Collider Phenomenology of Minimal Walking Technicolor

Using Lanhep/Calchep

Mads Toudal Frandsen

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In collaboration with:

Alexander Belyaev

Roshan Foadi

Matti O. Järvinen

Alexander Pukhov

Francesco Sannino

Model implementation based on

1. Minimal Walking Technicolor models (Sannino and Tuominen 05)
2. Effective theory (Foadi, M.T.F, Ryttov, and Sannino 07)
    - Parameter space constraints from LEP and unitarity (Dietrich, Sannino and Tuominen 05; Foadi, M.T.F and Sannino 07; Foadi and Sannino 08)
3. See also the talks by Foadi, Jarvinen and Kouvaris in this conference and comprehensive review by Sannino (Sannino 08)

LanHep/Calchep (A.Semenov/A.Pukhov)

1. LanHep (A.Semenov) allows automatic generation of Feynman rules from 'paper' Lagrangian. Checks for:
   - Hermiticity
   - BRST invariance
   - Electromagnetic charge conservation
   - Diagonalization of fields
2. CalcHep (A.Pukhov) allows immediate model implementation using LanHep and a user friendly graphical interface
   - Unitary and Feynman gauge implementations provide important cross checks

Model Content

1. Particles:
   - A Higgs boson.
   - Spin-1 vector and an axial resonances.
   - Eaten pions.
   - This is a complete description in NMWT. More bound states in MWT, due to the larger chiral symmetry and a new lepton doublet due to Witten anomaly.
2. Input parameters are M_H, M_{A}, $\tilde{g}$, γ, $r_1 + s$
   - S estimated from underlying theory.
   - M_V, r_2, r_3 fixed.
   - r_1, s independent in the MWT model.

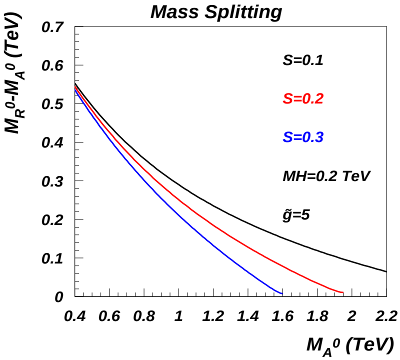
Implementation Status

1. Next to Minimal Walking Technicolor implemented in LanHep/CalcHep (A.Semenov/A.Pukhov)
   - Check decoupling limit: large vector masses and $S = 0$.
   - Check degenerate BESS limit:
     $M_V = M_A, r_1 = r_2 = r_3 = s = 0$ (Casalbuoni, De Andrea, De Curtis, Dominici, Gatto, Grazzini 95).
   - Compare decay widths with analytical computations.
   - Compare unitary gauge and 't Hooft-Feynman gauge implementations.
2. Minimal Walking Technicolor implementation in LanHep/CalcHep in progress.
3. Minimal Walking Technicolor implementation in Sherpa in progress (w/ J. Ferland and F.Krauss)

Signatures of (Next to) Minimal Walking Technicolor

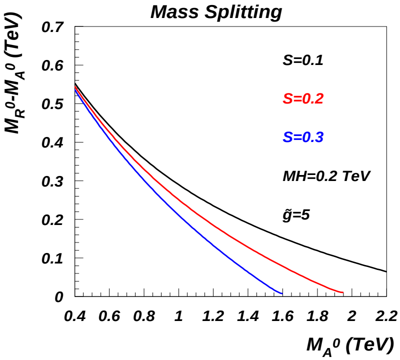
1. Drell-Yan production of heavy vector bosons
2. Vector Boson Fusion production of heavy vectors
3. Associate Higgs Production (Zerwekh 05)
4. Higgs $\rightarrow \gamma\gamma$ (Belyaev, Blum, Chivukula and Simmons 05)
5. Further signatures of MWT model
   - DM candidates (Gudnason, Kouvaris and Sannino 05; Kainulainen, Tuominen, Virkajarvi 06; Kouvaris 07)
   - New lepton family
   - Extra scalars

Vector-Axial Mass Splitting



Within the LHC reach, $M_V > M_A$ for small values of S.

Vector-Axial Mass Splitting



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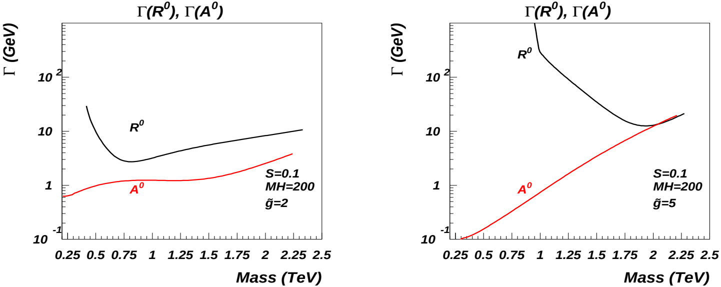
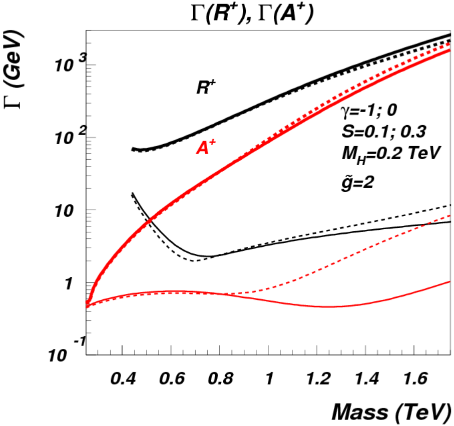
Vector and Axial Decay Widths



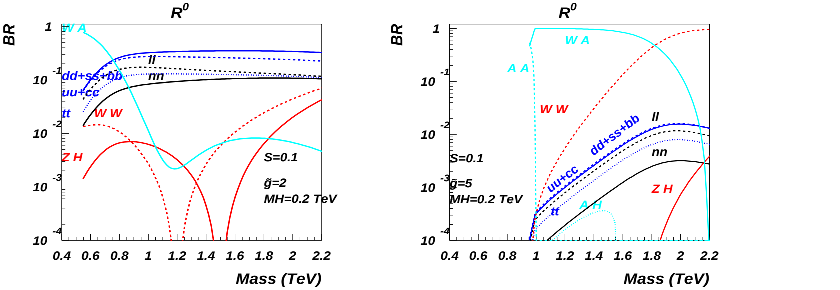
1. **The vector can be much wider than the axial because of the decay** $R^0 \to A^+A^-$.
2. **If** $M_{R^0} < 2M_{A^0}$, **both vector and axial are very narrow.**

Vector and Axial Decay Widths



1. This changes when γ is different from zero.

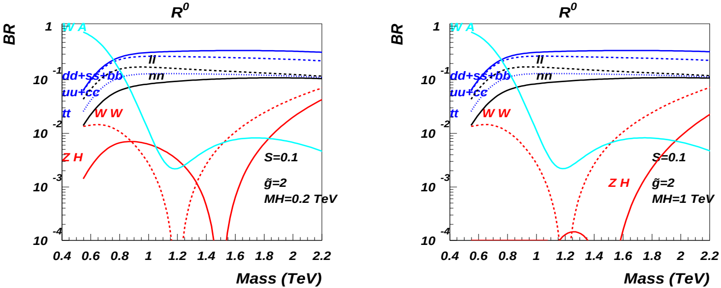
Vector Resonance Branching Ratios



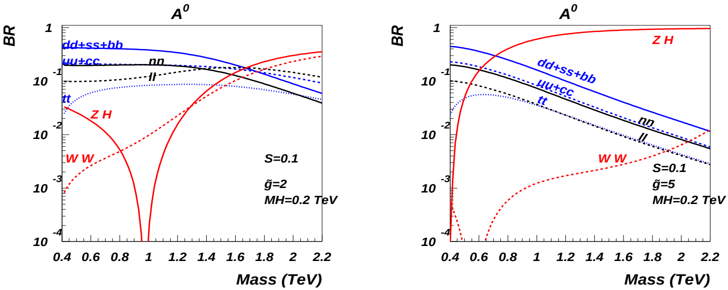
1. **The BR in WW drops to zero and rises: consequence of small S (minimality of the theory).**
2. **BR to fermions drops for large $\tilde{g}$ and for γ parameter close to -1.**

Vector Resonance Branching Ratios

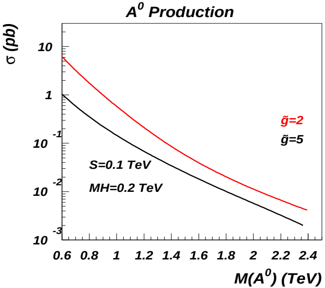
Compare BRs for different Higgs masses.

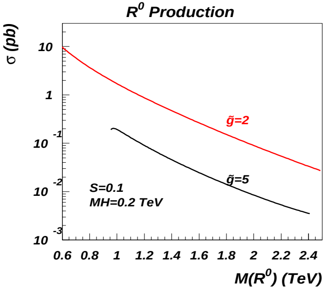


Axial Resonance Branching Ratios

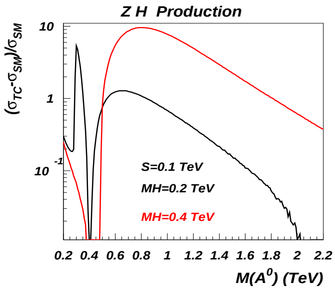


Vector and Axial Direct Production



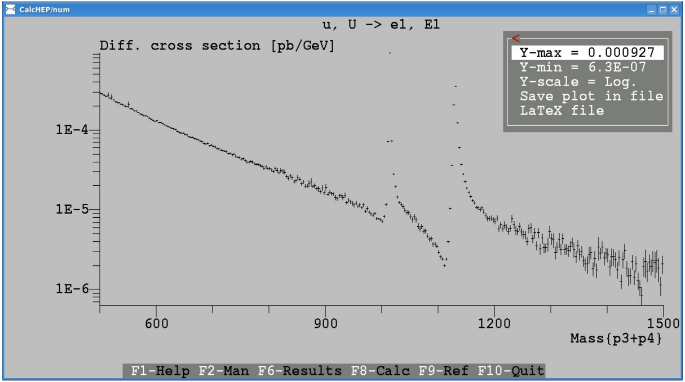


Associate Higgs Production

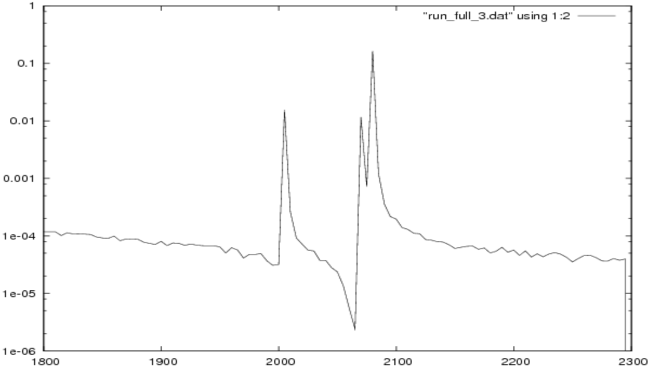


1. Notice the vanishing for finite values of the axial mass: consequence of small S.
2. Early analysis in a simpler Technicolor model. (Zerwekh 05)

Mass bumps in DY process for NMWT



...and in MWT using Sherpa - very preliminary!



Summary

1. Minimal Walking Technicolor implementation
    - NMWT model has been implemented in LanHeP/Calchep in unitary gauge and feynman gauge
    - MWT model is being implemented into LanHep/Calchep.
    - MWT model is being implemented into Sherpa.
2. Collider phenomenology will appear soon.
    - LHC signatures for heavy vectors and Higgs production in NMWT
    - Richer phenomenology in MWT including DM candidates, composite scalars and a new lepton family