CERN

FZU
Institute of Physics of the
Czech Academy of Sciences

ATLAS
EXPERIMENT

CERN, LHC, ATLAS and all that

Mgr. Jiří Kvita, Ph.D.
Joint Laboratory of Optics of the
Palacký University Olomouc and the Institute of Physics of the Academy of Sciences of the Czech Republic

Přírodovědecká
fakulta

Univerzita Palackého
v Olomouci

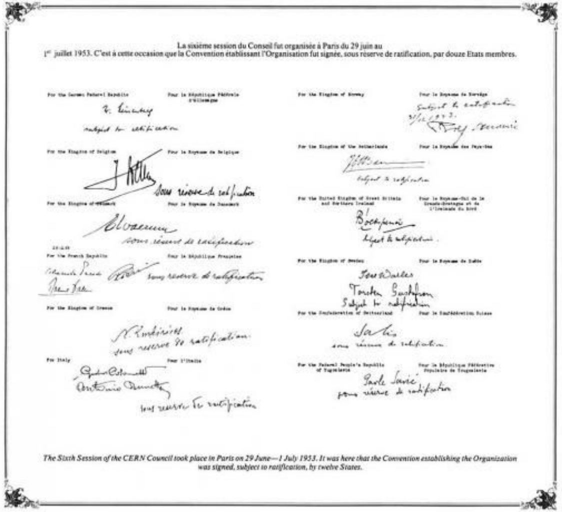
CERN

- Established 1954 ⇒ 70 years of CERN in 2024!
- Science in the service for humanity, CERN convention.
- https://timeline.web.cern.ch/timeline-header/89
- https://cerncourier.com/p/magazine/

17 MARCH 1954

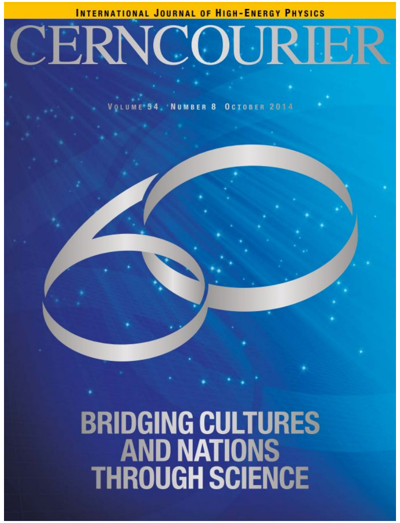
Breaking ground

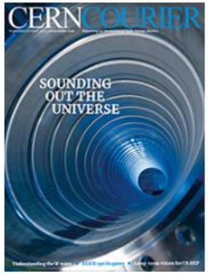
On 17 May 1954, the first shovel of earth was dug on the Meyrin site in Switzerland under the eyes of Geneva officials and members of CERN staff.



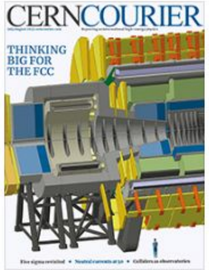
La sixième session du Conseil fut organisée à Paris du 29 juin au 1er juillet 1953. C'est à cette occasion que la Convention établissant l'Organisation fut signée, sous réserve de ratification, par douze Etats membres.

The Sixth Session of the CERN Council took place in Paris on 29 June—1 July 1953. It was here that the Convention establishing the Organization was signed, subject to ratification, by twelve States.





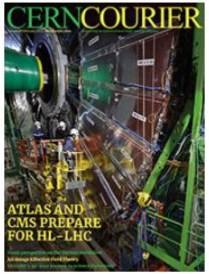
Sep/Oct 2023



Jul/Aug 2023

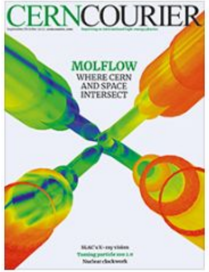
May/Jun 2023

Mar/Apr 2023

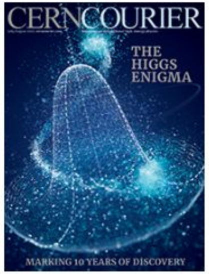


Jan/Feb 2023

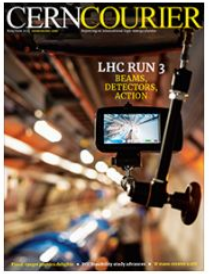
Nov/Dec 2022



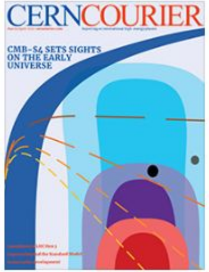
Sep/Oct 2022



Jul/Aug 2022



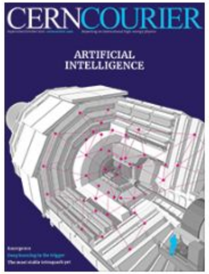
May/Jun 2022



Mar/Apr 2022

Jan/Feb 2022

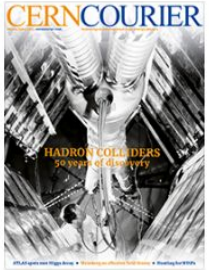
Nov/Dec 2021



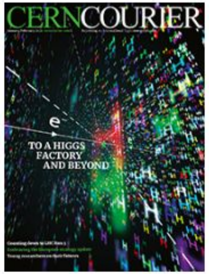
Sep/Oct 2021

Jul/Aug 2021

May/Jun 2021



Mar/Apr 2021



Jan/Feb 2021

Nov/Dec 2020

Sobota 7.10.2023

CERN
5 hod ·

Today, CERN inaugurates CERN Science Gateway, its new emblematic centre for science education and outreach. It will be open to the public from tomorrow, 8 October 2023.

Join us in celebration and watch the inauguration ceremony live today at 11.00 CEST: https://webcast.cern.ch/event/i1332909

#CERNScienceGateway

CERN
2 h ·

CERN launches Science Gateway

Today, CERN inaugurates its new emblematic centre for science education and outreach, CERN Science Gateway. The building was designed by architect Renzo Piano and funded through external donations, with the leading contribution coming from Stellantis.

CERN Science Gateway will be open to the public as of tomorrow, 8 October 2023.

Find out more: https://home.cern/.../cern-inaugurates-science-gateway...

#CERNScienceGateway Stellantis





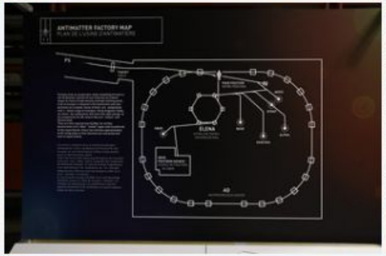
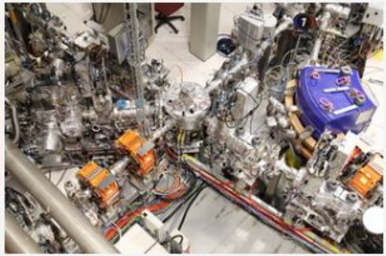


ATLAS


WHERE THE
WEB
WAS BORN



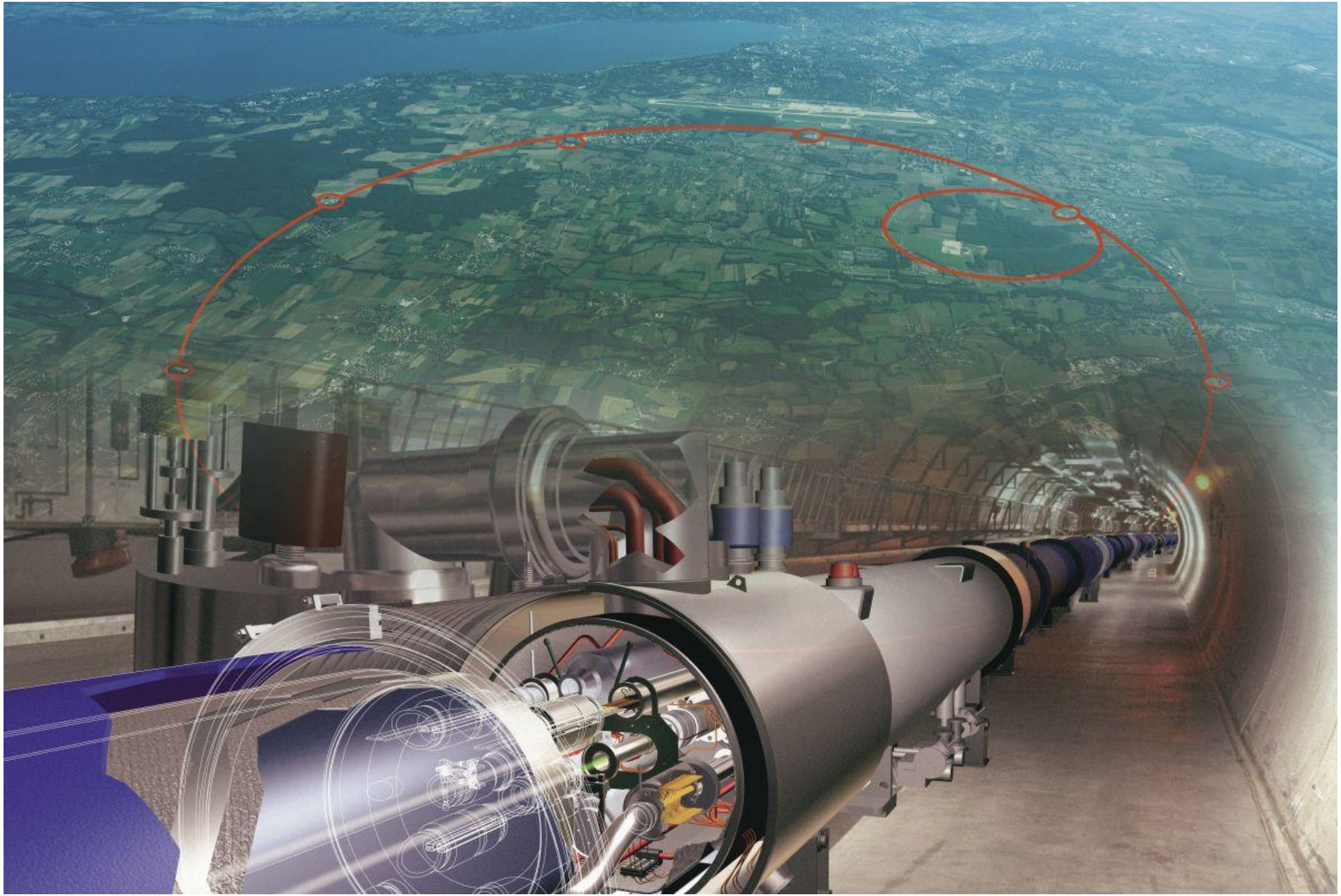
Route A. EINSTEIN
STOP

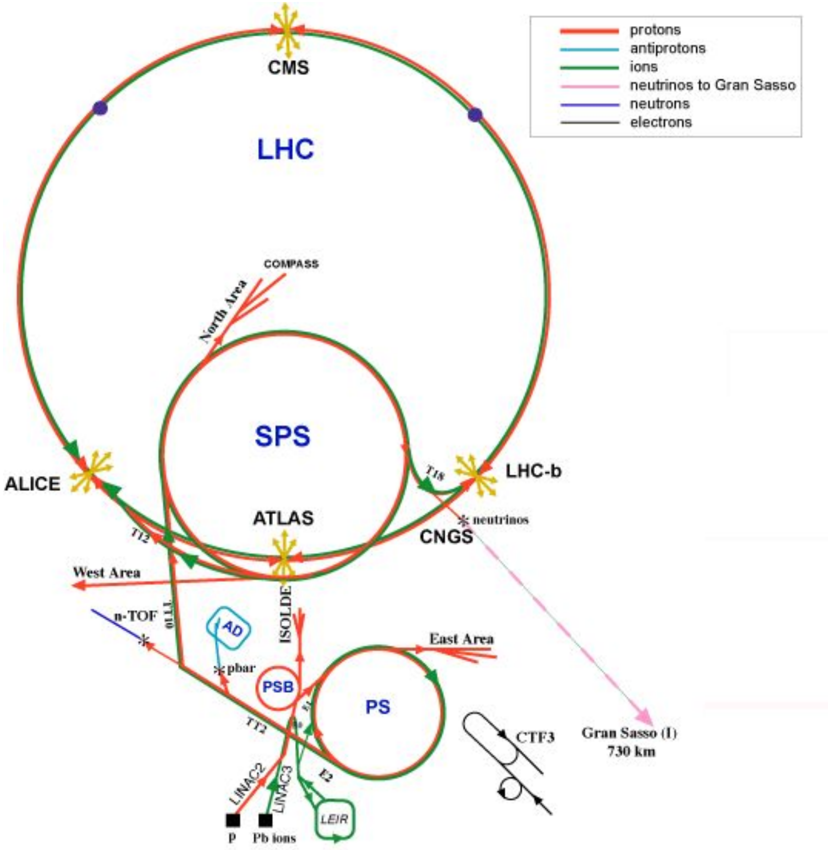

ANTIMATTER
FACTORY
ELENA




COMPASS


CERN

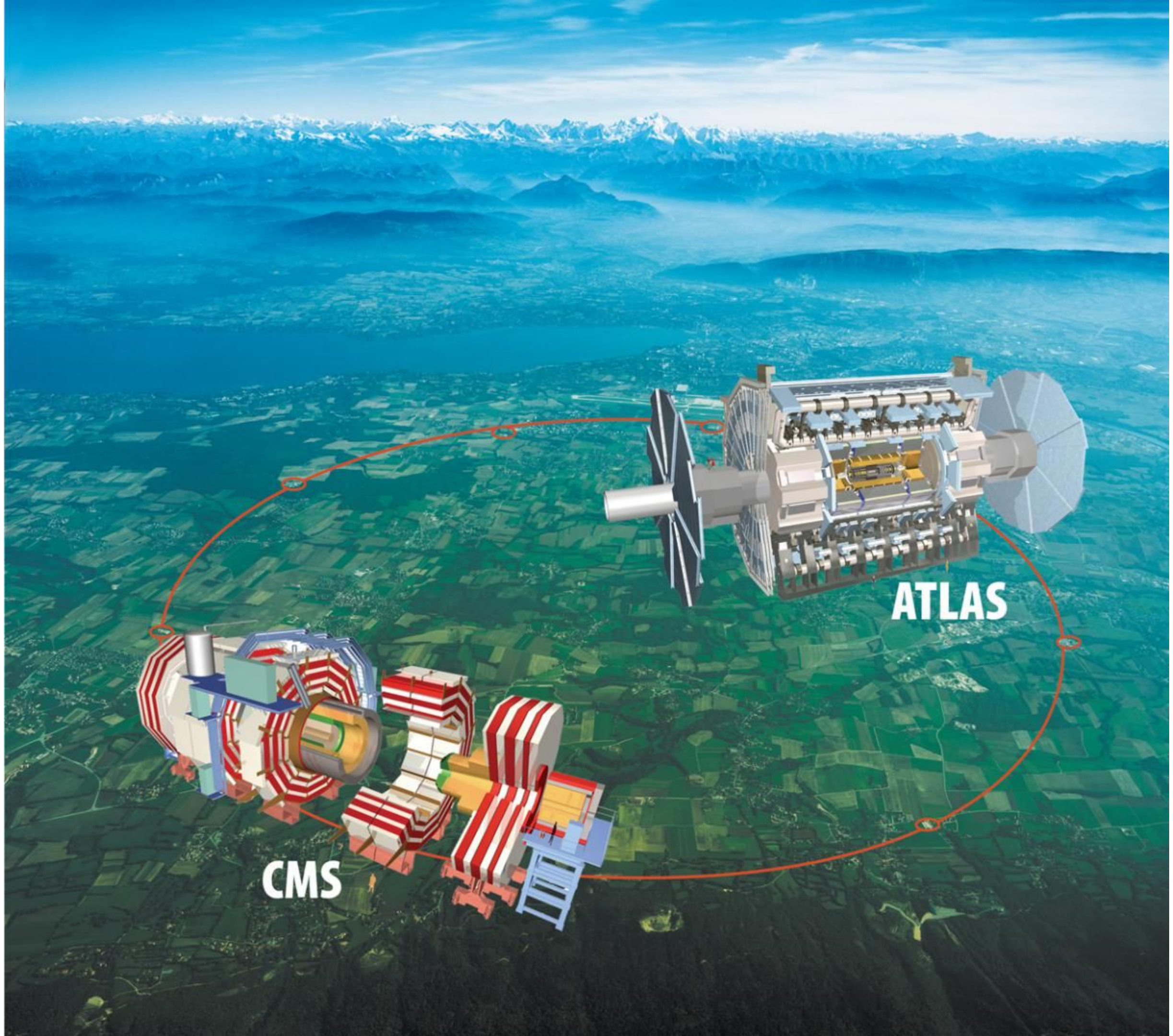
- Home to several accelerators.
- Platform to provide beams for experimental collaborations be formed.
- Accelerators – a unique expertise kept, compare to FERMILAB, KEK, DESY…
    - Synchrocyclotron (1957)
    - LINAC 1–4
    - Antiproton Accumulator, Decelerator, ELENA, Low Energy Antiproton/Ion Ring…
    - Proton Synchrotron – 24 GeV (1959)
    - Super Proton Synchrotron (1976)
        - converted to proton-antiproton collided (1981)
            - Carlo Rubbia, Simon van der Meer
                - W and Z discovery by the UA1 and UA2 collaborations (1983)
    - LEP = Large Electron-Positron Collided, non-superconducting (1989).
        - precision measurements of the Z and W bosons
            - Detectors: ALEPH, DELPHI, OPAL, L3.
    - LHC = Large Hadron Collider, uses LEP tunnel;) Superconducting (2008).
        - Detectors: ATLAS, ALICE, CMS, LHCb.
    - Future: CLIC? Future Circular Collider? (FCCee, FCCeh, FCChh)
    - Muon collider?





CNGS	CERN neutrino to Le Gran Sasso	PSB	proton synchotron booster
AD	antiproton decelerator	ISOLDE	on line isotope mass separator
PS	proton synchotron	LEIR	low energy ion ring

- Fixed target areas
  - North Area (French sector, high energy, 450 GeV primary, 120 GeV secondary beams)
  - East Area (Swiss, low energy PS Booster 24 GeV primary, ~1–8 GeV secondary beams)
- Neutrino beams to Gran Sasso (IT)
- (not just) pre-accelerators for the highest-energy LHC.

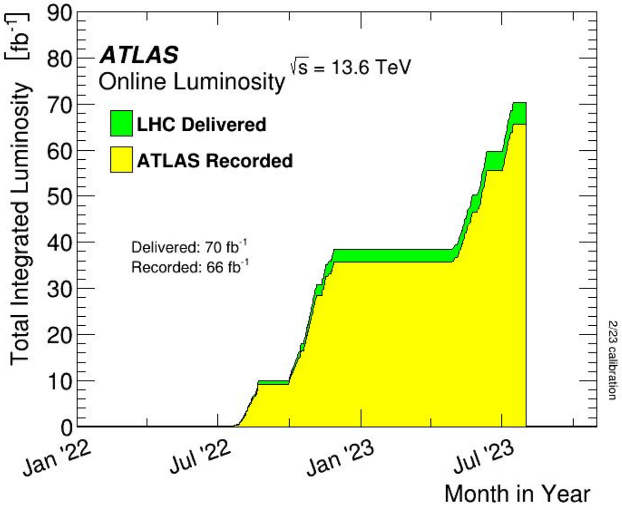

ATLAS
CMS

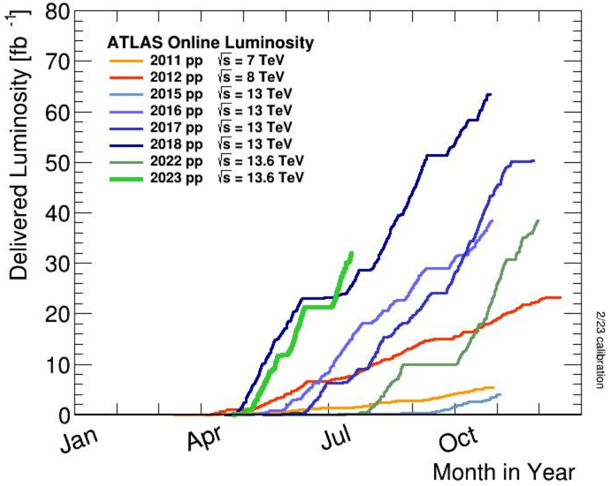
CERN Physics Programme

- https://home.cern/science/experiments
- LHC Physics
  - Versatile experiments
    - ATLAS, CMS
  - Dedicated experiments
    - LHCb (B-physics, CP violation)
    - ALICE (heavy ion physics)
    - LHCf – forward physics of neutral particles
    - FASER – neutrinos from a collider
- Neutrino Platform
  - ProtoDUNE
- Fixed Target Experiments
  - COMPASS, NA-62, CLOUD, …
- Small Experiments
  - Antiproton, antihydrogen experiments, OSQAR, …
  - R&D projects like MediPix3
- Dedicated facilities – IRRAD, ISOLDE
  - https://ps-irrad.web.cern.ch/ps-irrad/
- CERN-recognized Experiments
  - AMS-II – non-accelerator, ISS, control room @CERN
  - Water Cherenkov Test Experiment, waiting for Hyper-Kamiokande…

LHC Periods and *pp* c.m.s. energies

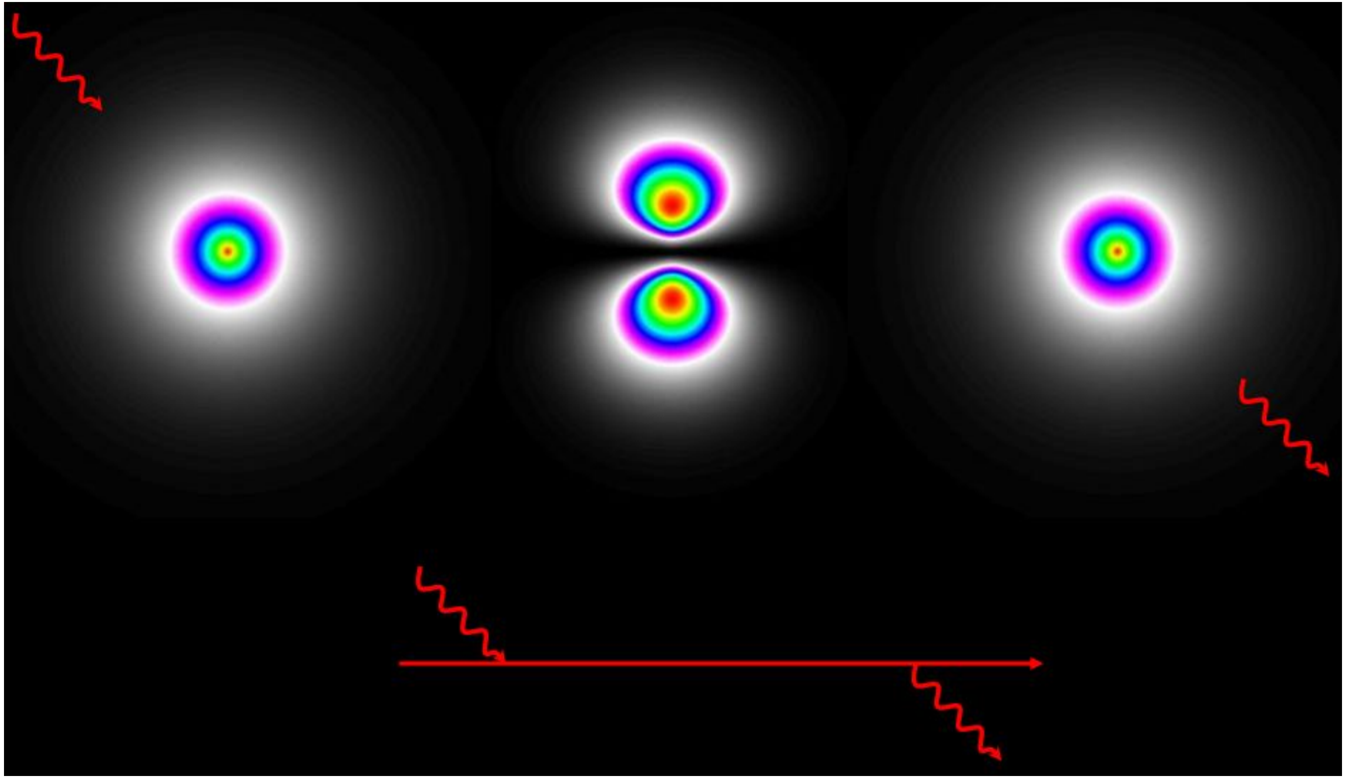
- 2008 start and crash
- 2009: **900 GeV** (SPS injection energy)
- 2010–2011: **7TeV**, L = 5 / fb
- 2012: **8 TeV**, L = 20 / fb
- 2015–2018: **13 TeV**, L = 90 / fb
- 2022-2025: **13.6 TeV**
- Design: 14 TeV
- And more:
  - LHC pp $\sqrt{s_{NN}}$ = 5.02 2015, 28 pb^{-1}
  - LHC PbPb $\sqrt{s_{NN}}$ = 5.02 2015, 0.49 nb^{-1}
  - LHC pPb $\sqrt{s_{NN}}$ = 5.02 2016, 0.5 nb^{-1}
  - LHC pPb $\sqrt{s_{NN}}$ = 8.16 2016, 0.16 pb^{-1}
  - LHC XeXe $\sqrt{s_{NN}}$ = 5.40 2017
  - LHC pp $\sqrt{s_{NN}}$ = 5.02 2017, 100-200 pb^{-1}
- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun3





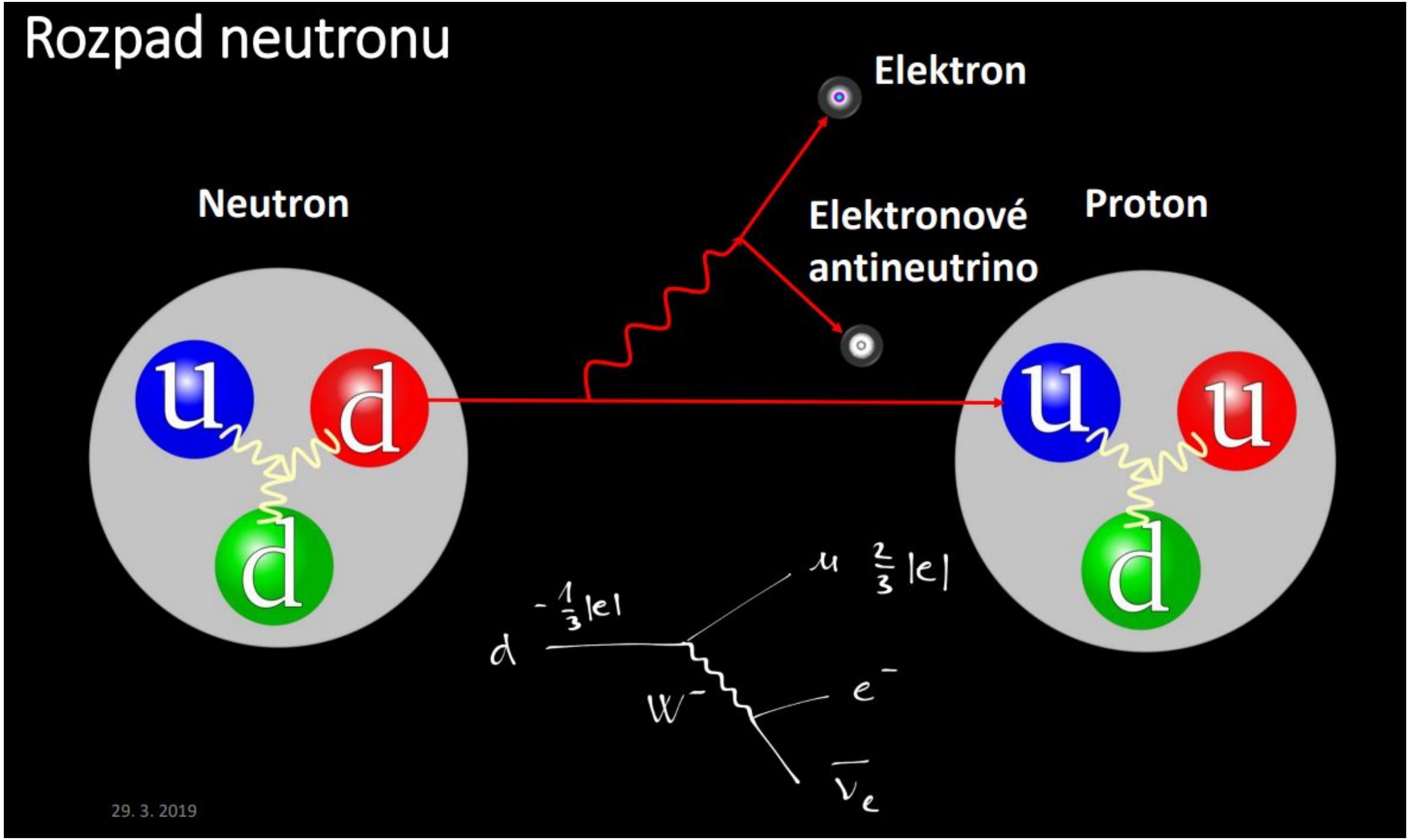
Interactions

-



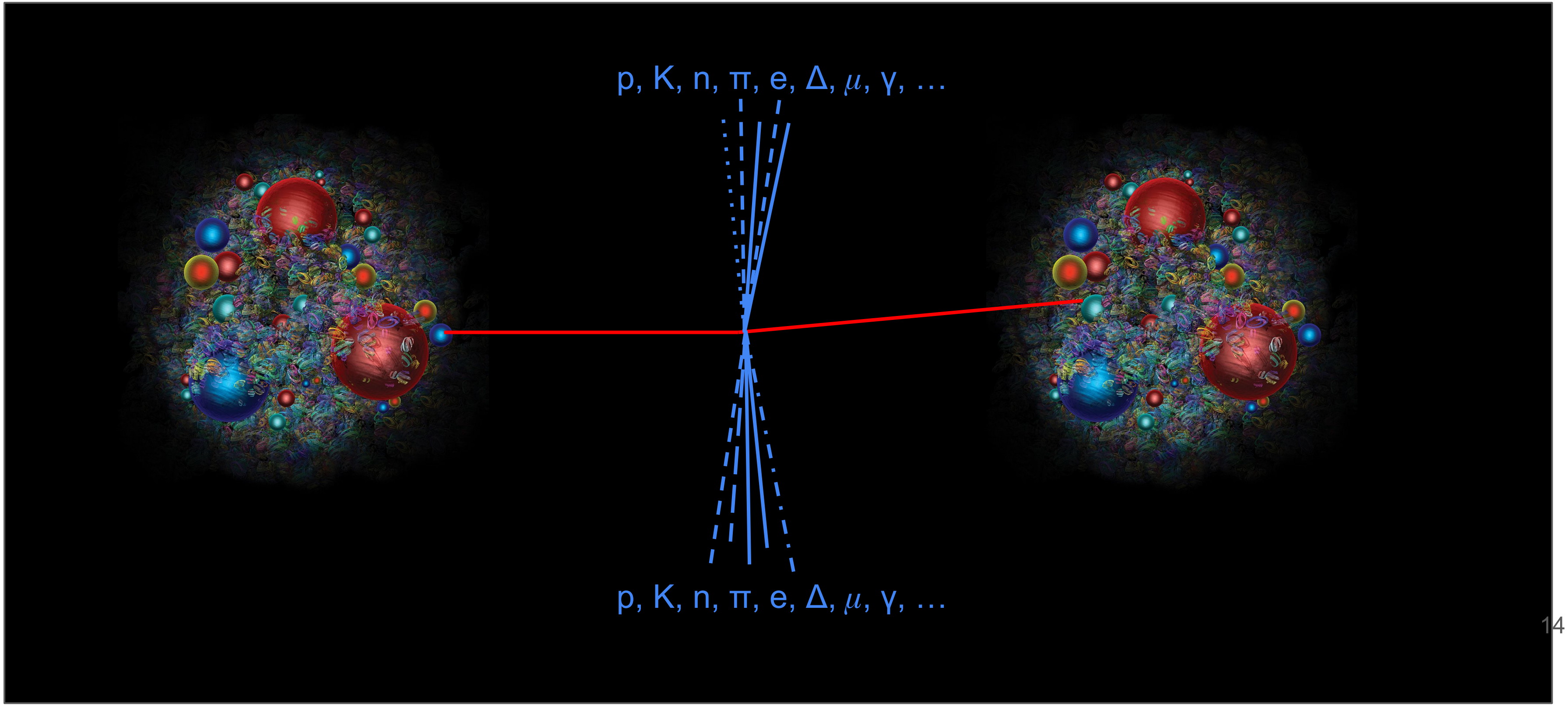
Interactions

-



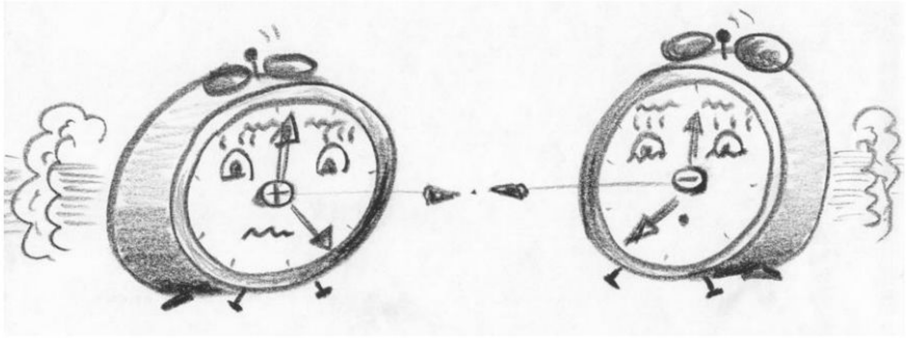
LHC Collisions

- Usually inelastic collisions where protons break apart, producing particles.
- But also large diffractive and elastic cross-section!



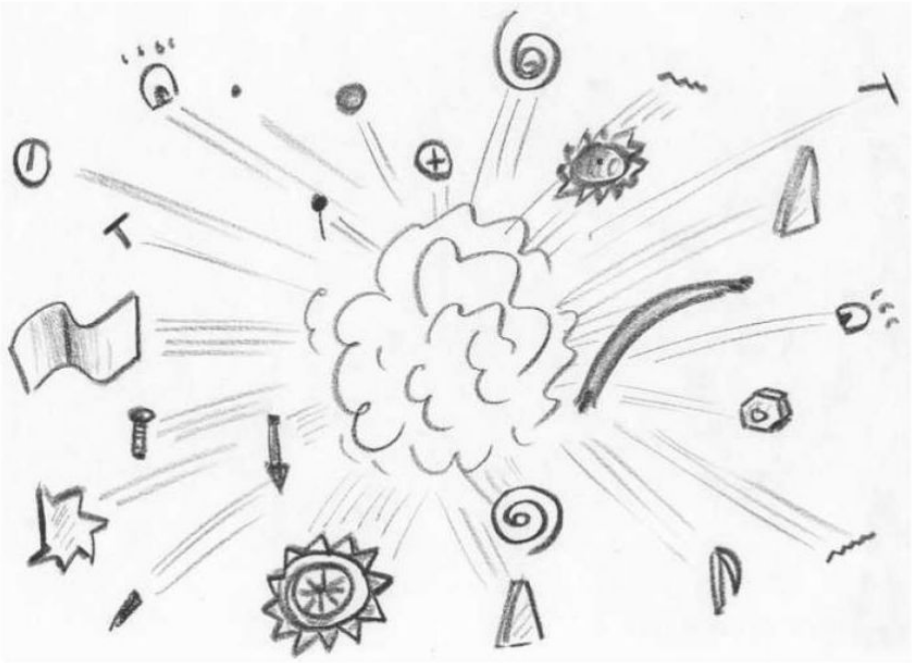
LHC Collisions

-

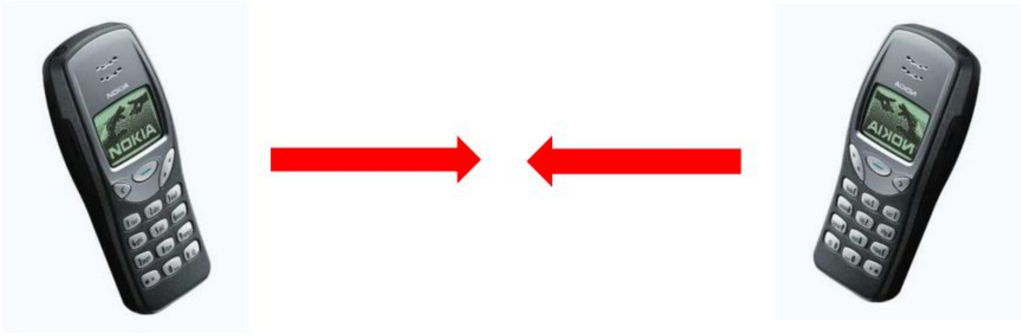


LHC Collisions

-



LHC Collisions



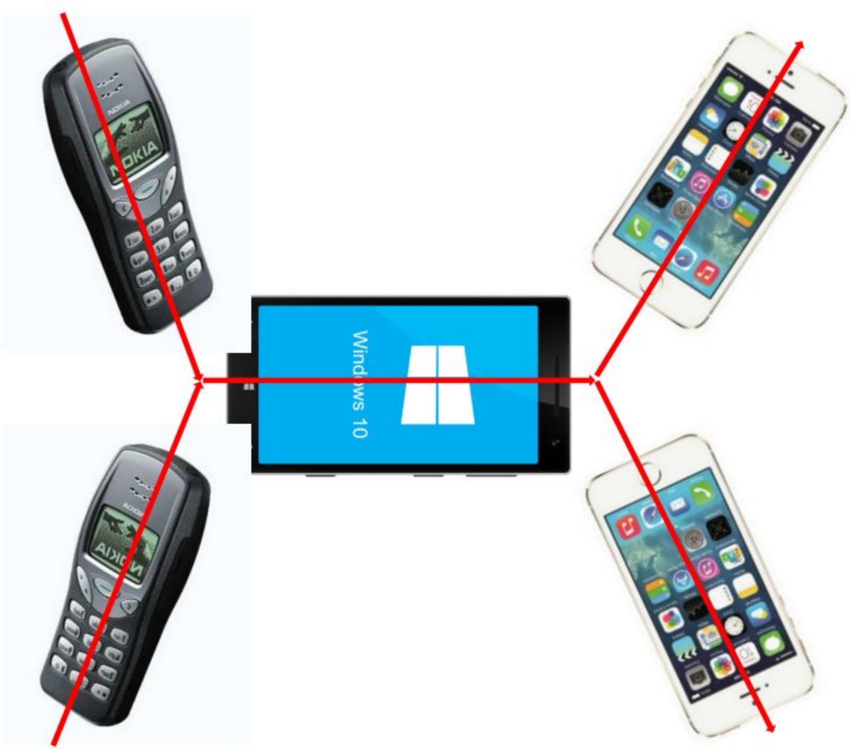
LHC Collisions

-

LHC Collisions

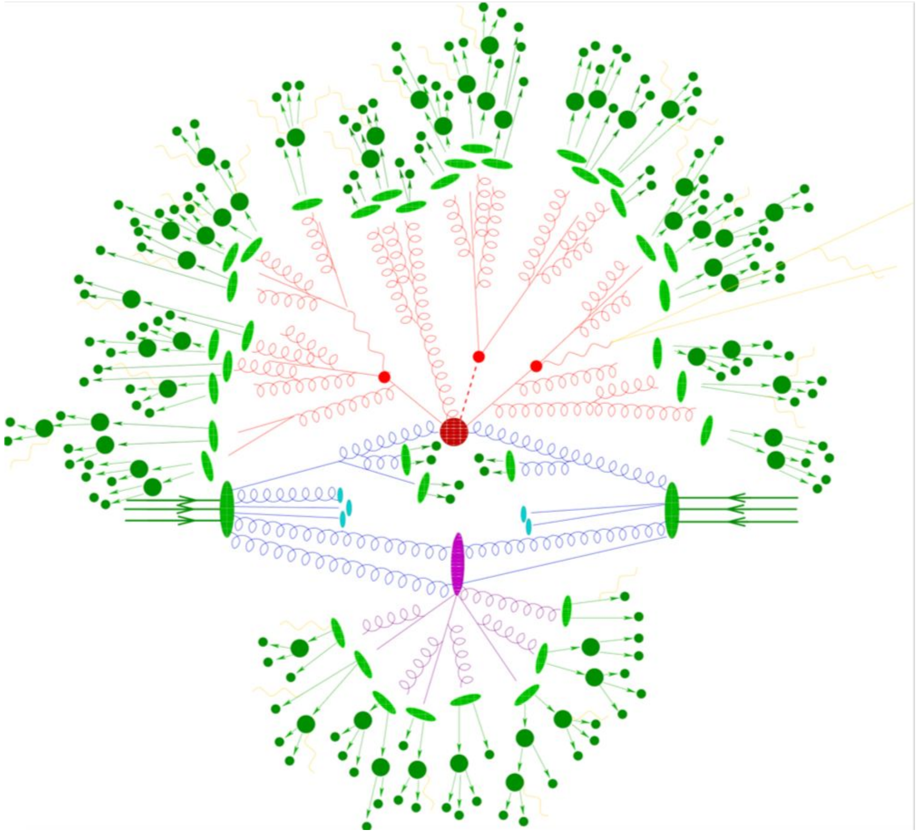
LHC Collisions

-



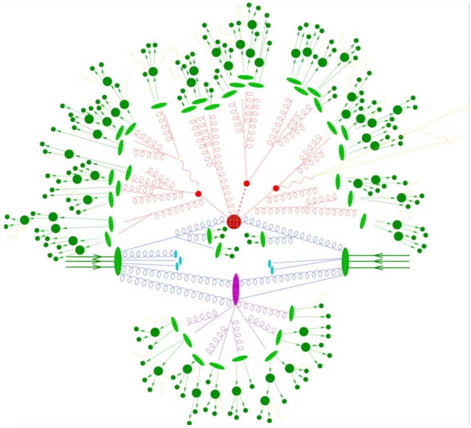
LHC Collisions

-



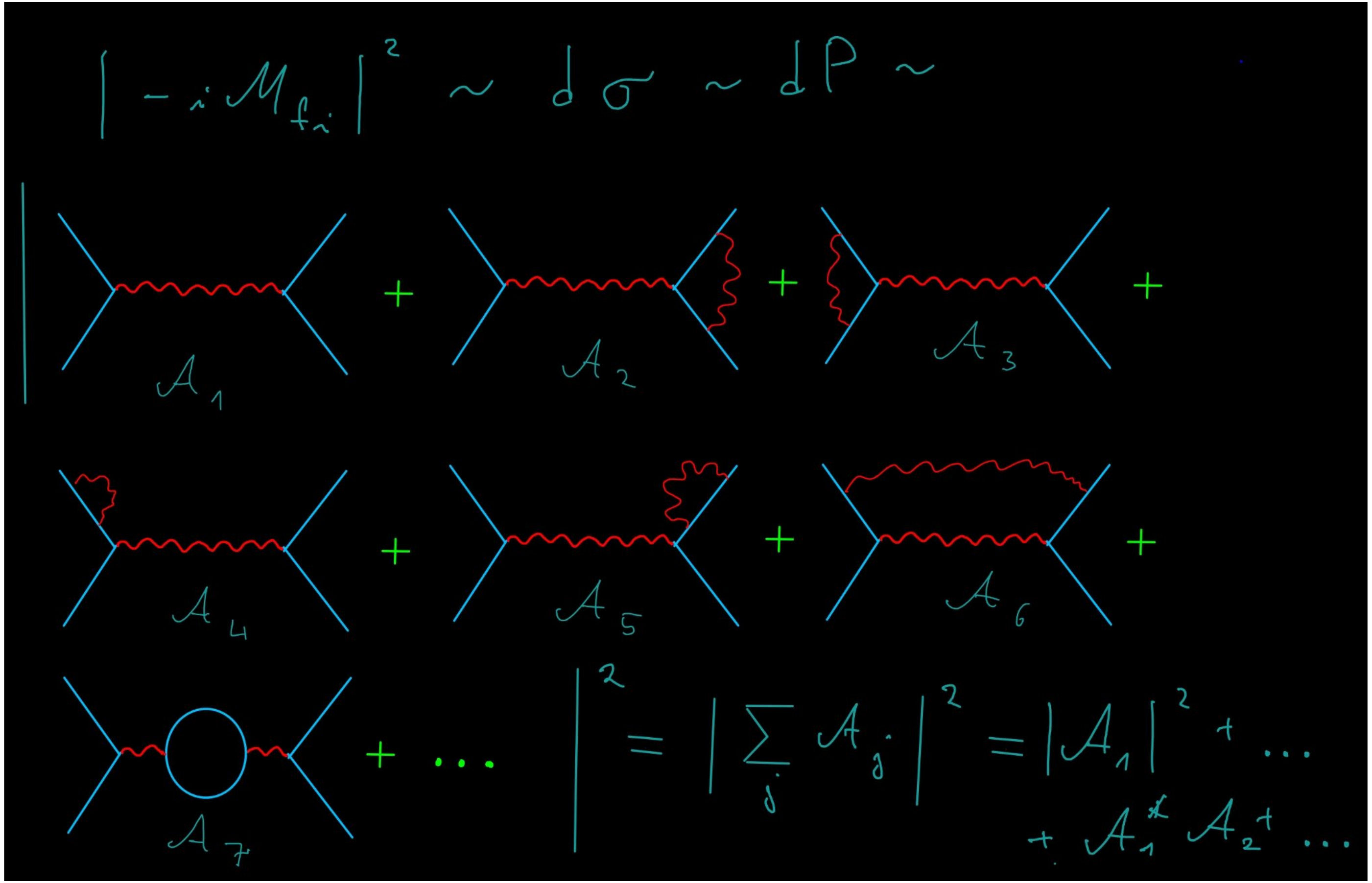
LHC Collisions

- Při vysokých energiích jsou kvarky v protonu téměř volné a nezávislé.
- Poruchová řada kvantové chromodynamiky má šanci konvergovat.
- Teorie: účinný průřez produkce systému X ve srážkách partonů
- Konvoluce s partonovými distribučními funkcemi dává
- Účinný průřez produkce X ve srážkách protonů.
- PDFs z předchozích experimentů (srážky *ep*, HERA, DESY)
- Hadronizace (fenomenologický model)
- Rozpady částic
- Interakce s detektorem – jeho plná simulace.
- Srovnání s daty

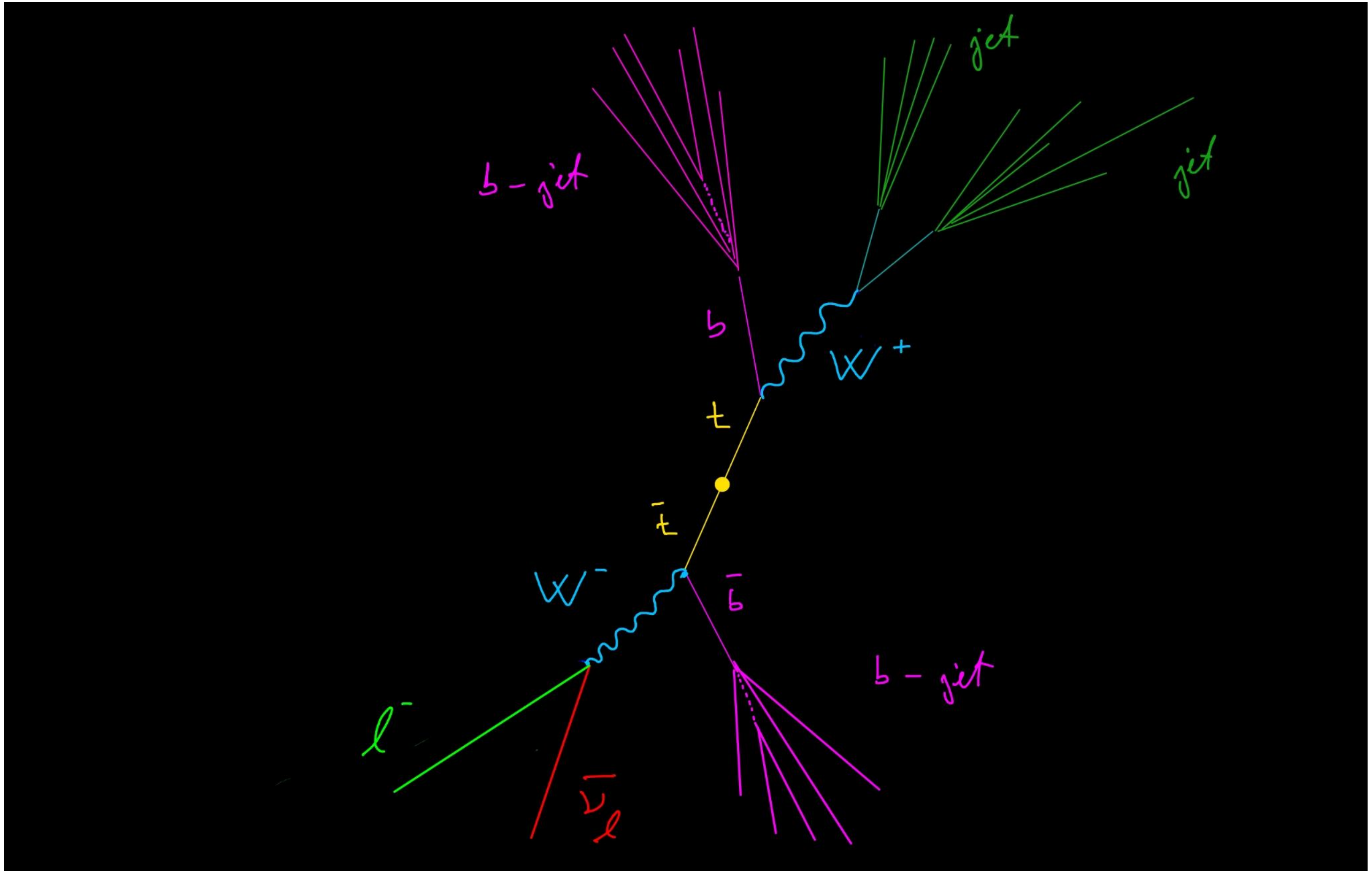


$$d\sigma_{h_1 h_2 \to X}(s) = \sum_{ij} \int_{\hat{s}_{\mathrm{thr}}}^{s} \left[f_{i/h_1}(\cdot, \mu_F) \otimes f_{j/h_2}(\cdot, \mu_F) \right](\hat{s}, \mu_F) \cdot d\hat{\sigma}_{ij \to X}(\hat{s}, \mu_R)\, d\hat{s}$$

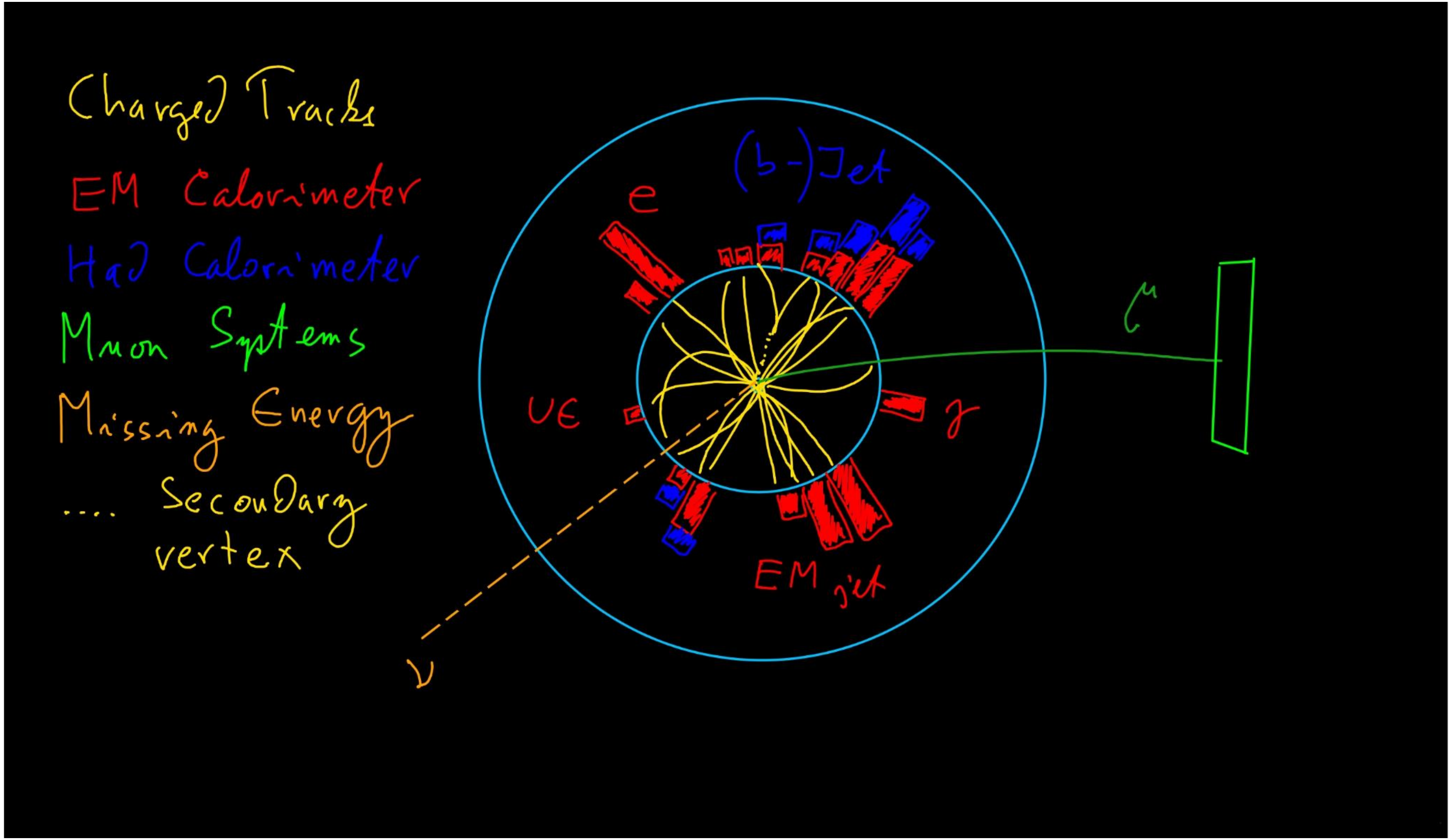
Theory



Expectations @ particle level



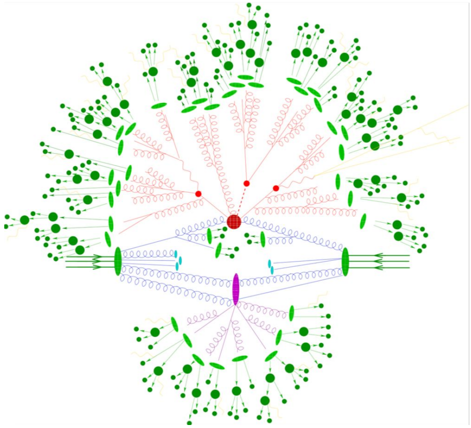
Experiment



Charged Tracks
EM Calorimeter
Had Calorimeter
Muon Systems
Missing Energy
.... Secondary vertex
(b-)Jet
e
UE
γ
μ
EM jet
ν

LHC Physics Programme

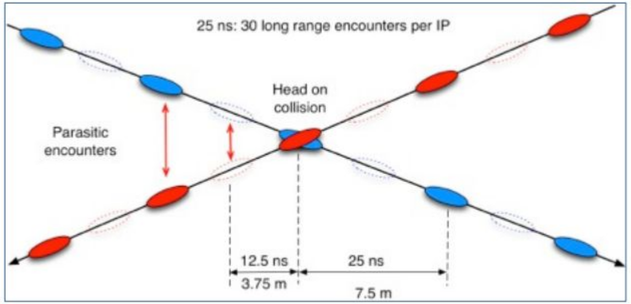
- Přesná měření procesů Standardního modelu
  - hledání vzácných procesů (ttH, WWZ, …)
  - měření diferenciálních účinných průřezů
  - ověřování přesnosti dostupných teoretických předpovědí
  - měření parametrů SM, narušení CP…
  - zpřesňování PDFs
  - měření ve srážkách těžkých iontů, efekty zhášení, GQ plasma
- Hledání možných nových procesů za Standardní model
  - SUSY, supersymetrické částice
  - narušení univerzality leptonů
  - Kaluza-Klein gravitons
  - Extenze grupy symetrií SM
  - dlouhožijící částice

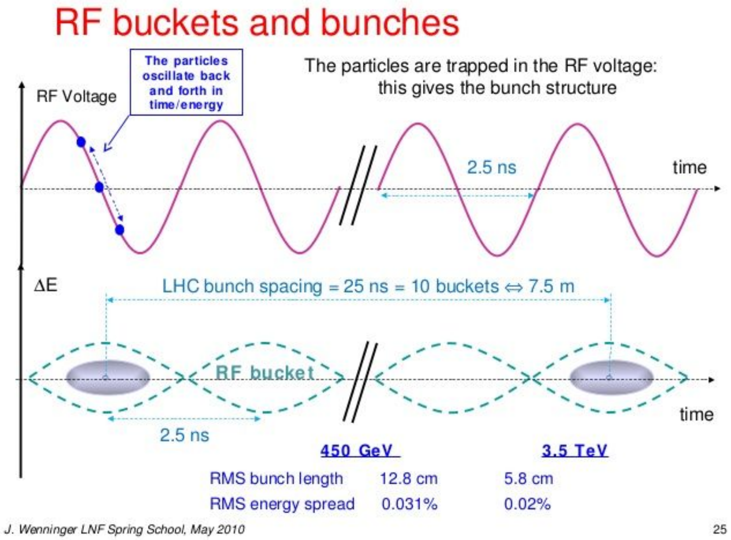


$$d\sigma_{h_1h_2\to X}(s) = \sum_{ij} \int_{\hat{s}_{\mathrm{thr}}}^{s} \left[f_{i/h_1}(\cdot,\mu_F) \otimes f_{j/h_2}(\cdot,\mu_F)\right](\hat{s},\mu_F) \cdot d\hat{\sigma}_{ij\to X}(\hat{s},\mu_R)\, d\hat{s}$$

The LHC

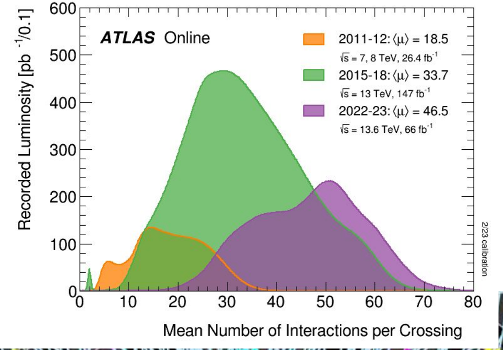
- Collision rate of 40 MHz, corresponding to 25ns
  - ATLAS diameter is 24m
- ~10^{11} particles in a bunch, O(2k) bunches
- Pile-up: O(100) pp collisions within a bunch crossing
- 2k superconducting dipole magnets at 2K
- bunches transverse size of O(100)mum!

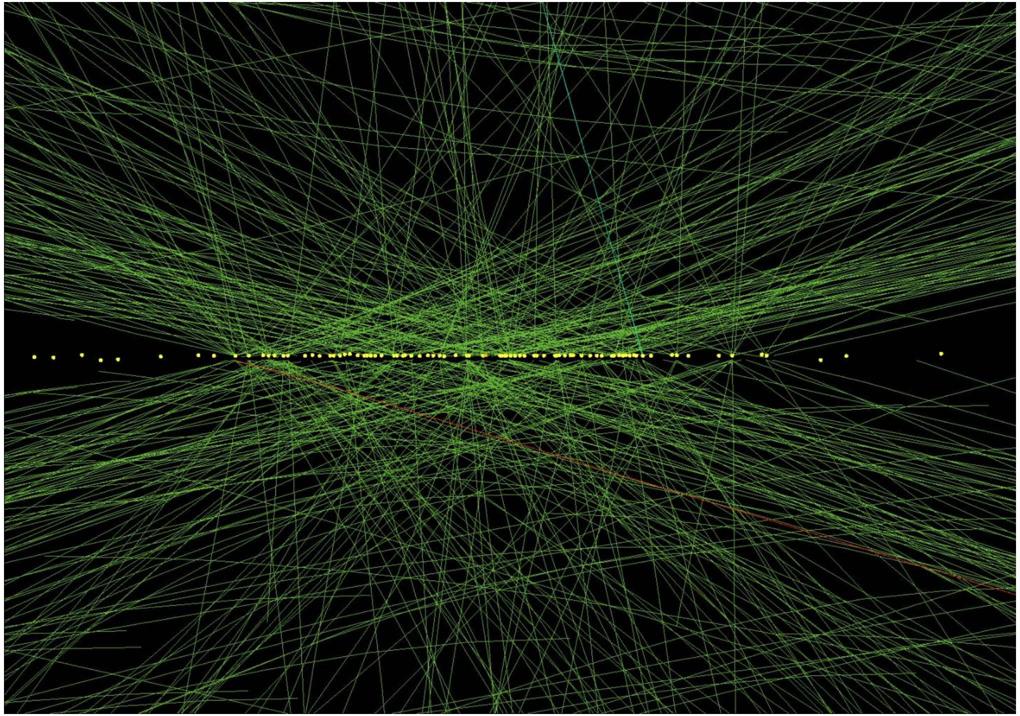


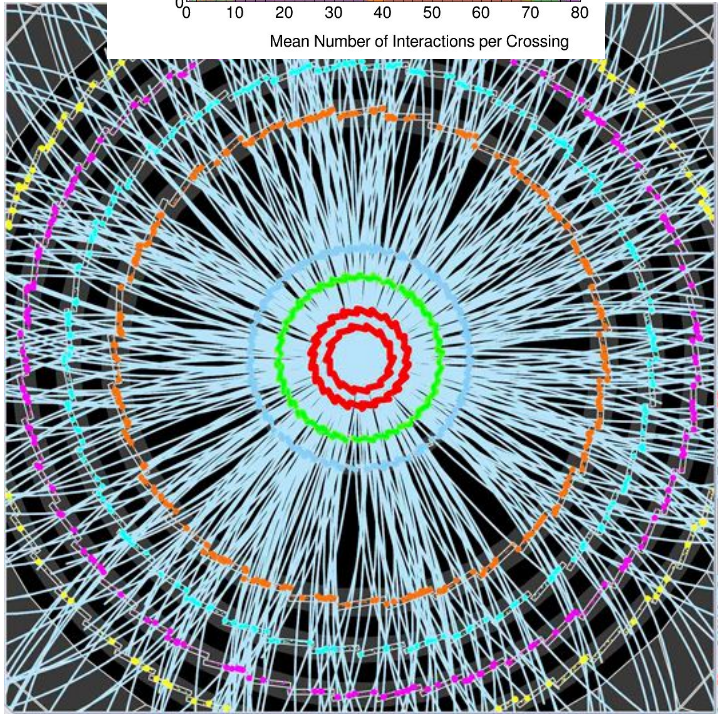


Pile-up at the LHC

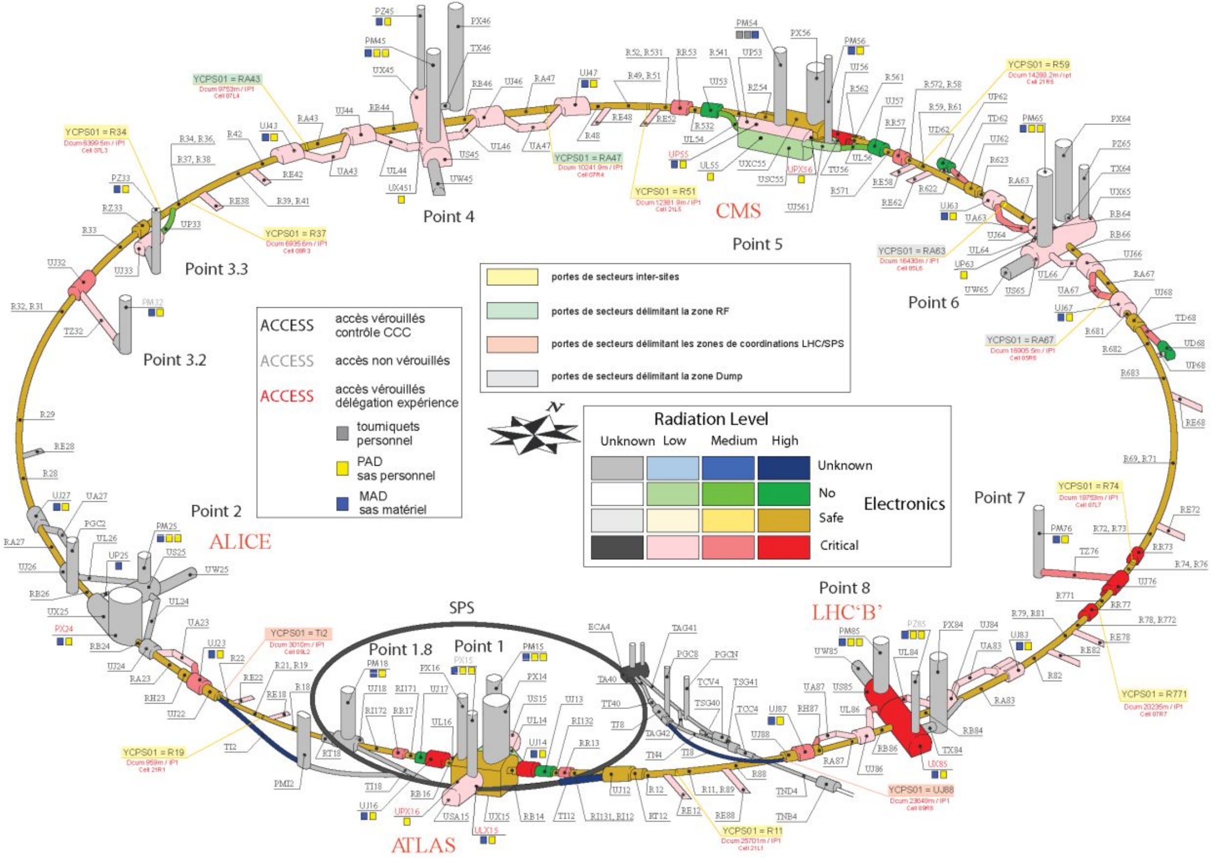
- Many *pp* collisions in one detector “picture”!
- Increases chances of interesting ones.
- Additional signal in the detector.





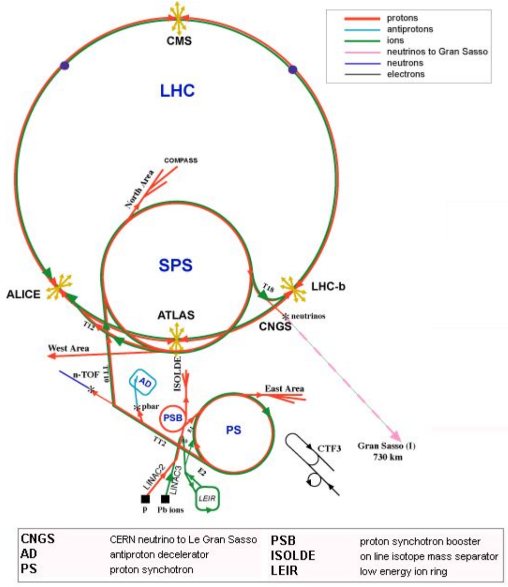


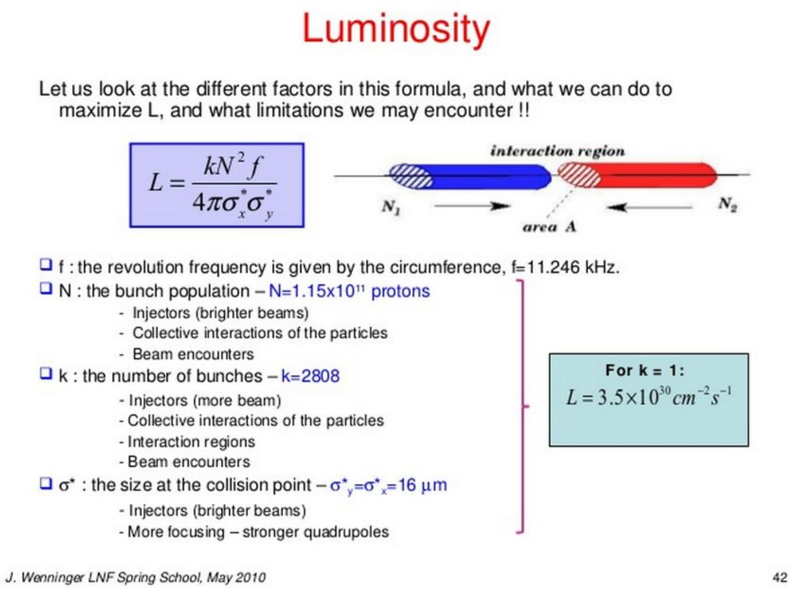
The LHC


Point 4
Point 5
CMS
Point 6
Point 7
Point 8
LHC'B'
Point 1
ATLAS
Point 1.8
SPS
Point 2
ALICE
Point 3.2
Point 3.3
portes de secteurs inter-sites
portes de secteurs délimitant la zone RF
portes de secteurs délimitant les zones de coordinations LHC/SPS
portes de secteurs délimitant la zone Dump
ACCESS accès vérouillés contrôle CCC
ACCESS accès non vérouillés
ACCESS accès vérouillés délégation expérience
tourniquets personnel
PAD sas personnel
MAD sas matériel
Radiation Level
Unknown
Low
Medium
High
Unknown
No
Safe
Critical
Electronics
N

The LHC

The LHC

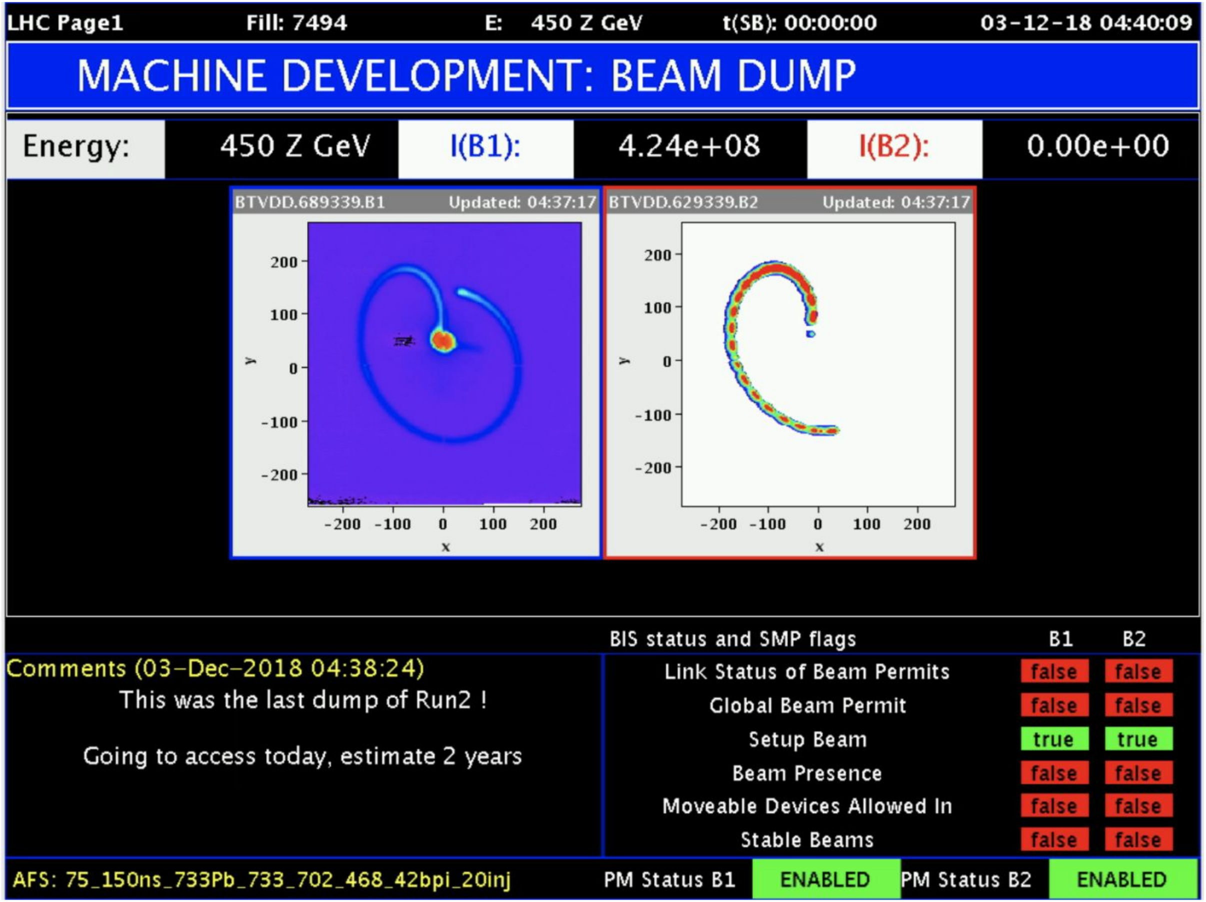

protons
antiprotons
ions
neutrinos to Gran Sasso
neutrons
electrons
CMS
LHC
COMPASS
North Area
SPS
ALICE
LHC-b
ATLAS
CNGS
neutrinos
West Area
n-TOF
AD
ISOLDE
pbar
PSB
PS
East Area
CTF3
Gran Sasso (I) 730 km
LINAC2
LINAC3
LEIR
P
Pb ions
CNGS CERN neutrino to Le Gran Sasso
AD antiproton decelerator
PS proton synchotron
PSB proton synchotron booster
ISOLDE on line isotope mass separator
LEIR low energy ion ring


Luminosity
Let us look at the different factors in this formula, and what we can do to maximize L, and what limitations we may encounter !!
$L = \frac{kN^2 f}{4\pi\sigma_x^*\sigma_y^*}$
interaction region
N_1
N_2
area A
f : the revolution frequency is given by the circumference, f=11.246 kHz.
N : the bunch population – N=1.15x10¹¹ protons
- Injectors (brighter beams)
- Collective interactions of the particles
- Beam encounters
k : the number of bunches – k=2808
- Injectors (more beam)
- Collective interactions of the particles
- Interaction regions
- Beam encounters
σ* : the size at the collision point – σ*y=σ*x=16 μm
- Injectors (brighter beams)
- More focusing – stronger quadrupoles
For k = 1:
$L = 3.5\times10^{30} cm^{-2}s^{-1}$
J. Wenninger LNF Spring School, May 2010
42


1 PS batch
(72 bunches)
1 SPS batch
(288 bunches)
Abort gap
Bunch Lengths [ns]
Bucket #

The LHC beam dump temperature map

https://home.cern/news/news/accelerators/lhc-report-another-run-over-and-ls2-has-just-begun



https://iopscience.iop.org/article/10.1088/1748-0221/16/11/P11019/pdf

Design and behaviour of the Large Hadron Collider external beam dumps capable of receiving 539 MJ/dump

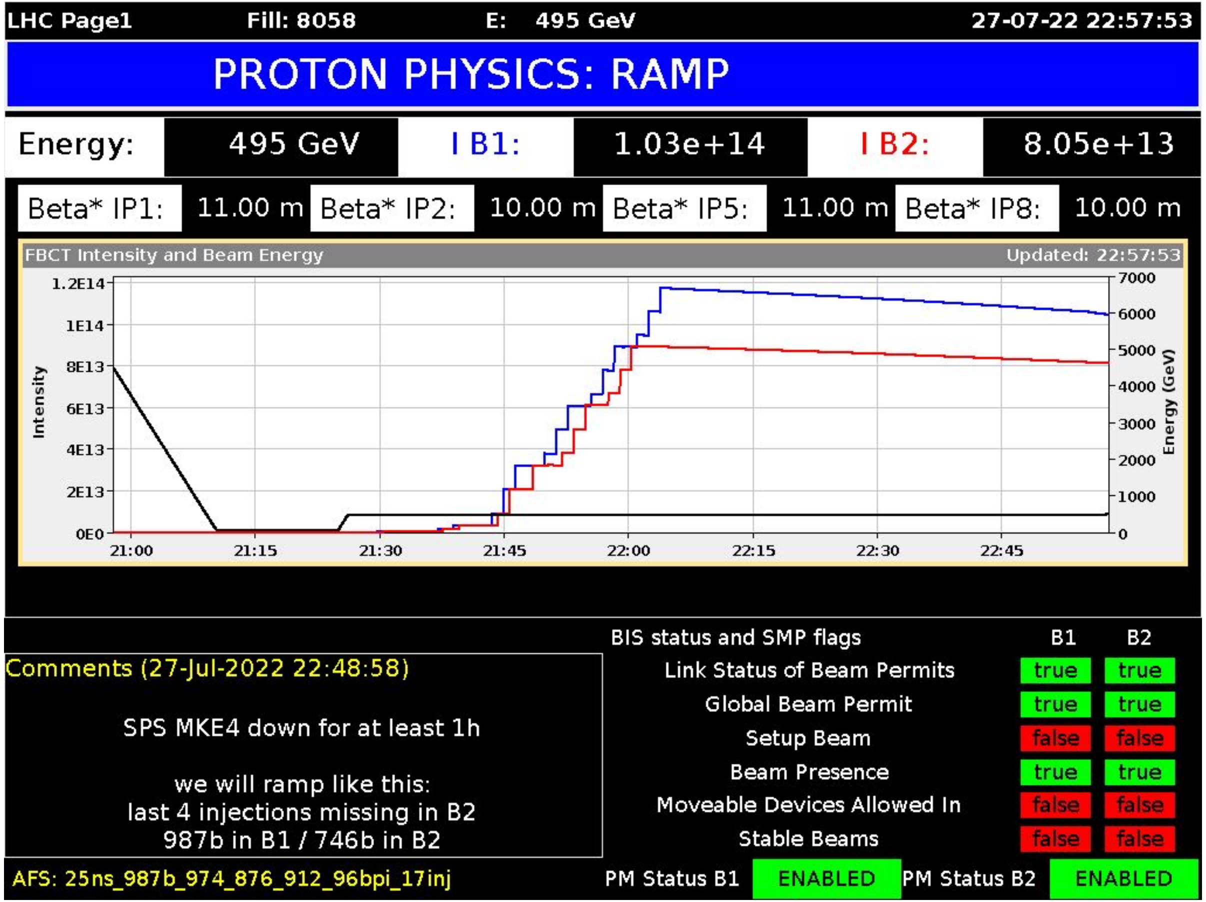
https://cerncourier.com/a/proton-ion-collisions-the-final-challenge/

https://www.lhc-closer.es/taking_a_closer_look_at_lhc/0.lhc_layout

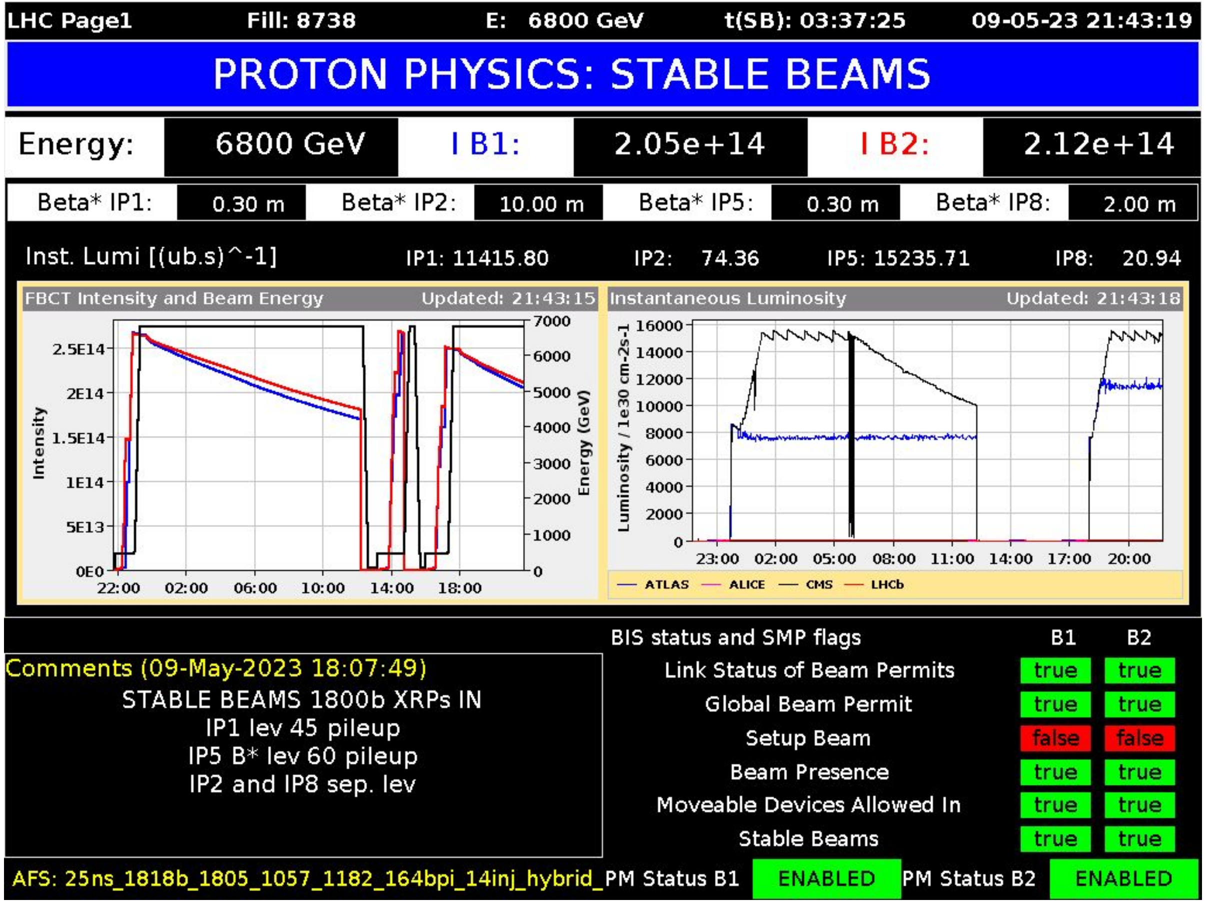
LHC States / Status

- http://jointlab.upol.cz/kvita/LHC.html
- http://jointlab.upol.cz/kvita/outreach/
- https://op-webtools.web.cern.ch/vistar/vistars.php

The LHC

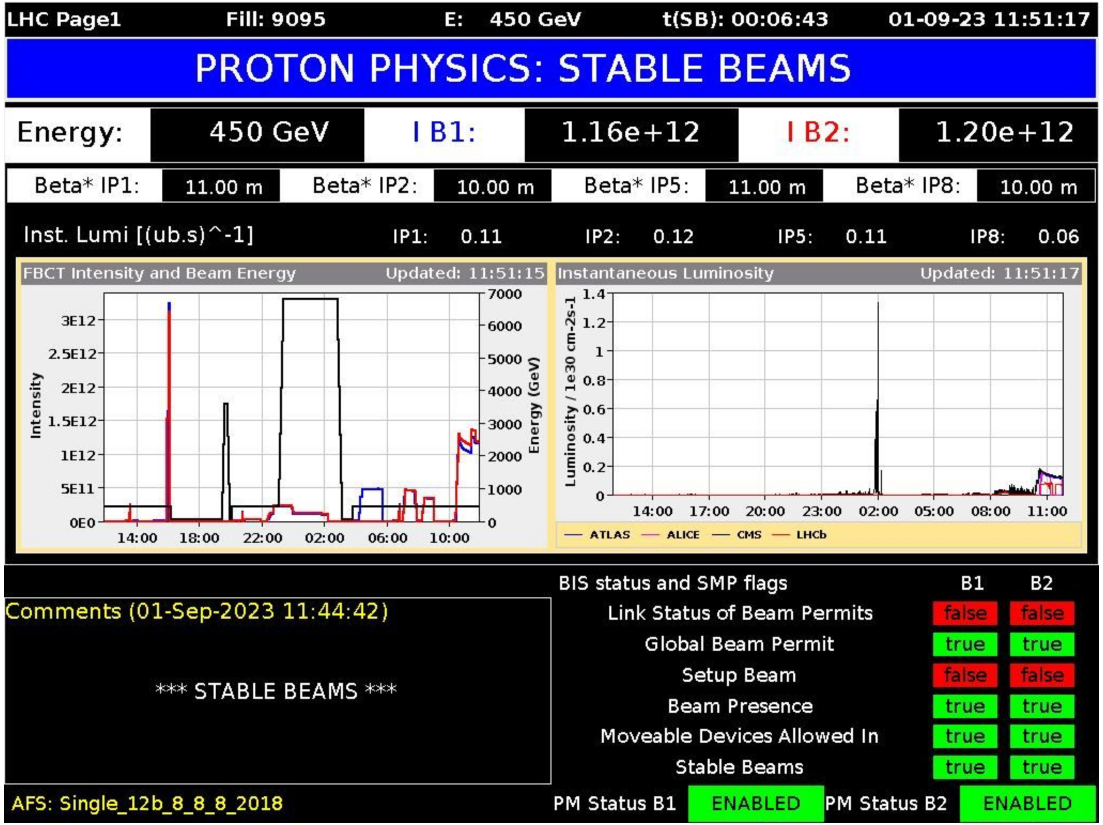

LHC Page1
Fill: 8058
E: 495 GeV
27-07-22 22:57:53
PROTON PHYSICS: RAMP
Energy:
495 GeV
I B1:
1.03e+14
I B2:
8.05e+13
Beta* IP1:
11.00 m
Beta* IP2:
10.00 m
Beta* IP5:
11.00 m
Beta* IP8:
10.00 m
FBCT Intensity and Beam Energy
Updated: 22:57:53
Intensity
1.2E14
1E14
8E13
6E13
4E13
2E13
0E0
Energy (GeV)
7000
6000
5000
4000
3000
2000
1000
0
21:00
21:15
21:30
21:45
22:00
22:15
22:30
22:45
Comments (27-Jul-2022 22:48:58)
SPS MKE4 down for at least 1h
we will ramp like this:
last 4 injections missing in B2
987b in B1 / 746b in B2
BIS status and SMP flags
B1
B2
Link Status of Beam Permits
true
true
Global Beam Permit
true
true
Setup Beam
false
false
Beam Presence
true
true
Moveable Devices Allowed In
false
false
Stable Beams
false
false
AFS: 25ns_987b_974_876_912_96bpi_17inj
PM Status B1
ENABLED
PM Status B2
ENABLED

The LHC



LHC Page1
Fill: 8738
E: 6800 GeV
t(SB): 03:37:25
09-05-23 21:43:19
PROTON PHYSICS: STABLE BEAMS
Energy: 6800 GeV
I B1: 2.05e+14
I B2: 2.12e+14
Beta* IP1: 0.30 m
Beta* IP2: 10.00 m
Beta* IP5: 0.30 m
Beta* IP8: 2.00 m
Inst. Lumi [(ub.s)^-1]
IP1: 11415.80
IP2: 74.36
IP5: 15235.71
IP8: 20.94
FBCT Intensity and Beam Energy
Updated: 21:43:15
Intensity
Energy (GeV)
Instantaneous Luminosity
Updated: 21:43:18
Luminosity / 1e30 cm-2s-1
ATLAS
ALICE
CMS
LHCb
BIS status and SMP flags
B1
B2
Comments (09-May-2023 18:07:49)
STABLE BEAMS 1800b XRPs IN
IP1 lev 45 pileup
IP5 B* lev 60 pileup
IP2 and IP8 sep. lev
Link Status of Beam Permits true true
Global Beam Permit true true
Setup Beam false false
Beam Presence true true
Moveable Devices Allowed In true true
Stable Beams true true
AFS: 25ns_1818b_1805_1057_1182_164bpi_14inj_hybrid_
PM Status B1 ENABLED
PM Status B2 ENABLED

The LHC



CERN

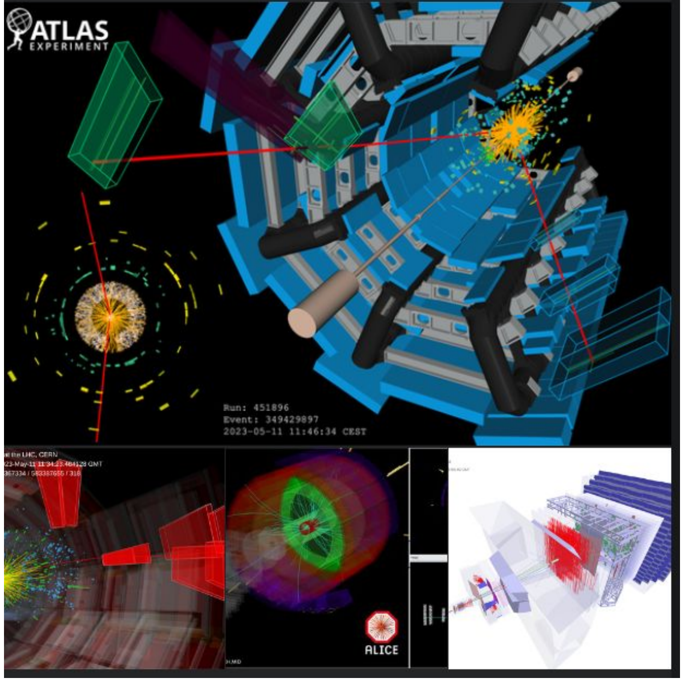
2 hod ·

The Large Hadron Collider is now colliding beams with 2400 proton bunches per beam, its target for #LHCRun3. Have you wondered what that looks like for the #physics experiments at the #LHC?

Take a look at these beautiful event displays from ATLAS Experiment at CERN, CMS Experiment at CERN, ALICE experiment and LHCb Experiment at CERN . 💙

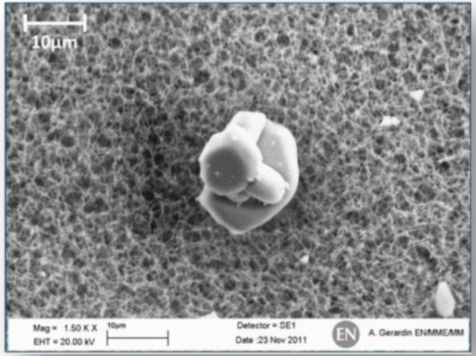
#DidYouKnow the particles are so tiny that making them collide is like trying to fire two needles 10 kilometres apart with such precision that they meet halfway?

Find out more about the third physics run, the #LHC and its experiments later today. Stay tuned!

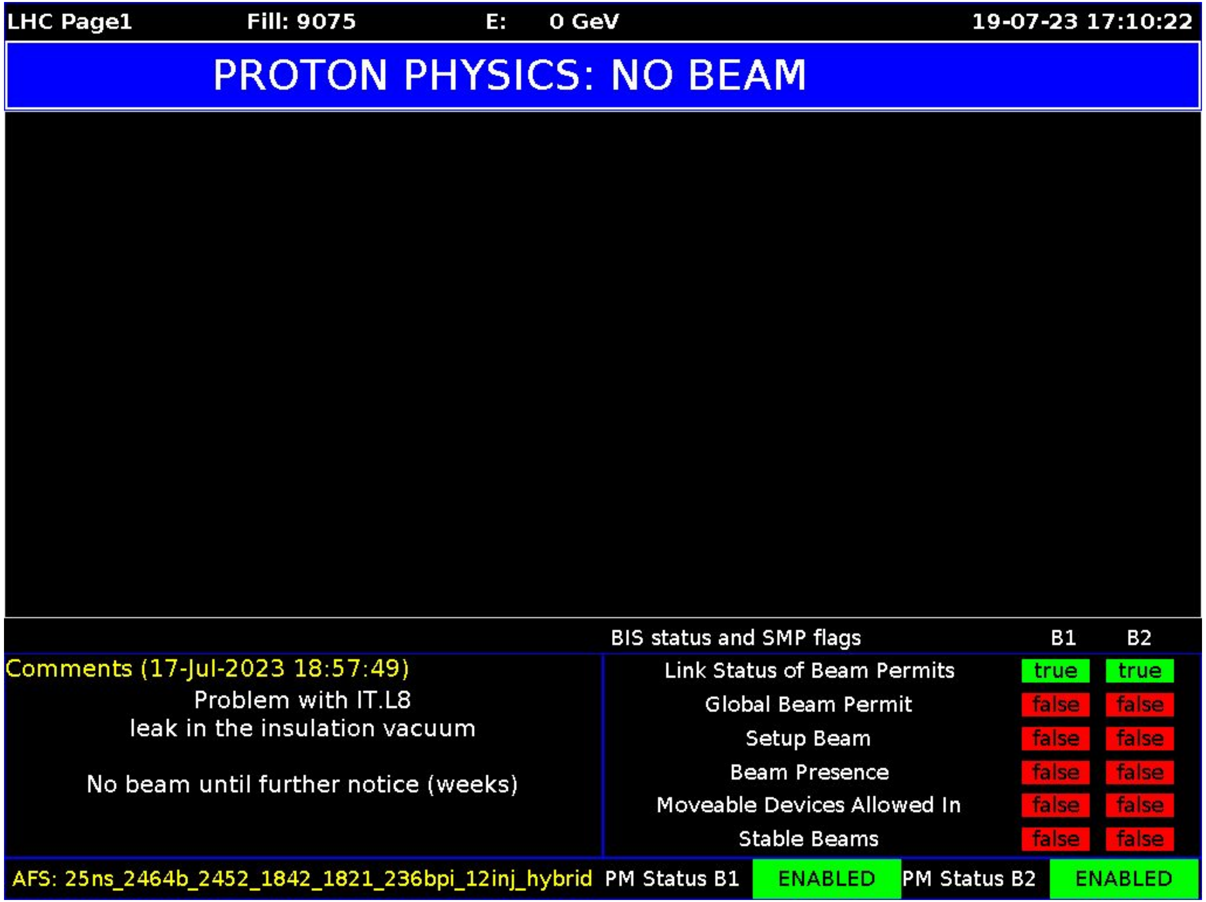


UFO (*Unidentified Falling Objects*)

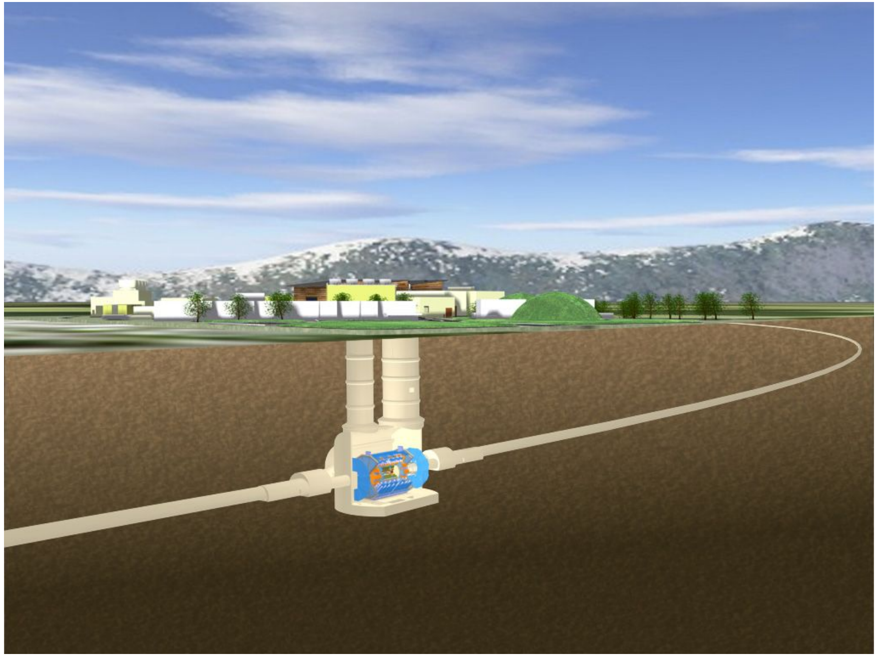
1. A **macroparticle** (dust) **falls** from the top of the beam screen
2. The **macroparticle is ionized** due to elastic collisions with the beam
3. The positively charged **macroparticle is subsequently repelled away** from the beam
4. During the above, there may be **significant losses due to inelastic collisions -> beam dump and/or magnet quench!**



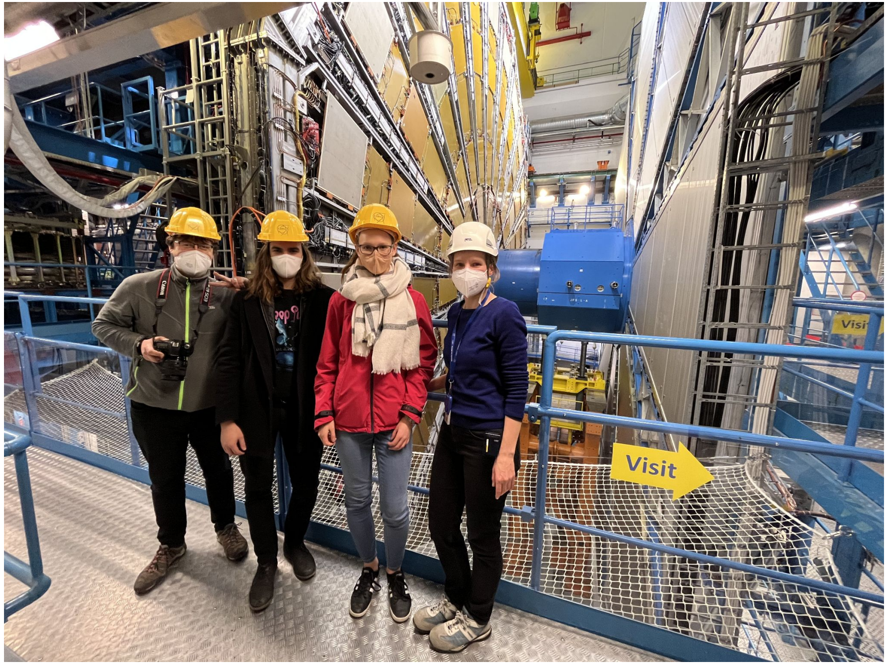
The LHC

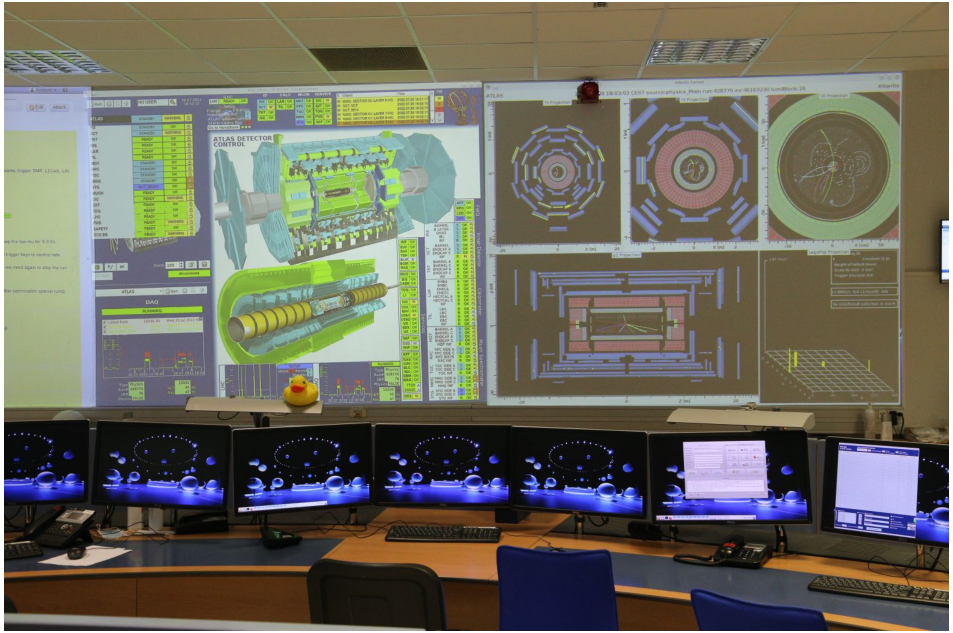

LHC Page1
Fill: 9075
E: 0 GeV
19-07-23 17:10:22
PROTON PHYSICS: NO BEAM
BIS status and SMP flags
B1
B2
Comments (17-Jul-2023 18:57:49)
Problem with IT.L8
leak in the insulation vacuum
No beam until further notice (weeks)
Link Status of Beam Permits
true
true
Global Beam Permit
false
false
Setup Beam
false
false
Beam Presence
false
false
Moveable Devices Allowed In
false
false
Stable Beams
false
false
AFS: 25ns_2464b_2452_1842_1821_236bpi_12inj_hybrid
PM Status B1
ENABLED
PM Status B2
ENABLED

The ATLAS Experiment

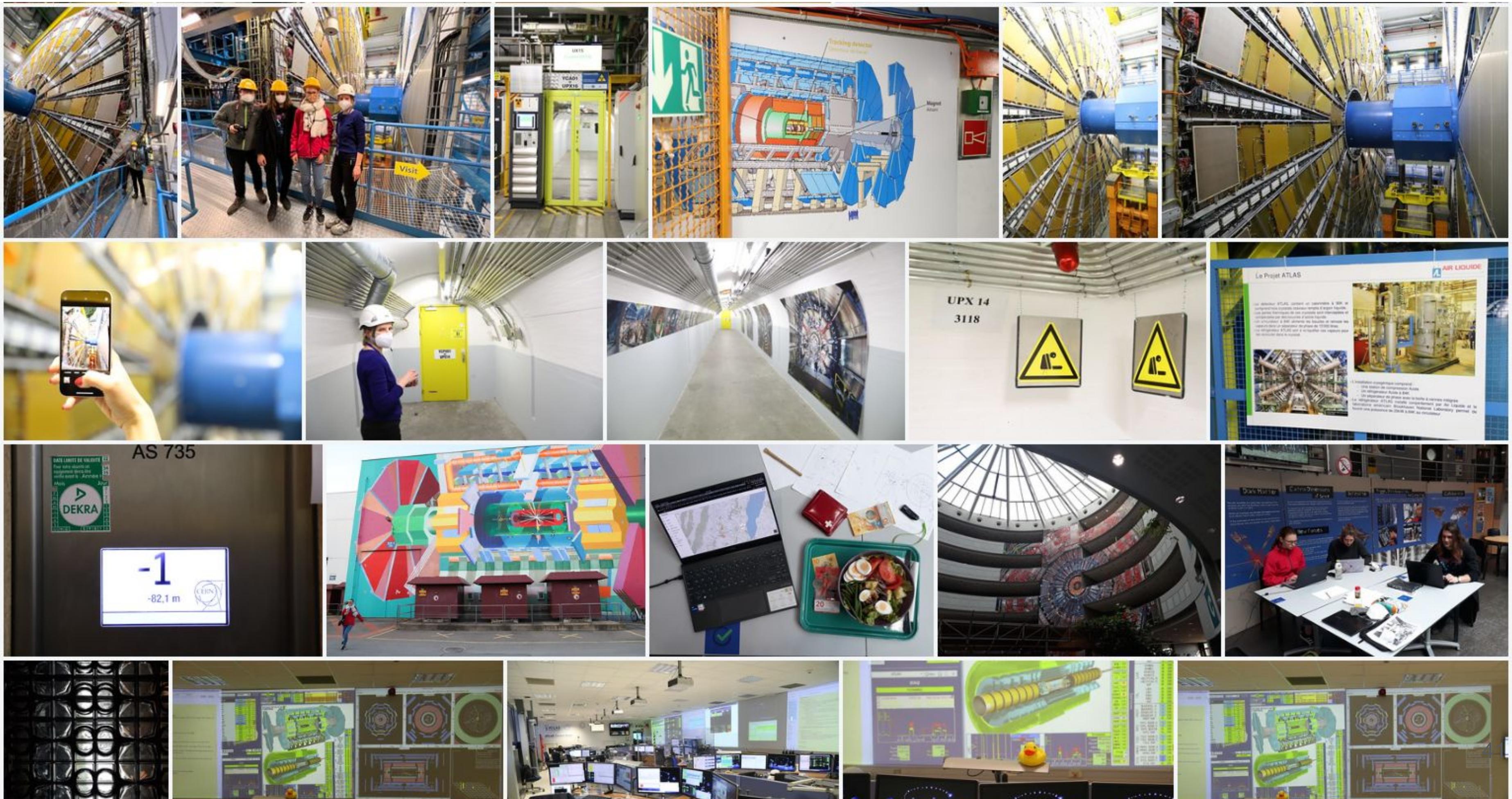


The ATLAS Experiment

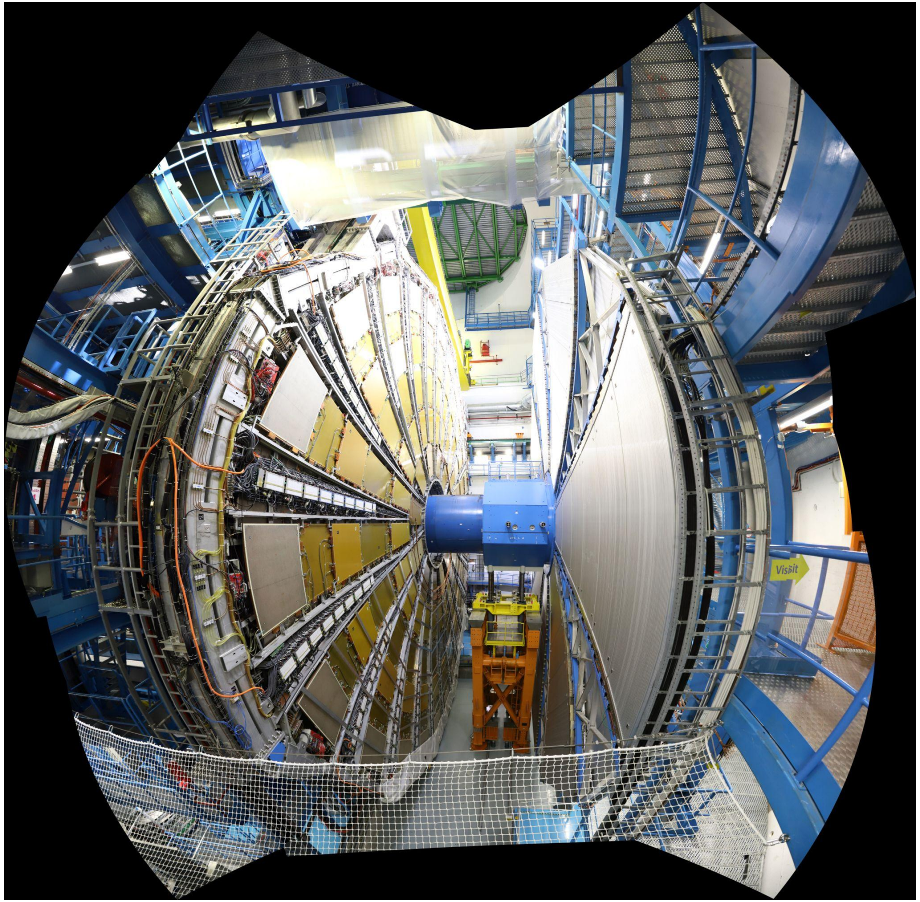


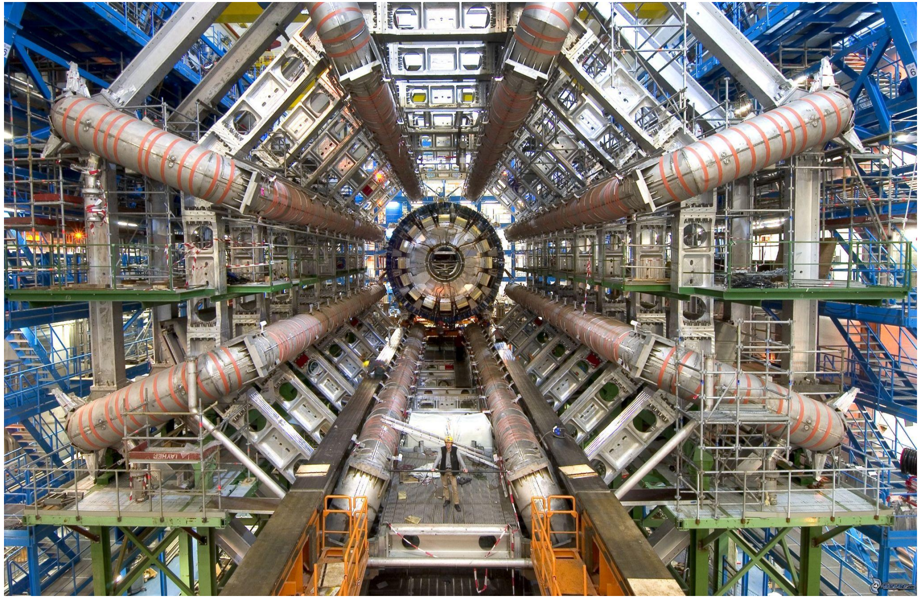


The ATLAS Experiment

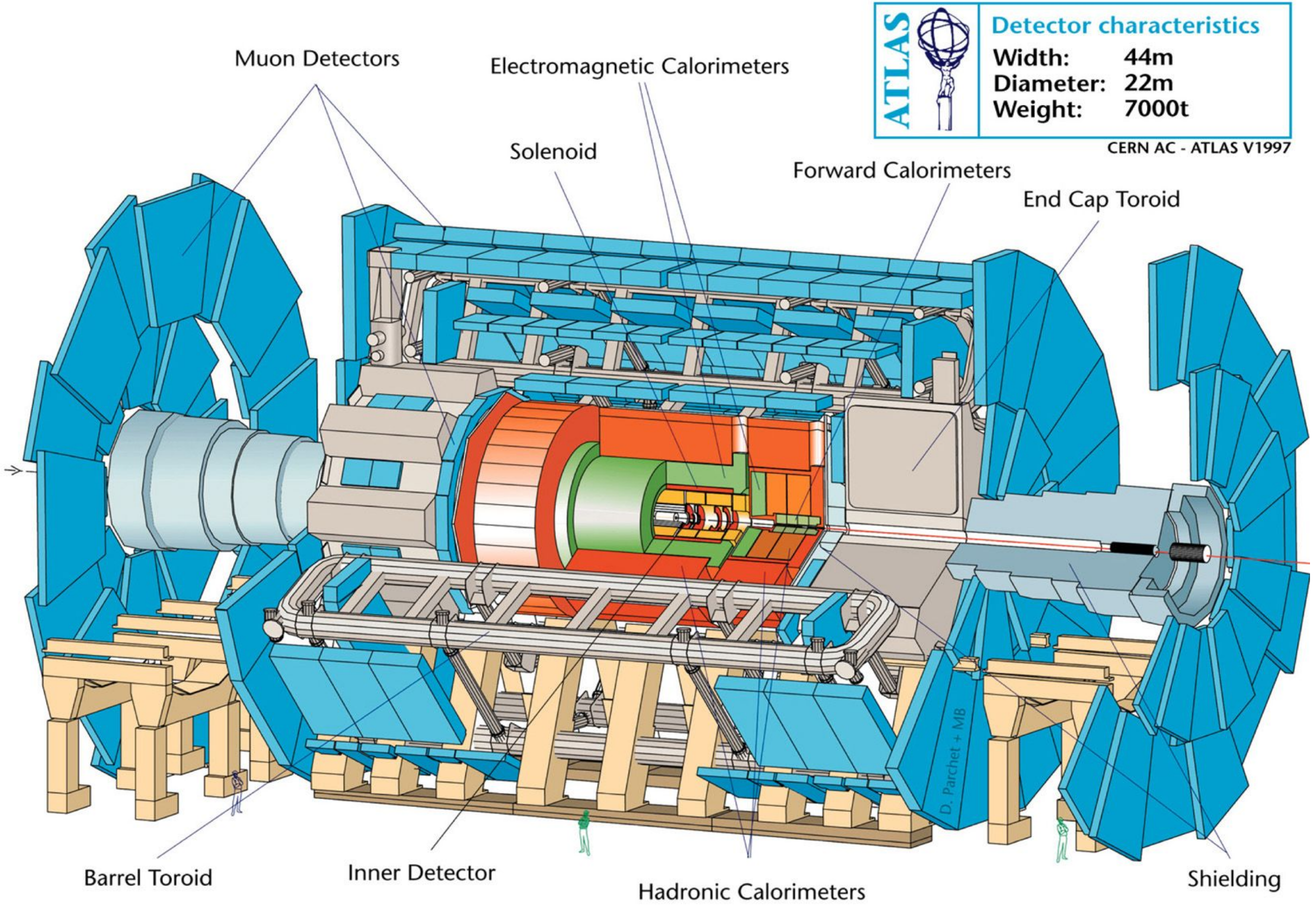


The ATLAS Experiment

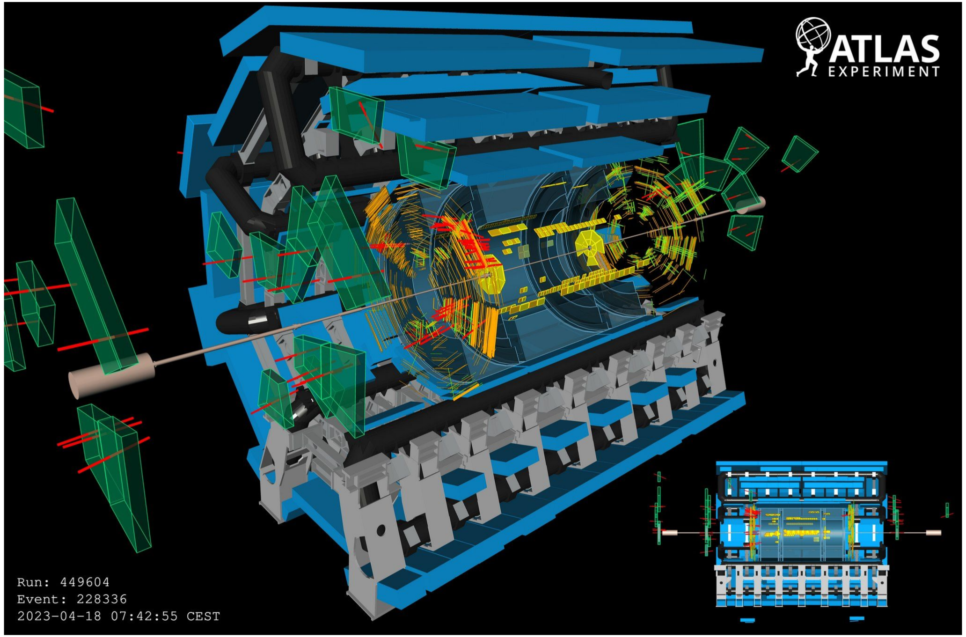




The ATLAS Experiment

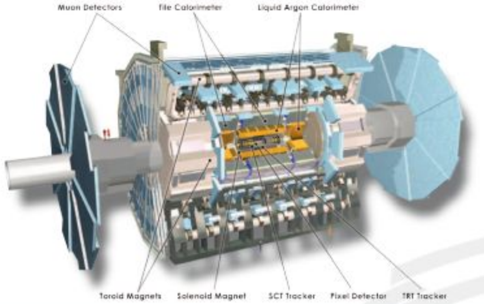


The ATLAS Experiment



The ATLAS Detector

- Diameter 25 m -- Length : 46 m
- Barrel toroid length 26 m
- Overall weight 7 000 tonnes
- ~ 100 million electronic channels
- ~ 3 000 km of cables



Calorimeters

Measure the energies carried by the particles

Liquid Argon (LAr) Calorimeter
- Barrel 6.4 m long, 53 cm thick, 110 000 channels.
- Works with Liquid Argon at -183° C
- LAr endcap consists of the forward calorimeter, electromagnetic (EM) and hadronic endcaps.
- EM endcaps each have thickness 0.632 m and radius 2.077 m.
- Hadronic endcaps consist of two wheels of thickness 0.8 m and 1.0 m with radius 2.09 m.
- Forward calorimeter has three modules of radius 0.455 m and thickness 0.450 m each.

Tile Calorimeter (TileCal)
- Barrel made of 64 wedges, each 5.6 m long and 20 tonnes.
- Each Endcap has 64 wedges, each 2.6 m long.
- 500 000 plastic scintillator tiles.

Muon System

Identifies and measures the momenta of muons

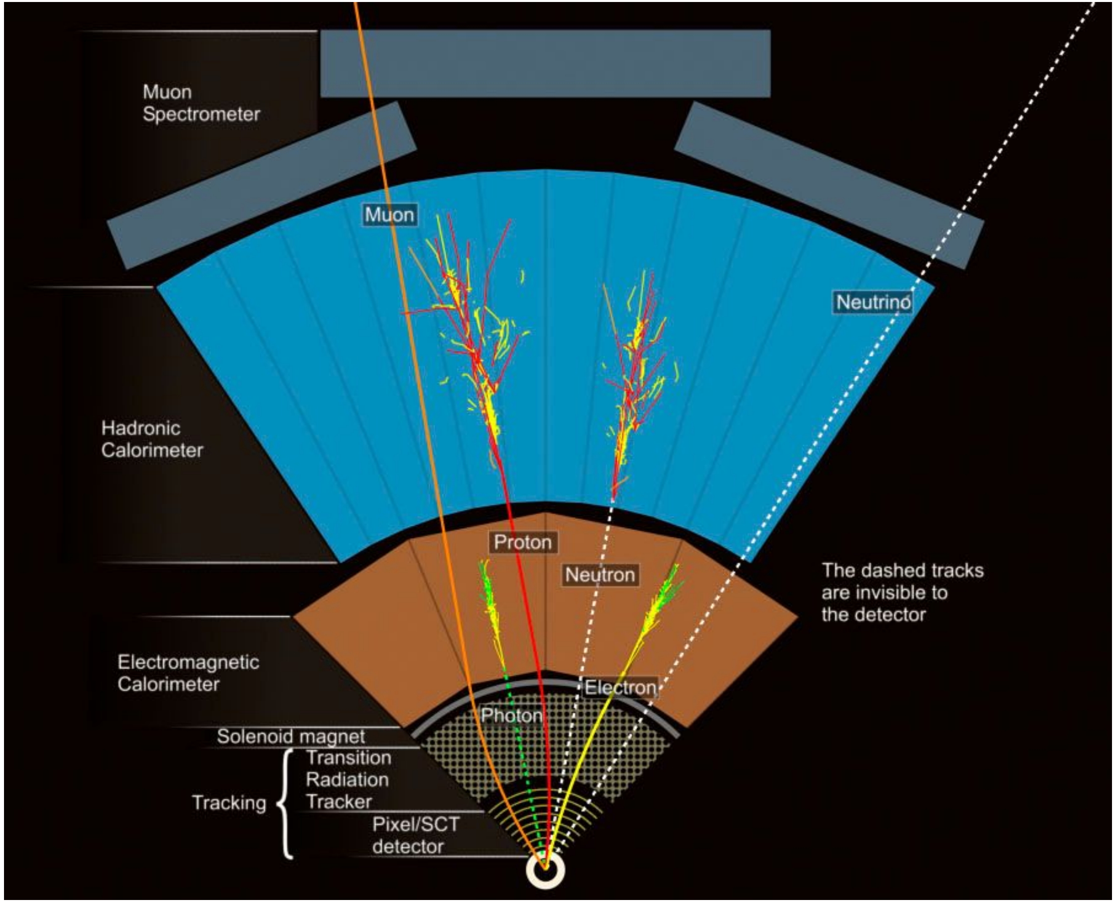
Thin Gap Chambers
For triggering and 2nd coordinate measurement (non-bending direction) at ends of detector.
- 440 000 channels

Resistive Plate Chambers
For triggering and 2nd coordinate measurement in central region.
- 380 000 channels
- Electric Field 5 000 V/mm

Monitored Drift Tubes
Measure curves of tracks.
- 1 171 chambers with total 354 240 tubes (3 cm diameter, 0.85-6.5 m long).
- Tube resolution 80 µm

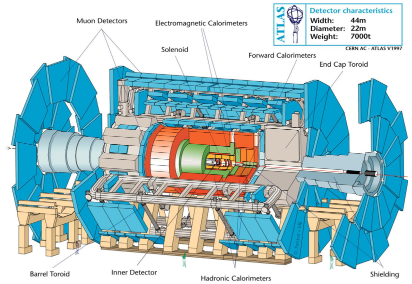
Cathode Strip Chambers
Measure precision coordinates at ends of detector.
- 70 000 channels
- Resolution 60 µm

The ATLAS Experiment – particle identification



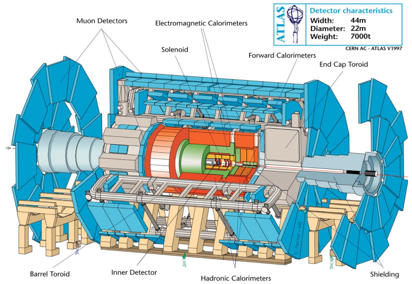
The ATLAS Experiment

- A large camera, object identification using combined techniques
  - electrons, photons, muons, hadronic final states = jets, tau
  - missing energy as a signature of the neutrino
  - mesons, baryons
  - reconstruct short-lived resonances decaying to “stable” particles
- Energy and momentum measurements of primary of parent particles
- Passage of particle through the matter!



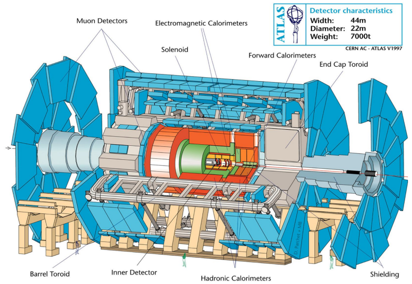
Fyzikální skupiny – ATLAS

- SM group
- Top group
- Higgs
- Higgs and Diboson
- SUSY
- Exotics
- B-physics
- Heavy ions
- Effective field theory interpretation
- Dark matter



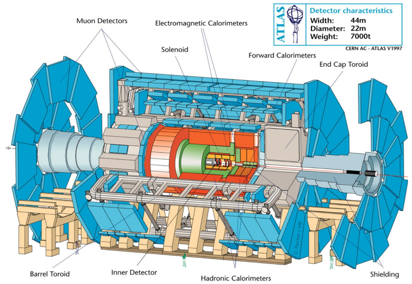
ID skupiny – ATLAS

- Muon Combined Performance Group
- Egamma group
- JetEtmiss group
- Tau ID
- Tracking
- Vertexing
- Flavour tagging
- Physics Modelling, Forward proton group
- Physics Validation, fake forum
- Data analysis model, software, luminosity, statistics…
- Trigger, Machine learning forum…
- Simulation and MC production

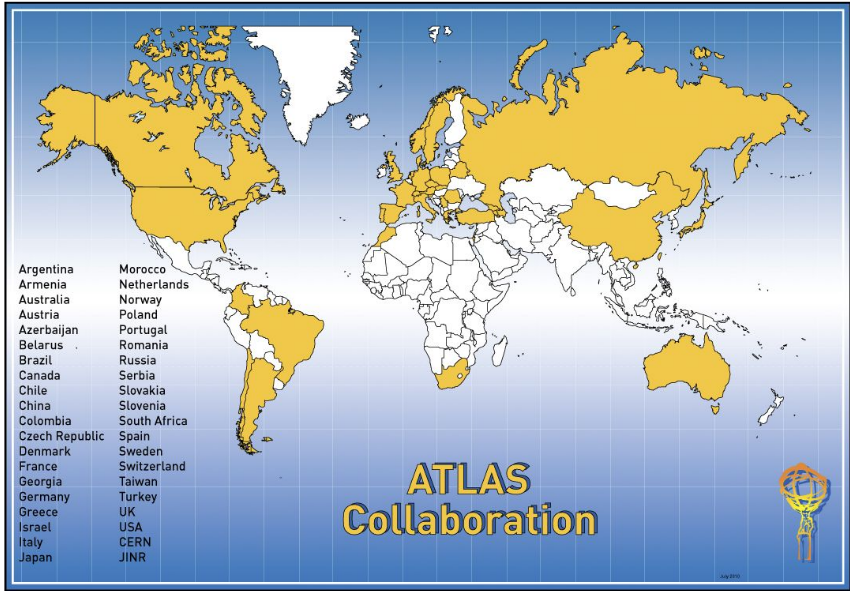


ATLAS

- Management
- Operations
- Upgrade
- Physics coordination
- Publication Committee

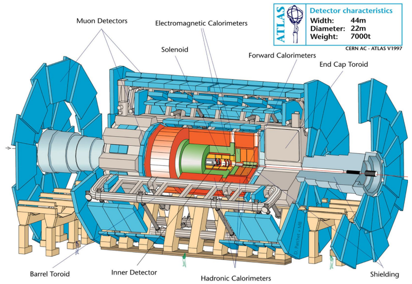


The ATLAS Experiment



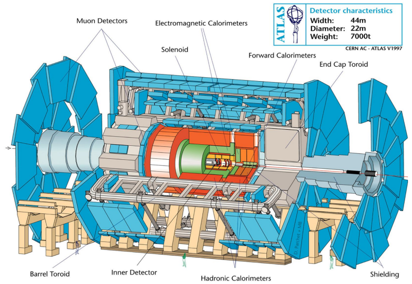
ATLAS Groups

- Detector operations
  - run control, shifts, repairs, liquids, gases, HV, LV, readout, DAQ, synchronization…
- Software, data preparation, good run list
- Physics modelling groups
  - Monte Carlo simulation, tuning
- Detector simulation, geometry
- Object identification, calibration, combined performace
  - jets, electrons, muons, tau ID energy scale and IDs
  - provide recommendations, official selection, systematics uncertainties
- Physics groups
  - Higgs, Top, Standard Model, Heavy Ions, Beyond-the-SM, SUSY



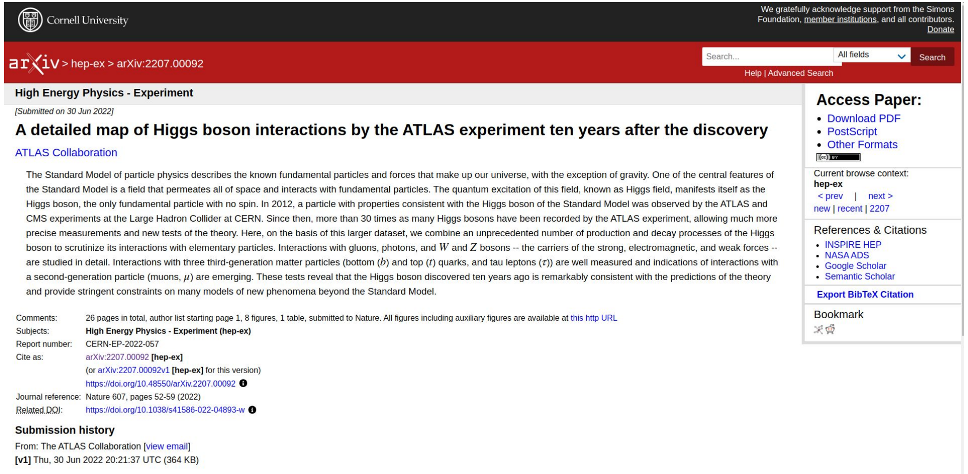
Authorship

- Collaboration rules
- Authorship committee
- Qualification task, supervisor
- Detector operations fees per non-student author
- ~3k ATLAS authors, no distinguished corresponding nor first authors
    - alphabetical



Analysis scrutiny

- Physics group
  - Physics subgroup
- Editorial board
- Physics Coordinators
- Publication Committee
- ATLAS collaboration circulation 1, 2



Cornell University

We gratefully acknowledge support from the Simons Foundation, member institutions, and all contributors. Donate

arXiv > hep-ex > arXiv:2207.00092

Search... All fields Search

Help | Advanced Search

High Energy Physics - Experiment

[Submitted on 30 Jun 2022]

A detailed map of Higgs boson interactions by the ATLAS experiment ten years after the discovery

ATLAS Collaboration

The Standard Model of particle physics describes the known fundamental particles and forces that make up our universe, with the exception of gravity. One of the central features of the Standard Model is a field that permeates all of space and interacts with fundamental particles. The quantum excitation of this field, known as Higgs field, manifests itself as the Higgs boson, the only fundamental particle with no spin. In 2012, a particle with properties consistent with the Higgs boson of the Standard Model was observed by the ATLAS and CMS experiments at the Large Hadron Collider at CERN. Since then, more than 30 times as many Higgs bosons have been recorded by the ATLAS experiment, allowing much more precise measurements and new tests of the theory. Here, on the basis of this larger dataset, we combine an unprecedented number of production and decay processes of the Higgs boson to scrutinize its interactions with elementary particles. Interactions with gluons, photons, and W and Z bosons -- the carriers of the strong, electromagnetic, and weak forces -- are studied in detail. Interactions with three third-generation matter particles (bottom (b) and top (t) quarks, and tau leptons (τ)) are well measured and indications of interactions with a second-generation particle (muons, μ) are emerging. These tests reveal that the Higgs boson discovered ten years ago is remarkably consistent with the predictions of the theory and provide stringent constraints on many models of new phenomena beyond the Standard Model.

Comments:	26 pages in total, author list starting page 1, 8 figures, 1 table, submitted to Nature. All figures including auxiliary figures are available at this http URL
Subjects:	High Energy Physics - Experiment (hep-ex)
Report number:	CERN-EP-2022-057
Cite as:	arXiv:2207.00092 [hep-ex]
	(or arXiv:2207.00092v1 [hep-ex] for this version)
	https://doi.org/10.48550/arXiv.2207.00092
Journal reference:	Nature 607, pages 52-59 (2022)
Related DOI:	https://doi.org/10.1038/s41586-022-04893-w

Submission history

From: The ATLAS Collaboration [view email]

[v1] Thu, 30 Jun 2022 20:21:37 UTC (364 KB)

Access Paper:

- Download PDF
- PostScript
- Other Formats

Current browse context:
hep-ex
< prev | next >
new | recent | 2207

References & Citations

- INSPIRE HEP
- NASA ADS
- Google Scholar
- Semantic Scholar

Export BibTeX Citation

Bookmark

Analysis scrutiny

https://arxiv.org/abs/2207.00092

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

ATLAS EXPERIMENT

CERN

Submitted to: Nature

CERN-EP-2022-057
4th July 2022

A detailed map of Higgs boson interactions by the ATLAS experiment ten years after the discovery

The ATLAS Collaboration

The Standard Model of particle physics [1–4] describes the known fundamental particles and forces that make up our universe, with the exception of gravity. One of the central features of the Standard Model is a field that permeates all of space and interacts with fundamental particles [5–9]. The quantum excitation of this field, known as Higgs field, manifests itself as the Higgs boson, the only fundamental particle with no spin. In 2012, a particle with properties consistent with the Higgs boson of the Standard Model was observed by the ATLAS and CMS experiments at the Large Hadron Collider at CERN [10, 11]. Since then, more than 30 times as many Higgs bosons have been recorded by the ATLAS experiment, allowing much more precise measurements and new tests of the theory. Here, on the basis of this larger dataset, we combine an unprecedented number of production and decay processes of the Higgs boson to scrutinize its interactions with elementary particles. Interactions with gluons, photons, and W and Z bosons – the carriers of the strong, electromagnetic, and weak forces – are studied in detail. Interactions with three third-generation matter particles (bottom (b) and top (t) quarks, and tau leptons (τ)) are well measured and indications of interactions with a second-generation particle (muons, μ) are emerging. These tests reveal that the Higgs boson discovered ten years ago is remarkably consistent with the predictions of the theory and provide stringent constraints on many models of new phenomena beyond the Standard Model.

Author contributions

All authors have contributed to the publication, being variously involved in the design and the construction of the detectors, in writing software, calibrating subsystems, operating the detectors and acquiring data, and finally analysing the processed data. The ATLAS Collaboration members discussed and approved the scientific results. The manuscript was prepared by a subgroup of authors appointed by the collaboration and subject to an internal collaboration-wide review process. All authors reviewed and approved the final version of the manuscript.

Competing financial interests

The authors declare no competing financial interests.

Data availability

The experimental data that support the findings of this study are available in HEPData with the identifier https://doi.org/10.17182/hepdata.130266.

Code availability

The ATLAS data reduction software is available at the following link: https://zenodo.org/record/4772550. Statistical modeling and analysis is based on the ROOT software and its embedded RooFit and RooStats modules, available at the following link: https://zenodo.org/record/4772550. Code to configure these statistical tools and to process their output is available upon request.

Analysis scrutiny

https://arxiv.org/abs/2006.09274

Cornell University

We grateful
Foundation,

arXiv > hep-ex > arXiv:2006.09274

Search...

Help | Advanced

High Energy Physics - Experiment

[Submitted on 16 Jun 2020 (v1), last revised 8 Mar 2021 (this version, v2)]

Measurements of top-quark pair single- and double-differential cross-sections in the all-hadronic channel in pp collisions at $\sqrt{s} = 13$ TeV using the ATLAS detector

ATLAS Collaboration

Differential cross-sections are measured for top-quark pair production in the all-hadronic decay mode, using proton−proton collision events collected by the ATLAS experiment in which all six decay jets are separately resolved. Absolute and normalised single- and double-differential cross-sections are measured at particle and parton level as a function of various kinematic variables. Emphasis is placed on well-measured observables in fully reconstructed final states, as well as on the study of correlations between the top-quark pair system and additional jet radiation identified in the event. The study is performed using data from proton−proton collisions at $\sqrt{s} = 13$ TeV collected by the ATLAS detector at CERN's Large Hadron Collider in 2015 and 2016, corresponding to an integrated luminosity of $36.1\ \mathrm{fb}^{-1}$. The rapidities of the individual top quarks and of the top-quark pair are well modelled by several independent event generators. Significant mismodelling is observed in the transverse momenta of the leading three jet emissions, while the leading top-quark transverse momentum and top-quark pair transverse momentum are both found to be incompatible with several theoretical predictions.

Comments:	79 pages in total, author list starting page 63, 24 figures, 18 tables, submitted to the Journal of High Energy Physics. All figures including auxiliary figures are available at this http URL
Subjects:	**High Energy Physics - Experiment (hep-ex)**
Report number:	CERN-EP-2020-063
Cite as:	arXiv:2006.09274 **[hep-ex]**
	(or arXiv:2006.09274v2 **[hep-ex]** for this version)
	https://doi.org/10.48550/arXiv.2006.09274
Journal reference:	JHEP 01 (2021) 033
Related DOI:	https://doi.org/10.1007/JHEP01%282021%29033

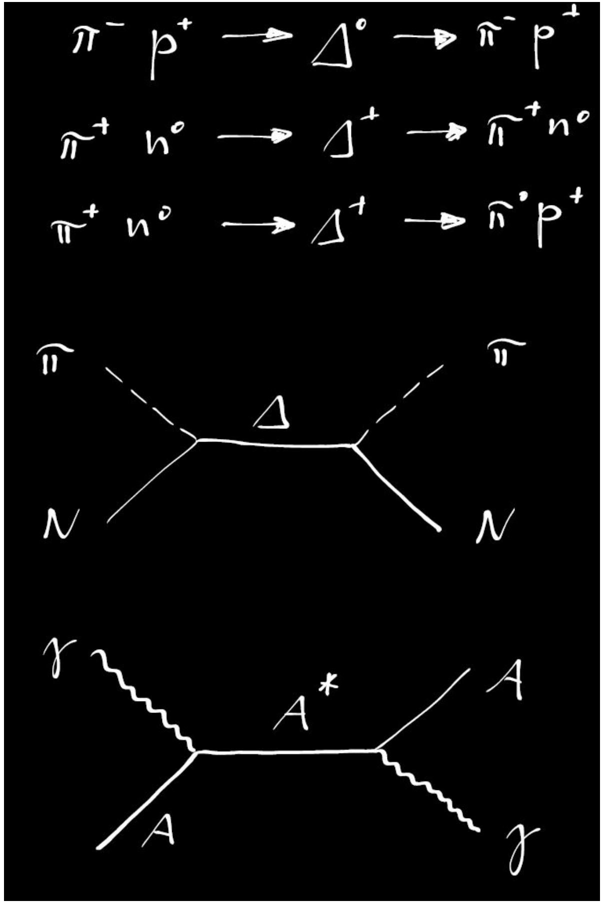
Submission history

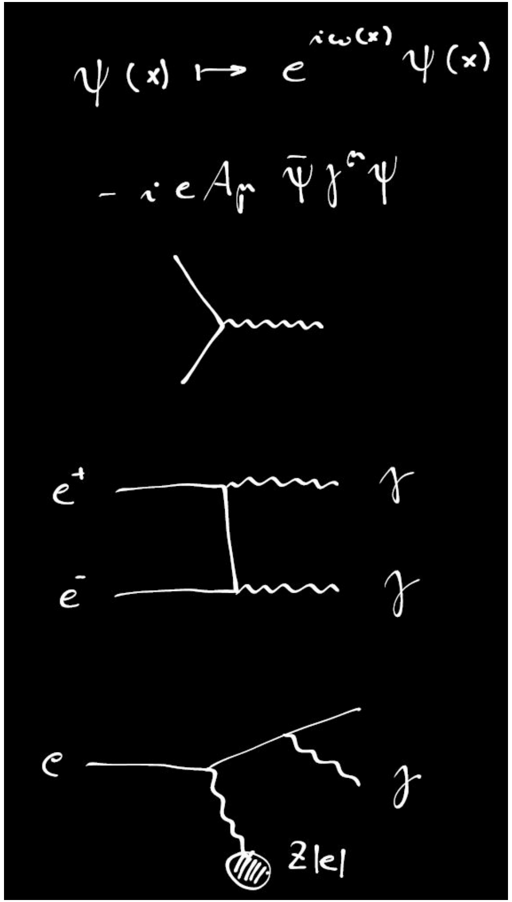
From: The ATLAS Collaboration [view email]

[v1] Tue, 16 Jun 2020 16:08:37 UTC (794 KB)

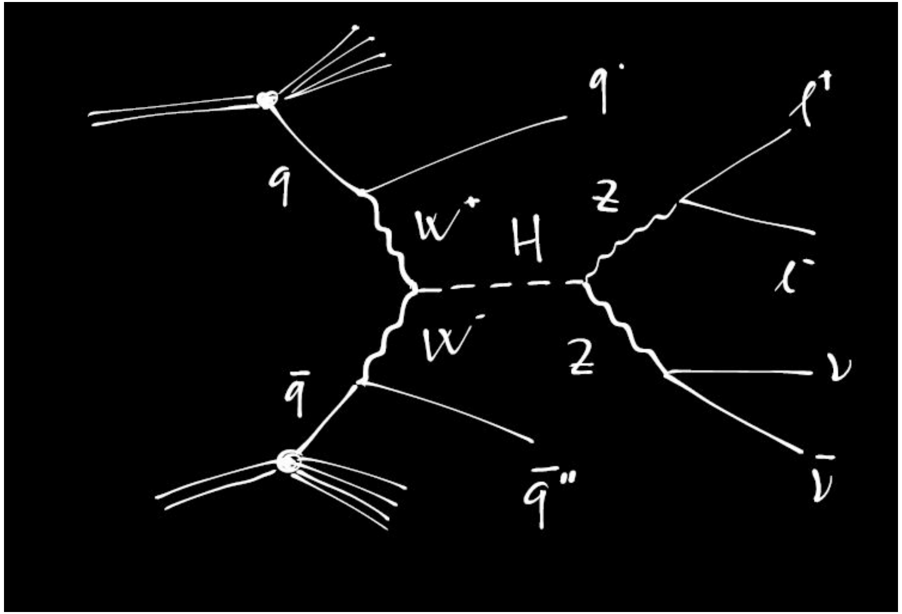
[v2] Mon, 8 Mar 2021 14:40:42 UTC (1,049 KB)

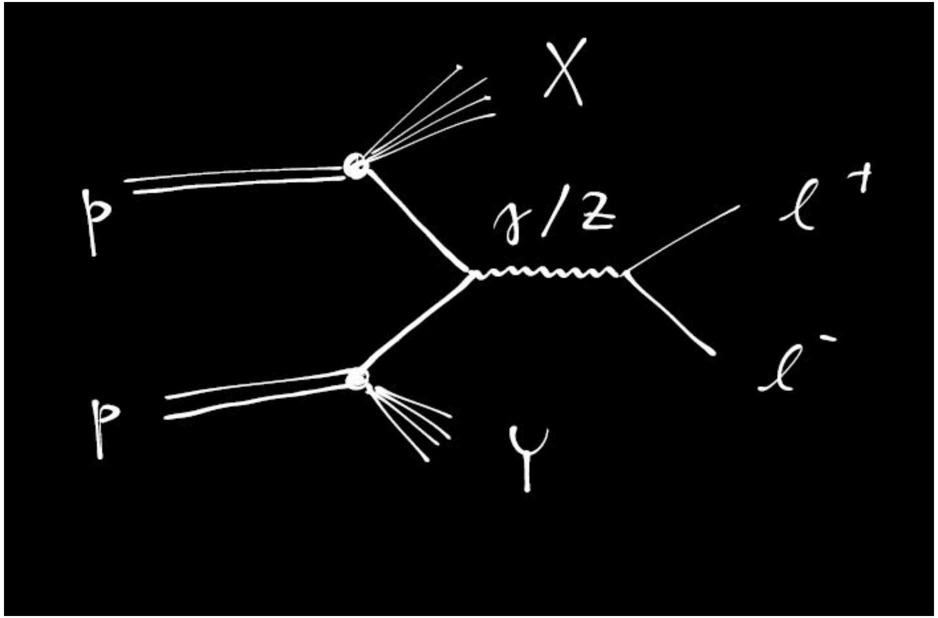
Interactions and Feynman Diagrams





pp Collisions: QCD, Electroweak interactions



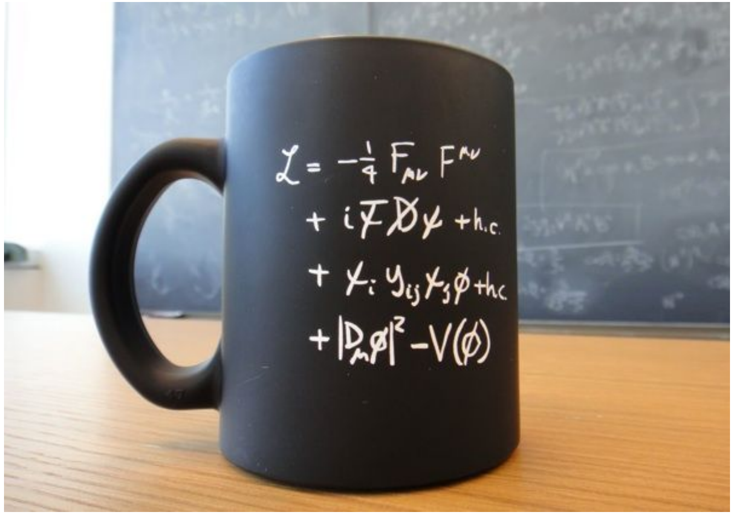


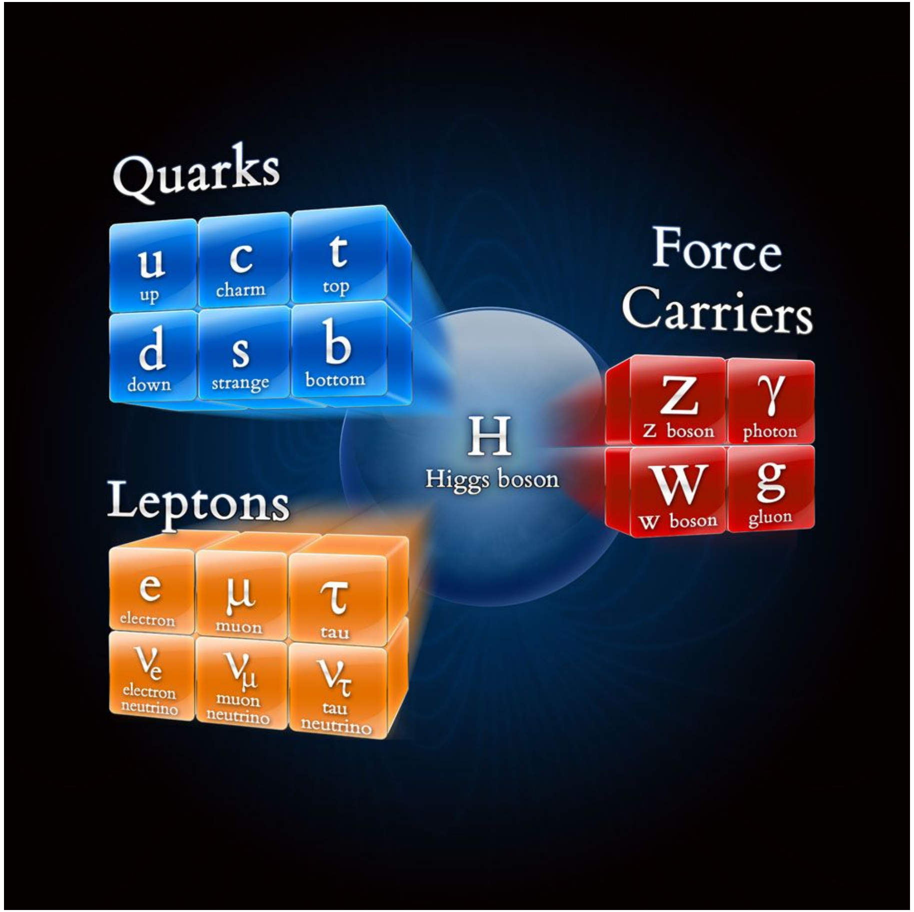
A typical analysis

- Physics process of interest
- Dataset choice: LHC energy, pile-up settings
- Detector level objects and their calibration and identification operation points
- Events selection
  - cut-based
  - multivariate techniques – BDTs, NNs, DNNs.. (also used in object IDs)
- Signal and backgrounds samples
- Data-MC comparison in control and signal regions
  - possibly adjusting bg. modelling in sidemands, blinding the signal region
- Counting experiment, cross-section extraction, differential cross-sections, correcting for resolution, searches for BSM processes and limits settings
  - precision physics vs. searches
- Presenting measurement at a particle level at some fiducial phase-space, publish and store results in HEP data database for the future comparison to models to come

Quarks, Leptons, Gauge Bosons and the BEH boson

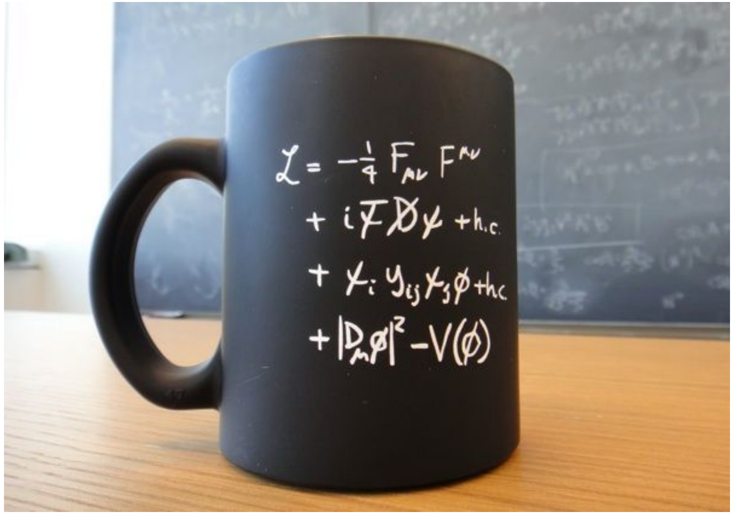
-

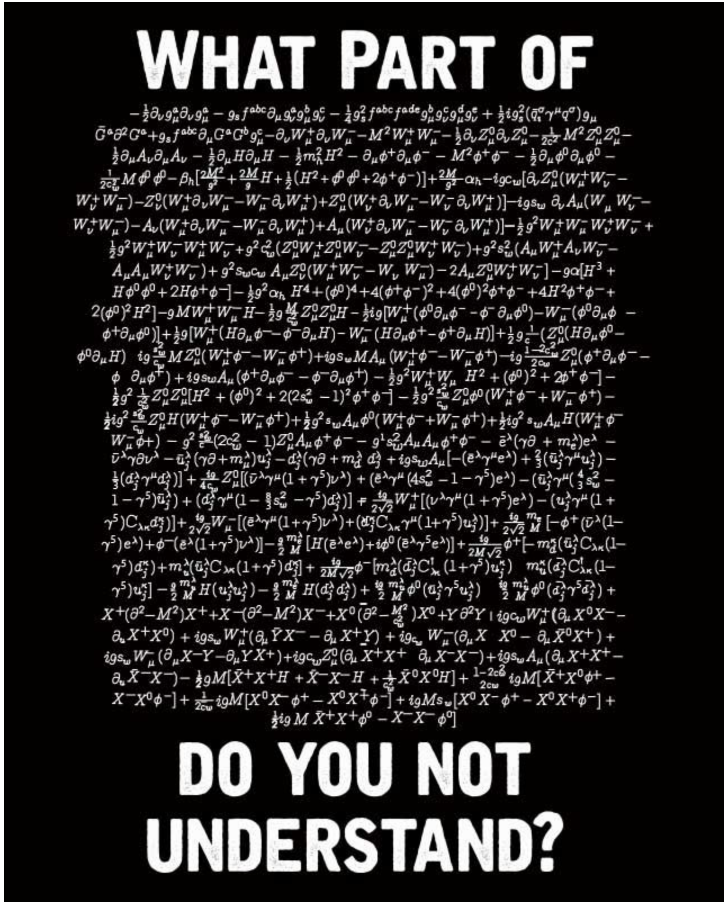




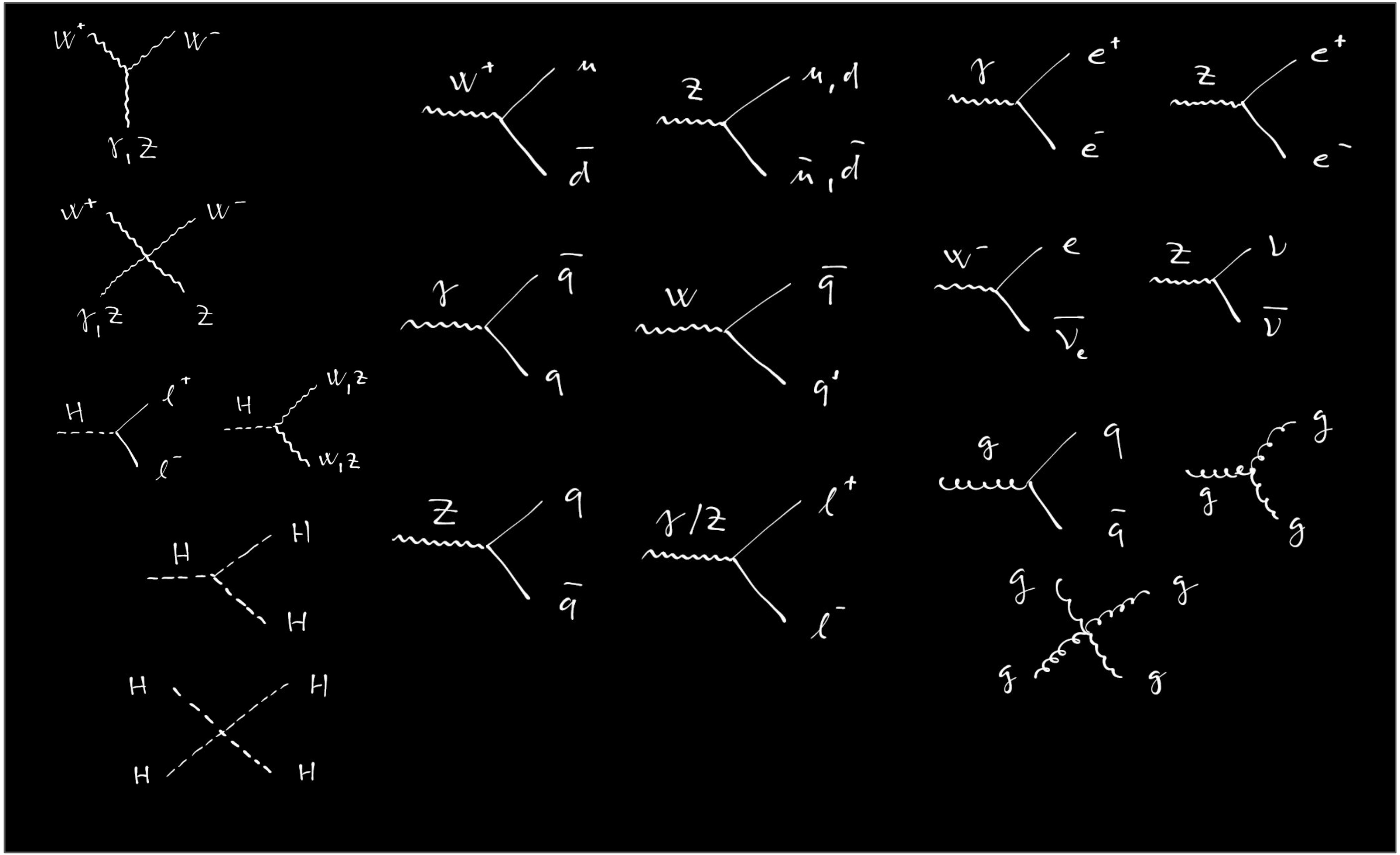
Quarks, Leptons, Gauge Bosons and the BEH boson

-



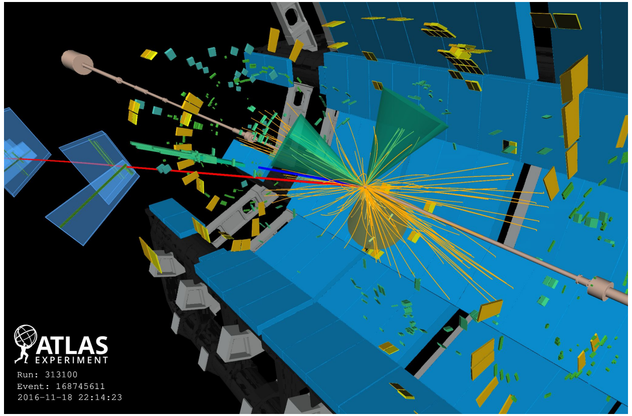


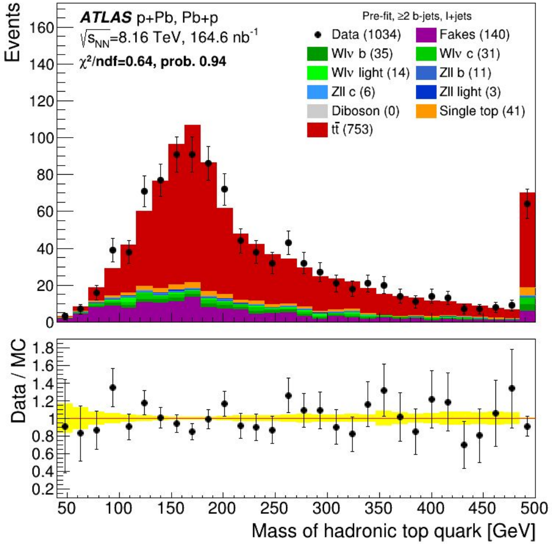
Quarks, Leptons, Gauge Bosons and the BEH boson



A typical analysis

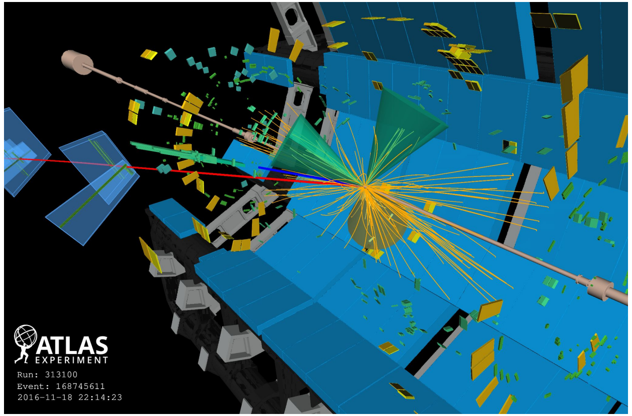
- Událost v detektoru obsahuje informace z jednotlivých poddetektorů
- Jsou zrekonstuovány a identifikovány fyzikální objekty
    - kandidáti na elektrony, miony, jety, gamma, tau, chybějící příčná energie…
- V rámci event selection jsou vybírány objekty na základě jejich požadovaného počtu a vlastností
    - podle očekávání toho, co by měl do detektoru přinášet signální proces
- Změřené spektrum musí být opraveno
    - kalibrace, linearita, rozlišení, efficiency (as function of…), data/simulation agreement

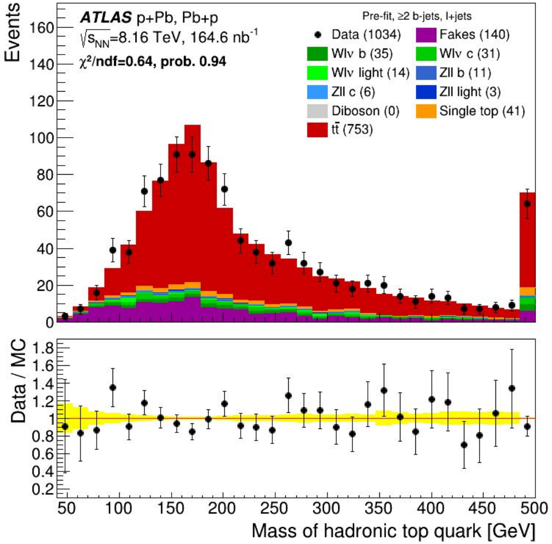




A typical analysis

- Potřebuje
  - preselecteted data sample
  - data quality, luminosity measurement
  - objects calibrations, reconstruction algos
  - simulation samples
    - to optimize the analysis
    - estimate signal
    - estimate, understand and model backgrounds





Invariantní hmota

$$E = mc^2$$

$$E = \sqrt{p^2c^2 + m^2c^4}$$

$$E^2 = p^2c^2 + m^2c^4$$

$$m^2 = E^2 - p^2 \qquad \text{v jednotkách } c = 1$$

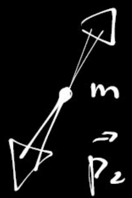
$$m^2 = \left(\sum_i E_i\right)^2 - \left(\sum \vec{p}_i\right)^2$$

$$E_i^2 = p_{ix}^2 + p_{iy}^2 + p_{iz}^2$$

$$E = \gamma m c^2$$

$$\gamma \equiv \frac{1}{\sqrt{1-\beta^2}} \qquad \beta \equiv \frac{v}{c}$$

$$E = \sqrt{p^2c^2 + m^2c^4}$$



$$E = E_1 + E_2$$

$$\vec{p} = \vec{p}_1 + \vec{p}_2$$

$$\vec{p}^{\,2} \equiv \vec{p}\cdot\vec{p} = \vec{p}_1^{\,2} + 2\vec{p}_1\cdot\vec{p}_2 + \vec{p}_2^{\,2}$$

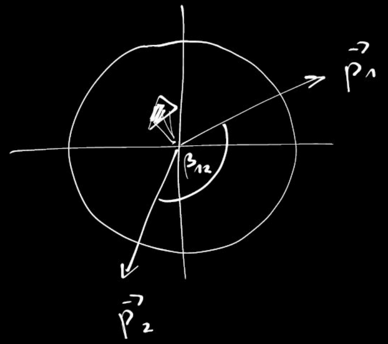
$$m_1 \simeq m_2 \simeq 0 \Rightarrow$$

$$\doteq E_1^2 + 2\vec{p}_1\cdot\vec{p}_2 + E_2^2$$

$$= E_1^2 + E_2^2 + 2E_1E_2\cos\beta_{12}$$

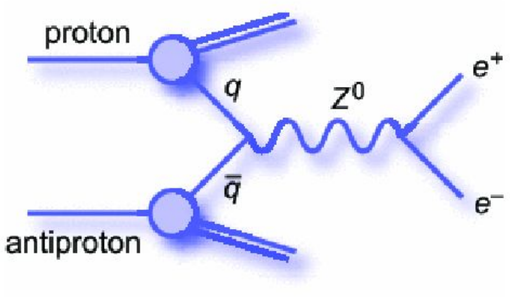
$$m^2 = (E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2$$

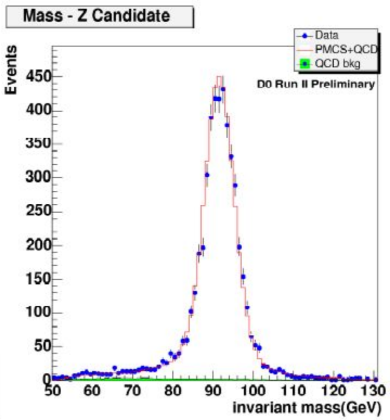
$$= \cancel{E_1^2} + 2E_1E_2 + \cancel{E_2^2} - \cancel{E_1^2} - \cancel{E_2^2} - 2E_1E_2\cos\beta_{12}$$

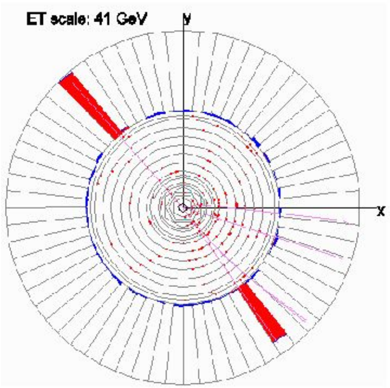


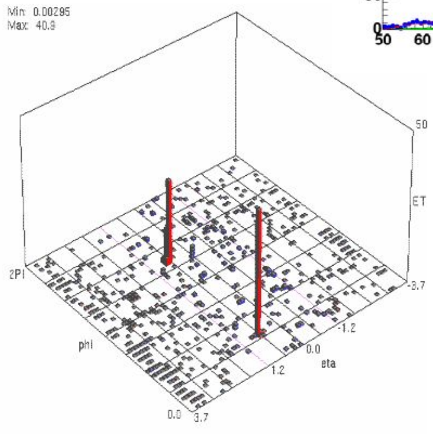
$$m^2 \simeq 2E_1E_2(1 - \cos\beta_{12})$$

Invariantní hmota

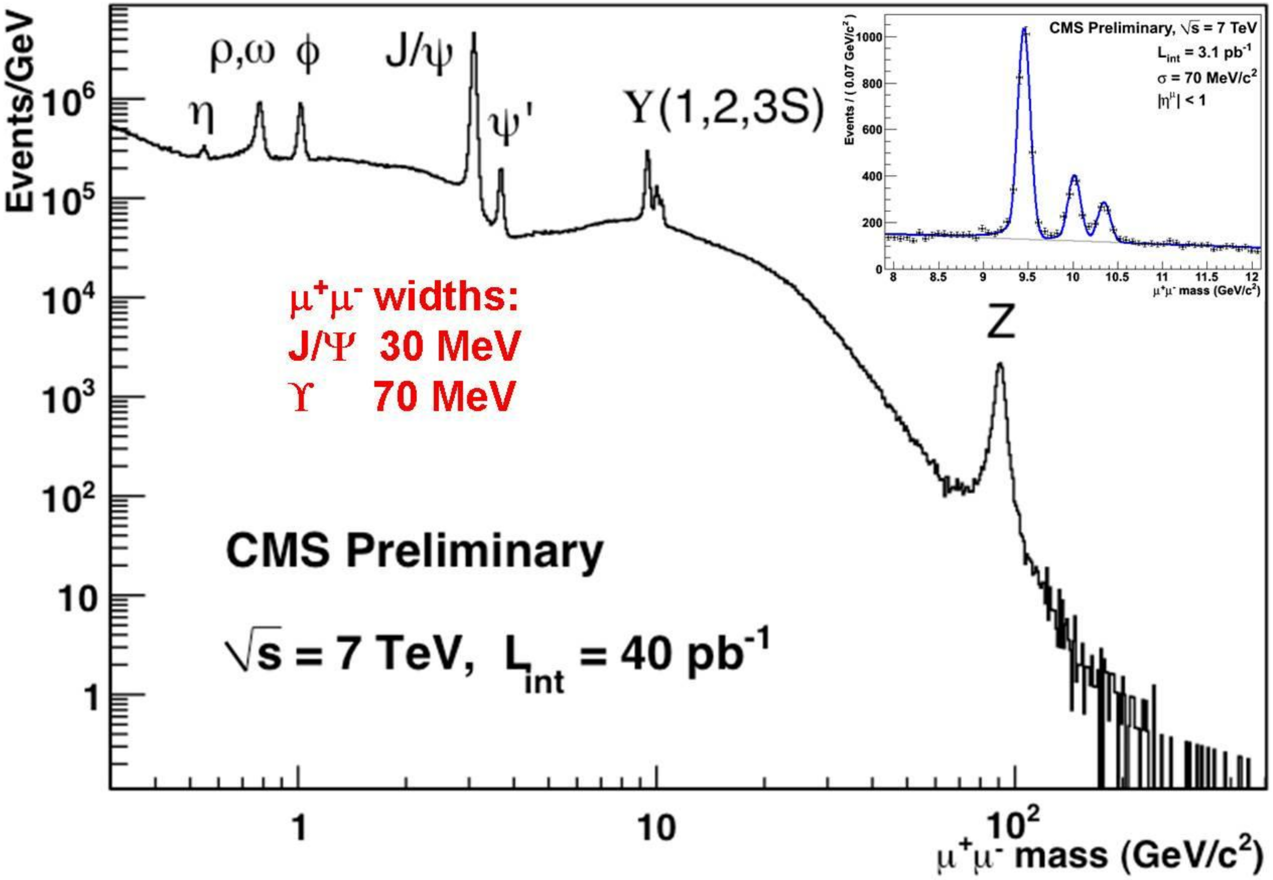








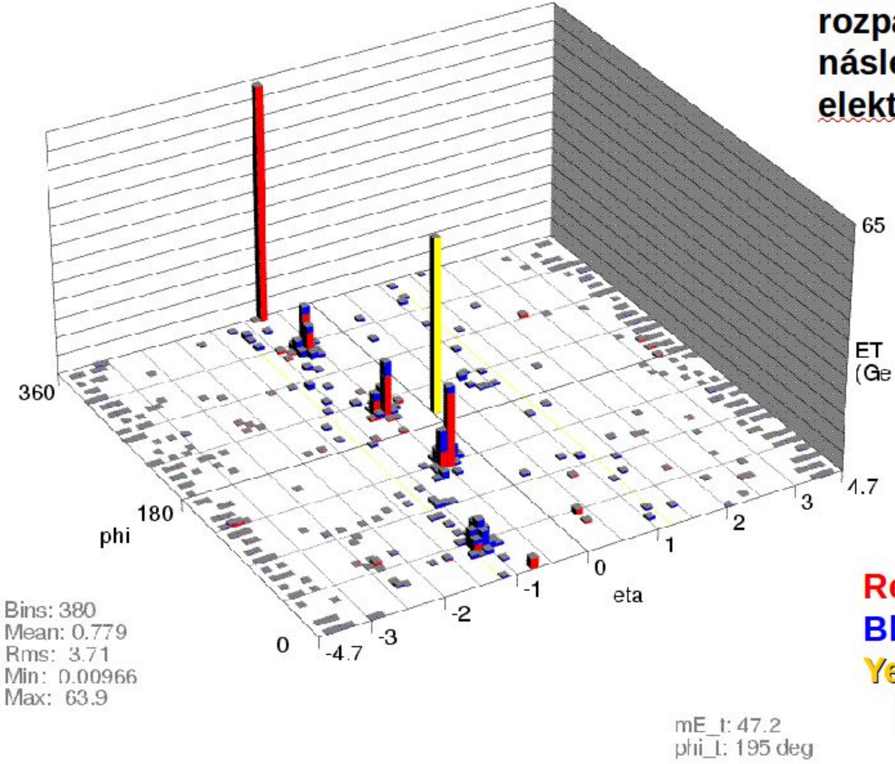
Invariantní hmota

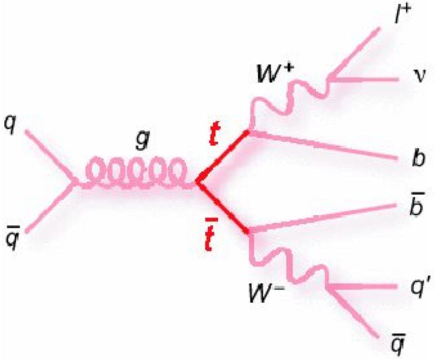


Invariantní hmota

Pár top-anti top rozpadající se na *WbWb* a následně na 4 jety, elektron a neutrino.

DZero experiment at Fermilab’s Tevatron, a proton-antiproton collider.

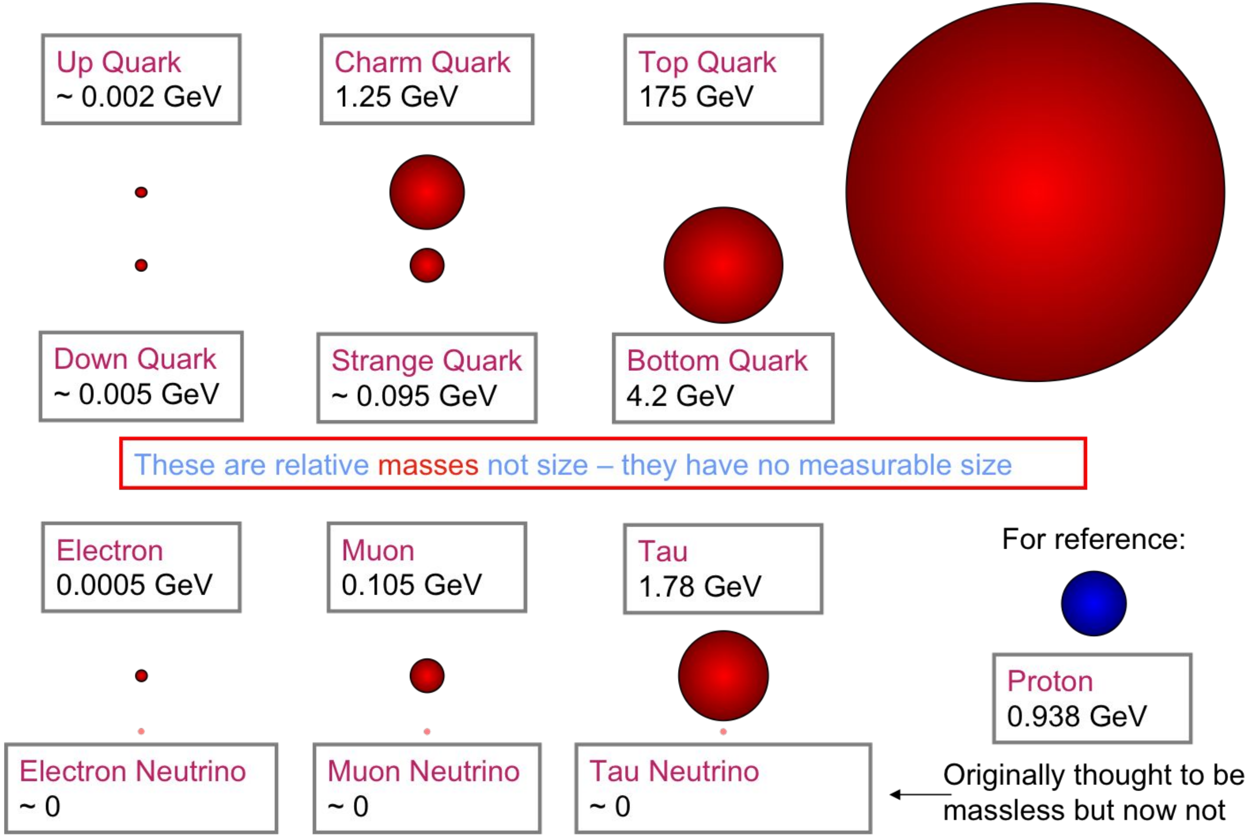




Red: EM Calorimeter
Blue: Hadronic Calorimeter
Yellow: Missing Energy (neutrino signature)

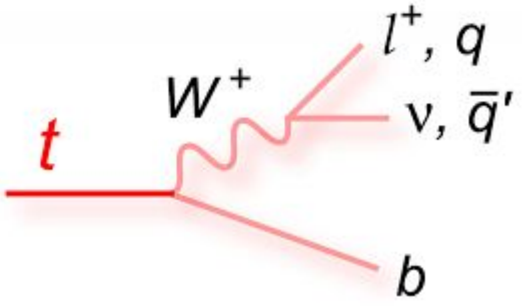
Quarks, Leptons, Gauge Bosons and the BEH boson

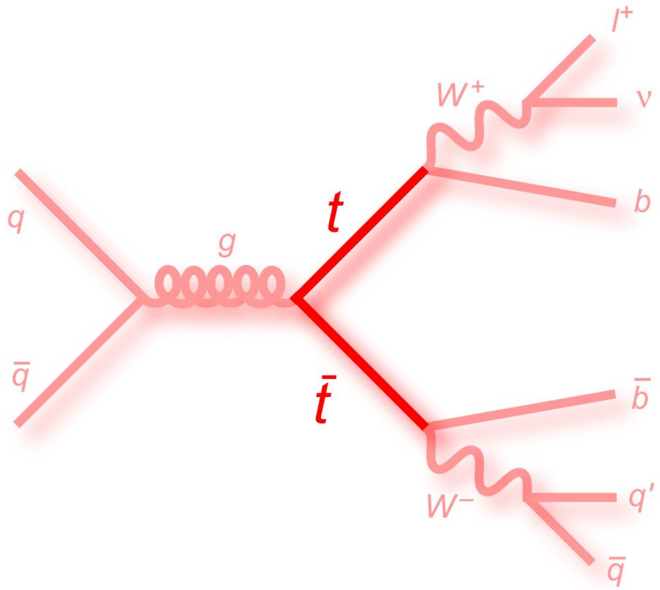
-

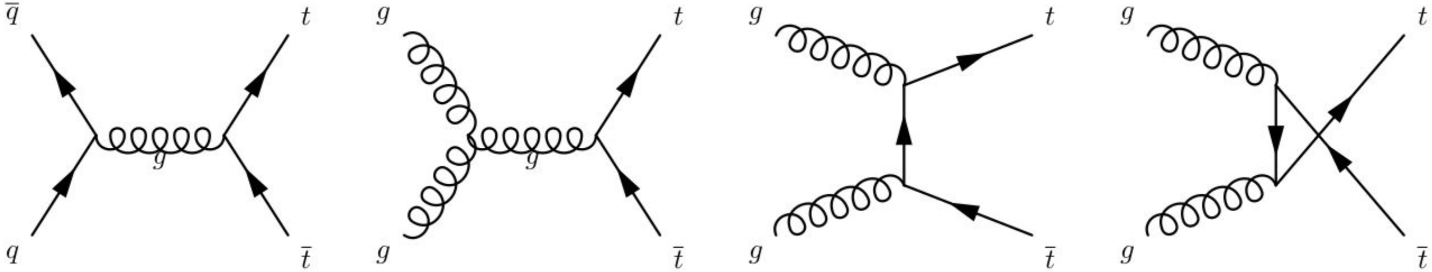


Top quark

-

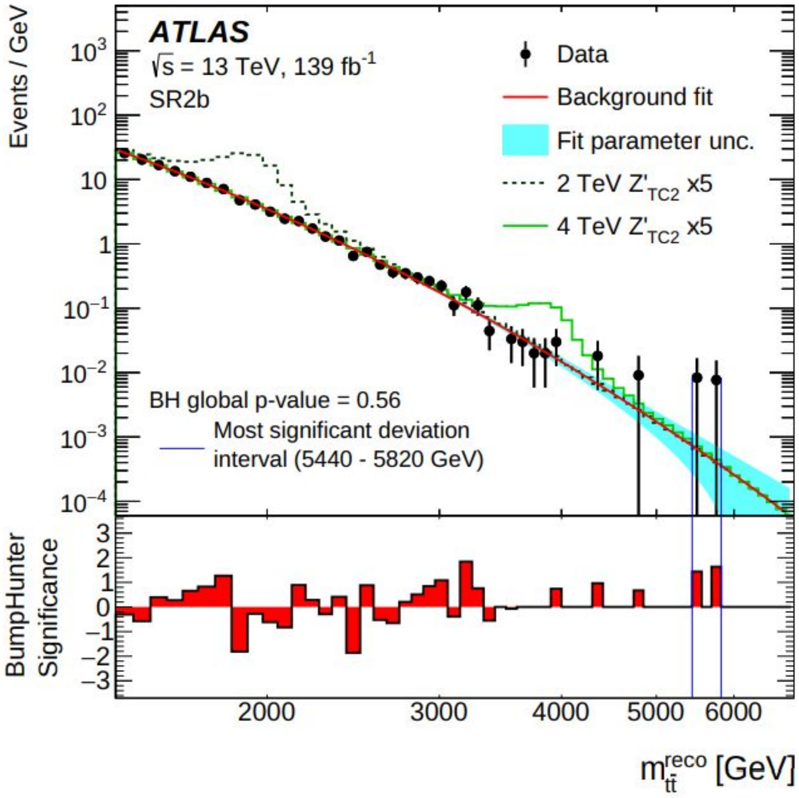


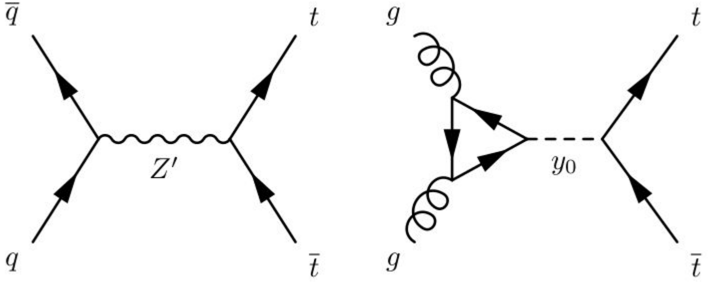


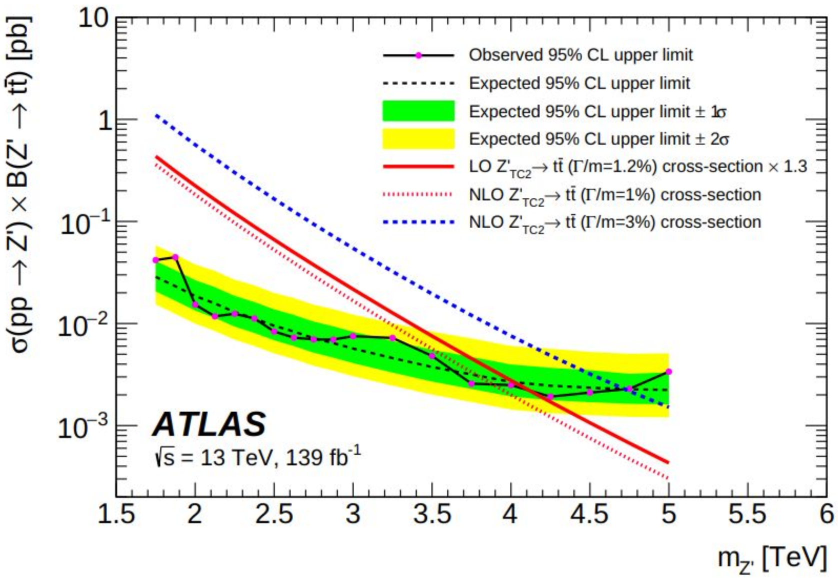


Top quark

- ttbar resonances

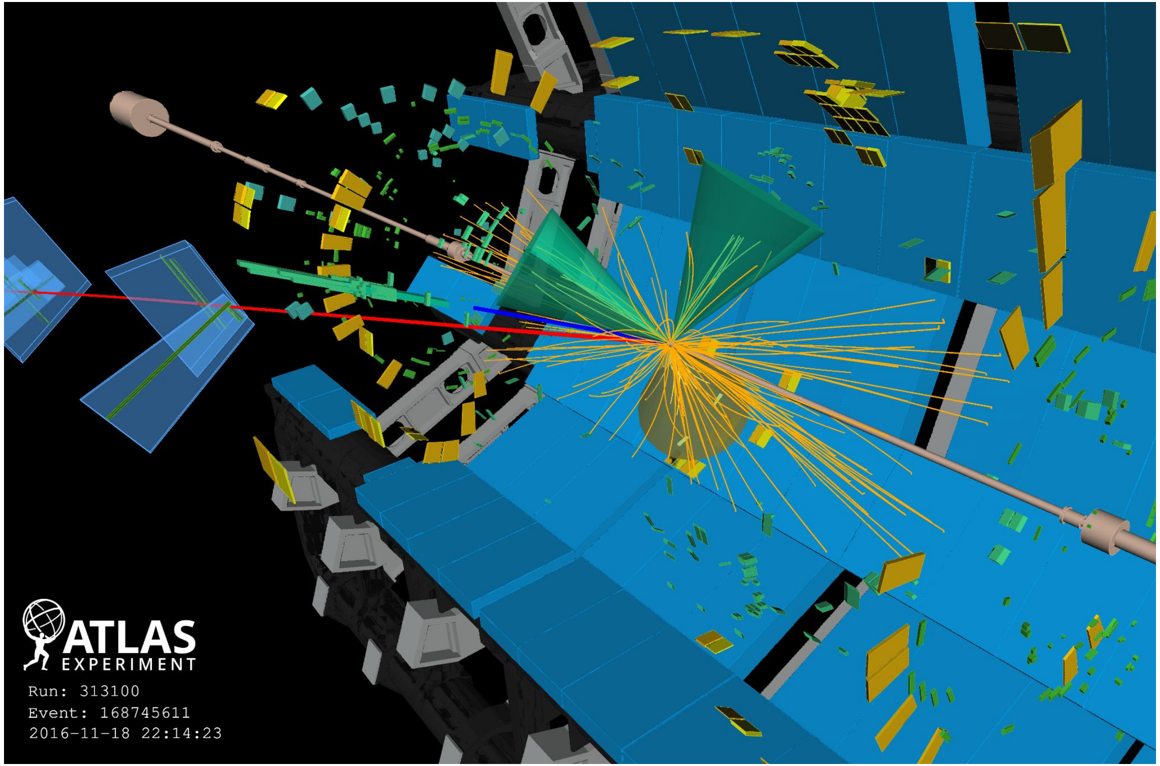


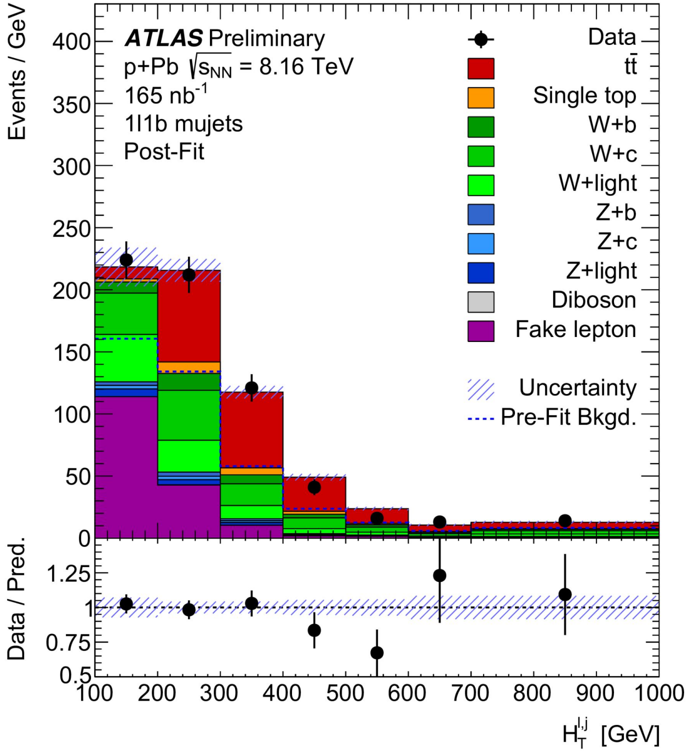




A typical analysis

- https://atlas.cern/Updates/Briefing/HI-Top-Observation





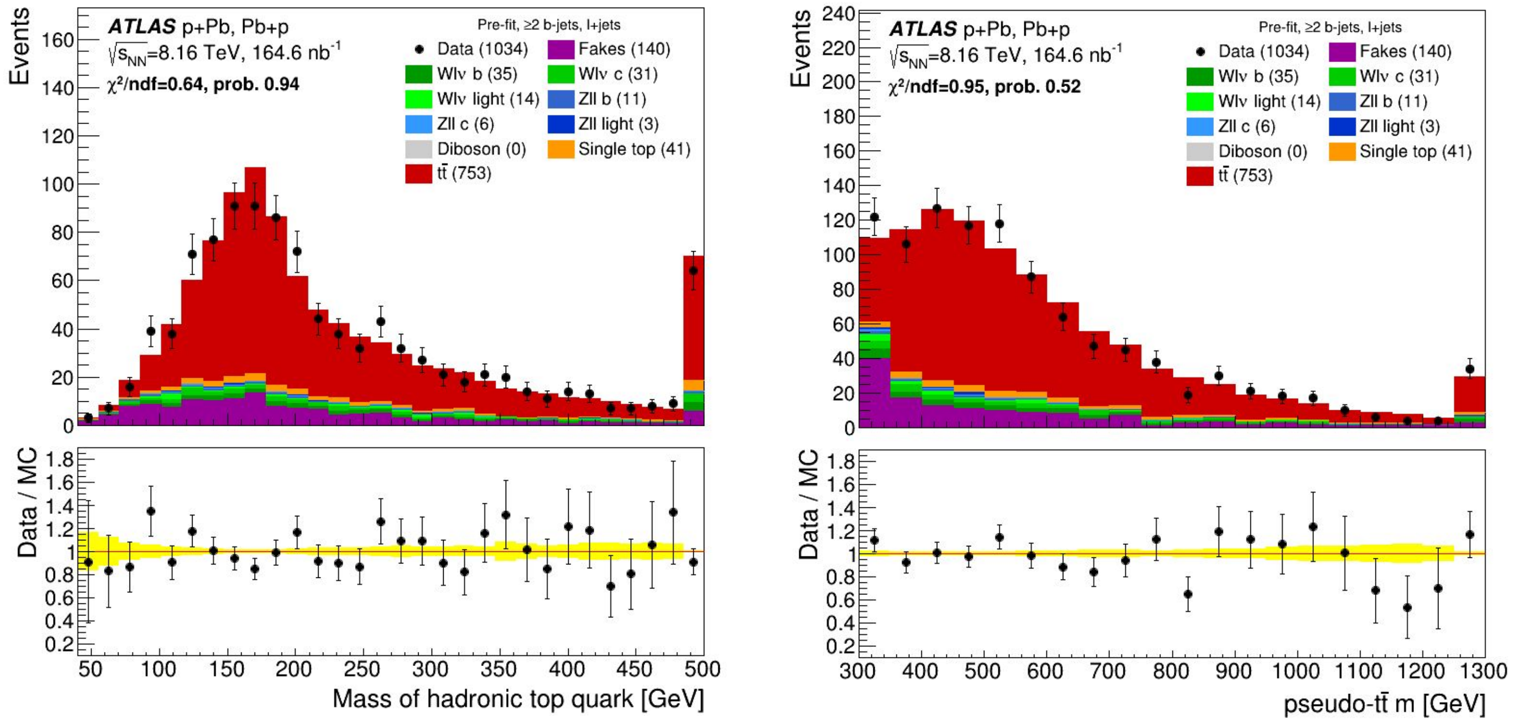
A typical analysis

- https://atlas.cern/Updates/Briefing/HI-Top-Observation

```
    cout << "*** Number of events in nominal and Alternative trees: " <<  nentriesNominal << ", " <<  nentriesNominalAlt << endl;

    // number of bytes read from TTrees
    Long64_t nbytes = 0;
    Long64_t nb_nominal = 0;
    Long64_t nb_nominalAlt = 0;
    Long64_t nb_ptcl = 0;
    Long64_t nb_truth = 0;
    m_ToRunOver = nentriesNominal;
    if (m_isMCsignal && m_runOverAllLevels) {
        // we need to go through all generated parton events
        // and find matching events in the detector nominal and particle trees
        m_ToRunOver = nentriesTruth;
    }
    if (m_isMCsignal && m_runOverPtclOnly) {
        m_ToRunOver = nentriesParticle;
    }
    // HACK!
    m_ToRunOver = 200000;

    this -> InitLoop();

    // +-----------+
    // |   LOOP!   |
    // +-----------+

    if (m_isData) {
        cout << "Will run over " << m_ToRunOver << " entries." << endl;
    } else {
        cout << "Will run over " << m_ToRunOver << " entries while sumWeights is " << m_sumWeights << endl;
        m_h_sumWeights -> SetBinContent(1, m_sumWeights);
        m_h_sumWeightsSq -> SetBinContent(1, m_sumWeightsSq);
    }



    for (Long64_t jentry = 0; jentry < m_ToRunOver; jentry++) {
        if (jentry % verbose == 0) {
            cout << "Processing " << jentry << "/" << m_ToRunOver << endl;
        }
        nb_nominal = 0;
```

A typical analysis

- https://atlas.cern/Updates/Briefing/HI-Top-Observation
- https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2023-063/

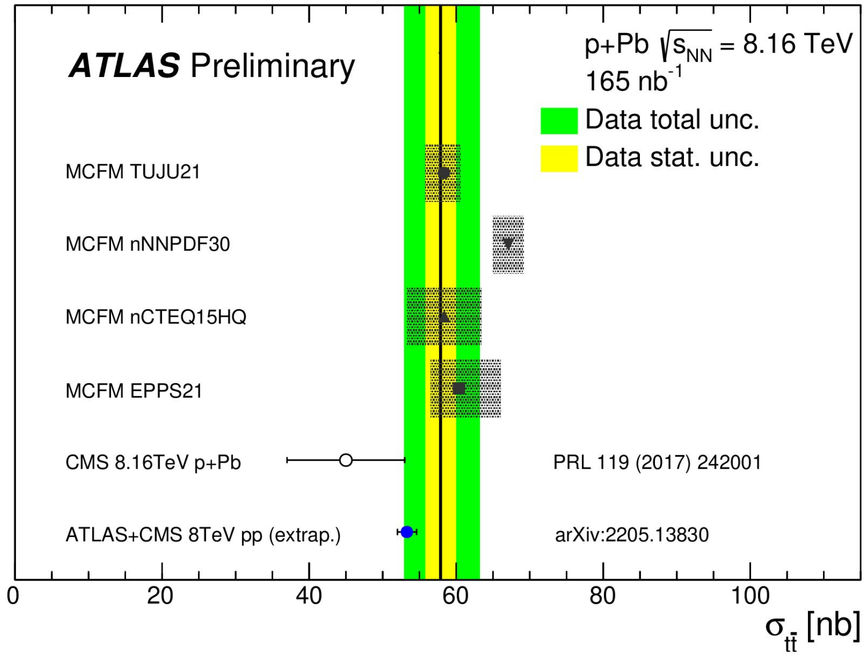


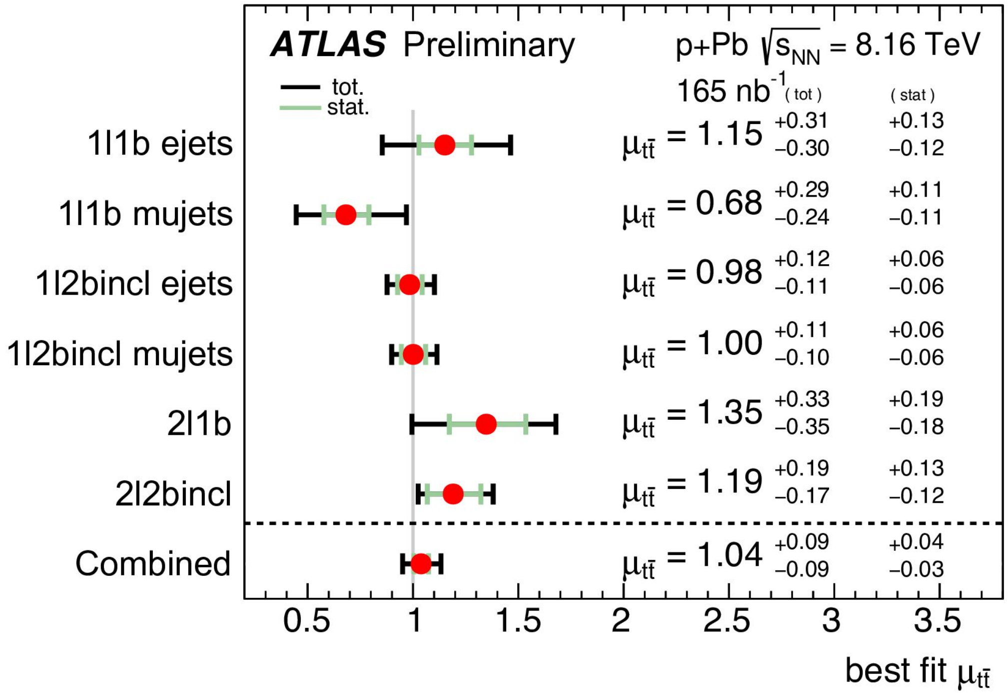
Binning choice and resolution

- TBF

A typical analysis

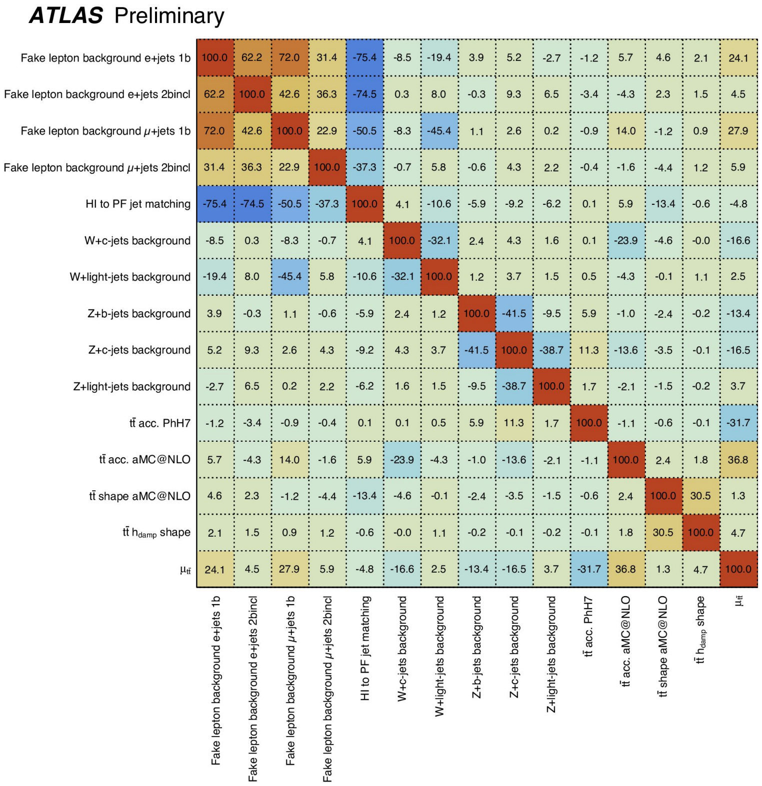
- https://atlas.cern/Updates/Briefing/HI-Top-Observation

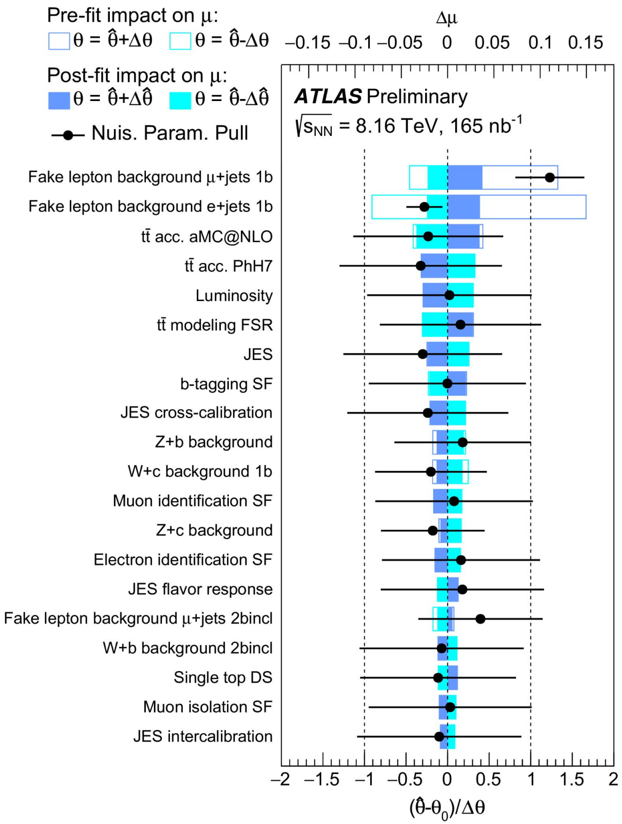




A typical analysis

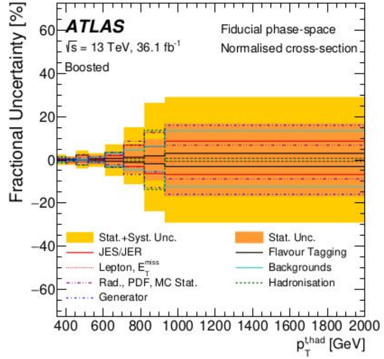
- https://atlas.cern/Updates/Briefing/HI-Top-Observation



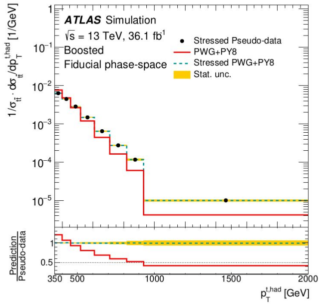


A more involved one – Unfolding

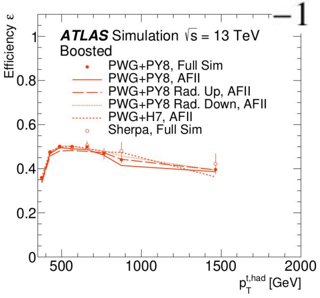
- Differential cross sections measurements
- Unfolding – correcting for detector resolution and efficiency
- Systematics uncertainties evaluation and propagation

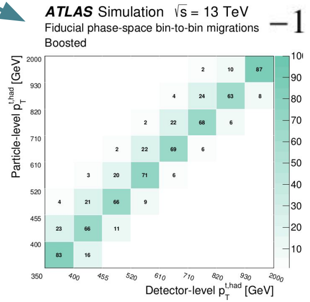


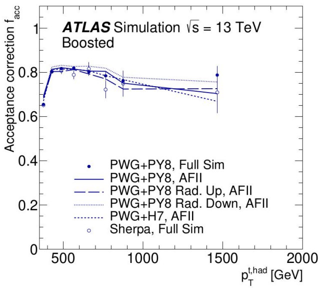
$$N_i^{\text{unf}} \equiv \frac{1}{\mathcal{B}} \cdot \frac{1}{\varepsilon^i} \cdot \sum_j \mathcal{M}_{ij}^{-1} \cdot f_{\text{dilep}}^j \cdot f_{\text{acc}}^j \cdot \left(N_{\text{detector}}^j - N_{\text{bkg}}^j\right)$$

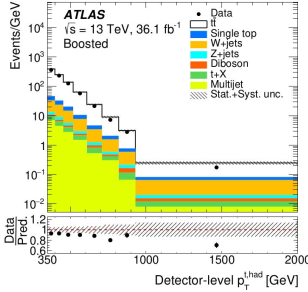


≡



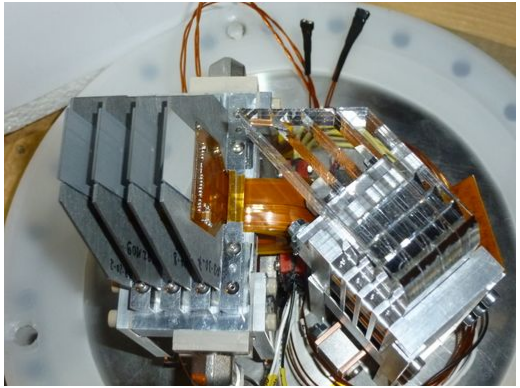


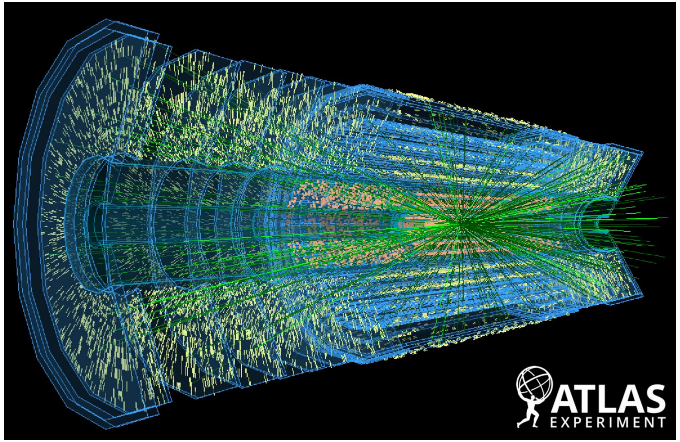


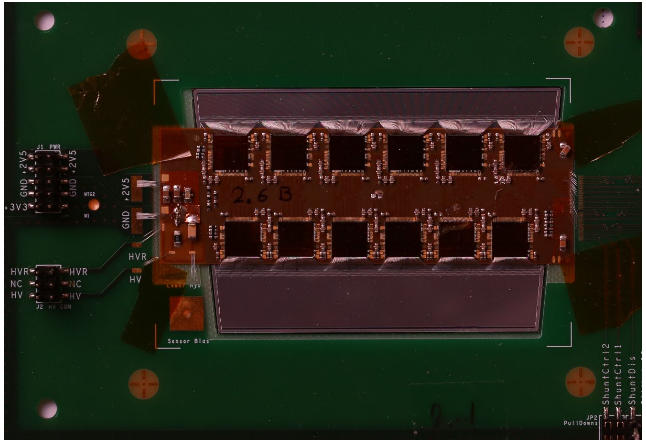


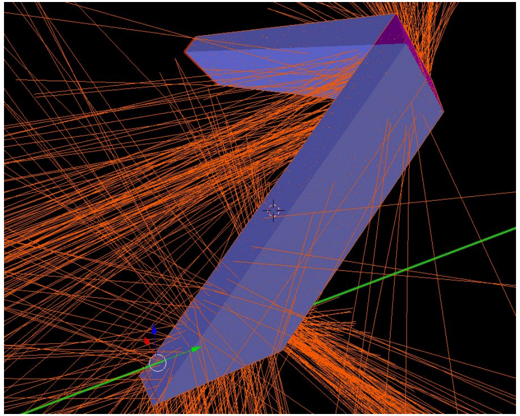
R&D and SLO UP

- ATLAS Forward Proton Detector
  - L. Nožka, K. Černý, T. Komárek, optická a mechanická dílna
  - Cherenkov radiator design, simulation, construction
  - electronics, installation, commissioning, data quality, shifts
  - physics analysis
- ATLAS Inner Tracker Strip detector upgrade
  - R. Přívara
  - silicon detectors simulation
  - beam test data taking and analysis



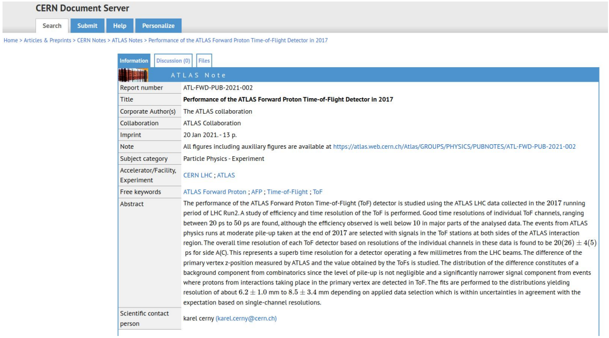






ATLAS and SLO UP

- ATLAS Top quark physics group
  - numerous 1D and 2D differential cross-sections with involvement of a number of students, in various roles including analysis contact editors etc.
  - Last: ttbar in pPb collisions
    - https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2023-063/
    - https://cds.cern.ch/record/2873517
- ATLAS Soft QCD subgroup of the Standard Modle Group
  - K. Černý co-convener
  - Forward physics and diffraction, ATLAS Forward Proton detector performance
  - Ex member: P. Hamal, Exclusive pion production in elastic collisions
    - https://arxiv.org/abs/2212.00664, Eur. Phys. J. C 83 (2023) 627
- ATLAS ITk and Time-of-flight R&D
  - https://cds.cern.ch/record/2749821/


CERN Document Server

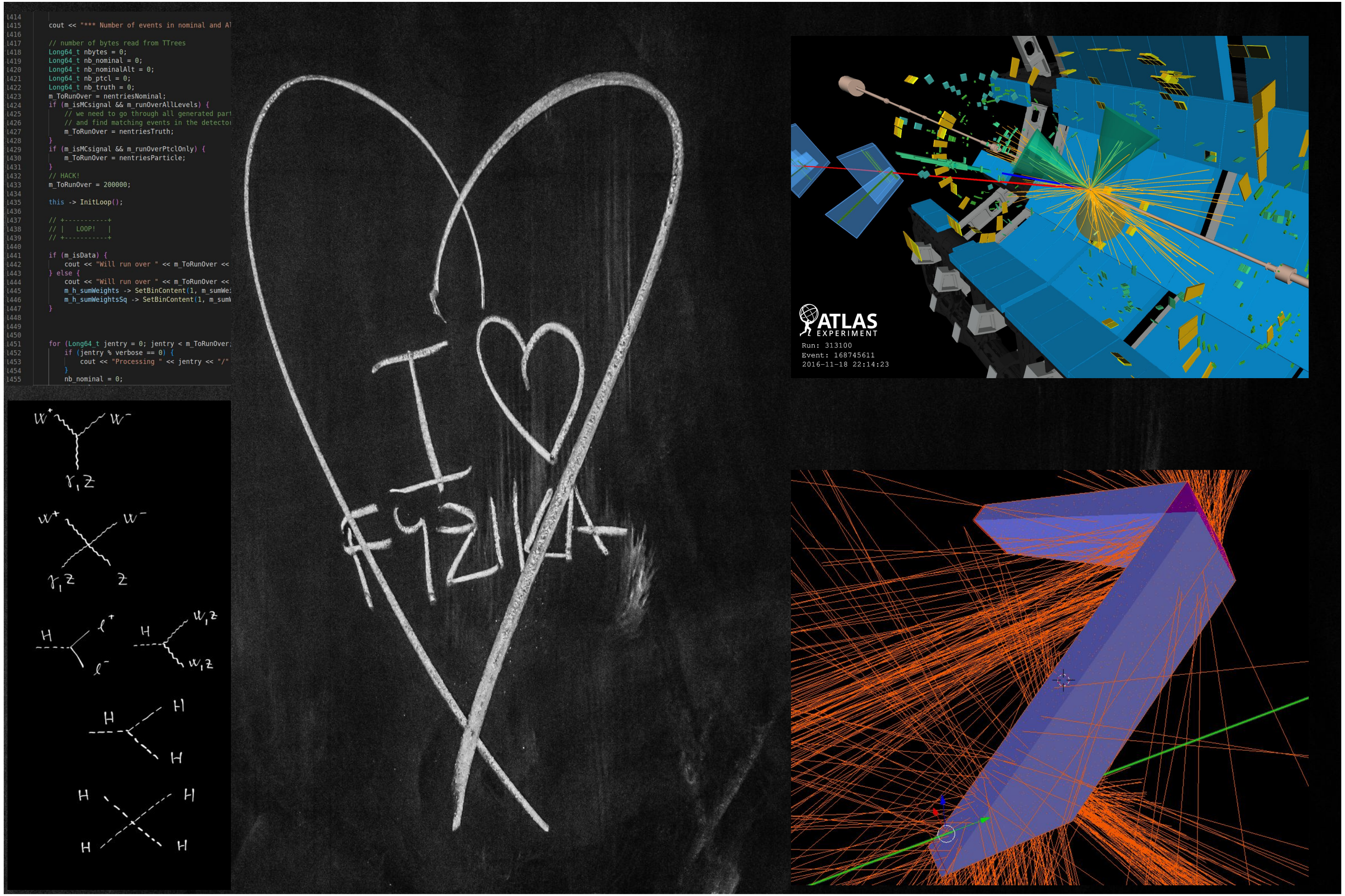
Search | Submit | Help | Personalize

Home > Articles & Preprints > CERN Notes > ATLAS Notes > Performance of the ATLAS Forward Proton Time-of-Flight Detector in 2017

Information | Discussion (0) | Files

ATLAS Note

Report number	ATL-FWD-PUB-2021-002
Title	**Performance of the ATLAS Forward Proton Time-of-Flight Detector in 2017**
Corporate Author(s)	The ATLAS collaboration
Collaboration	ATLAS Collaboration
Imprint	20 Jan 2021. - 13 p.
Note	All figures including auxiliary figures are available at https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-FWD-PUB-2021-002
Subject category	Particle Physics - Experiment
Accelerator/Facility, Experiment	CERN LHC ; ATLAS
Free keywords	ATLAS Forward Proton ; AFP ; Time-of-Flight ; ToF
Abstract	The performance of the ATLAS Forward Proton Time-of-Flight (ToF) detector is studied using the ATLAS LHC data collected in the 2017 running period of LHC Run2. A study of efficiency and time resolution of the ToF is performed. Good time resolutions of individual ToF channels, ranging between 20 ps to 50 ps are found, although the efficiency observed is well below 10 in major parts of the analysed data. The events from ATLAS physics runs at moderate pile-up taken at the end of 2017 are selected with signals in the ToF stations at both sides of the ATLAS interaction region. The overall time resolution of each ToF detector based on resolutions of the individual channels in these data is found to be $20(26) \pm 4(5)$ ps for side A(C). This represents a superb time resolution for a detector operating a few millimetres from the LHC beams. The difference of the primary vertex z-position measured by ATLAS and the value obtained by the ToFs is studied. The distribution of the difference constitutes of a background component from combinatorics since the level of pile-up is not negligible and a significantly narrower signal component from events where protons from interactions taking place in the primary vertex are detected in ToF. The fits are performed to the distributions yielding resolution of about 6.2 ± 1.0 mm to 8.5 ± 3.4 mm depending on applied data selection which is within uncertainties in agreement with the expectation based on single-channel resolutions.
Scientific contact person	karel cerny (karel.cerny@cern.ch)


I ♥ FYZIKA
ATLAS
EXPERIMENT
Run: 313100
Event: 168745611
2016-11-18 22:14:23