SEARCH FOR DARK MATTER AT LHC

Marco Cipriani

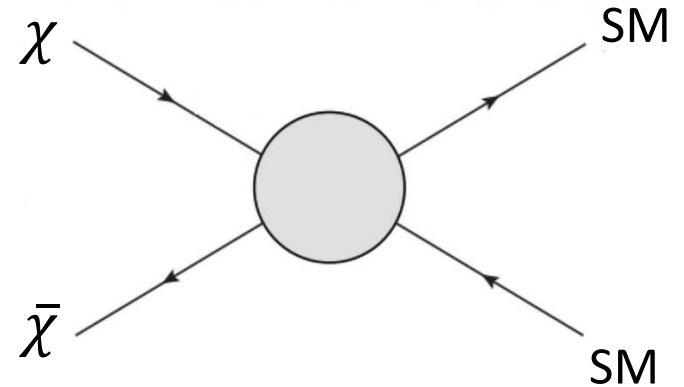Università di Roma La Sapienza

INFN Roma
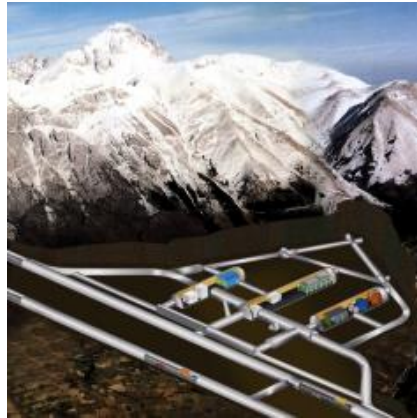
SHEDING LIGHT ON DARK MATTER

• **indirect search**:

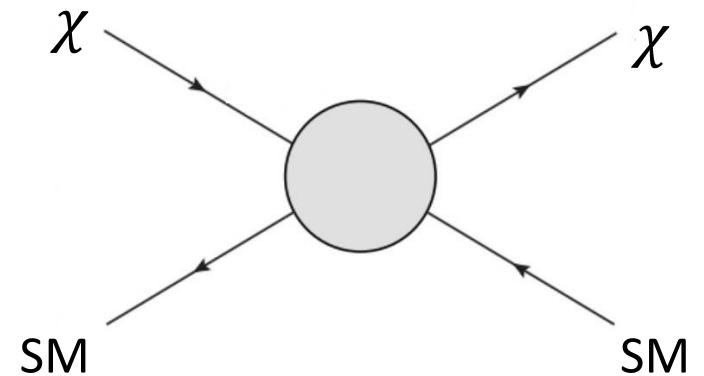Dark matter (DM) **annihilation** into Standard Model (SM) particles

SHEDING LIGHT ON DARK MATTER

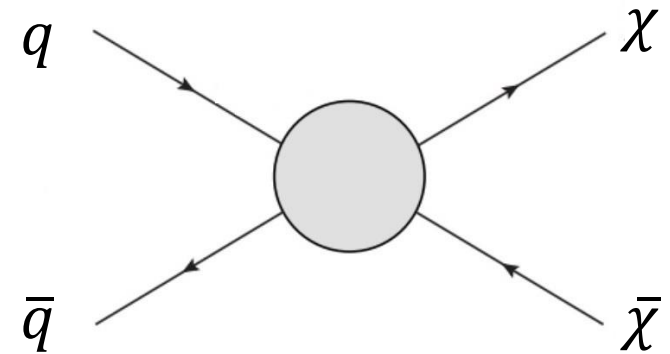- **direct search**:

DM **scattering** on nucleons

SHEDING LIGHT ON DARK MATTER

- ## search at colliders:

DM **production** from proton-proton collisions at LHC

$$q \rightarrow \chi$$
$$\bar{q} \rightarrow \bar{\chi}$$
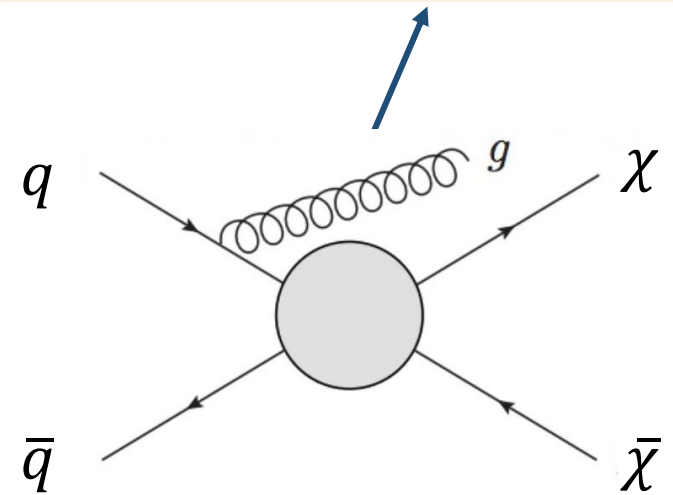
I will present CMS results

DARK MATTER SIGNAL AT LHC

MONOJET EVENT
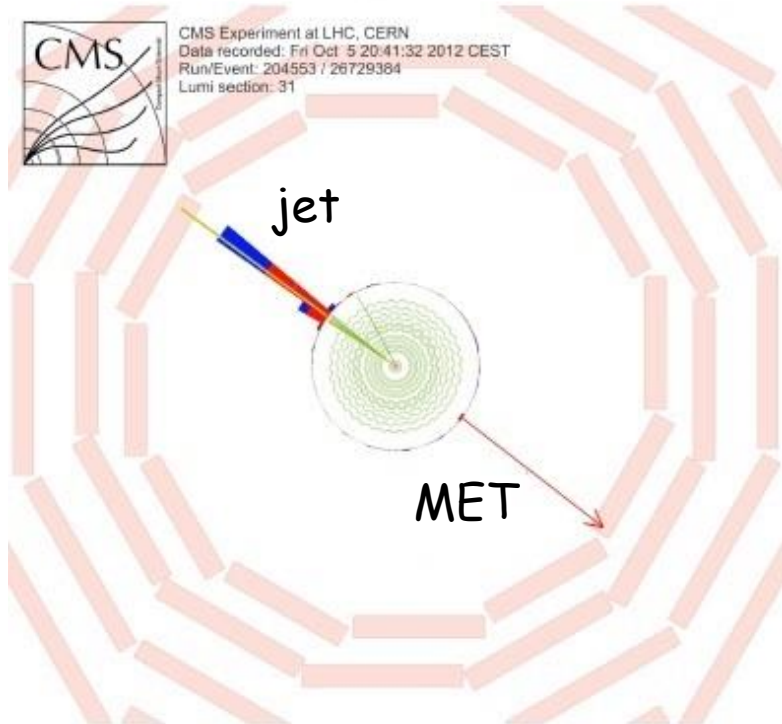
exploit radiation from initial state as a trigger

look for events with high missing transverse energy (MET or $\vec{E}_T$)

SIGNAL SELECTION

→ 1 high energy jet recoiling against $\not{E}_T$

- **MET** > 200 GeV

- **Njets** $\leq$ 2

- **noise cleaning** on leading jet

- **jet 1** p_T > 110 GeV;

- **second jet** allowed if:
  $\Delta\phi(jet1, jet2)$ < 2.5

- **photon veto**

- **lepton veto**

$$\vec{\not{E}}_T = - \sum_{\substack{all \\ particles}} \vec{p}_T$$

$\vec{p}_T$: momentum in transverse plane
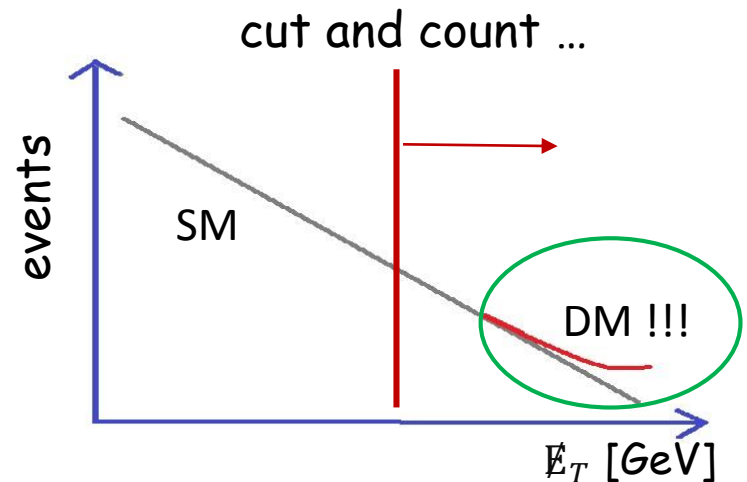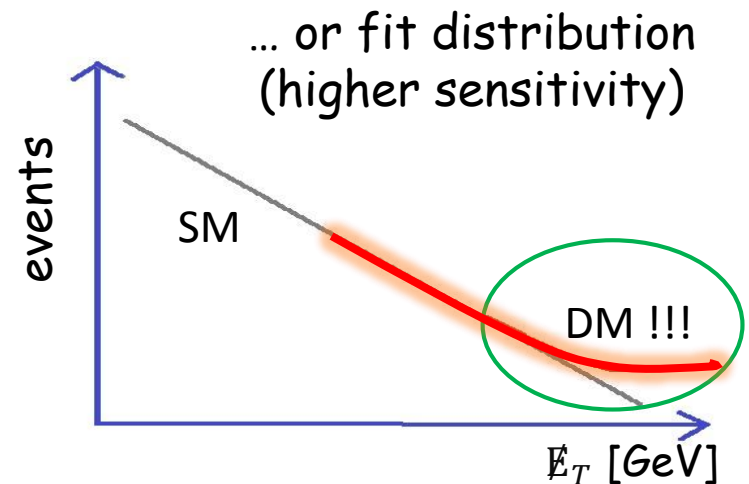
cut and count …

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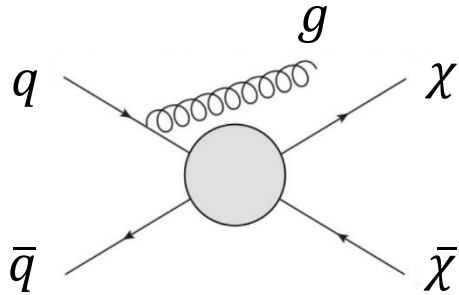$$\vec{\not{E}}_T = -\sum_{\substack{all \\ particles}} \vec{p}_T$$

$\vec{p}_T$: momentum in transverse plane

… or fit distribution (higher sensitivity)

events

SM

DM !!!
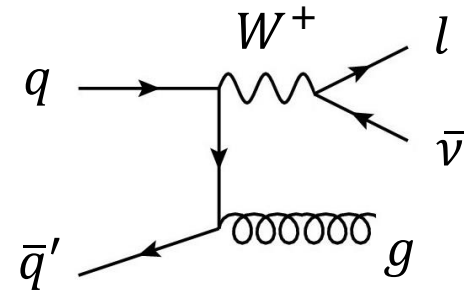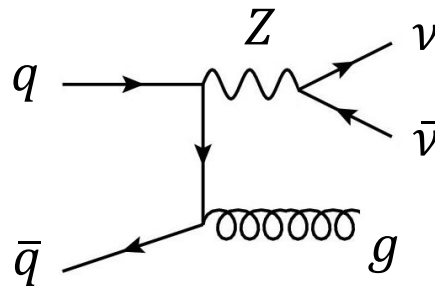
$\not{E}_T$ [GeV]

MONOJET BACKGROUNDS

everything in SM that produces jets and $\not{E}_T$

signal   backgrounds

main backgrounds

- $Z(\nu\nu) + jets$ (55%)
- $W(l\nu) + jets$ (40%) (if l is lost)
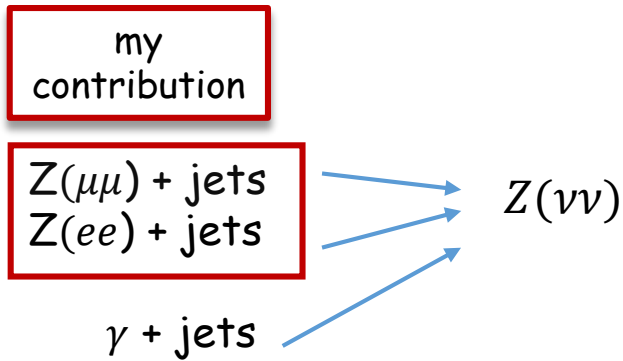
estimated from data using control samples

others:
- $t\bar{t}$, single top
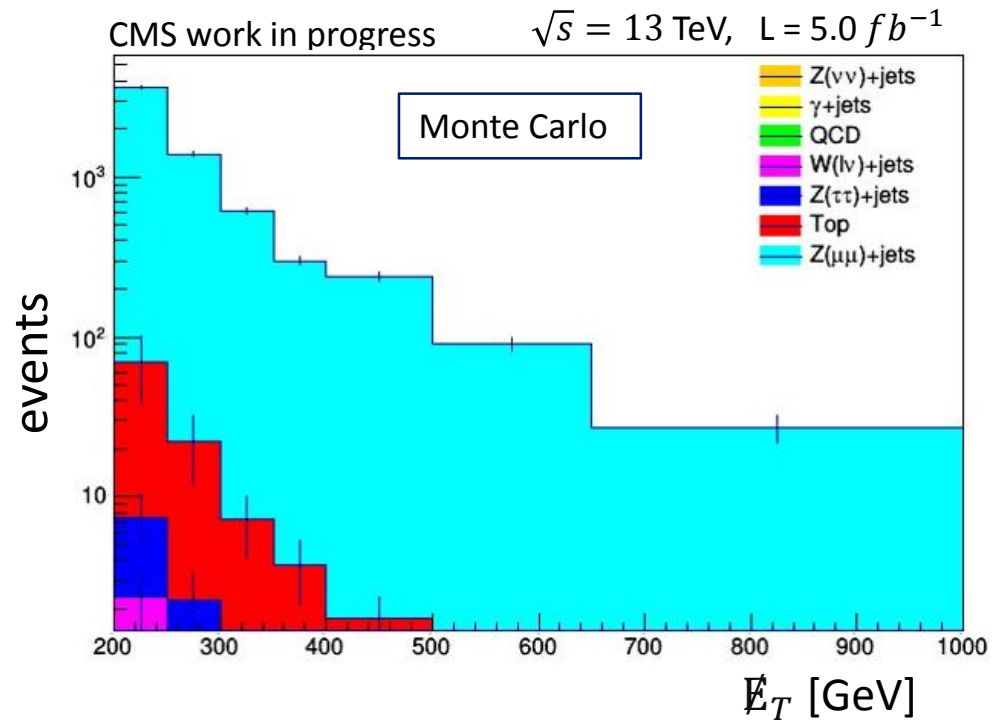- QCD multijet
- diboson

estimated from MC

DATA DRIVEN BACKGROUND ESTIMATE

- select a control sample in data

- use MC to get transfer factors from control region (CR) to signal region (SR)

$$\text{N}_{SR}^{data} = N_{CR}^{data} \times \frac{\text{N}_{SR}^{MC}}{\text{N}_{CR}^{MC}}$$

my contribution

$Z(\mu\mu)$ + jets
$Z(ee)$ + jets $\longrightarrow$ $Z(\nu\nu)$

γ + jets

MET defined here excluding
Z or γ p$_T$ in the sum

CMS work in progress $\qquad \sqrt{s} = 13$ TeV, L = 5.0 fb^{-1}

Monte Carlo

- Z(νν)+jets
- γ+jets
- QCD
- W(lν)+jets
- Z(ττ)+jets
- Top
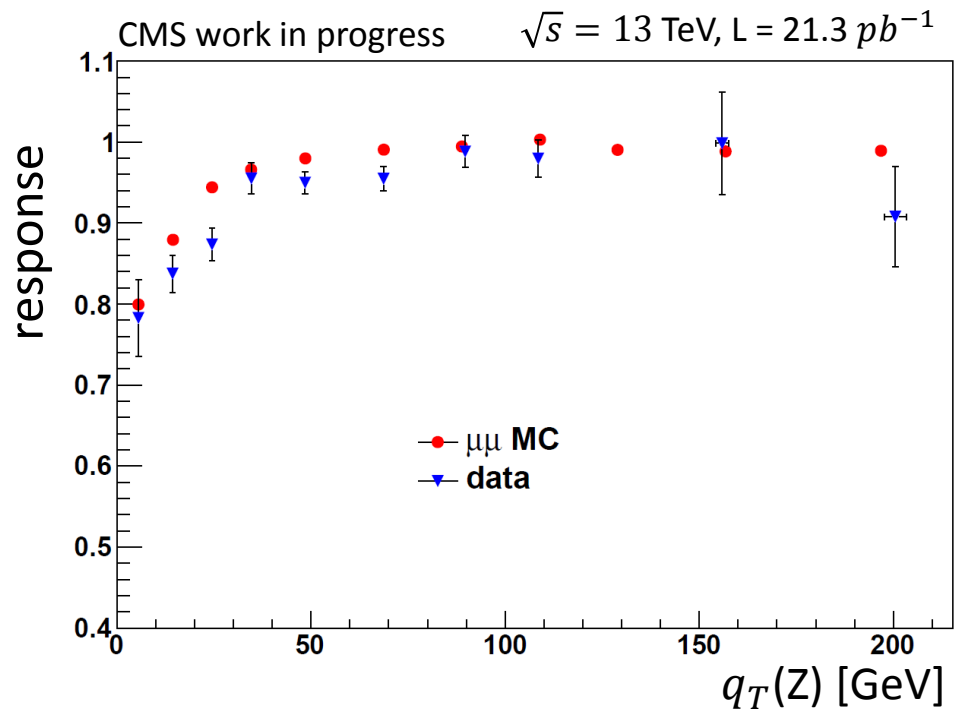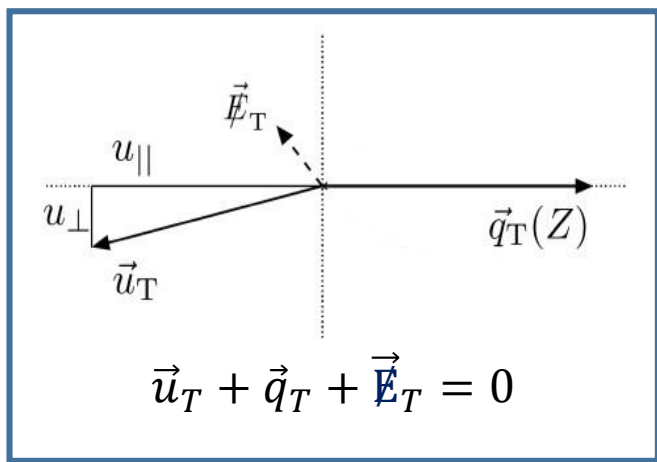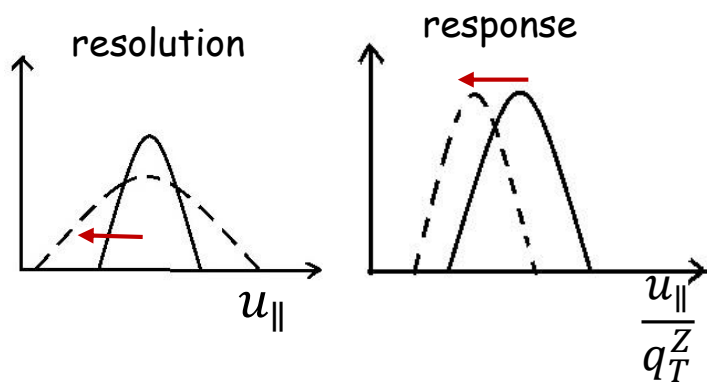- Z(μμ)+jets

events

$\not{E}_T$ [GeV]

MET RESOLUTION AND RESPONSE

my contribution

- assess the performance of the hadronic recoil reconstruction

Use $Z(ll) + jets$ **events**: induce MET by removing the well-measured leptons

resolution

response

$u_\parallel$

$\dfrac{u_\parallel}{q_T^Z}$

$\vec{E}_T$

$u_\parallel$

$u_\perp$

$\vec{u}_T$

$\vec{q}_T(Z)$

$$\vec{u}_T + \vec{q}_T + \vec{E}_T = 0$$

CMS work in progress $\sqrt{s} = 13$ TeV, L $= 21.3\ pb^{-1}$

response

q_T(Z) [GeV]

- μμ **MC**
- **data**

RUN 1 RESULTS
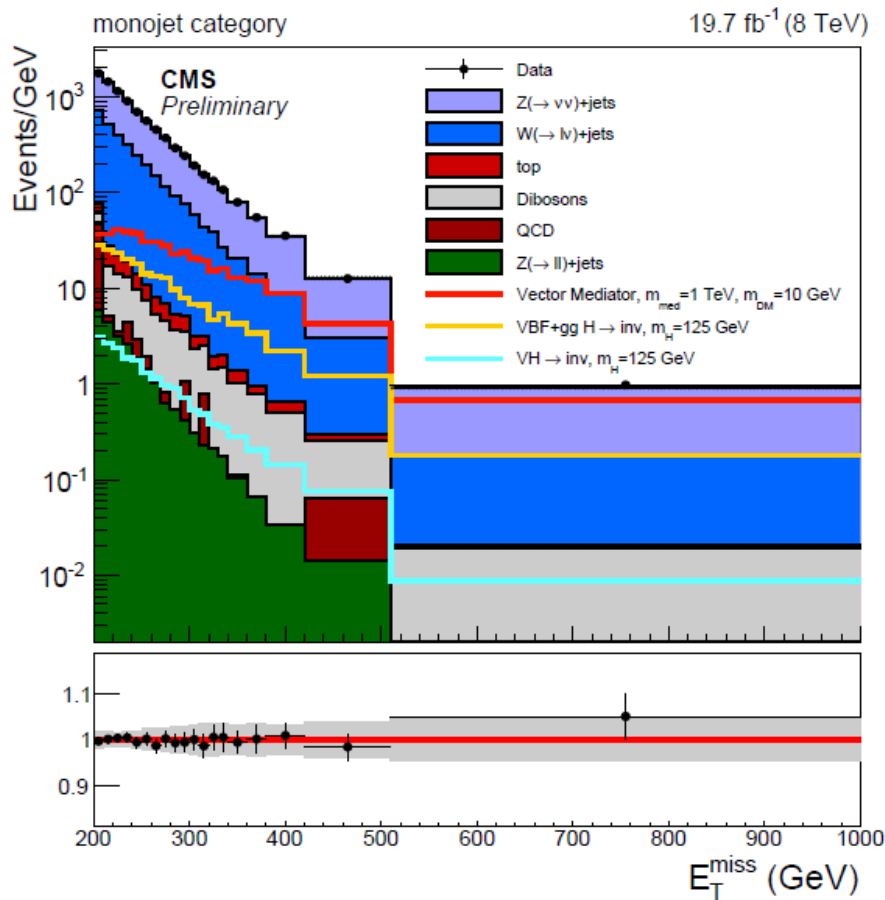
CMS-PAS-EXO-12-055
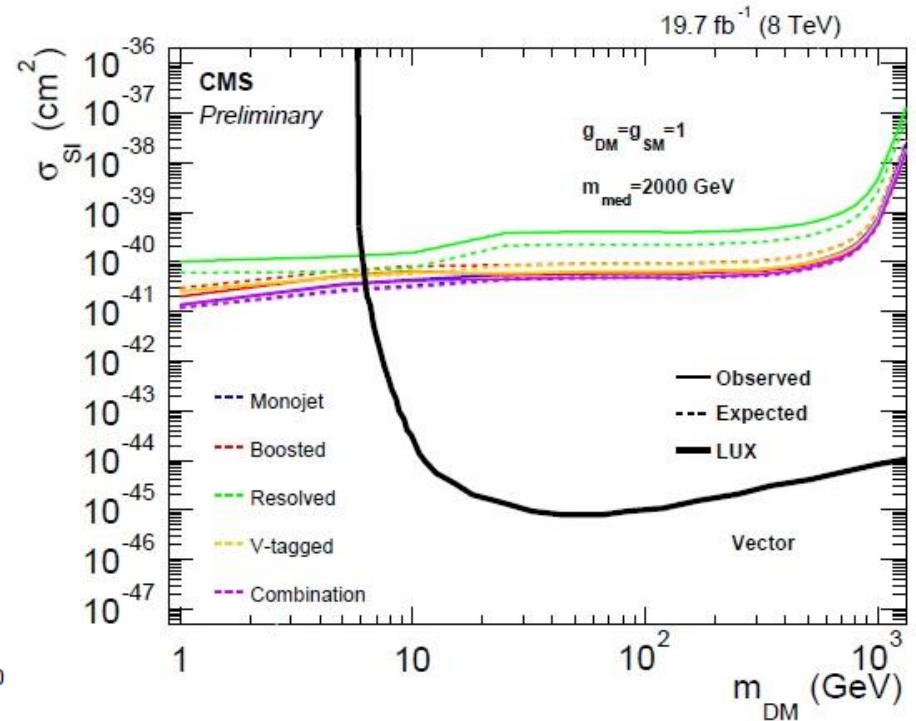
complementarity with respect to direct searches

collider searches are also sensitive to low DM mass

RUN 2 PERSPECTIVES

CMS Preliminary $\sqrt{s}$ = 13 TeV, L = 5.0 fb^{-1}

Monte Carlo

Legend:
- X_v 10 GeV
- $Z\nu\nu$+jets
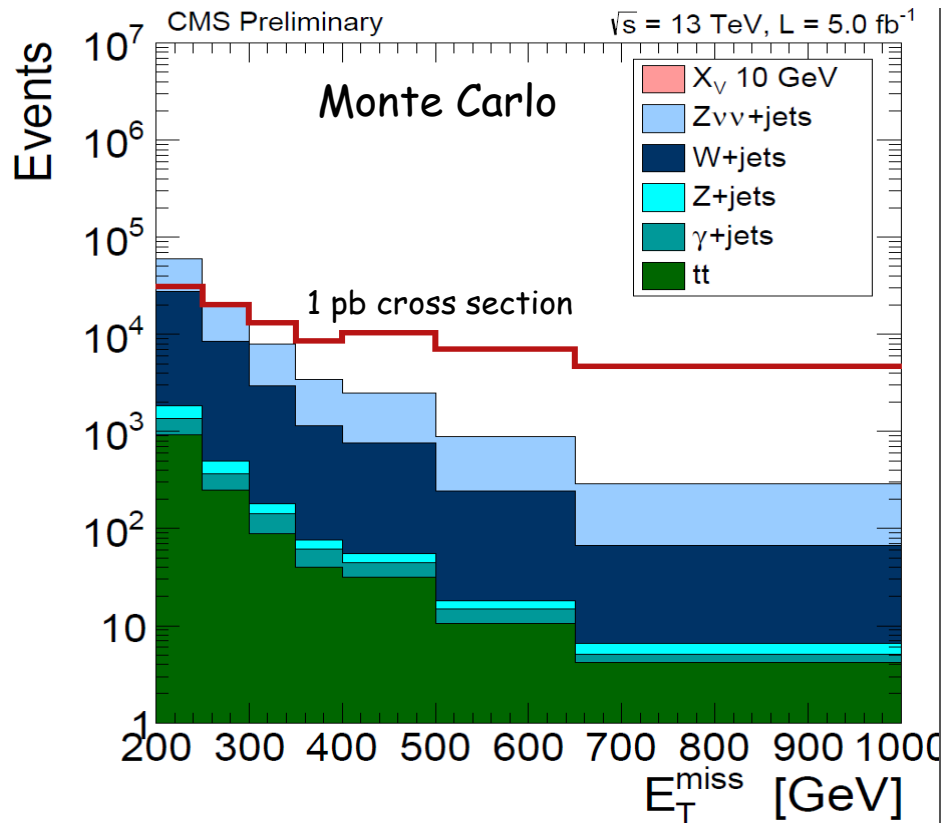- W+jets
- Z+jets
- γ+jets
- tt

1 pb cross section

E_T^{miss} [GeV]

Events

need 5 fb^{-1} at 13 TeV to be competitive with Run 1

- signal from fit to MET distribution: higher sensitivity than "cut&count"

- more control samples for background estimate

SUMMARY

✓ **monojet analysis for dark matter search at LHC presented**

- simple experimental signature: 1 jet and $\not{E}_T$

✓ **Run 2 and data taking at 13 TeV at LHC has begun**

- enhanced sensitivity thanks to higher energy collisions
- with $5fb^{-1}$ we are as sensitive as previous Run 1 ($\approx 20fb^{-1}$)

✓ **many improvements in the analysis during Run 2**

- more control samples to estimate the backgrounds

✓ **collider and direct searches complement each other**

BACKUP

COMPACT MUON SOLENOID

CMS DETECTOR
Total weight   : 14,000 tonnes
Overall diameter : 15.0 m
Overall length   : 28.7 m
Magnetic field   : 3.8 T

STEEL RETURN YOKE
12,500 tonnes

SILICON TRACKERS
Pixel (100x150 μm) ~16m² ~66M channels
Microstrips (80x180 μm) ~200m² ~9.6M channels

SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A

MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers
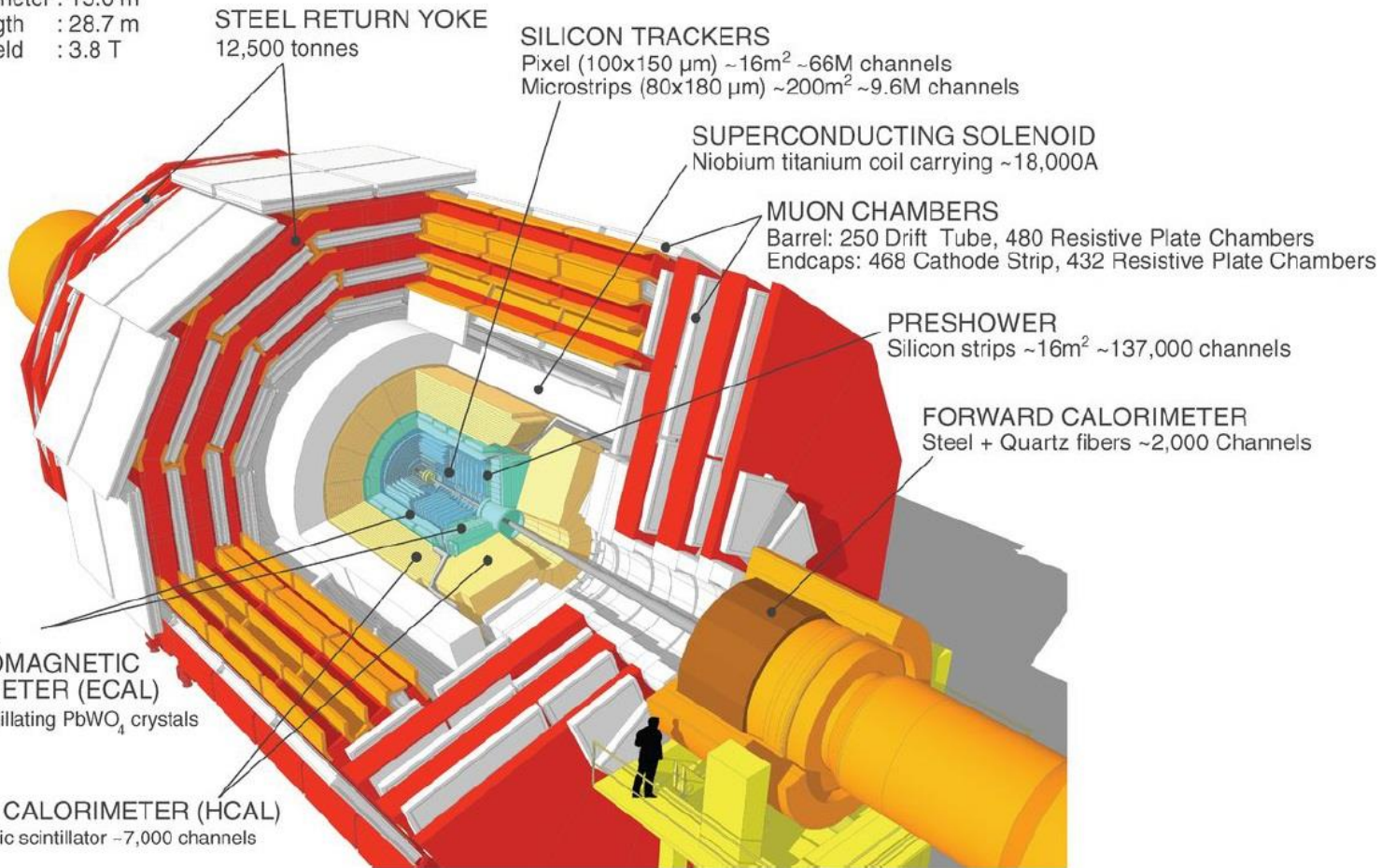
PRESHOWER
Silicon strips ~16m² ~137,000 channels

FORWARD CALORIMETER
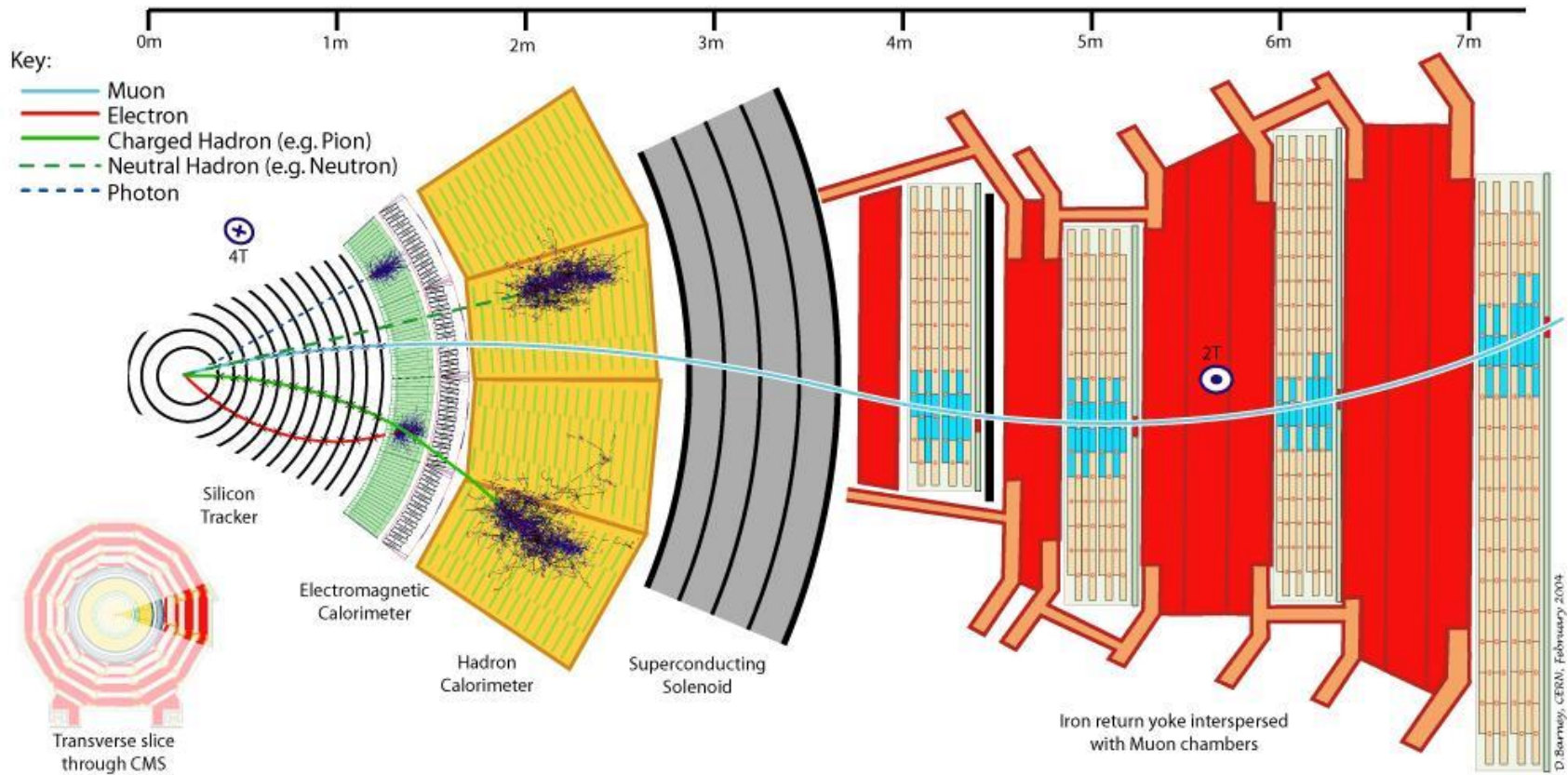Steel + Quartz fibers ~2,000 Channels

CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating PbWO₄ crystals

HADRON CALORIMETER (HCAL)
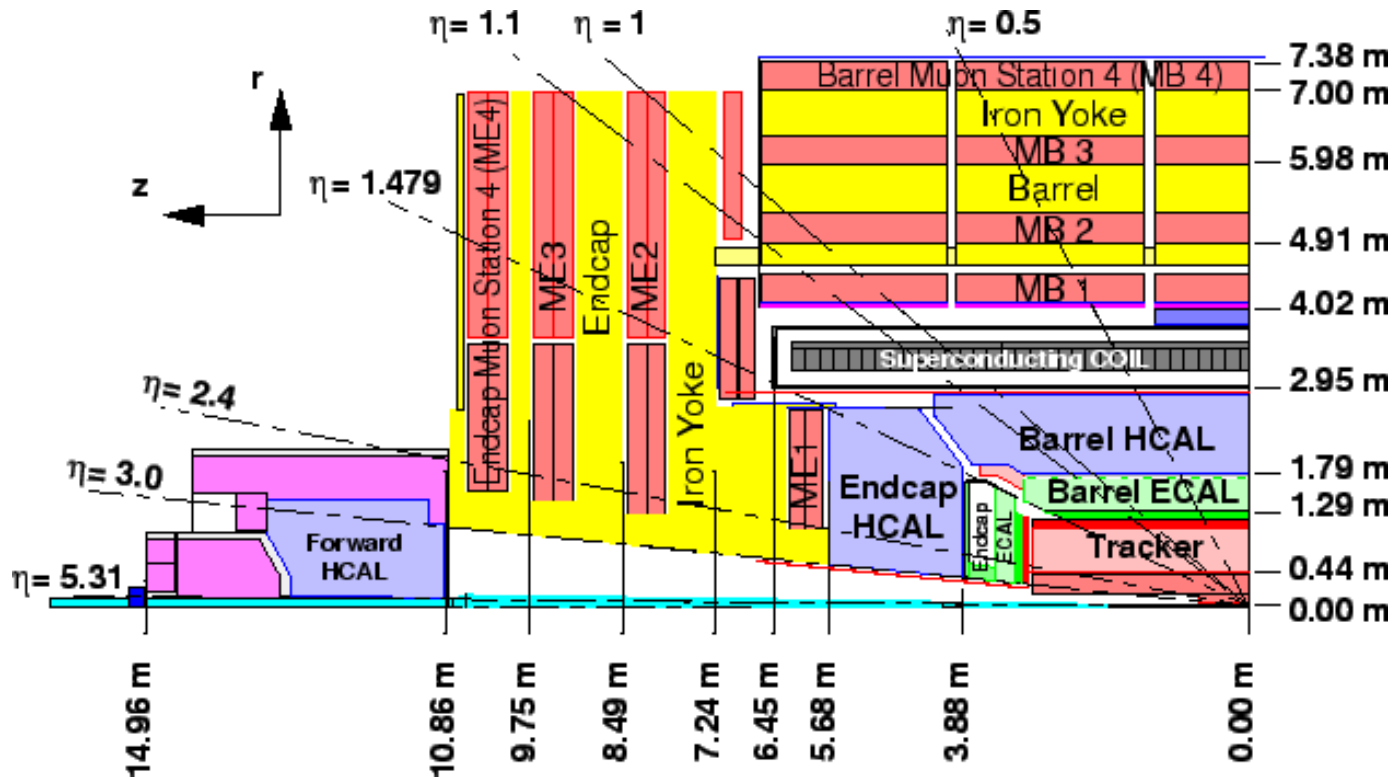Brass + Plastic scintillator ~7,000 channels

COMPACT MUON SOLENOID

Marco Cipriani

COMPACT MUON SOLENOID

$$\eta = -\ln tg\,\frac{\theta}{2}$$

η differences are Lorentz invariant for high energy particles

INTERPRETATIONS OF RUN 1 RESULTS

observed limit on cross section depends on DM mass and interaction with SM

can be translated into limit on DM-nucleon scattering cross section

different sensitivity from various experiments can lead to controversial results