Determination of Neutralino $\tilde{\chi}_2^0$ Branching Ratios in Leptonic Final States through Study of Selectron Pair Production

$$e^+e^- \rightarrow \tilde{e}_R\,\tilde{e}_L \rightarrow e\,\tilde{\chi}_1^0\,\bar{e}\,\tilde{\chi}_2^0$$

Blanka Sobloher

ECFA ILC Workshop, Vienna, November 2005

Corrections applied Nov. 23rd 2005

- ILC Parameters and Simulation
- Lepton Identification and 4-Lepton Selection
- SUSY Scenario SPS1a and Signal Process
- Determination of $\tilde{\chi}_2^0$ Branching Ratios
- Extrapolation Method
- Determination of $\tilde{e}_R\,\tilde{e}_L$ Partial Cross Sections

DESY

UH
Universität Hamburg

Simulation Environment

- ILC parameters for $e^+ e^-$
  - $\sqrt{s}$ = **500 GeV**
  - **Luminosity** ~ $2 \cdot 10^{34}$ /cm$^2 \cdot$s

    ΔL/L ≈ 10^{-4}
  - **Beam polarisations**
    $P_{max}(e^-) \approx 80\%$, both helicities
    $P_{max}(e^+) \approx 60\%$, both helicities
    ΔP ≈ 0,5%
- Simulation
  - **SUSY Spectrum:** SPheno 2.2 with interface to Pythia 6.3 via SLHA
  - **Event Generation:** Pythia 6.3 for SM and SUSY processes
  - **Parametrised Detector Simulation:** Simdet 4.1 (TESLA)

    → corresponds to current LDC

- Simulated processes
  - **Signal** $\tilde{e}_R \tilde{e}_L$**, pol.**

    $2\text{x}15 \cdot 10^6$ (> 30 ab^{-1} *)
  - **Background**
    - $\tilde{\chi}_2^0 \tilde{\chi}_2^0,\ \tilde{e}_L \tilde{e}_L,\ \tilde{\mu}_L \tilde{\mu}_L,\ \tilde{\tau}_2 \tilde{\tau}_2$, pol.
    - $\tilde{\nu}_e \tilde{\nu}_e,\ ZZ \to 4\ell$, unpol.

      > 30 ab^{-1} *
  - **Furthermore**
    - Complete SUSY process spectrum, mostly pol.

      > 30 ab^{-1} *
    - Complete 2f and 4f SM, unpol., (WW pol., $\gamma\gamma$: $170 \cdot 10^6$)

      > 500fb^{-1} *
    - 6f: WWZ^0 and eeWW, unpol.

      > 5 ab^{-1} *

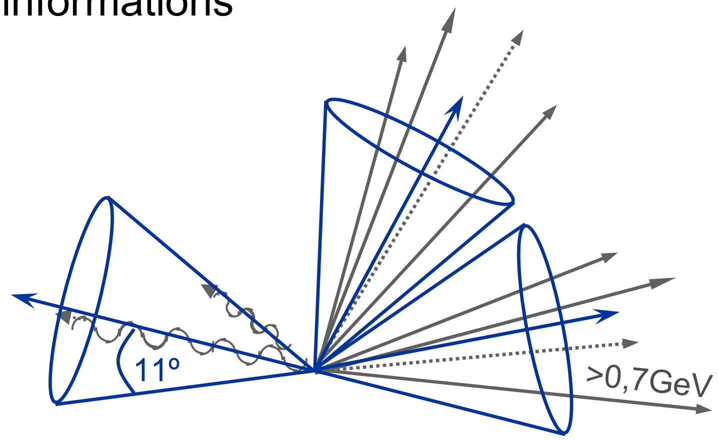
* counted for unpolarised beams

Lepton Identification

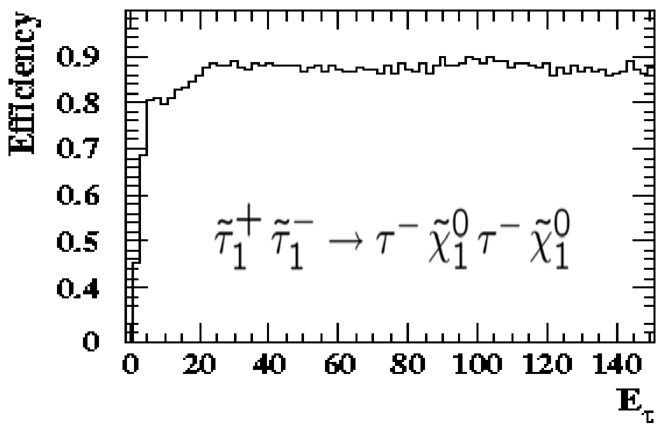
- Variable number of jets
- Isolated and collimated jets
- Low multiplicity

  → Cone Jet Algorithm

- Candidat: 1 cone
  - 1 or 3 tracks, Q = ±1
  - m_{inv} < 2 GeV, $|\eta|$ < 2 (≈ 15 º)
  - 15º isolation
- Classification
  - Electron (e), muon (μ) or hadron (1-prong, 3-prong) according to detector informations



- Single efficiencies from candidate pairs, e. g. $\tilde{\chi}_1^0 \tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 \tau^+ \tau^-$
  - e : ~ 80%
  - μ : ~ 80%
  - 1-prong : ~ 87%
  - 3-prong : ~ 72%
- Misidentification of hadrons as a candidate pair
  - $\gamma/Z \to qq$: $< 6 \cdot 10^{-6}$
  - $\gamma\gamma \to qq$: $< 2 \cdot 10^{-7}$



4-Lepton Selection with E_{mis}

- (1) For both 2 and 4 Leptons
  - $2 \leq N_{cand} \leq 6$, max 1 add. charged cone
  - $E_{cand1} > 4{,}5 \cdot \exp(0{,}45 \cdot \eta^2)$ GeV
  - $E_{neutral} < 20$ GeV, $|\cos(\theta_{neutral})|_{>3\ GeV} < 0{,}9$
  - $\cos(\alpha_{r\varphi}) > -0{,}99$
  - $p_t^{mis} > 20$ GeV/c, $|\cos(\theta_{mis})| < 0{,}85$
- (2) Specifically for 4 Leptons
  - $N_{cand} = 4$
  - Two pairs with $Q_1 \cdot Q_2 < 0$
  - No other charged cones
  - $E_{cand4} > 4$ GeV
  - 4f-veto:

    $E_{vis} < (25 \cdot \cos(\alpha_{r\varphi}) + 275)$ GeV

    $p_t^{mis} > (-97 \cdot \cos(\theta_{mis})^2 + 275)$ GeV/c
- Event numbers
  - $\sqrt{s} = 500$ GeV
  - $L = 500\ fb^{-1}$
  - unpolarised
  - Efficiencies good

Selection efficiencies are polarisation independent!

	2 fermion	4 + 6 fermion	$\tilde{e}_R \tilde{e}_L$ (16,5% in 4 ℓ)	$\tilde{\chi}_2^0 \tilde{\chi}_2^0$ (100% in 4 ℓ)	$\tilde{e}_L \tilde{e}_L$ (13% in 4 ℓ)	$\tilde{\nu}_e \tilde{\nu}_e$ (1% in 4 ℓ)	$\tilde{\tau}_2 \tilde{\tau}_2$ (13% in 4 ℓ)
total	9,8E+09	2,0E+07	78670	30450	21475	203270	7725
(1)	2,9E+06	6,2E+05	61893	28521	17326	30032	5712
(2) 4ℓ	0	177	4410	9697	2340	655	608
			5,6%	32%	11%	0,3%	8%

SUSY Scenario SPS1a

- mSUGRA type

  tanß = 10 $m_{1/2}$ = 250 GeV m_0 = 100 GeV

  A_0 = -100 GeV sgn(μ) = + 1

  → **Light sleptons and neutralinos**

  → **Dominant two body decays into leptons**

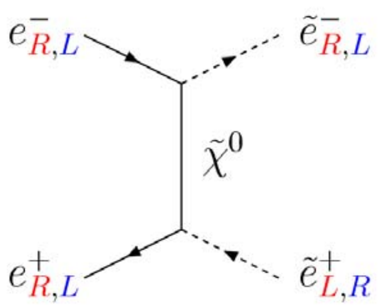
  → **Large branching fractions for tau leptons**

SPS1a Masses	
$\tilde{\chi}_1^0$	97.0 GeV
$\tilde{e}_R$	143.8 GeV
$\tilde{\chi}_2^0$	183.0 GeV
$\tilde{e}_L$	206.9 GeV

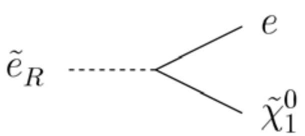
- Selectron pair production $\tilde{e}_R \tilde{e}_L$
  - Pure t-channel $\tilde{\chi}^0$ exchange
  - Association with incoming $e^{\pm}$:

    $e_R^- \leftrightarrow \tilde{e}_R^-$ $e_L^- \leftrightarrow \tilde{e}_L^-$ $e_R^+ \leftrightarrow \tilde{e}_L^+$ $e_L^+ \leftrightarrow \tilde{e}_R^+$
  - Contributions for beams of same helicity:

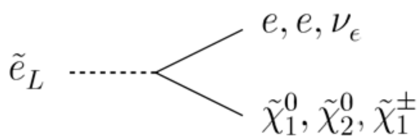
    $e_R^+ e_R^- \to \tilde{e}_L^+ \tilde{e}_R^-$ $e_L^+ e_L^- \to \tilde{e}_R^+ \tilde{e}_L^-$



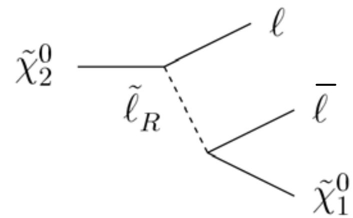
- Decays



100%



16.5% ($\tilde{\chi}_2^0$)



6.7% (ℓ = e)
6.9% (ℓ = μ)
86.0% (ℓ = τ)

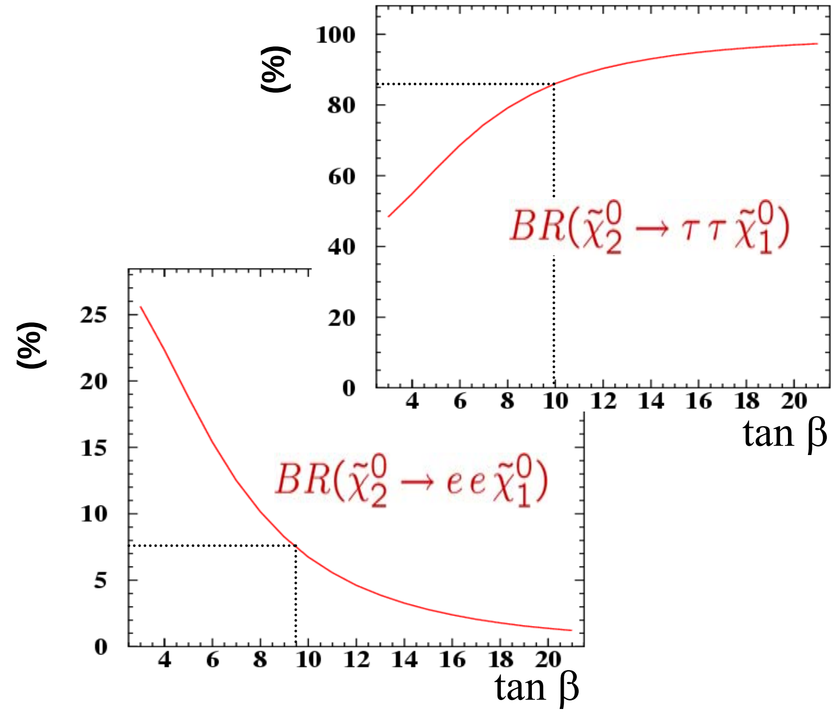
Determination of $\tilde{\chi}_2^0$ Leptonic Branching Ratios

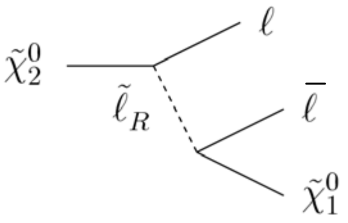
- Leptonic branching ratios sensitive to tanβ
- High values of tanβ
  - → Large branching ratios for decays into tau leptons
- $BR(ee)$, $BR(\mu\mu)$ and $BR(\tau\tau)$
  - → Sensitive to tanβ
- Define ratios

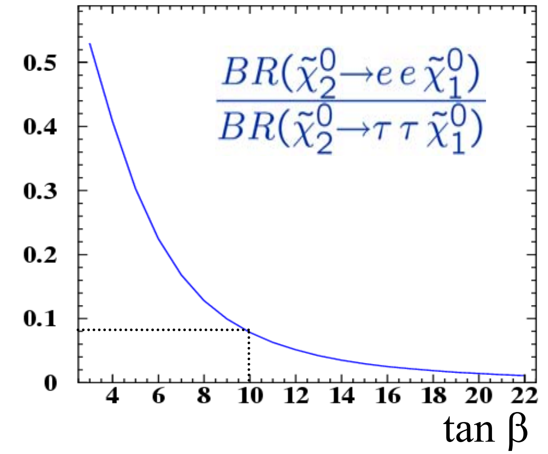
$$R_{e/\tau} := \frac{BR(\tilde{\chi}_2^0 \to e\, e\, \tilde{\chi}_1^0)}{BR(\tilde{\chi}_2^0 \to \tau\, \tau\, \tilde{\chi}_1^0)}$$

$$R_{\mu/\tau} := \frac{BR(\tilde{\chi}_2^0 \to \mu\, \mu\, \tilde{\chi}_1^0)}{BR(\tilde{\chi}_2^0 \to \tau\, \tau\, \tilde{\chi}_1^0)}$$

→ Sensitivity to tanβ also for Ratios $R_{e/\tau}$ and $R_{\mu/\tau}$

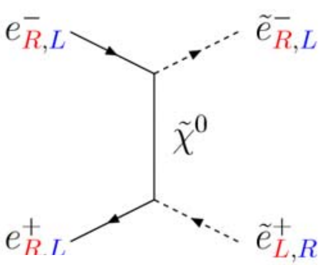






Determination of $\tilde{\chi}_2^0$ Leptonic Branching Ratios

- Selected production process
  - $e_R^+ e_R^- \rightarrow \tilde{e}_L^+ \tilde{e}_R^-$ or $e_L^+ e_L^- \rightarrow \tilde{e}_R^+ \tilde{e}_L^-$



- With 4-lepton channels $e^+e^-\ell^+\ell^-$ $(\ell = e, \mu, \tau)$
  - Event numbers:

$$C := \sigma \cdot \mathcal{L} \cdot BR(\tilde{e}_L \rightarrow e\,\tilde{\chi}_2^0)$$
$$N_{eeee} = C \cdot BR(\tilde{\chi}_2^0 \rightarrow e\,e\,\tilde{\chi}_1^0) \cdot \varepsilon_{ee}^{e} + C \cdot BR(\tilde{\chi}_2^0 \rightarrow \tau\,\tau\,\tilde{\chi}_1^0) \cdot \varepsilon_{ee}^{\tau} \;\; (+\textstyle\sum UG_{ee})$$
$$N_{ee\tau\tau} = C \cdot BR(\tilde{\chi}_2^0 \rightarrow \tau\,\tau\,\tilde{\chi}_1^0) \cdot \varepsilon_{\tau\tau}^{\tau} \; (+\textstyle\sum UG_{\tau\tau})$$

$$\Rightarrow \; R_{e/\tau} = \frac{BR(\tilde{\chi}_2^0 \rightarrow e\,e\,\tilde{\chi}_1^0)}{BR(\tilde{\chi}_2^0 \rightarrow \tau\,\tau\,\tilde{\chi}_1^0)} = \frac{\varepsilon_{\tau\tau}^{\tau}}{\varepsilon_{ee}^{e}} \cdot \frac{N_{eeee}}{N_{ee\tau\tau}} - \frac{\varepsilon_{ee}^{\tau}}{\varepsilon_{ee}^{e}}$$

  - Calculate $R_{\mu/\tau}$ with $N_{ee\mu\mu}$ and $N_{ee\tau\tau}$ analogue

- Efficiencies $\varepsilon_{ee}^{e}, \varepsilon_{\mu\mu}^{\mu}, \varepsilon_{ee}^{\tau}, \varepsilon_{\mu\mu}^{\tau}, \varepsilon_{\tau\tau}^{\tau}$ from MC
  - Polarisation independent (!)
- Assuming only leptonic decays of $\tilde{\chi}_2^0$ (SPS1a: 99.6%)
  - $BR(ee) + BR(\mu\mu) + BR(\tau\tau) = 1$

SPS1a Ratios

$R_{e/\tau}$	$7.795 \cdot 10^{-2}$
$R_{\mu/\tau}$	$8.067 \cdot 10^{-2}$

$\Rightarrow$ Absolute $\tilde{\chi}_2^0$ BRs $BR(ee)$, $BR(\mu\mu)$ and $BR(\tau\tau)$ from $R_{e/\tau}$ and $R_{\mu/\tau}$

Background Induced Bias

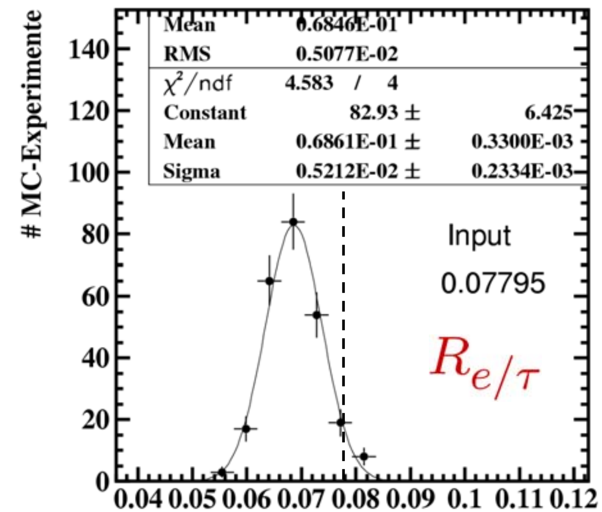
$$R_{e/\tau} = \frac{\varepsilon^{\tau}_{\tau\tau}}{\varepsilon^{e}_{ee}} \cdot \frac{N_{eeee}}{N_{ee\tau\tau}} - \frac{\varepsilon^{\tau}_{ee}}{\varepsilon^{e}_{ee}}$$

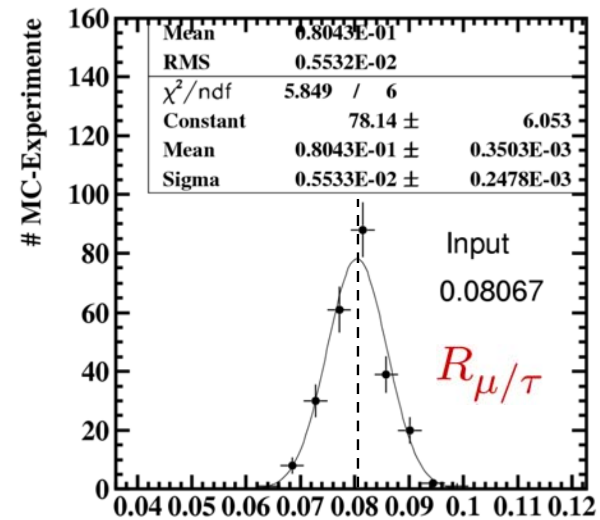
- High beam polarisation
  - **P_{e-} = 80% R, P_{e+} = 60% R**
- Background processes
  - $\tilde{\chi}^0_2\,\tilde{\chi}^0_2,\ \tilde{\nu}_e\,\tilde{\nu}_e,\ \tilde{e}_L\,\tilde{e}_L,\ \tilde{e}^+_R\,\tilde{e}^-_L,\ \tilde{\tau}_2\,\tilde{\tau}_2,\ \tilde{\mu}_L\,\tilde{\mu}_L,$ $ZZ \to 4\ell$
- Average event numbers
  - **L=250 fb^{-1}**

	N_{eeee}	$N_{ee\mu\mu}$	$N_{ee\tau\tau}$
$\tilde{e}^+_L\,\tilde{e}^-_R$	342	338	2439
$\sum BG$	65	102	747
N_{tot}/N_{sig}	1.19	1.30	1.31

$\rightarrow$ Background induces bias
- $R_{e/\tau}$: 12.2%, resp. 1.6 σ_{stat}
- $R_{\mu/\tau}$: 0.3% (just accidentally small)

$\rightarrow$ Make use of polarisation dependence of cross sections to extrapolate to BG free P_{e-} = 100% R, P_{e+} = 100% R





Extrapolation in Polarisation Plane

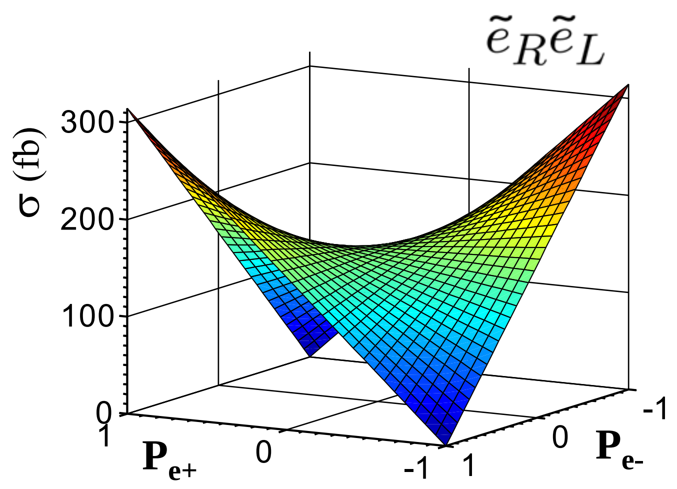
- Cross section for polarisation (P_{e-}, P_{e+}):

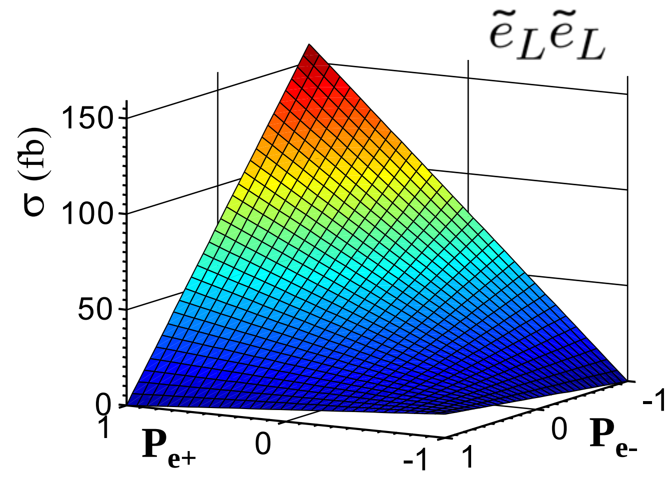
$$\begin{aligned}\sigma_{tot} &= \tfrac{1}{4}(1+P_{e^-})\cdot(1+P_{e^+})\cdot\sigma_{RR}\\ &+ \tfrac{1}{4}(1+P_{e^-})\cdot(1-P_{e^+})\cdot\sigma_{RL}\\ &+ \tfrac{1}{4}(1-P_{e^-})\cdot(1+P_{e^+})\cdot\sigma_{LR}\\ &+ \tfrac{1}{4}(1-P_{e^-})\cdot(1-P_{e^+})\cdot\sigma_{LL}\end{aligned}$$

- Need at least 4 points (P_{e-},P_{e+}) with event numbers N_{eeee}, $N_{ee\mu\mu}$ and $N_{ee\tau\tau}$
  - Extrapolation to (P_{e-}, P_{e+}) = (1, 1) or (-1, -1)

  → Background free event numbers

SPS1a $\sqrt{s}$ = 500 GeV	σ_{RR} [fb]	σ_{RL} [fb]	σ_{LR} [fb]	σ_{LL} [fb]
$\tilde{e}_R\tilde{e}_L$	314,69	0	0	314,69
$\tilde{\chi}^0_2\tilde{\chi}^0_2$	0	0,08	243,53	0
$\tilde{e}_L\tilde{e}_L$	0	12,32	159,48	0
$\tilde{\nu}_e\tilde{\nu}_e$	0	21,47	1604,67	0
$ZZ \to 4\ell$	0	15,96	38,92	0





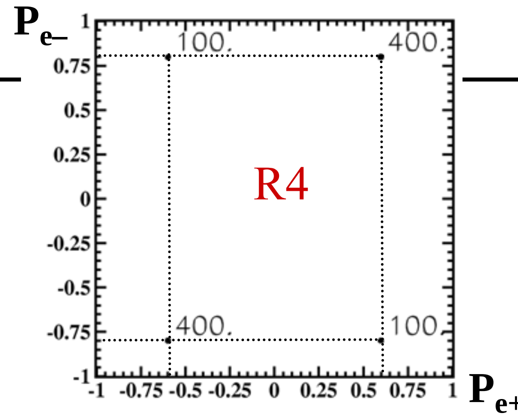
Extrapolation: Example Scenario

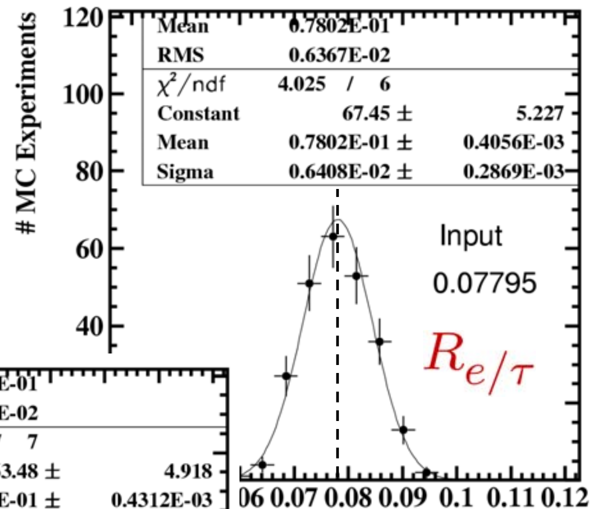
- Example with emphasis on RR and LL polarisations
  - 4 points with $\Sigma L_i = 1\ ab^{-1}$
- Pull distributions show normalized gaussian around zero

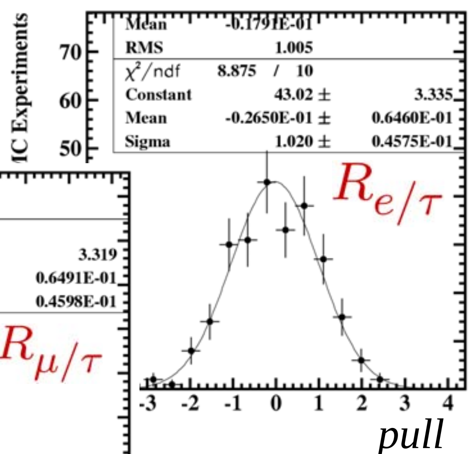
$$pull := \frac{R_{obs} - R_{theo}}{\delta R_{stat}}$$

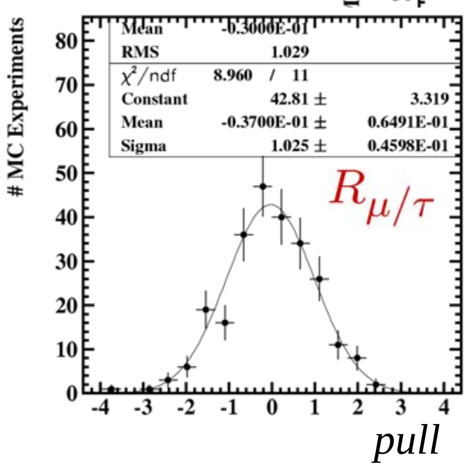
→ Observed widths correspond to expected statistical variances

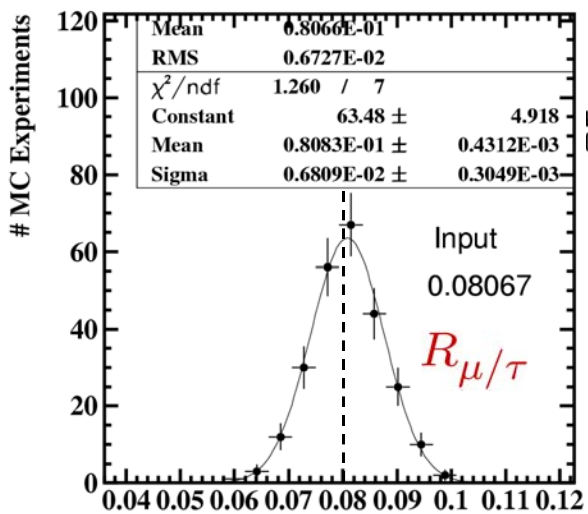
→ No systematic bias due to BG observed



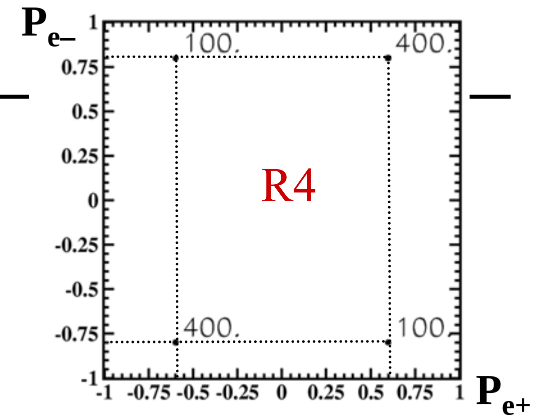








Results: Ratios



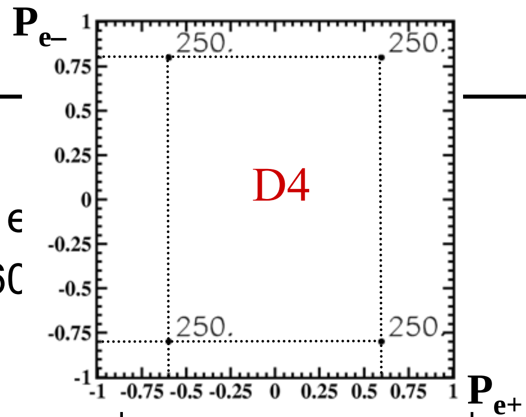
- Averaged results
  - With (without) BG: 250 (1000) MC experiments
  - Single Point: P_{e-} = 80% R, P_{e+} = 60% R, L = 250 fb^{-1}
  - Scenarios: Extrapolation to RR

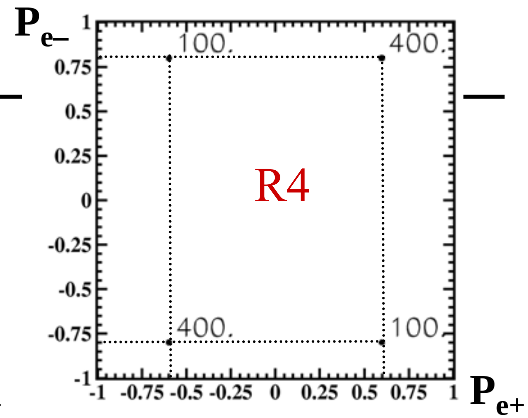
	Bias with BG	Statistical error without BG		Statistical Error with BG		Syst. Errors with BG	
						ΔP=0,5%	ΔL/L=10^{-4}
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$R_{e/\tau}$	$7.7953\cdot10^{-2}$						
Single point	**-12.2%**	**$0.60\cdot10^{-2}$**	**7.7%**	**$0.51\cdot10^{-2}$**	**7.4%**	**-**	**-**
R4	**<0.1%**	**$0.58\cdot10^{-2}$**	**7.4%**	**$0.64\cdot10^{-2}$**	**8.2%**	**0.5%**	**0.04%**

$R_{\mu/\tau}$	$8.0674\cdot10^{-2}$						
Single point	**-0.3%**	**$0.63\cdot10^{-2}$**	**7.9%**	**$0.55\cdot10^{-2}$**	**6.9%**	**-**	**-**
R4	**<0.1%**	**$0.53\cdot10^{-2}$**	**6.6%**	**$0.67\cdot10^{-2}$**	**8.3%**	**0.6%**	**0.05%**

Results: Ratios

- Averaged results
  - With (without) BG: 250 (1000) MC e
  - Single Point: P_{e-} = 80% R, P_{e+} = 60
  - Scenarios: Extrapolation to RR





	Bias with BG	Statistical error without BG		Statistical Error with BG		Syst. Errors with BG	
						ΔP=0,5%	$\Delta L/L=10^{-4}$
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
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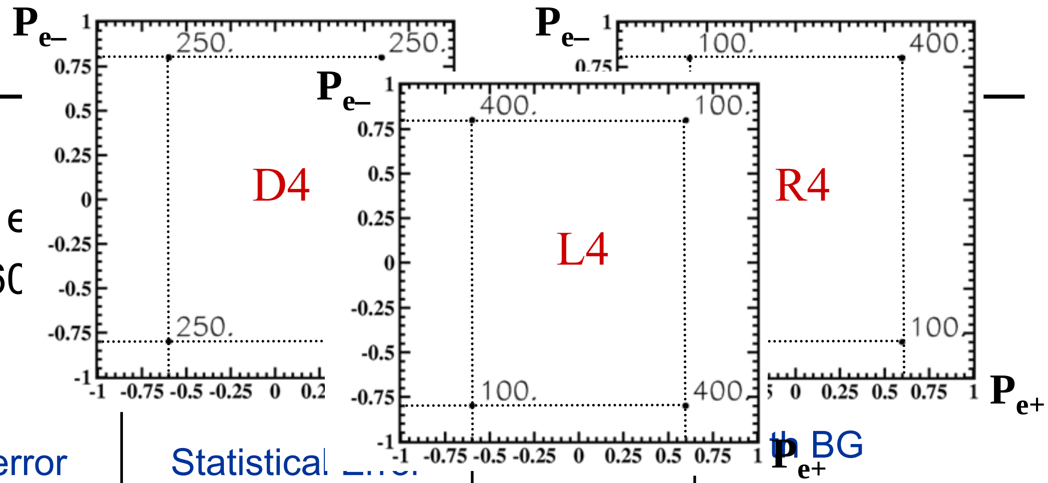
Single point	**-12.2%**	**$0.60\cdot10^{-2}$**	**7.7%**	**$0.51\cdot10^{-2}$**	**7.4%**	**-**	**-**
R4	**<0.1%**	**$0.58\cdot10^{-2}$**	**7.4%**	**$0.64\cdot10^{-2}$**	**8.2%**	**0.5%**	**0.04%**
D4	**<0.1%**	**$0.69\cdot10^{-2}$**	**8.8%**	**$0.75\cdot10^{-2}$**	**9.6%**	**0.6%**	**0.05%**

$R_{\mu/\tau}$	$8.0674\cdot10^{-2}$						
Single point	**-0.3%**	**$0.63\cdot10^{-2}$**	**7.9%**	**$0.55\cdot10^{-2}$**	**6.9%**	**-**	**-**
R4	**<0.1%**	**$0.53\cdot10^{-2}$**	**6.6%**	**$0.67\cdot10^{-2}$**	**8.3%**	**0.6%**	**0.05%**
D4	**<0.1%**	**$0.67\cdot10^{-2}$**	**8.3%**	**$0.82\cdot10^{-2}$**	**10.2%**	**0.7%**	**0.05%**

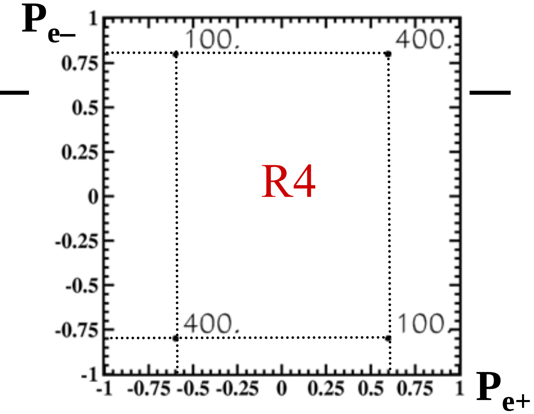
Results: Ratios



- Averaged results
  - With (without) BG: 250 (1000) MC e
  - Single Point: P_{e-} = 80% R, P_{e+} = 60
  - Scenarios: Extrapolation to RR

	Bias with BG	Statistical error without BG		Statistical error with BG		ΔP=0,5%	ΔL/L=10^{-4}
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$R_{e/\tau}$	$7.7953 \cdot 10^{-2}$						
Single point	**-12.2%**	**$0.60 \cdot 10^{-2}$**	**7.7%**	**$0.51 \cdot 10^{-2}$**	**7.4%**	**-**	**-**
R4	**<0.1%**	**$0.58 \cdot 10^{-2}$**	**7.4%**	**$0.64 \cdot 10^{-2}$**	**8.2%**	**0.5%**	**0.04%**
D4	**<0.1%**	**$0.69 \cdot 10^{-2}$**	**8.8%**	**$0.75 \cdot 10^{-2}$**	**9.6%**	**0.6%**	**0.05%**
L4	**<0.1%**	**$1.09 \cdot 10^{-2}$**	**13.8%**	**$1.22 \cdot 10^{-2}$**	**15.5%**	**0.9%**	**0.07%**
$R_{\mu/\tau}$	$8.0674 \cdot 10^{-2}$						
Single point	**-0.3%**	**$0.63 \cdot 10^{-2}$**	**7.9%**	**$0.55 \cdot 10^{-2}$**	**6.9%**	**-**	**-**
R4	**<0.1%**	**$0.53 \cdot 10^{-2}$**	**6.6%**	**$0.67 \cdot 10^{-2}$**	**8.3%**	**0.6%**	**0.05%**
D4	**<0.1%**	**$0.67 \cdot 10^{-2}$**	**8.3%**	**$0.82 \cdot 10^{-2}$**	**10.2%**	**0.7%**	**0.05%**
L4	**<0.1%**	**$1.08 \cdot 10^{-2}$**	**13.3%**	**$1.30 \cdot 10^{-2}$**	**16.0%**	**1.0%**	**0.06%**

Results: Absolute BRs



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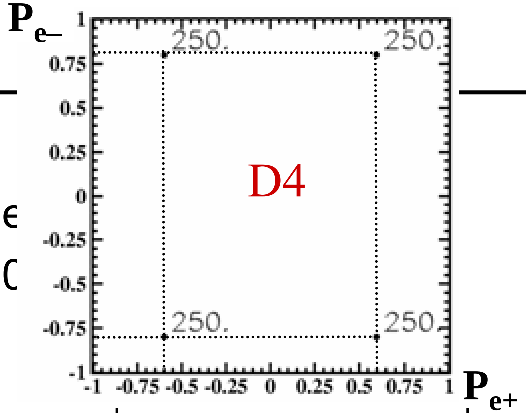
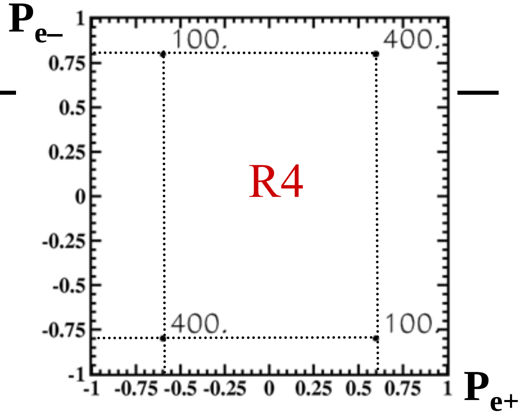
  - Scenarios: Extrapolation to RR

	Bias with BG	Statistical error without BG		Statistical Error with BG		Syst. Errors with BG	
						ΔP=0,5%	$\Delta L/L=10^{-4}$
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$BR(\tau\tau)$	86.31%						
Single point	**+0.85%**	**0.58%**	**0.7%**	**0.58%**	**0.7%**	**-**	**-**
R4	**<0.01%**	**0.62%**	**0.7%**	**0.74%**	**0.9%**	**0.06%**	**0.005%**
$BR(ee)$	6.73%						
Single point	**-11.5%**	**0.41%**	**7.0%**	**0.42%**	**7.0%**	**-**	**-**
R4	**0.04%**	**0.46%**	**6.8%**	**0.51%**	**7.6%**	**0.5%**	**0.04%**

Results: Absolute BRs



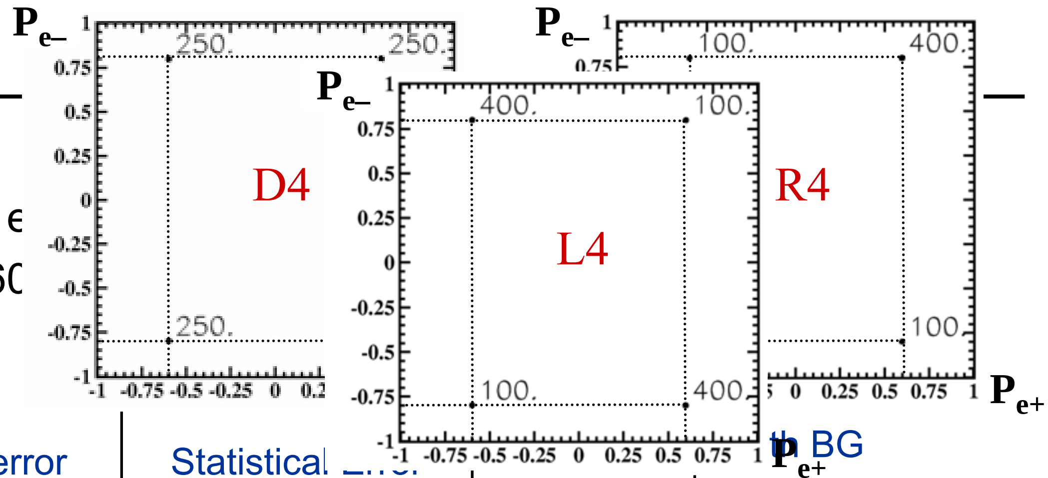


- Averaged results
  - With (without) BG: 250 (1000) MC e
  - Single Point: P_{e-} = 80% R, P_{e+} = 60
  - Scenarios: Extrapolation to RR

	Bias with BG	Statistical error without BG		Statistical Error with BG		Syst. Errors with BG	
						ΔP=0,5%	$\Delta L/L=10^{-4}$
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$BR(\tau\tau)$	86.31%						
Single point	**+0.85%**	**0.58%**	**0.7%**	**0.58%**	**0.7%**	**-**	**-**
R4	**<0.01%**	**0.62%**	**0.7%**	**0.74%**	**0.9%**	**0.06%**	**0.005%**
D4	**<0.01%**	**0.75%**	**0.9%**	**0.85%**	**1.0%**	**0.07%**	**0.006%**

$BR(ee)$	6.73%						
Single point	**-11.5%**	**0.41%**	**7.0%**	**0.42%**	**7.0%**	**-**	**-**
R4	**0.04%**	**0.46%**	**6.8%**	**0.51%**	**7.6%**	**0.5%**	**0.04%**
D4	**0.1%**	**0.55%**	**8.2%**	**0.60%**	**8.9%**	**0.6%**	**0.05%**

Results: Absolute BRs



- Averaged results
  - With (without) BG: 250 (1000) MC e
  - Single Point: P_{e-} = 80% R, P_{e+} = 6(
  - Scenarios: Extrapolation to RR

	Bias with BG	Statistical error without BG		Statistical ... with BG		ΔP=0,5%	...th BG ΔL/L=10^{-4}
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$BR(\tau\tau)$	86.31%						
Single point	**+0.85%**	**0.58%**	**0.7%**	**0.58%**	**0.7%**	**-**	**-**
R4	**<0.01%**	**0.62%**	**0.7%**	**0.74%**	**0.9%**	**0.06%**	**0.005%**
D4	**<0.01%**	**0.75%**	**0.9%**	**0.85%**	**1.0%**	**0.07%**	**0.006%**
L4	**<0.01%**	**1.17%**	**1.4%**	**1.43%**	**1.7%**	**0.10%**	**0.008%**
$BR(ee)$	6.73%						
Single point	**-11.5%**	**0.41%**	**7.0%**	**0.42%**	**7.0%**	**-**	**-**
R4	**0.04%**	**0.46%**	**6.8%**	**0.51%**	**7.6%**	**0.5%**	**0.04%**
D4	**0.1%**	**0.55%**	**8.2%**	**0.60%**	**8.9%**	**0.6%**	**0.05%**
L4	**1%**	**0.87%**	**8.9%**	**0.97%**	**14.3%**	**0.9%**	**0.06%**

Determination of Partial Cross Sections

- Partial cross section
  - Calculate from event number

$$N_{ee\tau\tau}(RR, LL) = \sigma_{RR,LL} \cdot \mathcal{L} \cdot BR(\tilde{e}_L \to e\,\tilde{\chi}_2^0) \cdot BR(\tilde{\chi}_2^0 \to \tau\,\tau\,\tilde{\chi}_1^0) \cdot \varepsilon_{\tau\tau}^{\tau}\,(+\sum UG_{\tau\tau})$$

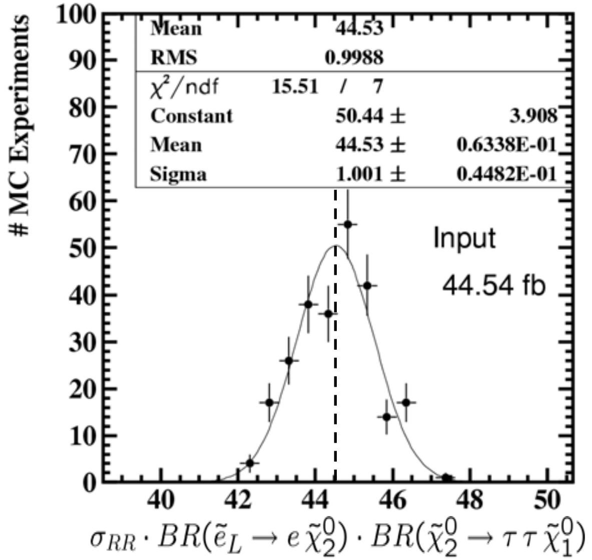
$$\Rightarrow \quad \sigma_{RR,LL} \cdot BR(\tilde{e}_L \to e\,\tilde{\chi}_2^0) \cdot BR(\tilde{\chi}_2^0 \to \tau\,\tau\,\tilde{\chi}_1^0)$$

- Assuming again only leptonic decays of $\tilde{\chi}_2^0$
  - $BR(ee) + BR(\mu\mu) + BR(\tau\tau) = 1$

$$\Rightarrow \quad \sigma_{RR,LL} \cdot BR(\tilde{e}_L \to e\,\tilde{\chi}_2^0)$$

SPS1a partial cross sections

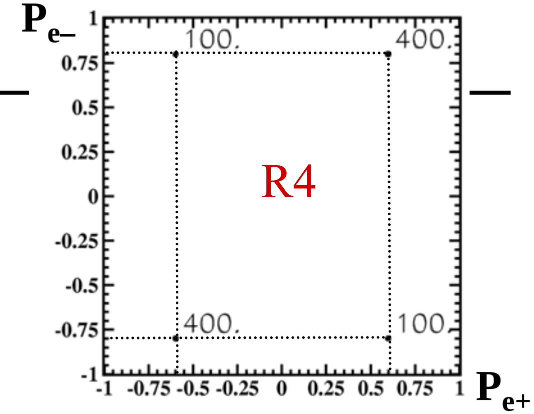
$\sigma_{RR,LL} \cdot BR(\tilde{e}_L \to e\,\tilde{\chi}_2^0) \cdot BR(\tilde{\chi}_2^0 \to \tau\,\tau\,\tilde{\chi}_1^0)$	44.54 fb
$\sigma_{RR,LL} \cdot BR(\tilde{e}_L \to e\,\tilde{\chi}_2^0)$	51.60 fb



→ These partial cross sections are essential part for the determination of the supersymmetric U(1) and SU(2) Yukawa couplings $\hat{g}$ and $\hat{g}'$

A. Freitas *et al.*, hep-ph/0310182

Results: Partial Cross Sections

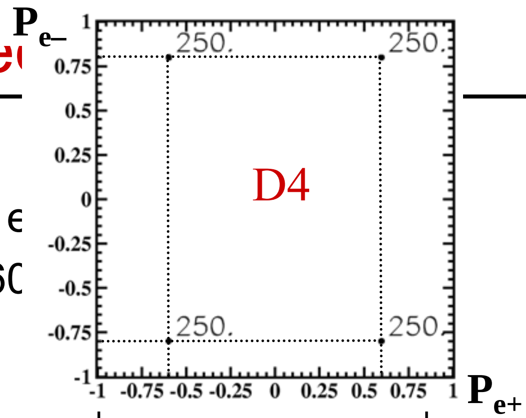


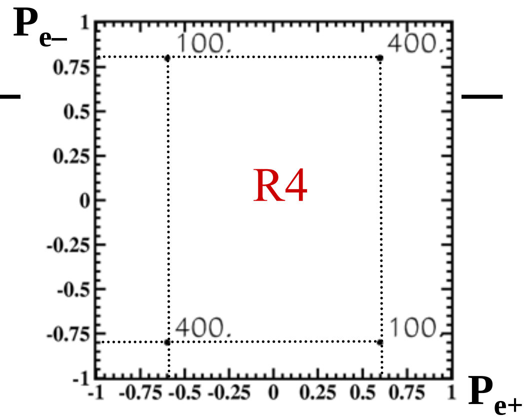
- Averaged results
  - With (without) BG: 250 (1000) MC experiments
  - Single Point: P_{e-} = 80% R, P_{e+} = 60% R, L = 250 fb^{-1}
  - Scenarios: Extrapolation to RR

	Bias with BG	Statistical error without BG		Statistical Error with BG		Syst. Errors with BG	
						ΔP=0,5%	ΔL/L=10^{-4}
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$\sigma_{RR,LL}\cdot BR(\tilde{e}_L \to e\,\tilde{\chi}^0_2)\cdot BR(\tilde{\chi}^0_2 \to \tau\,\tau\,\tilde{\chi}^0_1)$				44.54 fb	(Single point: 32.96 fb)		
Single point	**+27.2%**	**0.78 fb**	**1.9%**	**0.78 fb**	**1.9%**	**-**	**-**
R4	**<0.02%**	**0.81 fb**	**1.8%**	**1.00 fb**	**2.2%**	**0.2%**	**0.02%**

	Bias with BG	Statistical error without BG		Statistical Error with BG		Syst. Errors with BG	
						ΔP=0,5%	ΔL/L=10^{-4}
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$\sigma_{RR,LL}\cdot BR(\tilde{e}_L \to e\,\tilde{\chi}^0_2)$				51.60 fb	(Single point: 38.18 fb)		
Single point	**+26.1%**	**0.81 fb**	**1.7%**	**0.81 fb**	**1.7%**	**-**	**-**
R4	**<0.03%**	**0.83 fb**	**1.6%**	**1.01 fb**	**2.0%**	**0.1%**	**0.01%**

Results: Partial Cross Se



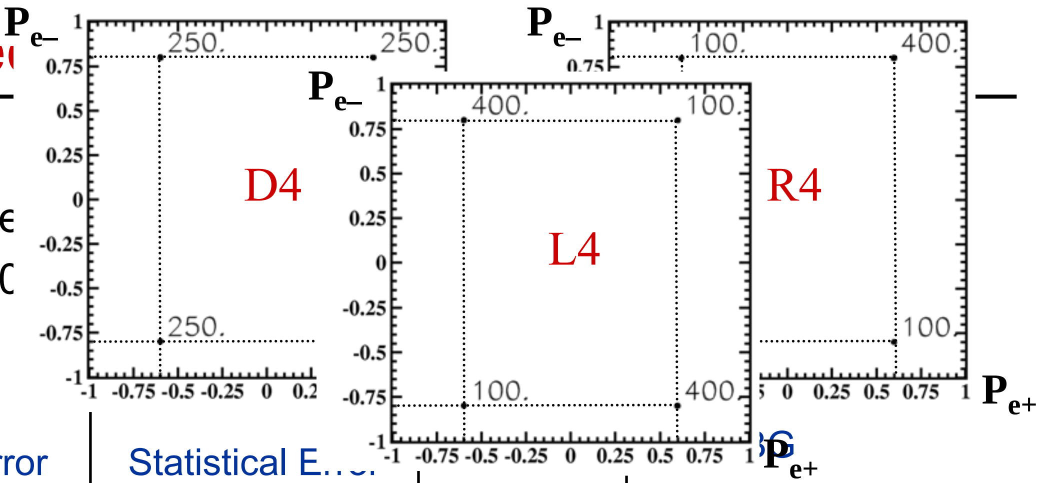


- Averaged results
  - With (without) BG: 250 (1000) MC e
  - Single Point: P_{e-} = 80% R, P_{e+} = 60
  - Scenarios: Extrapolation to RR

	Bias with BG	Statistical error without BG		Statistical Error with BG		Syst. Errors with BG	
						ΔP=0,5%	$\Delta L/L=10^{-4}$
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$\sigma_{RR,LL}\cdot BR(\tilde{e}_L \to e\,\tilde{\chi}_2^0)\cdot BR(\tilde{\chi}_2^0 \to \tau\,\tau\,\tilde{\chi}_1^0)$				44.54 fb	(Single point: 32.96 fb)		
Single point	**+27.2%**	**0.78 fb**	**1.9%**	**0.78 fb**	**1.9%**	**-**	**-**
R4	**<0.02%**	**0.81 fb**	**1.8%**	**1.00 fb**	**2.2%**	**0.2%**	**0.02%**
D4	**0.2%**	**0.99 fb**	**2.2%**	**1.26 fb**	**2.8%**	**0.2%**	**0.02%**

$\sigma_{RR,LL}\cdot BR(\tilde{e}_L \to e\,\tilde{\chi}_2^0)$				51.60 fb	(Single point: 38.18 fb)		
Single point	**+26.1%**	**0.81 fb**	**1.7%**	**0.81 fb**	**1.7%**	**-**	**-**
R4	**<0.03%**	**0.83 fb**	**1.6%**	**1.01 fb**	**2.0%**	**0.1%**	**0.01%**
D4	**0.1%**	**1.01 fb**	**2.0%**	**1.27 fb**	**2.5%**	**0.2%**	**0.02%**

Results: Partial Cross Se



- Averaged results
  - With (without) BG: 250 (1000) MC e
  - Single Point: P_{e-} = 80% R, P_{e+} = 60
  - Scenarios: Extrapolation to RR

	Bias with BG	Statistical error without BG		Statistical E... with BG		ΔP=0,5%	ΔL/L=10^{-4}
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$\sigma_{RR,LL} \cdot BR(\tilde{e}_L \to e\,\tilde{\chi}_2^0) \cdot BR(\tilde{\chi}_2^0 \to \tau\,\tau\,\tilde{\chi}_1^0)$				44.54 fb	(Single point: 32.96 fb)		
Single point	+27.2%	0.78 fb	1.9%	0.78 fb	1.9%	-	-
R4	<0.02%	0.81 fb	1.8%	1.00 fb	2.2%	0.2%	0.02%
D4	0.2%	0.99 fb	2.2%	1.26 fb	2.8%	0.2%	0.02%
L4	0.4%	1.51 fb	3.4%	1.87 fb	4.2%	0.3%	0.03%
$\sigma_{RR,LL} \cdot BR(\tilde{e}_L \to e\,\tilde{\chi}_2^0)$				51.60 fb	(Single point: 38.18 fb)		
Single point	+26.1%	0.81 fb	1.7%	0.81 fb	1.7%	-	-
R4	<0.03%	0.83 fb	1.6%	1.01 fb	2.0%	0.1%	0.01%
D4	0.1%	1.01 fb	2.0%	1.27 fb	2.5%	0.2%	0.02%
L4	0.3%	1.57 fb	3.1%	1.88 fb	3.7%	0.3%	0.02%

Summary and Outlook

- Lepton identification for e, μ, 1-prong and 3-prong τ
  - With high efficiency and purity
- General 4-lepton selection
  - SM BG is low, efficiency for most SUSY processes high
- Extrapolation method eliminates background induced bias in determinations
- Analysis of different measurement scenarios
  - The more luminosity in direction of RR and LL the better
- Determination of the ratios $R_{e/\tau}$ and $R_{\mu/\tau}$ of $\tilde{\chi}_2^0$ the branching ratios
  - Statistical errors between **8%** and **16%** seem to be feasible
- Determination of the partial cross sections $\sigma_{RR,LL} \cdot BR(\tilde{e}_L \rightarrow e\,\tilde{\chi}_2^0) \cdot BR(\tilde{\chi}_2^0 \rightarrow \tau\,\tau\,\tilde{\chi}_1^0)$
  - Statistical errors around **1fb** seem to be feasible
- All determinations are statistically dominated
  - Observed widths of a number of MC experiments correspond to the expected statistical variances
  - Systematic errors due to polarisation ($\Delta P \approx 0{,}5\%$) and luminosity ($\Delta L/L \approx 10^{-4}$) are negligible
  - Need to control detector efficiencies well, in particular $\Delta\varepsilon^{\tau}_{\tau\tau} / \varepsilon^{\tau}_{\tau\tau} \leq 1\%$

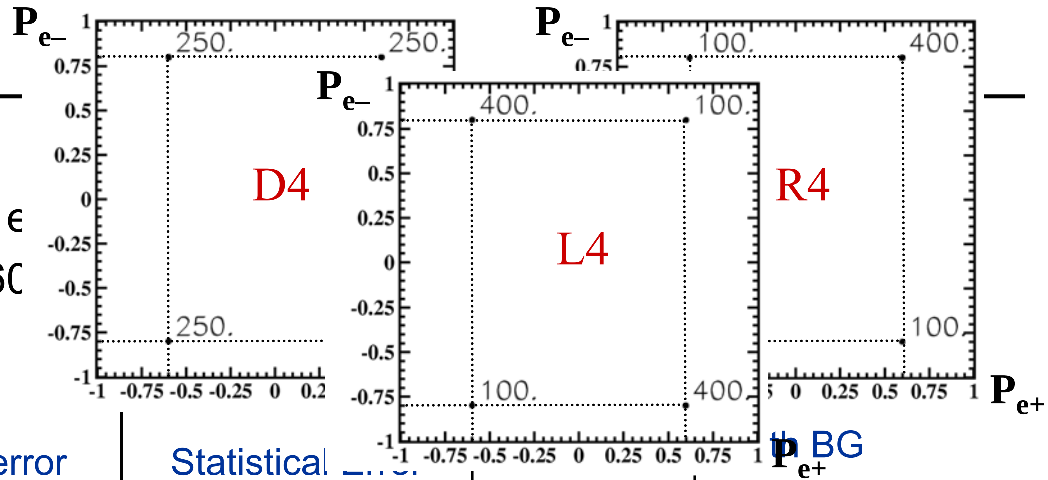
Backup

Background induced Bias

- High beam polarisation
  - **$P(e^-)$ = 80% R, P (e^+) = 60% R**
- Average event numbers
  - Luminosity **L=250 fb^{-1}**

	N_{eeee}	$N_{ee\mu\mu}$	$N_{ee\tau\tau}$
$\tilde{e}_L^+ \tilde{e}_R^-$	342	338	2839
$\tilde{e}_R^+ \tilde{e}_L^-$	10	9	68
$\tilde{\chi}_2^0 \tilde{\chi}_2^0$	20	41	324
$\tilde{e}_L \tilde{e}_L$	32	32	256
$\tilde{\nu}_e \tilde{\nu}_e$	3	2	66
$\tilde{\mu}_L \tilde{\mu}_L$	0	16	8
$\tilde{\tau}_2 \tilde{\tau}_2$	0	1	20
$ZZ \rightarrow 4\ell$	0	1	5
N_{tot}/N_{sig}	1.19	1.30	1.31

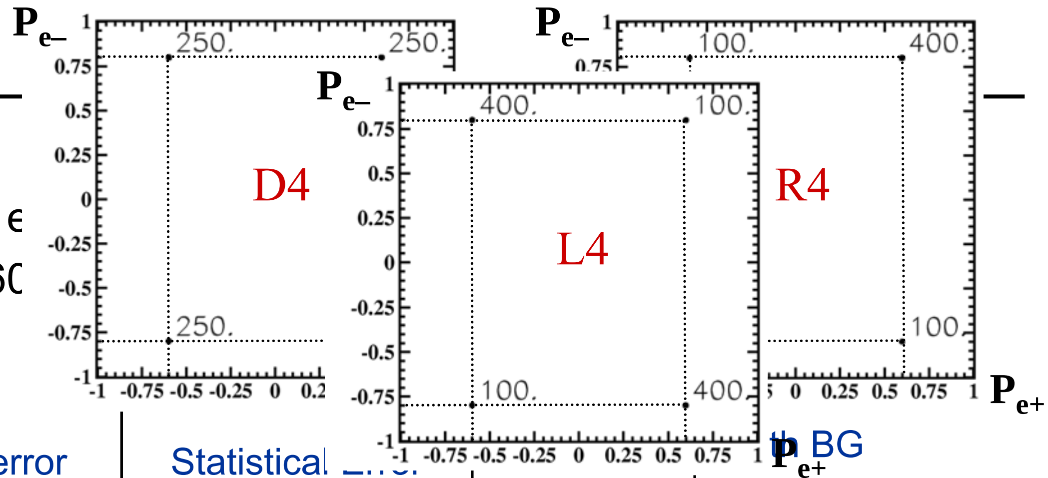
Results: Ratios



- Averaged results
  - With (without) BG: 250 (1000) MC e
  - Single Point: P_{e-} = 80% R, P_{e+} = 6(
  - Scenarios: Extrapolation to RR

	Bias with BG	Statistical error without BG		Statistical ... with BG		ΔP=0,5%	ΔL/L=10^{-4}
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$R_{e/\tau}$	$7.7953\cdot10^{-2}$						
Single point	-12.2%	$0.60\cdot10^{-2}$	7.7%	$0.51\cdot10^{-2}$	7.4%	-	-
R4	<0.1%	$0.58\cdot10^{-2}$	7.4%	$0.64\cdot10^{-2}$	8.2%	0.5%	0.04%
D4	<0.1%	$0.69\cdot10^{-2}$	8.8%	$0.75\cdot10^{-2}$	9.6%	0.6%	0.05%
L4	<0.1%	$1.09\cdot10^{-2}$	13.8%	$1.22\cdot10^{-2}$	15.5%	0.9%	0.07%
$R_{\mu/\tau}$	$8.0674\cdot10^{-2}$						
Single point	-0.3%	$0.63\cdot10^{-2}$	7.9%	$0.55\cdot10^{-2}$	6.9%	-	-
R4	<0.1%	$0.53\cdot10^{-2}$	6.6%	$0.67\cdot10^{-2}$	8.3%	0.6%	0.05%
D4	<0.1%	$0.67\cdot10^{-2}$	8.3%	$0.82\cdot10^{-2}$	10.2%	0.7%	0.05%
L4	<0.1%	$1.08\cdot10^{-2}$	13.3%	$1.30\cdot10^{-2}$	16.0%	1.0%	0.06%

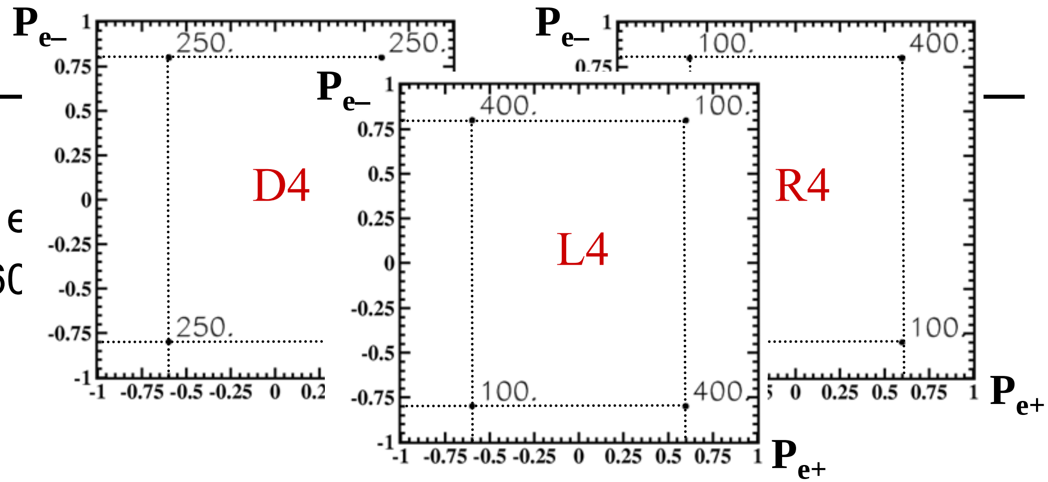
Results: Absolute BRs



- Averaged results
  - With (without) BG: 250 (1000) MC e
  - Single Point: P_{e-} = 80% R, P_{e+} = 6(
  - Scenarios: Extrapolation to RR

	Bias with BG	Statistical error without BG		Statistical error with BG		ΔP=0,5%	ΔL/L=10^{-4}
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$BR(\tau\tau)$	86.31%						
Single point	+0.85%	0.58%	0.7%	0.58%	0.7%	-	-
R4	<0.01%	0.62%	0.7%	0.74%	0.9%	0.06%	0.005%
D4	<0.01%	0.75%	0.9%	0.85%	1.0%	0.07%	0.006%
L4	<0.01%	1.17%	1.4%	1.43%	1.7%	0.10%	0.008%
$BR(ee)$	6.73%						
Single point	-11.5%	0.41%	7.0%	0.42%	7.0%	-	-
R4	0.04%	0.46%	6.8%	0.51%	7.6%	0.5%	0.04%
D4	0.1%	0.55%	8.2%	0.60%	8.9%	0.6%	0.05%
L4	1%	0.87%	8.9%	0.97%	14.3%	0.9%	0.06%

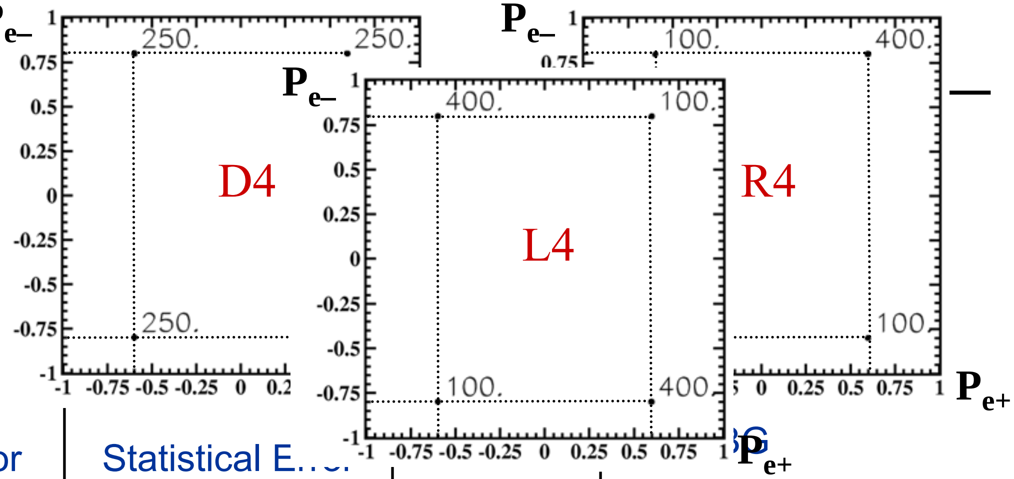
Results: Absolute BRs



- Averaged results
  - With (without) BG: 250 (1000) MC e
  - Single Point: P_{e-} = 80% R, P_{e+} = 60
  - Scenarios: Extrapolation to RR

	Bias	Statistical error without BG		Statistical Error with BG		Syst. Errors with BG ΔP=0,5%	Syst. Errors with BG ΔL/L=10^{-4}
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$BR(\mu\mu)$	6.96%						
Single	+0.5%	0.45%	6.4%	0.45%	6.4%	-	-
R4	<0.1%	0.42%	6.0%	0.53%	7.6%	0.5%	0.04%
D4	<0.2%	0.53%	7.6%	0.66%	9.5%	0.6%	0.05%
L4	<0.5%	0.86%	12.3%	1.06%	15.2%	0.9%	0.05%

Results: Partial Cross Se



- Averaged results
  - With (without) BG: 250 (1000) MC e
  - Single Point: P_{e-} = 80% R, P_{e+} = 6(
  - Scenarios: Extrapolation to RR

	Bias with BG	Statistical error without BG		Statistical E... with BG		ΔP=0,5%	$\Delta L/L=10^{-4}$
	rel.	abs.	rel.	abs.	rel.	rel.	rel.
$\sigma_{RR,LL}\cdot BR(\tilde{e}_L \to e\,\tilde{\chi}^0_2)\cdot BR(\tilde{\chi}^0_2 \to \tau\,\tau\,\tilde{\chi}^0_1)$				44.54 fb	(Single point: 32.96 fb)		
Single point	**+27.2%**	**0.78 fb**	**1.9%**	**0.78 fb**	**1.9%**	**-**	**-**
R4	**<0.02%**	**0.81 fb**	**1.8%**	**1.00 fb**	**2.2%**	**0.2%**	**0.02%**
D4	**0.2%**	**0.99 fb**	**2.2%**	**1.26 fb**	**2.8%**	**0.2%**	**0.02%**
L4	**0.4%**	**1.51 fb**	**3.4%**	**1.87 fb**	**4.2%**	**0.3%**	**0.03%**
$\sigma_{RR,LL}\cdot BR(\tilde{e}_L \to e\,\tilde{\chi}^0_2)$				51.60 fb	(Single point: 38.18 fb)		
Single point	**+26.1%**	**0.81 fb**	**1.7%**	**0.81 fb**	**1.7%**	**-**	**-**
R4	**<0.03%**	**0.83 fb**	**1.6%**	**1.01 fb**	**2.0%**	**0.1%**	**0.01%**
D4	**0.1%**	**1.01 fb**	**2.0%**	**1.27 fb**	**2.5%**	**0.2%**	**0.02%**
L4	**0.3%**	**1.57 fb**	**3.1%**	**1.88 fb**	**3.7%**	**0.3%**	**0.02%**

Wirkungsquerschnitte im SPS1a

SPS1a	σ_{RR} [fb]	σ_{RL} [fb]	σ_{00} [fb]	σ_{LR} [fb]	σ_{LL} [fb]
$\tilde{\chi}_1^0\tilde{\chi}_2^0$	0	23,37	63,62	232,12	0
$\tilde{\chi}_2^0\tilde{\chi}_2^0$	0	0,08	60,90	243,53	0
$\tilde{\chi}_1^+\tilde{\chi}_1^-$	0	0,80	143,17	571,88	0
$\tilde{\chi}_1^0\tilde{\chi}_3^0$	0	28,67	7,22	0,23	0
$\tilde{\chi}_1^0\tilde{\chi}_4^0$	0	2,81	0,90	0,78	0
$\tilde{e}_R\tilde{e}_R$	0	1098,16	42,95	43,81	0
$\tilde{e}_R\tilde{e}_L$	314,69	0	157,34	0	314,69
$\tilde{e}_L\tilde{e}_L$	0	12,32	285,49	159,48	0
$\tilde{\mu}_R\tilde{\mu}_R$	0	185,53	18,29	43,86	0
$\tilde{\mu}_L\tilde{\mu}_L$	0	12,32	57,34	60,86	0
$\tilde{\tau}_1\tilde{\tau}_1$	0	191,31	62,17	57,39	0
$\tilde{\tau}_1\tilde{\tau}_2$	0	4,05	2,37	5,45	0
$\tilde{\tau}_2\tilde{\tau}_2$	0	12,47	15,45	49,32	0
$\tilde{\nu}_e\tilde{\nu}_e$	0	21,47	406,54	1604,67	0
$\tilde{\nu}_\mu\tilde{\nu}_\mu$	0	21,73	12,74	29,23	0
$\tilde{\nu}_\tau\tilde{\nu}_\tau$	0	22,21	13,02	29,87	0

SM	σ_{00} [fb]
$\gamma\gamma$	1,96E+07
γ/Z^0	17390
Z^0ee	20450
WW	9777
$We\nu_e$	6320
Z^0Z^0	653,6
$eeWW$	240,1
$\nu_e\nu_e h^0$	193,7
h^0Z^0	70,0
eeh^0	27,3
$\nu_e\nu_e Z^0 \to \nu_e\nu_e ll$	26,67
$WWZ^0 \to l\nu l\nu(ll/\nu\nu)$	1,07

pol.

$\sqrt{s} = 500$ GeV

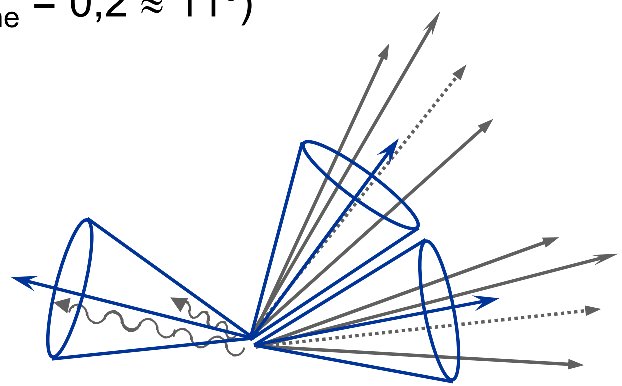
Lepton-Identifikation

- Variable Anzahl
- Isolierte und kollimierte Jets
- Geringe Multiplizität

  → Cone-Jet-Algorithmus

- Parameter
  - Energieschwelle des Anfangsteilchens (0,7 GeV)
  - Minimale Cone-Energie

    (= Energieschwelle)
  - Halbe Cone-Weite (θ_{cone} = 0,2 ≈ 11°)



- Kandidat: 1 Cone
  - 1 oder 3 Spuren
  - Ladungssumme: ±1
  - Invariante Masse < 2 GeV
  - Keine weiteren Spuren in einem 15° Isolations-Cone
  - $|\eta| < 2$ (≈ 15 °)
- Klassifikation
  - Elektron (e)
    - 1 Spur mit p > 4 GeV/c
    - $|1 - E_{ecal}/p_{Spur}| < 0,1$
    - $E_{hcal} < 1,5$ GeV
  - Muon (μ): *MIP*
    - 1 Spur mit p > 3 GeV/c
    - $E_{ecal} < 1,5$ GeV
    - 1,5 GeV < E_{hcal} < 3,5 GeV
  - Hadronisch (1prong, 3prong)
    - 1 oder 3 Spuren