



中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

2022年9-12月研究生考核报告

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- $J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta'$
 - ✓ η_c 参数化
 - ✓ X(1835) 参数化
- $J/\psi \rightarrow \gamma p \bar{p}$

➤ ATLAS 分析

- 电子和光子能量刻度修正
- Higgs 玻色子质量联合测量
- Early Run3 $H \rightarrow \gamma\gamma$ 衰变道基准截面测量

$J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta'$ 分析

➤ 研究动机

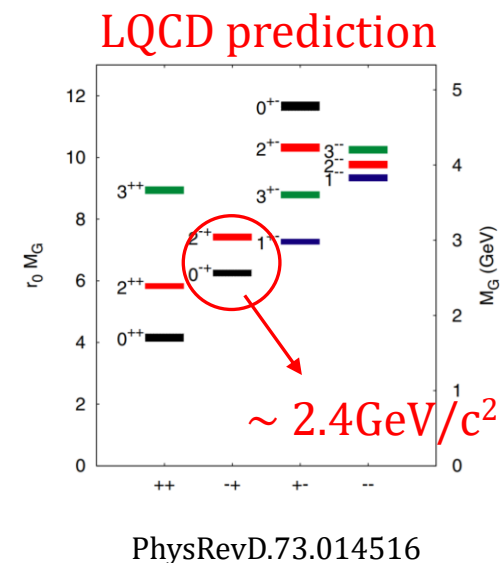
- 用分波分析方法测量 $J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta'$ 过程中的胶球候选者X(2370)的自旋宇称

➤ 研究进展

- 根据Referee Committee的两轮评论和建议，对memo做了相应地更新和修改
- memo链接:[DocDB-1077](#), [HyperNews-BAM-00603](#)

➤ 下一步

- 完成Paper draft并提交给Referee Committee



Spin-Parity determination of the X(2370) in $J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta'$

Yanping Huang^a, Shan Jin^b, and Xiaoyan Shen^a, and Peng Zhang^a

^aInstitute of High Energy Physics, CAS

^bNanjing University

Internal Referee Committee

Igor Boyko (Chair)^c, Yadi Wang^d, and Xiaolin Kang^e

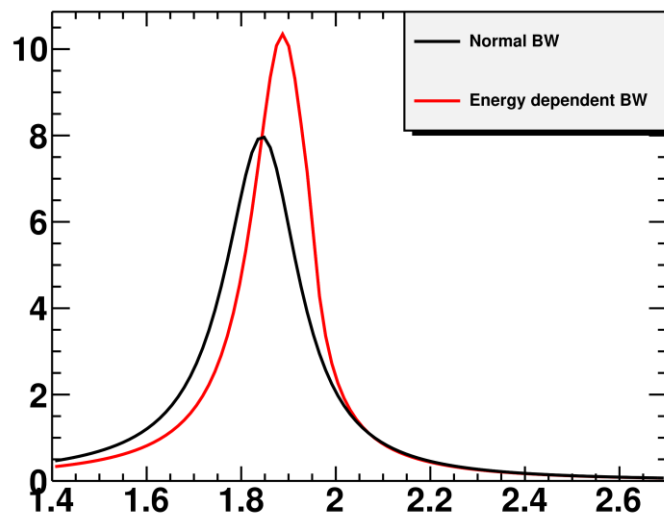
$J/\psi \rightarrow \gamma K_s^0 K_s^0 \eta'$ 分析: X(1835) 参数化

- 使用能量依赖形式的BW给X(1835)形状带来很大的影响

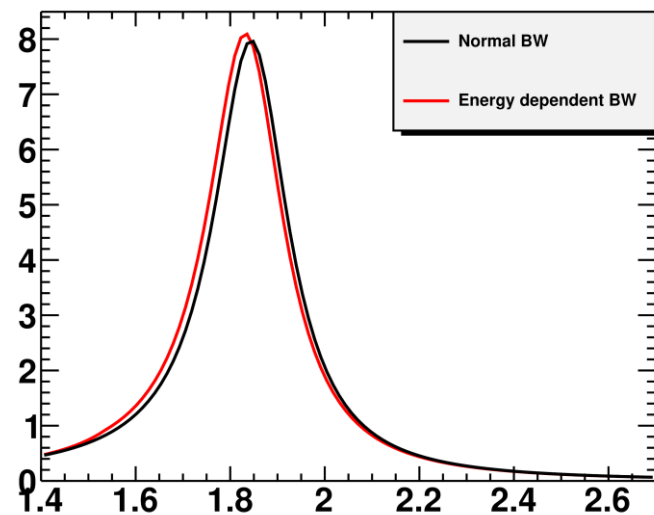
$$BW(s) = \frac{M_R \Gamma_R}{s - M_R^2 + i\sqrt{s}\Gamma(s)}$$

$$\Gamma(s) = \Gamma \left(\frac{q}{q_R} \right)^{2L+1} \left(\frac{M_R^2}{s} \right)$$

$$q^2 = \frac{[s - (m_1 + m_2)^2] \cdot [s - (m_1 - m_2)^2]}{4s}$$



$$|M_{X(1835)} - m_{f_0(980)} - m_{\eta'}| \approx 0.1 \text{ GeV}$$



$$|M_{X(1835)} - m_{f_0(980)} - m_{\eta'}| \approx 0.3 \text{ GeV}$$

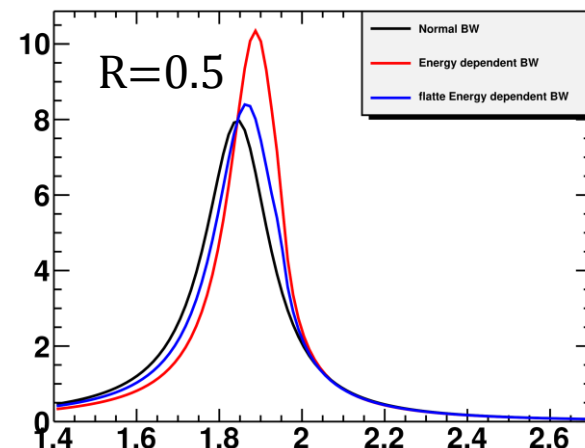
- 用类似Flatté的形式参数化近 $(K_s^0 K_s^0 \eta'$ 质量) 阈共振态X(1835)

$$BW(s) = \frac{M_R \Gamma_R}{s - M_R^2 + i\sqrt{s} \cdot \Gamma_{combined}}$$

$$\Gamma_{combined} = R \cdot \Gamma(s) + (1 - R) \cdot \Gamma_{const}$$

$R = B[X(1835) \rightarrow f_0(980)\eta']$, which is assumed to be 0.1 according to PDG

	R	$N_{X(2370)}$	S
Nominal	0.0	760	10039
	0.1	774	10040
	0.5	506	10046
	1.0	499	10050



$J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta'$ 分析: η_c 参数化

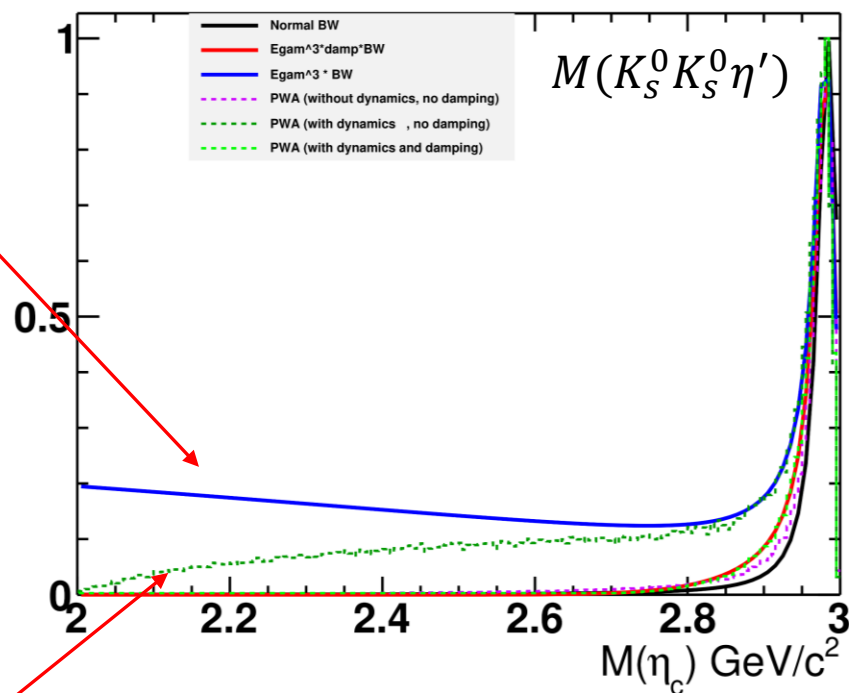
- 一般的 η_c 参数化方法,抑制因子(damping factor)用于压低近似动力学项 E_γ^3 带来的不收敛的尾巴贡献

$$f^{(\eta_c)} = E_\gamma^3 \times f_{damp}(E_\gamma) \times |BW(s)|^2$$

$$f_{damp}(E_\gamma) = e^{-\frac{E_\gamma^2}{8\beta^2}}, \beta = 0.065 \text{ GeV}$$

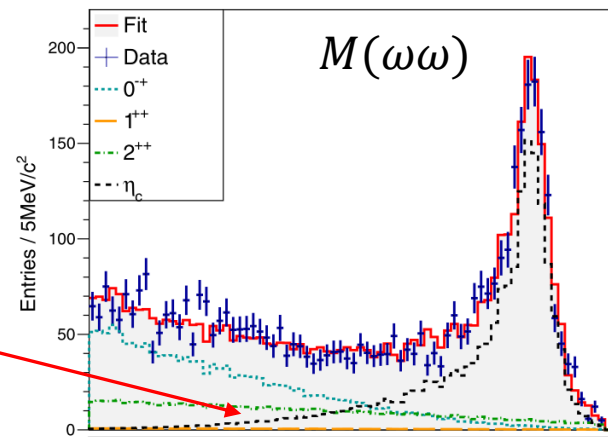
$$E_\gamma = \frac{m_{J/\psi}^2 - s}{2m_{J/\psi}}$$

$$BW(s) = \frac{M_{\eta_c} \Gamma_{\eta_c}}{s - M_{\eta_c}^2 + iM_{\eta_c} \Gamma_{\eta_c}}$$



- 协变张量(Covariant tensor)形式的分波振幅已经包含完整的动力学项, 无须使用抑制因子

- PDG最新的 η_c 质量宽度测量结果(基于helicity amplitude), 仍使用了抑制因子



Latest η_c
measurement
in PDG

$J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta'$ 分析

➤ 目前的两个分波解

state	J^{PC}	Decay mode	Mass (MeV/c^2)	Width (MeV/c^2)	Significance
X(2370)	0^{-+}	$f_0(980)\eta'$	2395^{+11}_{-11}	188^{+18}_{-17}	14.9σ
X(1835)	0^{-+}	$f_0(980)\eta'$	1844	192	$> 20\sigma$
X(2750)	0^{-+}	$f_0(980)\eta'$	2815^{+53}_{-54}	641^{+181}_{-108}	16.4σ
η_c	0^{-+}	$f_0(980)\eta'$	2983.9	32.0	$> 20.0\sigma$
PHSP	0^{-+}	$\eta'(K_S^0 K_S^0)_{S-wave}$	---	---	9.0σ
		$\eta'(K_S^0 K_S^0)_{D-wave}$	---	---	16.3σ

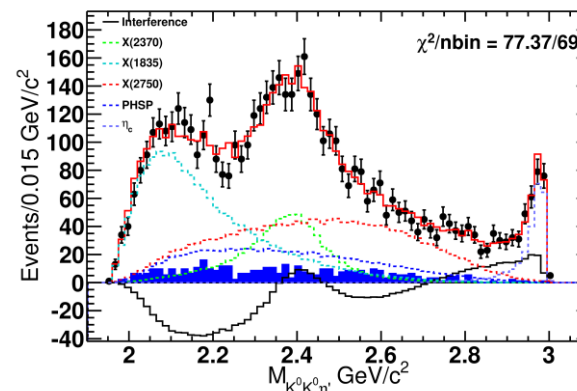
state	J^{PC}	Decay mode	Mass (MeV/c^2)	Width (MeV/c^2)	Significance
X(2370)	0^{-+}	$f_0(980)\eta'$	2405^{+13}_{-13}	167^{+20}_{-18}	12.7σ
X(2600)	0^{-+}	$f_0(980)\eta'$	2618.3	195	4.2σ
X(1835)	0^{-+}	$f_0(980)\eta'$	1844	192	$> 20\sigma$
X(2750)	0^{-+}	$f_0(980)\eta'$	2781^{+32}_{-35}	363^{+146}_{-81}	10.1σ
η_c	0^{-+}	$f_0(980)\eta'$	2983.9	32.0	$> 20.0\sigma$
PHSP	0^{-+}	$(K_S^0 K_S^0)_{S/D-wave}\eta'$	---	---	18.0σ

➤ X(2370)的测量结果

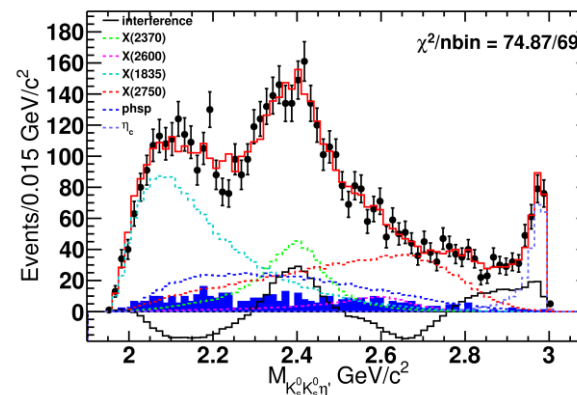
- $J^{PC} = 0^{-+}$
- Mass = $2395^{+11}_{-11}(\text{stat.})^{+11}_{-15}(\text{syst.}) MeV/c^2$, Width = $188^{+18}_{-17}(\text{stat.})^{+12}_{-21}(\text{syst.}) MeV/c^2$
- $B[J/\psi \rightarrow \gamma X(2370)] * B[X(2370) \rightarrow f_0(980)\eta'] * B[f_0(980) \rightarrow K_S^0 K_S^0] = 1.32 \pm 0.22(\text{stat.})^{+0.31}_{-0.25}(\text{syst.}) \times 10^{-5}$

Projection of combined channel:

$\eta' \rightarrow \pi^+ \pi^- \eta$ and $\eta' \rightarrow \gamma \rho^0$



Nominal



taken as syst.
uncertainty

$J/\psi \rightarrow \gamma p \bar{p}$ 分析

➤ 研究动机

- 用分波分析方法测量 $J/\psi \rightarrow \gamma p \bar{p}$ 过程中 $p \bar{p}$ 不变质量阈增长结构的质量和宽度

➤ 研究进展

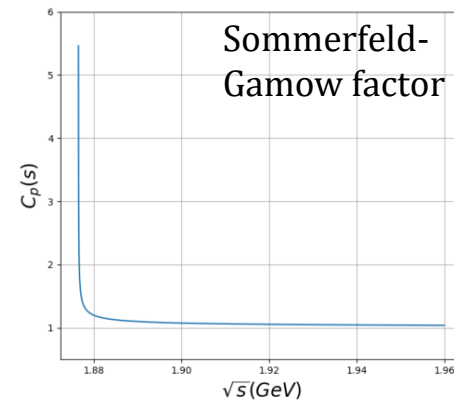
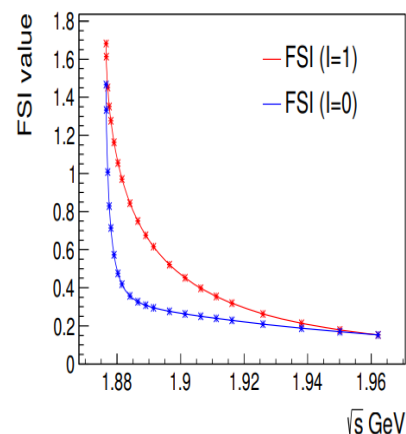
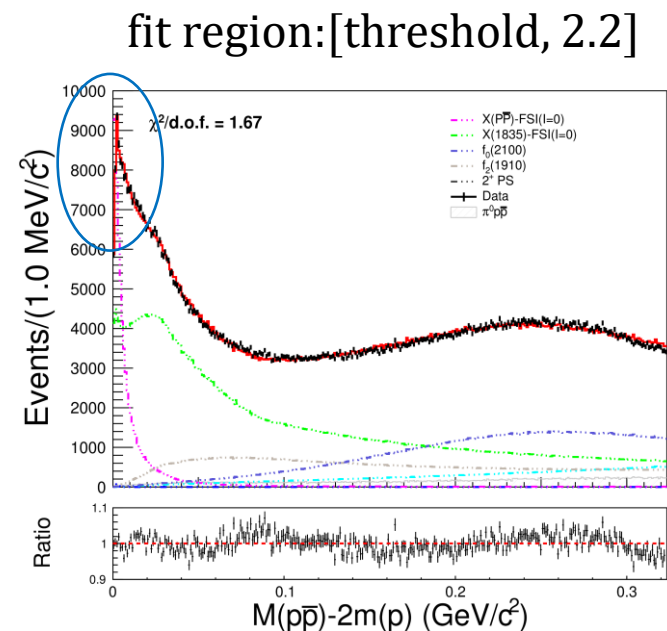
- 目前的分波解
 - ✓ 在共振态参数化的时候考虑了库伦因子(Sommerfeld-Gamow factor)
 - ✓ $\sqrt{FSI(I=0)} \times \sqrt{C_p(S)} \times BW_{propagator}$
 - ✓ 窄共振态 X(1879), 其参数为 $M=1879.3$ and $\Gamma=0.6$ MeV
- X($p \bar{p}$) 的测量结果:
 - ✓ $M=1876.4 \pm 0.1$ MeV/ c^2 , $\Gamma=8.5 \pm 0.2$ MeV/ c^2

- 额外相空间检查

➤ 下一步

- 继续优化分波解

Additional resonance	J^{PC}	$\ln(\mathcal{L})$	Significance
PHSP	0^{++}	-931295.23	<i>nominal</i>
	0^{-+}	-931311.25	5.31σ
	1^{++}	-931355.58	10.36σ
	2^{-+}	-931418.87	14.95σ
	2^{++}	-931518.17	19.87σ



Atlas: $J/\psi \rightarrow ee$ 电子和光子能量刻度修正

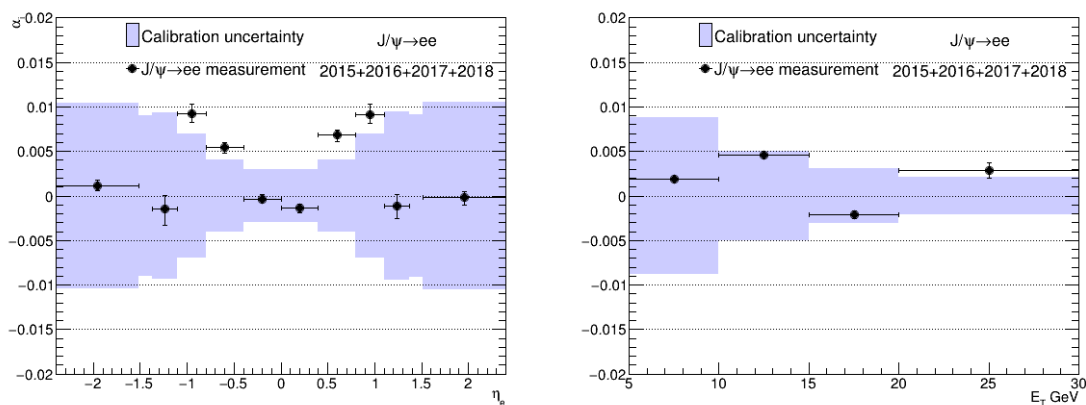
➤ 研究动机

- 通过 $J/\psi \rightarrow ee$ 过程验证低横向动量区间下基于 Zee 的能量刻度
- 通过 $Z \rightarrow ll\gamma$ 过程验证光子的能量刻度

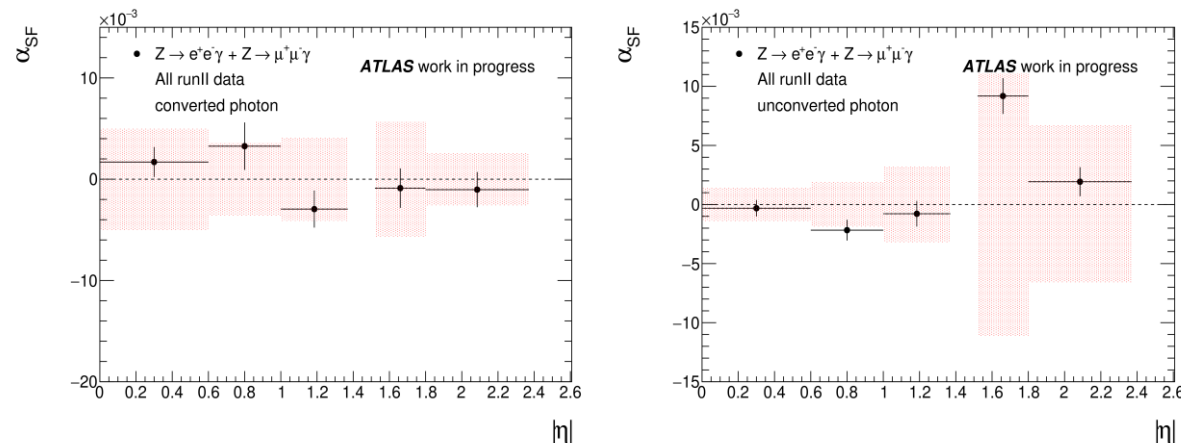
➤ 能量刻度修正

- 电子: 最大值约0.9%, 与 Zee calibration 的误差相符合
- 光子, $Z \rightarrow ee\gamma$: $(+0.97 \pm 0.81) \times 10^{-3}$
- 光子, $Z \rightarrow \mu\mu\gamma$: $(-0.03 \pm 0.44) \times 10^{-3}$

➤ 报告链接: [CLHCP 2022](#), 并在 [Egamma Calibration](#) 会上给了6次报告



$J/\psi \rightarrow ee$



$Z \rightarrow ll\gamma$

Higgs玻色子质量联合测量

➤ 联合分析的两个衰变道: $H \rightarrow \gamma\gamma$ 和 $H \rightarrow ZZ^* \rightarrow 4l$

➤ 目前的关联方案

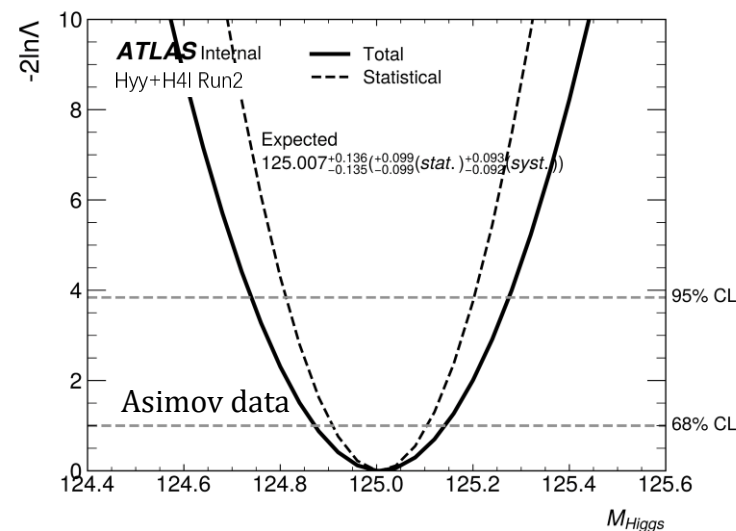
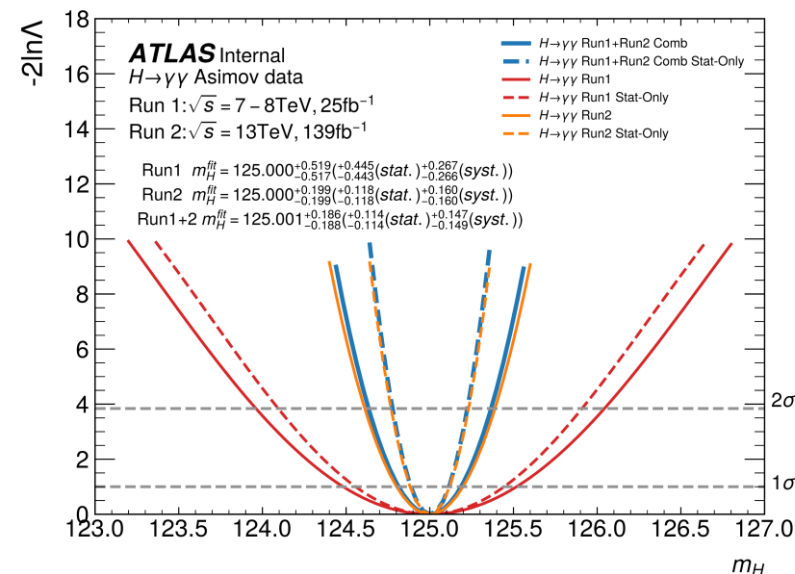
Correlated	POI	NP
Combined $H \rightarrow \gamma\gamma$ Run1+Run2	m_H and μ_V, μ_F	Experimental, energy scale(1) Experimental, energy resolution(4) Theoretical(4)
Combined $H \rightarrow \gamma\gamma$ + $H \rightarrow ZZ^*$ Run2	m_H and μ	No NP treated as correlated

➤ Higgs粒子质量测量结果, 基于Asimov data

- 报告链接: [Report](#)
- 继续研究系统误差及其关联

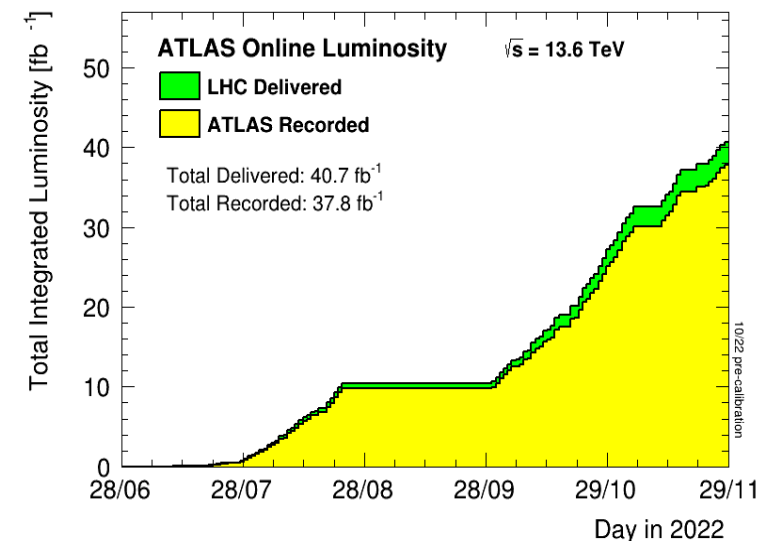
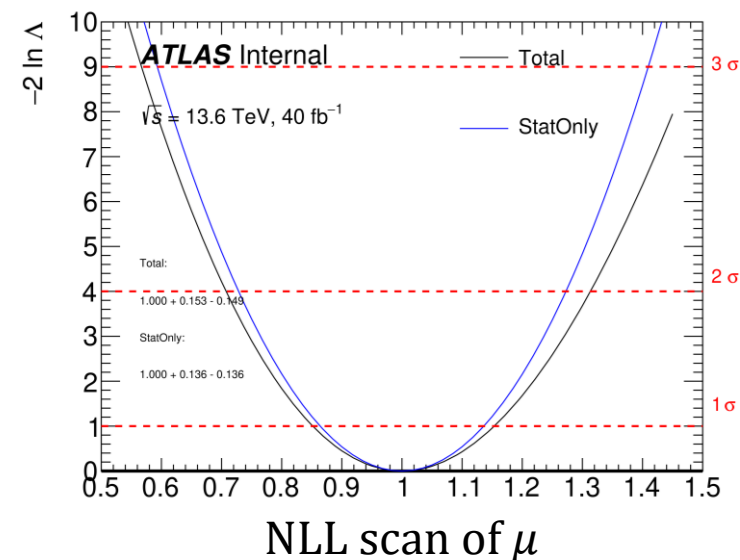
m_H (GeV)	Run1	Run2	Run1+Run2
H $\gamma\gamma$	125.000 ± 0.52	125.000 ± 0.20	125.001 ± 0.18
HZZ*	--	125.012 ± 0.19	--
H $\gamma\gamma$ +HZZ*		125.007 ± 0.14	TO DO

➤ 文章发表计划: 完成了EB申请([Approval Meeting](#), [INT Note](#)), 预计24年发表一篇CONF note



Run3 $H \rightarrow \gamma\gamma$ 衰变道基准截面测量

- 研究动机: $H\gamma\gamma$ 截面测量对研究希格斯玻色子的属性非常重要
- 上一轮的分析: $pp \rightarrow H \rightarrow \gamma\gamma$ Run 2 analysis ([differential XS](#), [coupling](#)) of 2015-2018 data
- 本轮分析与上一轮分析的不同
 - 使用Run 3 data @ 13.6 TeV, 并且Athena 版本更新到 Release 22
- 基于Rel21 mc16e和data18给出了初步结果(Rel22 下的样本正在产生中)
 - $\sigma_{fid} = 68.6_{-10.2}^{+10.5} \text{ fb} [\pm 9.3(stat.)_{-4.2}^{+4.8}(syst.)]$
- 担任supporting note editor, 并给了approval talk ([Approval Meeting](#), [INT Note](#))
- 文章发表计划: 已经完成EB申请, 预计23年发表一篇 CONF note 或者 paper (Moriond 2023)



[Current Run3 Lumi](#)

总结

➤ BESIII 分析

- $J/\psi \rightarrow \gamma K_S^0 K_S^0 \eta'$
 - ✓ 根据Referee Committee的两轮评论更新了memo, 正在撰写Paper Draft([HyperNews-BAM-00603](#))
 - ✓ 继续研究 η_c 的参数化形式
- $J/\psi \rightarrow \gamma p \bar{p}$
 - ✓ 继续优化分波解

➤ ATLAS 分析

- 电子和光子能量刻度修正
 - ✓ 基于最新的EGamma recommendations, 给出了能量刻度修正, 并和Zee calibration的误差做了比较
 - ✓ 结果在CLHCP 2022上做了汇报
- Higgs玻色子质量联合测量
 - ✓ 联合 $H \rightarrow \gamma\gamma$ 和 $H \rightarrow ZZ^* \rightarrow 4l$, 基于Asimov data和现有的关联方案, 给出了测量结果
 - ✓ 继续研究系统误差及其关联
- Run3 $H \rightarrow \gamma\gamma$ 衰变道基准截面测量
 - ✓ 担任内部文章编辑, 完成EB申请([Approval Meeting](#), [INT Note](#))



Thanks!



η_c parameterization

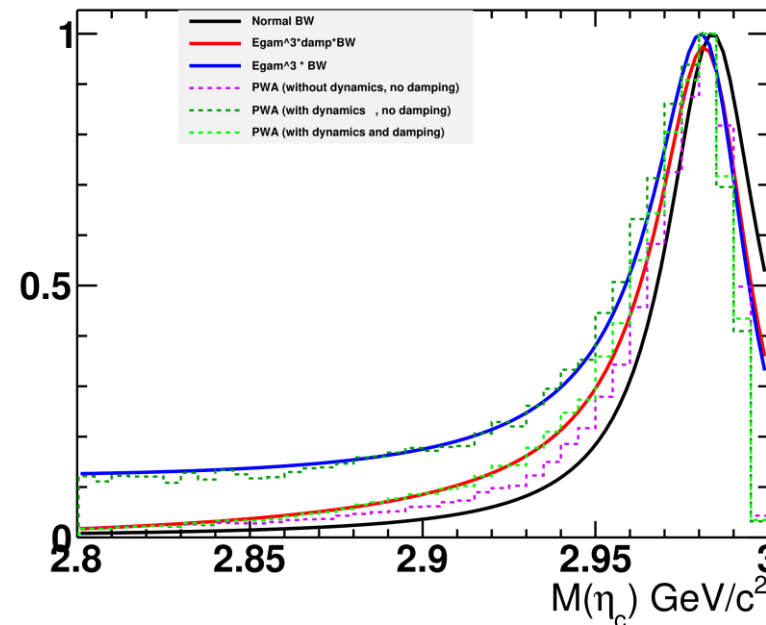
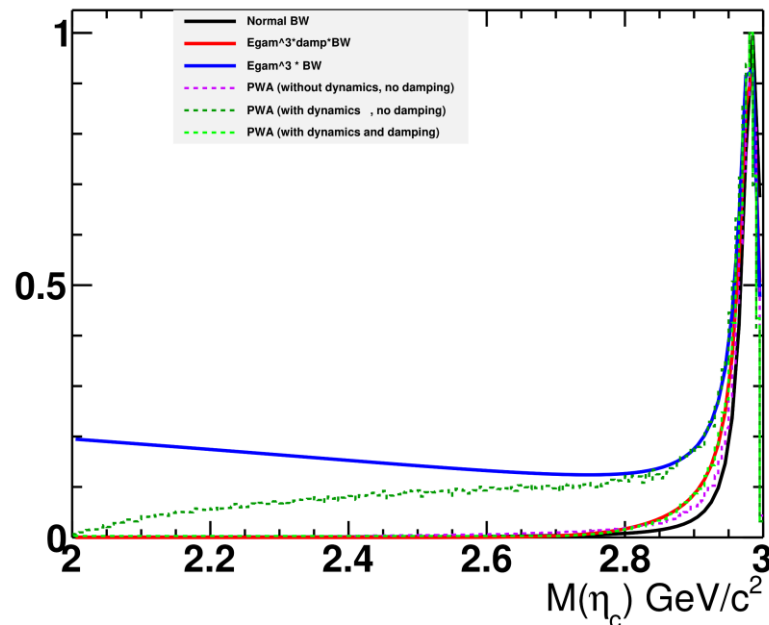
➤ Possible η_c lineshapes. Mass and width are from PDG

- Normal BW (without E_γ^3)
- BW and Apply: E_γ^3 and CLEO's damping factor
- BW and Apply: E_γ^3
- PWA (without dynamics, no damping)
- PWA (with dynamics, no damping)
- PWA (with dynamics and damping)

$$d(E_\gamma) = \exp\left(-\frac{E_\gamma^2}{8\beta^2}\right)$$

PWA framework: covariant tensor amplitude method

Bing-Song Zou and DV Bugg. Covariant tensor formalism for partial-wave analyses of ψ decay to mesons. *The European Physical Journal A-Hadrons and Nuclei*, 16(4):537–547, 2003.



NP classification for Hyy Run1 and Run2

Four NPs are classified into Migration uncertainty (comes from uncertainties on the variables used to build the categories), then the remaining systematic uncertainties can be classified into following other different types:

➤ Migration

- 4 NPs (Run1 only): ATLAS_mat, ATLAS_ConvEff_Mig, ATLAS_ConvFakeRate_Mig, ATLAS_pTmodel_ggH

➤ Experimental

- E/γ calibration (working on both normalization and shape)
 - ✓ Scale (Run1: 41 NPs, Run2: 68 NPs): only one NP is correlated, **ATLAS_EG_SCALE_ZEESYST**
 - ✓ Resolution (Run1: 4 NPs, Run2: 6 NPs): 4 NPs are correlated
- Photon
 1. **ATLAS_EG_RESOLUTION_ZSMEARING**
 2. **ATLAS_EG_RESOLUTION_MATERIAL_RUN1_RUN2**
 3. **ATLAS_EG_RESOLUTION_PILEUP**
 4. **ATLAS_EG_RESOLUTION_SAMPLINGTERM**
- Luminosity
- Pileup-reweighting
- Spurious signal and model bias

➤ Theoretical

- (Run1: 12 NPs, Run2: 10 NPs): 2 NPs are correlated, **ATLAS_QCDscale_ggH/ttH**