GEFÖRDERT VOM

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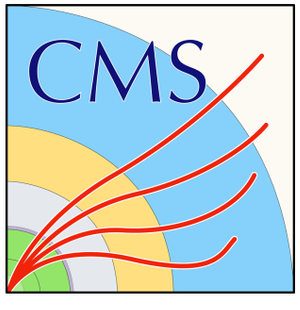

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SEARCH FOR DARK SECTOR IN CMS

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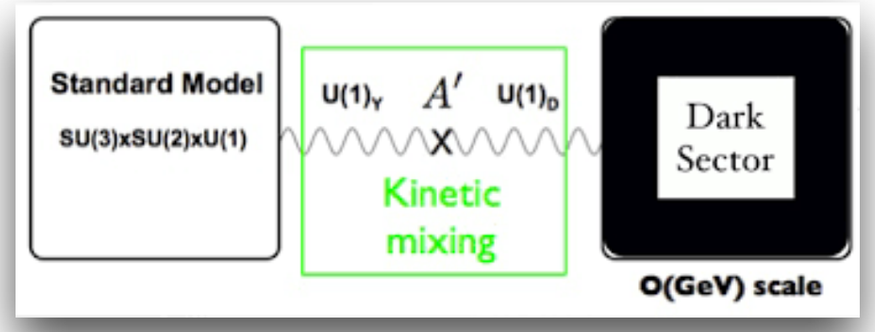
MOTIVATION FOR DARK SECTOR SEARCHES

- In this talk: focus on dark photons, and searches with full RunII data
- Hidden sector models introduce one extra **$U(1)_D$ gauge symmetry** and a corresponding gauge boson: the dark photon (Z_D /γ_D /A').
- Z_D serve as a **connection** between the SM and a dark sector.
- Z_D talks to SM particles through **kinetic mixing** (ε).
  - Interaction of Z_D with SM fermions is **similar** to that of Z and γ.
    - Interaction cross section **suppressed** by ε^2.
- Model assumptions
  - Other particles of dark sector are **heavy**.
    - Z_D can only decay on-shell to SM particles.
  - Z_D width does not depend on any dark sector interactions.
  - Z_D width only depends on ε, $M(Z_D)$ and known SM parameters.



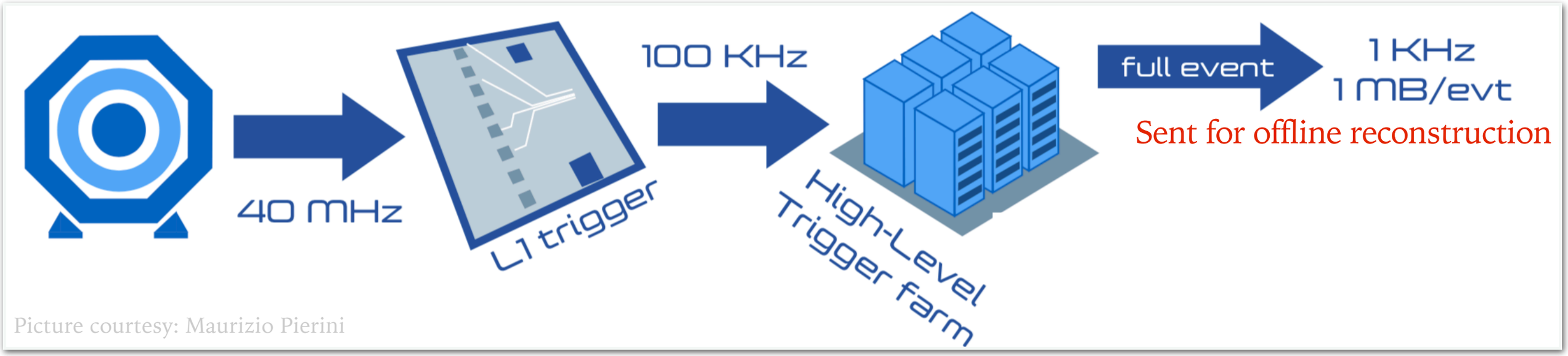
DARK PHOTON DECAYING TO DIMUON CHALLENGES IN LOW MASS

- Standard dimuon triggers in CMS have a threshold of ~**17/8 GeV** on muon p_T
- Very high acceptance for dimuon masses around and above the Z peak
- Searching in high-mass is not a problem
- But we suffer large acceptance loss for low (<40 GeV) dimuon masses

Is it possible to accept events with lower p_T muons?

Option 1: Lower the trigger threshold, i.e. accept more events

Not viable due to limited resource



Picture courtesy: Maurizio Pierini

We are limited by

Trigger Bandwidth = Event Rate × Event Size

$\sim$1 kHz × $\sim$1 MB

$\approx$**1 GB/sec**

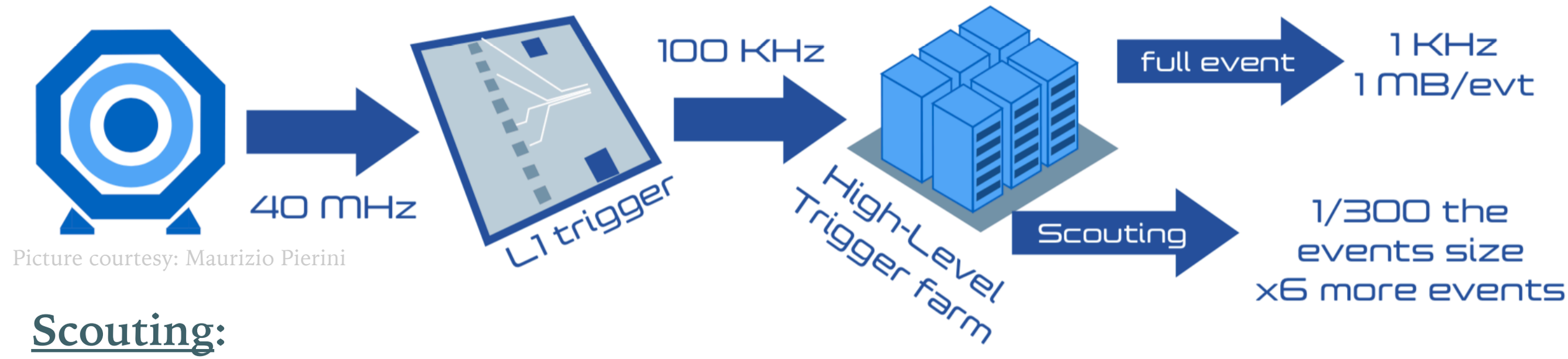
WHAT IS THE WAY OUT FOR LOW MASS ?

$$\text{Trigger Bandwidth} = \underbrace{\text{Event Rate}}_{\sim 1\ \text{kHz}} \times \underbrace{\text{Event Size}}_{\sim 1\ \text{MB}}$$

If we want to ***increase*** rate

We need to ***decrease*** event size

This is the idea of data scouting



Picture courtesy: Maurizio Pierini

Scouting:

no offline reconstruction

use HLT reconstructed objects

no RAW data saved

Practical (so far) only for specific topologies

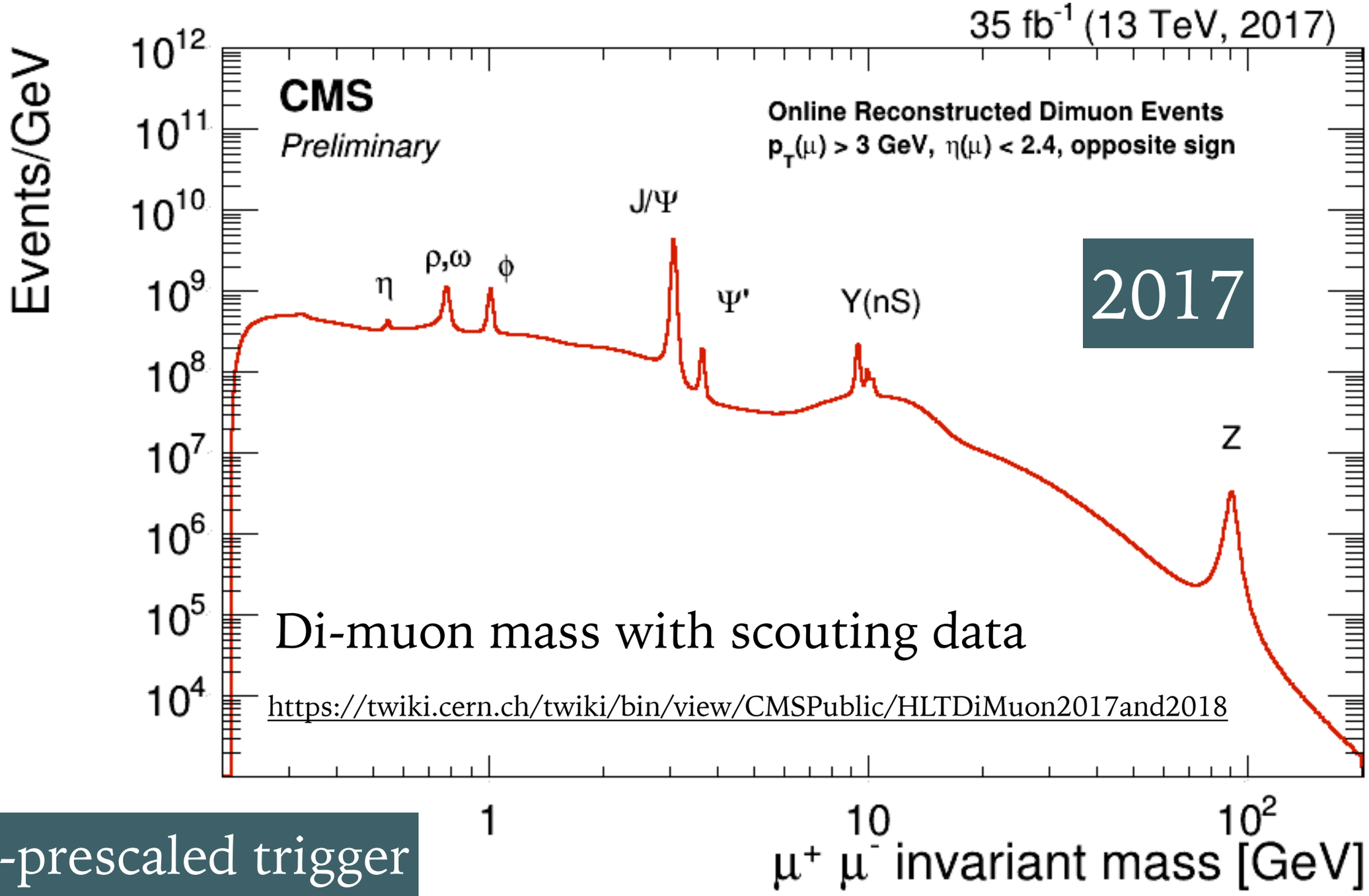
DIMUON SCOUTING TRIGGER

Dedicated dimuon scouting trigger designed in 2017

Loose HLT requirement:

At least 2 muons with p_T>3 GeV. **No invariant mass cut**.

Muon tracks should have >0 hit in pixel and overall >4 hits in tracker, hits in muon chamber

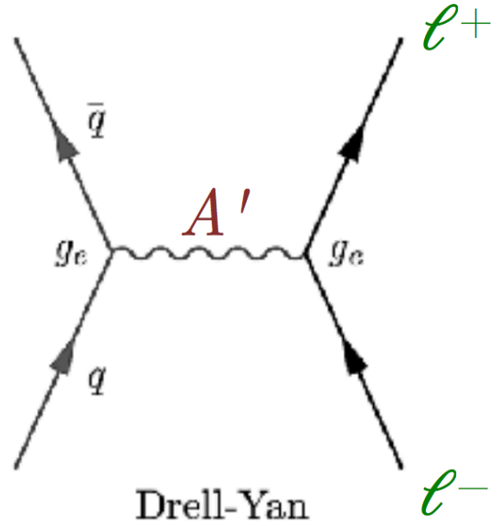


Di-muon mass with scouting data

https://twiki.cern.ch/twiki/bin/view/CMSPublic/HLTDiMuon2017and2018

Un-prescaled trigger

PROMPT DARK PHOTON SEARCH



- Probing $\varepsilon \sim 10^{-2}$ - 10^{-3}
- Look for bump in the di-muon mass spectrum
- Signal cross section ~ ε^2 x Drell-Yan cross section

  (also the main background)
- Search sensitivity depends on how many di-muon

  events in a given mass range we can save

Dark photon signal simulated at leading order using
Hidden Abelian Higgs Model (HAHM)

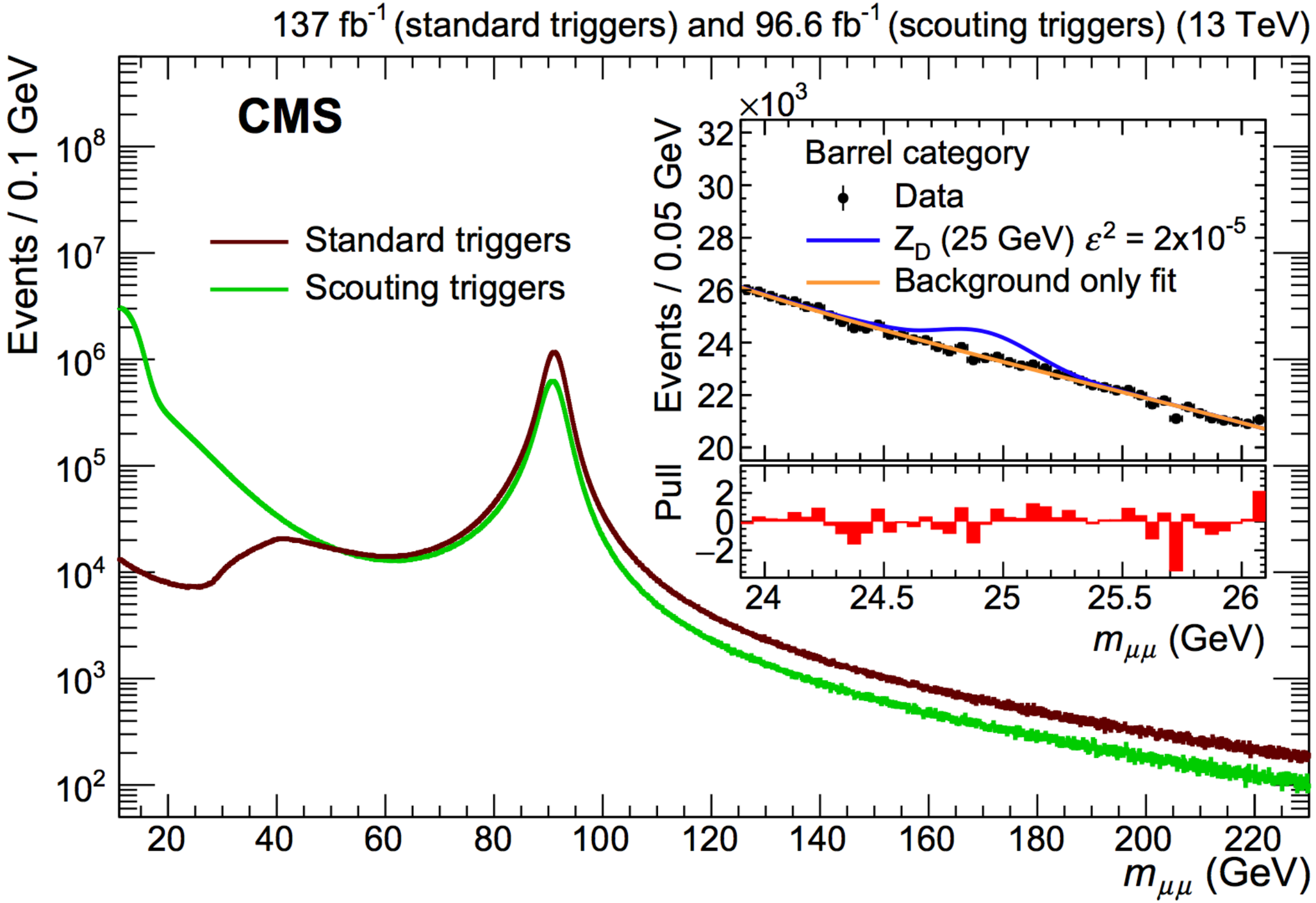
$Z_d \rightarrow \mu\mu$ ANALYSIS STRATEGY

Phys.Rev.Lett. 124 (2020) 13, 131802

- Low mass analysis (11.5<Mμμ<45 GeV)
  - Using HLT reconstruction (scouting)
  - Dimuon scouting trigger
  - Mass-dependent (offline) pT cut on muons
- High mass analysis (45<Mμμ<200 GeV, excluding Z mass region)
  - Using offline reconstruction
  - Dimuon and single muon triggers
  - Veto events containing b-tagged jet to suppress top quark background

- Background estimation data-driven.
- Events categorised in two η categories to enhance the sensitivity.
- Signal shape parametrised from MC, using double-sided Crystal ball function.
- Background shape parametrised from data.
- Fits performed in a window around dark-photon mass.

INVARIANT MASS SPECTRUM



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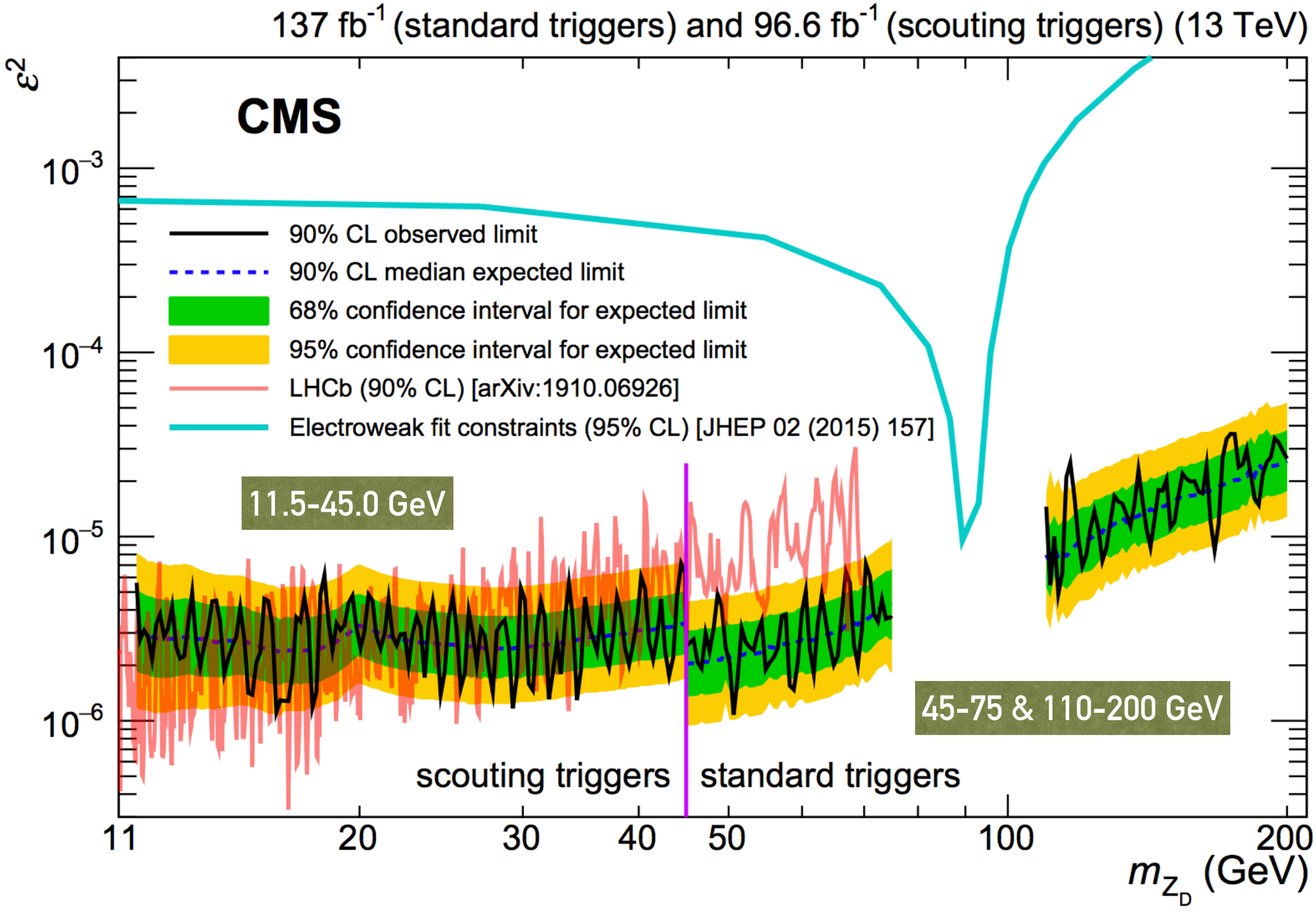
RESULTS: DARK PHOTON

First CMS analysis using non-hadronic scouting



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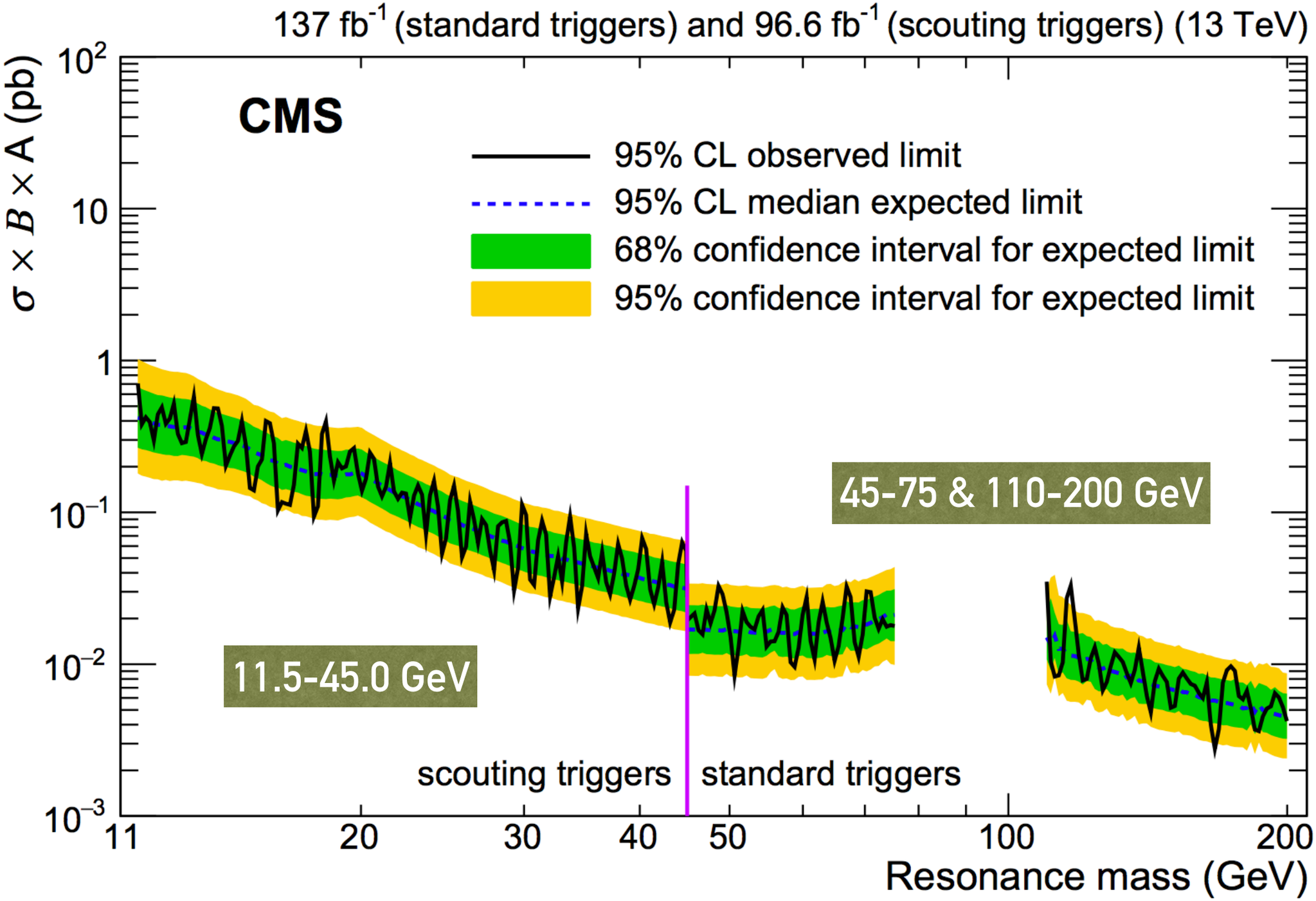

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ZH WITH H DECAYING TO DARK PHOTON

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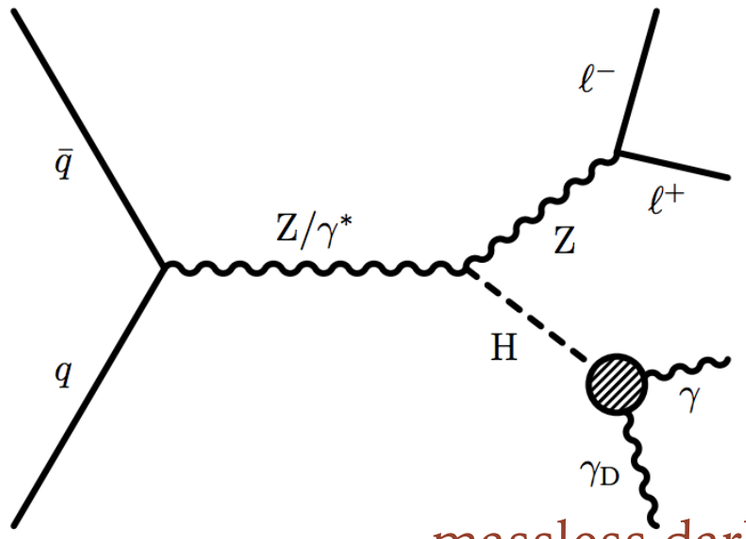

massless dark photon, undetected

Full RunII data used

Not sensitive to H → Zγ → νγ

Final state:

e+e- / μ+μ- from Z decay,

missing transverse energy

Isolated γ

Variable	Selection	Reject
Number of leptons	Exactly 2 leptons, $p_T > 25/20$ GeV	WZ, ZZ, VVV
Number of photons	≥1 photon, $p_T^\gamma > 25$ GeV	All but Zγ
$\lvert m_{\ell\ell} - m_Z \rvert$	<15 GeV	WW, Top quark
p_T^{miss}	>110 GeV	Zγ
$p_T^{\ell\ell}$	>60 GeV	Zγ
b jet veto	Applied	Top quark, VVV
Jet counting	≤2	Top quark, VVV
$\Delta\phi_{\overrightarrow{\ell\ell},\vec{p}_T^{miss}+\vec{p}_T^{\gamma}}$	>2.5 rad	Zγ
$\lvert p_T^{\vec{p}_T^{miss}+\vec{p}_T^{\gamma}} - p_T^{\ell\ell} \rvert / p_T^{\ell\ell}$	<0.4	Zγ
$\Delta\phi_{jet,\vec{p}_T^{miss}}$	>0.5 rad	Zγ
$m_{\ell\ell\gamma}$	>100 GeV	Zγ
m_T	<350 GeV	WW, Top quark

M_T SPECTRUM

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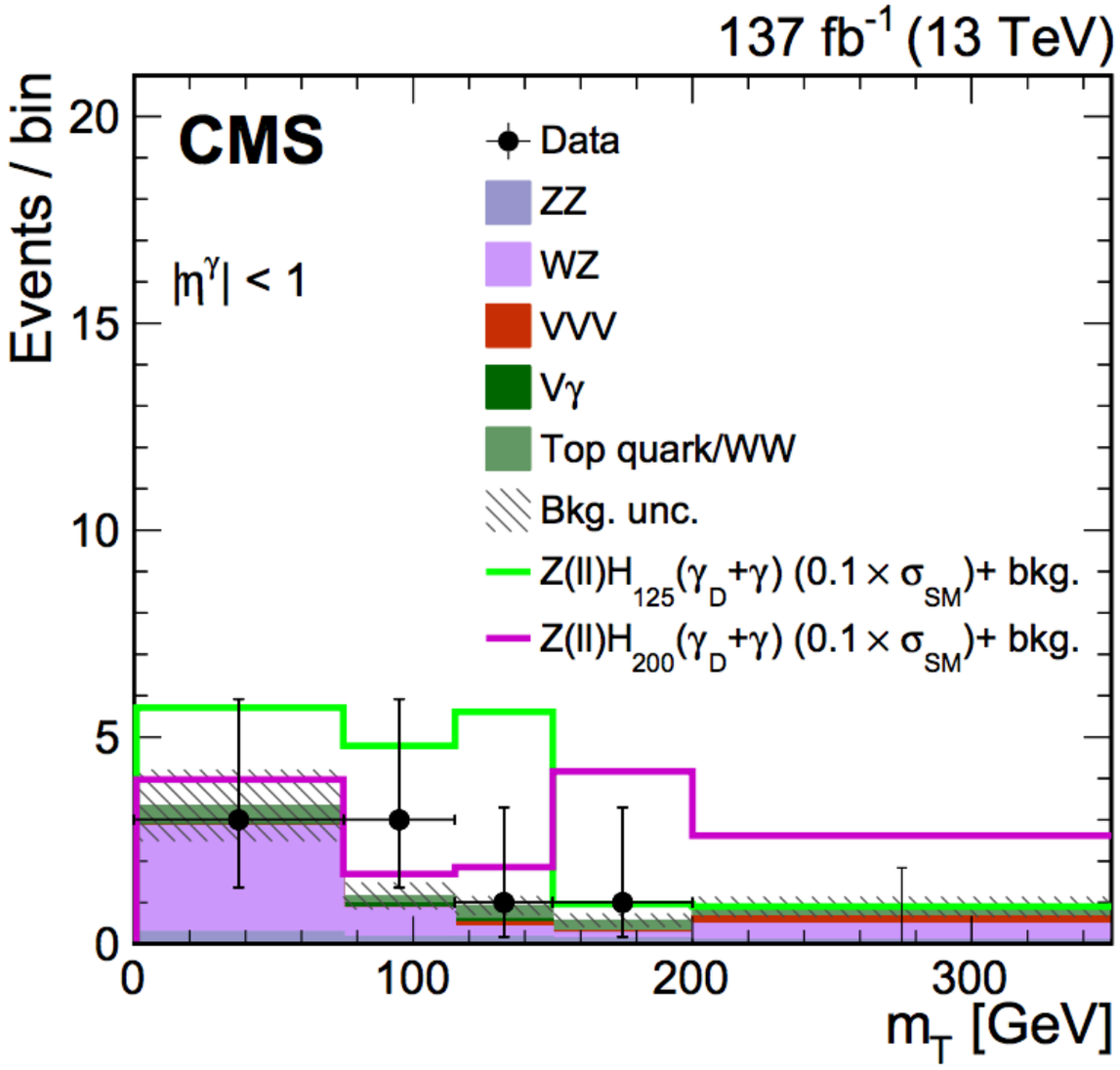

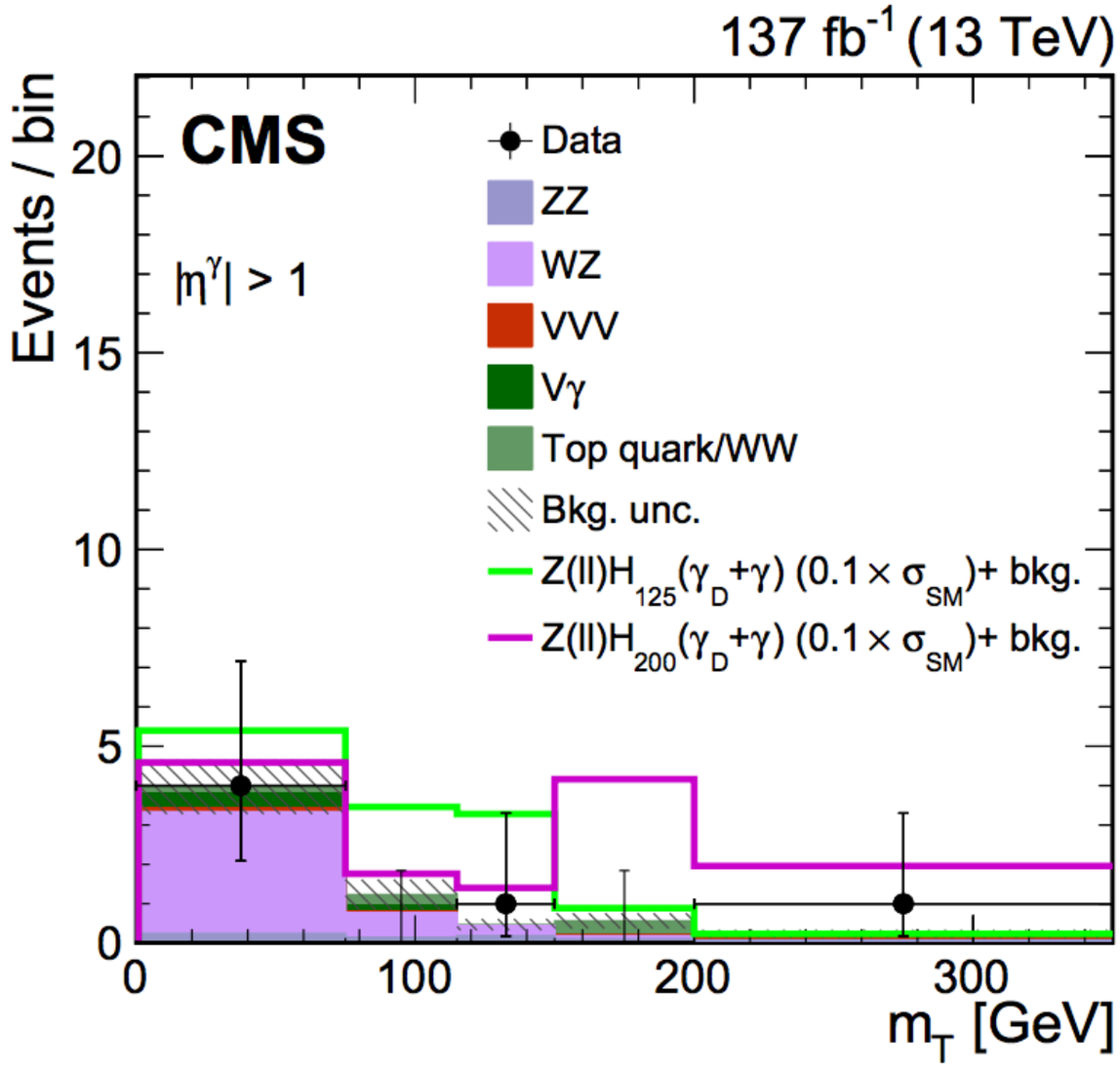

Main backgrounds: WZ and ZZ

Subleading backgrounds: WW, top production

Small contribution from multi boson production

Z(ll)H(Zγ) → llvvγ ignored (<0.1 events)

No significant excess

RESULTS

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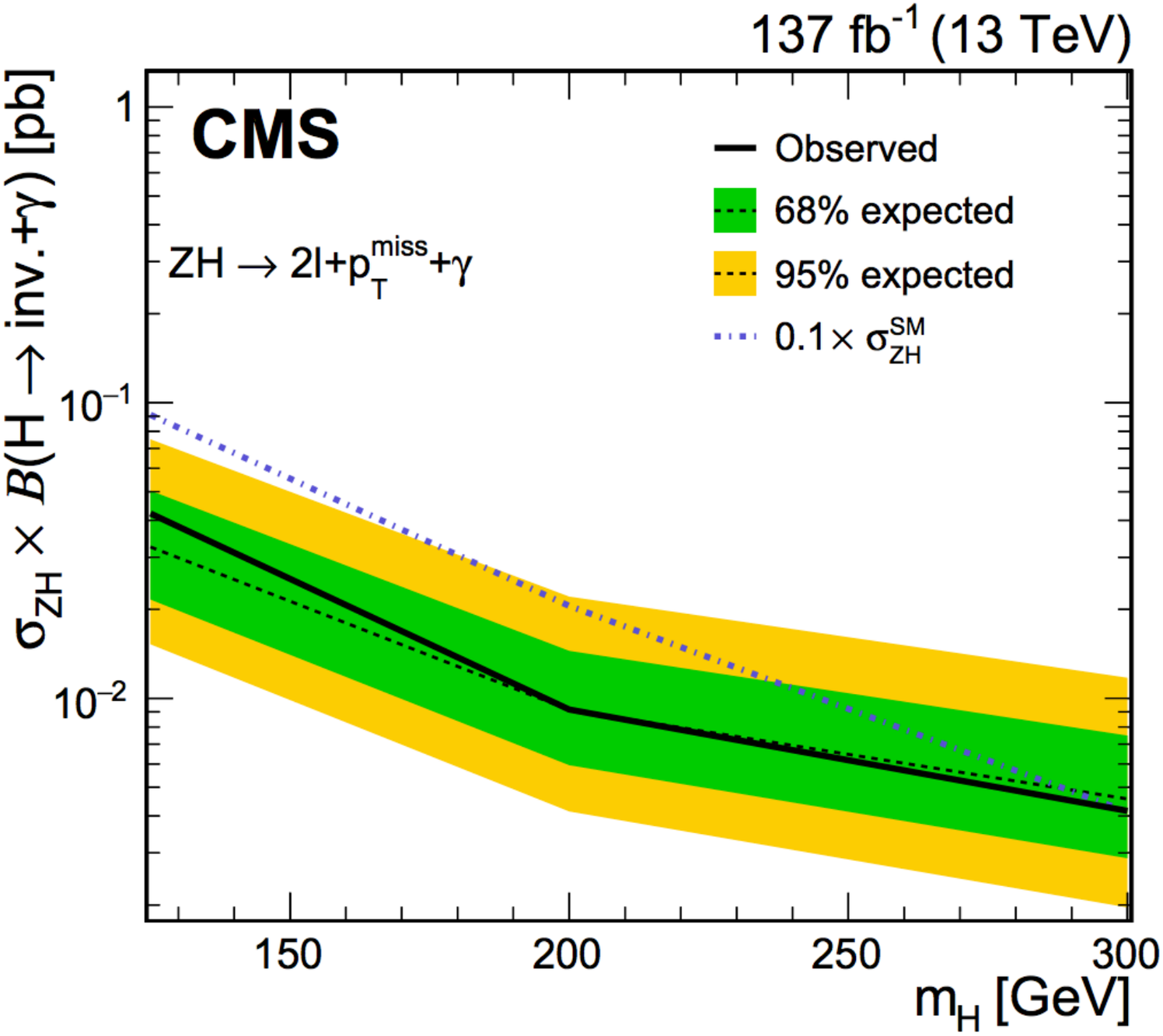


Statistical uncertainty dominates.

Systematics due to PDF choice, jet energy scale, object reconstruction/ identification efficiency, integrated luminosity etc taken into account.

Binned maximum-likelihood fit to mT spectrum performed.

For SM-like Higgs, obs (exp) upper limit on branching: 4.6 (3.6)% at 95% CL.

First limits on Higgs decaying to massless dark photon.

SUMMARY AND OUTLOOK

- CMS has diverse physics program for dark sector searches.
- Trying to reach so-far-unexplored territory with the help of scouting.
- Successful ‘prompt’ searches using scouting technique motivate more challenging attempts (eg. displaced dimuon search).
- Possibilities to expand scouting program in Run III.
- Leave no stone unturned. Do the best that can be done with CMS.

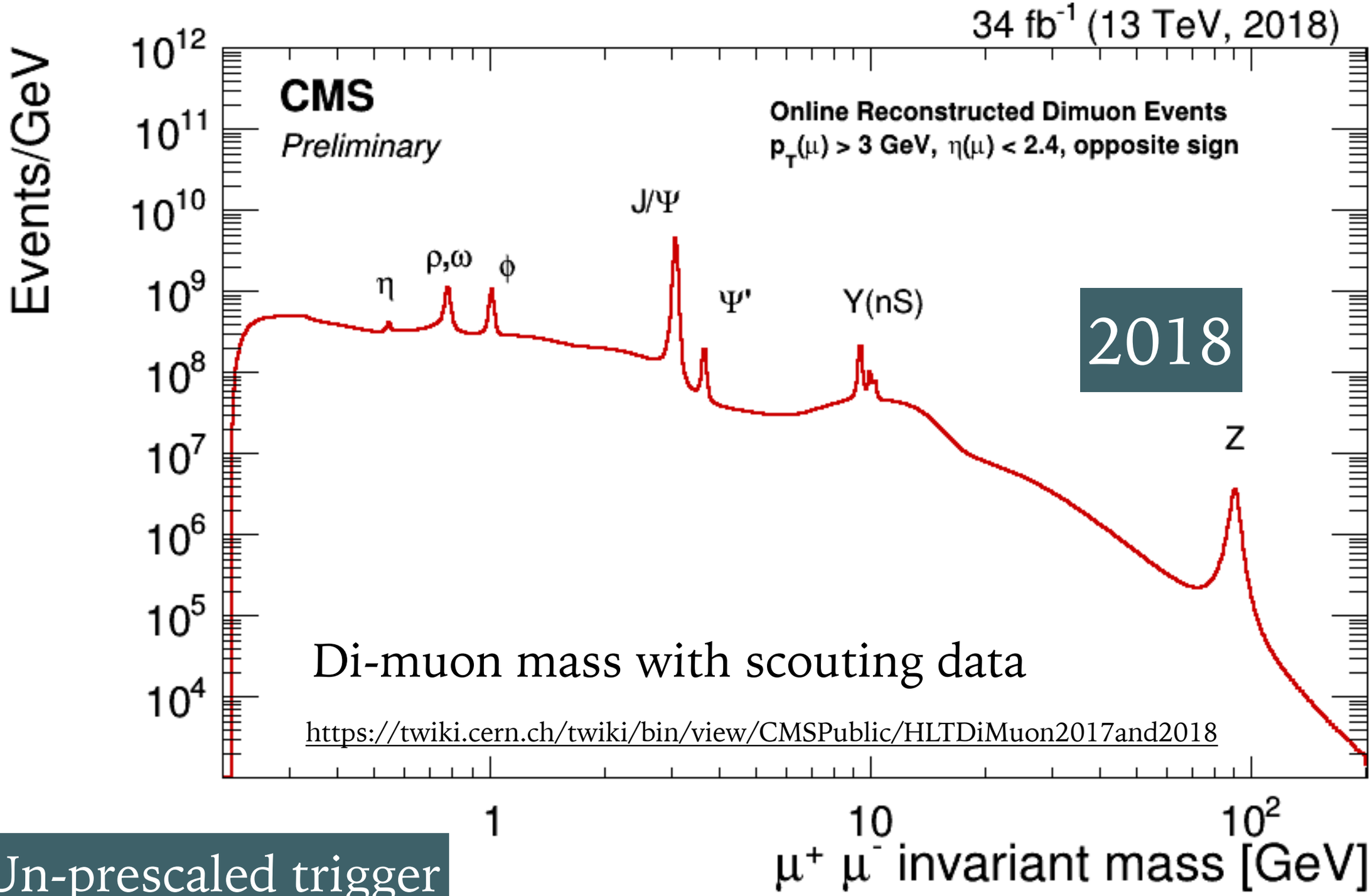
Stay tuned !

EXTRA SLIDES

DIMUON SCOUTING TRIGGER

~100 fb^{-1} data collected using dimuon scouting trigger in 2017 and 2018.

Low mass dimuon search performed with this data.



Un-prescaled trigger