Towards a fragmentation model for Sherpa

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- The event generator Sherpa: scope and some applications
- A cluster fragmentation model for Sherpa
  - Cluster formation model
  - Cluster decay model
- Outlook
Sherpa (Simulation of High Energy Reactions of PArticles) is a new multi-purpose event generator entirely written in C++

The scope:

- Full simulation of high energetic particle reactions at existing and future collider experiments, including $e^+e^-, \gamma\gamma, e\gamma, p\bar{p}$ and $pp$ collisions
- Account for multi-jet production by using tree level multi-jet matrix elements combined with the parton shower à la CKKW

Features:

- Modular structure of independent physics modules
- Modules are interfaced through abstract handler classes
- Bottom-up approach (slim overhead that can be easily adapted)
The Sherpa approach for $e^+e^-$ collisions

Split the simulation in parts:

- Beam setup
  - Initial state radiation
  - Laser backscattering for $e\gamma$ and $\gamma\gamma$
- Hard Process and decays via multi-jet ME’s
  - AMEGIC++ (see talk by S. Jadach on Thursday)
- Parton Shower
  - APACIC++
- Hadronization
  - interface to Pythia string fragmentation
  - own cluster model under development (not included in the official release yet)
Sherpa: Event shapes

1 - Thrust

Major

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LCWS, Paris, 19.–23. April 2004 – p.4
Sherpa: Four jet angles

\[ \alpha_{34} \]

\[ \cos(\alpha_{34}) \]

Bengtsson-Zerwas

\[ |\cos(\chi_{BZ})| \]

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Sherpa: inclusive Z production at Tevatron

CDF Data: $P\bar{P} \rightarrow Z + X$ at $\sqrt{s} = 1.8$ TeV

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modelling the non-perturbative dynamics of a partonic system

- Cluster-formation model
- Cluster-decay model

Features:
- Parametrization of primary-hadron generation
- LPHD and preconfinement
- Locality and universality
- Currently restricted to light-quark sector
Cluster-Formation Model

Parton shower ends up with colour-ordered parton list

- **Parton masses**
  - Constituent masses

- **Enforced gluon splitting**
  \[ g \rightarrow q\bar{q}, \quad g \rightarrow q_1 q_2 \bar{q}_1 \bar{q}_2 \]

- **Soft Colour Reconnection**
  - Kinematical weight
  \[ W_{ij,kl} = \frac{t_0}{t_0 + (w_{ij} + w_{kl})^2} \]

### Primary cluster mass distribution

- SHERPA preliminary
- uds only
- cm energy = 91.2 GeV

Legend:
- Blue: no CRM
- Dotted: CRM without KW
- Green: CRM with KW
- Mean: 2.48633
- Mean: 2.762
- Mean: 2.46078
Results for $e^+e^- \rightarrow \mathcal{H}$

Primary cluster mass distribution with CRM

- Primary cluster mass spectrum independent of cm energy of the hard subprocess
Cluster-Decay Model

**Ansatz:** Cluster mass \( \Rightarrow \) transition type

- **\( M_C \) in hadron regime**
  - \( \rightarrow \) 1-body decay \( C \rightarrow \mathcal{H} \)
  - weight: \( \mathcal{W} = \exp \left( -\frac{Q^2}{Q_0^2} \right)^2 \)

- **else 2-body decay** \( C \rightarrow \mathcal{X} \mathcal{Y} \)
  - determine \( M_X \) & \( M_Y \)
  - kinematics:
    - \( p_{1,2} = \left( 1 - \frac{Q_0}{M_C} \right) p_{1,2}^C \)
    - \( p_{\bar{f},f} = \frac{Q_0}{M_C} p_{2,1}^C \)
    - \( Q_0 = \hat{Q}_0 \frac{M_C}{M_C + M_0} \)

- channel selection
  - \( C \rightarrow CC \) / \( C \rightarrow \mathcal{H} \mathcal{H} \)
  - \( C \rightarrow C \mathcal{H} / \mathcal{H} C \)
Cluster-Decay Model: Soft Colour Reconnection

- direct and crossed flavour arrangement in cluster two-body decays

Diagram:

Cluster 1:
- C
- X
- Y
- 1
- 2
- 3
- 4

Cluster 2:
- C
- Y
- X
- 1
- 2
- 3
- 4
Results for $e^+ e^- \rightarrow \mathcal{H}$

charged-particle multiplicities for $uds$ events at $Z$-peak

<table>
<thead>
<tr>
<th></th>
<th>$\langle N_{ch}^{uds} \rangle$</th>
<th>$\langle N_{\pi^\pm}^{uds} \rangle$</th>
<th>$\langle N_{K^\pm}^{uds} \rangle$</th>
<th>$\langle N_{p,\bar{p}}^{uds} \rangle$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PYTHIA-6.1 ($uds$)</td>
<td>19.84</td>
<td>16.72</td>
<td>2.010</td>
<td>0.856</td>
</tr>
<tr>
<td>HERWIG-6.1 ($uds$)</td>
<td>18.86</td>
<td>15.37</td>
<td>1.693</td>
<td>1.568</td>
</tr>
<tr>
<td>SHERPA$\alpha$</td>
<td>20.15</td>
<td>16.83</td>
<td>2.018</td>
<td>1.047</td>
</tr>
<tr>
<td>DELPHI</td>
<td>$19.94 \pm 0.34$</td>
<td>$16.84 \pm 0.87$</td>
<td>$2.02 \pm 0.07$</td>
<td>$1.07 \pm 0.05$</td>
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<tr>
<td>SLD</td>
<td>$20.048 \pm 0.316$</td>
<td>$16.579 \pm 0.304$</td>
<td>$2.000 \pm 0.068$</td>
<td>$1.094 \pm 0.043$</td>
</tr>
</tbody>
</table>
Results for $e^+e^- \rightarrow \mathcal{H}$

Charged particle hemisphere multiplicity distribution

$cm\ energy = 91.2\ GeV$

$uds\ only$

MC simulation

SHERPA preliminary

mean: 10.0722

Experimental data

OPAL

Correction for heavy quarks

$$\langle N_{ch} \rangle = \langle N_{ch}^{uds} \rangle + f_c \delta_c + f_b \delta_b$$

$$\delta_c = 1.7 \pm 0.5 , \ \delta_b = 3.05 \pm 0.19$$
Results for $e^+e^- \rightarrow \mathcal{H}$

**Charged particle scaled momentum distribution**

*cm energy = 91.2 GeV*

- **Experimental data:**
  - SLD

**Charged particle log(1/x_p) distribution**

*cm energy = 91.2 GeV*

- **MC simulations**
  - PYTHIA-6.1
  - HERWIG-6.1
  - SHERPA preliminary

- **Experimental data:**
  - OPAL

Conclusion

Sherpa including the ME’s of AMEGIC++ and the CKKW prescription to combine them with the PS is a powerful tool to attempt the description of LEP and Tevatron data and to study the extrapolation to LC and LHC energies.

Outlook

- Extend cluster hadronization package
- Treatment of heavy quark sector
- Parameter tuning
- Application to hadron collisions
- Study of soft colour reconnection model

Sources

- current version SHERPAα-1.3 available under http://www.physik.tu-dresden.de/~krauss/hep