Outlook

Hitoshi Murayama (Berkeley, Kavli IPMU)

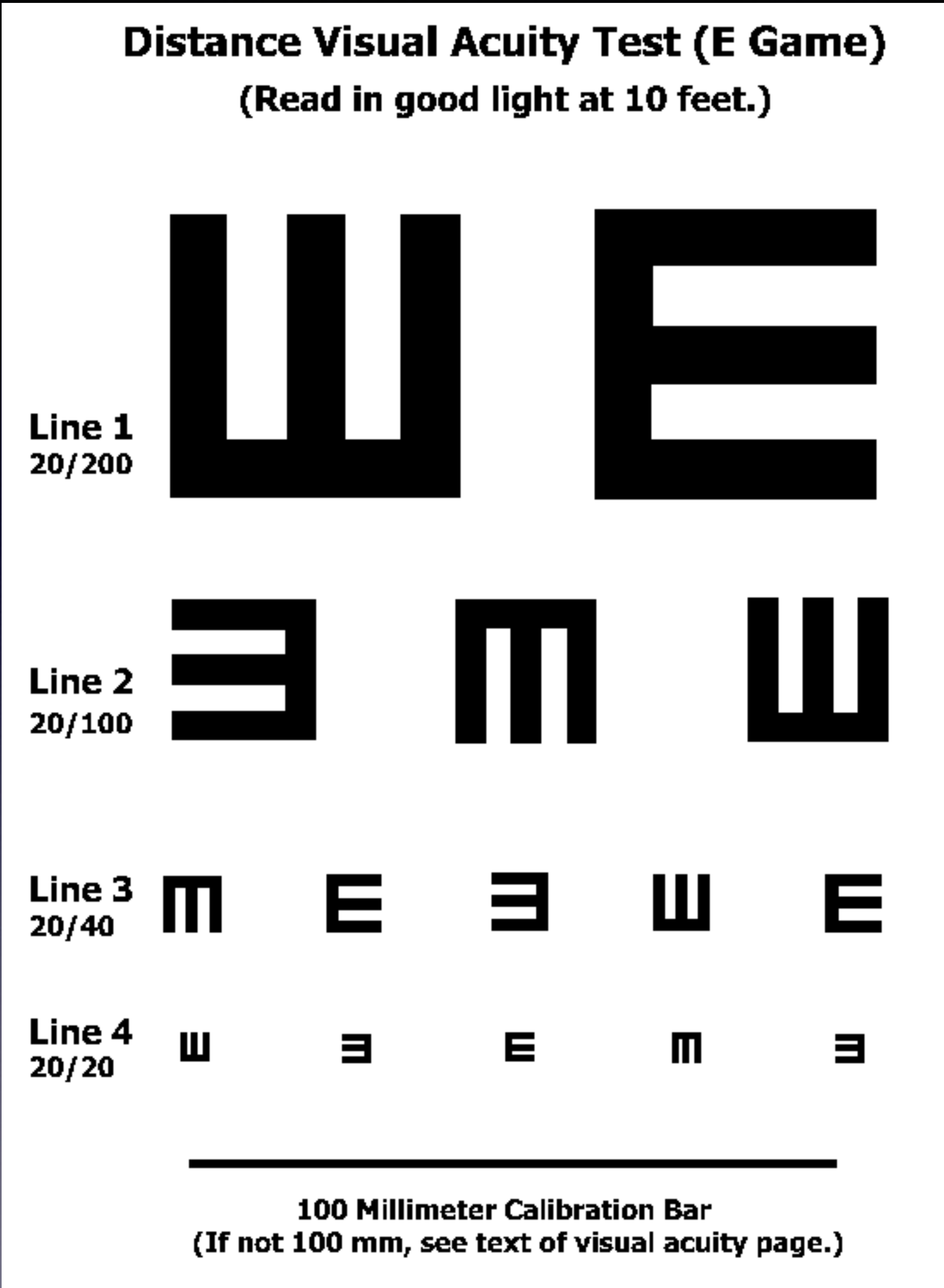
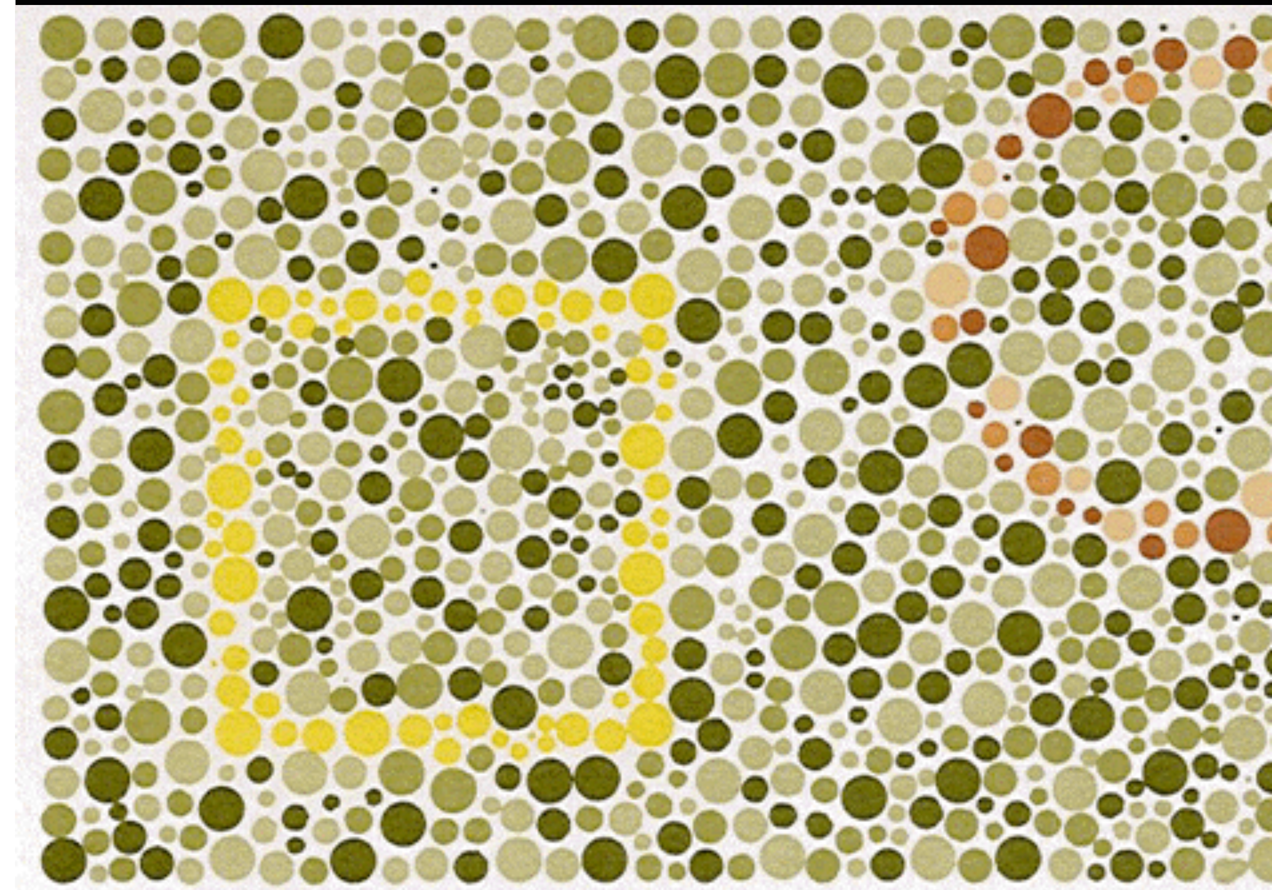
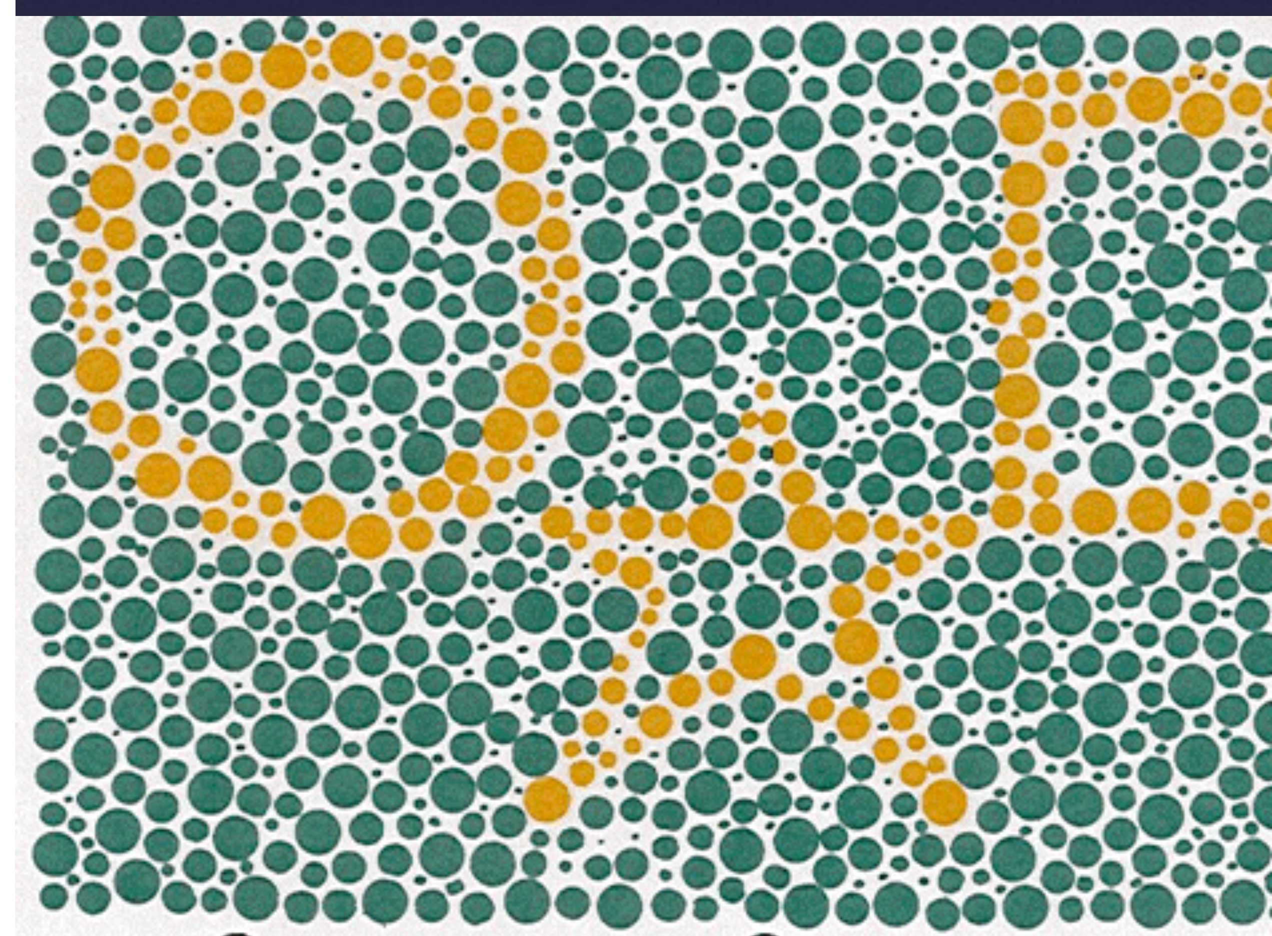
July 8, 2016

東京大学 THE UNIVERSITY OF TOKYO

BERKELEY CENTER FOR THEORETICAL PHYSICS

BERKELEY LAB

KAVLI IPMU


Distance Visual Acuity Test (E Game)
(Read in good light at 10 feet.)
Line 1
20/200
Line 2
20/100
Line 3
20/40
Line 4
20/20
100 Millimeter Calibration Bar
(If not 100 mm, see text of visual acuity page.)



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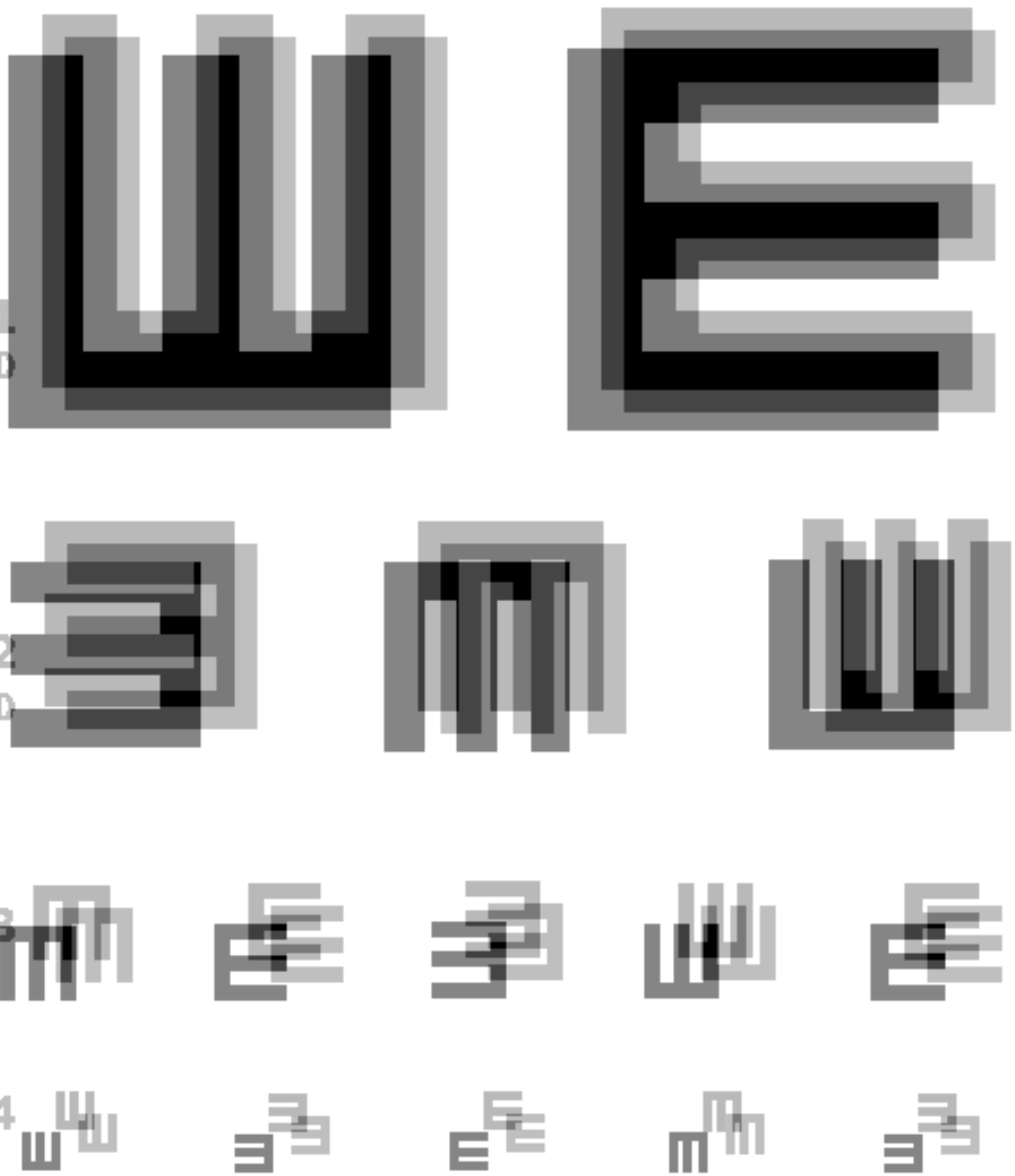

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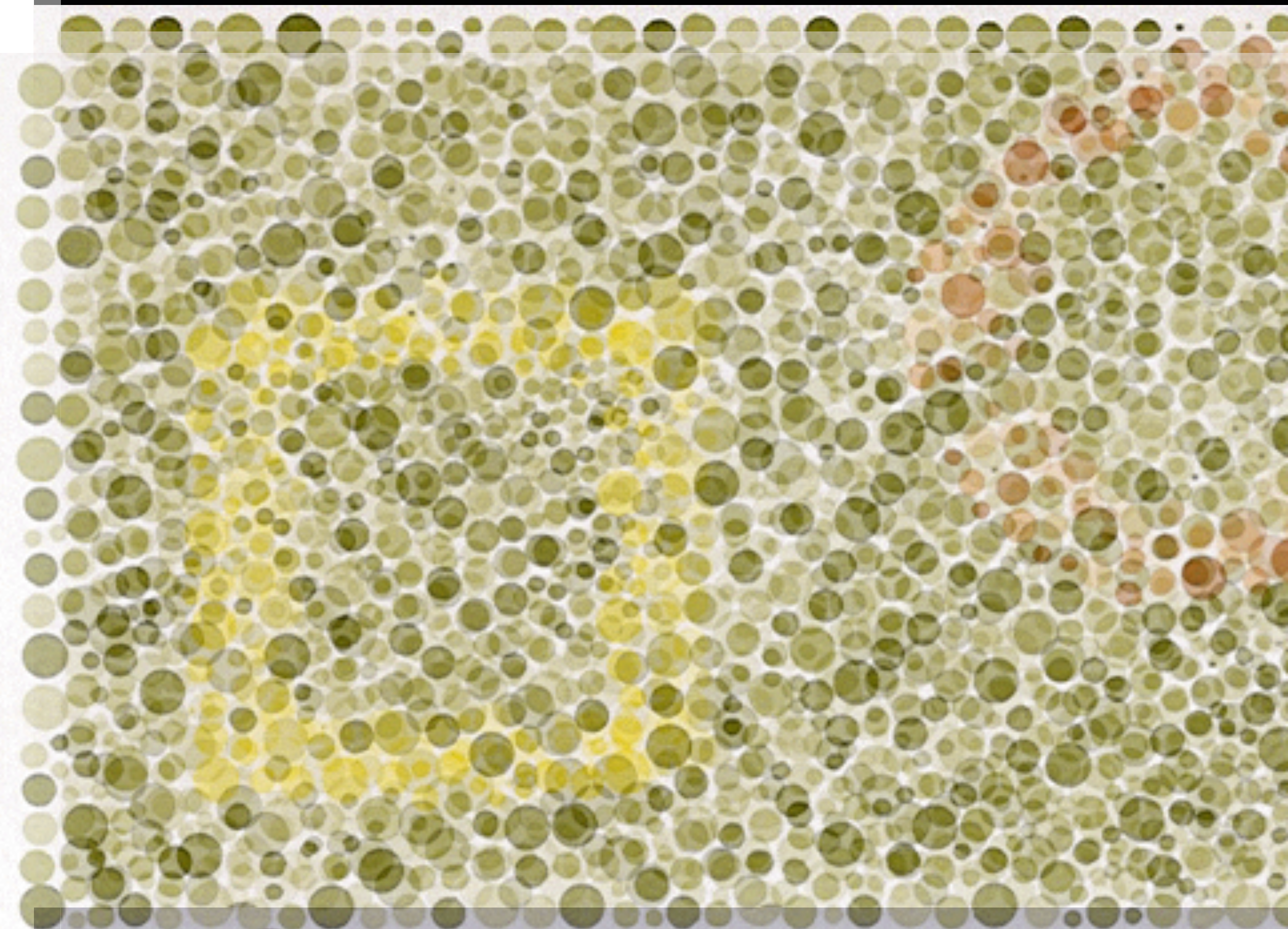
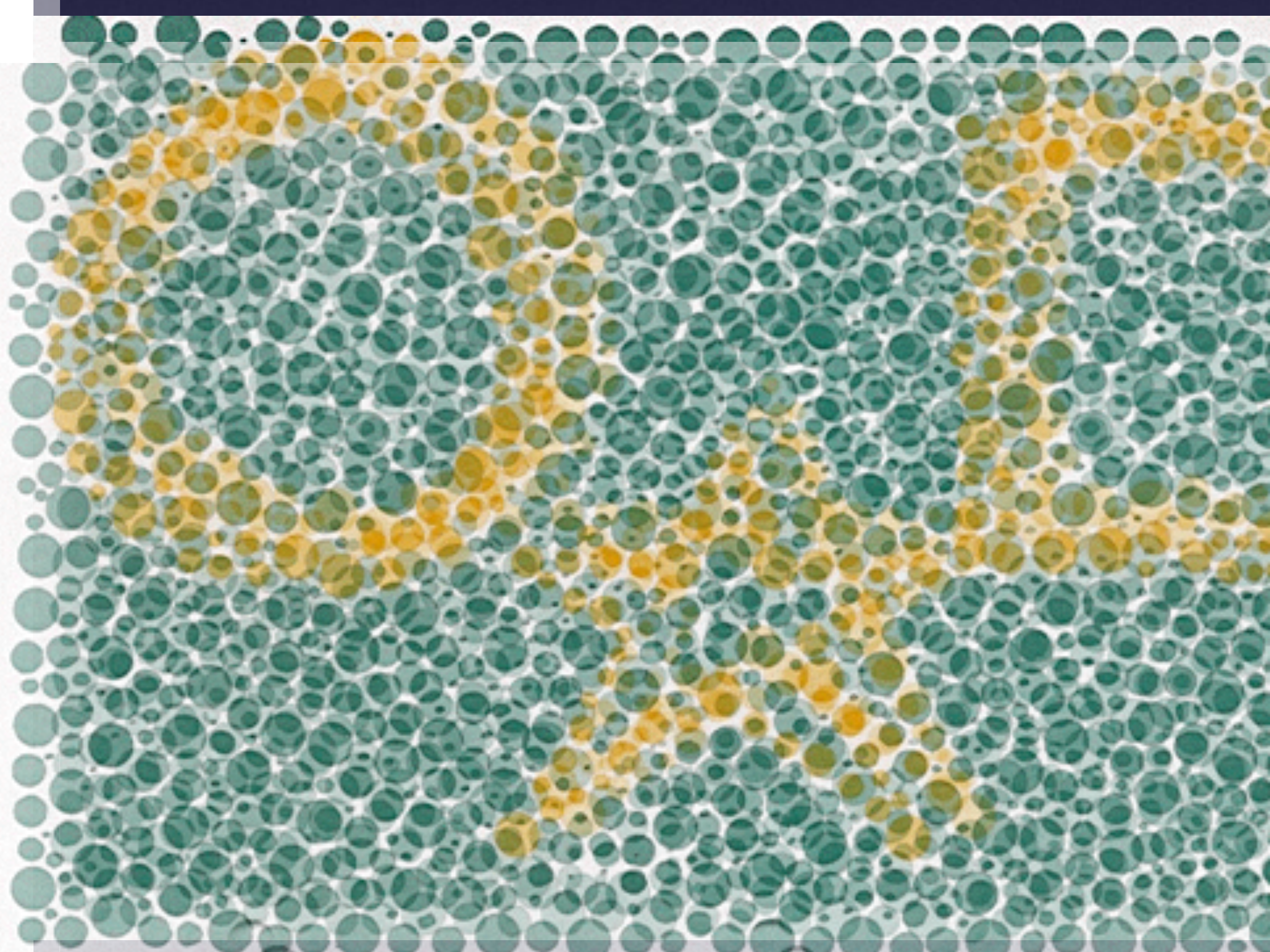




SUSY 2016 (Melbourne, Australia)
SUSY 2015 (Lake Tahoe, USA)
SUSY 2014 (Manchester, UK)
SUSY 2013 (Trieste, Italy)
SUSY 2012 (Beijing, China)
SUSY 2011 (Fermilab, USA)
SUSY 2010 (Bonn, Germany)
SUSY 2009 (Boston, USA)
SUSY 2008 (Seoul, Korea)
SUSY 2007 (Karlsruhe, Germany)
SUSY 2006 (Irvine, USA)
SUSY 2005 (Durham, UK)
SUSY 2004 (KEK, Japan)
SUSY 2003 (Arizona, USA)
SUSY 2002 (DESY, Germany)
SUSY 2001 (Dubna, Russia)
SUSY 2000 (CERN, Switzerland)
SUSY 1999 (Fermilab, USA)
SUSY 1998 (Oxford, UK)
SUSY 1997 (Pennsylvania, USA)
SUSY 1996 (Maryland, USA)
SUSY 1995 (Paris, France)
SUSY 1994 (Michigan, USA)
SUSY 1993 (Northeastern, USA)

24 SUSY conferences!

cf.
33 ICHEP
27 Lepton Photon
27 Neutrino

Squarks

$J=0$?

The following data are averaged over all light flavors, presumably u, d, s, c with both chiralities. For flavor-tagged data, see listings for Stop and Sbottom. Most results assume minimal supergravity, an untested hypothesis with only five parameters. Alternative interpretation as extra dimensional particles is possible. See KK particle listing.

SQUARK MASS

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
538±10	**OUR FIT**		**mSUGRA assumptions**
532±11	[1]ABBIENDI 11D	CMS	Missing ET with mSUGRA assumptions
541±14	[2]ADLER 11O	ATLAS	Missing ET with mSUGRA assumptions
• • • We do not use the following data for averages, fits, limits, etc • • •			
652±105	[3]ABBIENDI 11K	CMS	extended mSUGRA with 5 more parameters

[1]ABBIENDI 11D assumes minimal supergravity in the fits to the data of jets and missing energies and set $A_0=0$ and $\tan\beta = 3$. See Fig. 5 of the paper for other choices of A_0 and $\tan\beta$. The result is correlated with the gluino mass M_3. See listing for gluino.
[2]ADLER 11O uses the same set of assumptions as ABBIENDI 11D, but with $\tan\beta = 5$.
[3]ABBIENDI 11K extends minimal supergravity by allowing for different scalar masses-squared for Hu, Hd, 5* and 10 scalars at the GUT scale.

SQUARK DECAY MODES

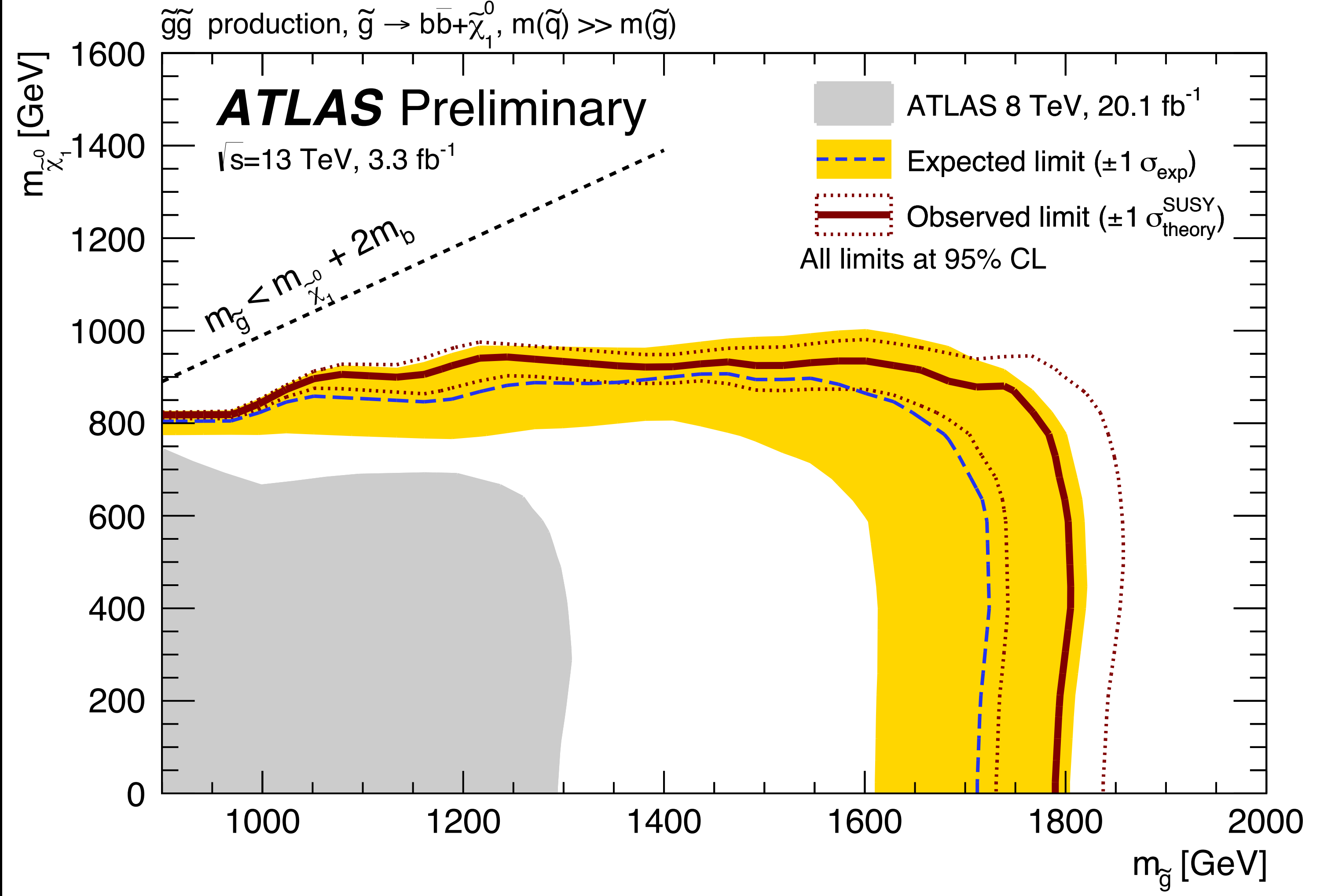
MODE	BR(%)	DOCUMENT ID	TECN	COMMENT
j+miss	32±5	ABE 10U	ATLAS	
j l+miss	73±10	ABE 10U	ATLAS	lepton universality
j e+miss	22±8	ABE 10U	ATLAS	
j μ +miss	25±7	ABE 10U	ATLAS	
q χ^+	seen	ABE 10U	ATLAS	

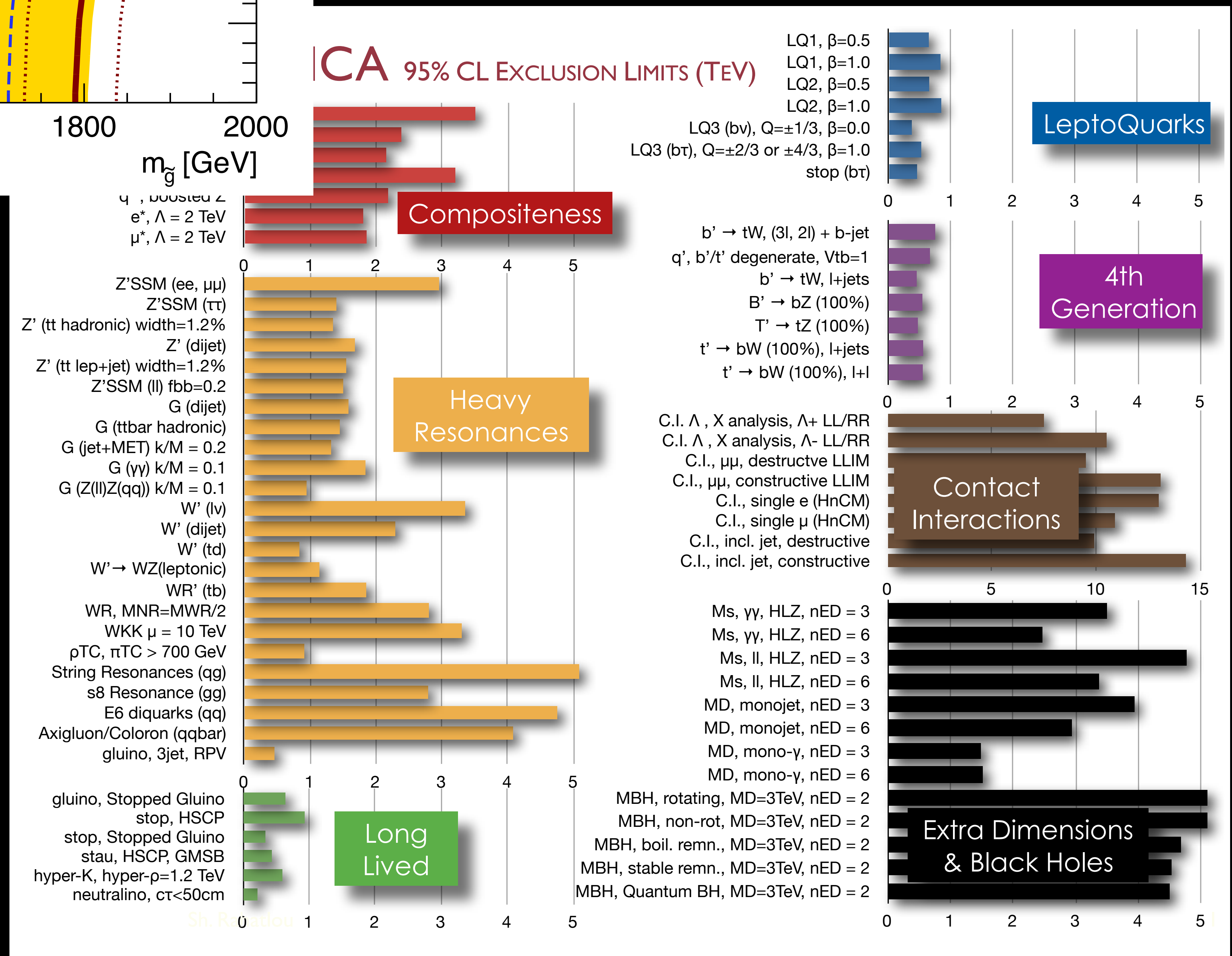
The New York Times

July 23, 2011

The Other Half of the Universe Discovered

Geneva, Switzerland





no sign of
new physics!

Why SUSY?

- mathematically interesting
- string theory needs it
- rationale for scalars
- helps stabilize inflaton potential
- gauge coupling unification
- dark matter candidate
- hierarchy (naturalness) problem
- fun for colliders
- baryogenesis?
- cosmological constant? 10^{-120} to 10^{-60}

Why not SUSY?

- flavor problem
- CP problem
- gravitino problem
- proton decay (both GUT and M_{Pl})
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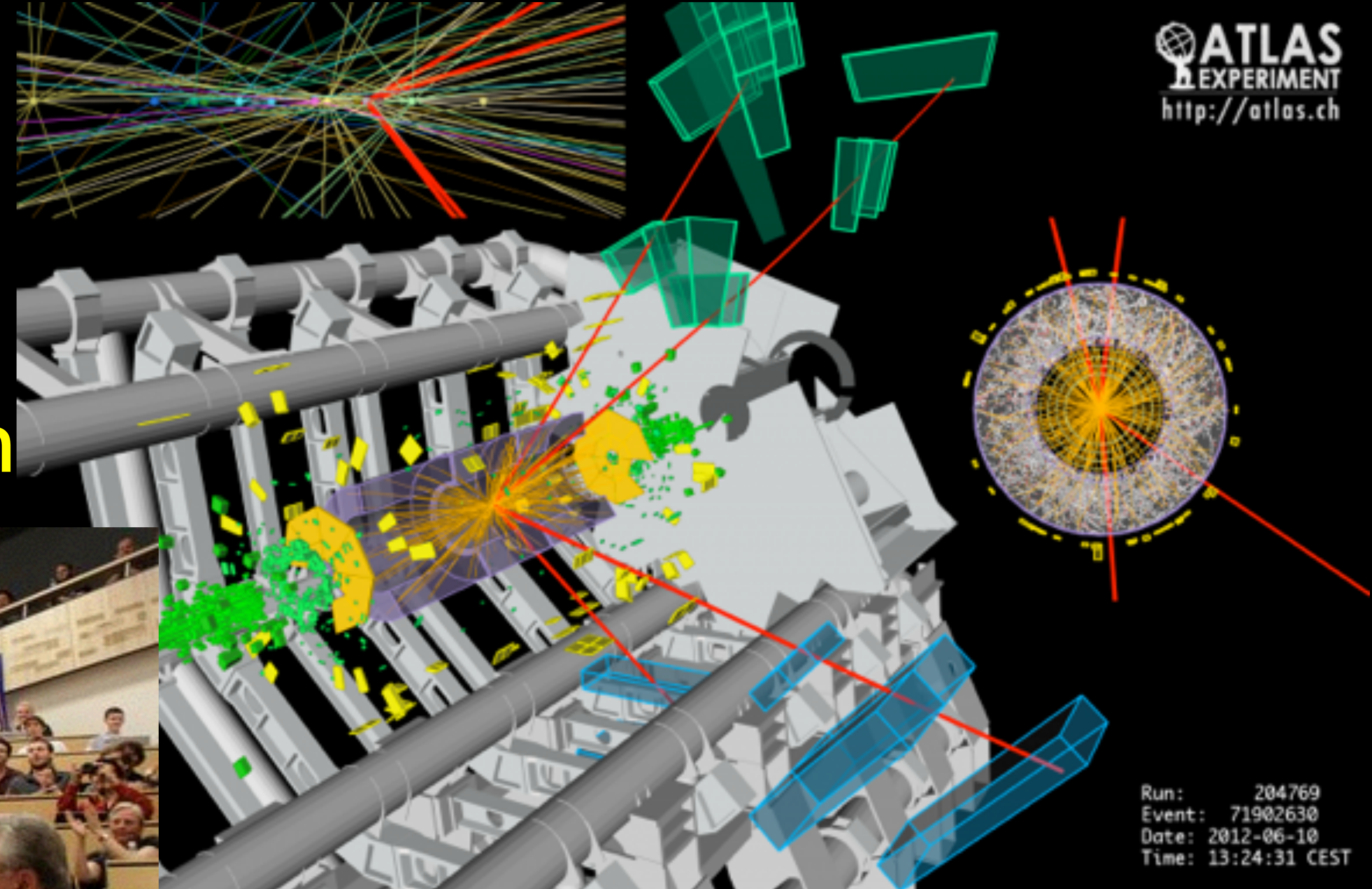
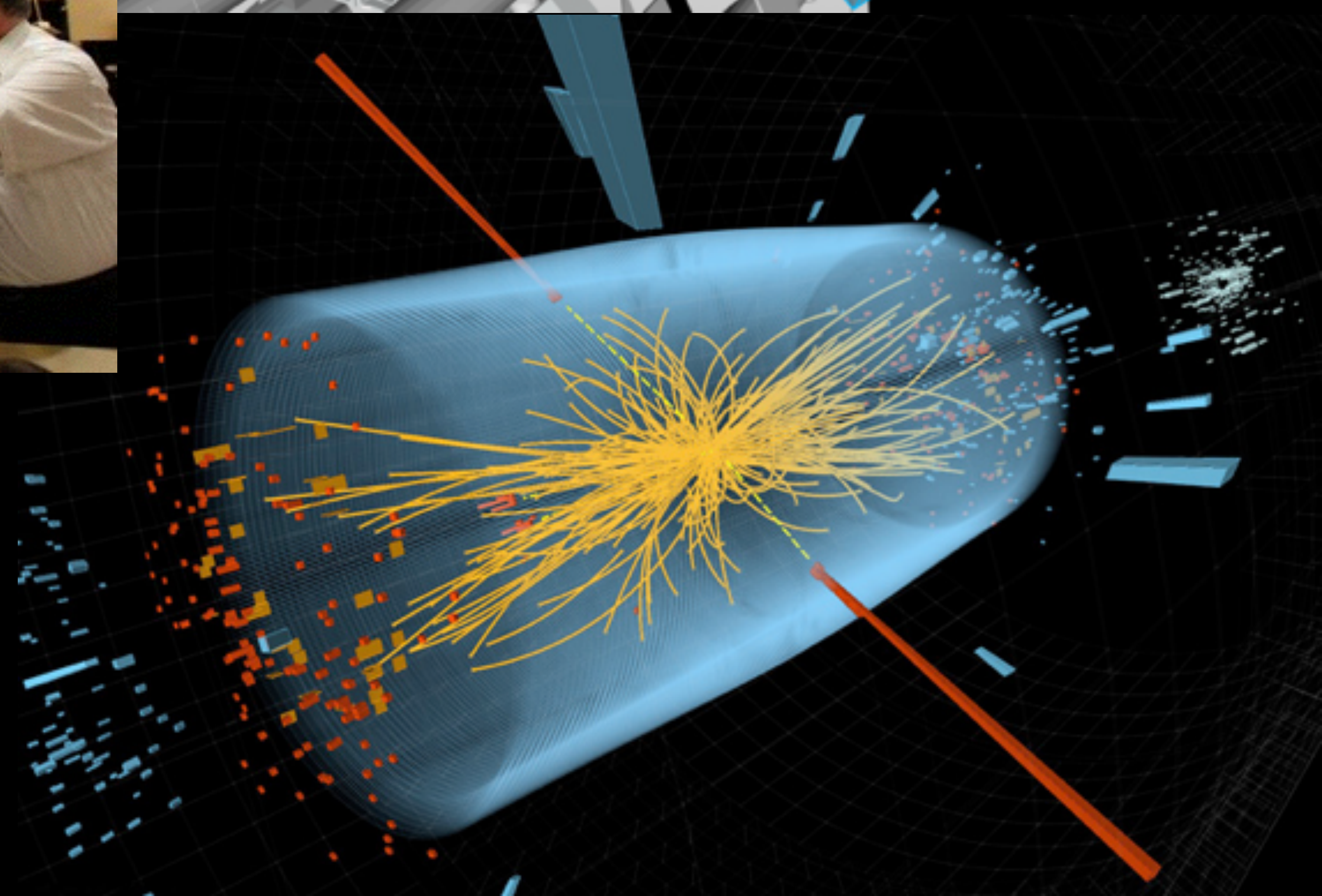
July 4, 2012

discovery of Higgs boson





theory：1964

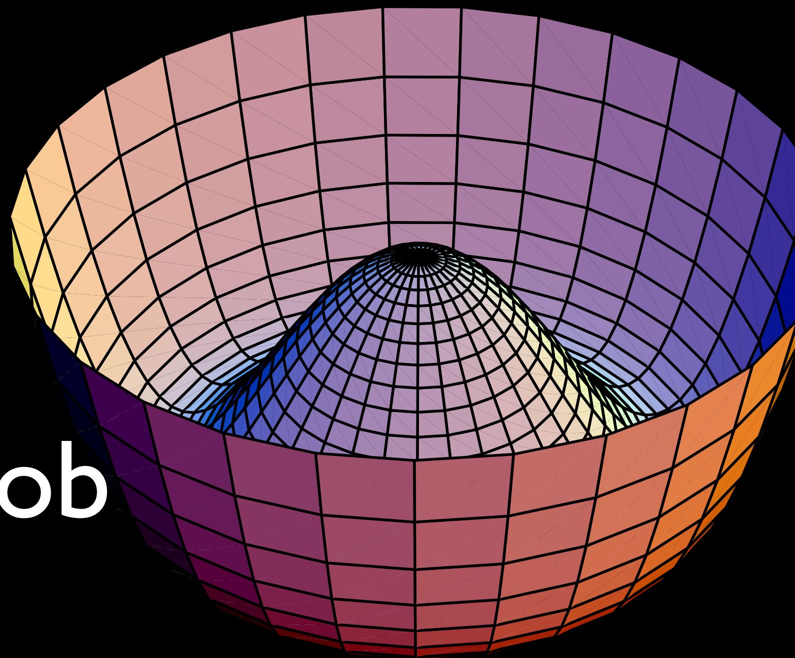
design：1984

construction：1998


Higgsdependence Day
July 4, 2012

naturalness

- Higgs boson is the *only spin 0 particle* in the standard model
  - it is *faceless*
  - one of its kind, no context
  - but does the most important job
- looks very artificial
- we still don't know *dynamics* behind the Higgs condensate
- *Higgsless theories*: now dead



Theoretical Foundation for Scalar Bosons?

Supersymmetry

- Higgs just one of *many* scalar bosons
- SUSY loops make m_h^2 negative

composite

- spins cancel among constituents
- condensate by a strong attractive force, holography

Extra dimension

- Higgs spinning in extra dimensions
- new forces from particles running in extra D

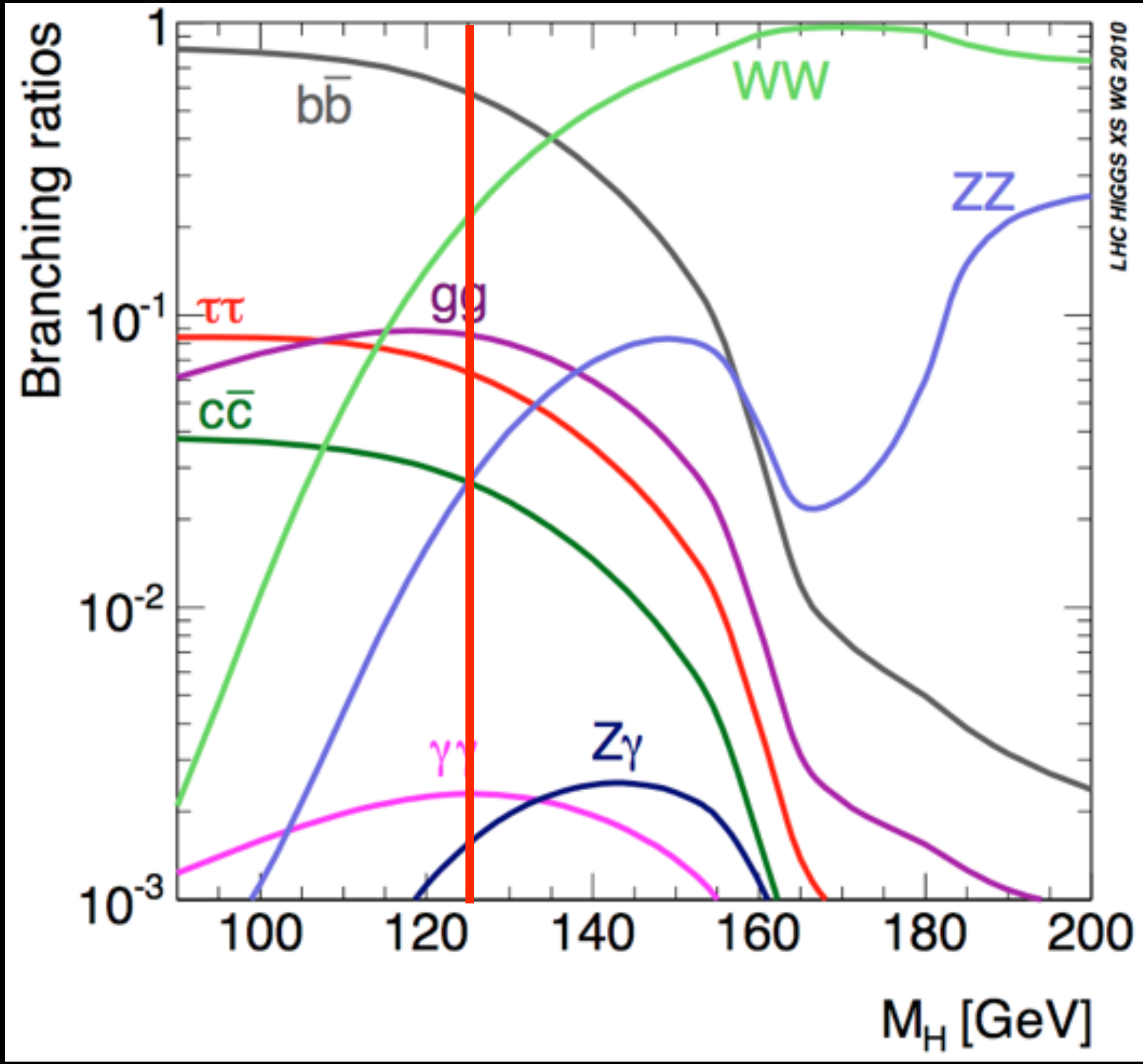
another "naturalness" argument


Multiverse
Naturalness

Nima's anguish

m_H=125 GeV seems almost maliciously designed to prolong the agony of BSM theorists….

dream case for experiments



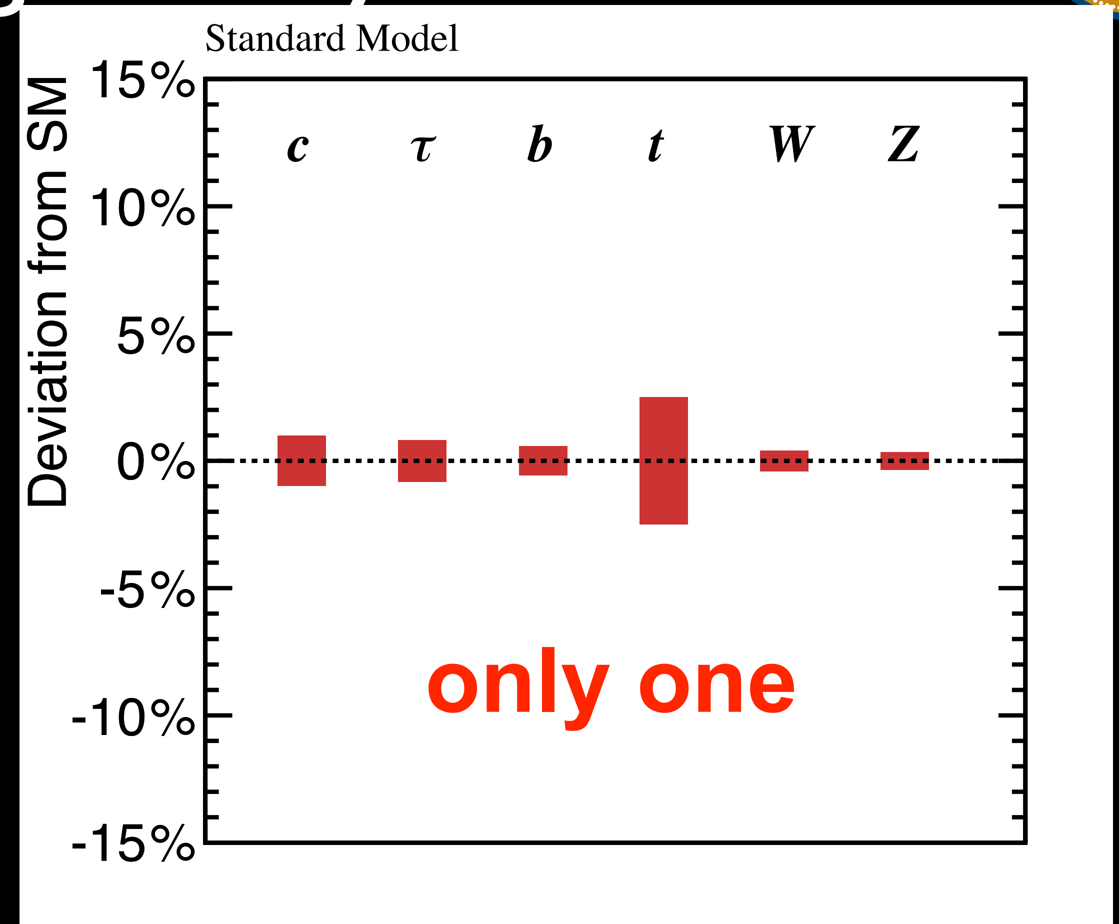
can measure them all!

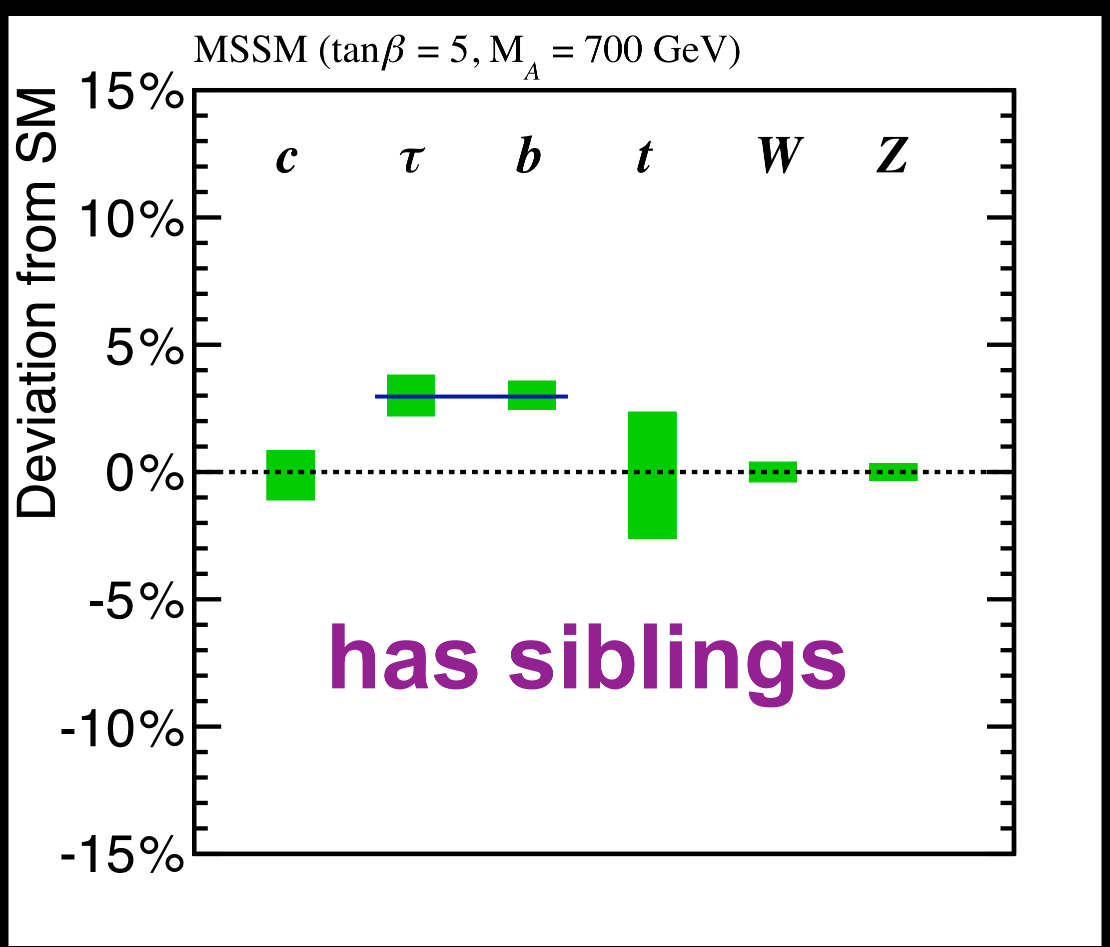
What is Higgs really?

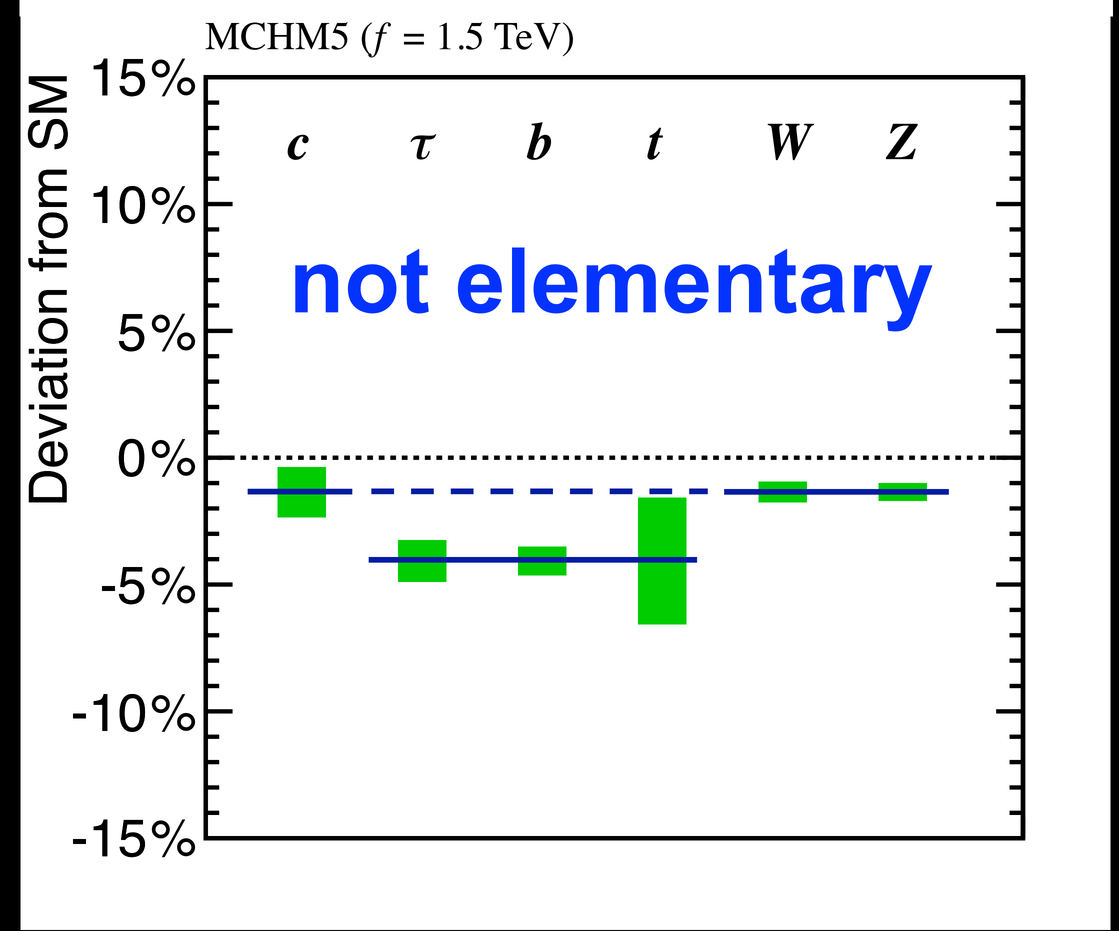
Only one? (SM)
has siblings? (2DHM)
not elementary?

ILC

Lumi 1920 fb-1, sqrt(s) = 250 GeV
Lumi 2670 fb-1, sqrt(s) = 500 GeV







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Electron mass is natural by doubling #particles

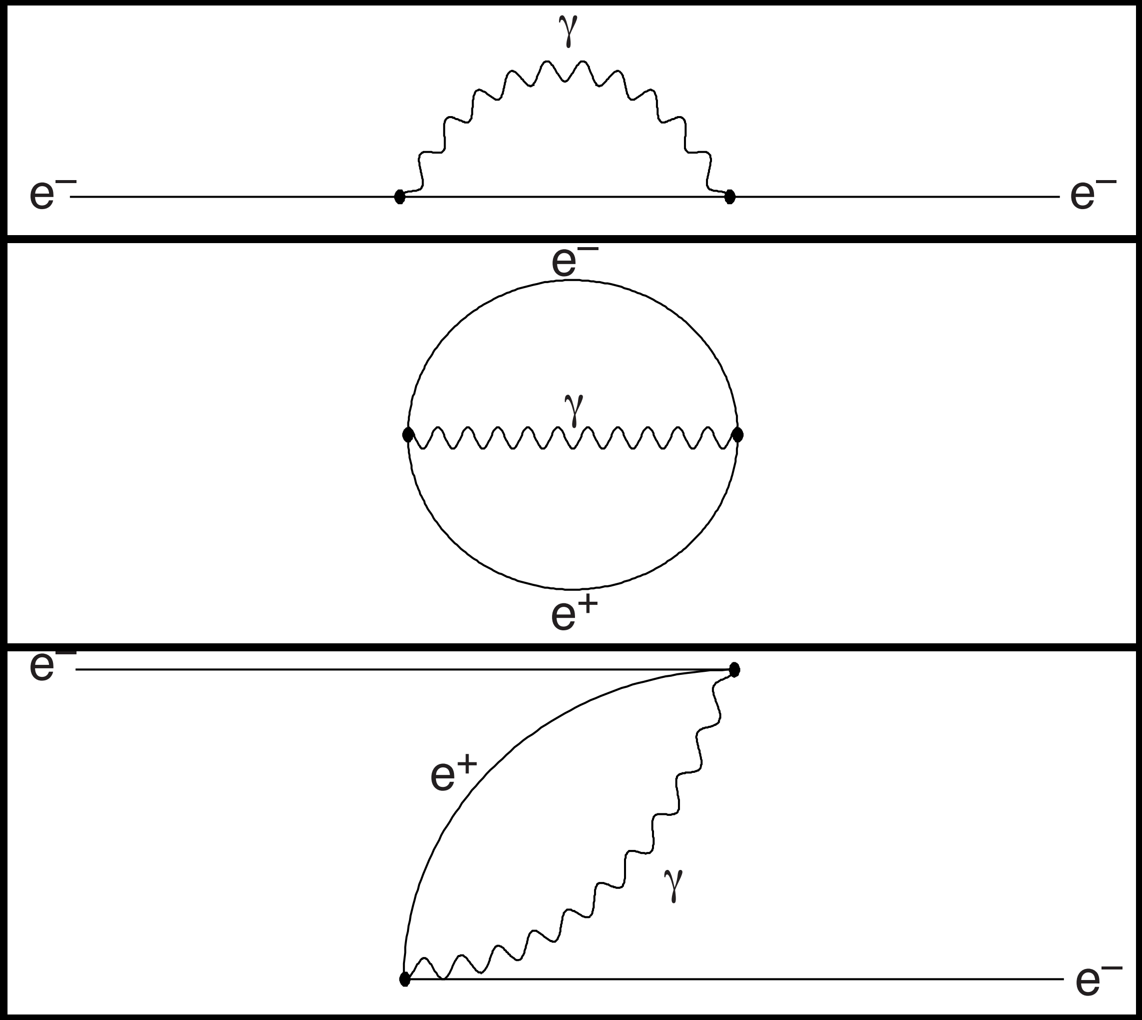
- Electron creates a force to repel itself

$$\Delta m_e c^2 \sim \frac{e^2}{r_e} \sim \mathrm{GeV}\frac{10^{-17}\mathrm{cm}}{r_e}$$

- 10^{-4} fine-tuning?
- quantum mechanics and anti-matter

⇒ only 10% of mass even

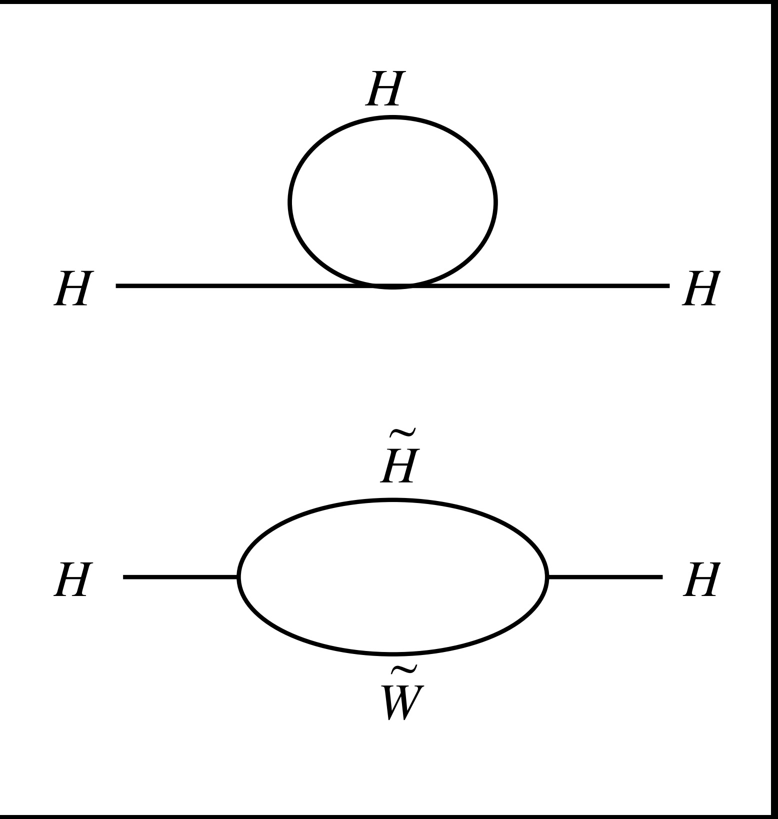
for Planck-size r_e~10^{-33}cm



$$\Delta m_e \sim m_e \frac{\alpha}{4\pi} \log(m_e r_e)$$

Higgs mass is natural by doubling #particles?

- Higgs also repels itself
- Double #particles again $\Rightarrow$ superpartners
- only log sensitivity to UV
- Standard Model made consistent up to higher energies

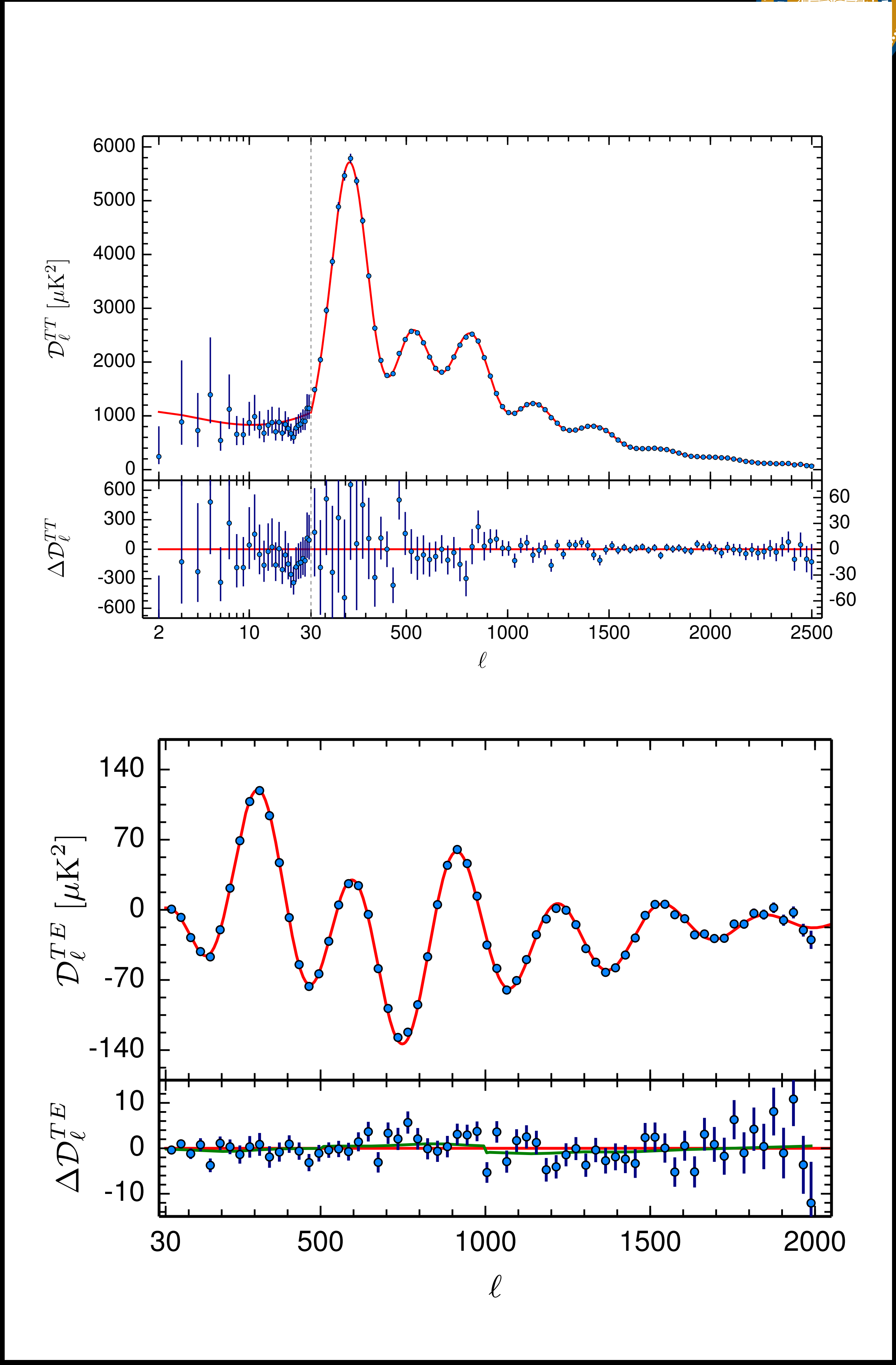


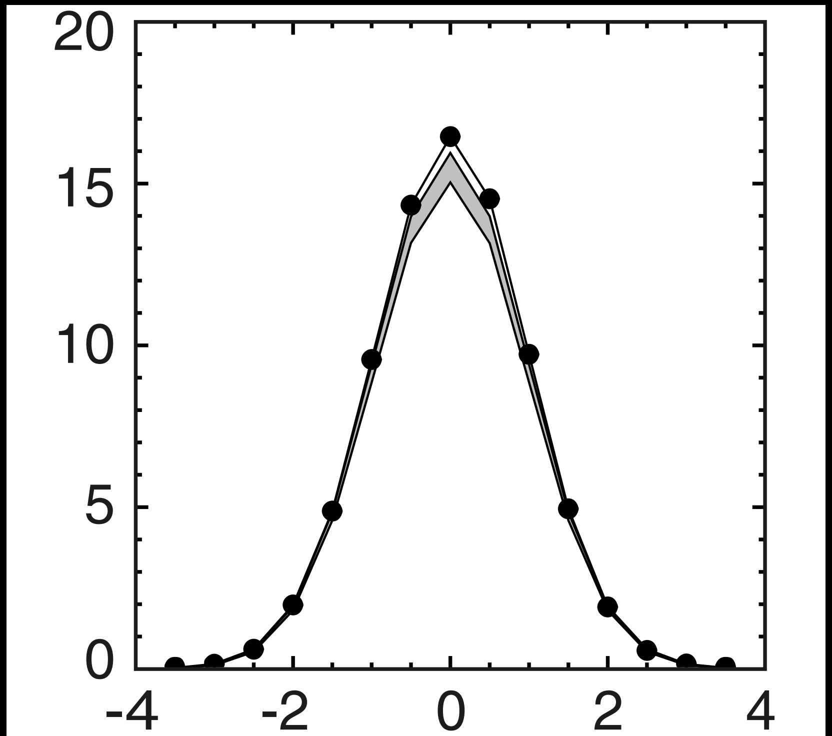
$$\Delta m_H^2 \sim \frac{\alpha}{4\pi} m_{SUSY}^2 \log(m_H r_H)$$

I still take it seriously

Naturalness works!

- Inflation
  - horizon problem
  - flatness problem
  - large entropy





ENGINEERING
Machines That Change Shape

MEDICINE
An Off Switch for Cancer

NEUROSCIENCE
How to Reach "Vegetative" Patients

SCIENTIFIC AMERICAN

ScientificAmerican.com

A CRISIS IN PHYSICS?

IF SUPERSYMMETRY DOESN'T PAN OUT, SCIENTISTS NEED A NEW WAY TO EXPLAIN THE UNIVERSE

0 74470 38529 5 0 5>
$5.99 U.S.
MAY 2014

been there before

The New York Times

Science

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH

ENVIRONMENT

315 Physicists Report Failure In Search for Supersymmetry

By MALCOLM W. BROWNE

Published: January 5, 1993

Three hundred and fifteen physicists worked on the experiment.

Their apparatus included the Tevatron, the world's most powerful particle accelerator, as well as a $65 million detector weighing as

been there before

- CMB anisotropy
- universe younger than oldest stars?
- cosmologists got antsy
- it turned out a little “fine-tuned”
  - low quadrupole
  - dark energy

1% tuning

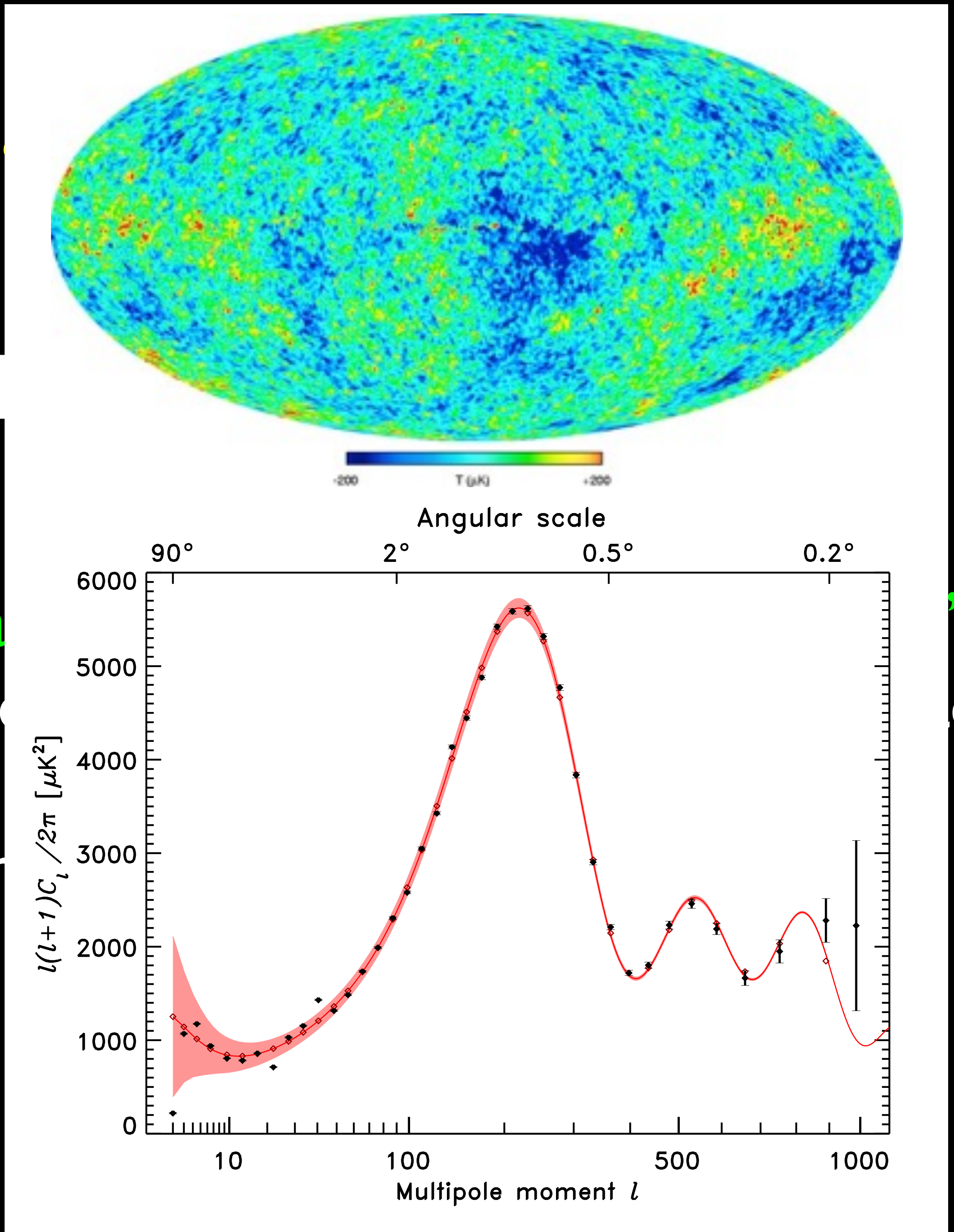
“

“Ba ”

A n e

the

Tim



experiments

healthy field!

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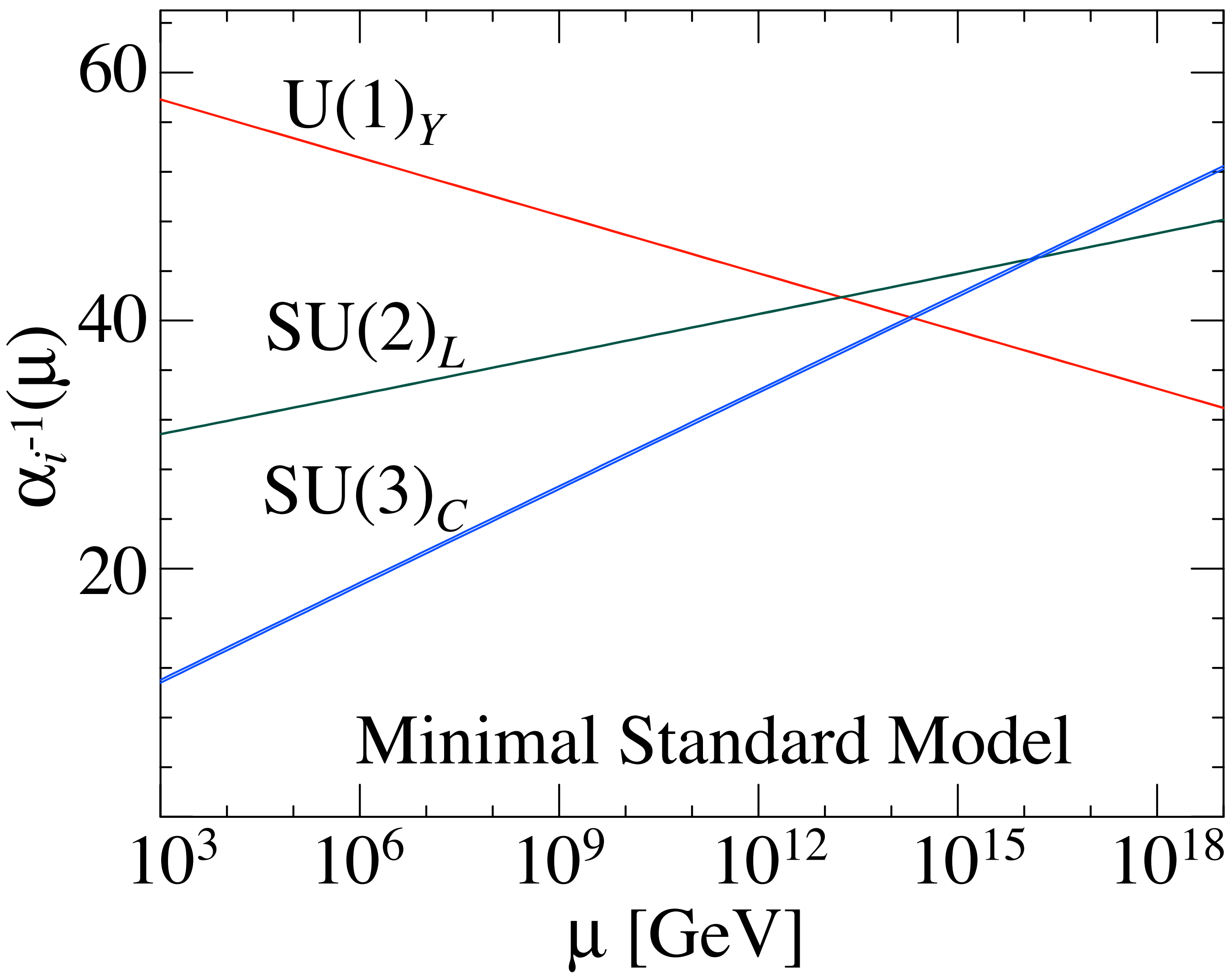
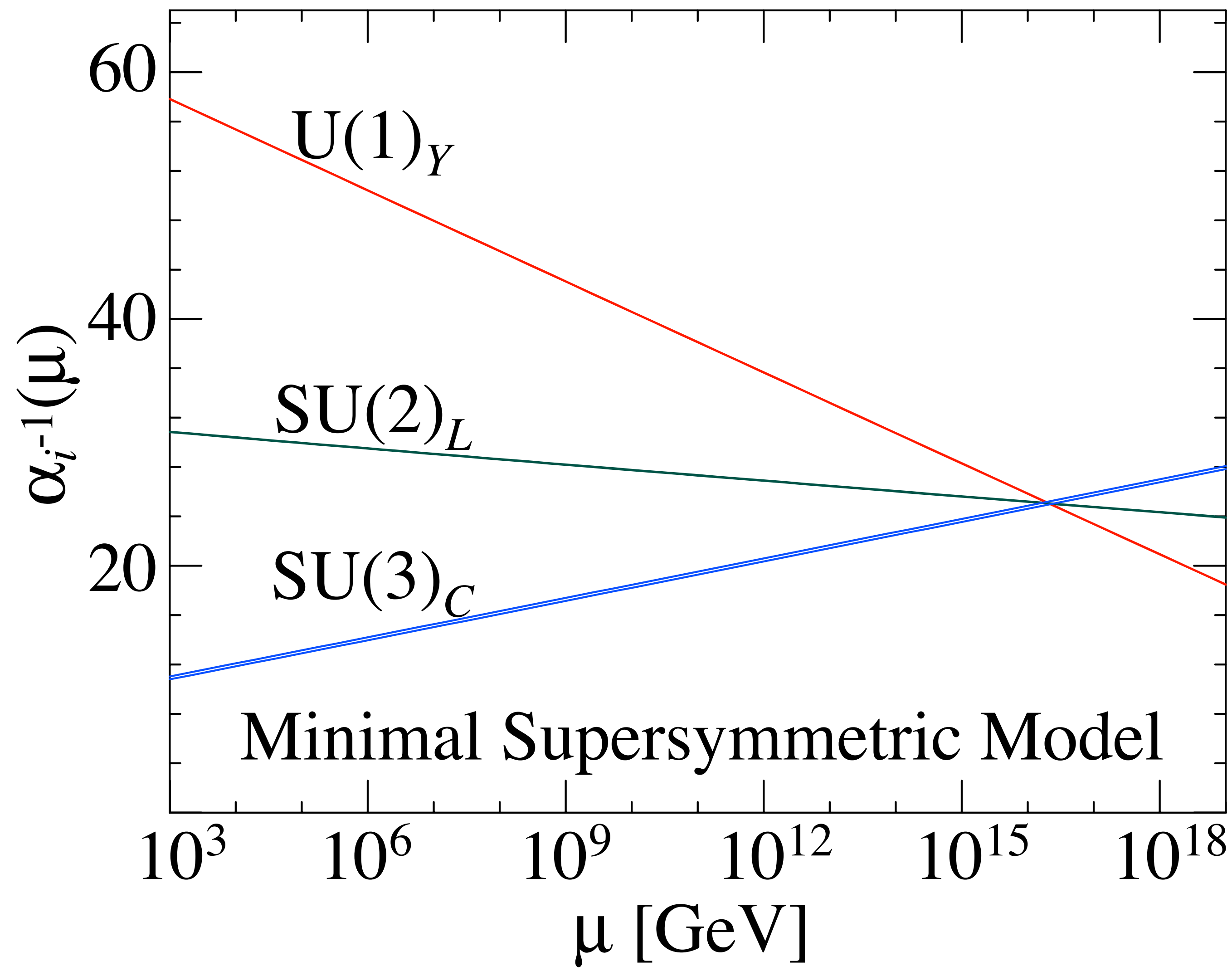
Grand Unification





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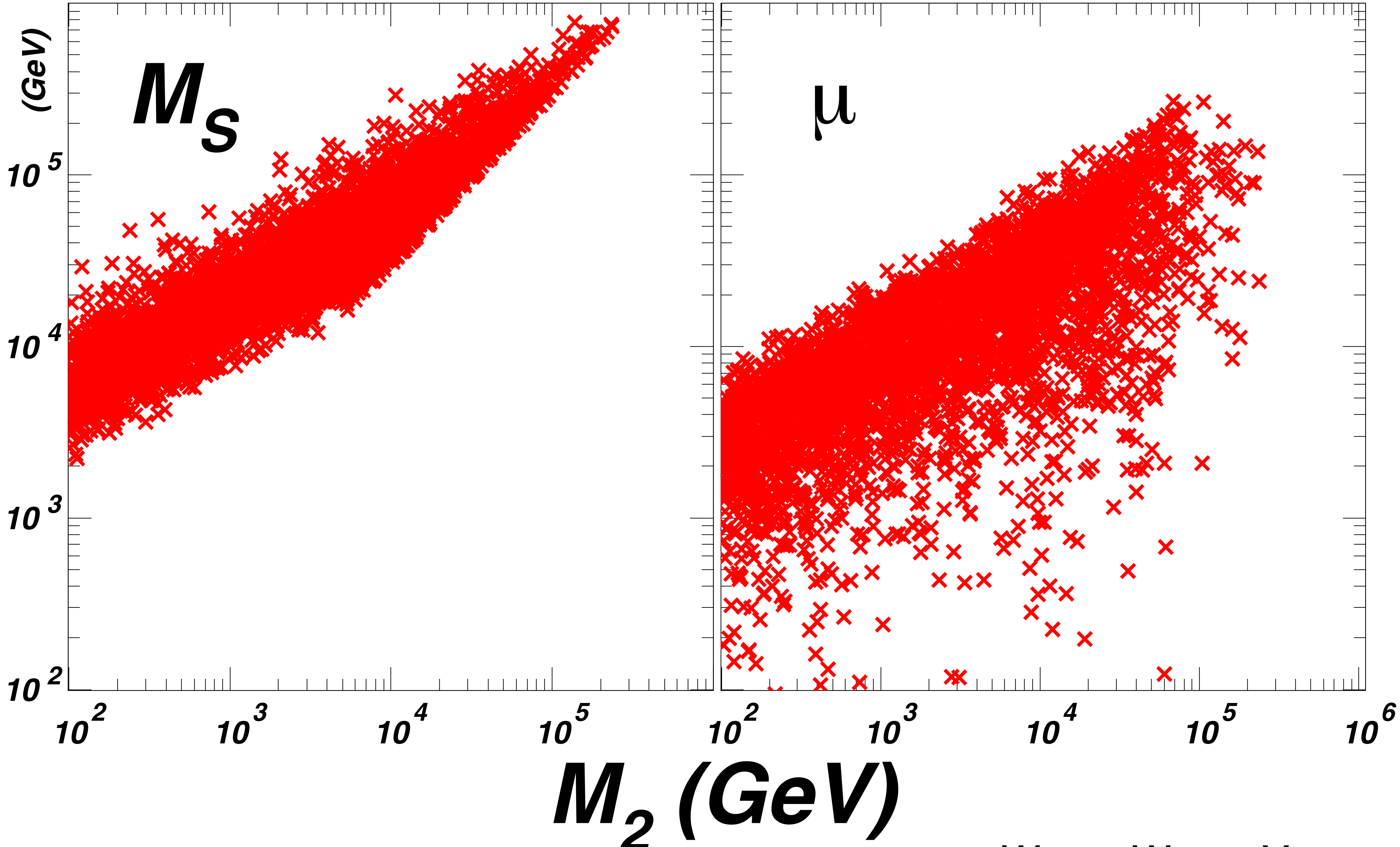
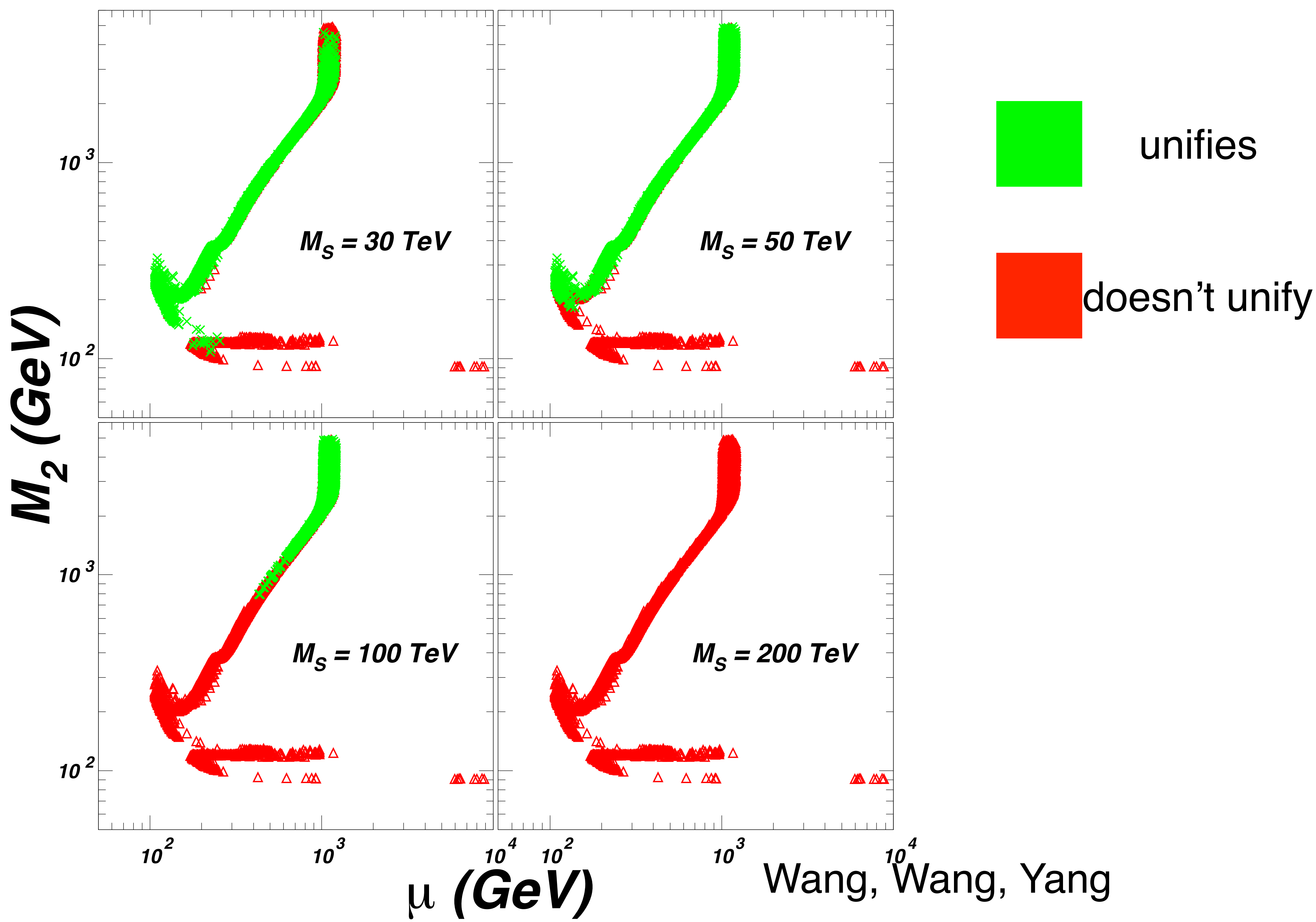


Wang, Wang, Yang

Dark Matter

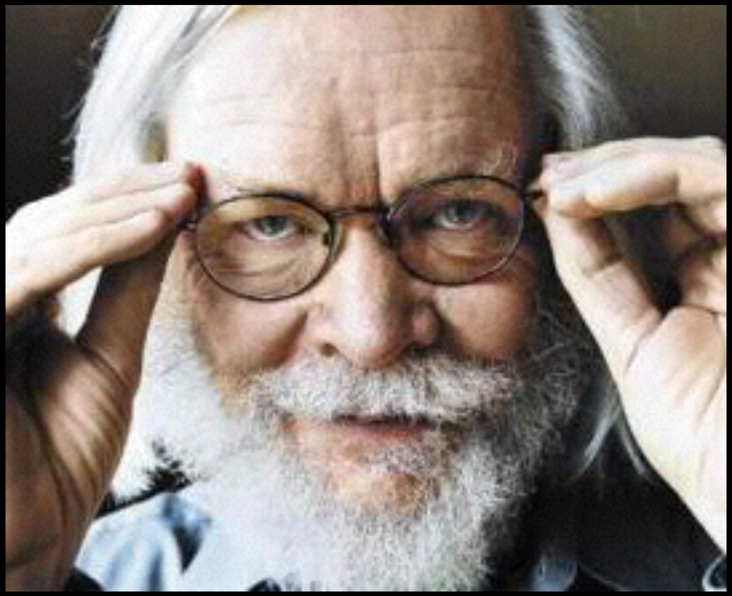


Wang, Wang, Yang

scalar top mass ≥ 10 TeV preferred

Giudice, Strumia

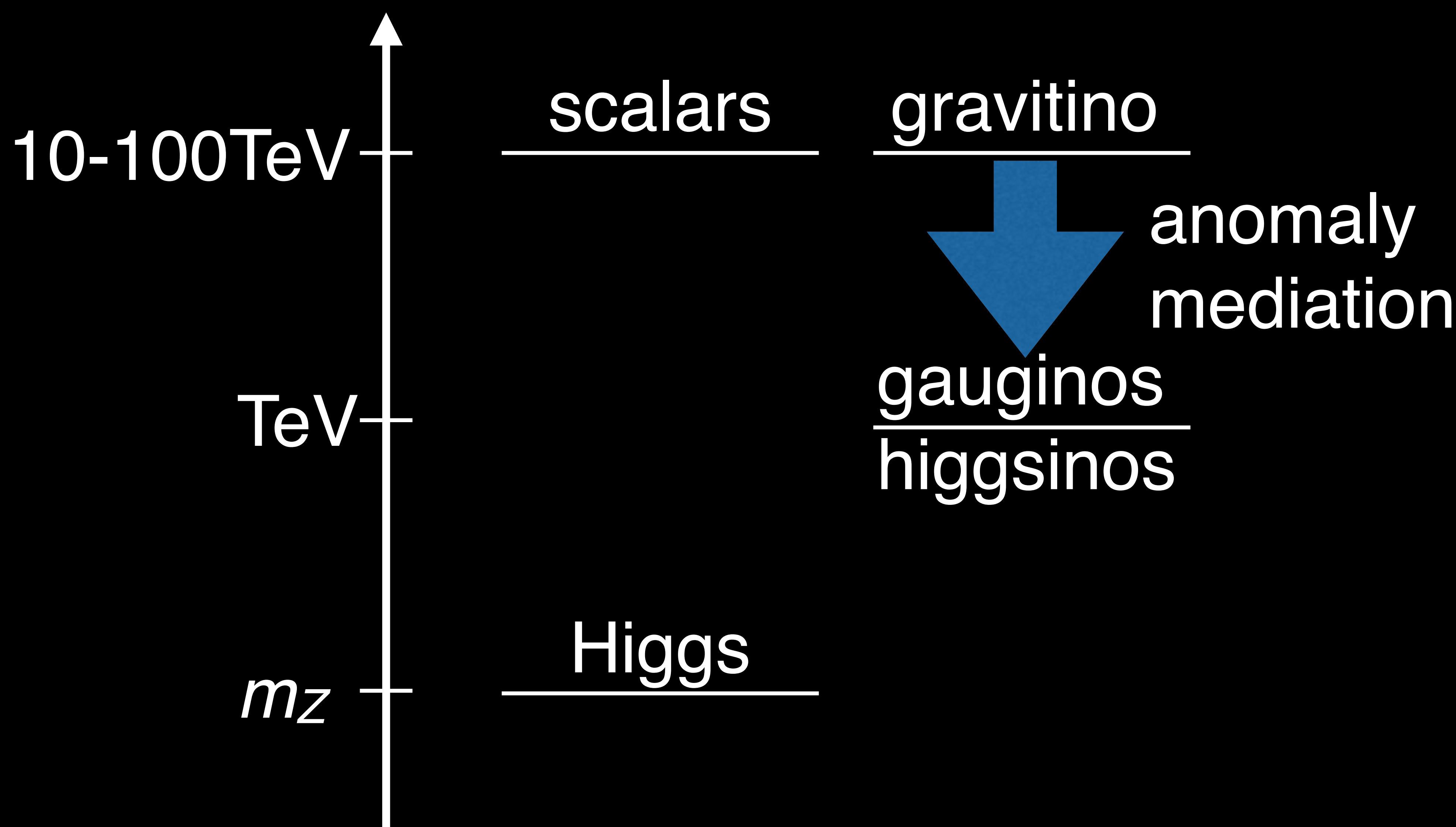
assumption: MSSM



Better Late Than Never

Even m_{SUSY}~10 TeV ameliorates fine-tuning from 10^{-36} to 10^{-4}

mini-split SUSY
pure gravity mediation



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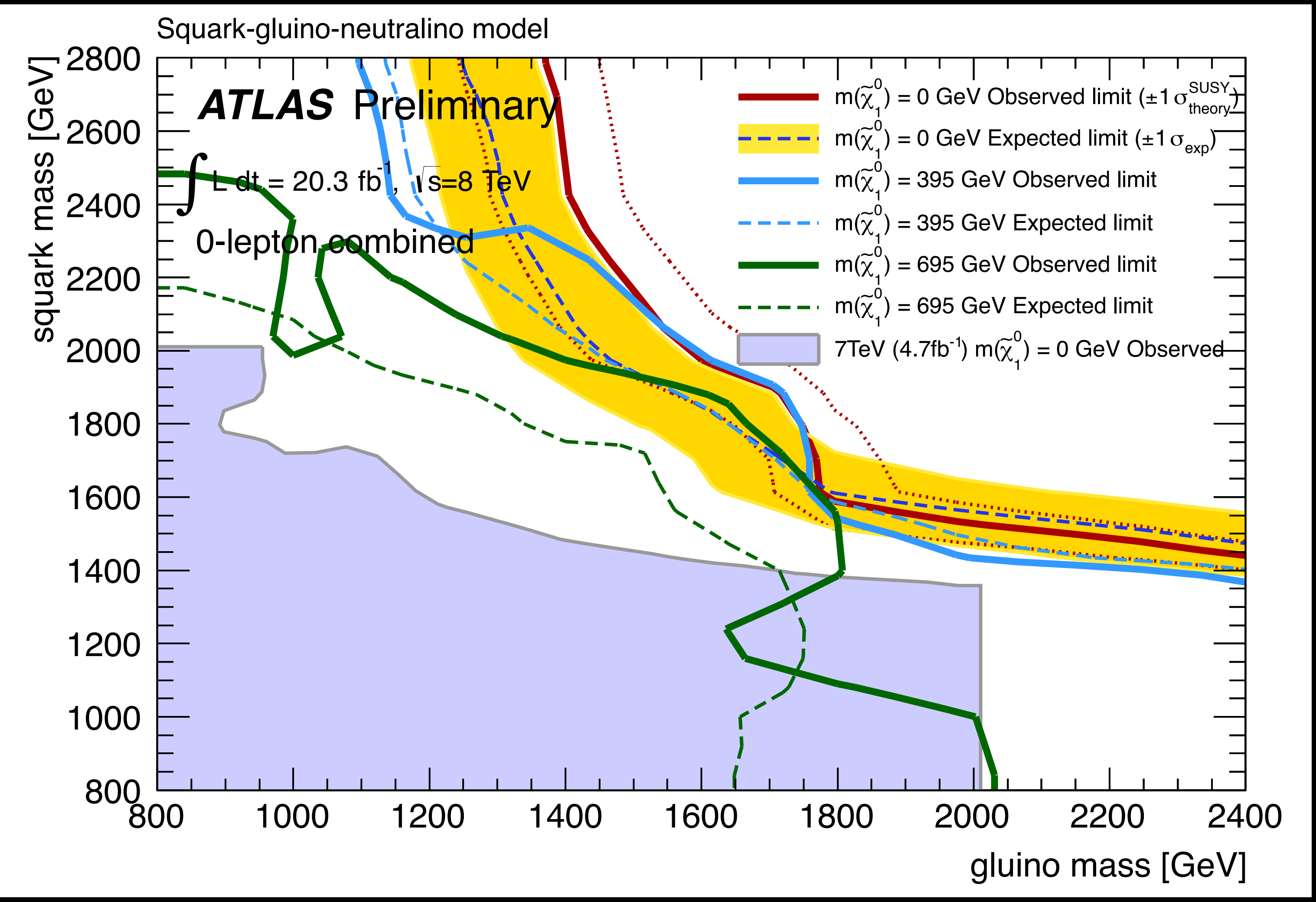
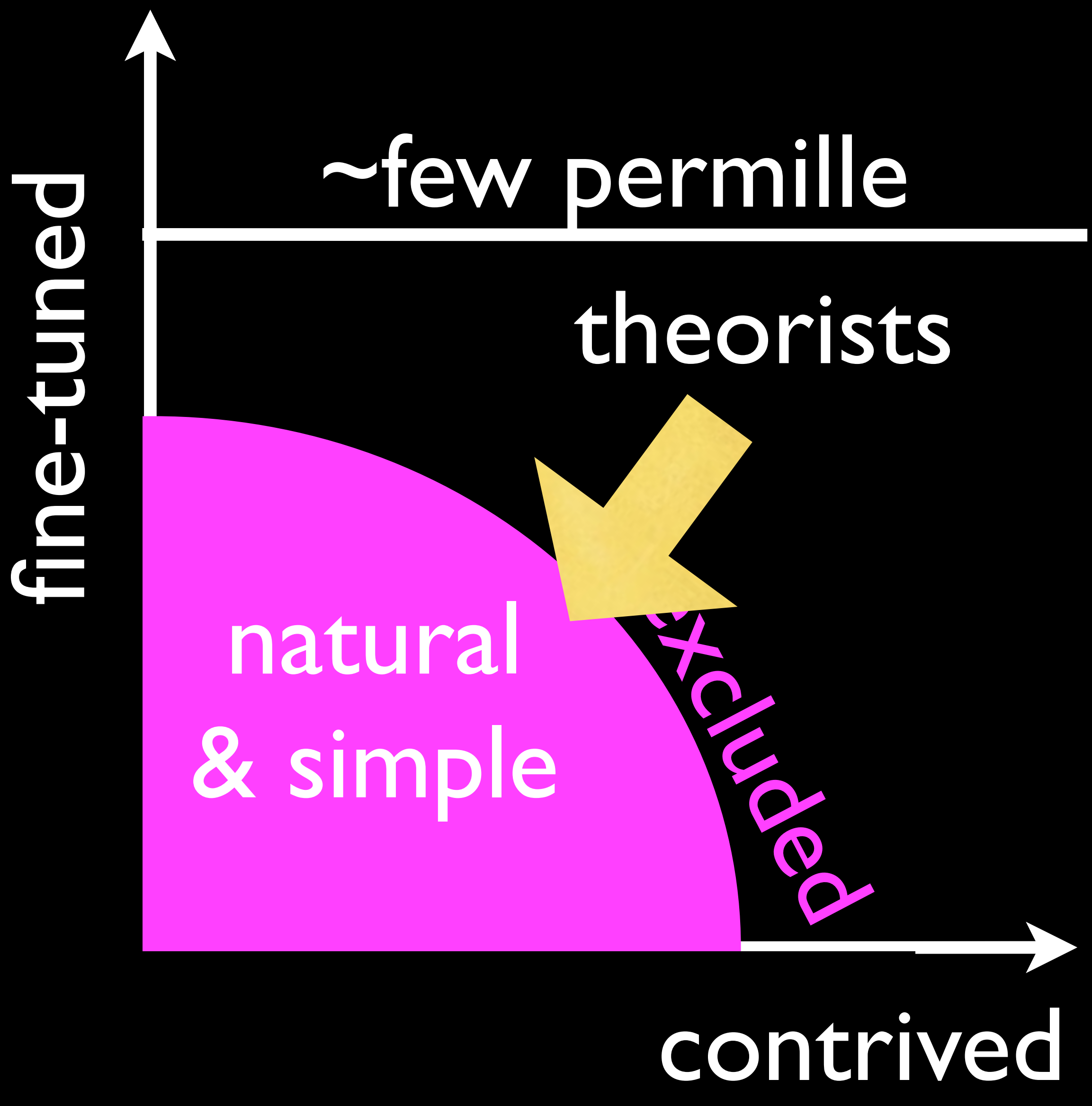
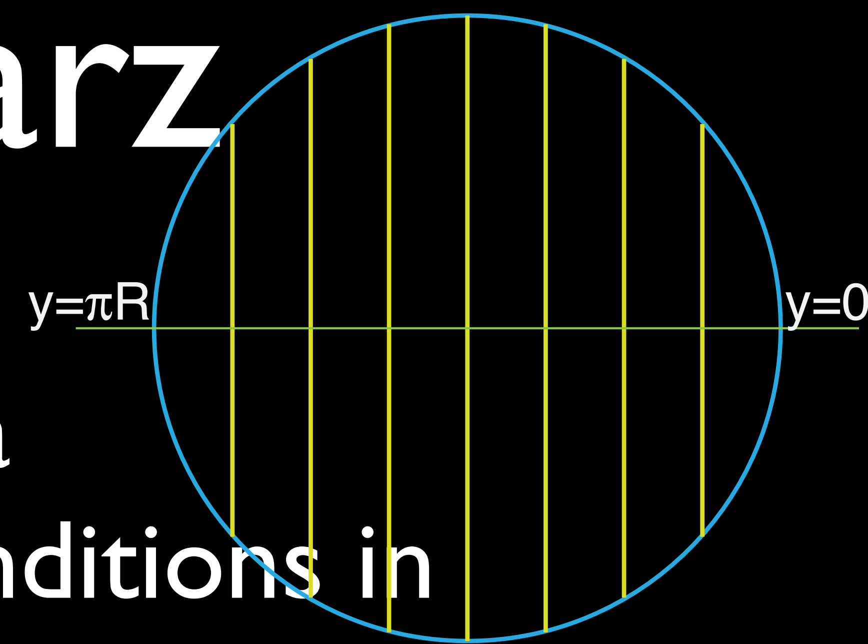




important to see any new experimental signatures

Scherk-Schwarz



- Maybe SUSY hidden in the data
- break SUSY with boundary conditions in 5D

$$PTP = T^{-1}, \quad P^2 = 1 \quad T = e^{i\alpha}$$

- @tree level, all SUSY particles degenerate at α/R similar to UED
- automatically compressed spectrum
- SUSY as light as 1TeV still OK

HM, Nomura, Shirai, Tobioka

tag ISR

HM, Nojiri, Tobioka

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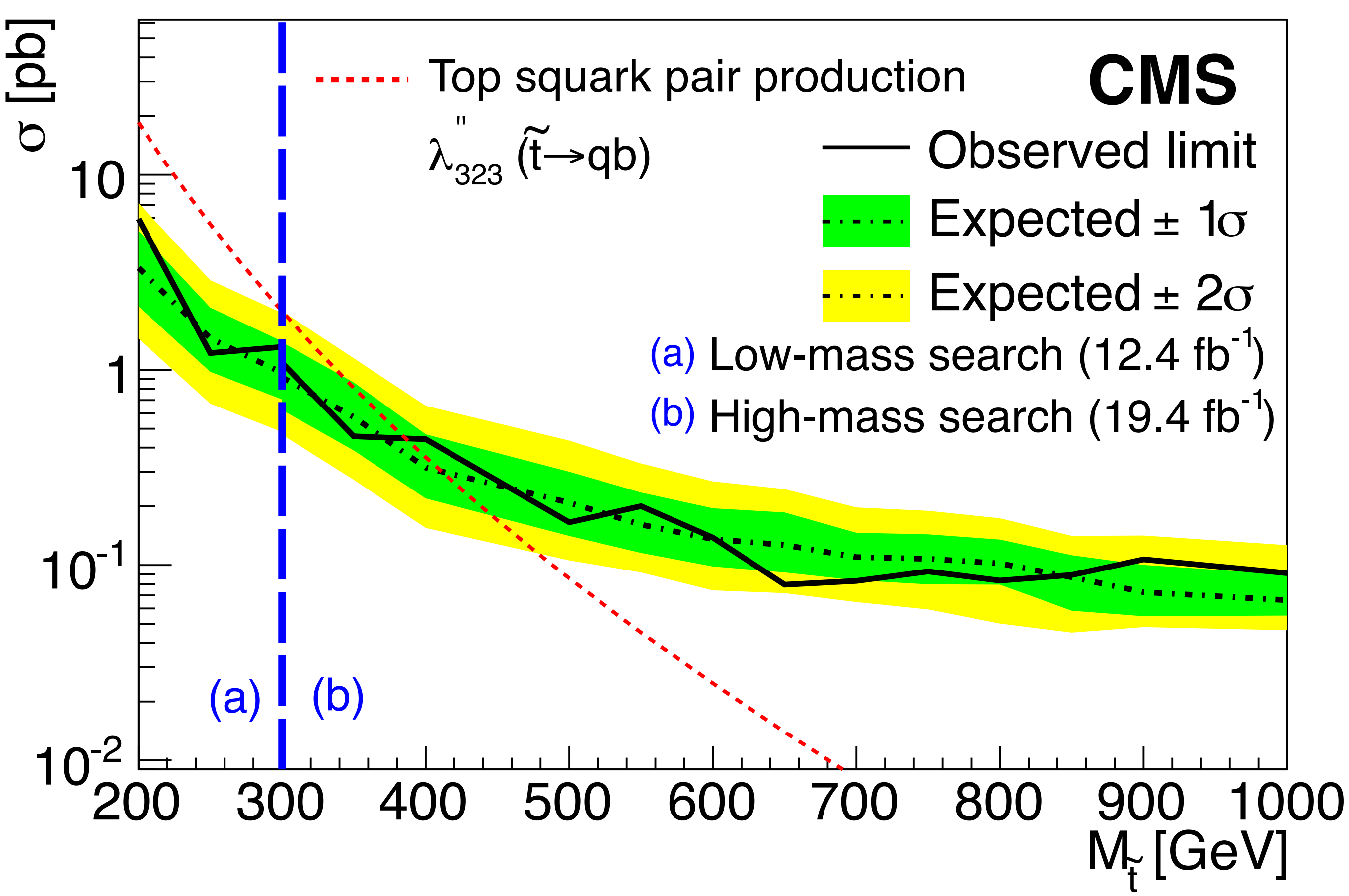
ed)

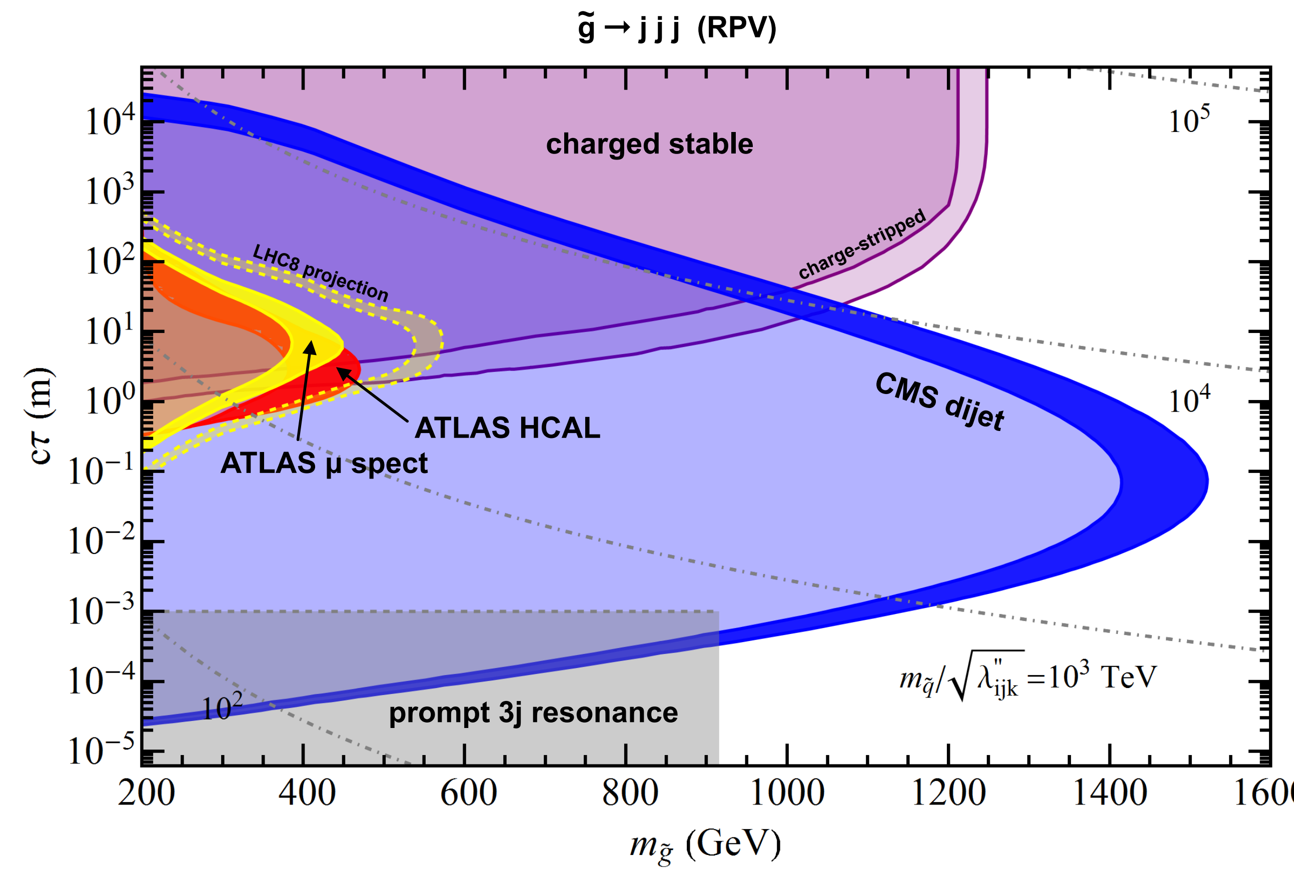
6

R-parity Violation

CMS di-jet pair, arxiv:1412.7706

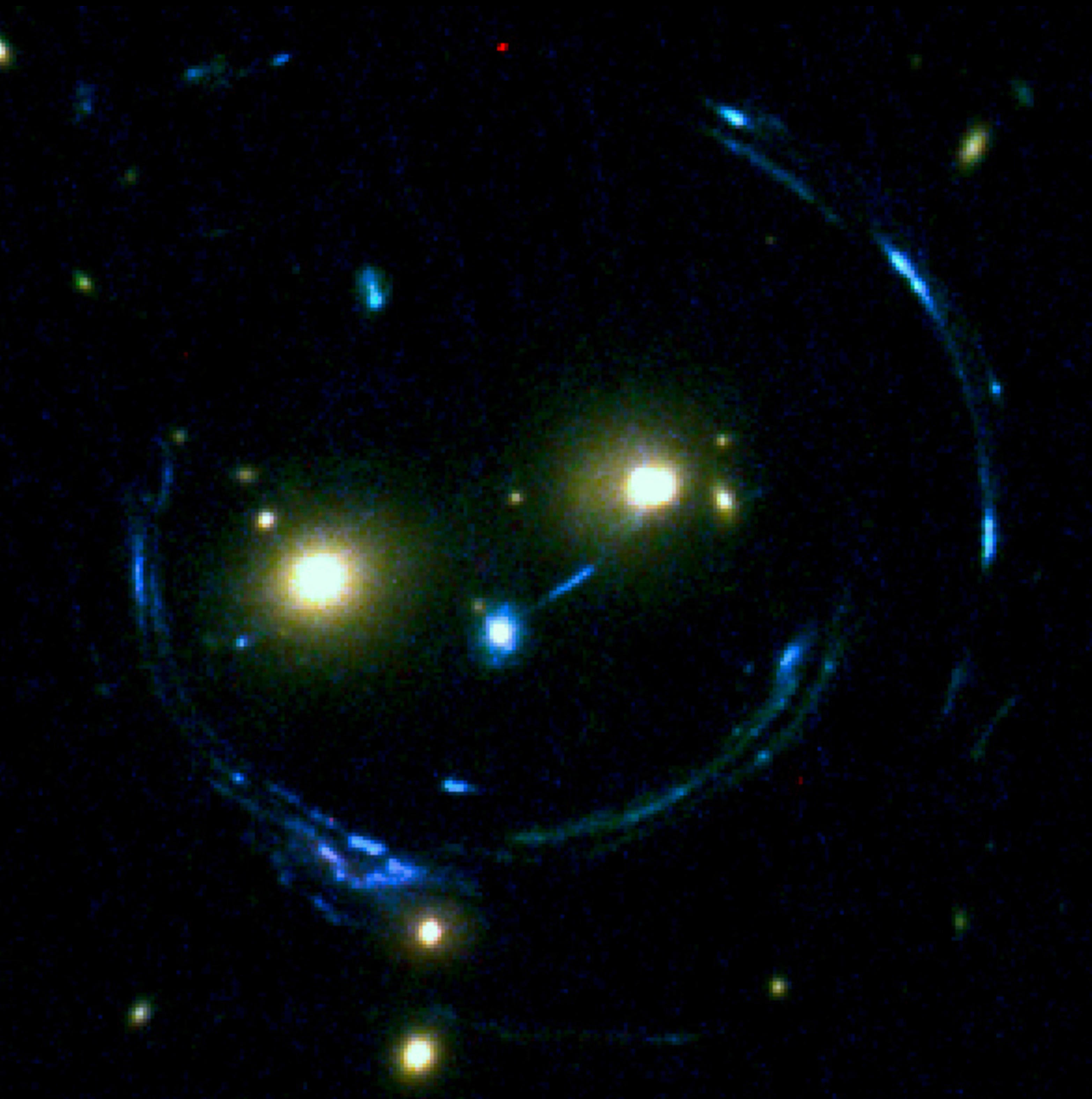


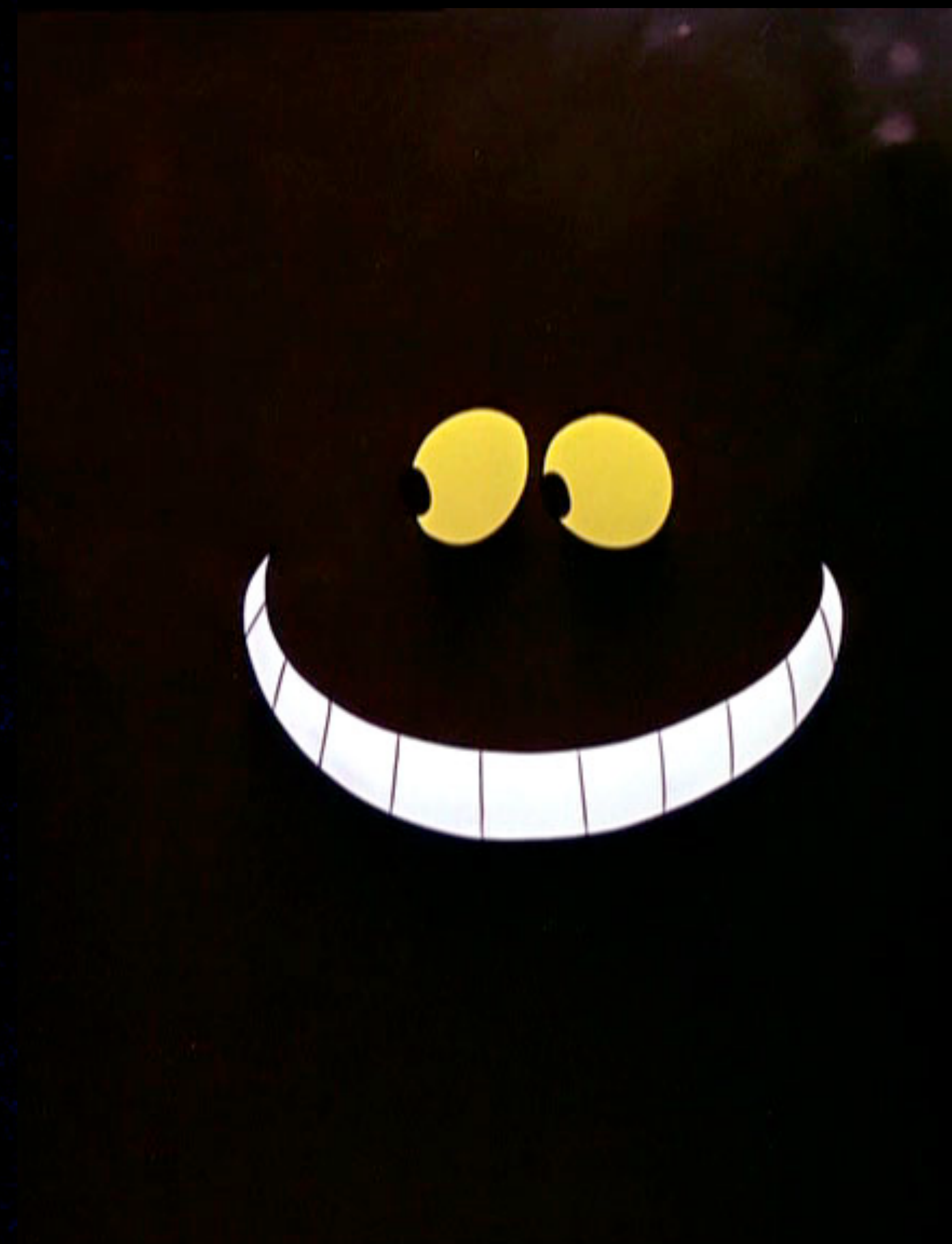
Liu&Tweedie, arxiv:1503.05923



n (e.g. K- or B-meson oscillations)

Ruth Pöttgen

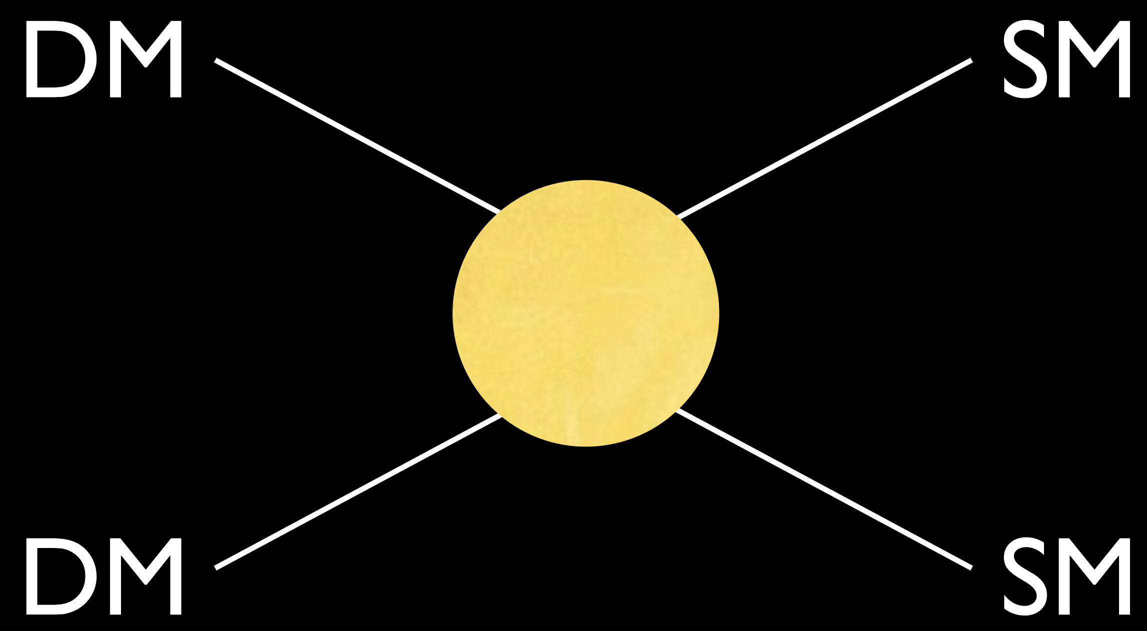




Ceshire cat

$$\frac{n_{\rm DM}}{s} = 4.4 \times 10^{-10} \frac{\rm GeV}{m_{\rm DM}}$$

Miracles

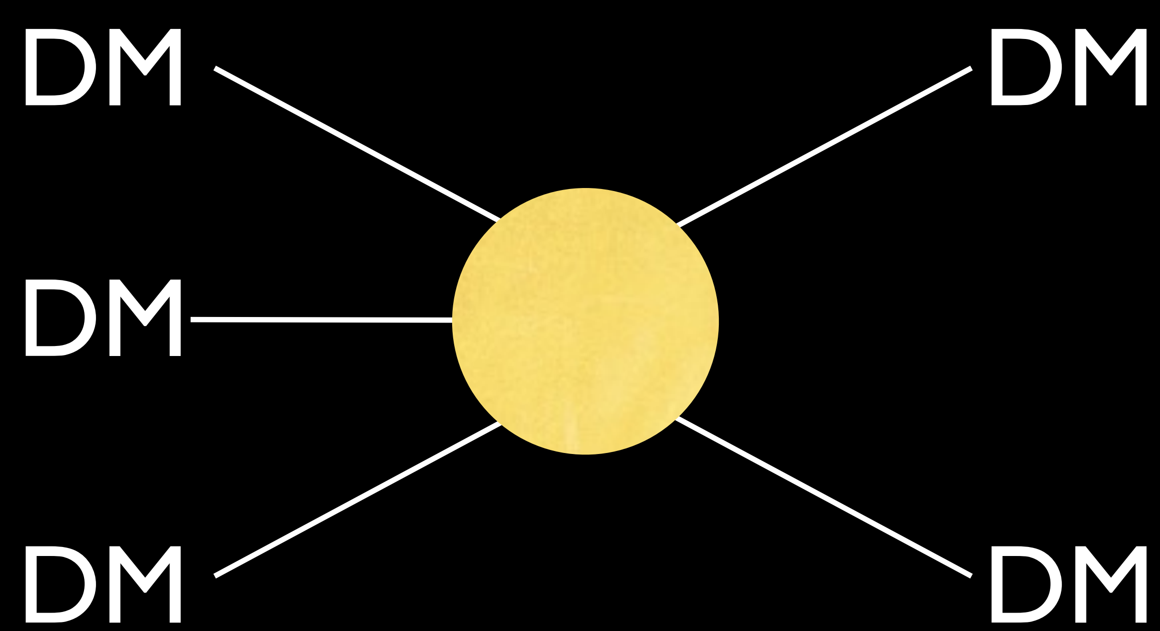


$$\langle \sigma_{2\to 2} v \rangle \approx \frac{\alpha^2}{m^2}$$

$$\alpha \approx 10^{-2}$$

$$m \approx 300 \text{ GeV}$$

WIMP miracle^2



$$\langle \sigma_{3\to 2} v^2 \rangle \approx \frac{\alpha^3}{m^5}$$

$$\alpha \approx 4\pi$$

$$m \approx 300 \text{MeV}$$

SIMP miracle^2

Hochberg, Kuflik, Volansky, Wacker arXiv:1402.5143

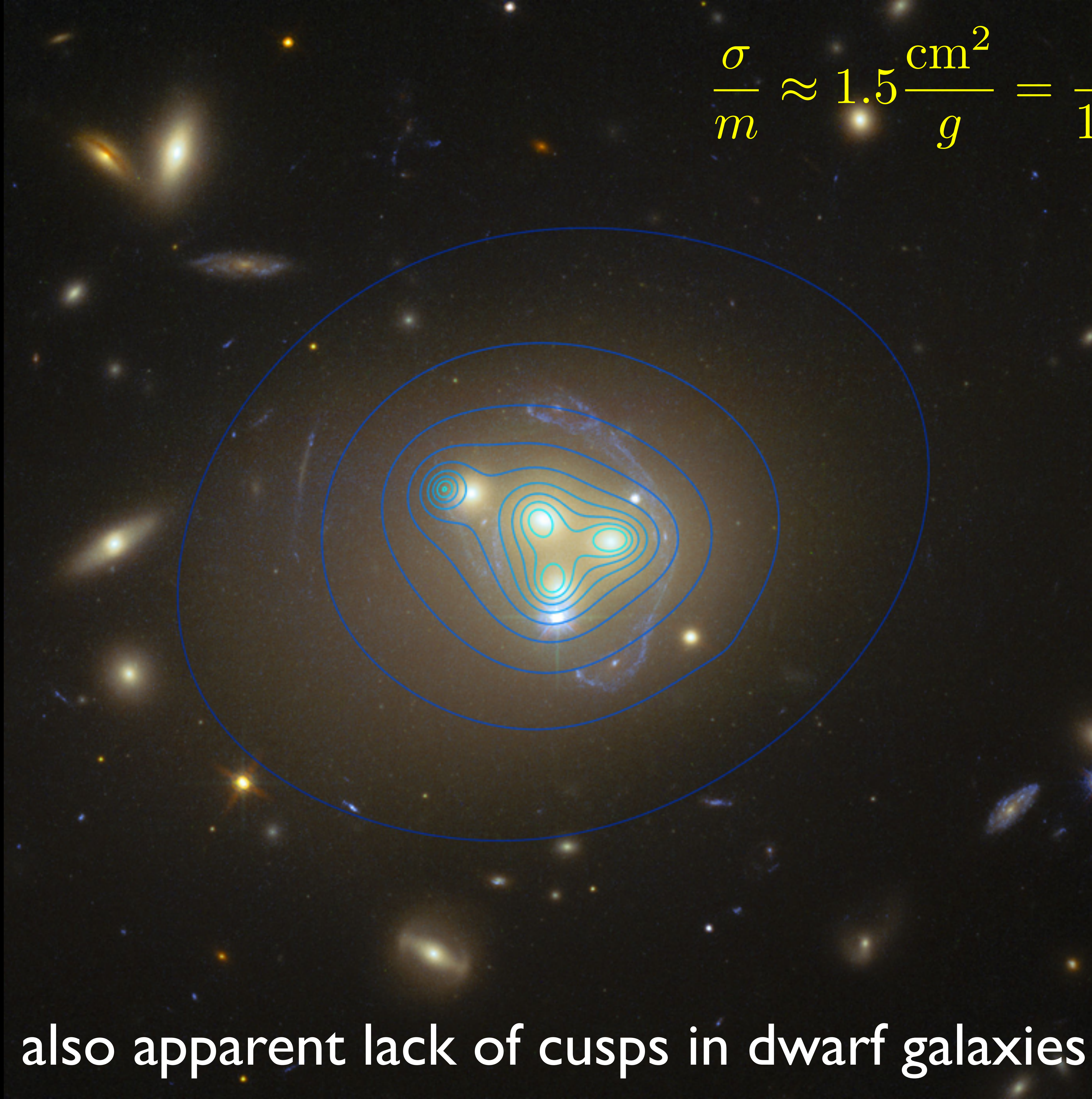
SIMPlest Miracle

Yonit Hochberg, Eric Kuflik, HM, Tomer Volansky, Jay Wacker

- SU(2) gauge theory with four doublets
- SU(4)=SO(6) flavor symmetry
- $\langle q^i q^j \rangle \neq 0$ breaks it to Sp(2)=SO(5)
- coset space SO(6)/SO(5)=S^5
- 5 stable pions
- $\pi_5(S^5)=Z \Rightarrow$ Wess-Zumino term
  - $\mathcal{L}_{WZ}=\varepsilon_{abcde}\,\varepsilon^{\mu\nu\rho\sigma}\,\pi^a\partial_\mu\pi^b\partial_\nu\pi^c\partial_\rho\pi^d\partial_\sigma\pi^e$

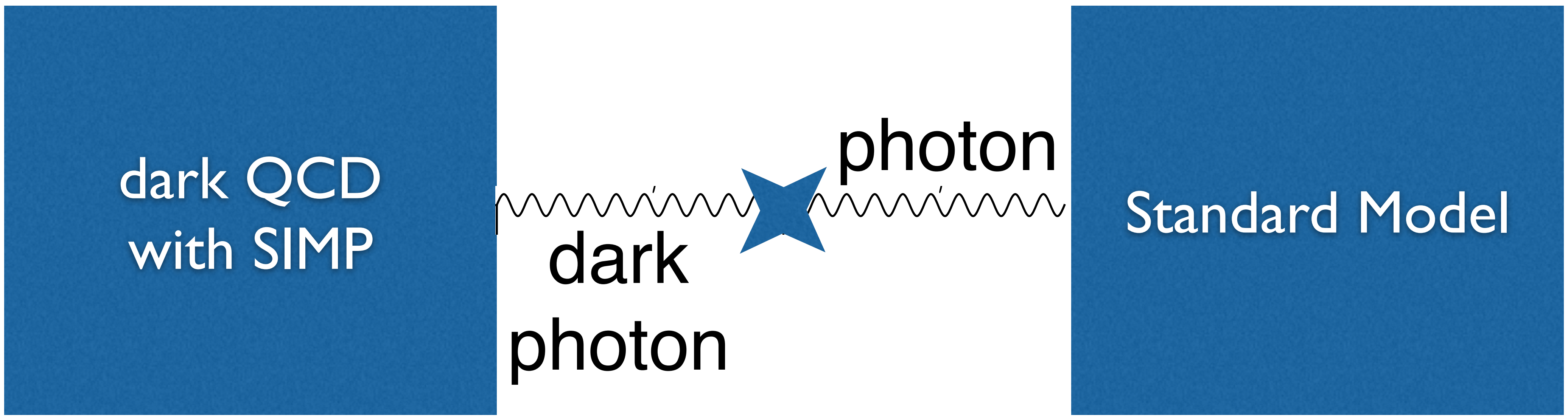
SIMP miracle^3

$$\frac{\sigma}{m} \approx 1.5 \frac{\mathrm{cm}^2}{g} = \frac{0.27\mathrm{b}}{100\mathrm{MeV}}$$

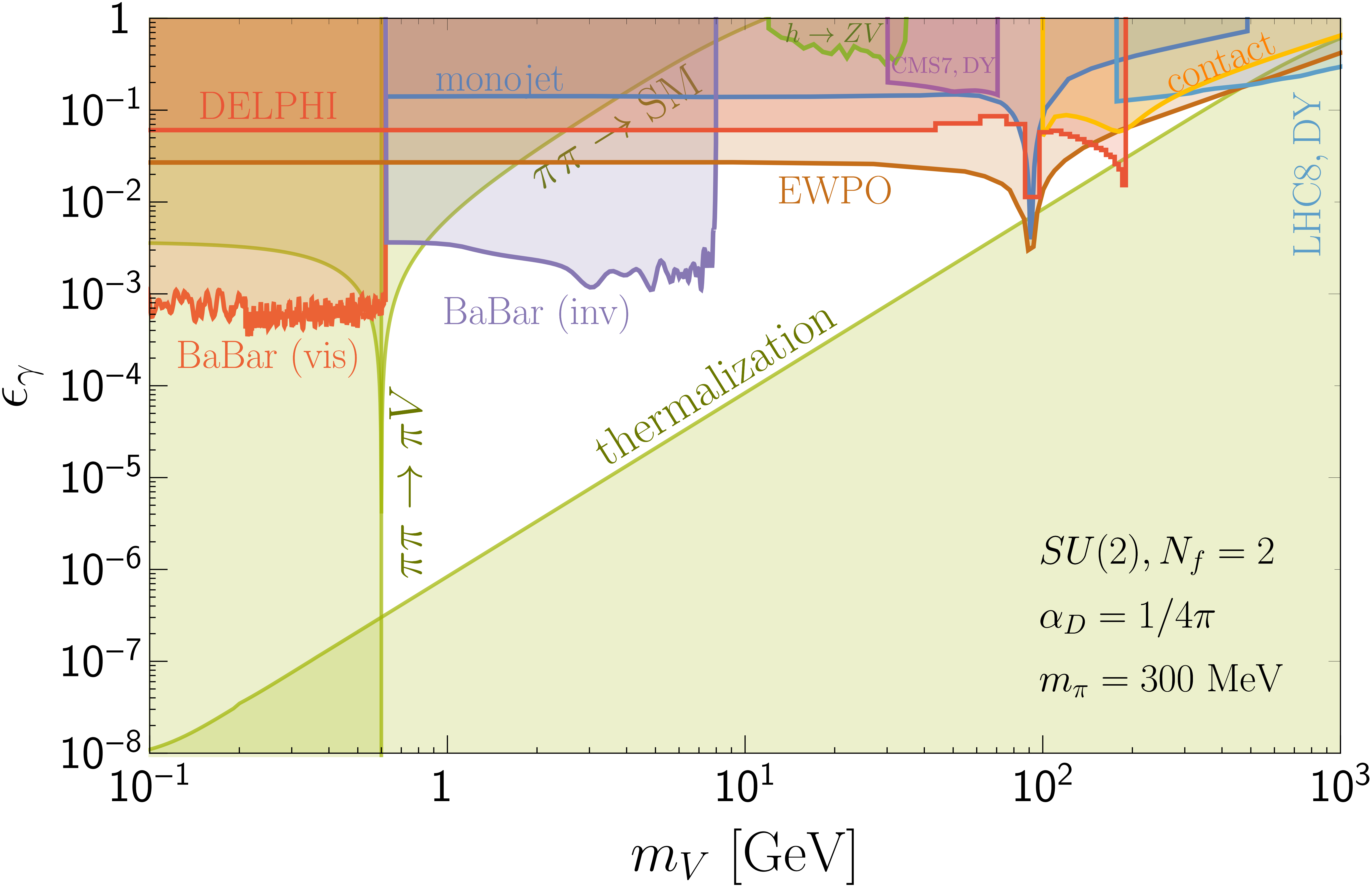


also apparent lack of cusps in dwarf galaxies

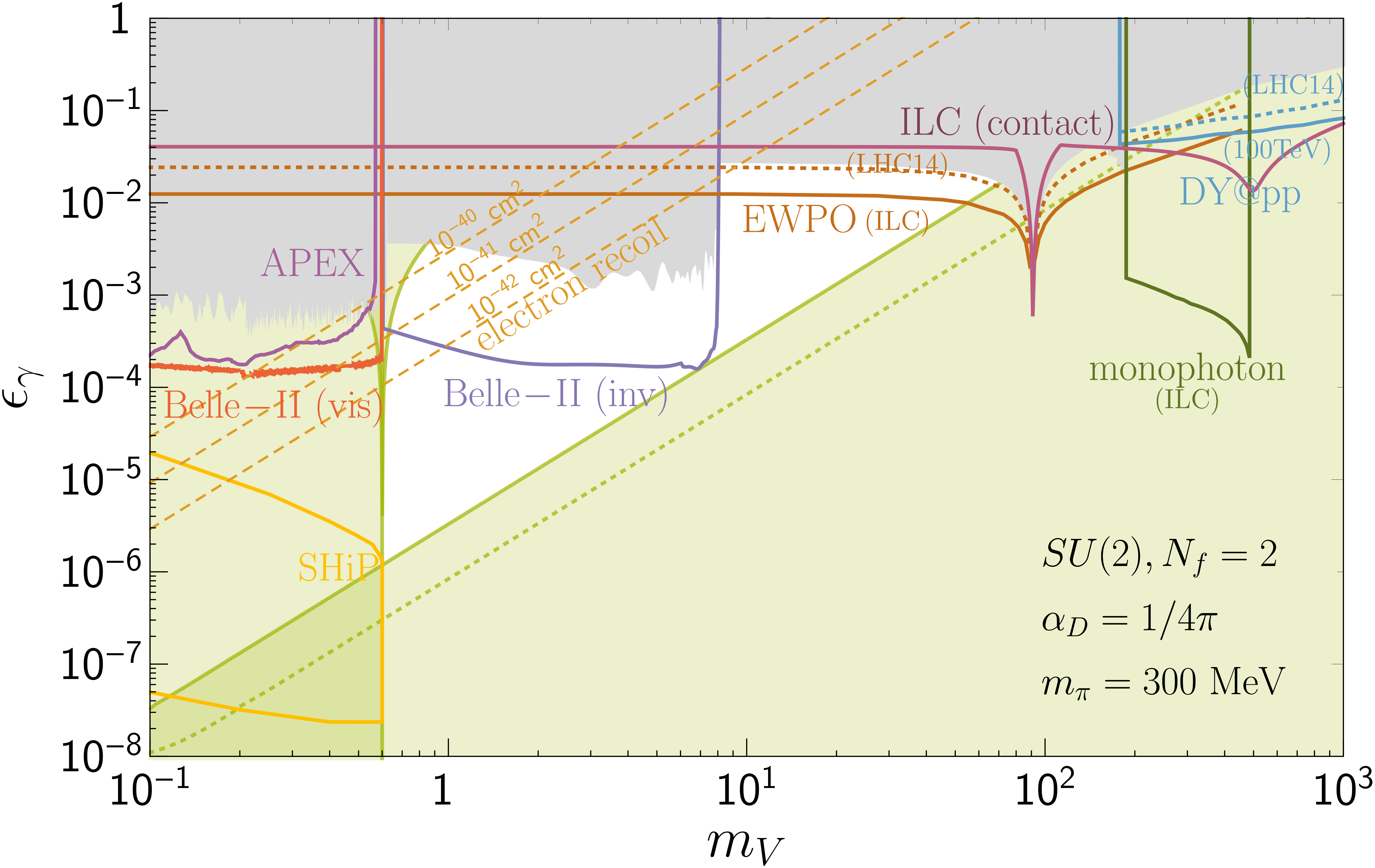
explore dark sector



$$\frac{\epsilon_\gamma}{2c_W} B_{\mu\nu} F_D^{\mu\nu}$$

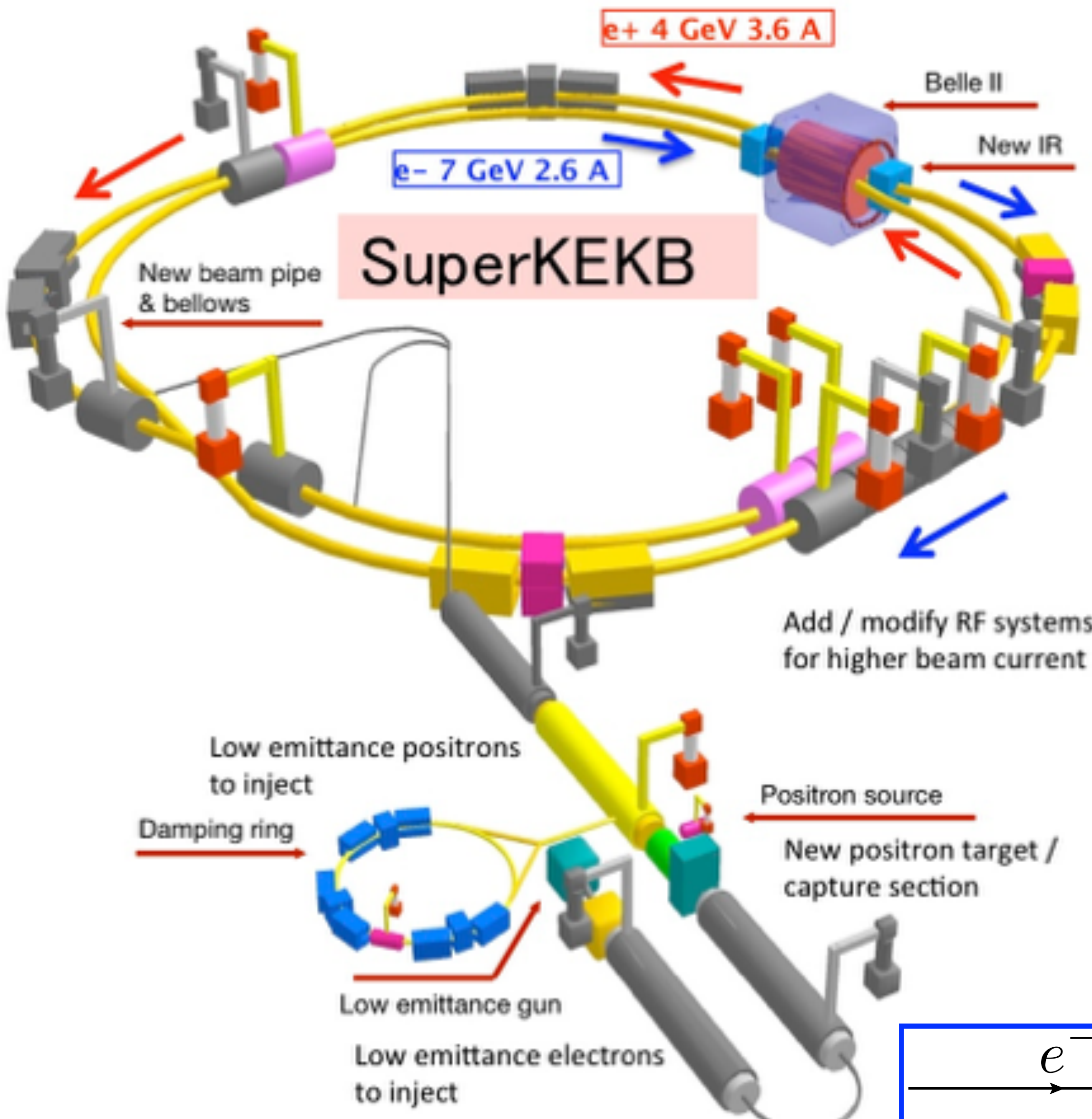


1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
ϵ_γ
10^{-1}
1
10^{1}
10^{2}
10^{3}
m_V [GeV]
DELPHI
monojet
$h \to ZV$
CMS7, DY
$\pi\pi \to$ SM
contact
LHC8, DY
EWPO
BaBar (inv)
BaBar (vis)
$\pi\pi \to \pi V$
thermalization
$SU(2), N_f = 2$
$\alpha_D = 1/4\pi$
$m_\pi = 300$ MeV

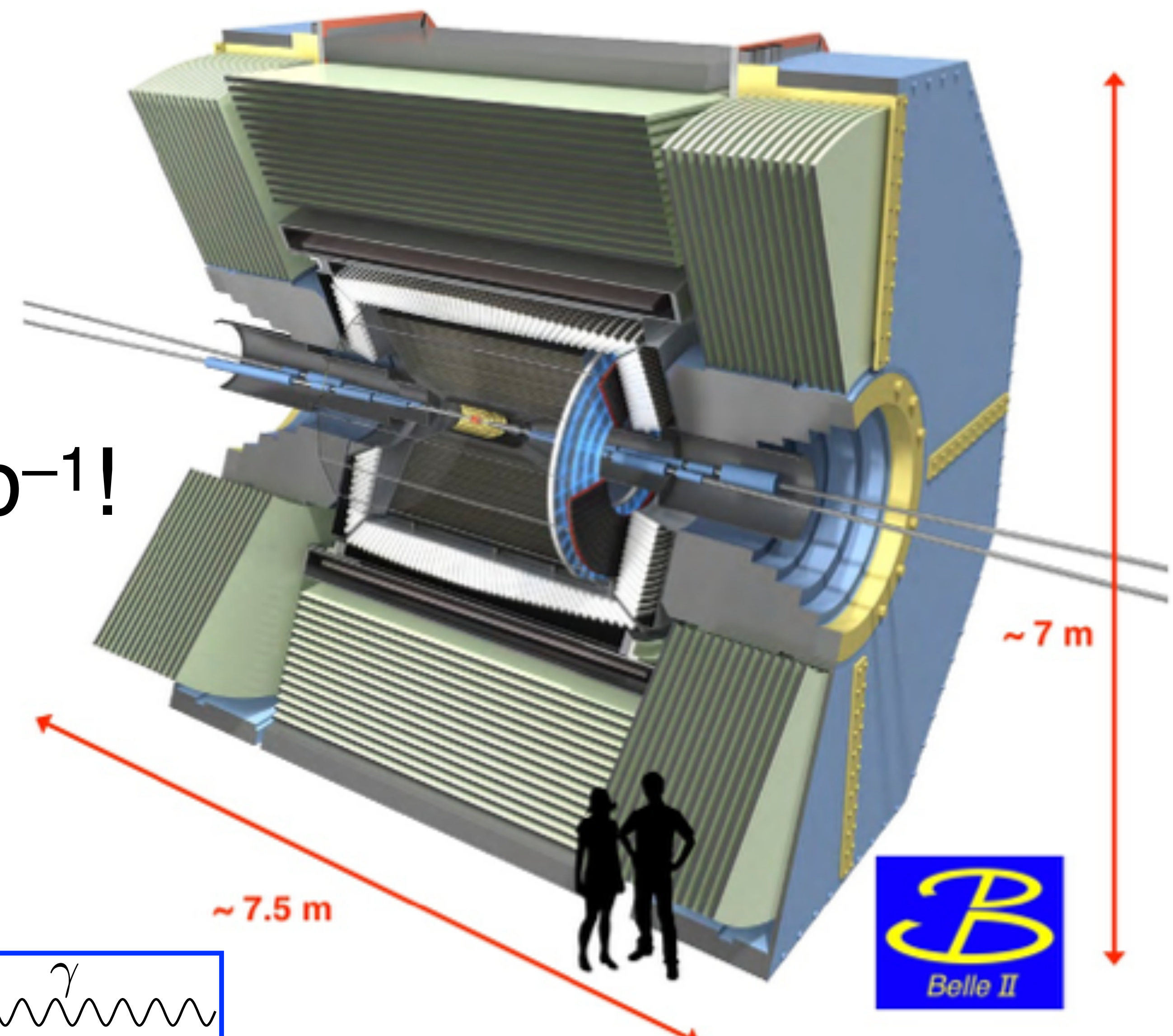


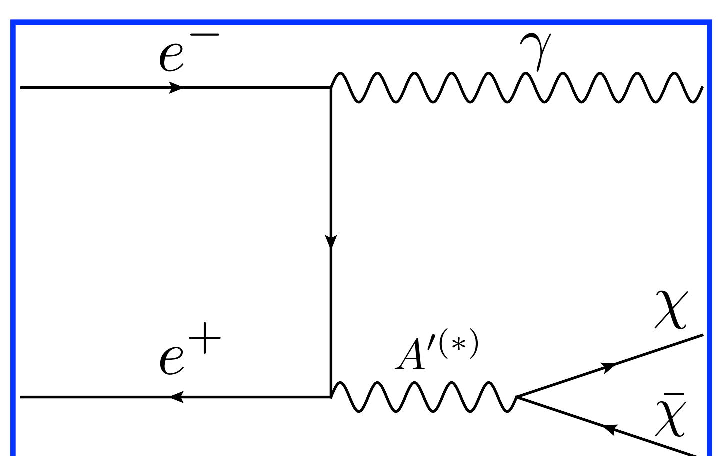
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
ϵ_γ
10^{-1}
1
10^{1}
10^{2}
10^{3}
m_V
ILC (contact)
(LHC14)
(LHC14)
(100TeV)
DY@pp
EWPO (ILC)
APEX
10^{-40} cm^2
10^{-41} cm^2
10^{-42} cm^2
electron recoil
Belle−II (vis)
Belle−II (inv)
monophoton
(ILC)
SHiP
$SU(2), N_f = 2$
$\alpha_D = 1/4\pi$
$m_\pi = 300$ MeV

Super KEK B & Belle II

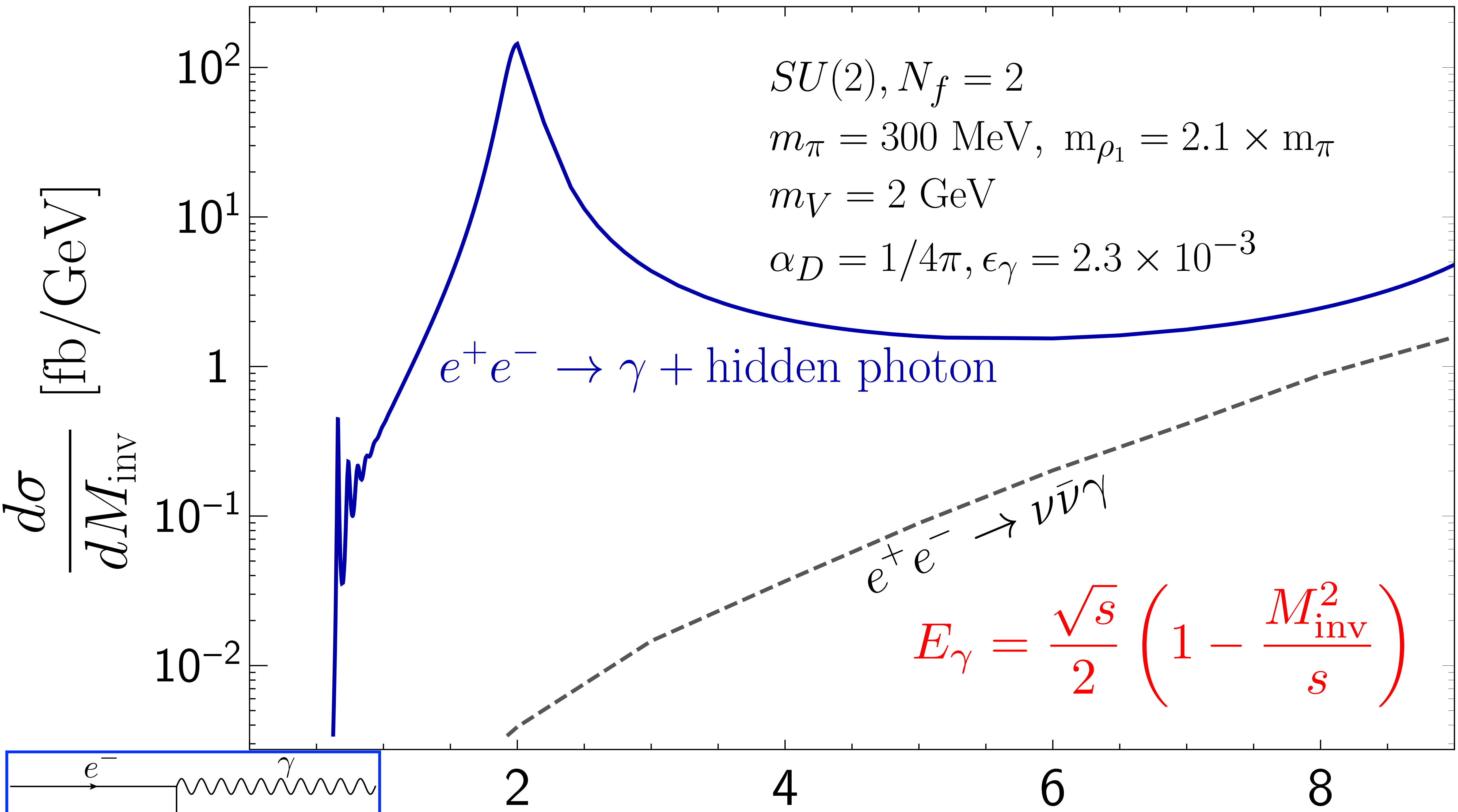


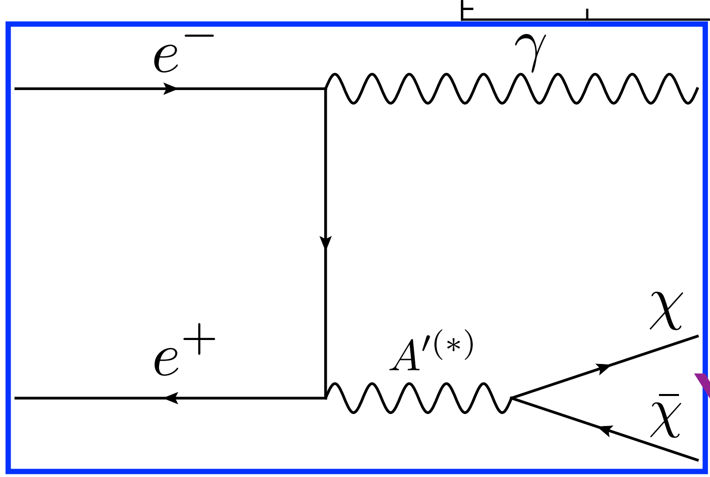
50 ab^{-1}!



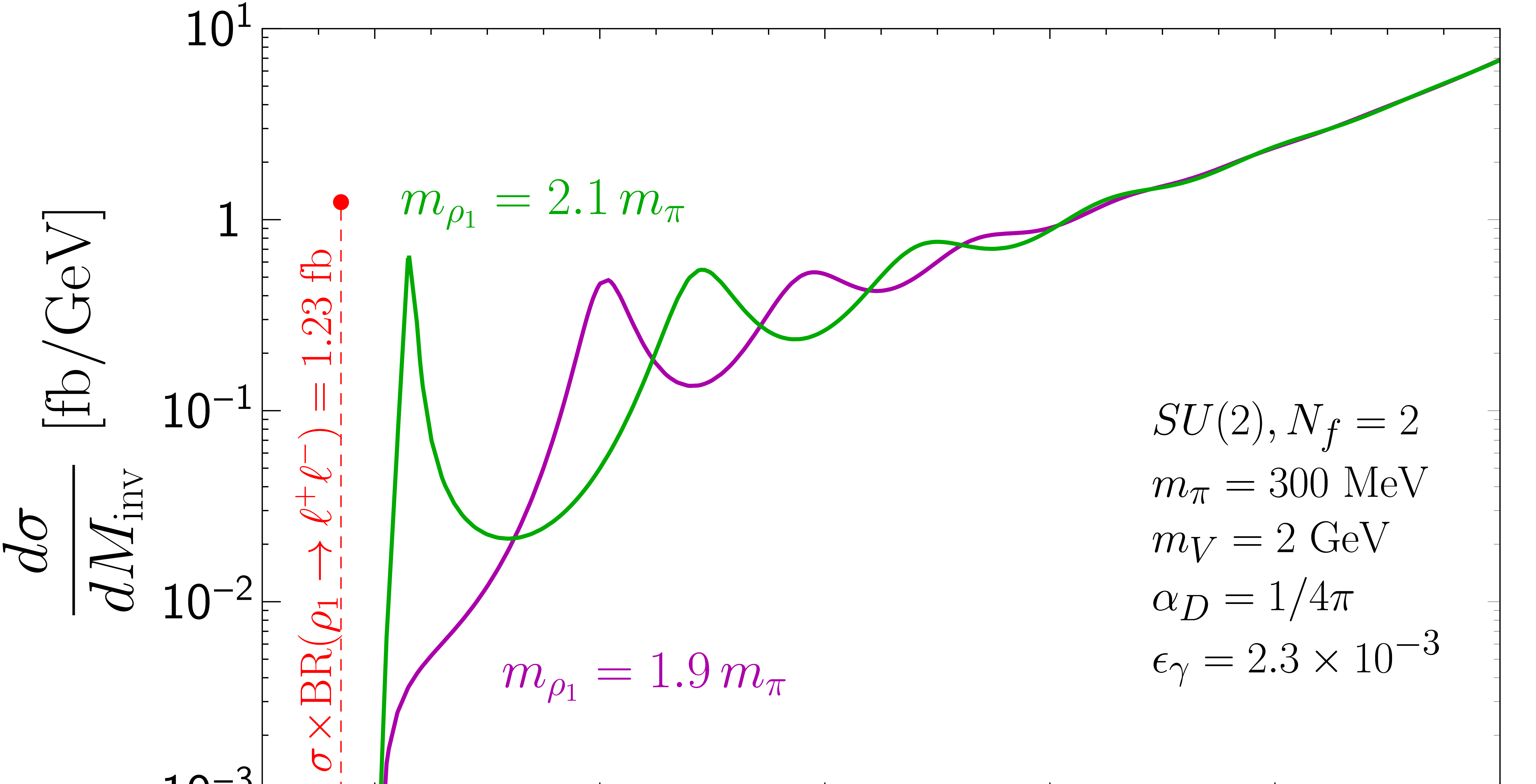


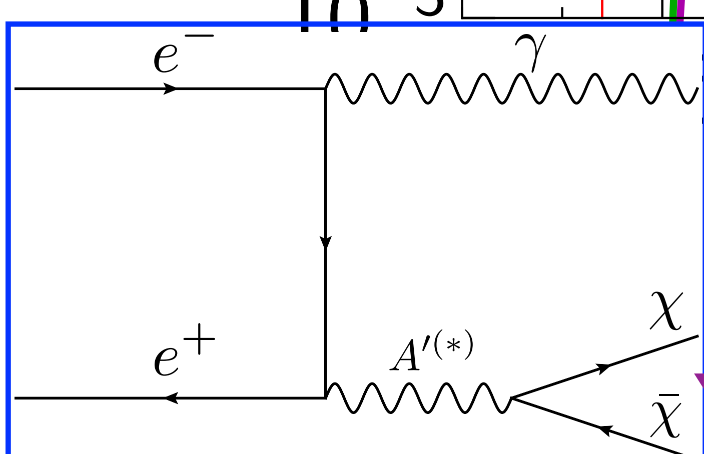
$$E_\gamma = \frac{\sqrt{s}}{2}\left(1 - \frac{M_{\rm inv}^2}{s}\right)$$



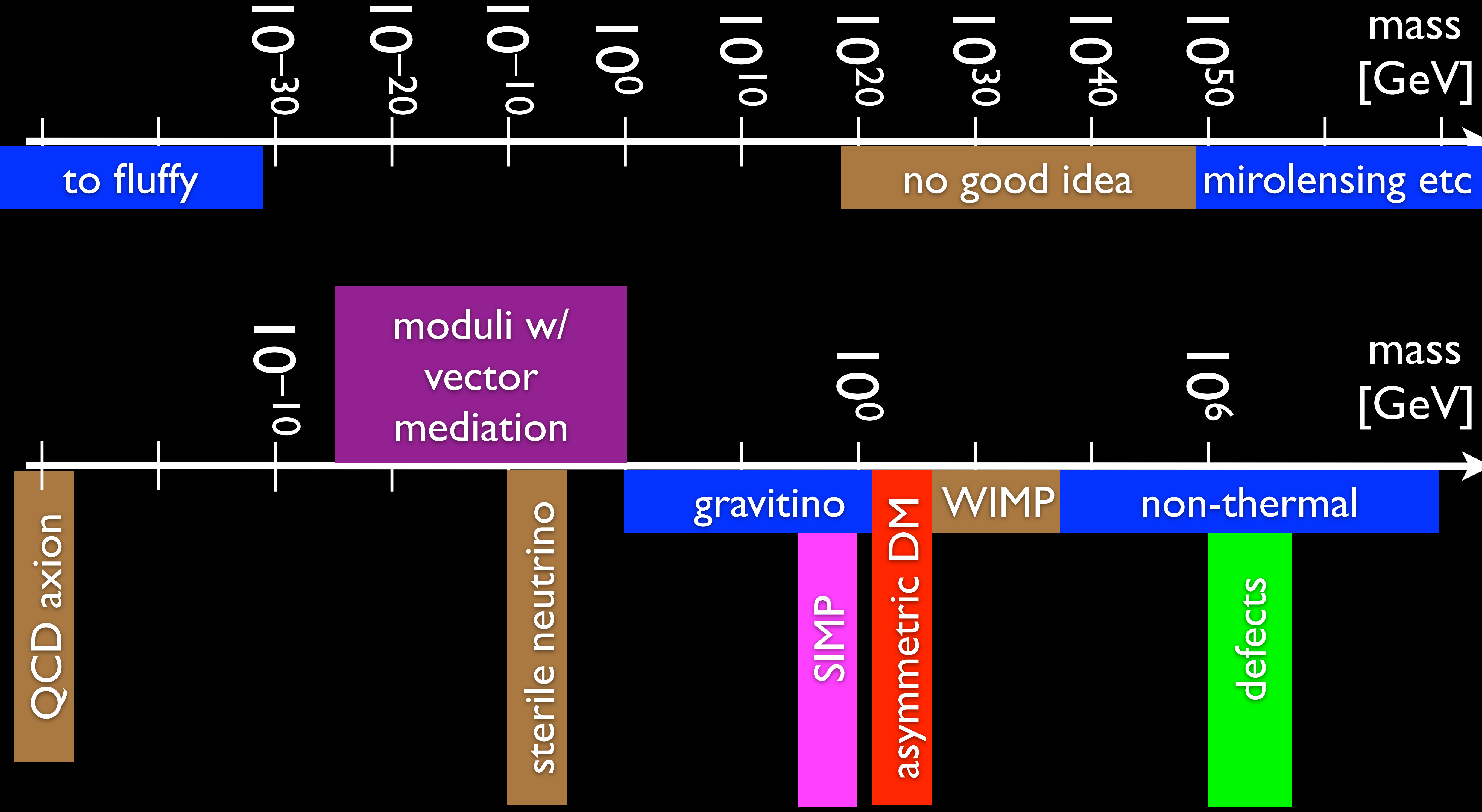


Yonit Hochberg, Eric Kuflik, HM





Yonit Hochberg, Eric Kuflik, HM



10^{-30}
10^{-20}
10^{-10}
10^{0}
10^{10}
10^{20}
10^{30}
10^{40}
10^{50}
mass [GeV]
to fluffy
no good idea
mirolensing etc
moduli w/ vector mediation
10^{-10}
10^{0}
10^{6}
mass [GeV]
QCD axion
sterile neutrino
gravitino
SIMP
asymmetric DM
WIMP
non-thermal
defects

Rare effects from high energies

- Effects of high-energy physics mostly disappear by power suppression

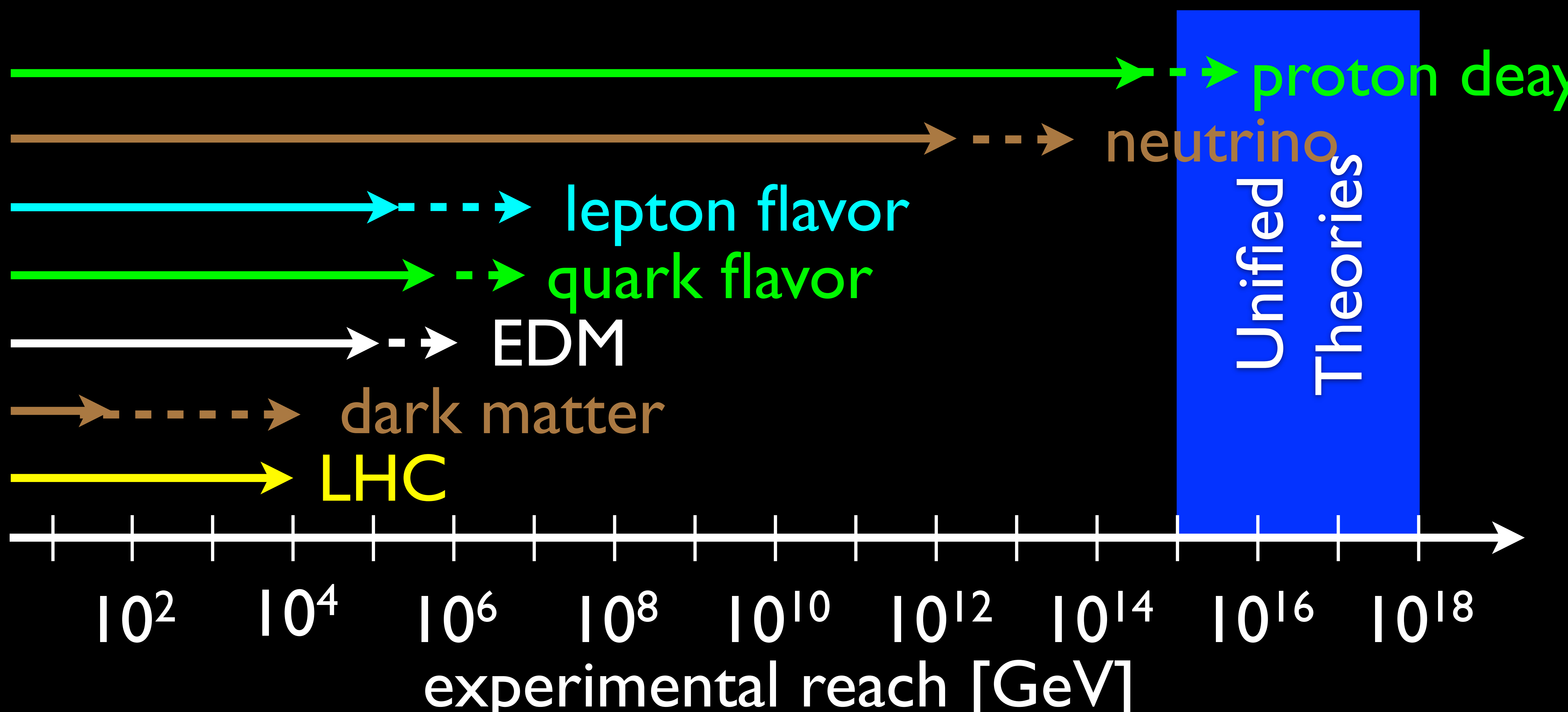
$$\mathcal{L} = \mathcal{L}_{\rm SM} + \frac{1}{\Lambda}\mathcal{L}_5 + \frac{1}{\Lambda^2}\mathcal{L}_6 + \cdots$$

- can be classified systematically

$$\mathcal{L}_5 = (LH)(LH) \to \frac{1}{\Lambda}(L\langle H\rangle)(L\langle H\rangle) = m_\nu \nu\nu$$

$$\mathcal{L}_6 = QQQL, \bar{L}\sigma^{\mu\nu}W_{\mu\nu}Hl, \epsilon_{abc}W_\nu^{a\mu}W_\lambda^{b\nu}W_\mu^{c\lambda}, \\ (H^\dagger D_\mu H)(H^\dagger D^\mu H), B_{\mu\nu}H^\dagger W^{\mu\nu}H, \cdots$$

Power of Expedition



(with significant simplifying assumptions)

courtesy: Zoltan Ligeti

Effective Operators

- Classification surprisingly difficult question
- In the case of the Standard Model
  - Weinberg (1980) on D=6 $\not{B}$, D=5 $\not{L}$
  - Buchmüller-Wyler (1986) on D=6 ops
    - 80 operators for N_f=1, B, L conserving
  - Grzadkowski et al (2010) removed redundancies and discovered one missed
    - 59 operators for N_f=1, B, L conserving
    - redundancies due to EOM, IBP
  - Mahonar et al (2013) general N_f
  - Lehman-Martin (2014,15) D=7 for general N_f, D=8 for N_f=1 (incorrect)

Main idea

Brian Henning, Xiaochuan Lu, Tom Melia, HM

- Take kinetic terms as the zeroth order Lagrangian $(\partial\phi)^2,\ \bar{\psi}i\partial\!\!\!/\psi,\ (F_{\mu\nu})^2$
- Classically, it is conformally invariant under SO(4,2)≃SO(6,$\mathbb{C}$)
- Operator-State correspondence in CFT tells us that operators fall into representations of the conformal group
  - equation of motion: short multiplets
  - remove total derivatives: primary states

$$H(\mathcal{D},\phi_1,\cdots,\phi_n)=\int d\mu_{\rm conf}d\mu_{\rm gauge}\sum_k \mathcal{D}^k\chi^*_{\Delta_0+k,0}PE\left[\frac{\phi_1}{\mathcal{D}^{d_1}}\chi_1\right]\cdots PE\left[\frac{\phi_n}{\mathcal{D}^{d_n}}\chi_n\right]$$

Terminal — tcsh — ttys001

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Hitoshi-no-MacBook-Pro.local 35: form hssm6.frm
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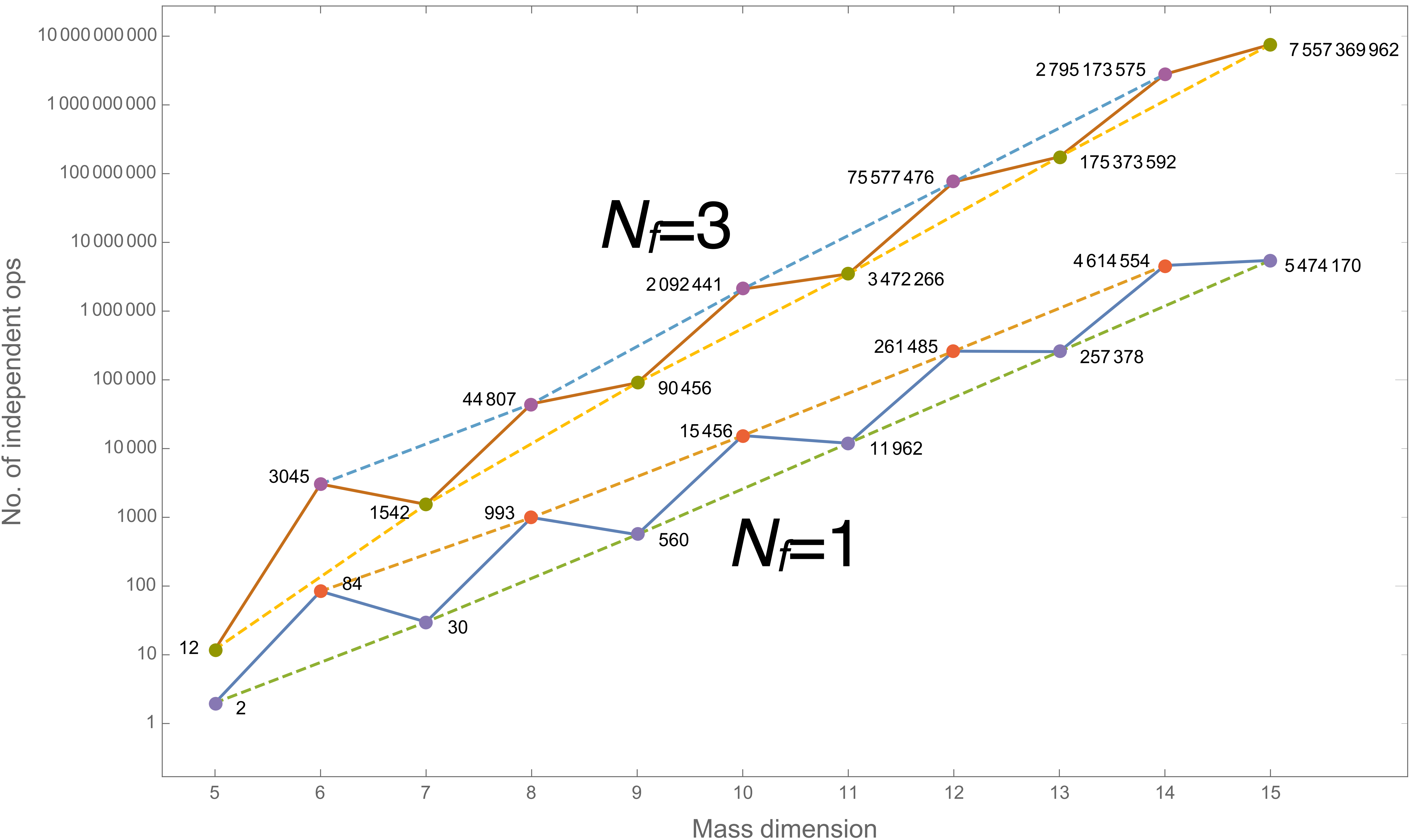
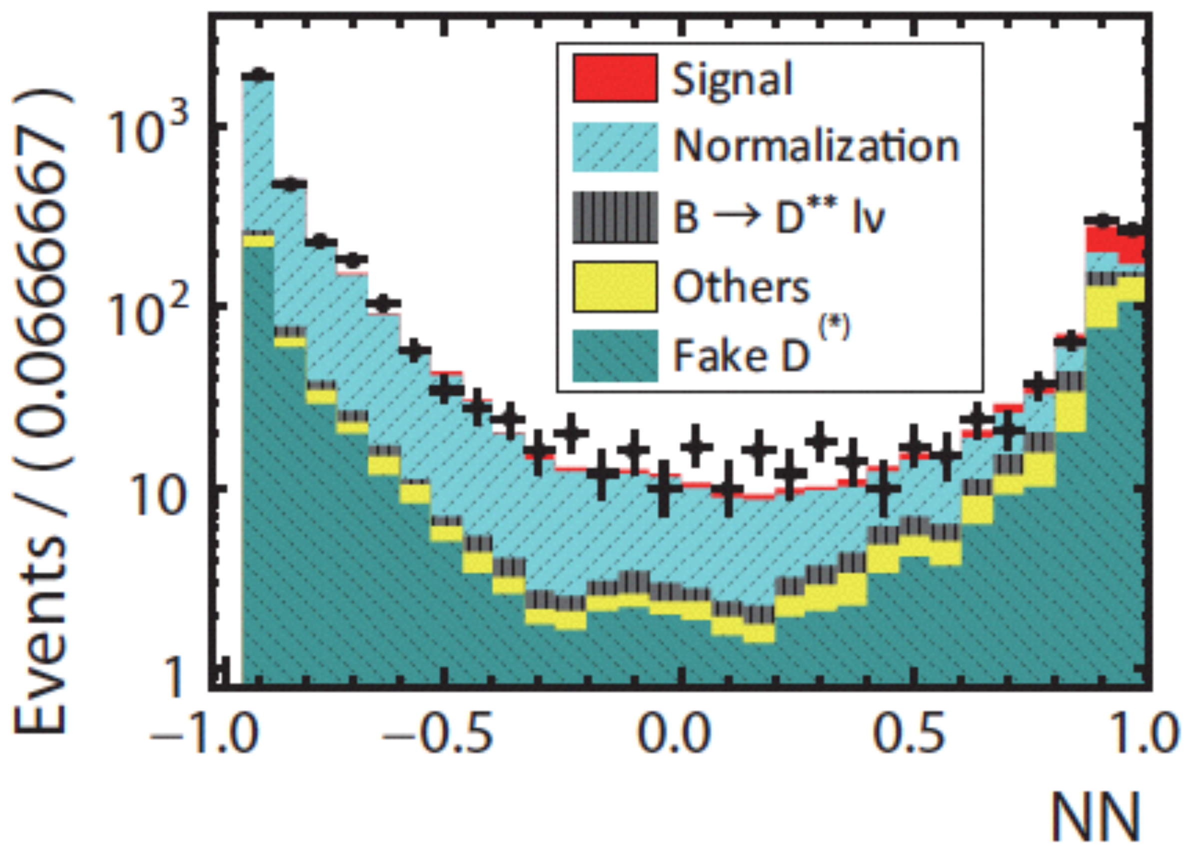


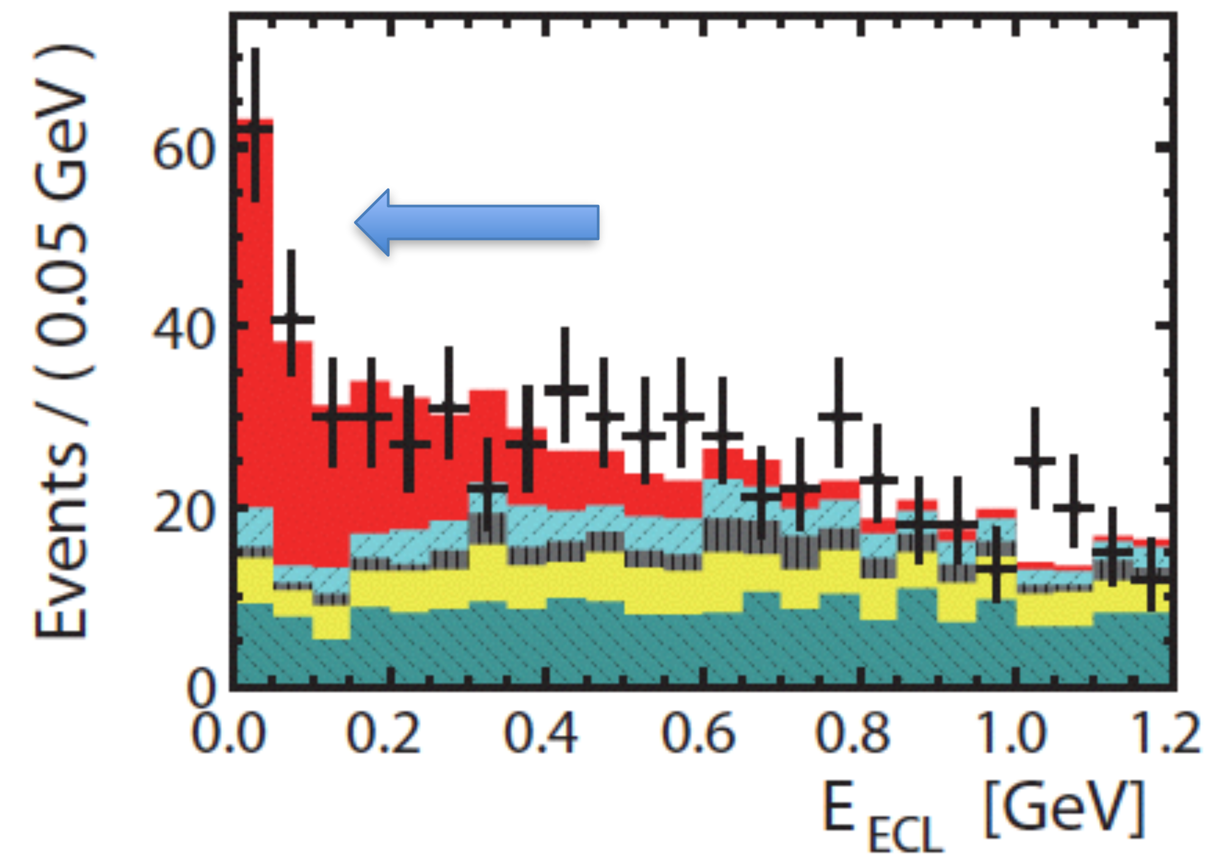
N_f=3
N_f=1
No. of independent ops
Mass dimension
10 000 000 000
1 000 000 000
100 000 000
10 000 000
1 000 000
100 000
10 000
1000
100
10
1
5
6
7
8
9
10
11
12
13
14
15
12
3045
1542
44 807
90 456
2 092 441
3 472 266
75 577 476
175 373 592
2 795 173 575
7 557 369 962
2
84
30
993
560
15 456
11 962
261 485
257 378
4 614 554
5 474 170

One more Belle update, March 2016 (Moriond)

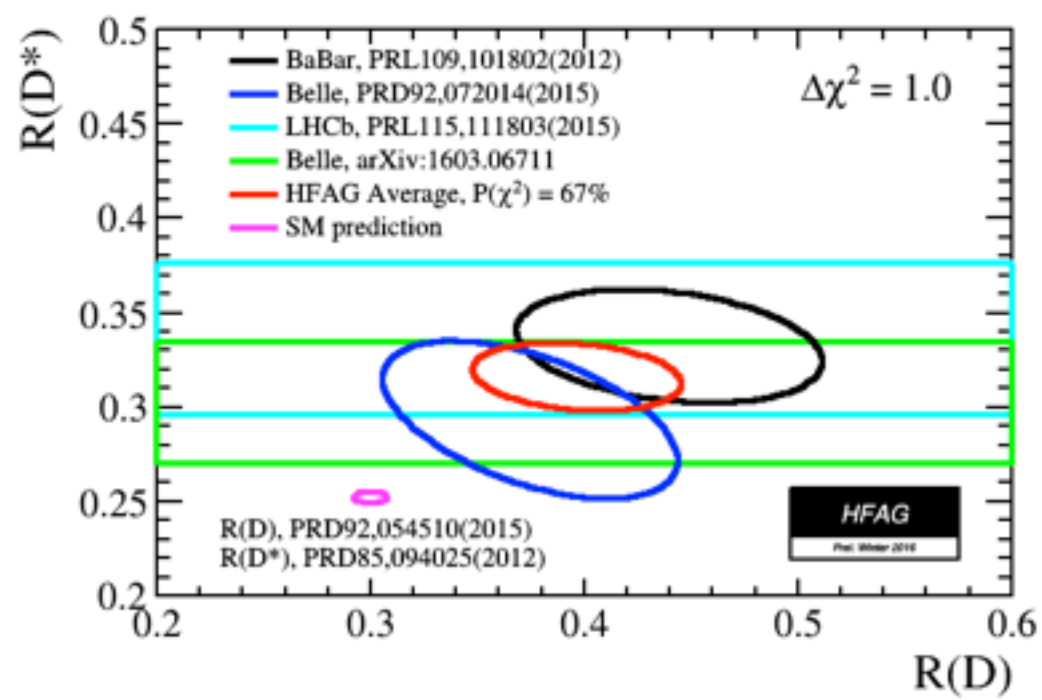
Uses semileptonic tagging

$$\mathcal{R}(D^*) = 0.302 \pm 0.030(\mathrm{stat}) \pm 0.011(\mathrm{syst}$$



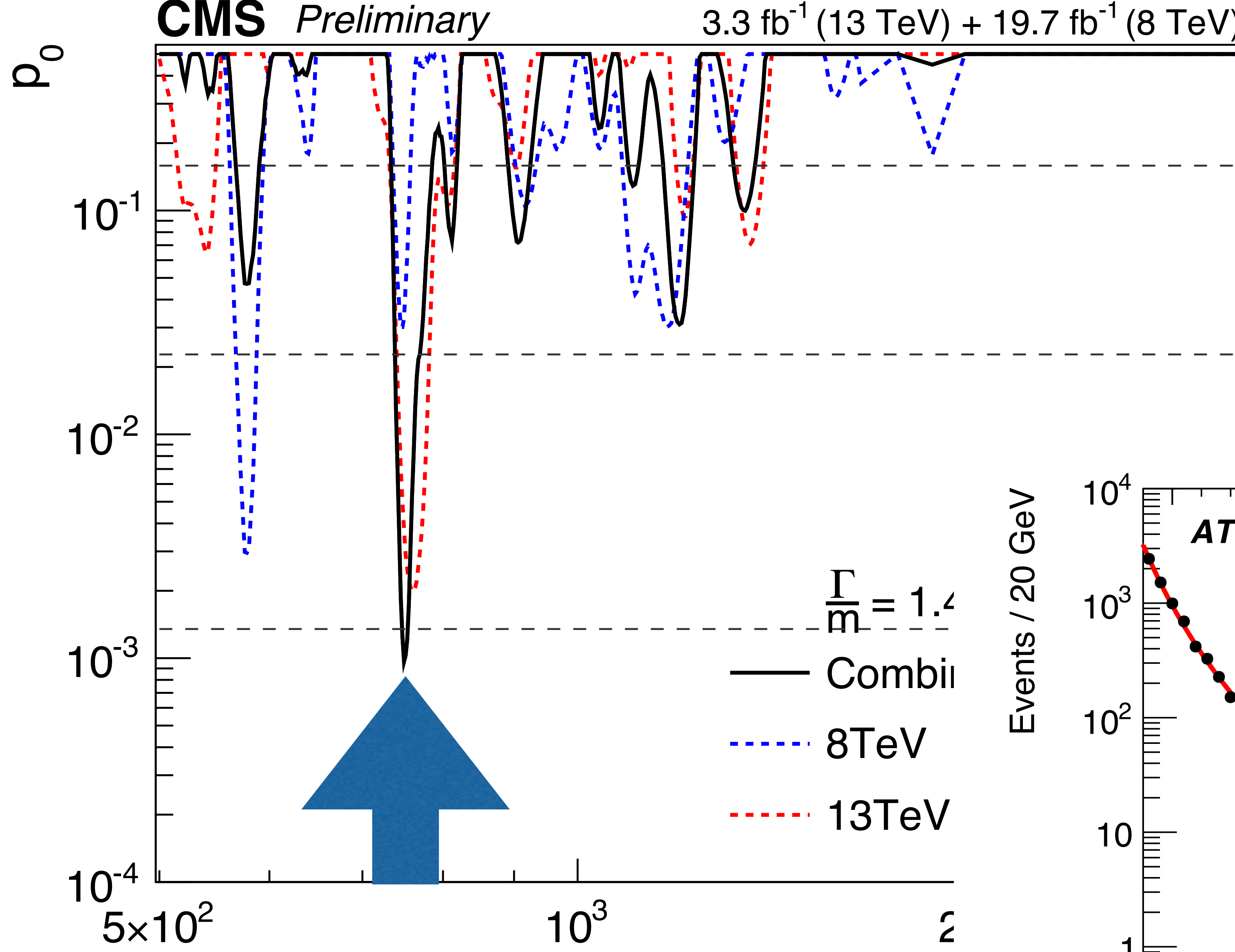


April 2016:
The WA is now
4.0σ from the SM

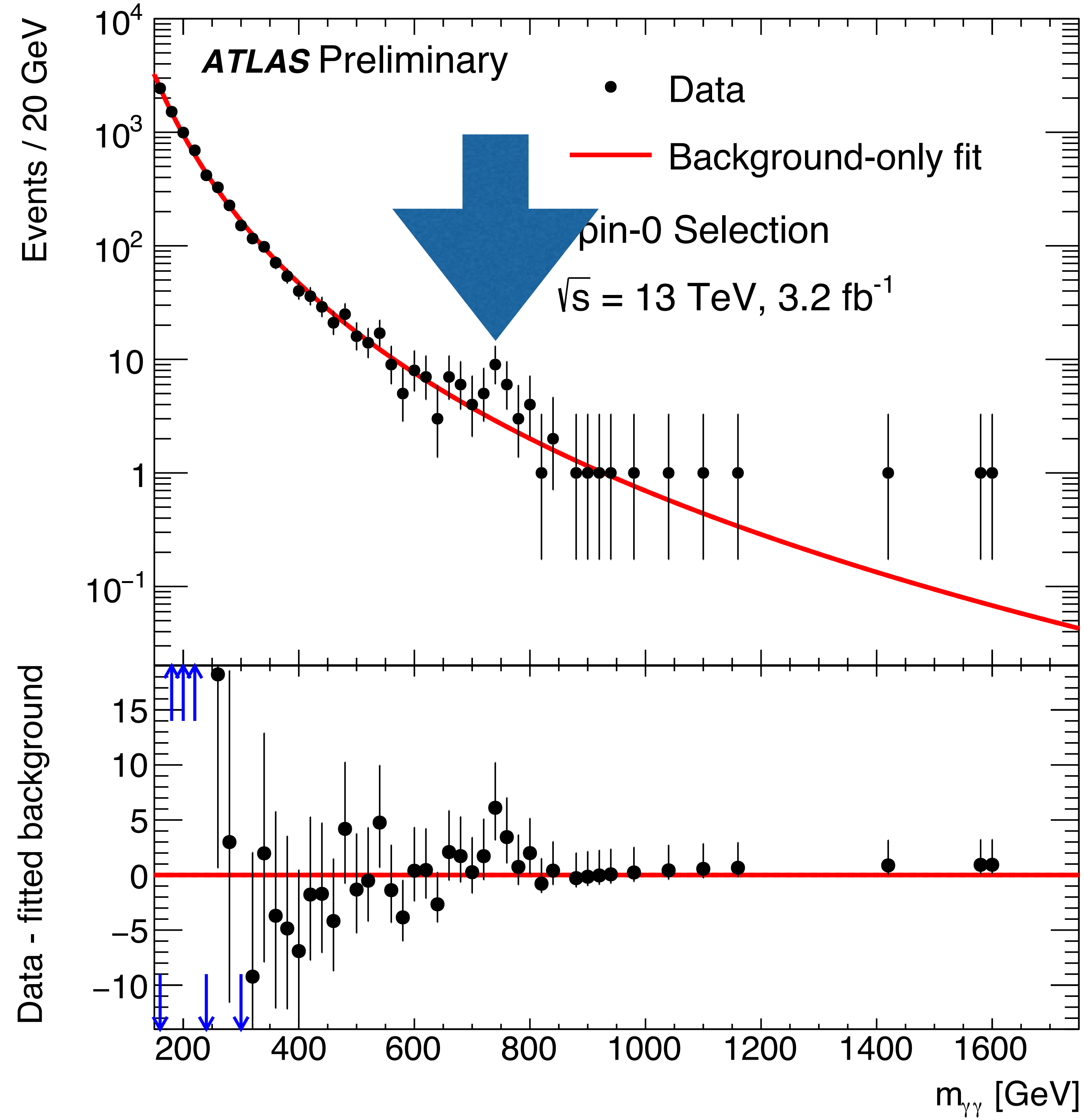


arXIv: 1603.06711

Tom Browder



diphoton resonance
@750 GeV



vector-like fermions?
KK graviton? radion?
compositeness?
extra Higgs?
Who ordered that?

IPEDIA
Encyclopedia

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article
o Wikipedia
a store

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Wikipedia
unity portal
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d changes
d file
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nent link
nformation
ta item

Ambulance chasing

From Wikipedia, the free encyclopedia

Ambulance chasing, sometimes known as **barratry**, refers to a lawyer soliciting for clients at a disaster site. The term "ambulance chasing" comes from the stereotype of lawyers that follow ambulances to the emergency room to find clients.[1]

Description [edit]

Ambulance chasing is prohibited in the US. Such conduct violates Rule 7.3[2] of the American Bar Association Model Rules of Professional Conduct. Some bar associations strongly enforce rules against barratry. For example, the State Bar of California dispatches investigators to large-scale disaster scenes to discourage ambulance chasers, and to catch any who attempt to solicit business from disaster victims at the scene.[3]

Ambulance chasing is also illegal in Australia, in accordance with clauses 20 and 22 of the Legal Profession Regulation of 1987.

Literally following an ambulance to take advantage of its ability to pass red lights can be considered a form of slipstreaming, and is also illegal in many jurisdictions.

See also [edit]

- Personal injury lawyer
- Barratry


38TH INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS
ICHEP
2016CHICAGO
AUGUST 3-10, 2016
AT SHERATON GRAND CHICAGO
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ABSTRACT SUBMISSION THROUGH FEB. 7, 2016
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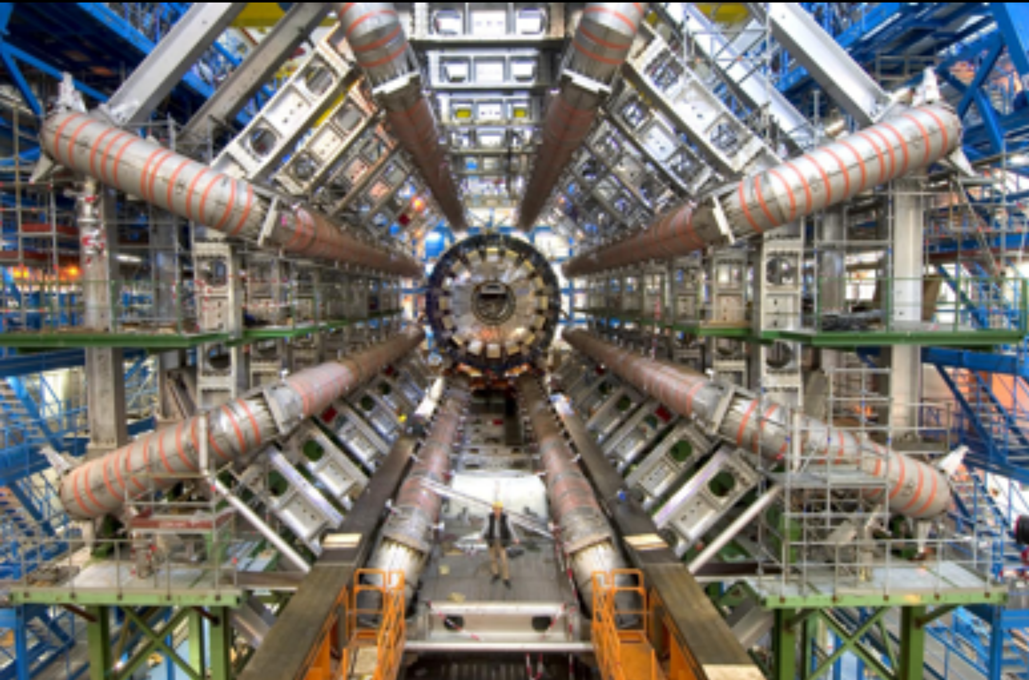
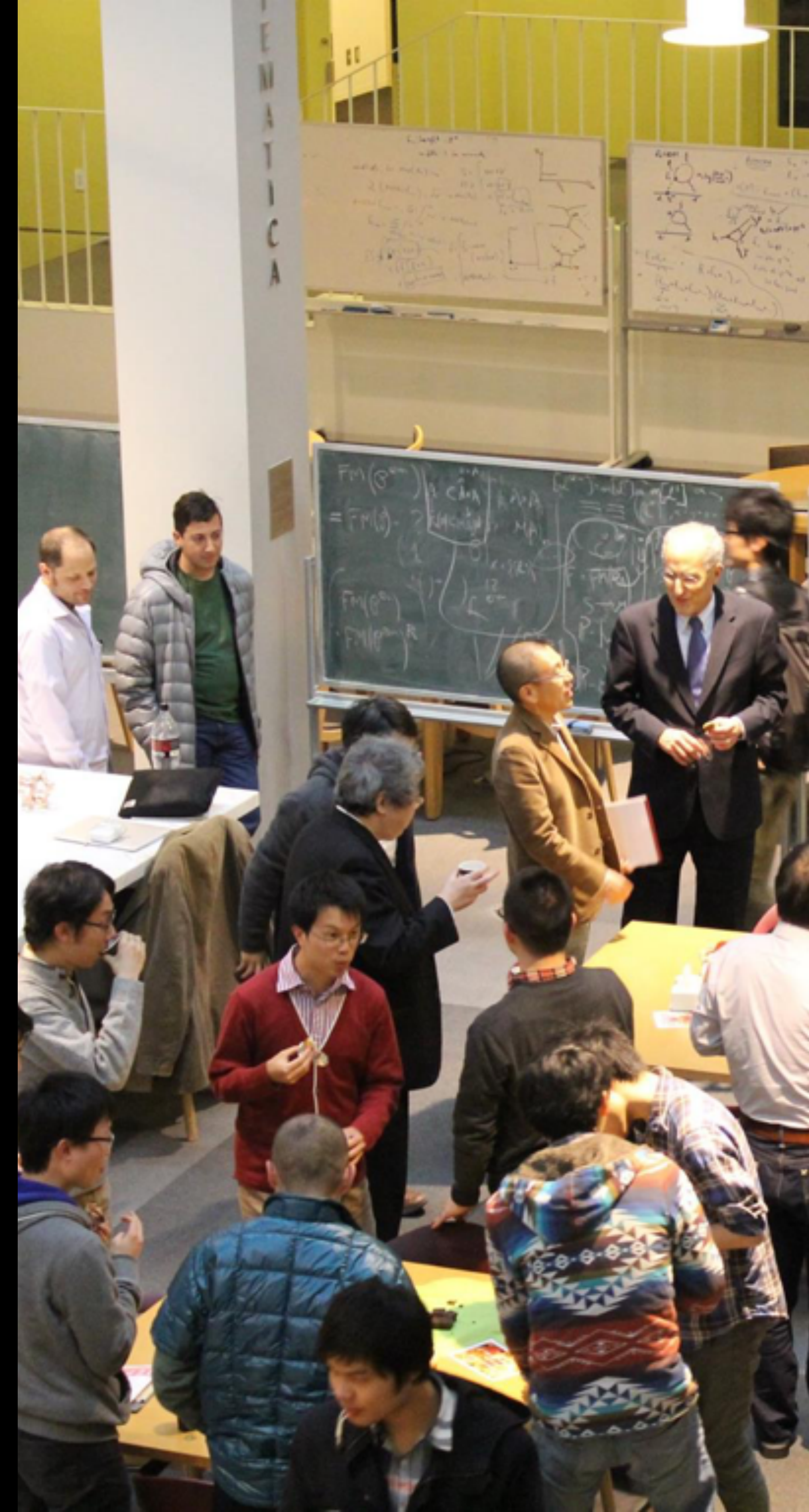
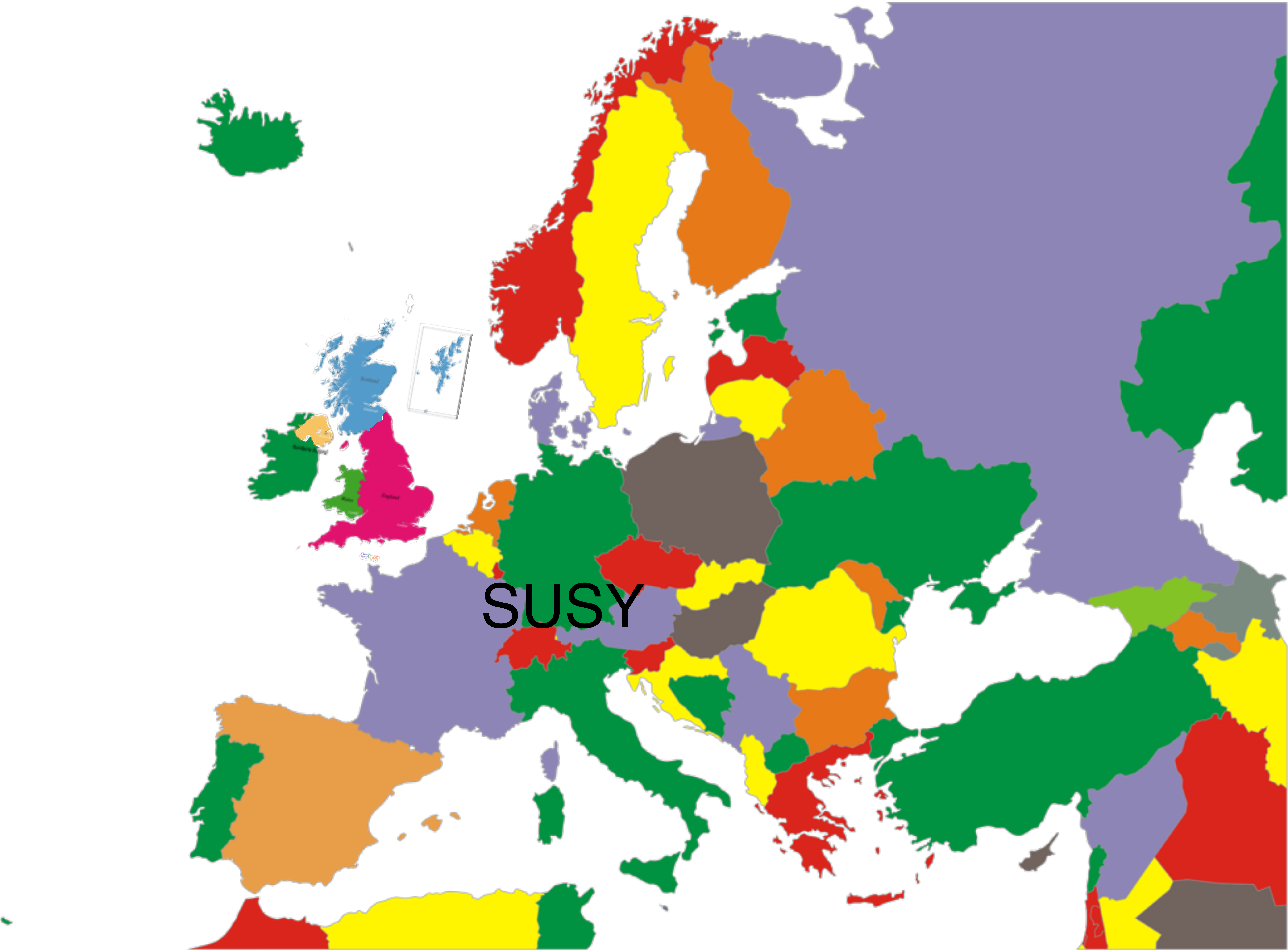
VISHNU ZUTSHI, NORTHERN ILLINOIS UNIVERSITY



SUSY

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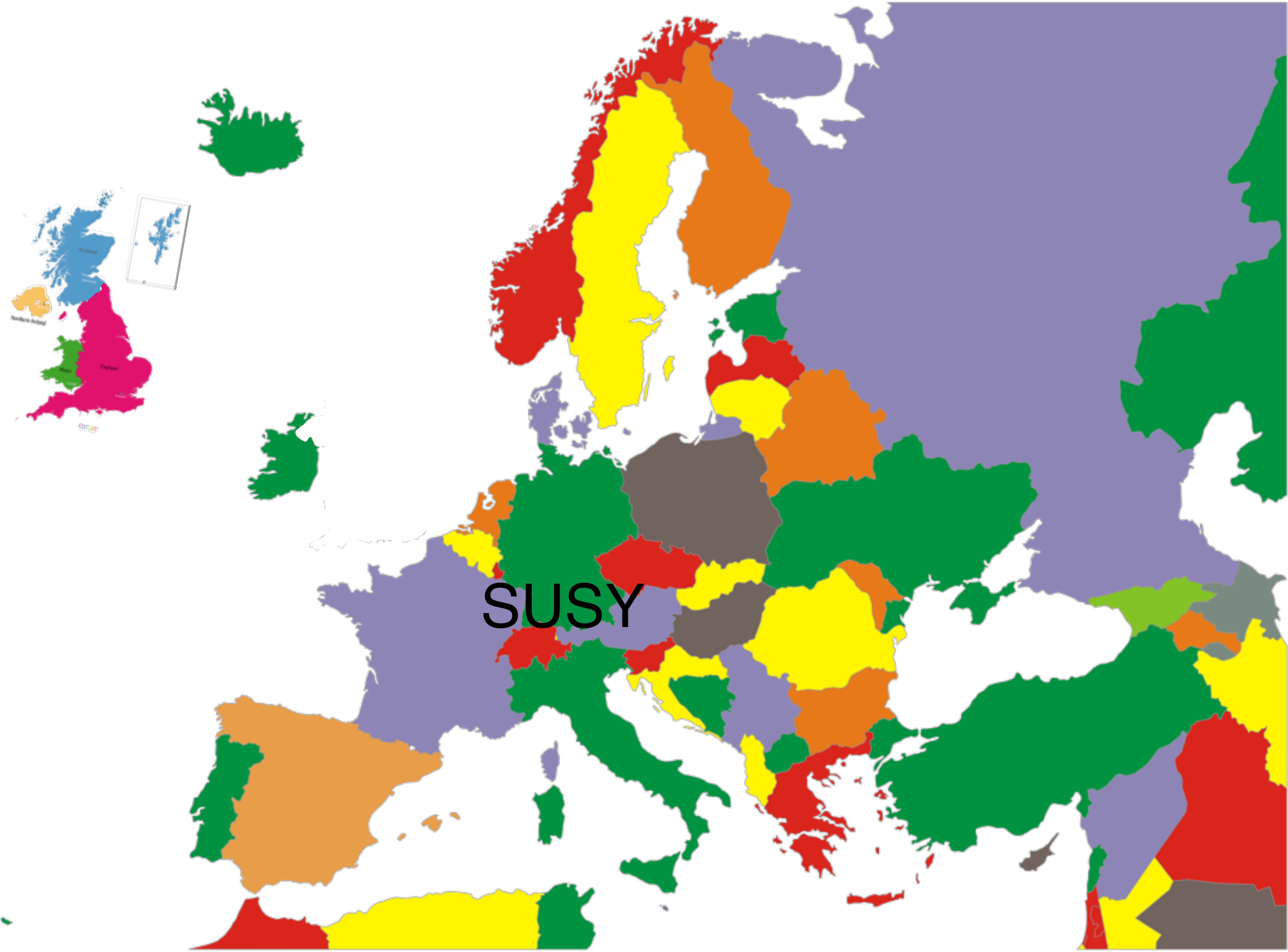
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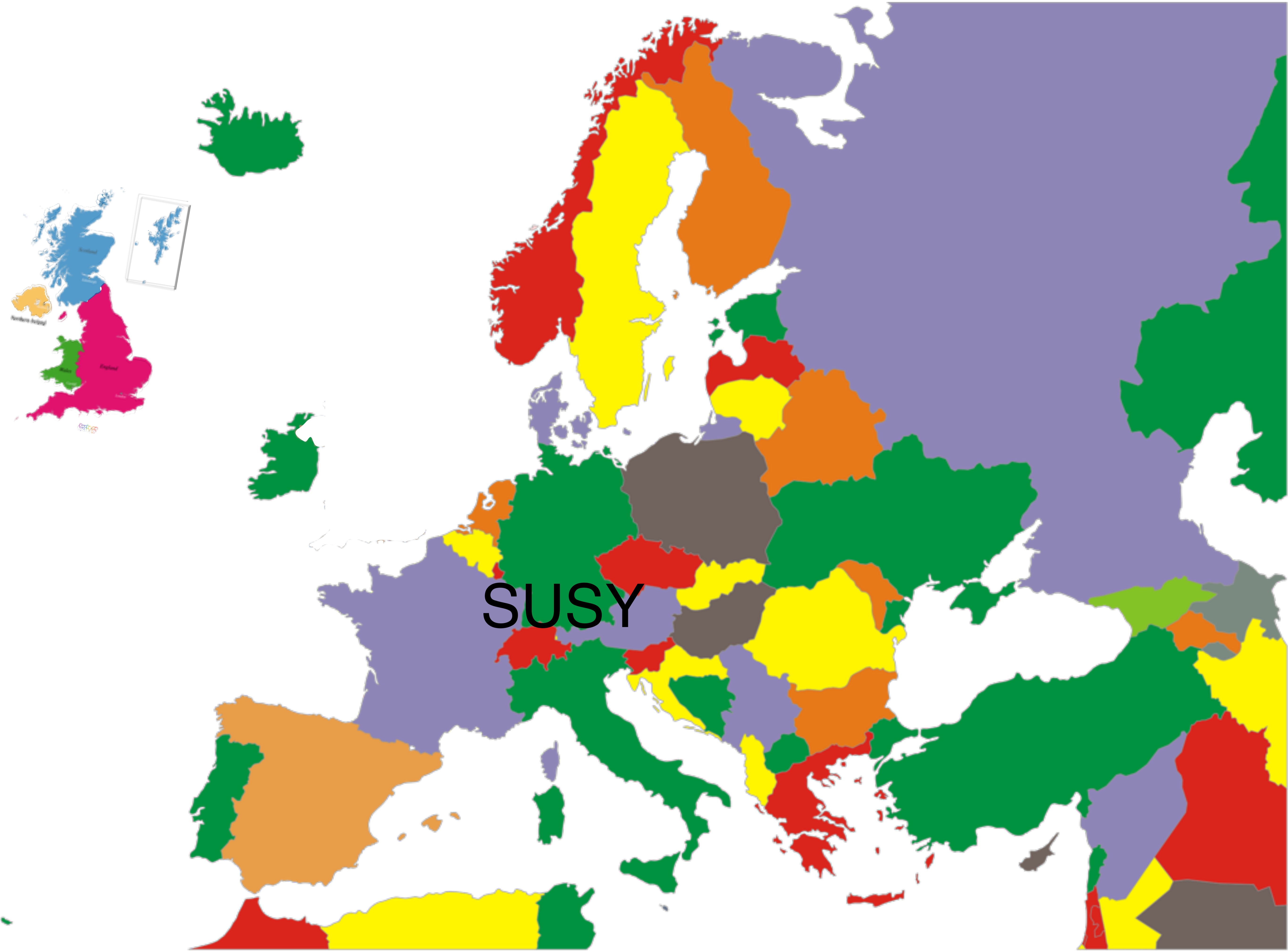
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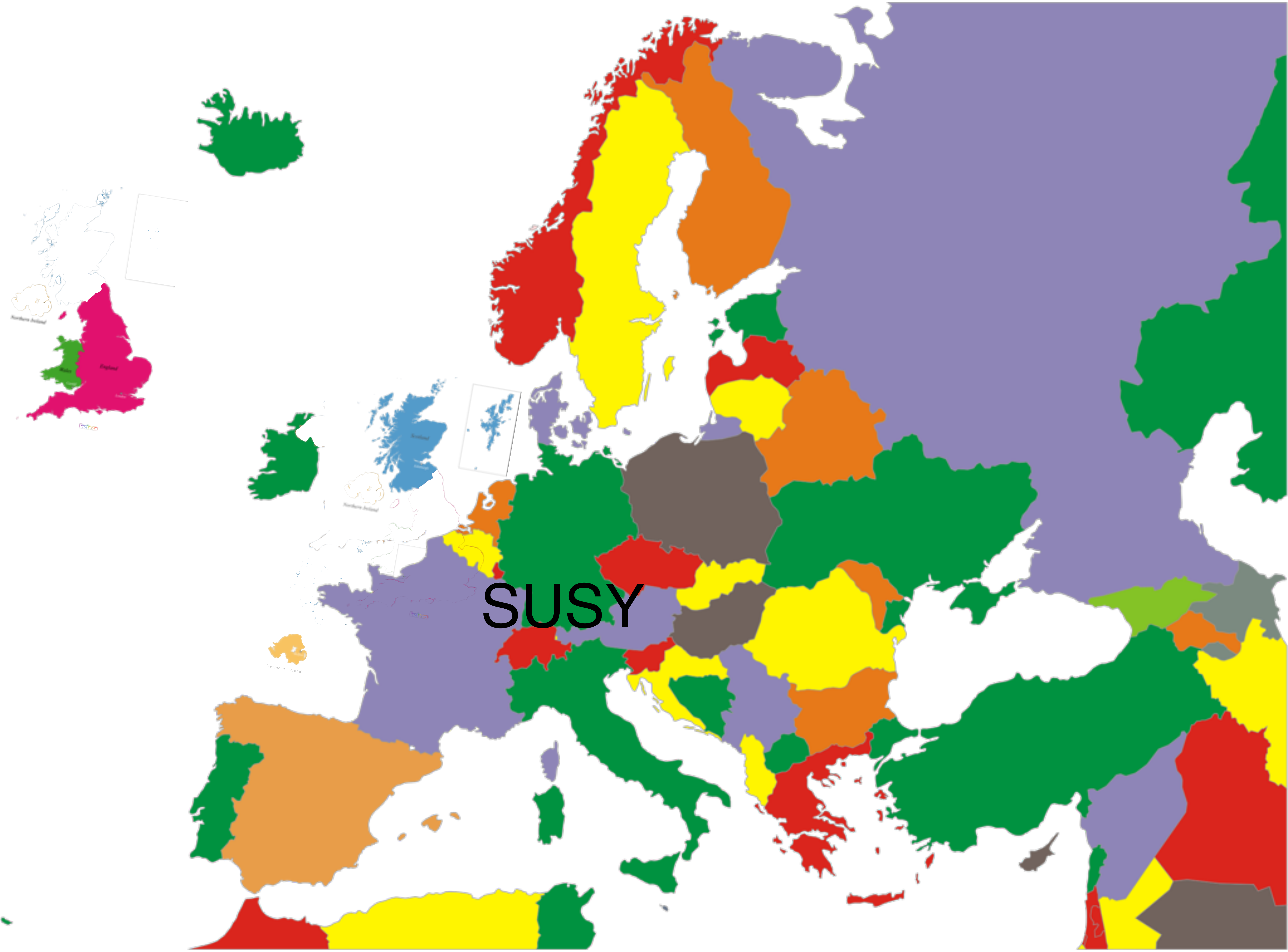
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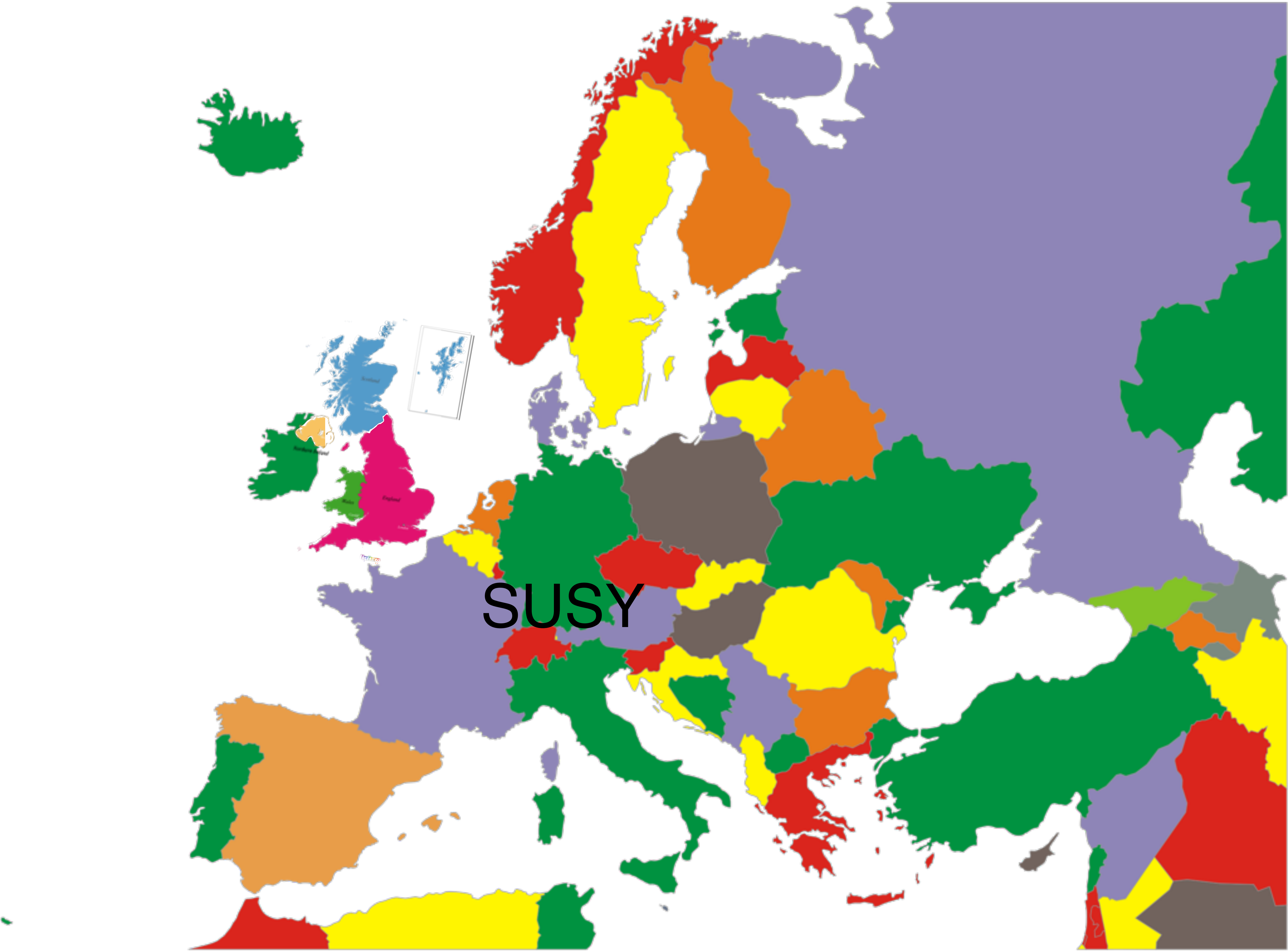
SUSY

The New York Times

July 23, 2020

The Other Half of the Universe Discovered

Geneva, Switzerland

SUSY 2036

SUSY 2036

Hilary Clinton
Lunar Station