# 答辩人简介

答辩人: 魏传顺

答辩秘书: 瞿和江

中国科学技术大学

# Basic information

Respondant: Chuanshun Wei

Defense secretary: Hejiang Qu

University of Science and Technology of China

# Personal Information

- Experience
  - Bachelor: University of Science and Technology of China
  - PhD: Joint PhD of University of Science and Technology of China & University of Michigan
- Graduation requirements:

| | | |
|---|---|---|
| 您适用的培养计划标准 | 物理学硕博连读 | 校验结果:合格 |
| 培养计划校验详情 | | |
| 培养计划备注 | 老系统迁移2019 | |
| **培养计划要求** | **已经获得学分** | **是否合格** |
| 总学分(带必修环节)>=45 | 总学分=49 | 合格 |
| 基础课【加权平均】>=75 | 基础课【加权平均】=83.6 | 合格 |
| 必修环节学分>=0 | 必修环节学分=2 | 合格 |
| 博士专业课学分>=4 | 博士专业课学分=4 | 合格 |
| 基础课学分>=16 | 基础课学分=20 | 合格 |
| 公共课程学分>=11 | 公共课程学分=11 | 合格 |
| 专业课学分>=0 | 专业课学分=12 | 合格 |
| 学位论文开题报告(19级之前专用) | 学位论文开题报告(19级之前专用)学分【必修环节】=2 | 合格 |

# Grades

| USTC SCHOLASTIC RECORD | NAME WEICHUANSHUN | DATE OF BIRTH 1995-11-04 |
|---|---|---|
| | DEPT. Department of Modern Physics | NO. BA19004051 |
| | SPECIALITY Particle Physics and Nuclear physics | |
| | DEGREE AWARDED | DATE |

| TERM | TITLE OF COURSE | | GRADE | CR.HRS. |
|---|---|---|---|---|
| 2018,Fall | FL05301 | Comprehensive English for Graduate Students | PASS | 2/40 |
| 2018,Fall | PH05101 | Advanced Quantum Mechanics | 75 | 4/80 |
| 2018,Fall | PH05102 | Modern Physics Progress | 82 | 4/80 |
| 2018,Fall | PH14201 | Group Theory in Physics | 90 | 4/80 |
| 2018,Fall | PH14203 | Particle Physics(I) | 94 | 4/80 |
| 2018,Fall | PH24211 | Technique of Particle Detection | 90 | 4/80 |
| 2018,Fall | PS05101a | Dialectics of Nature | PASS | 1/18 |
| 2018,Fall | PS05102a | Theory & Practice of Socialist Construction | PASS | 2/36 |
| 2018,Fall | PS06101a | Chinese Marxism and the Contemporary Era | PASS | 2/36 |
| 2019,Spring | ES15202 | Advanced Nuclear Electronics | 90 | 4/80 |
| 2019,Spring | ES15204 | Modern Information Proceesing | 87 | 4/80 |
| 2019,Spring | FL05303 | Oral English for Academic Purpose | PASS | 2/40 |
| 2019,Spring | PH25201 | Collision Physics | 81 | 4/80 |
| 2019,Spring | PH26204 | Frontier of experimental particle physics | 89 | 4/80 |
| 2026,Spring | FORL7101U | Academic Writing | PASS | 2/40 |

ALL course GPA: 3.6

GPA Calculation:

| Centesimal Grade | [95,100] | [90,95) | [85,90) | [82,85) | [78,82) | [75,78) | [72,75) | [68,72) | [65,68) | [64,65) | [61,64) | [60,61) | [0,60) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Letter Grade | A+ | A | A- | B+ | B | B- | C+ | C | C- | D+ | D | D- | F+/FF- |
| Point Value | 4.3 | 4 | 3.7 | 3.3 | 3 | 2.7 | 2.3 | 2 | 1.7 | 1.5 | 1.3 | 1 | 0 |

$$GPA = \frac{\sum(CourseCredit*CourseGP)}{\sum CourseCredit}$$

Graduate School of University of Science and Technology of China

2026-08-28

# Thesis reviews - 1

- 同意答辩
- 对学位论文的学术评语:
  - 该博士学位论文选题紧扣大型强子对撞机前沿物理与探测器升级两大核心方向，兼具基础物理探索与技术创新的双重价值。论文在物理分析上实现了高精度的标准模型检验与新物理探寻，特别是对暗物质模型的约束与探测器硬件研发的结合，体现了作者宽广的学术视野。研究思路清晰，从精确测量到新物理搜寻，再到探测器升级，逻辑层层递进，展现了系统完整的科研训练。写作规范，结构严谨，论述详实，反映出作者对粒子物理理论与实验方法均有深入掌握。整体而言，该论文工作量大、创新性突出，是一篇高水平的高能物理实验博士学位论文。
- 论文的不足之处和建议:
  - 论文已经很优秀了，有如下建议，希望作者考虑： 1. 论文的题目“在ATLAS 实验上基于双轻子和不可见末态精确测量ZZ 玻色子对产生截面并探测暗物质”，过于繁琐，虽然有必要追求准确性，但是也要尽量保证简洁性，现在是把做的物理分析的工作都放进来了。还有一个建议是，“探测暗物质”建议修改成“寻找暗物质”； 2. 第一句话“希格斯（Higgs）玻色子被发现后，粒子物理标准模型的理论体系得以进一步完善。”，其实我们都知道，希格斯发现很久之前，理论体系已经在那里了，它的发现没有促进理论体系的完善，只是确定了理论体系的合理性。类似的这种措辞，一定要准确。 3. 几个具体工作之间的起承转合做的不好。一篇博士论文不是简单的工作的记录，是要体现作者对这个行业的思考逻辑等细节部分的。

# Thesis reviews - 2

- 同意答辩
- 对学位论文的学术评语:
  - 该博士学位论文围绕粒子物理标准模型的精确检验、暗物质寻找以及探测器升级这三个前沿课题，基于大型强子对撞机上ATLAS实验的Run-2数据集，开展了系统而深入的研究。论文选题具有重要的科学意义和前沿性，研究内容充实，成果显著。论文结构合理，逻辑清晰，撰写规范，表明作者已具备坚实宽广的基础理论和系统深入的专门知识，具有很强的独立从事高水平科学研究的能力。 论文主要优点与创新性成果如下:
    - 1. 实现了迄今最高精度的ZZ产生截面测量： 1）论文在ZZ→？？νν末态中，通过精巧的多区域联合拟合和严格的本底压制策略，将单举基准截面测量的总不确定度由以往的7.0%显著降低至4.6%，达到了当前国际最高精度。这一结果是标准模型电弱部分的一项重要精密检验。 2）首次在该末态中，基于标准模型有效场论框架给出了对中性反常三玻色子耦合的严格限制，拓展了标准模型的检验边界。
    - 2. 给出了更为先进的暗物质与新物理探测限制： 1）在Mono-Z暗物质搜寻中，引入BDT算法，将希格斯玻色子不可见衰变分支比的上限在95%置信度下显著收紧至18.7%，相比以往结果有大幅提升。 2）针对简化暗物质模型及2HDM+a模型给出了更为严格的排除边界，并将其转化为与地下直接探测实验可比的散射截面限制，有力地证明了对撞机探测在低质量暗物质区间具有独特的物理互补性。
    - 3. 为探测器升级做出关键硬件贡献： 作者深度参与了ATLAS探测器为高亮度LHC升级的关键硬件工作，负责并完成了50个新型小径监测漂移管（sMDT）高精度探测器的组装与严格性能测试。宇宙射线测试结果表明其性能满足HL-LHC的要求，为未来大型强子对撞机的高精度物理研究奠定了坚实的硬件基础。
- 论文的不足之处和建议:
  - 章节2.2.3格式一致性问题： 该章节第一段内容的字体、段落格式及行间距与论文整体排版存在明显差异，建议统一调整，以确保全文格式规范一致。 图3.2时间节点更新： 当前图表中红星标识仍位于Run-3阶段，但鉴于目前已进入2026年，Run-3取数已实际结束，建议将红星位置同步更新至LS3（长停机3）阶段，以准确反映LHC运行的实际时序进展。 ATLAS探测器介绍篇幅： 第三章ATLAS探测器部分的介绍略显冗长，建议适当精简各子探测器的技术细节描述，使论述更加聚焦于与本文物理分析和硬件研究直接相关的关键性能参数。 Run-2积分亮度数值统一： 论文中ATLAS Run-2数据集的积分亮度表述存在140 fb？1和139 fb？1两种数值，建议全文统一采用实验合作组最新推荐的标准数值，以避免歧义。

# Thesis reviews - 3

- 同意答辩
- 对学位论文的学术评语:
  - 该论文基于大型强子对撞机上ATLAS实验在Run 2期间采集的全部140 fb？1质子-质子对撞数据，围绕粒子物理标准模型的精确检验与新物理探测两大核心目标，系统性地开展了三项紧密关联的研究工作。论文的核心物理分析是利用 ZZ → 双轻子加不可见末态的衰变道，对ZZ玻色子对的产生截面进行精确测量。该末态相较于四轻子末态拥有更大的产生截面，能提供更高的统计量。随后利用同一数据集开展了对暗物质及相关新物理现象的搜寻，主要聚焦于希格斯玻色子的不可见衰变。研究不仅针对希格斯不可见衰变，还检验了简化的暗物质模型和包含额外赝标量媒介子的双希格斯二重态模型等。最后，为应对未来高亮度LHC带来的极端辐射环境和高事例率挑战，ATLAS探测器正在进行全面升级。论文作者深度参与了缪子谱仪中新型小型监测漂移管探测器的研发与建设工作。完成了50个新型sMDT高精度探测器的完整组装，包括精密管的制备、腔室结构的搭建以及服务系统的安装。对所有组装完成的探测器进行了严格的质量控制和性能测试，包括宇宙射线测试，结果表明，sMDT探测器的单管空间分辨率优于90 μm，完全满足HL-LHC升级后的苛刻技术要求。此项硬件研究工作为ATLAS缪子谱仪在HL-LHC时代保持高精度的径迹重建能力和触发效率奠定了坚实的基础，保障了未来高亮度环境下物理分析的可靠性。
- 论文的不足之处和建议:
  - （1）不是自己做的图，应该给出参考文献。例如第一章的几个图，以及第三章的若干个图。只是我注意到第三章有一些图是有引用的，为什么不统一呢？
  - （2）第三章的表格，如果数据不是自己测的，也应该给出参考文献。
  - （3）第二章的内容过于理论化，这在一个实验为主的文章里比较怪异，另一方面，内容与后续实验部分没有直接联系，给人一种悬浮在表面的感觉。我建议把前两章合并，可以在1.1介绍粒子物理，1.2介绍标准模型，1.3介绍超越标准模型，1.4介绍原来的1.2内容，1.5介绍原来的1.3内容，1.6介绍论文内容安排。
  - （4）另外，之前SM和BSM的内容过于宽泛，建议缩减泛泛的理论部分（那些拉氏量对后面的内容没什么帮助），然后把后面chapter5和chapter6第一节的大部分内容（即相关的理论模型介绍等等）挪过来。后面每个章节前面，只需要介绍这个测量的目的和意义即可，如此读者在第一章会了解到你这个论文要研究的东西与什么物理有关，然后在看到具体工作章节时，可以聚焦于这个工作的重要性、以及后面的工作细节。

# Thesis reviews - 4

- 同意答辩稍作修改
- 对学位论文的学术评语:
  - The research content of this doctoral dissertation is highly specialized and specific. Focusing on both theoretical research and experimental detection, it is confined to the precise measurement of the ZZ boson pair production cross-section and the search for dark matter via the dilepton and invisible final states in the ATLAS experiment. Its purposes are twofold: first, to test the Standard Model, and second, to probe dark matter. This indeed represents a frontier topic in current particle physics. The innovative achievements are primarily threefold: First, the precise measurement of the total and differential cross-sections for the pp→ZZ→？？？？ν$\bar{\nu}$ process, which improves the measurement precision to 4.6%, thereby providing a high-precision test of the electroweak interaction in the Standard Model; Second, the search for dark matter particles via the Mono-Z channel, which found no significant deviation from the Standard Model predictions and set robust exclusion limits within multiple theoretical frameworks; Third, the construction and testing of the small-diameter monitored drift tube (sMDT) detector chambers for the ATLAS detector upgrade at the High-Luminosity Large Hadron Collider (HL-LHC), involving the rigorous assembly and quality control testing of 50 detector chambers. Overall, the above three aspects of innovation are incremental in nature. While they are conducive to the advancement of this research direction, they do not constitute disruptive breakthroughs within the field. The author possesses a solid theoretical foundation and experimental competence, with multiple papers published in important domestic and international academic journals. The dissertation is written in accordance with scientific norms, featuring clear logic, thorough narration, sound reasoning, and reliable conclusions. In summary, I consider this dissertation to have met the standards required for a doctoral thesis.
- 论文的不足之处和建议:
  - As for the future development of this research topic, on the one hand, regarding the test of the Standard Model, the author merely relies on the future capabilities of Run？3 and the HL LHC—this is overly narrow. In fact, the author could also consider the following two avenues: 1. Explore rarer processes: study processes such as ZZγ (two Z bosons with one photon) and tri boson production. These processes are highly sensitive to anomalous quartic gauge boson couplings (aQGC) in the Standard Model, and any tiny deviation could be a sign of new physics. 2. Combine multi channel analyses: merge the results from the ZZ→？？？？ν$\bar{\nu}$ channel with those from other decay channels (e.g., 4？ and ？？？？jj) to maximize experimental sensitivity and provide the most stringent combined test of the Standard Model. On the other hand, for dark matter searches, the author is currently only in the stage of “looking for signals”. In the future, the focus should shift toward “characterizing the properties of dark matter particles”. The following two aspects are suggested: 1. Search for new signals such as “dark radiation”: look for final states that, in addition to missing energy, also contain a dilepton resonance peak from the decay of a new Z' boson. 2. Combine multi messenger indirect detection: jointly analyze the collider results from Mono Z/Z' with those from astrophysical indirect detection experiments (e.g., Fermi LAT, AMS 02) and underground direct detection experiments (e.g., LZ, XENONnT).

# Thesis reviews - 5

- 同意答辩
- 对学位论文的学术评语:
  - This thesis presents the most precise measurement of Standard Model ZZ boson pair production at 13 TeV using 140 fb-1 of ATLAS data, achieving a fiducial cross-section of 21.0±1.0 fb with a total uncertainty reduced from 7.0% to 4.6%. It sets stringent constraints on anomalous gauge couplings and, using a BDT-based search, limits the Higgs invisible branching ratio to <18.7% at 95% CL. The collider results are translated into WIMP-nucleon scattering limits, demonstrating significant complementarity and a discovery advantage over direct detection experiments in the low dark matter mass region. Additionally, the work includes hardware contributions to the construction and quality control of sMDT chambers for the ATLAS HL-LHC upgrade. The researches presented in this thesis are generally well-motivated. The thesis is rich in research content, well-structured, logically coherent, thoroughly detailed, and written in a rigorous and formal academic style.
- 论文的不足之处和建议:
  - Major comment: It%ss not very clear what is the exact contribution of the author to the two ATLAS physics analysis when working in a large collaboration. Please emphasize this a bit more.
  - Minor comments:
    - ●2.3：Please provide some references for the theory of Supersymmetry (SUSY), Extra Dimensions and Hidden Sector Models.
    - ●Figure 4.3： What is the physics process used to determine the electron reconstruction and identification efficiency? What is the pileup level? Is the figure from Ref. [82]? Maybe it%ss better to add such information in the caption.
    - ●Period(s) are missing in a few places, e.g. 5.5.3 last paragraph, 5.5.5 first and second paragraphs
    - ●5.6.1 ○The resonse matrix is not defined here but later at page 97. ○Point 2. Since the systematic variation (e.g., a jet energy scale shift) affects not only the signal but also the background shapes and normalizations, we should subtract the varied background (which has been re-estimated under the same systematic variation) before unfolding, no? ○Point 4. For detector systematics, we should compare the unfolded varied distribution to the unfolded nominal distribution, not to the nominal truth, right?
    - ●5.7： The profile likelihood method is already used here, right? Maybe it%ss betetter to introduce the statistical analysis method as shown in 6.1.2 a bit already here.

# Thanks!