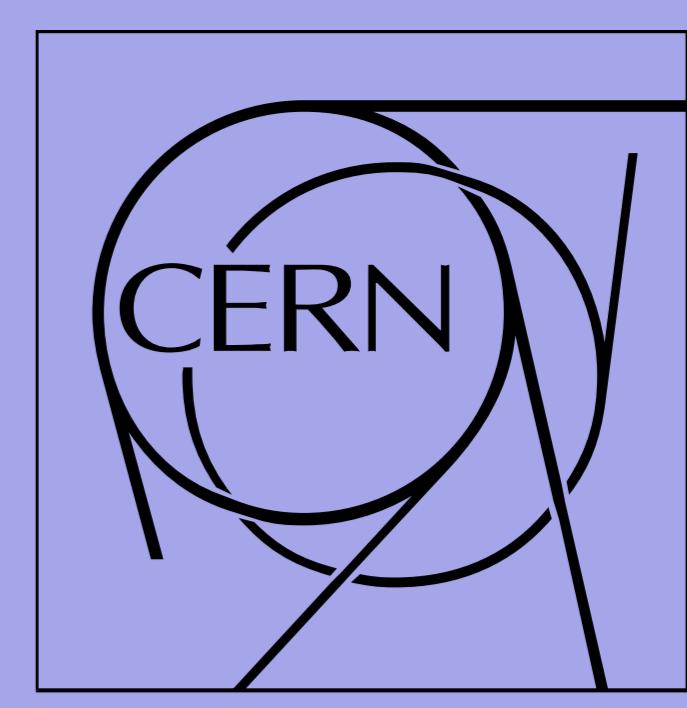


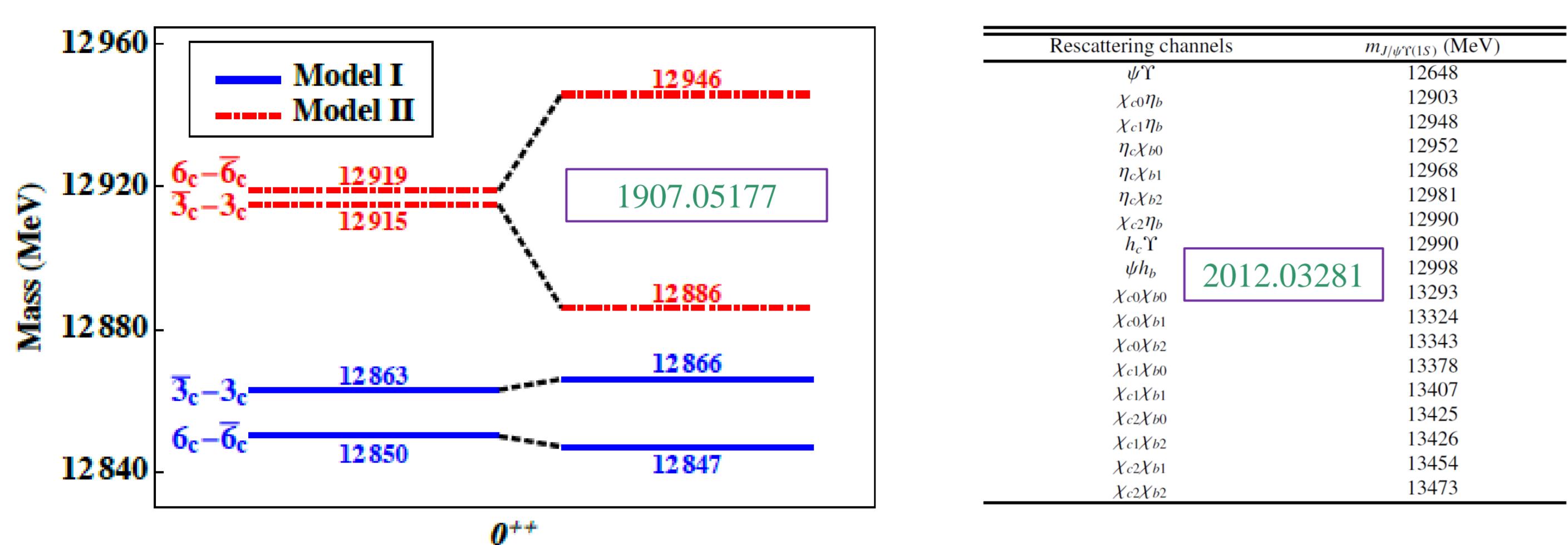
Search for structures near J/ ψ + Y mass threshold

Zhengchen Liang, Muhammad Ahmad, Zhenyu Dong, Yusui Li, Ying Zhang, Yiqiu Zhou



Theoretical Motivation

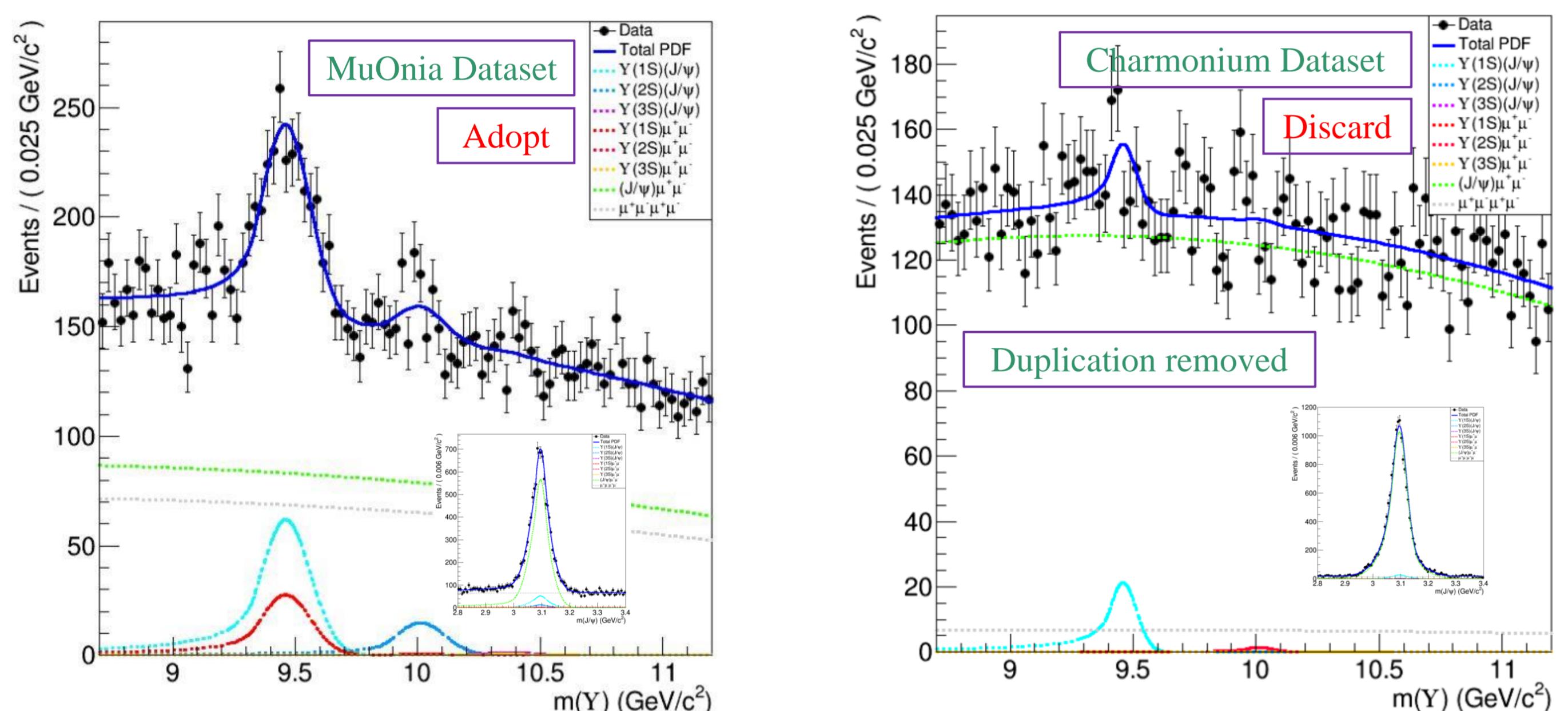
- Y. Iwasaki (1975) $cc\bar{c}c\bar{c}$ prediction:
Mass ~ 6.2 GeV.
- A. V. Berezhnoy (2012) $ccc\bar{c}$, $bbb\bar{b}$, $bcb\bar{c}$ prediction:
Mass above/below meson-meson threshold.
- New developments:
Resonance(s) vs. CUSP (i.e. dynamical peak(s))



Preliminary Event Selection

CMS Run 2 Datasets

- Preliminary cuts (CMS Run 2 ReReco datasets), 4 μ mass spectrum in full range
- Charmonium dataset provides no significant signal but only huge background in the Y mass region: discarded
- Using MuOnia dataset only

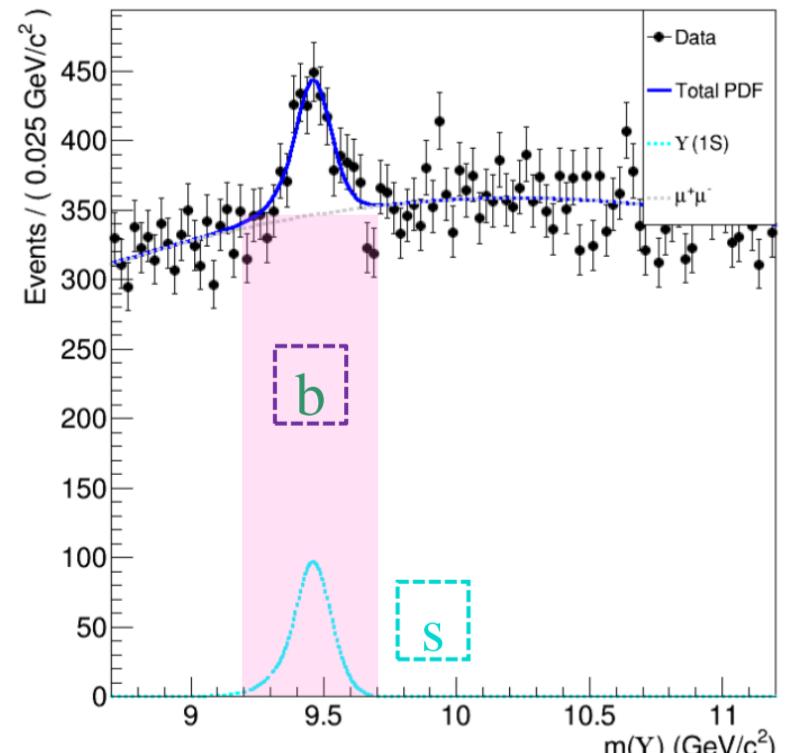


Cut Optimization and Final Event Selection

The cut optimization target

- Data-driven cut optimization strategy (Y 1D optimization, 4 μ range 12~15 GeV)

- s: The yield of function $C.B.(Y(1S))$, i.e. $s = N(Y(1S))$.
- b: The yield of function $Poly_2((\mu^+ \mu^-)_Y)$ within the mass range of 9.2-9.7 GeV.

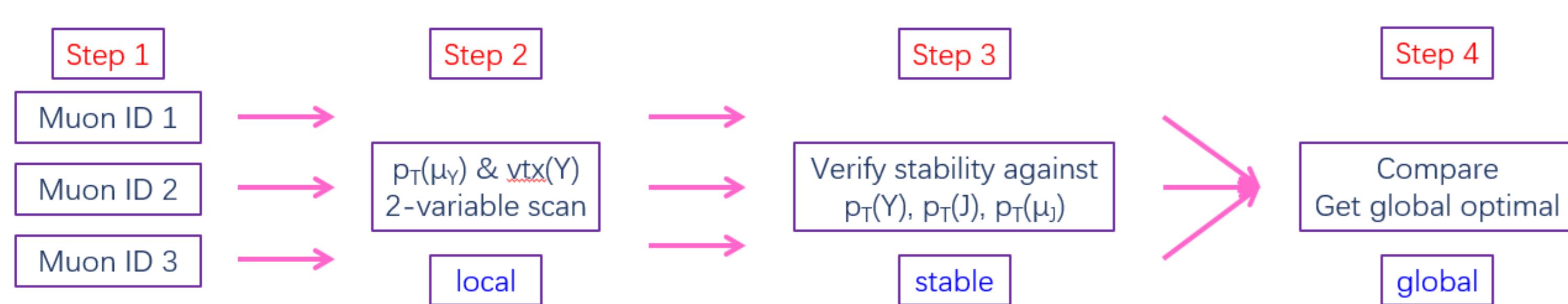


$$\text{Total PDF} = N(Y(1S)) [C.B.(Y(1S))] + N(\mu^+ \mu^-) [Poly_2((\mu^+ \mu^-)_Y)]$$

The cut optimization variables

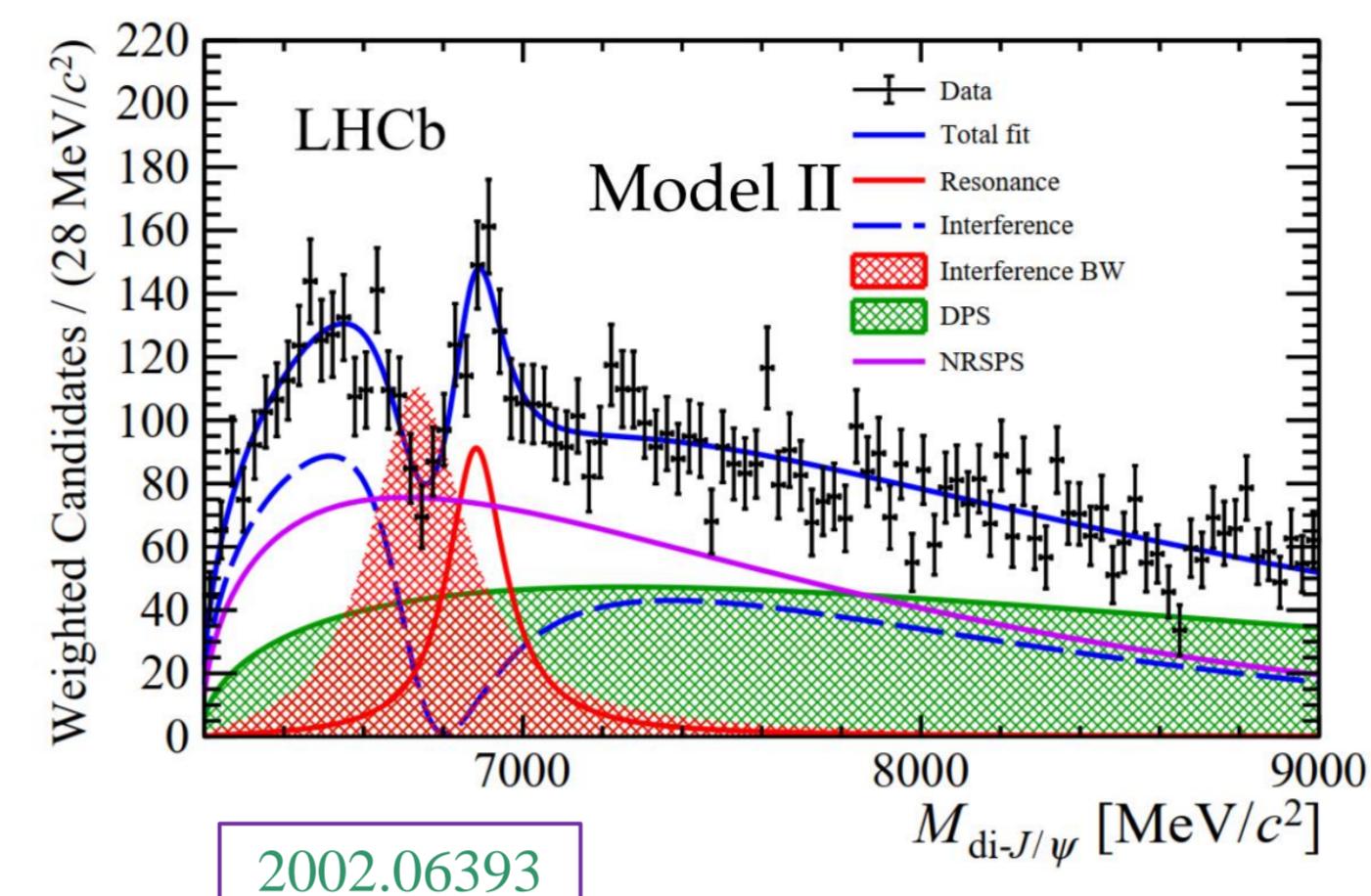
- Muon ID: a discrete variable from the 10-element set {4 muon soft, 4 muon loose, 4 muon medium, 4 muon tight, 2 muons from Y loose, 2 muons from Y medium, 2 muons from Y tight, 2 muons from J/ ψ loose, 2 muons from J/ ψ medium, 2 muons from J/ ψ tight}. Only 4 are sensitive in cleaning up the Y(1S) signal: {4 muon soft, 2 muons from Y loose, 2 muons from Y medium, 2 muons from Y tight.}
- $p_T(Y) \equiv p_T(Y(1S))$; $p_T(J) \equiv p_T(J/\Psi)$; $p_T(\mu_Y) \equiv [p_T(\mu) \text{ from } Y(1S)]$; $p_T(\mu_J) \equiv [p_T(\mu) \text{ from } J/\Psi]$: continuous variables.
- $vtx(Y) \equiv [\text{Vertex Probability of } Y(1S)]$: a continuous variable.

The cut optimization workflow

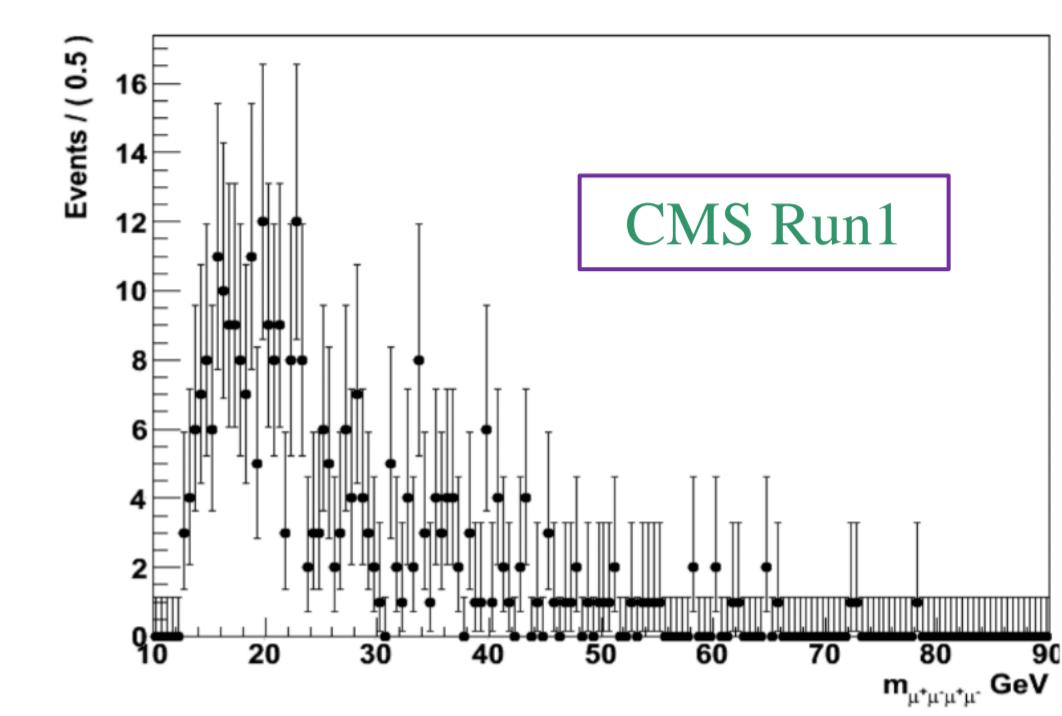


Experimental Motivation

- J/ ψ +Y in CMS Run 1: inadequate statistics
- J/ ψ +J/ ψ in LHCb: X(6900)
- J/ ψ +J/ ψ in CMS Run 2 (AN-20-006): ongoing
- J/ ψ +Y in CMS Run 2 (this analysis): ongoing
 - Any surprise in CMS Run2 data?
 - Analysis Note: AN-2020/155

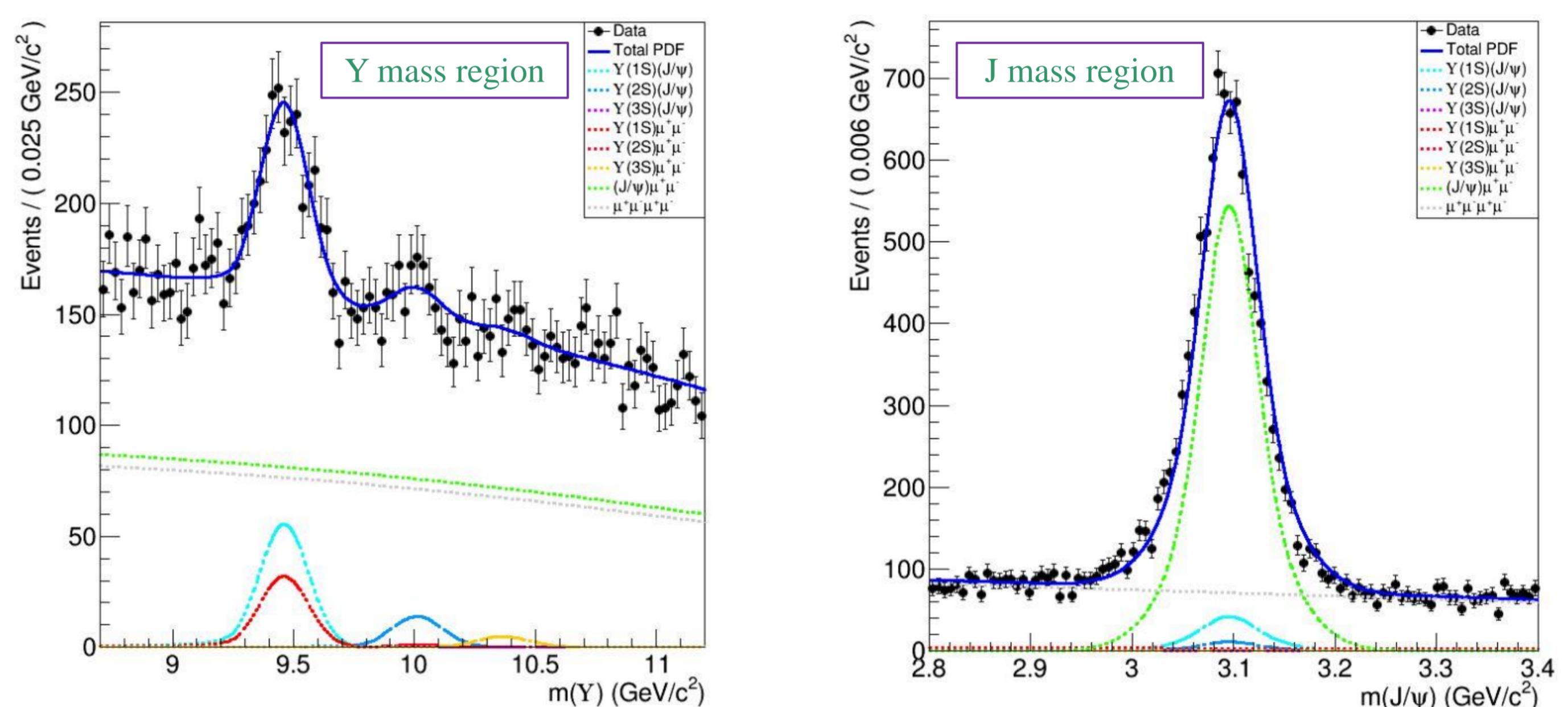


- $M(YJ/\psi)$ with background looks smooth, difficult to look for resonance due to high background under Y and low statistics.
- Maybe x-section measurement?



Ultra Legacy (UL) MuOnia Dataset

- Preliminary cuts (CMS Run 2 UL MuOnia dataset), 4 μ mass spectrum in full range
- The analysis has switched to UL configuration
- Using UL MuOnia dataset only
- Below plots are 2 μ mass distributions of UL MuOnia dataset in Y and J/ ψ mass regions

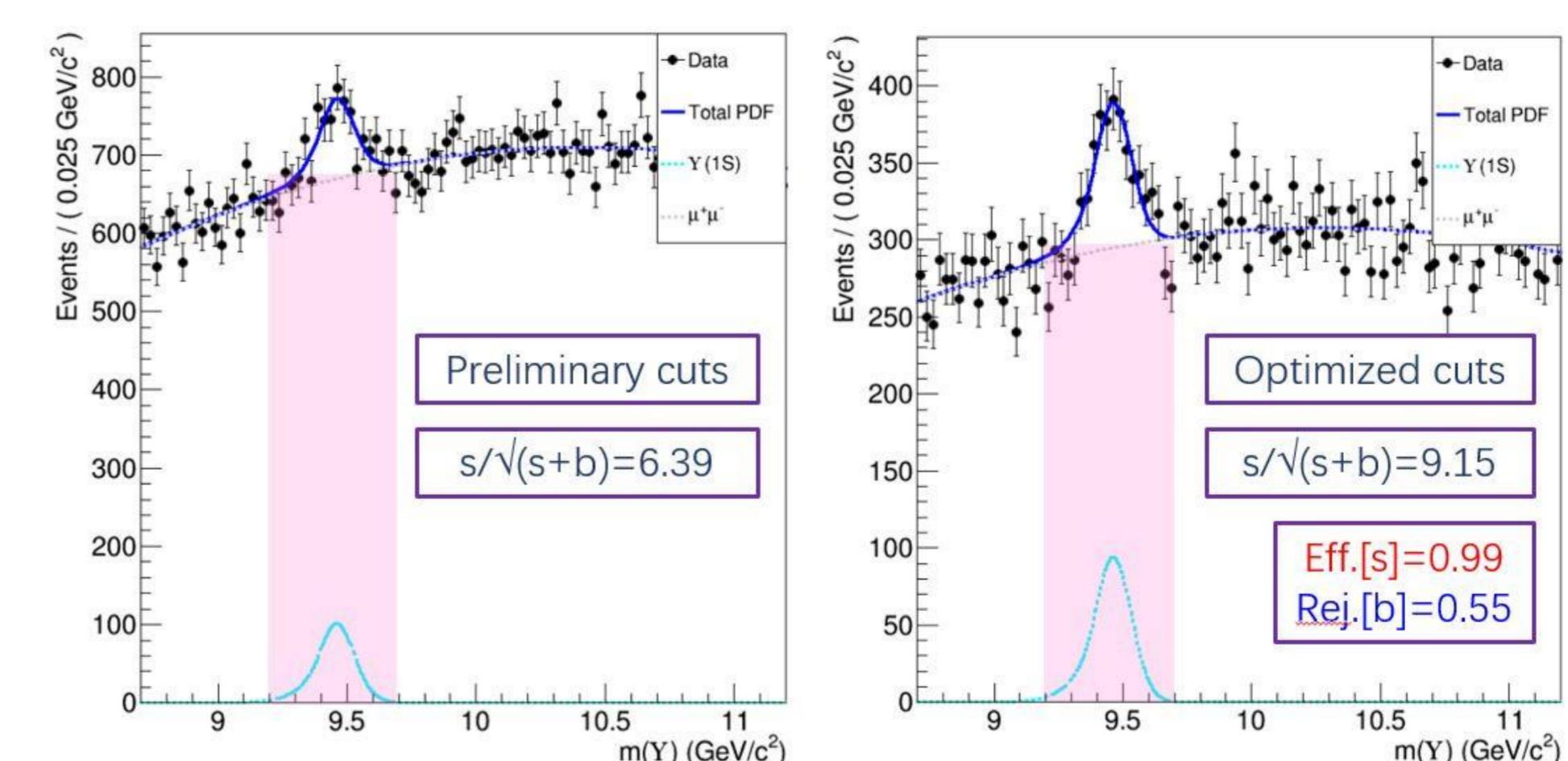


The cut optimization result

- Global optimal set of cuts: $p_T(\mu_Y) > 2.4 \ \&\& \ vtx(Y) > 0.225 \ \&\& \ ID(\mu_Y) == \text{loose}$

	muon ID	Best s/sqrt(s+b)	$p_T(\mu_Y)$	$vtx(Y)$
4 soft		8.40383	2.6	0.255
2 μ's from Y loose	9.15362	2.4	0.225	
2 μ 's from Y medium	8.81047	2.4	0.255	
2 μ 's from Y tight	7.18077	2.4	0.255	

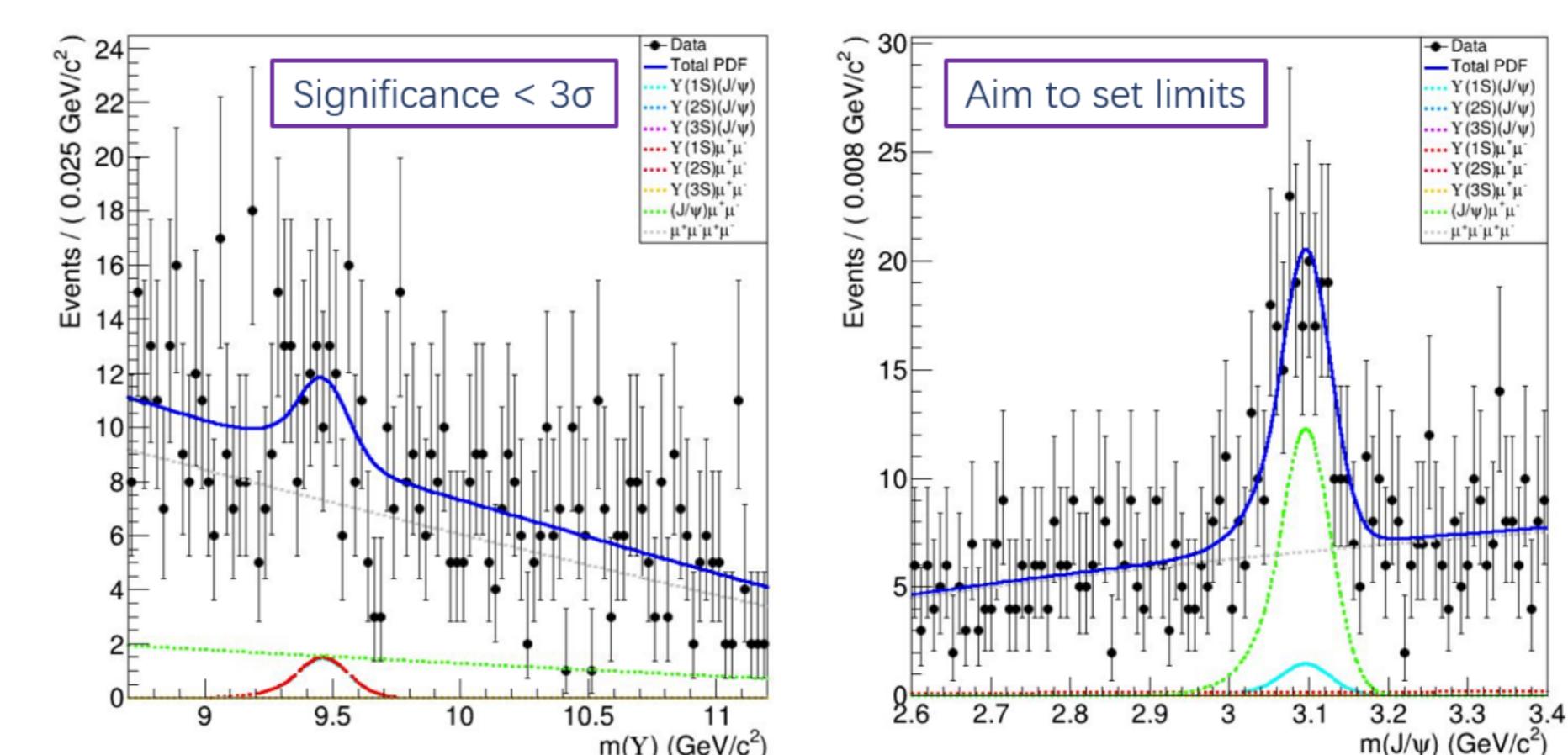
Final event selection: Y 1D fit



Preliminary:
 $S(Y(1S)) = 759 \pm 144$;
 $B(\mu\mu) = 67783 \pm 296$;
 $B(\mu\mu, \text{subrange}) = 13367$.

Optimized:
 $S(Y(1S)) = 758 \pm 92$;
 $B(\mu\mu) = 30729 \pm 196$;
 $B(\mu\mu, \text{subrange}) = 6123$.

Final event selection: J/ ψ + Y 2D fit



Yields from fit:
 $N(Y(1S) J/\psi) = 16 \pm 9$;
 $N(Y(1S) \mu\mu) = 16 \pm 12$;
 $N(\mu\mu J/\psi) = 131 \pm 16$;
 $N(\mu\mu \mu\mu) = 620 \pm 27$.