GRACE-SUSY

Vincent LAFAGE

***Minami-Tateya Group, IPNS, KEK,* TSUKUBA**

The GRACE System & GRACE-SUSY package

1. **The GRACE System**
   - **overview**
   - **lagrangian description**
   - **matrix element**
   - **program structure**

2. GRACE-SUSY
   - **demonstration**
   - **tests**
   - **the next step: GRACE-SUSY one-loop**

3. MUSE**: a multiscale spectrum evaluator**
   - **Motivation**
   - **RGE, thresholds, unification**
   - **radiative corrections**
   - **comparison**

Computational Techniques

Lagrangian
FEYNMAN's rules

- **parameters set**
- **gauge fixing**
- **auxiliary fields**

\+ `.mdl` **file**
\+ **unitary/R_ξ gauge**

$\Downarrow$

graphs building

- **n-loops**
- **graph selection**

$\Downarrow$

matrix element

- **helicity amplitude**
- `CHANEL` **library**

\+ **MAJORANA fermions**
\+ **color basis**

$\Downarrow$

integration package
events generator

- **Monte-Carlo**
  `BASES`
- **Kinematics library**
  `KINEM`
- **Events generator**
  `SPRING` **(unweighted)**
  interface to `JETSET`

$\Downarrow$

observables
(σ, distributions)

FEYNMAN's rules

generality: any model implemented as `.mdl` file

standard `.mdl` file are provided

particle content...

```
 Particle=Z["Z0"];      Antiparticle=Particle;
     Gname={"Z^0"};
     PType=Vector; Charge=0; Color=1; Mass=amz; Width=agz;
     PCode=4; KFCode=23; Gauge="zb";
 Pend;
%
 Particle=gluon["g"]; Antiparticle=Particle;
     Gname={"g"};
     PType=Vector; Charge=0; Color=8; Mass=amg; Width=0;
     PCode=8; Massless; KFCode=21;
     Gauge="gl"; PSelect="gluon";
 Pend;
%
 Particle=t["t"]; Antiparticle=t-bar["at"];
     PType=Fermion; Charge=2/3; Color=3;Mass=amuq(3/3);
     Width=aguq(3/3); PCode=63; KFCode=6;
 Pend;
%
 Particle=gluino["~g"]; Antiparticle=Particle;
    PType=Majorana; Charge=0; Color=8; Mass=AMGL; Width=AGSG;
    PCode=7080;  KFCode=70;
 Pend;
%
 Particle=Higgs1["h0"]; Antiparticle=Particle;
     Gname={"h"};
     PType=Scalar; Charge=0; Color=1; Mass=amh1; Width=agh1;
     PCode=7311; KFCode=25; PSelect="higgs";
 Pend;
```

... and couplings

```
 Vertex={positron,  electron, photon}; ELWK=1;
         FName=all(2,1/3); FType="V"; Vend;
 Vertex={photon, W-minus, W-plus}; ELWK=1; FName=AWW;
        Vend;
```

Helicity Amplitude / Color Basis

- **general: massive vector / fermion / scalar**
- **fast: N diagrams, N complex amplitudes**
- **accurate:**
  - **interferences are not quadratic**
  - **gauge independence is a good test**
- **numerical combination of analytic vertex amplitudes: (CHANEL library)**
  - **all standard gauge vertices**
  - **new vertices can be implemented: effective theories, non-linear gauge fixing**
- **access to polarisation information**
- **projection of amplitude on color basis: fast. provides information needed for hadronisation**

Fortran structure of integrator (quick overview of important routines)

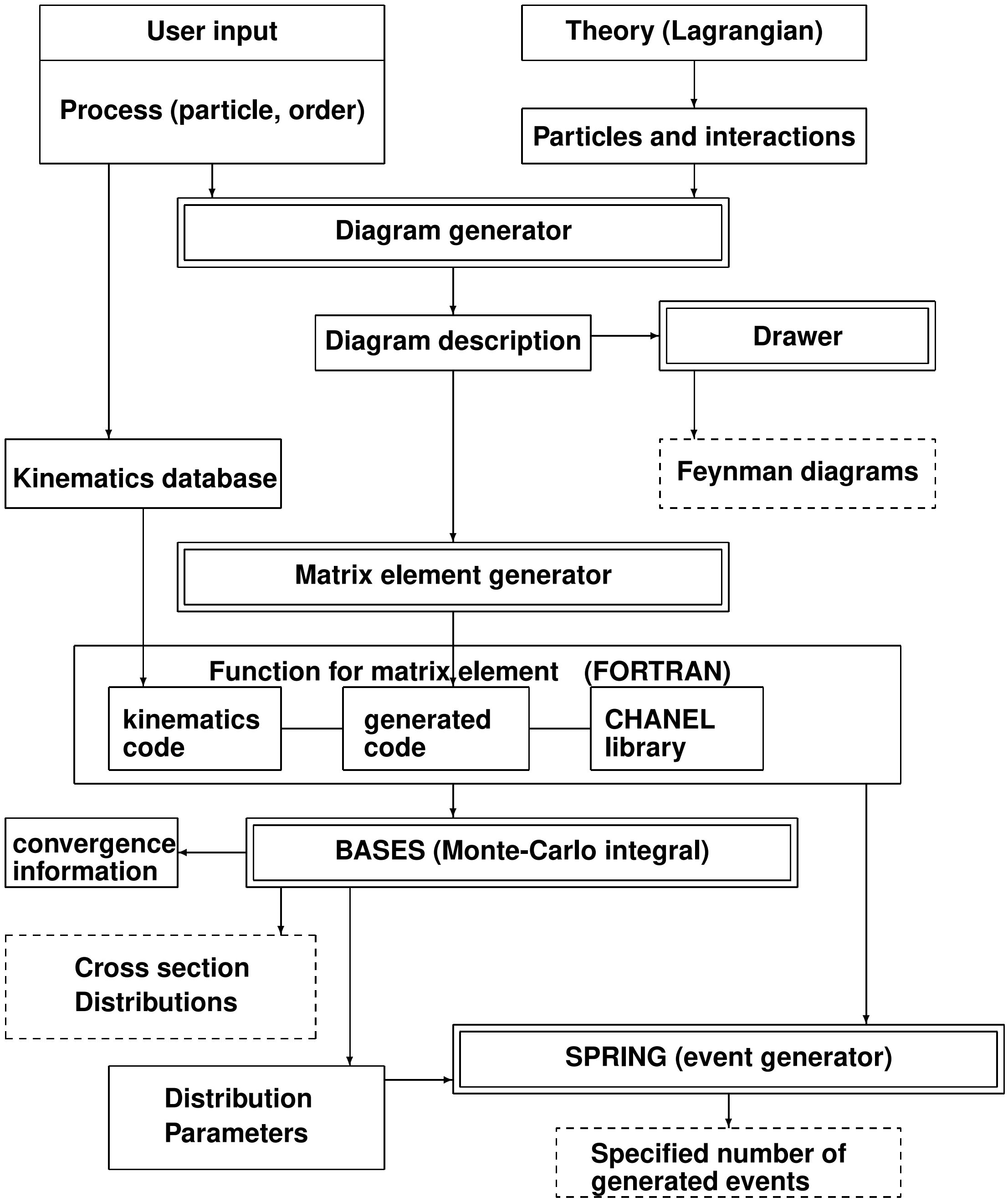
Initialisation:

- userin
  - setmdl — set masses & width
  - setcpl — set couplings
  - kinit — kinematics initialisation

Function integrated:

- kinem(..., x, p, yacob,...) — phase space mapping
- usrcut
- **Matrix element**
  - amptbl — compute amplitude for every graph
  - ampsum(ansm) — sum over helicities and colors
- kfill(..., x, p, pp,...) — for histogramming (interface to PAW)

Flowchart


User input
Process (particle, order)
Theory (Lagrangian)
Particles and interactions
Diagram generator
Diagram description
Drawer
Kinematics database
Feynman diagrams
Matrix element generator
Function for matrix element (FORTRAN)
kinematics code
generated code
CHANEL library
convergence information
BASES (Monte-Carlo integral)
Cross section Distributions
SPRING (event generator)
Distribution Parameters
Specified number of generated events

MSSM Model

KURODA (hep-ph/9902340)

- **minimal content in particles**

g	$\tilde{g}$	
$W^\pm$	$\tilde{W}^\pm$	
$\chi^\pm$	$\tilde{\chi}^\pm$	$\underline{\tilde{\chi}^\pm_{i=1,2}}$
$H^\pm$	$\tilde{H}^\pm$	
γ	$\tilde{\gamma}$	
Z^0	$\tilde{Z}^0$	
χ_3	$\tilde{\chi}_3$	
h^0	$\tilde{h}^0$	$\underline{\tilde{\chi}^0_{i=1,\cdots,4}}$
H^0	$\tilde{H}^0$	
A^0	$\tilde{A}^0$	
ν_f	$\tilde{\nu}_{f;L}$	
ℓ_f	$\tilde{\ell}_{f;i=1,2}$	
q_f	$\tilde{q}_{f;i=1,2}$	

- **R-parity preserving couplings (R-parity breaking test)**

- **all vertices have been tested (gauge invariance)**

- **goldstones are kept to work in different gauge**

- **ghosts are ready for one-loop**

How To ?

- **enter the process to be considered:**
  `in.prc` **file**

```
Model="/data1/grc2.1/model/mssm216.mdl";
Process;
  ELWK=3;
  Initial={electron, positron};
  Final  ={Higgs-minus, neutralino1, chargino1};
  Kinem="/data1/grc2.1/dbkinem/3009";
Pend;
```

- `grc` **generates description of each graph**
  $\Longrightarrow$ `out.grf` **file, according to** `.mdl` **file**

- `gracefig` **or** `grcdraw` **draws the diagrams**

- `grcfort` **generates the** `FORTRAN` **code for**
  - **matrix element,**
  - **gauge independence test (**`gauge`**), 32 digits**
  - **phase space integrator (**`integ`**)**
  - **event generator (**`spring`**),**
  - `Makefile`

Gauge independence check

$$e^+e^- \to H^- \tilde{\chi}_1^0 \tilde{\chi}_1^+$$

67 graphs in covariant gauge
57 graphs in unitary gauge

comparison on one phase space point at $\sqrt{s} = 1$ TeV:
$\xi_\gamma = 2 \quad ; \quad \xi_W = 3 \quad ; \quad \xi_Z = 4 \quad ; \quad \xi_g = 5$

```
  unitary            = 0.2992786257302350E-03
covariant            = 0.2992786257302350E-03
---------------------------------------------
unitary/covariant-1 = 0.
```

```
  unitary            = 0.29927862573024609767415322287816 3303E-0003
covariant            = 0.299278625730246097674153222878163352E-0003
---------------------------------------------
unitary/covariant-1 =-0.192592994438723585305597794258492732E-0033
```

32 digits agreement !

Tests: tree-level (gauge parameter independence)

any $2 \to 4$ MSSM process

- $582\,102$ **processes**
- $264\,029\,077$ **diagrams**
- **about 11month/(10 PA72000) CPU time**

Applications

- **chargino pair production with full 6 final state fermions and comparison to spin correlation approximation.**
- $\tilde{t}_1 \tilde{t}_1 h^0$ **associated production.**

Where to get it ?
(standard model package)

The Minami-Tateya homepage

`http://theory5.kek.jp/minami/`

- **Documentation**
- **Program Packages for High Energy Physics**
  - **BASES/SPRING (ftp)**
  - **CHANEL (ftp)**
  - **GRC (ftp)**
  - **GRACE v2.0(ftp)**
- **Event Generators**
  - **grc4f (ftp)**
  - **susy23 (ftp)**

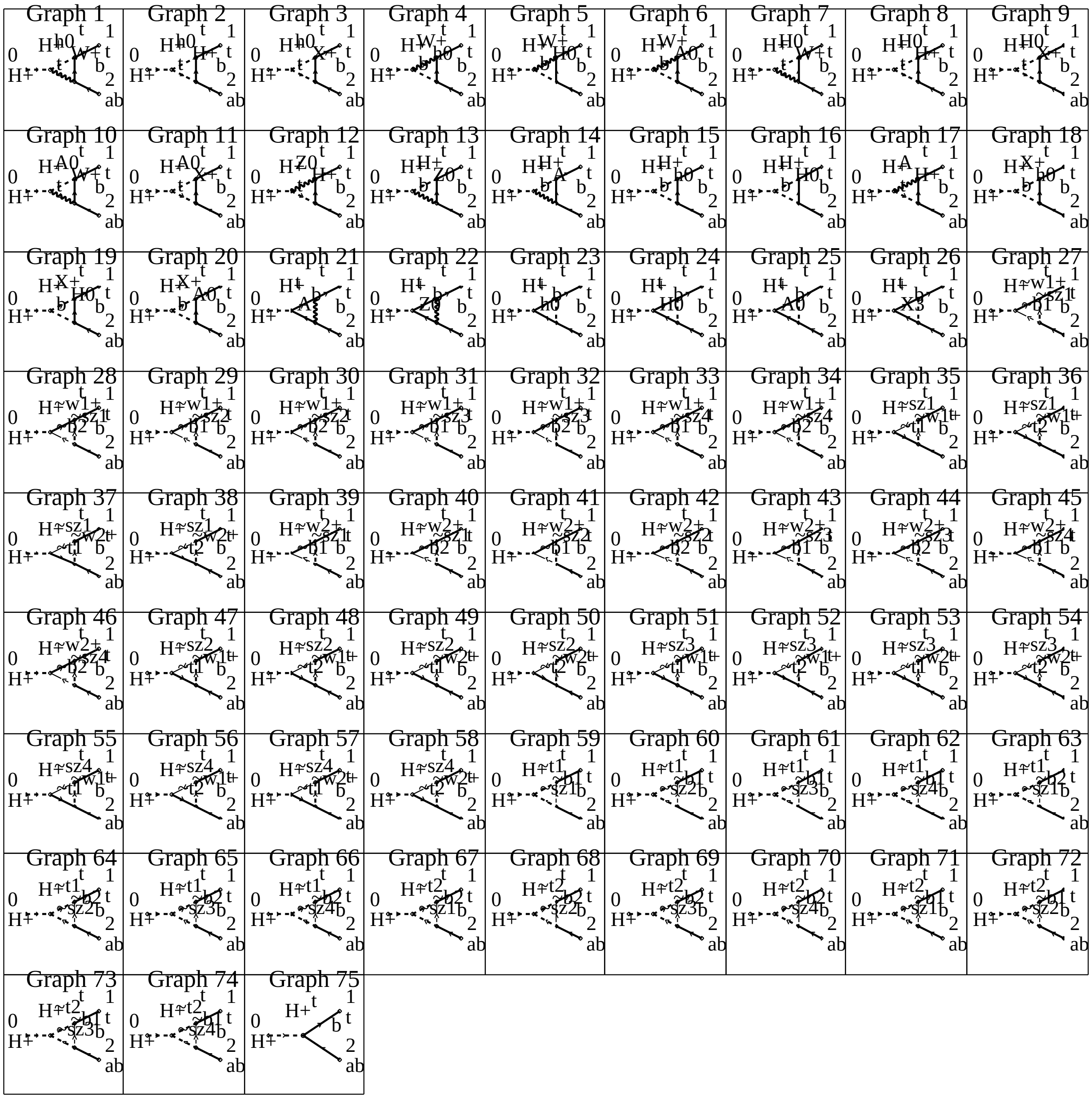
`lafage@minami.kek.jp`

GRACE-SUSY 1-loop

- $\overline{\mathrm{DR}}$ **regularisation implemented**
- **Majorana crashing dealt with**
- **all the 2-points functions are already computed**
- **study of** $H^+ \to t\bar{b}$ **in progress**
- **full MSSM renormalisation scheme: under construction**

GRACE-SUSY **1-loop**

$$H^+ \to t\bar{b}$$



Motivation

$\Longrightarrow$ mSUGRA paradigm:

- **minimal:** $M_{1/2}$, m_0^2, A_0, $\tan\beta$, $\mathrm{sgn}\,\mu$ @ Λ_{GUT}
- **many different results:** `Isajet`, `Spythia`, `SuSpect`
- **no hard-wired parameters**
- **exact unification**
- **scheme consistency ($\overline{\mathrm{DR}}$)**

MSSM parameters

- **gauge couplings,** g_i
- **superpotential: Yukawa's couplings** y_f **complex matrices in family space, mixing angles and phase and** μ * **in principle**
- **soft breaking terms:**
  - **the gaugino masses,** M_i
  - **the trilinear parameters,** a_f **(matrices in family space, but "aligned" with Yukawa's matrices) and the** b **mass term.**
  - **the scalar (higgs / sfermion) square masses** m^2**: also matrices in family space. but set proportional to identity to evade both FCNC and CP-violation.**

RGE
Renormalisation Group Equation

$$\frac{\mathrm{d}y_i}{\mathrm{d}t} = \beta_i(y_j, \{t\})$$

β	g	y	μ	M	a	b	m^2
β_g	$\times$	$\circ$					
β_y	$\times$	$\times$					
β_μ	$\times$	$\times$	$\times$				
β_M	$\times$	$\circ$		$\times$	$\circ$		
β_a	$\times$	$\times$		$\times$	$\times$		
β_b	$\times$	$\times$	$\times$	$\times$	$\times$	$\times$	
β_{m^2}	$\times$	$\times$		$\times$	$\times$		$\times$

$\times$**: dependency starting at 1-loop**
$\circ$**: dependency appearing at higher order**

Non-linear but polynomial $\Longrightarrow$ very-smooth (between thresholds)

*and R-parity breaking terms...

Specific models' spectra

besides usual user input in `setmdl`

- **RGE evolution of parameters :**
  - **gauge, yukawa and soft breaking**
  - **many boundary condition: M_Z, Λ_{GUT}, Λ_{EWSB} and all the pole masses**
- **input options:**
  - **Λ chosen as couplings' unification scale**
  - **α_3 chosen from unification condition**
  - **symmetry breaking enforced**
  - **soft breaking parameters from minimal SUGRA**
- **output flags:**
  - **non-perturbative parameter**
  - **no electroweak symmetry breaking**
  - **color symmetry breaking**

ODE integration
Results

Average number of derivative evaluations to get accuracy of ϵ (integrating one-loop β functions between M_Z and Λ_{GUT}).

ϵ	Step Doubling	CASH KARP	BULIRSCH STOER (polynomial)	BULIRSCH STOER (rational)	Predictor Corrector
5.10^{-4}	277	79	107	55	18
5.10^{-8}	507	130	136	110	42
5.10^{-12}	3221	742	225	226	100
5.10^{-16}	21227	4706	607	10270	204

— `Isajet` **starts with 800 derivative evaluations (but no error control and only 4th order).**

— **ODE integration is the core element of the computation: precision of other elements cannot be better.**

— **check effects of higher number of loops (without loosing them in numerical fluctuations).**

— **comparison with analytical solution**
In fact, not much to gain, neither in speed, nor in accuracy.

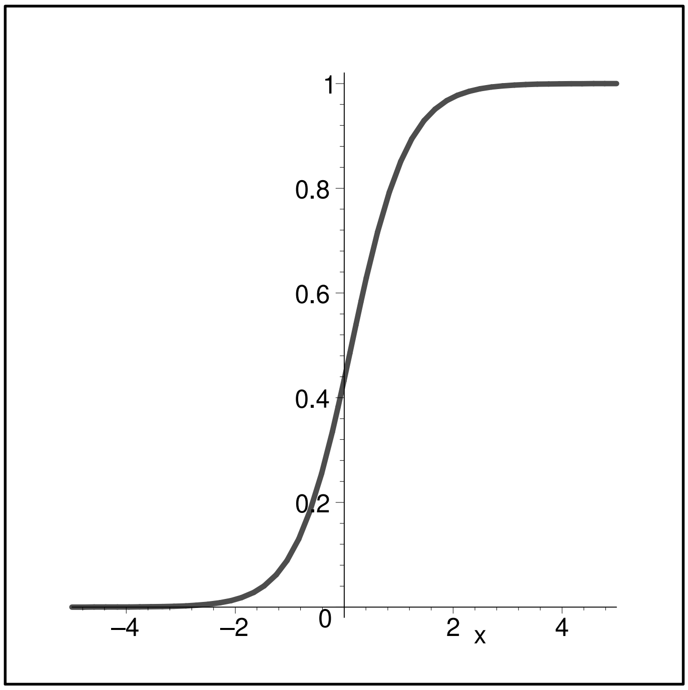
$$y_t = \frac{y_t^0 E_{12}(t)}{1 - b y_t^0 \int_0^t E_{12}(t')dt'} \qquad y_b = \frac{y_b^0 E_{21}(t)}{1 - b y_b^0 \int_0^t E_{21}(t')dt'} \tag{1}$$

$$E_i = e^{\int_0^t f_i(t')dt'} \tag{2}$$

$$E_{12}(t) = \frac{E_1(t)}{\left(1 - b y_b^0 \int_0^t \frac{E_2(t_1)dt_1}{\left(1 - b y_t^0 \int_0^{t_1} \frac{E_1(t_2)dt_2}{\left(1 - b y_b^0 \int_0^{t_2} \frac{E_2(t_3)dt_3}{\left(1 - b y_t^0 \int_0^{t_3} \ldots\right)^{a/b}}\right)^{a/b}}\right)^{a/b}}\right)^{a/b}} \tag{3}$$

Thresholds

- **Minimal substraction schemes ($\overline{\text{MS}}$ and $\overline{\text{DR}}$)**
$\Longrightarrow$ easier for computation:
β function have no explicit scale dependence ($\neq$ On-Shell (OS) scheme)



OS scheme

reproduce two effective theories with different β functions after and before the threshold
$\Longrightarrow$ HEAVISIDE step function θ (0-width threshold).
(1-loop threshold $\sim$ 2-loop effect; 1-loop threshold width $\sim$ 3-loop effect)

- **top quark threshold.**

- **one common SUSY threshold.**

  – **usual approximation** **(as the width blurr them all in one)**

  – $\Lambda_{SUSY} \sim 1$ **TeV?**

  – $\Lambda_{SUSY} \sim \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$**?**

  – $\Lambda_{SUSY} = |\mu| \left(\frac{M_2}{M_3}\right)^{\frac{28}{19}} \left(\frac{M_A}{\mu}\right)^{\frac{3}{19}} \left(\frac{M_2}{\mu}\right)^{\frac{4}{19}} \prod_i m_{\tilde{u}_{i2}}^{\frac{-15}{114}} m_{\tilde{d}_{i2}}^{\frac{1}{2}} m_{\tilde{u}_{i1}}^{\frac{-15}{57}} m_{\tilde{d}_{i1}}^{\frac{-9}{57}} m_{\tilde{\ell}_{i2}}^{\frac{7}{38}} m_{\tilde{\ell}_{i1}}^{\frac{-2}{19}} m_{\tilde{\nu}_i}^{\frac{-1}{38}}$
  $\sim |\mu|/5 < M_Z$

2 boundary conditions
High energy scale

- **Unification**

$$
\begin{aligned}
g_1(\Lambda_{GUT}) &= g_\infty \\
g_2(\Lambda_{GUT}) &= g_\infty
\end{aligned}
$$

- **common gaugino mass**

$$M_{1/2} = M_1 = M_2 = M_3$$

- **common scalar mass**

$$
\begin{aligned}
m_0^2 &= \tilde{m}_e^2 = \tilde{m}_\ell^2 \\
&= \tilde{m}_q^2 = \tilde{m}_u^2 = \tilde{m}_d^2 \\
&= \tilde{m}_{H_u}^2 = \tilde{m}_{H_d}^2
\end{aligned}
$$

- **common trilinear coupling**

$$A_0 = A_t = A_b = A_\tau$$

2 boundary conditions
Low energy conditions

- **Unification**

$$\widehat{\alpha} = \frac{\alpha_{em}}{1-\Delta\widehat{\alpha}} \quad ; \quad \sin^2\widehat{\theta}\cos^2\widehat{\theta} = \frac{\pi\alpha_{em}}{\sqrt{2}M_Z^2 G_\mu(1-\Delta\widehat{r})}$$

- **Yukawa's coupling**

$$\begin{aligned} y_t(m_t) &= \frac{\sqrt{2}\widehat{m}_t(m_t)}{v(m_t)\sin\beta(m_t)} \\ \textbf{with} \quad \widehat{m}_t(m_t) &= m_t + \Re e\left(\Sigma_t(m_t, Q=m_t)\right) \\ \textbf{and} \quad v^2(Q) &= 4\frac{\widehat{M}_Z^2(Q)}{g^2(Q)+g^2(Q)} \end{aligned}$$

- **Electroweak symmetry breaking**

$$\begin{aligned} |\mu|^2 + \bar{m}_{H_u}^2 &= b\cot\beta + \frac{\widehat{M}_Z^2}{2}\cos(2\beta) \\ |\mu|^2 + \bar{m}_{H_d}^2 &= b\tan\beta - \frac{\widehat{M}_Z^2}{2}\cos(2\beta) \end{aligned}$$

$$\bar{m}_{H_u}^2 = m_{H_u}^2 - \frac{t_u}{v_u} \qquad \bar{m}_{H_d}^2 = m_{H_d}^2 - \frac{t_d}{v_d}$$

$$\widehat{M}_Z^2(Q) = M_Z^2 + \Re e\left(\Pi_{ZZ}^T(M_Z^2, Q)\right)$$

Program structure

SM parameters
MSSM assumptions

- **parameters set (from file)**

$\Downarrow$

RGE $M_Z \to \Lambda$ **load for initial shoot**

$\Downarrow$

- **entry point for new load**

RGE $\Lambda \to m_t \to M_Z \to m_b$

$\Downarrow$

pole mass correction

tadpoles
(potential minimisation)
self-energy
Higgs effective potential

$\Downarrow$

fits at m_t**,** M_Z**,** m_b**?**

- **No:** **modify load and** $\Uparrow$
- **Yes:** **output results**

Parameters management

input parameters

```
30           'number of parameters'
26           'number of equations'
100          'ODE relative size of initial step'
1d-14        'ODE integration required accuracy'
1d-3         'ODE smallest step allowed as fraction of initial step'
1d-12        'NLE TOLF='
1d-12        'NLE TOLMIN='
1d-08        'NLE TOLX='
100d0        'NLE STPMX='
4            'ODE method : 1=CK, 2=SD, 3=BS, 4=PC, 5=PCS'
.t.          'polynomial extrapolation in BS method'
.t.          'uses MinPack routines ?'
2            'loop(s) for gauge  couplings RGE'
1            'loop(s) for yukawa couplings RGE'
1            'loop(s) for soft breaking RGE'
.t.          'uses thresholds in RGE'
.t.          'computed threshold ?'
.t.          'mSUGRA ?'
.t.          'unification at Lambda'
.t.          'gauge trinification'
.t.          'convert alpha strong from MSbar to DRbar'
.t.          'EW breaking enforcement'
.t.          'one-loop potential minimisation'
.f.          'minimisation at Z scale'
.t.          'Higgs correction by Carena et al.'
2.1117d16    'Scale Lambda'
100d0        'SUSY common threshold'
8d0          'scaling for conditioning'
.f.          'loud report'
.f.          'print flag for score'
0            'print flag for LSODE'
```

Parameters management

standard parameters

91.187d0	'Z^0 pole mass'
1.16639d-5	'Fermi constant'
137.0359895d0	'1/a_em(0)'
128.8d0	'1/a_em(M_Z)'
0.12d0	'a_S'
.51099907d-3	'e pole mass'
105.658389d-3	'\mu pole mass'
1.777d0	'\tau pole mass'
.010d0	'd mass'
.004d0	'u mass'
.200d0	's mass'
1.3d0	'c mass'
4.89d0	'b mass'
175d0	't pole mass'

SUSY breaking assumptions

2d0	'\tan\beta'
1d0	'\mu'
150d0	'm1/2'
300d0	'm0'
-600d0	'A0'

Comparison

DPF Point 1

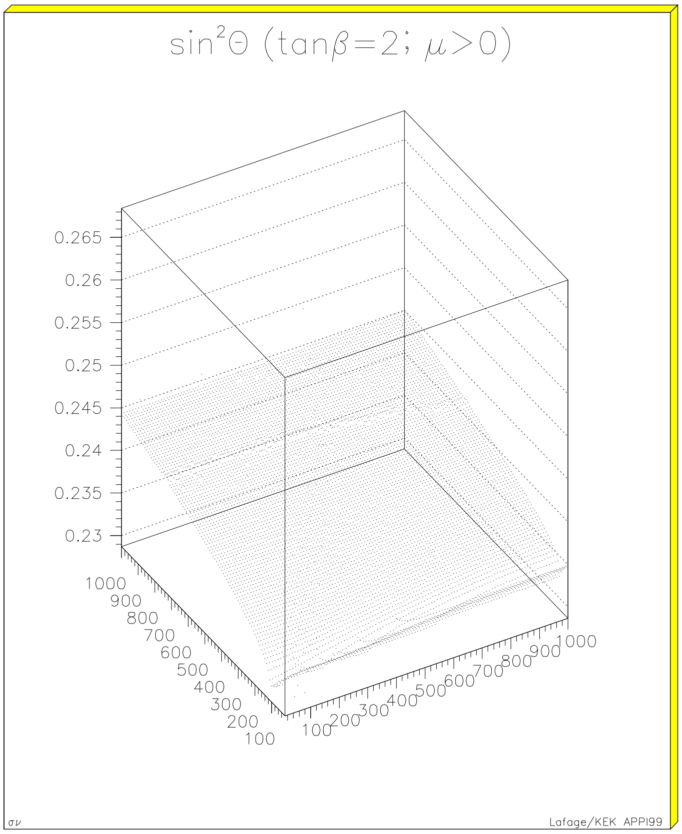
$$\mathbf{m_0 = 400} \quad \mathbf{M_{\frac{1}{2}} = 200} \quad \mathbf{A_0 = 0} \quad \tan\beta = \mathbf{2} \quad \mathrm{sgn}(\mu) = -$$

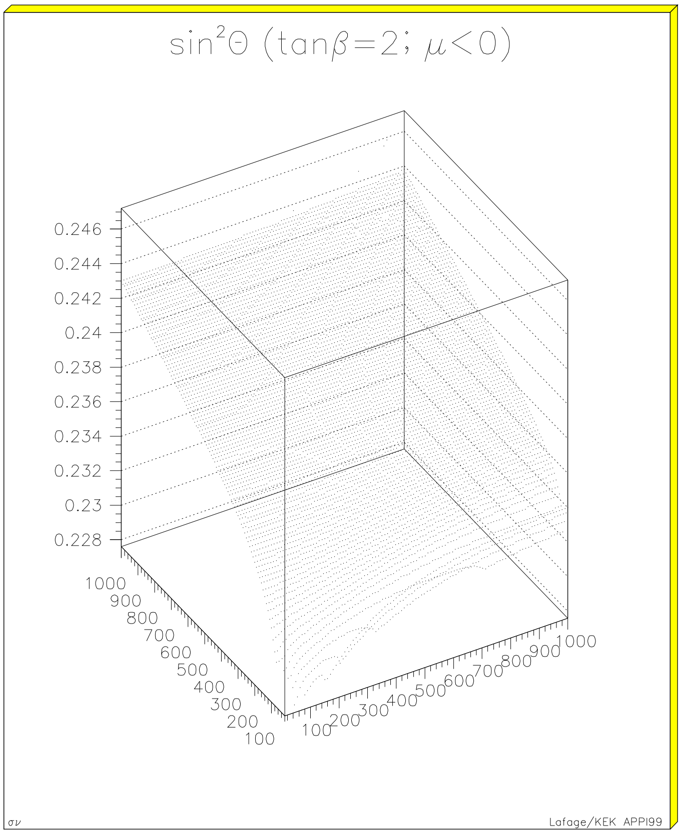
	Muse1	Muse2	Muse2′	Isajet	Suspect	Spythia
α_s	0.1054	0.1141	0.1138	0.1327	0.1049	0.1313
Λ_{GUT}	0.6650	1.0342	1.0052	2.1752	2.7465	
α_{GUT}	0.03856	0.03999	0.03994	0.04059	0.0417	0.0410
$\sin^2\theta_W$	0.2380	0.2379	0.2381	0.2305	0.2315	0.2320
A_{top}	−282.8	−312.4	−324.8	−342.7	−368.2	−340.0
μ	−494.3	−486.7	−491.1	−517.3	−504.9	−518.9
$\tilde{l}_1$	408.9	408.8	409.0	408.8	408.8	408.8
$\tilde{l}_2$	426.9	426.1	427.8	425.9	426.4	426.8
$\tilde{\nu}$	422.4	421.6	423.3	421.4	421.9	422.2
$\tilde{\tau}_1$	408.7	408.6	408.8	408.4	408.4	408.8
$\tilde{\tau}_2$	426.8	426.1	427.8	426.1	426.4	426.8
$\tilde{\nu}_\tau$	422.3	421.5	423.2	421.3	†	422.2
$\tilde{\chi}_1^0$	89.5	84.0	87.4	86.0	85.6	84.4
$\tilde{\chi}_2^0$	174.4	161.7	173.4	175.7	172.5	169.9
$\tilde{\chi}_3^0$	506.8	499.1	503.2	519.6	507.1	521.2
$\tilde{\chi}_4^0$	515.7	508.3	512.2	528.4	516.3	530.0
$\tilde{\chi}_1^\pm$	174.4	161.6	173.4	175.6	172.3	169.9
$\tilde{\chi}_2^\pm$	514.8	507.4	511.3	527.4	515.3	529.1
h_0	76.8	77.7	78.1	79.7	77.3	78.0
H_0	733.8	725.1	729.3	751.1	744.3	748.7
A_0	729.6	720.8	725.0	746.4	740.0	743.7
$H^\pm$	733.8	725.1	729.2	750.8	744.1	751.4
$\tilde{u}_1$	552.4	563.5	570.0	597.8	608.9	585.7
$\tilde{u}_2$	564.9	575.4	582.5	610.2	621.4	597.4
$\tilde{d}_1$	551.7	562.8	569.3	597.1	608.1	585.0
$\tilde{d}_2$	568.2	578.6	585.6	613.4	624.4	600.4
$\tilde{t}_1$	372.0	396.5	403.4	410.8	429.2	408.5
$\tilde{t}_2$	509.4	525.9	533.5	540.3	557.4	530.1
$\tilde{b}_1$	467.3	482.4	489.8	517.9	532.8	506.3
$\tilde{b}_2$	551.6	562.7	569.2	596.9	607.9	584.8
$\tilde{g}$	489.4	497.9	516.8	553.8	524.3	547.7

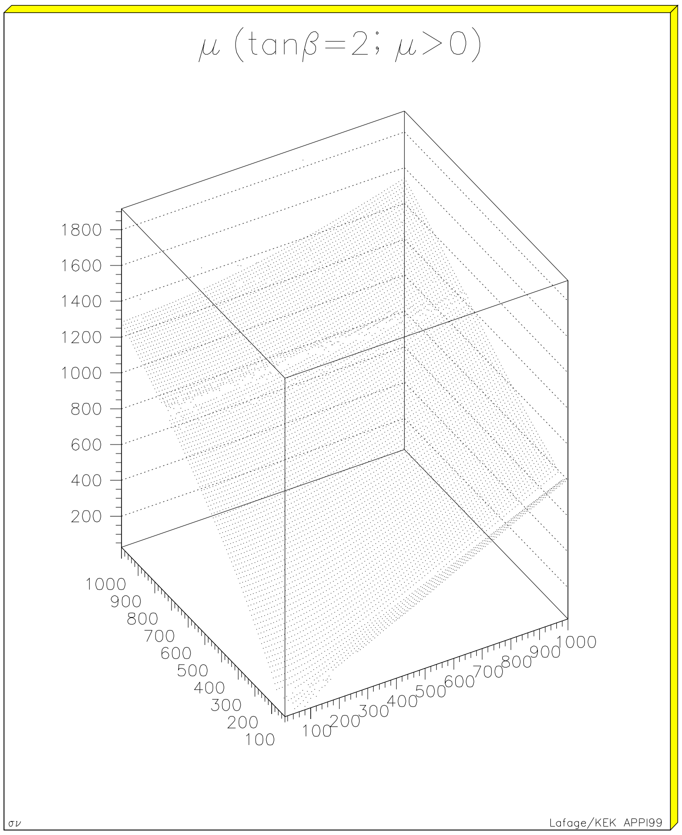
First comparisons

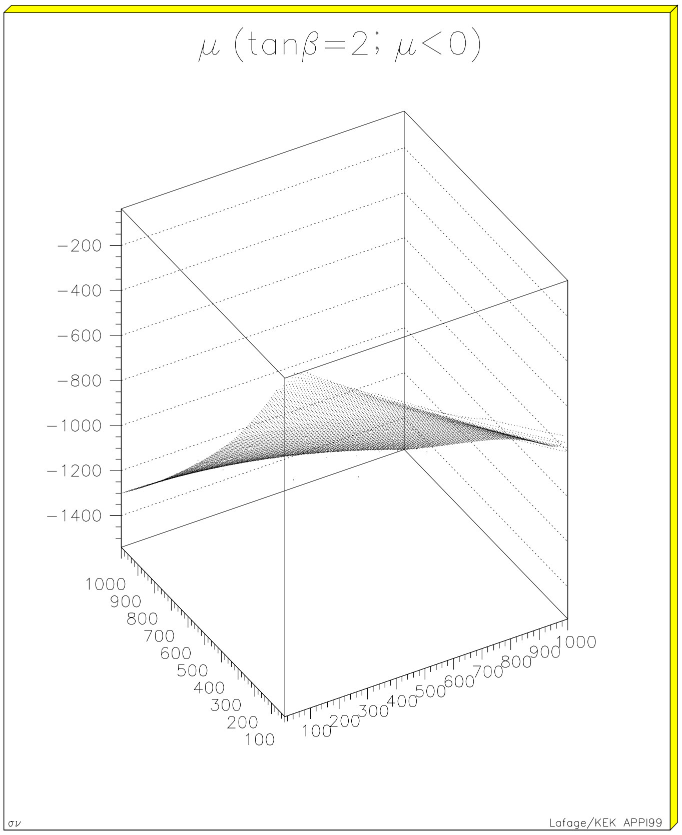
- Very good agreement on sleptons
  (not so much scale dependence)
- agreement on light charginos / neutralinos
- disagreement on heavy charginos / neutralinos
  $\Longrightarrow \mu$ and potential minimisation
- disagreement on squarks
- disagreement on higgs
- disagreement on gluino
- role of running
- 5% on α_s gives 2.5% on scalars running mass.

Scanning

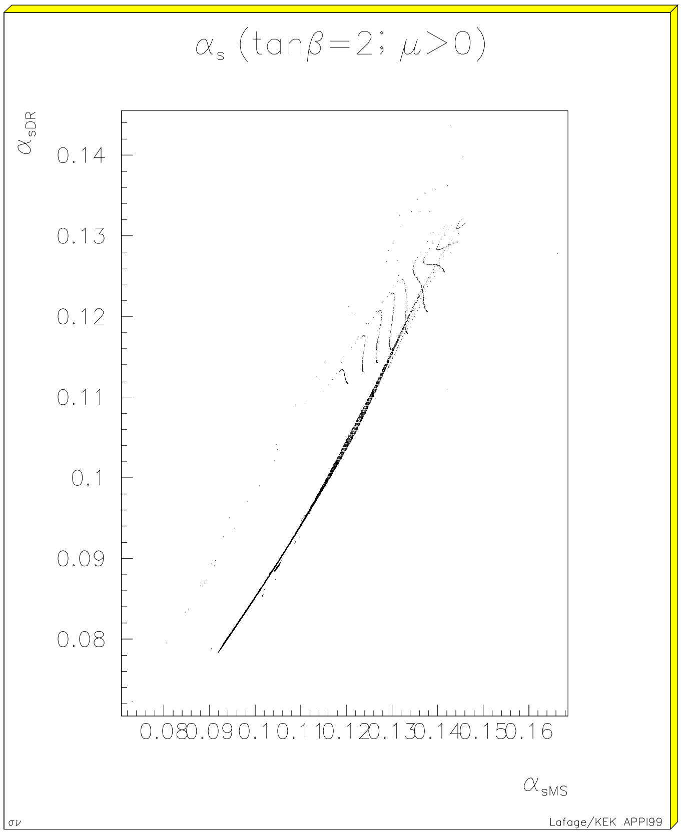

sin²Θ (tanβ=2; μ>0)
0.265
0.26
0.255
0.25
0.245
0.24
0.235
0.23
1000 900 800 700 600 500 400 300 200 100
100 200 300 400 500 600 700 800 900 1000
σν
Lafage/KEK APPI99

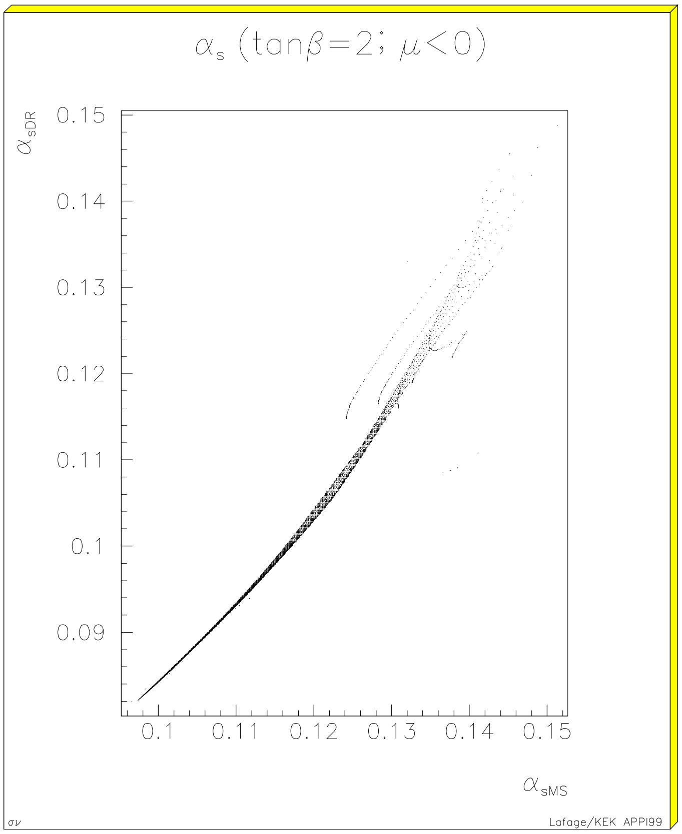

sin²Θ (tanβ=2; μ<0)
0.246
0.244
0.242
0.24
0.238
0.236
0.234
0.232
0.23
0.228
1000 900 800 700 600 500 400 300 200 100
100 200 300 400 500 600 700 800 900 1000
σν
Lafage/KEK APPI99


μ (tanβ=2; μ>0)
1800
1600
1400
1200
1000
800
600
400
200
1000 900 800 700 600 500 400 300 200 100
100 200 300 400 500 600 700 800 900 1000
σν
Lafage/KEK APPI99

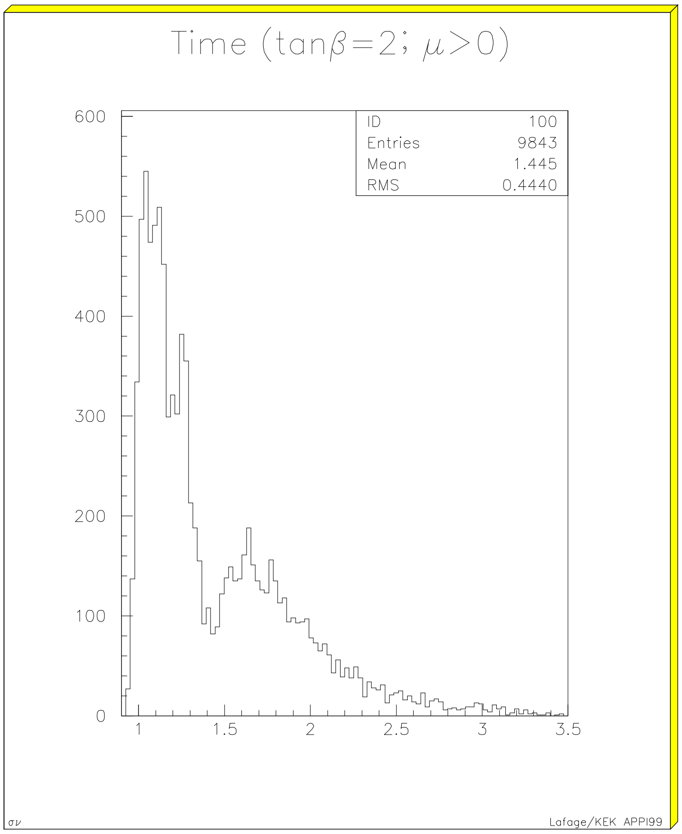

μ (tanβ=2; μ<0)
−200
−400
−600
−800
−1000
−1200
−1400
1000 900 800 700 600 500 400 300 200 100
100 200 300 400 500 600 700 800 900 1000
σν
Lafage/KEK APPI99

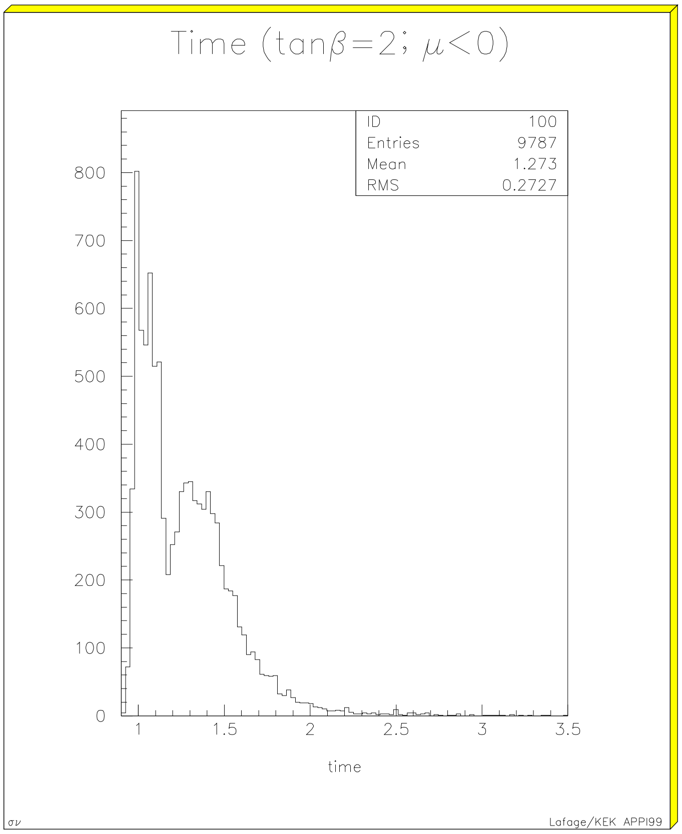
α_S

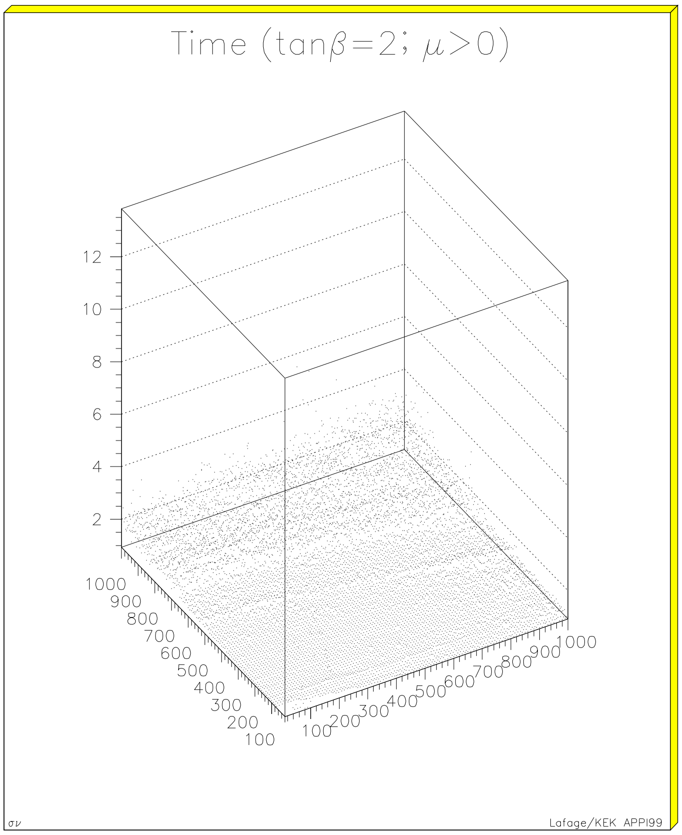

α_s (tanβ=2; μ>0)
α_{sDR}
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.080.090.10.110.120.130.140.150.16
α_{sMS}
Lafage/KEK APPI99

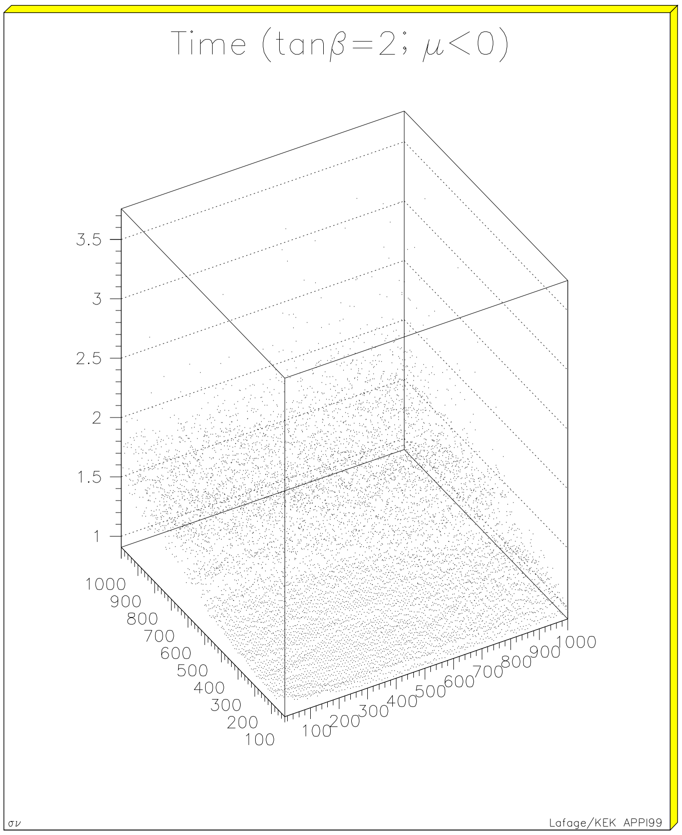

α_s (tanβ=2; μ<0)
α_{sDR}
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.1 0.11 0.12 0.13 0.14 0.15
α_{sMS}
Lafage/KEK APPI99

Efficiency


Time (tanβ=2; μ>0)
ID 100
Entries 9843
Mean 1.445
RMS 0.4440
Lafage/KEK APPI99


Time (tanβ=2; μ<0)
ID 100
Entries 9787
Mean 1.273
RMS 0.2727
time
Lafage/KEK APPI99


Time (tanβ=2; μ>0)
Lafage/KEK APPI99


Time (tanβ=2; μ<0)
Lafage/KEK APPI99

MUSE: Projects

- **comparison with other integrators (`Isajet`, `Spythia`, `SuSpect`) is well advanced.**
- **comparison of self-energies is under way.**
- **more refined thresholds**
- **others self-energies (-inos...)**
- **alternative expression of symmetry breaking**