Measurements of D Mesons at SPD

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Open Charm Productions

- In open charm channel, scattered charm and anticharm produce meson pairs
- Gluon fusion process dominates at SPD energies making charmed meson asymmetries sensitive to gluon spin distributions
- Of particular focus at SPD alongside charmonia and direct photon measurements

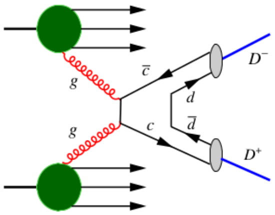

Figure 1: Schematic of open charm gluon fusion

D Meson Decay Channels of Interest

1. Among different possible decay modes of charmed mesons, SPD detectors can best measure in handronic decay channel. For example
2. $D^0 \to \pi^+ + K^-$, Branching Ratio 3.89%
3. $\bar{D}^0 \to \pi^- + K^+$
4. $D^+ \to \pi^+ + \pi^+ + K^-$, Branching Ratio 9.22%
5. $D^- \to \pi^- + \pi^- + K^+$

D Meson Cross-section Predictions

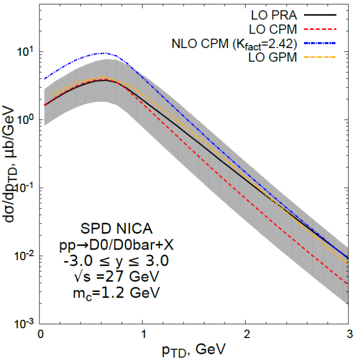

Figure 2: Inclusive $D0/\bar{D}0$ cross-section vs. p_T : A. Karpishkoff.

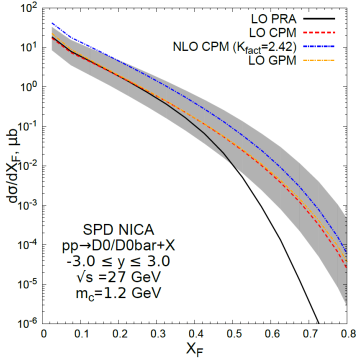

Figure 3: Inclusive $D0/\bar{D}0$ cross-section vs. x_F : A. Karpishkoff.

D Meson Asymmetry Predictions

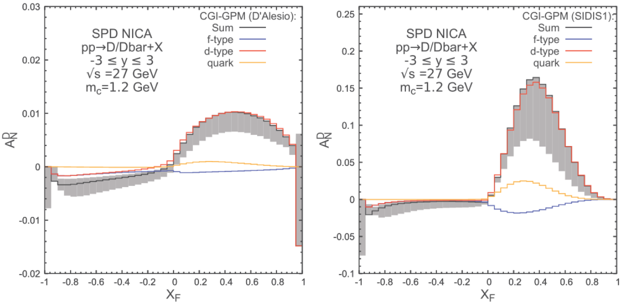

Figure 4: D Meson transverse single spin asymmetry predictions. V. Saleev et al.

Notice the (order of magnitude) model dependence. Makes new measurements extremely valuable in restricting models.

D Meson Simulation at SPD

- For simplicity, we study only reconstructed $D^0 \rightarrow \pi^+ K^-$ for now
- Study with Pythia8 event generator + SpdRoot (detector Geant4) version 4.1.3
- For signal, study open charm processes (gg2ccbar+qqbar2ccbar) at $\sqrt{s} = 27$ GeV in Pythia8 using default (NNPDF23 LO) PDF : $\sigma_{process} = 1.5x10^{-3}$ mb for $\hat{p_T}_{min} = 1$
- For background, study minimum bias events (except elastic) for the same energy. $\sigma_{tot} = 32.8$ mb
- Multiple orders of magnitude higher background (random combination of $\pi^+ K^-$). Requires heavy suppression
- About 1.5 M signal events and 5 million background events

D Meson Reconstruction at SPD

- Secondary vertex reconstruction is done with Kalman Filter based fitting procedure : KFParticle package
- Developed for reconstruction at CBM collaboration
- Sequentially adds (daughter)track KFParticle objects to find their point of closest approach
- Using proper magnetic field, can transport a KFParticle to any point or other KFParticle to calculate χ^2 and distance of closest approach (DCA)
- For reconstruction of secondary decays, calculates invariant mass, decay length etc. of the mother particle

The Basic : Invariant Mass

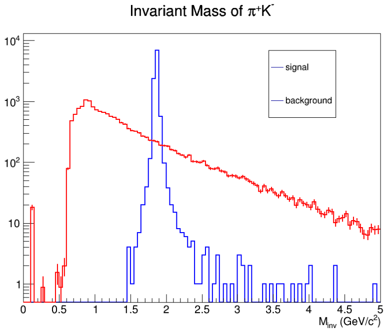

Figure 5: Invariant mass distributions from signal and background

- D0 invariant mass : 1.86 GeV$/c^2$
- For invariant $x_F \geq 0.2$
- From roughly same number of events (scaled), so remember 2.5×10^4 higher background

Comparison of Signal to Background : 1

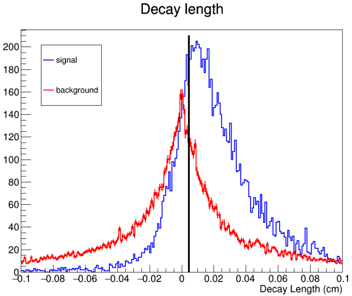

Figure 6: Decay length

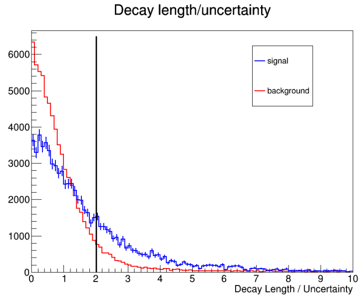

Figure 7: Decay length divided by its uncertainty

Later, cuts applied, $L > 0.005$, $\frac{L}{\delta L} > 2$.

Comparison of Signal to Background : 2

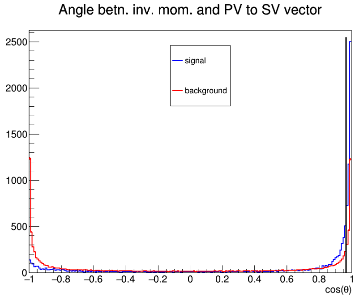

Figure 8: Cosine of the angle between invariant/mother particle and vector from primary to secondary vertex

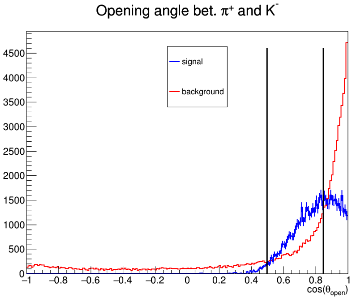

Figure 9: Cosine of opening angle between daughter tracks

Later, cuts applied, $cos(\theta) > 0.97$, $0.5 > cos(\theta_{open}) > 0.85$

Comparison of Signal to Background : 3

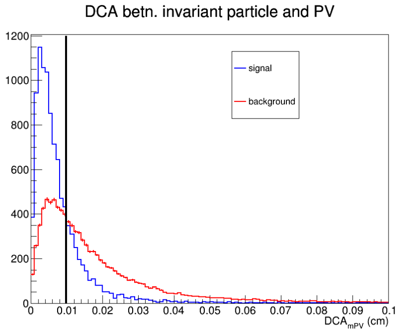

Figure 10: Distance of closest approach between invariant/mother particle and primary vertex

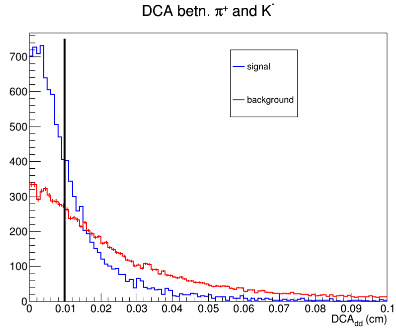

Figure 11: Distance of closest approach between daughter tracks

Later, cuts applied, $DCA_{mPV} < 0.01$, $DCA_{dd} < 0.01$

Comparison of Signal to Background : 4

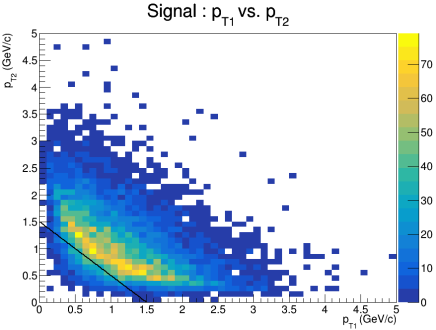

Figure 12: Correlation between transverse momenta of daughter tracks : Signal

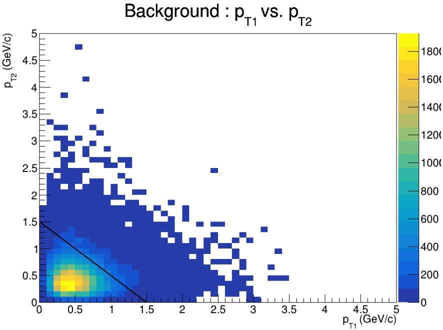

Figure 13: Correlation between transverse momenta of daughter tracks : Background

Best cut so far, $(pT_{\pi^+} + pT_{K^-}) > 1.5$

Effects of Cuts

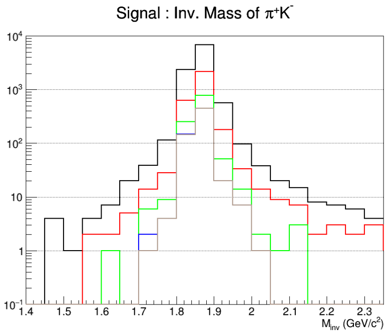

Figure 14: Invariant mass : Signal

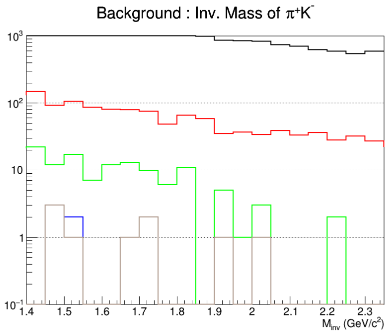

Figure 15: Invariant mass : Background

Need more statistics for background

Effects of Cuts : Comparison

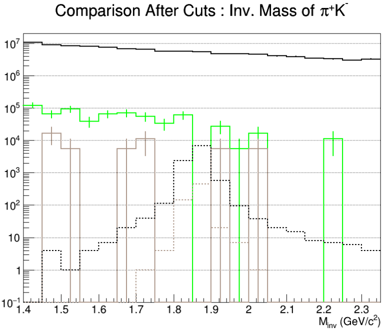

Figure 16: Invariant mass : Signal

Need more statistics for background

- Comparison of properly weighted background and signal in relevant mass window
- Signal reduction : a little more than an order of magnitude
- Background reduction : close to 3 orders of magnitude - requires MUCH more statistics for smooth curve

Signal and Background

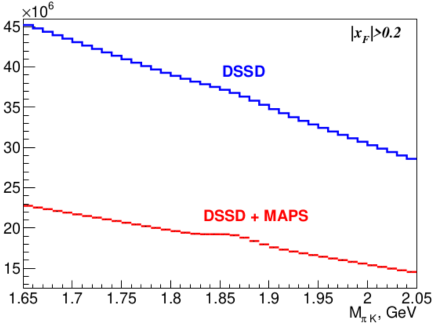

Figure 17: From CDR

- Early estimates presented at CDR with 5 layers of Inner Trackers (different options)
- 96% reduction of signal
- $\sim$ 3 orders of magnitude background suppression
- More realistic and detailed study seems in the ballpark
- May be improved with more careful study

Partonic Kinematic Range in D : 27 GeV

For open charm events with two detected D mesons :

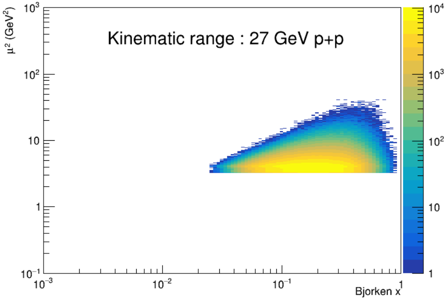

Figure 18: Partonic kinematic coverage for 27 GeV $p + p$ collision at SPD

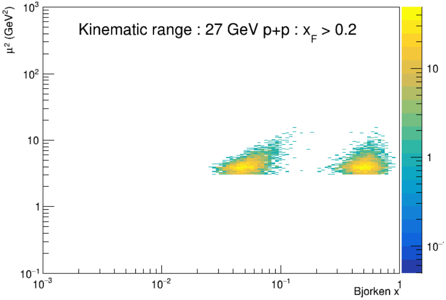

Figure 19: Partonic kinematic coverage for 27 GeV $p + p$ collision at SPD with D mesons above $x_F = 0.2$

energy scale μ^2 is the same as renormalization/factorization scale.
$\mu^2 = \Sigma m_i^2 + p_{T_i}^2$ for scattered partons i

Items Requiring More Study : 1

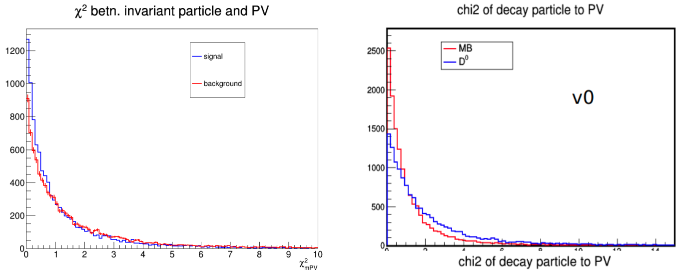

Figure 20: χ^2 between decay particle and primary vertex. Right plot from Vladimir Andreev

- χ^2 too similar for signal and background
- Previously Vladimir Andreev noticed different behaviour in study with early version of SpdRoot
- Requires more careful look at reconstruction algorithm

Items Requiring More Study : 2

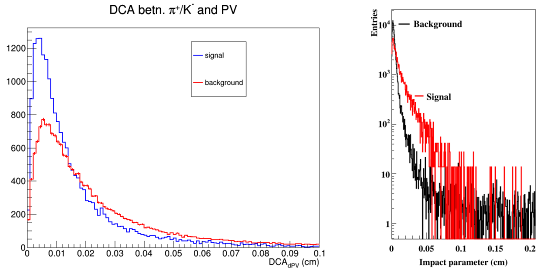

Figure 21: DCA between daughter tracks and primary vertex

- DCA of π/K from primary vertex shows unexpected behaviour
- Background π/K are produced at primary vertex, so expected it to peak at 0
- Notice the right plot from D0 analysis at CBM collaboration (Sergey Gorbunov et al.)

Summary and Outlook

- An important channel at SPD, cross-section will improve unpolarized gluon PDF, asymmetries will reduce model dependence of gluon Sivers
- Ongoing simulation study of the measurement and impact
- Full reconstruction is time consuming (1k events $\sim$ 2.5 hrs) and we need much more statistics for more precise estimate of background reduction
- Software event selection can help background suppression
- Some parts of software requires more careful investigation
- Indications are hopeful for good chamed meson mesurements

Thank You