2023－2024年度考核

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CMS组

2024年11月21日

一、 岗位职责

1. CMS/CEPC实验上物理研究(80%)

   -- Top/Higgs耦合等研究以及新物理寻找

   -- 新奇特态强子研究

1. CMS实验量能器升级(20%)

二、 本年度工作情况

1、 研究任务完成情况

CMS/CEPC实验上物理研究

✓ CMS顶夸克物理:3/4顶夸克研究;

-- 4tops标准模型测量 + 新物理寻找: 合作组review

-- 4tops新物理寻找: 合作组review + 3tops新物理寻找: 进展良好

✓ CMS上Higgs物理: 2/3Higgs研究

-- HHH(6b)标准模型研究:合作组review ;

-- HH共振态寻找 + HHH(4b2tau)标准模型研究 : 进展良好;

✓ CMS上J/Ψ物理:

-- J/ΨJ/Ψ(Ψ(2S)J/Ψ)截面测量:合作组review;

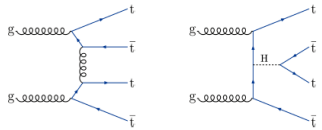
-- Ψ(2S)J/Ψ新结构寻找:合作组review;

✓ CEPC物理研究:

-- 顶夸克EW耦合 + 顶夸克质量 + Wwfusion截面 + Jet performance。

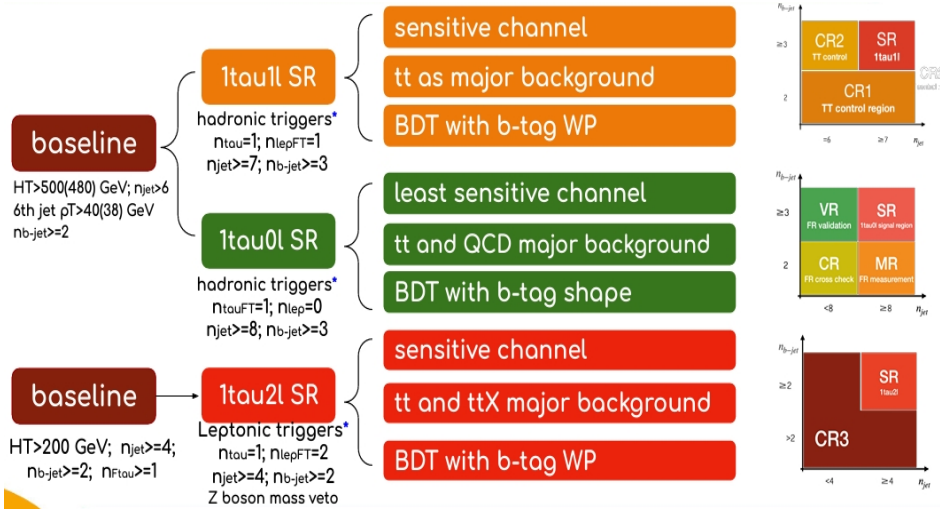
CMS实验量能器升级: Sensor测试, 模块组装和测试等等。

4tops研究：标准模型



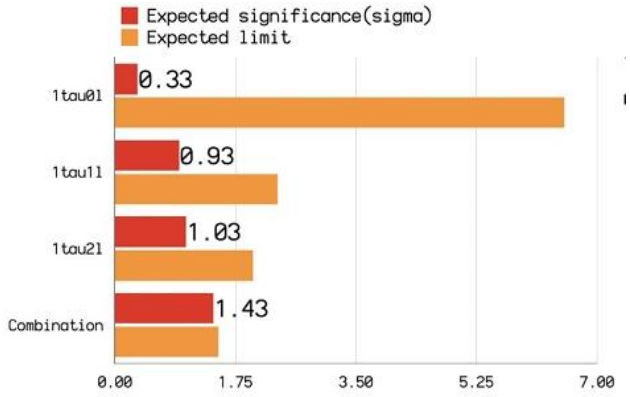
✓ 四顶夸克产生是标准模型中稀有过程；

✓ 标准模型检验 + **top-Higgs耦合研究** + 新物理寻找；

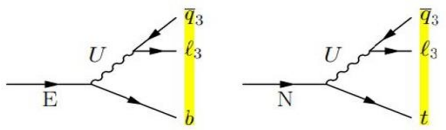


➢ 首次陶子末态研究；

➢ 预期结果好于0/1L

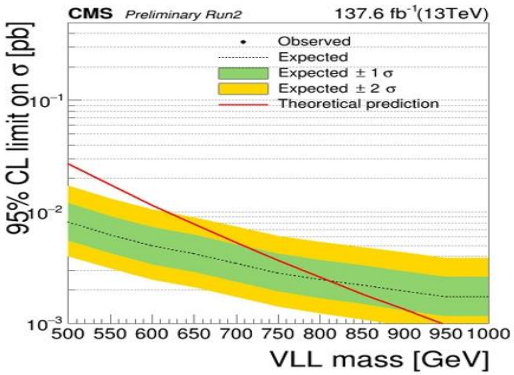


VLL_4321: decay mode and final states



- Depending on how top quark and tau lepton decay
  - E->b(tv), E->b(btau)
  - N->t(tv), N->t(btau)
- Final state can have up to 4 tau, 4l
- Four top tau phase space perfect for VLL search

Channel	VLL decay mode	Final state
1tau0l	$EE \to b(t\nu_\tau)b(t\nu_\tau)$	$\tau+0l+4b+2j+3\nu_\tau+0\nu_l$
	$EE \to b(t\nu_\tau)b(br)$	$\tau+0l+3b+2j+1\nu_\tau+0\nu_l$
	$EN \to b(t\nu_\tau)t(t\nu_\tau)$	$\tau+0l+4b+6j+2\nu_\tau+0\nu_l$
	$EN \to b(t\nu_\tau)t(br)$	$\tau+0l+3b+4j+1\nu_\tau+0\nu_l$
	$EN \to b(br)t(t\nu_\tau)$	$\tau+0l+4b+4j+1\nu_\tau+0\nu_l$
	$EN \to b(br)t(br)$	$\tau+0l+4b+0j+1\nu_\tau+0\nu_l$
	$NN \to t(t\nu_\tau)t(t\nu_\tau)$	$\tau+0l+4b+6j+3\nu_\tau+0\nu_l$
	$NN \to t(t\nu_\tau)t(br)$	$\tau+0l+4b+6j+1\nu_\tau+0\nu_l$
1tau1l	$EE \to b(t\nu_\tau)b(t\nu_\tau)$	$\tau+1l+4b+0j+3\nu_\tau+1\nu_l$
	$EE \to b(br)b(t\nu_\tau)$	$\tau+1l+4b+0j+2\nu_\tau+1\nu_l$
	$EN \to b(t\nu_\tau)t(t\nu_\tau)$	$\tau+1l+3b+0j+2\nu_\tau+1\nu_l$
	$EN \to b(t\nu_\tau)t(br)$	$\tau+1l+4b+2j+1\nu_\tau+1\nu_l$
	$EN \to b(br)t(t\nu_\tau)$	$\tau+1l+4b+2j+1\nu_\tau+1\nu_l$
	$NN \to t(t\nu_\tau)t(t\nu_\tau)$	$\tau+1l+4b+4j+1\nu_\tau+1\nu_l$
	$NN \to t(br)t(t\nu_\tau)$	$\tau+1l+4b+4j+1\nu_\tau+1\nu_l$
1tau2l	$EN \to b(t\nu_\tau)t(t\nu_\tau)$	$\tau+2l+4b+0j+3\nu_\tau+2\nu_l$
	$EN \to b(t\nu_\tau)t(br)$	$\tau+2l+4b+0j+2\nu_\tau+2\nu_l$
	$EN \to b(br)t(t\nu_\tau)$	$\tau+2l+4b+0j+1\nu_\tau+2\nu_l$
	$NN \to t(t\nu_\tau)t(t\nu_\tau)$	$\tau+2l+4b+4j+3\nu_\tau+2\nu_l$
	$NN \to t(br)t(t\nu_\tau)$	$\tau+2l+4b+2j+1\nu_\tau+2\nu_l$

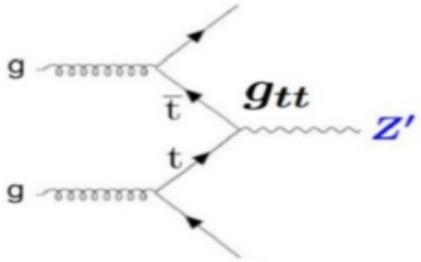


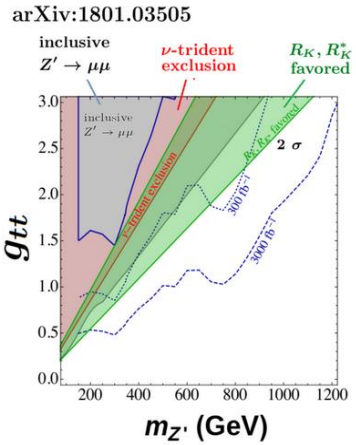
正在进行CMS内部review

✓ 预期结果好于已发表结果

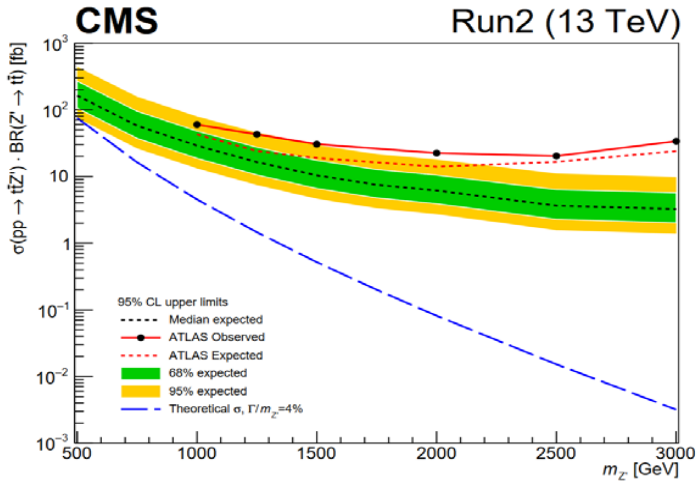
4/3tops研究：新物理寻找

- ✓ 很多新物理模型，如复合希格斯模型等，预言“top-philic”共振态；
- ✓ ATLAS的ttZ’ run2结果灵敏度不够好；
- ✓ 在CMS上着重考虑1TeV以下区间；
- ✓ 结果可对B-anomalies限制；

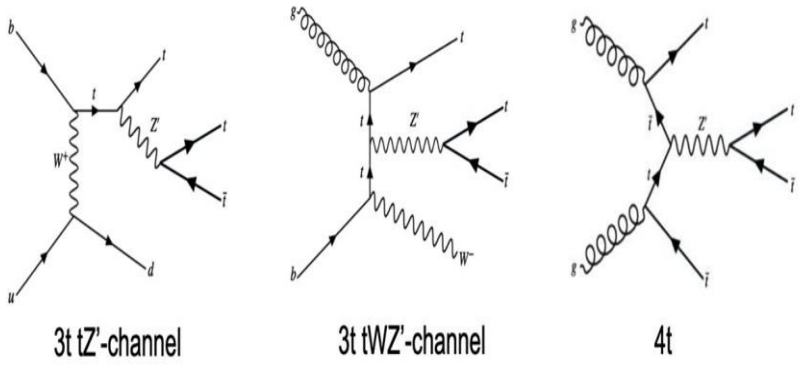




- ✓ 复杂系统重建提高信噪比；
- ✓ 选择优化+分类优化等；
- ✓ Cadi：B2G-24-009；
- ✓ 预期年底或明年初发表结果。



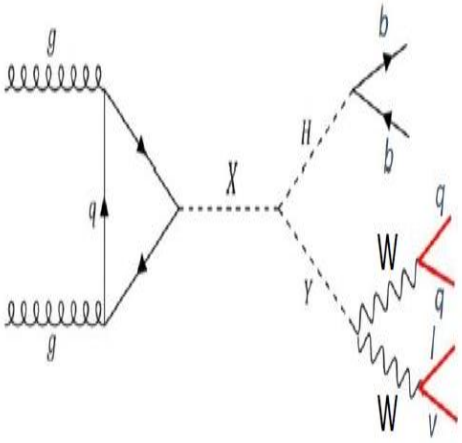
略好于ATLAS

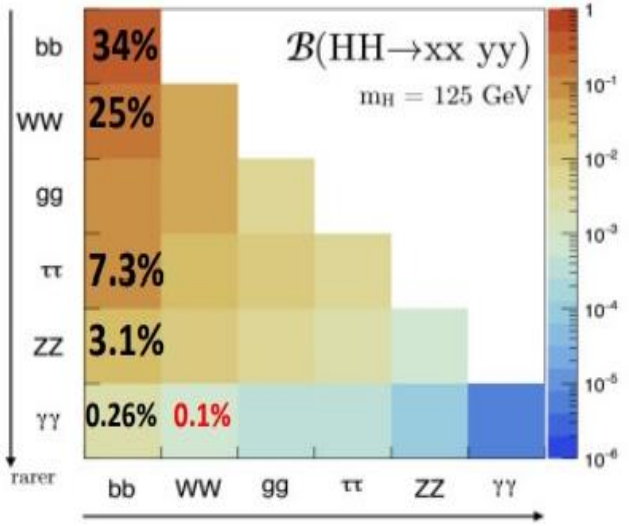


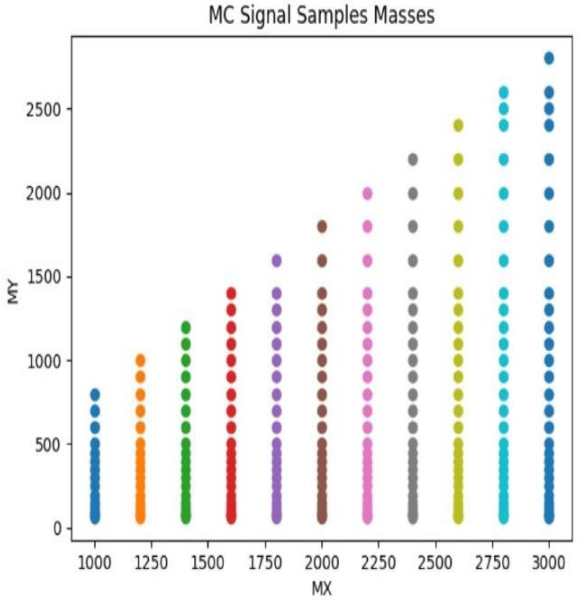
- ✓ 同时在3tops末态开展Z’寻找；
- ✓ 为在LHC寻找稀有3tops过程做准备；

HH研究

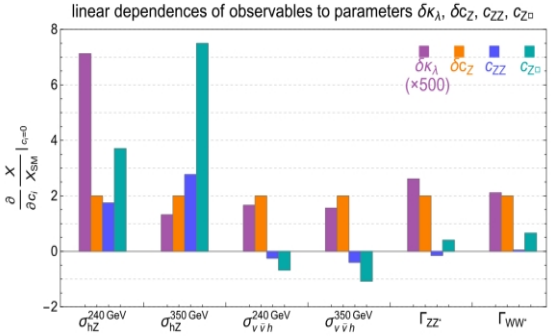
- Many BSM theories predict resonant Higgs-pair production： 2HDM MSSM, NMSSM, 2HDM+S.....
- Study of having direct coupling with Resonant **X** → $\boldsymbol{HHlYH \rightarrow W\,W}$**bb**







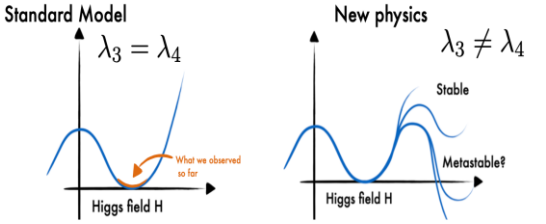
- ✓ 分支比相对比较大，轻子末态效率高易触发；
- ✓ 分析框架，样本准备，事例初选等基本完成；
- ✓ 基本完成run2数据分析；
- ✓ 正在开展run3数据分析；

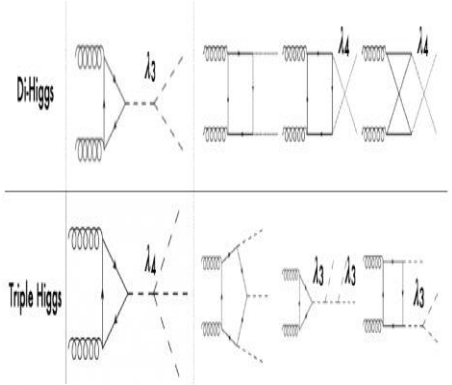


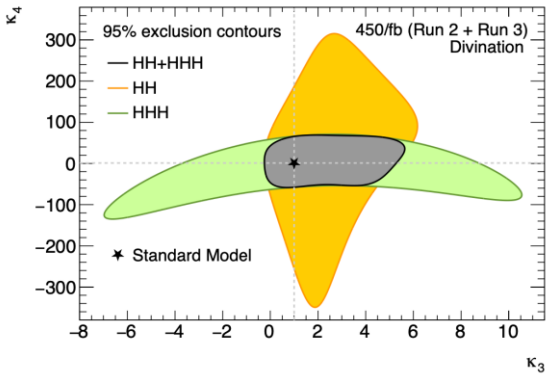
HHH 研究

- 研究Higgs自耦合也可以通过HHH过程，并对新物理很敏感
- 截面比HH小，但是HH和HHH对耦合的限制可以互补

$$V(H) = \frac{1}{2}m_H^2 H^2 + \lambda_3 v H^3 + \frac{1}{4}\lambda_4 H^4$$



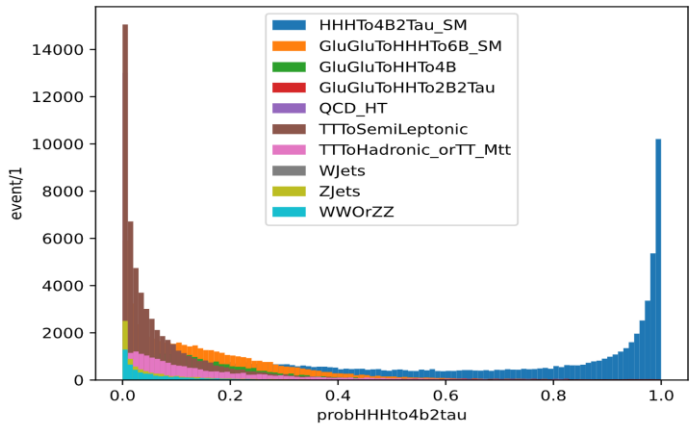




- **HHH → 6b: 19.5%**
- **HHH → bbbbττ: 6.3%; bbbb$\tau_h\tau_h$: 2.7%**

分支比大 本底高
分支比小 本地低

相似的灵敏度



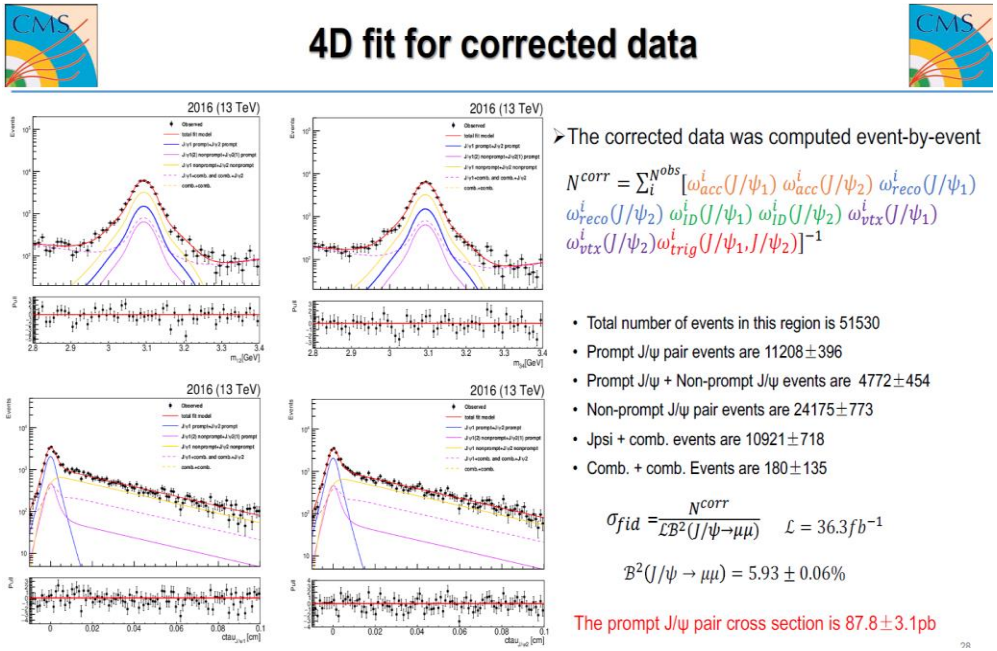
- ✓ 参与HHH6b分析(Cadi： HIG-24-012)
- ✓ 主导HHH4b2tau;
- ✓ PNet在btag和boosted上应用;
- ✓ SPANet高效率重建复杂系统，显著提升信号和本底的区分;
- ✓ SPANet有潜力提升HH2b2tau灵敏度,有助于提升HH2b2W灵敏度;
- ✓ 同时在系统研究SPANet的应用和优化。

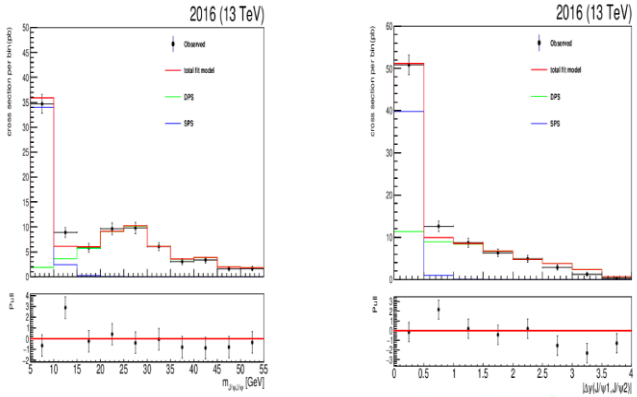
双J/Ψ研究

- 基于完整Run2数据，在4muons末态开展3个全新物理分析：

1. 双J/Ψ产生截面测量：ATLAS和CMS均无13TeV结果，LHCb相空间互补；
2. 双J/Ψ产生过程的SPS/DPS成分测量：暂无实验结果；
3. 双J/Ψ不变质量谱上新共振态寻找。

✓ 1/2中测量结果为分析3中主要本底





P&P Meeting

Inclusive $J/\psi J/\psi$ Cross Section Measurement

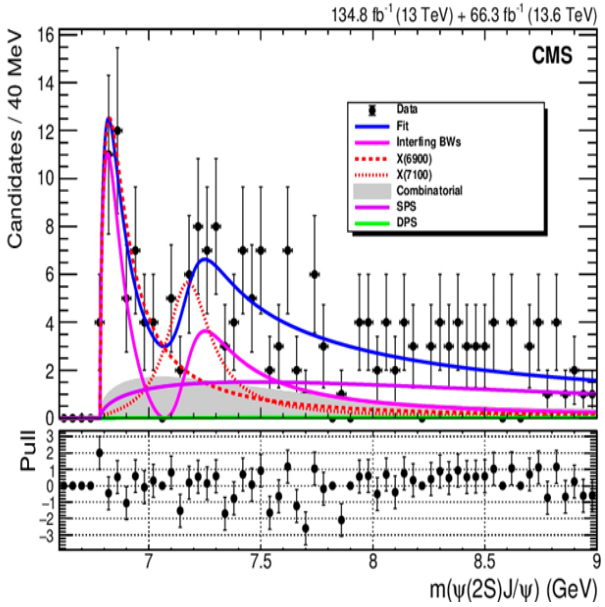
Muhammad Ahmad[3], Gerry Bauer[1], Zhen Hu[1], Hongbo Liao[2], Zhengchen Liang[1], **Jinfeng Liu**[1], Ruobing Tu[2], Kai Yi[1,4], Taozhe Yu[2], Shunliang Zhang[1]

- 首次测量，主导分析；
- Cadi：BPH-24-006

Ψ(2S)J/Ψ研究

- 基于完整Run2数据，在Ψ(2S)J/Ψ的4muons末态中：

1. Ψ(2S)J/Ψ产生截面测量：
   -- 全新测量，统计量较低，分析策略和双J/Ψ分析相似；
   -- 参与分析，交叉检验清华团队结果，预期明年年初完成分析。
2. 在新末态中寻找确认新结构X(6900)。
   -- 预期以超过5σ在新末态中确认双J/Ψ末态中发现的新结构X(6900)；
   -- 参与分析，已经通过合作组初审，预期很快发表。



Pre-approval of BPH-22-004:
Search for X(6900) in the $\psi(2S)J/\psi$ channel at CMS

Gerry Bauer, Liangliang Chen, Yufei Chen, Zhipeng Cui, Andrei Gritsan, Jinjing Gu, Zhen Hu, Bolin Li, Hongbo Liao, Jordan Martins, Yasar Onel, Hui Wang, Xining Wang, Meng Xiao, Kai Yi, Jingqing Zhang, Yilin Zhou

BPH PAG General meeting, 2024.12.05

- An excess observed in $\psi(2S)J/\psi$ channel [Significance: BW2 (6.1σ), BW3 (2.9σ)]

Without considering interference effect:

$BW2: m = 6824\,^{+16}_{-13}(stat)\,^{+3}_{-5}(syst)\,MeV, \Gamma = 92\,^{+73}_{-35}(stat)\,^{+17}_{-15}(syst)MeV;$

With considering interference effect:

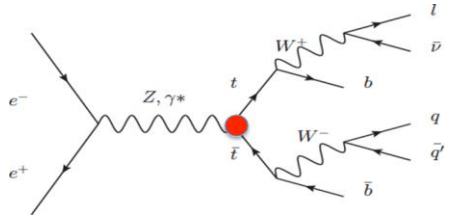
$BW2: m = 6861\,^{+44}_{-34}(stat)\,^{+27}_{-46}(syst)\,MeV, \Gamma = 231\,^{+319}_{-119}(stat)\,^{+350}_{-124}(syst)\,MeV;$

$BW3: m = 7185\,^{+65}_{-105}(stat)\,^{+41}_{-107}(syst)\,MeV, \Gamma = 242\,^{+185}_{-165}(stat)\,^{+127}_{-111}(syst)\,MeV.$

- Consistent with X(6900) observed in $J/\psi J/\psi$ analysis
- ATLAS claims only a 4.7σ excess in $\psi(2S)J/\psi$ channel

CEPC上顶夸克EW耦合研究 + 质量宽度测量

- Studying the Top EW couplings is very important because of the sensitivity to new physics
- ✓ It is possible to perform this measurement at CEPC



$$\chi^2 = \left(\frac{\sum_{b_H b_L jjlv} E_i - 360}{\sigma_E}\right)^2 + \left(\frac{\sum_{b_H b_L jjlv} P_{x_i}}{\sigma_{P_x}}\right)^2 + \left(\frac{\sum_{b_H b_L jjlv} P_{y_i}}{\sigma_{P_y}}\right)^2 + \left(\frac{\sum_{b_H b_L jjlv} P_{z_i}}{\sigma_{P_z}}\right)^2$$

$$+ \left(\frac{M_{b_H jj} - M_t}{\sigma_{M_{t_H}}}\right)^2 + \left(\frac{M_{b_L lv} - M_t}{\sigma_{M_{t_L}}}\right)^2 + \left(\frac{M_{jj} - M_W}{\sigma_{M_{W_H}}}\right)^2 + \left(\frac{M_{lv} - M_W}{\sigma_{M_{W_H}}}\right)^2$$

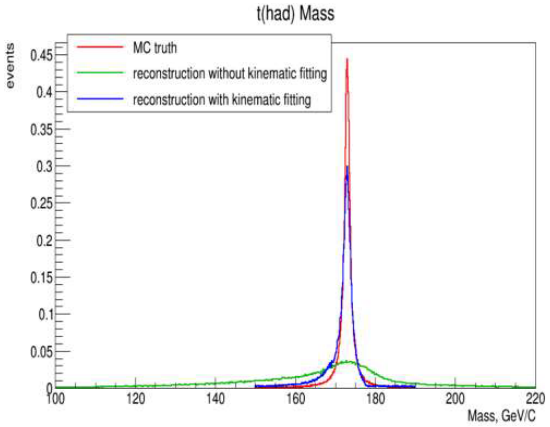
8 Kinematic Consrtraints

$$+ (sf_{b_H} - 1)^2 + (sf_{b_L} - 1)^2 + (sf_{jj} - 1)^2 + (sf_l - 1)^2$$

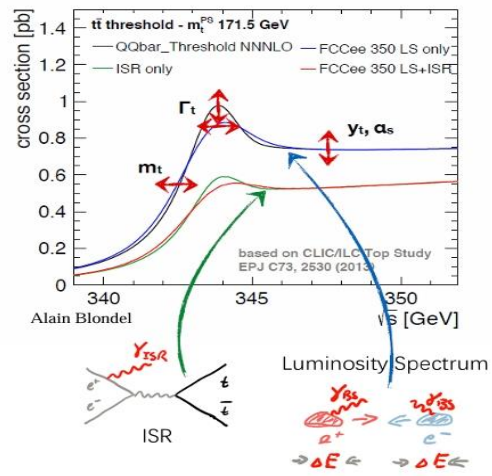
1 Degree

7 Unknows: 4 scalefactors($sf_{b_H}, sf_{b_L}, sf_{jj}, sf_l$) and 3-momentum of neutrino($P_{x_\nu}, P_{y_\nu}, P_{z_\nu}$).

where $M_t, M_W, \sigma_E, \sigma_{P_x}, \sigma_{P_y}, \sigma_{P_z}, \sigma_{M_{t_H}}, \sigma_{M_{t_L}}, \sigma_{M_{W_H}}, \sigma_{M_{W_H}}$ are the parameters to be determined.

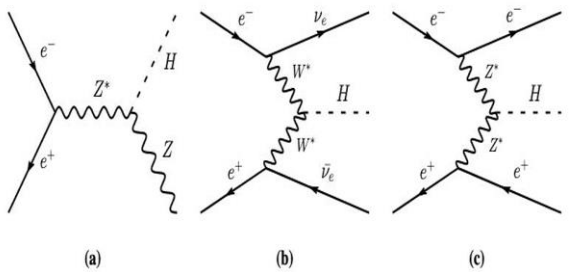


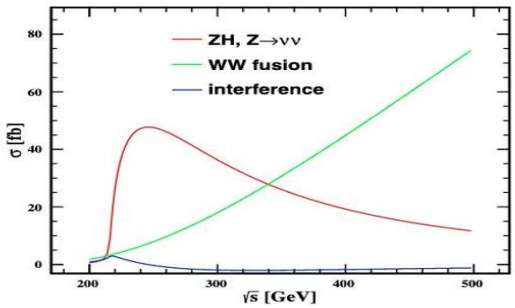
Process	$TTbar$	Single Top	$q\bar{q}$	W^+W^-	$b\bar{b}$	ZW^+W	ZZZ	ZZ
Events	1,000,000	20,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
$W_L \to \mu/e$ directly	66.67%	66.49%	0.72%	21.81%	0.60%	27.7%	16.6%	12.23%
4 jets	66.67%	66.49%	0.72%	15.66%	0.60%	26.19%	15.18%	9.24%
$\sum_{4jets} BTag = 2$	46.48%	44.73%	0.019%	0.096%	0.21%	2.18%	1.7%	0.58%
$\log(y_{34}) > -3.2$	46.38%	44.49%	0.0097%	0.033%	0.13%	2.05%	1.64%	0.38%
$\log(y_{45}) > -4.1$	46.36%	44.46%	0.0094%	0.033%	0.13%	2.05%	1.64%	0.38%
PFOs > 38	46.33%	44.42%	0.0094%	0.024%	0.13%	1.9%	1.52%	0.30%
Charged PFOs > 18	46.31%	44.40%	0.0094%	0.023%	0.13%	1.89%	1.51%	0.29%
PMax < 105	46.25%	43.27%	0.0092%	0.0091%	0.13%	1.69%	1.39%	0.076%
200 < TotalE < 344	46.14%	42.97%	0.0051%	0.0078%	0.094%	1.6%	0.56%	0.034%
Sphericity < 0.23	46.02%	42.82%	0.0021%	0.0056%	0.034%	1.59%	0.56%	0.034%
Thrust > 0.92	46.02%	42.82%	0.0021%	0.0056%	0.034%	1.59%	0.56%	0.034%
$\chi^2 < 1$	34.06%	14.14%	0.0001%	0.00%	0.0022%	0.23%	0.093%	0.0024%
Survived Events	59766	2239	4	0	15	34	1	16

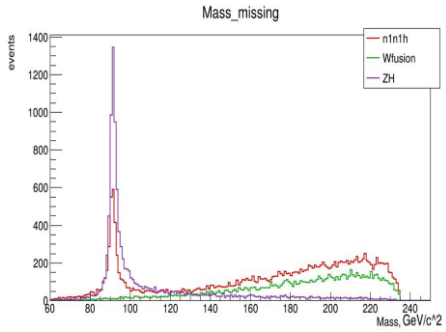


- ✓ 主持每周例会讨论进展；
- ✓ 多团队合作(高能所李刚方亚泉 + 南大张雷 + 北大孙小虎)；
- ✓ 首次在CEPC上选择并重建顶夸克对事例；
- ✓ EW耦合研究预期明年年中完成；
- ✓ 质量宽度等测量预期明年年底完成；
- ✓ 后者可借鉴使用前者的经验和结果。

CEPC上WWfusion研究



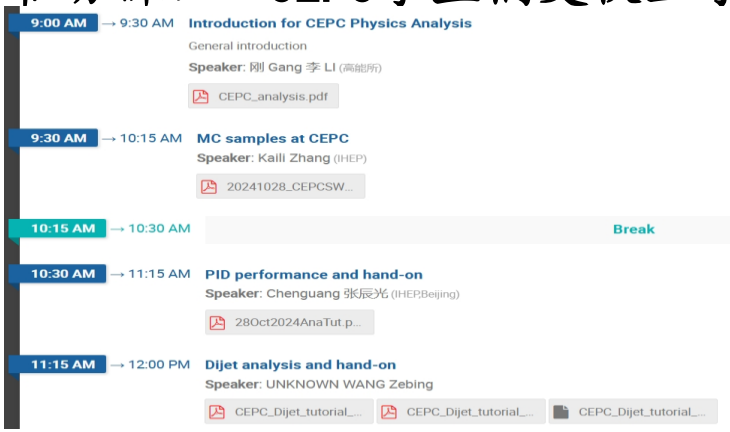




- ✓ Wwfusion截面测量精度有助于精确测量Higgs width;
- ✓ 基于CEPCSW,更好的理解探测器以及模拟重建等等;

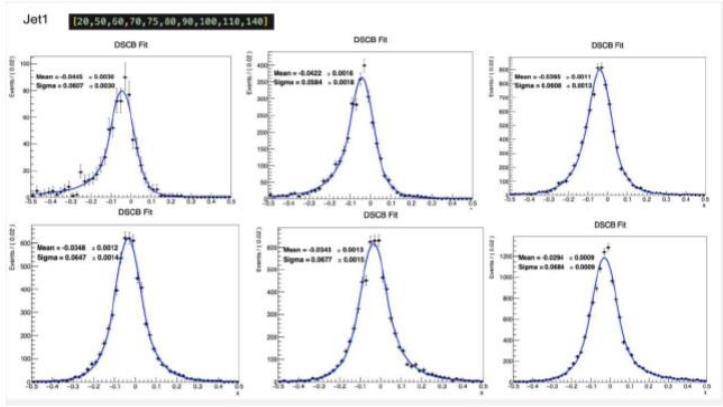
CEPC Physics Analysis tutorial

- ✓ 28/10/2024, 多学科大楼226会议室;
- ✓ 帮助新加入CEPC学生们更快上手。



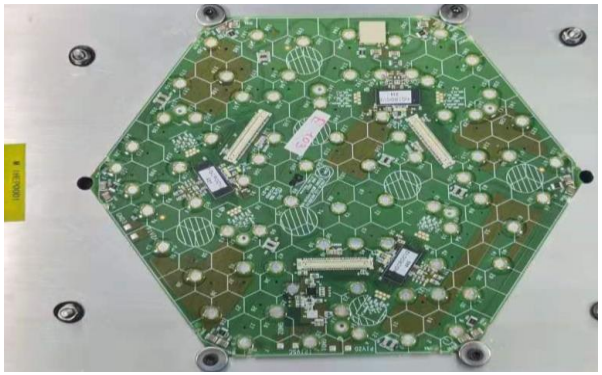
Jet performance 研究

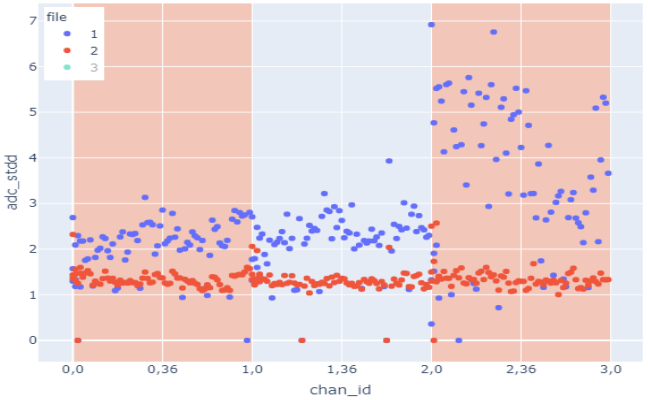
With different Energy bins.



CMS实验高粒度量能器模块生产测试

指导学生以及本人参与：





- ✓ 华慧玲和候霄楠
  - -- 在高能所参与模块绑定
  - -- 在CERN参与sensor测试
- ✓ 涂若冰和侯瑛琦参与高能所模块组装，负责OGP测量工作；
- ✓ 余涛哲承担高能所模块测试，Anwar Zada和涂若冰参与
- ✓ 其它工作：模块束流测试，采购等等，工作重心逐步向整体组装工作倾斜

--Performance of CMS High Granularity Calorimeter prototype to charged pion beams of 20-300 GeV /c, JINST 18 (2023) 18 P08014

-- Neutron Irradiation and Electrical Characterization on the First 8” Silicon Pad Sensor Prototypes for the CMS Endcap Calorimeter Upgrade, JINST 18 (2023) 08, P08024

二、 本年度工作情况

2、本人研究成果与经费情况

✓ 研究成果：

□ 预期在今年年底—明年上半年完成(合作组内部审核中)

1. 4tops寻找(Top-Higgs耦合研究)
2. 4tops新物理寻找：B2G-24-009
3. HHH(6b)研究：HIG-24-012
4. J/ΨJ/Ψ截面测量：BPH-24-006
5. Ψ(2S)J/Ψ新结构寻找：Pre-approval

□ 预期在明年年中—年底完成

6. CEPC上top耦合等研究
7. HH(WWbb)共振态寻找
8. HHH(4b2τ)研究
9. Ψ(2S)J/Ψ截面测量
10. 3tops新物理寻找

□ 升级相关文章

-- Performance of CMS High Granularity Calorimeter prototype to charged pion beams of 20-300 GeV /c, JINST 18 (2023) 18 P08014

-- Neutron Irradiation and Electrical Characterization on the First 8” Silicon Pad Sensor Prototypes for the CMS Endcap Calorimeter Upgrade, JINST 18 (2023) 08, P08024

二、 本年度工作情况

2、本人研究成果与经费情况

✓ 经费情况：

□ 主持：

--科技部重点研发项目(物理)子课题：600万(2024-2028)

□ 参与：

--基金委国际合作项目(物理)：900万(2021-2025)

--科技部重点研发项目(升级)：2000万(2023-2027)

□ 其它：

--北京市公派出国访问项目：12个月资助

--中比国际合作基金，面上基金均未通过

二、 本年度工作情况

3、学术交流

✓ 大会报告

Hongbo Liao, "Quantum entanglement in the highest energy at LHC and top physics summary", 10th CLHCP, November, 2024, Qingdao

✓分会报告及其它

新生培训 **Hongbo Liao**, "Higgs Physics at the LHC and CEPC", 2024.09

分会报告：

Xiaonan Hou, "Search for a heavy resonance produced in association with and decaying to a tt pair in the single lepton final state with CMS at √s = 13TeV", CLHCP2024, Nov. Qingdao

Mustapha BIYABI, Hongbo Liao.etc, "Top Quark EW Coupling Precision Measurement", The 2024 international workshop on the CEPC, Oct, 2024, Hangzhou

二、 本年度工作情况

4、公共服务

- ✓ **Hongbo Liao: CMS conference committee / CMS值班取数**
- ✓ **Huiling Hua: TOP trigger contact**
- ✓ **Anwar Zada: Hgg MC contact**
- ✓ **Xiaonan Hou: Ecal on-call**

Coordinator Load

Hongbo Liao manages 27 conferences with 365 presentations
Arnd Meyer manages 50 conferences with 364 presentations
Serguei Petrushanko manages 54 conferences with 210 presentations
Borislav Pavlov manages 19 conferences with 208 presentations
Ulrich Goerlach manages 10 conferences with 124 presentations
Niki Saoulidou manages 3 conferences with 122 presentations
Sung Won Lee manages 5 conferences with 108 presentations
Silvano Tosi manages 12 conferences with 91 presentations
Oliver Pooth manages 1 conference with 90 presentations

5、 其它

- ✓ 主持4tops/2Jpsi/Top coupling周会;
- ✓ 协助参与若干座谈招聘(所内/CERN);
- ✓ 参与若干评审,答辩,考核等;
- ✓ 指导科创计划学生5名;
- ✓ 指导本科毕业设计论文1名;
- ✓ 招收研究生1名;

三、 存在问题

- ✓ 经费争取不够
- ✓ 团队建设需加强
- ✓ 硬件软件方面工作需加强

四、 下年度工作计划

- ✓ 推进CMS/CEPC上top/Higgs/ J/Ψ现有多个物理分析;
- ✓ 进一步参与CEPC物理相关研究;
- ✓ 参与run3运行等各项工作;
- ✓ 参与CMS量能器升级：模块组装(IHEP) + 整体组装(CERN)
- ✓ 继续积极申请各项经费;

请各位老师，评委批评指导！

谢 谢！