Study of $B^+ \to K^+ \tau^+ \tau^-$ using hadronic tagging
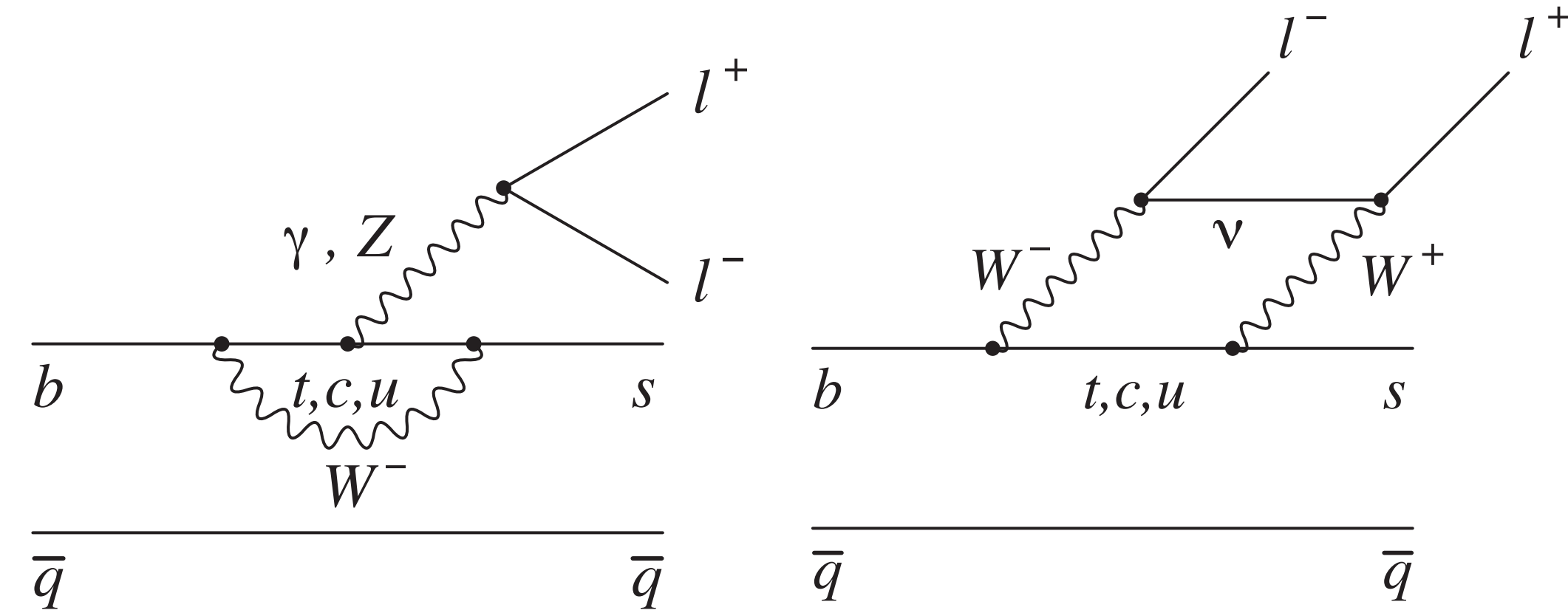
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August 12, 2022

Study of $B^+ \to K^+ \tau^+ \tau^-$

Motivation:

1. FCNC: highly suppressed in SM, $\mathcal{O}(10^{-7})$
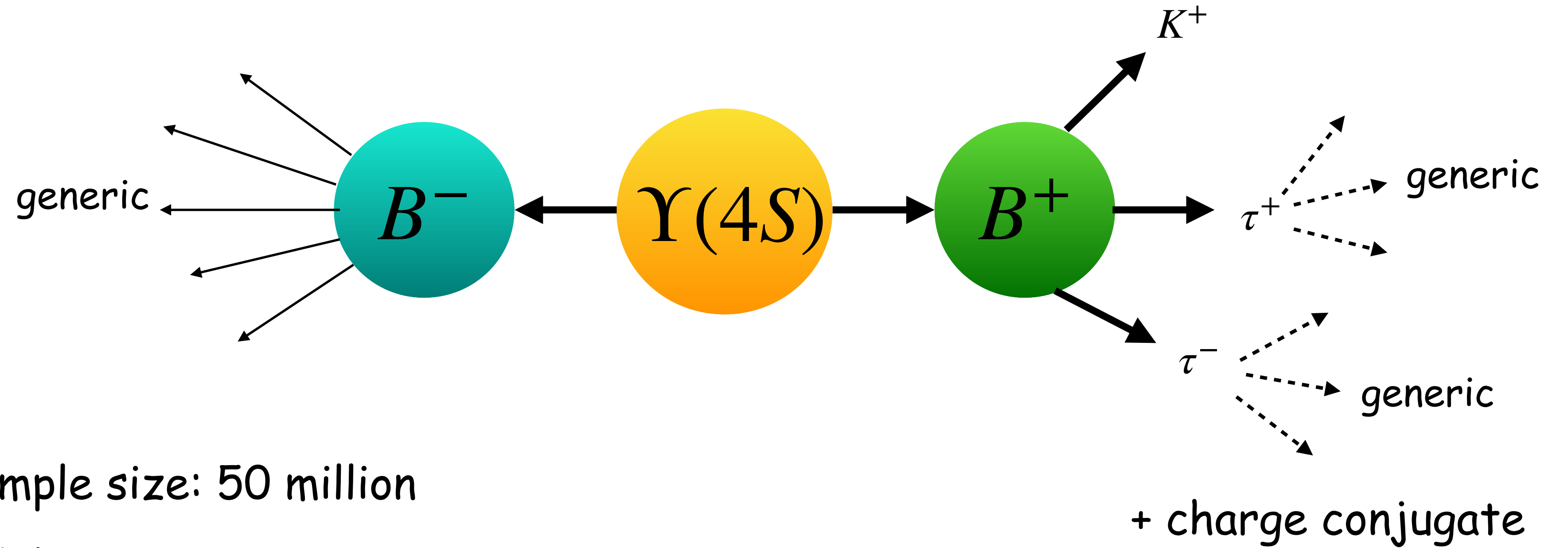2. 3rd generation strongly couples to NP

Earlier searches:

1. Attempt in Belle (by Simon Wehle, 2016): Belle Note- 1394
   upper limit at 90% confidence level, $\mathscr{B}(B^+ \to K^+ \tau^+ \tau^-) < 3.17 \times 10^{-4}$

2. BaBar (2017): arXiv:1605.09637
   upper limit at 90% confidence level, $\mathscr{B}(B^+ \to K^+ \tau^+ \tau^-) < 2.25 \times 10^{-3}$

Initial step: Perform similar to Simon's study in Belle II

modify Vidya's reconstruction script for Belle II

SignalMC generator

#simulated sample size: 50 million

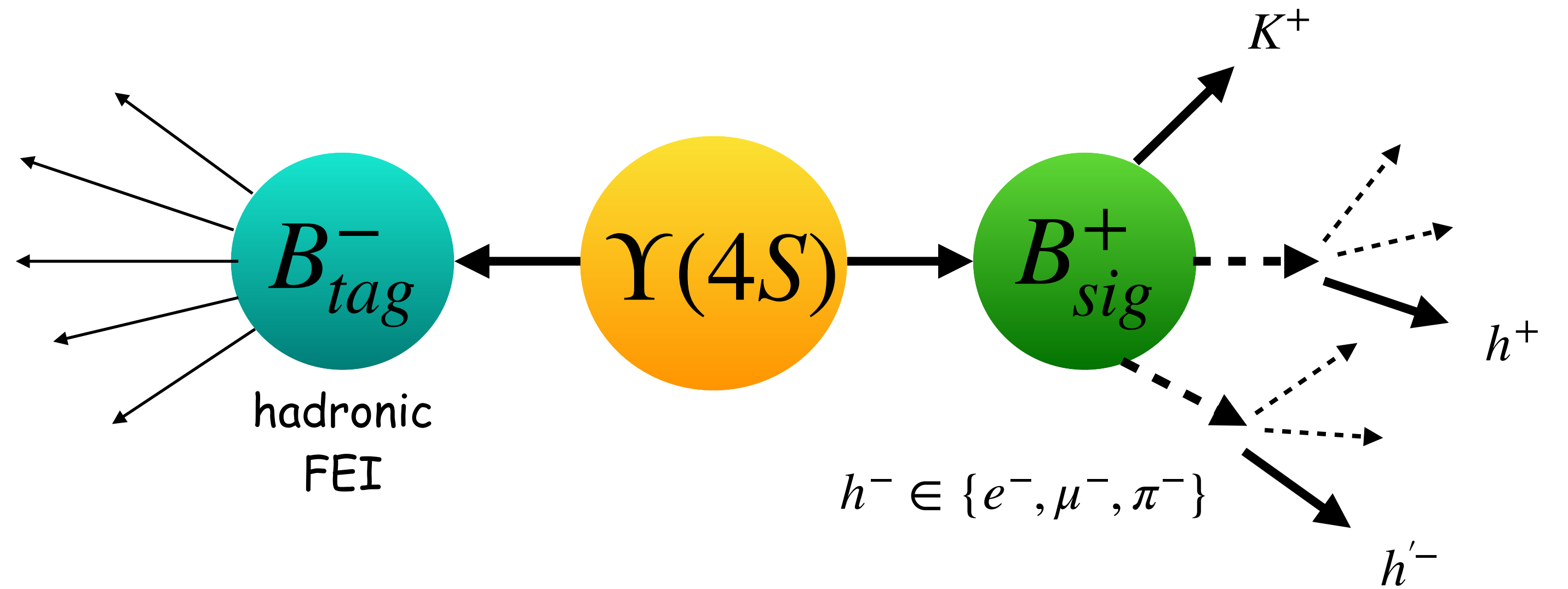generator model: BTOSLLBALL

release-06-00-10

globalTag: mc_production_MC15ri_a

bkg: early phase III (release-06-00-05), BGx1

Reconstruction

B_{sig}^+ is composed of $K^+, h^+,$ and h'^-:

1. $K^+ e^+ e^-$
2. $K^+ e^+ \mu^-$
3. $K^+ e^- \mu^+$
4. $K^+ e^+ \pi^-$
5. $K^+ e^- \pi^+$
6. $K^+ \mu^+ \mu^-$
7. $K^+ \mu^+ \pi^-$
8. $K^+ \mu^- \pi^+$
9. $K^+ \pi^+ \pi^-$

B_{tag}^-

hadronic
FEI

$\Upsilon(4S)$

B_{sig}^+

K^+

h^+

h'^-

$h^- \in \{e^-, \mu^-, \pi^-\}$

Selection

Charged tracks (e, μ, K, π) cuts:

- transverse distance from IP, $dr < 0.5$
- distance in beam direction from IP, $|dz| < 2$
- polar angle is with in CDC acceptance (thetaInCDCAcceptance)

PID cuts:
- e: $\mathscr{L}(\text{electronID}) > 0.9$
- μ: $\mathscr{L}(\text{muonID}) > 0.9$
- K: $\mathscr{L}(\text{kaonID}) > 0.6$
- π: $\mathscr{L}(\text{pionID}) > 0.6$

photon: use all photons (gamma:all)

Selection

Reconstruct FEI hadronic B_{tag}:

- weight file prefix - 'FEIv4_2021_MC14_release_05_01_12'
- two most probable B_{tag} candidates are accepted
- $M_{bc} > 5.27$
- $|\Delta E| < 0.1$
- FEI signal probability > 0.001
- ROE of B_{tag} has 3 charged tracks

Continuum suppression:

- event sphericity > 0.2
- cosTBTO < 0.9

ROE mask:

- $dr < 0.5, |dz| < 2$, thetaInCDCAcceptance
- $E > 0.06$ and $|$cluster time$| < 20$

Analysis globalTag: 'analysis_tools_light-2203-zeus'

Reconstruction

- Reconstruct B_{sig}^+ with $K^+ h^+ h^{'-}$ combinations

- Reconstruct $\Upsilon(4S) \to B_{sig}^+ B_{tag}^-$

- Build ROE with mask and reconstruct ROE π^0

ROE mask:

- $dr < 0.5, |dz| < 2,$ thetaInCDCAcceptance

- $E > 0.06$ and $|$cluster time$| < 20$

ROE π^0:

- daughter photons are in ROE and passes ROE mask
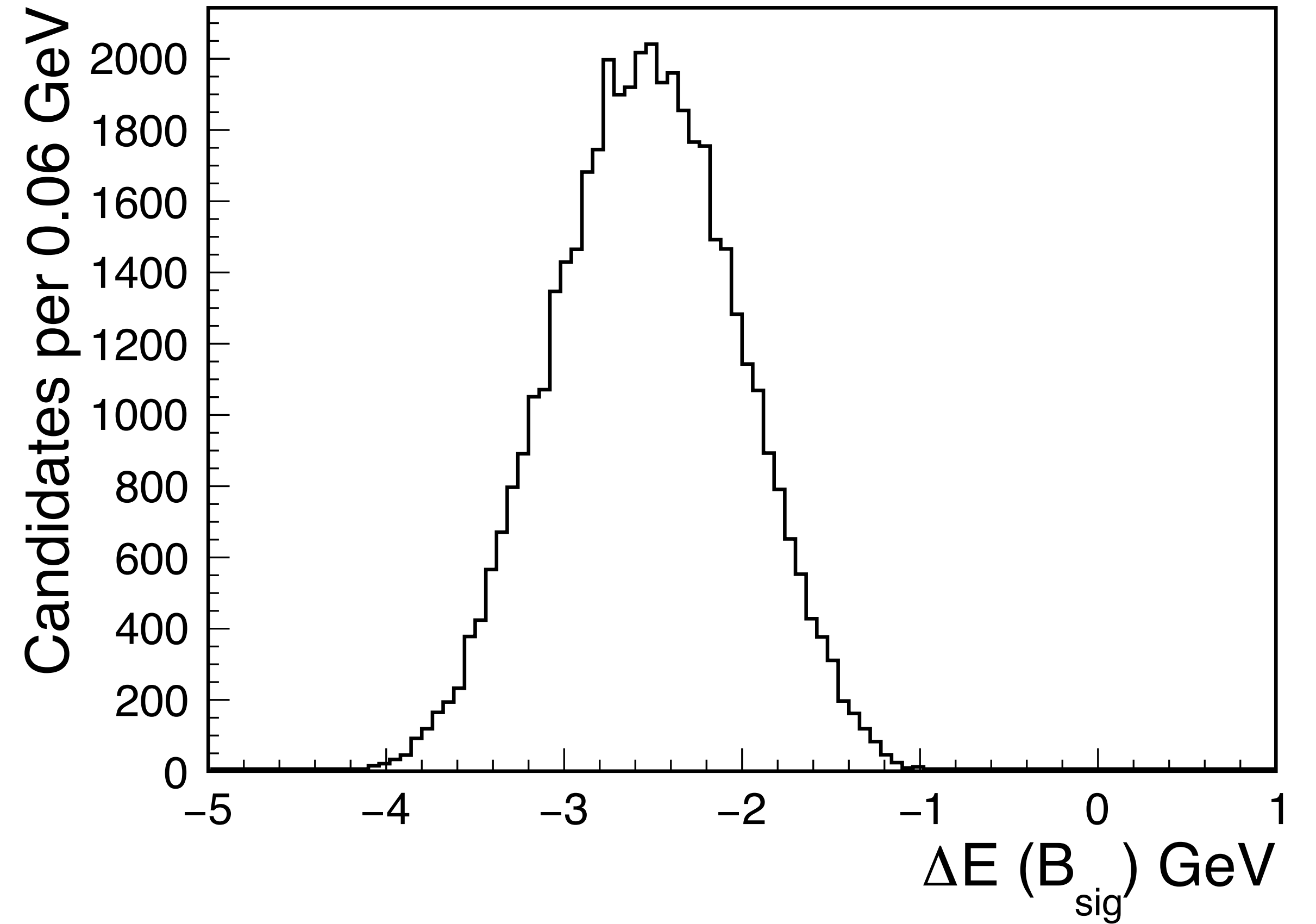- select π^0 with least difference between M and InvM
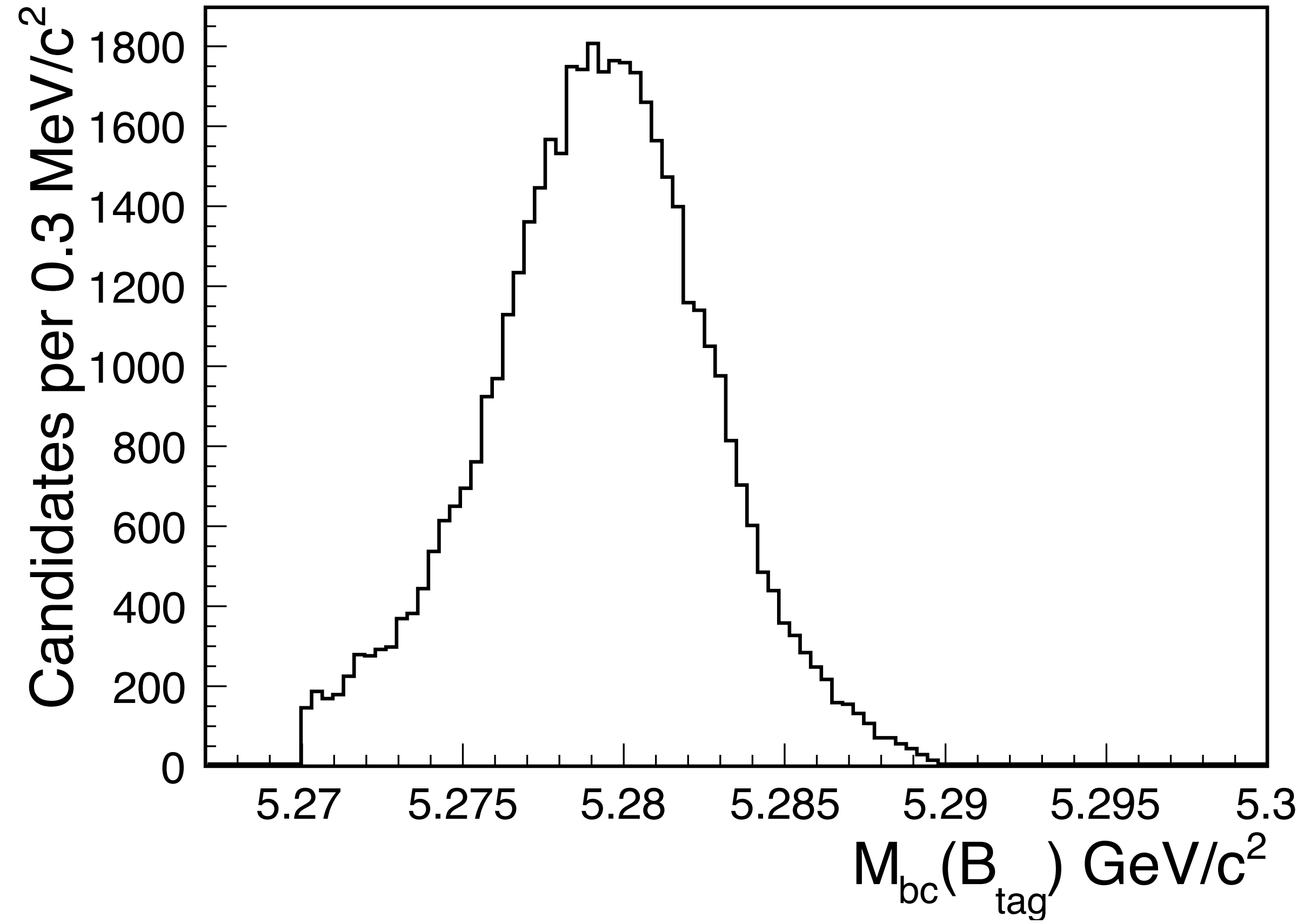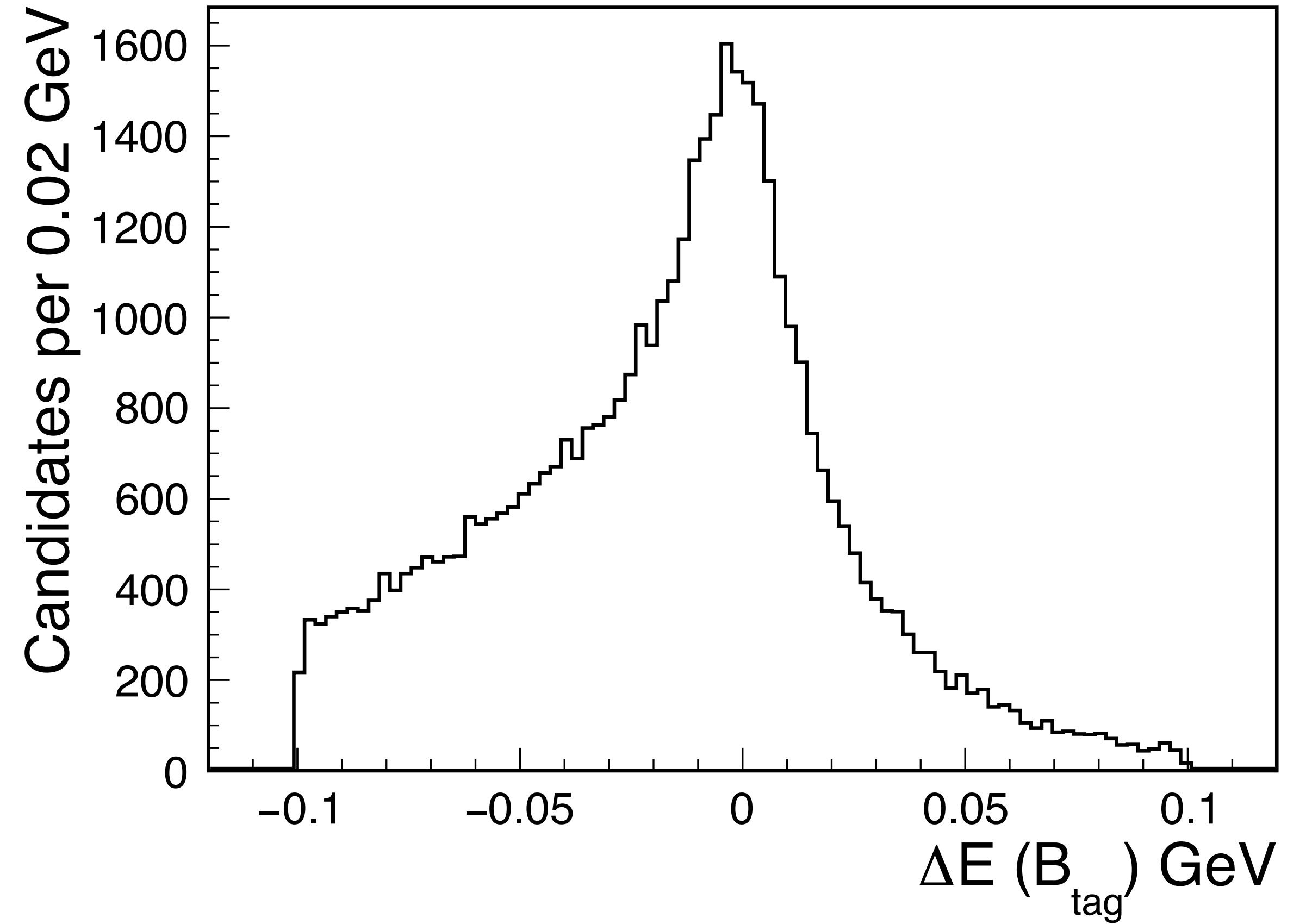
..let's look at few distributions

Signal side

M_{bc}

ΔE

"signal" is selected by "isSignalAcceptMissingNeutrino"
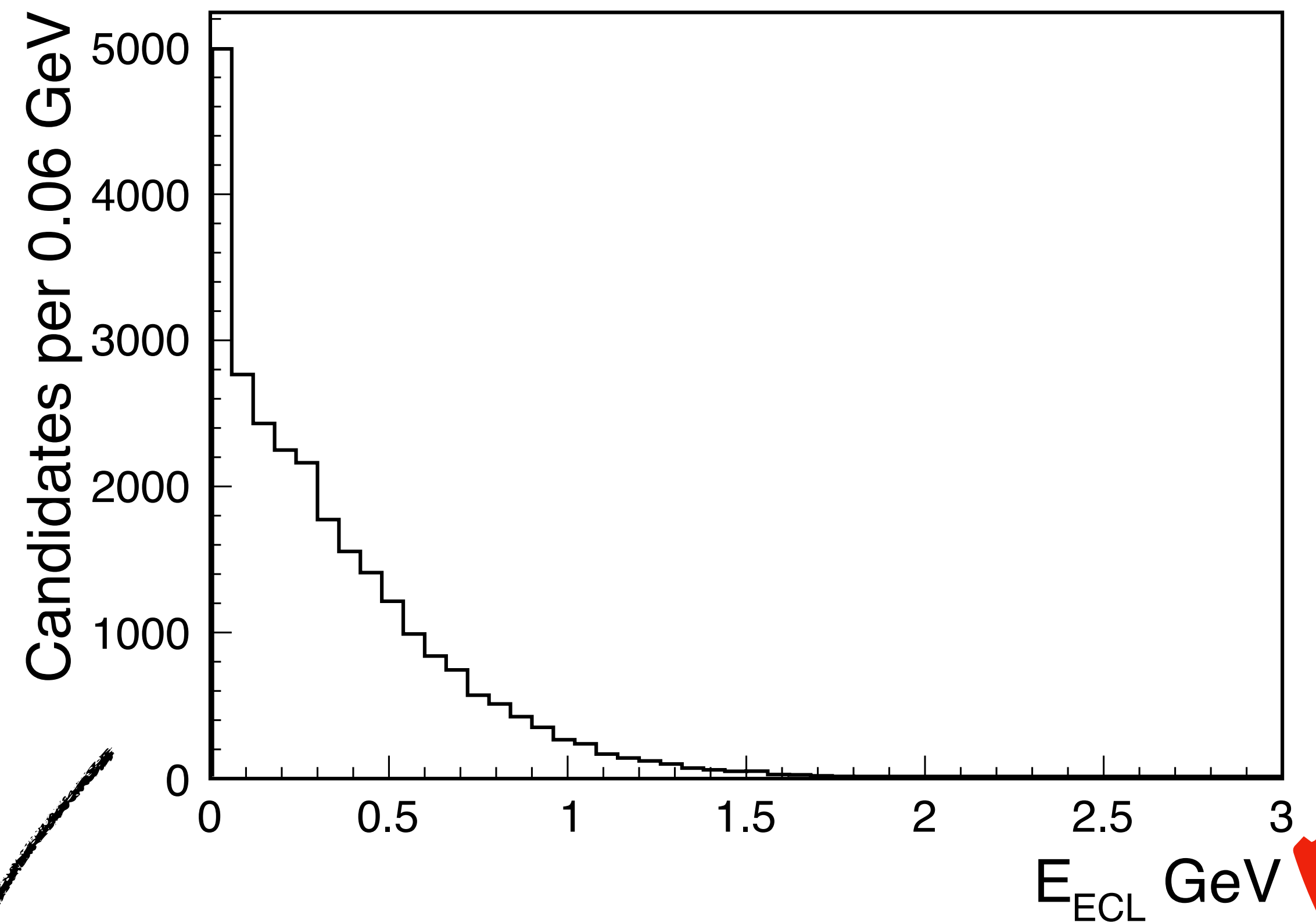
Tag side

M_{bc}

ΔE

Extra ECL energy (E_{ECL})

Energy left in ECL cluster after removing B_{tag} and B_{sig} related deposition
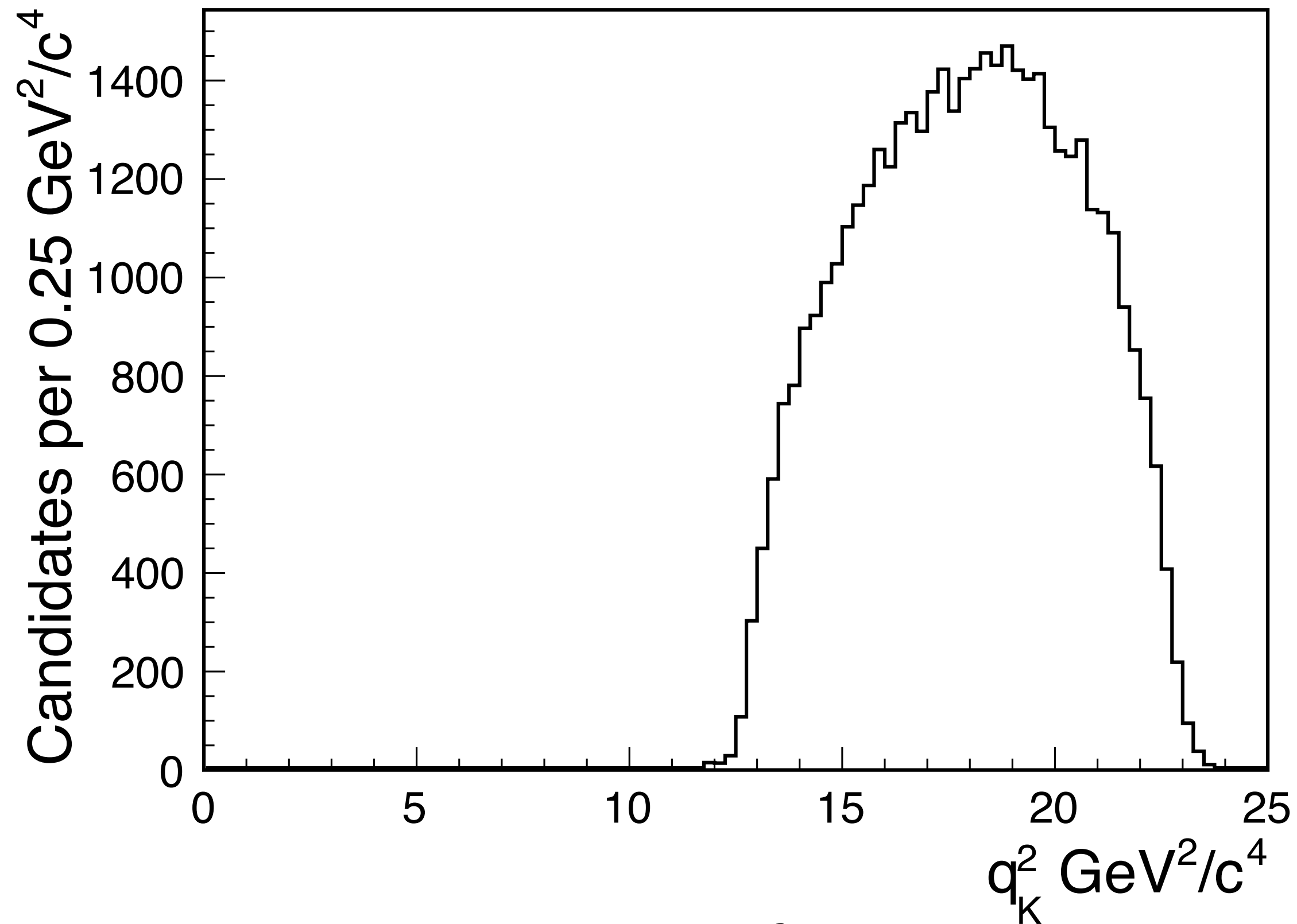

Ideally it should peak at zero

subtract energy of ROE π^0 from E_{ECL}

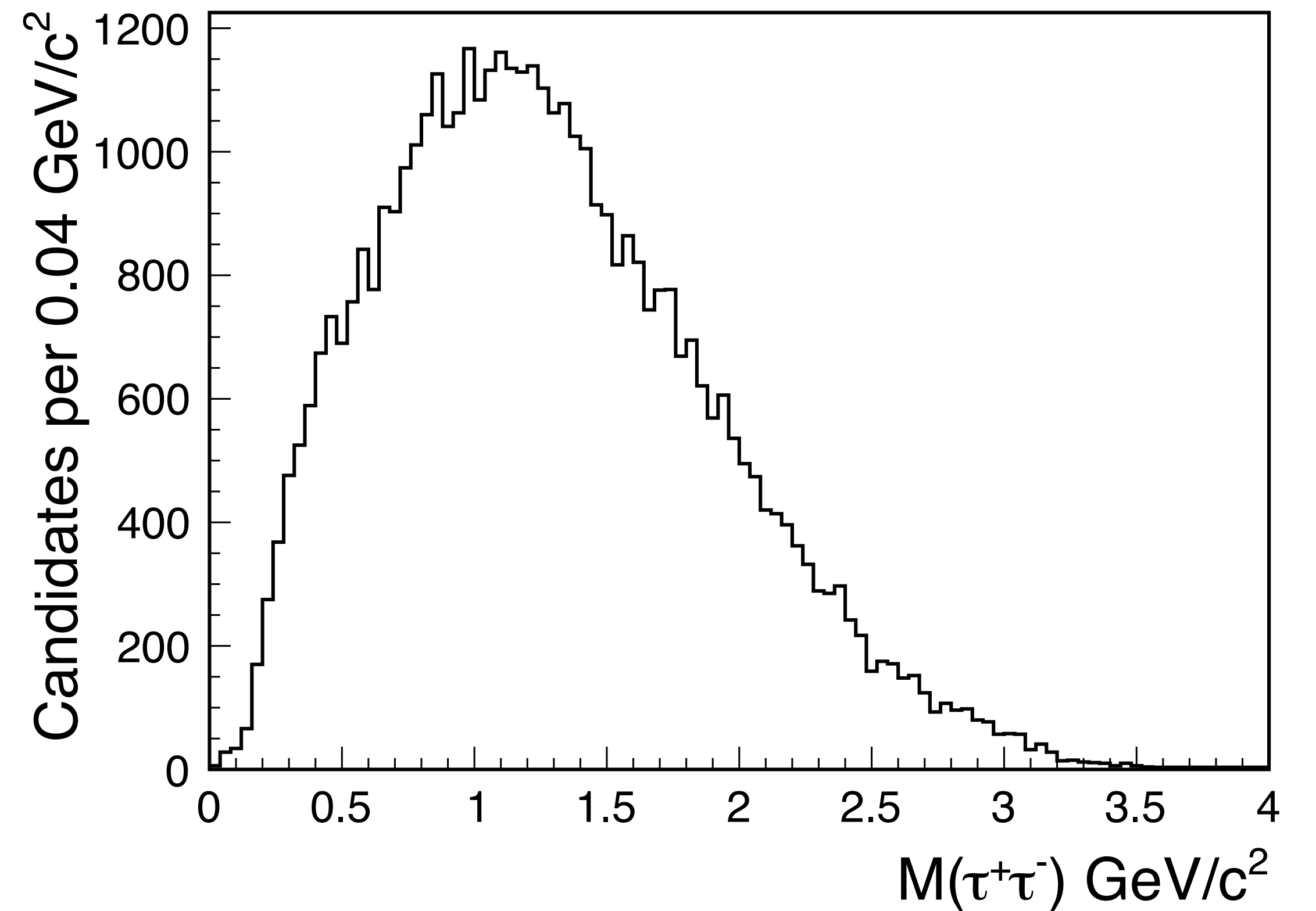bug in ROE π^0 reconstruction: multiple π^0 got selected instead of one

q_K^2 and $M(\tau^+\tau^-)$

Constraint invariant mass of τ pair:

$$q_K^2 \equiv (p_{\Upsilon(4S)} - p_{B_{tag}} - p_K)^2$$

where $p_{\Upsilon(4S)}$ is the four momentum of beam

reconstructed invariant mass of τ pair

$$M(\tau\tau) \equiv \sqrt{(p_h + p_{h'})^2}$$
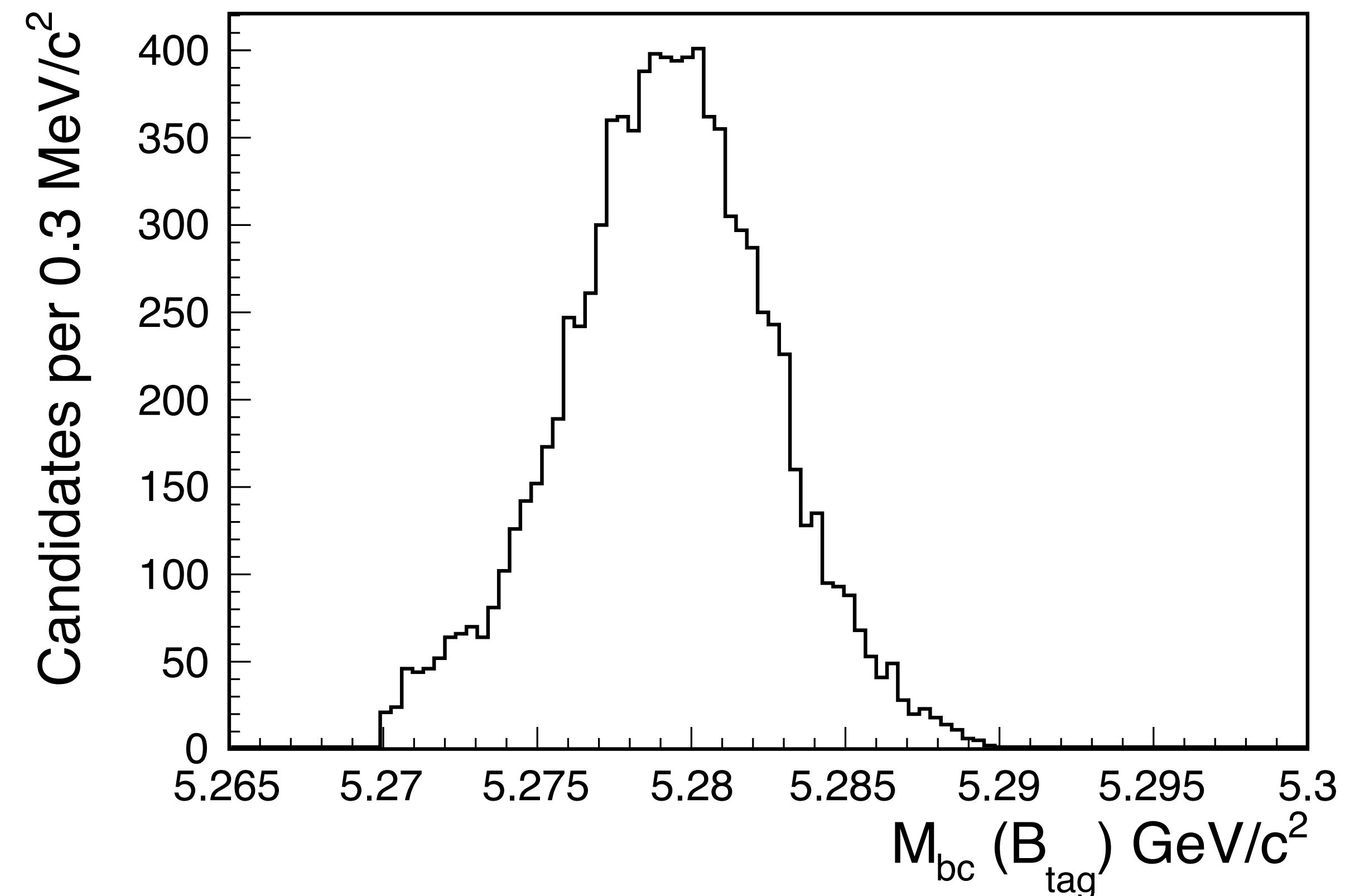
Generic MC   MC14ri_a ($\sim 300\,fb^{-1}$)   [12 files failed to run before shutdown]
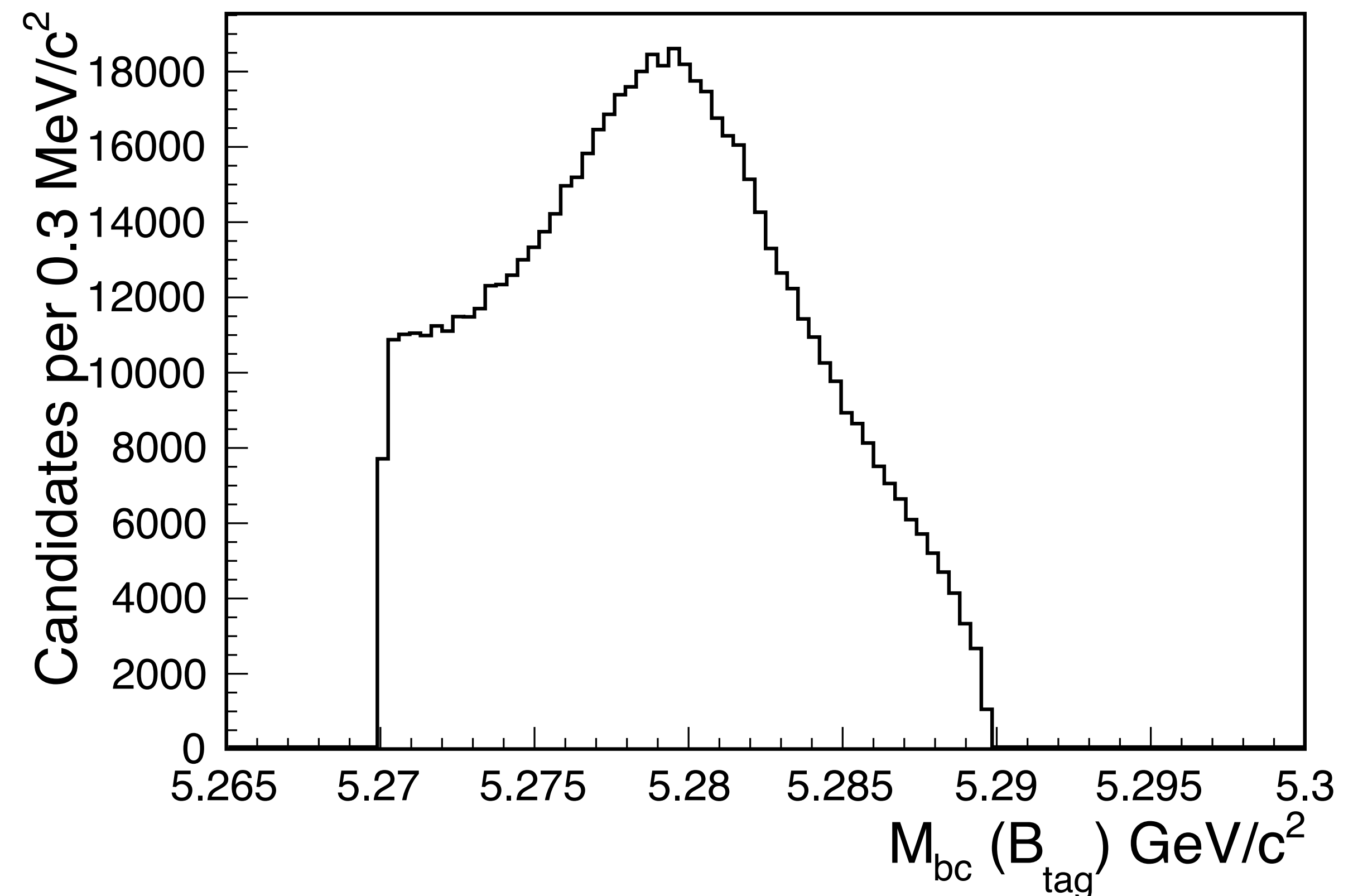
#signal= 9323; #background= 680116
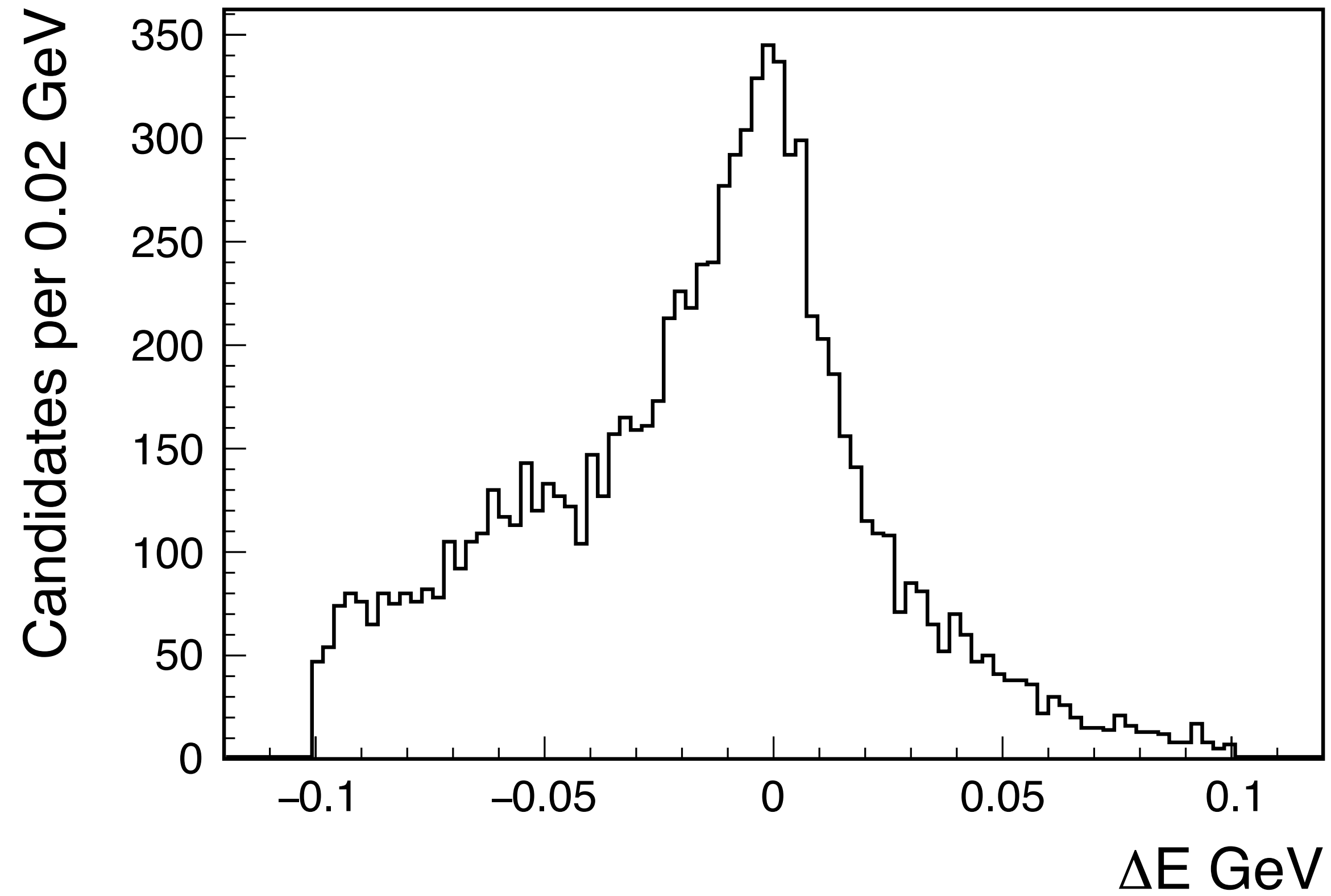
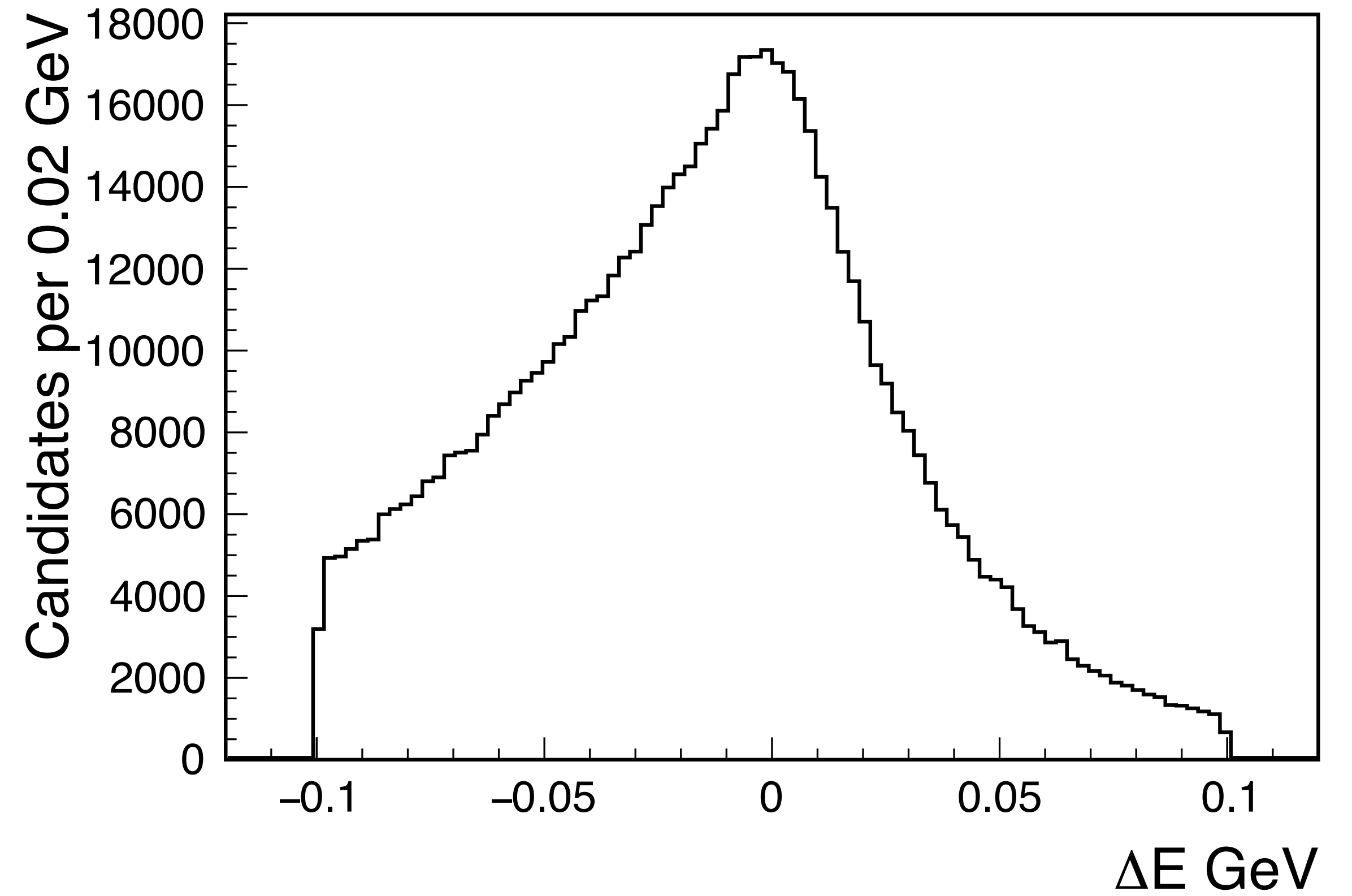## Tag side M_{bc} cut: $(M_{bc})_{tag} > 5.27$

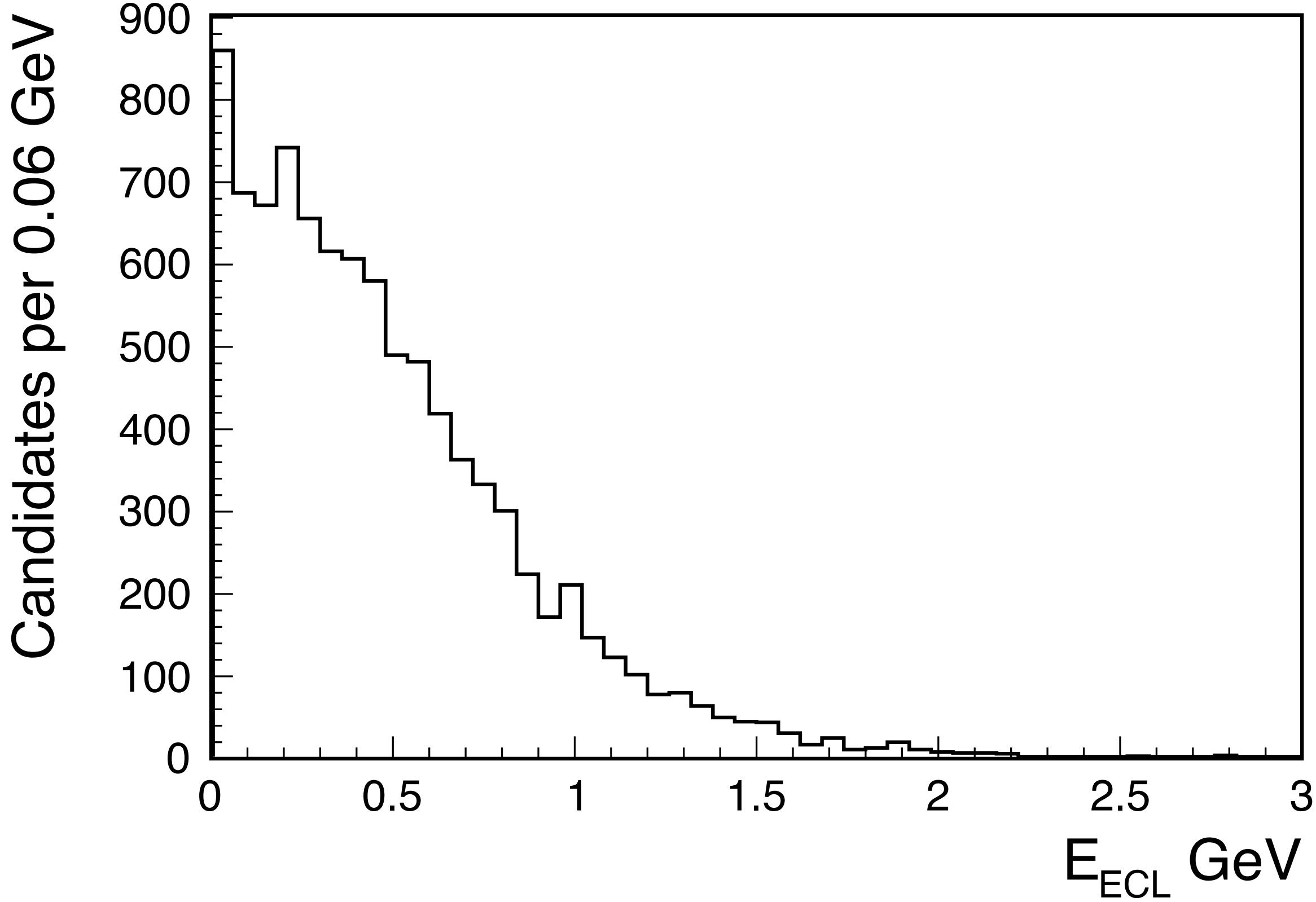signal

background
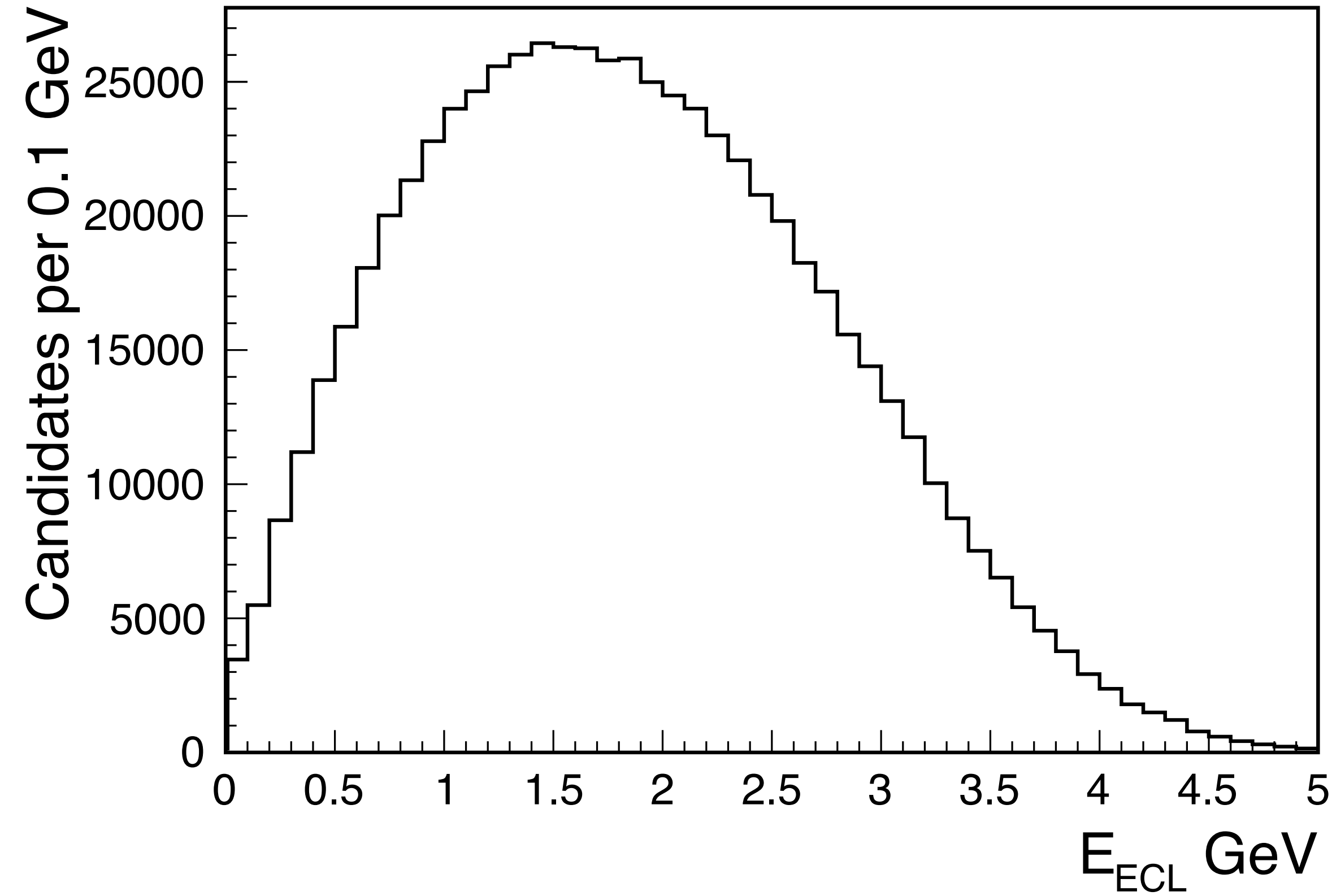
Tag side ΔE

signal

background

Extra ECL energy (E_{ECL})

Must apply π^0 veto. Due to the bug it is not applied.
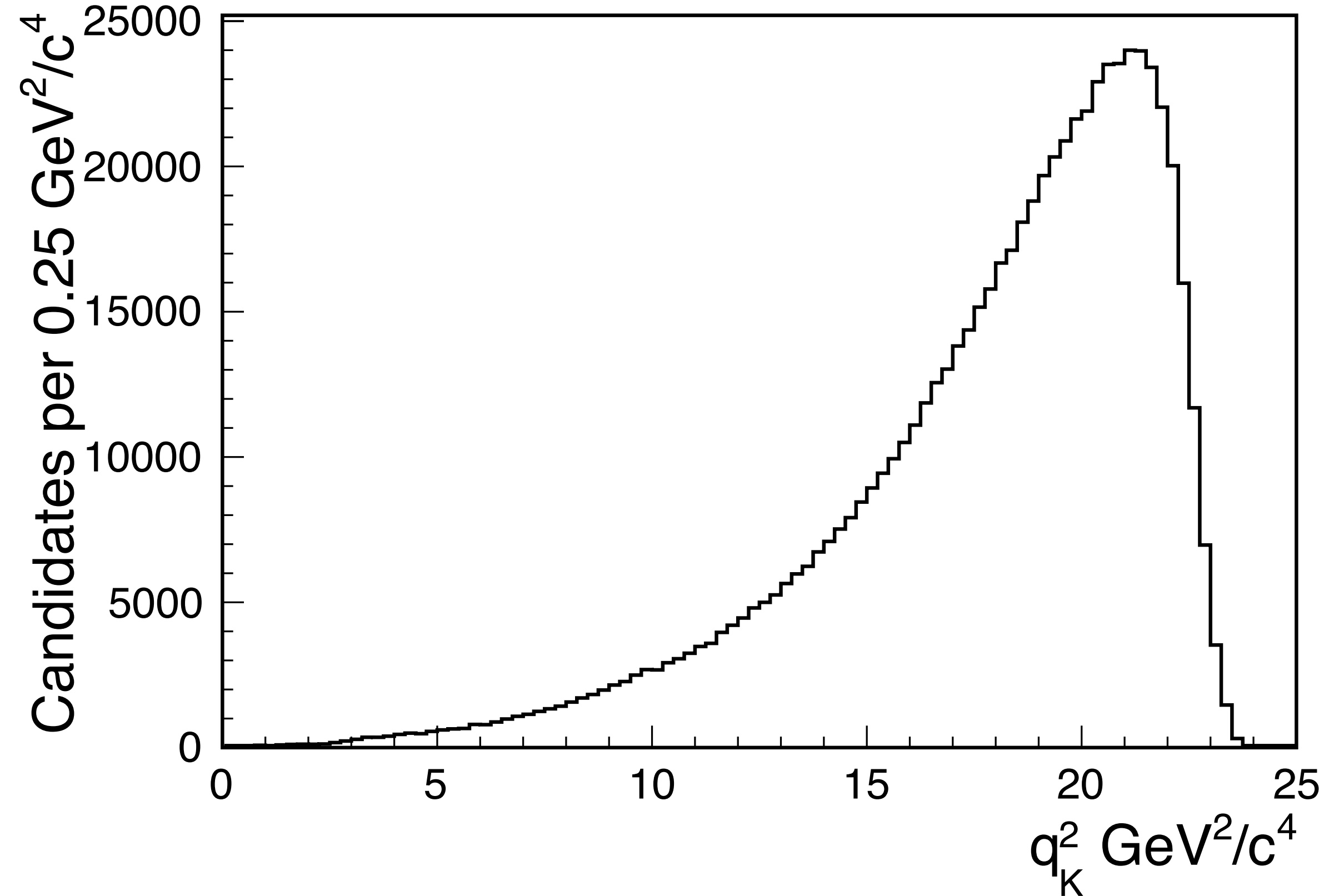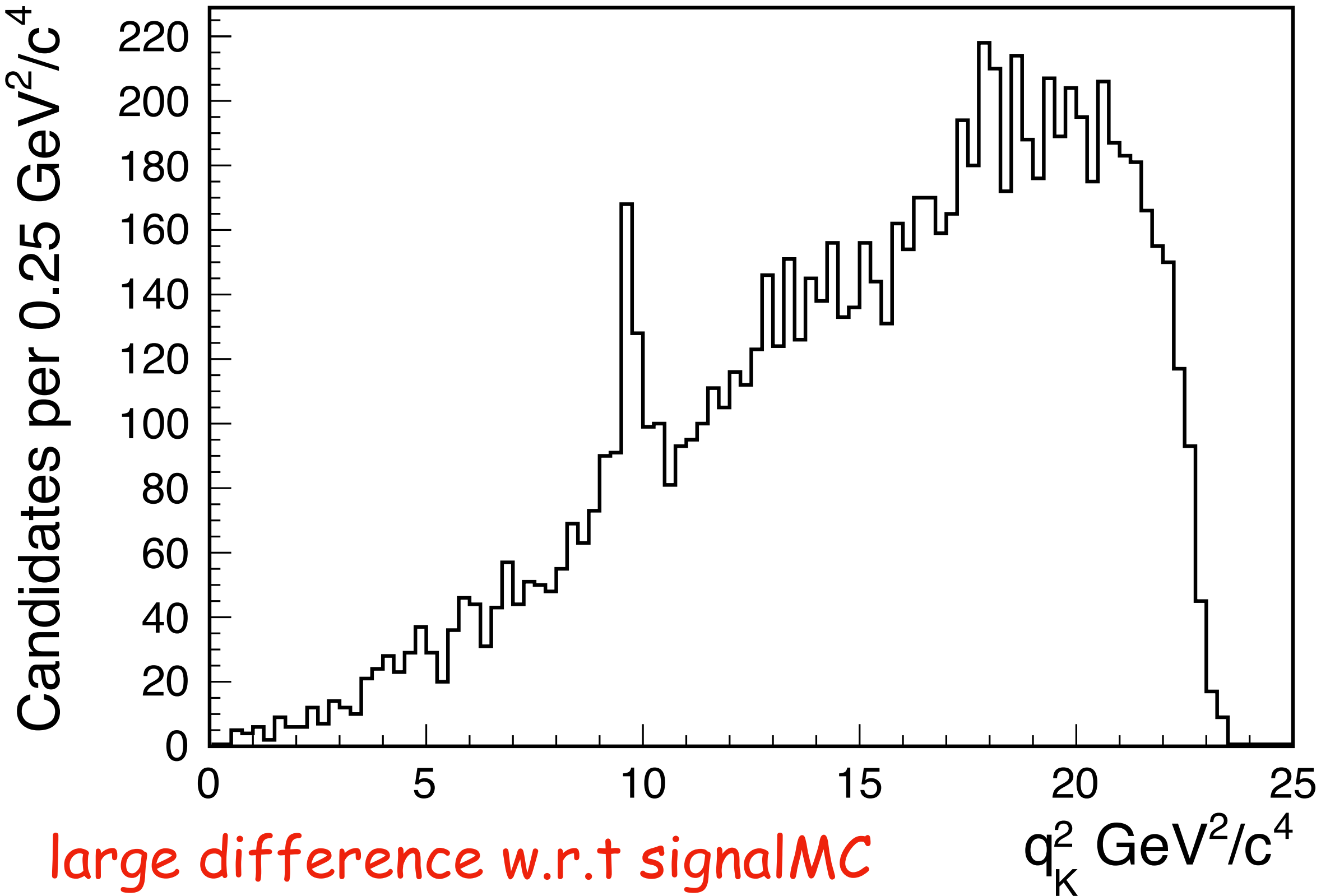
signal

background

Simon put a cut $E_{ECL} < 1.5$ to separate signal from background

q_K^2

beam constraint invariant mass of τ pair, $q_K^2 \equiv (p_{\Upsilon(4S)} - p_{B_{tag}} - p_K)^2$
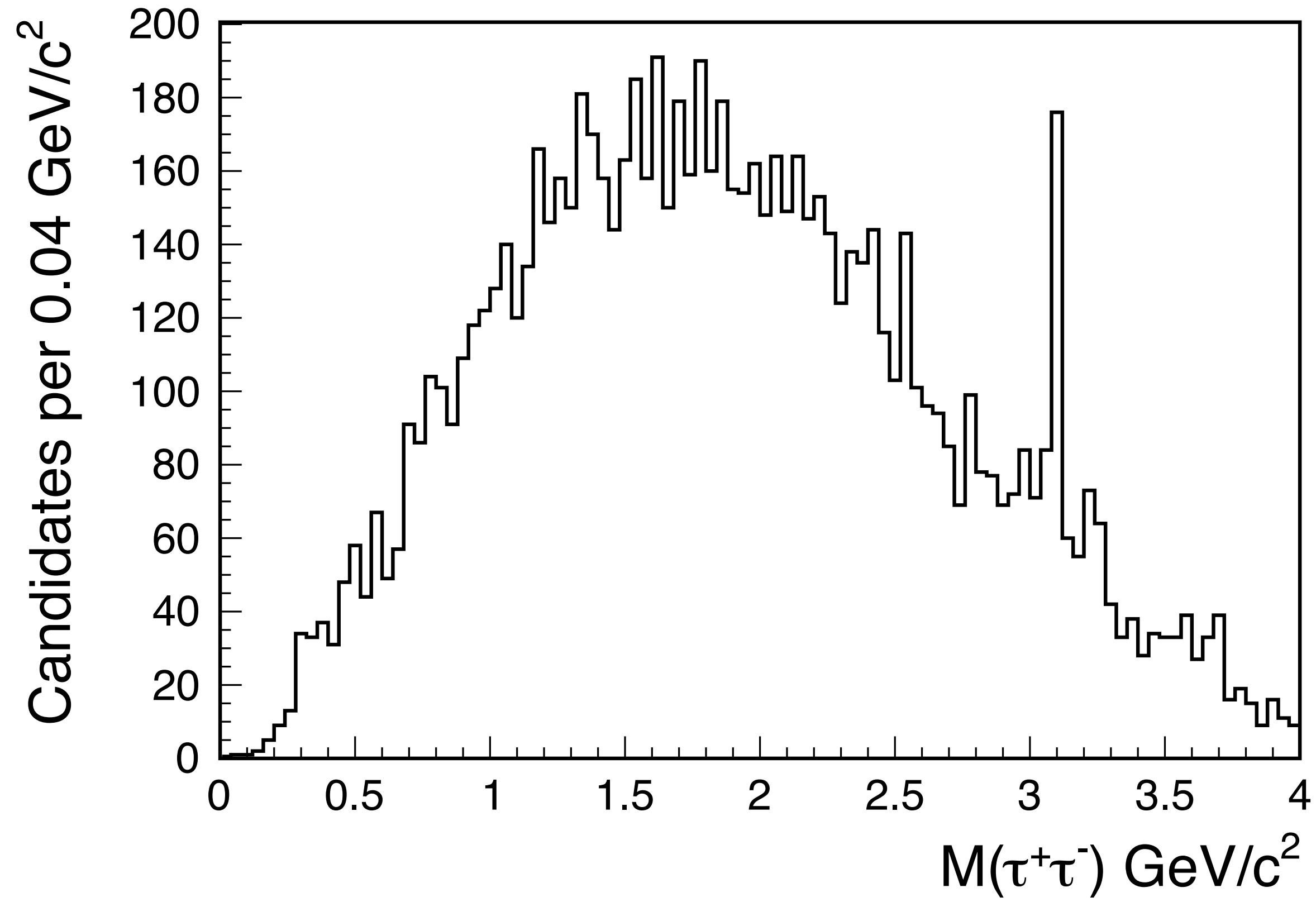
signal

background

large difference w.r.t signalMC

Simon put a cut $q_K^2 > 12$ to separate signal from background

$M(\tau^+\tau^-)$

signal

background