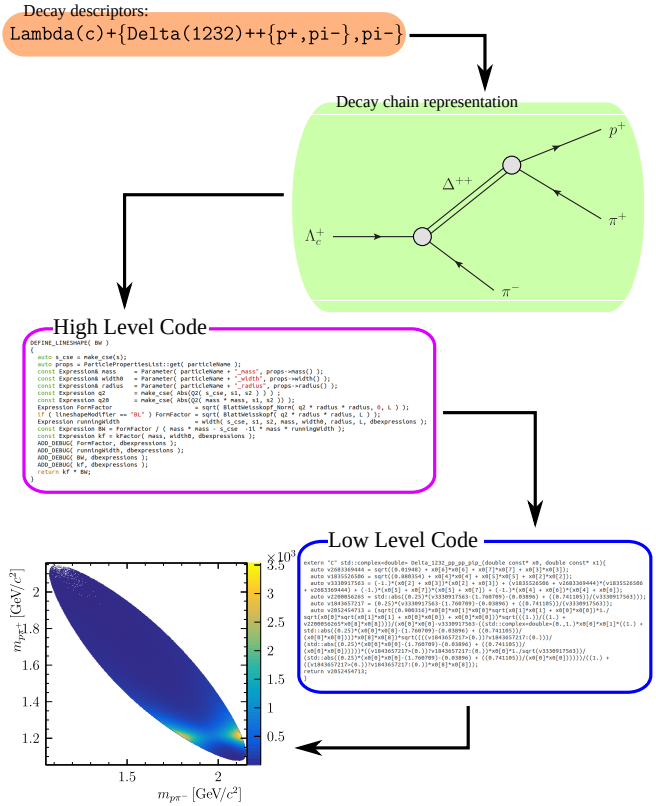
AMPGEN

- AmpGen is a library for fitting and generating multibody particle decays.
- Takes a decay chain representation and converts into fast, low-level code.
- Fairly agnostic about the types of particles in the initial / final state (pseudoscalars, **NEW** fermions, photons ...)
- No hard limit on number of particles in the final state, practically, more than about six bodies is a difficult.
- "Classic" three-body (pseudoscalar) decays are a two-body problem (A Dalitz plot). Four-body decays are a five-dimensional problem $\implies$ only unbinned fits are practical.
- Speed is critical as already have $\mathcal{O}(10^6)$ candidates in many channels, and expecting $10 \to 50\times$ these yields by 2030.
- For a typical four-body amplitude, can perform $\sim 10^6$evaluations/s/core on consumer laptop.
- Part of the GooFit organisation on GitHub.



More on the user interface

- User specifies couplings between different particles, either partially or as full decay chains, for example:

```
D0{K*(892)bar0,rho(770)0}
```

  Couples a D^0 meson to a pair of vectors, then if you add the couplings:

```
K*(892)bar0{K-,pi+}
K*(892)bar0{K0S0,pi0}
K*(892)bar0{K0L0,pi0}
rho(770){pi+,pi-}
```

  You can generate the amplitude coupling the D^0 meson to the various final states.

- You can add additional orbital couplings as

```
D0[P]{K*(892)bar0,rho(770)0}
D0[D]{K*(892)bar0,rho(770)0}
```

- Which will be coherently summed to give the total amplitude, mod-squared to give the differential rate:

$$\mathcal{P}(\psi)\mathrm{d}\psi \propto \left|\sum_i g_i \mathcal{A}_i(\psi)\right|^2 \mathrm{d}\psi \tag{1}$$

Developments this year

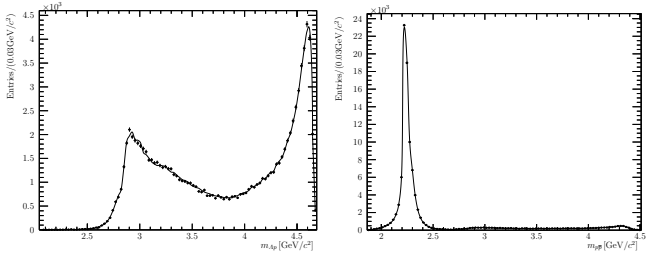
- Big development is the inclusion of spin-half particles in the initial/final state.
- Have to deal with additional spin-indicies in the probability / need to incoherently sum the different spin configurations.
- In general, this leads to a rate equation that looks like (for an initial state polarised as $\hat{\rho}$

$$P\left(\psi,\hat{\rho}\right)d\psi=\sum_{ll'}g_l g'_l\sum_{imm'}\left(\delta_{mm'}+\sigma_{mm'}\hat{\rho}\right)\mathcal{A}^{l}_{mi}(\psi)\left(\mathcal{A}^{l'}_{m'i}(\psi)\right)^{*} \tag{2}$$

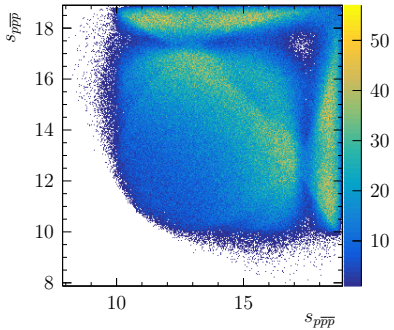
- A tricky thing to calculate (and normalise) efficiently!

Toy examples

$\Lambda_b \to \Lambda p\overline{p}$ with intermediate spin-3/4 contributions:



$B \to p\overline{p}pp$



Future developments

- With some minor modifications, can generate CUDA kernels that can be integrated into GooFit
- Evaluate amplitude $D^0 \to K_2^*(1430)^0 [K^-\pi^+]\pi^0$ on 8.4 million events with 1 CPU core (i7-8550U CPU @ 1.80GHz) vs 1 GPU (GeForce GTX 1050M)
- GPU version is about a factor of two faster than the OpenMP version (i.e. using 8 cores rather than 1 for the CPU version). Further tuning of the code generator has given another factor of $2 \to 3$ compared to what is shown here.