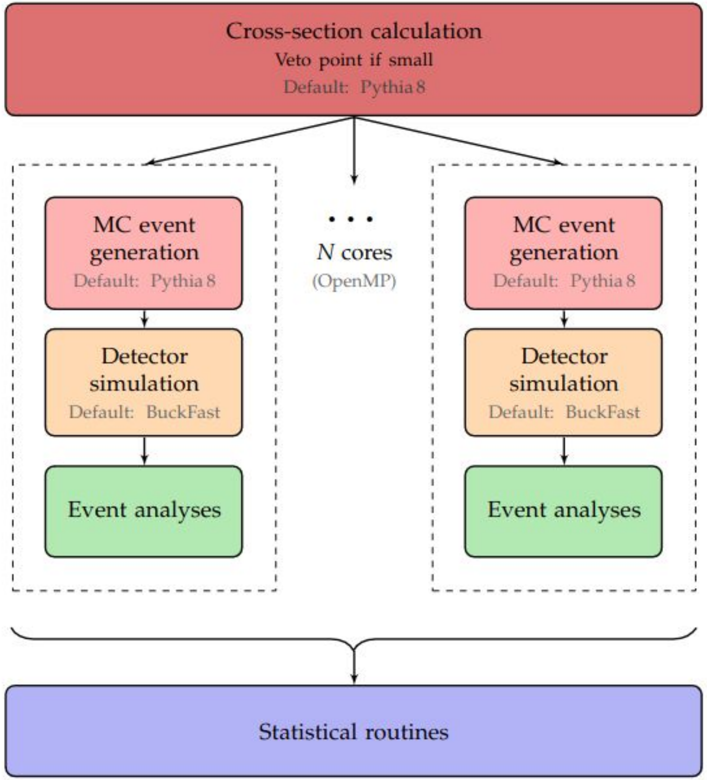
ColliderBit Working Group Update

Working Group Convenors: Are, Chris
GAMBIT XVI
Frascati 2024

What does ColliderBit do?

Calculates collider observables/likelihoods for LHC and LEP searches / measurements.



Monte Carlo Event Generation

Calculate a cross-section from Pythia or external sources (tools/tables).

Generate MC events with Pythia, or from interpolating tabulated values calculated externally.

For speedup, we avoid some of the physics not essential for BSM global fits (e.g. MPI interactions, FSR)

For detector sim, we usually use the default BuckFast (fast 4-vector smearing).

```
/// LHC Loop Manager
void operateLHCLoop(MCLoopInfo& result)
{
  Loop::executeIteration(BASE_INIT);

  // For every collider requested in the yaml file:
  for (auto& collider : result.collider_names)
  {
    Loop::executeIteration(COLLIDER_INIT);

    Loop::executeIteration(COLLIDER_INIT_OMP);

    Loop::executeIteration(XSEC_CALCULATION);

    Loop::executeIteration(START_SUBPROCESS);

    // Convergence loop
    while(not *Loop::done)
    {
      Loop::executeIteration(thread_my_iteration);
    }

    Loop::executeIteration(COLLIDER_FINALIZE);
  }
  Loop::executeIteration(BASE_FINALIZE);
}
```

Event Analysis

Each Collider analysis is it's own C++ class

Performs a series of cuts on events to count the # of events predicted in a given signal region

Validate these by trying to reproduce cutflow tables supplied by the experiments (not always easy).

We also use Contur to form likelihoods for LHC measurements.

```
class Analysis_Example : public Analysis
{

  public:

    // Counters for the number of accepted events for each signal region
    std::map<string, EventCounter> _counters = {{"SR1", EventCounter("SR1")}}

    // Required detector sim
    static constexpr const char* detector = "ATLAS";

    Analysis_Example()
    {
      set_analysis_name("Example");
      set_luminosity(139.);
    }

    void run(const HEPUtils::Event* event)
    {
      double met = event->met();

      // Fill SR's
      if (met > 100) {_counters.at("SR1").add_event(event);}
    }

    void collect_results()
    {
      add_result(SignalRegionData(_counters.at("SR1"), 12, {11.8, 1.2 }));
    }

};
```

Selection	Weighted events	Raw events
Initial number of events ($\mathcal{L} \times \sigma$)	256690	–
Initial number of events ($\mathcal{L} \times \sigma_{\geq 1 \text{ jet}}$)	59885	–
Initial number of events ($\mathcal{L} \times \sigma_{\geq 1 \text{ jet}} \times \mathcal{B}$)	5909	–
Generator Filters	3141.05	1800000
$E_{\mathrm{T}}^{\mathrm{miss}}$ trigger	1216.93	75111
1 lepton and ≥ 1 track	443.08	27501
veto 3 GeV $< m_{\ell\ell} <$ 3.2 GeV	440.39	27324
Lepton author 16 veto	437.09	27137
$E_{\mathrm{T}}^{\mathrm{miss}} > 200$ GeV	178.79	11486
$\min(\Delta\phi(\text{any jet}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}})) > 0.4$	170.79	10931
$\Delta\phi(j_1, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}) > 2.0$	169.33	10813
$0.5 < m_{\ell\mathrm{track}} < 5$ GeV	15.30	1009
$\Delta R_{\ell\mathrm{track}} > 0.05$	15.30	1009
Number of jets ≥ 1	15.29	1008
Leading jet $p_{\mathrm{T}} > 100$ GeV	15.21	1002
$E_{\mathrm{T}}^{\mathrm{miss}}/H_{\mathrm{T}}^{\mathrm{lep}} > 30$	8.60	568
$\Delta R_{\ell\mathrm{track}} < 1.5$	8.40	554
Lepton $p_{\mathrm{T}} < 10$ GeV	7.88	525
Track $p_{\mathrm{T}} < 5$ GeV	7.88	525
$\Delta\phi(\ell, E_{\mathrm{T}}^{\mathrm{miss}}) < 1.0$	5.81	405
Same flavor lepton-track pair	5.62	391
Opposite charge lepton-track pair	5.39	377
$m_{\ell\mathrm{track}} < 5$ GeV	5.39	377
$m_{\ell\mathrm{track}} < 4$ GeV	5.03	351
$m_{\ell\mathrm{track}} < 3$ GeV	3.66	257
$m_{\ell\mathrm{track}} < 2$ GeV	1.55	105
$m_{\ell\mathrm{track}} < 1.5$ GeV	0.55	39

Collider Likelihood

$$\mathcal{L}_{search}(s,\gamma) = \prod_{i=1}^{n_{SR}} \left[\frac{(s_i + b_i + \gamma_i)^{n_i} e^{-(s_i+b_i+\gamma_i)}}{n_i!} \right] \times \frac{1}{\sqrt{det 2\pi\Sigma}} e^{-\frac{1}{2}\gamma^T \Sigma^{-1} \gamma}$$

s_i: Predicted events in SR i

b_i: Expected background events in SR i

γ_i: nuisance scaling factor in SR i

n_i: Observed events in SR i

Σ: Covariance matrix for nuisances parameters

To calculate the likelihood independent of nuisance parameters, we either profile or marginalise over γ_i.

Members (according to the email list)

- Adil Jueid
- Alex Woodcock
- Anders Kvellestad
- Andy Buckley
- Are Raklev (convenor)
- Andre Scaffidi
- Ben Farmer
- Chris Chang (convenor)
- Christopher Rogan
- Csaba Balazs
- Holly Pacey
- Ida Marie Johansson
- Jeriek Abeele
- Jonathan Cornell
- Felix Kahlhoefer
- Lasse Braseth
- Nazilla Mahmoudi
- Martin White
- Matthias Danninger
- Marcin Chrzaszcz
- Nicola Serra
- Pat Scott
- Peter Athron
- Philip Grace
- Tomas Gonzalo
- Tomasz Procter
- Patrick Tunney
- Victor Ananiev
- Yang Zhang
- Pengxuan zhu

Work in progress from GAMBIT XV

Xsec: Interface:

- Simplify LEP cross-section capability structure
- Xsec backend: cmake system and some testing
- Finalise Prospino backend (stability)
- Fix how we get the initial cross-section maximum estimates from Pythia

Monte carlo:

- Backend MadGraph for event generation
- Complete the Pythia 8.3 move
- Swap to using Pythia's parallelism
- Pacer project: Speeding up event generation

Analyses:

- Switch to subcapability system for analyses
- Unify the way we use cutflows inside of Analyses
- LHC Analyses that rely on neural nets
- Analysis Backend collector
- Baseline selection Analyses

Other:

- ColliderBit Solo (CBS)
- Make Interpolated yields system more general (less model-specific)
- Event class extension for long-lived particle searches
- Implement alternative to capped likelihood
- SModelS backend
- Beam dump constraints (MadDump as backend)
- Multiple jet collections
- Simplify how we use fastjet
- TACO

Some things achieved since the last meeting

- Many new collider analyses added as part of SUSYRun2/SMEFT projects
- Added Beam dump constraints (Sub-GeV project)
- Allow multiple jet collections
- Baseline selection analyses
- Analyses that rely on neural nets

ColliderBit Updates: New Collider Analyses

As a part of SUSY Run 2 and SMEFT projects, many new analyses have been added:

- ATLAS_13TeV_0LEPStop_139invfb
- ATLAS_13TeV_1OR3LEP_StopHZ_139invfb
- ATLAS_13TeV_2OR3LEP_139invfb
- ATLAS_13TeV_2LEPJETS_EW_139invfb
- ATLAS_13TeV_2LEP0JET_EW_139invfb
- ATLAS_13TeV_2LEPJETS_RJR_139invfb
- ATLAS_13TeV_2LEPsoft_139invfb
- ATLAS_13TeV_3b_NN_139invfb
- ATLAS_13TeV_3LEP_eRJR_139invfb
- ATLAS_13TeV_4b_139invfb
- ATLAS_13TeV_4b_allyears_139invfb
- ATLAS_13TeV_4b_discoverySR_139invfb
- ATLAS_13TeV_bTaus_StopStau_139invfb
- ATLAS_13TeV_EXOT_TT_WbWb_36invfb
- CMS_13TeV_0LEP_chargino_VV_VH_137invfb
- CMS_13TeV_0LEPStop_137invfb
- CMS_13TeV_1LEPbb_137invfb
- CMS_13TeV_2LEPsoft_137invfb
- CMS_13TeV_2LEPsoft_ewinos_137invfb
- CMS_13TeV_2LEPsoft_stop_137invfb
- CMS_13TeV_2OSLEP_EW_Production_137invfb
- CMS_13TeV_Photon_GMSB_137invfb)
- CMS_13TeV_2Higgs_4b_neutralino_137invfb
- Baselines

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- Simplify LEP cross-section capability structure
- Switch to subcapability system for analyses
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- Simplify how we use fastjet

Added since the last face-to-face:

- Exact-approximate collider likelihoods
- SR Flip-Flopping strategising
- TACO