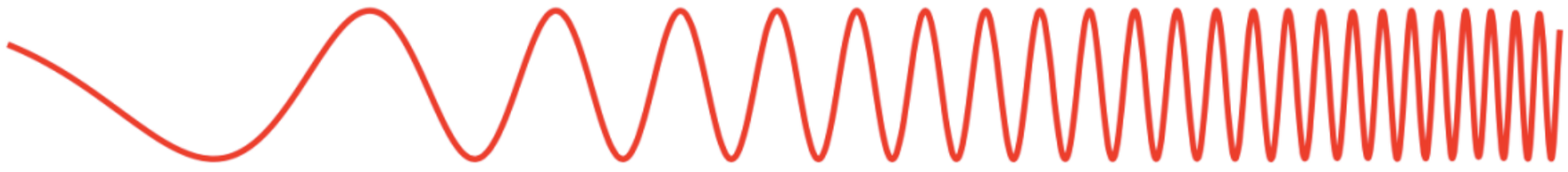
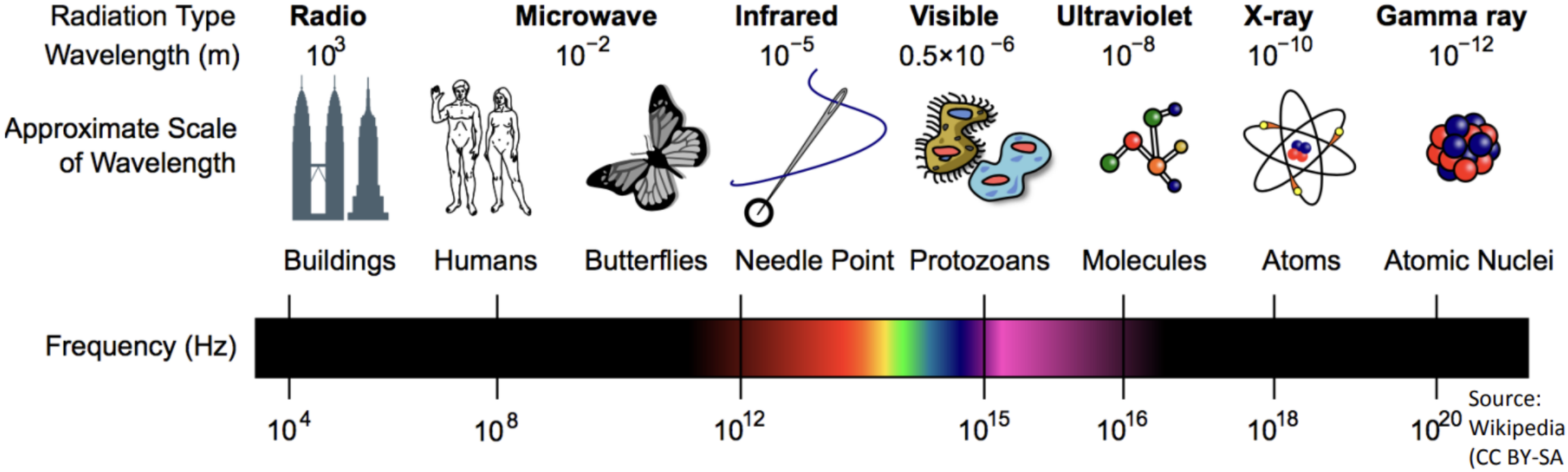
Search for heavy resonance in the Higgs boson and photon final state with the ATLAS detector

报告人　：刘波
合作导师：娄辛丑 研究员
　　梁志均 青年研究员

Understand the principle of the world





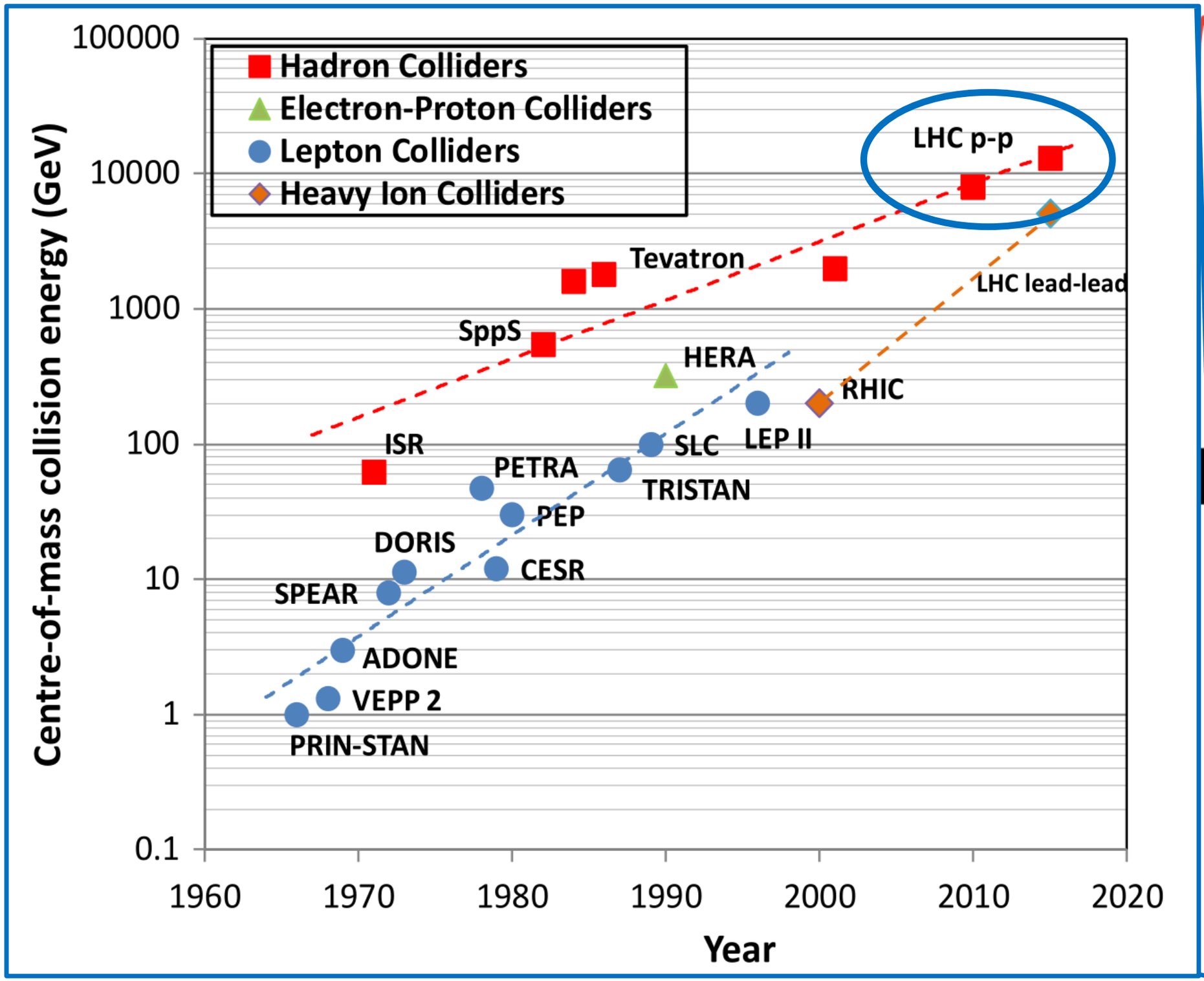
de Broglie wavelength $\lambda = \frac{h\,c}{E}$

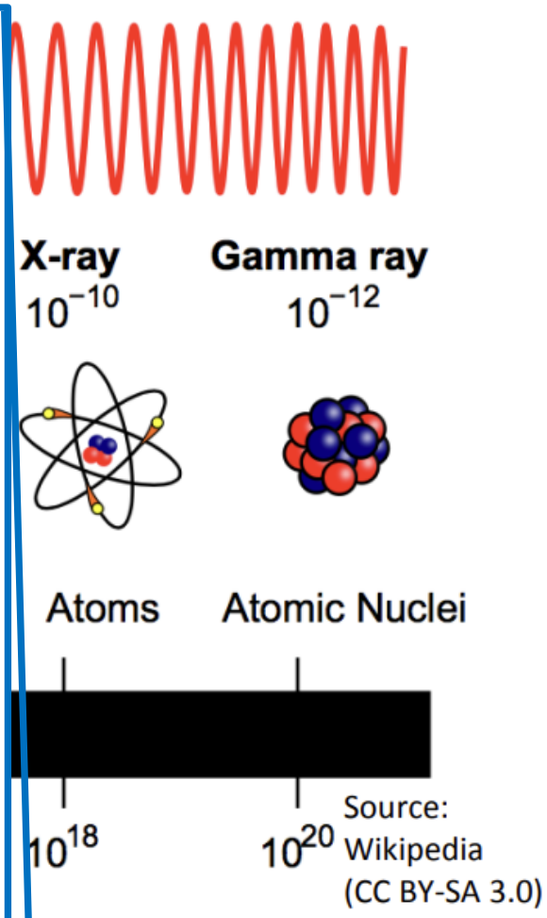
Visible
~400 → 700 nm

X-ray
~0.01 → 10 nm

Particle accelarators
λ<0.01 nm

Understand the principle of the world



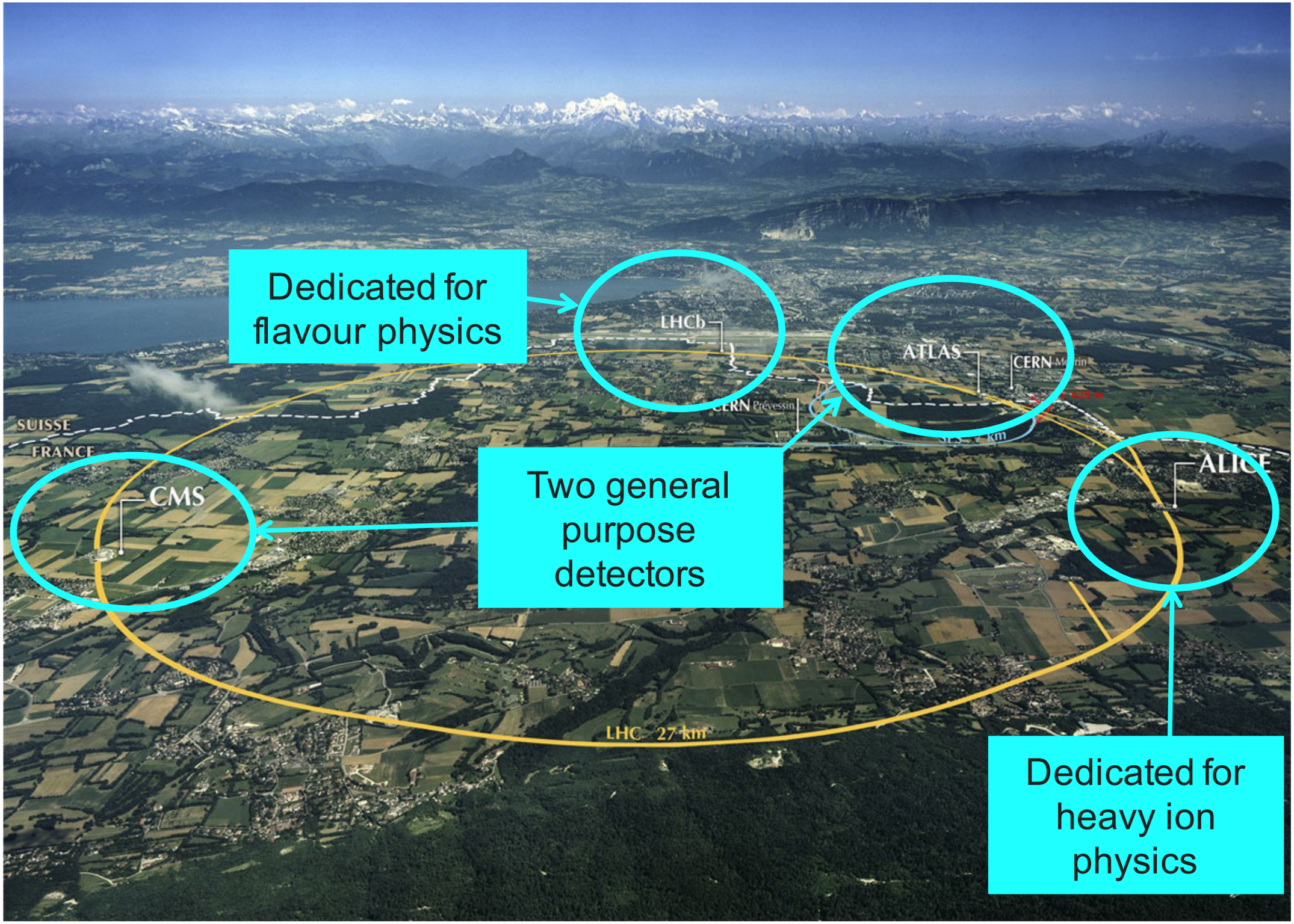


Particle accelarators
λ<0.01 nm

Large Hadron Collider

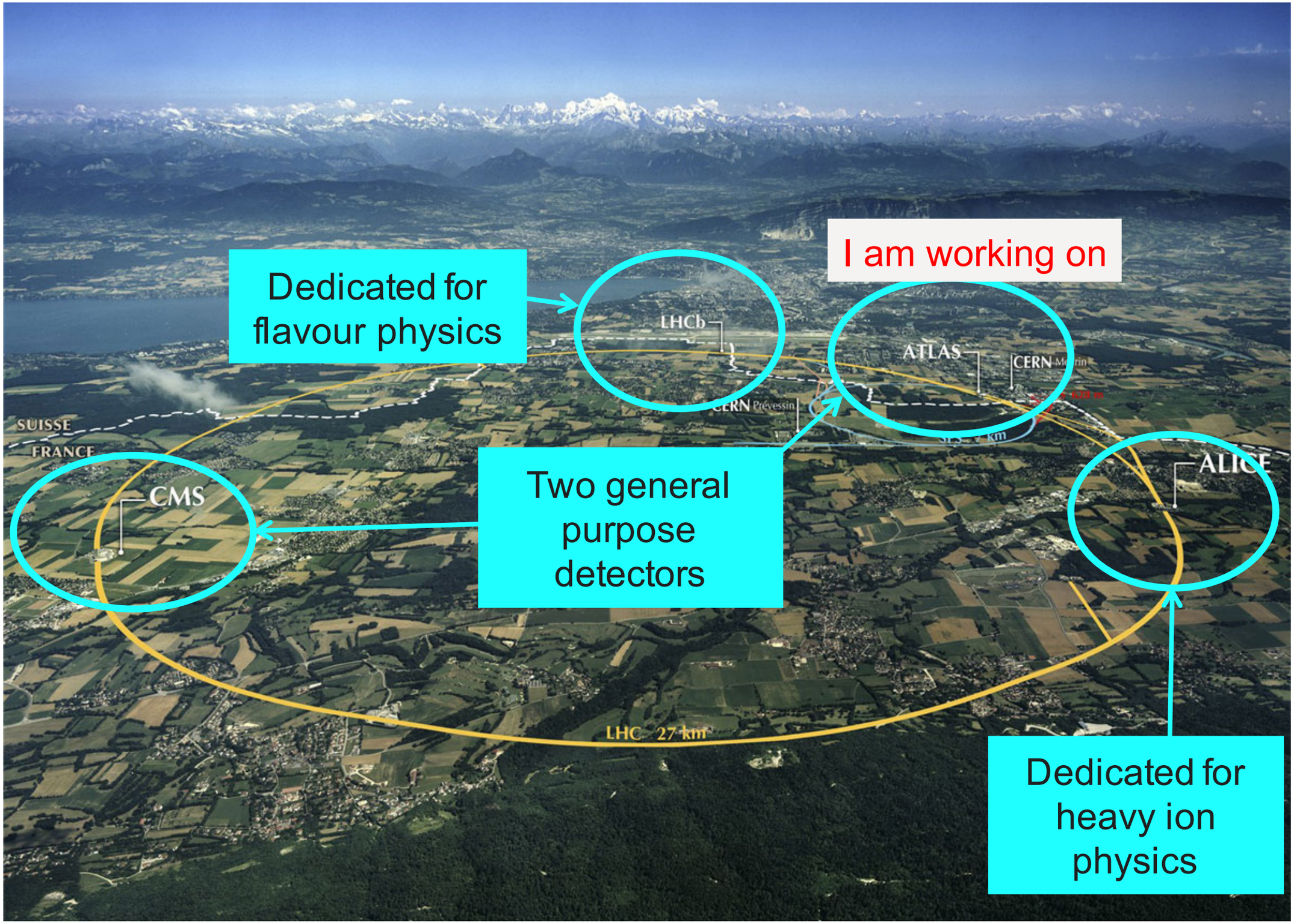
- ✓ Currently, the largest and highest energy collider.
  → Unique chance to understand properties of elementary particles.

Large Hadron Collider



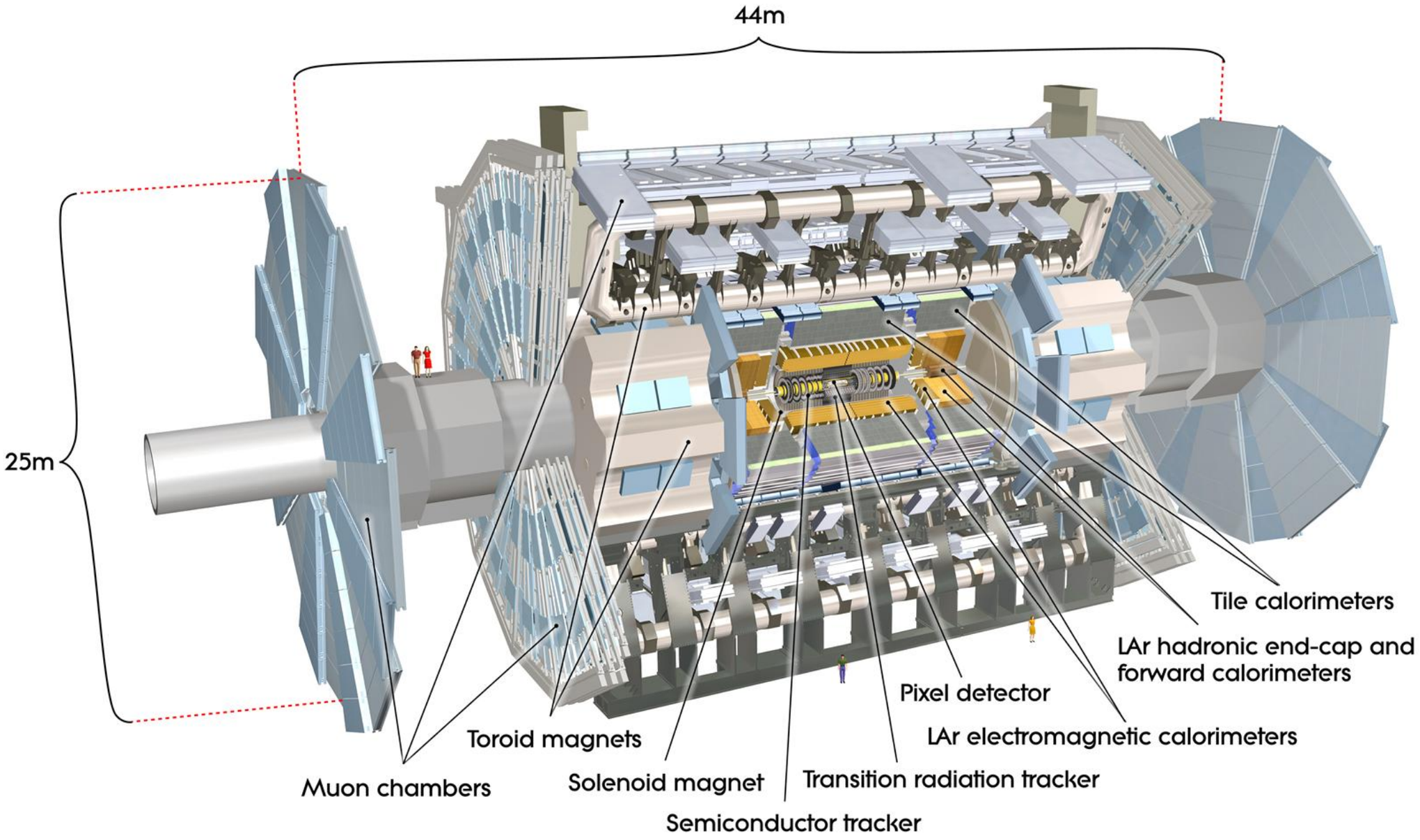
- ✓ Currently, the largest and highest energy collider.
  → Unique chance to understand properties of elementary particles.

Large Hadron Collider



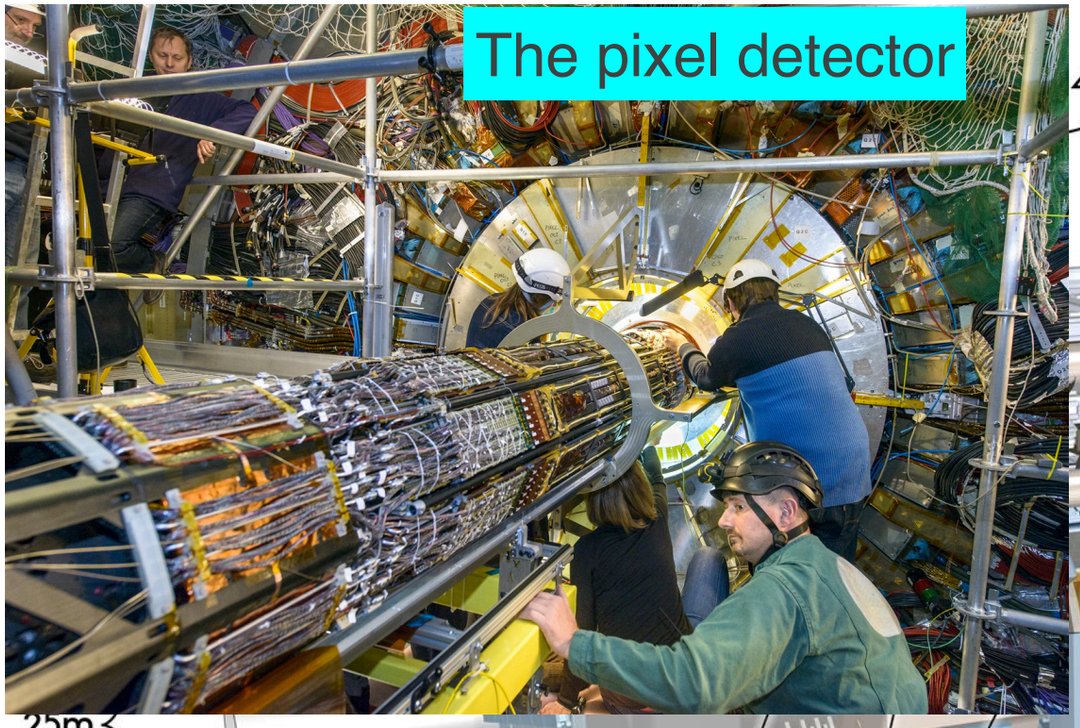
- ✓ Currently, the largest and highest energy collider.
  → Unique chance to understand properties of elementary particles.

The ATLAS detector



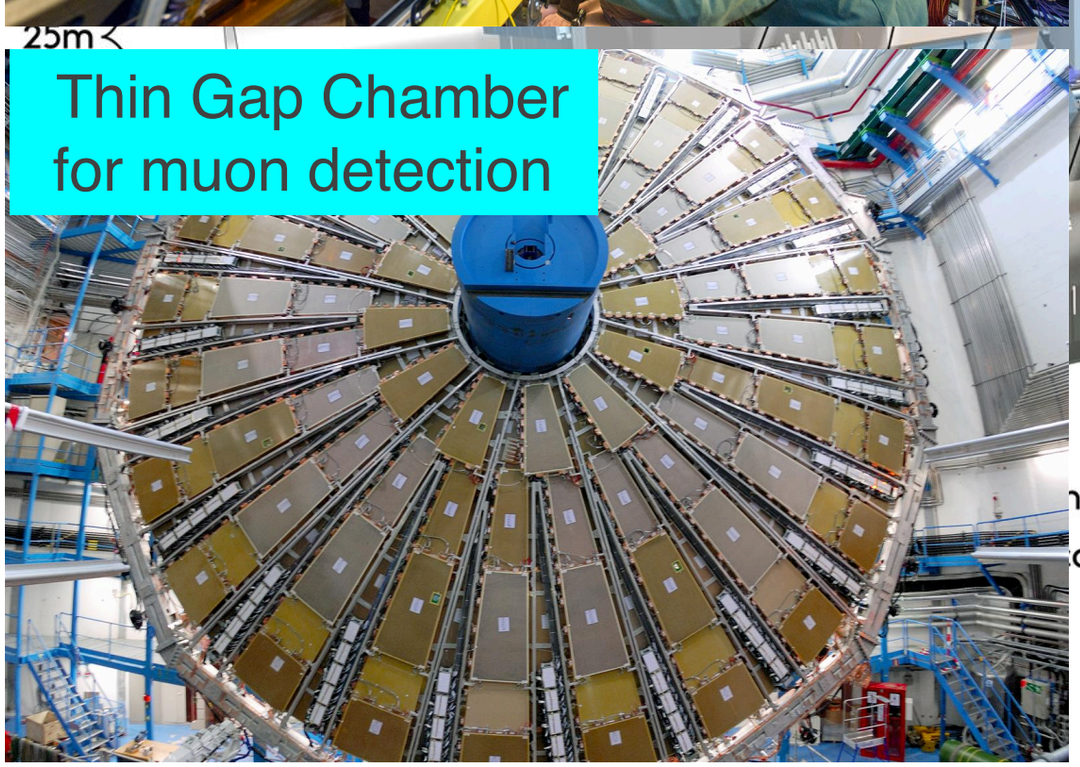
- Largest detector in the LHC.
- A collection of advanced particle detection technologies.
- Will be upgraded for Phase-II (after run-III) operation.

The ATLAS detector

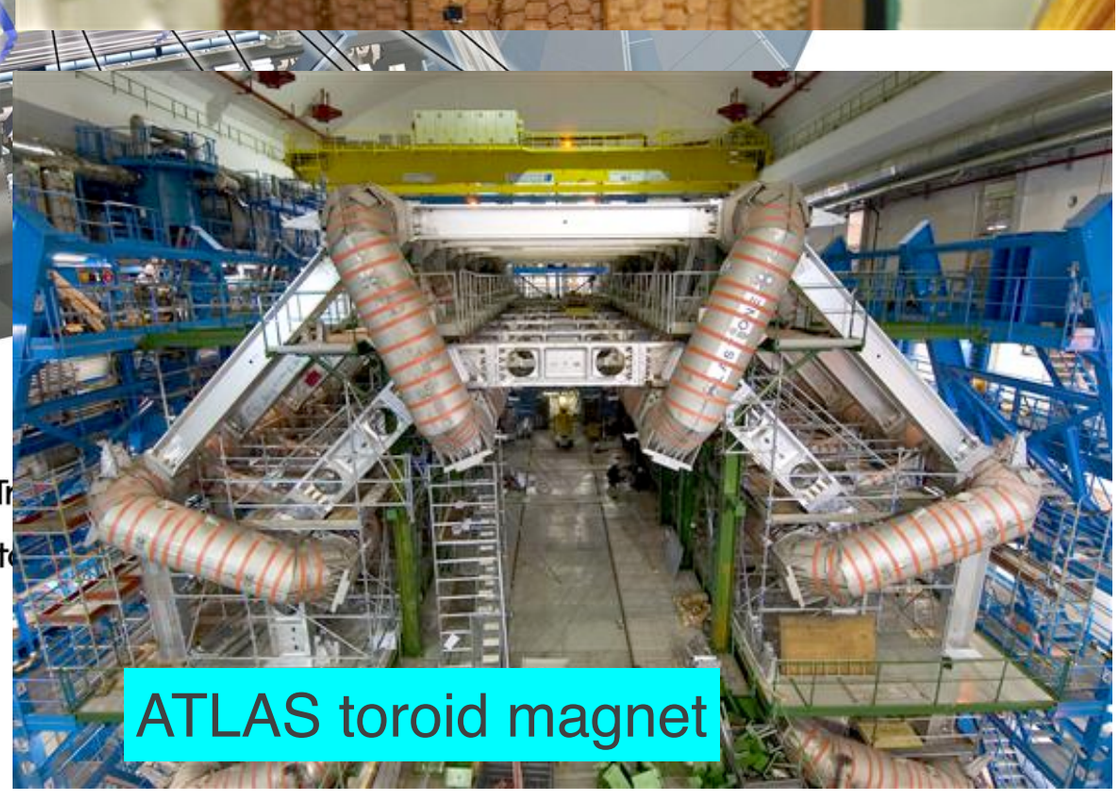


The pixel detector

Liquid Argon Calorimeter



Thin Gap Chamber for muon detection



ATLAS toroid magnet

- Largest detector in the LHC.
- A collection of advanced particle detection technologies.
- Will be upgraded for Phase-II (after run-III) operation.

A world wide collaboration

A large collaboration with members all over the world

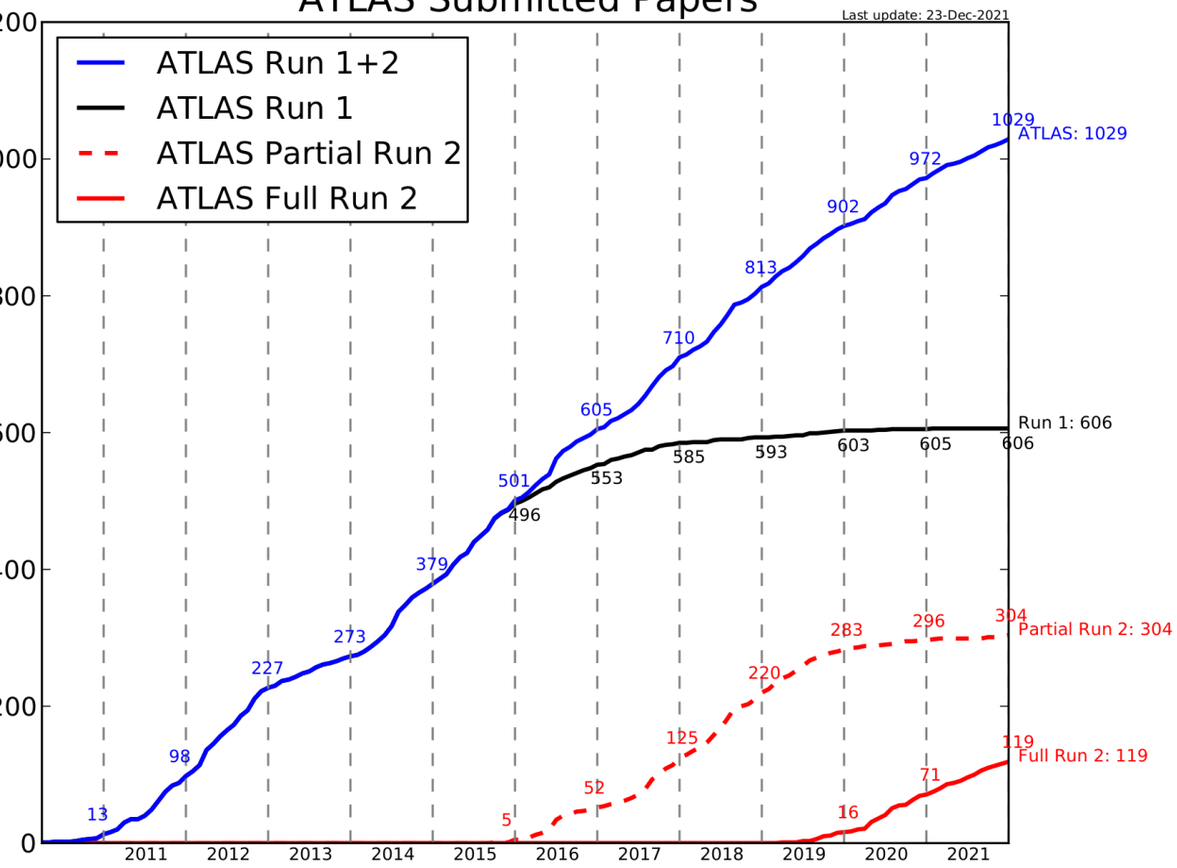
A world wide collaboration

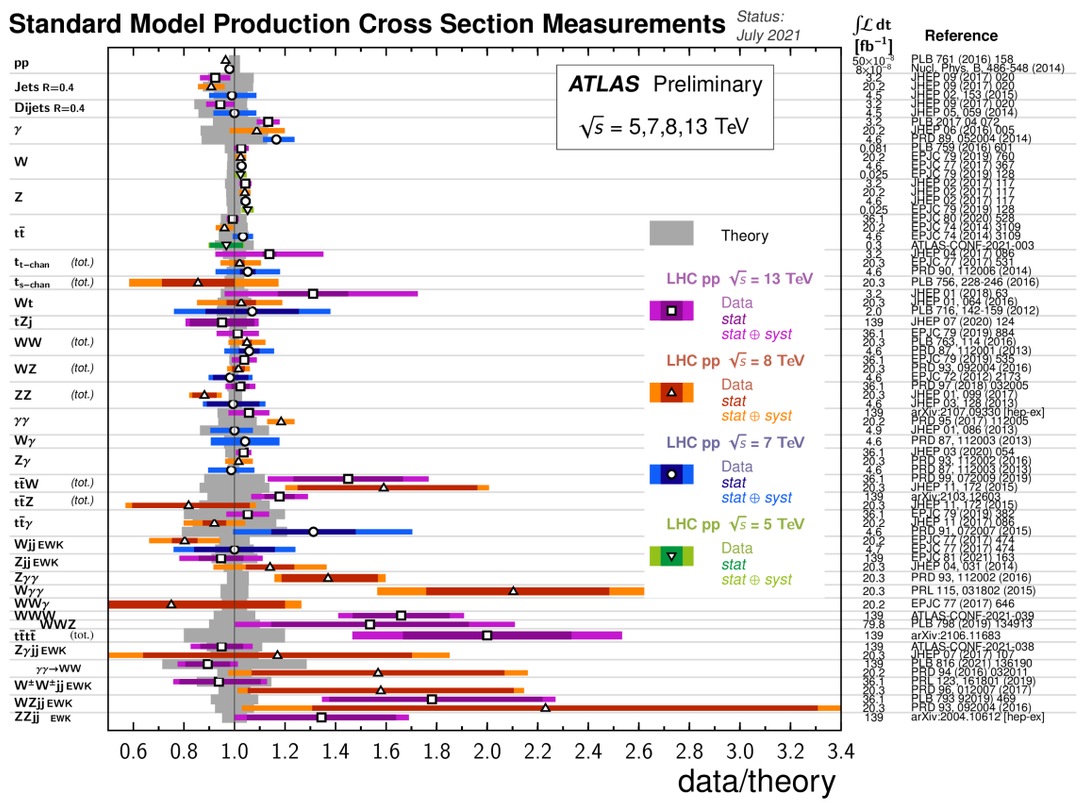
Chinese institutes (Two clusters):

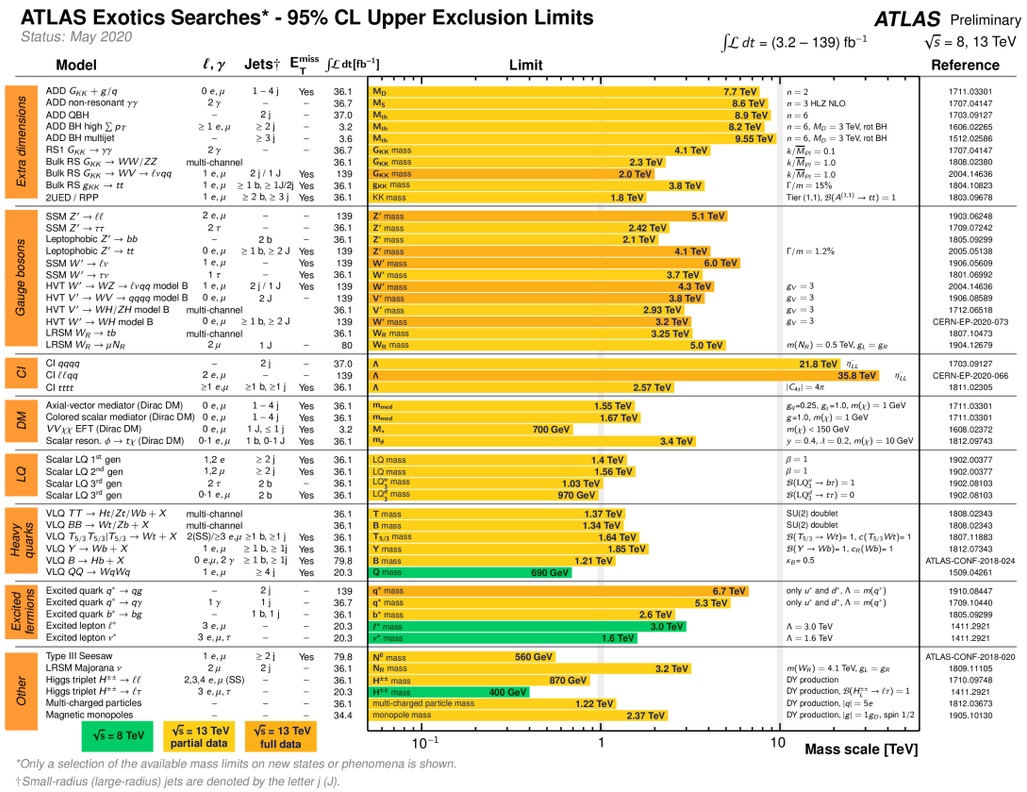
- IHEP-NJU-THU
  - Institute of High Energy Physics
  - Nanjing University
  - Tsinghua University
- USTC-SDU-SJTU
  - University of Science and Technology of China
  - Shandong University
  - Shanghai Jiaotong University

A large collaboration with members all over the world

Significant achievements

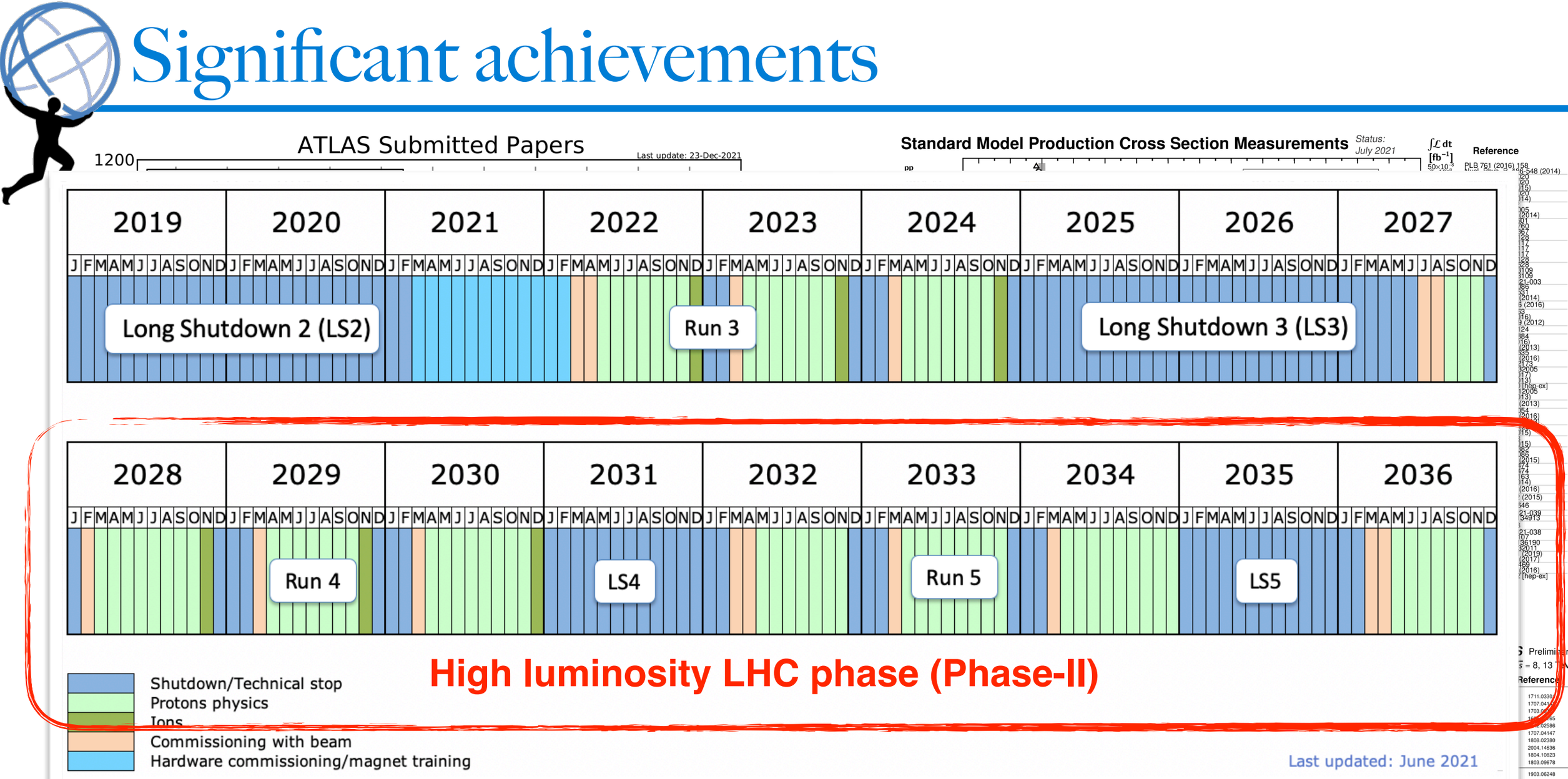






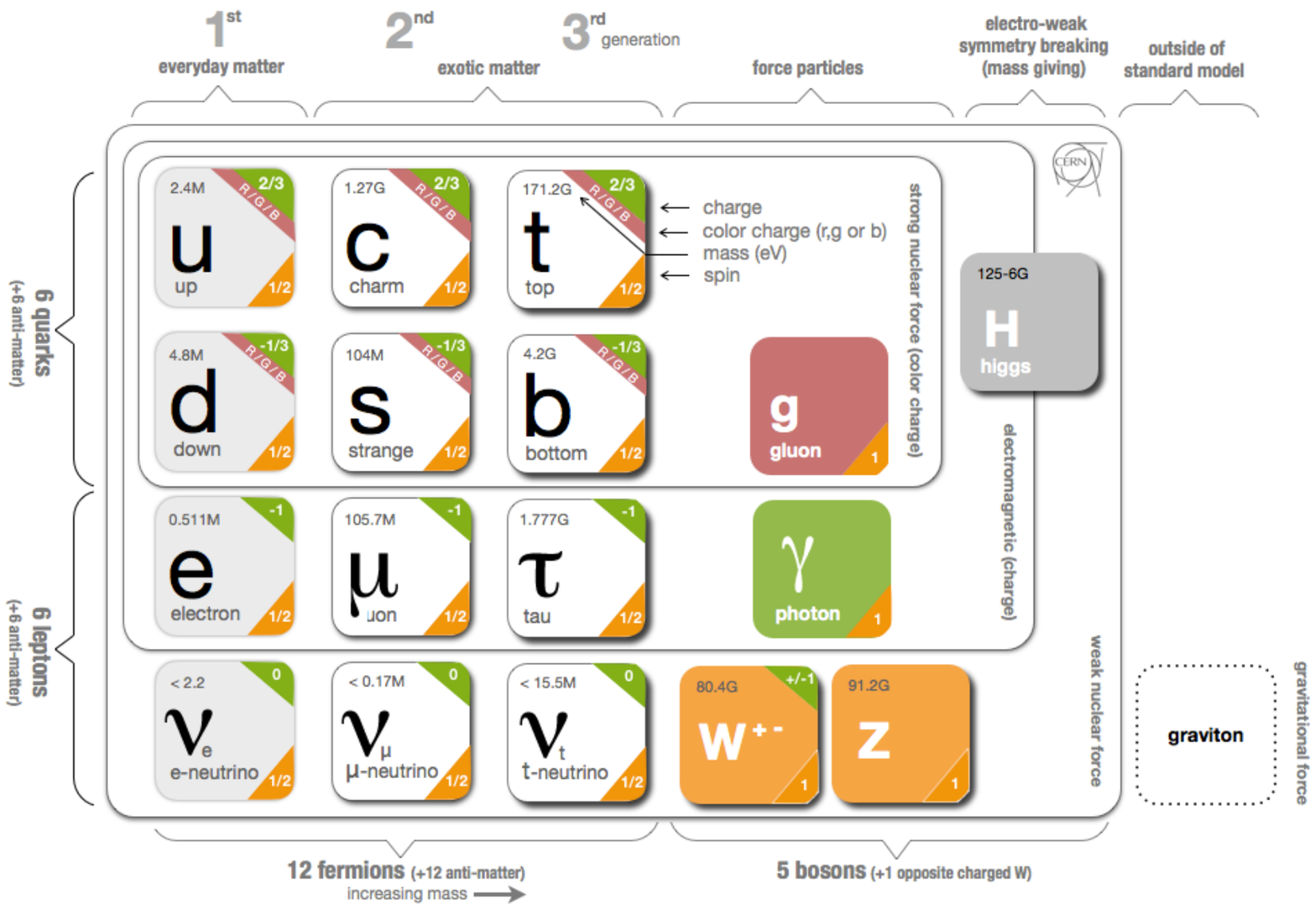
- A lot of interesting physics results published.

Significant achievements



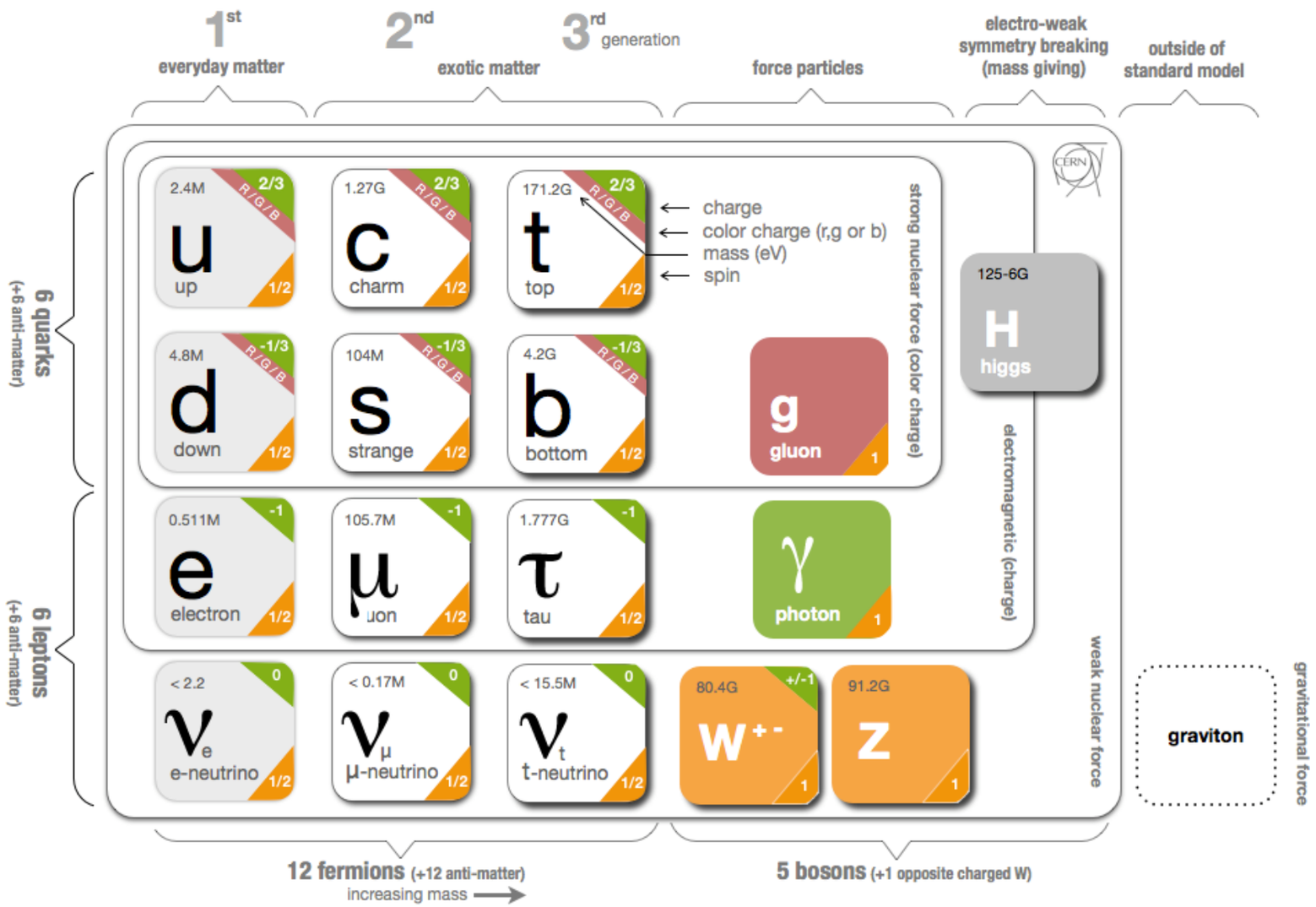
- A lot of interesting physics results published.
- Still at the young age of the LHC, very rich phenomena to explore with the LHC data.
- Only 5% expected collision data collected compared to whole lifetime of the LHC.

The Higgs boson

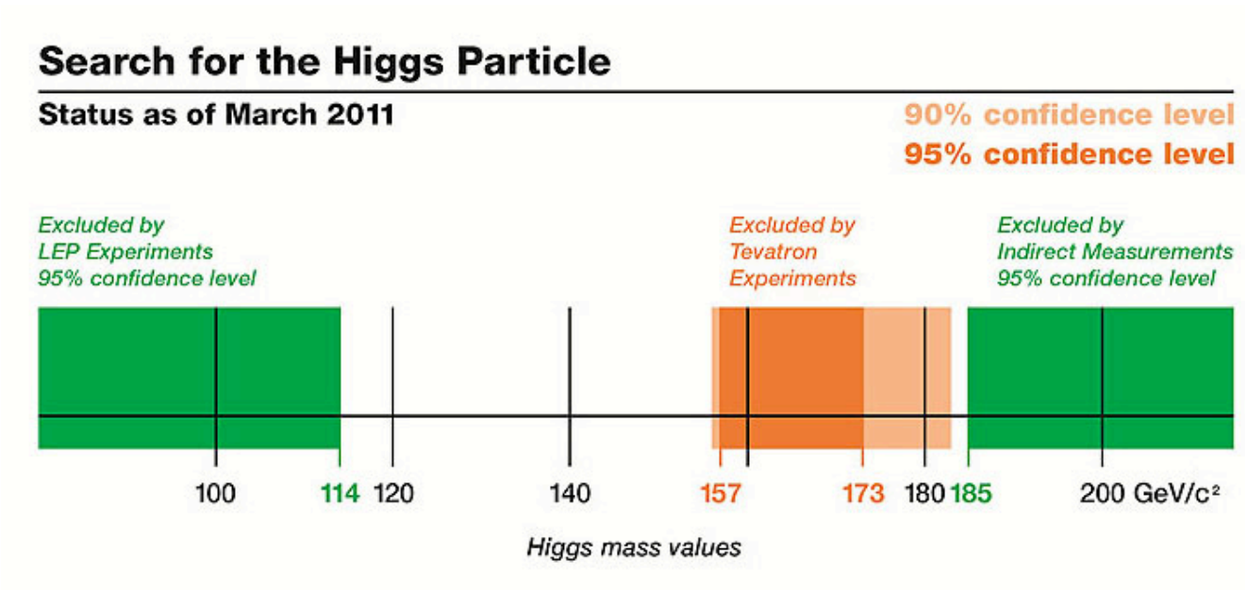


- The SM is a successful model of the particle physics.
- Higgs boson play an unique role in the SM of giving mass to other particles via EW SSB.

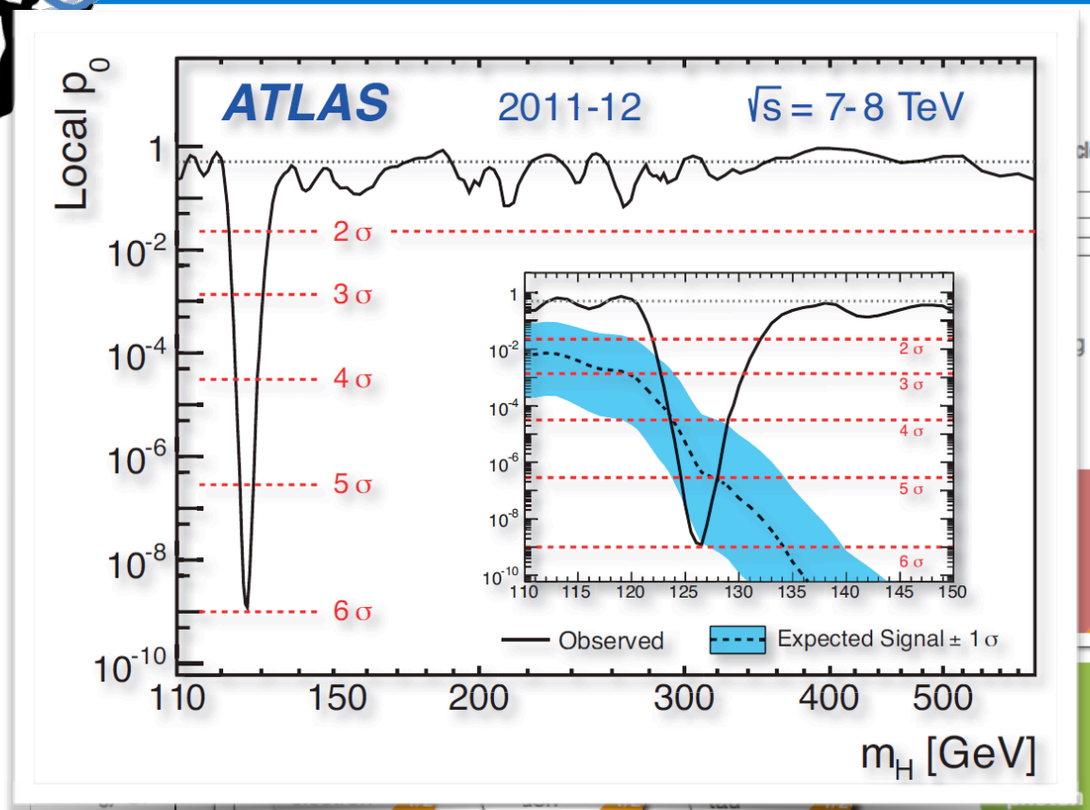
The Higgs boson

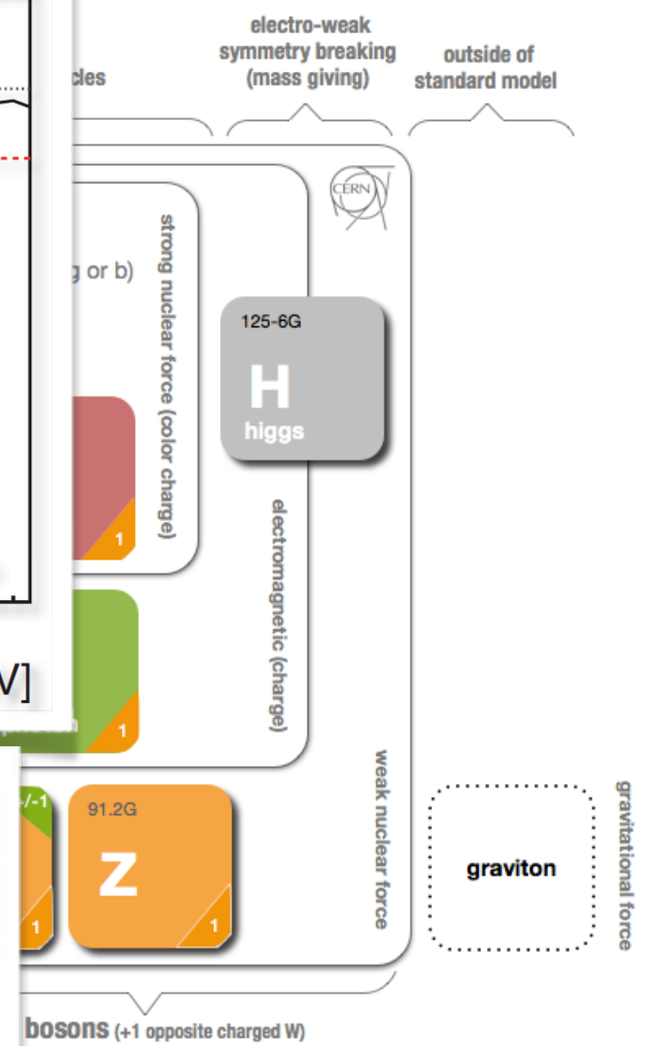


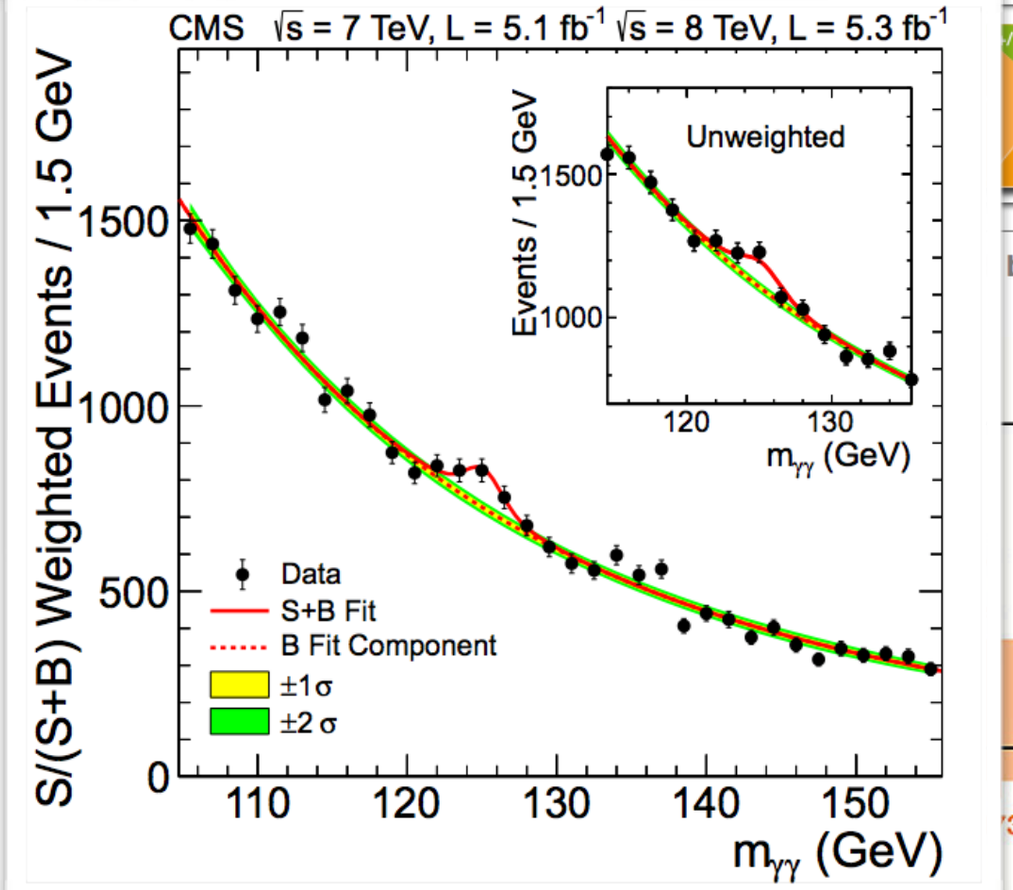
- The SM is a successful model of the particle physics.
- Higgs boson play an unique role in the SM of giving mass to other particles via EW SSB.
- Long effort to search for the Higgs boson since it was predicted in 1964.

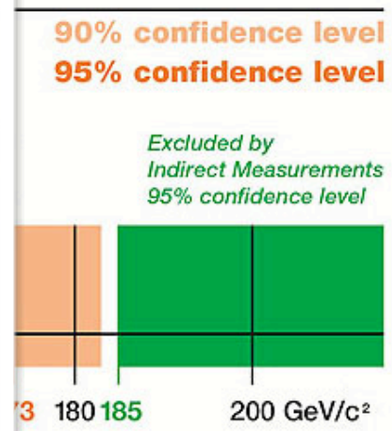


The Higgs boson



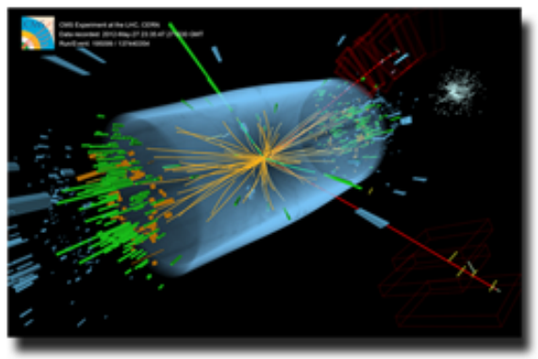


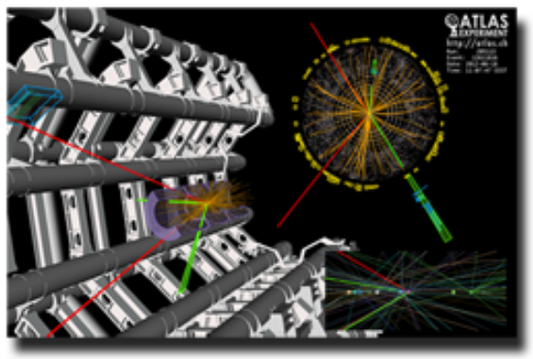


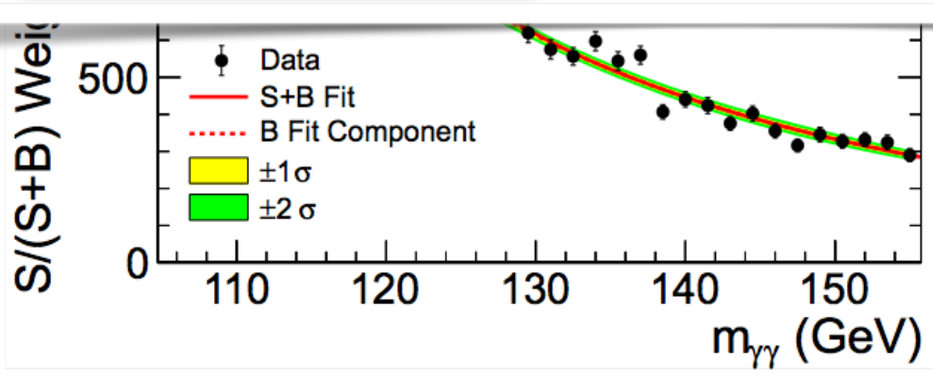


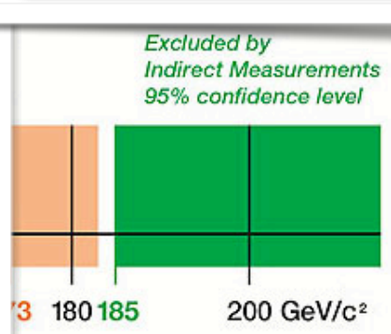
- The SM is a successful model of the particle physics.
- Higgs boson play an unique role in the SM of giving mass to other particles via EW SSB.
- Long effort to search for the Higgs boson since it was predicted in 1964.
- Was discovered by ATLAS and CMS in 2012 with bosonic decay channels.

The Higgs boson





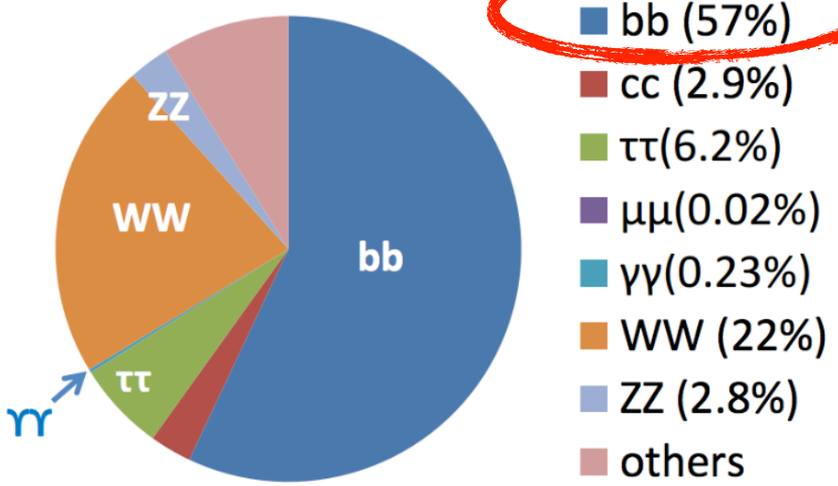




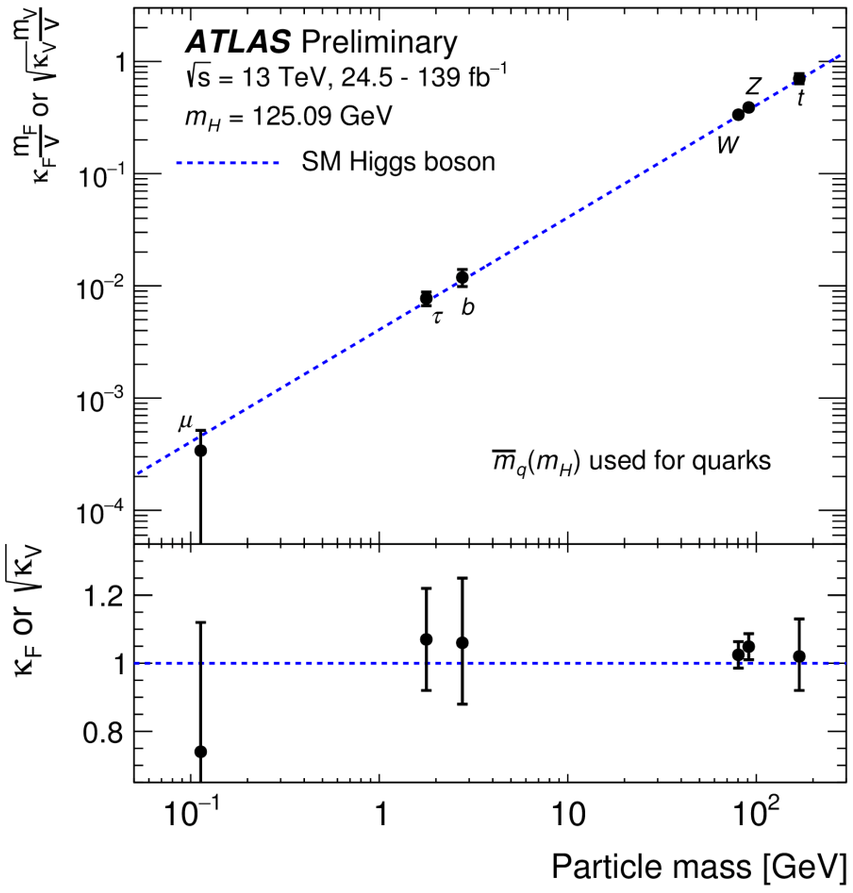
- The SM is a successful model of the particle physics.
- Higgs boson play an unique role in the SM of giving mass to other particles via EW SSB.
- Long effort to search for the Higgs boson since it was predicted in 1964.
- Was discovered by ATLAS and CMS in 2012 with bosonic decay channels.
- Peter Higgs and Francois Englert were awarded the Noble Prize for Physics in 2013.

Beyond the discovery of the Higgs boson

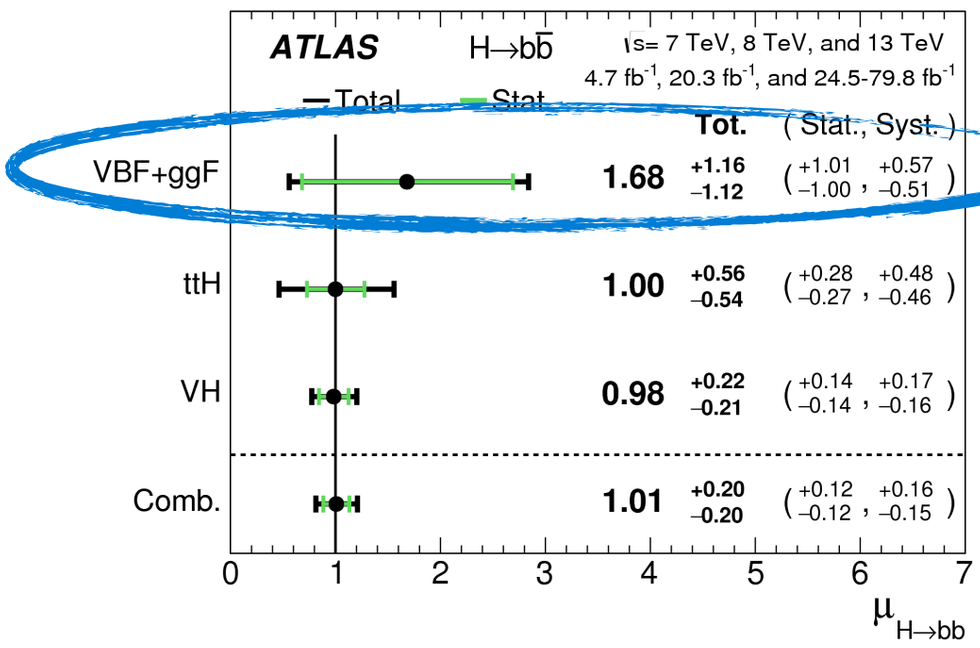
The decay BRs for 125 GeV Higgs boson.



Measure the coupling of the Higgs boson to SM particles.

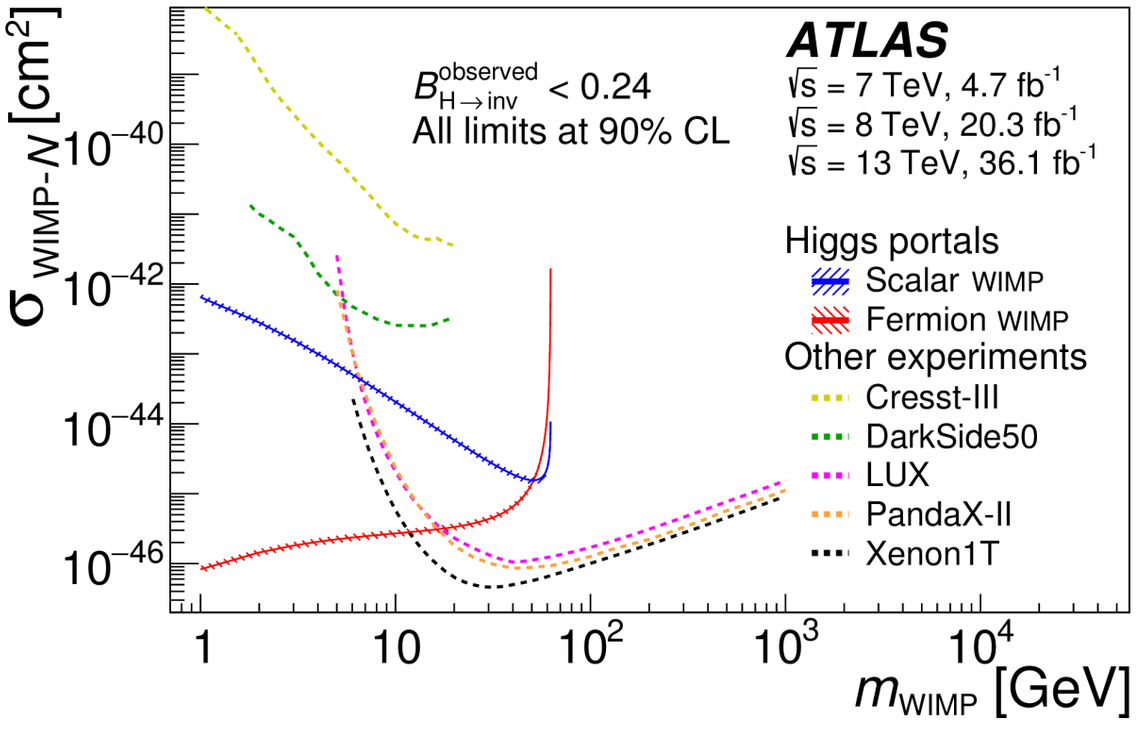


Discovery of H→bb decay channel (highlight of breakthrough by APS in 2018).



I am working on VBF channel.
Now we have about 3σ significance for VBF only.

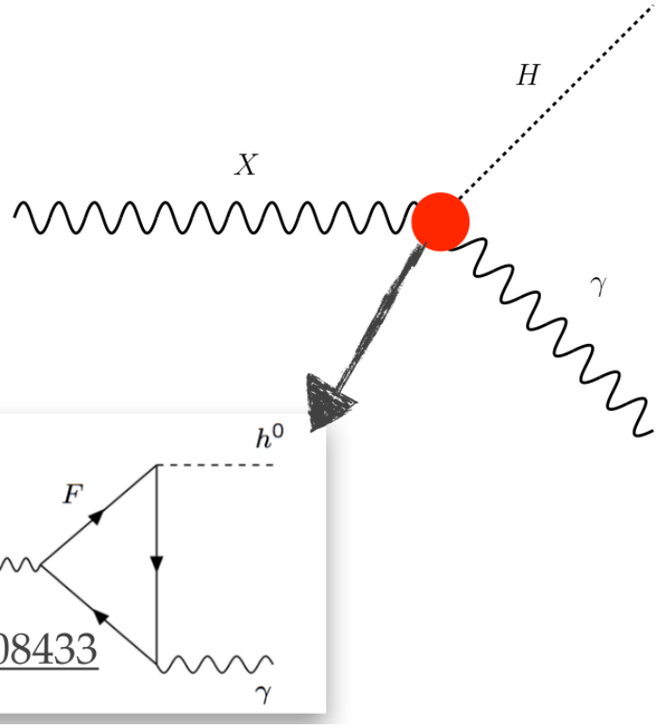
Using the Higgs boson as a portal to detecting dark matter.

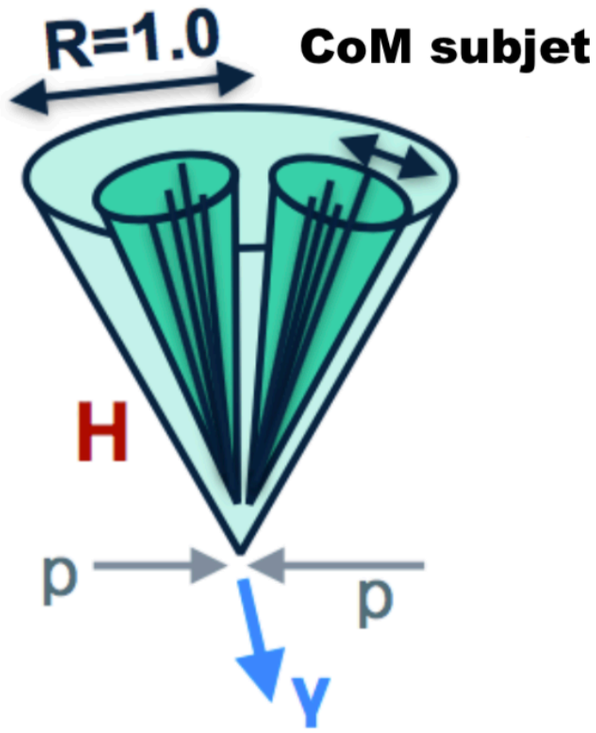


I worked on ZH channel for invisible Higgs boson searches.

Search for heavy resonance with $H+\gamma$

- Search for heavy resonances decaying to H+photon final states with H→bb.
- Use Higgs boson as a portal to explore high energy scale physics.
- Aim to detect new coupling effects on the H+photon interaction.



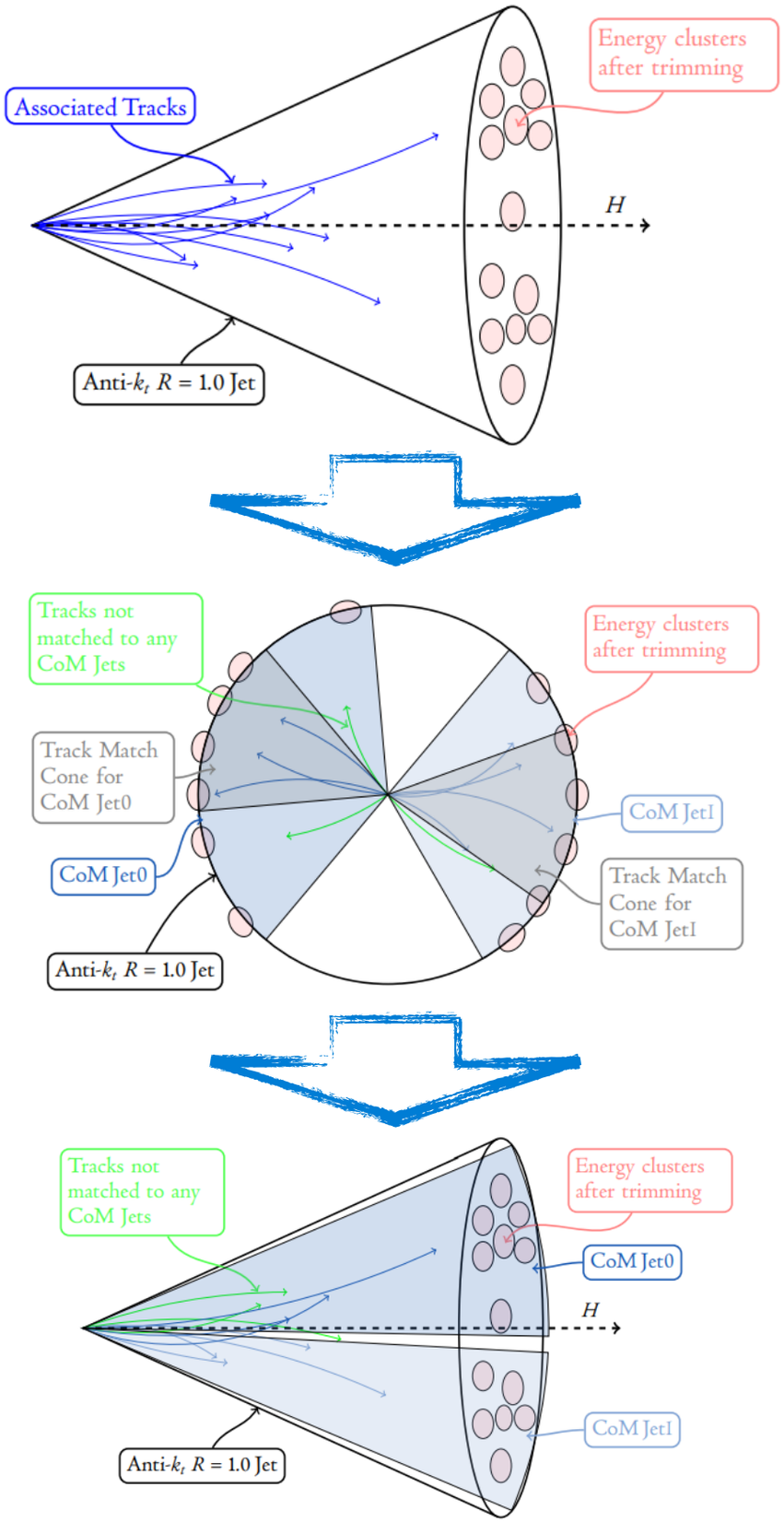


- Team members from several institutes
  - ✓ IHEP, SJTU
  - ✓ Iowa State University, Duke University

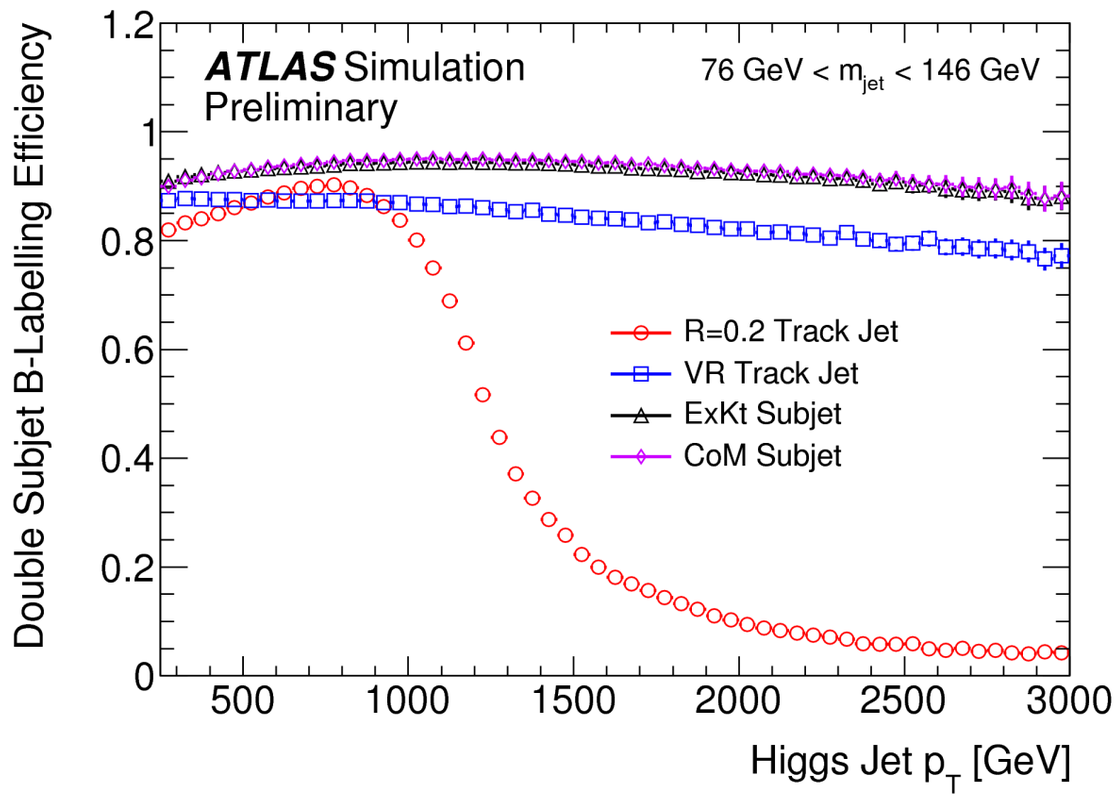
- Explore the region of a boosted Higgs boson.
  - ✓ Advantage of hadron collider.
    - ➡ Could explore new physics at TeV scale.
  - ✓ Dense environment. Challenge for jet reconstruction.
    - ➡ All final state particles merge together.
    - ➡ Difficult to clearly separate two b-quark jets.
  - ✓ Introduced new b-quark jets reconstruction method (CoM tagger) to improve performance.

PhysRevLett.125.251802

Center-of-mass tagger



- Center-of-mass (CoM) tagger
  - ✓ Based on a phenomenology paper of our ISU colleague (Phys. Rev. D **87**, 074007).
  - ✓ Firstly implemented this algorithm in ATLAS software.
  - ✓ Firstly used in an research paper.
  - ✓ Much better improvement compared to our original algorithm.



ATL-PHYS-PUB-2017-010

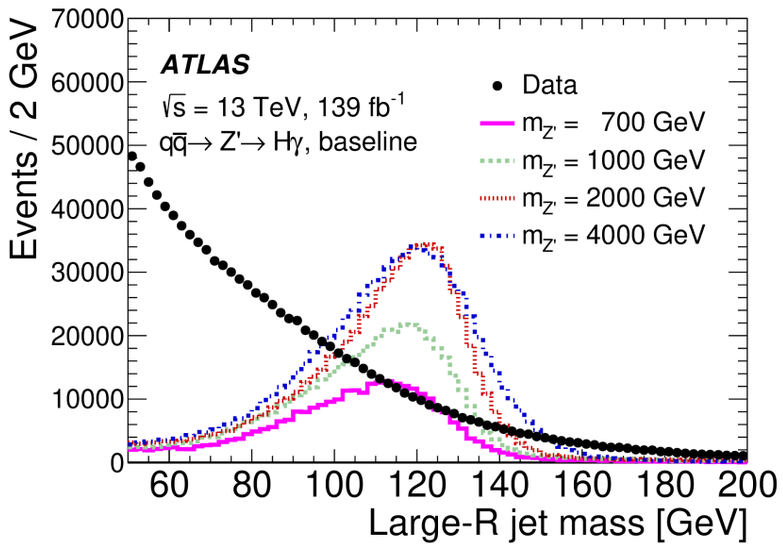
Optimization

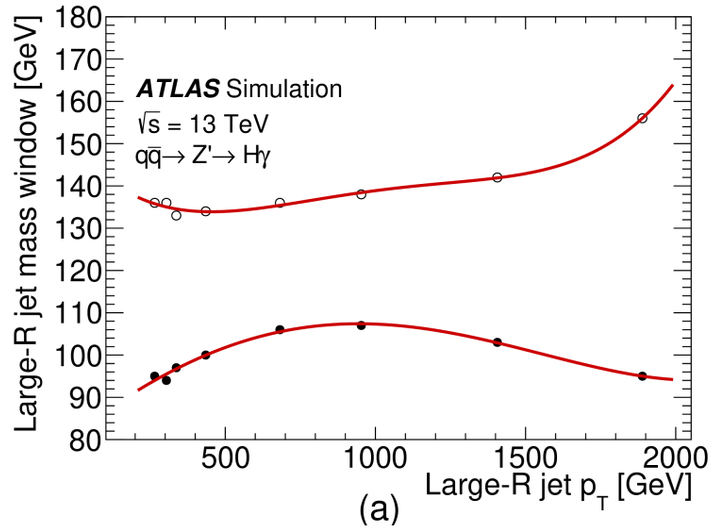
- Baseline selection
  - Photons
    - pT> 200 GeV, |η|<1.37
    - TighID and Tight isolation
  - Large-R jets
    - pT>200 GeV, |η|<2
    - 50 GeV<mJ<200 GeV

- Photon and jet pT are further optimized for various mass according to significance

$$\frac{\varepsilon}{\frac{a}{2}+\sqrt{B}}, a = 3$$

- Jet mass selection is also optimized with similar definition





Optimization

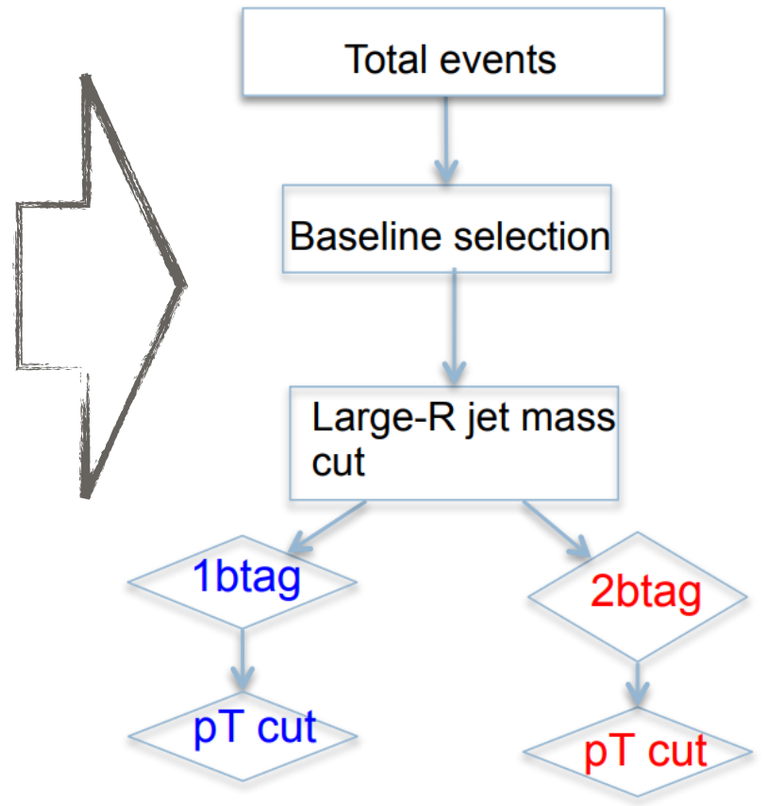
- Baseline selection
  - Photons
    - pT> 200 GeV, |η|<1.37
    - TighID and Tight isolation
  - Large-R jets
    - pT>200 GeV, |η|<2
    - 50 GeV<mJ<200 GeV

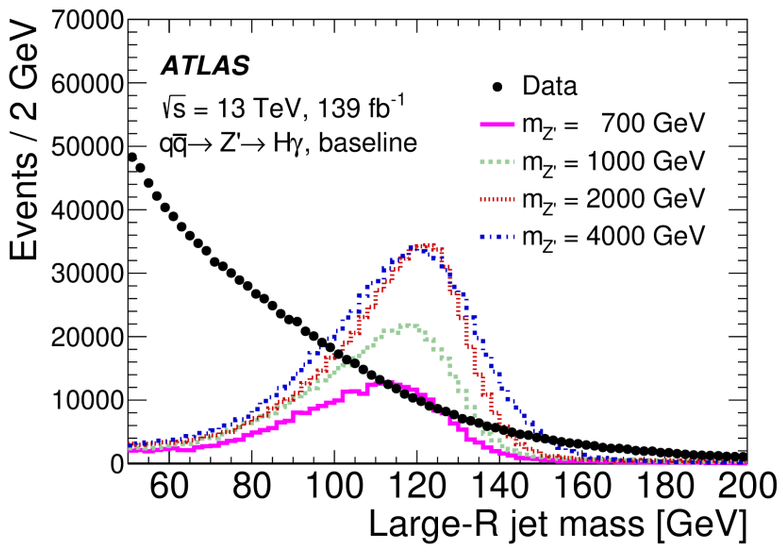
- Photon and jet pT are further optimized for various mass according to significance

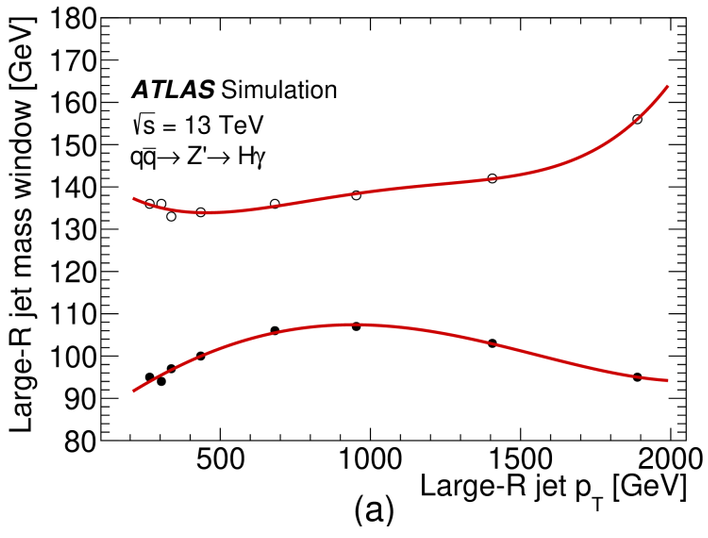
$$\frac{\varepsilon}{\frac{a}{2}+\sqrt{B}}, a = 3$$

- Jet mass selection is also optimized with similar definition

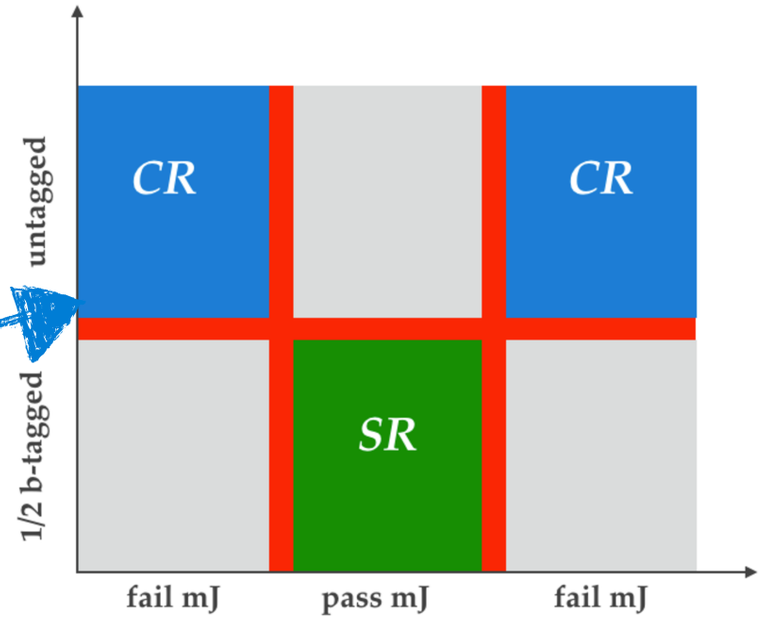
Categorization

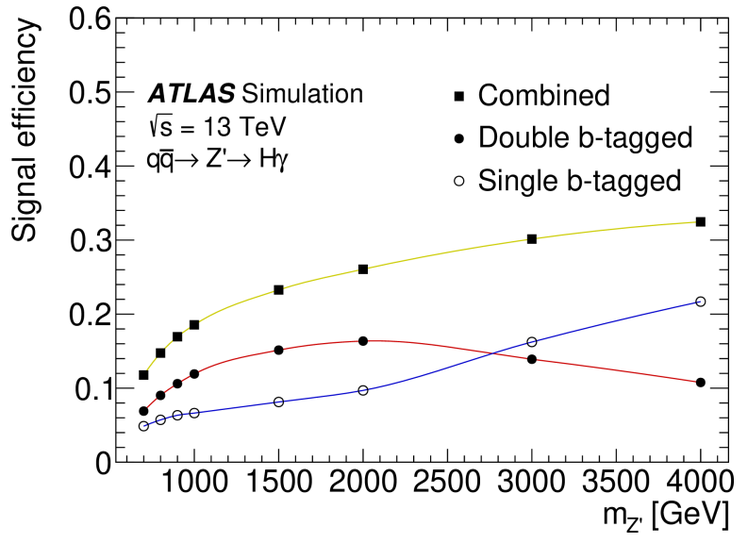




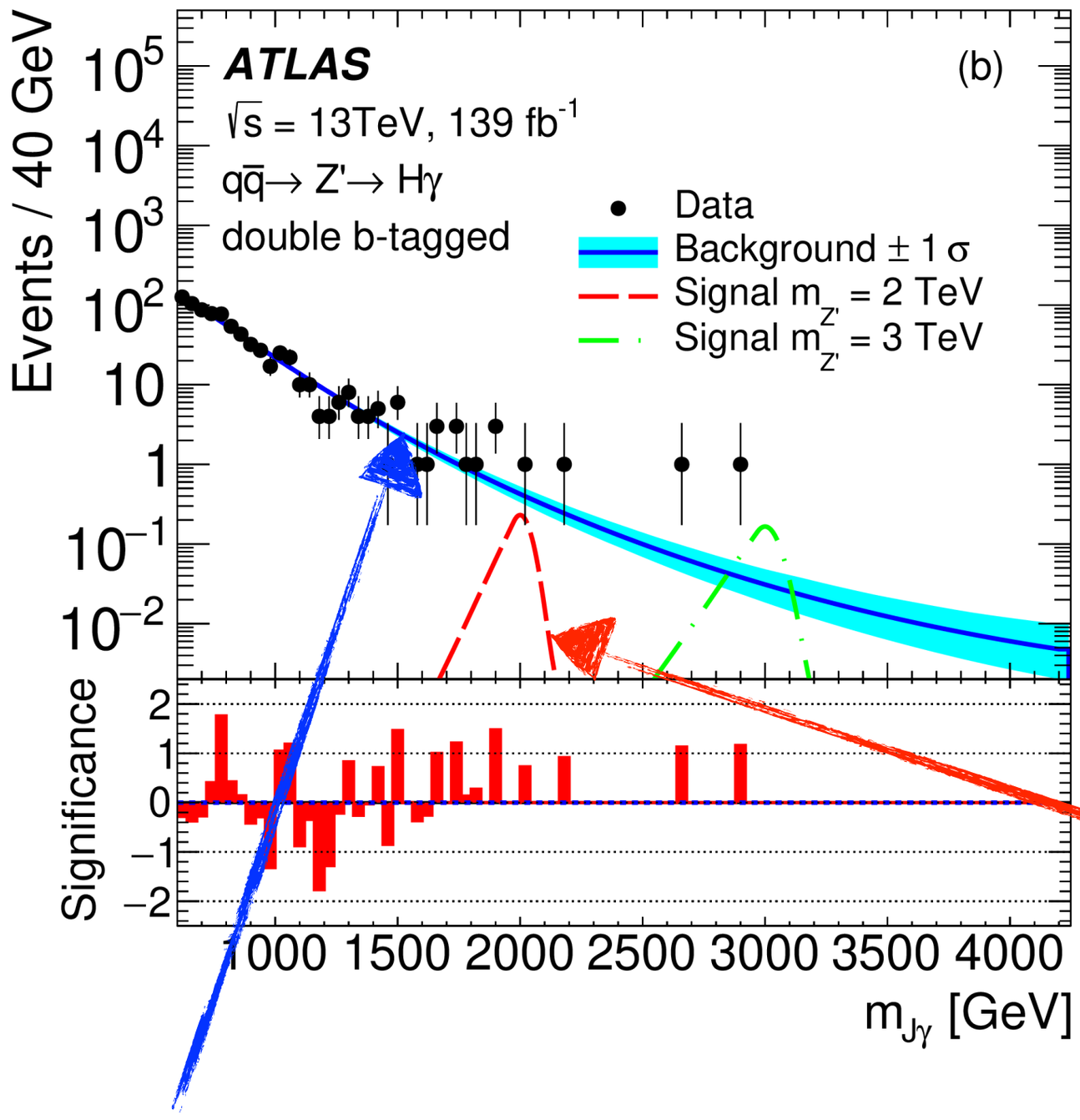


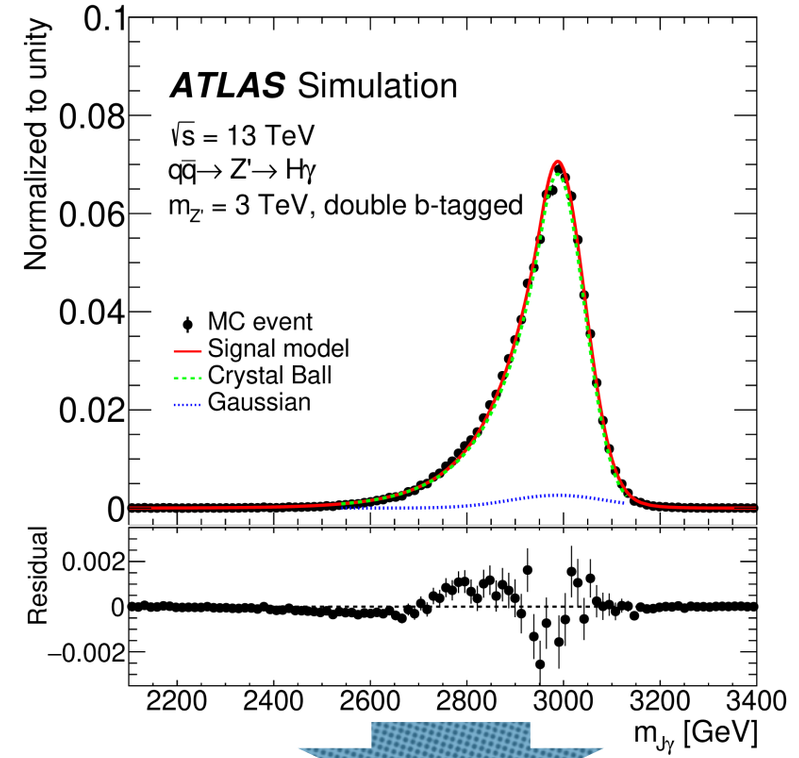
Control regions are defined for background studies

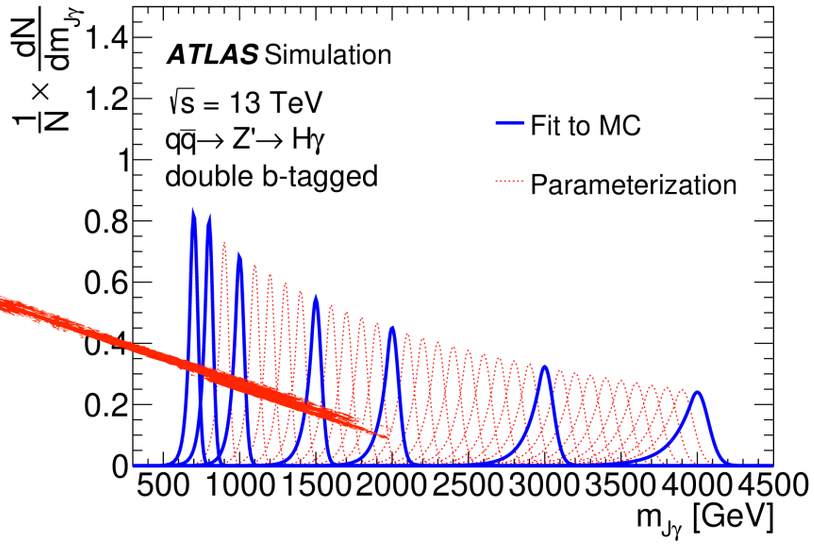




Results



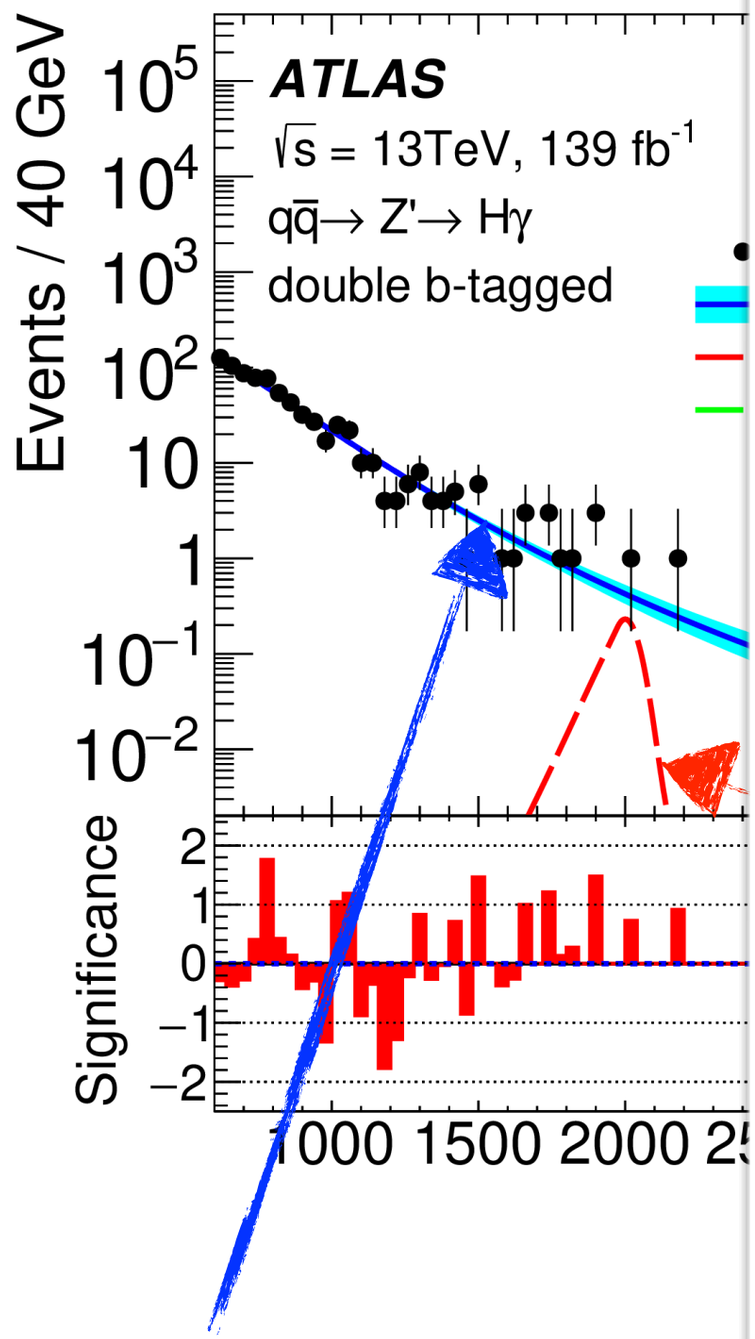


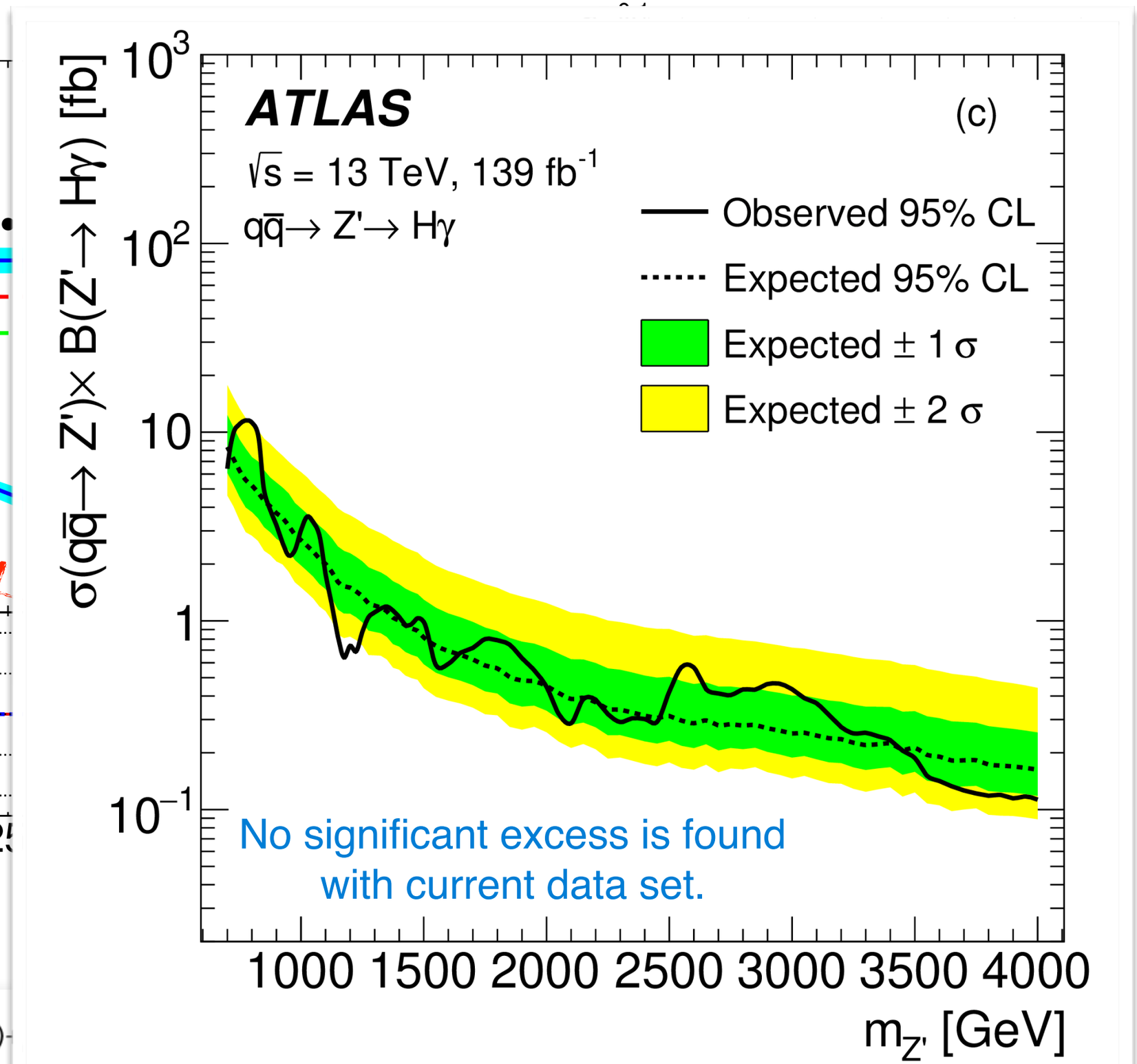


$$B(m_{J\gamma};p_i) = (1-x)^{p_1}\, x^{p_2+p_3\,\log(x)+p_4\,\log^2(x)+p_5\,\log^3(x)},\ x = m_{J\gamma}/\sqrt{s}$$

Signal and backgrounds are both modelled with analytic functions.

Results





$$B(m_{J\gamma}; p_i) = (1-x)^{p_1} x^{p_2+p_3 \log(x)}$$

analytic functions.

Summary

- The Large Hadron Collider play an important role for understanding the principle of the world.
  - ✓ Provide unique data to directly study the properties of elementary particles.
  - ✓ Up to now, the only machine can produce sizeable Higgs bosons.
    - ➡ To test the SM, we need precise properties measurements of the Higgs boson.
    - ➡ Higgs boson could be a key for new physics.
  - ✓ The LHC can also help to explore new phenomena at the TeV scale.
  - ✓ No significant hint for the new physics beyond the SM is found with current LHC data.
    - ➡ only a 5% fraction of expected luminosity for LHC.
    - ➡ Quite much room to improve with future data.

Keep looking like a child.
Be curious about the unknown.

Achievements

1. M.Li, Y.Fan, B.Liu et al, The performance of IHEP-NDL LGAD sensors after neutron irradiation, JINST, 16(08):P08053, 2021, https://iopscience.iop.org/article/10.1088/1748-0221/16/08/P08053, 期刊文章，重要贡献者
2. ATLAS Collaboration, Measurements of Higgs Bosons Decaying to Bottom Quarks from Vector Boson Fusion Production with the ATLAS Experiment at √s=13 TeV, Eur. Phys. J. C. 81 (2021) 537, https://link.springer.com/article/10.1140/epjc/s10052-021-09192-8, 期刊文章，重要贡献者
3. ATLAS Collaboration, Search for Higgs boson production in association with a high-energy photon via vector-boson fusion with decay into bottom quark pairs at √s=13 TeV with the ATLAS detector, JHEP 03 (2021) 268, https://link.springer.com/article/10.1007/JHEP03(2021)268, 期刊文章，主要贡献者，主要作者之一，文章撰稿人
4. ATLAS Collaboration, Search for heavy resonances decaying into a photon and a hadronically decaying Higgs boson in pp collisions at √s=13 TeV with the ATLAS detector, Phys. Rev. Lett. 125 (2020) 251802, 13 August 2020, https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.125.251802, 期刊文章，主要贡献者，主要作者之一，该物理分析的联系人
5. ATLAS Collaboration, Measurement of ZZ production in the llνν nal state with the ATLAS detector in pp collisions at √s=13 TeV, JHEP 10 (2019) 127, https://link.springer.com/article/10.1007/JHEP10(2019)127, 期刊文章，主要贡献者，主要作者之一
6. L.Shi, Z.Liang, B.Liu,and Z.He,Constraining the anomalous Higgs boson coupling in H+γ production, Chin. Phys. C, 43(4):043001, 2019, https://iopscience.iop.org/article/10.1088/1674-1137/43/4/043001, 期刊文章，重要贡献者
7. ATLAS Collaboration, Observation of $H \to b\bar{b}$ decays and V H production with the ATLAS detector, Phys. Lett. B 786 (2018) 59, https://www.sciencedirect.com/science/article/pii/S0370269318307056, 期刊文章，重要贡献者
8. ATLAS Collaboration, Search for Higgs bosons produced via vector-boson fusion and decaying into bottom quark pairs in √s=13 TeV pp collisions with the ATLAS detector, Phys. Rev. D 98 (2018) 052003, https://link.aps.org/doi/10.1103/PhysRevD.98.052003, 期刊文章，重要贡献者
9. ATLAS Collaboration, Search for heavy resonances decaying to a photon and a hadronically decaying Z/W /H boson in pp collisions at √s=13 TeV with the ATLAS detector, Phys. Rev. D 98 (2018) 032015, https://link.aps.org/doi/10.1103/PhysRevD.98.032015, 期刊文章，主要贡献者，主要作者之一
10. ATLAS Collaboration, Search for an invisibly decaying Higgs boson or dark matter candidates produced in association with a Z boson in pp collisions at √s= 13 TeV with the ATLAS detector, Phys. Lett. B 776 (2018) 318, https://www.sciencedirect.com/science/article/pii/S0370269317309413, 期刊论文，主要贡献者，主要作者之一
11. ATLAS Collaboration, Search for heavy ZZ resonances in the $l^+l^-l^+l^-$ and $l^+l^-\nu\nu^-$ final states using proton proton collisions at √s=13 TeV with the ATLAS detector, Eur. Phys. J. C 78 (2018) 293, https://link.springer.com/article/10.1140/epjc/s10052-018-5686-3, 期刊论文，主要贡献者，主要作者之一

国家自然科学基金青年项目，“利用具有高能量的希格斯玻色子寻找超出标准模型的新物理”，主持，2022–2024