Integration of GRACE and PYTHIA

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Collaboration between **Atlas-Japan** and **Minami-Tateya**

to develop

event generators for hadron collider experiments:

LHC (pp) and Tevatron ($\bar{p}p$)

Atlas-Japan

K. Sato, S. Tsuno (Tsukuba U.)

S. Odaka (KEK)

Minami-Tateya

J. Fujimoto, T. Ishikawa, Y. Kurihara (KEK)

GRACE

by the Minami-Tateya group

Automatic generation of Feynman diagrams
and **FORTRAN codes** for calculating the cross sections
based on their **amplitudes**

including
cross-section integration and event generation tools
BASES/SPRING

$\Rightarrow$ **general-purpose event-generator generation framework**

powerful for **multi-body** production processes
e.g., `grc4f` for LEP2

GRACE for hadron collisions

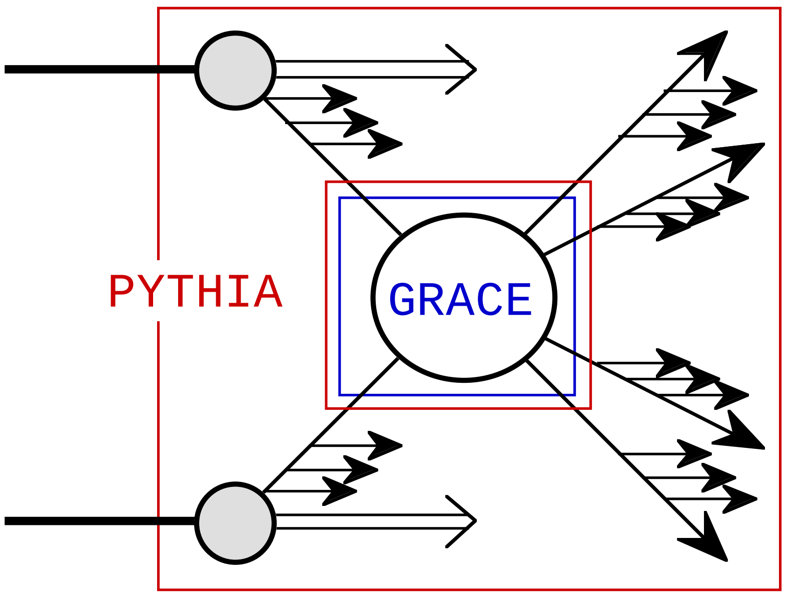
Multi-particle productions will become more important
at future (higher energy) hadron colliders;
multiple **heavy-particle** (*W/Z*, top, *H*) production,
cascade decay of **SUSY** particles

e.g., pp (or $p\bar{p}$) $\rightarrow b\bar{b}H^0 + X \rightarrow b\bar{b}b\bar{b} + X$
5 (9) processes and 144 (240) diagrams

However,
GRACE deals with hard scattering only

→ need to add Parton Distribution Function (**PDF**)
and QCD evolution **(parton radiation)**

⇒ connection to a **general-purpose event generator**
e.g., **PYTHIA**, ISAJET, HERWIG

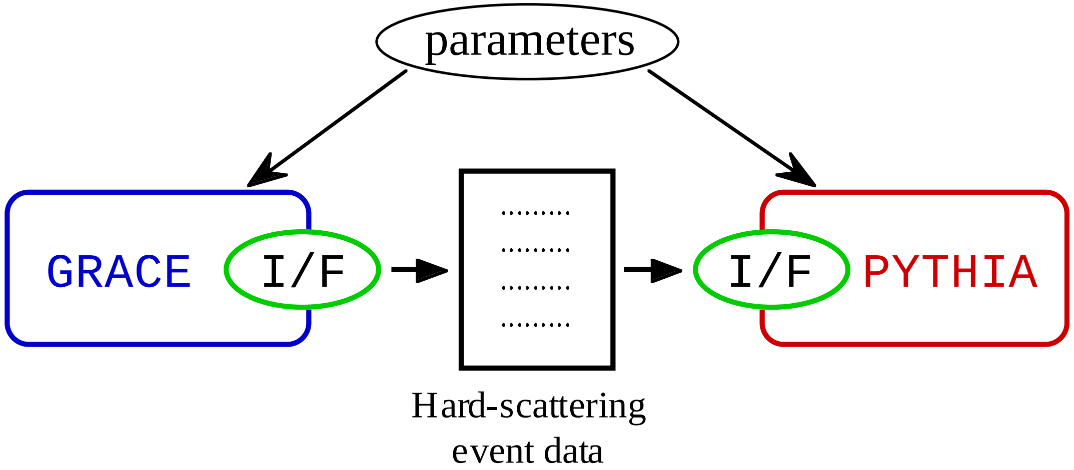


How to connect ?

Interfacing using data files

flexible and portable
easier to code

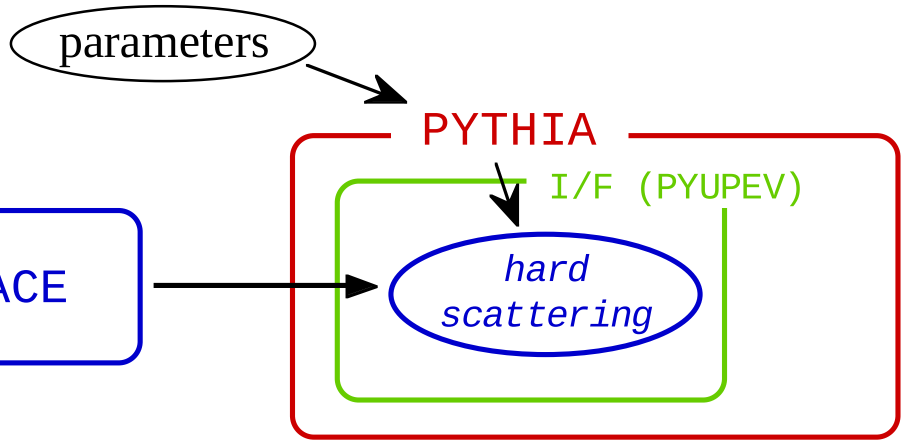
used in
`GRAPE` (`GRACE+PYTHIA` for *ep* interactions)
`CompHEP+PYTHIA`



Embedding

easy to handle in event generation
one-step generation

our choice



Kinematics

(x_1, x_2) and momenta of produced particles ⟷ uniform random numbers

Choice of variables and mapping to the random numbers

$\tau \equiv x_1 x_2,\ \ y \equiv \frac{1}{2} \ln \frac{x_1}{x_2}$
and *singularity*-oriented choice for produced particles

two methods were developed

Functional mapping by users

may be more efficient, if skillful

final sampling by `PYTHIA`

Grid mapping by BASES

detailed tuning is not required

event generation by `SPRING`

PYUPEV

Initialization stage to be called by PYUPIN

- calculation of “total” cross section for every “process” using BASES

→ SIGMAX

Event generation stage

- choose one of the “processes”

- determine a set of random numbers
- convert them to kinematic variables according to the chosen “kinematics”
- calculate the differential cross section using the GRACE output code

→ SIGEV = PDF * differential cross section * Jacobian

- read the BASES output
- event generation by SPRING

→ SIGEV = SIGMAX

i.e., no rejection

- set the color flow (automatic)
- Lorentz boost

(event sampling using SIGEV/SIGMAX in PYTHIA)

Processes tested

$$pp \;(\text{or } p\bar{p}) \rightarrow q\gamma + X$$

$$\rightarrow Wg + X \rightarrow \mu\nu g + X$$

2/3-body

$$\rightarrow HW + X \rightarrow b\bar{b}\mu\nu + X$$

$$\rightarrow b\bar{b}_{\text{(QCD)}}W + X \rightarrow b\bar{b}\mu\nu + X$$

4-body

$$\rightarrow Hb\bar{b} + X \rightarrow b\bar{b}b\bar{b} + X$$

$$\rightarrow b\bar{b}b\bar{b}_{\text{(QCD)}} + X$$

4-body
(under development)

Performance (example)

$$pp \to gW^{\pm} + X \quad \text{at} \ \sqrt{s} = 14 \ \text{TeV}, \ p_{\mathrm{T}}(g) \geq 5 \ \text{GeV}$$

	User-defined kinematics	BASES/ SPRING	PYTHIA `ISUB=16`
Total cross section (nb)	63.36 ± 0.20	63.43 ± 0.13	63.17 ± 0.20
Generation efficiency (%)	19	35	19
CPU time for 100 k events (min)	12.5	20.3	4.6

Linux PC (Pentium II, 300 MHz)

CKM-diagonal diagrams only

Without parton radiation and hadronization/decay (another 45 min. needed for them)

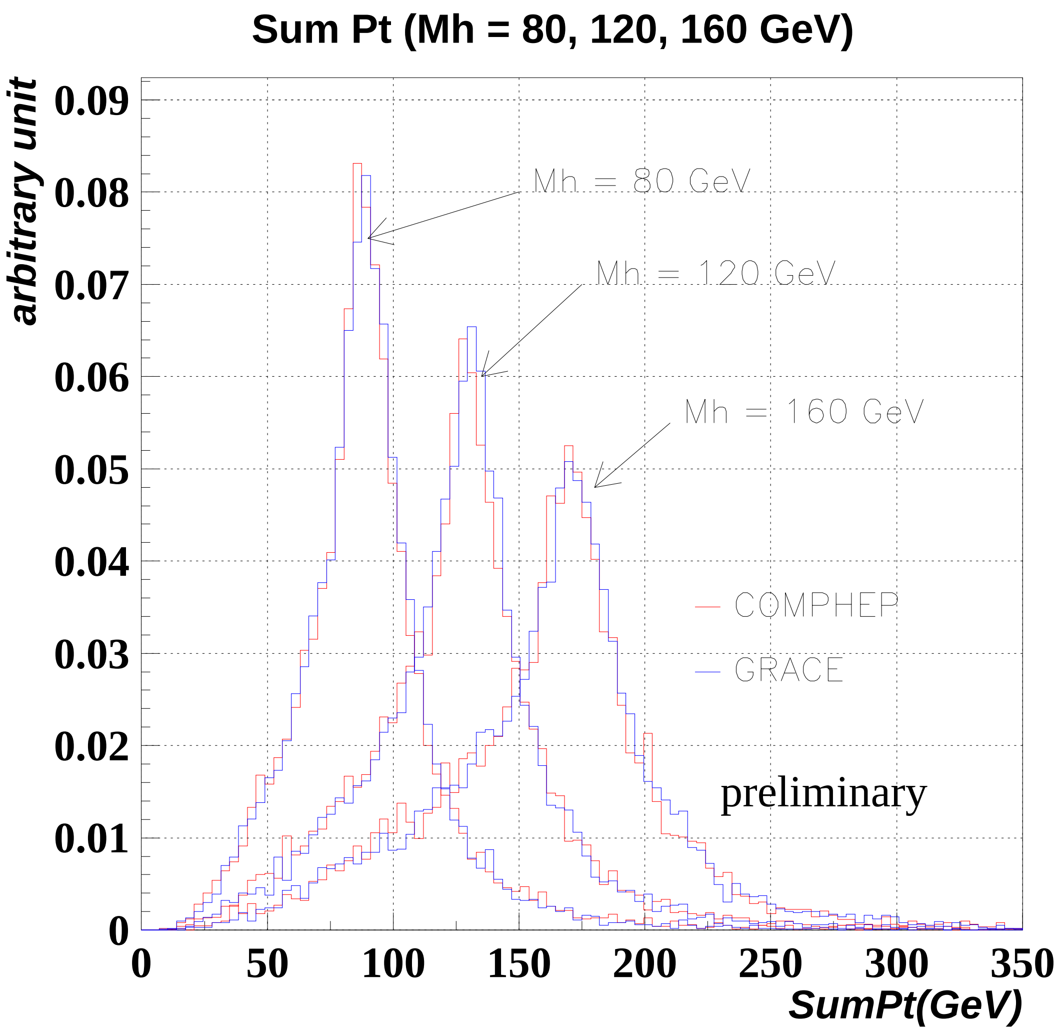
$$p\bar{p} \rightarrow Hb\bar{b} + X \rightarrow b\bar{b}b\bar{b} + X \quad \text{at } \sqrt{s} = 2 \text{ TeV}$$

Sum Pt Distribution

Mh = 80 GeV
Γ_{tot} = 4.161 MeV
COMPHEP : σ = 6.083 fb
GRACE : σ = 6.006 fb

Mh = 120 GeV
Γ_{tot} = 6.537 MeV
COMPHEP : σ = 1.002 fb
GRACE : σ = 0.9892 fb

Mh = 160 GeV
Γ_{tot} = 60.677 MeV
COMPHEP : σ = 0.3561 fb
GRACE : σ = 0.3565 fb



Possible improvements

- Multi-process BASES/SPRING
- Automatic generation of hand-written codes
- Variable mass and coupling (reduction of the "processes" and built-in implementation of the CKM matrix)

Summary

- We have established a technique for embedding the `GRACE` output codes into `PYTHIA`.
- This is a powerful tool for developing event generators for **multi-body production** processes in high-energy **hadron collisions**.
- Some "improvements" are planned to make the development easier.