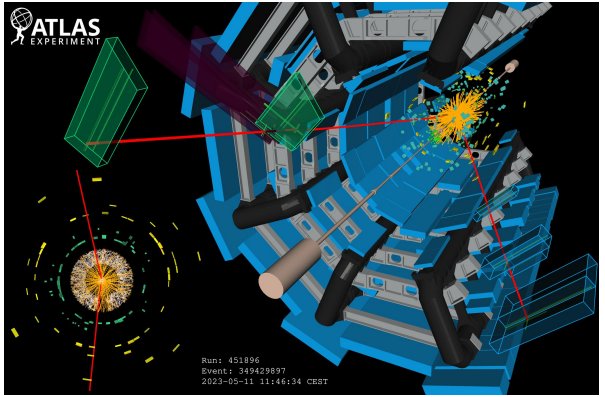
PALACKÝ UNIVERSITY OLOMOUC

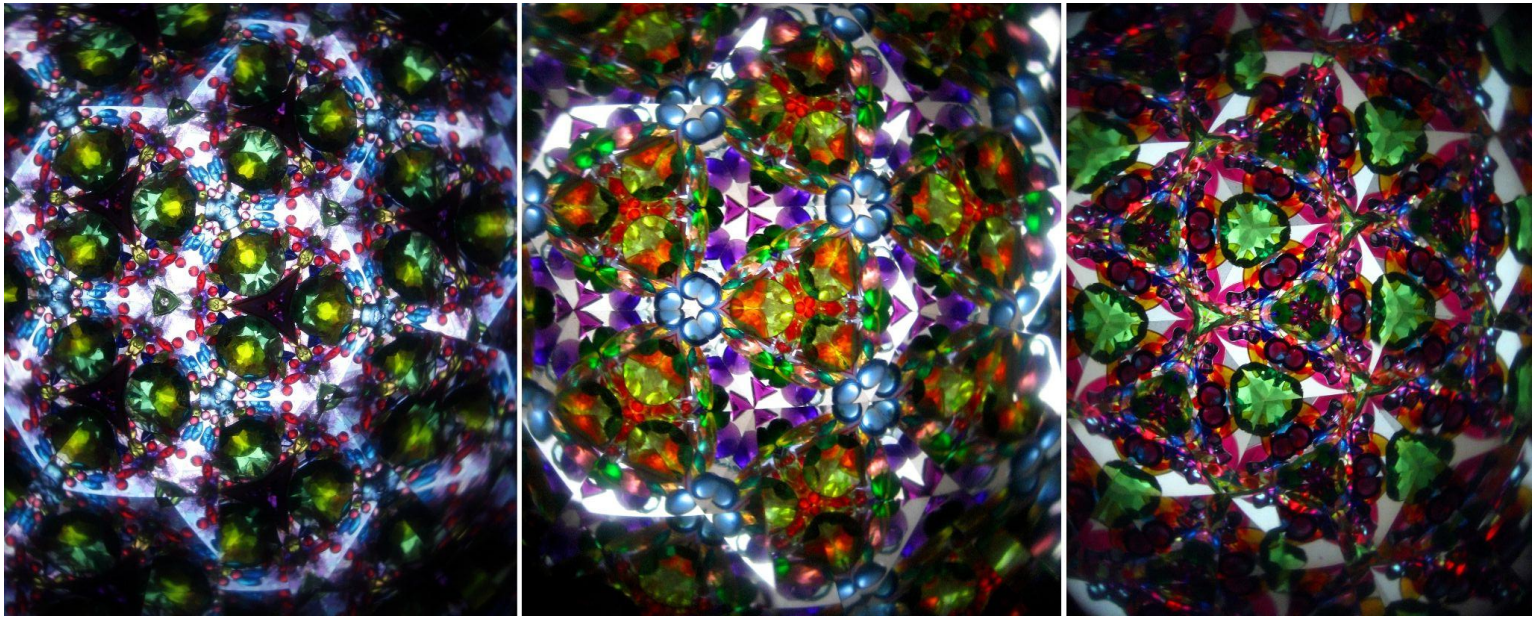


Fyzikální laboratoř CERN

Fyzikální Καλεῖδοσκοπ 2024
Mgr. Jiří Kvita, Ph.D.
Společná laboratoř optiky
UP a FZÚ AV ČR

Etymology [edit]

Coined by its Scottish inventor David Brewster,[1] "kaleidoscope" is derived from the Ancient Greek word καλός (*kalos*), "beautiful, beauty",[2] εἶδος (*eidos*), "that which is seen: form, shape"[3] and σκοπέω (*skopeō*), "to look to, to examine",[4] hence "observation of beautiful forms."[5] It was first published in the patent that was granted on July 10, 1817.[6]



https://upload.wikimedia.org/wikipedia/commons/f/f4/Kaleidoscopes.jpg

Etymology [edit]

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Science for peace

CERN's convention states: "The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available."

CERN

United Nations / Founded

October 24, 1945, San Francisco, California, United States

NASA / Founded

July 29, 1958, United States

CERN

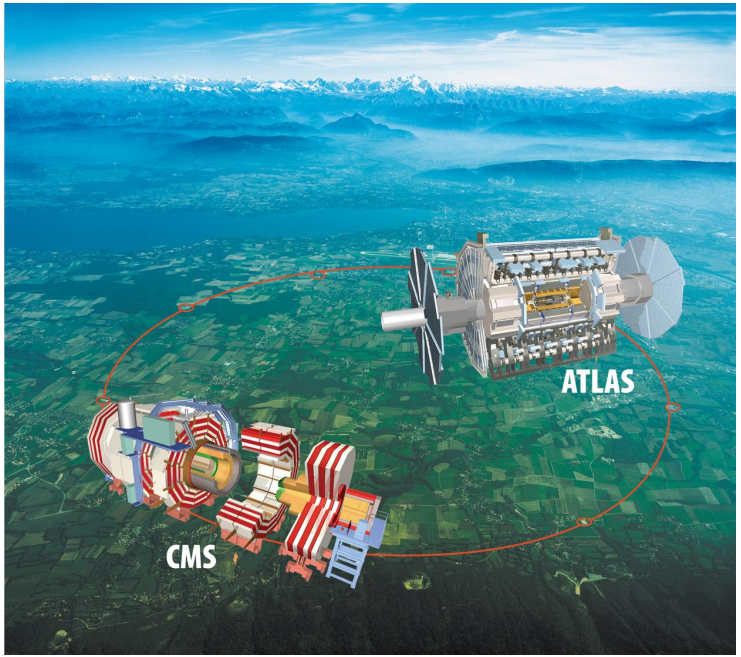
23 členských zemí + pozorovatelské státy

CERN

Domov největšího a nejenergetičtějšího urychlovače na světě – Large Hadron Collider, LHC

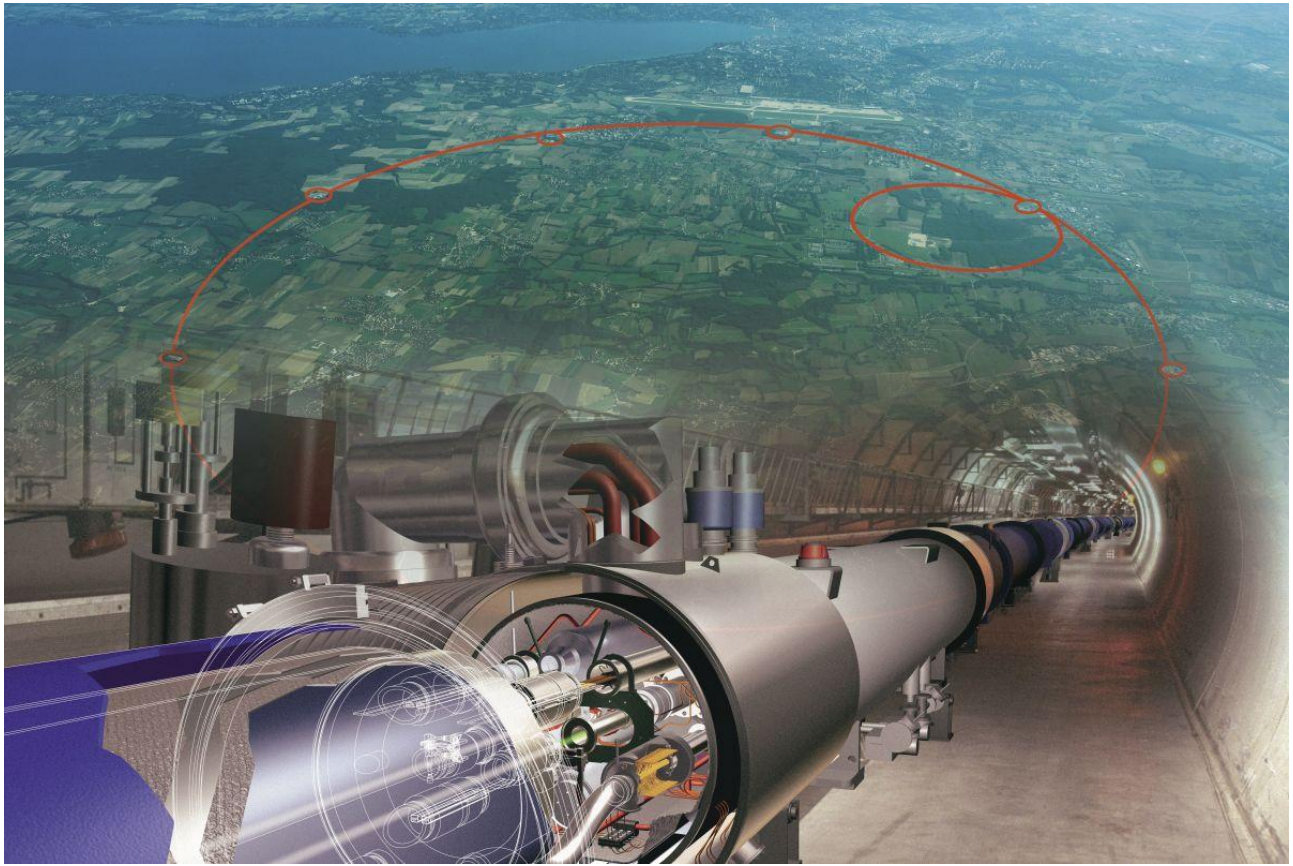
CERN

Domov největšího a nejenergetičtějšího urychlovače na světě – Large Hadron Collider, LHC

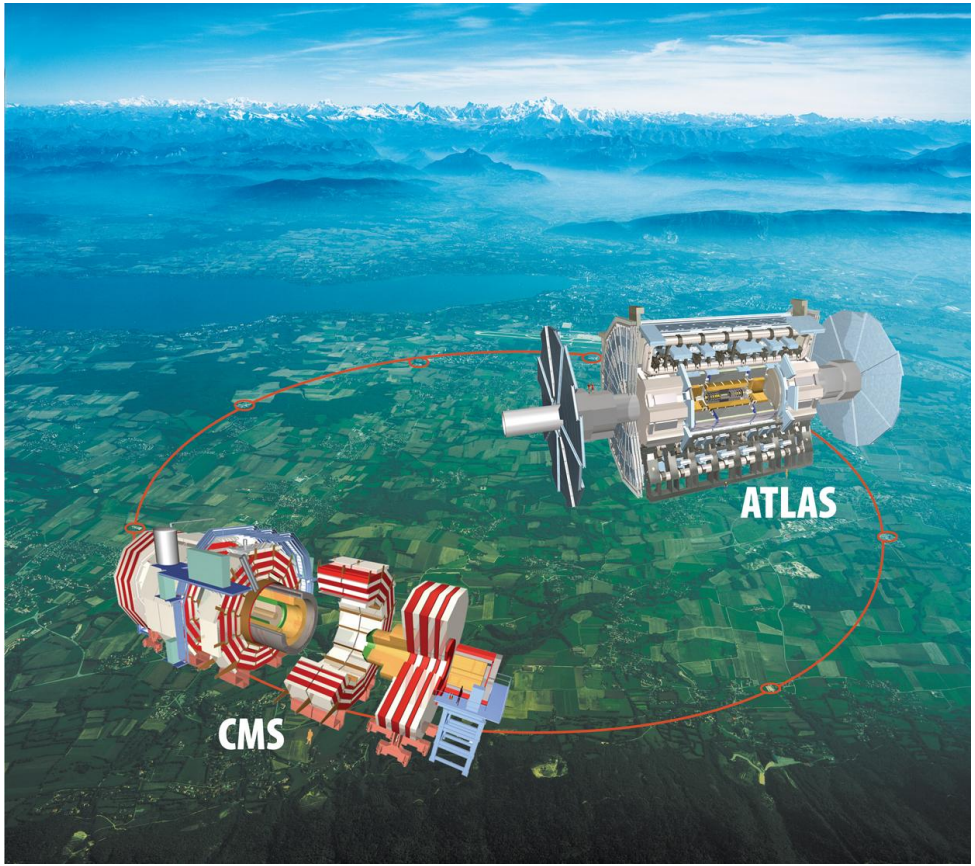


CERN

Domov největšího a nejenergetičtějšího urychlovače na světě – Large Hadron Collider, LHC

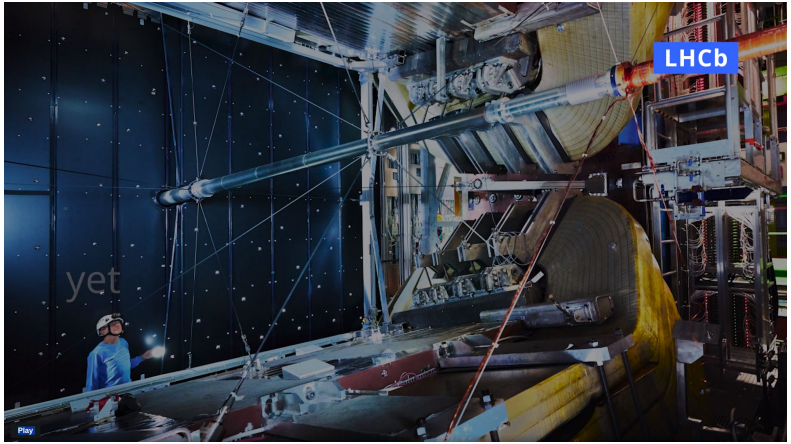


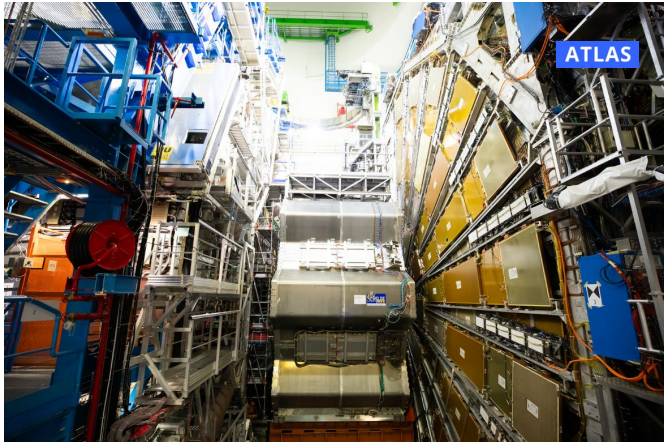
CERN – Hlavní LHC Experimenty

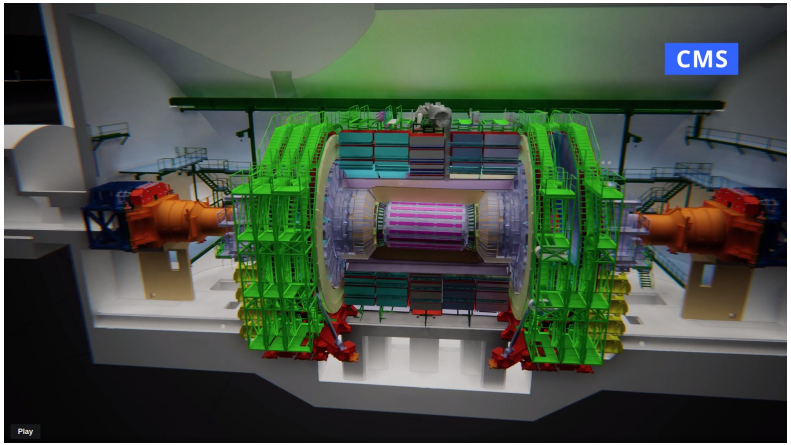


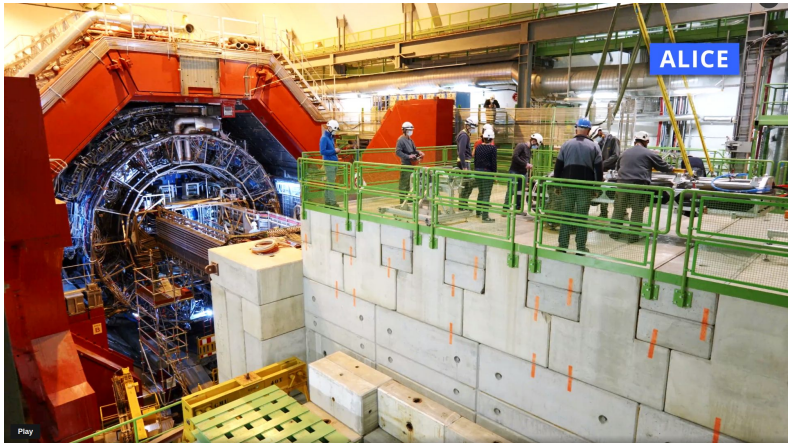
CERN – Hlavní LHC Experimenty

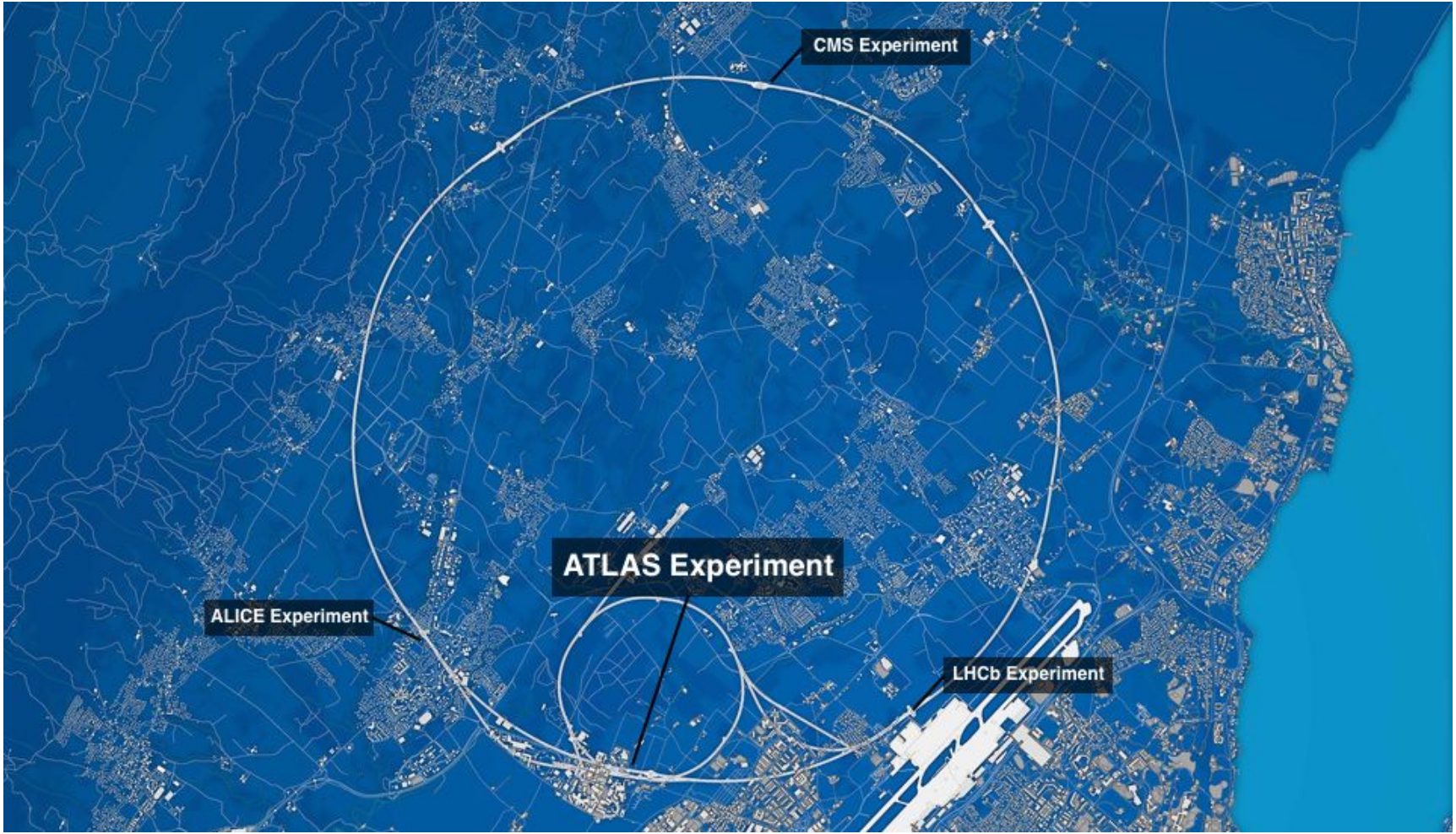
CERN – Hlavní LHC Experimenty










CMS Experiment
ATLAS Experiment
ALICE Experiment
LHCb Experiment

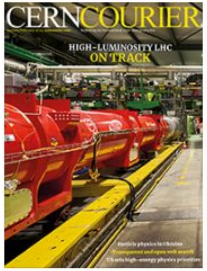
$CERN$


CERN
CERN
1 Fr
1912

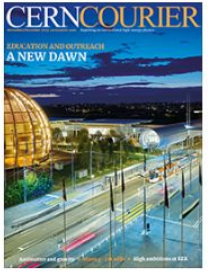

Ristretto Fr.1.70
2 Ristretti Fr.3.40
Cappuccino Fr.2.20
Ristretto hot milk Fr.1.80
Espresso Fr.1.70
2 Espressi Fr.3.40
Laitfroid/coldmilkFr.1.50
Espresso hot milk Fr.1.80
Café Fr.1.70
2 Cafés Fr.3.40
LaitChaud/hotmilkFr.1.50
Café hot milk Fr.1.80
Thé Fr.1.70
Renversé Fr.1.90
Latte Macchiato Fr.2.20
EspressoMacchiatoFr.1.80
FRANKE
A800


WHERE THE
WEB
WAS BORN
In the offices of this corridor, all the fundamental technologies of the World Wide Web were developed.
Started in 1990 from a proposal made by Tim Berners-Lee in 1989, the effort was first divided between an office in building 31 of the Computing and Networking Division (CN) and one in building 2 of the Electronics and Computing for Physics Division (ECP).
In 1991 the team came together in these offices, then belonging to ECP. It was composed of two CERN staff members, Tim Berners-Lee (GB) and Robert Cailliau (BE), aided by a number of Fellows, Technical Students, a Coopérant and Summer Students.
At the end of 1994 Tim Berners-Lee left CERN to direct the WWW Consortium (W3C), a world-wide organization devoted to leading the Web to its full potential. The W3C was founded with the help of CERN, the European Commission, the Massachusetts Institute of Technology (MIT), the Institut National pour la Recherche en Informatique et en Automatique (INRIA), and the Advanced Research Projects Agency (ARPA).
In 1995 Tim Berners-Lee and Robert Cailliau received the ACM Software System Award for the World Wide Web. In 2004, Tim Berners-Lee was awarded the first Millenium Technology Prize by the Finnish Technology Award Foundation.
The CERN Library
June 2004

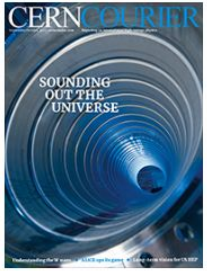
https://cerncourier.com/p/magazine/



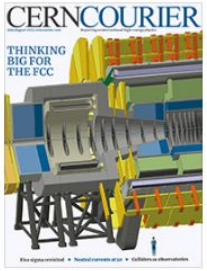
Jan/Feb 2024



Nov/Dec 2023



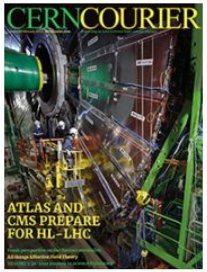
Sep/Oct 2023



Jul/Aug 2023

May/Jun 2023

Mar/Apr 2023



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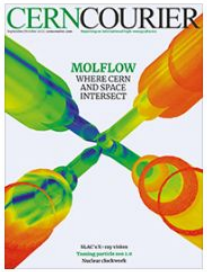
Nov/Dec 2022



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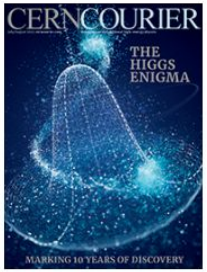
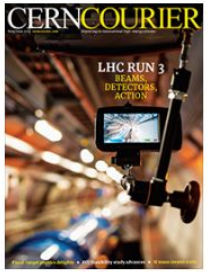
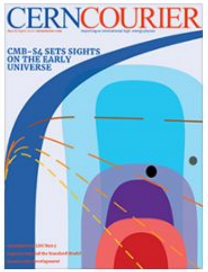


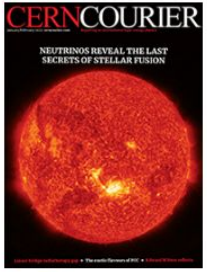
Jul/Aug 2022



May/Jun 2022

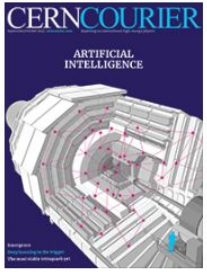


Mar/Apr 2022



Jan/Feb 2022

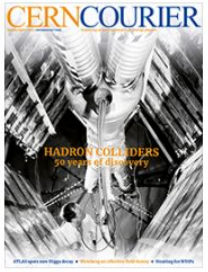
Nov/Dec 2021



Sep/Oct 2021

Jul/Aug 2021

May/Jun 2021



Mar/Apr 2021

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.

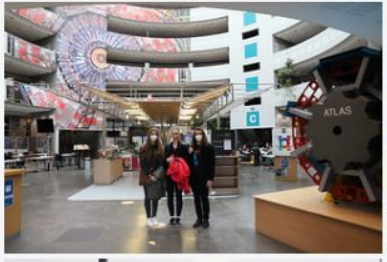
CERN Science Gateway will be open to the public as of tomorrow, 8 October 2023.

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

#CERNScienceGateway Stellantis



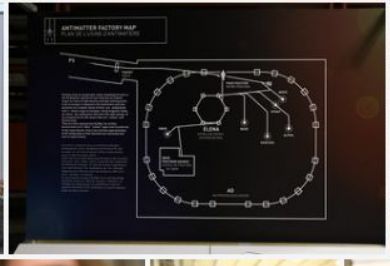
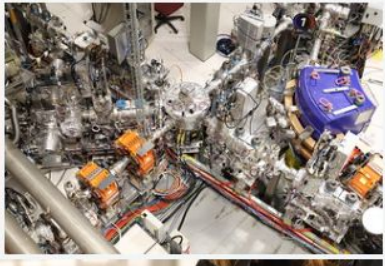




ATLAS


WHERE THE
WEB
WAS BORN



ROUTE A. EINSTEIN
STOP

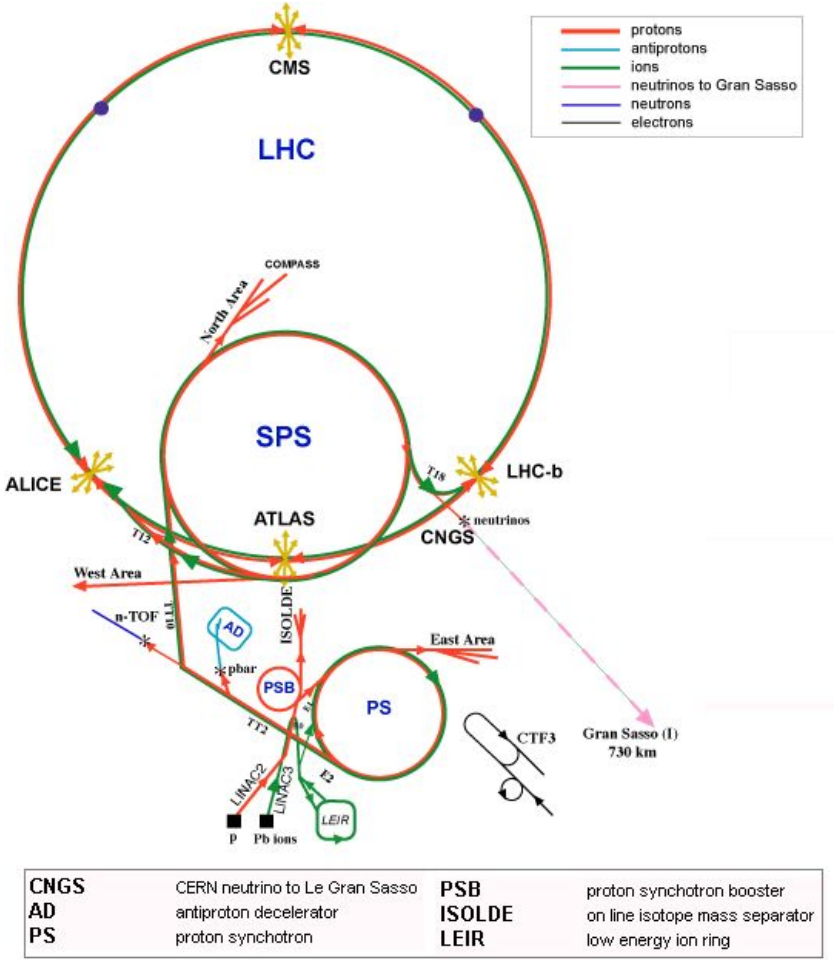

ANTIMATTER
FACTORY
ELENA

ANTIMATTER FACTORY MAP



COMPASS


LHC

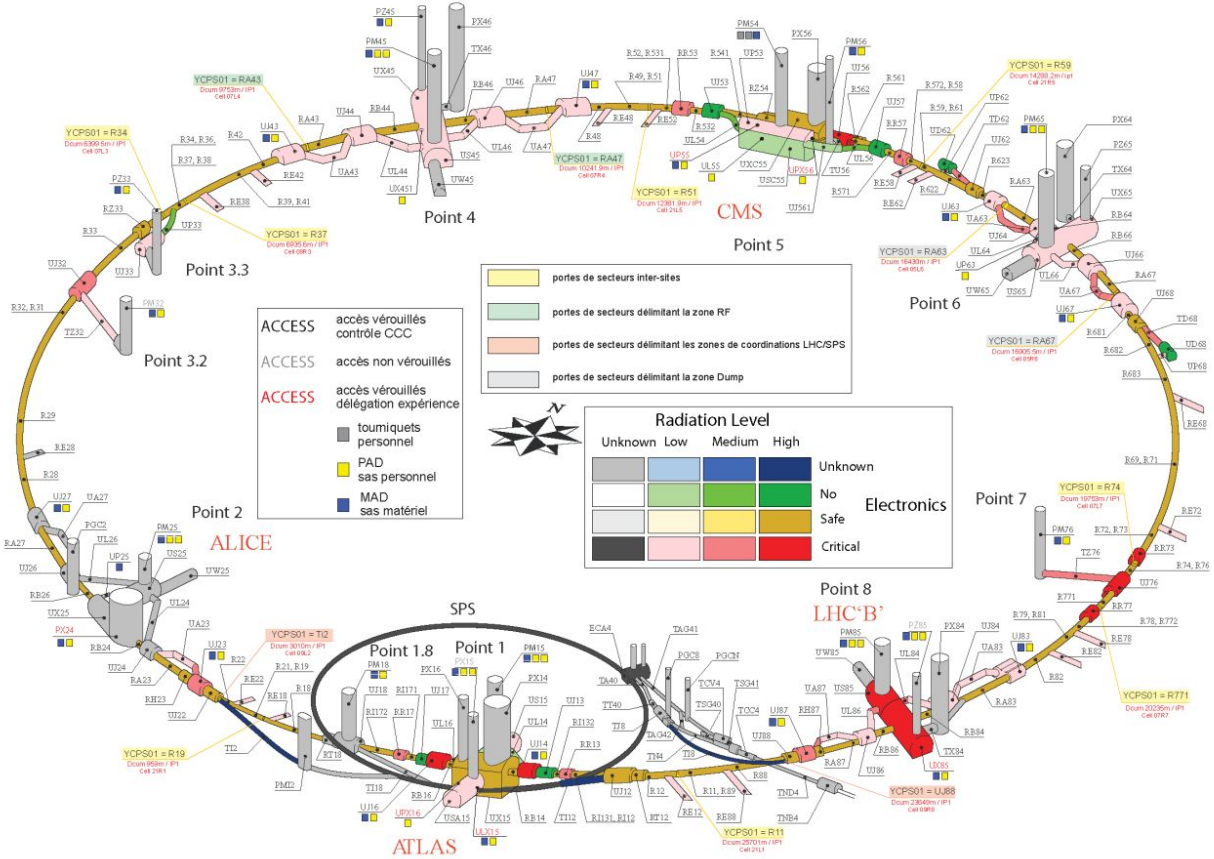
- Obvod 26.66km
- Urychluje protony na energii 6.8 TeV (design 7 TeV)
  - silně relativistické, rychlosti blízké rychlosti světla
  - celk. těžišťová energie srážek: 13.6 TeV (design 14 TeV)
- Dipólových magnetů: 1232
  - délka 14.3m, 35t, 2-in-1 design, 0.5M CHF.
  - B=8.33T, R=2804m
  - Teplota: 1.9 K, proud: 12 kA
- Všech magnetů: 9.6k
- Cena: 4332 MCHF

https://cds.cern.ch/record/2262862/files/fermilab-conf-15-635-td.pdf
https://home.cern/resources/faqs/facts-and-figures-about-lhc



- 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.

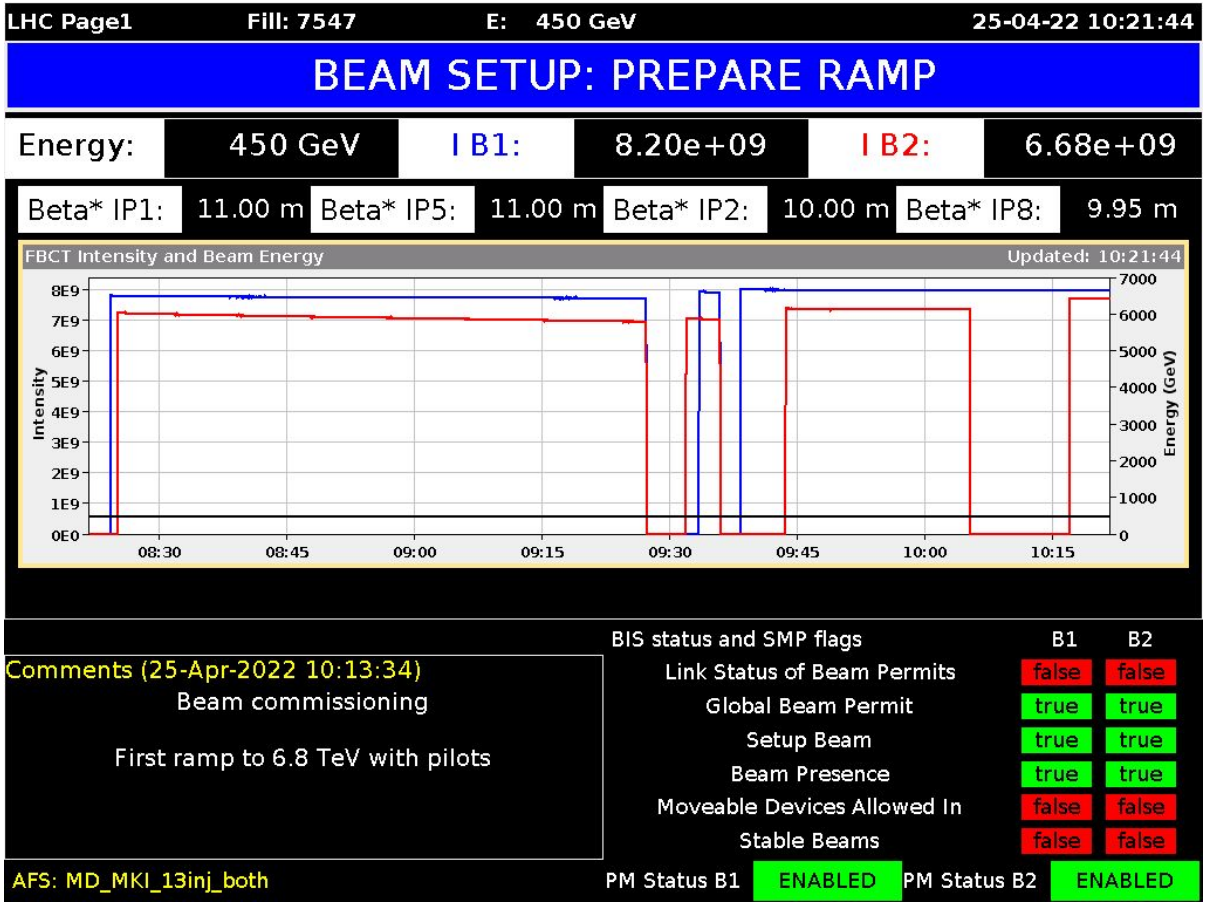
The LHC


Point 4
CMS
Point 5
Point 6
Point 7
Point 8
LHC 'B'
Point 3.3
Point 3.2
Point 2
ALICE
Point 1.8
Point 1
SPS
ATLAS
ACCESS
accès vérouillés contrôle CCC
ACCESS
accès non vérouillés
ACCESS
accès vérouillés délégation expérience
tourniquets personnel
PAD sas personnel
MAD sas matériel
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
Radiation Level
Unknown Low Medium High
Unknown
No
Safe
Critical
Electronics

The LHC

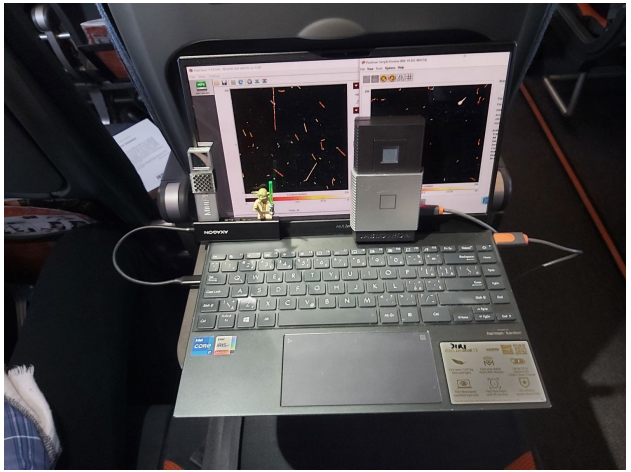
The LHC

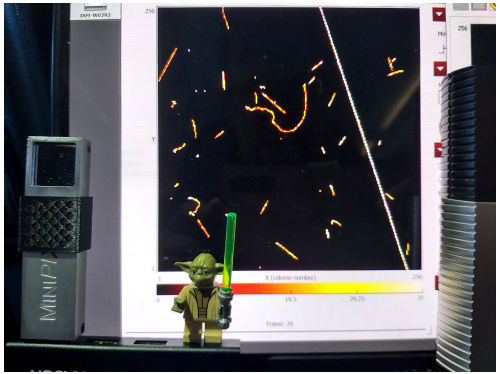
https://jointlab.upol.cz/kvita/LHC.html

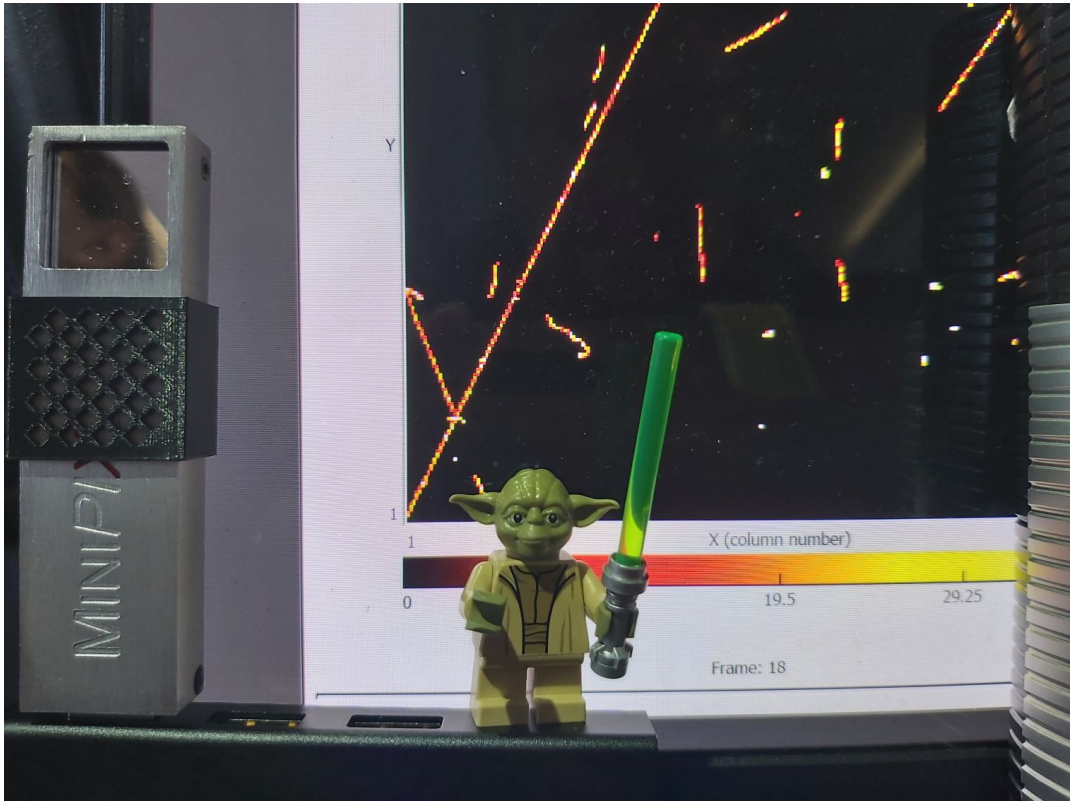


Going to CERN

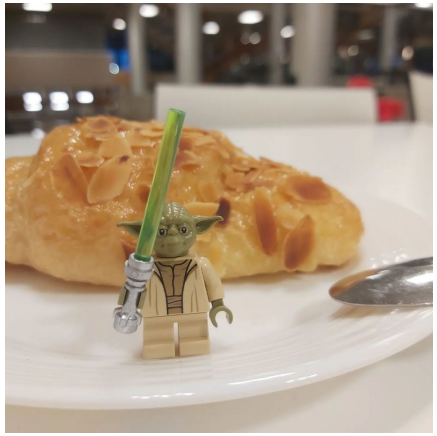
Flying to CERN – with particle cameras!



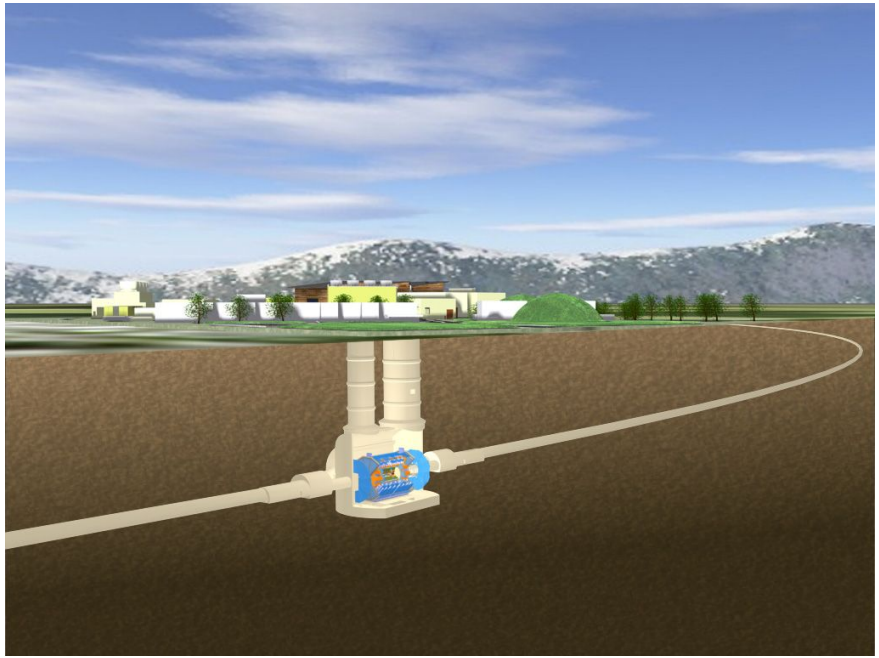




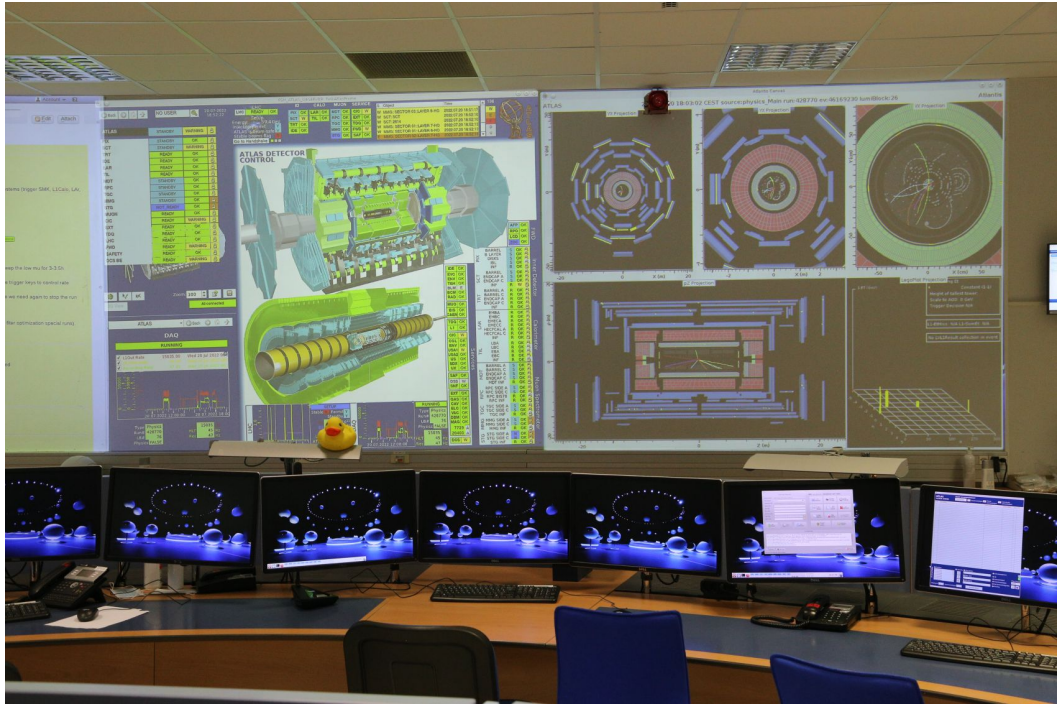
Excursion Day

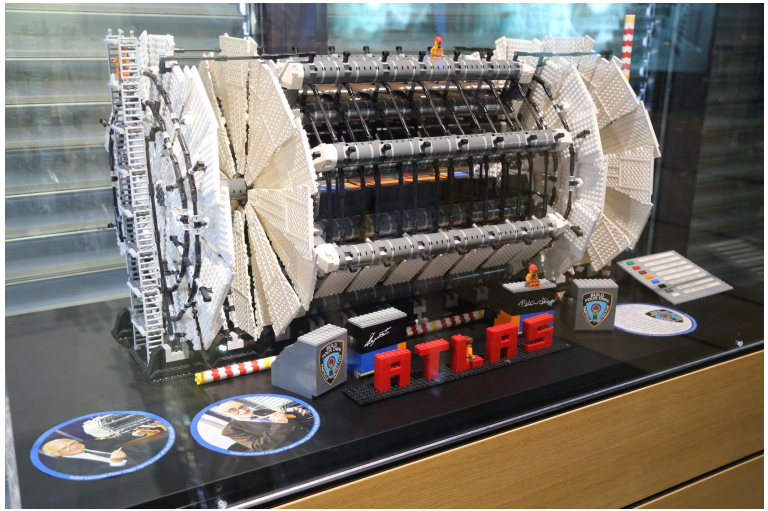


The ATLAS Experiment

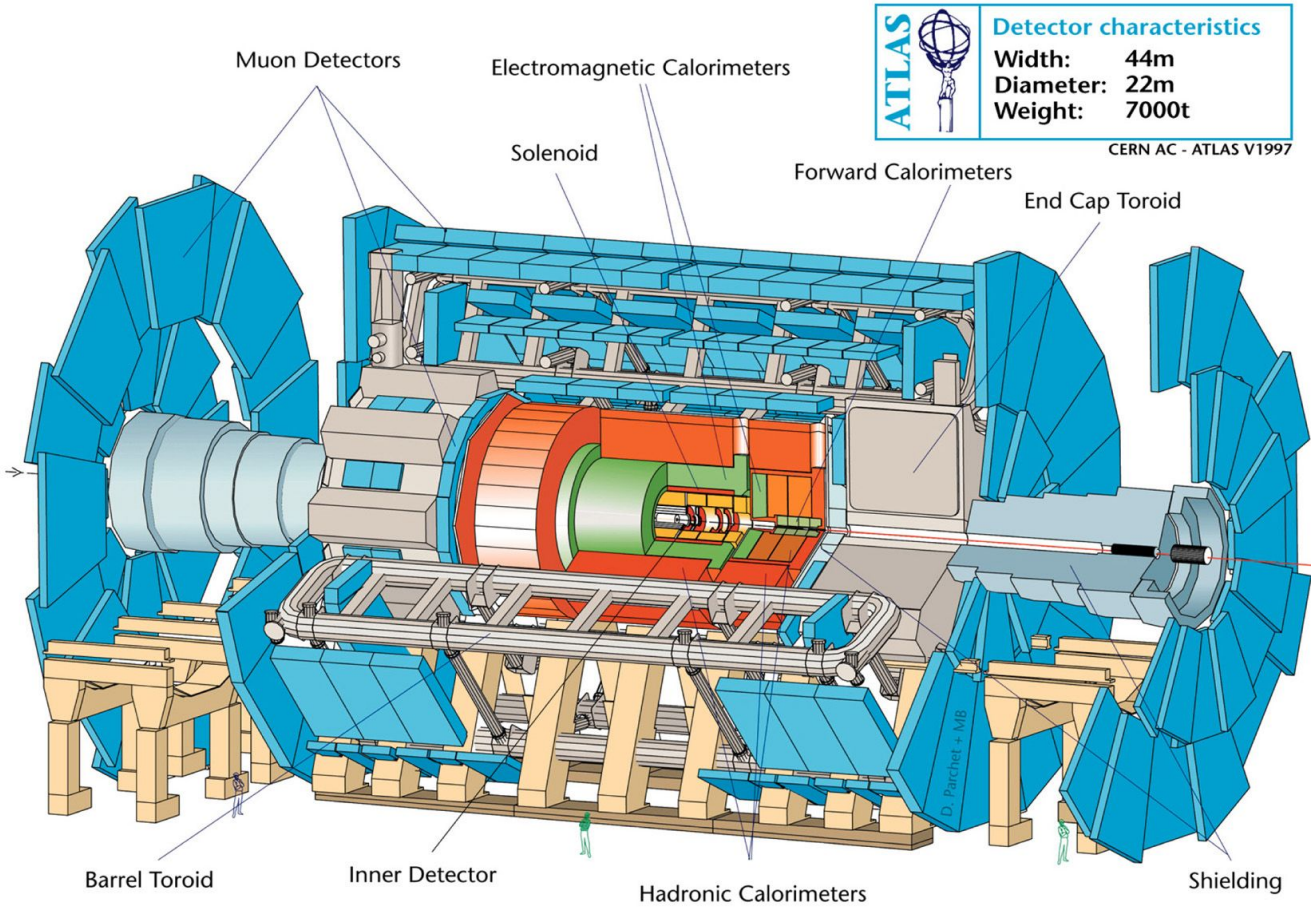


The ATLAS Experiment



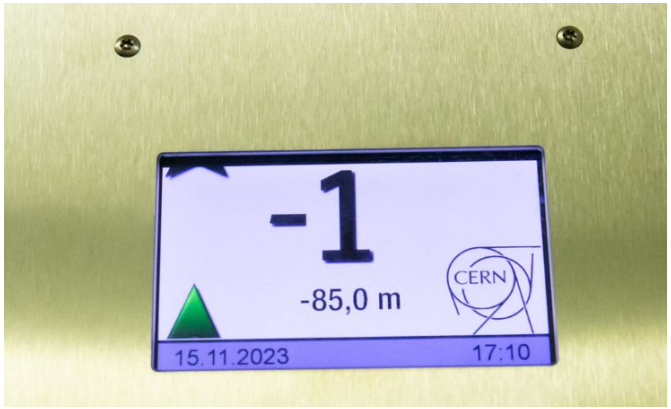


The ATLAS Experiment

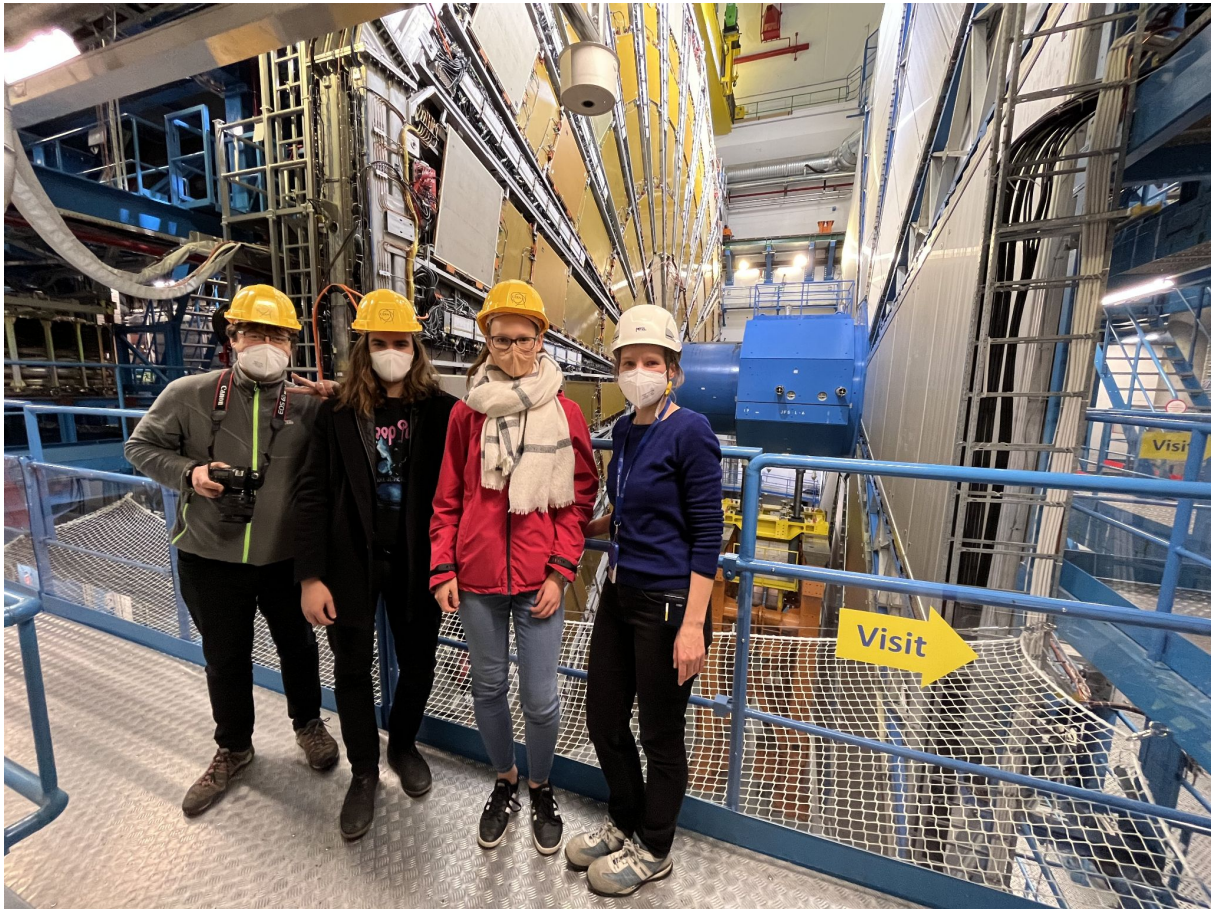


The ATLAS Experiment

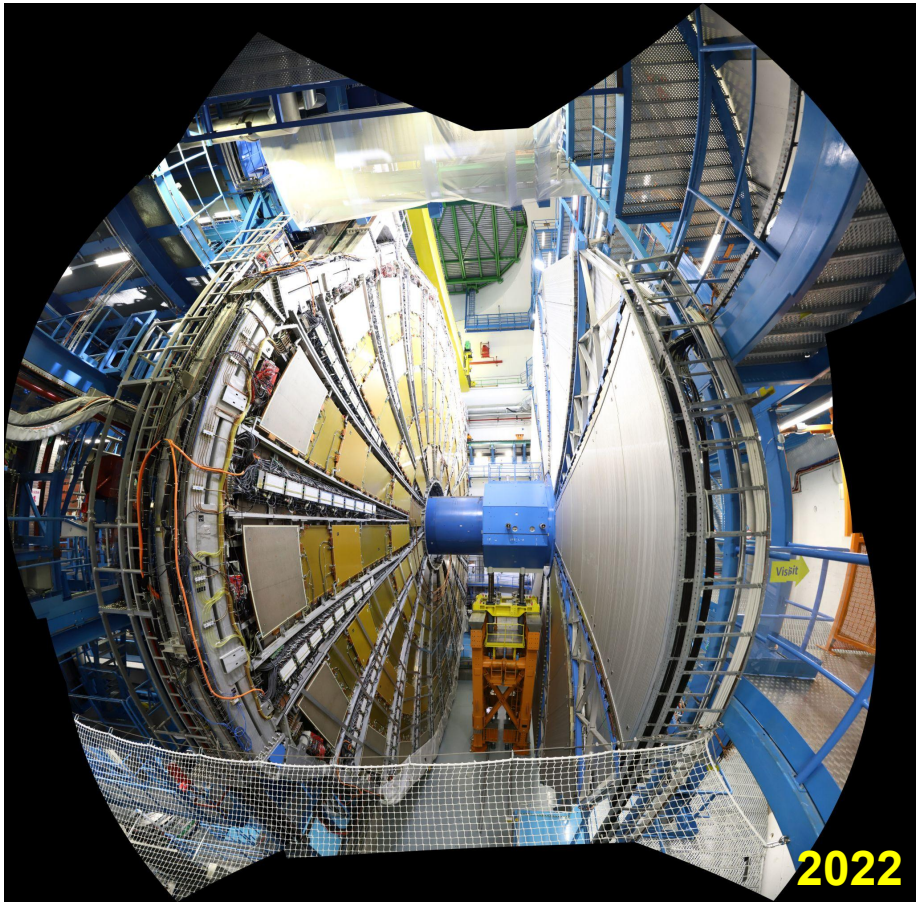
The ATLAS Experiment

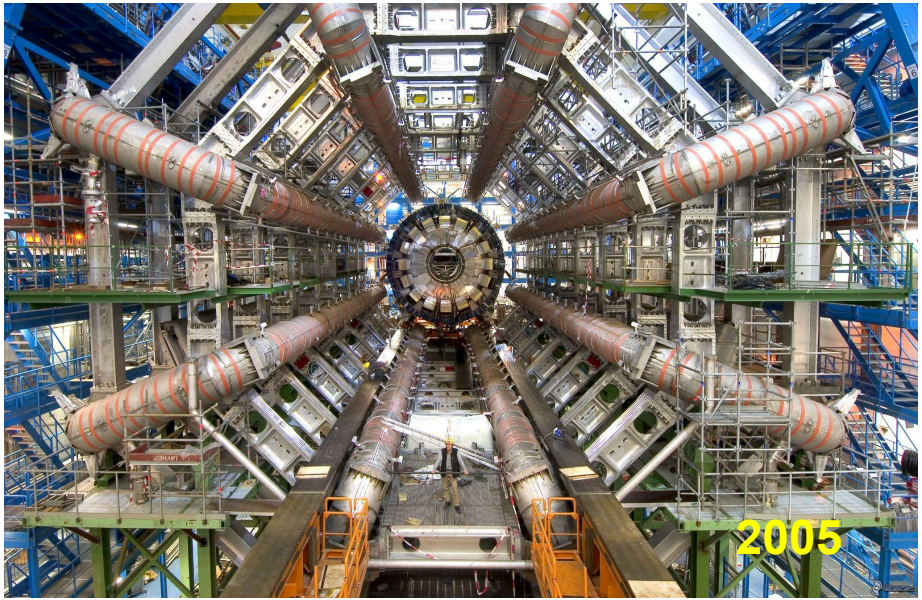


The ATLAS Experiment



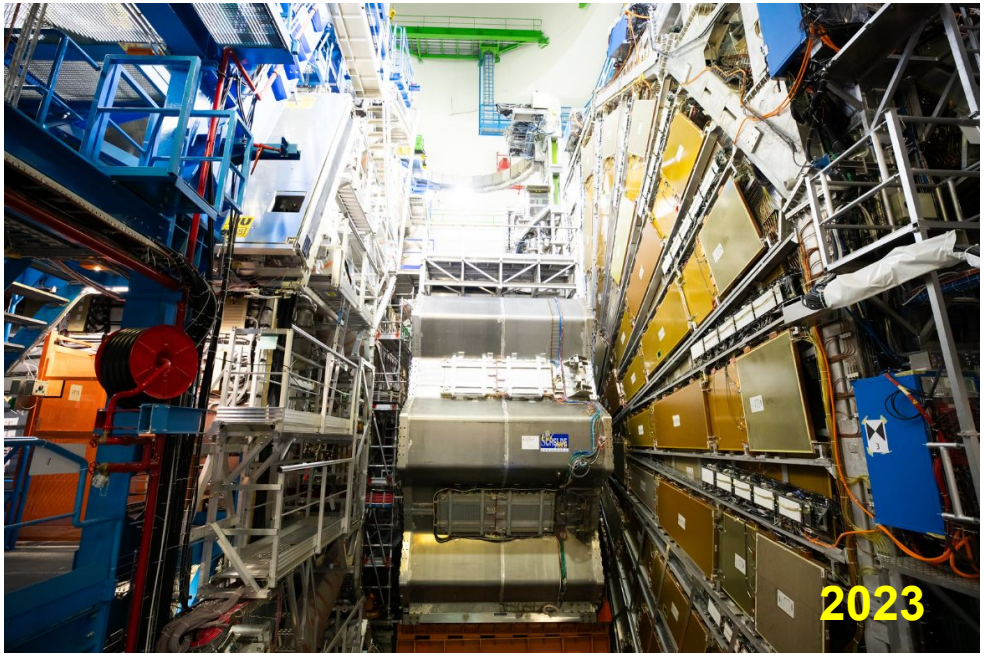
The ATLAS Experiment

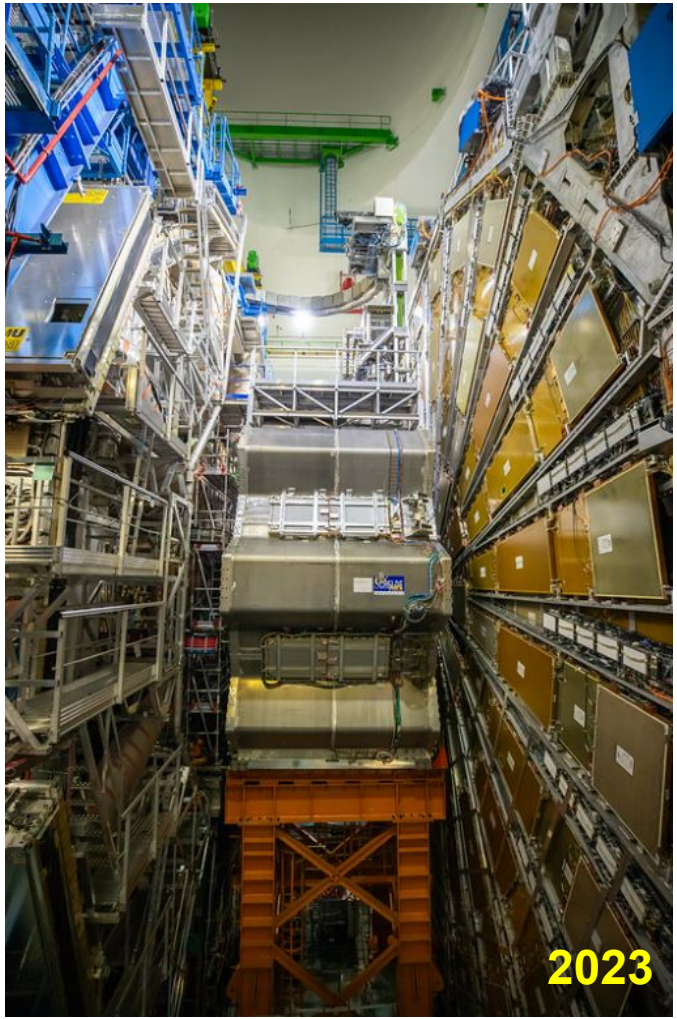




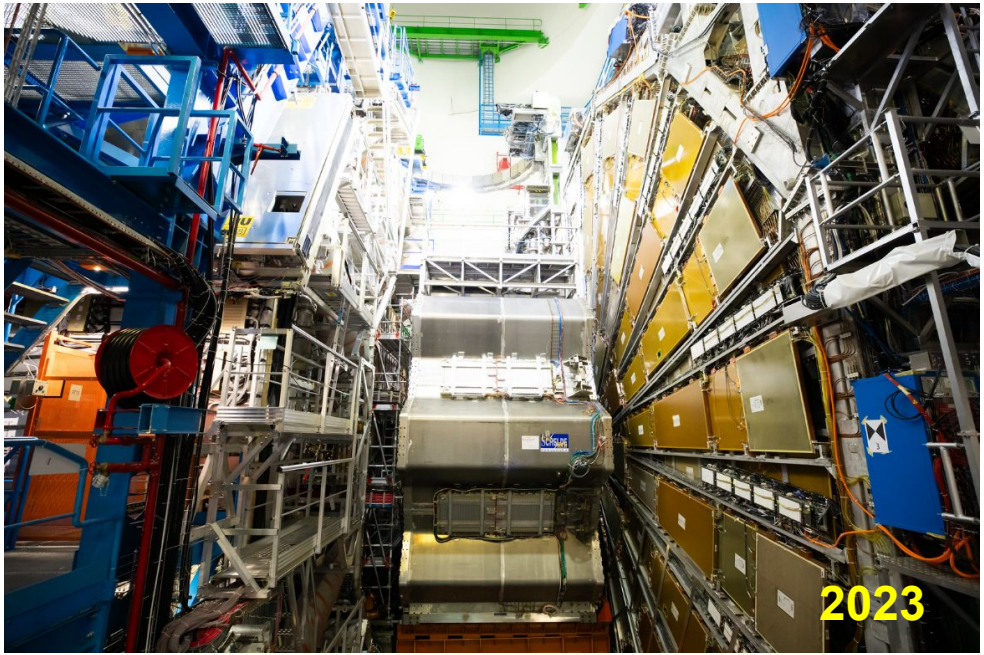
https://timeline.web.cern.ch/timeline-header/143

The ATLAS Experiment





The ATLAS Experiment



SWI swissinfo.ch Swiss perspectives in 10 languages

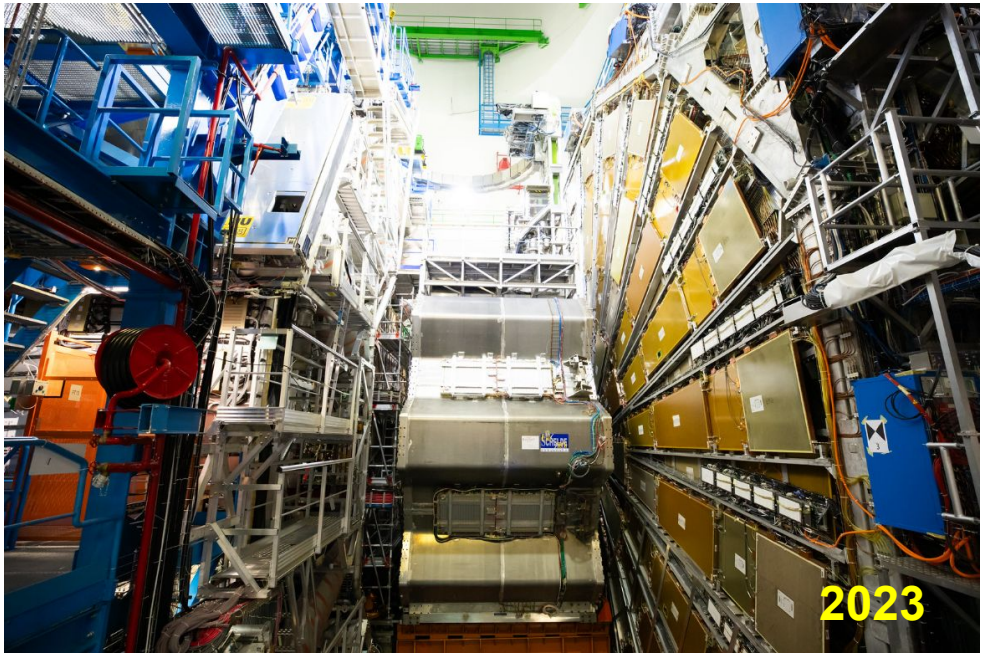
▲ French President Emmanuel Macron, left, with Fabiola Gianotti, Director General of CERN, and Swiss President Alain Berset in the ATLAS experiment on Thursday © Keystone / Martial Trezzini

read aloud

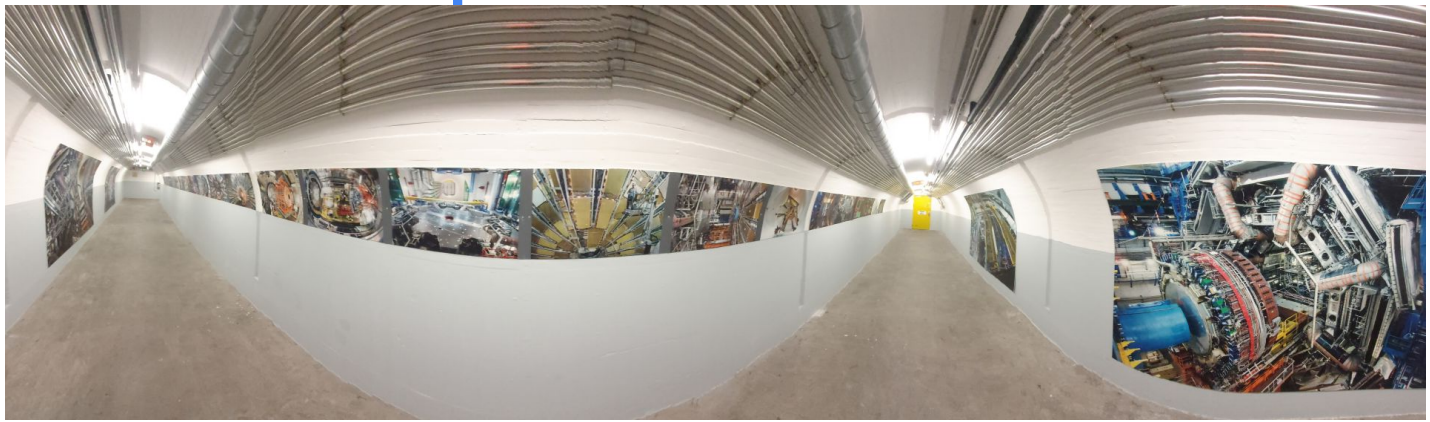
French President Emmanuel Macron spoke on Thursday of France's ambitions to remain in "first place" during a visit to the world's most powerful particle accelerator on the Franco-Swiss border, where a successor, even more powerful, is being studied.

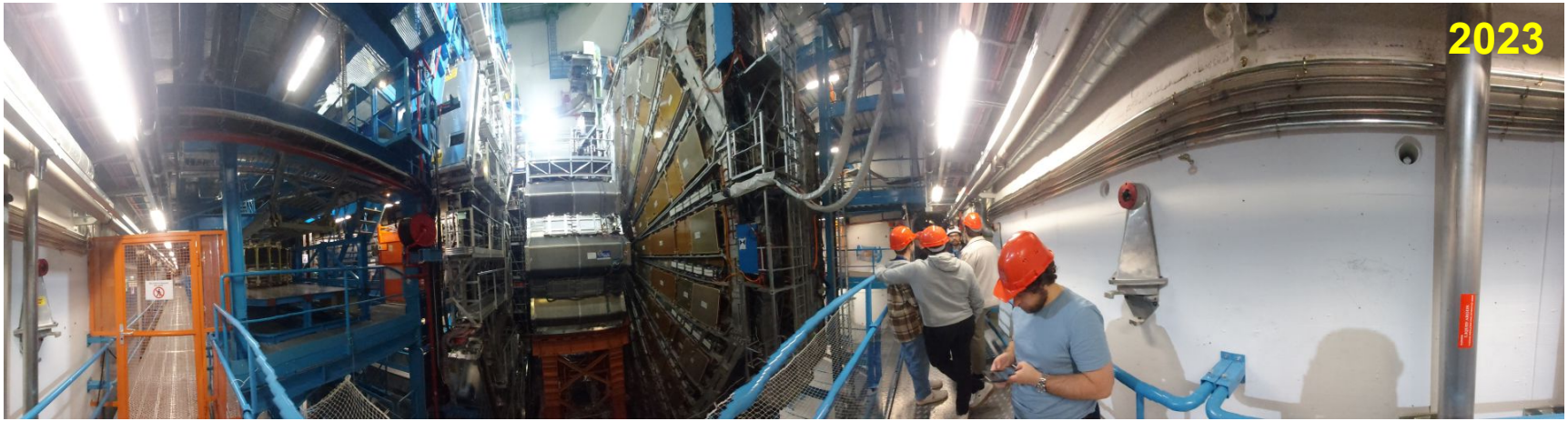
November 17, 2023 - 10:33 2 minutes

The ATLAS Experiment

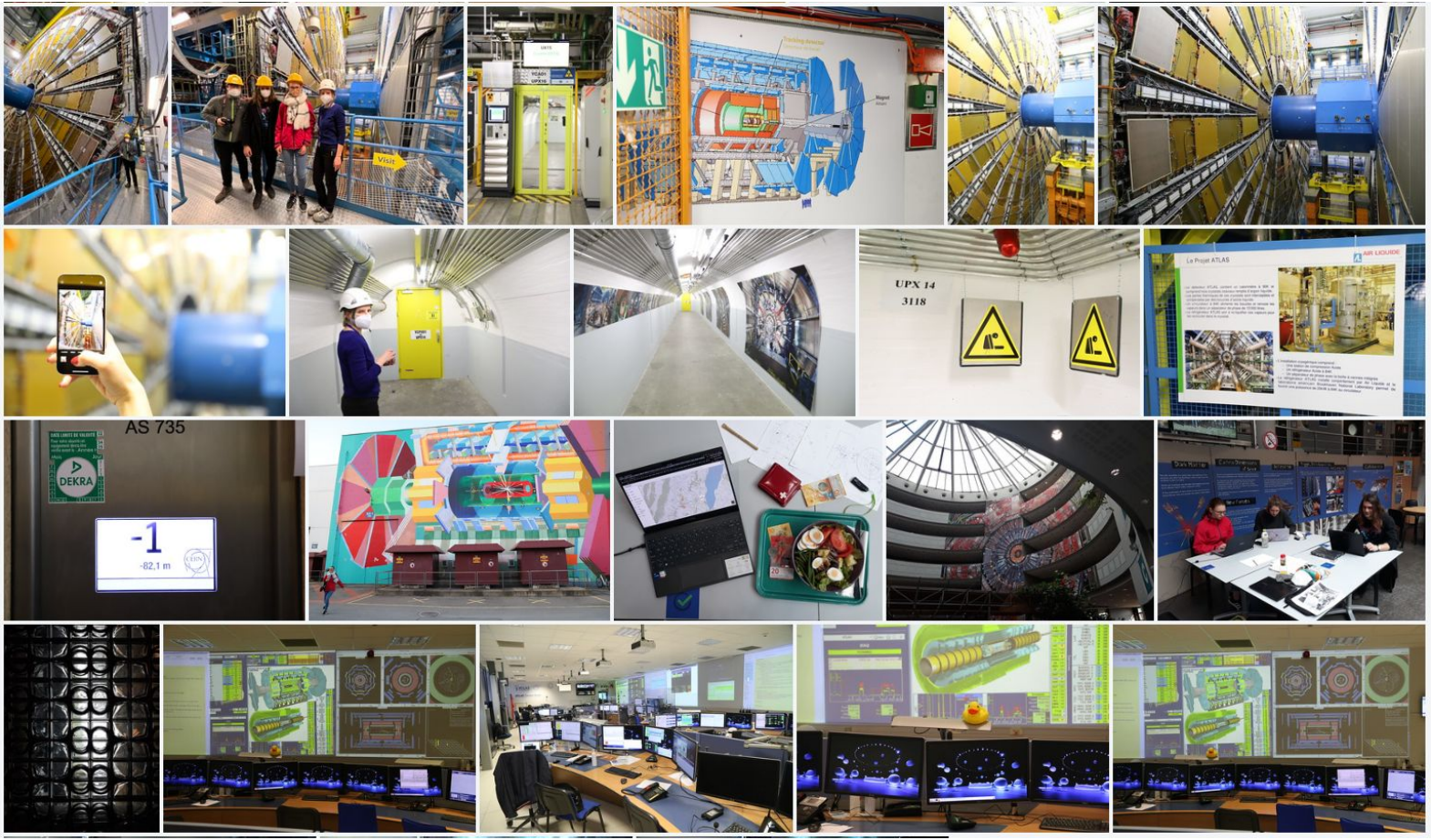


The ATLAS Experiment

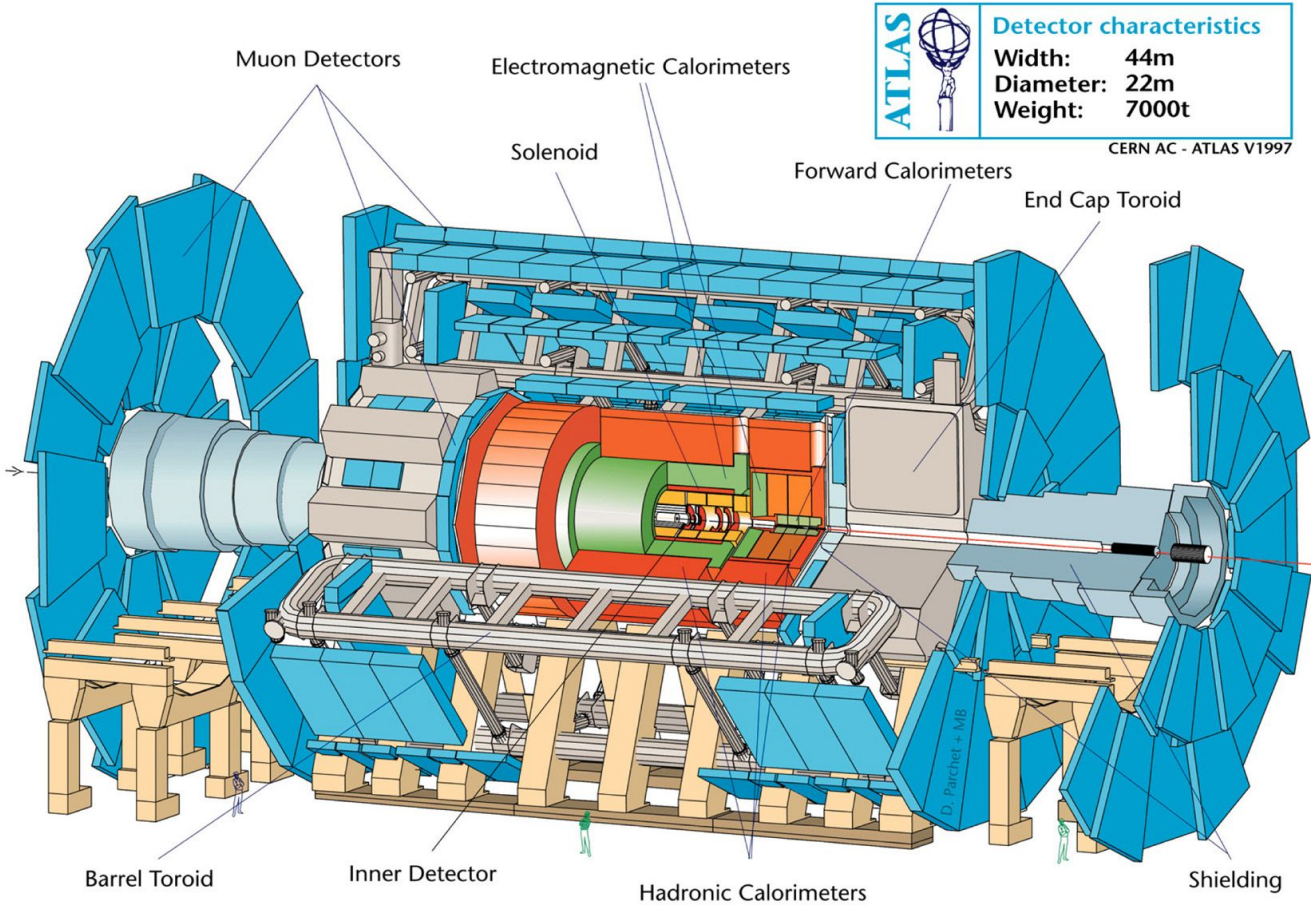




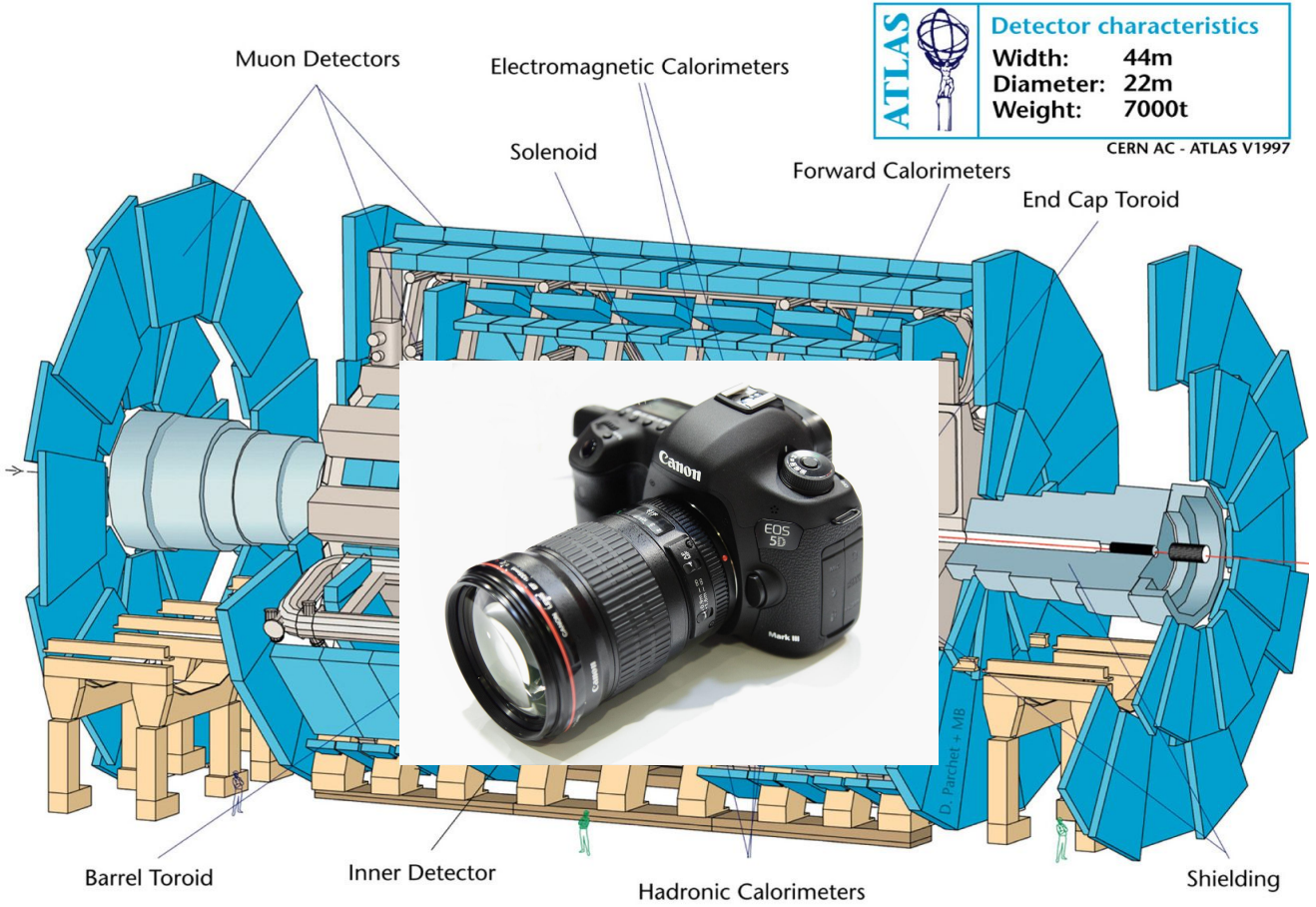
The ATLAS Experiment



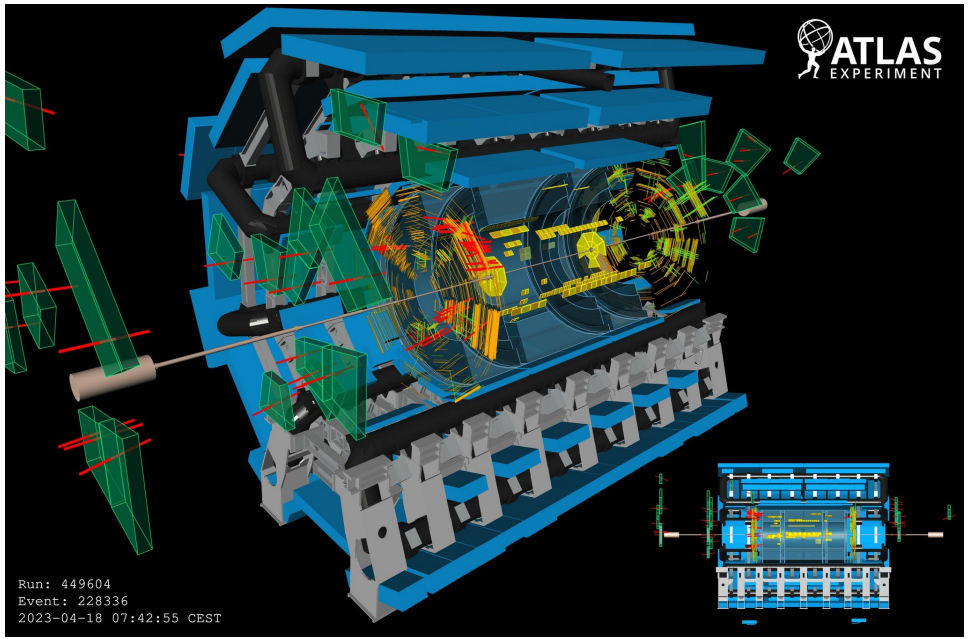
The ATLAS Experiment



The ATLAS Experiment

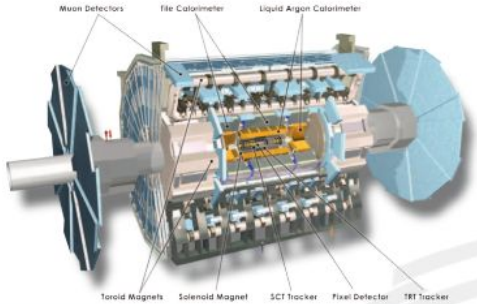


The ATLAS Experiment



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

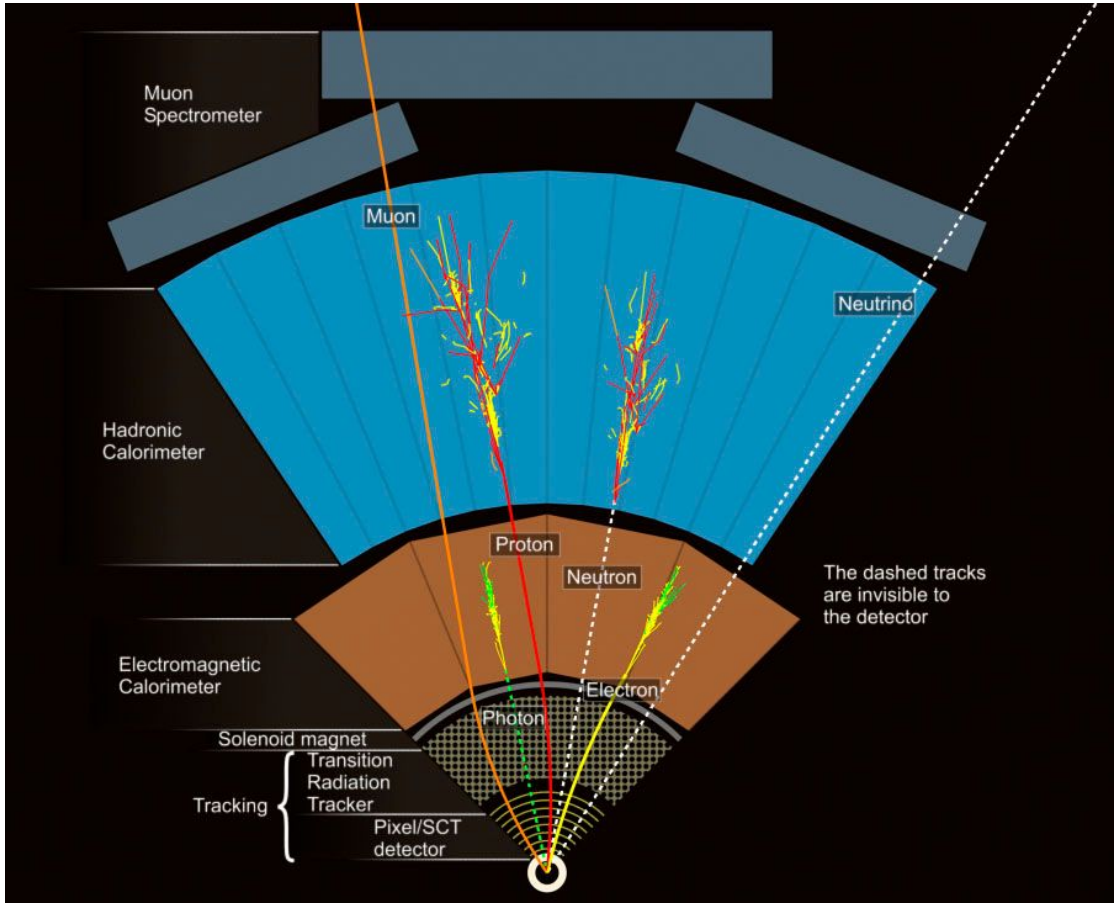
Thin Gap Chambers
For triggering and 2nd coordinate measurement (non-bending direction) at ends of detector.
- 440 000 channels

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

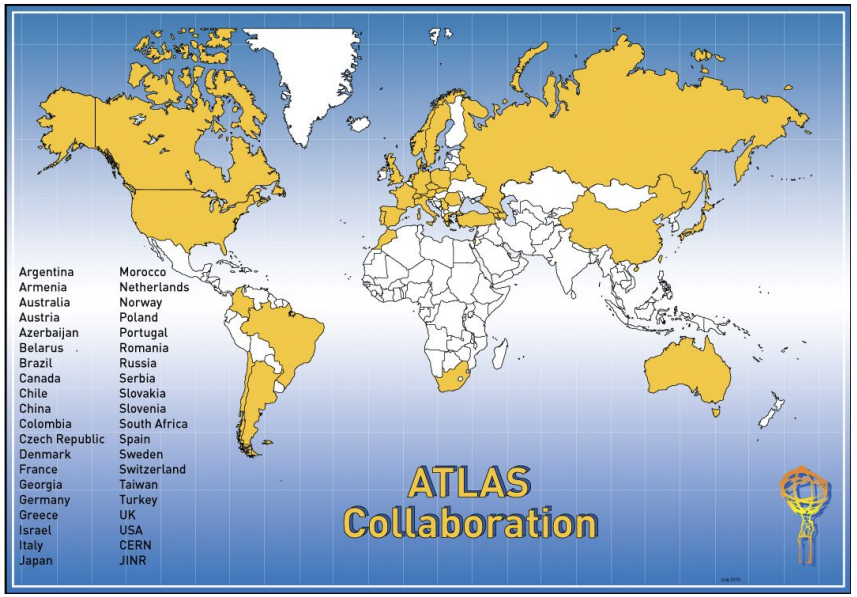
Monitored Drift Tubes
Measure curves of tracks.
- 1 171 chambers with total 354 240 tubes (3 cm diameter, 0.85-6.5 m long).
- Tube resolution 80 µm

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

The ATLAS Experiment – particle identification



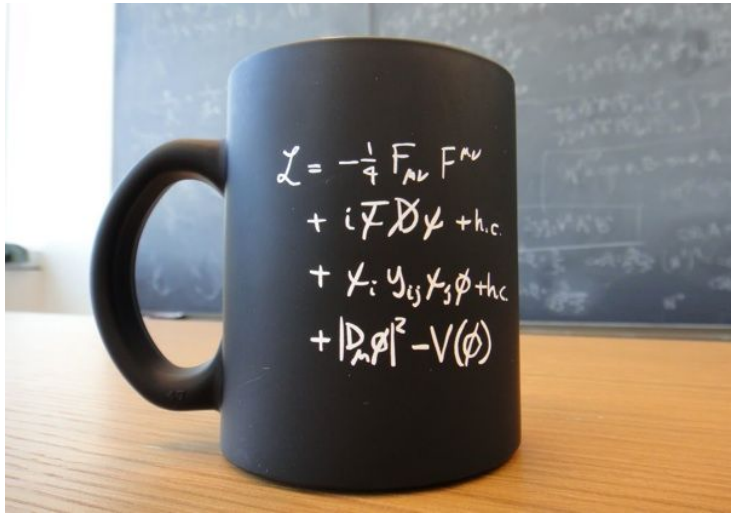
The ATLAS Experiment

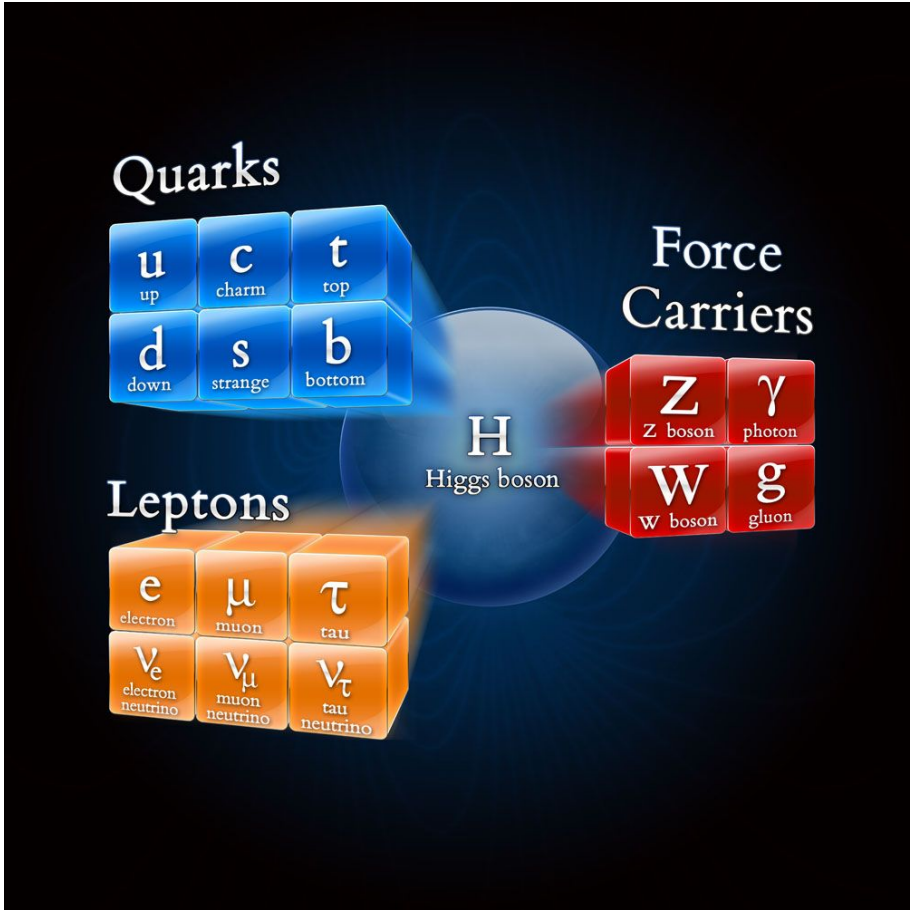


https://atlas.cern/Discover/Collaboration

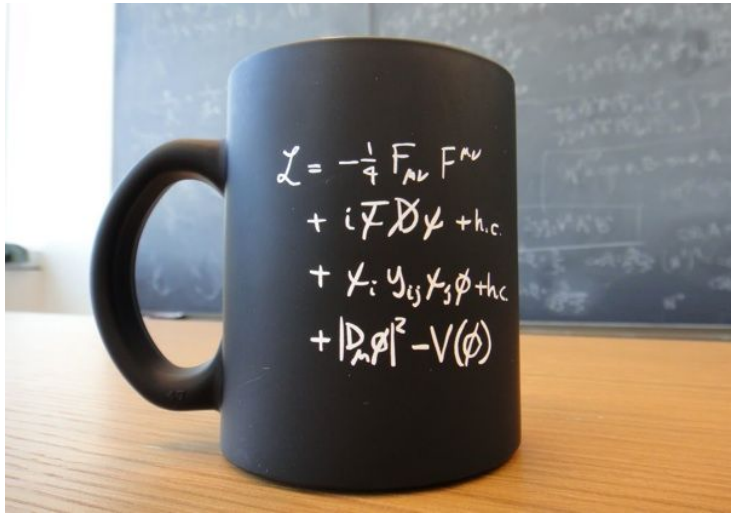
- 6000 členů
- 3000 vědeckých autorů
- 182 institucí z 42 zemí
- 1200 doktorských studentů

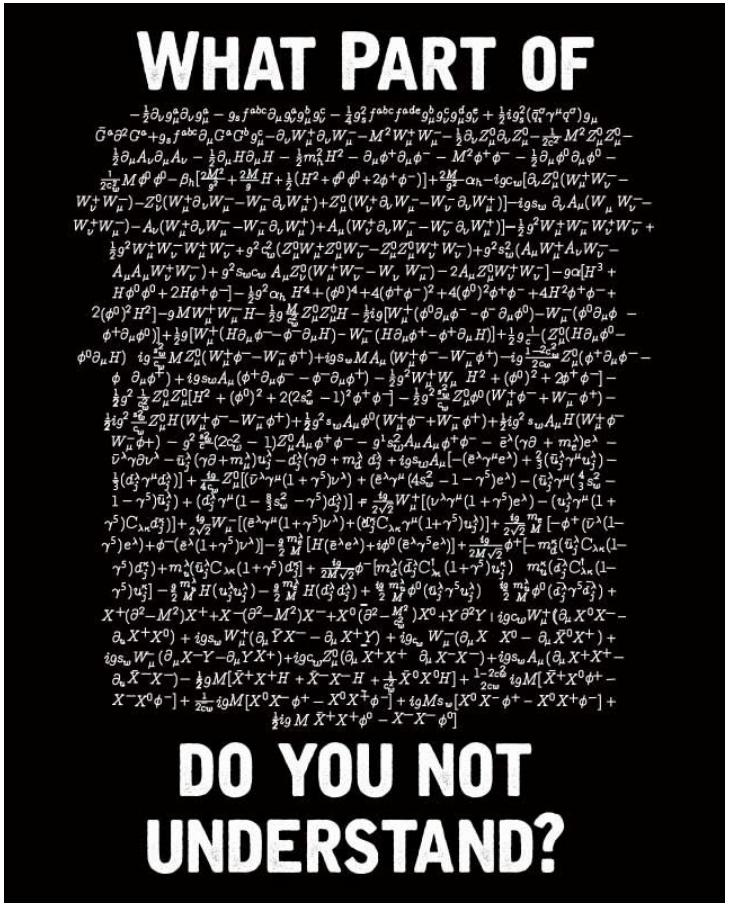
Quarks, Leptons, Gauge Bosons and the BEH boson



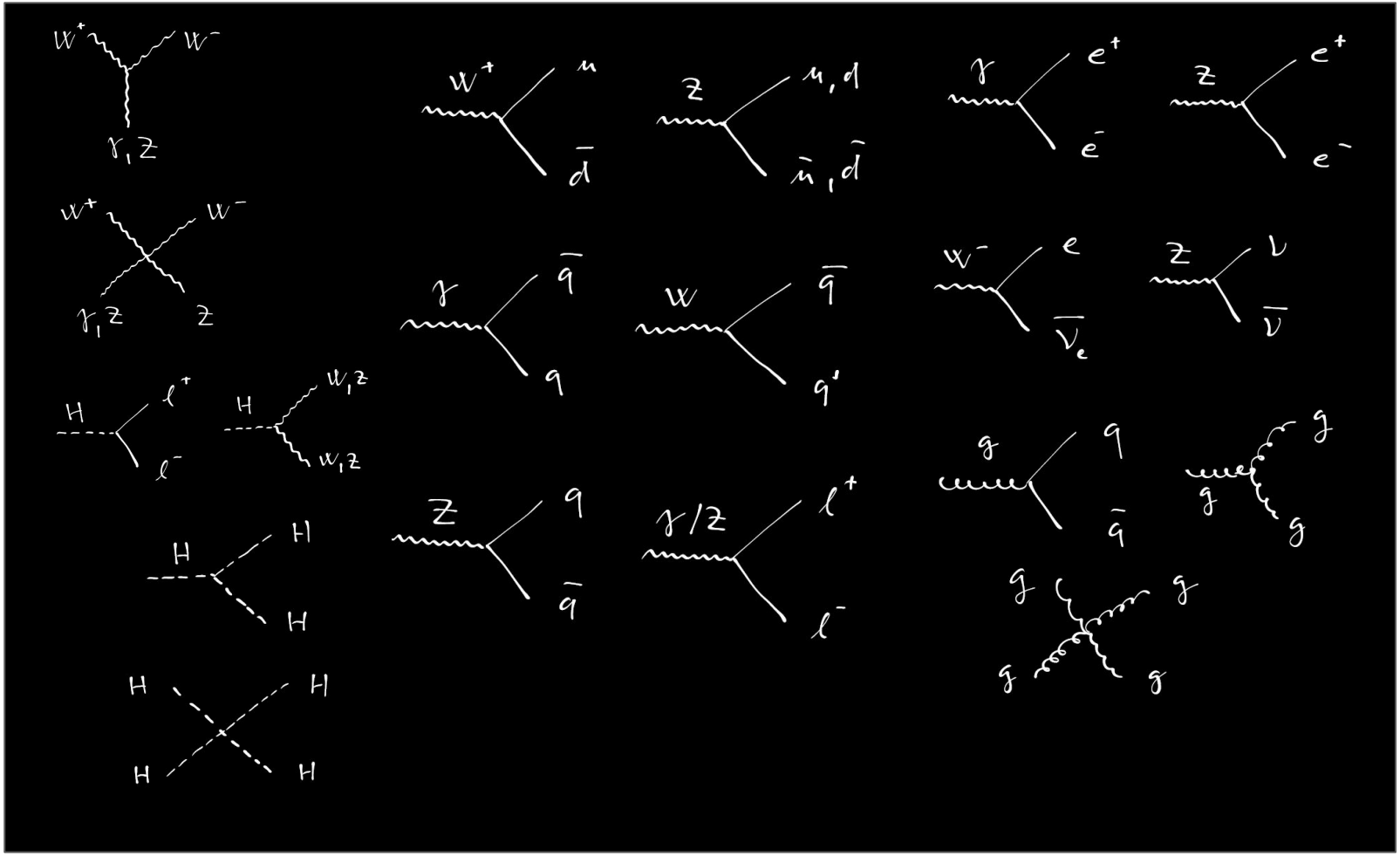


Quarks, Leptons, Gauge Bosons and the BEH boson

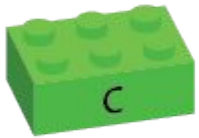
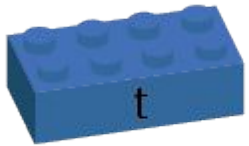
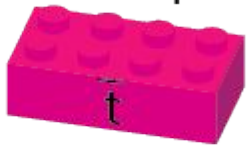
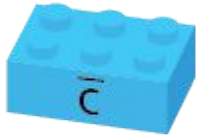
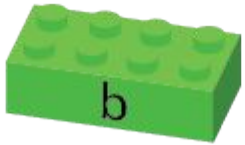
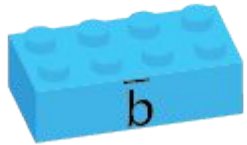




Quarks, Leptons, Gauge Bosons and the BEH boson

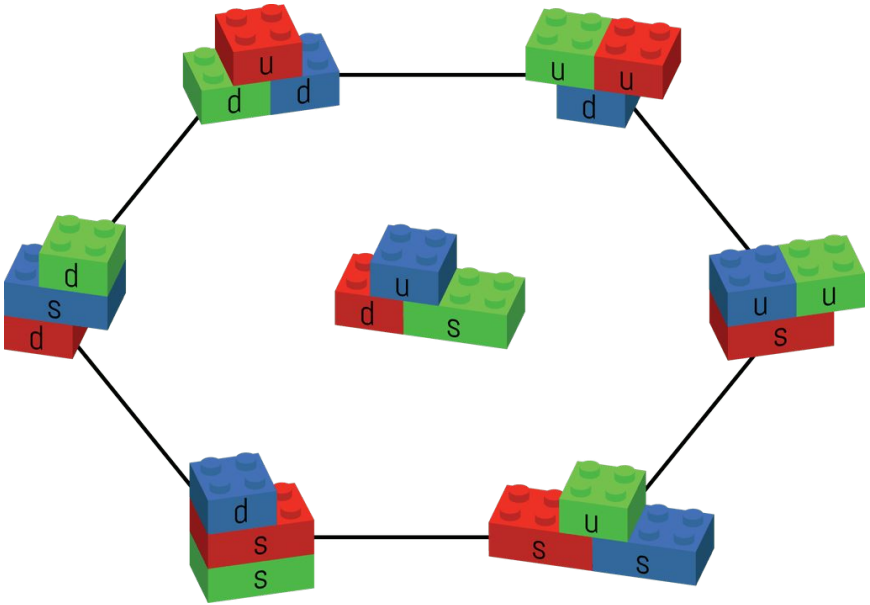


Kvarky a antikvarky

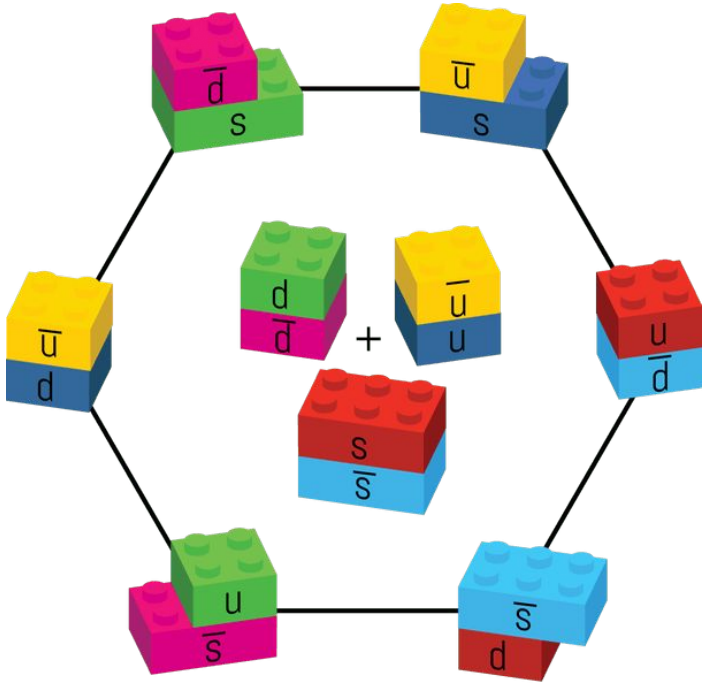
Quarks			Antiquarks		
1	2	3	3	2	1
Up	Charm	Top	Antitop	Anticharm	Antiup
					
					
Down	Strange	Bottom	Antibottom	Antistrange	Antidown

Hadrony, skládání kvarků u, d, s

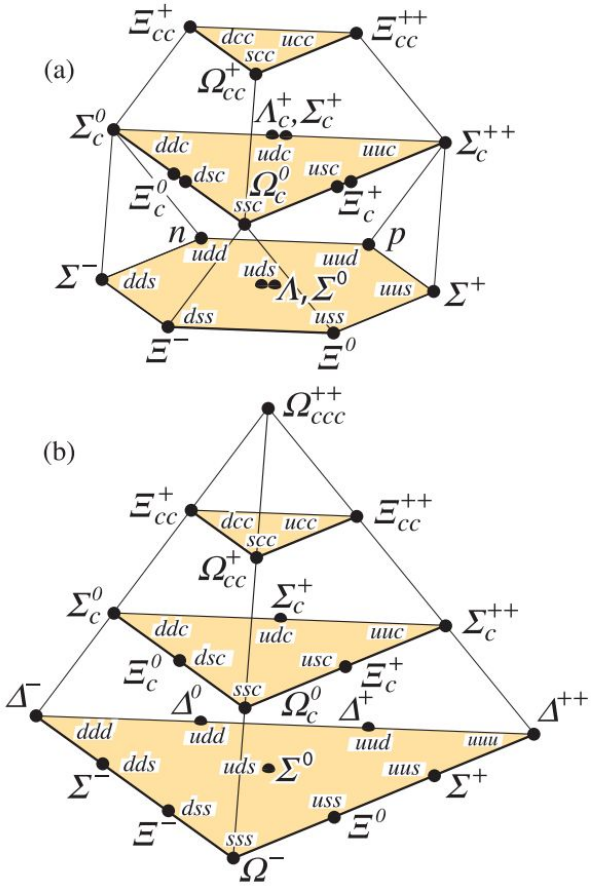
Baryony = qqq

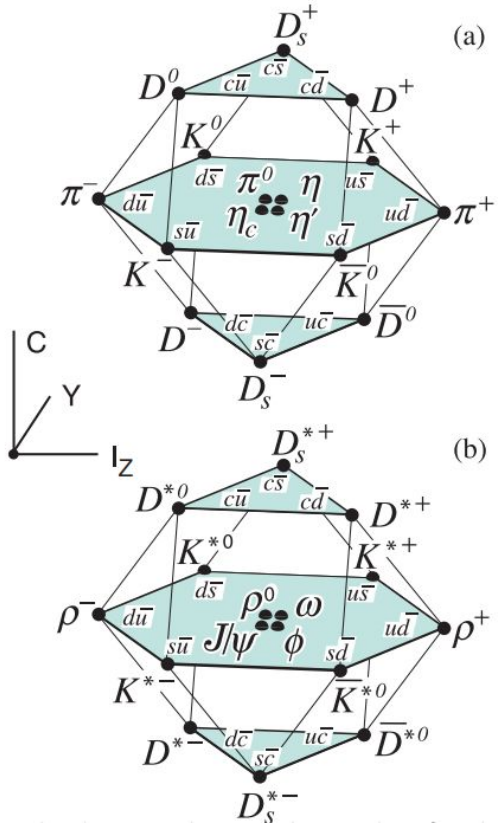


Mesony = q + anti-q

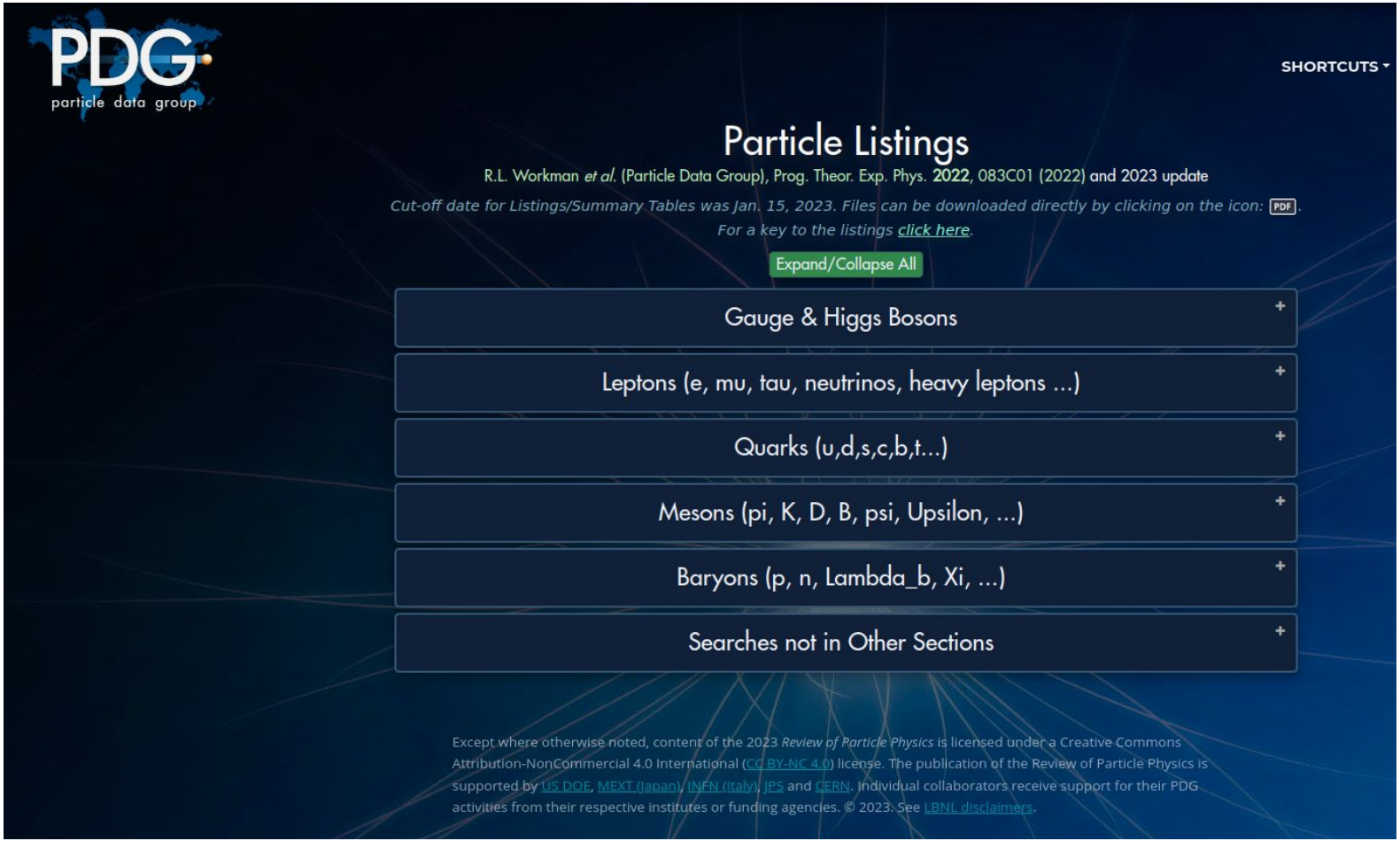


Skládání kvarků u, d, s, c



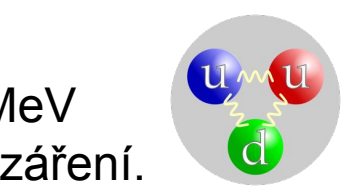


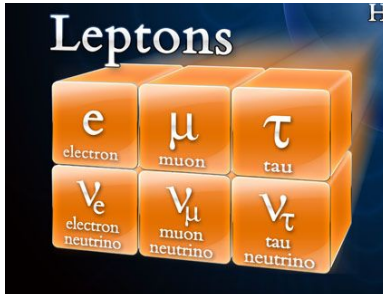
“Stabilní” částice: pozorovatelné v detektoru

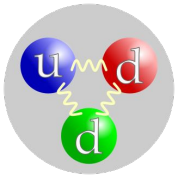


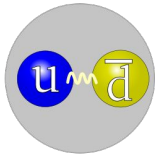
“Stabilní” částice: pozorovatelné v detektoru

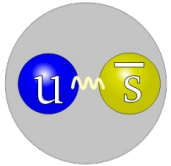
- Fotony, m=0
- Elektrony e^-, mc^2 = 0.511 MeV
  - Pozitrony e^+
- Protony p^+ , 938.3 MeV
- Neutrony n^0 , 939.6 MeV
- Neutrina – málo interagující
- Miony $\mu^\pm$ – doba života 2μs, cτ = 600m. mc^2 = 105.6 MeV
  - 200x těžší než elektrony, pronikavější, kosmické záření.
- Piony, 140 MeV
  - $\pi^\pm$ – doba života 26ns, cτ = 7.8m
  - π^0 – rychle se rozpadá
- Kaony
  - K^+, K^-: , cτ = 3.7m
  - K^0, anti-K^0











“Stabilní” částice: pozorovatelné v detektoru

$m_e c^2 \doteq 0.511\ \text{MeV}$

$m_\mu c^2 \doteq 105.7\ \text{MeV}$

$m_p c^2 \doteq 938\ \text{MeV}$

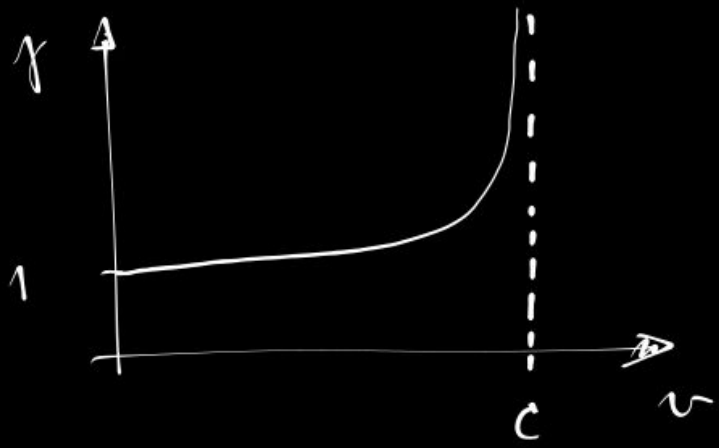
$m_n c^2 \doteq 939\ \text{MeV}$

$m_{\pi^\pm} c^2 \doteq 140\ \text{MeV}$

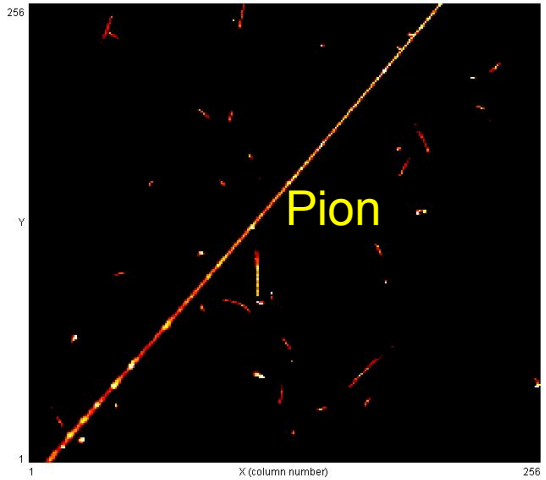
$m_{\pi^0} c^2 \doteq 135\ \text{MeV}$

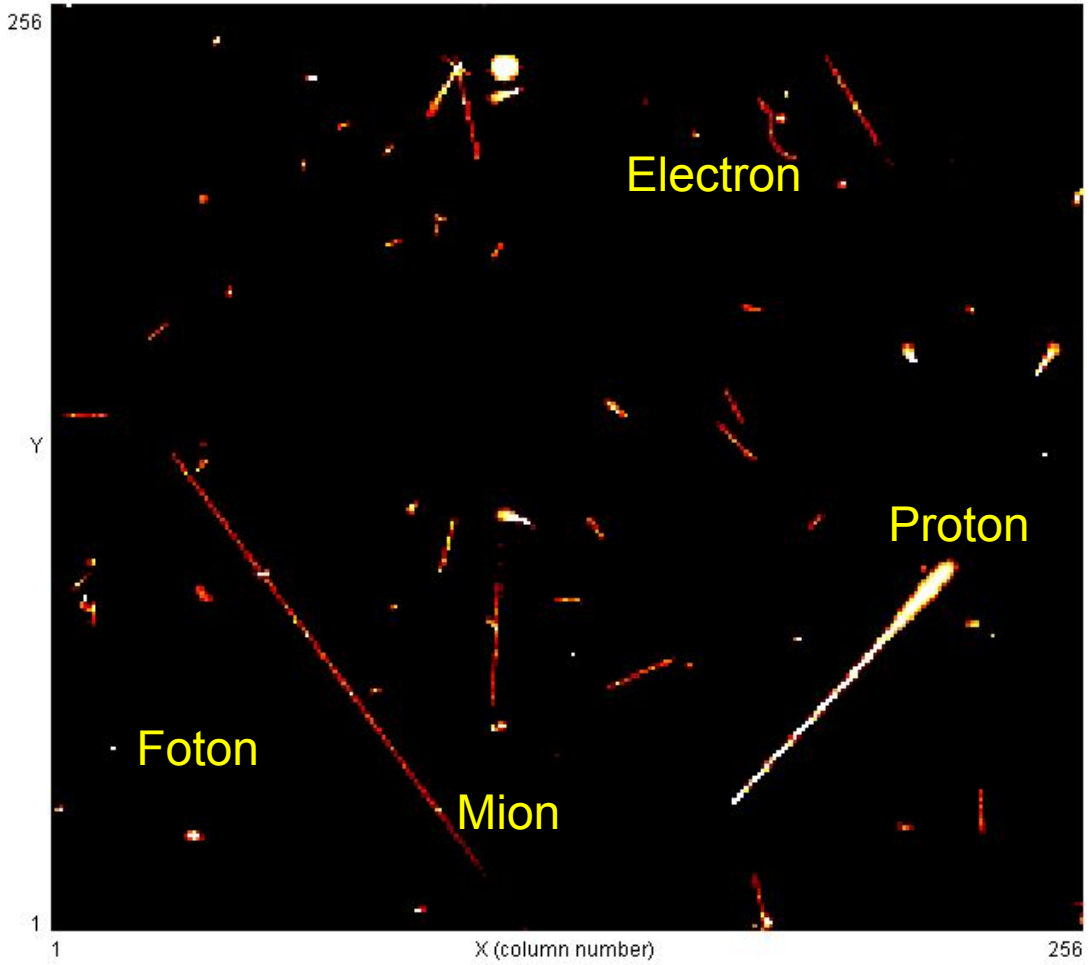
$$E = \gamma m c^2$$

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



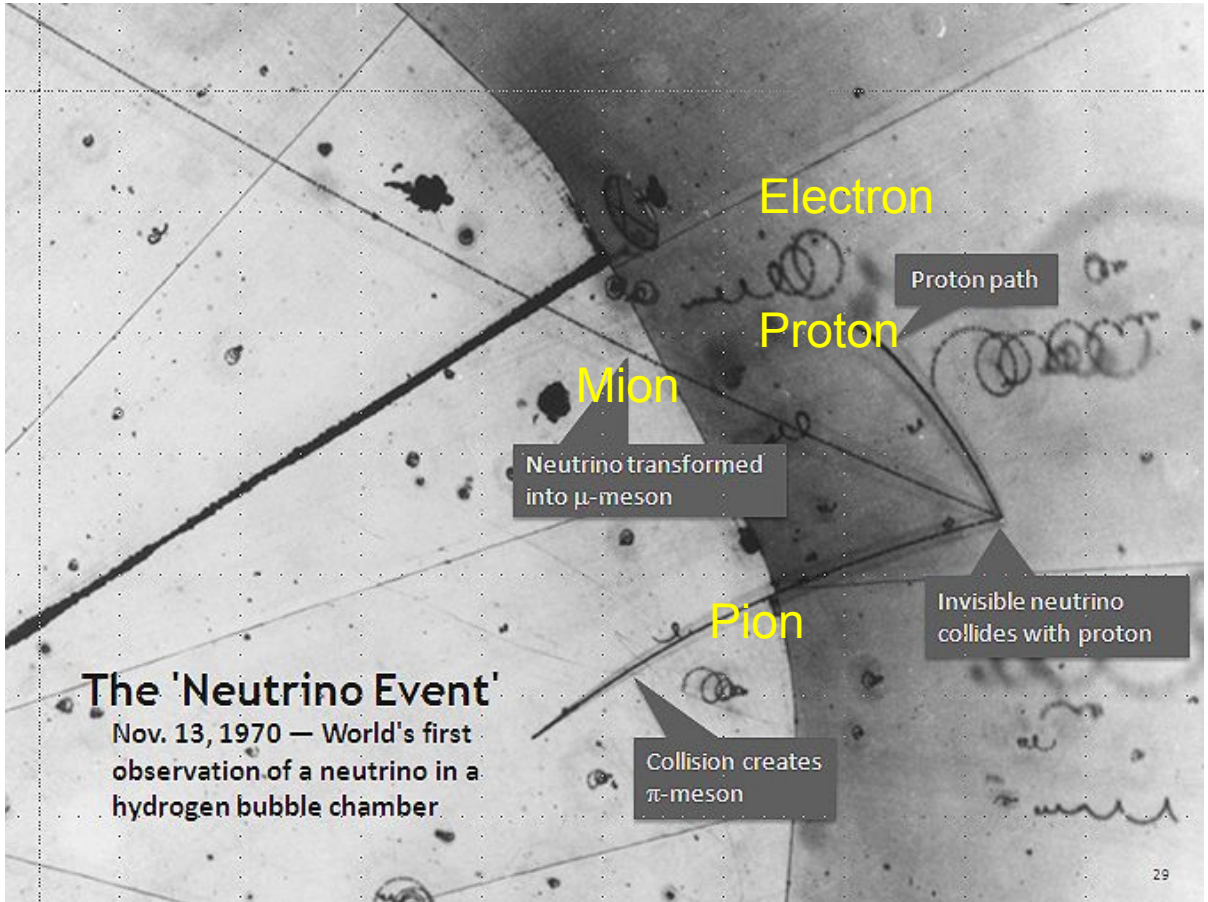
Částicová kamera



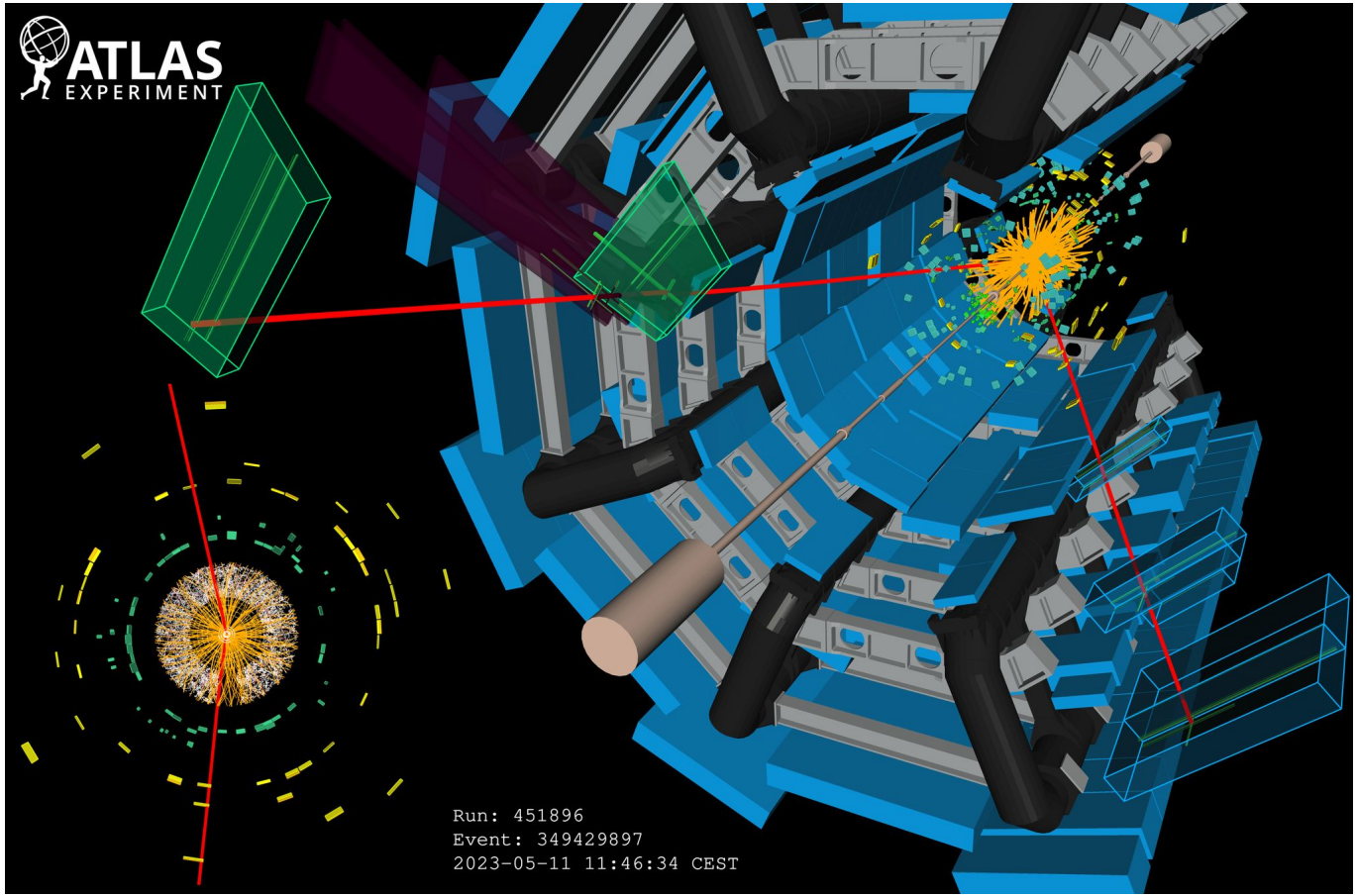


Bublinová komora

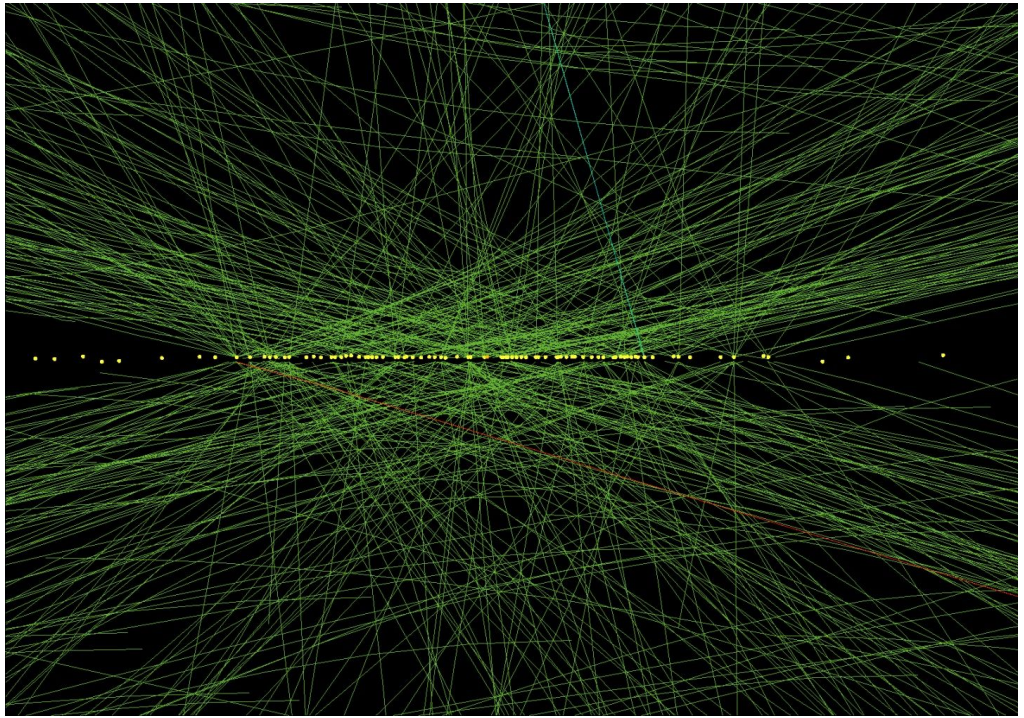
https://en.wikipedia.org/wiki/Neutrino

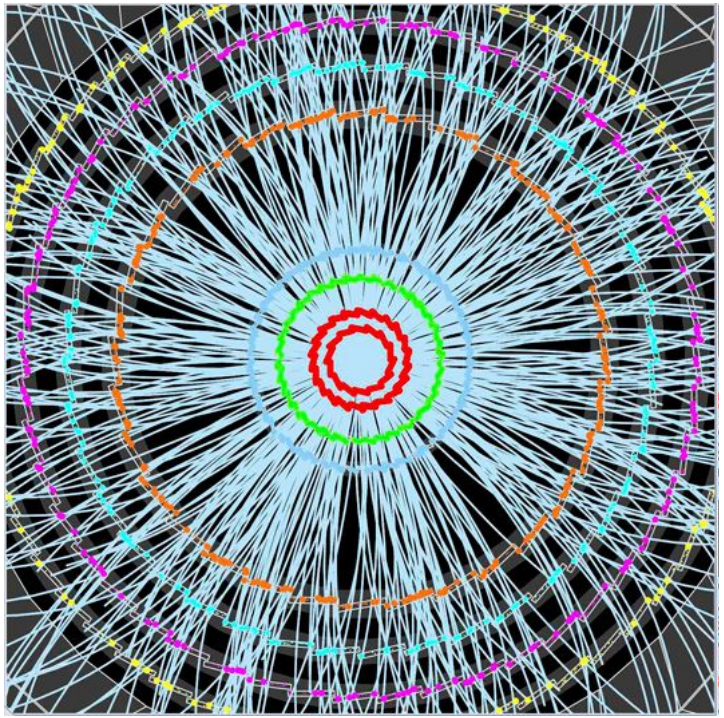


Data data data data data data data data data data …

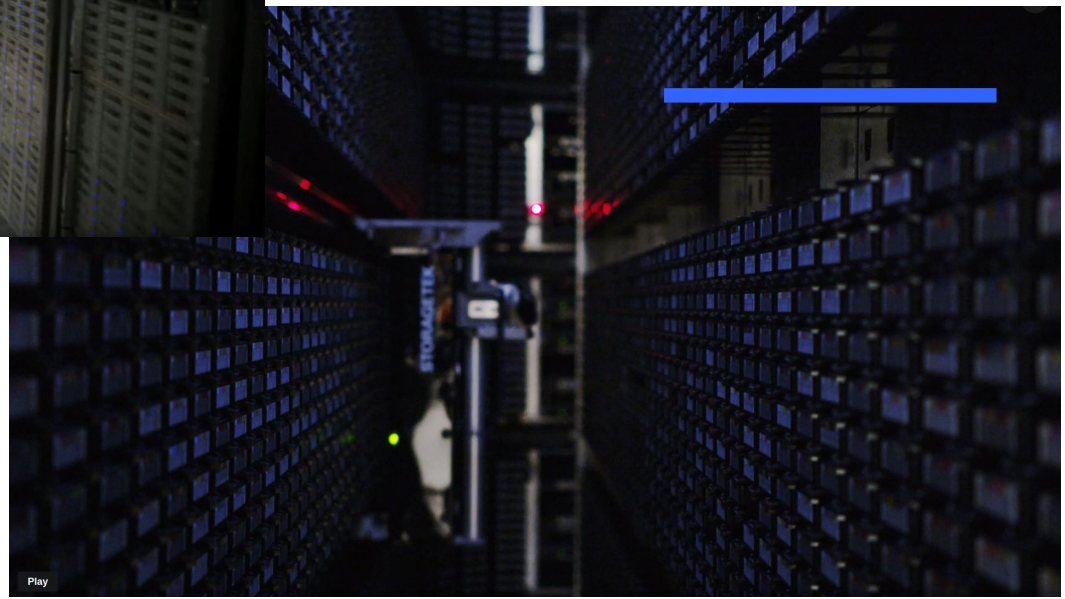


Data data data data data data data data data data data…





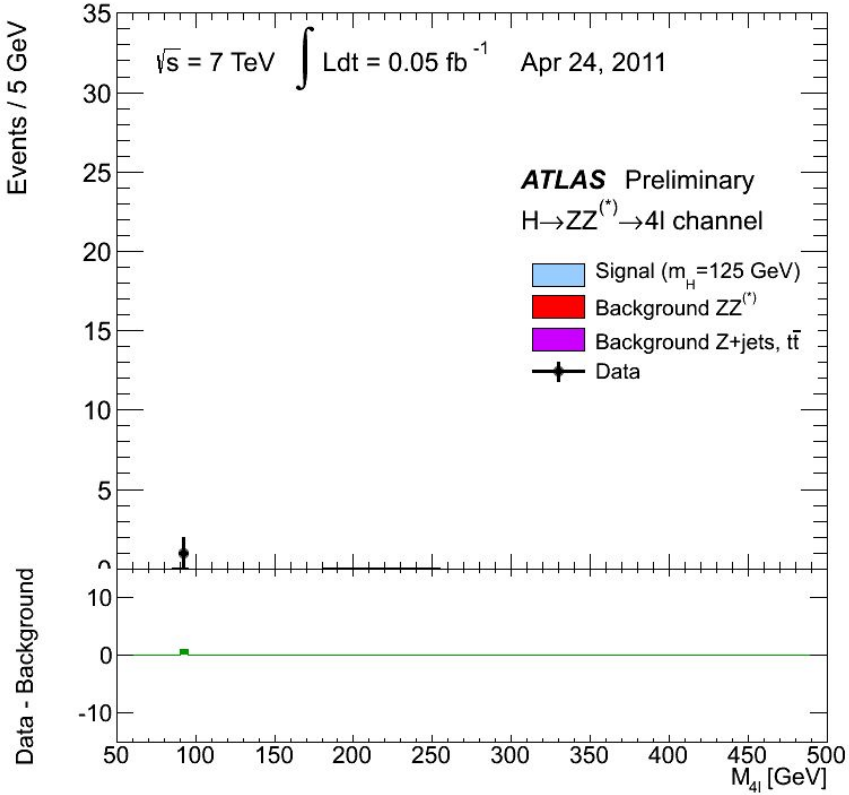
Data data data data data data data data data data data …

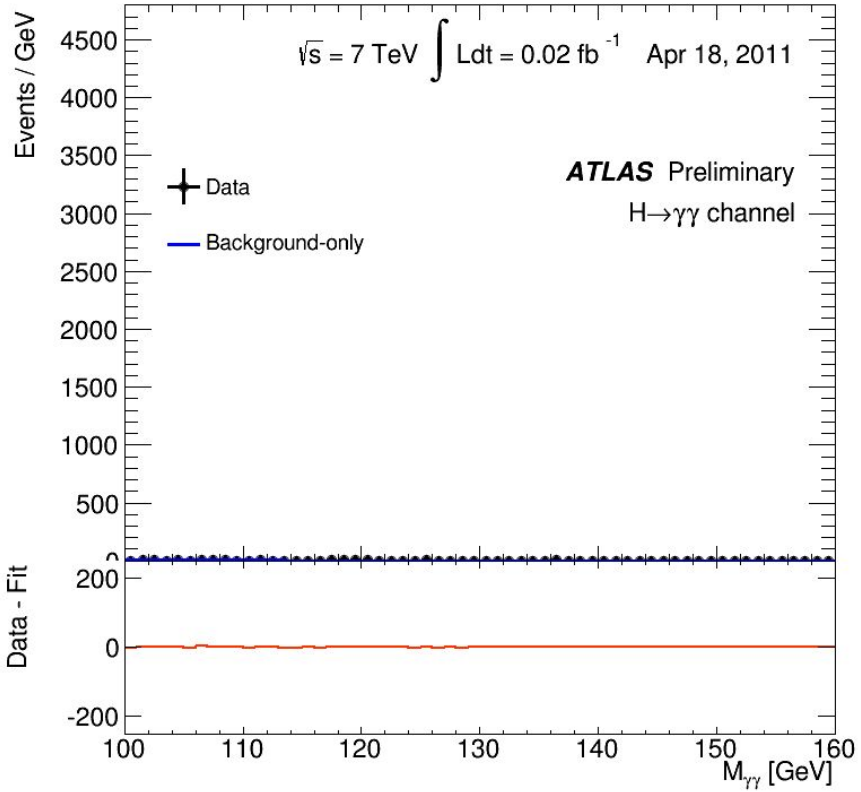


Data data data data data data data data data data …

```
1414
1415    cout << "*** Number of events in nominal and Alternative trees: " <<  nentr
1416
1417    // number of bytes read from TTrees
1418    Long64_t nbytes = 0;
1419    Long64_t nb_nominal = 0;
1420    Long64_t nb_nominalAlt = 0;
1421    Long64_t nb_ptcl = 0;
1422    Long64_t nb_truth = 0;
1423    m_ToRunOver = nentriesNominal;
1424    if (m_isMCsignal && m_runOverAllLevels) {
1425        // we need to go through all generated parton events
1426        // and find matching events in the detector nominal and particle trees
1427        m_ToRunOver = nentriesTruth;
1428    }
1429    if (m_isMCsignal && m_runOverPtclOnly) {
1430        m_ToRunOver = nentriesParticle;
1431    }
1432    // HACK!
1433    m_ToRunOver = 200000;
1434
1435    this -> InitLoop();
1436
1437    // +-----------+
1438    // |   LOOP!   |
1439    // +-----------+
1440
1441    if (m_isData) {
1442        cout << "Will run over " << m_ToRunOver << " entries." << endl;
1443    } else {
1444        cout << "Will run over " << m_ToRunOver << " entries while sumWeights i
1445        m_h_sumWeights -> SetBinContent(1, m_sumWeights);
1446        m_h_sumWeightsSq -> SetBinContent(1, m_sumWeightsSq);
1447    }
1448
1449
1450
1451    for (Long64_t jentry = 0; jentry < m_ToRunOver; jentry++) {
1452        if (jentry % verbose == 0) {
1453            cout << "Processing " << jentry << "/" << m_ToRunOver << endl;
1454        }
1455        nb_nominal = 0;
```

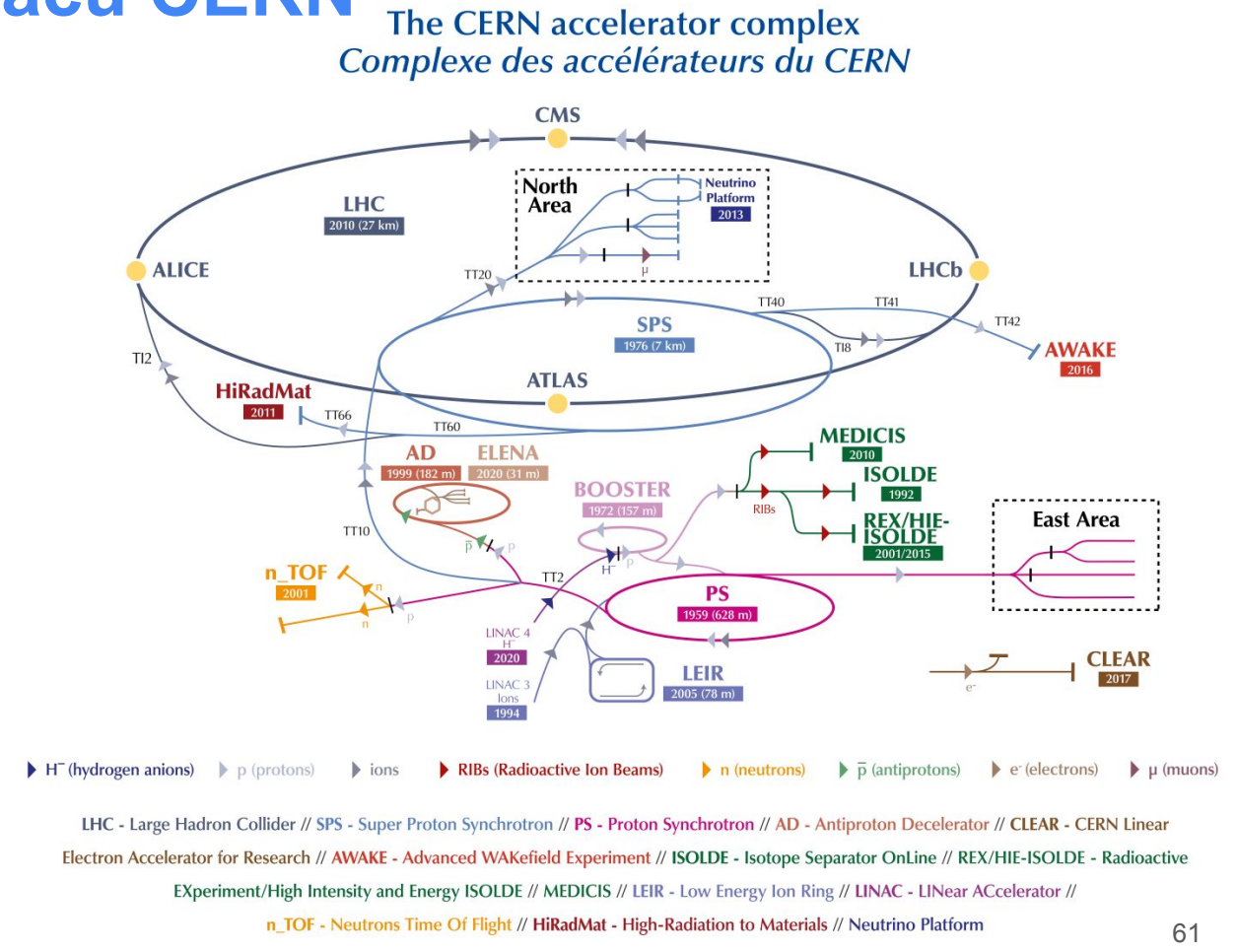
Data data data data data data data data data data …





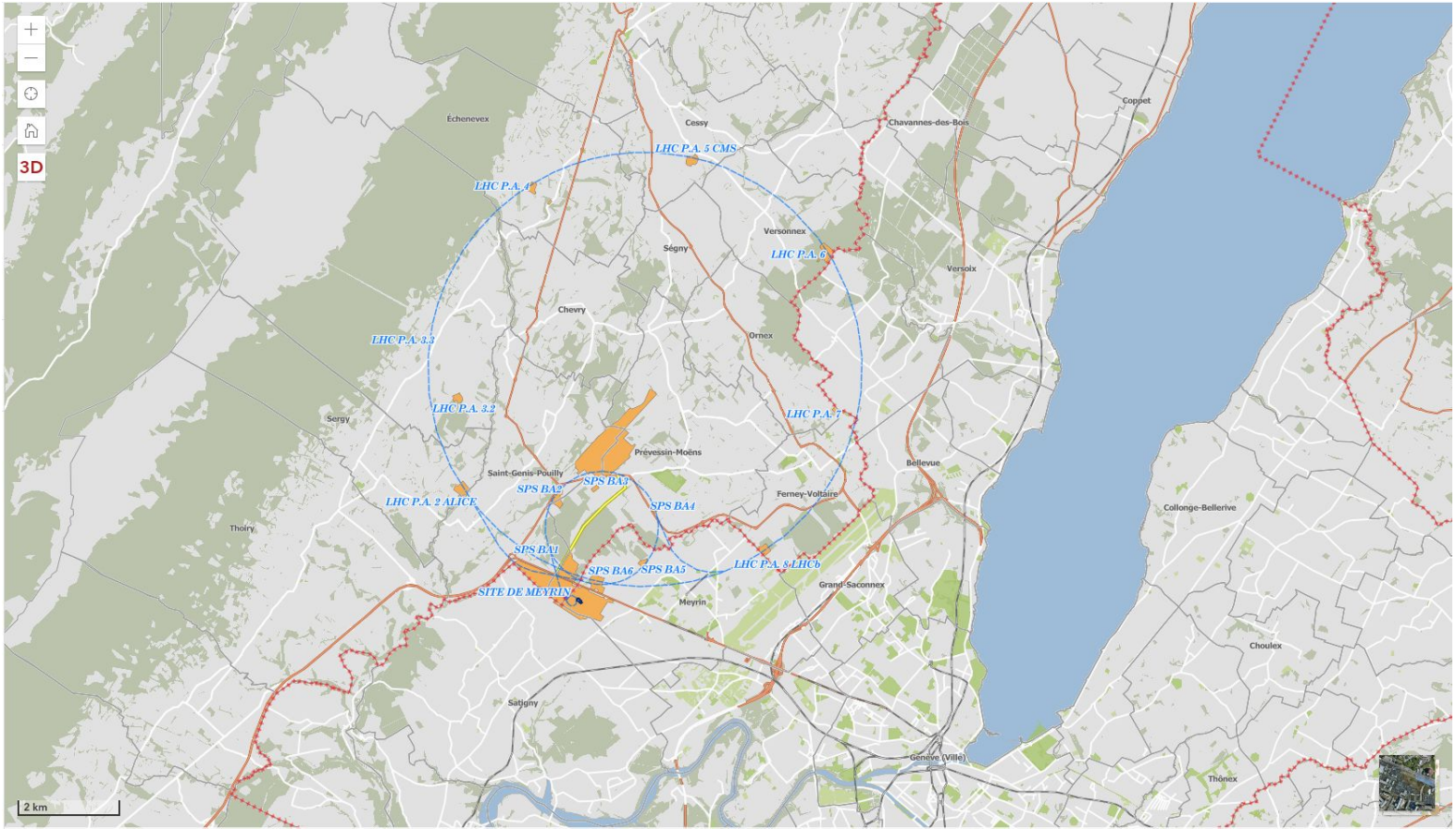
And now…
From Big Data
and
Big Experiments…
To Table-Top Experiments!

Komplex urychlovačů CERN



https://home.cern/science/accelerators/accelerator-complex

CERN :: https://maps.web.cern.ch/



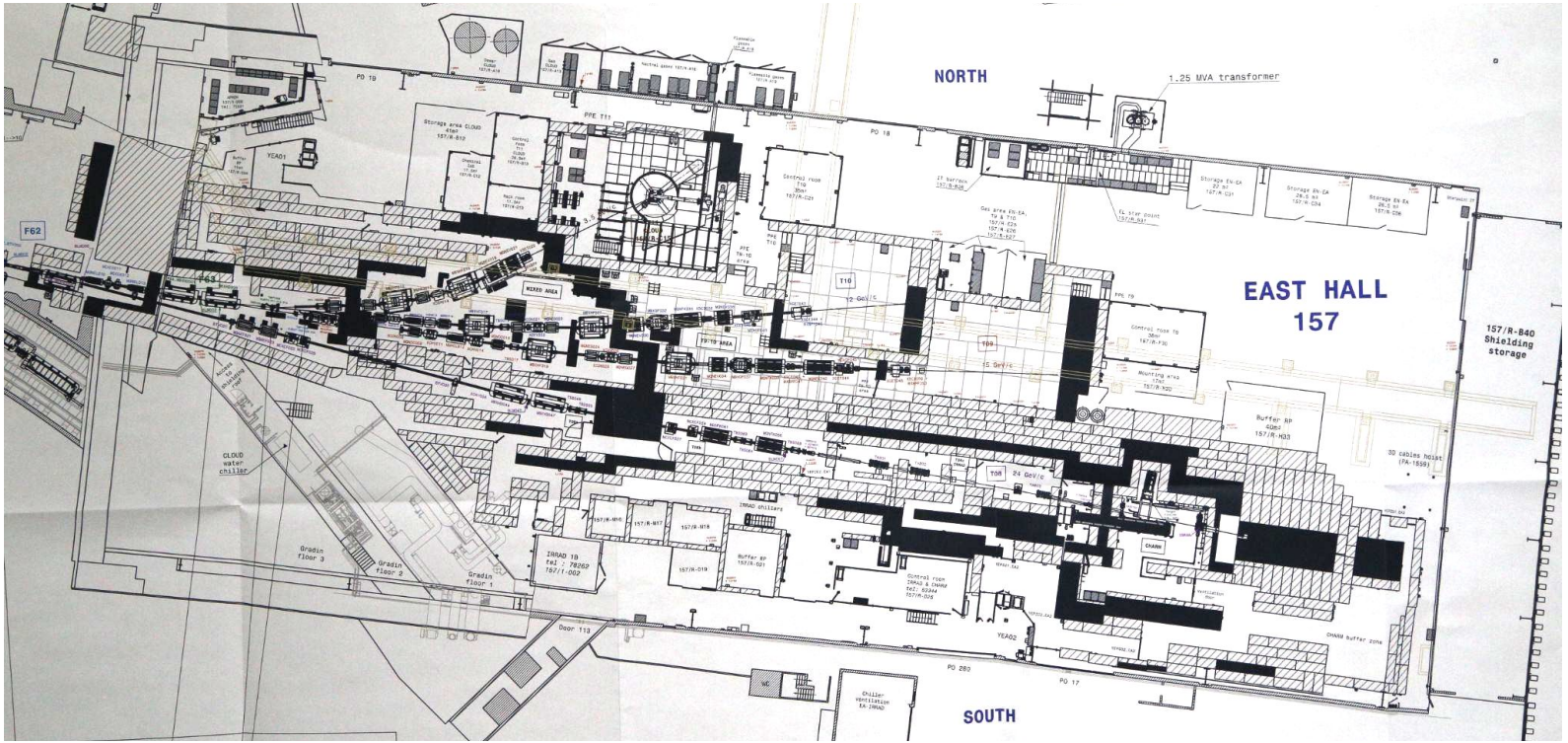
CERN :: https://maps.web.cern.ch/

East Area 2022

- Building 157 at CERN's Meyrin site, large experimental hall housing also the CLOUD experiment, T8, T9 and T10 beam lines.

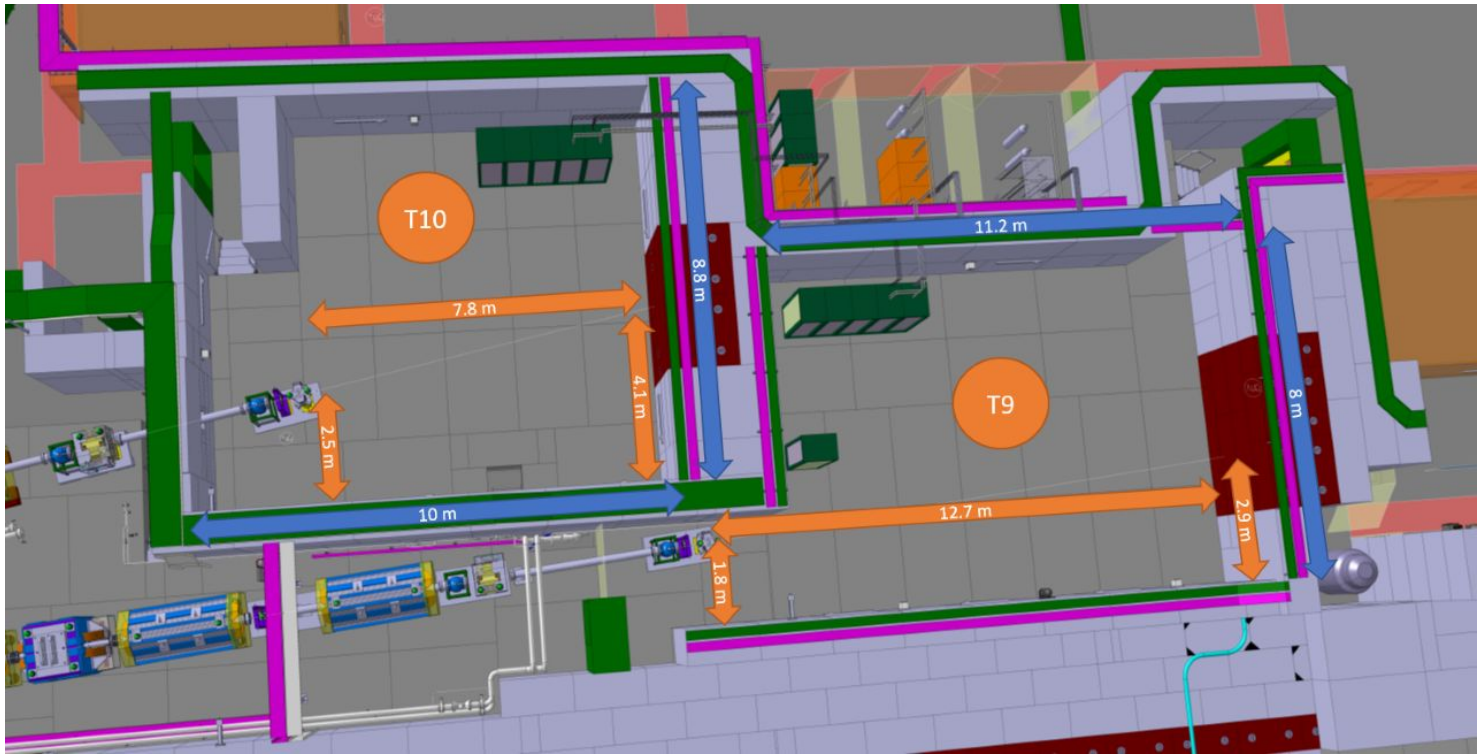
East Area

- Building 157 at CERN's Meyrin site, large experimental hall housing also the CLOUD experiment, T8, T9 and T10 beam lines.



East Area

- Building 157 at CERN's Meyrin site, large experimental hall housing also the CLOUD experiment, T8, T9 and T10 beam lines.



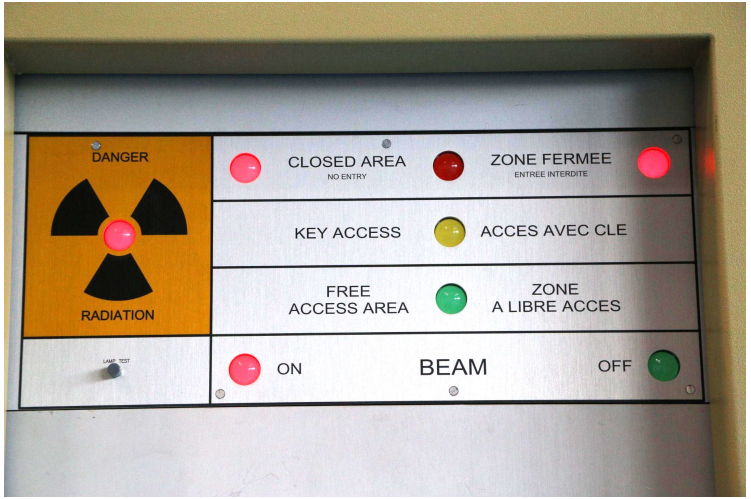
East Area

- Building 157 at CERN’s Meyrin site, large experimental hall housing also the CLOUD experiment, T8, T9 and T10 beam lines.

East Area

East Area 2022

- Experimentální hala v budově 157
- Svazkové linie T8, T9 and T10, CLOUD experiment…



East Area 2023

- Experimentální hala v budově 157
- Svazkové linie T8, T9 and T10, CLOUD experiment…

East Area 2023

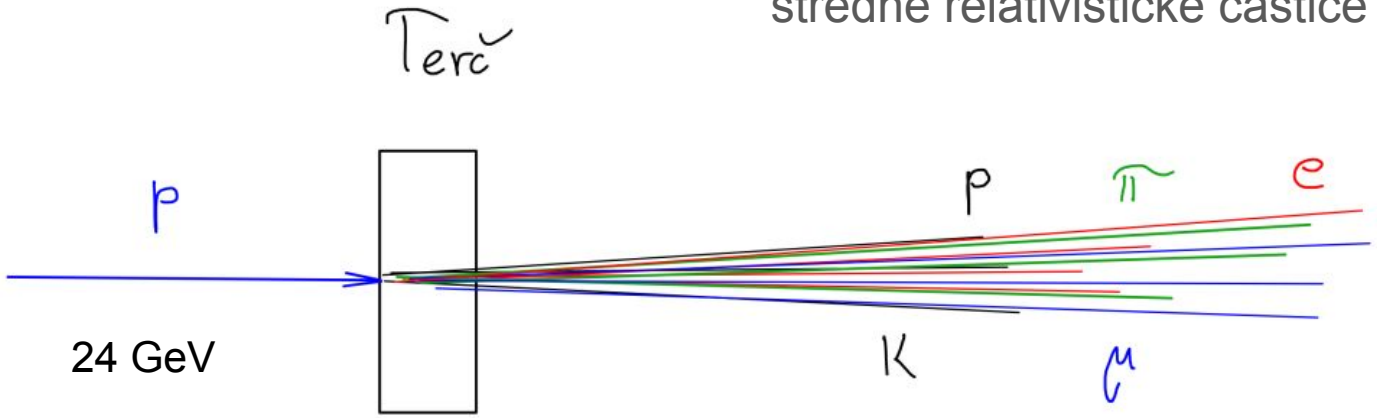
- Experimentální hala v budově 157
- Svazkové linie T8, T9 and T10, CLOUD experiment…

East Area 2023

- Experimentální hala v budově 157
- Svazkové linie T8, T9 and T10, CLOUD experiment…

East Area: Sekundární svazky částic pro testování

středně relativistické částice



$|\vec{p}|$ 200 MeV ≃ 1 GeV

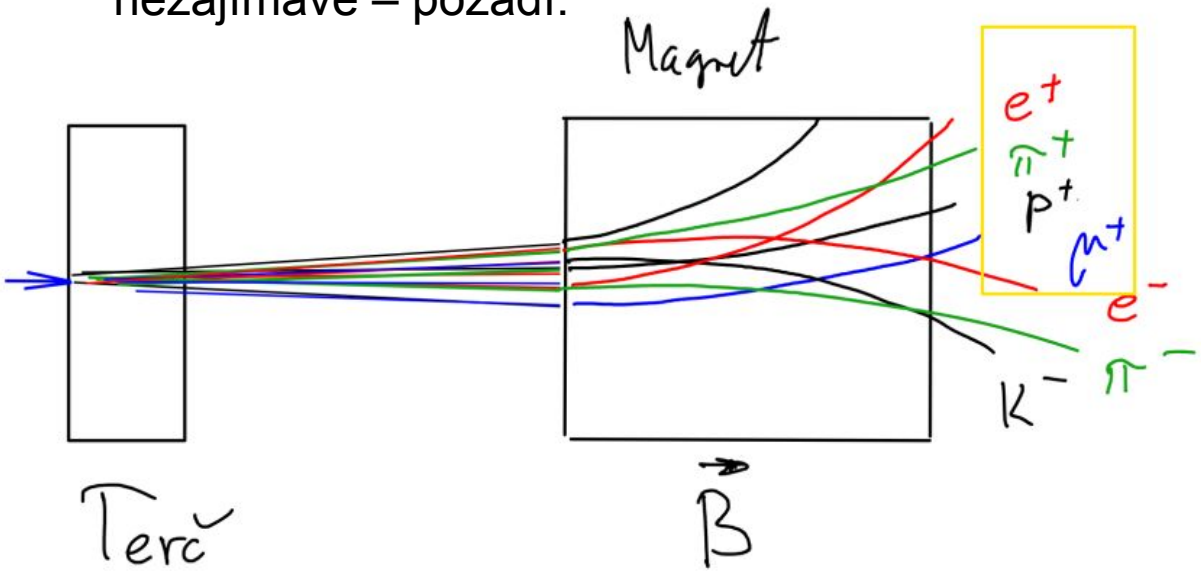
Analýza složení svazku

$$p = m v \qquad \beta \equiv \frac{v}{c}$$

$$p = \gamma m v = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} m v$$

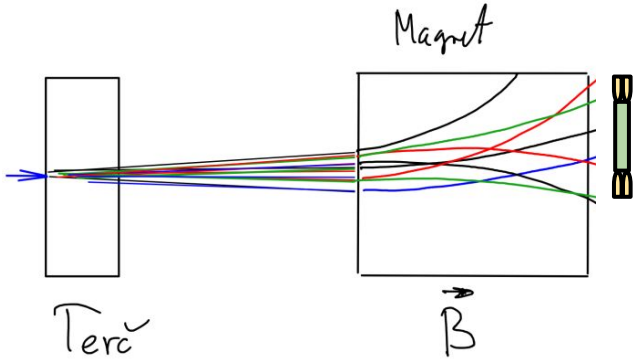
$$p = \beta \gamma mc = \frac{1}{\sqrt{1 - \beta^2}} \beta mc$$

- Sekundární svazek částic o různých hybnostech
- Dominováno elektrony, ale ty mohou být nezajímavé – pozadí.

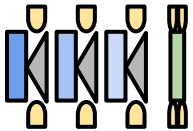


Analýza složení svazku

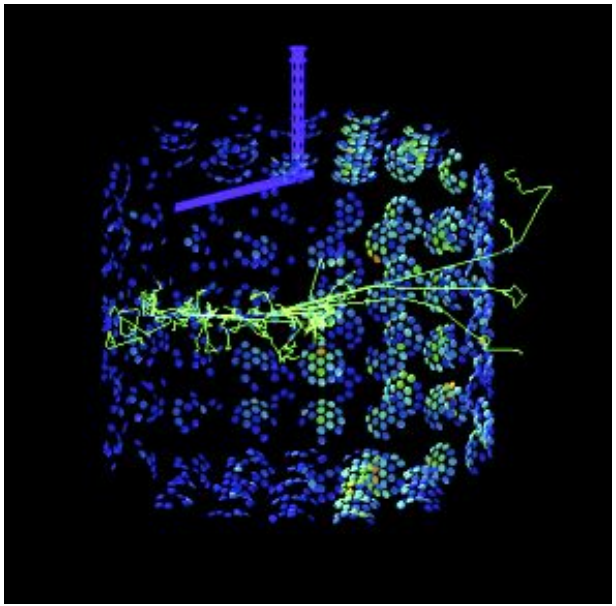
- Jaké je složení svazku?
- Bude v něm dost pionů a mionů na kalibraci odezvy detektoru na tyto částice?
- ⇒ Identifikace částic!
    - pro budovaný experiment.



Monitor svazku

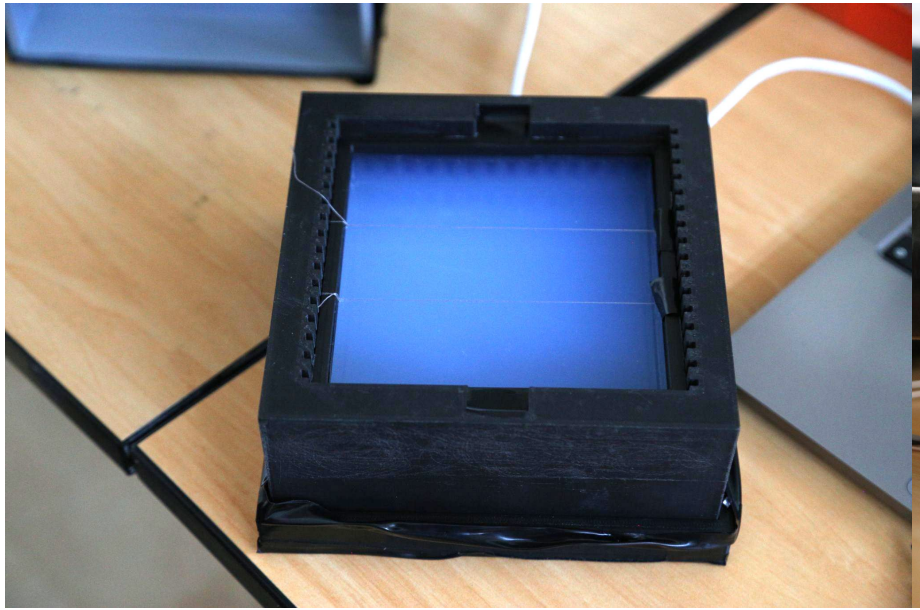


Budoucí experiment



Installation :: Aerogelové Čerenkovské detektory

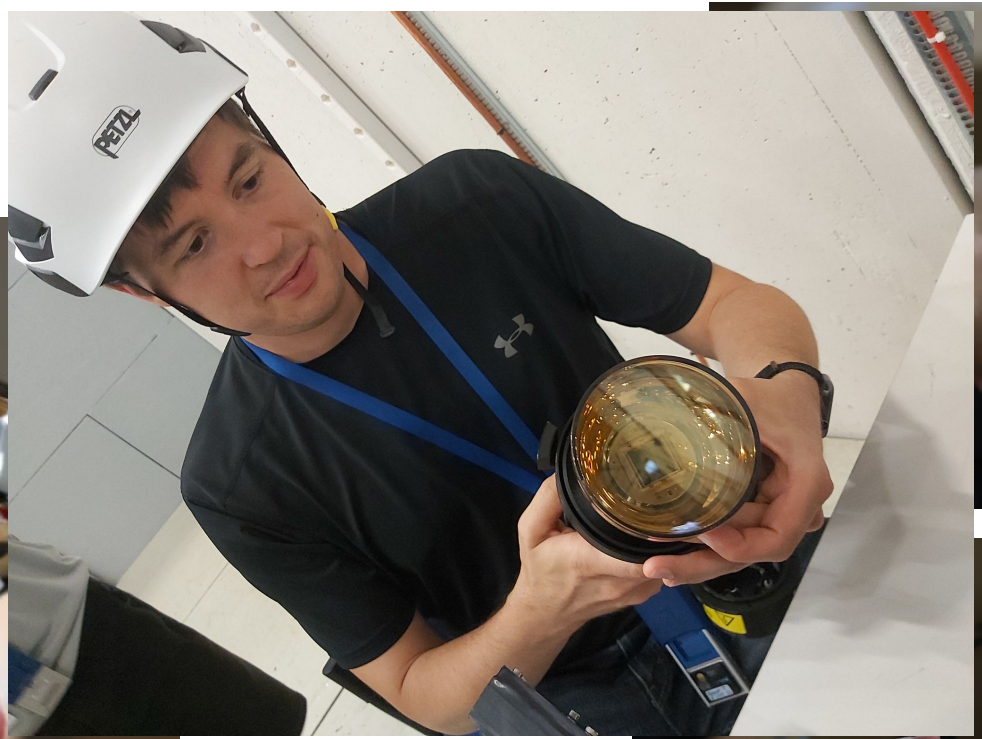
- Průhledný materiál, v kterém září částice, pokud se pohybují rychlostí větší než rychlost světla v daném prostředí: elektromagnetická rázová vlna.
- **Aerogel: Nejlehčí pevná látka!**
- Světlo je reflexní fólií odraženo do citlivých detektorů světla, fotonásobičů (PhotoMultiplier Tube, PMT):

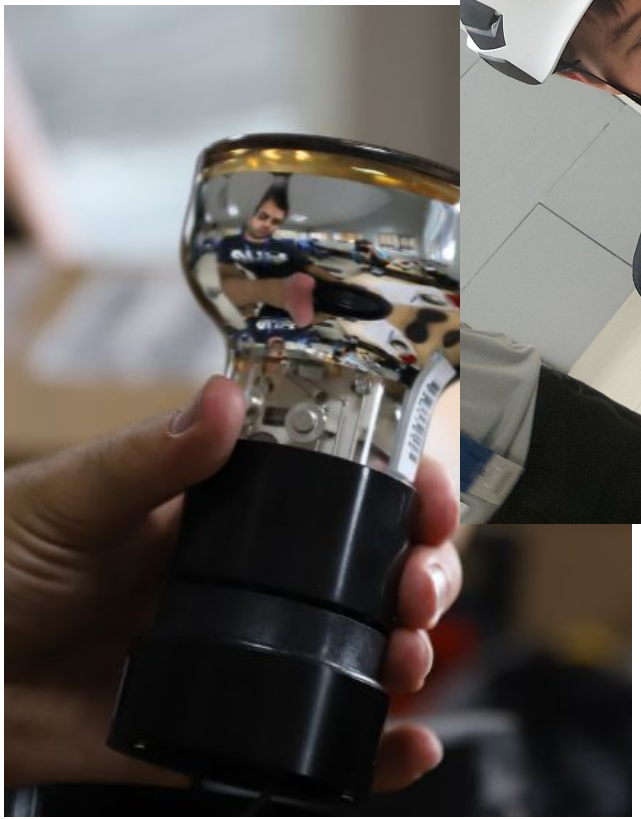


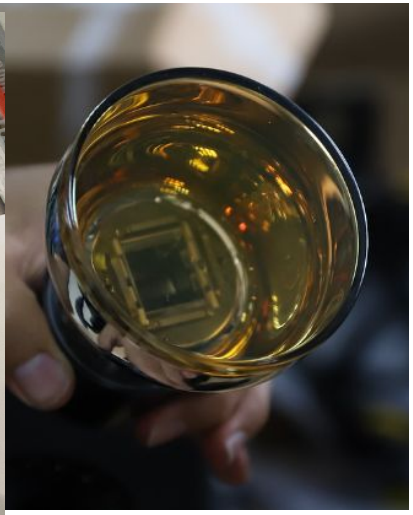
Aerogel

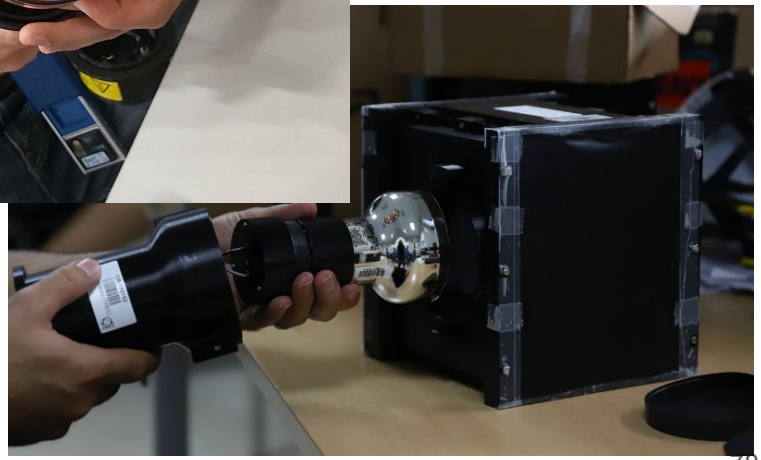
- **Nejlehčí pevná látka: World's Lightest Solid!**
  - https://www.youtube.com/watch?v=AeJ9q45PfD0&ab_channel=Veritasium

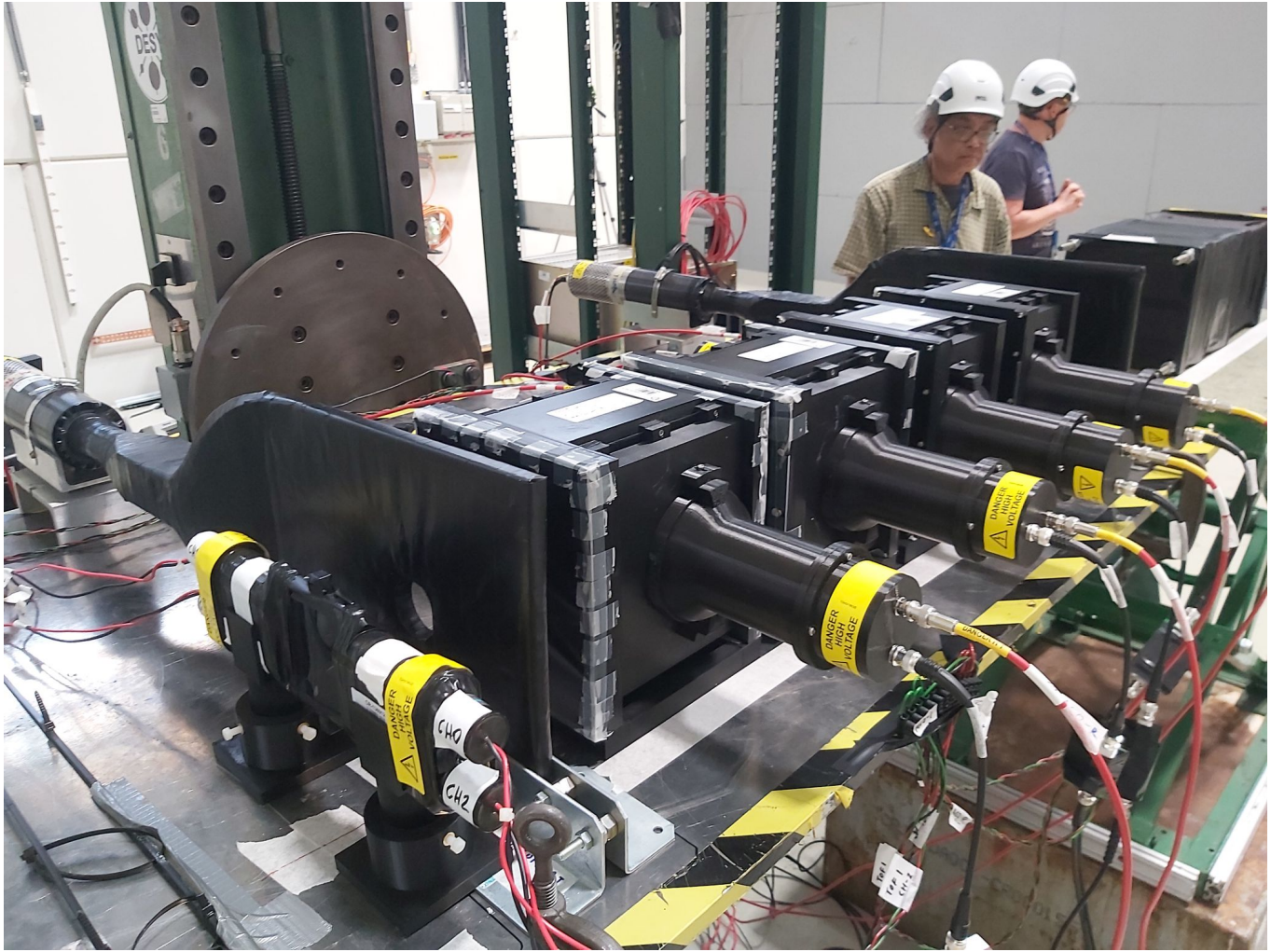
Fotonásobič

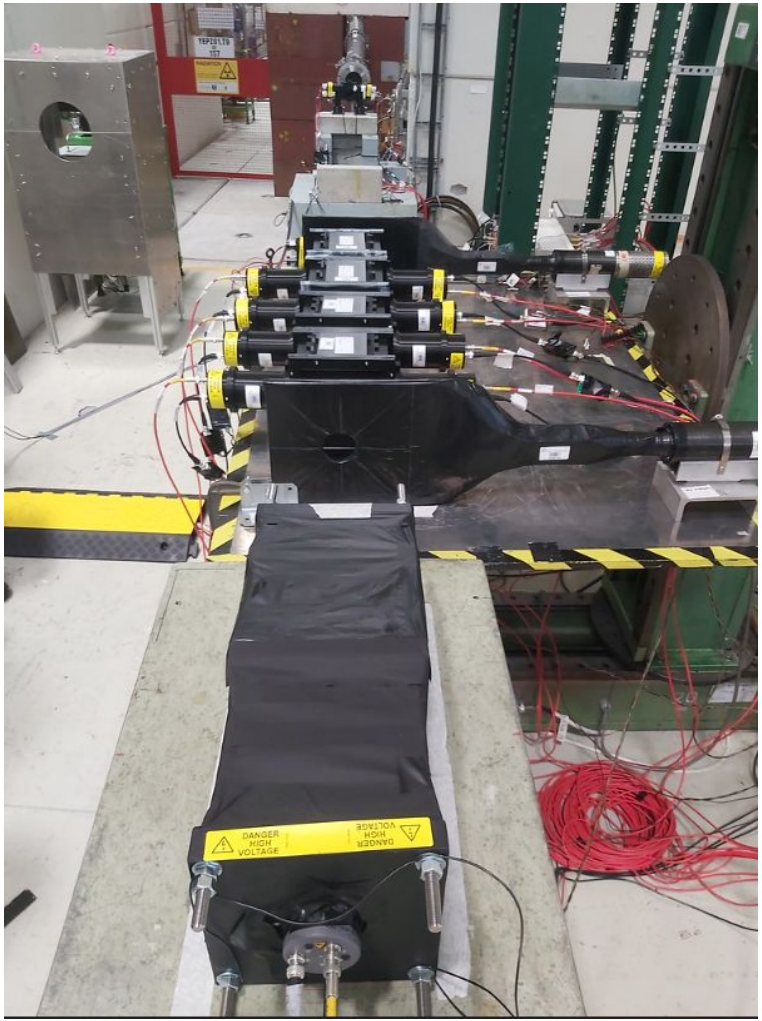






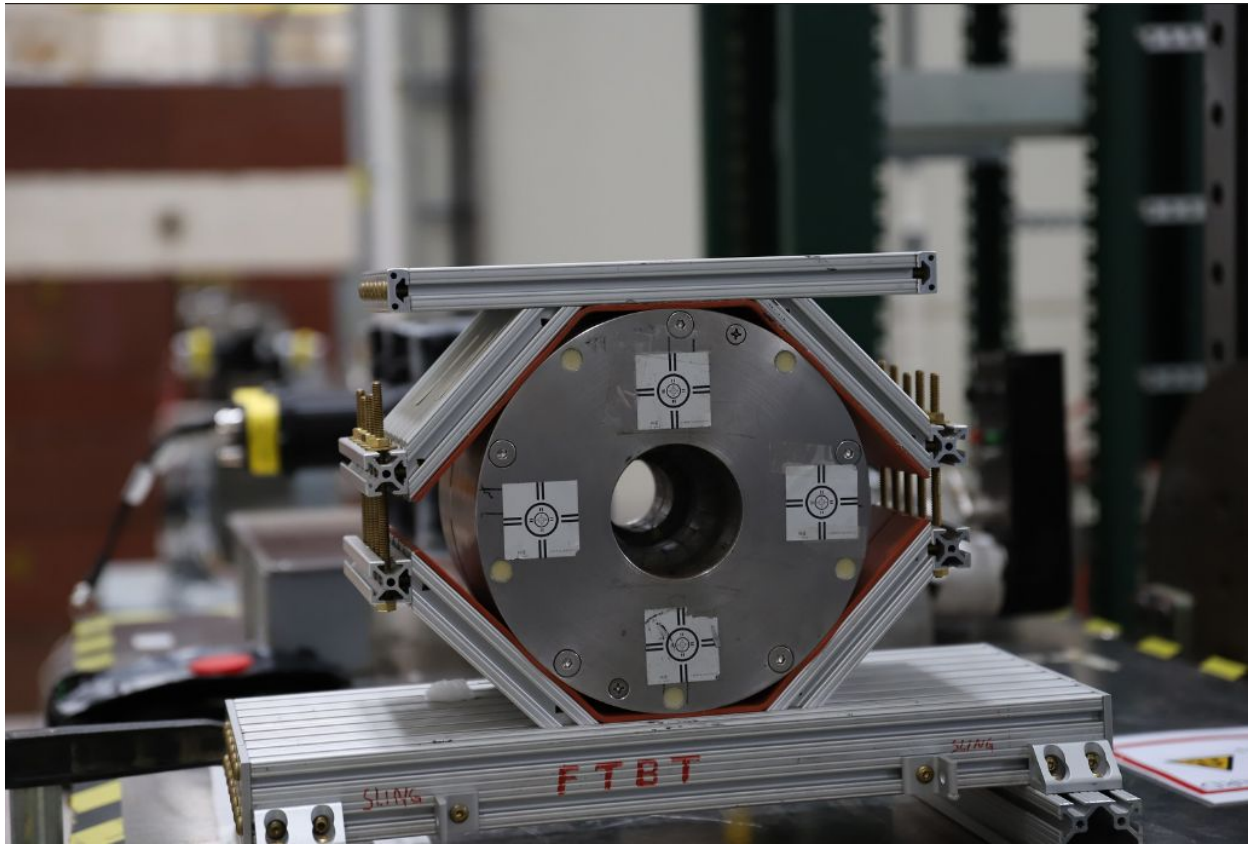



DANGER
HIGH
VOLTAGE
DANGER
HIGH
VOLTAGE
DANGER
HIGH
VOLTAGE
CH2
CH2

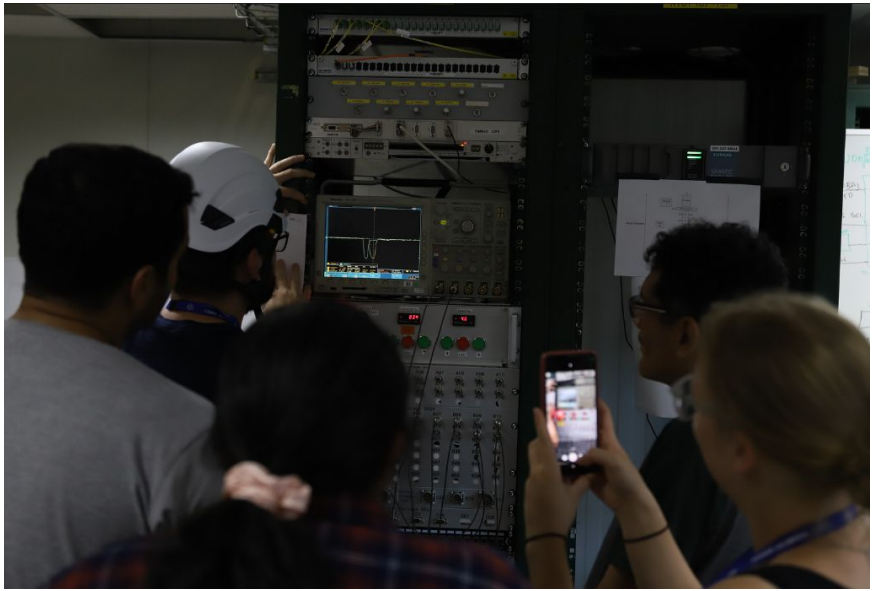

DANGER
HIGH
VOLTAGE

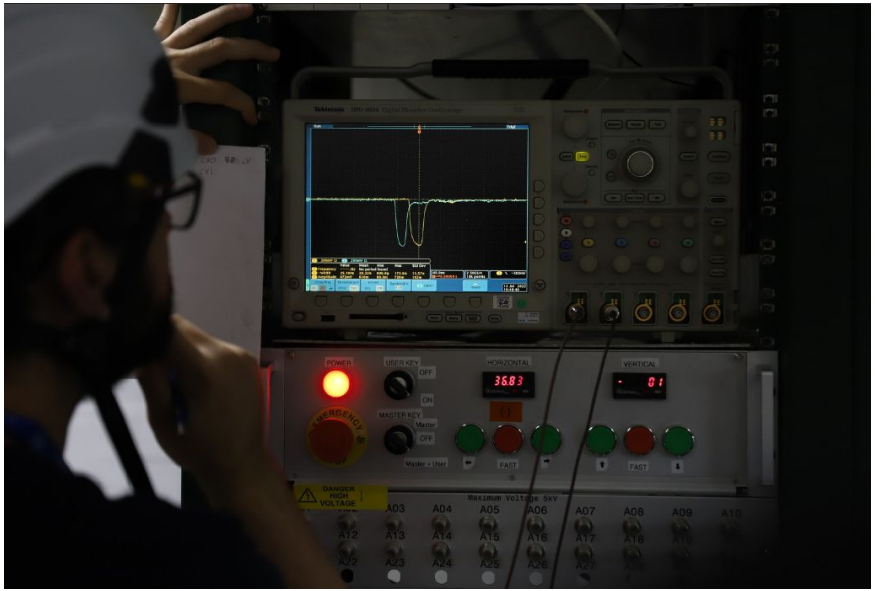

DANGER H T
15
Pb glass

Meet Mr. Permanent Magnet of 1.7T!

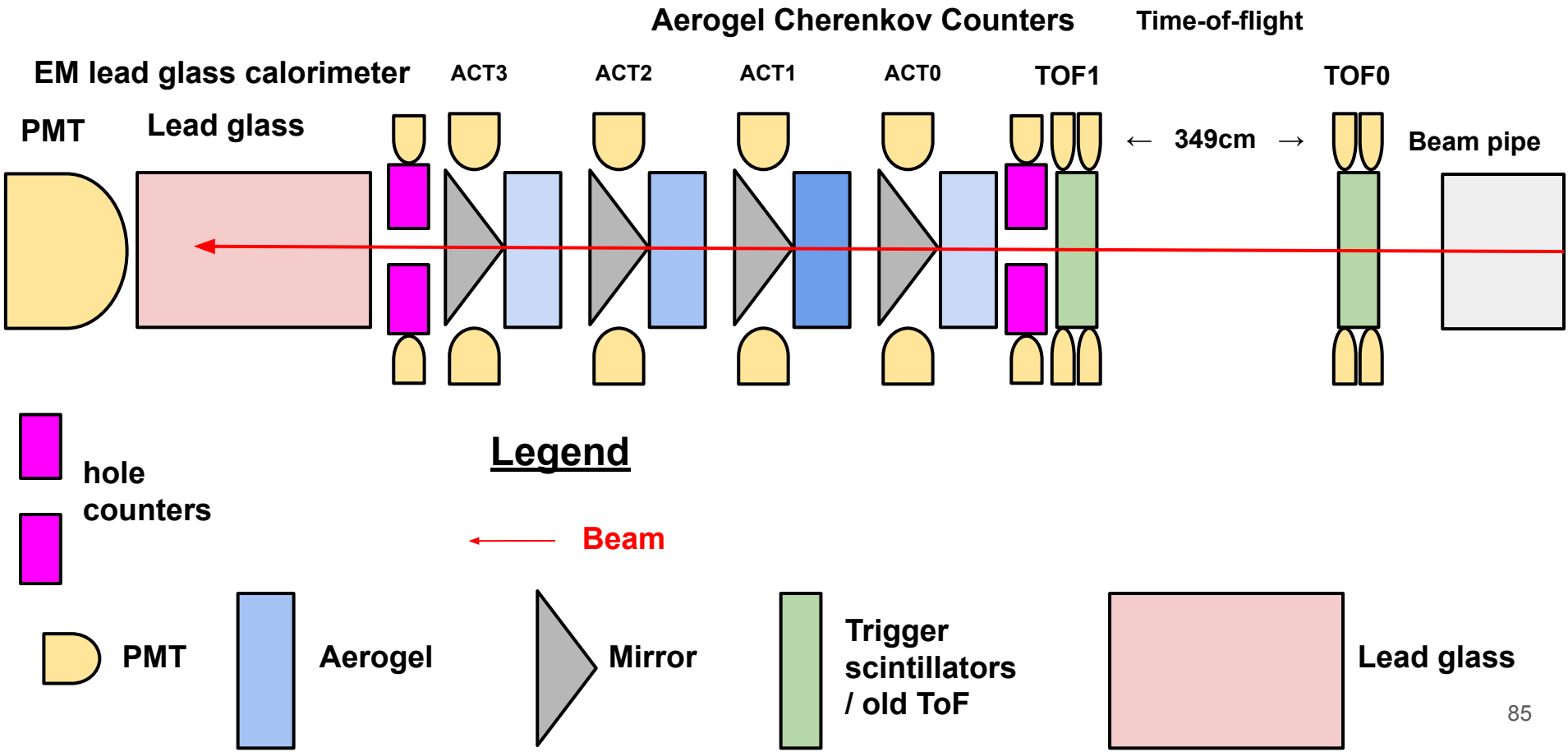



SEARCH
BUA
INCINERABLE RADIOACTIVE WASTE
DECHET INCINERABLE RADIOACTIF
ELECTRONIC & CABLE RADIOACTIVE WASTE
DECHET ELECTRONIQUE + CÂBLE RADIOACTIF
METALLIC RADIOACTIVE WASTE
DECHET METALLIQUE RADIOACTIF
CONVENTIONAL WASTE
DECHETS CONVENTIONNELS
72504

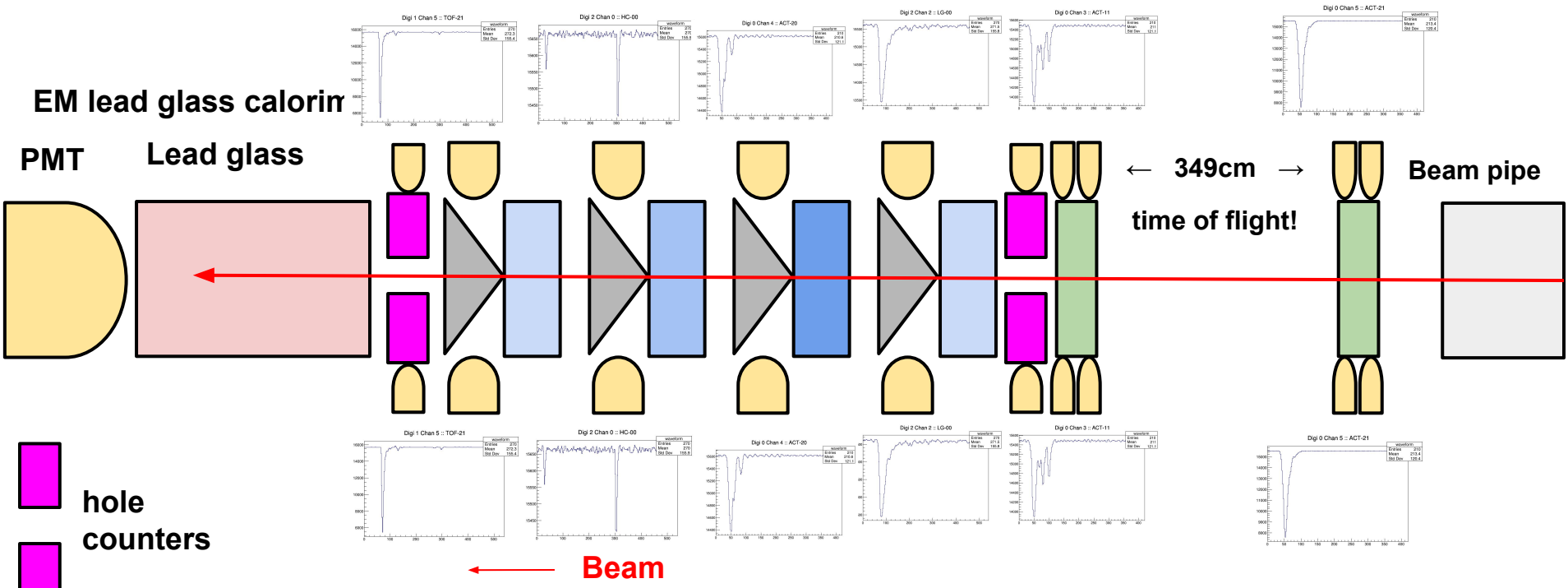



POWER
USER KEY
OFF
ON
MASTER KEY
Master
OFF
HORIZONTAL
3683
VERTICAL
01
EMERGENCY
FAST
FAST
DANGER
HIGH
VOLTAGE
Maximum Voltage 5kV

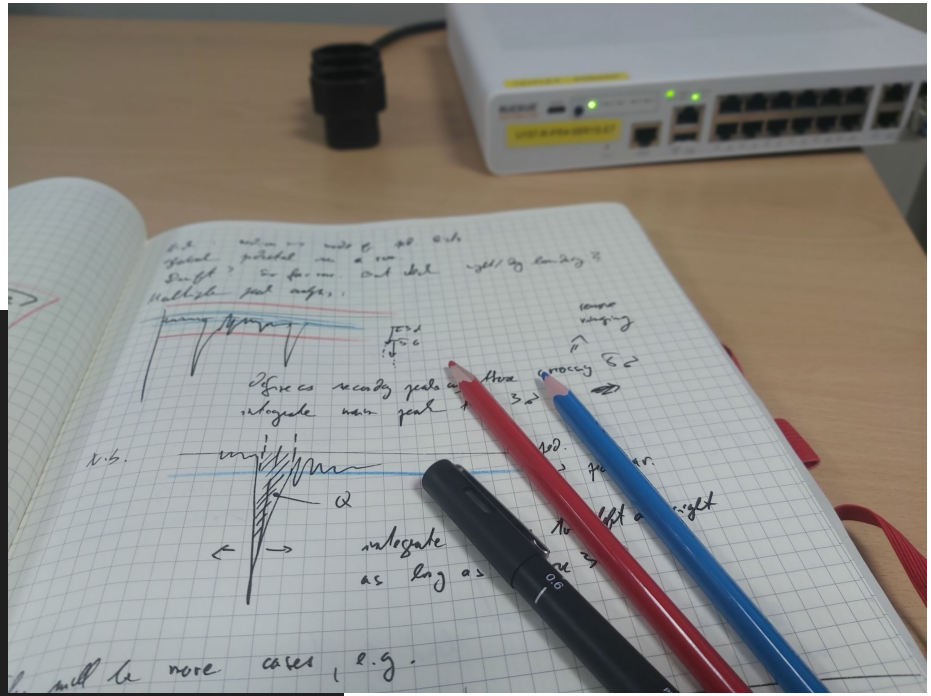
Setup overview updated 2023



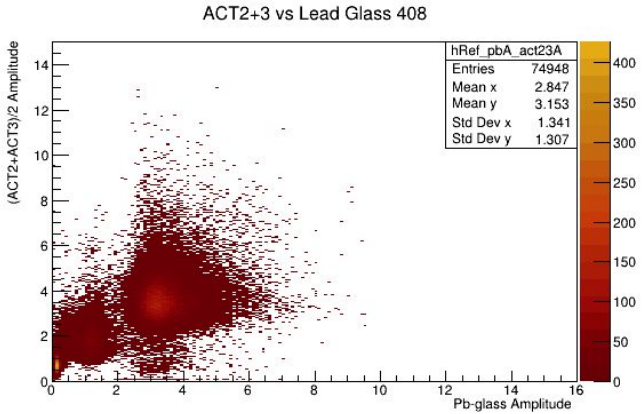
Setup overview updated 2023

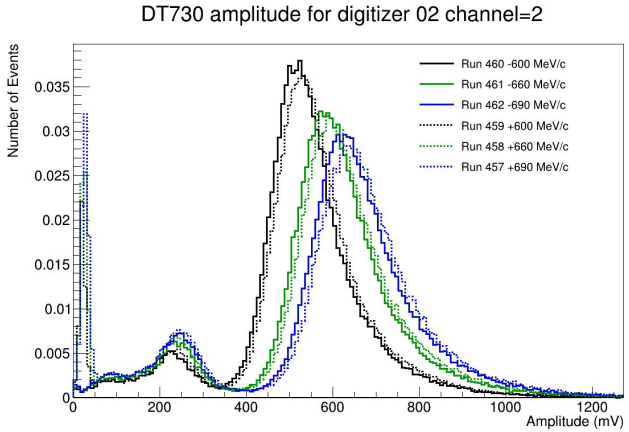


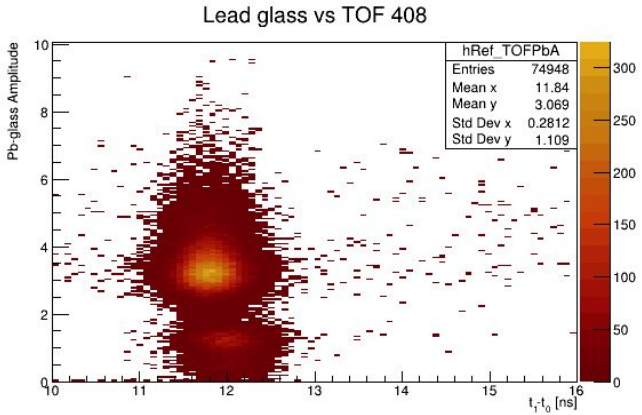
```
366   // +--------------------------------+
367   // |         event loop             |
368   // +--------------------------------+
369
370   cout << "Event loop!" << endl;
371
372   // TODO:
373   // check also the number of entries in the trees?
374
375   for(int ientry = 0; ientry < _ent[0]; ientry++) {
376
377     if (ientry % verbose == 0) {
378       cout << "processing " << ientry << " / " << _ent[0] << endl;
379     }
380
381     _eventInfo -> GetEntry(ientry);
382     Long64_t  RunNumber = _eventInfo -> RunNumber;
383     Int_t EventNumber = _eventInfo -> EventNumber;
384     Int_t SpillNumber = _eventInfo -> SpillNumber;
385     //    cout << " RunNumber=" << RunNumber << " EventNumber=" << EventNumber << " SpillNumber=" << SpillNumber << endl;
386
387     for (int ich = 0; ich < _nChannels; ++ich) {
388       if (_debug) cout << "getting entry for " <<  _treeNames[ich] << endl;
389       _reader[ich] -> GetEntry(ientry);
390     }
391     if (_debug)      cout << "done" << endl;
392
393
394     this -> ReadChannels();
395
396     // peak cuts on demand
397     if (!_isHodoscopeRun) {
398       if (! this -> PassedPeakCuts())
399   continue;
```

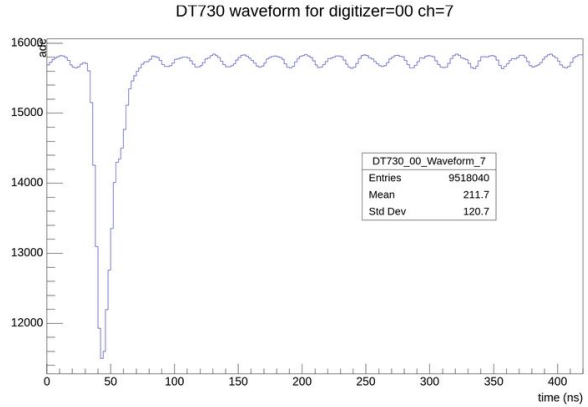


Současná analýza dat z více fotonásobičů



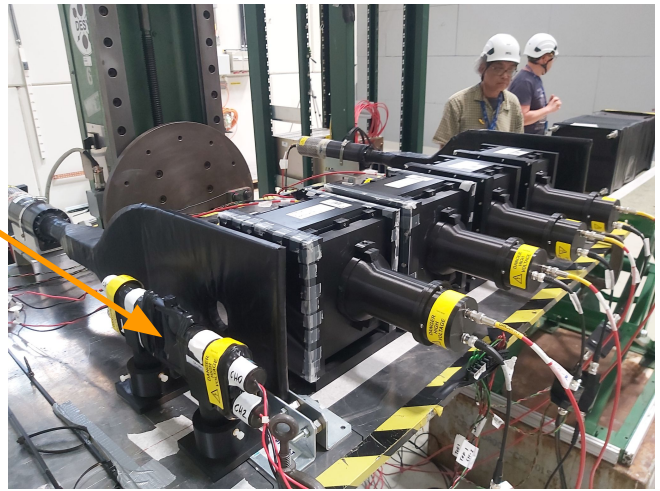






Měření doby letu částic = time of flight!

- Lze použít k identifikaci částic.
- Time-of-flight scintillators, 349cm apart.

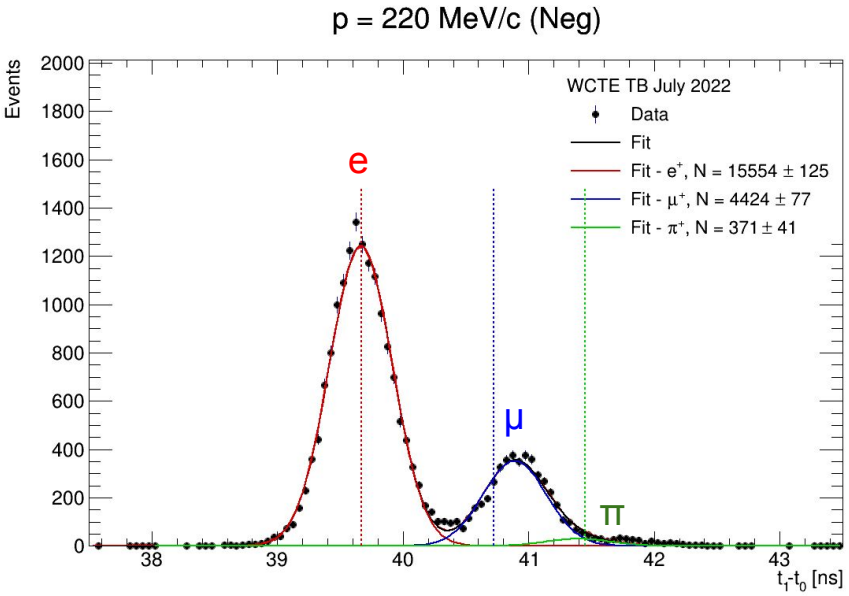


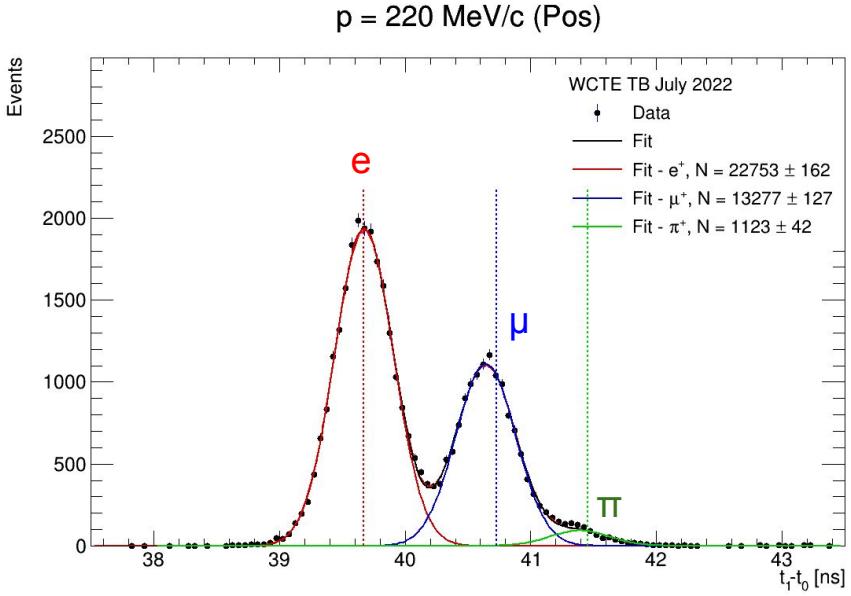
Měření doby letu částic = time of flight!

- Lze použít k identifikaci částic.
- Time-of-flight scintillators, 349cm apart.

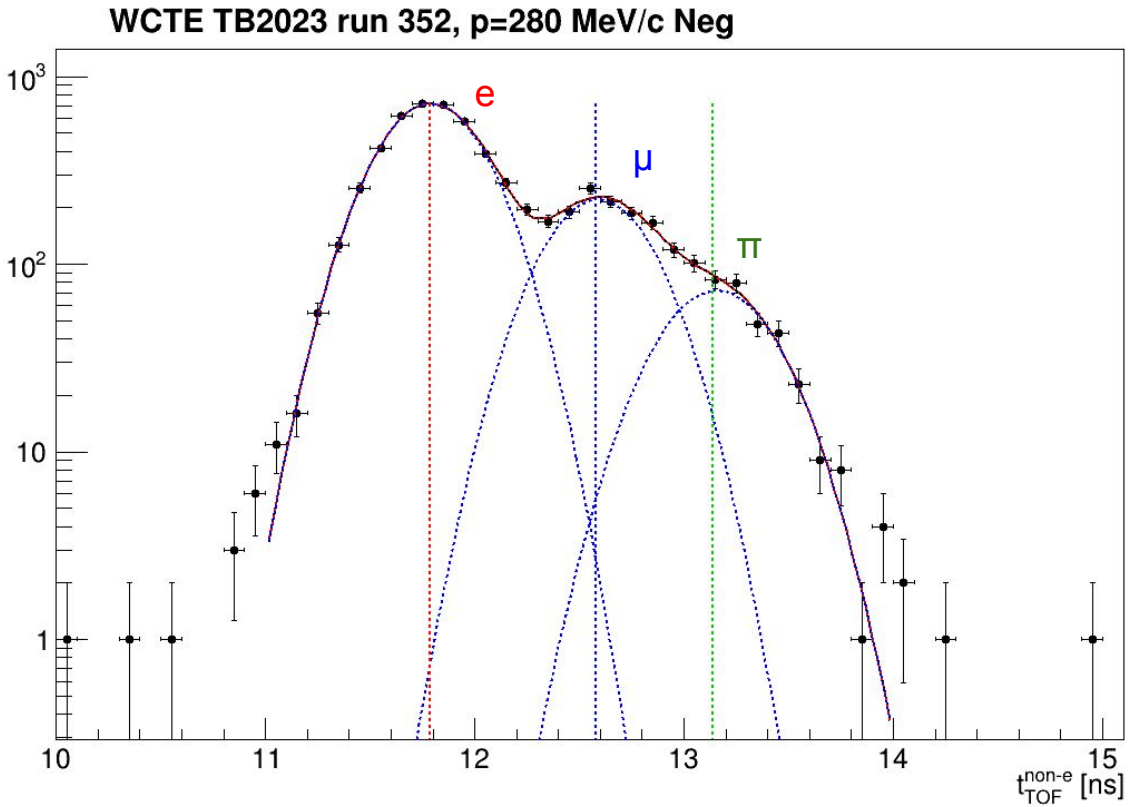
Výsledky 2022

- Vertikální linky: teoretické časy příletu μ a π za peakem elektronů.



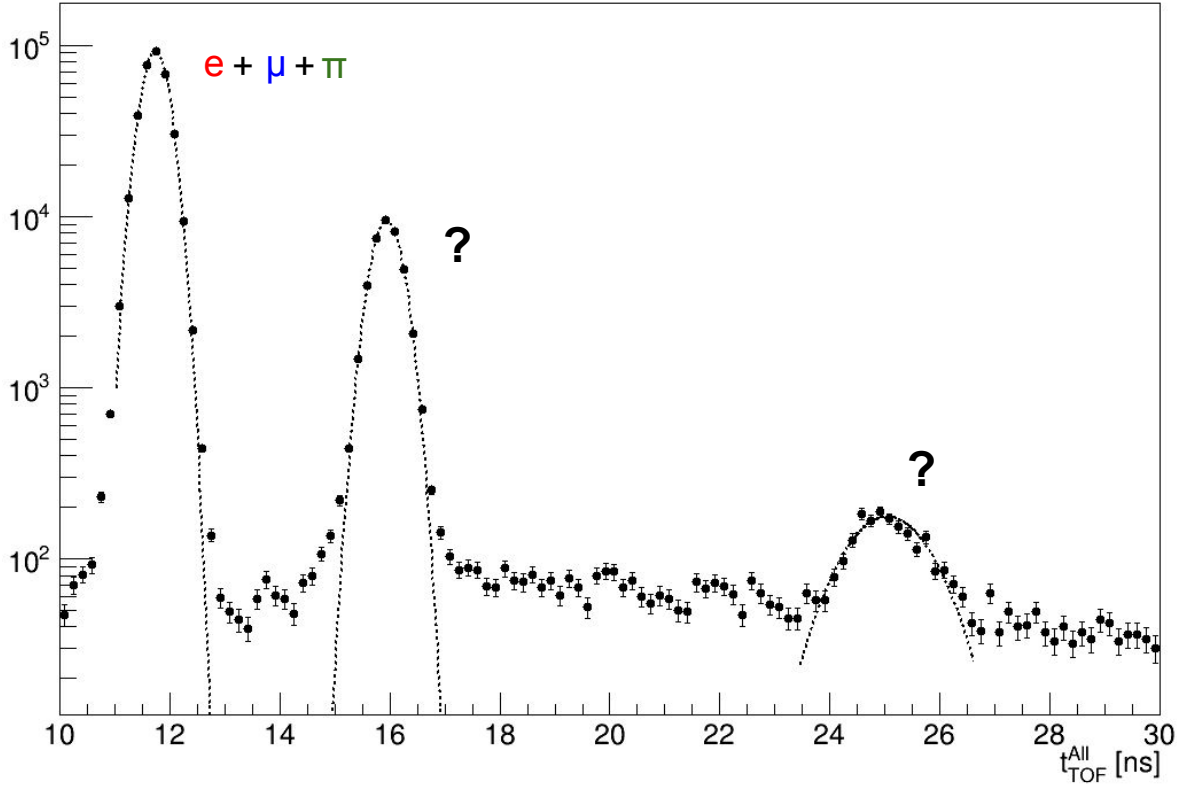


Výsledky 2023



Kladně nabité částice, větší hybnost 1000 MeV/c

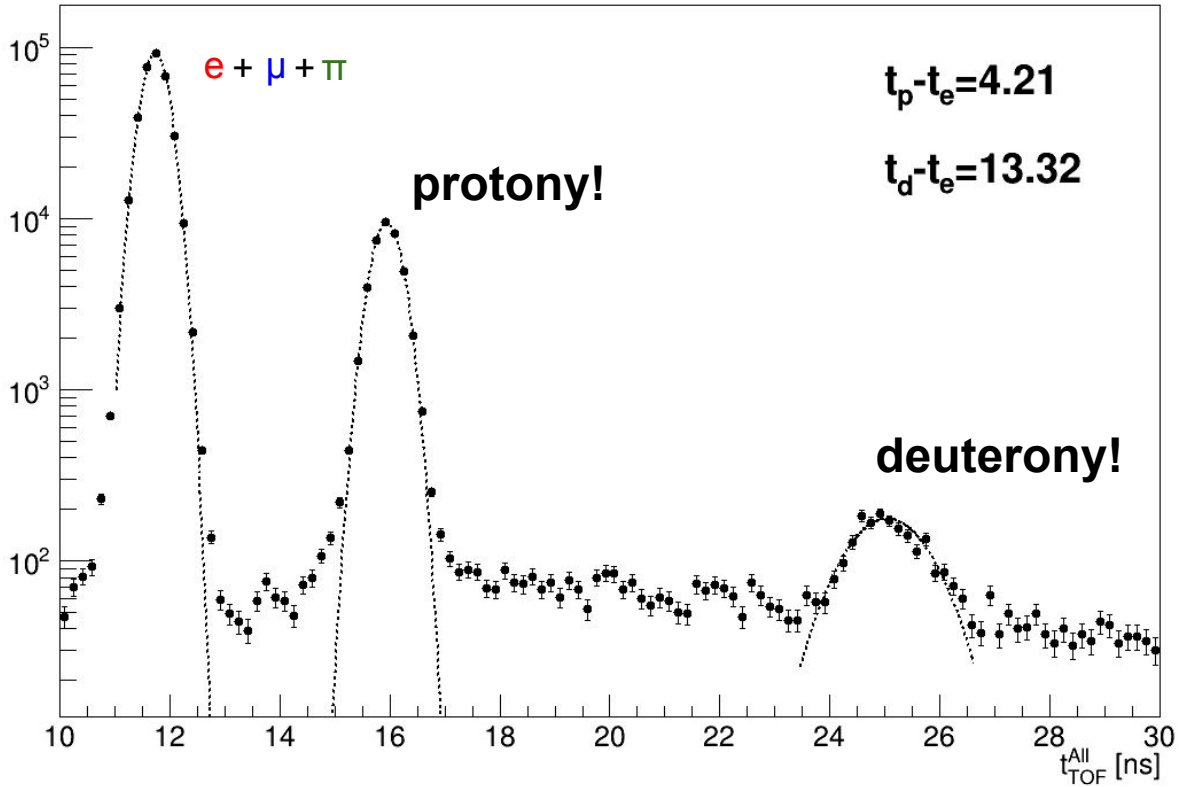
- Při vyšších hybnostech časy příletu elektronů, mionů a pionů už splývají.
- Ale objevují se další peaky ve svazku pozitivních částic…



Doba letu

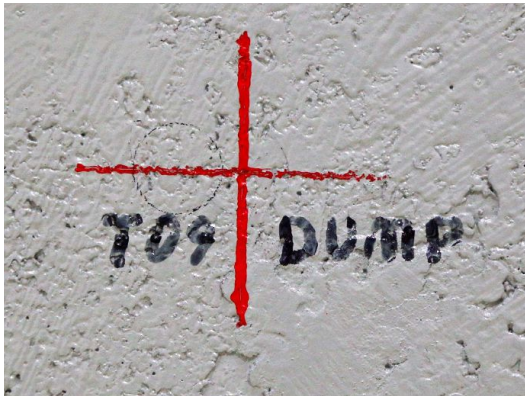
- Pro známou hybnost svazku lze spočítat očekávané časy přílrtu
- Kdy doletí elektron, mion, pion…?
  - $m_e c^2 = 0.511$ MeV
  - $m_\mu c^2 = 105.6$ MeV
  - $m_\pi c^2 = 139.6$ MeV
  - $m_p c^2 = 938.27$ MeV
  - $m_n c^2 = 939.565$ MeV
  - $m_D c^2 = 1875.613$ MeV

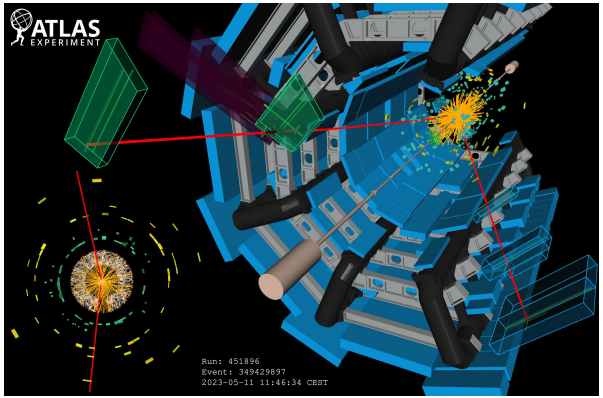
Kladně nabité částice, větší hybnost 1000 MeV/c



You identified and found your own particle!

The End


TOP DUMP


ATLAS
EXPERIMENT
Run: 451896
Event: 349429897
2023-05-11 11:46:34 CEST


No visitors beyond this point
UX15
3126
U0 - 037

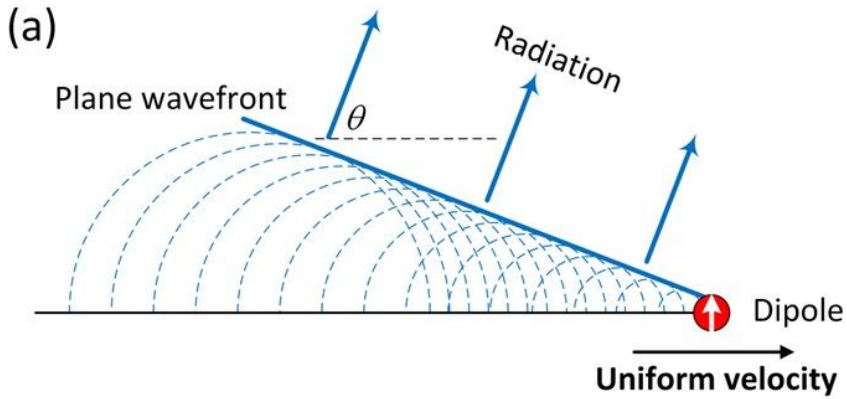
Zdroje

- https://home.cern/about/who-we-are/our-history
- https://home.cern/news/news/cern/year-celebrate-cerns-70th-anniversary
- https://visit.cern/science-gateway
- https://home.cern/about/who-we-are/our-history
- https://home.cern/news/news/cern/cern-highlights-2023

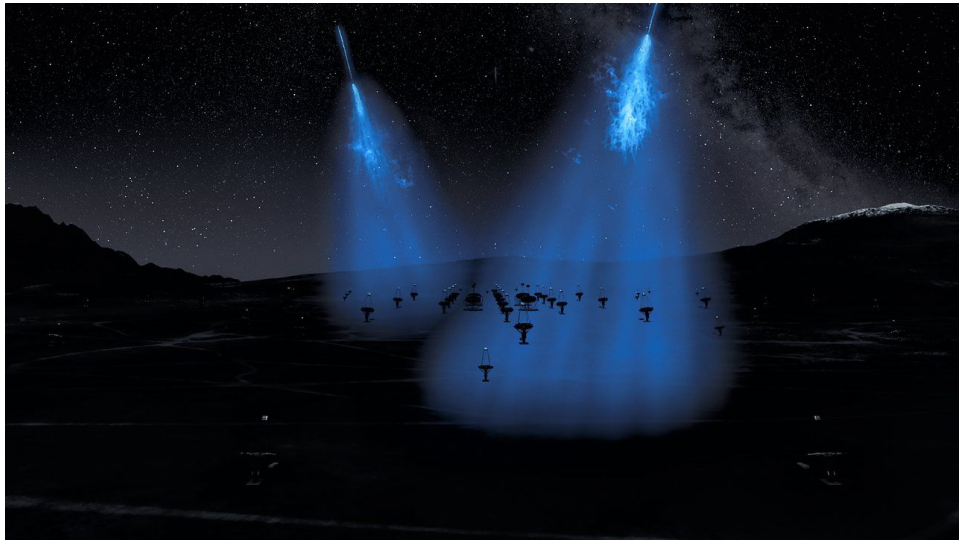
Backup

Čerenkovovo záření

- Nabitá částice překračuje rychlost světla v hmotném prostředí
  - ideálně transparentní médium
- $v_{světla}$ = c / index lomu = c / n

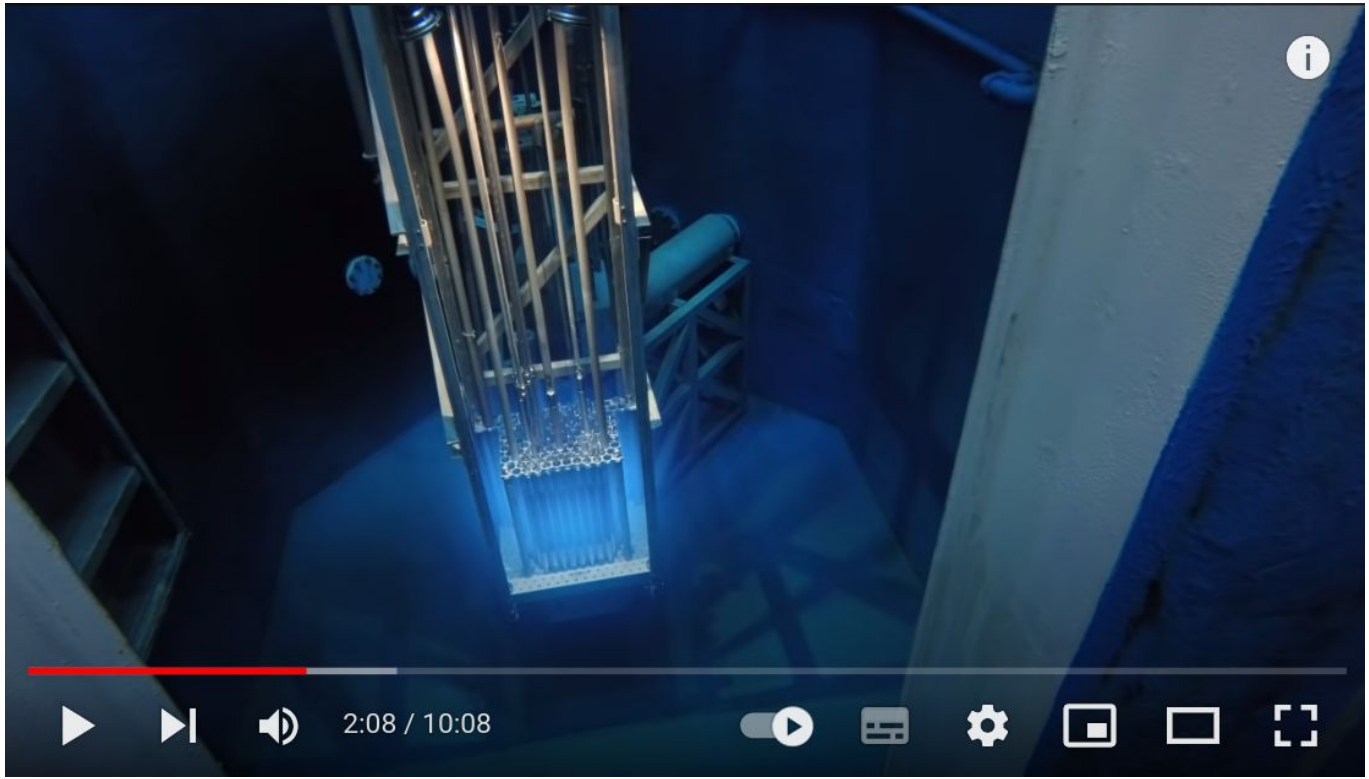


https://www.nature.com/articles/s41598-017-08705-4



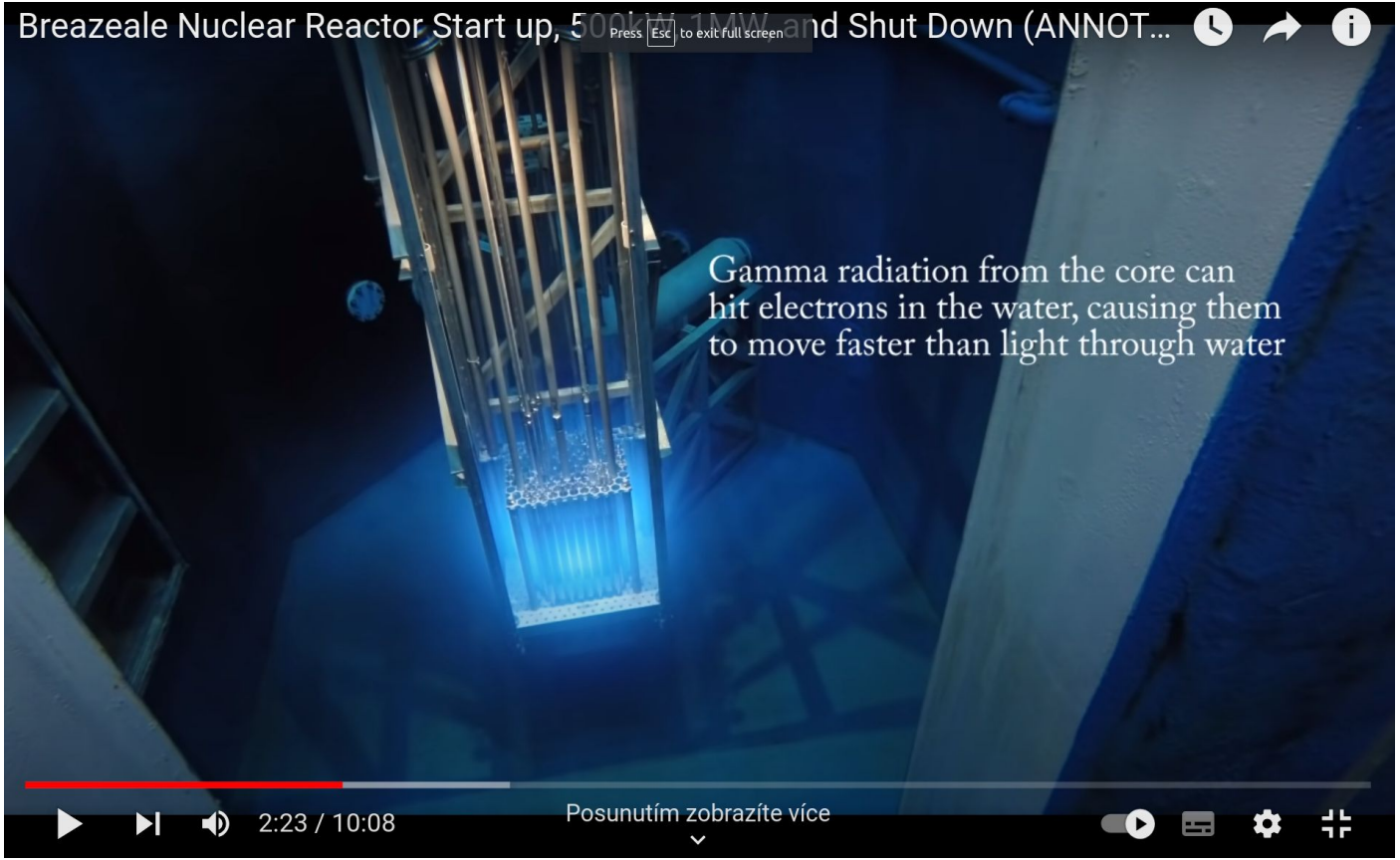
https://www.eso.org/public/czechrepublic/images/eso1841i/

Čerenkovovo záření



https://www.youtube.com/watch?v=uYrhWO_ZLYw&t=516s&ab_channel=AlexLandress

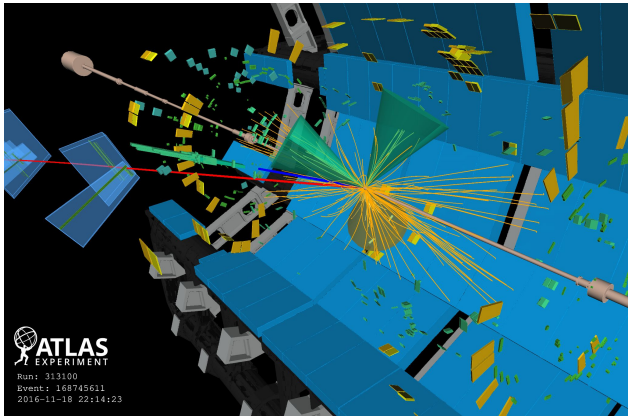
Čerenkovovo záření

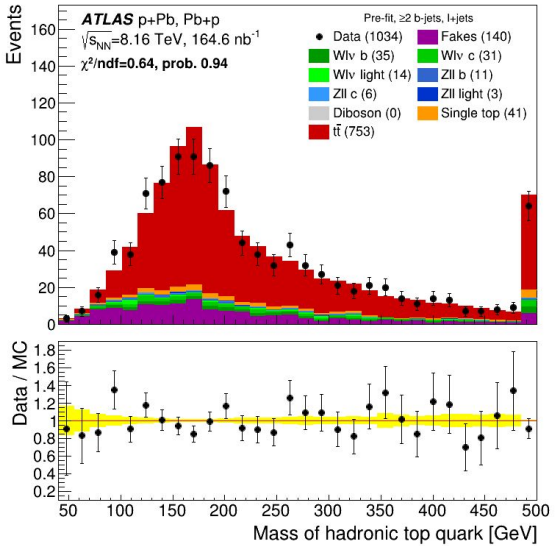


https://www.youtube.com/watch?v=uYrhWO_ZLYw&t=516s&ab_channel=AlexLandress

A typical analysis

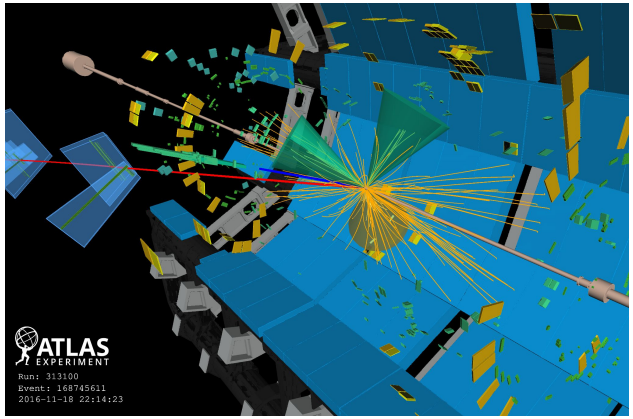
- Událost v detektoru obsahuje informace z jednotlivých poddetektorů
- Jsou zrekonstuovány a identifikovány fyzikální objekty
  - kandidáti na elektrony, miony, jety, gamma, tau, chybějící příčná energie…
- V rámci event selection jsou vybírány objekty na základě jejich požadovaného počtu a vlastností
  - 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

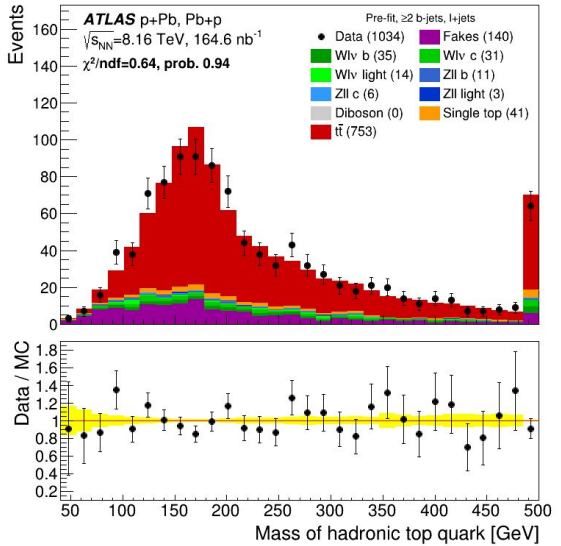




A typical analysis

- 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

$$E = mc^2$$

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

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

v jednotkách $c = 1$

$$m^2 = E^2 - p^2$$

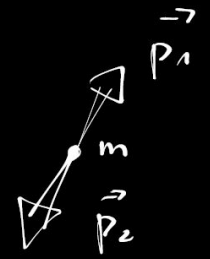
$$m^2 = \left(\sum_i E_i\right)^2 - \left(\sum \vec{p}_i\right)^2$$

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

$$E = \gamma mc^2$$

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

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



$$E = E_1 + E_2$$

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

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

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

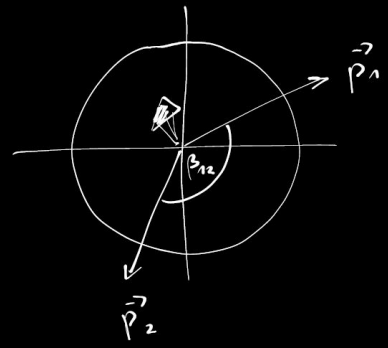
$$\doteq E_1^2 + 2\vec{p}_1\cdot\vec{p}_2 + E_2^2$$

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

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

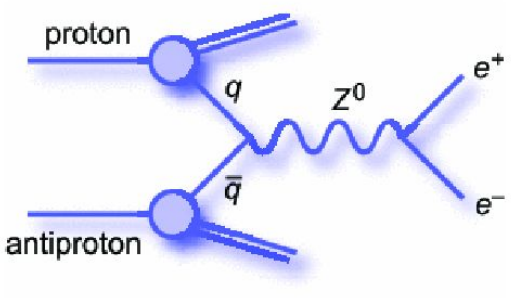
$$= \cancel{E_1^2} + 2E_1E_2 + \cancel{E_2^2}$$

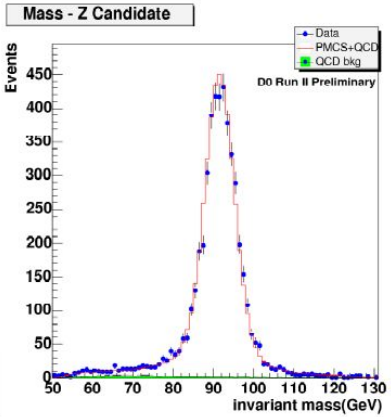
$$- \cancel{E_1^2} - \cancel{E_2^2} - 2E_1E_2\cos\beta_{12}$$

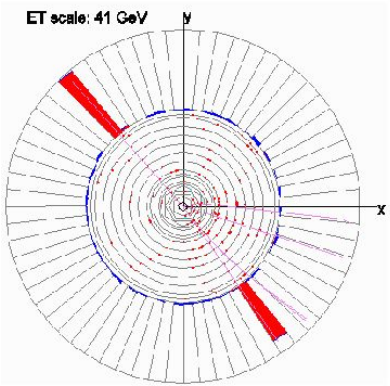


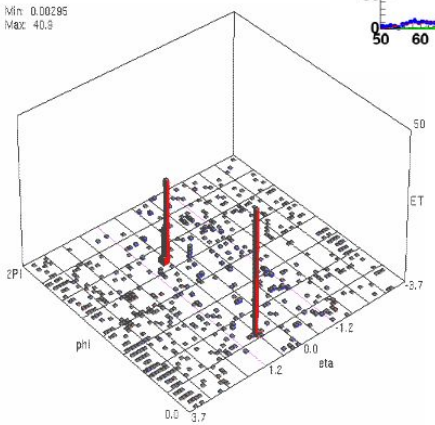
$$m^2 \simeq 2E_1E_2(1 - \cos\beta_{12})$$

Invariantní hmota

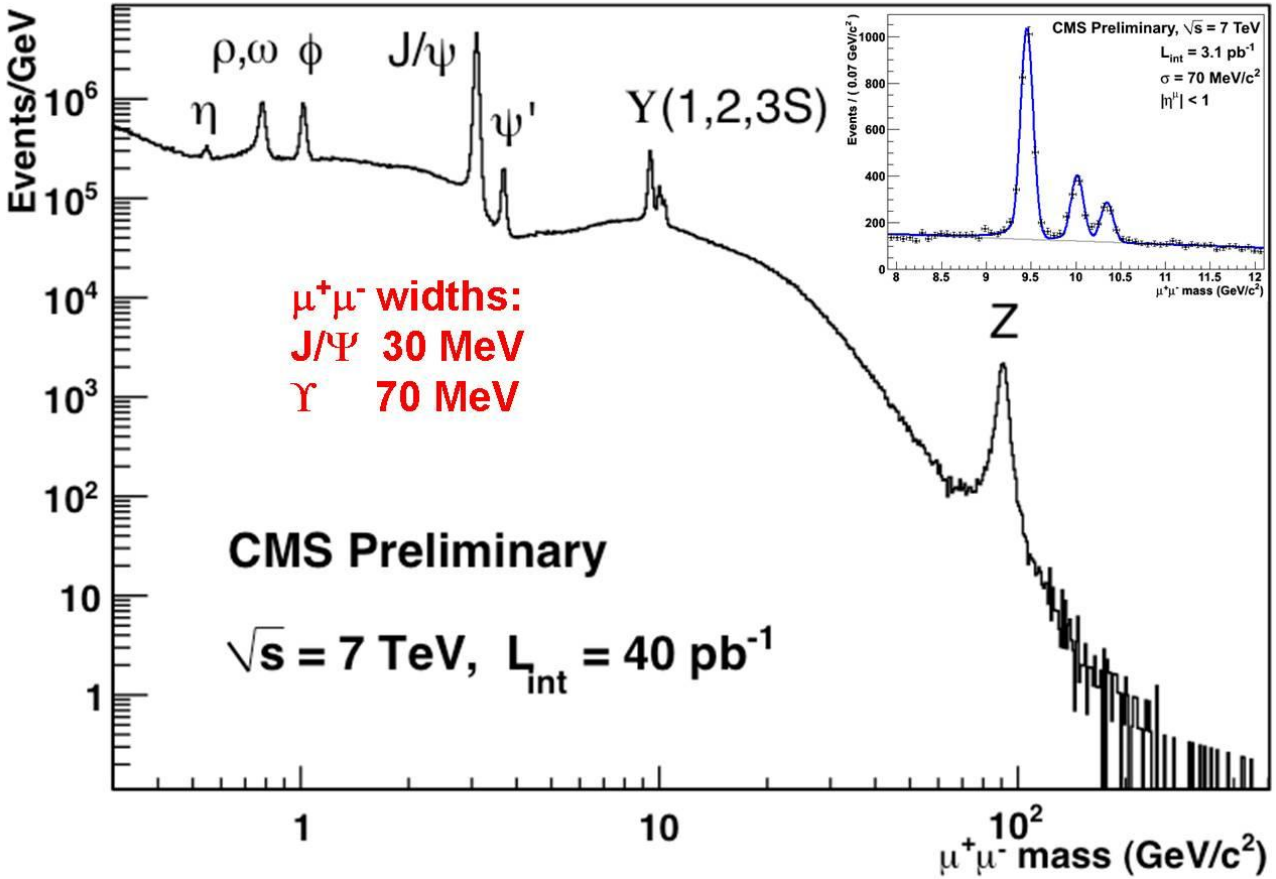




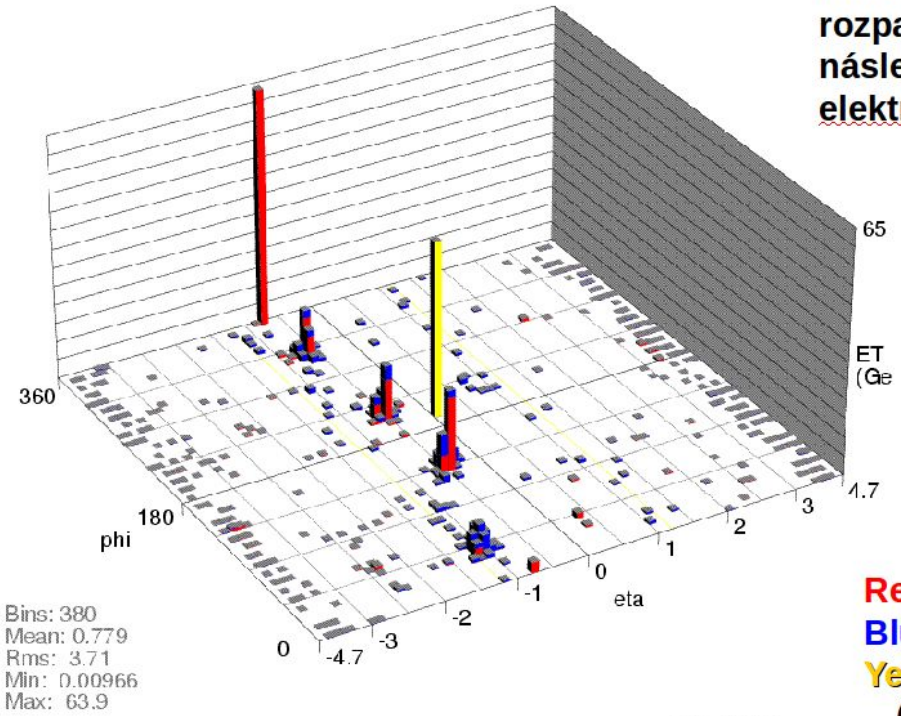




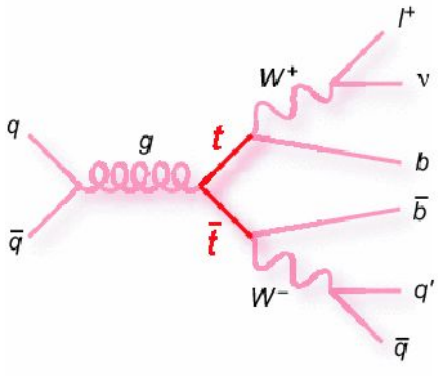
Invariantní hmota



Invariantní hmota



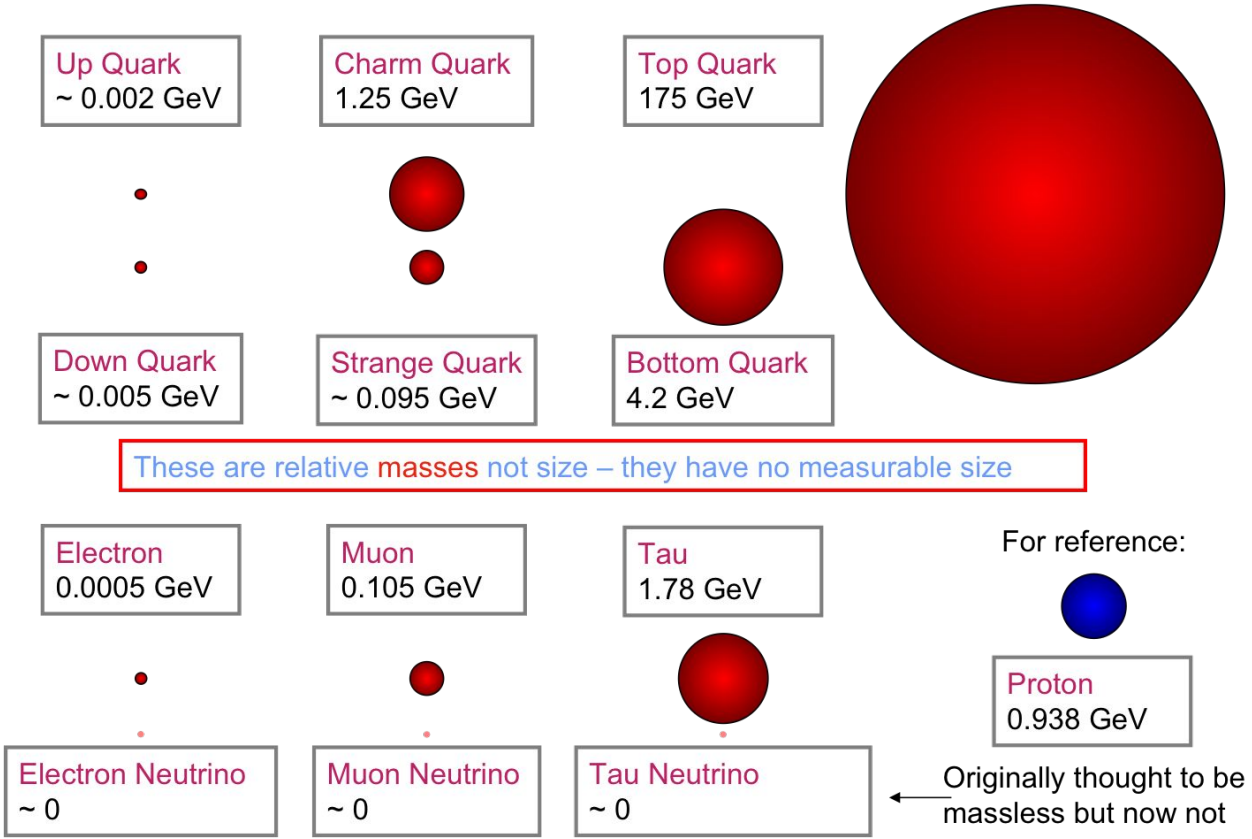
Pár top-anti top rozpadající se na *WbWb* a následně na 4 jety, elektron a neutrino.



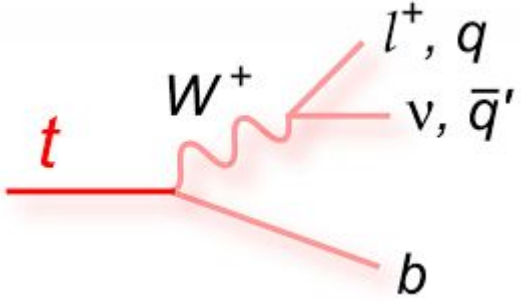
Red: EM Calorimeter
Blue: Hadronic Calorimeter
Yellow: Missing Energy (neutrino signature)

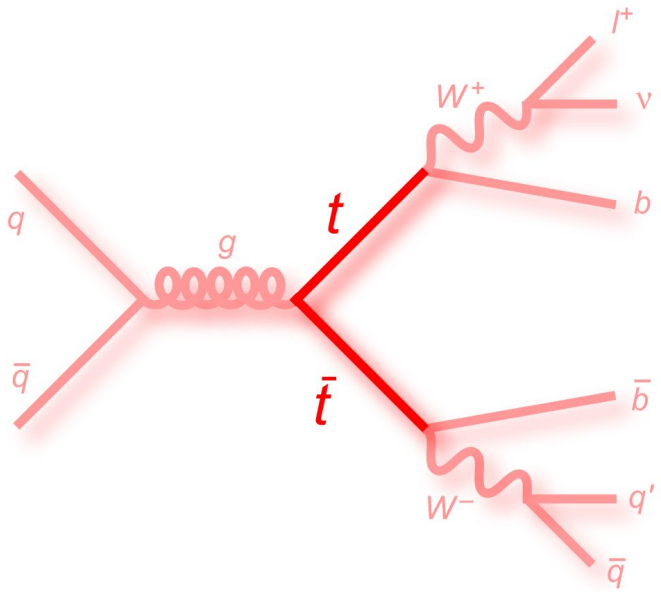
DZero experiment at Fermilab's Tevatron, a proton-antiproton collider.

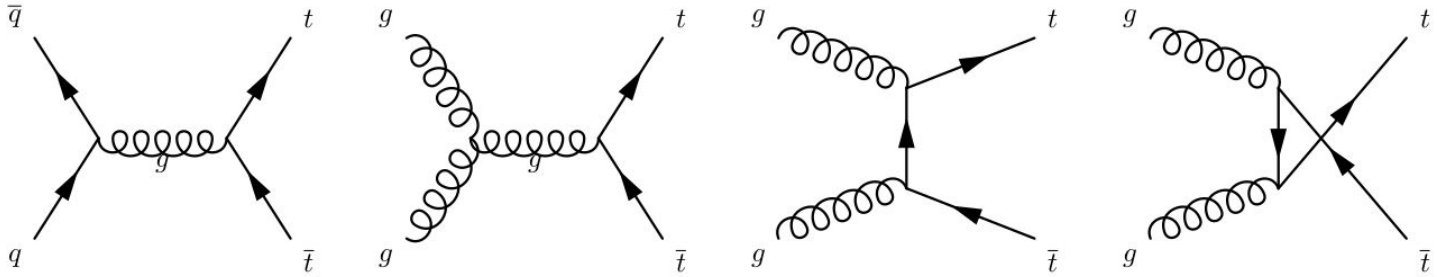
Quarks, Leptons, Gauge Bosons and the BEH boson



Top quark

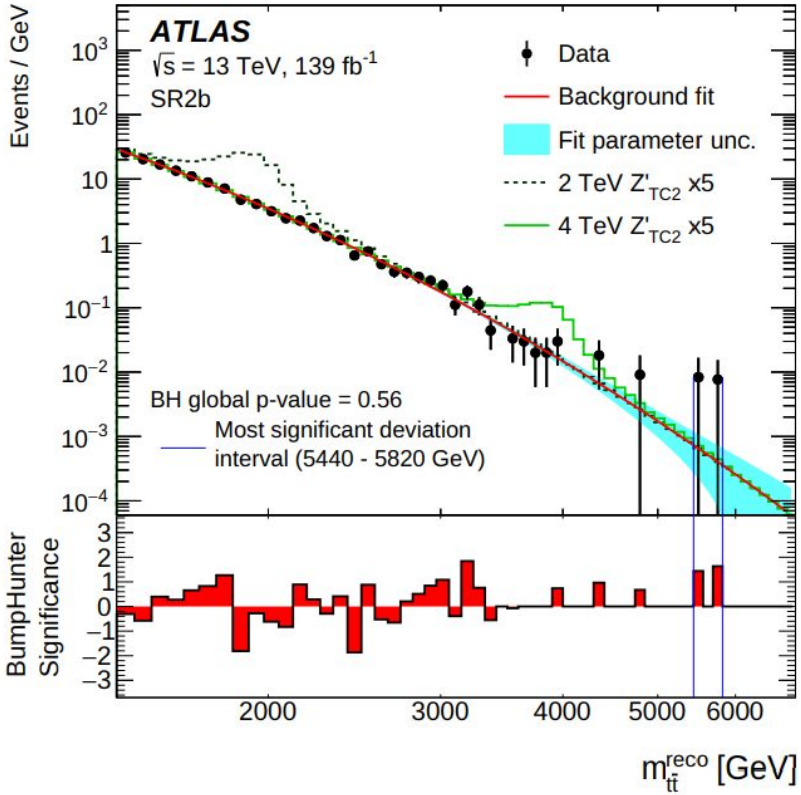
- 

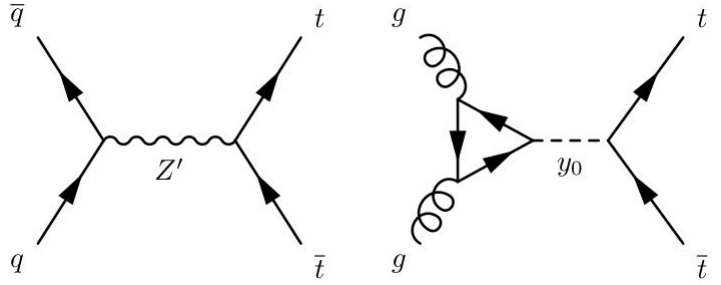


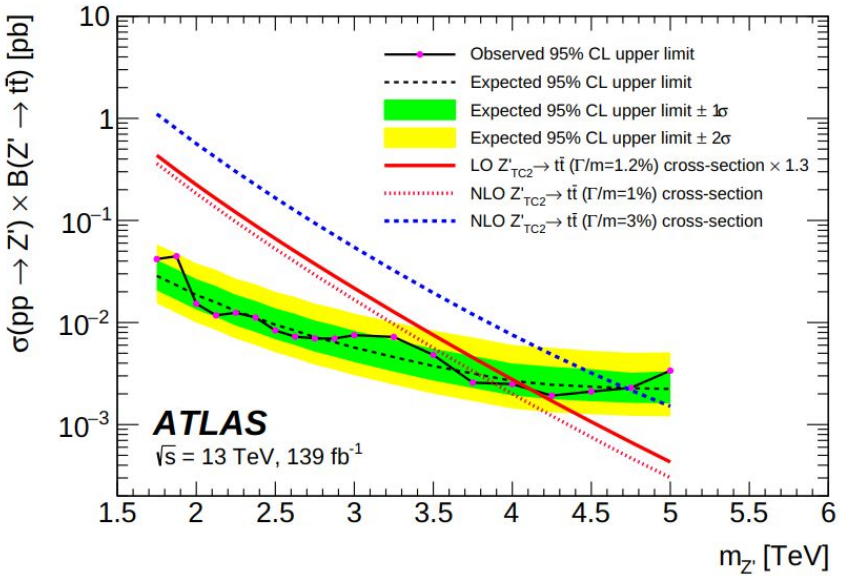


Top quark

- ttbar resonances

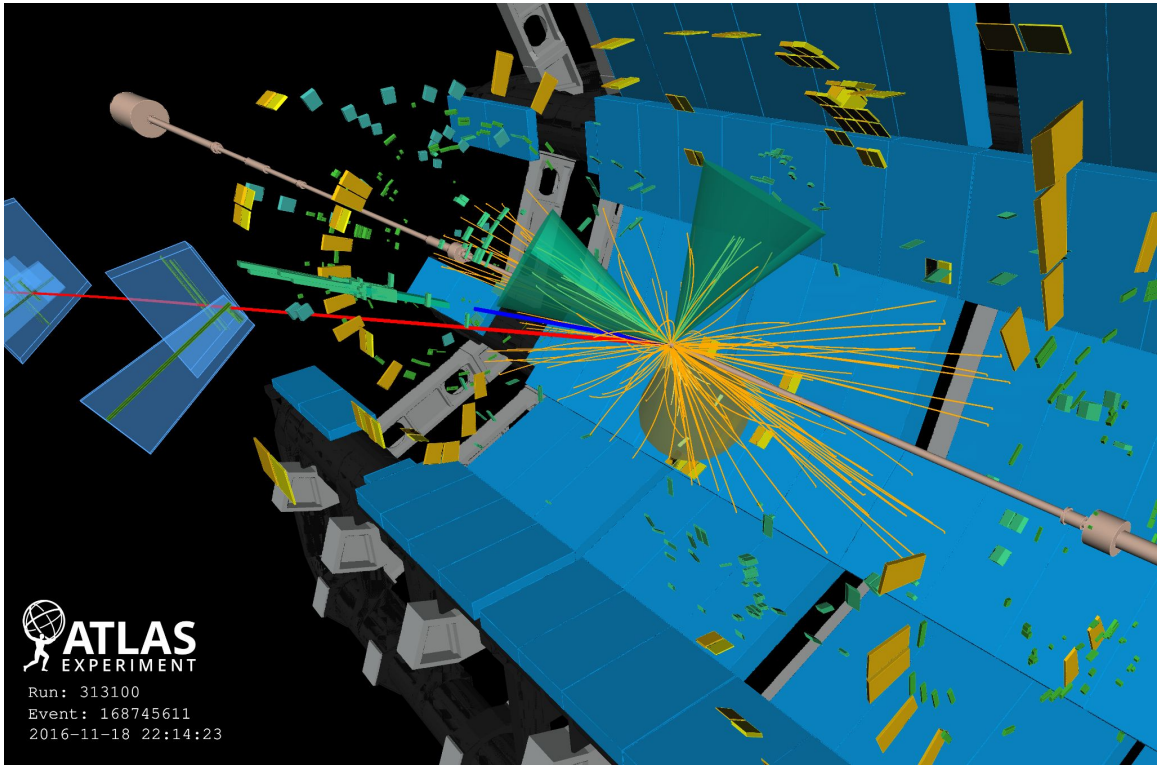


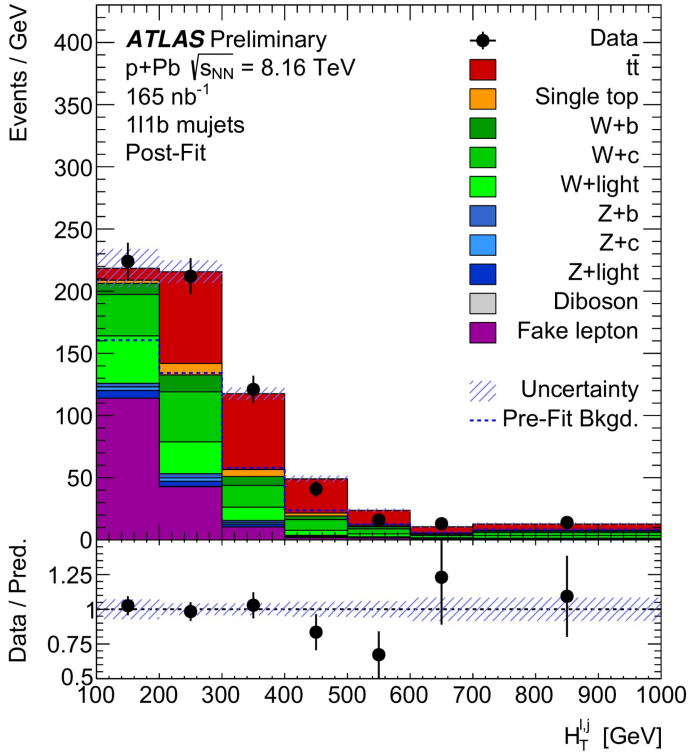




A typical analysis

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





Experiment Kamiokande(-II) :: 3kt H_20

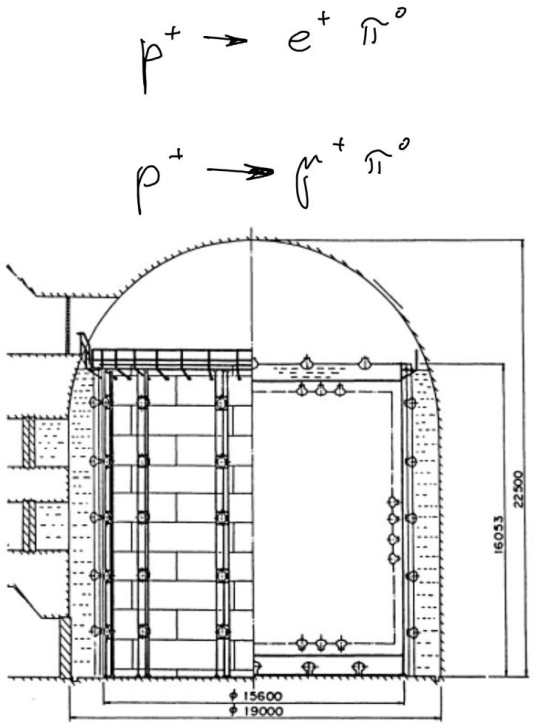
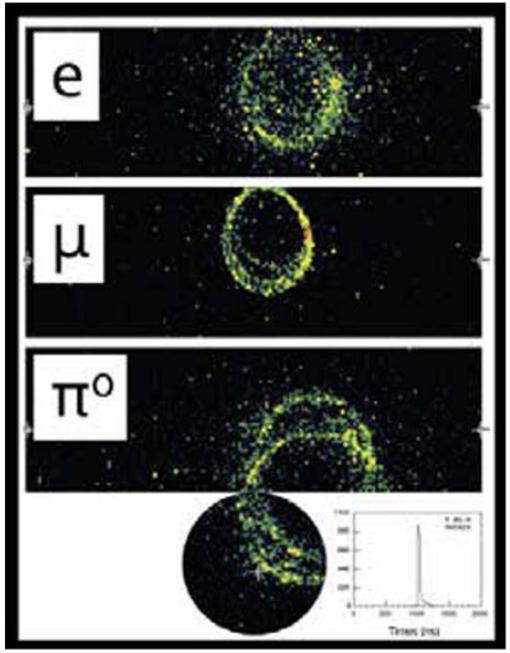


Figure 2: The detector of KAMIOKANDE -II. The dimensions are given in millimeters.



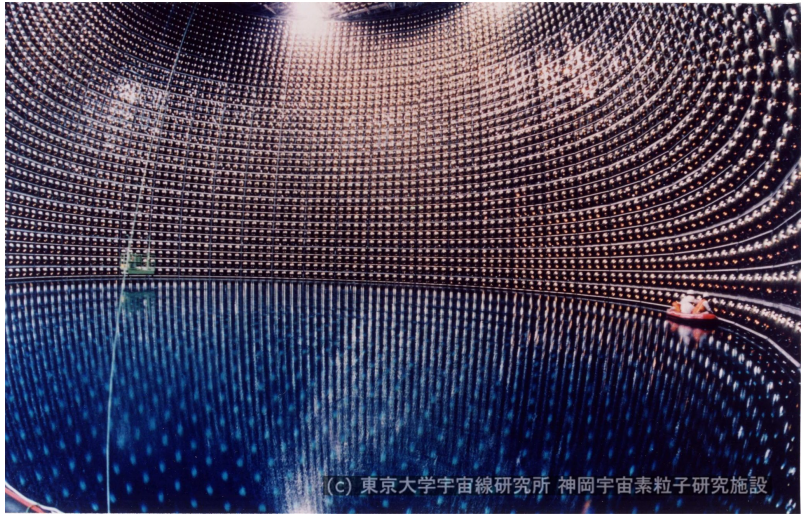
Neutrino identification

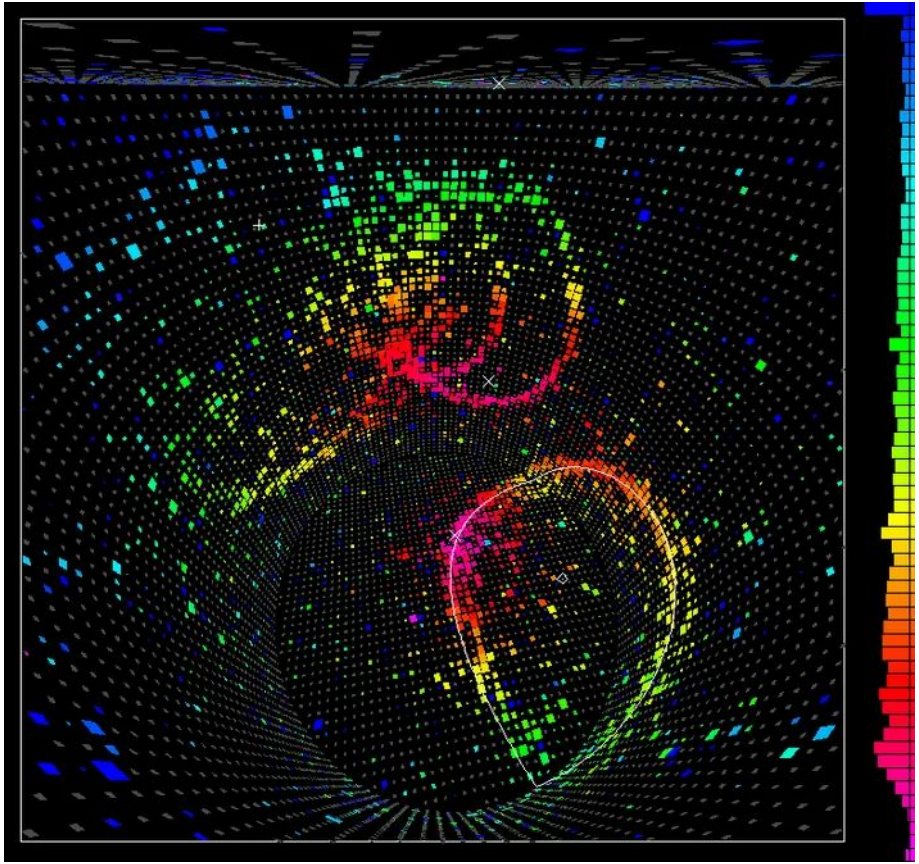
https://articles.adsabs.harvard.edu//full/1987ESOC...26..219K/0000220.000.html

Super Kamiokande :: 50kt H_20
Kamioka Nucleon Decay Experiment

https://www-sk.icrr.u-tokyo.ac.jp/en/sk/about/history/

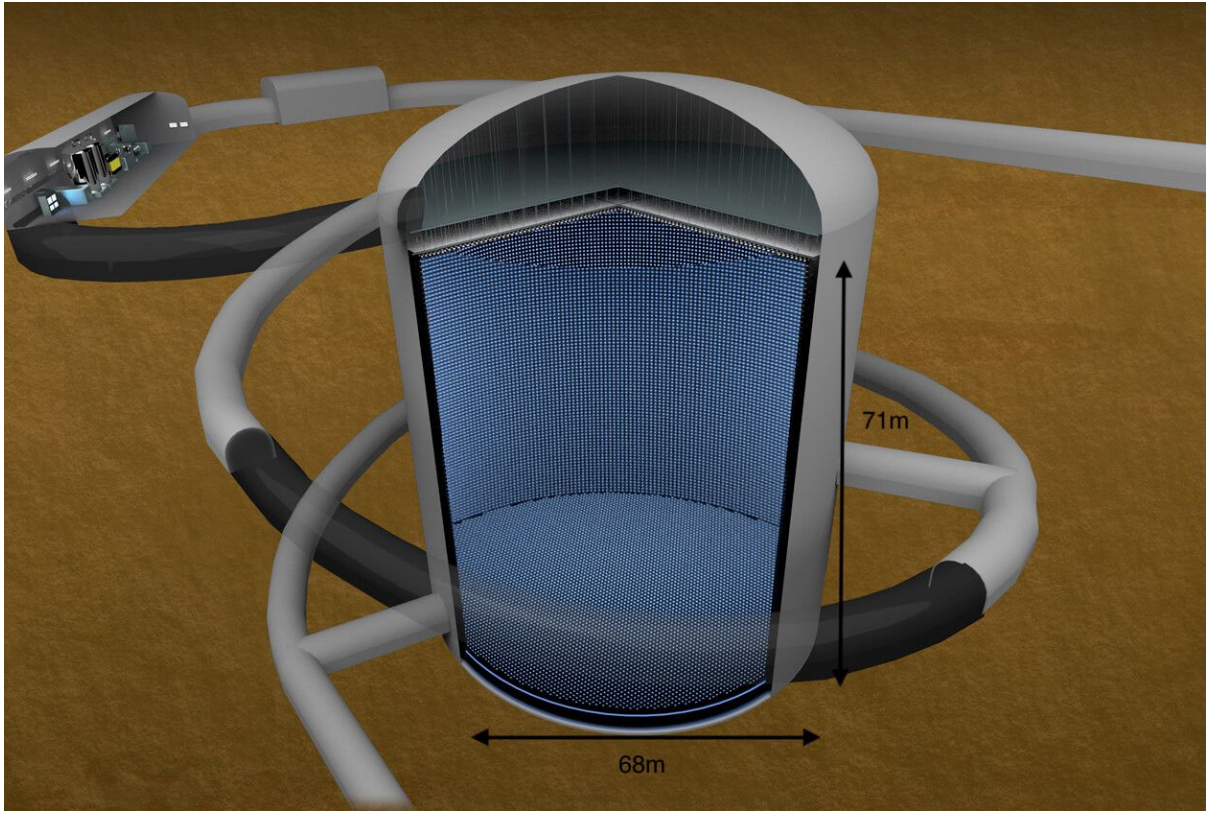
https://www-sk.icrr.u-tokyo.ac.jp/en/sk/experience/gallery/
https://www.forbes.com/sites/startswithabang/2018/12/05/is-there-really-a-fourth-neutrino-out-there-in-the-universe/





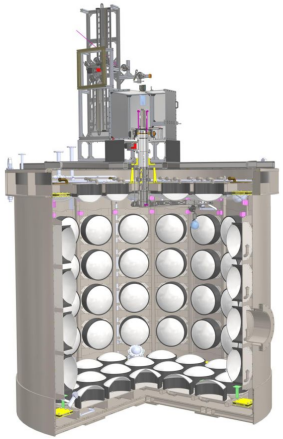
Hyper Kamiokande :: 250kt H_20

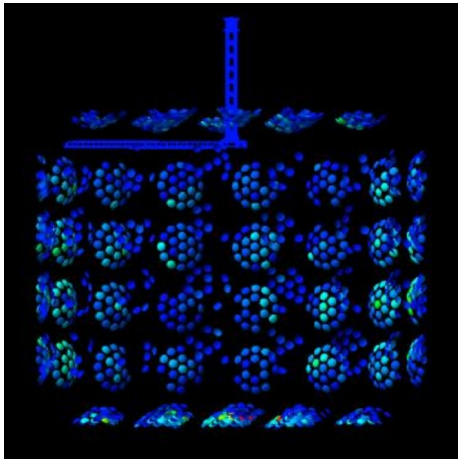
https://www-sk.icrr.u-tokyo.ac.jp/en/hk/about/detector/
https://www-sk.icrr.u-tokyo.ac.jp/en/hk/



YT :: Hyper-Kamiokande
https://www.youtube.com/watch?v=JFOE3D2z7LM&t=12s&ab_channel=Hyper-Kamiokande

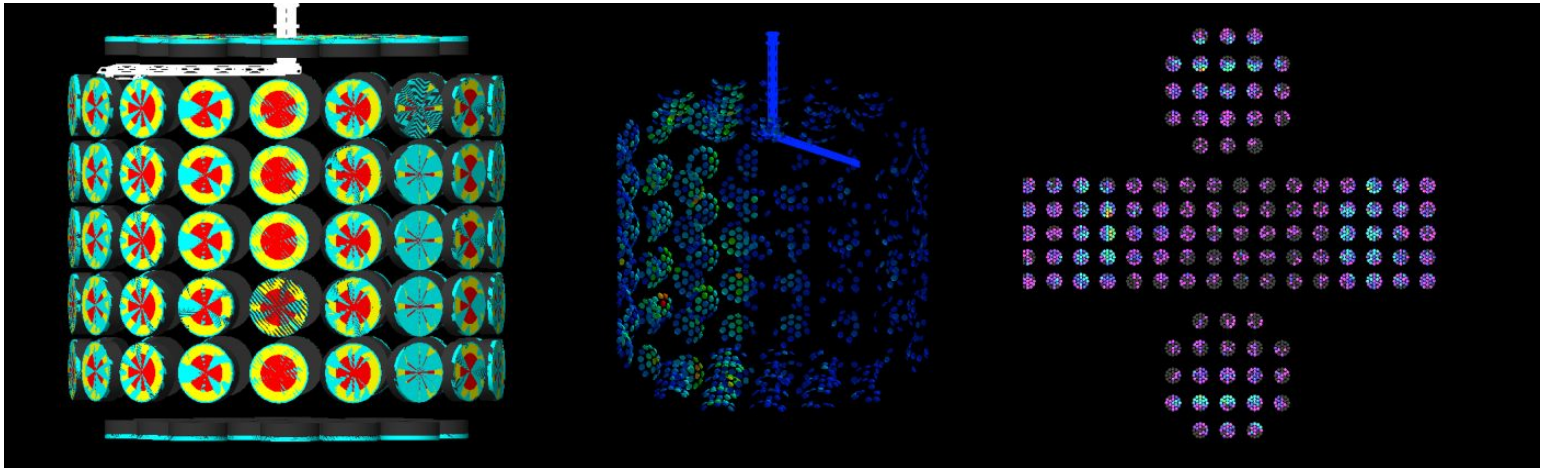
Water Cherenkov Test Experiment :: 50t H_2O @ CERN



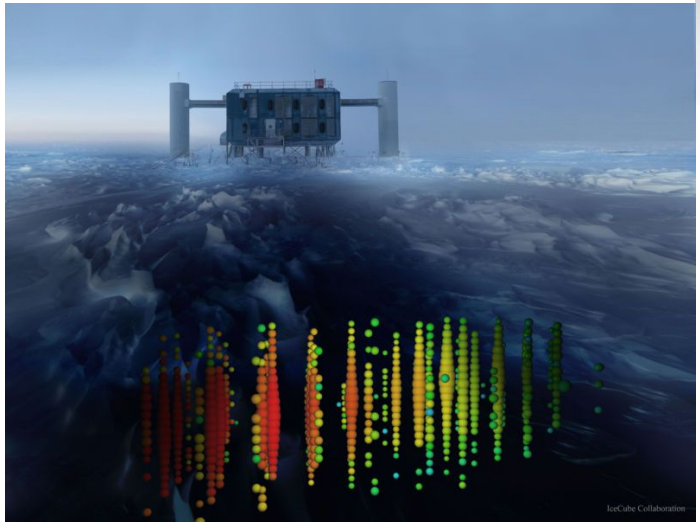


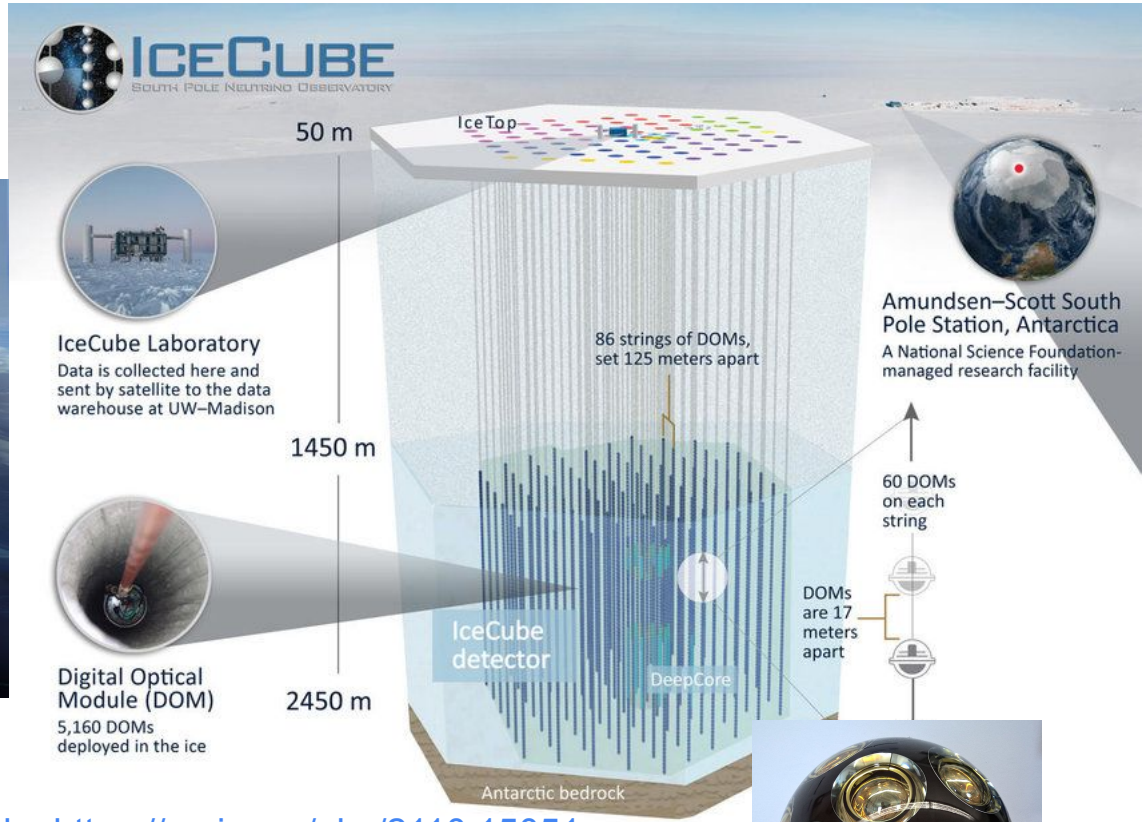
- Cíl: porozumět interakcím částic vznikajících v neutrinových reakcích.
- Pro kalibrace velkých neutrinových experimentů.

https://indico.cern.ch/event/855372/contributions/4452155/attachments/2304577/3921520/WCTE@CERN_NuFACT-2021-09-08_LAnthony.pdf



IceCUBE





Francis Halzen

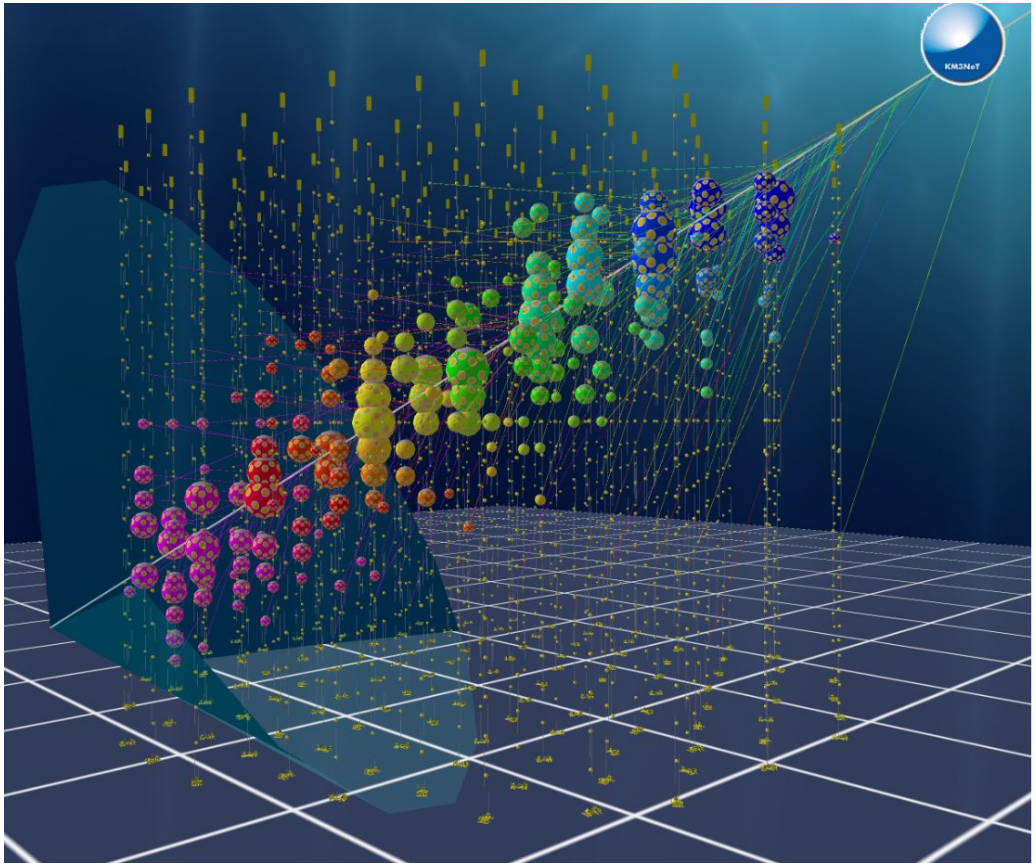
http://jointlab.upol.cz/kvita/idpacs2022.html :: https://arxiv.org/abs/2110.15051

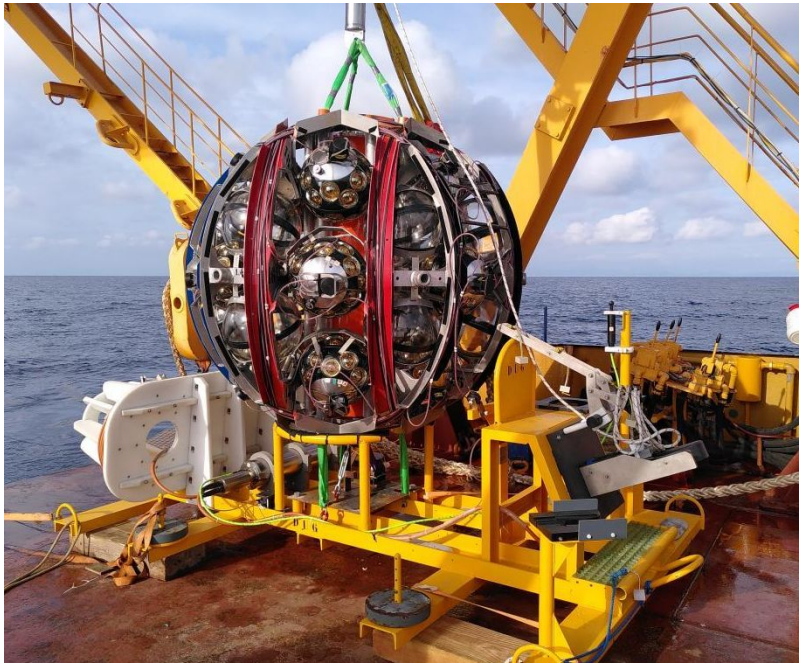
https://www.nature.com/articles/s41586-021-03256-1

https://sciencesprings.wordpress.com/tag/u-wisconsin-icecube-collaboration/

https://www.researchgate.net/figure/Prototypes-of-an-mDOM-left-and-an-D-Egg-right-for-the-IceCube-Upgrade_fig8_351199668

KM3NeT





Neutrina:)

Original - Photocopie of PLC 0393

Abschrift/15.12.30 PM

Offener Brief an die Gruppe der Radioaktiven bei der Gauvereins-Tagung zu Tübingen.

Abschrift

Physikalisches Institut
der Eidg. Technischen Hochschule
Zürich

Zürich, 4. Dez. 1930
Gloriastrasse

Liebe Radioaktive Damen und Herren,

Wie der Ueberbringer dieser Zeilen, den ich huldvollst ansuhören bitte, Ihnen des näheren auseinandersetzen wird, bin ich angesichts der "falschen" Statistik der N- und Li-6 Kerne, sowie des kontinuierlichen beta-Spektrums auf einen verzweifelten Ausweg verfallen um den "Wechselsatz" (1) der Statistik und den Energiesatz zu retten. Nämlich die Möglichkeit, es könnten elektrisch neutrale Teilchen, die ich Neutronen nennen will, in den Kernen existieren, welche den Spin 1/2 haben und das Ausschliessungsprinsip befolgen und sich von Lichtquanten ausserdem noch dadurch unterscheiden, dass sie nicht mit Lichtgeschwindigkeit laufen. Die Masse der Neutronen müsste von derselben Grössenordnung wie die Elektronenmasse sein und jedenfalls nicht grösser als 0,01 Protonenmasse.- Das kontinuierliche beta- Spektrum wäre dann verständlich unter der Annahme, dass beim beta-Zerfall mit dem Elektron jeweils noch ein Neutron emittiert wird, derart, dass die Summe der Energien von Neutron und Elektron konstant ist.

Nun handelt es sich weiter darum, welche Kräfte auf die Neutronen wirken. Das wahrscheinlichste Modell für das Neutron scheint mir aus wellenmechanischen Gründen (näheres weiss der Ueberbringer dieser Zeilen) dieses zu sein, dass das ruhende Neutron ein magnetischer Dipol von einem gewissen Moment μ ist. Die Experimente verlangen wohl, dass die ionisierende Wirkung eines solchen Neutrons nicht grösser sein kann, als die eines gamma-Strahls und darf dann μ wohl nicht grösser sein als $e \cdot (10^{-13}$ cm).

Ich traue mich vorläufig aber nicht, etwas über diese Idee zu publizieren und wende mich erst vertrauensvoll an Euch, liebe Radioaktive, mit der Frage, wie es um den experimentellen Nachweis eines solchen Neutrons stände, wenn dieses ein ebensolches oder etwa 10mal grösseres Durchdringungsvermögen besitzen würde, wie ein gamma-Strahl.

Ich gebe zu, dass mein Ausweg vielleicht von vornherein wenig wahrscheinlich erscheinen wird, weil man die Neutronen, wenn sie existieren, wohl schon längst gesehen hätte. Aber nur wer wagt, gewinnt und der Ernst der Situation beim kontinuierliche beta-Spektrum wird durch einen Ausspruch meines verehrten Vorgängers im Amte, Herrn Debye, beleuchtet, der mir kürzlich in Brüssel gesagt hat: "O, daran soll man am besten gar nicht denken, sowie an die neuen Steuern." Darum soll man jeden Weg zur Rettung ernstlich diskutieren.- Also, liebe Radioaktive, prüfet, und richtet.- Leider kann ich nicht persönlich in Tübingen erscheinen, da ich infolge eines in der Nacht vom 6. zum 7 Dez. in Zürich stattfindenden Balles hier unabkömmlich bin.- Mit vielen Grüssen an Euch, sowie an Herrn Back, Euer untertänigster Diener

gez. W. Pauli

Wolfgang Pauli

SN1987A 24.2.1987 :: 170kly

https://en.wikipedia.org/wiki/SN_1987A

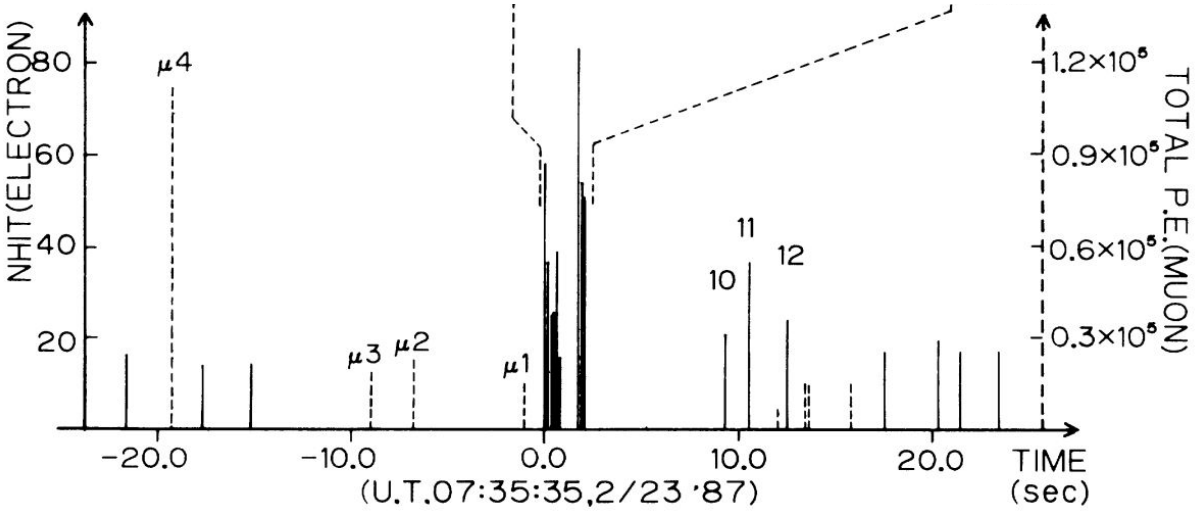
https://www-sk.icrr.u-tokyo.ac.jp/en/news/detail/324

Experiment Kamiokande(-II) :: 3kt H_20

VOLUME 58, NUMBER 14 PHYSICAL REVIEW LETTERS 6 APRIL 1987

Observation of a Neutrino Burst from the Supernova SN1987A

K. Hirata,[a] T. Kajita,[a] M. Koshiba,[a,b] M. Nakahata,[b] Y. Oyama,[b]
N. Sato,[c] A. Suzuki,[b] M. Takita,[b] and Y. Totsuka[a,c]
University of Tokyo, Tokyo 113, Japan



Experiment Kamiokande(-II) :: 3kt H_20

- Počátky neutrinové astronomie! :-)
- 1 Erg is a unit of energy equal to 10^{-7} Joules (100 nJ)

form volume distribution. Additional support is provided by the correlation in angle of the first two observed events with the direction to SN1987A. The event burst occurred roughly 18 h prior to the first optical sighting.[1] Correcting for energy-dependent detection efficiency, and assuming that nine of the twelve events are due to $\bar{\nu}_e p^+ \rightarrow e^+ n$, we obtain an integral flux of 1.0×10^{10} $\bar{\nu}_e$ cm^{-2} for the burst, where the $\bar{\nu}_e$ energy (the observed electron energy plus 1.3 MeV) is above 8.8 MeV. This, in turn, leads to the $\bar{\nu}_e$ output of SN1987A of 8×10^{52} ergs for an assumed average energy of 15 MeV.

This observation is the first direct observation in neutrino astronomy, and coincides remarkably well with the current model of supernova collapse and neutron-star formation.[6] In that model an aged, massive star, having exhausted its nuclear fuel, undergoes a supernova explosion. In supernovae of Type II almost all of the gravitational binding energy of the resultant neutron star, $\sim3\times10^{53}$ ergs, is radiated within a few seconds in the form of 10^{58} neutrinos of all flavors with average energy in the vicinity of 10–15 MeV.