Protocol

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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

2.1 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
$\Gamma_l = \Gamma_e = \Gamma_\mu = \Gamma_T$	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}

2.2 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 %

2.3 Differential cross-section

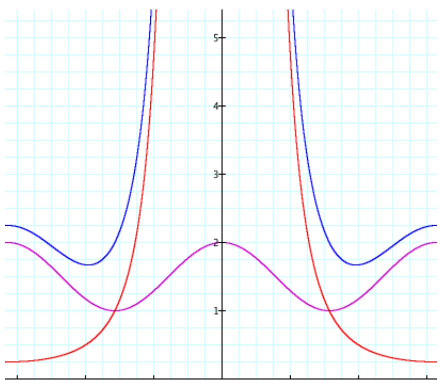

Abbildung 1: Differential cross-section on Θ qualitatively. Red: t-channel, violet: s-channel, blue: s-channel + t-channel

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 $Theta$)

2.4 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

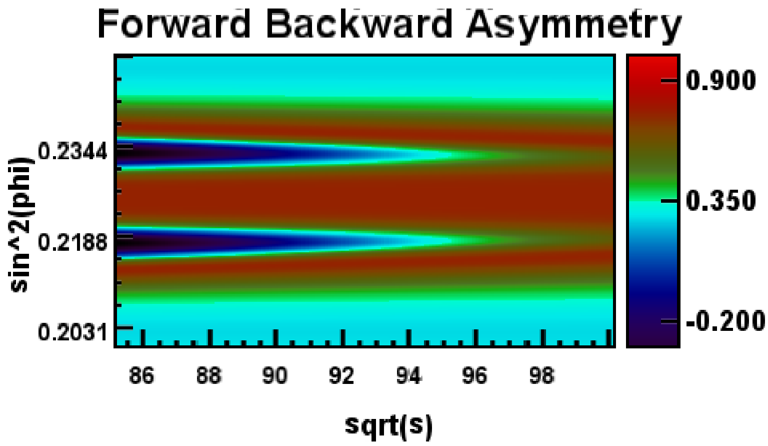

Abbildung 2: Forward-Bckward asymmetry

3 Analyzing Data

3.1 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.

3.1.1 Z->e^+, e^-

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

3.1.2 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.

3.1.3 Z->τ^+, τ^-

3.2 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

3.3 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:

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

3.4 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:

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

Also we include monte carlo correction factor

$$\mathcal{M} = \begin{pmatrix} 4.0961279303 \\ 1.060006996 \\ 1.2627697592 \\ 1.0152181196 \end{pmatrix} \tag{19}$$

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

$$\sigma = \begin{pmatrix} 2.66565 \cdot 10^{-01} & 3.02468 \cdot 10^{-01} & 3.53996 \cdot 10^{-01} & 7.47017 \\ 6.97041 \cdot 10^{-01} & 6.47807 \cdot 10^{-01} & 7.03198 \cdot 10^{-01} & 1.44138 \cdot 10^{+01} \\ 1.12577 & 1.20711 & 1.255 & 2.59911 \cdot 10^{+01} \\ 1.67049 & 1.87841 & 1.86789 & 4.10152 \cdot 10^{+01} \\ 1.09134 & 1.36129 & 1.36046 & 2.93176 \cdot 10^{+01} \\ 3.26344 \cdot 10^{-01} & 6.0869 \cdot 10^{-01} & 6.93407 \cdot 10^{-01} & 1.38972 \cdot 10^{+01} \\ 2.43212 \cdot 10^{-01} & 3.56132 \cdot 10^{-01} & 3.73723 \cdot 10^{-01} & 8.3877 \end{pmatrix} \tag{20}$$

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

$$\Delta\sigma = \sqrt{\left(\frac{\partial\sigma}{\partial N_{True}}\Delta N_{True}\right)^2 + \left(\frac{\partial\sigma}{\partial(\mathcal{L}dt)}\Delta\mathcal{L}dt\right)^2} = \sqrt{\left(\frac{1}{\mathcal{L}dt}\Delta N_{True}\right)^2 + \left(-\frac{N_{True}}{(\mathcal{L}dt)^2}\Delta\mathcal{L}dt\right)^2} \tag{21}$$

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

$$\Delta\mathcal{L}dt = \pm \begin{pmatrix} 4.249604 \\ 5.691792 \\ 4.454466 \\ 16.43293 \\ 4.848926 \\ 4.276552 \\ 6.104764 \end{pmatrix} [nb^{-1}] \tag{22}$$

Finally we get

$$\Delta\sigma = \begin{pmatrix} 2.0603 \cdot 10^{-03} & 2.0057 \cdot 10^{-03} & 2.8681 \cdot 10^{-03} & 4.96 \cdot 10^{-02} \\ 5.6236 \cdot 10^{-03} & 3.9419 \cdot 10^{-03} & 5.2671 \cdot 10^{-03} & 8.5376 \cdot 10^{-02} \\ 8.9322 \cdot 10^{-03} & 7.9929 \cdot 10^{-03} & 9.747 \cdot 10^{-03} & 1.6571 \cdot 10^{-01} \\ 1.2284 \cdot 10^{-02} & 1.0296 \cdot 10^{-02} & 1.3589 \cdot 10^{-02} & 2.1885 \cdot 10^{-01} \\ 1.0112 \cdot 10^{-02} & 1.065 \cdot 10^{-02} & 1.2499 \cdot 10^{-02} & 2.2052 \cdot 10^{-01} \\ 3.9891 \cdot 10^{-03} & 6.0496 \cdot 10^{-03} & 7.716 \cdot 10^{-03} & 1.3245 \cdot 10^{-01} \\ 3.6702 \cdot 10^{-03} & 3.8727 \cdot 10^{-03} & 4.8643 \cdot 10^{-03} & 8.506 \cdot 10^{-02} \end{pmatrix} \tag{23}$$

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

$$\sigma = \begin{pmatrix} 7.2261 \cdot 10^{-01} & 7.3882 \\ 1.5423 & 1.4262 \cdot 10^{+01} \\ 2.7749 & 2.5717 \cdot 10^{+01} \\ 4.1898 & 4.0562 \cdot 10^{+01} \\ 2.8525 & 2.8949 \cdot 10^{+01} \\ 1.1928 & 1.3686 \cdot 10^{+01} \\ 6.0966 \cdot 10^{-01} & 8.238 \end{pmatrix} \tag{24}$$

with an error of

$$\Delta\sigma = \begin{pmatrix} 6.9341 \cdot 10^{-03} & 4.96 \cdot 10^{-02} \\ 1.4833 \cdot 10^{-02} & 8.5376 \cdot 10^{-02} \\ 2.6672 \cdot 10^{-02} & 1.6571 \cdot 10^{-01} \\ 3.6169 \cdot 10^{-02} & 2.1885 \cdot 10^{-01} \\ 3.3262 \cdot 10^{-02} & 2.2052 \cdot 10^{-01} \\ 1.7755 \cdot 10^{-02} & 1.3245 \cdot 10^{-01} \\ 1.2407 \cdot 10^{-02} & 8.506 \cdot 10^{-02} \end{pmatrix} \tag{25}$$

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