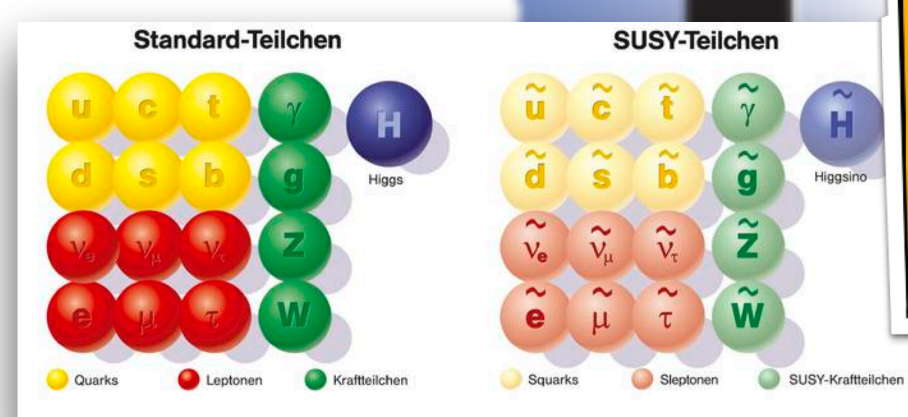
SuSpect takes a SUSY-HIT Status Report

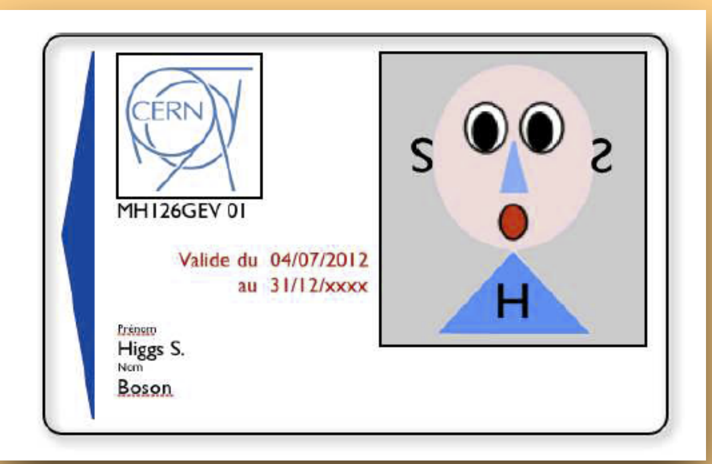
Jean-Loic Kneur (PI), Gilbert Moultaka, Margarete Mühlleitner (PI), Michael Spira, Dirk Zerwas

Third DMLab Meeting



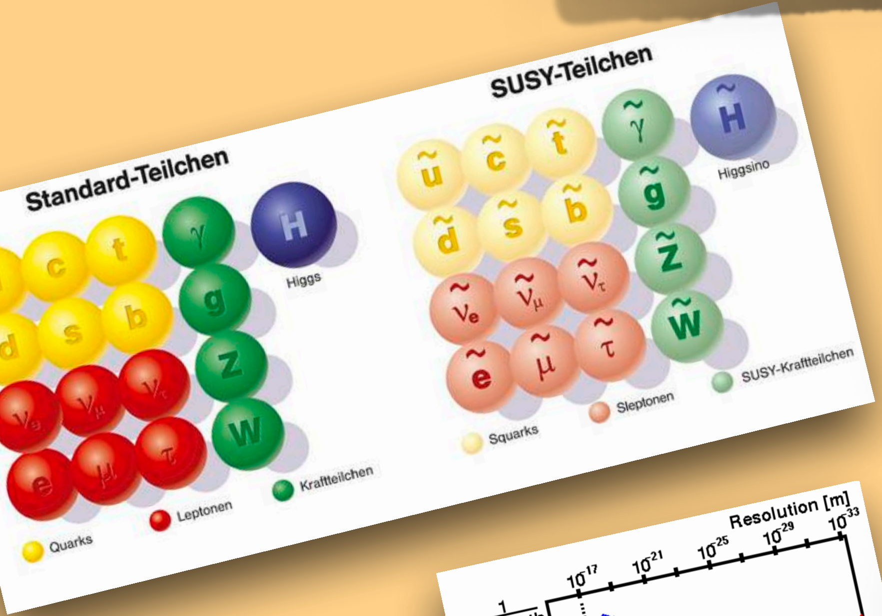
Status Quo Particle Physics

Discovery of a SM-like Higgs boson
SM tested to highest precision

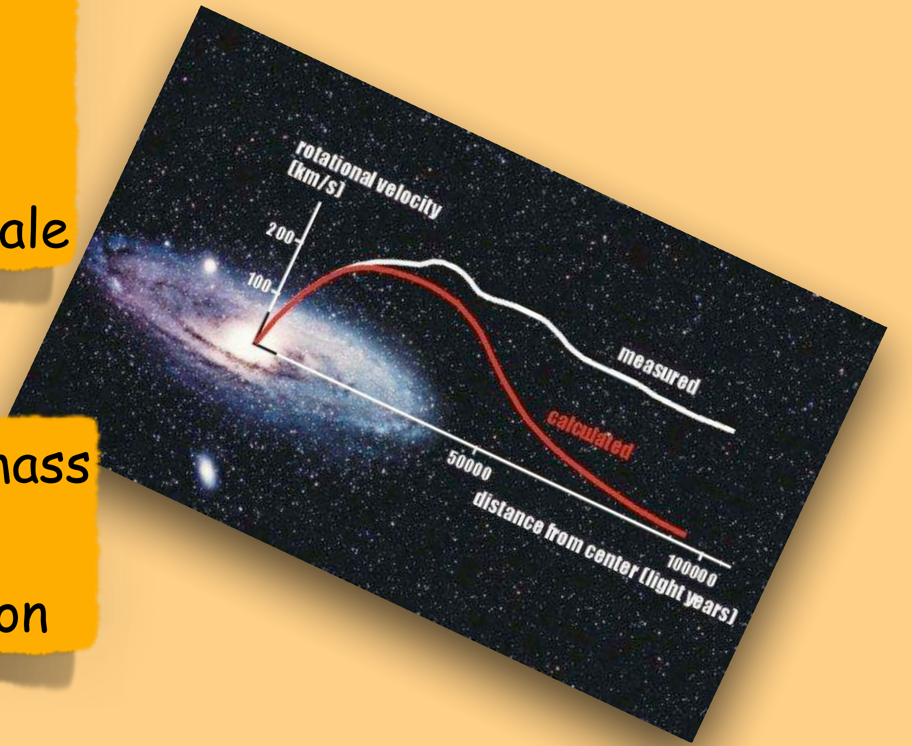


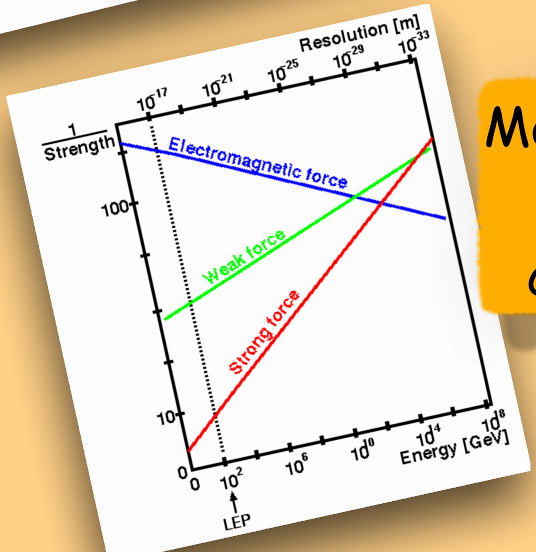
Still open questions, BUT
no direct discovery of New Physics
so far

Supersymmetry one of the most popular New Physics extensions
very well motivated and able to address open questions



- solve hierarchy problem
- candidate for DM
- gauge coupling unification
- window on physics up to GUT scale





Moreover, the Higgs boson with mass
m_H=125 GeV
could still be a SUSY-Higgs boson

Higher-Order Corrections and SUSY Parameter Space

The Higgs boson mass: in supersymmetry Higgs boson mass given in terms of the gauge couplings

=> mass of lightest Higgs boson $m_H \leq M_Z$ at tree level

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- crucial to shift the Higgs boson mass to the measured 125 GeV
- include as many loop corrections as possible to reduce the theory uncertainty to match the experimental accuracy

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Higher-order corrections to the Higgs boson decays:

- Higgs decays determine the phenomenology of the Higgs particle: model has to be consistent with measured SM-like Higgs data and the exclusion bounds from additional Higgs and SUSY searches
- Experimental constraints hence indirectly constrain the viable parameter space of the model
- A meaningful deduction of the allowed parameter space requires highest precision in the Higgs observables and hence also the decays

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SUSY breaking
- no SUSY particles discovered so far => SUSY is broken => introduces many new parameters
- Number of parameters reduced by well motivated boundary conditions at some high scale

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Higher-order co… 125 GeV
to the Higgs bos… the theory

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How can we combine these requirements in a consistent way at highest precision, i.e. including higher-order corrections, to make meaningful predictions and thus test our model?

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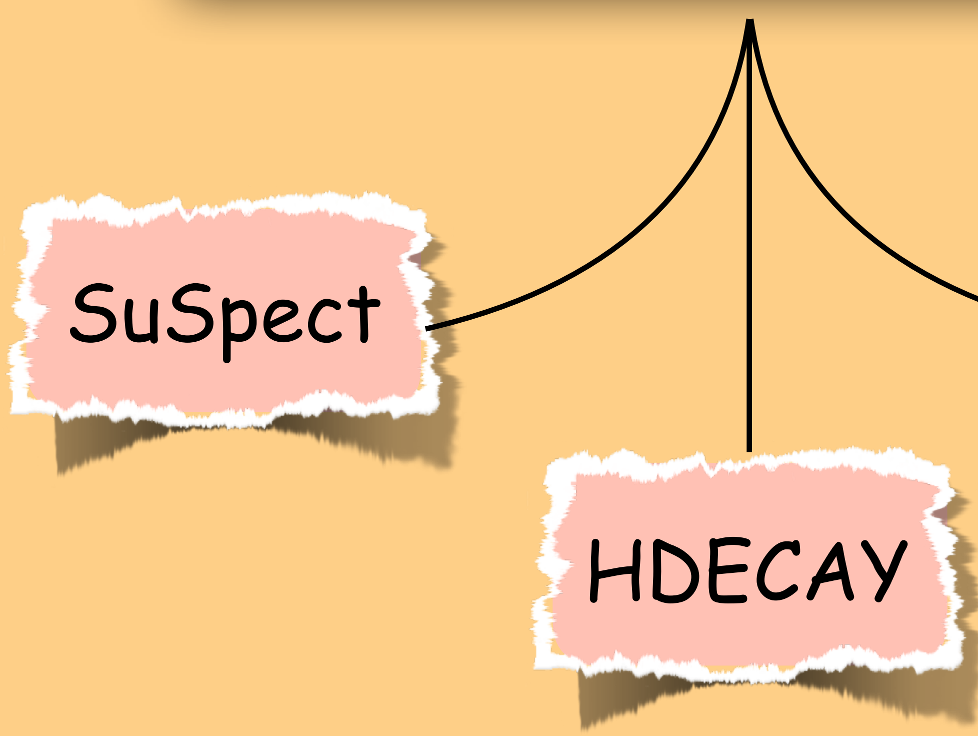
SUSY-HIT

Program Package SUSY-HIT - SU(spect)-S(deca)Y-H(decay)-I(n)Terface

A program package for the calculation of the particle spectrum and the decay widths and branching ratios of the Higgs bosons and supersymmetric particles in the framework of the MSSM, including higher order corrections.

released by A.Djouadi, M.Mühlleitner, M.Spira

Authors: A. Djouadi,
J.-L. Kneur
G. Moultaka,
M. Ughetto,
D. Zerwas



Authors: A. Djouadi,
M. Mühlleitner,
Y. Mambrini

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J. Kalinowski,
M. Mühlleitner,
M. Spira

Goal of the Project

Update SuSpect

Update SDECAY

Update the Interface to C++

Project Team:
Jean-Loic Kneur (PI), Gilbert Moultaka,
M. Mühlleitner (PI), Michael Spira, Dirk Zerwas

DARK MATTER LAB

SuSpect

Authors: A. Djouadi,
J.-L. Kneur
G. Moultaka,
M. Ughetto,
D. Zerwas

SuSpect

Code Description:
- computation of the MSSM Higgs and SUSY particle mass spectrum including higher-order corrections
- taking into account boundary conditions of specific models: pMSSM, mSUGRA, GMSB, AMSB

Programming language:
- originally Fortran

Method:
- RGEs (at 1- and 2-loop) for the evolution of the particles from one scale to the other (up to 5 different energy scales)
- Model-dependent boundary conditions applied at appropriate scale
- Electroweak symmetry breaking calculated iteratively at the EW scale
- Radiative corrections to the Higgs and sparticle masses => precise pole masses

SuSpect

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SuSpect

Code Descri

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NEW Update to SuSpect3 NEW

Autors: A. Djouadi, J.-L. Kneur, G. Moultaka, M. Ughetto, D. Zerwas

- Rewrite of code in C++
- 1st & 2nd generation SUSY sfermion parameters now independent
- Full one-loop radiative corrections in the gaugino sector (pole masses)
- Extended range of supported models
- Added option for tree-level pseudoscalar mass as input for EWSB
- Added option for h mass as input in EWSB to determine A_t
- Input compatible with SLHA format [Skands et al.]
- EWSB defined by input values instead of a special variable
- Block QEXTPAR added for input scale of the mu parameter
- Option to get scale dependent parameters at other scales than those defined by the model available for all models now

HDECAY

HDECAY

Authors: A. Djouadi, J. Kalinowski, M. Mühlleitner, M. Spira

Code Description:

- computation of the partial decays widths and branching ratios of the Higgs bosons within the SM (w/ 3&4 generations), a general two-Higgs doublet model and the MSSM
- it includes the dominant higher-order effects: radiative corrections and multi-body channels

Programming language:

- Fortran

Method:

- Computation of partial decay widths and branching ratios from input parameters
- Link to SuSpect to get particle spectrum and soft SUSY breaking parameters, also possible link to FeynHiggs or input from SLHA file

DARK MATTER LAB

HDECAY

HDECAY

Authors: A. Djouadi,
J. Kalinowski,
M. Mühlleitner,
M. Spira

Code Descriptio

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-Higgs

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Programming lan

Method:

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file

Updates

Autors: A. Djouadi, J. Kalinowski, M. Mühlleitner, M. Spira

- Continuous updates over the years

- New manual more than 20 years after first publication describing updates since then ['18]

HDECAY: Twenty++ Years After

Abdelhak Djouadi[a], Jan Kalinowski*[b,c], Margarete Mühlleitner[d], and Michael Spira[e]

SDECAY

SDECAY

Authors: A. Djouad
M. Mühlleitner,
Y. Mambrini

Code Description:
- computation of the partial decays widths and branching ratios of the SUSY particles of the MSSM
- it includes the dominant higher-order effects, loop induced 2-body decays and important 3- and 4-body decays

Programming language:
- Fortran

Method:
- Computation of partial decay widths and branching ratios from input parameters
- Link to SuSpect to obtain the mass spectrum and the soft-SUSY breaking parameters, or input from SLHA file
- Within SUSY-HIT it is linked also to HDECAY to get the MSSM Higgs boson decay widths and branching ratios

DARK MATTER LAB

SDECAY

SDECAY

Authors: A. Djouadi, M. Mühlleitner, Y. Mambrini

Code Description: - computation of the partial decays widths and branching ratios of the

2-body

Planned update

within DMLab project

- Update links to newest SuSpect and HDECAY versions

- Improve treatment of decays at kinematic thresholds

Programming lang

Method: rom input

parameters

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<u>Planned update</u>

within DMLab project

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SUSY-HIT v1 $\Rightarrow$ SUSY-HIT v2

- Improve treatment of decays at kinematic thresholds

Work in Progress: SUSY-HIT v1 -> SUSY-HIT v2

SUSY-HIT1

- 100% Fortran
- Input files: SLHA*, susyhit.in, hdecay.in
- Communication between suspect2 and SDECAY/HDECAY: SLHA spectrum file

SUSY-HIT2:

- Upgrade to hdecay v6.61
- Move to SuSpect3 (C++)
- Communication SuSpect3 - SDECAY/HDECAY in memory (more efficient for large parameter scans)
- C++ calling Fortran

C++ inheritage:

- Object SLHA4suspect: SLHA memory implementation of SLHA (limited to BLOCKS)
- Object SLHA4susyhit: inherits from SLHA4suspect and adds BLOCK DCINFO and DECAY of SLHA

Code maintance:

- Implemented CI tests for example files

Testing:

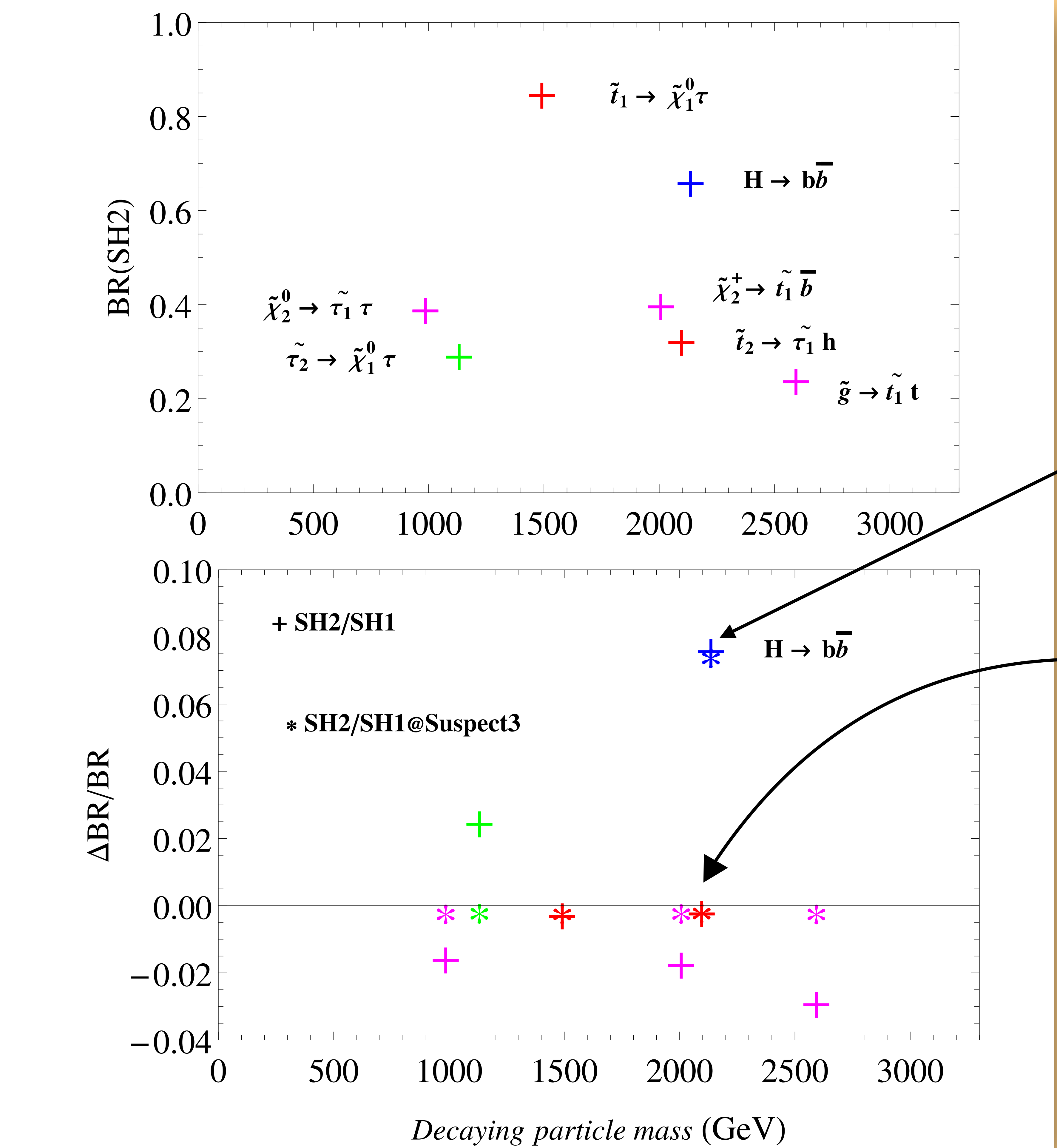
- Intrinsic comparisons: communication via file versus memory
- Change comparisons: SUSYHIT v1 versus SUSYHIT v2

Availability: Soon

* SLHA: SUSY Les Houches Accord format

```
#          PDG            Width
DECAY   1000021     4.51015016E+00   # gluino decays
#           BR         NDA      ID1       ID2
     2.11421275E-02    2     1000001        -1   # BR(~g -> ~d_L  db)
     2.11421275E-02    2    -1000001         1   # BR(~g -> ~d_L* d )
     5.06628143E-02    2     2000001        -1   # BR(~g -> ~d_R  db)
     5.06628143E-02    2    -2000001         1   # BR(~g -> ~d_R* d )
     2.73930365E-02    2     1000002        -2   # BR(~g -> ~u_L  ub)
     2.73930365E-02    2    -1000002         2   # BR(~g -> ~u_L* u )
     5.02331604E-02    2     2000002        -2   # BR(~g -> ~u_R  ub)
     5.02331604E-02    2    -2000002         2   # BR(~g -> ~u_R* u )
     2.11421275E-02    2     1000003        -3   # BR(~g -> ~s_L  sb)
     2.11421275E-02    2    -1000003         3   # BR(~g -> ~s_L* s )
     5.06628143E-02    2     2000003        -3   # BR(~g -> ~s_R  sb)
     5.06628143E-02    2    -2000003         3   # BR(~g -> ~s_R* s )
     2.73930365E-02    2     1000004        -4   # BR(~g -> ~c_L  cb)
```

First Comparisons



Comparison of + and *:

Effect due to upgrade to latest HDECAY version

Effect due to upgrade to SUSPECT3 (small)

Summary

DMLab Support

Short term visit:

Dirk Zerwas and Jean-Loic Kneur at KIT in 10/2023

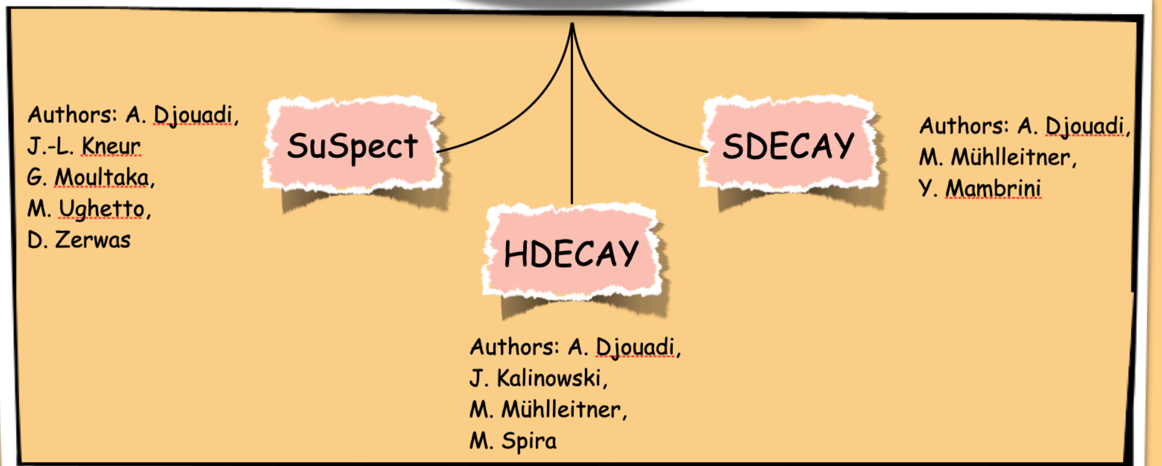
-> boost for project big and quick progress

Update SuSpect - Done

Update SDECAY

Update the Interface to C++ in Progress

SUSY-HIT



Project Team:
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Thank You
For Your
Attention!