Inflating the MSSM

Anja Butter, Laurent Duflot, Sophie Henrot-Versille, G.M., Vincent Vennin, Gilles Weymann-Despres, Dirk Zerwas, Richard von Eckardstein,

APC, IJCLab, ITP, L2C,...& DMLab ☺

(Gilbert Moultaka)

DMLab kickoff meeting, DESY-Zoom, 9-10 Dec '21

No Outline

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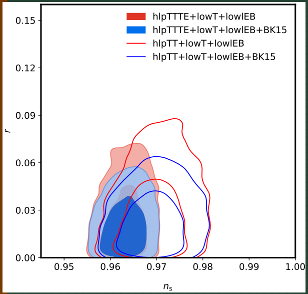
Is there a relation between...?



M. Tristram *et al*, A&A 647, A128 (2021)

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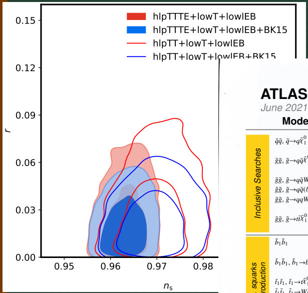

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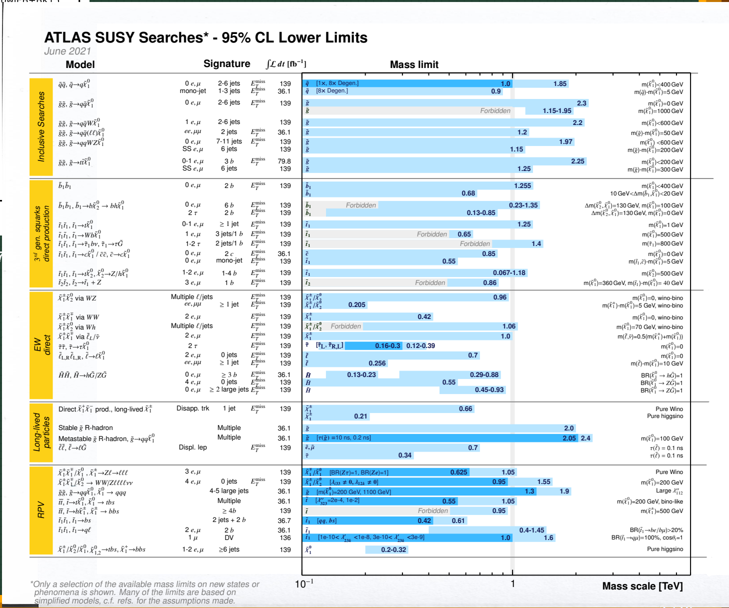
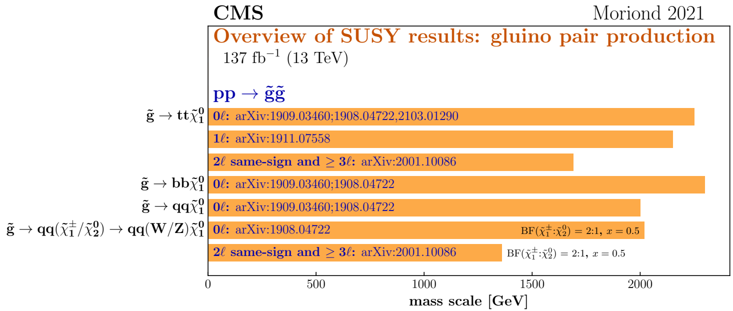
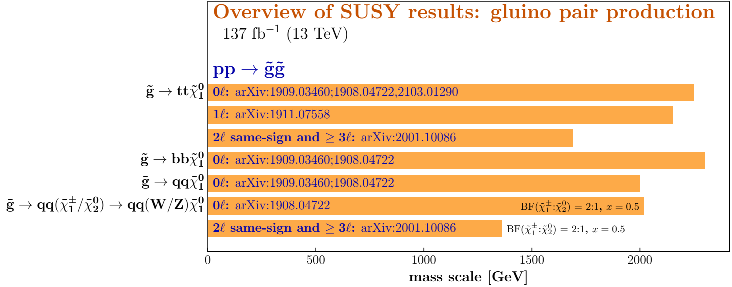
and this →





Selection of observed limits at 95% C.L. (theory uncertainties are not included). Probe **up to** the quoted mass limit for light LSPs unless stated otherwise. The quantities ΔM and x represent the absolute mass difference between the primary sparticle and the LSP, and the difference between the intermediate sparticle and the LSP relative to ΔM, respectively, unless indicated otherwise.

CMS Moriond 2021



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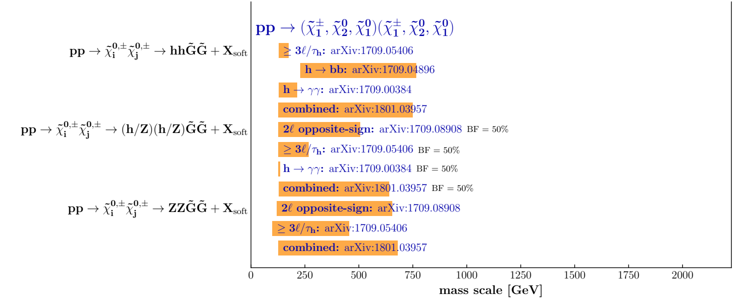

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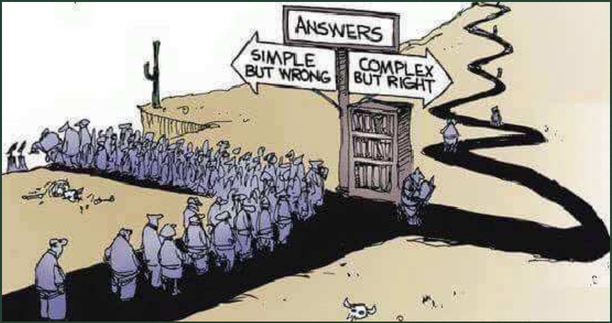
Introductory motivations

Where is –Is there– (TeV) New Physics ??

message from (the) BSM at the LHC (?)



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→ SUSY DM candidates still viable, even for (relatively) light LSP, despite direct / indirect search limits and LHC constraints.

SUSY flat directions

SUSY flat directions

$$V_{susy} = \sum_k |F_{\phi_k}|^2 + \frac{1}{2} \sum_A g_A^2 \vec{D}^A \cdot \vec{D}^A$$

$$F_{\phi_k} := \frac{\partial W}{\partial \phi_k}, \quad \vec{D}^A := \Phi^\dagger \vec{T}^A \Phi, \quad (\Phi \text{ multiplet of } \phi_k{}'s)$$

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BUT...

SUSY flat directions

a flat direction:

- ◦ has to be lifted...
- ◦ and by not too much $\rightarrow$ slow-roll/enough e-folding to fit observations

$\rightarrow$ three main lifting sources:

- renormalizable superpotential (MSSM)
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e.g. $\rightarrow$ LLe or udd flat directions lifted by

$$W^{LLe} = \frac{\lambda}{M_p^3}(LLe)(LLe) \text{ resp. } W^{udd} = \frac{\lambda}{M_p^3}(udd)(udd)$$

The saddle point MSSM-Inflation model

Inflation along these directions (Enqvist & collab. '06 +)

$$\phi \sim \tilde{L}_i + \tilde{L}_j + \tilde{e}_k, \ \phi \sim \tilde{u}_i + \tilde{d}_j + \tilde{d}_k$$

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$\rightarrow$ Adjust the parameters to make this minimum as shallow as possible
$+$ initial condition for the inflaton field ϕ to get slow-roll.

$\rightarrow$ exact saddle-point at $\phi_0 = \left(\frac{M_p^3 m_\phi}{\lambda\sqrt{10}}\right)^{1/4}$ with $A = \sqrt{40} m_\phi$.

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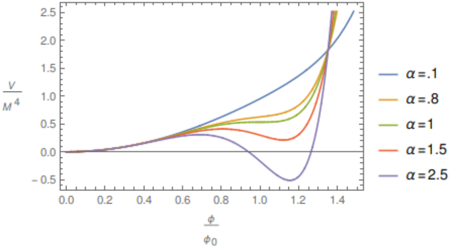

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Boehm et al. '13

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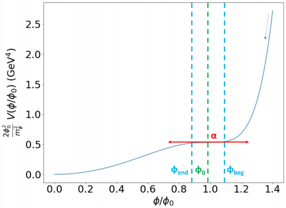

courtesy Gilles Weymann-Despres (IJCLab)

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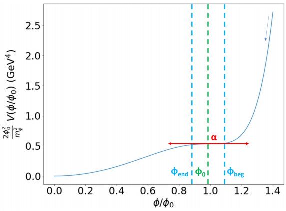

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Slow-roll parameters

$$\varepsilon_1 \simeq \frac{M_p^2}{2} \left(\frac{V'(\phi)}{V(\phi)} \right)^2$$

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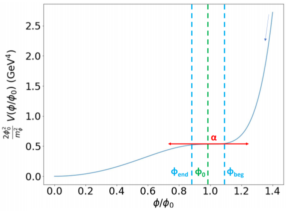

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Scalar perturbations power spectrum

$$\mathcal{P}_s(k) = A_s\left(\frac{k}{k*}\right)^{n_s-1}$$

Planck:

$$n_s = 0.9665 \pm 0.0038,$$

$$A_s = (2.196 \pm 0.055) \times 10^{-9}$$

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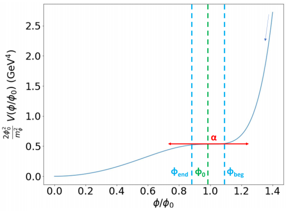

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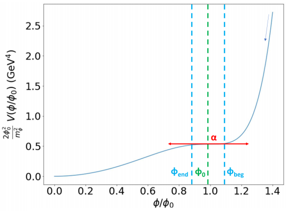

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$V'(\phi_0) \neq 0, V''(\phi_0) = 0 \rightarrow \alpha$ extremely fine-tuned: $\alpha \neq 1$ and $1 - \alpha < 10^{-8}$

Martin, Ringeval, Vennin '13

The Wall

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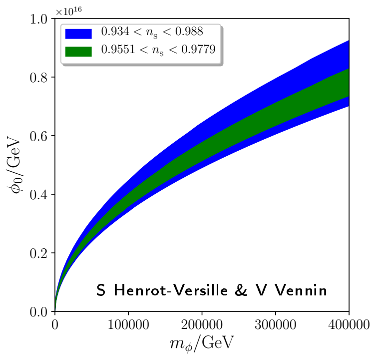

×10^16
1.0
0.8
0.6
0.4
0.2
0.0
ϕ_0/GeV
0.934 < n_s < 0.988
0.9551 < n_s < 0.9779
S Henrot-Versille & V Vennin
0
100000
200000
300000
400000
m_ϕ/GeV

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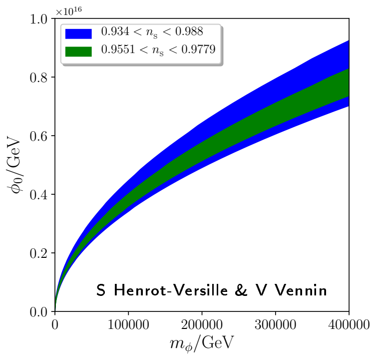

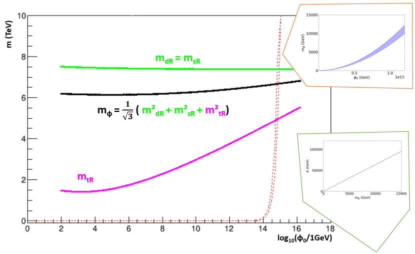

Richard von Eckardstein & D Zerwas

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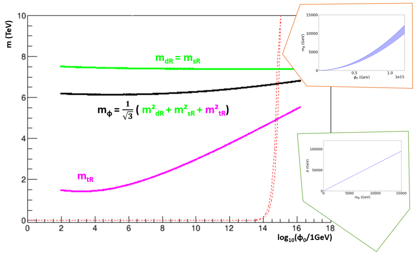

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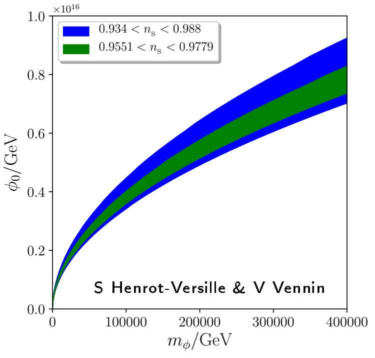

There is always a solution!

The Effective Potential

Improve the Potential $\rightarrow$ loop corrections $\rightarrow$ $\log \frac{\phi}{\phi_0}$ resummation.

$$V_{inflation}^{tree} = \frac{1}{2} m_\phi^2 \phi^2 - A\lambda \frac{\phi^6}{6M^3} + \lambda^2 \frac{\phi^{10}}{M^6}$$

$m_\phi^2 \rightarrow \overline{m}_\phi^2(\phi)$, $A \rightarrow \overline{A}(\phi)$, $\lambda \rightarrow \overline{\lambda}(\phi)$, $\phi \rightarrow \overline{\phi}(\phi)$

$V_{inflation}^{tree} \rightarrow V_{inflation}^{loop} \leftarrow$ 'slight' shape modification

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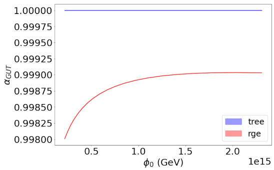

Gilles Weymann-Despres

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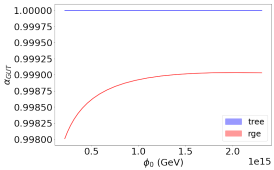

Gilles Weymann-Despres

Might look like RGEs reduce tremendously the fine-tuning

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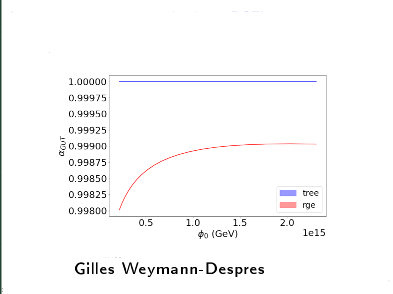
$$V^{tree}_{inflation} \rightarrow V^{loop}_{inflation} \leftarrow \text{'slight' shape modification}$$



Might look like RGEs reduce tremendously the fine-tuning

In fact α should be redefined!

Implemented in SUSPECT3

- Included Inflation scale
- Included high scale boundary conditions relating A to MSSM soft breaking couplings.
- Included RGEs for m_ϕ^2, A and λ for all LLe and udd directions, including 3rd generation Yukawa effects.

Ready for a full-fledged analyses:

Outlook

- Although (particularly) fine-tuned, the saddle-point MSSM inflation is an interesting set-up $\rightarrow$ relates high scale inflation to low scale particle physics.
- The on-going collaboration: brings together exp & theo/cosmo & particle, expertise and related analysis tools (ASPIC/SuSpect3/SFitter)
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- The DMLab as a hub is a real opportunity for us: short-term visits, feedback from experts, the SuSpect/SUSY-HIT project,...

THANK YOU FOR YOUR ATTENTION

BACKUP SLIDES