Chargino-Neutralino pair production and b-jet identification with ATLAS at Run 2

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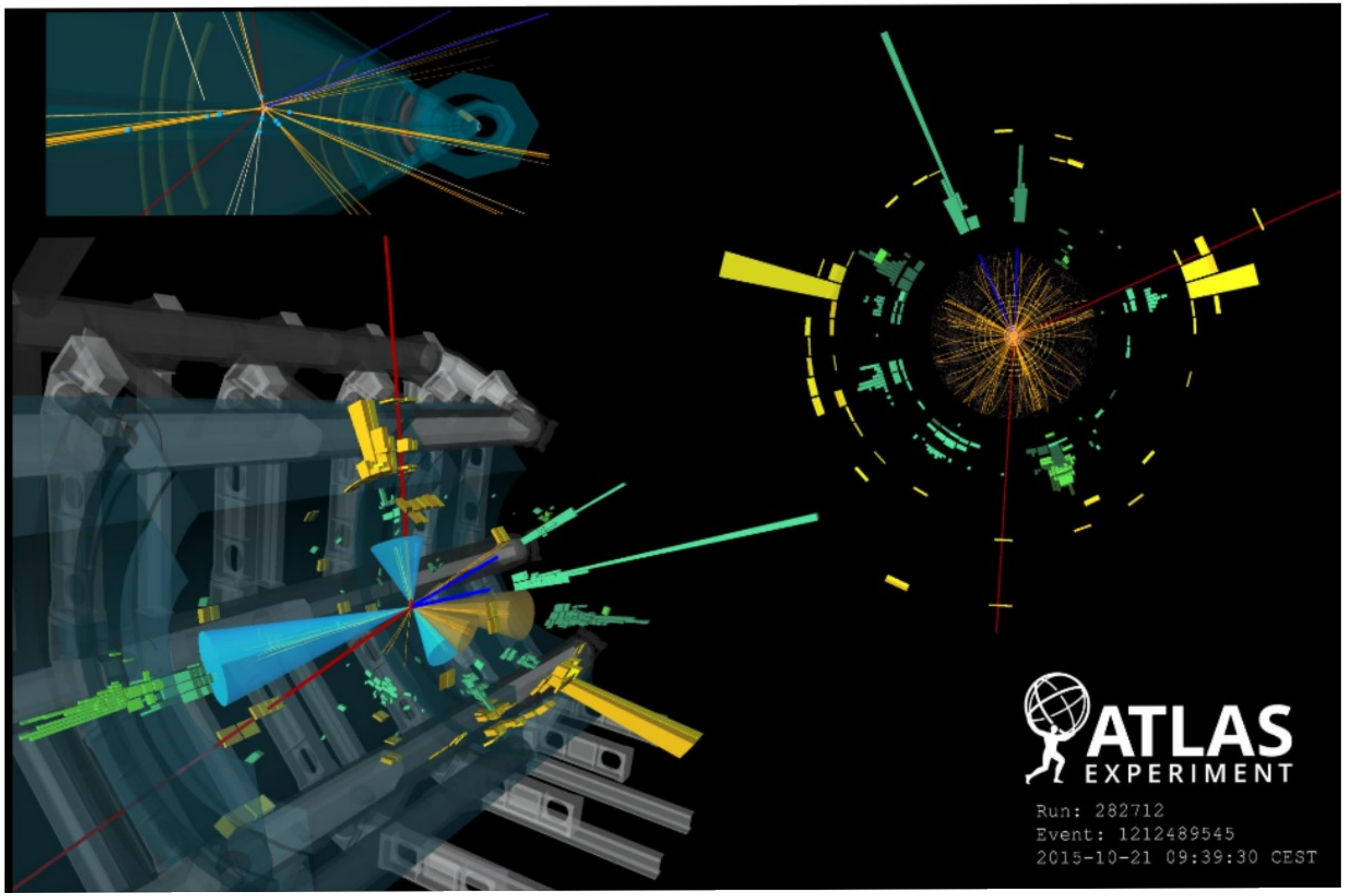

LABORATOIRE CHARLES COULOMB MONTPELLIER

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About my PhD

PhD between **CPPM** in Marseille and **L2C** in Montpellier with 2 parts:

Experimental:

→ Search for **Chargino-Neutralino pair production with ATLAS at LHC Run 2**

→ Improvement of b-jets identification

Phenomenology:

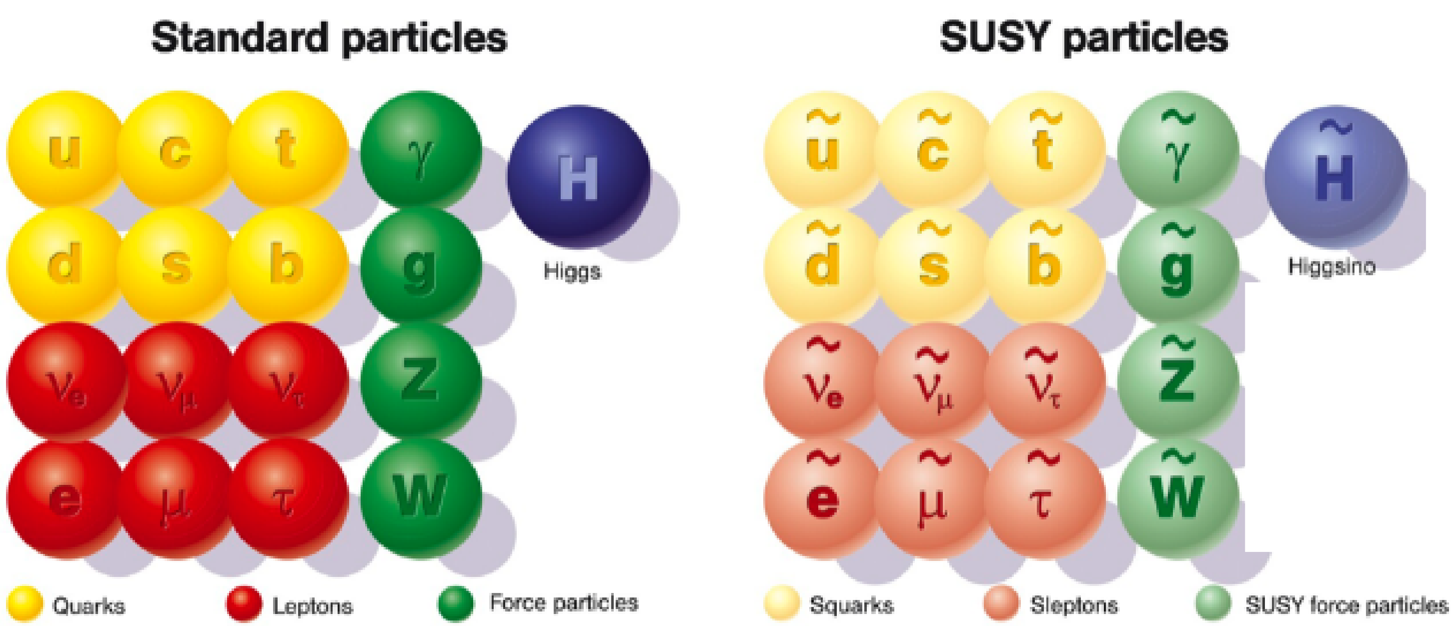
→ Contribution to SUSY spectrum calculator "Suspect 3" developed at Montpellier

Outline

- Supersymmetry
- Search for ElectroWeak SUSY (**Chargino-Neutralino)**
- b-jets identification
- Suspect 3 new version

Supersymmetry (SUSY)

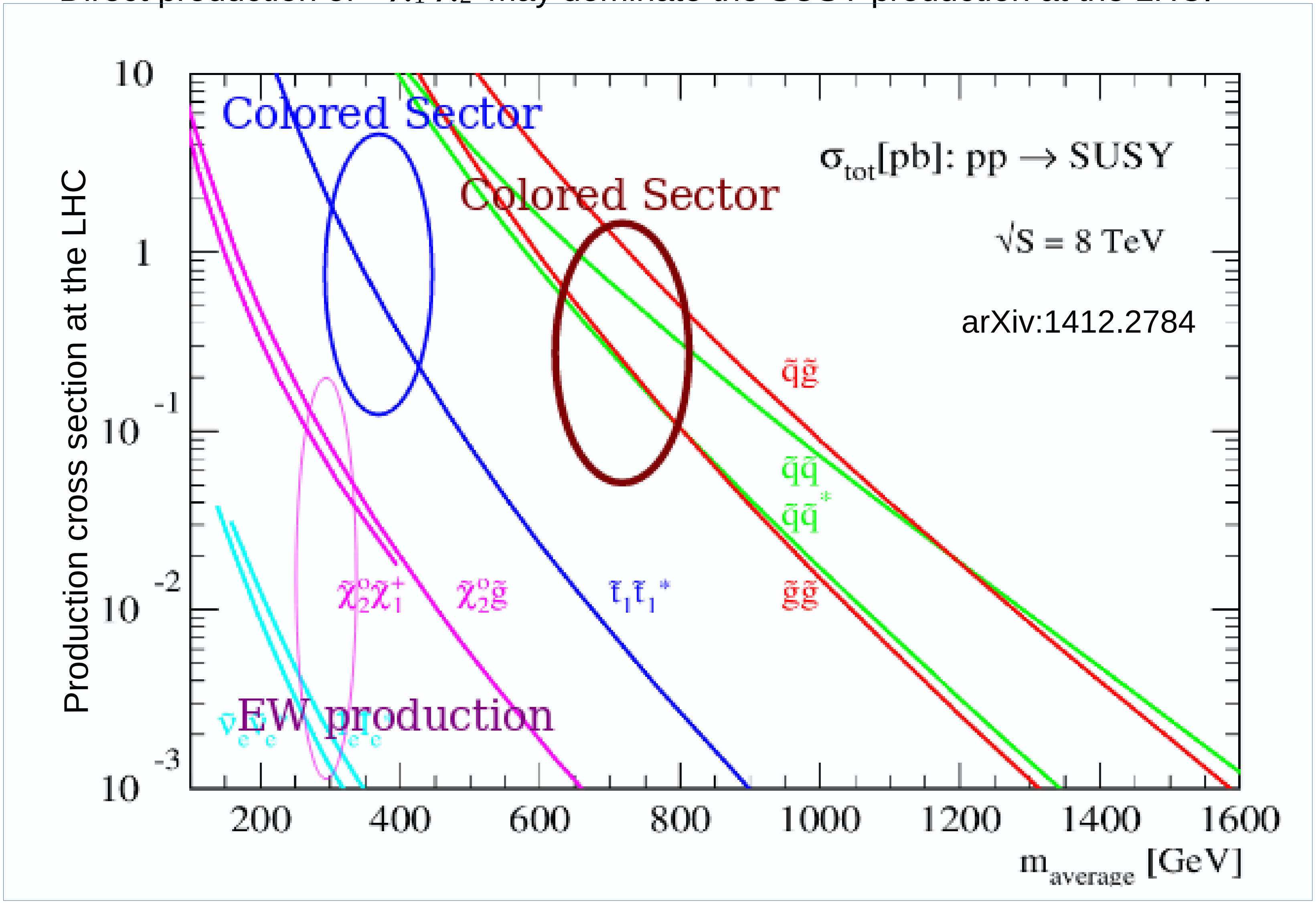
- SM is incomplete and SUSY is the most motivated theory beyond it
- Introduces a new symmetry between fermions (spin-1/2) and bosons (spin-1)
- New discrete Quantum number: R-parity: $R = (-1)^{3(B-L)+2S}$ = +1 SM particles
  = - 1 SUSY particles
- Conserved R parity: → SUSY particles produced/annihilated in pairs
  → Lightest SUSY particle (LSP) stable neutral weakly interacting
  → DM candidate

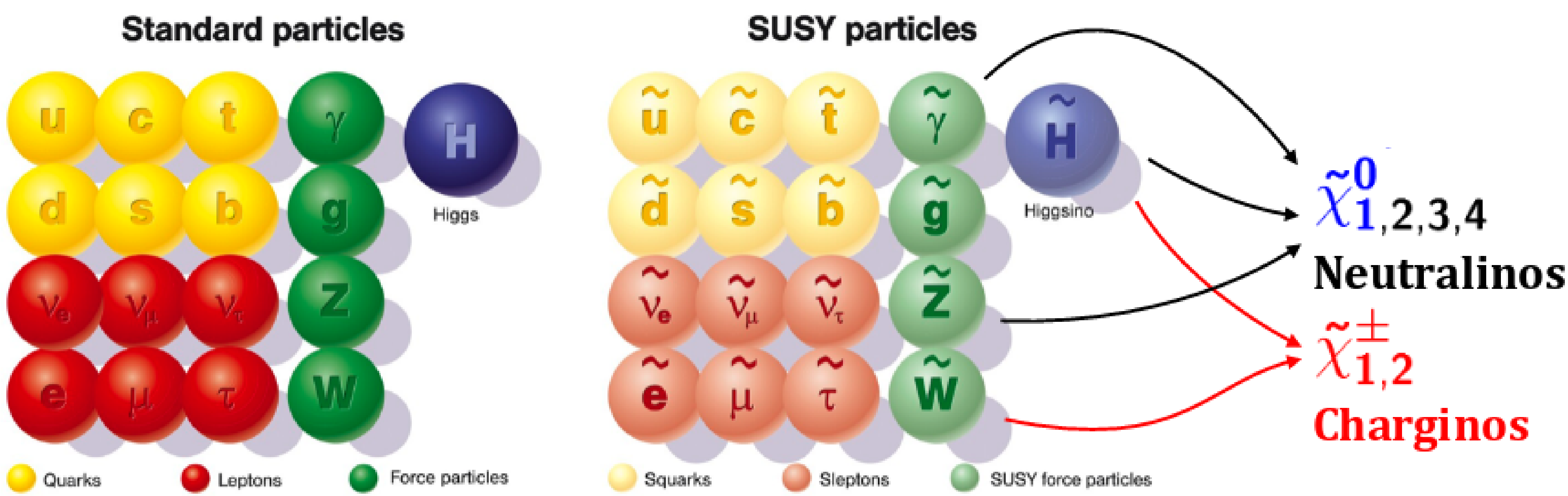


Search for Electroweak (EW) SUSY

- LHC searches were focusing on **strong production** of SUSY with larger cross sections than EW
- However, limits were set for masses $\tilde{g}, \tilde{q} > 1$ TeV

→ Direct production of $\tilde{\chi}_1^{\mp}\tilde{\chi}_2^{0}$ may dominate the SUSY production at the LHC.





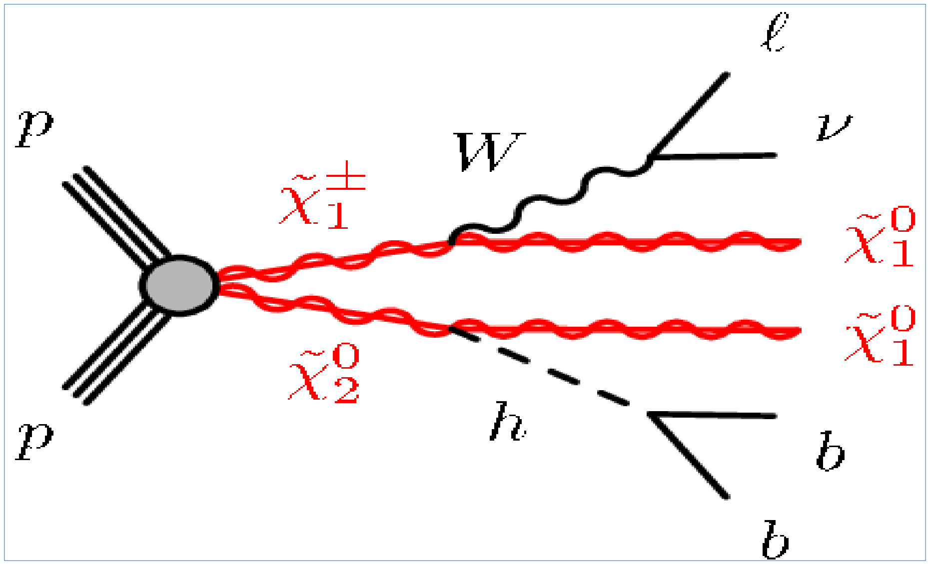
- If the higgsino mass parameter is large

→ $\tilde{\chi}^{\mp}_1$ is a Wino-like

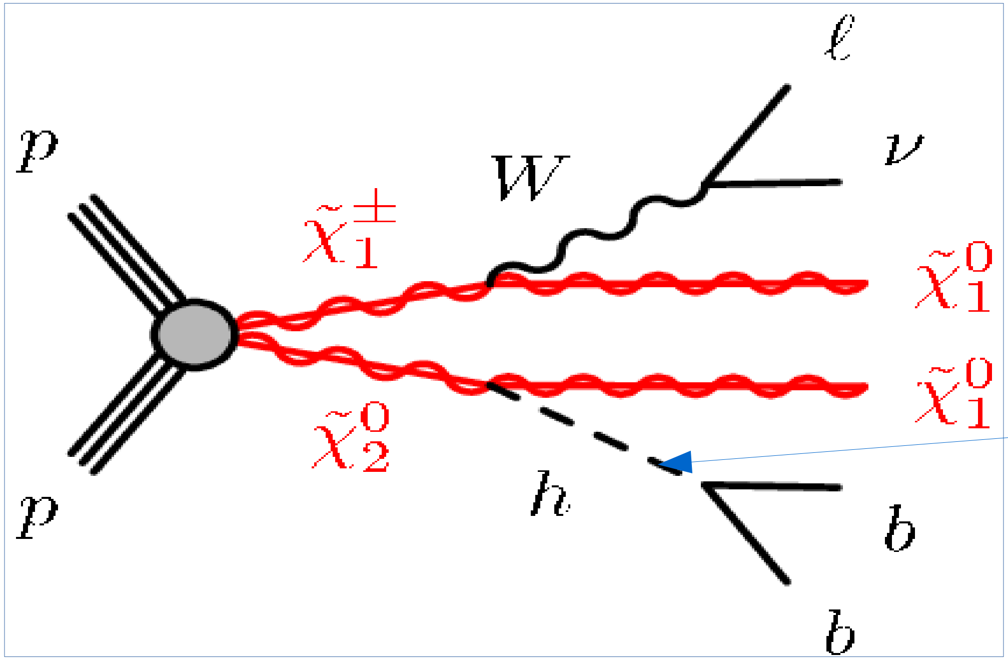
→ interacts with fermions by gauge couplings

→ $\tilde{\chi}^0_1$ is a Bino-like

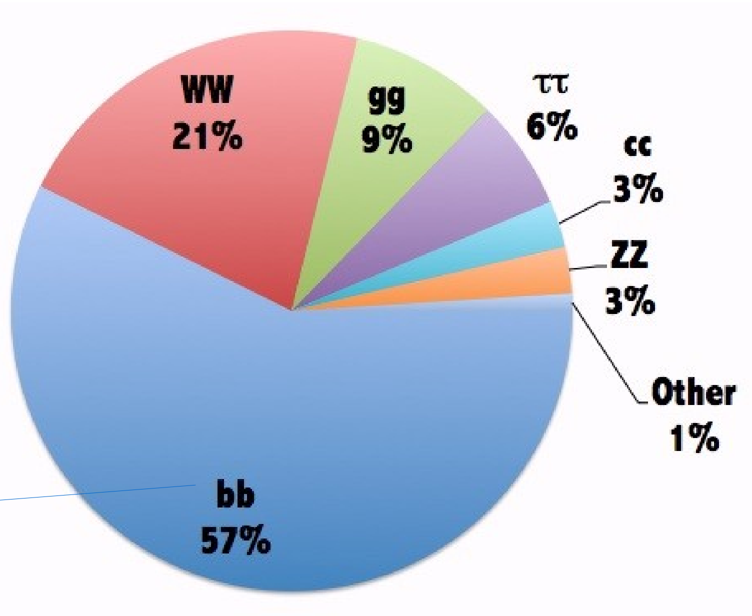
→ interacts by g1



- We're looking for $\tilde{\chi}_1^{\mp}\tilde{\chi}_2^{0} \longrightarrow$ W+ h +MET
- **Final states** : 1 lepton (e,μ)+ bb+ MET



Higgs boson decay at m_h=125 GeV



- **Invariant mass of bb** system compatible with Higgs boson mass of 125 GeV
- High MET (>100 GeV) is required
- Tagging correctly the 2 jets is crucial to better separate signal from background
- **Main backgrounds**: ttbar, W+jets

Results

- Run 1

→ No significant excess observed wrt SM

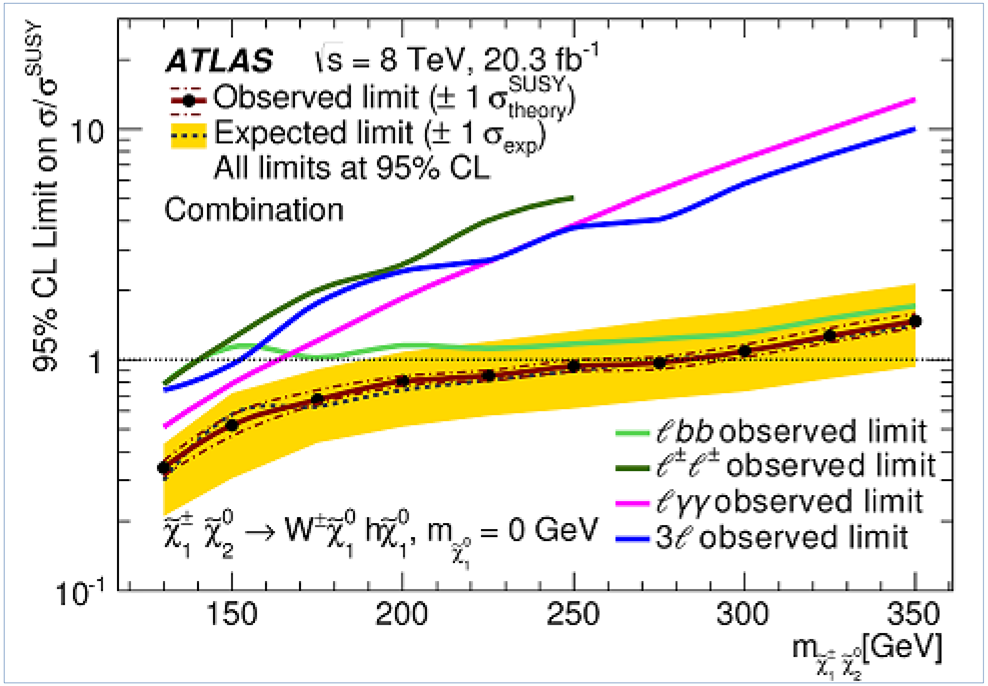
→ Exclusion limit at 95% C.L. set at

$m_{\tilde{\chi}_1^{\mp},\tilde{\chi}_2^0}$ >250 GeV for $m_{\tilde{\chi}_1^0}$ = 0 GeV

	Run 1 2012	Run 2 2015-2018
Center of mass energy	8 TeV	13 TeV
Integrated luminsity	20 fb^{-1}	100 fb^{-1}
signal cross section	0.1 pb	0.7 pb
ttbar cross section	0.25 fb	0.83 fb

x7

x4



- Run 2

→ Enhance the search sensitivity.

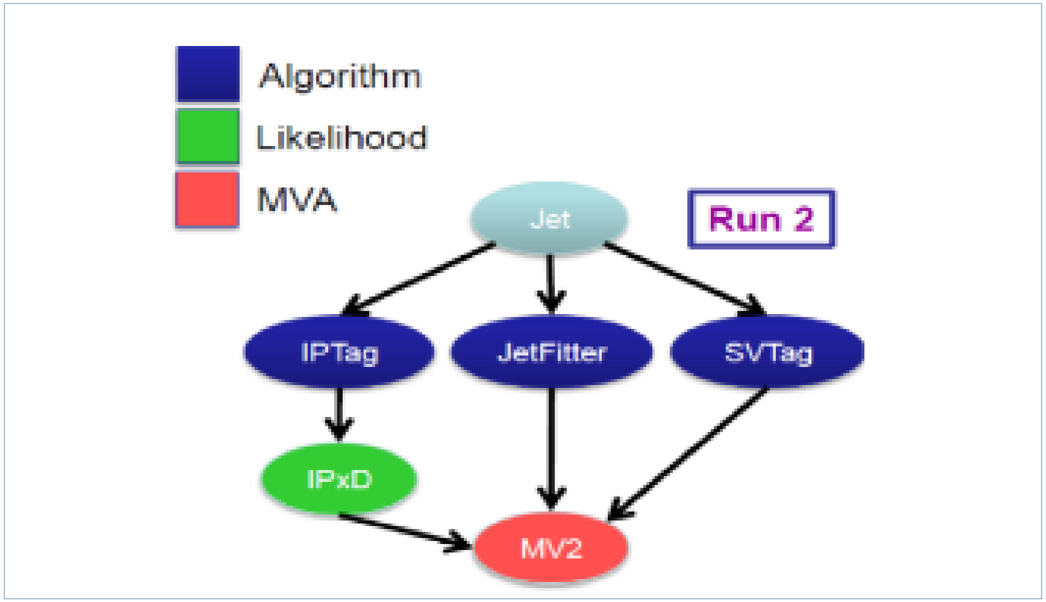
- Goal: Paper combining the different Higgs decay channels results after summer 2017 conf

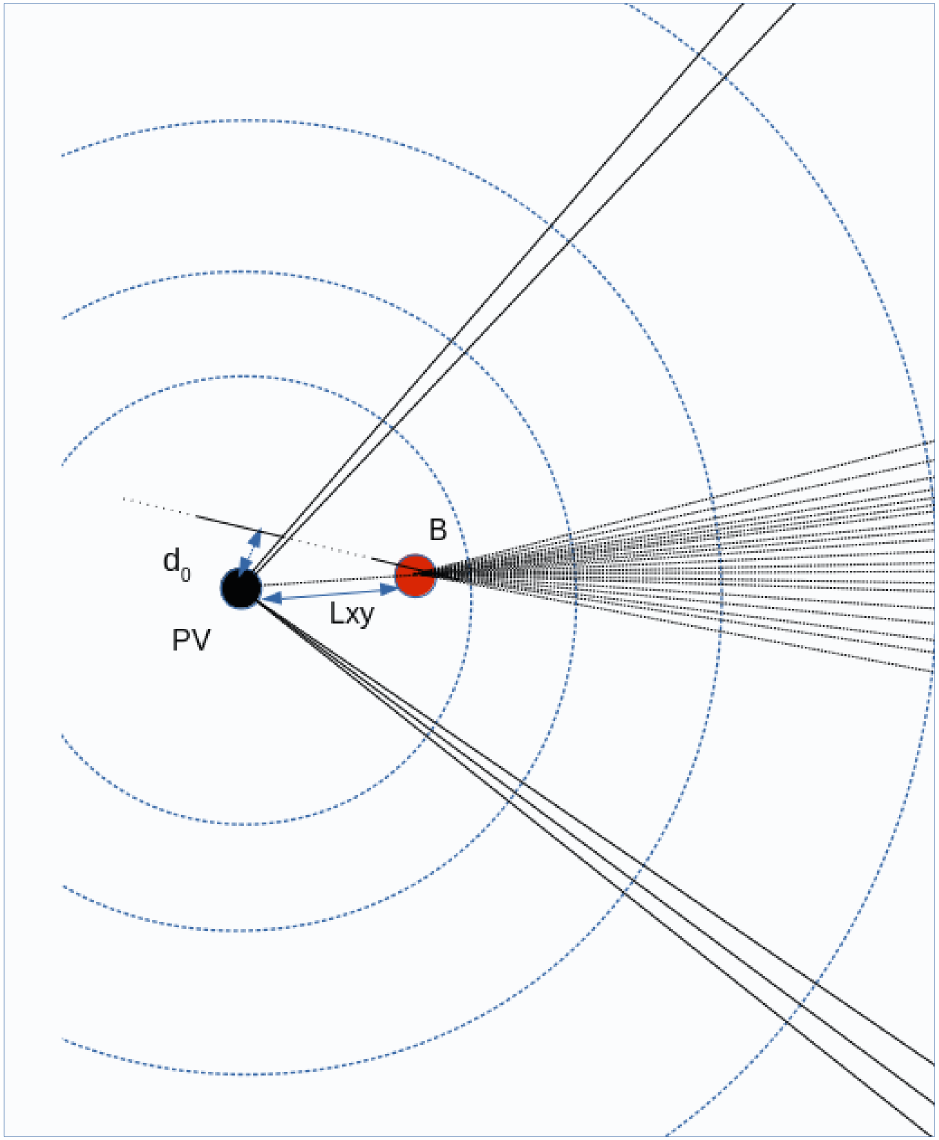
b-jet identification with Atlas at LHC Run 2

b-tagging

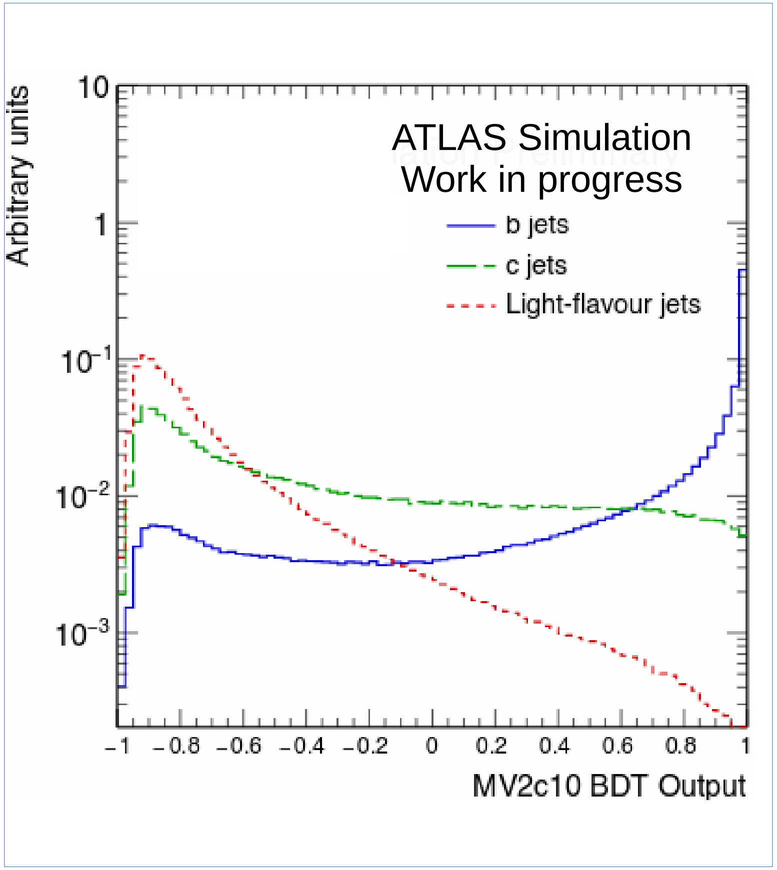
- **Jets:**
  - ► Collimated bundles of particles from hadronization of quarks, gluons
  - ► Reconstructed using energy deposited in calorimeters
- **b-jet:** jet from b-quark, it contains a B-hadron
- Properties of B-hadrons:
  - ► Travel before decaying
  - ► Longer lifetime.

► B-hadron forms secondary vertex,
tracks have large impact parameter d_0

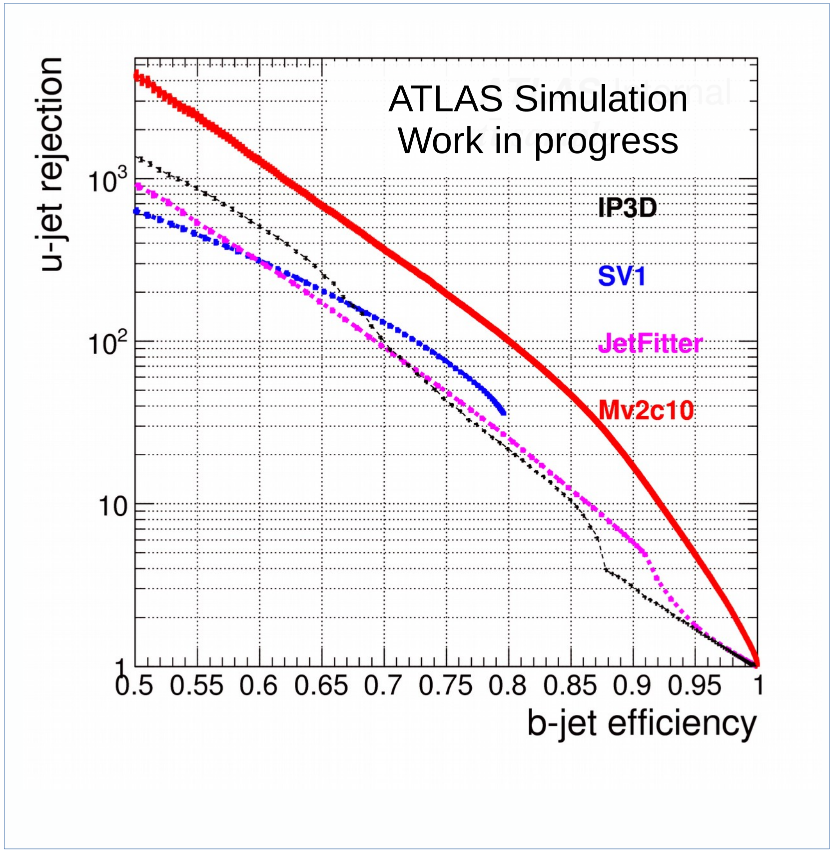




- Performance of a b-tagging algorithm ⟺ its power to separate b from c and light-jets
- Represented as the light-jet rejection vs b-jet efficiency,



obtained by varying cuts on b-/light-/c- jet distributions of the discriminating variable



- Operating points (OP) ⟺ single cut value on the discriminating variable of an algorithm
- Cut is chosen to provide a specific b-jet efficiency on a simulated sample

b-tagging and IBL

- The tracker is the most important for b-tagging

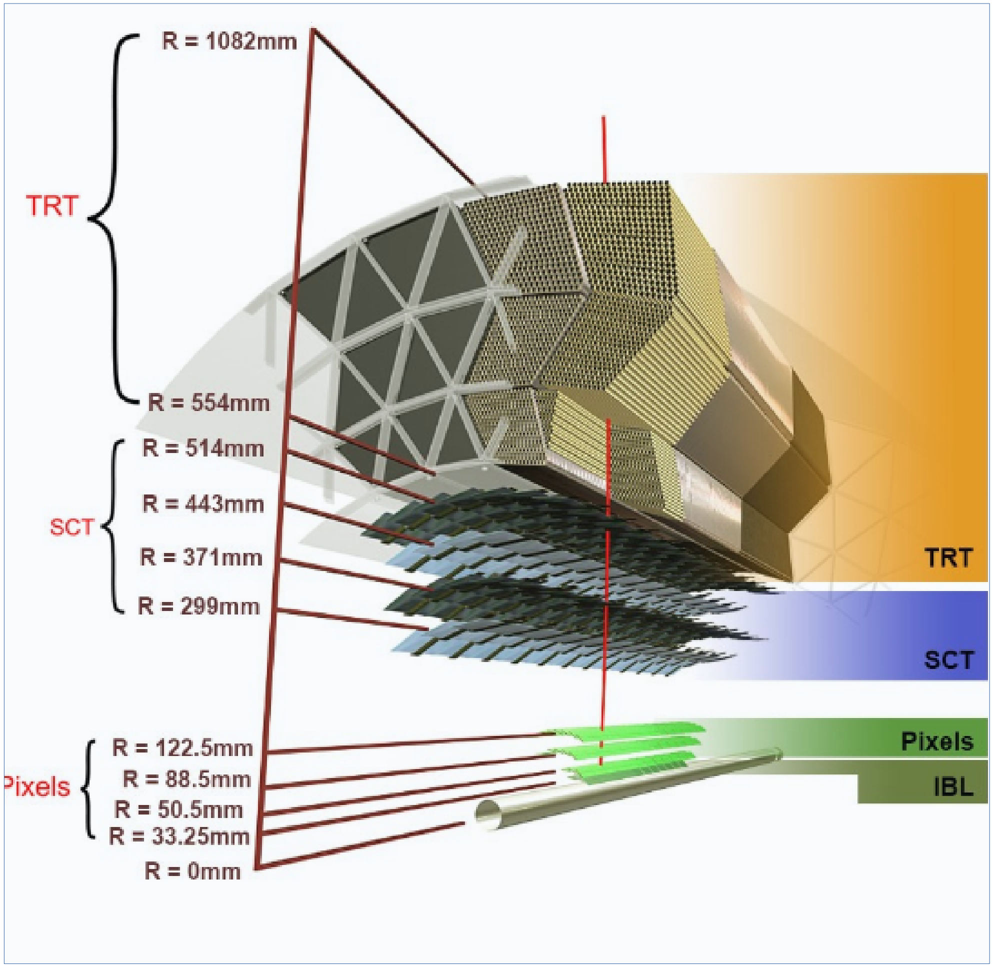
  2468 pixel modules

- Resolution on position improved:

  10µm in (R, φ) and 70 µm in Z

  ► good accuracy on impact parameters measurement

  ► good SV reconstruction



- However, pixel modules can turn inactive

  ► affect badly the reconstruction of the tracks, b-tagging performance as well.

- It was needed to quantify the impact on the b-tagging performance for such scenarios

b-tagging

- We simulated several scenarios with varying **the fraction of inactive pixel modules** (y) from 6% to 35% in IBL (L0, L1, L2).
- Scenarios with an entire layer disabled were also produced to estimate the highest effect
- We used two different samples (ttbar and Z' mix) to cover all the jet pt ranges
- Configurations produced are:

	ttbar sample (y%)	Z' mix (y%)
IBL scenarios	{6, 9, 15, 25, 35. 100}	{35. 100}
L0 scenarios	{6, 9, 15, 25, 35, 100}	{35. 100}
L1 scenarios	{6, 9, 100}	{100}
L2 scenarios	{6, 9, 100}	{100}

- Performance of IP3D, SV1, JetFitter and Mv2c10 were compared to the baseline

b-tagging

- Differences seen by comparing the scenarios wrt baseline:
  → Impact parameter resolution of tracks
  → Track multiplicity in jet
  → b-tagging algorithms discriminant distributions

- The discriminating distributions are varying per scenario

  ⇒ OP doesn't correspond to the same b-jet efficiency in the baseline and in a scenario

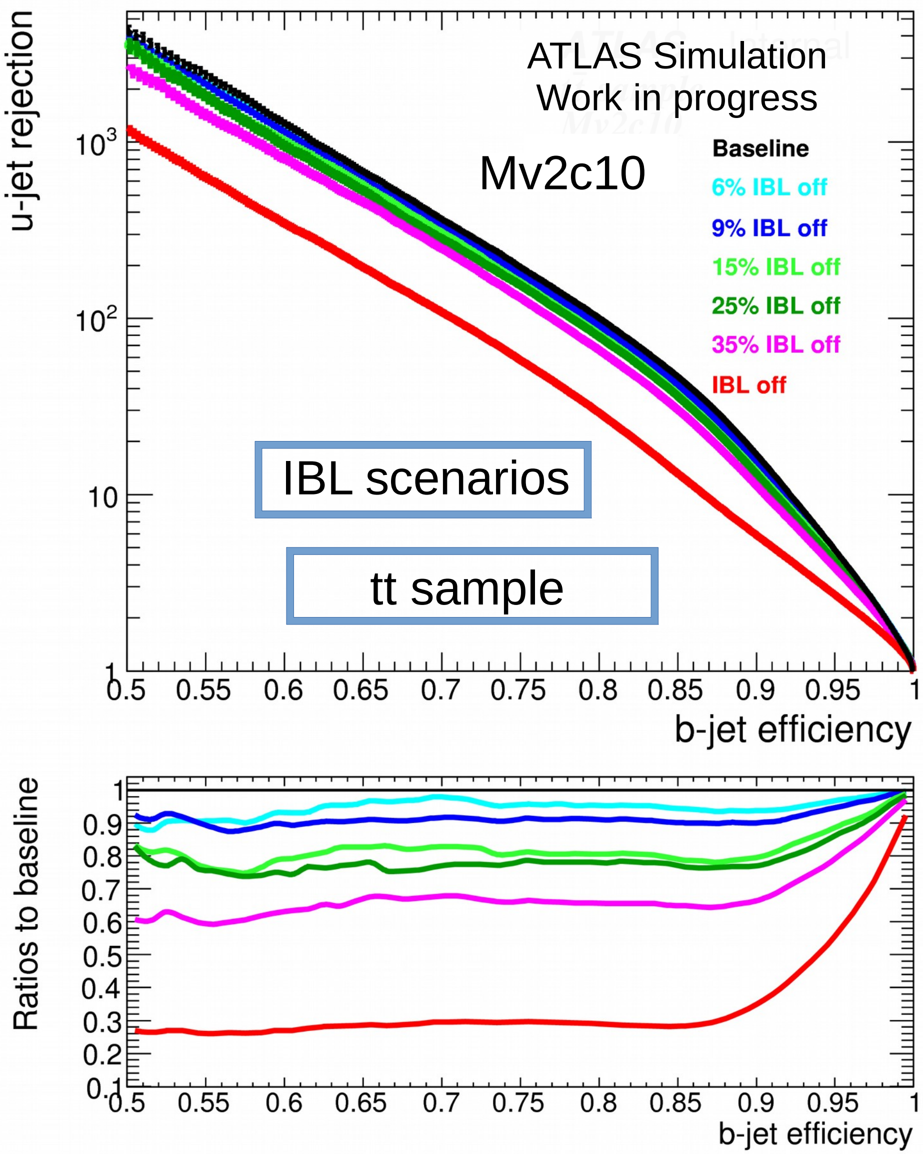
- 2 ways to look for performance degradation for a scenario wrt baseline

  → By modifying the OP to reach the same b-jet efficiency and then compare light jet rejection

  → Without modifying the OP, check the degradation per scenario in b-jet efficiency, light-jet rejection and c-jet rejection

b-tagging

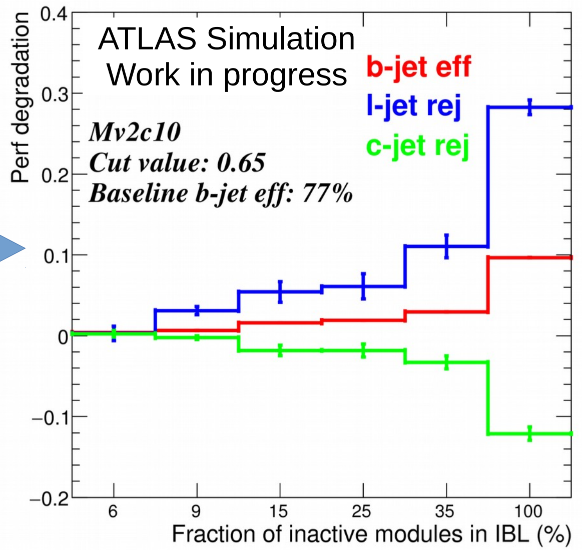
- Modify the OP depending on each scenario



- Without modifying the OP
- Each bin of the x axis shows a IBL scenario
- Y axis shows the perf degradation wrt baseline of:

b-jet efficiency
light jet rejection
c-jet rejection

The OP corresponding to 77% Mv2c10 b-jet efficiency



Phenomenology: Suspect 3 new version

Suspect 3

- Add the 125 GeV Higgs boson mass as input to Suspect 3

→ Suspect 3 is a SUSY spectrum calculator

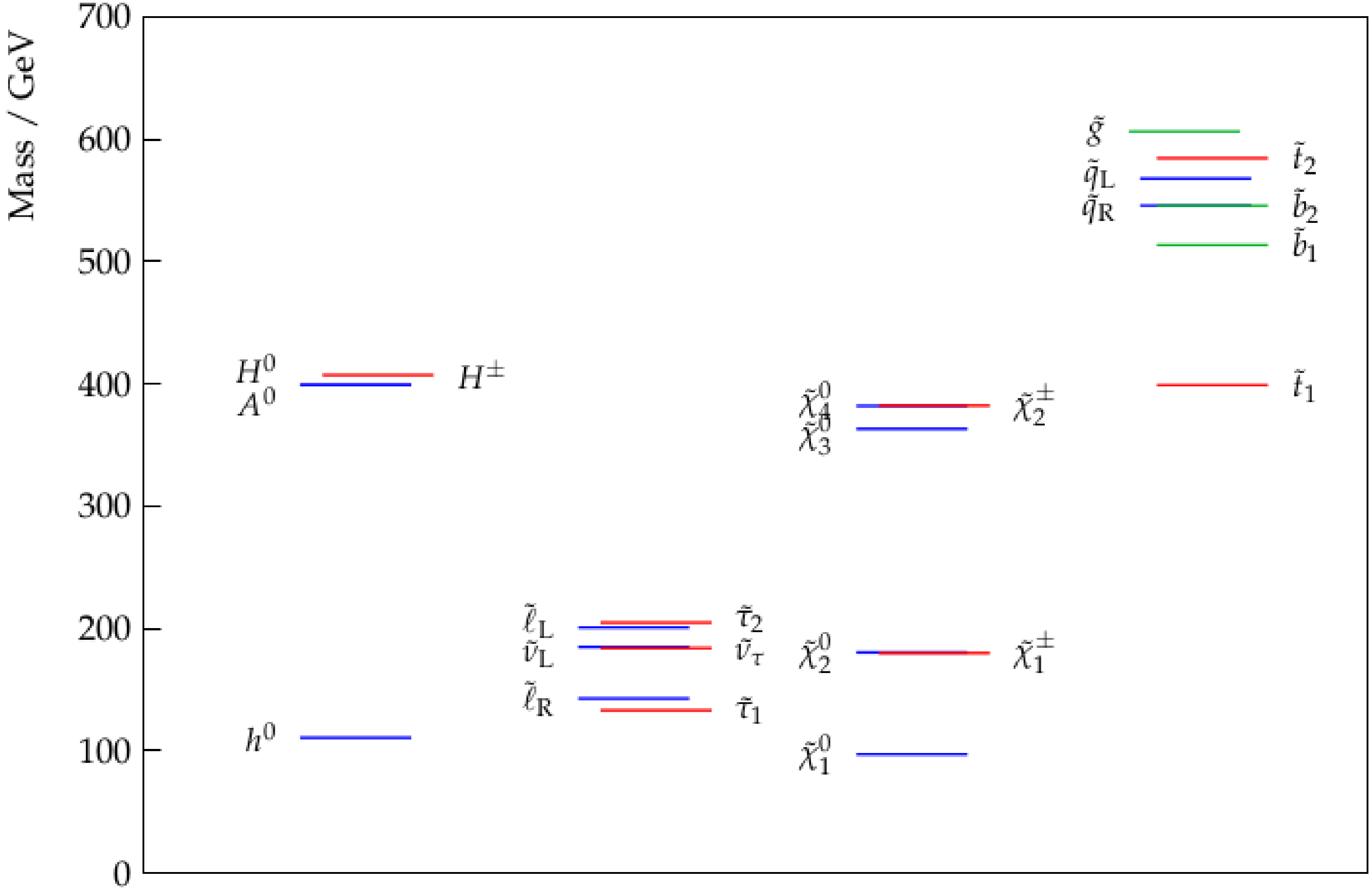
→ In the present version this mass is calculated as output

- Benefit for all SUSY analyses:

→ Facilitates pMSSM scans by avoiding large number of incompatible models

- Task: Look for free parameters in the Higgs and stop sectors (i.e.:μ, A_t , tanβ) computable **for a known Higgs boson mass**

Suspect 3



Mass / GeV
700
600
500
400
300
200
100
0
$\tilde{g}$
$\tilde{t}_2$
$\tilde{q}_L$
$\tilde{q}_R$
$\tilde{b}_2$
$\tilde{b}_1$
H^0
A^0
$H^\pm$
$\tilde{\chi}_4^0$
$\tilde{\chi}_3^0$
$\tilde{\chi}_2^\pm$
$\tilde{t}_1$
$\tilde{\ell}_L$
$\tilde{\nu}_L$
$\tilde{\ell}_R$
$\tilde{\tau}_2$
$\tilde{\nu}_\tau$
$\tilde{\tau}_1$
$\tilde{\chi}_2^0$
$\tilde{\chi}_1^\pm$
h^0
$\tilde{\chi}_1^0$

Suspect 3

- Authors:

→ Fortran: A. Djouadi, J-L Kneur, G. Moultaka

→ C++: A. Djouadi, J-L Kneur, G. Moultaka, M. Ughetto, D. Zerwas.

- Aim:

→ Computes pMSSM spectrum for SUSY breaking models mSUGRA, AMSB and GMSB.

→ Implements the radiative corrections at full one loop for the masses and the dominant two loops for the Higgs.

- Input: SLHA file containing

→ SM inputs ($M_{Z,}$ M_{top}, $\alpha(M_Z)$, $\alpha_s(M_Z)$,…)

→ Boundary conditions of the SUSY breaking model.

Suspect 3

- Reminder of the simple approximation for the Higgs mass radiative corrections (RC)

$$m_h^2 = m_h^{2,tree} + \frac{3g_2^2 m_t^4}{8\pi^2 m_w^2 sin^2(\beta)} [ln(\frac{m_{\tilde{t}1} m_{\tilde{t}2}}{m_t^2}) + \frac{X_t^2}{2M_s^2} - \frac{X_t^4}{12M_s^4}]$$

With $X_t = A_t - \mu cot(\beta)$

$$M_s^2 = \sqrt{m_Q^2 m_{tR}^2 + m_t^2(m_Q^2 + m_{tR}^2) + m_t^4}$$

$$m_{\tilde{t}1} m_{\tilde{t}2} = \sqrt{M_s^4 - 4m_t^2 X_t^2}$$

- Possible inversions:

125 Higgs boson mass $\xrightarrow{1}$ A_t

$\xrightarrow{2}$ μ

$\xrightarrow{3}$ tanβ

$\xrightarrow{4}$ $m_{H_u}^2, \; m_{H_d}^2$

Suspect 3

- Example: A_t computation:

- Input: tan(β), μ, $m^2_{H_u}$, $m^2_{H_d}$

- Procedure: $m_A \longrightarrow m_H^{tree} \longrightarrow$ RC, Quadratic equation in X_t^2

$\longrightarrow$ multiple A_t solutions

- Technical difficulties:

- Multiple solutions: **Need Constraints to reject unwanted solutions**

- Convergence of the iterative procedure

- **Status**: First code version with the 4 inversions working well and in validation.

- **Future work:** Replace RC with the **full one loop for the masses and the dominant two loops for the Higgs relation**

- We computed $m^2_{H_u}, m^2_{H_d}$ using inversion 4 for A_t = -2000.

Input	Output
type of inversion= 1	A_t
m_H exp= 125 GeV	m_A^{tree}= 65 GeV
m_{top}= 173 GeV	m_H^{tree}= 62.5 GeV
m_W= 80.1 GeV	RC= 11719.3 GeV^2
m_Z= 90.1 GeV	
m_{t_R}= 2000 GeV	A_{t_1}= -2004.48 correct value,
m_Q= 2000 GeV	relative deviation=0.24%
g_c= 0.64	
tan(β)= 10	A_{t_2}= 2204.48 unwanted value
μ= 1000	
sign of μ= +1	
$m^2_{H_u}$= -984135 GeV	
$m^2_{H_d}$= -1.01164e+06 GeV	

Summary

- Ongoing work on a new version of Suspect to add Higgs boson mass

- Impact of pixel dead modules on b-tagging performance was studied (Authorship done)

- SUSY EW search for $\tilde{\chi}_1^{\mp}\tilde{\chi}_2^{0} \longrightarrow$ W+h+MET could be the key for SUSY production at LHC Run 2

If I have ever made any valuable discoveries, it has been owing more to patient attention, than to any other talent.

Isaac Newton,
mathematician &
physicist (1642 - 1727)

Thank you for your attention!

Backup

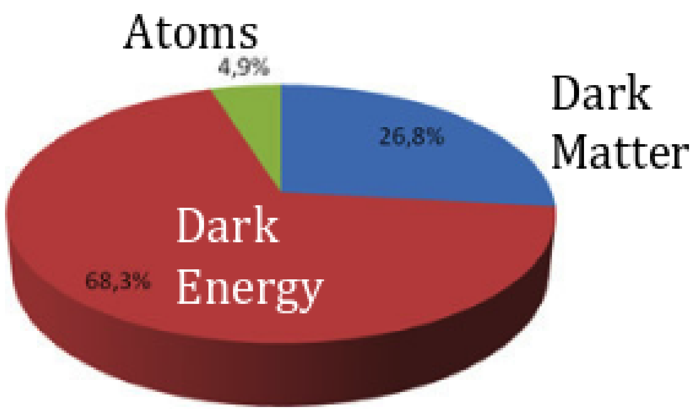
Nice features of SUSY:

Solving hierarchy problem:

→ SUSY contributions to Higgs mass cancel SM contributions ⇒ fix its mass to 125 GeV

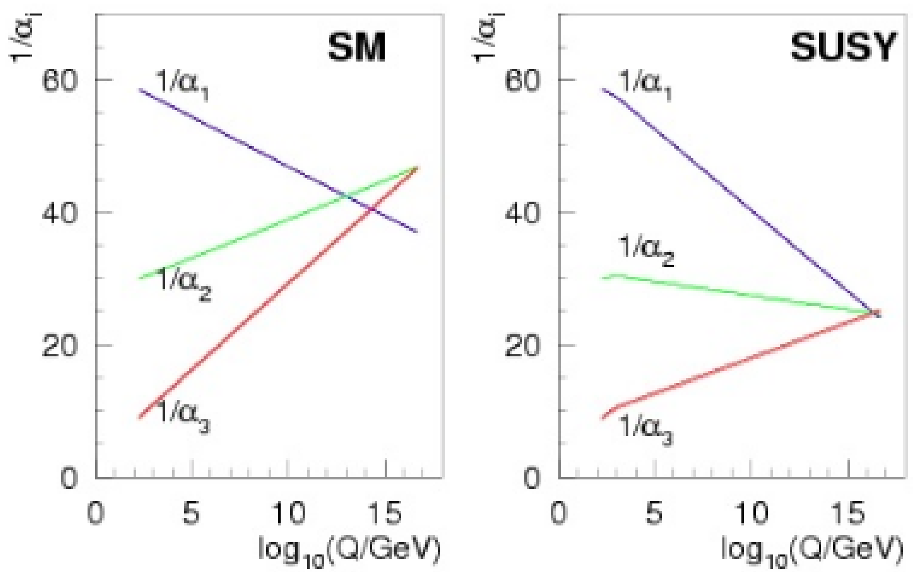
Provides Dark Matter candidate

→ Lightest SUSY particle (LSP) can be stable and only weakly interacting



Unification of gauge couplings

→ New particle content changes running of coupling



Connection of gravity and gauge symmetries

Some arguments are most convincing for SUSY particles at ~TeV scale