粒子物理前沿卓越创新中心成员年度工作汇报

2017-2018

答辩人：高 俊

依托单位：上海交通大学

2018年11月23日 北京

内容提要

一. 个人经历及研究方向

二. 年度科研论文

三. 基金申请及奖项

四. 学术会议及报告

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一. 个人经历及研究方向

二. 年度科研论文

三. 基金申请及奖项

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五. 总结

教育及科研工作经历

教育经历：

- 2002.9-2006.7， 北京大学， 元培计划理学学士
- 2006.9-2011.7， 北京大学， 理论物理专业博士

工作经历：

- 2011.9-2014.9， Southern Methodist University，博士后
- 2014.9-2016.9， Argonne National Laboratory，博士后
- 2016.10- ， 上海交通大学物理与天文学院，特别研究员
  中组部第十三批“青年千人”计划

研究方向

粒子物理的对撞机唯象学：顶夸克物理、希格斯物理、微扰QCD、质子部分子分部函数

发表论文

期刊	论文数
Phys.Rev.Lett.	6
Physics Reports	1
JHEP	11
Phys.Rev.D	23
Euro.Phys.J.C	2
J.Phys.G	2
Comp.Phys.Comm	2
总计	47

引用统计

Citations Summary

57 papers found, 57 of them citeable (published or arXiv)

	Citeable papers	Published only
Number of papers analyzed:	57	47
Number of citations:	2987	2948
Citations per paper (average):	52.4	62.7
h_{HEP} index [?]	23	22

Breakdown of papers by citations:

	Citeable papers	Published only
Renowned papers (500+)	2	2
Famous papers (250-499)	1	1
Very well-known papers (100-249)	2	2
Well-known papers (50-99)	5	5
Known papers (10-49)	27	26
Less known papers (1-9)	16	11
Unknown papers (0)	4	0

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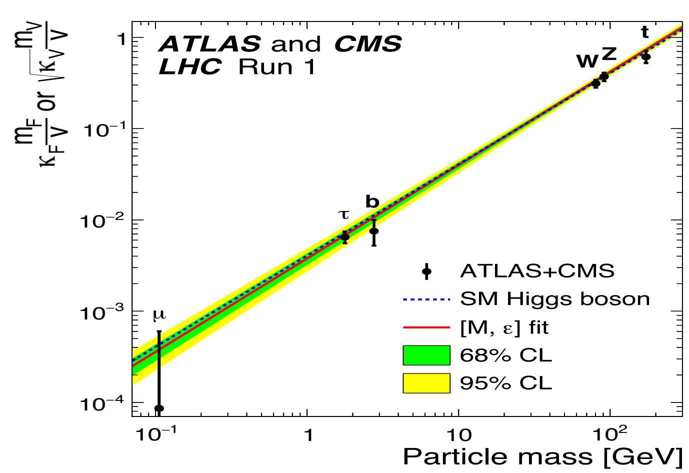
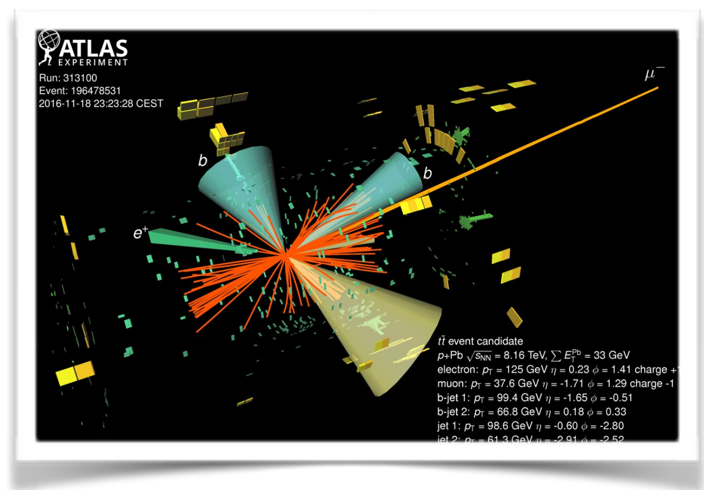
2017-2018年度论文统计

2017.9至今共发表9篇论文(1篇Physics Reports, 4篇JHEP, 3篇PRD, 1篇EPJC)，拟结合(HL-)LHC,CEPC等高能量前沿装置研究解决以下关键物理问题：

费米子的Yukawa耦合

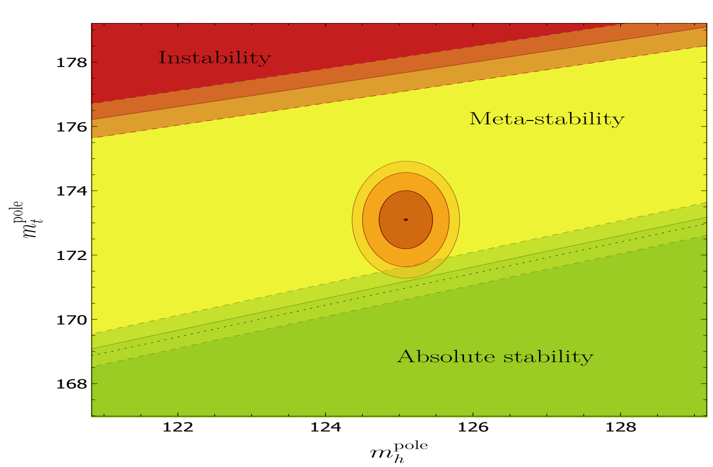




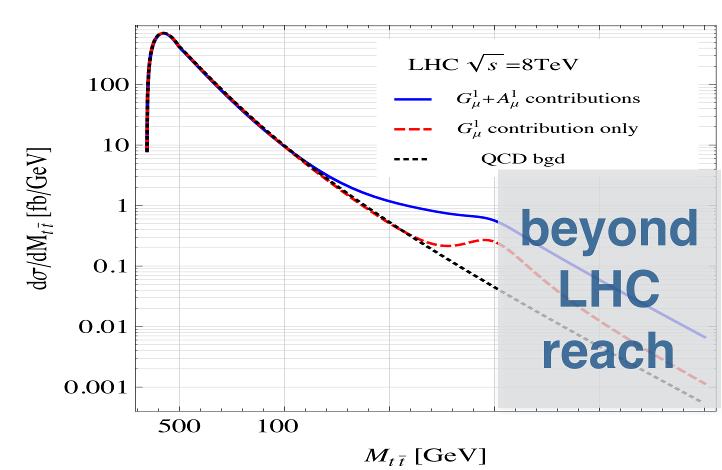
希格斯粒子总宽度和寿命

Particle	Width(GeV)	lifetime(fm/c)
top	1.3	0.15
Higgs	0.004	47
Z	2.5	0.08
W	2.1	0.09

顶夸克质量及电弱相互作用



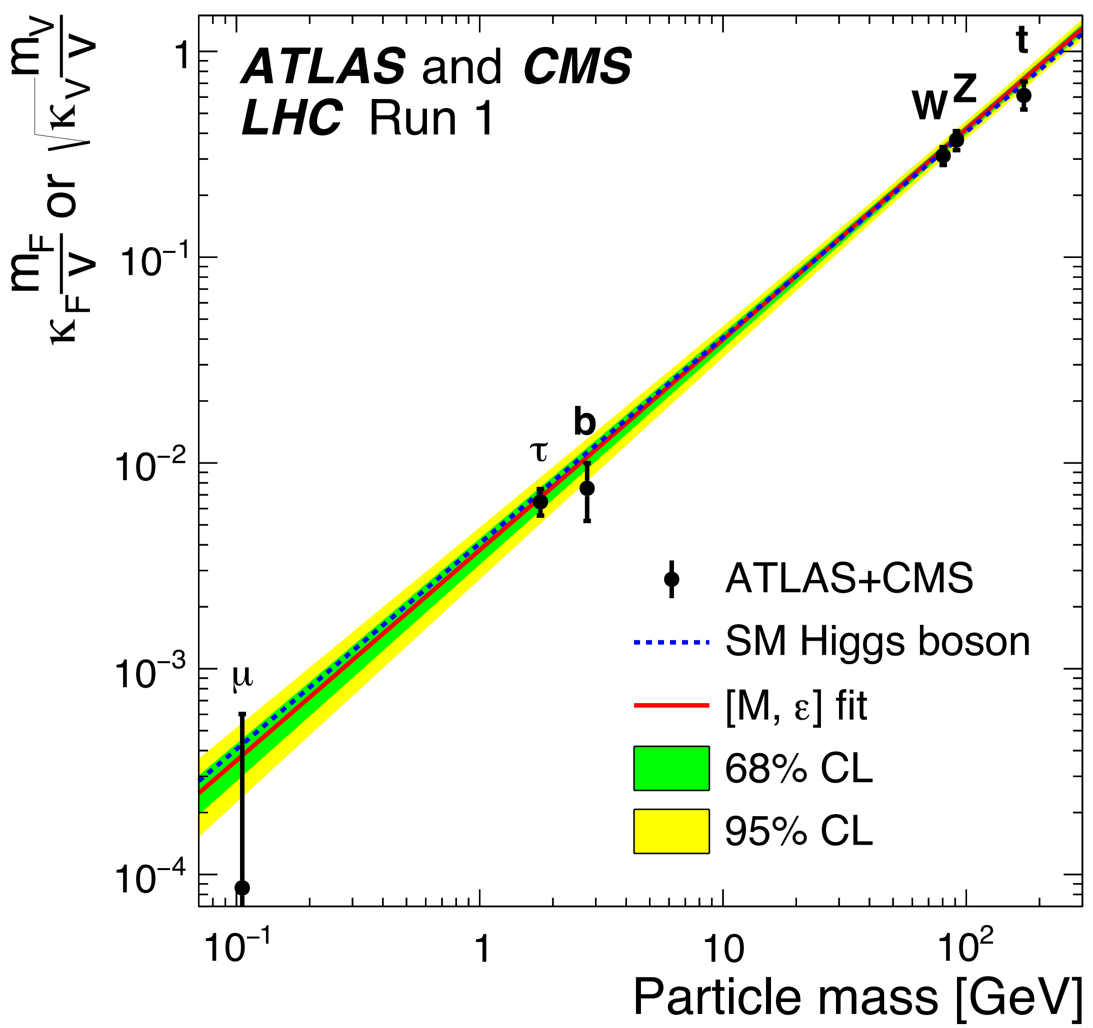
large-x部分子和BSM寻找



利用全局事例形状变量检验轻夸克Yukawa耦合

费米子质量起源机制的检验

希格斯耦合 vs. 质量

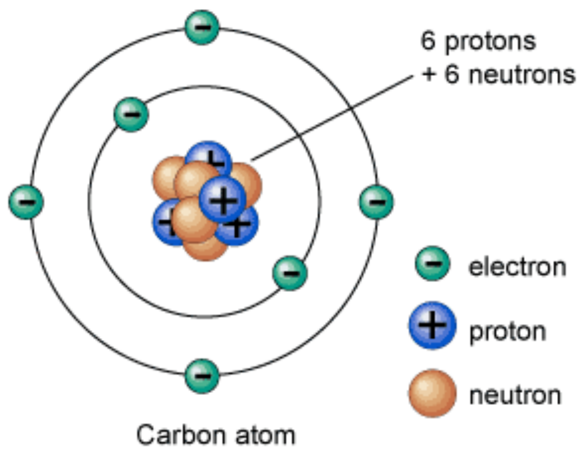


顶夸克 vs. 电子

m_t=173.3 GeV, y_t≃1

$$\beta_\lambda = \frac{1}{16\pi^2}\left(24\lambda^2 + 12y_t^2\lambda - 6y_t^4 + \dots\right)$$

m_e=511 keV, y_e≃2×10^{-6}



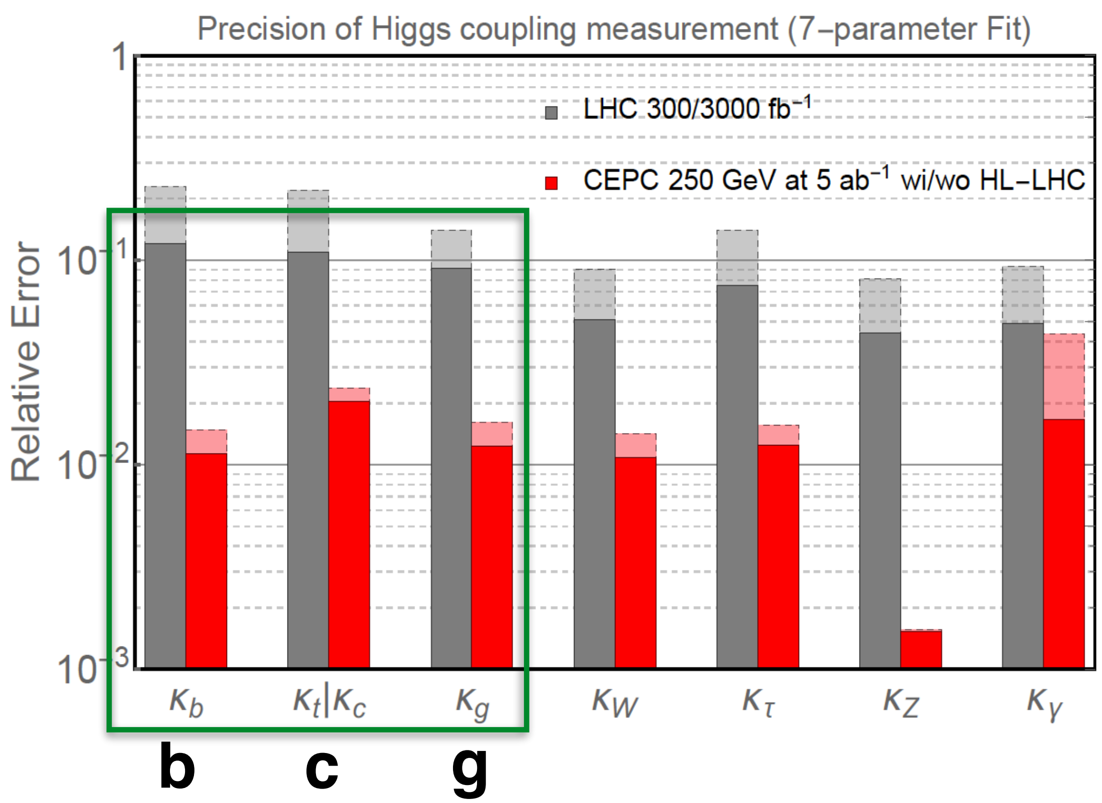
$$a_0 = \frac{\hbar}{m_e\, c\, \alpha}$$

☆ **轻费米子包括轻夸克Yukawa耦合的检验至关重要，并且实验测量极具挑战性**

利用全局事例形状变量检验轻夸克Yukawa耦合

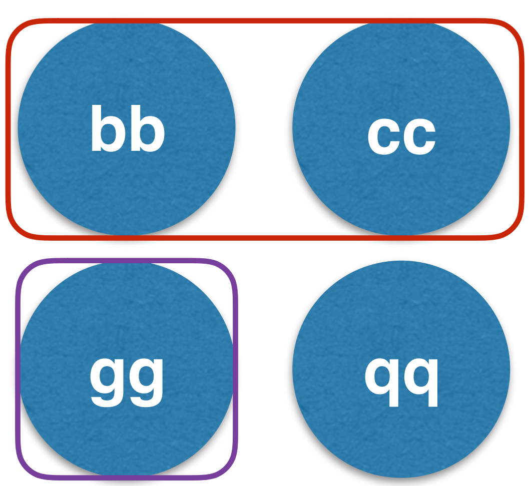
利用事例形状变量来筛选Higgs到轻夸克末态

CEPC Higgs 耦合预期精度



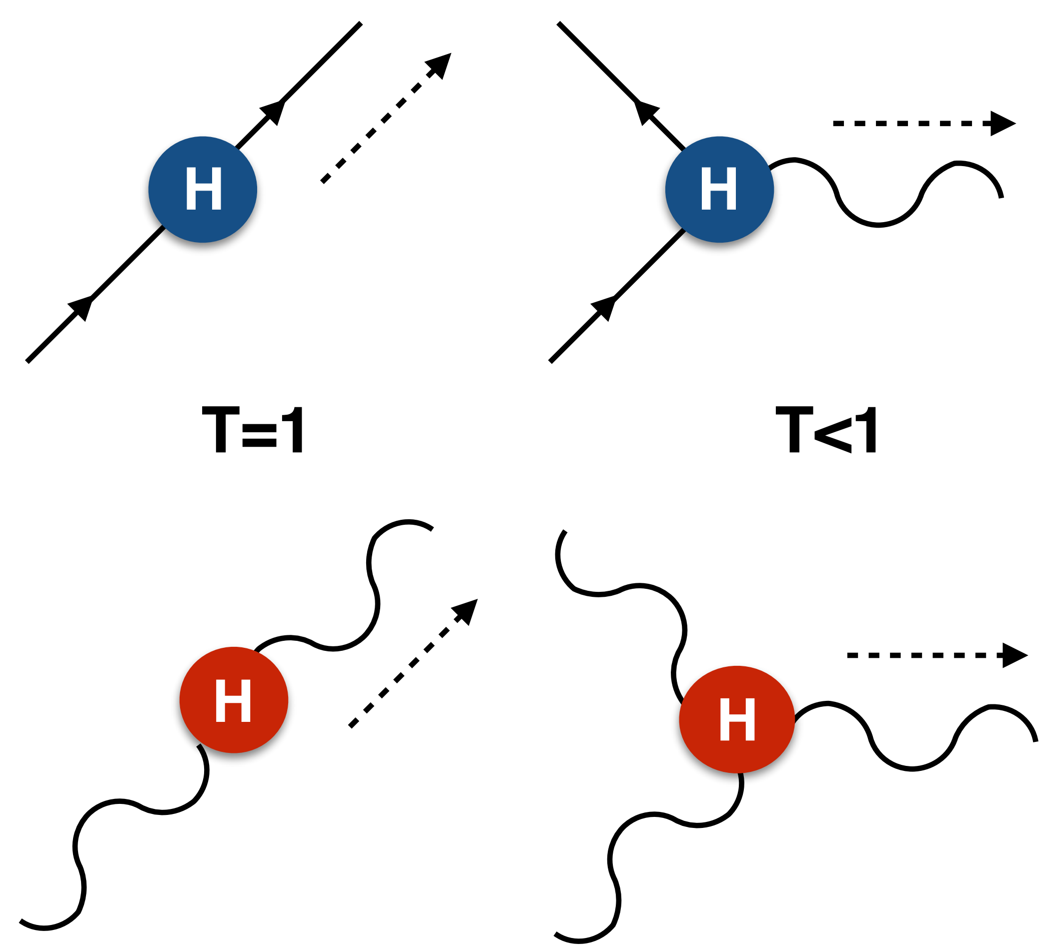
重味标记

夸克胶子甄别



冲度变量甄别双胶子 / 夸克末态

$$T = \max_{\vec{n}} \left(\frac{\sum_i |p_i \cdot \vec{n}|}{\sum_i |p_i|} \right)$$



冲度分布依赖于QCD色因子

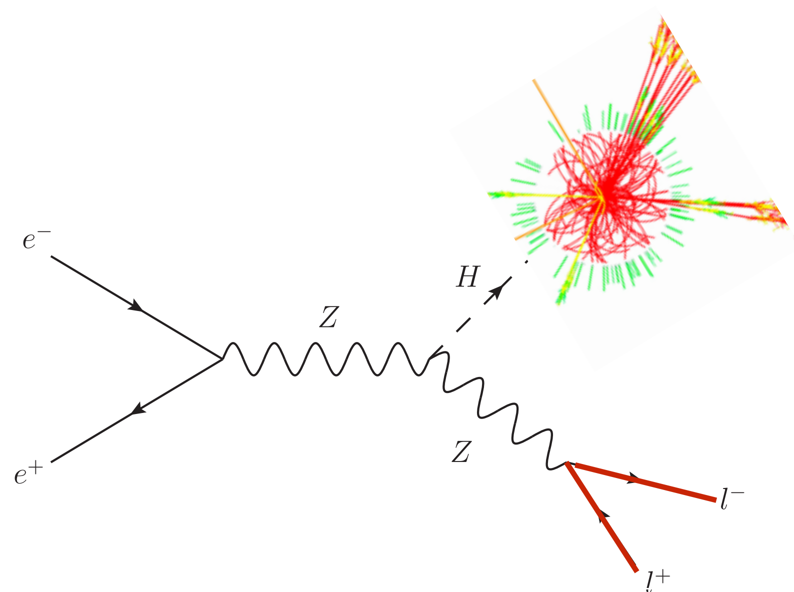
利用全局事例形状变量检验轻夸克Yukawa耦合

对轻夸克Yukawa耦合给出极高灵敏度

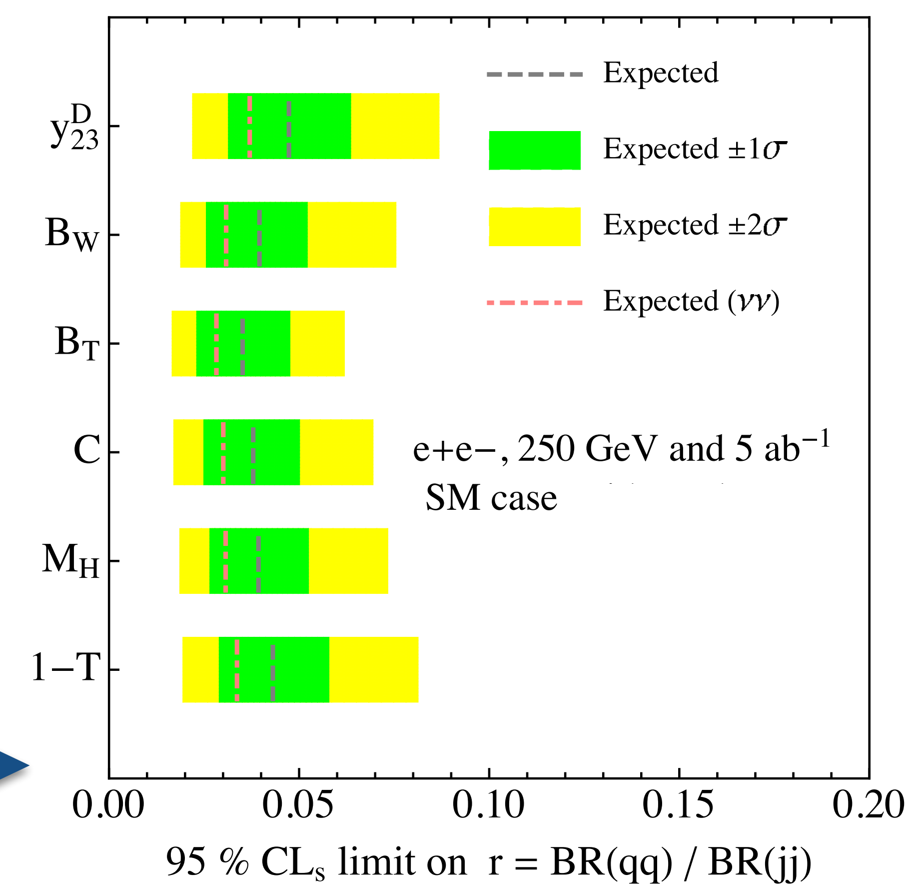
CEPC Higgs 强子末态预期事例数

$Z(l^+l^-)H(X)$	gg	$b\bar{b}$	$c\bar{c}$	$WW^*(4h)$	$ZZ^*(4h)$	$q\bar{q}$
BR [%]	8.6	57.7	2.9	9.5	1.3	~ 0.02
N_{event}	6140	41170	2070	6780	930	14

利用Z反冲衰变运动学可完全重建



轻夸克分支比预期灵敏度



☆ 预计CEPC将可探测奇异夸克Yukawa至4倍标准模型预言

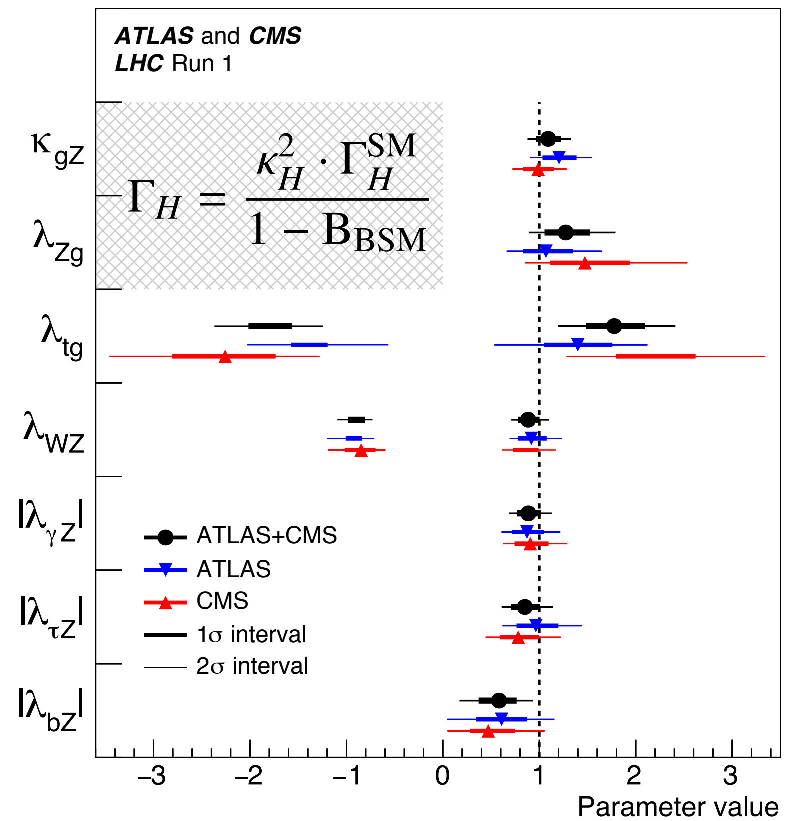
QGP环境下检验Higgs粒子寿命

相对论性重离子碰撞中Higgs的产生及衰变

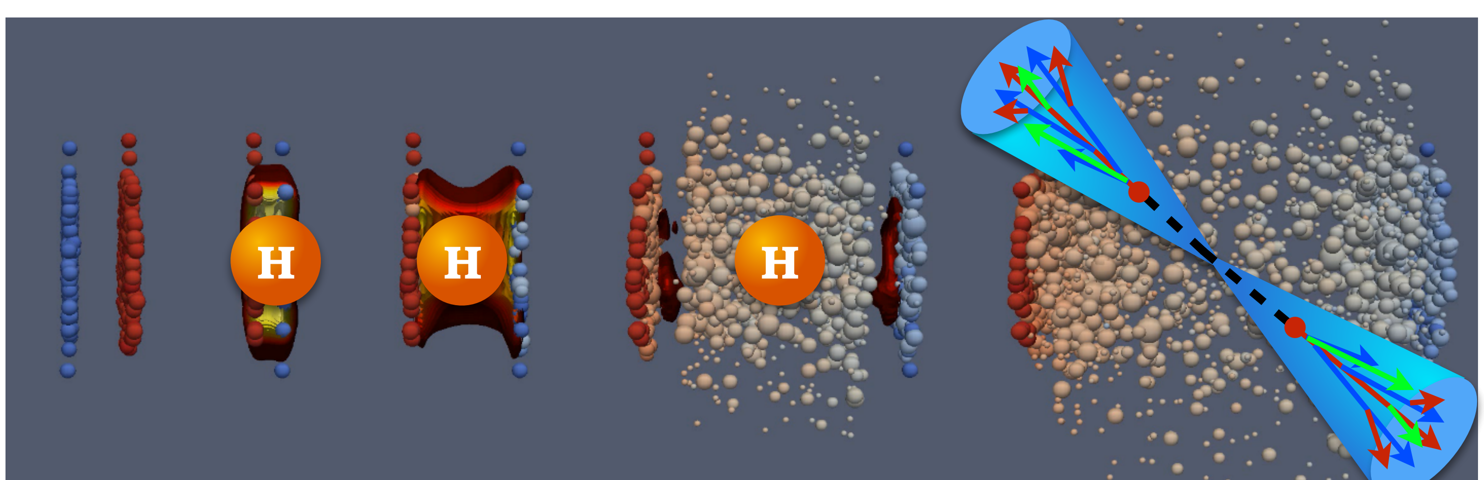
LHC上无法直接测量Higgs粒子总宽度

Particle	Width(GeV)	lifetime(fm/c)
top	1.3	0.15
Higgs	0.004	47
Z	2.5	0.08
W	2.1	0.09

直接影响Higgs绝对耦合的抽取



PbPb碰撞夸克胶子等离子体及Higgs粒子的时间演化

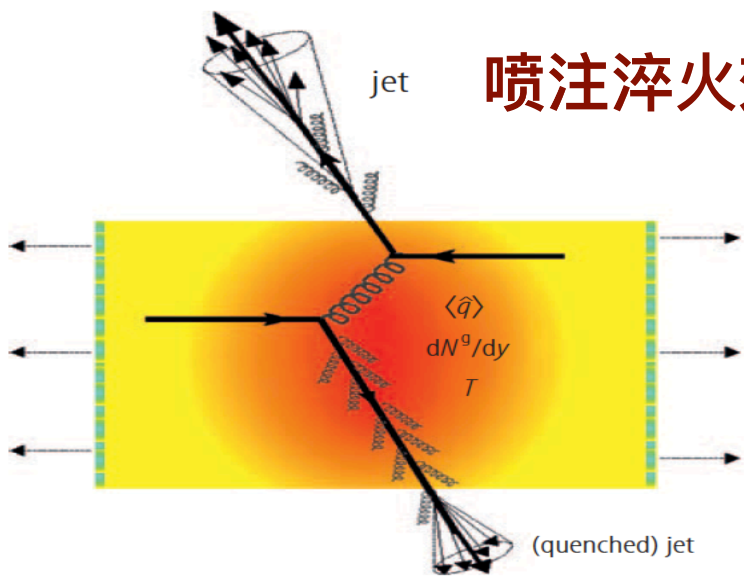


- ☆ 利用QGP(~10 fm/c)做为时间标尺检验Higgs寿命
- ☆ 检验Higgs衰变出的双喷注(bb)是否受QGP影响

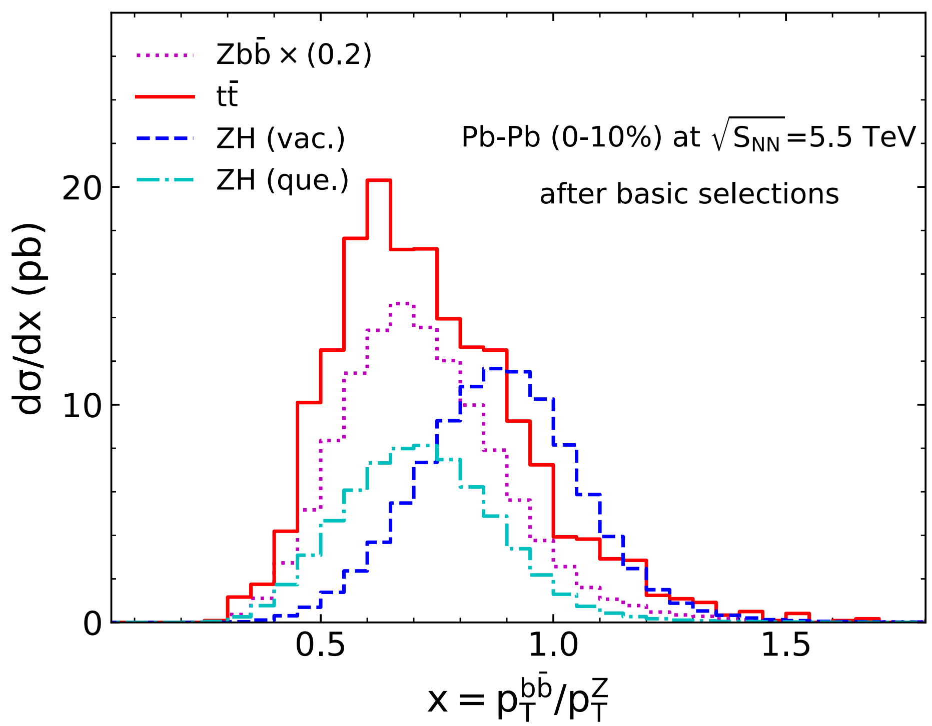
QGP环境下检验Higgs粒子寿命

相关信号和背景的模拟及分析

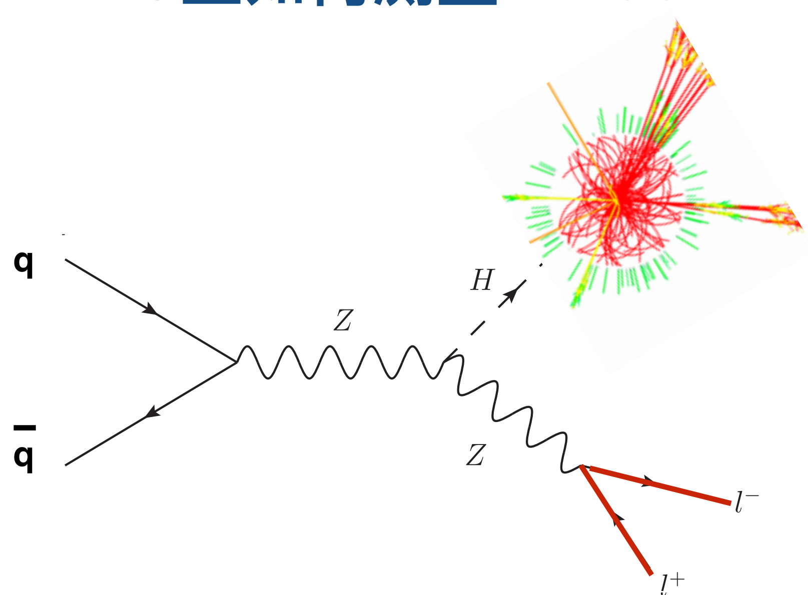
QGP介质增强QCD辐射



PbPb碰撞下横动量比值pT(bb)/pT(Z)的分布



LHC上如何测量H->bb

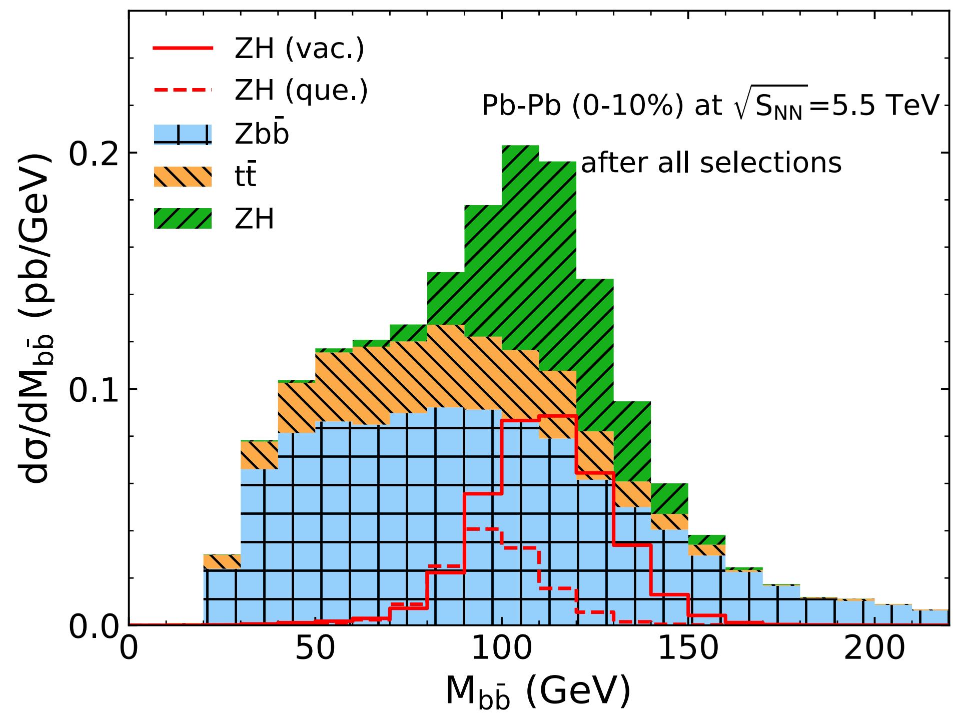


- ☆ 与Higgs信号不一样PbPb碰撞下背景过程会受喷注淬火影响
- ☆ 背景截面被压低并且具有不同的运动学特征

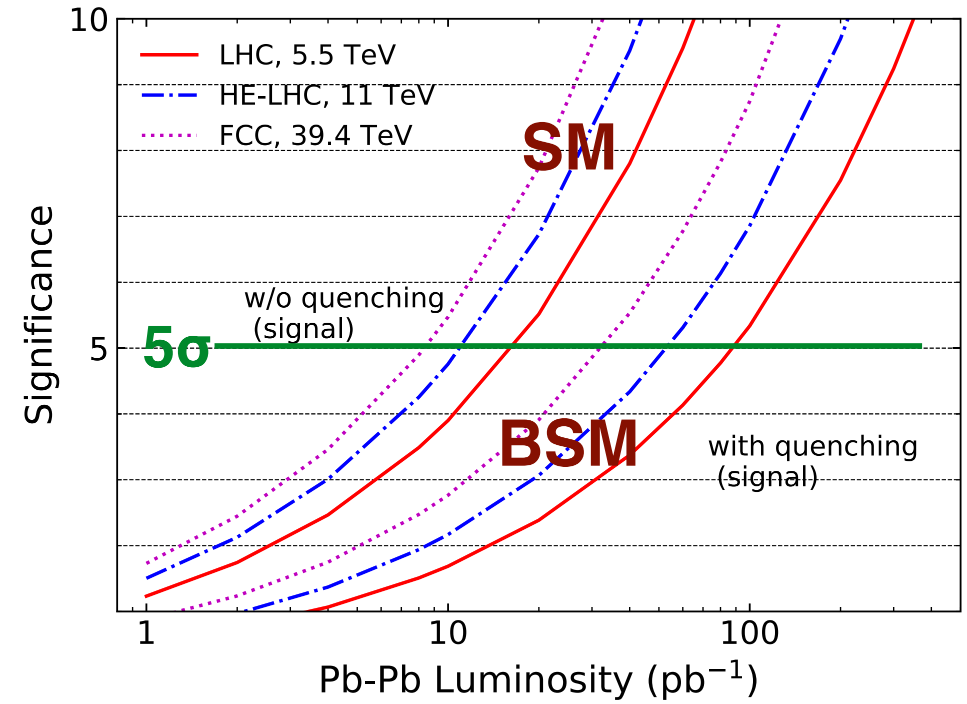
QGP环境下检验Higgs粒子寿命

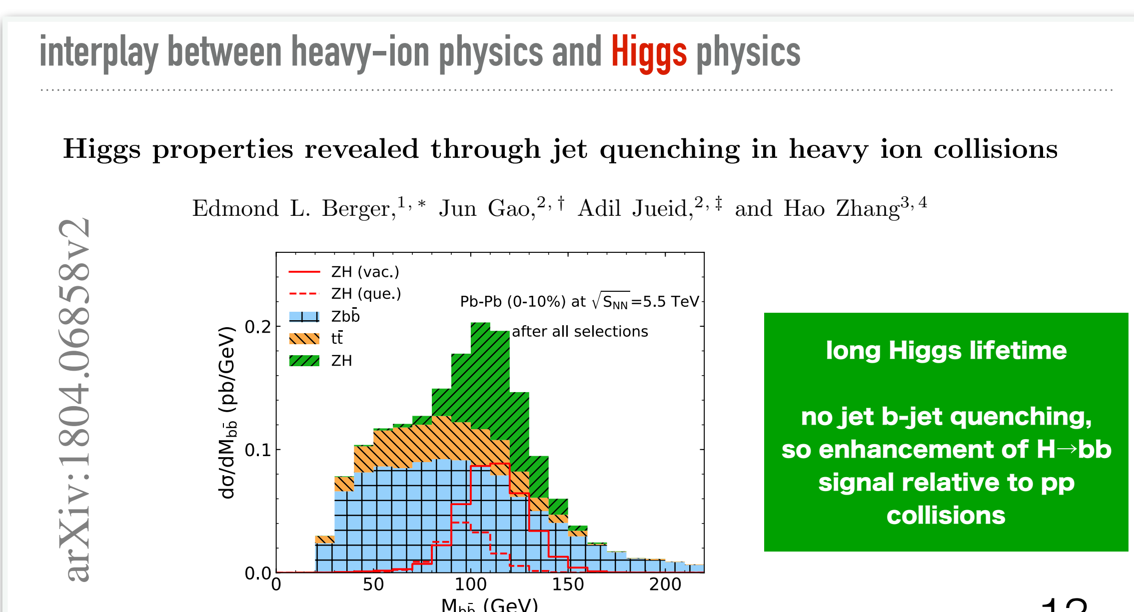
预言PbPb碰撞中发现Higgs强子衰变所需亮度

双喷注(bb)不变质量分布



统计显示度 vs. 离子亮度



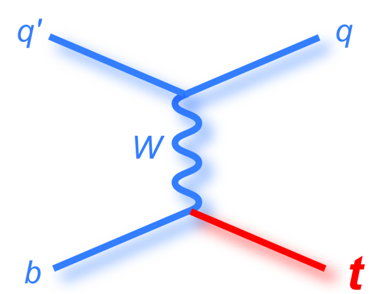


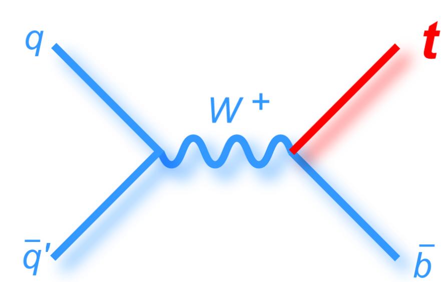
LHCP18大会上理论视野
报告重点介绍 by G. Salam

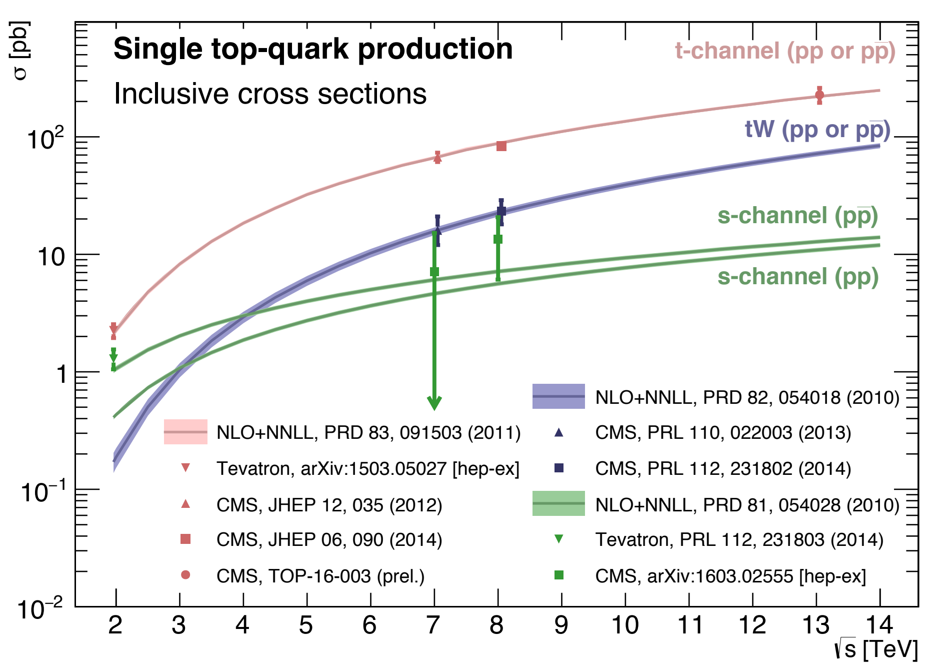
精确预言LHC上单个顶夸克产生及衰变

顶夸克电弱耦合(tbW及CKM Vtb)的直接检验

单个顶夸克产生，t-道和s-道





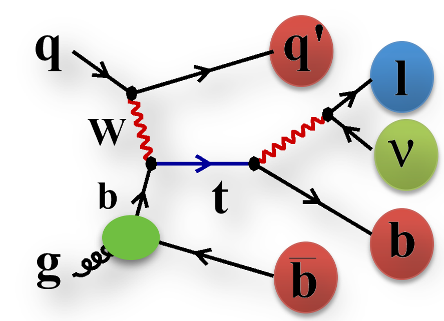


产生截面 vs. 对撞能量

CMS 13 TeV 截面测量

Uncertainty source	$\Delta\sigma_{t\text{-ch.},t}/\sigma^{\text{obs}}_{t\text{-ch.},t}$	$\Delta\sigma_{t\text{-ch.},\bar{t}}/\sigma^{\text{obs}}_{t\text{-ch.},\bar{t}}$	$\Delta R_{t\text{-ch.}}/R_{t\text{-ch.}}$
Statistical uncert.	±5.3%	±11.5%	±9.7%
Profiled exp. uncert.	±5.7%	±4.9%	±3.3%
Total fit uncert.	±7.8%	±12.5%	±10.3%
Integrated luminosity	±2.7%	±2.7%	-
Signal modelling	±8.2%	±8.5%	±5.3%
$t\bar{t}$ modelling	±4.3%	±4.5%	±4.0%
W+jets modelling	−1.6/+2.3%	−2.5/+2.3%	−1.7/+2.0%
μ_R/μ_F scale t-channel	−5.7/+5.2%	−7.2/+5.1%	−0.7/+1.2%
μ_R/μ_F scale $t\bar{t}$	−3.5/+4.1%	−4.7/+3.1%	−1.1/+1.0%
μ_R/μ_F scale tW	−0.6/+0.8%	−1.1/+0.7%	−0.2/+0.1%
μ_R/μ_F scale W+jets	−3.5/+3.0%	−4.9/+3.8%	−1.2/+0.9%
PDF uncert.	−2.1/+1.6%	−1.8/+2.1%	−2.2/+2.5%
Top quark p_T modelling	±0.2%	±0.2%	±0.1%
Total theory uncert.	−12.2/+12.1%	−13.6/+12.9%	±7.5%
Total uncert.	±14.7%	−18.7/+18.2%	±12.7%

- ☆ 1/5的有效体积
- ☆ 采用多变量分析

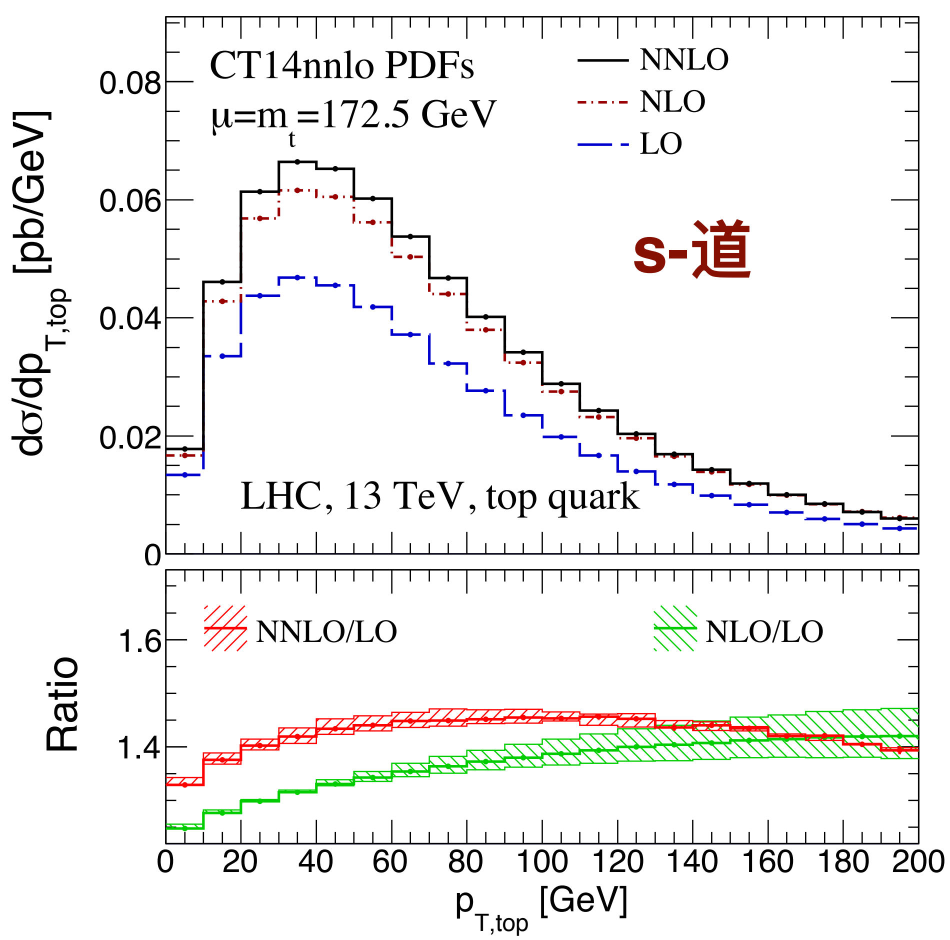


QCD修正的理论误差占主导

精确预言LHC上单个顶夸克产生及衰变

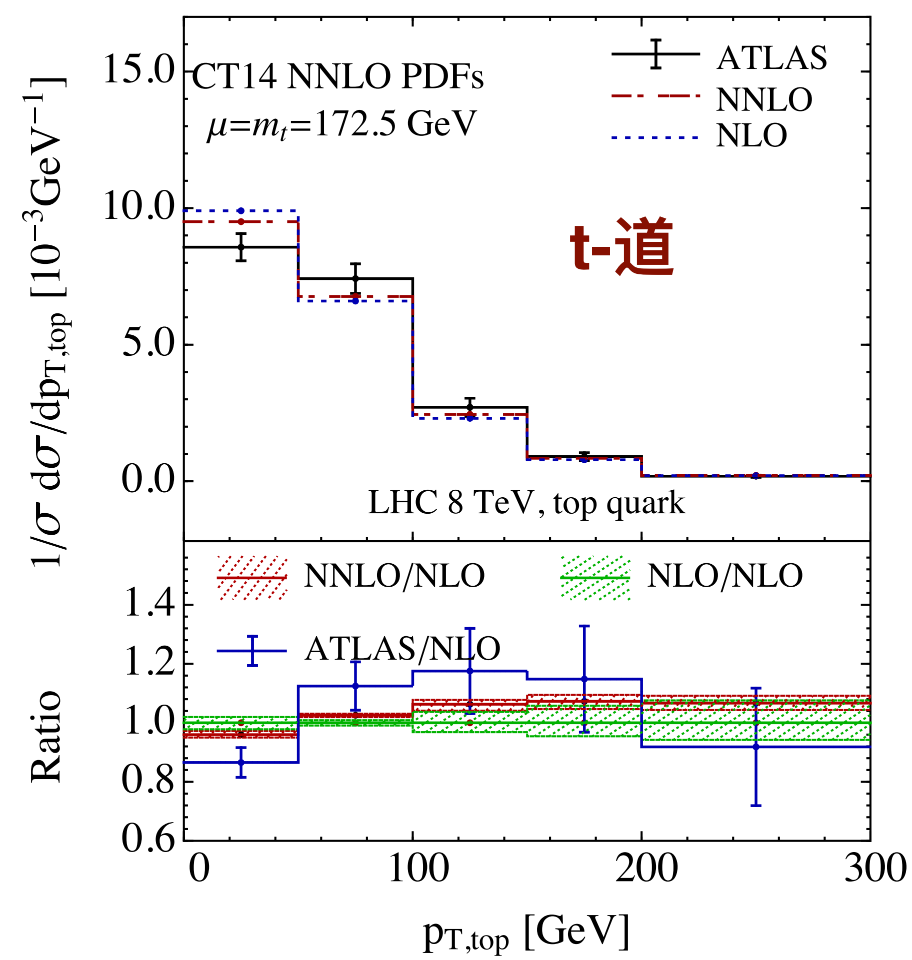
首次计算全微分产生及衰变的NNLO QCD修正

10%的NNLO修正；理论误差降低



LHC上顶夸克横动量分布的预言

理论误差降低3倍



与ATLAS测量结果符合更好

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2017-2018年度基金

2018年成功申请自然科学基金面上项目一项、作为骨干成员成功申请自然科学基金重点项目一项(2019执行)；另主持CEPC理论研究课题一项(2018-2019)

资助类别：面上项目

亚类说明：

附注说明：

项目名称：高能对撞机上量子色动力学的应用

直接费用：60万元　执行年限：2019. 01-2022. 12

负 责 人：高俊

希格斯粒子强子衰变道的末态全局形状变量及喷注的理论研究

申请人：高俊　依托单位：上海交通大学　邮箱：jung49@sjtu.edu.cn

选题依据：CEPC希格斯工厂预计可产生上百万个希格斯粒子用以精确测量希格斯粒子的耦合。如表1所示我们注意到其衰变主要是到各种部分子，最终到强子末态。与LHC不同，在

资助类别：重点项目

亚类说明：

附注说明：标准模型物理与新物理（A0502）

项目名称：TeV新物理理论与实验检验

直接费用：330万元　执行年限：2019. 01-2023. 12

负 责 人：何红建

项目组主要成员

编号	姓名	出生年月	性别	职称	学位	单位名称
1	何红建	1965. 04	男	教授	博士	上海交通大学
2	高俊	1984. 10	男	研究员	博士	上海交通大学
3	周宁	1981. 11	男	研究员	博士	上海交通大学
4	李亮	1977. 11	男	研究员	博士	上海交通大学

发表LHC上PDF研究的综述文章

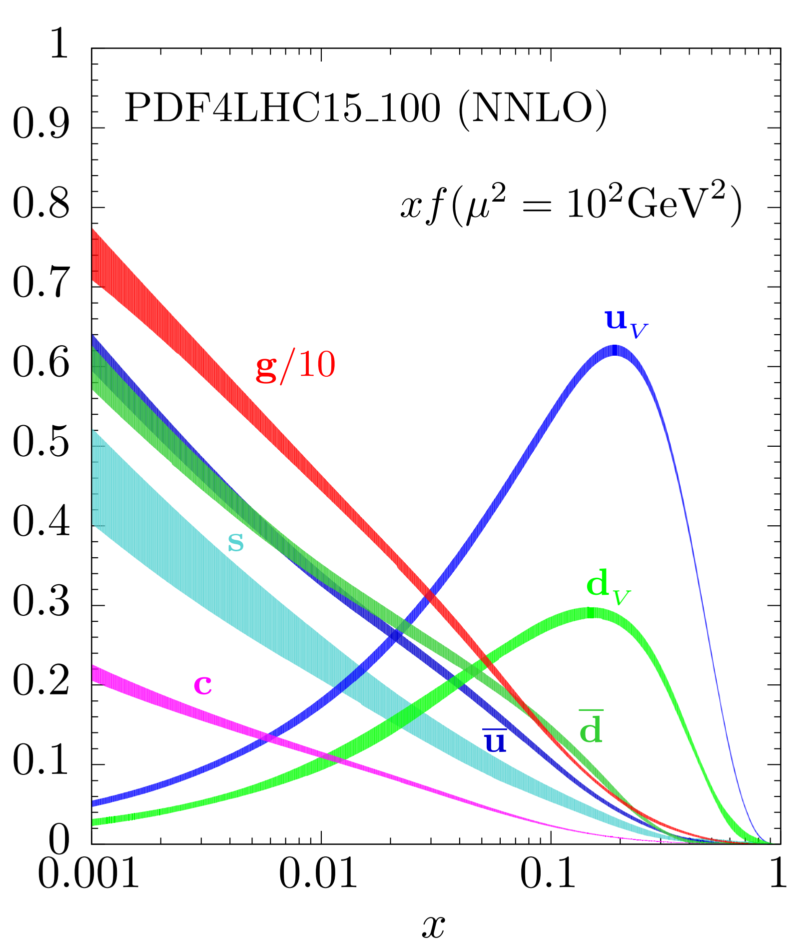
ELSEVIER

Physics Reports

Volume 742, 1 May 2018, Pages 1-121

The structure of the proton in the LHC precision era

Jun Gao [a], Lucian Harland-Lang [b], Juan Rojo [c, d]



impact factor： 20

Contents

2017-2018年度获得奖项

被授予2018年度Guido Altarelli粒子物理理论奖项（经由提名及DIS国际会议委员会评选）以表彰在对撞机QCD精确预言及核子结构研究方面的突出贡献

CENTRO FERMI
MUSEO STORICO DELLA FISICA E CENTRO STUDI E RICERCHE ENRICO FERMI
World Scientific
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EPJ.org

Guido Altarelli Award

awarded to

Jun Gao

for innovative contributions to the precision QCD theory of collider processes and nucleon structure

Prof Luisa Cifarelli	Dr Christian Caron	Prof K.K. Puha	Prof Aharon Levy
(President Centro Fermi)	(Springer Executive Editor)	(Chairman WS Publishing)	(Chair IAC of DIS2017)

26th International Workshop on Deep-Inelastic Scattering and Related Subjects 16-20 April 2018, Kobe, Japan

CERN COURIER

Volume 58 Number 6 July/August 2018

Guido Altarelli Award goes to Gao and Hen

The third Guido Altarelli Award was presented to two researchers during the 2018 international workshop on deep-inelastic scattering and related subjects (DIS18), which took place in Kobe, Japan, on 16–20 April. The award, which honours the memory of CERN theorist Guido Altarelli, recognises exceptional achievements from young scientists in the field of deep-inelastic scattering and related subjects. Jun Gao from Shanghai Jiao Tong University, China, is one of the main developers of the so-called CTEQ family of parton densities, and was recognised for his innovative contributions to precise QCD calculations. The other recipient, Or Hen from the Massachusetts Institute of Technology, US, received the award for his role in uncovering a striking relation between the nuclear "EMC effect" and nucleon–nucleon correlations, with implications for valence up- and down-quark distributions.

H Hiramoto

Jun Gao (left) and Or Hen (right) received their prizes at the DIS18 workshop.

- **2016(第一届)，F. Caola (AP at Univ. Durham), J. Kretzschmar (AP at Univ. Liverpool)**

理论 **实验**

- **2017(第二届)，M. Ubiali (AP at Univ. Cambridge), P. Gunnellini (PD at Univ. Hamburg)**

- **2018(第三届)，Jun Gao (SJTU)，Or Hen (AP at MIT)**

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2017-2018年度会议报告

参加国际会议并作报告4次，其中包括TOP 17’和DIS 18’的两个大会报告

1. Single Top Production and Decay: theory overview, plenary talk at the 10th International Workshop on Top Quark Physics, Braga, Portugal, September 2017 **大会报告**
2. Altarelli-Parisi (DGLAP) equation from one to three loops, plenary talk at the 26th International Workshop on DIS and Related Topics, Kobe University, Japan, April 15, 2018 **大会报告**
3. Massive charged-current DIS at NNLO and impact on strange distributions, 26th International Workshop on DIS and Related Topics, Kobe University, Japan, April 18, 2018
4. Yukawa couplings and Higgs boson going beyond LHC, The second Workshop on QCD, Nankai University, China, May 5, 2018
5. Top quark at the LHC era: theory overview, Topical Mini-Workshop of the new Physics at the Terascale, Shanghai Jiao Tong University, China, August 4, 2018 **大会报告**
6. The structure of the Proton in the LHC precision Era, 48th International Symposium on Multiparticle Dynamics, Nanyang Technological University, Singapore, Sep. 5, 2018 **理论综述报告**

2017-2018年度会议组织

协助组织BSM研讨会2次、QCD理论暑期学校1次，另参与CEPC CDR的QCD部分撰写及HL/HE-LHC YR的 WG1(SM)中部分子函数相关研究的起草

1. Summer School on QCD and effective theory, T. D. Lee institute and Shanghai Jiao Tong University, July 1-20, 2018
2. Workshop on Physics beyond the Standard Model, T. D. Lee institute and Shanghai Jiao Tong University, July 1-3, 2018
3. Topical Mini-Workshop of the new Physics at the Terascale, T. D. Lee institute and Shanghai Jiao Tong University, August 4-6, 2018

HL/HE-LHC Physics Workshop Report

Standard Model physics opportunities

European Strategy for Particle Physics Update

Ultimate Parton Distributions at the HL-LHC

Abdul Khalek[1], Shaun Bailey[2], Jun Gao[3], Lucian Harland-Lang[2], and Juan Rojo[1].

CEPC

Conceptual Design Report

Volume II - Physics & Detector

2.4.2 JET RATES AT CEPC

Another distinct feature of CEPC compared with LEP is its unprecedented luminosity, in particular above the Z pole. The higher luminosity opens the door for the precision study of multi-jet production at an e^+e^- collider.

As an example, we show in Figure 2.38 the four-jet production cross sections at CEPC

2.4.4 QCD EVENT SHAPES AND LIGHT QUARK YUKAWA COUPLING

The SM Higgs boson decays dominantly to various hadronic final states with a total branching fraction of more than 80%. These hadronic decays provide a new source for QCD studies at CEPC (in its Higgs factory mode). In particular, Higgs decays produce a

一. 个人经历及研究方向

二. 年度科研论文

三. 基金申请及奖项

四. 学术会议及报告

五. 总结

2017-2018年度小结

1，共在Physics Reports,JHEP,PRD,EPJC发表9篇论文

2，获得自然科学基金面上项目资助1项(主持)，重点项目1项(参与)，主持高能所CEPC理论研究课题1项

3，获得2018年度Guido Altarelli理论奖项

4，参加国际会议并作报告4次，参与CEPC CDR及CERN YR的撰写

致谢

感谢各位评委专家！

敬请批评指正！