Impact of SVD Design on the D^0 Asymmetry Measurements

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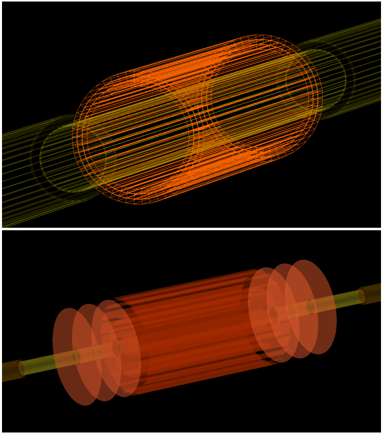
May 24, 2024

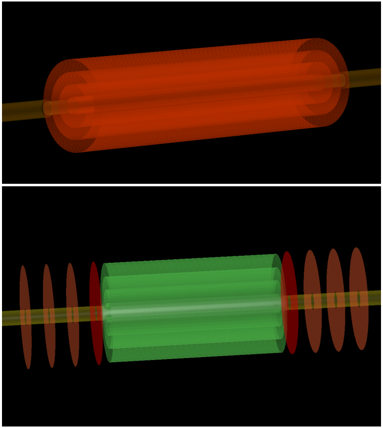
Vertex Detector Configurations

- MicroMegas : 1 (super)layer barrel, barrel z-length = 90 cm, layer thickness $\sim 1120\ \mu$m ($3 \times 0.4\%\ X_0$ in Si, $X_0 = 9.37$ cm)
- DSSD : 3 layer barrel + 3 layers endcap, barrel z-length 74 cm, layer thickness 500 μm ($\sim 0.53\%\ X_0$)
- MAPS TDR config : 4 layers in barrel, z-length 150 cm, layer thickness 750 μm ($\sim 0.8\%\ X_0$)
- MAPS 'wishlist' config : 4 layers barrel + 4 layer endcap, barrel z-length 74 cm, layer thickness 330 μm ($\sim 0.35\%\ X_0$)

Possible Inner Tracker Configurations

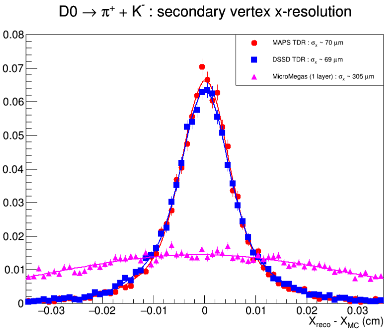


MicroMegas (above) and DSSD (below) TDR configurations

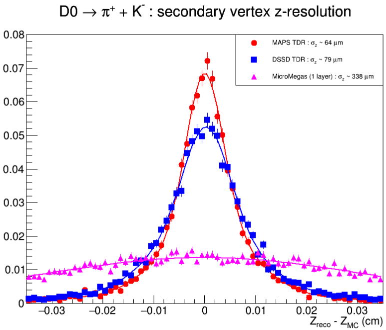


MAPS : TDR (above) and 'wishlist' (below) configurations

Sec Vtx Res Comparison : TDR Options for VD



VD resolutions : x-direction



VD resolutions : z-direction

$\sim$ 20% better Z-resolution for MAPS compared to DSSD, both TDR configurations.

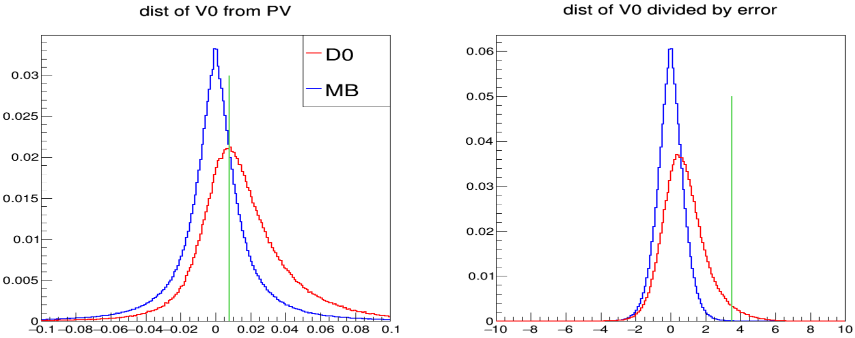
Studies So Far

- Performance of MAPS based SVD in fair detail : expected statistical uncertainties of TSSA measurements D^0 and D^+ projected for one year of recorded data
- Detailed analysis note available at : https://indico.jinr.ru/event/4594/ (will be updated with new studies) - *we can now store SPD analysis notes on Indico*
- It is probably more likely we might end up with DSSD as SVD (or in the worse case scenario, keep the same MicroMegas in stage II)
- Here presented : a comparison of performance (D^0 stat. errors) of different configurtaions of the silicon vertex detector in charmed meson asymmetry measurements

Simulation Scheme

- Pythia8 + SpdRoot
- Signal : Open-charm process : $D^0 \rightarrow \pi^+ K^-$ forced
- Background : Minimum Bias : elastic not included
- Event vertex Z : Gaussian profile with $\sigma_z = 30$ cm
- KFParticle to reconstruct secondary vertex (D^0) from daughter particle candidate pairs (π^+, K^-)
- 4-5 million signal (open-charm) events and 40-50 million background (min-bias) events were generated for EACH of the results (offline production, PLEASE!) - this is inefficient

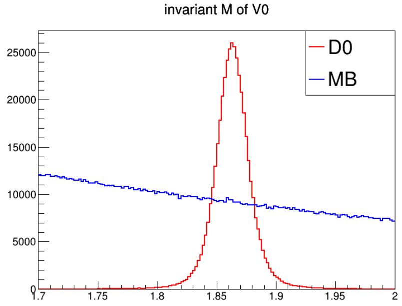
The Best Discriminator

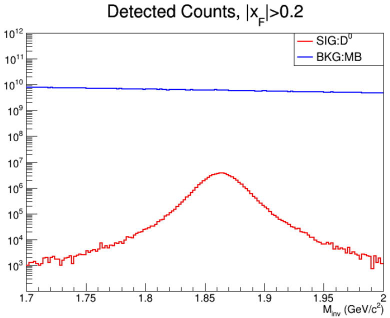


Decay length (left) and decay length divided by its uncertainty (notice the cut retains only a small fraction of the signal but also reduces the background drastically)

In a similar way distance (DCA) and χ^2 from reconstructucted secondary vertices are also useful

Invariant Mass Spectra : Raw

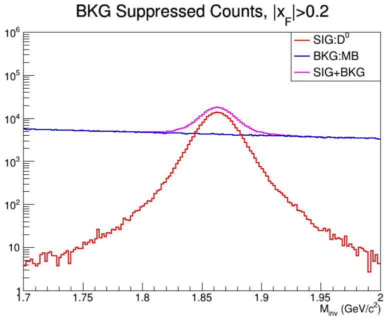




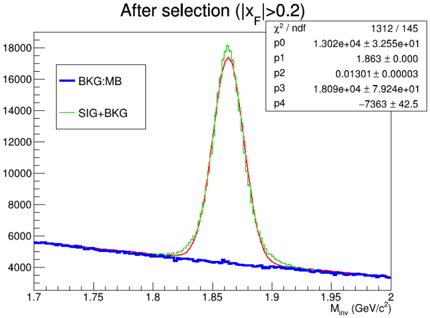
Reconstructed from simulations

Projected for one year of recorded data

Invariant Mass Spectra : After Selections

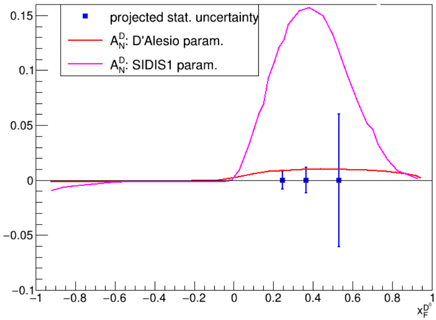


Projected for one year of recorded data

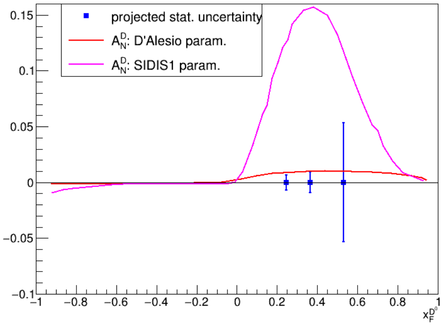


Fit (Gaussian signal + linear background) to the invariant mass spectra projected for one year of recorded data

Statistical Uncertainties : DSSD and MAPS



DSSD



MAPS

Details of the calculation of statistical uncertainties prented in the last collaboration meeting (an in the analysis note)

Similar performances : MAPS 15 – 20 % better

Comparison of DSSD to MAPS Performances

Statistical uncertainties : MAPS and DSSD

- x_F (0.2 - 0.3) : 0.00676, 0.00808
- x_F (0.3 - 0.5) : 0.00938, 0.01173
- x_F (0.5 - 1.0) : 0.05325, 0.06031

Cut efficiencies for the MAPS and DSSD :

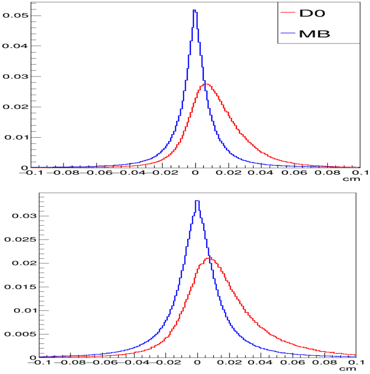
- signal : 0.00825, 0.00368 (we retain less than a per cent)
- background : $5.92x10^{-6}$, $7.02x10^{-7}$

MAPS in fact allowed for even tighter cut ($L/\delta L > 4$) and therefore, better background suppression, but DSSD did not (with limited simulation statistics), comparison used ($L/\delta L > 3.5$) for both

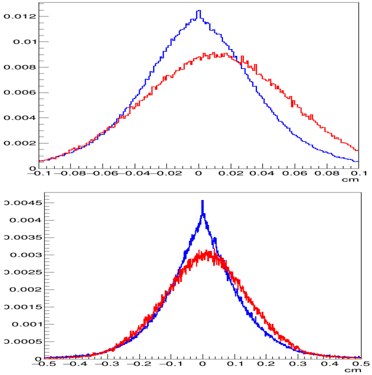
Without-SVD or MicroMegas

Absence of silicon vertex detector or the presence of the MicroMegas ($300 - 350$ μm secondary vertex position resolution) completely ruins the biggest discriminators between the intended signal and the combinatorial background (D^0 decay length ~ 110 μm)

Comparison of Decay Length Distributions



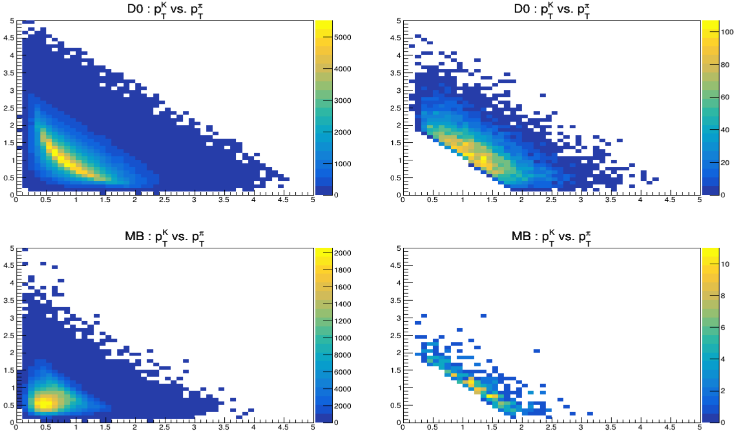
MAPS(above), DSSD(below)



MicroMegas(above), no SVD(below)

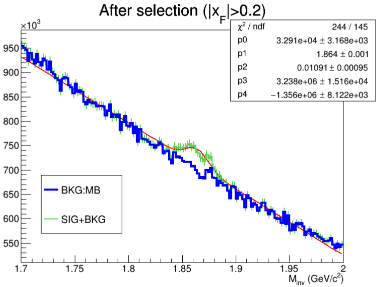
notice how the distrbutions becomes wider and distinctions go away

Most Powerful Discriminator for Bad SVD

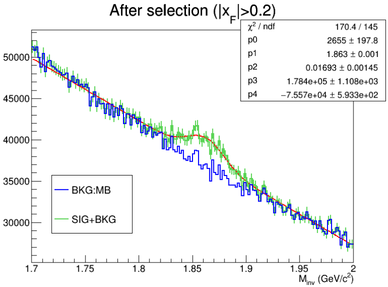


Correlation of pion and kaon transverse momenta

Challenge of Background Suppression with Poor SVD

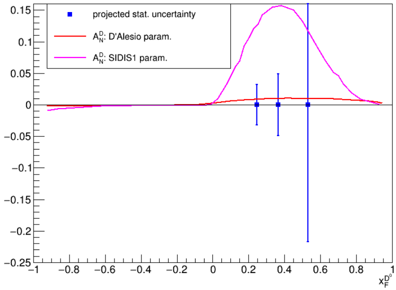


Fit to the invariant mass spectra after selections for Micromegas SVD

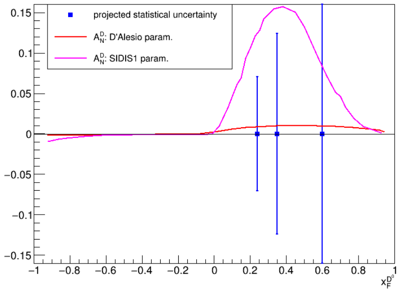


Fit to the invariant mass spectra after selections for No SVD

Leads to Poor quality Asymmetry Measurements



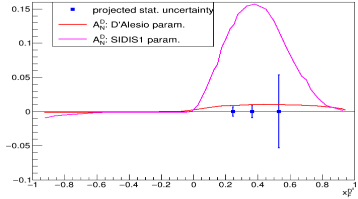
Projected statistical uncertainties of D^0 A_N for Micromegas SVD

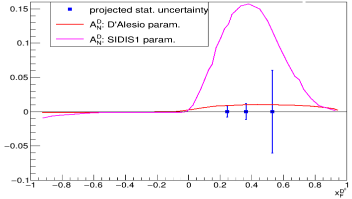


Projected statistical uncertainties of D^0 A_N for one year of data for No SVD case

Relative Performances of Different SCD Scenario

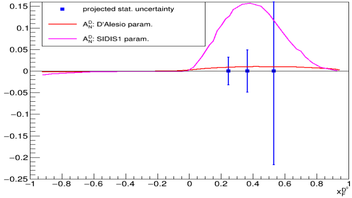
MAPS

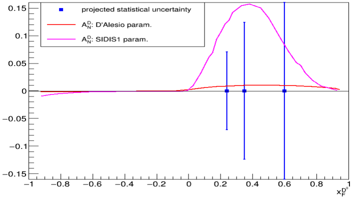




DSSD

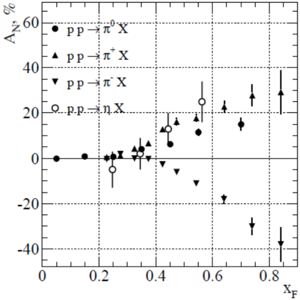
MicroMegas

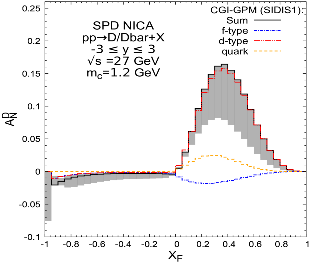


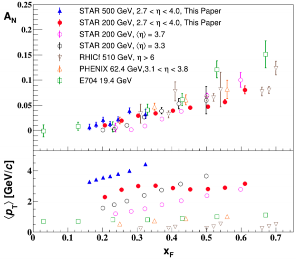


No SVD

A Side Note About x_F Range







- We have been quoting $x_F \sim 0.2$ as when A_N is expected to be relevant, but that is an after-effect of looking at pion A_N plots
- Our Samara colleagues tell us for D mesons, appreciable A_N probably starts at just +ve x_F i.e. left bottom plot

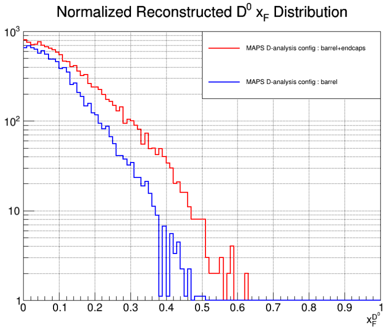
Summary

- High quality silicon vertex detector is essential for D-meosn decay reconstruction - SVD helps suppress random background
- MAPS performs better ($15 - 20\%$) than DSSD (TDR configs)
- Demonstrated before that a MAPS based SVD similar to DSSD geometry (shorter barrel and with end-caps) performs better than MAPS TDR config. and has better x_F coverage (with longer - 40 cm or longer - bunch shape, need to test)
- May be we should start binning x_F even less than 0.2 for charmed mesons transverse single spin asymmetries (TSSA)

Thank You

Backup

Vertex Detector : Importance of EndCaps



Reconstructed $x_F^{D^0}$ with and without Endcaps

- 'Wishlist' MAPS configuration : 4 barrel layers, 4 endcap layers, barrel layer z-length 74 cm, layer thickness 330 μm
- x_F distribution of reconstructed D^0 shows more counts with endcaps
- Factor of 2-3 gain at $x_F = 0.2, 0.3, 0.4$
- Further reach in x_F as well