This work is supported by DOE grant DE-FG02-94ER4084



Sylvester Joosten sylvester.joosten@temple.edu



SoLID Collaboration Meeting, October 2017

...much more than a J/ψ Generator

- Based on my generator for Hall C charmed-pentaquark search
- Modular event generator library
 - J/ ψ generator uses this library
 - Written in modern C++ (C++14)
 - Can handle multiple processes in parallel
 - Easily extensible
- Accept-reject MC, no weighting necessary!
 - Able to events for a given integrated luminosity
- Modular event output
 - Currently supports gemc LUND and ROOT format
 - Plan to add HepMC3 and ProMC



Event generation loop

Generate initial hard scattering Randomly pick a process depending on relative generation space size Generate the process Accept or reject Handle particle decays Update estimated total cross section and integrated luminosity Repeat if we requested

more luminosity (or events)





Initial state generation



Everything written in terms of four-vectors and invariants

Simulate beam-within-beam:

- Virtual photon in electron beam (Tsai, et al., Phys.Rev. 149 (4).)
- Bremsstrahlung photon in electron beam (Budnev et. al., 1975, Physics Reports 15 (4))
- Nucleon in nucleus



Heavy quarkonia in photo-production

- t-channel production of heavy quakonium (2- and 3-gluon exchange)
 - (formalism from Brodsky et al., PLB498, 23-28 (2001))



- Resonant production of Pc(4380) and Pc(4450)
 - (formalism from Wang Q., et al., PRD 92-3 (2015) 034022-7)





Heavy quarkonia in lepto-production

Starting from photo-production formalism:

$$\frac{d\sigma}{dQ^2 dy dt} = \Gamma_T (1 + \epsilon R) D \frac{d\sigma_\gamma}{dt}$$

R based on fit to world data

$$R = \left(\frac{AM_V^2 + Q^2}{AM_V^2}\right)^{n_1} - 1$$

- Martynov, et. al., "Photoproduction of Vector Mesons in the Soft Dipole Pomeron Model." PRD 67 (7), 2003. doi:10.1103/PhysRevD. 67.074023
- R. Fiore et al., "Exclusive Jpsi electroproduction in a dual model." PRD80:116001, 2009"
- Dipole-like form factor similar to ρ^0 production

$$D = \left(\frac{M_V^2}{M_V^2 + Q^2}\right)^{n_2}$$

- A. Airapetian et al, "Exclusive Leptoproduction of rho0 Mesons on Hydrogen at Intermediate W Values", EPJ C 17 (2000) 389-398
- Adams et al., "Diffractive production of ρ0 mesons in muon-proton interactions 470 GeV", ZPC74 (1997) 237-261.
- M Tytgat, "Diffractive production of $\rho 0$ and ω vector mesons at HERMES" DESY-Thesis 2001-018 (2001)
- P. Liebing, "Can the Gluon Polarization be Extracted From HERMES Data", DESY-Thesis (2004)



Angular dependence of the decay lepton pair

- SHCH Distribution in **old SoLID** J/**\phi** generator describes decay of vector meson to scalar particles
 - This is wrong for decay to fermions (e+e-)

$$\mathcal{W}(\cos\theta_h) = \frac{3}{4}(1 - r_{00}^{04} + (3r_{00}^{04} - 1)\cos^2\theta_h)$$

Correct distribution for decay to fermions

$$\mathcal{W}(\cos\theta_h) = \frac{3}{8}(1 + r_{00}^{04} + (1 - 3r_{00}^{04})\cos^2\theta_h)$$

- Favors more asymmetric decay at low Q²
- Reduces to $\sim \cos^2 \theta_h$ for photo-production

 $(r_{00}^{04} \to 0 \text{ as } Q^2 \to 0)$

FORMULA FOR TWO FERMION DECAY

- J. Breitweg et al. (ZEUS), Exclusive electro-production of rho0 and J/ psi mesons at HERA, EPJ-C 6-4 (1999)
- Chekanov et al. (ZEUS), Exclusive photo production of J/psi mesons at HERA (2002)





J/ψ rates still better than original proposal!

Photo-production

- **2-fold** coincidence + **recoil** proton 9
- *t*-channel J/ ψ rate: **1627 per day** 6
- Pc(4450) rate: 927 per day
 - (5% coupling)

Electro-production

- **3-fold** coincidence (3 leptons)
- *t*-channel J/ψ rate: **86 per day**
- *Pc*(4450) rate: **36 per day**
 - \Rightarrow (5% coupling)





In progress: J/ψ – Bethe-Heitler interference

Interference between elastic J/ψ production near threshold and Bethe-Heitler

Forward-backward asymmetry near the J/ψ invariant mass peak Sensitive to real part of the scattering amplitude, and therefore $a_{\psi p}$ and $B_{\psi p}$



In progress: Radiative J/w decay

$J/\psi(1S)$ DECAY MODES



THANK YOU!

