D^{*+} reconstruction in C-C collisions at 25A GeV in the CBM experiment

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Open charm production

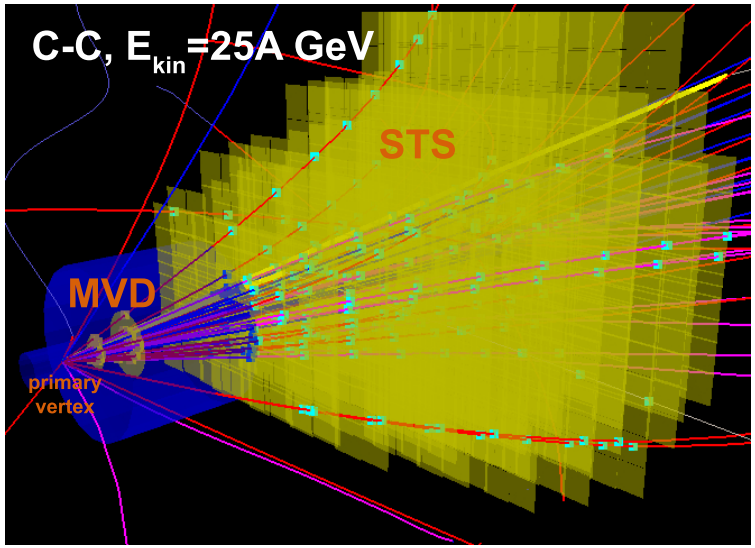
D mesons are produced in the early stages of nucleus-nucleus collisions. Multiplicity at FAIR energies ($E_{\mathrm{kin}} = 25$A GeV) is very low.

Meson	Mass [GeV]	Multiplicity (by HSD model)	
		C-C	Au-Au
D^0	1.864	$4.1 \cdot 10^{-7}$	$2.8 \cdot 10^{-5}$
$\overline{D}^0$	1.864	$11.6 \cdot 10^{-7}$	$7.59 \cdot 10^{-5}$
D^+	1.869	$4.26 \cdot 10^{-7}$	$2.91 \cdot 10^{-5}$
D^-	1.869	$9.68 \cdot 10^{-7}$	$6.17 \cdot 10^{-5}$
D^{*0}	2.007	$6.26 \cdot 10^{-7}$	$4.59 \cdot 10^{-5}$
$\overline{D}^{*0}$	2.007	$34.9 \cdot 10^{-7}$	$22.3 \cdot 10^{-5}$
D^{*+}	2.010	$7.51 \cdot 10^{-7}$	$5.56 \cdot 10^{-5}$
D^{*-}	2.010	$19.4 \cdot 10^{-7}$	$12.6 \cdot 10^{-5}$

Event reconstruction

Event simulation and reconstruction with CBMROOT

- Event generator UrQMD plus D^{*+} source
- Transport code GEANT 3



UrQMD central C-C, 25 A GeV
$\sim$ 24 tracks reconstructed with Cellular Automation and Kalman Filter algorithms

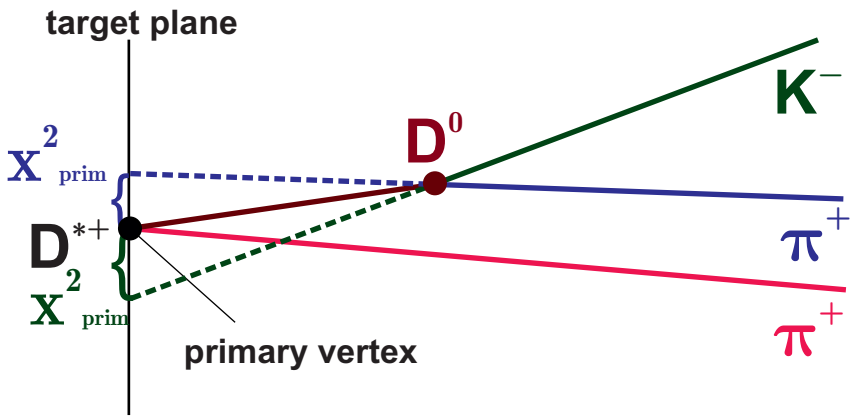
Micro Vertex Detector

- Monolithic pixel detectors
- Two vertex stations in vacuum vessel
- Vertex resolution 50 μm

Silicon Tracking System

- Silicon microstrip detectors
- Eight tracking stations
- Momentum resolution $\Delta p/p \approx 1\,\%$

D mesons reconstruction



Decay modes

D^{*+} and D^0 are reconstructed via hadronic decays:

D^{*+} : $D^{*+} \to D^0\pi^+$ ($c\tau \sim 10^{-12}$ m, branching ratio 67.7%)

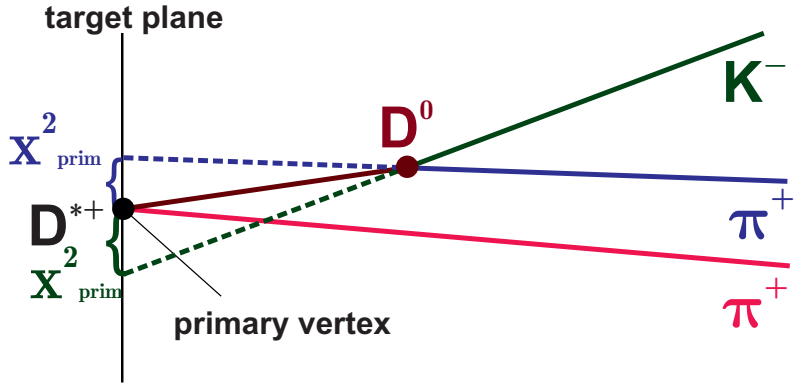
D^0 : $D^0 \to K^-\pi^+$ ($c\tau = 123$ μm, branching ratio 3.87%)

Main challenges

- Low multiplicity
- Low branching ratio
- A lot of background

D^0 reconstruction

D^0 is reconstructed via $K^-\pi^+$ decay. All reconstructed negative tracks are assigned kaon mass, and all positive ones – pion mass, and then combined.



Cuts used to distinguish D^0 signal from background

- $\chi^2_{\text{prim}} > \chi^2_{\text{primcut}}$ ($\chi^2_{\text{primcut}} = 4 - 7$) and $b < 1$ mm cuts on daughter tracks impact parameter in the target plane.
- $\chi^2_{\text{geo}} < 3$ cut on distance of minimum approach between daughter tracks.
- $\chi^2_{\text{topo}} < 3$ cut on D^0 impact parameter in the target plane.
- $z > 350$ μm cut on D^0 decay vertex z-coordinate.

D^0 invariant mass distribution calculation

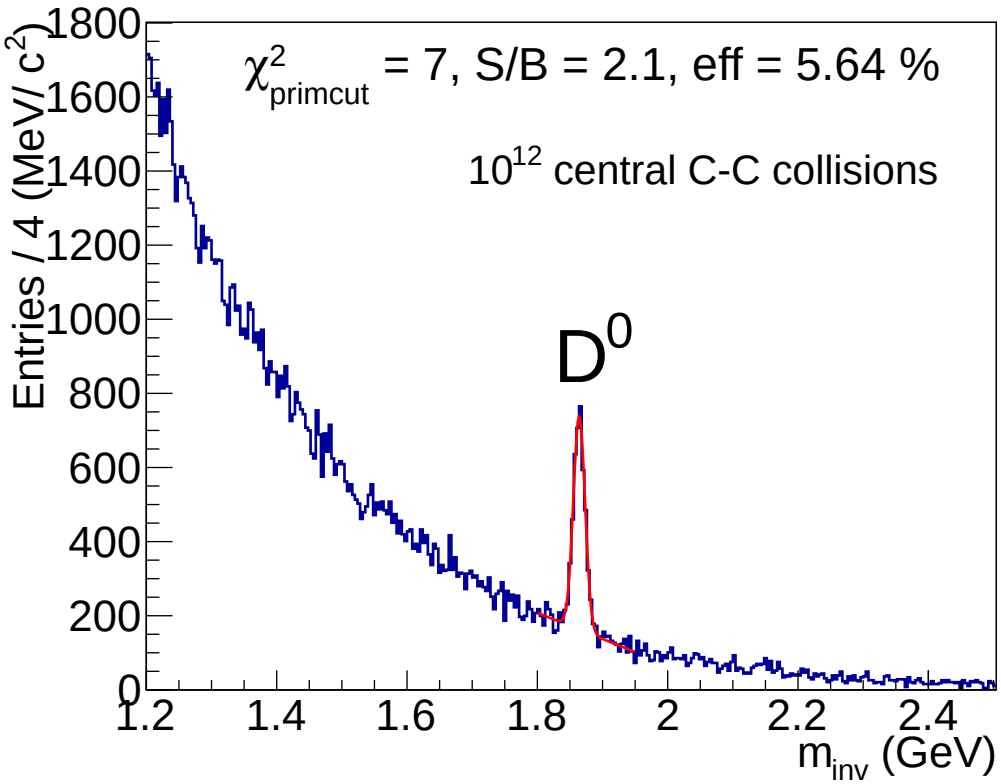
Signal calculation algorithm

1. 10^5 UrQMD events with embedded D^{*+} meson, decaying into D^0, are simulated and reconstructed.
2. D^0 is reconstructed using all the cuts and Monte Carlo verification to obtain signal.
3. Result is renormalized for 10^{12} C-C collisions using multiplicities of D mesons.

Background calculation algorithm

1. 5000 UrQMD events without D mesons are simulated and reconstructed.
2. Tracks, satisfying χ^2_{prim} cut are identified as D^0 daughter candidates.
3. They are combined with each other to construct background for effectively $2.5 \cdot 10^7$ events and then renormalized for 10^{12} events.

D^0 invariant mass distribution



$\chi^2_{primcut}$	Signal	Efficiency	S/B (2σ)
4	6167	10.46%	0.33
5	5075	8.60%	0.83
6	4120	6.97%	1.54
7	3331	5.64%	2.06

D^{*+} detection

D^{*+} is reconstructed via decay into D^0 and π^+.

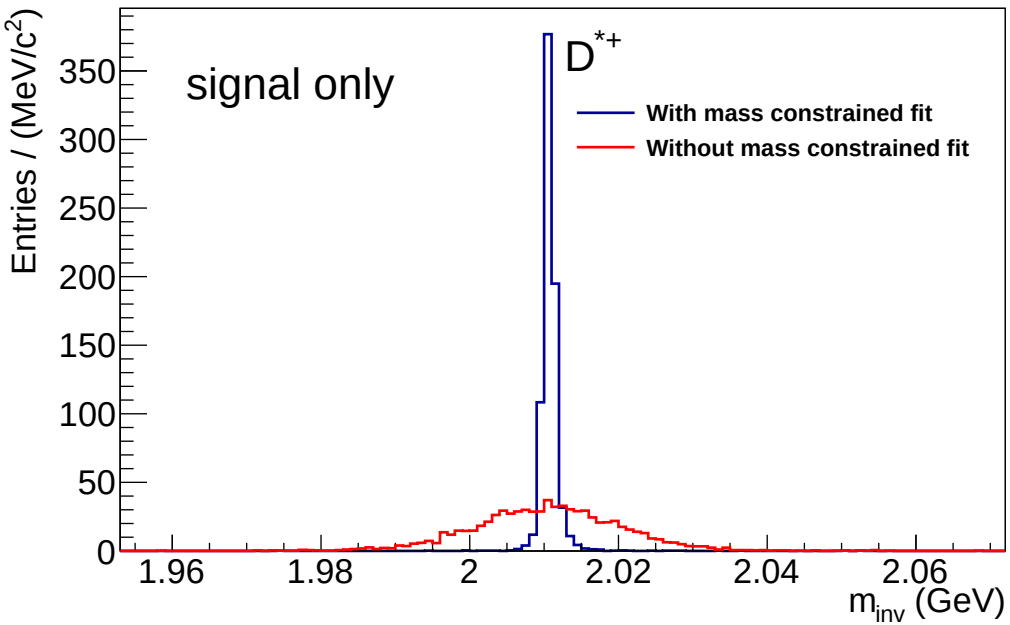
Algorithm

1. 10^5 events with D^{*+} are simulated and reconstructed.
2. D^0 daughter tracks are identified using above cuts and constraint $1.84 < M_{D^0}(\text{GeV}) < 1.89$.
3. D^0 is combined with all positive tracks which are assigned pion mass and satisfy $\chi^2_{\text{prim}} < 3$ cut.
4. D^{*+} signal and background is obtained using Monte Carlo verification.
5. D^{*+} background is renormalized to include contribution from events without D^{*+}.

Mass constrained fit for D^{*+}

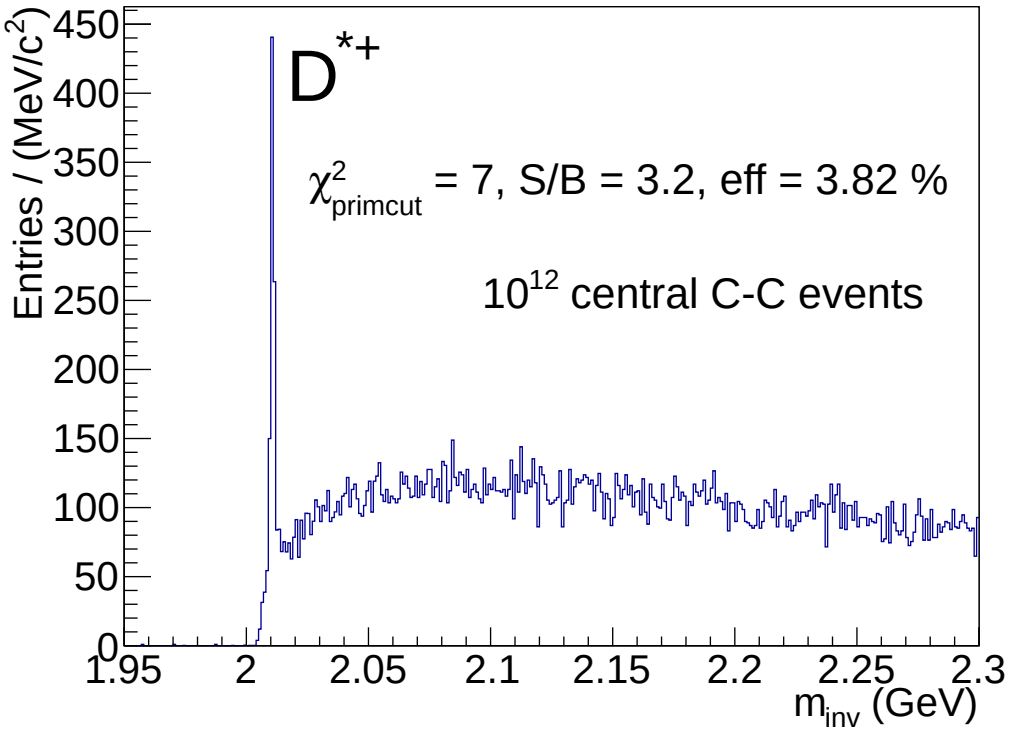
Reconstructed D^{*+} mass is corrected:

$$M_{D^{*+}} = \widetilde{M}_{D^{*+}} - M^{rec}_{D^0} + M^{mc}_{D^0}.$$



- Allows to effectively exclude error from D^0 mass determination.
- Essential to distinguish signal from background!

D^{*+} invariant mass distribution



$\chi^2_{primcut}$	Signal	Efficiency	S/B (2σ)
4	1283	7.11%	1.08
5	1054	5.83%	2.06
6	852	4.71%	2.81
7	692	3.82%	3.19

Summary

1. Algorithm to detect D^{*+} signal in central C-C collisions was developed.

2. Reconstruction method allows to collect about 3300 D^0 mesons (with signal to background ratio $S/B_{2\sigma} = 2.1$ and efficiency $\epsilon = 5.64\%$) and about 700 D^{*+} mesons ($S/B_{2\sigma} = 3.2$, $\epsilon = 3.82\,\%$) per 10^{12} central C-C events.

3. $\chi^2_{primcut}$ values of 6-7 for a cut on D^0 daughter tracks's impact parameter were found to be optimal for D^0 and D^{*+} detection.

Thanks for your attention!