CF2: Theory Calculations (Perturbative)

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Perturbative Calculations: Motivation and Scope

- Perturbative calculations *essential* to predict collider observables etc.
- LHC and future colliders will not reach their scientific potential without precise theory predictions
  - Concise definition of observables, tell new physics apart from radiative effects
- Motivates improvements at various fronts, focus here:
  - Fixed order calculations, also at higher perturbative orders (NNLO, N3LO)
  - But should be seen as one component within a greater picture
- Precision theory relevant for multiple Snowmass frontiers and subgroups
  - TF6 “Precision”, TF4 “Amplitudes”, EF04 "Precision EW”, EF05 "Precision QCD"
- Peter Boyle initiated a leadership meeting on July 29 for CF02/Pert.Calc.
  - results of meeting and follow-up discussions summarized here

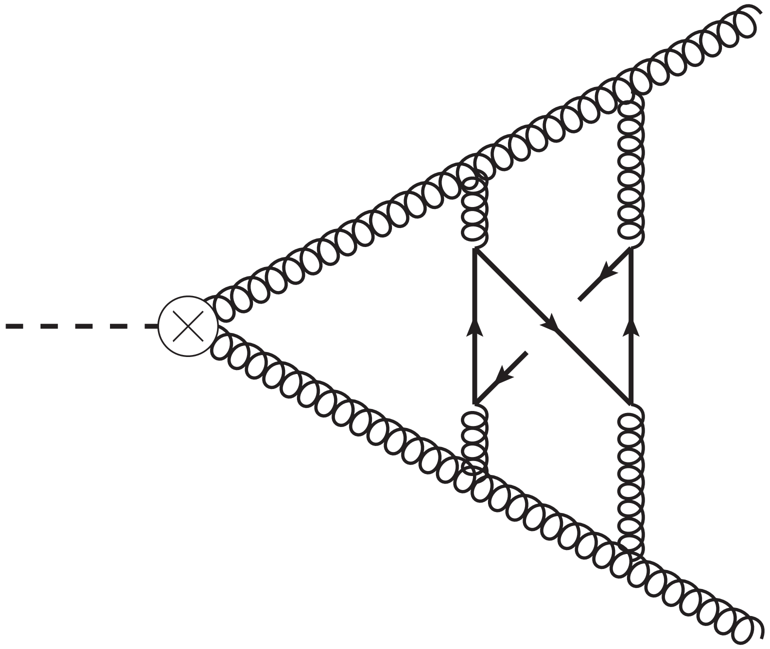
Building Blocks of Perturbative Calculations

- Typical workflow for perturbation theory based calculations:
  1. Scattering matrix element (reduced amplitude + master integrals)
     - Traditionally symbolic computer algebra, lots of serial code
  2. Subtraction of infrared divergences
  3. Phase space integration
     - Floating point numerics
  4. Parton distribution functions
  5. Monte Carlo events (parton shower, hadronization, decays)

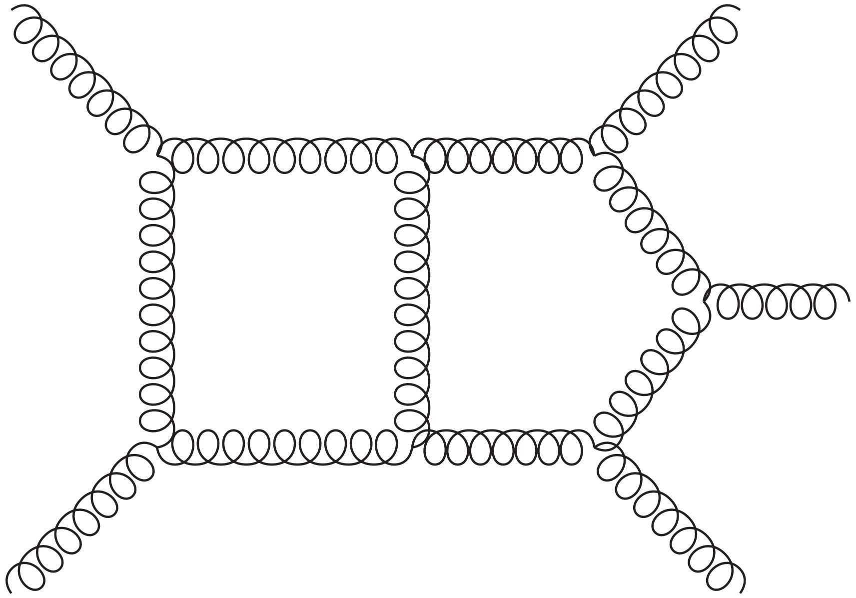
- Progress driven by
  - better mathematical approaches
  - better computational tools

Computational Tasks

- Computer algebra:
  - Calculation of reduced amplitudes involve complicated computer algebra
  - Example: four-loop ggH amp involved linear systems with 10^8 equations and symbolic coefficients
  - Other problems at NNLO (more legs, heavy particles) have many mass scales, complicated rational functions



- Numerical integration:
  - Higher dim phase space integration of complicated integrands



- Recent computational developments:
  - Computer algebra parallelization via finite field sampling and rational reconstruction → HPC
  - machine learning for phase space integration

Specific Computational Challenges

- Integer sampling sometimes >100TB tmp data
- Need large RAM nodes (>= 1TB) for computer algebra
- Need substantial CPU time for numerical integrations
- Workflow often involves complex chain of tools
  - custom codes, 3rd party
- Runtimes sometimes difficult to predict or difficult to break point
  - requires flexible batch policies
- Licensing for commercial software on clusters
  - Mathematica, Maple, …
- New architectures: difficult to port phase space integrations to GPUs
  - large amplitudes

Plans for LOIs

- US community working in precision theory is very small
  - additional support very important
- Emphasize need for precision theory in a *strong global letter*
  - Sally Dawson, Doreen Wackeroth, …
- Address computational needs of precision theory in CF LOIs
  - Even if small on overall scale, computing resources are important
- CF2/TF6 LOI focussing on multiloop calculations
  - Fernando Febres Cordero, Andreas von Manteuffel, …
  - possibly part of more comprehensive effort
- CF2: LOIs for multi-leg, phase-space integration, events ?

Perspectives for Support

- Train sufficient numbers of young researchers in the US
- Provide career paths
- Support for software developers
    - successful examples (labs) in other disciplines exist
- Interdisciplinary efforts with computational sciences
    - computer algebra, semi-numerical approaches, machine learning
- Access to suitable nodes in (large) clusters
    - Also address previous efforts
- SciDAC, Exascale computing project, …