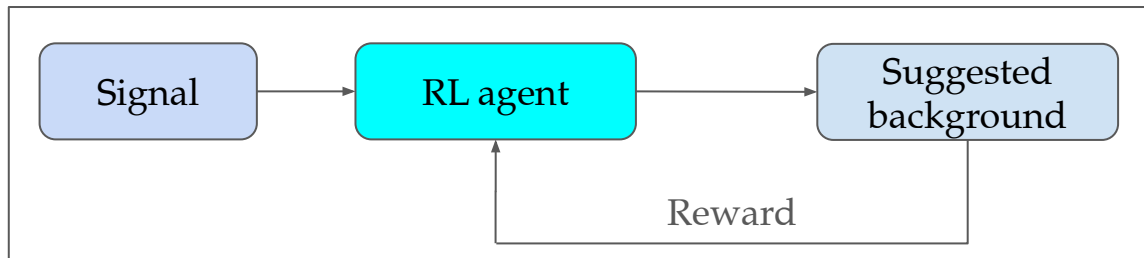# Reinforcement Learning for background determination in particle physics

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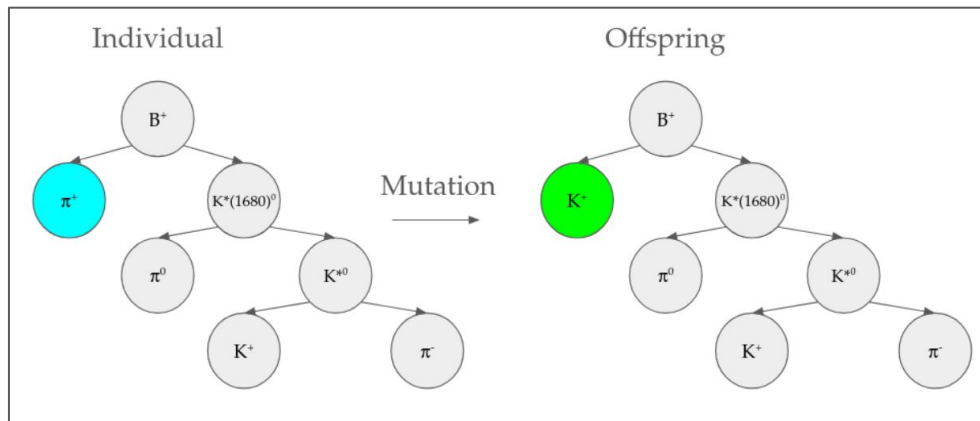
Approach

- Approach combines **Genetic Algorithms (GAs)**, **Reinforcement Learning (RL)** and **transformers**
  - GAs perform an efficient exploration
  - RL further explores, learns and generalizes
  - Transformer architecture for agent to deal with token sequences representing decays. Example:

- Signal: $B^0 \to K^+ \pi^0 \pi^-$

  K$^-$ and π^- are misidentified

- Background: $B^+ \to K^{*+}(K^+ \pi^0)(\pi^+)K^-$

  π^+ is not detected

| $B^0 \to$ | 1 | K^+ | 2 | π^- | 3 | π^0 | Sep. | $B^+ \to$ | $K^{*+}($ | 1 | K^+ | 3 | π^0 |) | Lost | π^+ | 2 | K^- | End | Void | ... |

Individual → Mutation → Offspring

Experiment

- Trained the agent with **16 training signals** (101 backgrounds)
- Checked its **generalization** ability with **4 new signals** (31 backgrounds). Chosen to be similar to the training signals.
- **Performance**:
  - GA performance (using a population of 4.000 individuals and 40 generations):
    - Found 89/101 training backgrounds
  - RL agent performance (measured building 100.000 sequences per signal):
    - 101/101 training backgrounds learnt by agent
    - 31/31 generalization backgrounds found by agent
- Example:
  - Signal used to check generalization ability (CP conjugate of one of the training signals):
    - $B^+ \rightarrow \pi^+ \pi^+ \pi^-$ anti-$D^0(K^+ \pi^-)$
  - Relevant backgrounds (according to toy model reward):
    - $B^+ \rightarrow \pi^+ \pi^+ D^-(K^+ \pi^- \pi^-)$
    - $B^+ \rightarrow \pi^+ \pi^+ \pi^-$ anti-$D^0(K^+ \pi^- \pi^0)$
    - $B^+ \rightarrow \pi^+$ anti-$D^0(\pi^+ \pi^- K^{*0}(K^+ \pi^-))$
    - $B^+ \rightarrow \pi^+$ anti-$D^0(\pi^+ \pi^- K^+ \pi^-)$
    - $B^+ \rightarrow \pi^+ \pi^+ \pi D^{*-}(\pi^-$ anti-$D^0(K^+ \pi^-))$
    - $B^+ \rightarrow \pi^+ \pi^+ D^{*-}(\pi^-$ anti-$D^0(K^+ \pi^-))$
    - $B^0 \rightarrow \pi^+ \pi^+ \pi^- D^-(K^+ \pi^- \pi^-)$
    - $B^0 \rightarrow \pi^+ \pi^+ \pi D^-(K^+ \pi^- \pi^-)$
    - $B^+ \rightarrow \pi^+ \pi^+ D^{*-}(\pi^-$ anti-$D^0(K^+ \pi^- \pi^0))$