The importance and strategy of direct searches for LHC Run 3 and beyond

Till Eifert (U of Texas Arlington & CERN), Workshop at Durham, UK, "Pushing the Boundaries — The SM and Beyond at the LHC.", September 2019



Disclaimer & Acknowledgements

The organisers asked me to present "many personal and possibly original and provocative points". Note that **I have a clear BSM bias towards SUSY**.

Thanks for input from: Federico Meloni, Klaus Mönig, Marie-Hélène Genest, Andreas Höcker.

The slides present my personal opinions. Any potential mistakes, oversights, etc. are on me!

Outline

• Setting the scene

Selected SUSY impressions from pre-LHC to post-Run2.

• Prospects of direct searches What sensitivity gains can we expect with the HL-LHC?

• Direct vs indirect searches Should we all go and do measurements?

• Strategy



Pre-LHC prologue



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Ô O

CERN — European Organization for Nuclear Research

LHCC Open SUSY Workshop

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30 October 1996

Transparencies from the workshop are provisionally available here thanks to the CERN WWW service.

Agenda

- Introduction to supersymmetry phenomenology (C.Wagner)
- <u>Supersymmetry searches at LEP</u> (M.Schmitt)
- Supersymmetry searches at the TeVatron and HERA (H.Montgomery)
- <u>Supersymmetry search by non-accelerator experiments</u>: cosmological dark matter (M.Spiro)
- Precision SUSY measurements with ATLAS:
 - Simulation tools and inclusive analyses (F.Paige)
 - Reconstruction of exclusive final states Part I (F.Gianotti)
 - Reconstruction of exclusive final states Part II (G.Polesello)
 - Extraction of model parameters and conclusions (D.Froidevaux)
- SUSY studies in CMS:
 - Optimisation of CMS for SUSY searches (D.Denegri)
 - Squark and gluino searches in leptons + jets + missing Et final states (S.Abdullin)
 - Possibilities to observe sleptons (L.Rurua)
 - Chargino / neutralino study (I.Iashvili)
 - Search for next-to-lightest neutralino (A. Kharchilava)
 - Conclusions (D.Denegri)

MS, 13 November 1996

Display a menu



LHCC 30 10 196

PRECISION SUSY MEASUREMENTS with ATLAS: RECONSTRUCTION of EXCLUSIVE FINAL STATES (Port 1)

presented

bγ

ATLAS-PHYS-No-107

Precision SUSY Measurements with ATLAS: Introduction and Inclusive Measurements*

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Abstract

If supersymmetry exists at the electroweak scale, then it should be discovered at the LHC. Determining masses, of supersymmetric particles however, is more difficult. In this paper, which serves as an introduction to a series of notes describing various SUSY studies within the ATLAS collaboration, the models used for simulation are discussed. A general method that can be applied to determine approximately the mass scale of the supersymmetric particles is described.

*This work was supported in part by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics of the U.S. Department of Energy under Contracts DE-AC03-76SF00098 and DE-AC02-76CH00016 and by Polish Government grants 2P03B00212 and 2P03B17210

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FABIOLA GIANOTTI

CERN and University of Milano

ATLAS-PHYS-No-107

Precision SUSY Measurements with ATLAS: Introduction and Inclusive Measurements*

The strategy developed within the ATLAS collaboration beginning at a meeting in Stockholm in January 1996 and culminating in the presentations to the LHC workshop in November 1996 [13] is reported in this series of papers [15][†] involves three steps. First, we use a simple inclusive analysis to establish a deviation from the Standard Model. We select events with at least four jets and large missing energy and plot the distribution of





First act: LHC Run-1



LHC Run-1 2010-2012



Pioneering data analyses: trigger, object reconstruction, tails, background estimation, ...

\rightarrow exciting time

We discovered the Higgs boson while not finding yet any evidence for new physics. Before first LHC results, word on the street was that SUSY would show up first.



As the first and last proton-lead run of 2013 draws to a close, the extensive maintenance programme of the LHC's first long shutdown is about to start

FEBRUARY, 2013 | By Caroline Du

Second act: LHC@13 TeV



LHC Run-2 2015-2018



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Observed limits

Expected limits

139.0 fb⁻¹

01 Ť

1L, t̃₁ → Wbχ̃⁰

[1708.03247]

tť, t̃, → tχ̃

[1903.07570] c0L, t̃, → cχ̃

[1805.01649] monojet, $\tilde{t}_1 \rightarrow c \tilde{\chi}_2^0$

[1711.03301]

[1506.08616]

monojet, $\tilde{t}_1 \rightarrow bff'\tilde{\chi}_1^0$ [1711.03301]

[ATLAS-CONF-2019-17]

 $\rightarrow t \tilde{v}^0 / \tilde{t} \rightarrow W h \tilde{v}^0$

2L, $\tilde{t}_1 \rightarrow t \tilde{\chi}_1^0 / \tilde{t}_1 \rightarrow Wb \tilde{\chi}_1^0 / \tilde{t}_1 \rightarrow bff' \tilde{\chi}_1^0$

 $\widetilde{\chi}_{1}^{0}/\widetilde{t}_{1} \rightarrow \text{bff}'\widetilde{\chi}_{2}^{0}$

Reactions ...



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2018 preview: Last chance for new physics at the LHC for years () () () () () () ()

PHYSICS 19 December 2017

By Leah Crane



Status today

- We learned that new physics was not around the corner.
- Naturalness: primary BSM guiding principle over the last decades.
 - key prediction: top quark partner (such as stop), mostly ruled out at the TeV level.
- Fundamental questions remain \rightarrow puzzling time

$\psi^*(r,t)\psi(r,t)$ What's the importance and strategy of direct searches for LHC Run 3 and beyond? $\psi(r,t) = \psi(r) \psi(t)$ Lp, A×≥

 $\mathcal{C} = \mathbf{x} + \mathbf{y} + \mathbf{x} = \mathbf{x} + \mathbf{y} + \mathbf{y} = \mathbf{x} + \mathbf{y} + \mathbf{y} + \mathbf{y} = \mathbf{x} + \mathbf{y} + \mathbf{y} + \mathbf{y} = \mathbf{x} + \mathbf{y} + \mathbf{y} + \mathbf{y} = \mathbf{y} + \mathbf{y} + \mathbf{y} + \mathbf{y} + \mathbf{y} = \mathbf{y} + \mathbf{y} +$

What's next at (HL) LHC?

LHC / HL-LHC Plan





On the (HL) LHC menu for next ~20 years:

- small increase ~8% in √s,
- large increase x20-x30 in ∫Ldt



Prospects of direct searches

to find signs of new physics



Prospects for finding NP at HL-LHC [1812.07831]

Heavy resonances and Lepto-Quarks



Expect ~50% increase in mass reach



Prospects for finding NP at HL-LHC

weakly coupled, DM



mono-jet search: from no sensitivity to higgsinos @ Run2, to 200 GeV at HL-LHC. (i.e. doubled wrt. LEP)



 $\Rightarrow \Delta m \sim independent limit (up to a few tens of GeV)$



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[1812.07831]

Prospects for finding NP at HL-LHC [1812.07831]

strong s-particle pair production



Expect ~50% increase in mass reach

Prospects for finding NP at HL-LHC electroweak s-particle pair production



Expect to ~double the mass reach

Important to also "deepen" the sensitivity (σ can vary, BFs not 100% etc.)

Prospects for finding NP at HL-LHC

ŀ	IL/HE-LHC	SUSY	Searche	HL-LHC , $\int \mathcal{L} dt = 3$	b^{-1} : 5σ discovery (95% CL exclusion)	Si	mulation Preliminary
	Model	e, μ, τ, γ	Jets	Mass limit			Section
	$\tilde{g}\tilde{g}, \tilde{g} { ightarrow} q \bar{q} \tilde{\chi}_1^0$	0	4 jets	ĝ	2.9 (3.2) TeV	$m(\tilde{\chi}_1^0)=0$	2.1.1
	$\tilde{g}\tilde{g},\tilde{g}{ ightarrow} q\bar{q}\tilde{\chi}_{1}^{0}$	0	4 jets	ğ	5.2 (5.7) TeV	$m(\tilde{\chi}_1^0)=0$	2.1.1
Gluino	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t t \tilde{\chi}_1^0$	0	Multiple	ĝ	2.3 (2.5) TeV	$m(\tilde{\chi}_1^0)=0$	2.1.3
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t \bar{c} \tilde{\chi}_1^0$	0	Multiple	ĝ	2.4 (2.6) TeV	$m(ilde{\mathcal{X}}_1^0){=}500~GeV$	2.1.3
	NUHM2, $\tilde{g} \rightarrow t\tilde{t}$	0	Multiple/2b	ĝ	5.5 (5.9) TeV		2.4.2
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$	0	Multiple/2b	Ĩ ₁	1.4 (1.7) TeV	$m(\tilde{\chi}_1^0)=0$	2.1.2, 2.1.3
top	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 {\rightarrow} t \tilde{\chi}_1^0$	0	Multiple/2b	\tilde{t}_1	0.6 (0.85) TeV	$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \sim m(t)$	2.1.2
S	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow b \tilde{\chi}^{\pm} / t \tilde{\chi}_1^0, \tilde{\chi}_2^0$	0	Multiple/2b	ĩ	3.16 (3.65) TeV		2.4.2
	$\tilde{\chi}_1^+ \tilde{\chi}_1^-, \tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$	2 e,µ	0-1 jets	$\tilde{\chi}_1^{\pm}$	0.66 (0.84) TeV	$m(\tilde{\chi}_1^0)=0$	2.2.1
iino, alino	$ ilde{\chi}_1^{\pm} ilde{\chi}_2^0$ via WZ	3 <i>e</i> , <i>µ</i>	0-1 jets	$\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$	0.92 (1.15) TeV	$m(\tilde{\chi}_1^0)=0$	2.2.2
harg eutra	$\tilde{\chi}_1^{\pm} \tilde{\chi}_2^0$ via <i>Wh</i> , <i>Wh</i> $\rightarrow \ell \nu b \bar{b}$	1 <i>e</i> , <i>µ</i>	2-3 jets/2b	$\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$	1.08 (1.28) TeV	$m(\tilde{\chi}_1^0)=0$	2.2.3
0 =	$\tilde{\chi}_{2}^{\pm}\tilde{\chi}_{4}^{0} {\rightarrow} W^{\pm}\tilde{\chi}_{1}^{0}W^{\pm}\tilde{\chi}_{1}^{\pm}$	2 <i>e</i> , <i>µ</i>	-	$ ilde{\chi}^{\pm}_2/ ilde{\chi}^0_4$	0.9 TeV	m($\tilde{\chi}_1^0$)=150, 250 GeV	2.2.4
0	$\tilde{\chi}_1^{\pm} \tilde{\chi}_2^0 + \tilde{\chi}_2^0 \tilde{\chi}_1^0, \tilde{\chi}_2^0 \rightarrow Z \tilde{\chi}_1^0, \tilde{\chi}_1^{\pm} \rightarrow W \tilde{\chi}_1^0$	2 <i>e</i> , µ	1 jet	$ ilde{\chi}_1^{\pm}/ ilde{\chi}_2^0$	0.25 (0.36) TeV	$m(\tilde{\chi}_1^0)=15GeV$	2.2.5.1
igsin	$\tilde{\chi}_1^{\pm} \tilde{\chi}_2^0 + \tilde{\chi}_2^0 \tilde{\chi}_1^0, \tilde{\chi}_2^0 \rightarrow Z \tilde{\chi}_1^0, \tilde{\chi}_1^{\pm} \rightarrow W \tilde{\chi}_1^0$	2 <i>e</i> , <i>µ</i>	1 jet	$ ilde{\chi}_1^{\pm}/ ilde{\chi}_2^0$	0.42 (0.55) TeV	$m(\tilde{\chi}_1^0)=15GeV$	2.2.5.1
Hig	$ ilde{\chi}_2^0 ilde{\chi}_1^{\pm}, ilde{\chi}_1^{\pm} ilde{\chi}_1^{\mp}, ilde{\chi}_1^{\pm} ilde{\chi}_1^0$	2 μ	1 jet	${ ilde \chi}^0_2$	0.21 (0.35) TeV	$\Delta m(\tilde{\chi}^0_2, \tilde{\chi}^0_1)$ =5 GeV	2.2.5.2
Wino	$ ilde{\chi}_2^{\pm} ilde{\chi}_4^0$ via same-sign WW	2 <i>e</i> , µ	0	Wino	0.86 (1.08) TeV		2.4.2
	$\tilde{\tau}_{L,R}\tilde{\tau}_{L,R}, \tilde{\tau} {\rightarrow} \tau \tilde{\chi}_1^0$	2 τ	-	$ ilde{ au}$	0.53 (0.73) TeV	$m(\mathcal{ ilde{X}}_1^0) {=} 0$	2.3.1
itau	$ ilde{ au} ilde{ au}$	$2\tau, \tau(e,\mu)$	-	$ ilde{ au}$	0.47 (0.65) TeV	$m(\tilde{\chi}_1^0)=0, m(\tilde{\tau}_L)=m(\tilde{\tau}_R)$	2.3.2
U	τ̃τ	$2\tau,\tau(e,\mu)$	-	$ ilde{ au}$	0.81 (1.15) TeV	$m(\tilde{\chi}_1^0)=0, m(\tilde{\tau}_L)=m(\tilde{\tau}_R)$	2.3.4
	$ ilde{\chi}_1^{\pm} ilde{\chi}_1^{\mp}, ilde{\chi}_1^{\pm} ilde{\chi}_1^0$, long-lived $ ilde{\chi}_1^{\pm}$	Disapp. trk.	1 jet	$ ilde{\chi}_1^{\pm} = [au(ilde{\chi}_1^{\pm}) = 1 \text{ns}]$	0.8 (1.1) TeV	Wino-like $\tilde{\chi}_1^{\pm}$	4.1.1
	$\tilde{\chi}_1^{\pm} \tilde{\chi}_1^{\mp}, \tilde{\chi}_1^{\pm} \tilde{\chi}_1^0$, long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk.	1 jet	$ ilde{\chi}_1^{\pm} [au(ilde{\chi}_1^{\pm})=1 \text{ns}]$	0.6 (0.75) TeV	Higgsino-like ${ ilde \chi}_1^{\pm}$	4.1.1
	MSSM, Electroweak DM	Disapp. trk.	1 jet	DM mass	0.88 (0.9) TeV	Wino-like DM	4.1.3
p s	MSSM, Electroweak DM	Disapp. trk.	1 jet	DM mass	2.0 (2.1) TeV	Wino-like DM	4.1.3
g-liv∈ ticle:	MSSM, Electroweak DM	Disapp. trk.	1 jet	DM mass	0.28 (0.3) TeV	Higgsino-like DM	4.1.3
Long	MSSM, Electroweak DM	Disapp. trk.	1 jet	DM mass	0.55 (0.6) TeV	Higgsino-like DM	4.1.3
	\tilde{g} R-hadron, $\tilde{g} \rightarrow qq \tilde{\chi}_1^0$	0	Multiple	$\tilde{g} = [\tau(\tilde{g}) = 0.1 - 3 \text{ ns}]$	3.4 TeV	$m(ilde{\chi}_1^0){=}100~{ ext{GeV}}$	4.2.1
	\tilde{g} R-hadron, $\tilde{g} \rightarrow qq \tilde{\chi}_1^0$	0	Multiple	$\tilde{g} = [\tau(\tilde{g}) = 0.1 - 10 \text{ ns}]$	2.8 TeV		4.2.1
	GMSB $\tilde{\mu} \rightarrow \mu \tilde{G}$	displ. μ	-	$\tilde{\mu}$	0.2 TeV	<i>cτ</i> =1000 mm	4.2.2
							arXiv:1812.07831
10^{-1} 1 Mass scale [TeV]							

Opportunities

LHC phase-2 detector upgrades

Timing detectors (4D reconstruction, long-lived particles)

New trigger systems with more information (high granularity calorimeter, tracking information, global "view" at level-1)

Improved systematics (det. understanding, theory calc.)

Systematics limited searches, for example:

low-mass resonances with tiny couplings

monojet (to access higgsino/wino DM)

Measurements

Improved tools to discriminate signal from background b-tagger, c-tagger, top-tagger, etc. tau identification

Prospects for finding NP at HL-LHC

ŀ	IL/HE-LHC \$	SUSY	Searche	HL-LHC, $\int \mathcal{L} dt = 3ab^{-1}$: 5 HE-LHC, $\int \mathcal{L} dt = 15ab^{-1}$: 5	σ discovery (95% CL exclusion)	Si	mulation Preliminar
	Model	e, μ, τ, γ	Jets	Mass limit			Section Section
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$	0	4 jets		2.9 (3.2) TeV	$m(\tilde{\chi}_1^0)=0$	2.1.1
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	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow t \tilde{\chi}_1^0$	0	Multiple/2b	\tilde{t}_1	1.4 (1.7) TeV	$m(\tilde{\chi}_1^0)=0$	2.1.2, 2.1.3
top	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$	0	Multiple/2b	$ ilde{t}_1$	0.6 (0.85) TeV	$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \sim m(t)$	2.1.2
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	$\tilde{\chi}_1^+ \tilde{\chi}_1^-, \tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$	2 <i>e</i> , <i>µ</i>	0-1 jets	$ ilde{\chi}_1^{\pm}$	0.66 (0.84) TeV	$m(\tilde{\chi}_1^0)=0$	2.2.1
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g-liv ticle	MSSM, Electroweak DM	Disapp. trk.	1 jet	DM mass	0.28 (0.3) TeV	Higgsino-like DM	4.1.3
Lon	MSSM, Electroweak DM	Disapp. trk.	1 jet	DM mass	0.55 (0.6) TeV	Higgsino-like DM	4.1.3
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	GMSB $\tilde{\mu} \rightarrow \mu \tilde{G}$	displ. μ	-	$ ilde{\mu}$	0.2 TeV	<i>cτ</i> =1000 mm	4.2.2
							arXiv:1812.07831

Ultra compressed spectrum

 $\tilde{\chi}_2^0$ $\rightarrow (Z^* \rightarrow \ell^+ \ell^-)$ $\rightarrow (W^* \rightarrow \text{soft objects})$ $\tilde{\chi}_1^{\pm}$ $\tilde{\chi}_1^0$ Δm = few hundred MeV -7 10 e 1 -8 10 10 0.8 **Branching Ratio** -10 **Branching Ratio** hadrons hadrons 10 -11 s/10[°] 0.6 π^+ π^+ -12 u d 10 u d 0.4 $16 M_{\chi}^{13} = M_{\chi}(\pi^{+})m(\pi^{+})$ π^+ π+ π^{0} π^{0} $\mathbf{c} \overline{\mathbf{s}}$ $c \bar{s}$ -14 10 π⁻π⁺ πτπ 0.2 π e, p -15 **e**, μ 10 τ τ -16 0 10 -1 -1 10 10 10 10 1 $\Delta M_{\chi} / M_{\chi}^{1} / GeV$ ΔM_{χ} / GeV M_{γ} / GeV

Journal of High Energy Physics, Volume 2003, JHEP03(2003)

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τ/S

Disappearing track

Hadronic recoil (ISR), trigger!







Disappearing track



Disappearing track with new Inner Tracker



Figure 2: The radial layouts of the current ATLAS tracker and the proposed upgrade, the ITk.

ATLAS Run2 ID gives x15 higher signal yield than ITK layout, for 4-hit tracklets (R ~ 12 cm vs 22 cm) and assuming a 400 GeV higgsino with τ = 0.05 ns.

While we expect x10 increase in int. Iuminosity when going from Run2+Run3 (300 fb⁻¹) to HL-LHC (3-4 ab⁻¹)

Opportunity in ATLAS for Run3, should try to benefit from special trigger!

The lifetime of the higgsino chargino varies 0.03 to 0.07 ns (the value decreases as the chargino mass increases).



Direct searches vs indirect constraints

"Given the direct searches' null results and prospects, should we re-direct efforts to measurements?"

As the sensitivity of direct searches saturates, and the larger dataset and improved detector understanding lead to increasingly higher precision measurements, (that will cover more and more phase-space) will there be a point when NP is most stringently constrained by measurements?

Higgs Compositeness?



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New resonances/particles/forces?

Seeing the peak. Reach:

- $M < \sqrt{s}$ for lepton colliders
- $M \leq 0.3-0.5 \sqrt{s}$ in hadron colliders for couplings ~ weak couplings

Deviations in high-M tails:

- Better suited for lepton colliders; sensitive to [mass/coupling] $\gg \sqrt{s}$
- Hadron colliders relevant for $g_{7'} > g_{SM}$ couplings: [mass/coupling] $\gg 0.5\sqrt{s}$





In what follows: using very simple model as example. Universal Z'. Clearly, many models with flavor dependence etc.

PPG: BSM physics

13

New resonances/particles/forces?



T. Eitert - Direct searches for LHC Run 3 and beyond - Workshop at Durham - Sep 2019

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Indirect constraints

What are the indirect constraints assuming no additional flavor & CP violation?

SUSY is a weakly coupled theory:*

 * coupling strength as in SM — if RPC: SM processes corrected @ 1-loop



Indirect: Higgs precision 1905.03764

HL-LHC+ kappa-3 scenario ILC₂₅₀ ILC₅₀₀ CLIC₃₈₀ CLIC₁₅₀₀ CLIC₃₀₀₀ CEPC FCC-ee₂₄₀ FCC-ee₃₆₅ FCC-ee/eh/hh 0.84 1.5 1.2 0.89 0.53 $\kappa_g(\%)$ 0.86 1.4 1.1 1.1 $\kappa_q = r_q - 1$ 2500 exclusion 2000 0.53 % $m_{\tilde{t}_2}({\rm GeV})$ 1500 0.85% FCC-ee/eh/hh 1000 CLIC₃₀₀₀, ILC₅₀₀ 5.% **Stringent limits for** 500 small Xt stop mixing $X_t = 0$ 500 1000 1500 2000 2500 m_{ĩ +} (Ge₩)

T. Elien - Direct searches for LHC Hun 3 and beyond - workshop at Dumam - Sep 2019

Indirect: Higgs precision



Similar picture in studies by Essig, Meade, Ramani, Zhong, <u>1707.03399</u>



Direct searches vs indirect constraints

Direct searches and measurements (indirect constraints) complementary.

- (Higgs) measurements appear not competitive for SUSY.
- Measurement programme may reveal signs of NP at energy above directly accessible level \Rightarrow SM EFT. $\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \frac{1}{\Lambda^2} \sum_{i} c_i \mathcal{O}_i + \cdots$

LEP indirect prediction of Higgs mass,



Higgs programme may reveal exotic decays, or invisible BF, or additional scalars (not sure these fall under direct or indirect searches).

Strategy for Run3 and beyond

Theory guidance?



Some feel that a <u>paradigm change</u> is required, moving beyond the organising principles based on symmetry and separation of scales.

Exp.: waiting for guidance from new paradigm(s).

New theoretical directions: dark/hidden sectors with feebly interacting particles.

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.



As long as no clear signs of NP \Rightarrow

broad and diversified <u>search</u> and <u>measurement</u> programme.

Large Exotic(s/a) search programme

Overview of CMS EXO results

			CMS		36 fb ⁻¹ (13 TeV)
	SSM 7/(11)	м	1803 06292 (2 /)	4.5	
v	SSM Z (m)	M_	1805.00252 (2)	2.7	
son	I = 10%	M_	1802.01122 (eu)	2.7	
Bo	SSM W'(lw)	M	1803 11133 (l + Emiss)	5.2	
lge	SSM $W(a\bar{a})$	M.w	1806.00843 (2i)	33	
gau	SSM $W'(\tau v)$	M	$1807 11421 (T + E^{miss})$	3.3	
Š	$IBSM W_{0}(lN_{0}) M_{M} = 0.5M_{W}$	M	1803,11116 (2l + 2i)	4	
lea	$I RSM W_{R}(\tau N_{R}), M_{N_{R}} = 0.5 M_{W_{R}}$	M	1811 00806 (2r + 2i)	3.5	
т	Axialuon Coloron $cot\theta = 1$	M _R	1806 00843 (2i)	5.5	
		MC		0.1	
	scalar I O (pair prod.), coupling to 1^{st} gen, fermions, $\beta = 1$	M. o	1811.01197 (2e + 2i)	1 44	
S	scalar I O (pair prod.), coupling to 1 st gen, fermions, $\beta = 0.5$	Mua	1811 01197 (2e + 2i + F ^{miss})	1 27	
lar	scalar LQ (pair prod.), coupling to 2^{nd} gen, fermions, $\beta = 1$	M. o	1808.05082 (2u + 2i)	1 53	
٥dr	scalar LQ (pair prod.), coupling to 2^{nd} gen, fermions, $\beta = 0.5$	M. a	$1808\ 05082\ (2\mu + 2i; \mu + 2i + F^{miss})$	1 29	
ept	scalar LQ (pair prod.), coupling to 2^{rd} gen, fermions, $\beta = 1$	M	1811.00806 (2T + 2i) 102	1.2.5	
Ľ	scalar LQ (single prod.), coup to 3^{rd} gen, form $\beta = 1, \lambda = 1$	M	$1806\ 03472\ (\mathbf{2r} + \mathbf{b})$ 0.74		
	Scalar EQ (single prodif, coupl to 5 gen remit, $p = 1, n = 1$	MLQ			
	excited light quark (<i>ga</i>). $\Lambda = m_{a}^{*}$	м.	1806.00843 (2i)	6	
н s	excited light quark (qv) , $f_s = f = f' = 1$. $\Lambda = m_z^*$	M ×	1711.04652 (v + i)	5 5	
ited	excited b guark, $f_s = f = f' = 1$, $\Lambda = m_s^*$	м	$1711.04652 (\mathbf{v} + \mathbf{i})$	1.8	
Exc	excited electron $f_c = f = f' = 1$ $\Lambda = m^*$	M •	$1811.03052 (\mathbf{v} + 2\mathbf{e})$	3.9	
- <u>i</u>	excited muon, $f_c = f = f' = 1$, $\Lambda = m^*$.	M .	1811.03052 (y + 2u)	3.8	
		mμ		5.0	
s	quark compositeness ($q\bar{q}$). $n_{\rm LURR} = 1$	۸+	1803.08030 (2i)		12.8
tior	quark compositeness (ℓl), $n_{\rm LVRR} = 1$	ΛLL/RR Λ+	1812.10443 (2 /)		20
nta	quark compositeness $(a\bar{q})$, $n_{\rm LURR} = -1$	Λ [_] LL/RR	1803.08030 (2i)		17.5
Te C	quark compositeness (ℓl), $n_{\rm LURR} = -1$	Λ ⁻	1812.10443 (2 /)		31
-		'LL/RR			51
	ADD (jj) HLZ, <i>n</i> _{ED} = 3	Mc	1803.08030 (2i)		12
	ADD ($\gamma\gamma$, $\ell\ell$) HLZ, $n_{\rm FD} = 3$	Mc	1812.10443 (2y, 2 <i>l</i>)	9.1	
	ADD G_{KK} emission. $n = 2$	з Мъ	1712.02345 (≥ 1i + E ^{miss})	9.9	
Ś	ADD OBH (ii), $n_{\text{FD}} = 6$	Мори	1803.08030 (2i)	8.2	
ion	ADD OBH $(e\mu)$, $n_{\text{FD}} = 6$	Мори	1802.01122 (eu)	5.6	
ens	BS $G_{VV}(a\bar{a}, a\bar{a}) k/\overline{M}_{Pl} = 0.1$	Мс	1806.00843 (2i)	1.8	
i	$BS G_{VV}(II) k/\overline{M}_{ol} = 0.1$	Mc	1803.06292 (2)	4.25	
g g	$RS G_{kk}(yy), k/M_{\text{pl}} = 0.1$	Mc	1809.00327 (2v)	4.1	
Exti	RS QBH (jj), $n_{ED} = 1$	Мори	1803.08030 (2 j)	5.9	
	RS QBH $(e\mu)$, $n_{ED} = 1$	Морц	1802.01122 (eµ)	3.6	
	non-rotating BH, $M_{\rm D} = 4$ TeV, $n_{\rm FD} = 6$	Мен	1805.06013 (≥ 7 j(ℓ, γ))	9.7	
	split-UED, $\mu \ge 4$ TeV	1/R	$1803.11133 (l + E_{+}^{miss})$	2.9	
	,	1,10			
	(axial-)vector mediator ($\chi\chi$), $g_{a} = 0.25$, $g_{DM} = 1$, $m_{\gamma} = 1$ GeV	Mmed	1712.02345 (≥ 1j + E ^{miss})	1.8	
k Matter	(axial-)vector mediator $(q\bar{q})$, $g_a = 0.25$, $g_{DM} = 1$, $m_y = 1$ GeV	Mmed	1806.00843 (2j)	2.6	
	scalar mediator (+ $t/t\bar{t}$), $g_{g} = 1$, $g_{DM} = 1$, $m_{y} = 1$ GeV	M _{med}	1901.01553 (0 , $1\ell + \ge 3j + E_T^{miss}$) 0.29		
	pseudoscalar mediator $(+t/t\bar{t})$, $q_{g} = 1$, $q_{DM} = 1$, $m_{y} = 1$ GeV	M _{med}	1901.01553 (0 , $1\ell + \ge 3j + E_T^{miss}$) 0.3		
Dar	scalar mediator (fermion portal), $\lambda_u = 1, m_y = 1$ GeV	M _A	1712.02345 (≥ 1 j + E ^{miss})	1.4	
	complex sc. med. (dark QCD), $m_{\pi_{\rm DK}} = 5$ GeV, $c\tau_{X_{\rm DK}} = 25$ mm	M _{Xnr}	1810.10069 (4j)	1.54	
	and - July	- UK			
Ē	Type III Seesaw, $B_e = B_\mu = B_\tau$	M _{Sigma}	1708.07962 (≥ 3 ℓ) 0.84		
oth	string resonance	Ms	1806.00843 (2j)	7.7	
			0.1 1	.0 10).0
			m	nass scale [TeV]	
C -	lastice of the ended available in limits at 0500 C L (these		a substitution and wat in all a land)		ianuary 2019

Large SUSY search programme @ LHC

ATLAS SUSY Searches* - 95% CL Lower Limits

July 2019

	Model	Sign	ature	$\int \mathcal{L} dt [\mathbf{f} \mathbf{b}^{-1}]$	¹] Mas	ss limit			Reference
Inclusive Searches	$\tilde{q}\tilde{q},\tilde{q}\! ightarrow\!q\tilde{\chi}_{1}^{0}$	0 <i>e</i> , μ 2-0 mono-jet 1-3	6 jets E_T^m 3 jets E_T^m	niss 36.1 niss 36.1		0.9 0.43 0.71	1.55	$m({ ilde \chi}_1^0){<}100~{ m GeV} \ m({ ilde q}){-}m({ ilde \chi}_1^0){=}5~{ m GeV}$	1712.02332 1711.03301
	$\tilde{g}\tilde{g}, \tilde{g} ightarrow q \bar{q} \tilde{\chi}_1^0$	0 <i>e</i> , <i>µ</i> 2-0	6 jets $E_T^{\rm m}$	^{niss} 36.1	ë ë	Forbidden	2.0 0.95-1.6	${f m}(ilde{\chi}^0_1){<}200{f GeV}\ {f m}(ilde{\chi}^0_1){=}900{f GeV}$	1712.02332 1712.02332
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q \bar{q}(\ell \ell) \tilde{\chi}_1^0$	3 e,μ 4 ee,μμ 2	jets E_T^{m}	36.1 ^{niss} 36.1	ĩg ĩg		1.85 1.2	m($ ilde{\chi}_1^0$)<800 GeV m($ ilde{g}$)-m($ ilde{\chi}_1^0$)=50 GeV	1706.03731 1805.11381
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow qqWZ\tilde{\chi}_1^0$	0 <i>e</i> ,μ 7-1 SS <i>e</i> ,μ 6	1 jets E_T^m jets	^{niss} 36.1 139	ĩc ĩc ĩc		1.8 1.15	$m(ilde{\chi}_1^0)$ <400 GeV $m(ilde{g})$ - $m(ilde{\chi}_1^0)$ =200 GeV	1708.02794 ATLAS-CONF-2019-015
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t \bar{t} \tilde{\chi}_1^0$	0-1 <i>e</i> ,μ SS <i>e</i> ,μ 6	$3 b E_T^m$ jets	^{niss} 79.8 139	ĩg ĩg		2.25 1.25	m($ ilde{\chi}_1^0$)<200 GeV m($ ilde{g}$)-m($ ilde{\chi}_1^0$)=300 GeV	ATLAS-CONF-2018-041 ATLAS-CONF-2019-015
ks on	$\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow b \tilde{\chi}_1^0 / t \tilde{\chi}_1^{\pm}$	Mւ Mւ Mւ	ultiple ultiple ultiple	36.1 36.1 139		0.9 Forbidden 0.58-0.82 Forbidden 0.74	m $m(\tilde{\chi}_1^0)=$	$\begin{array}{l} m(\tilde{\chi}^0_1){=}300~{\rm GeV},~BR(b\tilde{\chi}^0_1){=}1\\ (\tilde{\chi}^0_1){=}300~{\rm GeV},~BR(b\tilde{\chi}^0_1){=}BR(b\tilde{\chi}^1_1){=}0.5\\ 200~{\rm GeV},~m(\tilde{\chi}^\pm_1){=}300~{\rm GeV},~BR(t\tilde{\chi}^\pm_1){=}1 \end{array}$	1708.09266, 1711.03301 1708.09266 ATLAS-CONF-2019-015
	$\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow b \tilde{\chi}_2^0 \rightarrow b h \tilde{\chi}_1^0$	0 <i>e</i> , <i>µ</i>	$6 b E_T^m$	^{niss} 139	$egin{array}{ccc} & & & & & & \\ & & & & & & & \\ & & & & $	0.23-0.48	0.23-1.35	$\begin{array}{l} \Delta m(\tilde{\chi}^{0}_{2},\tilde{\chi}^{0}_{1}) \!=\! 130 \mathrm{GeV}, m(\tilde{\chi}^{0}_{1}) \!=\! 100 \mathrm{GeV} \\ \Delta m(\tilde{\chi}^{0}_{2},\tilde{\chi}^{0}_{1}) \!=\! 130 \mathrm{GeV}, m(\tilde{\chi}^{0}_{1}) \!=\! 0 \mathrm{GeV} \end{array}$	SUSY-2018-31 SUSY-2018-31
luct	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow W h \tilde{\chi}_1^0$ or $t \tilde{\chi}_1^0$	0-2 <i>e</i> , μ 0-2 je	ets/1-2 $b E_T^m$	^{niss} 36.1	\tilde{t}_1	1.0		$m(\tilde{\chi}_1^0)=1$ GeV	1506.08616, 1709.04183, 1711.11520
rod	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow W h \tilde{\chi}_1^0$	1 <i>e</i> ,μ 3 je	ets/1 b E_T^{m}	^{niss} 139	\tilde{t}_1	0.44-0.59		$m(\tilde{\chi}_1^0) = 400 \text{ GeV}$	ATLAS-CONF-2019-017
it p	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow \tilde{\tau}_1 bv, \tilde{\tau}_1 \rightarrow \tau \tilde{G}$	$1\tau + 1e, \mu, \tau 2je$	ets/1 b E_T^{m}	niss 36.1	\tilde{t}_1		1.16	$m(\tilde{\tau}_1)=800 \text{ GeV}$	1803.10178
irec	$\tilde{t}_1 \tilde{t}_1 \rightarrow c \tilde{\chi}_1^0 / \tilde{c} \tilde{c}_1 \rightarrow c \tilde{\chi}_1^0$	0 e, µ	$2c E_T^m$	niss 36.1	ĩ	0.85		$m(\tilde{\chi}_1^0)=0$ GeV	1805.01649
di X		0 <i>e</i> , μ mo	ono-jet E_T^m	^{niss} 36.1	\tilde{t}_1 \tilde{t}_1	0.46 0.43		$ \begin{array}{l} m(\tilde{t}_1,\tilde{c})\text{-}m(\tilde{\chi}_1^0) \text{=} 50 \text{ GeV} \\ m(\tilde{t}_1,\tilde{c})\text{-}m(\tilde{\chi}_1^0) \text{=} 5 \text{ GeV} \end{array} $	1805.01649 1711.03301
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + h$	1-2 e. u	$4 h E_{\pi}^{m}$	niss 36.1	Ĩ,	0.32-0.88		$m(\tilde{\chi}_{1}^{0})=0$ GeV $m(\tilde{t}_{1})-m(\tilde{\chi}_{1}^{0})=180$ GeV	1706.03986
	$\tilde{t}_2 \tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$	3 <i>e</i> , <i>µ</i>	$1b E_T^m$	niss 139	\tilde{t}_2	Forbidden 0.86	r	$n(\tilde{\chi}_1^0)$ =360 GeV, $n(\tilde{t}_1)$ - $m(\tilde{\chi}_1^0)$ = 40 GeV	ATLAS-CONF-2019-016
	$ ilde{\chi}_1^{\pm} ilde{\chi}_2^0$ via WZ	2-3 e, μ ee, μμ	$\geq 1 \qquad \begin{array}{c} E_T^{\rm m} \\ E_T^{\rm m} \end{array}$	niss 36.1 niss 139		0.6		$\mathbf{m}(ilde{\chi}_1^0) = 0 \ \mathbf{m}(ilde{\chi}_1^\pm) \cdot \mathbf{m}(ilde{\chi}_1^0) = 5 \ \mathbf{GeV}$	1403.5294, 1806.02293 ATLAS-CONF-2019-014
	$\tilde{\chi}_1^{\pm} \tilde{\chi}_1^{\mp}$ via WW	2 <i>e</i> , <i>µ</i>	$E_T^{\rm m}$	^{niss} 139	$\tilde{\chi}_1^{\pm}$	0.42		$m(\tilde{\chi}_1^0)=0$	ATLAS-CONF-2019-008
	$\tilde{\chi}_1^{\pm} \tilde{\chi}_2^0$ via Wh	0-1 <i>e</i> , <i>µ</i> 2	$b/2 \gamma E_T^m$	^{niss} 139	$\tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0}$ Forbidden	0.74		$m(\tilde{\chi}_1^0)=70 \text{ GeV}$	ATLAS-CONF-2019-019, ATLAS-CONF-2019-XYZ
∋ct ≤	$ ilde{\chi}_1^{\pm} ilde{\chi}_1^{\mp}$ via $ ilde{\ell}_L / ilde{ u}$	2 <i>e</i> , <i>µ</i>	$E_T^{\rm m}$	^{niss} 139	$\tilde{\chi}_1^{\pm}$	1.0		$m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2019-008
Ξi	$\tilde{\tau}\tilde{\tau}, \tilde{\tau} \rightarrow \tau \tilde{\chi}_1^0$	2 τ	$E_T^{\rm m}$	^{niss} 139	$\tilde{\tau} [\tilde{\tau}_L, \tilde{\tau}_{R,L}]$ 0.16-0.3	0.12-0.39		$m(\tilde{\chi}_1^0)=0$	ATLAS-CONF-2019-018
Ĩ	$\tilde{\ell}_{\mathrm{L,R}}\tilde{\ell}_{\mathrm{L,R}}, \tilde{\ell} \rightarrow \ell \tilde{\chi}_1^0$	2 e,μ 0 2 e,μ 2	jets $E_T^{\rm m}$ ≥ 1 $E_T^{\rm m}$	niss 139 niss 139	$\widetilde{\ell}$ 0.256	0.7		$m(ilde{\chi}_1^0) = 0 \ m(ilde{\chi}_1^0) = 10 \ GeV$	ATLAS-CONF-2019-008 ATLAS-CONF-2019-014
	$\tilde{H}\tilde{H},\tilde{H}{ ightarrow}h\tilde{G}/Z\tilde{G}$	$egin{array}{ccc} 0 & e, \mu & \geq \ 4 & e, \mu & 0 \end{array}$	$E 3 b E_T^m$ jets E_T^m	niss 36.1 niss 36.1	Ĥ 0.13-0.23 Ĥ 0.3	0.29-0.88		$\begin{array}{l} BR(\tilde{\chi}^0_1 \to h\tilde{G}){=}1 \\ BR(\tilde{\chi}^0_1 \to Z\tilde{G}){=}1 \end{array}$	1806.04030 1804.03602
lived cles	Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk 1	l jet E_T^m	^{niss} 36.1	$ \begin{array}{c} \tilde{\chi}_1^{\pm} \\ \tilde{\chi}_1^{\pm} \end{array} 0.15 \end{array} $	0.46		Pure Wino Pure Higgsino	1712.02118 ATL-PHYS-PUB-2017-019
Pg-	Stable \tilde{g} R-hadron	Mu	ultiple	36.1	Ĩ		2.0		1902.01636,1808.04095
БQ	Metastable \tilde{g} R-hadron, $\tilde{g} \rightarrow qq \tilde{\chi}_1^0$	Mu	ultiple	36.1	$\tilde{g} = [\tau(\tilde{g}) = 10 \text{ ns}, 0.2 \text{ ns}]$		2.05 2.	4 $m(\tilde{\chi}_1^0)=100 \text{ GeV}$	1710.04901,1808.04095
	$ EV _{pp} \rightarrow \tilde{y} + V _{pp} \rightarrow \mathfrak{gu}/\mathfrak{gr}/\mathfrak{gr}$	PH PT 11T		2.0	a a a a a a a a a a a a a a a a a a a		10)' -0.11)	1607.09070
	$\tilde{\mathbf{v}}^{\pm} \tilde{\mathbf{v}}^{\mp} / \tilde{\mathbf{v}}^{0} \qquad \text{WW} / 7 \ell \ell \ell \ell m$	<i>Δαμ</i> Ο	ioto F ^m	1155 26 1	\tilde{v}_{τ} $\tilde{v}^{\pm}/\tilde{v}^{0}$ () $\neq 0$) $\neq 0$]	0.82	1.22	$m(\tilde{v}^0)$ 100 CoV	1807.08079
	$\chi_1\chi_1/\chi_2 \rightarrow WW/ZUUUVV$	4 ε,μ 0 4-5 lar	L_T	- 30.1 26.1	$\tilde{\lambda}_1 / \tilde{\lambda}_2 [\lambda_{i33} \neq 0, \lambda_{12k} \neq 0]$	0.82	1.00	$m(\chi_1) = 100 \text{ GeV}$	1004.03502
>	$gg, g \rightarrow qq\chi_1, \chi_1 \rightarrow qqq$	4-5 iai Mu	ultiple	36.1	$\tilde{g} = [\mathcal{M}(x_1) = 200 \text{ GeV}, 1100 \text{ GeV}]$ $\tilde{g} = [\mathcal{M}'_{1,2} = 2e-4, 2e-5]$	1.0	1.3 1.9	$m(\tilde{\chi}_{1}^{0})=200 \text{ GeV bino-like}$	ATLAS-CONF-2018-003
RPV	\tilde{x} \tilde{z} \tilde{x}^0 \tilde{x}^0 z^0	N/II	Iltinle	26.1	\tilde{g} $[\lambda''] = 2e-4$ 1e-2]	0.55 1.0	5	$m(\tilde{v}^0)$ 200 Coll bins like	
	$\begin{array}{c} u, \ \iota \to \iota \chi_1, \ \chi_1 \to \iota DS \\ \tilde{\iota}, \tilde{\iota}, \ \tilde{\iota} \to bs \end{array}$	2 iot	$h \leq \pm 2h$	26.7	\tilde{t}_{1} [ag hs]	0.42 0.61		$m(x_1)=200$ GeV, bino-like	1710 07171
	$\iota_1\iota_1, \iota_1 \rightarrow \upsilon_S$ $\tilde{\iota}, \tilde{\iota}, \tilde{\iota}, \tilde{\iota} \rightarrow a\ell$	2 jet	0 h	30.7 26 1	$\tau_1 = [qq, vs]$	0.42 0.01	0.4-1.45	$RR(\tilde{t} \rightarrow ha/ha) \sim 200/$	1710.0/1/1
	· [1], · [-· 4c	1μ	DV	136	\tilde{t}_1 [1e-10< λ'_{23k} <1e-8, 3e-10< λ'_{23k}	<3e-9] 1.0	1.6	$BR(\tilde{t}_1 \rightarrow q\mu) = 100\%, \cos\theta_t = 1$	ATLAS-CONF-2019-006
Only	a selection of the available ma	ass limits on new	states or	r 1(0 ⁻¹		1	Mass scale [TeV]	

*Only a selection of the available mass limits on new states o phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made. **ATLAS** Preliminary

 $\sqrt{s} = 13 \text{ TeV}$

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 <u>ATLAS-CONF-2018-003</u>.
 - 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 ...

Publication cycle

LHC / HL-LHC Plan





LHC Run1 & Run2: have published ~full search programmes x(2-3) per Run, justified by the quick increase in dataset size and step in \sqrt{s} .

LHC Run4 & beyond: I expect 1 round of search publications after Run3 (300 fb⁻¹), and then ~every time the dataset size increases by x^2-3 .

Reinterpretation: likelihood, unfolding,...

- Our duty to provide and maintain data, procedures and tools to facilitate the reinterpretation of the beautiful LHC results.
 - CMS began to provide "simplified" likelihoods
 - ATLAS SUSY publications come with analysis code-snippets, and new in 2019: full likelihood as json file (can be used directly by pyhf tool), <u>ATL-</u> <u>PHYS-PUB-2019-029</u>



Reinterpretation: likelihood, unfolding,...

- Measurements typically have Rivet routines.
- Should we begin to unfold the phase-space probed by direct searches?
 - Added-value but extra work, might not be straight forward in some search regions.
 - I'd like to see this for all control region, and then see how useful it is in practise.
- Measurements that extend to more extreme phase space (regime of searches), to provide input to EFT fits (e.g. indirect constraints on Z') appears useful to me.

Summary

LHC + HL-LHC will continue to be the flagship machine for (at least) the next decade.

Privilege to harvest the rich physics from the (HL-)LHC dataset.

Direct searches and **indirect constraints** from measurements complementary in our quest to find hints of new physics.

Large increase of dataset x20-30: will increase our current mass reach by 50%-100%

No magic bullet \Rightarrow We already have a powerful physics programme.

but opportunities for additional discovery potential may be obtained from: new detectors, new triggers, improved systematics, new discrimination tools and new ideas!

