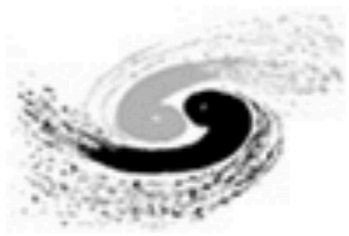
# 实验物理中心考核报告

徐达

2024–11-22



中国科学院高能物理研究所

Institute of High Energy Physics Chinese Academy of Sciences

# 报告内容

- 岗位职责
- 本年度工作情况
- 存在问题
- 下年度工作计划

# 岗位职责 (2023/11 — 2024/11)

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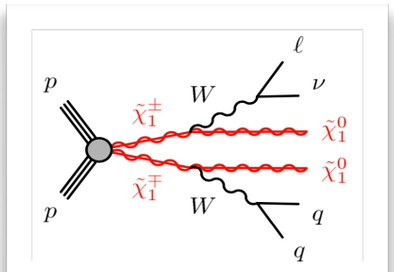
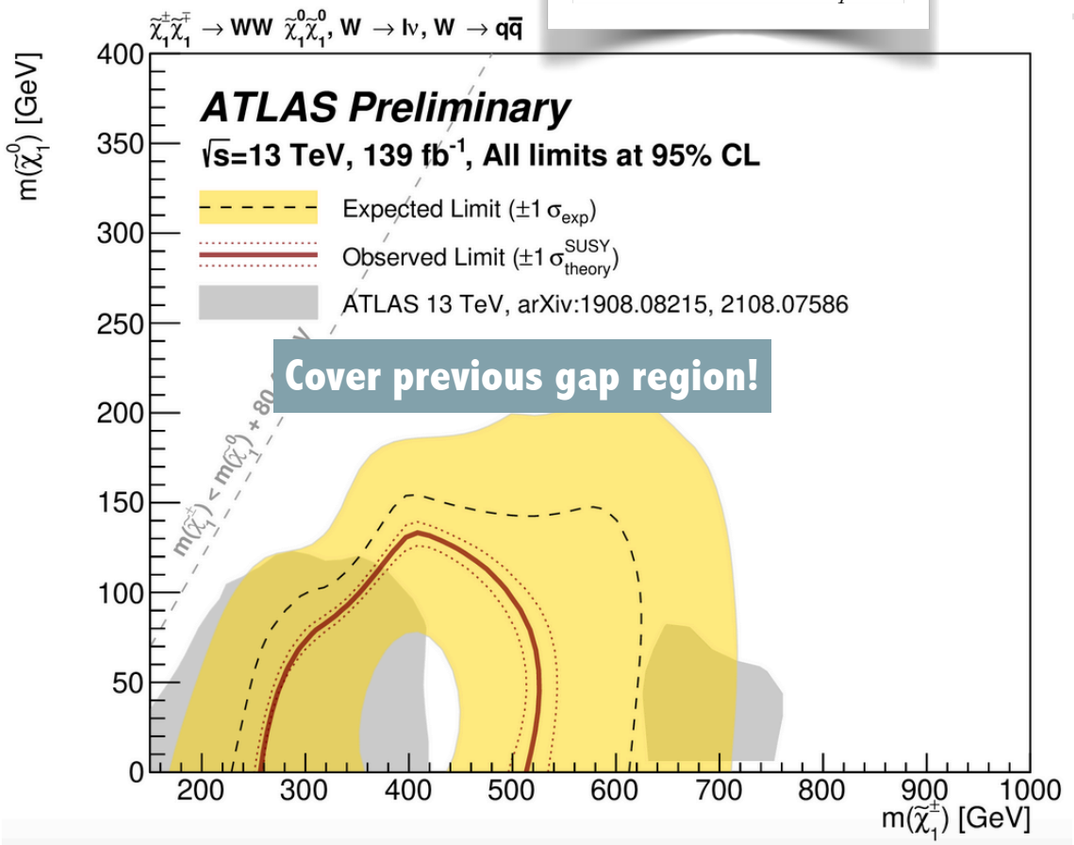
- 岗位职责：ATLAS实验中超对称及暗物质的寻找和HGTD时间探测器项目等。
- 主要工作：
  - ATLAS物理分析
    1. 单轻子末态 wino、bino的寻找 （Run2）
    2. 质量压缩空间wino、bino的寻找（Run2）
    3. tau末态 stau、wino、bino的寻找 （Run2）
    4. 1L/2L末态的wino、higgsino、bino寻找（Run2-3）
    5. 质量压缩空间stau的寻找（Run2-3）
    6. H-Za-ll$\gamma\gamma$的寻找（Run2-3）
    7. Constituent-based W tagger的研究
  - ATLAS Data preparation：Reprocessing coordinator
  - ATLAS高颗粒度时间探测器HGTD项目
  - ATLAS HistFitter expert
  - CEPC BSM

本年度工作完成情况

# 物理分析 1：单轻子末态 wino、bino的寻找

- 基于**full Run2**数据，**ATLAS**首次研究**wino-bino**单轻子末态的衰变。通过机器学习技术，提升原有**GAP**区域以及高挑战性的低质量差空间的敏感度。
- 担任分析负责人、通信作者，指导本所学生，本年度发表一篇**JHEP**，在**ATLAS Briefing**上报导。




ATLAS EXPERIMENT

ABOUT DISCOVER RESOURCES UPDATES SEARCH

All News Briefings Features Portraits Press Blog

**Together, these new analyses showcase the cutting-edge techniques being used to explore electroweakino production at the LHC.**

## Exploring electroweakino pair production

ATLAS researchers also set out to investigate electroweakino pair production, specifically chargino pairs and their interactions with neutralinos. The lightest neutralino, in addition to being a dark matter candidate particle, may hold the key to understanding the discrepancy between the g-2 measurement and Standard Model predictions.

For their new study, researchers looked for charginos decaying in three ways – via two W bosons (WW), a W boson and a Z boson (WZ), or a W boson and a Higgs boson (WH). These decay channels can all result in similar experimental signatures with one lepton. Researchers looked for unique collision-event signatures with isolated leptons, missing momentum and large-radius jets (or b-jets in the WH case). They applied improved cut-and-count strategies in the WW/WZ cases, and revised the previous cut-and-count WH analysis with new machine-learning techniques (see Figure 2). Using a BDT, researchers were able to enhance signal identification in scenarios where the chargino and next-to-lightest neutralino decays were mediated by a Higgs boson, or when their mass difference closely aligns with the mass of the Higgs boson itself.

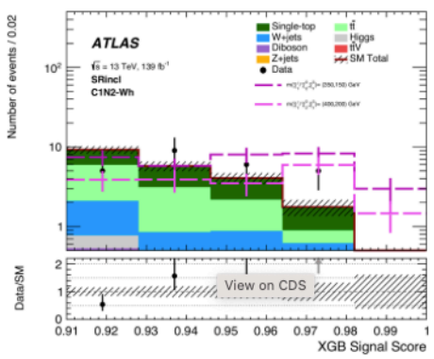
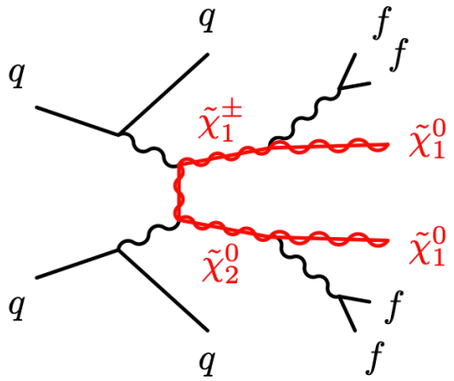


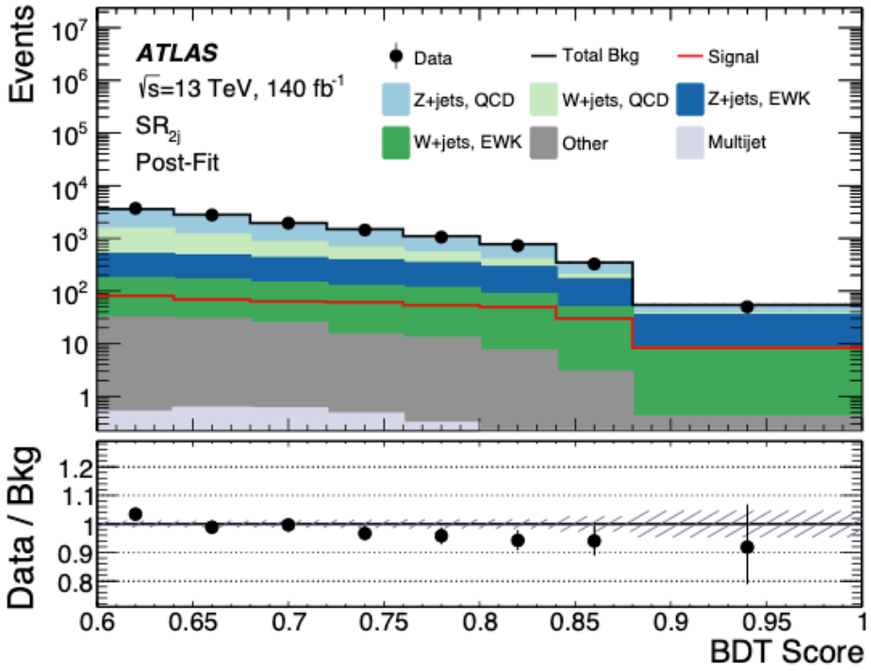

Figure 2: Post-fit distribution of the data (black points) and contributions from expected Standard Model processes (solid histograms) in the signal regions of Wh channel for the BDT signal output score. Two representative SUSY signal models are overlaid in purple dashed lines for illustration. The uncertainty bands plotted include all statistical and systematic uncertainties. (Image: ATLAS Collaboration/CERN)

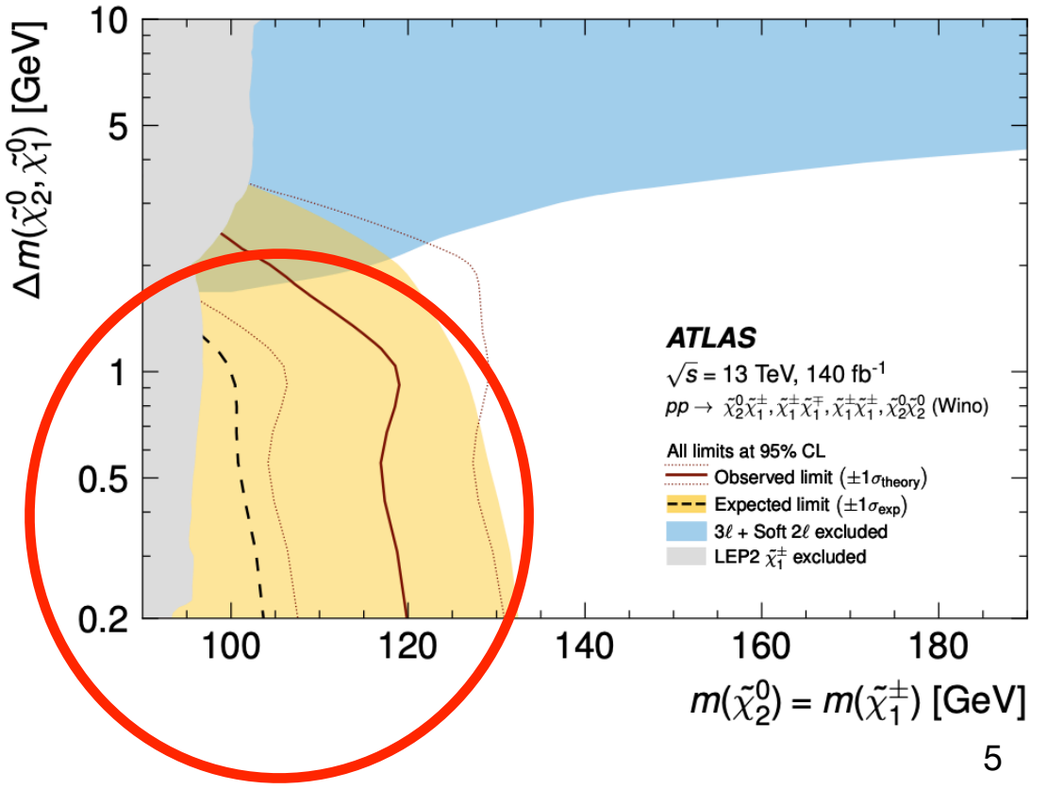
本年度工作完成情况

# 物理分析 2：质量压缩空间wino、bino的寻找

- 基于**full Run2**数据，研究**wino-bino** 质量极其压缩的空间**(dM<1GeV)**! 难度极高！
- **ATLAS**首次通过标记**VBF jet**来探寻该空间：**2 VBF jets+MET(0 lepton）**。
- 指导本所学生，代表分析组做超对称物理大组审核报告**SUSY approval**，文章已投稿**JHEP**。



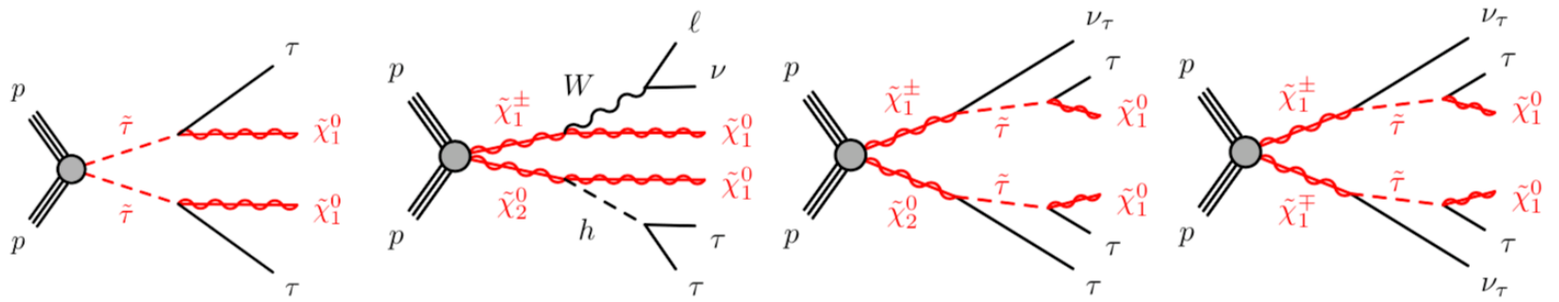



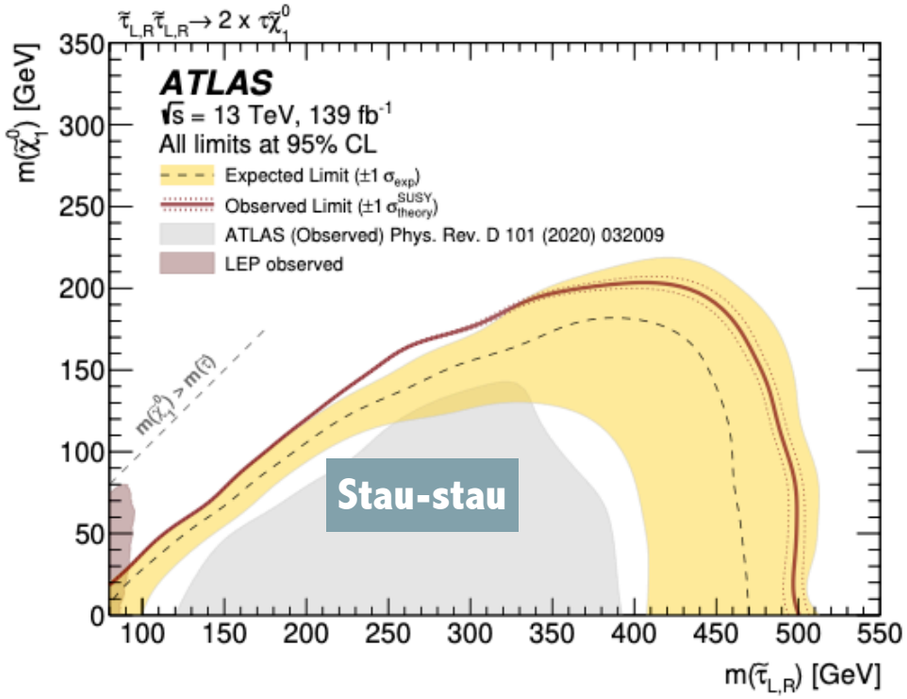



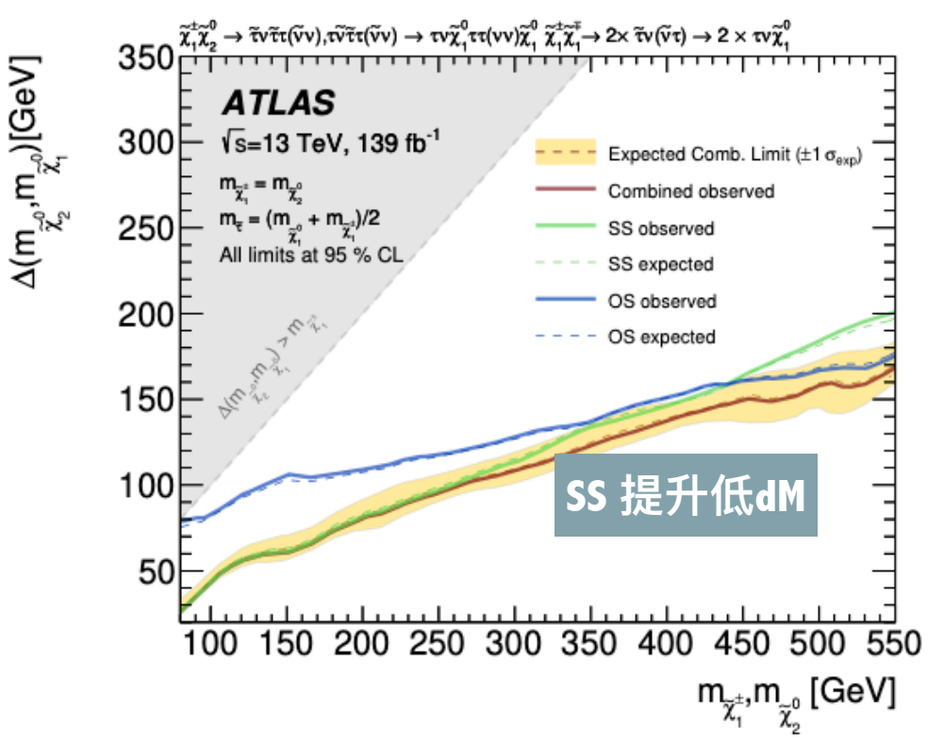
本年度工作完成情况

## 物理分析 3：tau末态 stau、wino、bino的寻找

- 基于**full Run2**数据，使用机器学习方法以及改进的**tau ID**鉴别技术，大幅提升**stau limit**，为当前最好结果。首次引入**Same-Sign tau**来提升紧致空间的信号敏感度。
- 指导本所学生工作进行信号优化等工作，本年度发表一篇**JHEP**。



本年度工作完成情况

## 物理分析 4：1L/2L末态的wino、higgsino、bino寻找

- **Run3新分析**。首次在**ATLAS**上提出研究**Higgsino-bino**过程，并由经典单轻子末态拓展为**1-2**轻子末态，如**N2N3->Zh->llbb**黄金衰变道。

- 指导本所学生工作，目前正在进行分析框架搭建，新信号设计、申请和产生等。

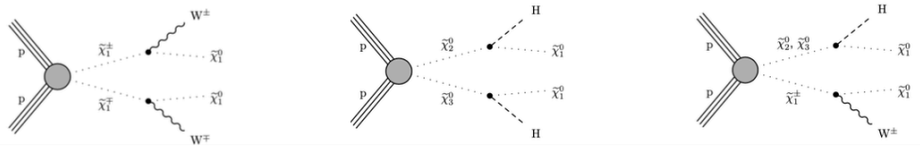
R&D

# Higgsino-bino model




- **Mass degenerate higgsino-like N2/N3/C1 and Bino-like N1 as LSP; decay via W/H**
  - **M1 < mu << M2,M3**
  - **Complementary to our familiar wino-bino or higgsino LSP model**
  - **In additional we would like to make some R&D of some not so simplified models**
- **Standard higgsino-bino model and proposed 1/2L channels**
  - **C1C1 — WWN1N1 (2L+MET; 1Ljj+MET)**
  - **C1N2 or C1N3 — WZN1N1 (1Ljj+MET; 2Ljj+MET)**
  - **C1N2 or C1N3 — WHN1N1 (1Lbb+MET)**
  - **N2N3 — ZHN1N1 (2Lbb+MET)**

→ **Similar scenarios to wino-bino C1N2/C1C1 models, can share the region design. Or have quick reinterpretation based on existing SRs.**

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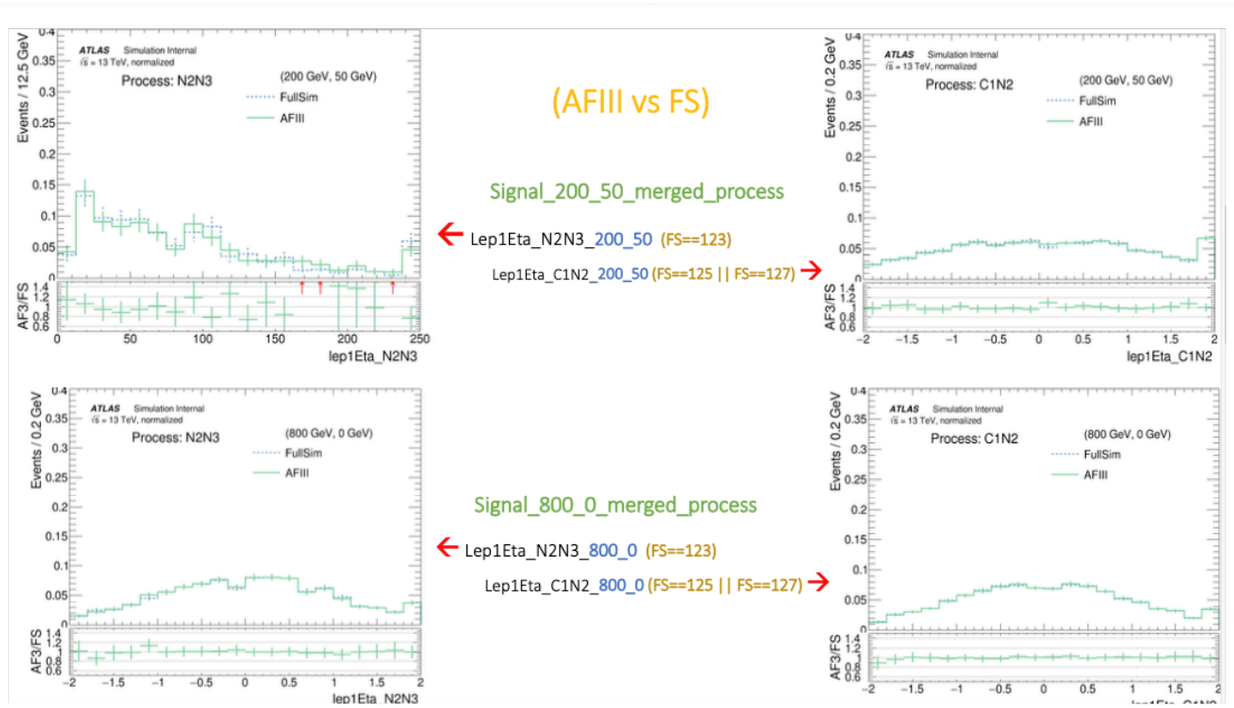
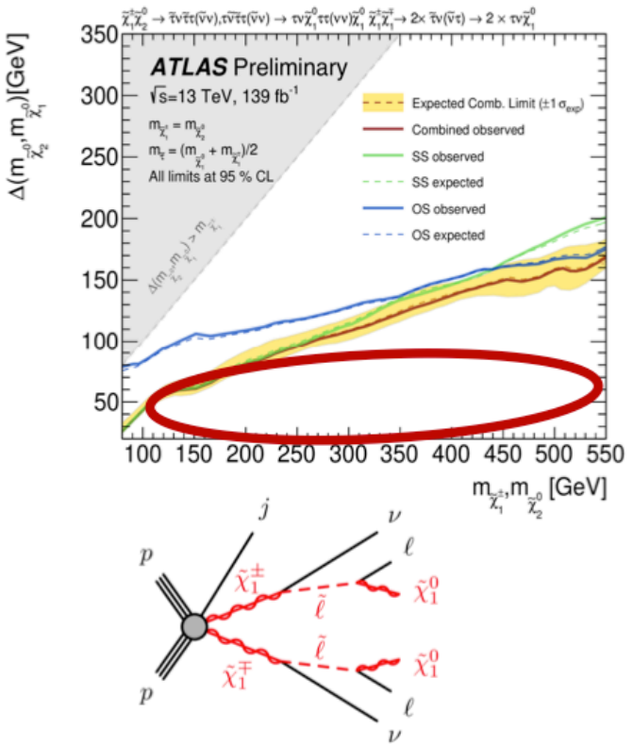


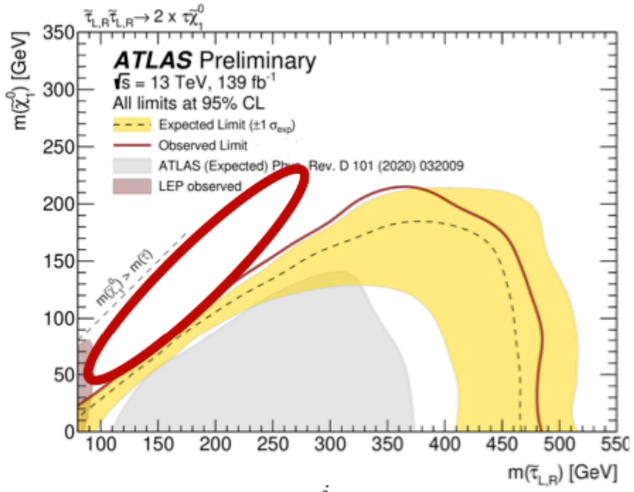
本年度工作完成情况

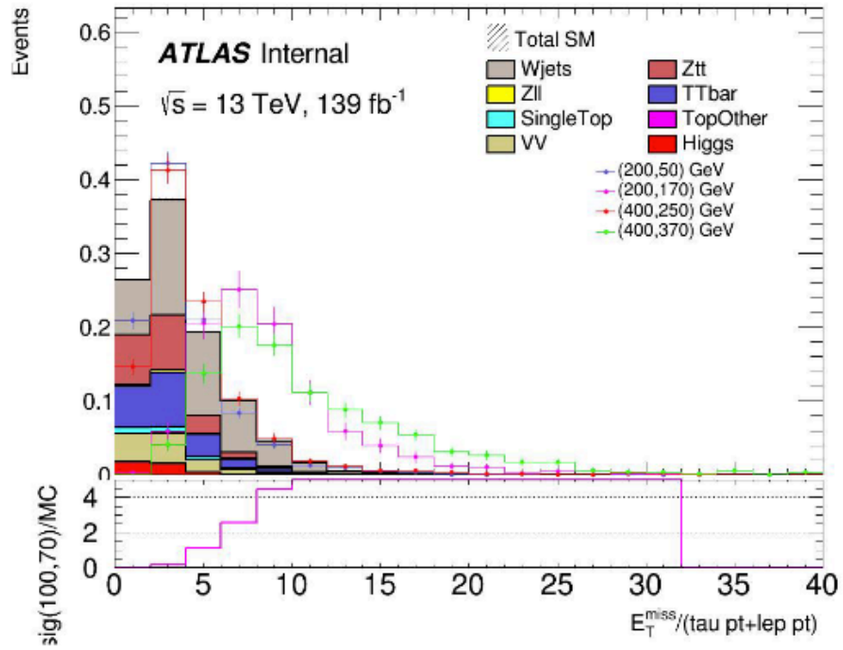
## 物理分析 5：质量压缩空间stau的寻找

- **Run3新分析**。目标空间为质量压缩区域的**soft stau**。由于末态粒子质量较软，计划通过**ISR**模式来触发事例，增强信号灵敏度。结合**2tau**的纯强子衰变末态（**had-had)**和含轻子衰变末态**(lep-had)**。

- 指导本所学生工作。目前已完成信号样本，正在基于机器学习对信号区域进行研究，初步结果已具备一定的信号灵敏度。计划使用**Run2+partial Run3**数据，明后年发表结果。



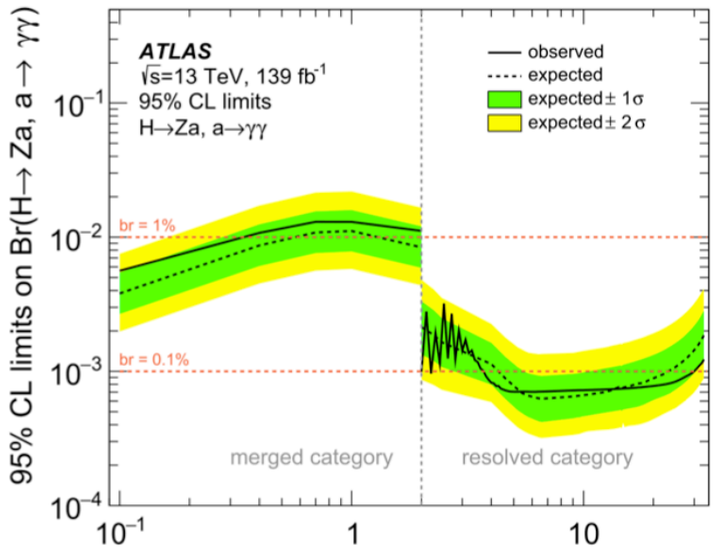
本年度工作完成情况

# 物理分析 6：H-Za-llγγ的寻找

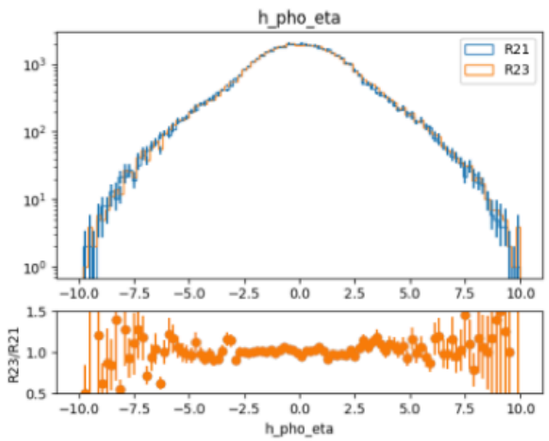
- **Run3新分析。经由H->Za过程寻找Axion-like particle；基于1L/2L进行触发；包含resolved与merged两个分类。**

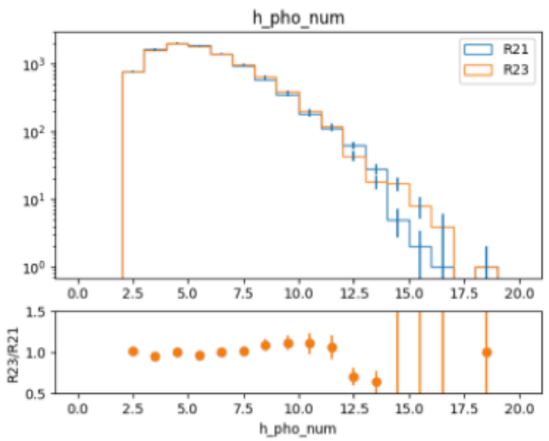
- **目前正在进行新release R23下的信号validation。**

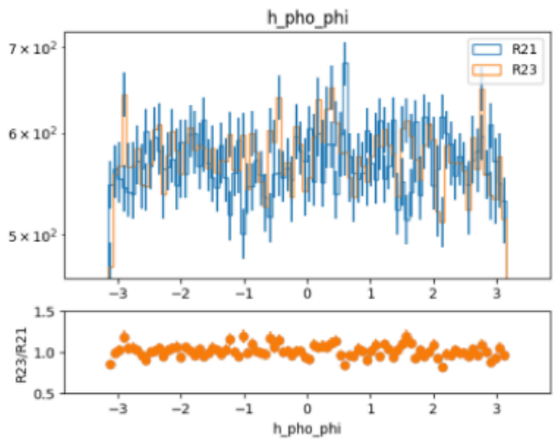
- **指导本所学生工作，计划使用Run2+partial Run3数据，26年发表结果。**

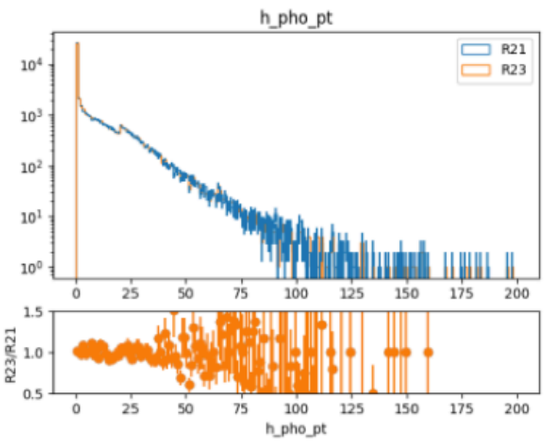



- Categories
  - Resolved (two separate photons)
    - $m_a \lesssim 2$ GeV
  - Merged (single cluster)
    - $m_a > 2$ GeV



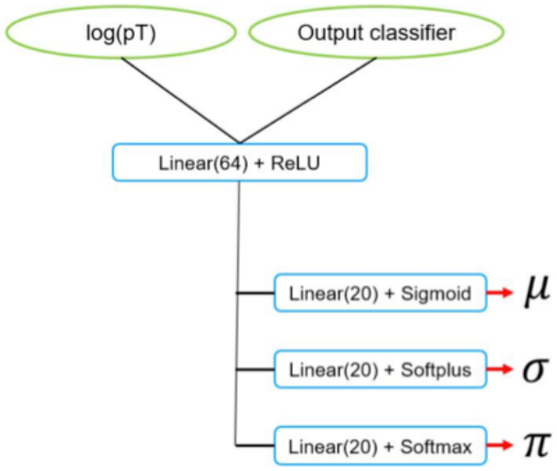



# 物理分析 7： Constituent-based W tagger

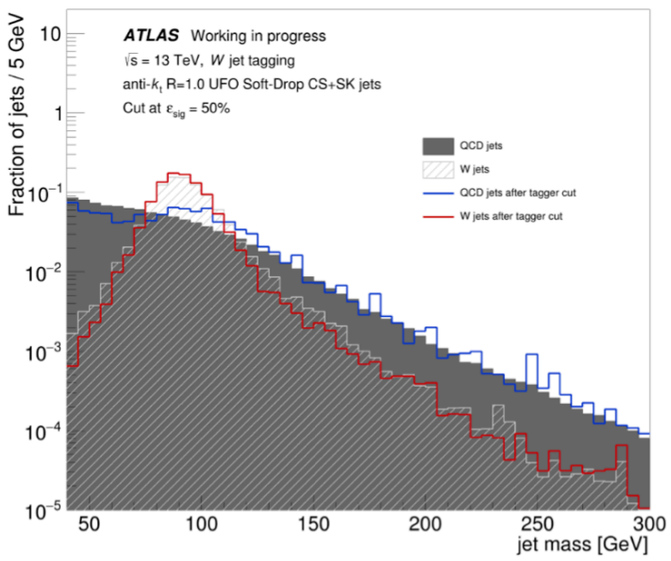
- 首次在**ATLAS**上基于先进的图神经网络**ParticleNet/ParticleTransformer**训练并研究不同**constituent-based W-taggers**的性能。去年发表**ATLAS PUB NOTE**的结果（**R21**）。本年度主要工作：
  - 研究在网络中引入**Adversary network**来对抗**jet mass sculpting**；
  - 基于**ATLAS**最新**R22**重新研究各类**W tagger**；
  - 计划完成**constituent W tagger** 包括**SF**等全套计算，加入**ATLAS official setup for Run2+Run3**，**Paper for end of 2025**；
- 代表合作组在**ICHEP2024**汇报 **“ATLAS hadronic jet tagging with ML”**。

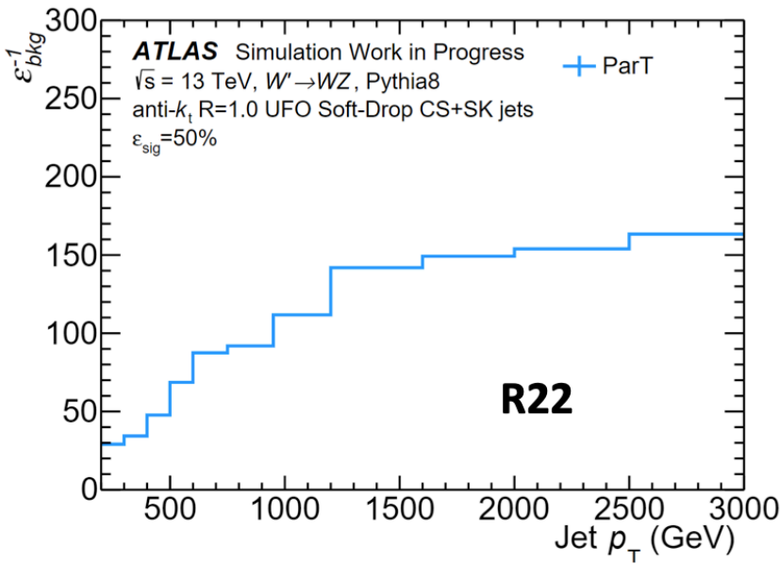



$$L_{\text{clf}}(\theta_{\text{clf}}) - \lambda L_{\text{adv}}(\theta_{\text{clf}}, \theta_{\text{adv}})$$

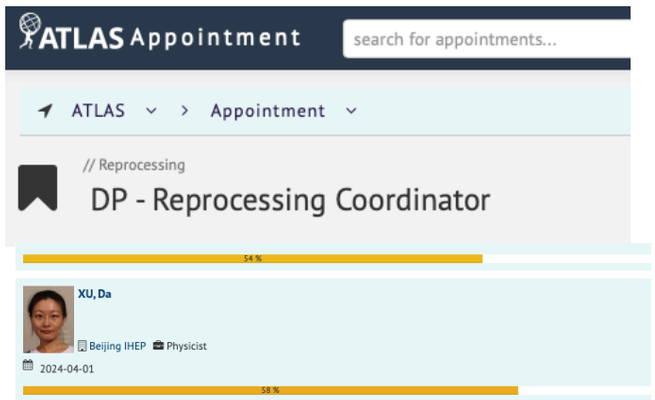
**ANN method for mass decorrelation:** $\lambda$ scan

- Model: ParT
- lr_clf = 1E-5, lr_adv=1E-2, $\lambda = 75$



# ATLAS Reprocessing coordinator




- 担任**ATLAS Data Preparation (L1) — Reprocessing Coordinator (L2)**
- 负责筹备和组织**ATLAS**所有数据的**reprocessing**，为**Physics**提供可分析数据；
- 近期完成**Run3**阶段**2022**、**2023**、**2024EF** 基于最新**release24**的**data reprocessing**，本人在**ATLAS Weekly meeting**报告**How to find Run3 dataset**；
- 目前协调子探测器**+**性能组，为明年初**2024 full data reprocessing**做**kick-off**准备。

**ATLAS Weekly**
==========

https://indico.cern.ch/event/1466104/

**How to find Run-3 datasets to do analysis (Da Xu)**

Da presented the status of data reprocessing in Run 3 (slides). This is one of several activities Data Preparation is responsible for (more info at this link), in collaboration with software & computing and detector groups, in addition to physics analysis and performance. The reprocessing of a specific dataset or stream can be requested via the DATREP JIRA project or via email. The 2022 and 2023 data were recently reprocessed using the latest muon alignment and detector conditions (2022 will be complete soon while 2023 is completely done). For the 2024 data, periods E and F were reprocessed as well. An open container exists to make the full 2024 pp dataset available. Multiple streams were reprocessed and a sizable number of different output formats were produced (AOD and various derived data formats for detector or CP studies).

## Run3 data (re-)processings

Run 3 - (re-)processed with release 23

| Year | Supercontainer |
|---|---|
| 2024 | Not processed in rel23 |
| 2023 | data23_13p6TeV.periodAllYear.physics_Main.PhysCont.AOD.pro32_v01 |
| 2022 | data22_13p6TeV.periodAllYear.physics_Main.PhysCont.AOD.repro30_v01 |
| Only to be used by PA groups at the moment | |

- The reprocessing of the 2022 and 2023 data after 2023 data-taking finished using **release 23** used improved conditions and ensured that a consistent muon reconstruction was used for both years

Run 3 - (re-)processed with release 24

| Year | Supercontainer |
|---|---|
| 2024 | data24_13p6TeV.physics_Main.OpenEnded.AOD.pro40_v01 |
| 2023 | data23_13p6TeV.periodAllYear.physics_Main.PhysCont.AOD.repro40_v01 |
| 2022 | data22_13p6TeV.periodAllYear.physics_Main.PhysCont.AOD.repro40_v01 |
| Only to be used by CP groups at the moment | |

- The Run 3 data (2022-2024E/F) was reprocessed in **release 24** in August 2024 to benefit from the improved muon alignment and updated conditions for detector systems (e.g. Tile). *N.B. for the rest period in 2024, the improved muon alignment was used*

## Technical details

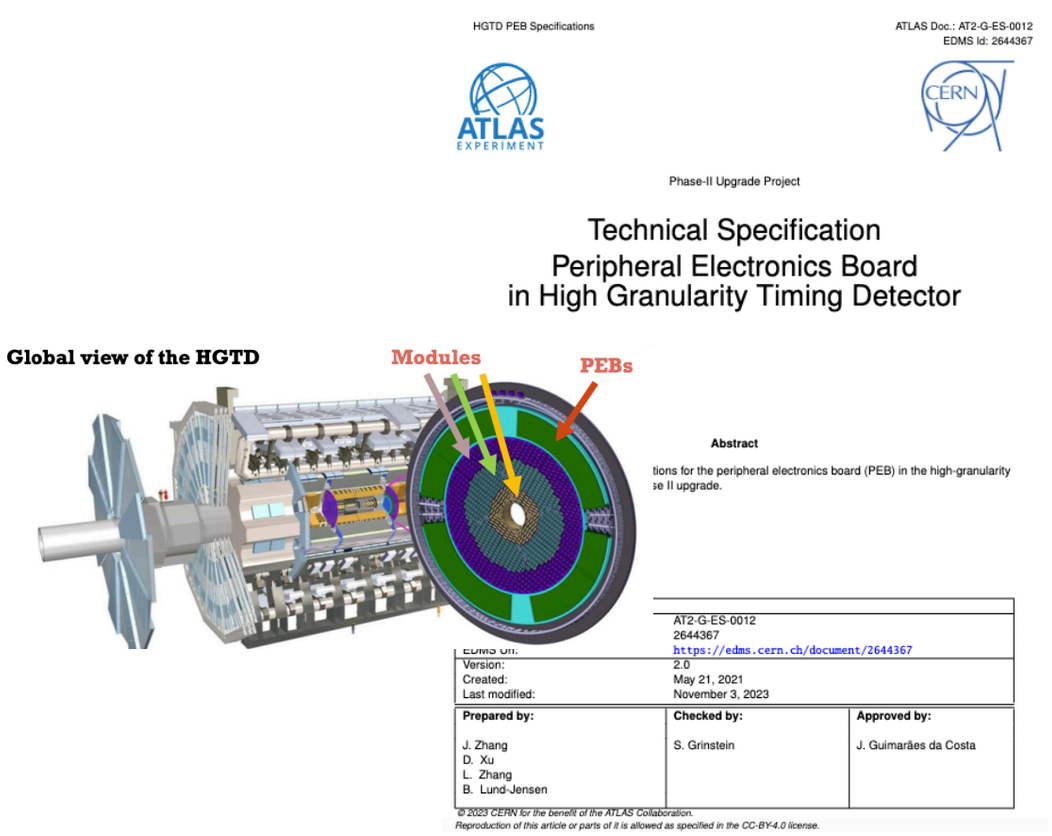
- Recent large reprocessing of Run3 data with release 24, including
  - **Data 2022** (DATREP-334) **Bulk done,** to run a new patched release to fix the remaining issues
  - **Data 2023** (DATREP-334) **Completely done**
  - **Data 2024 E & F period** (DATREP-331) **Completely done**
- Athena Release: **24.0.42**
- Stream: **physics_Main, physics_BphysDelayed, physics_VBFDelayed, physics_Late**
- Output format:
  - **physics_Main**: *AOD, HIST, DRAW_ZMUMU, DRAW_EGZ, DESDM_MCP, DAOD_IDTIDE, DAOD_ZMUMU, DAOD_L1CALO1EGZ, DAOD_L1CALO1ZMM*
  - **physics_BphysDelayed**: *AOD, DESDM_MCP*
  - **physics_VBFDelayed**: *AOD*
  - **physics_Late**: *AOD (not for data 2024)*

**Condition tag:**
**2022: CONDBR2-BLKPA-2022-15**
**2023: CONDBR2-BLKPA-2023-05**
**2024: CONDBR2-BLKPA-2024-03**
**Geometry tag: ATLAS-R3S-2021-03-02-00**

# ATLAS高颗粒度时间探测器（HGTD）升级项目

**HGTD是HL-LHC Phase-II升级的重要项目：通过track的时间分辨率来降低极高亮度时期的大量pile-up本底！本人工作包括**

- 外围电子板**PEB**的**Schedule**、**Risk**规划、文档编辑、芯片出入境运输管理；
- 指导学生进行**PEB**相关芯片测试，研究不同温度、不同磁场下**bPOL12V**各性能，发表一篇**JNIST proceeding**。


HGTD PEB Specifications

ATLAS Doc.: AT2-G-ES-0012
EDMS Id: 2644367

Phase-II Upgrade Project

Technical Specification
Peripheral Electronics Board
in High Granularity Timing Detector

**Global view of the HGTD**

Modules

PEBs

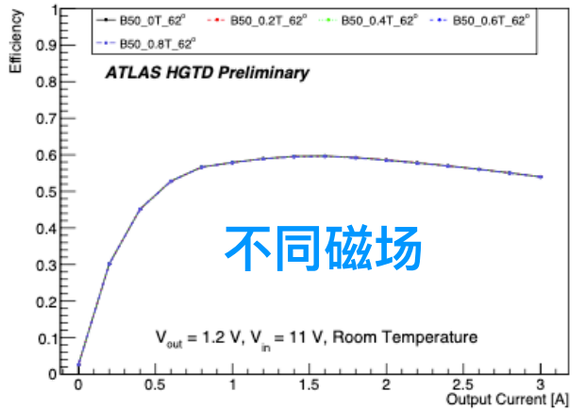
**Abstract**

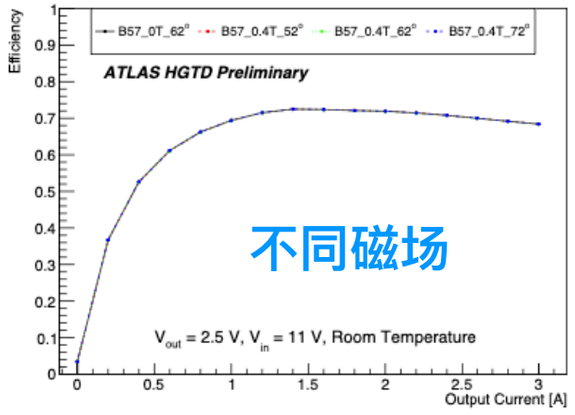
tions for the peripheral electronics board (PEB) in the high-granularity
se II upgrade.

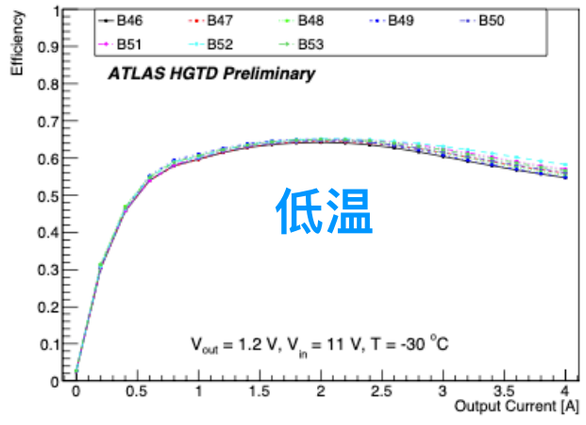
| | |
|---|---|
| EDMS Id: | AT2-G-ES-0012<br>2644367<br>https://edms.cern.ch/document/2644367 |
| Version: | 2.0 |
| Created: | May 21, 2021 |
| Last modified: | November 3, 2023 |

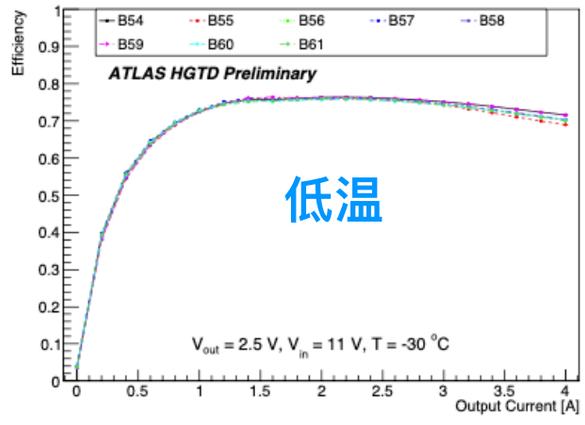
| Prepared by: | Checked by: | Approved by: |
|---|---|---|
| J. Zhang<br>D. Xu<br>L. Zhang<br>B. Lund-Jensen | S. Grinstein | J. Guimarães da Costa |





本年度工作完成情况

# CEPC BSM

- 参与**CEPC**新物理白皮书的编写与讨论，担任**SUSY**章节召集人。

- 参与**CEPC RefTDR** 物理组，协助指导学生在**smuon production**上的工作。

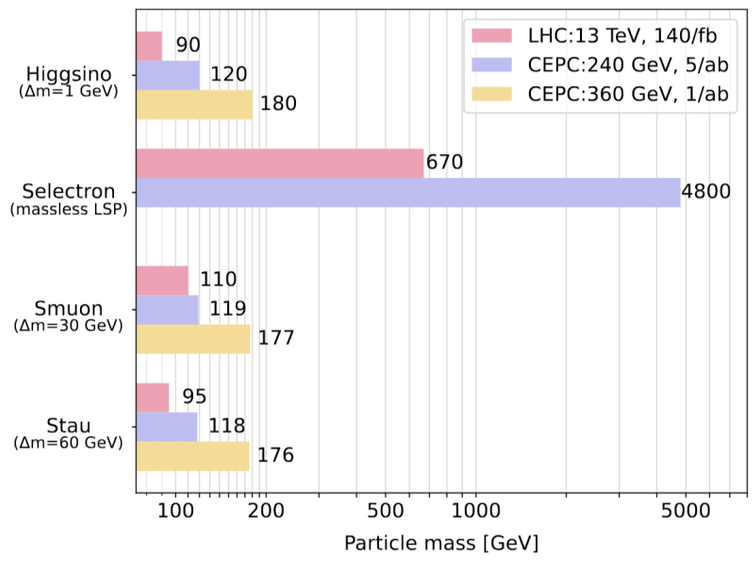



FIG. 67: The exclusion reaches for higgsino and slepton at CEPC and LHC. The compressed SUSY particles are picked for the comparison except for selectron.

**CEPC New Physics Potentials**

*Prepared for the CEPC BSM white paper*

CEPC BSM Physics Study Group

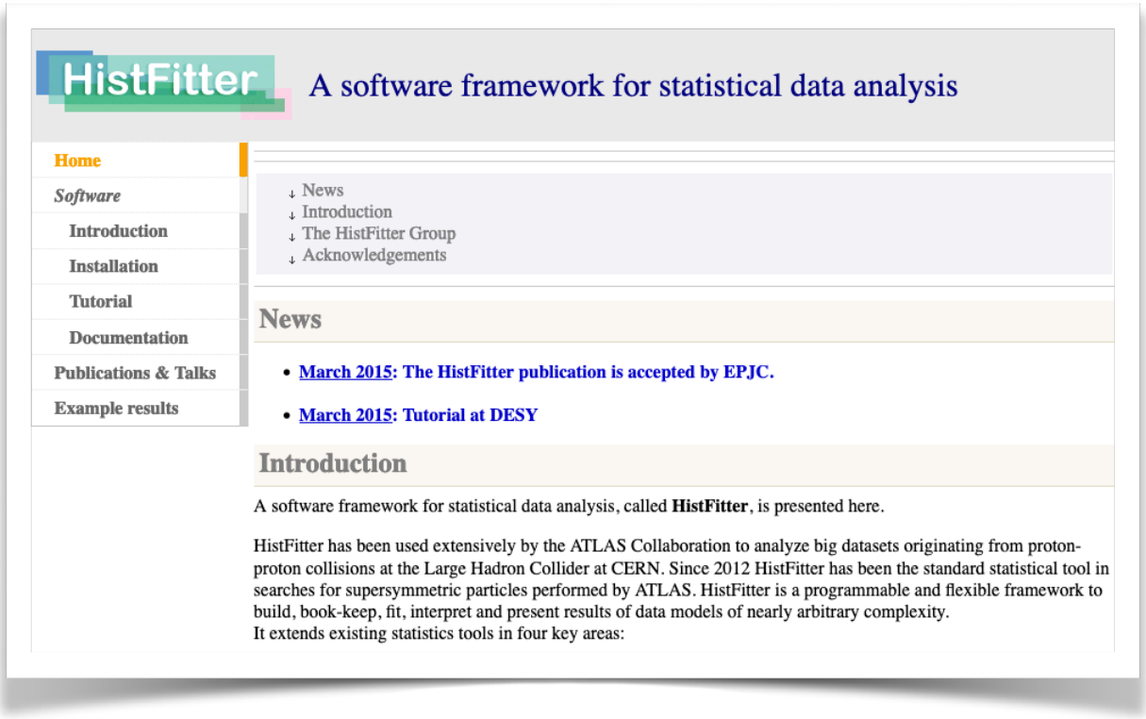
VII. Supersymmetry (Tianjun, Lei, Xuai, Da)
- A. Introduction
- B. Light electroweakino searches
- C. Light slepton searches
- D. Input from the European Strategy
- E. Summary

| Search | Production | $\sqrt{s}$ [GeV] | $\mathcal{L}[ab^{-1}]$ | Sensitivity | Figs. | Ref. |
|---|---|---|---|---|---|---|
| Light electroweakino | chargino pair | 240 | 5.05 | chargino excluded up to 120 GeV | 58 | [354] |
| | $e^+e^- \to \tilde{B}\tilde{B} \to \gamma\gamma\tilde{G}\tilde{G}$. | 240 | 5.6 | selectron excluded up to 4.5 TeV | 59 | [356] |
| Light slepton | smuon pair | 240 | 5.05 | smuon excluded up 118 GeV | 60 | [357] |
| | stau pair | 240 | 5.05 | stau excluded up 117 GeV | 60 | [357] |
| | smuon pair | 360 | 1 | smuon excluded up 178 GeV | 60 | [] |
| | stau pair | 360 | 1 | stau excluded up 175 GeV | 60 | [] |
| | off-shell smuon pair | 240 | 5 | smuon excluded up 126 GeV | 62 | [359] |
| | $e_R^+e_R^- \to \tilde{\chi}_1^0(\text{bino}) + \tilde{\chi}_1^0(\text{bino}) + \gamma$ | 240 | 3 | right-handed selectron excluded up to 210 GeV | 61 | [358] |
| | $\mathcal{F}$-$SU(5)$ | - | - | upper limits on $\tilde{\tau}_1$ up to 115 GeV | 63 | [360] |
| | $\mathcal{F}$-$SU(5)$ | - | - | upper limits on $\tilde{e}_R$ up to 150 GeV | 63 | [360] |

TABLE X: Recent results from the CEPC study on SUSY. The first column lists the signal signatures, the second column presents the corresponding production modes, the third and fourth columns provide the center-of-mass energy and the integrated luminosity, the fifth column shows the sensitivity to the coupling, suppression scale, or branching ratios, and the last column provides the references.

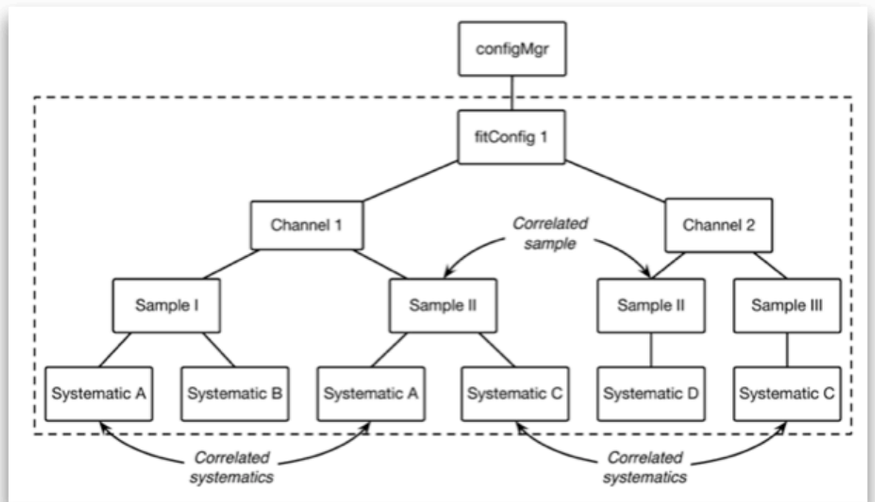
# 本年度工作完成情况

## ATLAS HistFitter expert



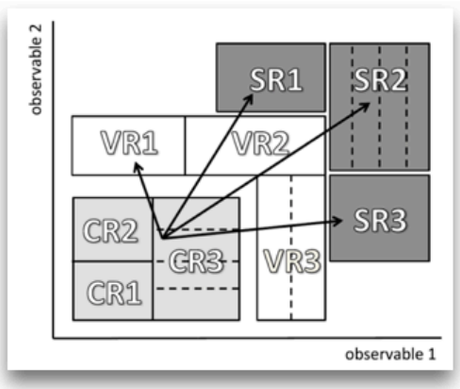

- **ATLAS**实验的官方统计软件**HistFitter**专家，负责软件维护升级、帮助**user**解决问题，在**ATLAS**软件学习中担任指导等工作。

构建**workspace**



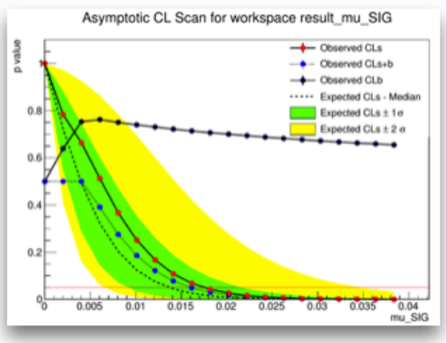

进行不同类型的拟合

**background/combined fit**
**model (in)dependent fit**




统计解释

**exclusion limit**
**upper limit etc.**



# 研究成果 & 经费情况

## 文章

- ***Search for direct production of electroweakinos in final states with one lepton, jets and missing transverse momentum in pp collisions at $\sqrt{s}$=13 TeV with the ATLAS detector, JHEP12(2023)167 [contact editor]***

- ***Search for electroweak production of supersymmetric particles in final states with two τ-leptons in √s = 13 TeV pp collisions with the ATLAS detector, JHEP 05 (2024) 150***

- ***Search for supersymmetry using vector boson fusion signatures and missing transverse momentum in pp collisions at √s=13 TeV with the ATLAS detector, arXiv:2409.18762, submitted to JHEP***

- ***Mingjie Zhai et al, HGTD DC/DC Converter in Low Temperature and Magnetic Field Operation, 2024 JINST 19 C02006***

## 经费

- **CEPC上的新物理研究，所创新项目，100万元，2022-2024， 参与**

- **机器学习在实验高能物理中的应用，所创新项目，150万元, 2023-2025, 参与**

- **中法粒子物理联合实验室，国家重点研发政府间国际科技创新合作，400万元，2023-2025，参与**

- **基于 ATLAS 高亮度数据检验标准模型和 Higgs 机制与寻找新物理：子课题：寻找新粒子新现象研究，国家重点研发大科学装置前沿研究，525万元，2024-2028，参与**

# 学术交流 & 学术发展

会议报告/讲座

1. SUSY search at LHC (plenary), China LHC Physics workshop 2023, 16-20 Nov 2023, Shanghai, China
2. Neutralino Search in ATLAS, 第三届地下和空间粒子物理与宇宙物理前沿问题研讨会, 7-11 May 2024, Xichang, China
3. Recent SUSY search at LHC, Seminar, HeiNan University, 26 May 2024, Kaifeng, China
4. Classifying hadronic objects in ATLAS with ML/AI algorithms, ICHEP 2024, 18-24 July 2024, Prague, Czechia
5. CEPC white paper -- Supersymmetry, CEPC New Physics Workshop 2024, 1 Sept 2024, Zhenzhou, China
6. ATLAS jet tagging,  IHEP ML Workshop, 16 Oct 2024, IHEP
7. How to find Run-3 datasets to do analyses, ATLAS Weekly, 22 Oct 2024, online

会议组织

8. China LHC Physics conference PC (2022-2024)

# 公共服务 & 学生

- **本年度担任3个ATLAS物理分析的Editorial Board/Reader**
  - **其中2个分析今年发表了期刊文章。**

**ATLAS-CONF-2023-055** SUSY EWK pMSSM summary Editorial Board - Member
CONF-SUSY-2023-19
2023-08-15
ATLAS Run 2 searches for electroweak production of supersymmetric particles interpreted within the pMSSM

**ATLAS-CONF-2023-048** SUSY EWK with multiple b-jets Editorial Board - Member
CONF-SUSY-2023-16
2023-08-09
Search for pair production of higgsinos in events with two Higgs bosons and missing transverse momentum in $\sqrt{s}=13$ TeV $pp$ collisions at the ATLAS experiment

PUB-SUSY-2022-09 Prospects for EWK all-had at HL-LHC Reader - Member
2023-01-16
Prospects for electroweak all-hadronic searches at HL-LHC

Editorial Board

**Editorial Board**
DE JONG, Paul (Nikhef) Chair
OIDE, Hideyuki (KEK)
XU, Da (Beijing IHEP)

**Editorial Board formed on**
Sunday, 23rd April, 2023

Editorial Board

**Editorial Board**
ARGUIN, Jean-Francois (Montreal) Chair
ROSSINI, Lorenzo (Freiburg)
XU, Da (Beijing IHEP)

**Editorial Board formed on**
Monday, 09th August, 2021

Readers Data

**Readers**
VIVARELLI, Iacopo (Bologna) 1st Reader
XU, Da (Beijing IHEP)

**First Reader chosen on**
Thursday, 19th January, 2023

- **IHEP实验物理中心科学传播委员会成员：新闻稿审稿、宣传视频审阅等工作**

- **学生👨‍🎓👩‍🎓指导：**
  - **【已毕业】翟明杰（副导师）： 1L/compressed/HGTD PEB**
  - **【已毕业】郭蕾（联培硕士、副导师）: HZa/compressed**
  - **梁诗怡（副导师）: compressed stau**
  - **Rabia：1L2L**
  - **王书栋: jet tagging**

# 存在问题

- 在国际合作实验中，热门课题竞争性强。希望保持已有的热门课题，同时拓展新课题，需要**人力资源（学生）**。

- ATLAS SUSY组目前学生较少，已出现两年断层（无新生），不利于热门课题的延展和senior-junior学生之间的承接。

# 下年度工作计划

- ATLAS reprocessing coordinator：完成full 2024 data reprocessing
- 进行并拓展ATLAS Run3 物理分析；完善constituent W tagger的研究
- HGTD：跟进PEB项目稳步进行
- CEPC：完成BSM方面相关工作

# Thanks!