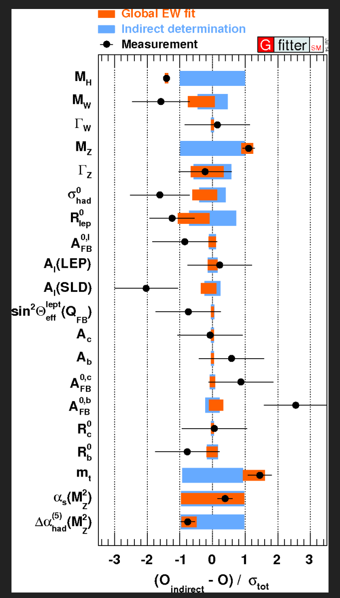
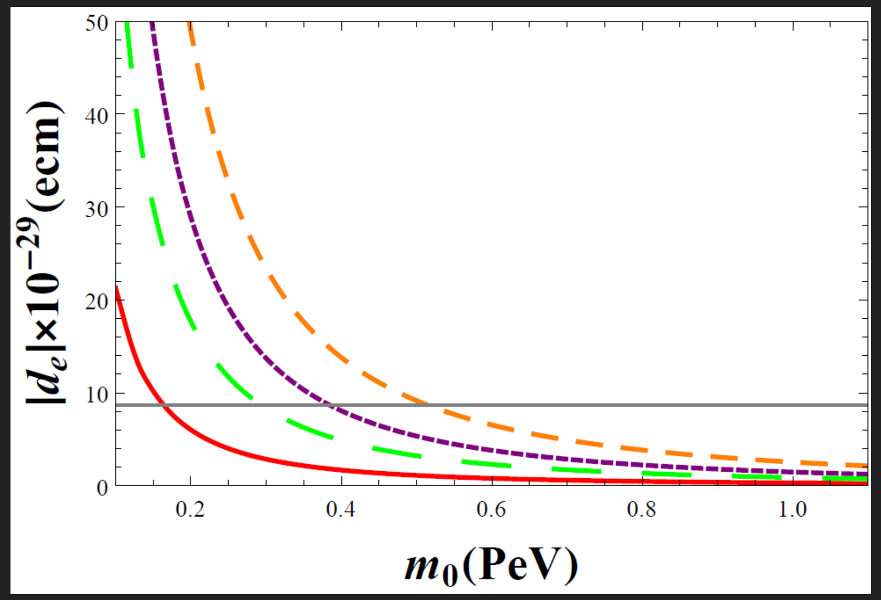
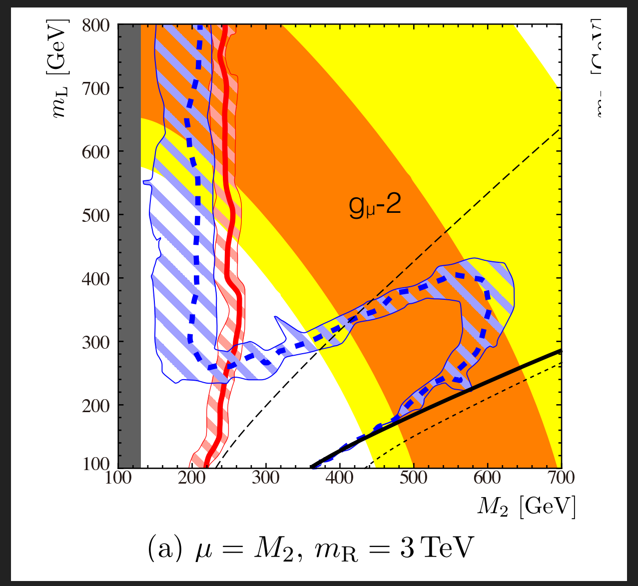
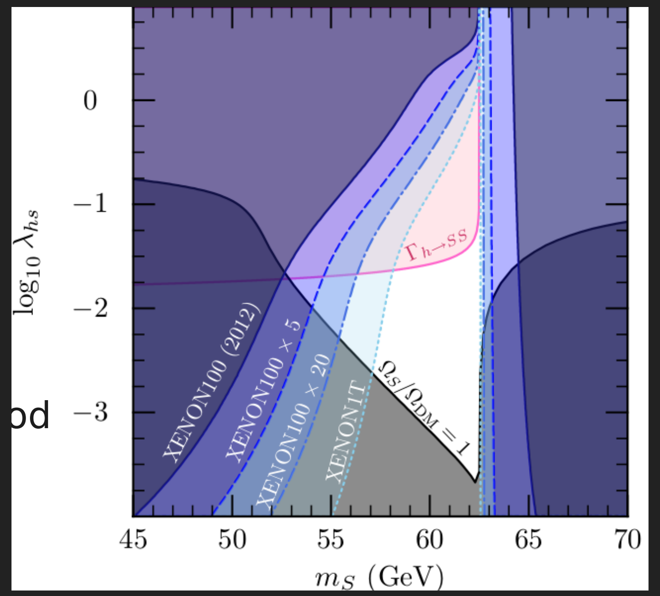
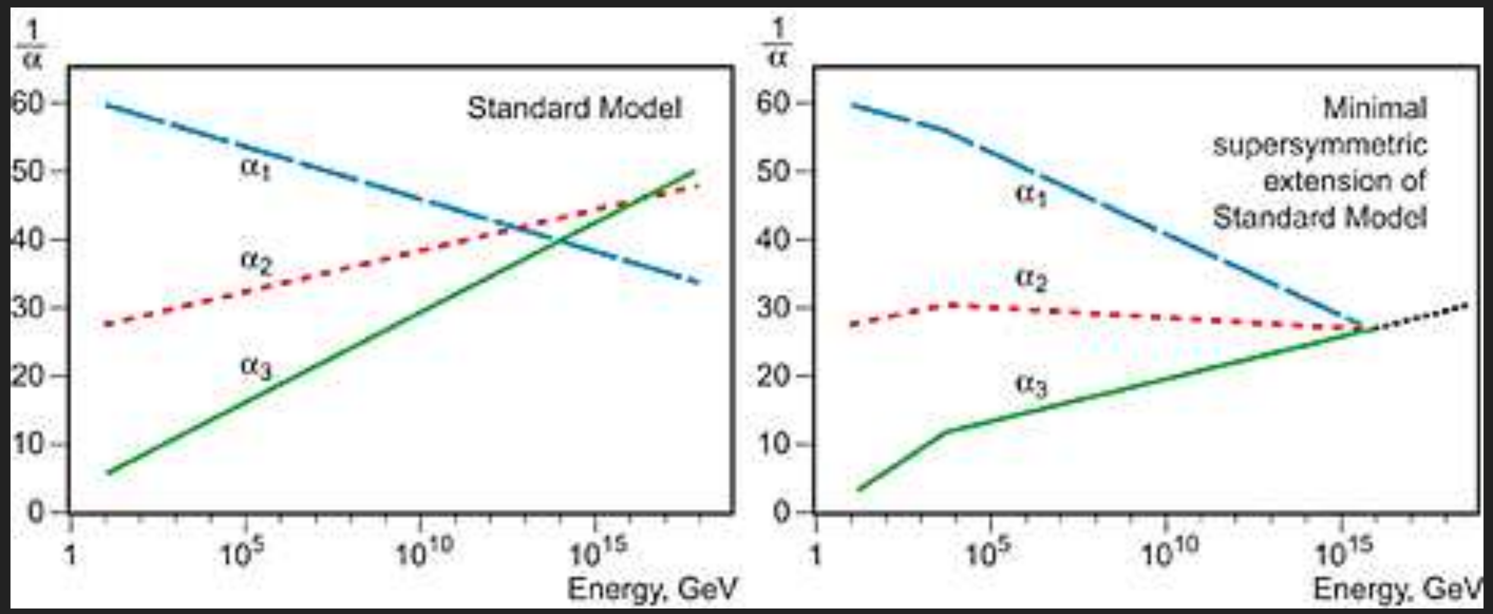
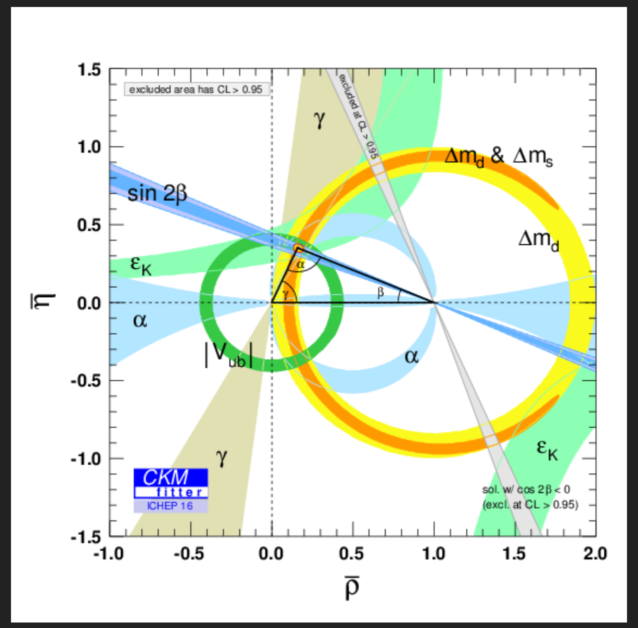


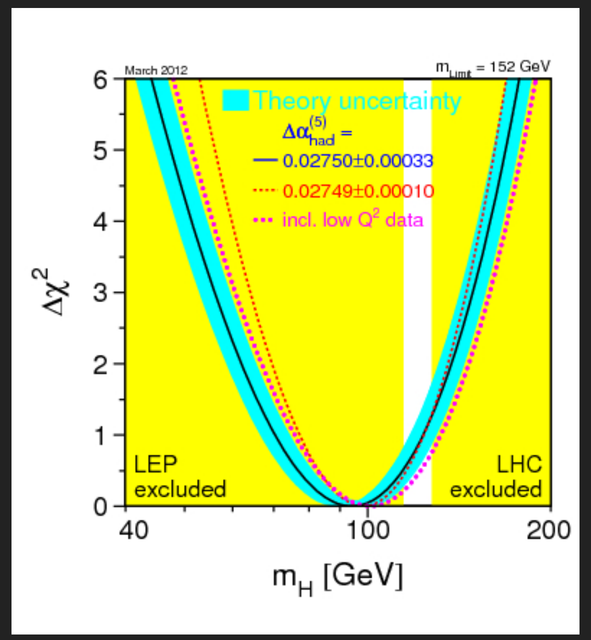


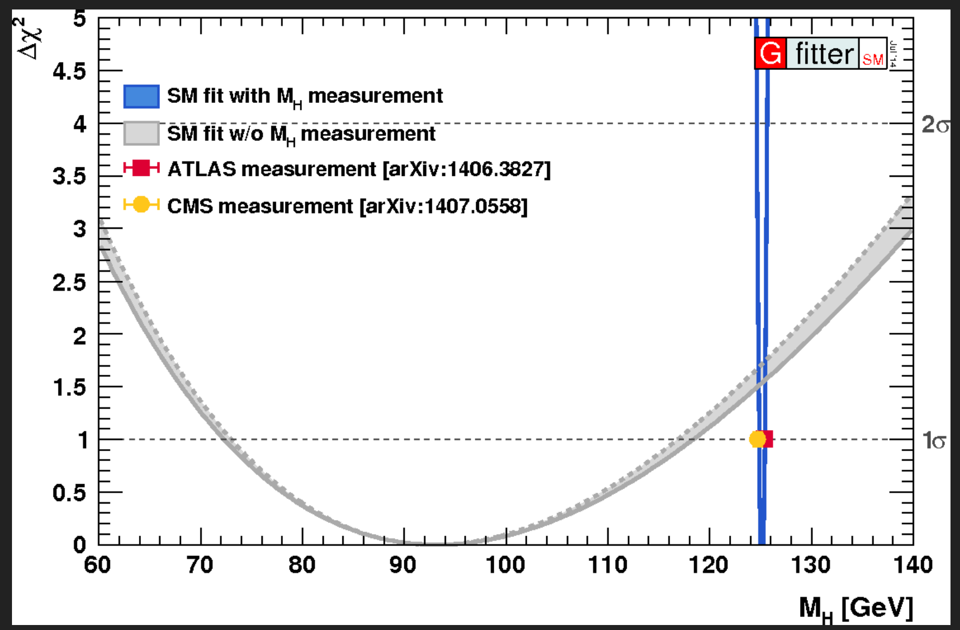


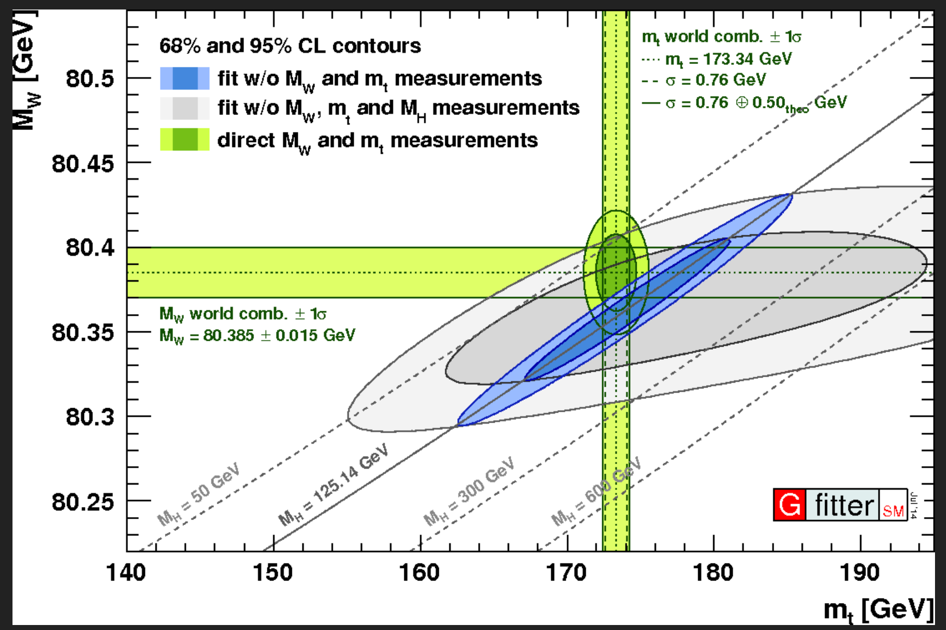


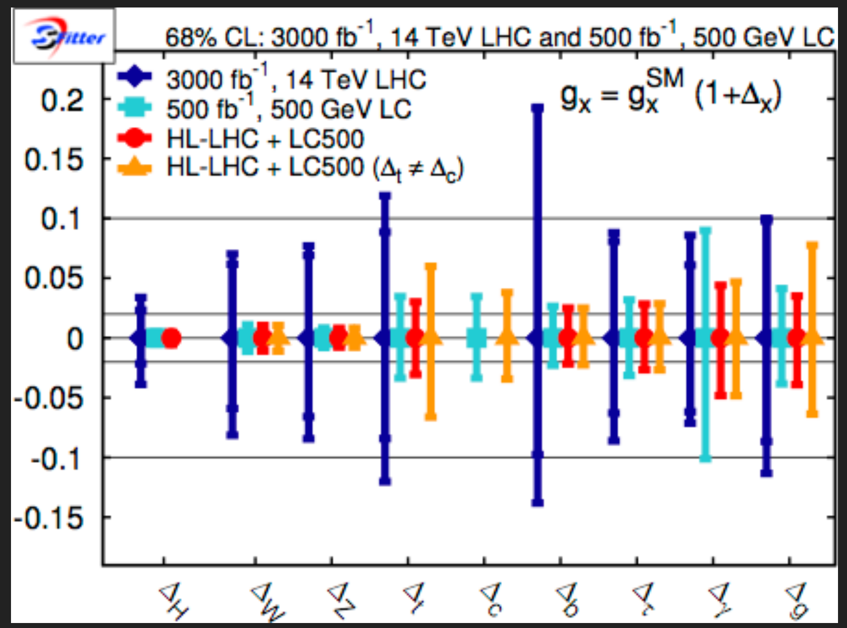


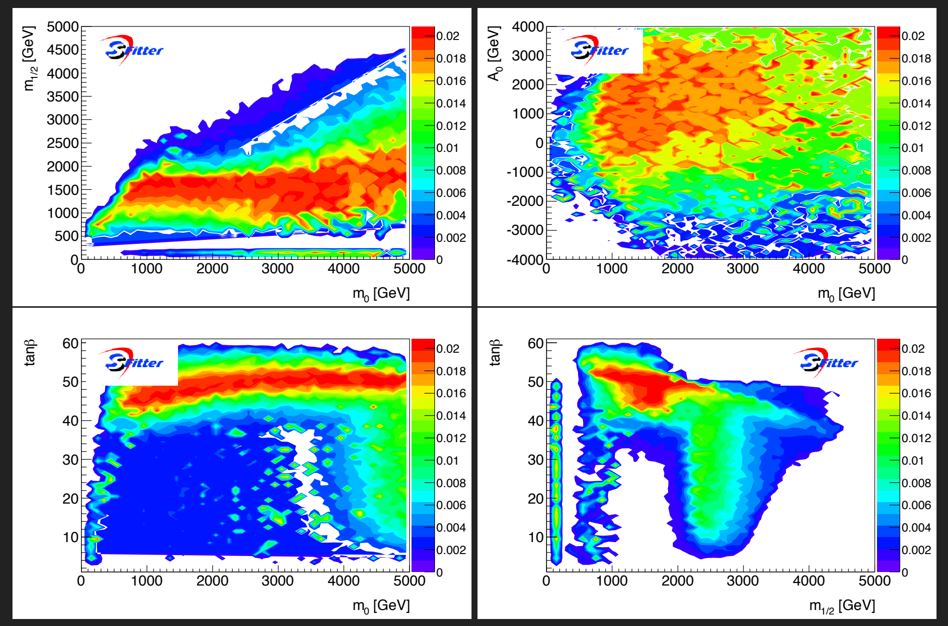






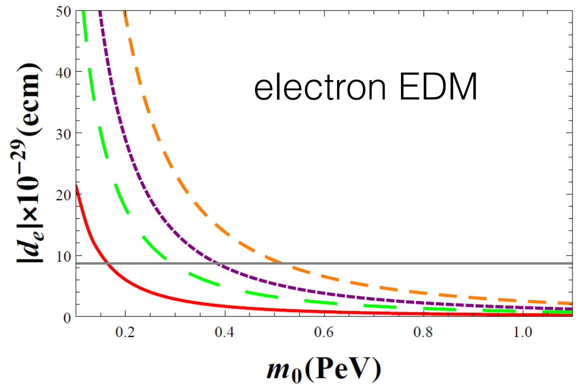


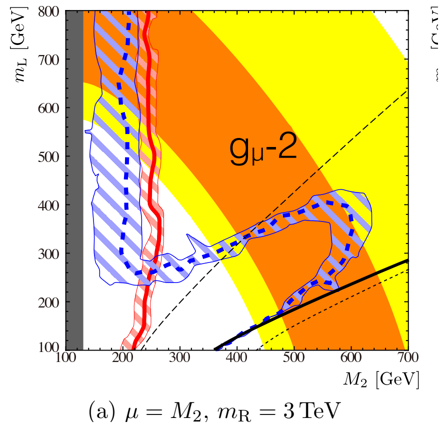


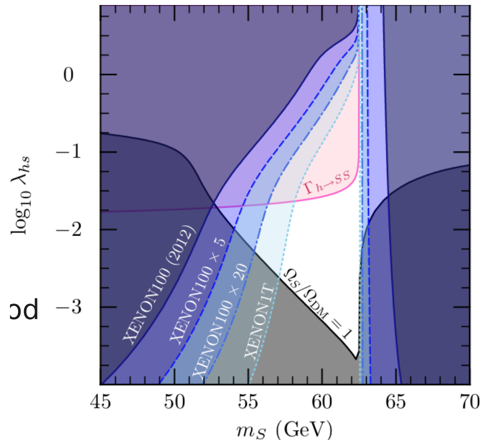


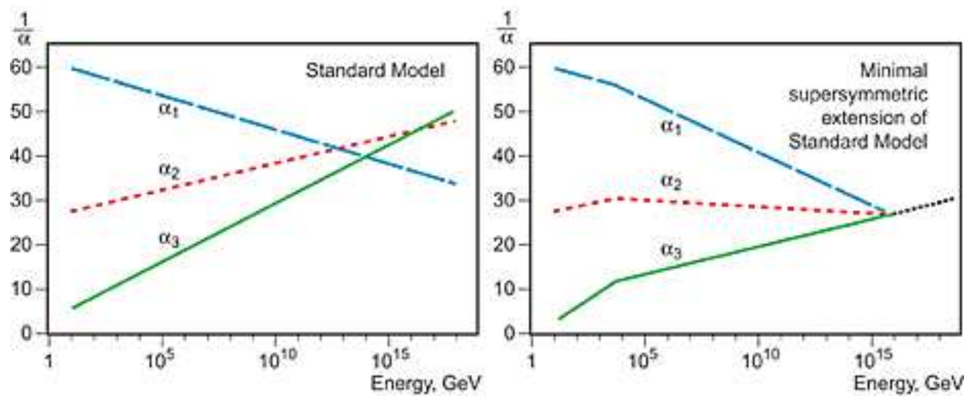
NIKHEF JAMBOREE 2017

GLOBAL (BEYOND) STANDARD MODEL ANALYSES









<u>Examples</u>:

Cosmology/CMB:	relic density
Dark Matter:	direct+indirect limits (detection)
Collider:	Higgs, (SUSY) Searches,
SM precision:	$\sin^2\theta_W$, M_W, alpha_s, delta rho
Flavour:	CKM, rare decays
Dedicated Precision:	EDM, g-2

Global Fits to HEP Data

- Why:

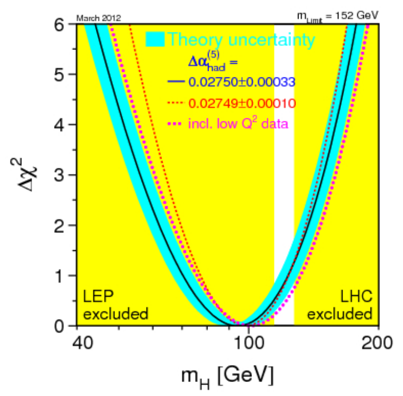
"Direct" NP observation?

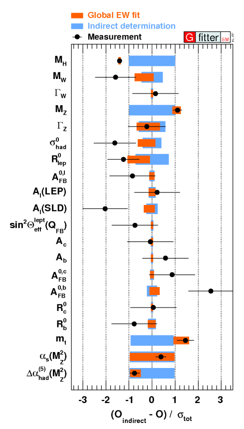
yes → Global fits required to get full picture

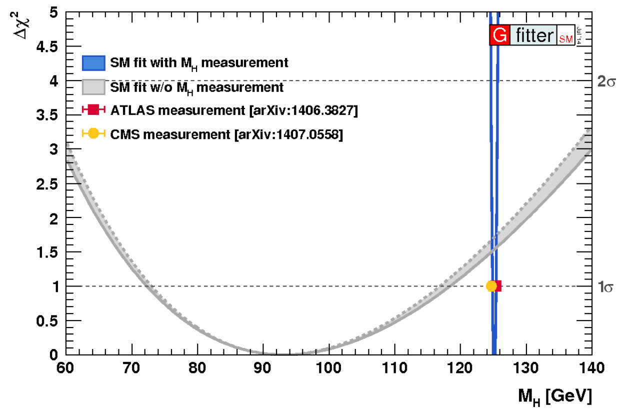
no →
- Global fits will be the first (only!) place to recognize new physics.
- Guides selection of most relevant measurements & models to pursue

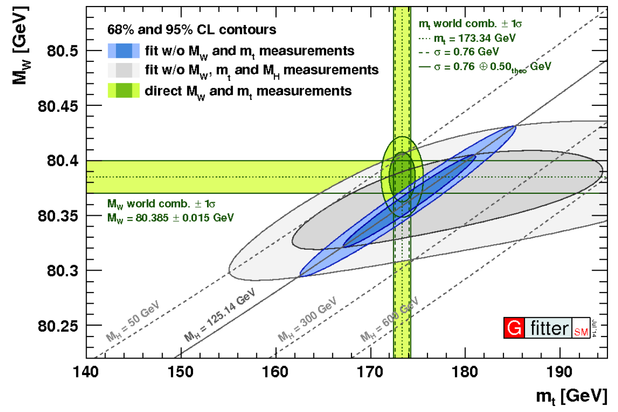
- Don't leave it to others to draw conclusions from our measurements.

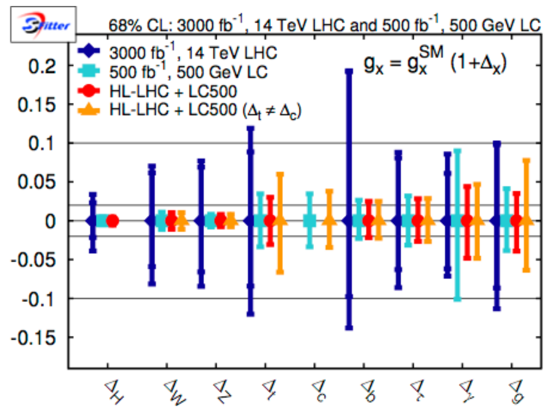
- Strength: present in many relevant experiments, can influence measurements strategy / delivery, have early access; theory/experiment/statistics expertise 'in house'
- Weakness: not (currently) member of one of the existing 'global combination' projects
- Opportunity: synergy across Nikhef programs, informs future strategy, future combinations will increase complexity, playing into our strengths
- Threat: many x small fraction of FTE = 0 impact

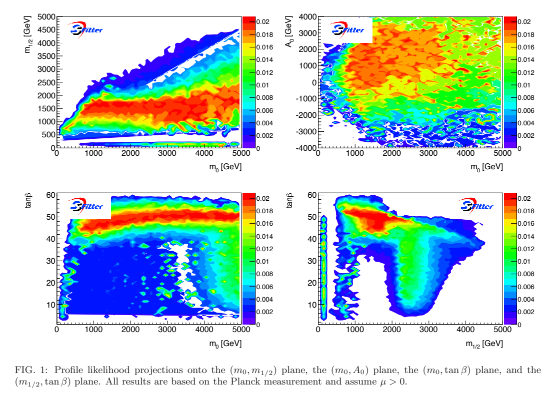


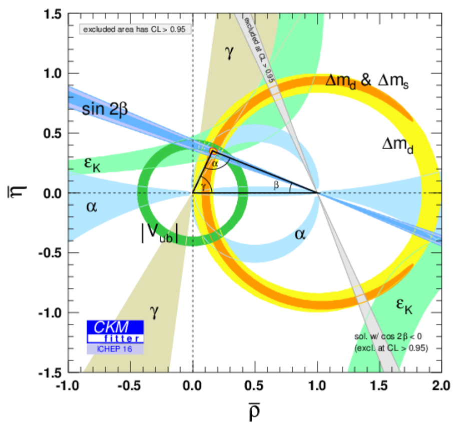










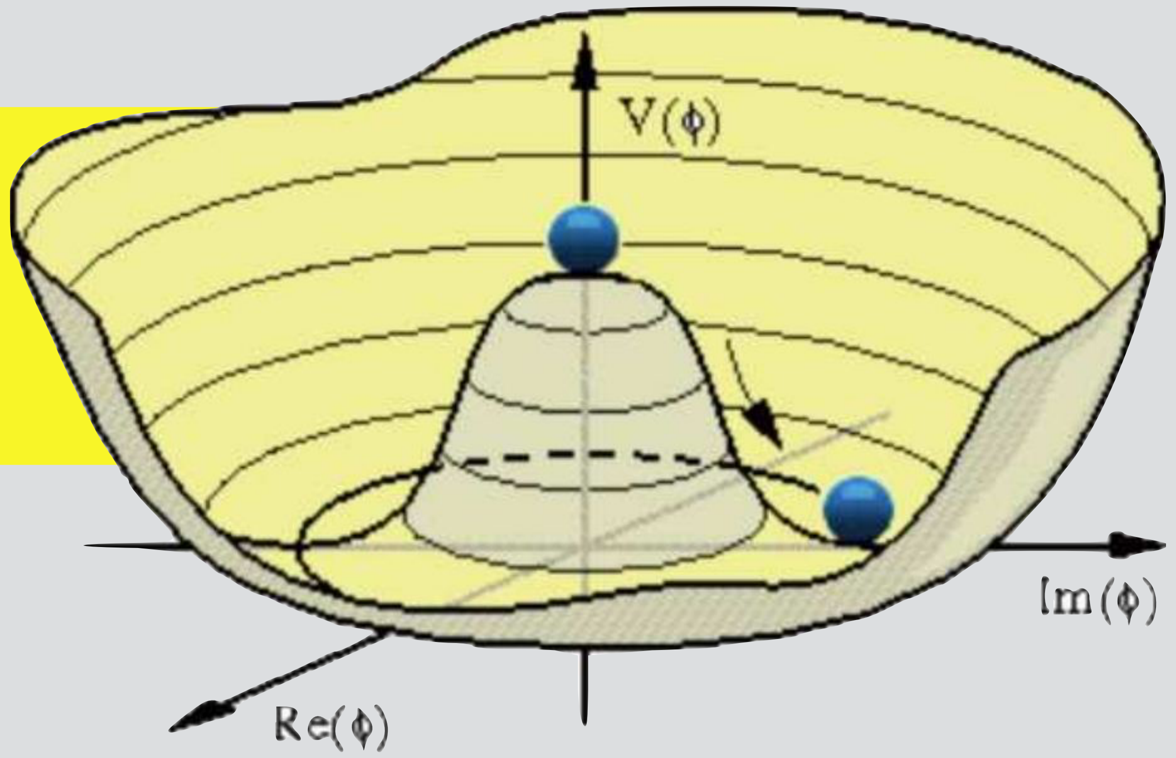


Nikhef

Beyond the Standard Model

After Higgs - fundamentally new challenges !

$$V_{Higgs} = V_0 - \mu^2\phi^\dagger\phi + \lambda\left(\phi^\dagger\phi\right)^2 + \left[\bar{\psi}Y\psi\phi + h.c.\right]$$



Large energy in vacuum:
Cosmological constant?

Large quantum corrections
Origin of Dark Matter?

Higgs self coupling:
Is our universum stable?

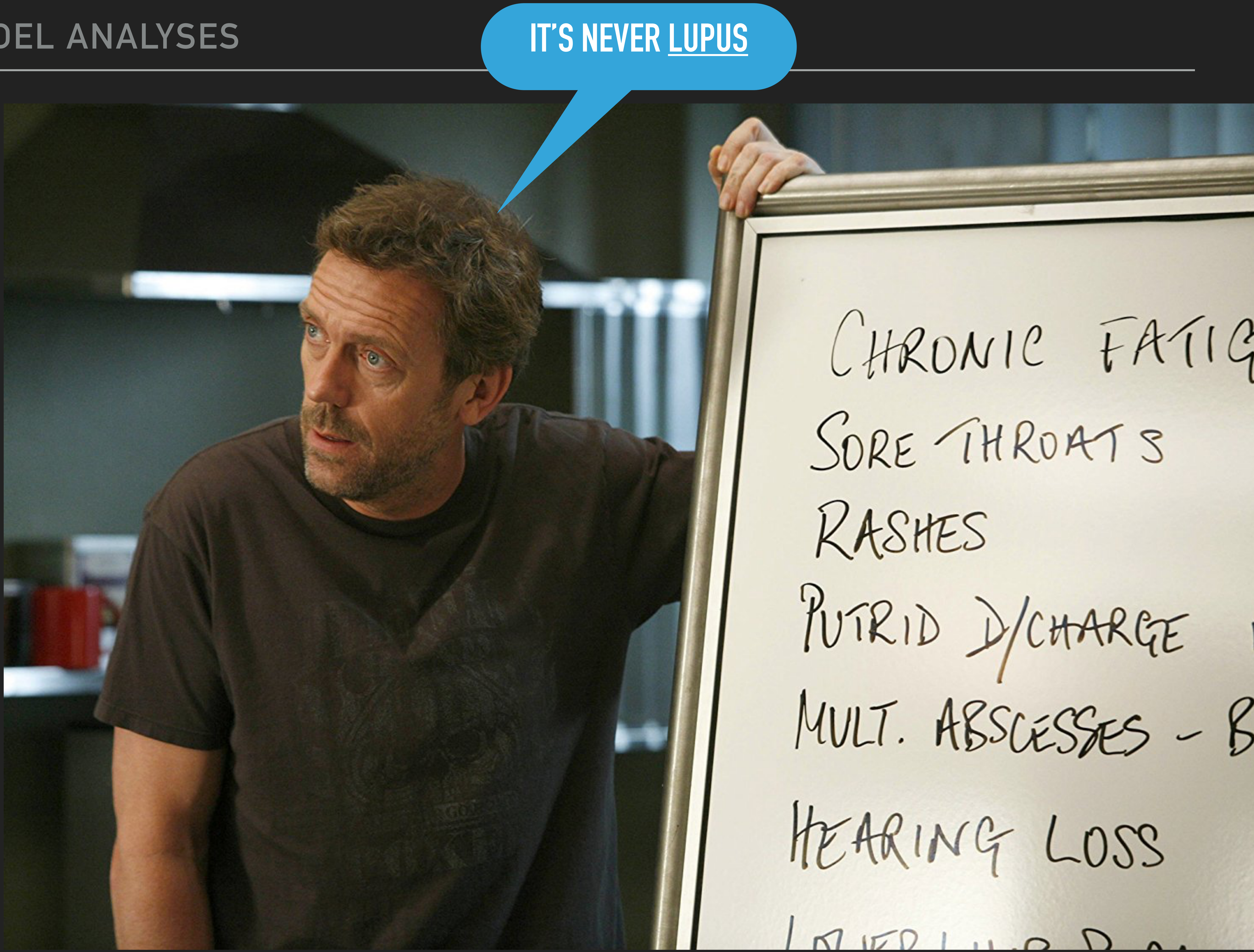
Higgs mass for particles:
Difference matter-anti-matter?
Mass of neutrino's?

Strategy Nikhef

1. ***High precision measurements - signal deviations Standard Model***
2. ***Higher energies - produce new heavier particles***
3. ***Astroparticle physics - observe (new) particles from universe***

DIFFERENTIAL DIAGNOSIS

- Differential diagnosis is the initial set of possible diagnoses prior to settling on a series of tests for a definitive diagnosis.
- In the differential, all diseases that cause the symptoms seen in the patient are considered.



IT'S NEVER A SCALAR LEPTOQUARK

DIFFERENTIAL DIAGNOSIS

- Differential diagnosis is the initial set of possible diagnoses prior to settling on a series of tests for a definitive diagnosis.
- In the differential, all diseases that cause the symptoms seen in the patient are considered.

FLAVOR PHYSICS

- Niels: 2015...

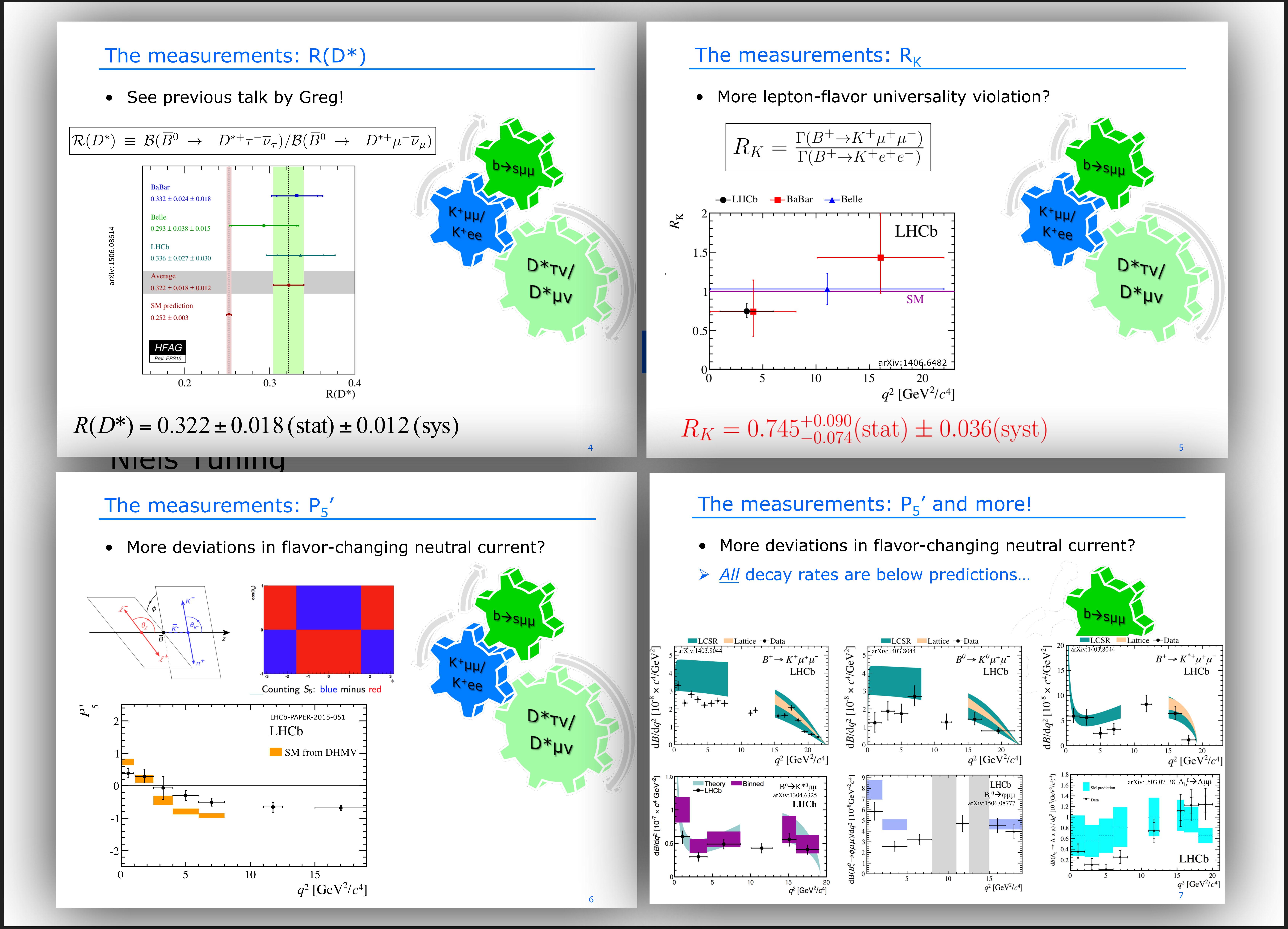
Tensions in flavor physics?

Niels Tuning

12 Dec 2015

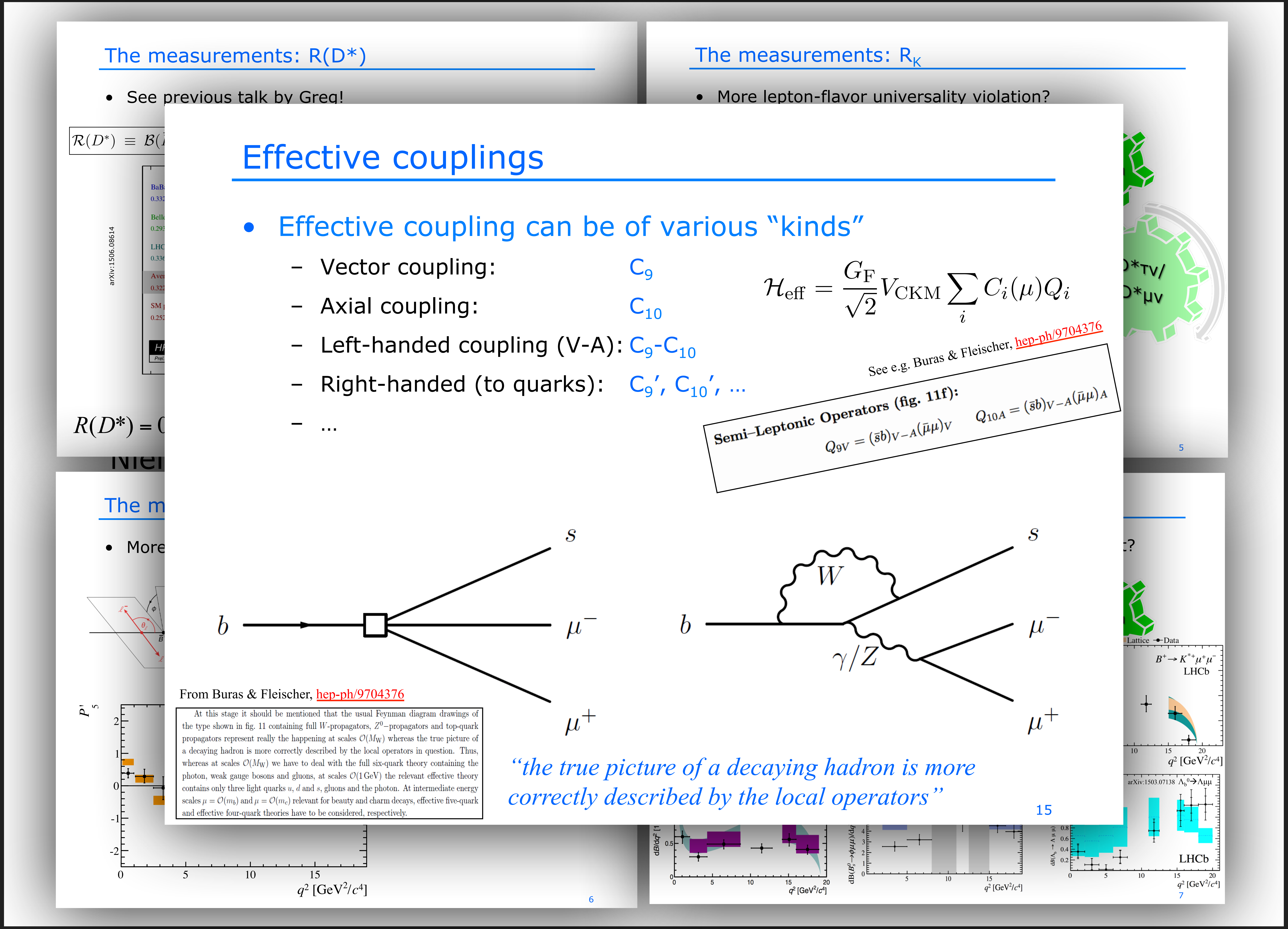
FLAVOR PHYSICS

- Niels: 2015…



FLAVOR PHYSICS

- Niels: 2015…
  - Effective Field Theory is the ‘lingua fracta’ connecting measurements & models
  - C_9 seems to be the common deviation
  - Is it a Z′?
  - Is it a scalar/vector leptoquark?



FLAVOR PHYSICS

- Niels: 2015…
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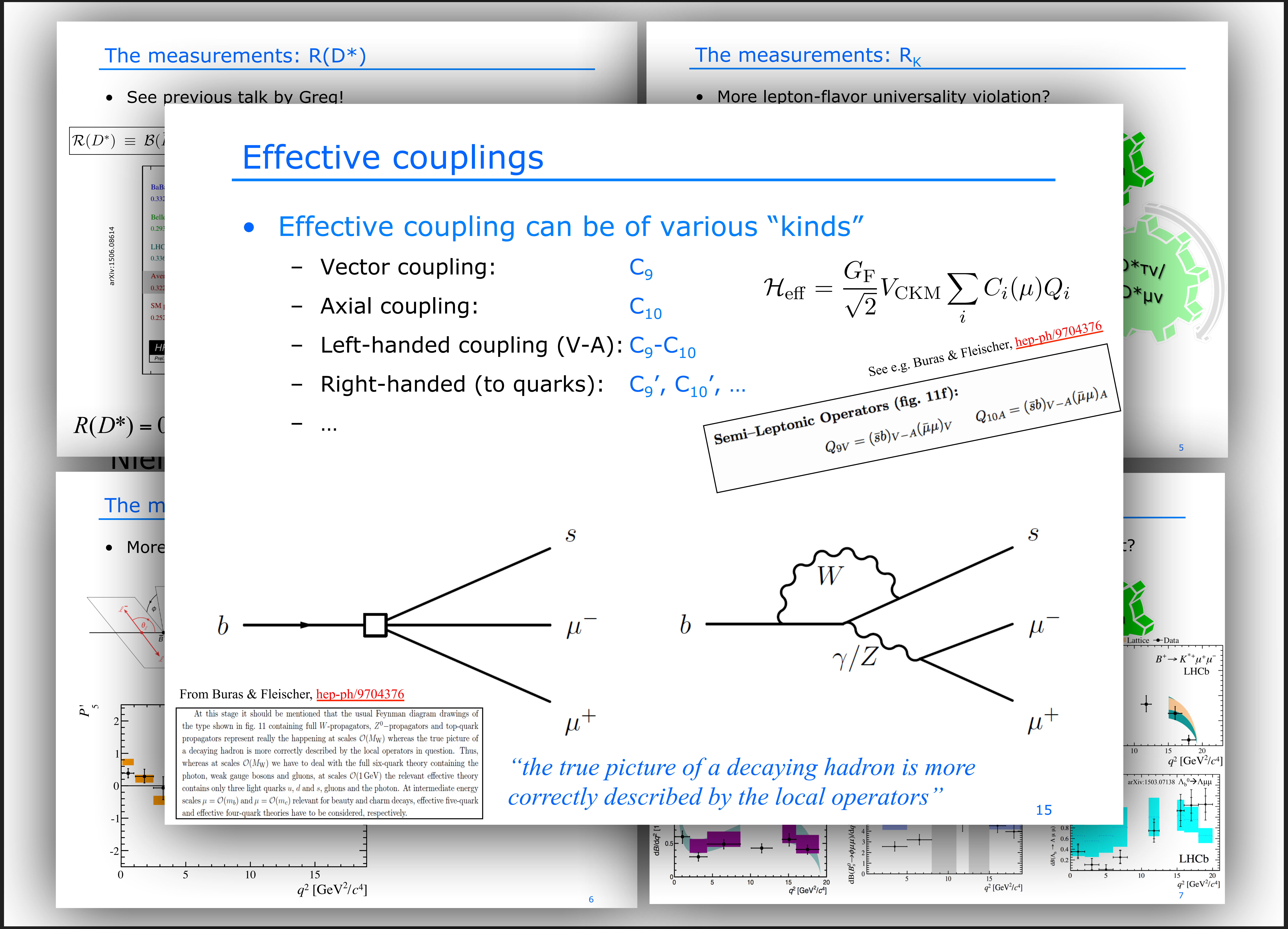
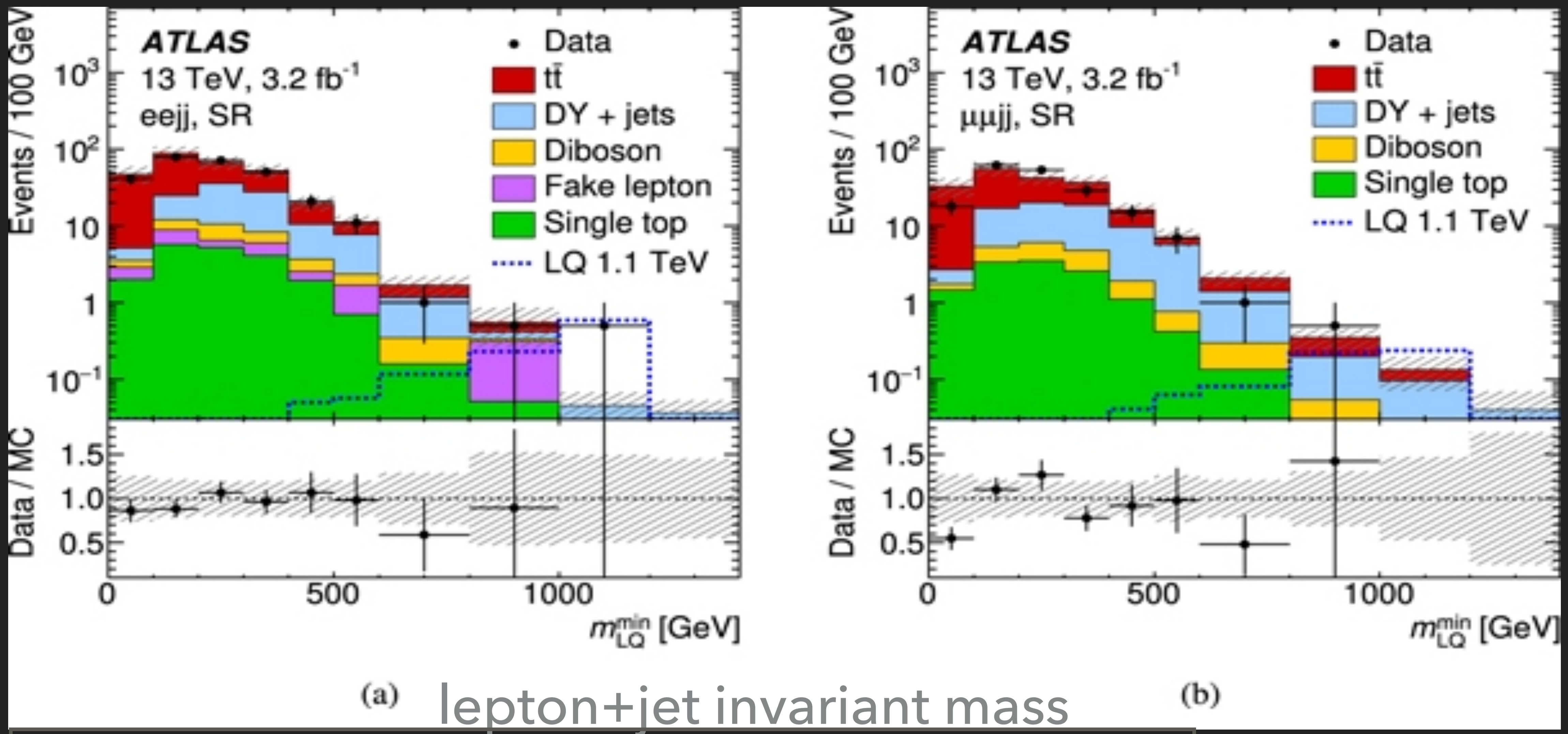
  - C_9 seems to be the common deviation
  - Is it a Z′?
  - Is it a scalar/vector leptoquark?
- … tomorrow: Mick

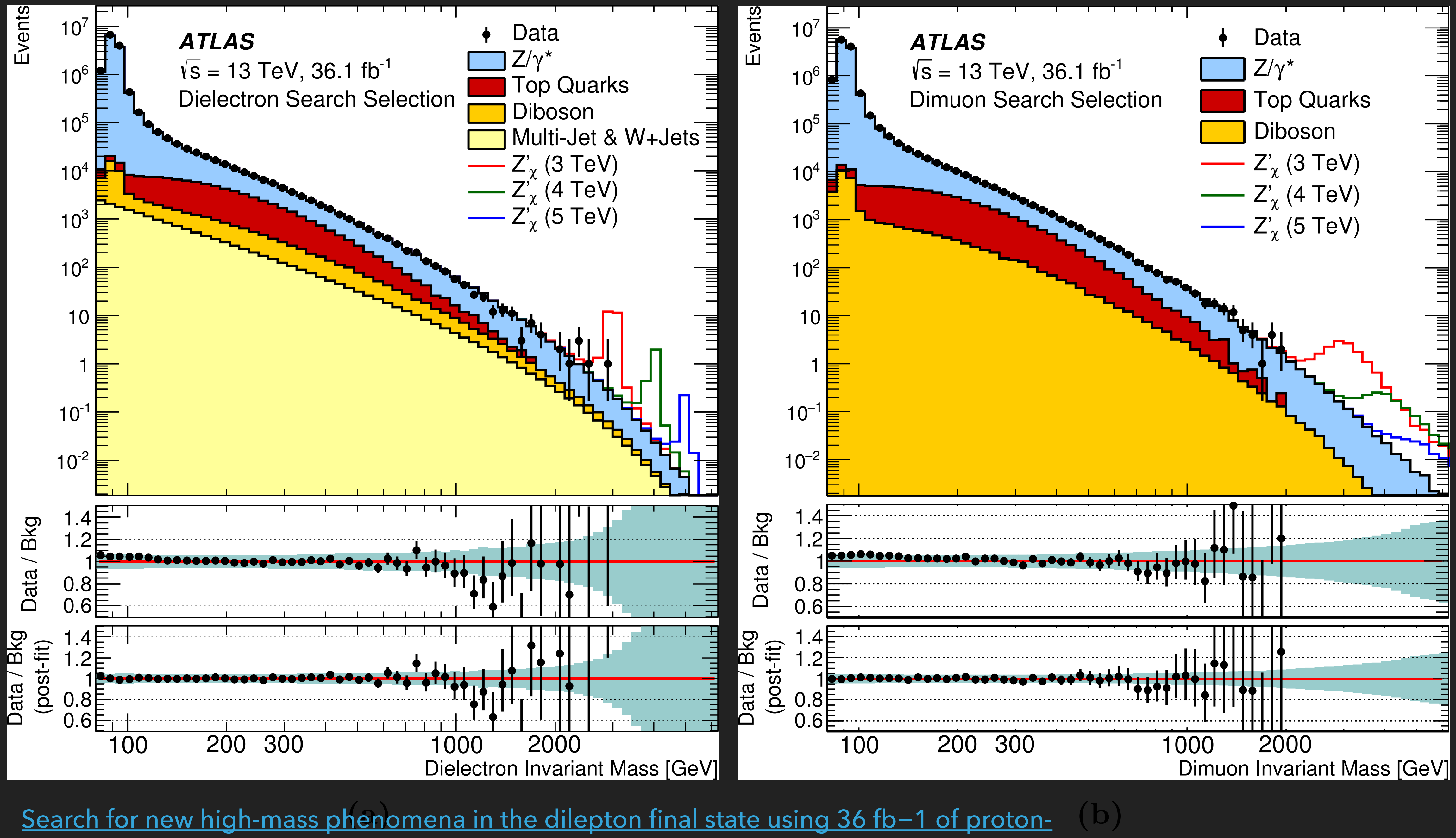


DIRECT LEPTOQUARK / Z' SEARCHES

- Atlas LQ search:
  - assuming "some small print" (eg. 100% br to e/μ + q; scalar):
  - M(LQ) > ~1.1 (e)/ 1.0 (μ) TeV @ 95 CL
- Atlas Z' search
  - assuming "some small print" (eg. $E_6 \rightarrow SO(10)xU(1)$, $SO(10) \rightarrow SU(4)xSU(2)_L xSU(2)_R$ or $SU(5)xU(1)$):
  - $M(Z'_X)$>4.1 TeV @ 95%CL
- Assumptions matter when designing/interpreting an analysis…



Search for scalar leptoquarks in pp collisions at = 13 TeV with the ATLAS experiment



Search for new high-mass phenomena in the dilepton final state using 36 fb−1 of proton-proton collision data at √s = 13 TeV with the ATLAS detector

ASSUMPTIONS (CAN BE) REVISITED

- Experiments (start to) publish more than just the results

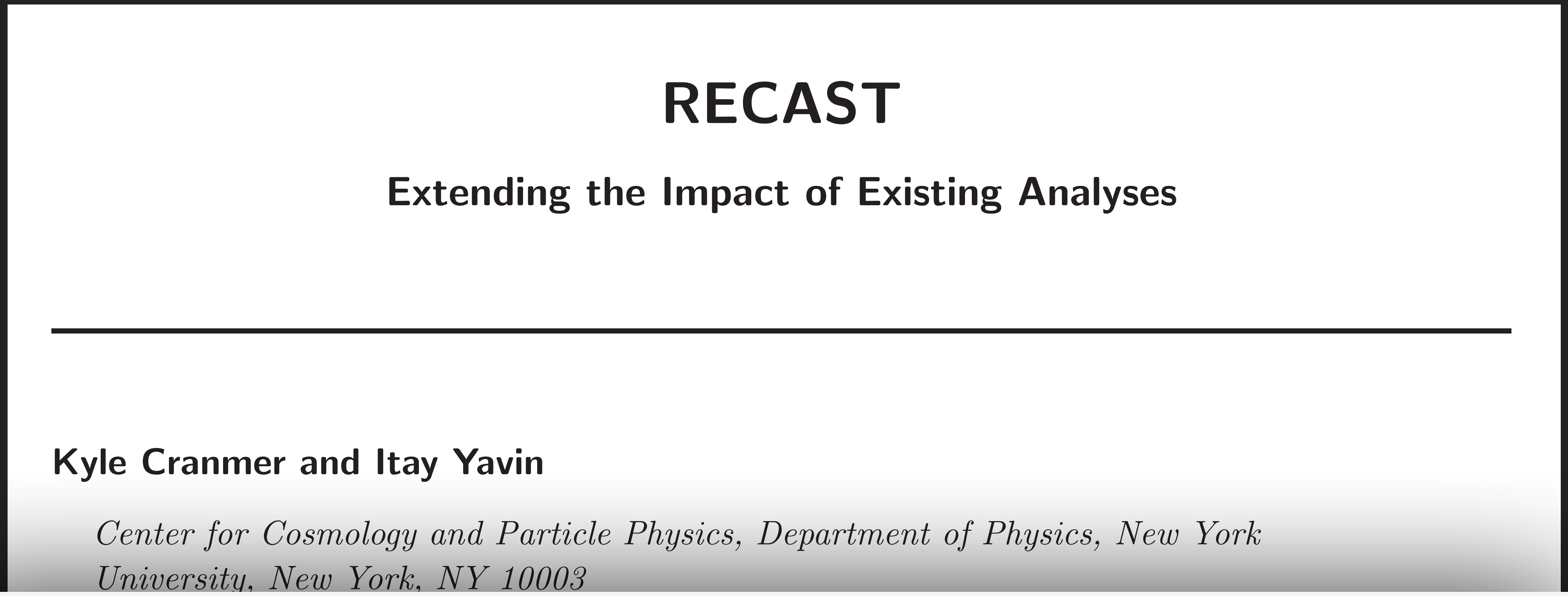
A Dilepton invariant mass tables

This appendix provides the exact bin edges and contents of the dilepton invariant mass plots presented in figures 1a, 1b, 3a, and 3b. These correspond to tables 8, 9, 10, and 11, respectively. Even more detailed information can be found in the Durham HEP database.[2]

Lower edge [GeV]	Upper edge [GeV]	Data [N]	Total Background [N]
80	85.549	1176847	1112000
85.549	91.482	6608874	6322000
91.482	97.828	3928394	3756000
97.828	104.61	432217	414400
104.61	111.87	162962	156100
111.87	119.63	93773	90620
119.63	127.93	63446	62270
127.93	136.8	47190	46740
136.8	146.29	36539	36090
146.29	156.43	29267	28990
156.43	167.28	23874	23740
167.28	178.89	19689	19550
178.89	191.29	16548	16400
191.29	204.56	13671	13590
204.56	218.75	11337	11460
218.75	233.92	9358	9499
233.92	250.15	7877	7868
250.15	267.5	6434	6570
267.5	286.05	5500	5427
286.05	305.89	4445	4477
305.89	327.11	3648	3667
327.11	349.79	2981	2995
349.79	374.06	2431	2403
374.06	400	1964	1957
400	427.74	1606	1565
427.74	457.41	1231	1265
457.41	489.14	1013	1008
489.14	523.06	776	805.6
523.06	559.34	622	628.7
559.34	598.14	464	492.3
598.14	639.63	403	392.6
639.63	683.99	300	304.4
683.99	731.43	219	234.3
731.43	782.16	202	183.2
782.16	836.41	133	140.2
836.41	894.43	107	107.1
894.43	956.46	82	85.13
956.46	1022.8	57	63.86
1022.8	1093.7	43	47.9
1093.7	1169.6	27	38.09
1169.6	1250.7	24	28.7
1250.7	1337.5	12	20.28
1337.5	1430.2	13	14.96
1430.2	1529.4	11	11.16
1529.4	1635.5	3	8.262
1635.5	1749	7	6.003
1749	1870.3	4	4.085
1870.3	2000	0	2.875
2000	2138.7	2	2.05
2138.7	2287.1	1	1.431
2287.1	2445.7	3	0.977
2445.7	2615.3	1	0.655
2615.3	2796.7	0	0.443
2796.7	2990.7	1	0.284
2990.7	3198.1	0	0.183
3198.1	3420	0	0.114
3420	3657.2	0	0.068
3657.2	3910.8	0	0.041
3910.8	4182.1	0	0.023
4182.1	4472.1	0	0.013
4472.1	4782.3	0	0.007
4782.3	5114	0	0.004
5114	5468.7	0	0.002
5468.7	5848	0	0.001
5848	6253.7	0	0

ASSUMPTIONS (CAN BE) REVISITED

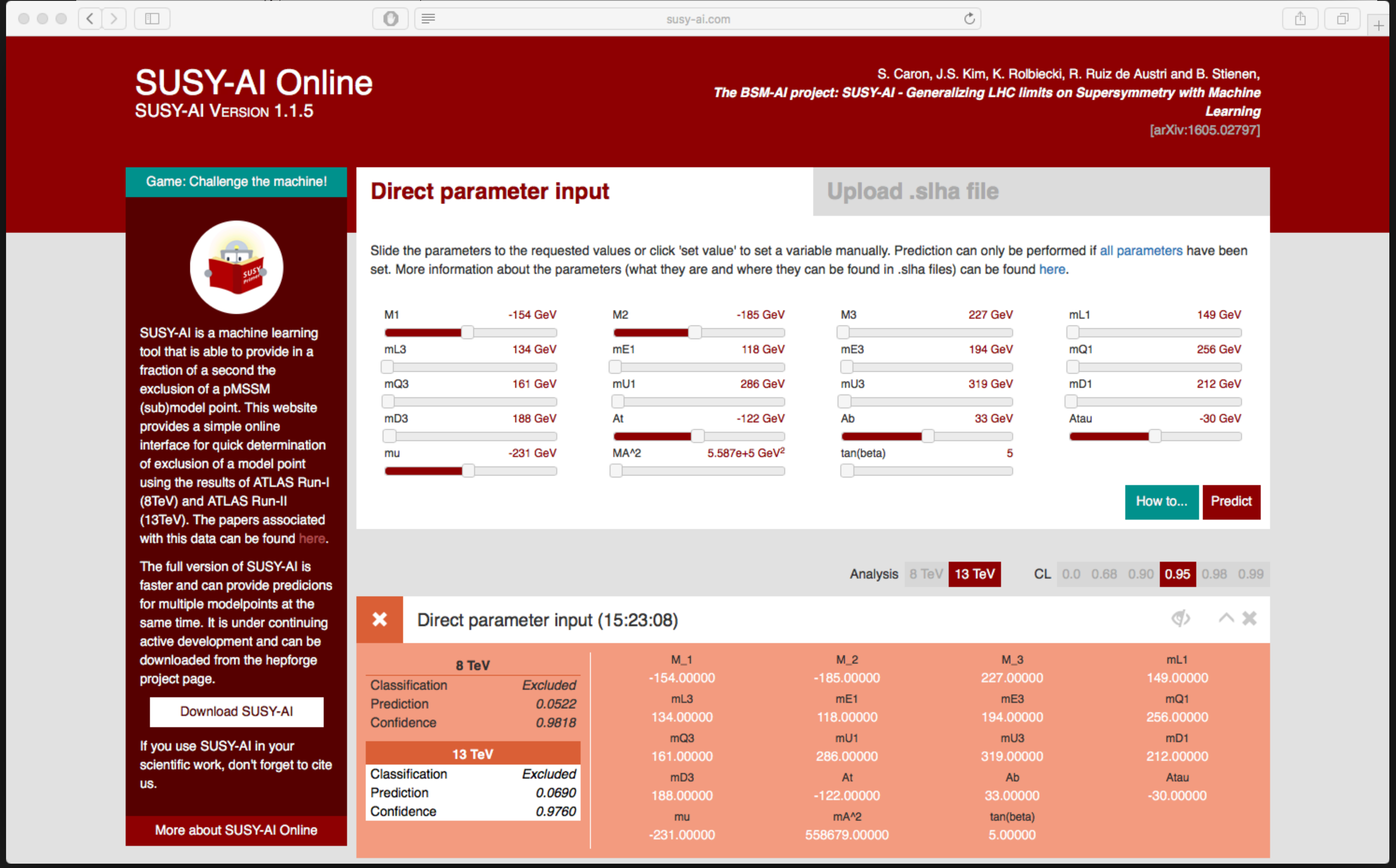
- Experiments (start to) publish more than just the results
- And one can build on top of these results
- And investigate more complex models…


RECAST

Extending the Impact of Existing Analyses

Kyle Cranmer and Itay Yavin

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



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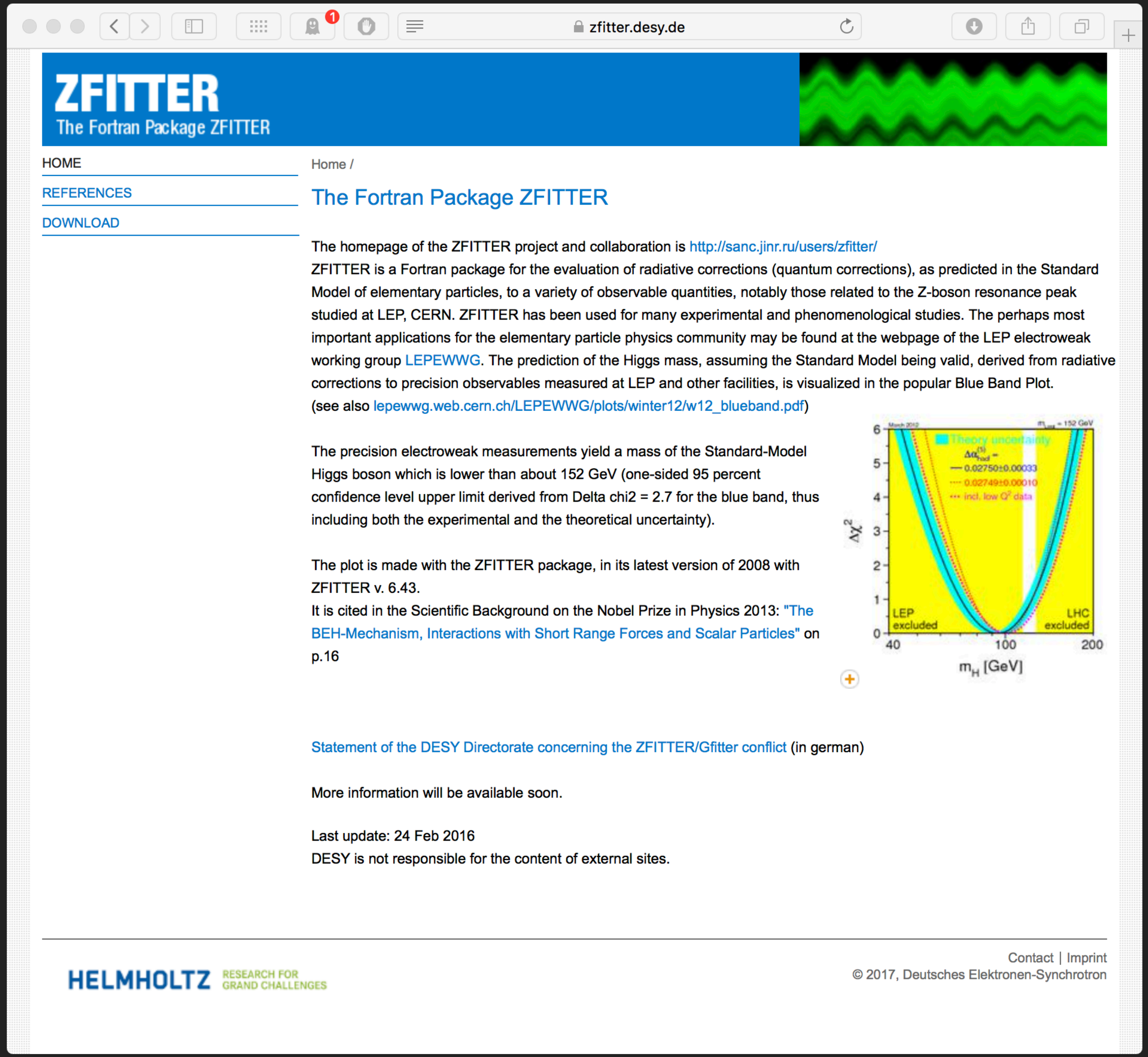

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The Fortran Package ZFITTER

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(see also lepewwg.web.cern.ch/LEPEWWG/plots/winter12/w12_blueband.pdf)

The precision electroweak measurements yield a mass of the Standard-Model Higgs boson which is lower than about 152 GeV (one-sided 95 percent confidence level upper limit derived from Delta chi2 = 2.7 for the blue band, thus including both the experimental and the theoretical uncertainty).

The plot is made with the ZFITTER package, in its latest version of 2008 with ZFITTER v. 6.43.
It is cited in the Scientific Background on the Nobel Prize in Physics 2013: "The BEH-Mechanism, Interactions with Short Range Forces and Scalar Particles" on p.16

Statement of the DESY Directorate concerning the ZFITTER/Gfitter conflict (in german)

More information will be available soon.

Last update: 24 Feb 2016
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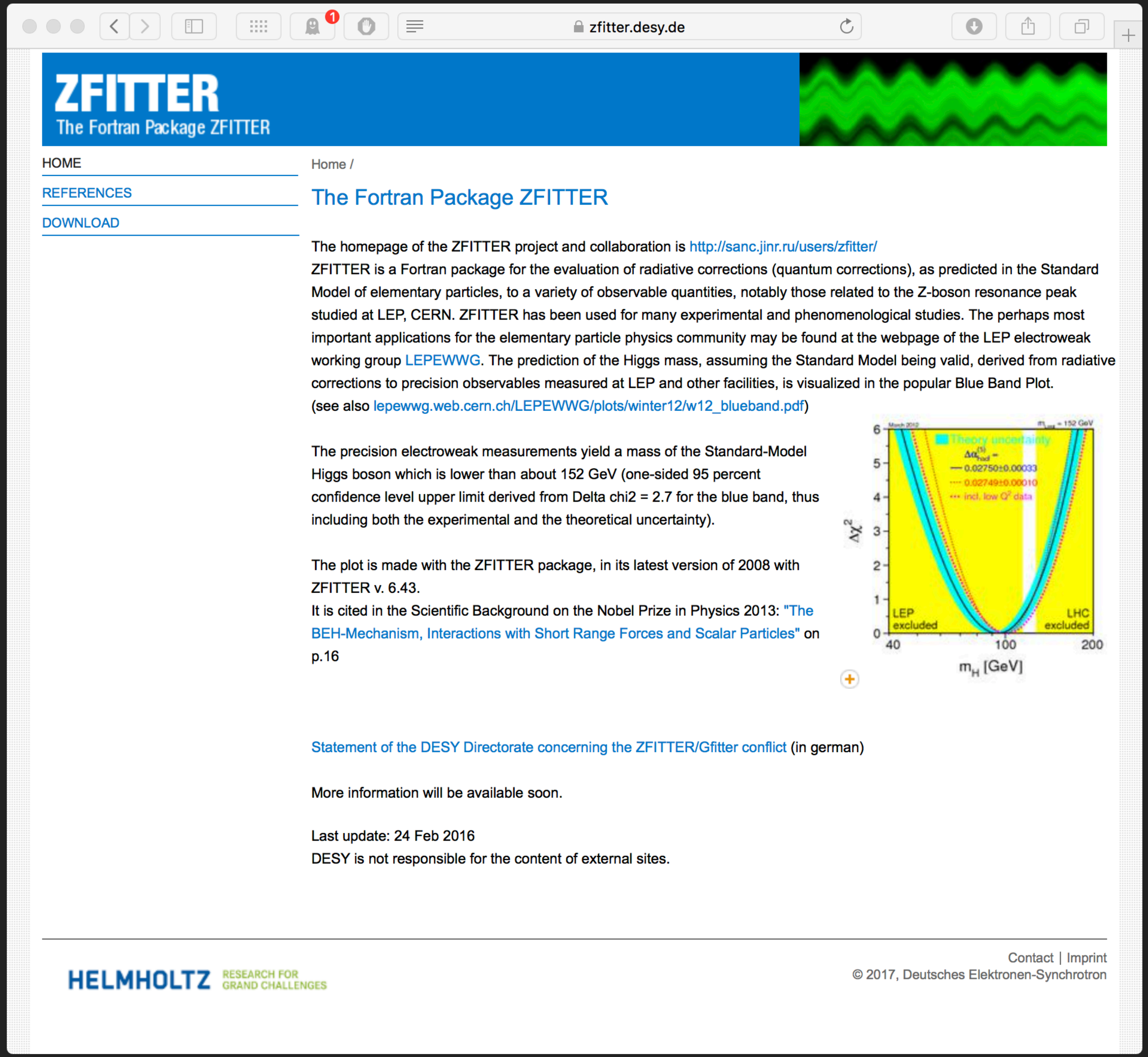

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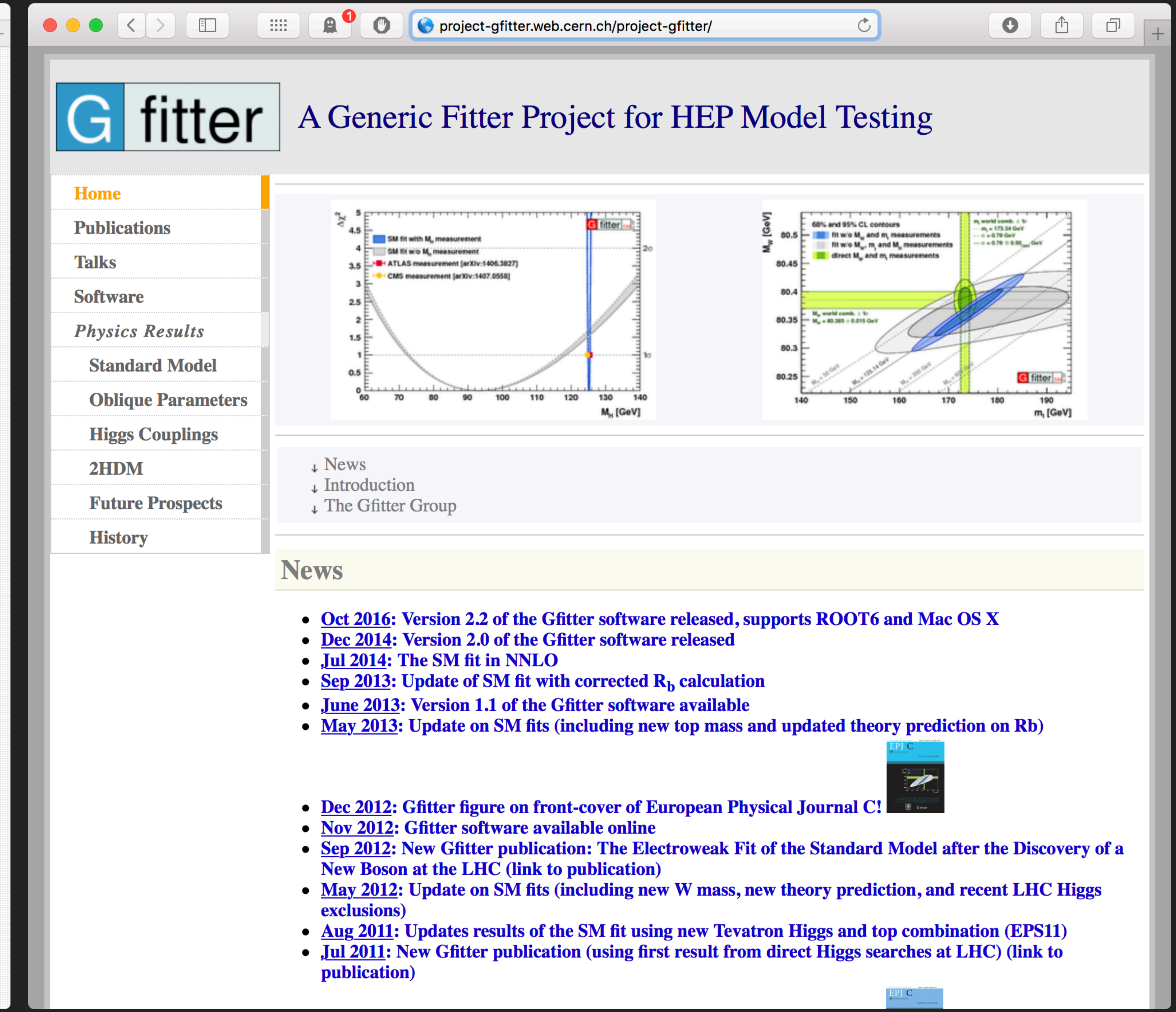

project-gfitter.web.cern.ch/project-gfitter/

G fitter

A Generic Fitter Project for HEP Model Testing

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Higgs Couplings
2HDM
Future Prospects
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↓ The Gfitter Group

News

- **Oct 2016: Version 2.2 of the Gfitter software released, supports ROOT6 and Mac OS X**
- **Dec 2014: Version 2.0 of the Gfitter software released**
- **Jul 2014: The SM fit in NNLO**
- **Sep 2013: Update of SM fit with corrected R_b calculation**
- **June 2013: Version 1.1 of the Gfitter software available**
- **May 2013: Update on SM fits (including new top mass and updated theory prediction on Rb)**
- **Dec 2012: Gfitter figure on front-cover of European Physical Journal C!**
- **Nov 2012: Gfitter software available online**
- **Sep 2012: New Gfitter publication: The Electroweak Fit of the Standard Model after the Discovery of a New Boson at the LHC (link to publication)**
- **May 2012: Update on SM fits (including new W mass, new theory prediction, and recent LHC Higgs exclusions)**
- **Aug 2011: Updates results of the SM fit using new Tevatron Higgs and top combination (EPS11)**
- **Jul 2011: New Gfitter publication (using first result from direct Higgs searches at LHC) (link to publication)**

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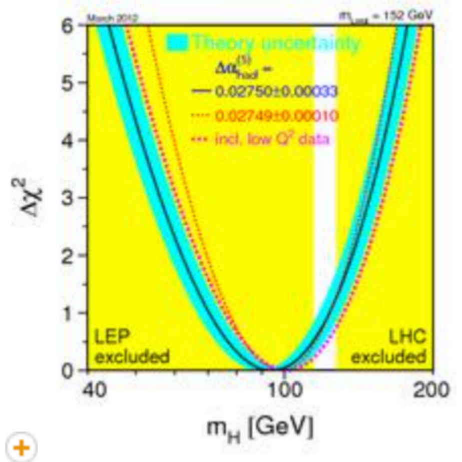

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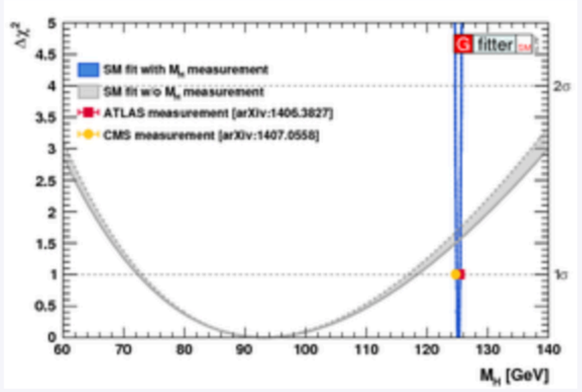

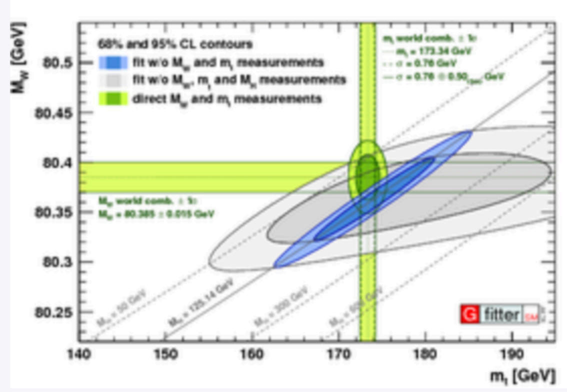

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- June 2013: Version 1.1 o
- May 2013: Update on SM
- Dec 2012: Gfitter figure
- Nov 2012: Gfitter softwa
- Sep 2012: New Gfitter pu New Boson at the LHC (
- May 2012: Update on SM exclusions)
- Aug 2011: Updates resul
- Jul 2011: New Gfitter pu publication)

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mastercode.web.cern.ch/mastercode/

MasterCode The MasterCode Project

- Introduction
- News
- Publications
- Downloads
- MasterCode wiki (private)

Introduction

The **MasterCode** is a computer code that allows to fit different versions of the Minimal Supersymmetric Standard Model (MSSM) to currently existing experimental data.

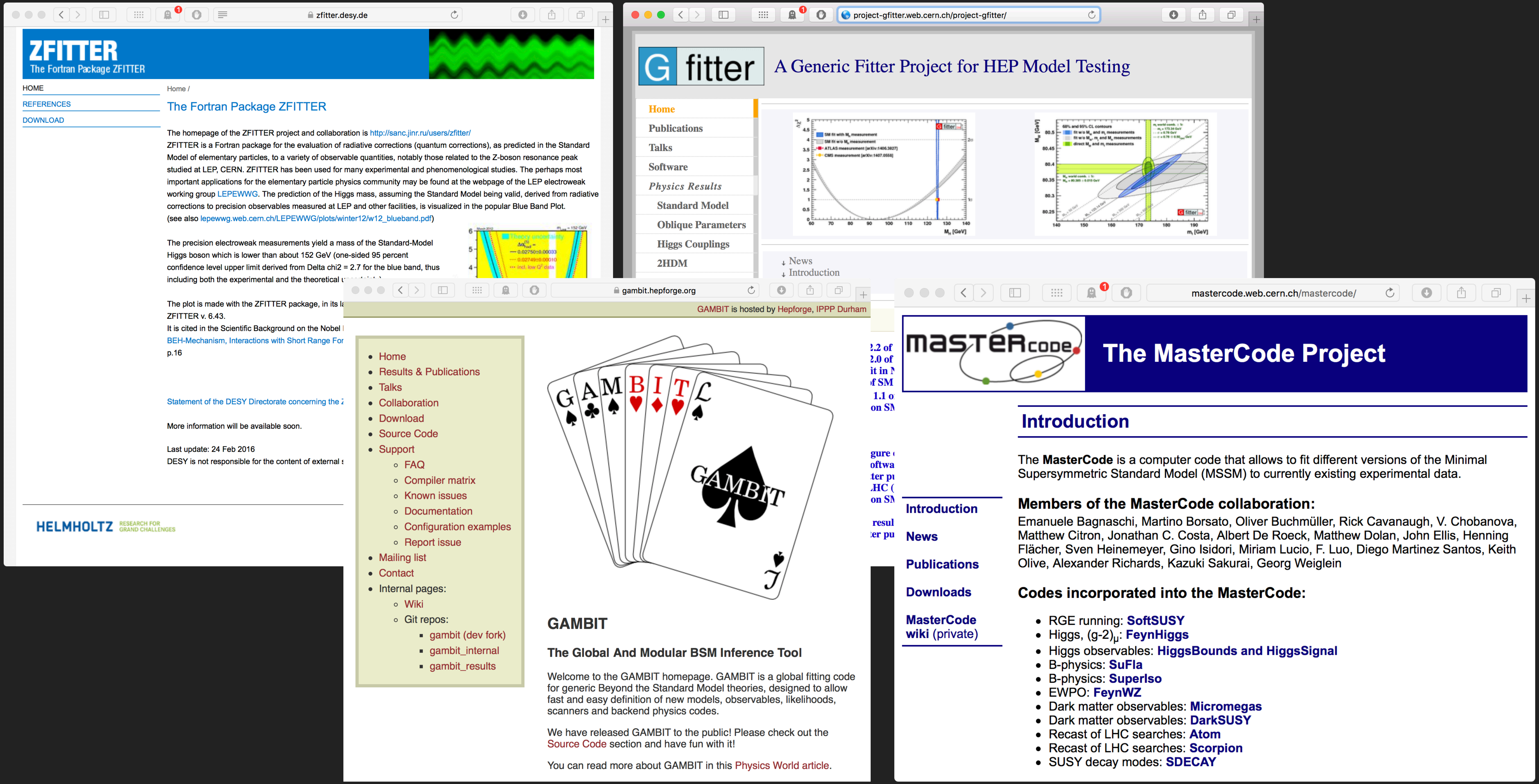
Members of the MasterCode collaboration:

Emanuele Bagnaschi, Martino Borsato, Oliver Buchmüller, Rick Cavanaugh, V. Chobanova, Matthew Citron, Jonathan C. Costa, Albert De Roeck, Matthew Dolan, John Ellis, Henning Flächer, Sven Heinemeyer, Gino Isidori, Miriam Lucio, F. Luo, Diego Martinez Santos, Keith Olive, Alexander Richards, Kazuki Sakurai, Georg Weiglein

Codes incorporated into the MasterCode:

- RGE running: **SoftSUSY**
- Higgs, $(g-2)_\mu$: **FeynHiggs**
- Higgs observables: **HiggsBounds and HiggsSignal**
- B-physics: **SuFla**
- B-physics: **SuperIso**
- EWPO: **FeynWZ**
- Dark matter observables: **Micromegas**
- Dark matter observables: **DarkSUSY**
- Recast of LHC searches: **Atom**
- Recast of LHC searches: **Scorpion**
- SUSY decay modes: **SDECAY**

GLOBAL (BEYOND) STANDARD MODEL ANALYSES



"MORE COMPLEX MODELS"

- "We" already seem to have an opinion on this

Peter Woit *says:*
May 24, 2017 at 7:00 am

Mitchell Porter,
I can see that much. What I don't understand is what is new about this, how this is different than previous efforts like MasterCode. What will this do that MasterCode didn't and why do the assumptions built into seem to be of a higher level of complexity than MasterCode?
I guess part of what I don't understand is that I would have expected that, as stronger and stronger LHC bounds rule out more and more of these kinds of models, I'd expect people to lose interest in this kind of thing, whereas instead we seem to be seeing a larger and larger group of people working on it.

Ryan *says:*
May 24, 2017 at 7:20 am

Yeah and apparently these efforts are well received by the pheno community. Here are some random tweets that popped up in my timeline:

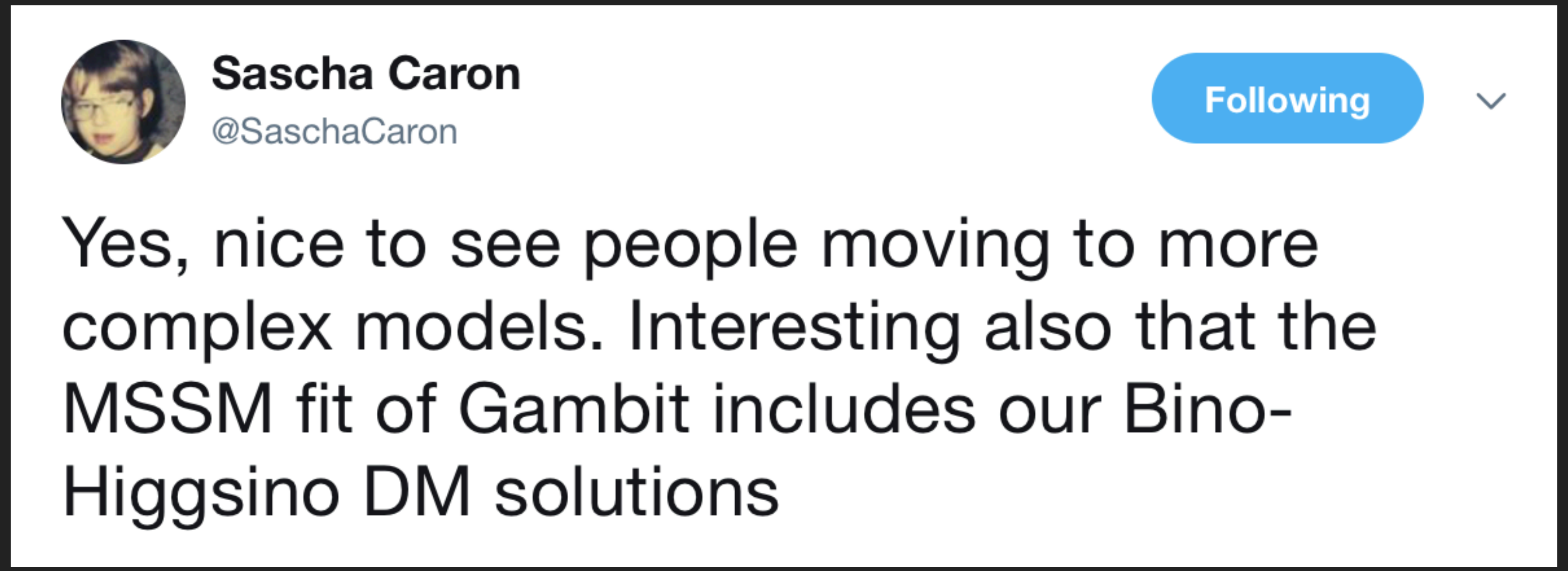
https://twitter.com/HEPAdelaide/status/867258318770683904
https://twitter.com/Tristan_duPree/status/867259714496757760
https://twitter.com/suchi_kulkarni/status/867273017474375680
https://twitter.com/SaschaCaron/status/867301364904456193

Maybe the last tweet sums up the mindset behind this kind of work: "Yes, nice to see people moving to more complex models."

No idea, what's nice about "more complex models". However, from a naive perspective it seems to make sense that the new bounds require more effort on the "model builder" side and thus more complex fitting codes…

"MORE COMPLEX MODELS"

- "We" already seem to have an opinion on this



"MORE COMPLEX MODELS"

- "We" already seem to have an opinion on this

Tristan du Pree @Tristan_duPree — Following

@SaschaCaron Several Gambit papers on the arXiv today arxiv.org/list/hep-ph/new

11:03 PM - 23 May 2017 from Amsterdam, The Netherlands

Sascha Caron @SaschaCaron — Following

Yes, nice to see people moving to more complex models. Interesting also that the MSSM fit of Gambit includes our Bino-Higgsino DM solutions

New submissions for Thu, 30 Nov 17

[3] arXiv:1711.10493 [pdf, other]

Flavoured Dark Matter Moving Left

Monika Blanke, Satrajit Das, Simon Kast

Comments: 21 pages, 11 figures

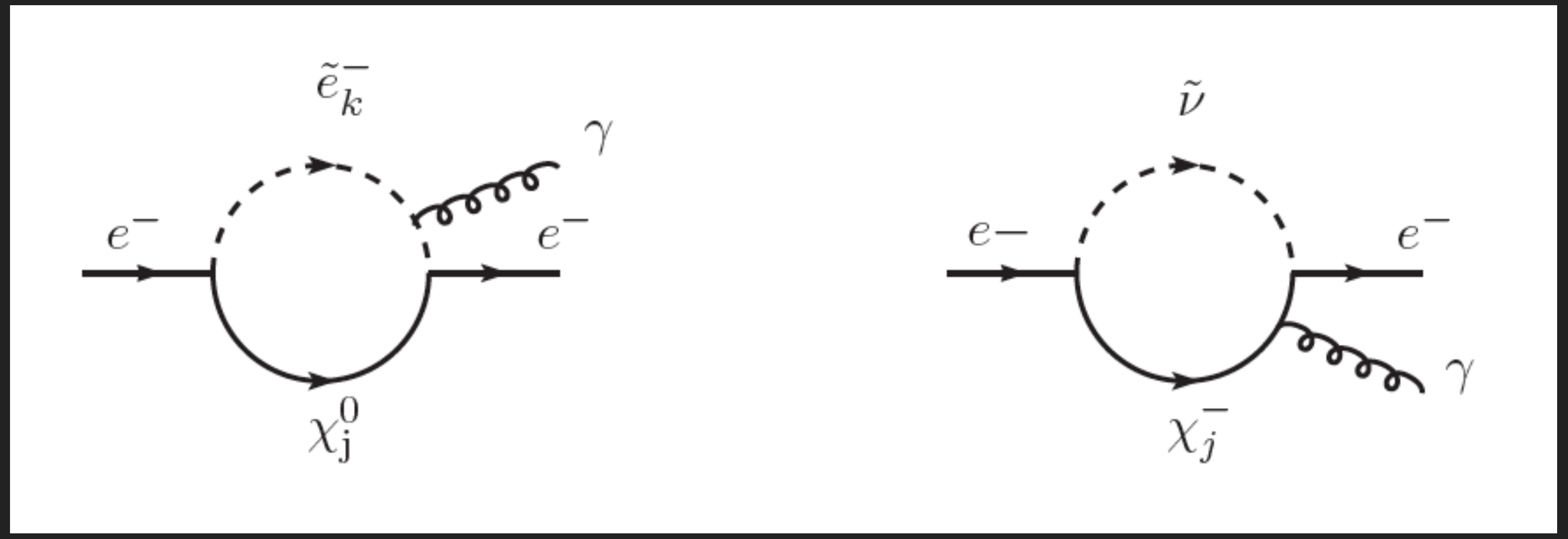
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)

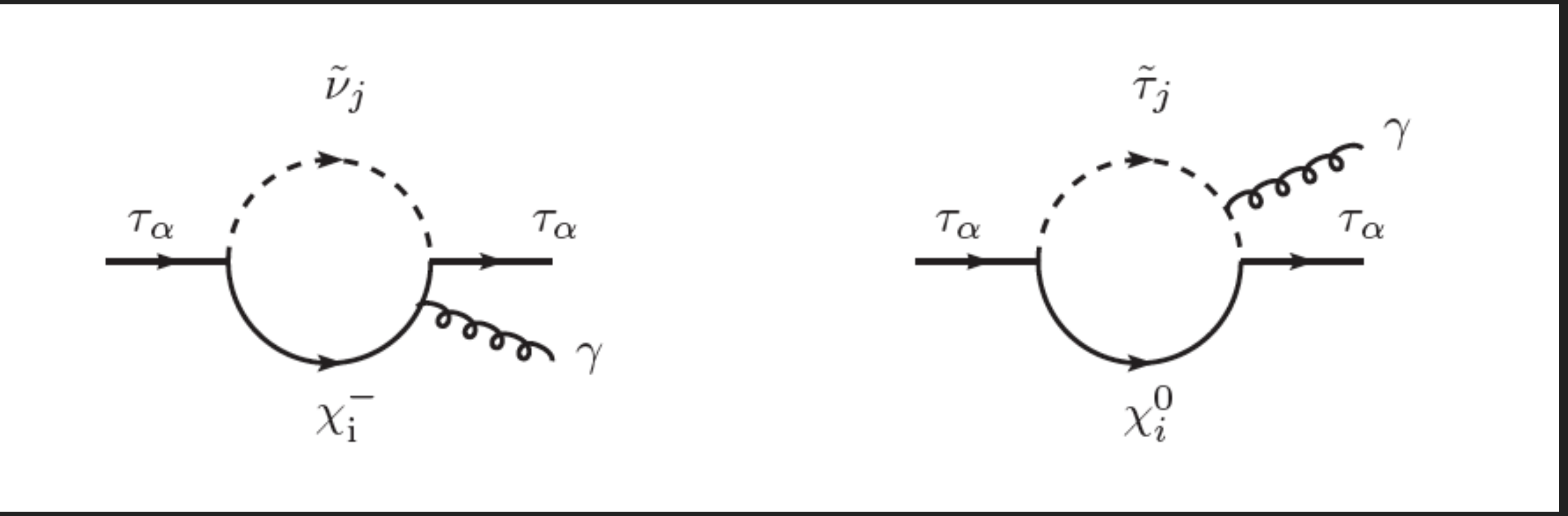
We investigate the phenomenology of a simplified model of flavoured Dark Matter (DM), with a dark fermionic flavour triplet coupling to the left-handed $SU(2)_L$ quark doublets via a scalar mediator. The DM-quark coupling matrix is assumed to constitute the only new source of flavour and CP violation, following the hypothesis of Dark Minimal Flavour Violation. We analyse the constraints from LHC searches, from meson mixing data in the K, D, and $B_{d,s}$ meson systems, from thermal DM freeze-out, and from direct detection experiments. Our combined analysis shows that while the experimental constraints are similar to the DMFV models with DM coupling to right-handed quarks, the multitude of couplings between DM and the SM quark sector resulting from the $SU(2)_L$ structure implies a richer phenomenology and significantly alters the resulting impact on the viable parameter space.

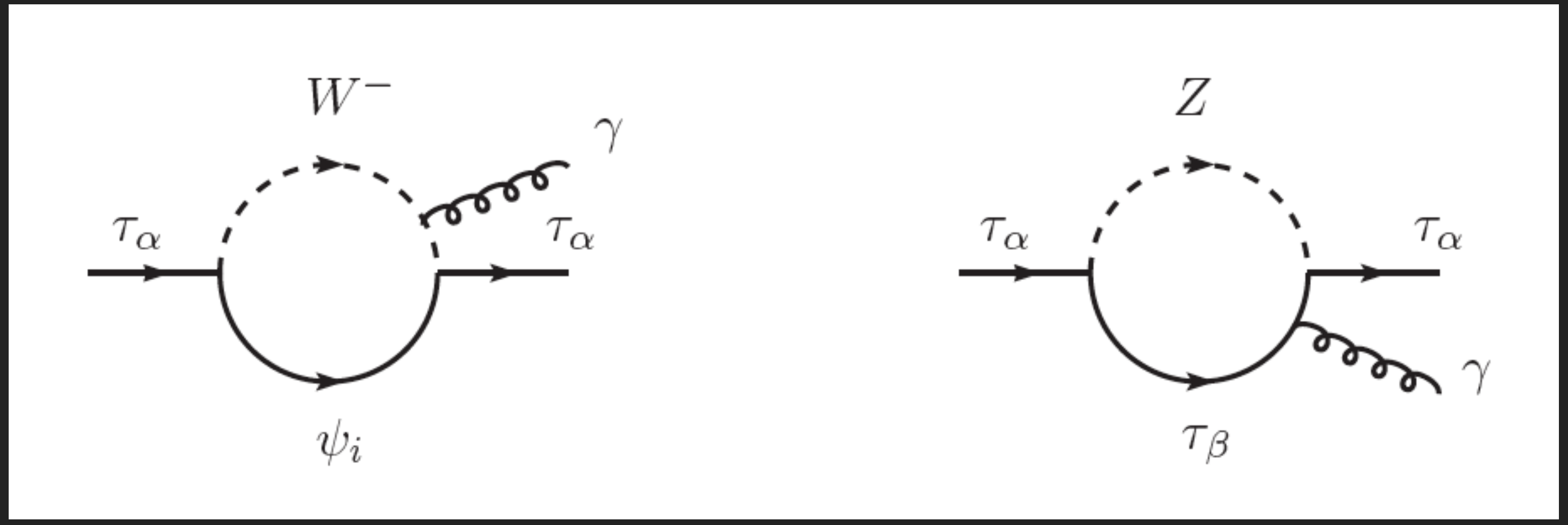
SUSY & DARK MATTER

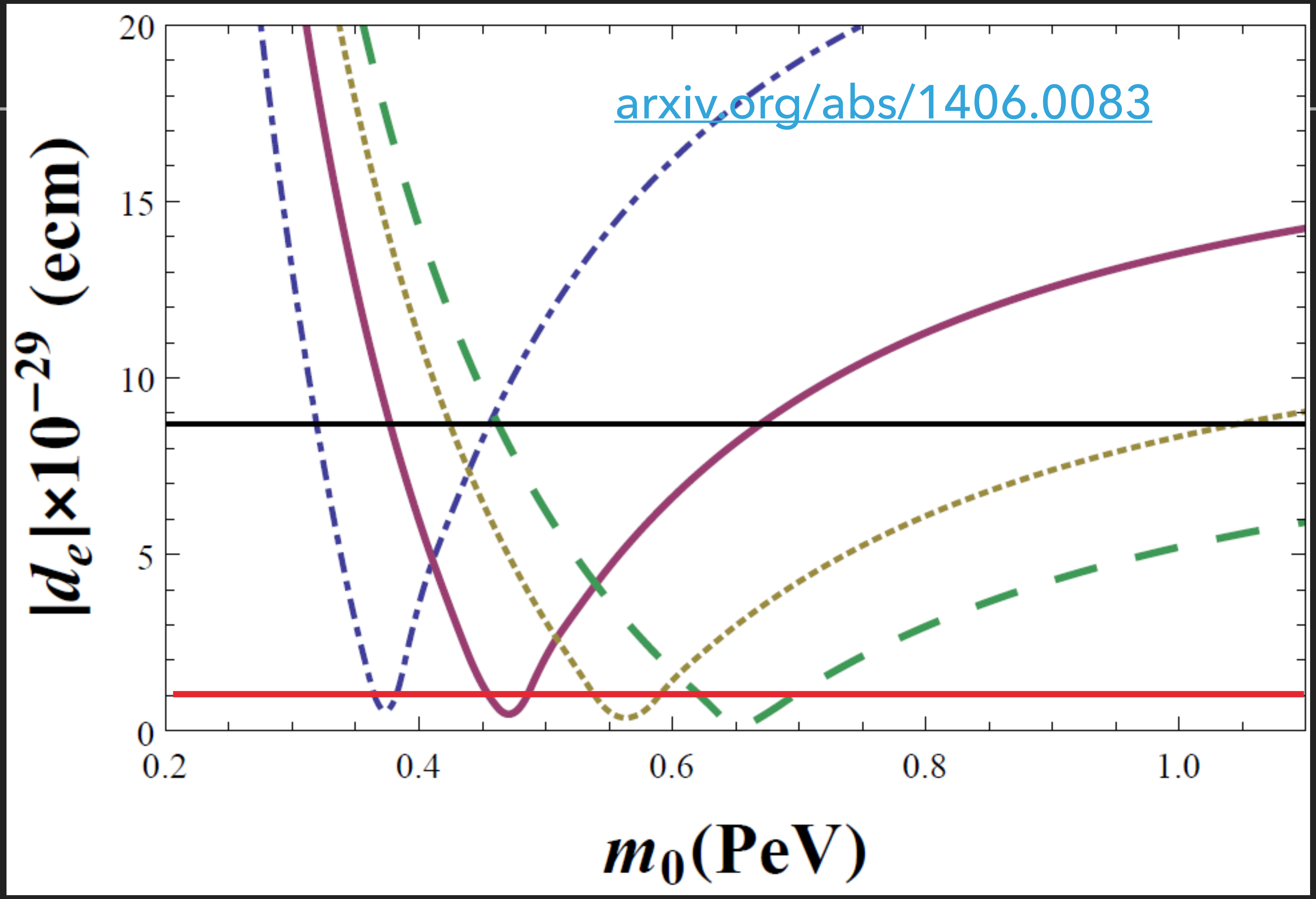
14:00		*Pakhuis De Zwijger*	13:15 - 14:30
	Standard Model Fits	*Pakhuis De Zwijger*	14:30 - 14:45
15:00	**Pierre Auger Observatory**	*Pakhuis De Zwijger*	14:45 - 15:25
	Coffee	*Pakhuis De Zwijger*	15:25 - 15:55
16:00	**Electron EDM**	*Pakhuis De Zwijger*	15:55 - 16:25
	Xenon	*Pakhuis De Zwijger*	16:25 - 17:05
17:00	**Dark Matter connections**	*Pakhuis De Zwijger*	17:05 - 17:30

SUSY & E-EDM









arxiv.org/abs/1406.0083

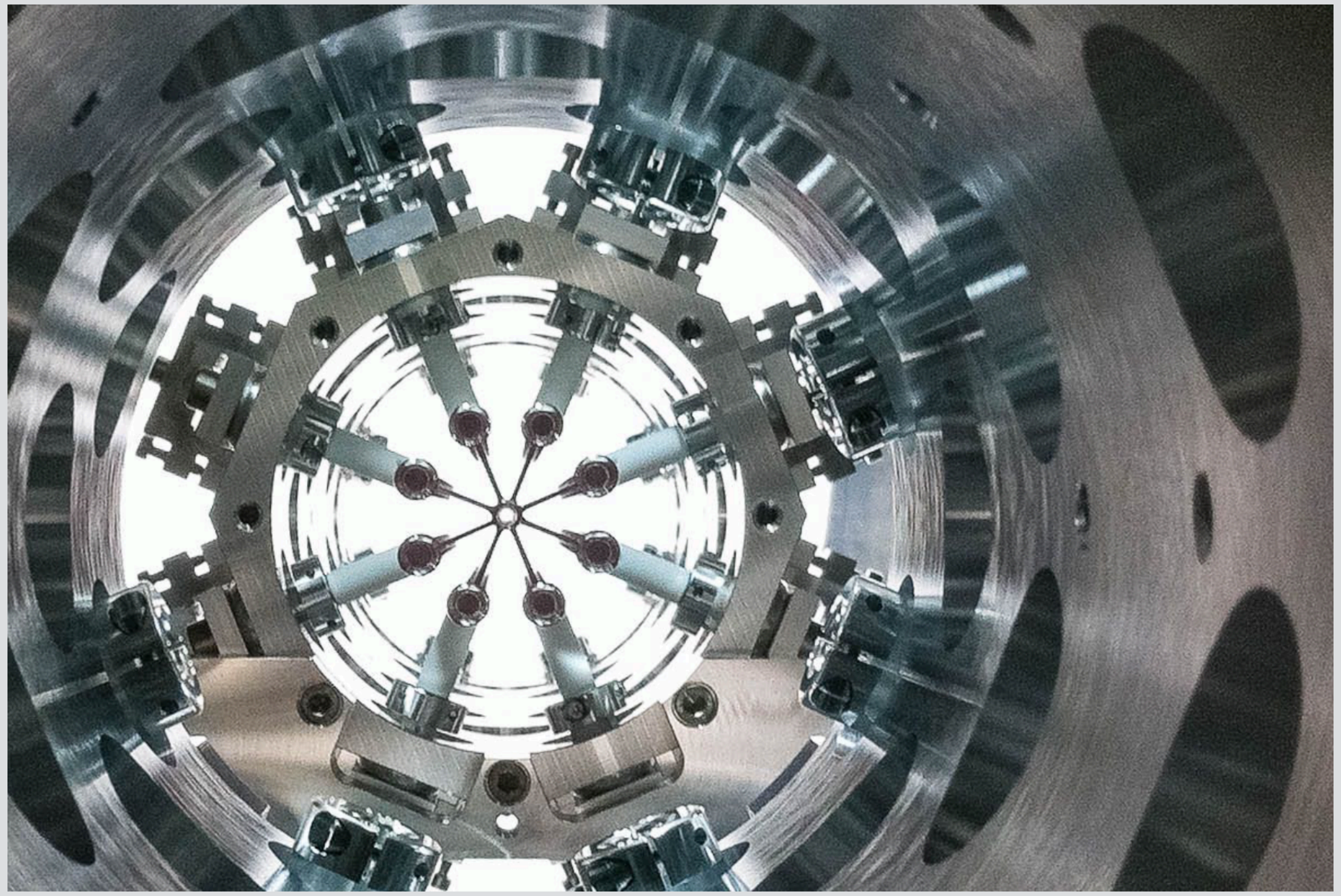
Figure 5: An exhibition of the dependence of $|d_e|$ on m_0 for various vector-like masses. The curves correspond to $m_N = m_E = 150$ (dot-dashed), $m_N = m_E = 200$ (solid), $m_N = m_E = 250$ (dotted), $m_N = m_E = 300$ (dashed). The parameters are $|\mu| = 4.1 \times 10^2$, $|M_1| = 2.8 \times 10^2$,$|M_2|$ $=3.4\times10^2$,$|A_0|=3\times10^6$,$m_{\tilde{\nu}}=4\times10^6$,$|A_{\tilde{\nu}}|=5\times10^6$,$\tan\beta=50$.The CP phases 00 are $\theta_\mu=1$,$\alpha_1=1.26$,$\alpha_2=0.94$,$\alpha_{A0}=0.94$,$\alpha_{A\tilde{\nu}}=1.88$. The f couplings are $|f_3|=$ $3.01\times$ 0 10^{-5}, $|f'| = 8.07\times10^{-6}$, $|f''| = 2.06\times10^{-5}$, $|f_4| = 8.13\times10^{-4}$, $|f'| =$ 3.50×10^{-1}, $|f''| = 6.29\times$ 33 44 10^{-1}, $|f_5| = 6.38\times10^{-5}$, $|f'| = 1.03\times10^{-6}$, $|f''| =$ 2.44×10^{-8}. Their corresponding CP phases 55 are $\chi_3=7.91 \times 10^{-1}$,$\chi'=7.87$ $\times 10^{-1}$,$\chi''=7.78 \times 10^{-1}$,$\chi_4=7.66 \times 10^{-1}$,$\chi'=8.38 \times$ 334 10^{-1},$\chi''=8.23\times10^{-1}$,χ_5 $=7.57\times10^{-1}$,$\chi'=7.54\times10^{-1}$,$\chi''=7.83\times10^{-1}$. All masses are 455 in GeV, phases in rad, and d_e in ecm.

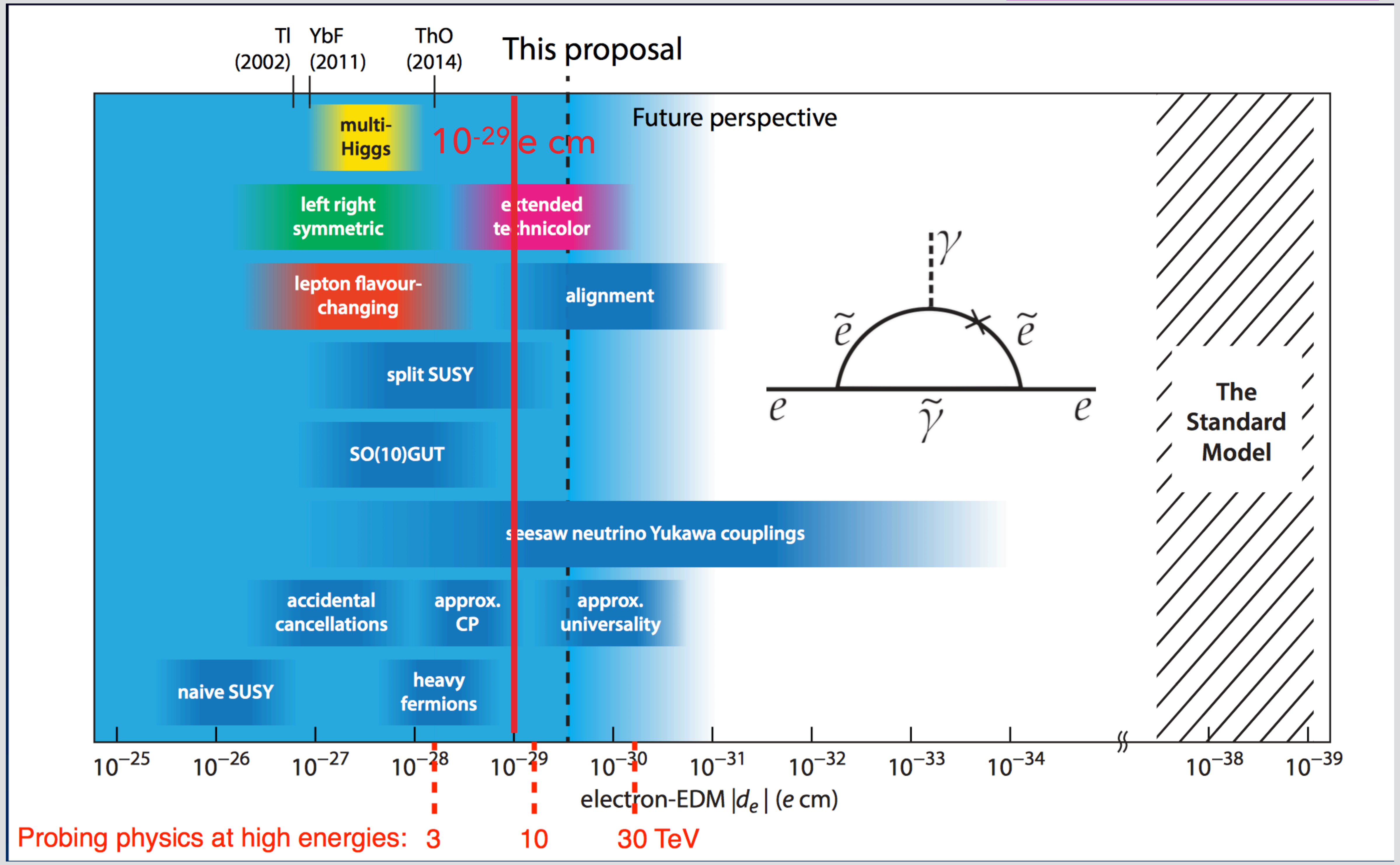
Nikhef

High precision electron EDM

- Measurement of electron Electric Dipole Moment in BaF
  - Use internal electric field in cold polar molecules to enhance by ~10^9
  - Decelerator in Groningen developed
  - Reach sensitivity in 2022

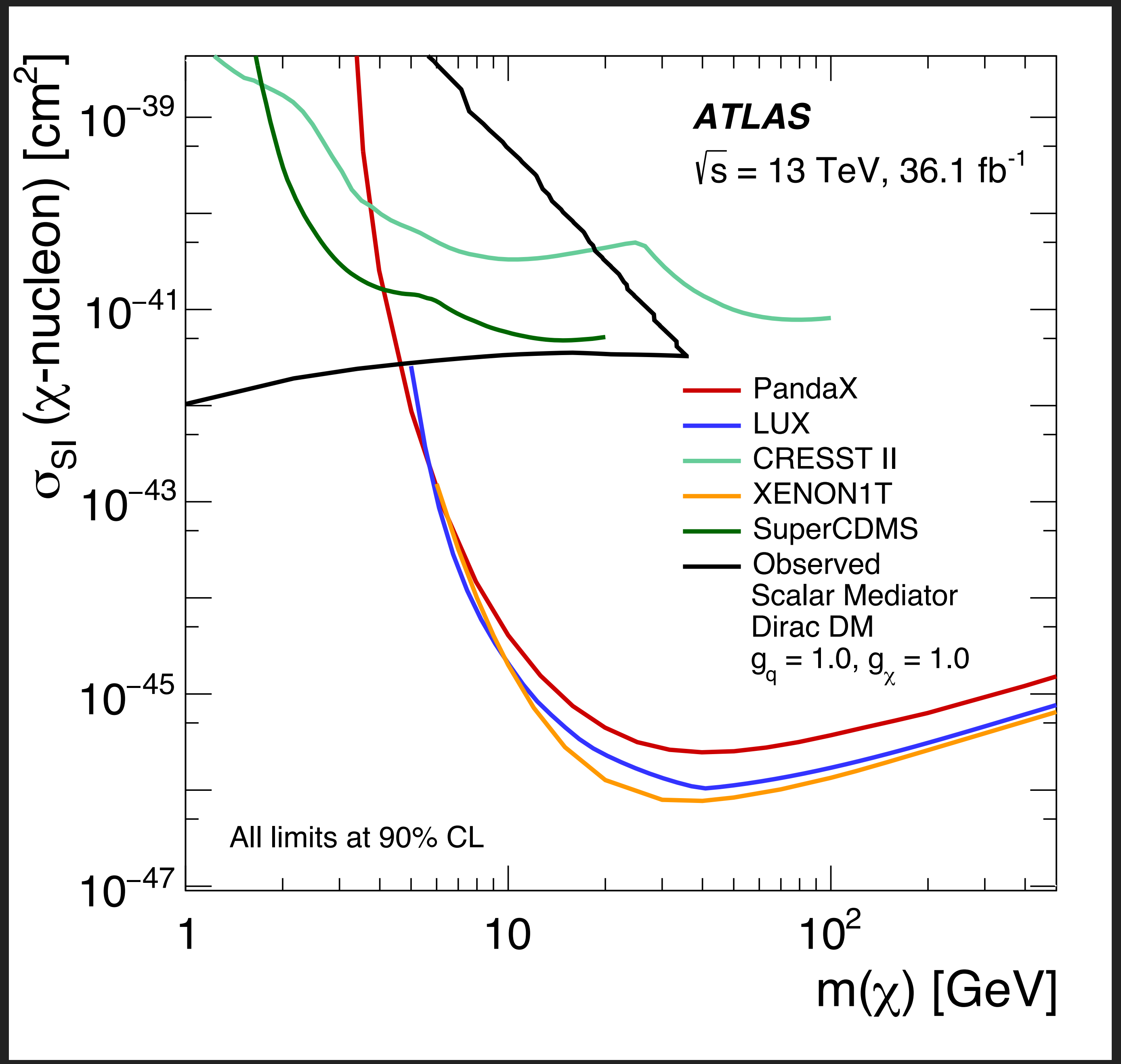
New - 2017





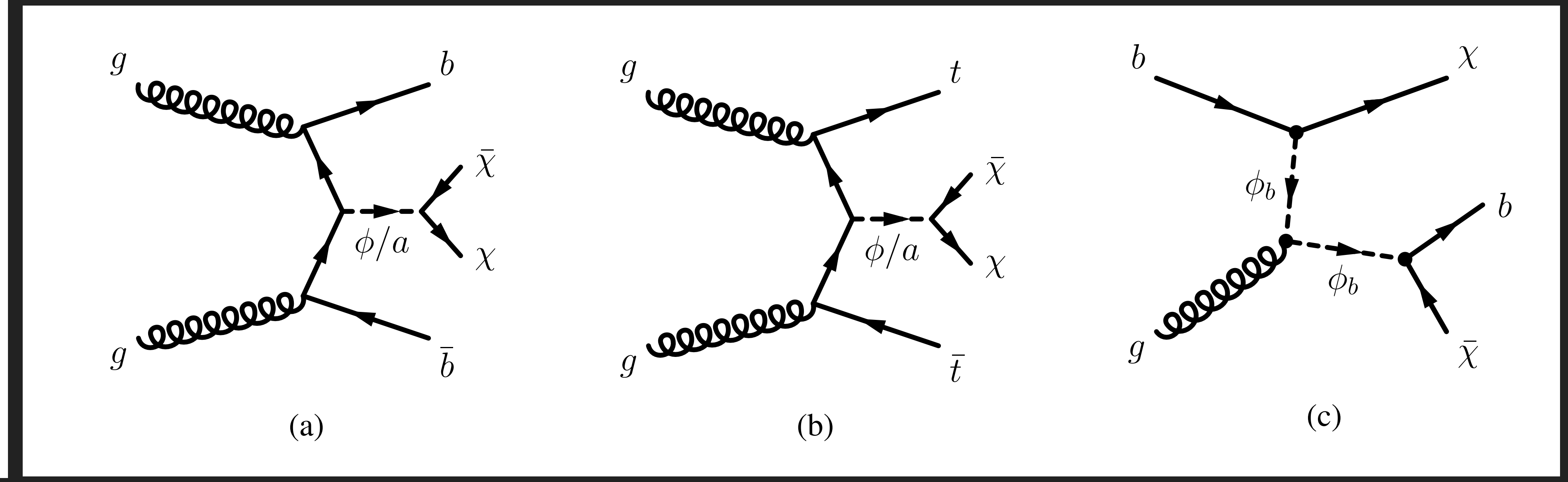
Stan Bentvelsen
NWO review Sep 2017

DARK MATTER (INSPIRED) SEARCHES



Search for dark matter produced in association with bottom or top quarks in $\sqrt{s}$ = 13 TeV pp collisions with the ATLAS detector

The ATLAS Collaboration



… a fermionic DM particle produced through the exchange of a spin-0 mediator … The couplings of the mediator to the SM fermions are severely restricted by precision flavour measurements.

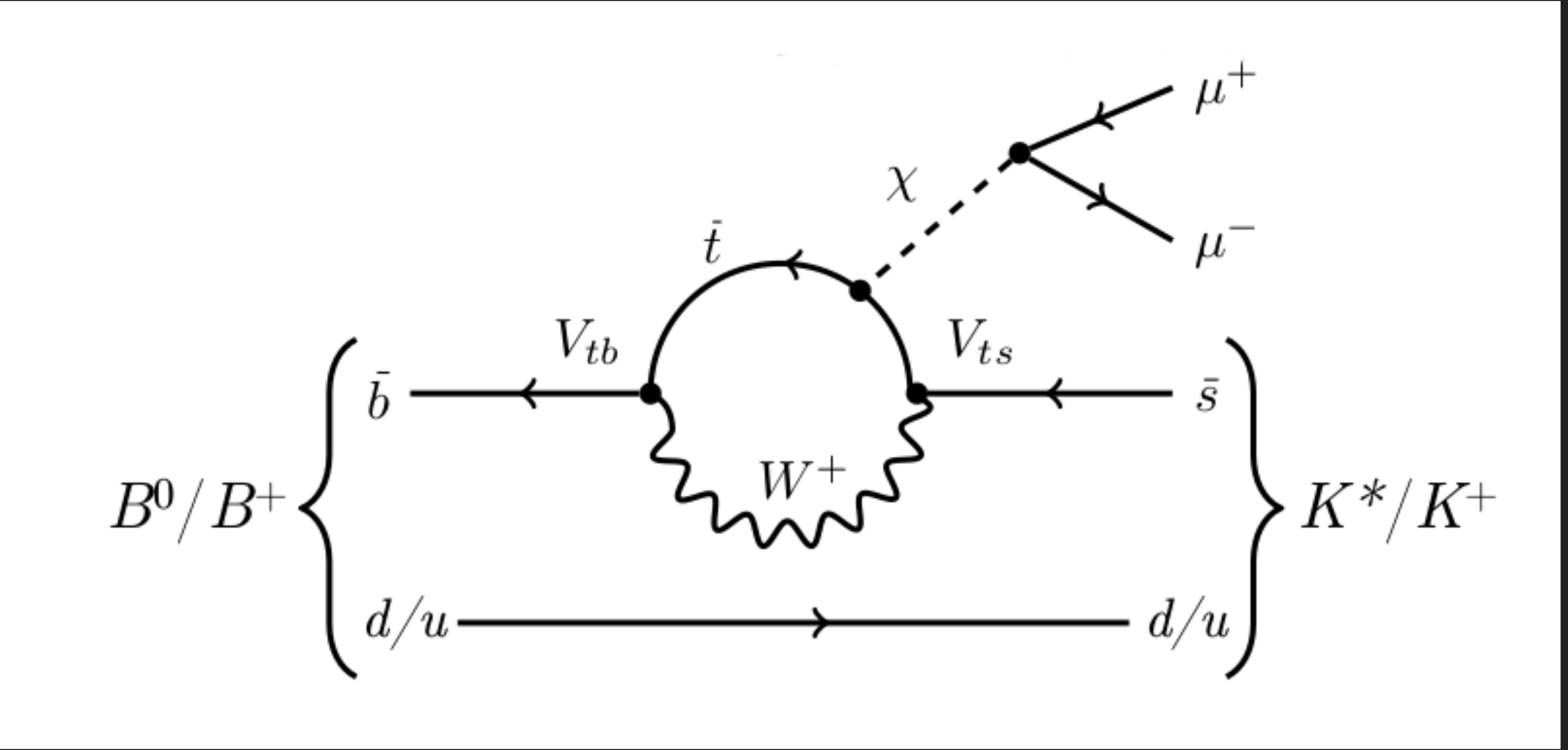
… except if Minimal Flavor Violation … the interaction between any new neutral spin-0 state and SM matter is proportional to the fermion masses via Yukawa-type couplings

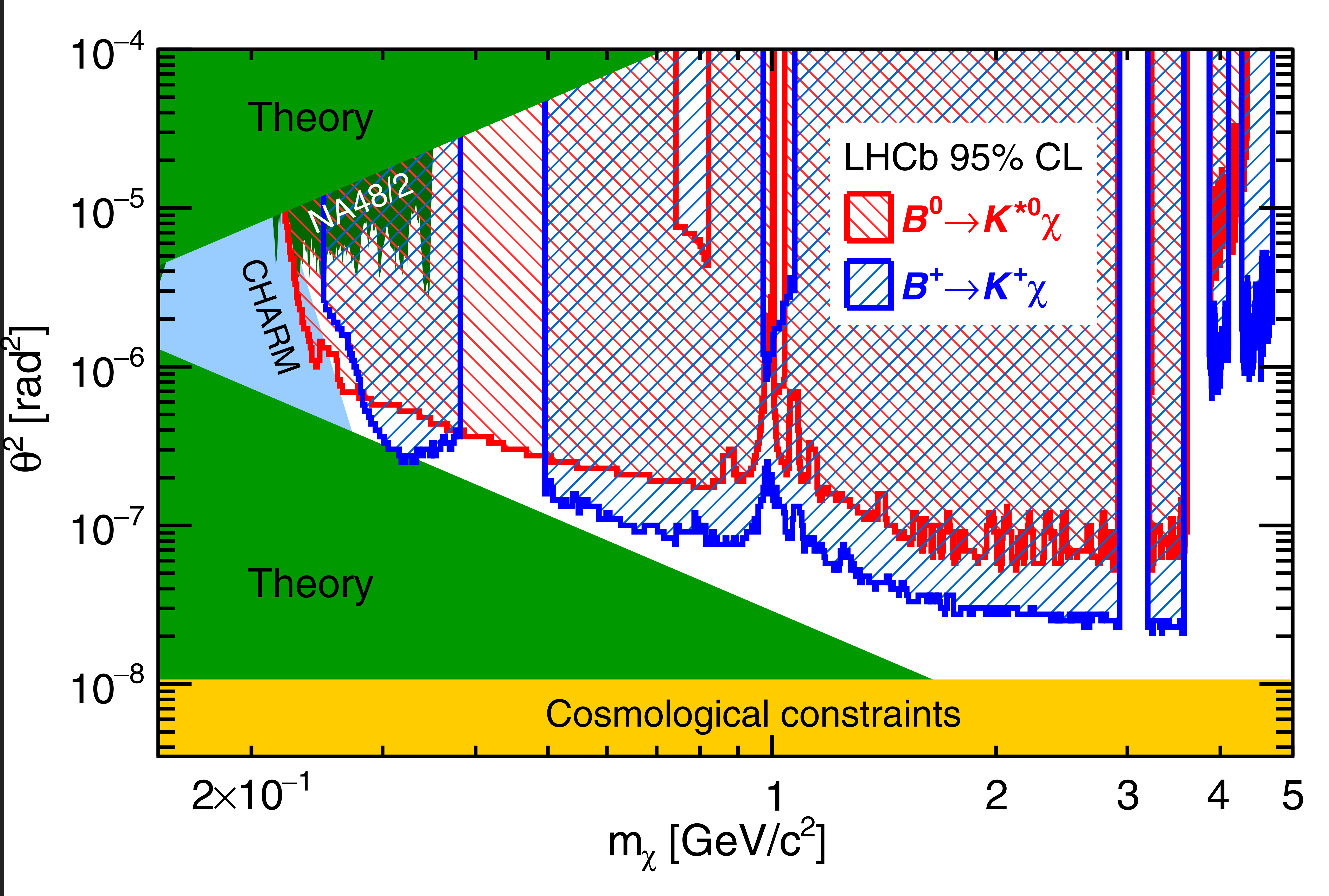
DARK MATTER (INSPIRED) SEARCHES

PHYSICAL REVIEW D **95,** 071101(R) (2017)

Search for long-lived scalar particles in $B^+ \to K^+\chi(\mu^+\mu^-)$ decays

R. Aaij *et al.*[*]
(LHCb Collaboration)
(Received 24 December 2016; published 14 April 2017)





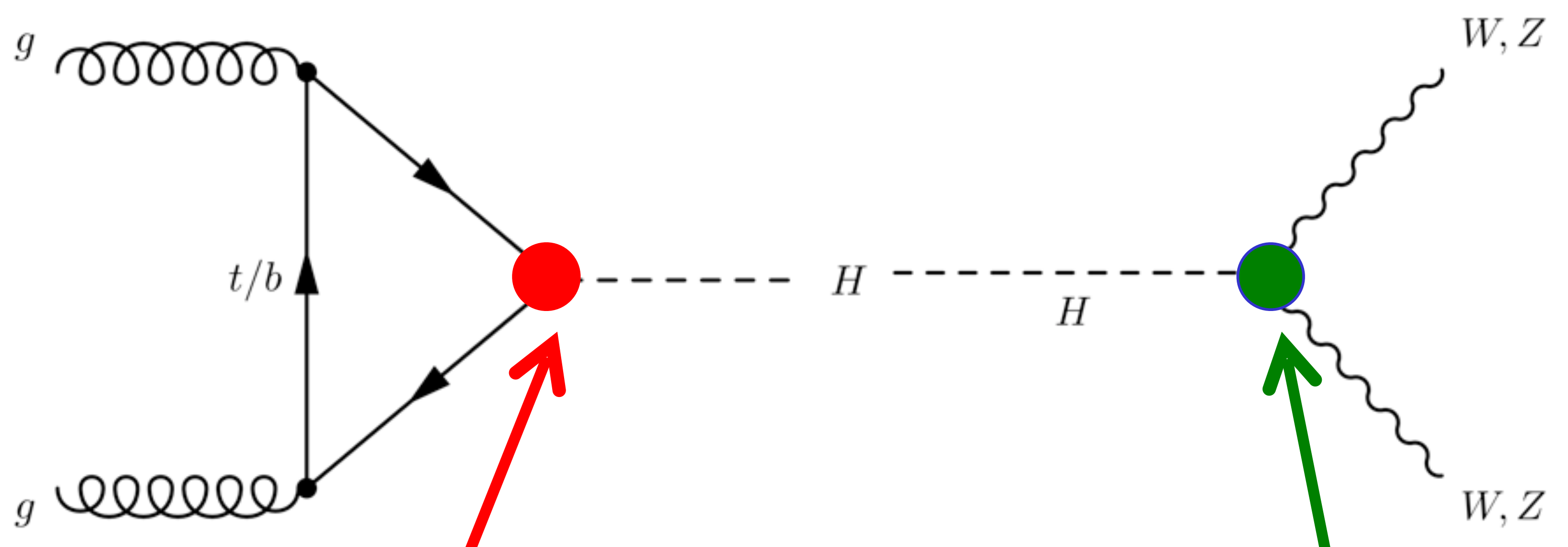
θ: inflaton-Higgs mixing angle

HIGGS COUPLINGS & EFT

- Higgs analysis depends on precise theory predictions
- κ framework :
  - consider (only!) scalar modifications of Higgs coupling
  - Differential distributions not fully utilized

Interpretation beyond signal strengths – the κ framework

- Parameters κ_j correspond to LO degrees of freedom
- Example for ggF production of H→VV



$\sigma_{ggF} = (1.06\,\kappa_t^2 + 0.01\kappa_b^2 - 0.07\kappa_b\kappa_t)\,\sigma_{ggF}(SM)$ $\Gamma_{W,Z} = \kappa^2_{W,Z}\,\Gamma_{W,Z}(SM)$

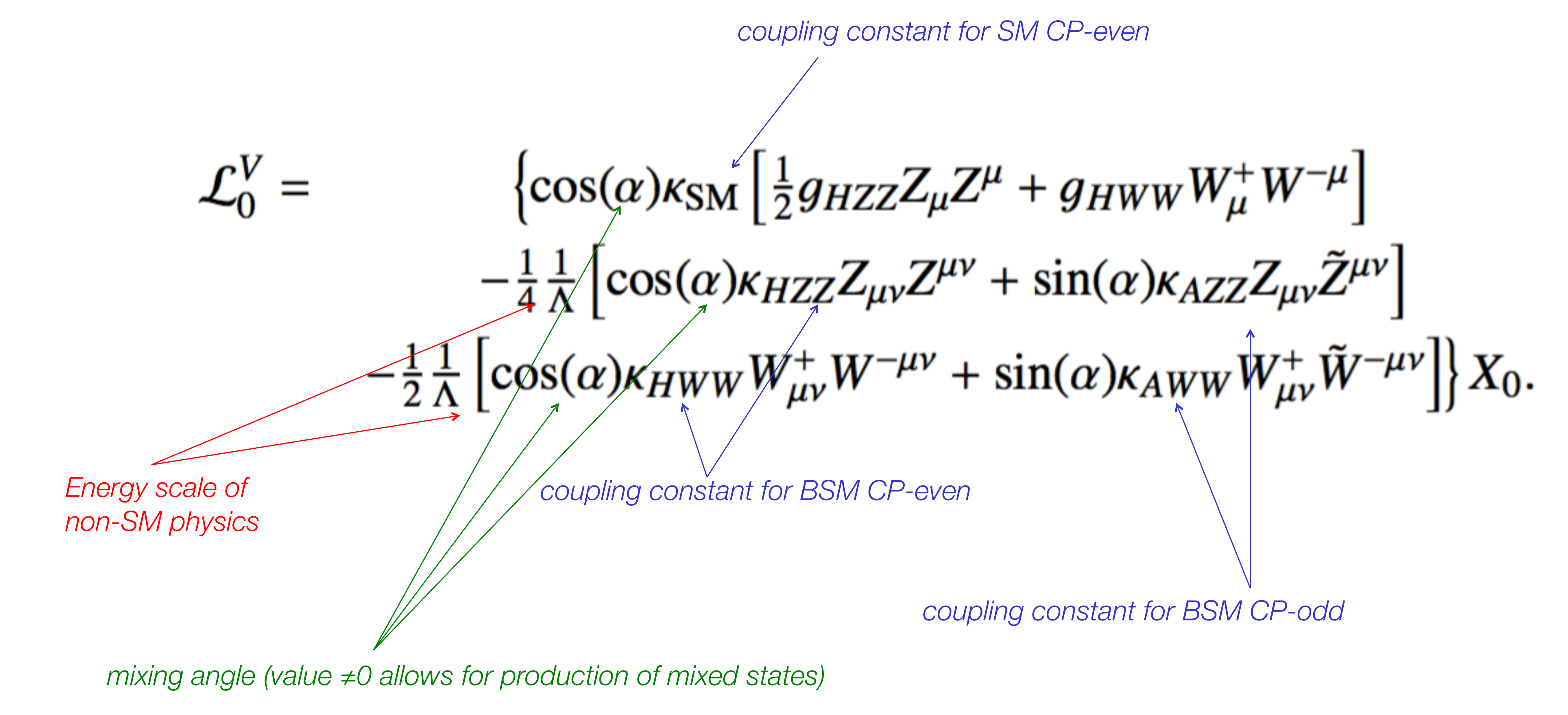
$$\sigma(i \to H \to f) = \frac{\sigma_i(\vec{\kappa}) \cdot \Gamma^f(\vec{\kappa})}{\Gamma_H}$$

NB: σ_{ggF}(SM) from NNLO(QCD) + NLO(EW) calculation!

HIGGS COUPLINGS & EFT

- Higgs analysis depends on precise theory predictions
- κ framework :
    - consider (only!) scalar modifications of Higgs coupling
    - Differential distributions not fully utilized
- Move towards Effective Field Theory!
    - Interpolate distributions by varying (combinations of) Wilson coefficients

$$\mathcal{L}_0^V = \Big\{\cos(\alpha)\kappa_{\rm SM}\left[\tfrac{1}{2}g_{HZZ}Z_\mu Z^\mu + g_{HWW}W_\mu^+W^{-\mu}\right] - \tfrac{1}{4}\tfrac{1}{\Lambda}\left[\cos(\alpha)\kappa_{HZZ}Z_{\mu\nu}Z^{\mu\nu} + \sin(\alpha)\kappa_{AZZ}Z_{\mu\nu}\tilde{Z}^{\mu\nu}\right] - \tfrac{1}{2}\tfrac{1}{\Lambda}\left[\cos(\alpha)\kappa_{HWW}W_{\mu\nu}^+W^{-\mu\nu} + \sin(\alpha)\kappa_{AWW}W_{\mu\nu}^+\tilde{W}^{-\mu\nu}\right]\Big\} X_0.$$



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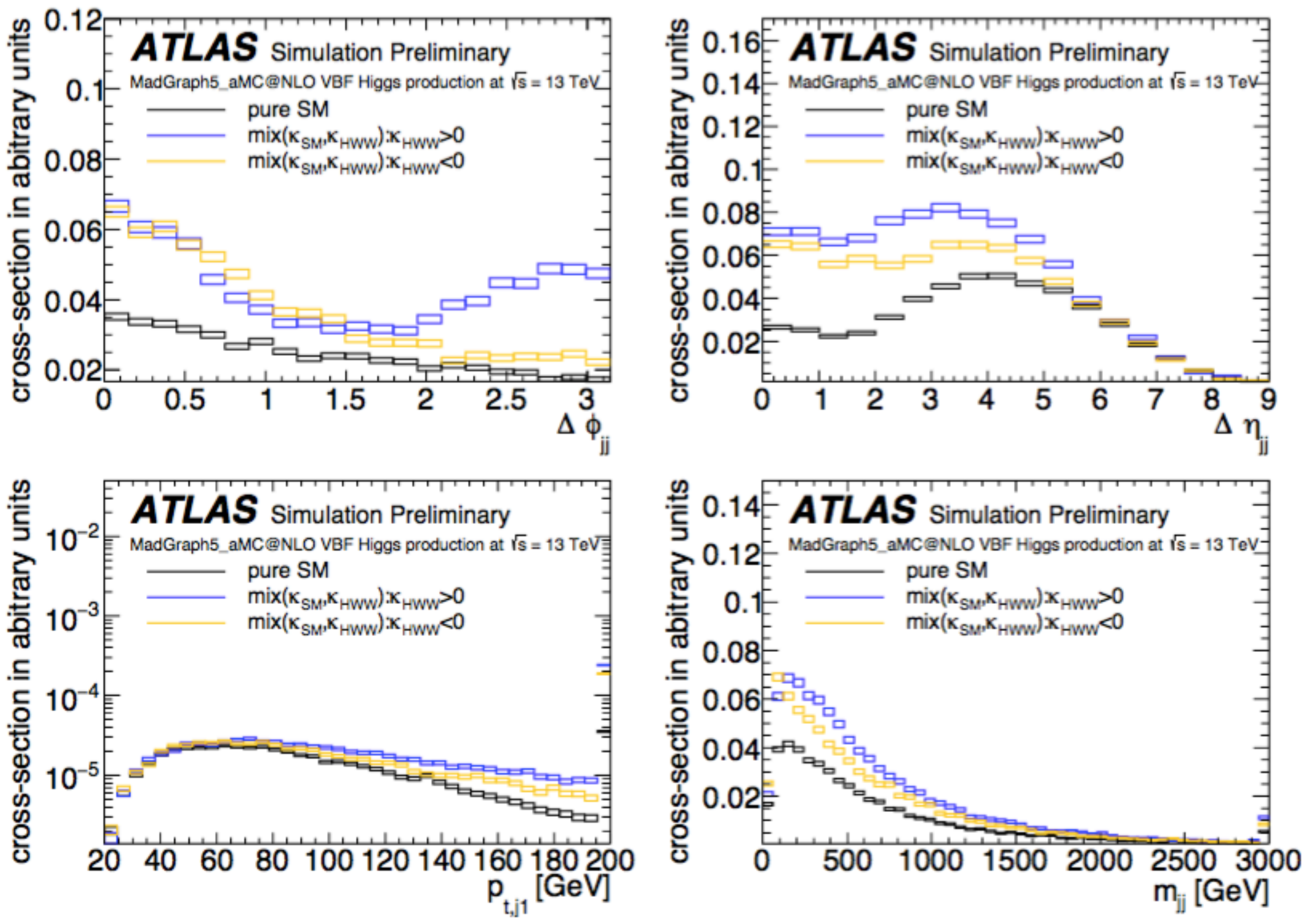
$$\begin{aligned}\mathcal{L}_0^V = & \left\{\cos(\alpha)\kappa_{\mathrm{SM}}\left[\tfrac{1}{2}g_{HZZ}Z_\mu Z^\mu + g_{HWW}W^+_\mu W^{-\mu}\right]\right. \\ & -\tfrac{1}{4}\tfrac{1}{\Lambda}\left[\cos(\alpha)\kappa_{HZZ}Z_{\mu\nu}Z^{\mu\nu} + \sin(\alpha)\kappa_{AZZ}Z_{\mu\nu}\tilde{Z}^{\mu\nu}\right] \\ & \left.-\tfrac{1}{2}\tfrac{1}{\Lambda}\left[\cos(\alpha)\kappa_{HWW}W^+_{\mu\nu}W^{-\mu\nu} + \sin(\alpha)\kappa_{AWW}W^+_{\mu\nu}\tilde{W}^{-\mu\nu}\right]\right\}X_0.\end{aligned}$$



HIGGS COUPLINGS & EFT

- Higgs analysis depends on precise theory predictions
- κ framework :
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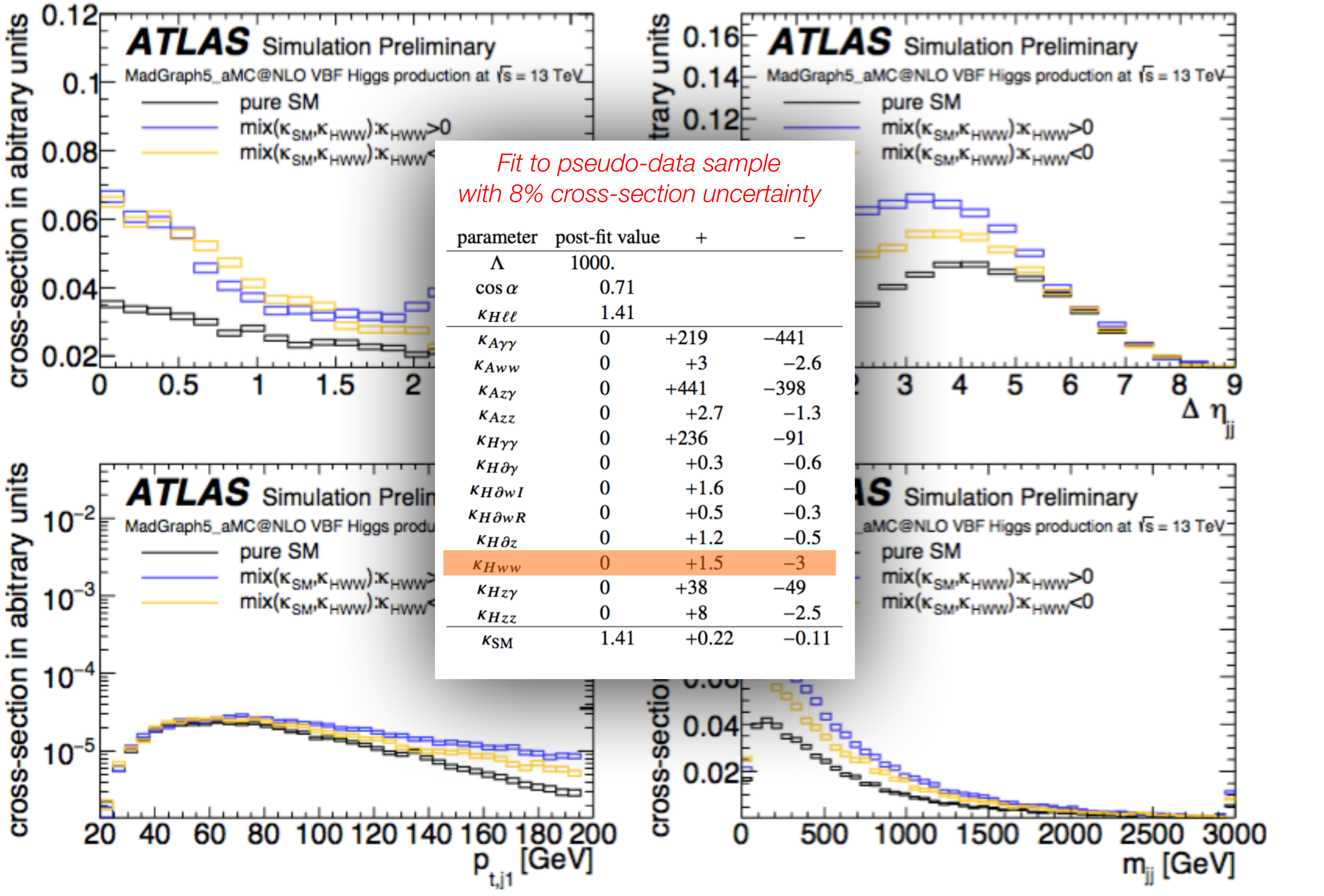
  - Differential distributions not fully utilized
- Move towards Effective Field Theory!
  - Interpolate distributions by varying (combinations of) Wilson coefficients
- A lot of work to do this right/consistent!
  - Need proper 'EFT matching' to link to eg. LHCb
  - Requires influence on the analysis procedures
  - Blurrs the theory/experiment boundary

$$\mathcal{L}_0^V = \Big\{\cos(\alpha)\kappa_{\rm SM}\left[\tfrac{1}{2}g_{HZZ}Z_\mu Z^\mu + g_{HWW}W^+_\mu W^{-\mu}\right] - \tfrac{1}{4}\tfrac{1}{\Lambda}\left[\cos(\alpha)\kappa_{HZZ}Z_{\mu\nu}Z^{\mu\nu} + \sin(\alpha)\kappa_{AZZ}Z_{\mu\nu}\tilde{Z}^{\mu\nu}\right] - \tfrac{1}{2}\tfrac{1}{\Lambda}\left[\cos(\alpha)\kappa_{HWW}W^+_{\mu\nu}W^{-\mu\nu} + \sin(\alpha)\kappa_{AWW}W^+_{\mu\nu}\tilde{W}^{-\mu\nu}\right]\Big\}X_0.$$



Fit to pseudo-data sample with 8% cross-section uncertainty

parameter	post-fit value	+	−
Λ	1000.		
$\cos\alpha$	0.71		
$\kappa_{H\ell\ell}$	1.41		
$\kappa_{A\gamma\gamma}$	0	+219	−441
κ_{Aww}	0	+3	−2.6
$\kappa_{Az\gamma}$	0	+441	−398
κ_{Azz}	0	+2.7	−1.3
$\kappa_{H\gamma\gamma}$	0	+236	−91
$\kappa_{H\partial\gamma}$	0	+0.3	−0.6
$\kappa_{H\partial wI}$	0	+1.6	−0
$\kappa_{H\partial wR}$	0	+0.5	−0.3
$\kappa_{H\partial z}$	0	+1.2	−0.5
κ_{Hww}	0	+1.5	−3
$\kappa_{Hz\gamma}$	0	+38	−49
κ_{Hzz}	0	+8	−2.5
$\kappa_{\rm SM}$	1.41	+0.22	−0.11

WHY SHOULD WE JOIN THE GAME?

Global “Across Experiment” analyses of precision measurements, together with precision theory will be (are!) crucial to the next phase of (discoveries in) Particle Physics.

Nikhef can and should play a key role:

- We have the necessary expertise ‘in house’: experiment, analysis, statistics, theory
- We can influence the strategy & delivery of measurements
- But to make progress requires a dedicated effort if we aim to make a real impact.

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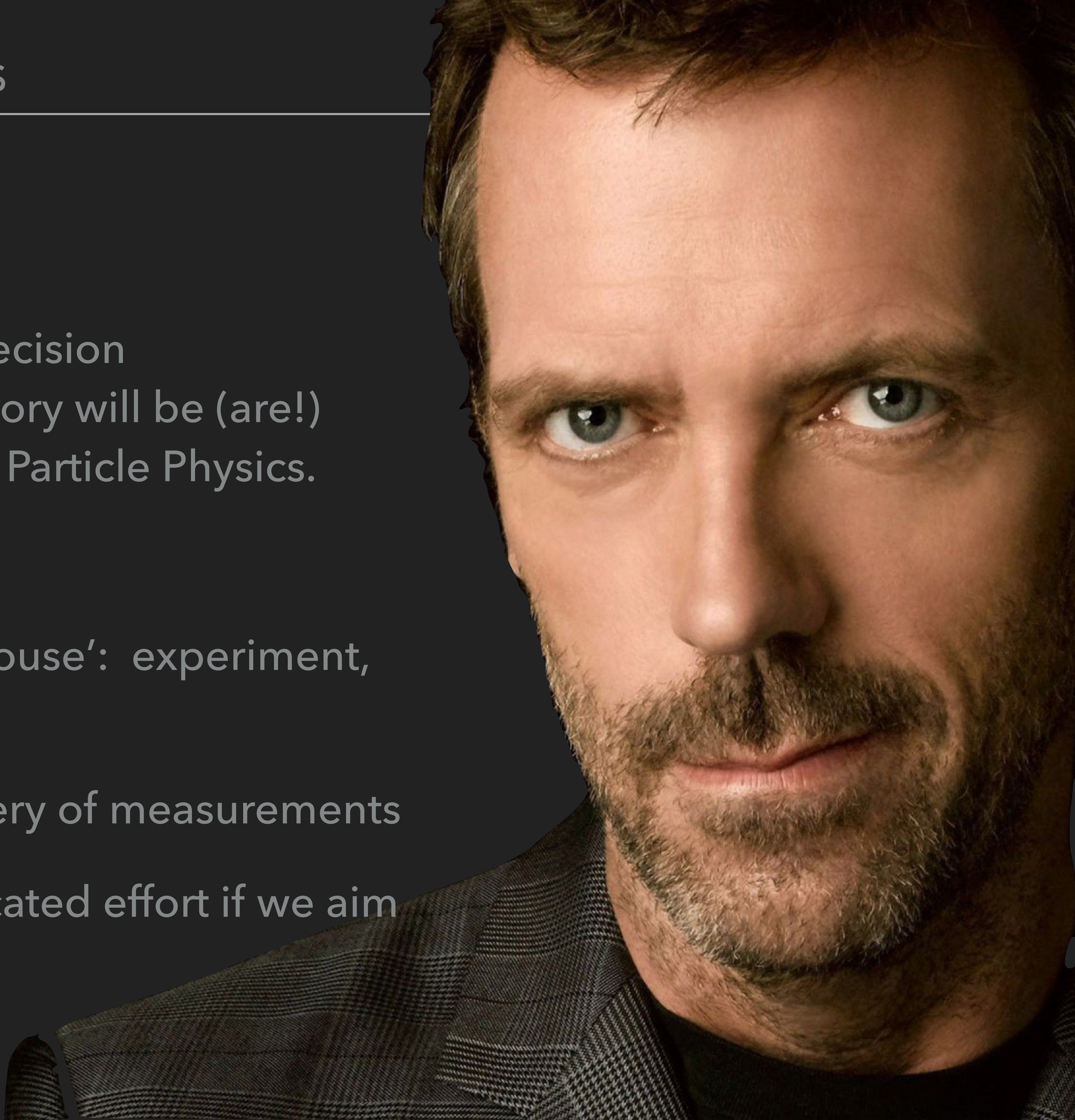

WHY SHOULD WE JOIN THE GAME?

“ANOMALIES BUG ME.” HOUSE, M.D.

"THERE'S NOTHING IN THIS UNIVERSE THAT CAN'T BE EXPLAINED — EVENTUALLY." HOUSE, M.D.

"IN THIS UNIVERSE EFFECT FOLLOWS CAUSE — I’VE COMPLAINED ABOUT IT BUT…” HOUSE, M.D.

“YOU COULD THINK I'M WRONG, BUT THAT'S NO REASON TO STOP THINKING.” HOUSE, M.D.

“TIME CHANGES EVERYTHING — THAT’S WHAT PEOPLE SAY, IT’S NOT TRUE: DOING THINGS CHANGES THINGS;” HOUSE, M.D.

MY BOSS TOLD ME TO HAVE A GOOD DAY…

…SO I WENT HOME.

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- Strength: present in many relevant experiments, can influence measurements strategy / delivery; have early access; theory/experiment/statistics expertise ‘in house’
- Weakness: (many) x (small fraction of FTE) = 0 impact
- Opportunity: synergy across Nikhef programs; informs future strategy; future combinations will increase complexity, playing into our strengths
- Threat: –

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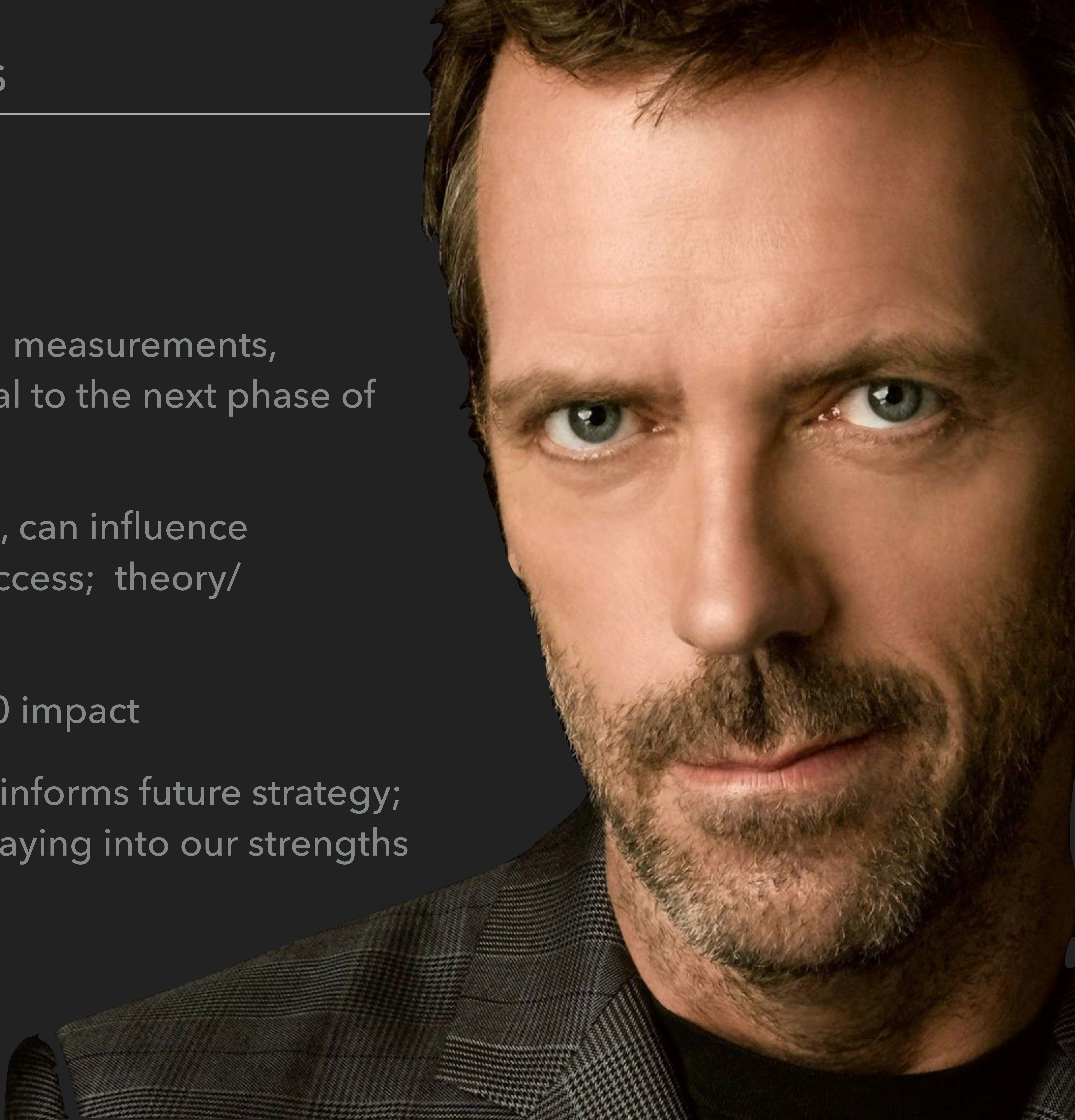


Flavored Dark Matter and the Galactic Center Gamma-Ray Excess

Prateek Agrawal,[1] Brian Batell,[2] Dan Hooper,[3,4] and Tongyan Lin[5]

[1] *Fermi National Accelerator Laboratory, Theoretical Physics Group, Batavia, IL, 60510*
[2] *Enrico Fermi Institute, University of Chicago, Chicago, IL, 60637*
[3] *Fermi National Accelerator Laboratory, Theoretical Astrophysics Group, Batavia, IL, 60510*
[4] *Department of Astronomy and Astrophysics, University of Chicago, Chicago, IL, 60637*
[5] *Kavli Institute for Cosmological Physics, University of Chicago, Chicago, IL, 60637*

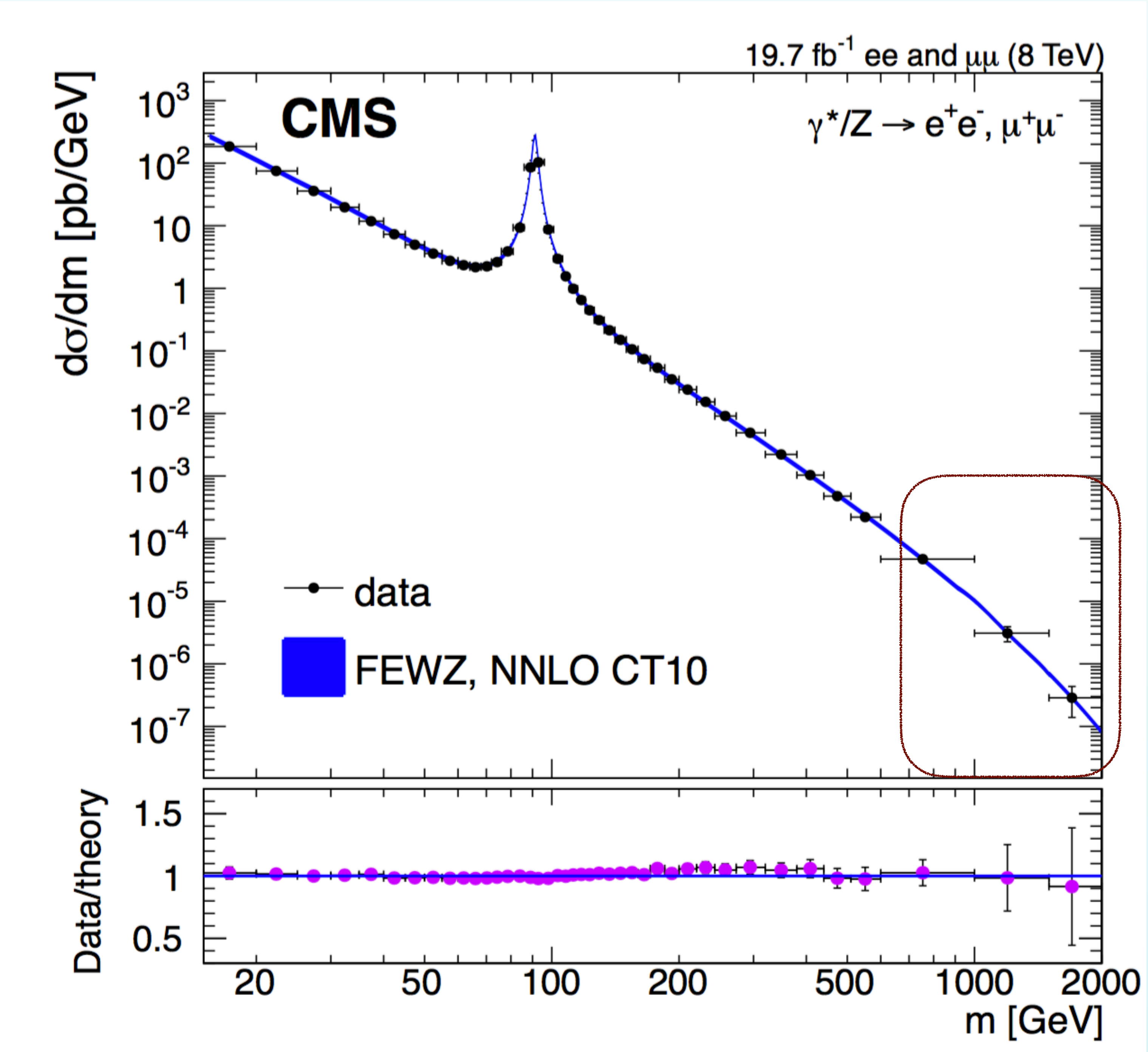
(Dated: April 8, 2014)

Thermal relic dark matter particles with a mass of 31-40 GeV and that dominantly annihilate to bottom quarks have been shown to provide an excellent description of the excess gamma rays observed from the center of the Milky Way. Flavored dark matter provides a well-motivated framework in which the dark matter can dominantly couple to bottom quarks in a flavor-safe manner. We propose a phenomenologically viable model of bottom flavored dark matter that can account for the spectral shape and normalization of the gamma-ray excess while naturally suppressing the elastic scattering cross sections probed by direct detection experiments. This model will be definitively tested with increased exposure at LUX and with data from the upcoming high-energy run of the Large Hadron Collider (LHC).

Why precision at the LHC?

To enhance the discovery potential of new **Beyond the Standard Model physics!**

- BSM physics could manifest as **subtle deviations** wrt to the Standard Model predictions
- Even for high-mass resonances, theory uncertainties **degrade or limit many BSM searches**
- The robustness of **global stress-tests of the SM** (electroweak fit, SM Effective Field Theory analysis) relies crucially in high-precision theoretical calculations



Generic SMEFT expansion

$$\sigma(E) = \sigma_{SM}(E)\left(1 + \epsilon\frac{m_{SM}^2}{m_W^2} + \epsilon\frac{E^2}{m_W^2} + \ldots\right)$$

For $\mathbf{E} \simeq \mathbf{1}$ **TeV**, a measurement with $\delta\sigma/\sigma \simeq \mathbf{10}\%$ is sensitive to $\epsilon \simeq \mathcal{O}(\mathbf{0.1}\%)$!

Marco Farina, HL/HE LHC workshop

BSM physics might very well hiding itself in the tails of distributions

Quantity	Value	Standard Model	Pull	Dev.
m_t [GeV]	$170.9 \pm 1.8 \pm 0.6$	171.1 ± 1.9	-0.1	-0.8
M_W [GeV]	80.428 ± 0.039	80.375 ± 0.015	1.4	1.7
	80.376 ± 0.033		0.0	0.5
M_Z [GeV]	91.1876 ± 0.0021	91.1874 ± 0.0021	0.1	-0.1
Γ_Z [GeV]	2.4952 ± 0.0023	2.4968 ± 0.0010	-0.7	-0.5
$\Gamma(\text{had})$ [GeV]	1.7444 ± 0.0020	1.7434 ± 0.0010	–	–
$\Gamma(\text{inv})$ [MeV]	499.0 ± 1.5	501.59 ± 0.08	–	–
$\Gamma(\ell^+\ell^-)$ [MeV]	83.984 ± 0.086	83.988 ± 0.016	–	–
σ_{had} [nb]	41.541 ± 0.037	41.466 ± 0.009	2.0	2.0
R_e	20.804 ± 0.050	20.758 ± 0.011	0.9	1.0
R_μ	20.785 ± 0.033	20.758 ± 0.011	0.8	0.9
R_τ	20.764 ± 0.045	20.803 ± 0.011	-0.9	-0.8
R_b	0.21629 ± 0.00066	0.21584 ± 0.00006	0.7	0.7
R_c	0.1721 ± 0.0030	0.17228 ± 0.00004	-0.1	-0.1
$A_{FB}^{(0,e)}$	0.0145 ± 0.0025	0.01627 ± 0.00023	-0.7	-0.6
$A_{FB}^{(0,\mu)}$	0.0169 ± 0.0013		0.5	0.7
$A_{FB}^{(0,\tau)}$	0.0188 ± 0.0017		1.5	1.6
$A_{FB}^{(0,b)}$	0.0992 ± 0.0016	0.1033 ± 0.0007	-2.5	-2.0
$A_{FB}^{(0,c)}$	0.0707 ± 0.0035	0.0738 ± 0.0006	-0.9	-0.7
$A_{FB}^{(0,s)}$	0.0976 ± 0.0114	0.1034 ± 0.0007	-0.5	-0.4
$\bar{s}_\ell^2(A_{FB}^{(0,q)})$	0.2324 ± 0.0012	0.23149 ± 0.00013	0.8	0.6
	0.2238 ± 0.0050		-1.5	-1.6
A_e	0.15138 ± 0.00216	0.1473 ± 0.0011	1.9	2.4
	0.1544 ± 0.0060		1.2	1.4
	0.1498 ± 0.0049		0.5	0.7
A_μ	0.142 ± 0.015		-0.4	-0.3
A_τ	0.136 ± 0.015		-0.8	-0.7
	0.1439 ± 0.0043		-0.8	-0.5
A_b	0.923 ± 0.020	0.9348 ± 0.0001	-0.6	-0.6
A_c	0.670 ± 0.027	0.6679 ± 0.0005	0.1	0.1
A_s	0.895 ± 0.091	0.9357 ± 0.0001	-0.4	-0.4
g_L^2	0.3010 ± 0.0015	0.30386 ± 0.00018	-1.9	-1.8
g_R^2	0.0308 ± 0.0011	0.03001 ± 0.00003	0.7	0.7
$g_V^{\nu e}$	-0.040 ± 0.015	-0.0397 ± 0.0003	0.0	0.0
$g_A^{\nu e}$	-0.507 ± 0.014	-0.5064 ± 0.0001	0.0	0.0
A_{PV}	$(-1.31 \pm 0.17)\cdot 10^{-7}$	$(-1.54 \pm 0.02)\cdot 10^{-7}$	1.3	1.2
$Q_W(\text{Cs})$	-72.62 ± 0.46	-73.16 ± 0.03	1.2	1.2
$Q_W(\text{Tl})$	-116.4 ± 3.6	-116.76 ± 0.04	0.1	0.1
$\frac{\Gamma(b\to s\gamma)}{\Gamma(b\to Xe\nu)}$	$\left(3.55^{+0.53}_{-0.46}\right) \cdot 10^{-3}$	$(3.19 \pm 0.08) \cdot 10^{-3}$	0.8	0.7
$\frac{1}{2}(g_\mu - 2 - \frac{\alpha}{\pi})$	$4511.07(74) \cdot 10^{-9}$	$4509.08(10) \cdot 10^{-9}$	2.7	2.7
τ_τ [fs]	290.93 ± 0.48	291.80 ± 1.76	-0.4	-0.4

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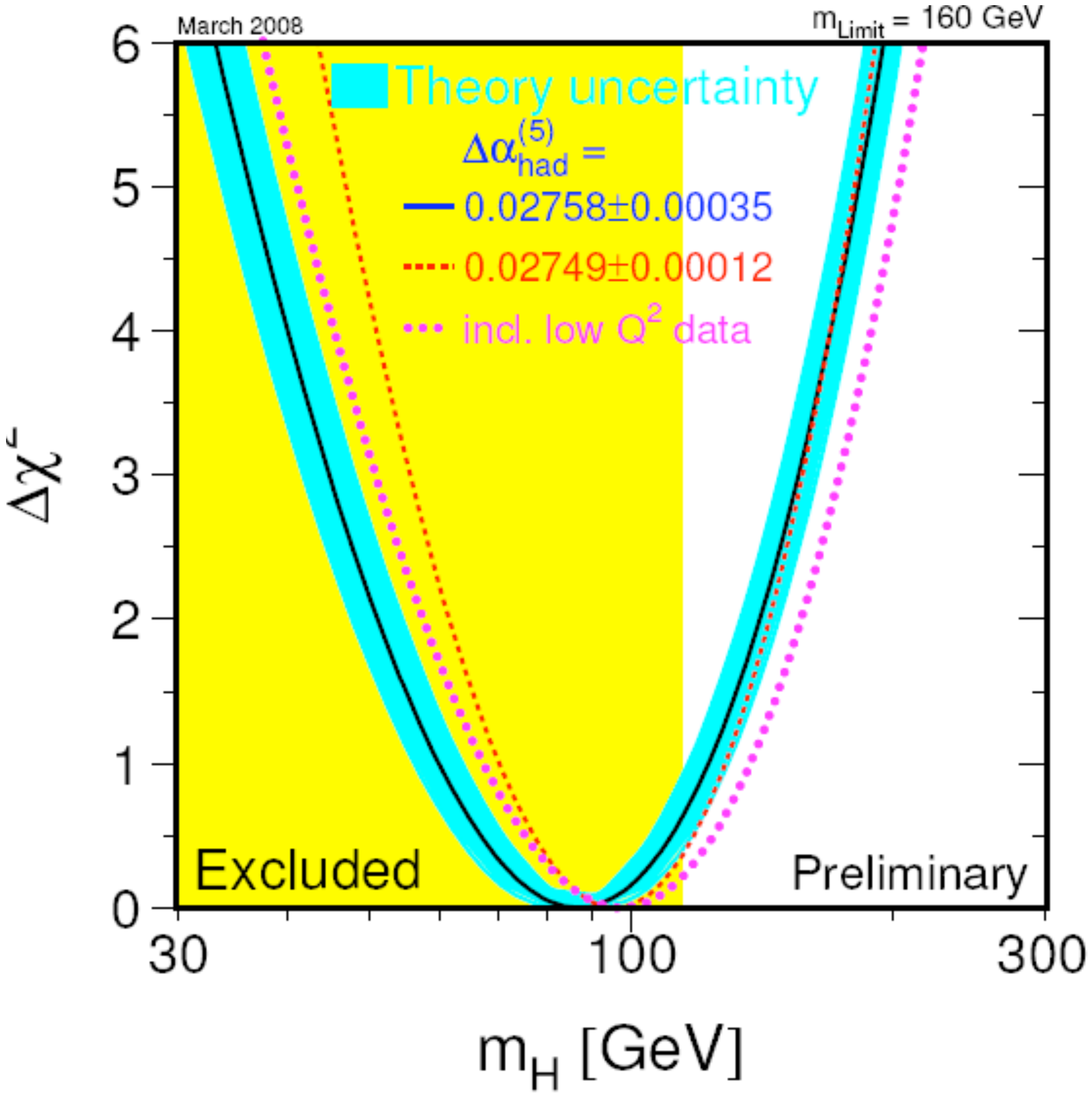

- The yellow band is LEP 95% CL exclusion (but there is more information than just a band)

- The fit yields :

$$M_H = 77^{+28}_{-22}\ \text{GeV}$$

- The 90% Confidence Interval :

$$42\ \text{GeV} \leq M_H \leq 124\ \text{GeV}$$

- Including LEP limit :

$$M_H \leq 167\ (155,\ 195)\ \text{GeV}$$

at $95\ (90,\ 99)\%\ \text{CL}$