Search for a high-mass Dark Matter mediator decaying to a dilepton final state

Ilia Zhizhin
Alexander Lanyov, Sergei Shmatov
Joint Institute for Nuclear Research, Dubna

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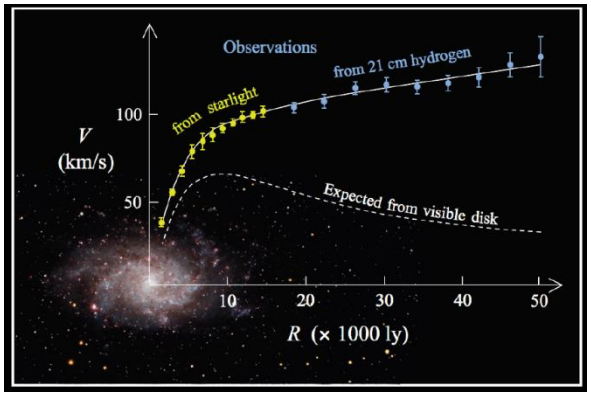
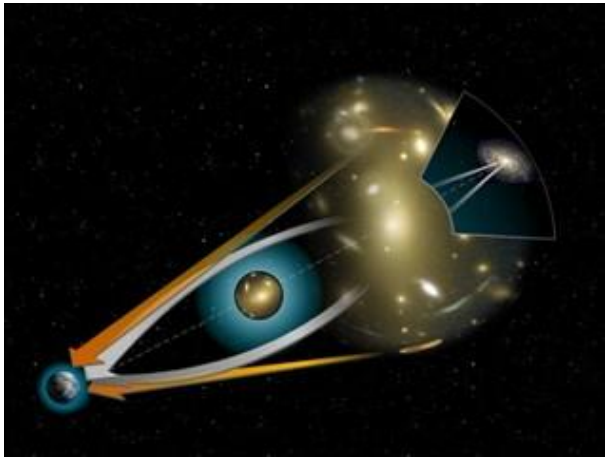
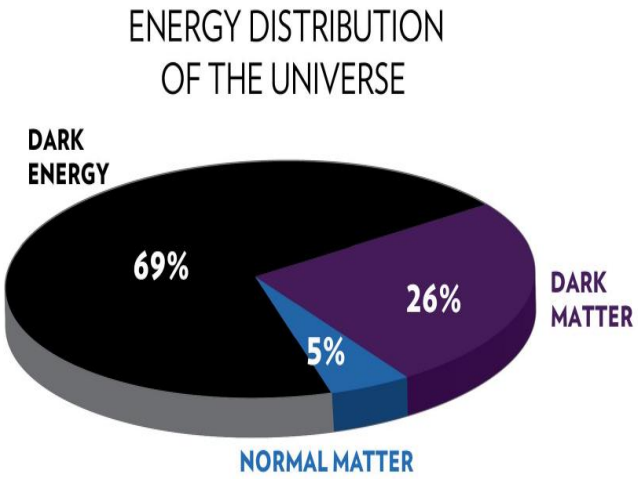
Motivation

Various astrophysical and cosmological observations provide strong hints for the existence of dark matter

- galactic rotation curves
- gravitational lensing
- Wilkinson Microwave Anisotropy (WMAP)

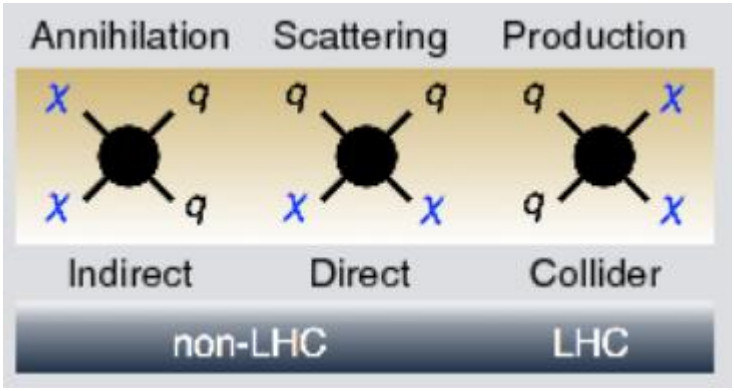


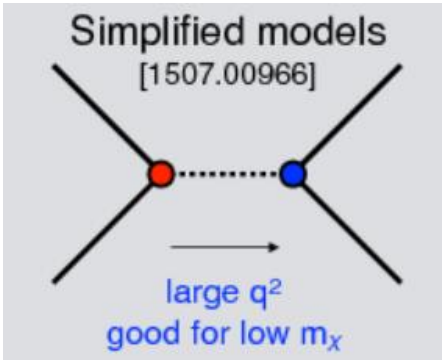




- etc

Dark Matter Searches

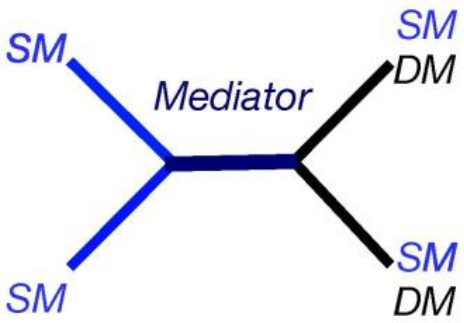




Simplified Dark Matter Model

Simplified model with a DM particle

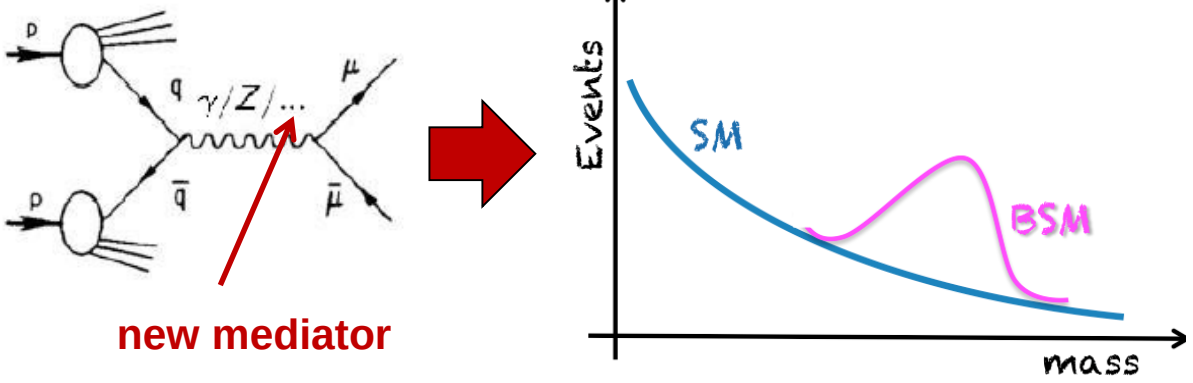
- ✓ has sizeable interactions with SM fermions through an additional spin-1 high-mass particle mediating the SM-DM interaction
- ✓ only one DM particle exists, which is assumed to be a Dirac fermion
- ✓ two cases with different sets of benchmark coupling values
  - — a vector mediator with small couplings to leptons
  - — an axial-vector mediator with equal couplings to quarks and leptons



While the DM particle is not probed directly, its mass indirectly modulates the sensitivity of the dilepton search: Drell-Yan type process (sensitive directly to m_{Med}, g_l ,g_q)

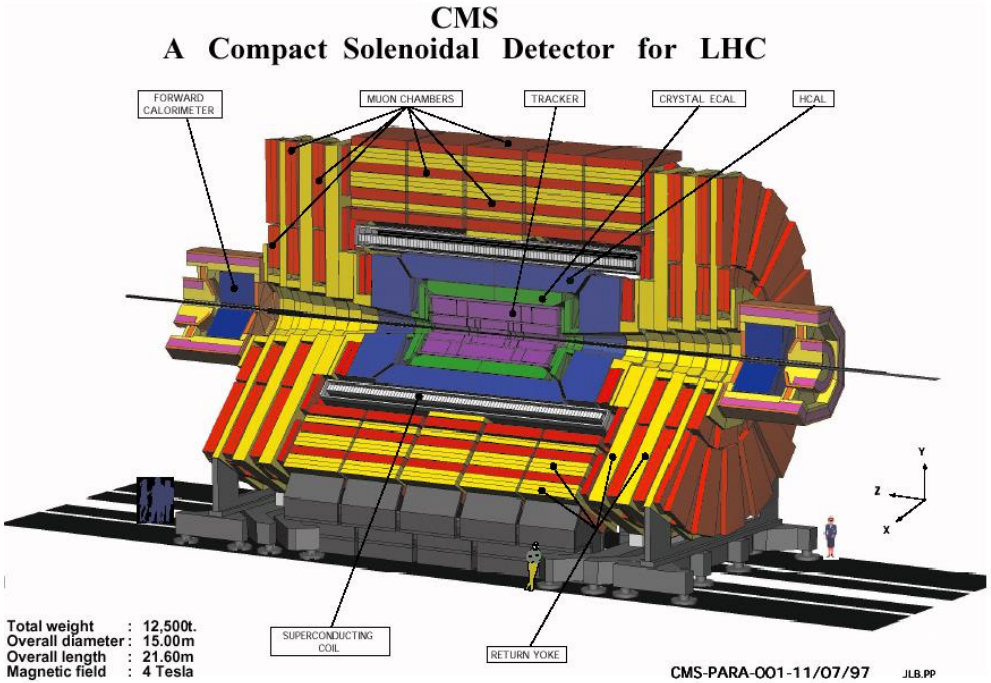
5 parameters:

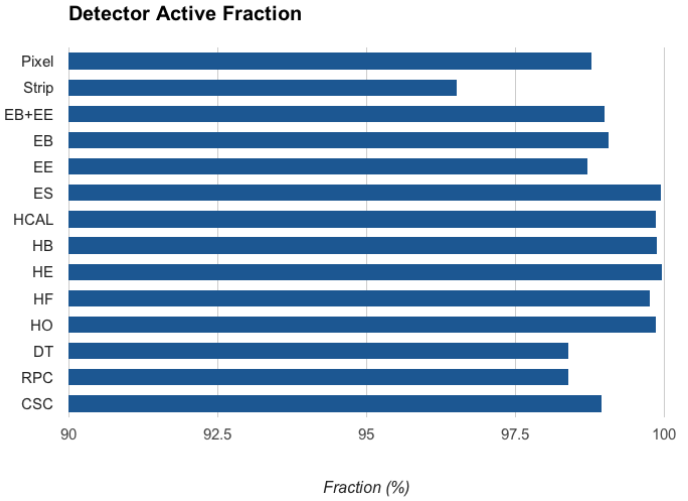
- m_{DM} - DM mass
- m_{Med} - mediator mass
- g_{DM} - coupling of a mediator-DM-DM vertex
- g_l - coupling with leptons
- g_q - coupling with quarks



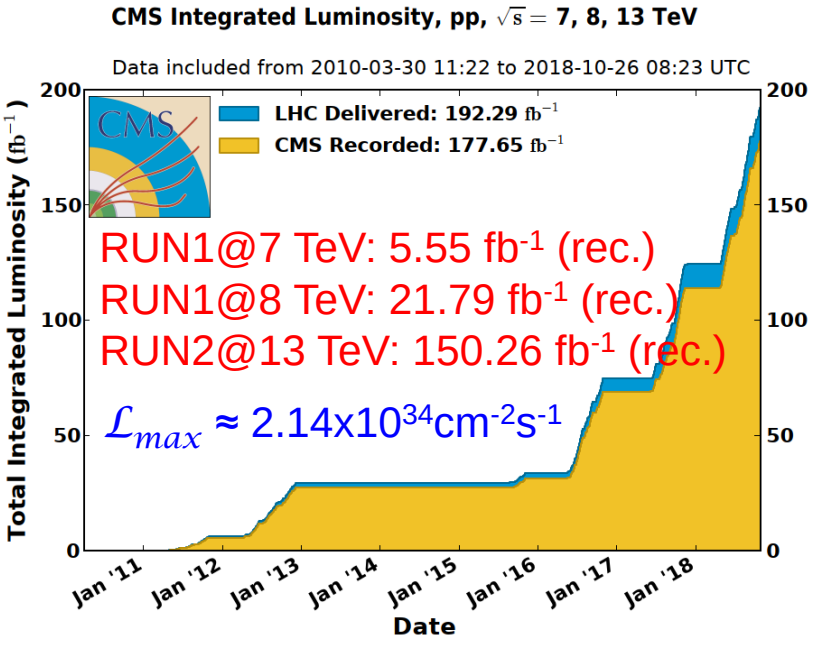
CMS Detector and Collected Data

Large general-purpose particle physics detector





Total weight ***12 500 t***
Overall diameter ***15.00 m***
Overall length ***21.6 m***
Magnetic field ***3.8 Tesla***



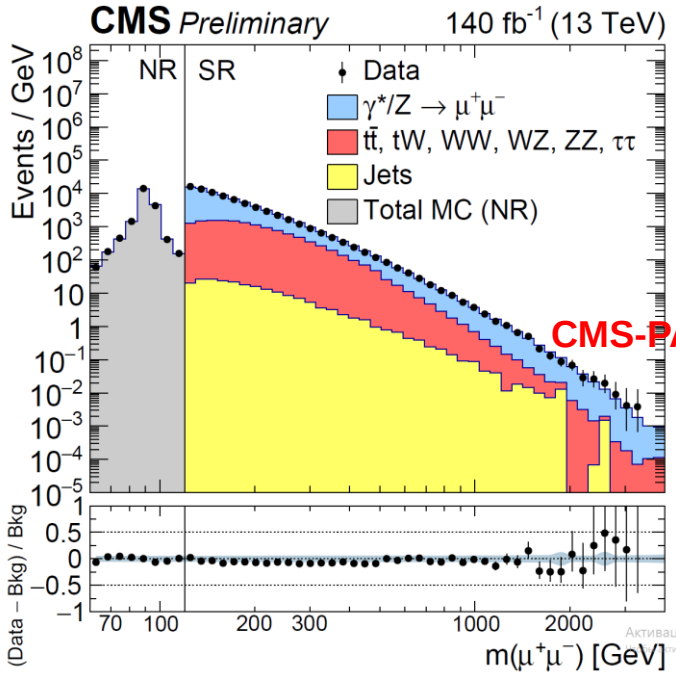
Detector subsystems are designed to measure: the energy and momentum of photons, electrons, muons, jets, missing ET up to a few TeV

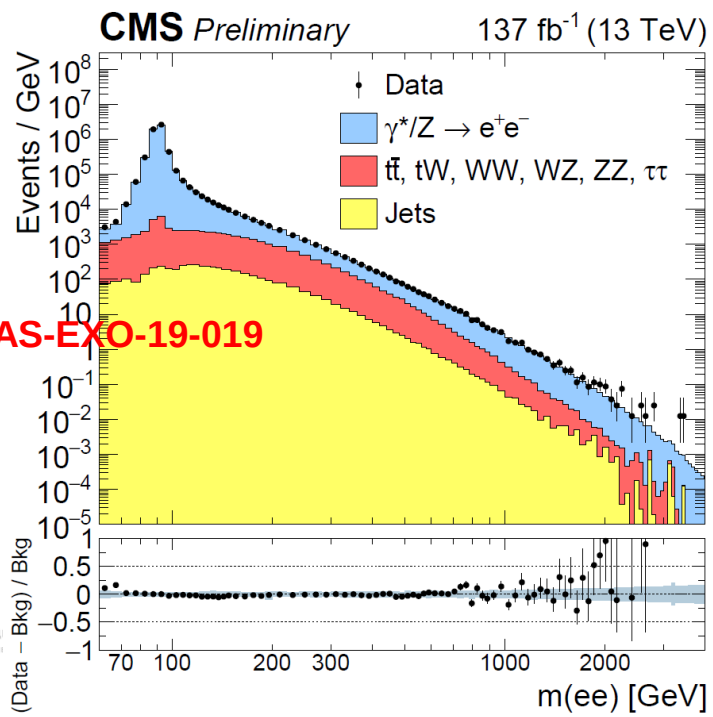
Dilepton Mass Spectra

The likelihood function is based on probability density functions (pdf) that describe the signal and background contributions to the invariant mass spectra

$$\mathcal{L}(m|R_\sigma, M, \Gamma, w, \alpha, \beta, \kappa, \mu_B) = \frac{\mu^N e^{-\mu}}{N!} \prod_{i=1}^{N} \left(\frac{\mu_S(R_\sigma)}{\mu} f_S(m_i|M, \Gamma, w) + \frac{\mu_B}{\mu} f_B(m_i|\alpha, \beta, \kappa) \right)$$

Interference DM with DY carriers (gamma / Z^0) is considered insignificant (<5%)





CMS-PAS-EXO-19-019

Simulation:

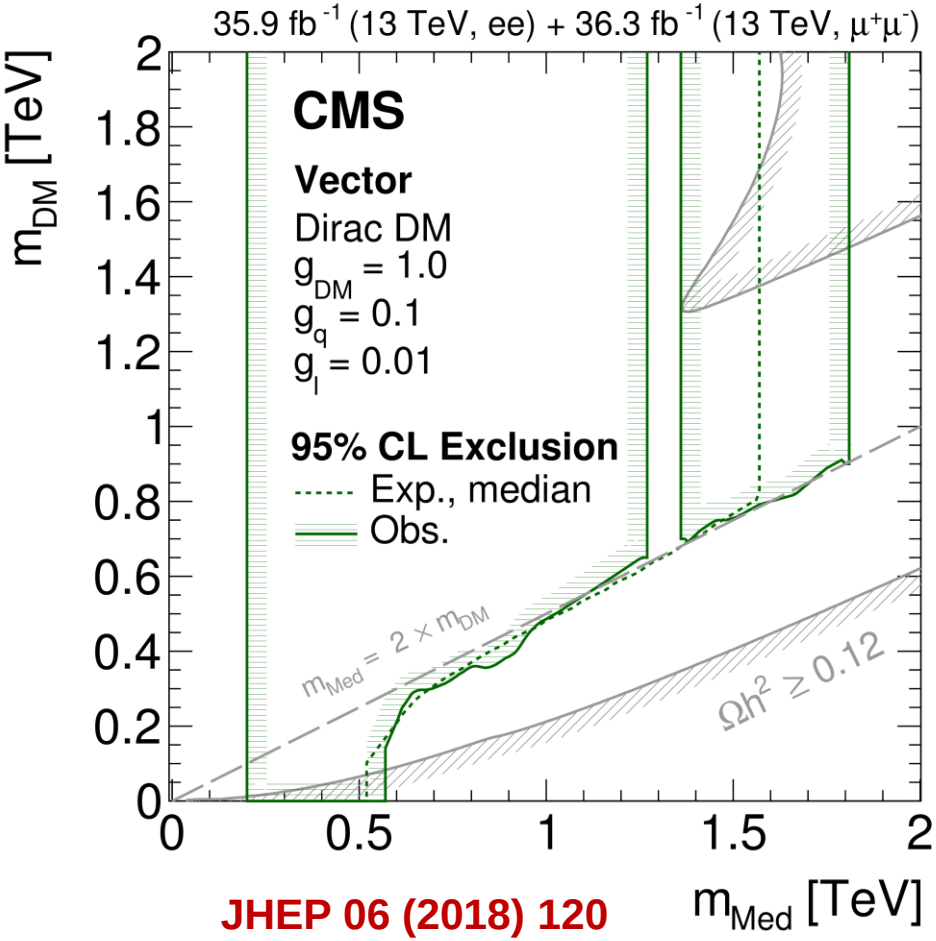
- ✓ DMSIMP implementation of the DM simplified model in MADGRAPH 5 aMC@NLO 2.5.2 (NLO)
- ✓ Drell-Yan with POWHEGv2 from next-to-leading order (NLO) matrix elements using the NNPDF3.0, $t\bar{t}$, tW and WW with POWHEGv2, WZ and ZZ with the PYTHIA8.205, $\tau^+\tau^-$ and W+jets is simulated at LO with the MADGRAPH5aMC@NLOversion 2.2.2

Results: Vector Mediator

Vector mediator with suppressed couplings to leptons:
g_q=0.1, g_{DM}=1.0, g_l=0.01

For low values $m_{DM}<m_{Med}/2$ the mediator boson will dominantly decay into DM particles

At high values of the DM particle mass $m_{DM}>m_{Med}/2$, the mediator cannot decay to the DM particles and the leptonic branching fraction becomes sizeable.



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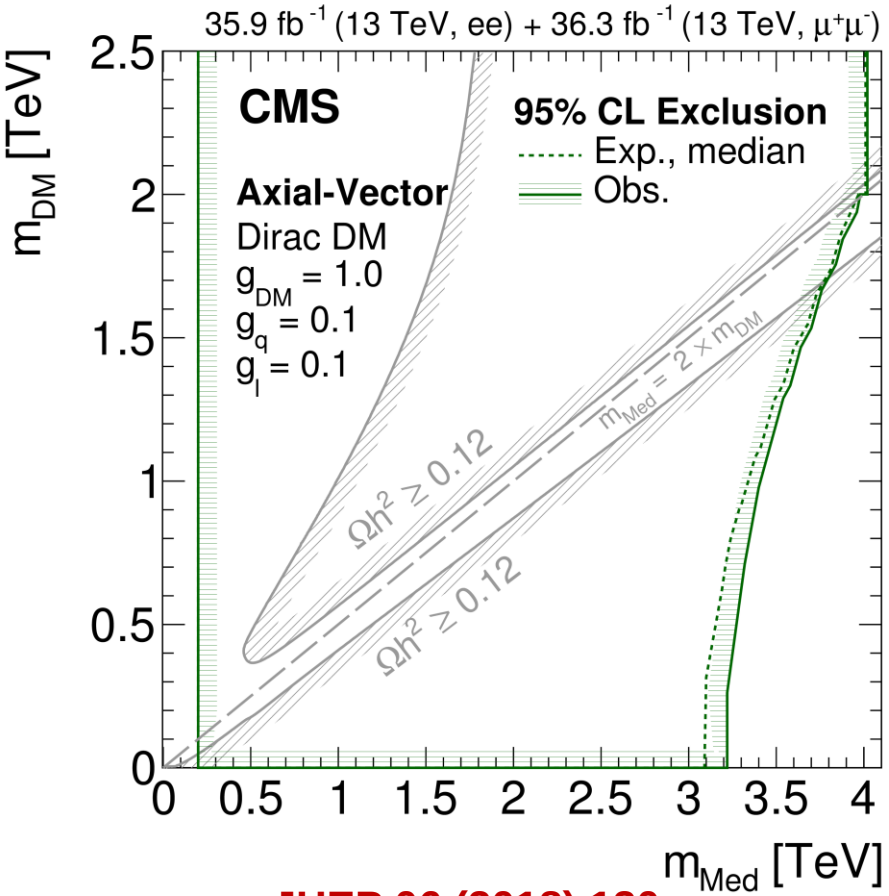
In the vector mediator model, the limit on the mediator mass reaches up to 1.8 TeV, depending on the mass of the DM particle

Results: Axial-Vector Mediator

Axial-vector mediator with equal couplings to quark and leptons:
g_{DM} =1.0, g_q=g_l=0.1

The leptonic couplings of the mediator are sizeable and an exclusion is also possible form $m_{DM} < m_{Med}/2$

The solid grey lines, marked as "$\Omega h^2 \geq 0.12$", correspond to parameter regions that reproduce the observed DM relic density in the universe



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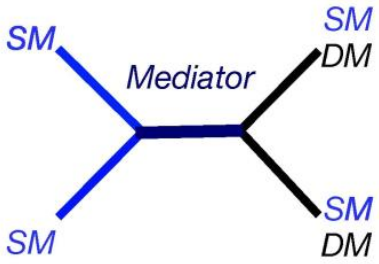
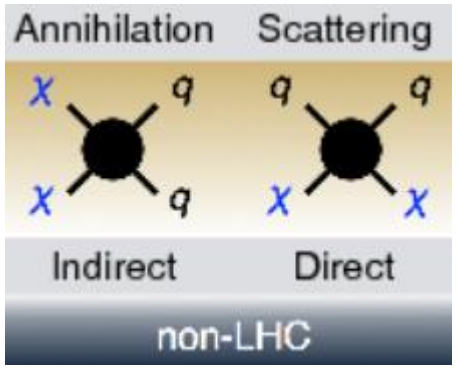
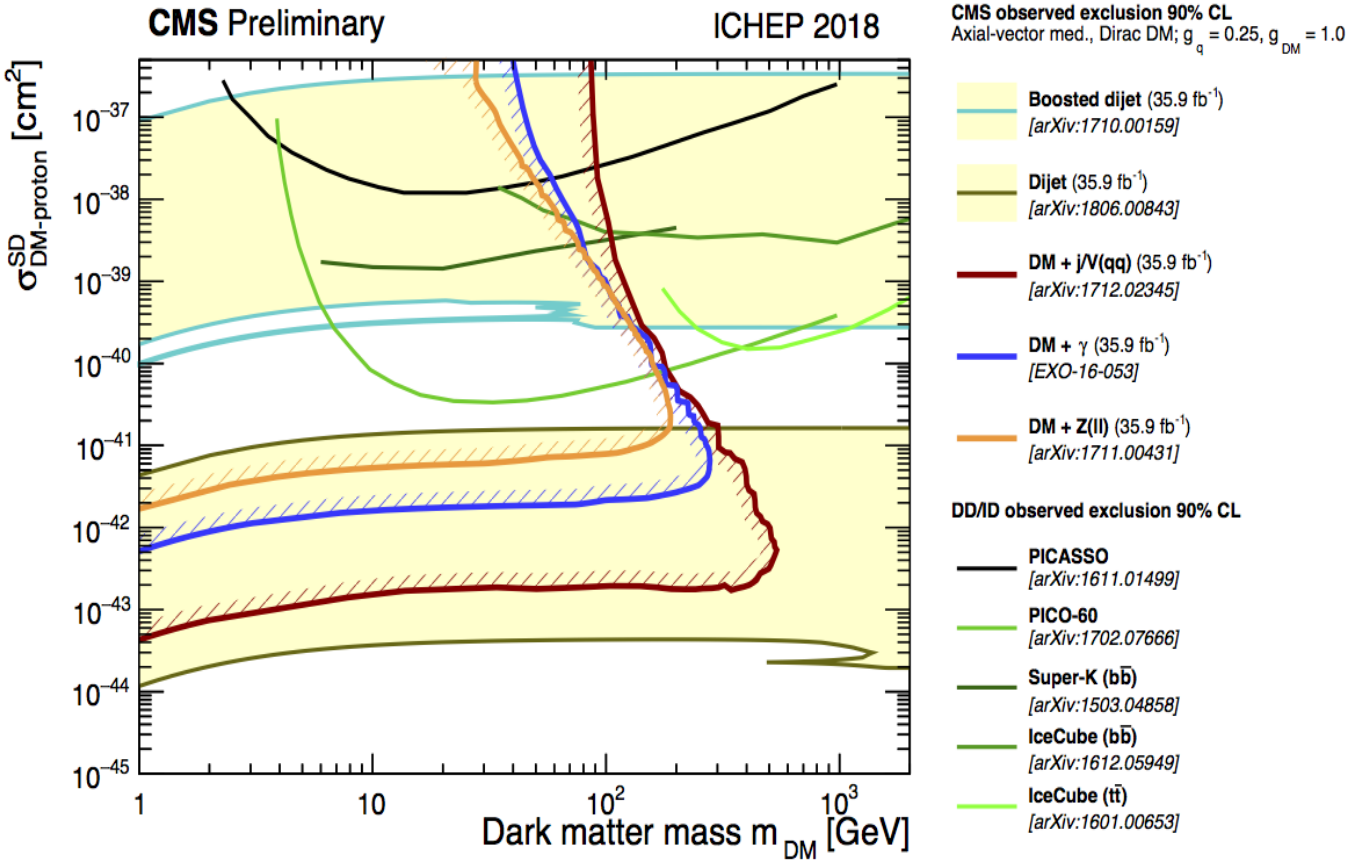
In the axial-vector mediator model, the limit on the mediator mass reaches up to 3-4 TeV, depending on the mass of the DM particle

CMS results vs Astrophysics Exp.

A comparison of CMS results to the DM-proton scattering $\sigma^{\text{DM-proton}}$ vs m_{DM} (dilepton results are not incorporated so far)







https://twiki.cern.ch/twiki/bin/view/CMSPublic/SummaryPlotsEXO13TeV#Dark_Matter_Summary_plots

Conclusions

- CMS realizes a wide program of search for dark matter signals
- During the LHC RUN2 we have been concentrated on searches for dark matter signal in dimuon channel.
- No signals are observed, new restrictions on the model parameters are set.
- These restrictions are included in summary plots for general restrictions on dark matter.

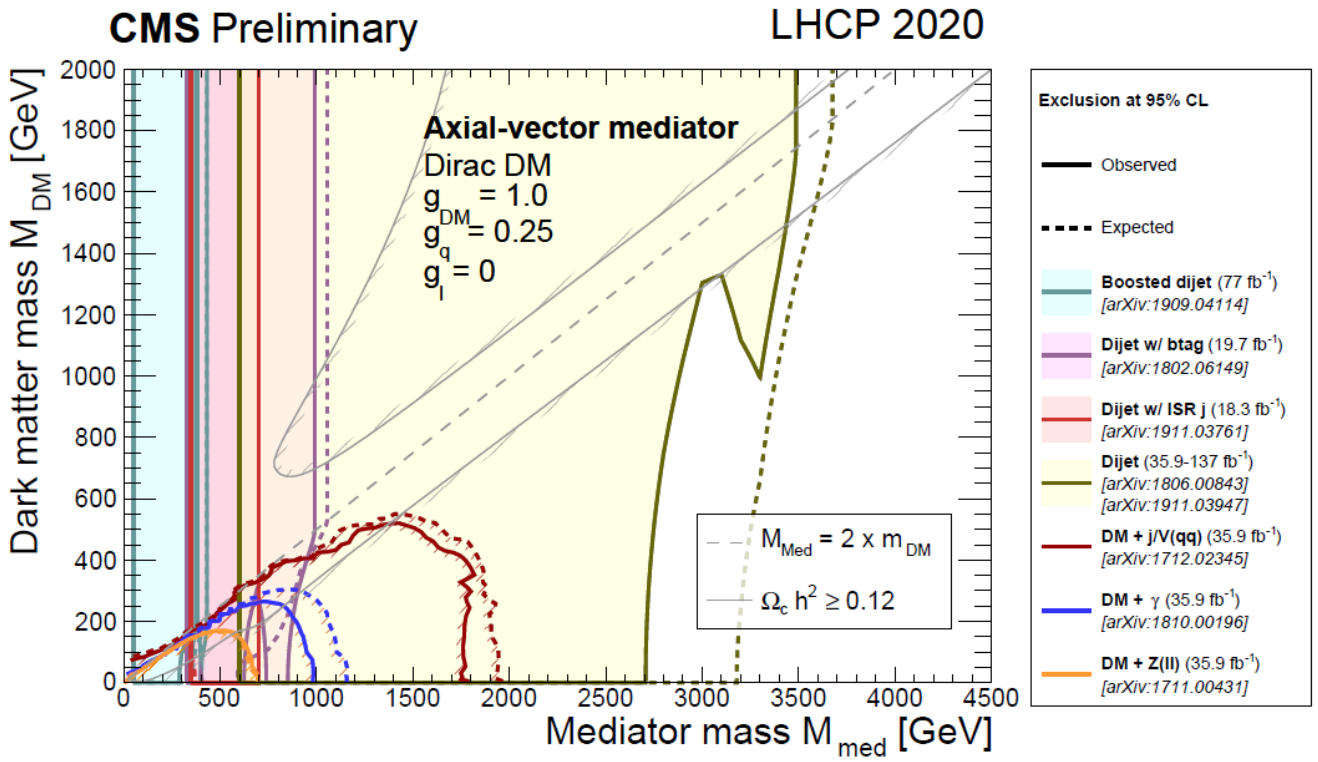
Producing and studying the properties of the dark matter particles at the LHC are an extremely exciting possibility that would open the door to a new understanding of the interplay between astrophysics, cosmology, and particle physics.

Results for full RUN2 data are being finalized.
Preparation for LHC RUN3 is going on.

Thank you for your attention!

CMS Dark Matter Summary

CMS Dark Matter Summary for axial-vector mediator (leptophobic scenario)



CMS Dark Matter Summary

CMS Dark Matter Summary for vector mediator