復旦大學
Fudan University

Study of Λ semileptonic decay $\Lambda \to p e^- \bar{\nu}_e$

Shun Wang

2021.10.26

Outline

Same to the talk at the collaboration meeting in summer of 2021

Double Tag

Event selection

Selection criteria

➢ Good Charged Tracks

- ✓ No vertex requirement is made due to existence of Λ
- ✓ $|cos\theta|$<0.93
- ✓ $N_{good}^{Tracks} = 4$
- ✓ $\sum_i^4 Q_i = 0$

➢ Particle Identification (only for electron)

Use Dedx, Tof1, Tof2 and EMC

- ✓ $\frac{\text{Prob(e)}}{\text{Prob(e)+Prob(π)+Prob(k)}} > 0.8$
- ✓ Prob(e) > 0.001

The other track is assumed to be a proton.

Event selection

Dominant background $J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to p\pi^-, \bar{\Lambda} \to \bar{p}\pi^+$

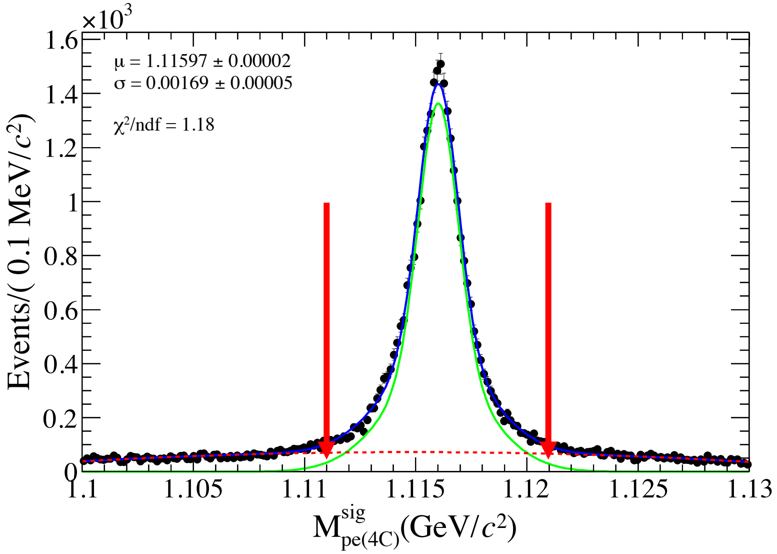
- **Reconstruction of Λ**
  - ✓ Vertex and Second Vertex Fit for Λ based on $p\pi^-$ hypothesis
  - ✓ Vertex/second vertex fit: $\chi^2 < 100$
  - ✓ $(L/\sigma_L) > 2$

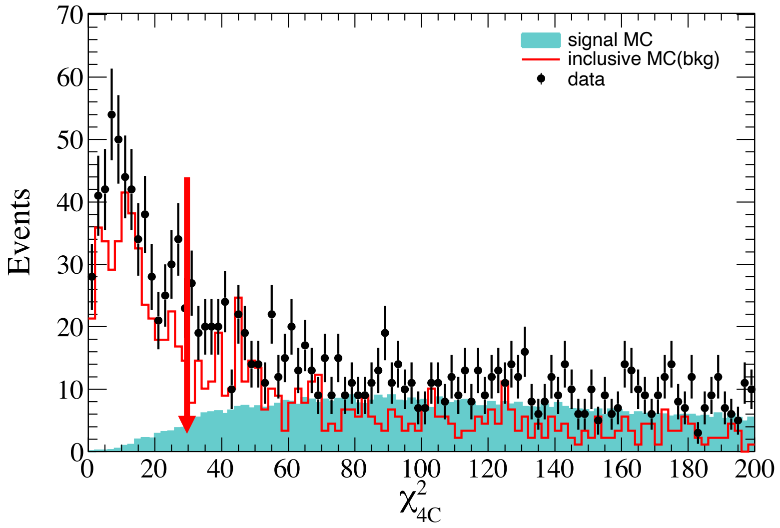
- **4C kinematic fit**
  - ✓ A 4C kinematic fit is performed to the two virtual particles (Λ and $\bar{\Lambda}$) hypothesis
  - ✓ $\chi^2_{4C} > 30$

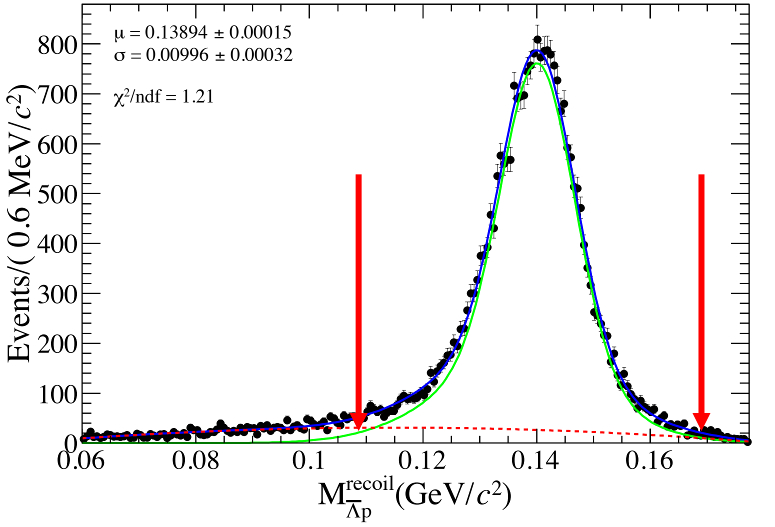
- **Mass of pe after 4C kinematic fit**
  - ✓ For this background, a Λ can be reconstructed based on $p\pi^-$ hypothesis
  - ✓ Veto 3σ: $\left|M^{sig}_{pe(4C)} - m^{PDG}_{\Lambda}\right| > 0.005\ (GeV/c^2)$

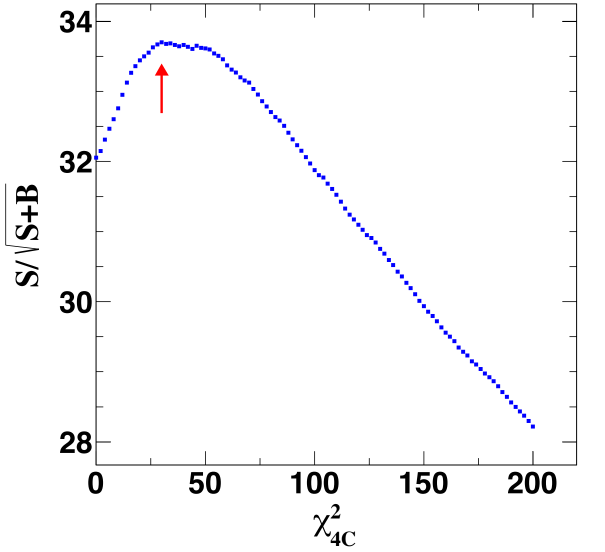
- **Recoiling mass of $\bar{\Lambda}$p**
  - ✓ For this background, recoiling mass of $\bar{\Lambda}$p is expected to be the invariant mass of π
  - ✓ Veto 3σ: $\left|M^{recoil}_{\bar{\Lambda}p} - m^{PDG}_{\pi}\right| > 0.030\ (GeV/c^2)$

Event selection

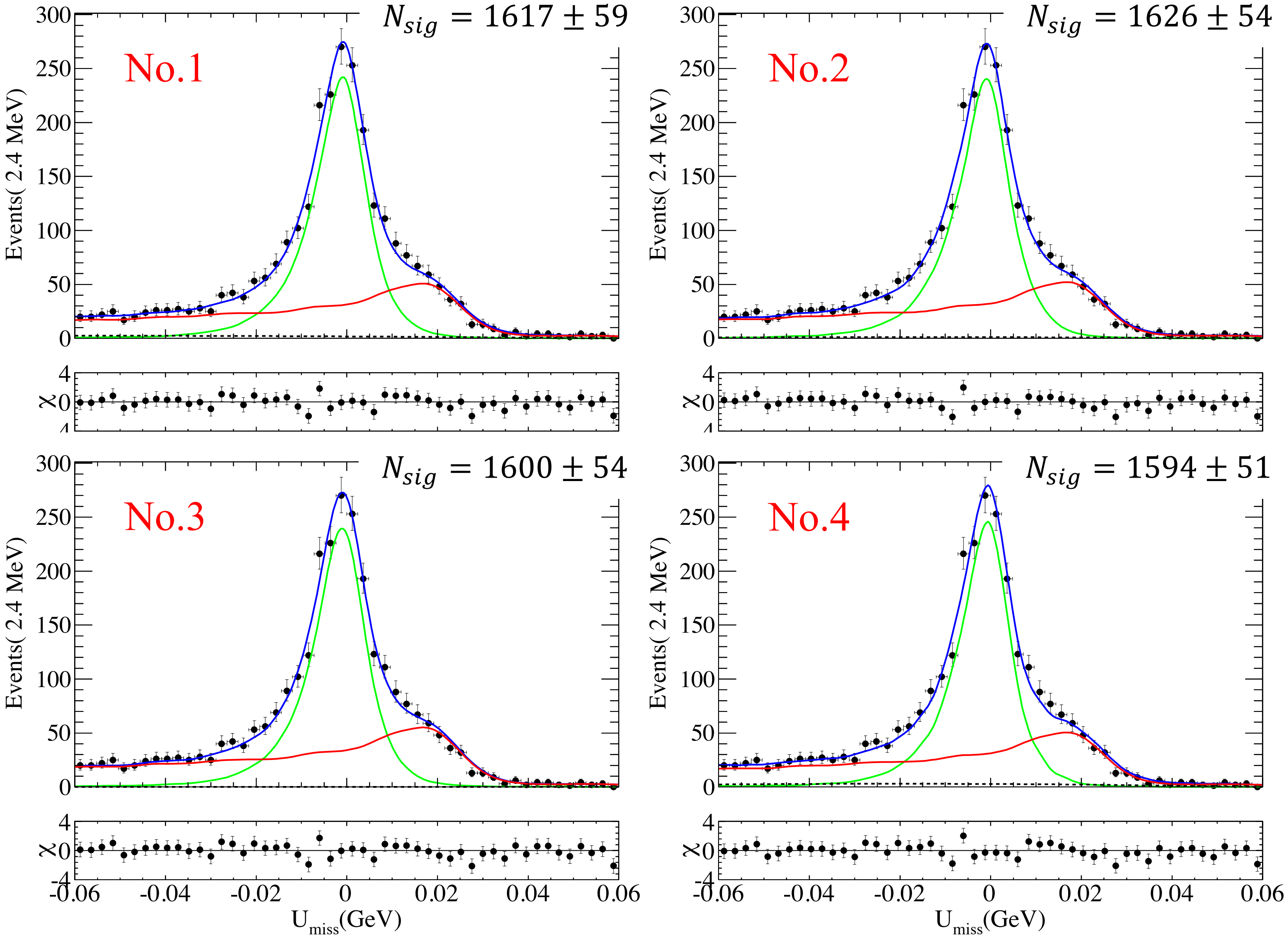








Fitting results



No.1 Varvara's formalism with "_corr2"

No.2 Varvara's formalism with "_corr3"

No.3 Ru-Min Wang's formalism PRD 100, 076008

No.4 Hybrid formalism with "_RMW2"

No.	χ^2/ndf	BF($\times 10^{-4}$)	Deviation
1	0.66	7.51 ± 0.27	2.66σ
2	0.68	7.49 ± 0.25	2.90σ
3	0.69	8.13 ± 0.27	0.62σ
4	0.73	7.23 ± 0.23	4.05σ

$$(PDG)\mathcal{B}_{(\Lambda\to pe^-\overline{\nu}_e)} = (8.32 \pm 0.14)\times 10^{-4}$$

Cut flow

Selection Criteria		Relative Efficiency(%)			
	Different signal MC	No.1	No.2	No.3	No.4
Double tag	Reconstruction of Λ	80.89	81.18	80.81	81.01
	$\chi^2_{4C} > 30$	98.89	98.88	99.36	98.86
	$\left\|M^{recoil}_{\bar{\Lambda}p} - m^{PDG}_{\pi}\right\| > 0.030\ (GeV/c^2)$	59.78	59.78	51.71	59.81
	$\left\|M^{sig}_{pe(4C)} - m^{PDG}_{\Lambda}\right\| > 0.005\ (GeV/c^2)$	80.29	80.13	78.37	80.10
Sum		8.16	8.23	7.45	8.35

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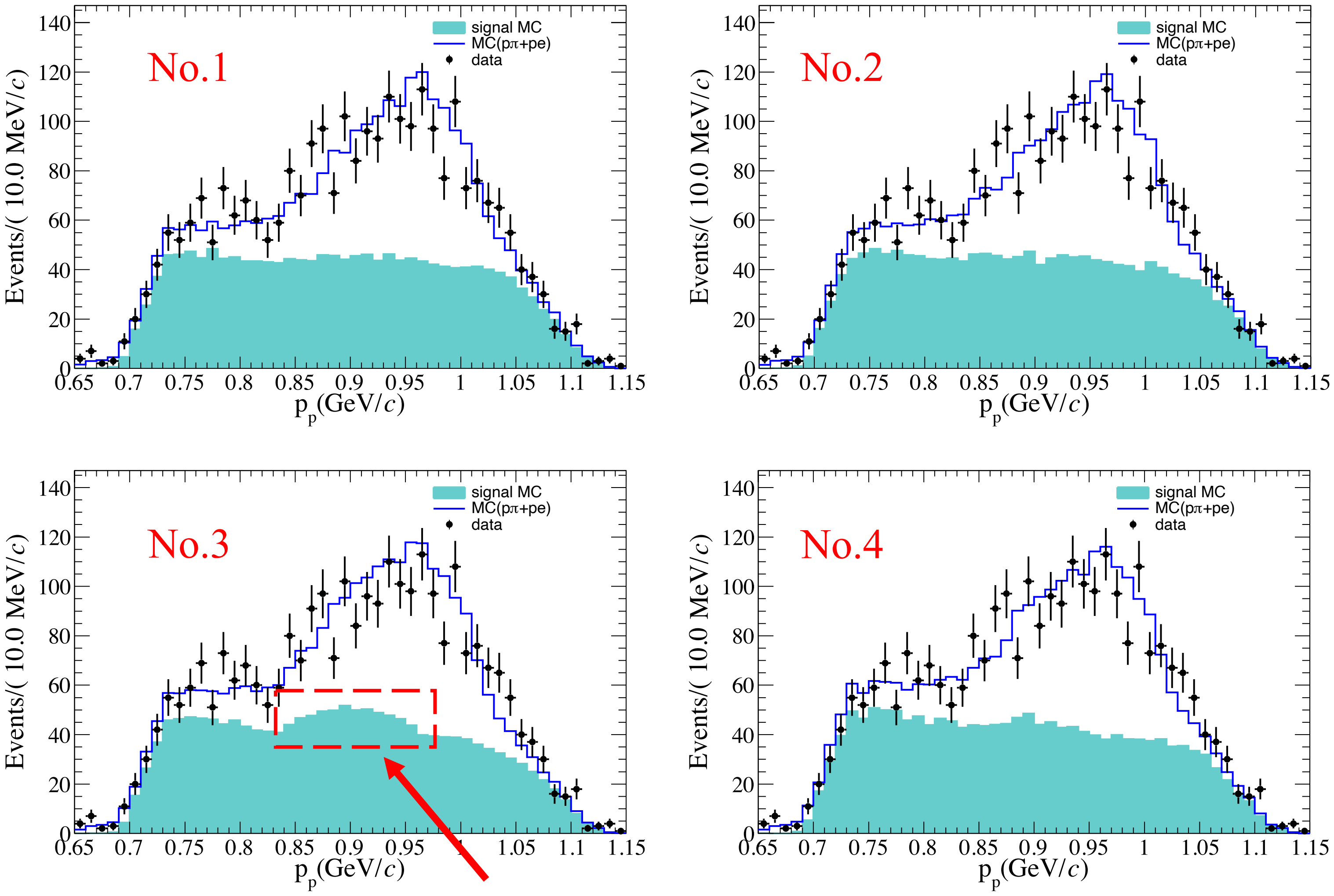
Comparison between MC and data



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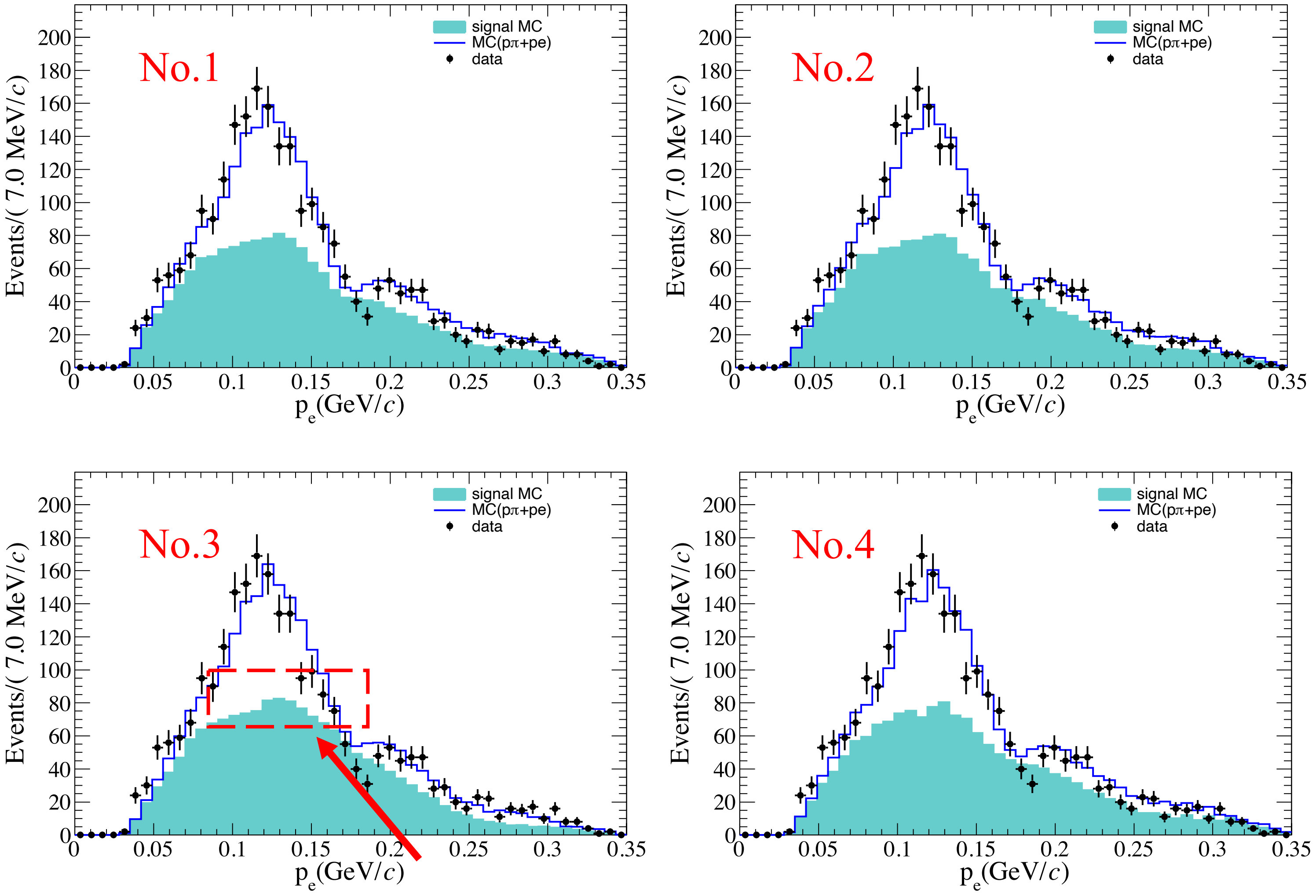

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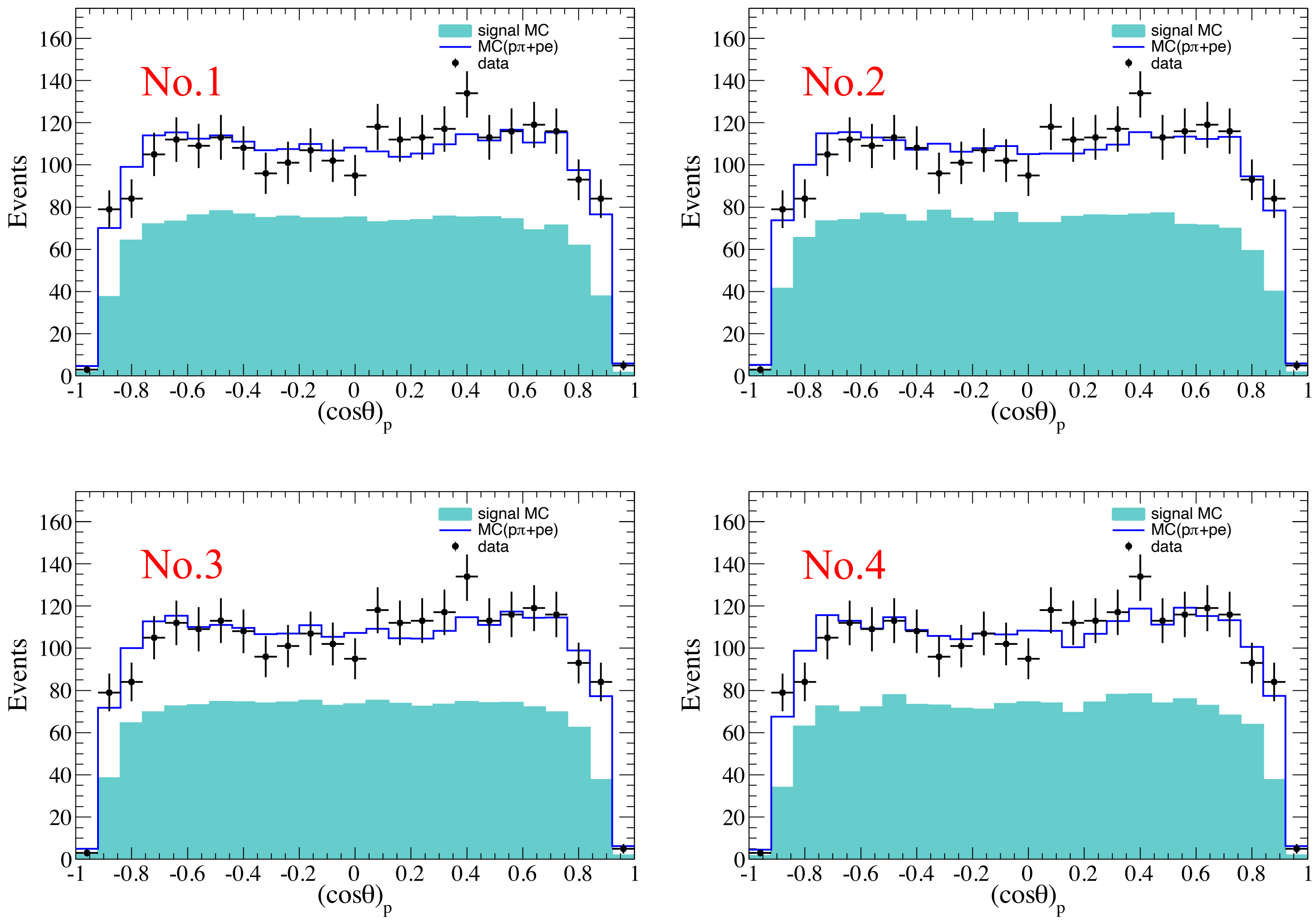

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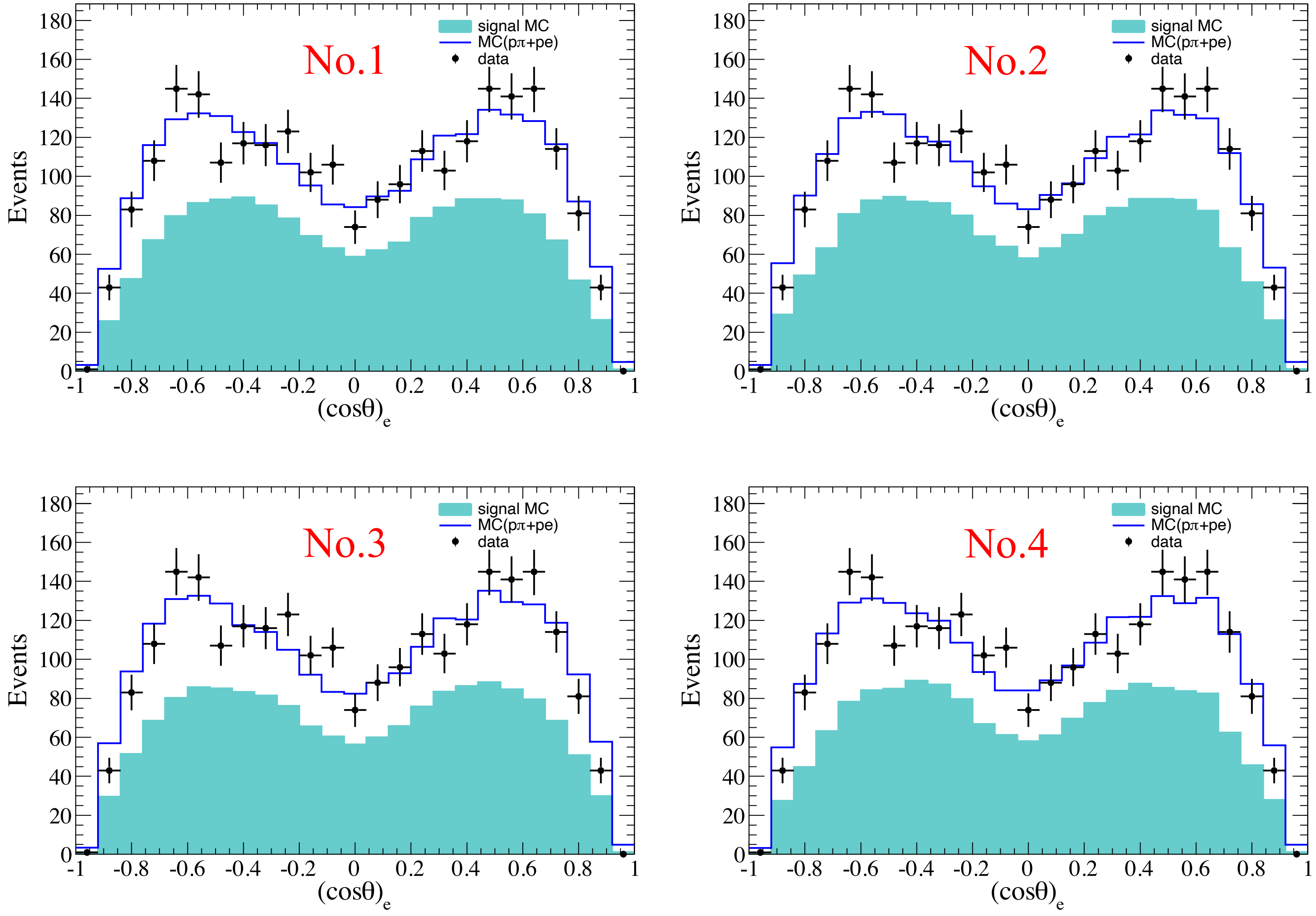

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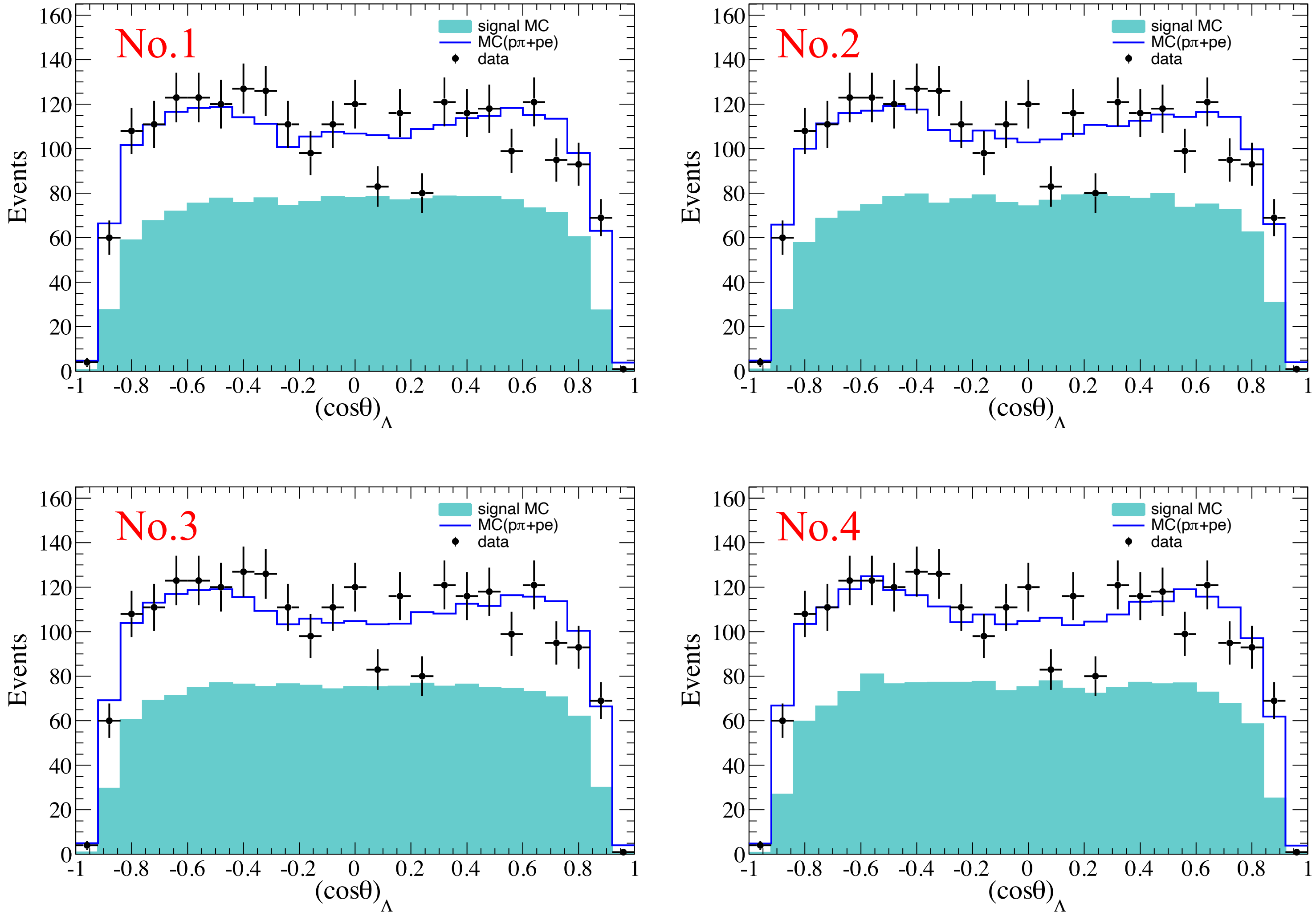

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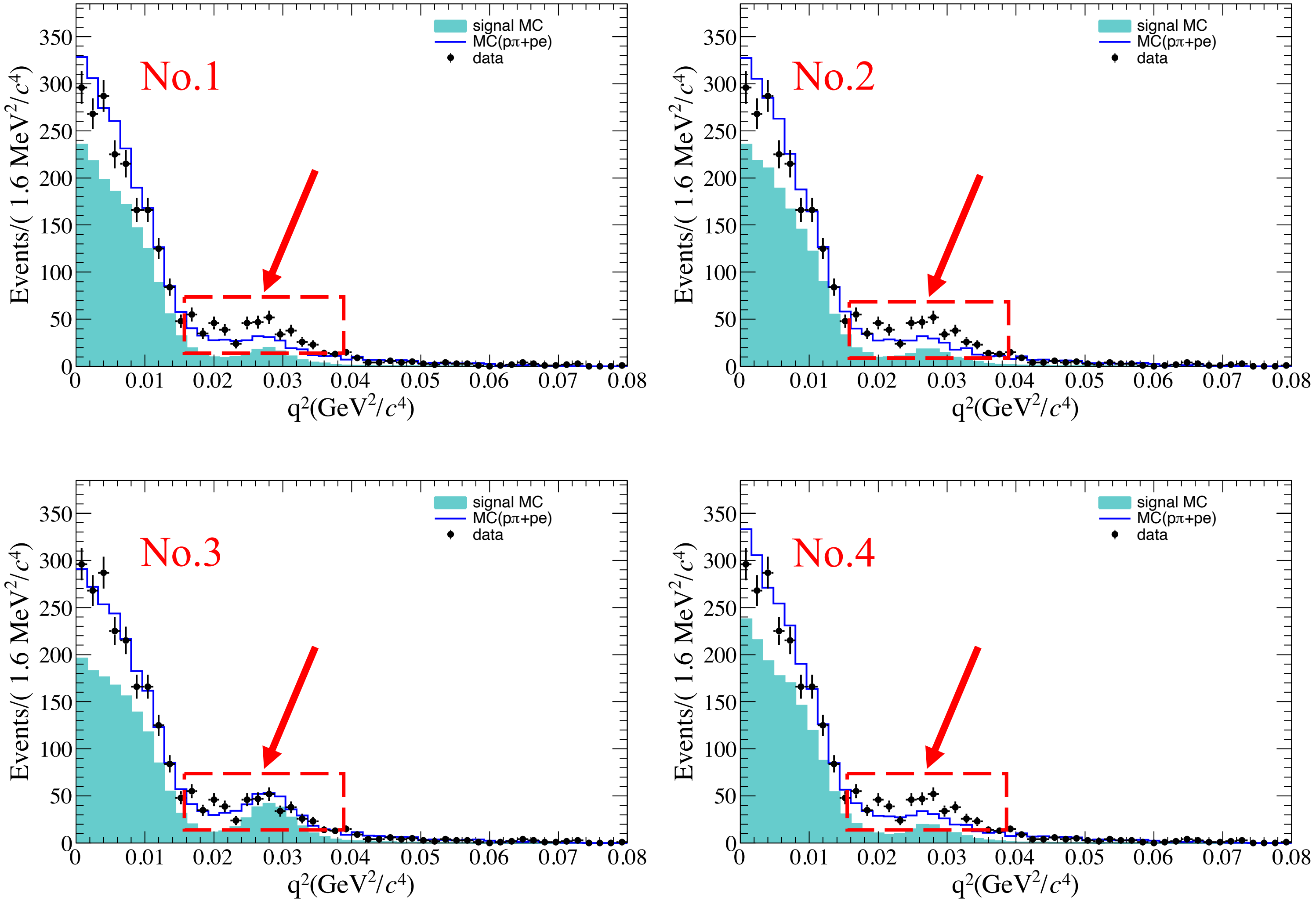

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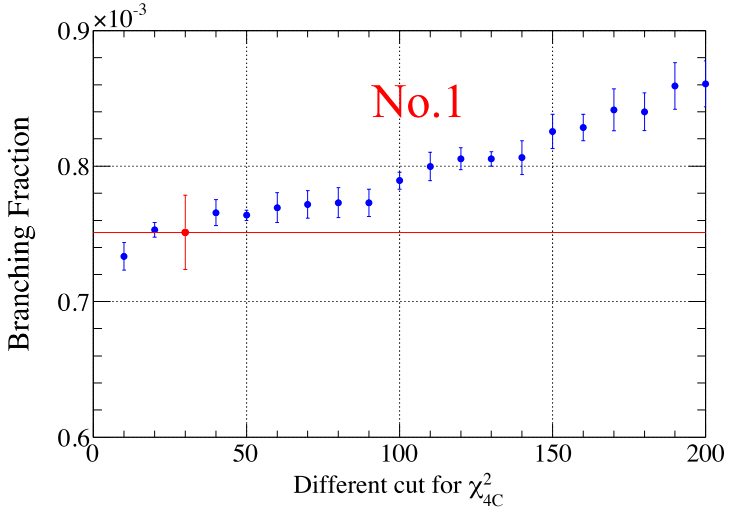
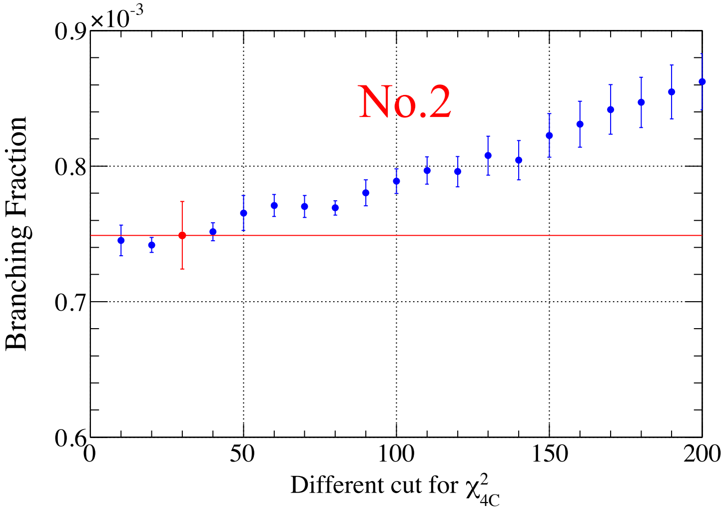
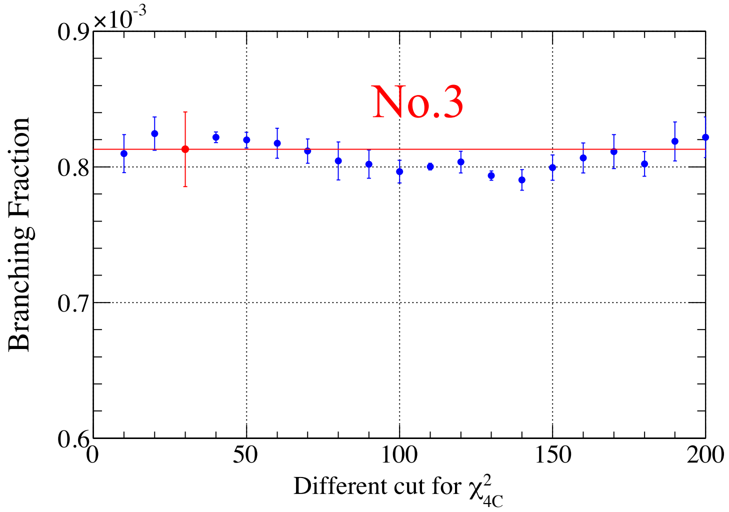
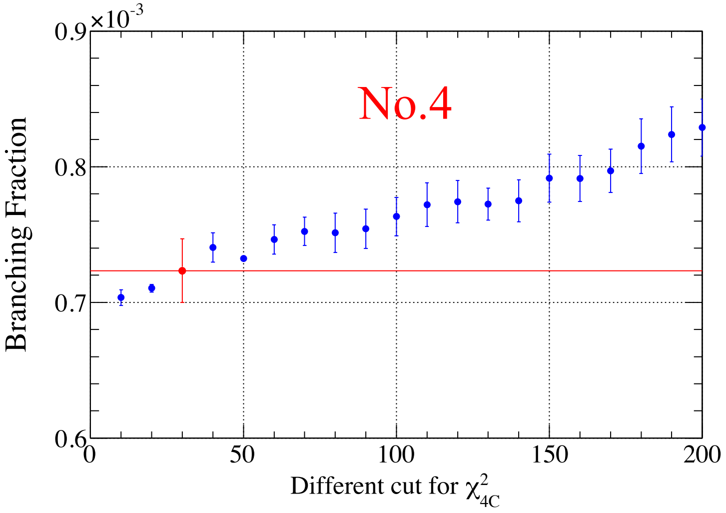
Barlow test









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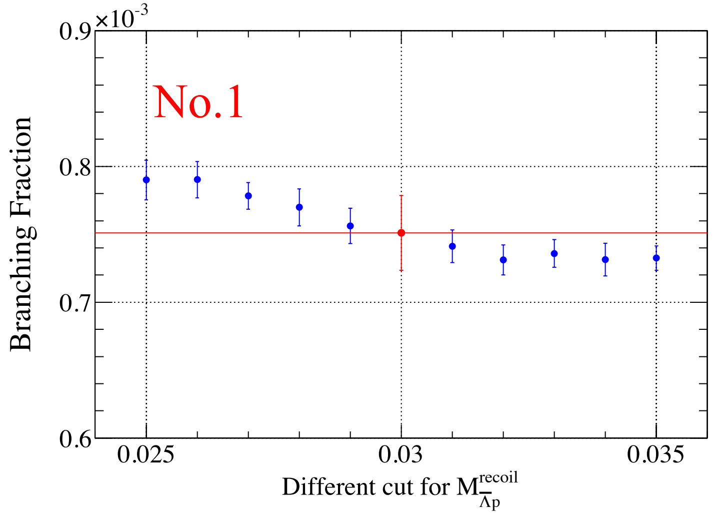

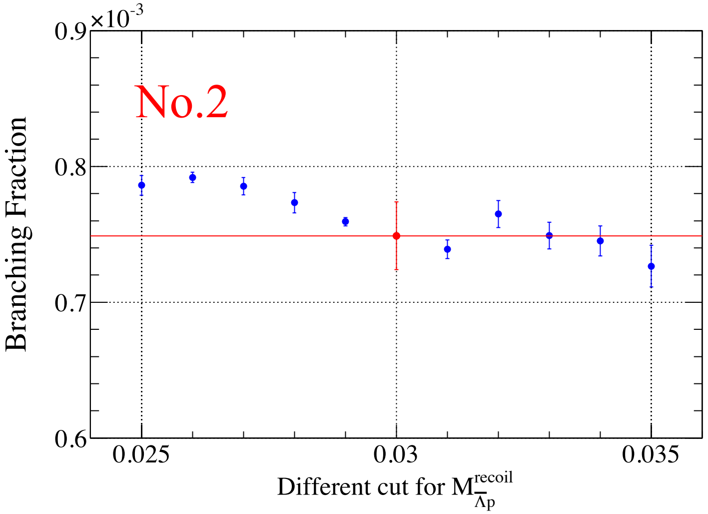

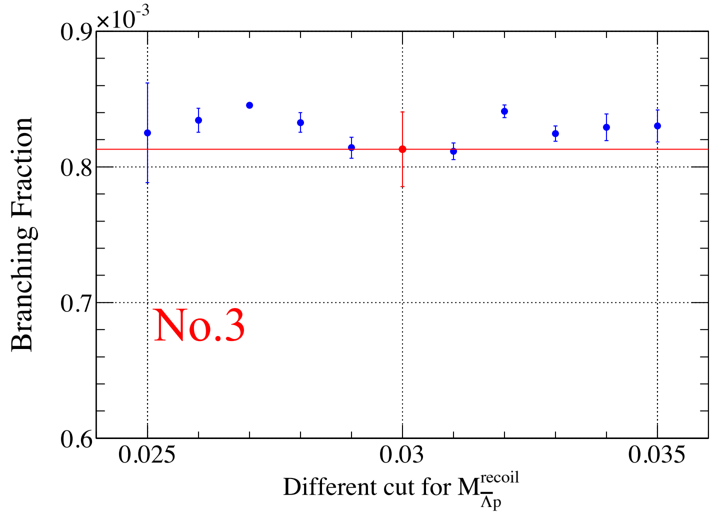

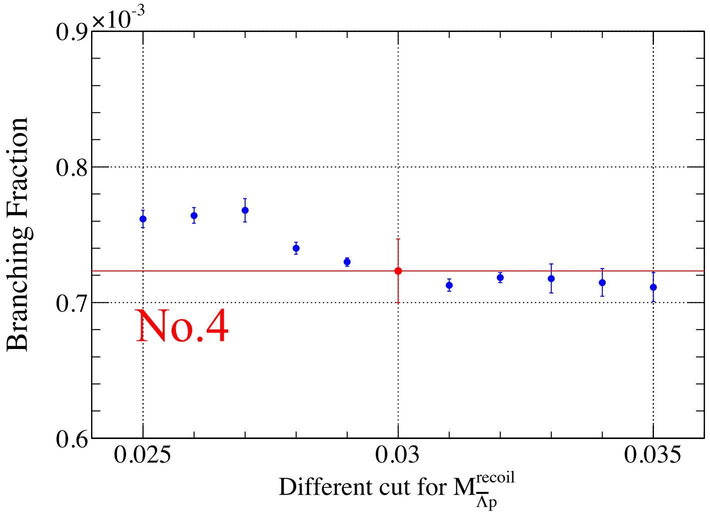

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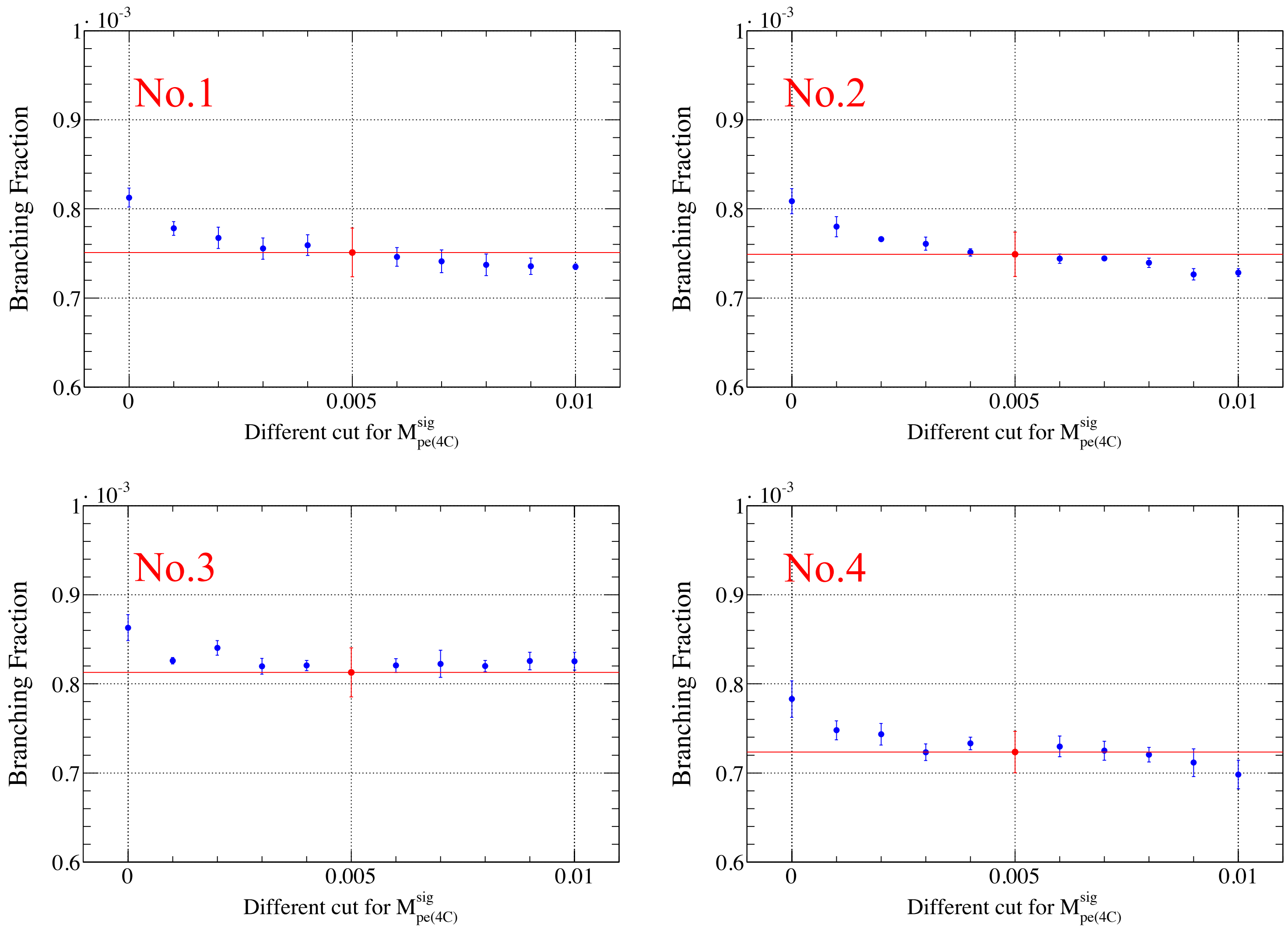

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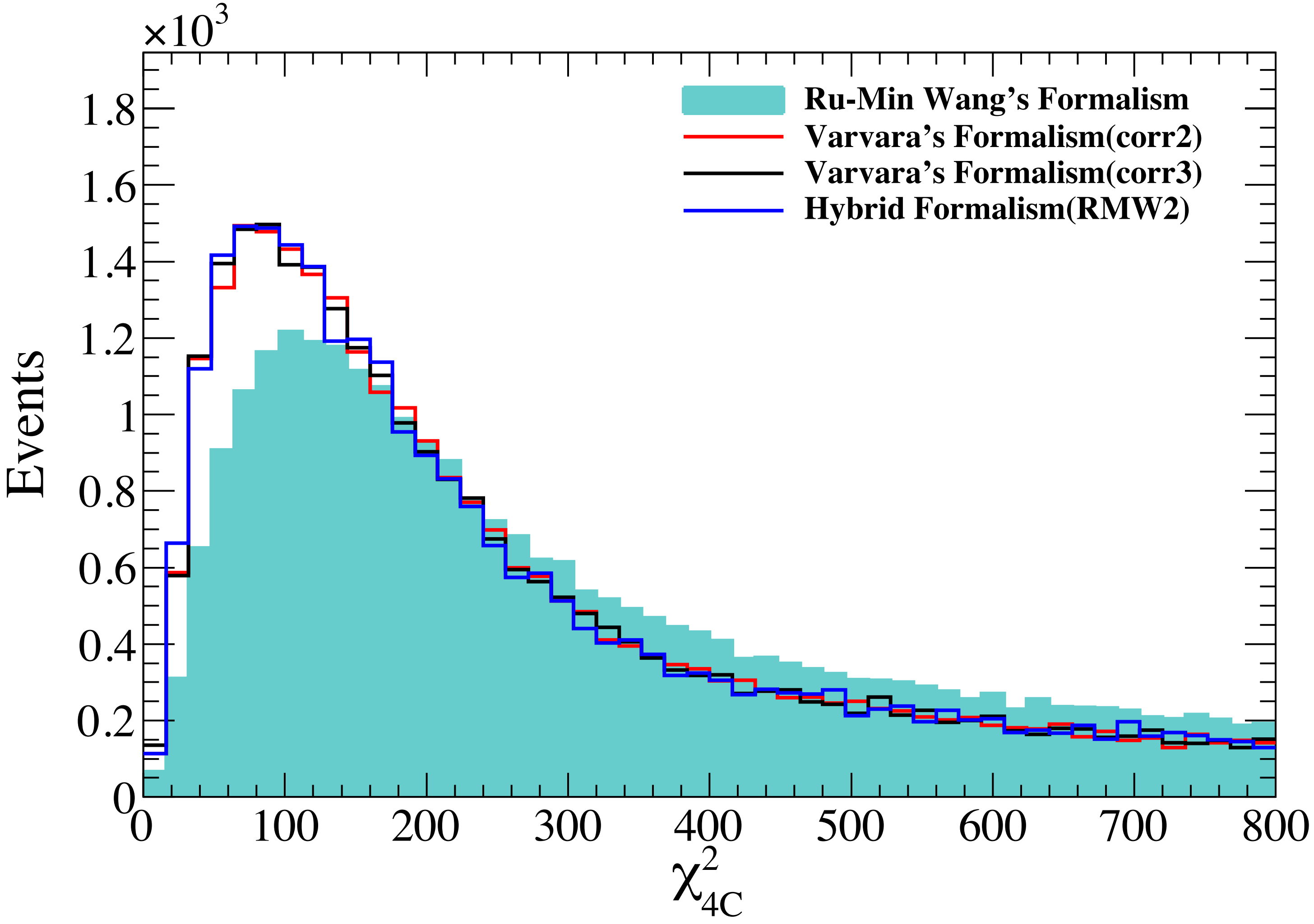
Compare the distributions from different MC



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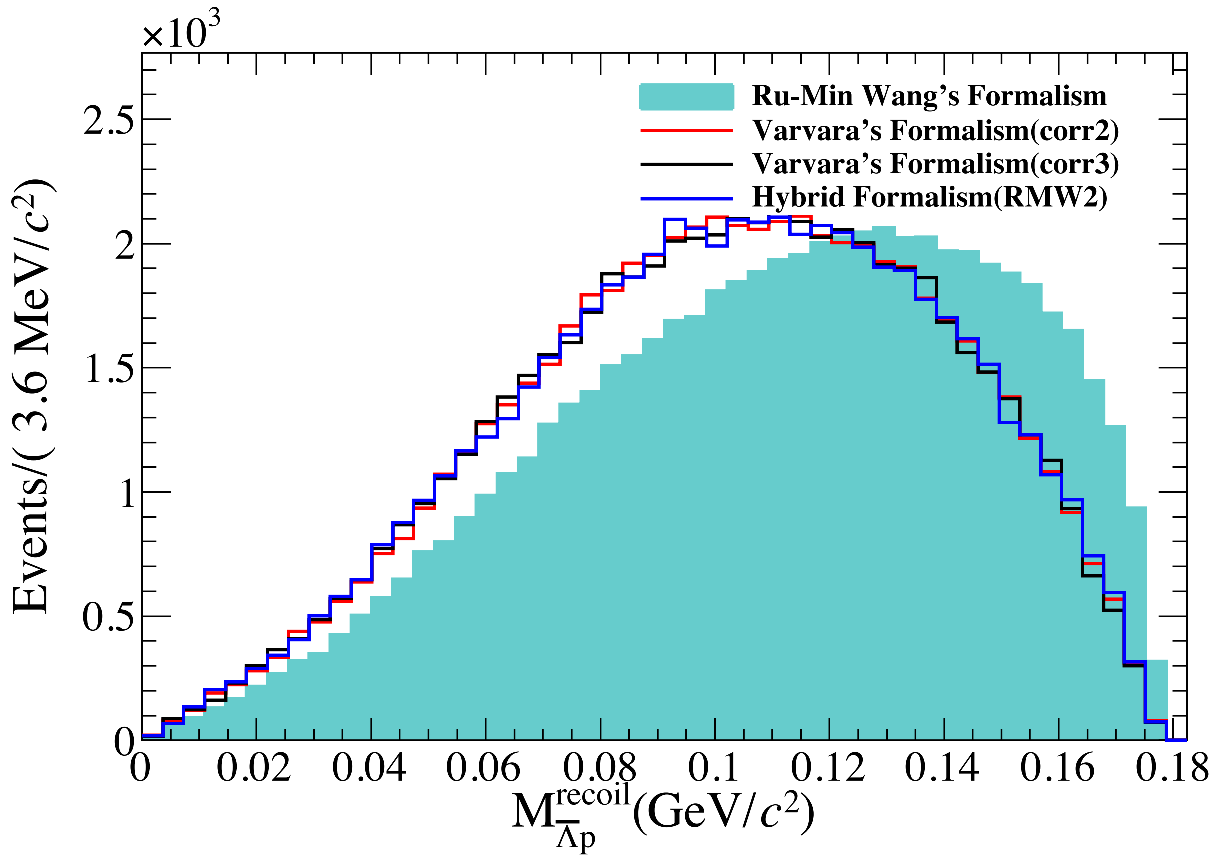

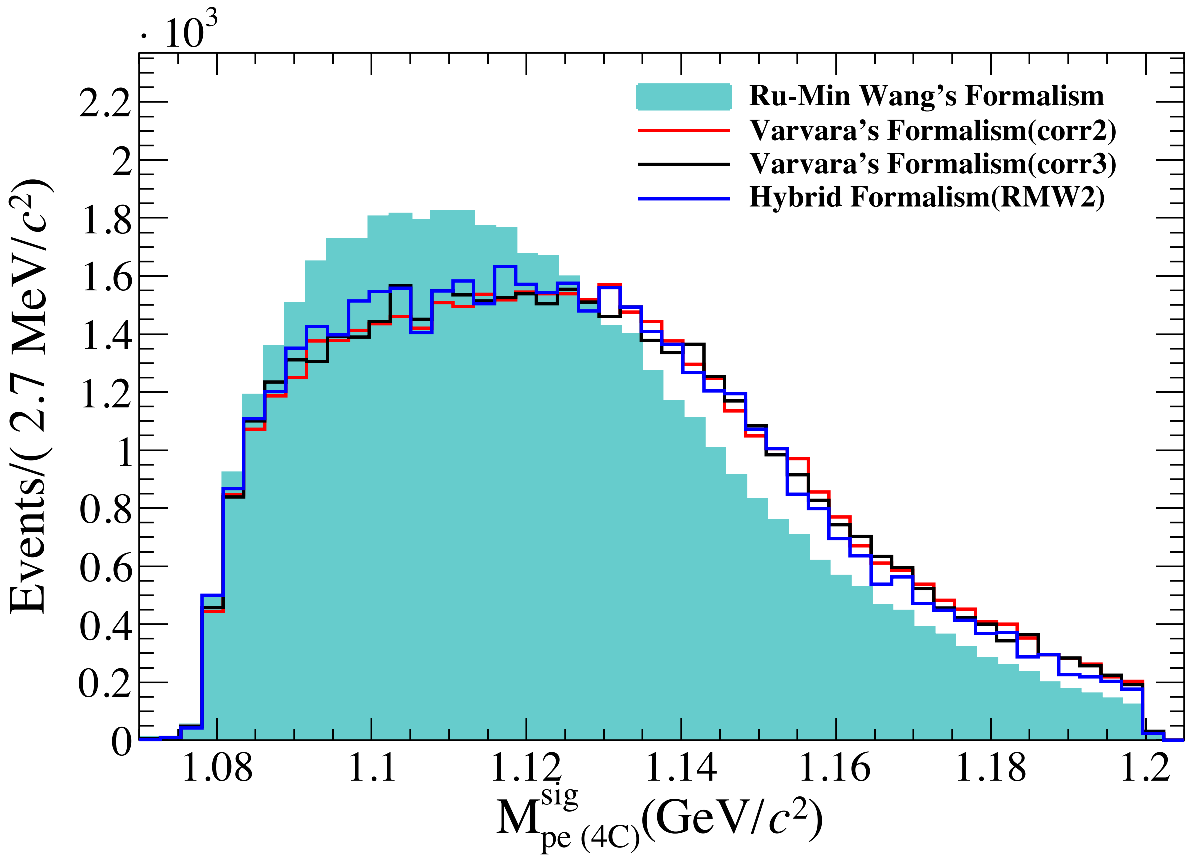

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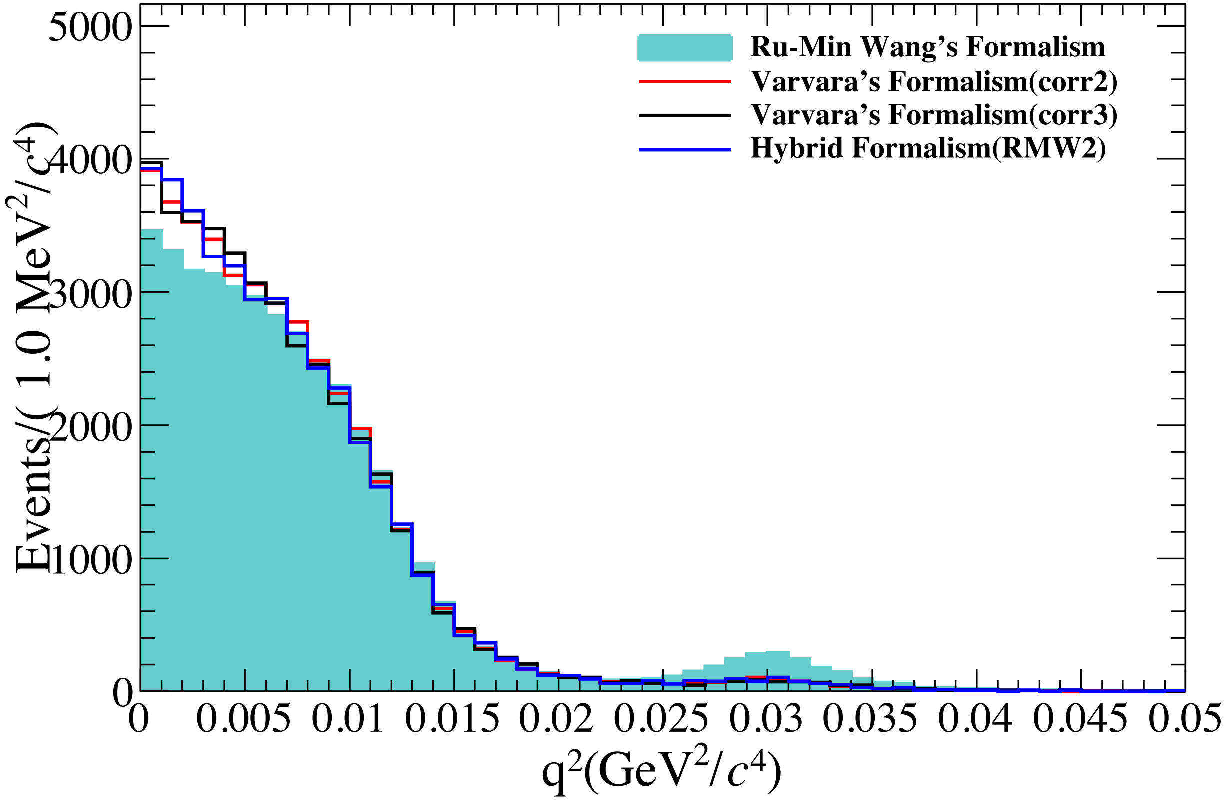
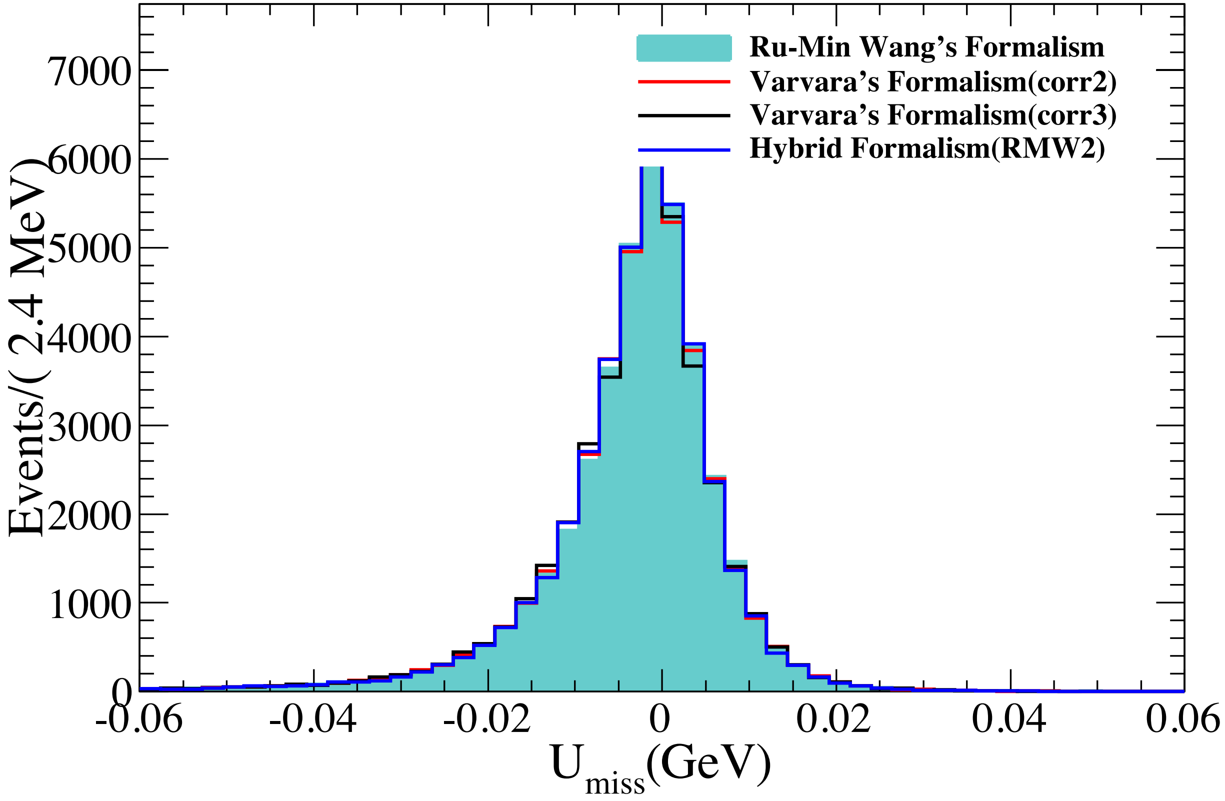
Back Up

Compare the distributions from different MC





Different form factor parametrization

$$F_i^{V,A}(q^2) = F_i^{V,A}(0)\prod_{n=0}^{n_i}\frac{1}{1-\frac{q^2}{m_{V,A}^2+n\alpha'^{-1}}} \approx F_i^{V,A}(0)\left(1+q^2\sum_{n=0}^{n_i}\frac{1}{m_{V,A}^2+n\alpha'^{-1}}\right) \equiv F_i^{V,A}(0)c_i^{V,A}(q^2)$$

	$F_i^{V,A}(0)(\Lambda\to p)$	$m_{V,A}$	α' [GeV^{-2}]	n_i
$F_1^V(q^2)$	$-\sqrt{\frac{3}{2}}$[1]	$m_{K^*(892)^0}$ $(J^P=1^-)$	0.9	$n_1=1$
$F_2^V(q^2)$	$\frac{M_\Lambda \mu_p}{2M_p}F_1^V(0)$[2]			$n_2=2$
$F_3^V(q^2)$	0[4]	-		$n_3=2$
$F_1^A(q^2)$	$0.719F_1^V(0)$[3]	$m_{K^*(1270)^0}$ $(J^P=1^+)$		$n_1=1$
$F_2^A(q^2)$	0[4]	−		$n_2=2$
$F_3^A(q^2)$	$\frac{M_\Lambda(M_\Lambda+M_p)}{(m_{K^-})^2}F_1^A(0)$[4]	m_K $(J^P=0^-)$		$n_3=2$

- [1] [PR135(1964)B1483], [PRL13(1964)264]
- [2] $\mu_p = 1.793$ [Lect.NotesPhys.222(1985)1], [Ann.Rev.Nucl.Part.Sci.53(2003)39], [JHEP0807(2008)132]
- [3] [PRD41(1990)780]
- [4] Vanish in the $SU(3)$ symmetry limit; Goldberger-Treiman relation [PR110(1958)1178], [PR111(1958)354]

the q^2 dependence of FFs,
which is used in the Varvara's formalism

$$F_i(q^2) = \frac{F_i(0)}{(1-q^2/M^2)^2}, \qquad (12)$$

where $M = 0.97(1.25)$ GeV for the vector (axial vector) form factors f_i (g_i) in the $s \to u\ell^-\bar{\nu}_\ell$ decays, and

the q^2 dependence of FFs,
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PRD 100, 076008