Pushing the Boundaries 2019

The Standard Model and Beyond (at LHC)

WRAP-UP

Antonella De Santo

University of Sussex

(IPPP Senior Experimental Fellow 2018/19)

Workshop Structure

Day 1

This Intro

Status and Outlook

ECR session #1

Day 2

Direct BSM Searches (at colliders and beyond) – with focus on EWK signalS

ECR session #2

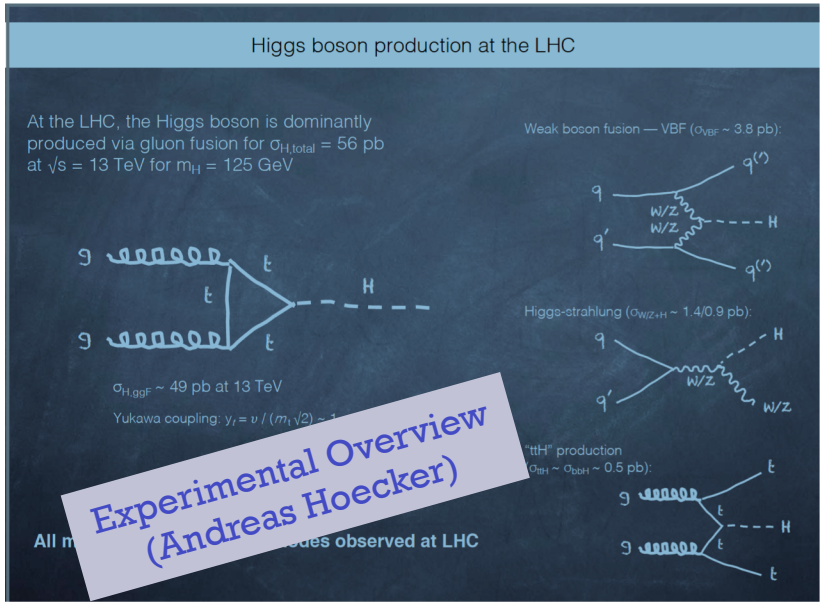
Day 3

BSM searches and EFT

Conclusions

Intense, but we learned a lot

Day 1 – An Overiew of the Landscape



Dark Matter

ADVANTAGES	DISADVANTAGES
• Definitely there	• We can only see it gravitationally
• There is so much, we can see it gravitationally	• We mostly know what it is not
• It is stable	• Not even sure it is a particle
• Points to a whole new sector	

Theory Overview (Jackub Scholtz)

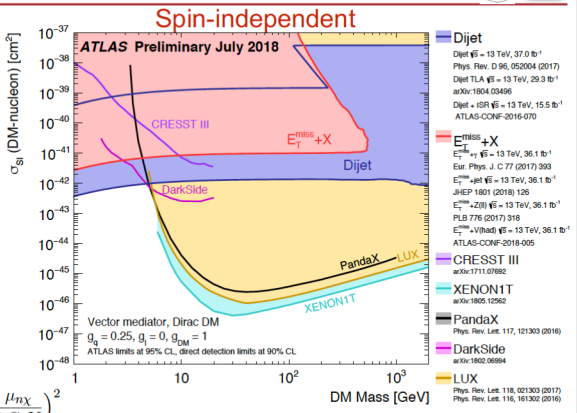
Day 2 – Direct BSM Searches

Dark Matter Searches (Henning Flaecher)

University of BRISTOL

Comparison of Collider and Direct Detection

- simplified
- at LHC into
- pace probed by direct
- ion experiments
- Caveat:
  - Limits depend on assumptions made for model parameters, i.e., fixed values for couplings
- Vector mediator ↔ spin independent DM – nucleon scattering



$$\sigma_{SI} \simeq 6.9 \times 10^{-43}\ \mathrm{cm}^2 \cdot \left(\frac{g_q g_{DM}}{1}\right)^2 \left(\frac{125\,\mathrm{GeV}}{M_{med}}\right)^4 \left(\frac{\mu_{n\chi}}{1\,\mathrm{GeV}}\right)^2$$

$\mu_{n\chi} = m_n m_{DM}/(m_n + m_{DM})$ is the DM-nucleon reduced mass

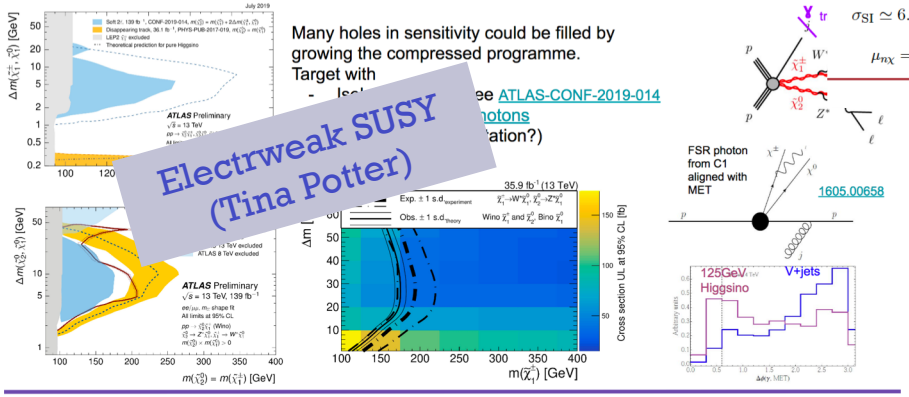
LHC only competitive for $m_{DM} < 6$ GeV

Henning Flaecher • Pushing the Boundaries - IPPP • 19th September 2019 20

Electrweak SUSY (Tina Potter)

Compressed SUSY: so hot right now

Many holes in sensitivity could be filled by growing the compressed programme.
Target with
- ee ATLAS-CONF-2019-014
- hotons
- ation?)



Tina Potter, University of Cambridge 12

Z' Explanations of Neutral Current B Anomalies

by
Ben Allanach
(University of Cambridge)

- Can we directly discover the Z' particles responible?
- Simplified models
- Third Family Hypercharge Model
- General SM$\times U(1)$ model

Those Anomalies.... (Ben Allanach)

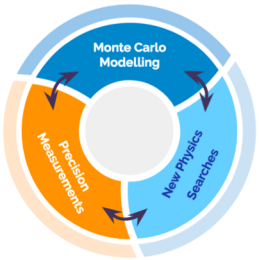
Cambridge Pheno Working Group
Where data and theory collide

Science & Technology Facilities Council

Day 2 – (Non-EFT) SM Approach to BSM

Advantages

- **Can compare directly to MC without simulating the detector**
  - Quick and CPU-cheap
  - Easy to scan wide parameter space
  - Accessible to everyone
  - Can update if SM modelling improves
- **Not targeting specific process**
  - Maintain sensitivity to many scenarios



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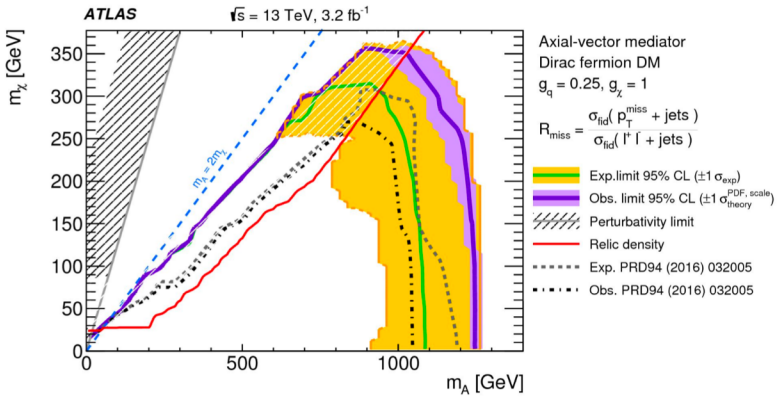
Zara Grout

Interpretations: Dark Matter



S-channel WIMP production

- Scan over mediator mass and DM mass
- Limits competitive with existing reconstruction-level analysis in mono-jet final state
- Use 95% CLs method and include correlations between all bins of all distributions in covariance matrix

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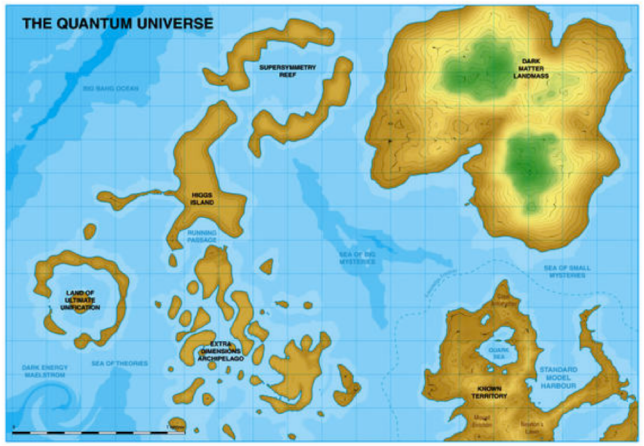
Strategy for LHC Run3 and Beyond

Strategy for Run3 and beyond

I think that our community is becoming more data-driven. Experimental results will have to guide the HEP community to the next stages of exploration.



Till Eifert

As long as no clear signs of NP ⇒

broad and diversified search and measurement programme.

Anything missing in search programmes?

- I am not aware of significant gaps in model / parameter space, perhaps not surprising given large community effort (~2 x 3000 exp physicists + th community) over past ~decade.
- New triggers for Run3 and beyond may create opportunities … requires good ideas and hard work!
- Long-lived particle searches:
  - I am a very excited about the LLP programme,
  - but I often hear: "There's still a lot of missing analyses / model space to be covered". I have not found many significant 'holes'.
  - For example, SUSY search coverage of LLP appears fairly robust. Example, study of sensitivity (gaps) between searches for prompt and long-lived particles in ATLAS-CONF-2018-003.
  - Exotica offers, as often, many crazy signatures. Are there signatures that we are not yet covering (i.e. completely uncovered ground)? Please let me know if you know one!
- New detectors (incl. LHC det. upgrades) can extend BSM reach.
- I haven't considered much FIPs …

Theory Uncertainties

Jet-veto resummations

- The zero-jet cross section is an example of a two-scale observable, affected by logarithms $L \equiv \ln(M/p_{\mathrm{t,veto}})$ that need to be resummed at all orders

$$\sigma_{0-\mathrm{jet}} \simeq \sigma_0 \left(1 - 2C_A \frac{\alpha_s(m_H)}{\pi} \ln^2 \frac{m_H}{p_{\mathrm{t,veto}}} + \dots\right)$$

$$\downarrow$$

$$\sigma_{0-\mathrm{jet}} \sim \sigma_0 \, e^{\underbrace{Lg_1(\alpha_s L)}_{\mathrm{LL}}} \times \left(\underbrace{1}_{} + \underbrace{\alpha_s}_{} + \dots + \underbrace{G_2(\alpha_s L)}_{\mathrm{NLL}} + \underbrace{\alpha_s G_3(\alpha_s L)}_{\mathrm{NNLL}} + \dots\right)$$



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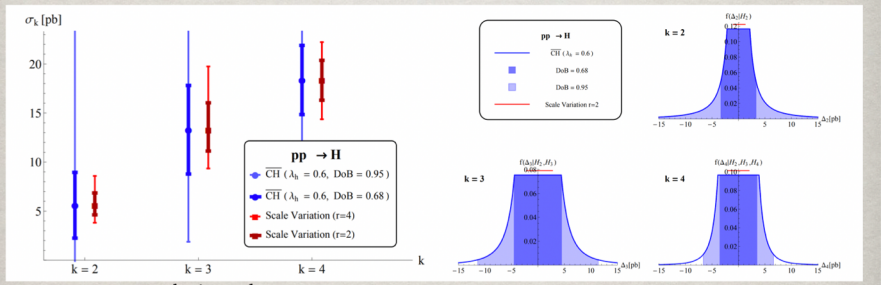
Andrea Banfi

Confidence in theory

- One can assign a degree of belief to theory uncertainty under the assumption it is dominated by the lowest missing PT order

[Cacciari Houdeau 1105.5152]

[Bagnaschi Cacciari Guffanti Jenniches 1409.5036]



perturbative order

- In general, there is no established procedure to translate scale variations into confidence intervals for theory predictions

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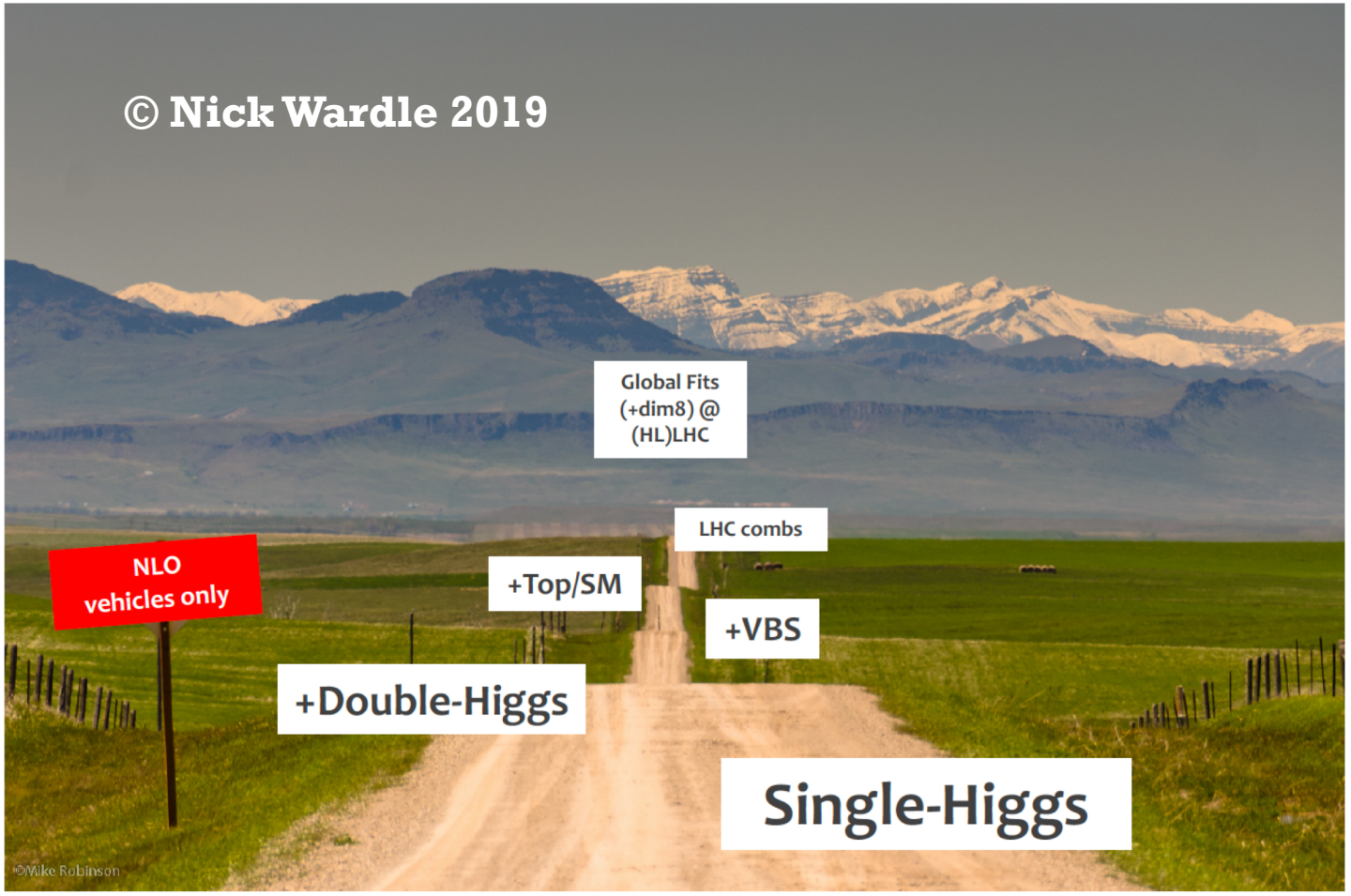
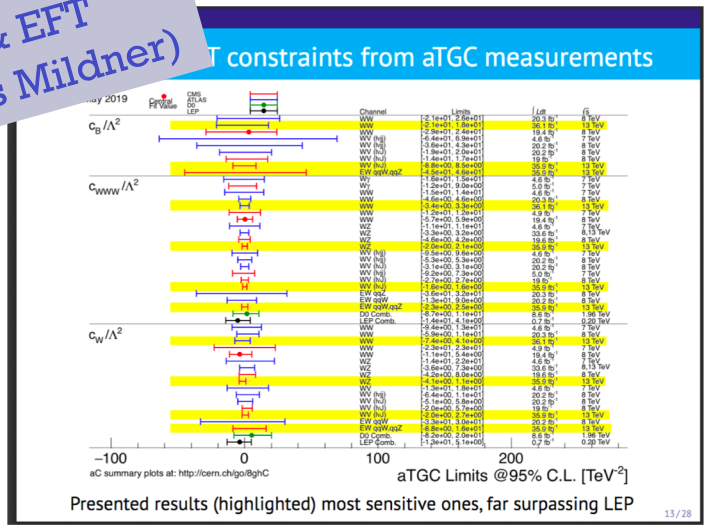
Day 3 – EFT (Theory & Experiments)

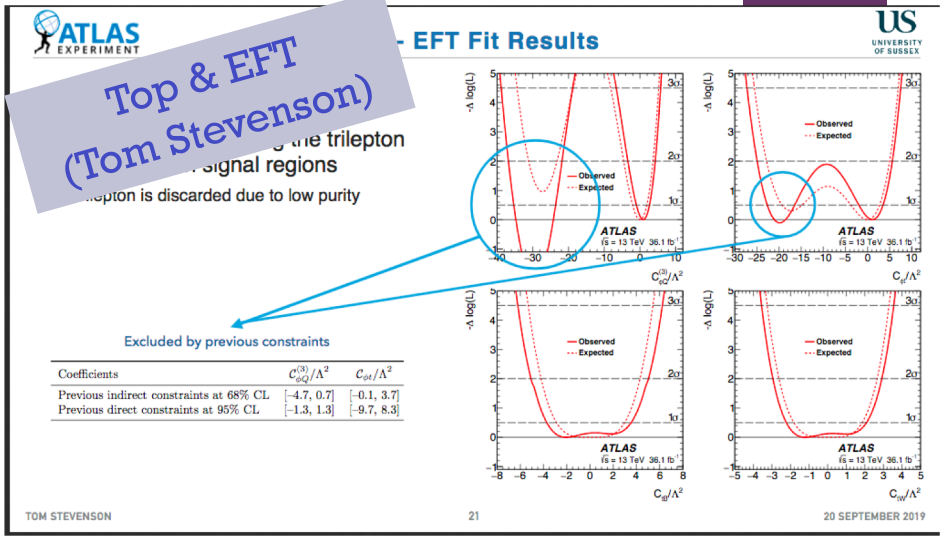


Day 3 – EFT (Theory & Experiments)

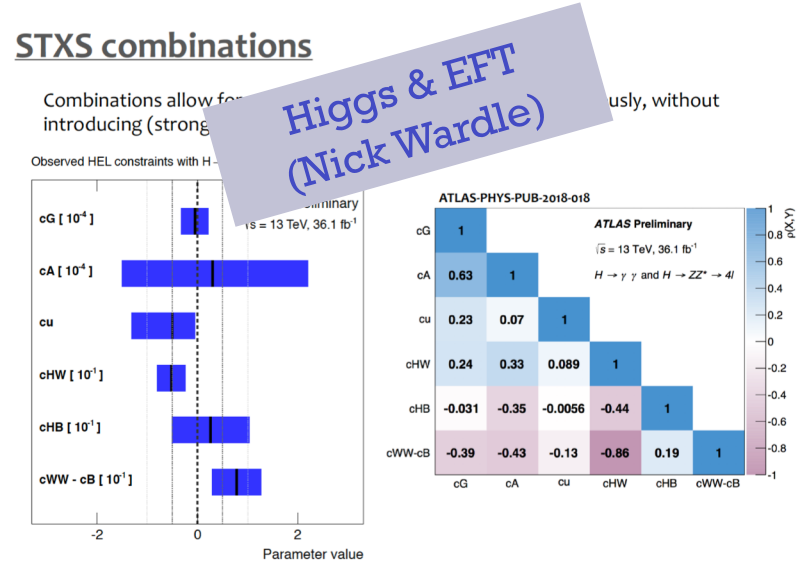
SM & EFT (Hannes Mildner)



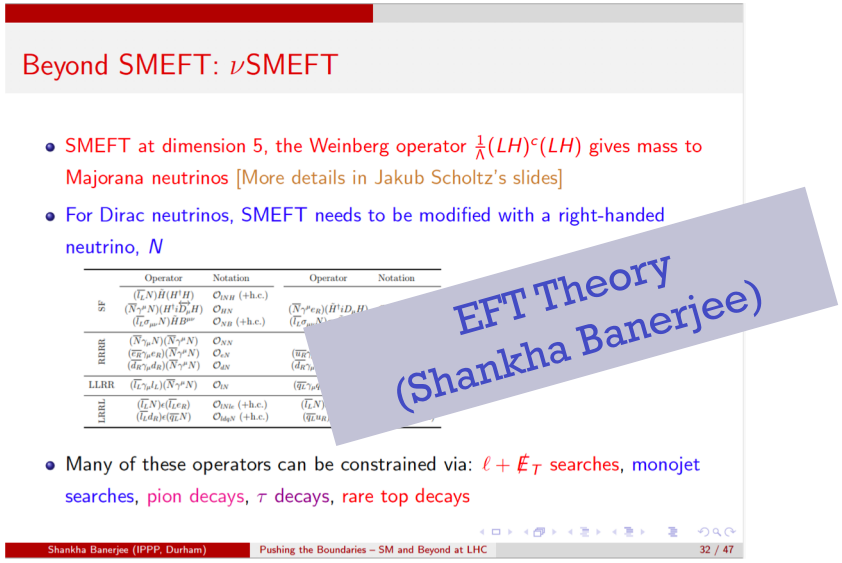
Top & EFT (Tom Stevenson)



Higgs & EFT (Nick Wardle)



EFT Theory (Shankha Banerjee)



Early Career Researchers

Excellent ECR session #1 (Julia Staedle, Daniela Koeck, Joey Reiness)

Equally excellent ECR session #2 (Fabrizio Trovato, Elliot Reid, Jonathon Langford)

Thank you and well done – the future is yours!

Thank You and Goodbye

goodbye

- **Our warmest welcome goes to all participants and particularly to all our speakers**
  - Thank you for joining us at a busy time of the year

- **A special thank you goes to IPPP**
  - For the excellent organization and hospitality
  - And for their generous financial contribution to the organization of this workshop through my Senior Experimental Fellowship (2018-19) award
    - https://www.ippp.dur.ac.uk/senior-experimental-fellowships2018-2019

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Huge Thank You to Trudy Forster

+

Postface

The Best Slide Prize

We are happy with **any** beyond the Standard Model roof

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Until next time!