# Update on $D^0$->$K^-\pi^+$ with hybrid approach

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# Towards quantitative estimates

- Need to estimate significance and back rejection improvement expected in data (what has been done is not from a MB MC sample)
- S,B = signal, background per event
  - for a given set of cut
- $\varepsilon = D^0$ efficiency, from charm enriched sample -> from Correction Framework & Hybrid approach (ongoing, feasible)
- $S_{corrected} = S/\varepsilon$ per event
- in many cases extrapolation, assumptions are needed
  - e.g. $R_{AA}$ below 2 GeV/c

Too poor stat. analysed from the MB sample
→Use the charm enriched sample
→ Not too big a bias since we then scale to data

not trivial it's 1

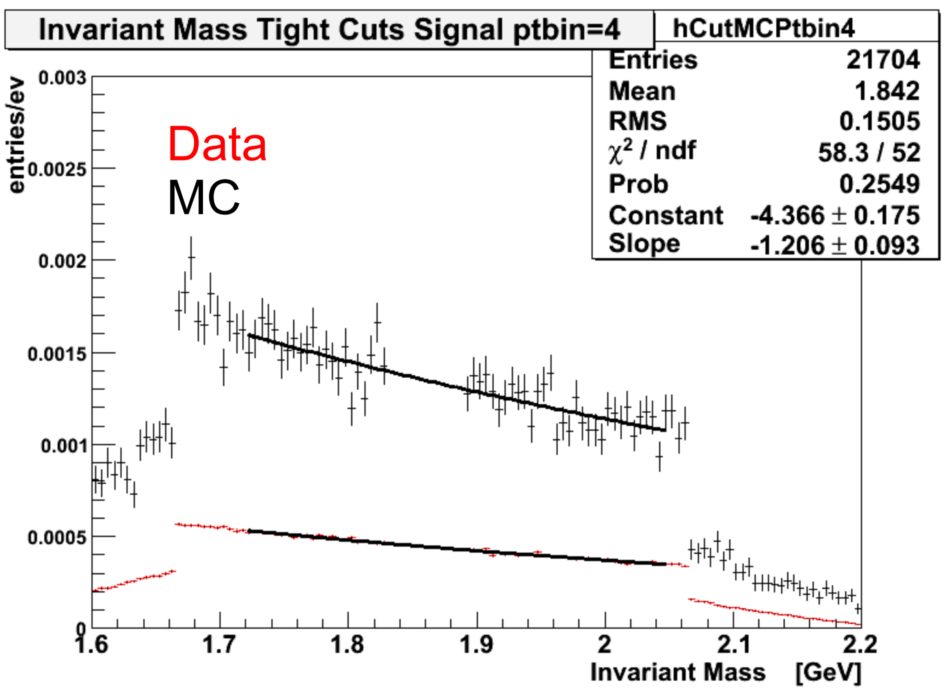
$$B_{ITSupg} = B^{MB\ MC}_{ITSupg} \times \frac{B^{data2010}_{ITScur}}{B^{MB\ MC}_{ITScur}}$$

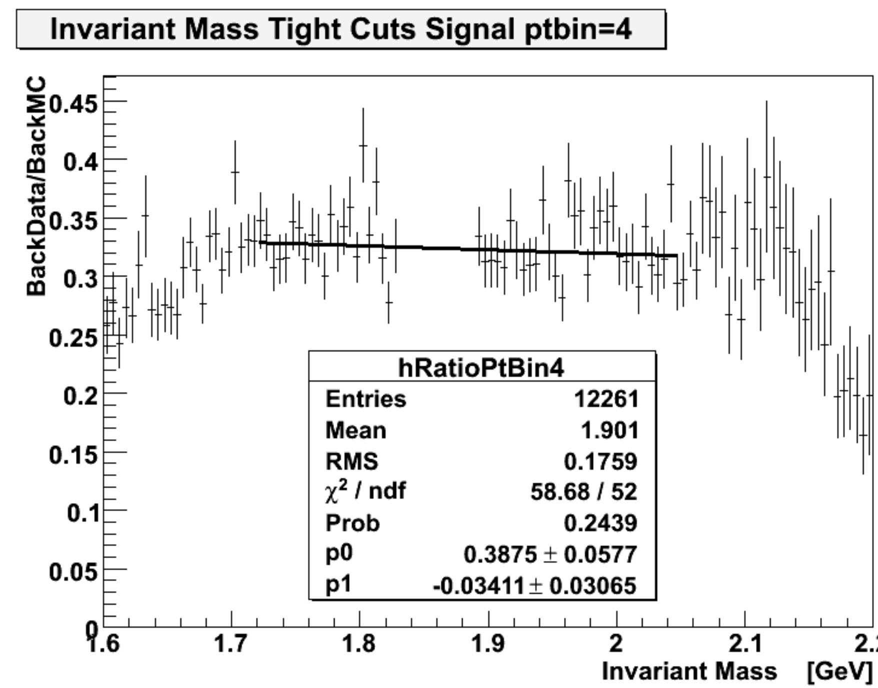
$$S_{ITSupg} = \epsilon_{ITSupg} \times S^{data2010}_{corrected}$$

$$Signif_{ITSupg}(N_{ev}) = \frac{S_{ITSupg} \times \sqrt{N_{ev}}}{\sqrt{S_{ITSupg} + B_{ITSupg}}} = \frac{\epsilon_{ITSupg} \times S^{data2010}_{corrected} \times \sqrt{N_{ev}}}{\sqrt{B^{MB\ MC}_{ITSupg} \times \frac{B^{data2010}_{ITScur}}{B^{MB\ MC}_{ITScur}} + \epsilon_{ITSupg} \times S^{data2010}_{corrected}}}$$

# Scaling factor for background

3 similar methods



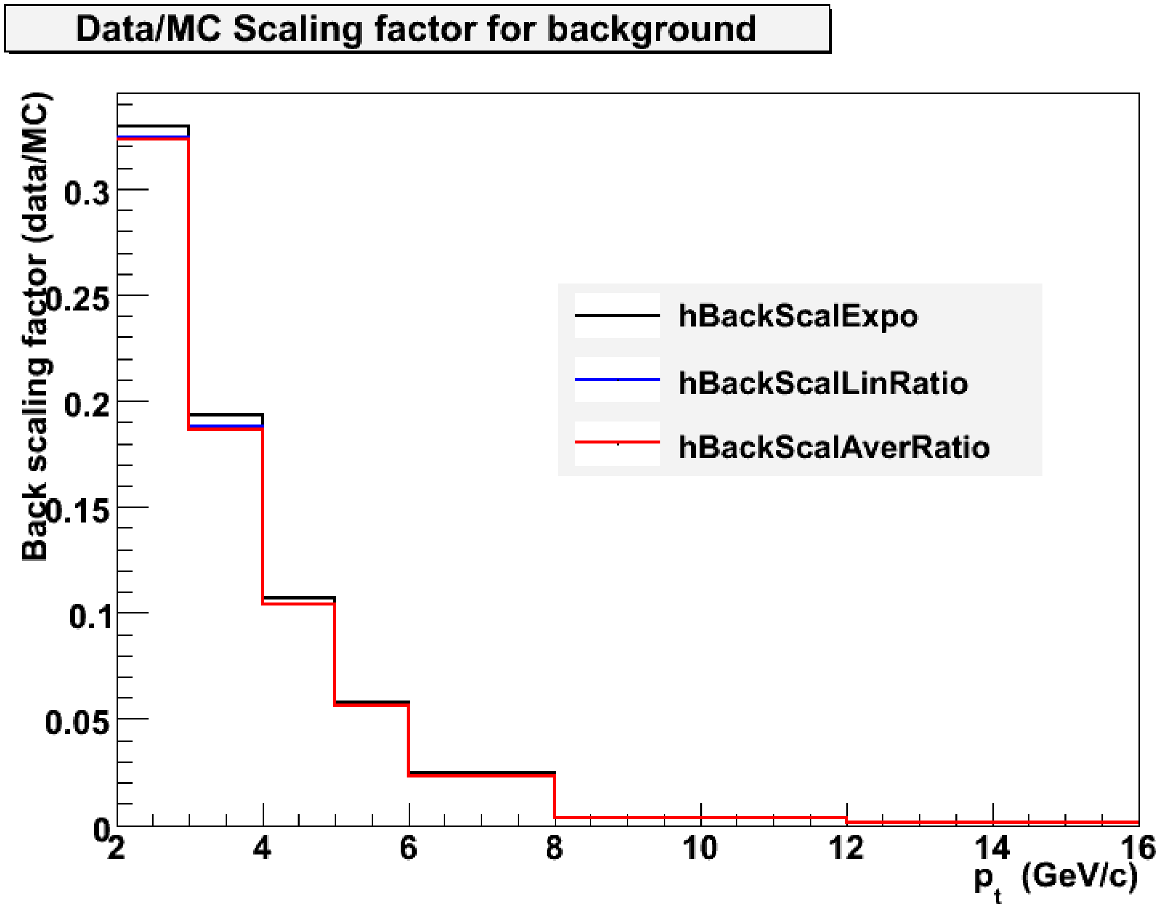

1) Fit the background in the mass plot side bands with an exponential function and then extrapolate to the D0 mass region to get the background amount. Then get the ratio of data/MC backgrounds

- Calculate the ratio data/MC bin by bin and then

2) get the average

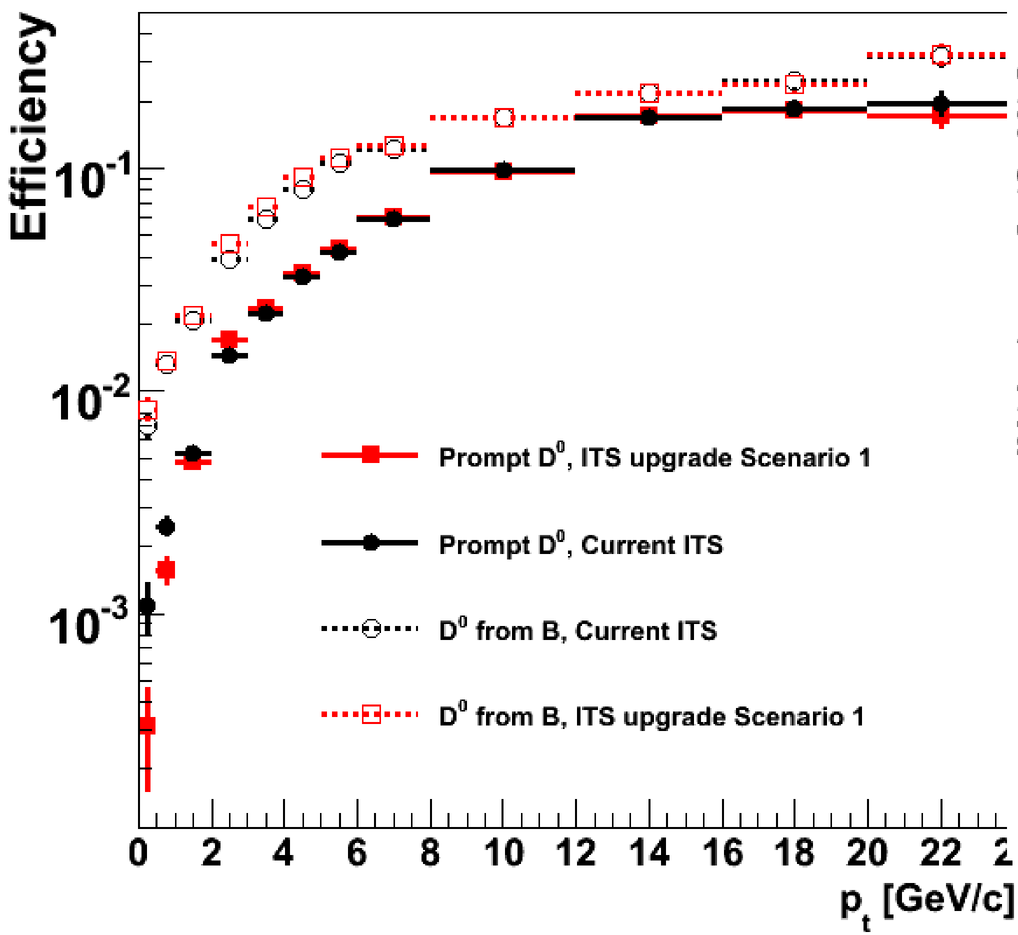
3) Fit with a straight line and get the value at the D0 mass

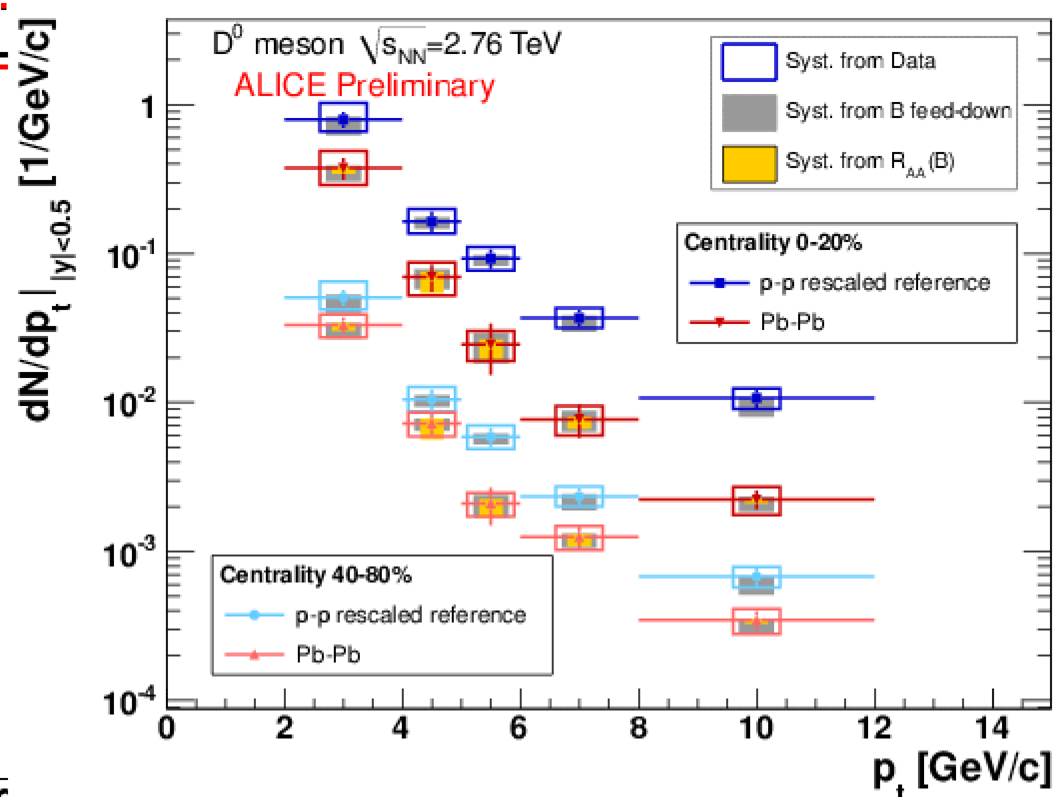
# Scaling factor for background



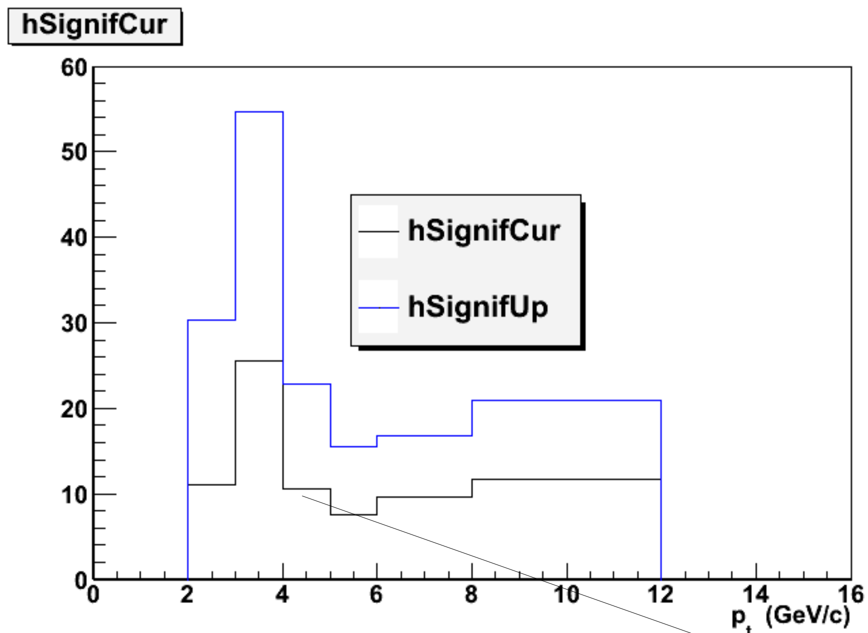

- Same results with the 3 methods, as expected
- Still have to think whether the recovered factors are reasonable

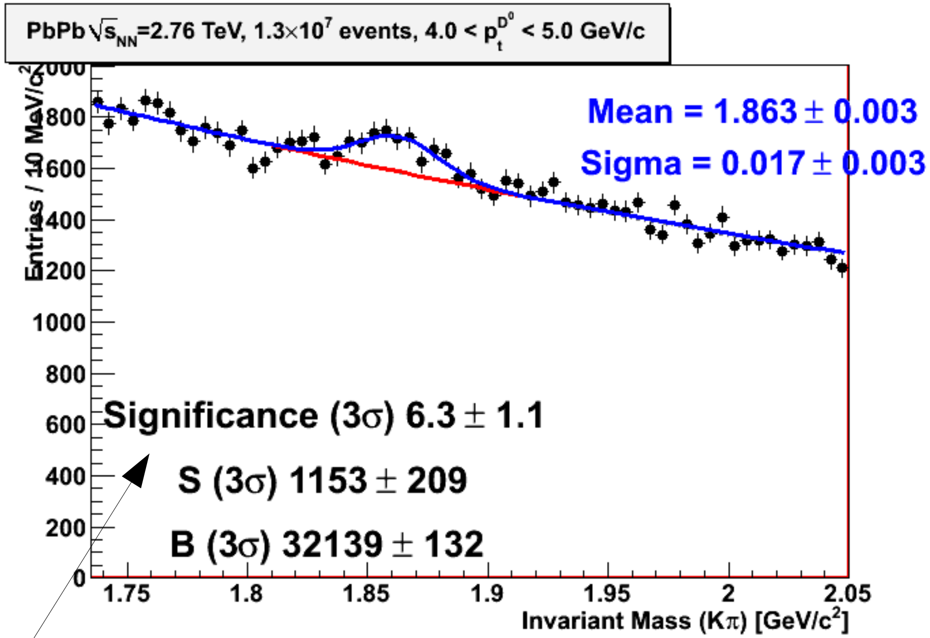
# Getting the signal: ingredients



# Scaling to data performance

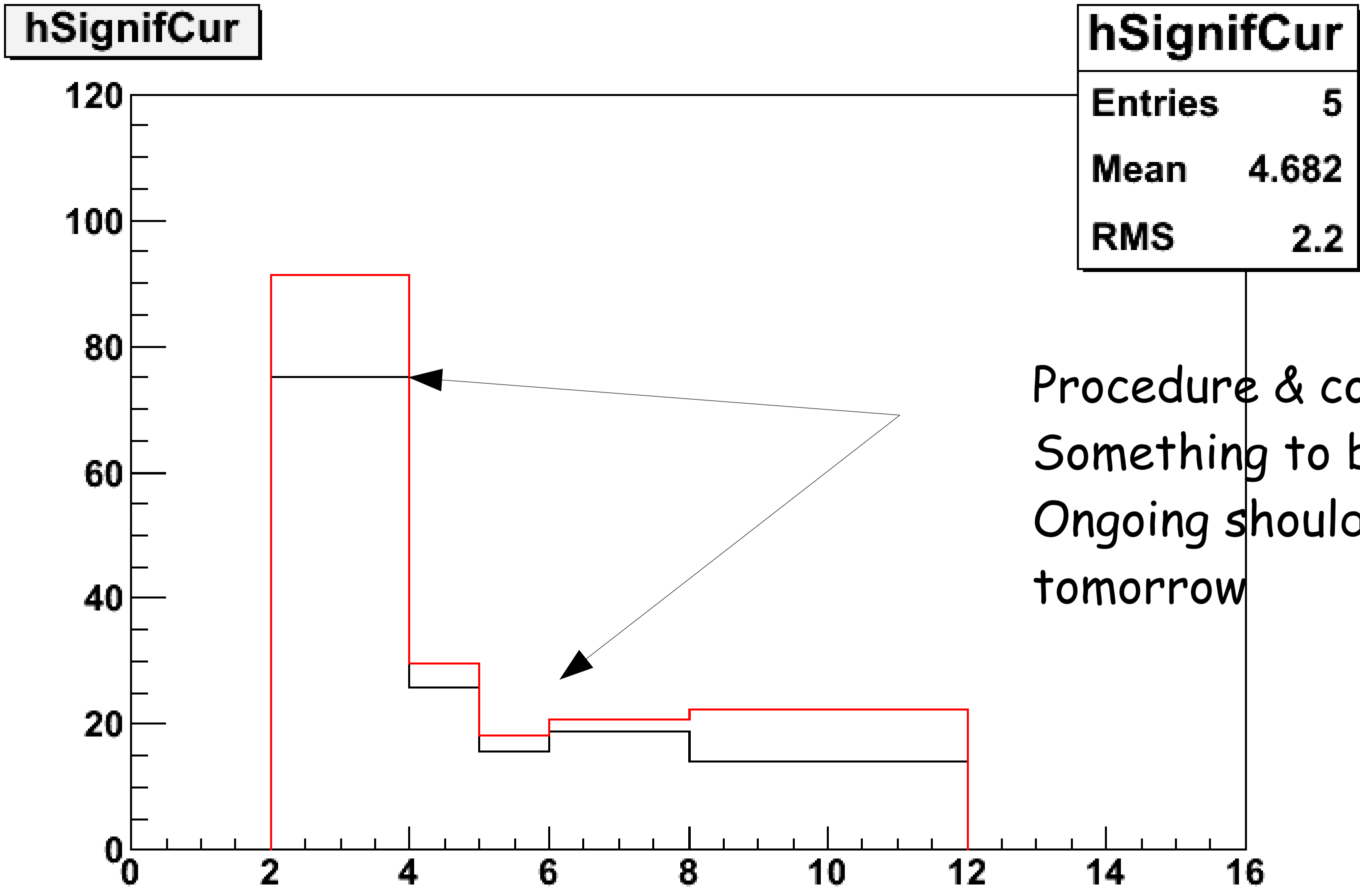



Scaled to $10^7$ central events
Need to merge bin in 2<pt<4 GeV/c to get proper info from measured spectrum (almost done)
For current case: do not rely on fit to get the background in the peak-> use MC sigma

Signif($3\times10^6$ ev): ~5.5
In agreement with data (with same set of cuts)

# Scaling to data performance




Procedure & code ready

Something to be fixed…

Ongoing should be finalized by tomorrow

# B from displaced D0

Started to write, figures on which I am working:

- comparison of prompt and secondary impact parameter in a given pt bin for current and upgrade OK
- comparison of D0 imp. par resolution in current and upgrade scenarios OK
- comparison of method performance to get the fraction of secondary D0
  - will not done with the best possible performance ongoing
    - should optimize the cut to reduce the fraction of prompt
- Should be feasible to get the text and preliminary figures ready by Friday but probably more time will be required for final results almost done

## 0.2 Measurement of Beauty production via displaced D0

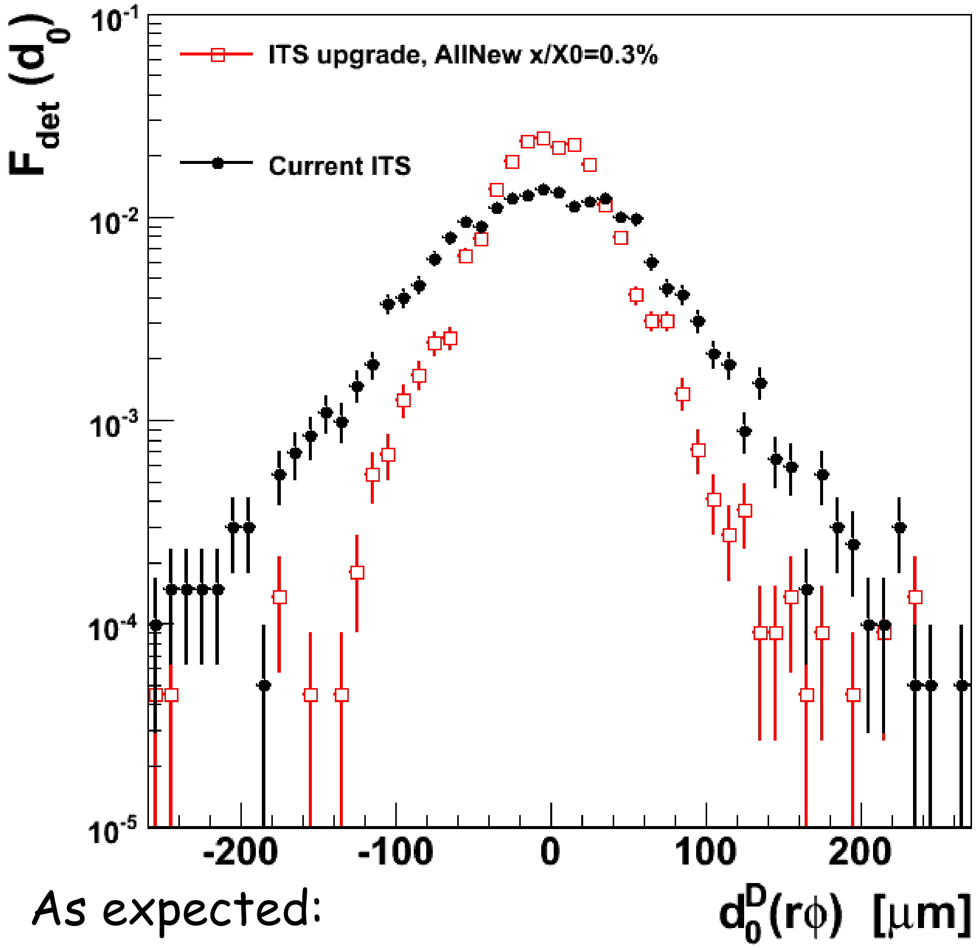
Most of the $B$ meson decay channels includes a $D^0(\bar{D}^0)$ or a $D^\star$, $\mathrm{BR}(b_{\mathrm{hadr.}} \to D^0 X) = 61.0 \pm 3.1\%$, $\mathrm{BR}(b_{\mathrm{hadr.}} \to D^\star X) = 17.3 \pm 2.0\%$, for $B^\pm/B^0/B^0_s/b-$baryon admixture [?]. According to FONLL prediction [?], the ratio between D0 from B decay and prompt D0 increases with transverse momentum from about 5% at $p_{\mathrm{t}} \approx 1GeV/c$ reaching **25%** at $p_{\mathrm{t}} \approx 20GeV/c$ in pp collisions at $\sqrt{s} = 7$ TeV. As depicted in Fig. 5, the kaon and pion tracks coming from secondary $D^0$ decay are, on average, more displaced from the primary vertex than those coming from a prompt D0 decay, due to the relatively long lifetime of $B$ mesons ($c\tau \approx 460 -$

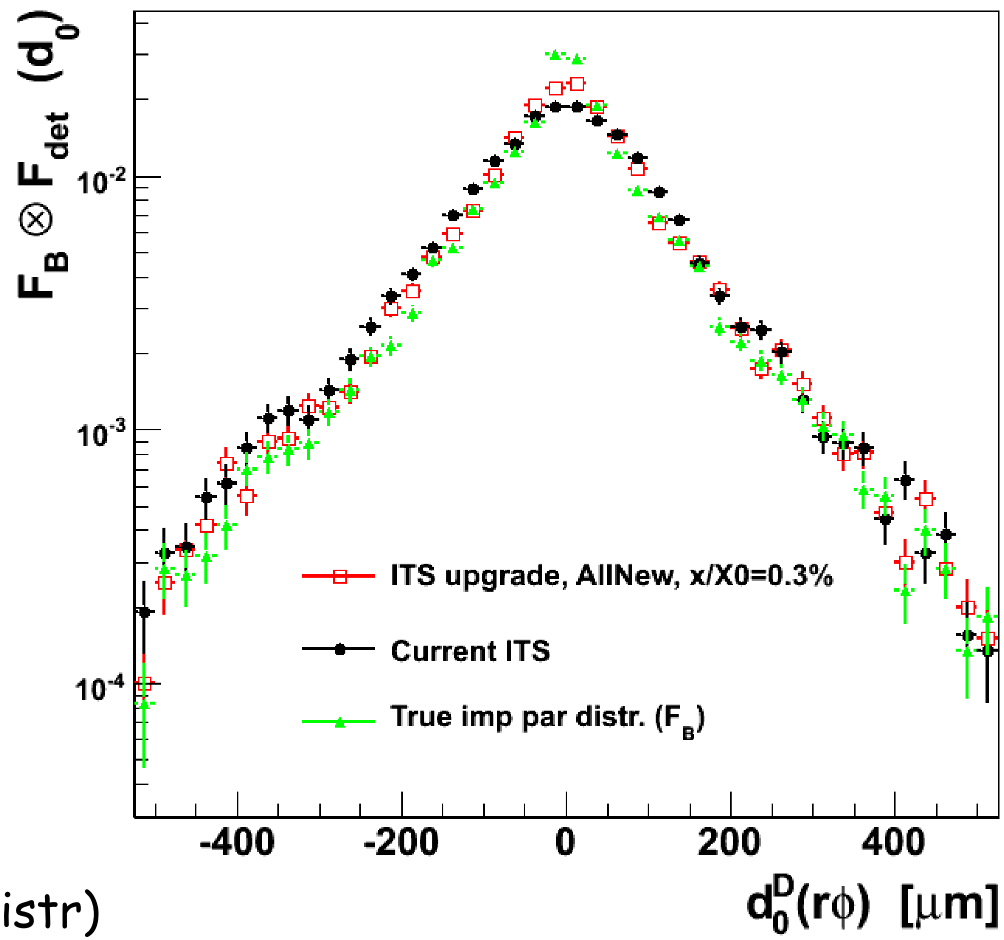
The impact parameter ($d_0$) distribution for $D^0$ mesons can be described with the following function:

$$F_{d_0} = f_D F_{\mathrm{det}}(d_0) + (1 - f_D) \int F_B(x) F_{\mathrm{det}}(d_0 - x) \mathrm{d}x \, . \tag{1}$$

In the above formula, $F_{\mathrm{det}}$ represents the *detector resolution function* for D0 meson, and describes the impact parameter distribution of primary D0, that is determined by the detector resolution on the kaon and pion track positions and momenta. The integral term is the convolution of the *true impact parameter distribution function* for secondary $D^0$ ($F_{B)}$) with $F_{\mathrm{det}}$: it expresses the probability to reconstruct an impact parameter $d_0$ if the true impact parameter ($x$) distribution is described by $F_B$. $f_D$ is the fraction of primary charm. By properly modelling each term, Eq. 2 can be used to fit the impact parameter distribution of the reconstructed candidate $D^0$ and recover $f_D$, treated as a fit parameter.

# B from displaced D0

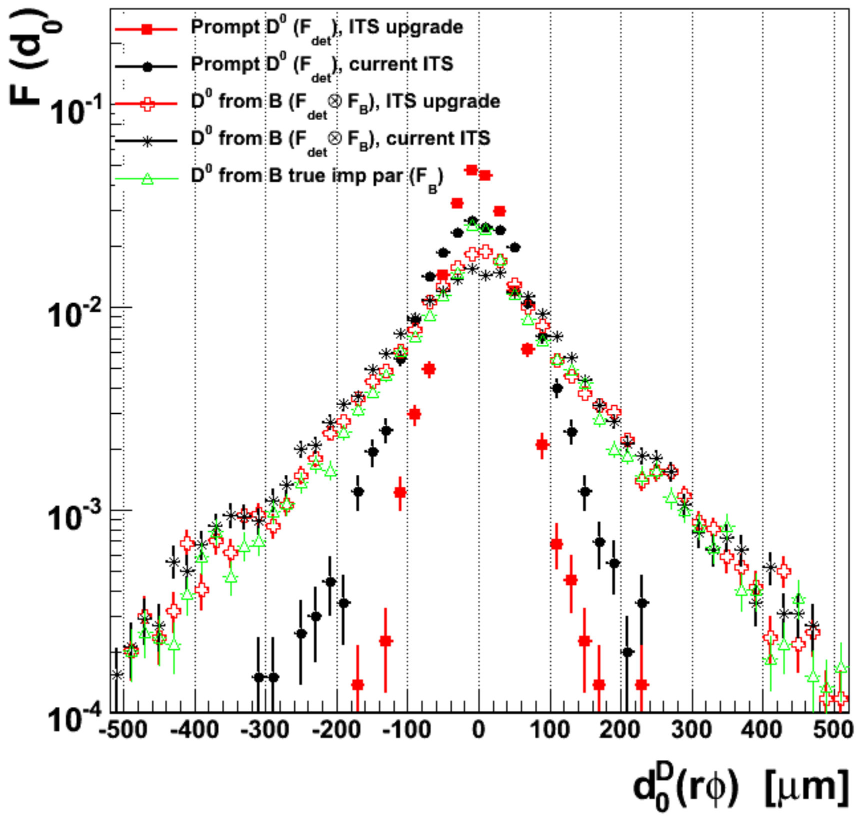


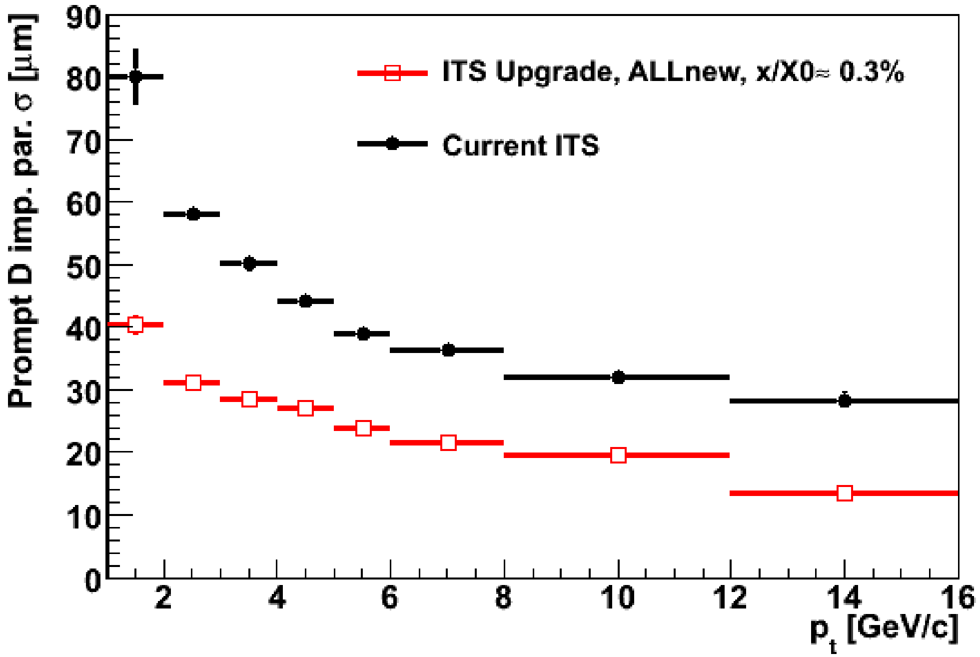




As expected:

- imp. par. distribution of prompt D meson changes a lot
- for secondary the difference is not too relevant (they are close to “true” imp. par distr)

# B from displaced D0




With ITS upgrade

- Better separation prompt/secondary
- S/B much higher-> less problem from background subtraction: probably the main point

# Extra

### 2.2.2 $D^0$ meson reconstruction as a benchmark for detector performance

*Authors: A. Rossi, S. Moretto*

As described in Section ?? and reference therein, ALICE measured the $D$ meson $R_{AA}$ in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV via the recontruction of the $D^0 \to K^-\pi^+$ (BR=3.89%, $c\tau \approx 123$ $\mu$m), $D^{*+} \to K^-\pi^+\pi^+$ (via $D^{*+} \to D^0\pi^+$, strong decay, BR=67.7%). $D^+ \to K^-\pi^+\pi^+$ (BR=9.4%, $c\tau \approx 312$ $\mu$m) decay channels (see [?] for

- Motivations
- Current/Upgrade performance on cut variables (sec. vertex resolution in the previous paragraph on the hybrid approach)
- Performance on signal extraction with current “standard cuts”
- Cut variation study to get the best performance achievable with the upgrade and comparison of current/upgrade in the terms of the best achivable
  - stat. error (significance)
  - purity (S/B)
  - efficiency (S)

## 2.2.2 $D^0$ meson reconstruction as a benchmark for detector performance

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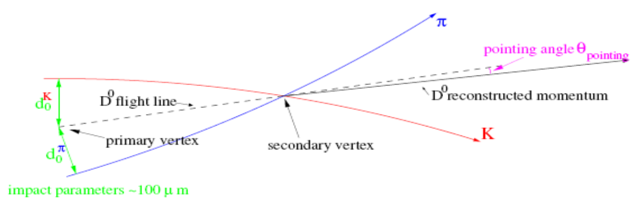



Figure 2.16: Schematic view of the $D^0$ decay in the $D^0 \to K^-\pi^+$ channel.

the decay properties quoted). All analyses are based on the reconstruction and selection of secondary vertex topologies with a few hundreds of microns separation from the primary vertex. Displaced tracks are selected and good alignment between the D meson momentum and the flight-line connecting the primary and decay vertex is required (i.e. small pointing angle, see the sketch of the $D^0$ decay in Fig. 2.16). The amount of $D^0$ and $D^+$ decaying in the selected channels is comparable because the larger $D^+ \to K^-\pi^+\pi^+$ BR is balanced by the more copious $D^0$ production (a factor about 2.3 [?]). However, despite the smaller lifetime, the two prong decay topology makes the signal extraction easier in the $D^0 \to K^-\pi^+$ case than in the $D^+ \to K^-\pi^+\pi^+$ case. The main reason is related to the higher combinatorial background, which rises proportionally to $N_{tr}^{n_{pr}}$ with $N_{tr}$ the event multiplicity and $n_{pr}$ the number of prongs. As shown in Fig. 2.16, due to the relativistic boost, the pion and kaon tracks have an intrinsic impact parameter in the transverse plane typically of the order of the $D^0$ $c\tau$ for sufficiently high $D^0$ transverse momentum, thus can be identified as displaced tracks if the track resolution in the vicinity of the vertex is of the order of tens of microns. The average pt of the decay tracks is lower for $D^+$ than for $D^0$, hence, especially at low $p_t$, $D^+$ tracks are more affected by multiple scattering effects. Therefore, the $D^0 \to K^-\pi^+$ decay channel was reconstructed in Pb–Pb collisions in a wider pt range, $2 < p_t < 12$ GeV/$c$, and yielded the most precise $R_{AA}$ measurement, with a statistical error of the order of 25% in the centrality range 0–20%. The better signal extraction and the possibility to have a realistic reference of the performance on real data, provide a more detailed understanding of the analysis and allows for a more realistic study of the benefits that would come from an upgrade of the ITS. Therefore, the $D^0$ case can be considered as a benchmark for all the $D$ meson analyses. In what follows a comparison of the performance achievable in Pb–Pb collisions with the current ITS and the upgrade scenarios described in Section ?? is presented. **The hyrbid simulation approach** described in Section ?? was used to account for the ITS track position and momentum resolutions for different upgrade scenarios. The precision on the measurement of $D^0$ production performed with 2010 Pb–Pb data has been considered as a reference: in central (0–20%) events the statistical significance was of the order of **8-10** in the $2 < p_t < 12$ GeV/$c$, depending on the $p_t$, and the statistical error (that can be estimated also as the inverse of the statistical significance) was at the level of 10–15%. The main cut variables used to extract the $D^0$ signal are the product of decay track impact parameters, the cosine of the pointing angle and the decay length. These last two variables are calculated also in the transverse plane only, to improve the separation between signal and background profiting of the better resolution in the $r\phi$ plane with respect to the $z$ coordinate (see Figure ??). For the background, composed mainly by pair of primary tracks, the distribution of the product of decay track impact parameters is symmetric and peaks at 0, the width being determined by the detector impact parameter resolution. For the D meson signal, the distribution is asymmetric because the displacement of the secondary vertex induces a large tail at negative values of the product. The cosine of the pointing angle is peaked towards 1 for signal candidates, while it has a flatter distribution for the background. The decay length distribution of reconstructed $D^0$ meson is the convolution of the true decay length distribution and a resolution term, which characterizes the background distribution. The narrower the background distribution is, the better the signal and background shapes can be distinguished. An improved detector resolution would provide a better separation between signal and background, thus the possibility to reject more background and release the cuts in order to keep more signal, increasing the selection efficiency. Generally, this also allows to reduce the systematic uncertainties arising from a not fully precise description of the detector properties (including alignment) and performance (e.g. vertex and track reconstruction precision). **Add a figure with the comparison of signal and background distribution for some variable, for example the product of impact parameters.**

A comparison of the signal over backround ratio and of the statistical significance obtained with the current ITS and in the upgrade scenario 1.. **here we should call it** is reported in Figure 2.20. The signal was obtained by multiplying the $D^0$ spectrum measured with the 2010 run data by the efficiency calculated from the simulation. In the Monte Carlo sample, the background shape and abundance do not reproduce realistically those observed in data. Therefore, the background in the $D^0$ mass peak region observed in the simulation was scaled in order to match the background level measured in the 2010 Pb–Pb data. The comparison of the efficiencies in the current and upgrade scenarios, displayed in Figure 2.21, shows that almost the same signal is selected in the two cases for $p_t > 2$ GeV/$c$. Conversely, the background rejection improves by a factor 6 for $p_t > 2$ GeV/$c$ and, consequently, the significance, normalized to the square root of the number of events, improves by a factor 2.

**HERE SIGNIFICANCE STUDY AND ALSO USE OF Z COORDINATE IN THE FUTURE** For the above comparison the selection used for measuring the $D^0$ $R_{AA}$ in 2010 was applied to the $D^0$ candidates in both the current and upgrade scenarios. The better separation between background and signal in the upgrade case allows to vary the values of the applied cuts in order to further increase:

- the statistical significance, thus reducing the statistical error, Current

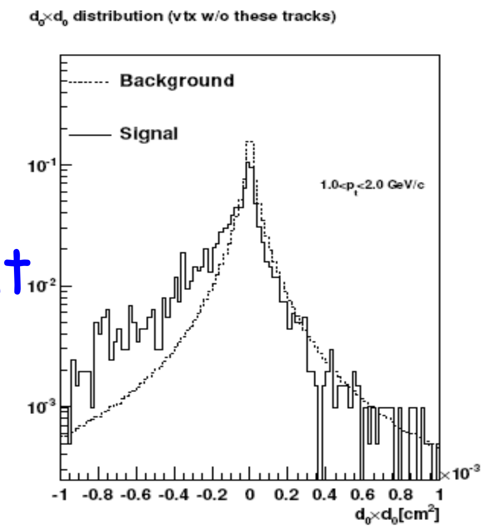



Figure 2.17: Products of the daughter impact parameters for background and signal candidates in the current configuration in two different $p_{\mathrm{t}}$ ranges. More details in the text.

Upgrade

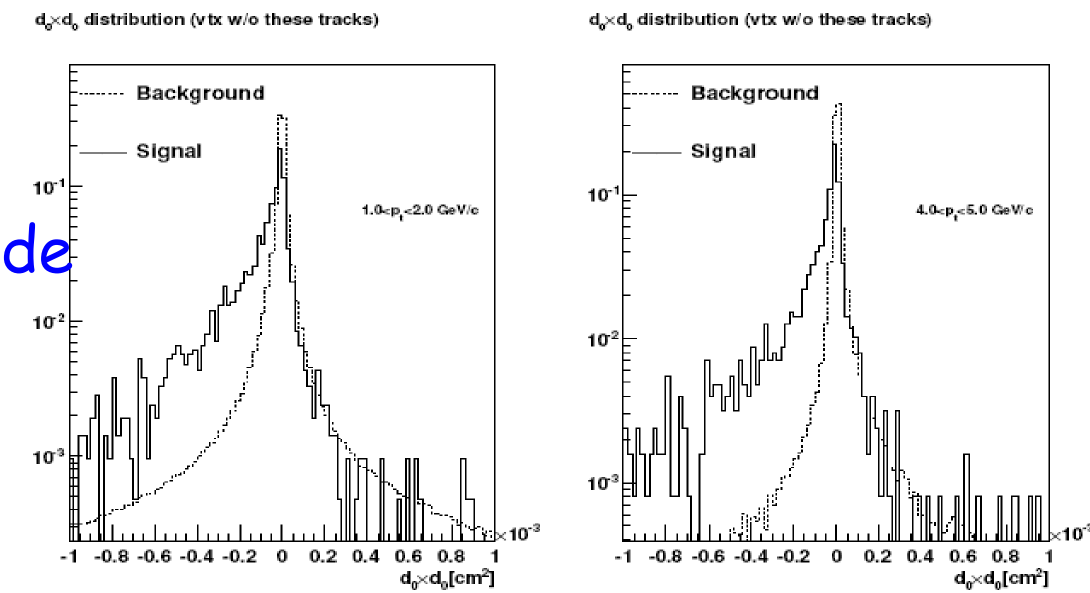



Figure 2.18: Products of the daughter impact parameters for background and signal candidates in the upgrade configuration in two different $p_{\mathrm{t}}$ ranges. More details in the text.

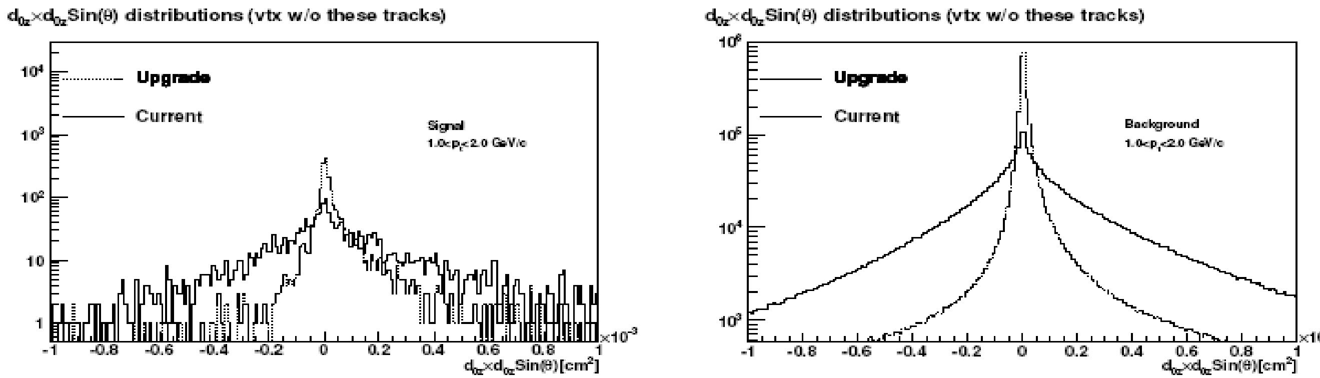



Figure 2.19: Comparisons of the products of the daughter impact parameters in the current and upgrade configurations for the signal(left) nad background (right)candidates in the $p_t$ range $1 < p_t < 2$ GeV/$c$. More details in the text.

al purity and the capability of "tagging" $D^0$ mesons, desirable for correlation studies,

- the signal amount, thus the efficiency, providing a better control of the systematic errors.

A scan of the cut values used was performed to look for the set of cuts optimizing the performances on the signal over background, significance and selected signal per event. The cut on the product of the impact parameter was varied between **ggg** and **ccc** while that on the cosine of the pointing angle was varied between **ggg** and **ccc**. The cut values used for other variables were fixed to the same considered for the analyses shown above. Figure ?? shows on the left panel the values of the significance obtained for each combination of the d0xd0 and cospoitning angle value with the current ITS scenario in the $p_t$ range $ptmin < p_t < ptmax$. The results for the upgrade scenario are shown in the right panel.

The $D^0$ $R_{AA}$ reported in Figure ?? is quite flat in the $p_t$ interval $5 < p_t < 12$ GeV/$c$, increases at lower $p_t$ values. The comparison with the pion $R_{AA}$ suggests that, at low pt the $D^0$ is less suppresed, even if the $R_{AA}$ are compatible within the systematic errors, which are quite large. As described in Section ??, many models describing the radiative energy loss of high energetic partons traversing the QGP medium predicted a pattern $R_{AA}$(pion)$< R_{AA}(D) < R_{AA}(B)$, induced by both the different coupling (Casimir factor) of the gluons and quarks to the gluons in the medium and by the suppression of the radiation at small angle with respect to the parton momentum for massive quarks (dead-cone effects). A higher precision (**should quantify**) and a lower $p_t$-reach on the $R_{AA}$ measurement would allow to better test these predictions. The low-$p_t$ region is also more affected by cold nuclear matter effects, like nuclear shadowing. Measuring the $D^0$ $R_{AA}$ down to $p_t = 0$ would allow to compute the total cross-section for charm production in

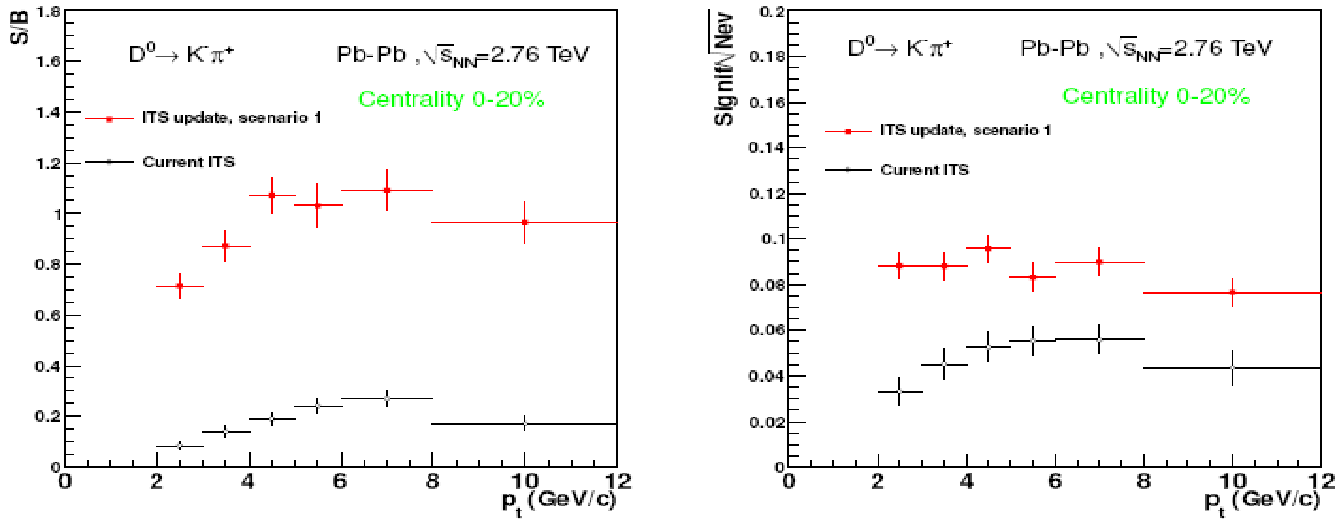
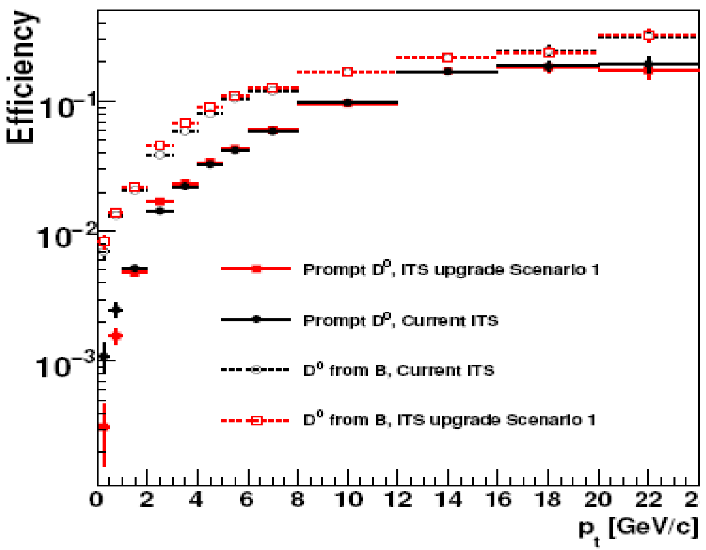



Figure 2.20: Comparison of the signal over background ratio (left) and significance (right) obtained for the current and upgrade ITS (scenario 1). More details in the text.




To be rescaled on the basis of the current performance on data (see later)

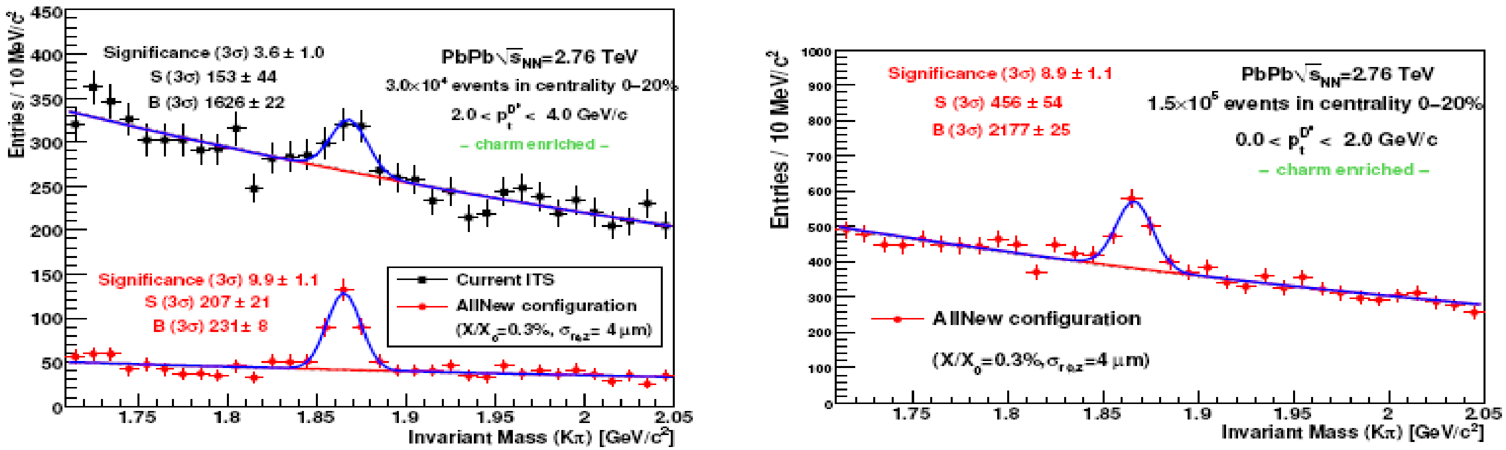



Figure 2.22: Left: comparison between the invariant mass distributions of $D^0$ candidates obtained for $2 < p_{\rm t} > 4$ GeV$/c$ obtained from the analysis of $\sim 3 \times 10^6$ **central (0–20%) Pb–Pb events at** $\sqrt{s_{\rm NN}} = 2.76$ TeV with the current and upgrade scenarios.

obtained from the MC sample described above in the current and upgrade ITS scenarios for $2 < p_{\rm t} < 4$ GeV$/c$. By scaling to the current performance on data, the improvement achievable with the upgrade of the ITS can be quantify in **a factor 00000** . In the pt range $0 < p_{\rm t} < 2$ GeV$/c$ (right panel) the background rejection improves by a factor 25 allowing the extraction of a clear $D^0$ signal (significance=9) that cannot be seen with the current ITS.