Search for $\eta \to e^+e^-$ and $\eta \to \mu^+\mu^-$

HTU Group Meeting

Yueying

2023.11.5

OUTLINE

1. Motivation
2. Data Set
3. Initial Event selection
4. Search for $\eta \to \mu^+\mu^-$
5. Search for $\eta \to e^+e^-$
6. Next To do

- PDG Value and previous experiment results of the branching fraction

$\boldsymbol{B}(\eta \to \boldsymbol{l}^+\boldsymbol{l}^-)$	PDG value	Experimental result
$B(\eta \to e^+e^-)$	$< 7 \times 10^{-7} (CL = 90\%)$	$< 4.14 \times 10^{-6} (CL = 90\%)$ [1]
$B(\eta \to \mu^+\mu^-)$	$(5.8 \pm 0.6) \times 10^{-6}$	$(5.88 \pm 0.09) \times 10^{-6}$ [2]

- Based on 1.3 billion J/ψ events, BESIII first observed $\eta' \to \pi^+\pi^-\mu^+\mu^-$ signal and found a few dozens of events peaked around the η meson mass in the dimuon mass spectrum . These events come from the $\eta' \to \pi^+\pi^-\ \eta$, followed by the rare decay $\eta \to \mu^+\mu^-$, which could give a compatible branching fraction with the present world average value[2].

- Using $(10087 \pm 44) \times 10^6$ J/ψ events, we perform a search for $\eta \to \mu^+\mu^-/\ e^+e^-$, via $J/\psi \to \gamma\eta'$, $\eta' \to \pi^+\pi^-\ \eta$.

[1] PhD Uppsala U. (2018)

[2] arXiv:2306.02810v1

- Boss version : 708
- Data sample : 2009+2012+2018+2019 J/ψ events
- Inclusive MC : 2009+2012 J/ψ events
- Signal MC : 45w events (2009+2012+2018+2019) (1:5:20:19)

Decay mode	Generation
$J/\psi \to \gamma\eta'$	HELAMP 1.0 0.0 1.0 0.0
$\eta' \to \pi^+\pi^- \eta$	DIY
$\eta \to \mu^+\mu^- / e^+e^-$	PHSP

➢ Initial Event selection

■ Good charged track

- $|R_Z| \leq 10\ cm$, $|R_{xy}| \leq 1\ cm$
- $|\cos\theta| \leq 0.93$
- $N_{good} = 4$
- $N_P = 2, N_m = 2$
- $N_{charge} = 0,$

■ Good photon

- $E_\gamma \geq 25MeV$, $|\cos\theta| < 0.8\ (Barrel)$
- $E_\gamma > 50MeV$, $0.86 < |\cos\theta| < 0.92\ (Endcap)$
- $0 \leq TDC_{EMC} \leq 14\ (\times 50ns)$
- $N_\gamma \geq 1$

■ PID && Kinematic fit

- Assuming the charged tracks are $\pi^+\pi^-e^+e^-$ or $\pi^+\pi^-\mu^+\mu^-$, the smallest $x^2_{\mathrm{pid+4c}}$ for $\gamma\ \pi^+\pi^-e^+e^-$ or $\gamma\ \pi^+\pi^-\mu^+\mu^-$ is selected.

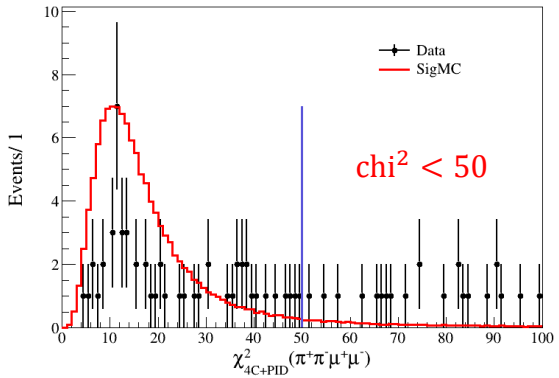
- Assuming the charged tracks to e, μ, π , define:

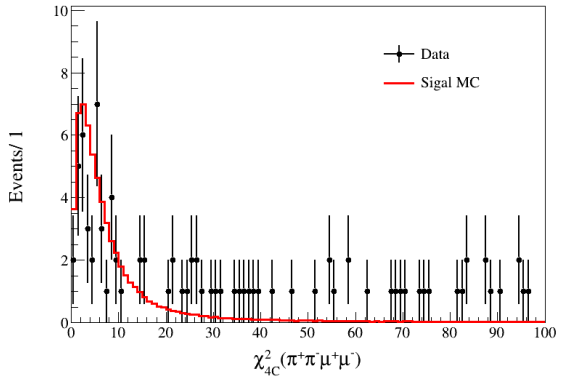
$$x^2_{\mathrm{pid+4c}} = x^2_{4c} + \sum_{i=1}^{4} x^2_{pid}\ (i)$$

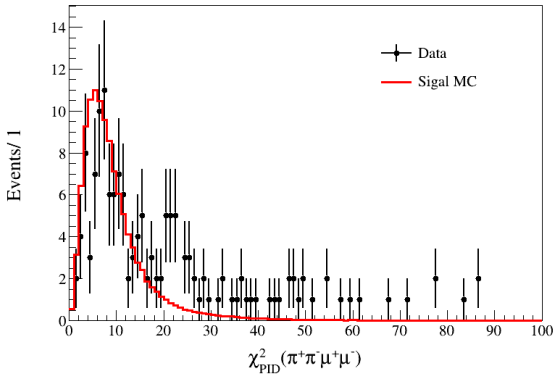
Search for $\eta \to \mu^+\mu^-$

➢ Futher Events selection

■ The distribution of x^2_{4C+PID}

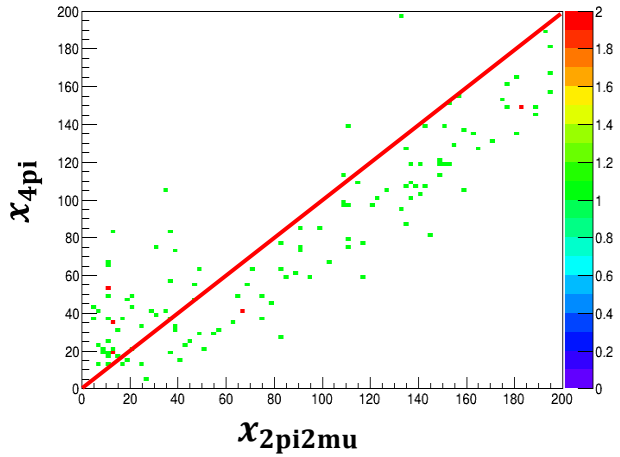




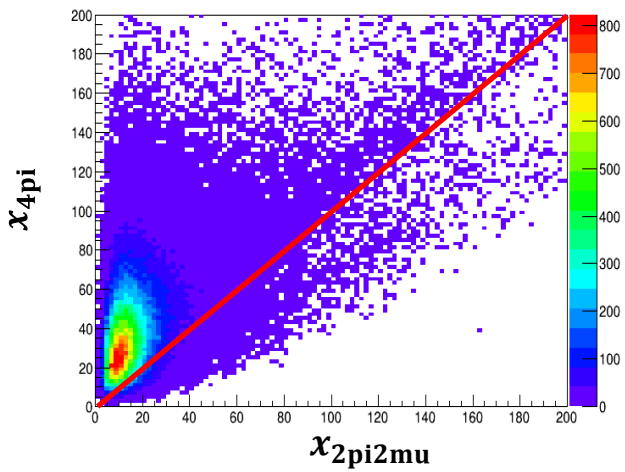


■ $(\pi^+\pi^-\mu^+\mu^-)$ versus $x^2_{pid+4c}(\pi^+\pi^-\pi^+\pi^-)$

Data

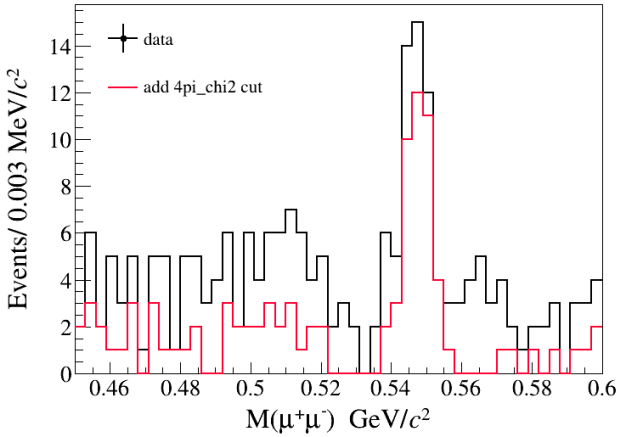


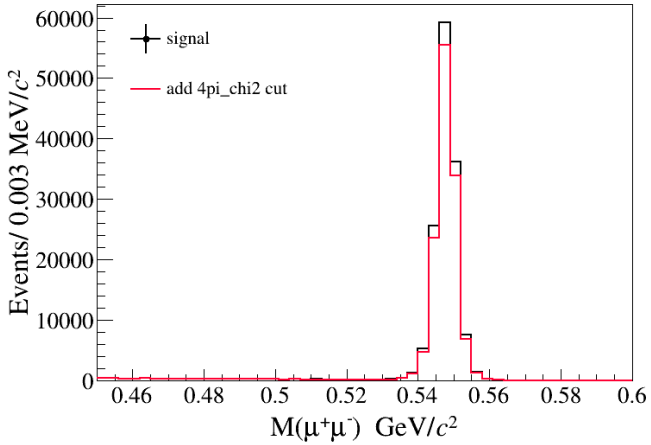
Signal



$x^2_{pid+4c}(\pi^+\pi^-\mu^+\mu^-) < x^2_{pid+4c}(\pi^+\pi^-\pi^+\pi^-)$?

- Comparison before and after adding $x^2_{pid+4c}(\pi^+\pi^-\mu^+\mu^-) < x^2_{pid+4c}(\pi^+\pi^-\pi^+\pi^-)$





- Cut flow and efficient

Cut	Data	Signal (45w)	$\eta' \to \pi^+\pi^-\pi^+\pi^-$ (50w)	$J/\Psi \to \pi^+\pi^-\pi^+\pi^-$ (100w)	$\eta' \to \pi^+\pi^-\mu^+\mu^-$ (100w)	$f'_0 \to \pi^+\pi^-\pi^+\pi^-$ (100w)
$0.945 < M_{\pi^+\pi^-\mu^+\mu^-} < 0.97$	2773	40.60%	0.65%	1.77%	39.83%	0.43%
$0.45 < M_{\mu^+\mu^-} < 0.6$	955	34.42%	0.18%	0.59%	1.79%	0.14%
$x^2_{PID+4C}(\pi^+\pi^-\mu^+\mu\text{-}) < 50$	211	32.27%	0.06%	0.45%	1.59%	0.11%
$x^2_{PID+4C}(\pi^+\pi^-\mu^+\mu\text{-}) < x^2_{PID+4C}(\pi^+\pi^-\pi^+\pi\text{-})$	93	30.00%	0.02%	0.07%	1.47%	0.02%

➢ Background Study

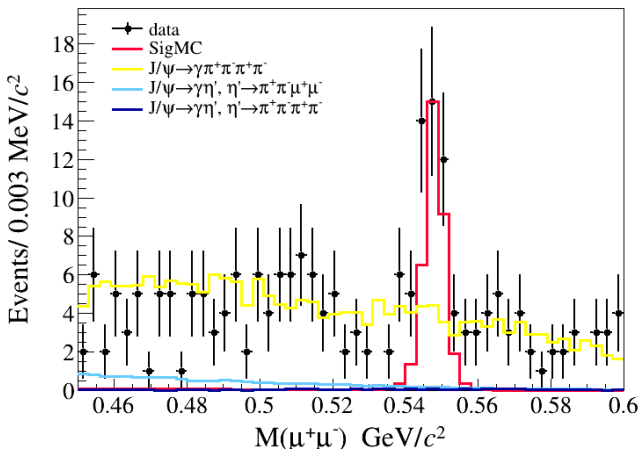
■ Topo

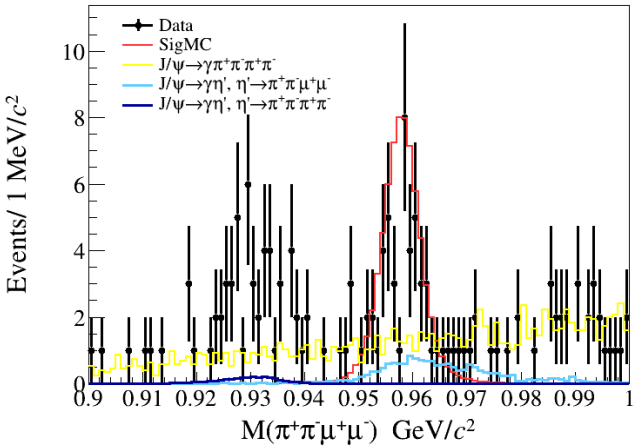
rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$J/\psi \to \pi^0\pi^+\pi^+\pi^-\pi^-$	$\pi^0\pi^+\pi^+\pi^-\pi^-$	1	50	50
2	$J/\psi \to \pi^+\pi^+\pi^-\pi^-\gamma^F$	$\pi^+\pi^+\pi^-\pi^-\gamma^F$	2	40	90
3	$J/\psi \to f_0'\gamma, f_0' \to \pi^+\pi^+\pi^-\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma$	0	38	128
4	$J/\psi \to K_S^0K_S^0\gamma, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma$	6	4	132
5	$J/\psi \to f_2(1270)\gamma, f_2(1270) \to \pi^+\pi^+\pi^-\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma$	4	3	135
6	$J/\psi \to f_0'\gamma, f_0' \to K_S^0K_S^0, K_S^0 \to \pi^+\pi^-, K_S^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma$	7	2	137
7	$J/\psi \to f_0'\gamma, f_0' \to \rho^0\rho^0, \rho^0 \to \pi^+\pi^-, \rho^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma$	8	2	139
8	$J/\psi \to \rho^0\rho^0\gamma, \rho^0 \to \pi^+\pi^-, \rho^0 \to \pi^+\pi^-$	$\pi^+\pi^+\pi^-\pi^-\gamma$	5	1	140
9	$J/\psi \to \eta'\gamma, \eta' \to \pi^+\pi^-\eta, \eta \to \mu^+\mu^-\gamma^F$	$\mu^+\mu^-\pi^+\pi^-\gamma^F\gamma$	3	1	141
10	$J/\psi \to \eta'\gamma, \eta' \to \pi^+\pi^-\eta, \eta \to \pi^+\pi^-\gamma^F$	$\pi^+\pi^+\pi^-\pi^-\gamma^F\gamma$	9	1	142

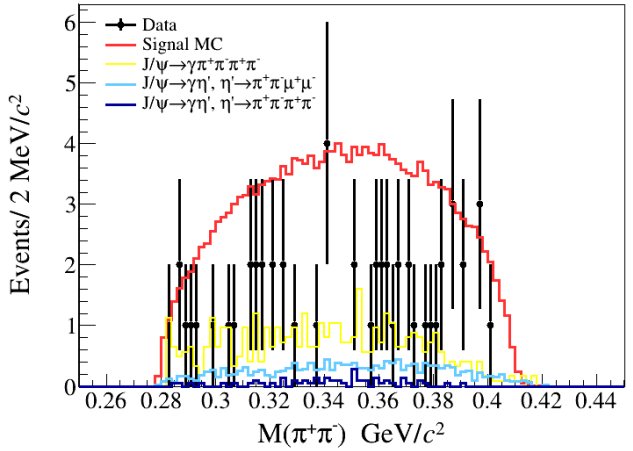
■ Background and Normalized Event Number

Decay mode	Normalized Event Number
$J/\psi \to \gamma\eta', \eta' \to \pi^+\pi^-\pi^+\pi^-$	2.67±0.29
$J/\psi \to \gamma\eta', \eta' \to \pi^+\pi^-\mu^+\mu^-$	16.83±3.38
$J/\psi \to \gamma\pi^+\pi^-\pi^+\pi^-$	free

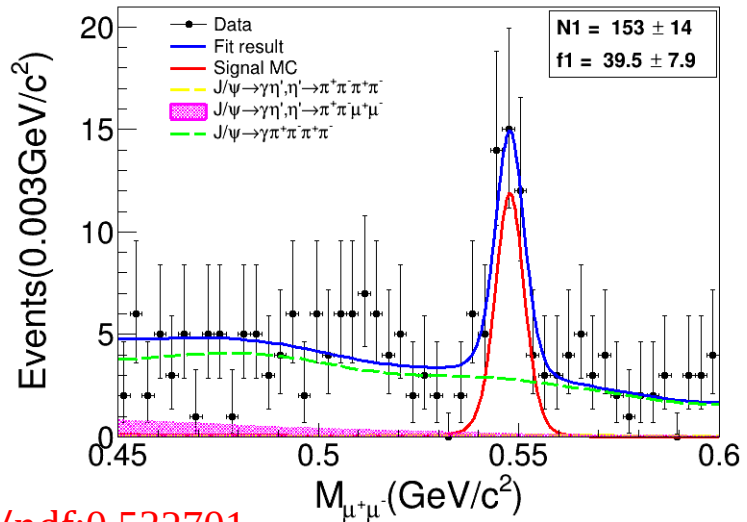
- The distribution of $M2_\mu, M_{2\pi 2\mu}, M_{2\pi}$



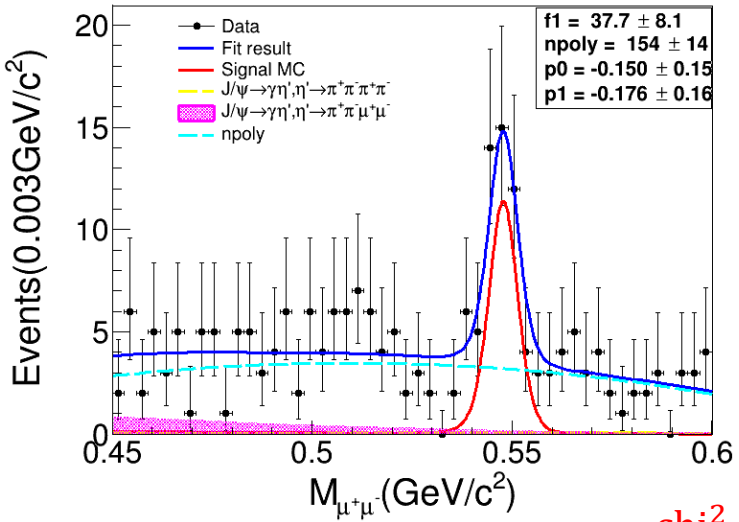




- Fit result



chi²/ndf:0.532701

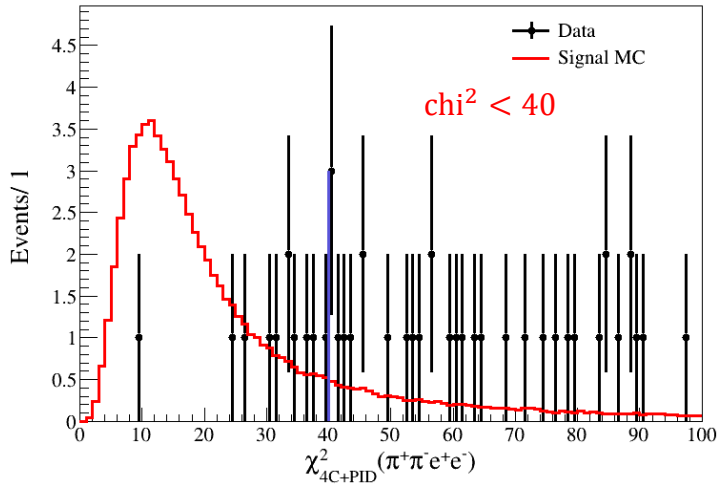


chi²/ndf: 0.458925

Search for $\eta \to e^+e^-$

➢ Futher Events selection

■ The distribution of x^2_{4C+PID}



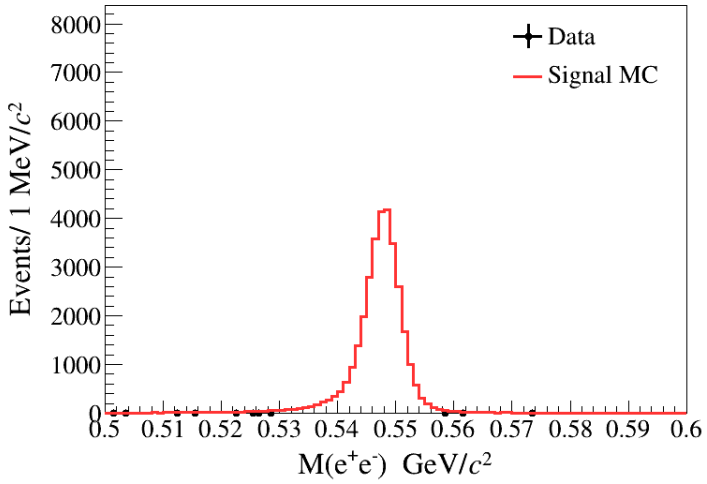
➢ Topo and cut flow

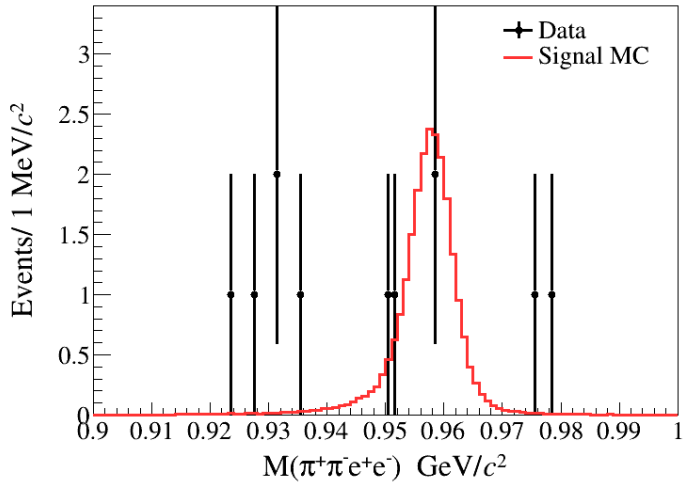
rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$J/\psi \to \eta'\gamma, \eta' \to e^+e^-\pi^+\pi^-$	$e^+e^-\pi^+\pi^-\gamma$	0	50	50
2	$J/\psi \to \eta'\gamma, \eta' \to \pi^+\pi^-\eta, \eta \to e^+e^-\gamma^F$	$e^+e^-\pi^+\pi^-\gamma^F\gamma$	1	6	56

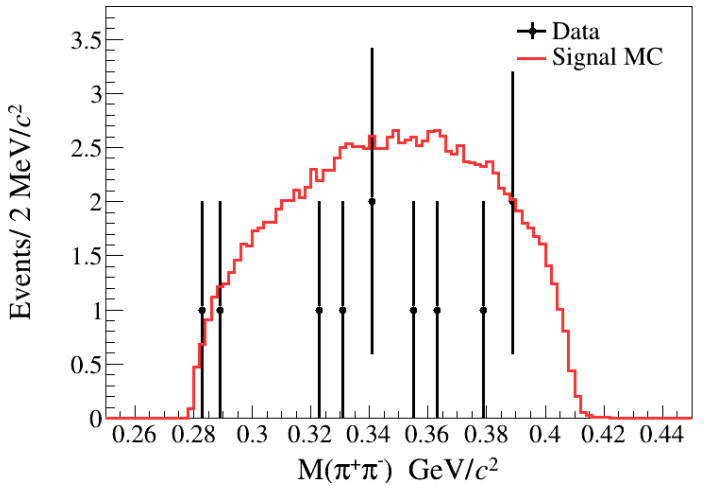
Cut	Efficiency
$0.9 < M_{\pi^+\pi^-e^+e^-} < 1$	35.97%
$0.5 < M_{e^+e^-} < 0.6$	35.39%
$x^2_{PID+4C}(\pi^+\pi^-e^+e\text{-}) < 40$	29.00%

➢ Futher Events selection

- The distribution of Mass







Next to do

- Further analysis of the background process of $\eta \to \mu^+\mu^-/\, e^+e^-$.
- Try to find a better event selection way for $\eta \to \mu^+\mu^-$decay mode.

Thank you!