Protocol

Nicolas Heimann

nicolas.heimann@studium.uni-hamburg.de

Jesse Hinrichsen

jesse.hinrichsen@studium.uni-hamburg.de

Universität Hamburg

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Zusammenfassung

An abstract...

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1 Introcution

2 Identifying events

Quantities for events:
Ctrk(Sump): Energy of charged traces
Ctrk(N): Number of charged traces
Ecal(SumE): Energy in electronic-kalorimeter
Hcal(SumE): Energy in hadronic-kalorimeter

Quantities					
Run	Event	Ctrk(Sump)	Ctrk(N)	Ecal(SumE)	Hcal(SumE)
00	ELECTRONS	AF	AFG	004	00
00	MUONS	AF	AFG	004	00
00	TAUS	AF	AFG	004	00
00	HADRONS	AF	AFG	004	00

3 Statistical analysis of Z^0 decay channels

3.1 Decay width and cross-section

Using equation (2.12) we calculate following decay width of the Z-boson into fermions and (2.14) for cross-section at peak.

Decay width for different channels	
Channel	Decay width
$\Gamma_l = \Gamma_e = \Gamma_\mu = \Gamma\tau$	85.9 MeV
Γ_ν	165.9 MeV
$\Gamma_u = \Gamma_c$	301.5 MeV
$\Gamma_d = \Gamma_s = \Gamma_b$	381.4 MeV
Γ_Z	2502.7 MeV
Γ_{hadr}	1747.3 MeV
Γ_{lept}[1]	257.8 MeV
Γ_{neutr}	497.6 MeV

Partial cross-section at peak	
σ_{lept}	5.35 KeV^{-2}
σ_{neutr}	10.32 KeV^{-2}
$\sigma_{u,c}$	18.76 KeV^{-2}
$\sigma_{d,s,c}$	23.73 KeV^{-2}

3.2 Estimating change of Z^0 decay width for additional channels

Decay width of Z^0 for additional channels		
Added channel	Z^0 width	relative increase
Lepton	2.589 GeV	3.5 %
Neutrino	2.669 GeV	6.6 %
u-Quark	2.804 GeV	12 %
d-Quark	2.884 GeV	15.2 %

3.3 Differential cross-section

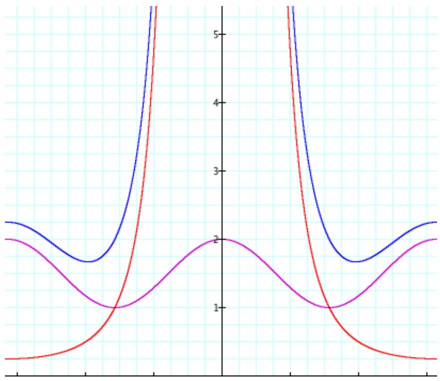

Abbildung 1: Differential cross-section on Θ qualitatively. Red: t-channel, violet: s-channel, blue: s-channel + t-channel

For s-channel: $\frac{d\sigma}{d\Omega} \propto 1 + \cos^2\Theta$ (for big $Theta$)
For t-channel: $\frac{d\sigma}{d\Omega} \propto (1 - \cos\Theta)^{-2}$ (for small $Theta$)

3.4 Forward-Backward Asymmetry

Based on equation (2.18)

Forward-Bckward asymmetry			
$\sqrt{s}$ / $\sin^2(\theta_W)$	0.21	0.23	0.25
89.225 GeV	0.547	0.321	0.285
91.225 GeV	0.530	0.407	0.284
93.225 GeV	0.515	0.480	0.284

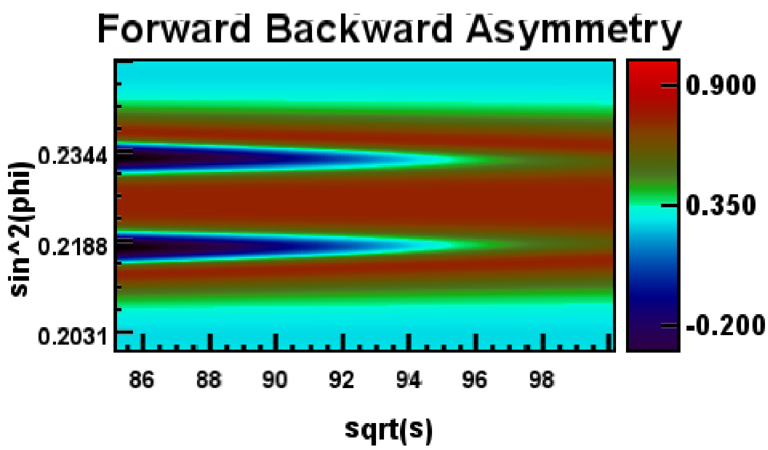

Abbildung 2: Forward-Bckward asymmetry

4 Analyzing Data

4.1 Pure Events

For the e^+, e^- detection we have to apply a cut for the $-0.71 \leq \cos(\theta) \leq 0.65$ and $-0.925 \leq \cos(\theta) \leq -0.85$ due to a problem in the detector.

4.1.1 Z->e^+, e^-

- All energy in Ecal
- None in Hcal
- 2 charged traces
- Momentum of charged traces around Z_M

4.1.2 Z->μ^+, μ^-

- None in Ecal
- Very little in Hcal
- 2 charged traces
- Momentum of charged traces around Z_M
- For $\cos(\theta) leq - 0.7$ and $\cos(\theta) geq 0.7$ the slope for differential cross-section is not as expected. Thus cut it.

4.1.3 Z->τ^+, τ^-

4.2 Seperating t-channel for e^+e^-

We want to find $\cos\theta$ so that we filter many t-channel events:

$$\frac{T}{T+S} \leq 0.05 \tag{1}$$

where $T = a(1-\cos\theta)^{-2}$ and $S = b(1+\cos^2\theta)$. The differential crossection is then

$$\frac{dN}{d\cos\theta} = \frac{a}{(1-\cos\theta)^2} + b(1+\cos^2\theta) \tag{2}$$

where we integrate over $\cos\theta$.

$$\int dN = \frac{a}{1-\cos\theta} + b\left(\cos\theta + \frac{1}{3}\cos^3\theta\right) \tag{3}$$

We obtain detector errors outside $cos\theta \in [-0.7, 0.7]$. Therefore the integration is performed only on that interval. Since we have two unkowns in the equation we split the integral into two integrals to get two linear equation:

$$\begin{aligned} 11786 &= a(\frac{1}{1-0.7} - 1) + b(0,7 + \frac{1}{3}0.7^3) = (2 + \frac{1}{3})a + 0,813433b \\ 9620 &= a(1 - \frac{1}{1+0.7}) + b(0,7 + \frac{1}{3}0.7^3) = 0,4117647a + 0,813433b \end{aligned} \tag{4}$$

With the power of basic linear algebra we get $a = 1127,2$ and $b = 9155,857$. We can now compute the True number of events in s-channel:

$$N_s = b\int_{-1}^{1} d\cos\theta(1+\cos^2\theta) = \frac{8}{3}b = 24413 \tag{5}$$

Insert a and b into condition (1) we get a upper boundary for $\cos\theta$

$$\frac{a}{(1-\cos\theta)^2}\frac{1}{\frac{a}{(1-\cos\theta)^2} + b(1+\cos^2\theta))} \leq 0.05 \iff \cos\theta \leq -0.188342 \tag{6}$$

Finally we will work with the following setup of cuts:

CUT	e	τ	μ	q
ECAL lower	85	0	8	15
ECAL upper	100	30	75	x
HCAL lower	x	0	x	x
HCAL upper	x	20	x	x
PCHARGED lower	x	70	8	x
PCHARGED upper	x	x	58	x
N lower	x	x	2	7
N upper	x	4	7	x-
$\cos\theta_1$ lower	-0,7	x	x	x
$\cos\theta_1$ upper	-0,188342	x	x	x
$\cos\theta_2$ lower	x	x	x	x
$\cos\theta_2$ upper	x	x	x	x

4.3 Create efficiency matrix

We create efficiency matrix ϵ where each element is defined as

$$\epsilon = \frac{N_{cut}}{N_{true}} \tag{7}$$

Thus apply the cuts which we found with help of monte carlo data on data-set 4 we find the following efficiency matrix.

$$\epsilon = \begin{pmatrix} 2.86 \cdot 10^{-01} & 1.0 \cdot 10^{-05} & 0 & 0 \\ 0 & 9.18 \cdot 10^{-01} & 5.77 \cdot 10^{-03} & 0 \\ 3.03 \cdot 10^{-03} & 9.13 \cdot 10^{-03} & 7.93 \cdot 10^{-01} & 4.05 \cdot 10^{-03} \\ 1.02 \cdot 10^{-03} & 0 & 1.2 \cdot 10^{-02} & 9.95 \cdot 10^{-01} \end{pmatrix} \tag{8}$$

This allows us to filter background from data N_{obs} so we get real events N_{true}

$$\epsilon^{-1} N_{obs} = N_{true} \tag{9}$$

with inverse efficiency matrix

$$\epsilon^{-1} = \begin{pmatrix} 3.5 & -3.81 \cdot 10^{-05} & 2.77 \cdot 10^{-07} & -1.13 \cdot 10^{-09} \\ 8.39 \cdot 10^{-05} & 1.09 & -7.92 \cdot 10^{-03} & 3.23 \cdot 10^{-05} \\ -1.33 \cdot 10^{-02} & -1.25 \cdot 10^{-02} & 1.26 & -5.13 \cdot 10^{-03} \\ -3.43 \cdot 10^{-03} & 1.51 \cdot 10^{-04} & -1.52 \cdot 10^{-02} & 1.01 \end{pmatrix} \tag{10}$$

The error of efficiency matrix is given by

$$\Delta\epsilon = \sqrt{\frac{\epsilon(1-\epsilon)}{N}} \tag{11}$$

Using $\epsilon \Delta\epsilon^{-1} + \Delta\epsilon\epsilon^{-1} = 0$ we get error for inverse efficiency matrix:

$$\Delta\epsilon^{-1} = -\epsilon^{-1}\Delta\epsilon\epsilon^{-1} = \begin{pmatrix} -3.55 \cdot 10^{-02} & 4.24 \cdot 10^{-07} & 1.08 \cdot 10^{-08} & -9.96 \cdot 10^{-11} \\ 1.43 \cdot 10^{-05} & -1.06 \cdot 10^{-03} & -3.9 \cdot 10^{-04} & 3.18 \cdot 10^{-06} \\ -1.6 \cdot 10^{-03} & -3.78 \cdot 10^{-04} & -2.21 \cdot 10^{-03} & -2.43 \cdot 10^{-04} \\ -6.42 \cdot 10^{-04} & 9.57 \cdot 10^{-06} & -4.77 \cdot 10^{-04} & -1.97 \cdot 10^{-04} \end{pmatrix} \tag{12}$$

4.4 Dataset4

Apply the cuts we used within monte carlo simulation we could find the total number of observed events for each $\sqrt{s} \in \{88.47939, 89.46793, 90.22266, 91.22430, 91.96648, 92.96465, 93.71712\}$:

$$N_{obs} = \begin{pmatrix} 2.0 \cdot 10^{+01} & 9.0 \cdot 10^{+01} & 1.0 \cdot 10^{+02} & 2.0 \cdot 10^{+03} \\ 8.0 \cdot 10^{+01} & 3.0 \cdot 10^{+02} & 3.0 \cdot 10^{+02} & 7.0 \cdot 10^{+03} \\ 9.0 \cdot 10^{+01} & 4.0 \cdot 10^{+02} & 3.0 \cdot 10^{+02} & 9.0 \cdot 10^{+03} \\ 6.0 \cdot 10^{+02} & 3.0 \cdot 10^{+03} & 2.0 \cdot 10^{+03} & 7.0 \cdot 10^{+04} \\ 1.0 \cdot 10^{+02} & 6.0 \cdot 10^{+02} & 5.0 \cdot 10^{+02} & 1.0 \cdot 10^{+04} \\ 4.0 \cdot 10^{+01} & 3.0 \cdot 10^{+02} & 3.0 \cdot 10^{+02} & 6.0 \cdot 10^{+03} \\ 6.0 \cdot 10^{+01} & 3.0 \cdot 10^{+02} & 3.0 \cdot 10^{+02} & 7.0 \cdot 10^{+03} \end{pmatrix} \tag{13}$$

Where each roch represents one CMS-energy. Using the inverse efficiency matrix (10) we get true number of events

$$N_{true} = (\epsilon^{-1} N_{obs}^T)^T = \begin{pmatrix} 6.995 \cdot 10^{+01} & 1.006 \cdot 10^{+02} & 1.08 \cdot 10^{+02} & 2.512 \cdot 10^{+03} \\ 2.833 \cdot 10^{+02} & 3.053 \cdot 10^{+02} & 2.966 \cdot 10^{+02} & 6.682 \cdot 10^{+03} \\ 3.183 \cdot 10^{+02} & 4.214 \cdot 10^{+02} & 3.838 \cdot 10^{+02} & 8.812 \cdot 10^{+03} \\ 2.207 \cdot 10^{+03} & 3.12 \cdot 10^{+03} & 2.635 \cdot 10^{+03} & 6.718 \cdot 10^{+04} \\ 3.987 \cdot 10^{+02} & 6.252 \cdot 10^{+02} & 5.346 \cdot 10^{+02} & 1.306 \cdot 10^{+04} \\ 1.294 \cdot 10^{+02} & 2.847 \cdot 10^{+02} & 2.805 \cdot 10^{+02} & 6.287 \cdot 10^{+03} \\ 1.959 \cdot 10^{+02} & 3.163 \cdot 10^{+02} & 2.812 \cdot 10^{+02} & 7.016 \cdot 10^{+03} \end{pmatrix} \tag{14}$$

with error of

$$\Delta N_{true} = \begin{pmatrix} -7.095 \cdot 10^{-01} & -1.284 \cdot 10^{-01} & -8.901 \cdot 10^{-01} & -5.511 \cdot 10^{-01} \\ -2.873 & -3.809 \cdot 10^{-01} & -2.443 & -1.487 \\ -3.228 & -5.185 \cdot 10^{-01} & -3.19 & -1.948 \\ -2.238 \cdot 10^{+01} & -3.771 & -2.367 \cdot 10^{+01} & -1.47 \cdot 10^{+01} \\ -4.044 & -7.586 \cdot 10^{-01} & -4.633 & -2.861 \\ -1.313 & -3.568 \cdot 10^{-01} & -2.236 & -1.375 \\ -1.987 & -3.866 \cdot 10^{-01} & -2.463 & -1.531 \end{pmatrix} \tag{15}$$

Next we calculate crossection by using equation (S-3.3):

$$\frac{dN}{dt} = \mathcal{L}\sigma \tag{16}$$

Using the following matrix for Strahlungskorrektur from table 5.5

$$\Lambda = \begin{pmatrix} 9.0 \cdot 10^{-02} & 9.0 \cdot 10^{-02} & 9.0 \cdot 10^{-02} & 2.0 \\ 2.0 \cdot 10^{-01} & 2.0 \cdot 10^{-01} & 2.0 \cdot 10^{-01} & 4.3 \\ 3.6 \cdot 10^{-01} & 3.6 \cdot 10^{-01} & 3.6 \cdot 10^{-01} & 7.7 \\ 5.2 \cdot 10^{-01} & 5.2 \cdot 10^{-01} & 5.2 \cdot 10^{-01} & 1.08 \cdot 10^{+01} \\ 2.2 \cdot 10^{-01} & 2.2 \cdot 10^{-01} & 2.2 \cdot 10^{-01} & 4.7 \\ -1.0 \cdot 10^{-02} & -1.0 \cdot 10^{-02} & -1.0 \cdot 10^{-02} & -2.0 \cdot 10^{-01} \\ -8.0 \cdot 10^{-02} & -8.0 \cdot 10^{-02} & -8.0 \cdot 10^{-02} & -1.6 \end{pmatrix} \tag{17}$$

And the following Luminosities given by table 5.6:

$$\mathcal{L}dt = \begin{pmatrix} 4.6398 \cdot 10^{+02} \\ 6.6752 \cdot 10^{+02} \\ 4.8676 \cdot 10^{+02} \\ 2.2466 \cdot 10^{+03} \\ 5.3591 \cdot 10^{+02} \\ 4.506 \cdot 10^{+02} \\ 7.097 \cdot 10^{+02} \end{pmatrix} \tag{18}$$

We calculate the crossection for each element $\sigma_{ij} = N_{true,ij}/(\mathcal{L}dt)_i + \Lambda_{ij}$:

$$\sigma = \begin{pmatrix} 1.33105 \cdot 10^{-01} & 2.9044 \cdot 10^{-01} & 2.99061 \cdot 10^{-01} & 7.38817 \\ 3.21344 \cdot 10^{-01} & 6.22457 \cdot 10^{-01} & 5.98488 \cdot 10^{-01} & 1.42622 \cdot 10^{+01} \\ 5.46949 \cdot 10^{-01} & 1.15915 & 1.06876 & 2.57169 \cdot 10^{+01} \\ 8.00873 \cdot 10^{-01} & 1.80151 & 1.58741 & 4.05623 \cdot 10^{+01} \\ 4.32723 \cdot 10^{-01} & 1.29668 & 1.12314 & 2.89486 \cdot 10^{+01} \\ 7.21127 \cdot 10^{-02} & 5.73666 \cdot 10^{-01} & 5.47035 \cdot 10^{-01} & 1.36859 \cdot 10^{+01} \\ -1.0932 \cdot 10^{-03} & 3.31443 \cdot 10^{-01} & 2.79308 \cdot 10^{-01} & 8.23799 \end{pmatrix} \tag{19}$$

The error of cross section in eq (16) is given by

$$\Delta\sigma = \sqrt{\left(\frac{\partial\sigma}{\partial N_{True}}\Delta N_{True}\right)^2 + \left(\frac{\partial\sigma}{\partial(\mathcal{L}dt)}\Delta\mathcal{L}dt\right)^2} = \sqrt{\left(\frac{1}{\mathcal{L}dt}\Delta N_{True}\right)^2 + \left(-\frac{N_{True}}{(\mathcal{L}dt)^2}\Delta\mathcal{L}dt\right)^2} \tag{20}$$

Where the error of $\mathcal{L}dt$ is given by

$$\Delta\mathcal{L}dt = \pm \begin{pmatrix} 4.249604 \\ 5.691792 \\ 4.454466 \\ 16.43293 \\ 4.848926 \\ 4.276552 \\ 6.104764 \end{pmatrix} [nb^{-1}] \tag{21}$$

Finally we get

$$\Delta\sigma = \begin{pmatrix} 2.0603 \cdot 10^{-03} & 2.0057 \cdot 10^{-03} & 2.8681 \cdot 10^{-03} & 4.96 \cdot 10^{-02} \\ 5.6236 \cdot 10^{-03} & 3.9419 \cdot 10^{-03} & 5.2671 \cdot 10^{-03} & 8.5376 \cdot 10^{-02} \\ 8.9322 \cdot 10^{-03} & 7.9929 \cdot 10^{-03} & 9.747 \cdot 10^{-03} & 1.6571 \cdot 10^{-01} \\ 1.2284 \cdot 10^{-02} & 1.0296 \cdot 10^{-02} & 1.3589 \cdot 10^{-02} & 2.1885 \cdot 10^{-01} \\ 1.0112 \cdot 10^{-02} & 1.065 \cdot 10^{-02} & 1.2499 \cdot 10^{-02} & 2.2052 \cdot 10^{-01} \\ 3.9891 \cdot 10^{-03} & 6.0496 \cdot 10^{-03} & 7.716 \cdot 10^{-03} & 1.3245 \cdot 10^{-01} \\ 3.6702 \cdot 10^{-03} & 3.8727 \cdot 10^{-03} & 4.8643 \cdot 10^{-03} & 8.506 \cdot 10^{-02} \end{pmatrix} \tag{22}$$

If we addup first three columns of the matrix we get:

$$\sigma = \begin{pmatrix} 7.2261 \cdot 10^{-01} & 7.3882 \\ 1.5423 & 1.4262 \cdot 10^{+01} \\ 2.7749 & 2.5717 \cdot 10^{+01} \\ 4.1898 & 4.0562 \cdot 10^{+01} \\ 2.8525 & 2.8949 \cdot 10^{+01} \\ 1.1928 & 1.3686 \cdot 10^{+01} \\ 6.0966 \cdot 10^{-01} & 8.238 \end{pmatrix} \tag{23}$$

with an error of

$$\Delta\sigma = \begin{pmatrix} 6.9341 \cdot 10^{-03} & 4.96 \cdot 10^{-02} \\ 1.4833 \cdot 10^{-02} & 8.5376 \cdot 10^{-02} \\ 2.6672 \cdot 10^{-02} & 1.6571 \cdot 10^{-01} \\ 3.6169 \cdot 10^{-02} & 2.1885 \cdot 10^{-01} \\ 3.3262 \cdot 10^{-02} & 2.2052 \cdot 10^{-01} \\ 1.7755 \cdot 10^{-02} & 1.3245 \cdot 10^{-01} \\ 1.2407 \cdot 10^{-02} & 8.506 \cdot 10^{-02} \end{pmatrix} \tag{24}$$

Where we used that $\Delta \sum_i a_i = \sqrt{\sum a_i^2}$.