Новости ICHEP 2022

Проф. Смирнова Л.Н.

29 сентября 2022

2022 - уникальный год для физики частиц:

- Десятилетний юбилей открытия бозона Хиггса
- Старт третьего сеанса БАК при новой энергии pp соударений 13,6 ТэВ – Run 3
- Тридцать лет публикации писем о намерениях основных экспериментов БАК-LHC (ATLAS,CMS,ALICE,LHCb)
- Состоялась крупнейшая международная конференция по физике высоких энергий

ICHEP 2022 в Италии, Болонья, 6-13 июля 2022

Крупнейшая международная конференция по физики высоких энергий ICHEP 2022 – зал конференции

Приглашенные обзорные доклады на ICHEP2022

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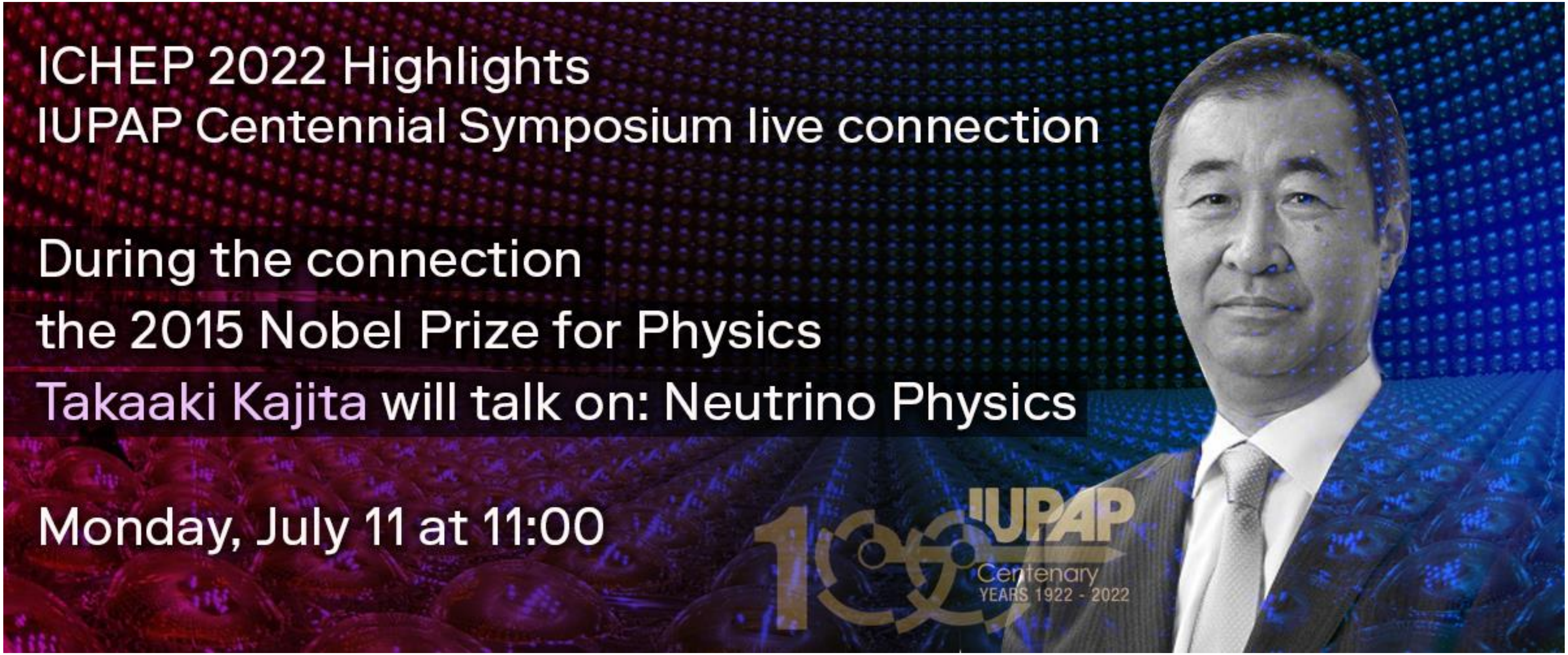


Доклад Генерального директора ЦЕРН Ф. Джианотти о пути к открытию бозона Хиггса

The discovery

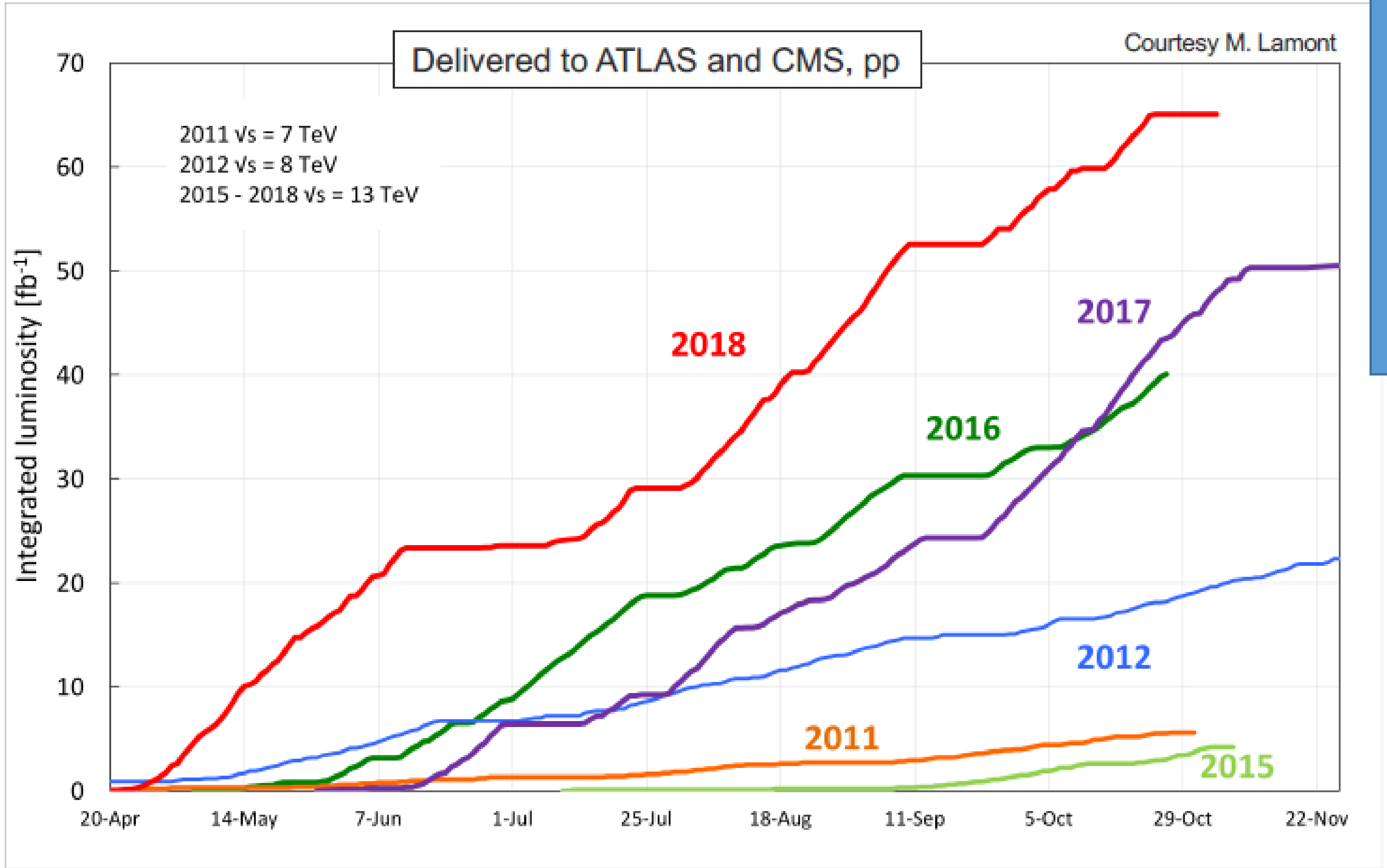
Announcement at CERN seminar on 4 July 2012, followed by publications submitted on 31 July 2012:

ATLAS Collaboration, Phys. Lett. B 716 (2012) 1
https://www.sciencedirect.com/science/article/pii/S037026931200857X

CMS Collaboration, Phys. Lett. B 716 (2012) 30
https://www.sciencedirect.com/science/article/pii/S0370269312008581

Results shown here are mainly based on the publications

Accelerator complex and luminosity



Эволюция параметров БАК - LHC

~ 90% of delivered luminosity used by the experiments (high data-taking efficiency and excellent data quality)

July 2012

Peak L ~ 7 x 10^{33} cm^{-2} s^{-1}
~ 12 fb^{-1} at √s = 7-8 TeV
~ 250 000 Higgs bosons produced per experiment

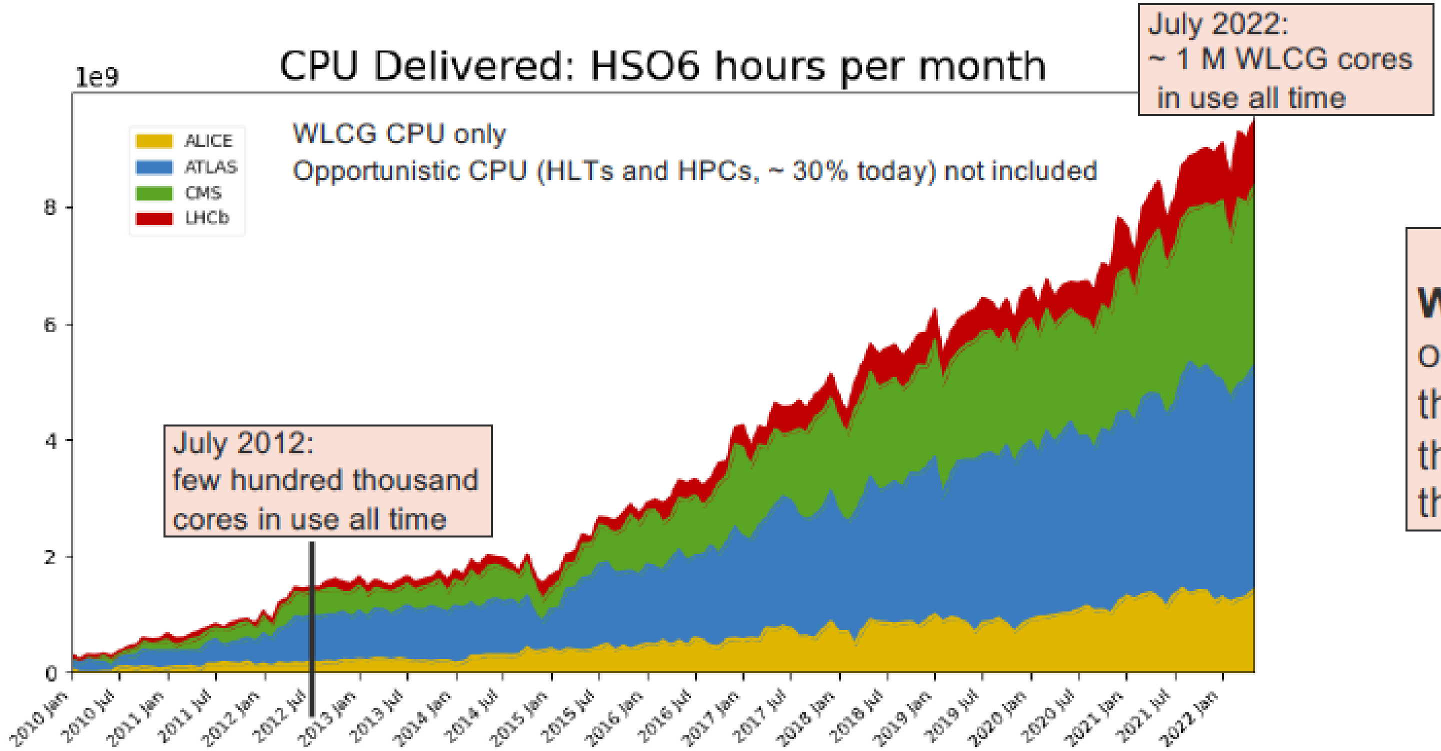
Today

Peak L ~ 2 x 10^{34} cm^{-2} s^{-1}
~ 189 fb^{-1} (~160 fb^{-1} at √s = 13 TeV)
~ 9 M Higgs bosons produced per experiment

Computing - WLCG

	2012	2022
T0 → T1 transfer rate (GB/s, peak)	5.7	33.4
Global WLCG transfer rate (GB/s, peak)	15	80 (during data challenges)
Total processing power (HS06 hours/month)	1.6 B	9.1 B
Number of cores in use (WLCG only)	~ 250 k	~ 1 M
Total disk space (PB)	170	750
Total tape (PB)	170	1200

В 9 раз возрос объем вычислительных мощностей, используемых в четырех основных экспериментах БАК

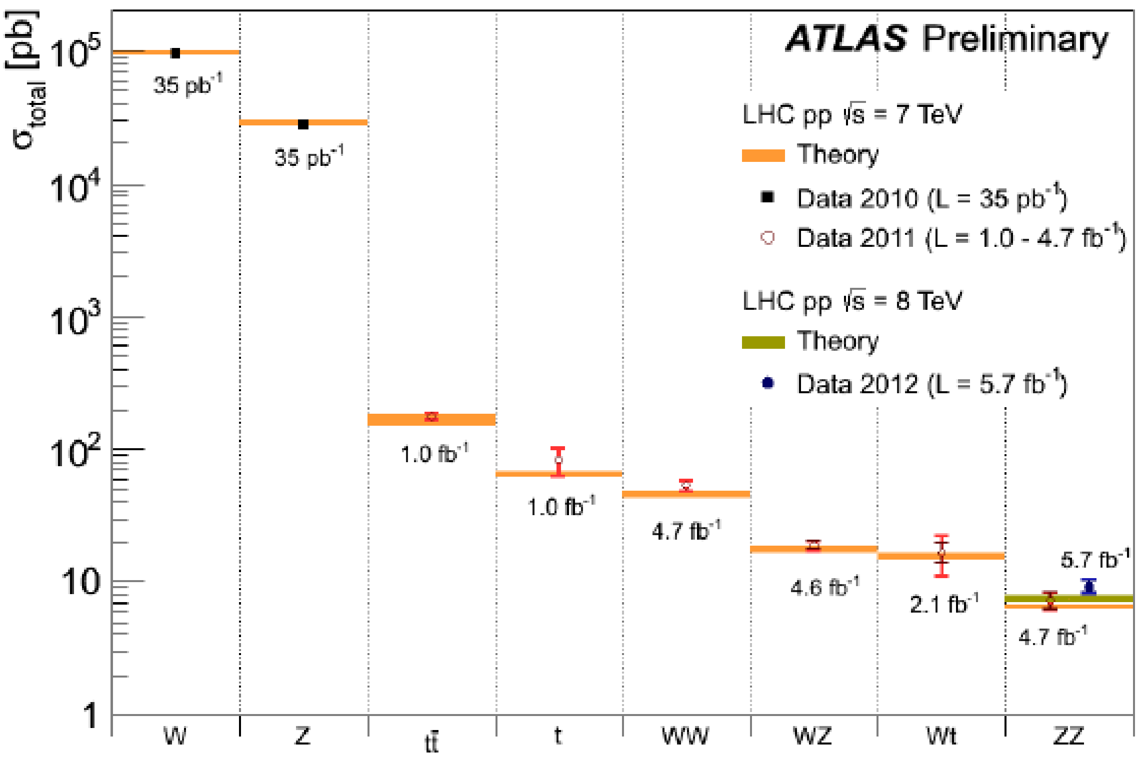


The big success of the **Worldwide LHC Computing Grid**: outstanding performance right from the beginning of the LHC operation, thanks also to the strong support of the Funding Agencies

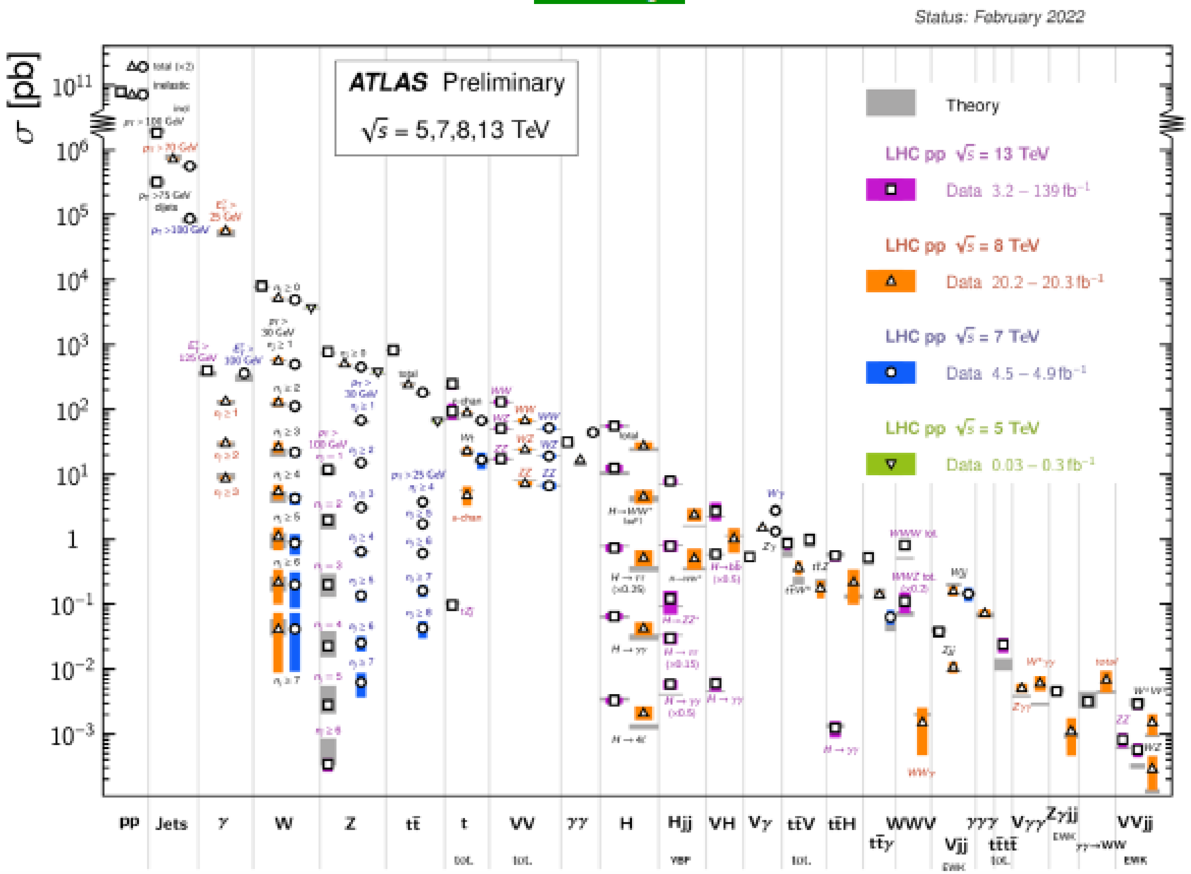
Standard Model cross-sections

Вошло в доклад из общей презентации ATLAS

4 July 2012



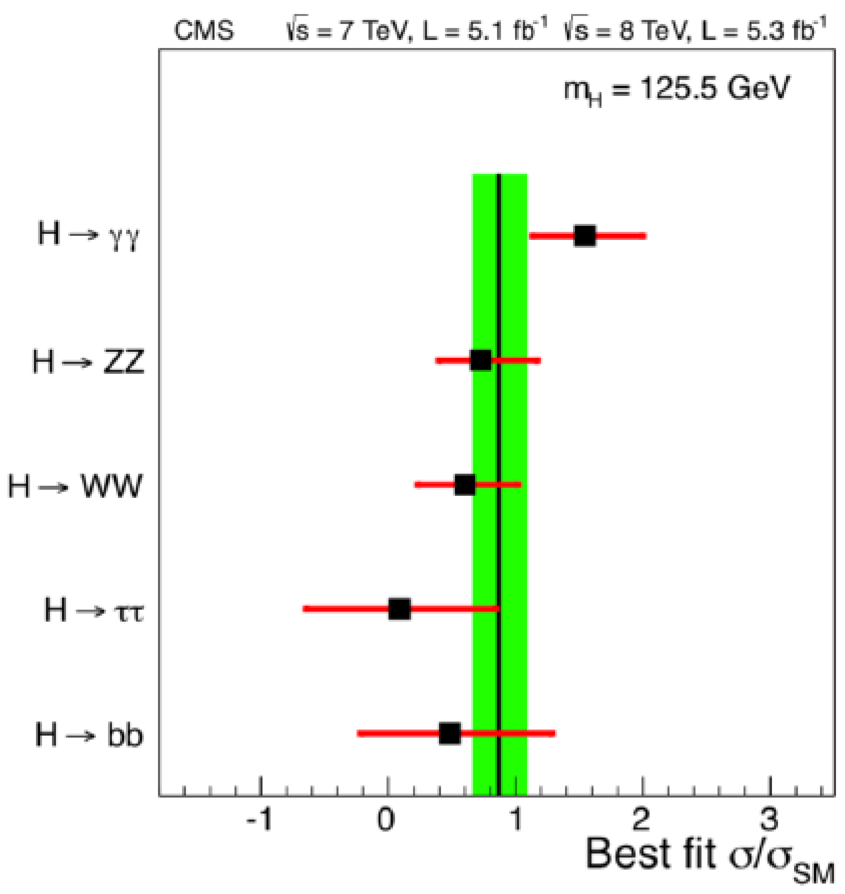
Today



Current precision on inclusive cross-sections: typically few percent over almost 14 orders of magnitude!

Higgs boson production and decay measurements

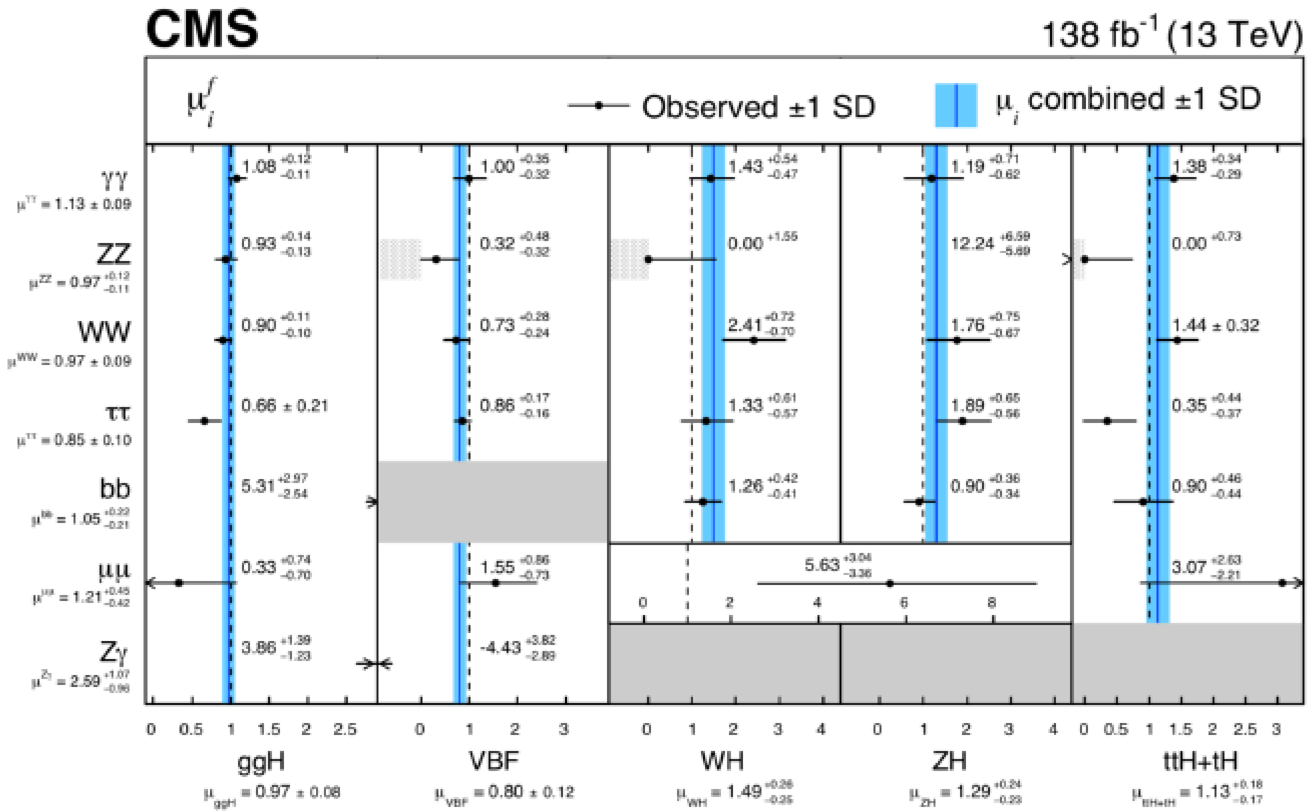
July 2012



Overall signal strength normalised to SM expectation:
$\mu = 0.87 \pm 0.23$

Today

→ see C. Mariotti's talk



Измерены вероятности распадов H->bb H->μμ для отдельных механизмов рождения H

Overall signal strength normalised to SM expectation:
$\mu = 1.002 \pm 0.057$

Вошло в доклад из общей презентации CMS

Conclusions

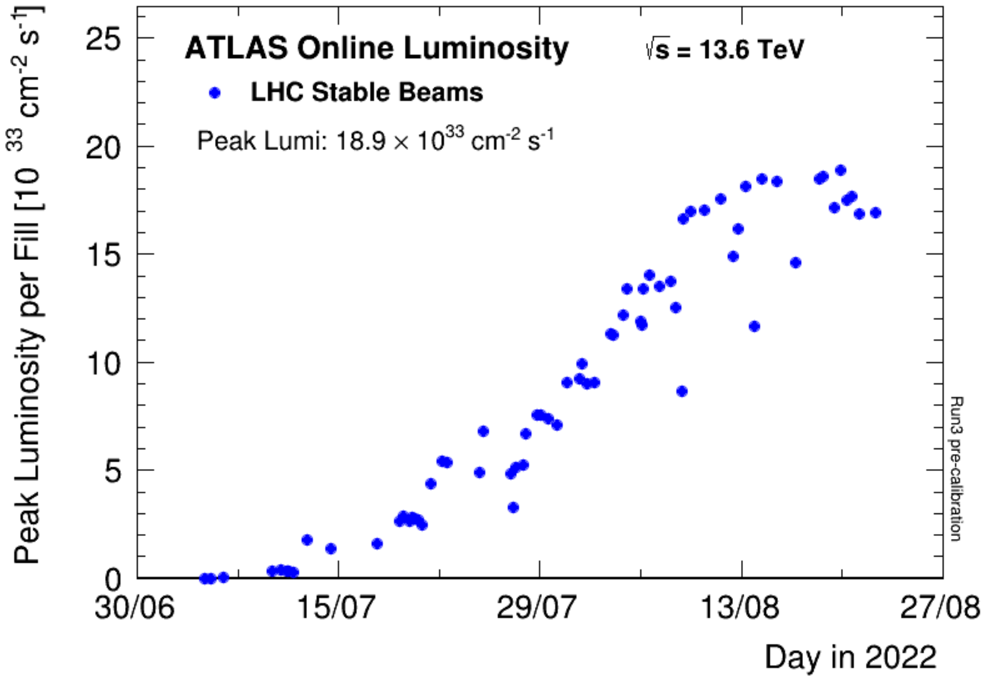
The Higgs boson discovery in 2012 opened a new era of exploration at the LHC, HL-LHC and future colliders.

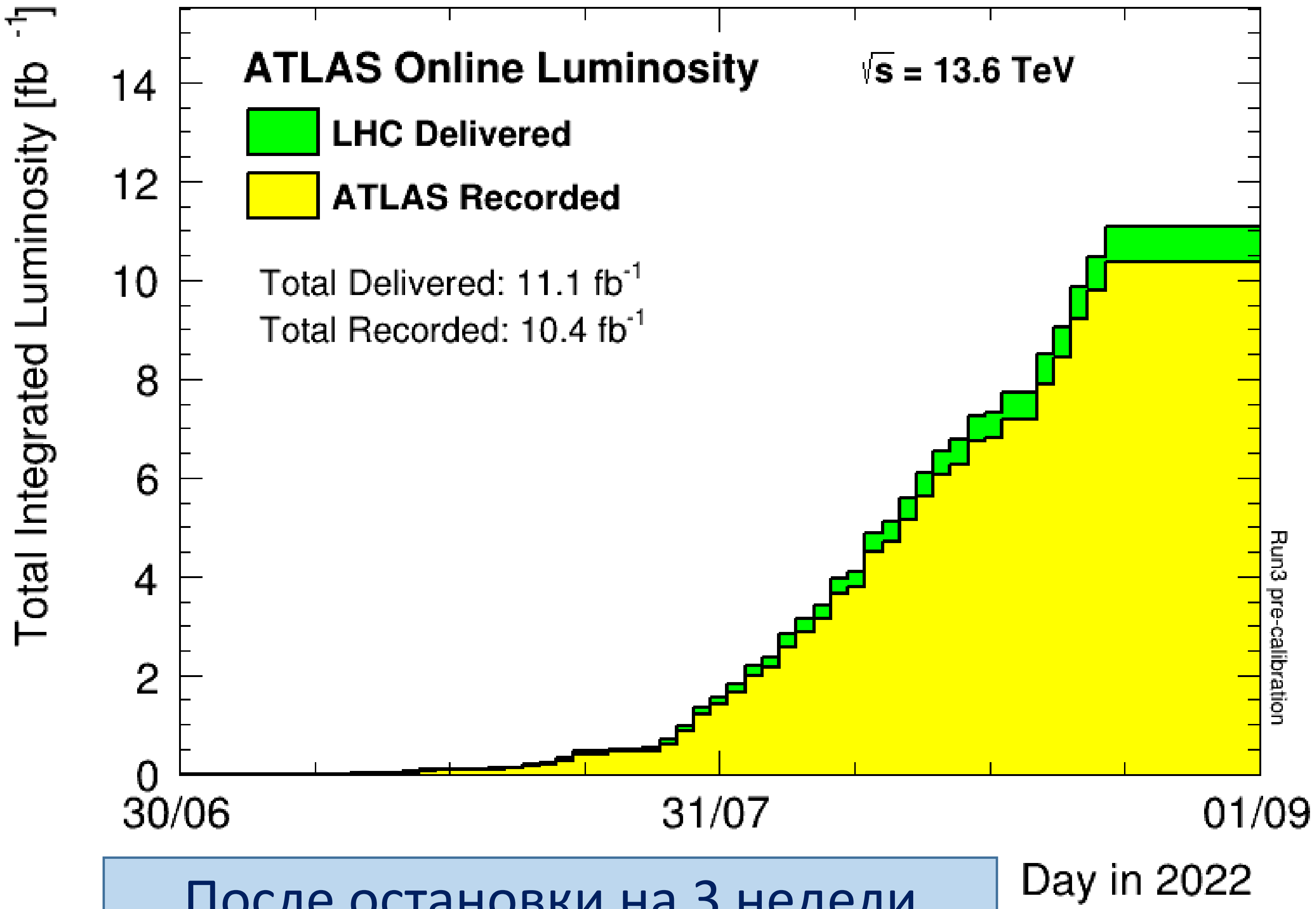
The fundamental questions surrounding the Higgs boson (naturalness, origin of flavor and masses, CP-violation and baryogenesis, vacuum stability, existence of additional Higgs bosons, portal to dark sector, etc.) make it an extraordinary discovery tool and motivate a broad and extensive programme of investigations (couplings to as many generations as possible, Higgs potential, rare decays, BSM decays, differential measurements, searches for extended Higgs sectors, etc.).

Progress in accelerator, detector and computing technologies, theory, and analysis techniques, as well as lots of ingenuity, will be needed to fully exploit the discovery power of this special particle at current and future colliders.
A bright future ahead for generations of scientists!

The Higgs boson discovery, and the many beautiful accomplishments at the LHC since then, demonstrate the talent, competence, perseverance and determination of the worldwide high-energy physics community, and its ability to deliver beyond expectation. These are crucial assets for future, even more ambitious projects

Статус RUN 3 (ATLAS)





После остановки на 3 недели
сейчас идет сеанс на LHCf

Достижения ATLAS: 30 новых результатов:

СМ, упругое рассеяние, Хиггс, поляризация W/Z, r_g

ATLAS Highlights

Guillaume Unal (CERN)
On behalf of the ATLAS Collaboration
ICHEP - Bologna July 11th, 2022

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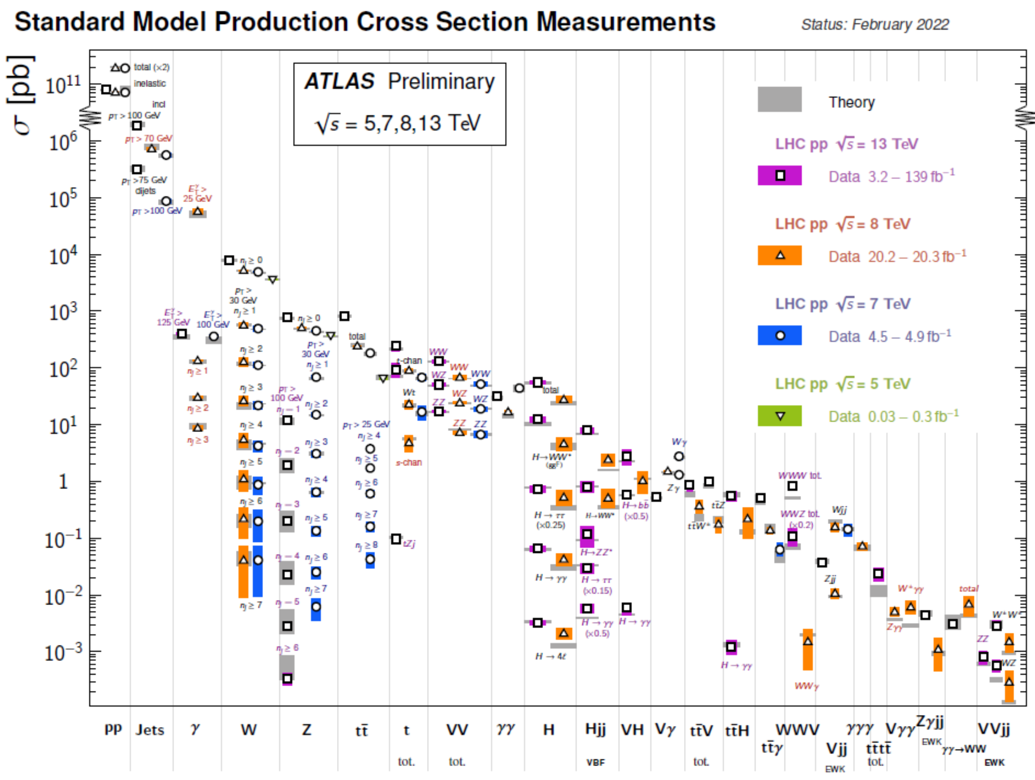


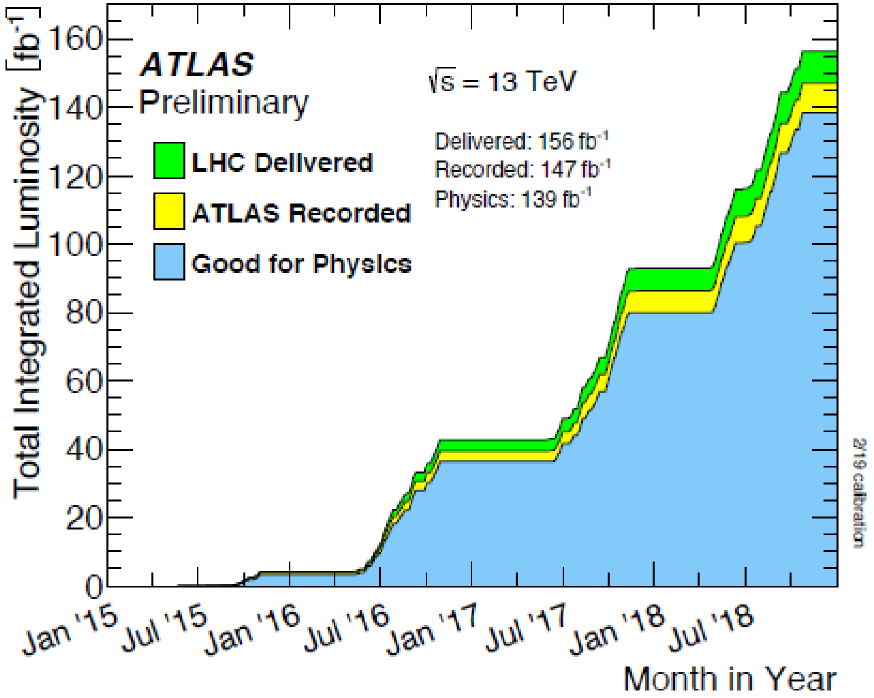
large benefit from recent theory developments and computations

5

ATLAS experiment at the CERN LHC collider

Vast and rich physics program at the high energy frontier

- Understanding of electroweak symmetry breaking and of the BEH mechanism
- Broad search program at the ~TeV scale addressing naturalness, dark matter, flavour
  - Also sensitive to feeble interactions
- Precise measurements of SM (EW, top, QCD) processes and heavy flavour properties
  - indirect probes to BSM physics
- Studies of the quark gluon plasma properties



Fantastic dataset recorded in run 2 (2015-2018) after the run 1 data set (2010-2012) (incl. PbPb, XeXe and pPb collisions)

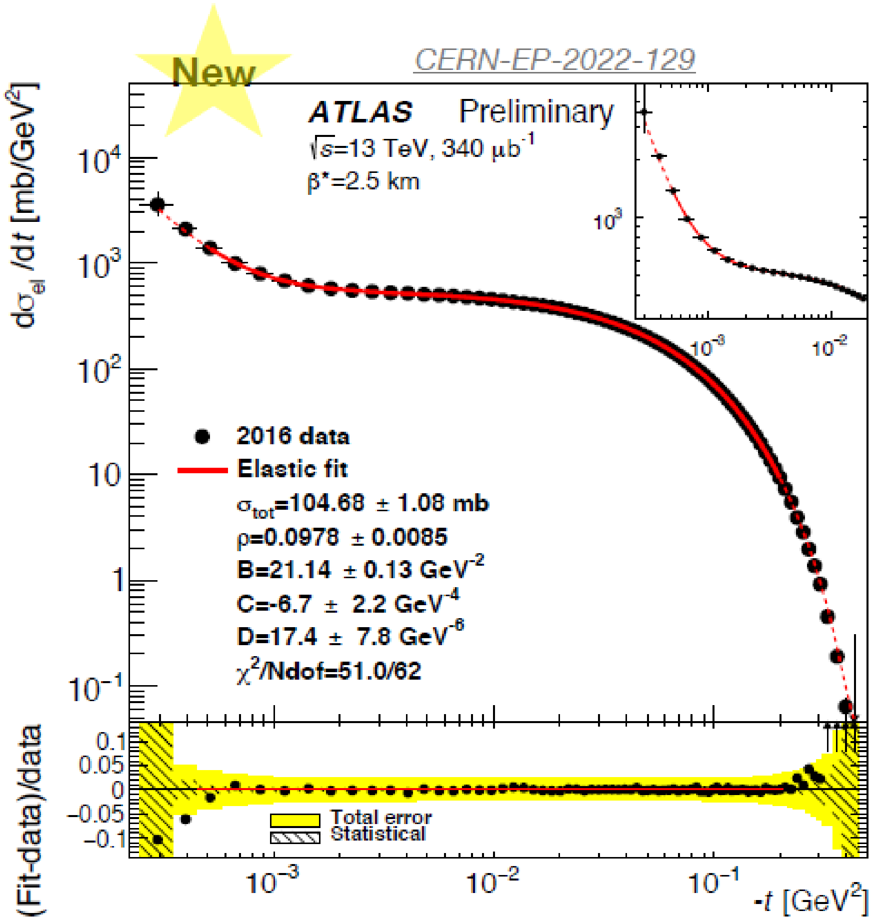
Thanks to the LHC

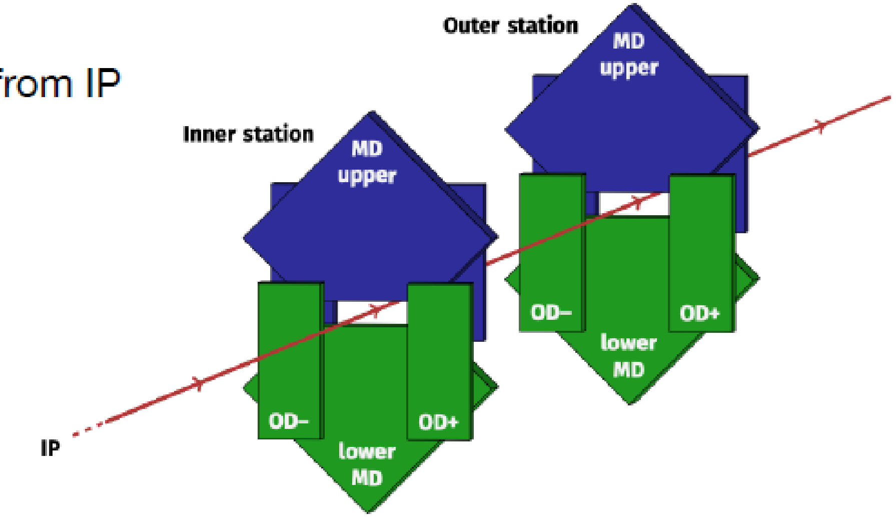
1070 papers submitted for publication
220 results with full run 2 p-p collision dataset

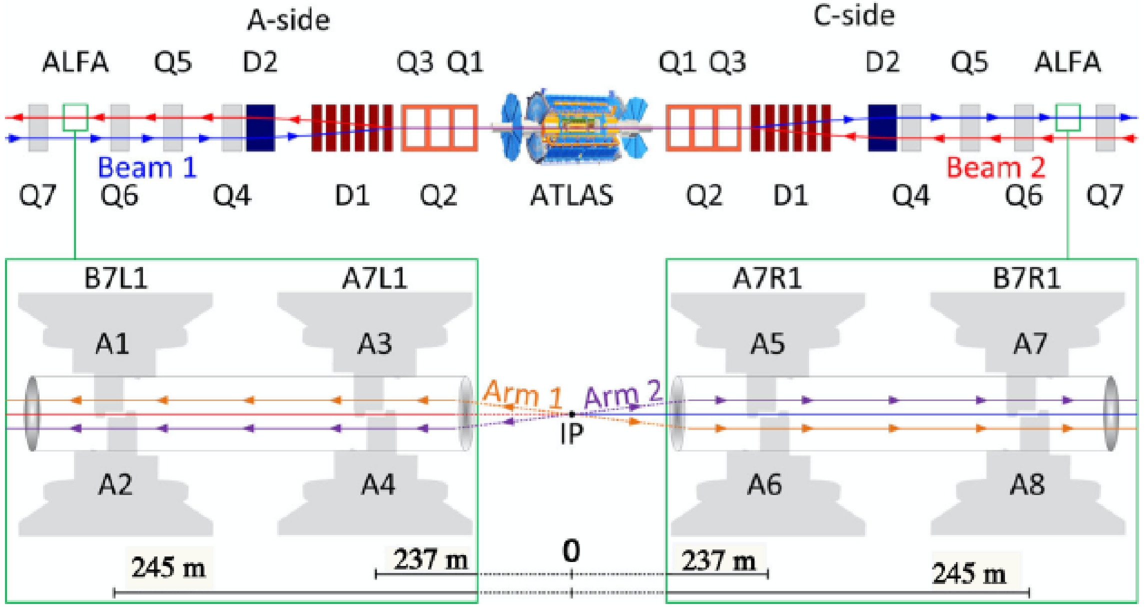
Из них 2 по B-физике (по одной в 2021 и 2022 гг.)

Elastic cross-section measurement

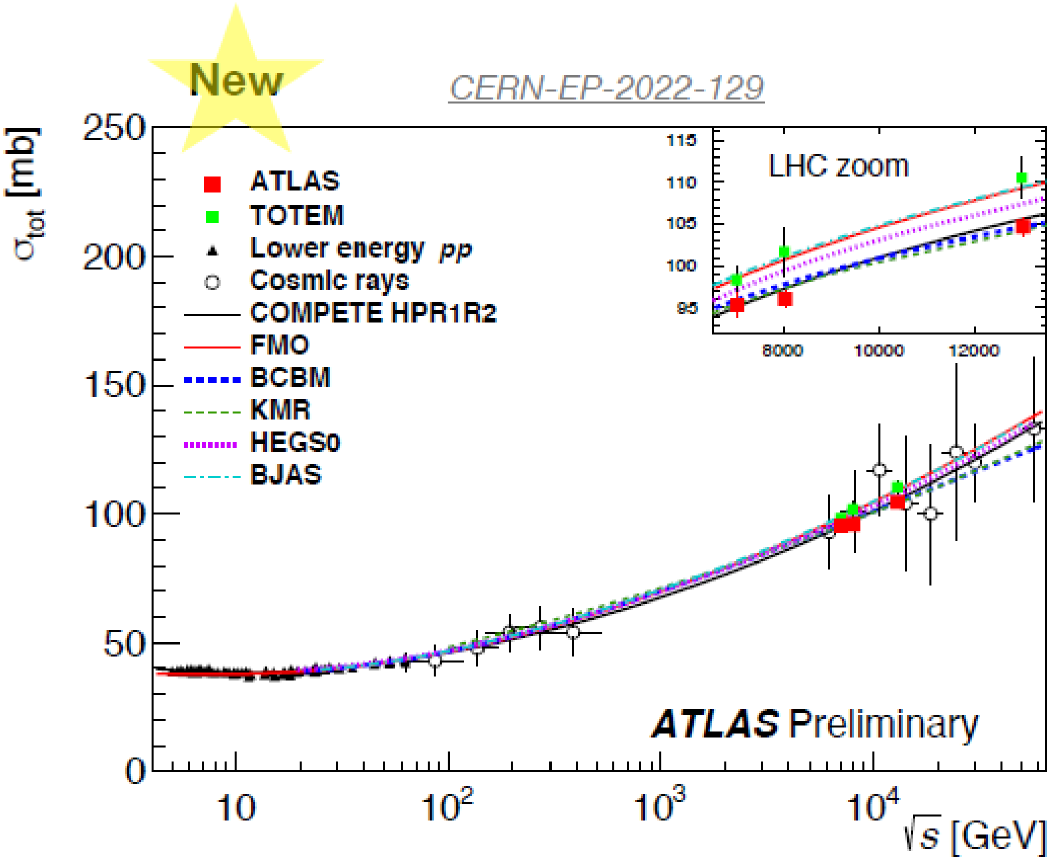
- Differential dσ/dt pp→pp elastic cross-section
  - Measure scattered protons with detectors located in roman pots ~240m from IP
  - Special data taking with large β* optics (2.5km)
  - Luminosity calibration from Van Der Meer scans

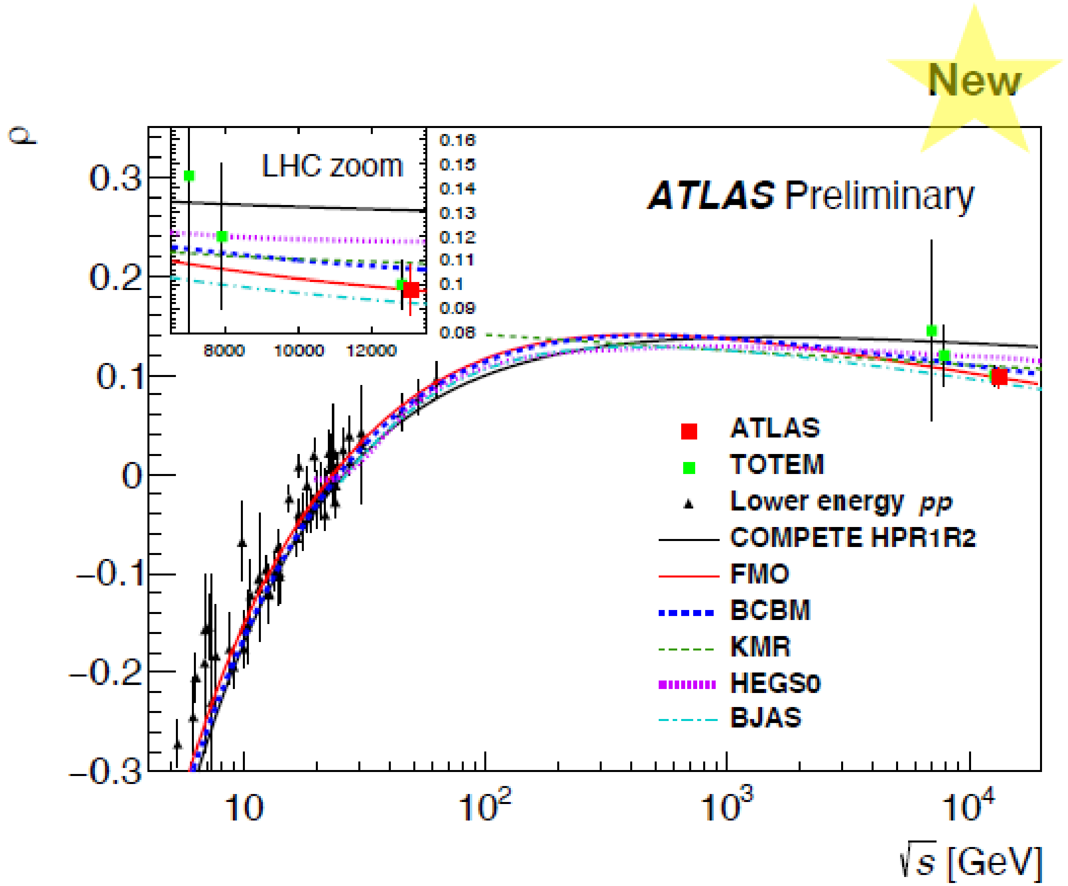






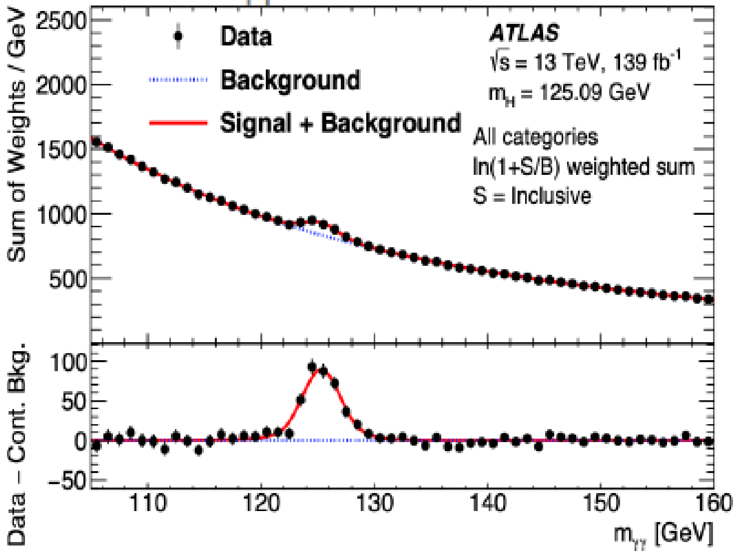
- From precise dσ/dt measurement can extract
  - ρ (Real/Imaginary part of elastic amplitude for t->0) **0.0975 ± 0.0106**
  - Total cross-section (from optical theorem) **104.68 ± 1.08 mb**
- common models don't accommodate well both measurements at the same time



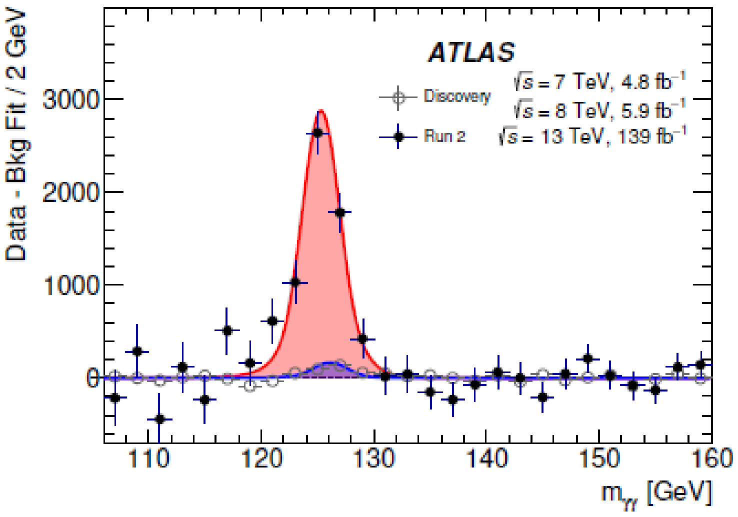


Higgs boson measurements

H→γγ Full run 2 dataset



Comparison with discovery dataset in 2012



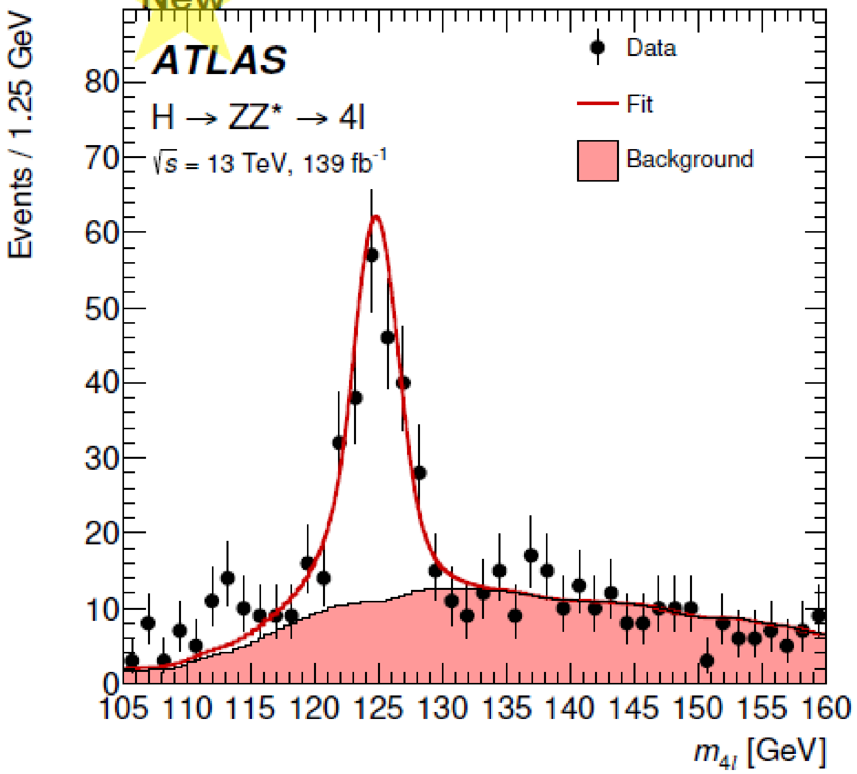
Precise mass measurement using H→4l

Event-by-event resolution, DNN for S/B separation, precise muon and electron momentum calibration

$$mH = 124.94 \pm 0.17(\text{stat.}) \pm 0.03(\text{syst.})\,\text{GeV}$$

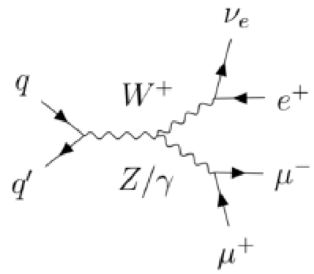
(combined with run 1 data)

arXiv:2207.00320



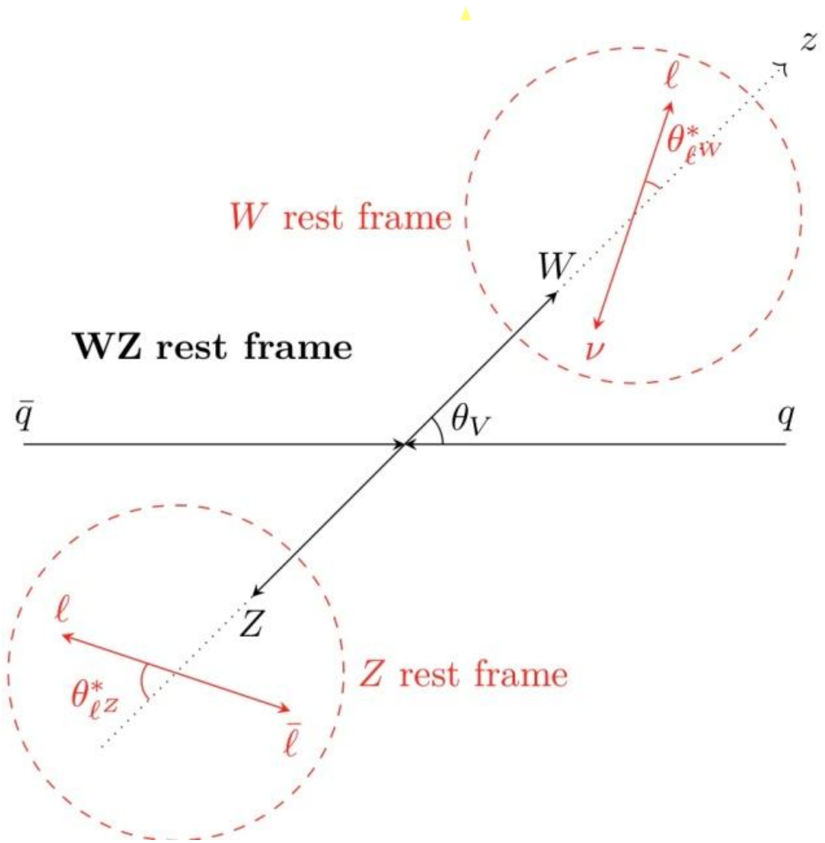
For the very first time, the ATLAS Collaboration has observed events with both a W and Z boson simultaneously polarised longitudinally.

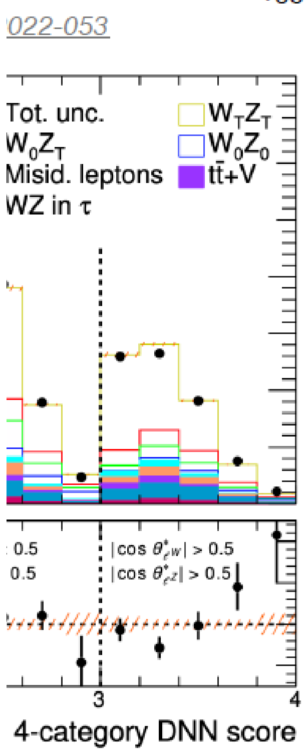
Precise studies of rare SM processes: polarization in WZ production

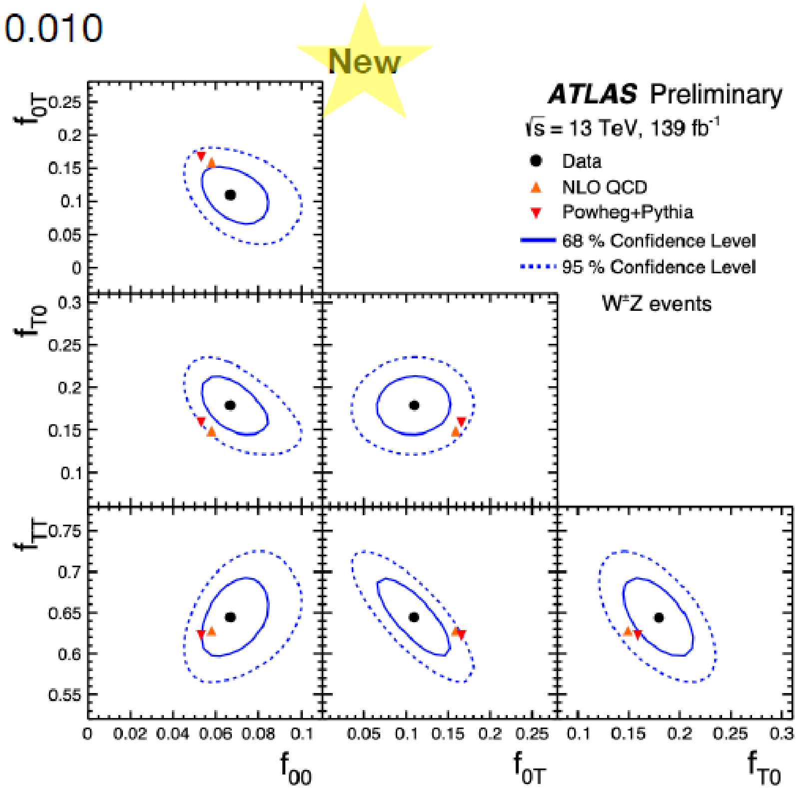


- Study W and Z polarisation in WZ events reconstructed in 3l+v decay mode
- Joint measurement of W and Z polarisation fraction, using deep neural network
- First observation of simultaneous production of longitudinally polarised W and Z bosons with 7.1σ

$f_{00} = 0.067 \pm 0.010$







Observation of di-charmonium excess in the 4μ final state

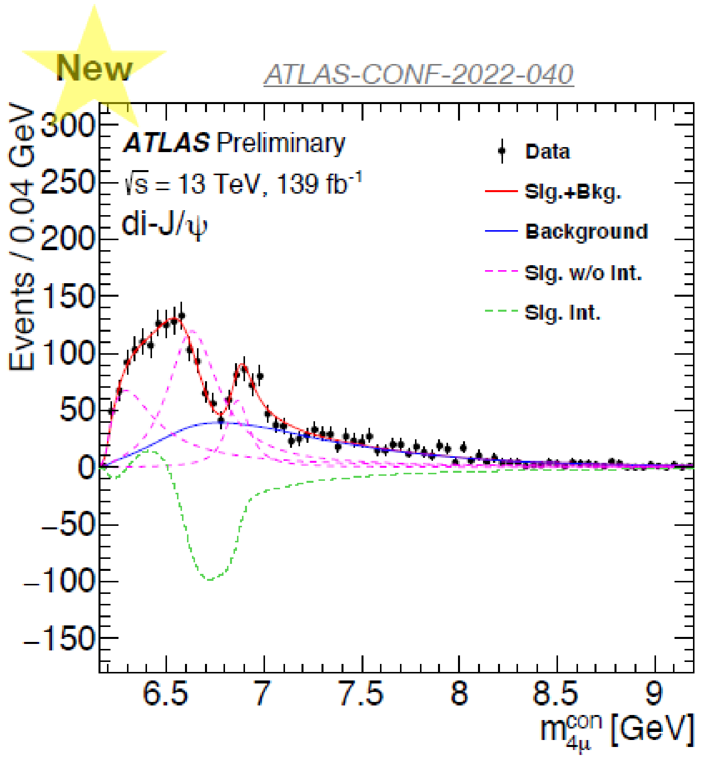
Motivated by Tetraquark

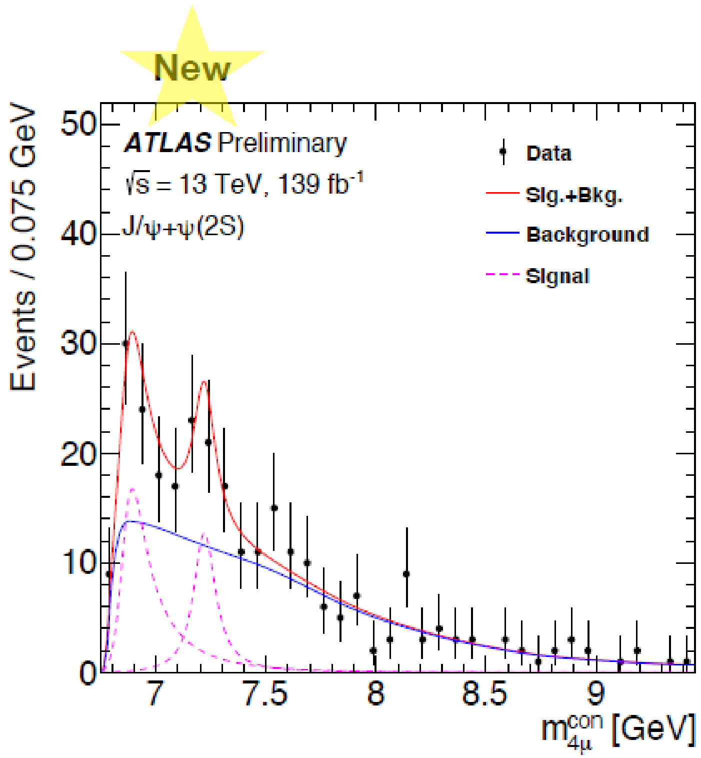
$$T_{cc\bar{c}\bar{c}} \to J/\psi\ J/\psi \to 4\mu$$
$$T_{cc\bar{c}\bar{c}} \to J/\psi\ \psi(2S) \to 4\mu,$$

Background from single parton and double parton scattering

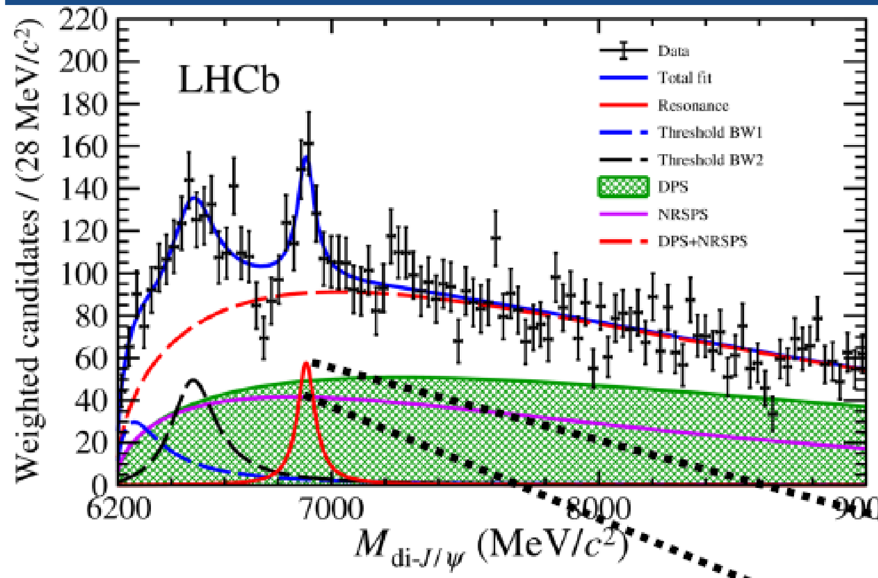
See large structures near threshold as well as narrow resonance at 6.9 GeV, confirming LHCb observation

ATLAS-CONF-2022-040





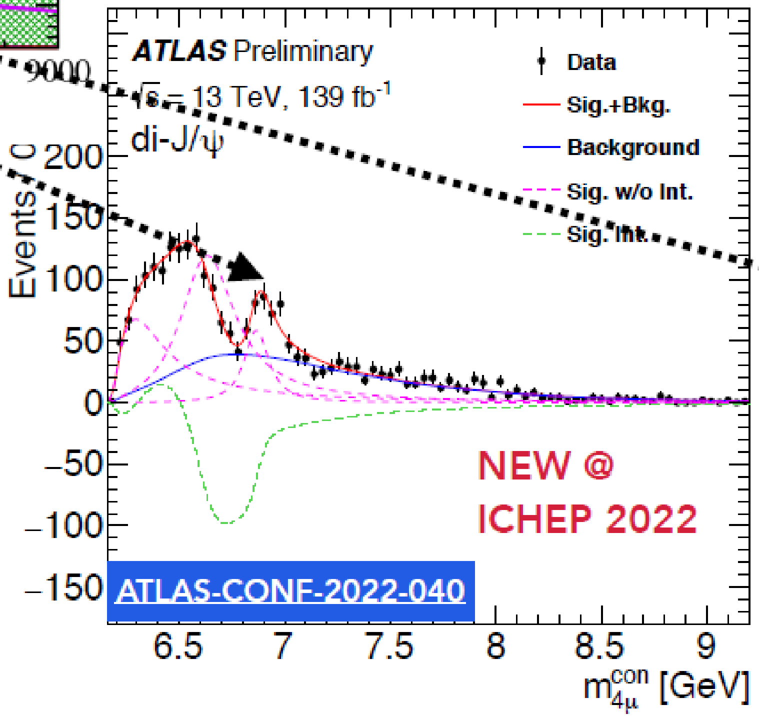
4-quark states: a growing family

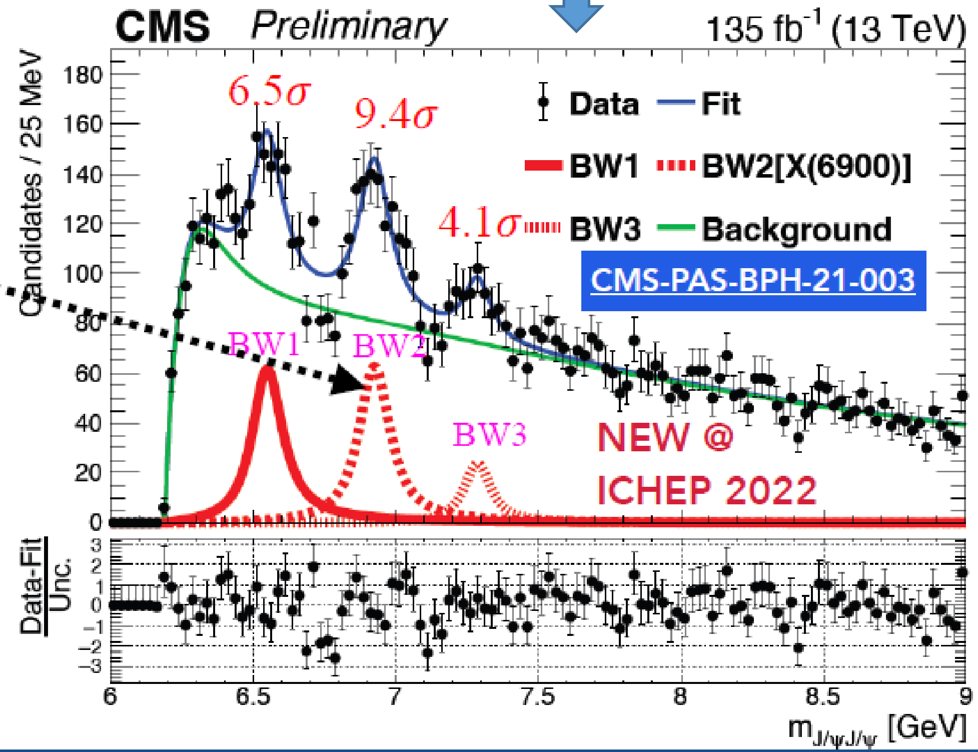


SCIENCE BULLETIN 65 (2020) 1983

CMS:

	BW1	BW2	BW3
m	$6552 \pm 10 \pm 12$	$6927 \pm 9 \pm 5$	$7287 \pm 19 \pm 5$
Γ	$124 \pm 29 \pm 34$	$122 \pm 22 \pm 19$	$95 \pm 46 \pm 20$
N	474 ± 113	492 ± 75	156 ± 56





Из пленарного доклада по Flavor physics by Vladimir Gligorov

Spectacular confirmation of LHCb's double-J/Ψ signal from ATLAS and CMS, and new discovery!

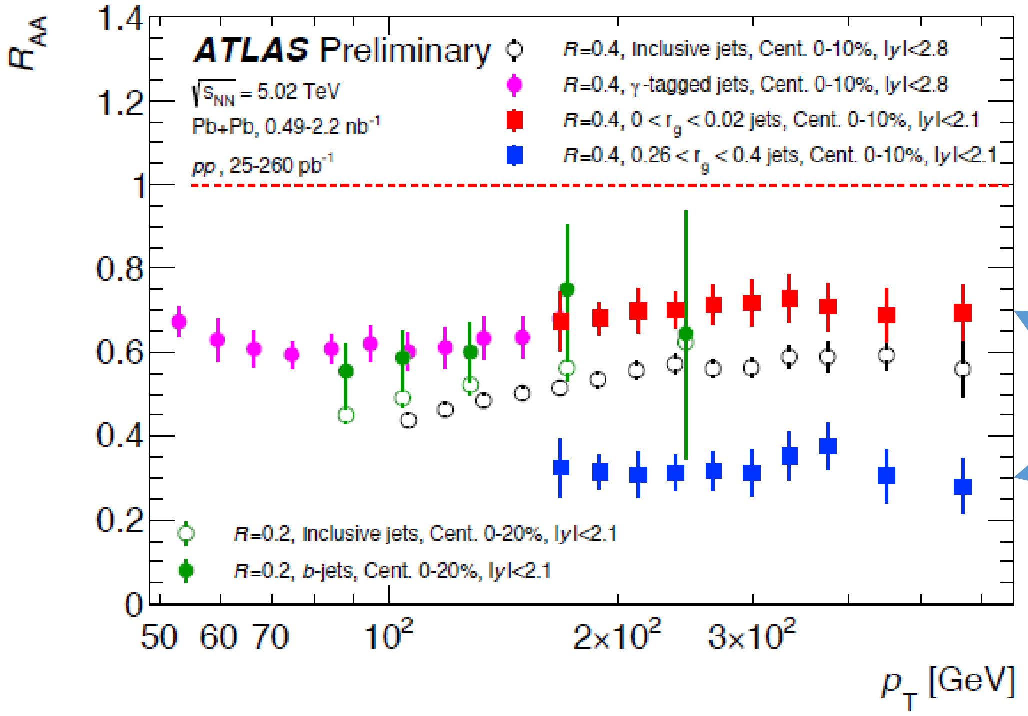
Physics with Pb Pb collisions

studies of jet quenching in quark-gluon plasma

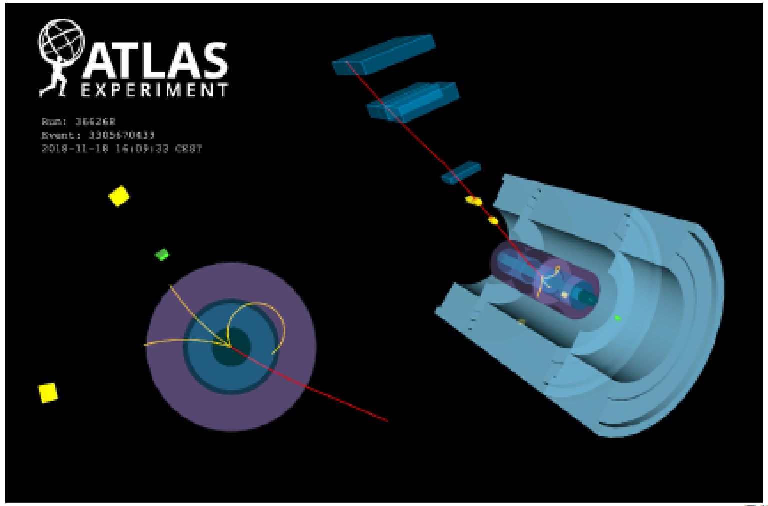
$$R_{AA} = \frac{1}{N_{coll}} \frac{[\text{A+A}]}{[\text{pp}]} = \frac{1}{N_{coll}} \frac{\frac{dN_{AA}}{dp_T}}{\frac{dN_{pp}}{dp_T}}$$

Scaled A+A

pp

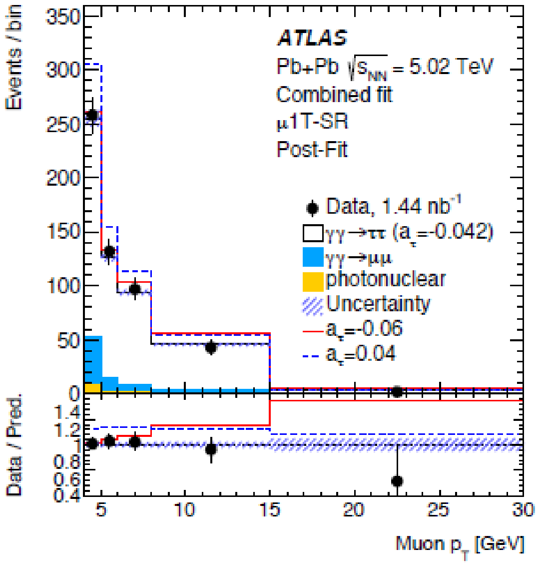


γγ→ττ process in ultra peripheral collisions



arXiv:2202.13478

Струи с разной когерентности излучения (время первого испускания жесткого глюона)

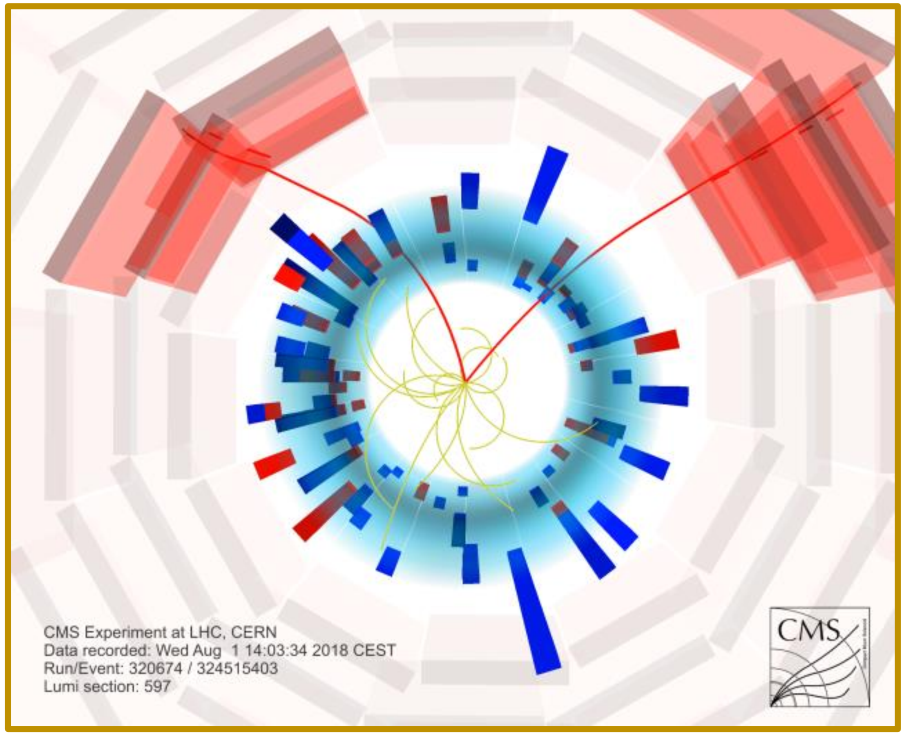


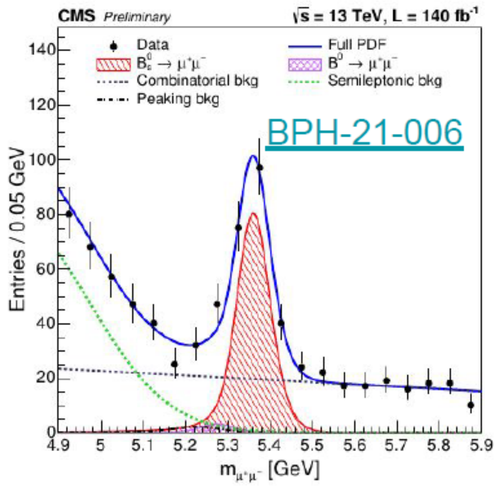
CMS достижения на ICHEP 2022 (A.Rizzi)

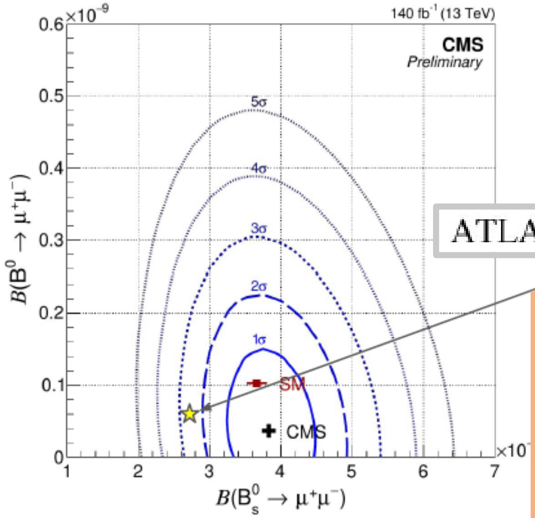
CMS@ICHEP
85 parallel talks
28 posters

CMS measures rare particle decay with high precision
Using LHC Run 2 data, CMS has precisely measured the rare decay of strange B mesons to muon–antimuon pairs. While its properties agree with Standard Model predictions, it may provide clues to new discoveries in Run 3

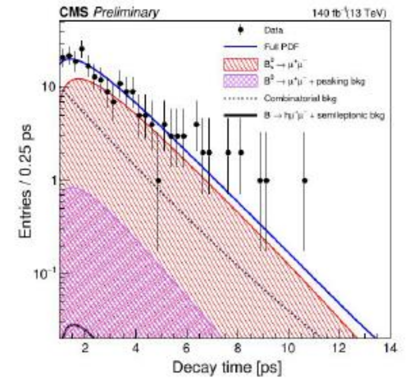
ATLAS and CMS release results of most comprehensive studies yet of Higgs boson's properties







$$\tau = 1.83\,^{+0.23}_{-0.20}\,(\text{stat})\,^{+0.03}_{-0.03}\,(\text{syst})\ \text{ps.}$$



$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \left[3.95\,^{+0.39}_{-0.37}\,(\text{stat})\,^{+0.29}_{-0.24}\,(\text{syst})\right] \times 10^{-9}$$

- Updated results with **full Run-2 luminosity**
- Most precise single experiment measurement to date
  - Highly compatible with SM prediction
- Most precise measurement of lifetime

..if you missed the parallel
Dedicated CERN Seminar on July 26th

18

Ten years since Higgs boson discovery

physics briefing!

CERN 10 years HIGGS boson discovery

nature

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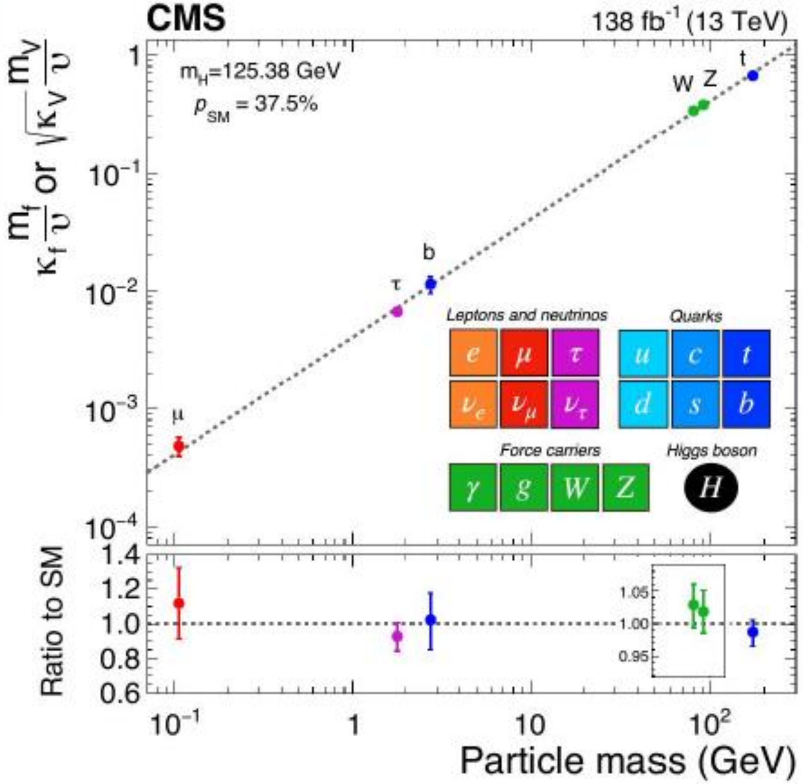
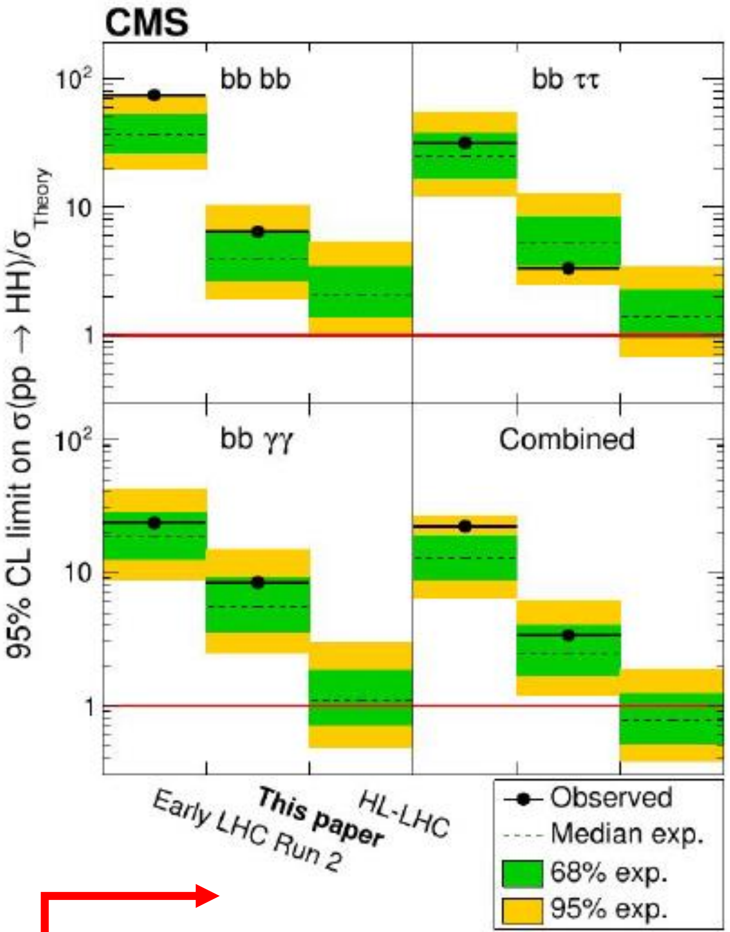
Article | Open Access | Published: 04 July 2022

A portrait of the Higgs boson by the CMS experiment ten years after the discovery

The CMS Collaboration

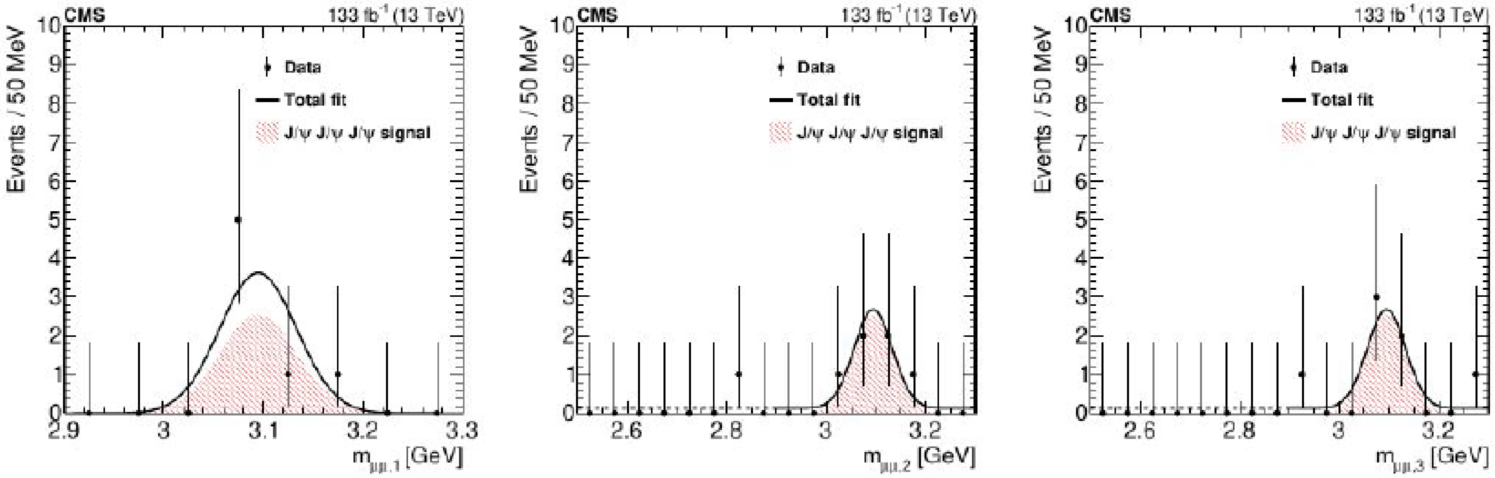


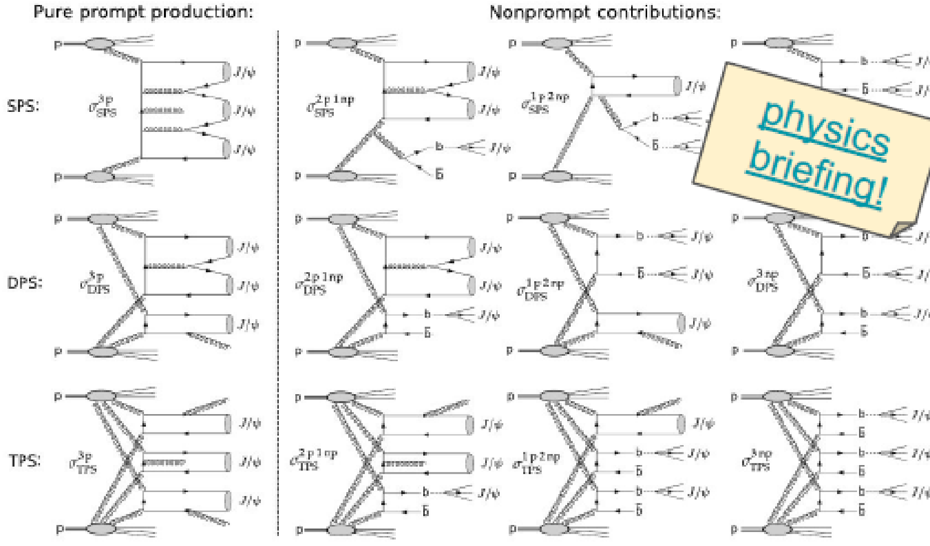


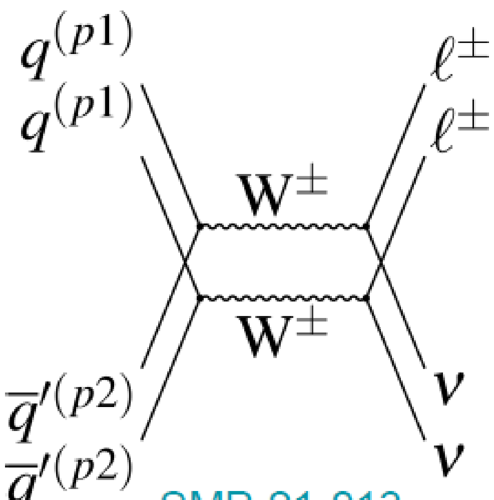
- Combination of multiple results fitting for *coupling modifiers*
- Combination of HH results for the three most sensitive channels (4b, 2b2τ, 2b2γ)
    - Reaching ~3x SM sensitivity, expect SM sensitivity with HL-LHC
- See our Nature paper for more details and **Chiara's talk tomorrow**

Triple J/ψ and WW Double Parton Scattering

BPH-21-004







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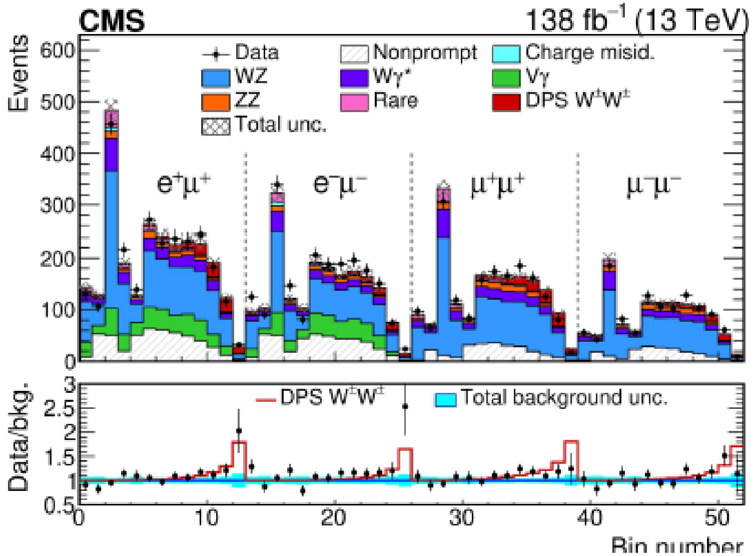
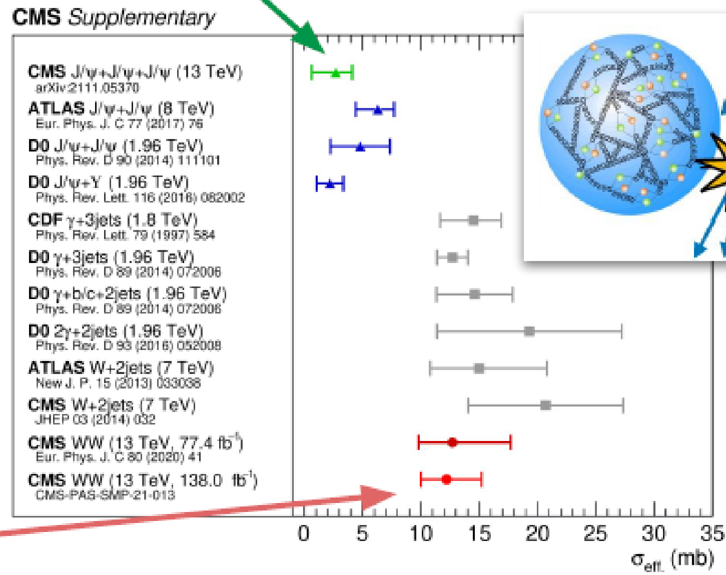
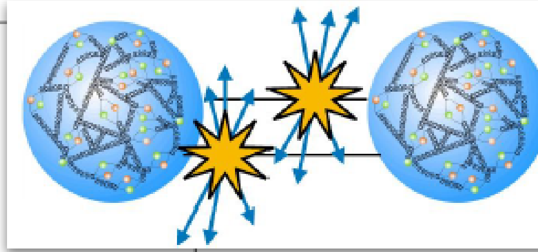






physics briefing!

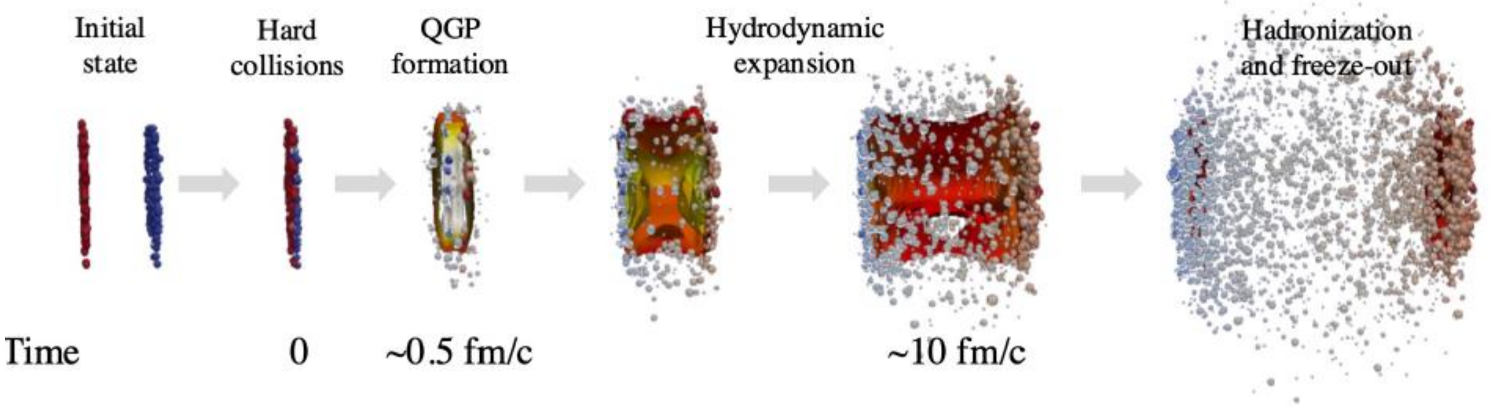
ALICE достижения ICHEP 2022 (A.Dienese)

A Large Ion Collider Experiment

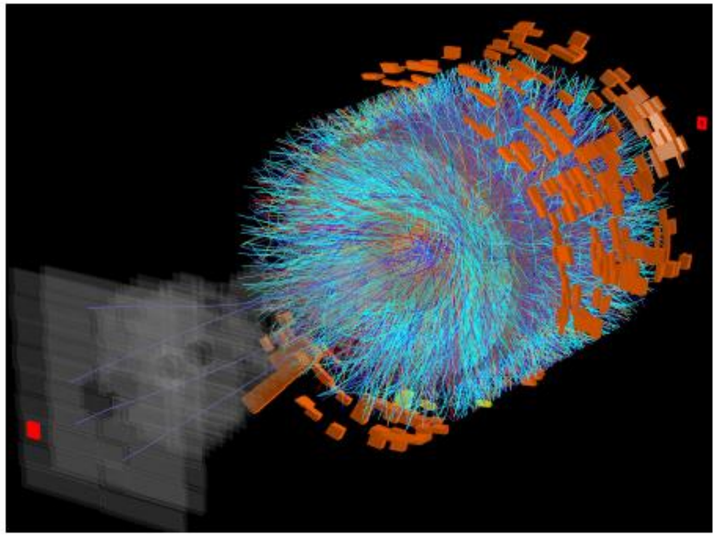
→ J. Bielcikova, C. Salgado, Wed plenary

ALICE physics with HI and pp collisions: quark-gluon plasma and much more QCD

- Explore the deconfined phase of QCD matter → quark-gluon plasma
- **LHC Pb-Pb → large energy density** (> 15 GeV/fm³) & **large volume** (~ 5000 fm³)

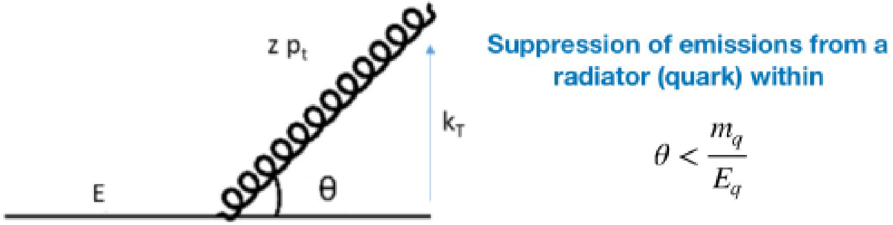


Visualization by J.E. Bernhard, arXiv:1804.06469

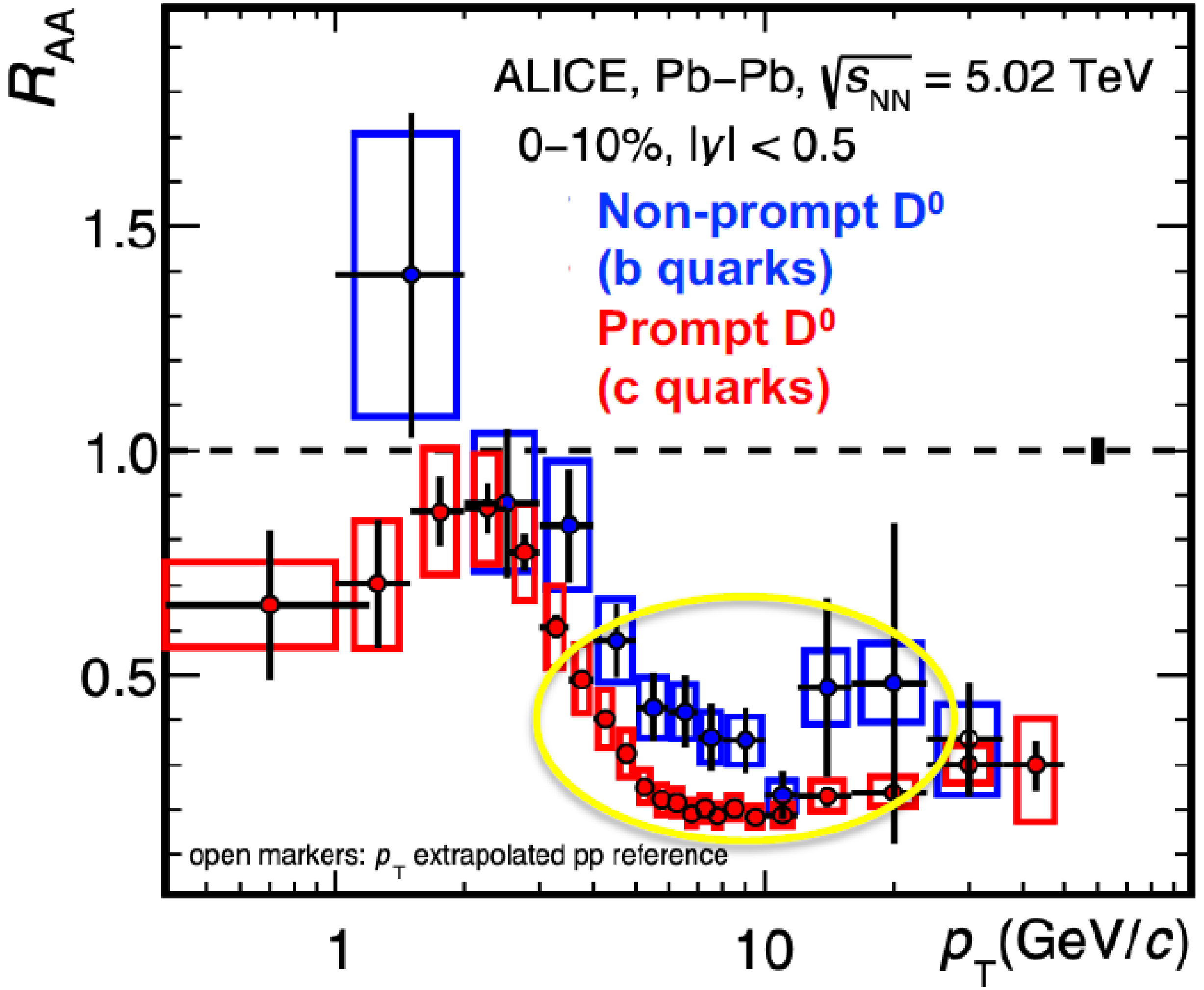


Quark-mass dependence of energy loss

- Energy loss predicted to depend on QGP density, but also on quark mass
- "Dead cone" effect reduces small-angle gluon radiation for high-mass quarks



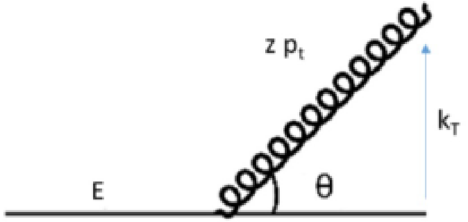
- Less suppression for (non-prompt) D mesons from B decays than prompt D mesons



arXiv:2202.00815

Quark-mass dependence of energy loss

- Energy loss predicted to depend on QGP density, but also on quark mass
- "Dead cone" effect reduces small-angle gluon radiation for high-mass quarks

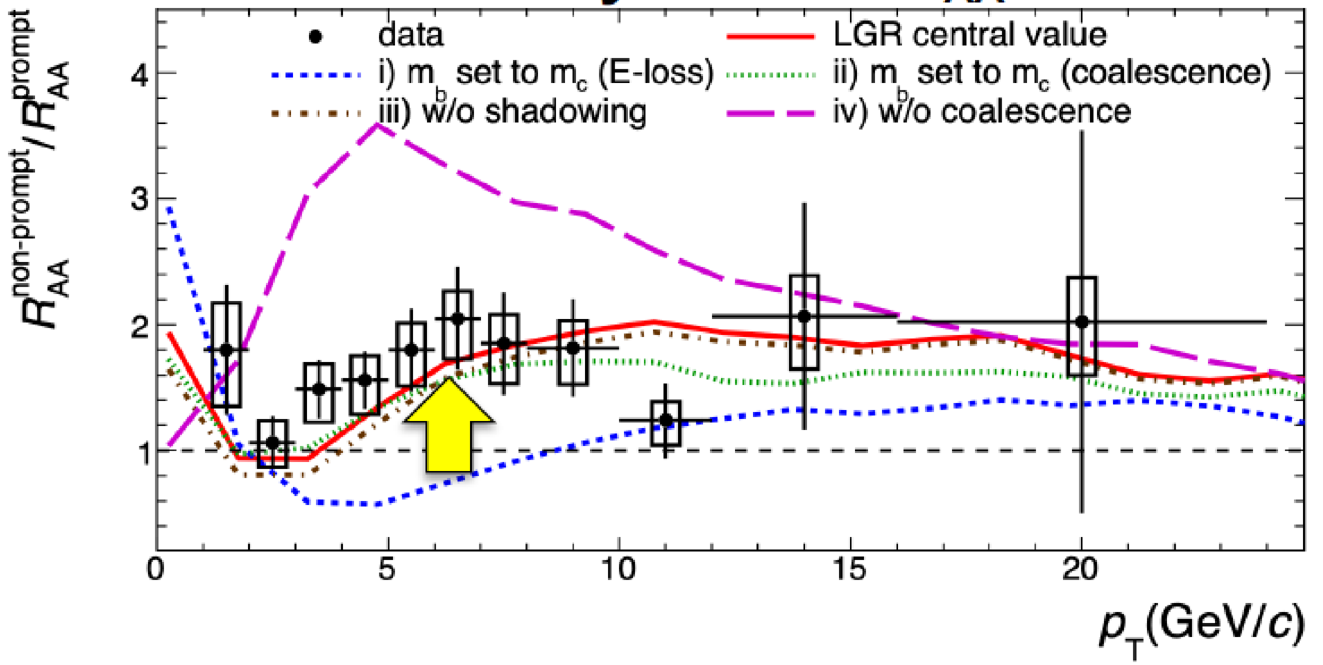


Suppression of emissions from a radiator (quark) within

$$\theta < \frac{m_q}{E_q}$$

- Less suppression for (non-prompt) D mesons from B decays than prompt D mesons
- Smaller energy loss for b quarks needed to describe the ratio of R_{AA}

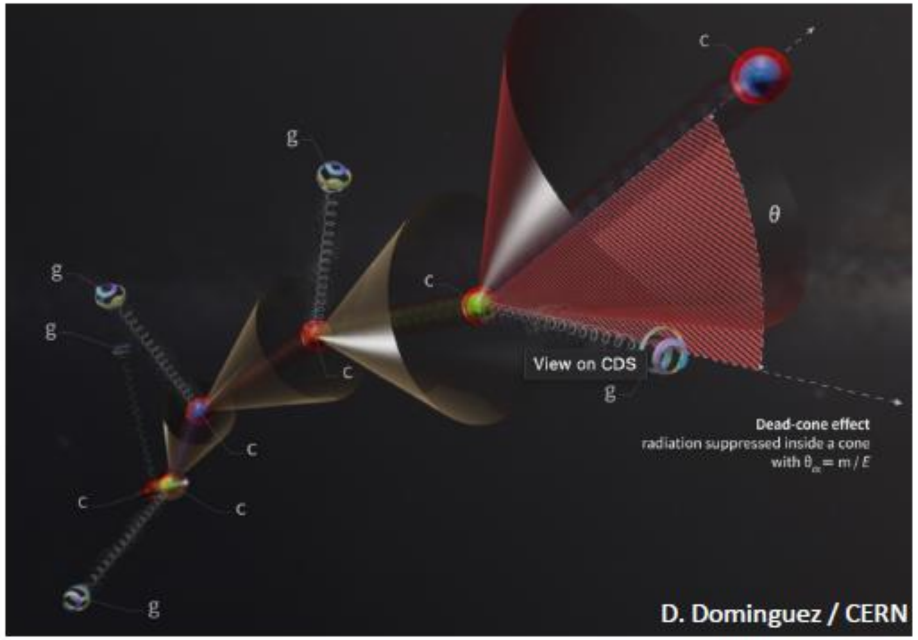
Beauty / charm R_{AA}



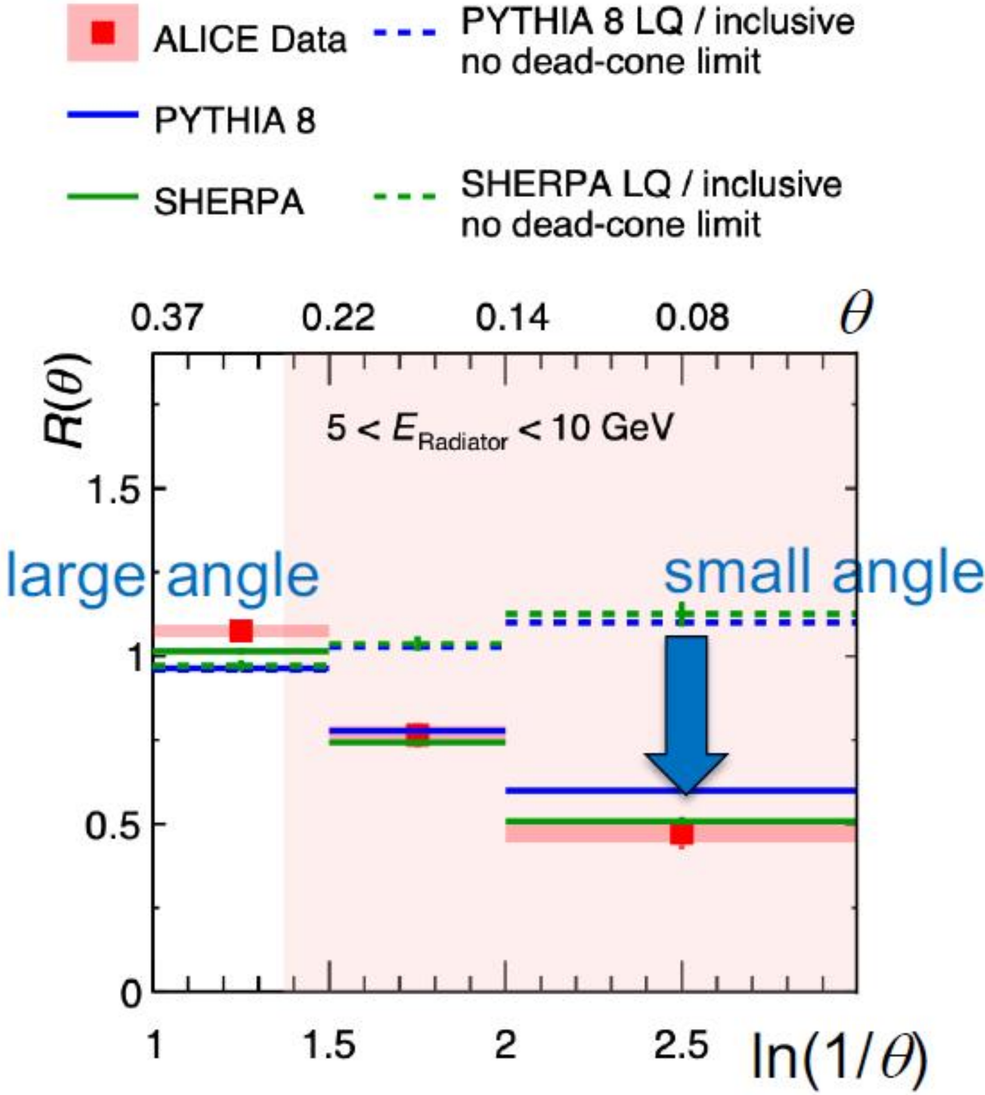
arXiv:2202.00815

In pp: dead-cone effect now exposed by ALICE

- Reduction of gluon radiation from heavy quarks at small angles Dokshitzer, Khoze, Troian, J.Phys.G 17 (1991) 1602



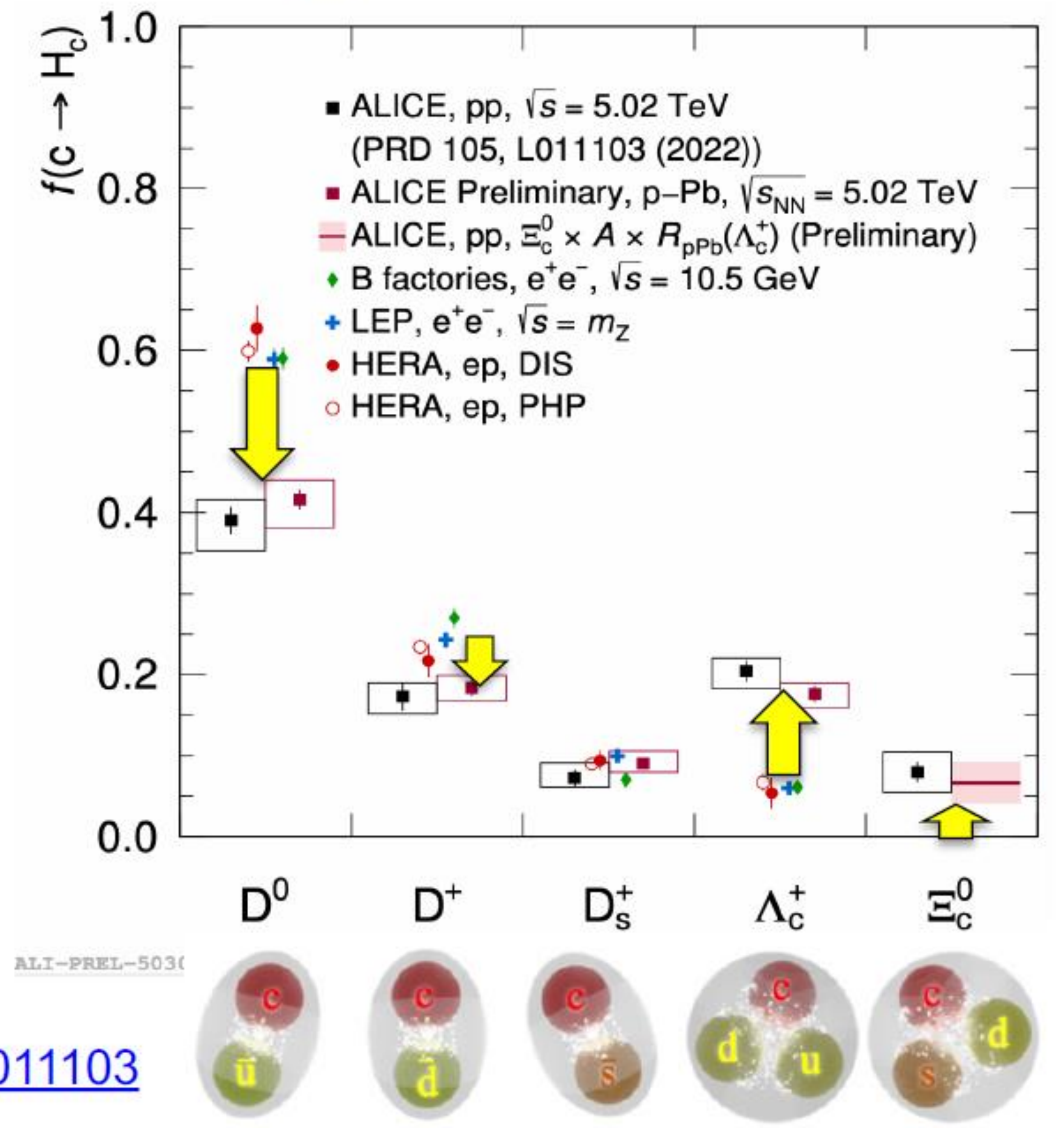
- First direct observation using jet iterative declustering and **Lund plane** analysis of jets that contain a soft D^0 meson



Nature 605 (2022) 7910, 440

Hadronization of charm quarks from pp …

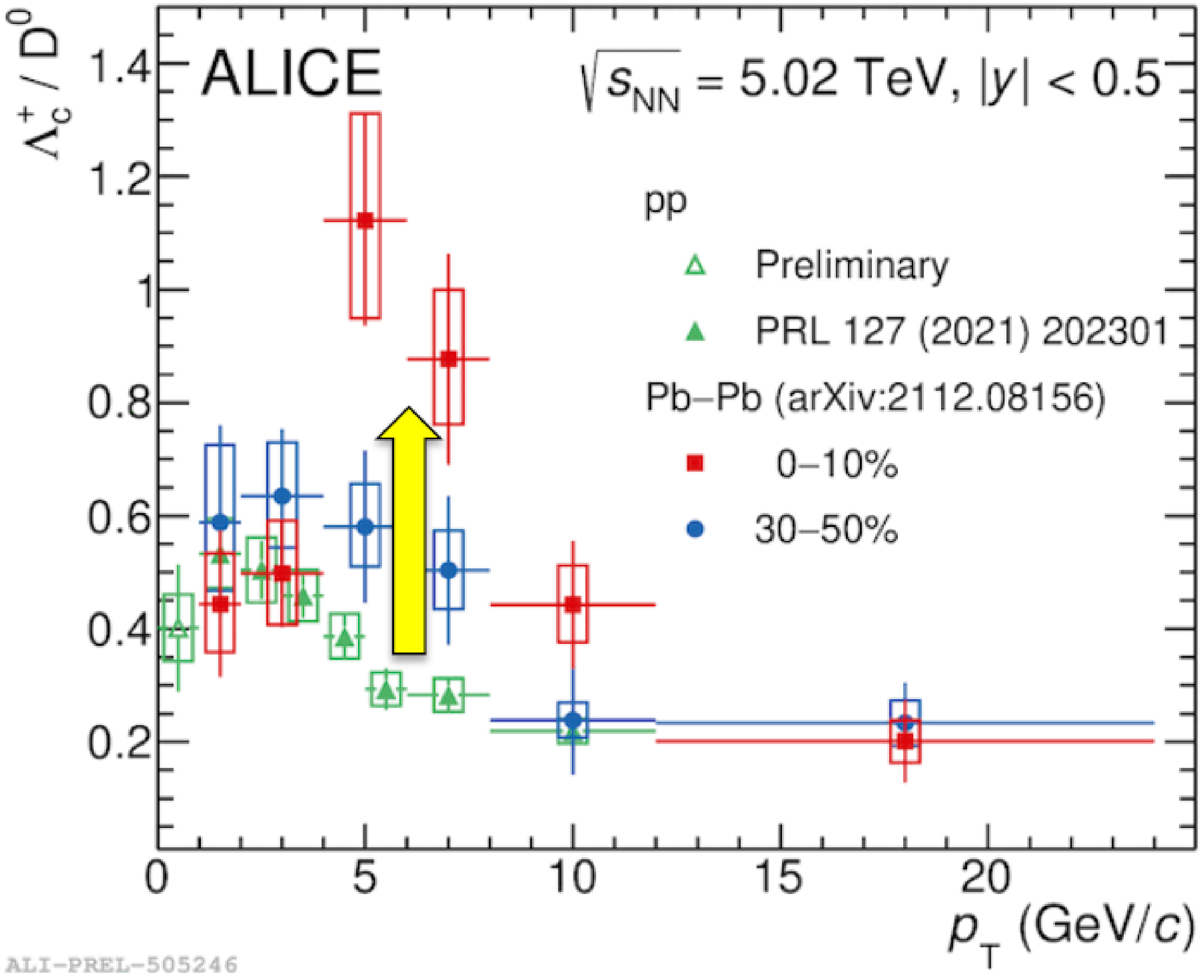
- Charm quarks hadronize to baryons with much larger probability in hadronic collisions than in ee and ep collisions
- ~ 30% c → baryons in pp and p-Pb
- *"Breakdown of jet universality, like for strangeness"* T. Sjöstrand (LHCP2022)
- Described by PYTHIA with beyond-leading colour effects, but only for Λ_c, and by hadronization via recombination



PRD105 (2022) L011103

Hadronization of charm quarks from pp to Pb-Pb

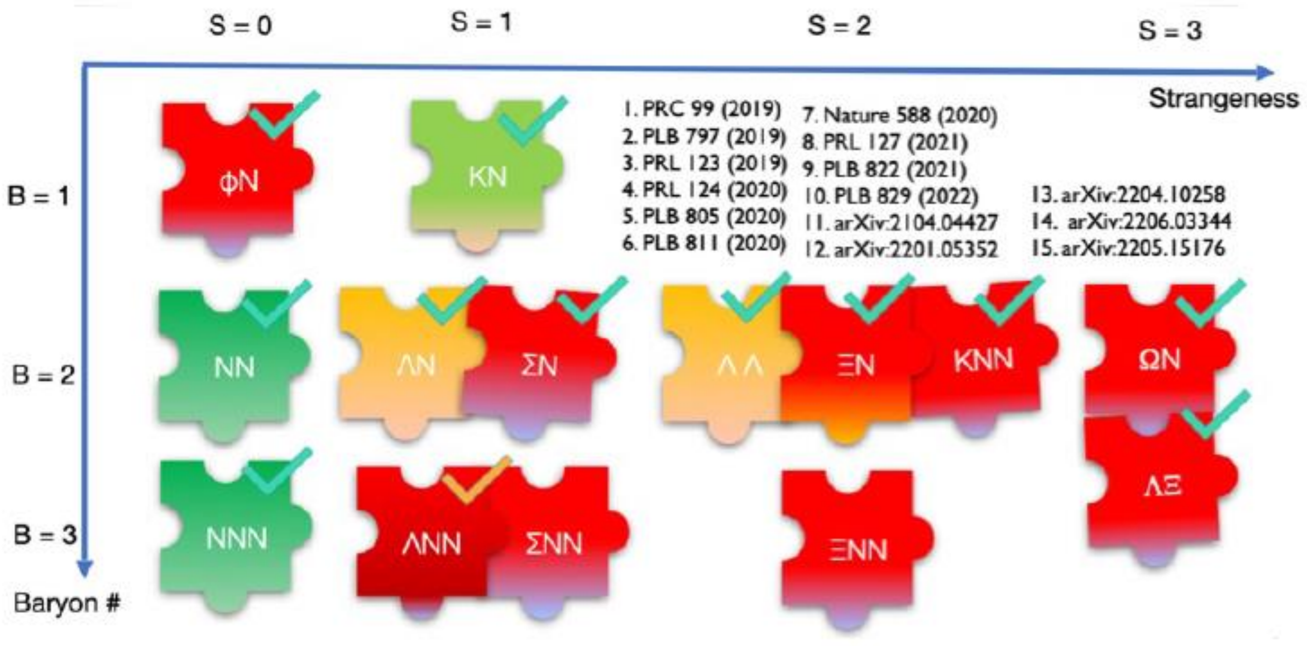
- Additional dynamics in central Pb-Pb collisions: Λ_c/D^0 enhancement at intermediate p_T
- Suggests hadronization by recombination + mass-dependent p_T shift from collective expansion
- Prospects: high-precision, and other baryons, from Run 3 data

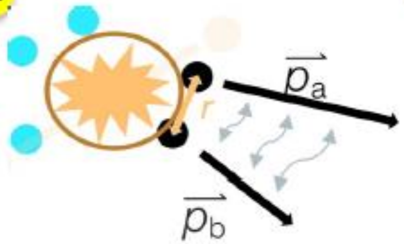


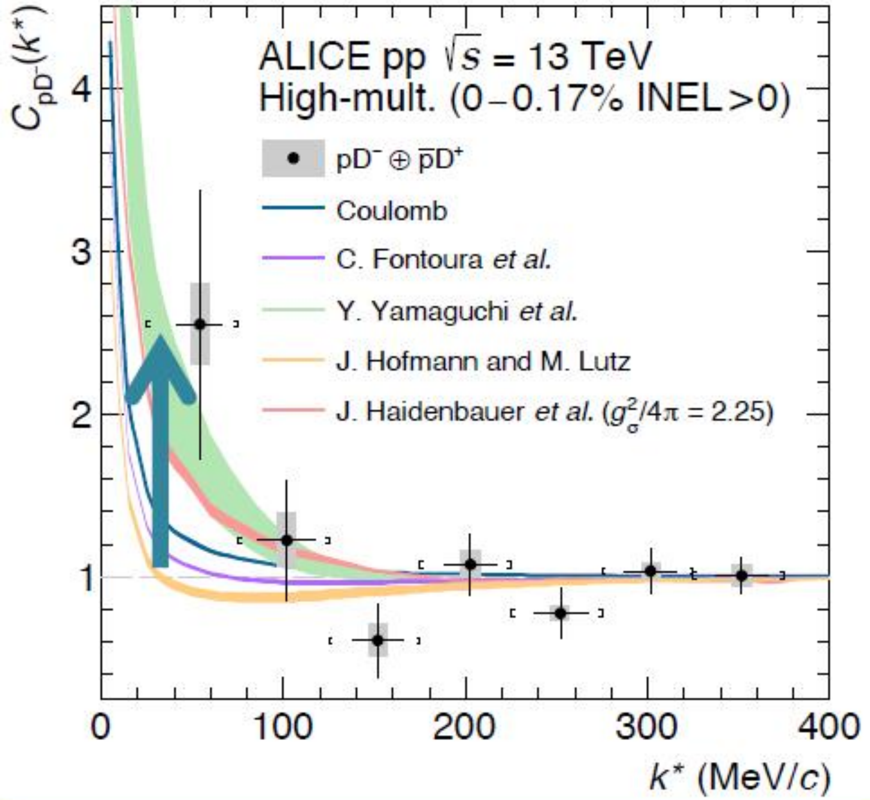
arXiv:2112.08156

QCD interaction among hadron pairs, and triplets

- Use femtoscopy technique to assess residual strong interaction in h-h and h-h-h
  - Poorly known for strange baryons
    - Relevant for neutron star modeling
  - Unknown for charm hadrons and 3-body







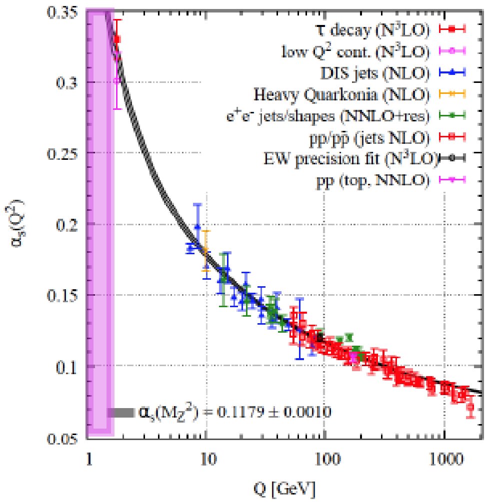
First measurement of p-D correlation function:
- Attractive interaction
- Estimate of QCD scattering parameters

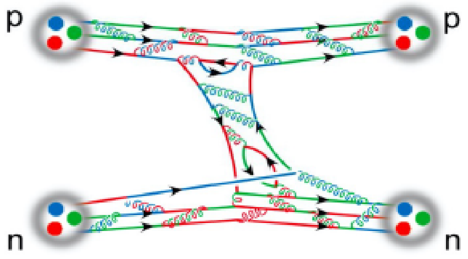
arXiv:2201.05352

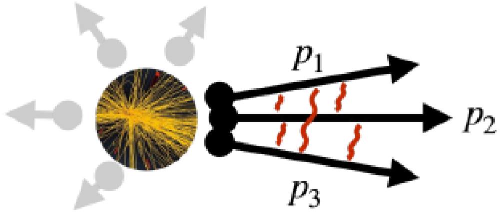
Recent results on strong interactions and hadron physics

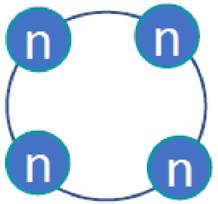
Laura Fabbietti, Technische Universität München

Residual strong interaction among hadrons









Non perturbative QCD → Q ~1 GeV, R ~ 1 fm

→ Effective theories with hadrons as degrees of freedom constrained to experimental data

<u>New results:</u>

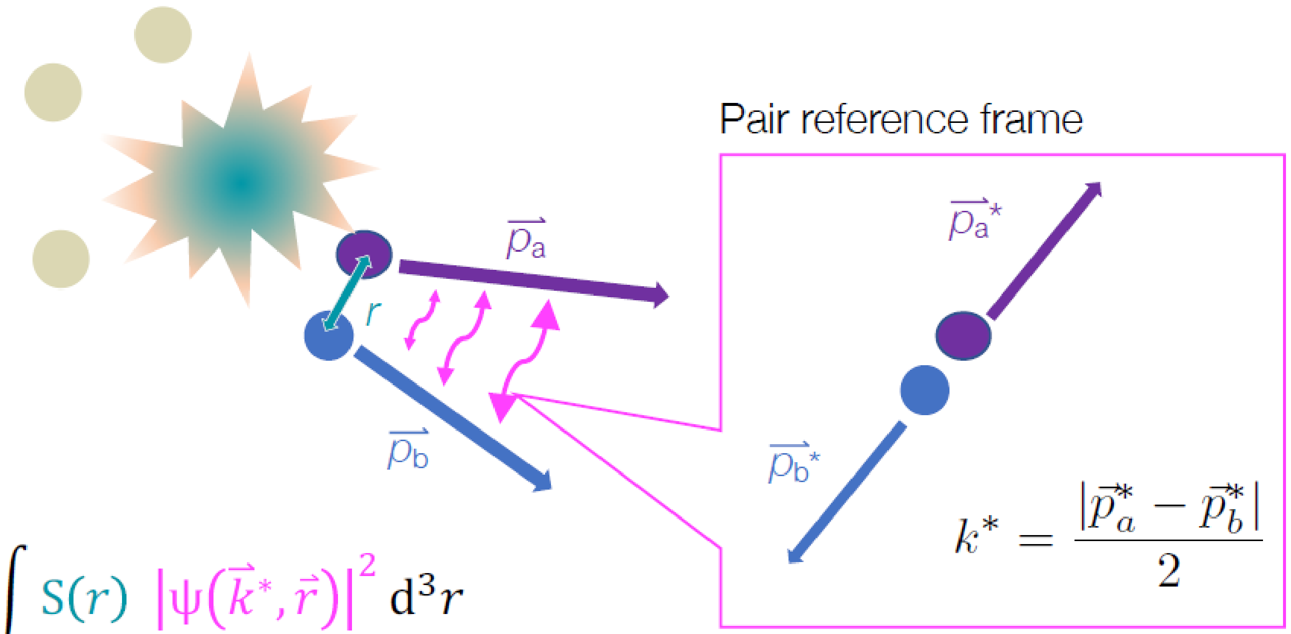
→ Understanding of the interaction starting from quark and gluons

→ New experimental methods to investigate three- and four-body systems

Метод изучения многочастичных систем – измерение корреляций

The Koonin-Pratt formalism

S. E. Koonin et al. PLB 70 (1977)



$$C(k^*) = \zeta(k^*) \cdot \frac{N_{same}(k^*)}{N_{mixed}(k^*)} = \int S(r)\ \left|\psi(\vec{k}^*, \vec{r})\right|^2 d^3r$$

Emission source

Two-particle wave function

Schrödinger Equation:

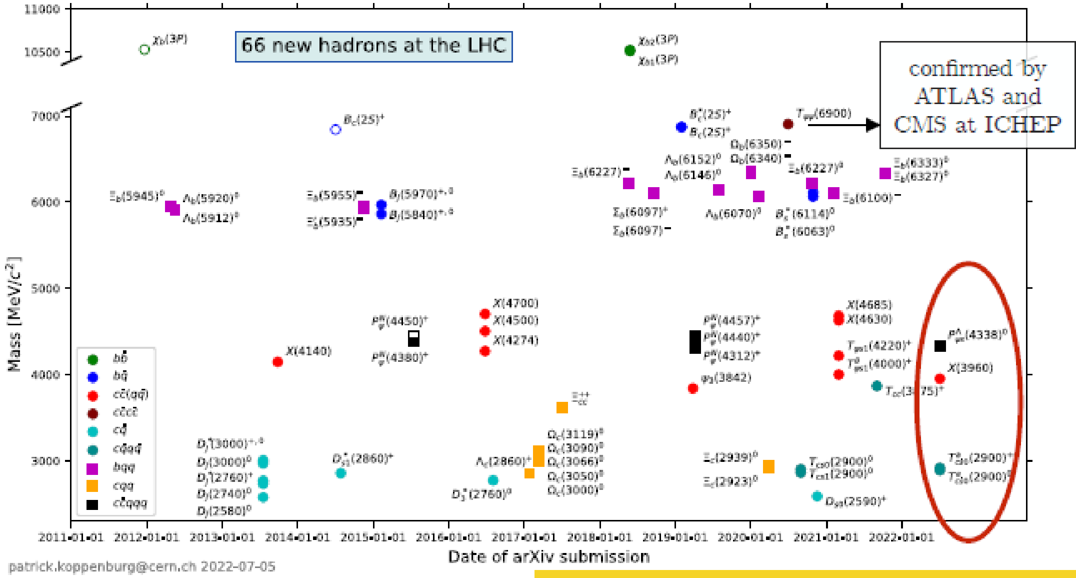
V(r) → $\left|\psi(\vec{k}^*, \vec{r})\right|^2$ relative wave function for the pair

LHCb достижения

- Новые адроны

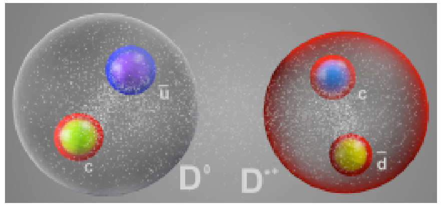
Search for exotic hadronic states

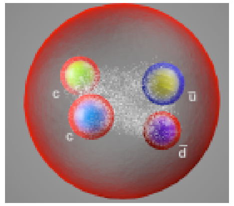
- Several conventional and exotic hadronic states discovered at the LHC, many of them (59/66) by LHCb
  - key to study of non-perturbative QCD



LHCb-FIGURE-2021-001 (update)

- nature of exotic states still unclear: loosely (hadronic molecule) or tightly bound?





Entering a new Era!

- LHCb report the observation of new exotic states
  - $T^{a}_{c\bar{s}0}(2900)^{++}$, $T^{a}_{c\bar{s}0}(2900)^{0}$ (tetra-quark states)
  - $P^{\Lambda}_{\psi s}(4438)^{0}$ (penta-quark state)

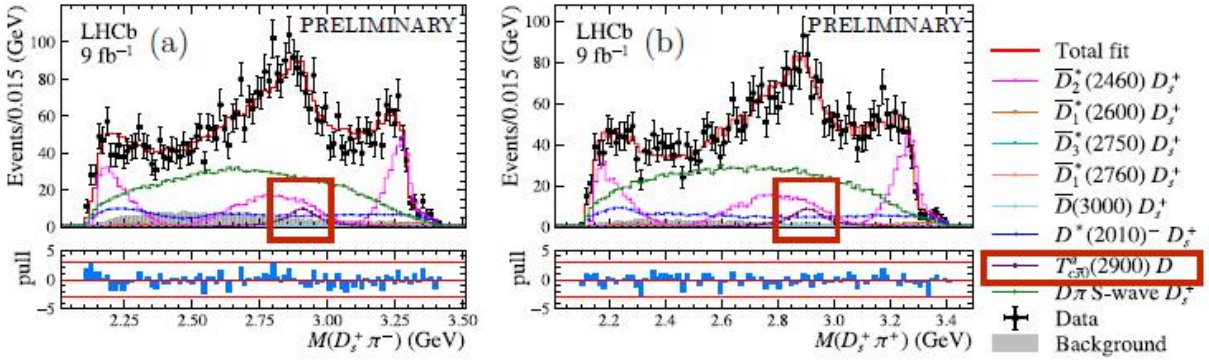
New naming convention proposed by LHCb

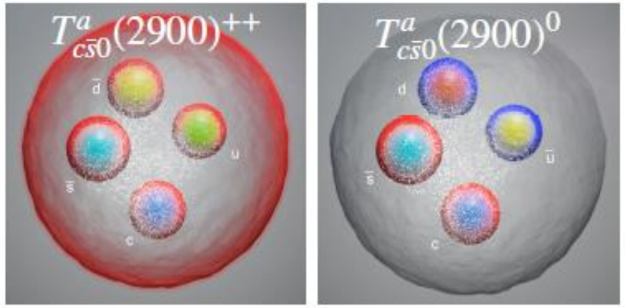
arXiv:2206.15233

New tetra- and pentaquark states

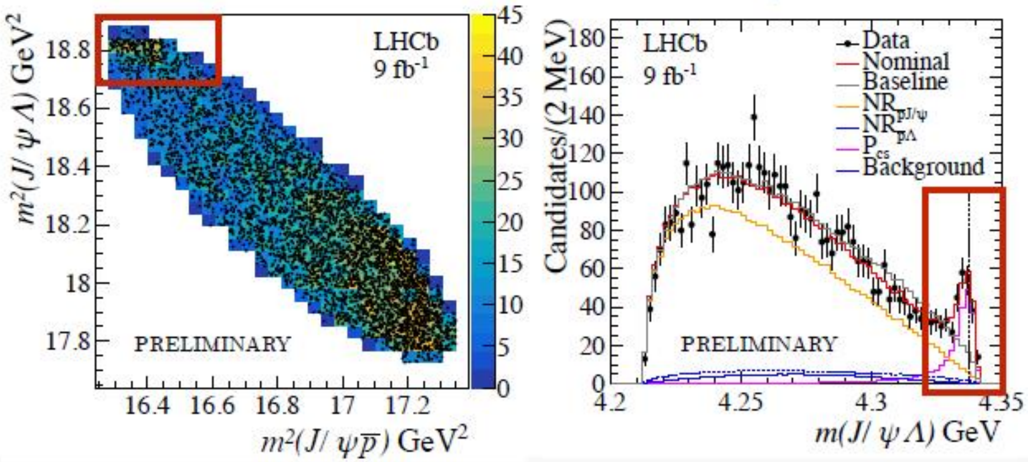
- Isospin pair of doubly charged and neutral tetraquarks: $T^a_{c\bar{s}0}(2900)^{++}$ $(c\bar{s}u\bar{d})$ and $T^a_{c\bar{s}0}(2900)^0$ $(c\bar{s}\bar{u}d)$

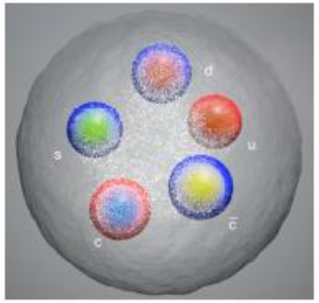
LHCb-PAPER-2022-026/027 (in preparation)





- First strange pentaquark: $P^{\Lambda}_{\psi s}(4438)^0$ $(c\bar{c}uds)$





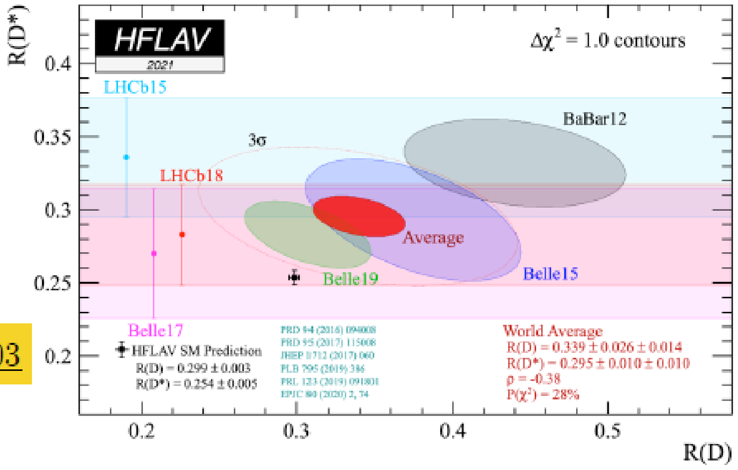
LHCb-PAPER-2022-031 (in preparation)

→ R. Ma & N. Neri in parallel sessions

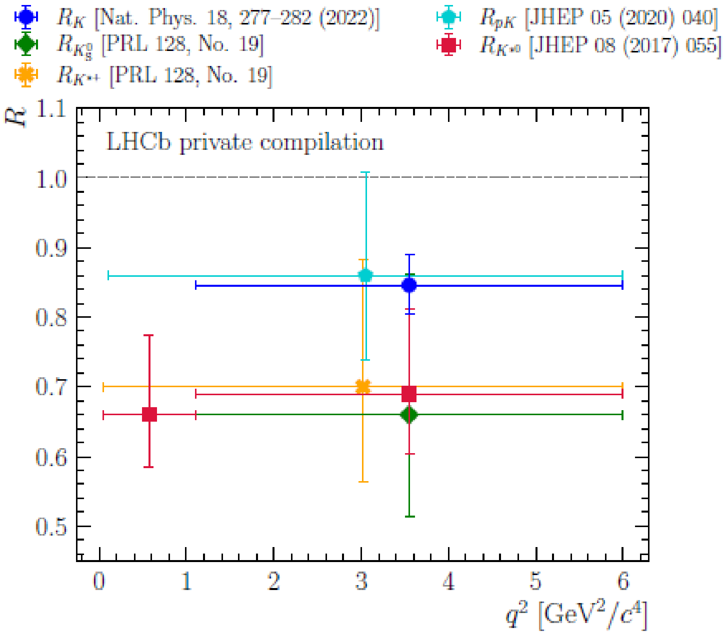
Новые 4-кварковые состояния (Т) и новые пентакварки (Р)

Lepton flavour universality

- LFU in $b \to c\ell\nu$ decays
  - tree-level processes involving 2nd & 3rd generations show 3.3σ tension with SM
  - Recent input from LHCb:
    - observation of $\Lambda_b^0 \to \Lambda_c^+ \tau^- \bar{\nu}_\tau$ PRL 128 (2022) 191803
      $\to R(\Lambda_c^+) = 0.242 \pm 0.026 \pm 0.040 \pm 0.059$
      compatible with SM $R(\Lambda_c^+)_{SM} = 0.340 \pm 0.004$ [PRD 99 (2019) 055008]



- LFU in $b \to s\ell\ell$ decays
  - $R \equiv \mathcal{B}(B \to X\mu^+\mu^-)/\mathcal{B}(B \to Xe^+e^-)$
  - R_K about 3.1σ below SM (Run 1+2, 9fb-1)
  - Updates in preparation on full data set:
    - R_{pK}, R_ϕ, $R_{K\pi\pi}$
    - unified analysis of R_K and R_{K*} with more q^2 bins, will provide final result on Run 1 + Run 2



→ S. Schmitt & R. Puthumanaillam in parallel sessions

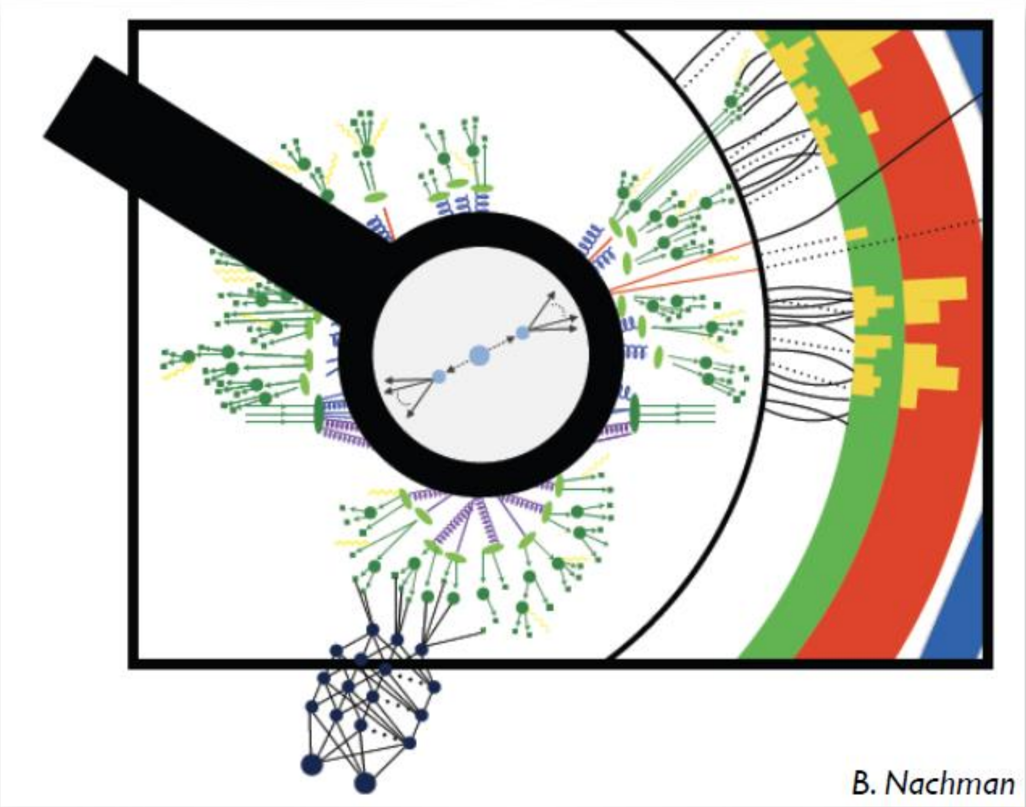
Проверка лептонной универсальности:

1) *b→clv* (2 и 3 поколения) согласие с СМ;
2) *b→Xμμ/Xee* отличие в 3σ от СМ предсказаний

Исследования ароматов для поиска BSM

Обзор результатов

Searching for What Lies Beyond the Standard Model



B. Nachman

Robin Erbacher - University of California, Davis

ICHEP 2022 - Bologna, Italy - July 12

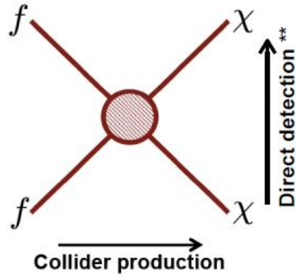
Dark Matter!

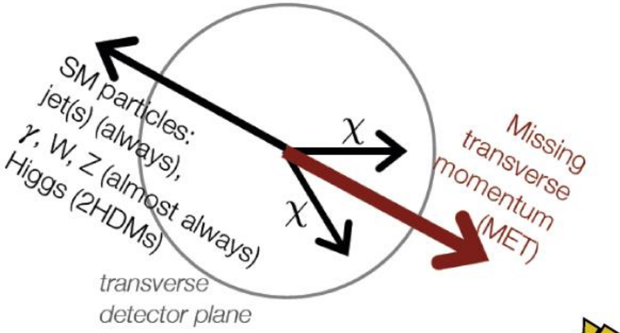
Definitive evidence for something beyond the SM—
we know something exists to explain!

Новые измерения по поиску BSM

Dark Matter!

Definitive evidence for something beyond the SM—
we know something exists to explain!

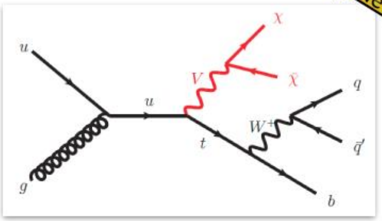




O. Brandt

New!

Ex: ATLAS "mono-top"
shown by G. Unal Monday →



ATLAS-CONF-2022-036

** *for astrophysical DM searches, see talk by Marradón Monday*

ATLAS searches for "Dark Higgs" S + DM: $S \to W^+W^- \to qql\nu$

New!

Semi-visible Jets
ATLAS-CONF-2022-038

CMS fully leptonic result: CMS-PAS-EXO-20-013

Large # of dark photon/dark sector searches at ATLAS, CMS, LHCb

CMS: S. Mukherjee

CMS and ATLAS have full programs of DM searches
using missing transverse energy/momentum (MET/$p_{T miss}$) or di-jets

Направления поиска:

Anomaly Detection

- ATLAS: search for boosted diboson "dijet" resonances with unsupervised NNs.

This is a great time to search for surprises!

Другие направления работы БАК-LHC

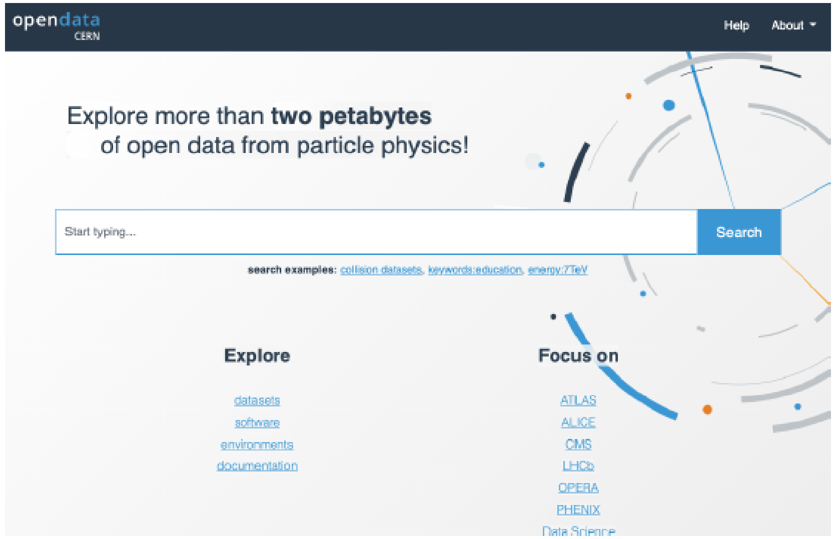
31

Open [Software, Data]

- The open source philosophy has long played an important role in software development
- At the LHC, first the **results**, then the **software**, then **data** and most recently the **likelihoods** of the LHC experiments have become open
  - **Reinterpretation** can probe additional models
  - However: can be challenging to use our software/data if you don't have direct access to experts and significant hardware resources
- CERN **Open Data Policy**

reana

https://reanahub.io/



Разработка софта

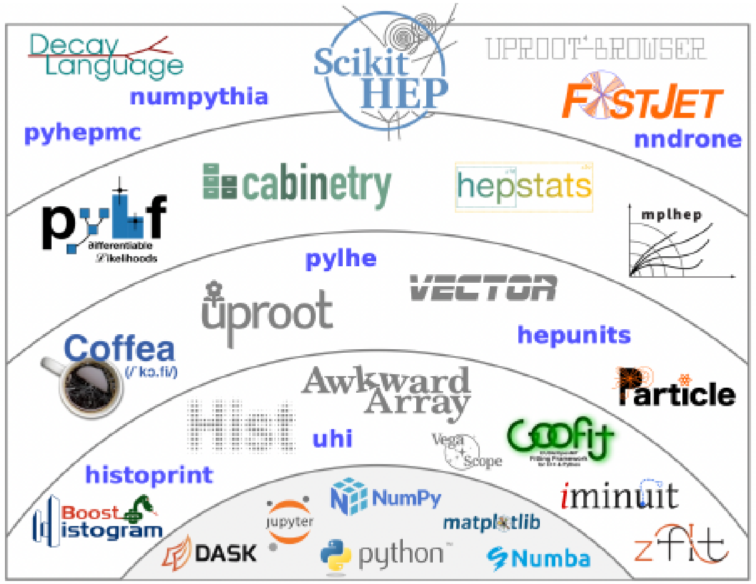
Политика открытости :
Результаты -> софт -> данные

Возможности новой интерпретации данных, проверки новых физических моделей

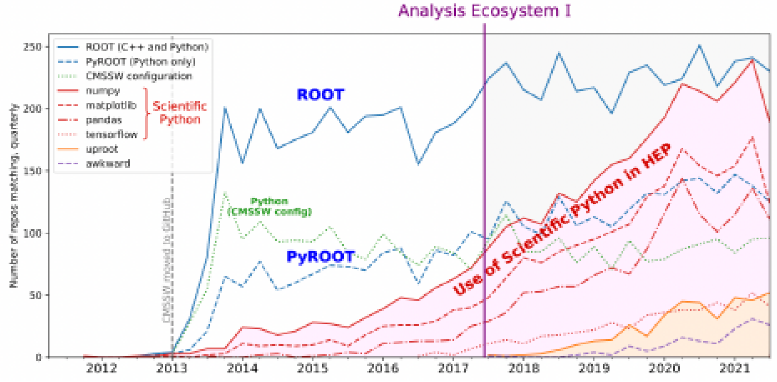
Python for Analysis

- Ongoing **boom** in the field of data science
- **Python** has become the language of choice for data science applications
  - Huge community has developed well-documented tools
  - numpy, matplotlib, pytorch, tensorflow, etc
- Balanced against our **own** designed-to-purpose and customized tools, in particular, ROOT
- **Python** is becoming increasing popular for analysis especially amongst the younger members of our community

ROOT
Data Analysis Framework



Source: "import XYZ" matches in GitHub repos for users who fork CMSSW.



J. Pivarski

Примеры разработок в области инструментов работы с данными и вклад в новые технологии, их приложения cnrs IN2P3 Les deux infinis

Omega

École Polytechnique IP PARIS

Technology and Industrial applications

convenors : Alessandro Montanari (INFN BO), Massimo Caccia (U.Insubria & INFN Milano), Hucheng Chen (BNL), Alexander Romanenko (Fermilab), Magnus Mager (CERN)

Ch. de LA TAILLE 13 july 2022

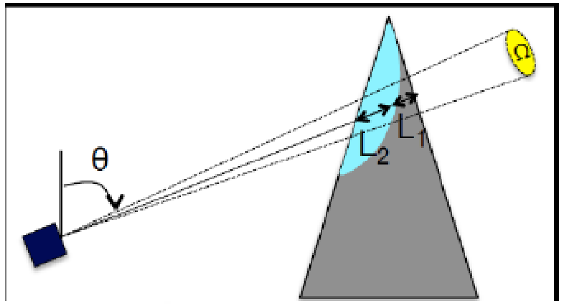
ICHEP 2022 BOLOGNA

ICHEP 2022 XLI International Conference on High Energy Physics Bologna (Italy)

6 13 07 2022

Некоторые приложения

Muon tomography for glaciers melting monitoring



Theta/Phi muon flux with ice

3D muon tomography

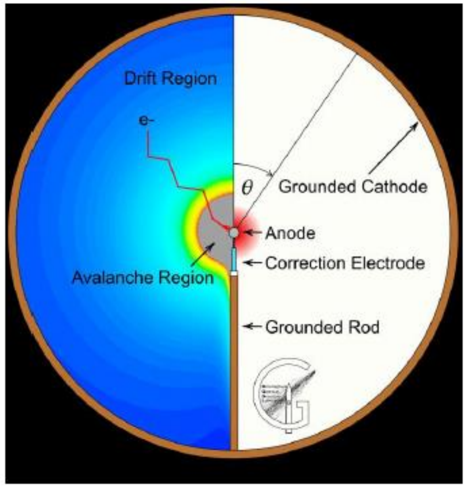
- Probing the underground with cosmic muons

Motivations
Expanding the spectrum of applications

Neutron detection with the Spherical Proportional Counter

Ioannis MANTHOS (Birmingham)

- Replace ^{3}He by Nitrogen
- Use Spherical Proportional counter
  - Low noise and pulse shape analysis
  - Low pressure reduces wall effect
- Neutron detection performed
  - in the Graphite stack and at the MC40 cyclotron facility in Birmingham
  - Foreseen at Boulby underground facility



JAGIELLONIAN UNIVERSITY IN KRAKÓW

- "Jagiellonian PET"
- The cost-effective total-body PET scanner based on plastic scintillators;
- PET scanner with positronium and multiphoton imaging capabilities;
- Modular and transportable PET scanner with the field of view adjustable to the patient size.
- Study of discrete symmetry

Разработка новых детекторов; промышленных ускорителей

Marco PERRI (CAEN)

Novel techniques for high density channel γ measurements based on SiPM

Comparing digitizer-based (D5720) to ASIC-based (A5202) readout

Nb_3Sn state-of-the-art

Grigory EREMEEV (FNAL)

Nb_3Sn SRF cavities are exciting for both high gradients (future) and high Q at higher temperatures (present)
R&D Nb_3Sn SRF cavities reached 24 MV/m
Accelerator cavities reached 15 MV/m with Q0 ~ 10^{10} at 4.4 K
Conduction cooling tests are ongoing
Key progress towards new applications such as compact **industrial accelerators**

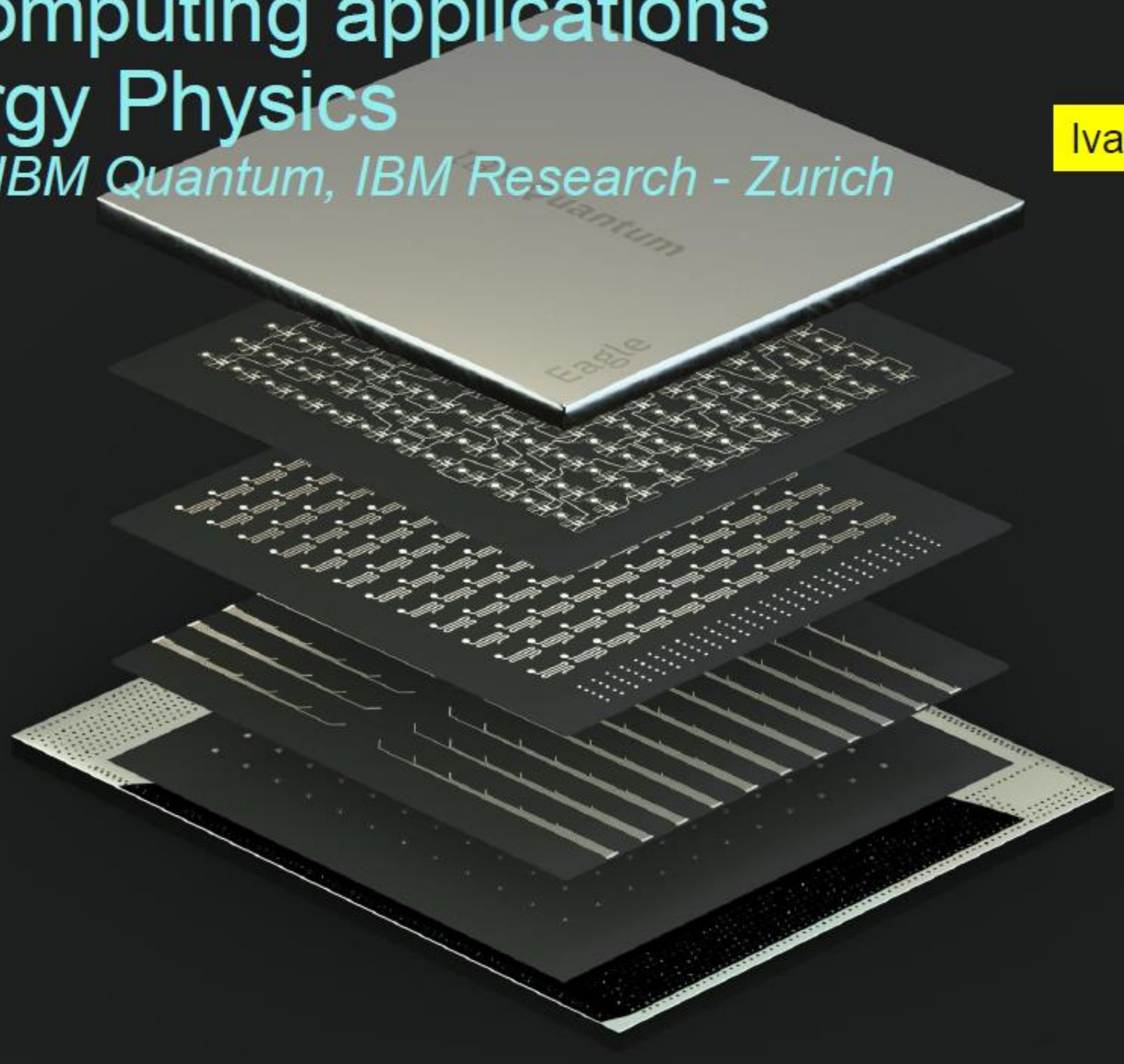
Квантовые компьютеры

Quantum Computing applications in High Energy Physics

Ivano Tavernelli   IBM Quantum, IBM Research - Zurich

IBM **Quantum**

Ivano TAVERNELLI (IBM)



Eagle chip with 127 qubits released in 2021

Digital quantum computers are there!

Are we ready?

ATTRACT: Why Detection and Imaging?

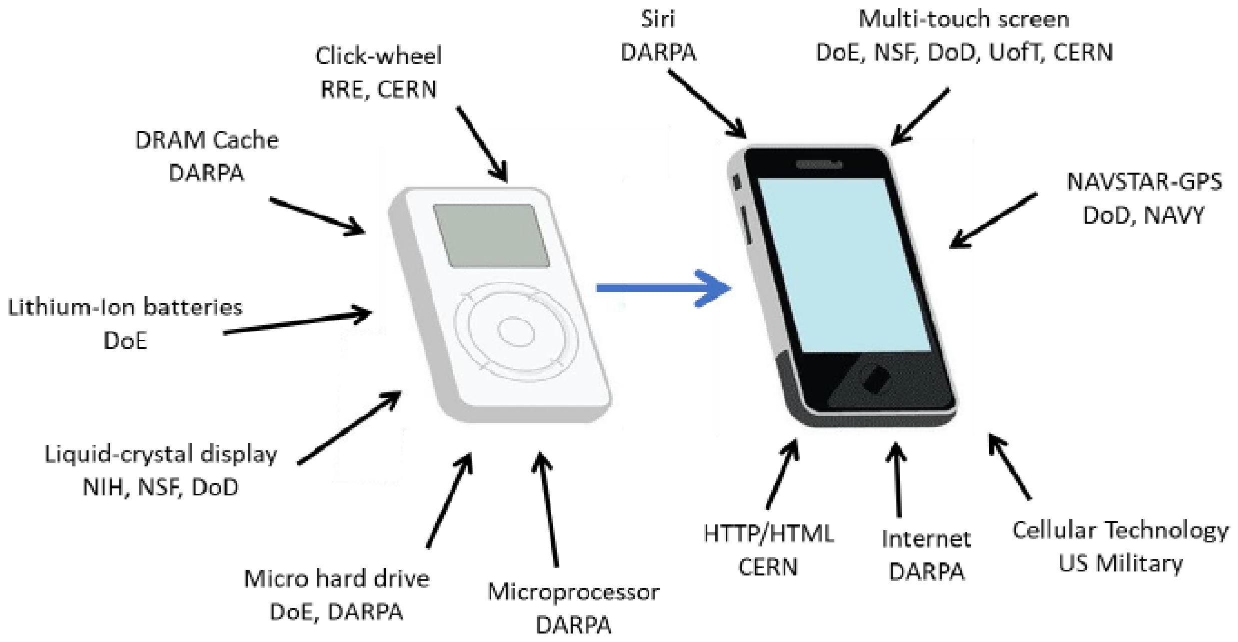
Are you able to point a field in the picture with nothing to do with Detection and Imaging?

- The scientific mission of European RIs as well as their R&D associated communities is strongly coupled with detection and imaging technology instrumentation (including computing).
- Detection and Imaging technologies are and will be at the core of future industrial developments applications and business (e.g. IoT, Smart Cities, Autonomous Transport, Sustainable Agriculture, etc).

ATTRACT: Key pillars (1)

"Where does breakthrough Innovation come from?"

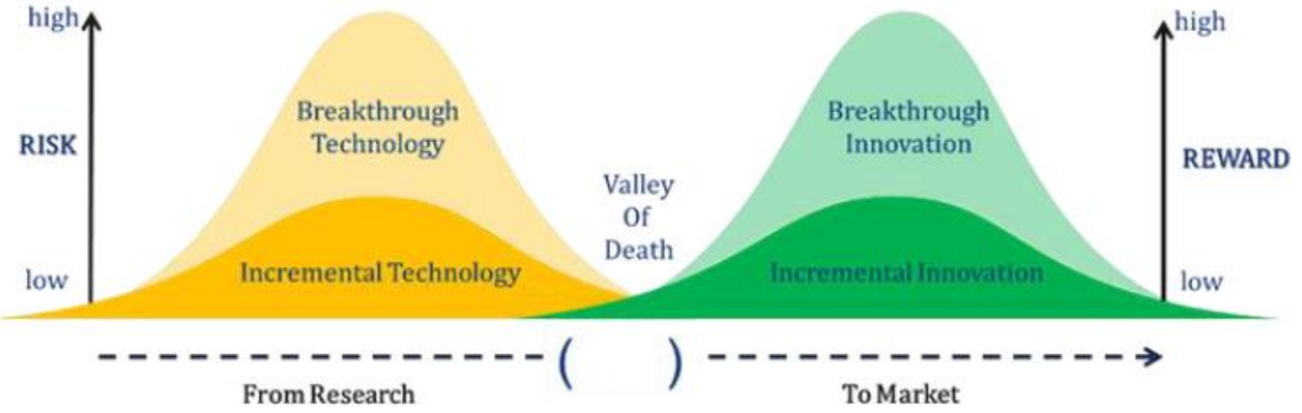
Public Funding: Key for helping nascent breakthrough technologies, many of them even at the conceptual level, mature for raising the interest of private capital .



DARPA: Defense Advance Research Project Agency
RRE: Royal Radar Establishment
CERN: European Organization for Nuclear Research
DoE: Department of Energy
NIH: National Institute of Health
NSF: National Science Foundation
DoD: Department of Defence
UofT: University of Toronto

ATTRACT: Key pillars (2)

"Not two Valleys of Death look the same"



Phase approach to funding: Breakthrough Technologies (coming from Fundamental Research) are very risky to invest upon for private capital.

De-risking them needs public funding:

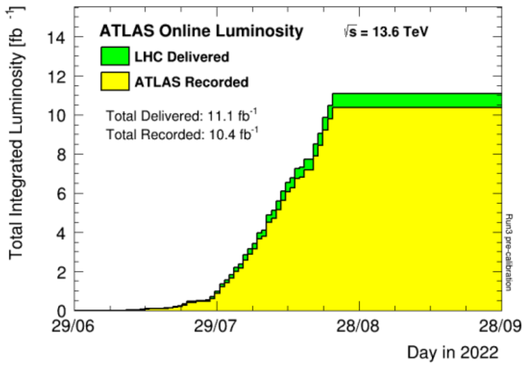
ATTRACT

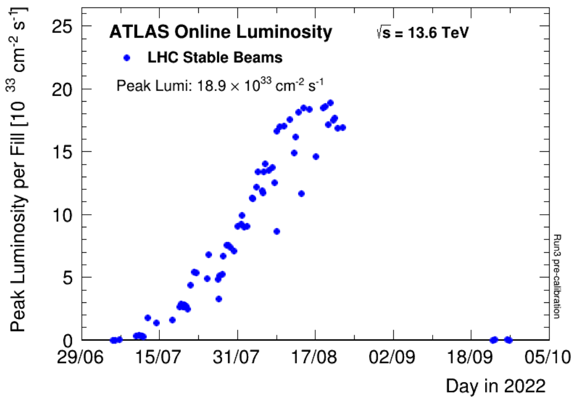
ATTRACT: Key pillars (4)

"Young people want to change the world"

Young Innovators Projects:

Заключение





- Десятилетие физики бозона Хиггса показало широкий спектр **результатов, согласующихся с предсказаниями СМ**
- Данные БАК используются в разных областях физики ядра и частиц: от прецизионных измерений EW физики до свойств адронных взаимодействий
- Успешно стартовал третий сеанс работы БАК – RUN 3 LHC. Достигнута плановая мгновенная светимость коллайдера и новая энергия pp соударений 13,6 ТэВ
- Ведутся интенсивные работы по модернизации детекторов в ожидании сеанса высокой светимости HL-LHC и далее

A Large Ion Collider Experiment

ALICE future: pushing the frontiers of precision

2010-2012		2015-2018		2022-2025		2029-2032		2035-2038		2040-2041
Run I	LS1	Run 2	LS2	Run 3	LS3	Run 4	LS4	Run 5	LS5	Run 6

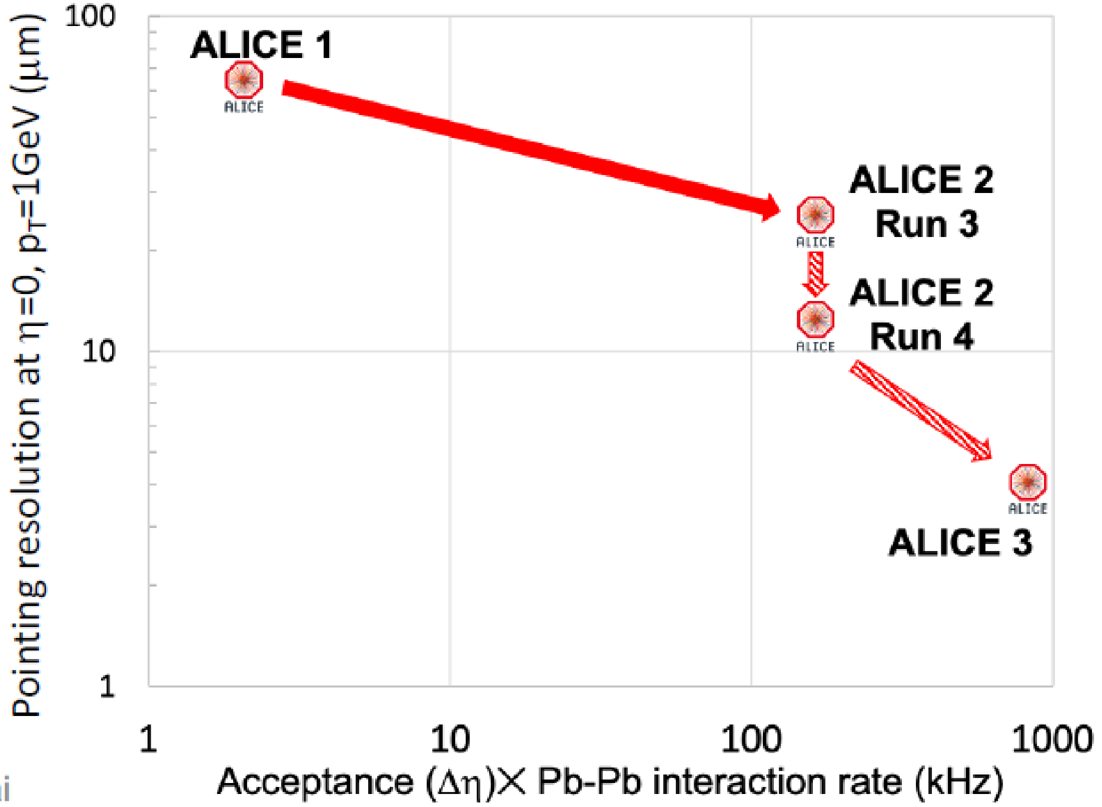
+ ITS3/FoCal

"ALICE 1" **Major upgrade** "ALICE 2" **New detector** "ALICE 3"

Enhance physics reach by improving:

- **rate capabilities & acceptance**
- **tracking precision**

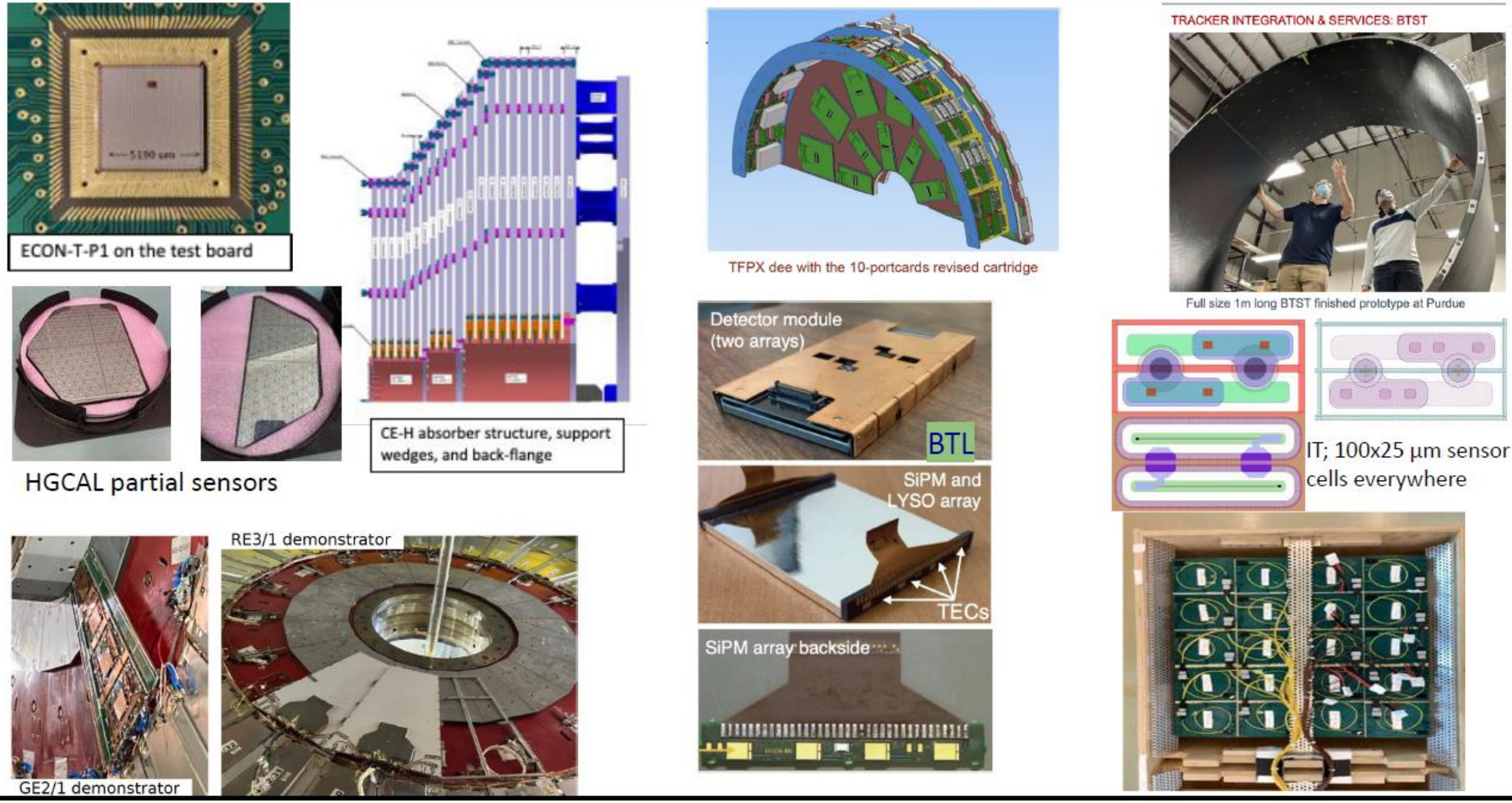
→ high precision, reduce backgrounds, access rarer probes



Проекты модернизации экспериментов БАК

CMS

Phase 2 Upgrade in a few pictures

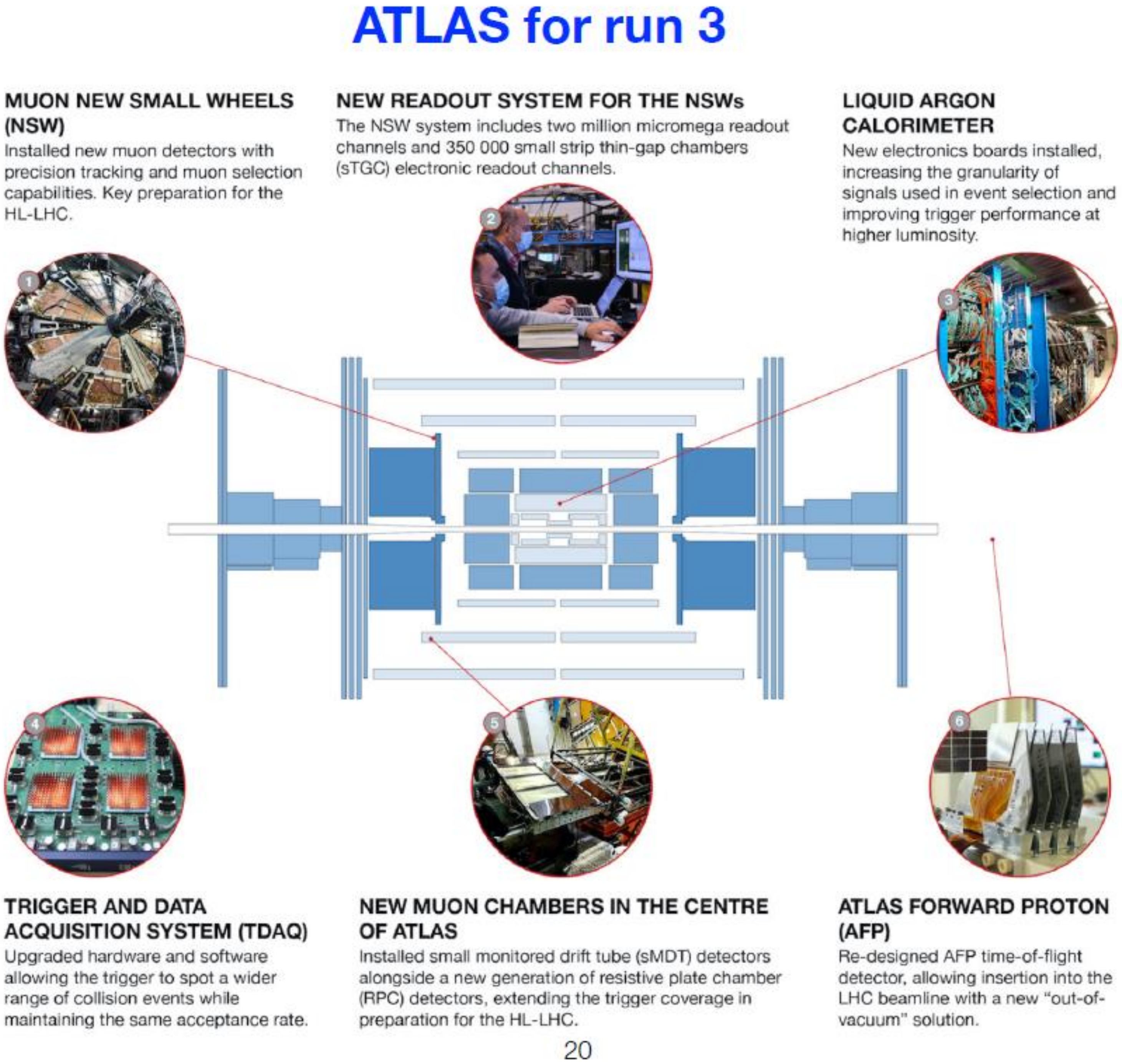


ATLAS

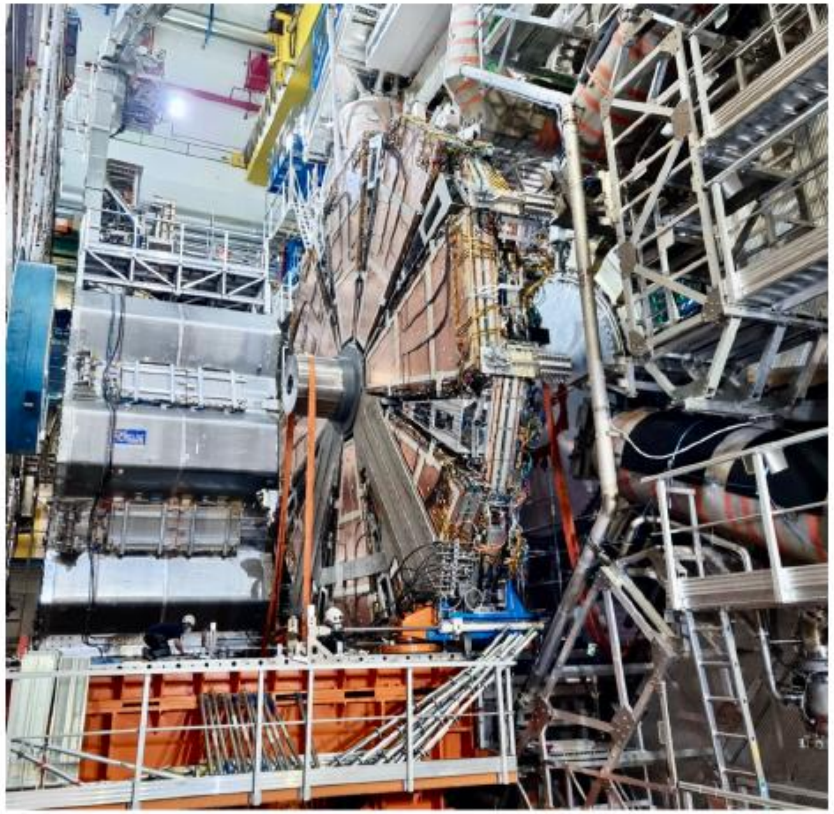
Новые мюонные камеры в центре и на торцах;

новая электроника жидко-аргонового калориметра, мюонных камер, триггера и системы сбора данных TDAQ;

удаленные детекторы протонов

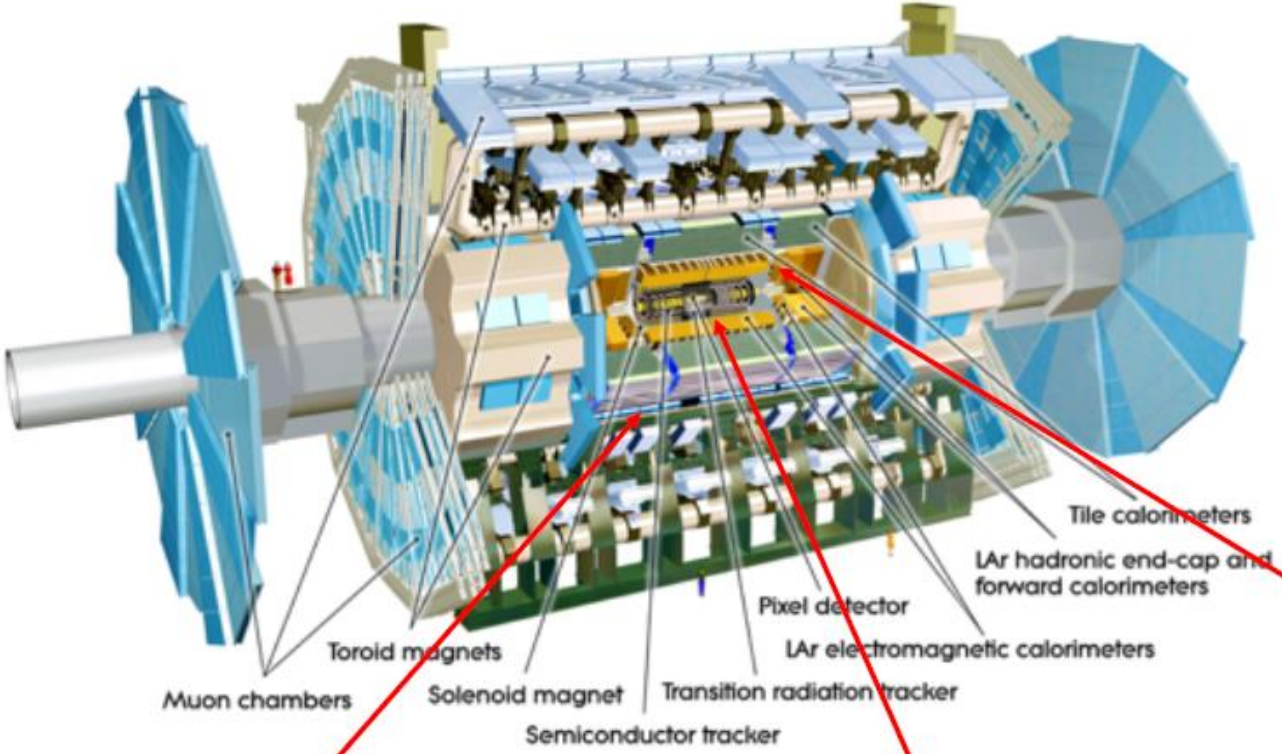


New Small Wheel for muon trigger+measurement



NSW being positioned

ATLAS Phase-2 Upgrade for HL-LHC



Upgraded Trigger and Data Acquisition system

Level-0 Trigger at 1 MHz

Improved High-Level Trigger
(150 kHz full-scan tracking)

Electronics Upgrades

LAr Calorimeter

Tile Calorimeter

Muon system

High Granularity Timing Detector (HGTD)

Forward region ($2.4 < |\eta| < 4.0$)

Low-Gain Avalanche Detectors (LGAD)
with 30 ps track resolution

New Muon Chambers

Inner barrel region with new
RPC and sMDT detectors

New Inner Tracking Detector (ITk)

All silicon, up to $|\eta| = 4$

Additional small upgrades

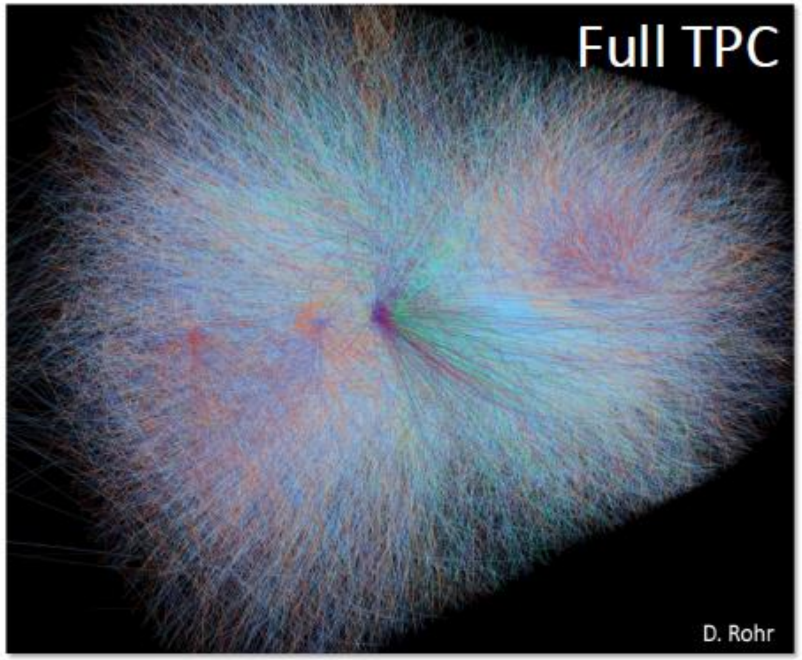
Luminosity detectors (1% precision goal)

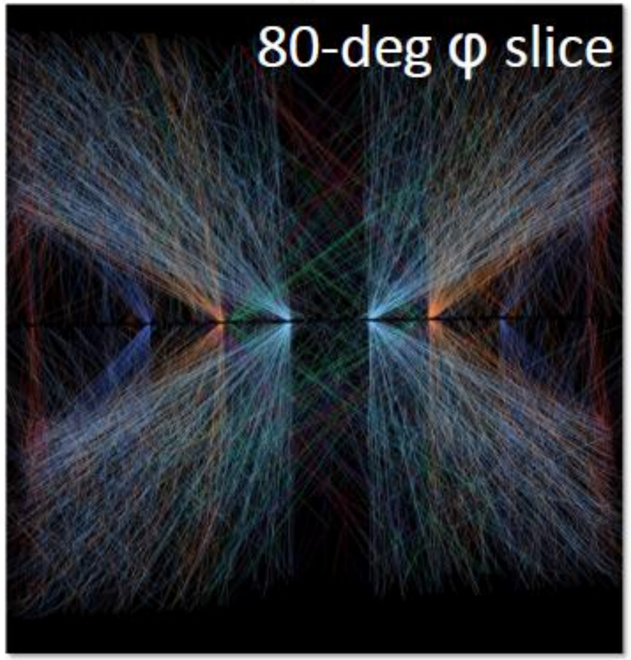
HL-ZDC

Detailed scope described in 7 TDRs approved by the CERN Research Board in 2017, 2018, 2020

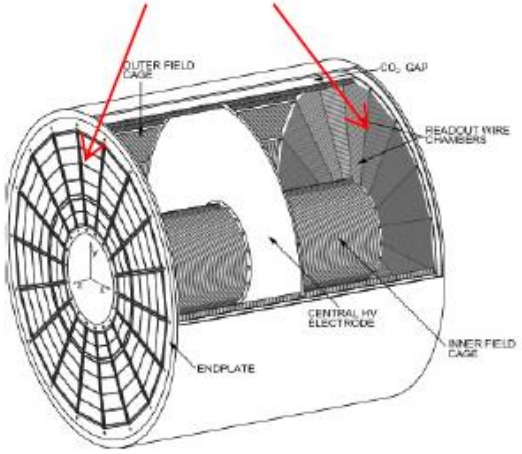
TPC with GEM readout for Pb-Pb at 50 kHz

- Current MWPC: readout rate limited by ion backflow
- New readout chambers (GEM): continuous readout of Pb-Pb at interaction rate of 50 kHz
  - preserve p_T and dE/dx resolution
- 5 interactions on average during TPC drift time (90 µs)
- Calibration and track-to-event assignment in O² system

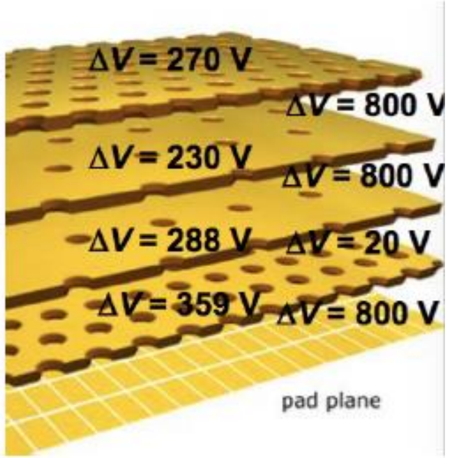


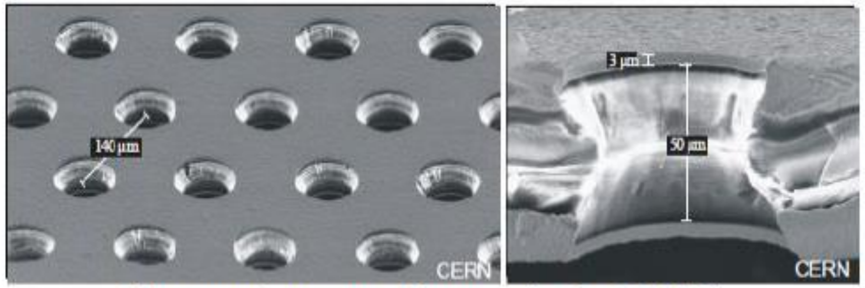


72 readout chambers



Stack of 4-GEM-foils



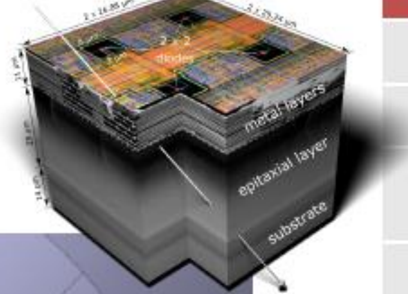


Electron microscope photograph of a GEM foil

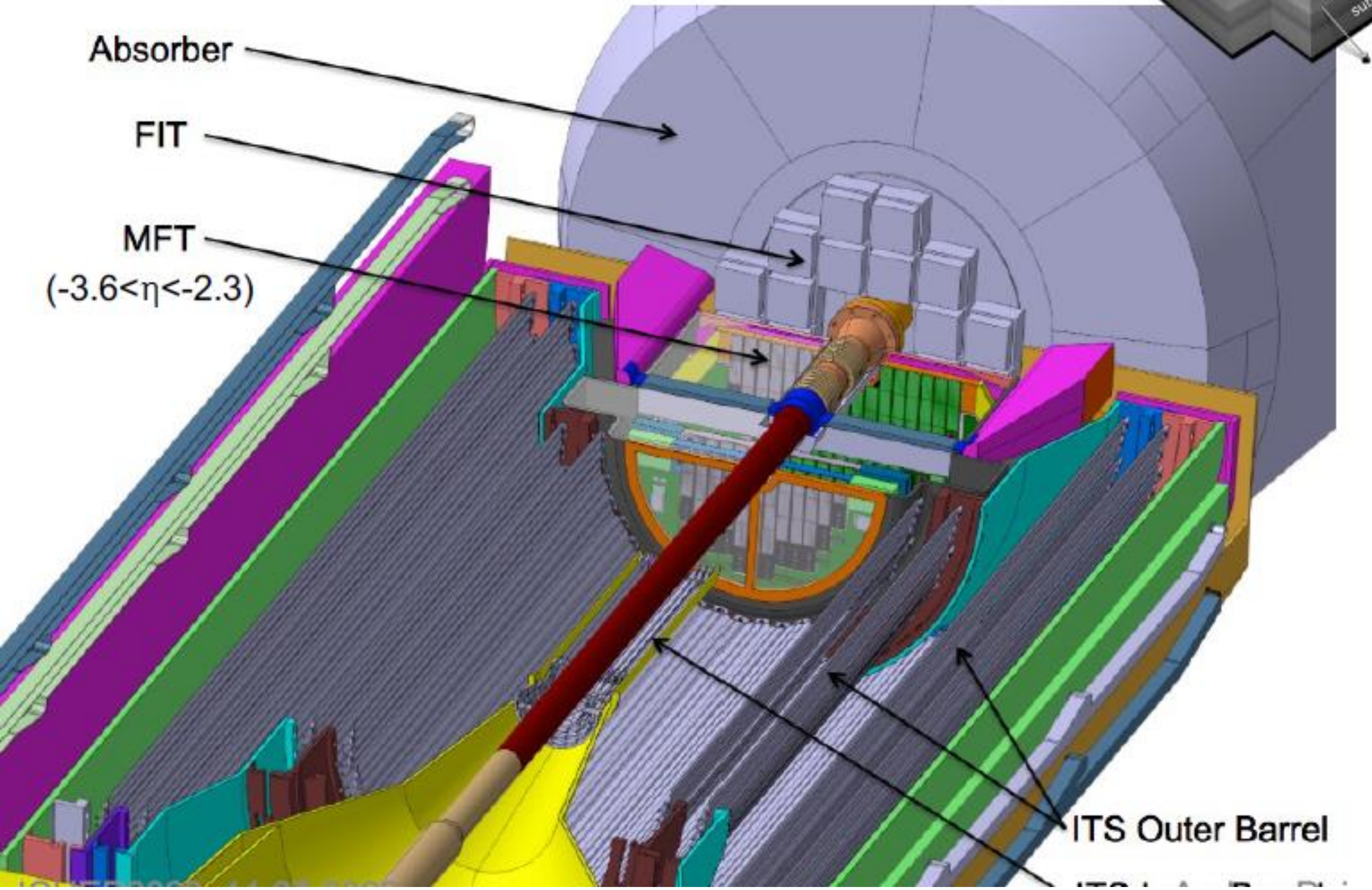
CERN-LHCC-2013-020

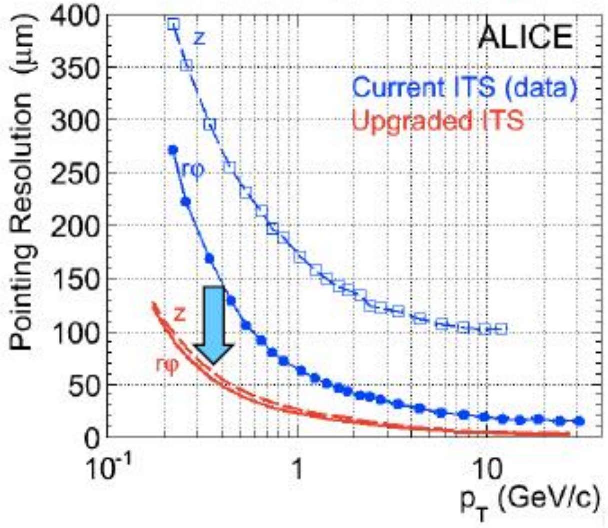
New all-pixel trackers: ITS2 and MFT

- Monolithic Active Pixel Sensors (MAPS)
  - Low resistivity, high efficiency, low thickness, low power consumption
  - Also chosen by sPHENIX and MPD@NICA

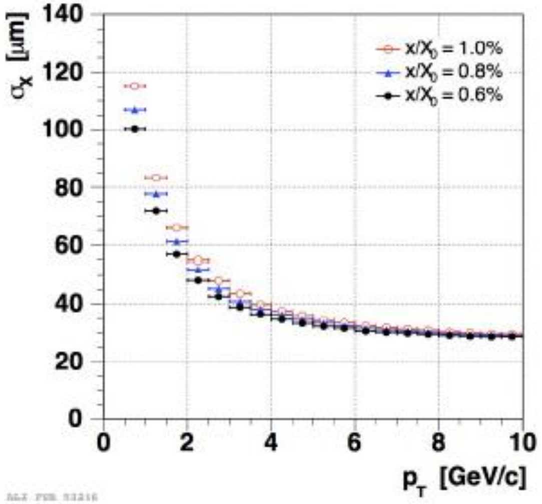


	Current ITS	New ITS2	MFT
N Layers	6	7	5
Inner radius	3.9 cm	2.3 cm	/
Layer thickness	~1.1% X_0	0.3-1.0% X_0	0.8% X_0
Spatial resolution	12x100 μm^2 35x20 μm^2 20x830 μm^2	~5x5 μm^2	~5x5 μm^2





ITS2 tracking precision x3 better in rφ plane, <20 μm above 1 GeV/*c*



MFT: <100 μm above 1 GeV/*c*

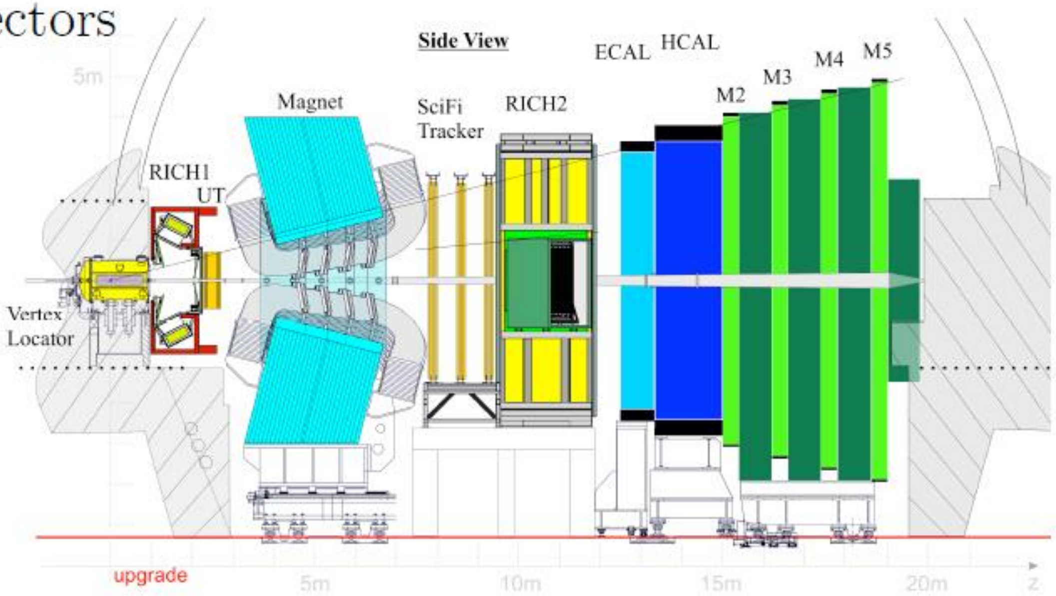
LHCb upgrade I (Runs 3+4)

- Major upgrade of all sub-detectors

→ $\mathscr{L}_{\text{peak}} = 2 \times 10^{33}\text{cm}^{-2}\text{s}^{-1}$

pile-up ≈ 5

→ fully software trigger for 40MHz readout



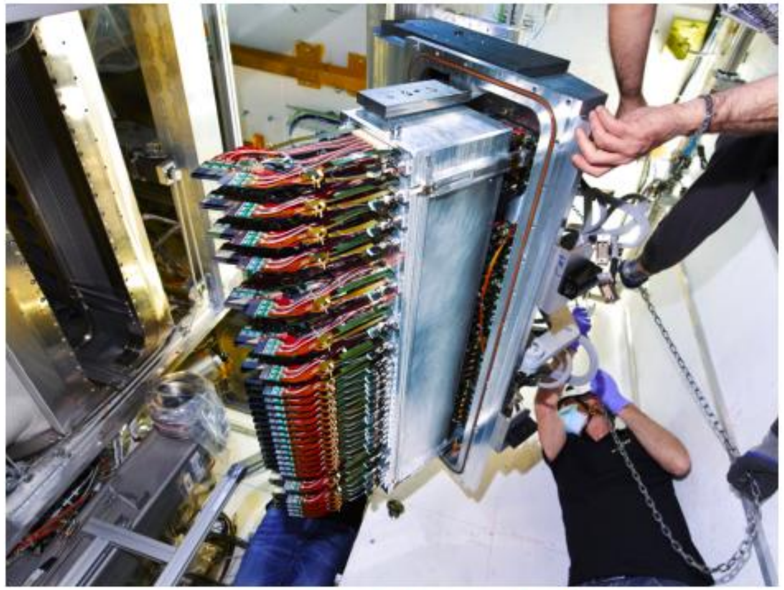
- New pixel-detector **VELO**
- New **RICH** mechanics, optics, photodetectors
- New Silicon strip upstream tracker **UT** (installation at end of year)
- New **SciFi** tracker
- New electronics for **MUON** and **CALO**
- New luminometer **PLUME**

Installed for operations in Run 3

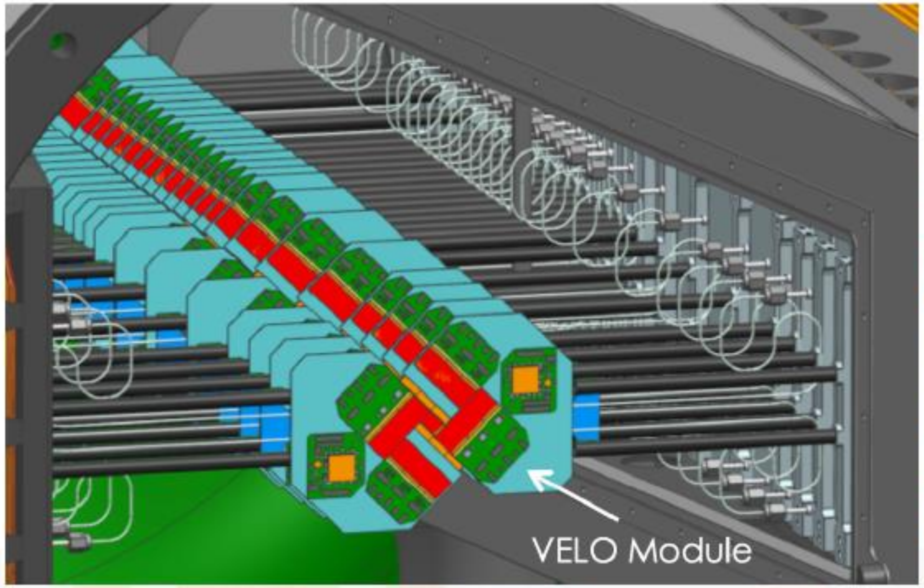
Upgrade I: VELO

CERN-LHCC-2013-021

- Vertex pixel detector, 5mm from beam
  - innovative microchannel CO_2 cooling
- Installation completed in May
- Commissioning progressing very well!
  - in process of calibration, time and spatial alignment, tuning, while maintaining detector safety

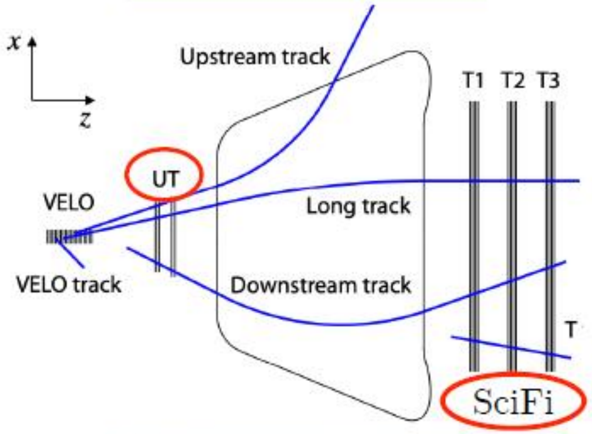


VELO installation

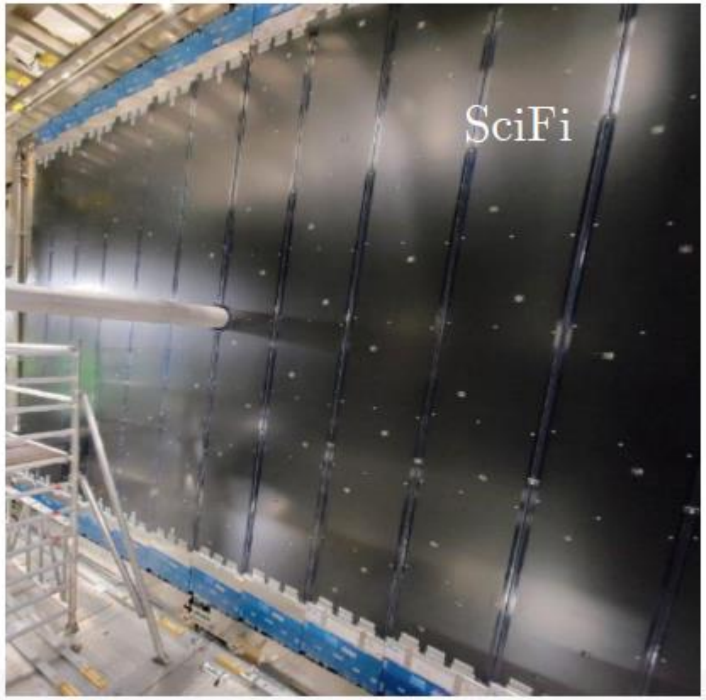


Upgrade I: UT and SciFi

CERN-LHCC-2014-001

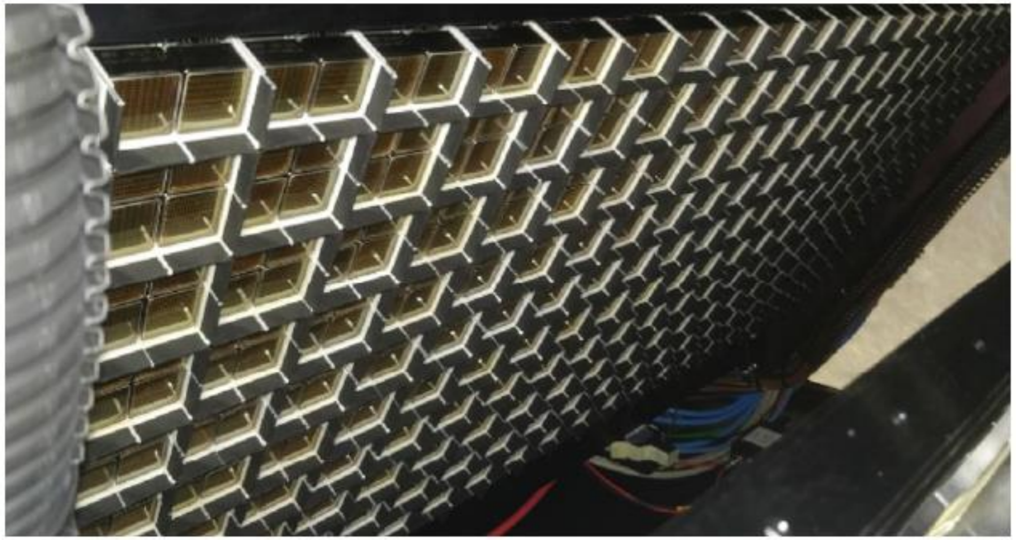


- UT Silicon strips tracker upstream of magnet
  - Silicon strip detector with integrated cooling
  - 68 staves, arranged in 4 planes
  - assembly ongoing, installation at end of year (not essential for early physics operation)
- SciFi tracker downstream of magnet
  - scintillating fibres readout by SiPMs
  - $340m^2$, 11'000 km scintillating fibres
  - 4096 128-channel SiPMs
  - fully installed for Run 3



Upgrade I: RICH 1+2 CERN-LHCC-2013-022

- Particle identification system essential for flavour physics programme
  - new MaPMTs with increased granularity
  - 40MHz readout electronics
  - new RICH1 mirrors with increased focal length ⇒ 1/2 occupancy
  - installed for Run 3



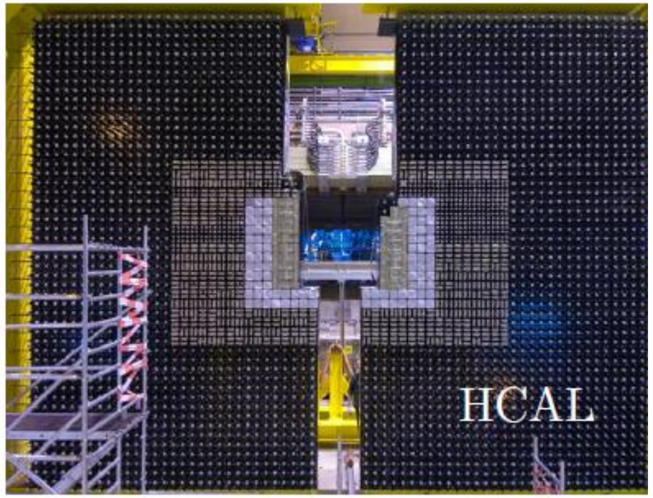
RICH 1 MaPMTs after installation (upper side)

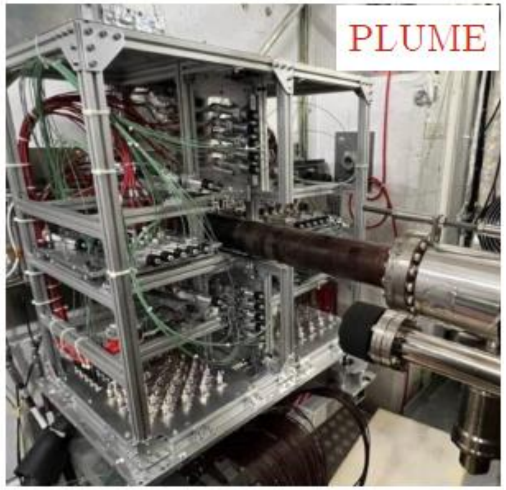
RICH 2 MaPMTs

Upgrade I: CALO, MUON, PLUME, ...

All installed for Run 3

- CALO + MUON: existing detectors + new electronics → 40MHz
- Shashlik calorimeters ECAL & HCAL
- MUON CERN-LHCC-2013-022
  - 4 MWPC layers
  - iron filters
- New luminometer: PLUME
  - quartz tablets readout with PMT CERN-LHCC-2021-002
  - per-bunch luminosity measurement
- SMOG2 gas target
  - for fixed-target physics
  - gas targets for He, Ne, Ar (+ possibly H_2, D_2, N_2, Kr, Xe) CERN-LHCC-2019-005



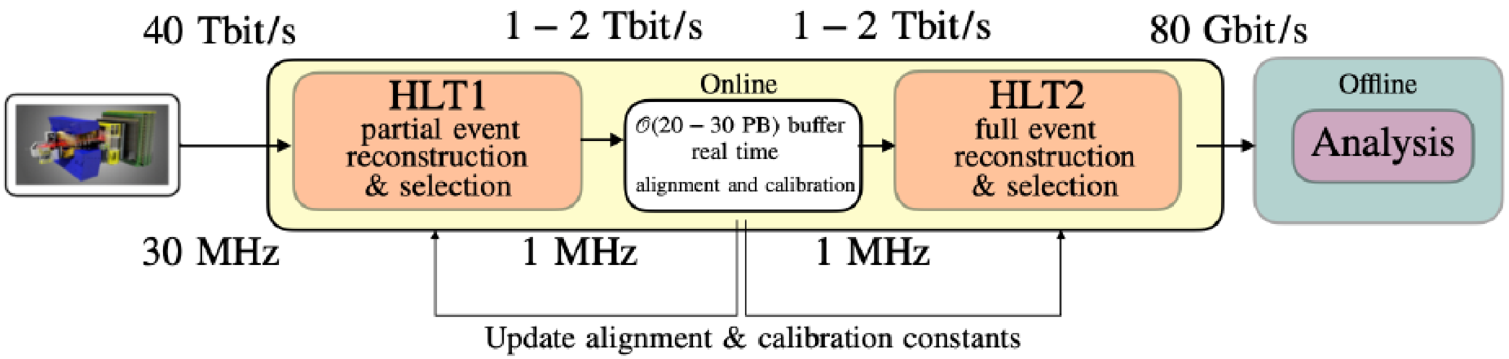


→ E. Spedicato in poster session & E. Graverini in parallel sessions

Upgrade I: Fully software trigger

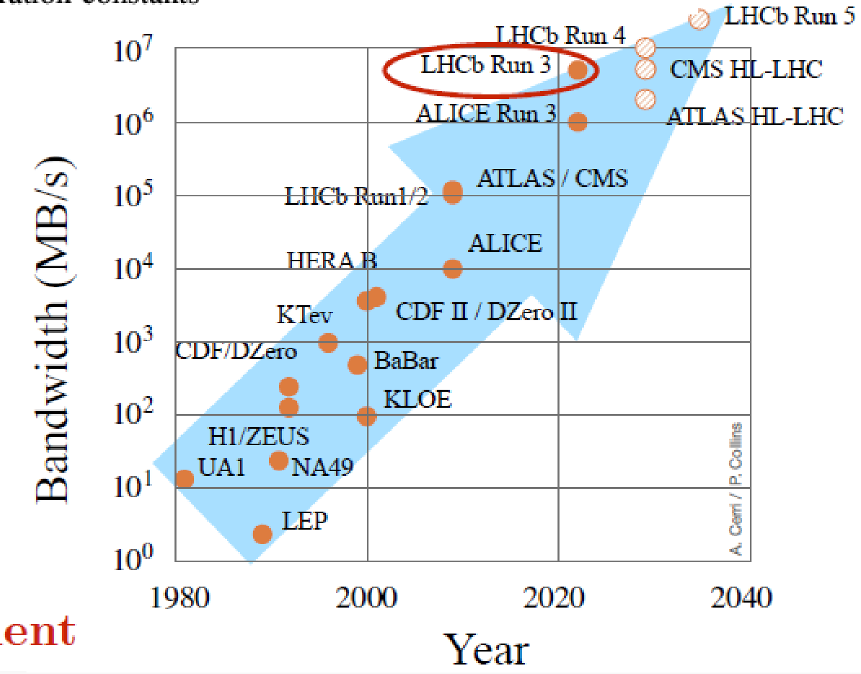
CERN-LHCC-2014-016
CERN-LHCC-2020-006

- All subdetectors read out at 40MHz → full software trigger



- 30MHz of inelastic collisions reduced to 1MHz in HLT1 (tracking +vertexing+muon ID)
  - running on GPUs

- Hadronic yield ×10 relative to Run 2



Highest throughput of any HEP experiment

→ Ch. Agapopoulou in parallel sessions