s Channel Production of Heavy Vector Bosons in the Three-Site Higgsless Model [arXiv:0809.0023]

C. Speckner
in collaboration with T.Ohl

Lehrstuhl für Theoretische Physik II, Universität Würzburg

HGF workshop — LHC-D session — SUSY and BSM
Aachen, 27.11.2008

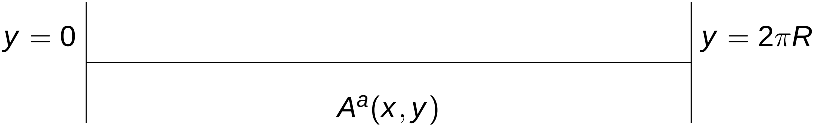
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

Outline:

Formalism:

5D gauge theory:

- space: $\mathbb{R}^4 \times [0; 2\pi R]$



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- space: $\mathbb{R}^4 \times [0; 2\pi R]$
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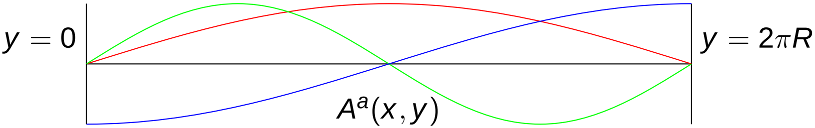
- interpretation: “tower” of Kaluza-Klein (KK) modes, $m_i = \left|k_i^5\right|$



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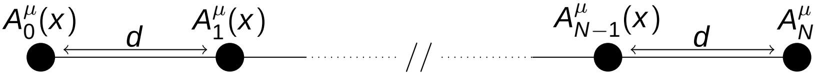

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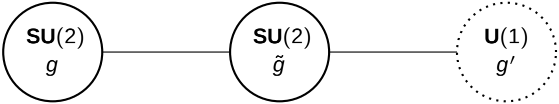
Minimal Three-site higgsless model [Chivukula et al, 2006]

- three lattice sites
- Standard Model + one set of KK modes (no KK gluons or photon)

Model structure:



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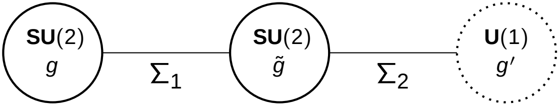

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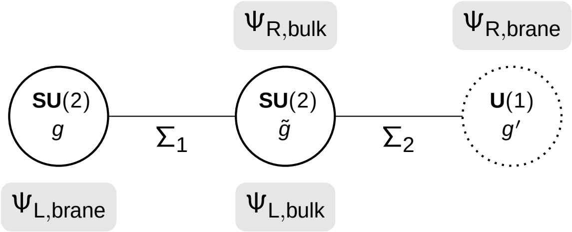

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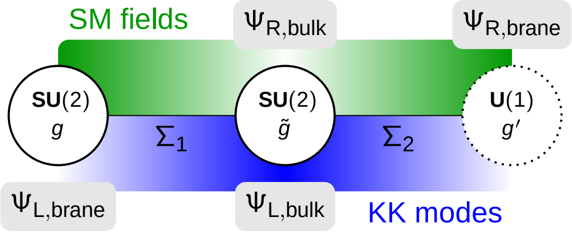

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Diagonalization:

- SM particles strongly localized at branes, KK partners in bulk
- couplings between SM fermions and KK bosons very small (exception: top, bottom)

Constraints from LEP & LEP2:

Tree Level: Chivukula, Simmons 2005 (hep-ph/050411)

Consistency with electroweak precision constraints

$\updownarrow$

vanishing couplings between SM fermions and heavy W (W')

$\rightarrow$ "ideal" delocalization of the fermions along the lattice

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One Loop: Abe, Matsuzaki, Tanabashi 2008 (arXiv:0807.2298)

Consistency with electroweak precision constraints

$\updownarrow$

$W'\bar{f}f$ coupling small but finite ($\mathcal{O}(10^{-2})$)

"nonideal" delocalization: both Z' and W' may be visible in the s channel

Pros of the model:

- Breaks electroweak symmetry without invoking any scalar field
- Consistent with electroweak precision observables
- Maintains exact gauge invariance while chopping off all but the lightest Kaluza-Klein modes
- Very limited particle spectrum $\leftrightarrow$ easy to implement into a Monte Carlo eventgenerator

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$\longrightarrow$ So:

No candidate for a fundamental model of nature, but might teach us something about the physics of scenarios without a Higgs that are not already forbidden by LEP data.

Free parameters in addition to standard model:

- W' mass: $380\,\mathrm{GeV} \leq m_{W'} \leq 600\,\mathrm{GeV}$
- $W'\bar{f}f$ coupling $g_{W'ff}(\epsilon_L)$ (ϵ_L: fermion delocalization parameter)

$$\frac{g_{W'ff}}{g} = \mathcal{O}\left(1\%\right)$$

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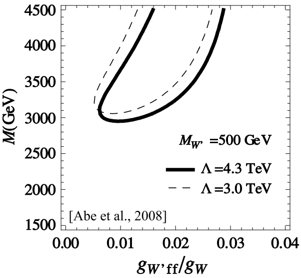
Particle spectrum:

- standard model particles
- heavy gauge bosons W', Z': quasidegenerate $\frac{m_{W'}}{m_{Z'}} = 1 + \mathcal{O}(1\%)$, relative width $\frac{\Gamma}{m} = \mathcal{O}(1\%)$
- heavy fermions: masses around M, $\frac{\Gamma}{m} = \mathcal{O}(10\%)$

- Bounds from electroweak precision observables on $\frac{g_{W'ff}}{g'}$ for $m_{W'} = 500\,\text{GeV}$, [Abe et al., arXiv:0807.2298]
- allowed region varies (increases) with (lower) $m_{W'}$



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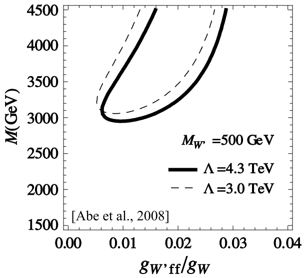

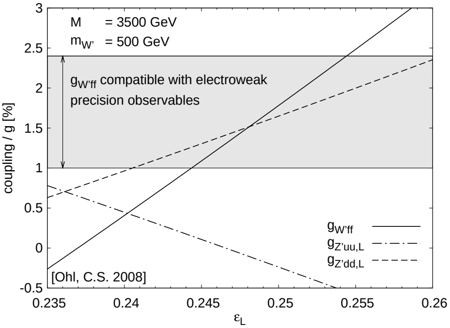

- influence of ϵ_L on left-handed $Z'\bar{f}f$ coupling
- changes to $g_{Z'uu,L}$ and $g_{Z'dd,L}$ tend to compensate each other in pp collisions
- no change to right-handed couplings which are of the same order of magnitude

Interesting processes with heavy vectors in s channel:

higher $\longrightarrow$ total cross section (signal) $\longrightarrow$ lower		
$pp \longrightarrow jjl\nu_l$	$pp \longrightarrow jjl\nu_l$	$pp \longrightarrow jjll$

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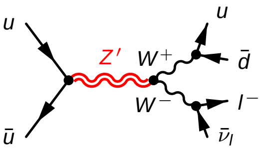		

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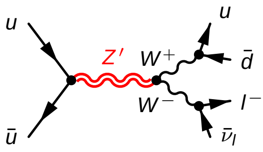	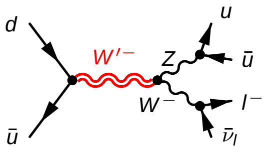	

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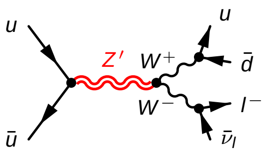	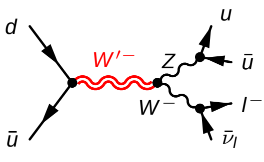	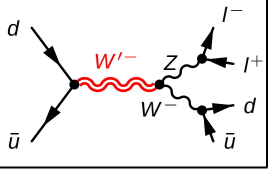

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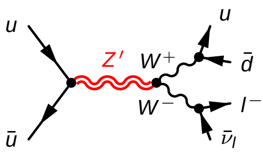
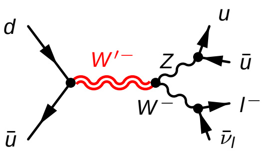
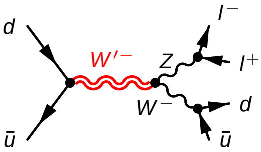
<tr><td>
</td><td>
</td><td>
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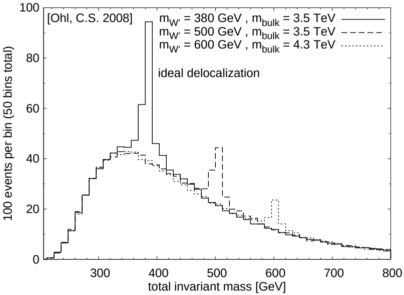
Monte Carlo simulation with WHIZARD / O'Mega:

- Full parton level simulations of $pp \rightarrow jjl\nu_l$ and $pp \rightarrow jjll$
  $\rightarrow$ includes irreducible and most reducible backgrounds
- Missing neutrino momentum: reconstructed from transverse momentum conservation and W, ν mass shell conditions
- Strict cuts for background reduction:
  $p_T \geq 50$ GeV for all particles and also for $p_{T,\text{miss}}$

Simulation results for $pp \longrightarrow jjl\nu_l$ (intermediary Z'):

- Simulations for integrated luminosity $\int dt\, \mathcal{L} = 100\,\text{fb}^{-1}$
- Signal drops with higher $m_{W'}$
- Runs for different values for ϵ_L: $\rightarrow$ Z' production mostly independent of ϵ_L



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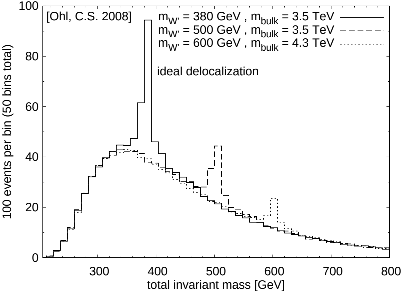
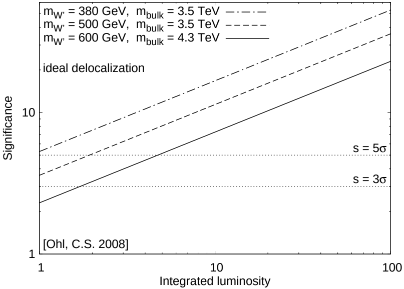


- Signal significance vs. integrated luminosity
- $\rightarrow$ Z' should be visible in the first $10 - 20\,\text{fb}^{-1}$



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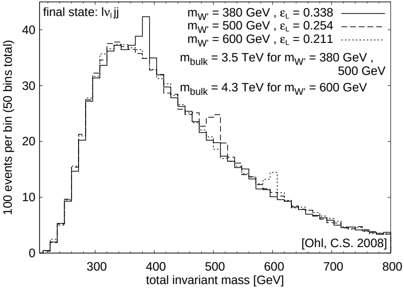

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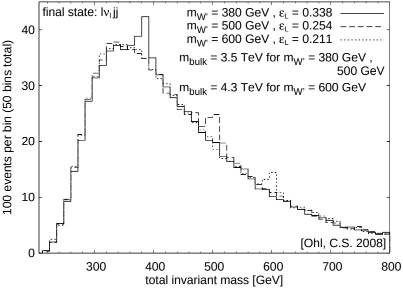

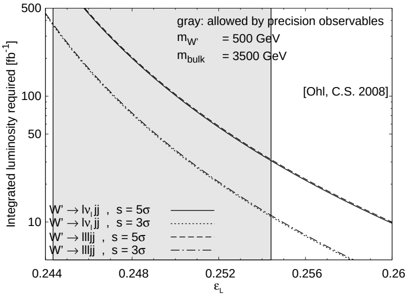

- Int. luminosity required for 5σ (3σ) discovery vs. ϵ_L
- Performance of $jjl\nu_l$ and $jjll$:
  - similar for $m_{W'} = 500$ GeV
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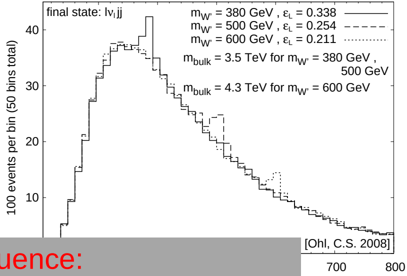

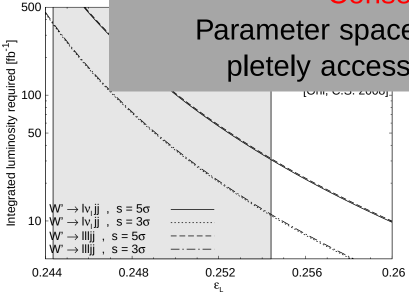

Consequence:
Parameter space may not be completely accessible at the LHC!

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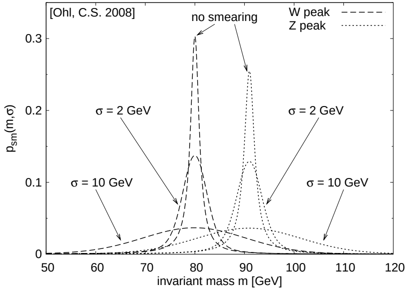

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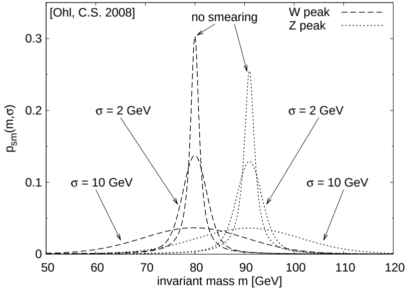

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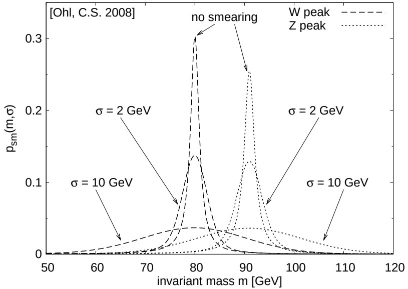
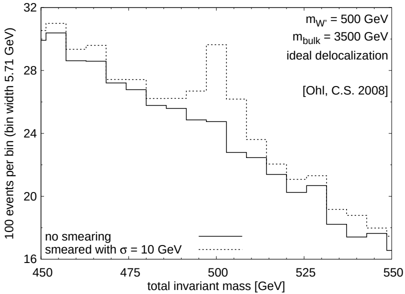
- Consequence: misidentified Z' events can fake a W'!





Possible solution:

- Smeared Breit-Wigner can be integrated for given cuts
- Gives propability matrix T for W/Z identification:

$$\begin{pmatrix} N_{W,\text{meas.}} \\ N_{Z,\text{meas.}} \end{pmatrix} = \begin{pmatrix} P_{WW} & P_{WZ} \\ P_{ZW} & P_{WW} \end{pmatrix} \begin{pmatrix} N_W \\ N_Z \end{pmatrix} = T \begin{pmatrix} N_W \\ N_Z \end{pmatrix}$$

- Invert to reconstruct “true” event counts

$$\begin{pmatrix} N_W \\ N_Z \end{pmatrix} = T^{-1} \begin{pmatrix} N_{W,\text{meas.}} \\ N_{Z,\text{meas.}} \end{pmatrix}$$

- Tried it: seems to work in our example!

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Problems:

- Requires separation of signal $\leftrightarrow$ assumptions about background shape
- Statistical error increased by reconstruction $\rightarrow$ greatly reduced significance

Conclusions:

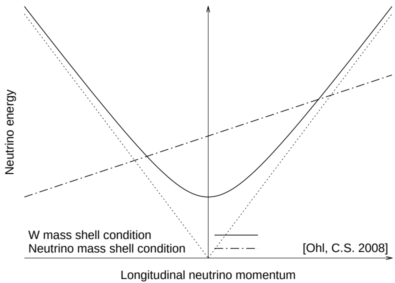
- Three Site Model is an interesting example of higgsless BSM modelbuilding
- Couplings to W'/Z' are severely constrained by electroweak precision observables $\rightarrow$ measurement crucial
- s Channel measurement seems be possible, but not the whole parameter space may be accessible
- Quasi-degeneracy of W'/Z' makes separation difficult in some channels $\leftrightarrow$ tricks like the T-matrix might help
- More in-depth study required including detector effects $\rightarrow$ in progress [T. Trefzger, F. Bach, Würzburg]

Thank you for your attention!

Reconstructing the neutrino momentum:

constraints on p_ν:

- ν mass shell condition:
$$p_\nu^2 = 0$$
- W mass shell condition:
$$(p_l + p_\nu)^2 = m_W^2$$
- transverse momentum conservation

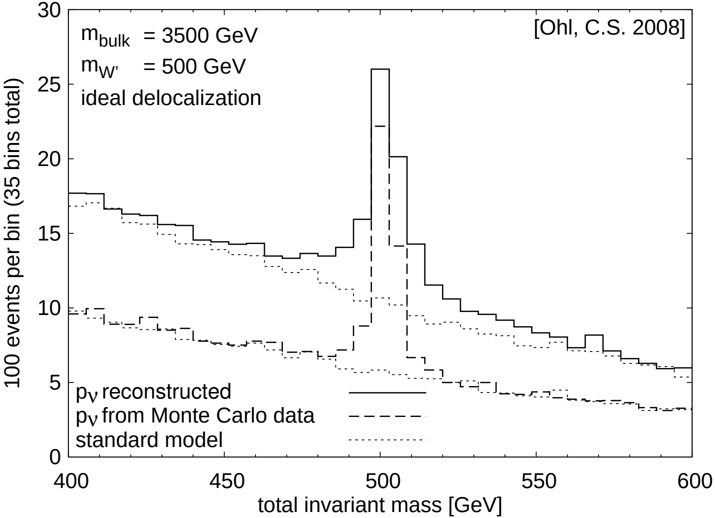


$\longrightarrow$ neutrino momentum can be solved for

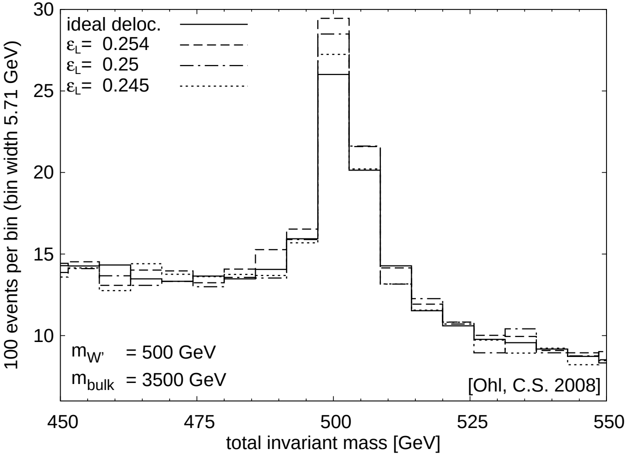
Problem: Two solutions

- Only one is correct
- None is prefered on kinematical grounds (in the general case)
- One (our) solution to this: count both into the histograms $\rightarrow$ more background!

Example: Z' production:

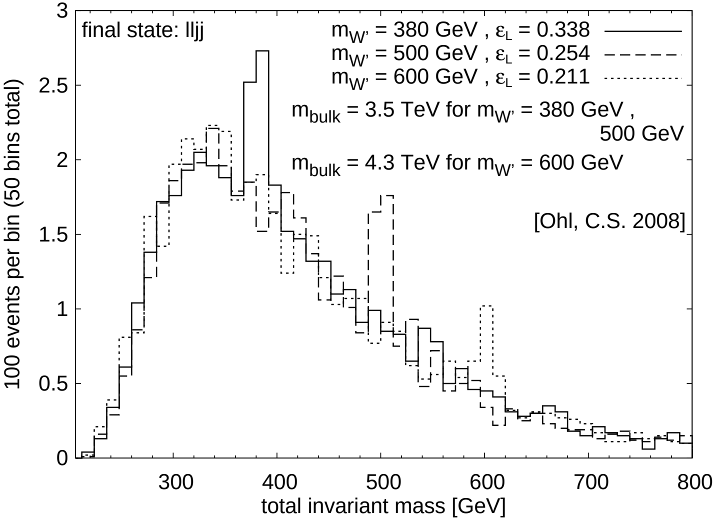


Effect of changing ϵ_L on the Z' production:



$\rightarrow$ makes no big difference in the whole allowed parameter space

Invariant mass distributions for W' production in $pp \longrightarrow jjll$:



Cuts:

- p_T cuts on all particles, including $p_{T,\text{miss}}$

$$p_T \geq 50\,\text{GeV}$$

- angular cuts on all visible particles

$$-0.95 \leq \cos\theta \leq 0.95$$

- small x cut on ingoing partons

$$x \geq 1.4 \times 10^{-3}$$

- mass shell cuts on fermion pairs

$$75\,\text{GeV} \leq m_W \leq 85\,\text{GeV} \quad , \quad 86\,\text{GeV} \leq m_Z \leq 96\,\text{GeV}$$