Search for η_b signal in $J/\psi J/\psi$ final state with CMS Run II data

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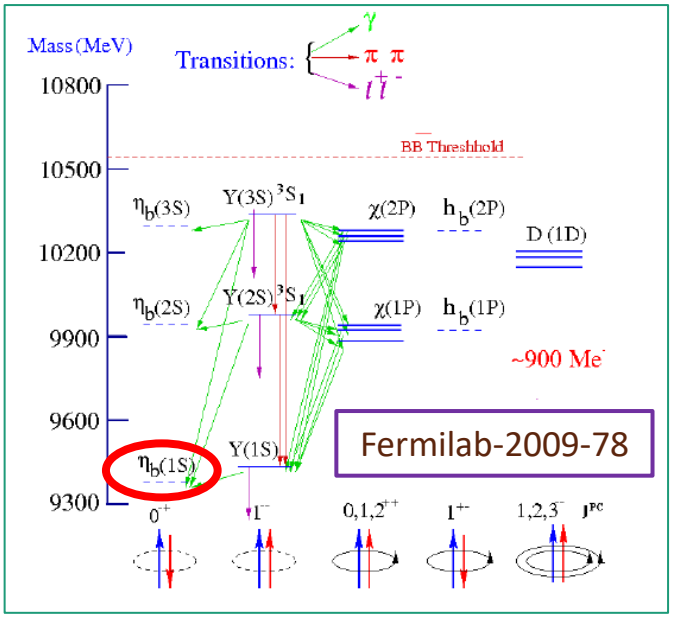
Outline

- Motivation
- Data samples
- Event selection
- Background study
- Cut optimization
- Summary

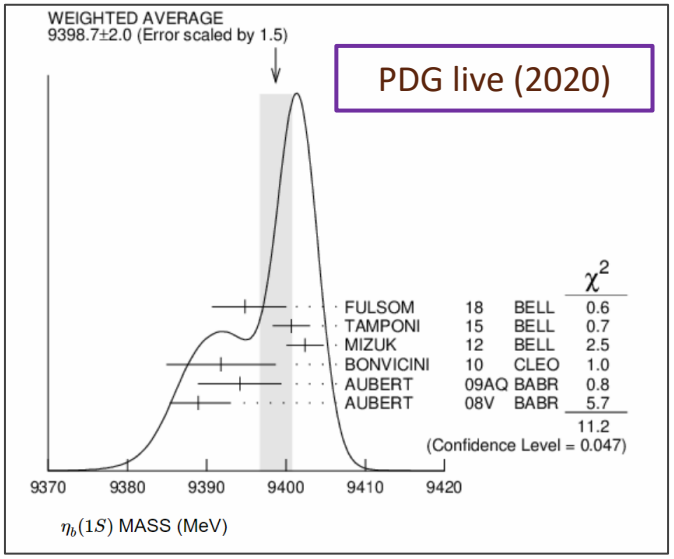
Motivation

- $\eta_b, 0^+(0^{-+})$ is the lightest bottomonium state for $b\bar{b}$ system.



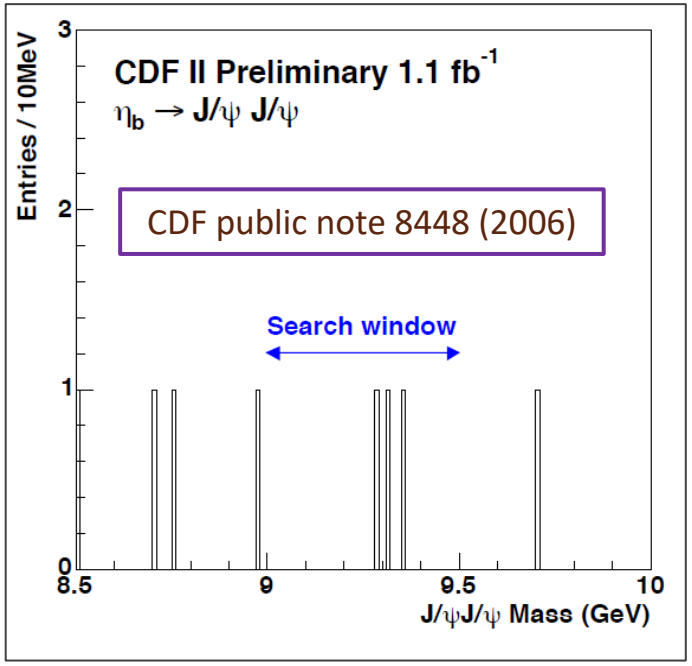
- Observations were reported by BABAR and Belle via inclusive searches.
  - $\Upsilon(3S) \to \gamma\eta_b$
    - [BABAR, Phys. Rev. Lett 101 (2008) 071801]
  - $h_b(1P)|h_b(2P) \to \gamma\eta_b$
    - [Belle, Phys. Rev. Lett 109 (2012) 232002]
  - $\Upsilon(2S) \to \gamma\eta_b$
    - [Belle, Phys. Rev. Lett. 121 (2018) 232001]

- No η_b observed from exclusive search.



Motivation

- Production of η_b at hardon collider should be on observable level, however no dominant decay mode.



- Similar process $\eta_c \to \phi\phi$ has unexpected large branching ratio ~10^{-3}, drive us to search for $\eta_b \to J/\psi J/\psi$ in CMS.
  - A good study and test of theories.
  - More precise measurement on η_b resonant parameters.

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- CDF presented the search in 2006 in 4-μ final state using 1.1 fb^{-1} of data, 3 candidates while 3.6 background events are observed.

Data samples

Data

- Dataset: Charmonium
- Data: Full Run II data, 135 fb^{-1}
- Json: corresponding to muon json.

Monte Calo

- Signal process
- Single-parton-scattering process (SPS)
- Double-parton-scattering process (DPS)

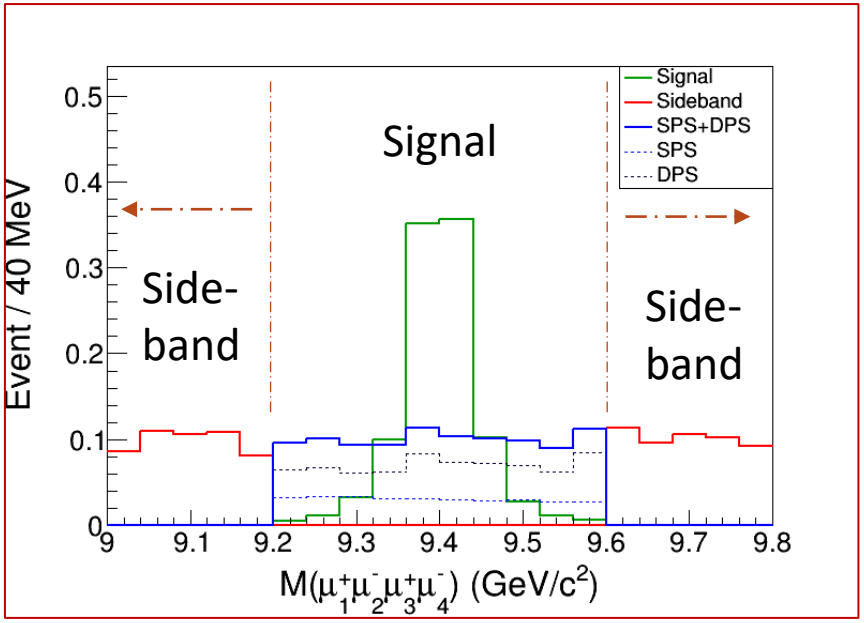
Trigger:

Year	Trigger
2016	HLT_Dimuon0_Jpsi_Muon
2017 / 2018	HLT_Dimuon0_Jpsi3p5_Muon2

Event selection

Event selection:

- Net charge == 0
- p_T >2.0 GeV
- $|\eta|$ < 2.4
- $Prob_{vertex}(4\mu)$ > 0.5%
- For each dimuon pair:
  - Valid mass constraint fit
  - $Prob_{vertex}(2\mu)$ > 0.1%
  - 2.95 <$|M - J/\psi|$ < 3.25 GeV
- $p_T^{leading\ J/\psi}$ > 13.5 GeV
- $p_T^{sub-leading\ J/\psi}$ > 8.0 GeV



Event category:

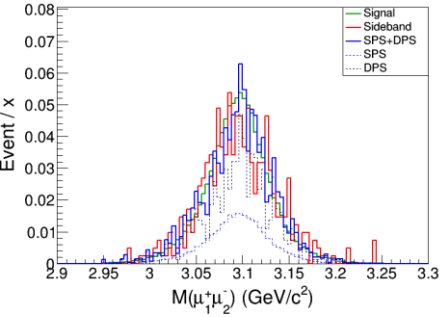
- $\boldsymbol{\mu_1^+, \mu_2^-}$ is for the J/ψ has higher p_T
- $\boldsymbol{\mu_3^+, \mu_4^-}$ is for the J/ψ has lower p_T

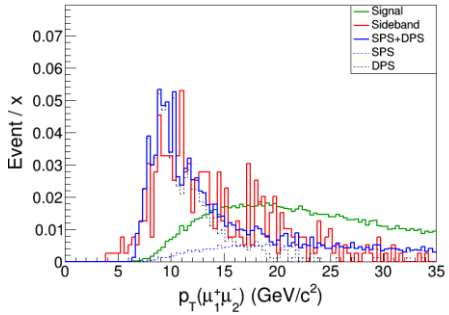
Signal region: $M_{J/\psi J/\psi} \in [9.2, 9.6]$

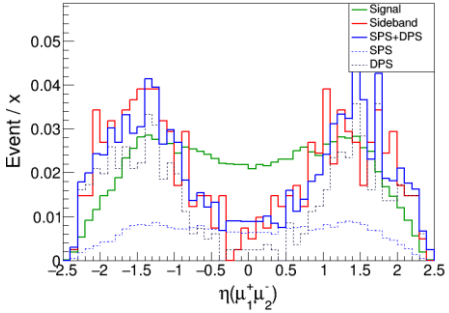
Sideband region: $M_{J/\psi J/\psi} \in [8.6, 9.2]$ || $[9.6, 10.2]$

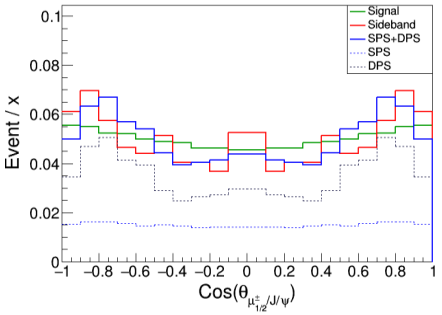
Background study

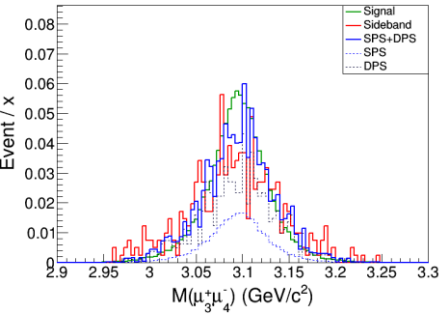
- To study the background fractions, we perform simultaneous fit on the data sideband events kinematics distributions with SPS and DPS shapes.

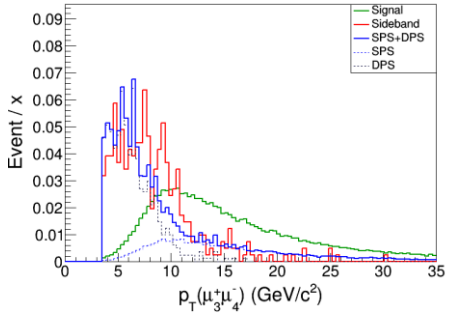


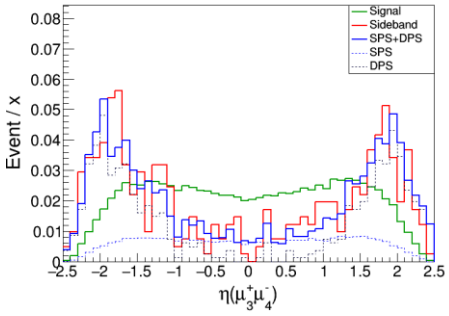


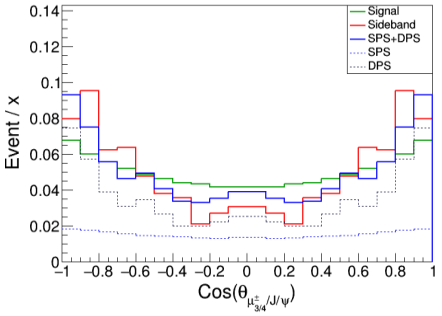












- The obtained SPS and DPS fractions are applied to make the mixed background for further cut optimizations.

Cut optimization

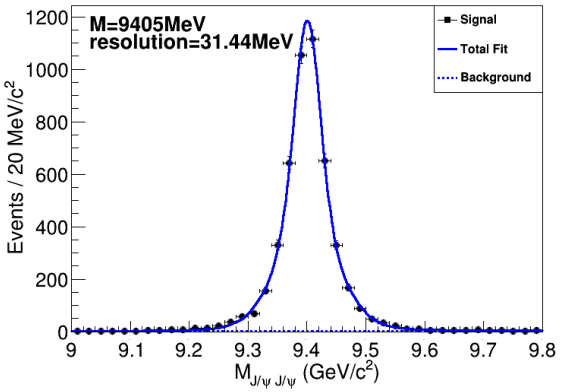
- To study the cut optimization, FOM method is used:

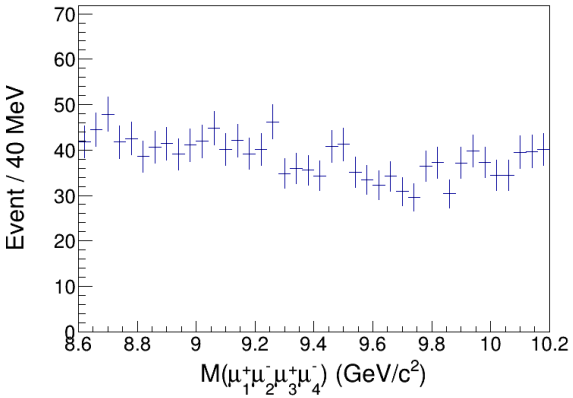
$$FOM = S/(\frac{3}{2} + \sqrt{B})$$

- $p_T^{leading\ J/\psi}$
- $p_T^{sub-leading\ J/\psi}$
- $p_T^{lowest\ \mu}$

S comes from signal MC samples, while B comes from normalized MC samples mixed by fractions obtained via simultaneous fit.

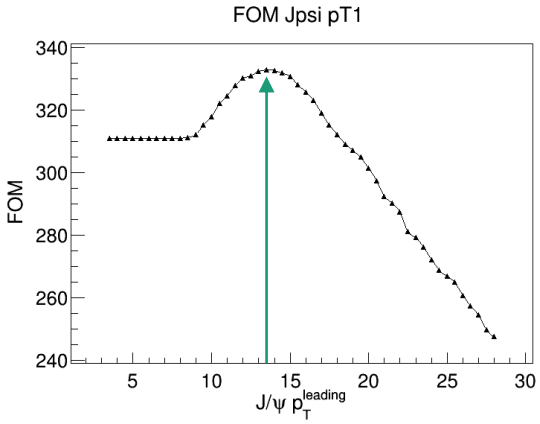
- The $M_{4\mu}$ distributions from **signal MC**/ **bkg MC** before applying the optimized cuts

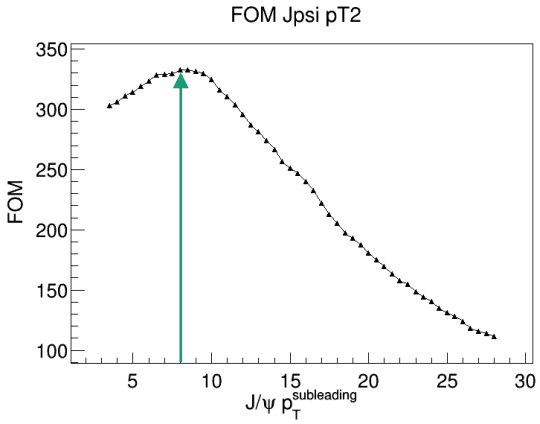


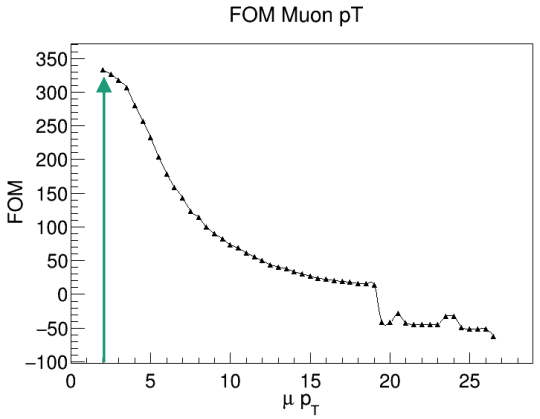


Cut optimization

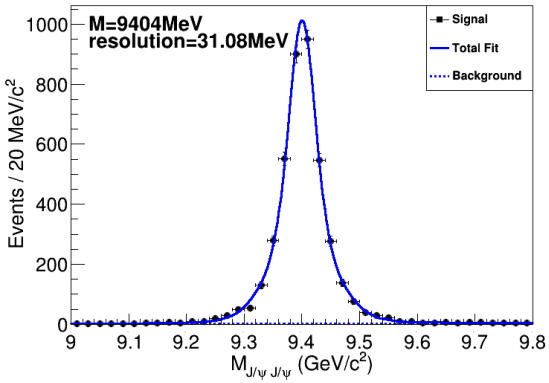
- $p_T^{leading\ J/\psi}$: > 13.5 GeV
- $p_T^{sub-leading\ J/\psi}$: > 8.0 GeV
- $p_T^{lowest\ \mu}$: > 2.0 GeV

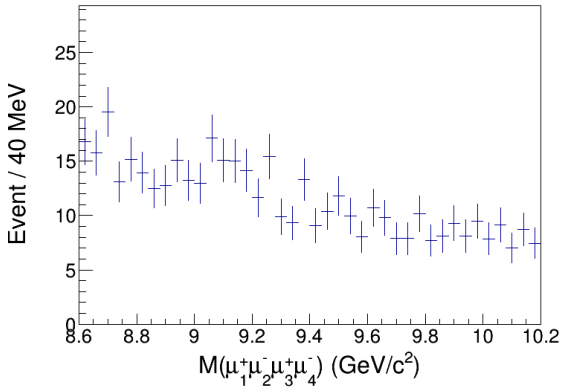






- The $M_{4\mu}$ distributions from **signal MC**/ **bkg MC** after applying the cuts





Summary

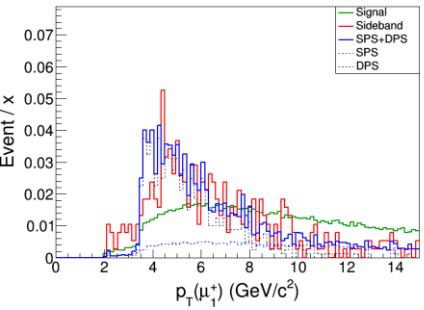
- An exclusive search for η_b signal in $J/\psi J/\psi$ final state with CMS Run II data
- All event selection strategies are set
- Continue to work for opening box

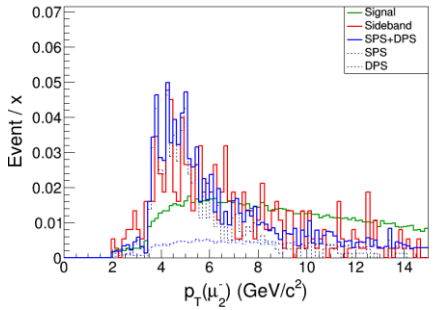
Back up

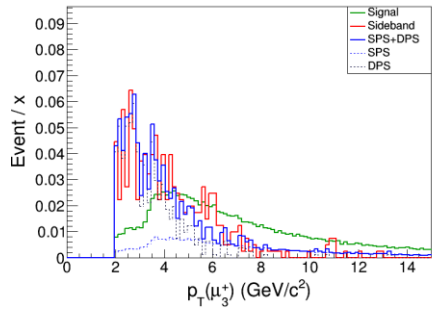
Analysis Note : AN-20-006

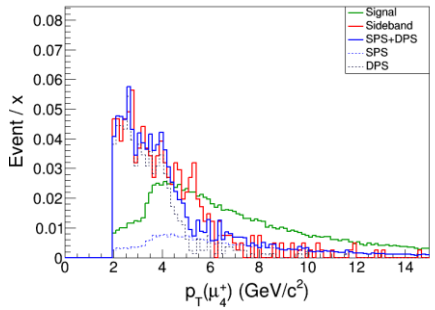
Background study

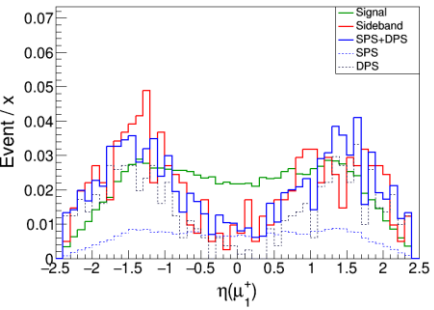
- The bkg shapes show good agreement in all kinematic distributions.

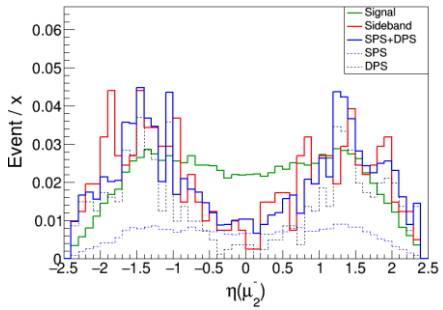


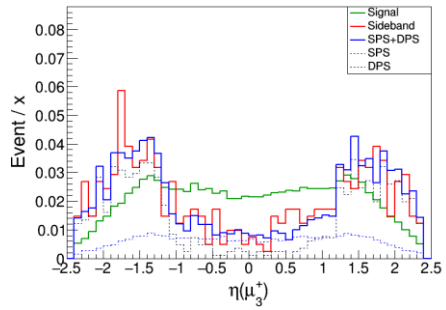


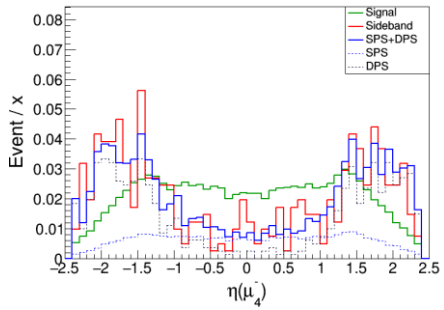


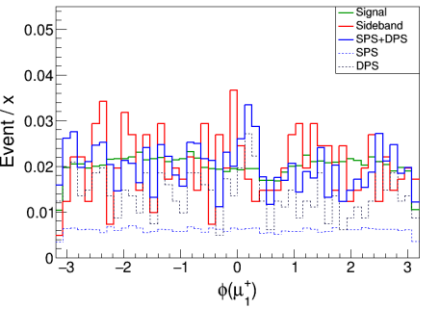


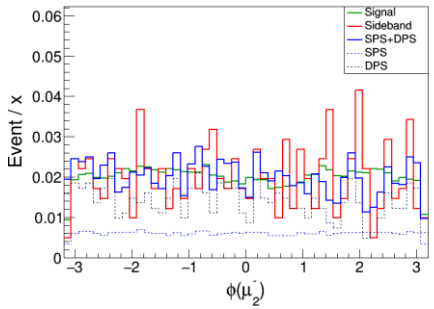


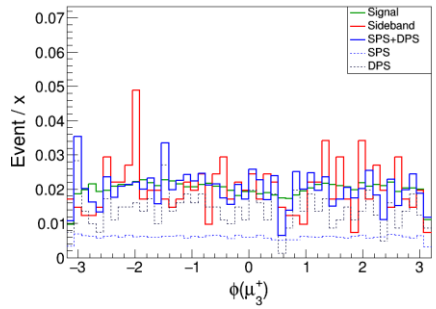


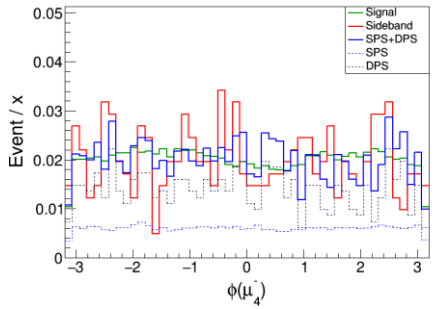












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