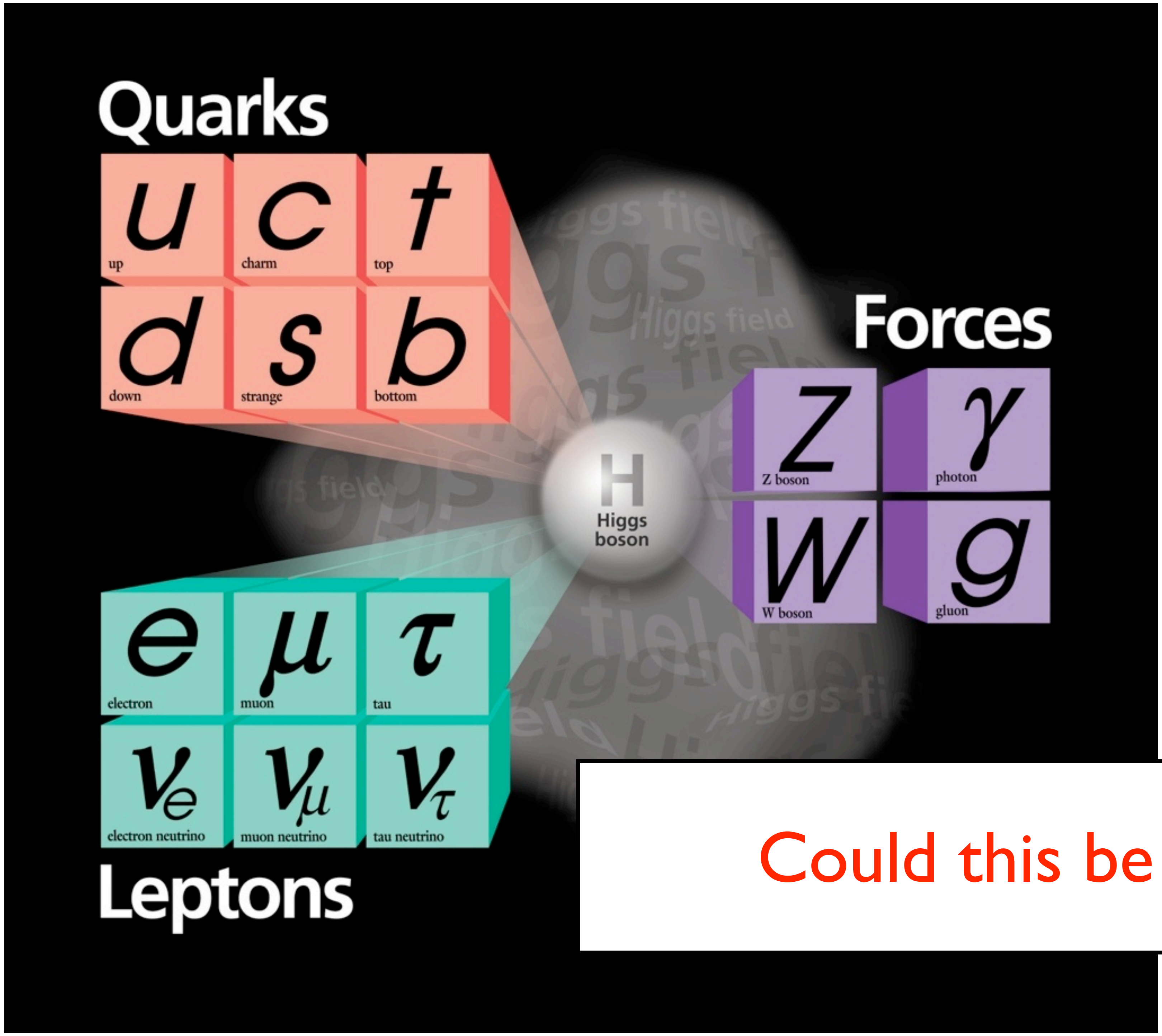
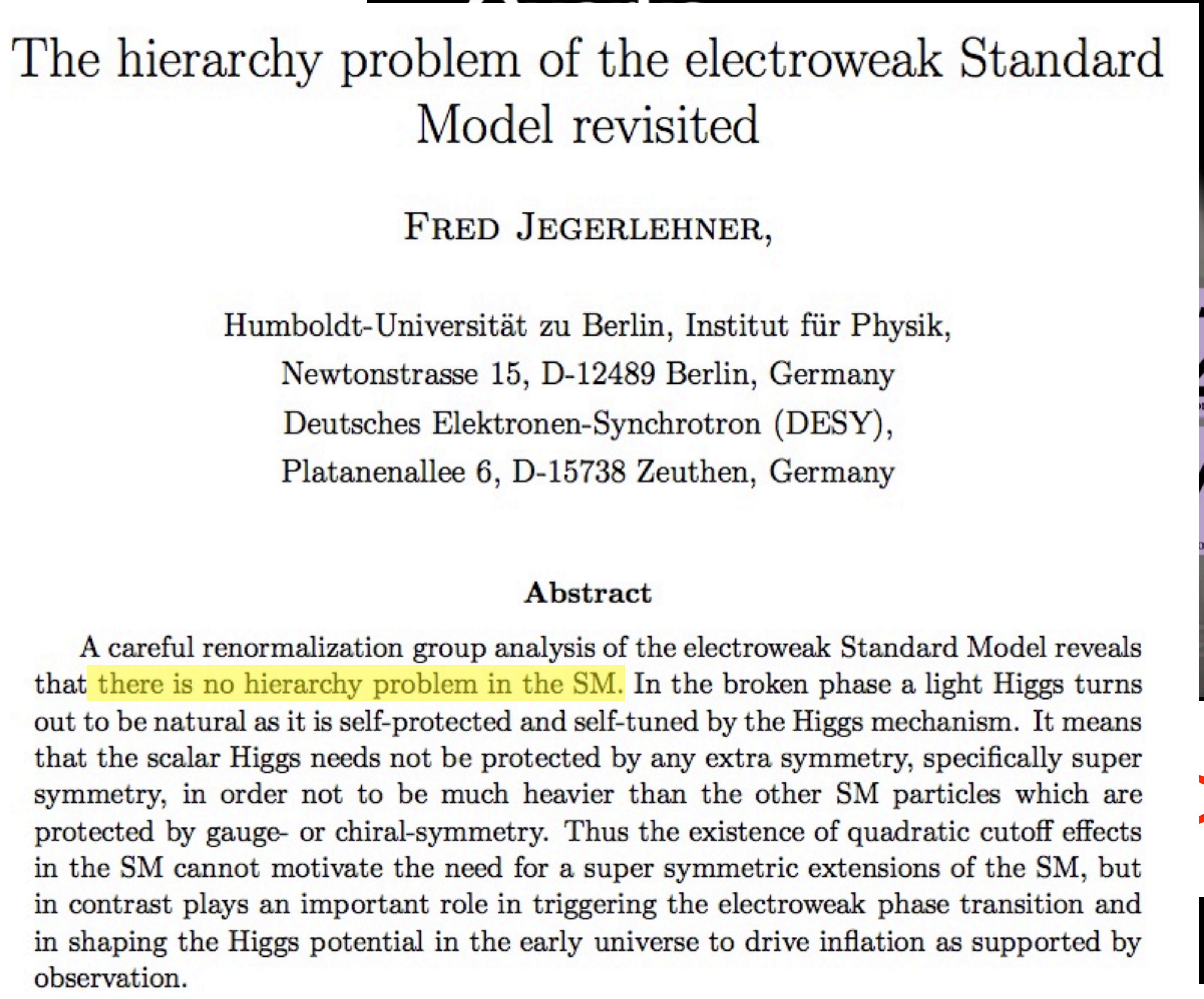
New Physics

New Physics?



Could this be it?

New Physics?



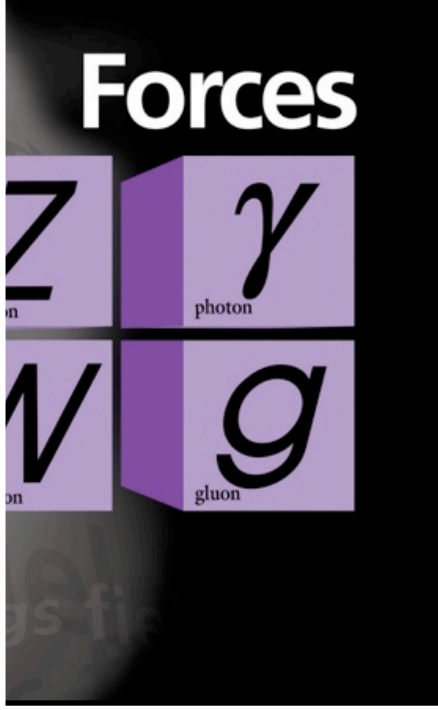
The hierarchy problem of the electroweak Standard Model revisited

FRED JEGERLEHNER,

Humboldt-Universität zu Berlin, Institut für Physik,
Newtonstrasse 15, D-12489 Berlin, Germany
Deutsches Elektronen-Synchrotron (DESY),
Platanenallee 6, D-15738 Zeuthen, Germany

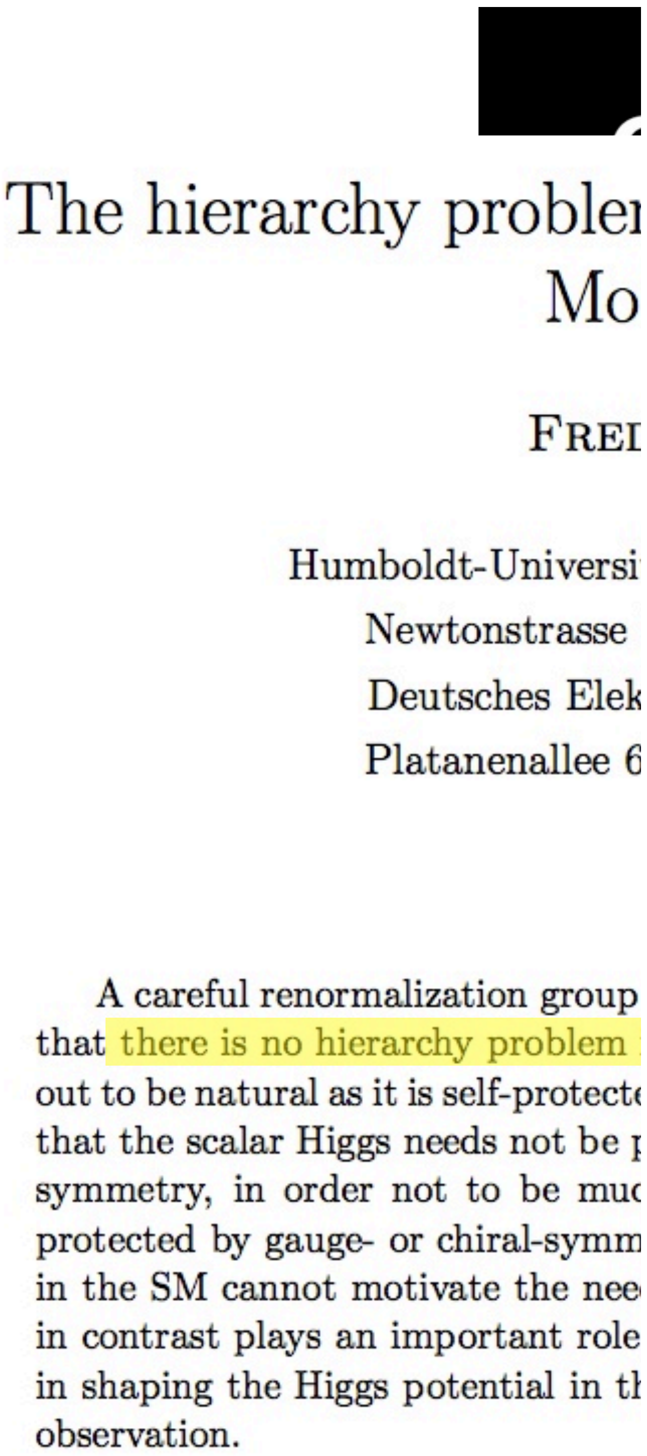
Abstract

A careful renormalization group analysis of the electroweak Standard Model reveals that there is no hierarchy problem in the SM. In the broken phase a light Higgs turns out to be natural as it is self-protected and self-tuned by the Higgs mechanism. It means that the scalar Higgs needs not be protected by any extra symmetry, specifically super symmetry, in order not to be much heavier than the other SM particles which are protected by gauge- or chiral-symmetry. Thus the existence of quadratic cutoff effects in the SM cannot motivate the need for a super symmetric extensions of the SM, but in contrast plays an important role in triggering the electroweak phase transition and in shaping the Higgs potential in the early universe to drive inflation as supported by observation.



ould this be it?

New Physics?



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The hierarchy probler
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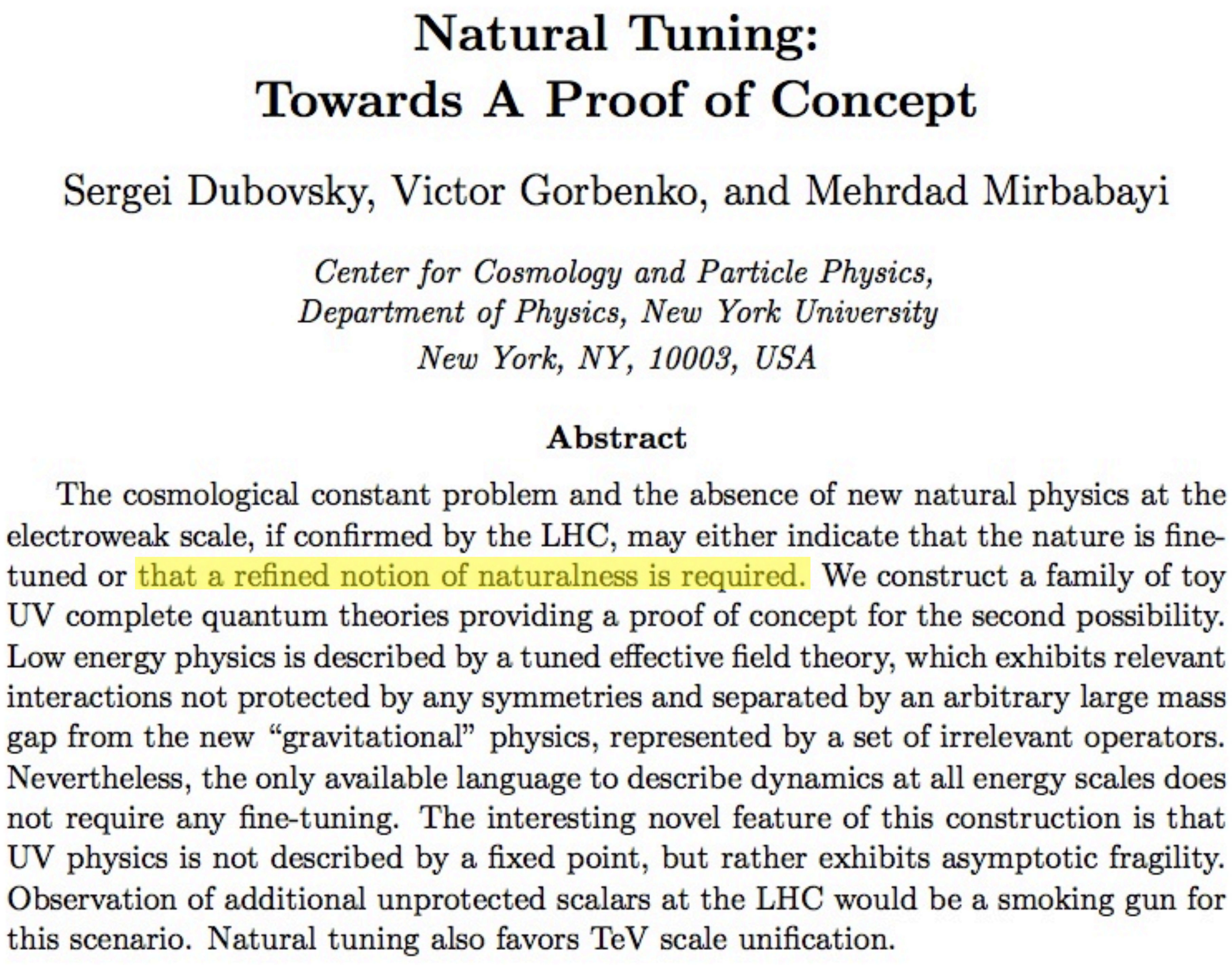


Natural Tuning: Towards A Proof of Concept

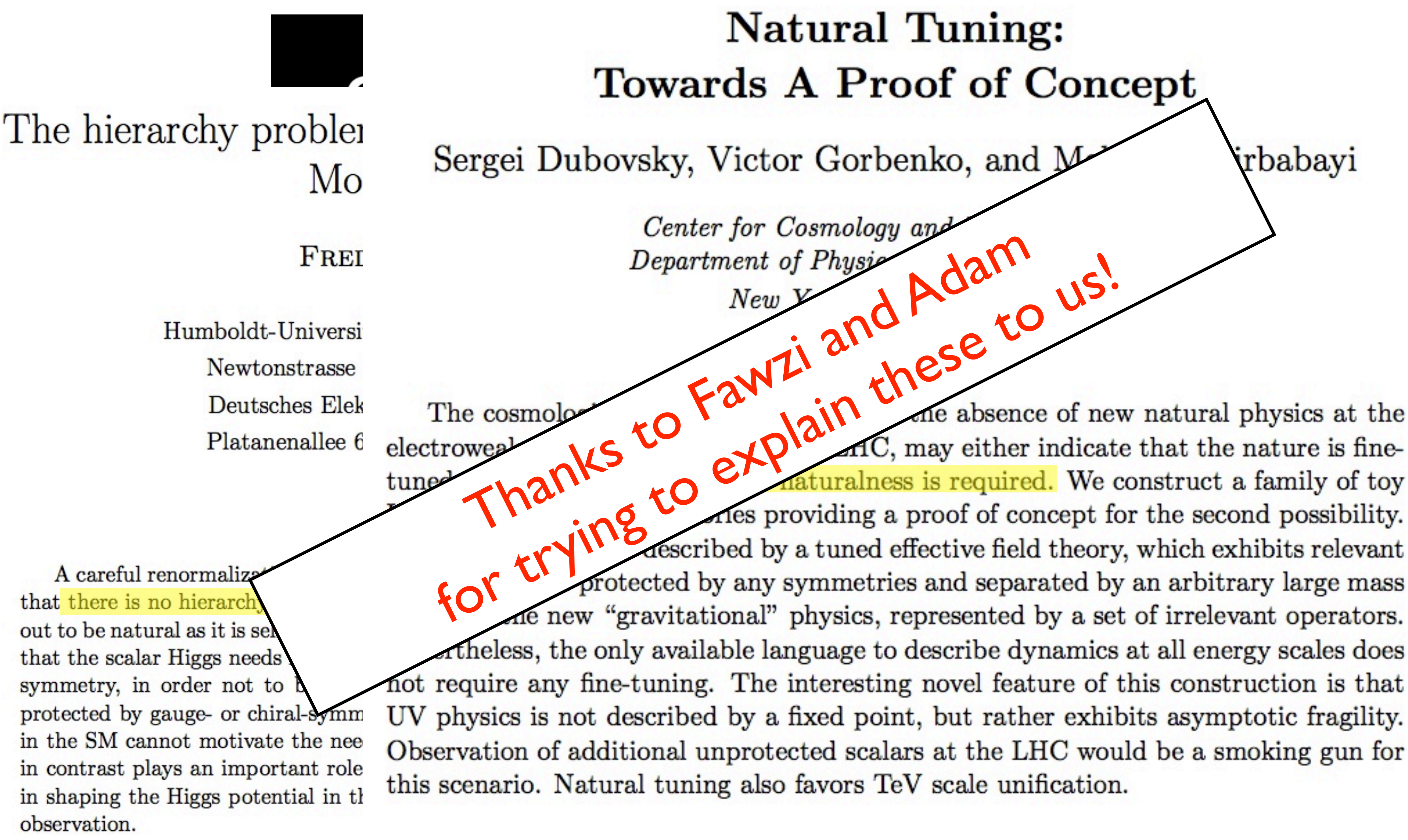
Sergei Dubovsky, Victor Gorbenko, and Mehrdad Mirbabayi

Center for Cosmology and Particle Physics,
Department of Physics, New York University
New York, NY, 10003, USA

Abstract

The cosmological constant problem and the absence of new natural physics at the electroweak scale, if confirmed by the LHC, may either indicate that the nature is fine-tuned or that a refined notion of naturalness is required. We construct a family of toy UV complete quantum theories providing a proof of concept for the second possibility. Low energy physics is described by a tuned effective field theory, which exhibits relevant interactions not protected by any symmetries and separated by an arbitrary large mass gap from the new "gravitational" physics, represented by a set of irrelevant operators. Nevertheless, the only available language to describe dynamics at all energy scales does not require any fine-tuning. The interesting novel feature of this construction is that UV physics is not described by a fixed point, but rather exhibits asymptotic fragility. Observation of additional unprotected scalars at the LHC would be a smoking gun for this scenario. Natural tuning also favors TeV scale unification.

New Physics?



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The hierarchy proble
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Natural Tuning:
Towards A Proof of Concept

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Center for Cosmology and
Department of Physic
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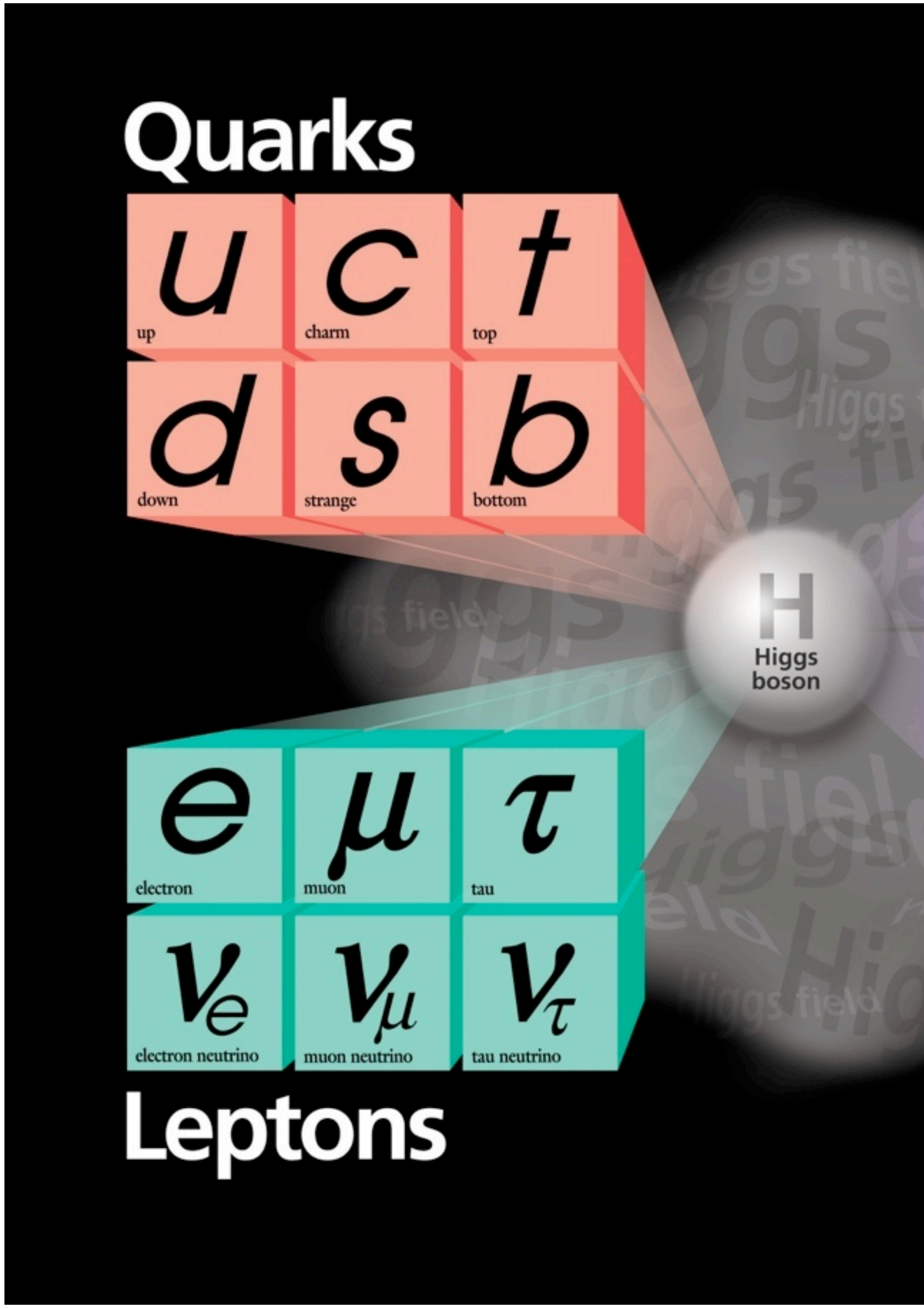
UV physics is not described by a fixed point, but rather exhibits asymptotic fragility.
Observation of additional unprotected scalars at the LHC would be a smoking gun for
this scenario. Natural tuning also favors TeV scale unification.

Thanks to Fawzi and Adam
for trying to explain these to us!

Nevertheless

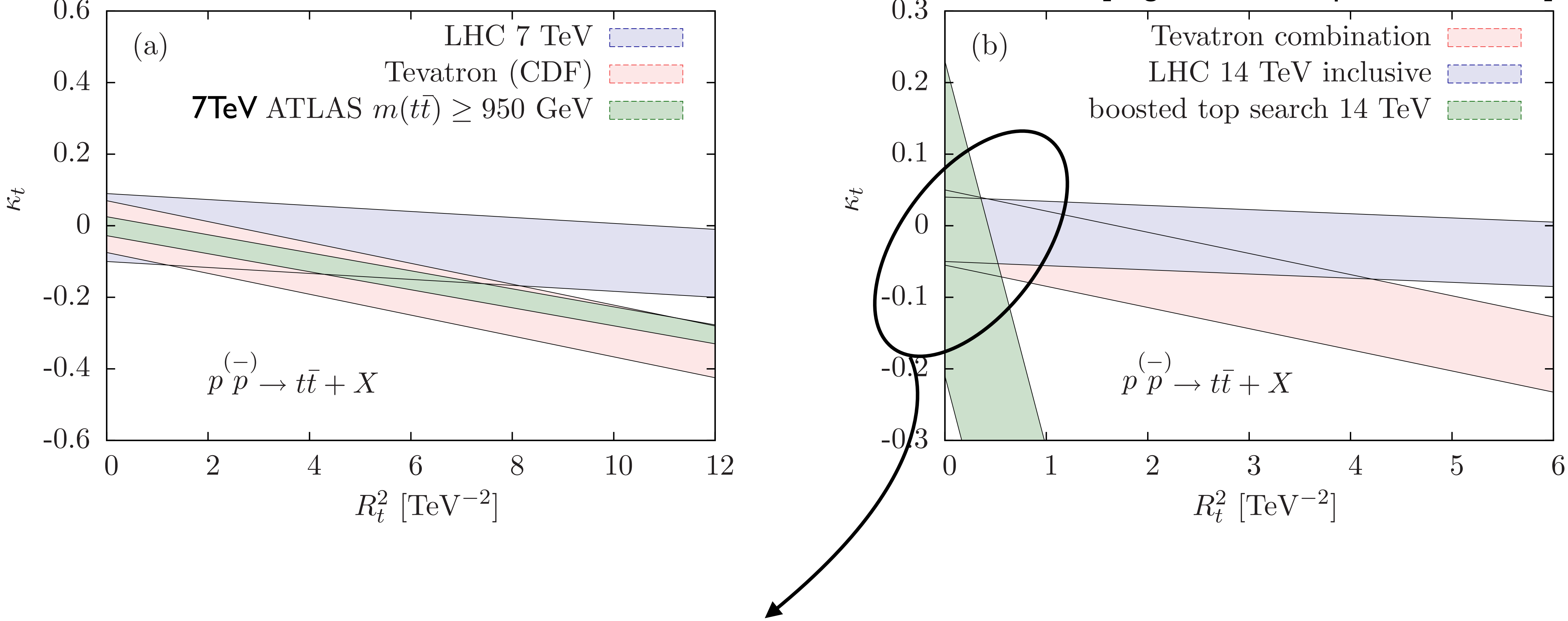
- Clear structure in fermionic sector unexplained
  - Evidence of some selective principle (why are there no neutral colored fermions?)
  - Proton stability, running of couplings suggestive of at least one other scale relevant to SM particles, ~10^{15} GeV
    - Either fine-tuning, or a closer scale



- lots of tops at the LHC, but only a few Higgses
- strongly interacting EW scale $\supset$ top compositeness

$$\begin{aligned}\mathcal{L}_R &= -g_s \frac{R_t^2}{6}\,\bar{t}\gamma^\mu\,\mathcal{G}_{\mu\nu}\,D^\nu\,t + \text{h.c.},\\ \mathcal{L}_\kappa &= g_s \frac{\kappa_t}{4m_t}\,\bar{t}\sigma^{\mu\nu}\,\mathcal{G}_{\mu\nu}\,t\,,\ldots\end{aligned}$$

[Englert, Freitas, Spira, Zerwas '12]



- Limitations by systematic uncertainties? Are there analysis-related issues? Impact of top-tagging?
- Complementarity to m(tt) shape analyses? Is it better?

Englert, Spannowski

Enhancing the longitudinal fraction of V's in VV scattering

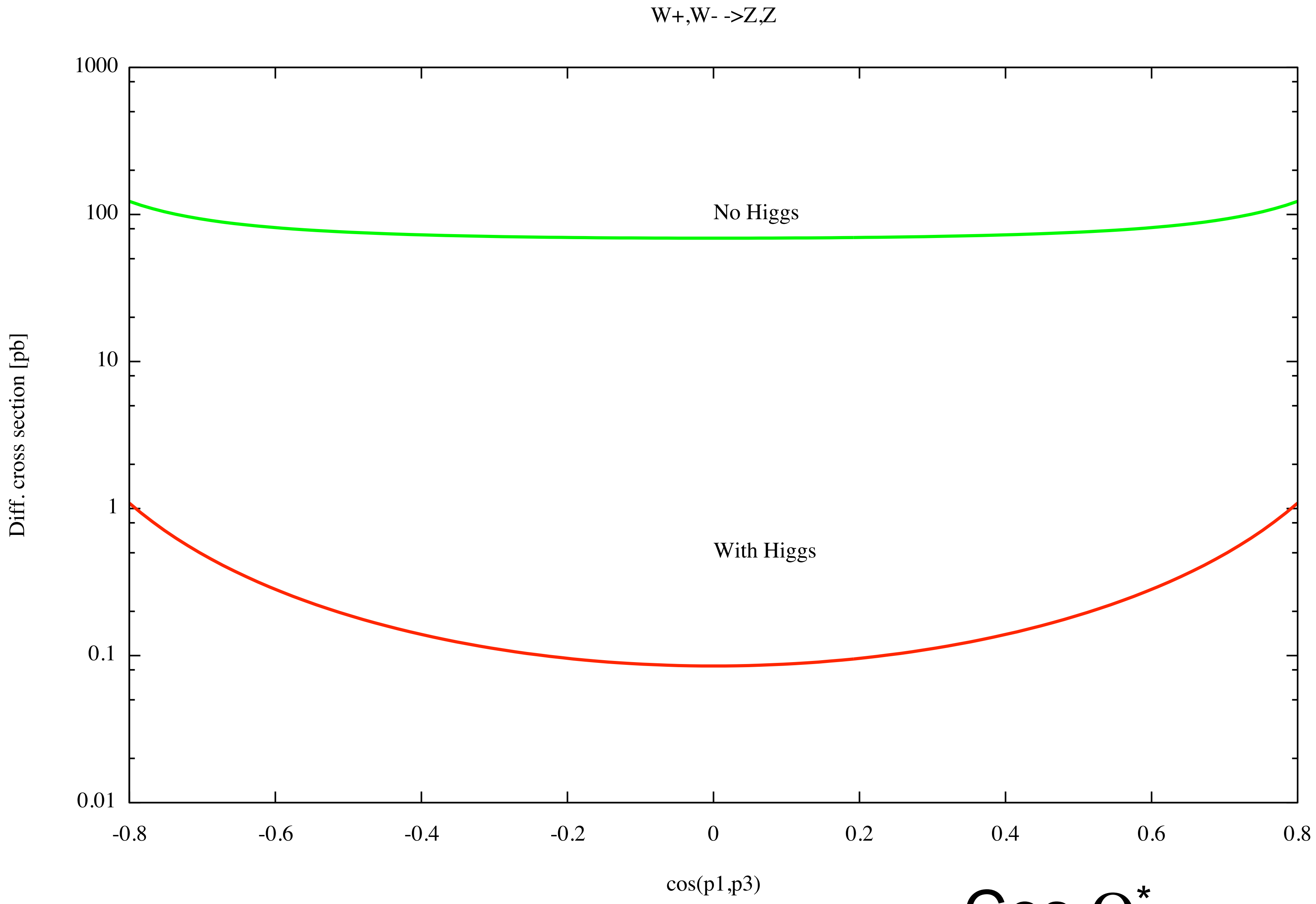
People involved: A. Belyaev, E. Boos, V. Bunichev, G. Cacciapaglia, , A. Deandrea , Y. Maravin, A. Pukhov, R. Rosenfeld… [add your name]
http://phystev.in2p3.fr/wiki/2013:participants:alexander.belyaev:wlwl

Motivation:
. to explore the LHC sensitivity to the new physics involving non-SM Higgs couplings to vector boson which lead to enhancement of the V_LV_L->V_LV_L amplitudes due to the violation of large cancellations which are provided by the SM Higgs boson

Goal:
. devise cuts to filter-out the transverse polarizations, which mask the presence of New Physics, and determine their efficiency.

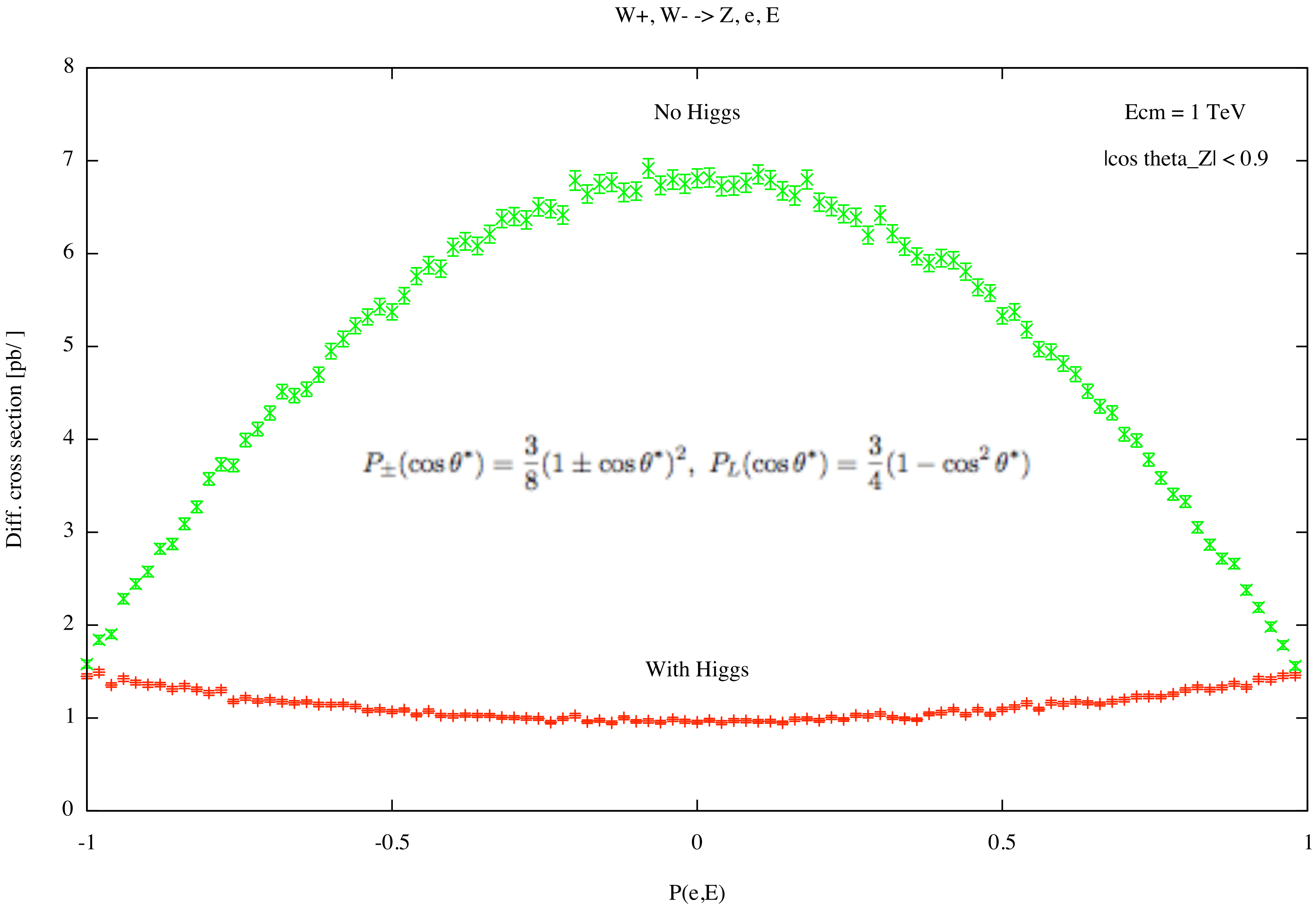
Huge literature about this, e.g.: Han et al (2009), Kalinowski at al (2012), …

Very simple preliminary tests



$\mathrm{Cos}\ \Theta^*_Z$

Angular distribution of electron in the rest frame of the parent Z after angular cut in the other Z angular distribution



W+, W- -> Z, e, E

Promising?

Constraining Natural SUSY

E. Conte, B. Fuks, S. Kraml, S. Kulkarni, L. Mitzka, B. O'Leary, S. Pataraia, W. Porod
S. Sekmen, D. Sengupta, N. Strobbe, F. Würthwein, W. Waltenberger

scenario considered:

- higgsino like states $\tilde{\chi}^0_{1,2}$, $\tilde{\chi}^+_1$, few GeV mass differences
- $\tilde{t}_1$, $\tilde{b}_1$, arbitrary nature
- $\tilde{g}$

mass hierarchy: $m_{\tilde{\chi}} < m_{\tilde{q}_1} < m_{\tilde{g}}$
two-fold strategy:

- constraining the scenario using existing simplified model results
- doing a proper analysis

compare results of both

Status:

- parameter ranges fixed
- agreement on how to set up the chain from SLHA input files to n-tuples
  $\Rightarrow$ runs will start in the next days

Natural SUSY and RPV

E. Conte, M. Dolan, B. Fuks, K. Howe, Y. Jiang, B. O'Leary, M. Marjanovic, S. Pataraia, W. Porod, P. Richardson, A. Raklev, N. Strobbe

scenario considered:

- higgsino like states $\tilde{\chi}^0_{1,2}$, $\tilde{\chi}^+_1$, few GeV mass differences
- $\tilde{t}_1$, $\tilde{b}_1$, arbitrary nature
- $\tilde{g}$

broken R-parity: any of them can be the LSP
Idea: systematically check which signatures have not yet been covered by existing analyses
Status: all final states worked out, check of LHC results still ongoing, two potentially interesting cases so far

- long lived LSP, in particular in case of the LLE-operator, e.g. $\tilde{g}$ five-body decays
- UDD-operator: in some corner of the parameter space one has $2h + 4j$ as final state

Top polarization in sbottom decays

R. Godbole, B. Fuks, W. Waltenberger, T. Golling, S. Kraml, G. Belanger, S. Kulkarni

- Effect of top polarization in stop decays is known to be significant
- Top polarization in sbottom decays can play a role in determining the reach for direct sbottom searches when sbottom decays to top + chargino are considered
- Aim: To quantify the reach for sbottom searches by including the effect of top polarization
- Two steps involved:
  - Quantify the effect of the spin co-relations on the reach of sbottom searches
  - Construct new observables which utilize the information of the top polarization in order to enhance signal
- Final states considered:
  - Case I. LSP is higgsino: Final state - ttbar + MET - results exist, will be used for cross-checks
  - Case II. LSP is bino or winolike: Final state - single lepton + jets + MET or same sign leptons + jets + MET - new case being considered
- Status: new benchmarks being searched for, basic machinery in place

Compressed SUSY spectrum at the LHC

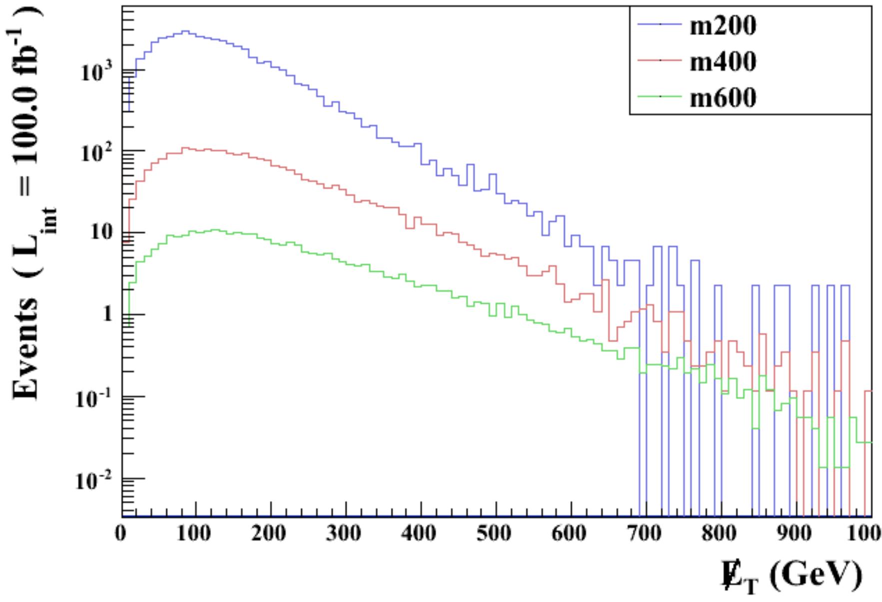
- People: B. Fuks, F. Moortgat, P. Richardson, A. Wilcock

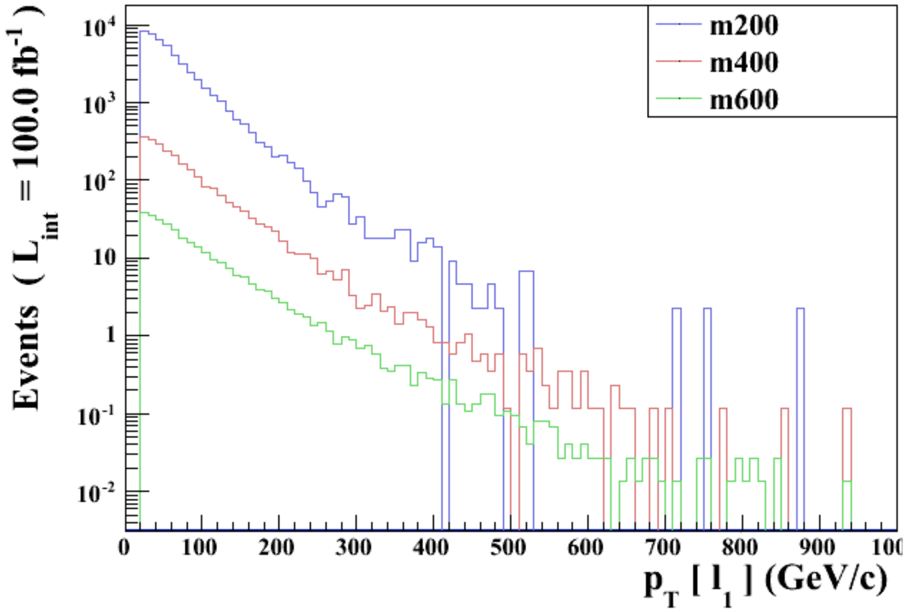
- Goal: accessing compressed SUSY spectra at 14 TeV through crazy topologies
  - Toy channel: $pp \to \tilde{g}\ \tilde{t}\ t \to t \not\!\!E_T$
  - Other tested channels: too low cross sections

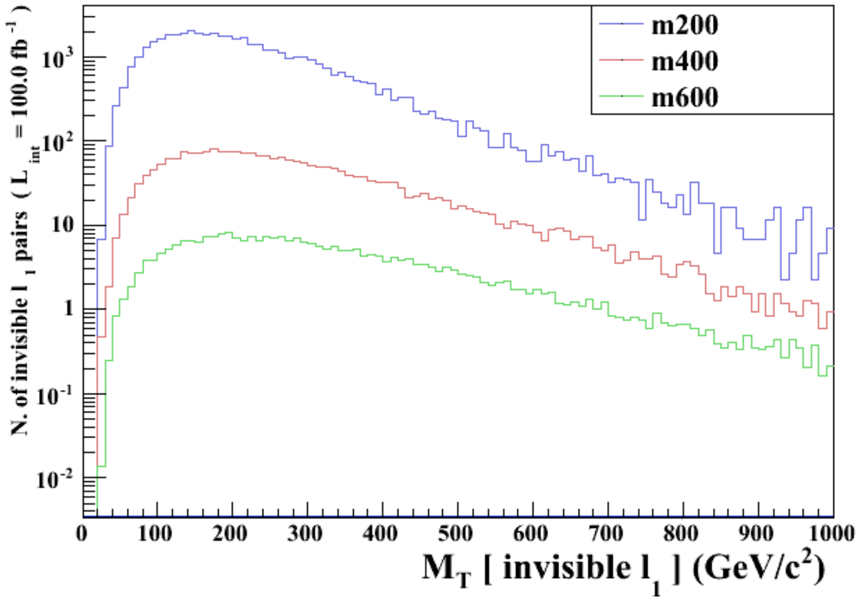
- Benchmark scenarios
  - sbottom, sgluino and stop masses at 200 GeV, 400 GeV, 600 GeV
  - neutralino mass at 190 GeV 390 GeV, 590 GeV

- Moderate cross sections:
  - 2 pb, 100fb and 10 fb for a SUSY scale of 200 GeV, 400 GeV and 600 GeV, respectively

- Some signal distributions for 100 fb^{-1} and for a leptonic top decay:







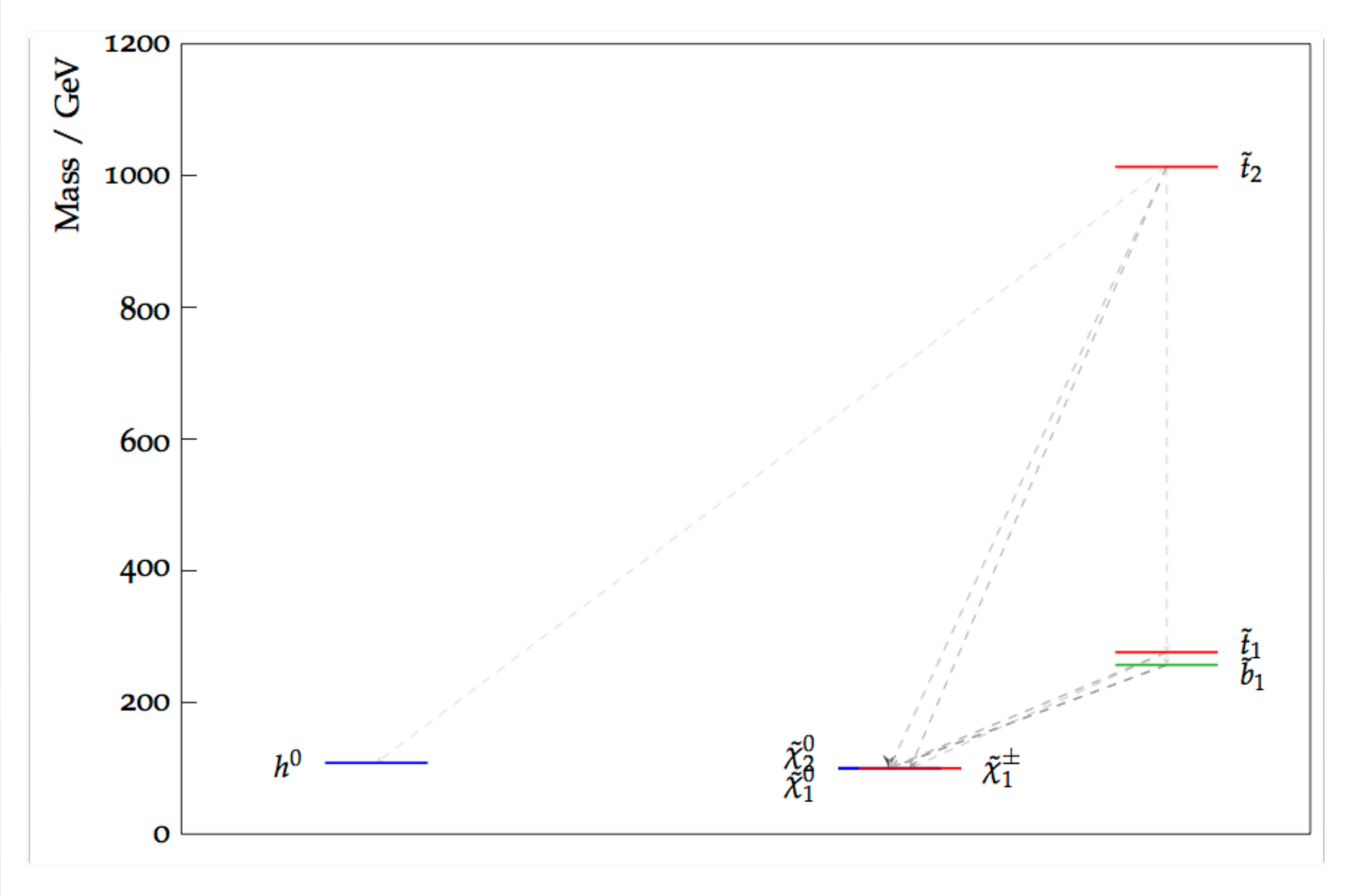
The Susy H-bomb

Englert, Spannowsky, Weiler, Brooijmans, Richardson

Super-spectrum:

Compressed spectrum, boosted topologies,

Higgs(es), natural, $m_{\tilde{t}_1} - m_{\tilde{\chi}_0} < 50\,\mathrm{GeV}$



$$\tilde{t}_2 \to \tilde{t}_1 h$$

Non Minimal Flavour Violation in the squark sector

K. De Causmaecker, B. Fuks, S. Sekmen, N. Strobbe, W. Porod, N. Mahmoudi

Goal

Study the effect of NMFV on current exclusion limits

Workflow

- scan over model space including NMFV
- check which points are allowed from low energy observables ($b \to s\gamma$, $B_s \to \mu\mu$, $B_u \to \tau\nu$, $b \to s\mu\mu$, Δa_μ, $\Delta M(B_s)$)
- identify several benchmark points/planes and generate events
- implement existing (CMS) analysis and study how the exclusion limits change

Model parameters

- Gaugino mass scale (M1:M2:M3 = 1:2:6), range [100,1600], step 250
- $M_{SUSY} = m_{\tilde{q}} = m_{\tilde{l}}$, range [100,1600], step 250
- $A_0 = A_{t/b/\tau} = \{0, 500, -1000, -5000, -10000\}$
- μ, range [100,850], step 250
- m_{A_0}, range [100,1600], step 250
- $\tan\beta = \{10, 40\}$
- $\lambda_{LL}, \lambda_{RR}, \lambda_{LR}$, range [-0.9,0.9], step 0.15

Higgs sector of the (unconstrained) MSSM with CP violation

A. Arbey, J. Ellis, R. Godbole, N. Mahmoudi

Study of the implications of the Higgs observables on the CP violating MSSM scenarios.

Parameters: pMSSM like scenario with 19 free parameters,
in addition to 6 CP phases: $\phi_1, \phi_2, \phi_3, \phi_{A_t}, \phi_{A_b}, \phi_{A_\tau}$

Considering all the available constraints from:

- Higgs sector
- EDMs
- flavour physics
- dark matter

Two approaches:

- Random flat scans over all the parameters
- Geometric approach for the CP phases to avoid large EDMs

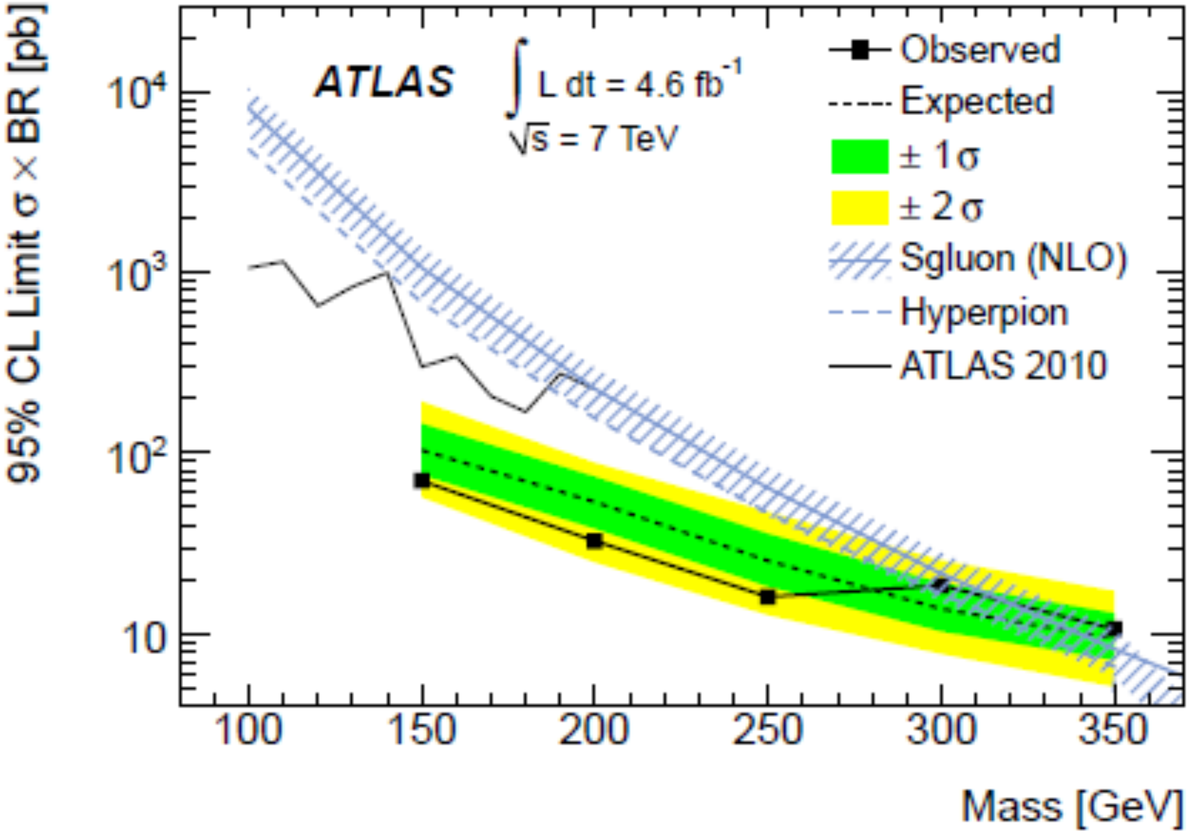
J. Ellis et al., arXiv:1006.3087

Pair produced sgluons

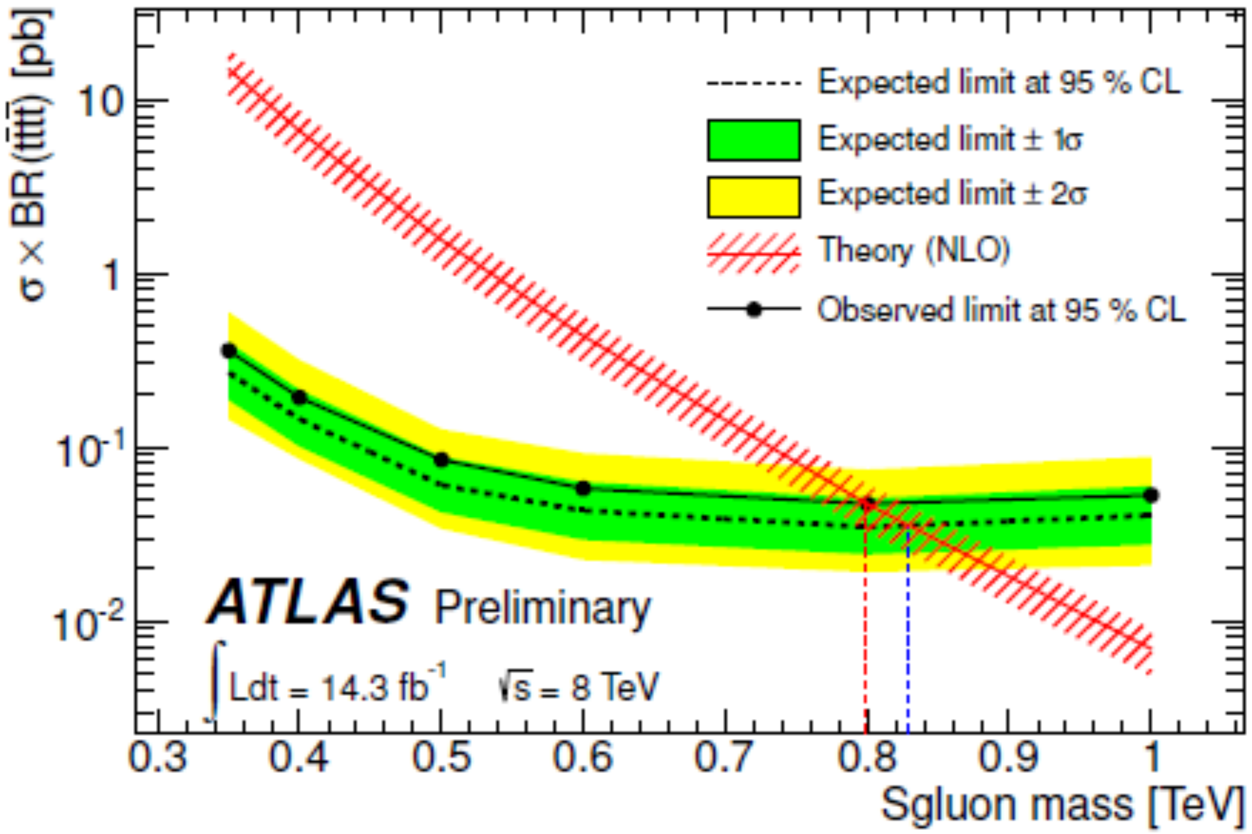
Benjamin Fuks, Dirk Zerwas + LPC Clermont-Ferrand

- Explore final states with several top quarks at the LHC
  - color octet scalars (SUSY: sgluon, TC:HyperPion+Coloron)
- Pair production and single production
- Final states (a choice):
  - gggg (done by ATLAS), tttt (done by LH11 and ATLAS), ttgg
- Chain at Les Houches:
  - PYTHIA8 with external dsigma/dcostheta*
  - DELPHES
  - Future: Feynrules (as in 2011)

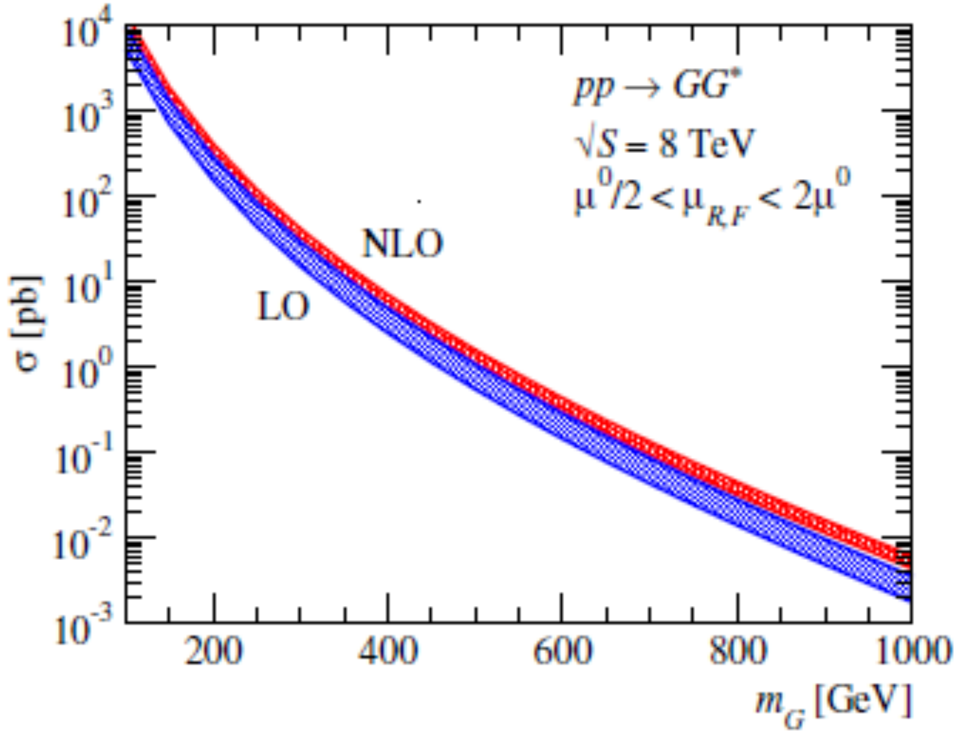
gggg



tttt



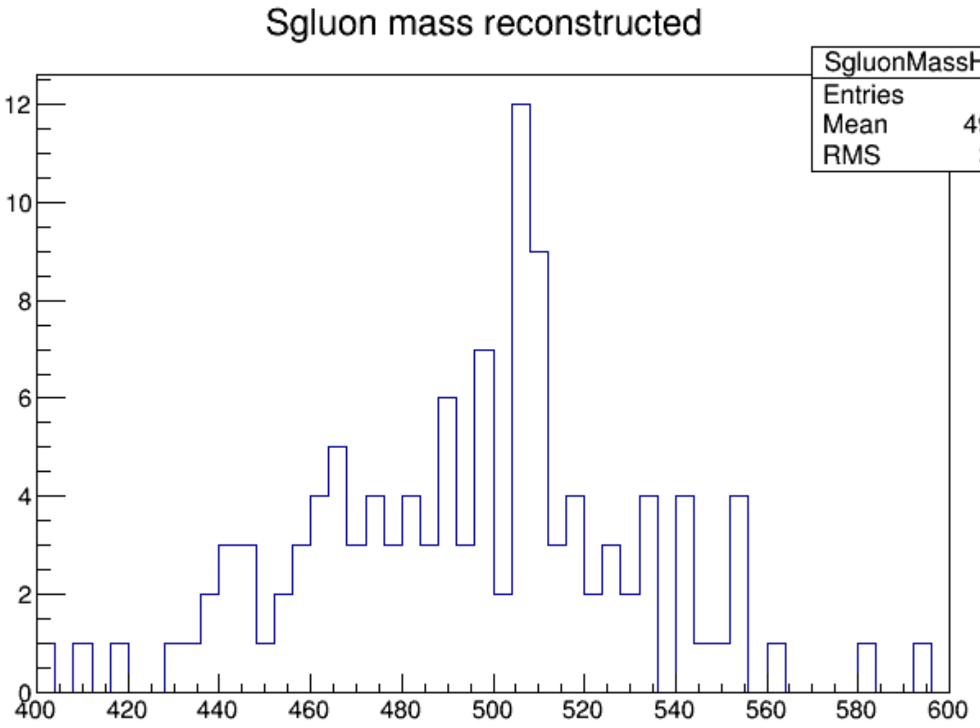
Scenarios and Status



Scenario ttgg:

- **Cross Section NLO (Goncalves-Netto et al. PRD 85 (2012) 114024)**
- **500GeV: 1.3pb * (BRmax=0.5) = 650fb**
- **PYTHIA8 Step: OK 10K ggtt produced**
- **DELPHES Step: OK 10K through fast simulation**

- **Sanity check of generation and simulation ok**
- **after DELPHES:**
- **at least 1 lepton**
- **jets > 30GeV**
- **example: is there a dijet mass combination close to 500GeV? (see figure)**
- **more checks/analysis necessary**



Natural focus point SUSY via mono-γ/j

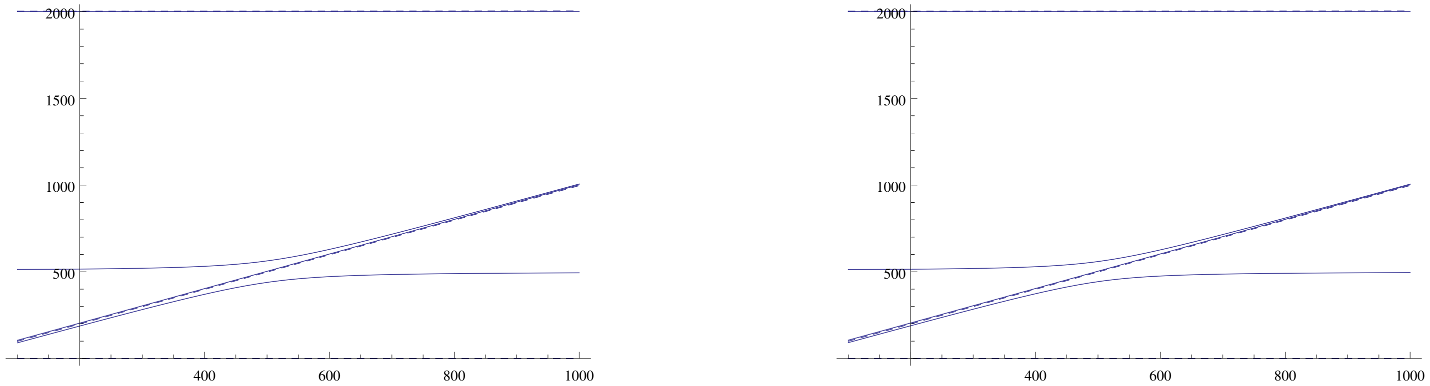
Comparing the capability of LHC13 with XENON1T in 2017

Consider Natural SUSY scenarios with light M_1

Focus points region: $\mu < M_1$ or $\mu \simeq M_1$ so $\Omega_\chi h^2 \lesssim 0.12$, $M_2 \sim 1\,\mathrm{TeV}$, $M_A \sim 1.5$ TeV, $\tan\beta =$10,40

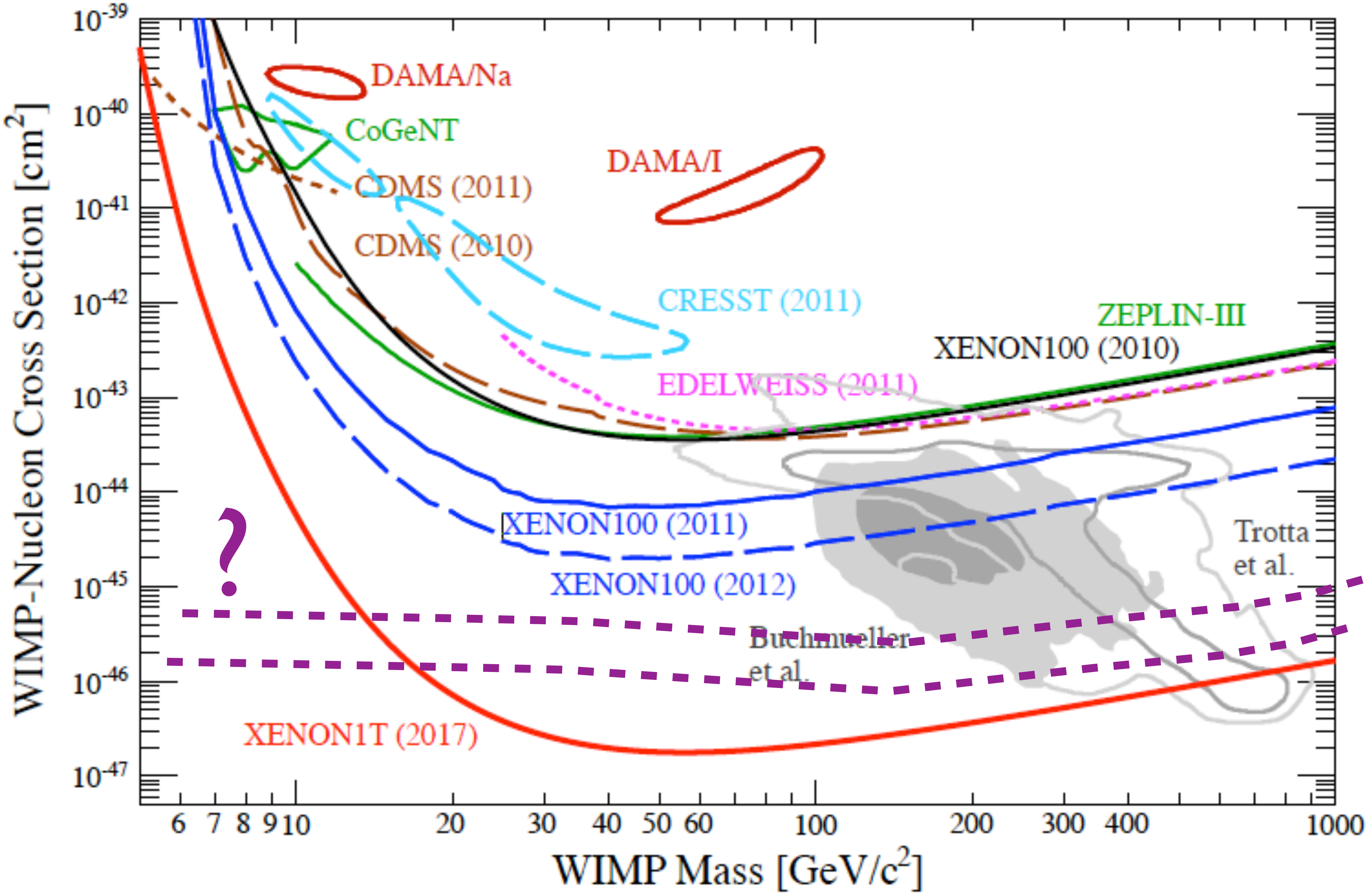
- Using MadGraph5 and Delphes for LHC@13.5,14 TeV
- Compare results to XENON1T curves

A.Belyaev, A.Bharucha, W.Porod, V.Sanz



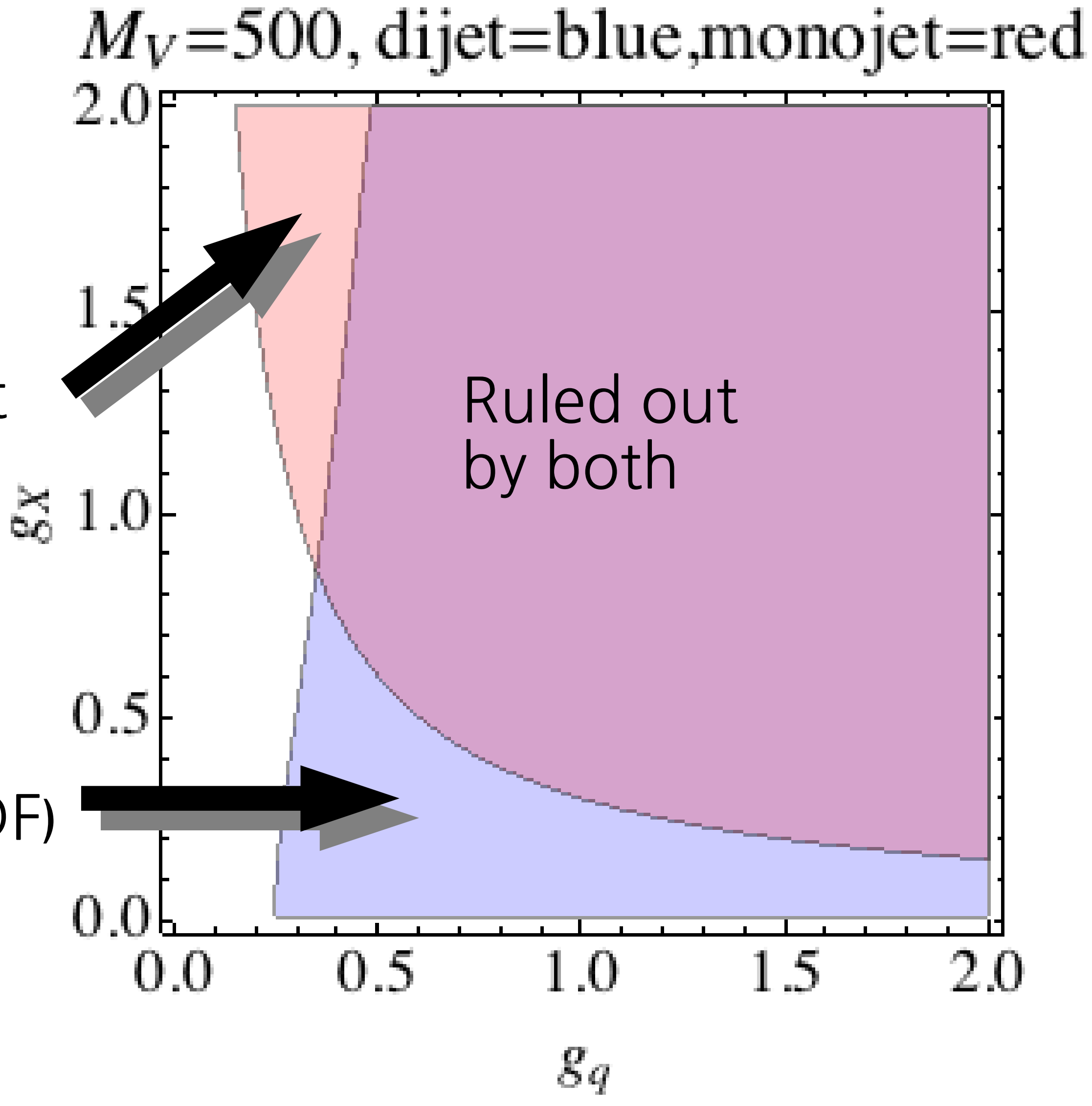
Chargino/Neutralino masses for $\tan\beta = 10, 40$

How low will the LHC13 go?



Exploring new signals for simple UV completions of effective dark matter

For simple UV completions of effective DM operators what other searches are complementary to monojet?

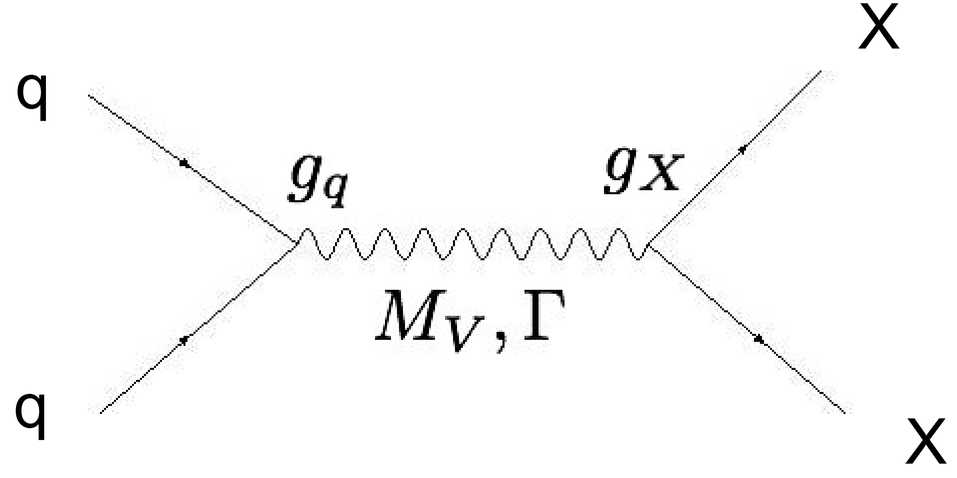


Ruled out by monojet (LHC)

Ruled out by both

Ruled out by dijet (CDF)

Vector operator simplified model:



Relevant searches:
Monojet, Dijet, Dilepton, Monophoton, Paired Dijet, Dijet res + MET, ...

Interested people:
A. Bharucha, A. Goudelis, K. Howe, G. Krnjaic, M. Marjanovic, B. Shuve

LHC monojet search interpretations: indirect detection and relic density

LHC monojet search results currently reinterpreted in terms of DM scattering cross-sections with matter (as for direct detection exp.), using effective/simplified models

→ Can we set also limits on indirect detection (gamma, proton, anti-proton spectra)?

→ Can we deduce a lower limit on the relic density?

→ Which effective models are the most strongly constrained?

→ What if more than one mediator/operator are present?

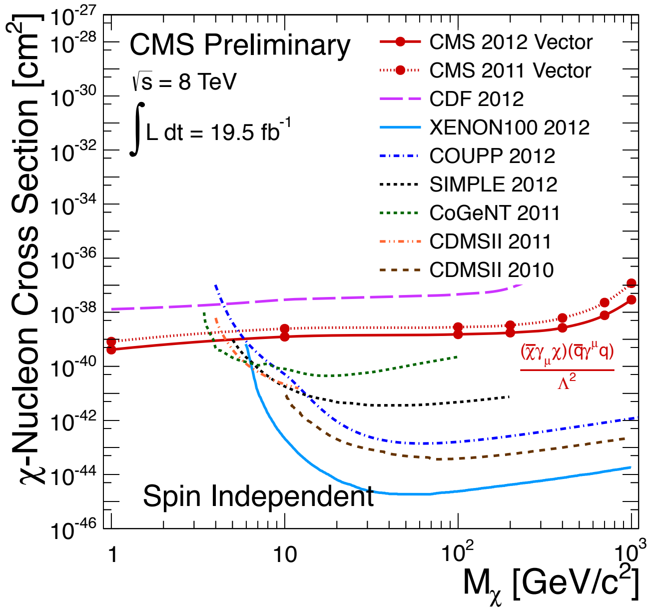
→ Which (full) models are the most interesting in this context?

→ Can we reinterpret the DM direct search results in terms of LHC cross-sections?

Interested people: A. Arbey, C. Balazs, G. Bélanger, F. Boudjema, A. Goudelis, Y. Jiang, N. Mahmoudi, S. Pukhov

Presentation of Results

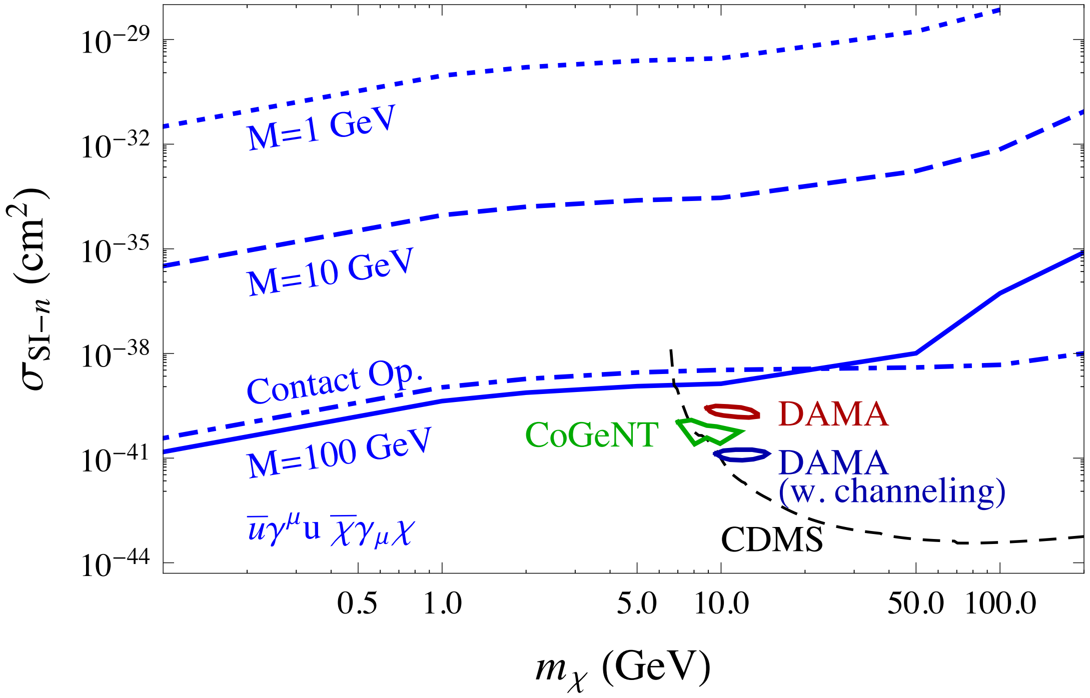
- Effective field theory for DM production at colliders
  - Ex.: $\mathcal{O} = 1/\Lambda^2 \bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu q$
- Current CMS plot, 8 TeV 20/fb (EXO-12-048-pas):

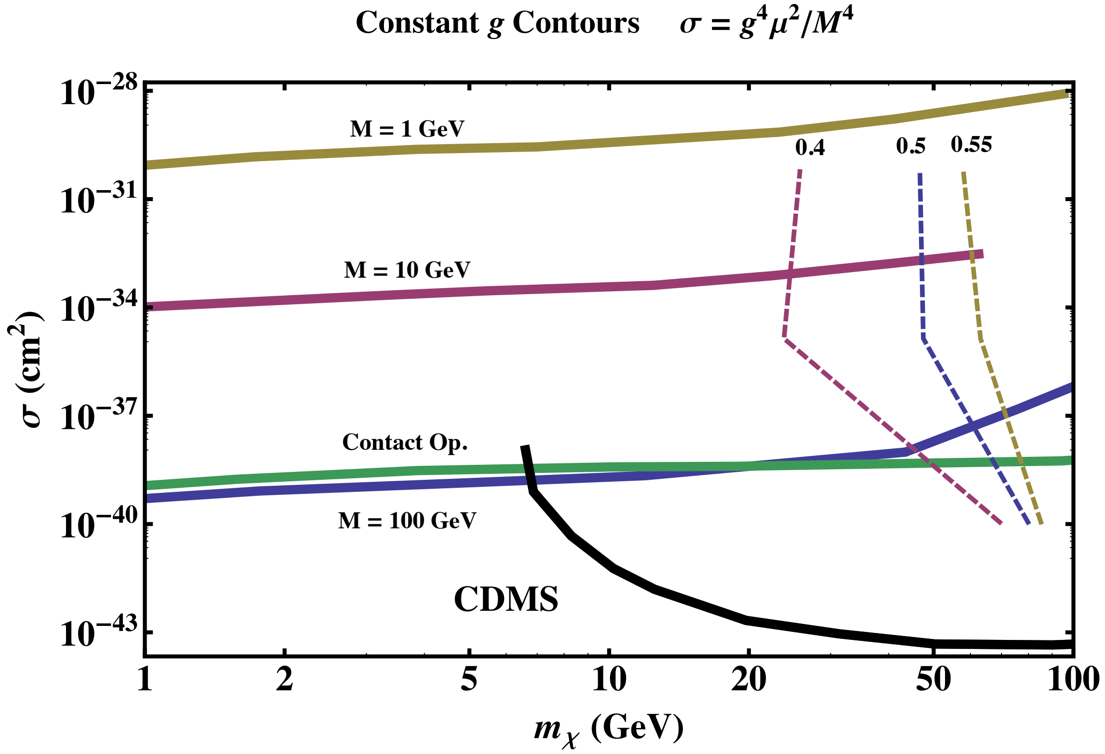


- For many parameters, effective field theory not valid
- Show where effects of mediator mass are important and perturbativity limits
- Always make clear whether effective operator is for **direct detection** or **LHC monojets**
  - CMS analysis mixes the two by quoting bounds on Λ even when bounding cross sections in the full theory
- Interested people: Alex Arbey, Csaba Balazs, Andreas Goudelis, Kiel Howe, Yun Jiang, Gordan Krnjaic, Brian Shuve

Presentation of Results

- Bai, Fox, Harnik, arXiv:1005.3797 plot on left, proposed plot on right ($\Gamma_{\text{med}} = M_{\text{med}}/100$):





- Include contours of mediator couplings (comparison with direct mediator search limits); makes it clear if theory is perturbative
- Can replace line for each mediator mass with a band that sweeps out different values of mediator width
- Similarly, can plot a band associated with the nuclear uncertainties for σ_{SI} for each mediator mass

End of Stay at Les Houches

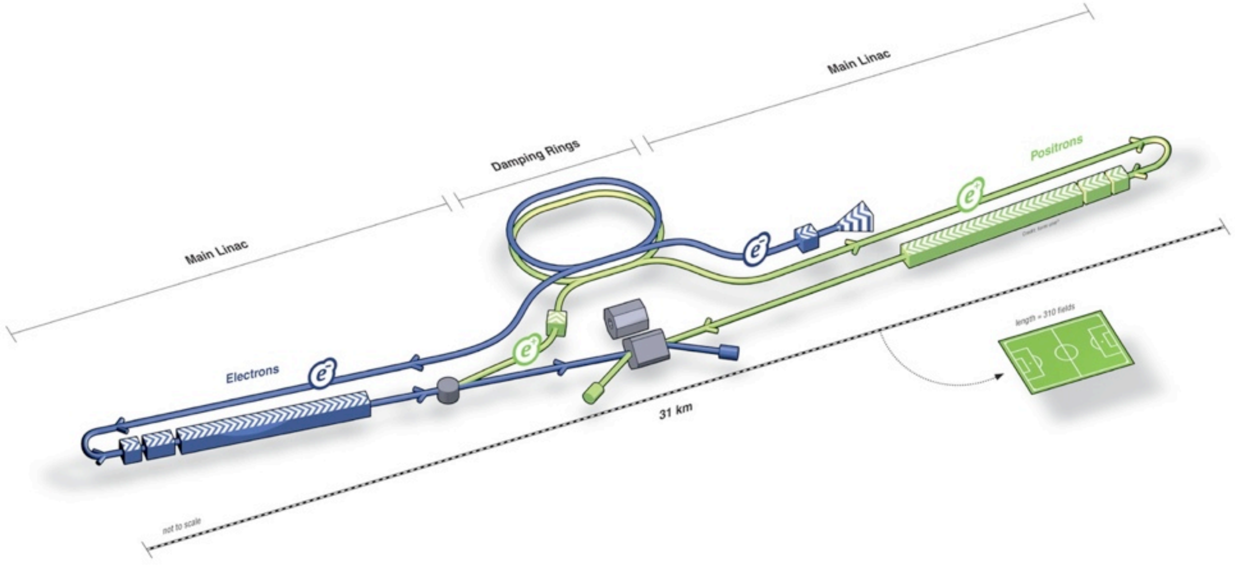
- Many interesting projects started...
  - ... and time to go home

End of Stay at Les Houches

- Many interesting projects started...
  - ... and time to go home
- Contributions to proceedings are due ~mid-December
  - Template and instructions on the web (not wiki)

End of Stay at Les Houches

- Many interesting projects started...
  - ... and time to go home
- Contributions to proceedings are due ~mid-December
  - Template and instructions on the web (not wiki)
- What should we push?



ILC Scheme | © www.form-one.de

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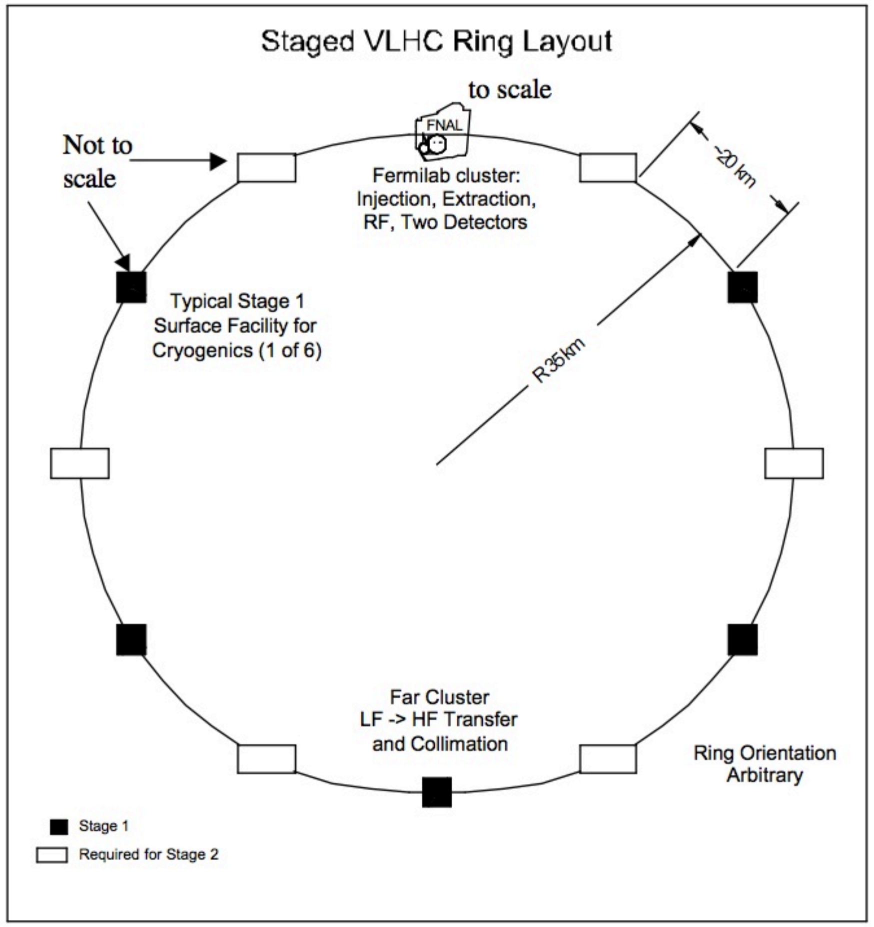
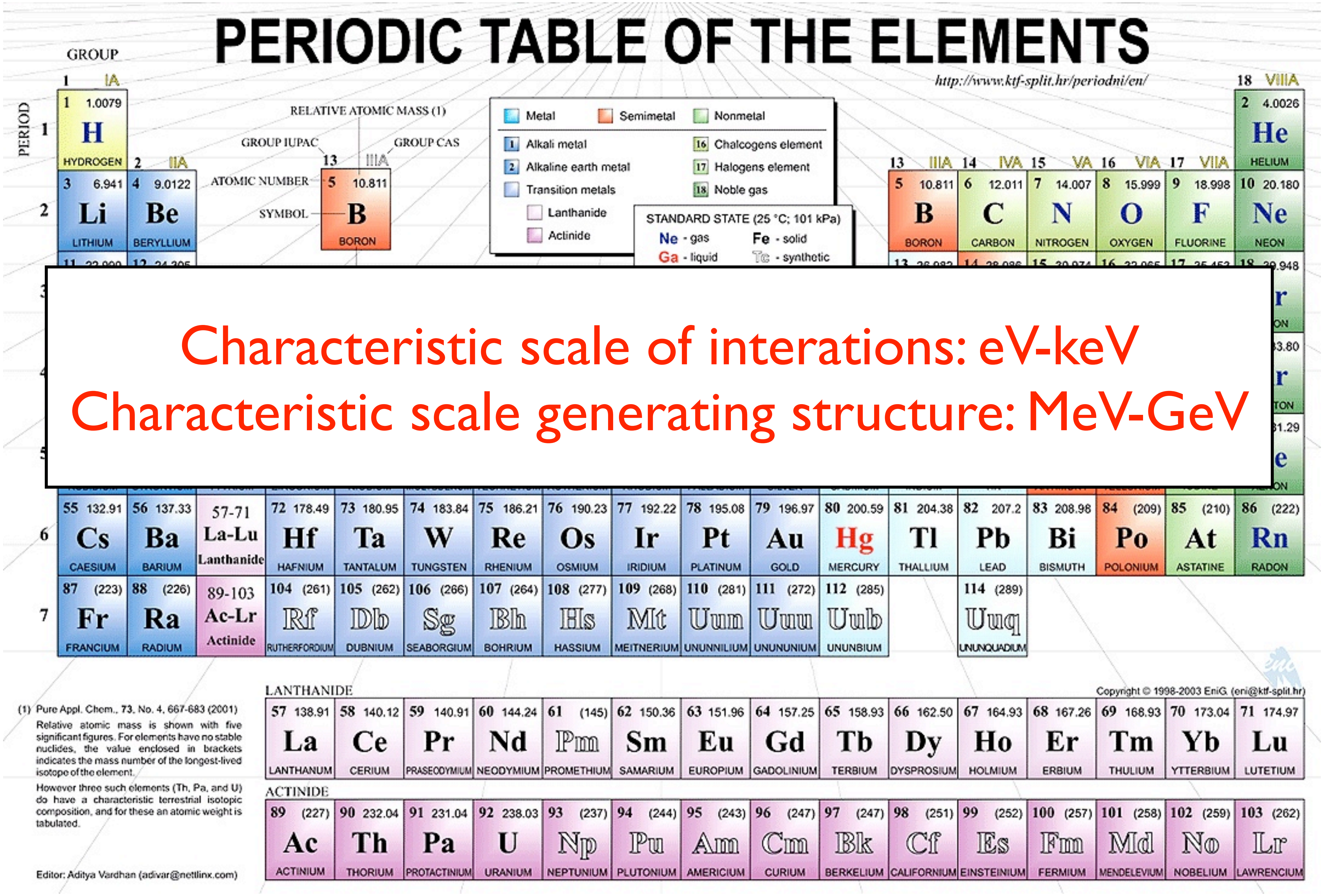


Care to Guess?



PERIODIC TABLE OF THE ELEMENTS

http://www.ktf-split.hr/periodni/en/

RELATIVE ATOMIC MASS (1)
GROUP IUPAC — 13 — IIIA — GROUP CAS
ATOMIC NUMBER — 5 — 10.811
SYMBOL — B
BORON

- Metal
- Semimetal
- Nonmetal
- 1 Alkali metal
- 2 Alkaline earth metal
- Transition metals
- Lanthanide
- Actinide
- 16 Chalcogens element
- 17 Halogens element
- 18 Noble gas

STANDARD STATE (25 °C; 101 kPa)
Ne - gas
Fe - solid
Ga - liquid
Tc - synthetic

PERIOD	1 IA	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.0079 H HYDROGEN																	2 4.0026 He HELIUM
2	3 6.941 Li LITHIUM	4 9.0122 Be BERYLLIUM											5 10.811 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON
6	55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57-71 La-Lu Lanthanide	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 196.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON
7	87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr Actinide	104 (261) Rf RUTHERFORDIUM	105 (262) Db DUBNIUM	106 (266) Sg SEABORGIUM	107 (264) Bh BOHRIUM	108 (277) Hs HASSIUM	109 (268) Mt MEITNERIUM	110 (281) Uun UNUNNILIUM	111 (272) Uuu UNUNUNIUM	112 (285) Uub UNUNBIUM		114 (289) Uuq UNUNQUADIUM				

LANTHANIDE														
57 138.91 La LANTHANUM	58 140.12 Ce CERIUM	59 140.91 Pr PRASEODYMIUM	60 144.24 Nd NEODYMIUM	61 (145) Pm PROMETHIUM	62 150.36 Sm SAMARIUM	63 151.96 Eu EUROPIUM	64 157.25 Gd GADOLINIUM	65 158.93 Tb TERBIUM	66 162.50 Dy DYSPROSIUM	67 164.93 Ho HOLMIUM	68 167.26 Er ERBIUM	69 168.93 Tm THULIUM	70 173.04 Yb YTTERBIUM	71 174.97 Lu LUTETIUM
ACTINIDE														
89 (227) Ac ACTINIUM	90 232.04 Th THORIUM	91 231.04 Pa PROTACTINIUM	92 238.03 U URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MENDELEVIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM

(1) Pure Appl. Chem., 73, No. 4, 667-683 (2001)
Relative atomic mass is shown with five significant figures. For elements have no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.

However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

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Characteristic scale of interations: eV-keV

Characteristic scale generating structure: MeV-GeV