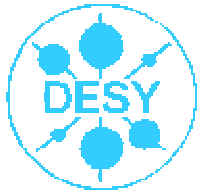



Status of $Z \rightarrow \tau\tau$-Analysis

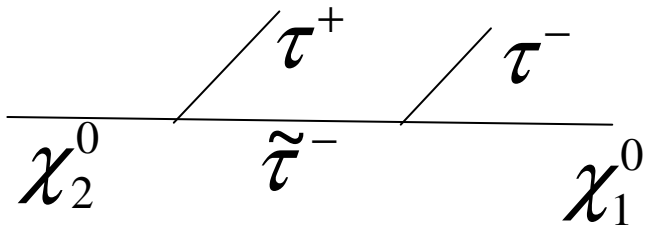
DESY-ATLAS-Meeting

Philip Bechtle, Sylvie Brunet,
Sebastian Johnert

Hamburg, 02.04.2008

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

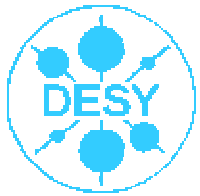
Datensatz	Events	WQ [pb]
$Z \rightarrow \tau\tau$	181700	1640
$Z \rightarrow ee$	14700	1670
$Z \rightarrow \mu\mu$	10000	1680
$W \rightarrow e\nu$	202250	17300
ttbar	111050	833
J0	201900	$17{,}6 \cdot 10^9$
J1	289850	$1{,}38 \cdot 10^9$
J2	194800	$93{,}3 \cdot 10^6$
J3	359550	$5{,}88 \cdot 10^6$
J4	314900	308000
J5	357335	12500

- **missing: $W \rightarrow \tau had$, $W \rightarrow \tau\nu$, $W \rightarrow \mu\nu$, GamJet1 – 3**
- **next week: change to Version 3 of SUSYView production with all datasets**
- **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

my analysis



- using SFrame
- analysis divided in two cycles:

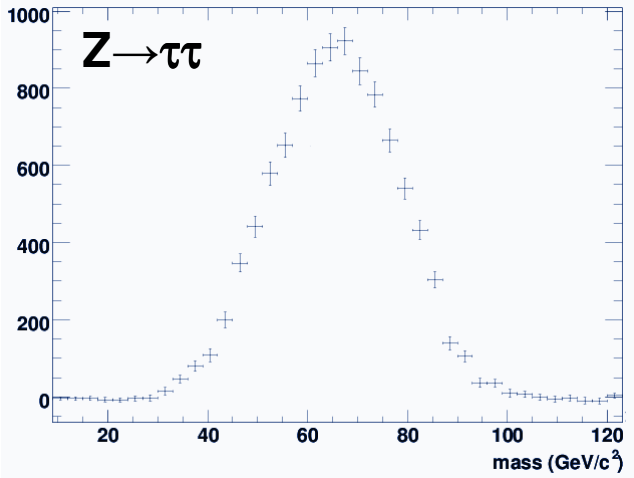
FirstCycle:

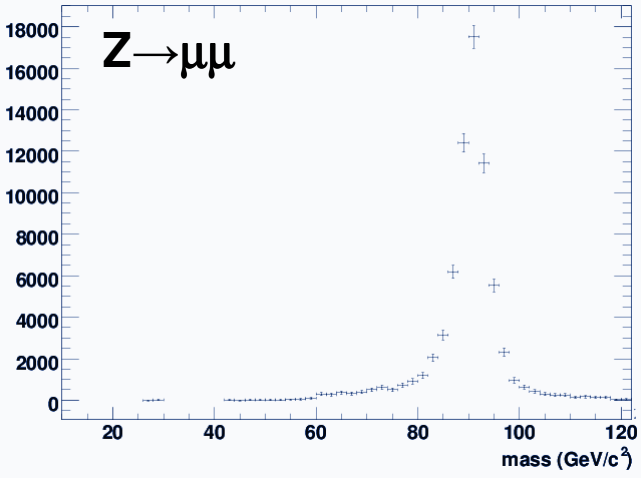
- decreasing of variables → size of ntuples smaller
- calculation of variables and parameters
- creation of control plots

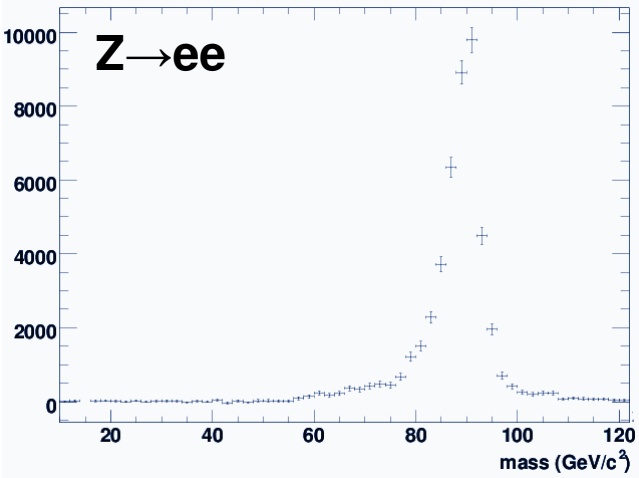
SecondCycle:

- real analysis
- integration of cuts
- results

expectation from signal







- reduction of combinatorial background: opposite sign – 2 x same sign (os - 2ss)
- 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

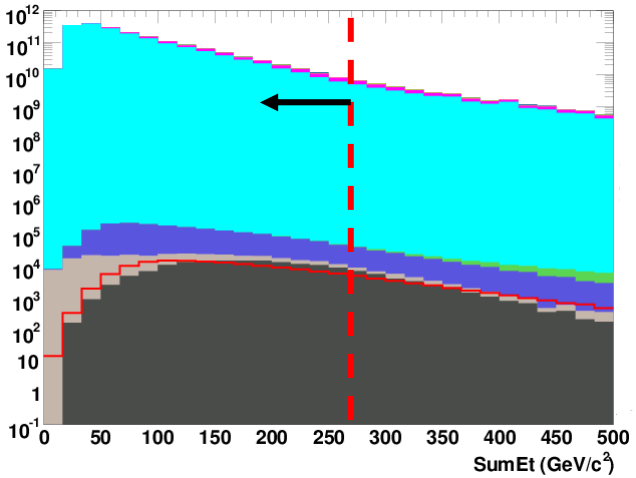
$Z \to \tau\tau$	$Z \to ee$	$Z \to \mu\mu$
SumEt < 260GeV		
$\|\eta\| < 2.5$		
pT > 15GeV		
pairs of back to back jets → veto ($\Delta\phi_l^j < 2.94 \vee > 3.34$)		
MET > 20GeV	MET > 15GeV	MET > 15GeV
mT < 45GeV	mT < 30GeV	mT < 55GeV
2 τ's	2 μ's	2 e's
$20GeV < M_{\tau\tau} < 100GeV$	$60GeV < M_{ee} < 120GeV$	$60GeV < M_{\mu\mu} < 120GeV$

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

$$mT = \sqrt{MET^2 - pT_l^2}$$

Transversal mass of lepton and missing transversal energy

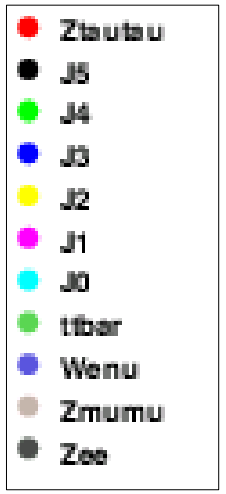
τ-selection



- SumEt cut at > 260 GeV

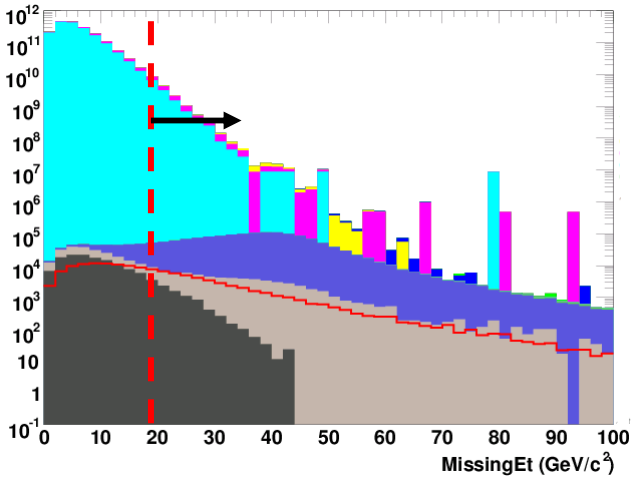
→ elimination of jets and ttbar

← Sum of transversal energy

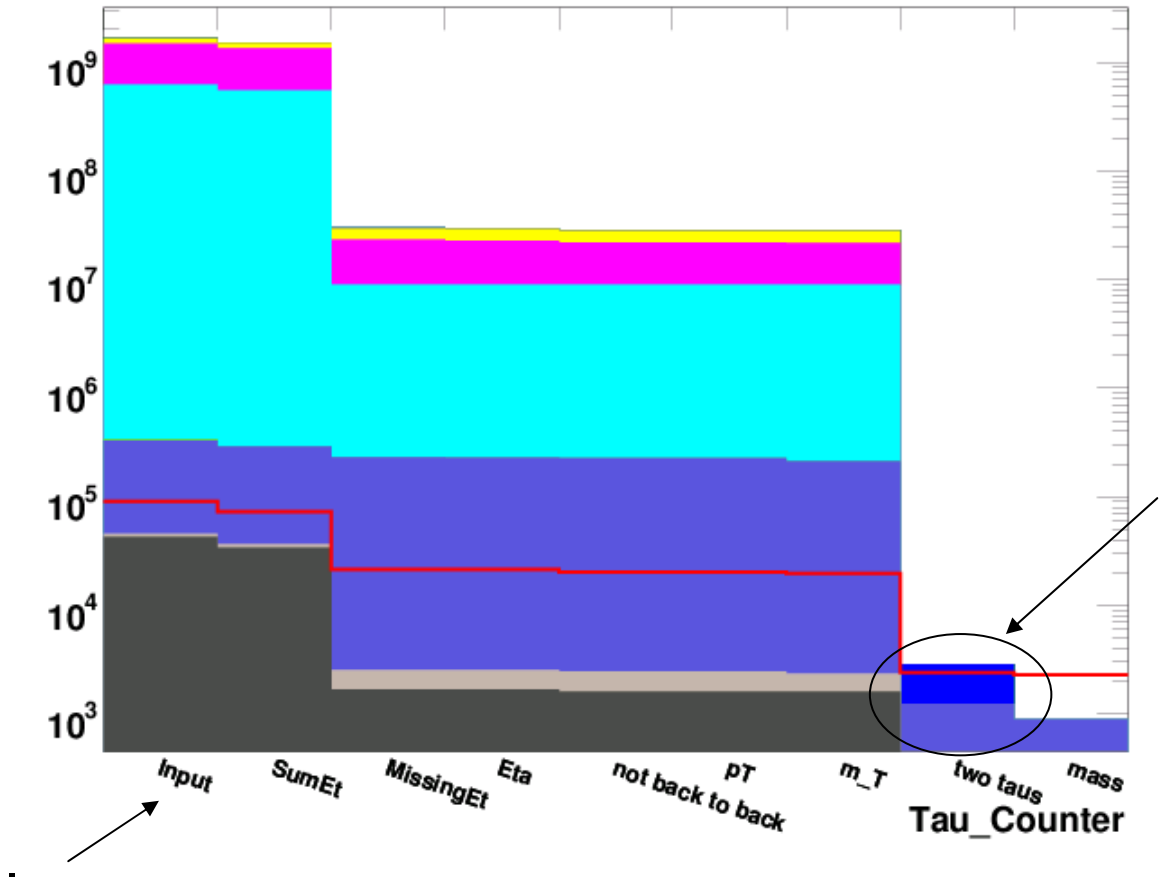


- suppression of jets with missing transversal energy < 20 GeV

Missing transversal energy after SumEt cut →

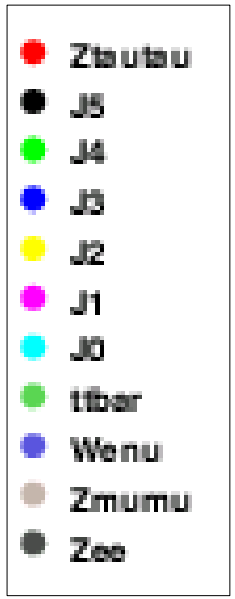


τ-selection



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

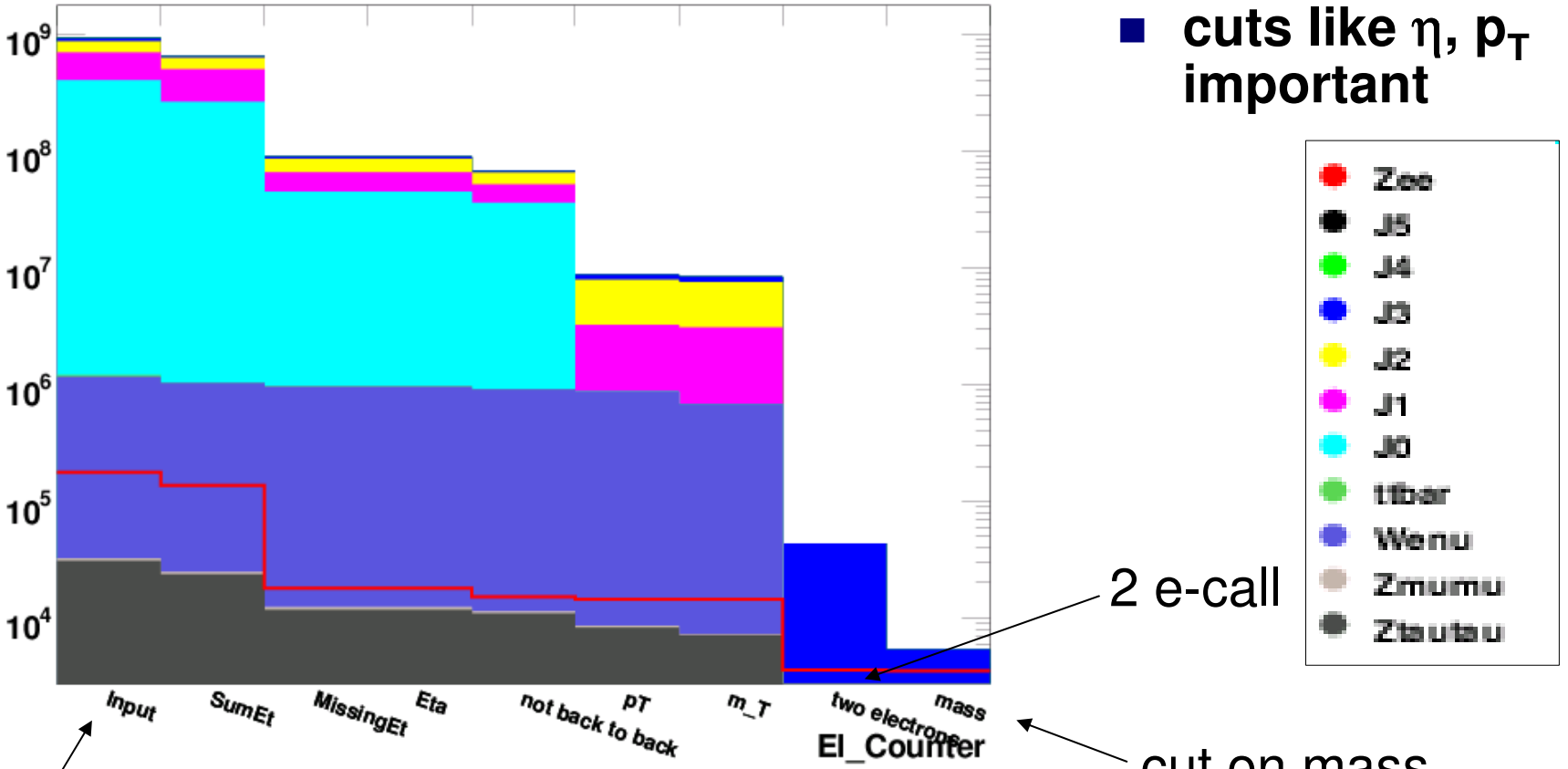
2 τ-call



Input

e-selection

El_Counter



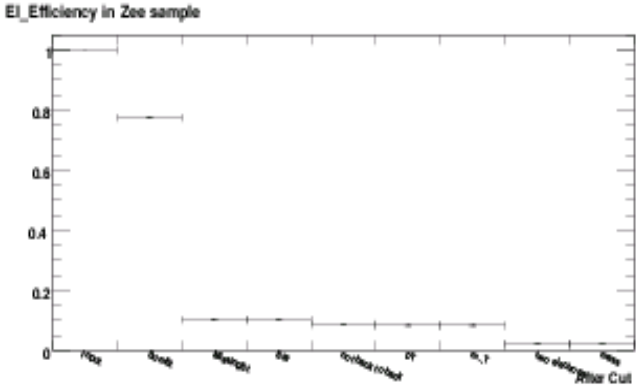
- cuts like η, p_T important

2 e-call

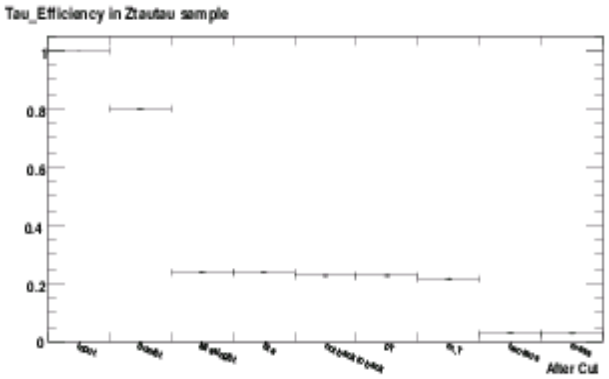
cut on mass

Input

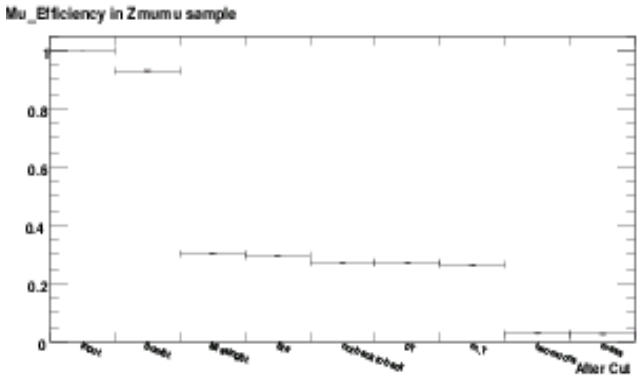
efficiency



e efficiency in $Z \rightarrow ee$



τ efficiency in $Z \rightarrow \tau\tau$

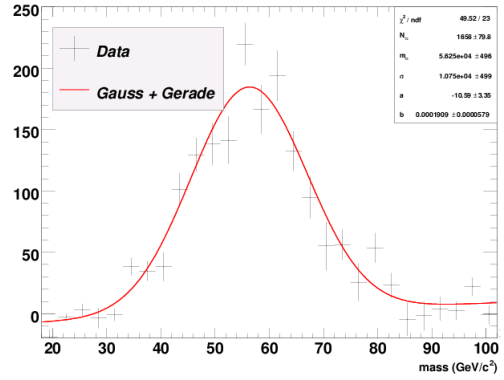


μ efficiency in $Z \rightarrow \mu\mu$

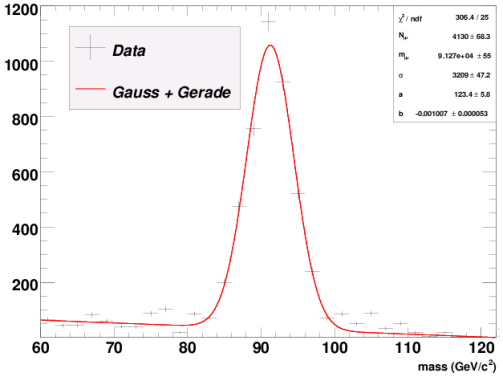
	τ pairs	μ pairs	e pairs
before cut (signal)	13653,8	71495,8	49247,9
after Cut (signal)	2299,85	5310,92	3510,41
same sign	240,996	0	34,08
opposite sign	2058,85	5310,92	3476,32
os - 2ss	1576,86	5310,92	3408,16
2 lepton efficiency	16,8%	7,4%	7,1%
signal efficiency	2,6%±0,05%	2,5%±0,03%	2,0%±0,03%
background efficiency	$5{,}4 \times 10^{-7} \pm 0.0$	$2{,}4 \times 10^{-6} \pm 1{,}6 \times 10^{-7}$	$5{,}8 \times 10^{-6} \pm 7{,}9 \times 10^{-8}$

mass peaks

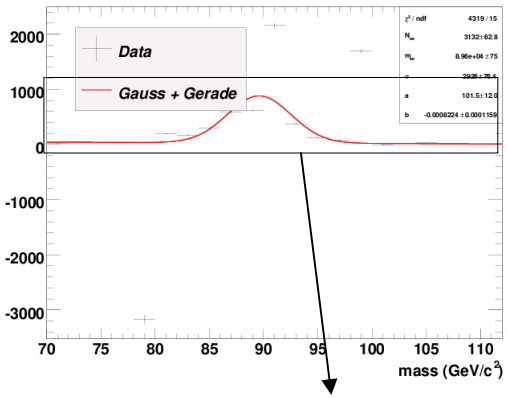
invariant mass of two taus in all samples (zoom)



invariant mass of two muons in all samples (zoom)



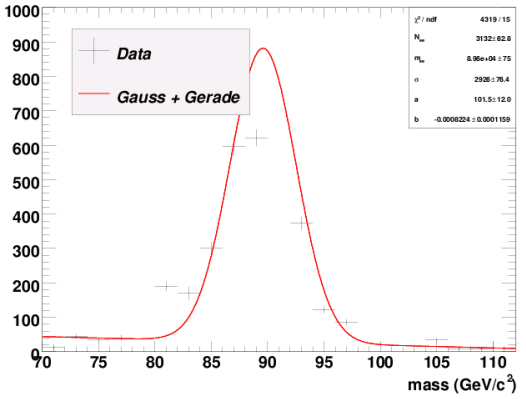
invariant mass of two electrons in all samples (zoom)



- current Z mass peaks
- "runaway" electrons due to J3 sample
- used os – 2ss

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

invariant mass of two electrons in all samples (zoom)



efficiency

- **overall efficiency $\varepsilon_{\tau\tau}$**
- **numbers of $Z\rightarrow\tau\tau \approx Z\rightarrow\mu\mu$ (BR's)**
- **ε_{kin} = 33,65% ± 3,37%**

  (assume error of 10% for ε_{kin})
- **$\varepsilon_{\tau 1} \approx \varepsilon_{\tau 2}$ assumed**

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

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

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

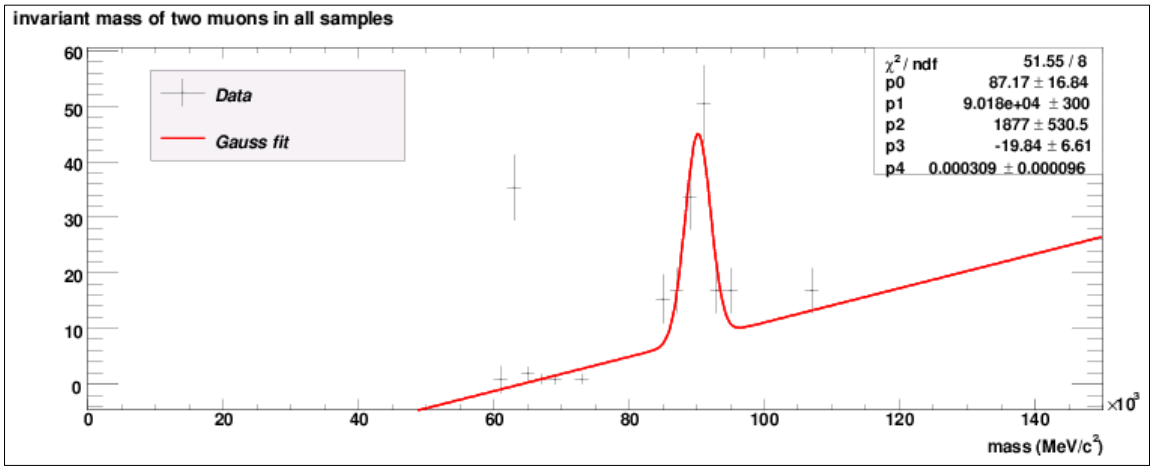
- ε_τ: averaged over all p_T
- equations converted to ε_τ

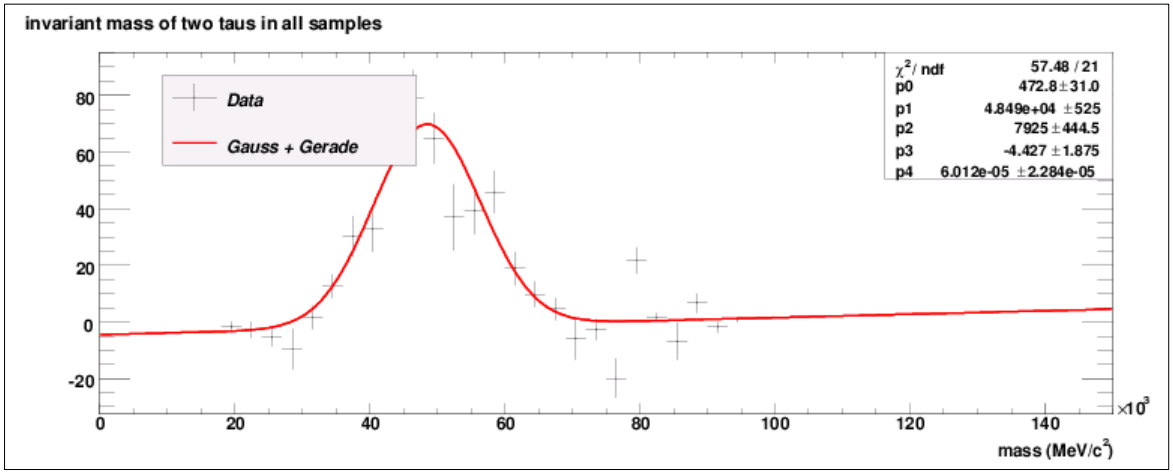
$$\varepsilon_\tau = \sqrt{\frac{n_{Z\to\tau\tau}(\text{sel.})}{n_{Z\to\mu\mu}(\text{init.}) \cdot BF^2(\tau \to \text{had.}) \cdot \frac{\sigma_{Z\to\tau\tau}}{\sigma_{Z\to\mu\mu}}}} \cdot \frac{1}{\varepsilon_{kin}}$$

- efficiency small due to the cuts (perhaps too strong, but clean sample)

number of initial μ–pairs	168000 ± 410
number of τ pairs (after	1658 ± 80
efficiency ε_τ	$25{,}5\% \pm 1{,}5\%$

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
- left: invariant mass for p_T between 15 and 30 GeV
- progress ongoing

plots and calculations preliminary

summary

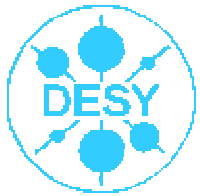
- control of current algorithms of τ-reconstruction in data
- clean selection $\rightarrow$ clean dataset, but no high efficiency
- understanding of first data with help of measured efficiencies and events

outlook

- efficiency for different p_T- and η-bins
- increasing of statistics: also semileptonic $Z \rightarrow \tau\tau$-decays
- still missing, but coming soon: include trigger efficiencies
- TauDPDMaker data will allow tag and probe trigger efficiency measurement, at the moment not possible

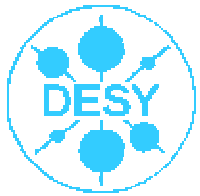
Backup

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

Analysenaufbau

- **FirstCycle:**
  - **Verkleinern des NTupels**
  - **Berechnung einiger Variablen und Parameter und Kontrollplots**
- **SecondCycle:**
  - **eigentliche Analyse**
  - **Cuts integriert**
  - **Ergebnisse**

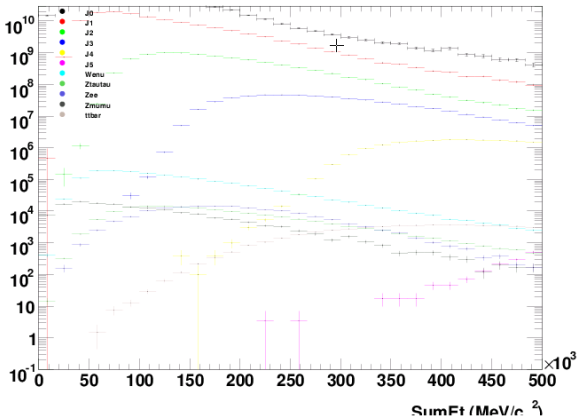
Luminositäten

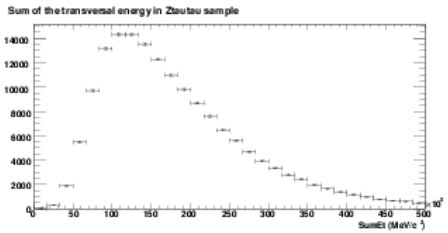
- alle Plots vorläufig, auf 100 pb^{-1} normiert → unterschiedliche Samples mit unterschiedlichem Gewicht
- Gewicht = 1 / Luminosität
- Luminosität = Events / WQ

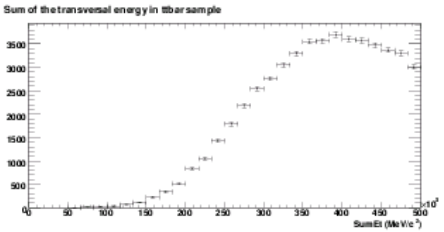
Datensatz		Luminosität [pb^{-1}]
$Z\tau\tau$	5188	110,79
Zee	5144	8,8024
$Z\mu\mu$	5145	5,95
Weν	5104	11,69
ttbar	5200	133,31
J0	5009	$1{,}147 \cdot 10^{-5}$
J1	5010	$2{,}1 \cdot 10^{-4}$
J2	5011	$2{,}09 \cdot 10^{-3}$
J3	5012	0,0611
J4	5013	1,022
J5	5014	28,59

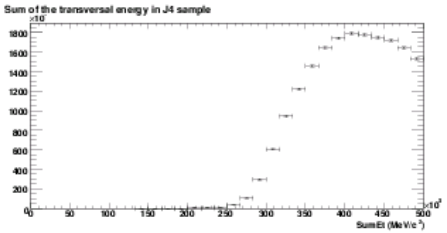
Cuts

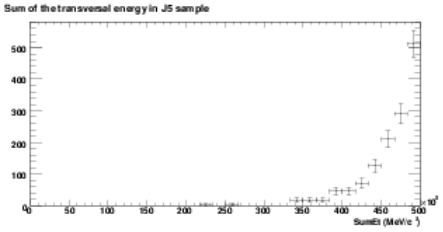
Sum of transversal energy



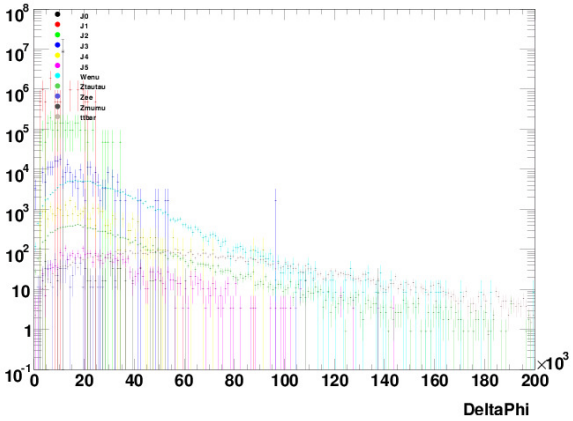


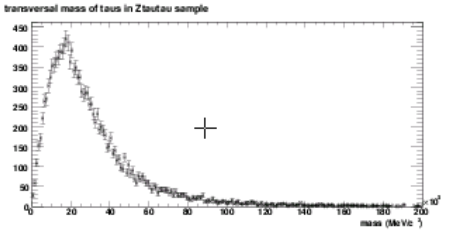


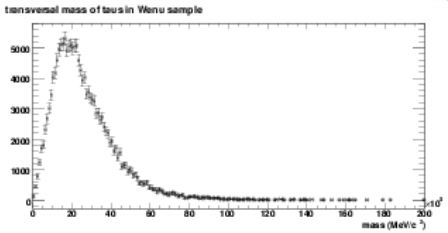


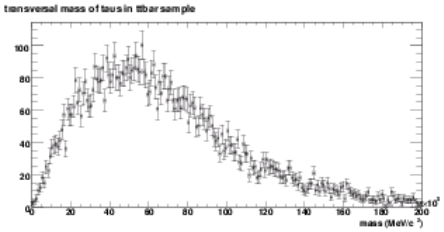


transversal mass of taus

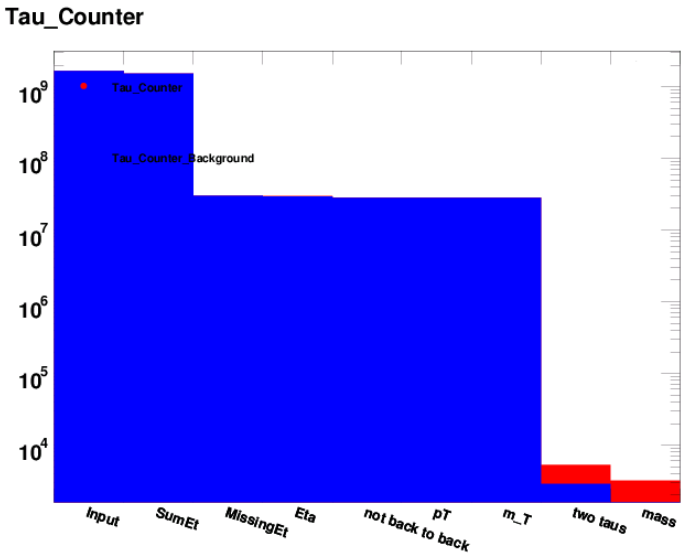


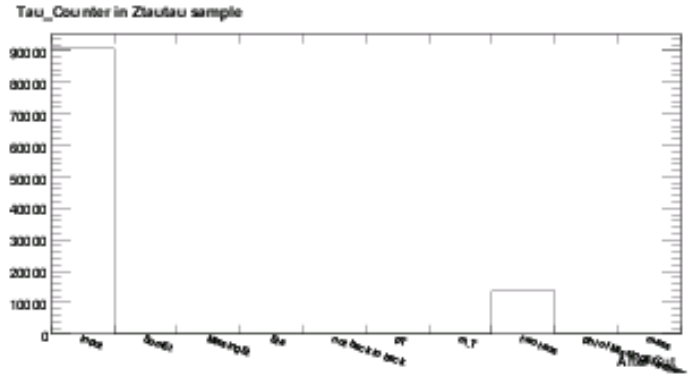


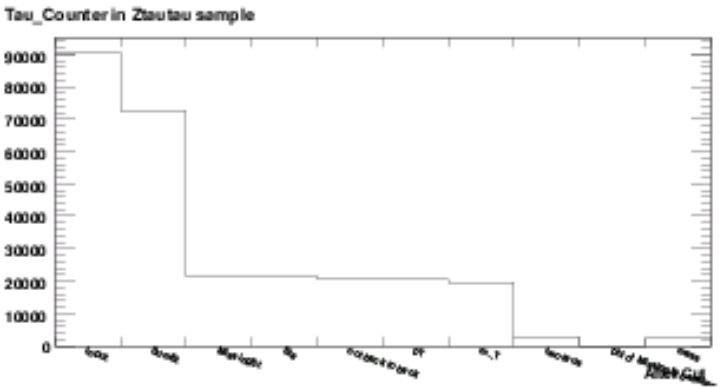




Cuts

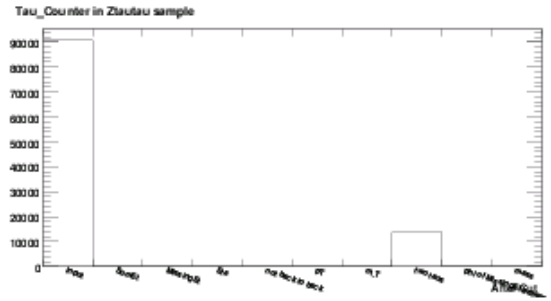


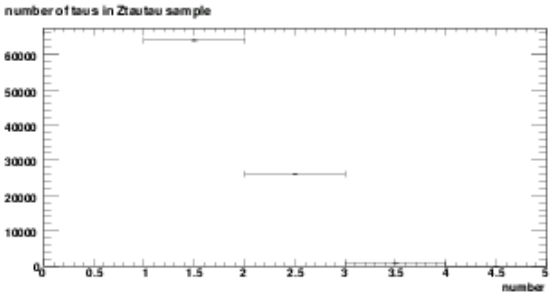


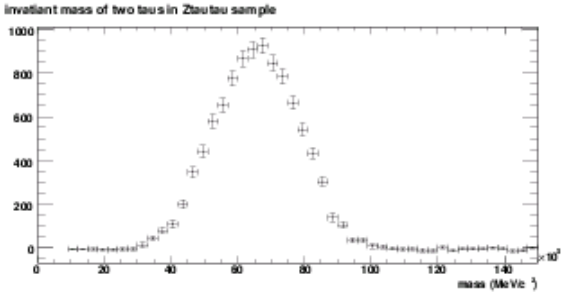


- vor Cuts (r.o.), nach Cuts (r.u.)
- inkl. Untergrund (l.o.)
- sauberes Sample

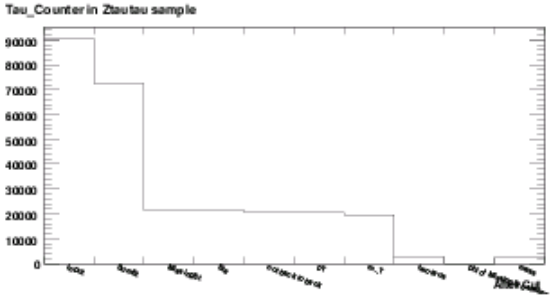
Cuts

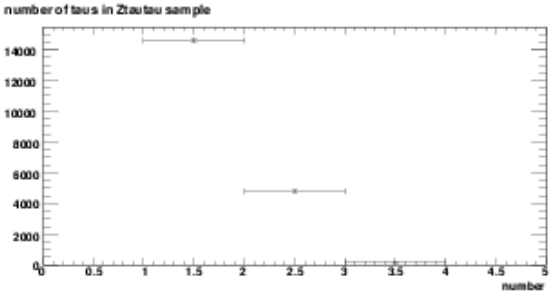


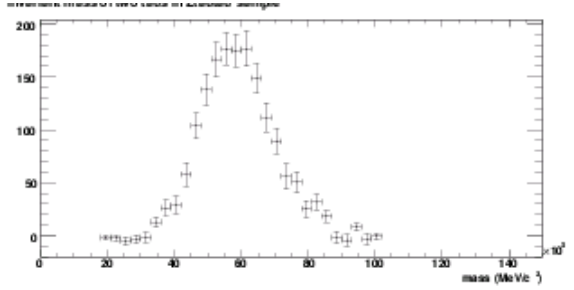




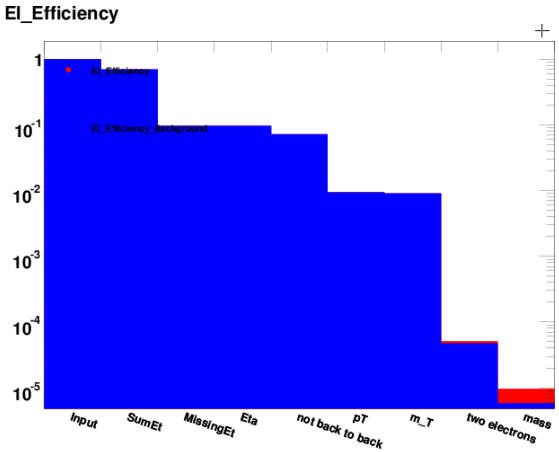
- Zττ-Sample
- vor Cuts (links)
- nach Cuts (rechts)
- viel Signal-verlust
- Counter und Effizienzen

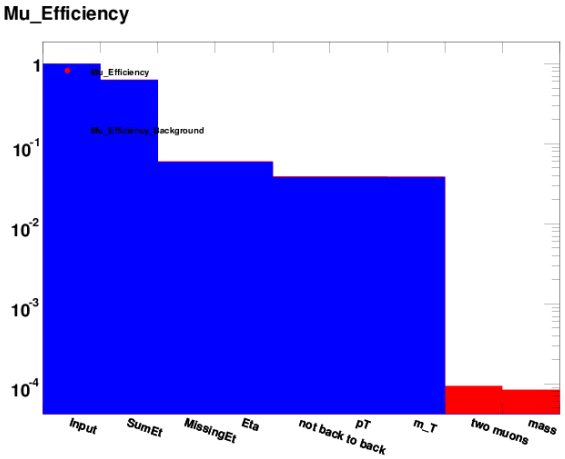


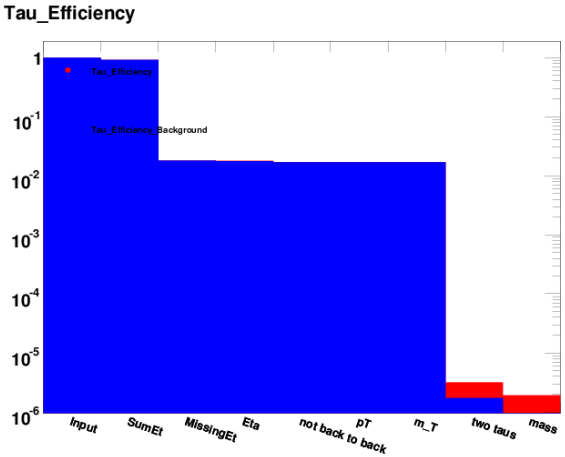




Effizienzen



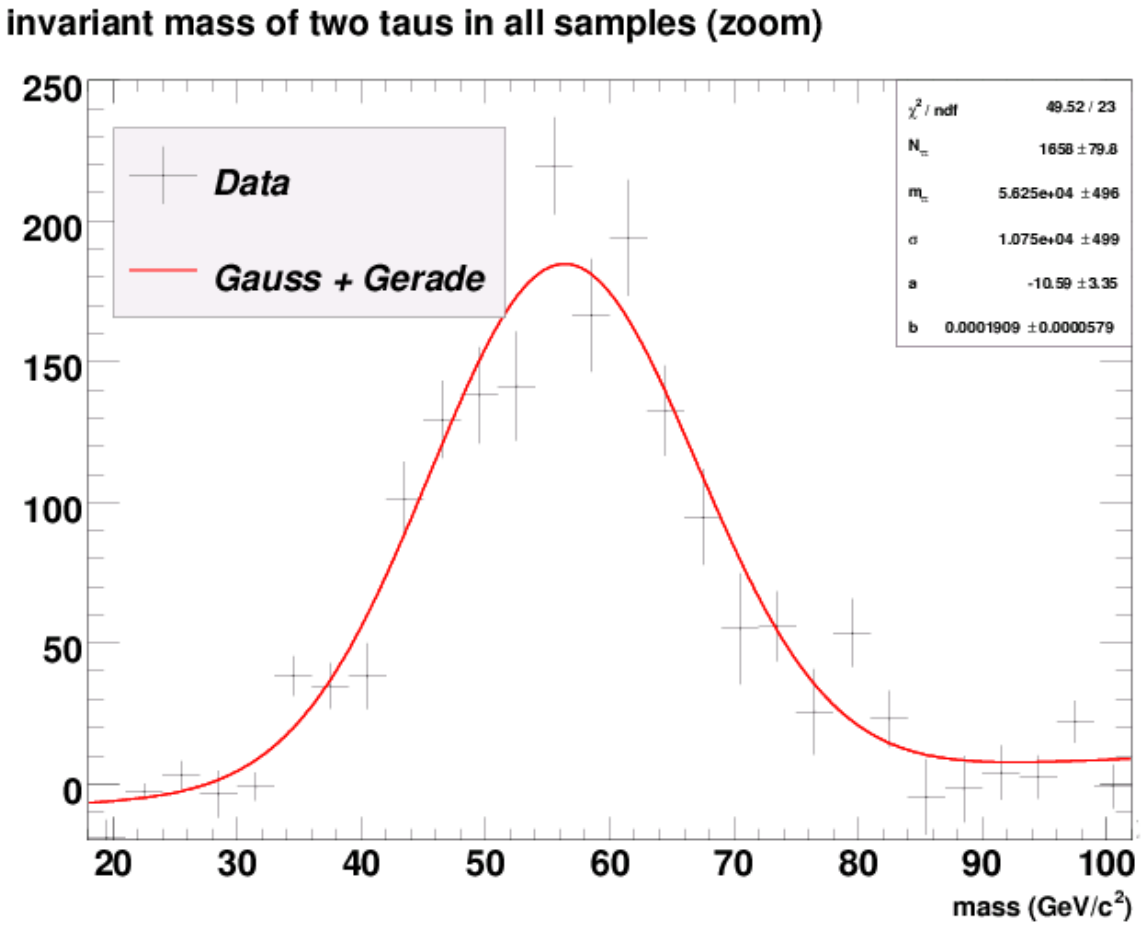




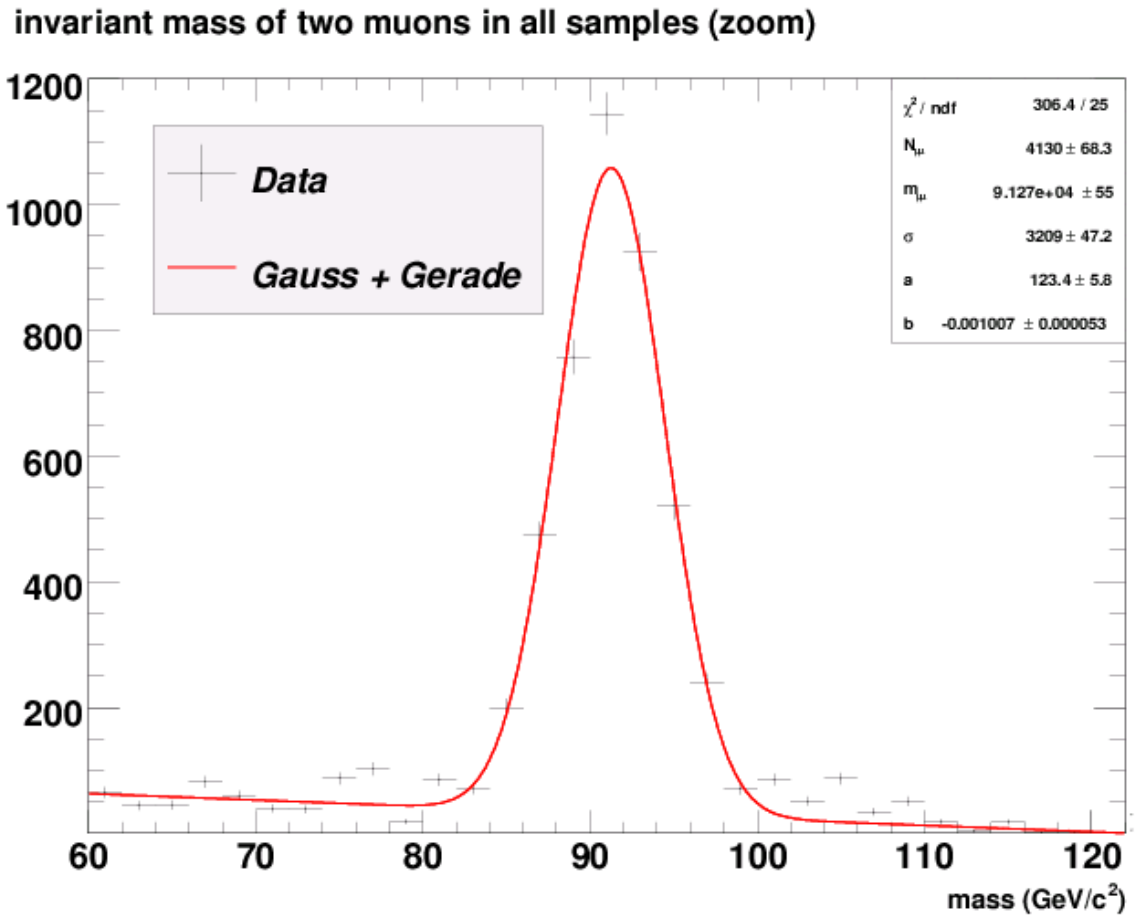
	τ	μ	e
vor Cut	$1{,}67 \cdot 10^{9}$	$6{,}51 \cdot 10^{7}$	$9{,}28 \cdot 10^{8}$
nach Cut	3193,11	5469,27	8891,42
Effizienz	$1{,}9 \cdot 10^{-6} \pm 0.0$	$8{,}4 \cdot 10^{-5} \pm 1{,}1 \cdot 10^{-6}$	$9{,}6 \cdot 10^{-6} \pm 1{,}0 \cdot 10^{-7}$

- **wahre Berechnung der Effizienz im Ausblick kurz vorgestellt**
- **hier aus Diagramm ausgelesen**

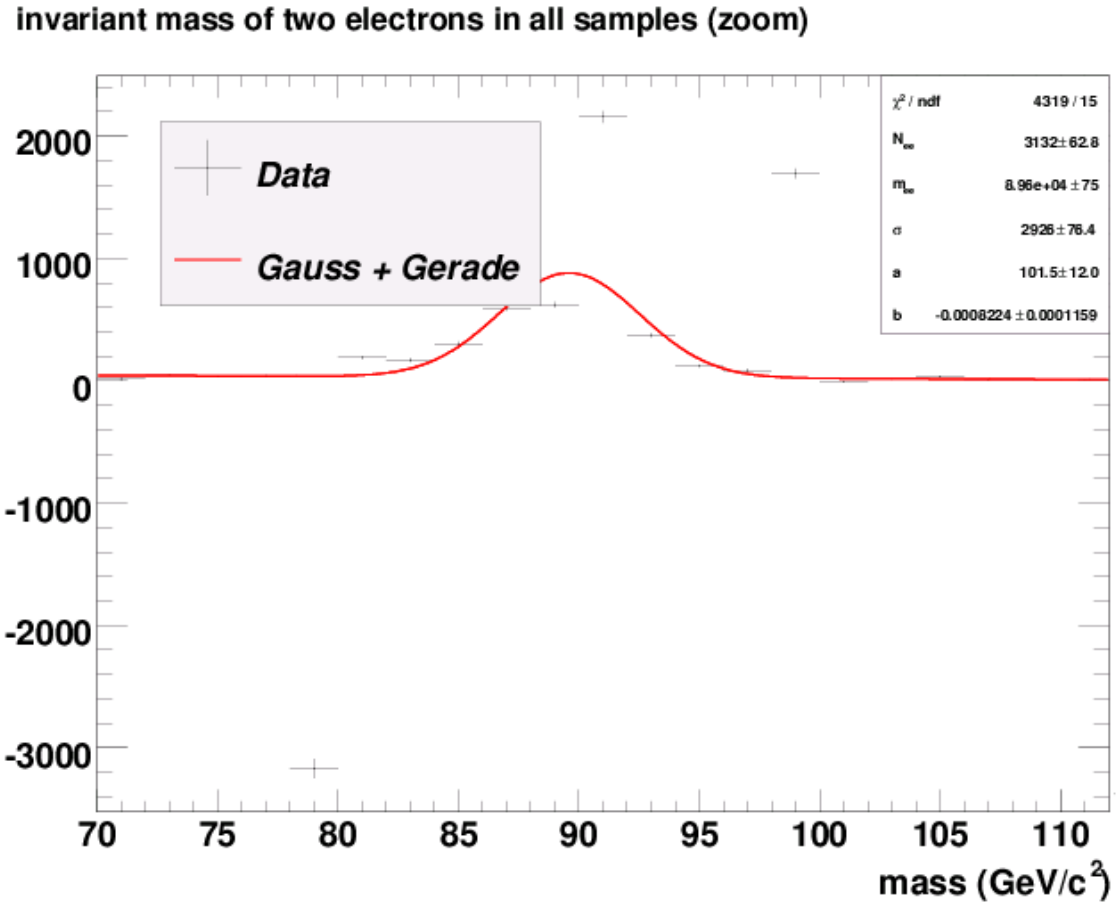
massplots


invariant mass of two taus in all samples (zoom)
Data
Gauss + Gerade
χ^2 / ndf 49.52 / 23
$N_{\tau\tau}$ 1658 ± 79.8
$m_{\tau\tau}$ 5.625e+04 ± 496
σ 1.075e+04 ± 499
a -10.59 ± 3.35
b 0.0001909 ± 0.0000579
250
200
150
100
50
0
20
30
40
50
60
70
80
90
100
mass (GeV/c^2)

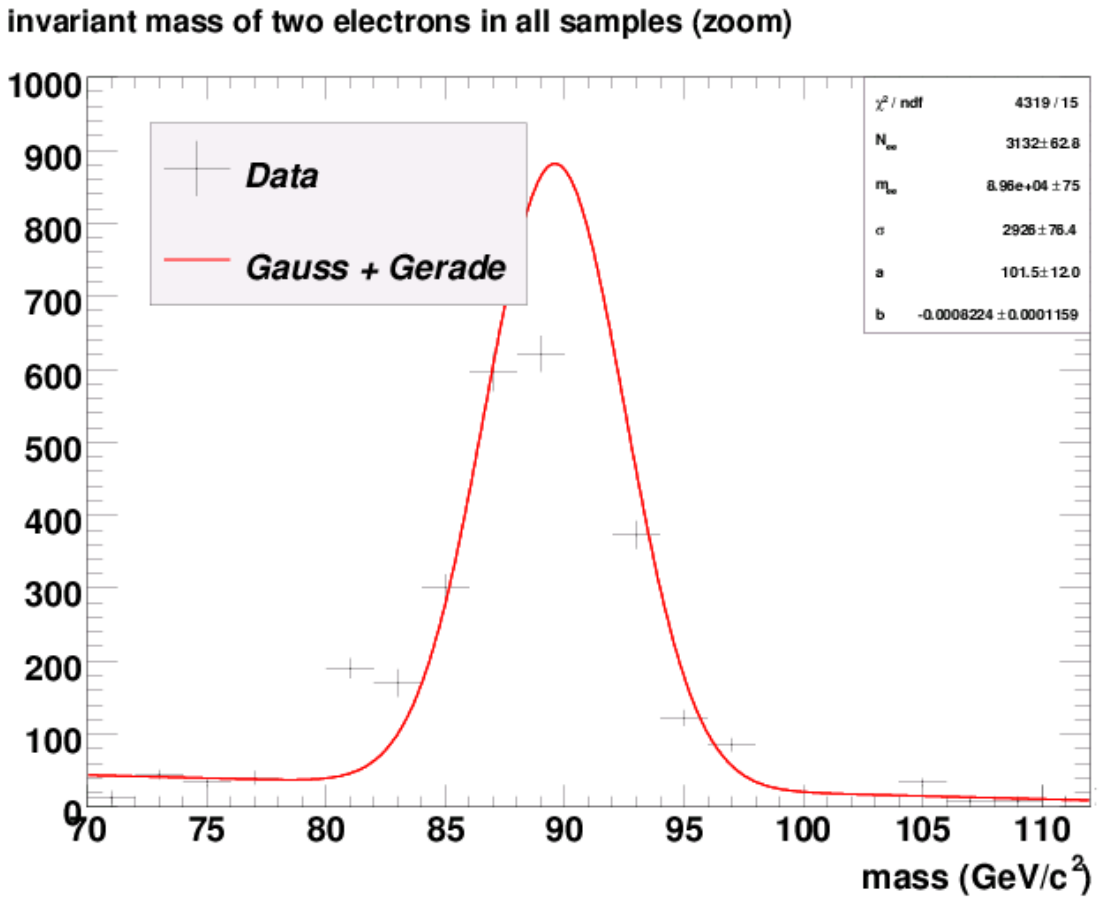
massplots


invariant mass of two muons in all samples (zoom)
Data
Gauss + Gerade
χ² / ndf 306.4 / 25
N_μ 4130 ± 68.3
m_μ 9.127e+04 ± 55
σ 3209 ± 47.2
a 123.4 ± 5.8
b -0.001007 ± 0.000053
1200
1000
800
600
400
200
60
70
80
90
100
110
120
mass (GeV/c²)

massplots


invariant mass of two electrons in all samples (zoom)
Data
Gauss + Gerade
χ² / ndf 4319 / 15
N 3132 ± 62.8
m 8.96e+04 ± 75
σ 2926 ± 76.4
a 101.5 ± 12.0
b -0.0008224 ± 0.0001159
2000
1000
0
-1000
-2000
-3000
70
75
80
85
90
95
100
105
110
mass (GeV/c²)

massplots


invariant mass of two electrons in all samples (zoom)
Data
Gauss + Gerade
χ² / ndf 4319 / 15
N_ee 3132 ± 62.8
m_ee 8.96e+04 ± 75
σ 2926 ± 76.4
a 101.5 ± 12.0
b -0.0008224 ± 0.0001159
1000
900
800
700
600
500
400
300
200
100
0
70
75
80
85
90
95
100
105
110
mass (GeV/c²)

efficiency

- **Overall efficiency $\varepsilon_{\tau\tau}$**
- **numbers of $Z \rightarrow \tau\tau \approx Z \rightarrow \mu\mu$ (BR's)**
- **ε_{kin} = 33,65% ± 3,37%**
  (assumption of error of 10% for ε_{kin})
- **ε_{τ}: averaged over all p_T**
- **BF ($\tau \rightarrow$ had) = 66 %**

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

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

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) %

number of initial μ–pairs	168000 ± 410
number of τ pairs (after Cut)	1658 ± 80
efficiency ε_{τ}	28,9% ± 0,9%

efficiency

- **overall efficiency $\varepsilon_{\tau\tau}$**
- **numbers of $Z\rightarrow\tau\tau \approx Z\rightarrow\mu\mu$ (BR's)**
- **ε_{kin} = 33,65% ± 3,37%**

  (assume error of 10% for ε_{kin})
- **$\varepsilon_{\tau 1} \approx \varepsilon_{\tau 2}$ assumed**

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

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

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

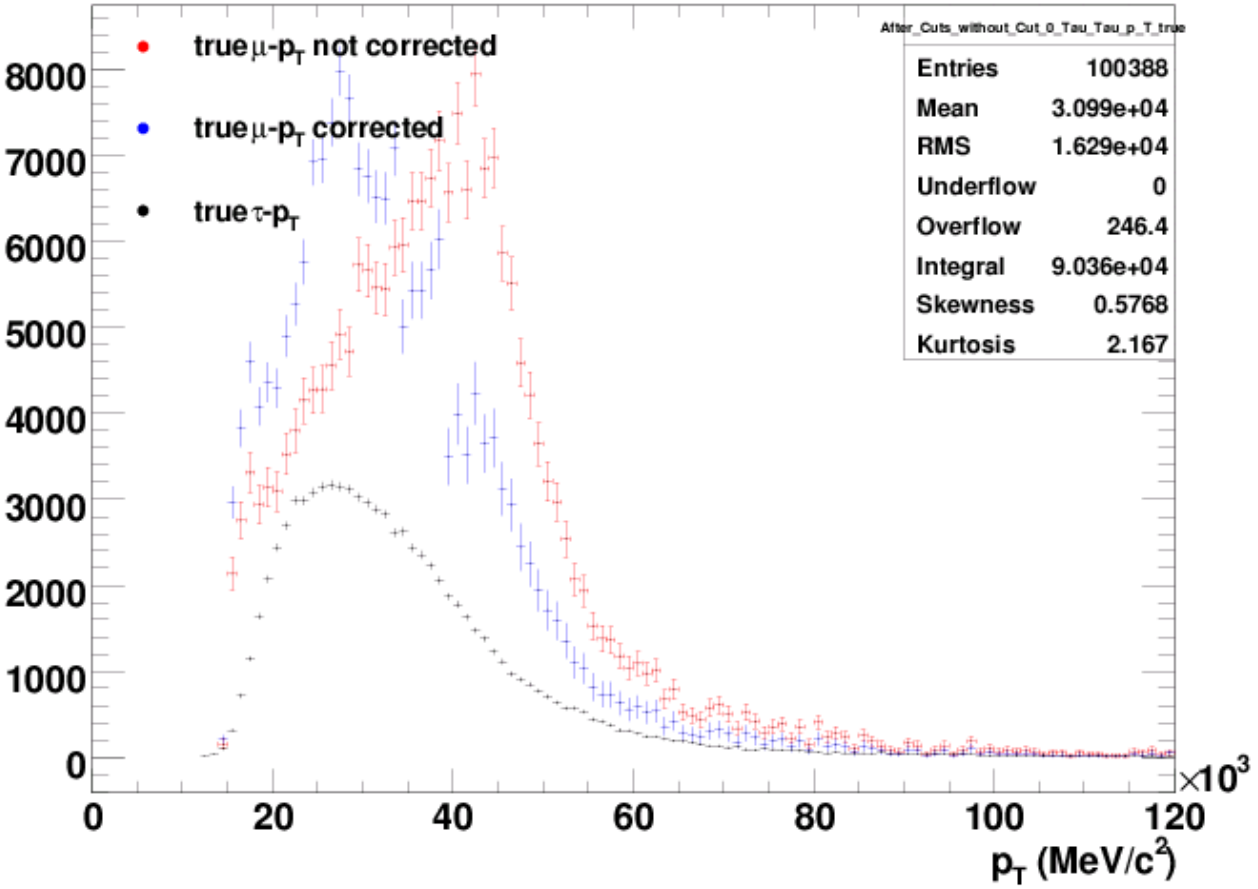
BF's for Z

- 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) %

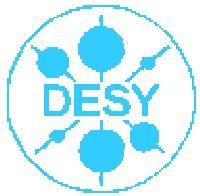
- **BF ($\tau\rightarrow$had): (67,9 ± 0,1) %**
- **$\sigma_{Z\rightarrow\tau\tau}$ = 1640 pb**
- **$\sigma_{Z\rightarrow\mu\mu}$ = 1670 pb**

correction factors

true transversal momentum of muons in Zmumu sample without any cuts

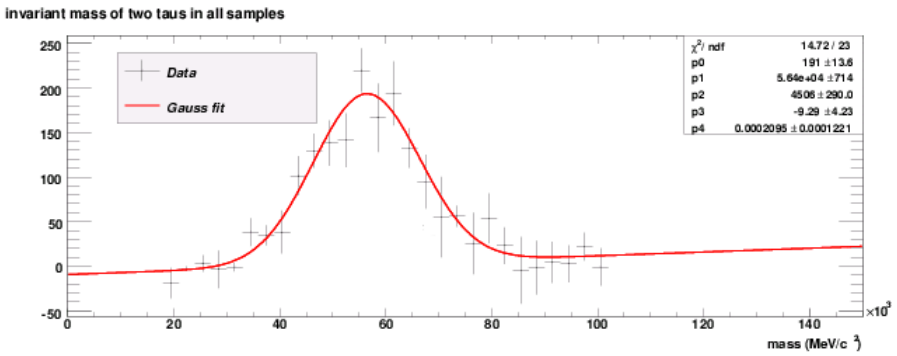


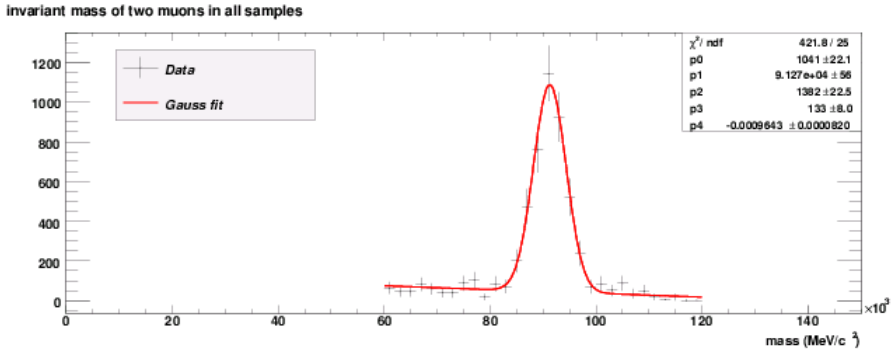
Ergebnisse



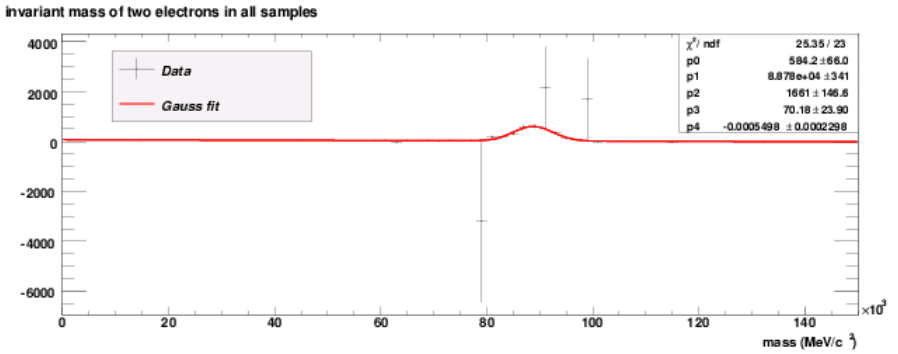
- vorher: 90611,1 τ-Ereignisse
- nachher: 2299,85 2-τ-Ereignisse
- nach Cuts: 2,6%
- für Myonen: 214202; 5310,92; 2,5%
- für Elektronen: 176361; 3510,41; 2,0%
- jeweils viel Signalverlust, dafür sauberes sample
- aber bei Myonen besser Hintergrund herausfiltern
- Bedenke: gewichtete Ereignisse

Zusammenfassung





derzeitige Z-Massenpeaks (unterschiedliche Gewichtung)



Effizienz

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