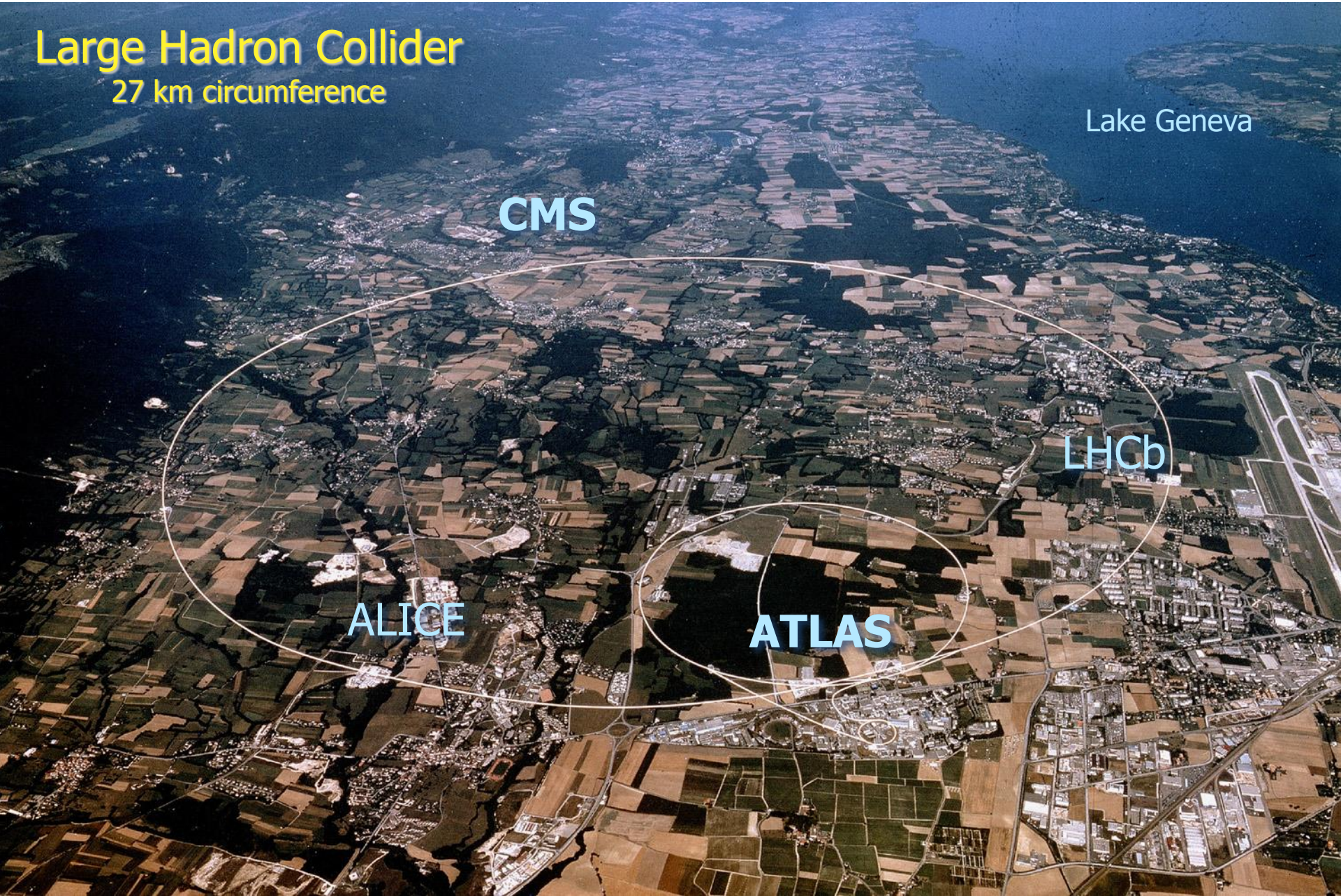
La physique au Run 2 : quel saut en énergie !

Journées LCG-France, CC-IN2P3

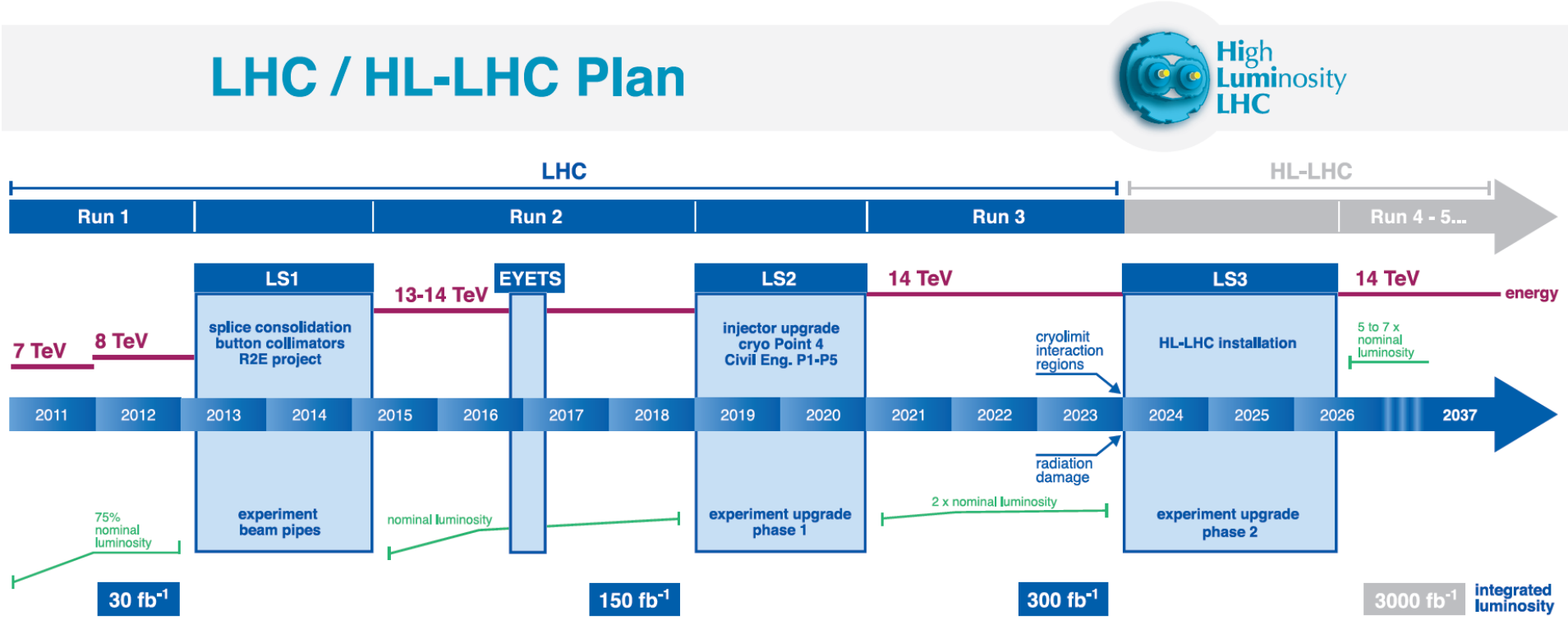
Patrice Verdier, IPN Lyon

14/12/2015

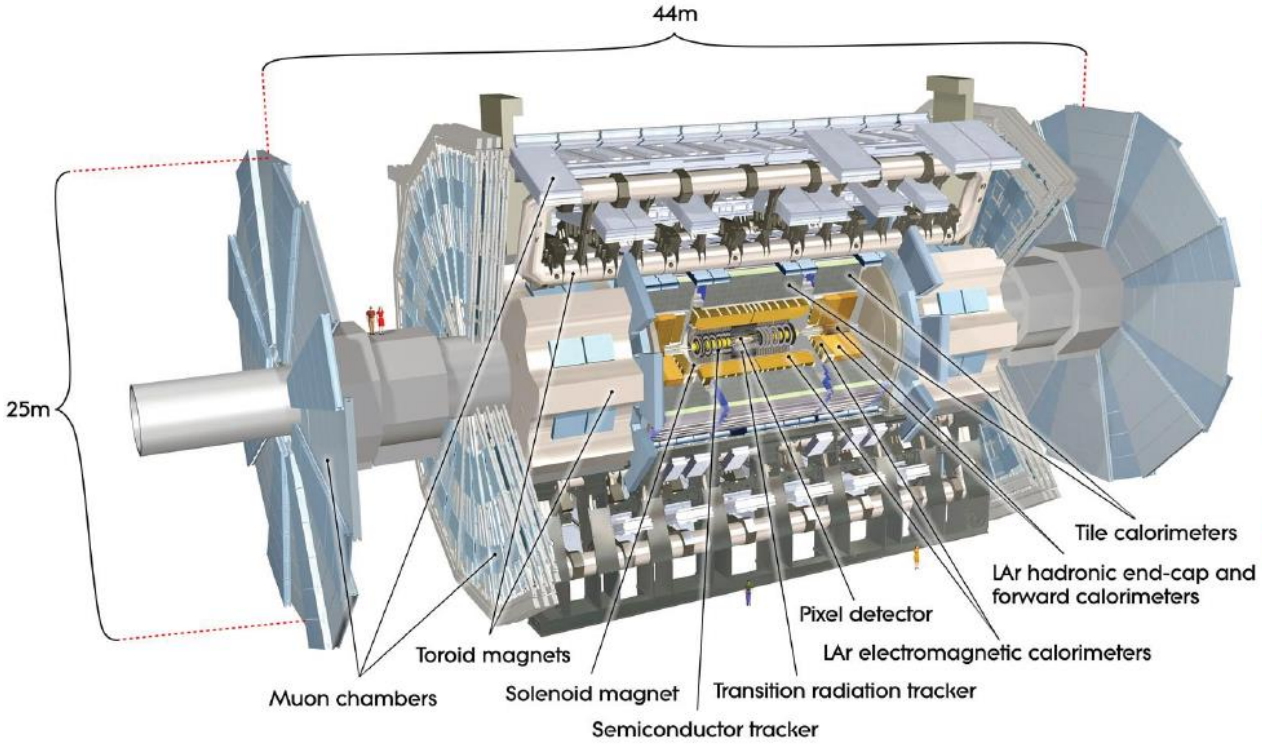
Le LHC


Large Hadron Collider
27 km circumference
Lake Geneva
CMS
LHCb
ALICE
ATLAS

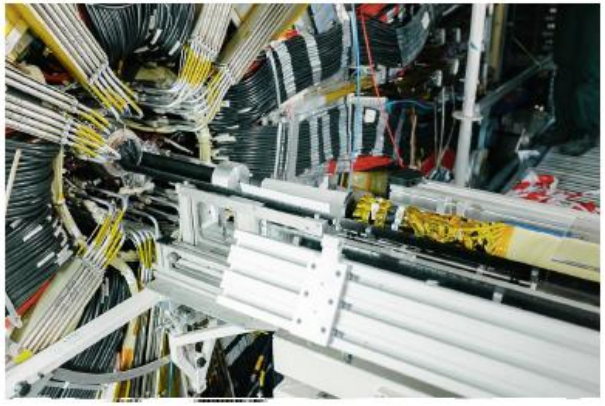
Programme du LHC/HL-LHC



ATLAS au Run 2

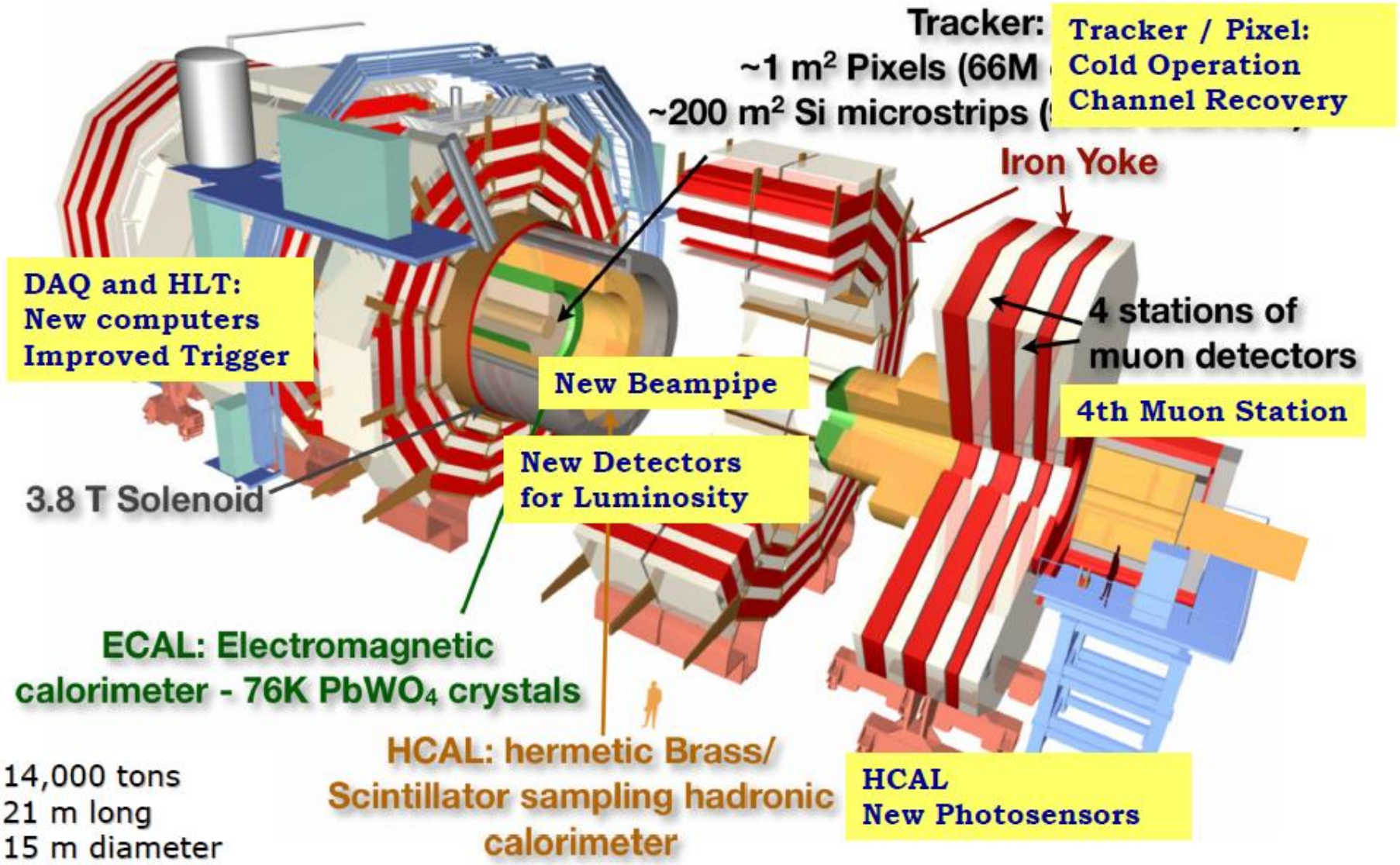


IBL Insertion: May 2014



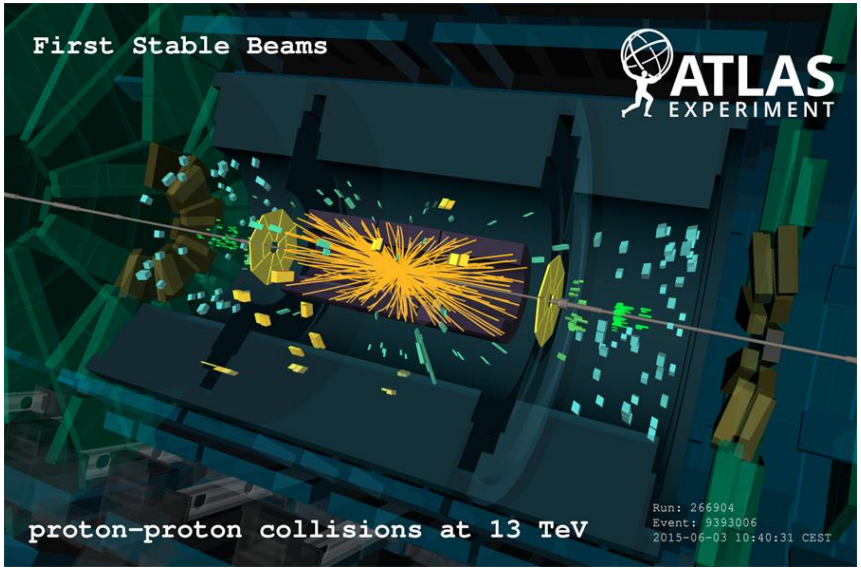
- **De nombreux travaux durant LS1 !**
  - Nouveau beampipe, amélioration système d'aimants et cryogénie
  - Couverture des chambres à muons (|η|entre 1.1 et 1.3) et réparations, améliorations readout (Taux L1 à 100 kHz), réparation modules pixel et électronique calorimètre, nouveau services pour les pixels, nouveau détecteur de luminosité
  - Détecteur IBL: 4ème couche pixel silicium à R=3,3 cm du beampipe
  - Nouveau trigger L1 topologique, nouveau trigger central, coincidence entre Tile et Muons, restructuration du HLT, nouveau Fast Track Triggern, Trigger L1 calorimètre amélioré
  - Software: de nombreuses améliorations à la simulation, la reconstruction, et au code d'analyse

CMS au Run 2


Tracker:
~1 m² Pixels (66M
~200 m² Si microstrips (
Tracker / Pixel:
Cold Operation
Channel Recovery
Iron Yoke
DAQ and HLT:
New computers
Improved Trigger
4 stations of
muon detectors
New Beampipe
4th Muon Station
New Detectors
for Luminosity
3.8 T Solenoid
ECAL: Electromagnetic
calorimeter - 76K PbWO4 crystals
HCAL: hermetic Brass/
Scintillator sampling hadronic
calorimeter
HCAL
New Photosensors
14,000 tons
21 m long
15 m diameter

Run 2


ATLAS


First Stable Beams
ATLAS
EXPERIMENT
proton-proton collisions at 13 TeV
Run: 266904
Event: 9393006
2015-06-03 10:40:31 CEST

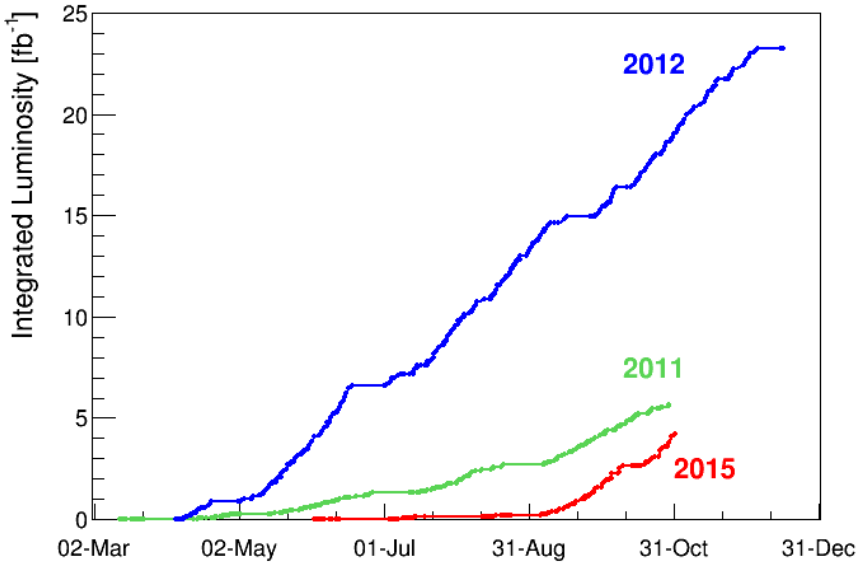

CMS

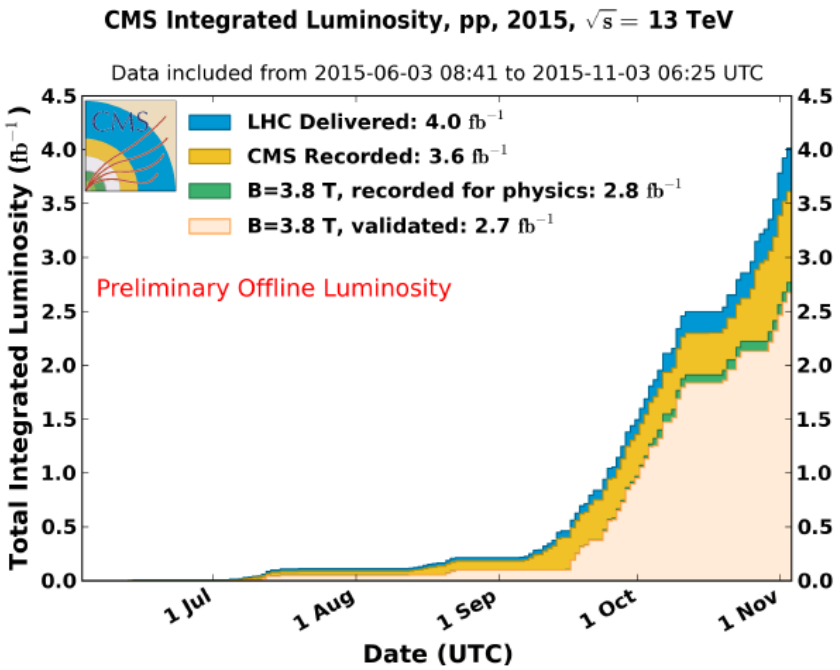

LHCb

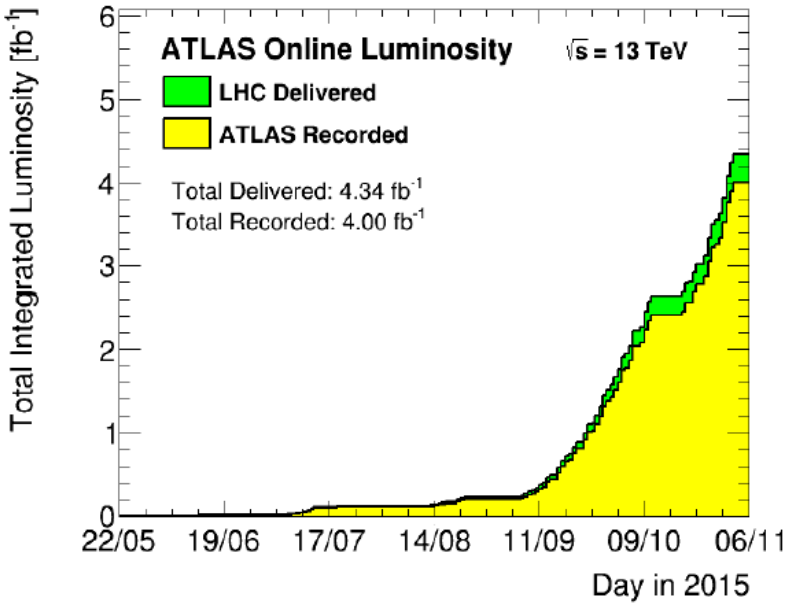
Performances du LHC en 2015

4 fb^{-1} ont été délivrés à ATLAS et CMS

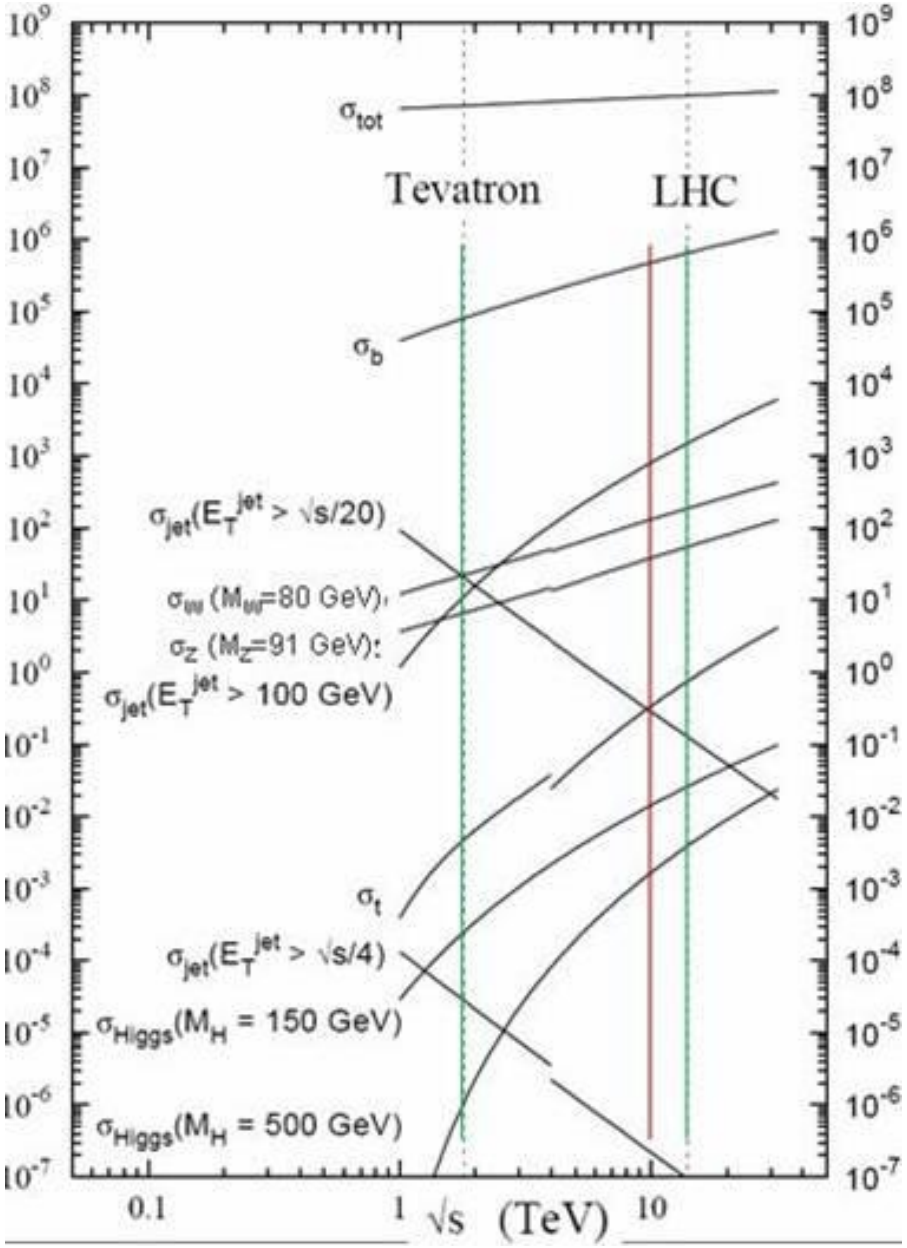
Plus d' 1 fb^{-1} la dernière semaine !





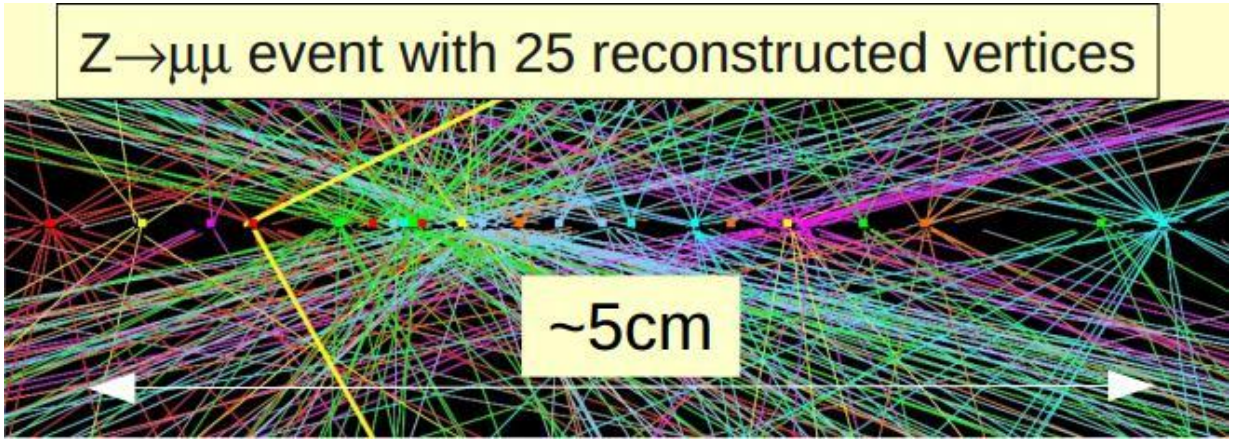


Le LHC : collisionneur de hadrons !



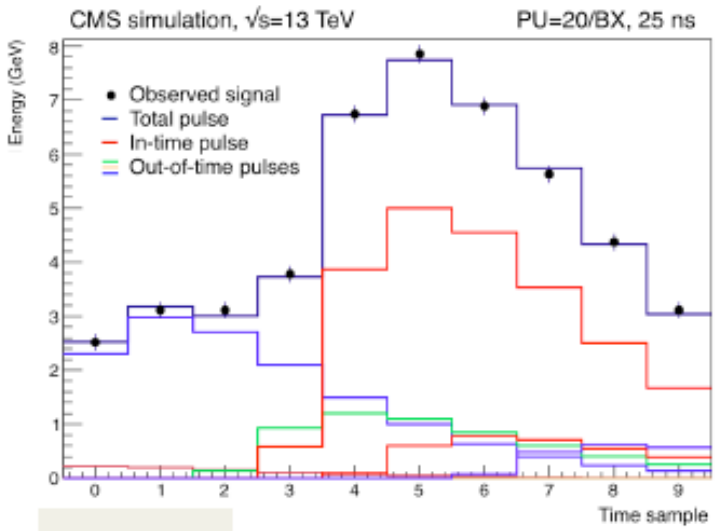
Il faut impérativement réduire le flux de données de plusieurs ordres de grandeur

Luminosité et empilement



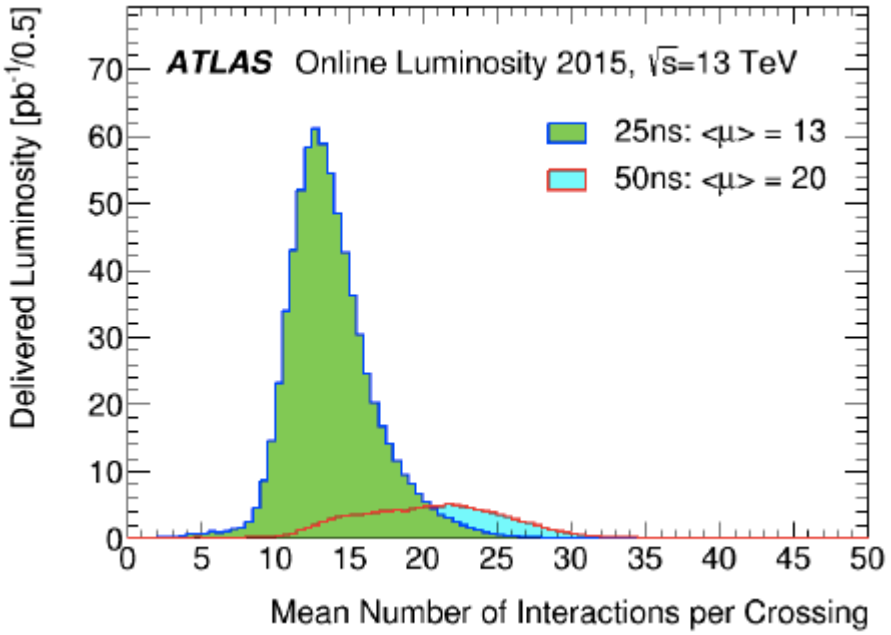
Empilement “en temps”

et “hors temps”

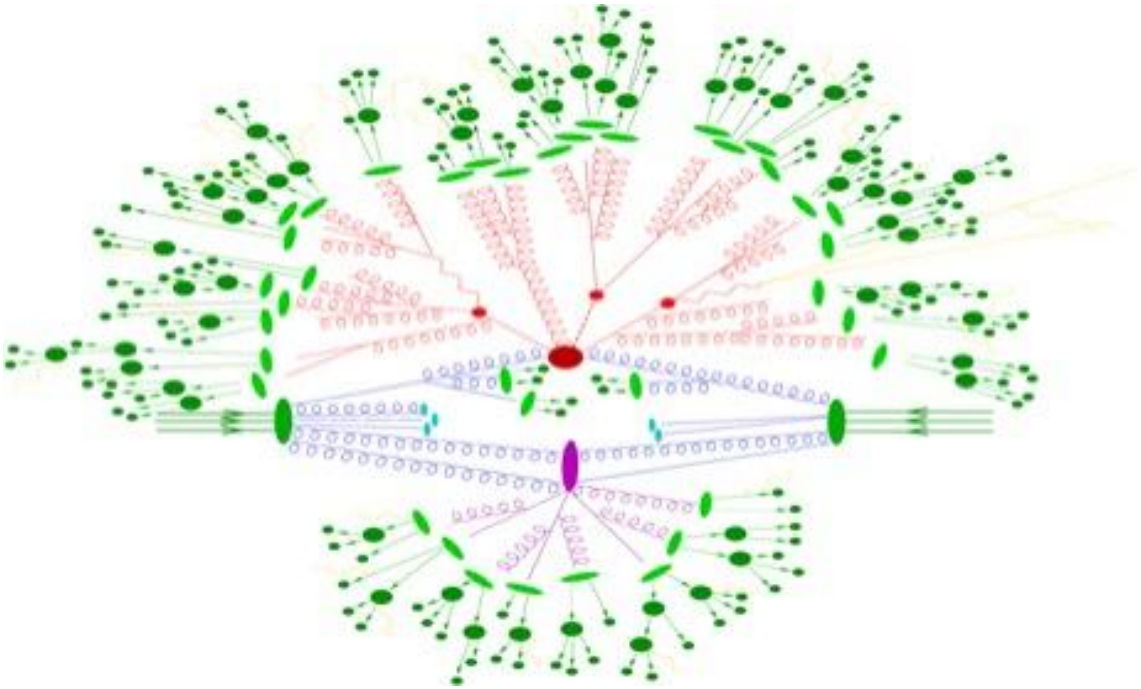


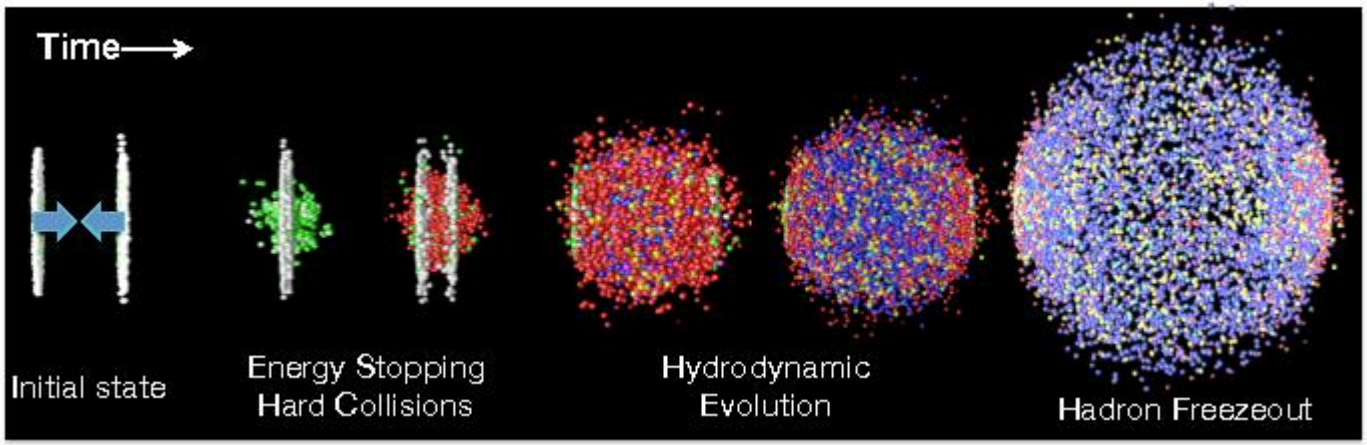
ECAL

En 2015, prise de donnée avec un interval de temps entre 2 croisements de faisceaux de 50ns (comme au Run1), puis de 25 ns

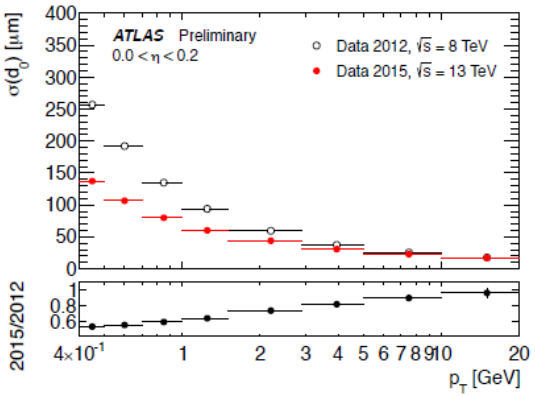


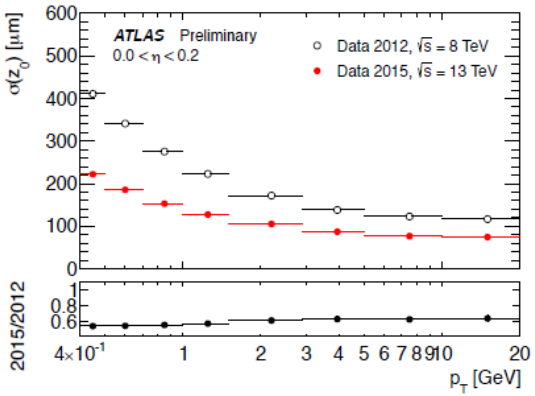
Des collisions complexes !

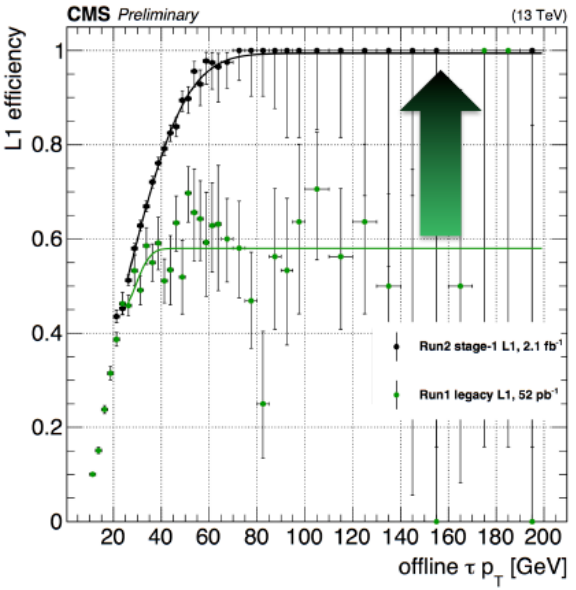


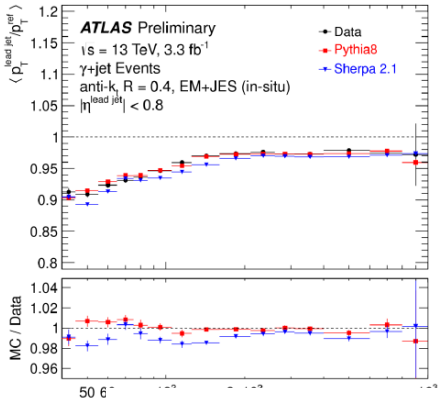


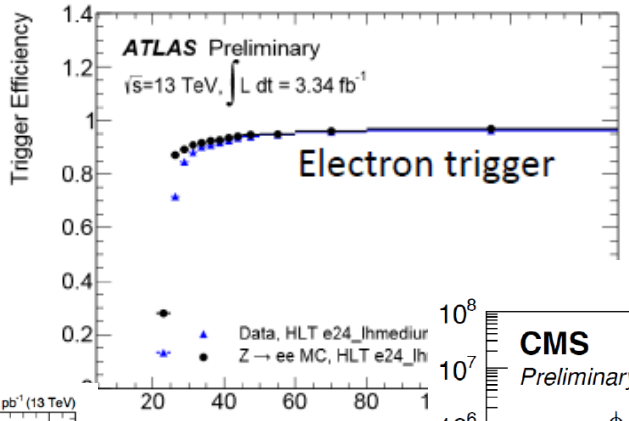
Re-commissioning

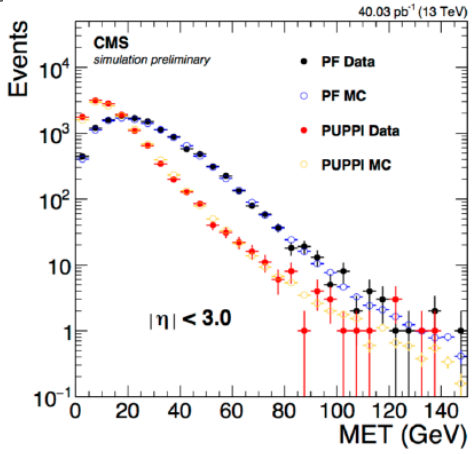


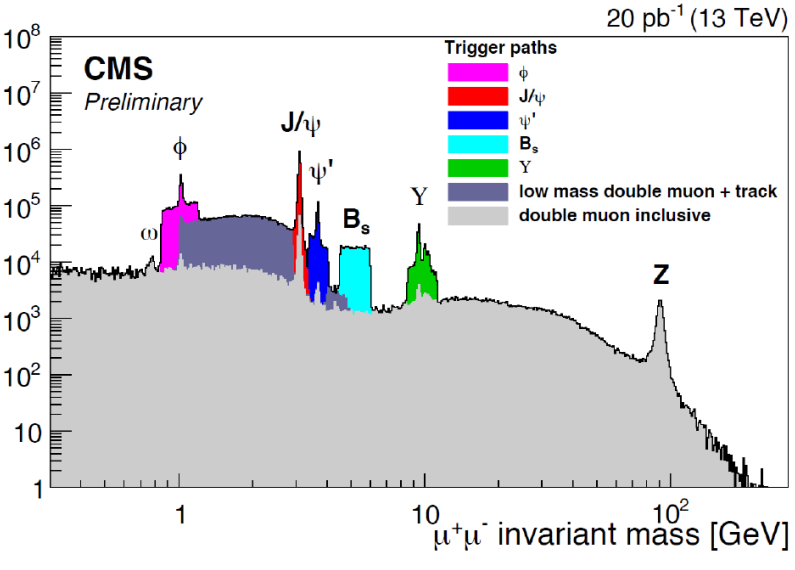




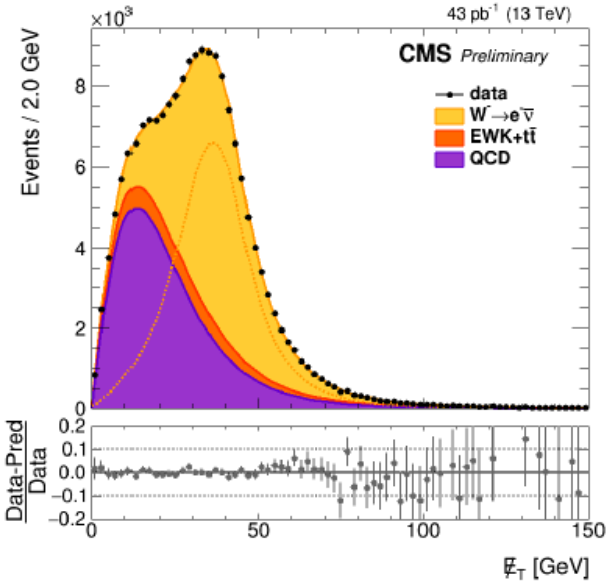


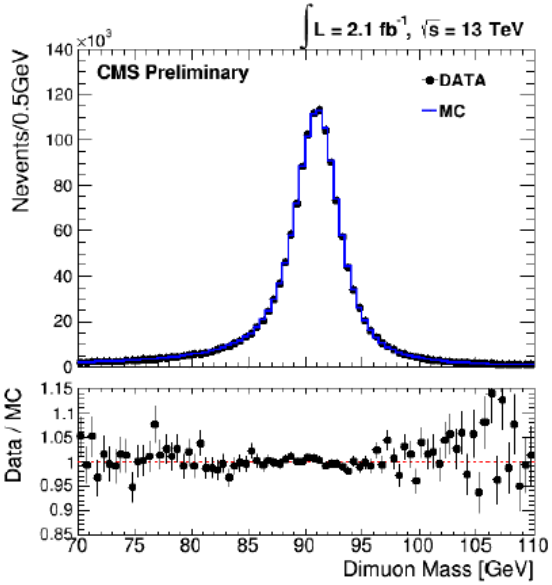


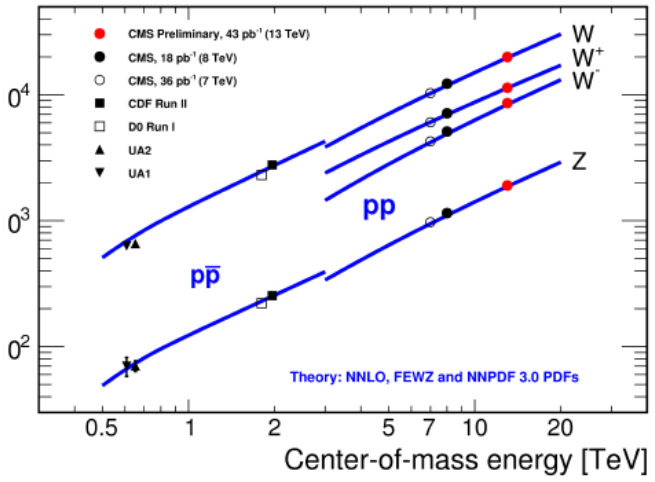


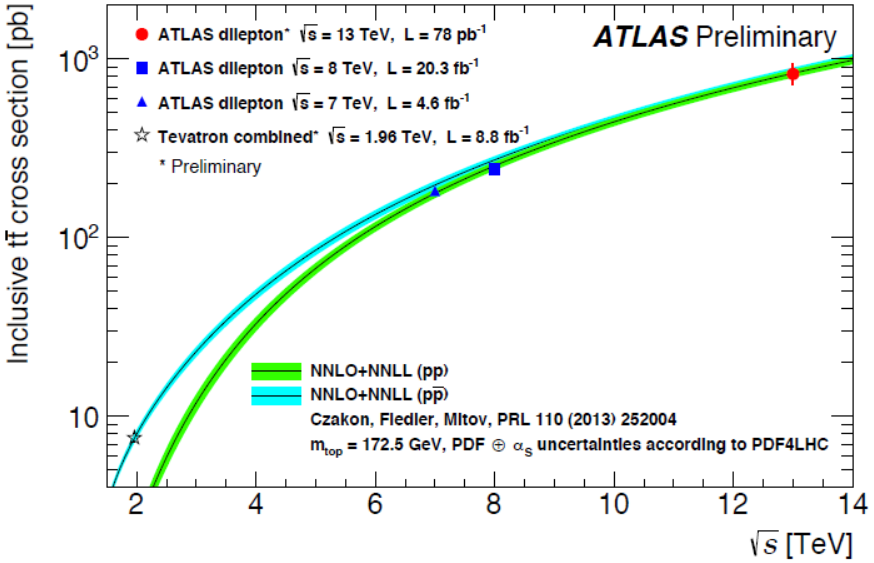


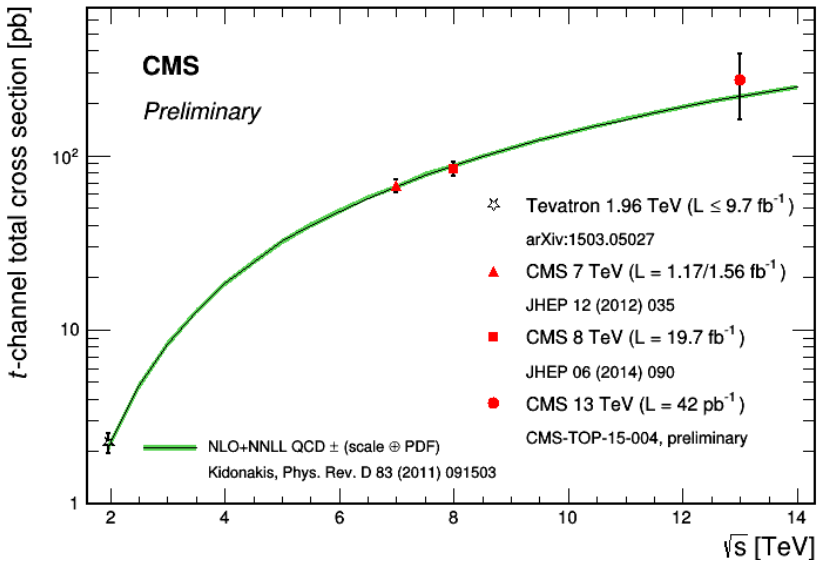
Le LHC : usine à W/Z et à top



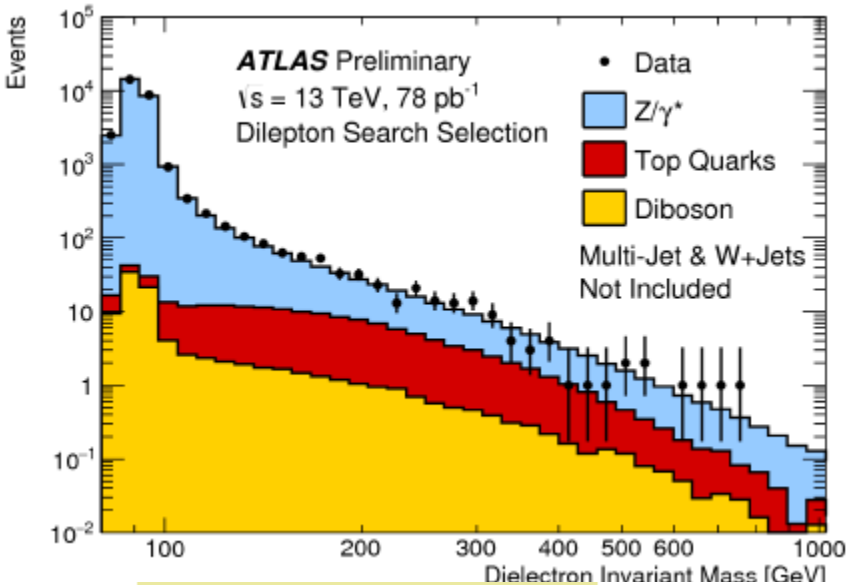


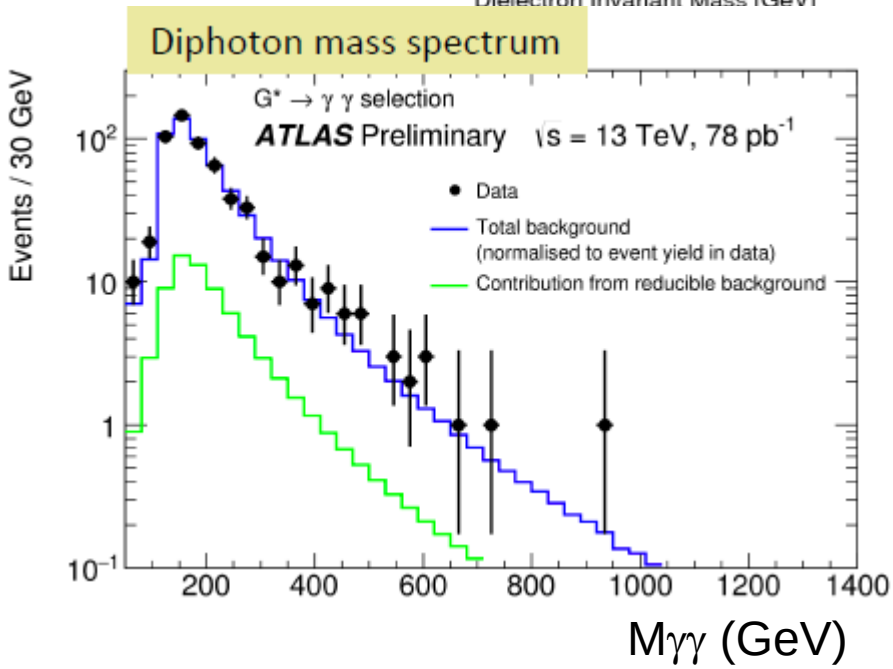


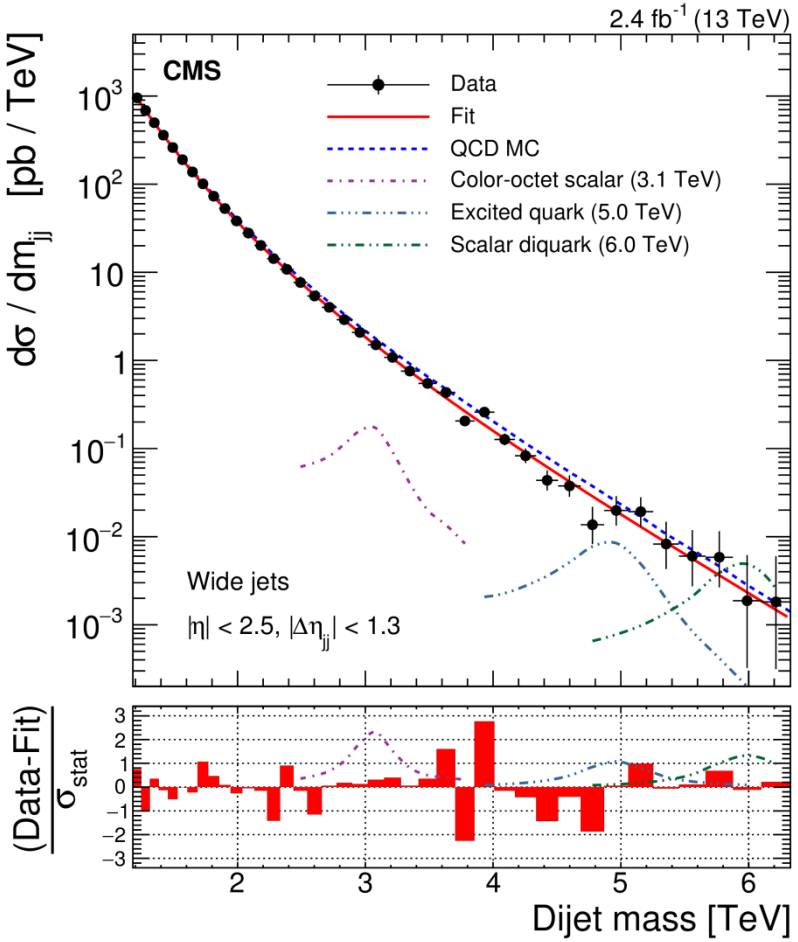




Recherche de NP: Run 2

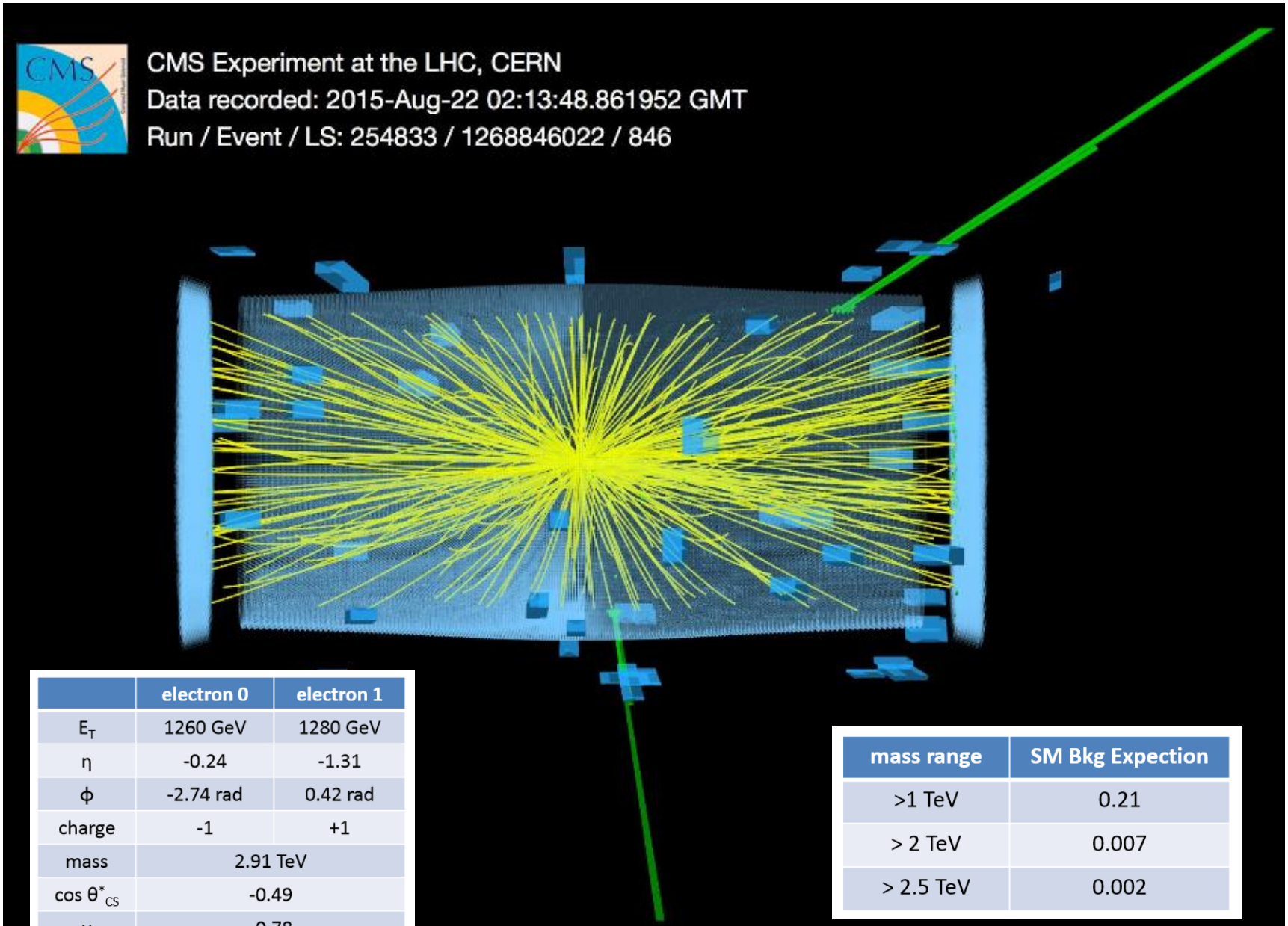






Beaucoup de nouveaux résultats présentés demain (15/12/2015) au LHC Jamboree au CERN

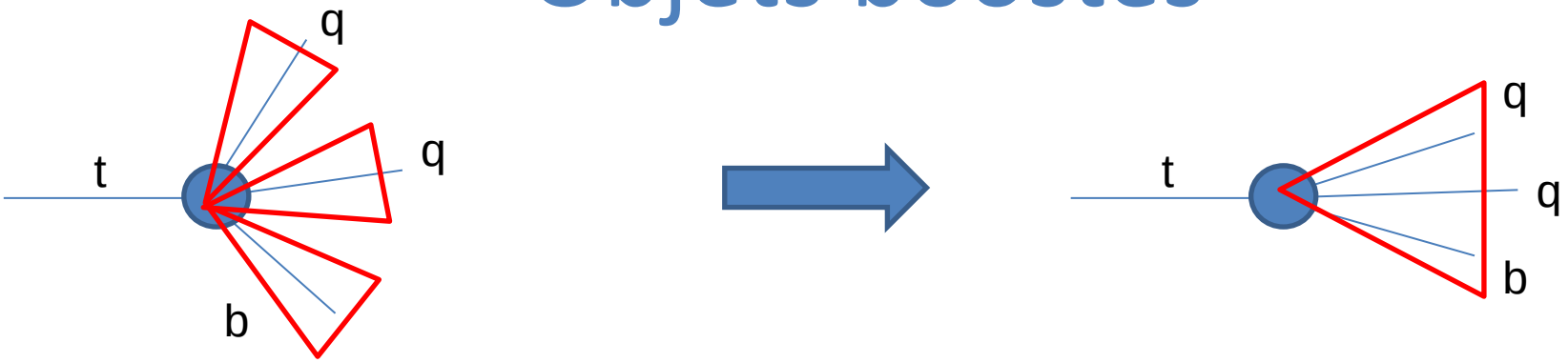
Recherche de nouvelle physique

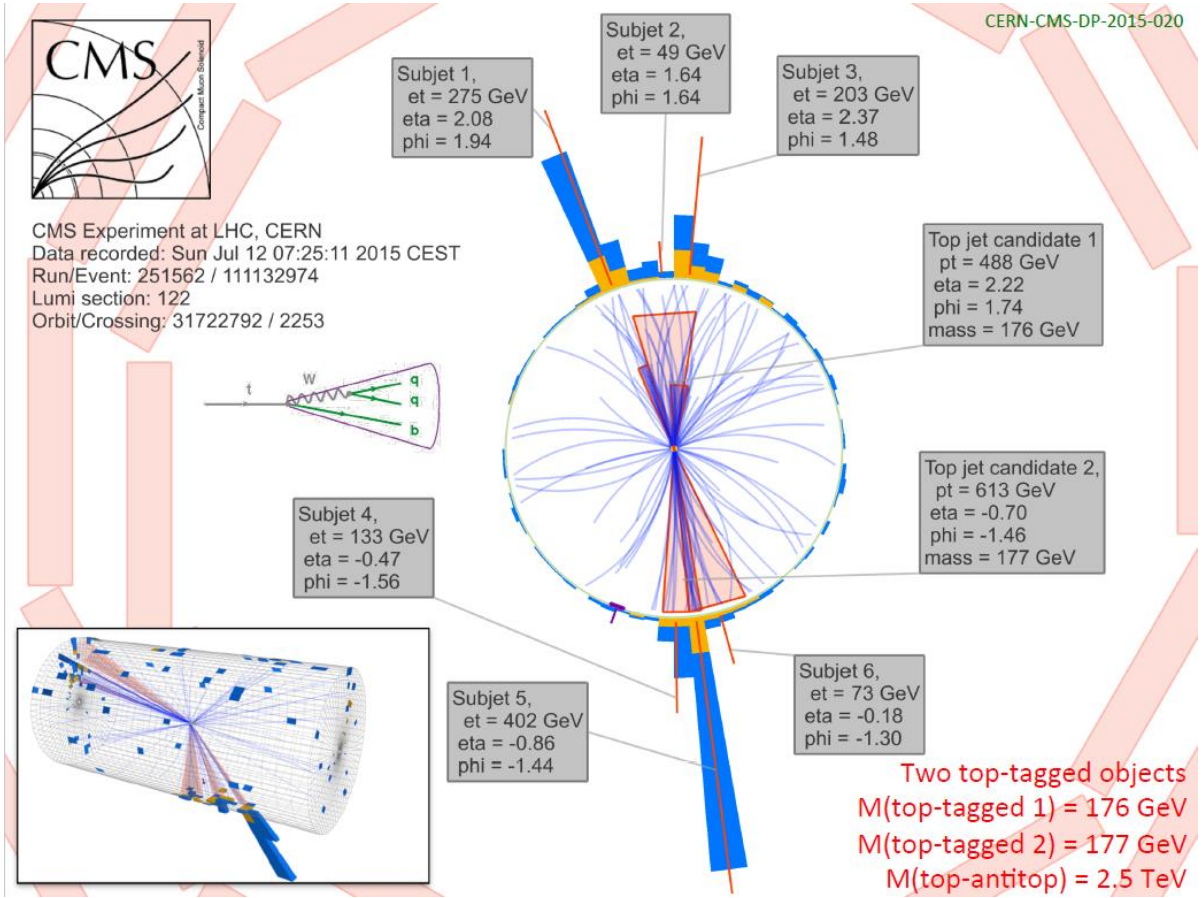


	electron 0	electron 1
E_T	1260 GeV	1280 GeV
η	-0.24	-1.31
ϕ	-2.74 rad	0.42 rad
charge	-1	+1
mass	2.91 TeV	
$\cos\theta^*_{CS}$	-0.49	
y	-0.78	

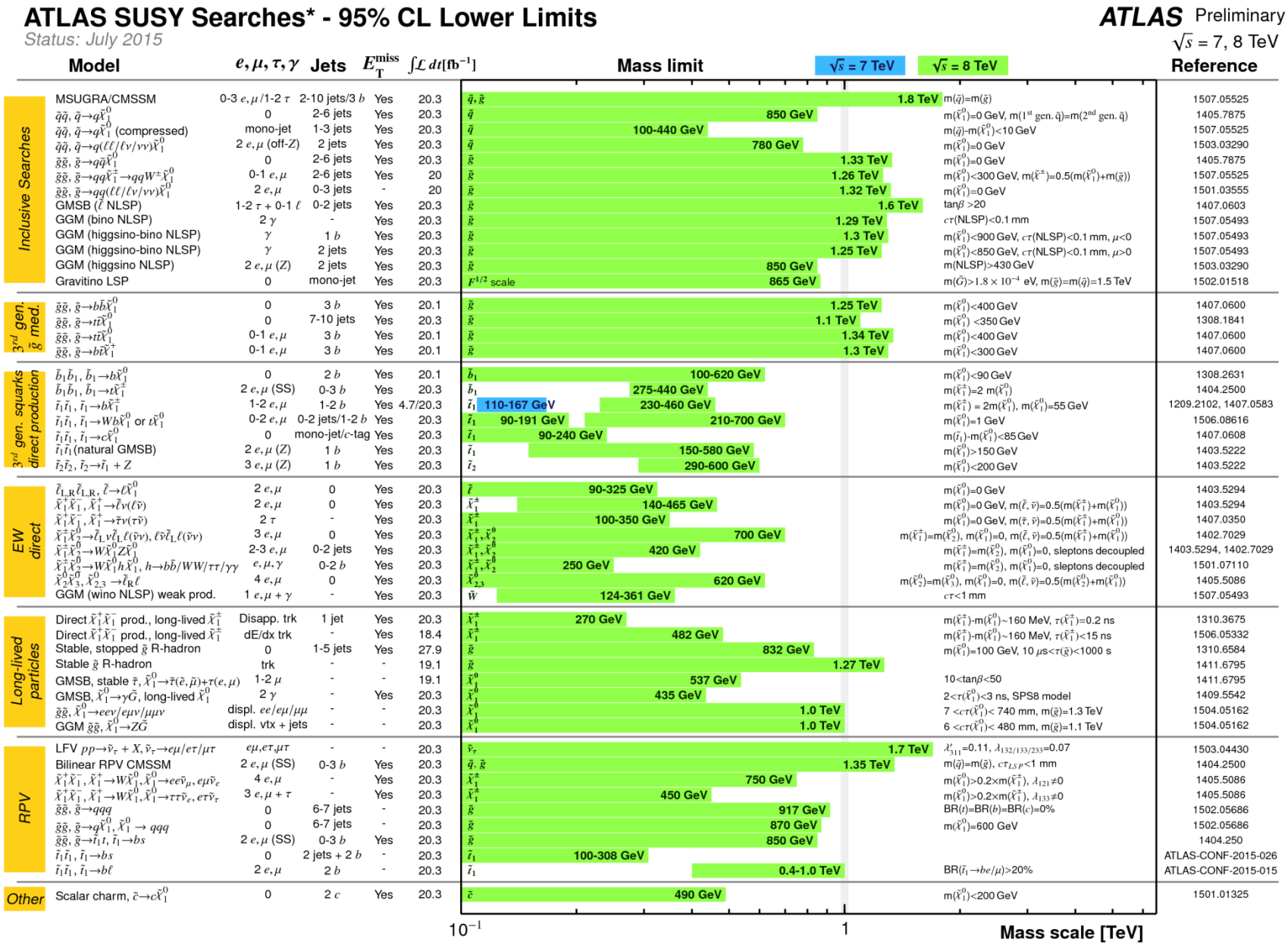
mass range	SM Bkg Expection
>1 TeV	0.21
> 2 TeV	0.007
> 2.5 TeV	0.002

Objets boostés



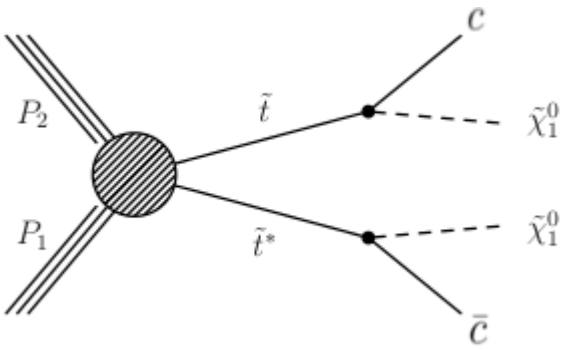


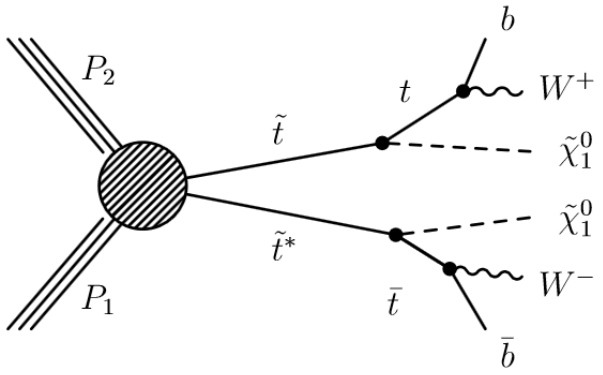
Recherche de NP: Run 1

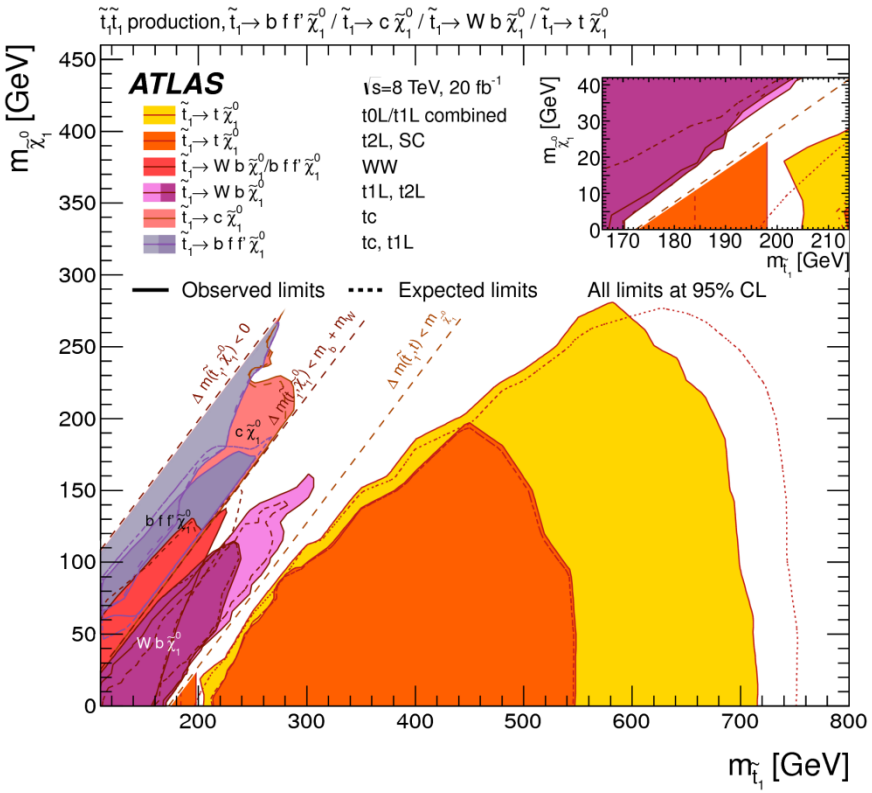


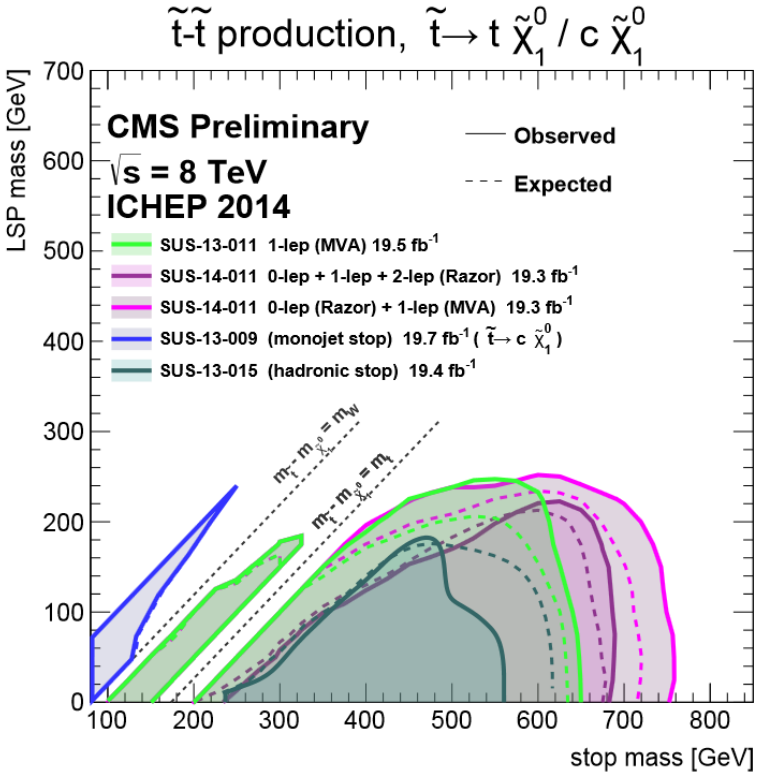
*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Recherche du stop: Run 1

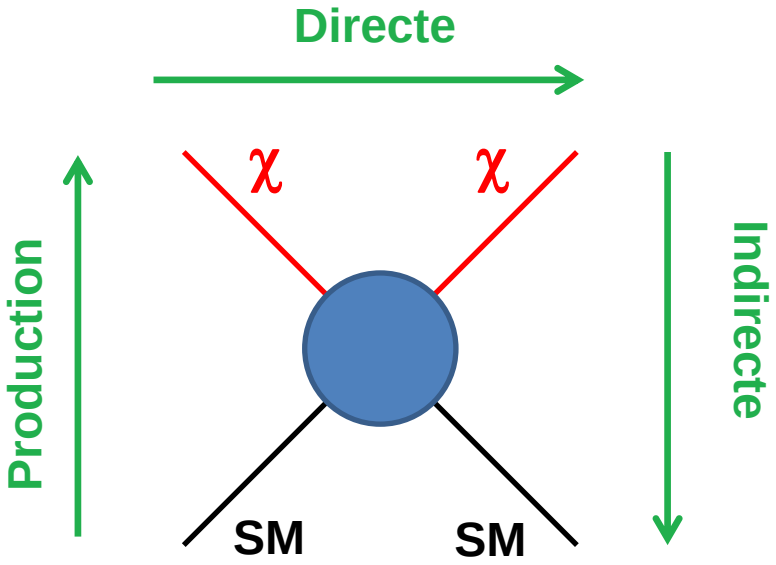


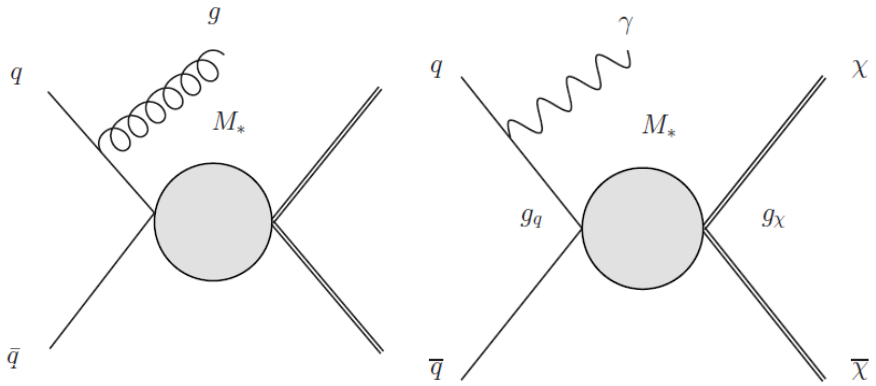


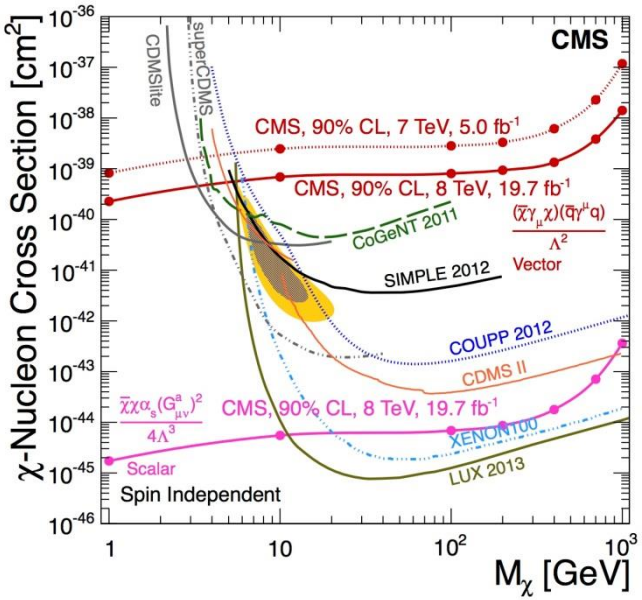


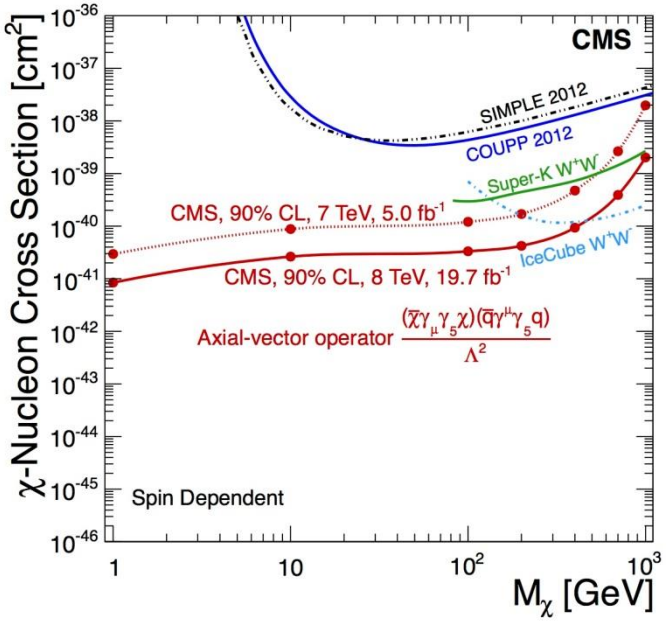


Recherche de matière noire

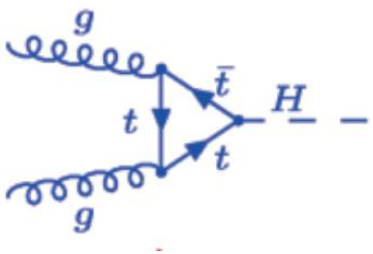




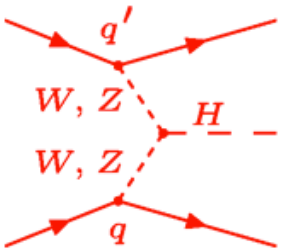




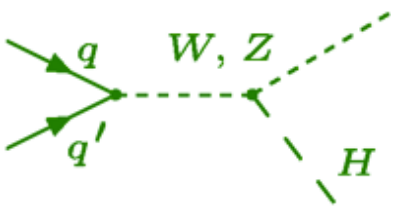
Production du Higgs



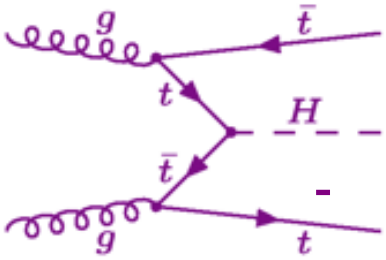
gluon fusion



vector boson fusion



associated W/Z production



associated tt production

Fusion de gluon:

processus dominant

Fusion de boson vecteurs (VBF)

signature spécifique avec 2 jets à l'avant

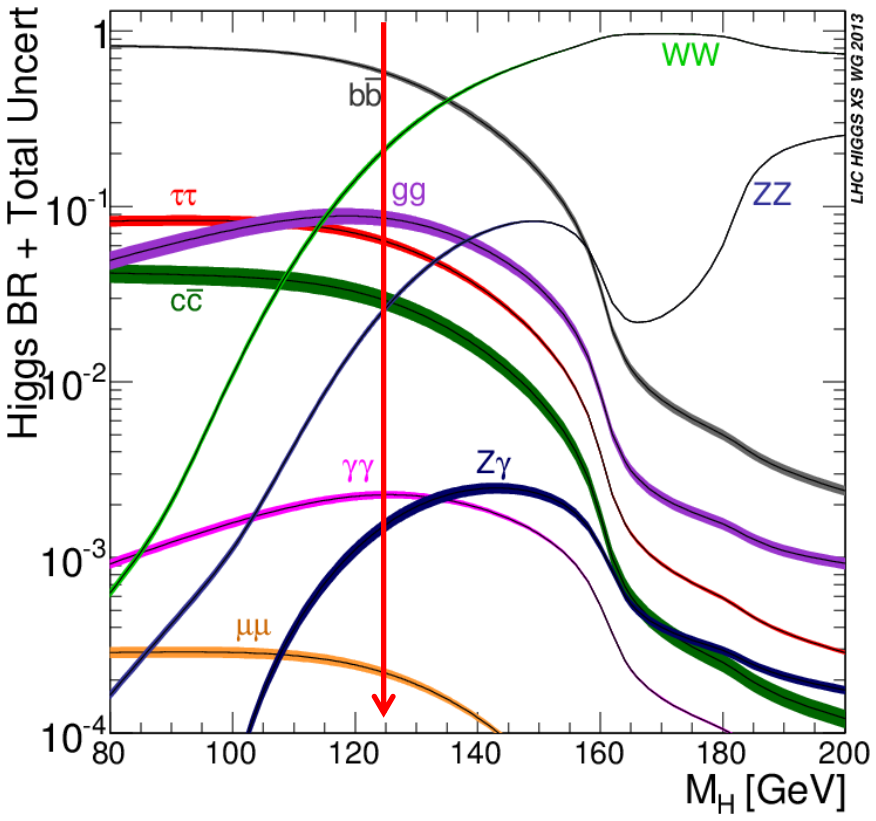
Production associée WH/ZH (VH)

désintégration leptonique du W ou du Z

Production associée ttbarH

	process	8 TeV	13 TeV
ggF	gluon-gluon fusion	19 pb	44 pb
VBF	vector-boson fusion	1.6 pb	3.7 pb
VH	associated production	1.1 pb	2.2 pb
ttH	associated production	0.13 pb	0.51 pb
tH	Associated production	~20 fb	~90 fb

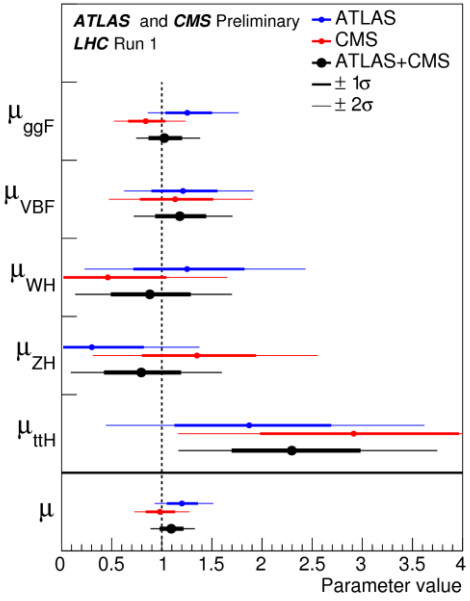
Désintégration du Higgs

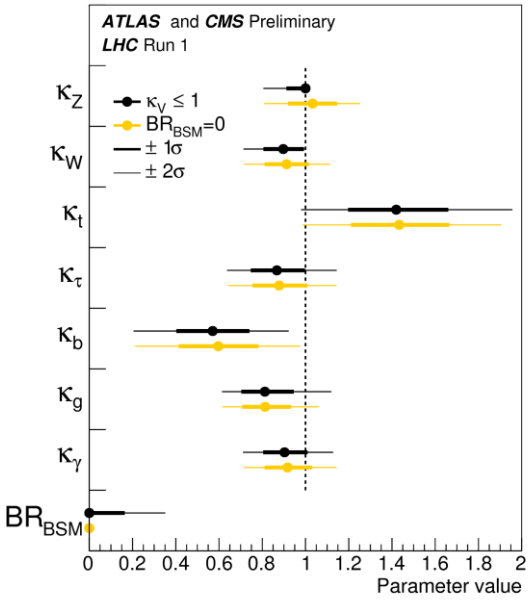


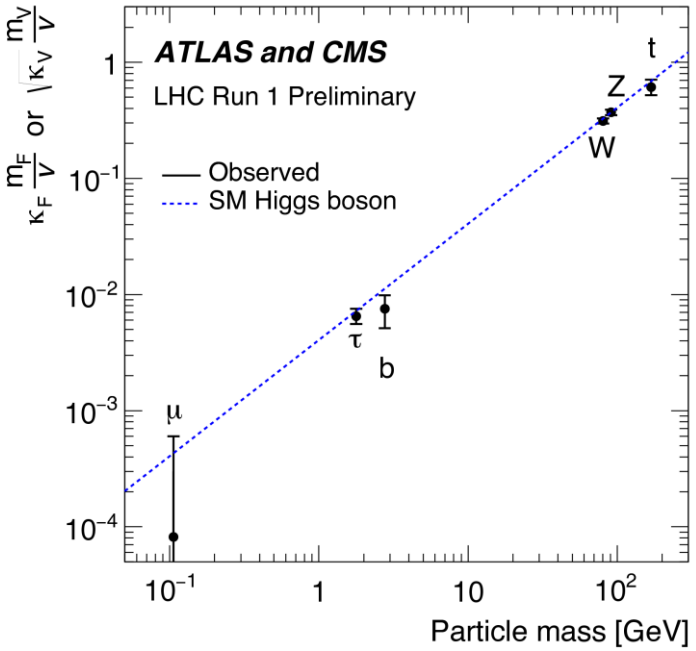
M_H = 125.09 GeV

Process	Br
bb	0.58
WW	0.22
ττ	0.06
ZZ	0.027
γγ	0.0023
Zγ	0.0016
μμ	0.0002

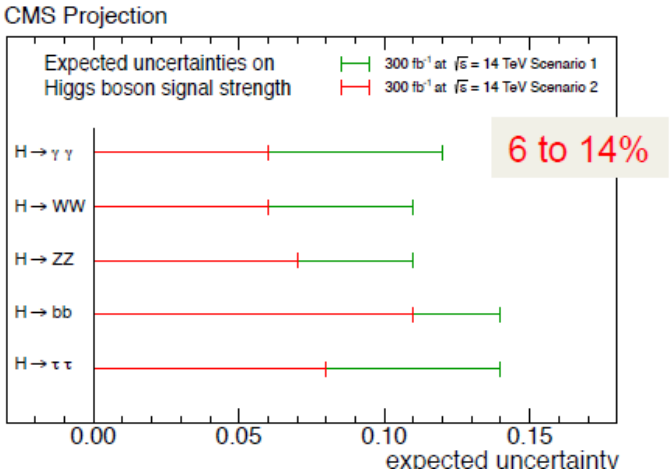
Combinaison ATLAS/CMS Run 1

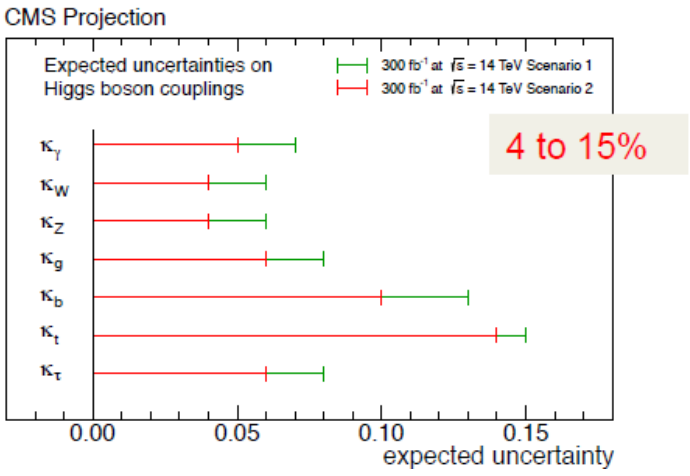






Statistique multipliée par ~10 pour 2018 et ~20 pour 2023





Higgs(es): SM ou BSM ?

1) Mesurer avec la plus grand précision possible les caractéristiques du boson higgs découvert à 125 GeV et comparer avec les prédictions du modèles standard

2) Désintégration exotique:

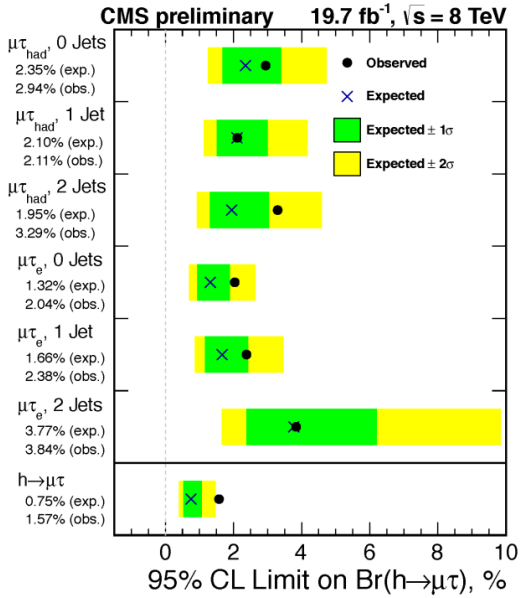
3) Recherche de bosons de Higgs supplémentaires:

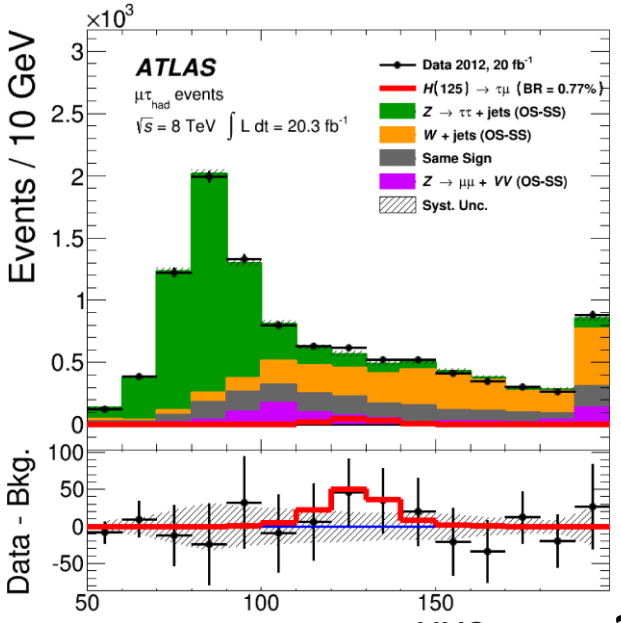
Modèle à 2 doublets, ex: SUSY, h,H, A, H+/-

NMSSM : singlet supplémentaire

4) Production de Higgs par paire

LFV Higgs Decay



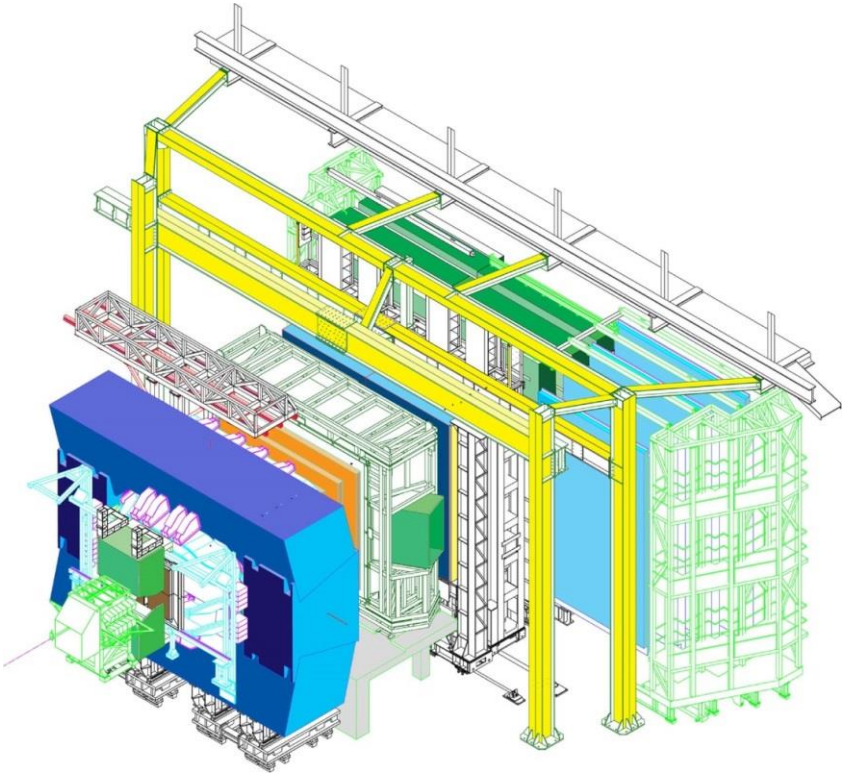


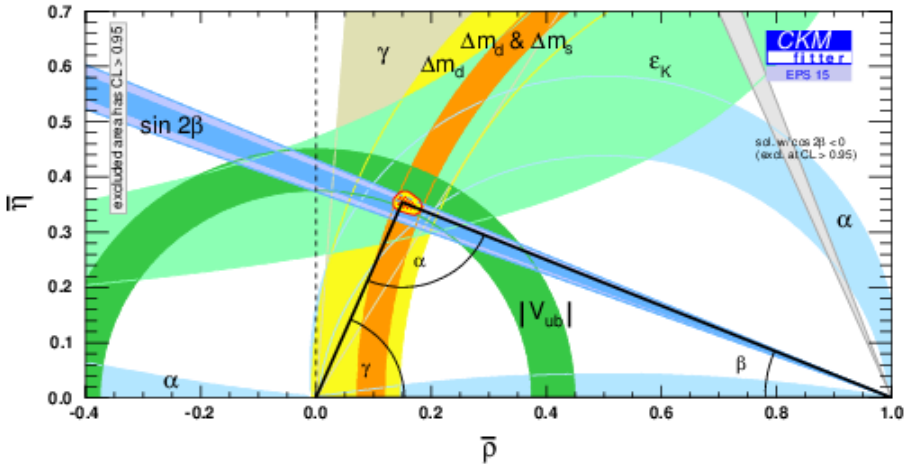
Best-fit : B (H → μτ)

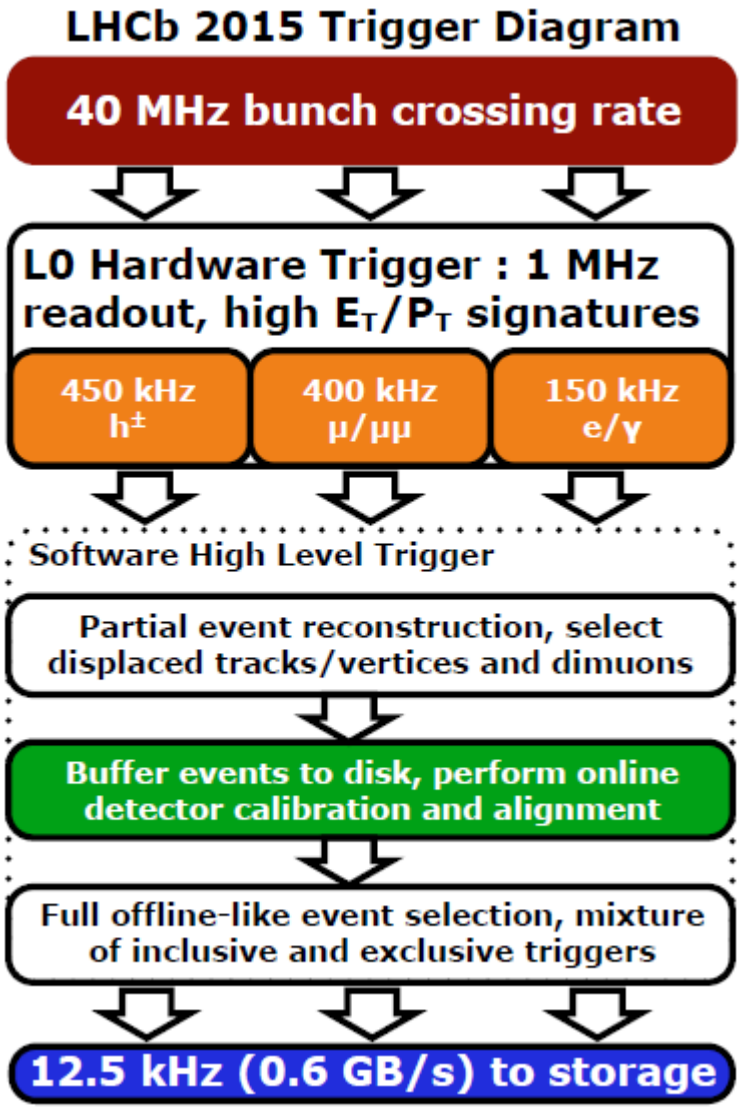
CMS (2.46 σ) : 0.89 $^{+0.40}_{-0.37}$ %

ATLAS (1.30 σ) : 0.77 ± 0.62 %

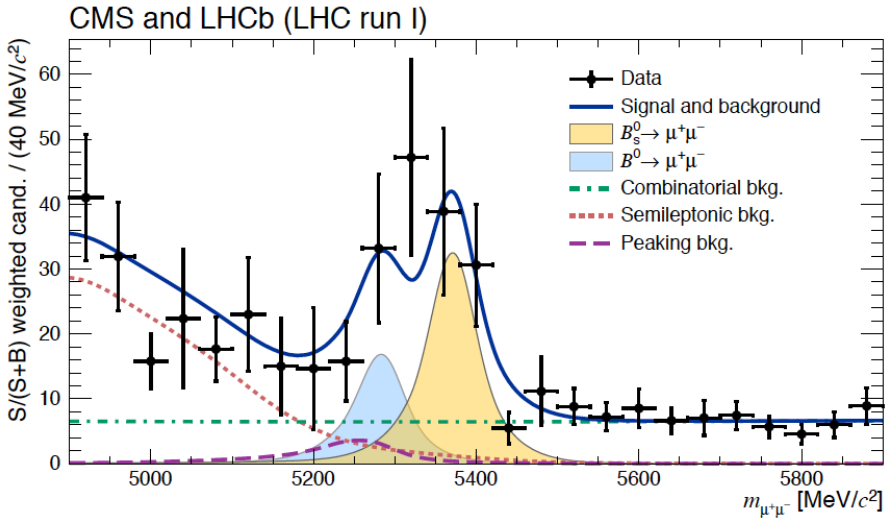
LHCb

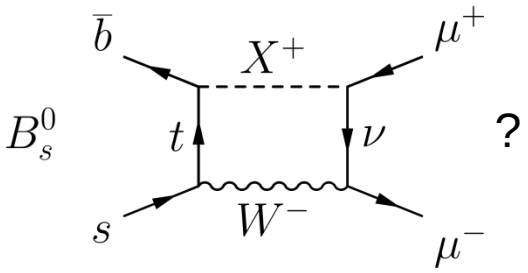



0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
$\bar{\eta}$
$\bar{\rho}$
excluded areas at CL > 0.95
sin 2β
γ
Δm_d
Δm_d & Δm_s
ε_K
CKM fitter
EPS 15
sol. w/ cos 2β < 0 (excl. at CL > 0.95)
α
α
α
$|V_{ub}|$
γ
β


LHCb 2015 Trigger Diagram
40 MHz bunch crossing rate
L0 Hardware Trigger : 1 MHz readout, high E_T/P_T signatures
450 kHz $h^{\pm}$
400 kHz $\mu/\mu\mu$
150 kHz e/γ
Software High Level Trigger
Partial event reconstruction, select displaced tracks/vertices and dimuons
Buffer events to disk, perform online detector calibration and alignment
Full offline-like event selection, mixture of inclusive and exclusive triggers
12.5 kHz (0.6 GB/s) to storage

Désintégration $B^0_s \rightarrow \mu\mu$

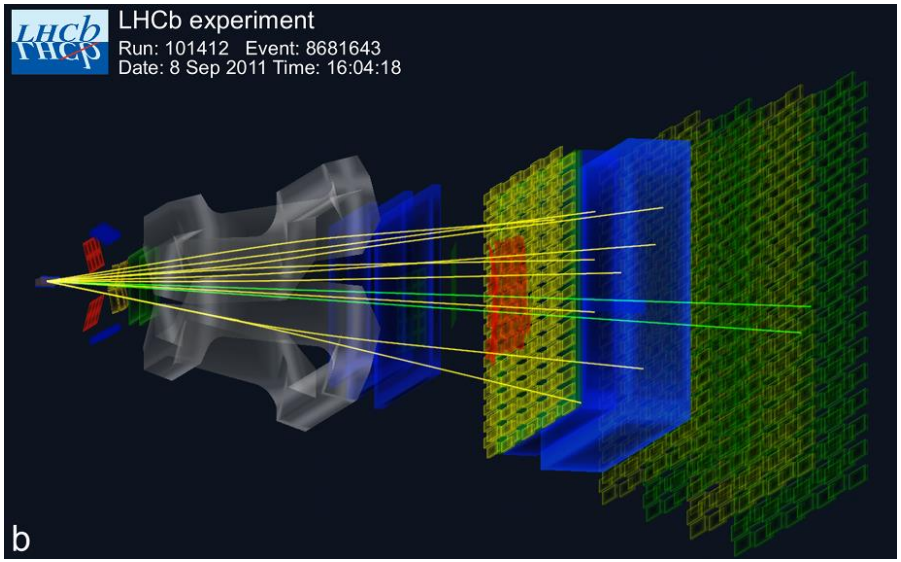


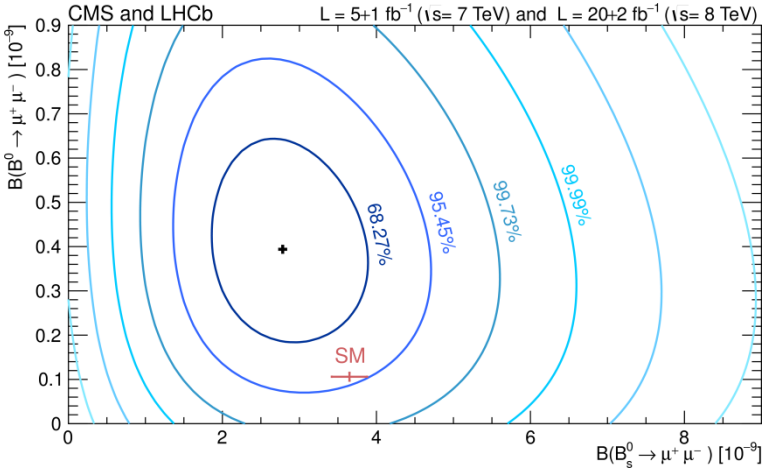


Après 30 ans de recherche:

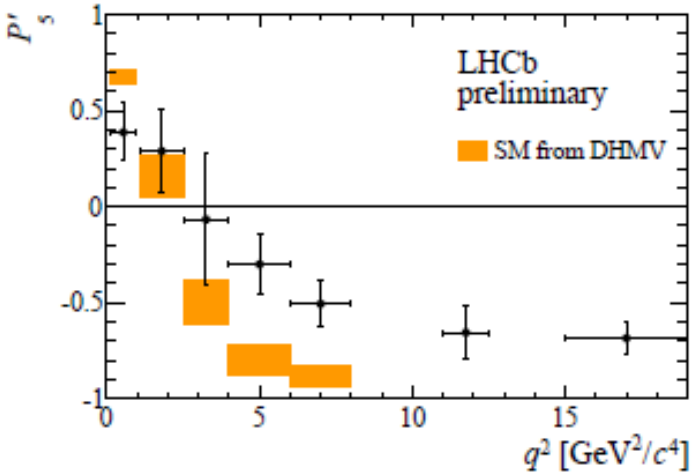
$$\mathcal{B}(B^0_s \rightarrow \mu^+\mu^-) = \left(2.8\,^{+0.7}_{-0.6}\right) \times 10^{-9}$$

$$\mathcal{B}(B^0 \rightarrow \mu^+\mu^-) = \left(3.9\,^{+1.6}_{-1.4}\right) \times 10^{-10}$$

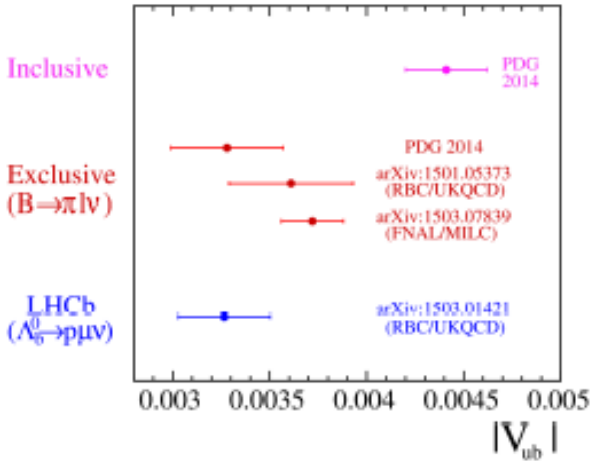




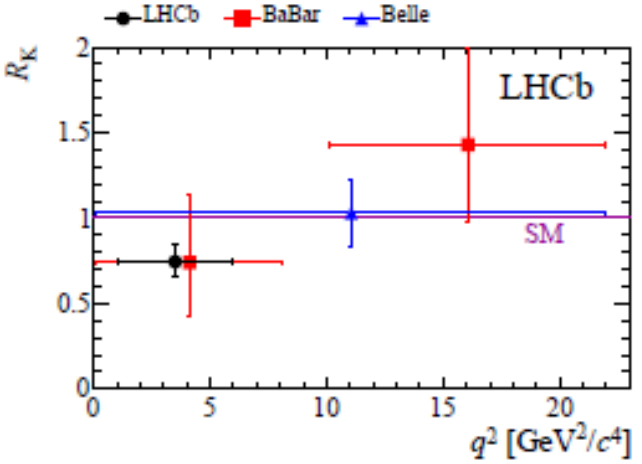
Des anomalies …



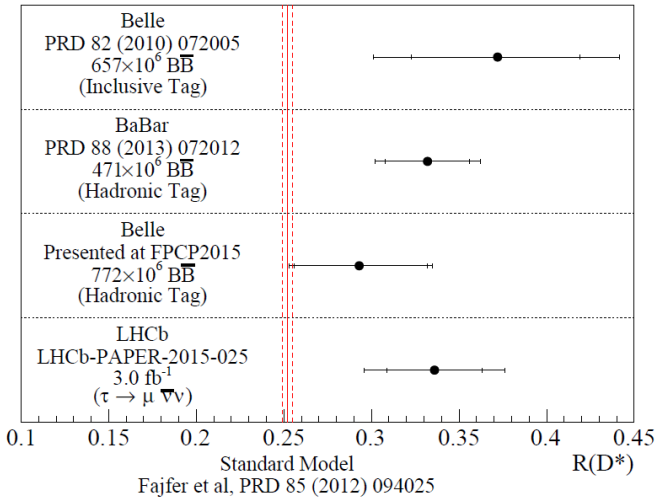
P'_5 in $B \to K^* \mu^+ \mu^-$ [LHCb-CONF-2015-002]



V_{ub} puzzle [Nature Physics 3415 (2015)]

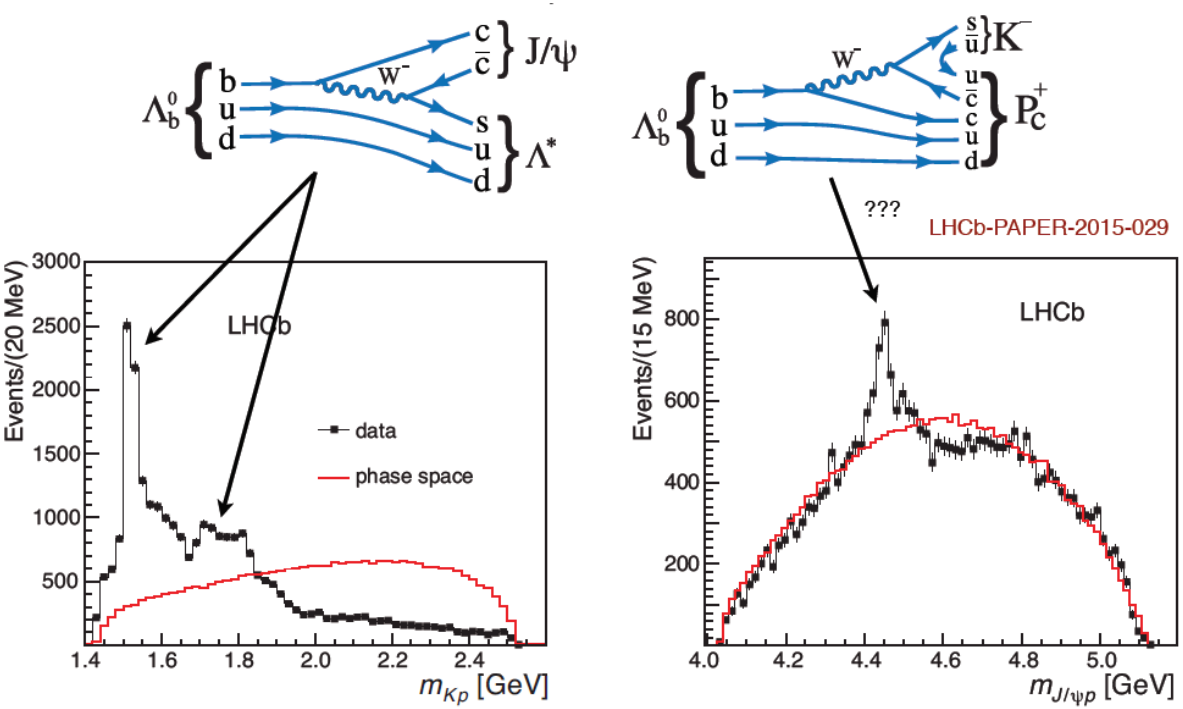


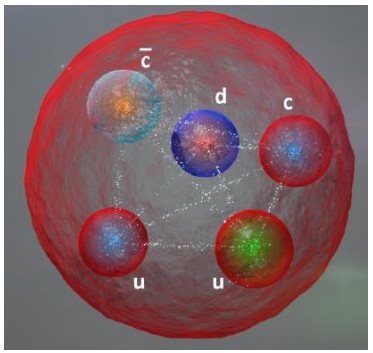
Lepton universality [Phys. Rev. Lett. 113 (2014) 151601]



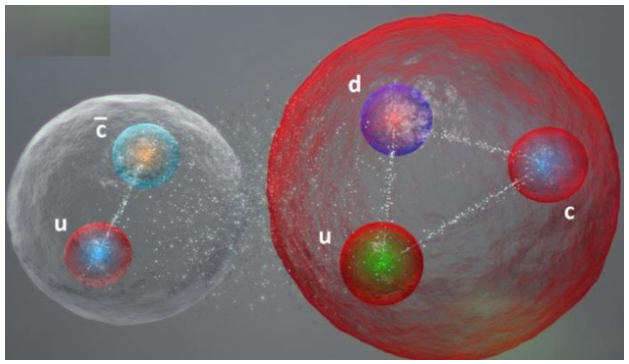
$B \to D^* \tau \nu$ [arXiv:1504.06339]

Pentaquarks



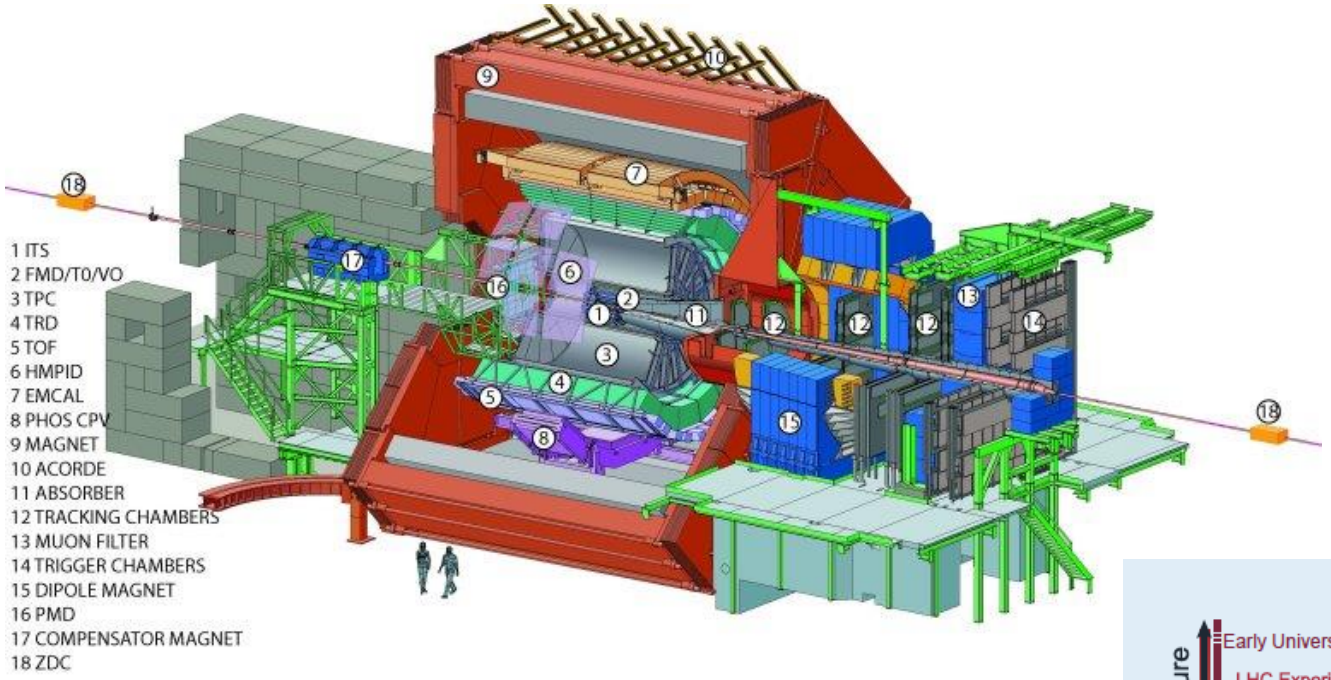


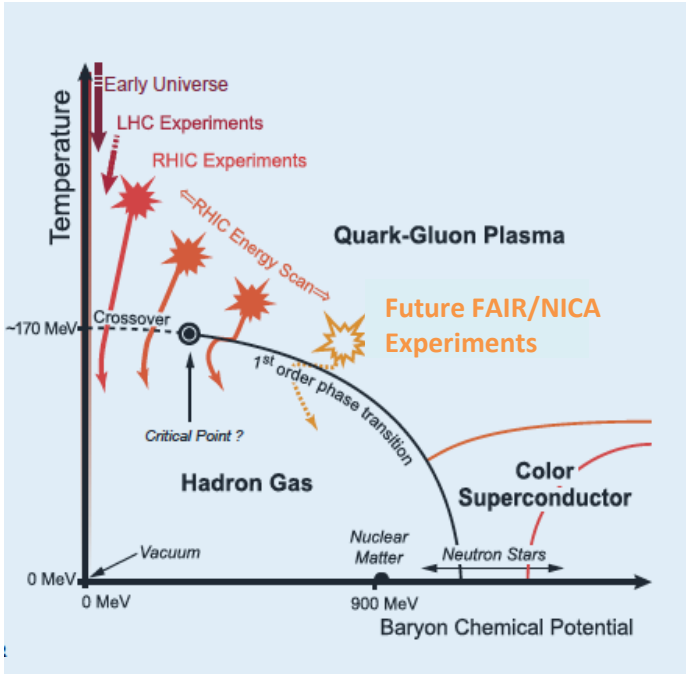
ou



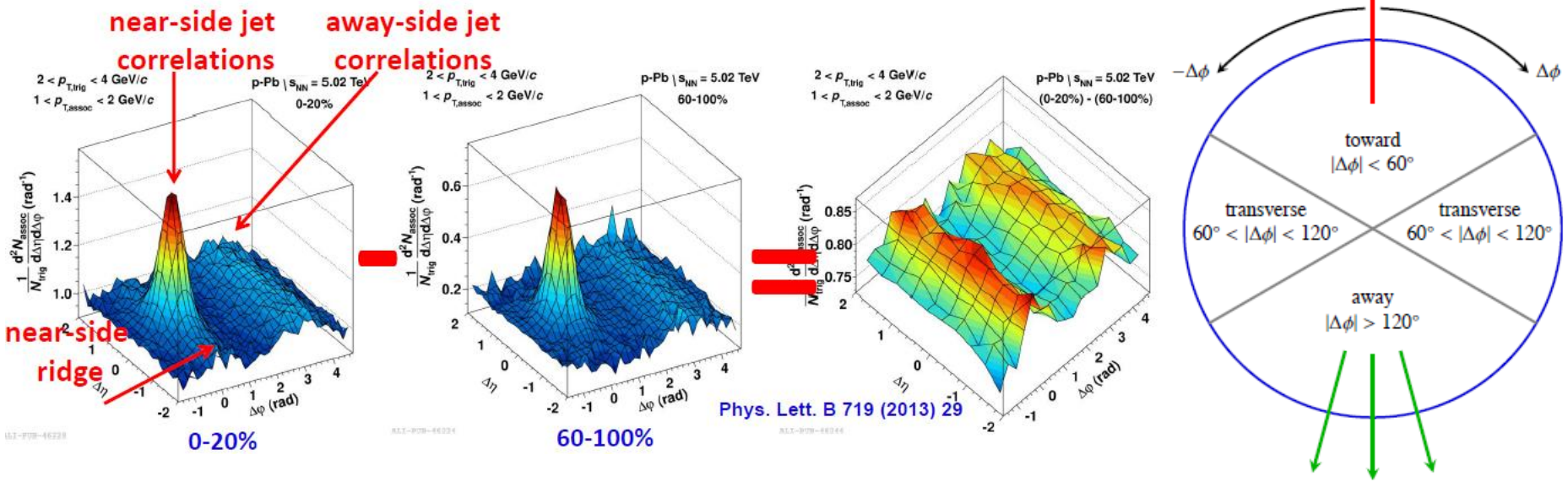
ou … ?

ALICE

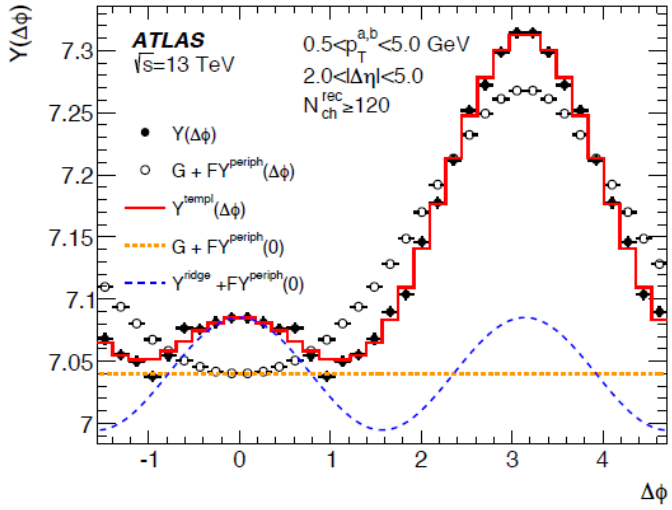

1 ITS
2 FMD/T0/VO
3 TPC
4 TRD
5 TOF
6 HMPID
7 EMCAL
8 PHOS CPV
9 MAGNET
10 ACORDE
11 ABSORBER
12 TRACKING CHAMBERS
13 MUON FILTER
14 TRIGGER CHAMBERS
15 DIPOLE MAGNET
16 PMD
17 COMPENSATOR MAGNET
18 ZDC

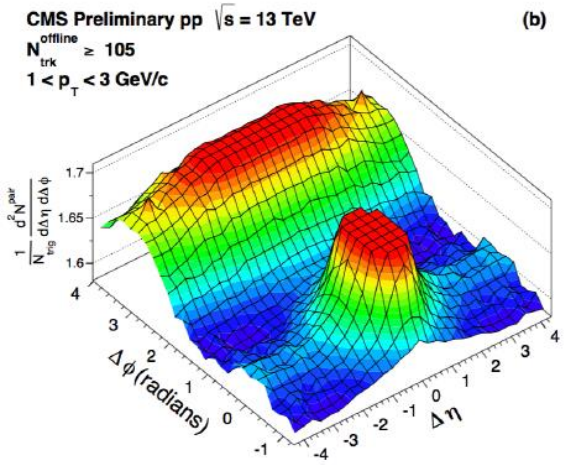

Temperature
Early Universe
LHC Experiments
RHIC Experiments
RHIC Energy Scan
Quark-Gluon Plasma
Future FAIR/NICA Experiments
~170 MeV
Crossover
1st order phase transition
Critical Point ?
Hadron Gas
Color Superconductor
Vacuum
Nuclear Matter
Neutron Stars
0 MeV
0 MeV
900 MeV
Baryon Chemical Potential

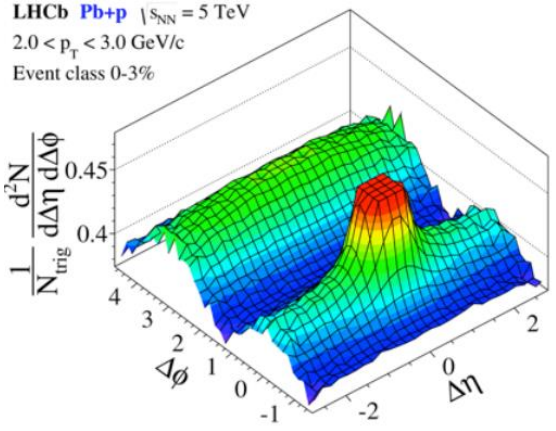
Double ridge

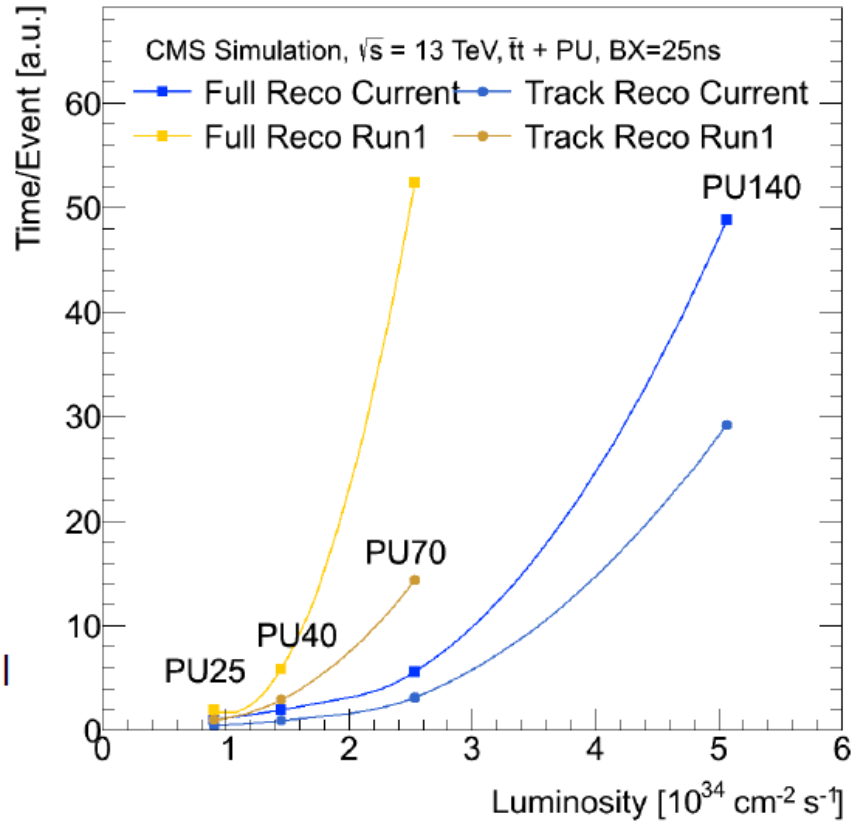


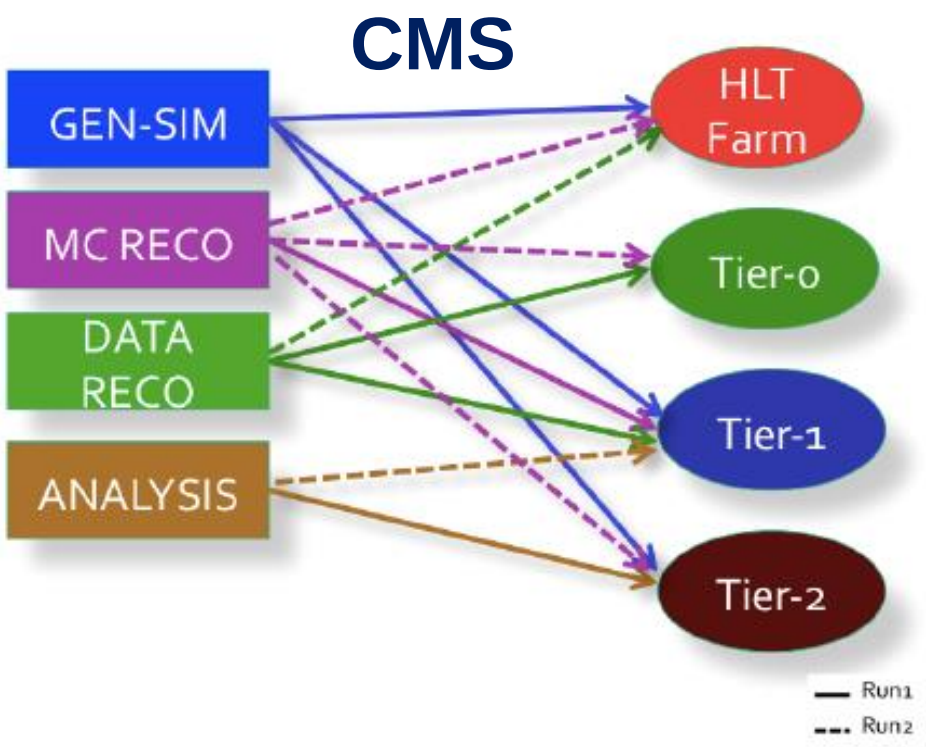
high multi



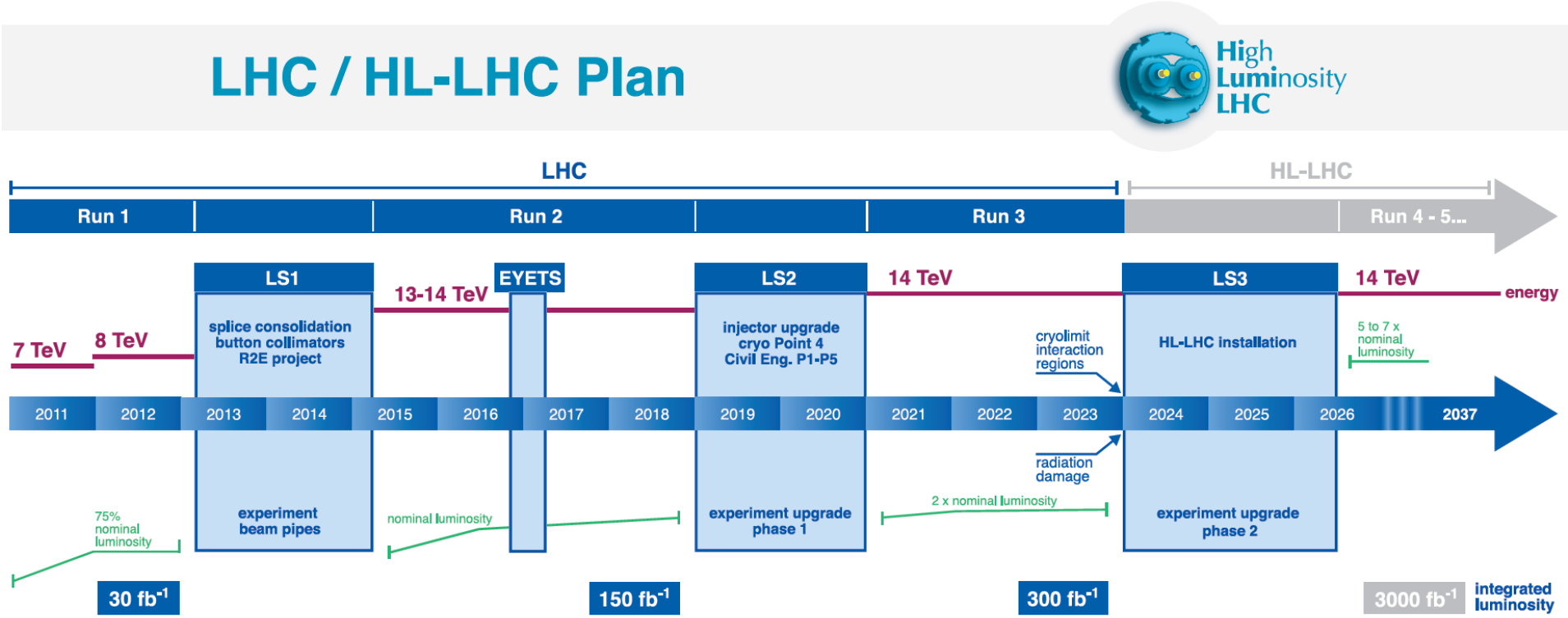


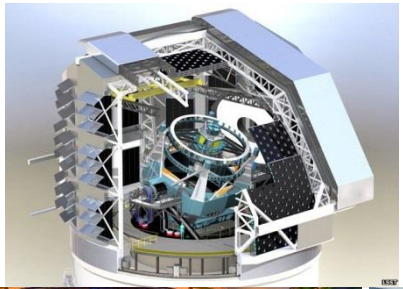


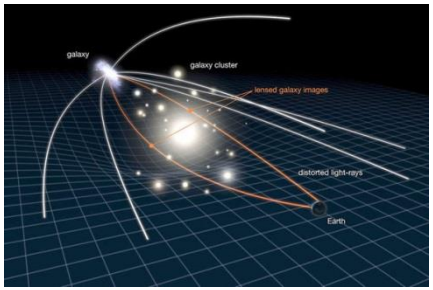

CMS Simulation, √s = 13 TeV, tt̄ + PU, BX=25ns
Full Reco Current
Track Reco Current
Full Reco Run1
Track Reco Run1
PU140
PU70
PU40
PU25
Time/Event [a.u.]
Luminosity [10^34 cm^-2 s^-1]
0
10
20
30
40
50
60
0
1
2
3
4
5
6

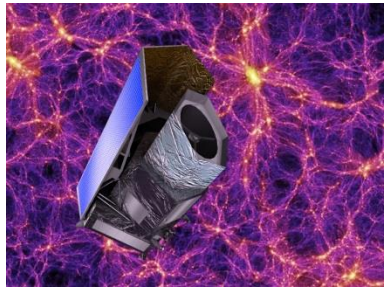

CMS
GEN-SIM
MC RECO
DATA RECO
ANALYSIS
HLT Farm
Tier-0
Tier-1
Tier-2
Run1
Run2

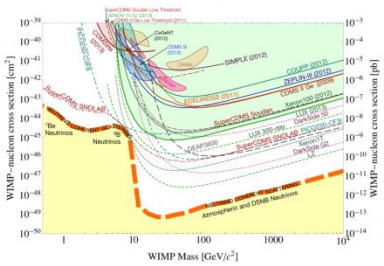
Conclusion

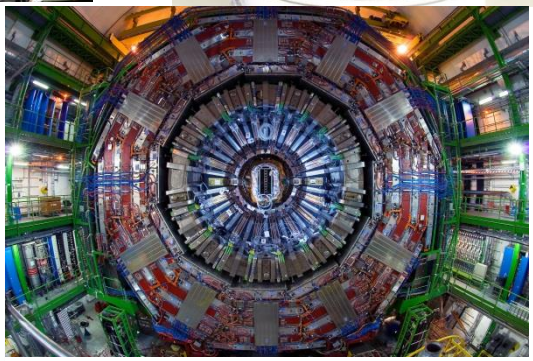

LHC / HL-LHC Plan
High Luminosity LHC
LHC
HL-LHC
Run 1
Run 2
Run 3
Run 4 - 5...
LS1
EYETS
LS2
LS3
14 TeV
14 TeV
energy
7 TeV
8 TeV
13-14 TeV
splice consolidation
button collimators
R2E project
injector upgrade
cryo Point 4
Civil Eng. P1-P5
cryolimit
interaction
regions
HL-LHC installation
5 to 7 x
nominal
luminosity
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2037
radiation
damage
75%
nominal
luminosity
experiment
beam pipes
nominal luminosity
experiment upgrade
phase 1
2 x nominal luminosity
experiment upgrade
phase 2
30 fb-1
150 fb-1
300 fb-1
3000 fb-1
integrated
luminosity

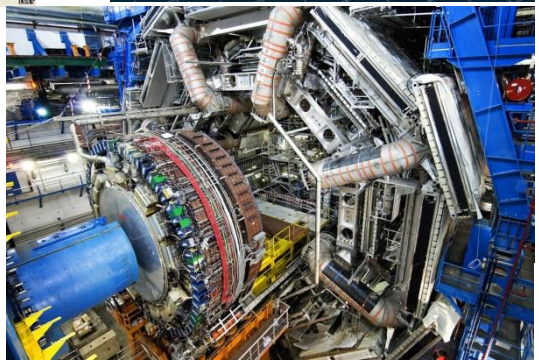


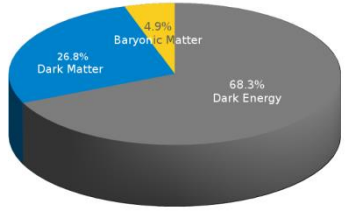

galaxy
galaxy cluster
lensed galaxy images
distorted light-rays
Earth

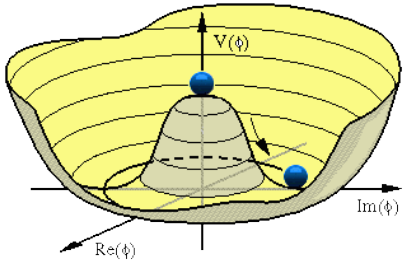


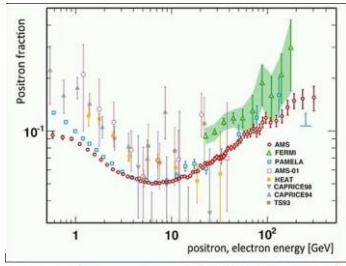

WIMP-nucleon cross section [cm²]
WIMP-nucleon cross section [pb]
WIMP Mass [GeV/c²]
SuperCDMS SNOLAB
Atmospheric and DSNB Neutrinos

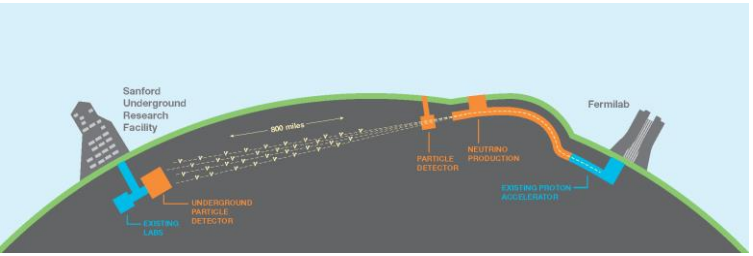


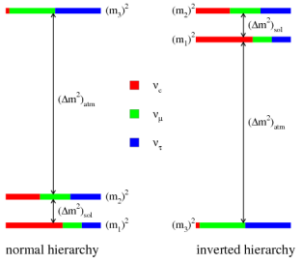



4.9%
Baryonic Matter
26.8%
Dark Matter
68.3%
Dark Energy


V(ϕ)
Im(ϕ)
Re(ϕ)


Positron fraction
positron, electron energy [GeV]
AMS
FERMI
PAMELA
AMS-01
HEAT
CAPRICE98
CAPRICE94
TS93


Sanford
Underground
Research
Facility
800 miles
Fermilab
PARTICLE DETECTOR
NEUTRINO PRODUCTION
EXISTING PROTON ACCELERATOR
UNDERGROUND PARTICLE DETECTOR
EXISTING LABS


normal hierarchy
inverted hierarchy


LIGO Lab/Virgo