



THE
ROYAL
SOCIETY

UCL

Pushing the precision frontier at the LHC

Sarah Alam Malik
University College London

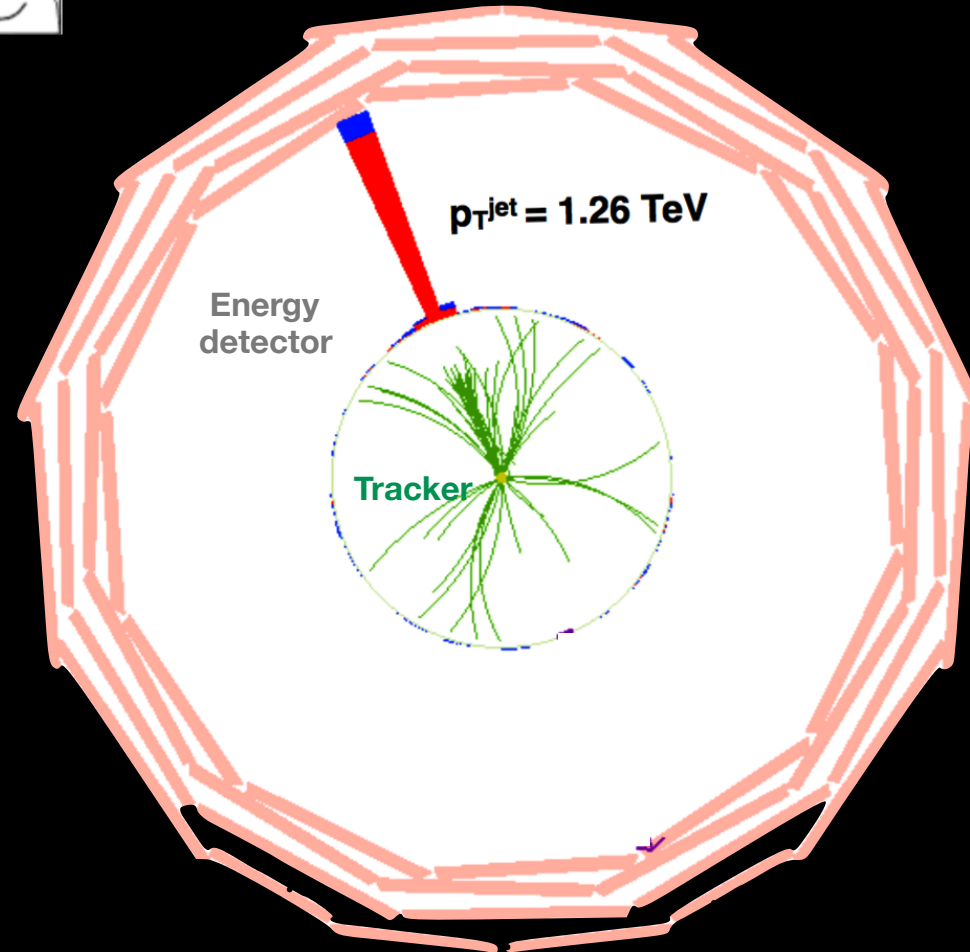
Z invisible decay

Rate of decay of the **Z boson** to particles that evade detection (**'invisible'**)

Z invisible decay

Rate of decay of the **Z boson** to particles that evade detection ('invisible')

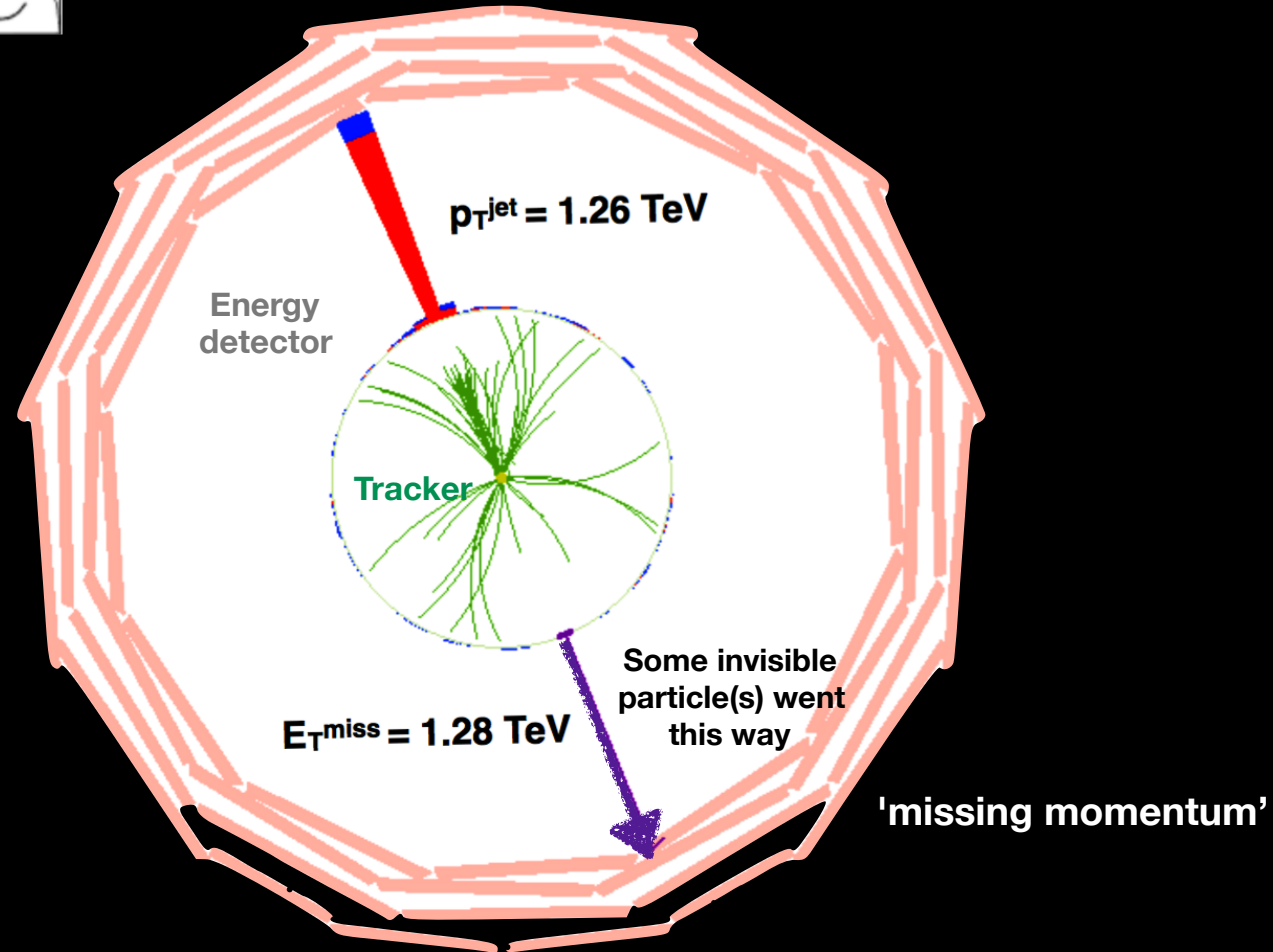
How do we detect invisible particles?



Z invisible decay

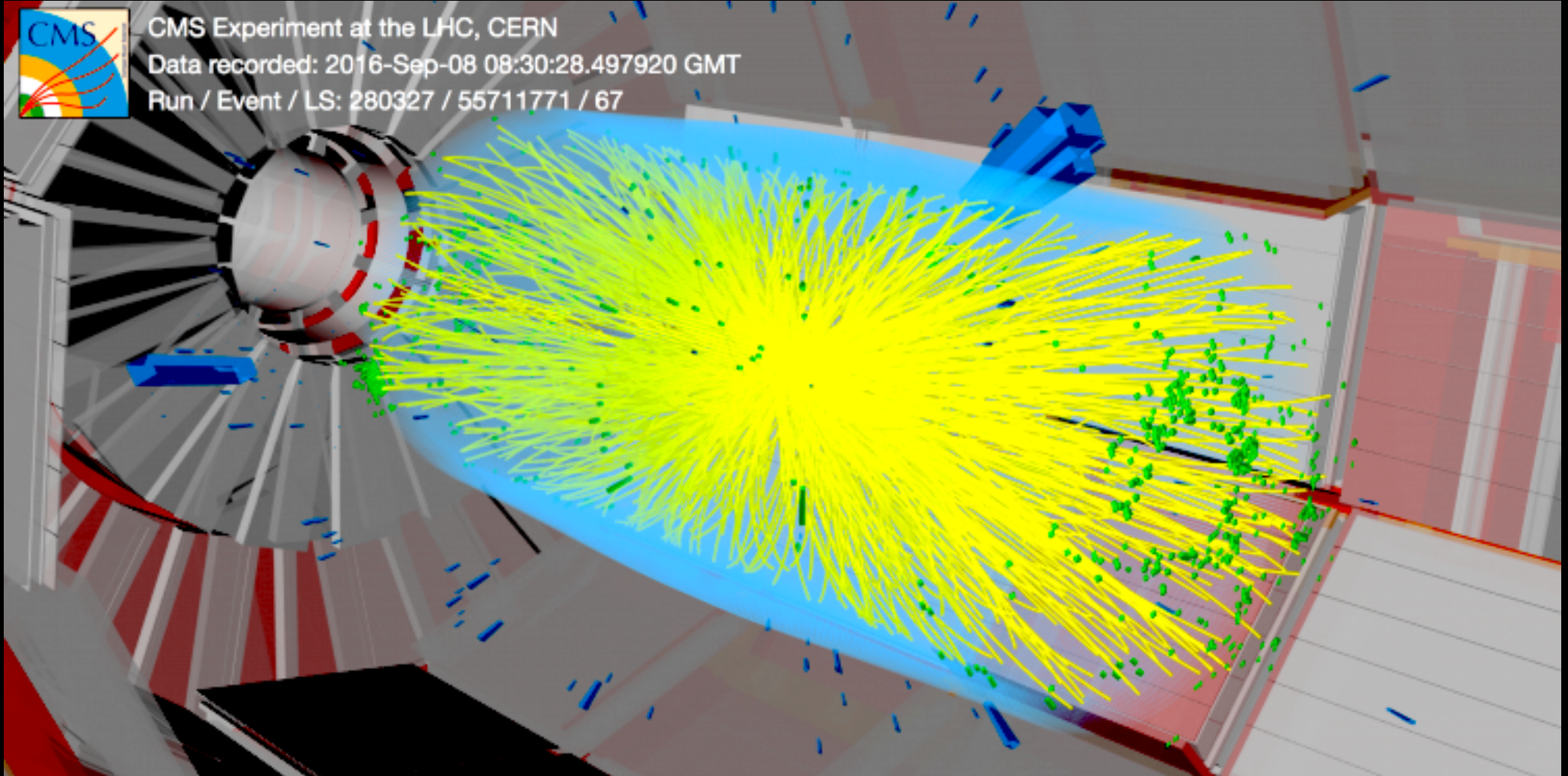
Rate of decay of the **Z boson** to particles that evade detection (**'invisible'**)

How do we detect invisible particles?



Z invisible decay

Rate of decay of the **Z boson** to particles that evade detection ('invisible')



Z invisible decay at the LHC

CMS measurement : 523 ± 16 MeV

First precise measurement of invisible Z decays at a hadron collider

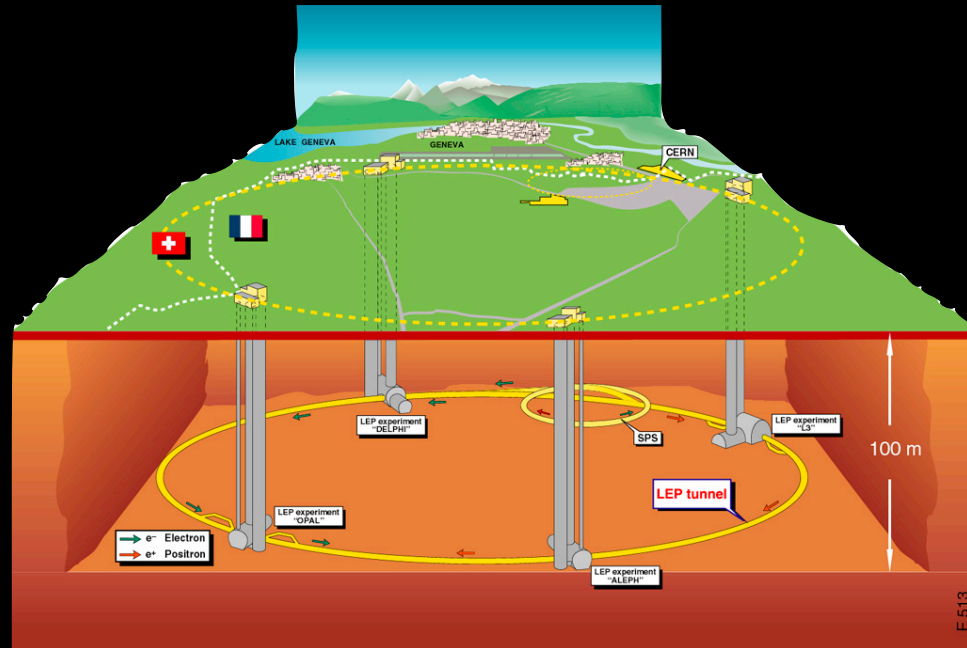
Z invisible decay at the LHC

CMS measurement : 523 ± 16 MeV

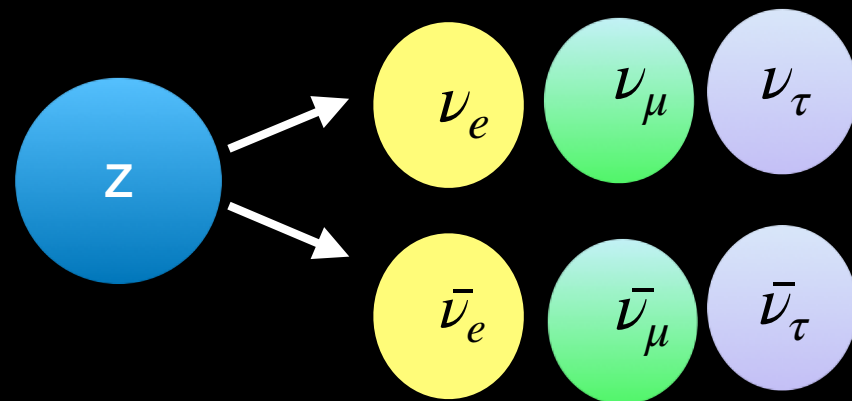
Source of systematic uncertainty	Uncertainty (%)
Muon identification efficiency (syst.)	2.1
Jet energy scale	1.8–1.9
Electron identification efficiency (syst.)	1.6
Electron identification efficiency (stat.)	1.0
Pileup	0.9–1.0
Electron trigger efficiency	0.7
τ_h veto efficiency	0.6–0.7
p_T^{miss} trigger efficiency (jets plus p_T^{miss} region)	0.7
p_T^{miss} trigger efficiency ($Z/\gamma^* \rightarrow \mu\mu$ region)	0.6
Boson p_T dependence of QCD corrections	0.5
Jet energy resolution	0.3–0.5
p_T^{miss} trigger efficiency (μ +jets region)	0.4
Muon identification efficiency (stat.)	0.3
Electron reconstruction efficiency (syst.)	0.3
Boson p_T dependence of EW corrections	0.3
PDFs	0.2
Renormalization/factorization scale	0.2
Electron reconstruction efficiency (stat.)	0.2
Overall	3.2

Z invisible decays at LEP collider

Large Electron Positron collider: Highest energy electron-positron collider ever built (1989 - 2000)

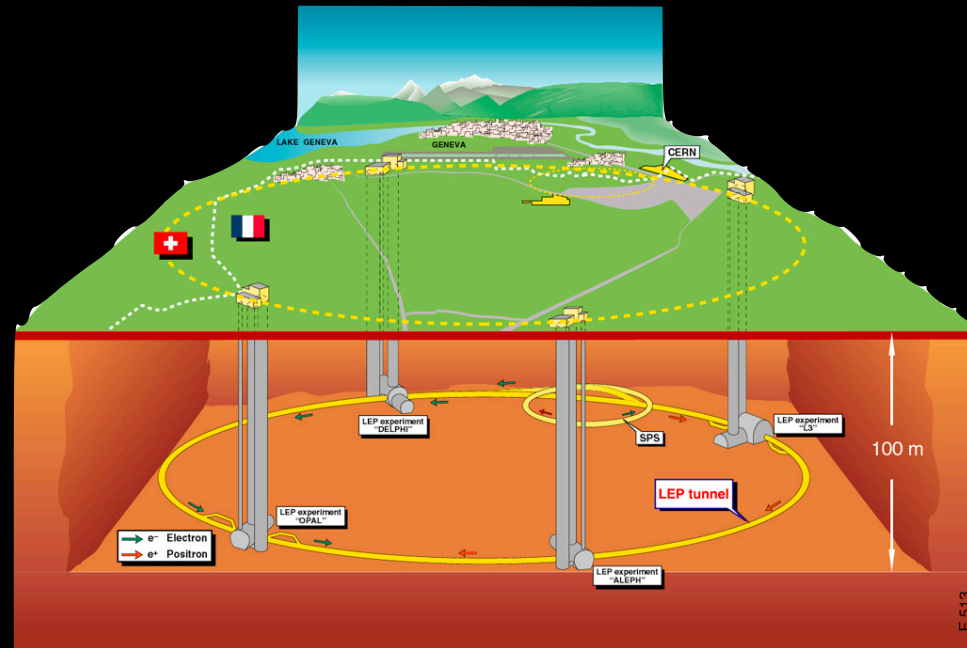


- **LEP legacy: properties of the Z boson measured to unprecedented precision**
- **Direct and indirect measurement of Z boson invisible decays, indirect measurement used to deduce three species of light neutrinos**



Z invisible decays at LEP collider

Large Electron Positron collider: Highest energy electron-positron collider ever built (1989 - 2000)



LEP combined direct measurement : 503 ± 16 MeV

Z invisible decay at the LHC

CMS measurement : 523 ± 16 MeV

LEP combined measurement : 503 ± 16 MeV

Z invisible decay at the LHC

CMS measurement : 523 ± 16 MeV

LEP combined measurement : 503 ± 16 MeV

Standard Model : 501.44 ± 0.04 MeV

Z invisible decay at the LHC

CMS measurement : 523 ± 16 MeV

LEP combined measurement : 503 ± 16 MeV

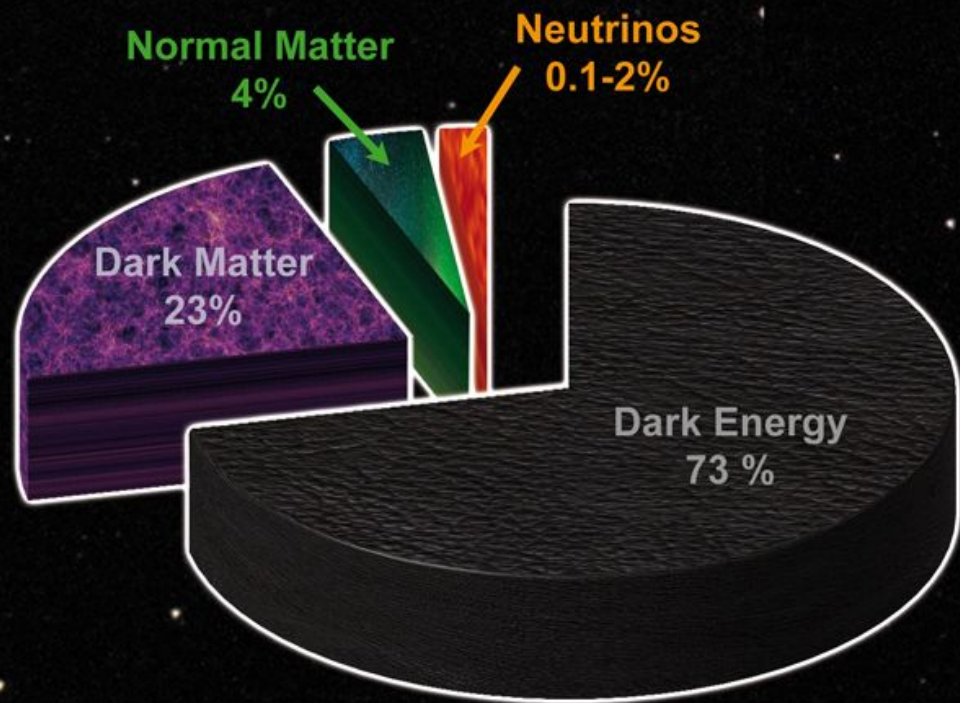
Standard Model : 501.44 ± 0.04 MeV

CMS result : Single most precise direct measurement in the world

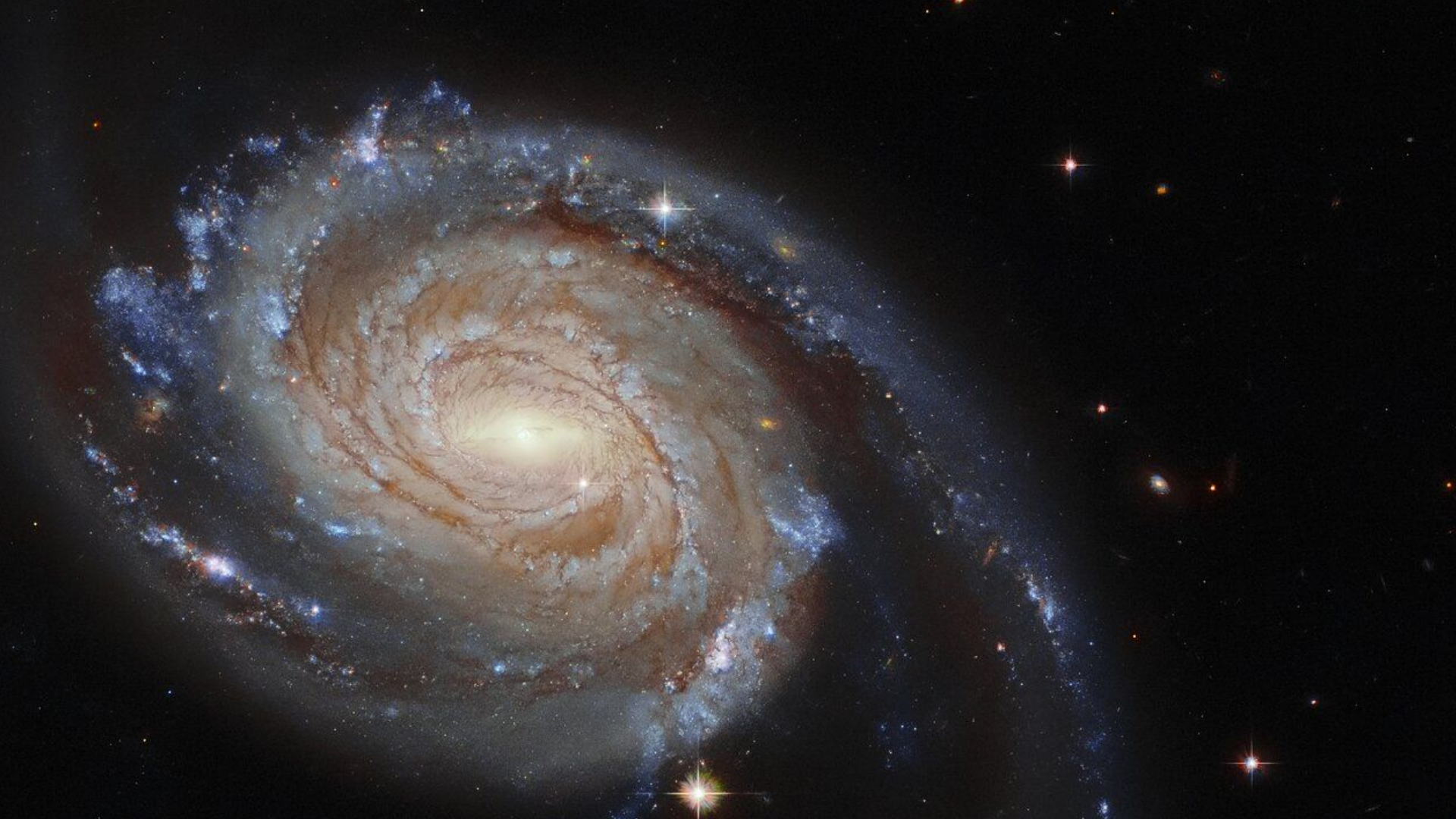
A vibrant, multi-colored visualization of the cosmic web, showing a complex network of filaments and clusters of matter. The colors range from deep blues and purples to bright greens, yellows, and oranges, with numerous small white stars scattered throughout. The overall appearance is that of a vast, interconnected structure of matter in space.

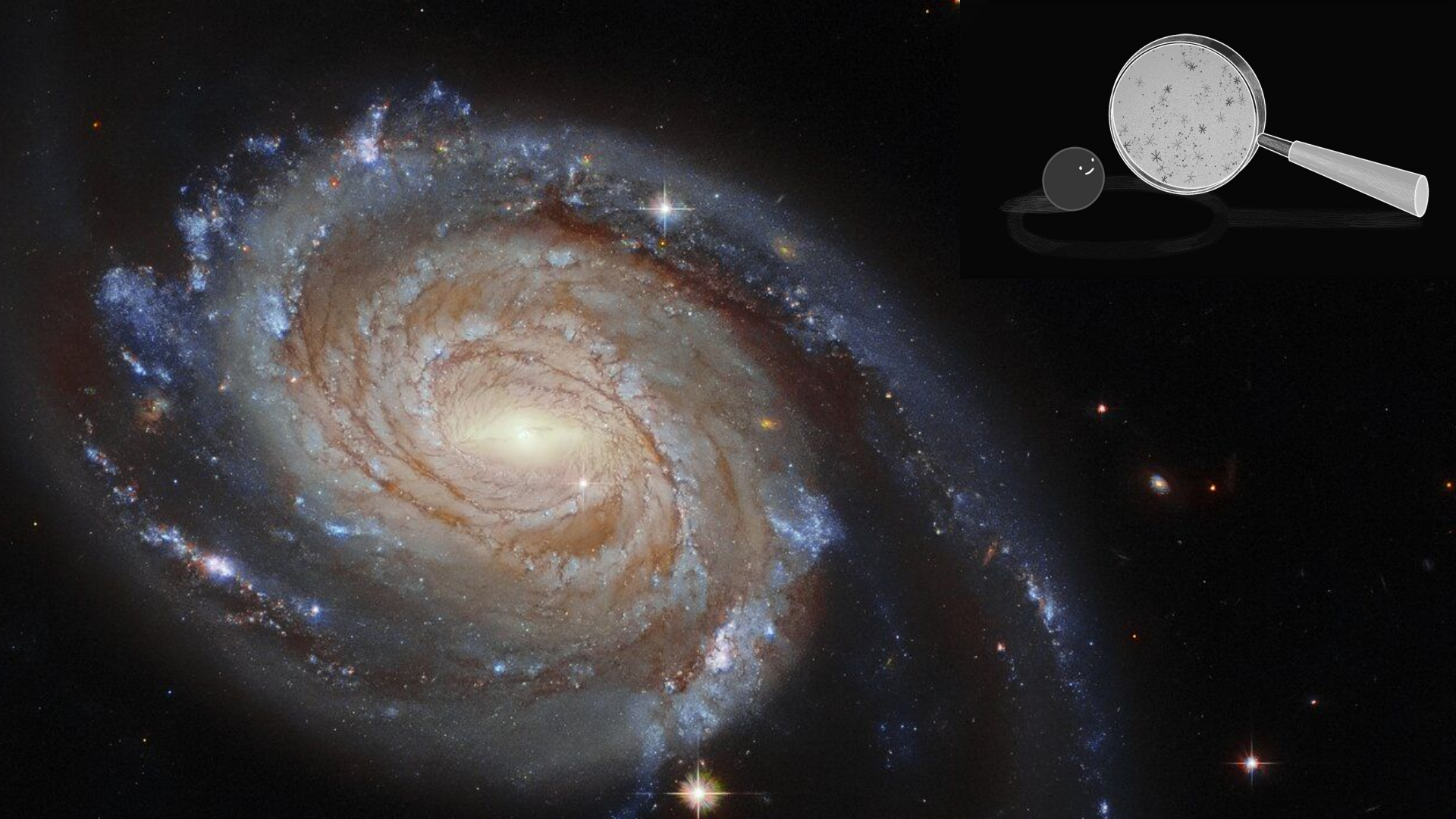
Dark matter and dark energy at the LHC: from the very big to the very small

Michaela Queitsch-Maitland
University of Manchester

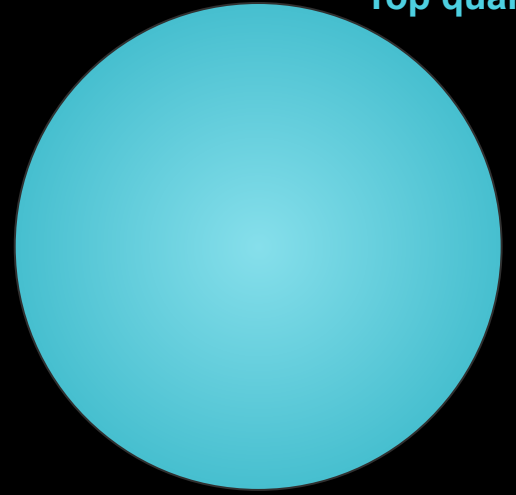


Content of the Universe



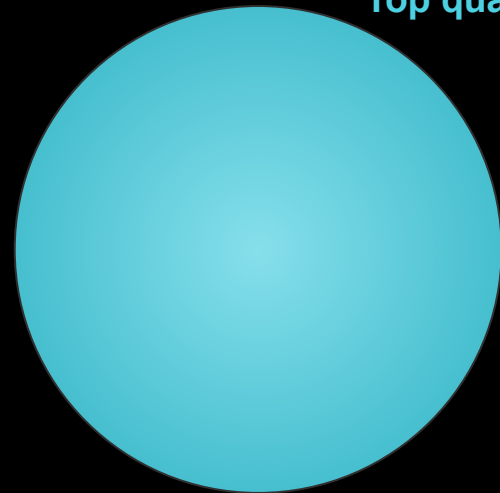
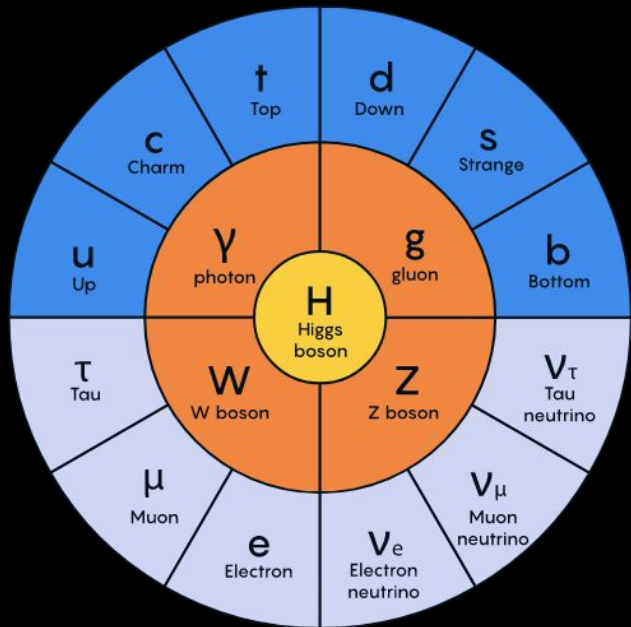


Top quark

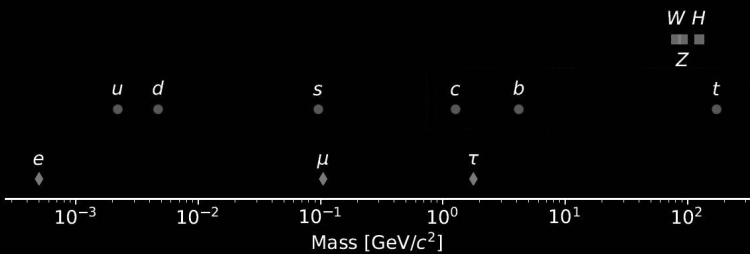


The Standard Model

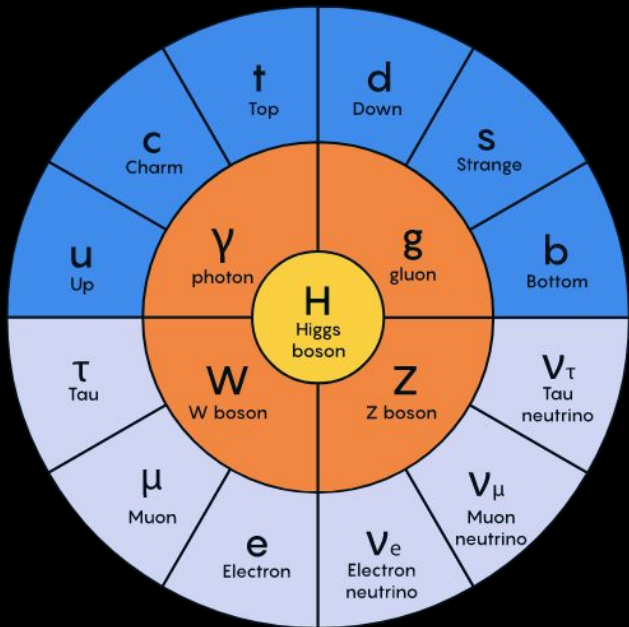
Top quark



FERMIONS (MATTER) BOSONS (FORCE CARRIERS)
 ● QUARKS ● LEPTONS ● GAUGE BOSONS ● HIGGS BOSON



The Standard Model



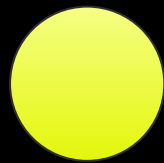
FERMIONS (MATTER)

● QUARKS ● LEPTONS

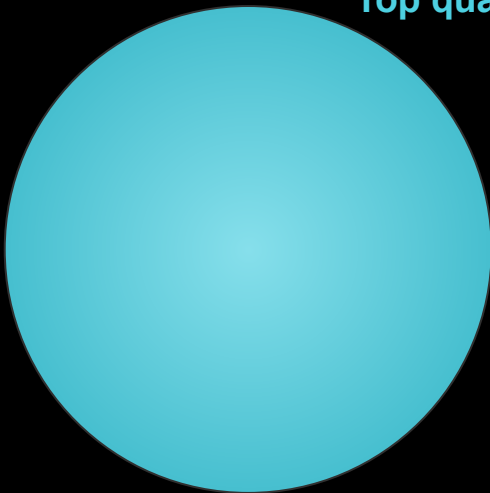
BOSONS (FORCE CARRIERS)

● GAUGE BOSONS ● HIGGS BOSON

Bottom quark



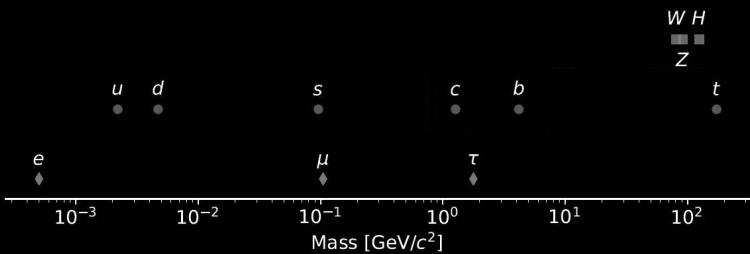
Top quark



Proton



Gold atom

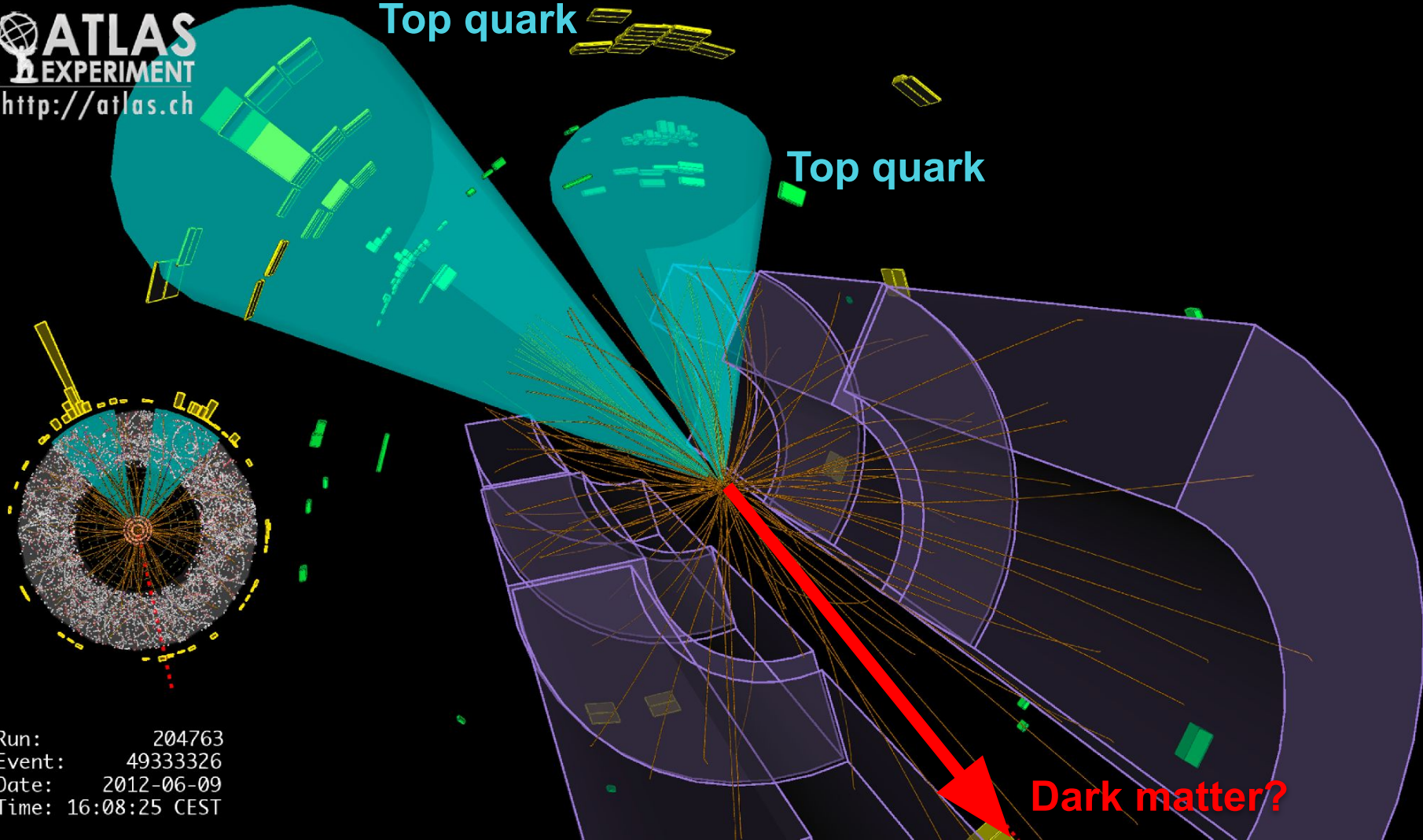


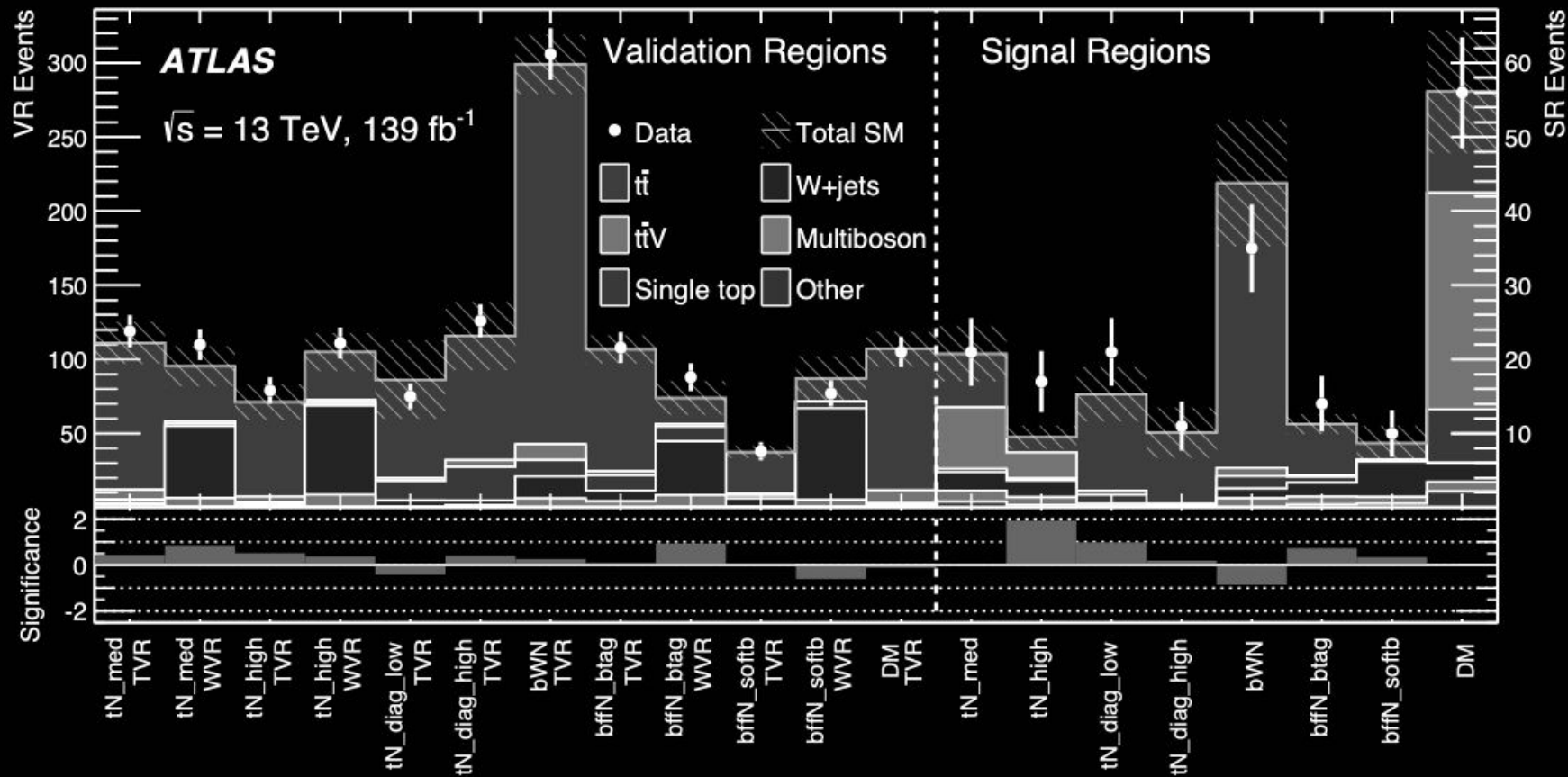
Top quark

Top quark

Dark matter?

Run: 204763
Event: 4933326
Date: 2012-06-09
Time: 16:08:25 CEST





Constraints on mediator-based dark matter and scalar dark energy models using $\sqrt{s} = 13$ TeV pp collision data collected by the ATLAS detector



The ATLAS collaboration

E-mail: atlas.publications@cern.ch

ABSTRACT: Constraints on selected mediator-based dark matter models and a scalar dark energy model using up to 37 fb^{-1} $\sqrt{s} = 13$ TeV pp collision data collected by the ATLAS detector at the LHC during 2015–2016 are summarised in this paper. The results of experimental searches in a variety of final states are interpreted in terms of a set of spin-1 and spin-0 single-mediator dark matter simplified models and a second set of models involving an extended Higgs sector plus an additional vector or pseudo-scalar mediator. The searches considered in this paper constrain spin-1 leptophobic and leptophilic mediators, spin-0 colour-neutral and colour-charged mediators and vector or pseudo-scalar mediators embedded in extended Higgs sector models. In this case, also $\sqrt{s} = 8$ TeV pp collision data are used for the interpretation of the results. The results are also interpreted for the first time in terms of light scalar particles that could contribute to the accelerating expansion of the universe (dark energy).

KEYWORDS: Dark matter, Hadron-Hadron scattering (experiments)

ARXIV EPRINT: [1903.01400](https://arxiv.org/abs/1903.01400)



PUBLISHED FOR SISSA BY SPRINGER

RECEIVED: March 8, 2019

ACCEPTED: May 9, 2019

PUBLISHED: May 23, 2019

Constraints on mediator-based dark matter and scalar dark energy models using $\sqrt{s} = 13$ TeV pp collision data collected by the ATLAS detector



The ATLAS collaboration

E-mail: atlas.publications@cern.ch

ABSTRACT: Constraints on selected mediator-based dark matter models and a scalar dark energy model using up to 37 fb^{-1} $\sqrt{s} = 13 \text{ TeV}$ pp collision data collected by the ATLAS detector at the LHC during 2015–2016 are summarised in this paper. The results of experimental searches in a variety of final states are interpreted in terms of a set of spin-1 and spin-0 single-mediator dark matter simplified models and a second set of models involving an extended Higgs sector plus an additional vector or pseudo-scalar mediator. The searches considered in this paper constrain spin-1 leptophobic and leptophilic mediators, spin-0 colour-neutral and colour-charged mediators and vector or pseudo-scalar mediators embedded in extended Higgs sector models. In this case, also $\sqrt{s} = 8 \text{ TeV}$ pp collision data are used for the interpretation of the results. The results are also interpreted for the first time in terms of light scalar particles that could contribute to the accelerating expansion of the universe (dark energy).

KEYWORDS: Dark matter, Hadron-Hadron scattering (experiments)

ARXIV EPRINT: [1903.01400](https://arxiv.org/abs/1903.01400)

OPEN ACCESS, Copyright CERN,
for the benefit of the ATLAS Collaboration.
Article funded by SCOAP³.

[https://doi.org/10.1007/JHEP05\(2019\)142](https://doi.org/10.1007/JHEP05(2019)142)

JHEP05(2019)142



Searches for new phenomena in events with two leptons, jets, and missing transverse momentum in 139 fb⁻¹ of $\sqrt{s} = 13$ TeV pp collisions with the ATLAS detector

The ATLAS Collaboration

Abstract

A search for new phenomena in events with two leptons, jets, and missing transverse momentum is presented using 139 fb⁻¹ of $\sqrt{s} = 13$ TeV pp collision data collected by the ATLAS detector at the LHC during 2015–2016. The search is sensitive to a wide range of new physics models, including those with large cross-sections and those with small cross-sections. The search is performed in a model-independent manner, and the results are presented in terms of exclusion limits on the cross-section of the new physics process. The search is also sensitive to new physics models with large cross-sections and those with small cross-sections. The search is performed in a model-independent manner, and the results are presented in terms of exclusion limits on the cross-section of the new physics process.

Search for CP violation using \bar{T} -odd correlations in $B^0 \rightarrow \rho^+ K^+ \pi^-$ decays

LHCb collaboration

Abstract

A search for CP violation in the decay $B^0 \rightarrow \rho^+ K^+ \pi^-$ is presented using 3.62 fb⁻¹ of pp collision data collected by the LHCb detector at the LHC during 2011–2012. The search is sensitive to CP violation in the form of a non-zero value of the observable \bar{T} , which is a correlation between the ρ^+ and K^+ decay products. The search is performed in a model-independent manner, and the results are presented in terms of exclusion limits on the magnitude of \bar{T} .

Search for CP violating top quark couplings in pp collisions at $\sqrt{s} = 13$ TeV

The CMS Collaboration

Abstract

Results are presented from a search for CP violation in top quark pair production, using proton-proton collision data at a center-of-mass energy of 13 TeV. The search is sensitive to CP violation in the form of a non-zero value of the observable C_1 , which is a correlation between the t and \bar{t} decay products. The search is performed in a model-independent manner, and the results are presented in terms of exclusion limits on the magnitude of C_1 .

Search for the doubly charmed baryon Ξ_{bc}^+ in pp collisions at $\sqrt{s} = 13$ TeV

The ATLAS Collaboration

Abstract

The ATLAS experiment has searched for the doubly charmed baryon Ξ_{bc}^+ in pp collisions at $\sqrt{s} = 13$ TeV using the ATLAS experiment and the full Run 2 dataset. The search is sensitive to the production of Ξ_{bc}^+ in pp collisions, and the results are presented in terms of exclusion limits on the cross-section of the new physics process.

Search for electroweak production of neutralinos and charginos in pp collisions at $\sqrt{s} = 13$ TeV

The CMS Collaboration

Abstract

The LHC experiment has searched for the electroweak production of neutralinos and charginos in pp collisions at $\sqrt{s} = 13$ TeV using the CMS experiment and the full Run 2 dataset. The search is sensitive to the production of neutralinos and charginos in pp collisions, and the results are presented in terms of exclusion limits on the cross-section of the new physics process.

Search for flavour-changing neutral-current couplings between the top quark and the photon with the ATLAS detector at $\sqrt{s} = 13$ TeV

The ATLAS Collaboration

Abstract

Neutral currents are searched for in pp collisions at $\sqrt{s} = 13$ TeV using the ATLAS experiment and the full Run 2 dataset. The search is sensitive to the production of neutral currents in pp collisions, and the results are presented in terms of exclusion limits on the cross-section of the new physics process.

Search for heavy, long-lived, charged particles with large ionisation energy loss in pp collisions at $\sqrt{s} = 13$ TeV using the ATLAS experiment and the full Run 2 dataset

The ATLAS Collaboration

Abstract

The ATLAS experiment has searched for heavy, long-lived, charged particles with large ionisation energy loss in pp collisions at $\sqrt{s} = 13$ TeV using the ATLAS experiment and the full Run 2 dataset. The search is sensitive to the production of heavy, long-lived, charged particles in pp collisions, and the results are presented in terms of exclusion limits on the cross-section of the new physics process.

Search for the doubly charmed baryon Ξ_{bc}^+ decaying to $J/\psi \Xi_c^+$

The LHCb collaboration

Abstract

A search for the doubly charmed baryon Ξ_{bc}^+ decaying to $J/\psi \Xi_c^+$ is presented using 3.62 fb⁻¹ of pp collision data collected by the LHCb detector at the LHC during 2011–2012. The search is sensitive to the production of Ξ_{bc}^+ in pp collisions, and the results are presented in terms of exclusion limits on the cross-section of the new physics process.

Search for long-lived particles decaying to a pair of muons in proton-proton collisions at $\sqrt{s} = 13$ TeV

The CMS Collaboration

Abstract

An inclusive search for long-lived particles decaying to a pair of muons is presented using 36.1 fb⁻¹ of pp collision data collected by the CMS experiment at the LHC during 2011–2016. The search is sensitive to the production of long-lived particles in pp collisions, and the results are presented in terms of exclusion limits on the cross-section of the new physics process.

Search for electroweak production of neutralinos and charginos in pp collisions at $\sqrt{s} = 13$ TeV

The CMS Collaboration

Abstract

The LHC experiment has searched for the electroweak production of neutralinos and charginos in pp collisions at $\sqrt{s} = 13$ TeV using the CMS experiment and the full Run 2 dataset. The search is sensitive to the production of neutralinos and charginos in pp collisions, and the results are presented in terms of exclusion limits on the cross-section of the new physics process.

