Measurements of D Mesons at SPD : Updates

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Open Charm Productions

- Inner tracker and endcaps
- PID limitations and requirements
- Secondary vertex reconstruction resolution
- Expected signal to background

Inner Tracker Changes

- Still two open options : DSSD and MAPS
- DSSD : 3 layers + endcaps
- MAPS : 4 layers no endcap
- Material budget was underrepresented so far, Igor Denisenko made recent changes to address that
- Layer positions, ladder sizes also modified
- First layer of vertex detector now starts at 4 cm from beam line
- SpdRoot wiki has instructions how to choose one or the other option for the vertex detector under 'Simulation'

SPD PID Capabilities and Limitations

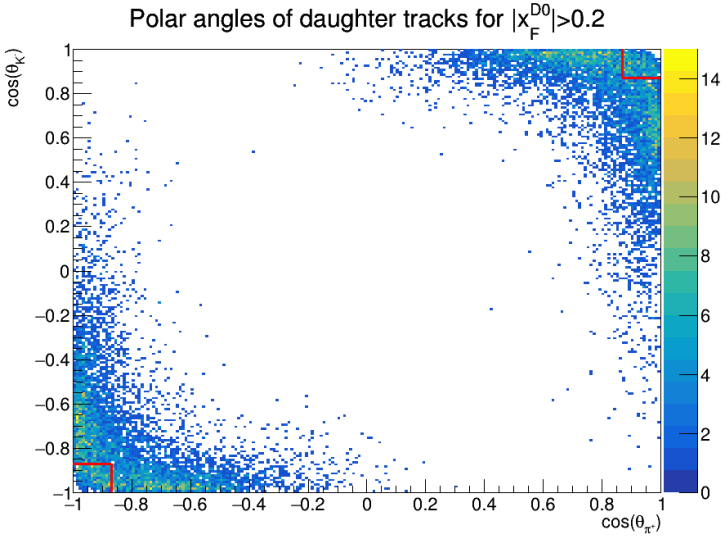


Figure 1: Cosine of polar angles for pions and kaons from D0 decays. Red boxes represent both daughter tracks going to endcap

- SPD π/K separation :
- STRAW+TOF : up to 1.5 GeV/c
- Aerogel : up to 2.5 GeV/c
- However, AGel is only in the endcaps (red box zones)
- Left : plot for cosine of daughter track polar angles : Alexander Korzenev probably wanted to see this distribution
- Significant fraction of the D0 will have one or both of the daughter tracks in barrel where PID for tracks is limited to 1.5 GeV/c

Track Distribution vs. x_F^{D0}

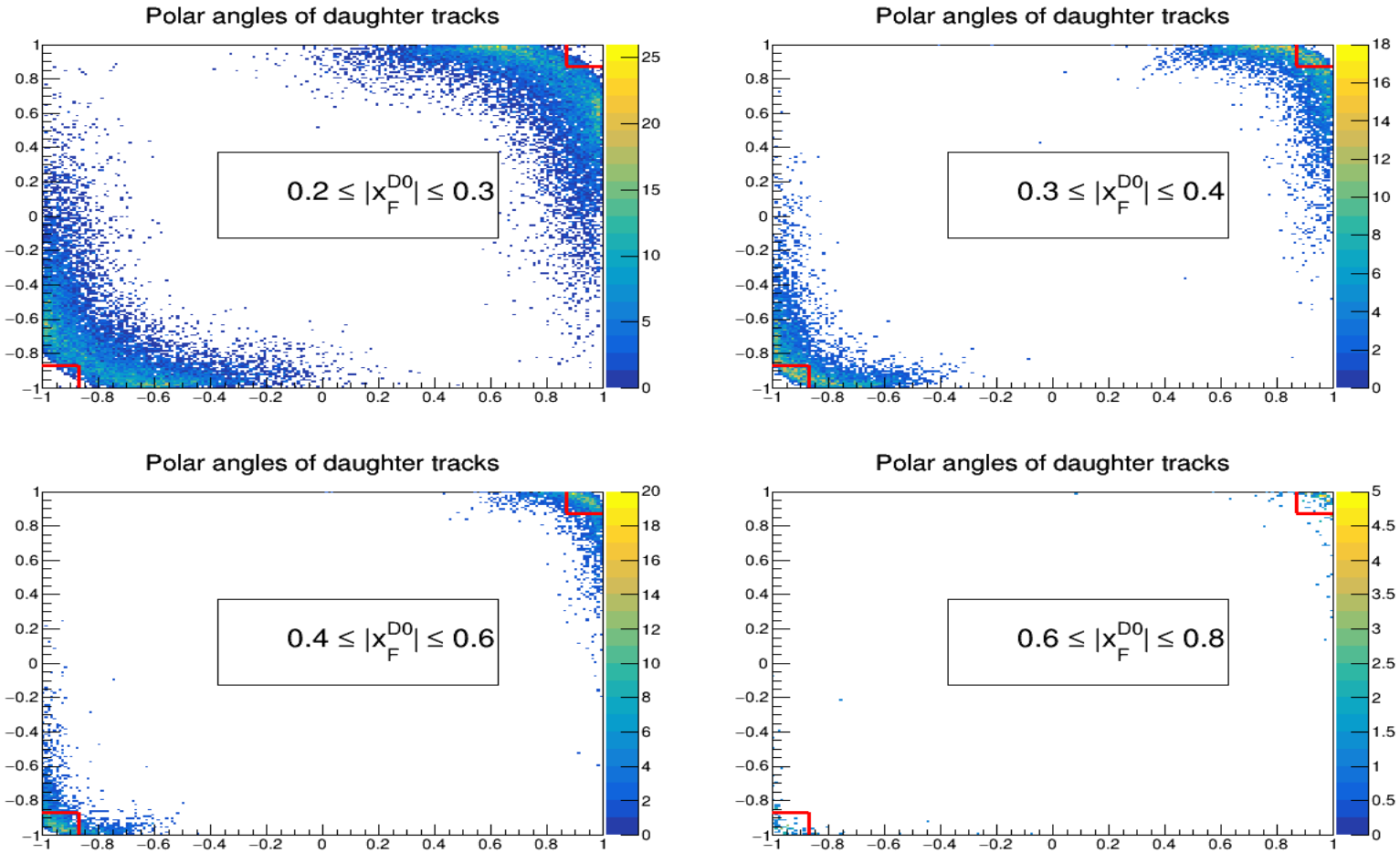


Figure 2: Polar angle distribution of daughter tracks of D0 as function of Feynman-x

Need for More PID Capabilities

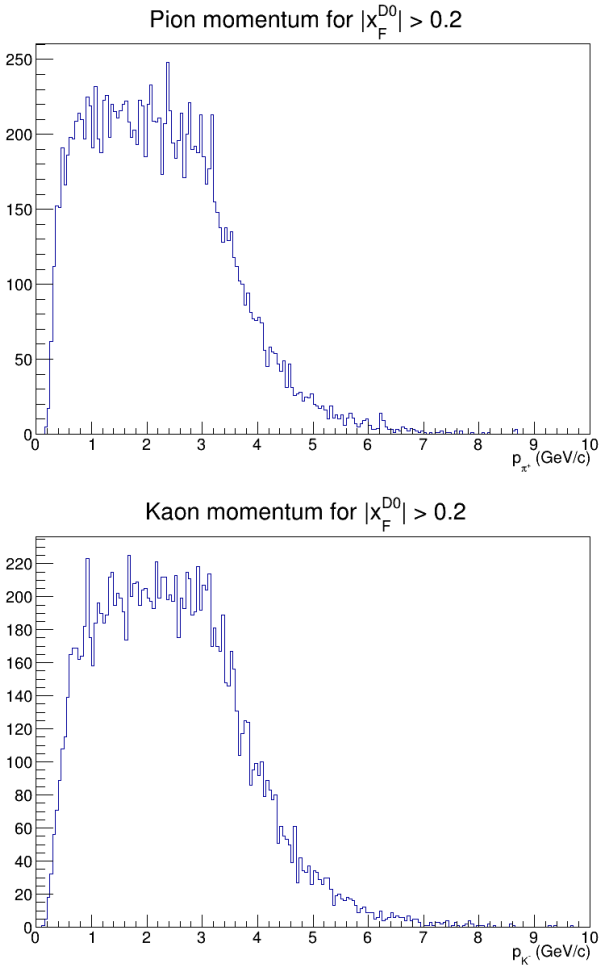


Figure 3: Pion (above) and Kaon (below) momentum for $x_F^{D0} > 0.2$

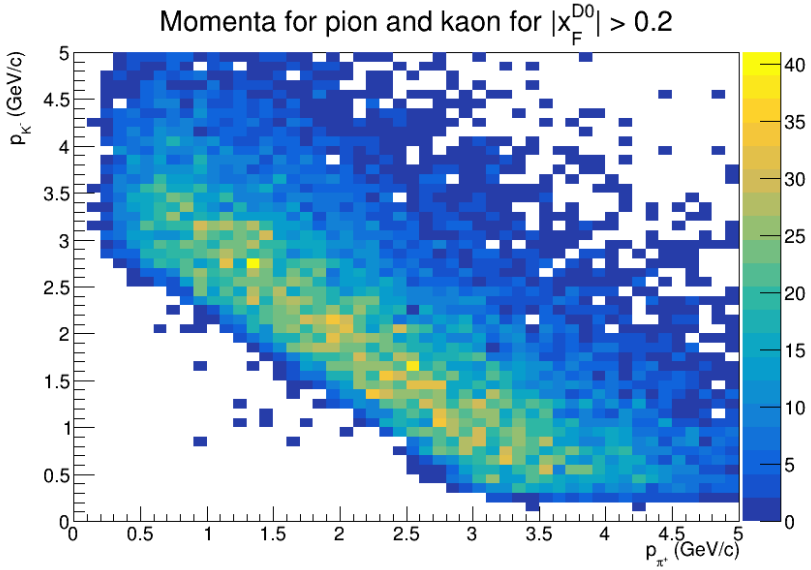


Figure 4: 2D distribution of D0 daughter particles momenta

Notice that majority of each particle are above 1.5 GeV/c
We need better PID capability in the barrel part of the detector

Secondary Vertex Resolution

- With improved and more realistic configurations of the inner tracker/vertex detector, we need to look at resolution of secondary vertex reconstruction
- For detailed changes to Vertex Detector, see Igor's presentation
- Two methods tested for vertex reconstruction
  1. Iterative reconstruction using reconstructed tracks and particle hypothesis (can be obtained from PID detectors). Same technique as used for primary vertex finding
  2. Decay particle reconstruction using KFParticle package (also require PIDs)
- The need for particle hypothesis stresses the need for the best possible PID capability in both the endcaps and the barrel part of the detector
- We do this for both DSSD and MAPS configurations

Iterative Vertex Fit : x-dir

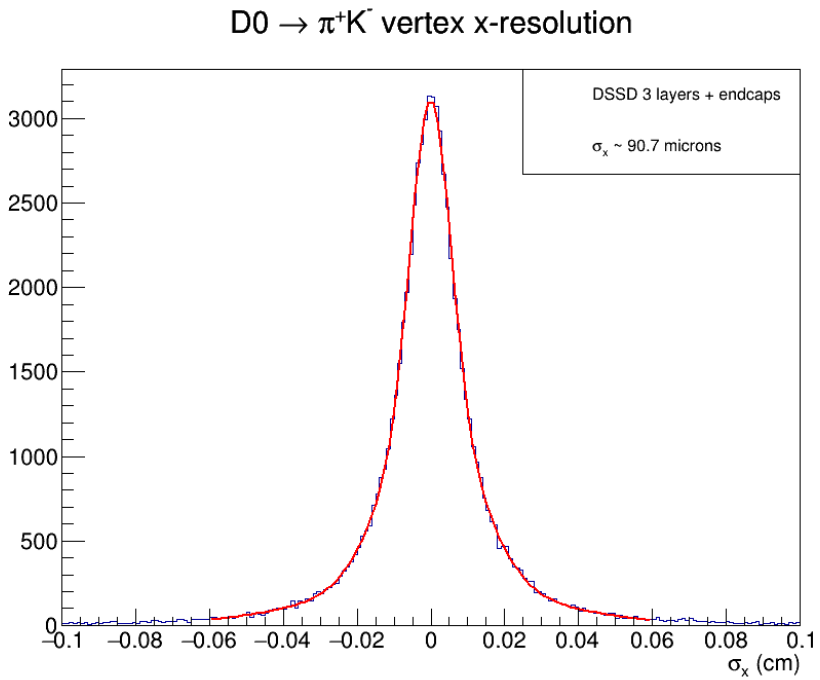


Figure 5: DSSD : $\sigma_x \sim 91\ \mu$

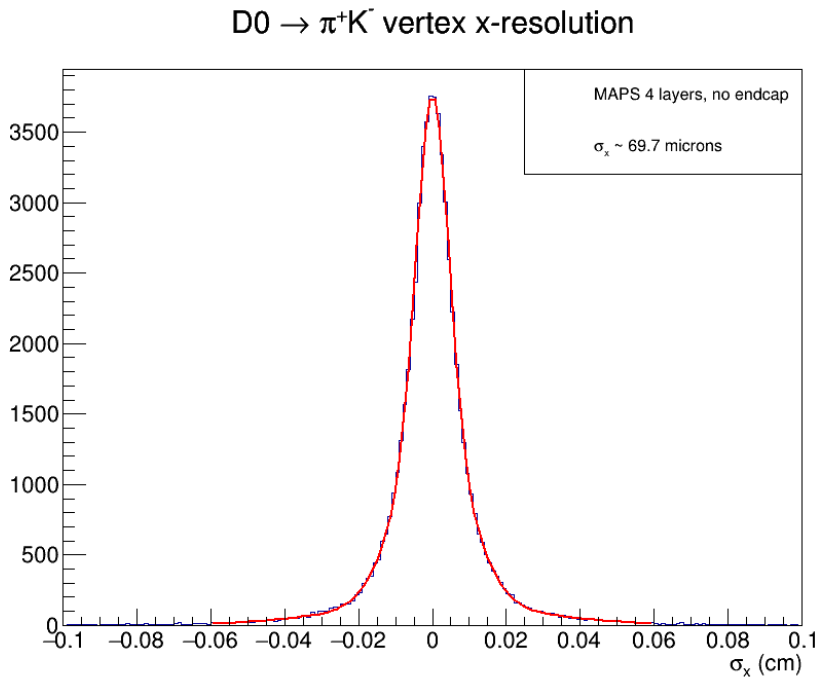


Figure 6: MAPS : $\sigma_x \sim 70\ \mu$

Multi-gaussian fits, effective resolution shown

MAPS outperforms DSSD by $\sim 30\%$

D0 decay-length $\sim 120\ \mu$

Iterative Vertex Fit : z-dir

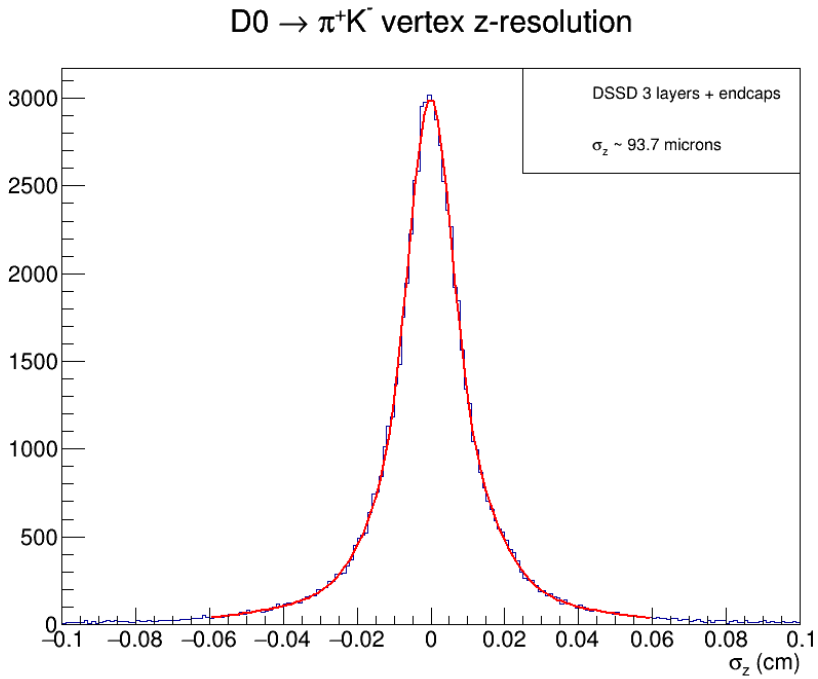


Figure 7: DSSD : $\sigma_z \sim 94\ \mu$

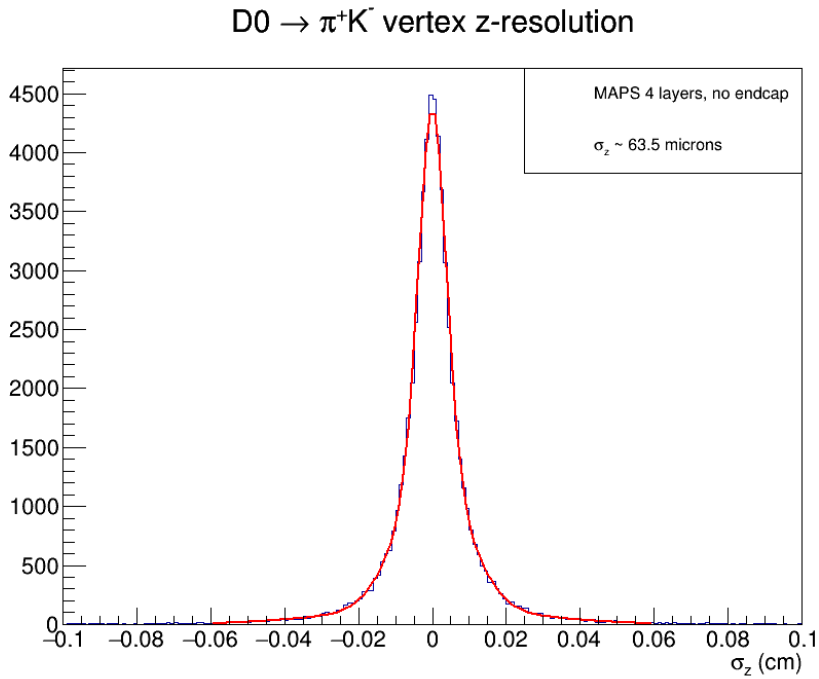


Figure 8: MAPS : $\sigma_z \sim 64\ \mu$

MAPS outperforms DSSD by $\sim 47\%$

D0 decay-length $\sim 120\ \mu$

KFParticle Reconstruction : z-dir

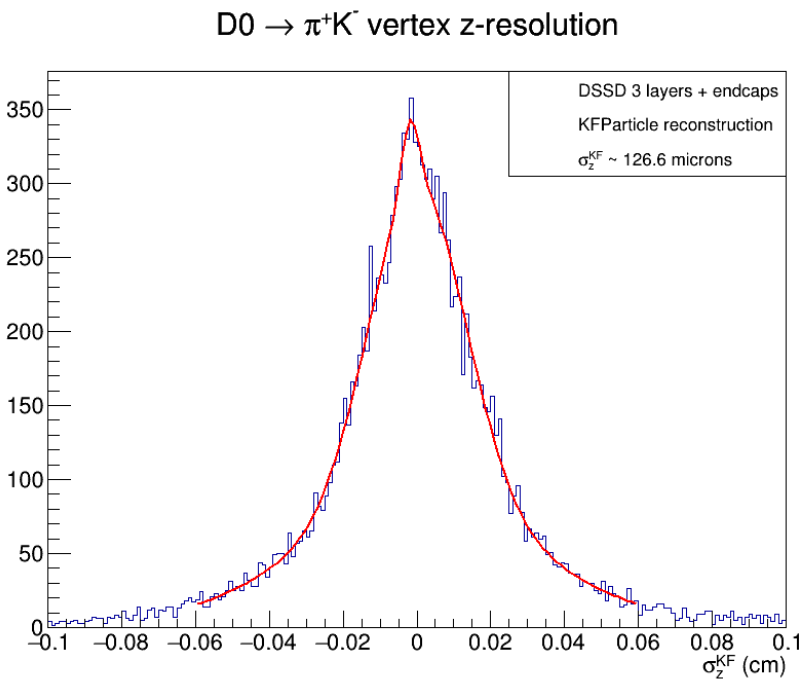


Figure 9: DSSD : $\sigma_z \sim 127\ \mu$

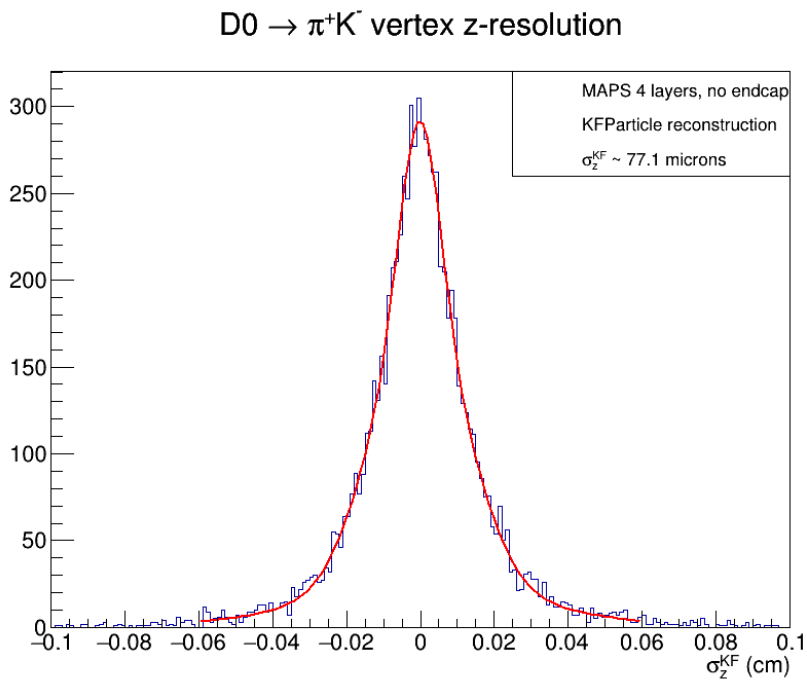


Figure 10: MAPS : $\sigma_z \sim 77\ \mu$

KFParticle reconstruction worse by $\sim 35\%$ for DSSD and $\sim 20\%$ for MAPS

Moreover, DSSD resolution is same as D0 decay-length

Dependence of Resolution on Primary Vertex Position

- Ideally, we require the proton bunches to have $\sigma_z \sim 30$ cm
- During collaboration meeting, collider group mentioned much longer bunches ($\sigma_z \sim 1$ m)
- Started looking at the dependence of the secondary vertex resolution on primary vertex (z-)position
- First look : for ideal case $\sigma_z \sim 30$ cm

Dependence of Resolution on Primary Vertex Position

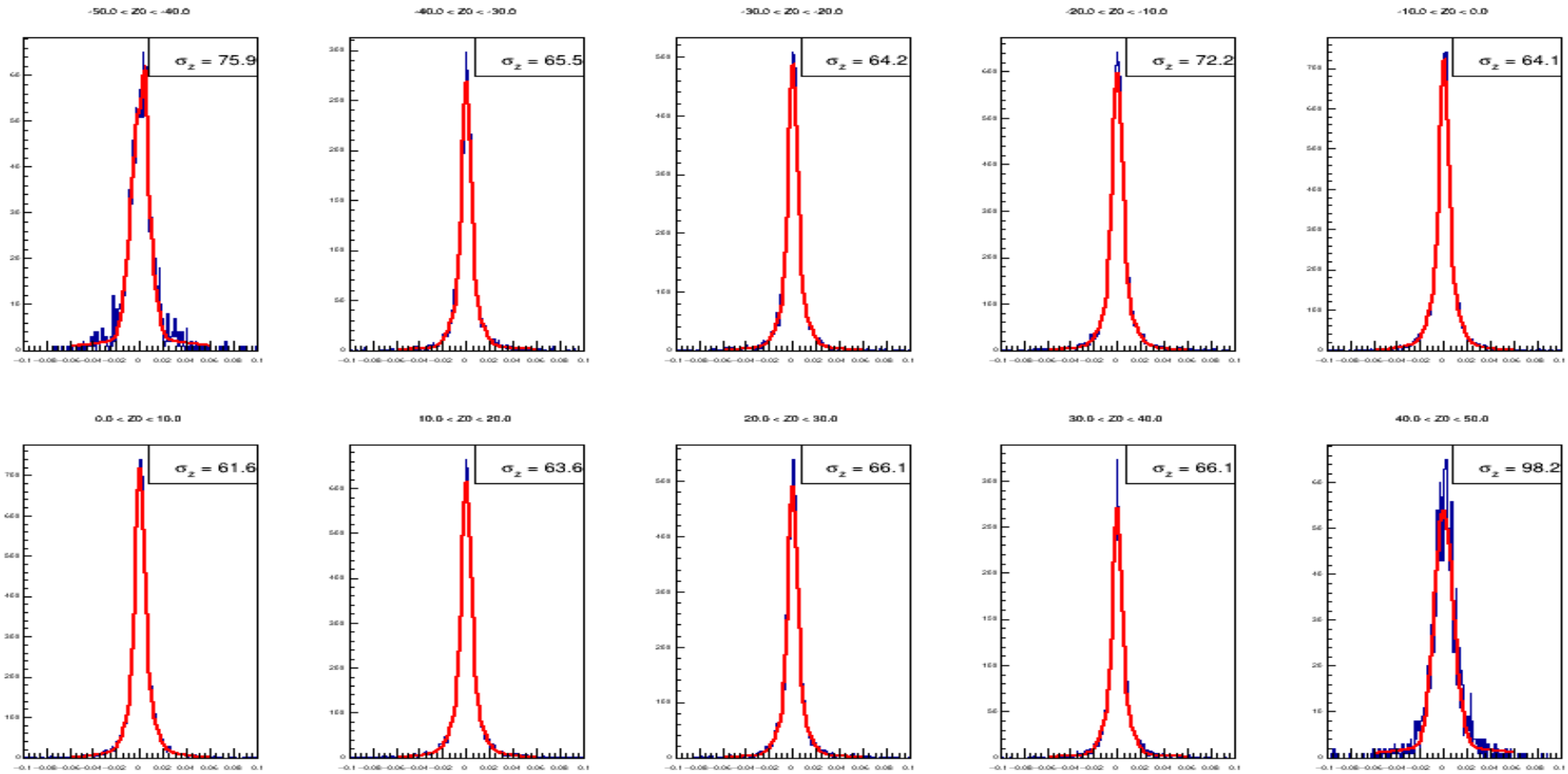


Figure 11: For MAPS, D0 vertex z-resolution in bins of primary vertez Z0

Analysis Cuts for Background Suppression

Looking at comparison of variables (ref. presentation at Collabroation Meeting), cuts are applied to keep as much signal as posisble while suppressing background ($\sim 2.5 \times 10^4$ times more) :

- $L \geq 0.005$ cm, $\frac{L}{\delta L} \geq 2$
- $cos(A) \geq 0.97$, $0.5 \leq cos(\theta_{open}) \leq 0.85$, A is angle between invariant particle momentum and vector from PV to SV
- DCA of invariant particle to PV ≤ 0.01 cm, DCA between two daughters ≤ 0.01 cm
- $p_T^{\pi^+} + p_T^{K^-} \geq 1.5$ GeV/c

Effects of Cuts : Comparison : Last Shown

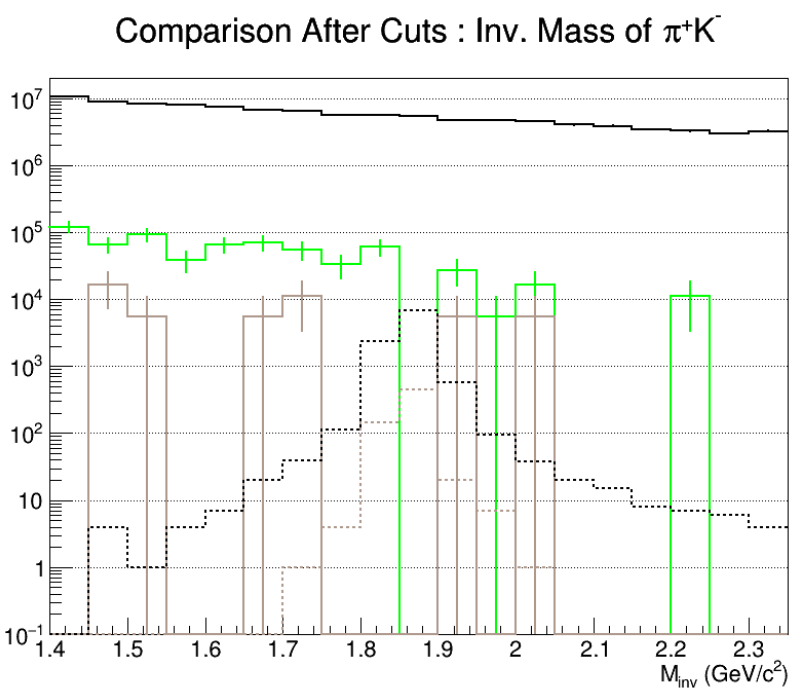


Figure 12: Invariant mass : Signal

- Signal and Background shown at Collaboration Meeting
- Needed more statistics for background simulation for reliable plot
- Increased statistics since then, HOWEVER :
- This was done with old DSSD config and spdroot 4.1.3
- Need to redo the analysis for new MAPS and with spdroot 4.1.3
- A problem with magnetic field

Reconstruction Time and Magnetic Field

- Magnetic field prescribed in SimuQslPy8.C in spdroot 4.1.3 is a detailed map, a close alternate is a constant field with $B_z = 11$ kG (1.1 T)
- Reconstruction time for tracks with these two options are significantly different. Detailed map takes ~ 2.7 times longer
- Estimate : 1000 event processing takes 2 hr 15 minutes
- With about 240 nodes on lxpub, about 1 M events per day
- Plots next slide include ~ 21 million bakground (minbias) events : just over two weeks of simulation
- The new magnetic field may blow the project to over a month and half
- I am sticking to const. field for now, but we need to look at why the new mag. field makes so much difference

Effects of Cuts : Background

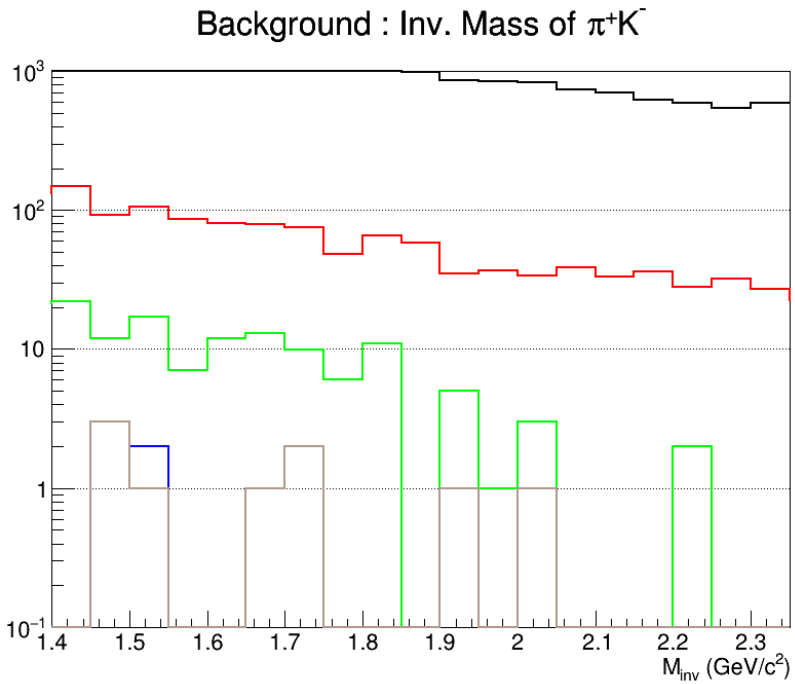


Figure 13: Background shown in Collabortaion Meeting

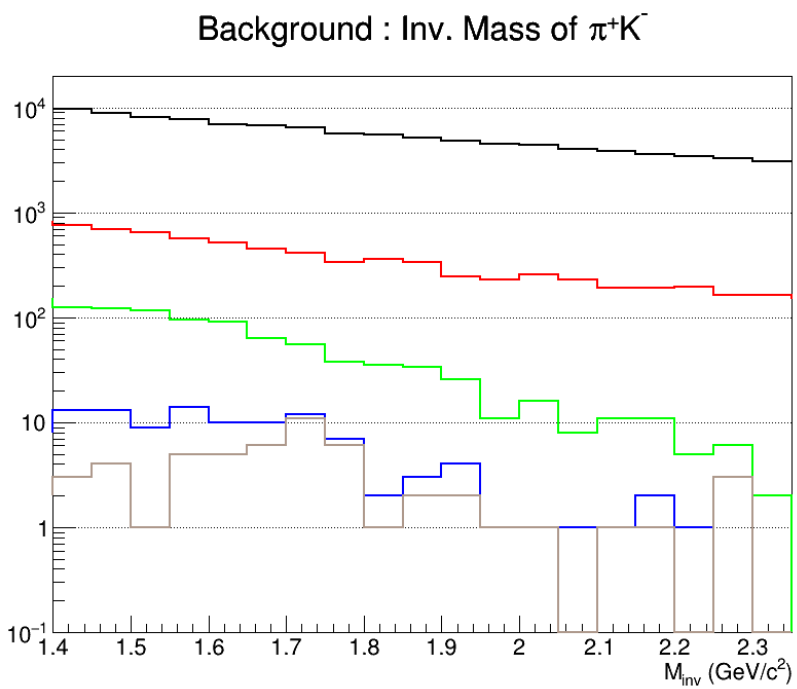
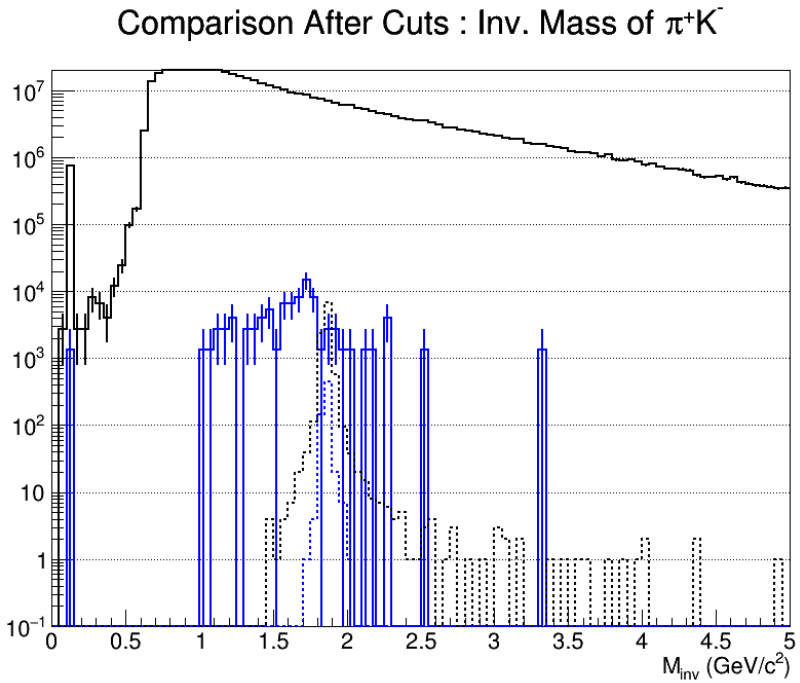


Figure 14: Background now : 10 times more statistics

Effects of Cuts : Signal and Background Comparison



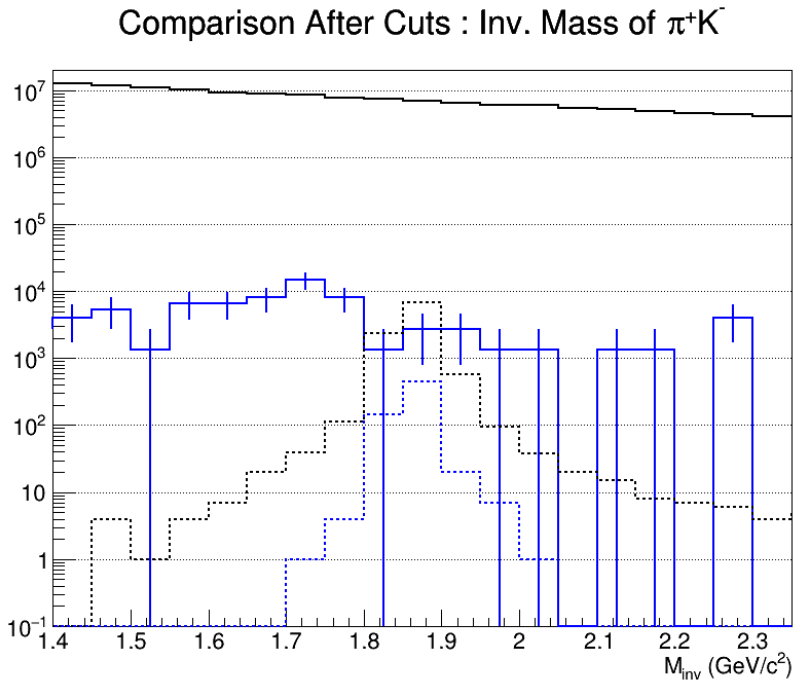


Figure 15: D0 : signal and background

Figure 16: D0 : signal and background

Background reduced by 3.5 orders of magnitude

Summary and Outlook : 1

- Time is a major factor for large scale realistic simulation
- Require at least 100 times more statistics for background to realistically look at S to B in individual xF or pT bins
- Plan to access SLURM batch queue : NEED spdroot 4.1.4 in /cvmfs area for sl6 (currently only for Centos 7)
- About 30 % of the D0 survive the KFParticle reconstruction after track quality cuts for DSSD for $x_F^{D0} \geq 0.2$
- For MAPS, it might be an even smaller fraction without endcaps
- At a crude estimate, with ideal PID, in one year of data at stage II, 360M D0 will be produced and we might be able to detect 300k (accounting for BR, reco. eff. etc.)
- The number will decrease because of real detector PID

Summary and Outlook : 2

- Vertex reconstruction algorithm might need a revisit (see Igor's talk) - performance study, efficiency etc. (Vladimir Andreev?)
- Need to look at depndence of secondary vertex resolution on PV z-position for longer proton bunches (will try the extreme 1 m width next)
- We NEED as good PID capabilities as possible for SPD stage II for meaningful charm-meson measurements
- Also the best vertex tracker posisble. Right now, DSSD shows resolution close to the D0 decay length
- Any chance of MAPS with endcaps and AGel in barrel?

Thank You