A Search for Low Mass Dark Photons in the Standard Model Photon + Jet Final State at CMS

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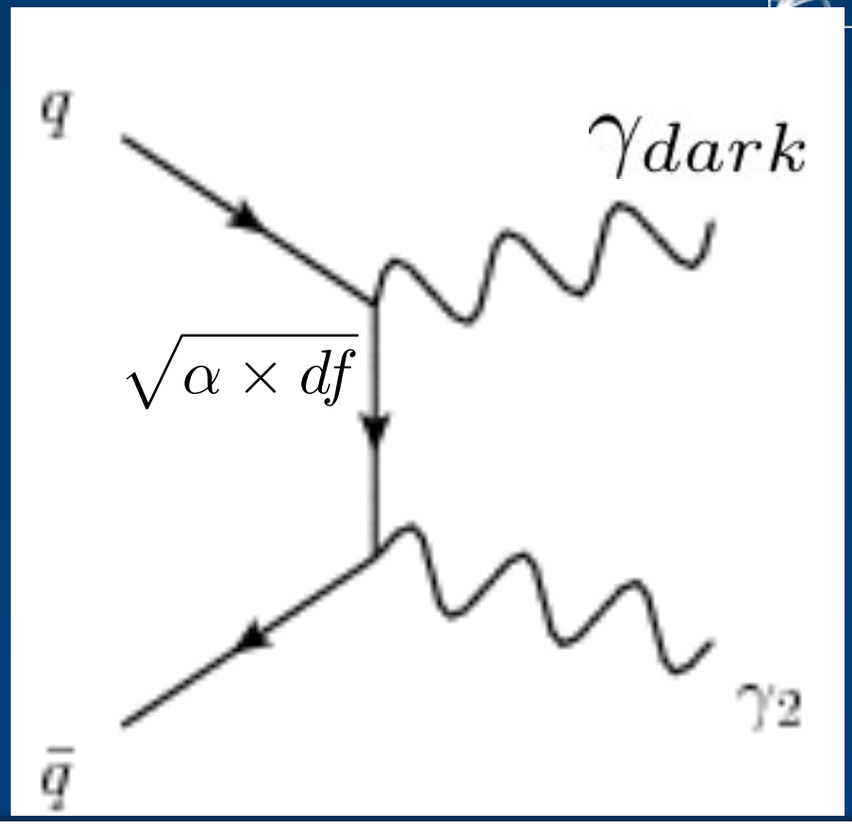
Dark Photon

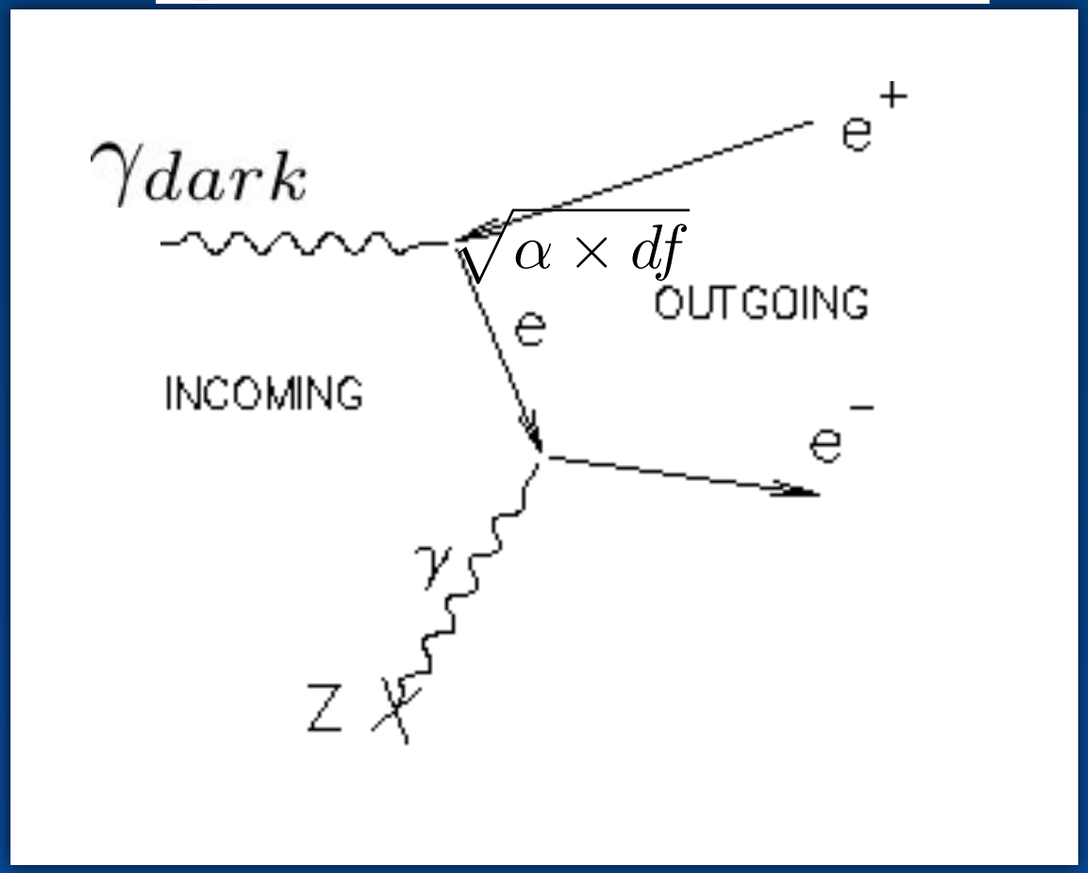
- A new U1 gauge boson: Dark Photon (DP)
- Couples to charged particles similar to Standard Model EM.
  - All quarks are given unit dark charges.
  - $\alpha_{Dark} = \alpha_{EM}$ x df [df = dark factor]
- Low mass favored in some cosmological models. If DP mass <1 MeV, there is no e^+e^- decay. (DP -> e^+e^- is a separate analysis).
- This is the first ever model independent search for low mass Dark Photons with CMS.

Dark Photon Interactions

- Focus on γ + DP production because backgrounds for this process have been extensively studied.
- DP is produced similarly as SM photon only with a different quark charge and DP coupling.
- The dark factor modifies the production cross section linearly.
  - $\sigma_{DP} = df \times \sigma_{df=1}$
- The dark factor also modifies the interaction of the dark photon with the detector.
- A SM photon conversion in matter gets modified by the df as well.

$$\sigma_{DP+N->e^+e^-} = df \times \sigma_{\gamma+N->e^+e^-}$$

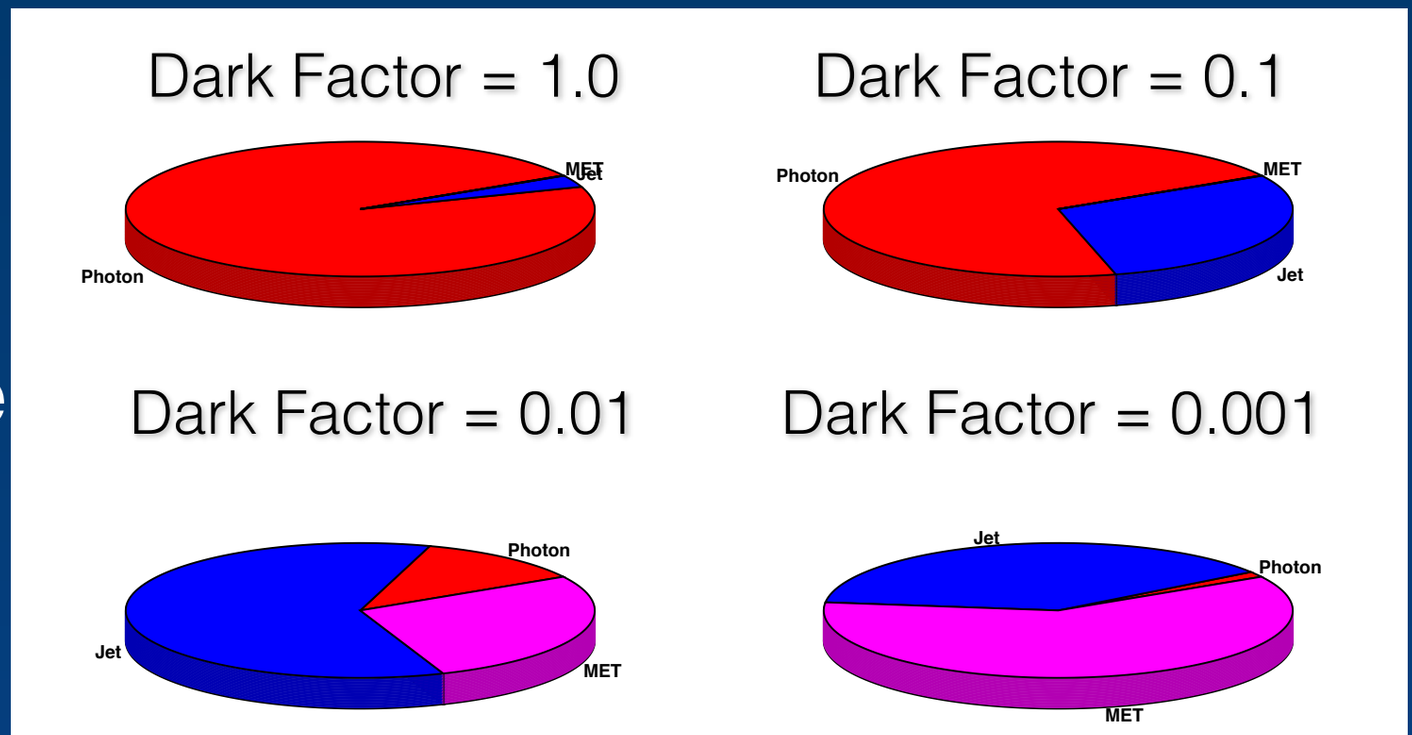




Detector Response to DP

- Detector response changes as a function of df. As df is lowered DP interaction moves ECal->HCal->Escape

- Hence, DP appears as Photon->Jet-> MET

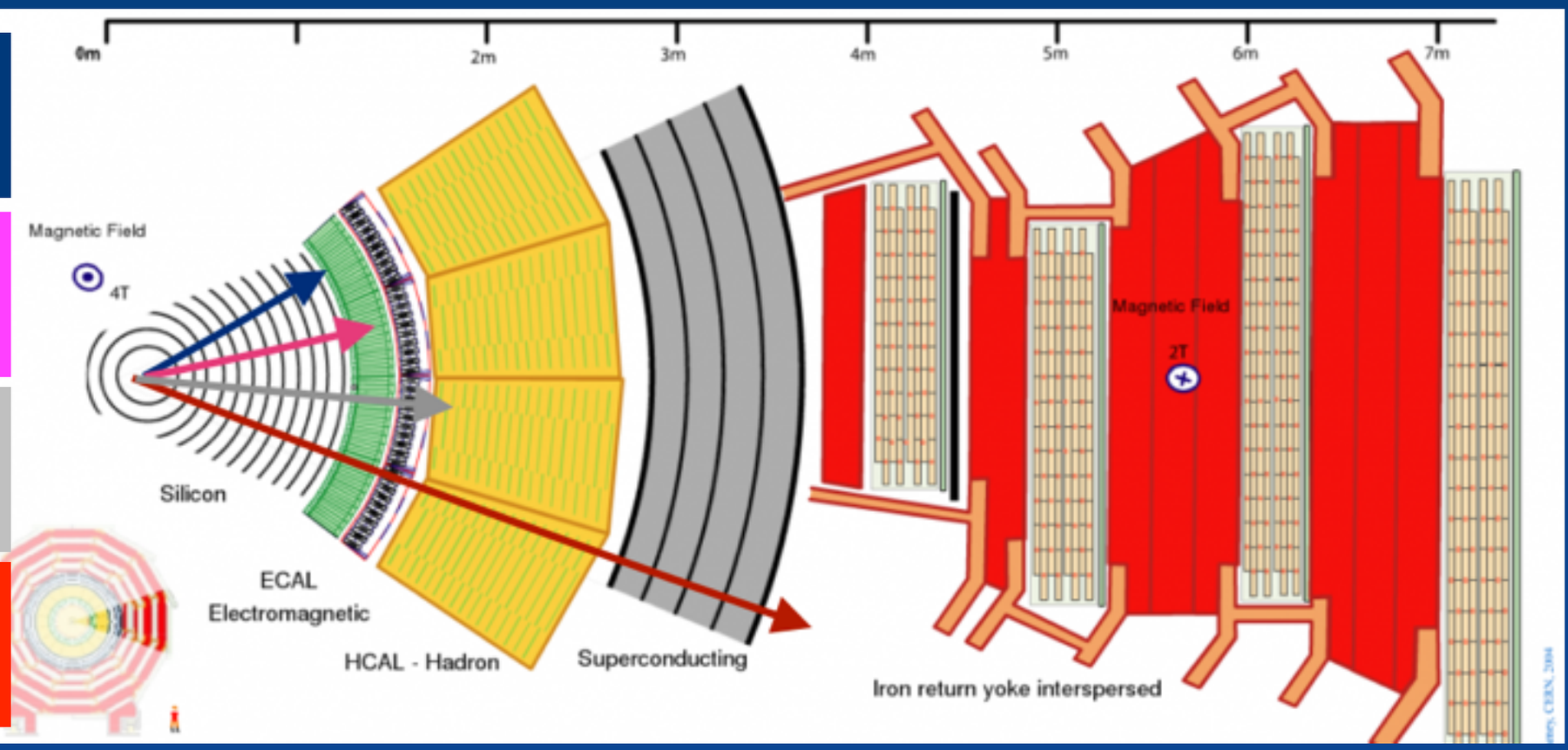


df = 1.0

df = 0.1

df = 0.01

df=0.001



Event Selection

Trigger

One Photon with Pt > 165 GeV
Integrated Luminosity=26.3 fb^{-1}

Offline Photon Requirements

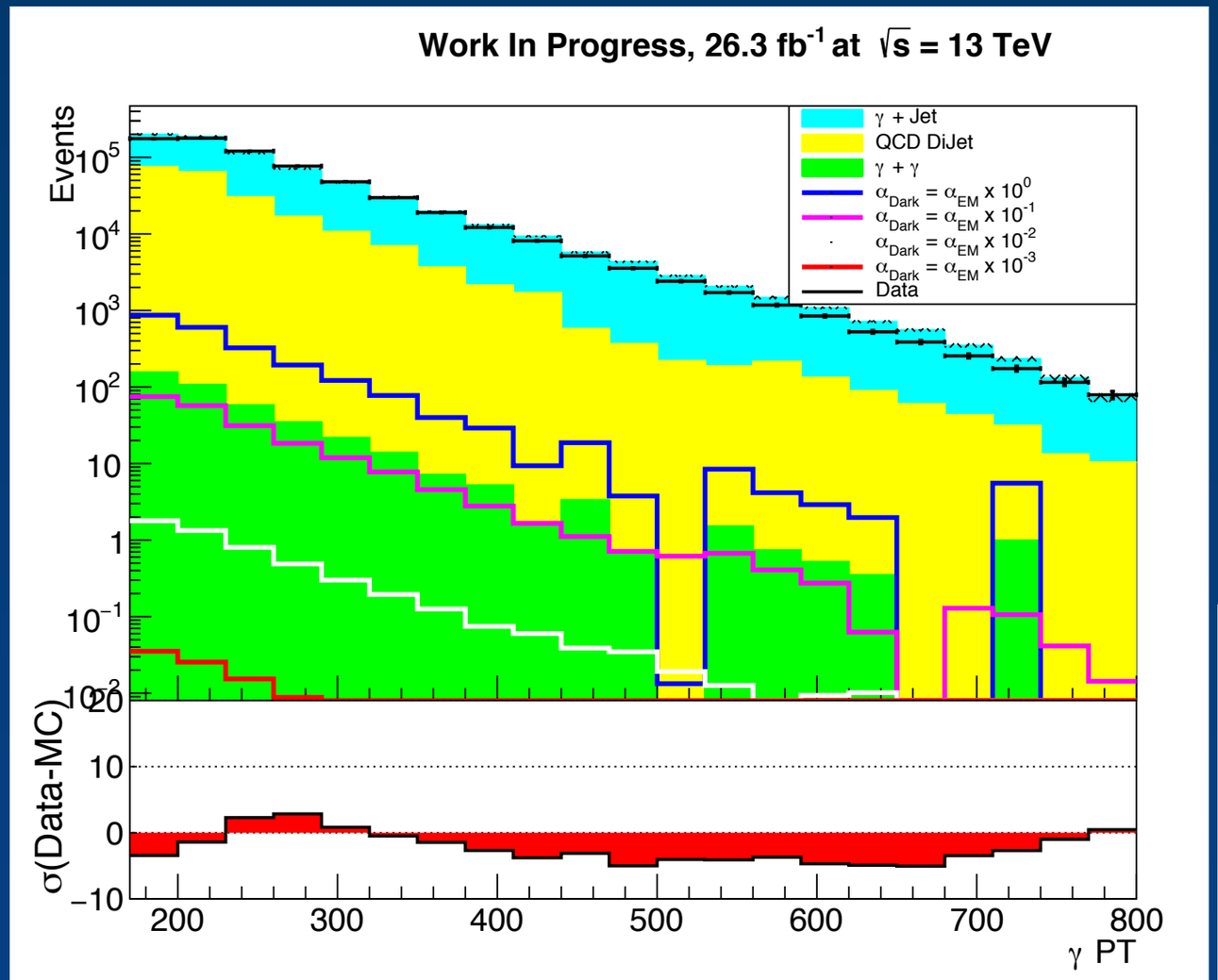
Photon Supercluster Et > 175 GeV
Photon $|\eta| < 1.4442$

Offline Jet Requirements

Jet Pt > 170 GeV
Jet $|\eta| < 2.4$
ΔR(Jet, Electrons) > 0.5
ΔR(Jet, Muons) > 0.5
ΔR(Jet, Identified Photon) > 0.5

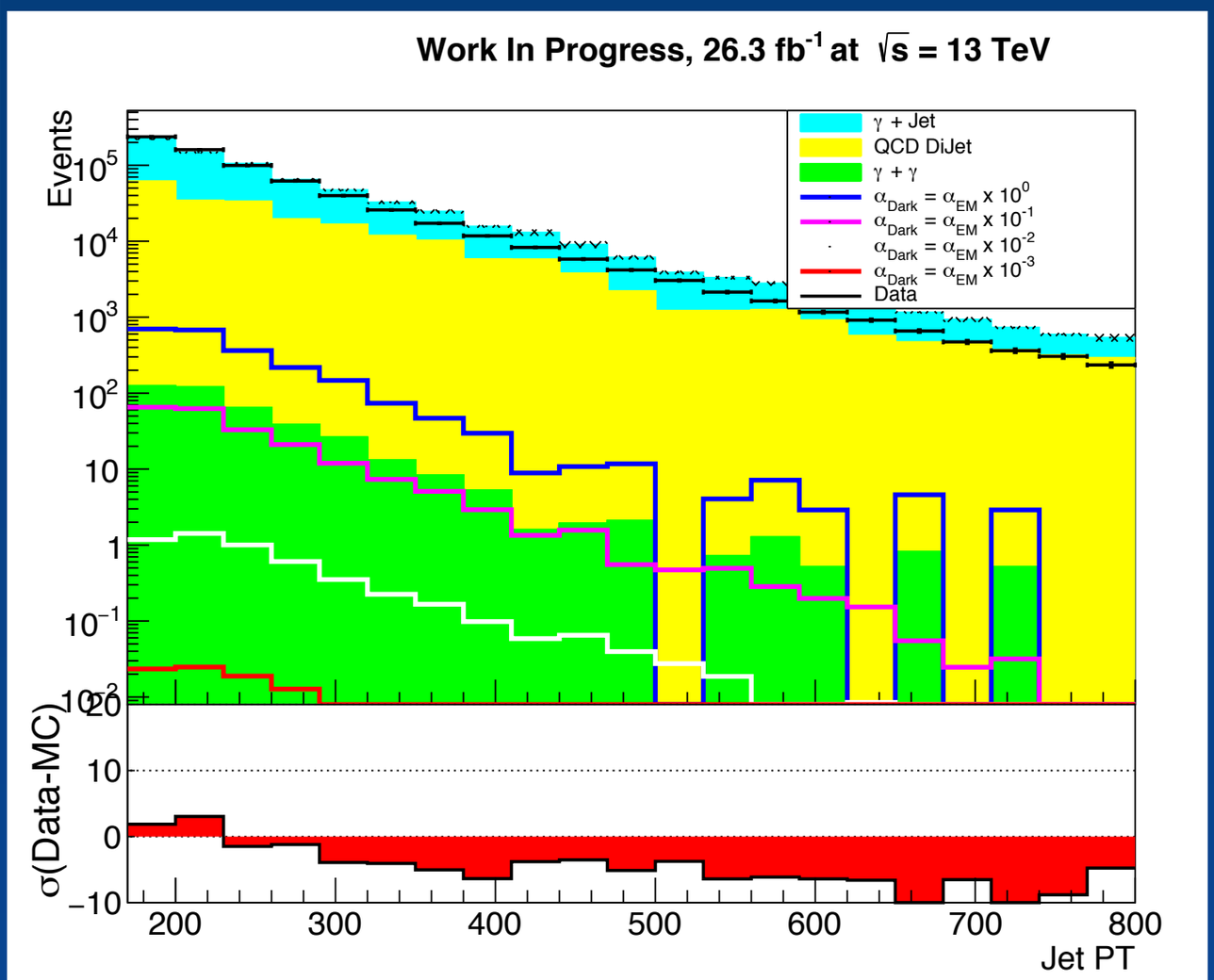
- Trigger on single high energy photon.
- Apply offline requirement for one high pt photon recoiling from a high pt Jet.
- Look for unique properties of the Jet.
  - Neutrality: Jet should be especially neutral as the dark photon has zero electromagnetic charge.
  - ShowerShape: The shower from the jet should be pencil-like in thinness.

Kinematic Variables

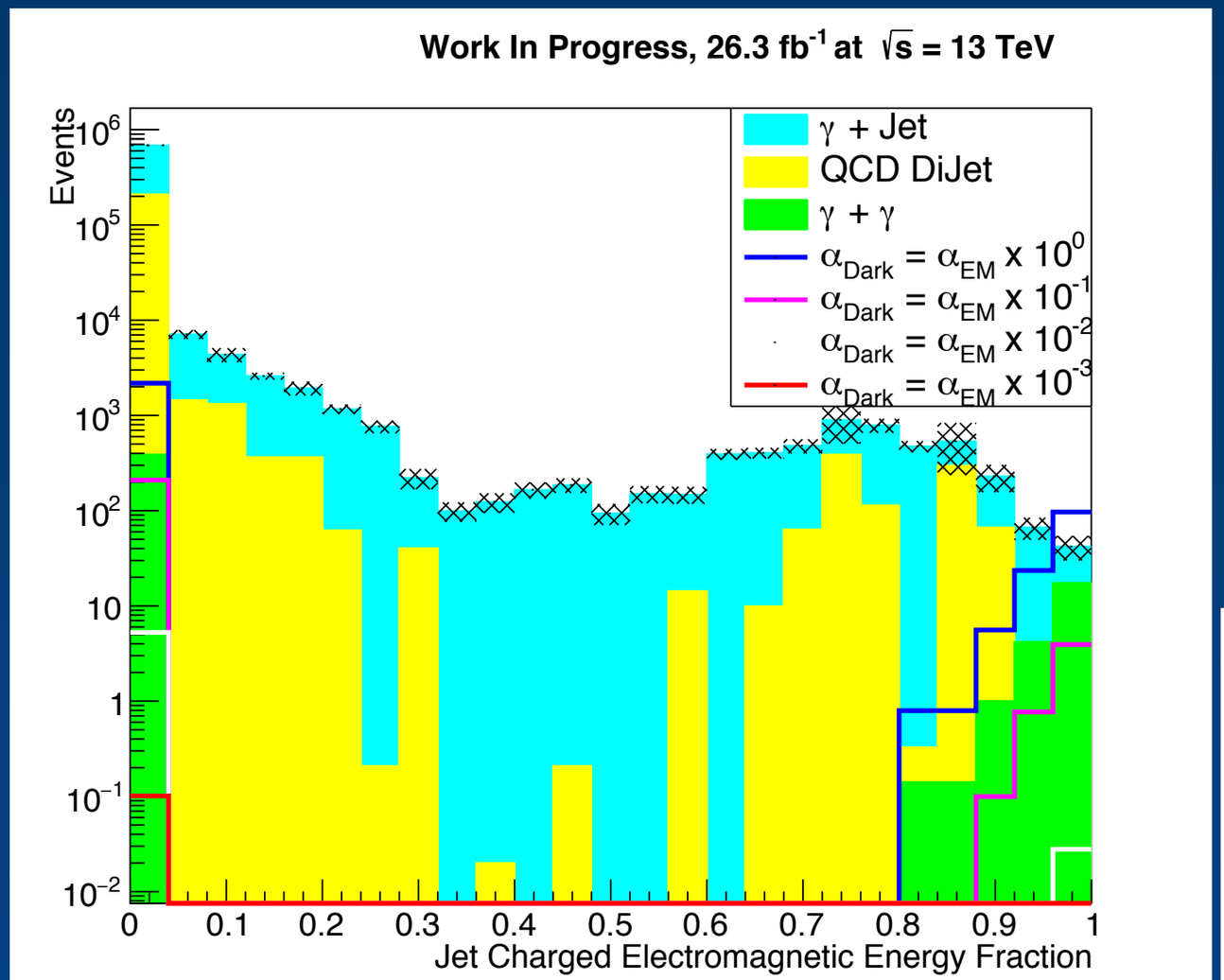


- Initial plots with only kinematic cuts.
- Using Monte Carlo generated Signal and Background samples.

	Events
$\gamma+\gamma$	412
QCD DiJet	213060
γ+Jet	495695
Total Backgrounds	709167
Data	683921
df = 1.0	2308
df = 0.1	214
df = 0.01	5
df = 0.001	0.1

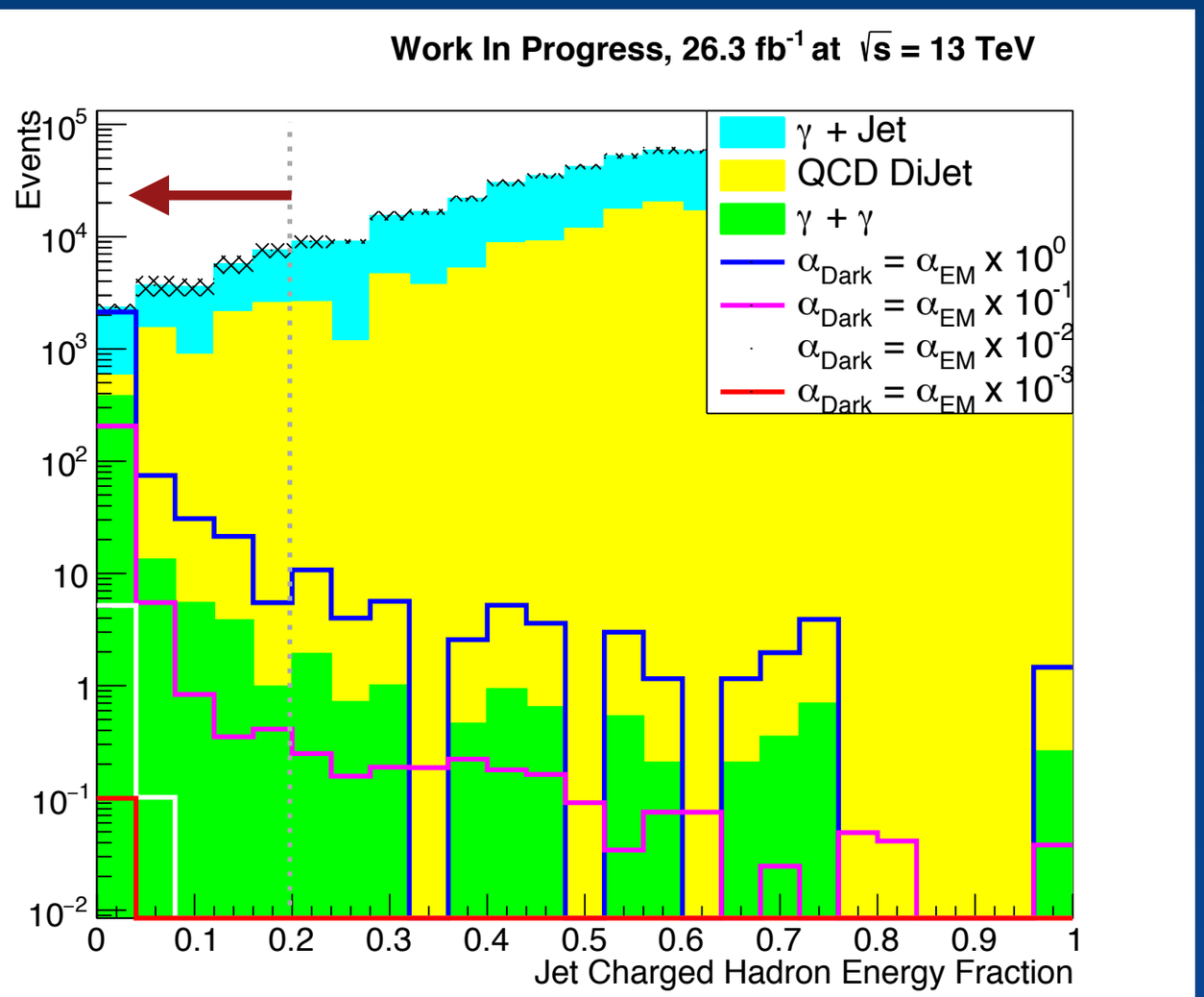


Jet Neutrality

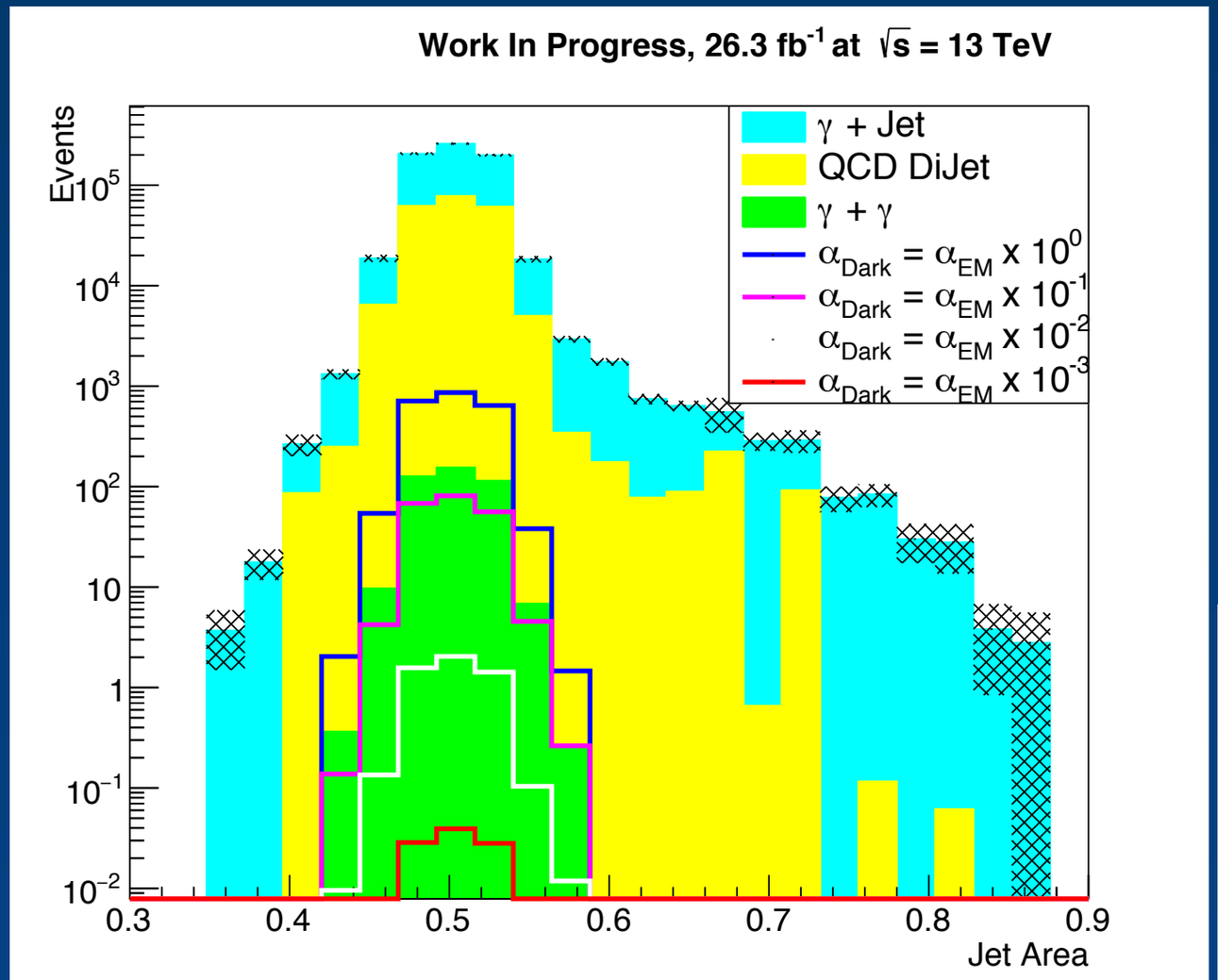


1. Neutral Jets=> very little charged hadron energy fraction and low electromagnetic energy fraction (except when photon converts to e^+ e^-).

A cut is made on Charged Hadron Energy Fraction (right).

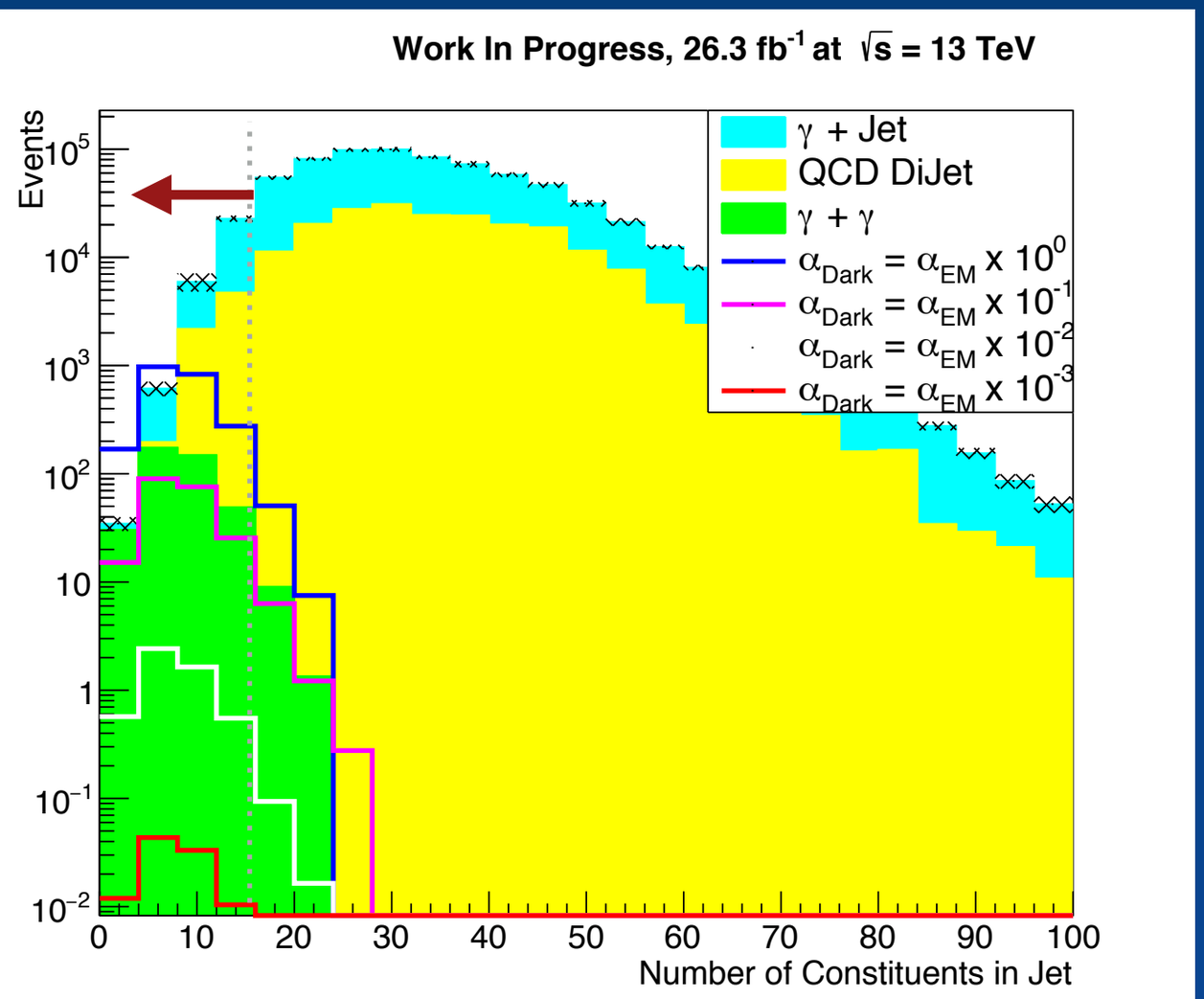


Jet ShowerShape

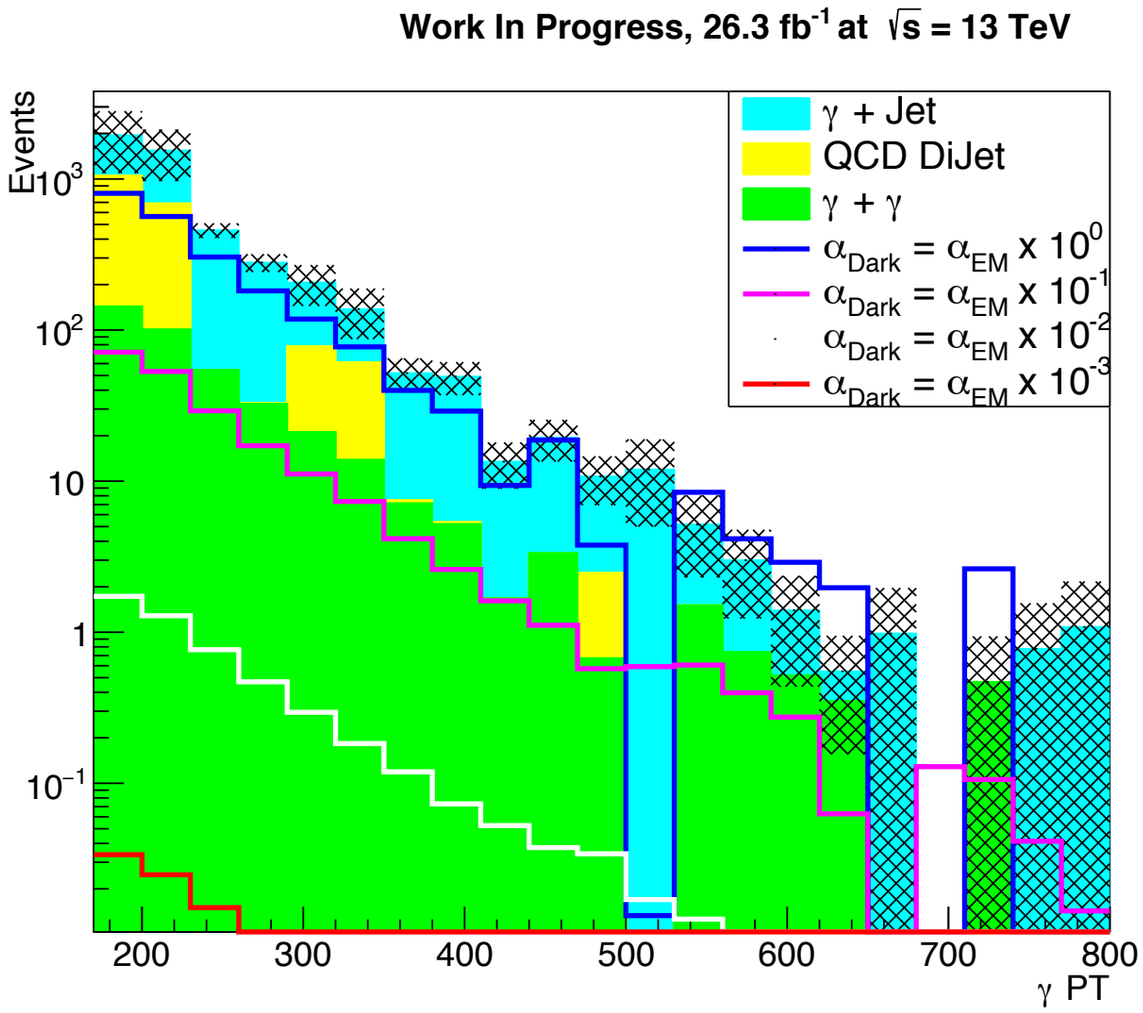


2. Pencil-like => small footprint and low total number of constituents in Jet.

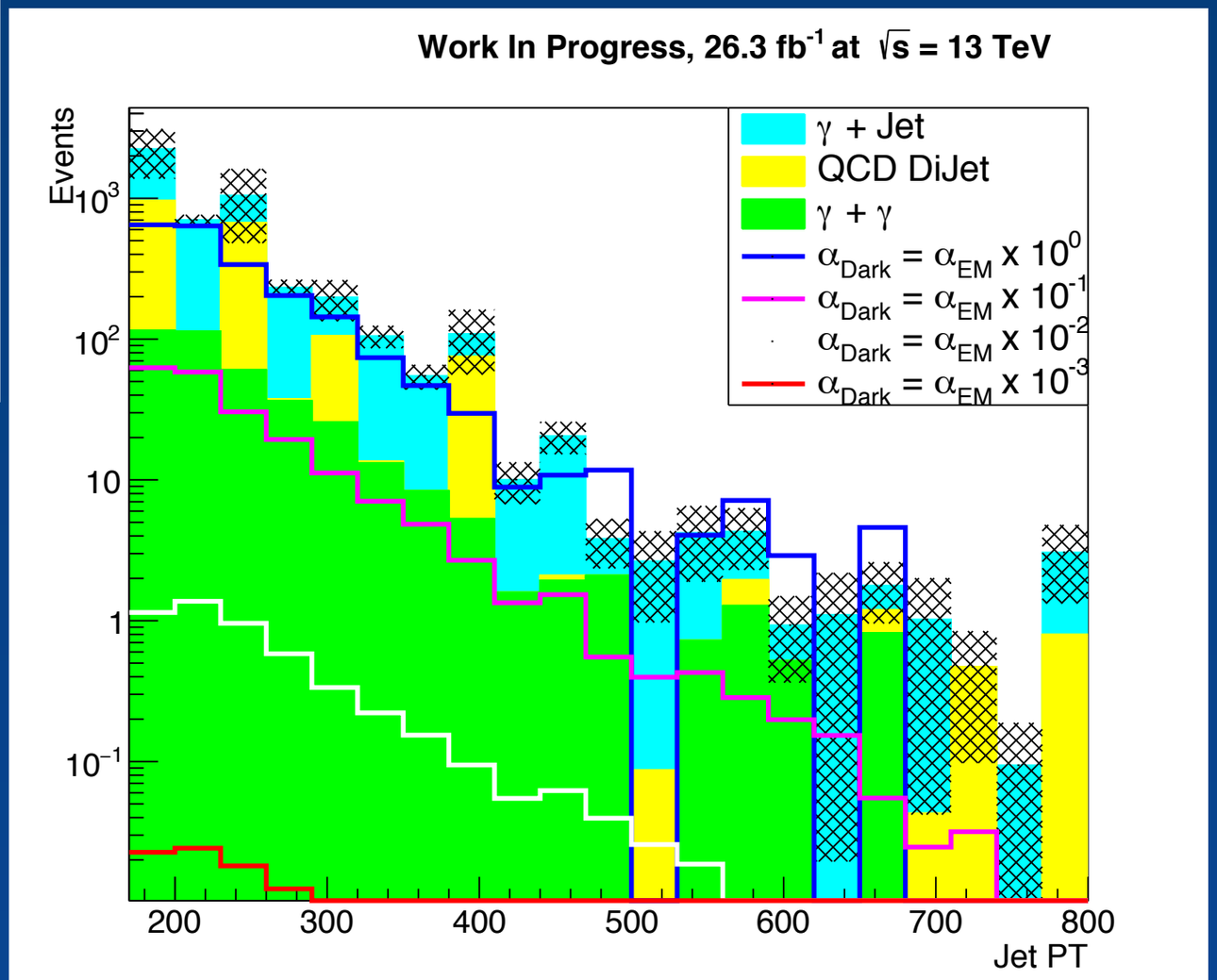
A cut is made on Number of Constituents in Jet (right).



Further Jet Selection



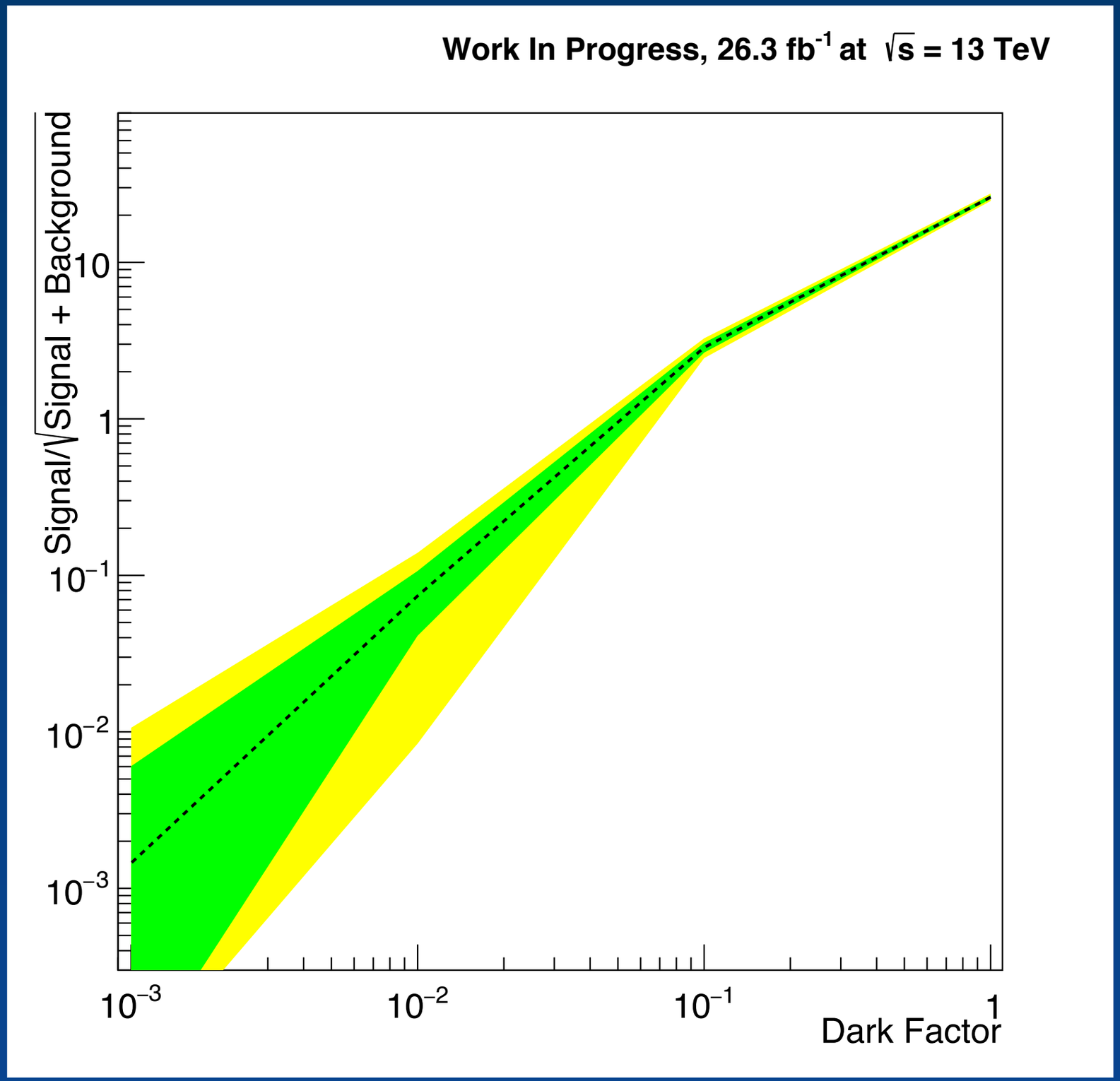
- Additional Cuts applied:
  - Jet Charged Hadron Energy Fraction < 0.2
  - Number of Jet Constituents < 15



	Events
$\gamma+\gamma$	387
QCD DiJet	1610
γ+Jet	2754
Total Backgrounds	4751
Data	Blinded
df = 1.0	2171
df = 0.1	201
df = 0.01	5
df = 0.001	0.1

Expected Limits

- Calculate the significance for dark factors from 10^{-3} to 1.
- Significance is calculated using estimated signal and background yields after cutting on Jet variables.
- A dark factor of >0.1 x standard model EM coupling can be excluded with significance > ~3σ



Conclusions

- An analysis searching for low mass (<1MeV) Dark Photons in the Photon + Jet final state is under way.

- The interaction of a Dark Photon in the CMS detector is parameterized by a dark factor.

- A similar search for Dark Photons in the Photon + MET was considered but produced weaker limits.

- A dark factor of >0.1 x standard model EM coupling can be excluded with significance > ~3σ

- Further characterization of the Dark Photon jet will provide better limits [Work in Progress].