WHIZARD, O'Mega and FeynRules

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What is WHIZARD?

Verbatim from the website:

> “WHIZARD is a program system designed for the efficient calculation of multi-particle scattering cross sections and simulated event samples.”

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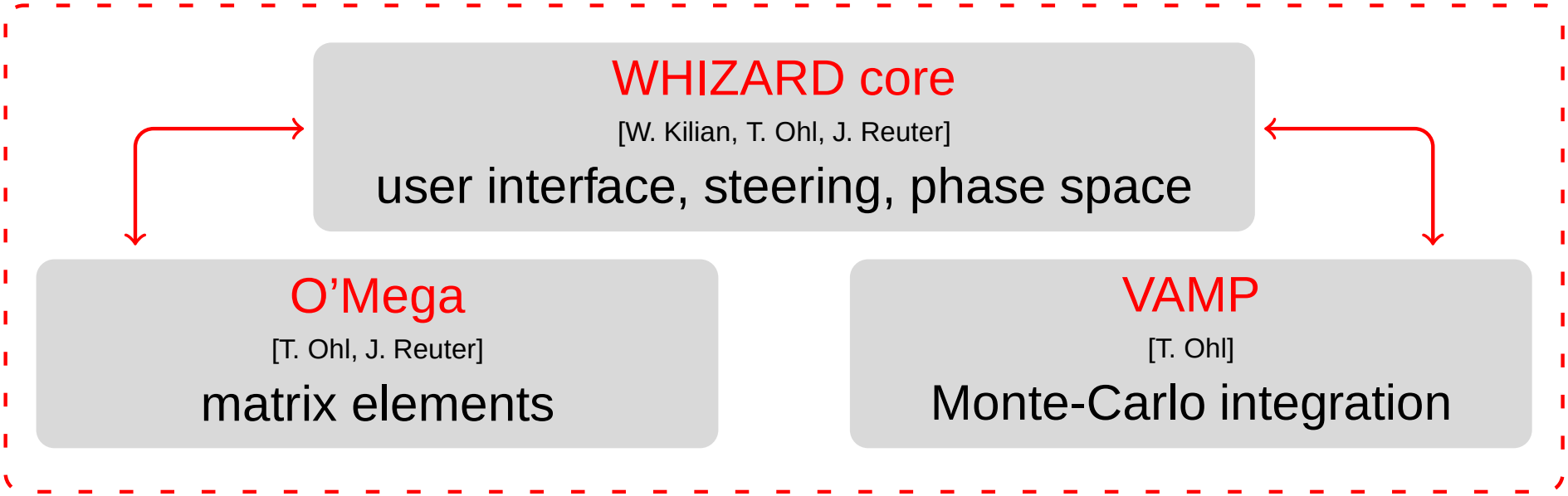

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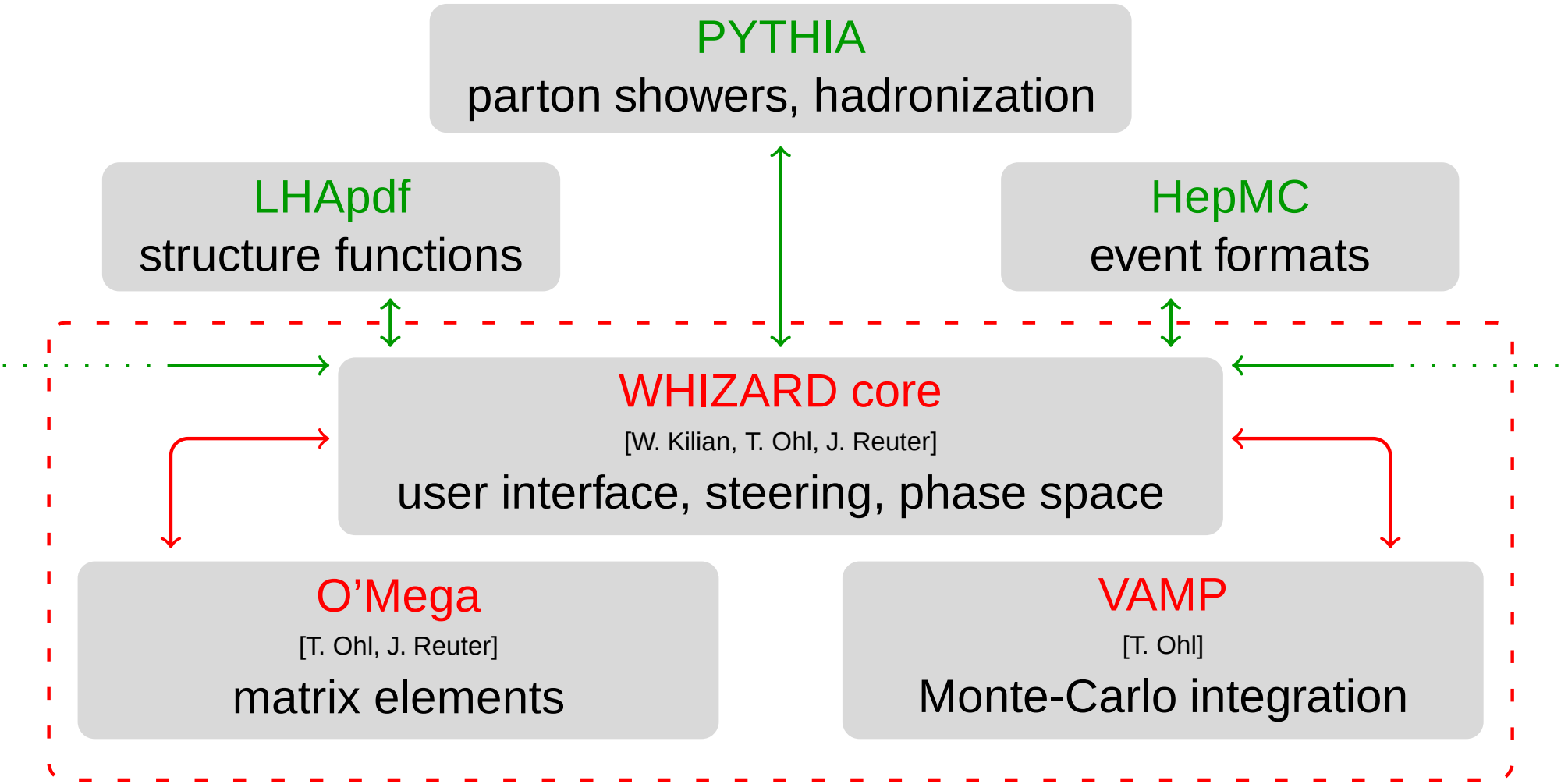

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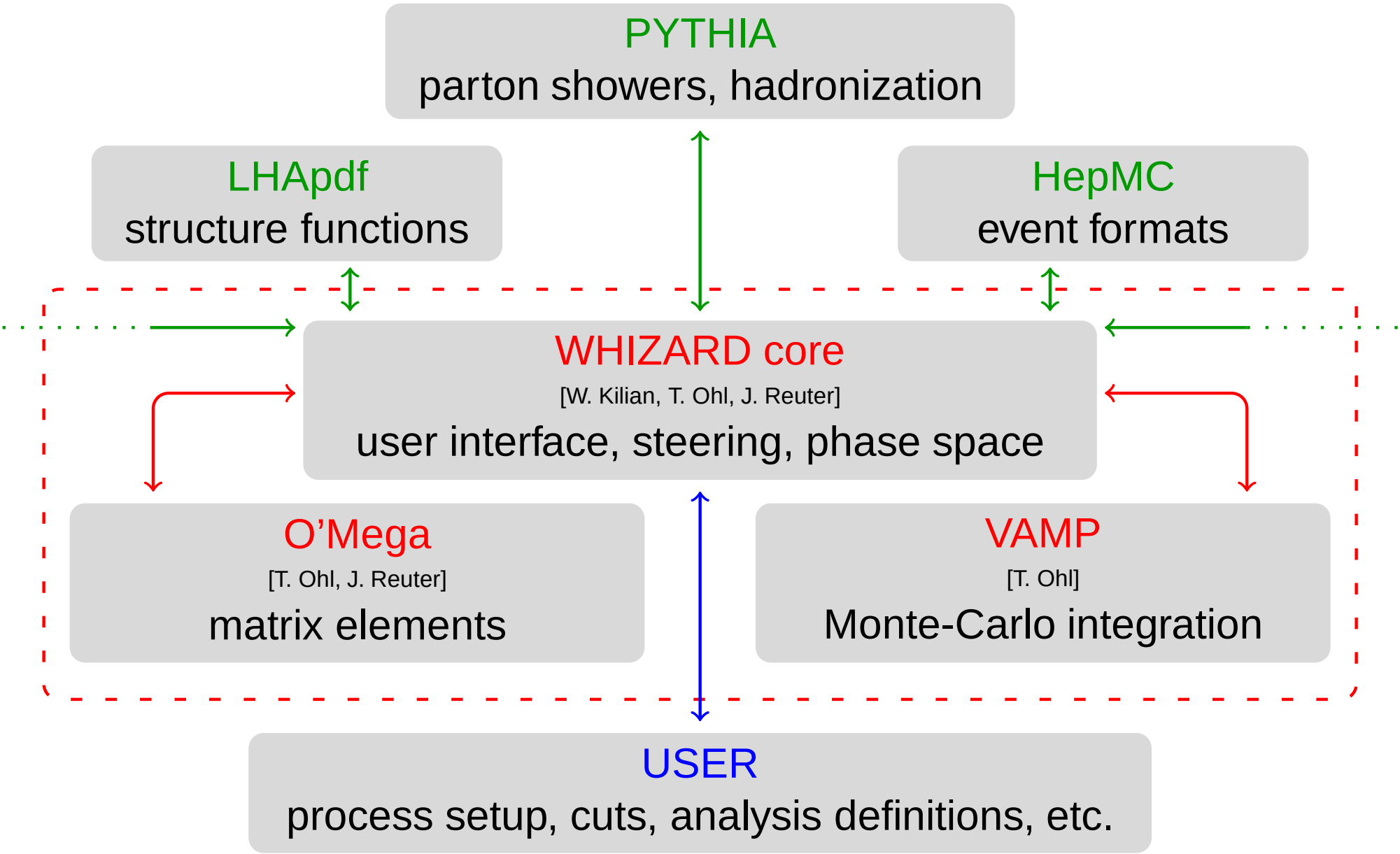
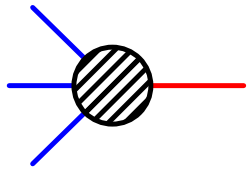


A few words on O'Mega

Physics and algorithm:

- 1-particle off-shell wavefunction (1POW):

$$\langle \text{in} |\, \phi(x) \,| 0 \rangle \quad =$$



- Number of 1POWs grows exponentially
- Use 1POWs instead Feynman Diagrams $\longleftrightarrow$ exponential complexity (instead of factorial one)
- 1POWs satisfy Ward identity $\longrightarrow$ nontrivial gauge cancellations in every step, numerical stability

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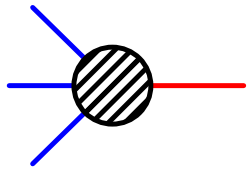

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Implementation:

- Written in O'Caml (impure functional language)
- Graph of 1POWs transformed into FORTRAN 95 code
- Numerical calculation of helicity amplitudes
- No limit on the arity of vertices

WHIZARD core — version 1.x

Structure:

- PERL for automatic code generation
- FORTRAN 95 for phase space / infrastructure / misc. physics
- Top level control by Makefiles (autoconf for portability)

Running WHIZARD:

1. User creates process definitions, invokes make
2. Make invokes PERL code → calls O'Mega and generates glue code
3. Compilation of the generated code together with WHIZARD F95 components → WHIZARD executable
4. User prepares beam setup, cut and analysis definitions and runs WHIZARD executable
5. Go back to 1 for different model / process selection

WHIZARD core — version 2.0

Structure:

- One self-contained FORTRAN 2003 program
- Code generation and dynamic loading of process libraries controlled by WHIZARD executable
- Control language “sindarin” for steering all aspects of the run

Running WHIZARD:

1. Configure, compile and install WHIZARD via autoconf / make
2. Prepare sindarin input (process definitions, beam setup, cuts, analysis), run WHIZARD executable
3. WHIZARD calls O’Mega, compiles matrix elements and dynamically loads process library
4. WHIZARD proceeds to actual integration and event generation
5. Go back to 2 for different process selection

WHIZARD features (not exhaustive):

- Speed (unweighted events for to up to 8 final state particles)
- Integrated analysis facilities
- Many BSM models implemented: NMSSM, Little Higgs, UED, Three-Site model and more
- Sindarin (W2): Powerful command language for elaborate cut and analysis variables, possibility to scan over parameters

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Planned improvements (equally not exhaustive):

- Integrated parton showers (S. Schmidt)
- Jet algorithms for cuts and analysis (D. Wiesler)
- Multiple interactions (H. Boschmann)
- Arbitrary lorentz structures
- Parallelization

Components of a WHIZARD model

1. O'Mega component: written in O'Caml, compiled to executable
2. WHIZARD component: custom syntax, parsed by WHIZARD core
3. FORTRAN glue, compiled into WHIZARD libraries

Challenge for the BSM phenomenologist:

Implementing a new model is possible, but not straightforward, and programming skills definitely help.

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Enter the FeynRules interface:

- Supports WHIZARD 1.92+ (including W2)
- Emits O'Mega, WHIZARD and FORTRAN parts
- Includes utilities to integrate the model into the WHIZARD framework

$\longrightarrow$ makes adding new models much easier for those less technically inclined

State of the interface:

- Supports spin $0, \frac{1}{2}, 1$
- Handles all gauge invariant dimension 4 operators
- Can do unitarity, Feynman and R_ξ gauges
- Majoranas + clashing arrows work
- Validated in SM, 3SHL, MSSM (in progress)
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- Support spin $\frac{3}{2}$ and 2
- Extend the range of supported operators
- Check and validate with more model (Randall-Sundrum, ...)
- Cleanup and misc. small improvements to the “user experience”

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FeynRules wishlist:

- Maybe: more information about quantum numbers (flavor!)
- Esentially: I’m happy

Conclusions

- WHIZARD: not monolithic, several components
  - O'Mega
  - VAMP
  - WHIZARD core
- Link to external packages to extend functionality
- WHIZARD 2
  - Major rewrite
  - Easier to use (less fragile, sindarin)
  - New physics features: cascade decays, more planned
- FeynRules interface for easy import of new models