A Study of Open Charm Production at SPD

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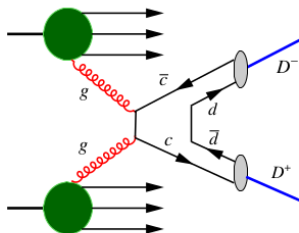
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Dec 15, 2021

Open Charm Productions

- When $c\bar{c}$ form partonic scattering produce two charmed mesons i.e. $D^0\bar{D}^0$, D^+D^-
- Measurements of open charm meson asymmetries can access gluon spin distributions

Open Charm Productions

▶ We are interested in channels : $D^0 \longrightarrow \pi^+ + K^-$ and
$D^+ \longrightarrow \pi^+ + K^- + \pi^+$ and their anti-particle counterparts

▶ Charmed mesons are selected within certain window of reconstructed
invariant mass from daughter particle info

▶ Good PID and momentum reconstructions are requisites for the
reconstructions

▶ Background from random combinations of pions and kaons other
hard scattering processes are very high

▶ Secondary vertex reconstructions with good resolution can be crucial
for background suppression

Open Charm Asymmetries

- As has been measured for other particles at different experiments and different energies, significant SSA are expected in forward x_F region
- Predictions from theoretical calculations from our Samara Univ. colleagues also show that
- However, the asymmetry predictions are heavily model dependent
- Order of magnitude difference between D'Alesio and SIDIS parametrizations
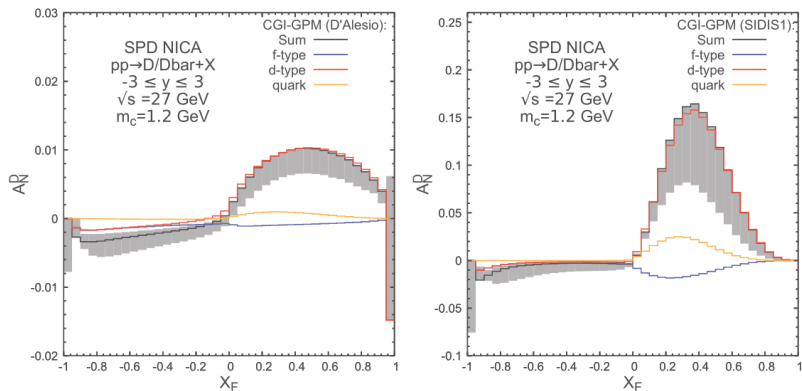- Measurements will be very helpful in understanding

A_N Predictions (for all Open Charm)

Figure: Transverse spin asymmetry predictions : V. Saleev et al.

Pythia Simulations

- Using PYTHIA 8.3, 1 Billion $p + p$ events generated at $\sqrt{s} = 27$ GeV
- Only HardQCD processes switched on (3.46 mb total cross-section in Pythia)
- PDF set : default Pythia (NNPDF2.3 QCD+QED LO, $\alpha_s(M_Z) = 0.130$)
- We consider only $D^+ \longrightarrow K^- \pi^+ \pi^+$ and $D^- \longrightarrow K^+ \pi^- \pi^-$ for detection
- We consider only $D^0 \longrightarrow K^- \pi^+$ and $\bar{D}^0 \longrightarrow K^+ \pi^-$ for detection
- For context : $p + p$ MinBias cross-section at this energy is 39.8 mb and projected integrated luminosity for 1 year is 1 fb^{-1}

Bjorken-x of Interacting Partons

For D^+D^- events :


Bjorken-x of two partons
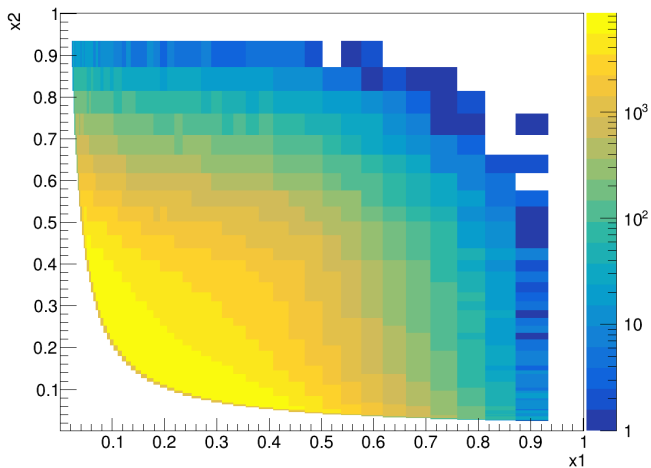
Particle Detection Details

- Momentum smearing $\frac{\delta p}{p} = 0.02 + 0.002|p|$
- Both p_T and p_z smeared, x and y components obtained using azimuthal angle and p_T
- Each daughter particle (charged pions and kaons) $p_T \geq 0.2$ GeV in tracker for decent track reconstruction requirement and $-3 \leq y \leq 3$ for acceptance within SPD
- Particle ID (mass) was assumed to study total production
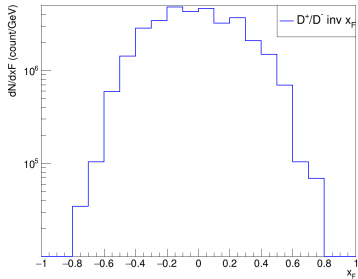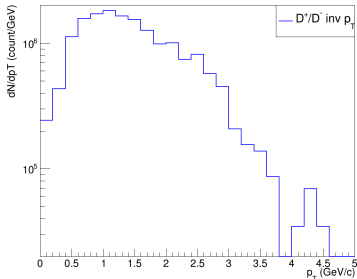
Invariant Mass of Charged D Mesons
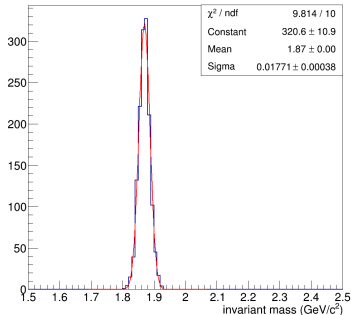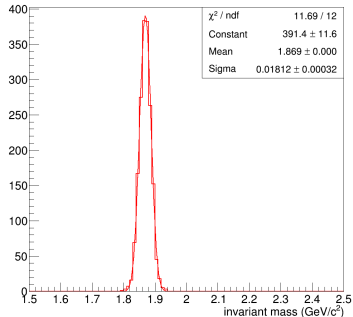
Charged D mesons accepted within $\pm 3\,\sigma$ window around mean value of invariant mass
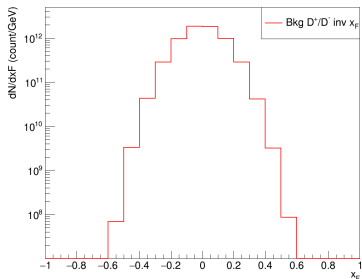
Distribution of Individual Charged D Mesons
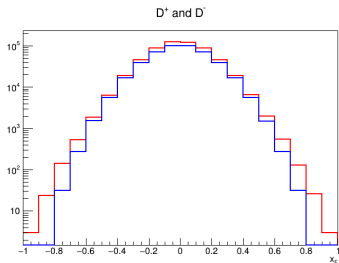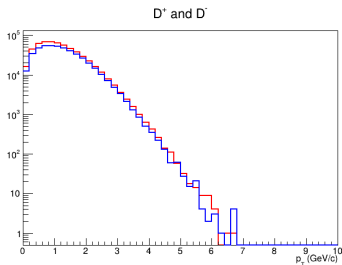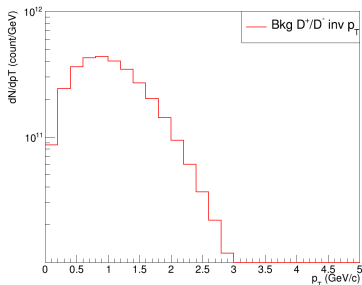

D^+ and D^- p_T and x_F distributions

Distribution of $D^+ D^-$ Invariant Systems

Counts scaled to 1 year of data

Distribution of Background D^+D^-

Counts scaled to 1 year of data. Background distributions seem somewhat narrower but orders of magnitude higher.
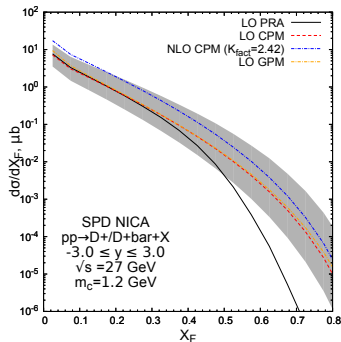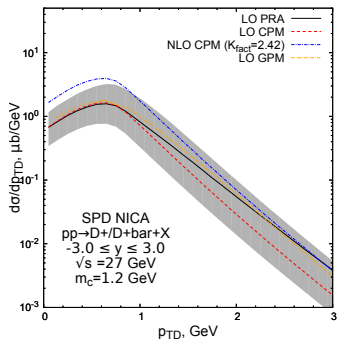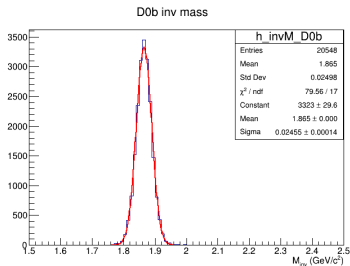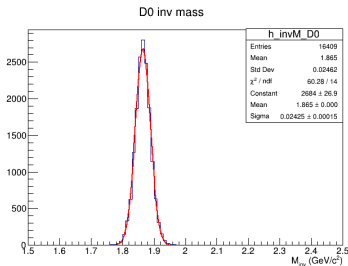
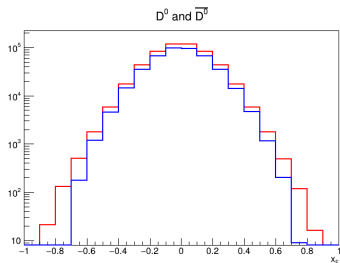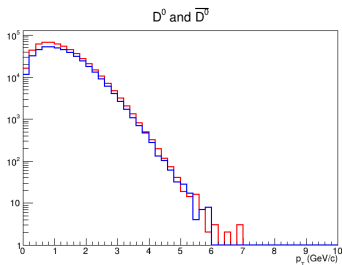# Cross-Section Predictions (for D^+D^- Pairs)

Figure: D^+D^- vs p_T : A. Karpishkov   Figure: D^+D^- vs x_F : A. Karpishkov

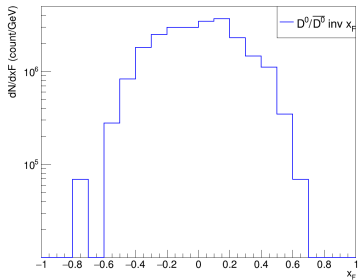# Invariant Mass of Neutral D Mesons
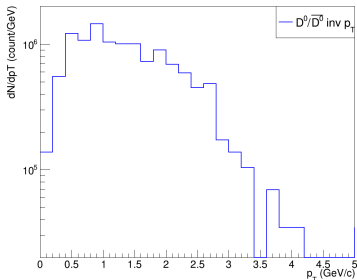

Neutral D mesons accepted within $\pm 3\ \sigma$ window around mean value of invariant mass

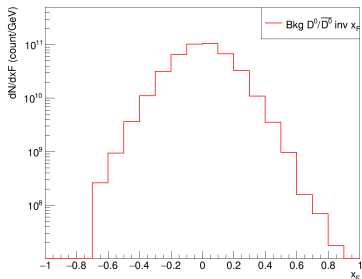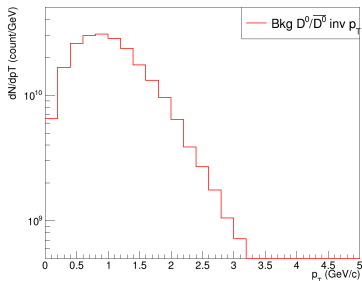# Distribution of Individual Neutral D Mesons

D^0 and $\bar{D}^0$ p_T and x_F distributions

Distribution of $D^0\bar{D}^0$ Invariant Systems

Counts scaled to 1 year of data

Distribution of Background $D^0\bar{D}^0$

Counts scaled to 1 year of data. Background distributions orders of magnitude higher.

Cross-Section Predictions (for $D^0\bar{D}^0$ Pairs)
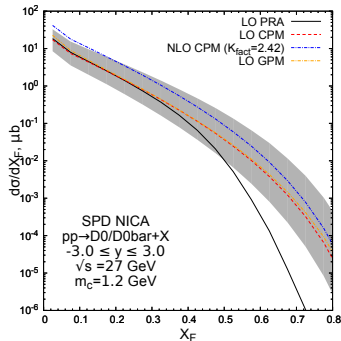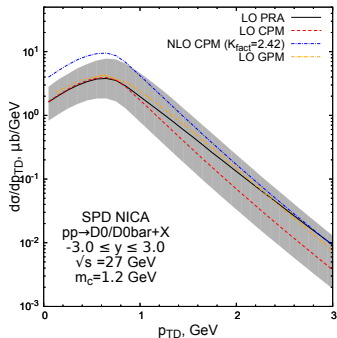

Figure: $D^0\bar{D}^0$ vs p_T : A. Karpishkov

Figure: $D^0\bar{D}^0$ vs x_F : A. Karpishkov

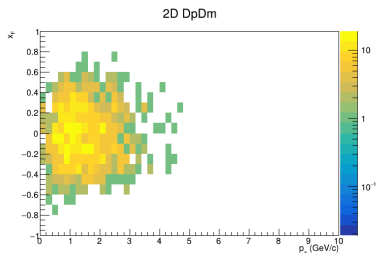# D Meson Pairs Kinematic Distributions
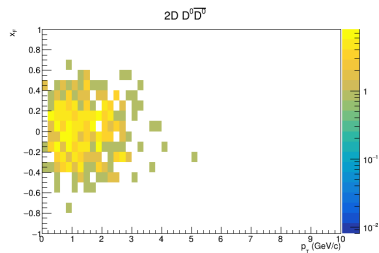

Figure: D^+D^- pairs : unscaled counts

Figure: $D^0\bar{D}^0$ pairs : unscaled counts

Some Numbers

- Using PYTHIA 8.3, 1 Billion $p + p$ HardQCD events generated at $\sqrt{s} = 27$ GeV
- Among them 509232 $D^0 \bar{D}^0$ and 145330 $D^+ D^-$ events
- About 4.4% of $D^+ D^-$ and 12% $D^0 \bar{D}^0$ are from higher resonances (D^* decays)
- $D^+ \longrightarrow K^- \pi^+ \pi^+$ branching fraction $\sim 9.38\%$ (PDG value 9.22%)
- Both of the pair should decay through this channel for us to be able to detect $\sim 0.88\%$ of the produced $D^+ D^-$ pairs
- $D^0 \longrightarrow K^- \pi^+$ branching fraction $\sim 3.82\%$ (PDG value 3.89%)
- Both of the pair should decay through this channel for us to be able to detect $\sim 0.15\%$ of the produced $D^0 \bar{D}^0$ pairs

Outlook

- ▶ An extremely challenging measurement due to very high background
- ▶ Two techniques can directly help in background suppression
- ▶ 1) Event selection that can record events with charmed mesons with high likelihood
- ▶ A very difficult task for the online event selection - ML techniques might help
- ▶ 2) Secondary vertex reconstruction with high precision (decay length for these charmed mesons $100 - 300$ μm) can be crucial in meaningful measurements at SPD
- ▶ Of course this is probably more relevant for the later stage of upgrades at SPD

Thank You