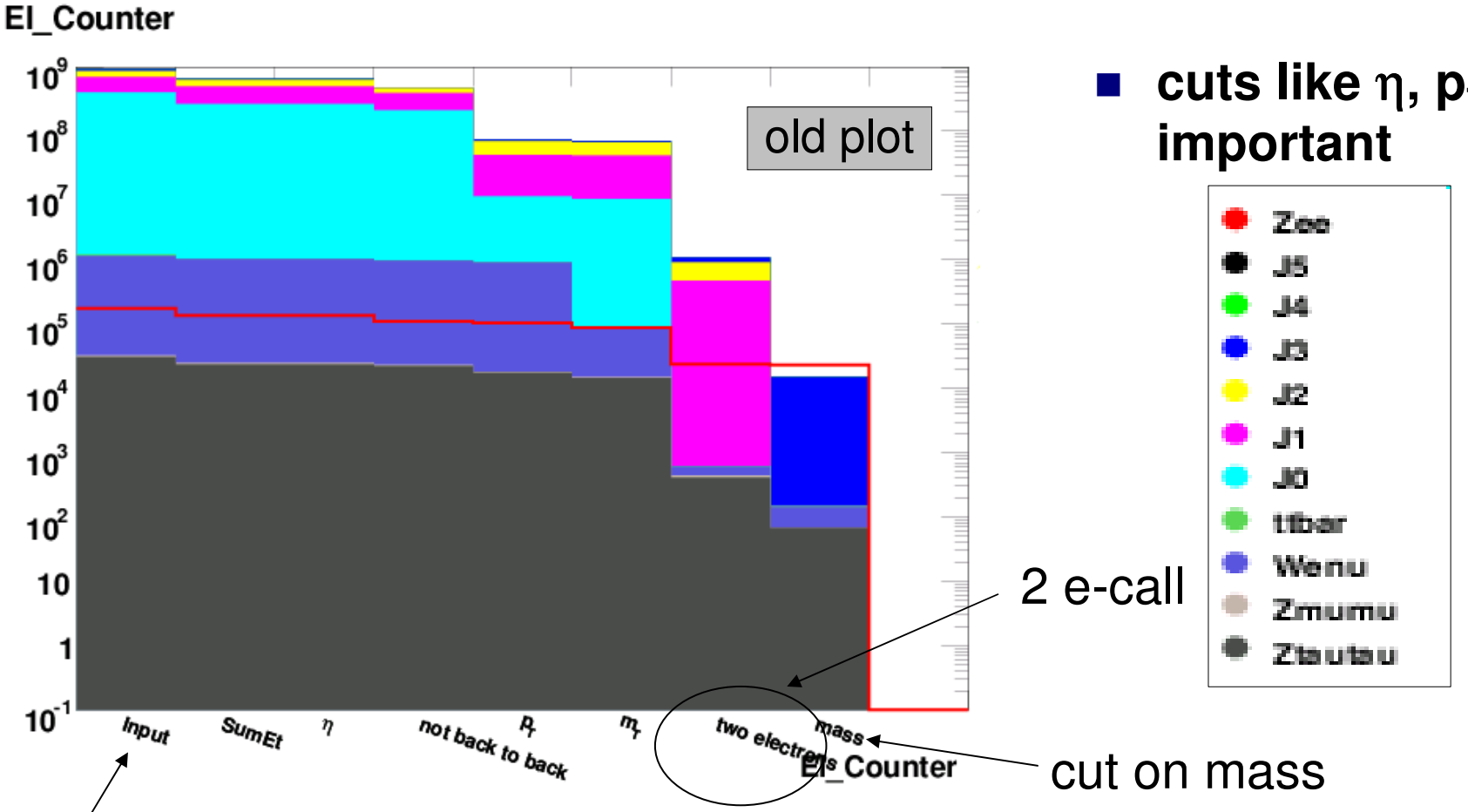
- **requirement of 2 τ's extremely strong**
- **deficit on statistics**
- **but clean sample**

2 τ-call



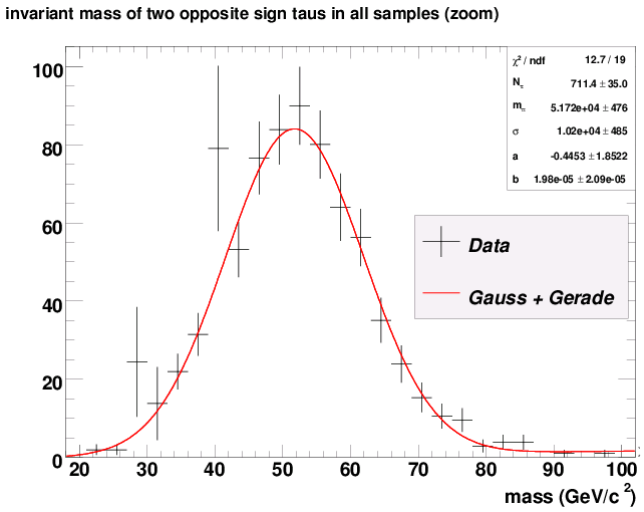
Input

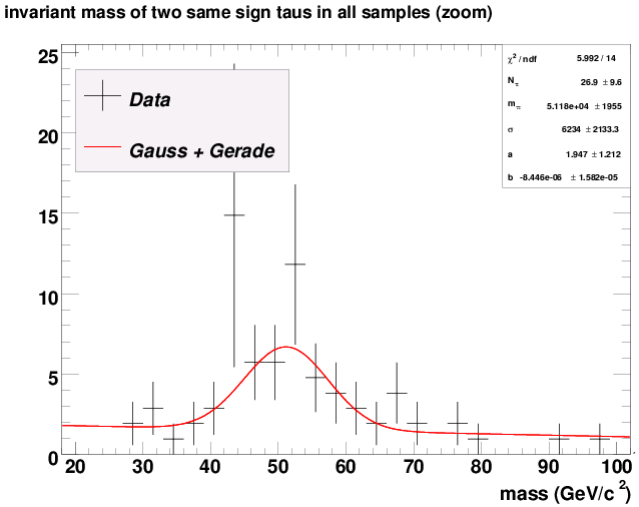
Z→ee-selection



- **cuts like η, p_T important**

mass peak Z→ττ





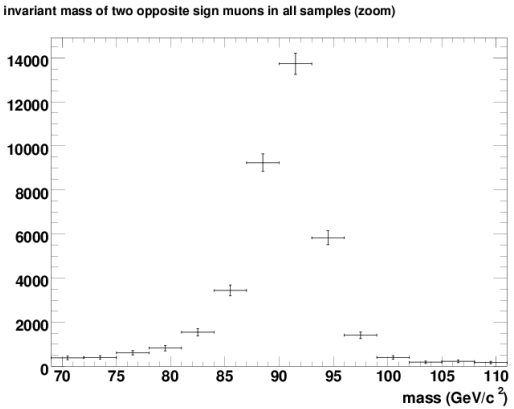
- fit single same sign and opposite sign peak including background
- determines rate of charge misidentification
- get total number of Z→ττ as sum of os and ss peak contribution

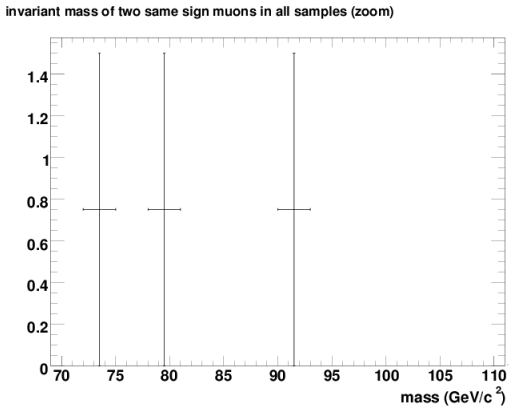
mass peaks

opposite sign (os)

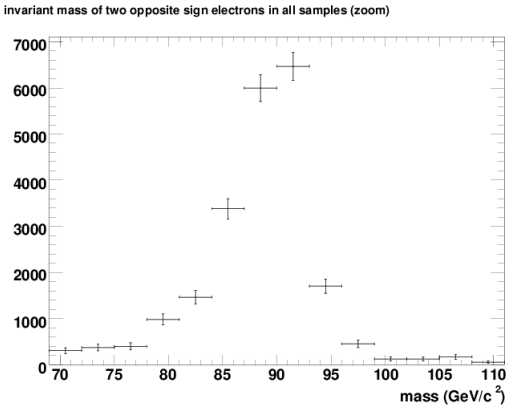
same sign (ss)

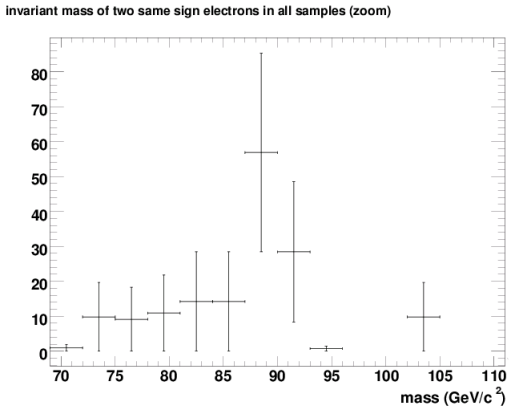
Z→μμ





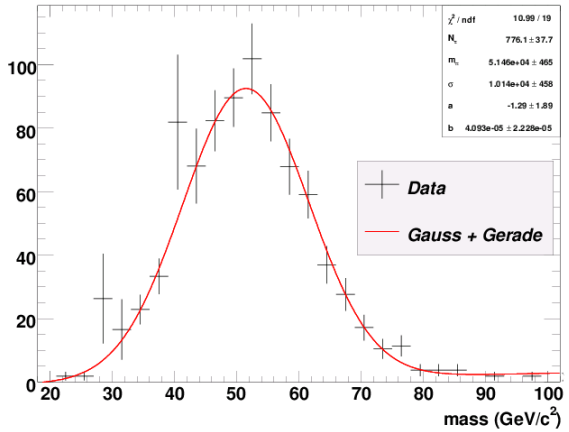
Z→ee





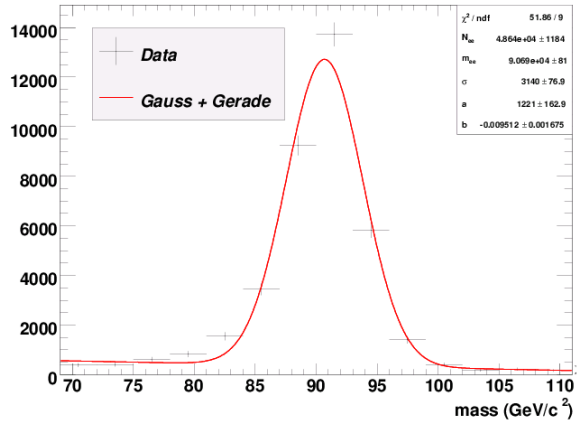
mass peaks

invariant mass of two taus in all samples (zoom)



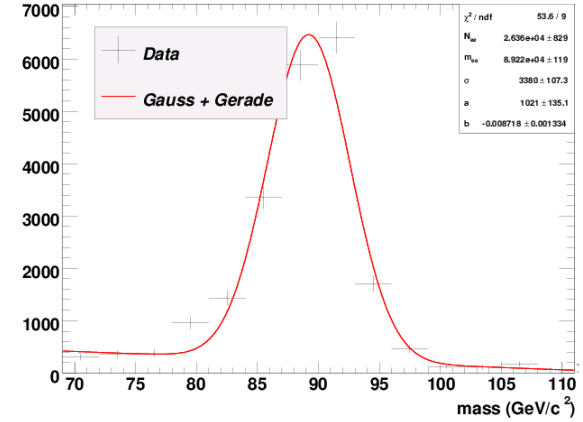
$Z \rightarrow \tau\tau$

invariant mass of two muons in all samples (zoom)



$Z \rightarrow \mu\mu$

invariant mass of two electrons in all samples (zoom)



$Z \rightarrow ee$

- current Z mass peaks
- "runaway" leptons due to statistic

$$Fit = N_{ll} \cdot \frac{1}{\sigma \cdot \sqrt{2\pi}} \cdot e^{-0,5 \cdot \frac{(x - m_{ll})^2}{\sigma^2}} + a + b \cdot x$$

efficiency

- **overall efficiency $\varepsilon_{\tau\tau}$**
- **numbers of $Z\rightarrow\tau\tau \approx Z\rightarrow\mu\mu$ (BR's)**
- **$\varepsilon_{\tau}^{kin} = 2.8\% \pm 0.28\%$**
  (assume error of 10% for ε_{kin})
- **$\varepsilon_{\mu}^{kin} = 51.5\% \pm 5.15\%$**
- **$\varepsilon_{\mu} = 75.6\% \pm 5.0\%$**
- **$\varepsilon_{\tau 1} \approx \varepsilon_{\tau 2}$ assumed**

$$n_{Z\rightarrow\tau\tau}(\text{init.}) = n_{Z\rightarrow\mu\mu}(\text{init.}) = \frac{n_{Z\rightarrow\mu\mu}(\text{sel.})}{\varepsilon_{Z\rightarrow\mu\mu}} = \frac{n_{Z\rightarrow\mu\mu}(\text{sel.})}{\varepsilon_{\mu}^{2}\cdot\varepsilon_{\mu}^{kin}}$$

$$\varepsilon_{\tau\tau} = \varepsilon_{\tau}^{kin}\cdot\underbrace{\varepsilon_{\tau_1}(p_T)\cdot\varepsilon_{\tau_2}(p_T)}_{=\varepsilon_{\tau}^{2}}$$

$$\varepsilon_{\tau\tau} = \frac{n_{Z\rightarrow\tau\tau}(\text{sel.})}{\frac{n_{Z\rightarrow\mu\mu}(\text{sel.})}{\varepsilon_{\mu}^{2}\cdot\varepsilon_{\mu}^{kin}}\cdot BF^{2}(\tau\rightarrow\text{had.})\cdot\frac{\sigma_{Z\rightarrow\tau\tau}}{\sigma_{Z\rightarrow\mu\mu}}}$$

BF's for Z

- Zee: (3.363 ± 0.004) %
- Zmumu: (3.366 ± 0.007) %
- Ztautau: (3.370 ± 0.0023) %
- invisible: (20.00 ± 0.06) %
- hadrons: (69.91 ± 0.06) %

- **BF ($\tau\rightarrow$had): (67.9 ± 0.1) %**
- **$\sigma_{Z\rightarrow\tau\tau}$ = 1640 pb**
- **$\sigma_{Z\rightarrow\mu\mu}$ = 1680 pb**

efficiency

- ε_τ: averaged over all p_T
- equations converted to ε_τ

$$\varepsilon_\tau = \frac{\varepsilon_\mu}{BF(\tau \to \text{had.})} \cdot \sqrt{\frac{n_{Z\to\tau\tau}(\text{sel.}) \cdot \sigma_{Z\to\mu\mu}}{n_{Z\to\mu\mu}(\text{sel.}) \cdot \sigma_{Z\to\tau\tau}} \cdot \frac{\varepsilon_\mu^{kin}}{\varepsilon_\tau^{kin}}}$$

- efficiency quite high due to a likelihood cut of 2 in SUSYView-NTuples

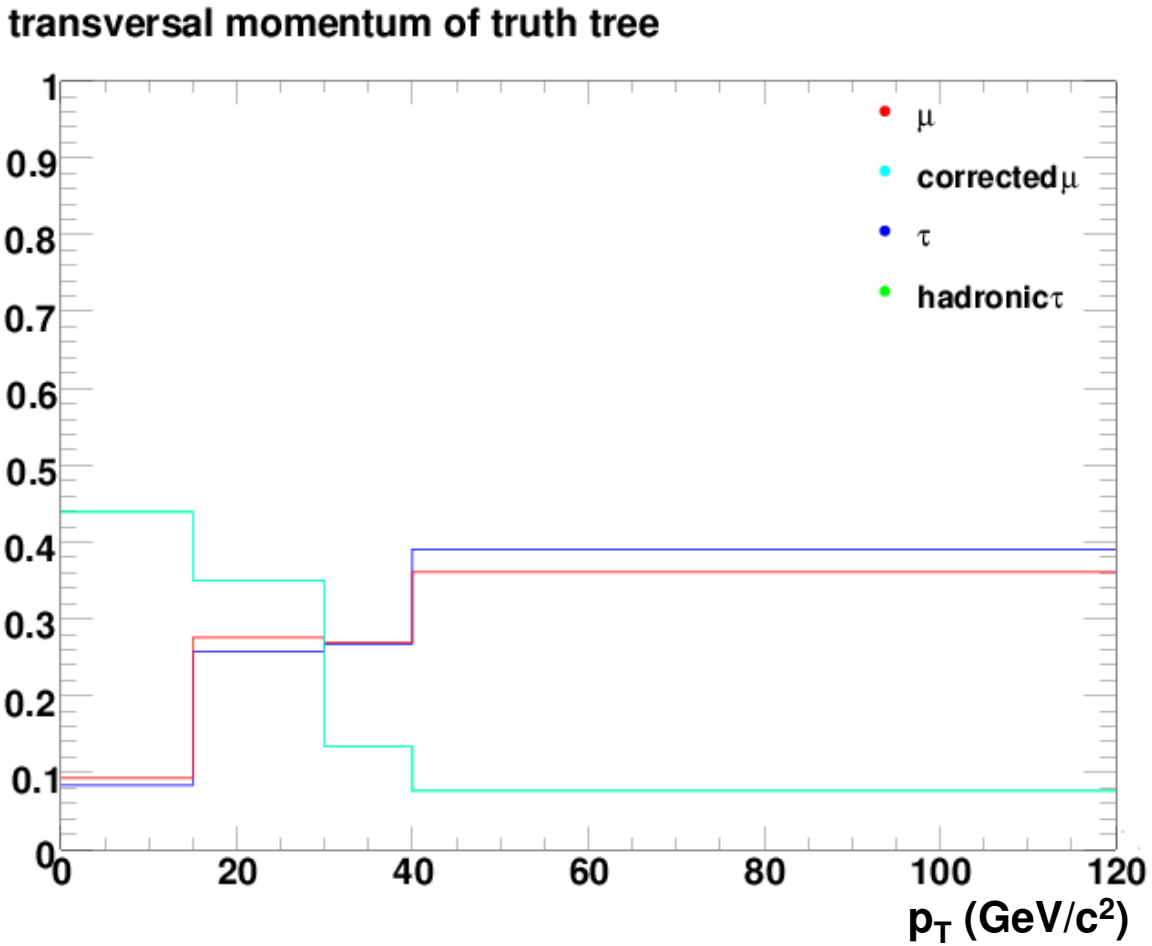
number of μ pairs (after cut)	49452 ± 1171
number of τ pairs (after cut)	738 ± 36
efficiency ε_τ	$59.2\% \pm 6.0\%$

efficiency in bins of p_T

- plan to calculate efficiencies in different bins of p_T and η with the help from μ's
- reweight μ-p_T-distribution to match visible τ-p_T-distribution
- choosed binning:

  0 – 15 GeV, 15 – 30 GeV, 30 – 40 GeV, 40 – 120 GeV
- method only if true τ-p_T including ν's overlaps with μ-p_T
- next slide: corrected μ-p_T-distribution

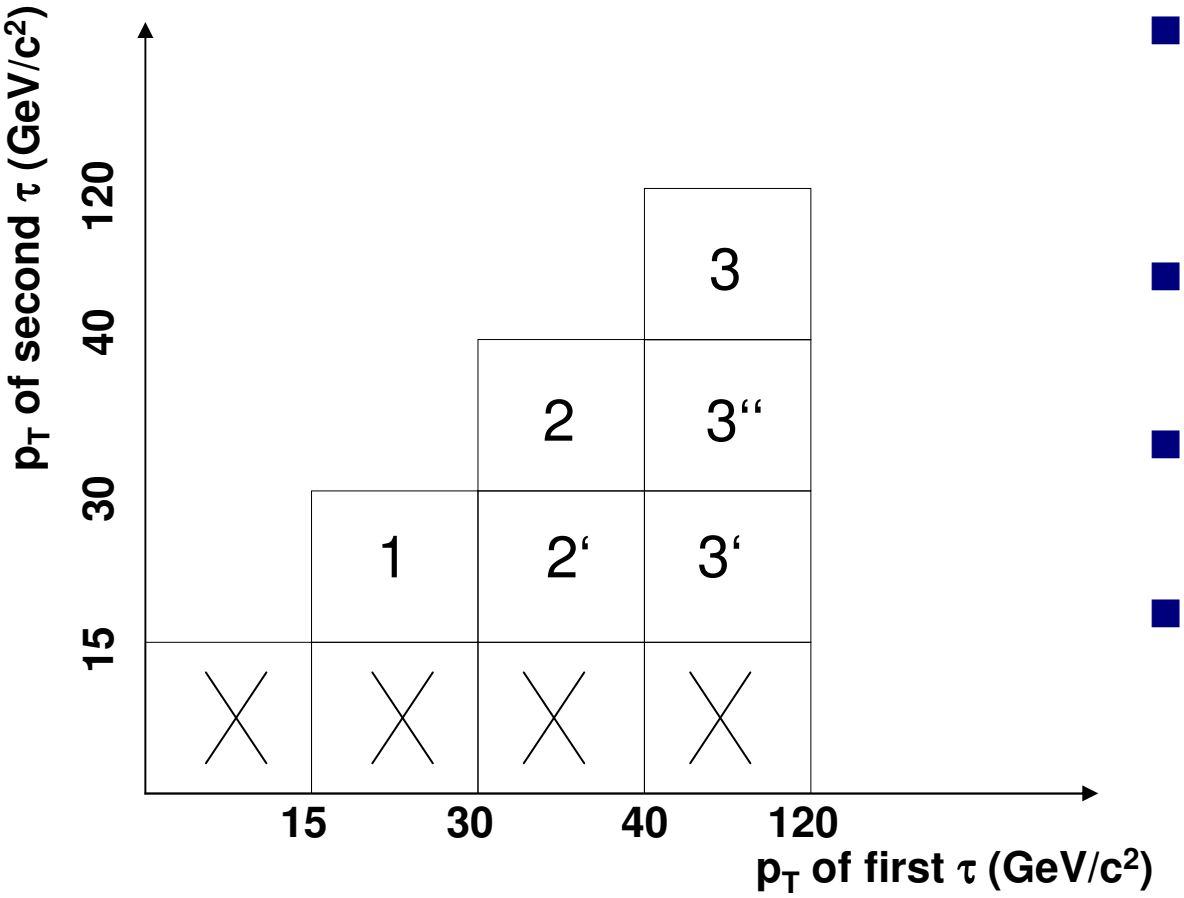
efficiency in bins of p_T



- overlap of τ (including ν) with μ → method works
- corrected μ and hadronic τ identical now

correction factors (CF)
0 – 15 GeV: 4.706
15 – 30 GeV: 1.272
30 – 40 GeV: 0.497
40 – 120 GeV: 0.211

efficiency in bins of p_T

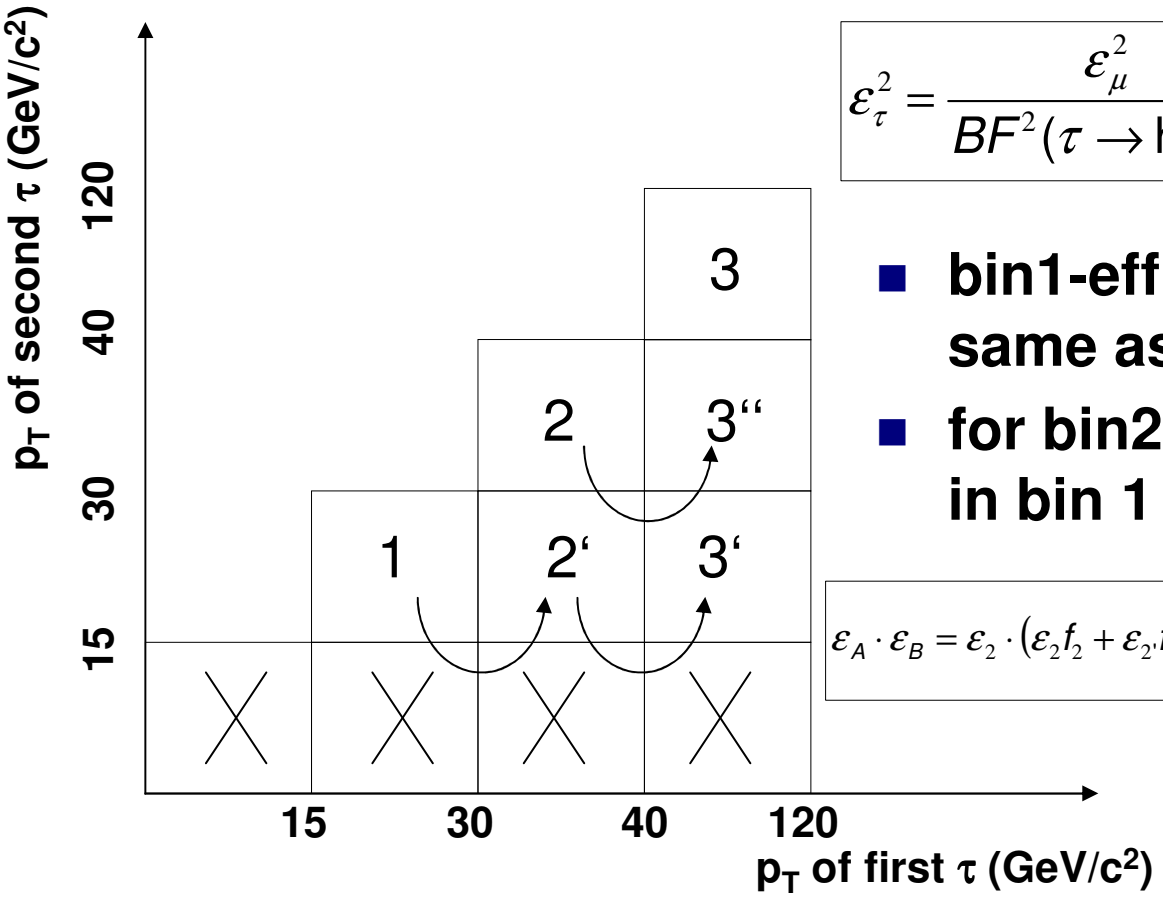


- want to calculate τ-efficiency in bin 1, 2 and 3
- no problem with bin 1
- bin 2 and 3: too low statistic
- solution: help of bins 2’, 3’ and 3’’ to increase statistics

efficiency in bins of p_T

bin 1:

$$\varepsilon_\tau^2 = \frac{\varepsilon_\mu^2}{BF^2(\tau \to \text{had.})} \cdot \frac{n_{Z\to\tau\tau}(\text{sel.}) \cdot \sigma_{Z\to\mu\mu}}{n_{Z\to\mu\mu}(\text{sel.}) \cdot \sigma_{Z\to\tau\tau}} \cdot \frac{\varepsilon_\mu^{kin}}{\varepsilon_\tau^{kin}}$$



- **bin1-efficiency calculation same as overall τ-efficiency**
- **for bin2: calculating efficiency in bin 1 and using it in bin 2’**

$$\varepsilon_A \cdot \varepsilon_B = \varepsilon_2 \cdot (\varepsilon_2 f_2 + \varepsilon_{2'} f_{2'}) = \frac{\varepsilon_\mu^2}{BF^2(\tau \to \text{had.})} \cdot \frac{n_{Z\to\tau\tau}(\text{sel.}) \cdot \sigma_{Z\to\mu\mu}}{n_{Z\to\mu\mu}(\text{sel.}) \cdot \sigma_{Z\to\tau\tau}} \cdot \frac{\varepsilon_\mu^{kin}}{\varepsilon_\tau^{kin}}$$

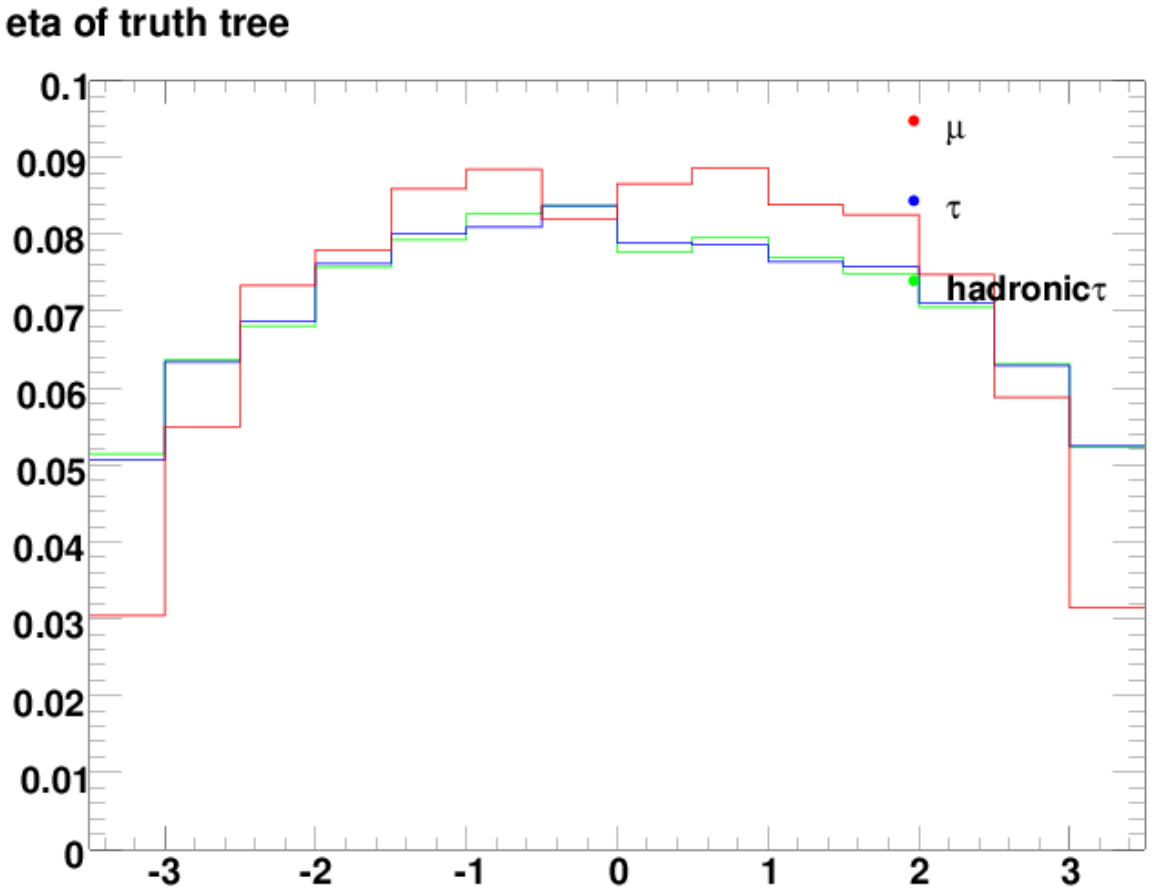
efficiency in bins of p_T

bin 2:

$$\varepsilon_A \cdot \varepsilon_B = \varepsilon_2 \cdot \left(\varepsilon_2 f_2 + \varepsilon_{2'} f_{2'}\right) = \frac{\varepsilon_\mu^2}{BF^2(\tau \to \text{had.})} \cdot \frac{n_{Z\to\tau\tau}(\text{sel.}) \cdot \sigma_{Z\to\mu\mu}}{n_{Z\to\mu\mu}(\text{sel.}) \cdot \sigma_{Z\to\tau\tau}} \cdot \frac{\varepsilon_\mu^{kin}}{\varepsilon_\tau^{kin}} \quad \text{with } f_{2,2'} = \frac{N_{2,2'}}{N_2 + N_{2'}}$$

- in $\varepsilon_{2'}$ used ε_1 for calculation of ε_2
- right side of equation looking at the following bin: first τ from 30 to 40 GeV, second τ from 15 to 40 GeV
- sure: using sum of corrected $N_{Z\to\mu\mu}$ in bin 2 and 2'
- same ansatz for the last p_T-range 40 – 120 GeV
- no completely debugged results yet

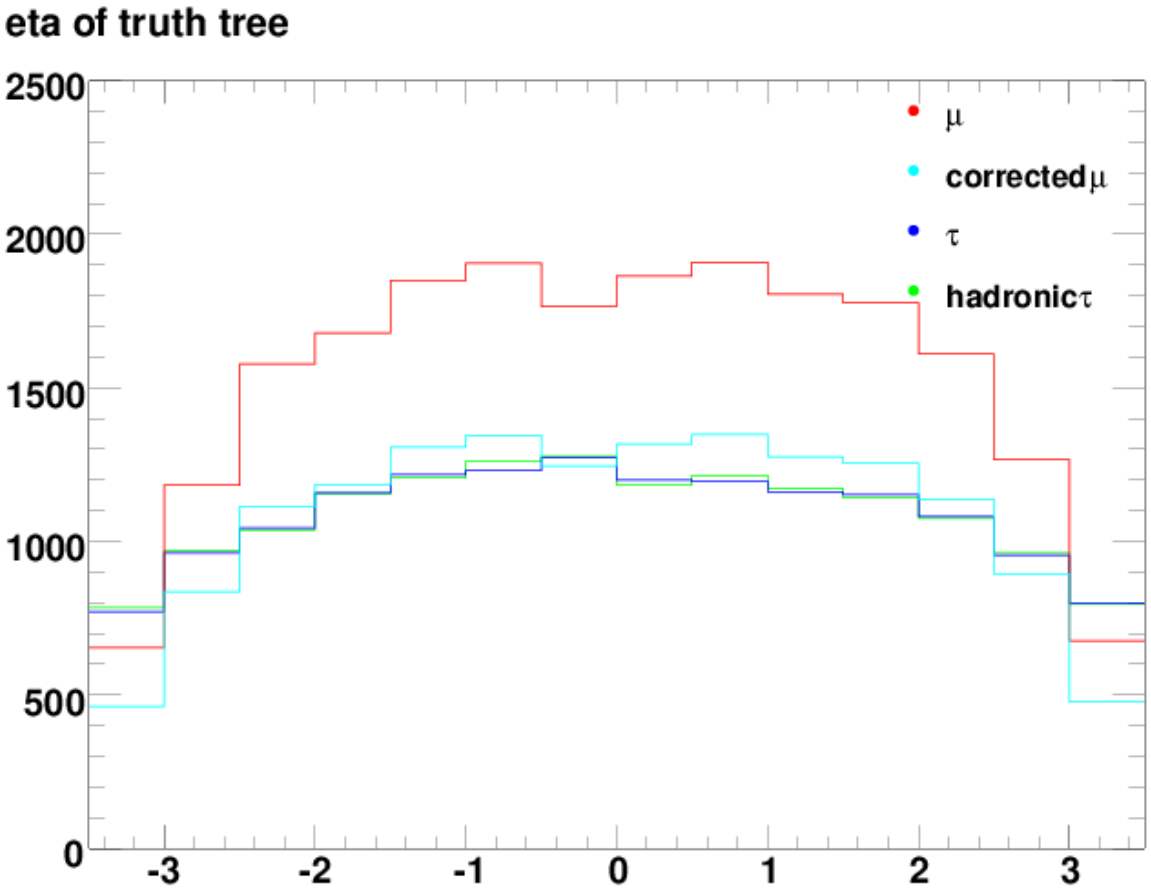
efficiency in bins of η



- good overlap of visible hadronic τ and of τ (including ν) with μ in scaled distributions

  → no correction factors necessary
- but…

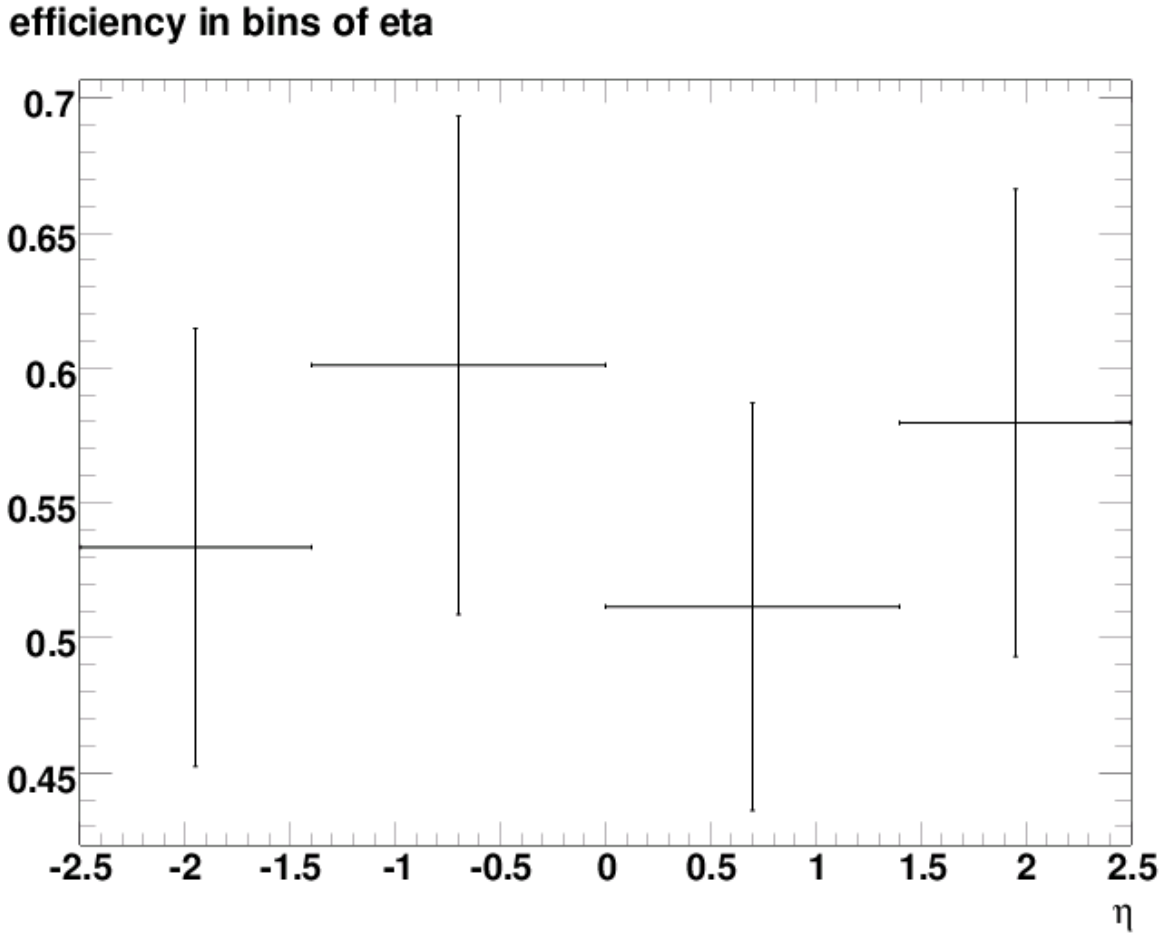
efficiency in bins of η



- but…
- global factor = 0.71 needed to correct whole numbers of μ's and τ's
- left plot: unscaled η-distribution

efficiency in bins of η

- quite good agreement with overall efficiency
- some fluctuations



trigger efficiency

- at the moment trigger efficiencies and trigger prescales are not taken into account
- reasons for that:

1. using release 12.0.6, outdated list of triggers, no di-τ-triggers
2. technical implementation for single τ- and di-τ-triggers exists
3. using single τ-trigger shows: high prescales (even rel. 13 or 14) of single τ-triggers prevent feasibility of this measurement with 100 pb^{-1}
4. will implement an expectation for di-τ-trigger for the final version of the study

- tag and probe determination of trigger efficiencies unfortunately not feasible due to missing links and variables in release 12.0.6 SUSYView-NTuples
- order of magnitude of these results should be somehow realistic in release 14 using unprescaled di-τ- and single τ-triggers

summary

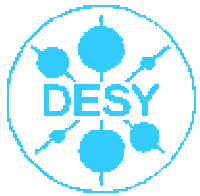
- successful demonstration of measurement of τ-efficiency relative to μ-efficiency from "real" data
- in 100 pb^{-1} τ-efficiency of 59.2% $\pm$ 6.0%
- efficiency in η good agreement with overall efficiency
- result depends on assumptions on uncertainties of μ-efficiency and kinematic selection (MET, Jet-energy-resolution, …)
- those are hopefully measured by other groups.;-)

outlook

- finish efficiency measurement for different p_T- and η-bins
- systematic uncertainties from background level
- include prospects for different trigger scenarios and prescales
- TauDPDMaker data will allow tag and probe trigger efficiency measurement, at the moment for me not possible
- extend study: combine hh- and lh-τ-decays, separate measurement for 1p and 3p, different algorithms, …

Backup

Datensätze



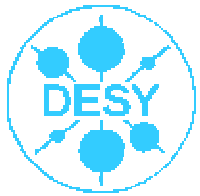
- **NTupel der SUSYView-Produktion (https://twiki.cern.ch/twiki/bin/view/Atlas/CoordinatedSusyviewFiles)**
- **Kooperationsprojekt verschiedener Institute (ursprünglich Hamburg und Freiburg)**
- **jetzt auch einige andere → siehe Twiki-Page**

Analysenframework

- SUSYView basierend auf EventView
- Verwendung von SFrame für Analyse

  (https://twiki.cern.ch/twiki/bin/view/Main/SFramePage)
- auf Root basiertes HEP-Analyse-Programm
- Einige nette Feature (Gewichtung, Laden mehrerer Trees, …)
- meine Analyse: gesplittet in zwei Zyklen

my analysis



- using SFrame
- analysis divided in two cycles:

  FirstCycle:
  - decreasing of number of variables
    → size of ntuples smaller
  - calculation of variables and parameters
  - creation of control plots

  SecondCycle:
  - real analysis
  - integration of cuts
  - results

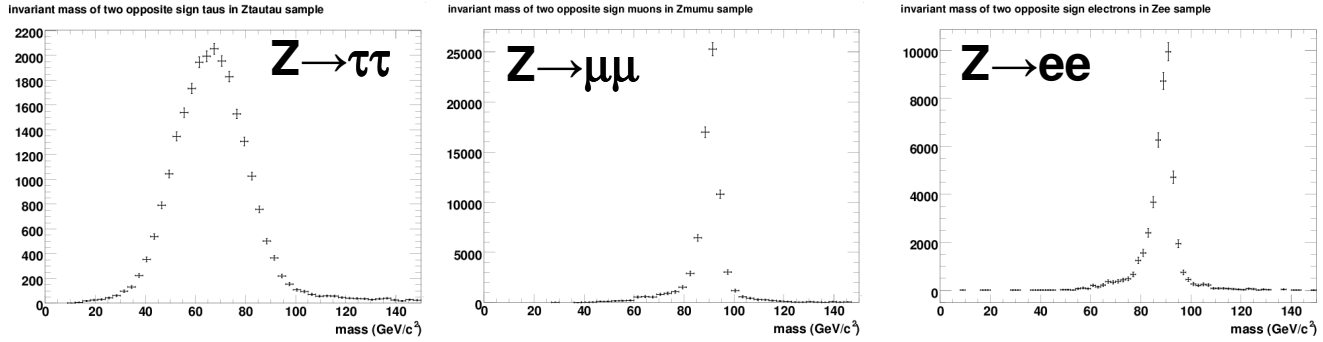
expectation from signal

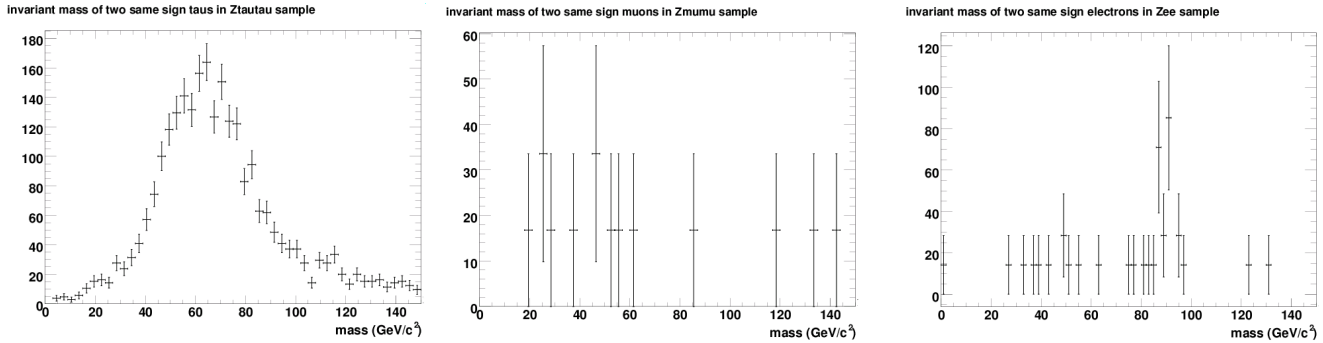
opposite sign (os)

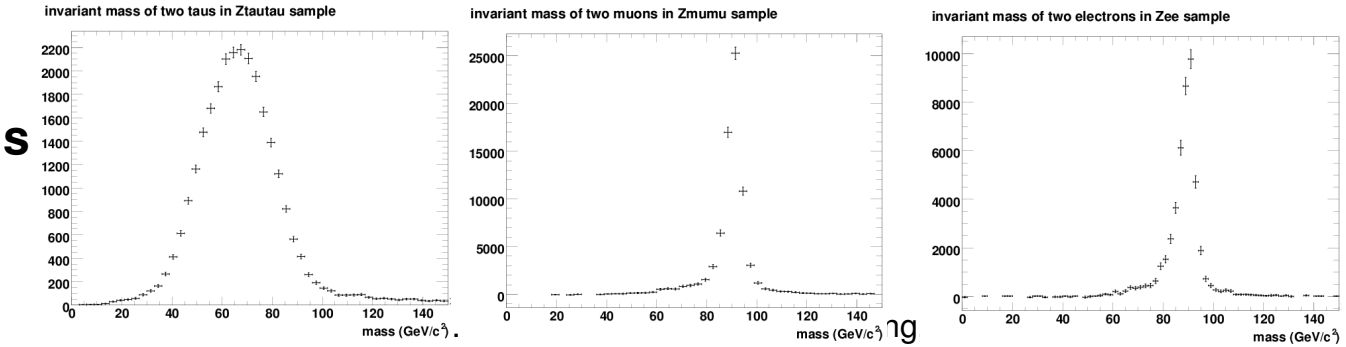
same sign (ss)

ss+os for τ's

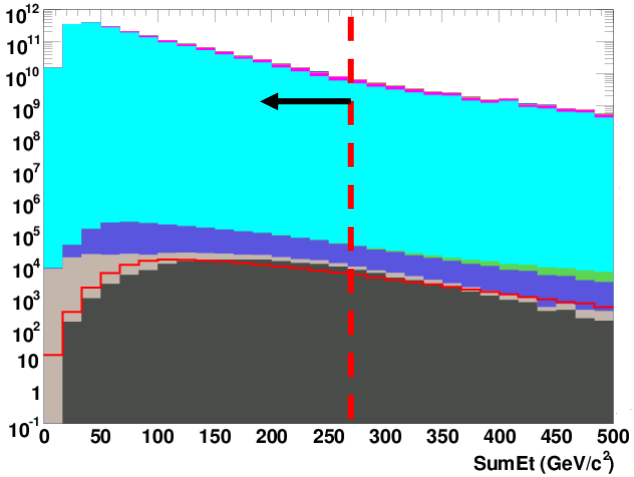
os – 2ss







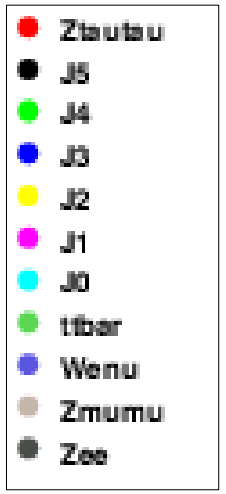
Z→ττ-selection



- **SumEt cut at > 260 GeV**

→ elimination of jets and ttbar

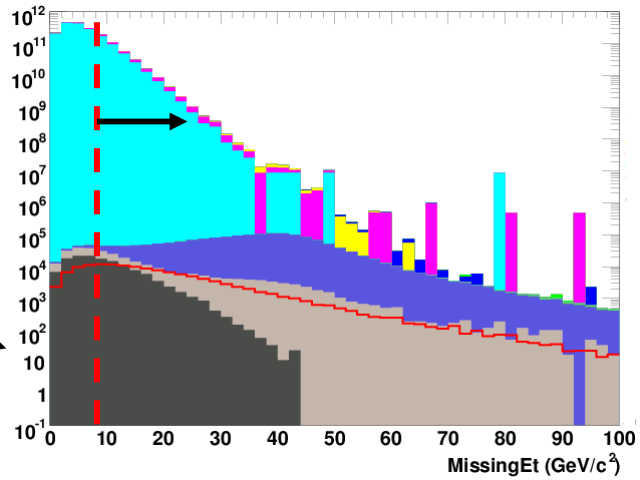
Sum of transversal energy



- **suppression of jets with missing transversal energy < 20 GeV**

- old plots , not including all backgrounds
- new plots in progress
- but tendency/trend clear

Missing transversal energy after SumEt cut



Effizienz

$$\sigma_{\varepsilon_\tau} = \frac{1}{2 \cdot \sqrt{\frac{n_{Z\to\tau\tau}}{n_{Z\to\mu\mu} \cdot BF^2 \cdot \frac{\sigma_{Z\to\tau\tau}}{\sigma_{Z\to\mu\mu}} \cdot \varepsilon_{kin}}}} \cdot \sqrt{\left(\frac{\sigma_{n_{Z\to\tau\tau}}}{n_{Z\to\mu\mu} \cdot BF^2 \cdot \frac{\sigma_{Z\to\tau\tau}}{\sigma_{Z\to\mu\mu}} \cdot \varepsilon_{kin}} \right)^2 + \left(- \frac{n_{Z\to\tau\tau} \cdot \sigma_{n_{Z\to\mu\mu}}}{n_{Z\to\mu\mu}^2 \cdot BF^2 \cdot \frac{\sigma_{Z\to\tau\tau}}{\sigma_{Z\to\mu\mu}} \cdot \varepsilon_{kin}} \right)^2 + \left(- \frac{2 \cdot n_{Z\to\tau\tau} \cdot \sigma_{BF}}{n_{Z\to\mu\mu} \cdot BF^3 \cdot \frac{\sigma_{Z\to\tau\tau}}{\sigma_{Z\to\mu\mu}} \cdot \varepsilon_{kin}} \right)^2 + \left(- \frac{n_{Z\to\tau\tau} \cdot \sigma_{\varepsilon_{kin}}}{n_{Z\to\mu\mu} \cdot BF^2 \cdot \frac{\sigma_{Z\to\tau\tau}}{\sigma_{Z\to\mu\mu}} \cdot \varepsilon_{kin}^2} \right)^2}$$

Effizienz

$$\sigma_{\varepsilon_\tau} = \frac{1}{2 \cdot \sqrt{\frac{n_{Z\to\tau\tau}}{\frac{n_{Z\to\mu\mu}}{\varepsilon_\mu} \cdot BF^2 \cdot \frac{\sigma_{Z\to\tau\tau}}{\sigma_{Z\to\mu\mu}} \cdot \varepsilon_{kin}}}} \cdot \sqrt{\left(\frac{\sigma_{n_{Z\to\tau\tau}}}{\frac{n_{Z\to\mu\mu}}{\varepsilon_\mu} \cdot BF^2 \cdot \frac{\sigma_{Z\to\tau\tau}}{\sigma_{Z\to\mu\mu}} \cdot \varepsilon_{kin}} \right)^2 + \left(\frac{n_{Z\to\tau\tau} \cdot \sigma_{\varepsilon_\mu}}{n_{Z\to\mu\mu} \cdot BF^2 \cdot \frac{\sigma_{Z\to\tau\tau}}{\sigma_{Z\to\mu\mu}} \cdot \varepsilon_{kin}} \right)^2 + \left(- \frac{n_{Z\to\tau\tau} \cdot \sigma_{n_{Z\to\mu\mu}}}{\frac{n^2_{Z\to\mu\mu}}{\varepsilon_\mu} \cdot BF^2 \cdot \frac{\sigma_{Z\to\tau\tau}}{\sigma_{Z\to\mu\mu}} \cdot \varepsilon_{kin}} \right)^2 + \left(- \frac{2 \cdot n_{Z\to\tau\tau} \cdot \sigma_{BF}}{\frac{n_{Z\to\mu\mu}}{\varepsilon_\mu} \cdot BF^3 \cdot \frac{\sigma_{Z\to\tau\tau}}{\sigma_{Z\to\mu\mu}} \cdot \varepsilon_{kin}} \right)^2 + \left(- \frac{n_{Z\to\tau\tau} \cdot \sigma_{\varepsilon_{kin}}}{\frac{n_{Z\to\mu\mu}}{\varepsilon_\mu} \cdot BF^2 \cdot \frac{\sigma_{Z\to\tau\tau}}{\sigma_{Z\to\mu\mu}} \cdot \varepsilon^2_{kin}} \right)^2}$$