Updates on
Search for the $Z_c(4430)$

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Preamble

What and Why

Study of two exotic states through the chain

$e^+e^- \rightarrow (Y(4660) \rightarrow) Z_c(4430)\,\pi \rightarrow \psi(2S)\,\pi\,\pi \rightarrow J/\psi\,\pi\,\pi\,\pi\,\pi \rightarrow 2\ell\,4\pi$

Z^+_c(4430) was **observed** and studied in the B meson decays in the $\pi\psi(2S)$ invariant mass **by BELLE** [PRD **88**, 074026] (and by LHCb [PRL **112**, 222002])

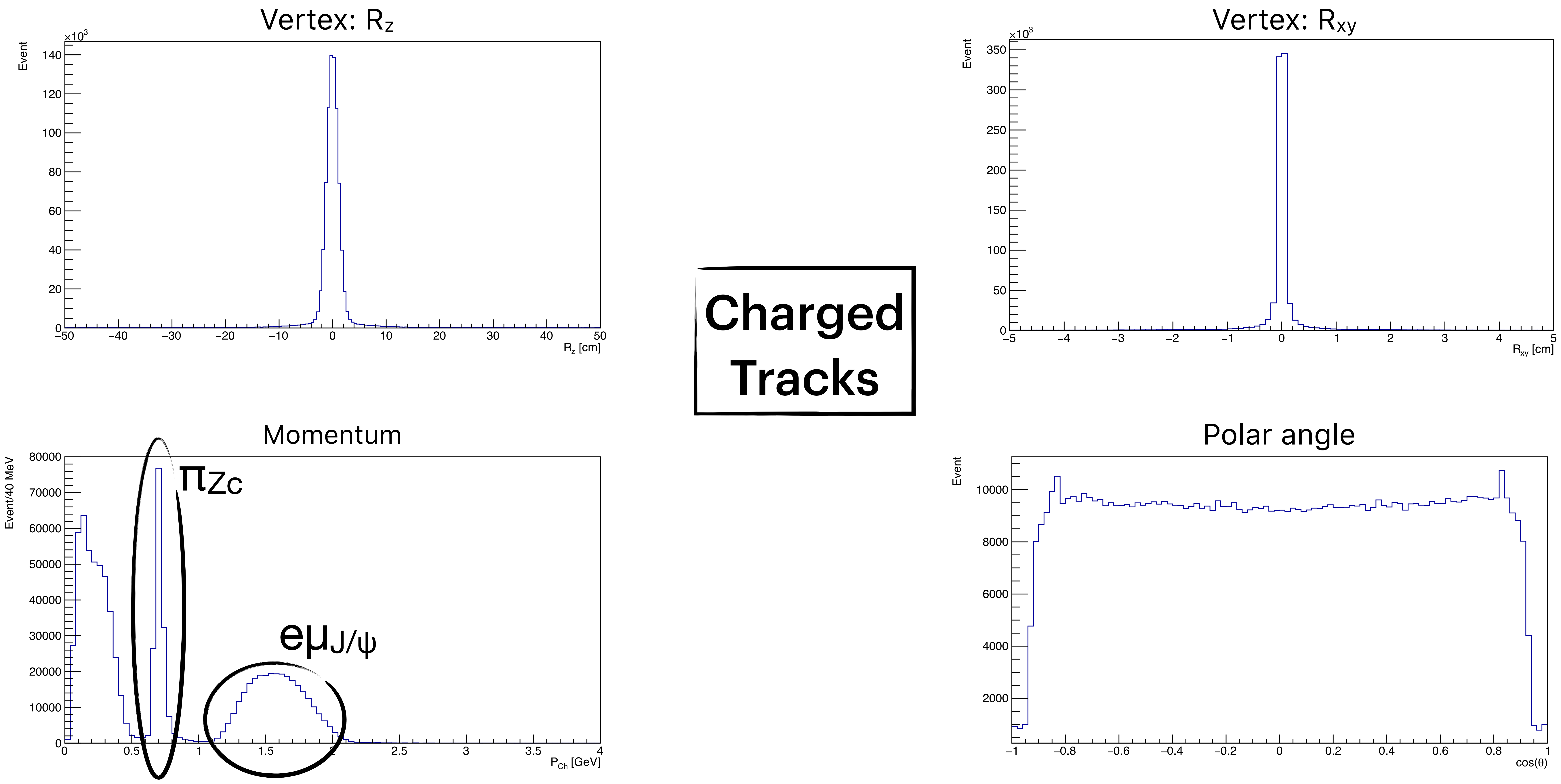
Y(4660), already **observed by BaBar** [PRD **89**, 111103(R)] and **BELLE** [PRD **91**, 112007], was **hypothesised** to be a **baryonium**

How

The study will make use of the **~5 fb^{-1}** data @$\sqrt{s}$ > 4.6 GeV

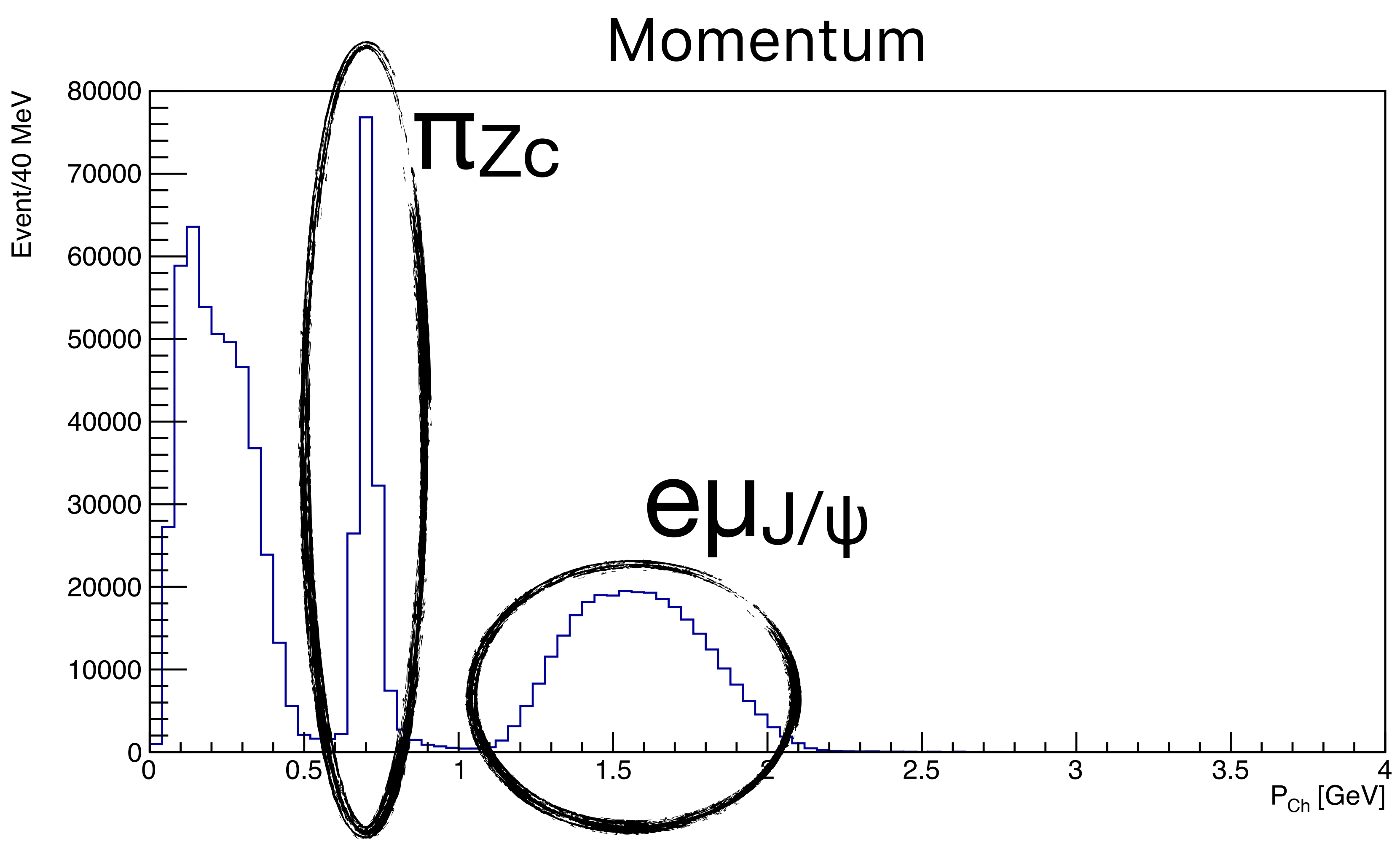
No Z^+_c(4430) signal was observed in the mono-energetic datasets, so the main idea is to merge all the data @$\sqrt{s}$ > 4.6 GeV to use the whole statistics

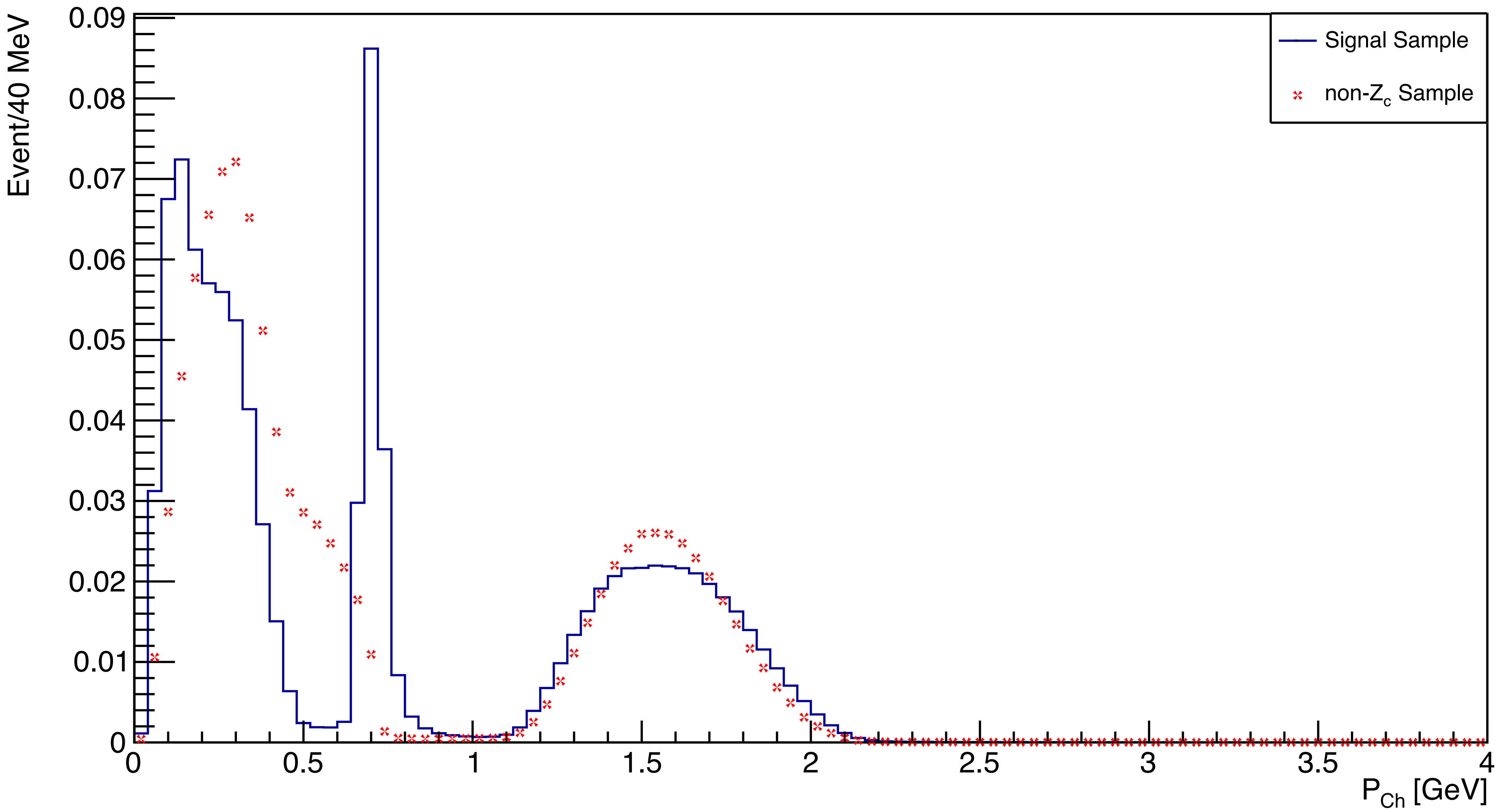
Signal MC Studies



Signal MC Studies

Charged Tracks

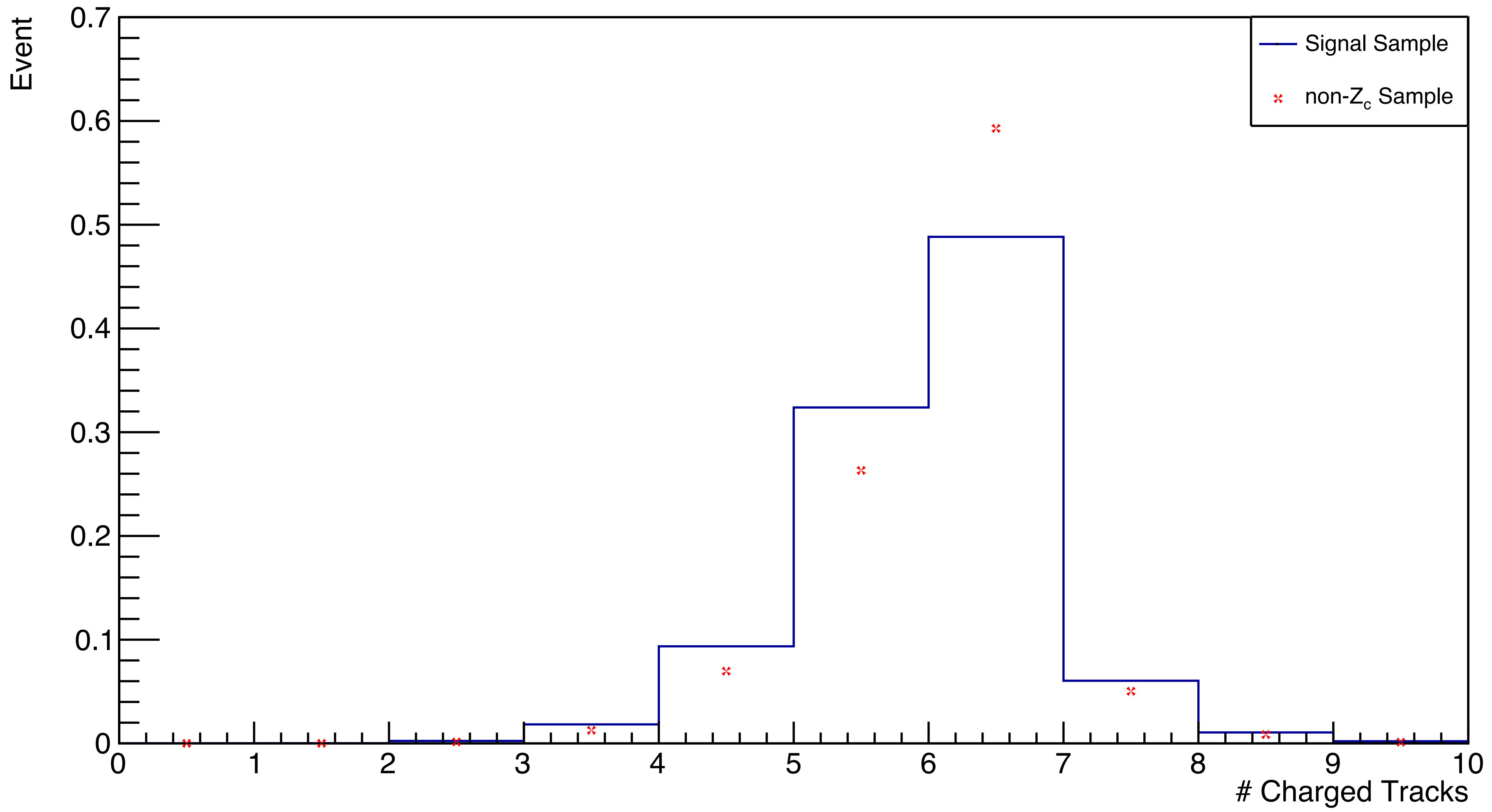


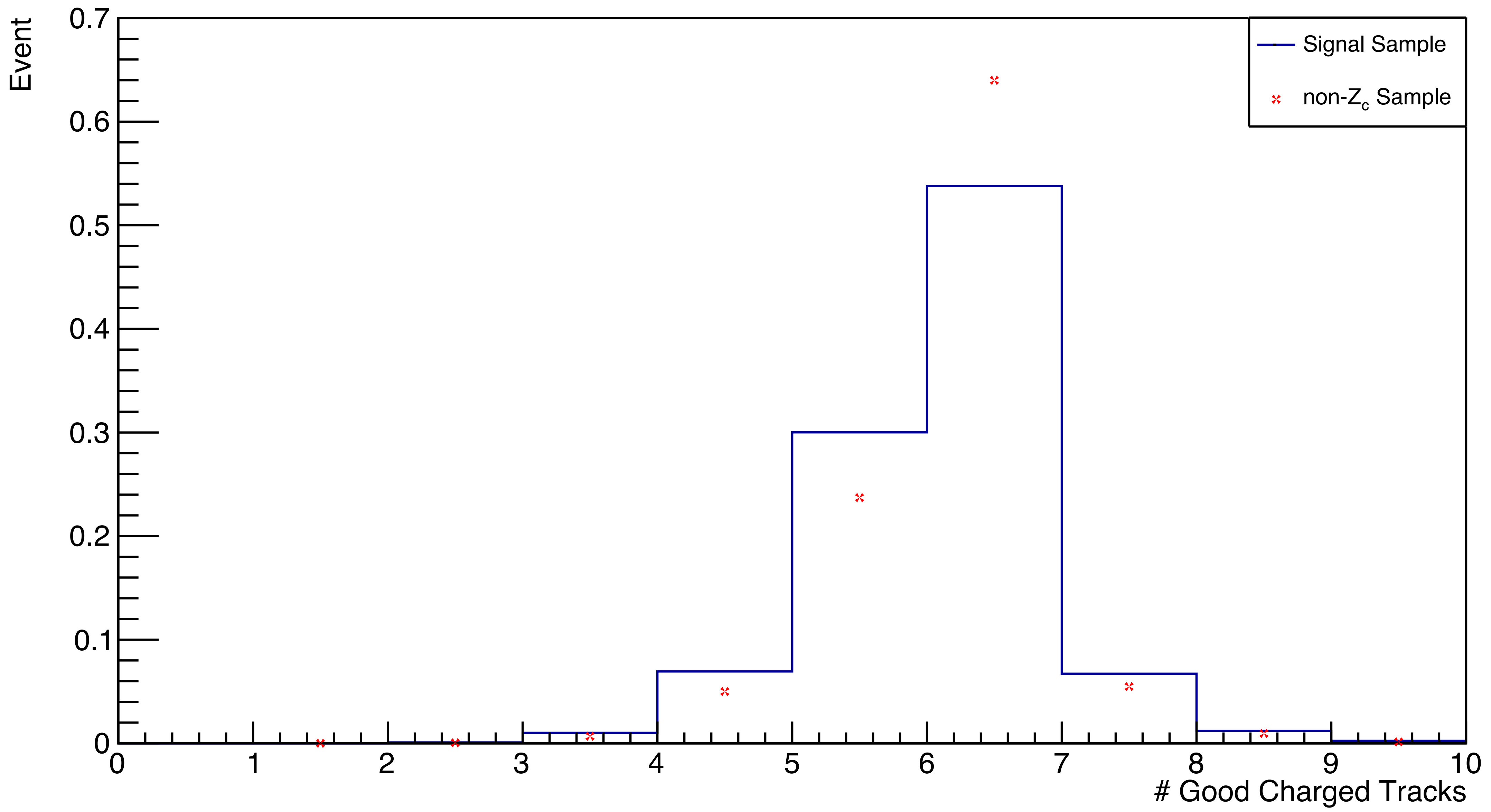


Continuum vs Resonant Comparison

Signal MC Studies

Continuum vs Resonant Comparison





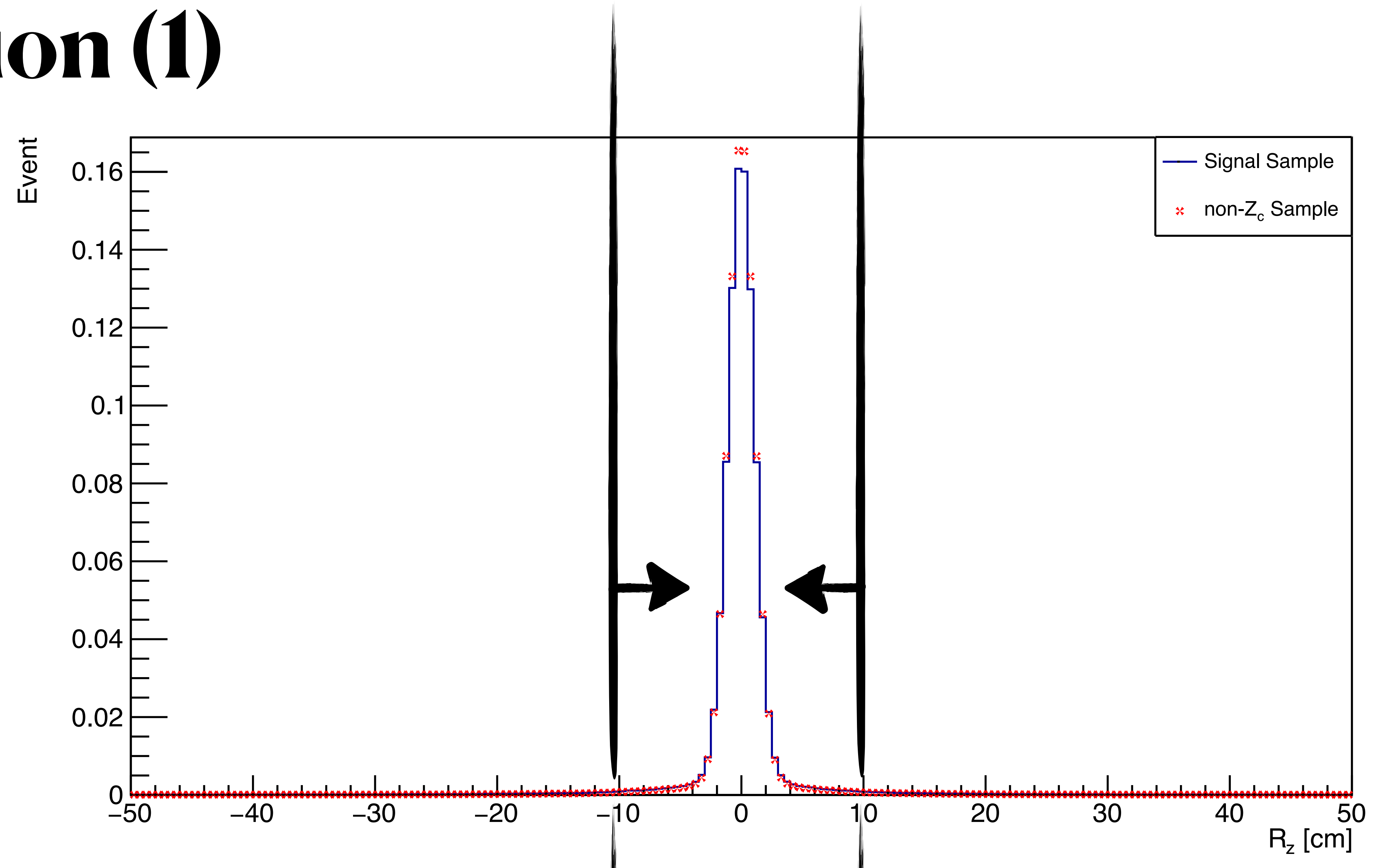
Signal MC Studies

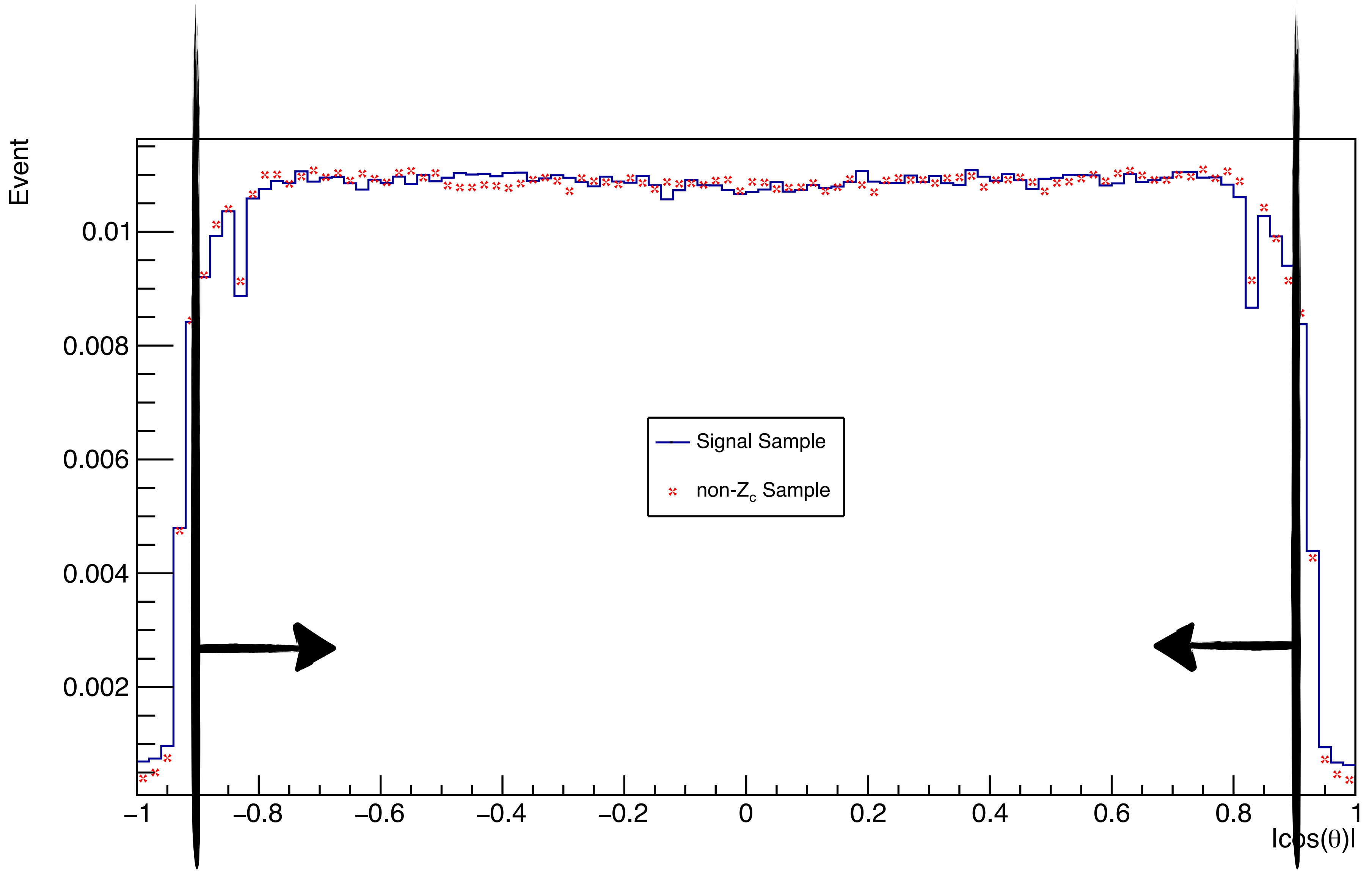
Event Selection (1)

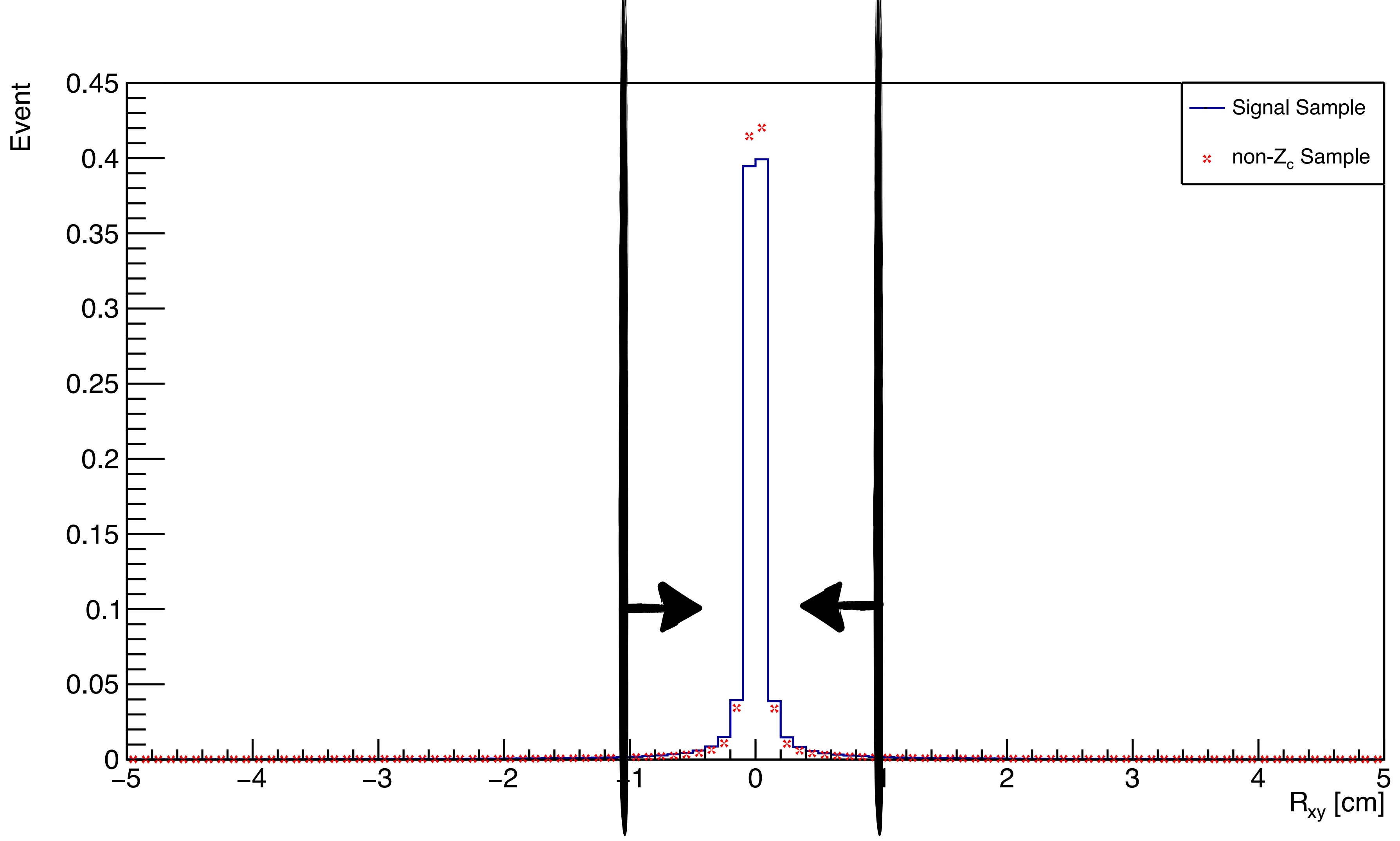
Goodness Cuts

Vertex: R_{xy} < 1cm & R_z < 10 cm

Polar angle: |cos θ| < 0.93







Signal MC Studies

Event Selection (1)

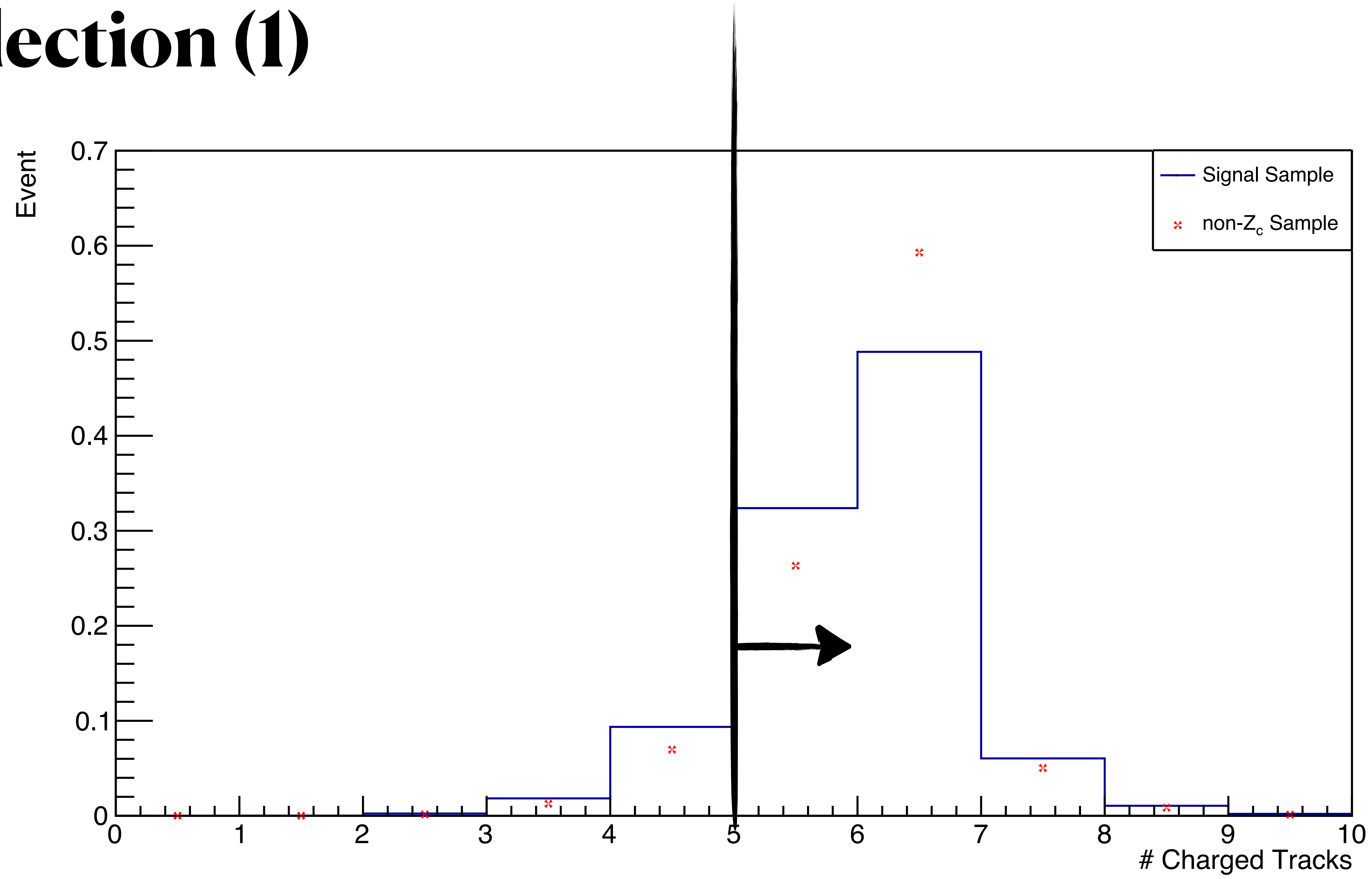
Goodness Cuts

Vertex: R_{xy} < 1cm & R_z < 10 cm

Polar angle: |cos θ| < 0.93

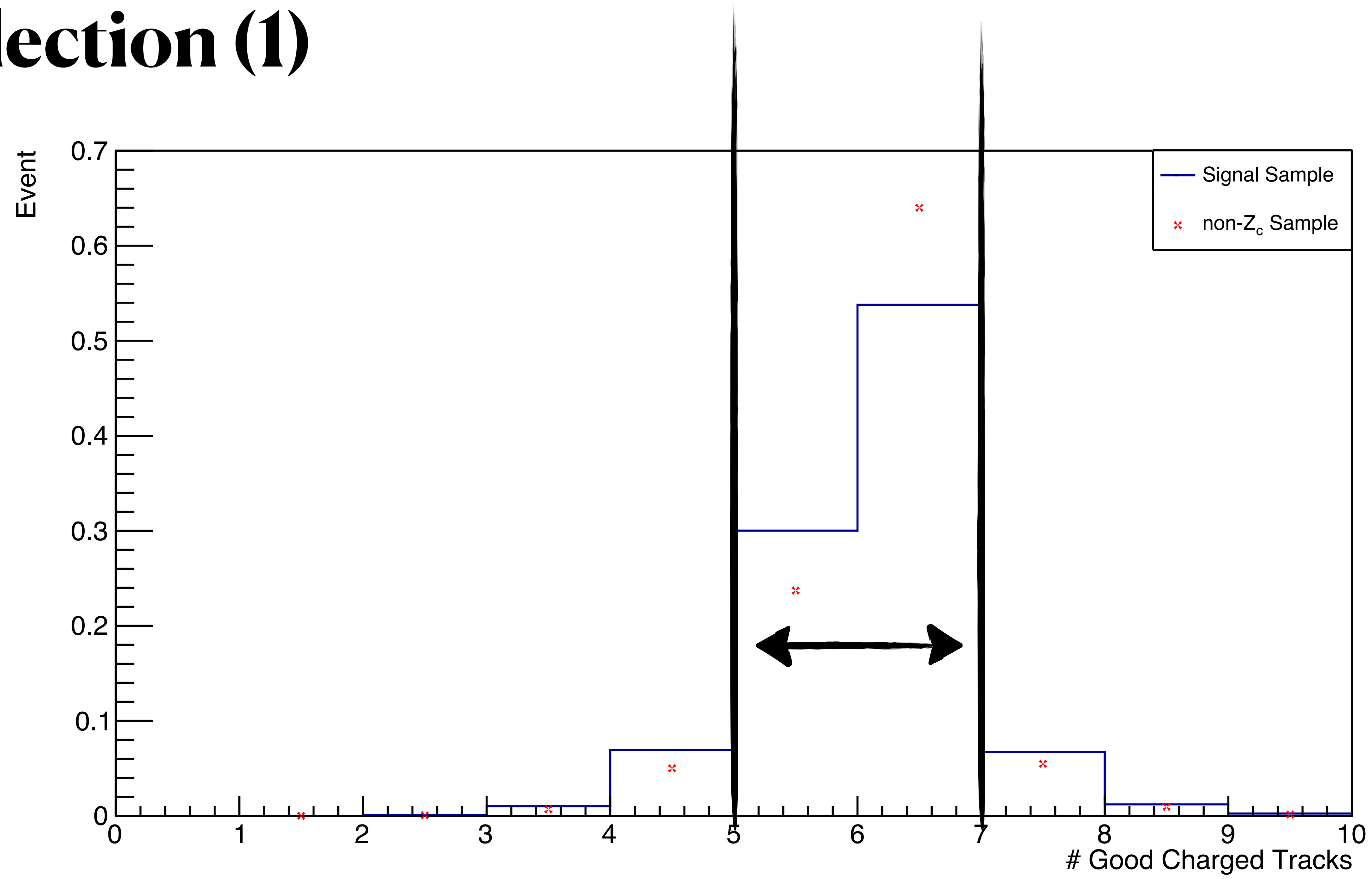
Channel ID

charged tracks > 4



Signal MC Studies

Event Selection (1)



Goodness Cuts

Vertex: R_{xy} < 1cm & R_z < 10 cm

Polar angle: |cos θ| < 0.93

Channel ID

charged tracks > 4

2 good charged topologies

$2\ell\, 3\pi$

$2\ell\, 4\pi$

Signal MC Studies

Event Selection (1)

Goodness Cuts

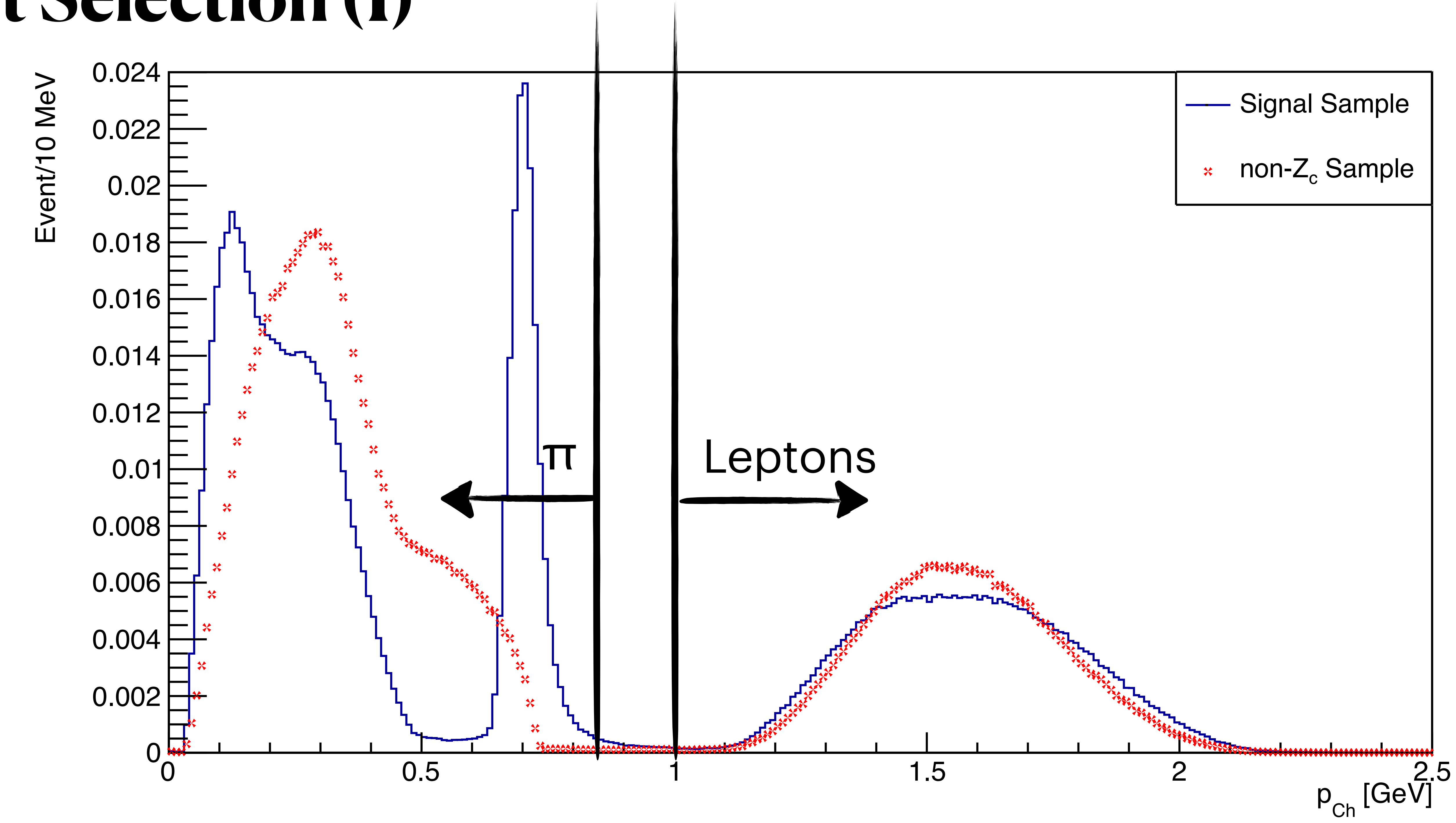
Vertex: R_{xy} < 1cm & R_z < 10 cm

Polar angle: $|\cos\theta|$ < 0.93

Channel ID

charged tracks > 4

Leptons	Pions
p_T > 1 GeV	p_T < 0.85 GeV



2 topologies

$2\ell\,3\pi$

$2\ell\,4\pi$

Signal MC Studies

Event Selection (1)

Goodness Cuts

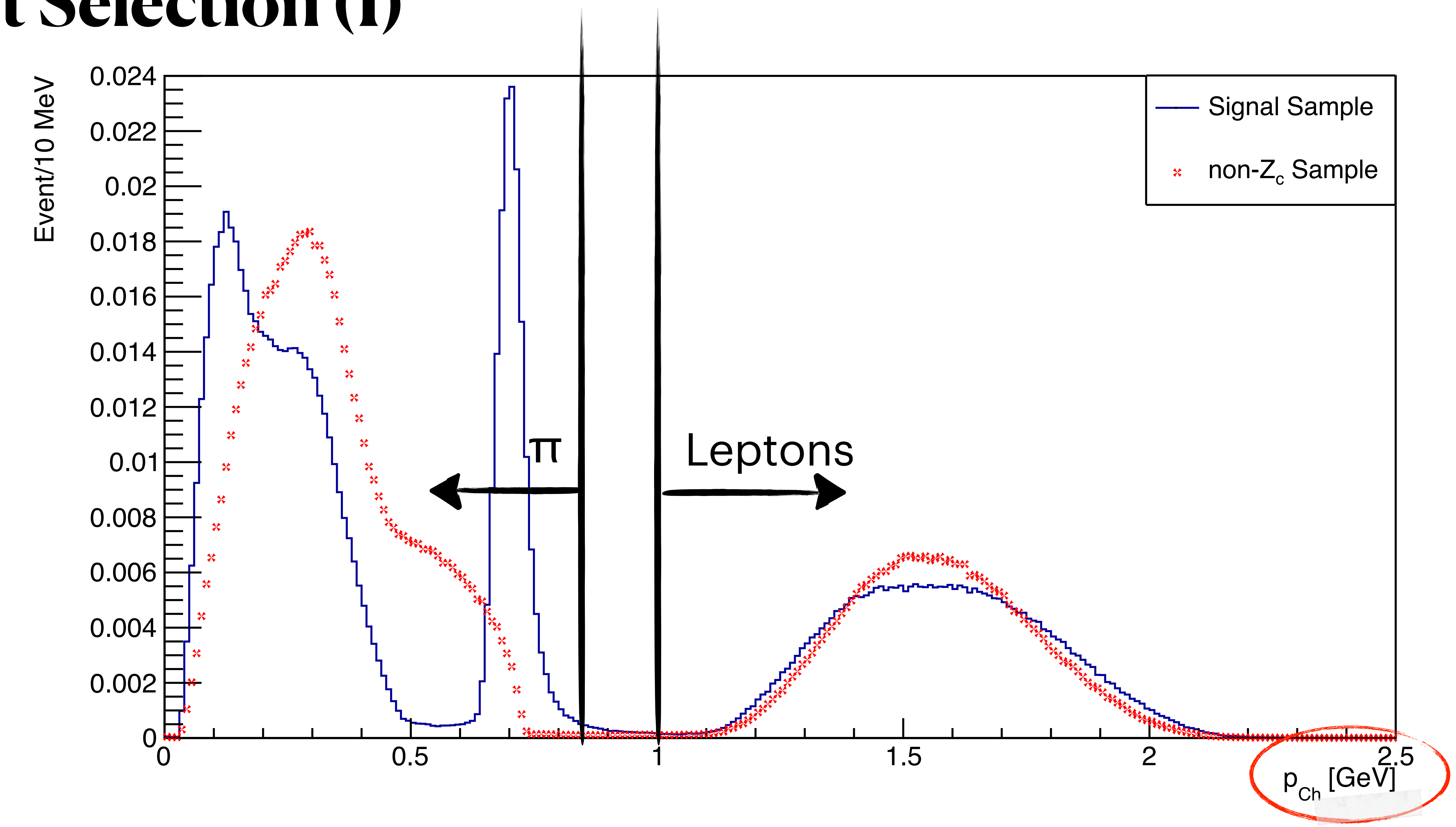
Vertex: $R_{xy} < 1cm$ & $R_z < 10$ cm

Polar angle: $|\cos\theta| < 0.93$

Channel ID

charged tracks > 4

Leptons	Pions
$p_T > 1$ GeV	$p_T < 0.85$ GeV



Will be optimised later on

2 topologies

$2\ell\,3\pi$

$2\ell\,4\pi$

Signal MC Studies

Event Selection (1)

Goodness Cuts

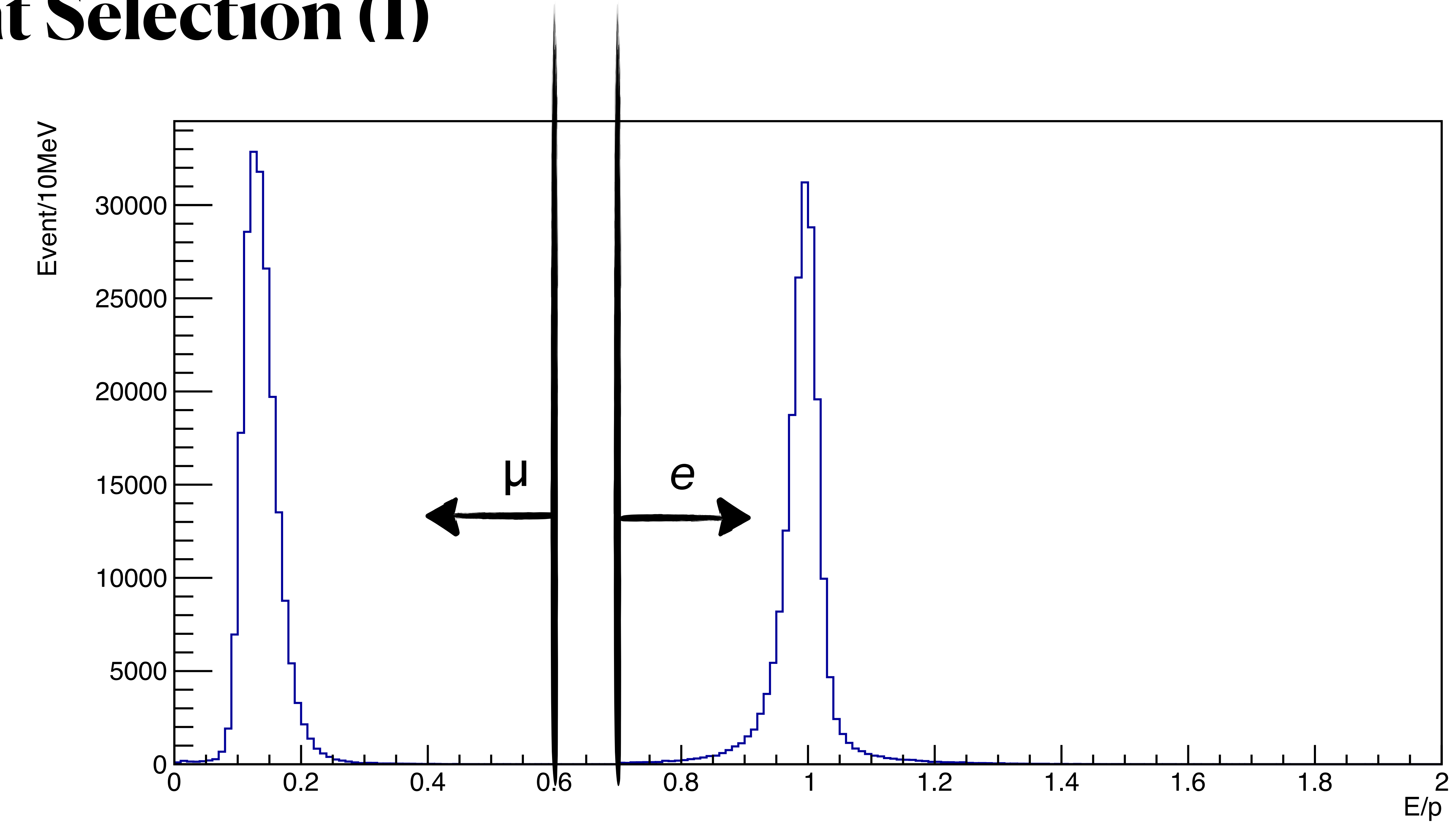
Vertex: R_{xy} < 1cm & R_z < 10 cm

Polar angle: |cos θ| < 0.93

Channel ID

charged tracks > 4

Leptons	Pions
p_T > 1 GeV	p_T < 0.85 GeV
E/p (e) > 0.7	
E/p (μ) < 0.6	



2 topologies

$2\ell\,3\pi$

$2\ell\,4\pi$

Signal MC Studies

Event Selection (1)

Goodness Cuts

Vertex: $R_{xy} < 1$cm & $R_z < 10$ cm

Polar angle: $|\cos\theta| < 0.93$

Channel ID

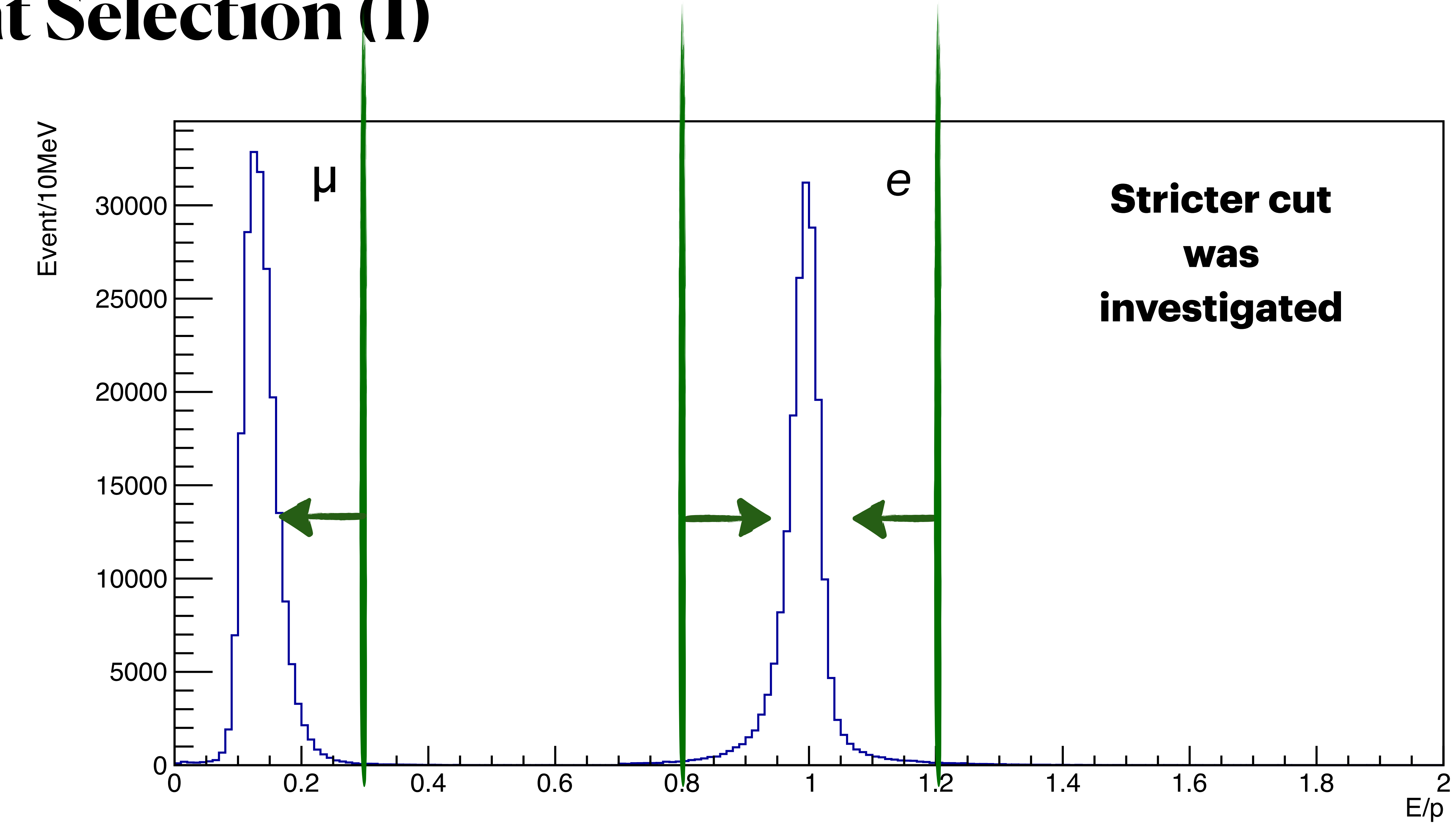
charged tracks > 4

Leptons	Pions
$p_T > 1$ GeV E/p (e) > 0.7 E/p (μ) < 0.6	$p_T < 0.85$ GeV

2 topologies

$2\ell\,3\pi$

$2\ell\,4\pi$



Signal MC Studies

Event Selection (2)

Topology dependent KALMAN Fits

$2\ell 4\pi$

5C Kalman fit

4C on the p_{Tot} = (0.051, 0, 0, $M_{Y(4660)}$)
1C on the $M_{\psi(2S)}$

The ππ couples are selected via the best χ^2

$2\ell 3\pi$

2C Kalman fit

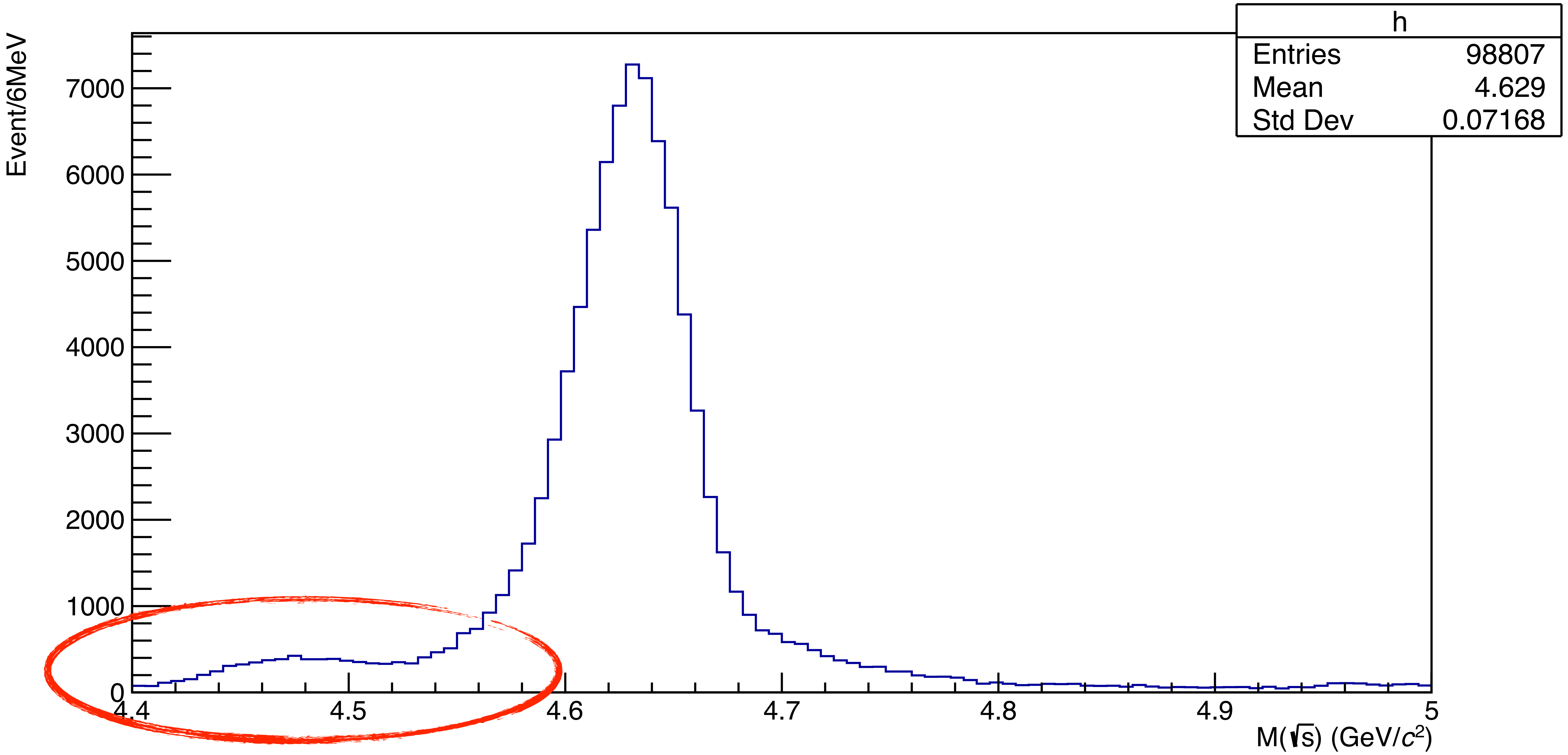
1C on the $M_{J/\psi}$
1C on the $|\mathbf{p}_{Tot}|$

π_{Miss} can come either from the Zc-ψ(2S) system (i.e. *Y(4660) decay*) or from the ψ(2S) decay

The ππ and $\pi\pi_{Miss}$ couples are selected by minimising the $M^{Reco}_{\psi(2S)}$-$M^{PDG}_{\psi(2S)}$ difference

Signal MC Studies

$2\ell3\pi$

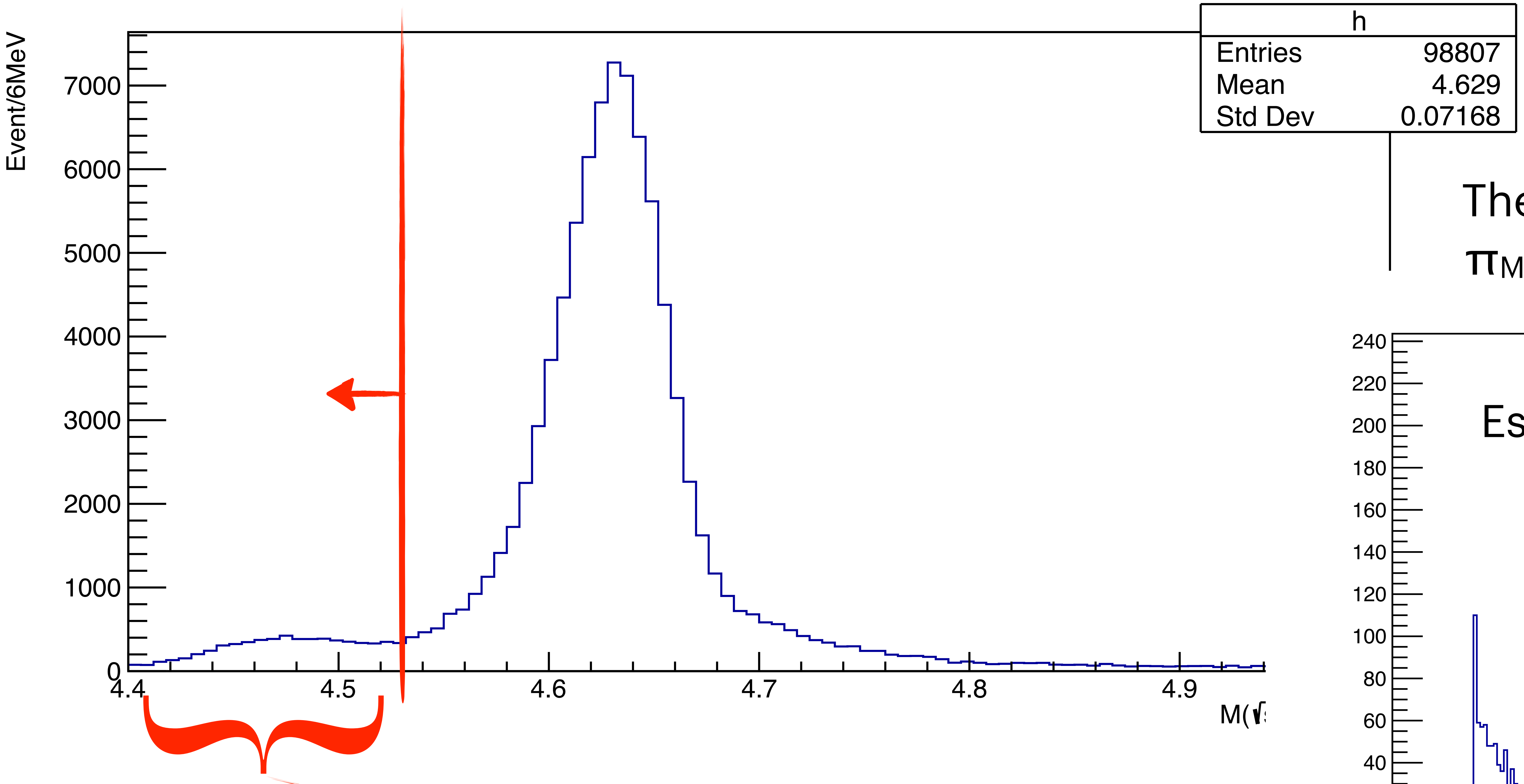


Reconstructed total invariant mass

A peculiar feature at low energies and a long tail at high momenta were found

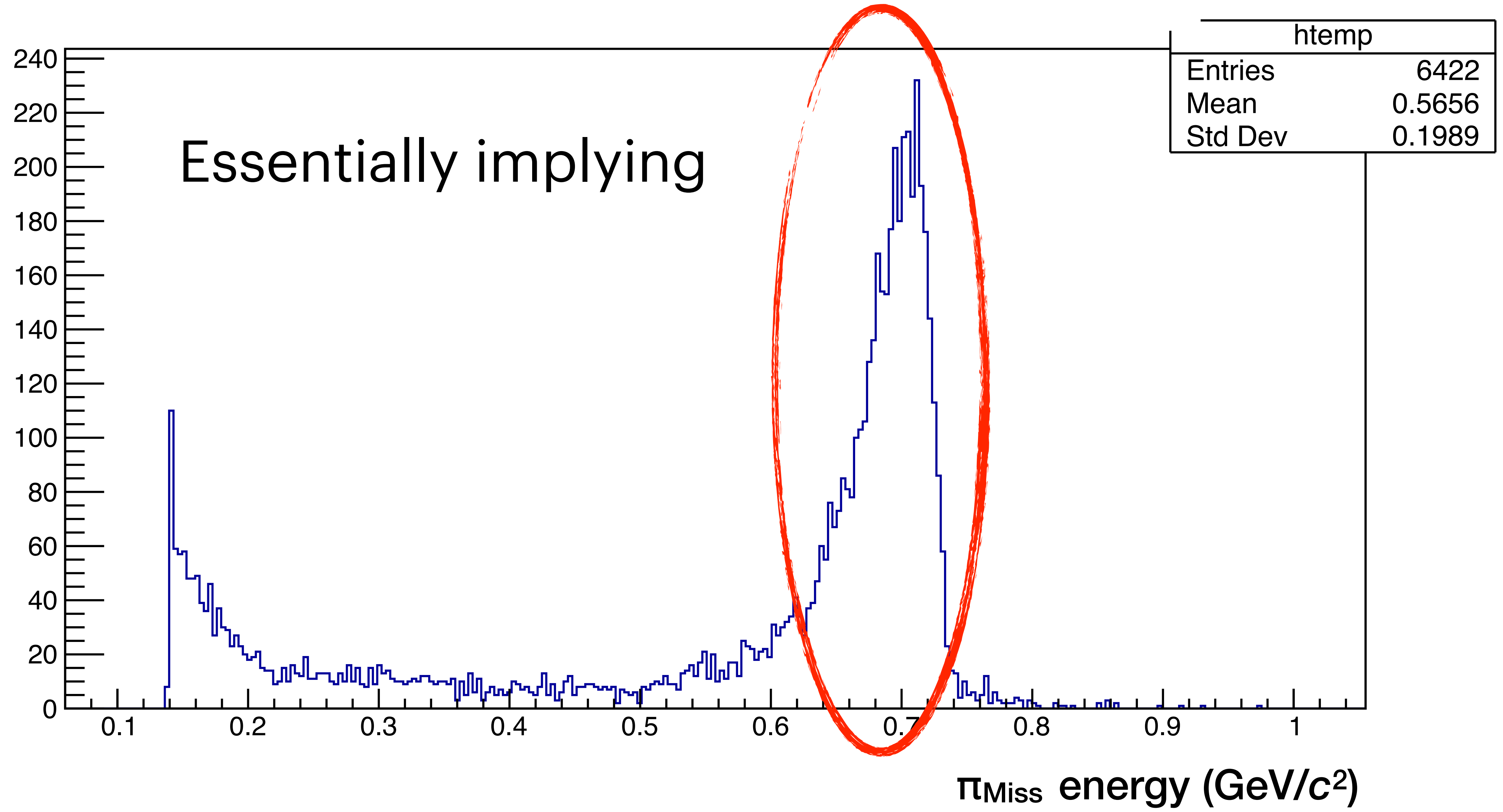
Signal MC Studies

$2\ell 3\pi$



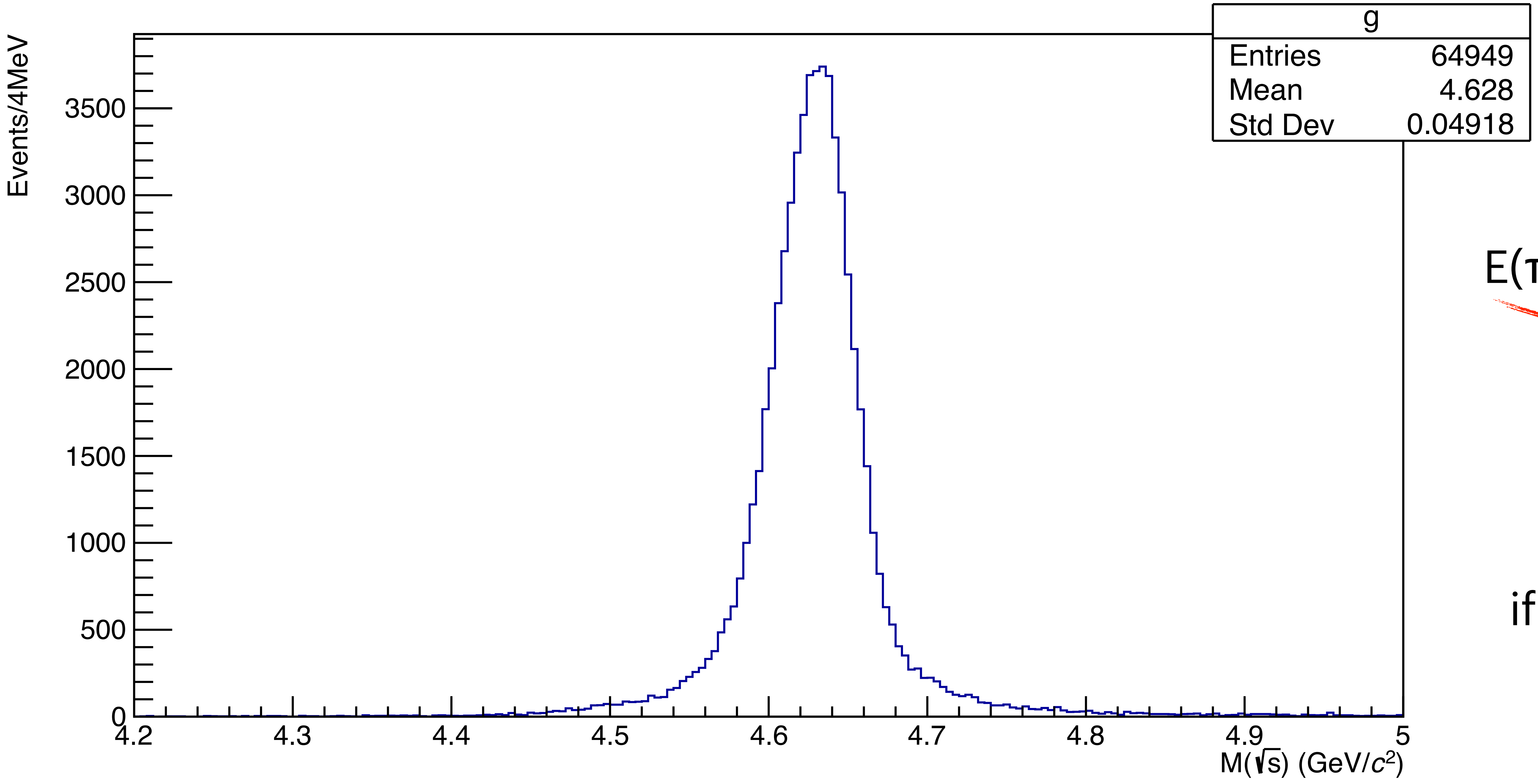
The shape was found to be originated from the π_{Miss} coming from the $Z_c(4430) \rightarrow \psi(2S)$ decay

Essentially implying



Signal MC Studies

$2\ell 3\pi$



Removing all the events with $E(\pi_{Miss}) > 0.5$ GeV/c^2 and with $p(\pi_{Miss}) > E(\pi_{Miss})$

Hard to kinematically constrain the event, if the π_{Miss} comes from the $Z_c(4430)$ decay

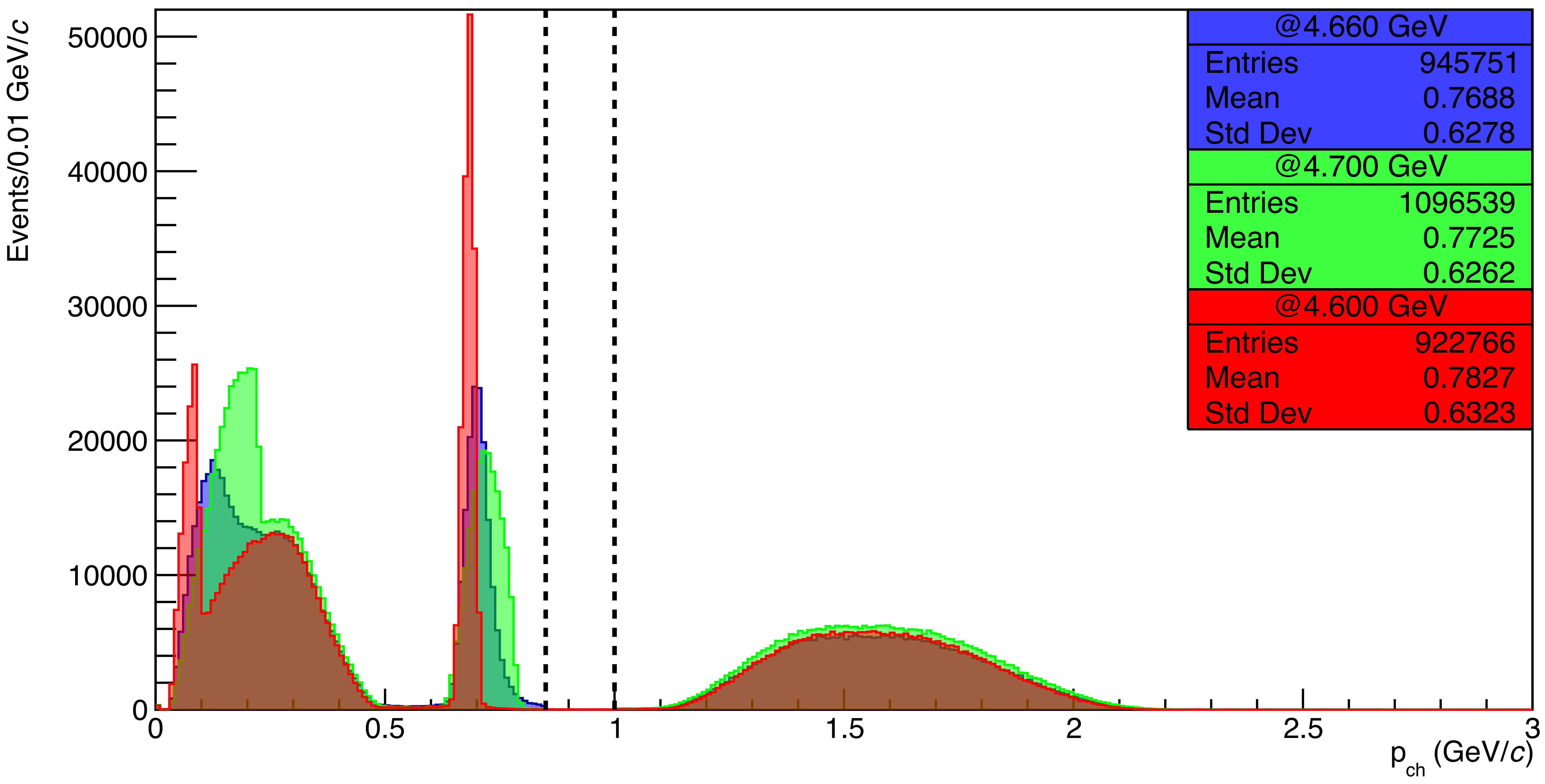
Unphysical events

Signal MC Studies

p_{ch} comparison

Started checking p_{ch} for different $\sqrt{s}$

4.6 GeV and 4.7 GeV were taken as references (as they're the minmax bounds of this ana)



Signal MC Studies

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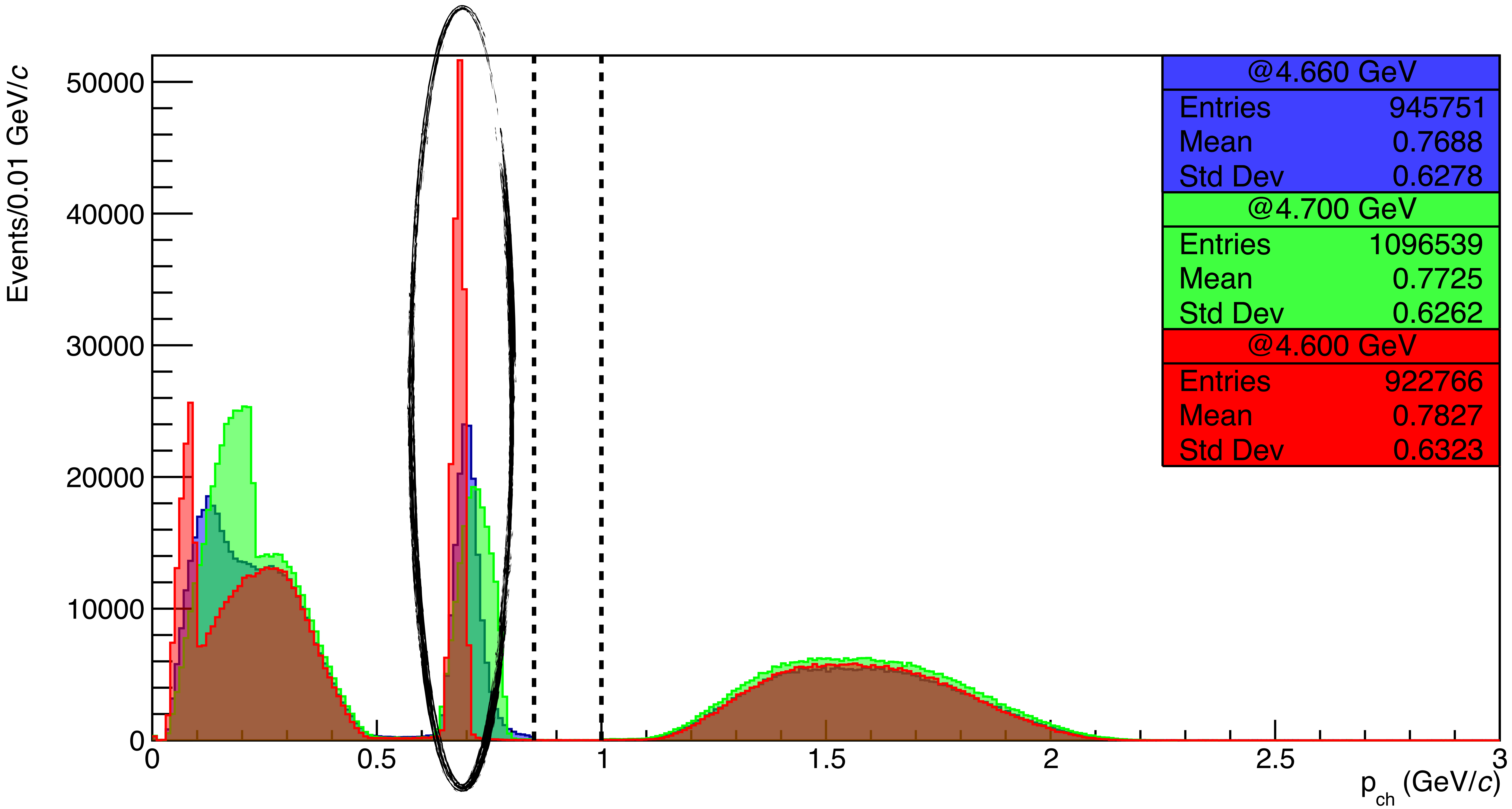


Increasing $\sqrt{s}$, the π_{Zc} peak can be seen moving rightwards and broadening

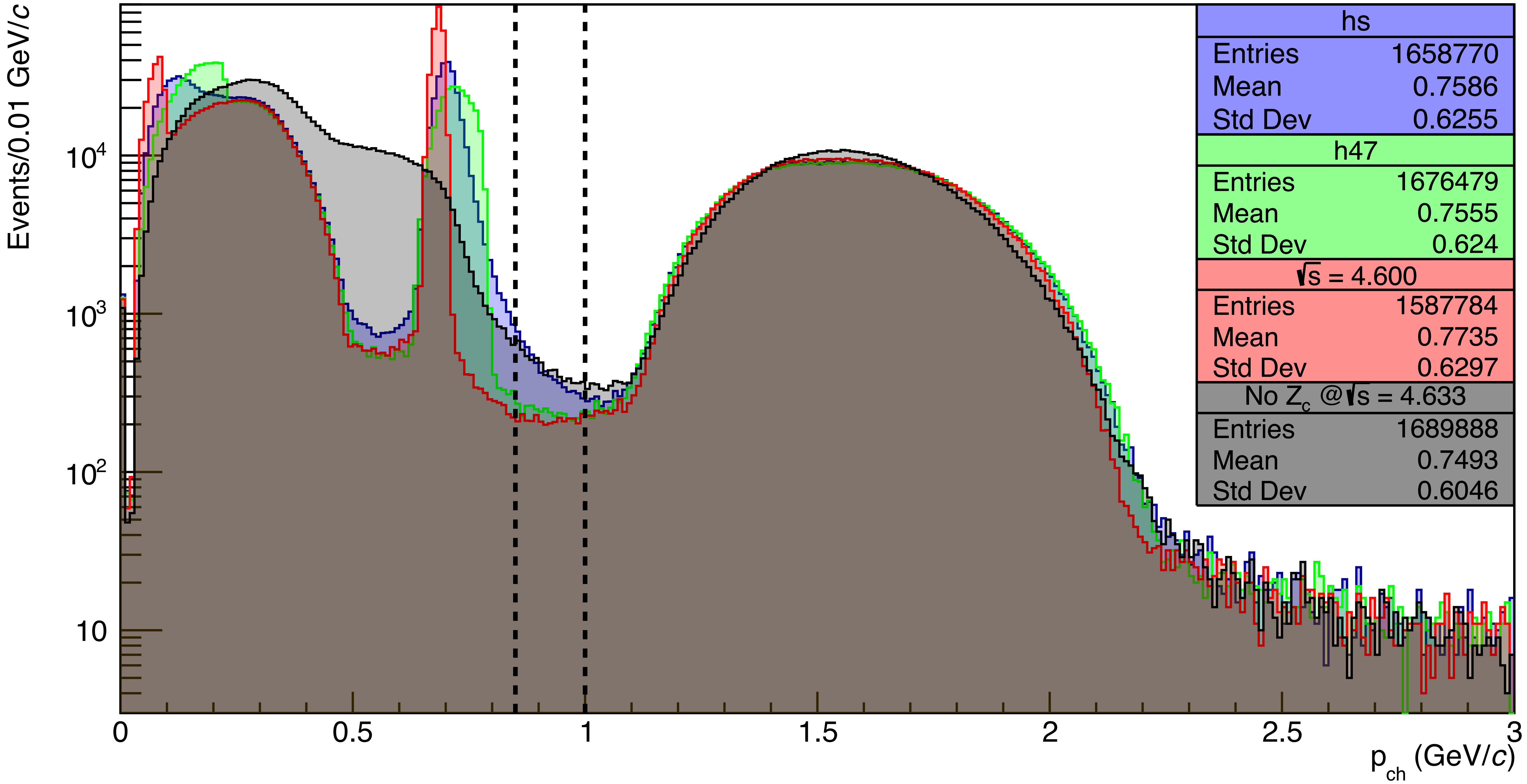
Signal MC Studies

p_{ch} comparison

Let's check it in more detail… the upper bound for πs (< 0.85 GeV) can be improved?

↓

S(Sig$_{MC}$)/B(Inc$_{MC}$) optimisation



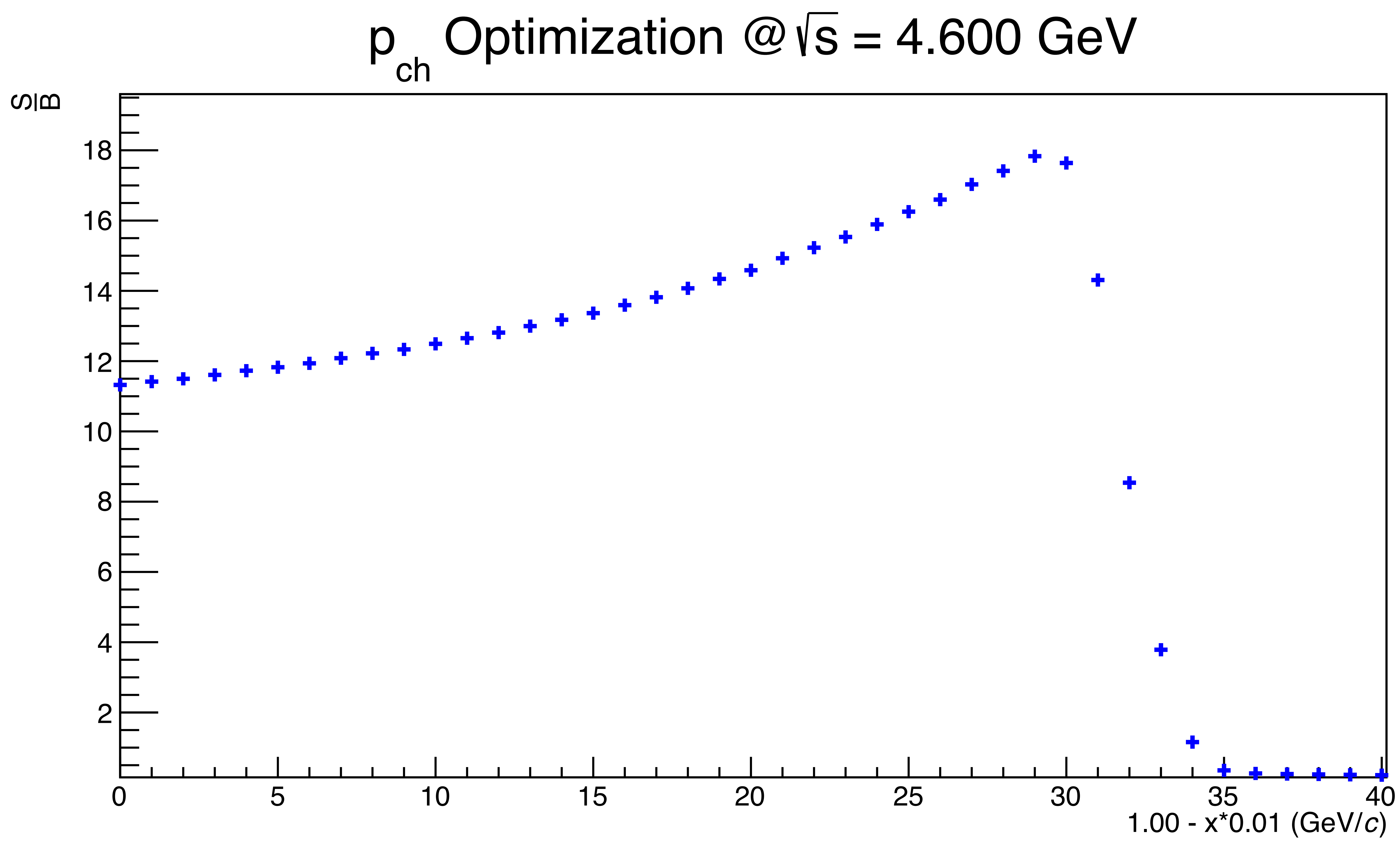
MC Studies

p_{ch} Optimization

S(Sig_{MC})/B(Inc_{MC}) optimisation
∀ √s and using only MC datasets

Optimal values were found quite different wrt nominal one (i.e., 0.85 GeV)

√s	p_{ch} [GeV/*c*]
4.600	0.71
4.612	0.72
4.626	0.73
4.640	0.74
4.660	0.75
4.680	0.77
4.700	0.78



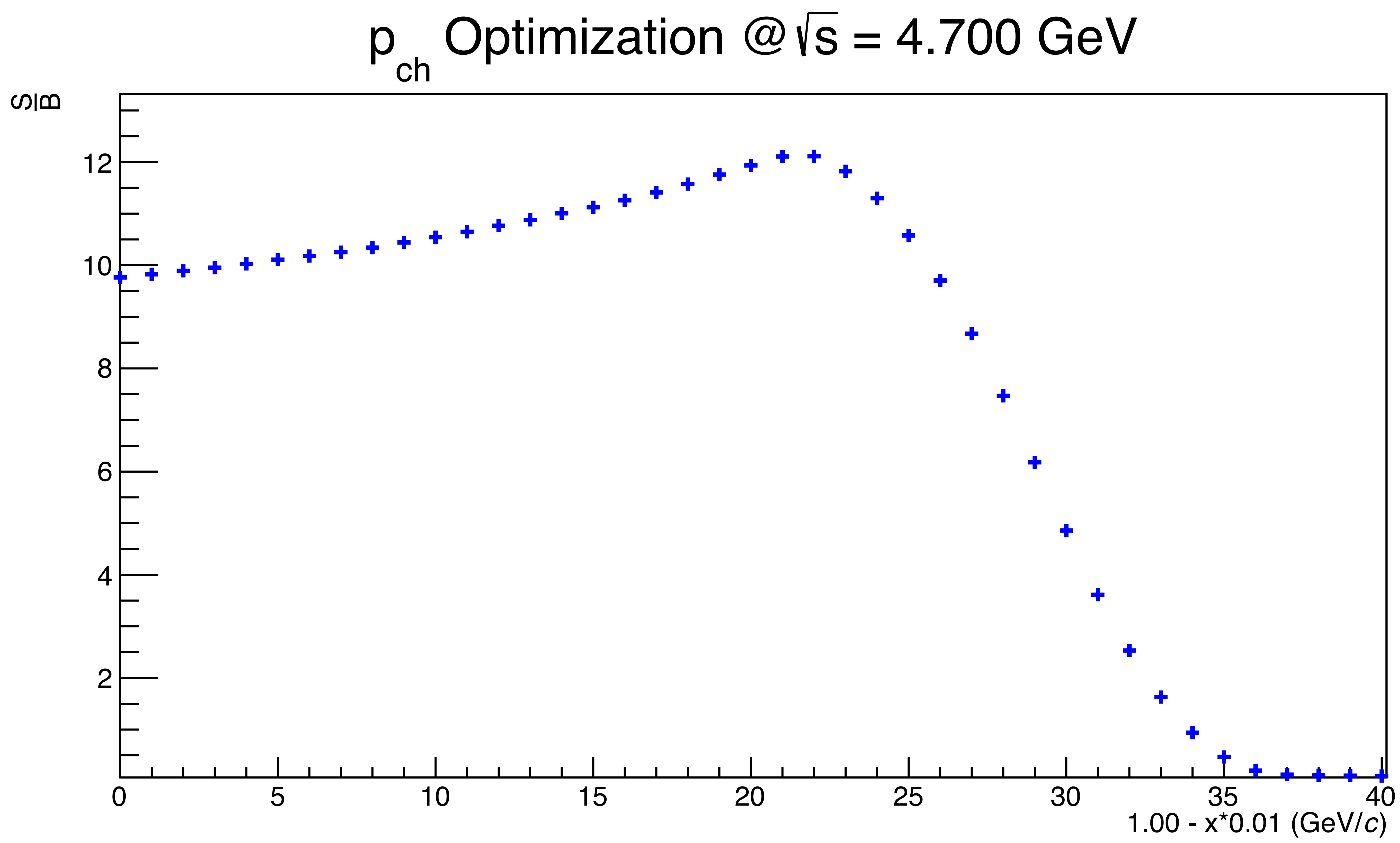
MC Studies

p_{ch} Optimization

S(Sig$_{MC}$)/B(Inc$_{MC}$) optimisation
$\forall$ $\sqrt{s}$ and using only MC datasets

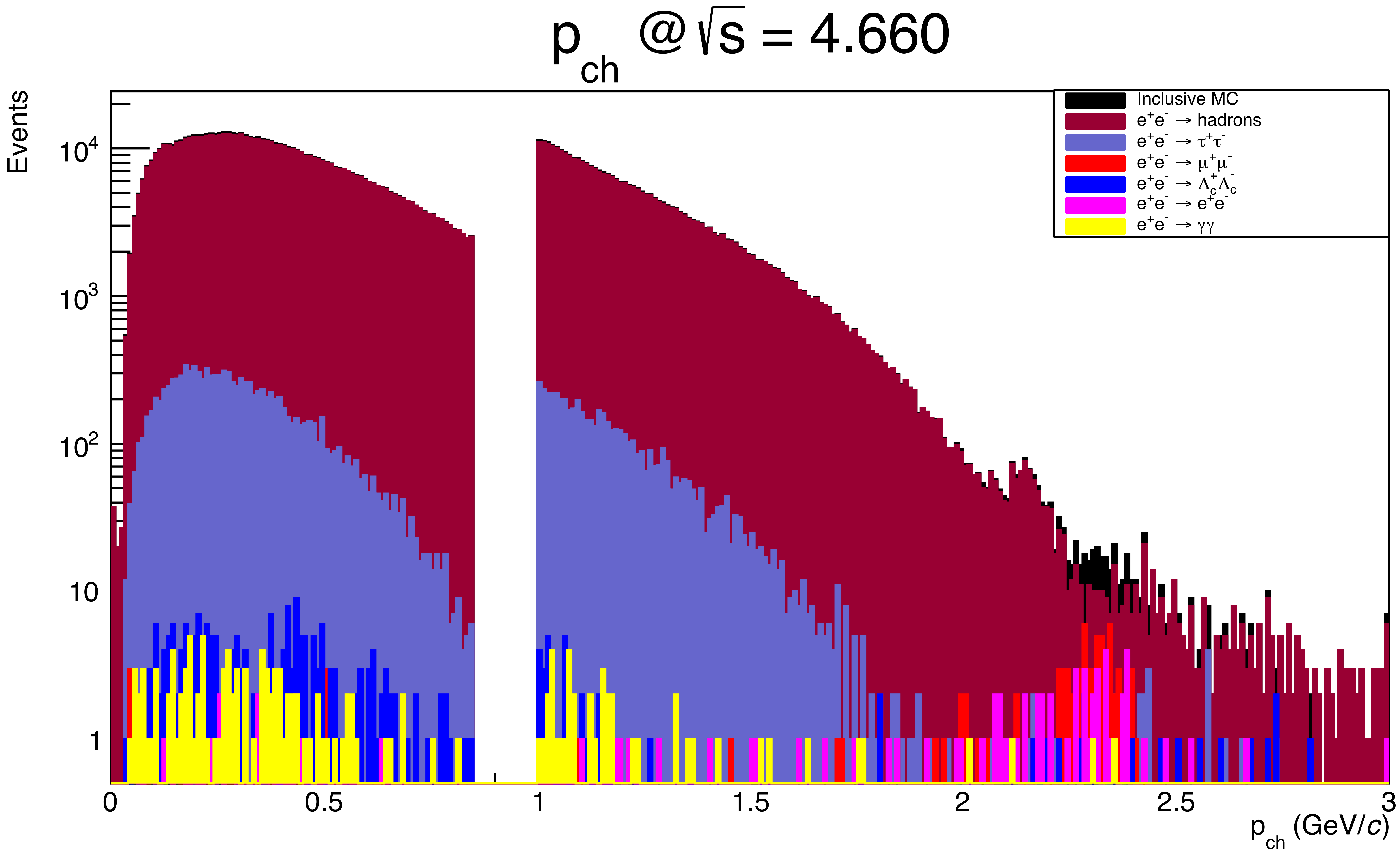
Optimal values were found quite different wrt nominal one (i.e., 0.85 GeV)

$\sqrt{s}$	p_{ch} [GeV/*c*]
4.600	0.71
4.612	0.72
4.626	0.73
4.640	0.74
4.660	0.75
4.680	0.77
4.700	0.78



MC Studies

Inclusive MC Checks wrt Topology



Two main contributions

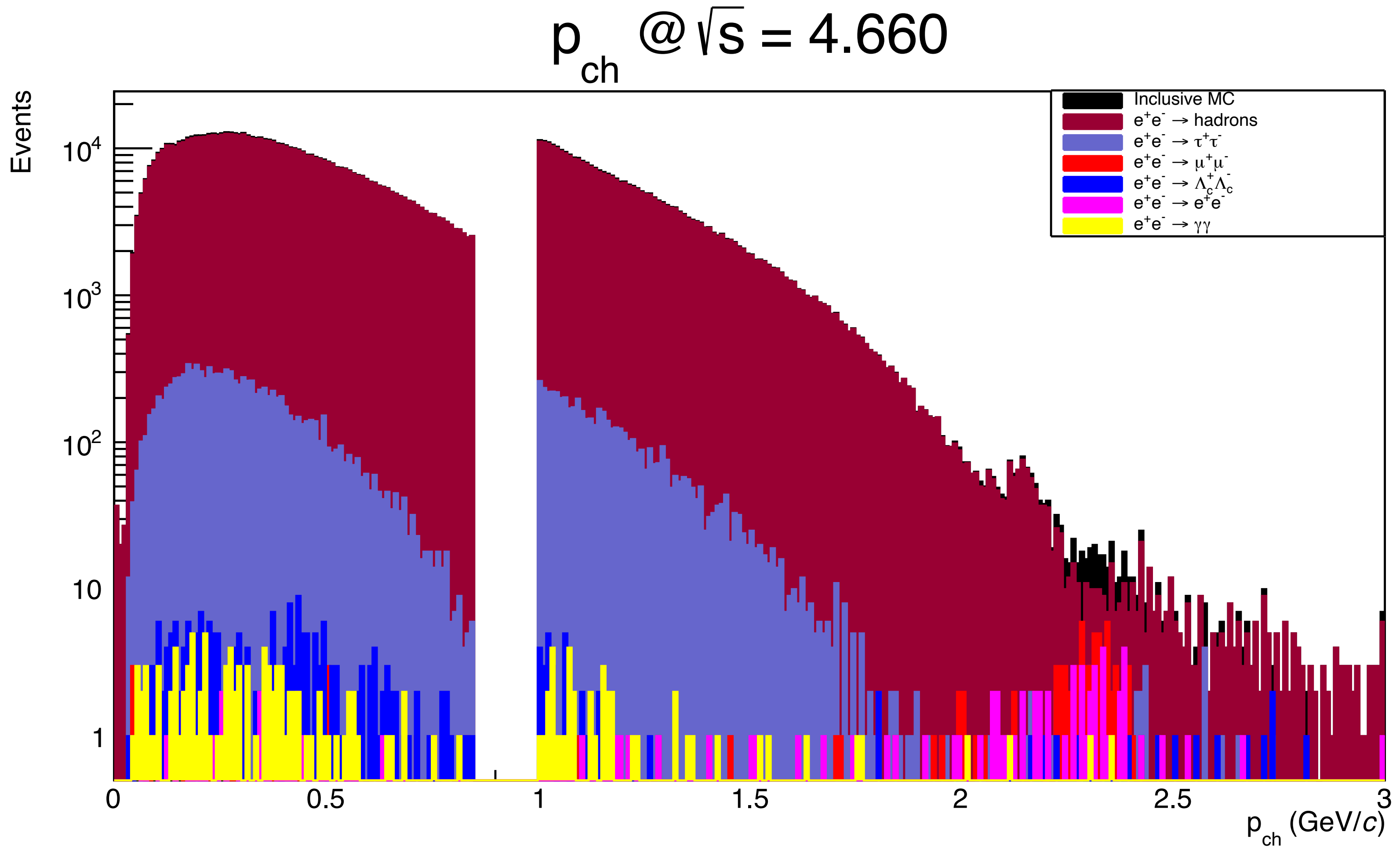
1. Hadrons
2. Tauons

...

3. QED & Λ_c

MC Studies

Inclusive MC Checks wrt Topology



Multi-π states and
the continuum (ee -> ππψ(2S))
will be the main irreducible bkg

Hadrons

rowNo	decay tree (decay initial-final states)	iDcyTr	nEtr	nCEtr
1	$e^+e^- \rightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-$ $(e^+e^- \dashrightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-)$	24	9802	9802
2	$e^+e^- \rightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-, \pi^+ \rightarrow \mu^+\nu_\mu, \mu^+ \rightarrow e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^+\pi^+\pi^-\pi^-\pi^-)$	3	7344	17146
3	$e^+e^- \rightarrow vgam\gamma^I, vgam \rightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-$ $(e^+e^- \dashrightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-\gamma^I)$	16	5062	22208
4	$e^+e^- \rightarrow vgam\gamma^I, vgam \rightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-, \pi^+ \rightarrow \mu^+\nu_\mu, \mu^+ \rightarrow e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^+\pi^+\pi^-\pi^-\pi^-\gamma^I)$	69	4463	26671
5	$e^+e^- \rightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-, \pi^- \rightarrow \mu^-\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow \mu^-\bar{\nu}_\mu\pi^+\pi^+\pi^+\pi^-\pi^-)$	66	1510	28181
6	$e^+e^- \rightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-, \pi^+ \rightarrow \mu^+\nu_\mu, \pi^+ \rightarrow \mu^+\nu_\mu, \mu^+ \rightarrow e^+\nu_e\bar{\nu}_\mu, \mu^+ \rightarrow e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+e^+\nu_e\nu_e\nu_\mu\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^+\pi^-\pi^-\pi^-)$	115	1347	29528
7	$e^+e^- \rightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-, \pi^+ \rightarrow \mu^+\nu_\mu, \pi^- \rightarrow \mu^-\bar{\nu}_\mu, \mu^+ \rightarrow e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^+\pi^+\pi^-\pi^-)$	328	1089	30617
8	$e^+e^- \rightarrow vgam\gamma^I, vgam \rightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-, \pi^+ \rightarrow \mu^+\nu_\mu, \pi^+ \rightarrow \mu^+\nu_\mu, \mu^+ \rightarrow e^+\nu_e\bar{\nu}_\mu, \mu^+ \rightarrow e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+e^+\nu_e\nu_e\nu_\mu\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^+\pi^-\pi^-\pi^-\gamma^I)$	171	943	31560
9	$e^+e^- \rightarrow \pi^+\pi^+\pi^-\pi^-\eta, \eta \rightarrow \pi^0\pi^+\pi^-, \pi^+ \rightarrow \mu^+\nu_\mu, \mu^+ \rightarrow e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^0\pi^+\pi^+\pi^-\pi^-\pi^-)$	63	891	32451
10	$e^+e^- \rightarrow vgam\gamma^I, vgam \rightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-, \pi^- \rightarrow \mu^-\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow \mu^-\bar{\nu}_\mu\pi^+\pi^+\pi^+\pi^-\pi^-\gamma^I)$	40	805	33256

MC Studies

Just a bit more...

Need to clean more the signal...

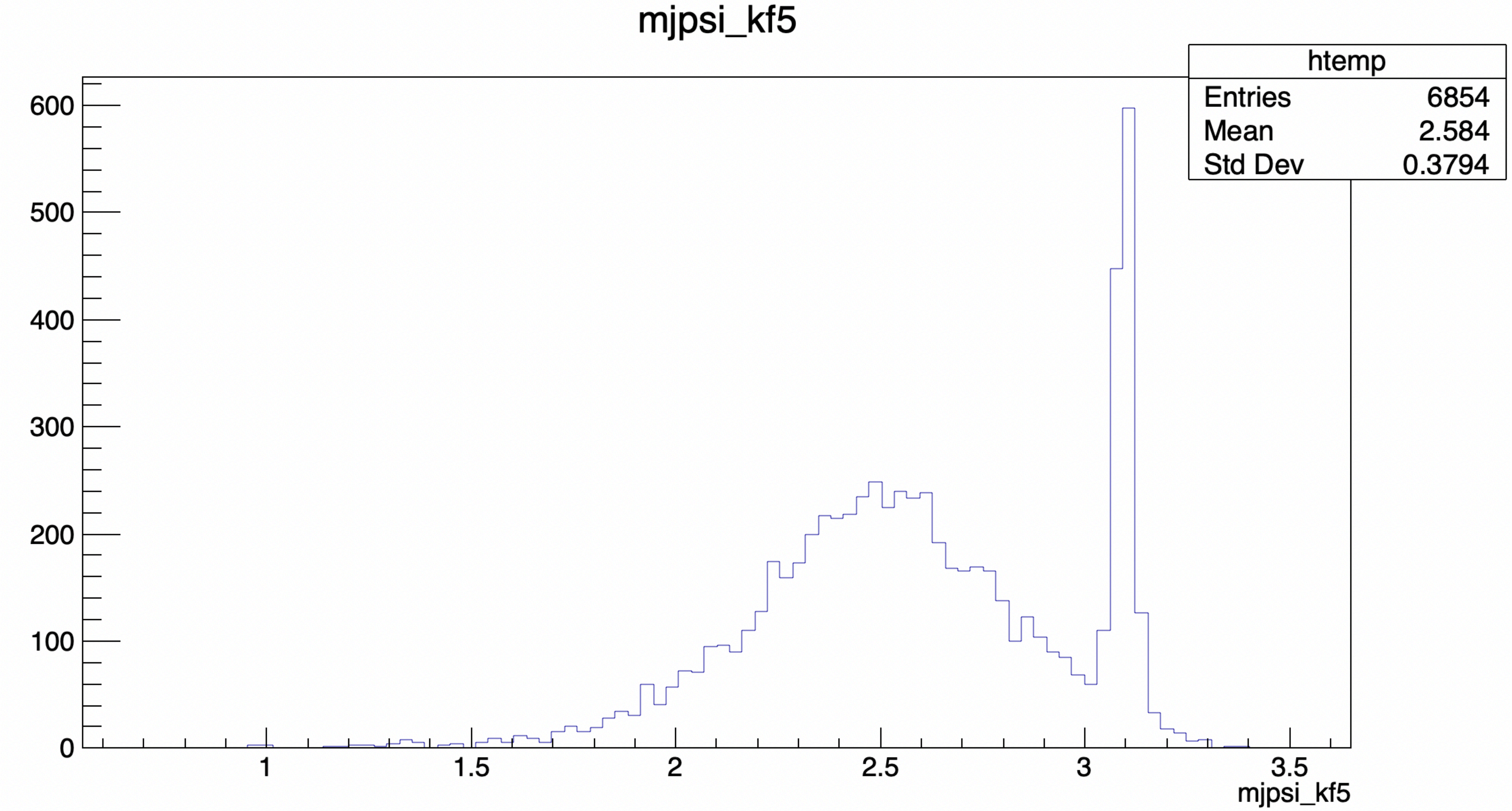
MC Studies

Just a bit more…

Need to clean more the signal…

Let's apply cuts on

M(ψ(n)) both for **2ℓ4π** and 2ℓ3π
M_{Miss}(π) for 2ℓ3π



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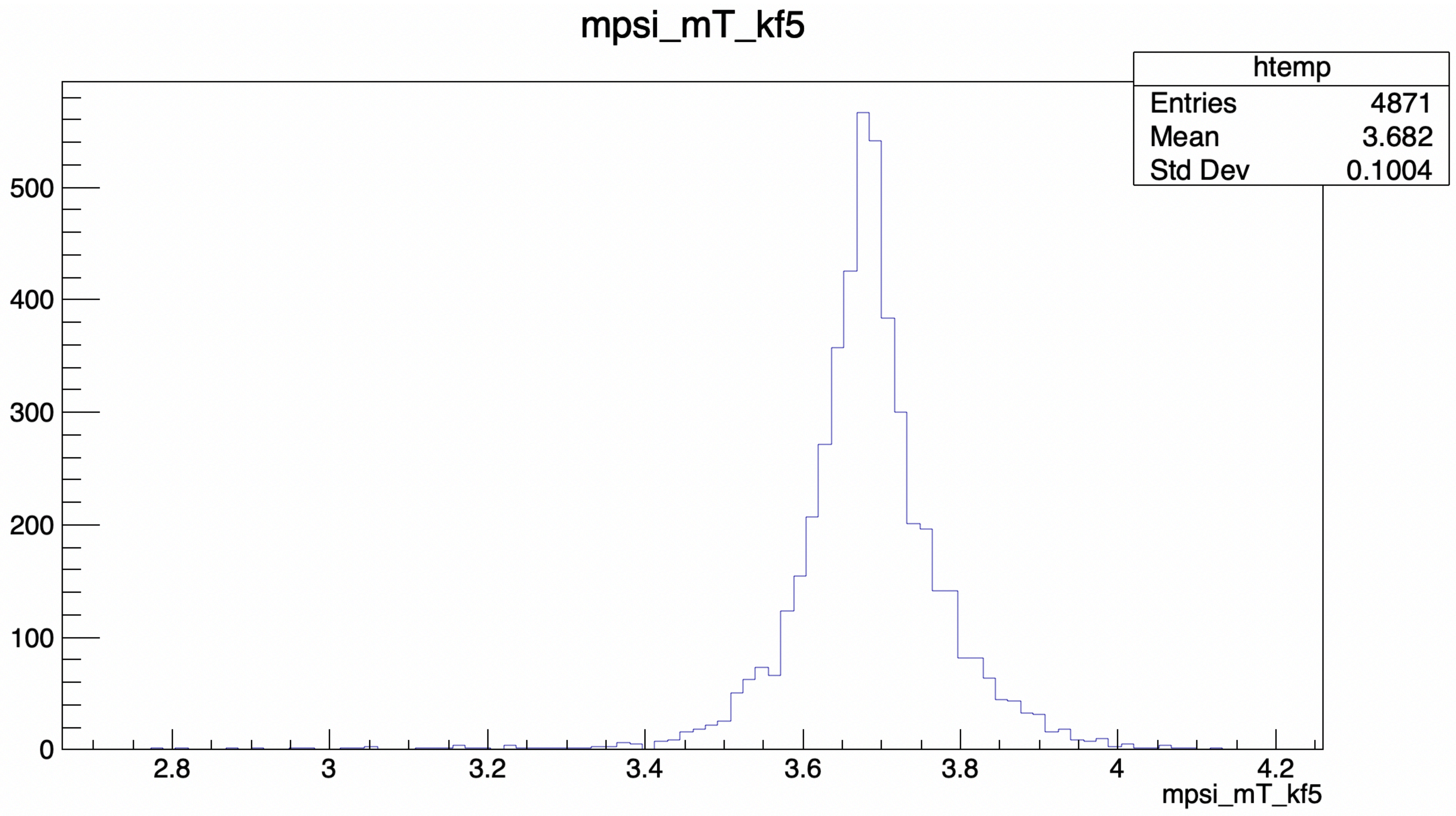

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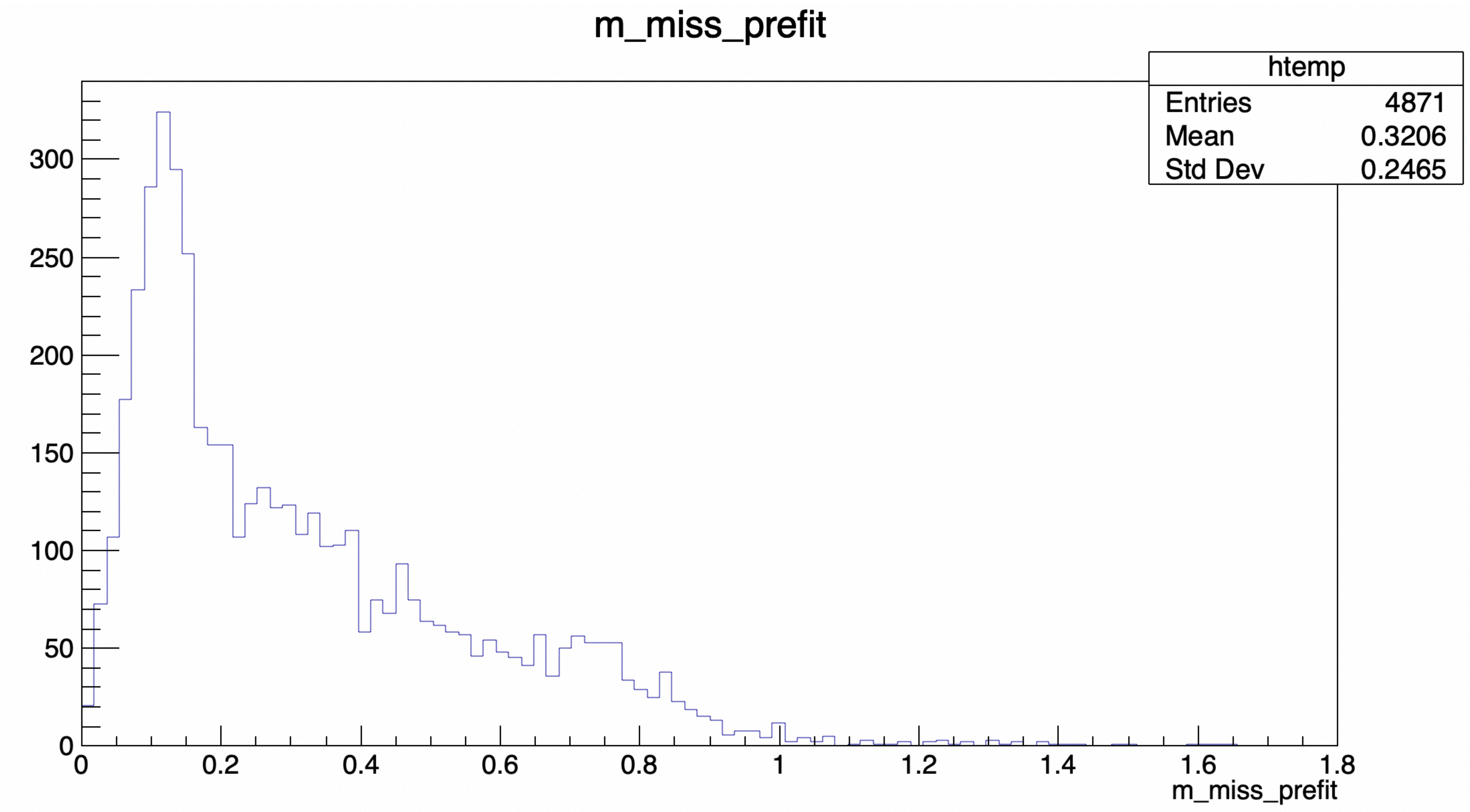


MC Studies

Just a bit more...

Summary of the mass selections

√s	σ(J/ψ) 6t ee	σ(J/ψ) 6t μμ	σ(ψ(2S)) 6t ee	σ(ψ(2S)) 6t μμ	σ(J/ψ) 5t ee	σ(J/ψ) 5t μμ	σ(ψ(2S)) 5t ee	σ(ψ(2S)) 5t μμ
4.600	21	20	22	21	20	20	22	21
4.612	21	20	22	21	20	20	23	21
4.626	21	20	22	21	20	19	24	22
4.640	21	20	22	21	20	19	24	22
4.660	21	20	22	21	20	19	25	22
4.680	21	20	22	21	19	19	25	23
4.700	21	20	22	21	20	19	25	23

Given the width (σ) of the distribution,∀ √s:

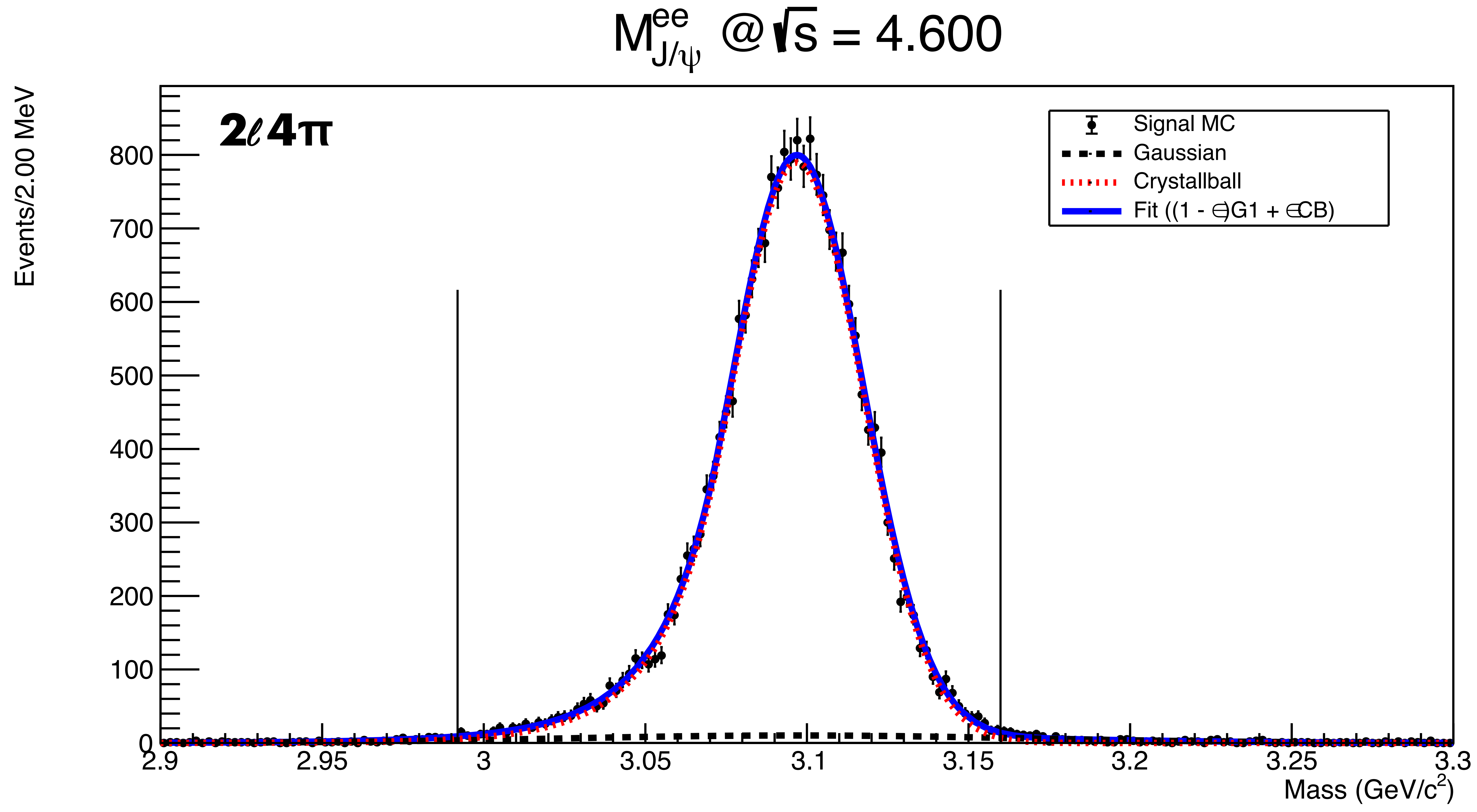
ee channel: $-5\sigma < M < +3\sigma$
μμ channel: $-3(5)\sigma < M < +3\sigma$

Discussion sparked:

Are you using preFit variables also for reconstructing the Z_c?

MC Studies

Just a bit more...



preFit variables

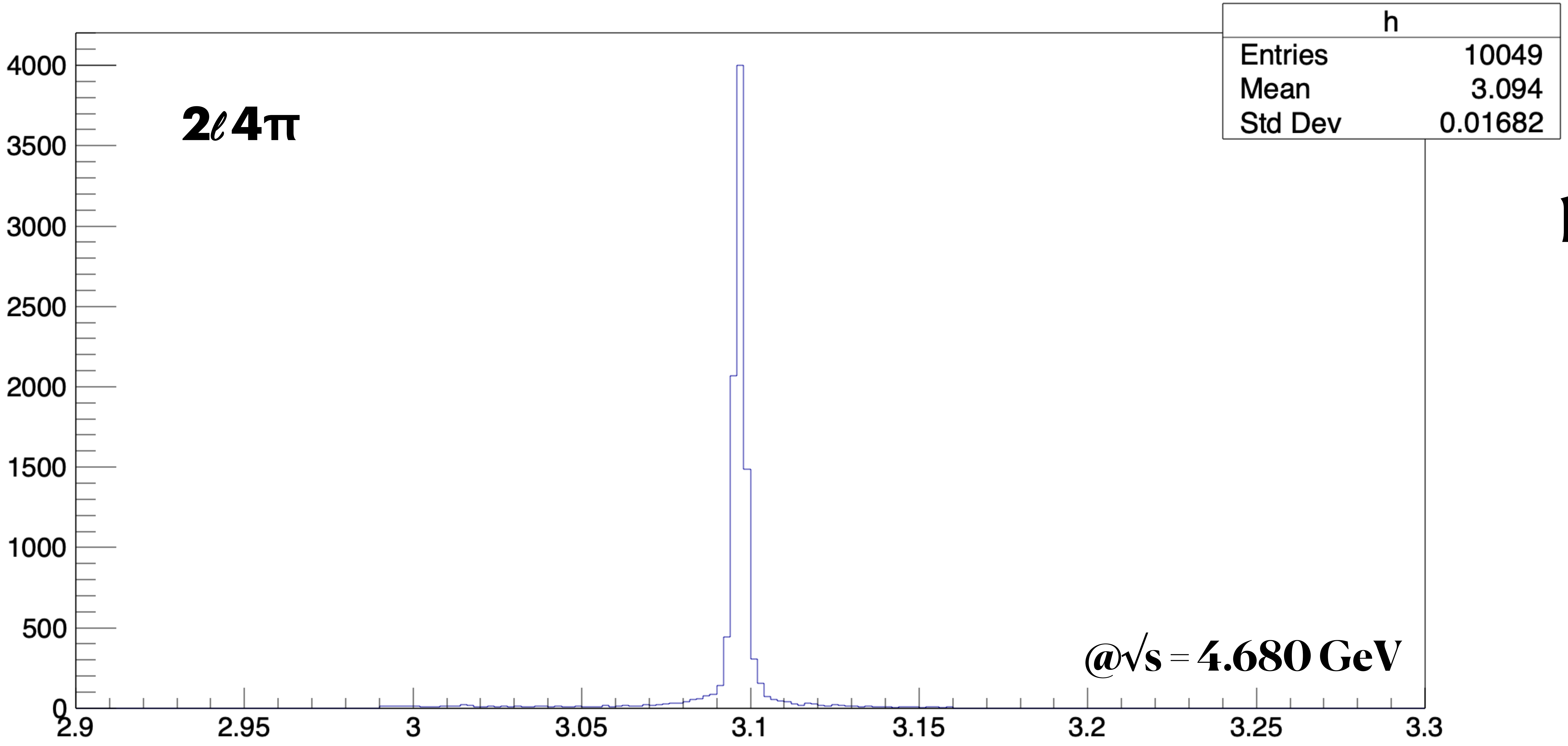
Given the width (σ) of the distribution, ∀ √s:

ee channel: -5σ < M < +3σ

μμ channel: -3(5)σ < M < +3σ

MC Studies

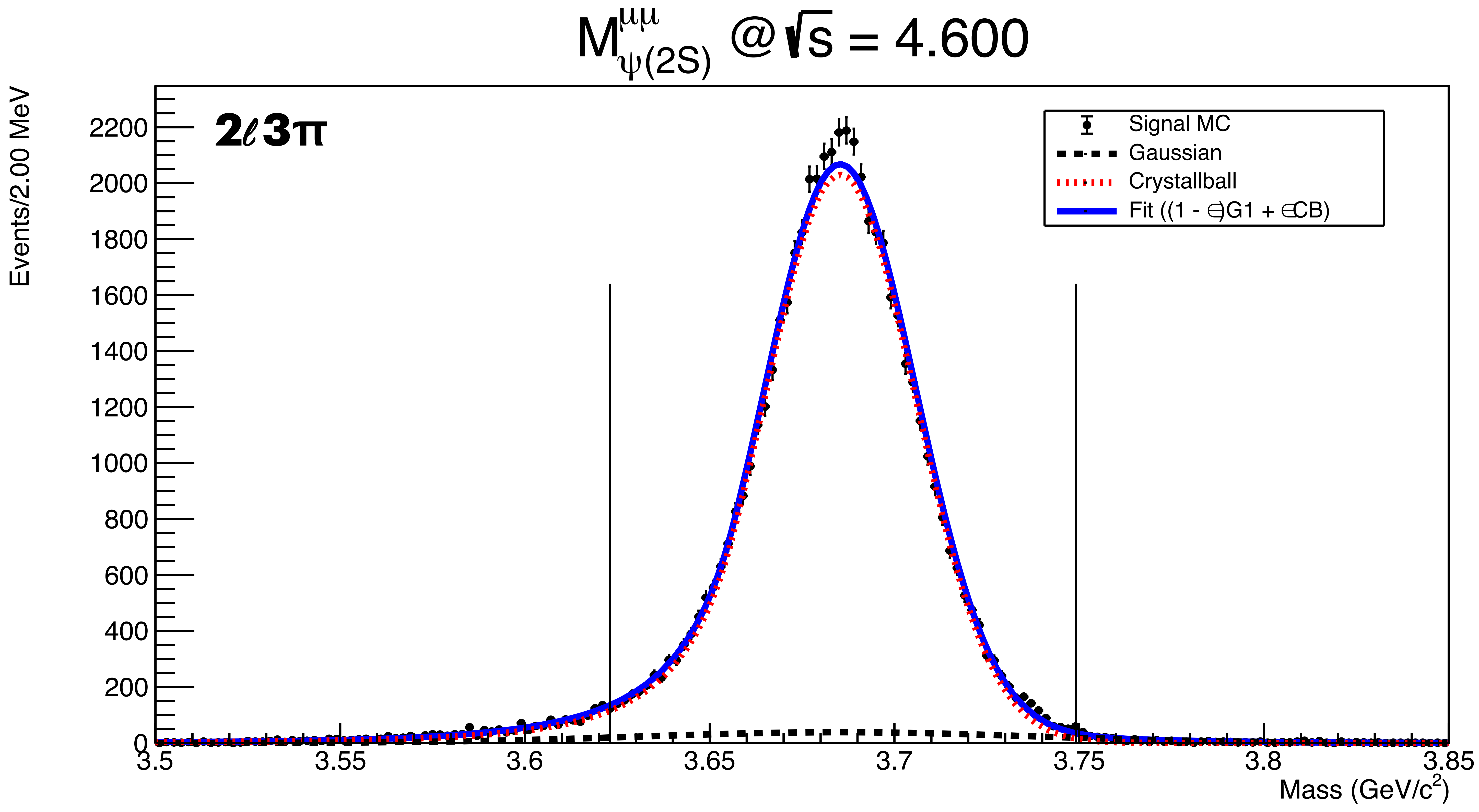
Just a bit more...



postFit variables

MC Studies

Just a bit more...



preFit variables

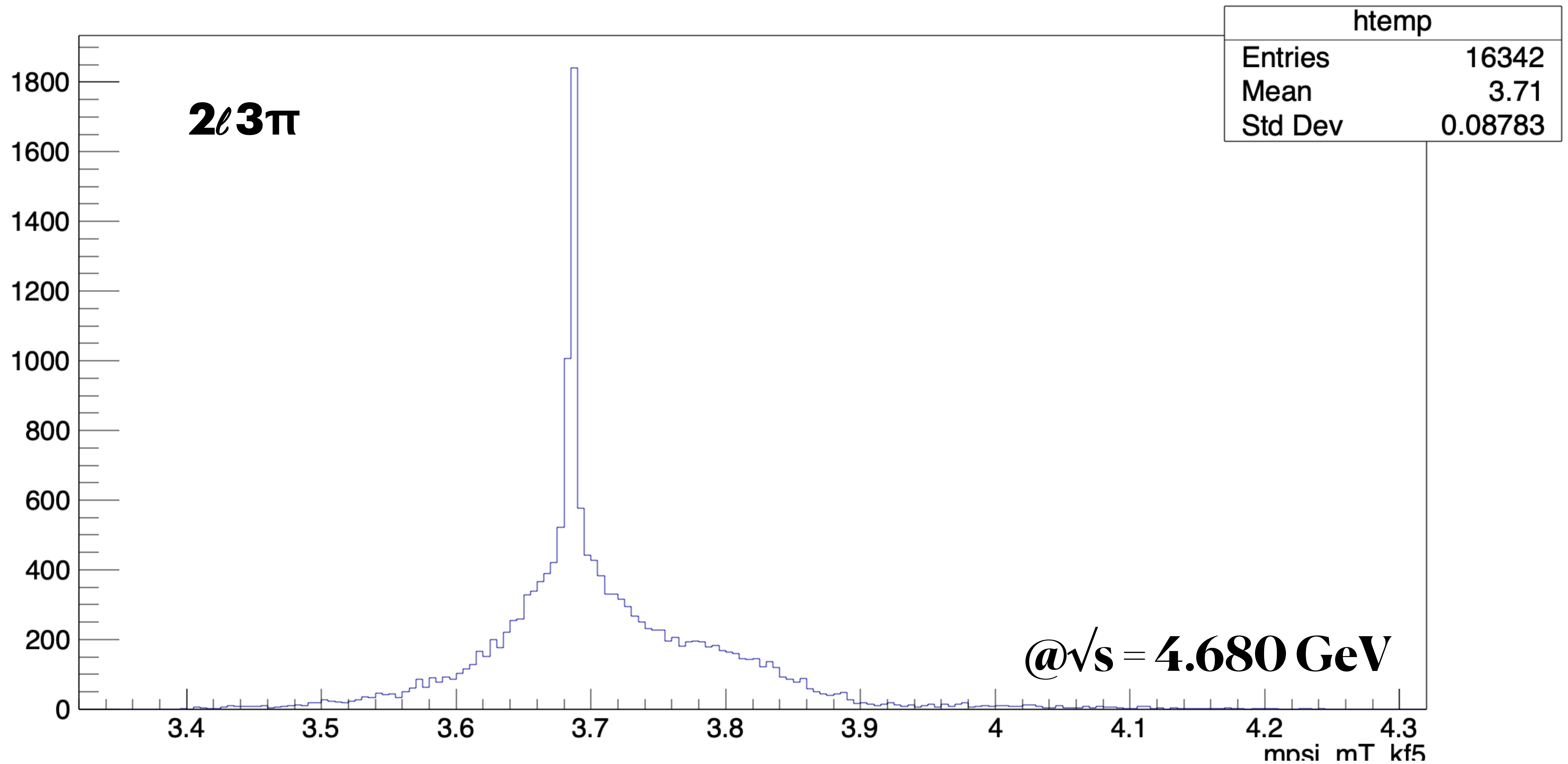
Given the width (σ) of the distribution, ∀ $\sqrt{s}$:

ee channel: -5σ < M < +3σ

μμ channel: -3(5)σ < M < +3σ

MC Studies

Just a bit more...



postFit variables

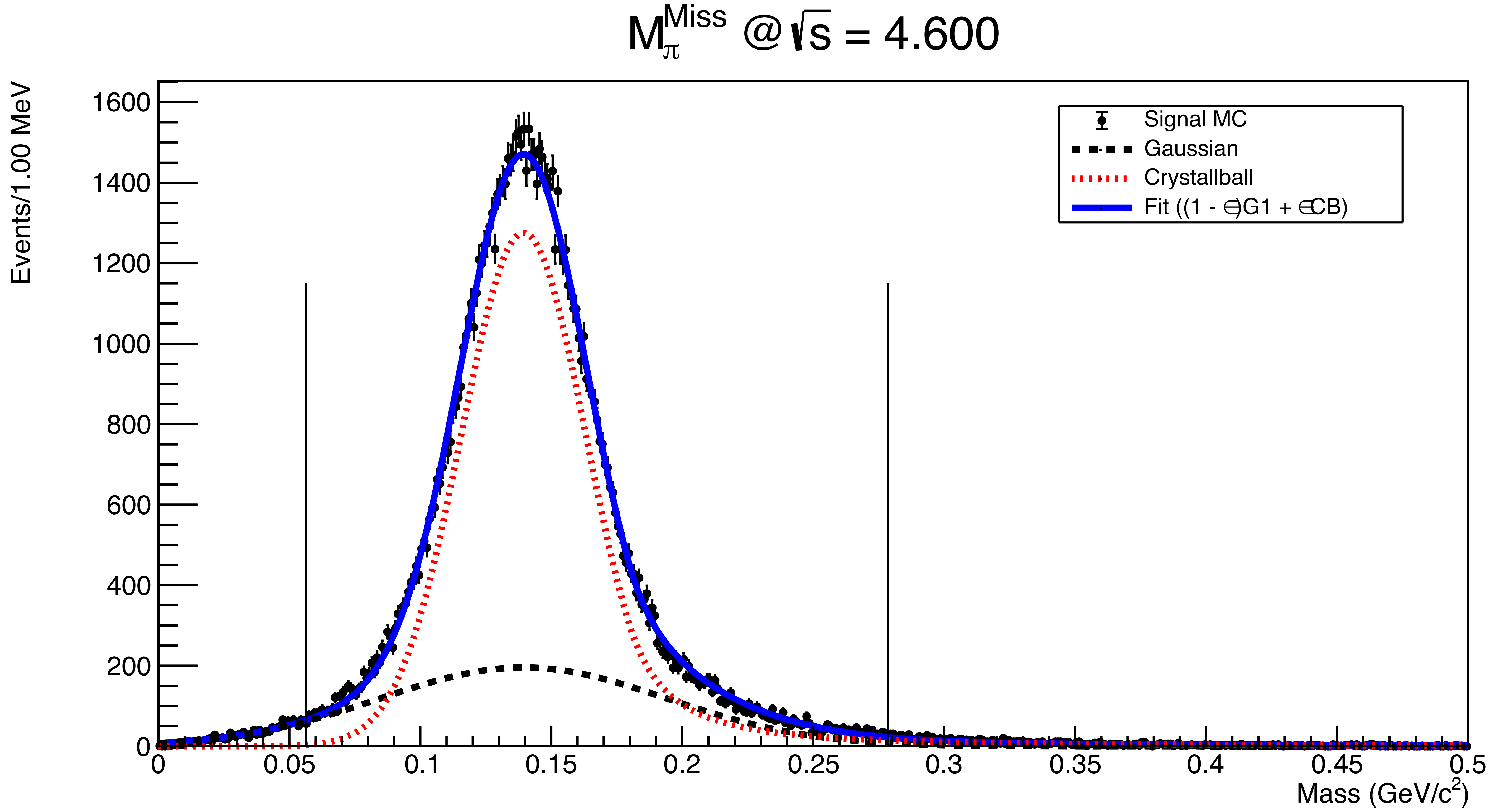
MC Studies

Just a bit more...

√s	σ(Miss-π)
4.600	28
4.612	29
4.626	30
4.640	32
4.660	34
4.680	35
4.700	37

Given the width (σ) of the distribution, ∀ √s:

$$-3\sigma < M < +5\sigma$$



MC Studies

Finally... the Efficiencies

√s = 4.660 GeV	Events	Efficiency [%]
NTot	300000	100
NCutCh	236736	78,91
NCutGoodCh	201704	67,23
NCut_5trks	73647	24,55
NCut_6trks	86103	28,70
NCut_Alltrks	159750	53,25

Esplicative sample (@$\sqrt{s}$ = 4.660 GeV)

But overall efficiency ~ 50% ∀ $\sqrt{s}$

While maintaining a high signal efficiency...

MC Studies

Finally… the Efficiencies

√s = 4.660 GeV	μμ	Hads	γγ	ττ	$\Lambda_c\Lambda_c$	ee	Tot	Efficiency [%]
NTot	22177980	91669850	10988890	17646380	3561640	17880870	163925610	100
NCutCh	290	30385767	46827	479421	1274044	267	32186616	19,63
NCutGood Ch	101	308412	71	5866	85	70	314605	0,19
NCut_5trk s	0	1248	0	0	0	0	1248	0,001
NCut_6trk s	0	1235	0	0	0	0	1235	0,001
NCut_Alltr ks	0	2483	0	0	0	0	2483	0,002

The “efficiency” in the background is ~ 20ppm

Once again, this is true ∀ √s

And virtually only hadron component is surviving after the mass window cuts

MC Studies

Finally… the Efficiencies

√s = 4.660 GeV	μμ	Hads	γγ	ττ	$\Lambda_c\Lambda_c$	ee	Tot	Efficiency [%]
NTot	22177980	91669850	10988890	17646380	3561640	17880870	163925610	100
NCutCh	290	30385767	46827	479421	1274044	267	32186616	19,63
NCutGood Ch	101	308412	71	5866	85	70	314605	0,19
NCut_5trk s	0	1248	0	0	0	0	1248	0,001
NCut_6trk s	0	1235	0	0	0	0	1235	0,001
NCut_Alltr ks	0	2483	0	0	0	0	2483	0,002

NB

The total number of events in the *hadronic* Inclusive MC is a x10 wrt data

Overall ~3000 events are to be expected (as it can be estimated from *PRD* **104** 052012)

MC Studies

We might've hit the bedrock?

rowNo	decay tree (decay initial-final states)	iDcyTr	nEtr	nCEtr
1	$e^+e^- \to \pi^+\pi^-\psi', \psi' \to \pi^+\pi^- J/\psi, \pi^+ \to \mu^+\nu_\mu, J/\psi \to \mu^+\mu^-, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+\nu_e\mu^+\mu^-\nu_\mu\bar{\nu}_\mu\pi^+\pi^-\pi^-)$	5	3617	3617
2	$e^+e^- \to \pi^+\pi^-\psi'\gamma^I, \psi' \to \pi^+\pi^- J/\psi, J/\psi \to \mu^+\mu^-$ $(e^+e^- \dashrightarrow \mu^+\mu^-\pi^+\pi^+\pi^-\pi^-\gamma^I)$	0	3233	6850
3	$e^+e^- \to \pi^+\pi^-\psi', \psi' \to \pi^+\pi^- J/\psi, \pi^+ \to \mu^+\nu_\mu, J/\psi \to e^+e^-, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+e^+e^-\nu_e\nu_\mu\bar{\nu}_\mu\pi^+\pi^-\pi^-)$	6	3193	10043
4	$e^+e^- \to \pi^+\pi^-\psi'\gamma^I, \psi' \to \pi^+\pi^- J/\psi, J/\psi \to e^+e^-$ $(e^+e^- \dashrightarrow e^+e^-\pi^+\pi^+\pi^-\pi^-\gamma^I)$	3	2835	12878
5	$e^+e^- \to \pi^+\pi^-\psi', \psi' \to \pi^+\pi^- J/\psi, J/\psi \to \mu^+\mu^-$ $(e^+e^- \dashrightarrow \mu^+\mu^-\pi^+\pi^+\pi^-\pi^-)$	16	2624	15502
6	$e^+e^- \to \pi^+\pi^-\psi', \psi' \to \pi^+\pi^- J/\psi, J/\psi \to e^+e^-$ $(e^+e^- \dashrightarrow e^+e^-\pi^+\pi^+\pi^-\pi^-)$	30	2407	17909
7	$e^+e^- \to \pi^+\pi^-\psi', \pi^+ \to \mu^+\nu_\mu, \psi' \to \pi^+\pi^- J/\psi, \mu^+ \to e^+\nu_e\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu, J/\psi \to \mu^+\mu^-,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+e^+\nu_e\nu_e\mu^+\mu^-\nu_\mu\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^-\pi^-)$	1	1459	19368
8	$e^+e^- \to \pi^+\pi^-\psi', \pi^+ \to \mu^+\nu_\mu, \psi' \to \pi^+\pi^- J/\psi, \mu^+ \to e^+\nu_e\bar{\nu}_\mu, \pi^+ \to \mu^+\nu_\mu, J/\psi \to e^+e^-,$ $\mu^+ \to e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+e^+e^+e^-\nu_e\nu_e\nu_\mu\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^-\pi^-)$	15	1339	20707
9	$e^+e^- \to \pi^+\pi^-\psi', \pi^+ \to \mu^+\nu_\mu, \psi' \to \pi^+\pi^- J/\psi, \mu^+ \to e^+\nu_e\bar{\nu}_\mu, J/\psi \to \mu^+\mu^-$ $(e^+e^- \dashrightarrow e^+\nu_e\mu^+\mu^-\nu_\mu\bar{\nu}_\mu\pi^+\pi^-\pi^-)$	2	1106	21813
10	$e^+e^- \to \pi^+\pi^-\psi', \pi^+ \to \mu^+\nu_\mu, \psi' \to \pi^+\pi^- J/\psi, \mu^+ \to e^+\nu_e\bar{\nu}_\mu, J/\psi \to e^+e^-$ $(e^+e^- \dashrightarrow e^+e^+e^-\nu_e\nu_\mu\bar{\nu}_\mu\pi^+\pi^-\pi^-)$	22	963	22776
11	$e^+e^- \to \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-, \pi^+ \to \mu^+\nu_\mu, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+\nu_e\nu_\mu\bar{\nu}_\mu\pi^+\pi^+\pi^-\pi^-\pi^-)$	32	581	23357
12	$e^+e^- \to \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-\gamma^I$ $(e^+e^- \dashrightarrow \pi^+\pi^+\pi^+\pi^-\pi^-\pi^-\gamma^I)$	8	507	23864
13	$e^+e^- \to \pi^+\pi^-\psi', \psi' \to \pi^+\pi^- J/\psi, \pi^- \to \mu^-\bar{\nu}_\mu, J/\psi \to \mu^+\mu^-$ $(e^+e^- \dashrightarrow \mu^+\mu^-\mu^-\bar{\nu}_\mu\pi^+\pi^+\pi^-)$	37	359	24223
14	$e^+e^- \to \pi^+\pi^-\psi', \psi' \to \pi^+\pi^- J/\psi, \pi^- \to \mu^-\bar{\nu}_\mu, J/\psi \to e^+e^-$ $(e^+e^- \dashrightarrow e^+e^-\mu^-\bar{\nu}_\mu\pi^+\pi^+\pi^-)$	31	317	24540
15	$e^+e^- \to \pi^+\pi^-\psi', \psi' \to \pi^+\pi^- J/\psi, \pi^+ \to \mu^+\nu_\mu, \pi^- \to \mu^-\bar{\nu}_\mu, J/\psi \to \mu^+\mu^-, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+\nu_e\mu^+\mu^-\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^+\pi^-)$	60	316	24856
16	$e^+e^- \to \pi^+\pi^-\psi', \psi' \to \pi^+\pi^- J/\psi, \pi^+ \to \mu^+\nu_\mu, \pi^- \to \mu^-\bar{\nu}_\mu, J/\psi \to e^+e^-, \mu^+ \to e^+\nu_e\bar{\nu}_\mu$ $(e^+e^- \dashrightarrow e^+e^+e^-\nu_e\mu^-\nu_\mu\bar{\nu}_\mu\bar{\nu}_\mu\pi^+\pi^-)$	35	284	25140

Out of **~30000** total **IncMC events**, more of the **80%** of events are from **ππ ψ(2S)** continuum **and multi-π states**

Signal MC Studies

Event Selection (Update)

Topology dependent KALMAN Fits

$2\ell 4\pi$

6C Kalman fit

1C on the $M_{J/\psi}$
1C on the $M_{\psi(2S)}$
4C on the p_{Tot} = (0.051, 0, 0, $M_{Y(4660)}$)

The $\pi\pi$ couples are selected via the best χ^2

$2\ell 3\pi$

6C Kalman fit

1C on the $M_{J/\psi}$
1C on the $M_{\psi(2S)}$
4C on the p_{Tot} = (0.051, 0, 0, $M_{Y(4660)}$)

π_{Miss} either from prompt production or from $\psi(2S)$ decay

$\pi\pi$ and $\pi\pi_{Miss}$ couples are selected by minimising $M^{Reco}_{\psi(2S)}$-$M^{PDG}_{\psi(2S)}$

Signal MC Studies

Event Selection (Update)

Topology dependent KALMAN Fits

$2\ell 4\pi$

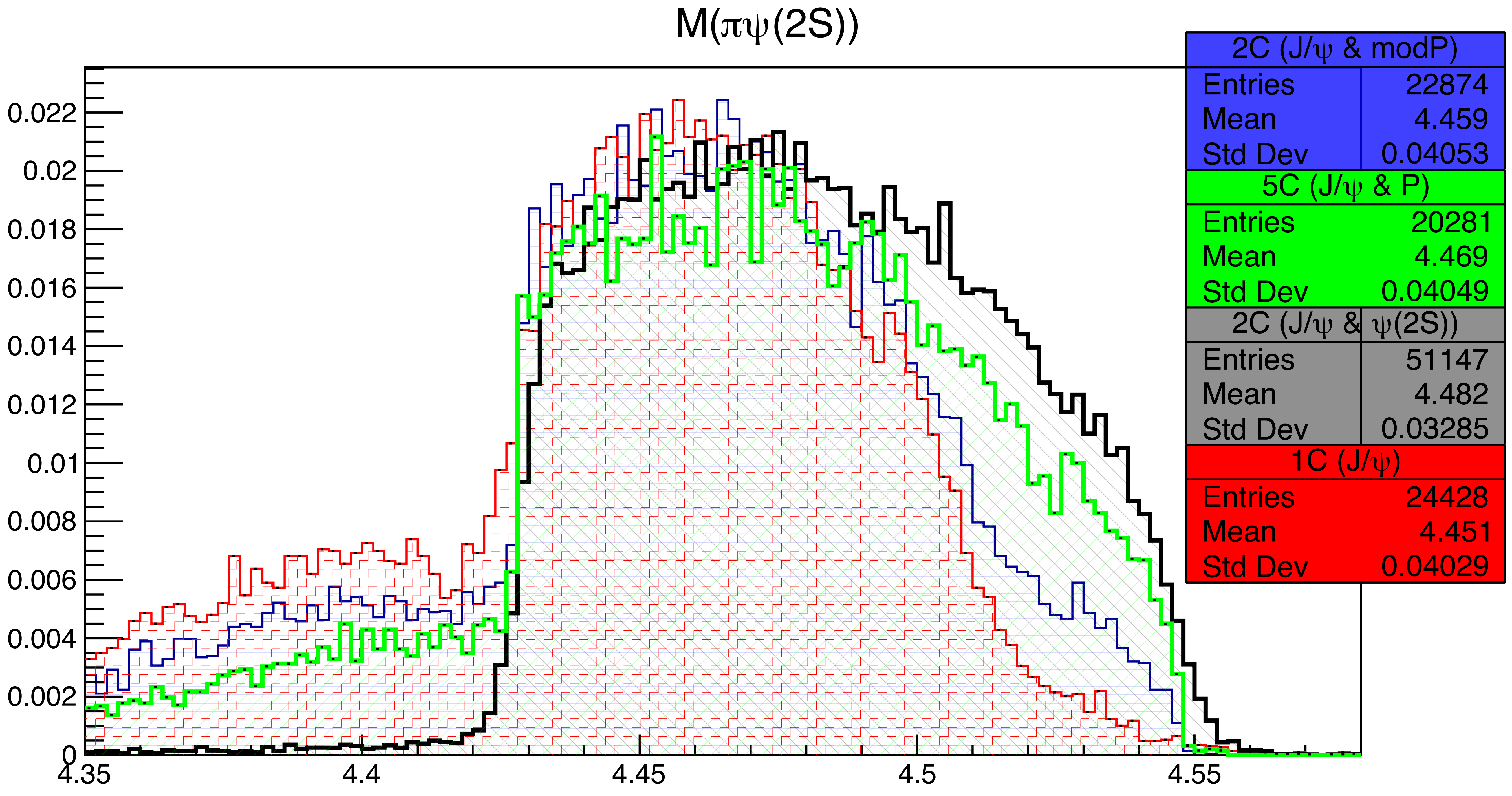
6C Kalman fit

1C on the $M_{J/\psi}$

1C on the $M_{\psi(2S)}$

4C on the p_{Tot} = (0.051, 0, 0, $M_{Y(4660)}$)

The ππ couples are selected via the best χ^2



Summary & Outlook

The **event selection** is **finalised**
(just to understand that hiccup regarding the Z_c mass)

Topology is studied and well defined

Once the Z_c distribution is understood, **efficiencies** will be **re-estimated**

With all these information a **study of significance** will be performed and…

then I'll proceed **unboxing data**

Thanks for your attention!

Back-up Slides

DEC Cards

Y and Z_c Resonant

```
noPhotos

Decay dummy00_1
  0.5000 dummy10_1 pi- PHSP;
  0.5000 anti-dummy10_1 pi+ PHSP;
Enddecay

Decay dummy10_1
  1.0000 pi+ psi(2S) PHSP;
Enddecay

Decay anti-dummy10_1
  1.0000 pi- psi(2S) PHSP;
Enddecay

Decay psi(2S)
  1.0000 pi+ pi- J/psi PHSP;
Enddecay

Decay J/psi
  0.5000 e+ e- PHSP;
  0.5000 mu+ mu- PHSP;
Enddecay

End
```

Y(4660)
$M_Y = 4633 \pm 7$ MeV
$\sigma_Y = 64 \pm 9$ MeV

$Z_c(4430)$
$M_{Zc} = 4478^{+15}_{-18}$ MeV
$\sigma_{Zc} = 181 \pm 31$ MeV

VVPIPI

PHOTOS VLL
PHOTOS VLL

Signal MC sample
300k events

DEC Cards

Non-resonant Continuum

```
noPhotos

Decay dummy00_1
  0.5000 dummy10_1 pi- PHSP;
  0.5000 anti-dummy10_1 pi+ PHSP;
Enddecay

Decay dummy10_1
  1.0000 pi+ psi(2S) PHSP;
Enddecay

Decay anti-dummy10_1
  1.0000 pi- psi(2S) PHSP;
Enddecay

Decay psi(2S)
  1.0000 pi+ pi- J/psi PHSP;
Enddecay

Decay J/psi
  0.5000 e+ e- PHSP;
  0.5000 mu+ mu- PHSP;
Enddecay

End
```

VVPIPI

PHOTOS VLL
PHOTOS VLL

```
noPhotos
Particle vpho 4.633 0

Decay vpho
  1.0000 pi+ pi- psi(2S) PHSP;
Enddecay

Decay psi(2S)
  1.0000 pi+ pi- J/psi PHSP;
Enddecay

Decay J/psi
  0.5000 e+ e- PHSP;
  0.5000 mu+ mu- PHSP;
Enddecay

End
```

VVPIPI

VVPIPI

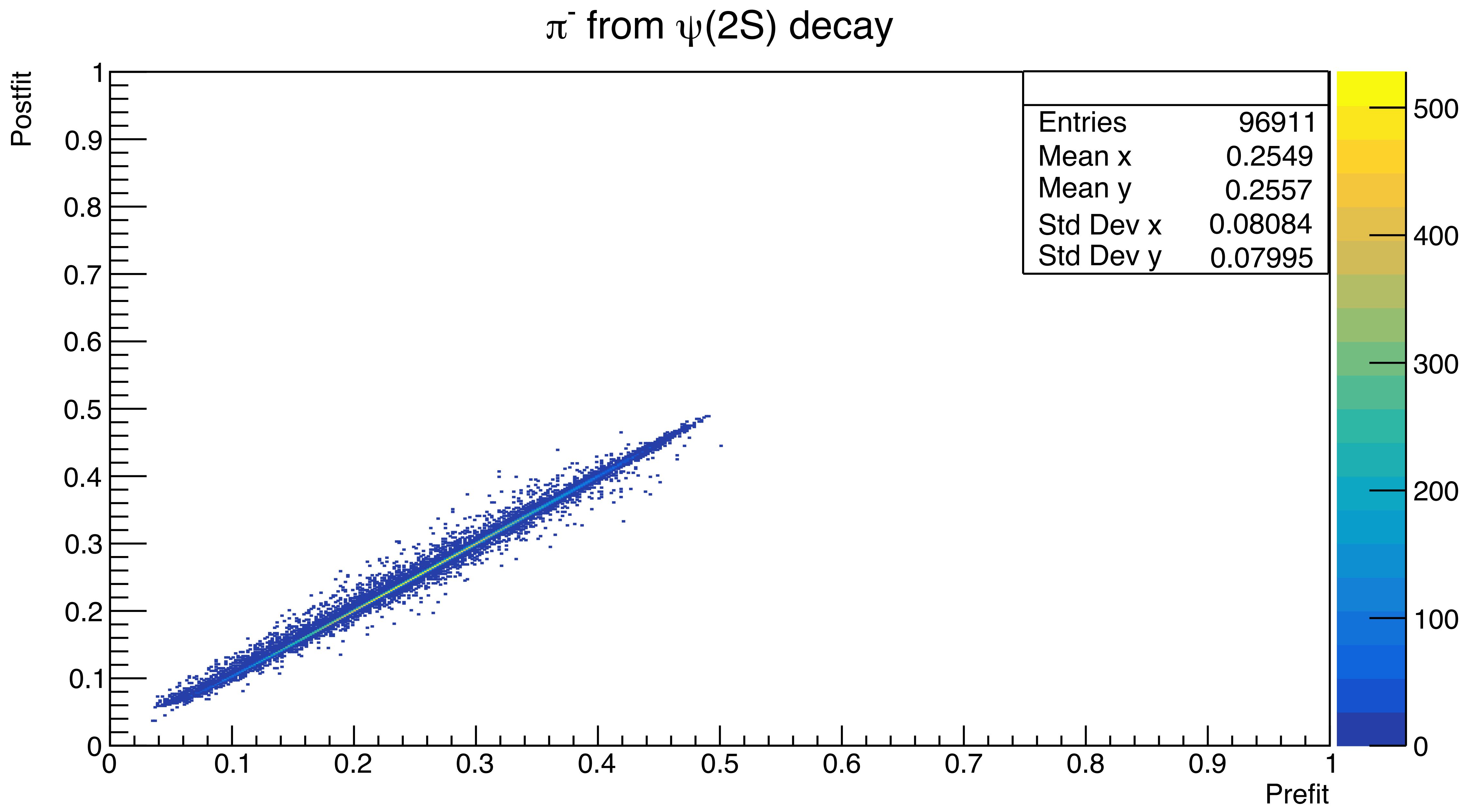
PHOTOS VLL
PHOTOS VLL

MC samples
300k events

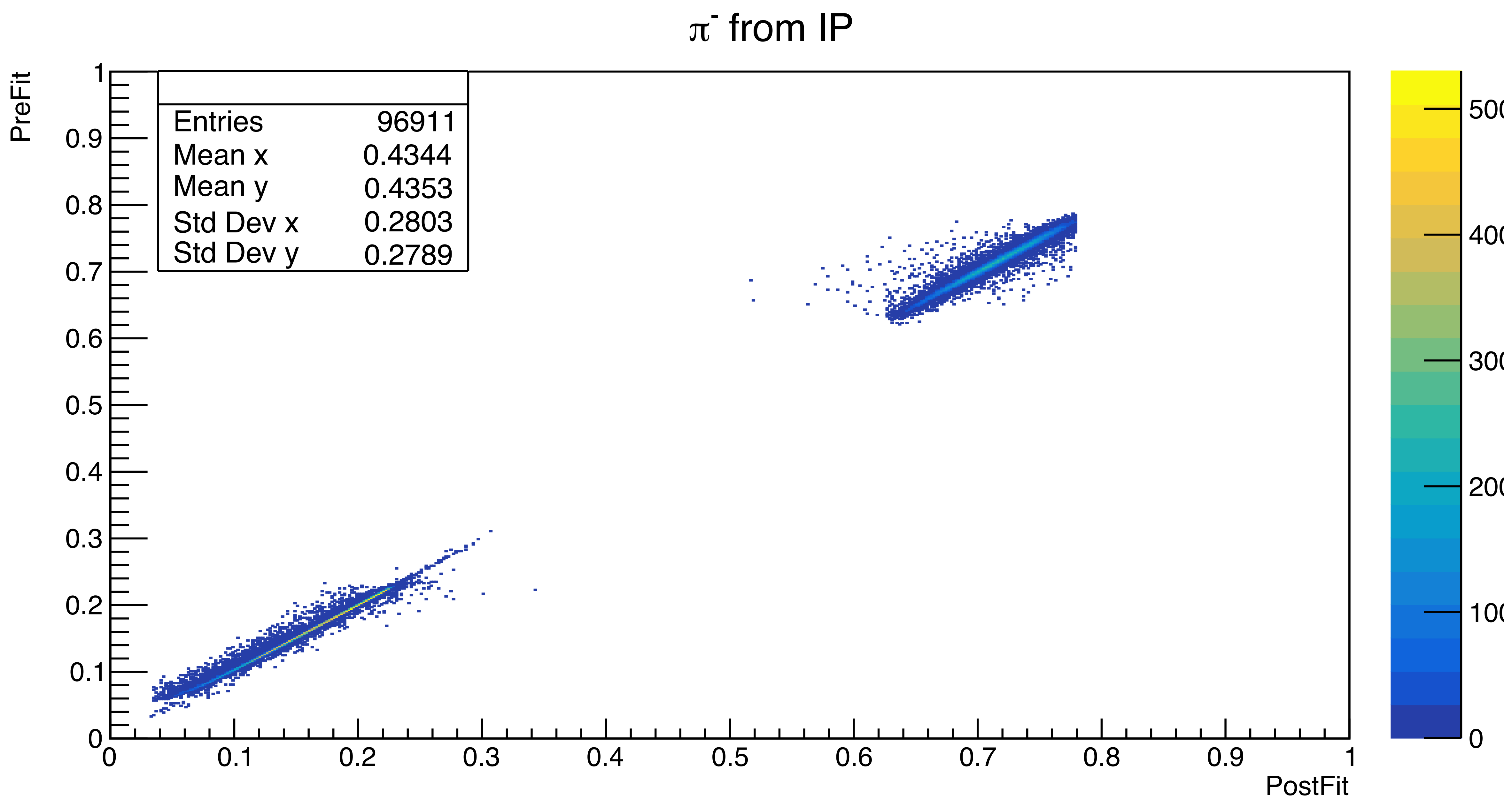
“Panettone” gate

Sig MC

π momenta



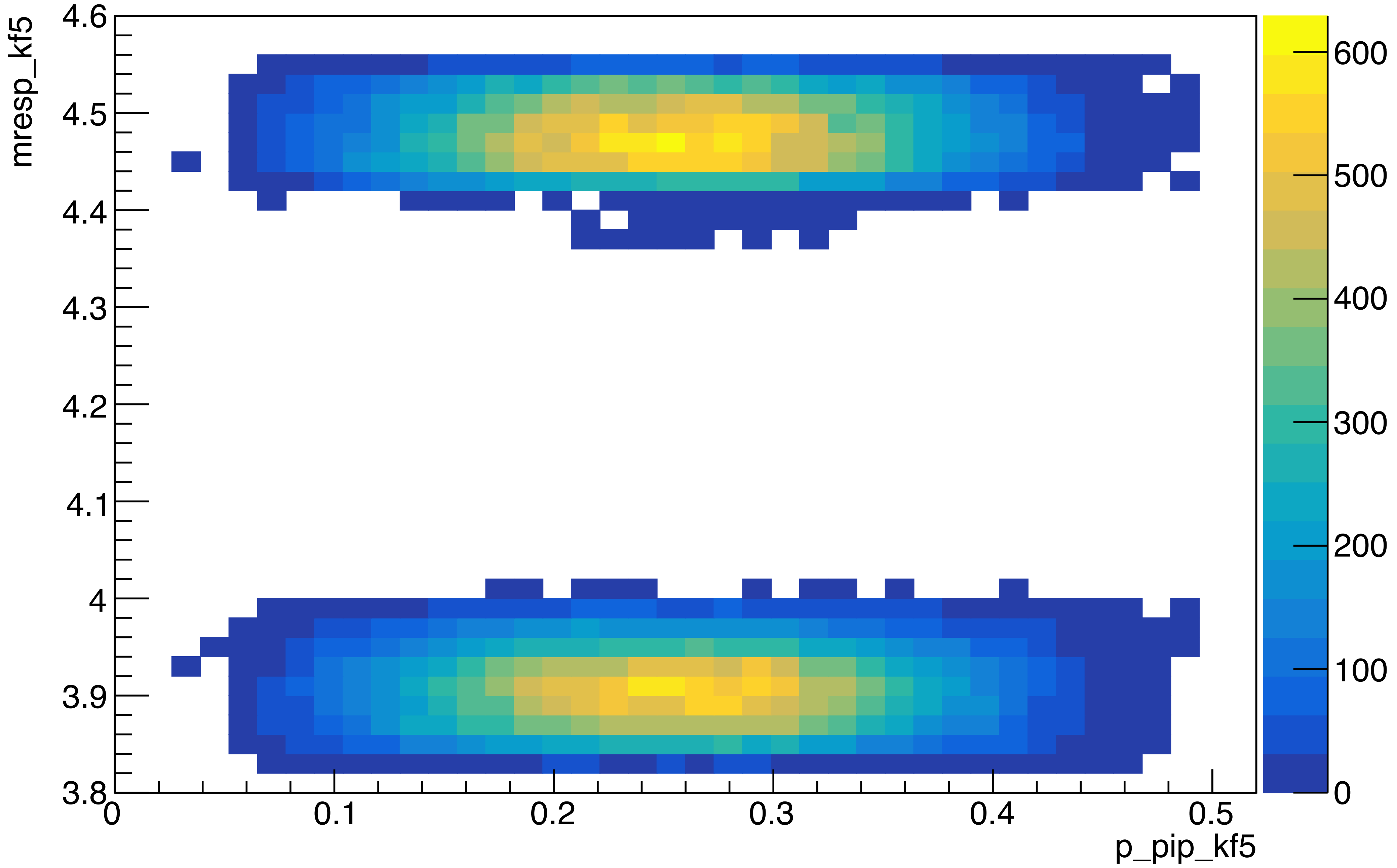
$2\ell\,4\pi$



“Panettone” gate

Sig MC

Z_c mass *vs* π from ψ(2S) **Z_c mass *vs* π momenta**



2ℓ 4π

Invariant mass of the ππ couple of the ee —> ππ ψ(2S)

Z_c mass *vs* π from IP