Update on Kinematic Fits

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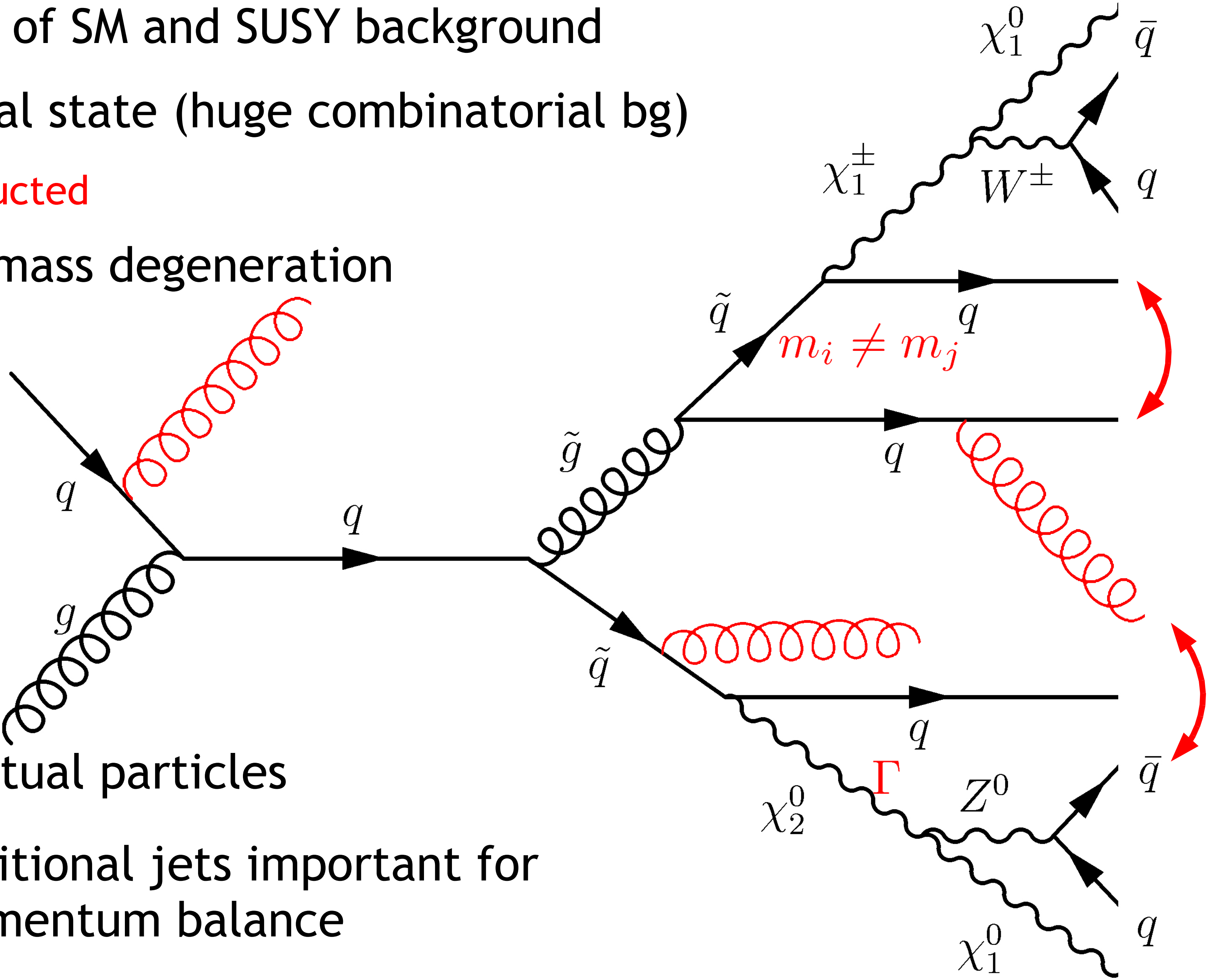
Potential Problems

- Suppression of SM and SUSY background
- 7 jets in final state (huge combinatorial bg)
  - all reconstructed
- No perfect mass degeneration



- Width of virtual particles
- +FSR
- +ISR

additional jets important for momentum balance

Commonly Used Approach

- Constrained fitting via Lagrangian Multiplier

$$\sum_{i=1}^{N_m}\left(\frac{m_i - t_i}{\sigma_i}\right)^2 + 2\cdot\sum_{i=1}^{N_c}\lambda_i\cdot f_i$$

- Find extremum where all derivatives vanish
- If constraints are linear find perfect solution within one Gauss-Newton step
- Invariant mass constraints are (highly) non-linear → linearization and iterative approach
- **General problem:** Fit can converge at local (and not global) minimum

Alternative Approach

- Formulation of constraints as additional χ^2 term → “cost function”
- To interpret cost function as χ^2 all correlations have to be taken into account

$$\left(\frac{M_{\mathrm{inv}}(j_1, j_2, j_3) - M}{\sigma}\right)^2$$

  with

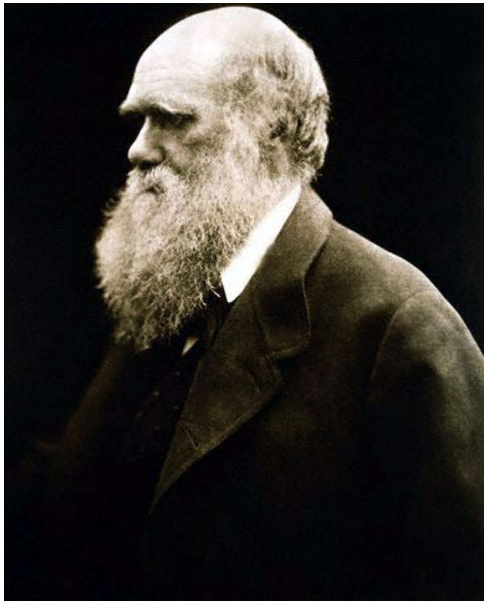
$$\sigma^2 = \sum_{i=1}^{N_m} \left(\frac{\partial M_{\mathrm{inv}}}{\partial i}\right)^2 \cdot \sigma_i^2 + \Gamma_m^2$$

- Minimize cost function: many possible algorithms (gradient, simplex, LBFGS, simulated annealing ... genetic algorithm)

Genetic Algorithm

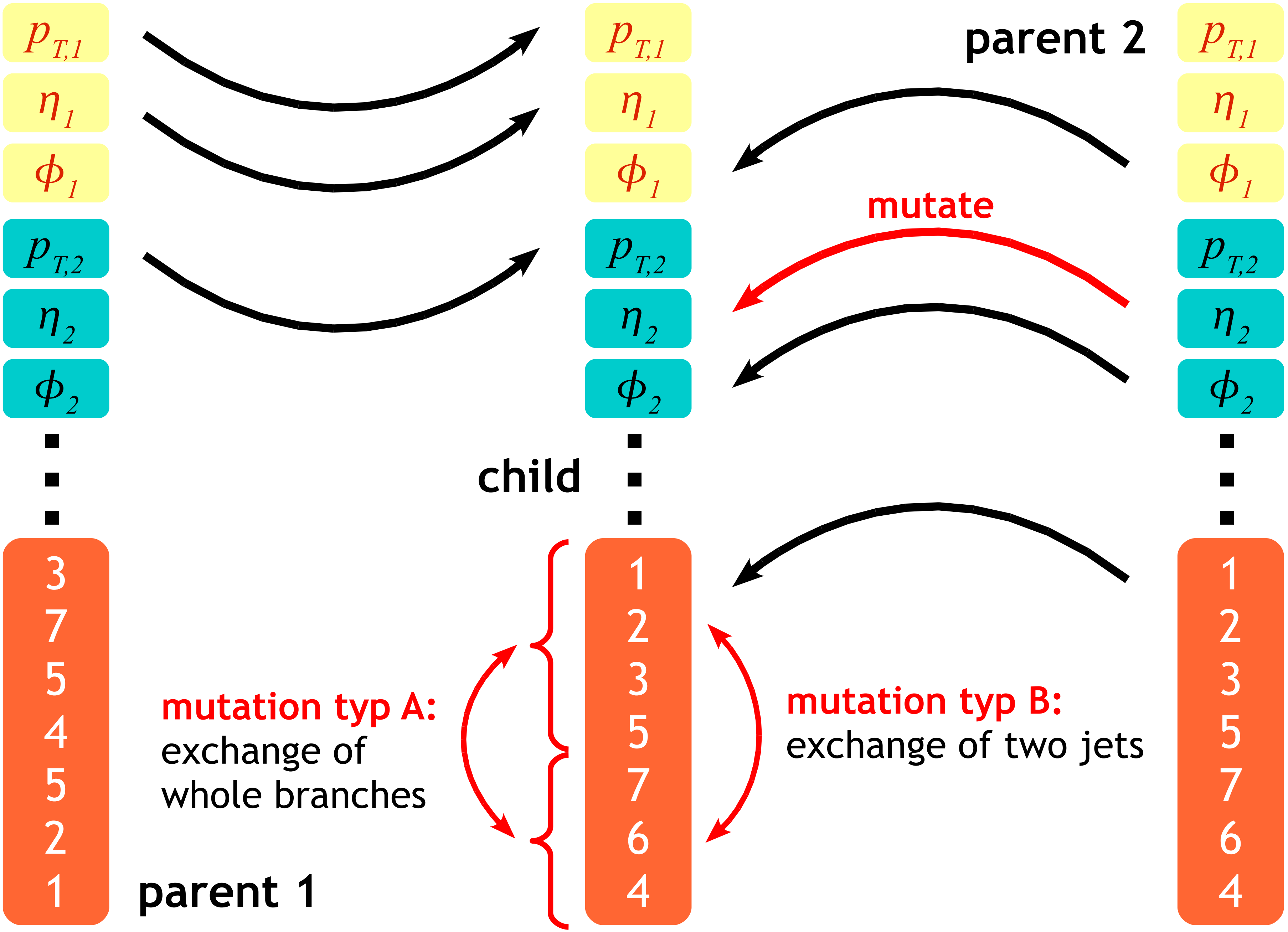
- Final state 4-momenta are properties (*genes*) of *individuum*; jet combination is one additional *gene*
- A fitness function (here χ^2) defines if a *individuum* is *fittest*

1) Starting from starting values create a first *generation* of *individua* (starting *population*): use all possible jet combinations (1260 for 7 jets)
2) Select N best fitting *individua* (here 20)
3) Create M (here 1000) new *individua* by selecting randomly two *parents* and take randomly the *genes* from either one or the other *parent*
4) *Mutate* (variation within the measurement errors) each *gene* (except jet combination) with a given probability (here 10 %)
5) Back to step 2) until convergence is reached (here: no change within 3 *generations*) or fixed iteration number is reached (here 200)



Charles Darwin
(**1809** – 1882)
On the origin of species (**1859)**

Genetic Algorithm (cont.)



mutation typ A:
exchange of
whole branches

mutation typ B:
exchange of two jets

Starting Values for Neutralinos

- In typical Susy scenarios: $m_{\chi_1^\pm} - m_{\chi_1^0} \gtrsim m_W$

→ small relative momentum of W and χ^0

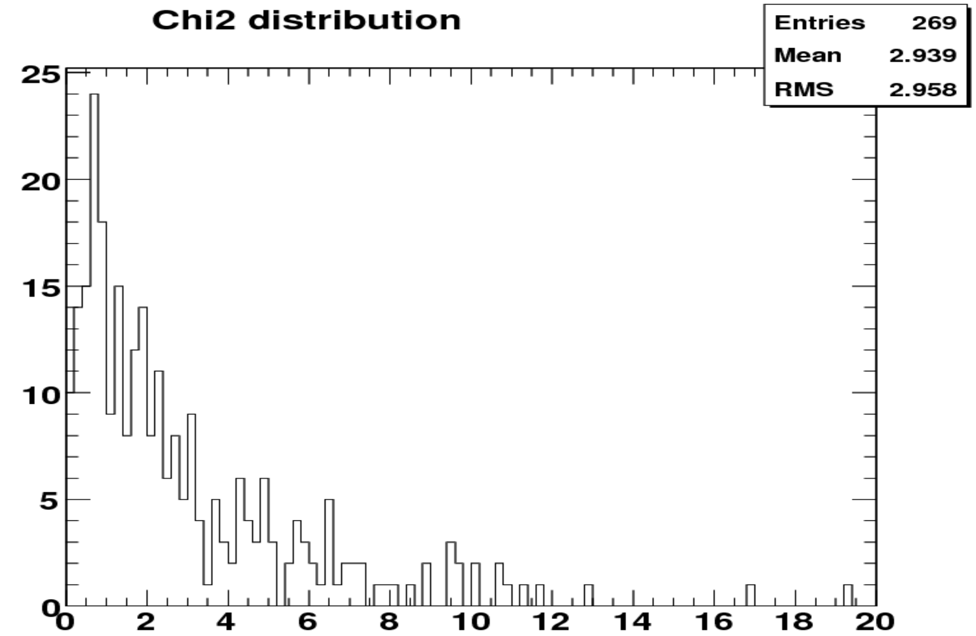
- Assume same direction of W and χ^0 and adjust χ^0 momentum to fulfill mass constraint

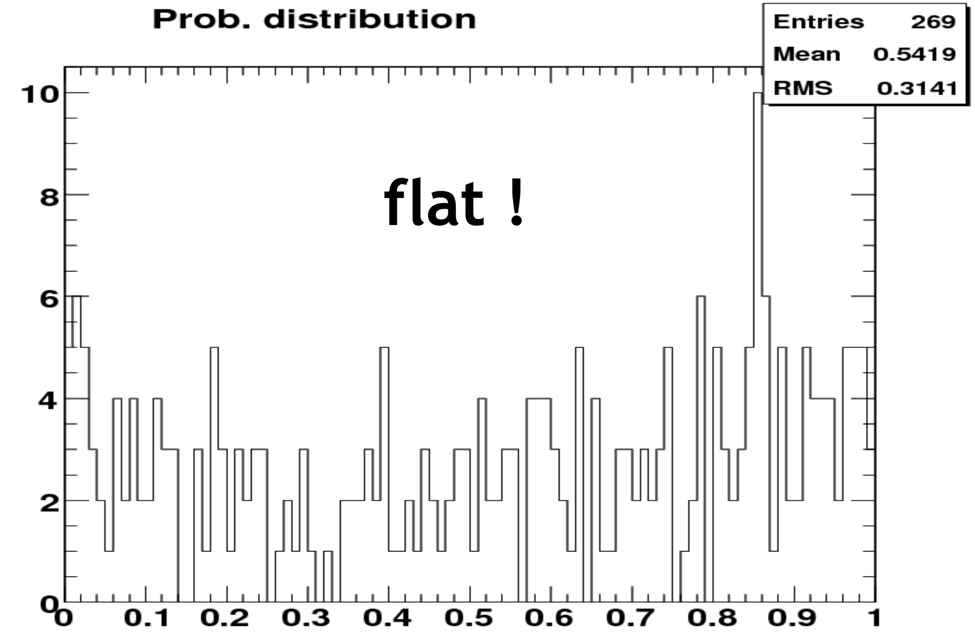
$$0 \overset{!}{=} f(x) = m^2_{\chi_1^\pm} - \left(\left(E_W + \sqrt{m^2_{\chi^0} + (x \cdot p_W)^2} \right)^2 - (1+x)^2 \, p_W^2 \right)$$

- Solve analytically or numerically by Newtons method

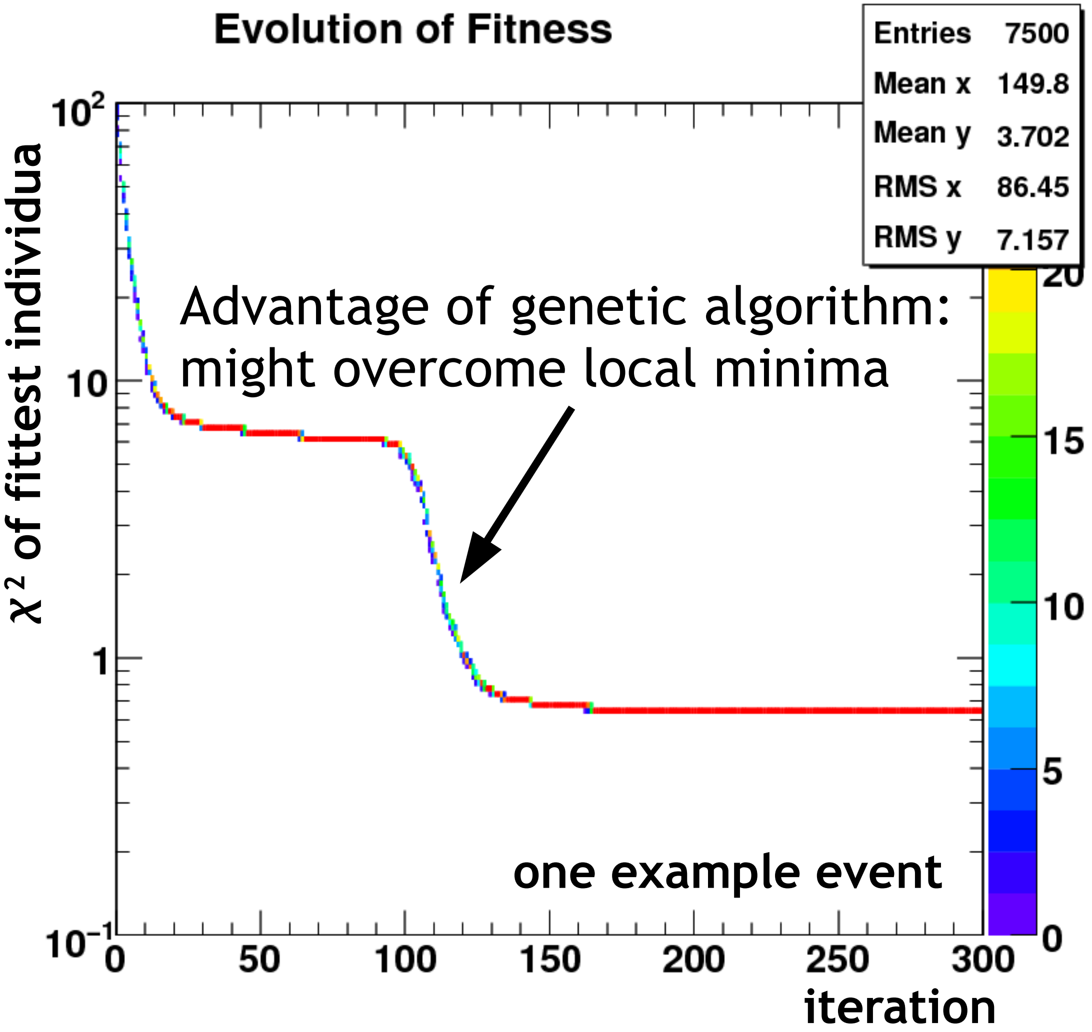
$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

Fundamental Behaviour





flat !



Advantage of genetic algorithm: might overcome local minima

one example event

Input:

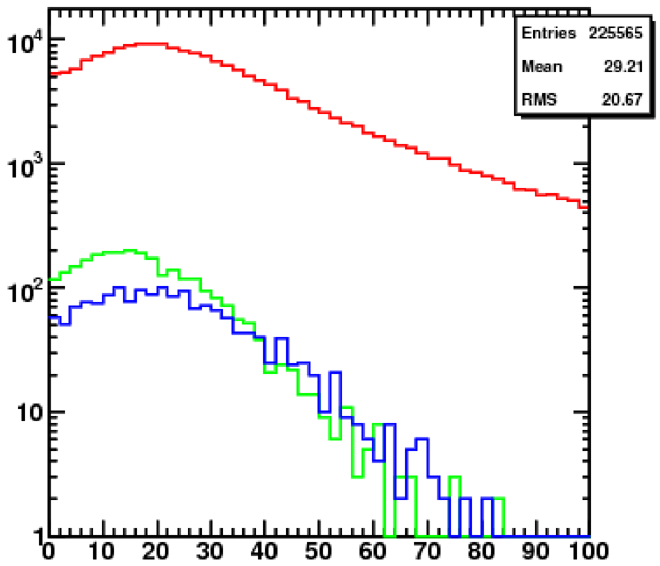
no combinatorial bg

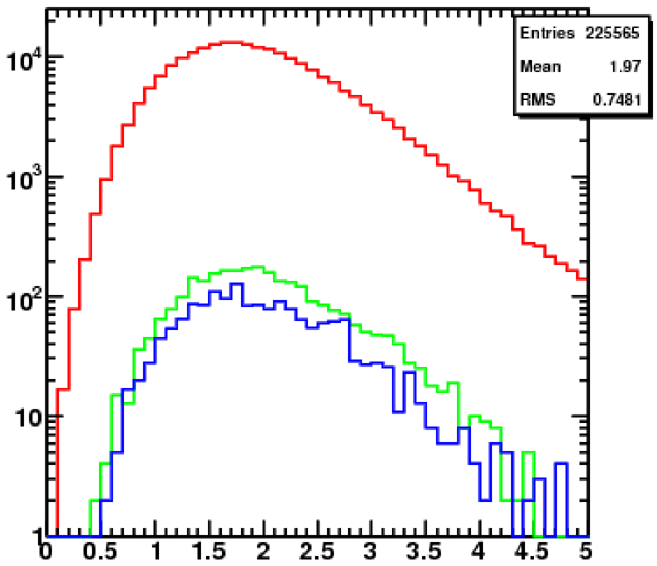
no SUSY bg

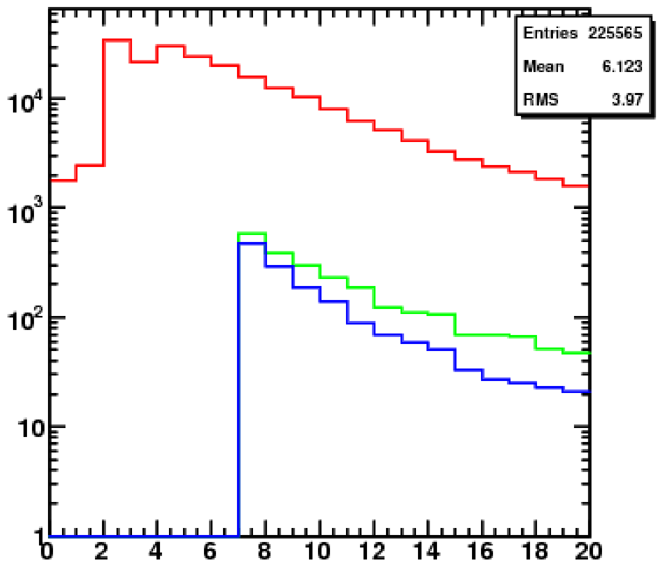
ISR for momentum balance from MC

Preselection

- Demand exactly 7 jets with:
  - $p_T > 20\ \mathrm{GeV}$
  - $|\eta| < 3.0$
- This will reject many signal events with hard ISR or FSR, but combinatorics is reduced


pT of softest jet (wrong)


largest abs(eta) of jet (wrong)


position of softest jet (wrong)

Dependence on Starting Values

Before genetic algorithm:

```
Chi2 (staring values, no combinatorics) = 18.6535

probability = 1.56763e-05

Chi2 (KinFitter, no combinatorics) = 4.09197

probability = 0.251702
```

After genetic algorithm:

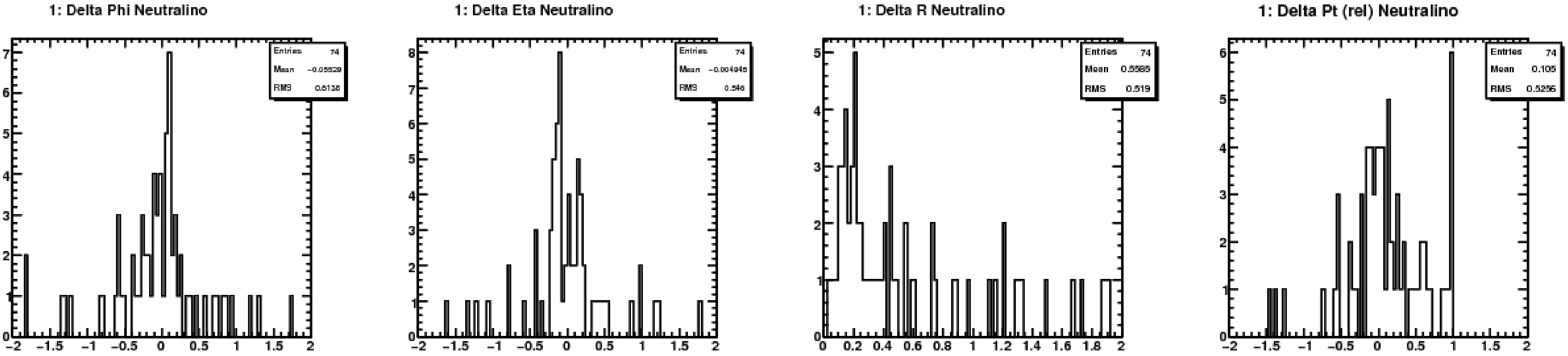
```
Chi2 (fitted values) = 8.03493

probability = 0.00458838

Chi2 (KinFitter, starting values and combinatorics from gen. fit) = 1.15671

probability = 0.763404
```

KinFitter result (and convergence) depends strongly on starting values

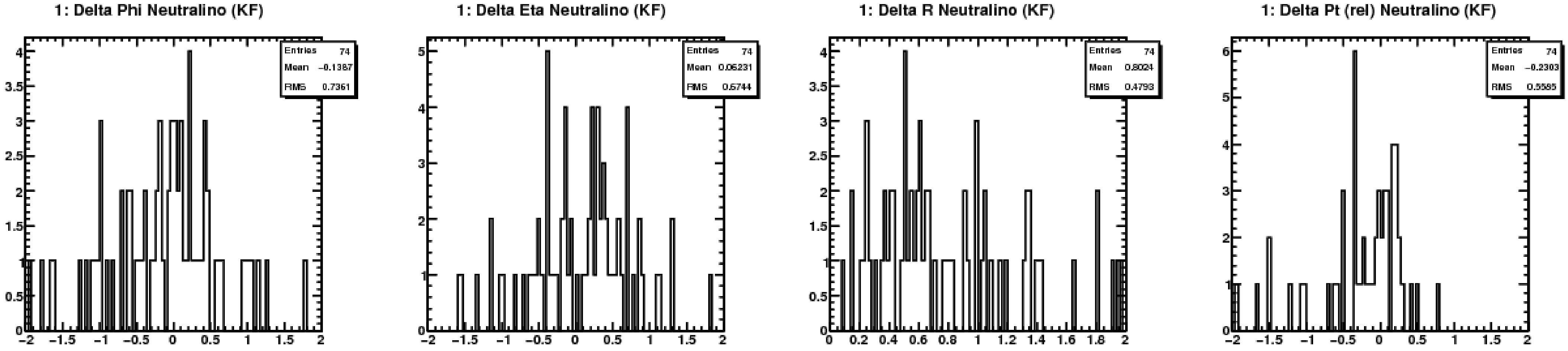
χ^2 of genetic Fit and KinFitter not directly comparable (different treatment of mass constraints)

Resolution of Unmeasured Particles

- Genetic algorithm: RMS (ΔR) = 0.56



- KinFitter (with starting values from genetic fit): RMS (ΔR) = 0.50



Fit Results Including Bgs

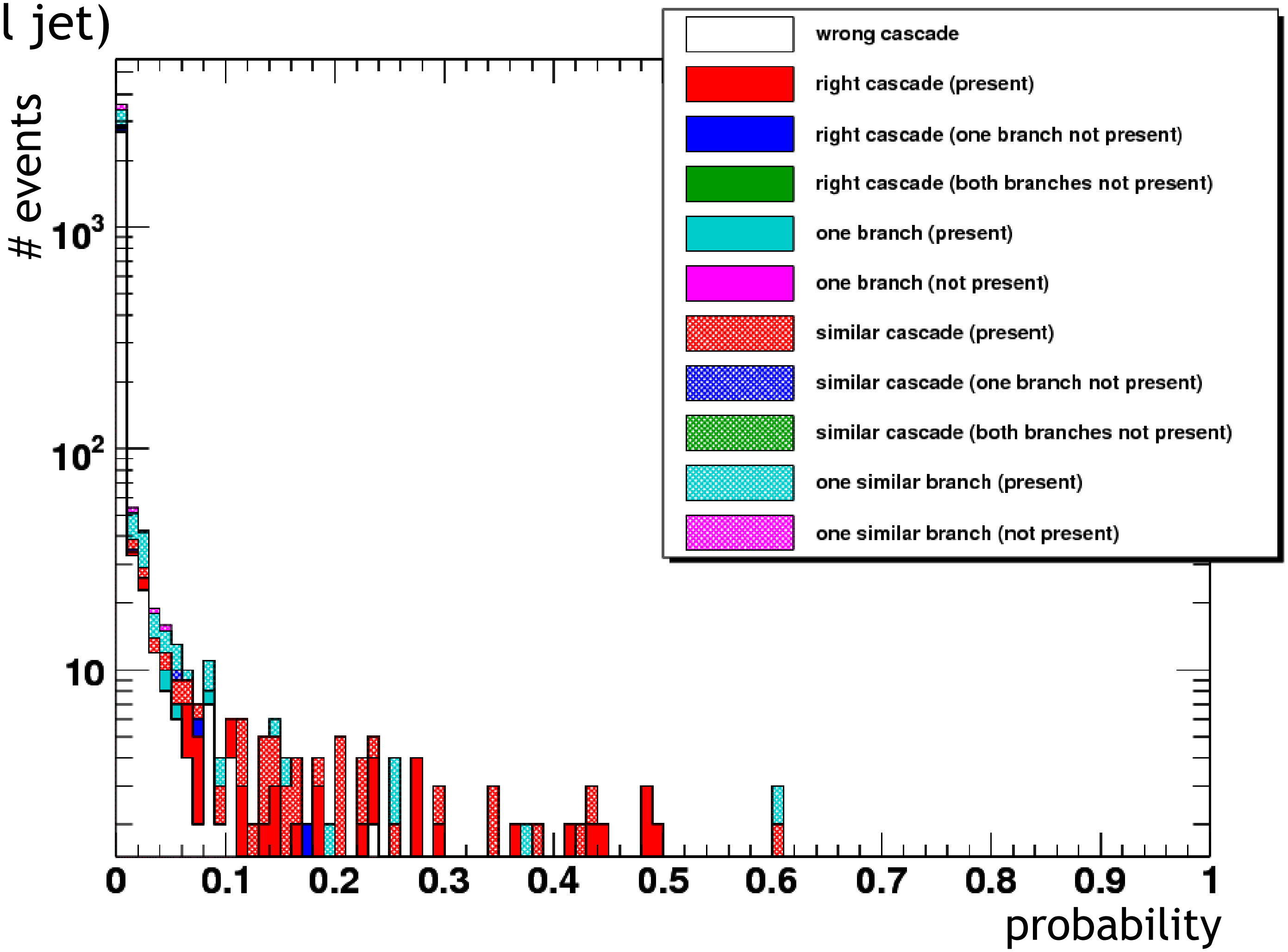
- Included backgrounds:
  - SUSY
  - signal cascades but not all signal jets selected (at least one ISR or FSR jet is harder than one signal jet)

Signal cascade:
only left handed squarks of first two generations

Similar cascades:
other squarks

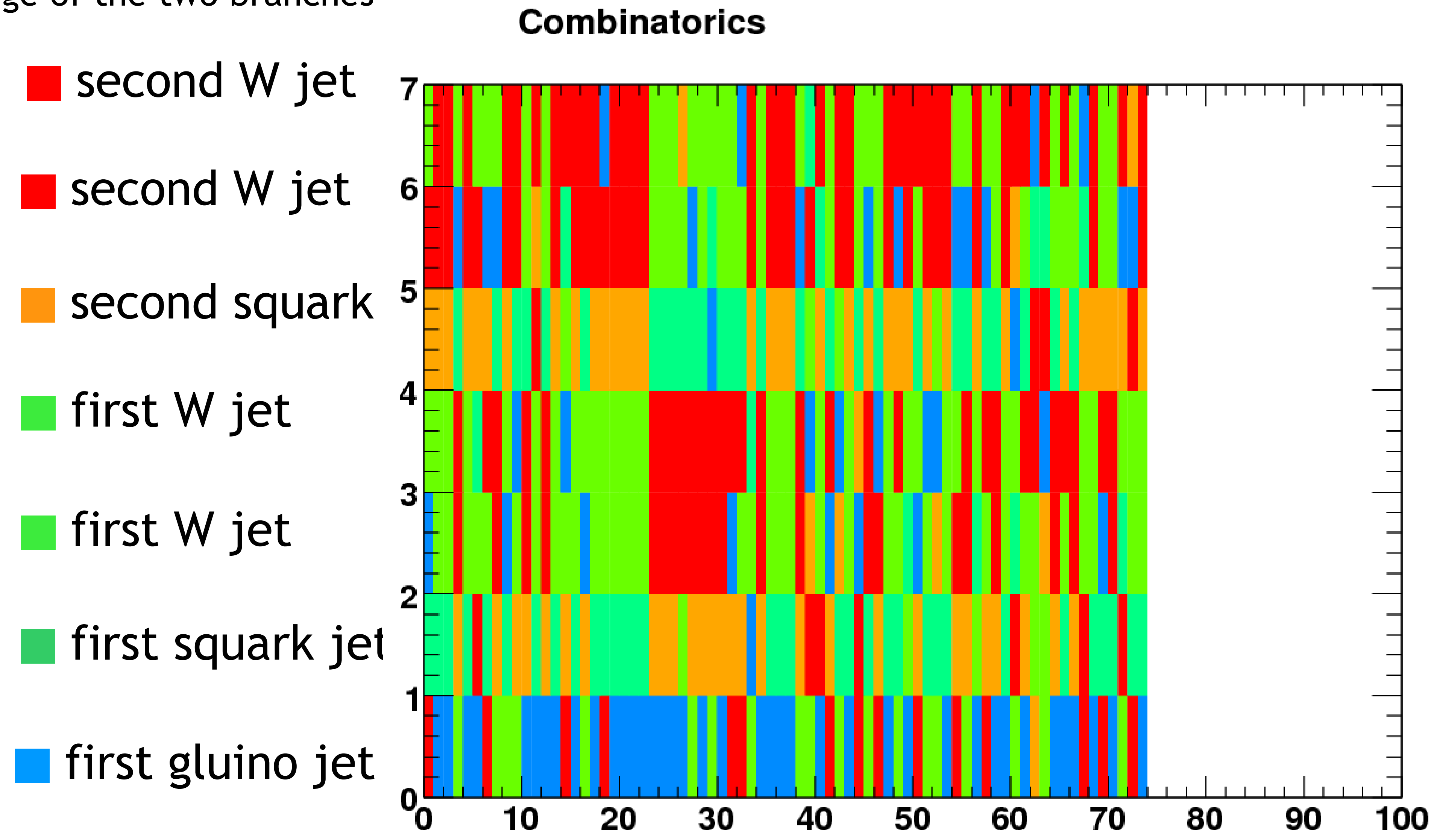
→ Prob. distribution not flat due to missing ISR

→ SUSY bg peaks at small probabilities



Visualization of Best Combinations

~ 20% complete right cascade
most wrong combinations are
exchange of the two branches



Plans and Ideas

- Scan over mass hypothesis or mSUGRA parameters
  - Use NAF ⟶
  - First try with: $M_1 : M_2 : M_3 = 1 : 2 : 6$

- Use leptonic Z-decays (smaller combinatorics, bg, and statistics)
- Include ISR jets in event selection (treat higher statistics vs. larger combinatorial bg) (maybe not for SUSY09)
- Include systematic uncertainties (likely not for SUSY09)
- Think about “dynamic hypothesis selection“ (surely not for SUSY09)