Standard Model & Beyond @ EPFL

Riccardo Rattazzi

People

- Mikhail Shaposhnikov (LPPC)
  - Fedor Bezrukov
  - Oleg Ruchaiysky
  - Jean Sebastien Gagnon
  - Alberto Salvio
- Riccardo Rattazzi (LPTP)
  - Ben Gripaios
  - Michele Redi
  - Andrea Wulzer
  - Hyung Do Kim
- Claudio Scrucca (Prof Boursier FNS)
- Stefano Frixione
- Julien Lesgourgues (01/01/2008)

} Joint CERN/EPFL
6 year staff

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New!

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Research

- Shaposhnikov
  - link between particle physics and cosmology: baryogenesis, dark matter, inflation,...
  - a neutrino centered model : νMSM
- Rattazzi

  weak scale physics, supersymmetry, Grand Unification,....
- Scrucca

  strings, D-branes, supersymmetry, supergravity... ...and their potential relevance to the real world
- Frixione

  perturbative QCD and collider physics:
  - higher order computations NNLO
  - improving MC tools, ex. MC@NLO
- Lesgourgues

  cosmology: CMB, large scale structure, neutrinos, ...

My own research

- The mistery of the Fermi scale
  - building models of electroweak symmetry breaking
  - collider phenomenology and constraints
  - implications and constraints from early universe

- Issues in Quantum Field Theory
  (motivated by model building effort)
  - properties of effective field theories
  - conformal field theory
  - modifications of gravity at cosmological scales & dark energy
  - ...

Main motivation for new physics at the Fermi scale

Higgs mass parameter

- uncalculable
- diverges with power of UV cut-off scale $\quad m_H^2 \propto \Lambda_{UV}^2$

Natural to expect 'new physics' right at the Fermi scale to soften this UV dependence

Past examples of power divergences *softened* by

☐ electrostatic mass of classical electron	☑ QFT and the positron
☐ electroweak contribution to $K\bar{K}$ mixing	☑ GIM mech. and charm
☐ electromagnetic contribution to $m_{\pi^+}^2 - m_{\pi^0}^2$	☑ QCD and hadrons

LHC will likely tell us what lies behind this apparent paradox

Main possibilities

- Supersymmetry

- Composite Higgs boson

technicolor
composite Higgs
Little Higgs
....

equivalent!!!

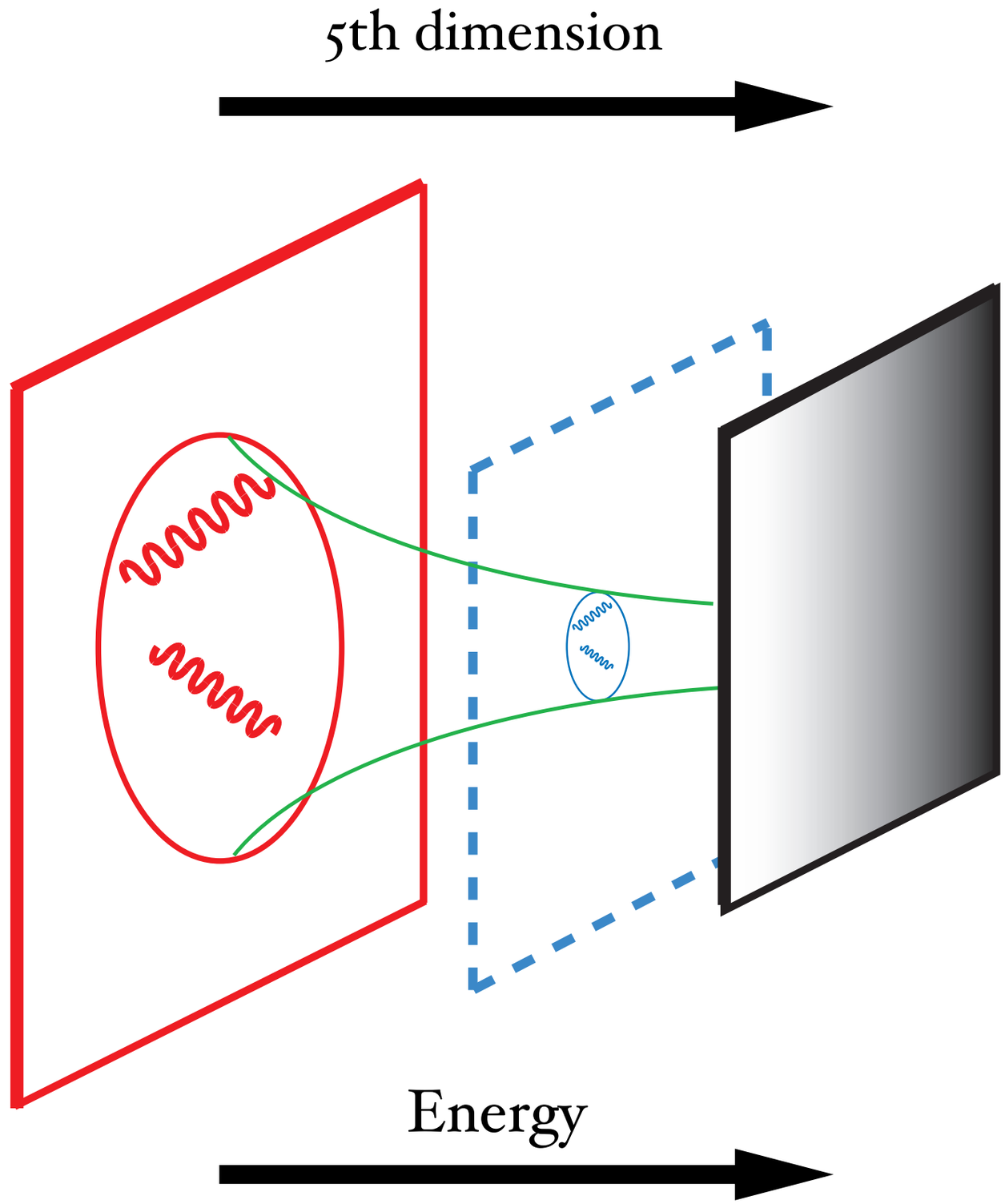
- Extra-dimensions

Large extra-dimensions
warped compactifications
....

Maldacena 1997 : 5D-gravity/4D-gauge theory correspondence

Randall, Sundrum 1999

Arkani-Hamed,Porrati,Randall 2000
Rattazzi, Zaffaroni 2000



Fermi brane

$\langle H \rangle \sim 100\,\mathrm{GeV}$

Planck brane

$M_{Planck} = 10^{19}\,\mathrm{GeV}$

Quantum-gravitational origin of Fermi mass scale in supersymmetry

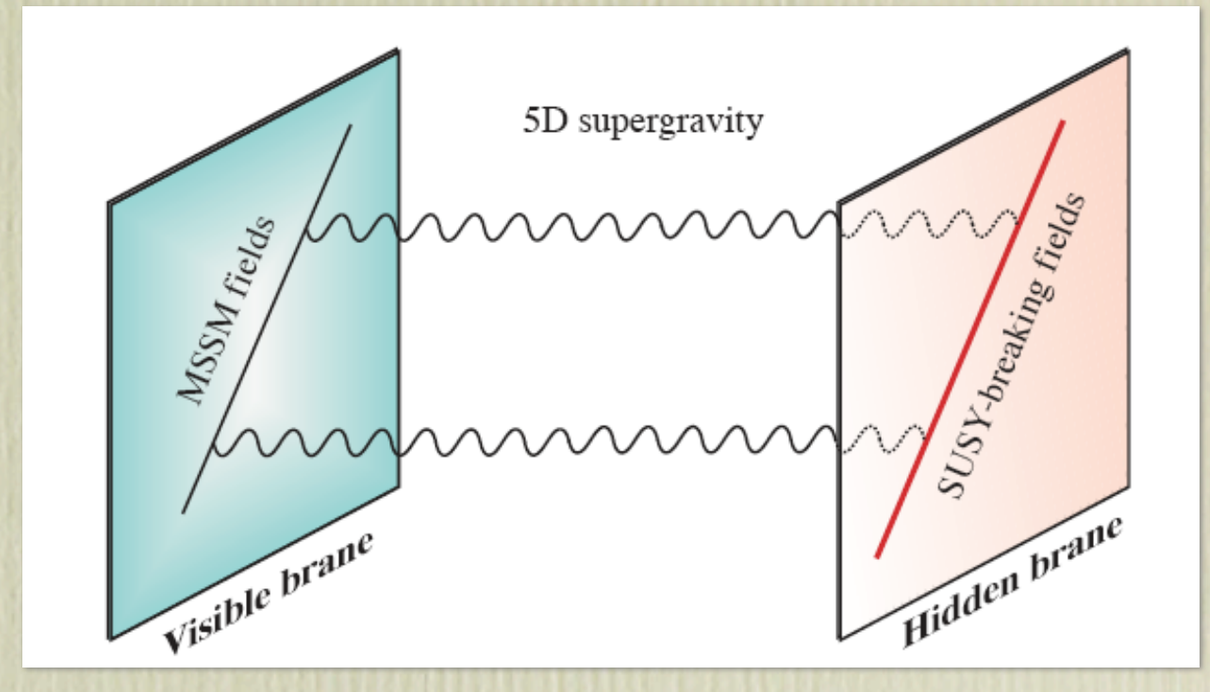
I. Subtle contribution from dilatation anomaly
(Anomaly Mediated Supersymmetry breaking)

Randall,Sundrum '98
Giudice,Luty,
Murayama,Rattazzi '98

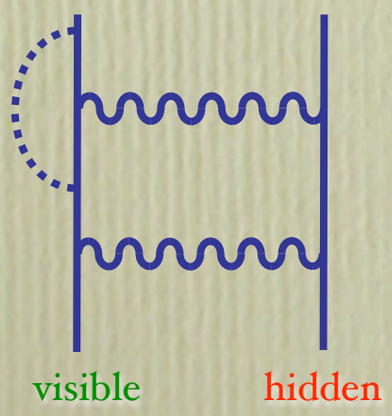
II. Brane-to-brane contribution
(calculable quantum-gravitational effect)

.....

Gregoire, Rattazzi, Scrucca '05



- Flavor universal masses of squarks and sleptons: no dangerous FCNC
- Higher orders predict interesting flavor breaking phenomena



$$Br(\mu \to e\gamma) \sim 5 \times 10^{-13} \left(\frac{\lambda_t}{0.8}\right)^4 \left(\frac{150GeV}{m_{\tilde{\ell}}}\right)^4$$

If a light Higgs is found, how can we tell if it is elementary or composite ?

- Relatively easy if we also find new strongly interacting resonances
- But if the new states are too heavy to be produced at LHC ?

Characterize deviations from SM via an effective Lagrangian

Giudice, Grojean, Pomarol, Rattazzi 07

Principles

- Custodial & Goldstone symmetry
- Minimal Flavor Violation: no-mixing other than CKM

4 relevant parameters $f, \quad c_y, \quad c_g, \quad c_\gamma$

Anomalous Higgs production and decay rates

Enhancement of cross sections $V_L V_L \to V_L V_L$, $V_L V_L \to hh$

- LHC with 300 fb^{-1} tests compositeness up to $4\pi f \lesssim 4\,\mathrm{TeV}$
- ILC with 500 fb^{-1} and $\sqrt{s} = 500\,\mathrm{GeV}$ $4\pi f \lesssim 30\,\mathrm{TeV}$

Use of effective Lagrangian to parametrize new physics below threshold dictated S,T,U parametrization of precision electroweak observables

widely used in LEP era, but...

No natural model reduces to S,T,U at low energy!

In all cases, S,T,U is either a redundant or an incomplete set

General parametrization of universal new physics at LEP is in terms of 4 quantities

S, T, Y, W

Barbieri, Pomarol, Rattazzi, Strumia 04

- LEP1/SLC not sufficient to fully constrain the 4 quantities
- LEP2 less precise but energy higher ➡ as relevant as LEP1

In the 70's Wilson understood the deep physical meaning of renormalization

Any field theory should be treated as 'effective': valid below a certain cut-off

No real need for renormalizability, to describe physics below cut-off

huge freedom in choosing the structure of allowed theories, compatibly with usual constraints: stability, unitarity, absence of anomalies,...

New, subtle, constraints on effective field theories were recently discovered (based on causality, holography,....and satisfied by string theory)

- A gauge theory cannot be weaker than gravity (!!!)

  Arkani-Hamed, Motl, Nicolis, Vafa 06

- Certain coefficients of higher derivative interactions must be positive in order of avoid superluminal propagation over arbitrary backgrounds

  Adams, Arkani-Hamed, Dubovsky, Nicolis, Rattazzi 06

The even remote possibility that measurements in particle physics or cosmology may falsify these constraints is worth keeping in mind