ATLAS 中国组工作成果和进展

庄胥爱

中国科学院高能物理研究所

代表ATLAS 中国组

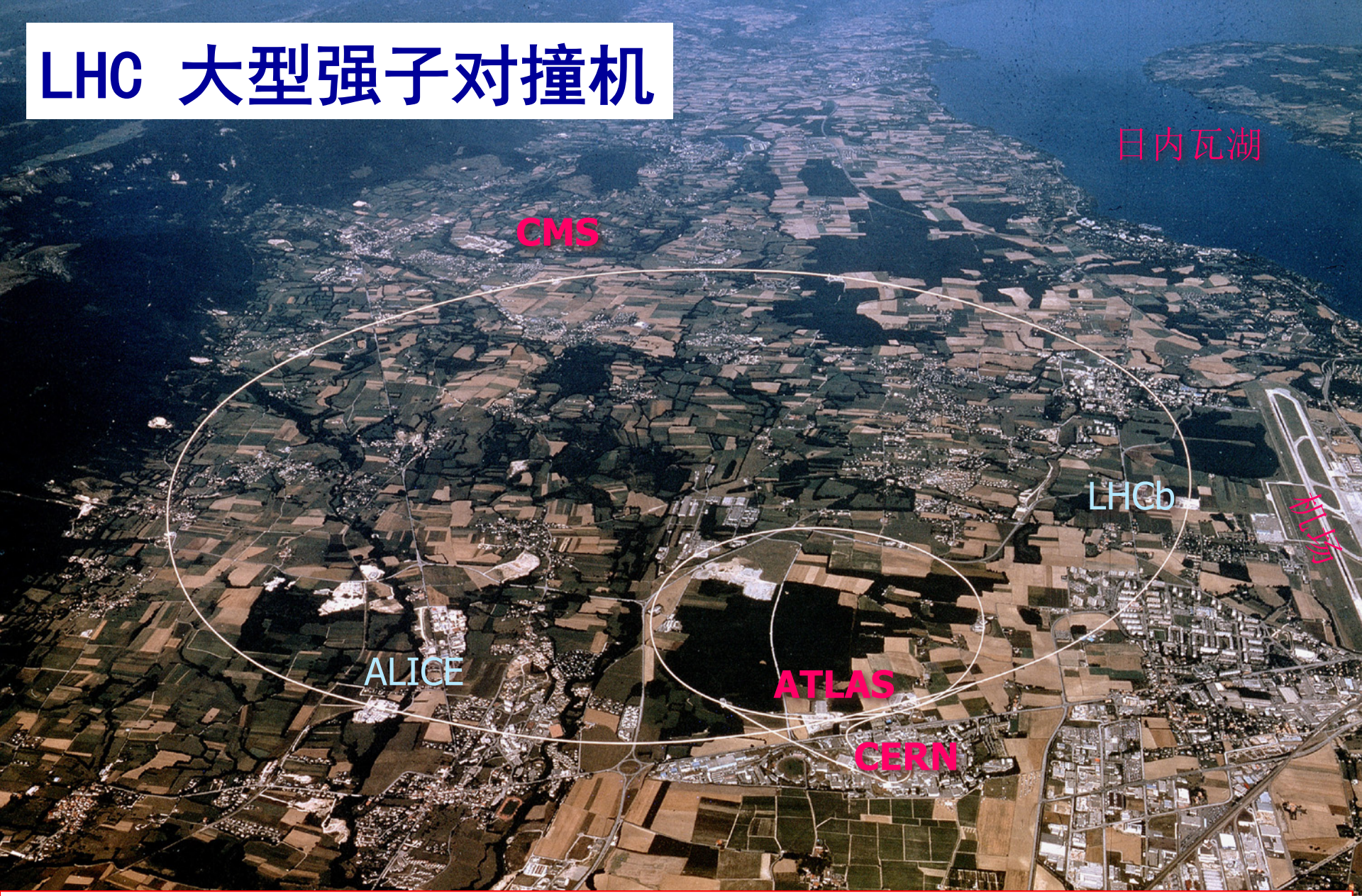
第四届CLHCP会议，武汉，19-22 Dec. 2018

感谢刘衍文，杨海军，马连良，张雷，陈新，金山等各位老师提供材料

报告内容

- 研究队伍介绍
- 主要物理成果总结
- 探测器运行和升级工作
- 总结

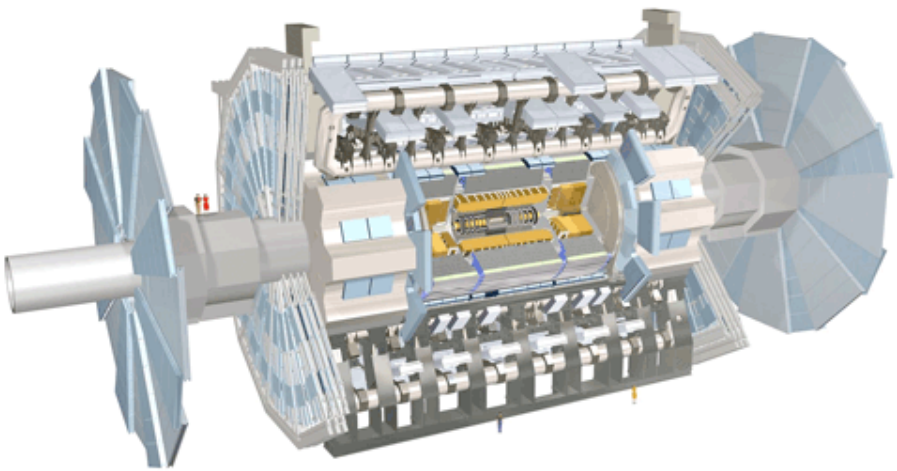
LHC 大型强子对撞机

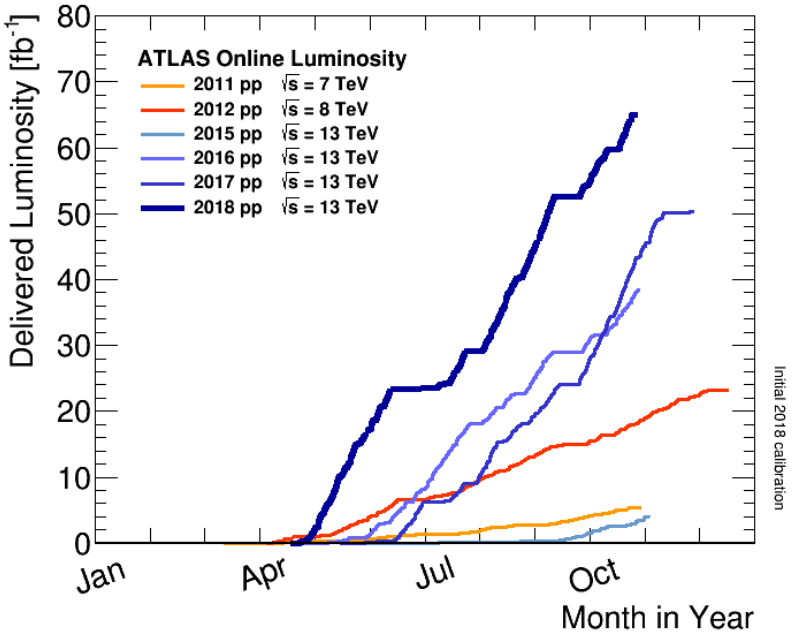


- 周长 27 公里，隧道深100米，跨越瑞士法国国境
- 世界最大，能量最高的加速器，进行最前沿的粒子物理研究

ATLAS实验

ATLAS是LHC上主要的通用实验之一，是世界上最大的粒子物理探测器。





LHC Run-1： 2010-2012 7-8TeV 质子–质子对撞 ~ 26 fb^{-1}

Run-2： 2015-2018 13TeV 质子–质子对撞 ~ 150 fb^{-1}

ATLAS 中国组

- ☞ ATLAS 中国组共两个cluster，7家单位
- ☞ ATLAS 中国组现有40名教职员工，其中院士1名、万人计划领军人才2名、杰青3名、优青1名，其他人才若干，还有博士后、学生、工程师和技术人员，共193名

■ ***IHEP-NJU-THU Cluster（高能所-南大-清华联合组）***

- □ Institute of High Energy Physics (高能所)
  娄辛丑、 Joao Costa、欧阳群、庄胥爱、方亚泉、朱宏博 、黄燕萍 、梁志均、史欣 、李一鸣 、吕峰、单连友、徐达
- □ Nanjing University (南大)
  陈申见、金山、祁鸣，张雷，闵天觉
- □ Tsinghua University （清华）
  陈新

■ ***USTC-SDU-SJTU Cluster（科大-山大-交大联合组）***

- □ University of Science and Technology of China (科大)
  赵政国、韩良、蒋一、刘衍文、刘建北 、彭海平、朱莹春、刘明辉、吴雨生 、孙勇杰、Rustem Ospanov
- □ Shandong University (山大)
  张学尧、马连良 、冯存峰、祝成光、李海峰
- □ Shanghai Jiao Tong University （上海交大）
  杨海军 、李亮 、郭军 、周宁
- □ T.D. Lee Institute（李政道研究所）李数

→ATLAS中国组是中国参加LHC 实验最大的一支研究队伍，竞争力非常强

LHC/ATLAS 物理目标

ATLAS和CMS实验于2012年发现希格斯粒子后，LHC/ATLAS实验的主要物理目标为：

- 精确测量希格斯粒子的性质，理解真空对称性自发破缺机制
- 寻找超出标准模型的新物理

主要物理成果总结

- ☞ 标准模型 Higgs 性质测量 & 高质量 Higgs 粒子寻找
- ☞ SUSY粒子和其他新物理寻找
- ☞ 标准模型测量检验

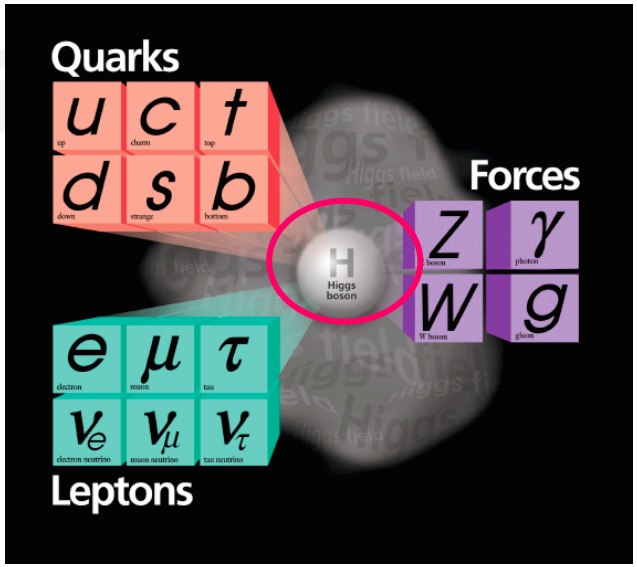
中国组有贡献的课题非常多，仅统计主导或主要贡献的课题，主要highlight主导贡献的成果。

- **主导贡献：** 在该物理分析中担任分析联系人（Analysis Contact）或在ATLAS内部撰写期刊文章或会议文集 ATLAS-CONF-NOTE 时担任联系编辑（Contact Editor）

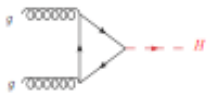
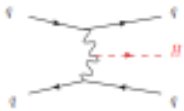
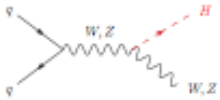
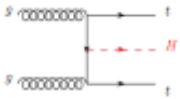
- **主要贡献：** 做合作组内各层级的批准报告（approval talks）或担任文章、会议文集的内部编辑（Editors）或代表合作组在国际会议报告与该分析相关的研究成果

主要物理成果总结

- 标准模型 Higgs 性质测量 & 高质量 Higgs 粒子寻找
- SUSY粒子和其他新
- 标准模型测量检验



ATLAS 实验 Higgs粒子性质研究全景

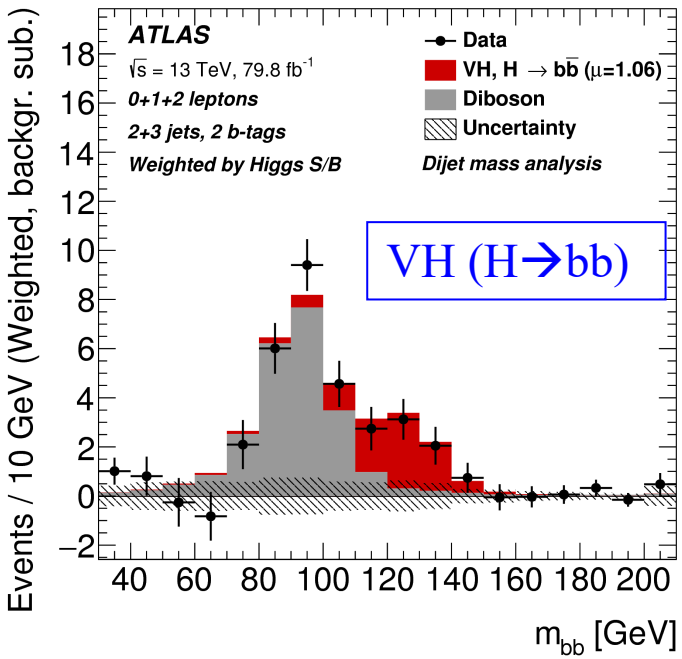
Channel	ggF 	VBF 	VH 	ttH 	Mass	CP	X-sec.	Width
γγ	★ ★	★ ★	★★	★	★ ★	★★	★ ★	★
ZZ*(4l)	★ ★	★ ★	★★	★★	★ ★	★ ★	★ ★	★ ★
WW*(lνlν)	★ ★	★ ★	★ ★	★ ★		★★	★★	★ ★
ττ	★ ★	★ ★	★ ★	★				
bb	★ ★		★ ★	★ ★				
Zγ	★ ★							
μμ	★★	★ ★						
invisible	★★	★ ★	★ ★					

★ ATLAS进行的分析 ★中国组贡献的分析

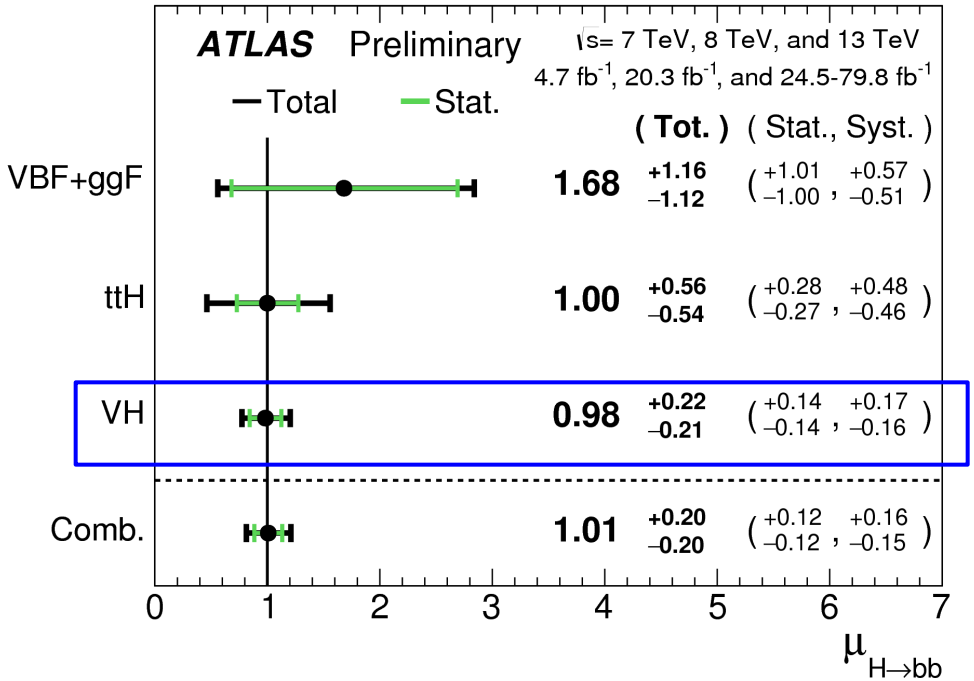
中国组广泛深入地参与了ATLAS实验的 Higgs 粒子性质测量研究。

ATLAS 实验发现 H→bb

首次发现了H→bb的衰变，
验证了汤川耦合



PLB 786(2018)59



Run 2 VH, H→bb sign.: 4.9σ (4.3σ) obs (exp)

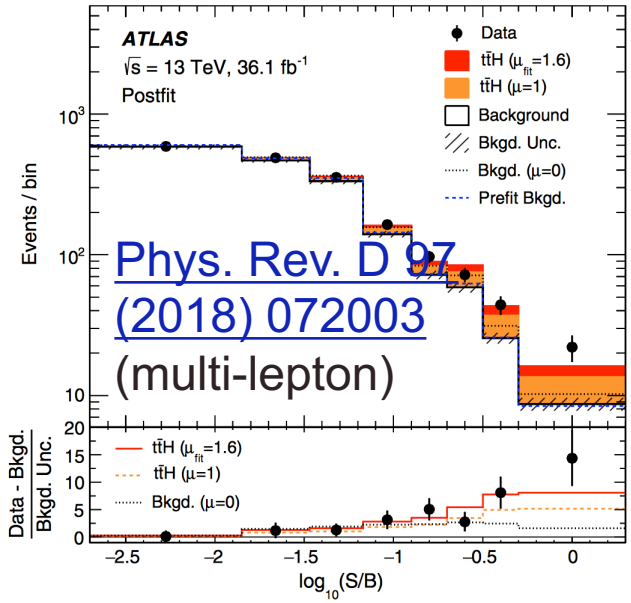
Combined with Run 1: 4.9σ (5.1σ) obs (exp)

Combined with *VBF(+ggF) and ttH (Run1+Run2)*: 5.4σ (5.5σ) obs (exp)

南大、山大、科大、交大在最灵敏的VH 分析中做出主要贡献（editors）
高能所主导了 VBF 分析 （contact）

Observation of ttH production

中国4家单位参与



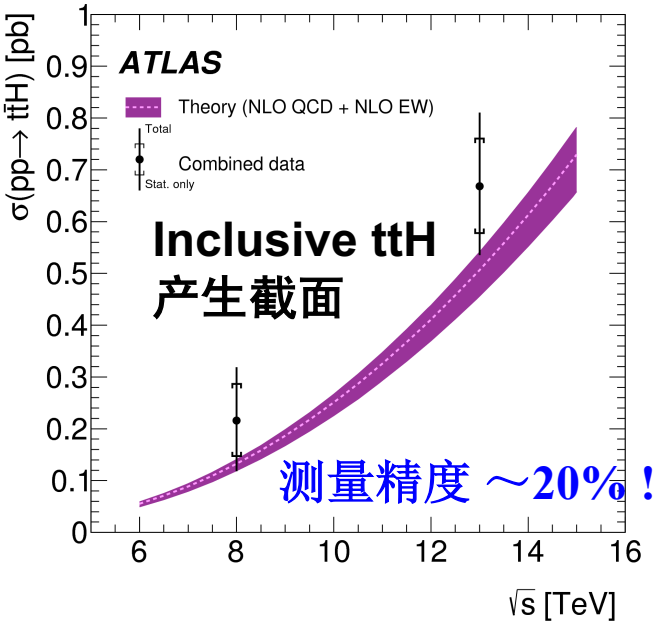
Phys. Rev. D 97 (2018) 072003 (multi-lepton)

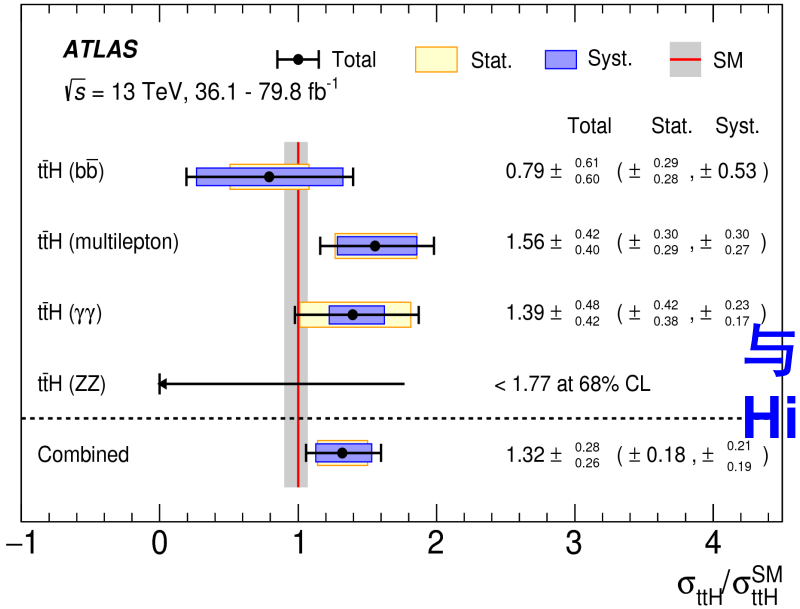
Analysis	Integrated luminosity [fb^{-1}]	$t\bar{t}H$ cross section [fb]	Obs. sign.	Exp. sign.
$H \to \gamma\gamma$	79.8	$710\ ^{+210}_{-190}$ (stat.) $^{+120}_{-90}$ (syst.)	4.1 σ	3.7 σ
$H \to$ multilepton	36.1	790 $\pm$150 (stat.) $^{+150}_{-140}$ (syst.)	4.1 σ	2.8 σ
$H \to b\bar{b}$	36.1	400 $^{+150}_{-140}$ (stat.) $\pm$ 270 (syst.)	1.4 σ	1.6 σ
$H \to ZZ^* \to 4\ell$	79.8	<900 (68% CL)	0 σ	1.2 σ
Combined (13 TeV)	36.1–79.8	670 $\pm$ 90 (stat.) $^{+110}_{-100}$ (syst.)	5.8 σ	4.9 σ
Combined (7, 8, 13 TeV)	4.5, 20.3, 36.1–79.8	–	6.3 σ	5.1 σ

主要贡献

Direct observation of top Higgs coupling.
Confirmation of Yukawa coupling to fermions.

Phys. Lett. B 784 (2018) 173 （combination）





高能所，山大，科大，交大

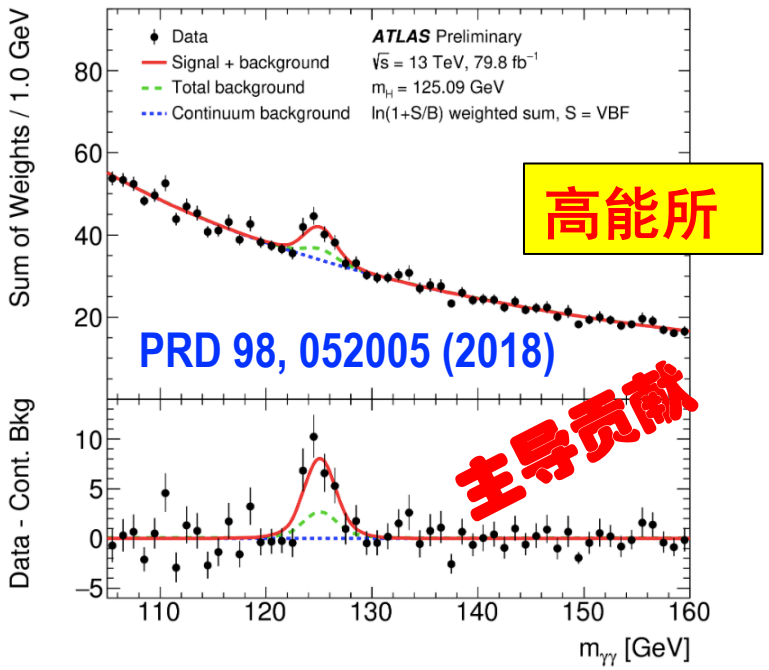
与标准模型Higgs一致

Gauge boson and Yukawa fermion coupling

Interaction with gauge bosons:

Run1: Higgs boson discovered at 7-8TeV.
Main channels: $H \to \gamma\gamma$, $H \to ZZ$, $H \to WW$

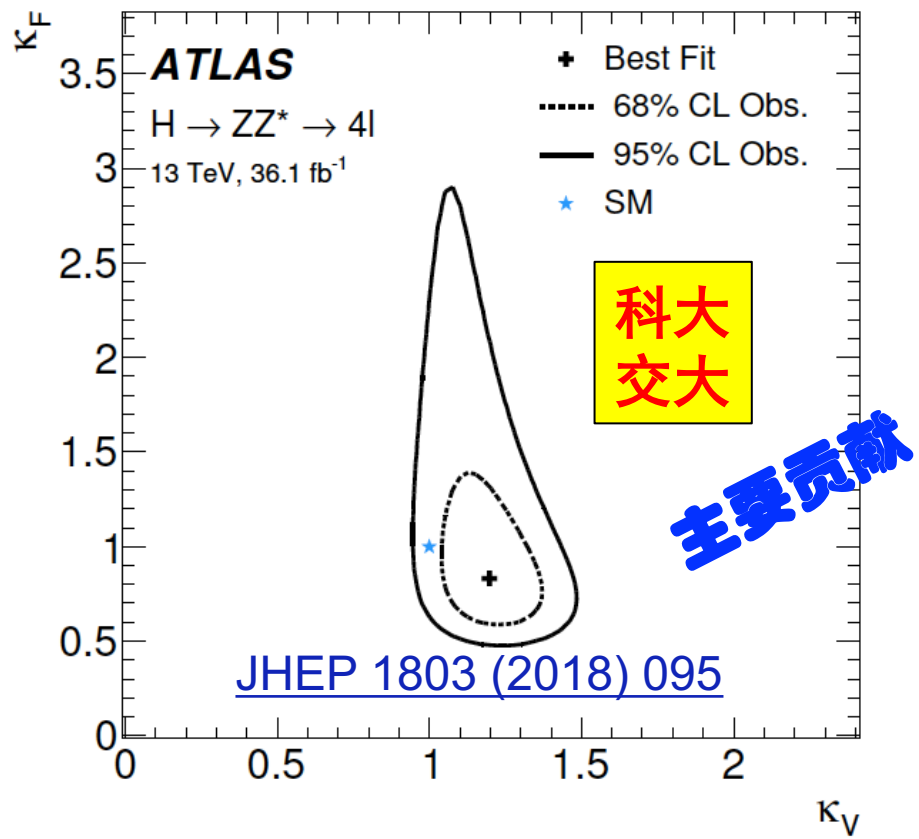
Recent Run2 results: VBF $H \to \gamma\gamma$



PRD 98, 052005 (2018)

观测到5σ的VBF信号，主要贡献来自H->γγ

Recent Run2 results: $H \to ZZ$



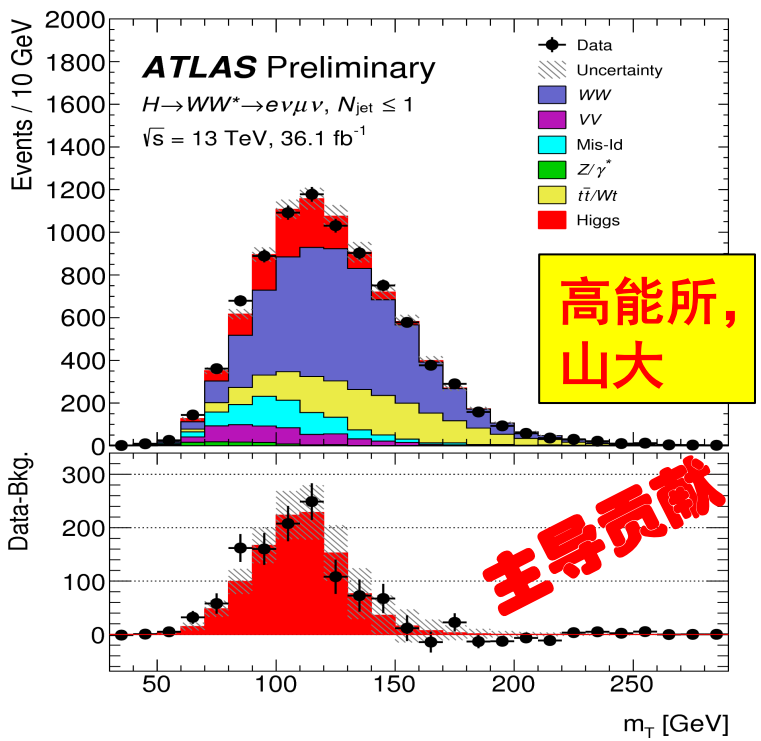
JHEP 1803 (2018) 095

Gauge boson and Yukawa fermion coupling

Interaction with gauge bosons:

Run1: Higgs boson discovered at 7-8TeV.
Main channels: H → γγ, H →ZZ, H → WW

Recent Run2 results: H → WW

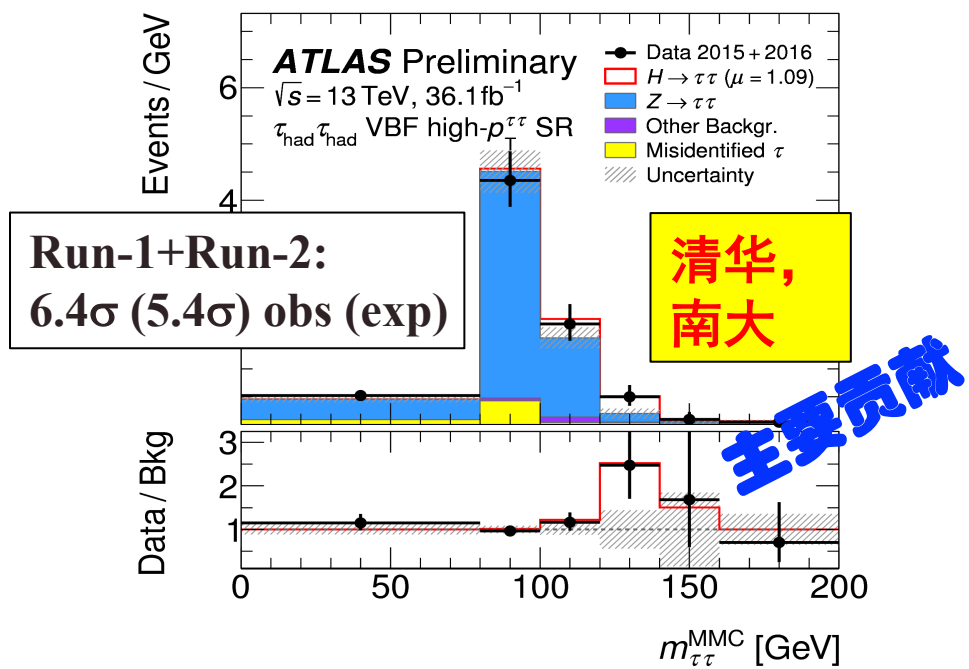


arXiv:1808.09054

Yukawa coupling to fermions:

Run1: Only glimpse at 7-8 TeV (2012)
ATLAS/CMS combined H→ττ:
5.5σ (5.0σ) obs (exp) for 7/8 TeV (JHEP 08 (2016) 045)

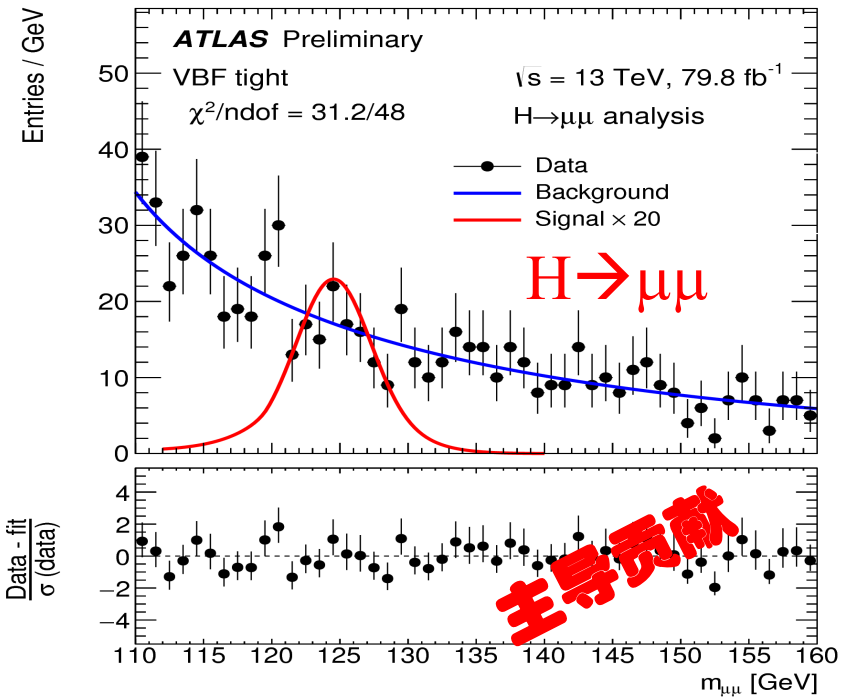
Recent Run2 results: H → ττ



arXiv:1811.08856

Higgs rare decays H→μμ

山大，科大



ATLAS-CONF-2018-026

VBF+ggF

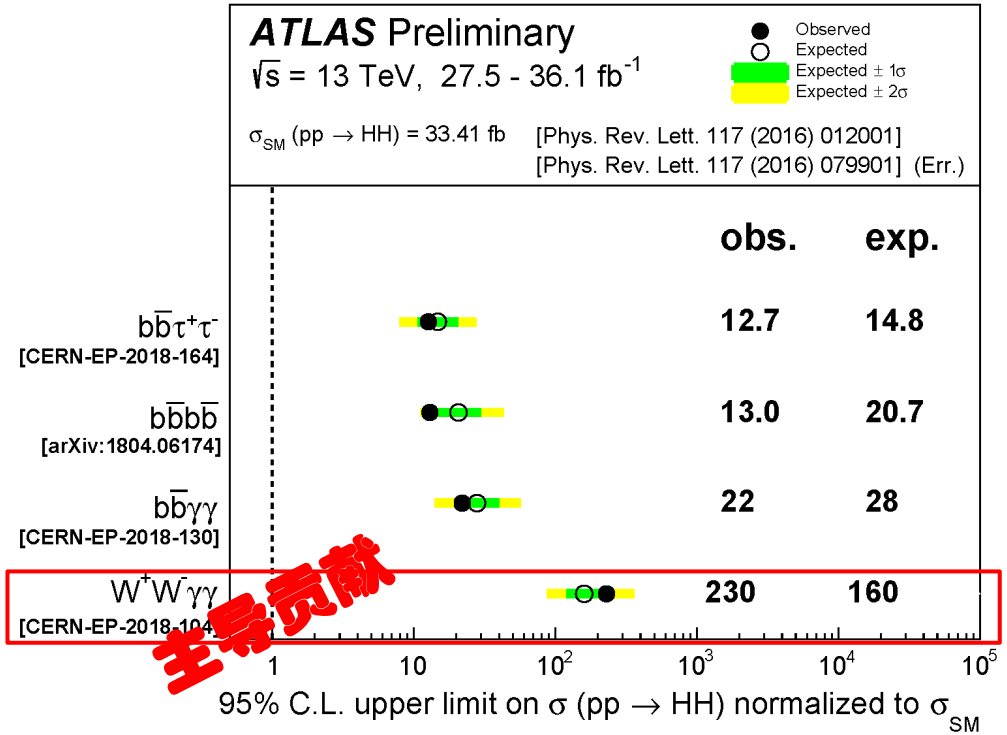
$\sigma_{limit}/\sigma_{SM} < 2.1$ (obs)

Signal strength $\mu = 0.1^{+1.0}_{-1.1}$

SM Di-higgs production

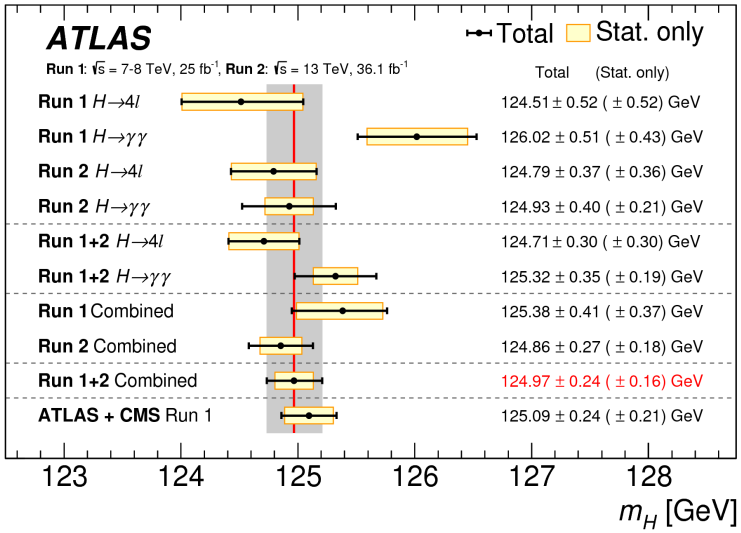
- Di-Higgs production process is direct probe of SM trilinear coupling.
- Strong destructive interference between processes.

高能所



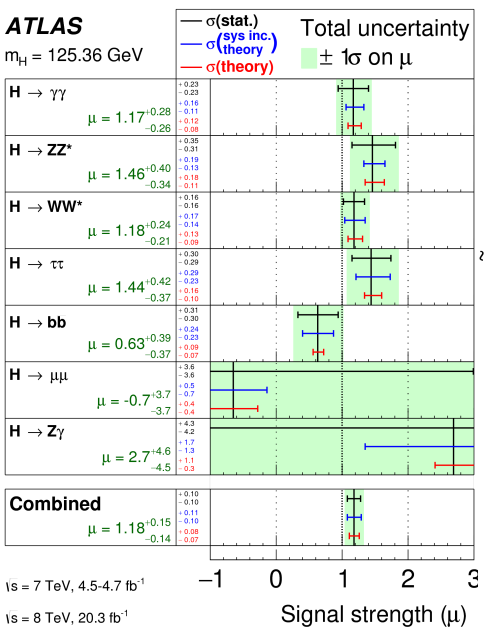
Limit approaching: $\sigma_{limit}/\sigma_{SM} \sim 10$

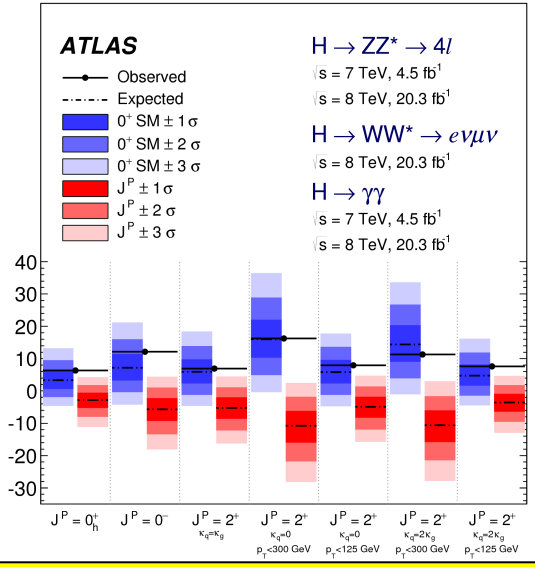
Higgs 粒子性质测量

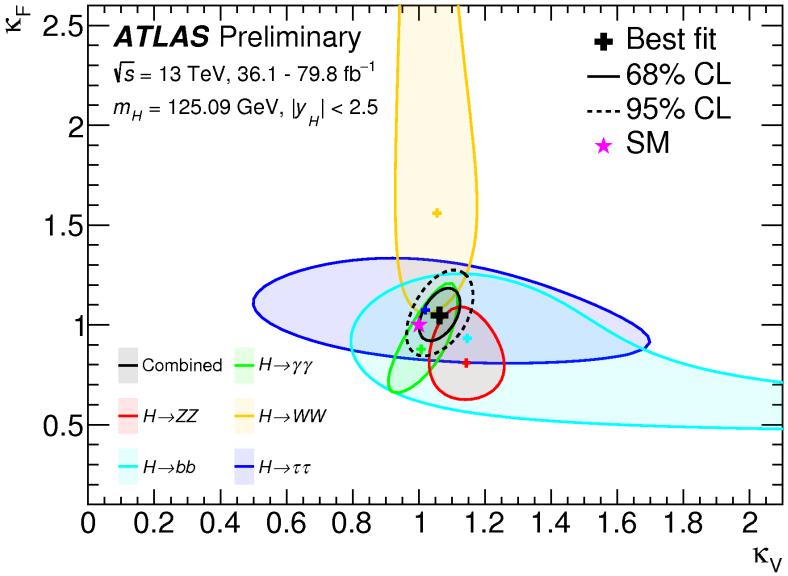


Results are consistent with the SM!

- **Higgs mass: 124.97 ± 0.24 GeV**
  (CMS HZZ4l: 125.26± 0.21 GeV)
- **Higgs strength: $\mu = 1.18^{+0.15}_{-0.14}$ (run1)**
  (CMS 13 TeV 2016 comb: $1.17^{+0.1}_{-0.1}$)
- **Spin/Parity: 0^+**
- **Couplings: agree with SM predictions**

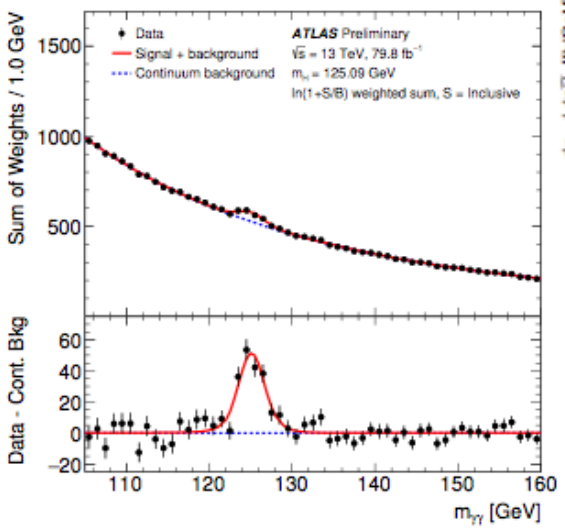




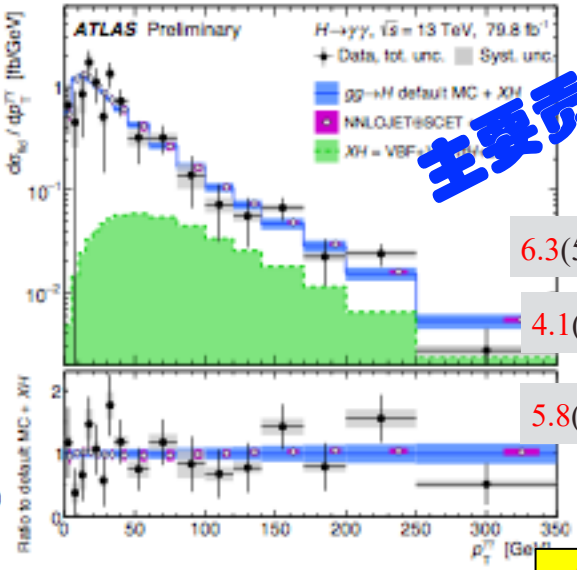


中国组7个单位都广泛参与了各个方面的研究工作

双光子末态Higgs性质的测量　　Higgs性质的联合测量



PRD 98（2018）052005



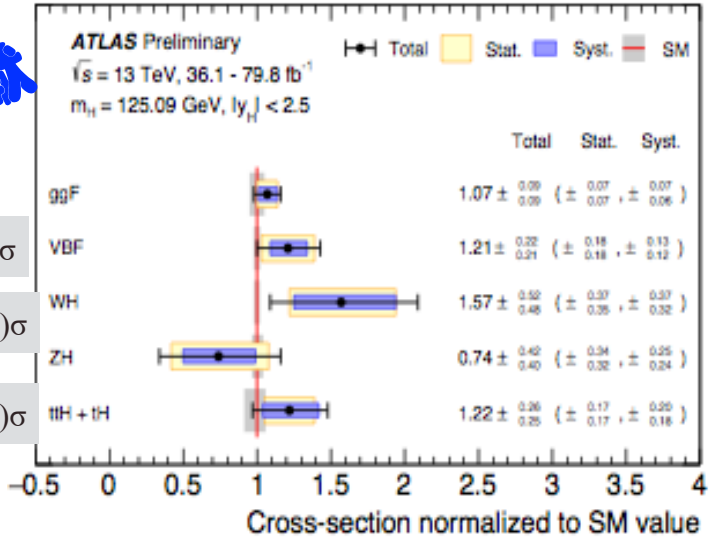
主要贡献

6.3(5.2)σ

4.1(3.7)σ

5.8(5.3)σ

ATLAS-CONF-2018-028

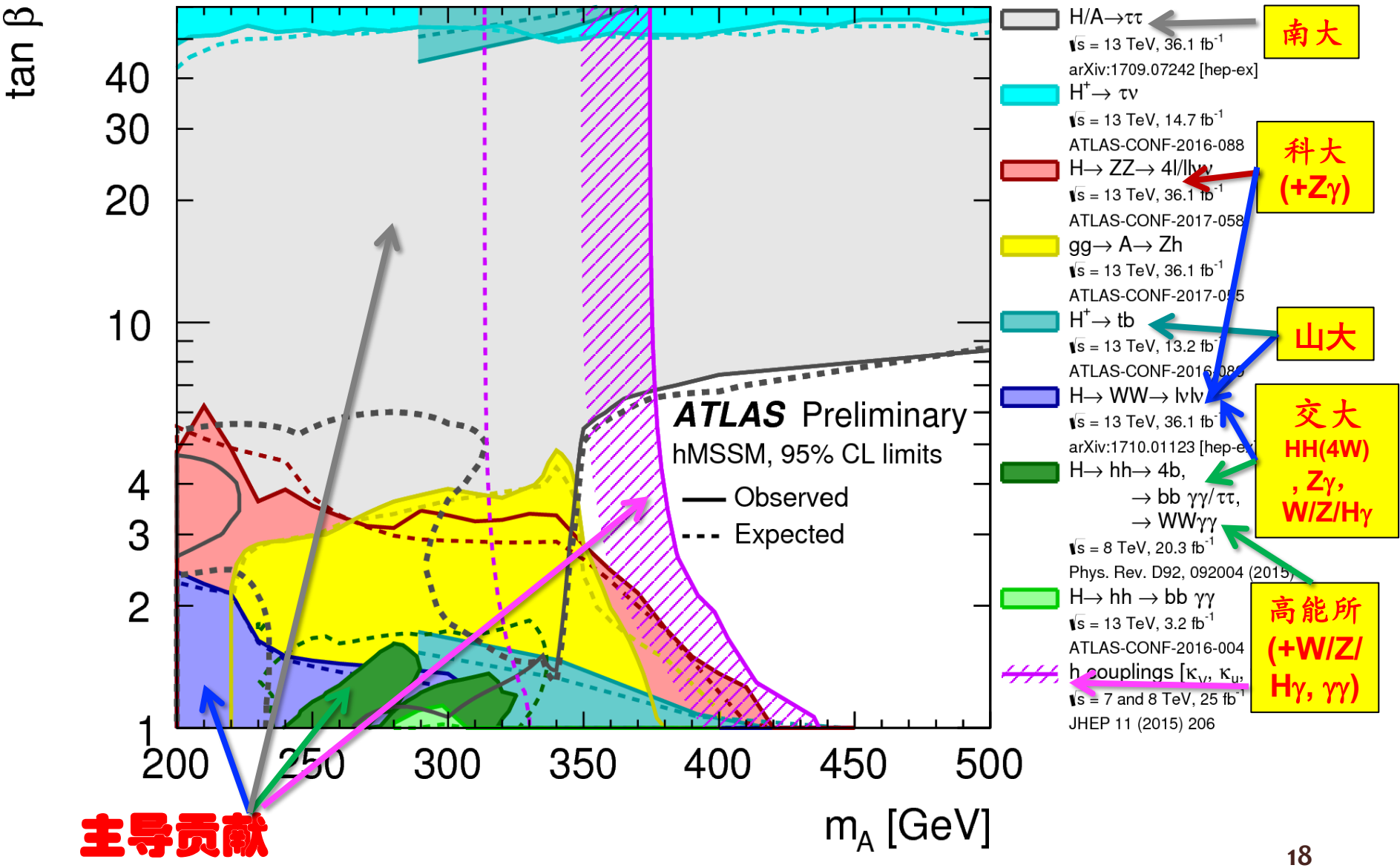


高能所交大

ATLAS-CONF-2018-031

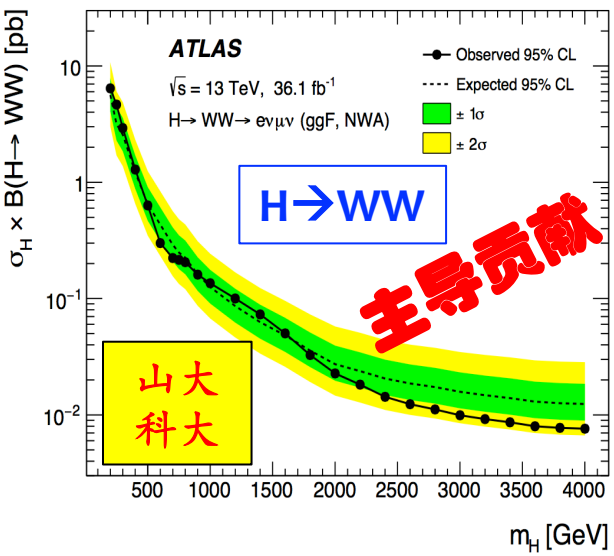
- 综合考虑测量灵敏度和模型无关性，进行了双光子广泛全面的测量，包含耦合常数、简化模式截面、基准/微分截面的测量和有效场论的分析。
- 联合测量：全局信号强度为 $\mu = 1.13^{+0.09}_{-0.08}$（8%），VBF和ttH两个产生模式均>5σ，与标准模型很好符合。

BSM Higgs exclusion in the hMSSM:

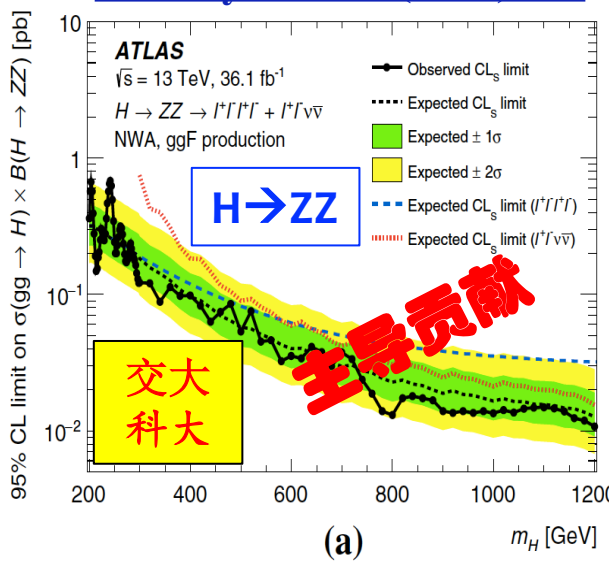


BSM Higgs searches

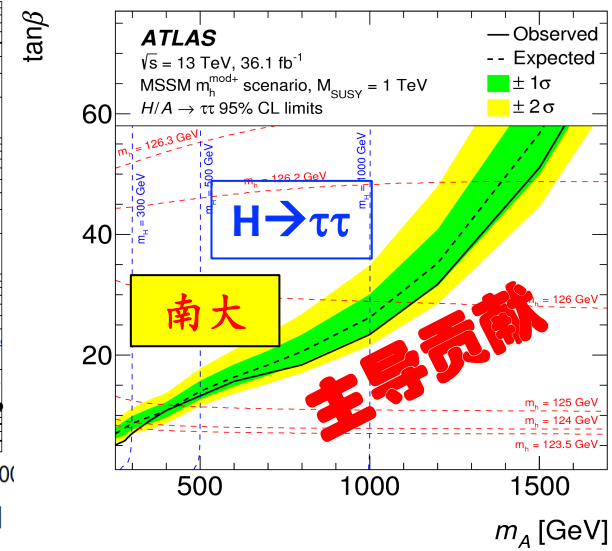
Eur. PHys. J. C 78 (2018) 24



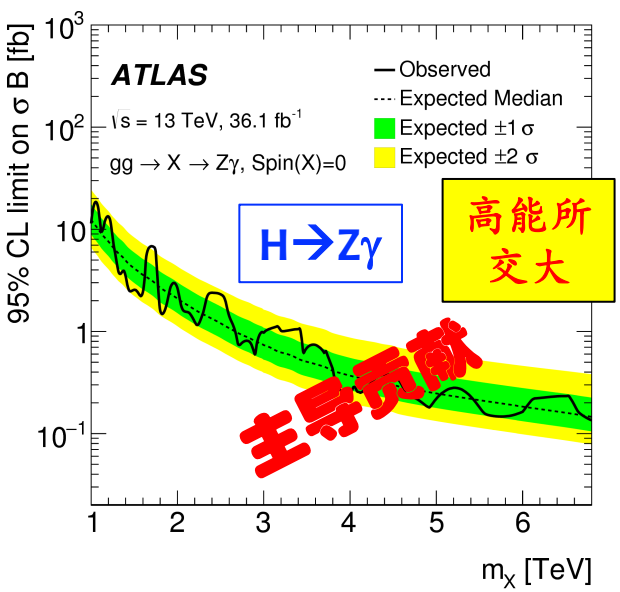
Eur.Phys.J. C78 (2018) 293



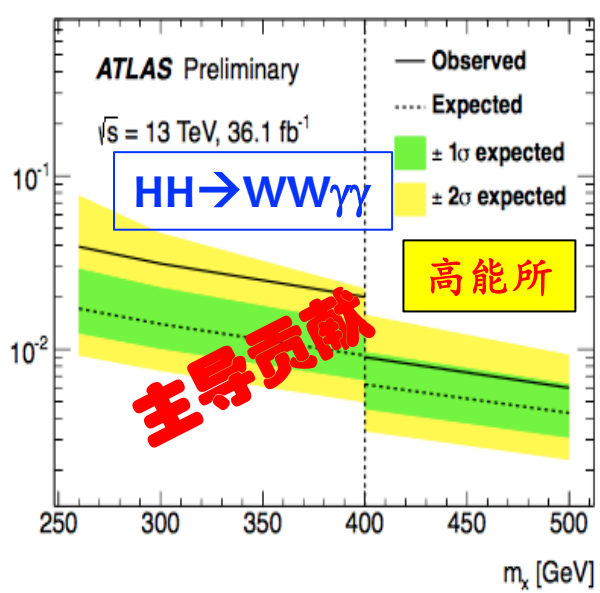
JHEP 01 (2018) 055



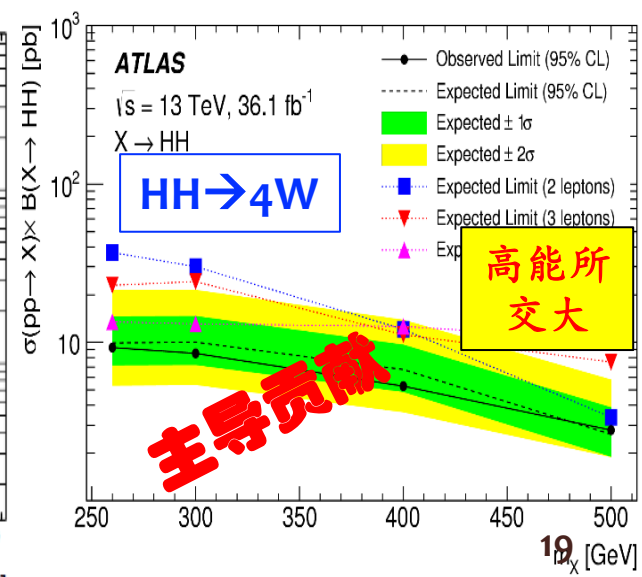
PRD 98 (2018) 032015



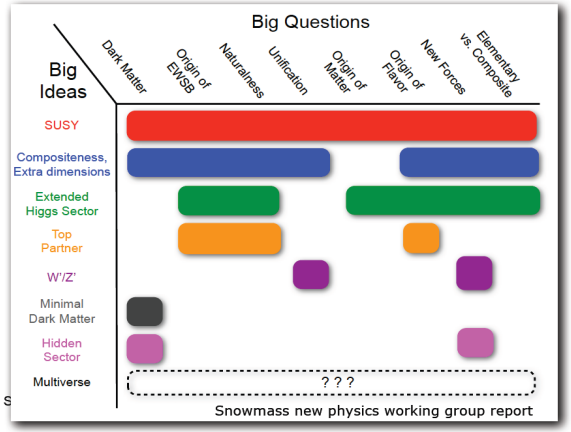
CERN-EP-2018-104



arXiv:1811.11028

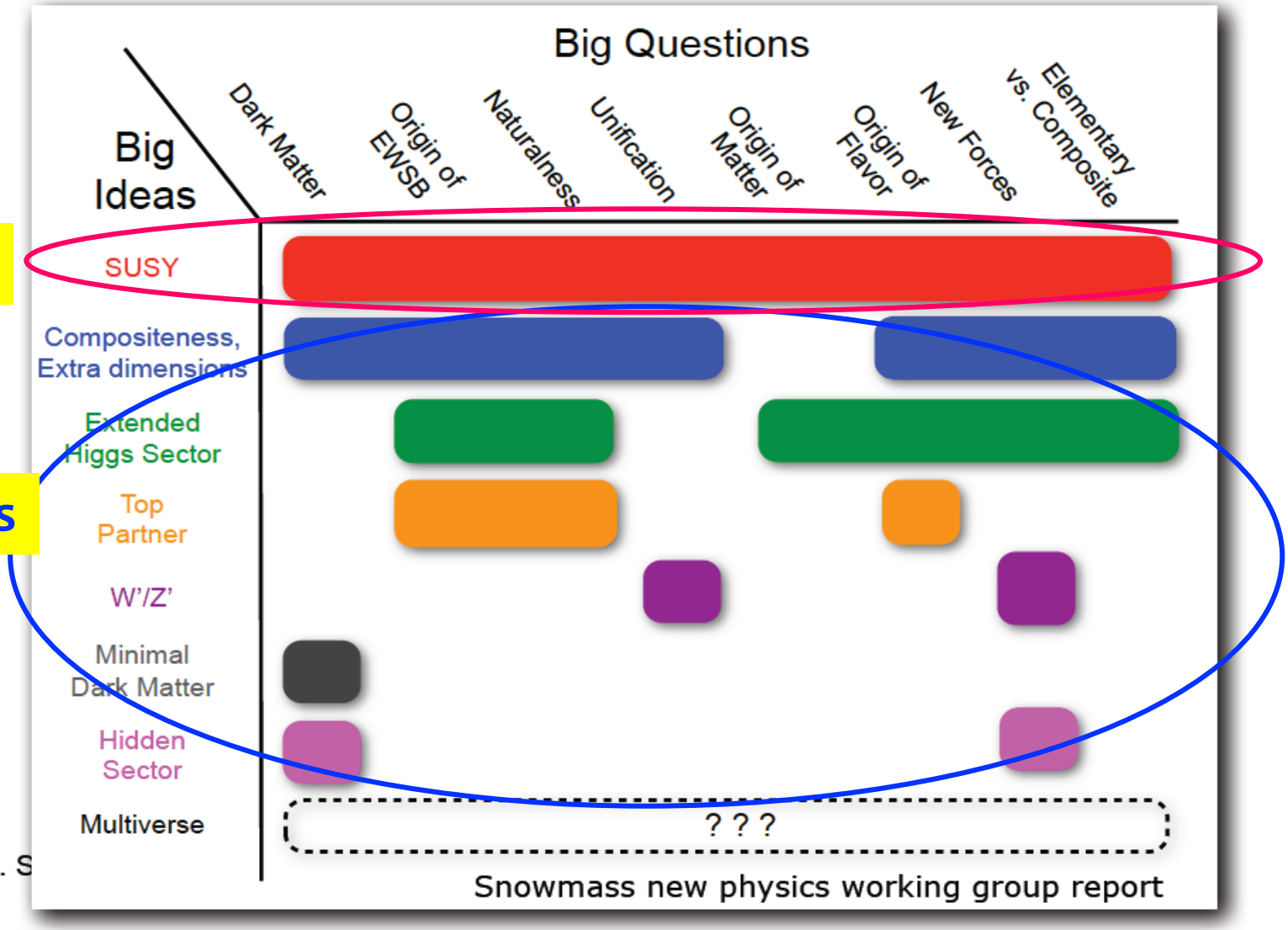


主要物理成果总结



- ☞ 标准模型 Higgs 性质测量 & 高质量 Higgs 粒子寻找
- ☞ **SUSY粒子和其他新物理寻找**
- ☞ 标准模型测量检验

New Physics beyond the SM



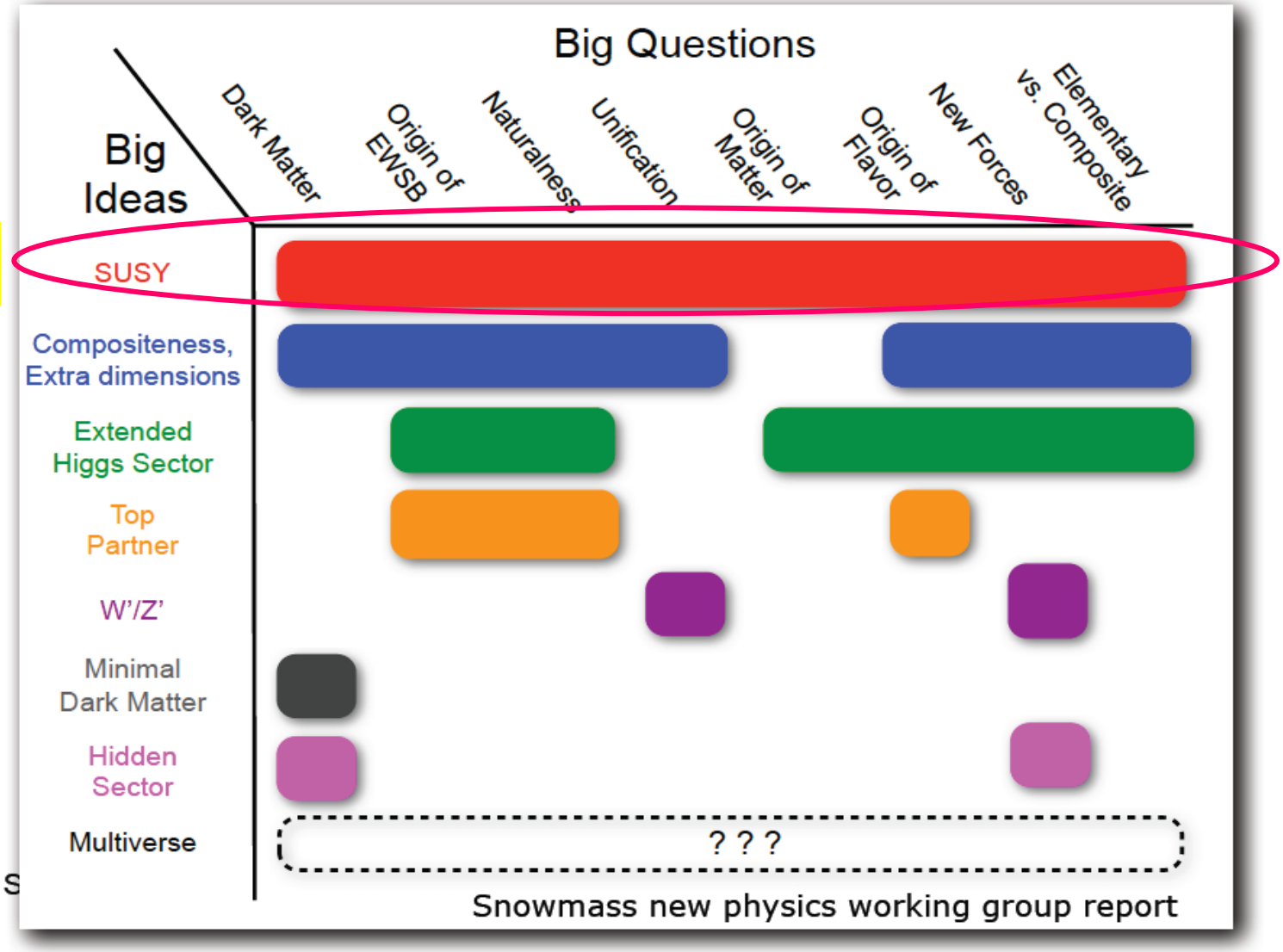
SUSY

exotics

S. S

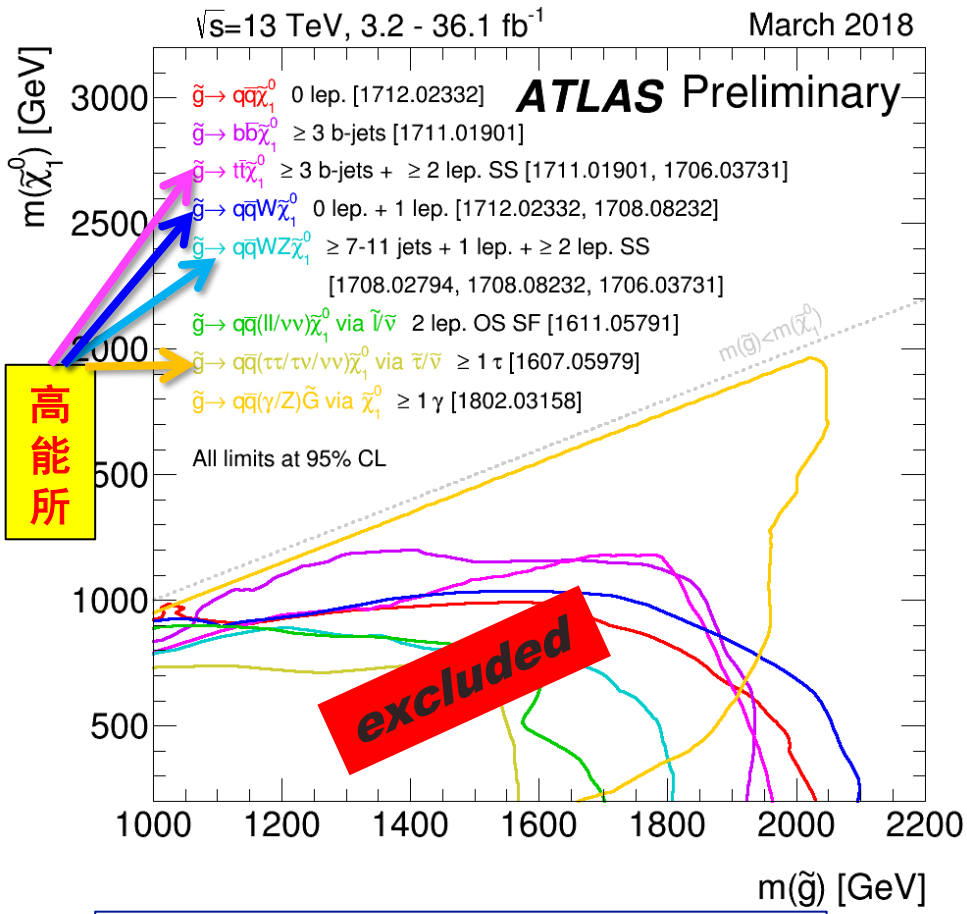
New Physics beyond the SM

SUSY

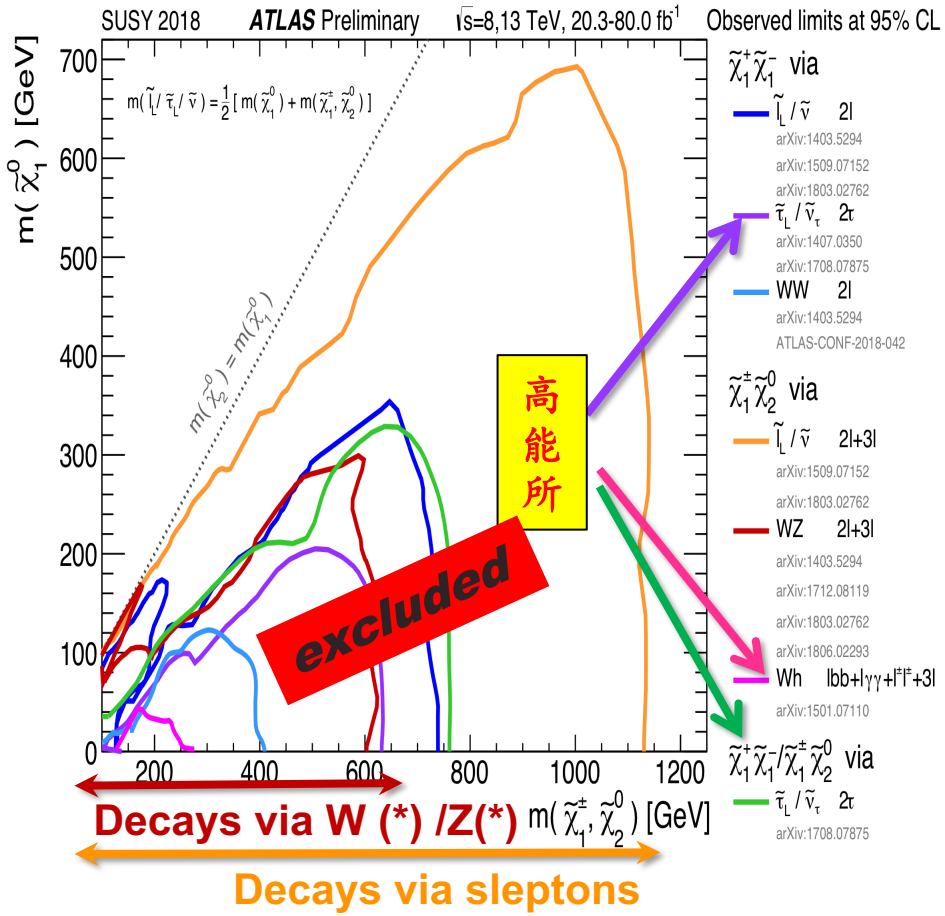


S. S

Strong Production



EWK production



高能所：*1L, SS/3L, tau 末态*

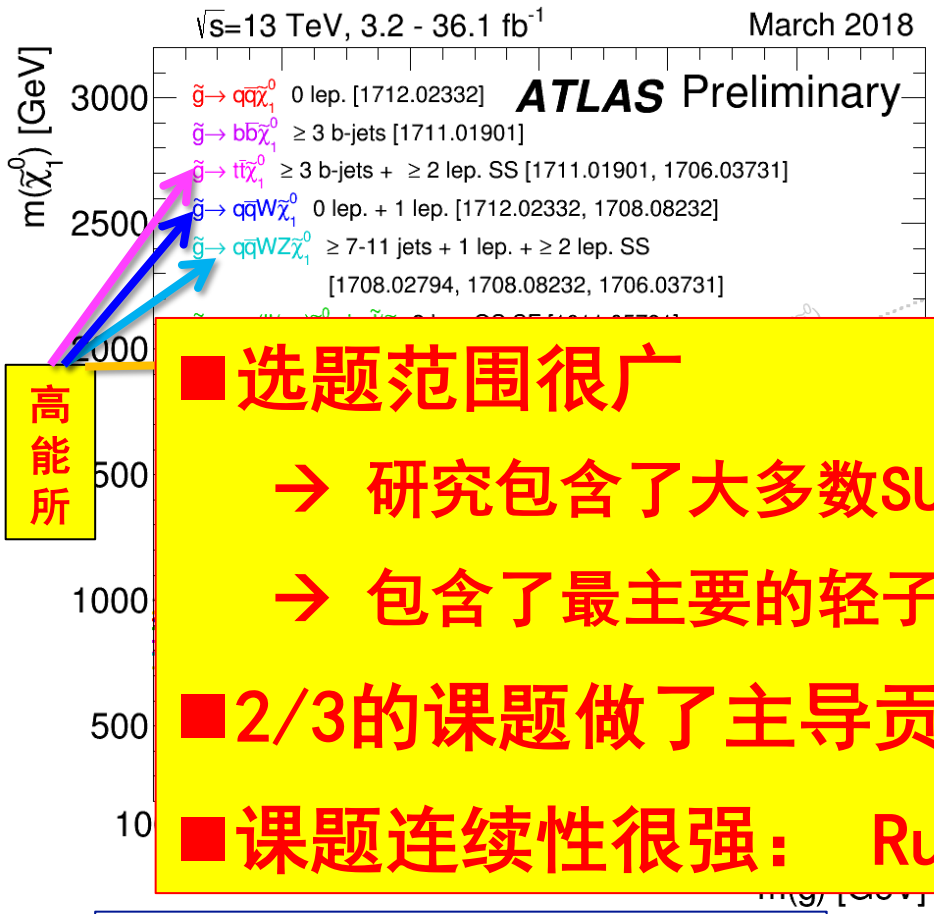
- Gluino pair: 1L, SS/3L, tau
- Squark pair: 1L
- Stop pair: SS/3L
- Sbottom pair: SS/3L
- RPV scenario: SS/3L

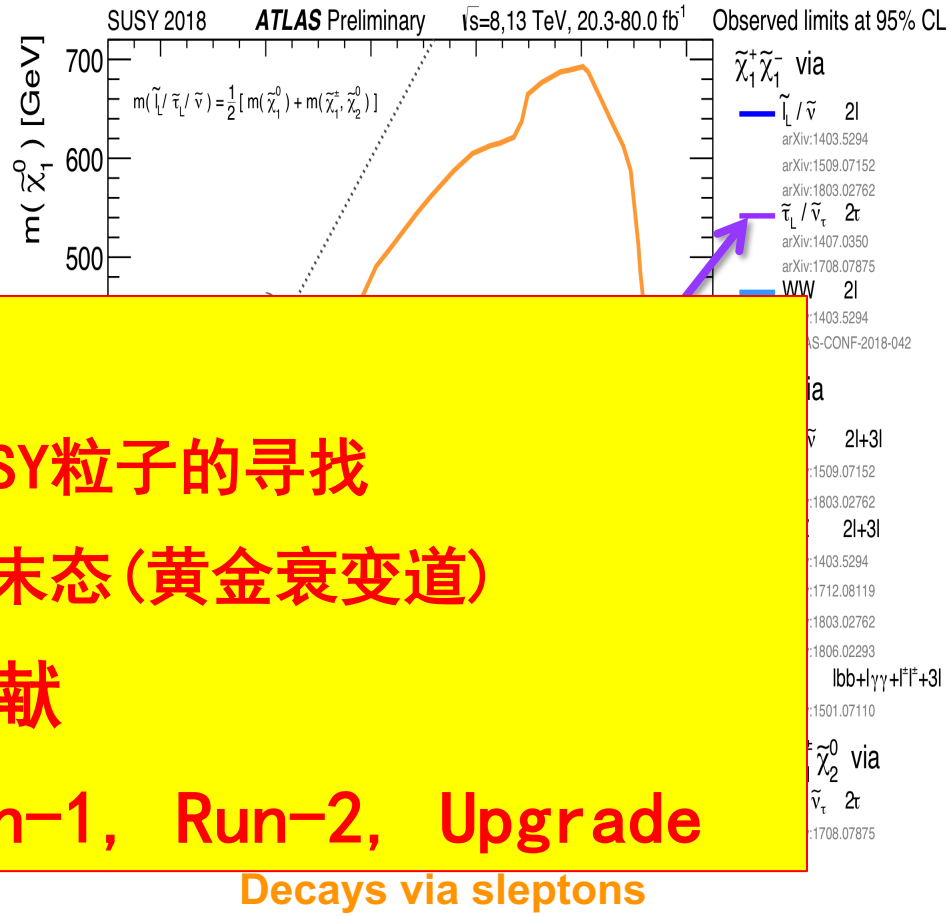
高能所：*di-tau, 1L, SS/3L 末态*

- C1C1/C1N2 via stau
- C1N2 via Wh (1lbb, 1lττ, SS)
- C1C1 via WW
- Direct stau

Strong Production

EWK production





高能所

■选题范围很广

→ 研究包含了大多数SUSY粒子的寻找

→ 包含了最主要的轻子末态(黄金衰变道)

■2/3的课题做了主导贡献

■课题连续性很强： Run-1， Run-2， Upgrade

高能所：*1L, SS/3L, tau 末态*

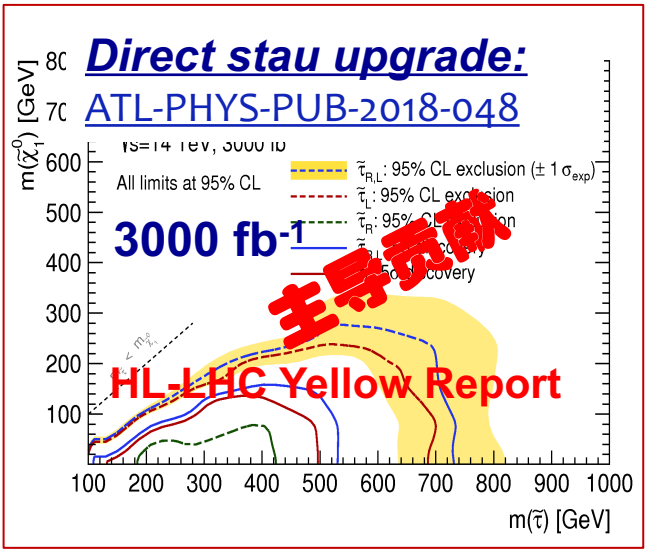
- Gluino pair: 1L, SS/3L, tau
- Squark pair: 1L
- Stop pair: SS/3L
- Sbottom pair: SS/3L
- RPV scenario: SS/3L

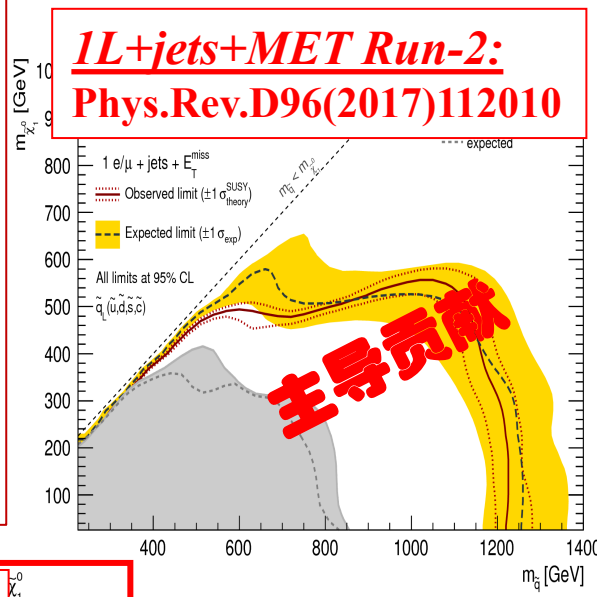
高能所：*di-tau, 1L, SS/3L 末态*

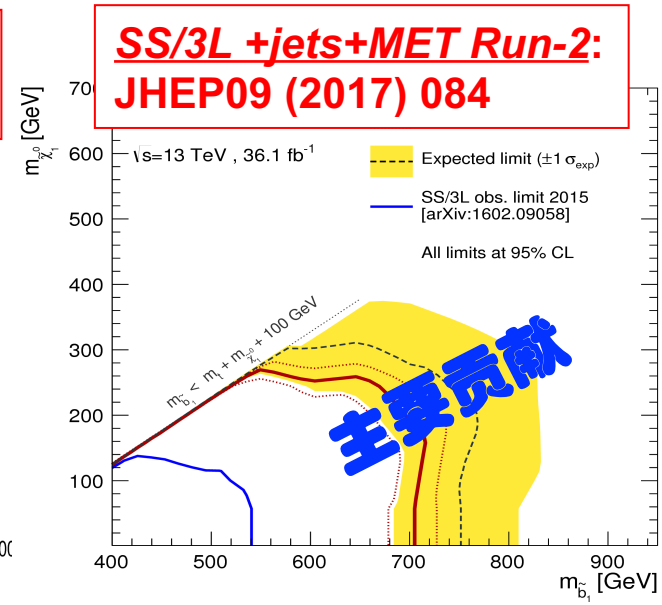
- C1C1/C1N2 via stau
- C1N2 via Wh (1ltt, SS)
- C1C1 via WW
- Direct stau

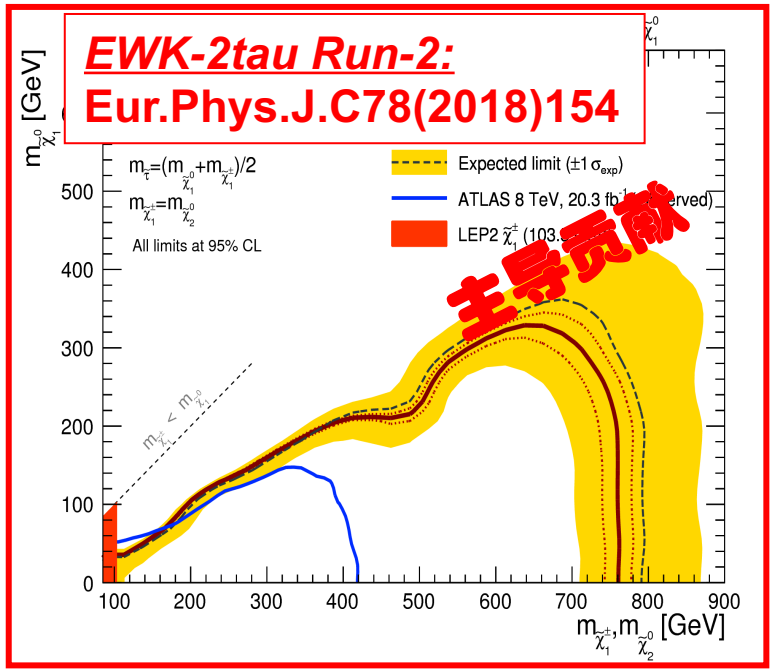
Highlights for SUSY searches

高能所



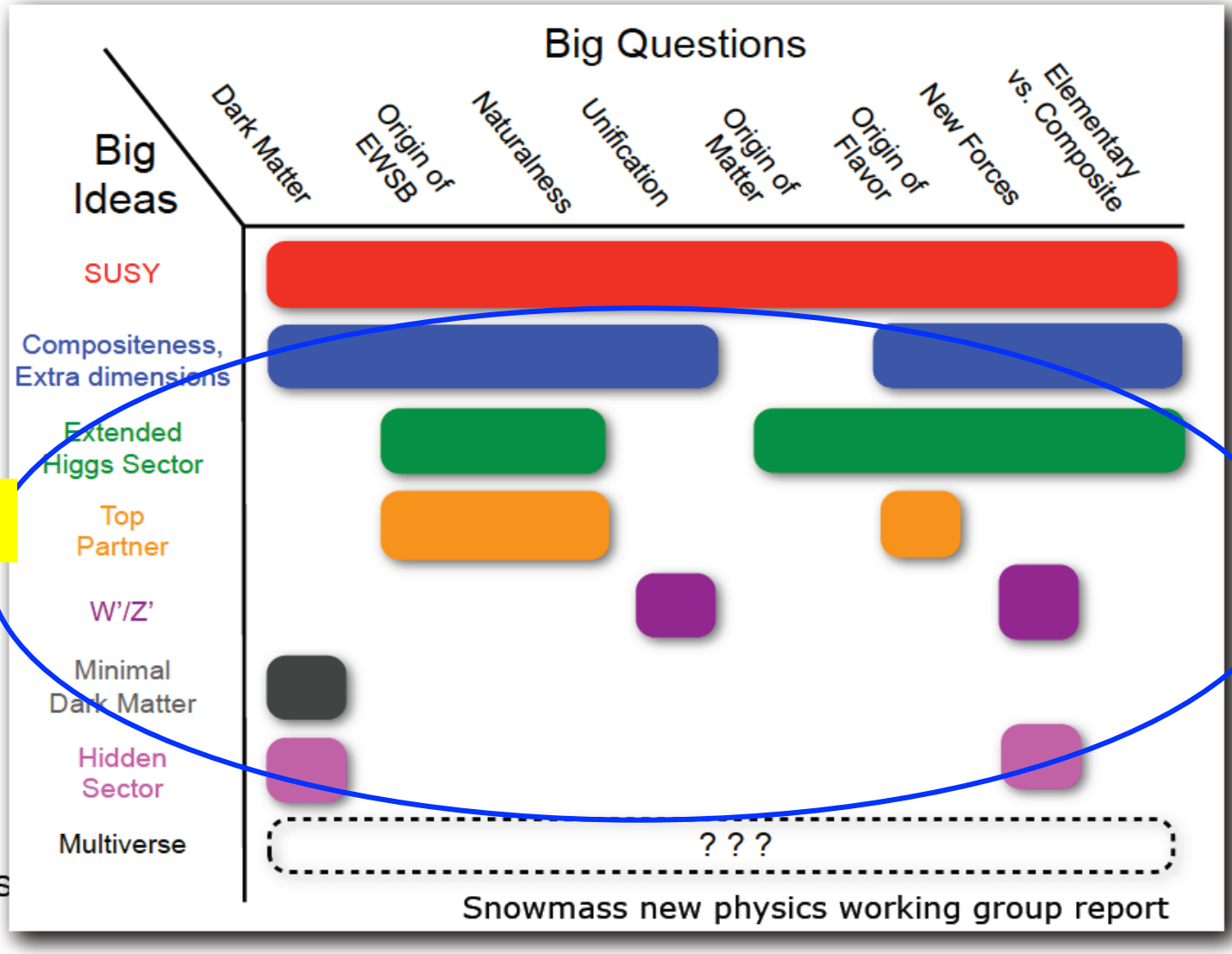






- 中国组创新性地提出通过双tau粒子对的强子衰变末态寻找stau等超对称粒子—— 一直主导该分析研究。
- Run-2（部分数据）排除SUSY粒子灵敏度比Run-1大幅度提高

New Physics beyond the SM



exotics

S. S

ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits

Status: July 2018

ATLAS Preliminary

$\int \mathcal{L}\, dt = (3.2 - 79.8)\ \mathrm{fb}^{-1}$ $\sqrt{s}$ = 8, 13 TeV

	Model	ℓ, γ	Jets†	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	0 e, μ	1 – 4 j	Yes	36.1	M_D 7.7 TeV	$n = 2$	1711.03301
	ADD non-resonant $\gamma\gamma$	2 γ	–	–	36.7	M_S 8.6 TeV	$n = 3$ HLZ NLO	1707.04147
	ADD QBH	–	2 j	–	37.0	M_{th} 8.9 TeV	$n = 6$	1703.09217
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2 j	–	3.2	M_{th} 8.2 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1606.02265
	ADD BH multijet	–	≥ 3 j	–	3.6	M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \rightarrow \gamma\gamma$	2 γ	–	–	36.7	G_{KK} mass 4.1 TeV	$k/\overline{M}_{Pl} = 0.1$	1707.04147
	Bulk RS $G_{KK} \rightarrow WW/ZZ$	multi-channel			36.1	G_{KK} mass 2.3 TeV	$k/\overline{M}_{Pl} = 1.0$	CERN-EP-2018-179
	Bulk RS $g_{KK} \rightarrow tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	36.1	g_{KK} mass 3.8 TeV	$\Gamma/m = 15\%$	1804.10823
	2UED / RPP	1 e, μ	≥ 2 b, ≥ 3 j	Yes	36.1	KK mass 1.8 TeV	Tier (1,1), $\mathcal{B}(A^{(1,1)} \rightarrow tt) = 1$	1803.09678
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	2 e, μ	–	–	36.1	Z' mass 4.5 TeV		1707.02424
	SSM $Z' \rightarrow \tau\tau$	2 τ	–	–	36.1	Z' mass 2.42 TeV		1709.07242
	Leptophobic $Z' \rightarrow bb$	–	2 b	–	36.1	Z' mass 2.1 TeV		1805.09299
	Leptophobic $Z' \rightarrow tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	36.1	Z' mass 3.0 TeV	$\Gamma/m = 1\%$	1804.10823
	SSM $W' \rightarrow \ell\nu$	1 e, μ	–	Yes	79.8	W' mass 5.6 TeV		ATLAS-CONF-2018-017
	SSM $W' \rightarrow \tau\nu$	1 τ	–	Yes	36.1	W' mass 3.7 TeV		1801.06992
	HVT $V' \rightarrow WV \rightarrow qqqq$ model B	0 e, μ	2 J	–	79.8	V' mass 4.15 TeV	$g_V = 3$	ATLAS-CONF-2018-016
	HVT $V' \rightarrow WH/ZH$ model B	multi-channel			36.1	V' mass 2.93 TeV	$g_V = 3$	1712.06518
	LRSM $W'_R \rightarrow tb$	multi-channel			36.1	W' mass 3.25 TeV		CERN-EP-2018-142
CI	CI $qqqq$	–	2 j	–	37.0	Λ 21.8 TeV	η_{LL}^-	1703.09217
	CI $\ell\ell qq$	2 e, μ	–	–	36.1	Λ 40.0 TeV	η_{LL}^-	1707.02424
	CI $tttt$	≥ 1 e, μ	≥ 1 b, ≥ 1 j	Yes	36.1	Λ 2.57 TeV	$\lvert C_{4t} \rvert = 4\pi$	CERN-EP-2018-174
DM	Axial-vector mediator (Dirac DM)	0 e, μ	1 – 4 j	Yes	36.1	m_{med} 1.55 TeV	g_q=0.25, g_χ=1.0, $m(\chi) = 1$ GeV	1711.03301
	Colored scalar mediator (Dirac DM)	0 e, μ	1 – 4 j	Yes	36.1	m_{med} 1.67 TeV	g=1.0, $m(\chi) = 1$ GeV	1711.03301
	$VV\chi\chi$ EFT (Dirac DM)	0 e, μ	1 J, ≤ 1 j	Yes	3.2	M_* 700 GeV	$m(\chi) < 150$ GeV	1608.02372
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	3.2	LQ mass 1.1 TeV	$\beta = 1$	1605.06035
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	3.2	LQ mass 1.05 TeV	$\beta = 1$	1605.06035
	Scalar LQ 3rd gen	1 e, μ	≥ 1 b, ≥ 3 j	Yes	20.3	LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \rightarrow Ht/Zt/Wb + X$	multi-channel			36.1	T mass 1.37 TeV	SU(2) doublet	ATLAS-CONF-2018-XXX
	VLQ $BB \rightarrow Wt/Zb + X$	multi-channel			36.1	B mass 1.34 TeV	SU(2) doublet	ATLAS-CONF-2018-XXX
	VLQ $T_{5/3}T_{5/3} \rightarrow Wt + X$	2(SS)/≥ 3 e, μ	≥ 1 b, ≥ 1 j	Yes	36.1	$T_{5/3}$ mass 1.64 TeV	$\mathcal{B}(T_{5/3} \rightarrow Wt)$= 1, $c(T_{5/3}Wt)$= 1	CERN-EP-2018-171
	VLQ $Y \rightarrow Wb + X$	1 e, μ	≥ 1 b, ≥ 1j	Yes	3.2	Y mass 1.44 TeV	$\mathcal{B}(Y \rightarrow Wb)$= 1, $c(YWb)$= $1/\sqrt{2}$	ATLAS-CONF-2016-072
	VLQ $B \rightarrow Hb + X$	0 e, μ, 2 γ	≥ 1 b, ≥ 1j	Yes	79.8	B mass 1.21 TeV	κ_B= 0.5	ATLAS-CONF-2018-XXX
	VLQ $QQ \rightarrow WqWq$	1 e, μ	≥ 4 j	Yes	20.3	Q mass 690 GeV		1509.04261
Excited fermions	Excited quark $q^* \rightarrow qg$	–	2 j	–	37.0	q^* mass 6.0 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1703.09127
	Excited quark $q^* \rightarrow q\gamma$	1 γ	1 j	–	36.7	q^* mass 5.3 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1709.10440
	Excited quark $b^* \rightarrow bg$	–	1 b, 1 j	–	36.1	b^* mass 2.6 TeV		1805.09299
	Excited lepton ℓ^*	3 e, μ	–	–	20.3	ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	3 e, μ, τ	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	Type III Seesaw	1 e, μ	≥ 2 j	Yes	79.8	N^0 mass 560 GeV		ATLAS-CONF-2018-020
	LRSM Majorana ν	2 e, μ	2 j	–	20.3	N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$	2,3,4 e, μ (SS)	–	–	36.1	$H^{\pm\pm}$ mass 870 GeV	DY production	1710.09748
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\tau$	3 e, μ, τ	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, $\mathcal{B}(H_L^{\pm\pm} \rightarrow \ell\tau) = 1$	1411.2921
	Monotop (non-res prod)	1 e, μ	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{\text{non-res}} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV	DY production, $\lvert q \rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	monopole mass 1.34 TeV	DY production, $\lvert g \rvert = 1g_D$, spin 1/2	1509.08059

$\sqrt{s}$ = 8 TeV $\sqrt{s}$ = 13 TeV

10^{-1} 1 10 **Mass scale [TeV]**

*Only a selection of the available mass limits on new states or phenomena is shown.

†Small-radius (large-radius) jets are denoted by the letter j (J).

额外维粒子

W', Z'

Contact interactions

Dark matter

leptoquark

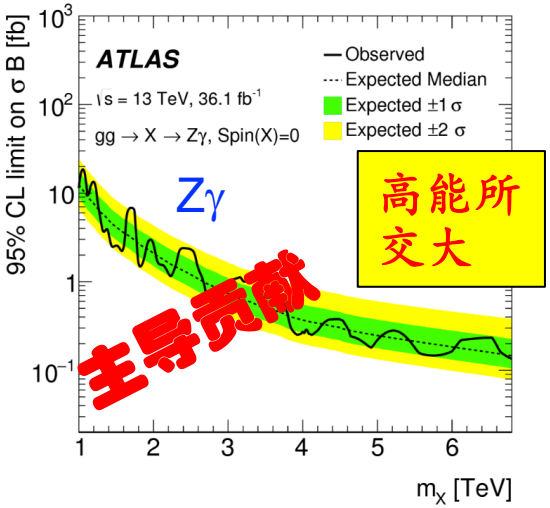
Heavy quark

重费米子

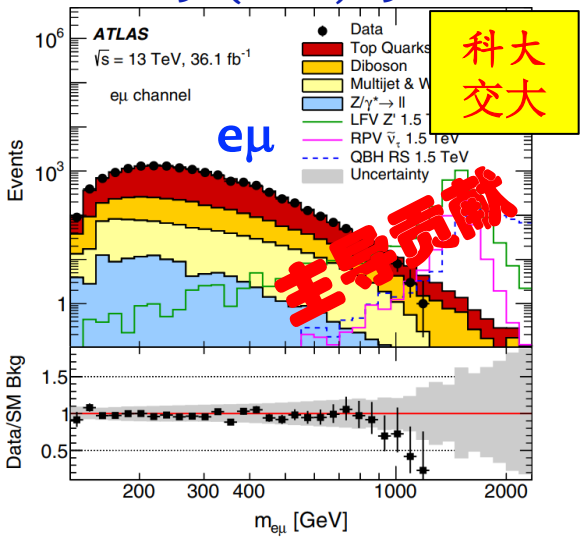
其他

Resonance (di-X: X=lep, jet, photon, boson etc.)

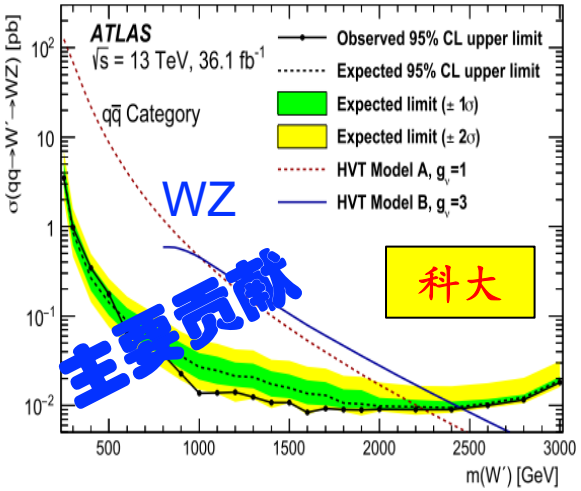
PRD 98 (2018) 032015

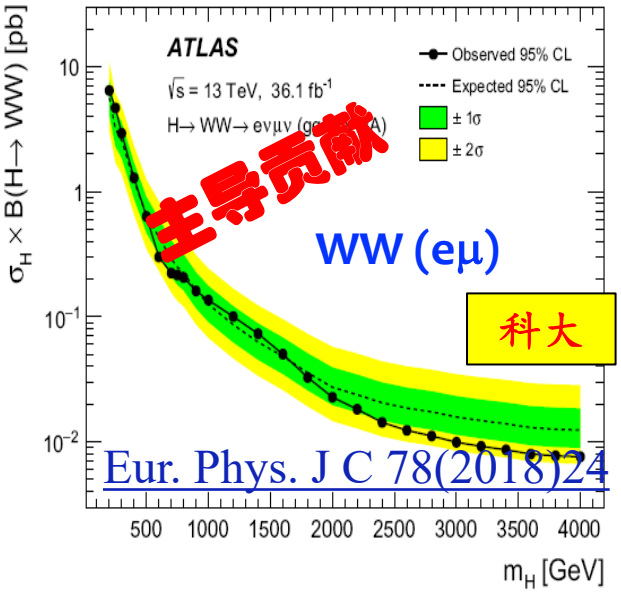


PRD98(2018)092008

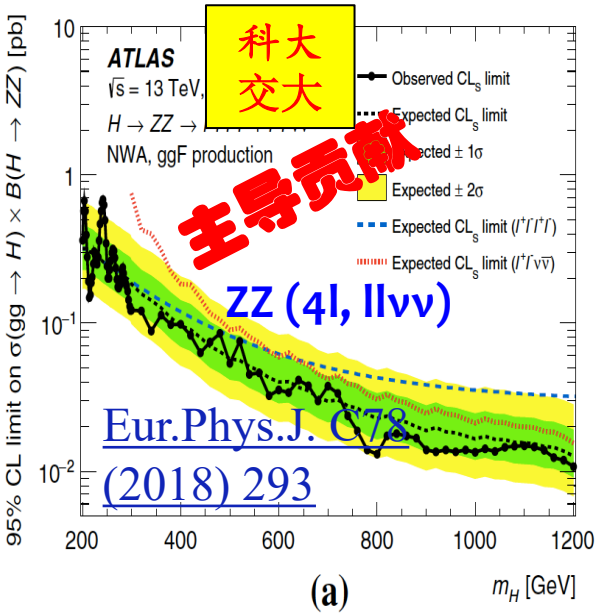


PLB787(2018)68

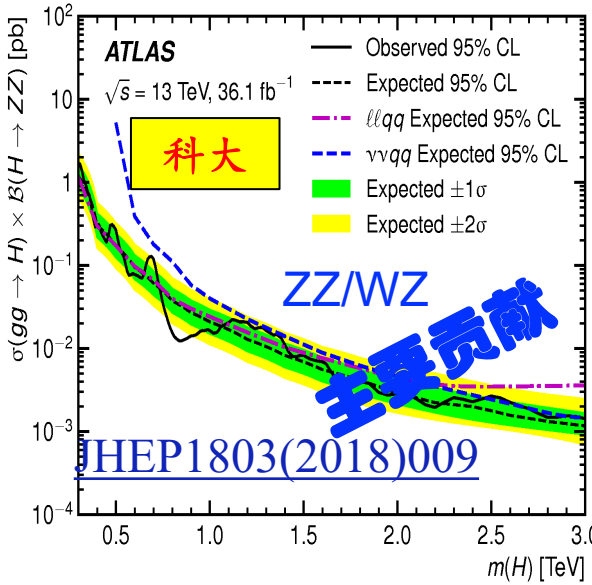




Eur. Phys. J C 78(2018)24



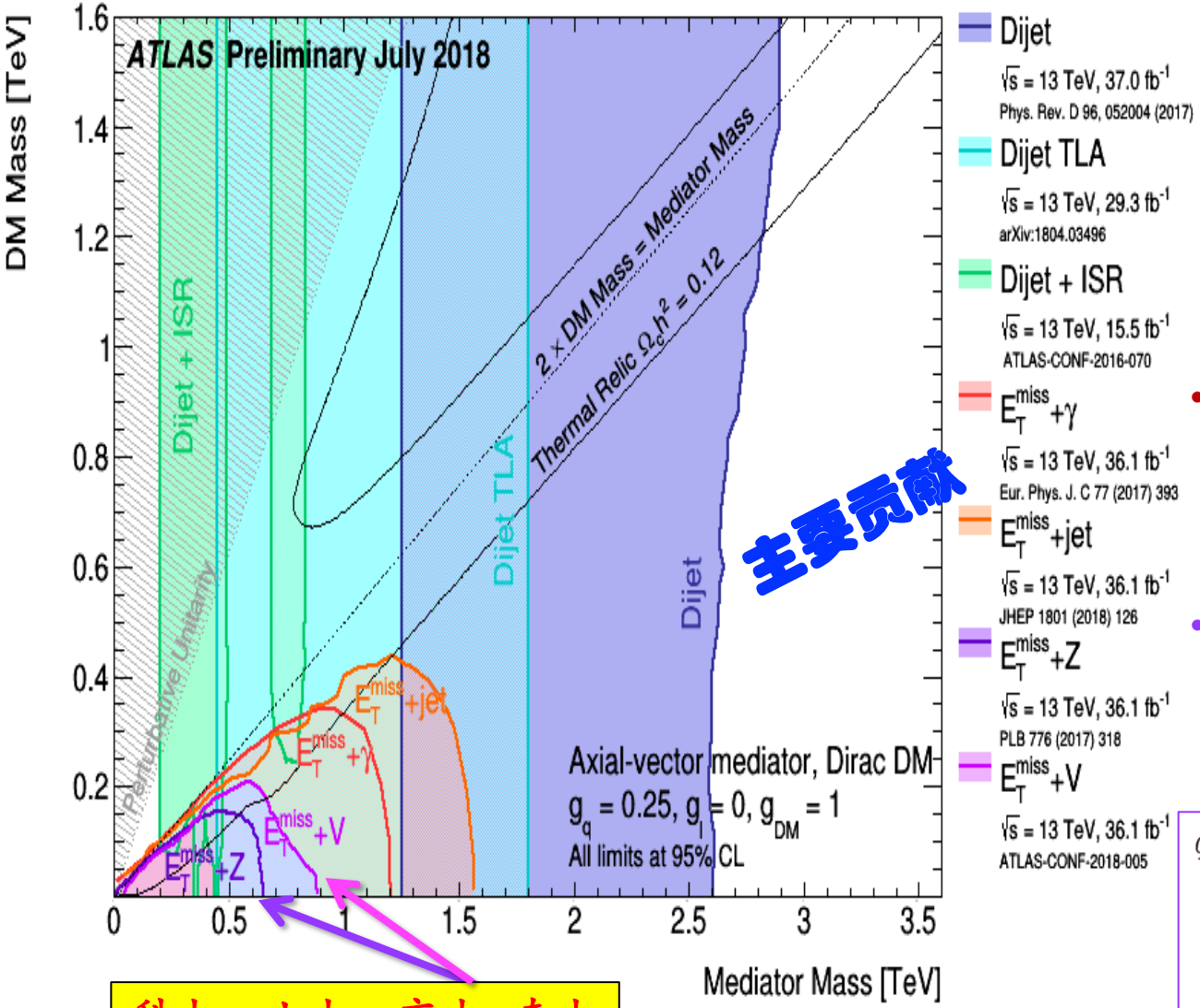
Eur.Phys.J. C78 (2018) 293



JHEP1803(2018)009

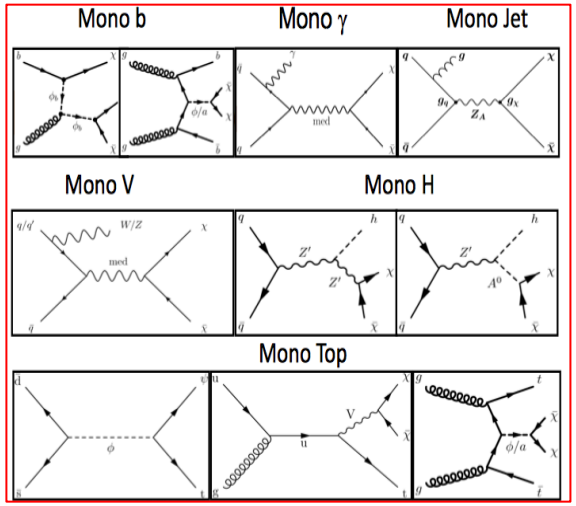
Dark Matter

Searches with MET+X or mediator

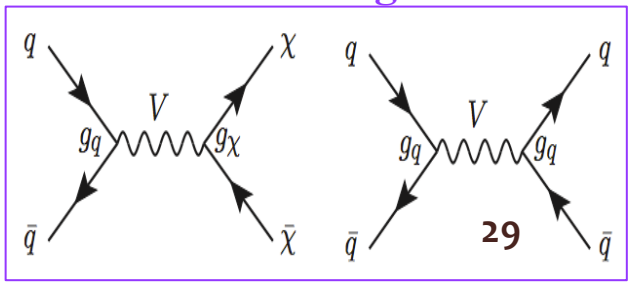


主要贡献

科大，山大，交大，南大



- **Searches in the Mono-X final states: Many models constrained up to 1-2 TeV**
- **Searches also in the Di-Jet final states exclude up to 2.6 TeV for almost whole DM range**

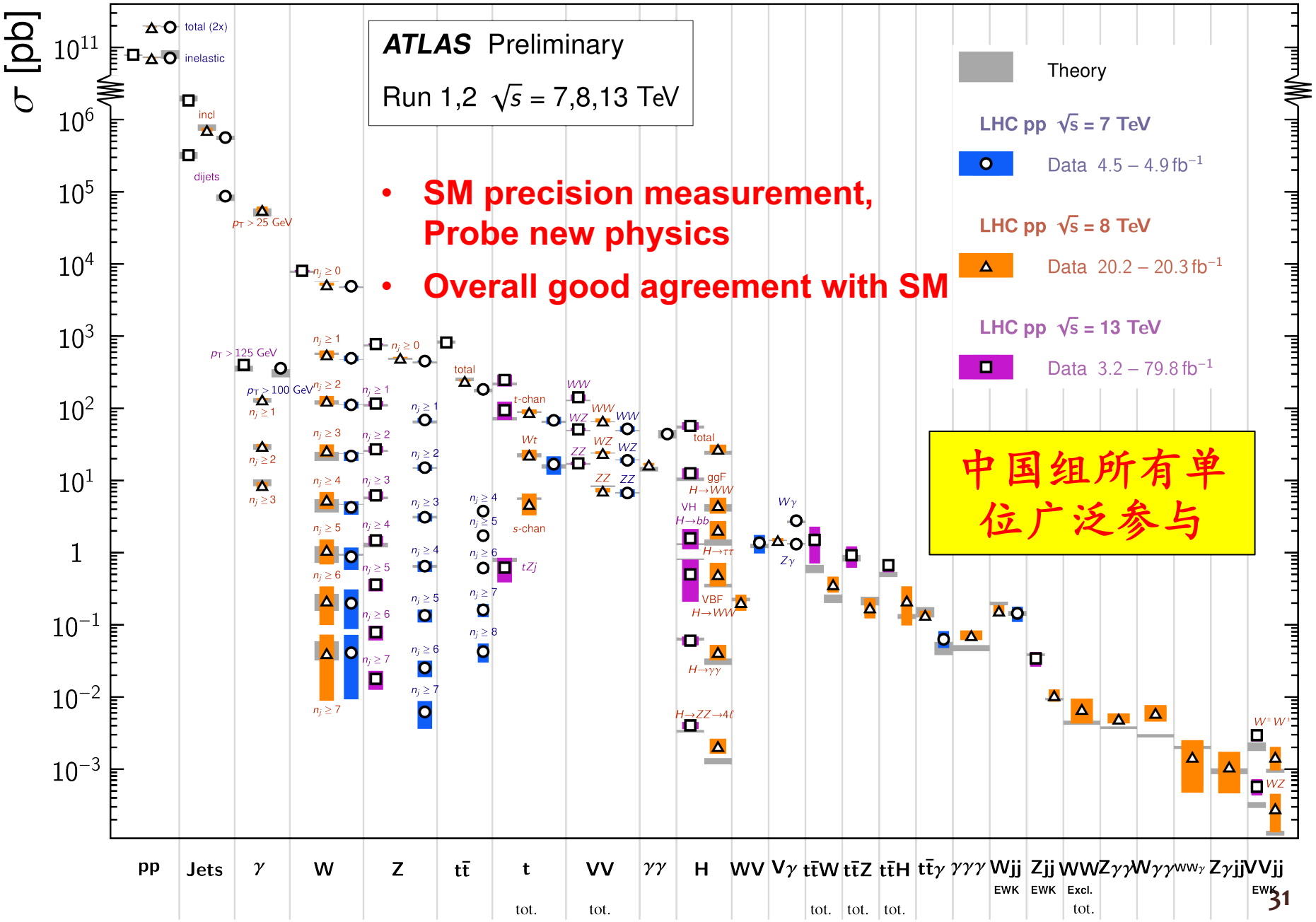


主要物理成果总结

- ☞ 标准模型 Higgs 性质测量 & 高质量 Higgs 粒子寻找
- ☞ SUSY粒子和其他新物理寻找
- ☞ 标准模型测量检验

Standard Model Production Cross Section Measurements

Status: July 2018



- **SM precision measurement, Probe new physics**
- **Overall good agreement with SM**

中国组所有单位广泛参与

ATLAS首次发现矢量玻色子散射过程

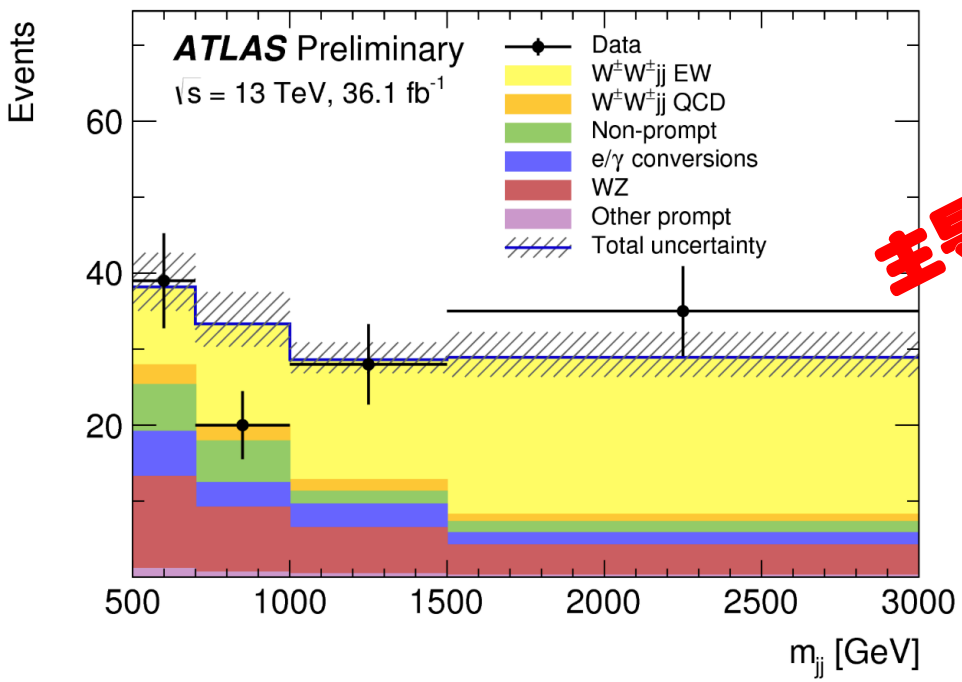
same-sign WW VBS (6.9σ)

ATLAS-CONF-2018-030

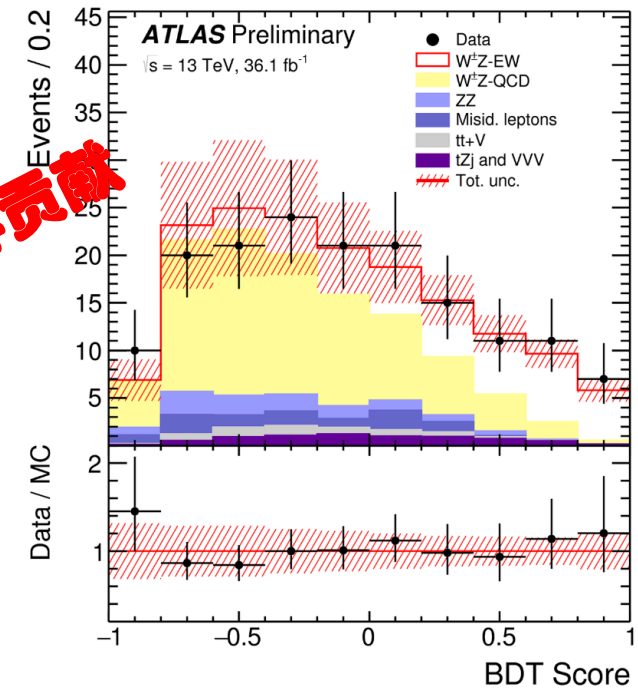
WZ VBS (5.6σ)

ATLAS-CONF-2018-033

科大
交大



主导贡献

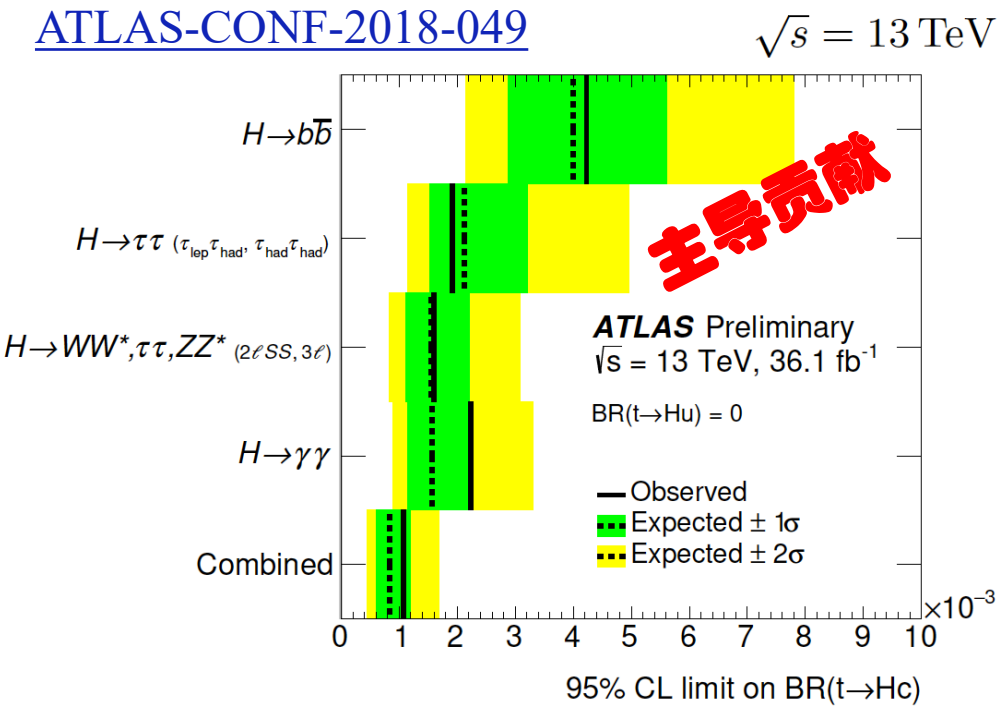


http://atlas.cern/updates/physics-briefing/weak-lightsabers

- ICHEP2018会议上，ATLAS首次公布发现了两个矢量玻色子散射产生过程。
- 中国组主导上述物理分析，担任Analysis Contact和Contact Editor。

Top FCNC

ATLAS-CONF-2018-049



清华

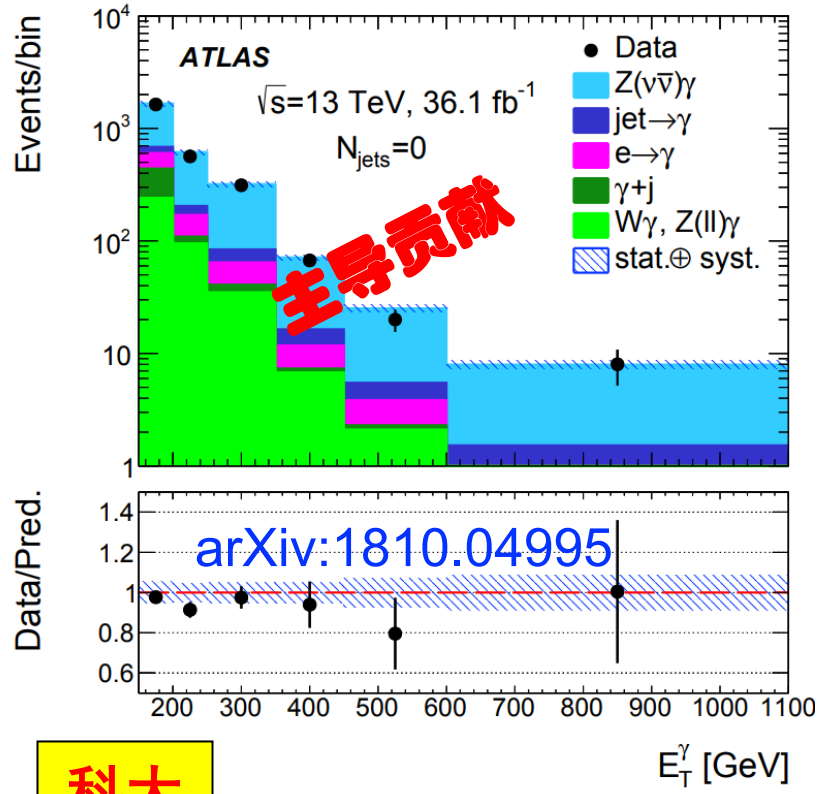
From $H \to \tau\tau$ analysis,
$B(t \to uH) < 0.17\%(0.20\%)$
$B(t \to cH) < 0.19\%(0.21\%)$

综合上限：$B(t \to uH) < 1.2 \times 10^{-3}$

$B(t \to cH) < 1.1 \times 10^{-3}$

这是目前世界最好结果，已经达到某些理论模型的最乐观预期。

Zγ production



科大

- 测得的截面与标准模型预期一致
- 限制反常耦合系数

2018物理分析成果总结

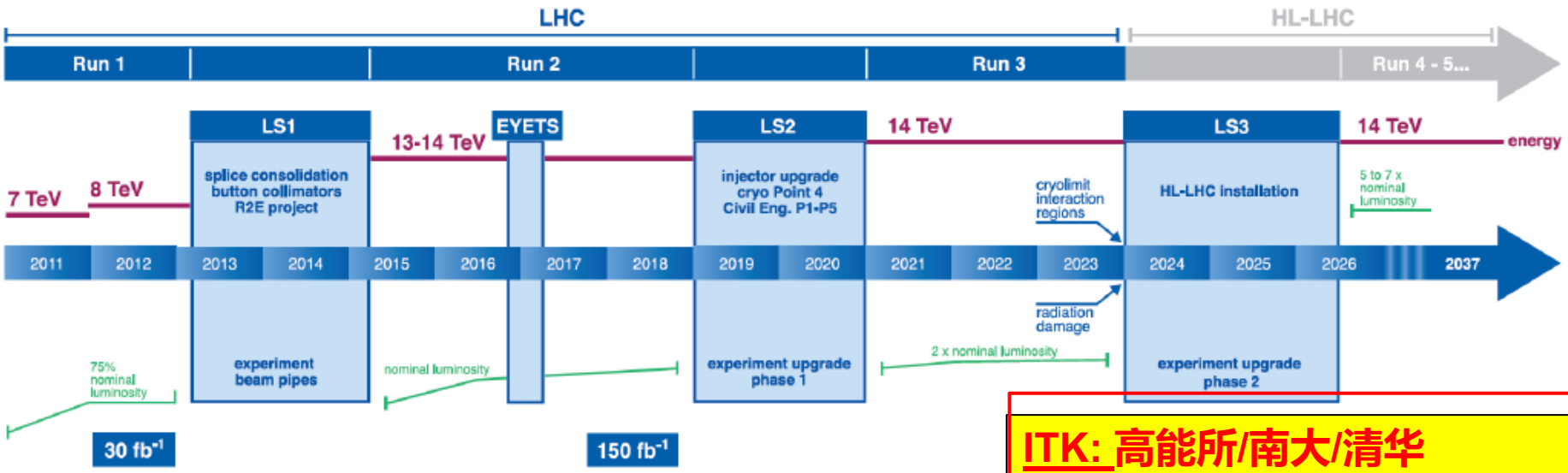
- ATLAS中国组在H→bb和ttH的发现、Higgs性质研究、SUSY和其他新物理寻找及标准模型检验等40多个热点分析成果中做出了主导或主要贡献，并在其中20多个分析中发挥了主导作用（担任分析负责人，文章编辑等）。
- 共发表期刊文章或CONF-NOTEs 40多篇。
- 代表ATLAS合作组国际会议报告40多个。

探测器运行和升级工作

具体请参考朱宏博的大会报告

LHC / HL-LHC Plan

High Luminosity LHC



ITK: 高能所/南大/清华
μ探测器RPC: 科大/交大/山大

ATLAS Phase-0

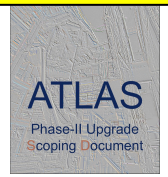
New inner pixel layer
Detector consolidation
2015: FTK deployment

ATLAS Phase-1

Improve L1 Trigger, NSW and LAr electronics to cope with higher rates

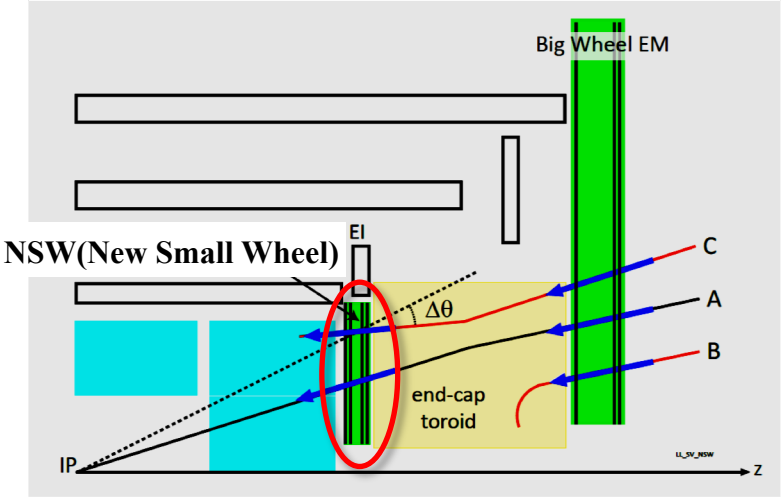
NSW: 科大/山大

ATLAS Phase-2



Prepare for 140-200 pile-up events
Replace Inner Tracker
New L0/L1 trigger scheme
Upgrade muon/calorimeter electronics
Upgrade of DAQ detector readout

ATLAS Phase-I NSW 升级 (2014-2020) 科大/山大

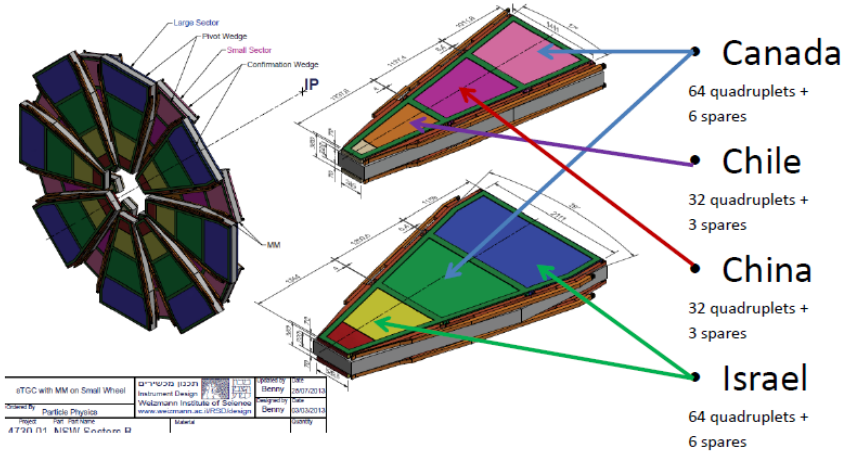


- Muon 2/3 trigger coverage
- Acceptable trigger rate
  @ 5×10^{34} $cm^{-2}s^{-1}$
  e.g. L1MU20 20kHz
- Challenge:

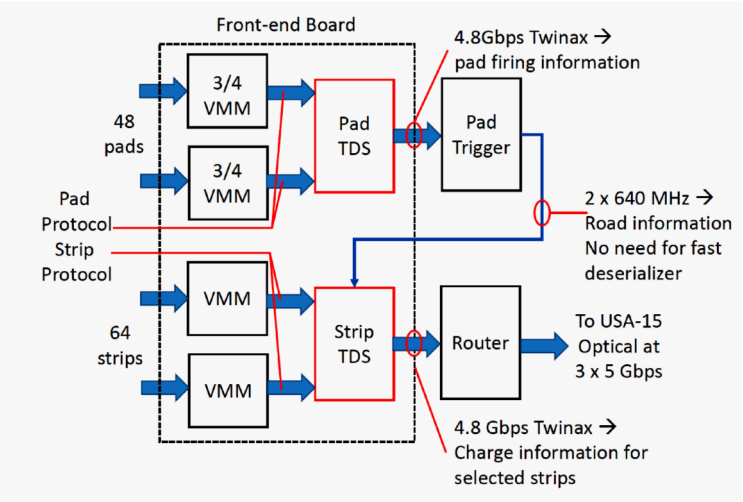
✓ High background ~15kHz/cm^2

✓ Spatial resolution ~100μm

■ 山东大学: 144 sTGC chambers, 目前已经生产14 modules, 共56个chambers



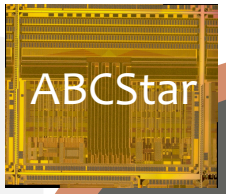
■ 科大: 前端读出板的设计和生产



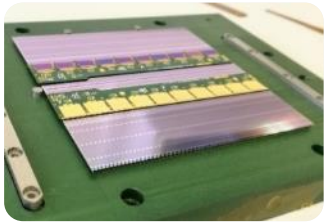
ATLAS Phase-2 硅径迹探测器升级

■负责为ATLAS提供1000个抗辐照的硅微条探测器模块，其500个在英国卢瑟福合作完成，另500个在高能所完成。即将签署合作协议；

- **读出ASIC芯片设计：**
与CERN等单位合作，设计数字单元及完成验证工作。最新设计流片已经返回，在卢瑟福实验室开展初步电气测试。



- **承担建造任务：**
与英国卢瑟福实验室紧密合作，掌握探测器模块制作工艺流程，定义质量控制关键步骤。完成多个模块，参与束流测试等工作。



2019开始预生产，通过生产点审查后，将开展批量生产（2021-2023）。所内洁净间即将完工，重要设备已采购。

- **前沿探测器技术研究：**
像素型CMOS微条探测器，未来大面积硅探测器的重要候选技术。与SLAC等合作测试样片CHESS-2深入理解内电路性能。

■拓展关键工作至其他方面，包括在卢瑟福开展芯片测试、模块加载，以及后期在CERN参加探测器集成、安装、测试及运行。

高能所/南大/清华

ATLAS Phase-2 缪子探测器升级

具体请参考朱宏博、孙勇杰的报告

科大/交大/山大

中国组承担科技部大科学装置前沿研究的“大型强子对撞机（LHC）实验探测器升级”中的的ATLAS缪子探测器升级课题（2016.7-2021.6）

- 科大、山大、交大：负责RPC phase 2中50%前放板以及50%singlet制作和测试
  - 计划2020年底完成设计，尝试以读出条两端时间差得到位置信息
- 科大：MDT TDC ASIC设计与测试，2017第一版流片，2018第二版设计优化
- 科大：前向缪子探测器升级中的高时间分辨的多层阻性GEM方案研发

在ATLAS合作组内的显示度显著提高

- ATLAS合作组委员会顾问组成员：
  - ✓ 金山 （南大 2010-2011）
  - ✓ 赵政国（科大 2012-2013）
  - ✓ 庄胥爱（高能所 2016-2017）
  - ✓ 杨海军（交大 2018-2019）
- 执行委员会委员：金山（南大 2016-2017）；
- ATLAS ITK and Pixel Steering Committee 成员：娄辛丑（高能所 2016-至今 ）
- Muon IB Chair: Antonio Baroncelli (科大 2017-2019）
- Speakers Committee 顾问组：陈新（清华 2017-2018）
- Speakers Committee ：吴雨生（科大 2018-2021）
- 中国组自2015年共有15人次担任物理分析组和探测器运行组*召集人/协调人*

在ATLAS合作组内的显示度显著提高

物理组和基础软件组：

- ☞ 庄胥爱（高能所）：SUSY EW Group convener (2015-2016)
- ☞ Joao Barreiro Guimaraes Da Costa (高能所）； HWW group convener (2016-2017)
- ☞ 黄燕萍（高能所）： Photon ID group convener (2016-2018)
- ☞ Claudia Bertella（高能所）：LHC Higgs Cross Section WG1-VBF Group convener (2017）
- ☞ 吴雨生（科大） ： Convener of Subgroup Quarkonia production and b cross section measurements（2017-2019）
- ☞ 李数（交大/李所）：ATLAS SM Electroweak group convener, 2017.04~2018.03
- ☞ 张雷（南大）：LHC Higgs Cross Section bbH/bH Group convener (2017-2019）
- ☞ Claudia Bertella（高能所）： HWW Group Convener（2018 - 2019）
- ☞ Javier Llorente Merino（高能所） ： photon+jet Group Convener（2018 - 2019）
- ☞ 李数（交大/李所）： ATLAS MC generator development and tuning group convener(2018)
- ☞ 李数（交大/李所）： LHC(ATLAS+CMS+LHCb)Electroweak multi-boson group convener（2018)
- ☞ 徐达（高能所） ：SUSY EW Group Convener (2019-2020)

探测器运行组：

- ☞ JuanAn Pascual（高能所）： Pixel DAQ Coordinator (2017/4-2018/1)
- ☞ JuanAn Pascual（高能所）： Pixel Run Coordinator (2018/4-2018/9)
- ☞ Jason Mansour（高能所） ： Inner Detector online and DAQ Coordinator（2016）

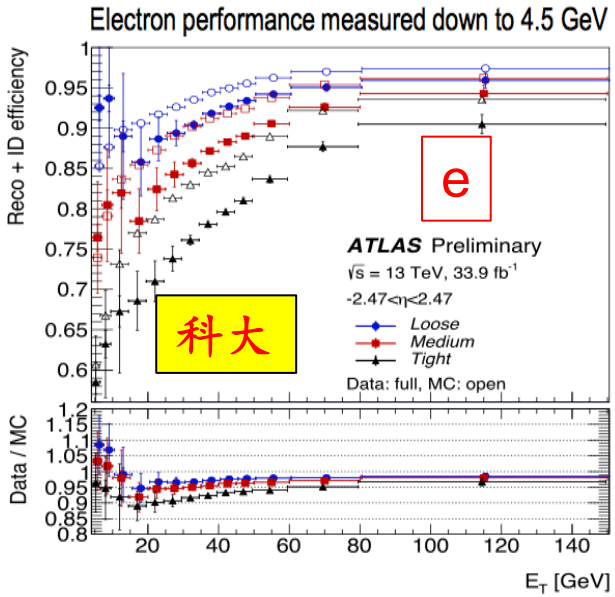
总结和展望

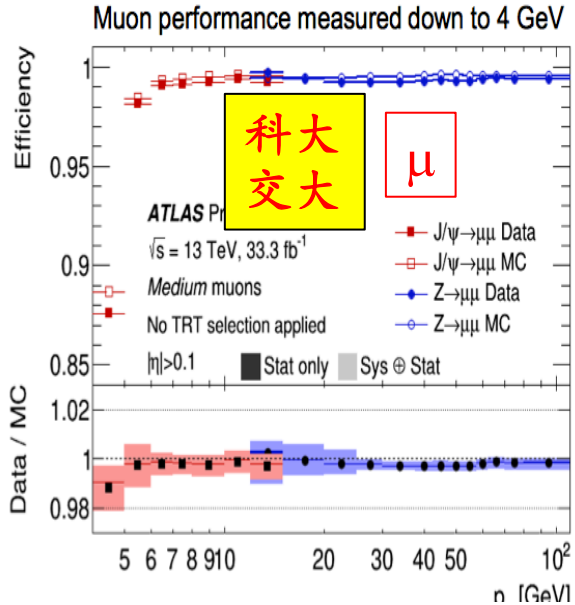
- 2018年ATLAS中国团队在物理分析、核心软件和基础工作、探测器升级各个方面取得丰硕成果和重要进展。
- 在H→bb和ttH的发现、Higgs性质研究、SUSY和其他新物理寻找等20多个热点分析中做出主导或主要贡献，共发表文章和Conf-notes 40多篇，代表ATLAS国际会议报告40多个。
- 在ATLAS实验的显示度大幅度提高：在ATLAS决策和管理层担任多项职务，担任多个重要物理分析组/软件组/探测器运行组召集人… →充分显示了ATLAS中国组具有非常强的研究活力， 这与最近几年大量吸引各类人才等密不可分。
- 期待继续得到基金委、科技部和中科院领导以及全国同行的大力支持！

感谢各位领导和同事的长期大力支持！

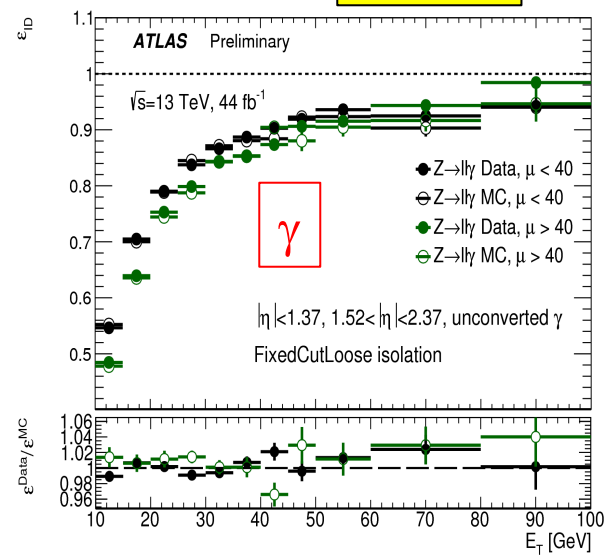
谢谢大家！

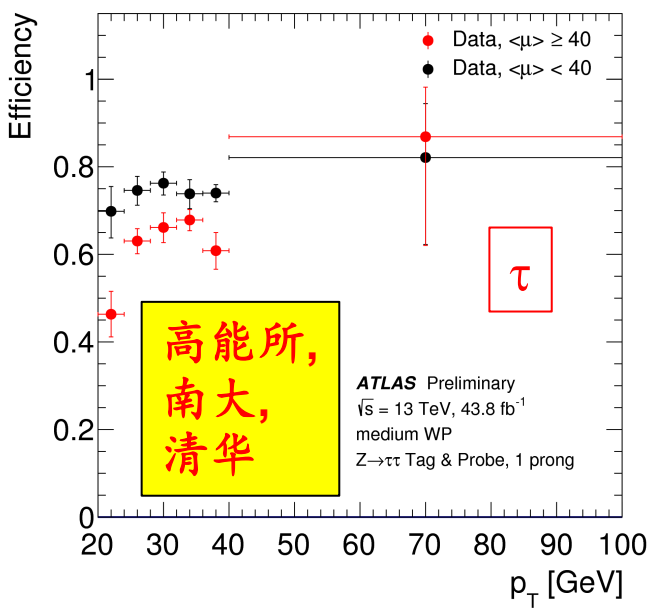
Detector performance Highlights

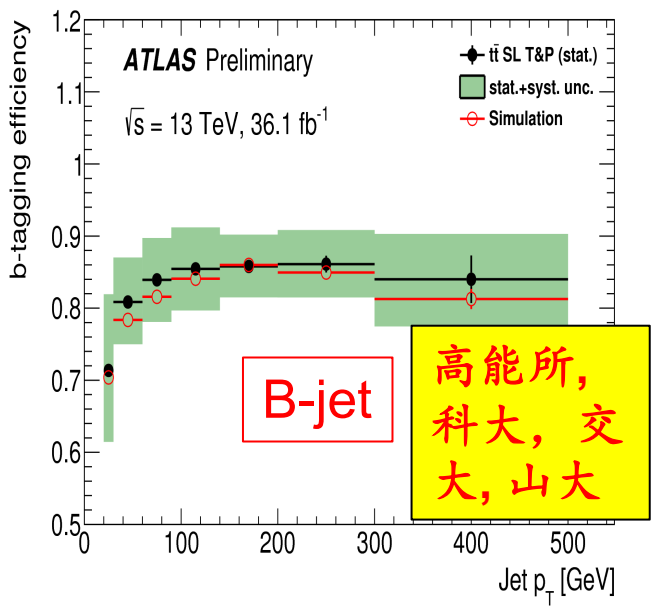


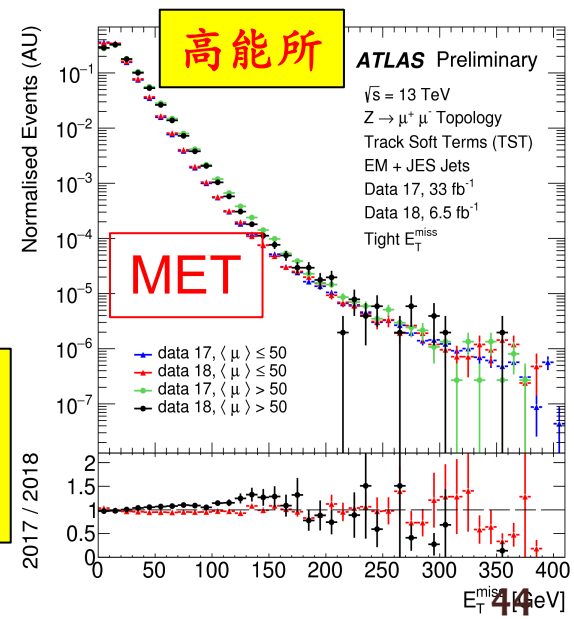


高能所



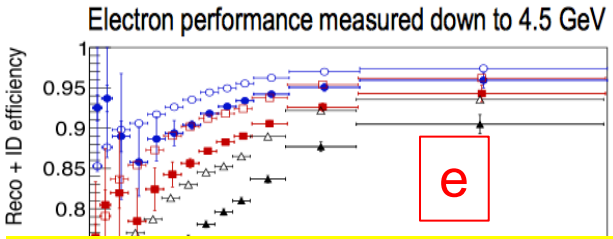


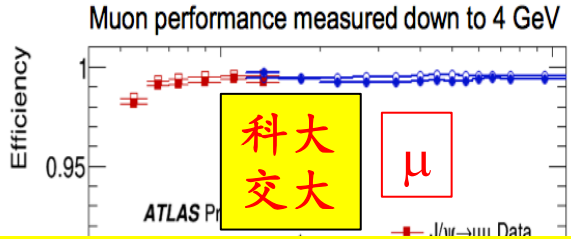


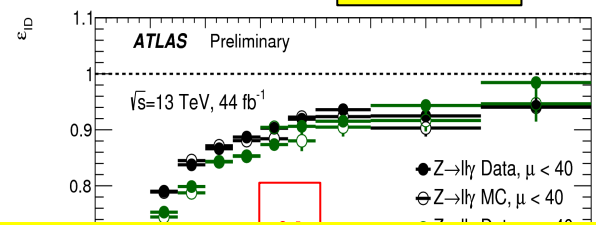


Detector performance Highlights

高能所

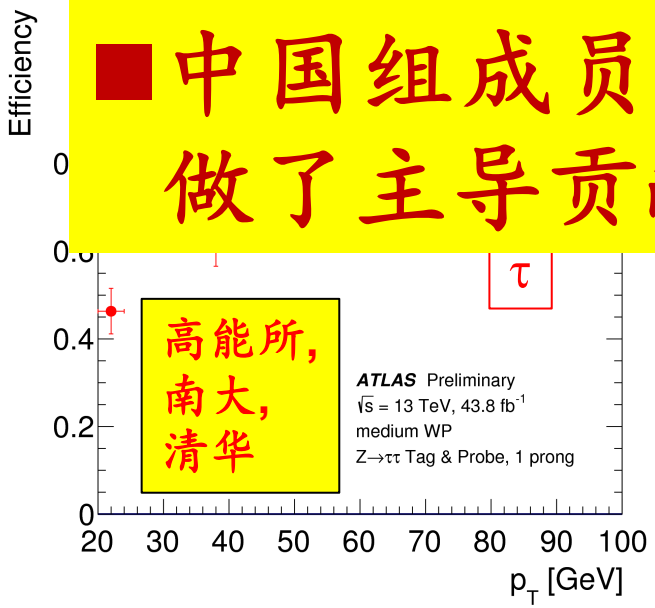


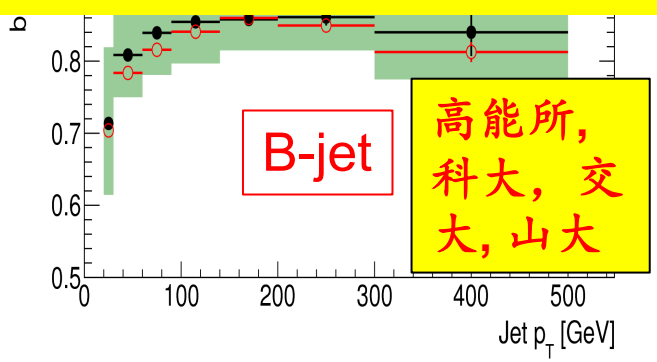


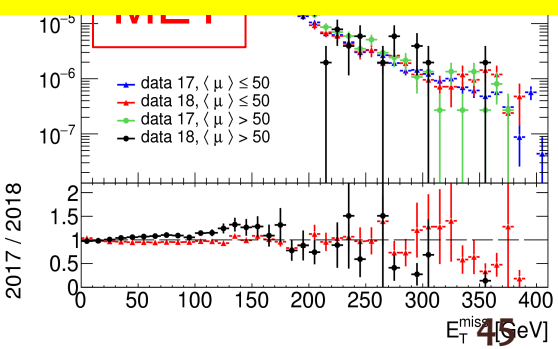


■中国组广泛参与了大部分的object性能研究，为物理分析提供必要的recommendation。

■中国组成员担任了光子鉴别组召集人，做了主导贡献。





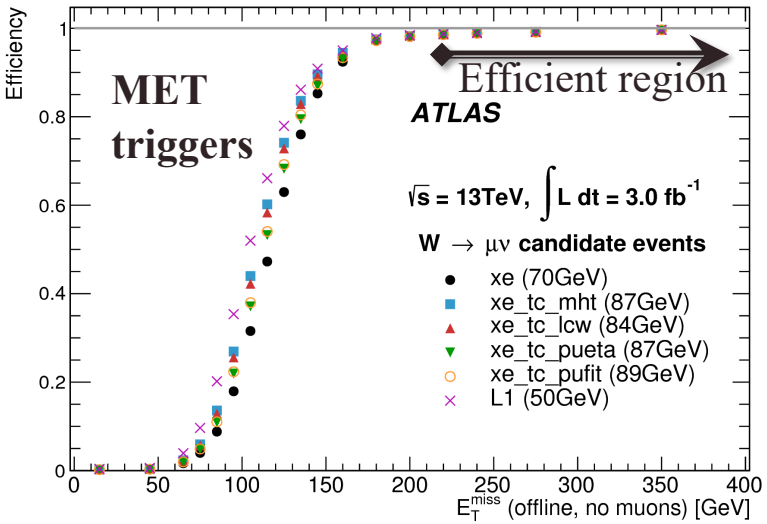


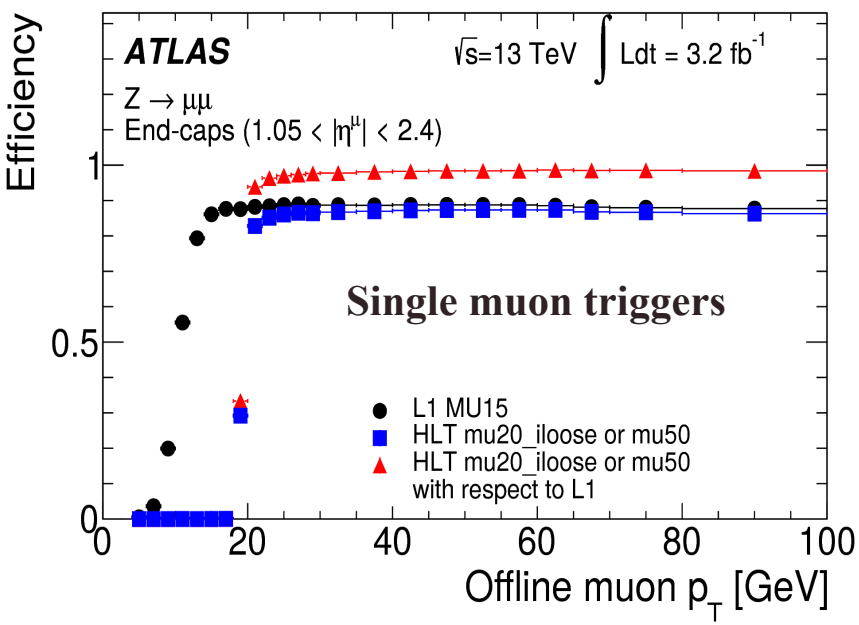
中国组发展的ATLAS数据分析方法

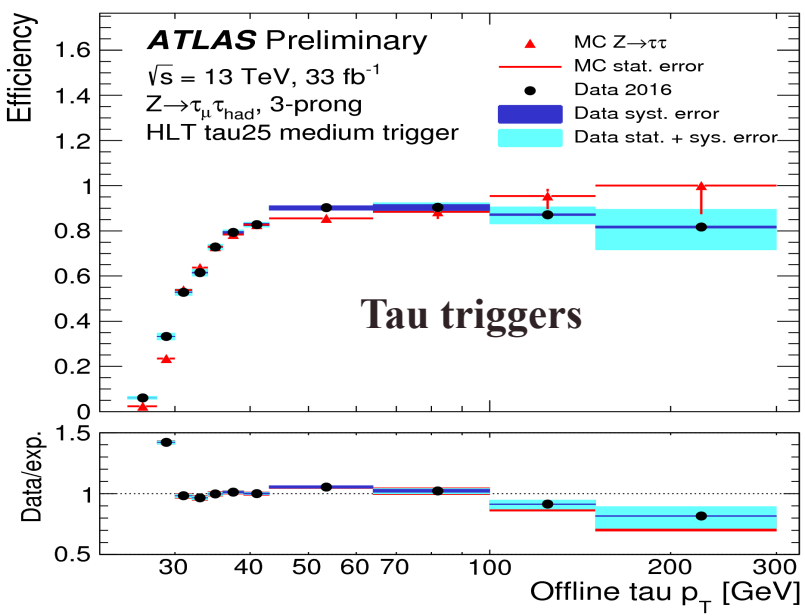
- **tau 重建性能研究：** tau 重建优化；发展并维护 Tau 数据质量监测程序
- **顶点重建：** 研发并优化了“普适的次级顶点重建”算法；协助 ATLAS 用户在物理分析工作中应用该程序包
- **像素探测器数据获取：** 研发了程序块用以确认探测器模块的配置参数，优化了数据光纤电气参数扫描的程序以提高时效，压低“死时间”
- **光子鉴别效率测量—电子外推方法(EEM)：** ICHEP2016 （编辑）
- **光子转化(conversion)效率的研究：** 在光子鉴别中做出重要贡献，中方成员今年10月份被任命为ATLAS光子鉴别组convener
- **丢失横向动量性能研究：** 中方成员引入了利用带电径迹来压低堆积顶点贡献的丢失横向动量的算法，Eur. Phys. J. C77 (2017) 241，至今有32次引用记录

Trigger performance Highlights

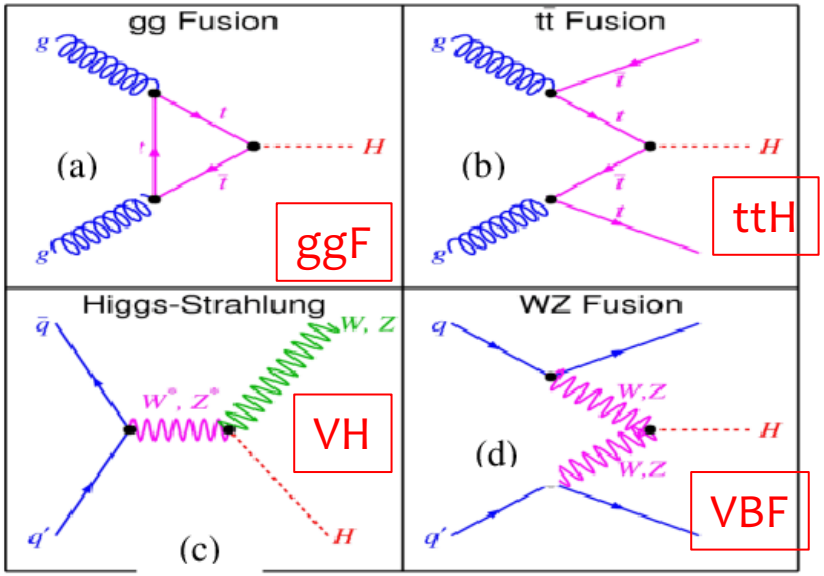
- ATLAS trigger and DAQ systems form the basis for a successful data-taking.
- Main physics triggers for SUSY searches: Generic missing ET, jet, lepton triggers



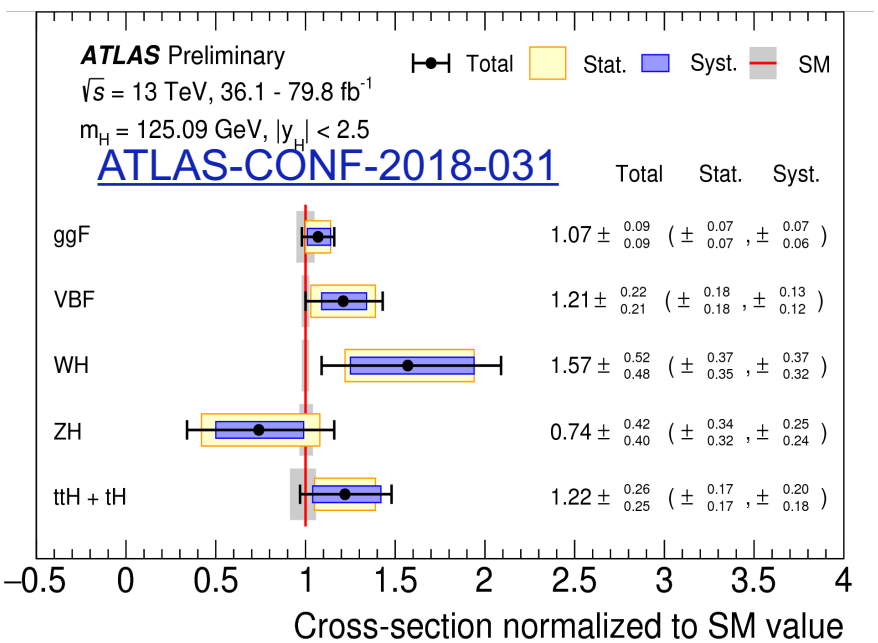




Higgs 产生/衰变模式



Decay mode	Branching fraction [%]	中国组贡献
$H \to bb$	57.5 ± 1.9	✓
$H \to WW$	21.6 ± 0.9	✓
$H \to gg$	8.56 ± 0.86	✓
$H \to \tau\tau$	6.30 ± 0.36	✓
$H \to cc$	2.90 ± 0.35	
$H \to ZZ$	2.67 ± 0.11	✓
$H \to \gamma\gamma$	0.228 ± 0.011	✓
$H \to Z\gamma$	0.155 ± 0.014	✓
$H \to \mu\mu$	0.022 ± 0.001	✓



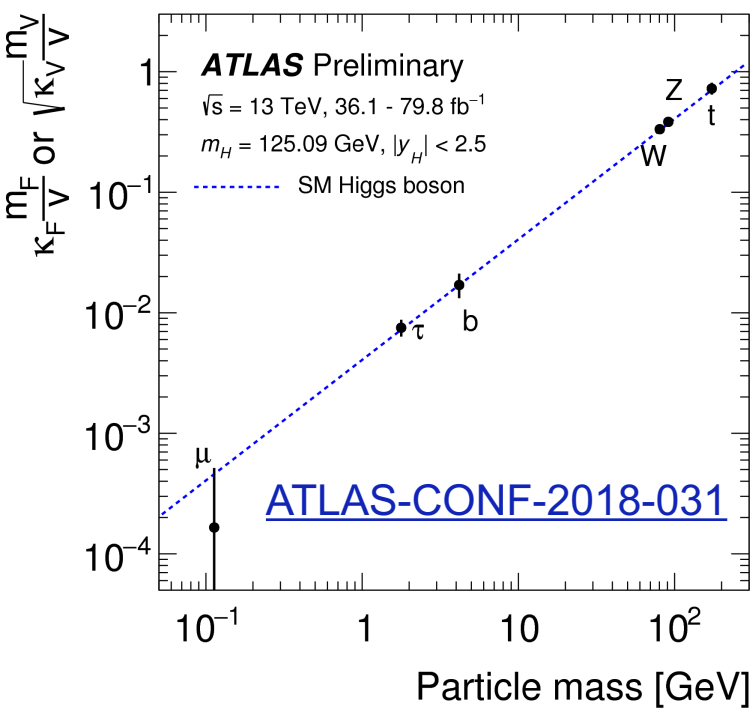
- (a) Gluon-gluon fusion (ggF) 于2012年被发现并被用来精确测量 (~10%)

Prod. mode	Obs.	Exp.	Ref.
(c) VH	5.3σ	4.8σ	ATLAS-CONF-2018-036
(d)VBF	6.5σ	5.3σ	ATLAS-CONF-2018-031
(b) ttH	6.3σ	5.1σ	arXiv:1806.00425

- 发现了所有主要的Higgs 产生模式！→ 与标准模型一致！

Higgs coupling measurements

Higgs coupling (to fermions or bosons) depends on the particle mass



- **All couplings to high mass particles measured.**
- **Next challenge: muon, charm-quark...**

Interaction with gauge bosons:

H →γγ ATLAS-CONF-2018-028

H →ZZ* ATLAS-CONF-2018-018

Above well established in run-1

H →WW* *ATLAS-CONF-2018-004*

6.3 (5.2) σ obs (exp) (run-2 only)

Yukawa coupling to fermions:

Top-quark: ttH ***(80 fb^{-1})***

6.3σ (5.1σ) obs (exp) *Phys. Lett. B 784 (2018) 173*

Bottom-quark H→bb ***(80 fb^{-1})***

5.4σ (5.5σ) obs (exp) *ATLAS-CONF-2018-036*

Tau-lepton:

H→ττ

6.4σ (5.4σ) obs (exp) *ATLAS-CONF-2018-021*

Muon H→μμ ***(80 fb^{-1})***

$\sigma_{limit}/\sigma_{SM}$ *<2.1 (obs)* *ATLAS-CONF-2018-026*

Charm-quark: H→cc

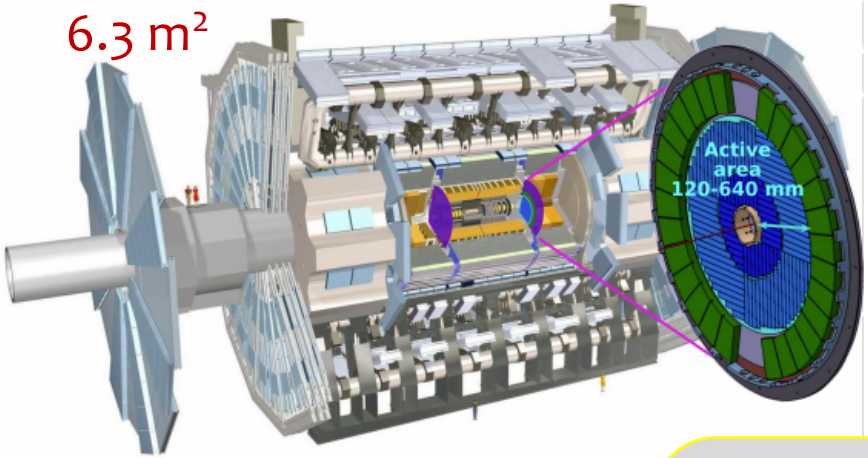
$\sigma_{limit}/\sigma_{SM}$ *<104 (obs)* *PRL 120 (2018) 211802*

ATLAS Phase-2高颗粒度高时间分辨（HGTD）探测器

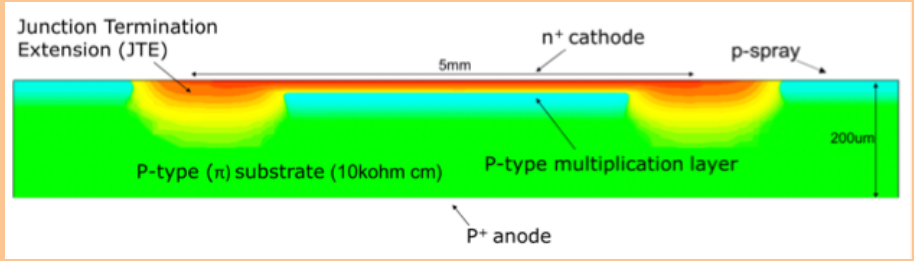
大面积超高时间分辨(10ps)

解决LHC高亮度对撞产生顶点堆积问题

6.3 m²



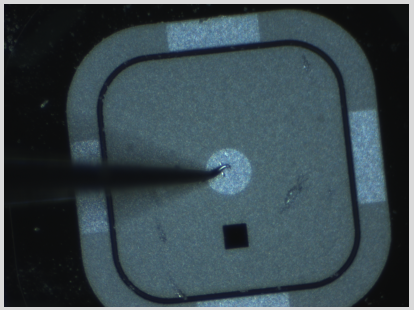
高能所设计的最尖端超快LGAD硅传感器

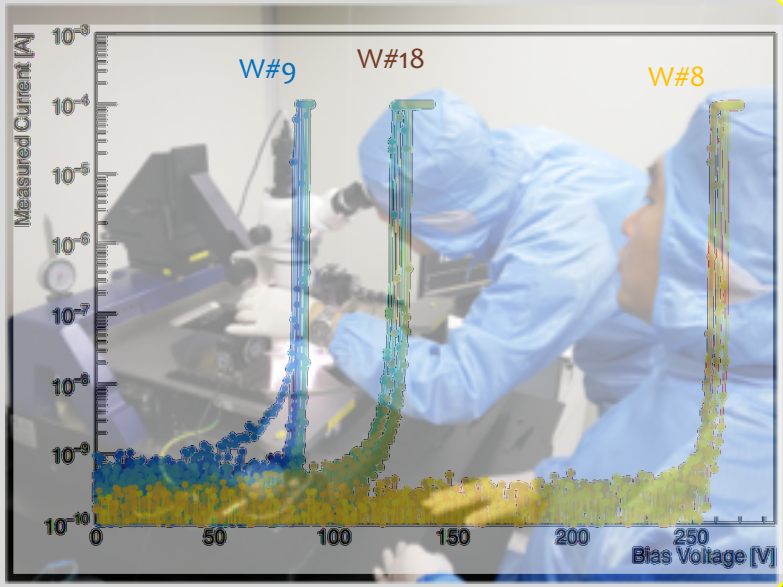


参与单位：
高能所，科大，
南大，山大，交大

中国组任务:
传感器，读出芯片，
探测器模块研制

高能所的
传感器测试





2018 文章 包含待发表(33)

1. VBF H→gg: PRD98(2018)052005
2. H→ZZ*→4-lepton: JHEP 03(2018)095
3. H→WW: arXiv:1808.09054
4. H→tautau截面测量： arXiv:1811.08856, submitted to PRD
5. H→bb衰变发现1：PLB 786(2018)59
6. H→bb衰变发现2: Phys.Rev. D98 (2018) 052003
7. ttH 产生证据1: PRD97(2018)072003
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