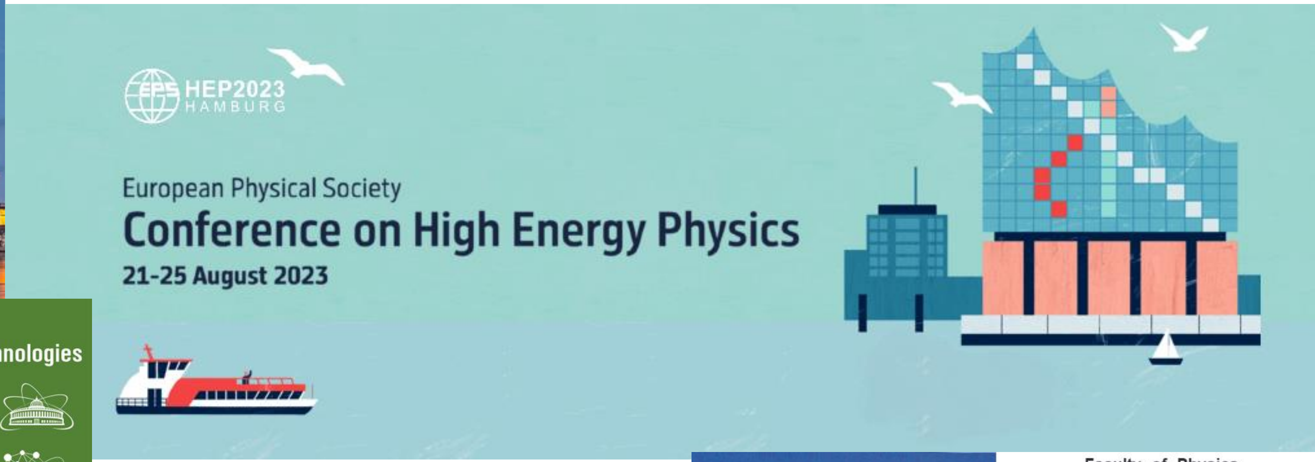


Обзор

результатов экспериментов Большого адронного

коллайдера по материалам летних конференций 2023г.

СЕМИНАР ОЭФВЭ

ПРОФ. Л.Н. СМИРНОВА

5 ОКТЯБРЯ 2023

Летние конференции по физики высоких энергий июнь-август 2023

21 Ломоносовская конференция по физике элементарных частиц , 24-30 августа 2023, Москва, МГУ

17 конференций

EPS-HEP2023 | Start Date: 21 Aug 2023 at Hamburg, Germany | 71 talks.

Vietnam2023 | Start Date: 06 Aug 2023 at Quy Nhon, Vietnam | 10 talks.

BOOST2023 | Start Date: 31 Jul 2023 at LBL, Berkeley, California, USA | 13 talks.

SUSY 2023 | Start Date: 17 Jul 2023 at Southampton, UK, United Kingdom | 19 talks

LP2023 | Start Date: 17 Jul 2023 at Melbourne, Australia | 34 talks

HHHWS2023 | Start Date: 14 Jul 2023 at Dubrovnik, Croatia | 4 talks.

SM@LHC2023 | Start Date: 10 Jul 2023 at Fermilab, Batavia, IL, USA | 10 talks.

ICNFP2023 | Start Date: 10 Jul 2023 at Kolymbari, Crete, Greece | 29 talks

GRID2023 | Start Date: 03 Jul 2023 at JINR, Dubna, Russia | 2 talks.

WIN2023 | Start Date: 03 Jul 2023 at Zhuhai, Guangdong Province, China | 6 talks

LundJetPlane2023 | Start Date: 03 Jul 2023 at CERN, Geneva, Switzerland | 2 talks.

Beauty2023 | Start Date: 03 Jul 2023 at Clermont-Ferrand, France | 6 talks

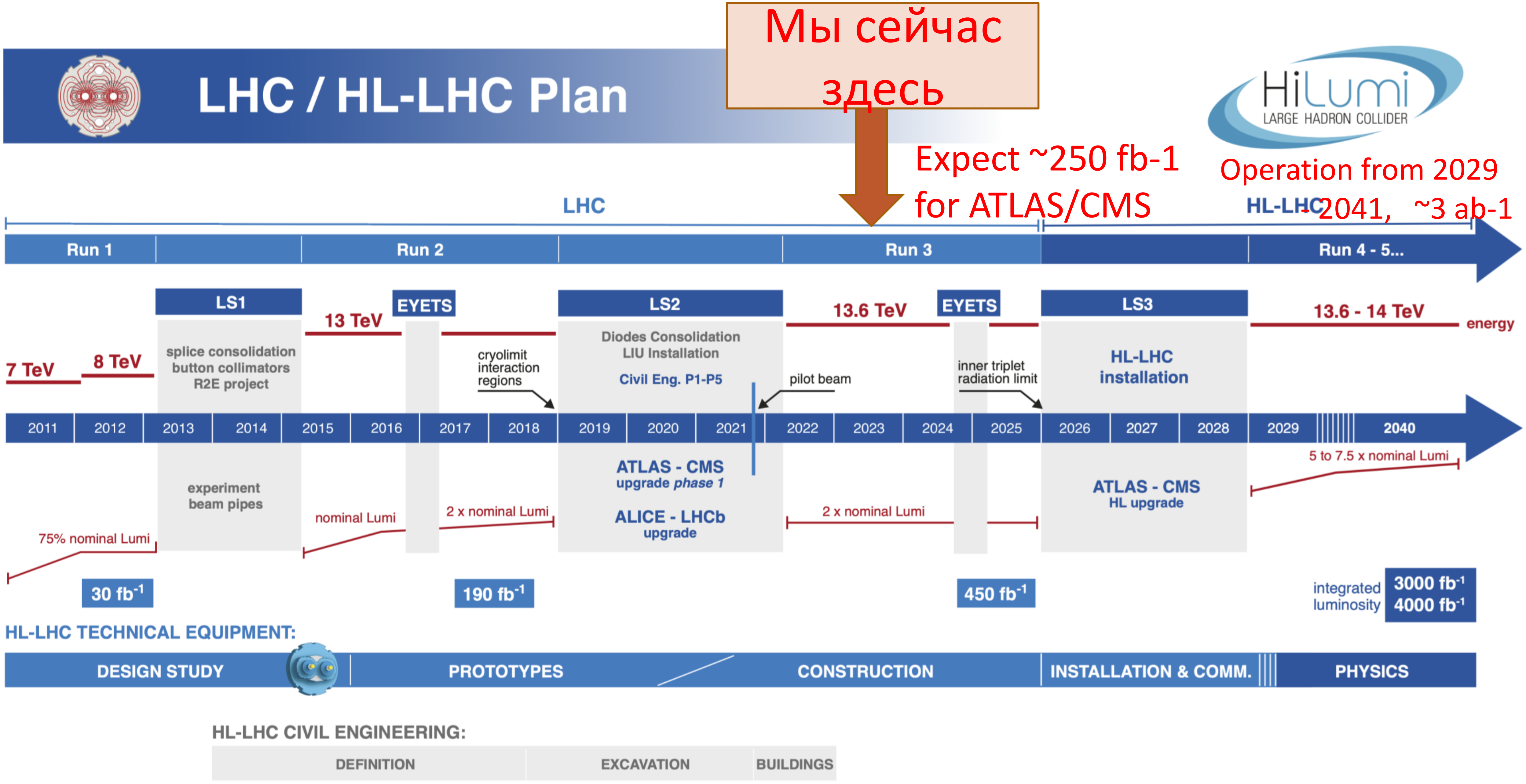
MOCAST2023 | Start Date: 28 Jun 2023 at Athens, Greece | 1 talks.

iWorid2023 | Start Date: 25 Jun 2023 at Oslo science park, Norway | 3 talks.

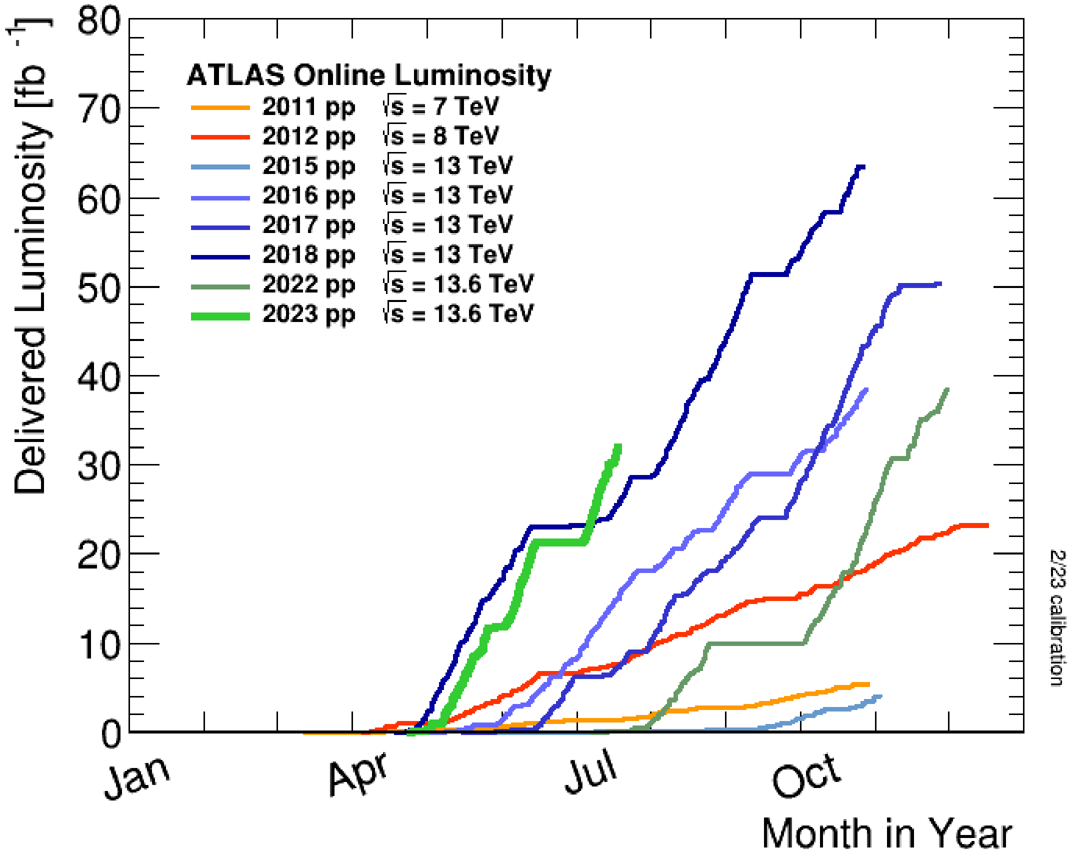
CLFV2023 | Start Date: 20 Jun 2023 at Heidelberg, Germany | 1 talks

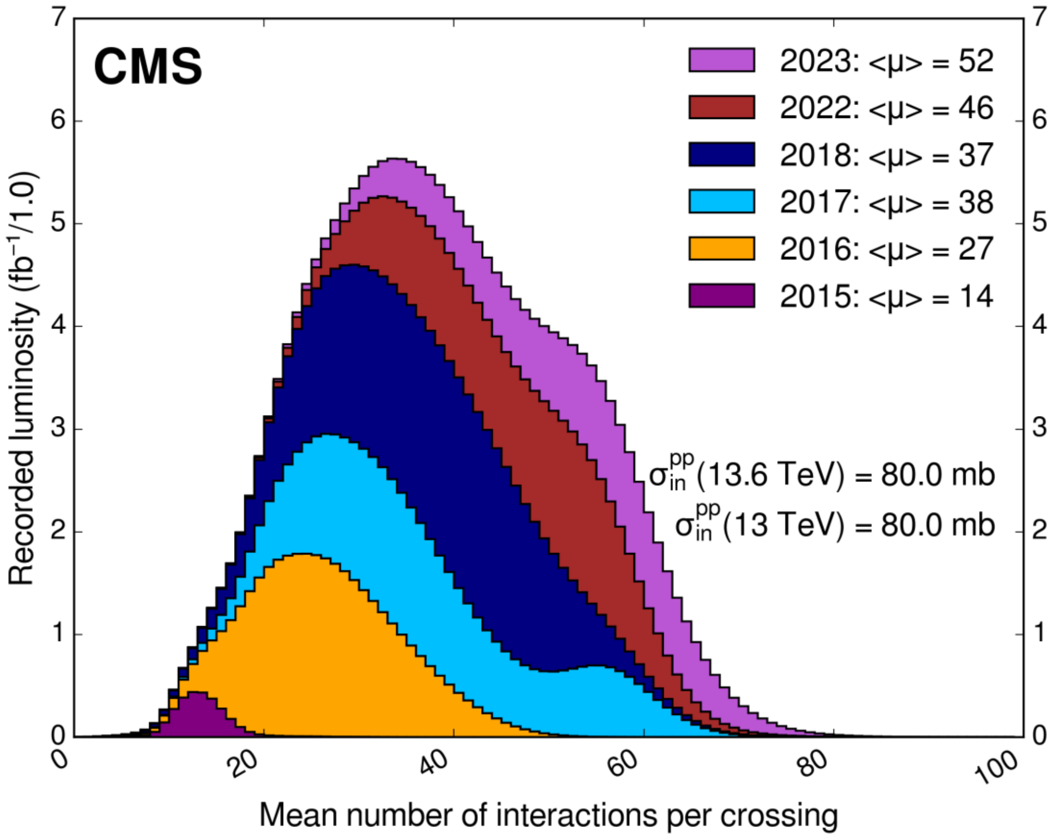
HADRON 2023 | Start Date: 05 Jun 2023 at Genova, Italy | 3 talks.

График работы Большого адронного коллайдера



Параметры соударений пучков протонов





Направления работ на БАК

Significant upgrades towards HL-LHC for both machine and detectors (esp. triggers)

Expect ~250 fb^{-1} for ATLAS/CMS, 25-30 fb^{-1} for LHCb and 7 nb^{-1} PbPb for ALICE

More than doubling the Run-2 dataset

Injector/LHC improvements (e.g. lumi-levelling)

New detector capabilities bring new possibilities

Starting to see first results from Run3 data

HL-LHC upgrade is coming (Run-4 ++)

Operation from 2029-2041, ~3 ab-1

Major upgrades of ATLAS+CMS for Run-4

LHCb and ALICE scoping their phase2b upgrades for Run-5 (2035 onwards)

Challenges everywhere – data analysis, operations and construction of new detectors

GRID 2023

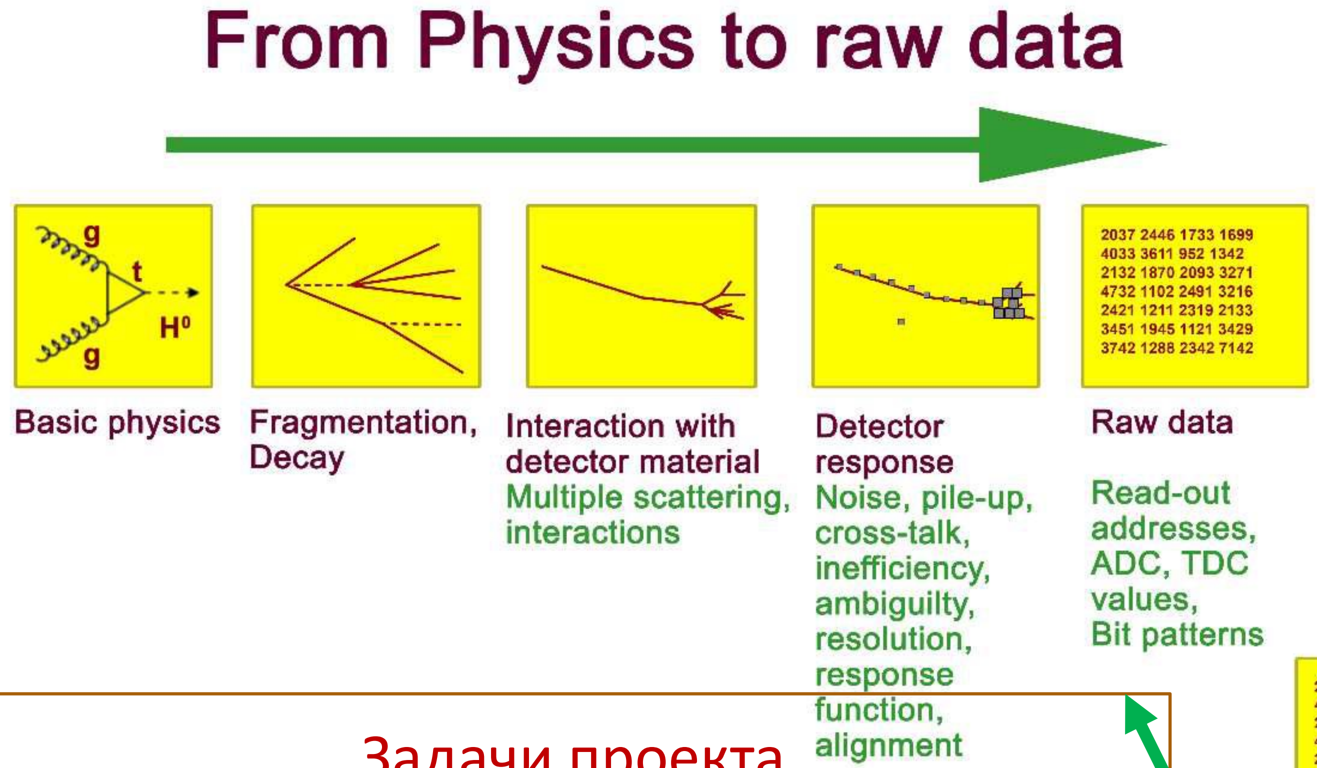
“GOVORUN” supercomputer for JINR tasks

10th International Conference "Distributed Computing and Grid Technologies in Science and Education" (GRID'2023)
3–7 Jul 2023

D.V. Podgainy
Meshcheryakov Laboratory of Information Technologies

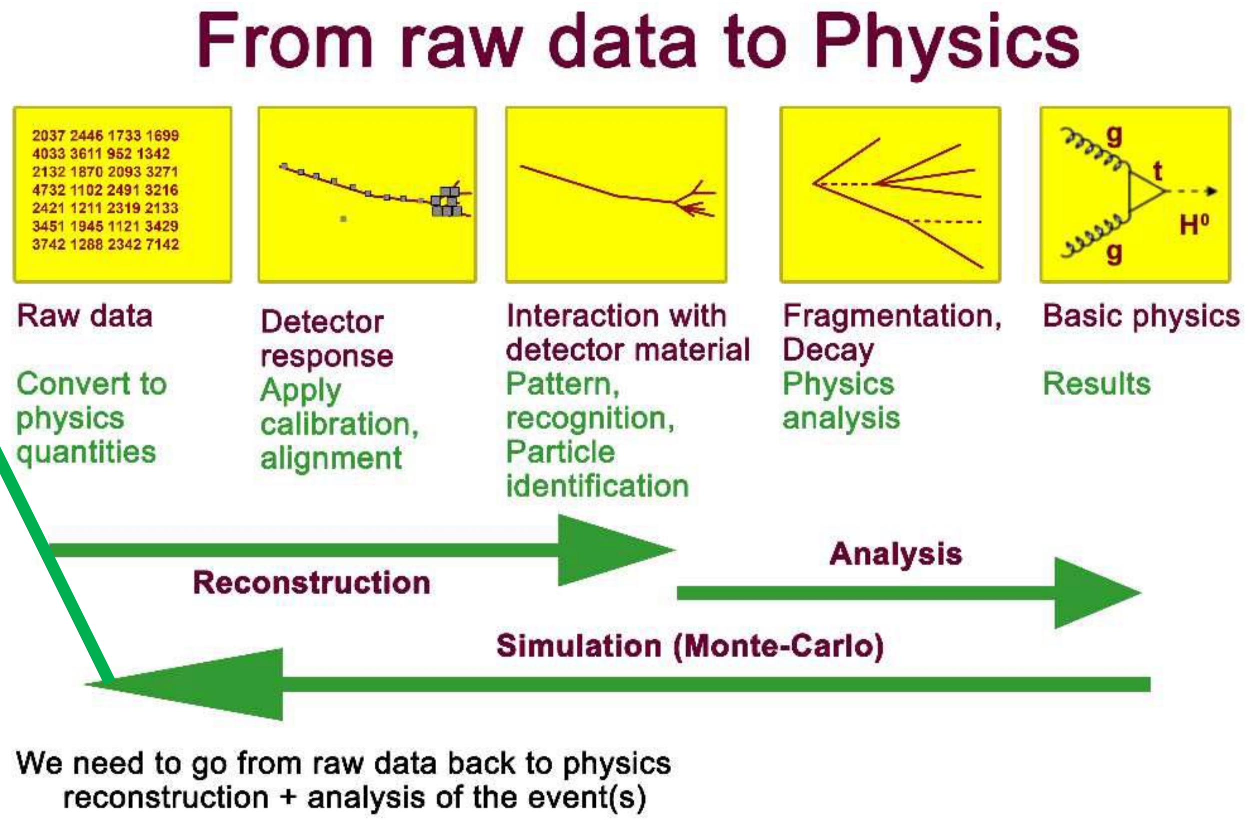
Quantum polygon

Потоки данных в экспериментах физики высоких энергий (пример проекта НИКА)



Задачи проекта

1. Необходимо обеспечить скорость обработки данных от «сырых» данных, или первичных, к реконструкции событий и физического анализа
2. Обеспечить хранение и доступ большого объема данных



The resources of the “Govorun” supercomputer are used by scientific groups from all the Laboratories of the Institute within 25 themes of the JINR Topical Plan for solving a wide range of tasks in the field of theoretical physics, as well as for the modeling and processing of experimental data.
Research results obtained using the supercomputer resources are presented in 260 publications.

Using the results obtained at the Govorun SC, 2 publications were prepared in Nature Physics:

- M. Kircher … , O. Chuluunbaatar et al. Kinematically complete experimental study of Compton scattering at helium atoms near the threshold. Vol. 16. № 4. Pp. 756-760
- BM@N Collaboration. Unperturbed inverse kinematics nucleon knockout measurements with a 48 GeV/c carbon beam. Vol. 17. Pp. 693-699

ПРИМЕР: Программа докладов 6.07.2023 GRID2023

Artificial Neural Networks in High Energy Physics data processing (succinct survey) and probable future development Andrey Shevel

Dr Dmitry Namiot

On Certification of Artificial Intelligence Systems

Alexey Stadnik

Исследование влияния фильтрации негативных эффектов погодных явлений на детекцию объектов

Denis Karachev

Использование признаков скрытого пространства диффузионных нейросетей в задаче смешивания изображений.

Evgeniy Stepanov

On Traffic Routing in Network Powered by Computing Environment: ECMP vs UCMP vs Multi-Agent MAROH

Aleksandr Bugay

Mathematical Modeling and Computing in Radiation Biology

Marko Ćosić

Classical patterns in the quantum rainbow channeling of high energy electrons

sergey ulyanov

Квантовая ИТ- инженерия в задачах интеллектуального управления физическими системами: физические и информационные ограничения

Программа первого дня (lomcon.ru)

D.Grigoriev (Budker Inst. of Nucl. Phys.) Status of the COMET experiment P.Pakhlov (Higher School of Economics) Hot topic from Belle and Belle II

H.B.Li (IHEP, CAS)Precision hyperon physics at BESIII

I.Bozovic Jelisavcic (Univ. of Belgrade) Higgs physics at future e+e- colliders

A.Starobinsky (Landau Inst.) Adding baryogenesis to minimal viable inflationary models

K.Dimopoulos (Lancaster Univ.) Cosmic inflation and dark energy (M.Giammarchi (INFN, Milan) Antimatter gravitation and fundamental laws M.Rebelo (CFTP/IST, Univ. of Lisbon) Aspects of models with vector-like singlet quarks

W.Wang (Sun Yat-sen Univ.) The PandaX experiment and its latest results (S.Gariazzo (INFN, Turin) Neutrino masses in cosmology Sh.Udo (Kanagawa Univ.) Recent results and status of TA/TALE/TAx4 experiment

I.Denisenko (JINR) SPD experiment at JINR

V.Riabov (NRC «Kurchatov Inst.» - PNPI) Status and preparations for the first physics with the MPD

The topics of the 52th ISMD in Gyöngyös, Hungary will include the followings:

- Collectivity in high energy collisions: jets, flows, ...
- Cosmic ray and astroparticle physics
- Femtoscopy
- Forward physics: Diffraction, Odderon and Pomeron
- Hadronic final states in high pT interactions
- Multiparticle correlations and fluctuations
- Proton structure, small-x and large-x physics
- Physics of X17 and other beyond standard model states
- Other important new developments in HEP
- Science outreach (in Tokaj on August 26, Saturday)

Названия секций EPS-HEP 2023

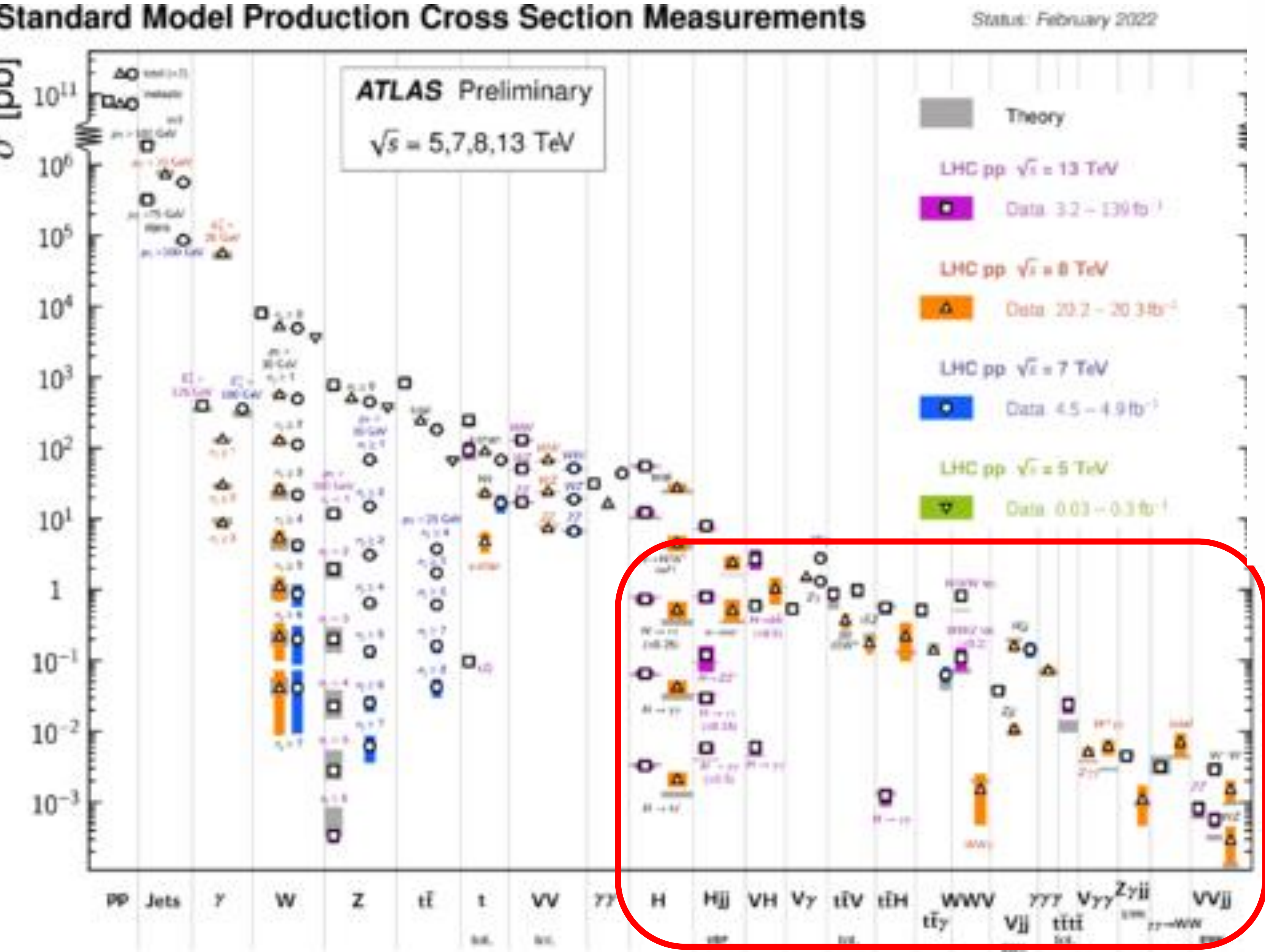
- Астрофизика и гравитационные волны
- Физика нейтрино
- КХД и адронная физика
- Физика ароматов и CP нарушение
- Физика бозона Хиггса
- Поиски новой физики
- Разработка детекторов и управление данными
- Соударения ультрарелятивистских ядер
- Темная материя
- Квантовая теория поля и теория струн
- Топ кварк и электрослабые взаимодействия
- Ускорители физики высоких энергий

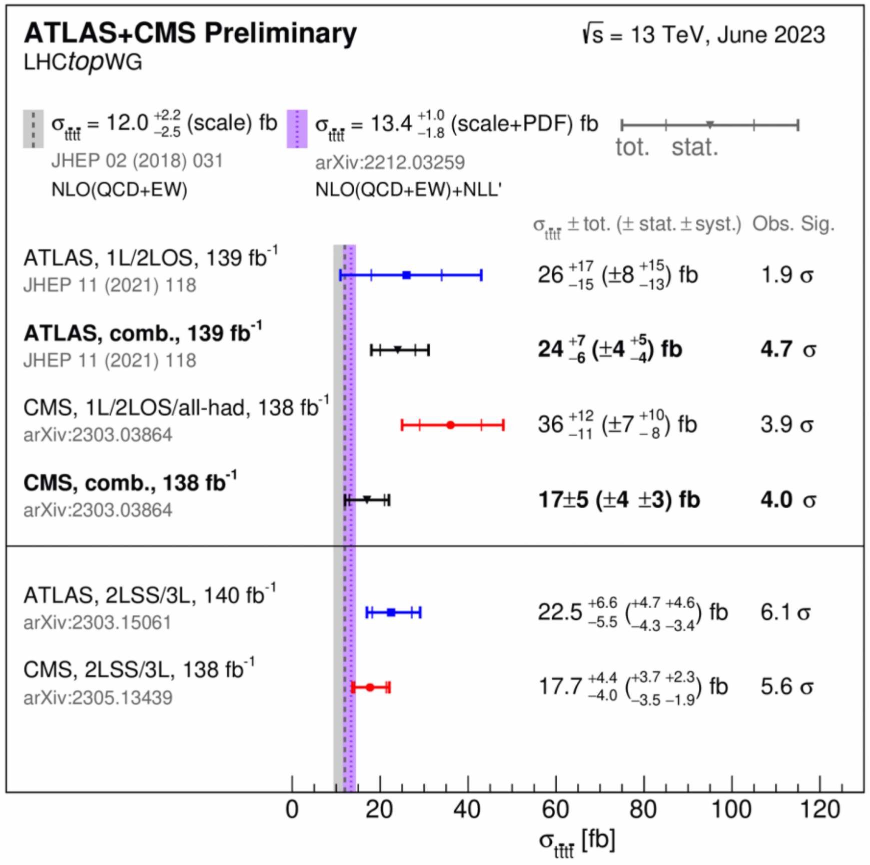
ATLAS results (P.Ferrari (Nikhef & Radboud University) ESP-HEP 2023

~40 new results released this summer:
most with well-understood Run-2 dataset,
first cross-section measurements at 13.6 TeV, incl. Higgs boson re-observation:

- New high-precision measurements of α_s, m(W), m(H), and various cross sections
- Observation and measurement of rare processes (4-top, VBS, etc) for deep tests of the SM
- Continued progress in exploring Higgs boson physics
- Broad search program benefiting from ever more sophisticated analyses

Проверка Стандартной модели

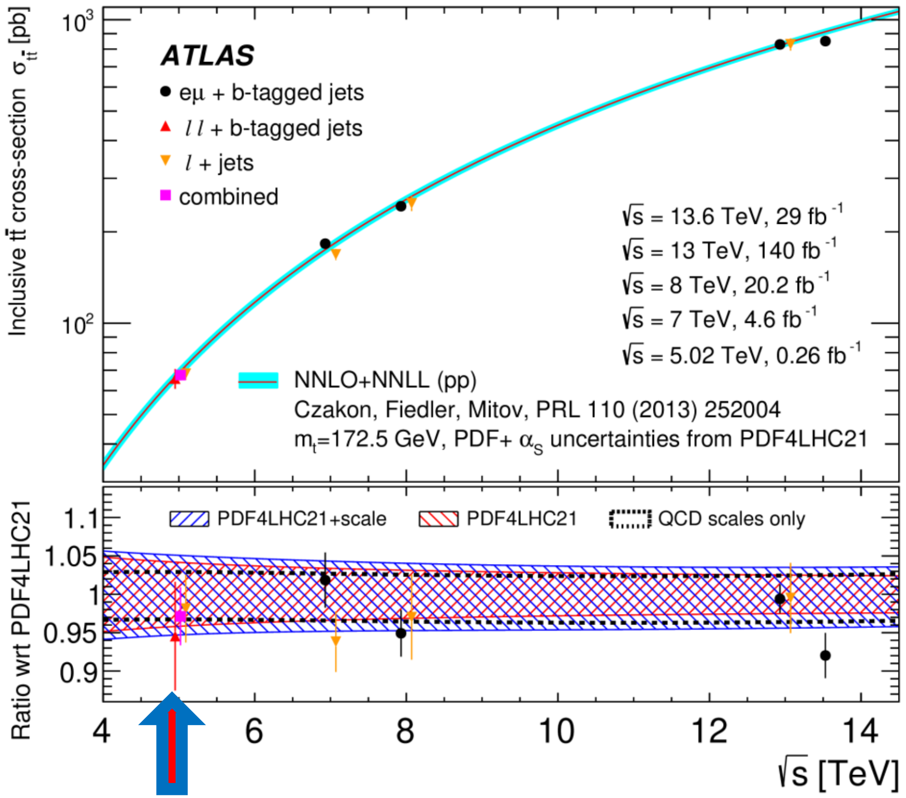




Recent SM “discoveries”. Observation: tttt (ATLAS, CMS), tγ (ATLAS), WWγ (CMS), Wγγ (ATLAS); Evidence: tWZ (CMS) ! Today’s rare processes; tomorrow’s precision

ATLAS

tt total. tt/Z. Z fiducial x-sections @13.6 TeV



arXiv:2308.09529

$$\sigma_{t\bar{t}} = 850 \pm 3(\text{stat.}) \pm 18(\text{syst.}) \pm 20(\text{lumi.})\ \text{pb},$$

$$R_{t\bar{t}/Z} = 1.145 \pm 0.003(\text{stat.}) \pm 0.021(\text{syst.}) \pm 0.002(\text{lumi.}),$$

$$\sigma^{\text{fid.}}_{Z\to\ell\ell} = 743.6 \pm 0.2\ (\text{stat.}) \pm 10.7\ (\text{syst.}) \pm 16.9\ (\text{lumi.})\ \text{pb}$$

New high-precision measurements of α_s, m(W), m(H), and various cross sections

Recent measurement @5 TeV, spans wide range of √s that allows to test √s dependence of gluon PDFs

Measured σ(tt) slightly lower than SM (within 1.5σ)
Measured σ(Z) agrees with SM prediction within 1σ

$H\to\gamma\gamma$ and $H\to ZZ^*\to 4l$ Run3 @13.6 TeV

arXiv:2306.11379

WpT and ZpT spectra @ √s=5.02 and 13 TeV

ATLAS-CONF-2023-028

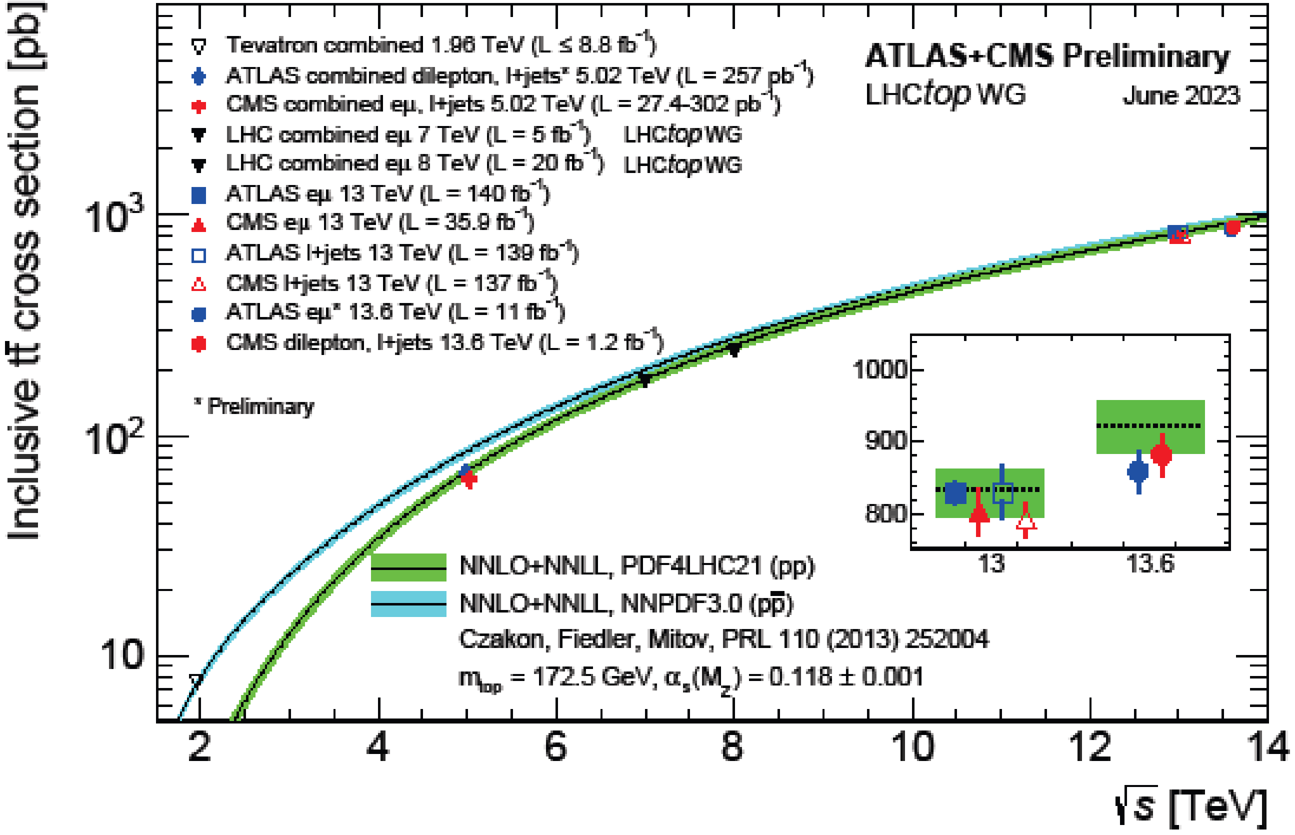
$$\sigma_{t\bar{t}t\bar{t}} = 22.5^{+4.7}_{-4.3}(\text{stat})^{+4.6}_{-3.4}(\text{syst})\ \text{fb} = 22.5^{+6.6}_{-5.5}\ \text{fb}.$$

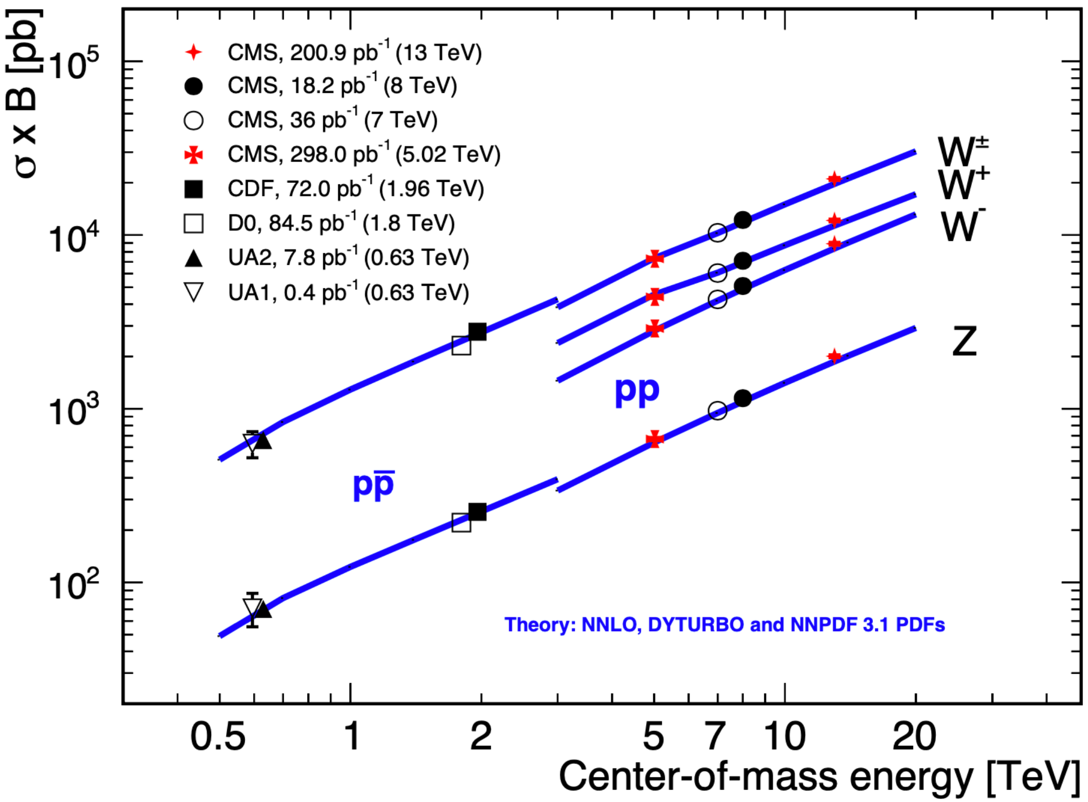
Новые результаты CMS

Измерения сечений векторных бозонов

Сечения рождения пар tt кварков

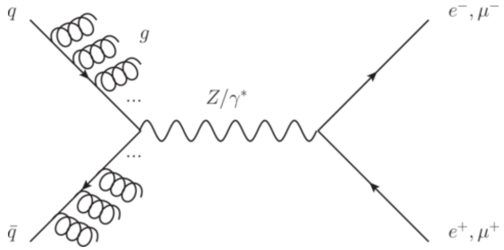
Figure 10: Summary of the measurements of the total W^+, W^-, W, and Z production cross sections times branching fractions versus center-of-mass energy for CMS and experiments at lower-energy colliders.

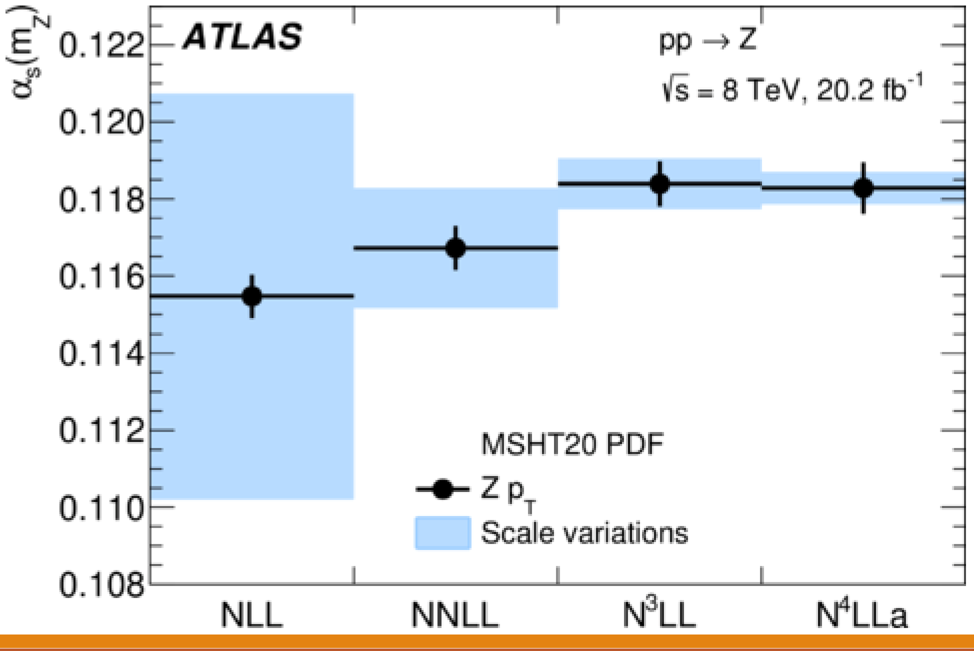


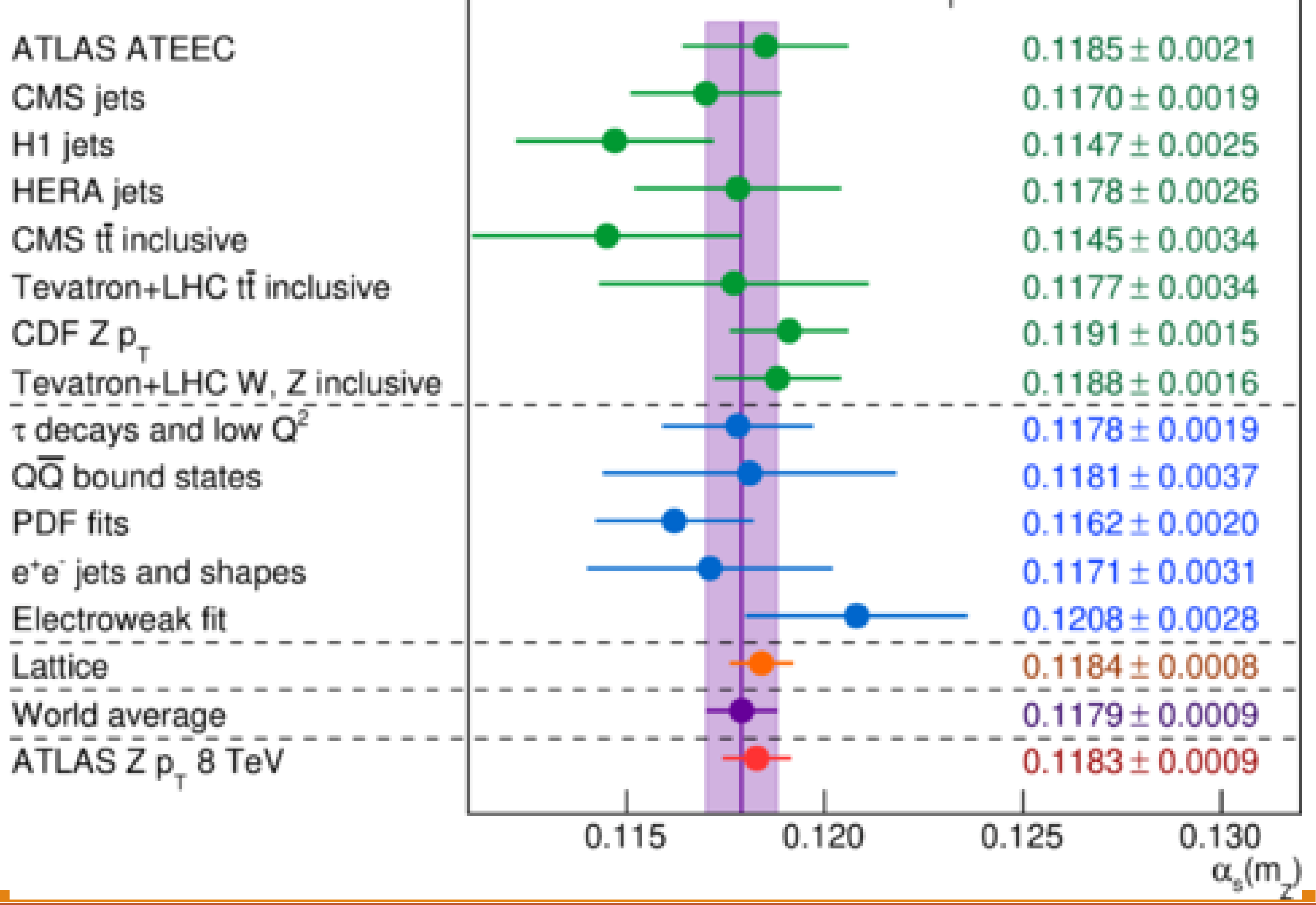


arXiv:2309.12986

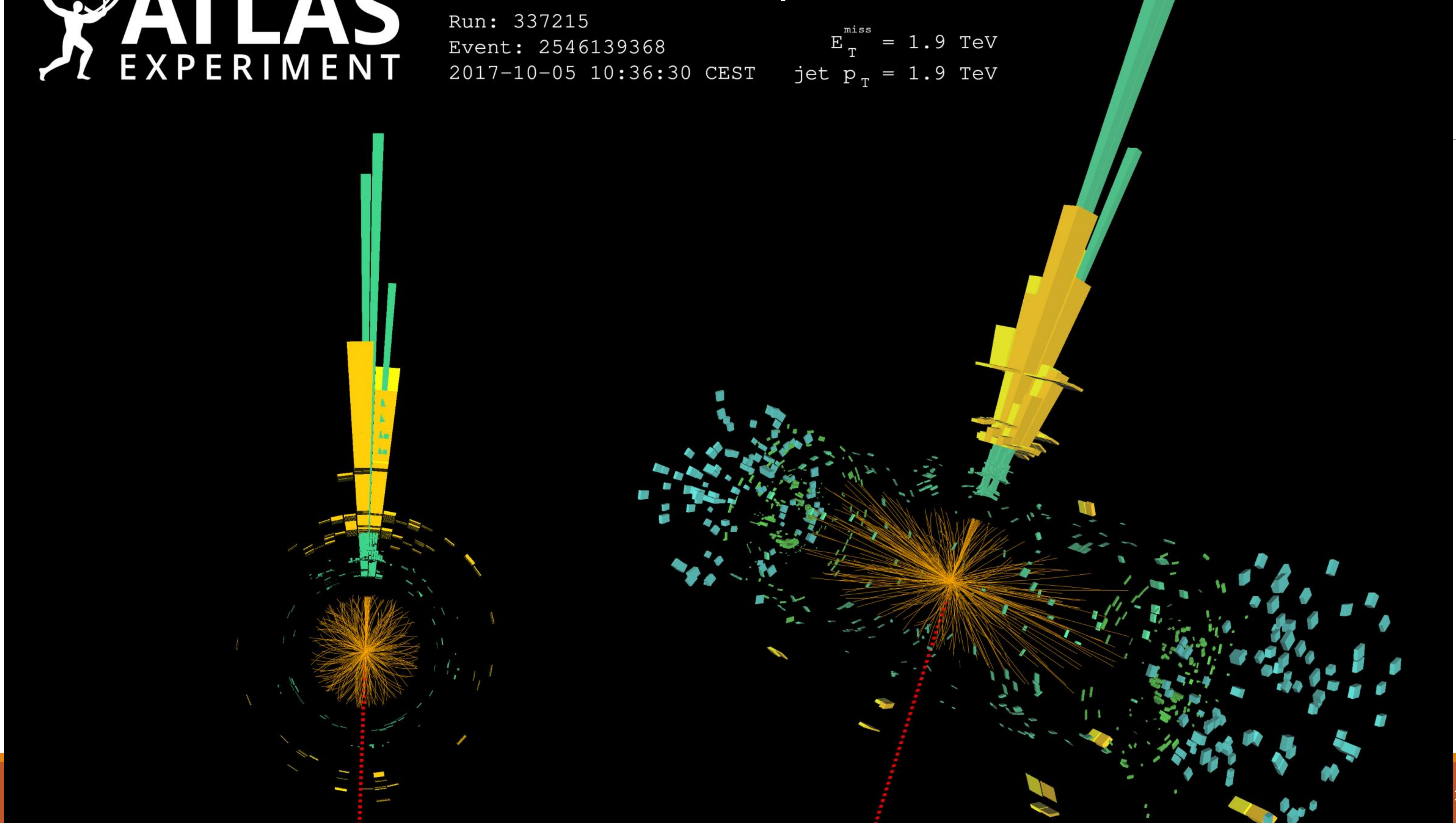
The analysis is based on predictions evaluated at third order in perturbative QCD, supplemented by the resummation of logarithmically enhanced contributions in the low transverse-momentum region of the lepton pairs. The determined value of the strong coupling at the reference scale corresponding to the Z-boson mass is $\alpha_s(m_Z)=0.1183\pm0.0009$. This is the most precise experimental determination of $\alpha_s(m_Z)$ achieved so far.







Searches for invisible decays or missing Energy are a powerful tool to search for dark matter: here a monojet in ATLAS



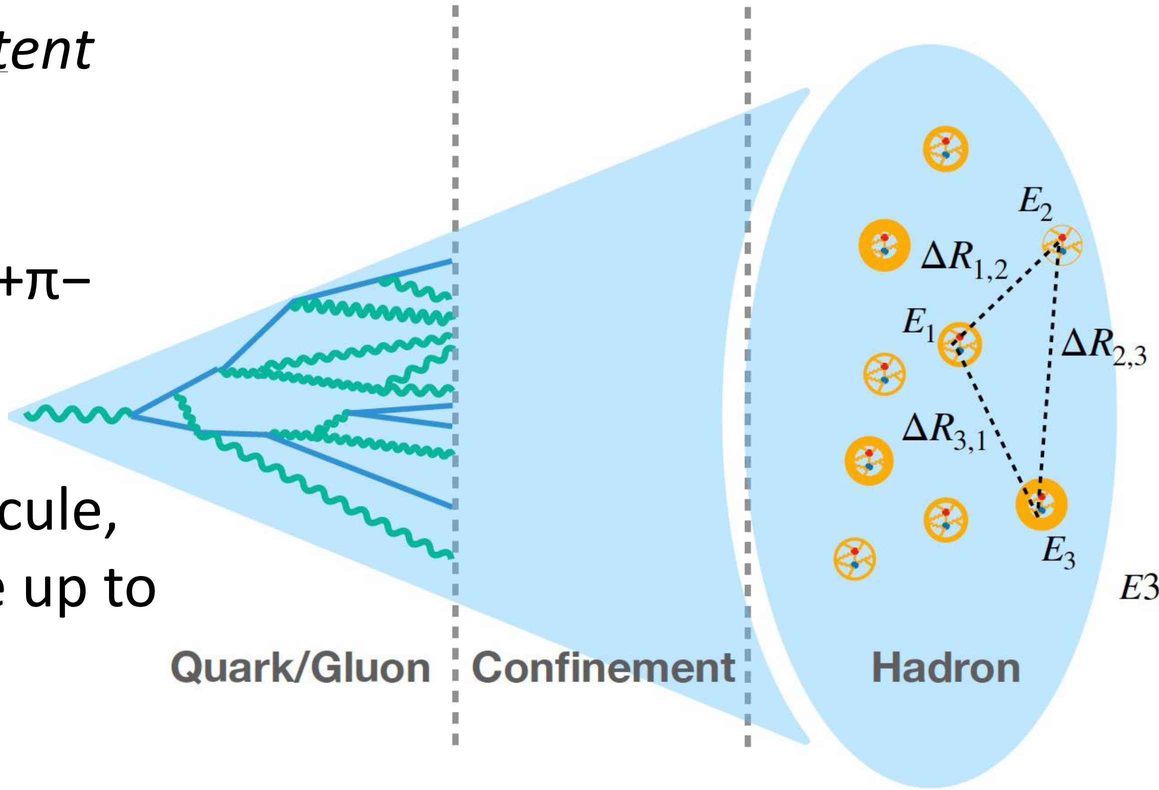
CMS достижения

The number of constituent quarks of f^0(980) is consistent with 2

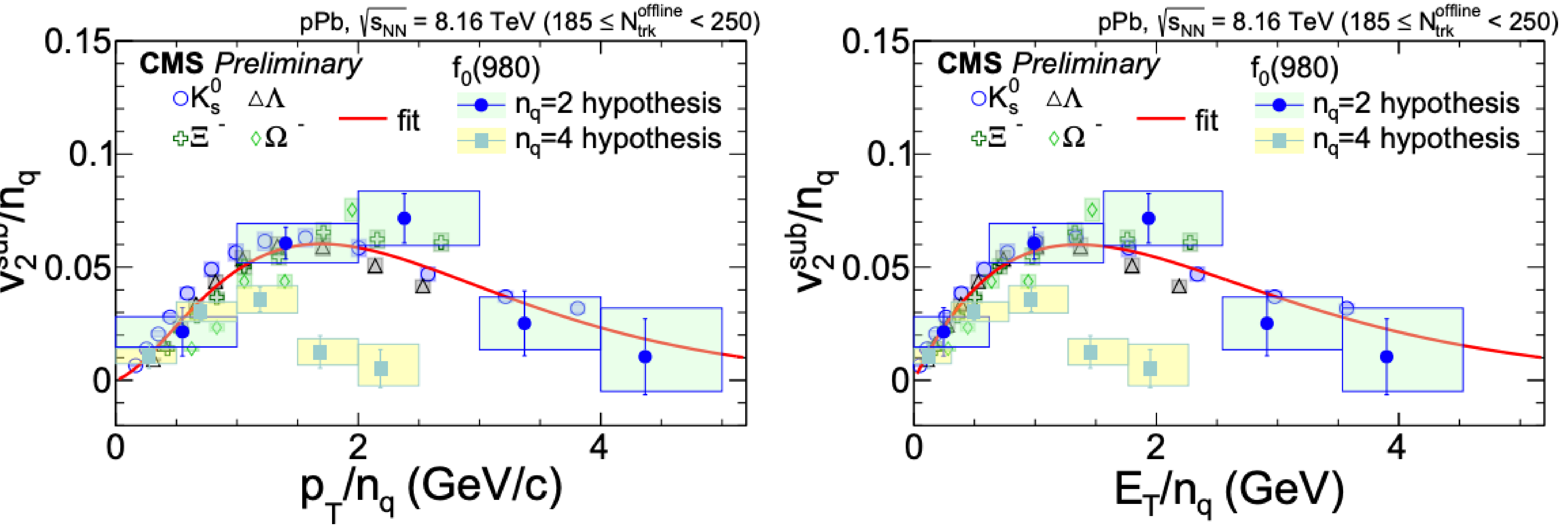
Using pPb data, the f0(980) is reconstructed via the invariant mass of its main decay channel $f^0(980) \rightarrow \pi+\pi-$

Measure the elliptic flow anisotropy v_2 of f^0(980) as function of pT

7.7 σ away from being a tetraquark state or KK molecule, or 6.3 σ (3.1 σ) if considering only restricted pT range up to 8 GeV (6 GeV)



Сколько кварков в составе $f_0(980)$



Новые измерение массы бозона Хиггса

Mass Measurement

• Fundamental parameter in the SM, it determines production and decay rates of Higgs

Need to measure experimentally

• H→γγ has excellent mass resolution

320 MeV (previous Run 2 results) и 80 MeV

Measured Higgs mass with H→γγ (Run 1+2)

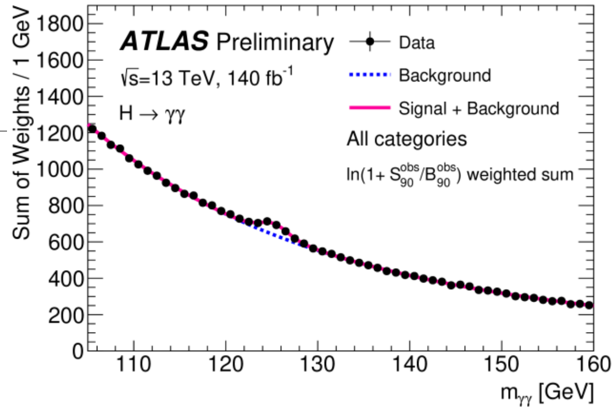
125.22±0.11(stat)±0.09(syst) GeV

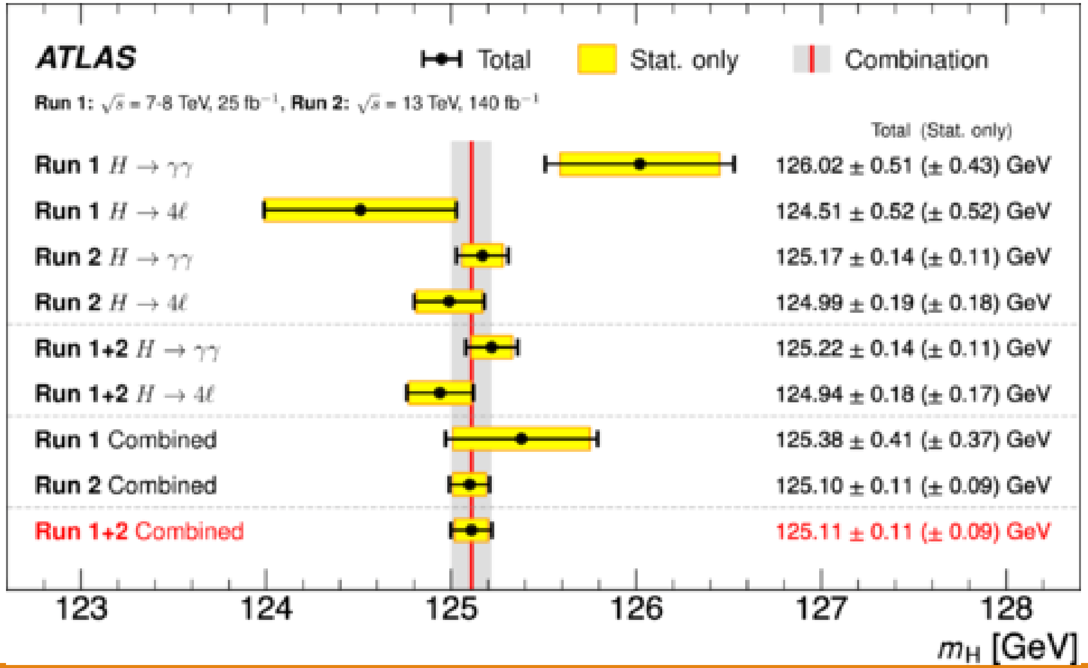
(0.11% precision!)

EPS-HEP 2023 @ Hamburg 2023

Combine H →γγ and H → ZZ→4l channels (Run1+Run2)

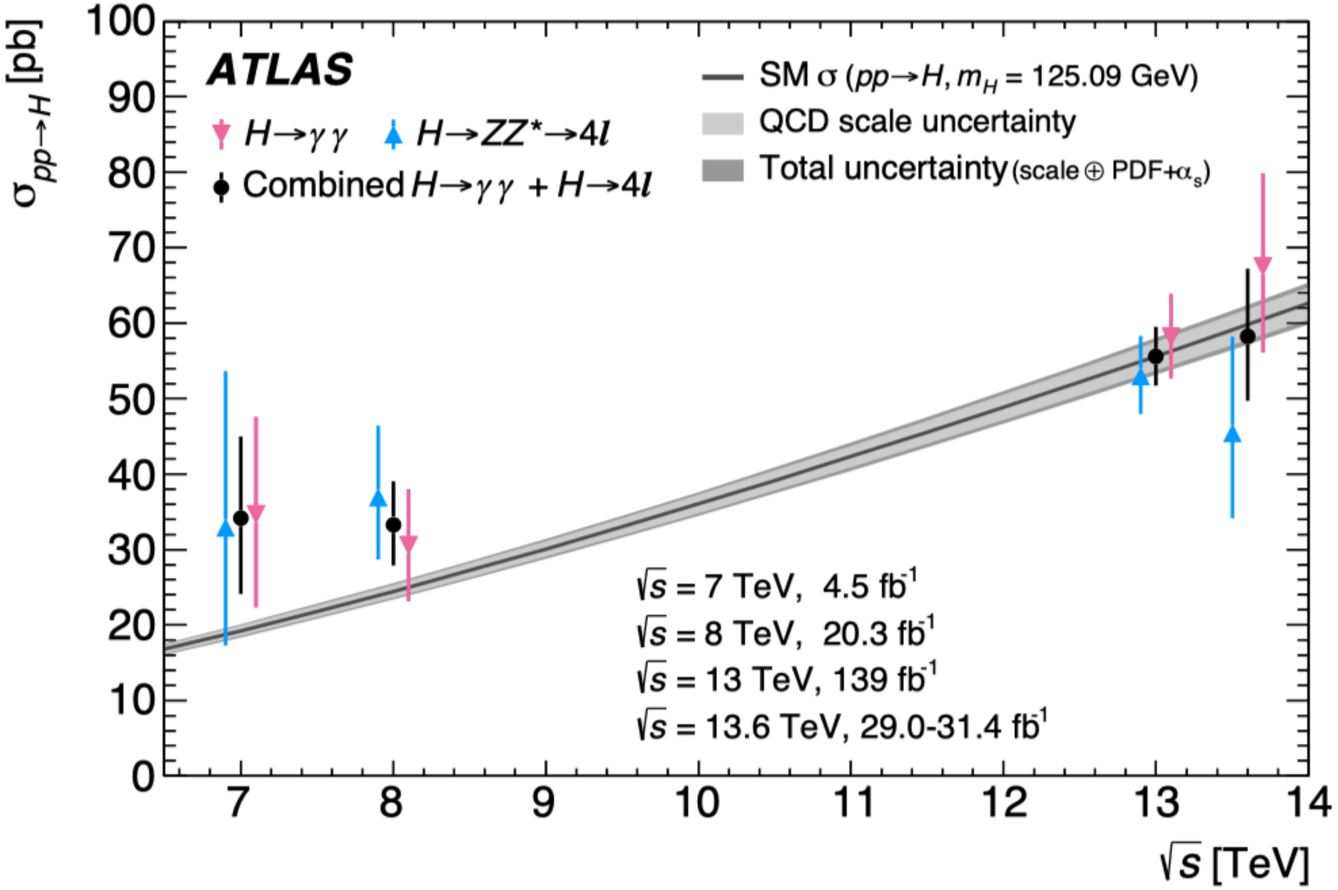
125.11±0.09(stat)±0.06(syst) GeV (0.09% precision!)





Измерение сечений бозона Хиггса при 13.6 ТэВ

arXiv:2306.11379



Measure fiducial and total cross section with H →γγ, H →ZZ →4l channels at 13.6 TeV in 2022 data

- Measured total cross-section

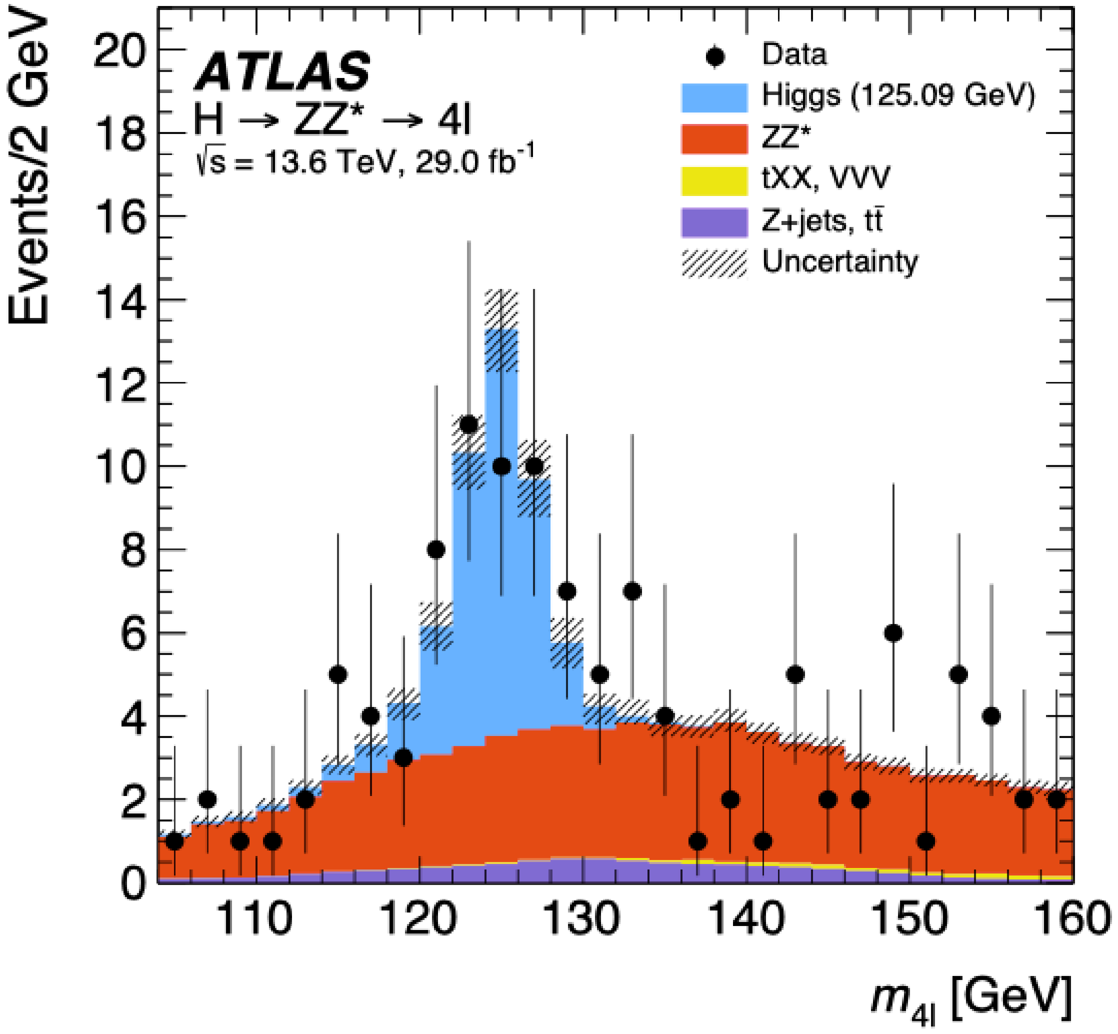
. **67+12-11 pb for H →γγ**

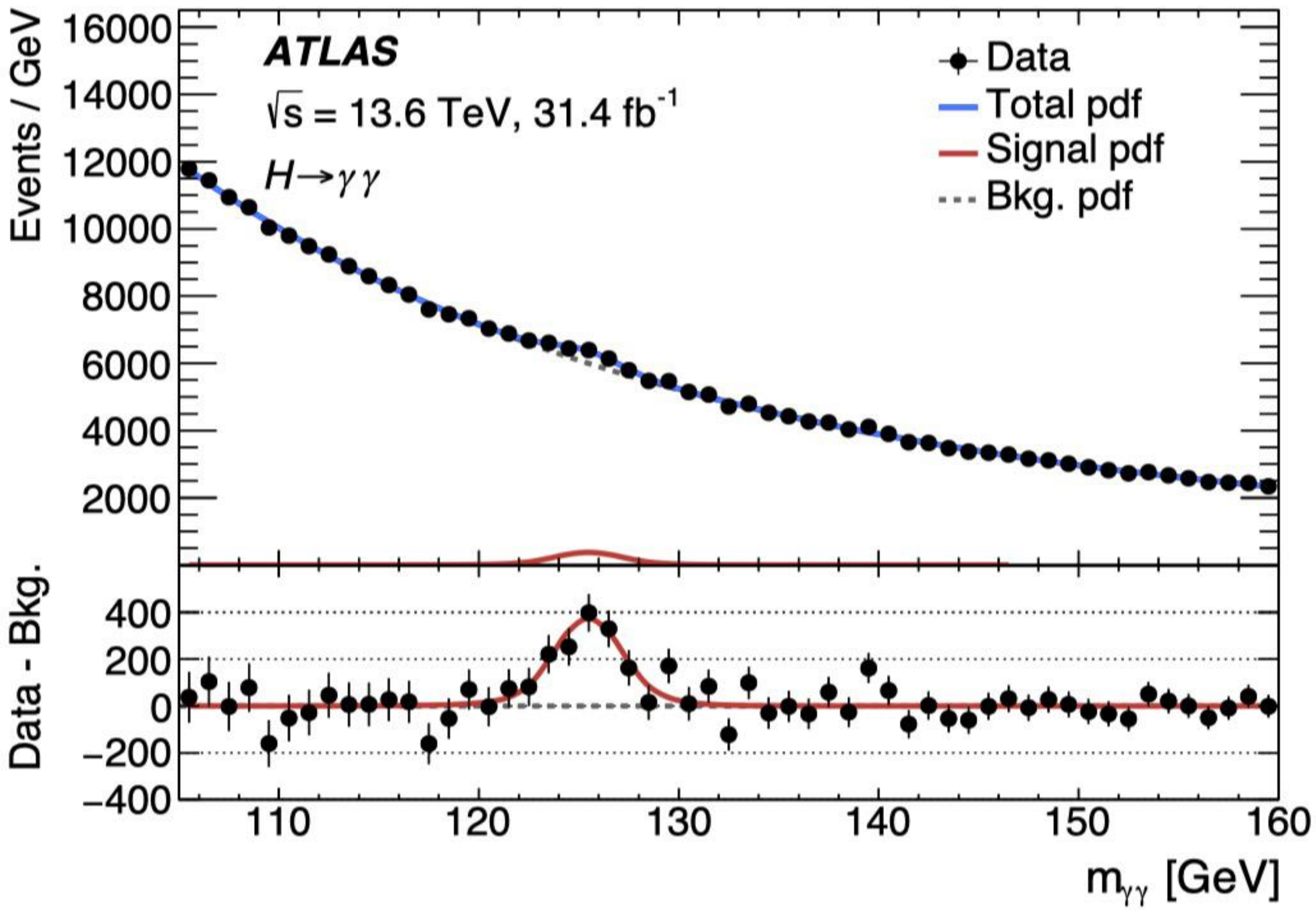
. **46±12 pb for H →ZZ →4l**

. **58.2±8.8 pb for combined**

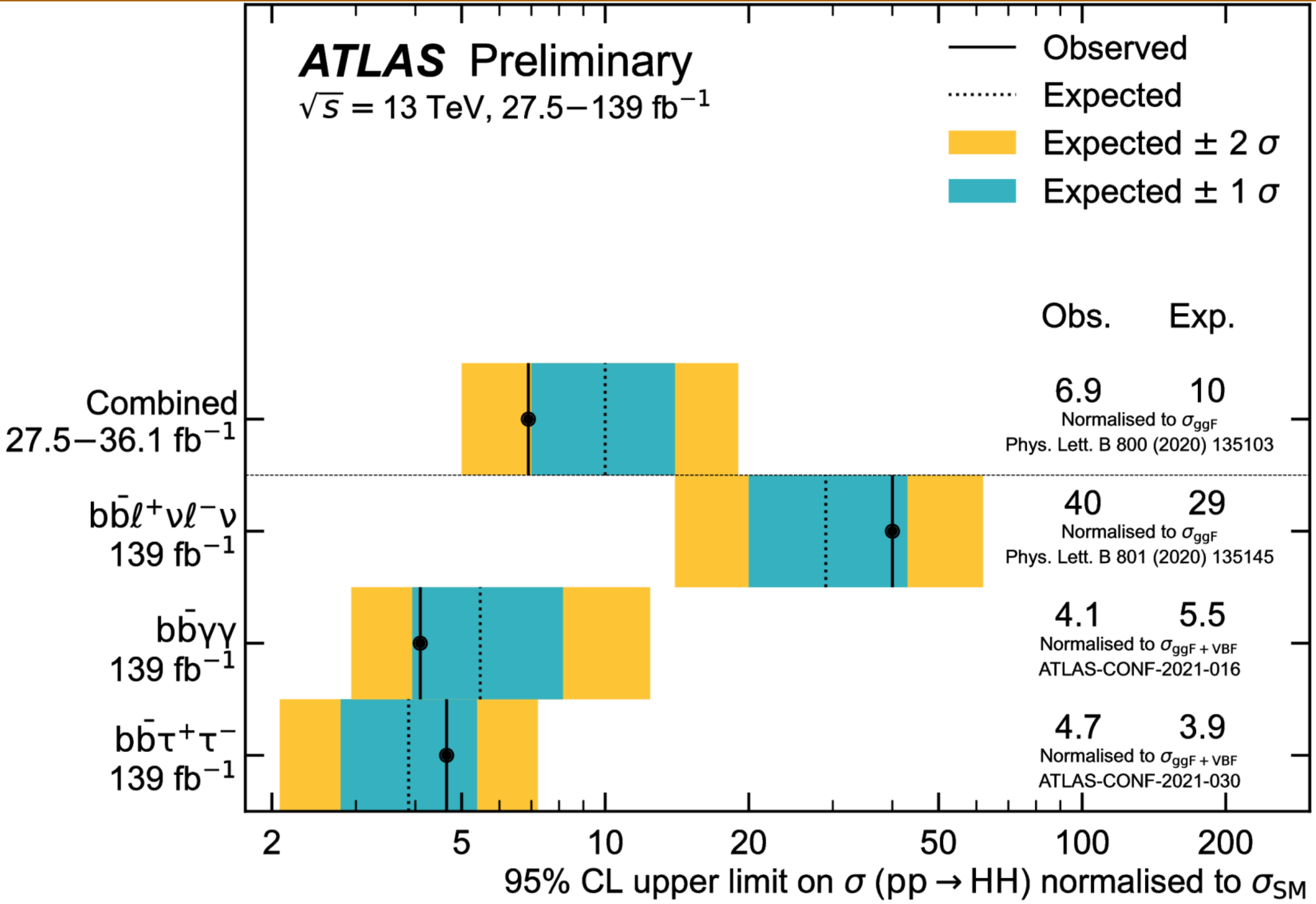
и **Good agreement with SM prediction (59.9±2.6pb)**

arXiv:2306.11379





Новые ограничения на сечение рождения пары бозонов Хиггса



The excess around 95 GeV

CMS γγ excess at 95 GeV:

◊ 2.9σ (local) released for Moriond 2023

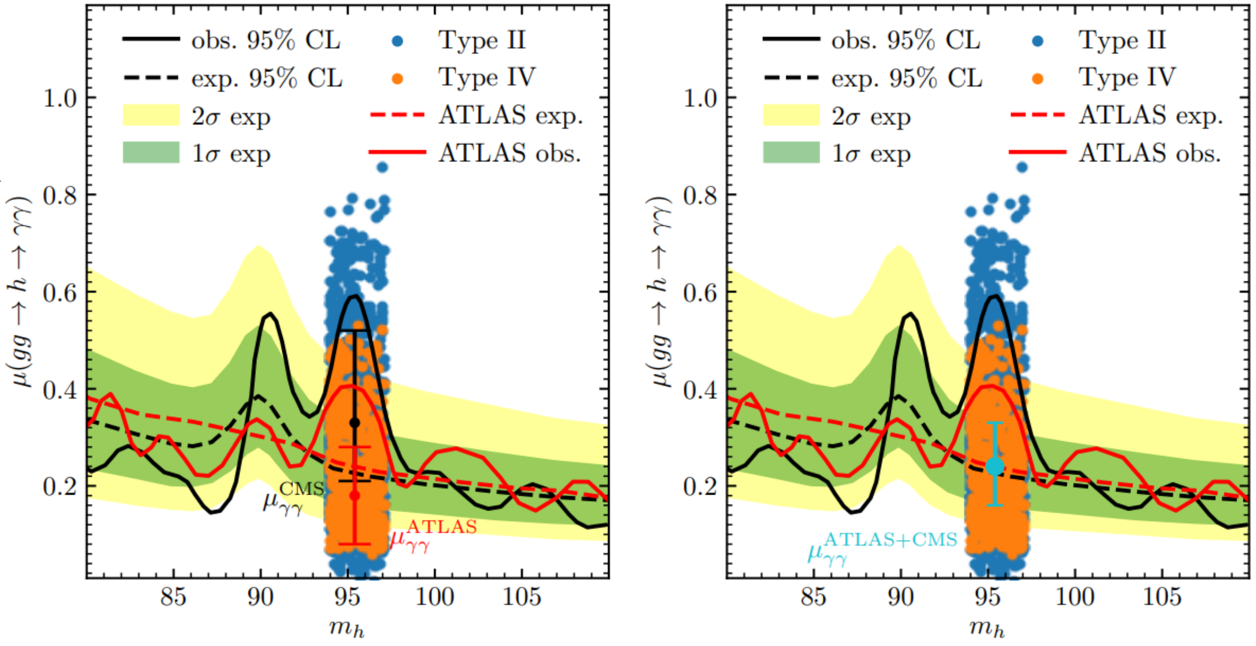
◊ ATLAS result in June 23: 1.7σ

◊ same mass as for LEP $b\bar{b}$, CMS ττ excesses

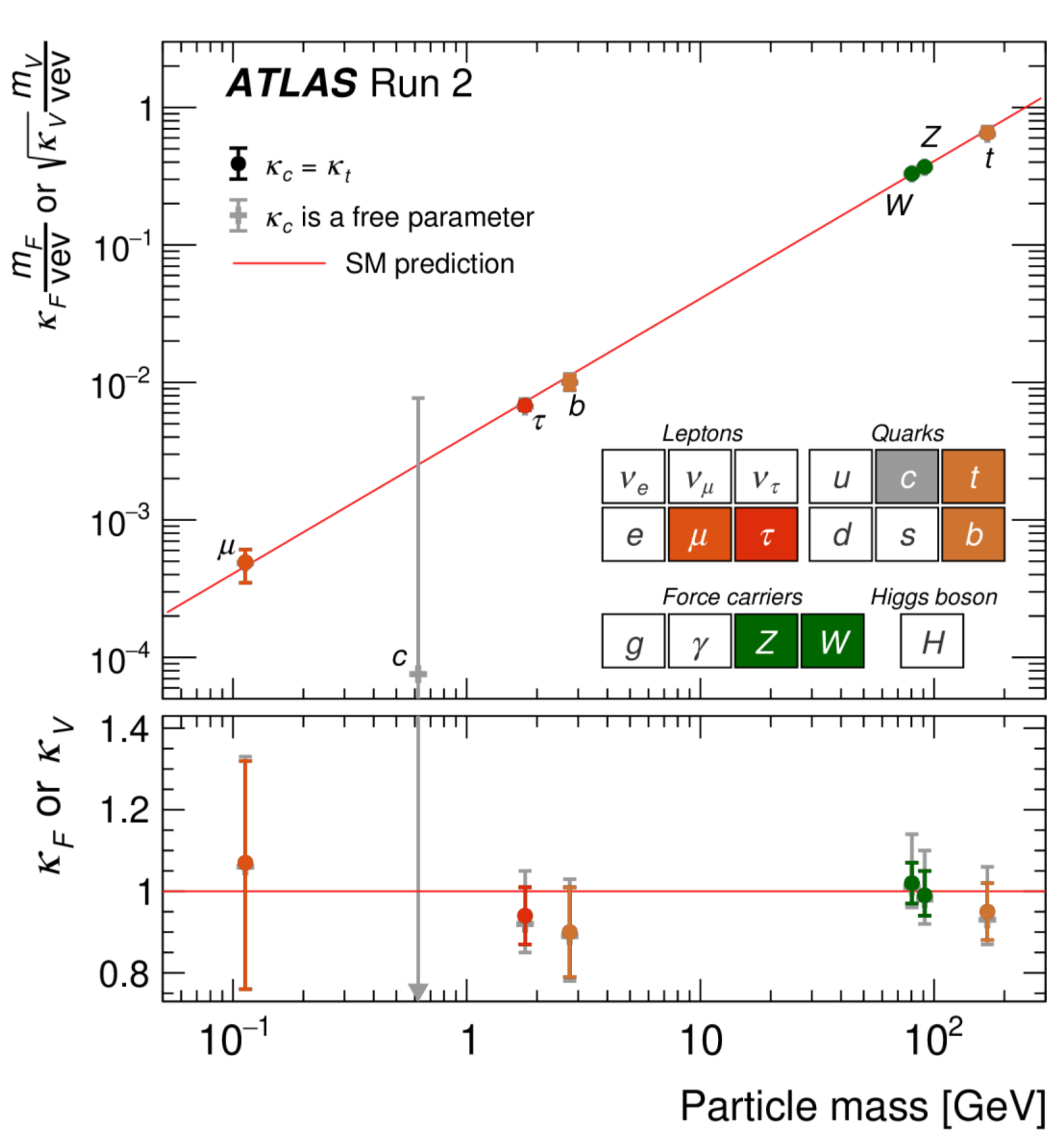
2HDM interpretation?

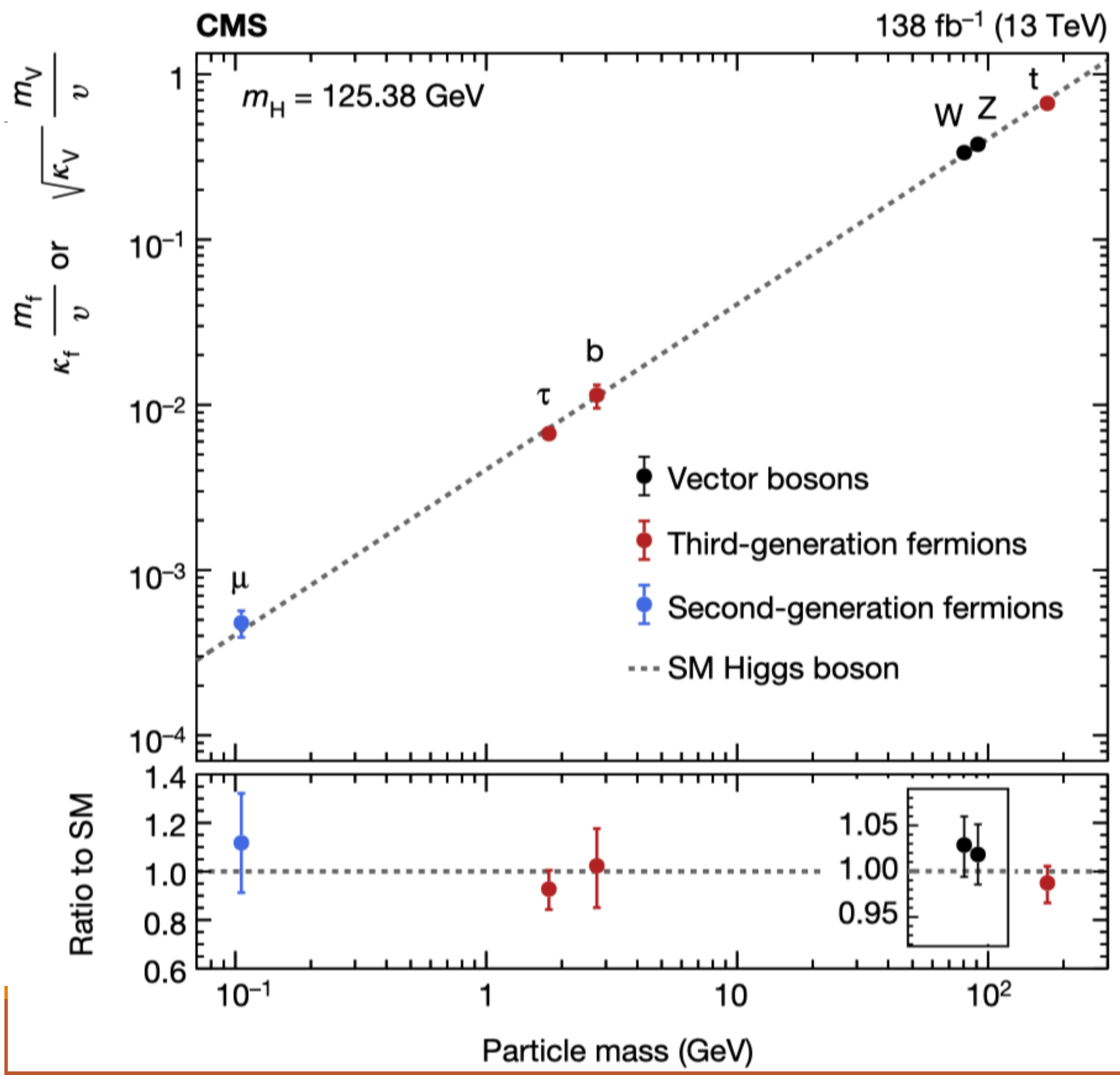
◊ excess may be the A in 2HDM model

◊ would work better as an additional scalar⇒ S2HDM



Измерения констант связи бозона Хиггса





Измерение ширины H СМ (LHCP 2023 May)

$$\sigma^{\text{on-shell}}_{gg\to H\to ZZ} \sim \frac{g^2_{\text{ggH}} g^2_{\text{HZZ}}}{m_H \Gamma_H} \quad \sigma^{\text{off-shell}}_{gg\to H\to ZZ} \sim \frac{g^2_{\text{ggH}} g^2_{\text{HZZ}}}{m^2_{ZZ}} \quad \frac{\Gamma_H}{\Gamma_H^{\text{SM}}} = \frac{\mu_{\text{off-shell}}}{\mu_{\text{on-shell}}}$$

ATLAS: Γ_{H} = 4.5+3.3 −2.5 MeV @68% C. L.

CMS: Γ_{H} = 3.2+2.4 −1.7 MeV @68% C. L.

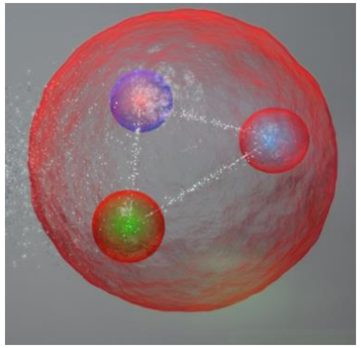
First evidence of **off-shell** Higgs boson production

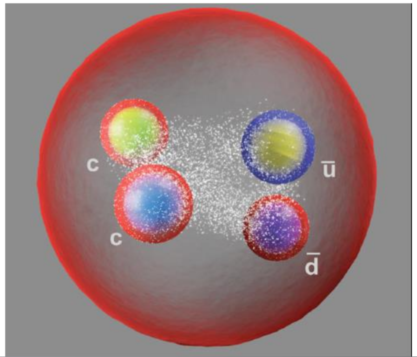
Chiara Arcangeletti *on behalf of the ATLAS and CMS Collaborations* LHCP2023, Belgrade – 26th May 2023

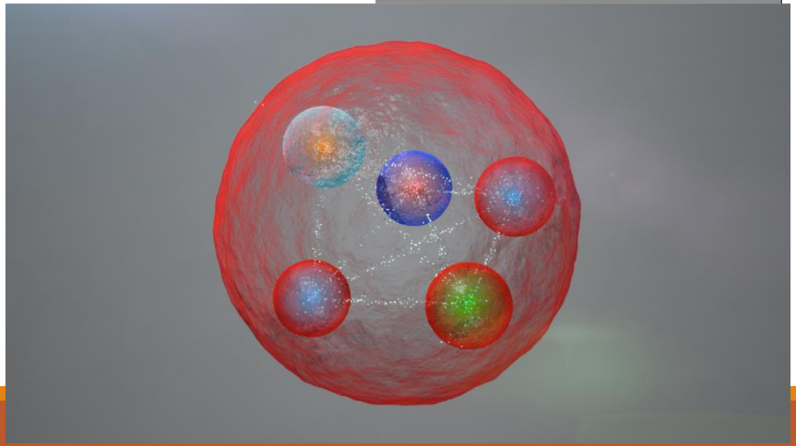
LHCb достижения – направления:

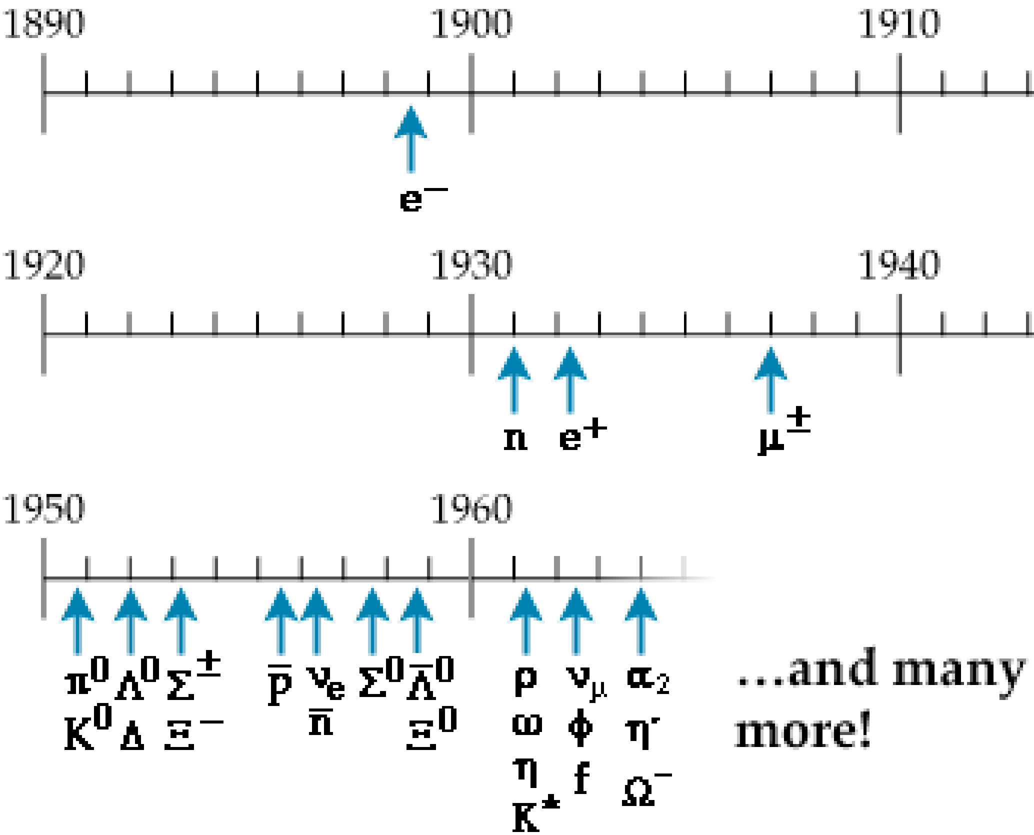
1. Спектроскопия адронных состояний
2. Соударения ядер с неподвижной мишенью
3. Лептонная универсальность
4. Модернизация установки

Manuel Franco Sevilla *University of Maryland*





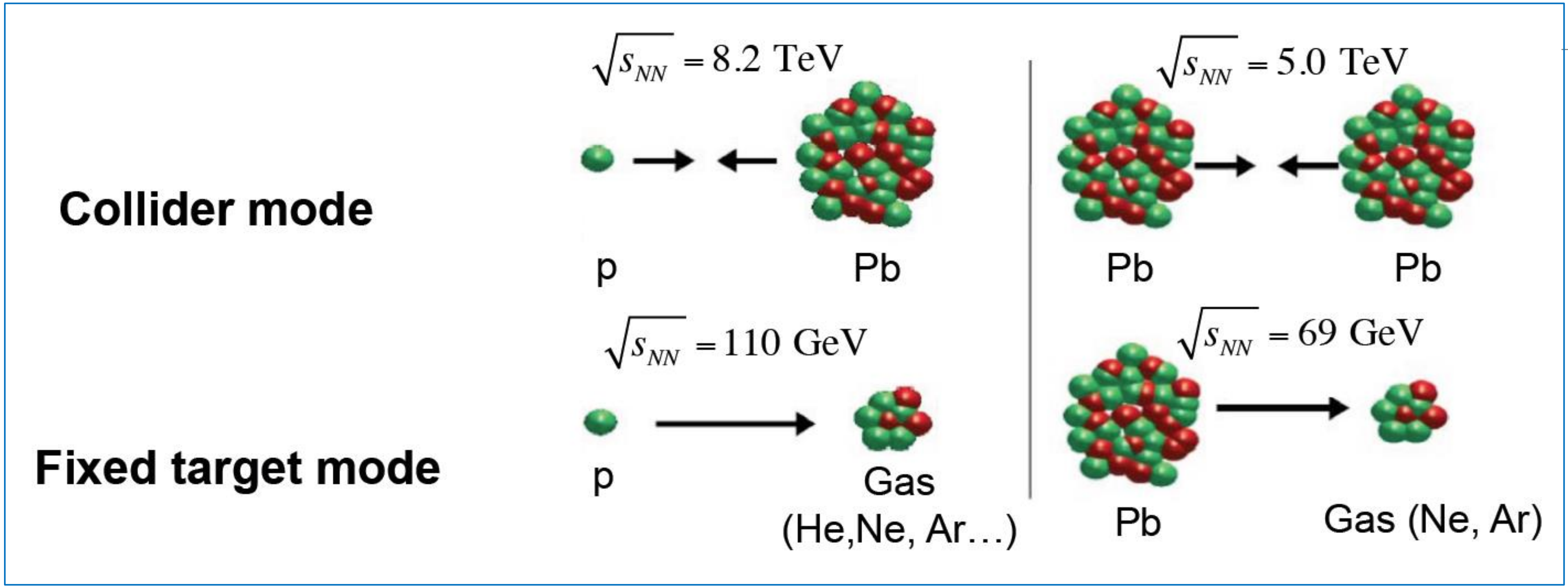




Новейшие состояния от LHCb:

1. Новое состояние $T^0_{\psi\phi}$ (3960) [$c\bar{c}s\bar{s}$] arXiv:2210.15153
2. First doubly-charged tetraquark and isospin partner $\boldsymbol{T^a_{\bar{c}s0}(2900)^{++}}$ **[$\boldsymbol{\bar{c}s u \bar{d}}$], $\boldsymbol{T^a_{\bar{c}s0}(2900)^0}$ [$\boldsymbol{\bar{c}s d \bar{u}}$] Phys.Rev.Lett. 131, 041902 (2023)**
3. First pentaquark with strangeness $\boldsymbol{P^\Lambda_{\psi s}(4338)^0}$ **[$\boldsymbol{\bar{c}cuds}$]** PRL 131, 031901 (2023)
4. New resonant structure with 4σ, 5.4σ with isospin constrained, $T^0_{\psi s1}(4000)^0$ [$c\bar{c}d\bar{s}$]

Соударения ядер с неподвижной мишенью на LHCb



EPJC 83 (2023) 541 pNe p_{prot} = 2,5 TeV, $\sqrt{s_{NN}}$ = 68,5 GeV

EPJC 83 (2023) 625 pNe p_{prot} = 2,5 TeV, $\sqrt{s_{NN}}$ = 68,5 GeV $c\bar{c}$ production

Гипертритон ${}^{3}_{\Lambda}H \rightarrow {}^{3}He\ \pi^{-}$
LHCb-CONF-2023-002

LFU

SM: same electroweak couplings to all lepton generations: g_Z, g_W, g_γ

$Z \rightarrow ee, \mu\mu, \tau\tau$ - g_Z

To **0.28%** in Z decays **$\Gamma Z \rightarrow \mu\mu / \Gamma Z \rightarrow ee$ = 1.0009 ± 0.0028** LEP, Phys. Rept. 427 (2006) 257

To **0.8%** in W decays **$\mathcal{B}(W \rightarrow e\nu) / \mathcal{B}(W \rightarrow \mu\nu)$ = 1.004 ± 0.008** CDF + LHC, JPG: NPP, 46, 2 (2019)

$\Gamma J/\psi \rightarrow \mu\mu / \Gamma J/\psi \rightarrow ee$ = 1.0016 ± 0.0031 PDG (BESIII), RPP, Chin. Phys. C40 (2016) 100001

To **0.14%** in $\tau \rightarrow \ell\nu\nu$ **$g\mu/ge$ = 1.0018 ± 0.0014** PDG, A. Pich, Prog. Part. Nucl. Phys. 75 (2014) 41 PiENu, Phys. Rev. Lett. 115, 071801 (2015)

To **0.2%** in meson decays **$\Gamma\pi \rightarrow e\nu / \Gamma\pi \rightarrow \mu\nu$ = (1.234 ± 0.003) × 10–4**

$\Gamma Z \rightarrow \tau\tau / \Gamma Z \rightarrow ee$ = 1.0019 ± 0.0032 LEP, Phys. Rept. 427 (2006) 257

$\Gamma Ds \rightarrow \tau\nu / \Gamma Ds \rightarrow \mu\nu$ = 9.95 ± 0.61 HFLAV, Eur. Phys. J. C77 (2017) 8

LFU in B decays

$\mathcal{R}_{K(*)} = \mathcal{B}(B \rightarrow K(*)\mu\mu) \,/\, \mathcal{B}(B \rightarrow K(*)ee$

R = 0,846 $^{+0,042+0,013}_{\qquad\qquad\quad -0.039}$

Nature 18 (2022) 277

Отличие 3,1 σ от СМ

Physics with ALICE https://cds.cern.ch/record/2025215 7 / 32

Broad and multi-disciplinary physics program study of different collision systems. Selected results in this talk:

pp collisions: testing pQCD and hadronization

Pb-Pb collisions: initial-state effects and medium properties

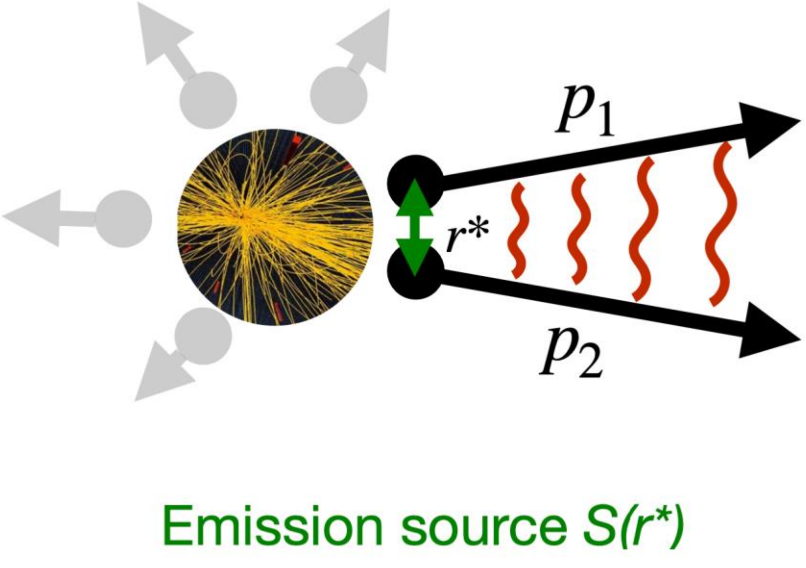
Antimatter: production mechanism and astrophysical applications

Hadron interaction: antimatter absorption and many-body force

First ever measurement of the **antitriton** using the ALICE detector materials as absorbers

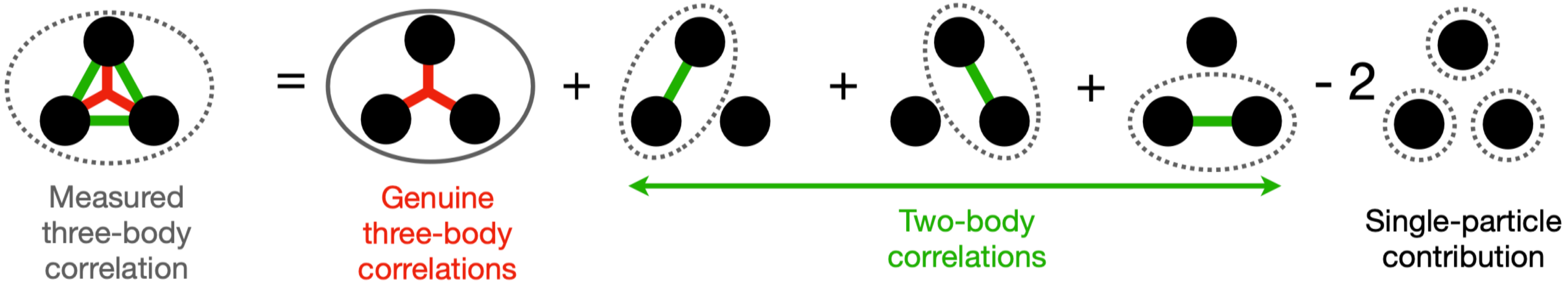
Complement of (**Nature Physics vol. 19, 61–71 (2023)**) study the isospin dependence of inelastic interaction

Измерение корреляций



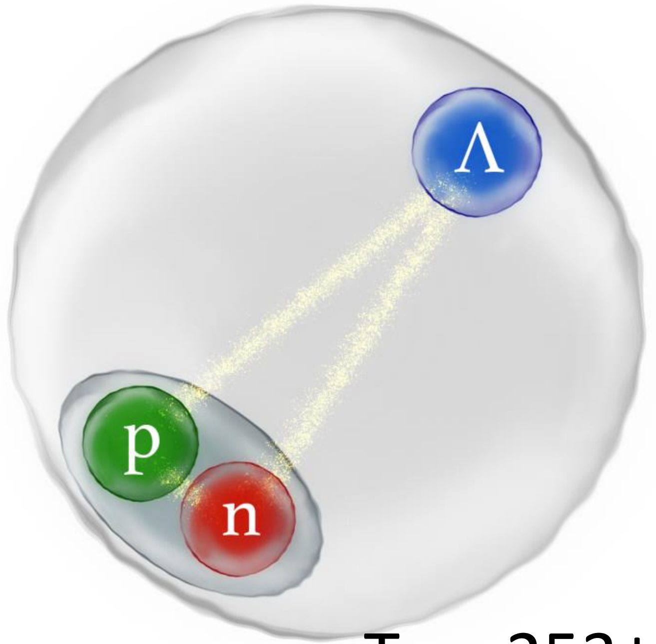
p-d correlation function: not described by models using an effective two-body system sensitive to NN interactions of a three-particle system

arXiv:2306.02478



arXiv:2209.07360 [nucl-ex]

ALICE Измерения гипертритона



Hypertriton lifetime and Λ separation energy (B_Λ) measured with unprecedented precision

ALICE measurements confirm a weakly bound system

Hypertriton "lifetime puzzle" now solved

T = 253±11(stat.)±6(syst.) ps and B_Λ= 72±63(stat.)±36(syst.) keV are compatible with predictions from effective field theories and conclusively confirm that the $^3{}_\Lambda$H is a weakly-bound system.

Прецизионное измерение времени жизни Λ гиперона: Phys. Rev. D 108, 032009 (2023)

New measurement of the lifetime: a factor 3 more precise than the world average (PDG) Λ ~ $2.631\pm0.020\ 10^{-10}$ s = 263,1 ± 2,0 ps (May 2023)

A new, more precise measurement of the Λ hyperon life time is performed using a large data sample of Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE. The Λ and ¯Λ hyperons are reconstructed at midrapidity using their two-body weak decay channel Λ→p+π− and ¯Λ→¯p+π+. The measured value of the Λ life time is τ = 261.07 ±0.37 (stat) ± 0.72(syst) ps. The relative difference between the life time of Λ and ¯Λ, which represents an important test of CPT invariance in the strangeness sector, is also measured. The obtained value ð(τΛ−τ¯Λ)/τΛ = 0.0013 ± 0.0028 (stat) ±0.0021 (syst) is consistent with zero within the uncertainties. Both measurements of the Λ hyperon lifetime and of the relative difference between τΛ and τ¯Λ are in agreement with the corresponding world averages of the Particle Data Group and about a factor of three more precise.

Заключение

1. Результатов много
2. Открытий значительных не объявлено
3. Внимание к исследованию вселенной , квантовой физики
4. Компьютинг в фокусе внимания
5. Активность по конференциям – широкое общение, обмен информацией

~**Ion-ion** collisions have **QGP and Cold Nuclear Matter (CNM)** effects

➞ **Proton-ion** collisions **ideal** laboratory **for CNM .**

~**Heavy quarks key** to **QGP**

➞ Mostly produced during the early stages of collision

✦$t_{prod} \ll t_{QGP}$ → experience whole time evolution of collisions

➞$m_{c,b} \gg \lambda_{QCD}$ → perturbative calculations

➞ Several QGP models predict **s-quark production enhanced** in **heavy-ion collisions**

~**LHCb** has **unique capabilities** ➞ Access to **nPDFs** at **low** and **high x**

➞ Precision measurements of heavy quark probes

arXiv:2306.11379