RPC timing for slow muons

Reminder

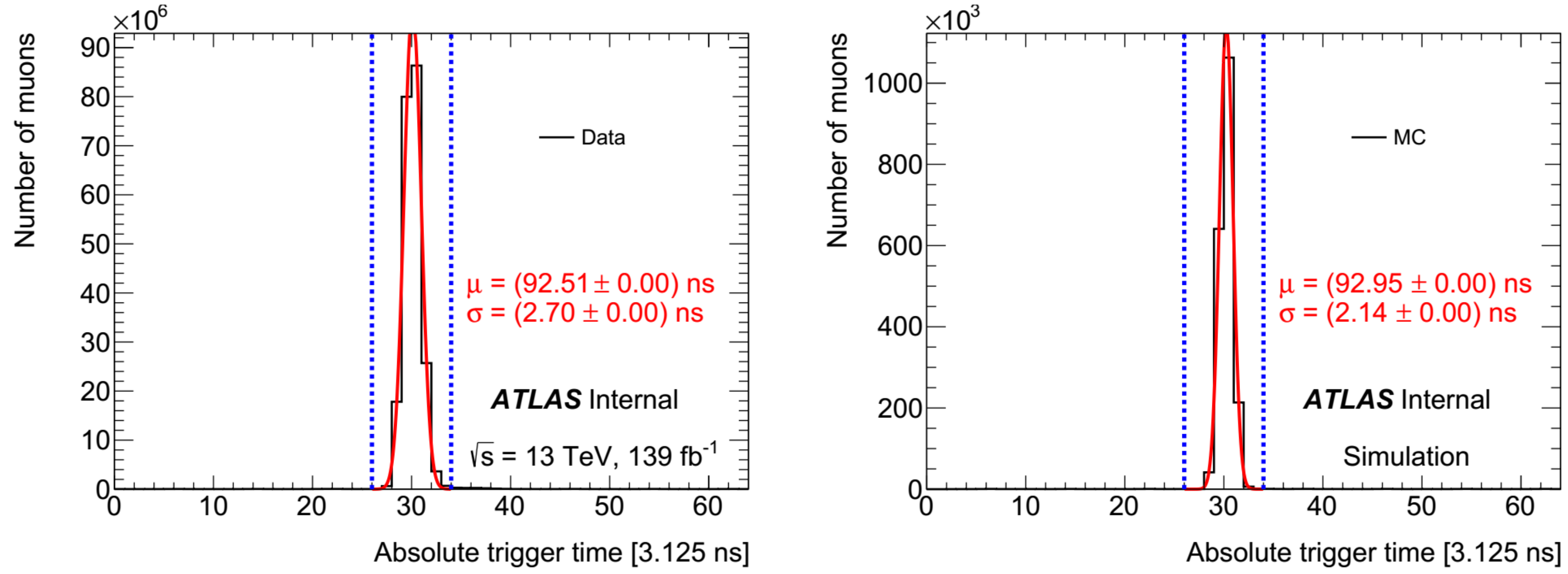
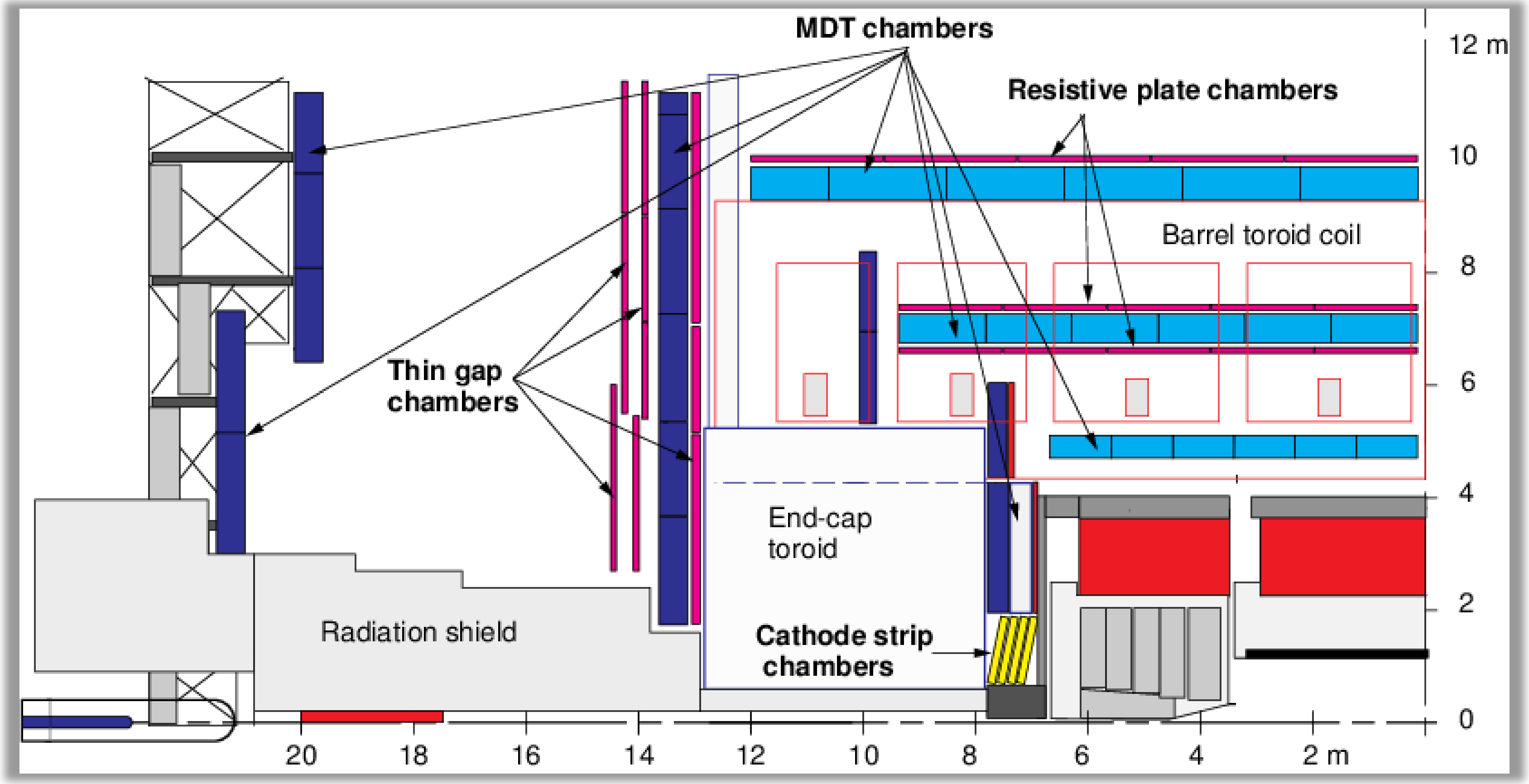


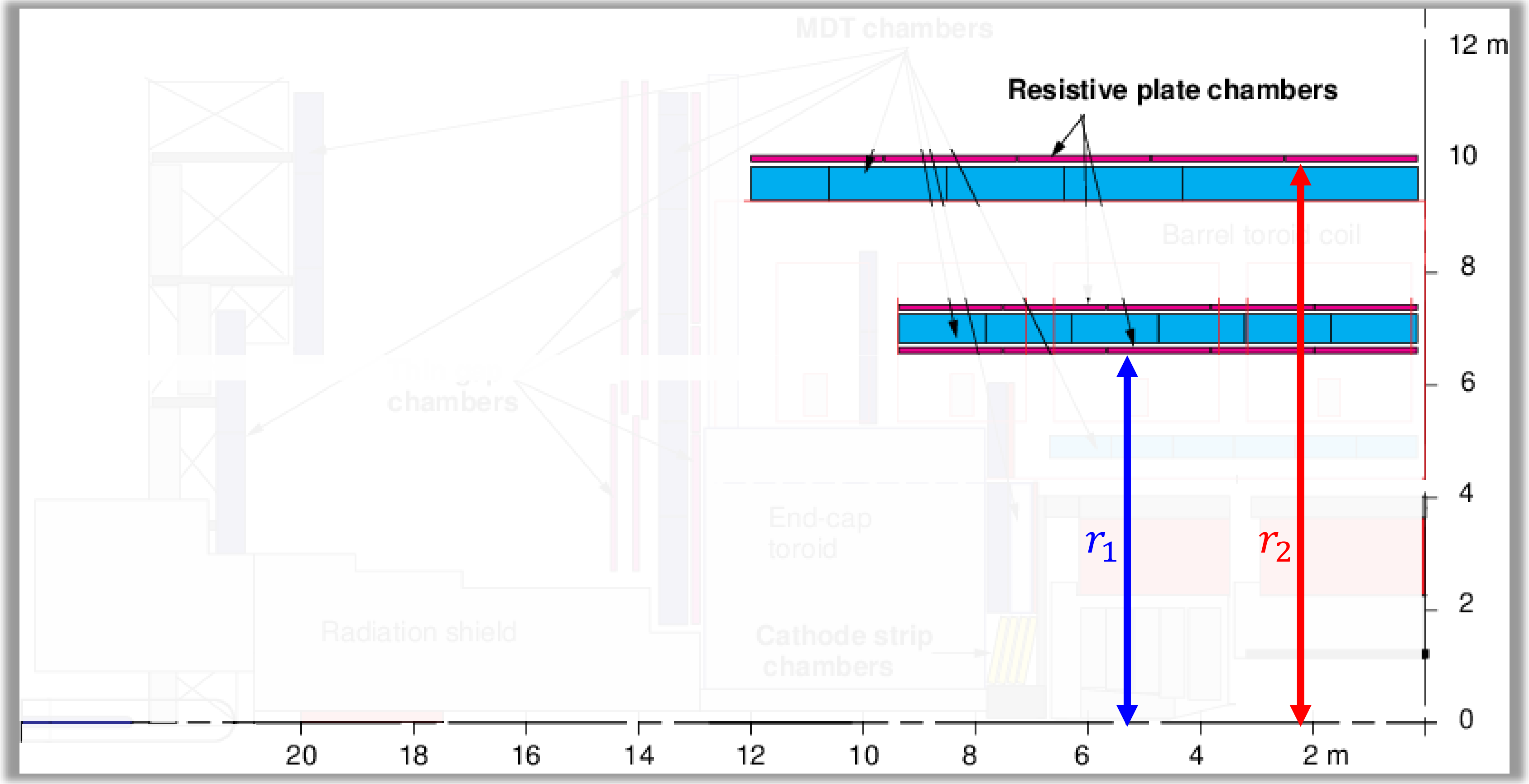
Figure 26: Hit arrival time of L1 RPC triggers in data **(left)** and Monte Carlo **(right)**. Gaussian fits and their parameters are shown in red. Vertical dashed blue lines denote the 25 ns-wide trigger timing windows.

Geometry



MDT chambers
Resistive plate chambers
Barrel toroid coil
Thin gap chambers
End-cap toroid
Radiation shield
Cathode strip chambers
12 m
10
8
6
4
2
0
20
18
16
14
12
10
8
6
4
2 m

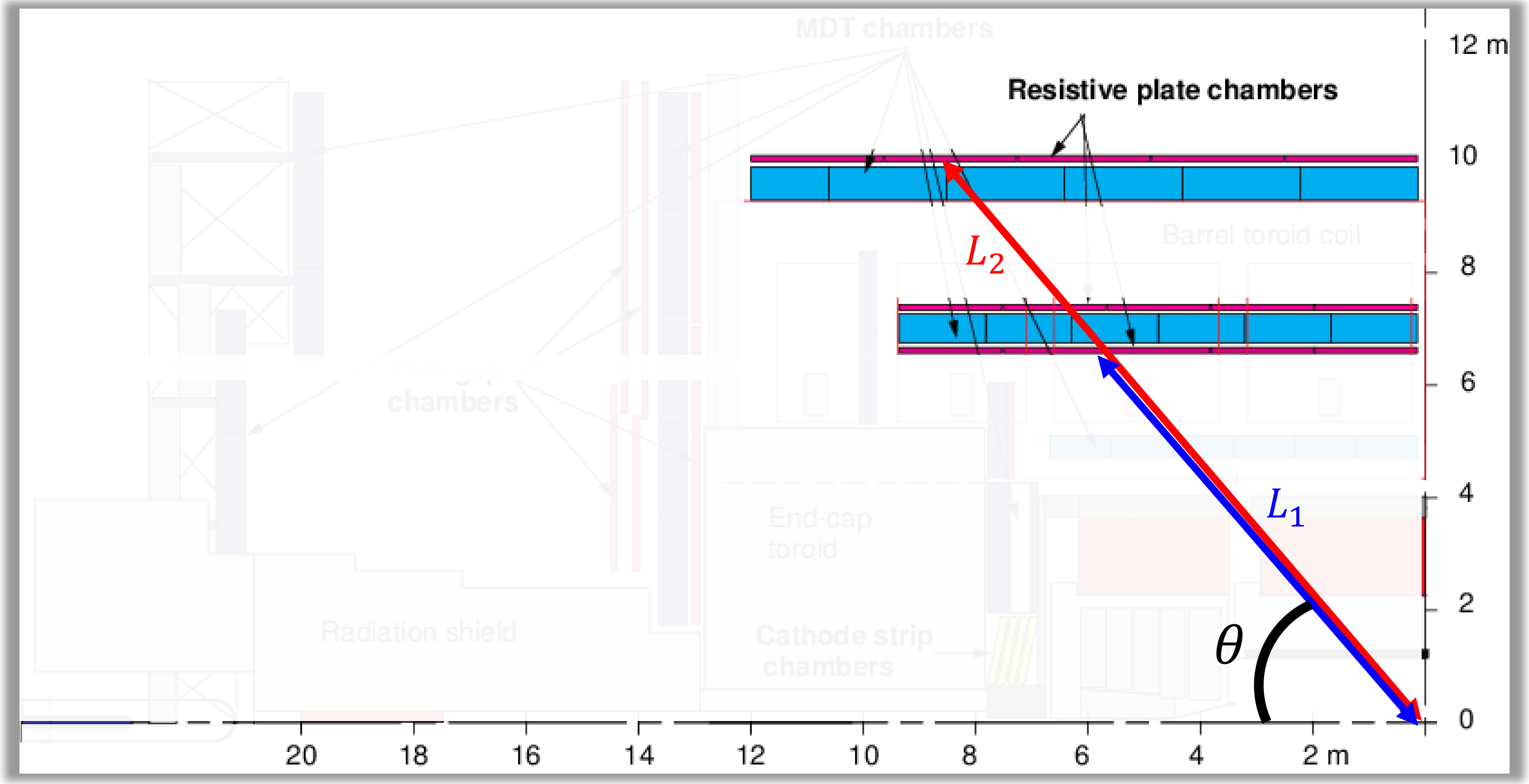
Geometry & nomenclature



$r_1 = 6.6$ m – the distance between the IP and the innermost RPC plane

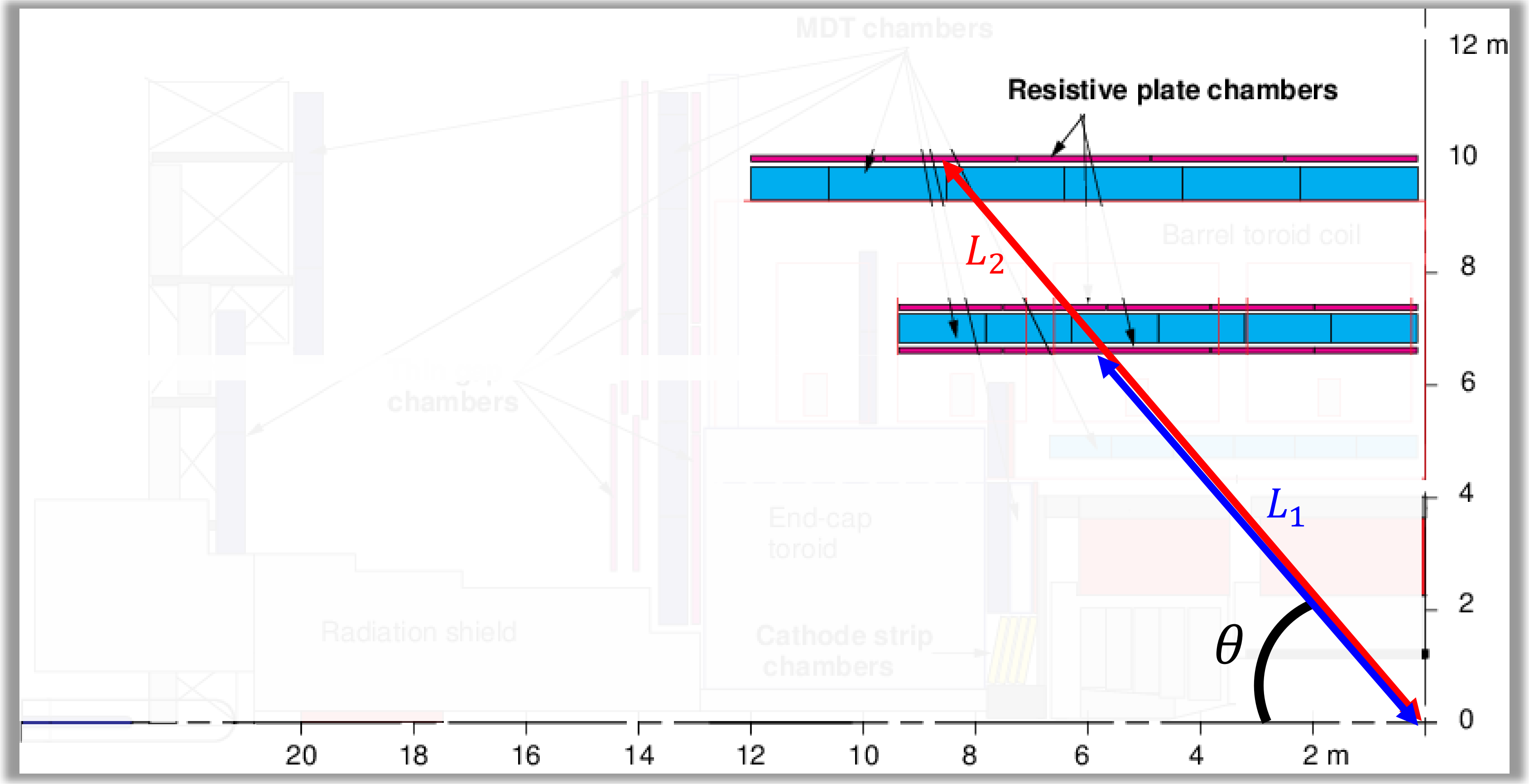
$r_2 = 10.0$ m – the distance between the IP and the outermost RPC plane

Geometry & nomenclature



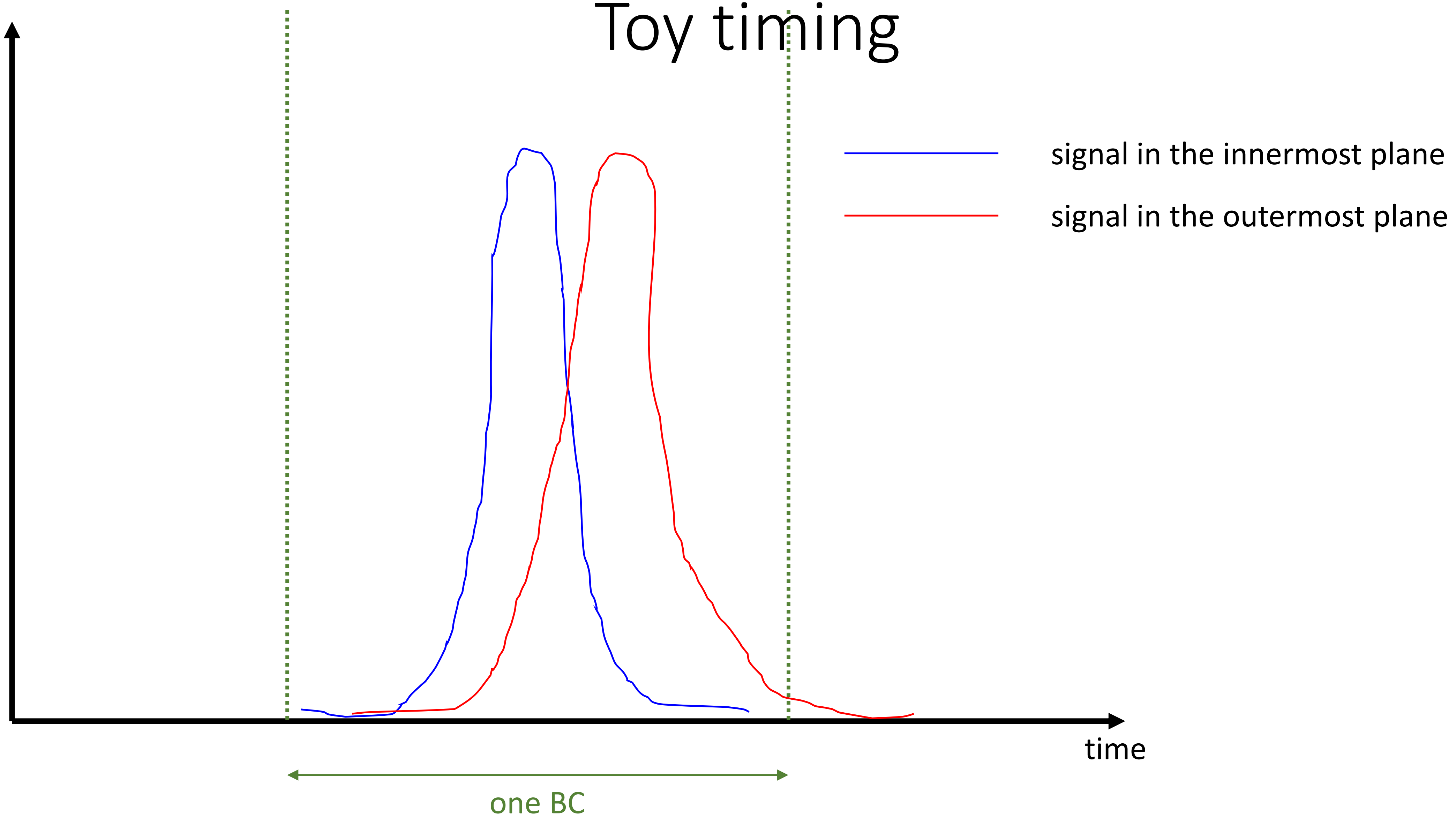
$L_{1,2} = \frac{r_{1,2}}{\sin\theta}$ – corresponding track-segment lengths

Geometry & nomenclature

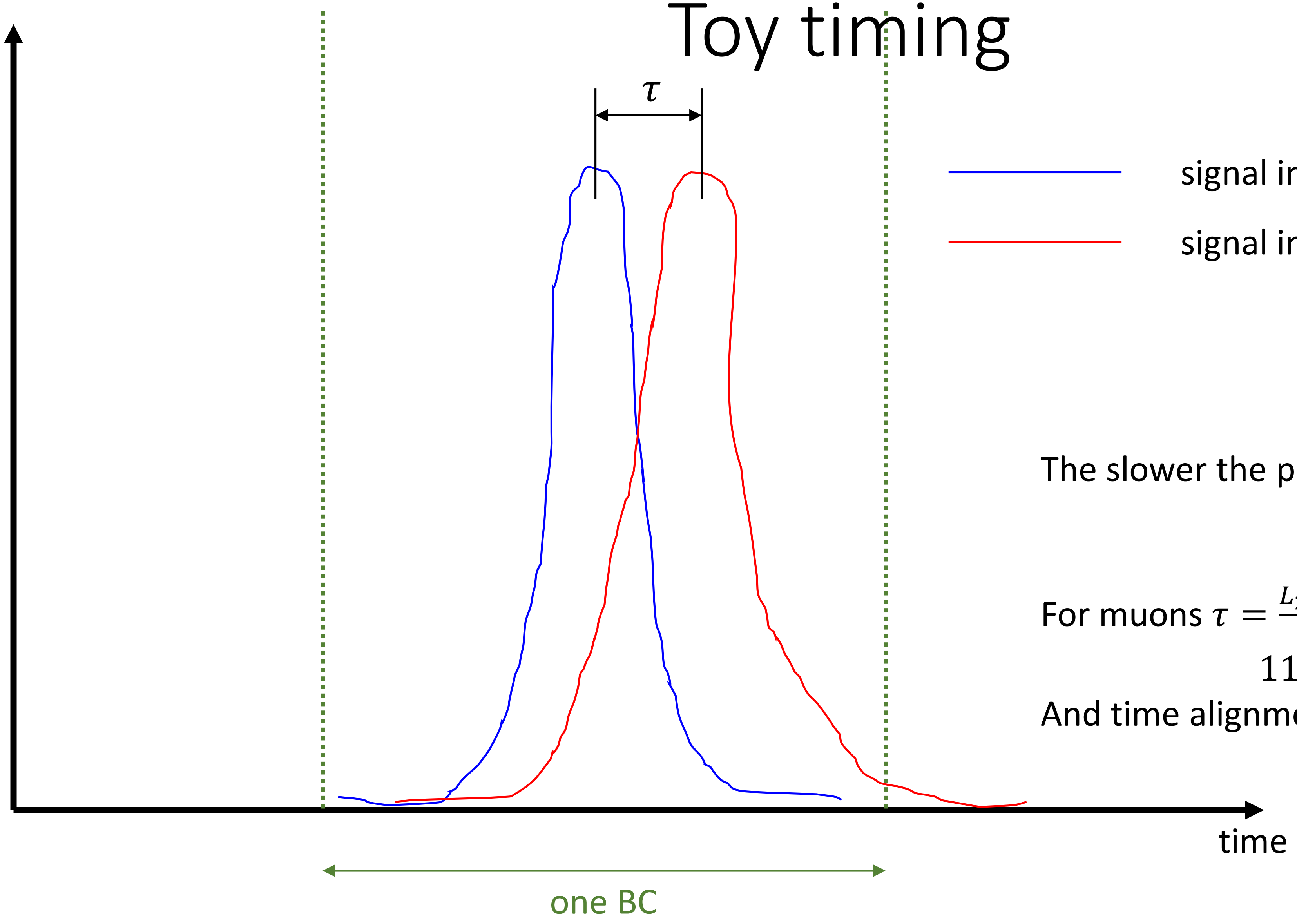


In order for the late-muon trigger to fire, the muon-like particle has to reach both the innermost and the outermost RPC planes within the same BC: the next one after the one where the L1_J50 fired.

Toy timing


signal in the innermost plane
signal in the outermost plane
time
one BC

Toy timing



signal in the innermost plane

signal in the outermost plane

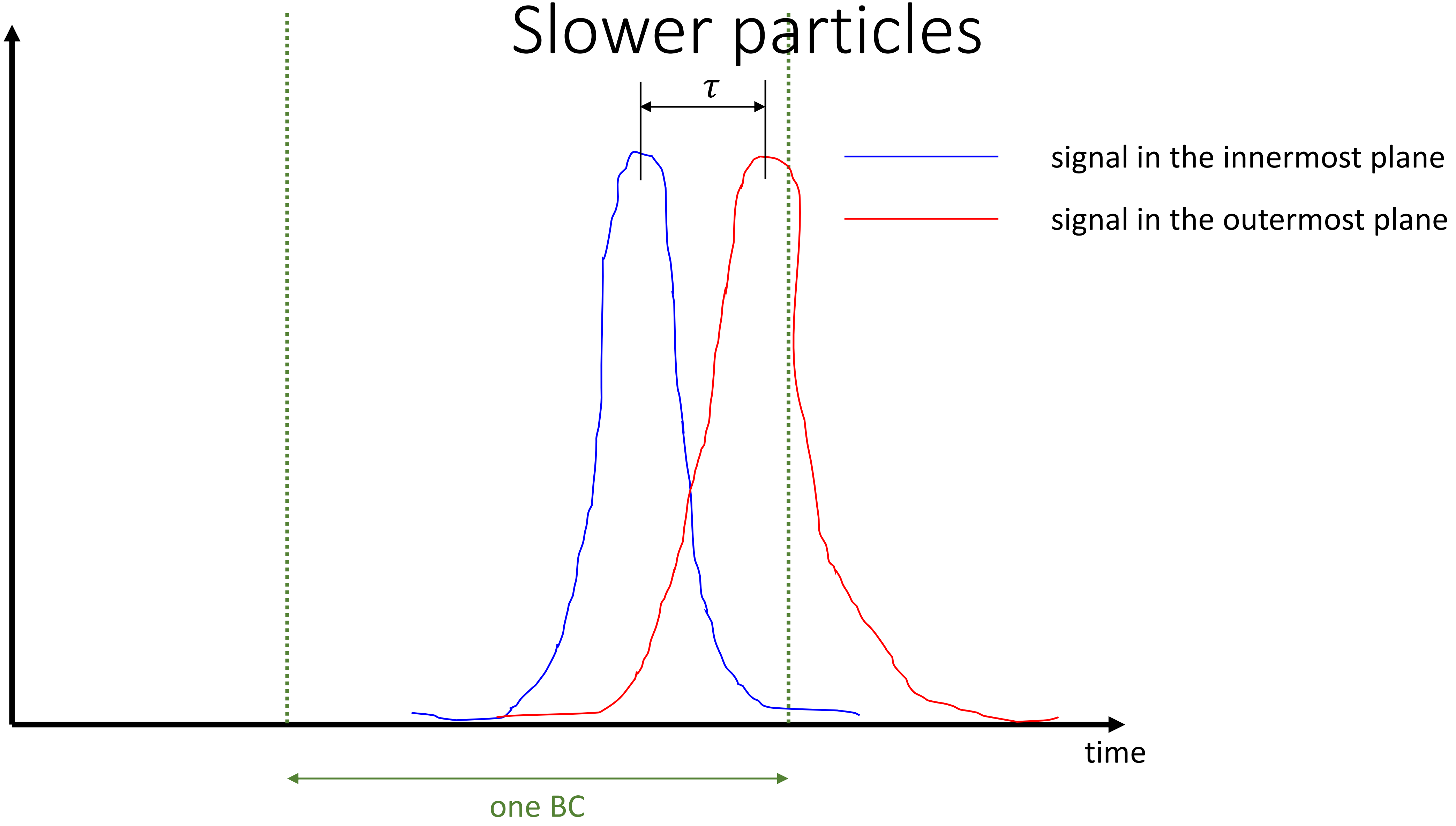
The slower the particles, the larger the τ.

For muons $\tau = \frac{L_2 - L_1}{c} = \frac{11.3\ ns}{\sin\theta}$, $0.62 \leq \sin\theta \leq 1 \Rightarrow$

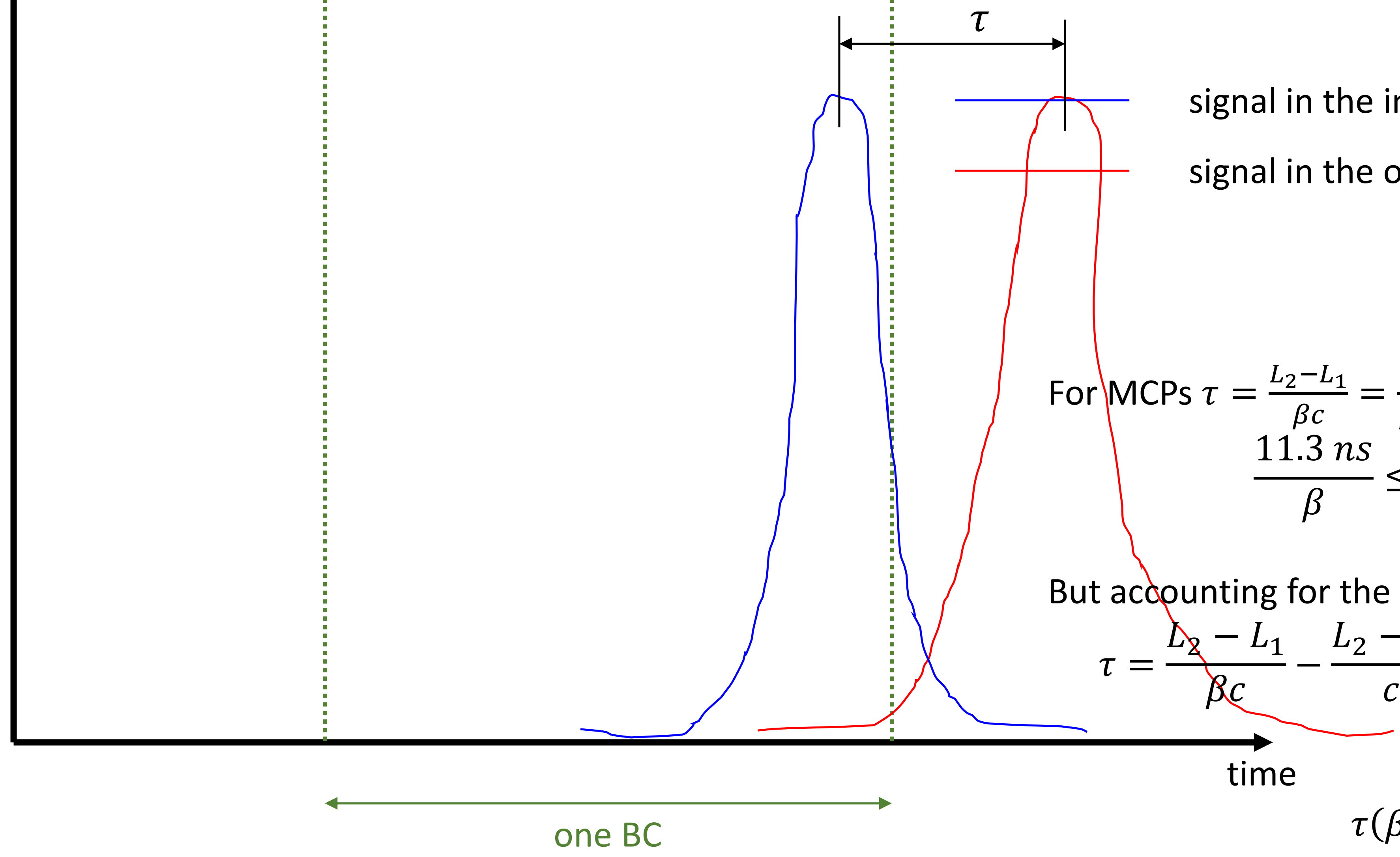
$$11.3\ ns \leq \tau \leq 18.3\ ns$$

And time alignment sets this to zero.

Slower particles



Even slower particles



For MCPs $\tau = \frac{L_2 - L_1}{\beta c} = \frac{11.3\ ns}{\beta \sin\theta}$, $0.62 \leq \sin\theta \leq 1 \Rightarrow$

$$\frac{11.3\ ns}{\beta} \leq \tau \leq \frac{18.3\ ns}{\beta}$$

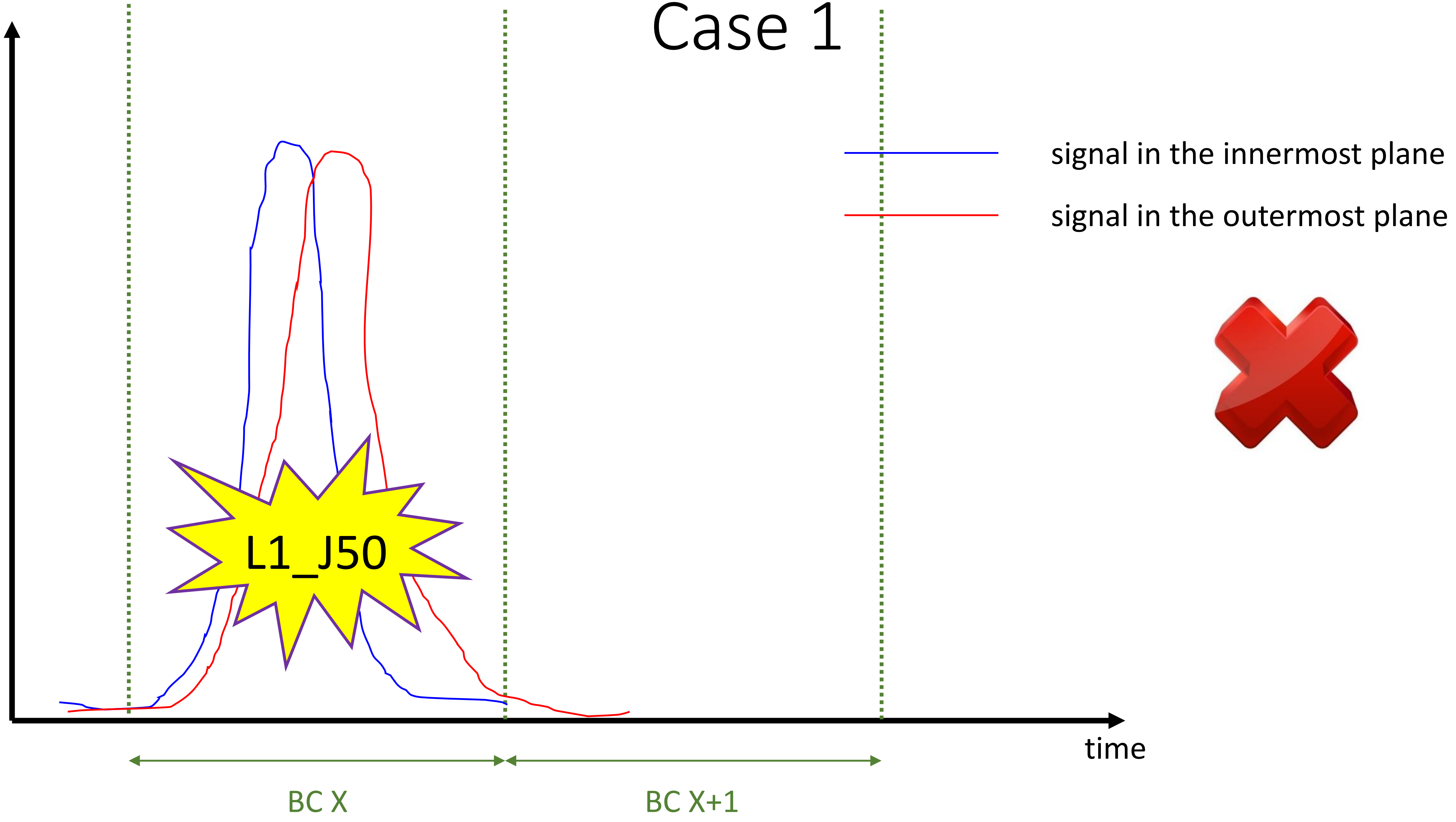
But accounting for the time alignment, we get

$$\tau = \frac{L_2 - L_1}{\beta c} - \frac{L_2 - L_1}{c} = \frac{(L_2 - L_1)(1 - \beta)}{\beta c}$$

$$\tau(\beta = 0.7,\ \eta = 0.5) = 5.5\ ns$$

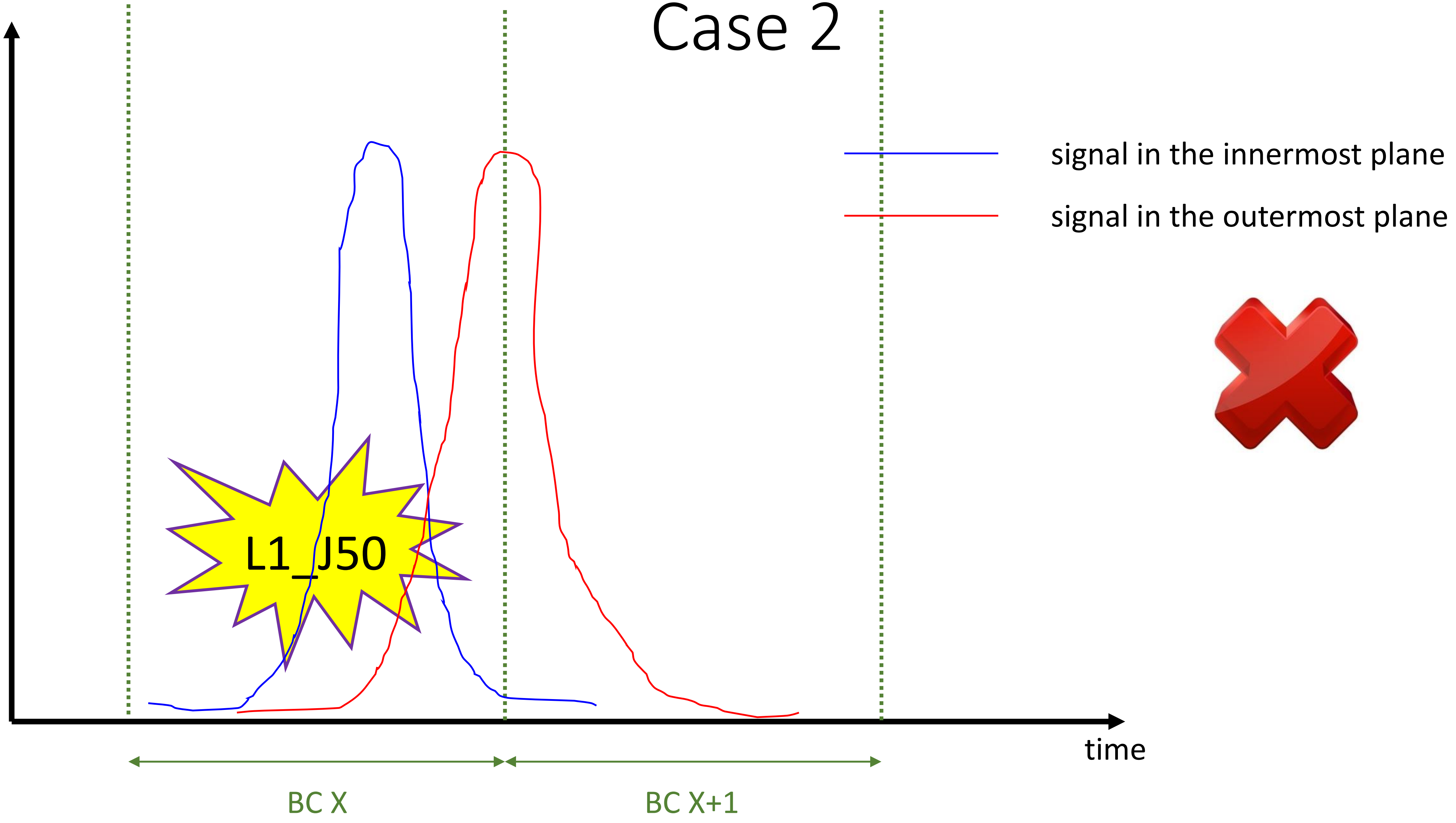
Will the late-muon trigger fire in the following cases?

Case 1



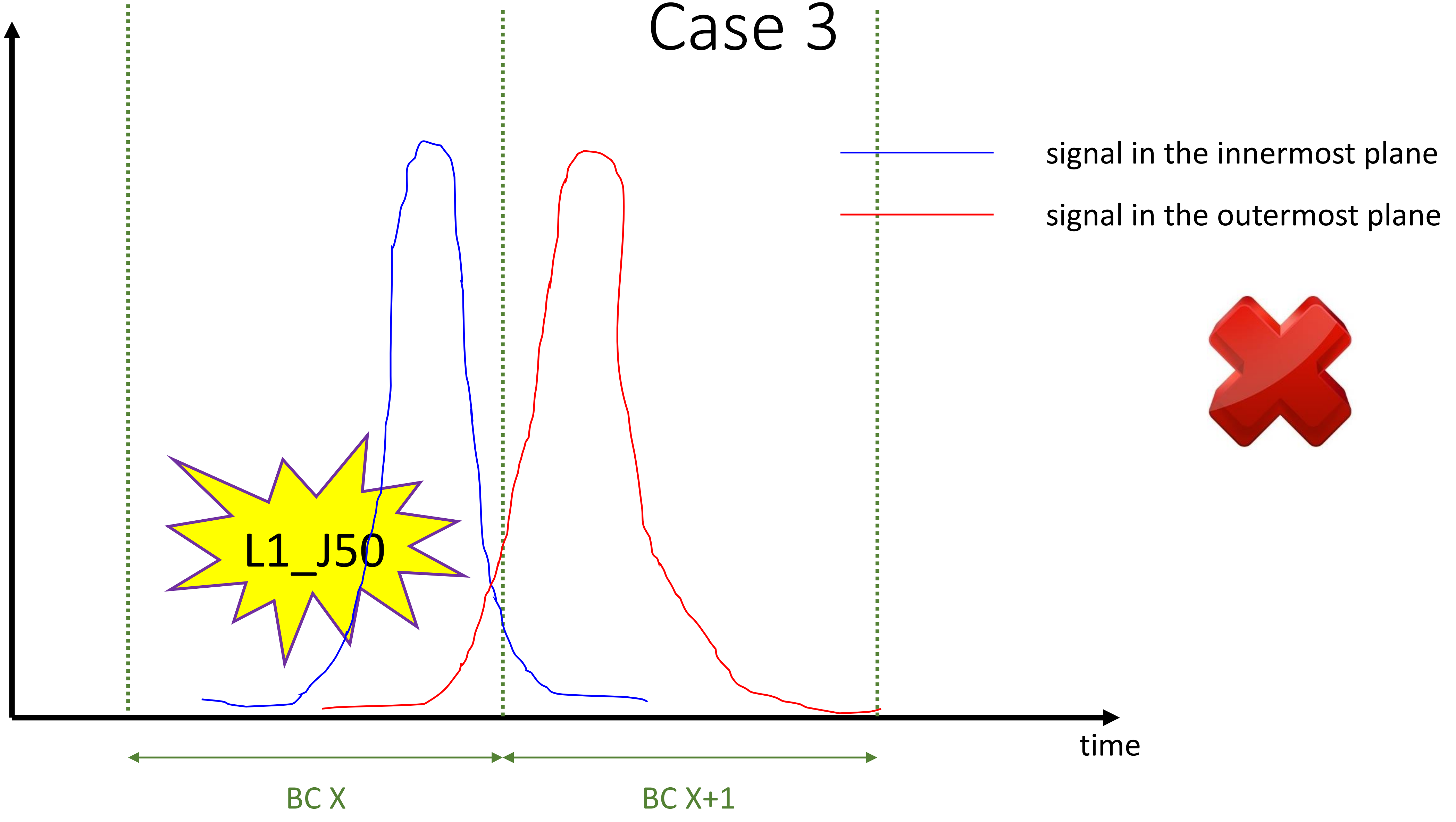
signal in the innermost plane
signal in the outermost plane
L1_J50
time
BC X
BC X+1

Case 2

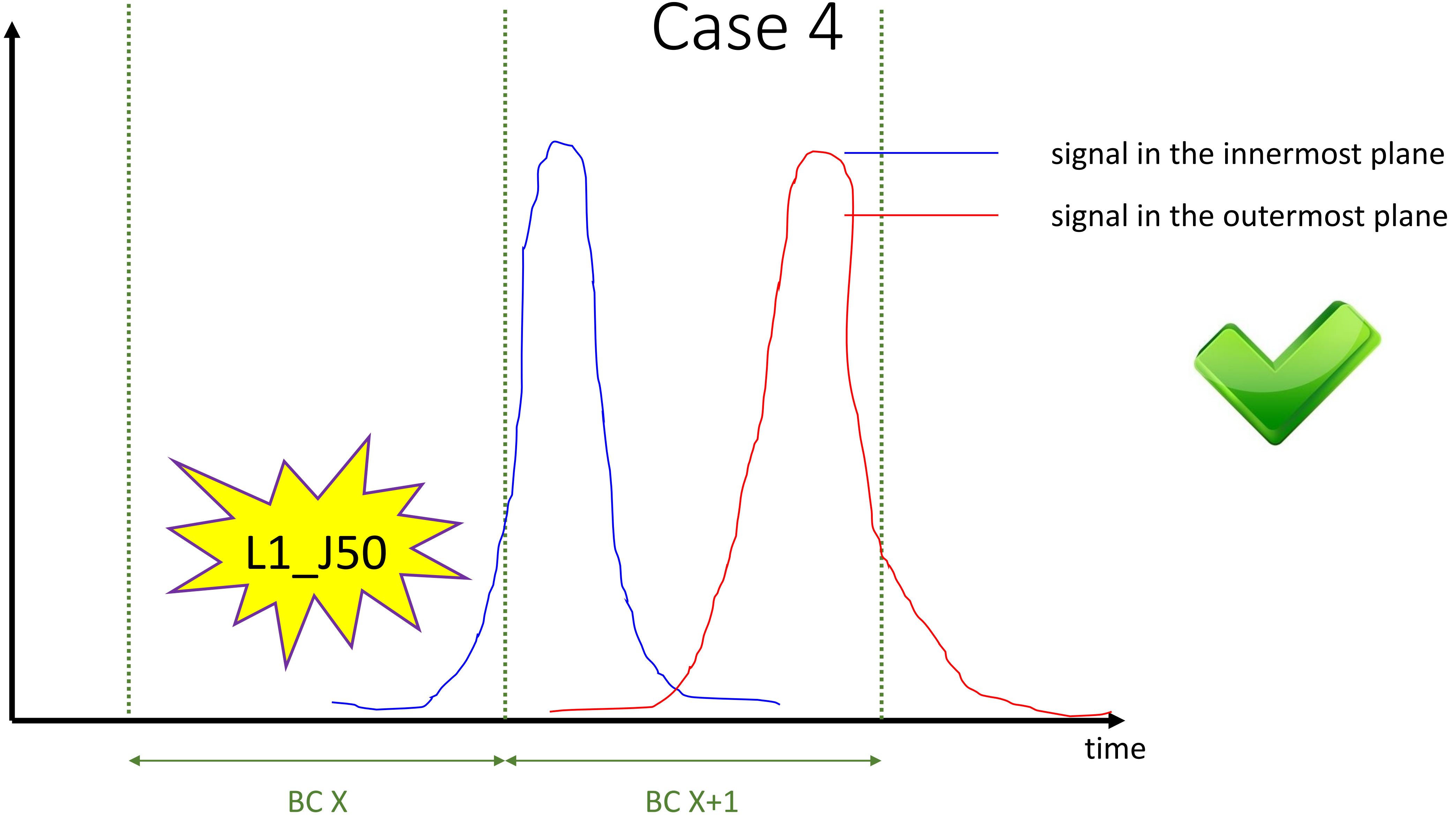


signal in the innermost plane
signal in the outermost plane
L1_J50
time
BC X
BC X+1

Case 3

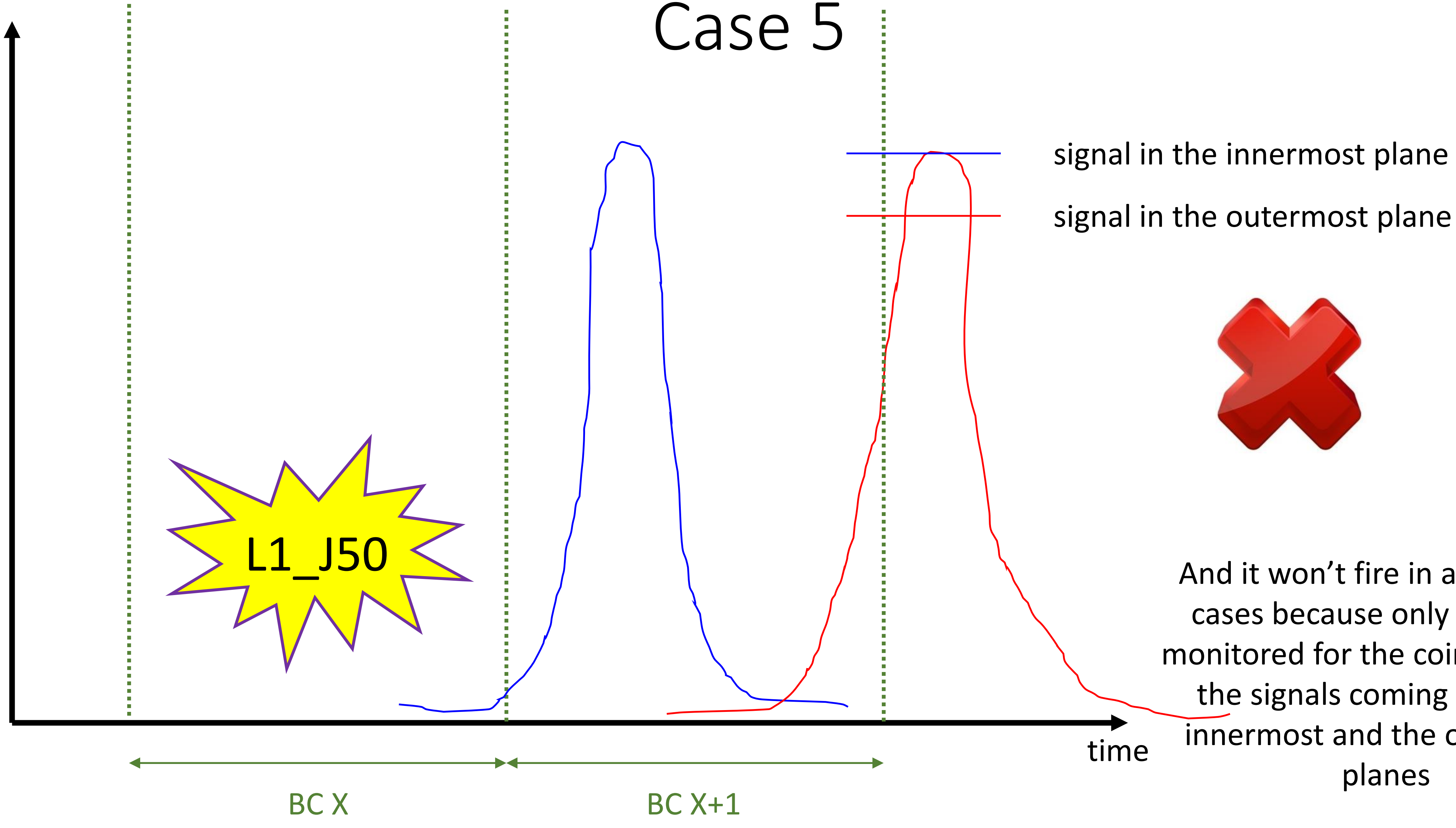

signal in the innermost plane
signal in the outermost plane
L1_J50
time
BC X
BC X+1

Case 4



signal in the innermost plane
signal in the outermost plane
L1_J50
time
BC X
BC X+1

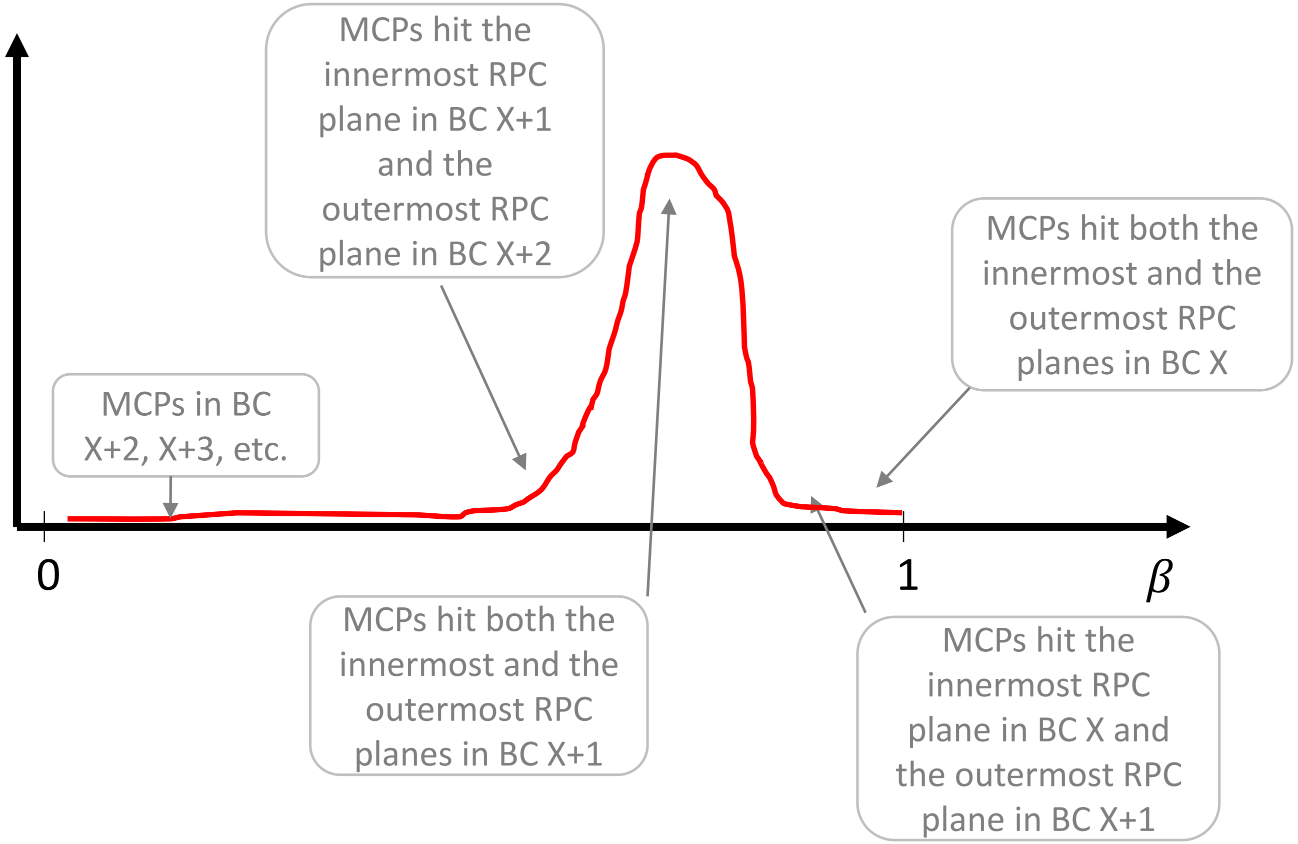
Case 5



And it won't fire in any further cases because only BC X+1 is monitored for the coincidence of the signals coming from the innermost and the outermost planes

Velocity: expectation

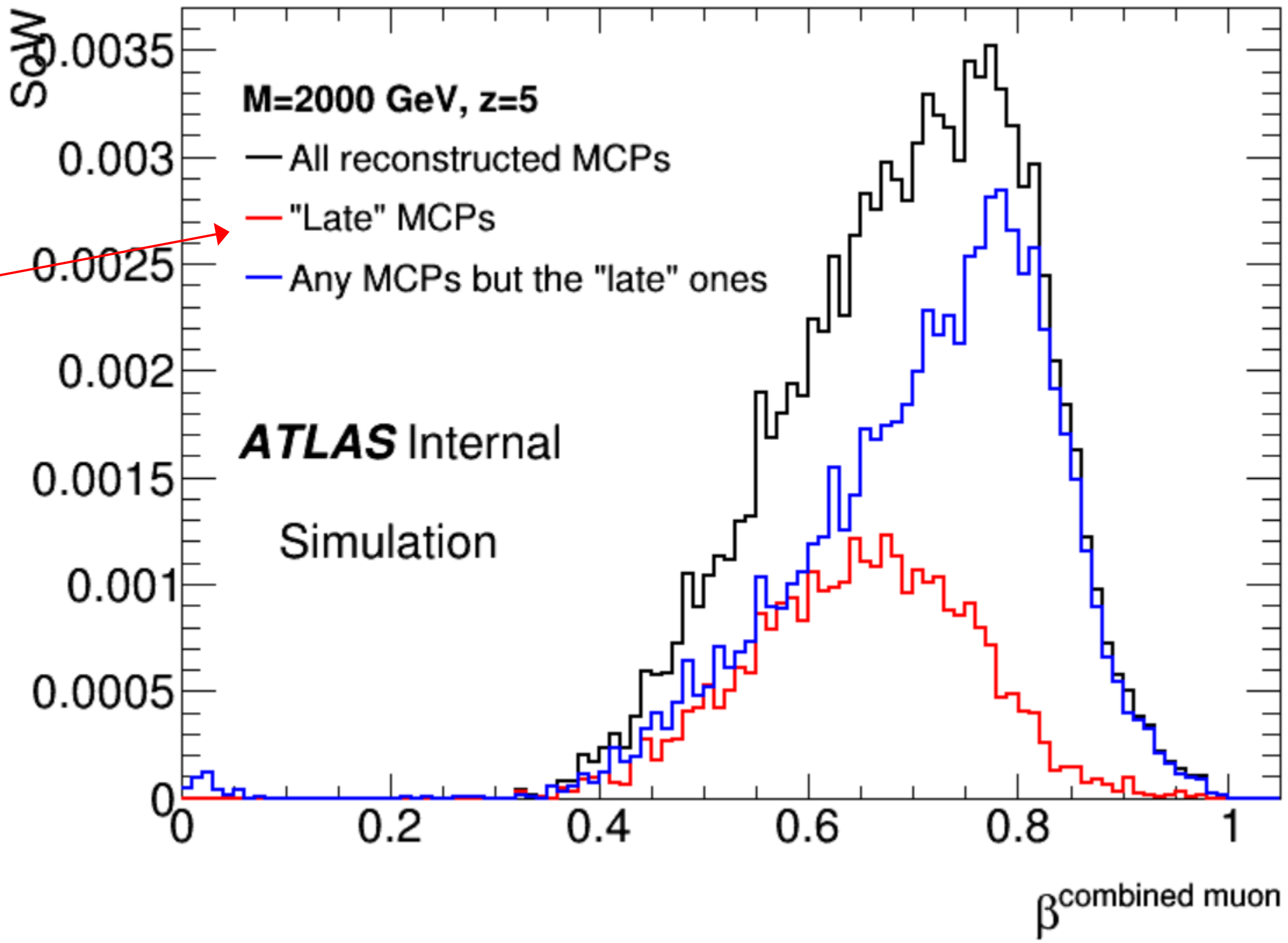
All this means that the velocity spectrum of MCPs in events triggered by the late-muon trigger (and not by any other trigger) should look like that:



In reality, the width of the Gaussian may differ from this cartoon: it may be wider or narrower depending on the exact timing parameters.

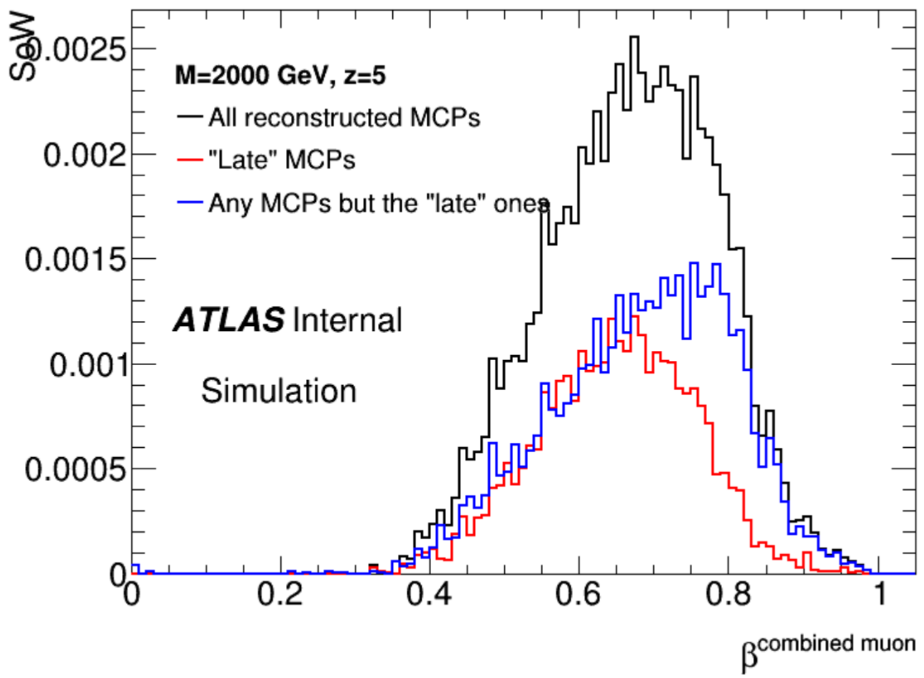
Velocity: reality

Only those MCPs that made the late-muon trigger fire

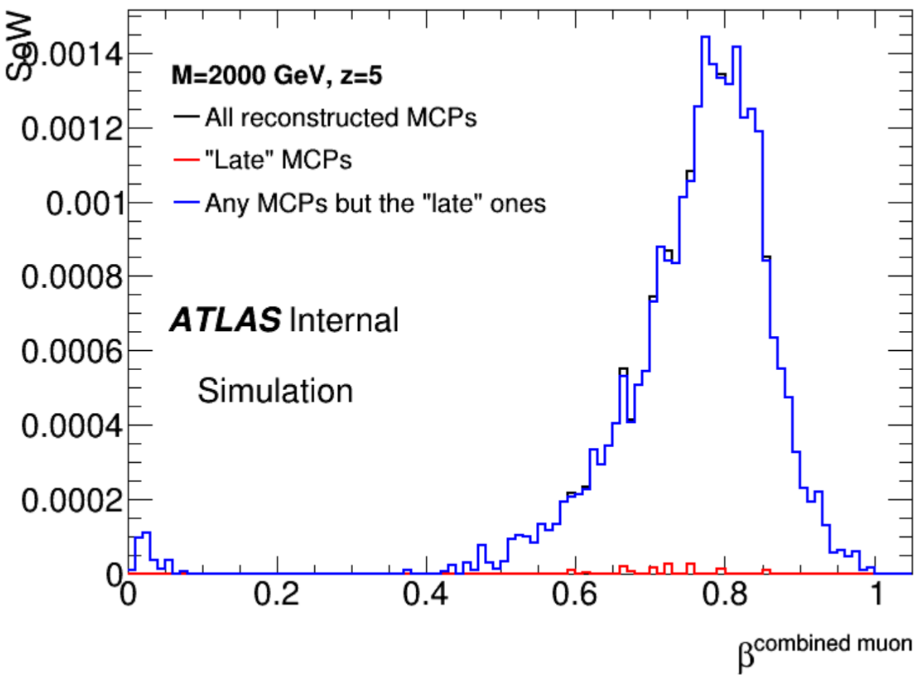


Velocity of MCPs hitting/not hitting RPCs

Hitting RPCs ($|\eta| < 1.05$)

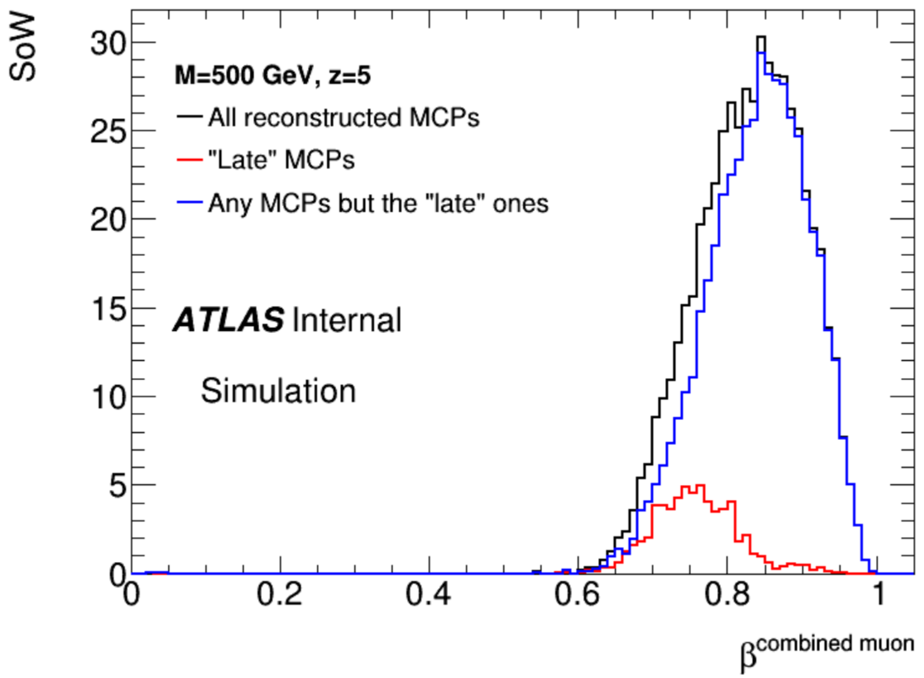


Not hitting RPCs (i.e. hitting TGCs, $1.05 < |\eta| < 2.0$)

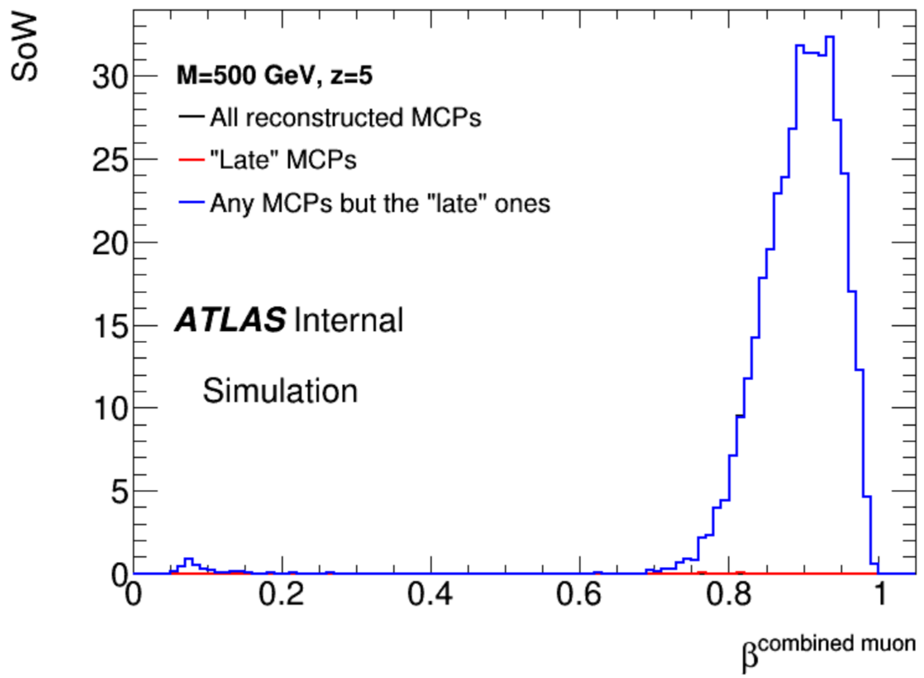


Same but for lighter MCPs

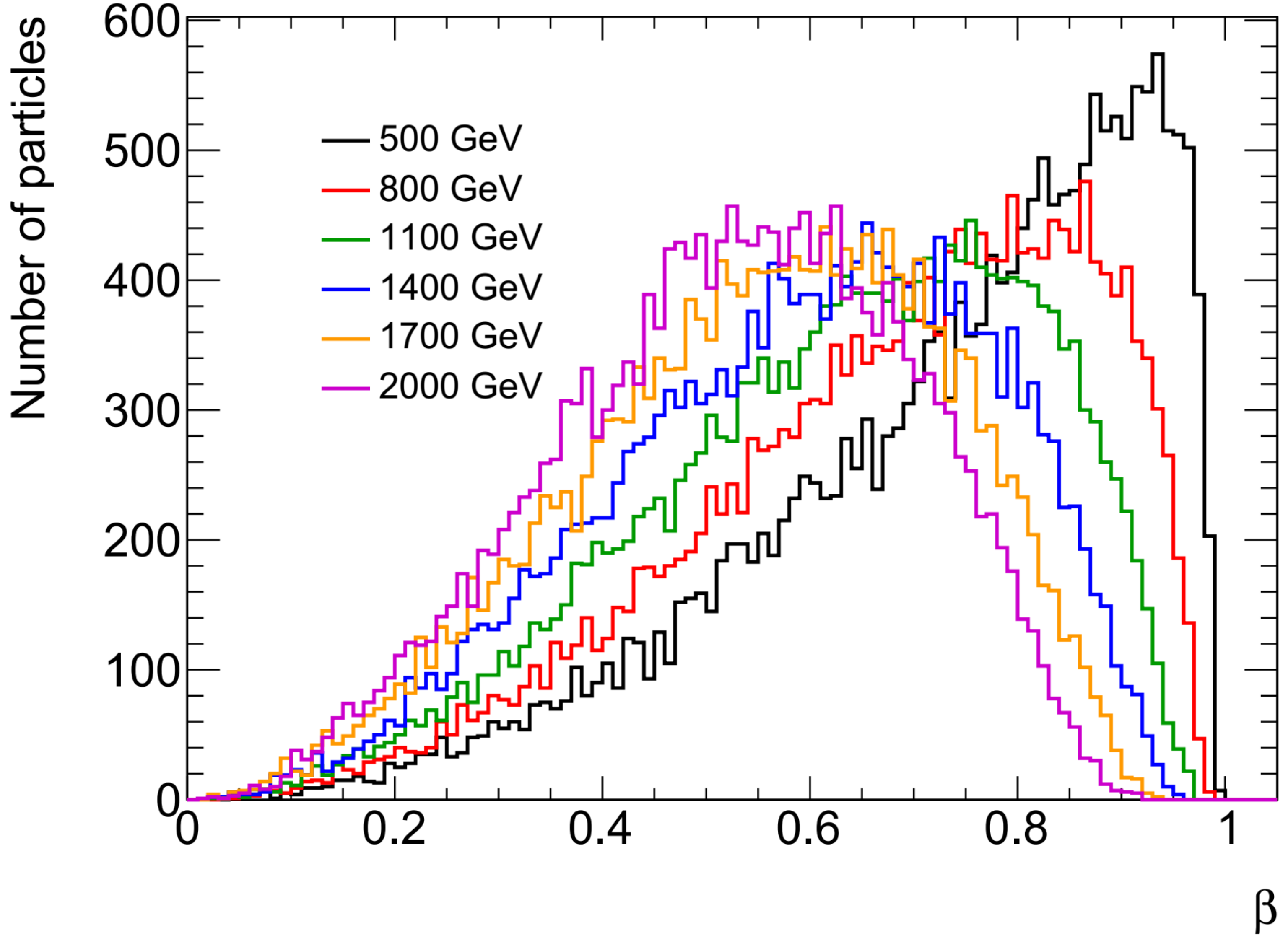
Hitting RPCs ($|\eta| < 1.05$)



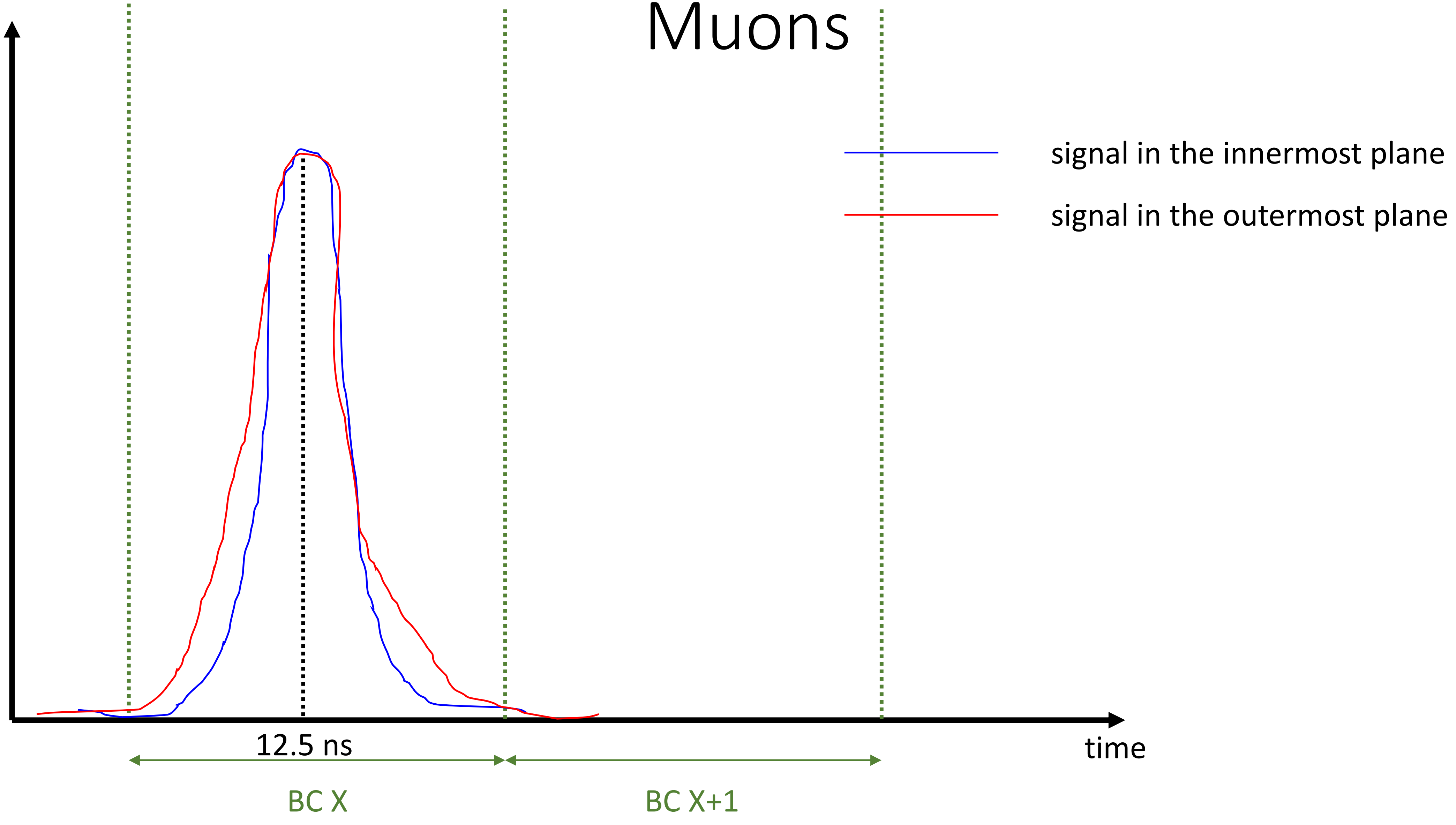
Not hitting RPCs (i.e. hitting TGCs, $1.05 < |\eta| < 2.0$)



β_{truth} plots



Muons


signal in the innermost plane
signal in the outermost plane
12.5 ns
time
BC X
BC X+1

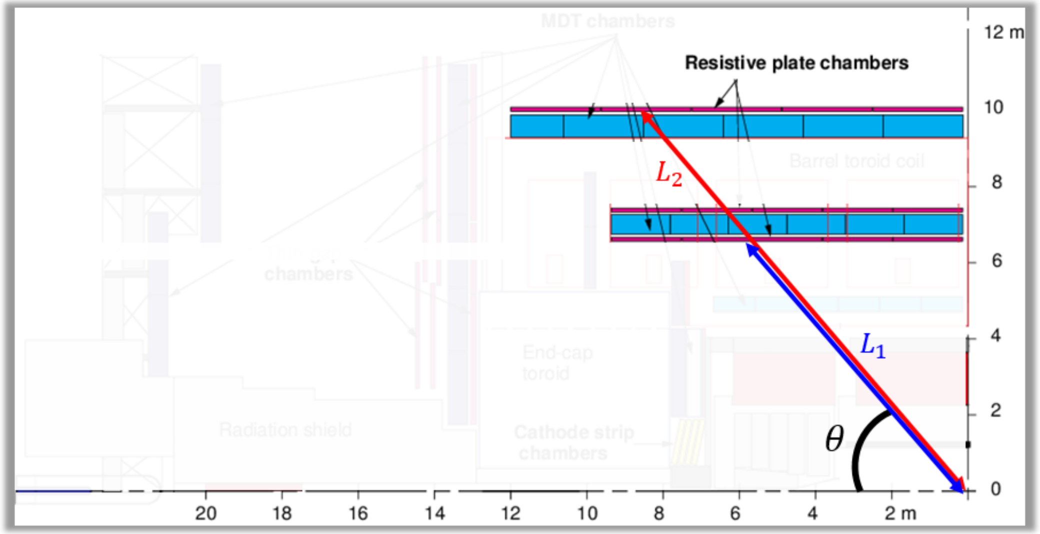
Which β values are possible in order for an MCP (hitting RPCs) to fire the late-muon trigger?

Innermost plane:

$$12.5\,ns < \frac{L_1}{\beta c} \cdot (1-\beta) < 37.5\,ns$$

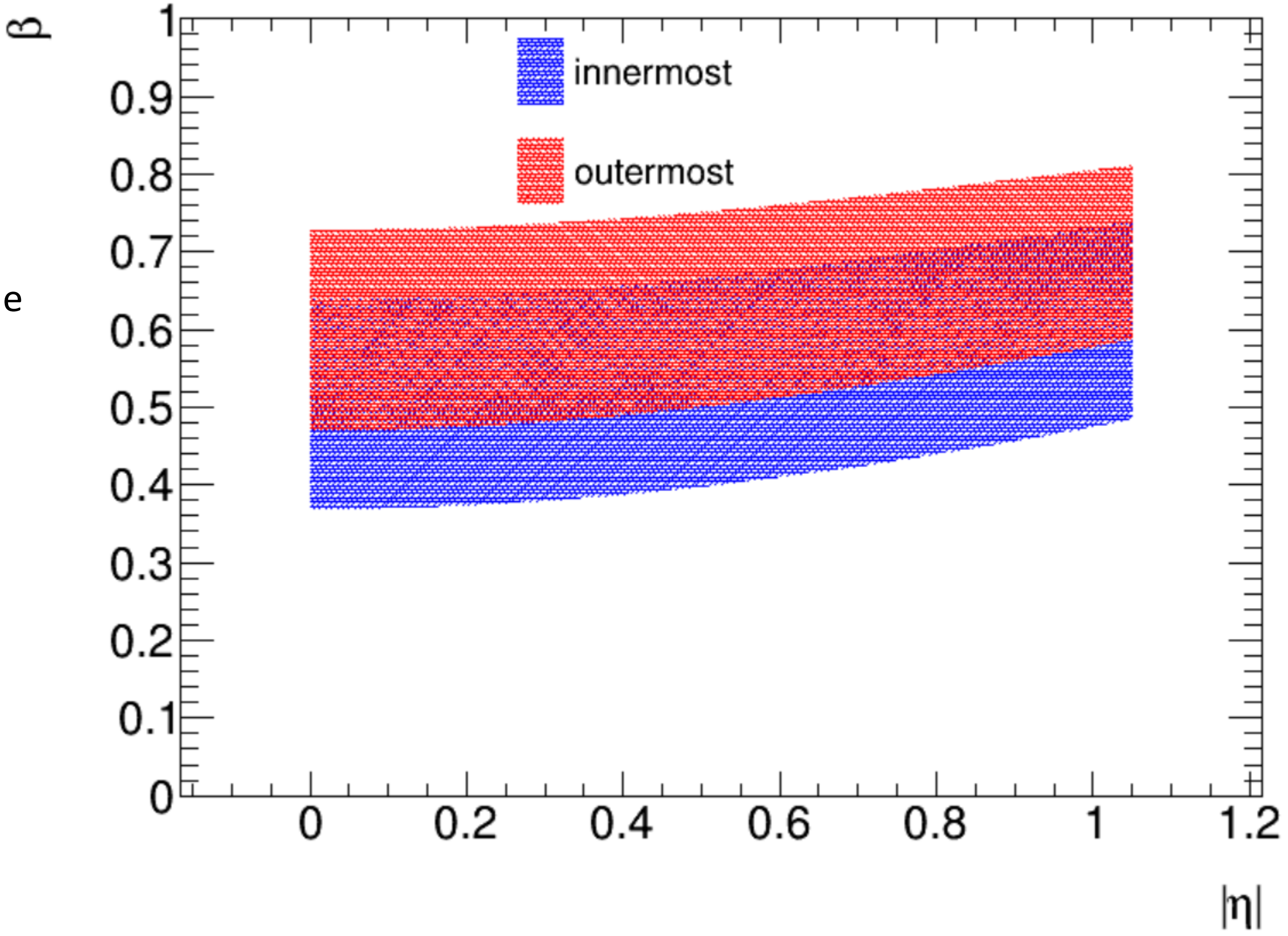
Outermost plane:

$$12.5\,ns < \frac{L_2}{\beta c} \cdot (1-\beta) < 37.5\,ns$$

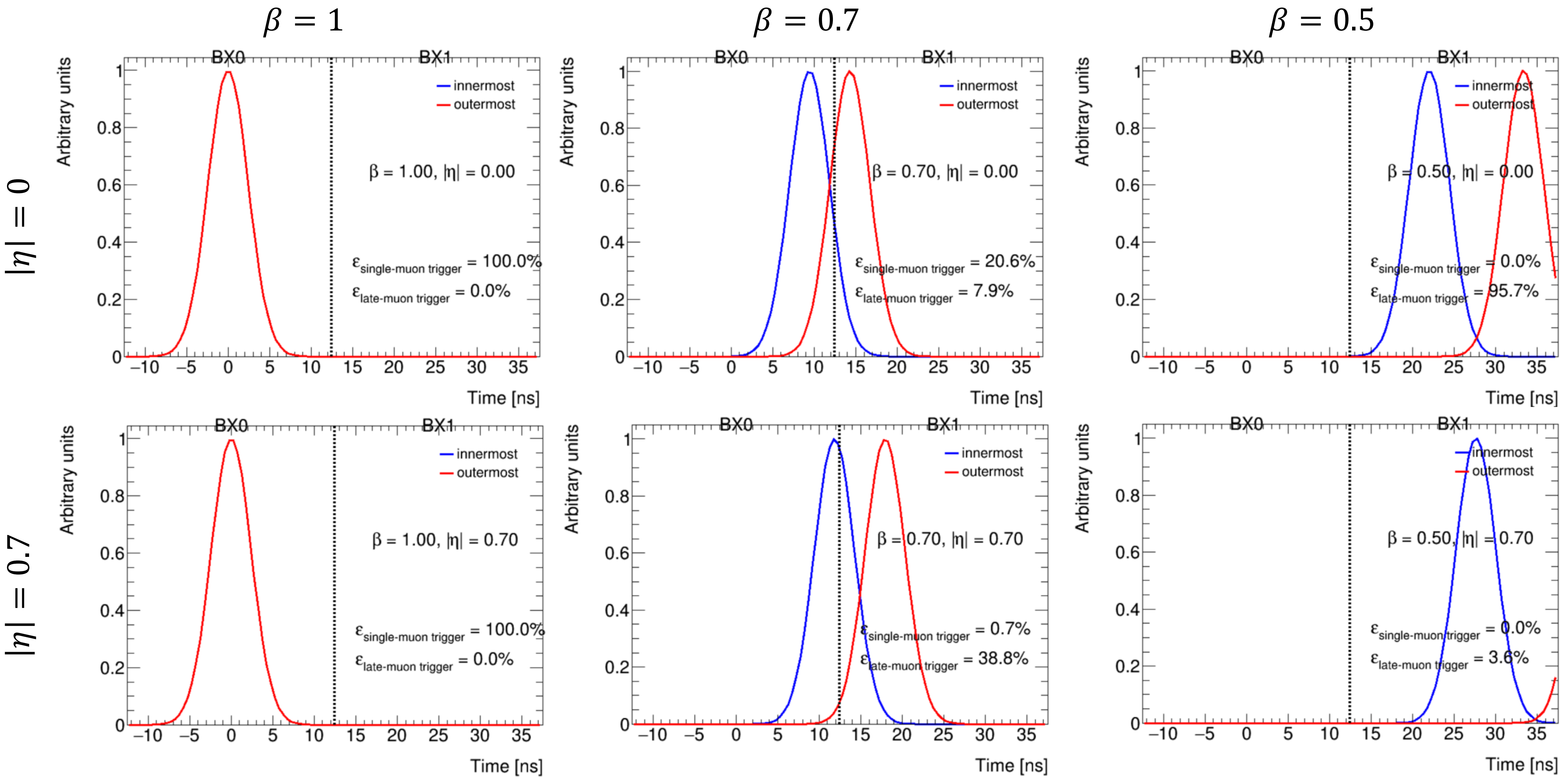


Which β values are possible in order for an MCP (hitting RPCs) to fire the late-muon trigger?

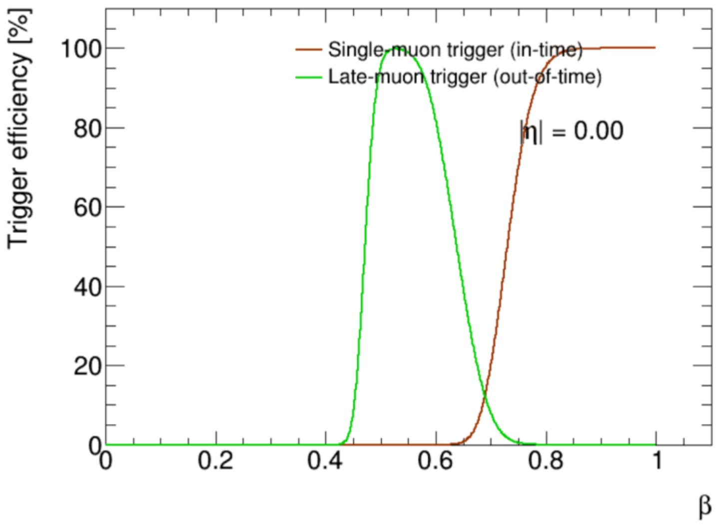
Only the area where the trigger fires with a probability of >50% is shown

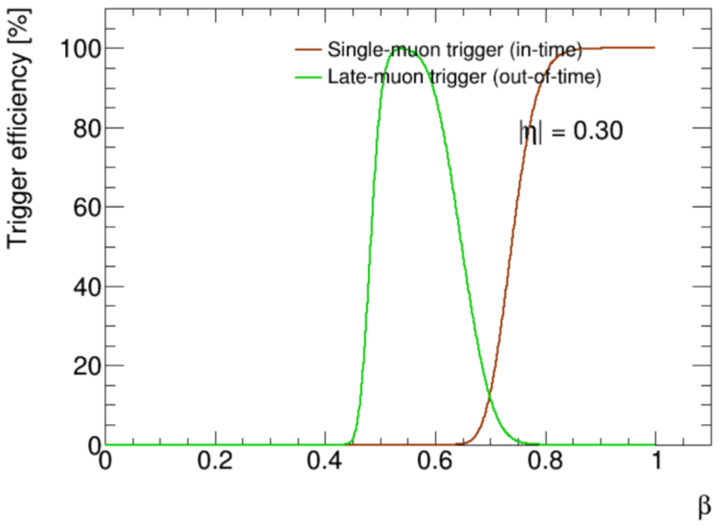


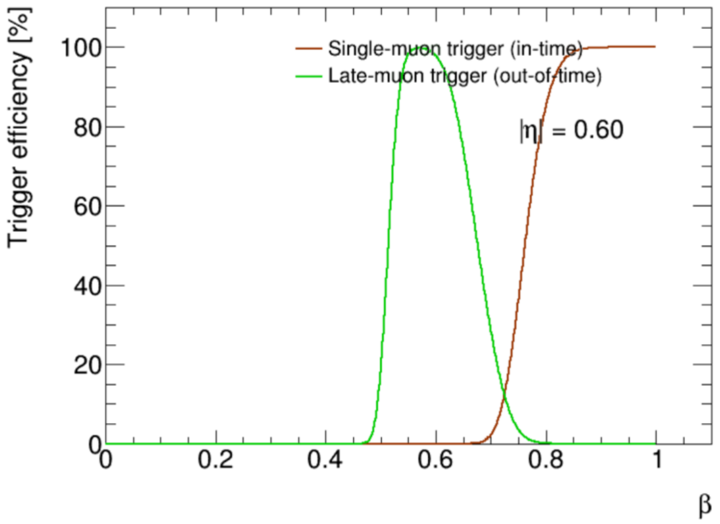
Single-muon and late-muon trigger efficiencies from toy MC

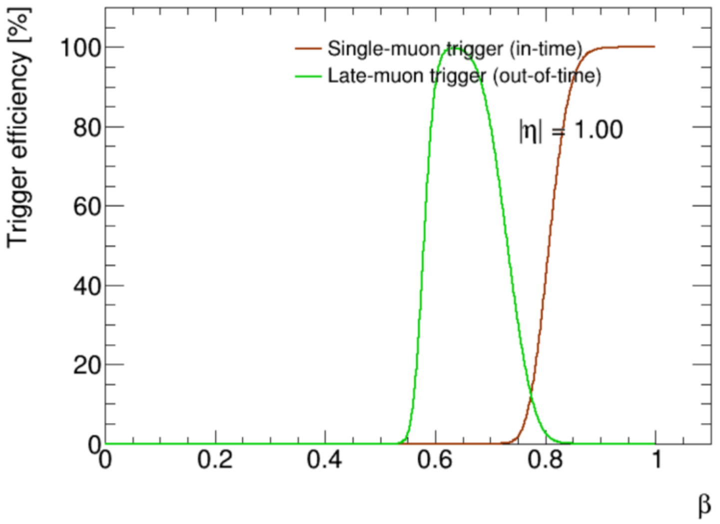


Single-muon and late-muon trigger efficiencies vs β

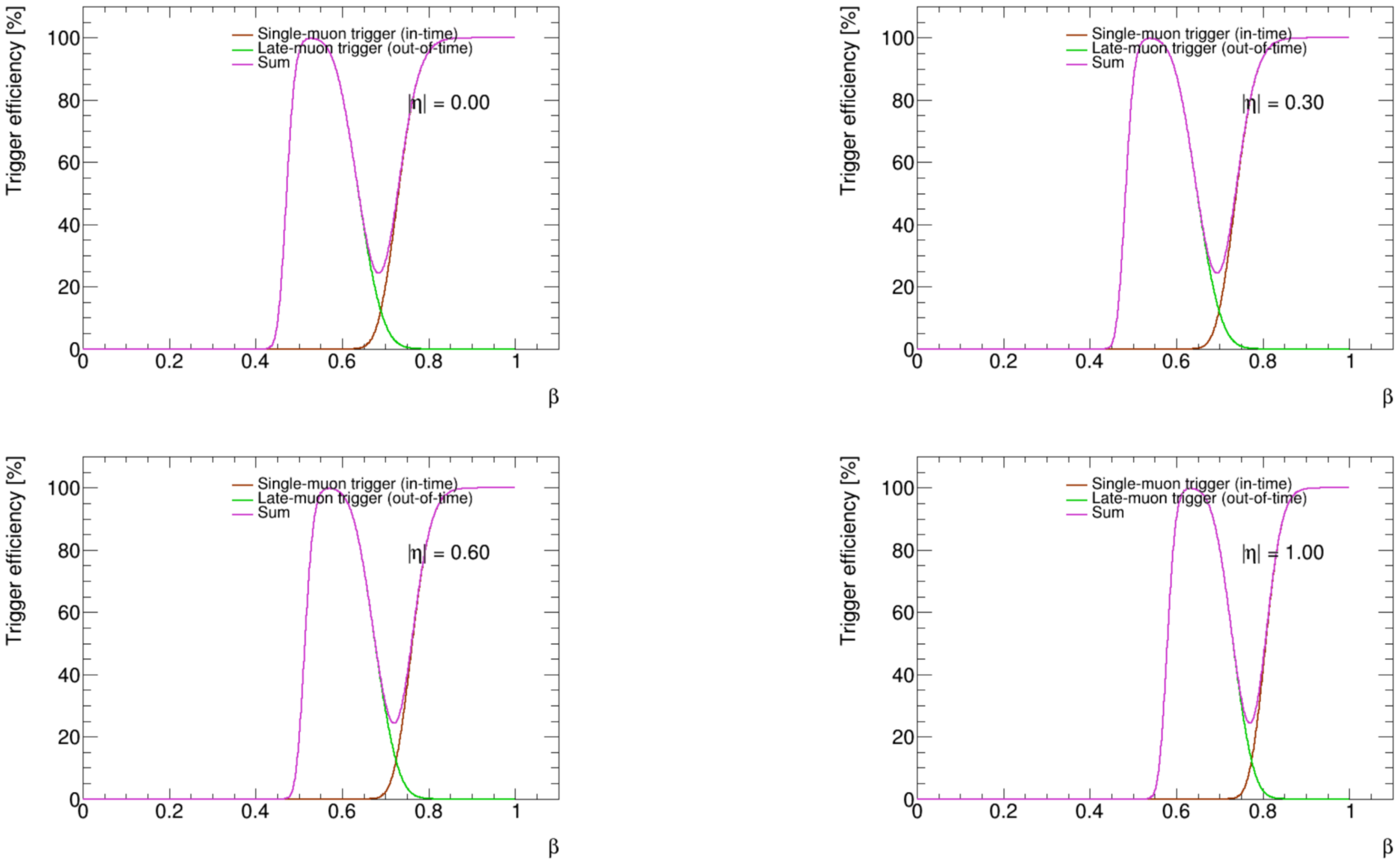




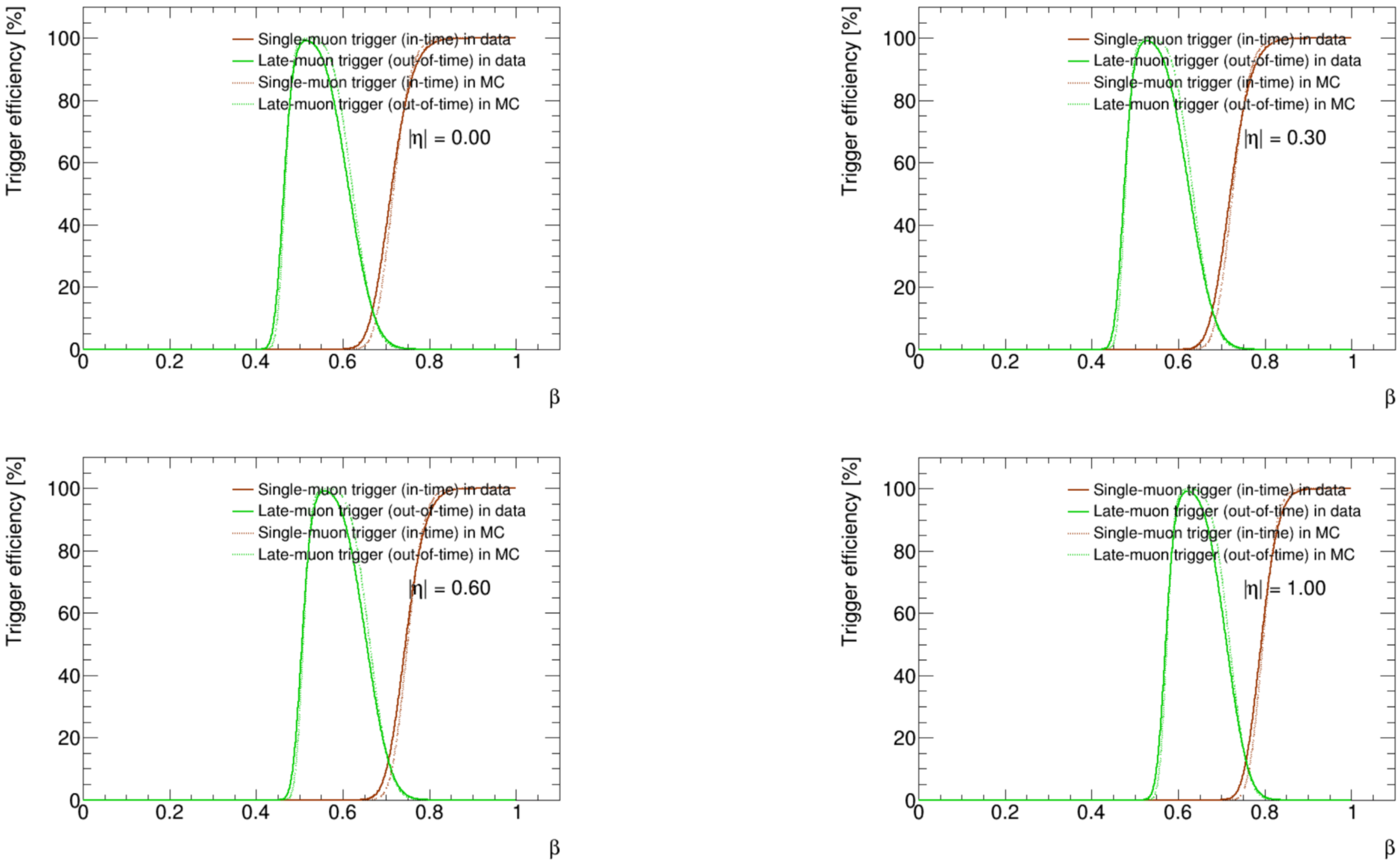




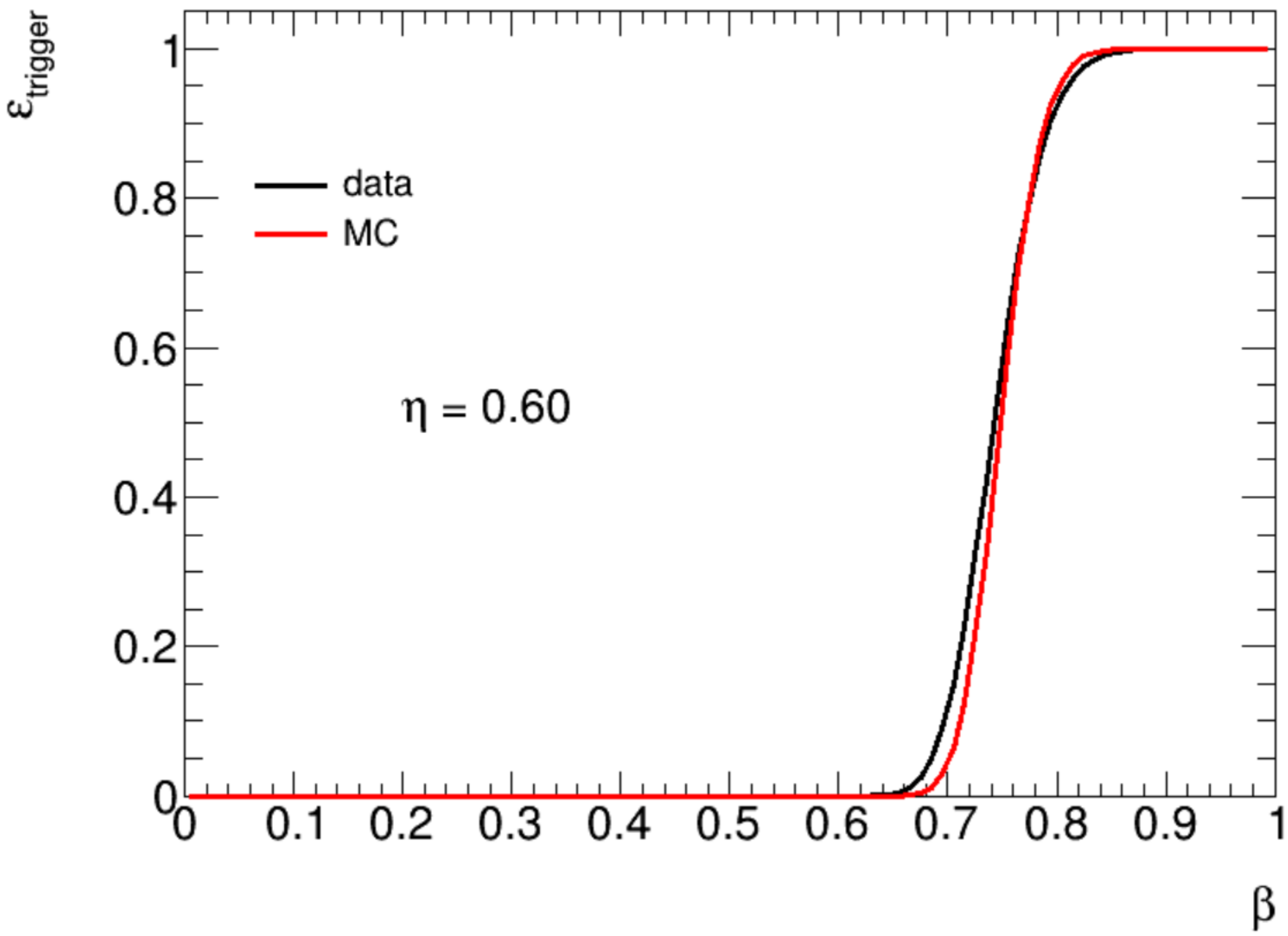
Single-muon and late-muon trigger efficiencies vs β



The same for data and MC separately

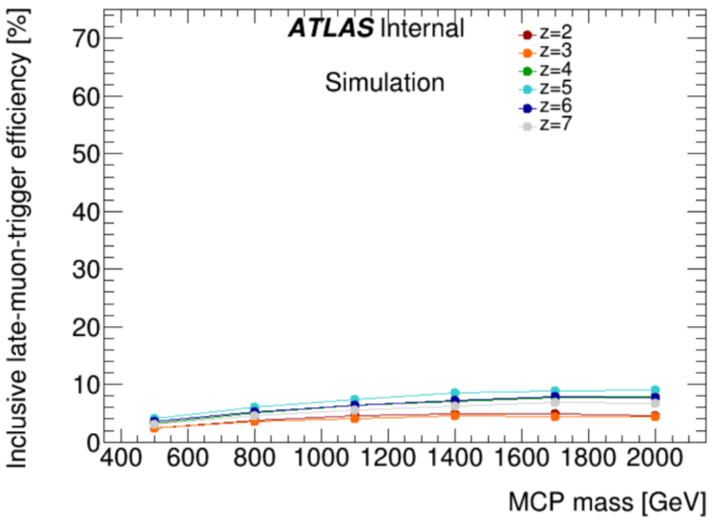


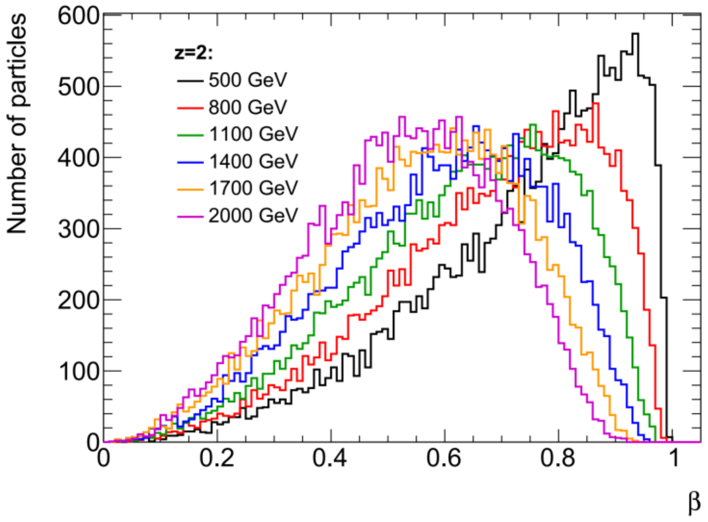
Previous plot we had for the single-muon trigger



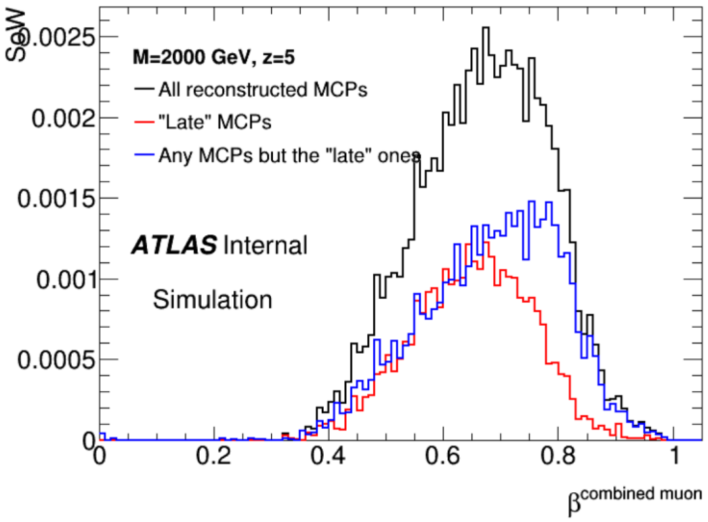
Open questions

Why is the late-muon-trigger efficiency so low even though there are lots of beta<1 MCPs?





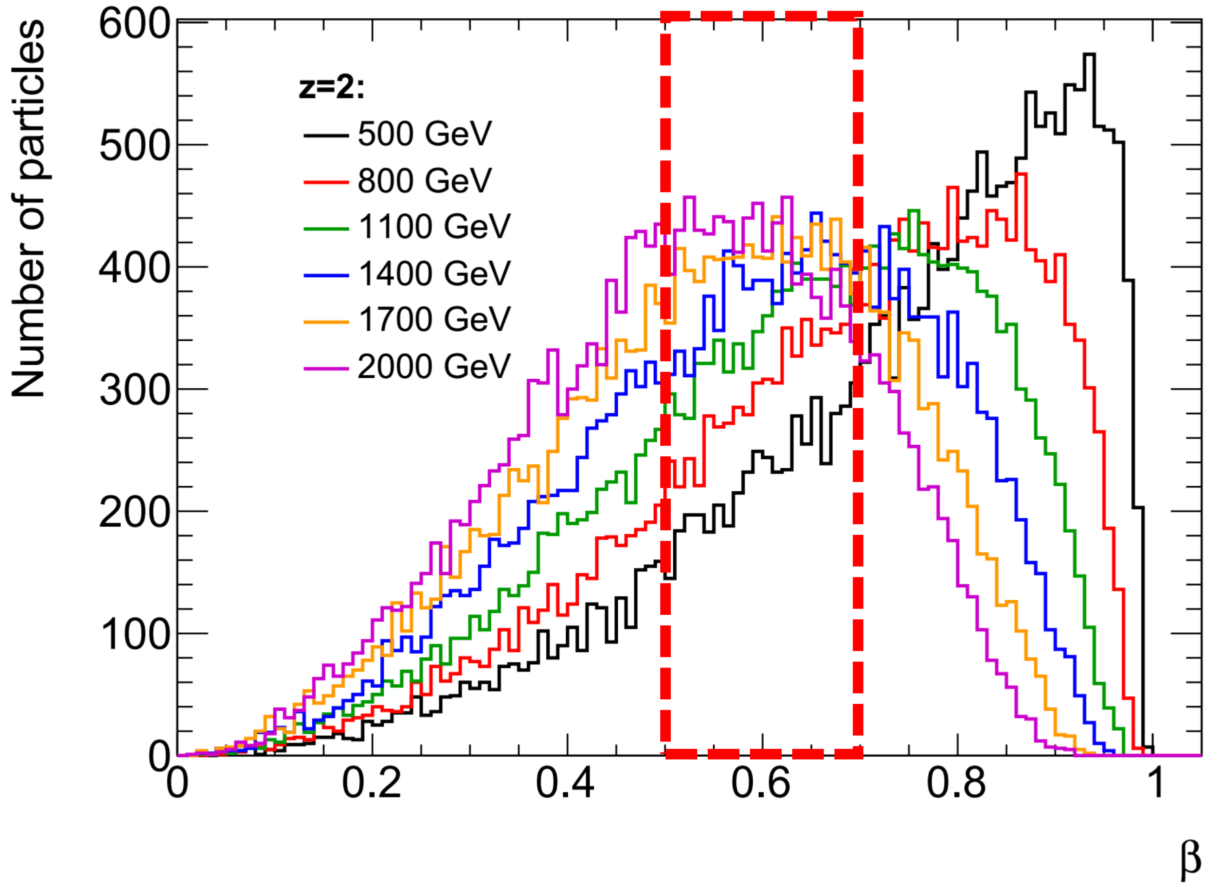
How come the late-muon trigger fires due to MCPs with beta > 0.8?



Fraction of signal-MC events (in %) in which L1_J50 fires

	2e	3e	4e	5e	6e	7e
500 GeV	25	27	36	56	76	85
800 GeV	27	28	39	61	77	83
1100 GeV	28	28	42	64	76	82
1400 GeV	29	28	43	65	77	80
1700 GeV	29	28	44	66	77	80
2000 GeV	28	27	45	65	75	79

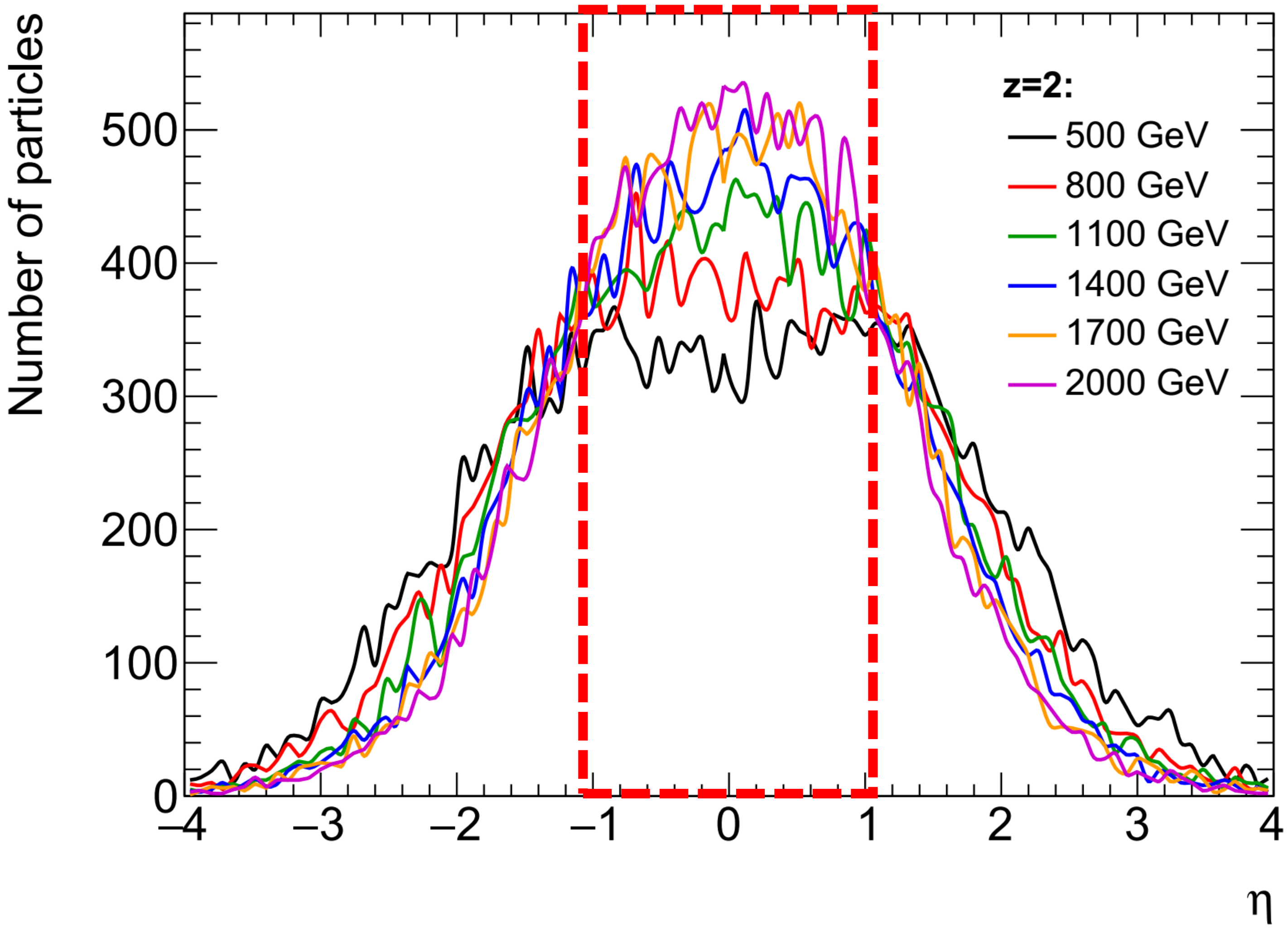
Fraction of truth-level MCPs (in %) with $0.5 < \beta < 0.7$



500 GeV	25%
800 GeV	32%
1100 GeV	37%
1400 GeV	40%
1700 GeV	43%
2000 GeV	43%

Most of these are expected to fire the late-muon trigger

Same but considering only the RPC pseudorapidity range



Same but considering only the RPC pseudorapidity range

Work is ongoing…