Sibyll with charm

Eun-Joo Sein Ahn

with

Ralph Engel, Tom Gaisser, Paolo Lipari, Todor Stanev
Current official Sibyll version is: 2.1

- 2.2: small improvements from 2.1
  - current version quite successful but has shortcomings as well;

- 2.2c: above with charm addition
  - include charm: more complete, prompt muons and neutrinos.

2.2 & 2.2c not public yet, will be shortly
Ingredients of Sibyll:

- dual parton model: quark+antiquark // quark+diquark
- string fragmentation
- minijets
- eikonal formalism
- hard interaction: electron form factor
- soft: minimal Regge theory
- GRV parton distribution functions (post-HERA)
- diffraction: two channel eikonal based on Good-Walker model
- semi-superposition model for nucleus-nucleus interaction
- partons: u, d, s, g
- projectiles: π^0, π^+, π^-, K^{0,+}, K^{0,-}, p, n, Nucleus(A=1-56)
- target: Nucleus (A=1-56)
- \( E_{CM} = 10 - 10^7 \text{ GeV} \) (\( E_{lab} > 100 \text{ GeV} \))
Overall structure

hadron-target / nucleus-target

how many nucleons in target involved?

non-diffractive / diffractive

hard / soft

minijets, strings / strings

fragment / decay
Overall structure

hadron-target / nucleus-target

how many nucleons in target involved?

non-diffractive / diffractive

hard / soft

minijets, strings / strings

fragment

semi-superposition model

nucleus-nucleus intxn, projectile nucleus -> determine intxn pts for nucleons
Overall structure

- **hadron-target** / **nucleus-target**
  - **how many nucleons in target involved?**
    - **non-diffractive** / **diffractive**
      - **hard** / **soft**
        - **minijets, strings**
        - **strings**
          - **fragment**
    - **decay**
      - semi-superposition model
        - nucleus-nucleus intxn, projectile nucleus \(\rightarrow\) determine intxn pts for nucleons
        - decay unstable Sibyll particles
New to 2.2c:

1. Charm quark added

2. Smoother diffraction - non-diffraction transition
   - increase phase-space ("fireball") decay range
   - non-sharp distribution of diffracted particle's energy

3. Minor bugfix
   - better $p_T$, higher multiplicitiy

4. Increased $s$ quark fraction
Charm addition

- mesons & baryons: D, \(\eta_c\), \(J/\psi\), \(\Lambda_c\), \(\Xi_c\), \(\Sigma_c\), \(\Omega_c\)

- charm created via branching ratio from s formation:
  
  ‣ cross section set by branching ratio = 0.004 (\(P_{s/u}\) & \(P_{us/ud} = 0.3\))
  ‣ valance s quark do not change to c
  ‣ along string fragmentation, branching ratio from strange qq or dq–dq
  ‣ automatically get leading \(\Lambda_c\)

- \(<p_T> = 1.5\text{ GeV/c for baryons, 1.0 GeV/c for mesons}\)
  
  - larger \(<p_T>\) than non-c particles (0.3 - 0.6 GeV/c)

- Peterson/SLAC fragmentation function \(f(z)\)

\[
f(z) \propto \frac{1}{z \left(1 - \frac{1}{z} - \frac{\epsilon_Q}{1-z}\right)^2}
\]

\(\epsilon_Q \propto 1/m_Q^2 = 2\)

(other particles use Lund fragmentation function)
String fragmentation

q or qq at end

qq or qq-qq pair inserted

particle forms, new string end

string end + q/qq -> particle

string mass decrease

final two hadrons
String fragmentation

- q or qq at end
  - no charm at ends

- qq or qq-qq pair inserted

- particle forms, new string end
  - string end + q/qq -> particle

- string mass decrease
  - s→c conversion
  - c particles get different $p_T$ & $f(z)$

- final two hadrons
Experimental data used:

1. **LEBC-EHS** : $E_{\text{lab}} = 400$ GeV, p-p,  
   - all D

2. **LEBC-MPS** : $E_{\text{lab}} = 800$ GeV, p-p  
   - all D
Experimental data used:

1. LEBC-EHS : $E_{\text{lab}} = 400$ GeV, p-p,
   - all D

2. LEBC-MPS : $E_{\text{lab}} = 800$ GeV, p-p
   - all D

3. E769 : $E_{\text{lab}} = 250$ GeV p $\pi^+$ K$^+$ beam on nuclei target (in /nucleon),
   - p target used in simulations - nucleus mass scaling verified
   - all D
Experimental data used:

1. LEBC-EHS : $E_{\text{lab}} = 400$ GeV, $p$-$p$,
   - all D

2. LEBC-MPS : $E_{\text{lab}} = 800$ GeV, $p$-$p$
   - all D

3. E769 : $E_{\text{lab}} = 250$ GeV $p$ $\pi^+ K^+$ beam on nuclei target (in /nucleon),
   - $p$ target used in simulations - nucleus mass scaling verified
   - all D

4. Selex : $E_{\text{lab}} = 615$ GeV ($\pi^-$), 540 GeV ($p$), on nuclei target
   - $N$ target used in simulations
   - no absolute normalisation given
   - $\Lambda_c$ & anti-$\Lambda_c$
To do:

- Final minor tuning remains;
- Usage of other experimental data – shortage of charm baryons:
  - E791: 500 GeV, $\pi^-$ beam-nucleon, D
  - ISR data $\Lambda_c$ with new normalisation?
To do:

- Final minor tuning remains;
- Usage of other experimental data – shortage of charm baryons:
  - E791: 500 GeV, π⁻ beam-nucleon, D
  - ISR data Λ_c with new normalisation?

Summary

- Sibyll 2.1 -> 2.2c has charm quark added
- charm forms along strang fragmentation, simple but effective with 4 parameters
- Will be released after final tunings

larger-scale update of Sibyll is underway