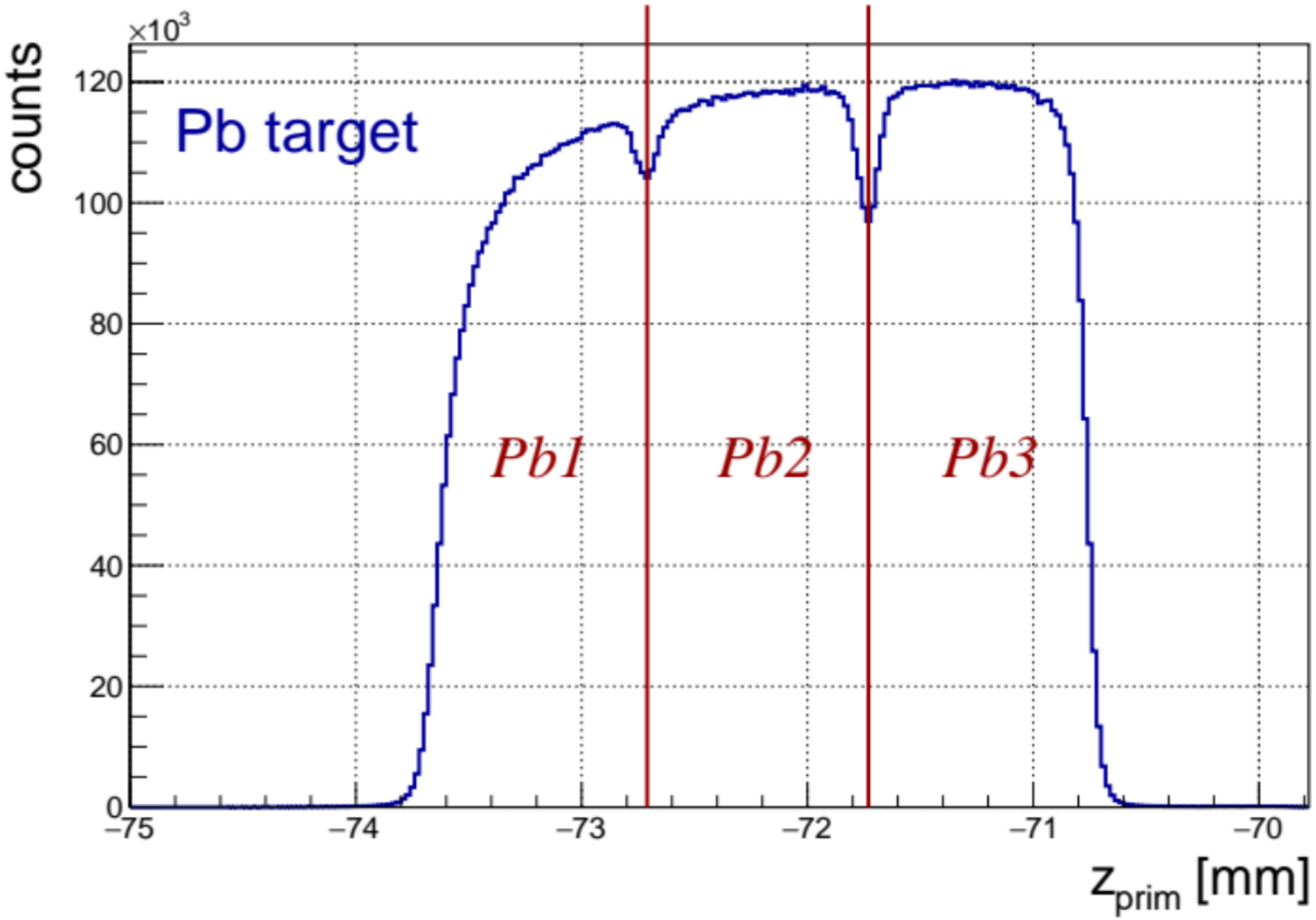
Why do we need segmented Pb target for charm data taking?

Paweł Staszel & Mateusz Bajda

06.11.2024

Motivation

Paweł results on experimental data (*VD Status and plans* - CERN, 23.09.2024)



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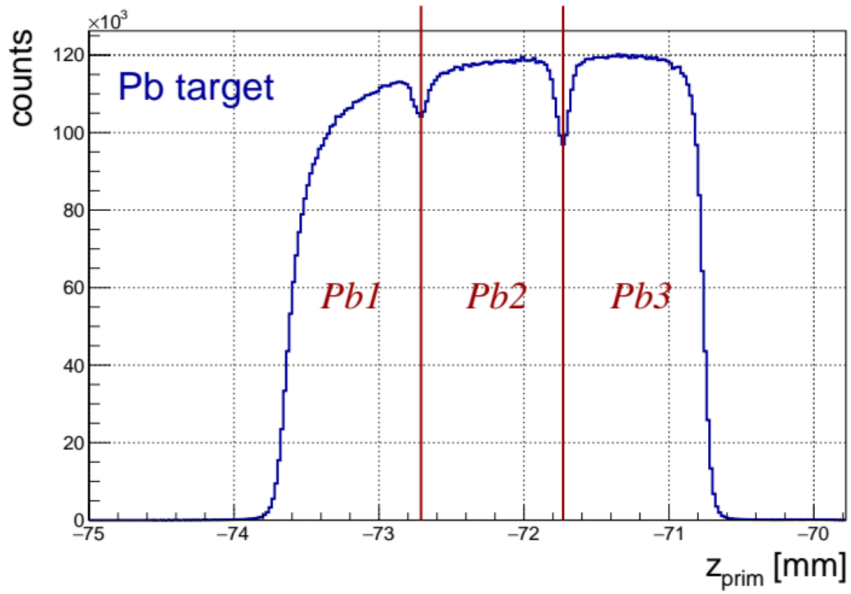

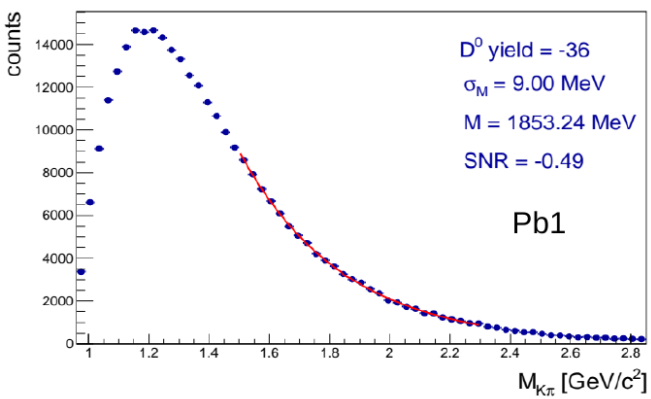

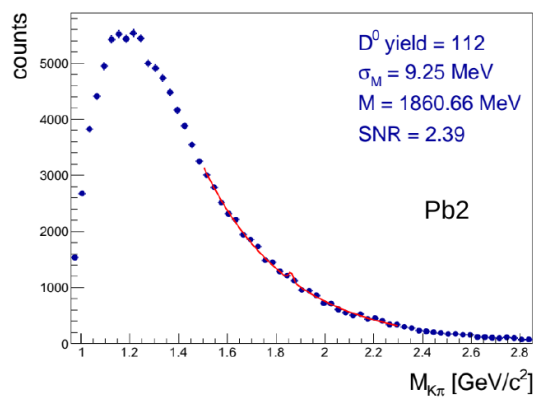

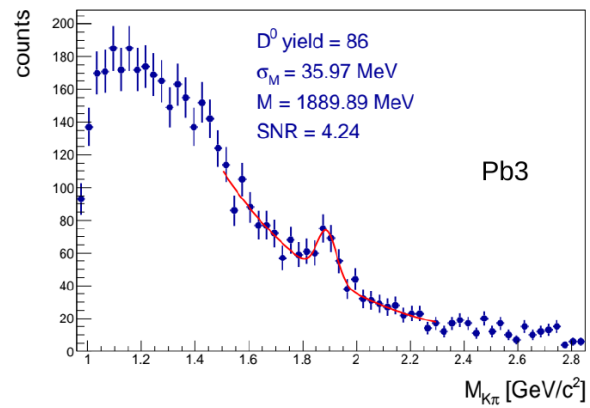

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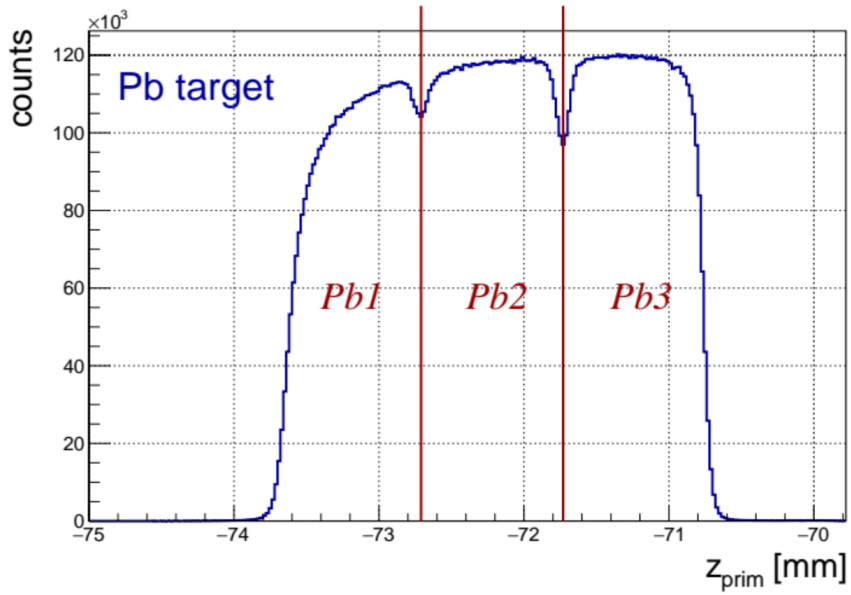

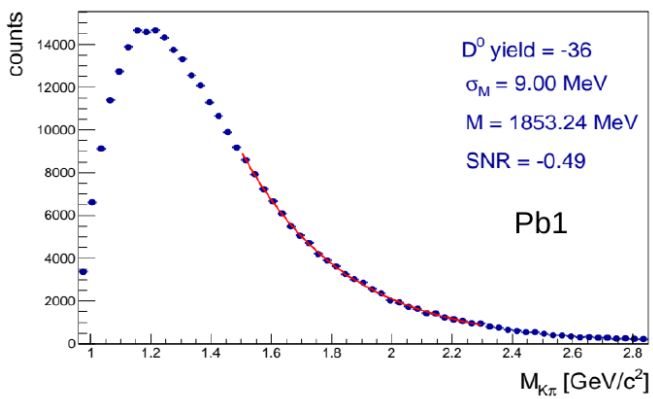

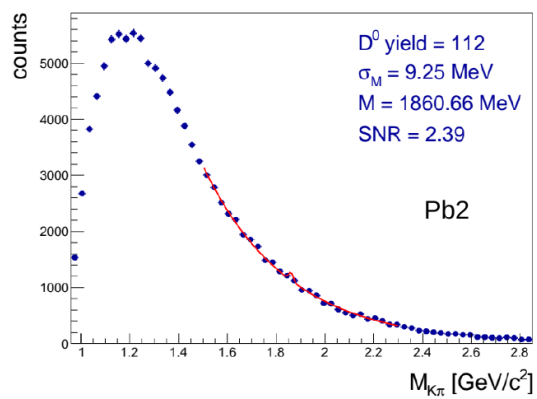

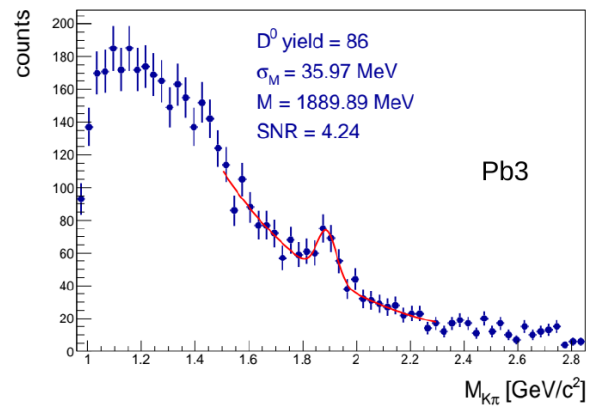

R: The background increase & SNR decrease.

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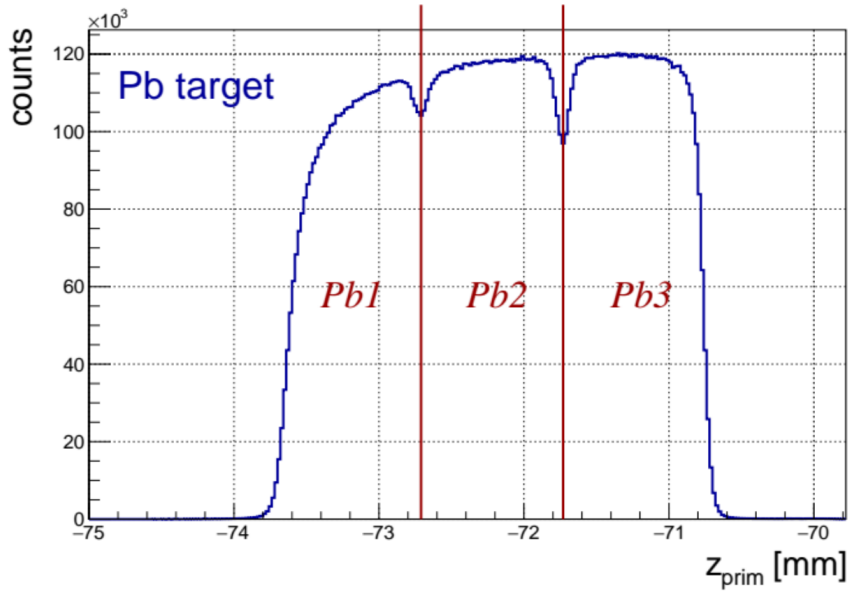
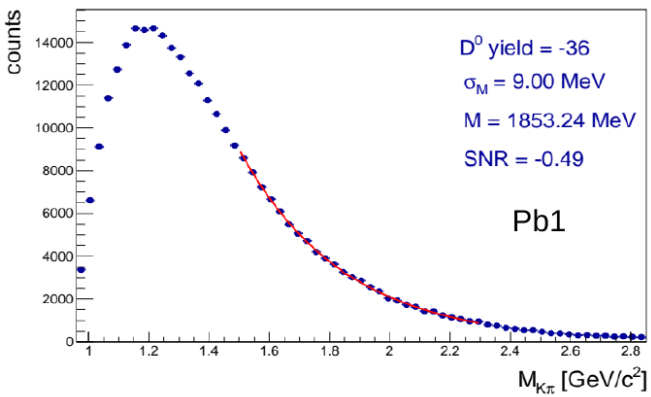
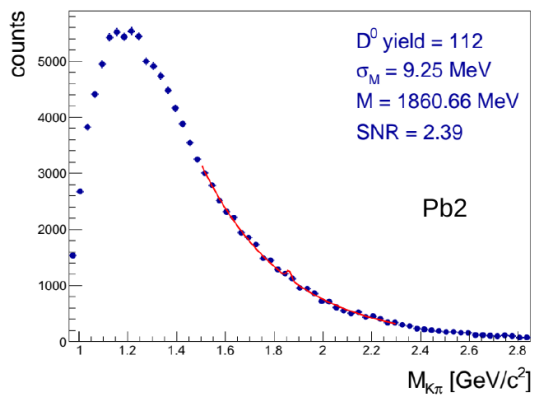
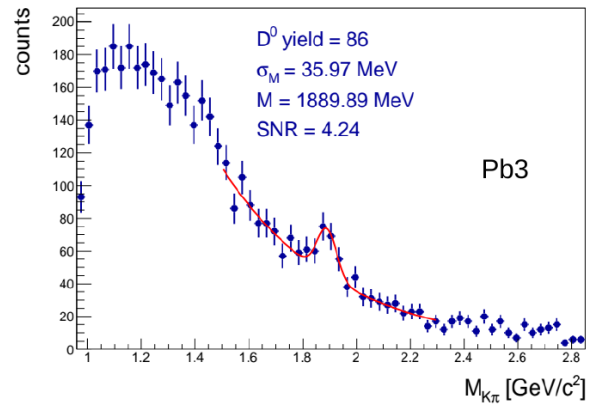






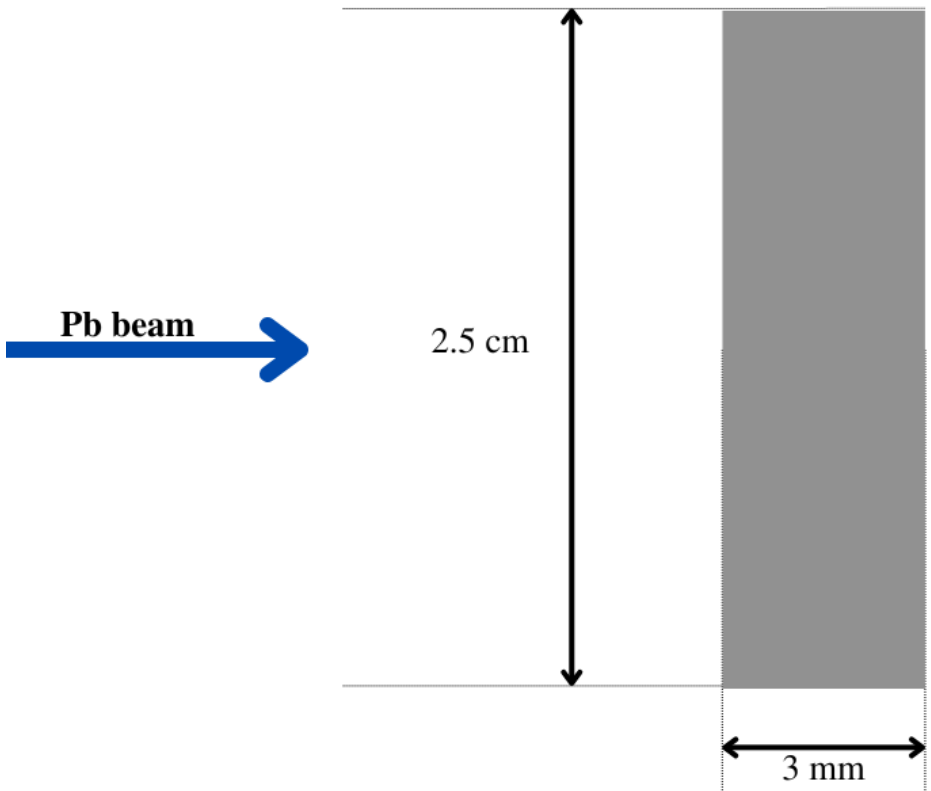


R: The background increase.

Q: Will I observe the same effect in the simulation?

Simulation with solid (continuous) 3 mm target

The solid (continuous) target in simulations (BR = 1 for $D^0 \to \pi + \mathrm{K}$)



Size of target

2.5 cm x 2.5 cm x 3 mm

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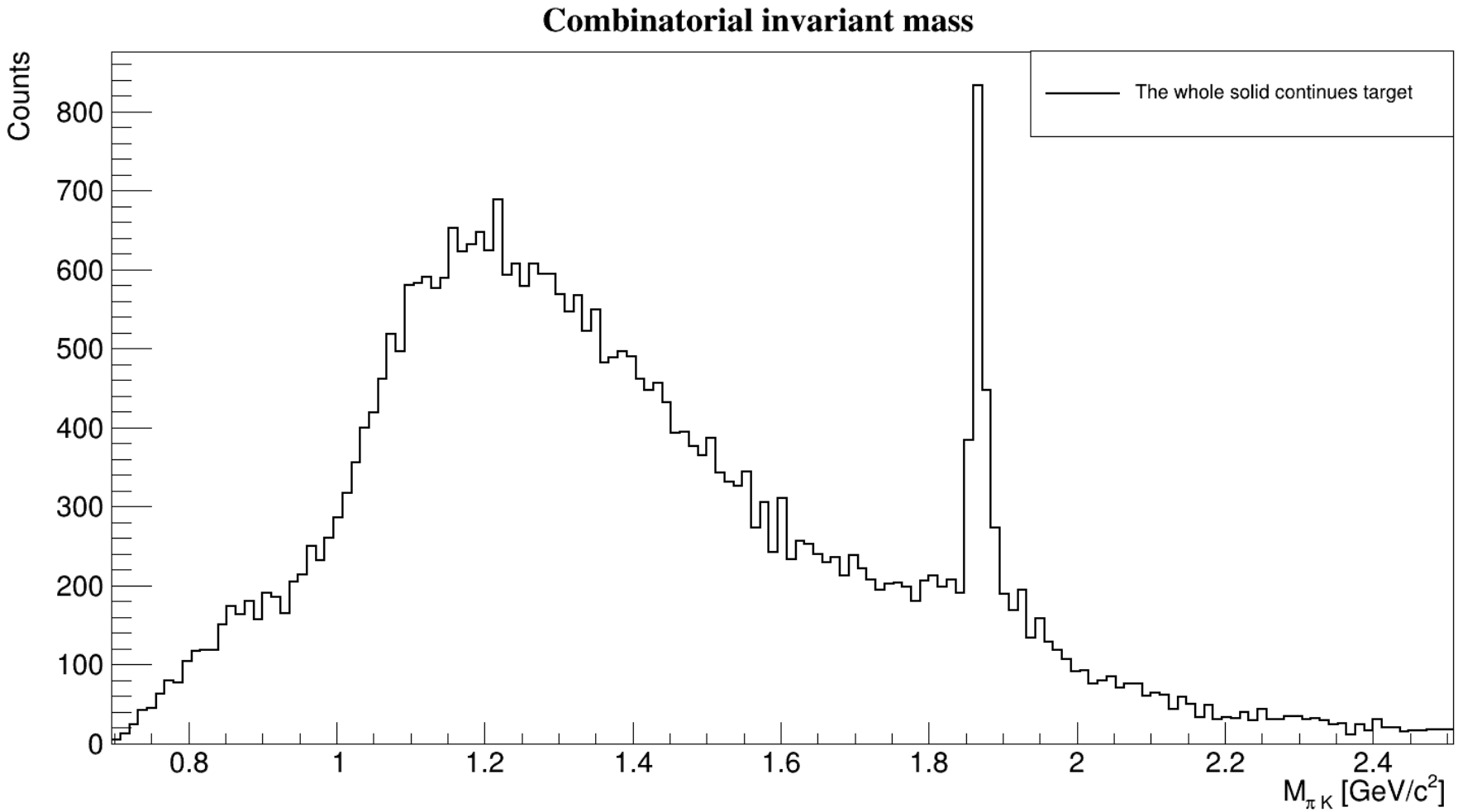

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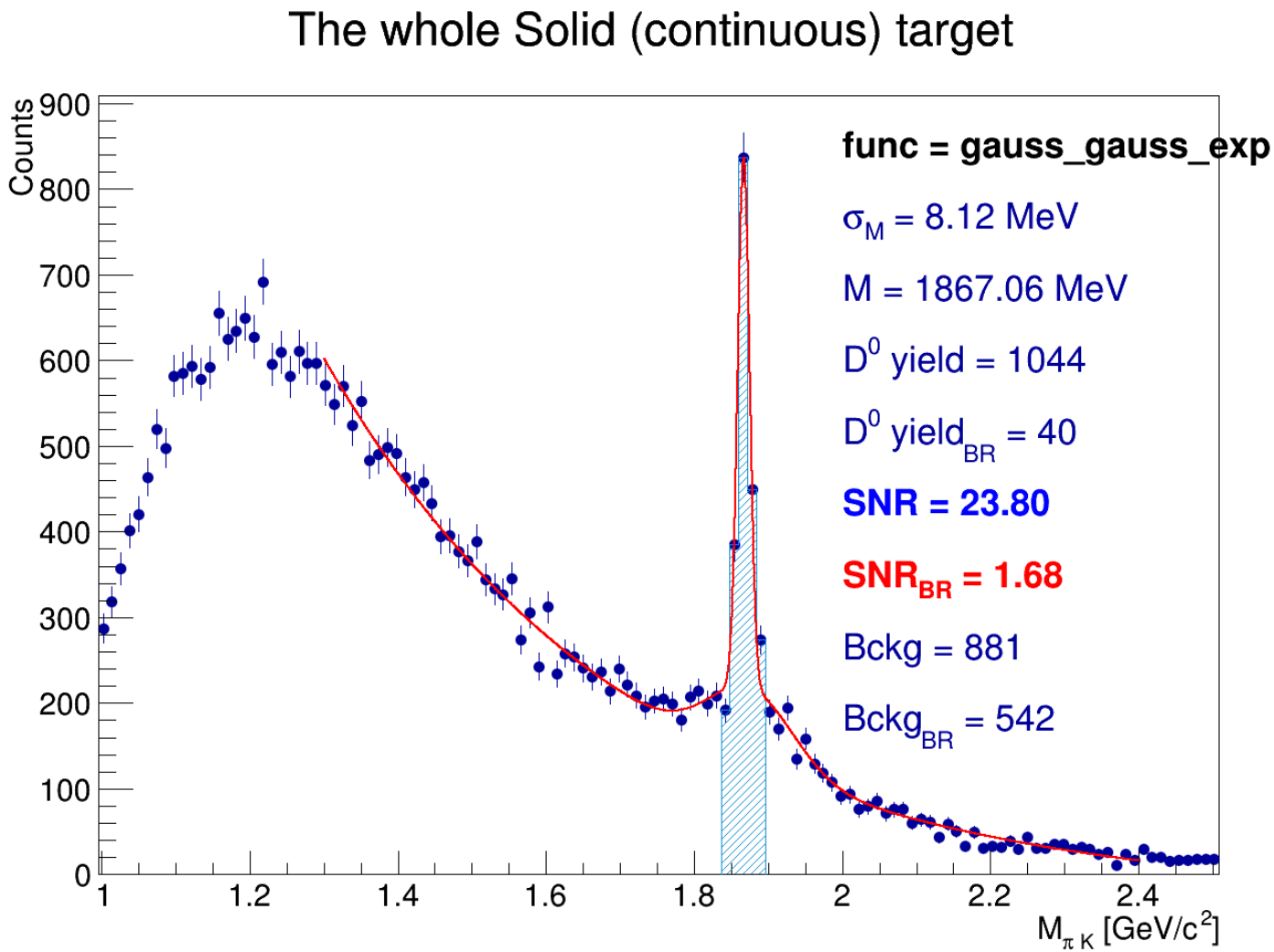

The strategy for finding $D^0 \to \pi + \mathrm{K}$

$$\mathrm{RecoTrack}_1(M_K) + \mathrm{RecoTrack}_2(M_\pi) \to M_{D^0} \quad \text{or} \quad \mathrm{RecoTrack}_1(M_\pi) + \mathrm{RecoTrack}_2(M_K) \to M_{D^0}$$

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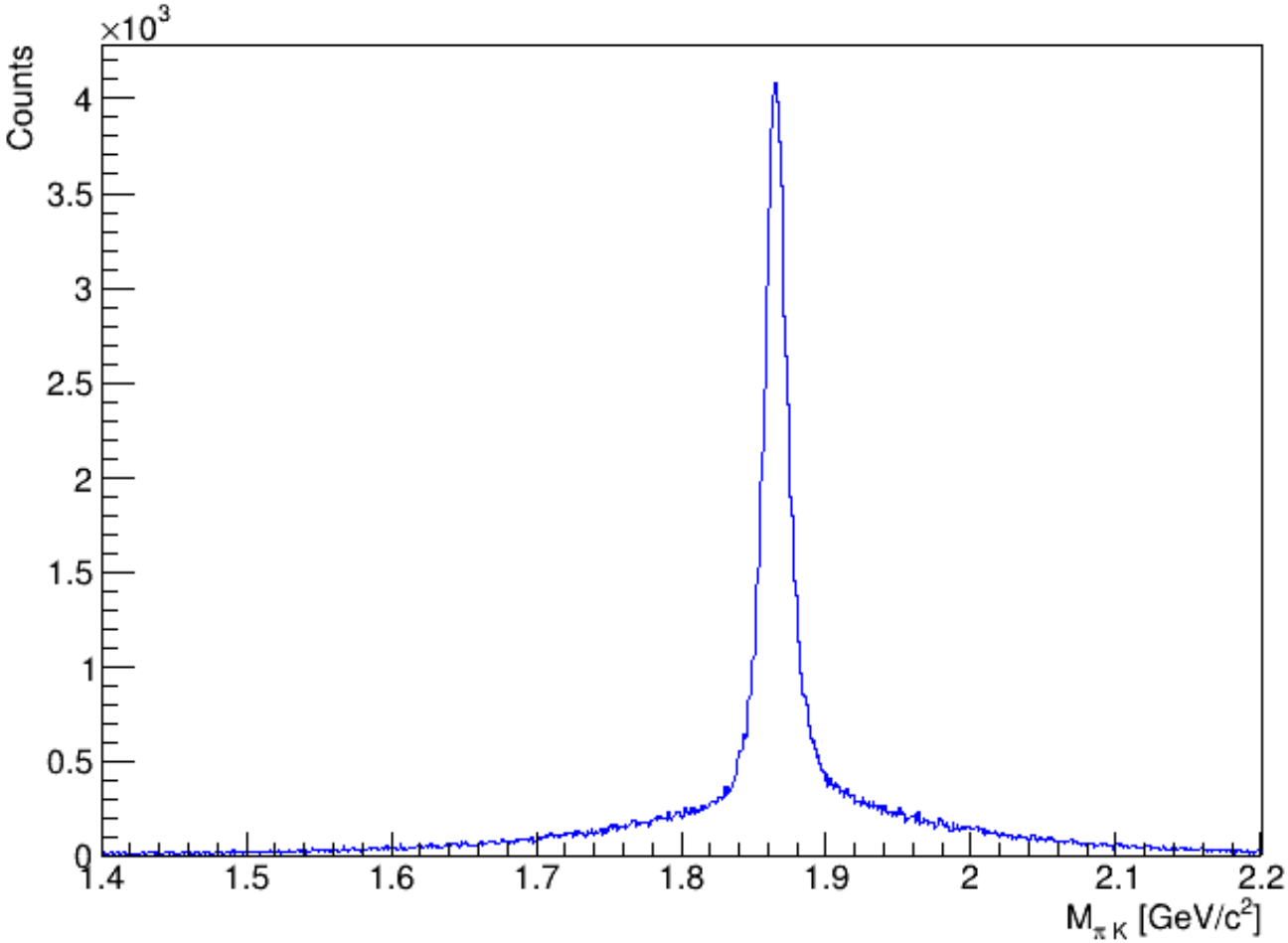

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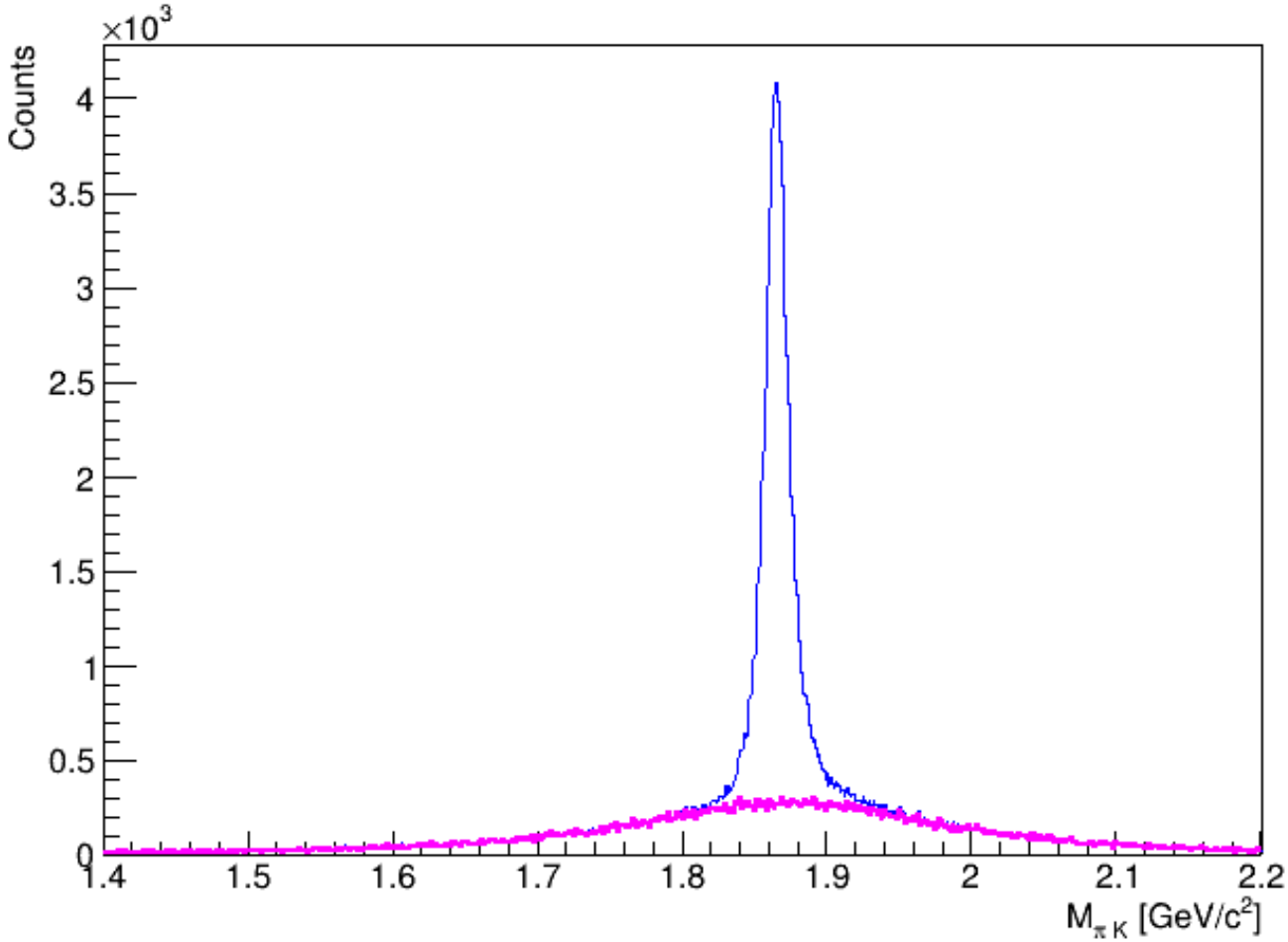

Background (improperly assumed masses of daughter)

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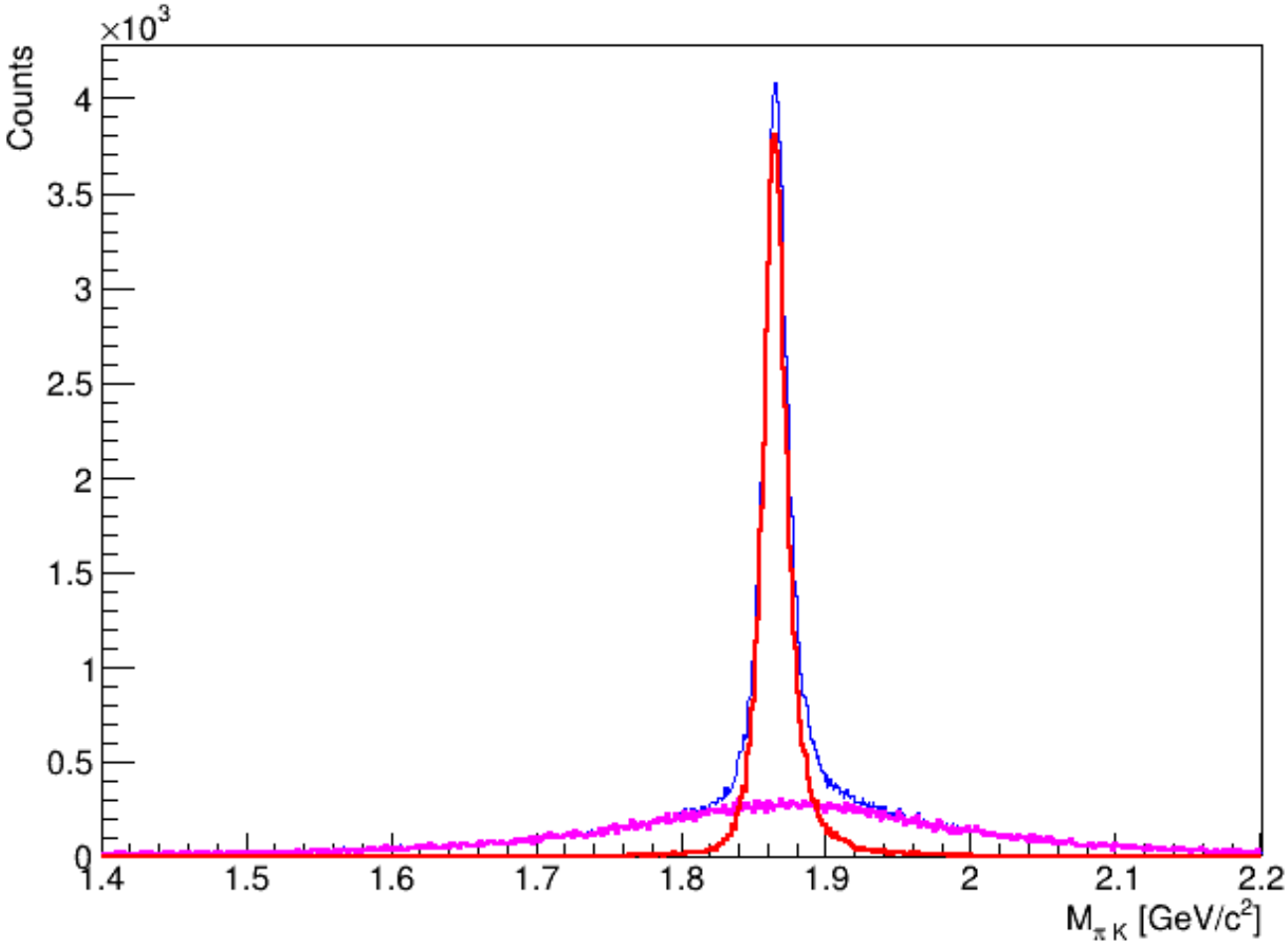

Background (improperly assumed masses of daughter)

Signal (correct assumed masses of daughter)

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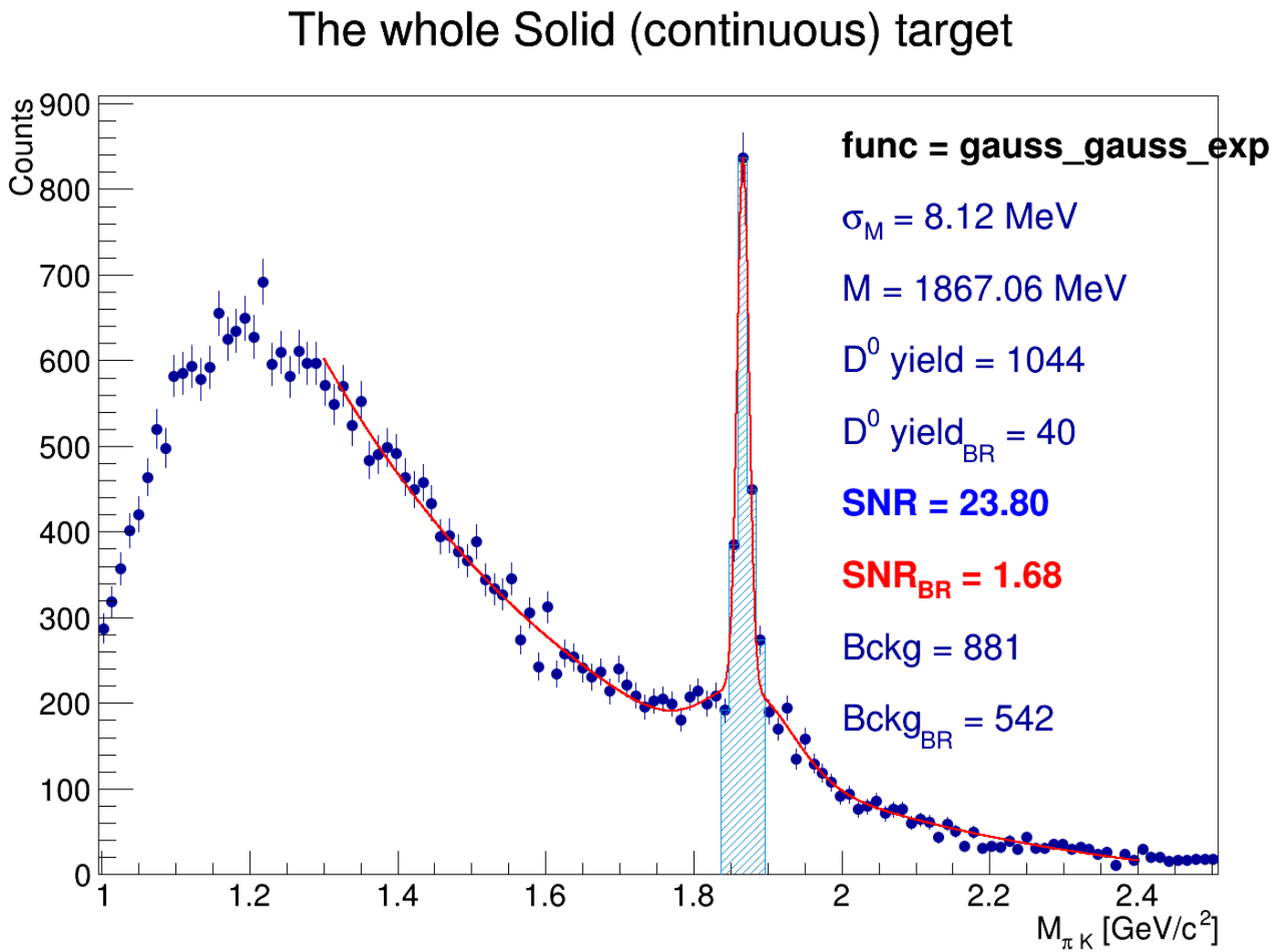
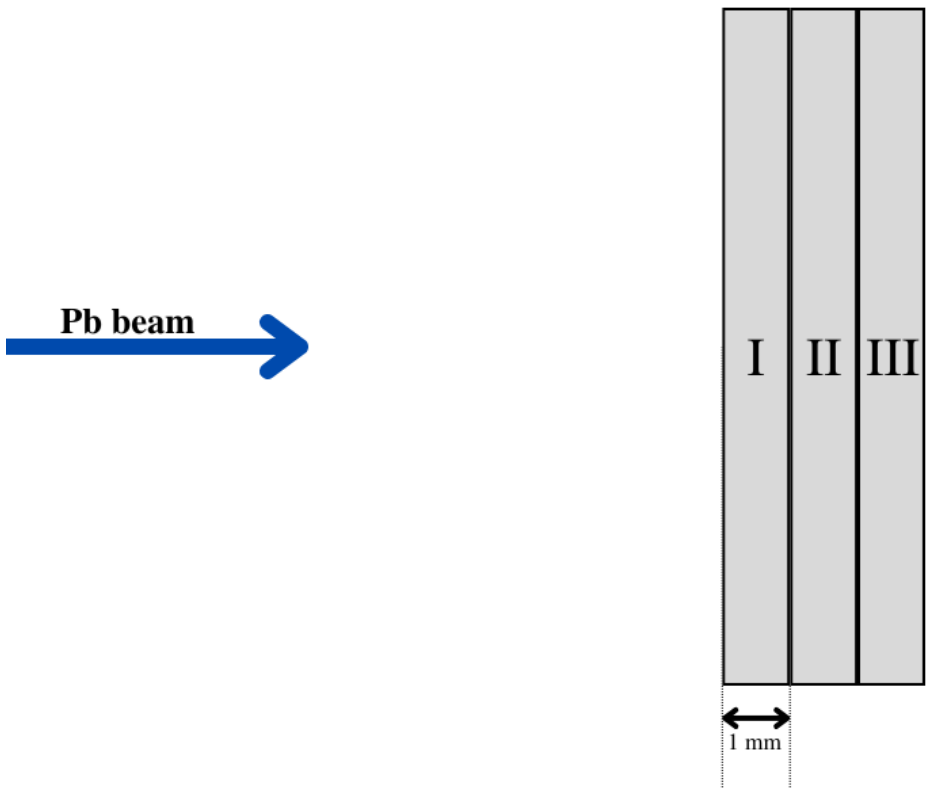


The solid (continuous) target in simulations (BR = 1 for $D^0 \to \pi + \mathrm{K}$)



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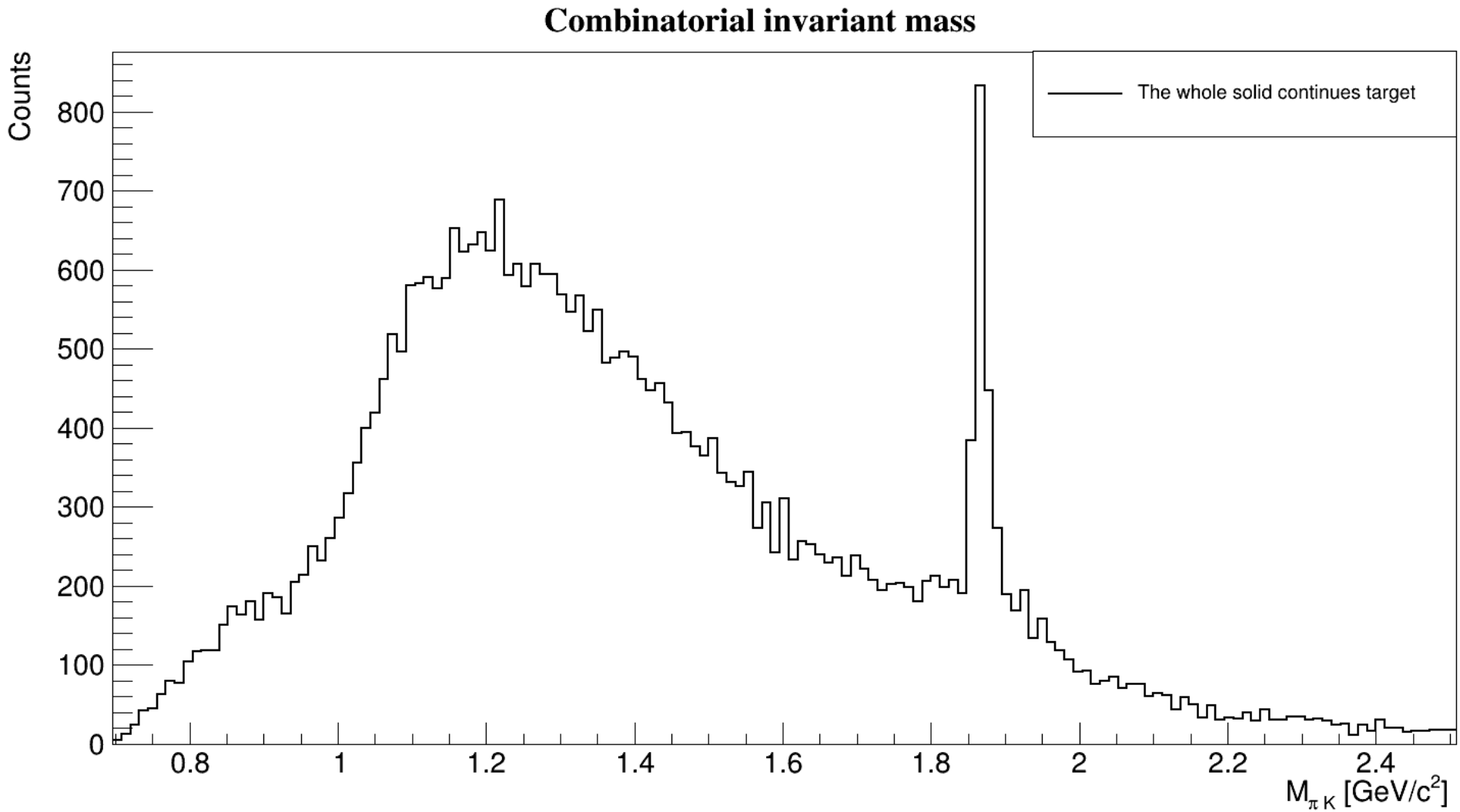

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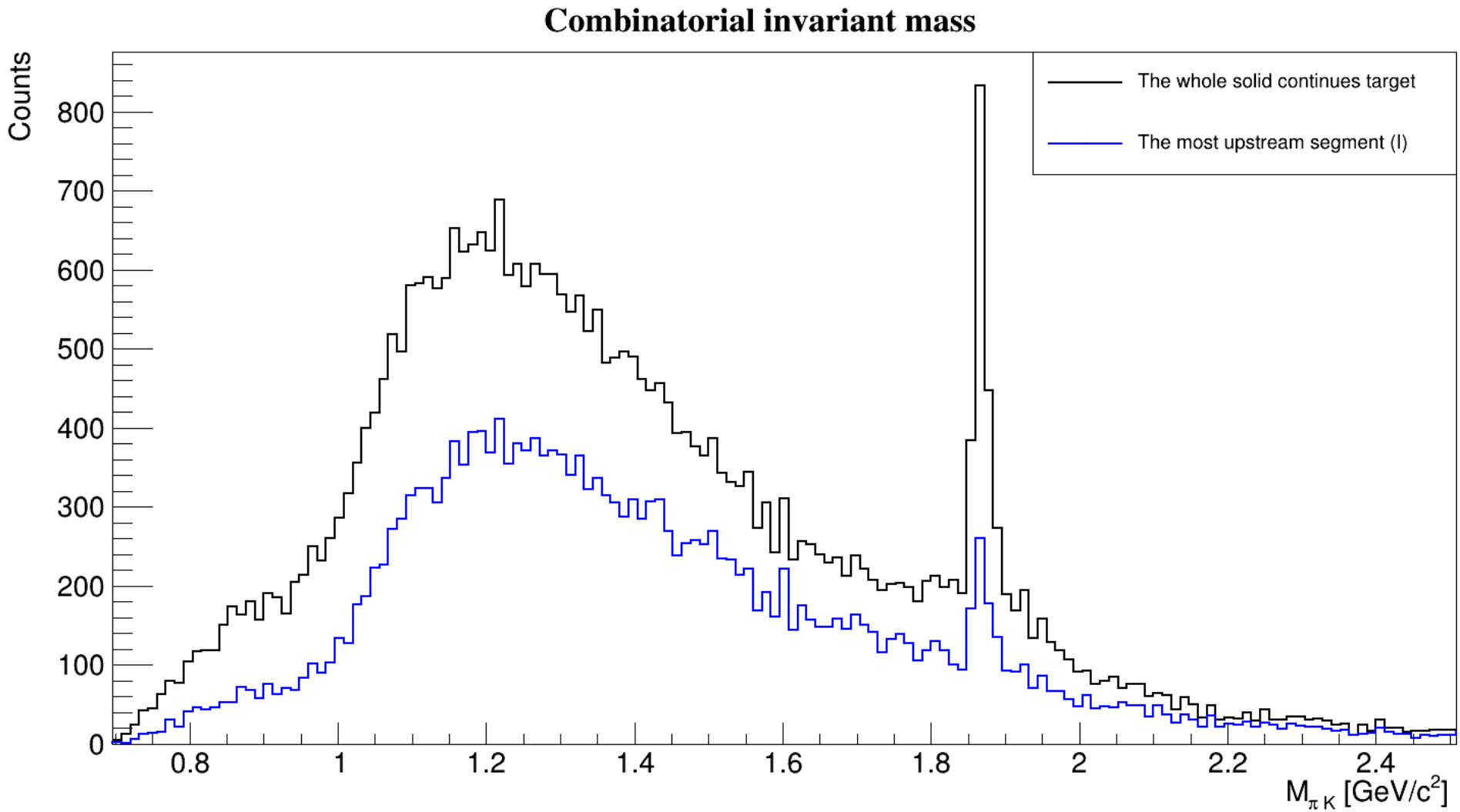

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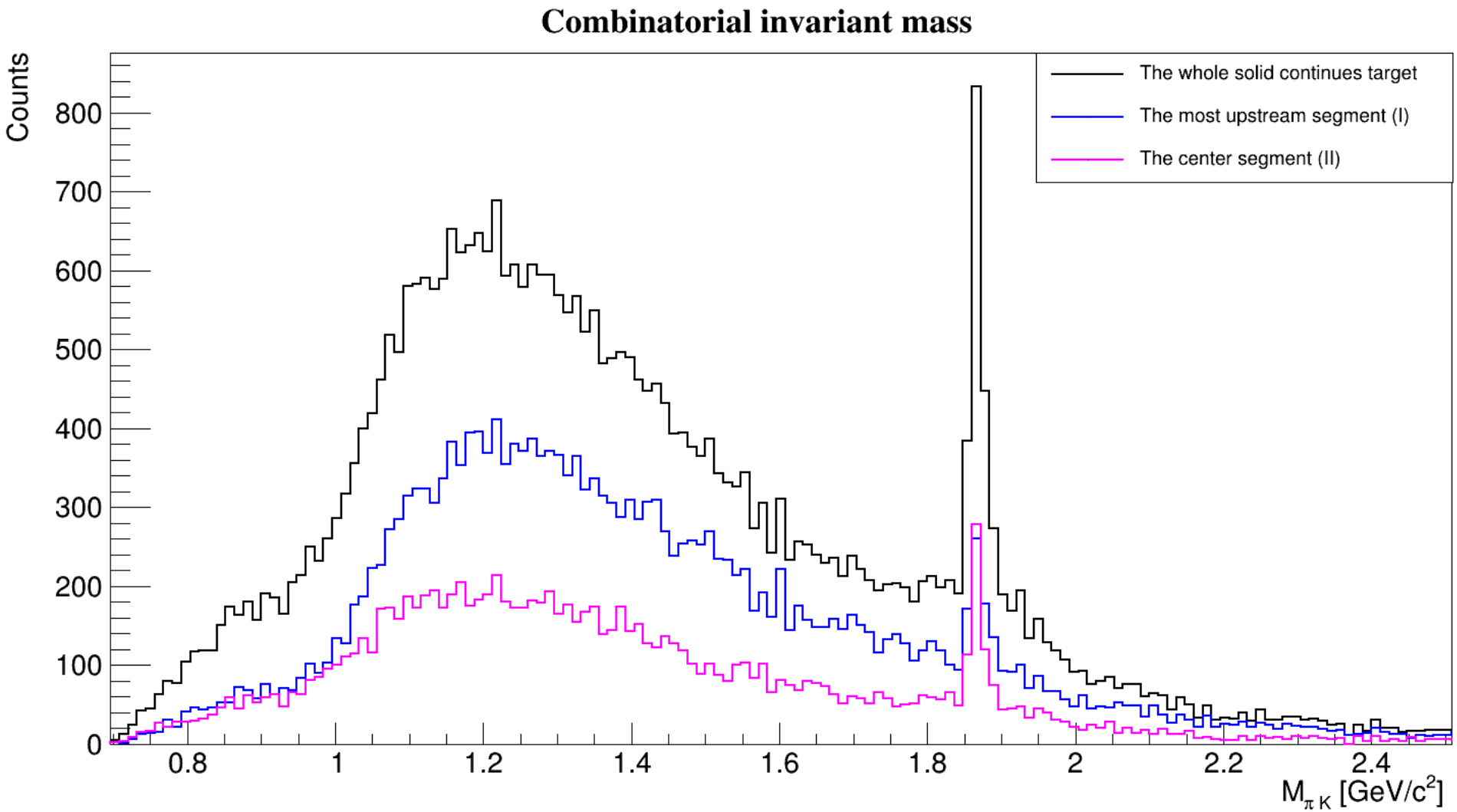

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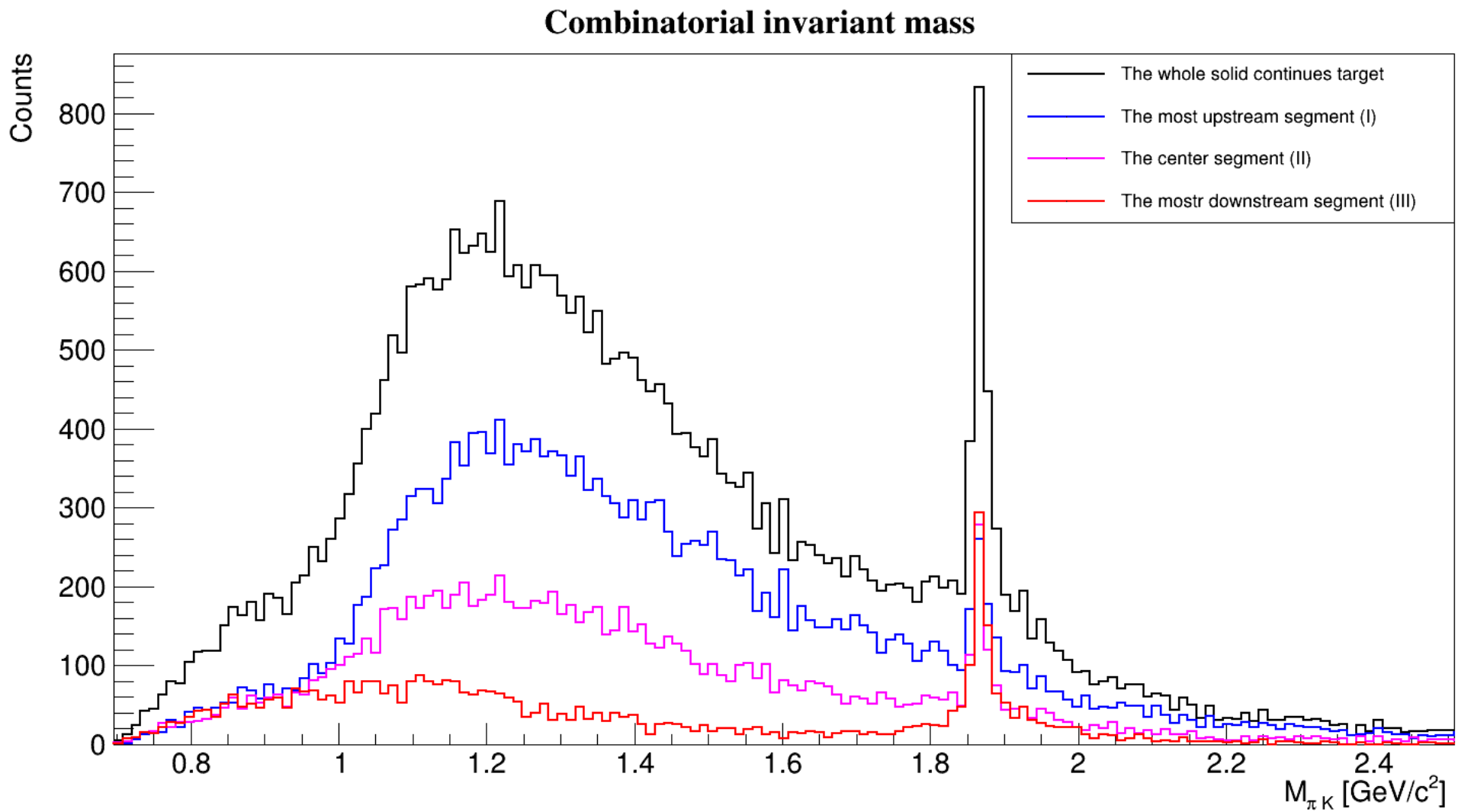
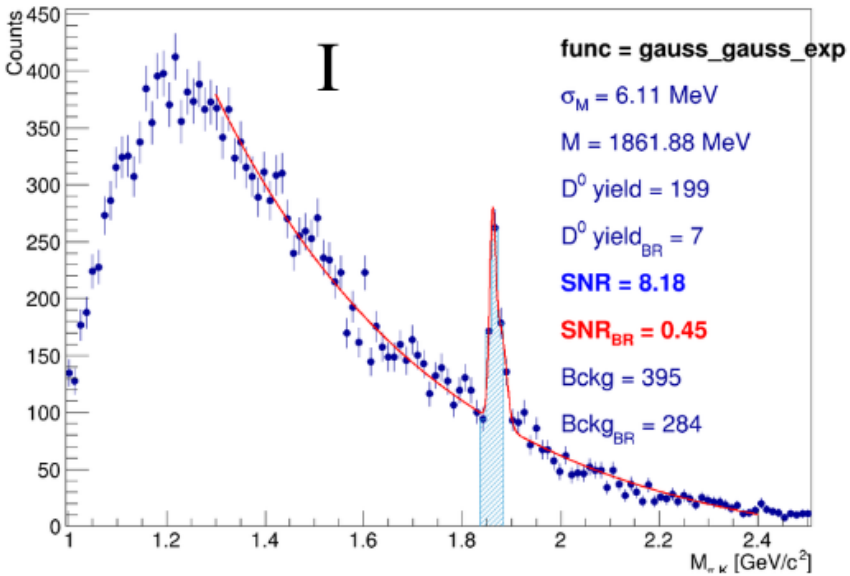
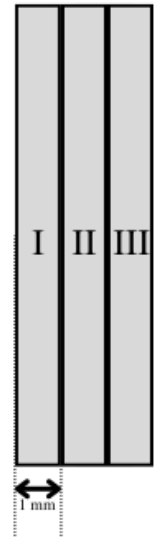
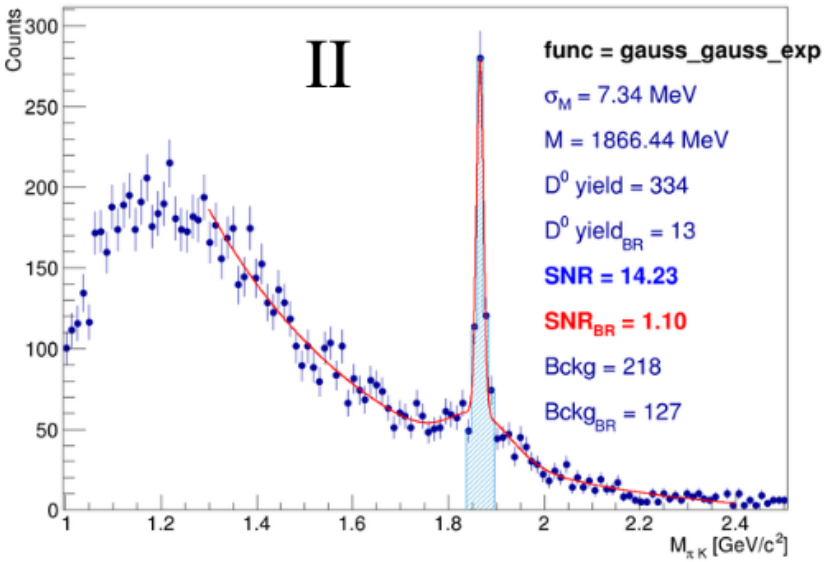


The most upstream segment (Solid (continuous) target)

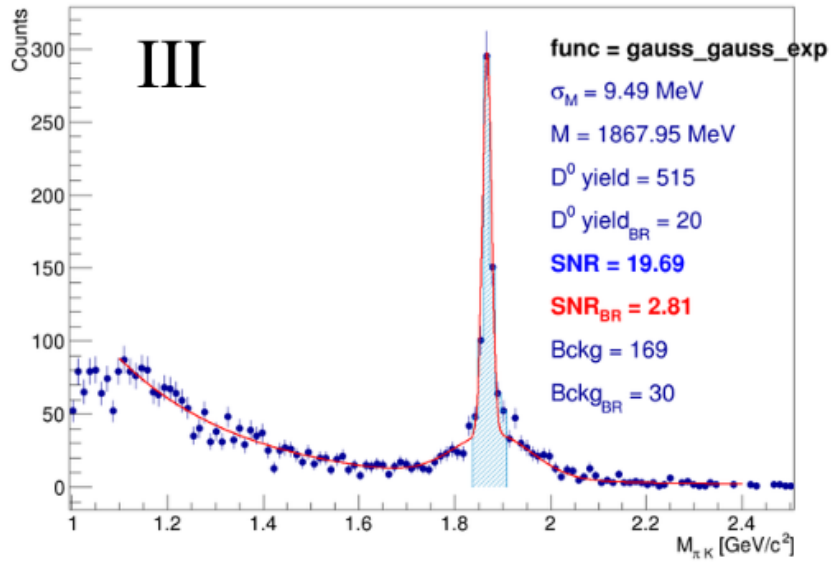




The center segment (Solid (continuous) target)



The most downstream segment (Solid (continuous) target)



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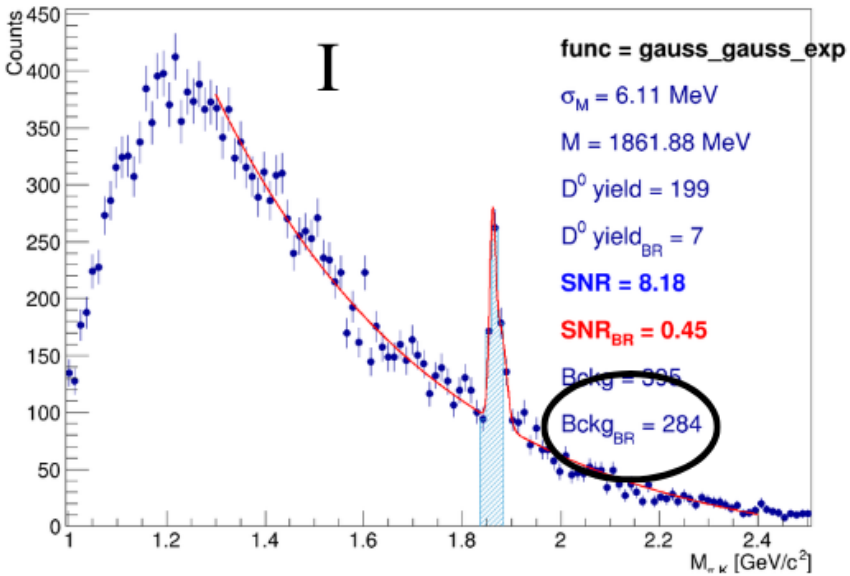
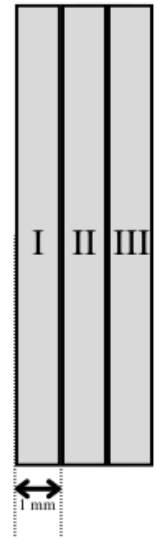


Around peak
the background changed
by factor **~5**



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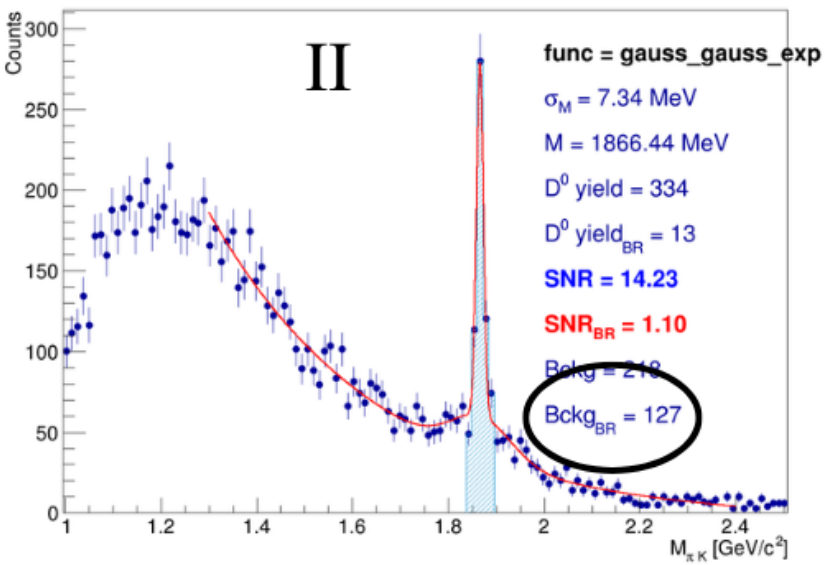

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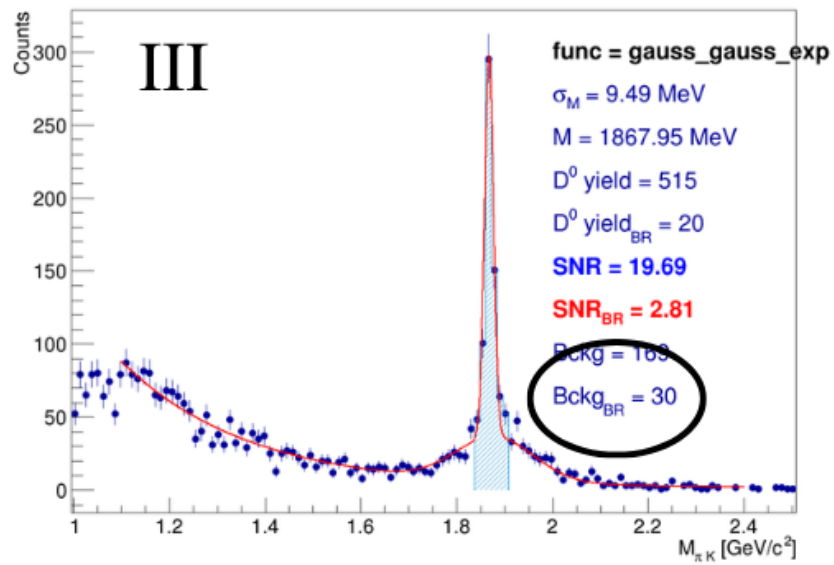

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Answer:

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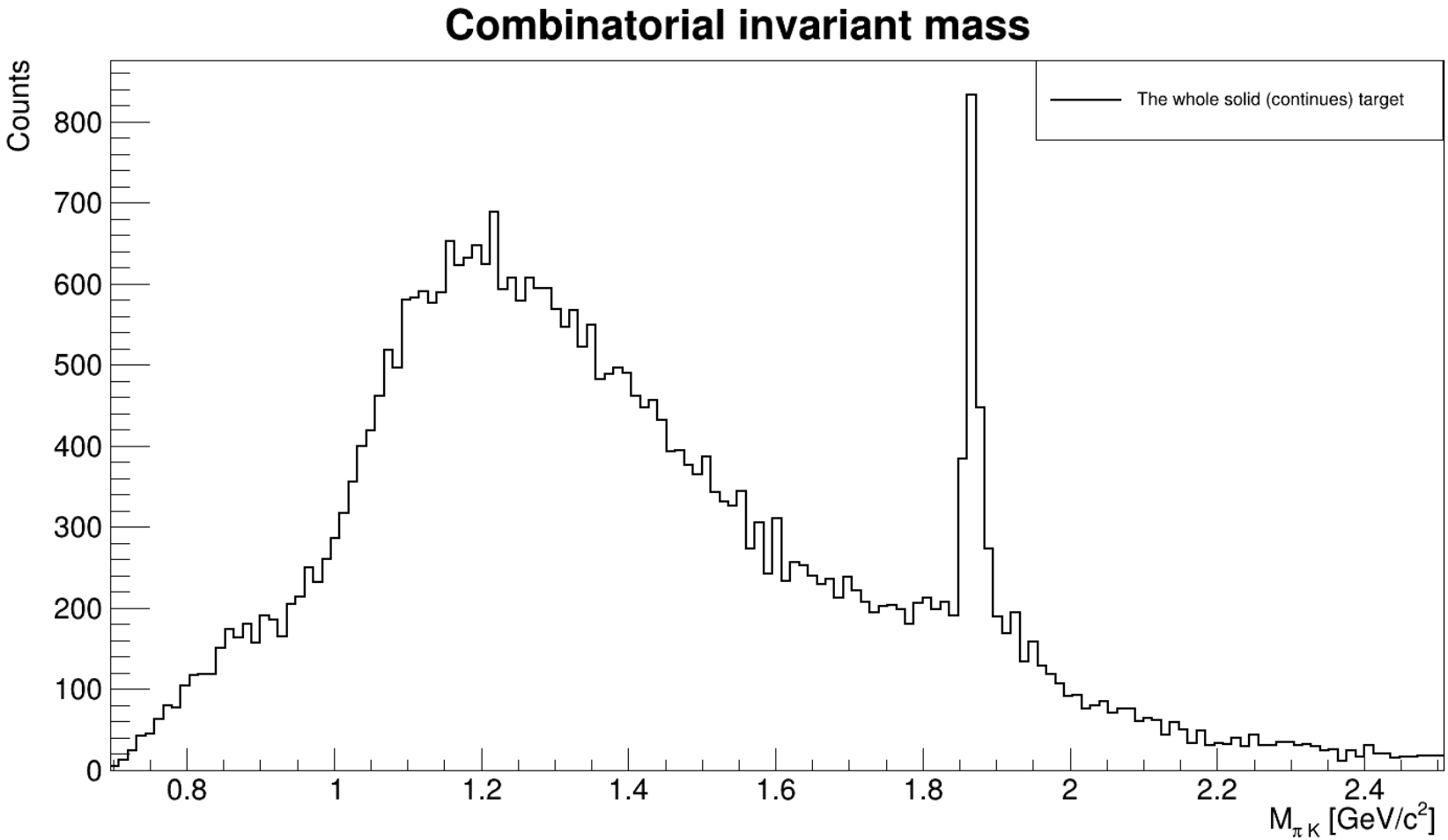

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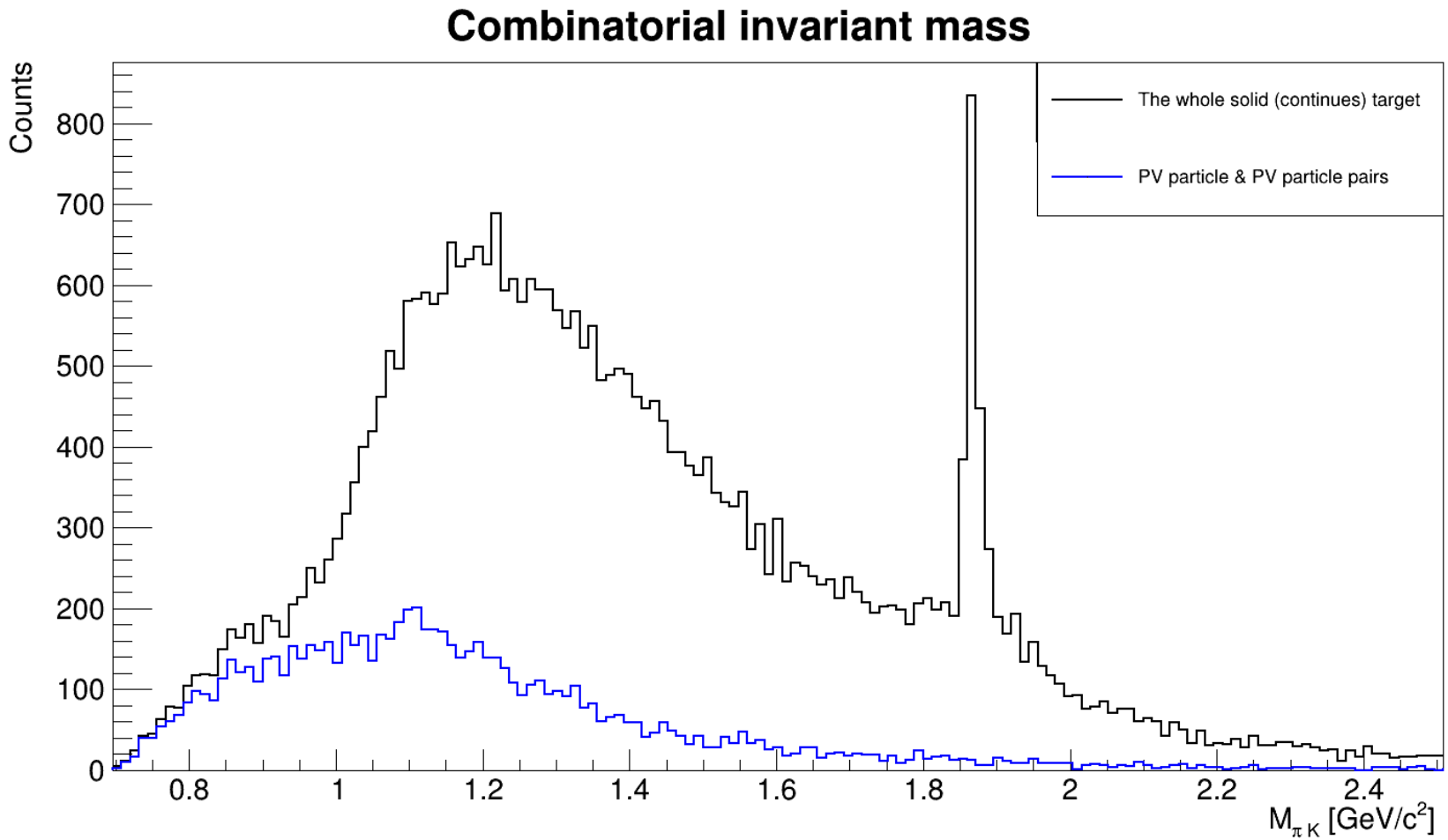

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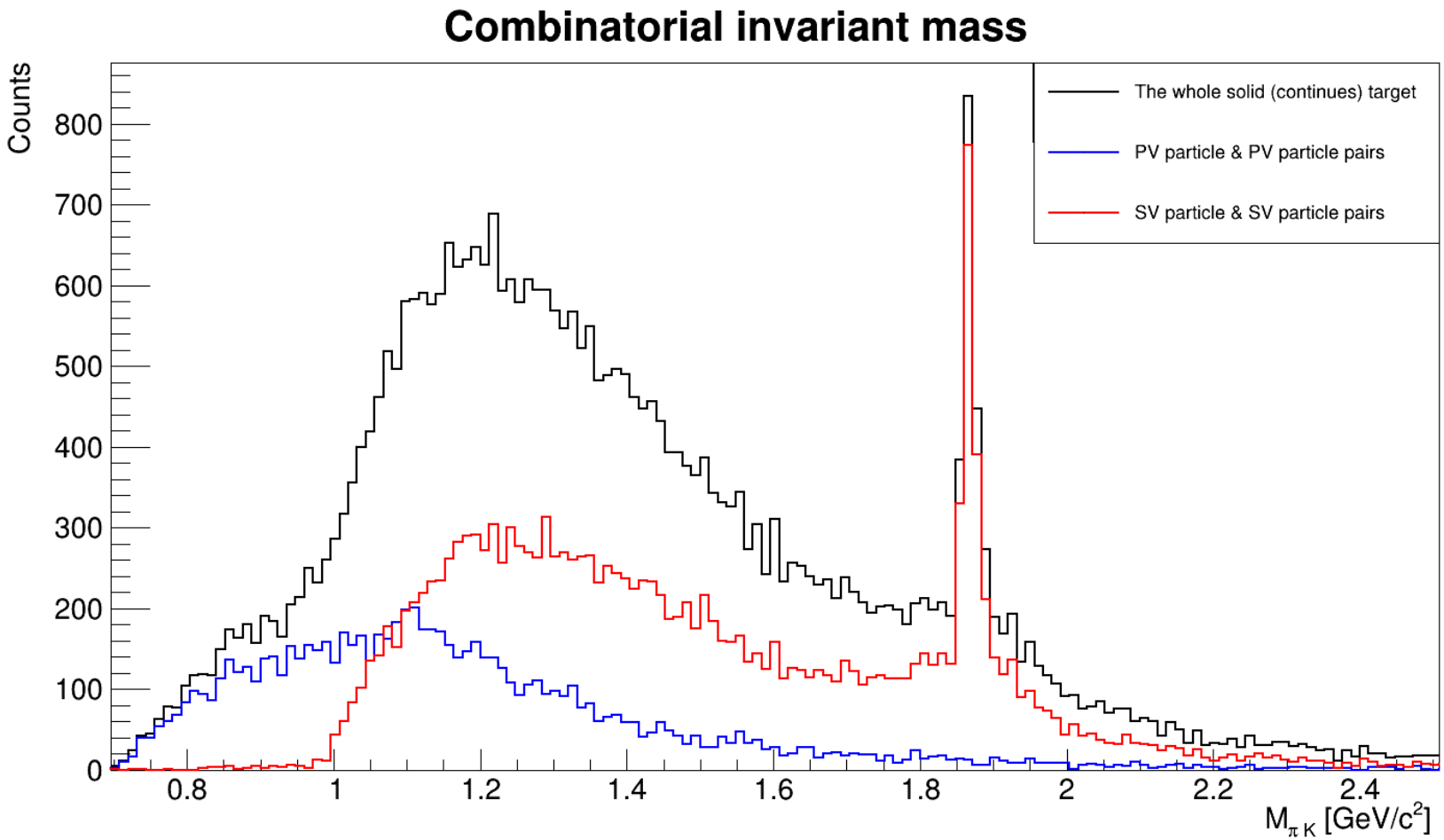

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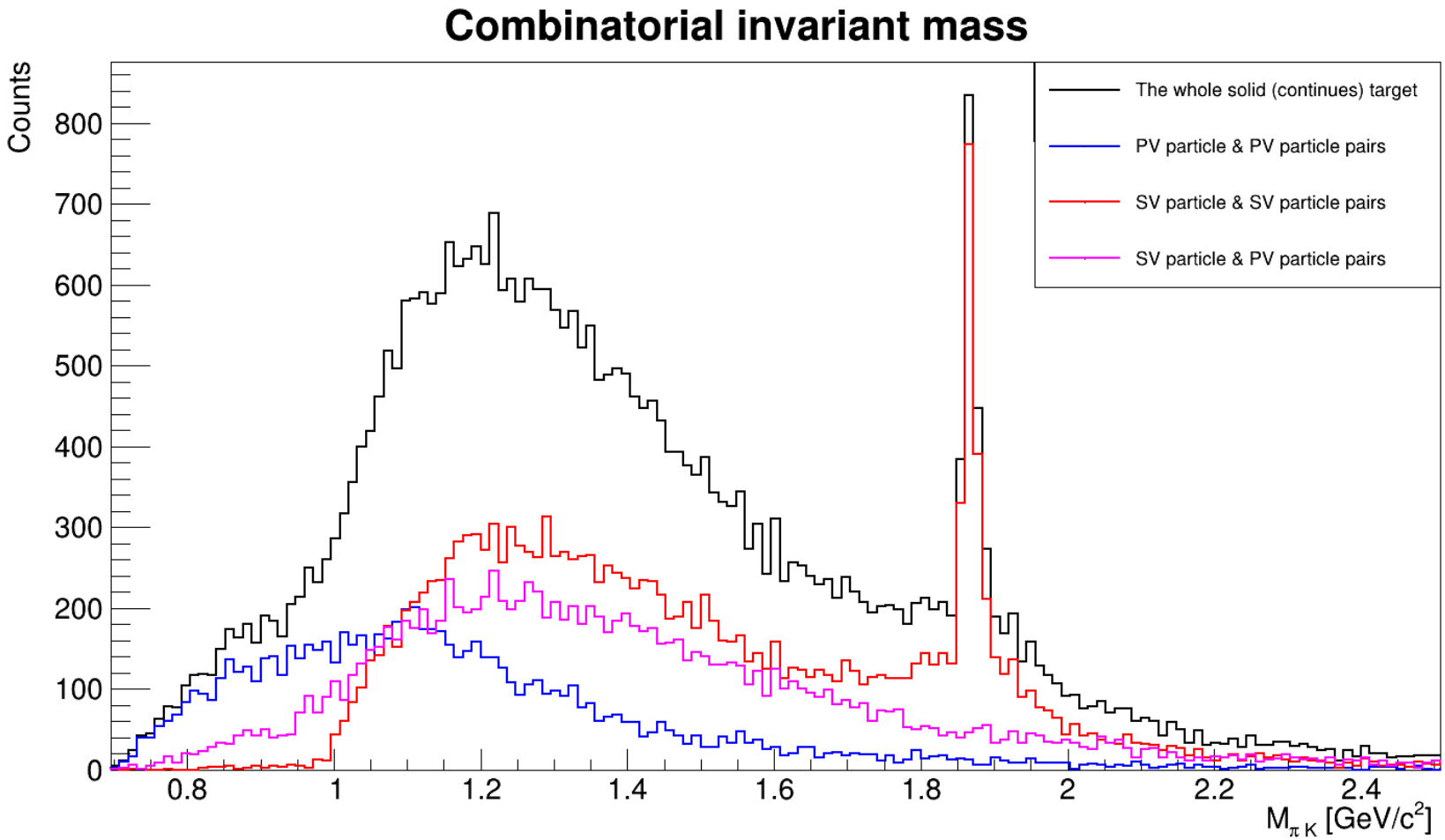

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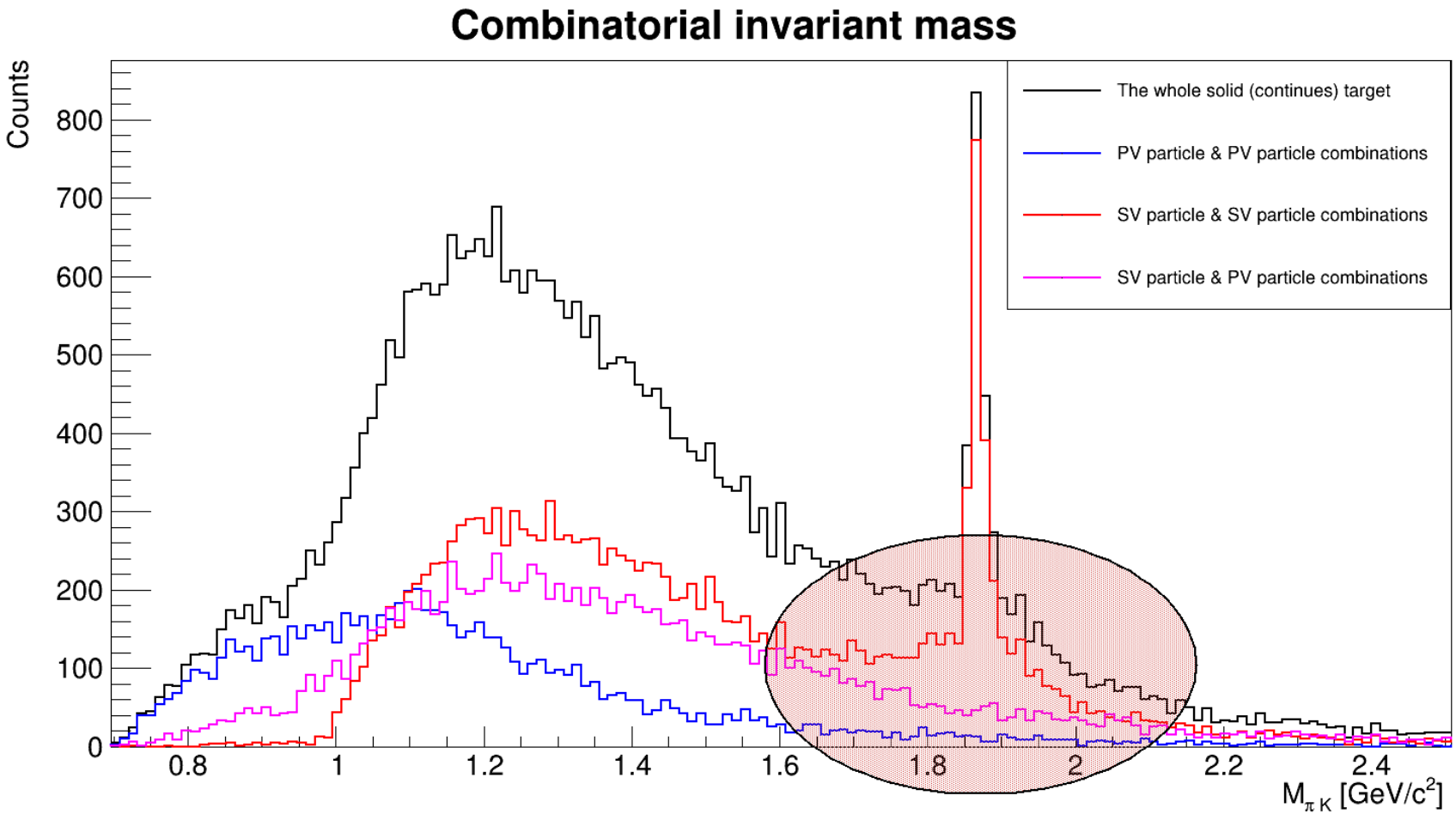

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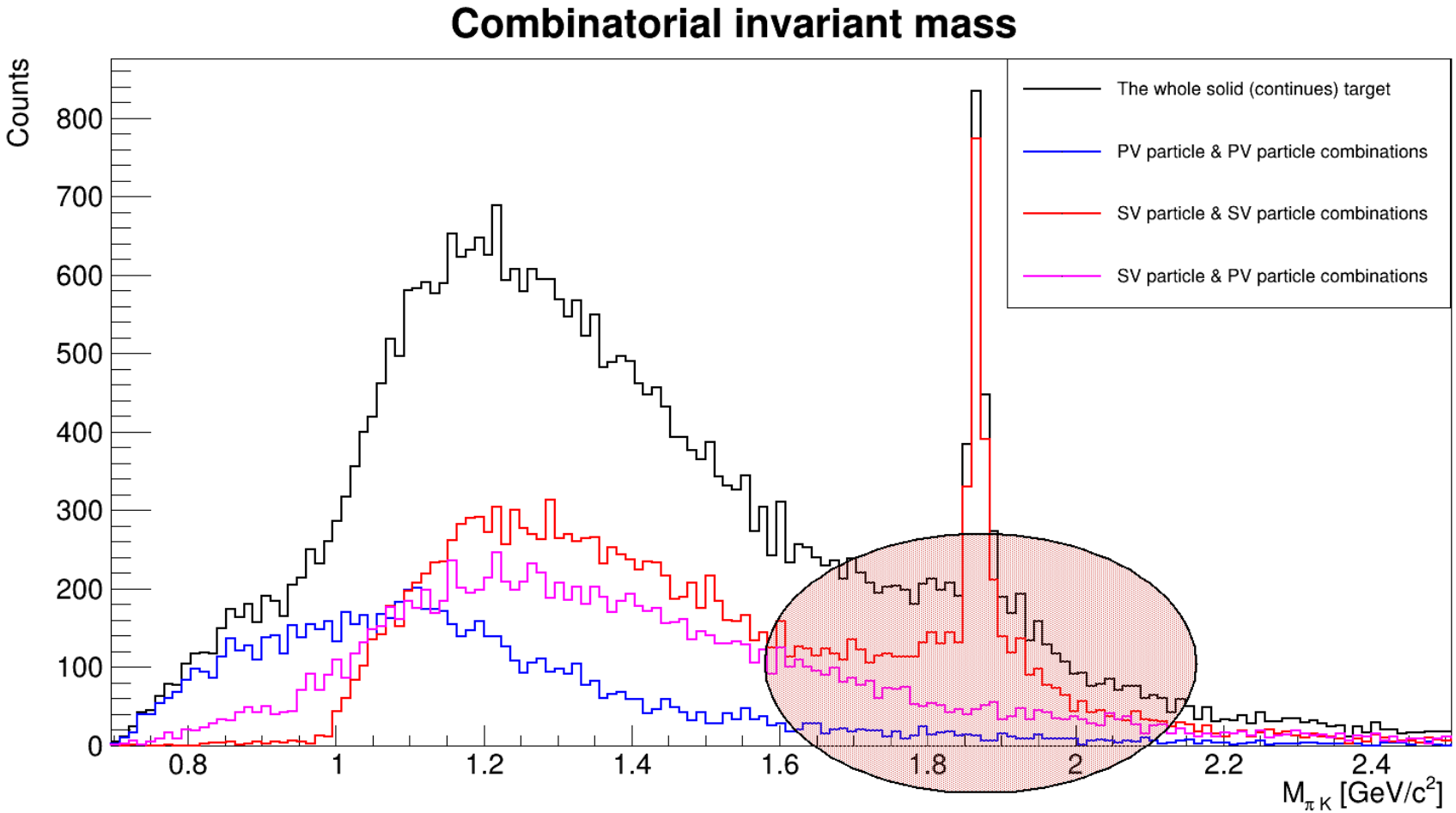

Result: To increase SNR (signal-to-background ratio), we need to decrease or "remove" (somehow) secondary processes.

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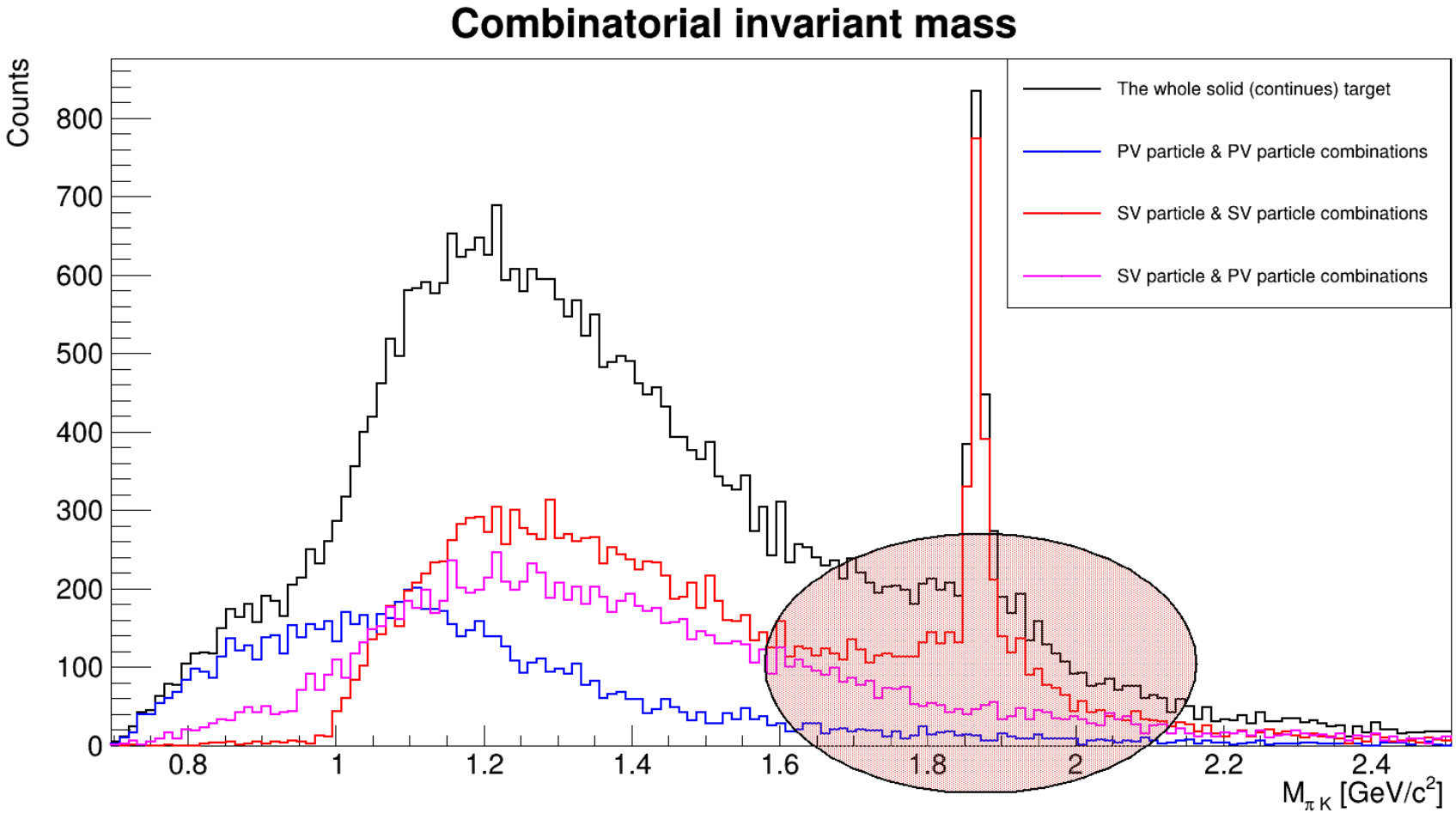
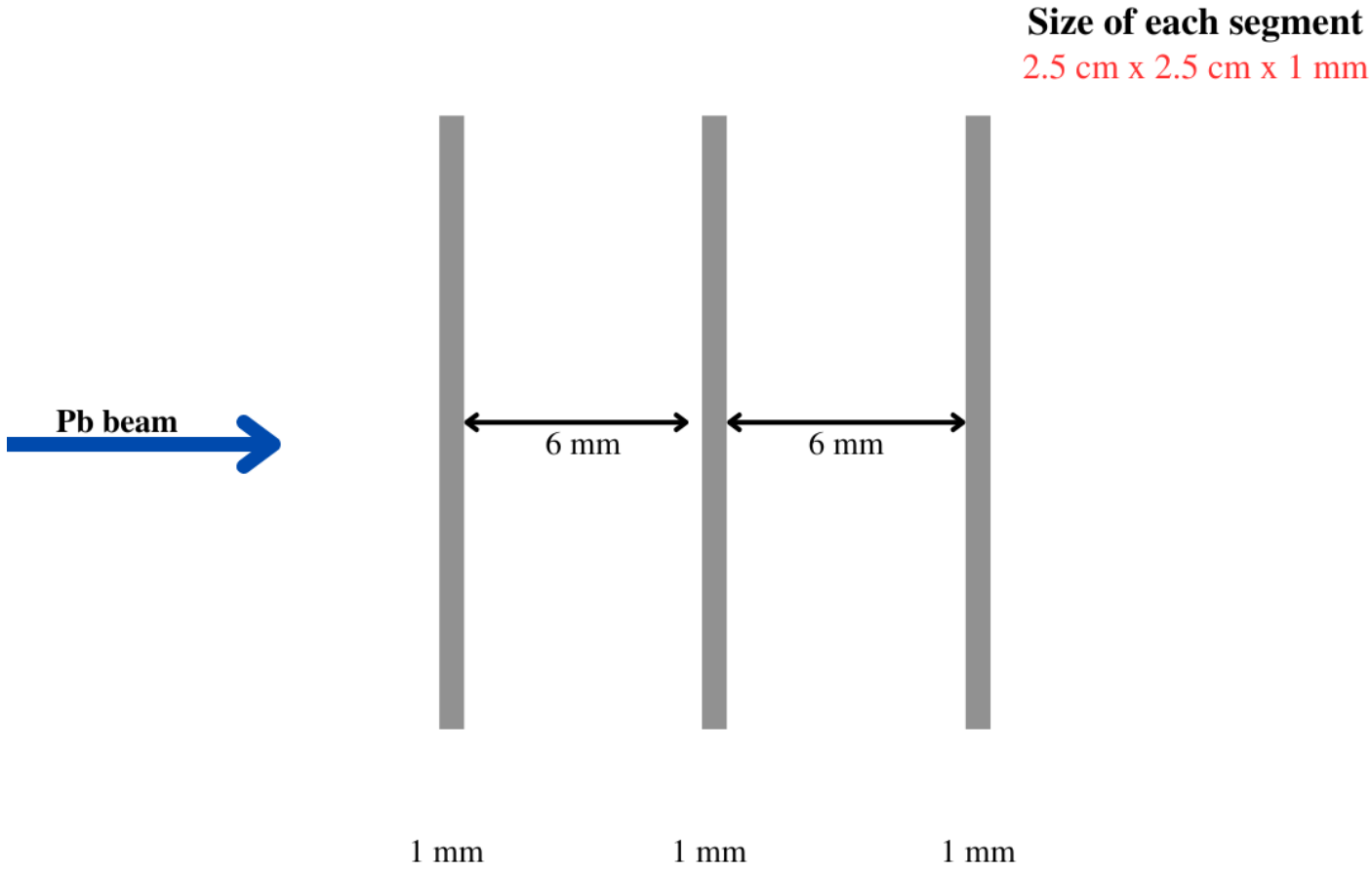


Result: To increase SNR (signal-to-background ratio), we need to decrease or "remove" (somehow) secondary processes. → **Idea**: **The segmented target.**

Simulation with segmented target

The segmented target scheme



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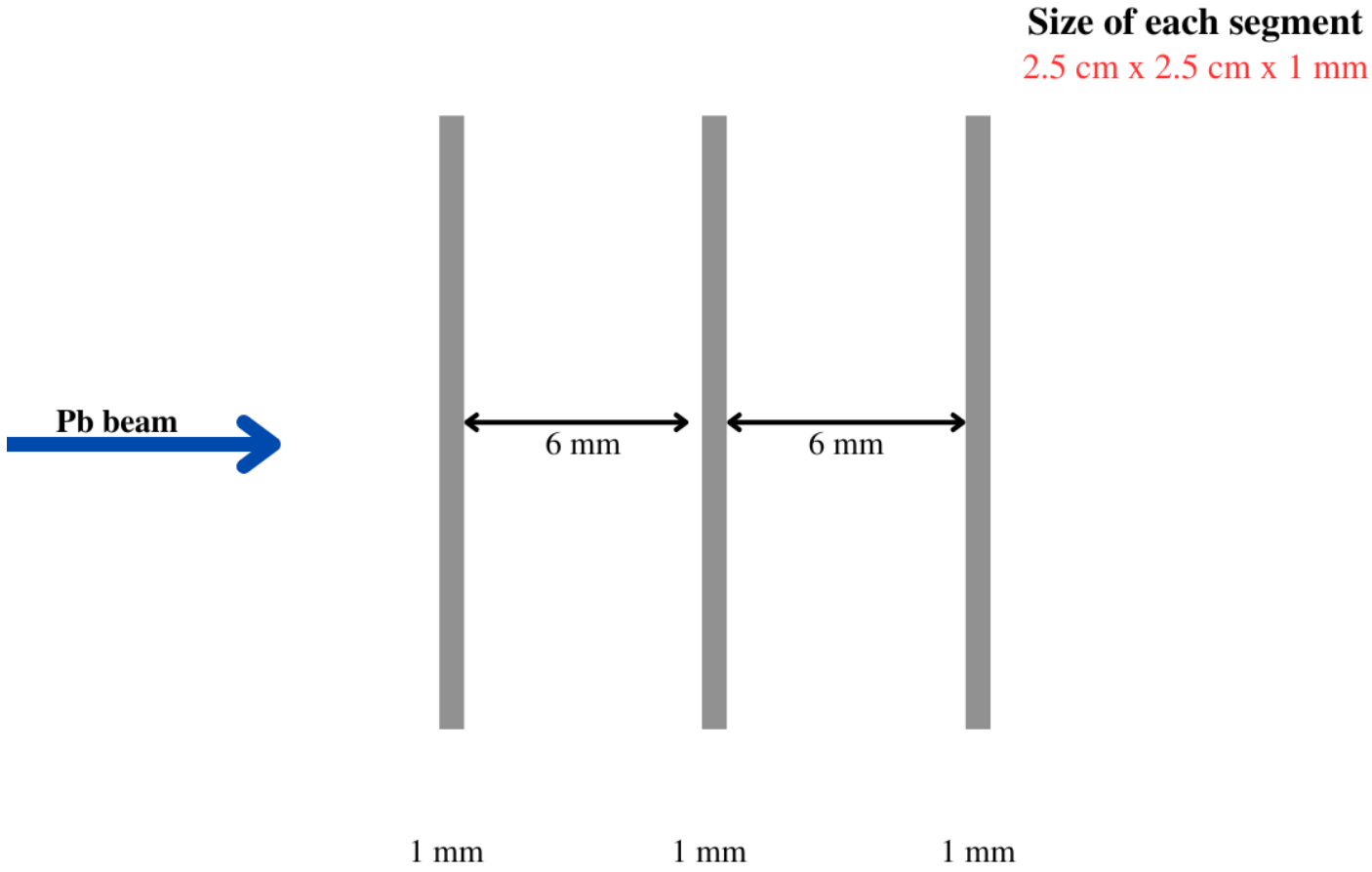
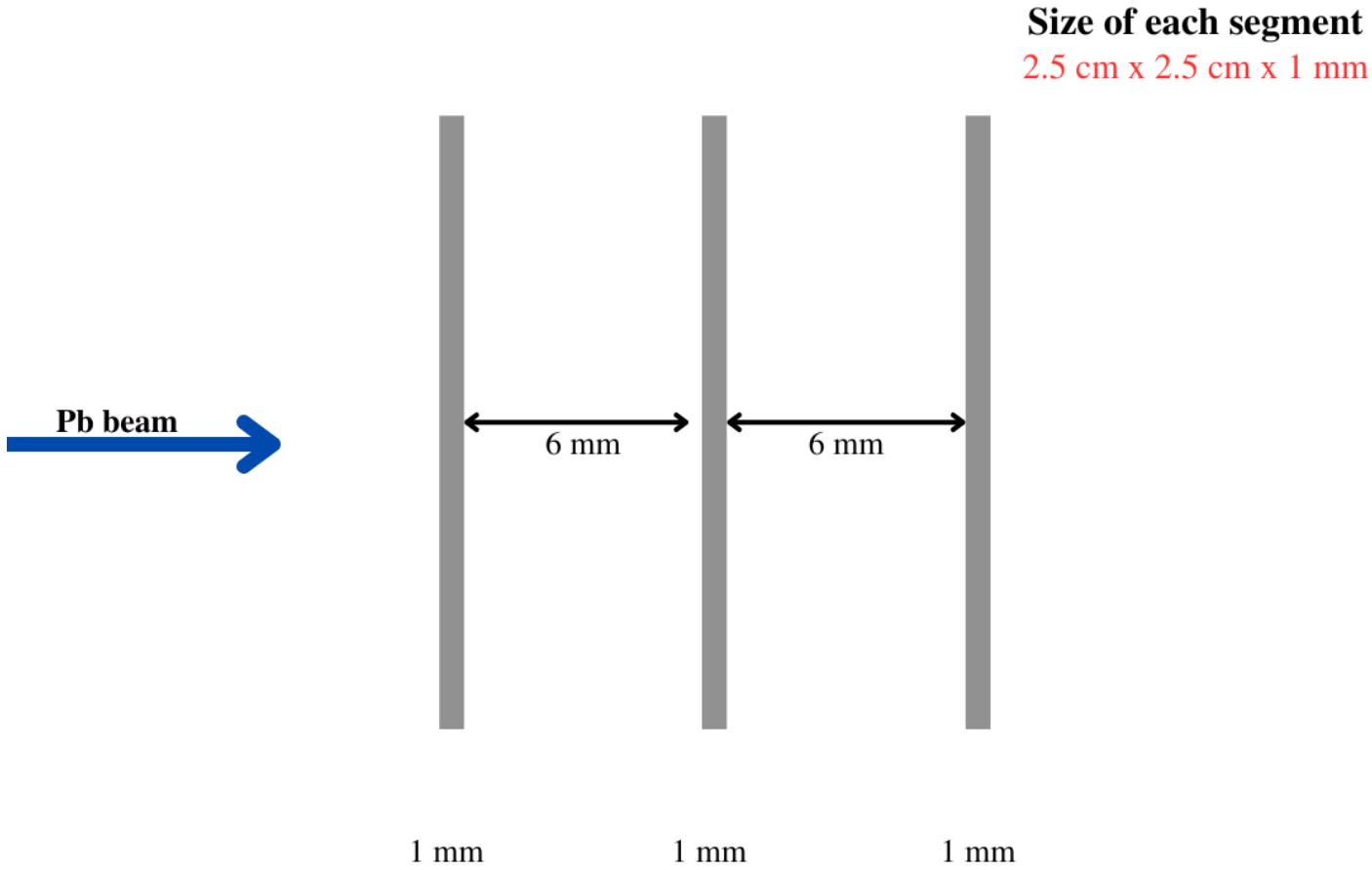


Question: *Why the distance between segments is 6 mm?*
Why not, e.g. 4 mm or 12 mm?

The segmented target scheme



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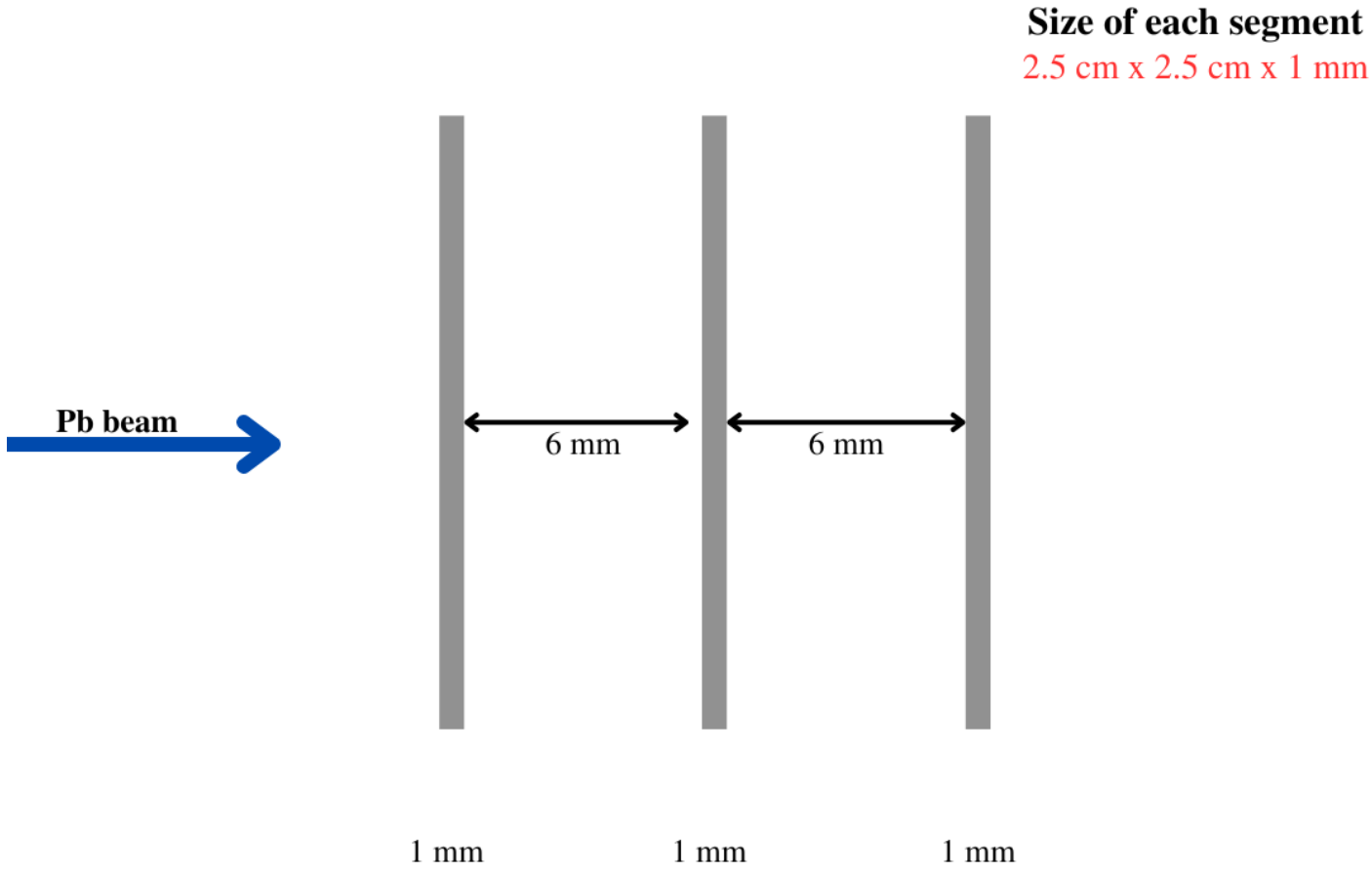
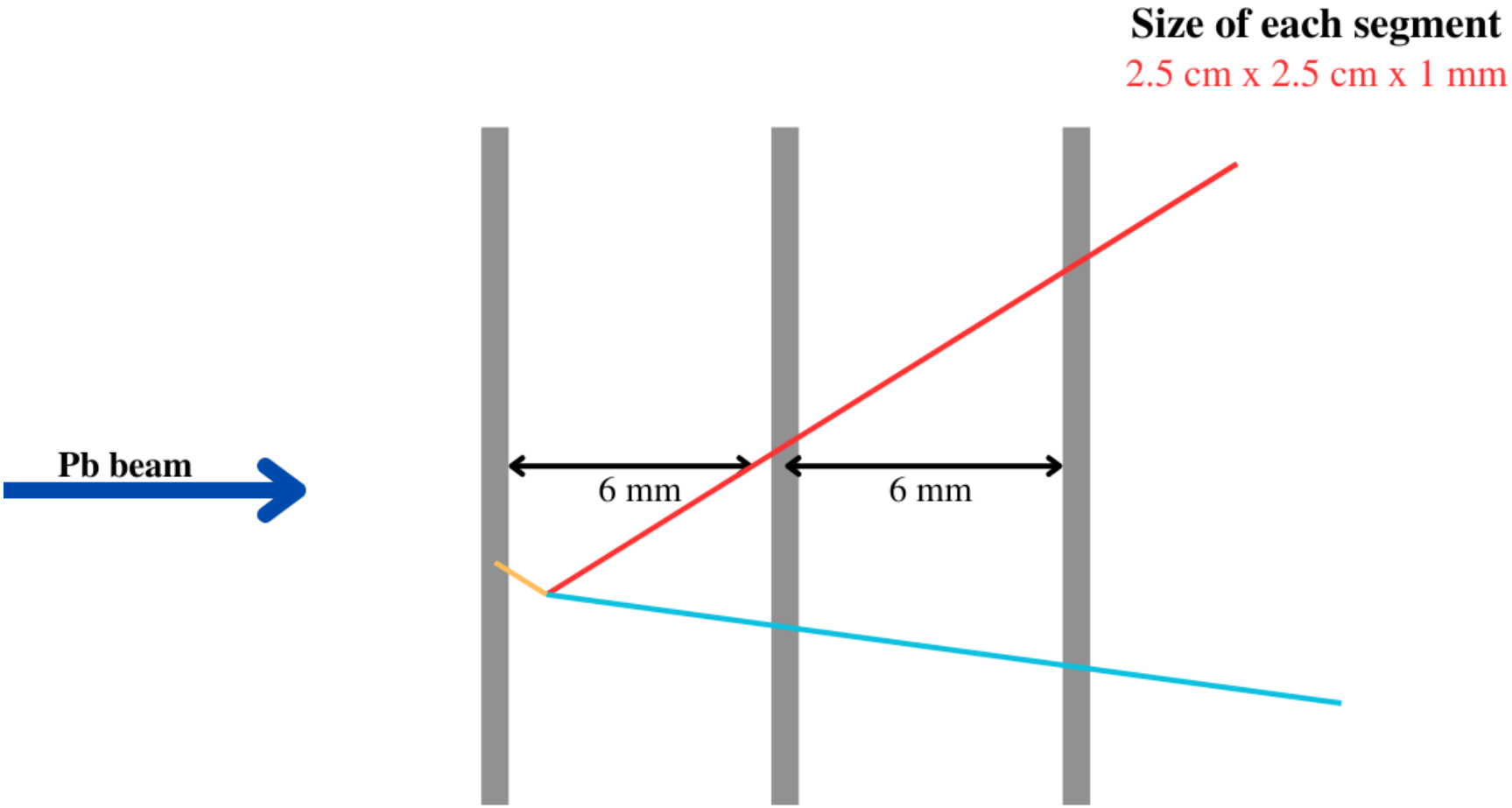


Question: *Why the distance between segments is 6 mm?*
Why not, e.g. 4 mm or 12 mm?

Answer: This distance is related to the characteristics of D^0 decays (specifically the decay distance in LAB).

D^0 decay distance



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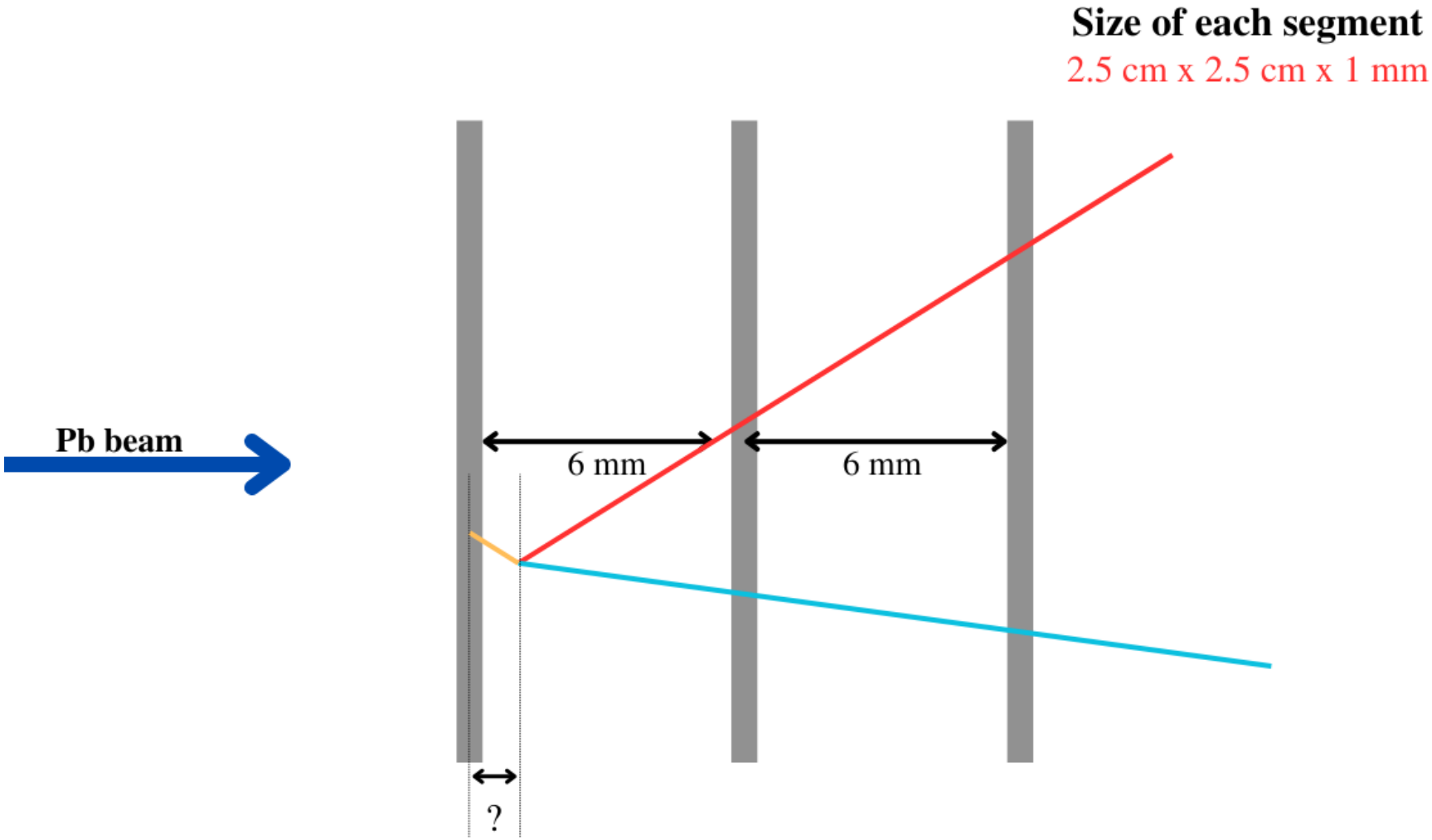

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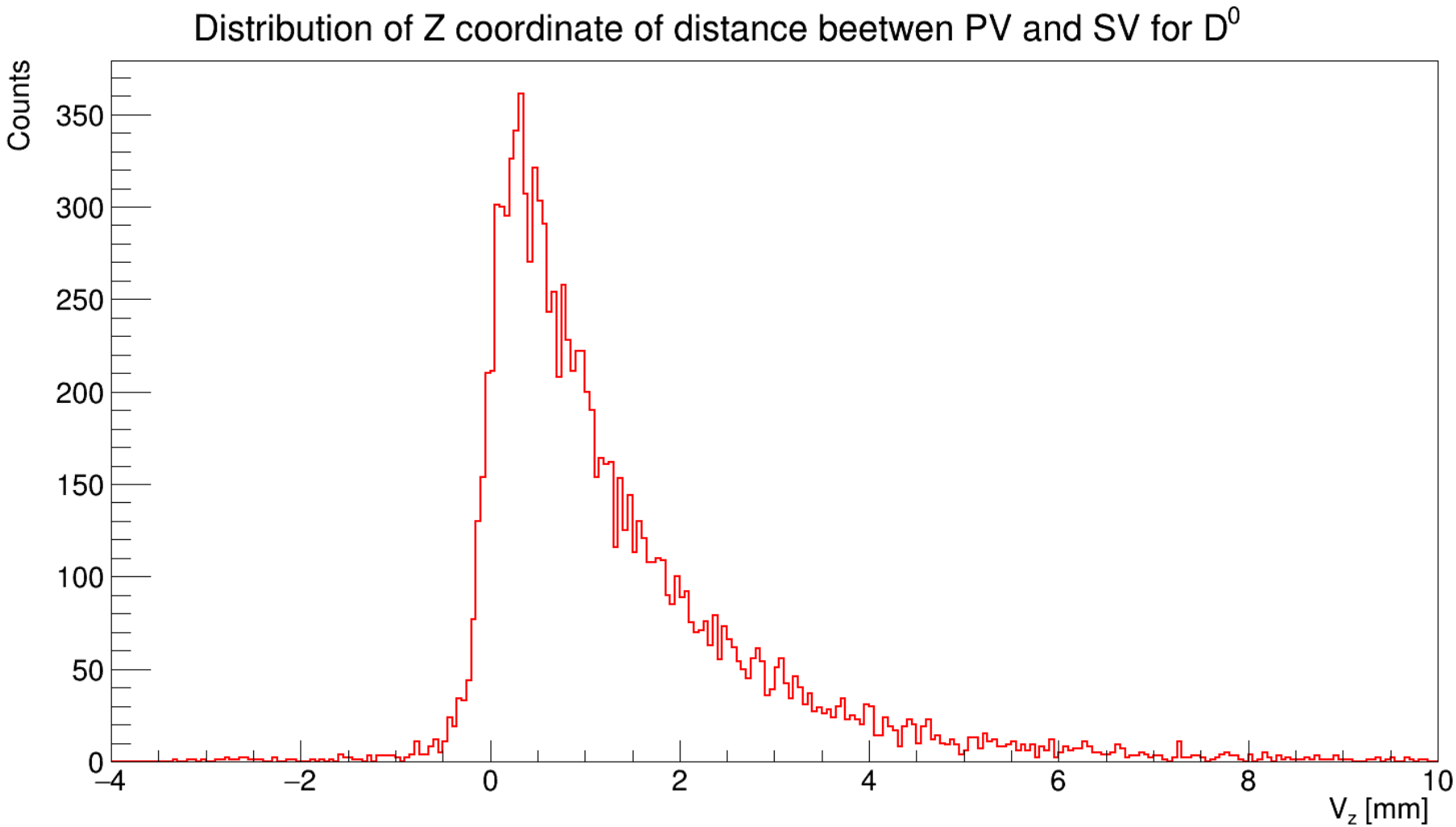

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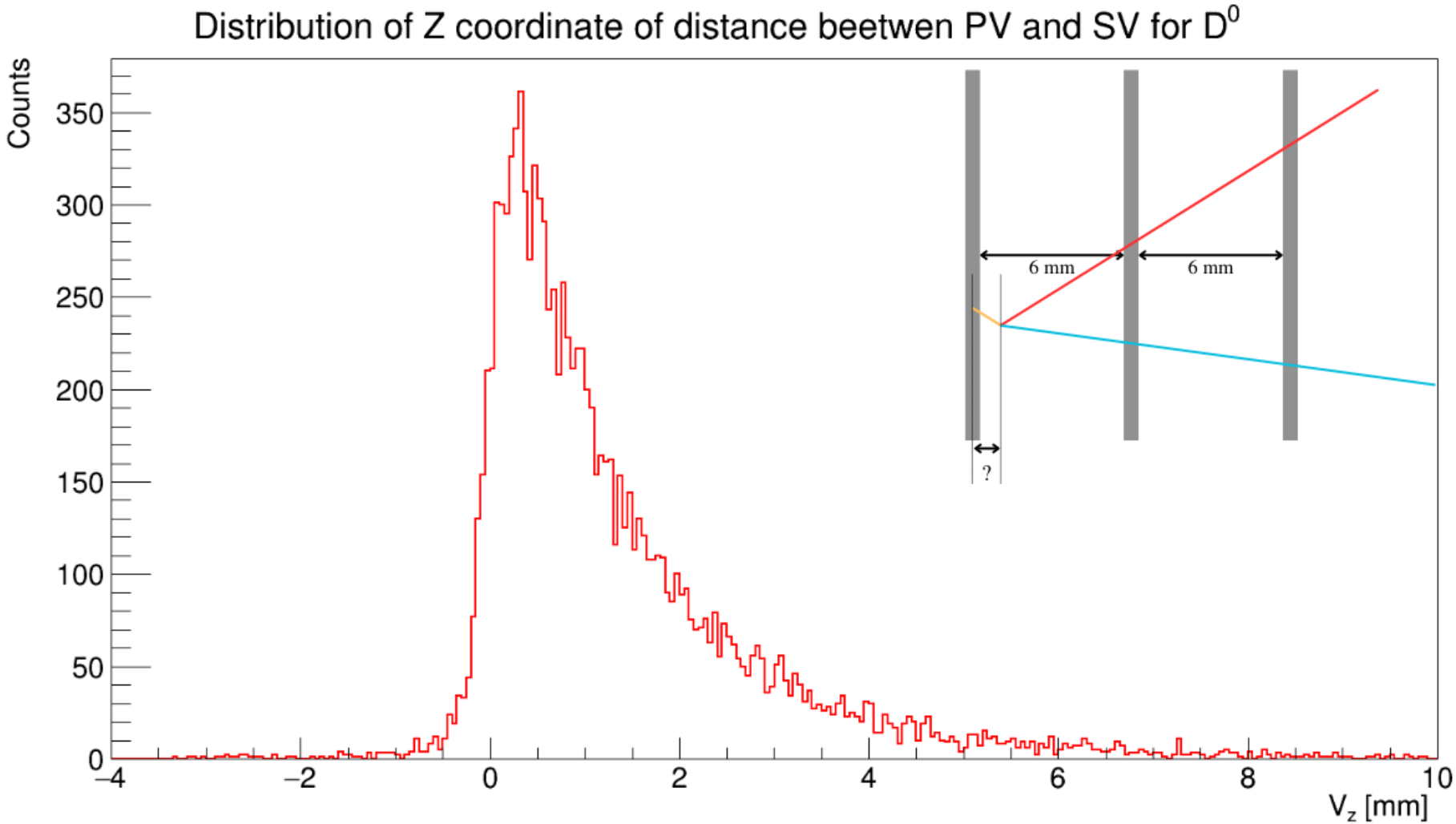
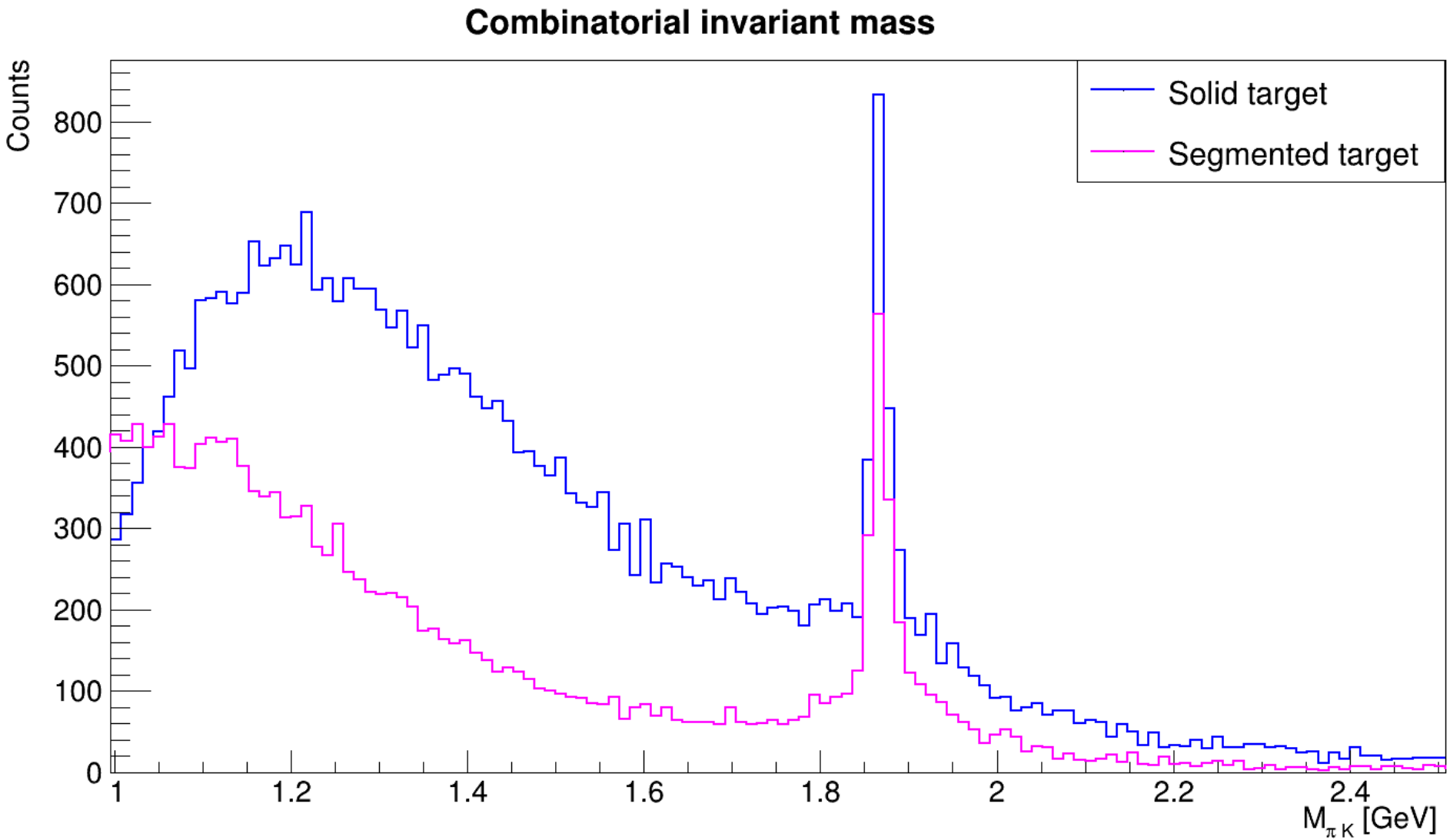
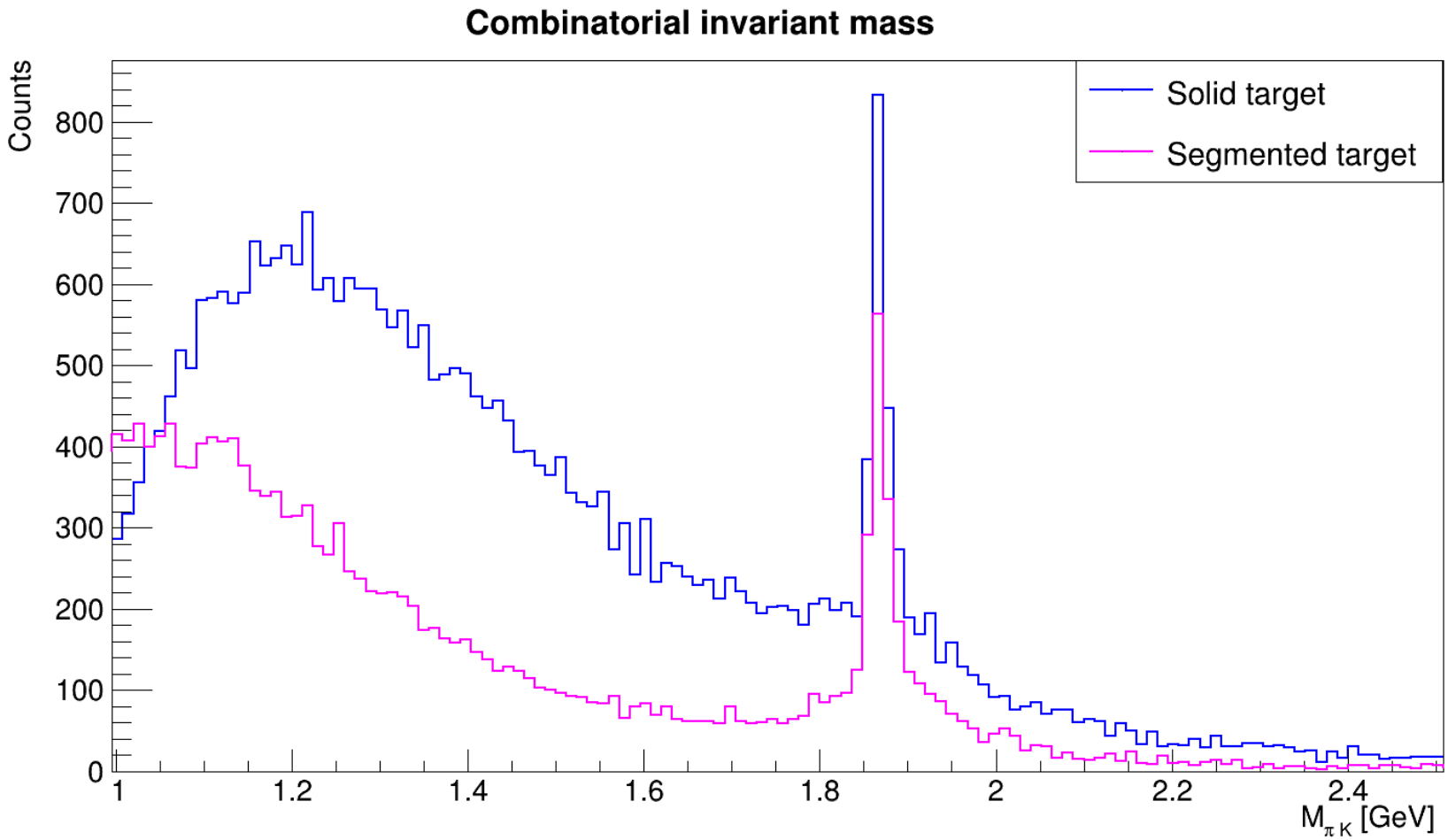


Comparison of targets

Comparison between solid and segmented target (Invariant Mass distribution)



Comparison between solid and segmented target (Invariant Mass distribution)



R: Visually, we observe that **the background around the D^0 mass peak is reduced**.

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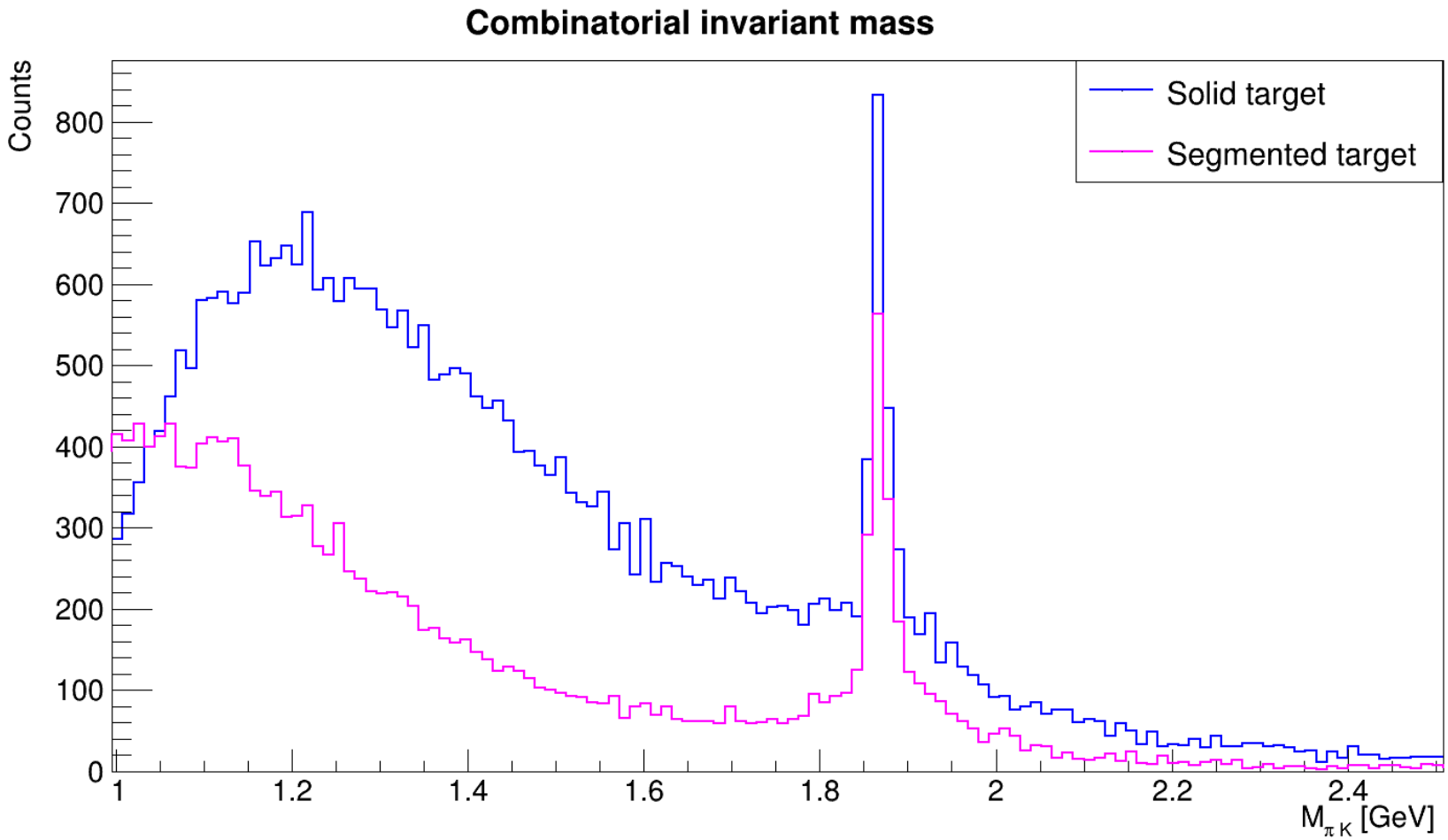
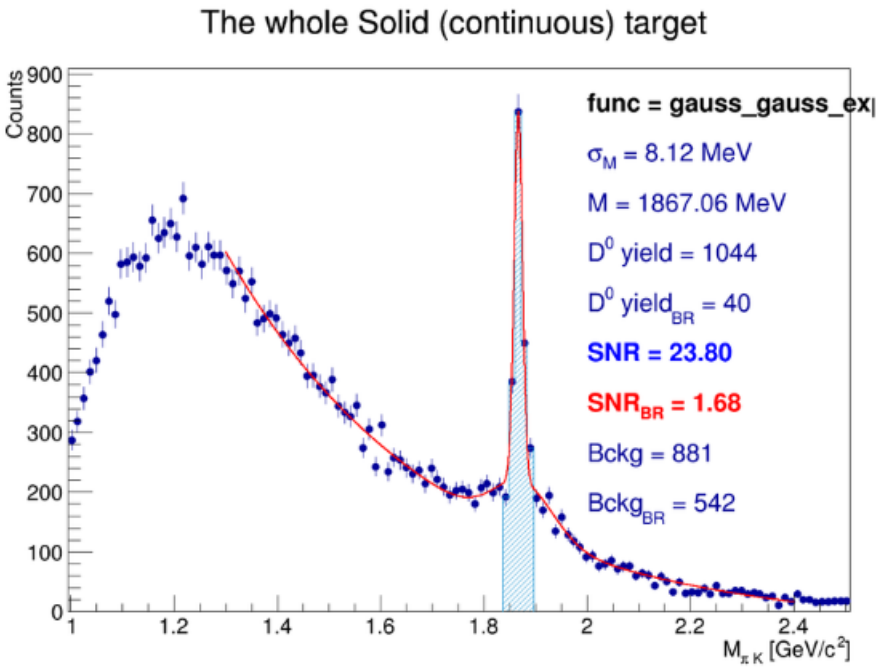
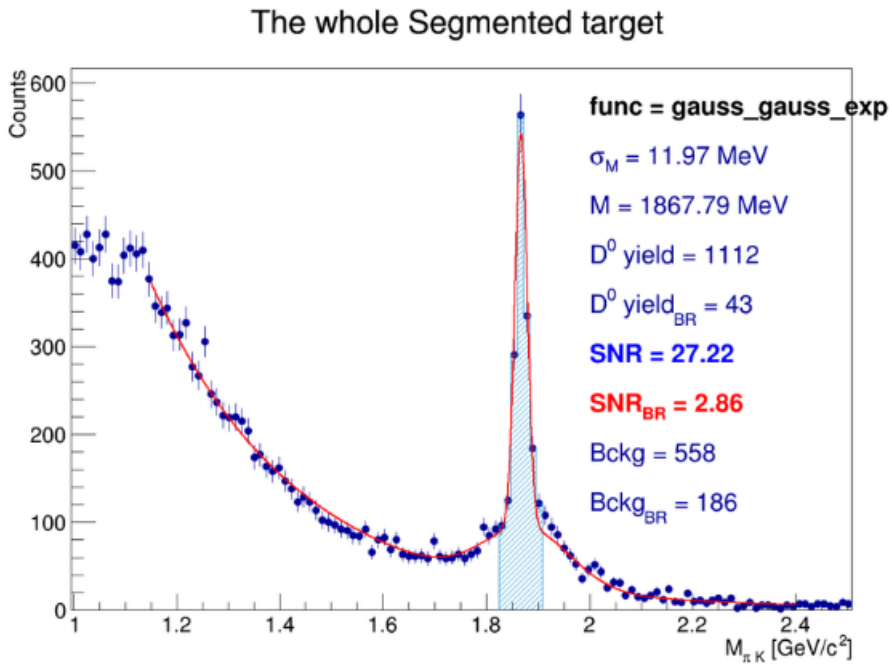


R: Visually, we observe that **the background around the D^0 mass peak is reduced**.

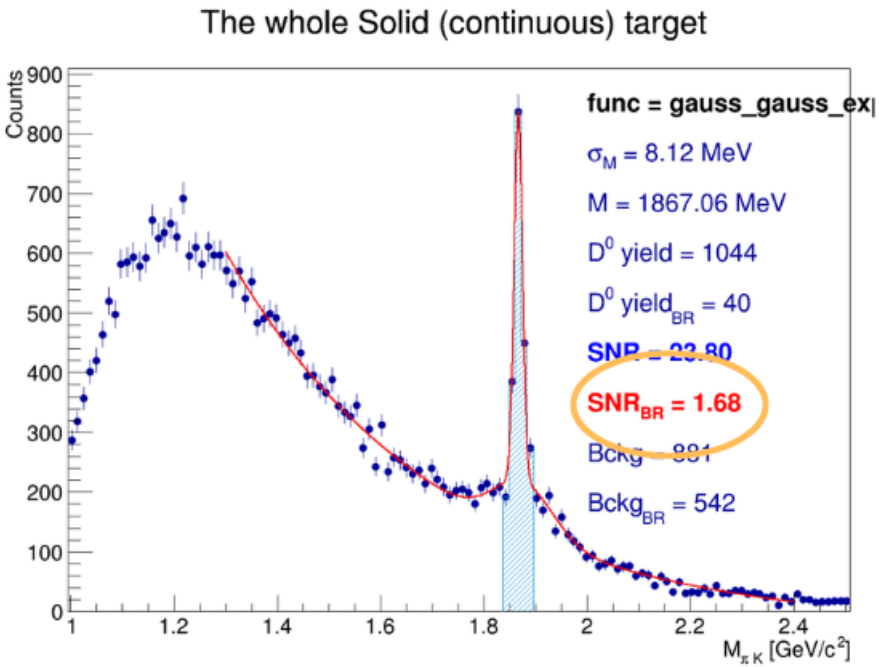
Q: *What is the SNR? What is the background level under the peak?*

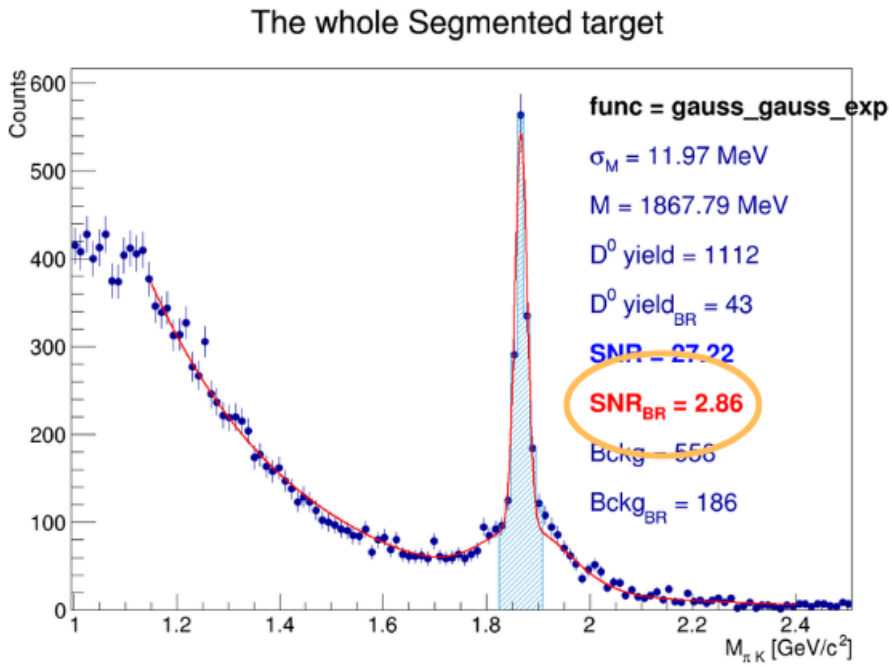
Comparison between solid and segmented target (in $\pm 3\sigma$ range around fitted mean)





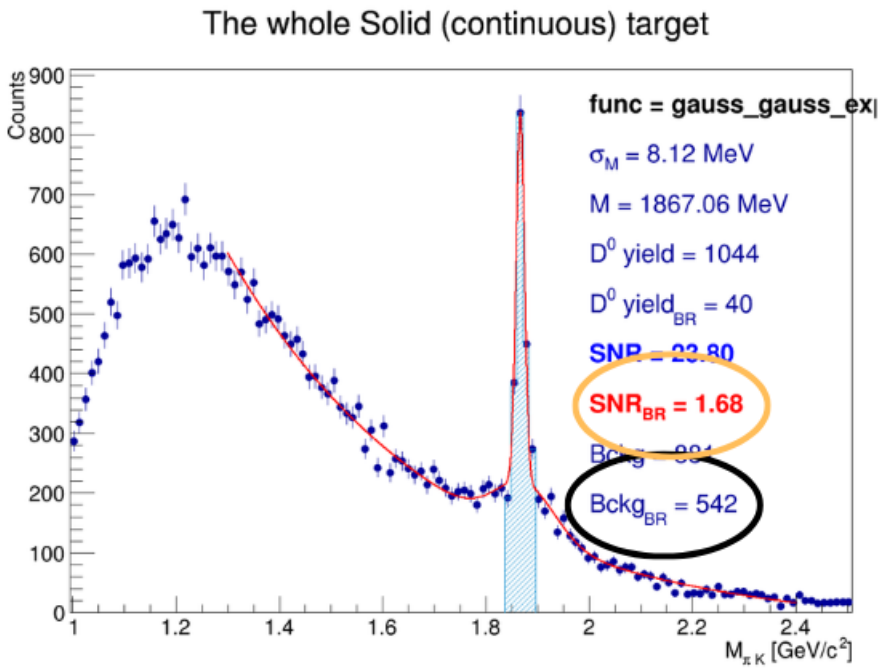
Comparison between solid and segmented target (in $\pm 3\sigma$ range around fitted mean)

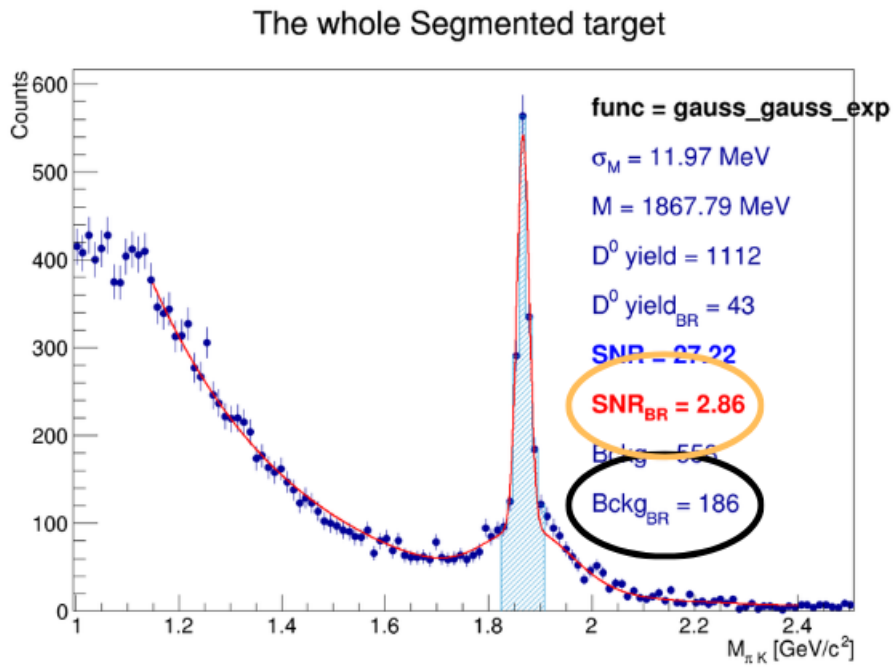




Result:

Comparison between solid and segmented target (in $\pm 3\sigma$ range around fitted mean)





Result:

Question: *What is the background composition in* ***the segmented target****?*

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Answer: Reverse to the situation in solid (continuous) target (!)

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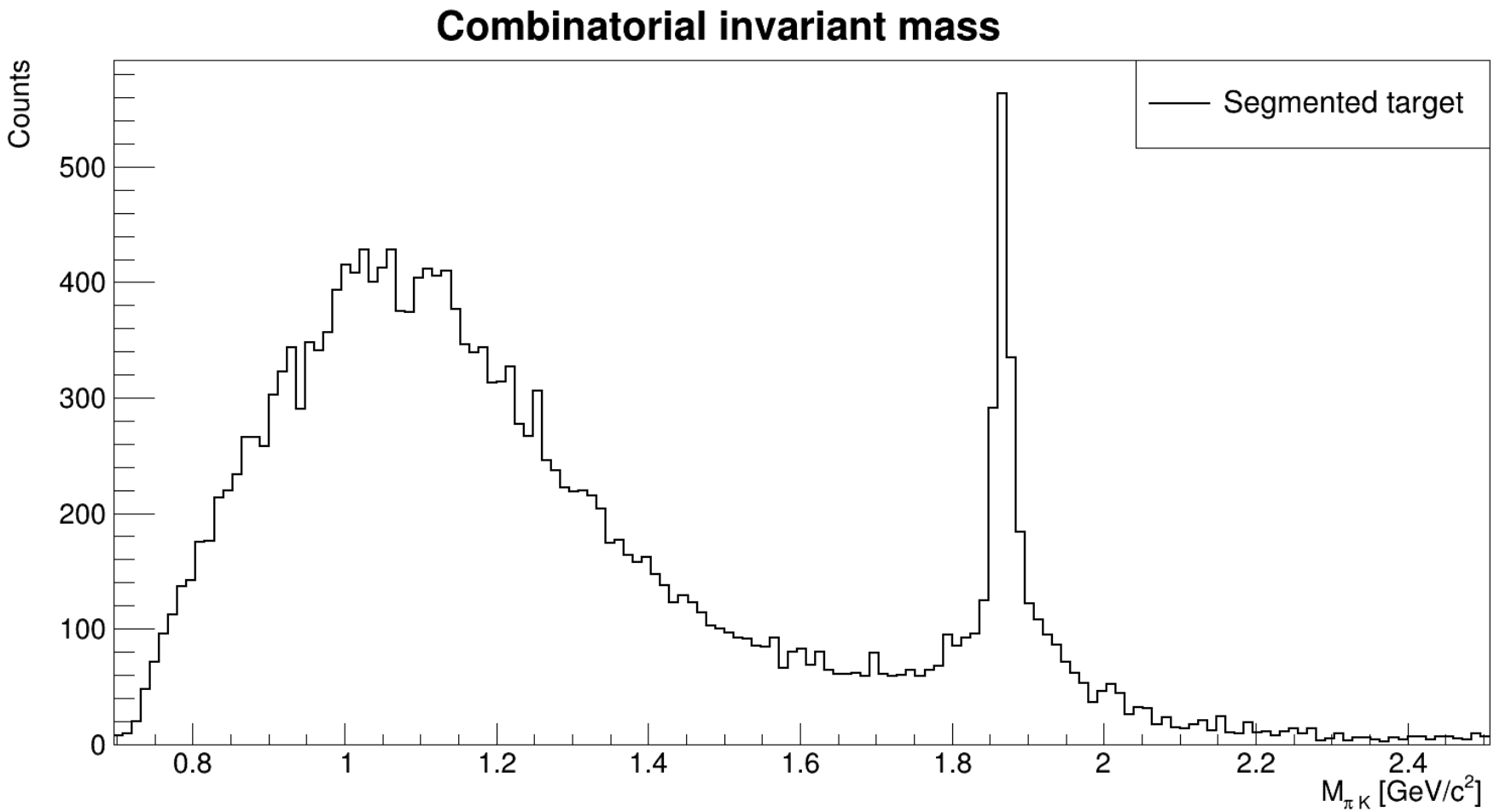
- ~~$\sim 70\%$~~ $\sim 30\%$ particles from secondary processes (decays, hadron interactions etc.) (SV).



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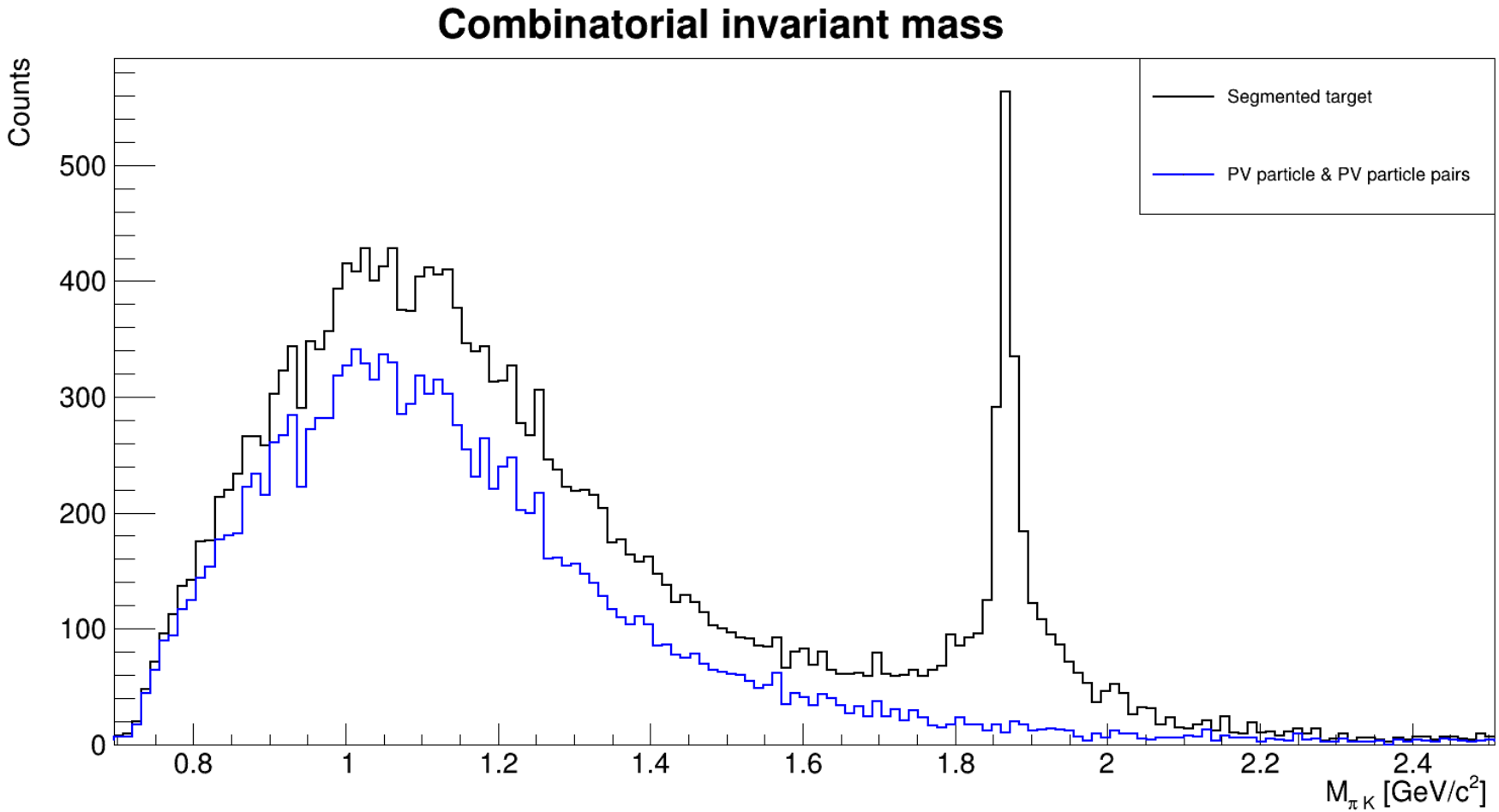

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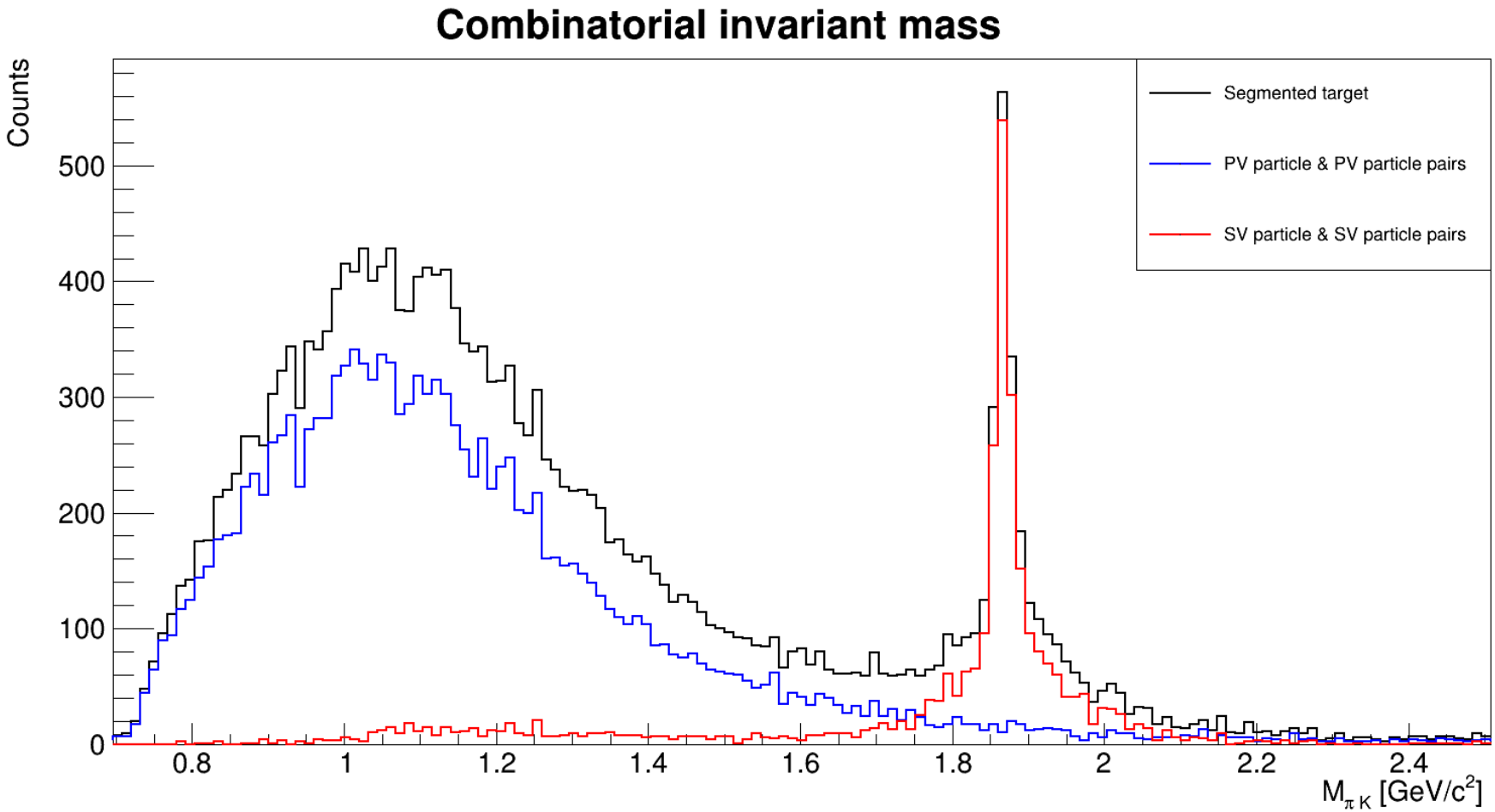

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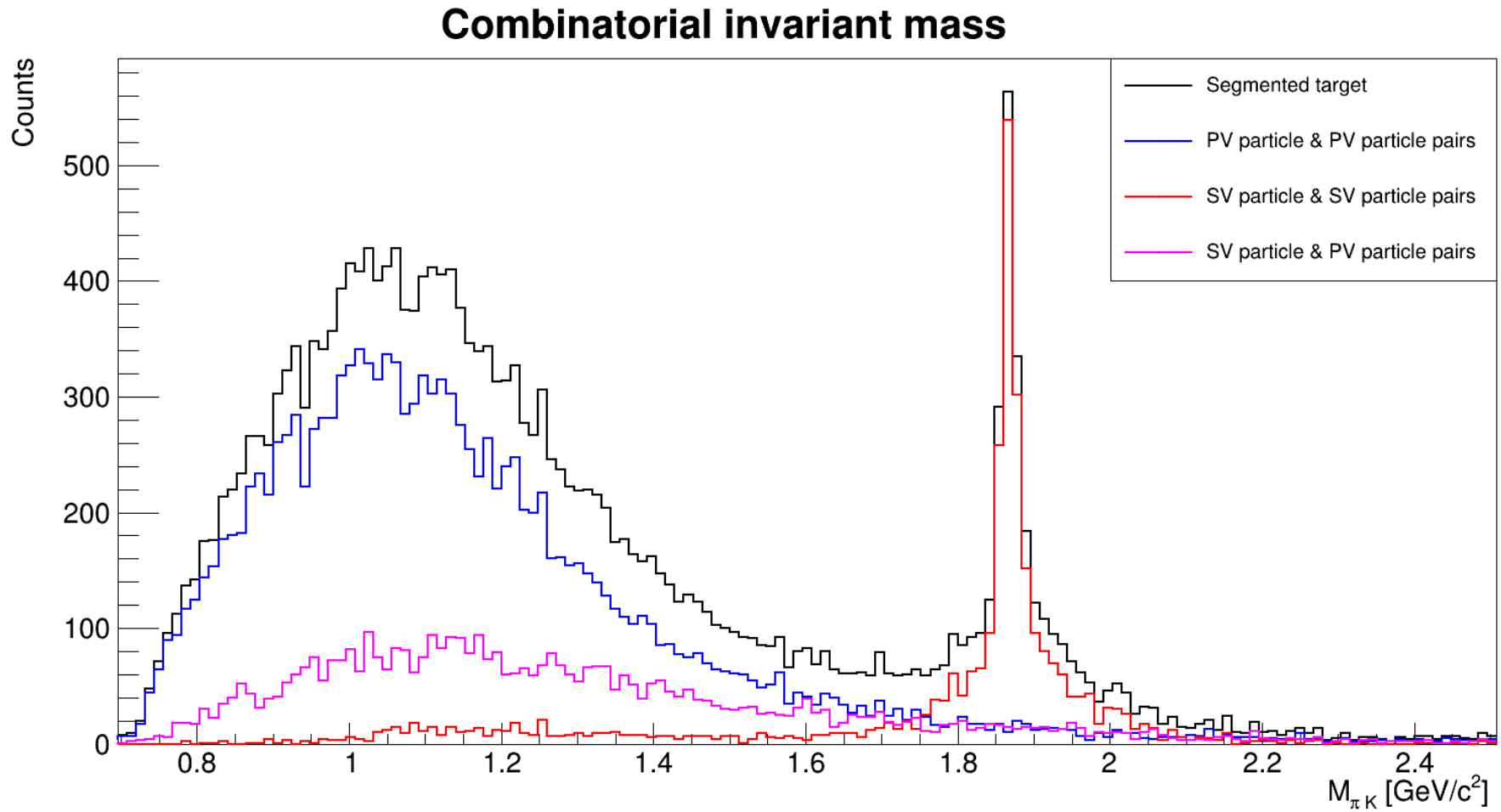

Summary

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Question: *Why do we need segmented Pb target for charm data taking?*

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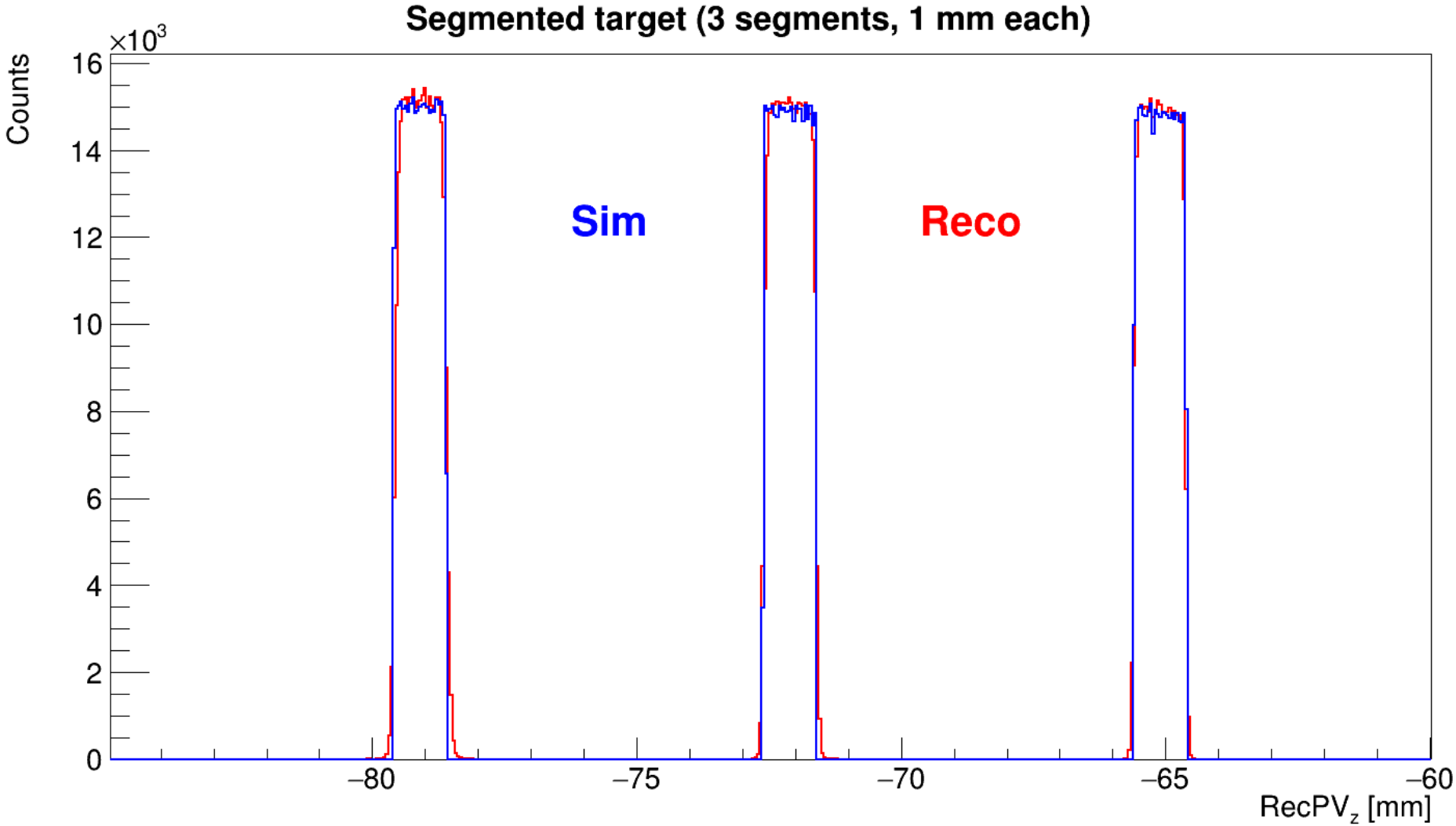
Question: *Why do we need segmented Pb target for charm data taking?*

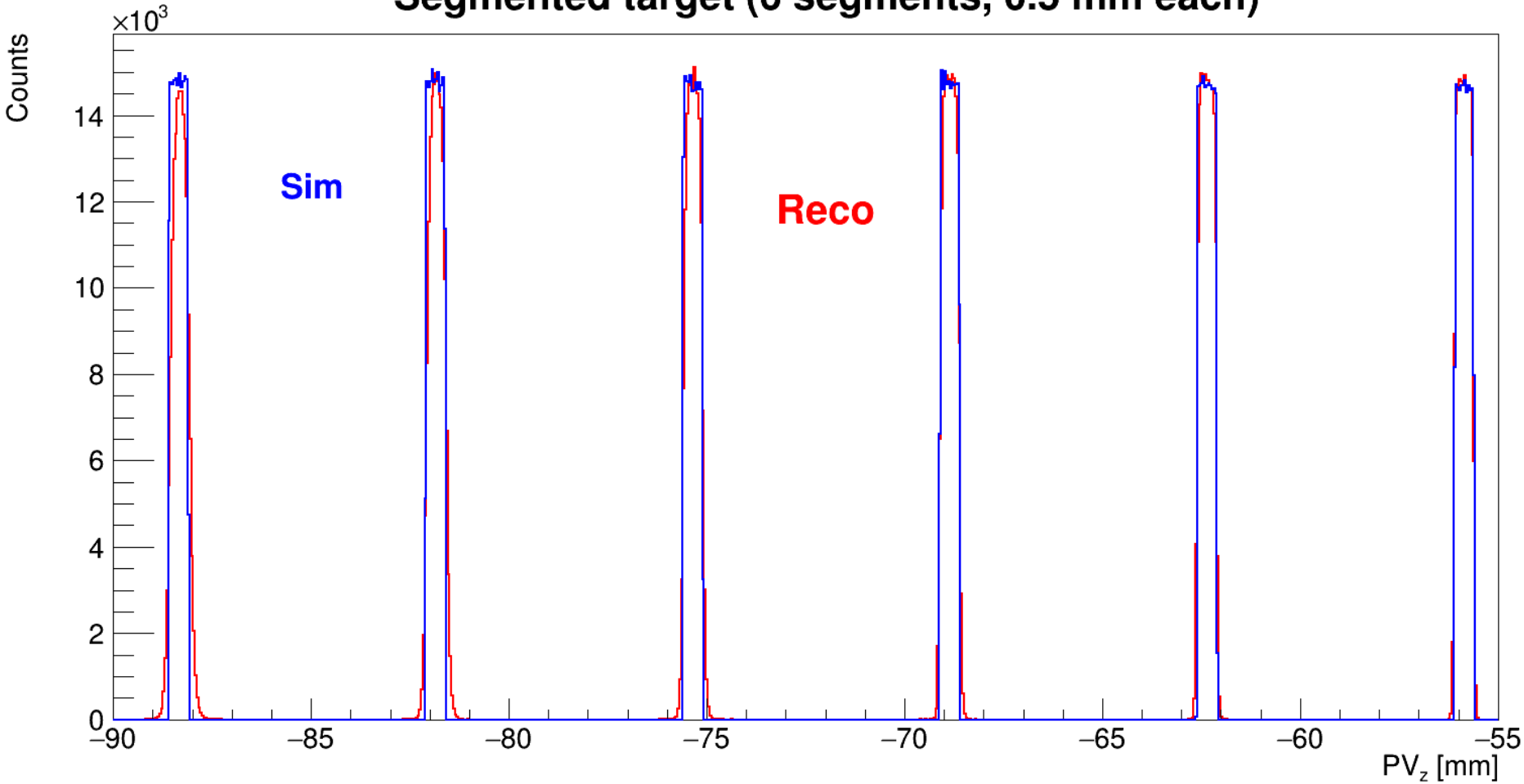
Answer:
Using a segmented target:

- We can more effectively suppress background (especially the secondary interactions), isolating charm decay signals,
- This improves the signal-to-noise ratio (SNR), allowing clearer identification of rare charm decays,

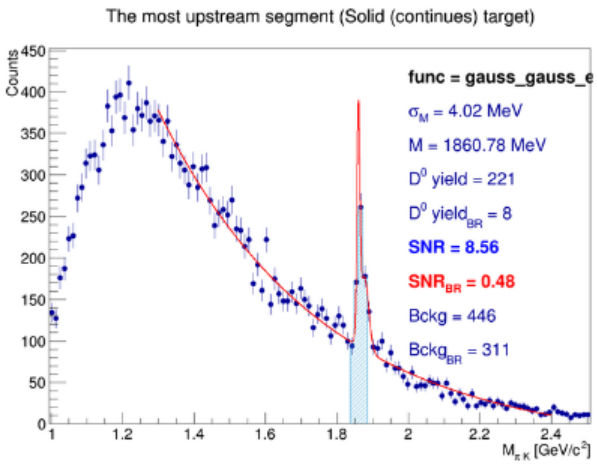
That's all, thank you.

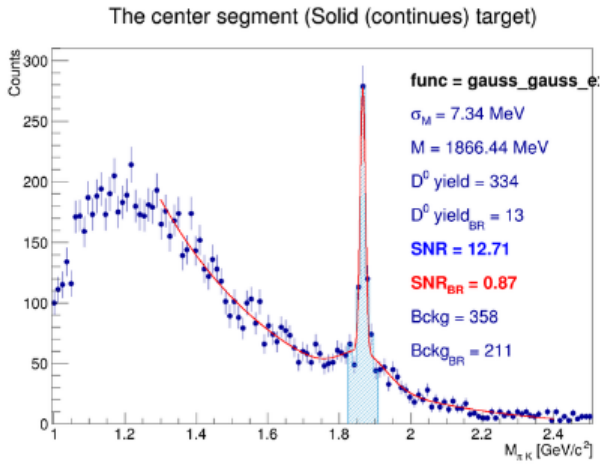
BACKUP SLIDES

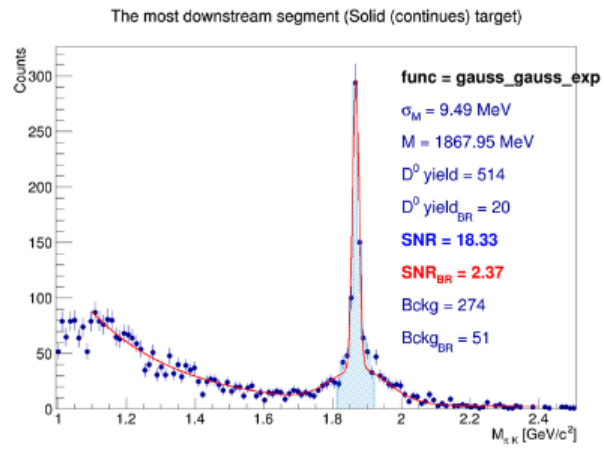

Segmented target (3 segments, 1 mm each)
Counts
×10³
16
14
12
10
8
6
4
2
0
Sim
Reco
−80
−75
−70
−65
−60
RecPV_z [mm]

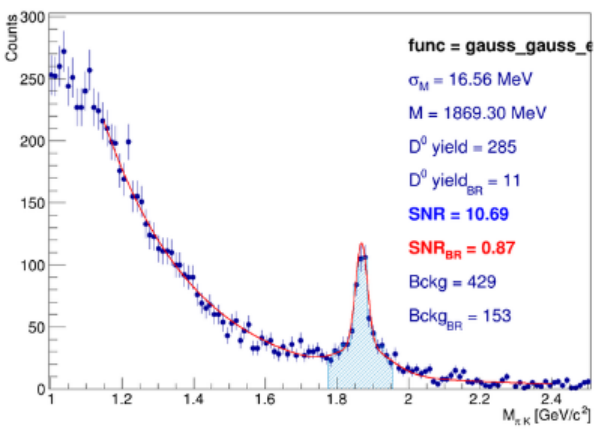

Segmented target (6 segments, 0.5 mm each)
Counts
×10^3
14
12
10
8
6
4
2
0
Sim
Reco
−90
−85
−80
−75
−70
−65
−60
−55
PV_z [mm]

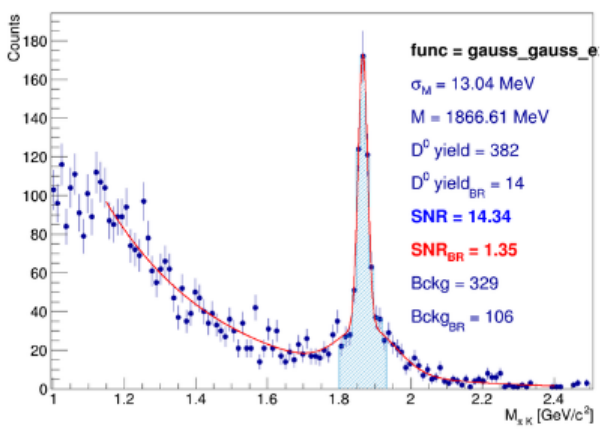
Comparison between solid and segmented target in each segments

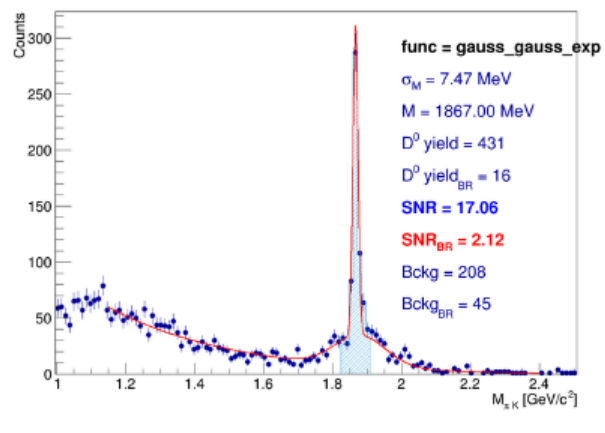






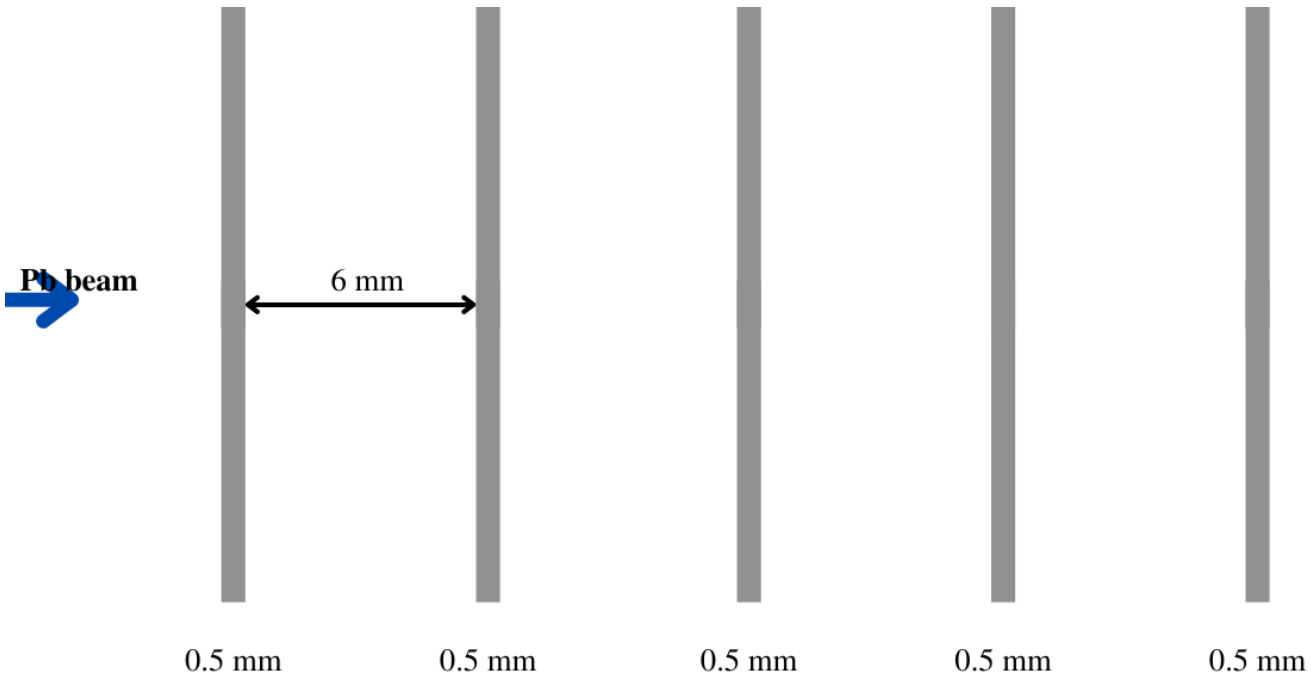


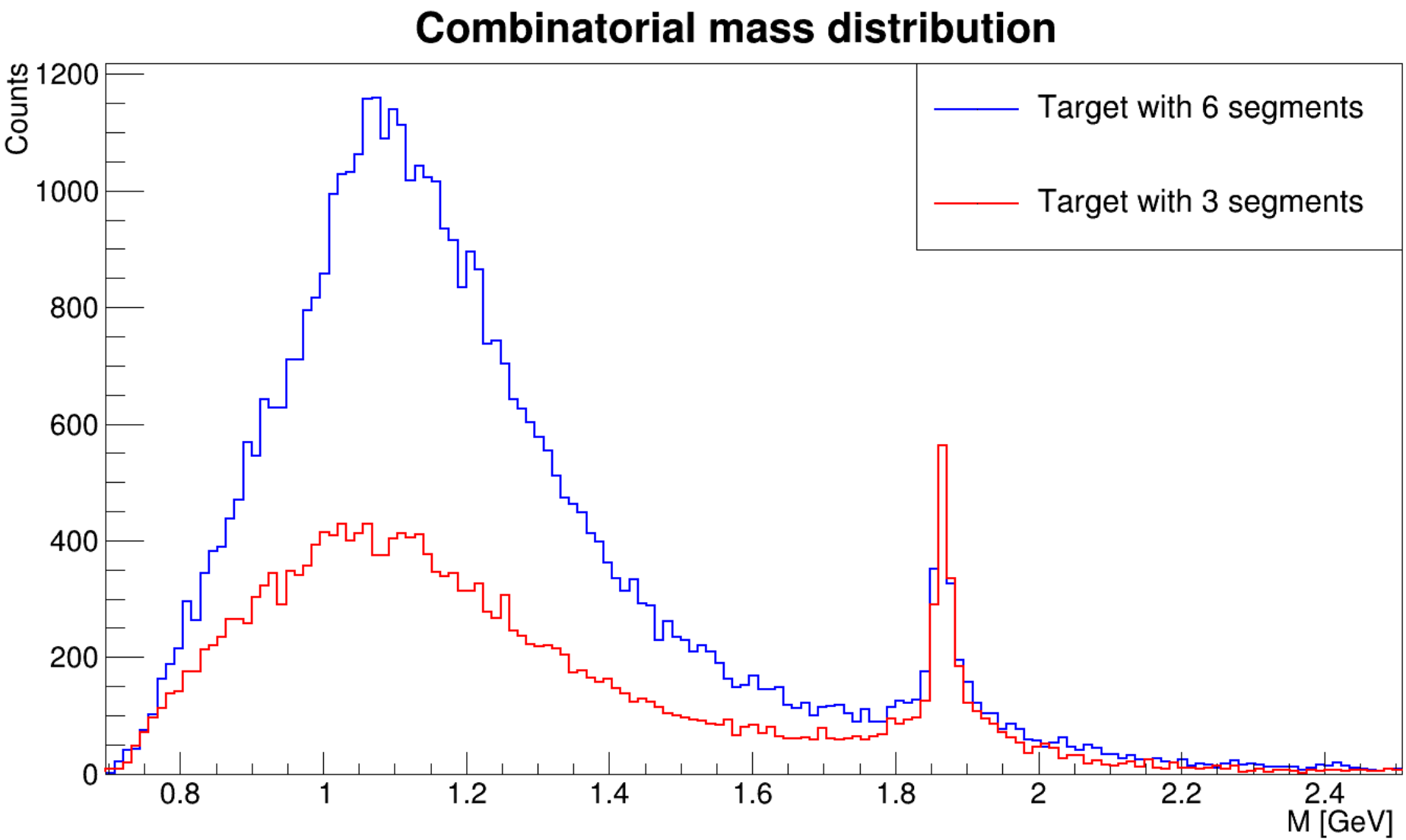




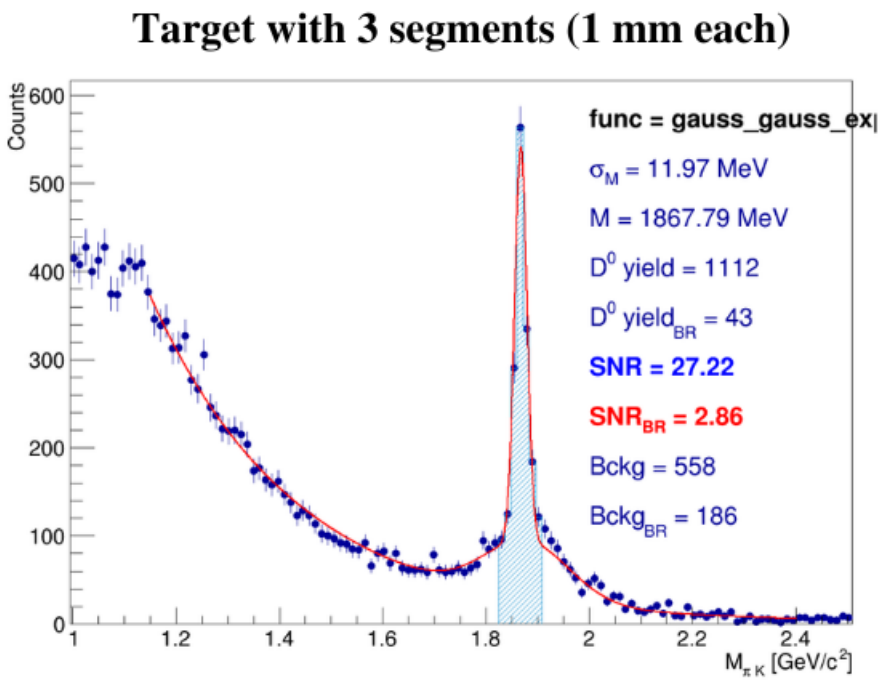
More segmented target

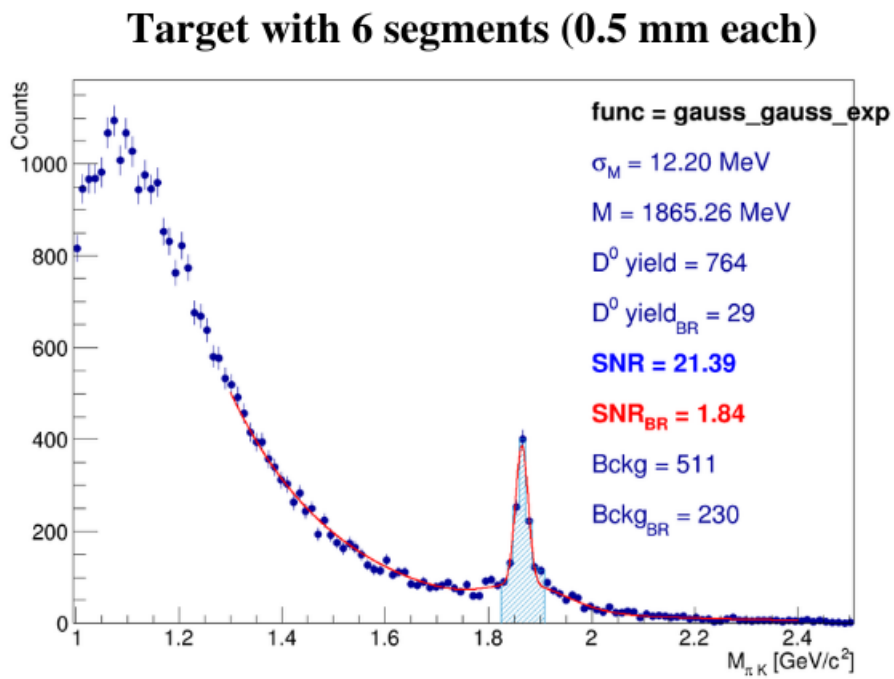
Question: *Maybe more segmentd target it's better?*



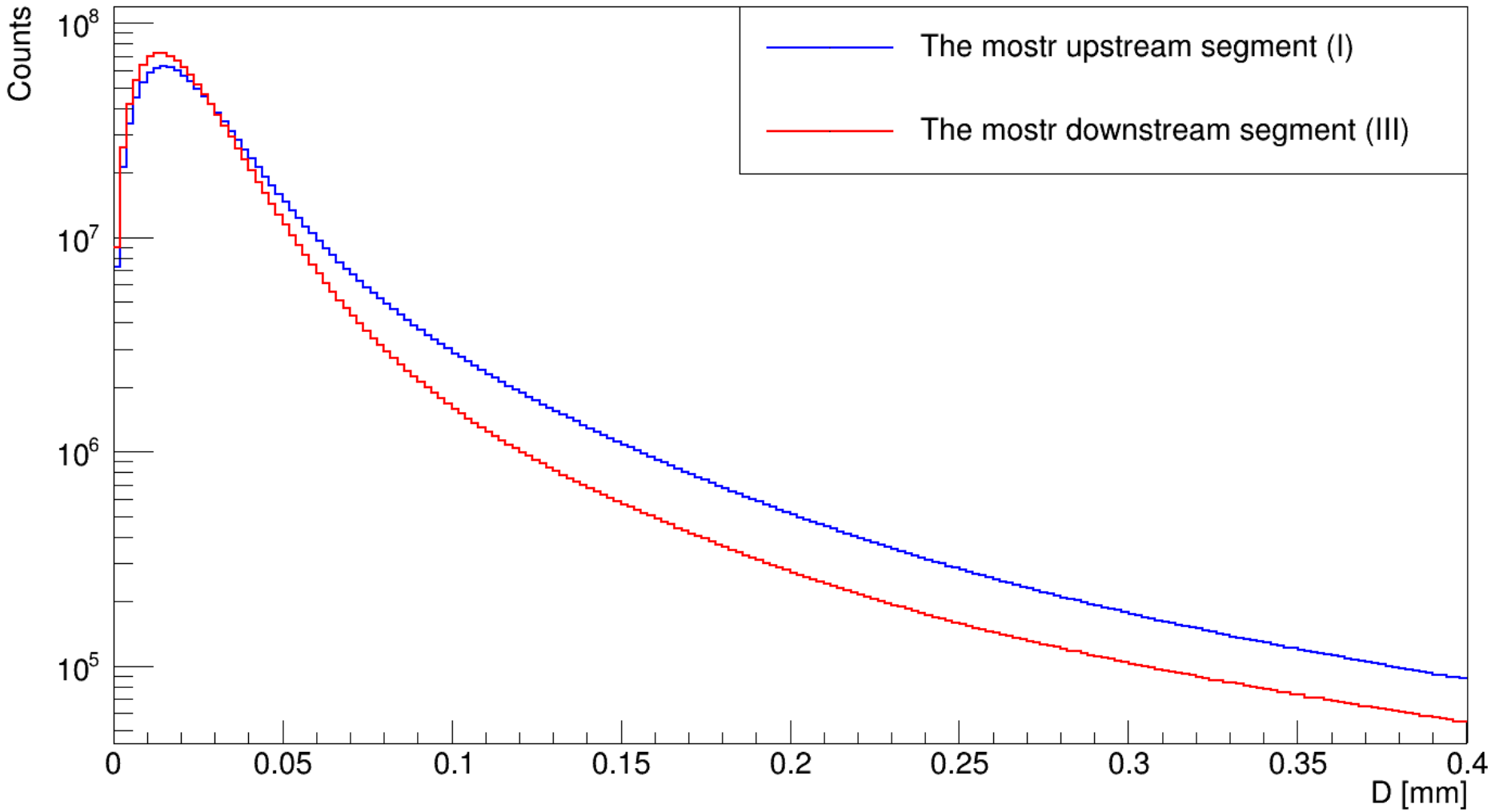

Combinatorial mass distribution
Counts
1200
1000
800
600
400
200
0
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
M [GeV]
Target with 6 segments
Target with 3 segments

Comparison between the segmented targets (3 segments each 1 mm vs 6 segments each 0.5 mm)

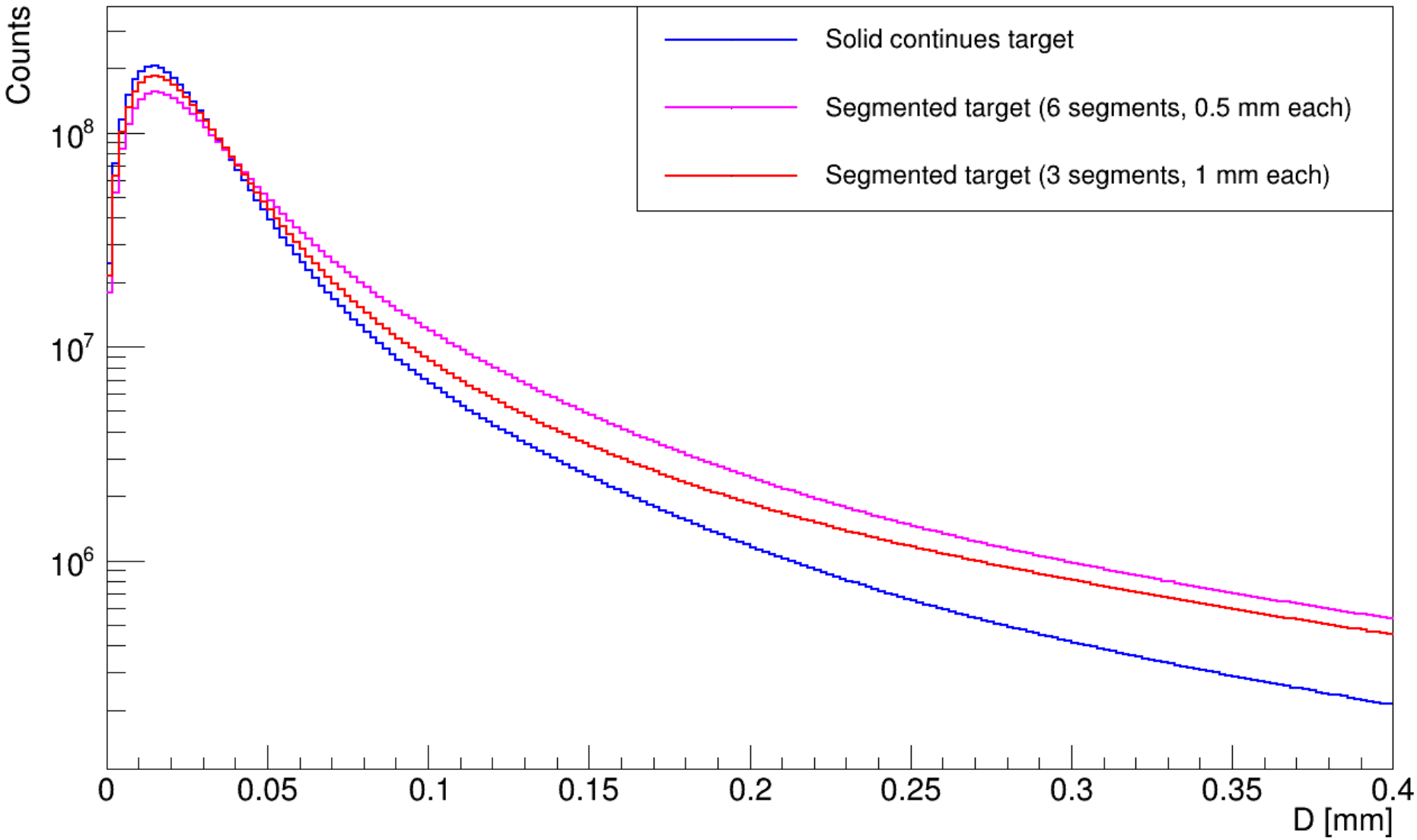




Parent impact parameter distribution (all combination) for solid target segments



Parent impact parameter distribution (all combination) for different target



Background suppresion cuts

In my analysis, I accept particles (or particle pairs, depending on the cut) that pass through the following cuts:

- $p_T \in (0.35, 1.8)$ GeV$/c^2$,
- $d \in (0.055, 1)$ mm,
- $\mathrm{V}_z \in (1, 5.5)$ mm,
- $\mathrm{D} \in (0, 0.02)$ mm,
- $\mathrm{DCA} \in (0, 0.04)$ mm.

The definition of cuts

1. Single particle cuts:

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   - p_T,
   - d, (*particle impact parameter*, i.e. the closest distance between the reconstructed track and reconstructed primary vertex)

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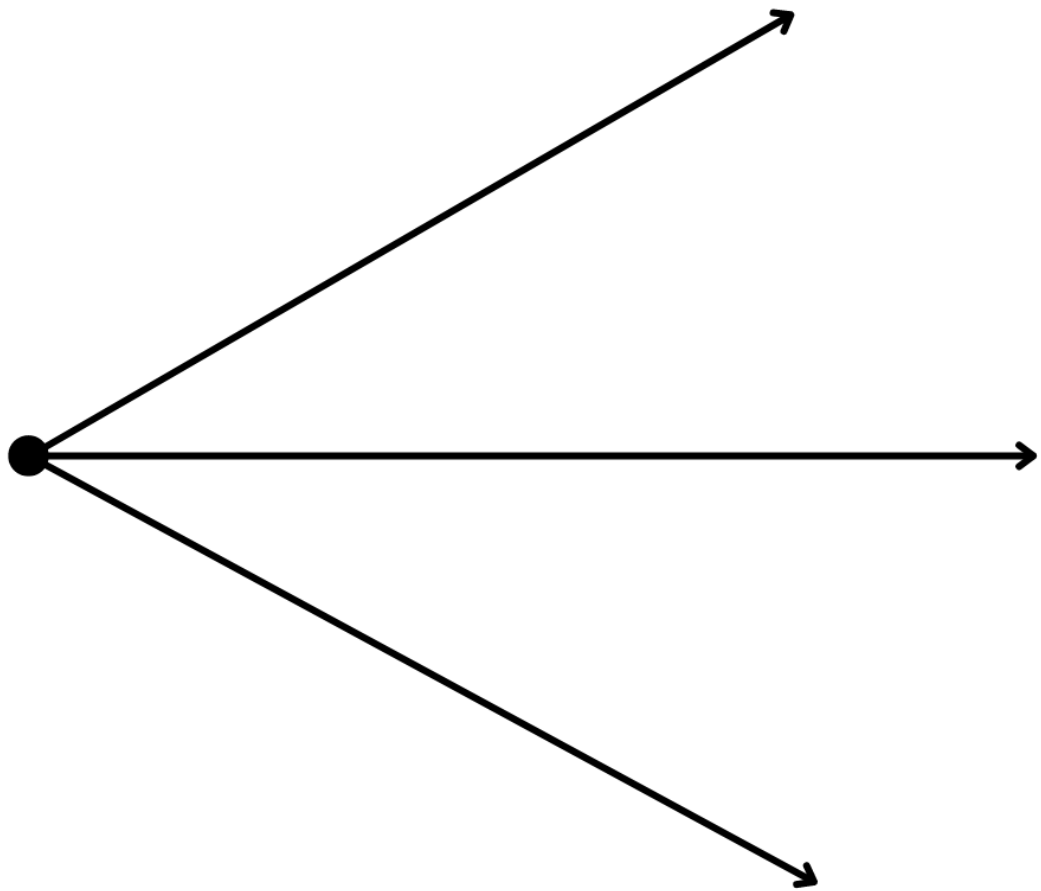

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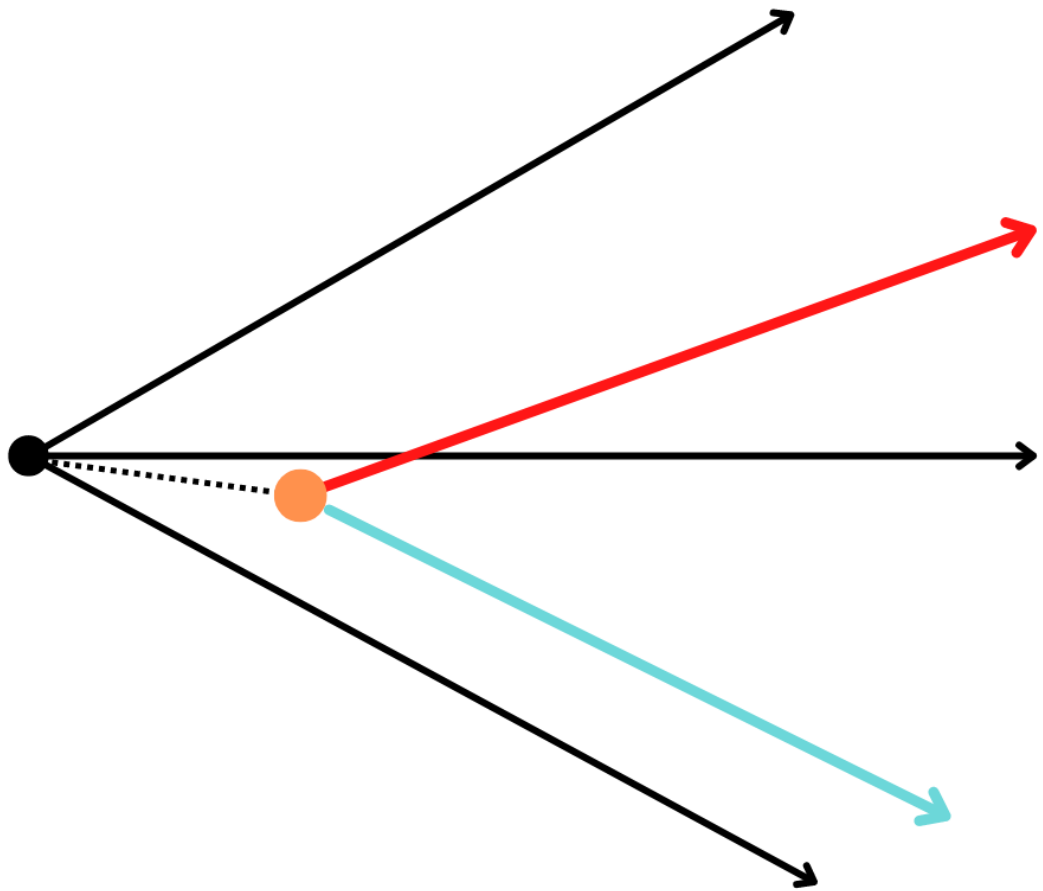

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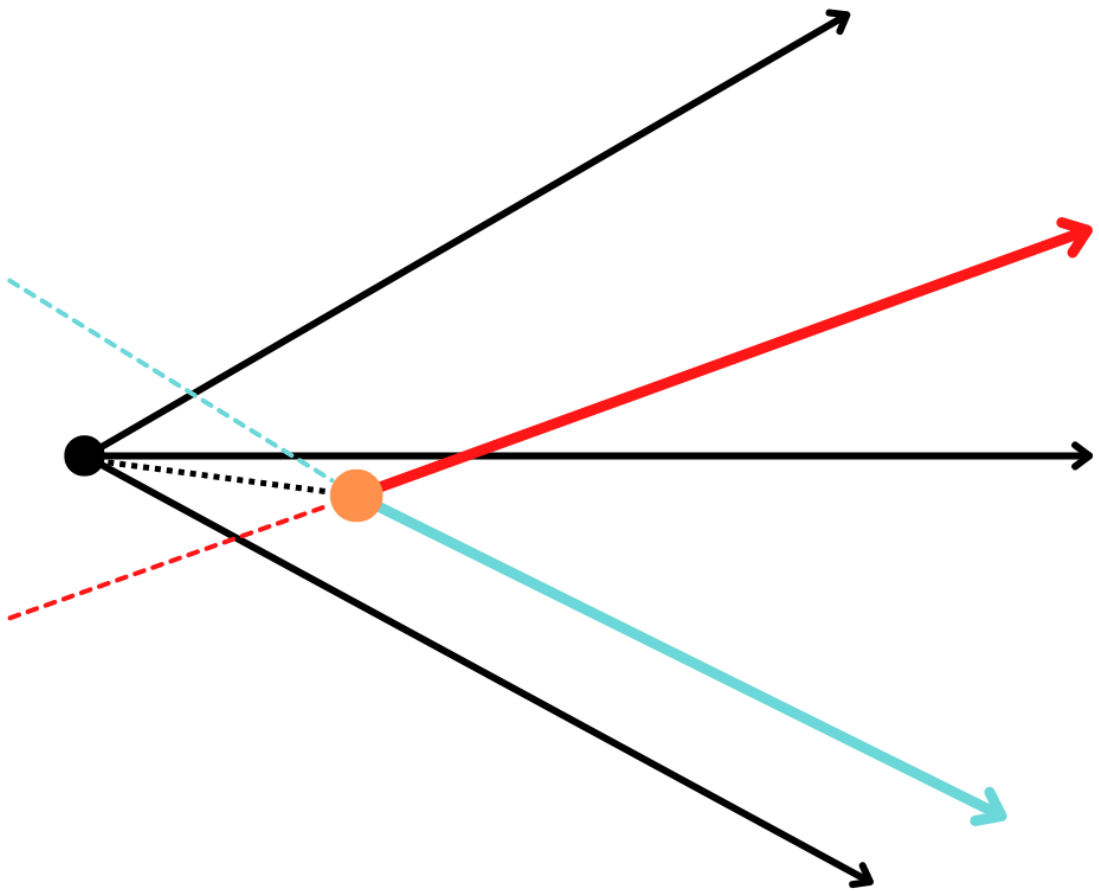

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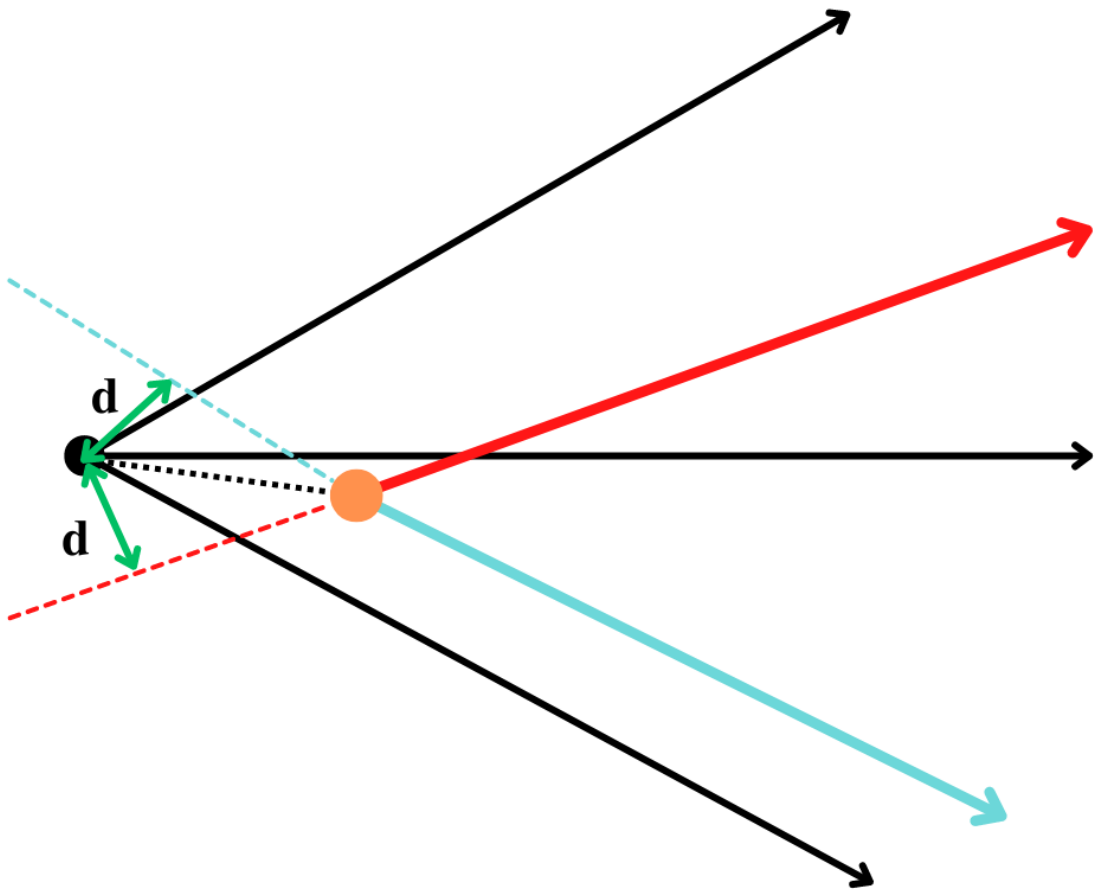

The definition of cuts

1. Single particle cuts:
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   - d, (*particle impact parameter*, i.e. the closest distance between the reconstructed track and reconstructed primary vertex)

2. Two tracks cuts:

The definition of cuts

1. Single particle cuts:
   - p_T,
   - d, (*particle impact parameter*, i.e. the closest distance between the reconstructed track and reconstructed primary vertex)

2. Two tracks cuts:
   - V_z, (distance in z direction between reconstructed primary and secondary vertex)

The definition of cuts

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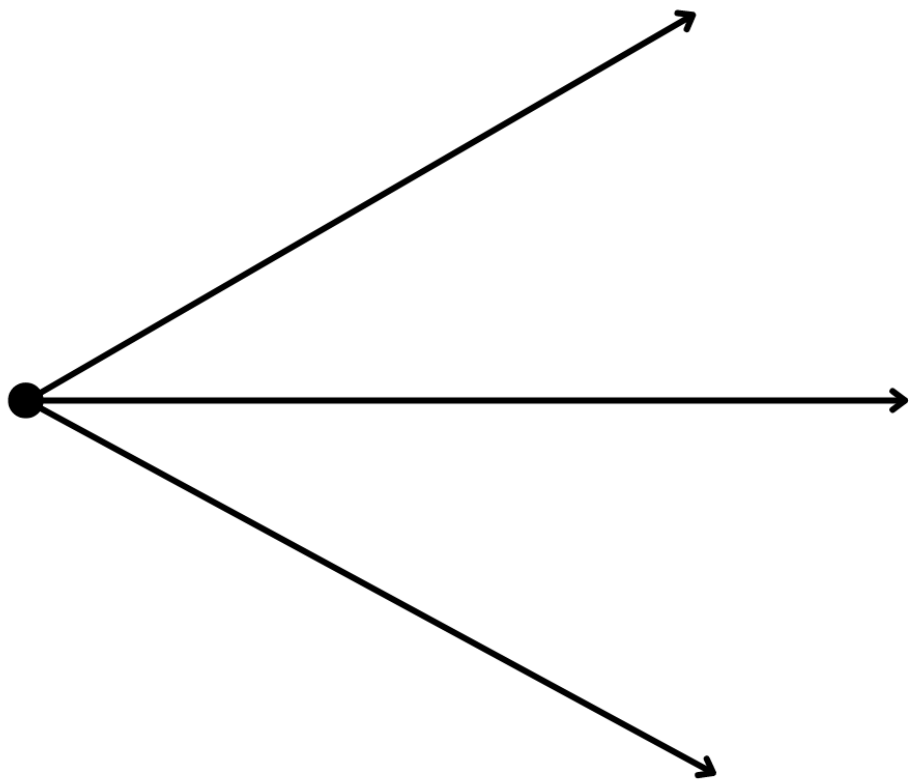
   - p_T,
   - d, (*particle impact parameter*, i.e. the closest distance between the reconstructed track and reconstructed primary vertex)
2. Two tracks cuts:
   - V_z, (distance in z direction between reconstructed primary and secondary vertex)



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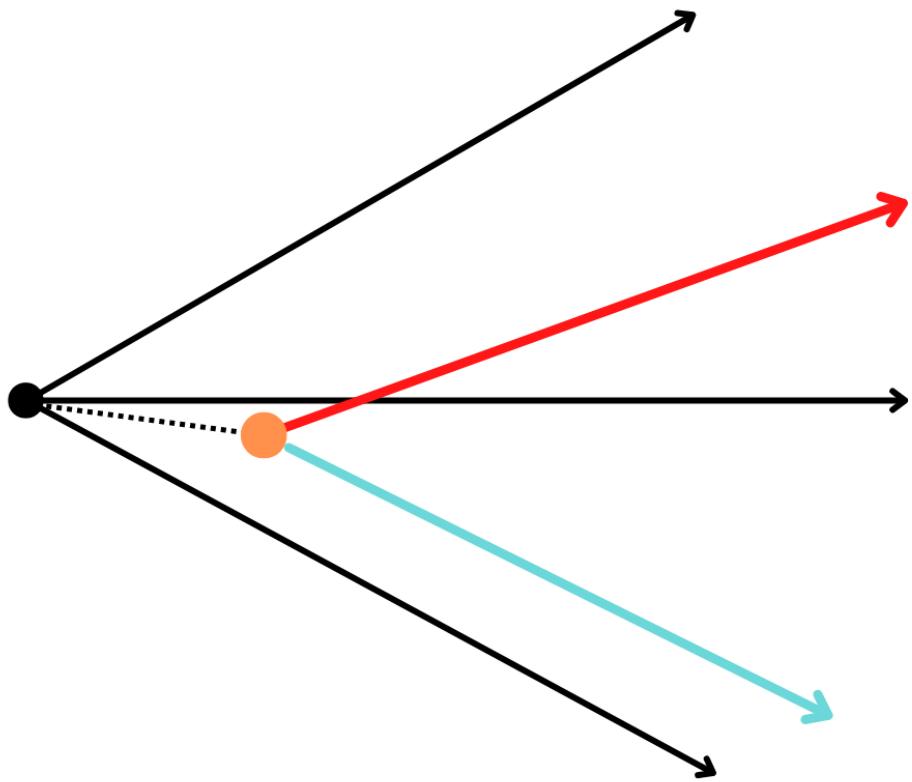

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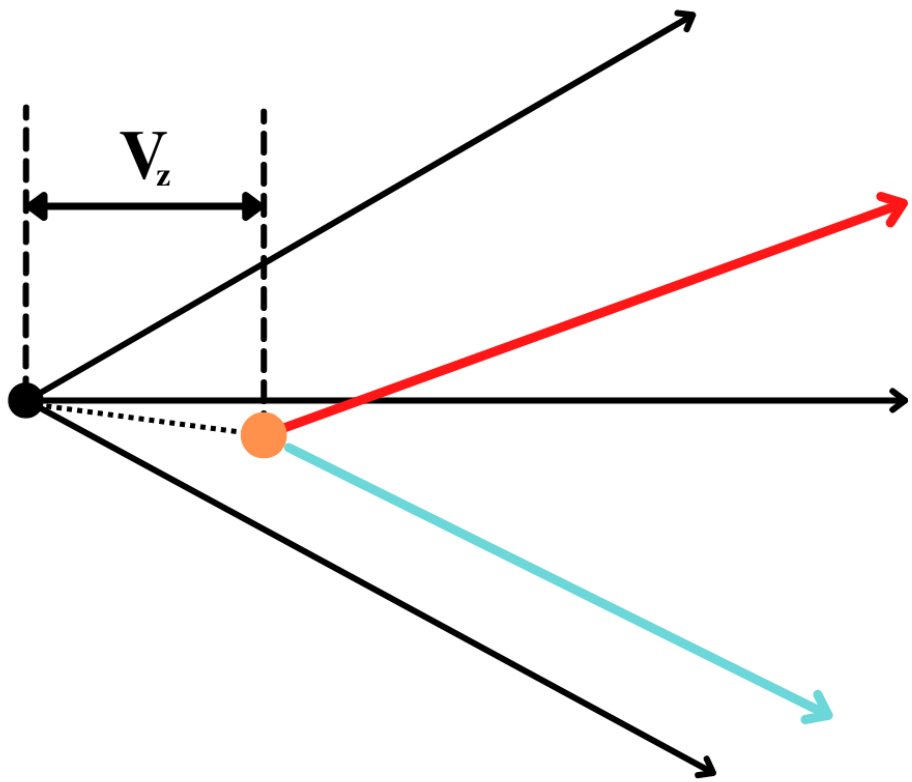

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   - D, (*parent impact parameter*, i.e. closest distance between reconstructed parent and reconstructed primary vertex)

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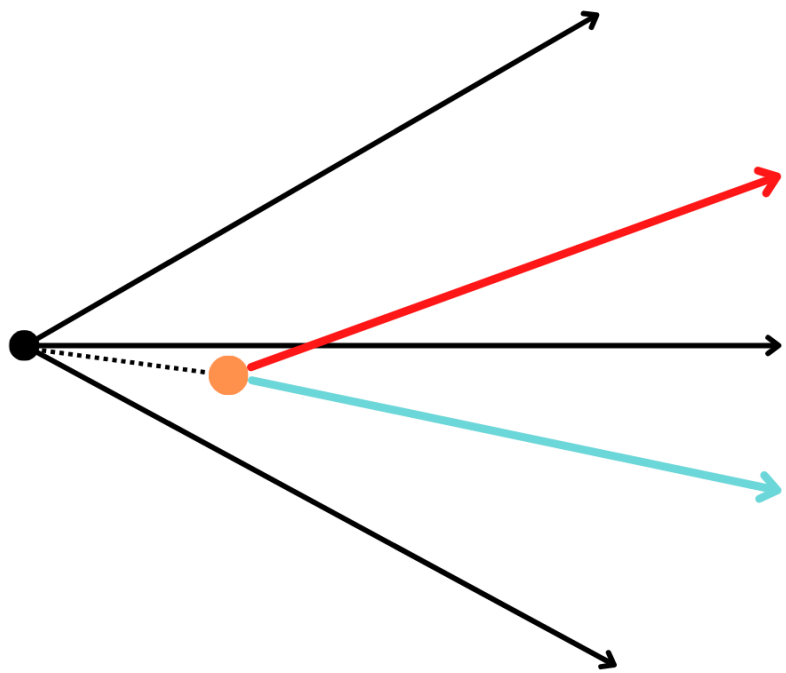
   - D, (*parent impact parameter*, i.e. closest distance between reconstructed parent and reconstructed primary vertex)



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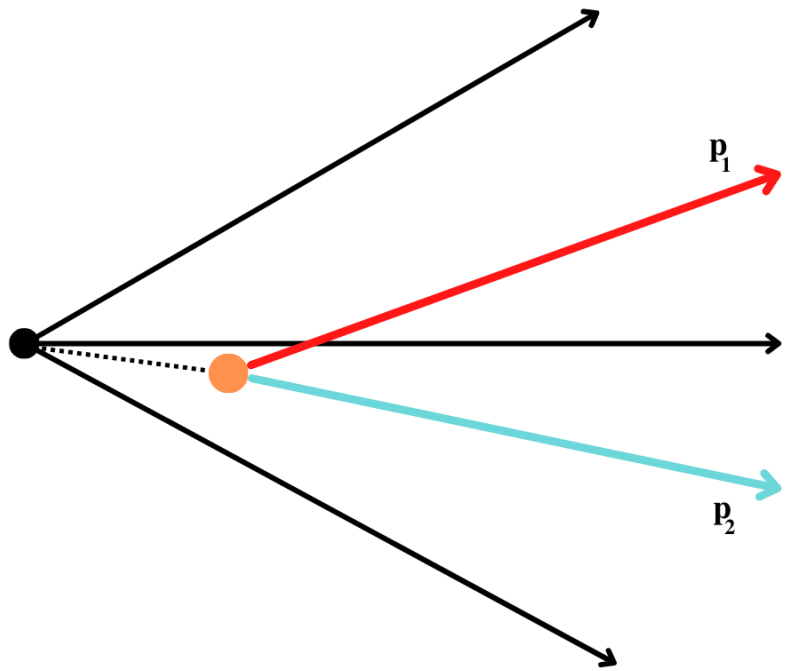

The definition of cuts

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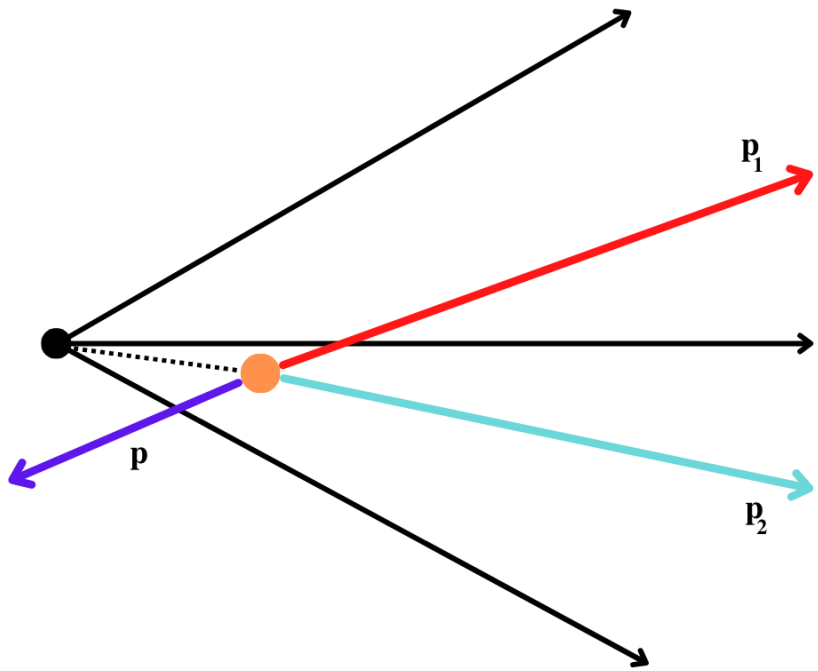
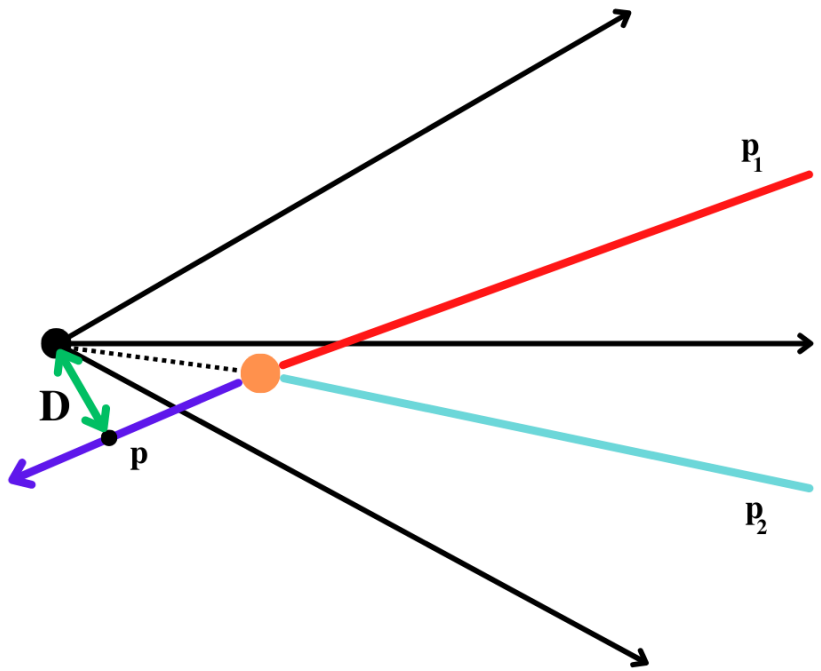
   - p_T,
   - d, (*particle impact parameter*, i.e. the closest distance between the reconstructed track and reconstructed primary vertex)
2. Two tracks cuts:
   - V_z, (distance in z direction between reconstructed primary and secondary vertex)
   - D, (*parent impact parameter*, i.e. closest distance between reconstructed parent and reconstructed primary vertex)



The definition of cuts

1. Single particle cuts:
   - p_T,
   - d, (*particle impact parameter*, i.e. the closest distance between the reconstructed track and reconstructed primary vertex)
2. Two tracks cuts:
   - V_z, (distance in z direction between reconstructed primary and secondary vertex)
   - D, (*parent impact parameter*, i.e. closest distance between reconstructed parent and reconstructed primary vertex)



The definition of cuts

1. Single particle cuts:
   - p_T,
   - d, (*particle impact parameter*, i.e. the closest distance between the reconstructed track and reconstructed primary vertex)

2. Two tracks cuts:
   - V_z, (distance in z direction between reconstructed primary and secondary vertex)
   - D, (*parent impact parameter*, i.e. closest distance between reconstructed parent and reconstructed primary vertex)
   - DCA (Distance of Closest Approach of two tracks).