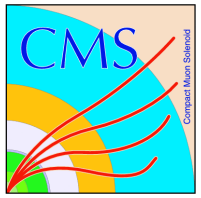


Recent results from a search for Dark Matter production in the CMS experiment

Shruti Shrestha

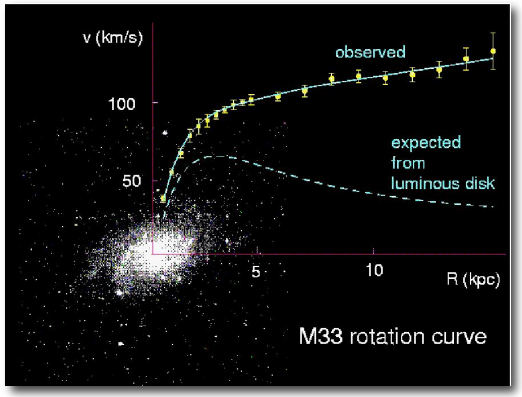
On behalf of the CMS collaboration

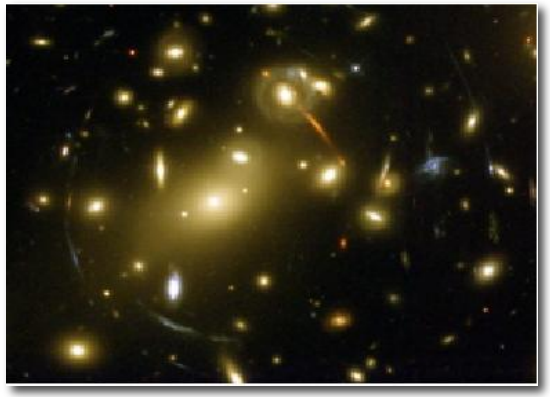
May 8, 2012

Evidence For Dark Matter

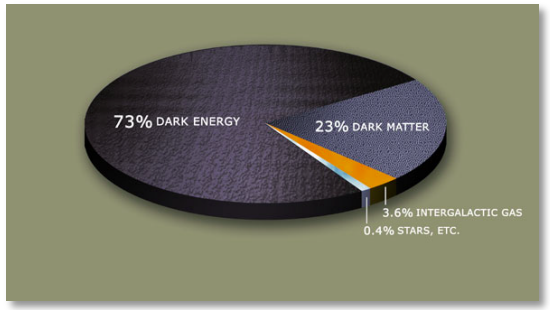
- Astrophysical evidence for the existence of Dark Matter (DM)

  galaxy rotational curves, gravitational lensing, collided galaxy clusters

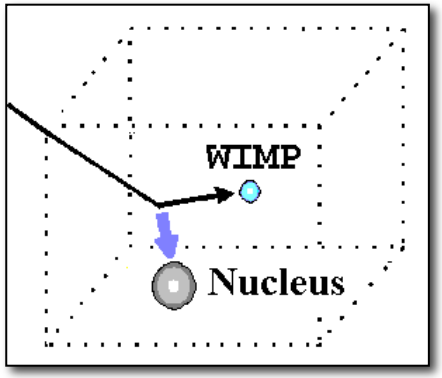




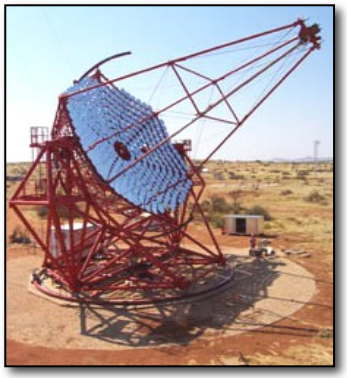
- Limited knowledge about Dark Matter (DM)
  - DM candidate gravitates and non baryonic
  - It is about five times abundant in the universe
  - It is the only evidence for physics beyond the Standard Model



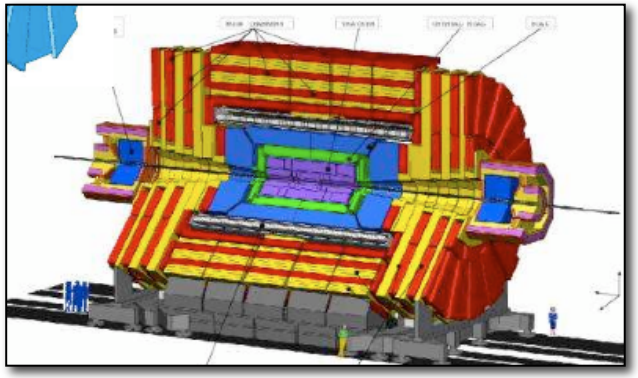
Dark Matter Searches



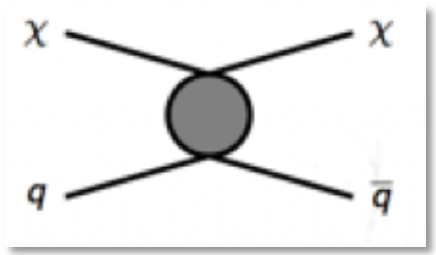
Direct Detection



Indirect Detection

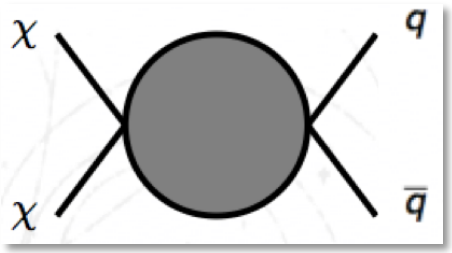


Collider Searches



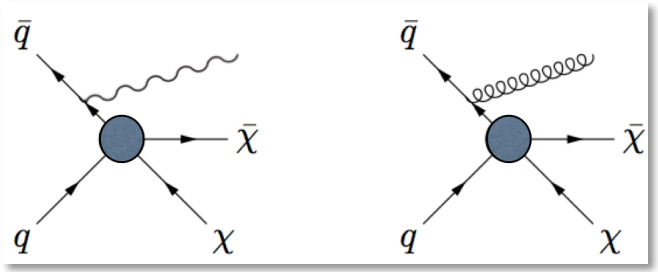
Direct Search

Scattering of Dark Matter particles off atomic nuclei within a detector



Indirect Search

Look for the products of WIMP annihilations

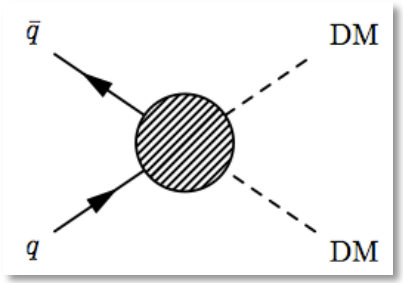


Collider Search

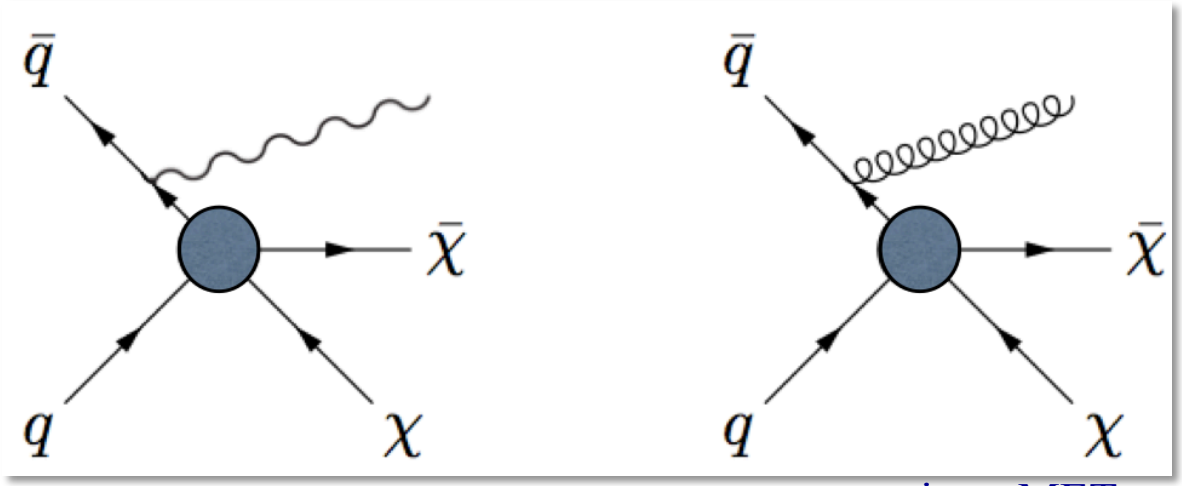
Dark matter pair production escape undetected resulting in a transverse energy imbalance

Collider searches

Signature:



- Use initial state radiation from incoming quarks to "tag" DM event
- Results is a "monophoton" or "monojet" signature with missing transverse energy (MET) balancing the photon or jet



monophoton + MET

monojet + MET

Selection Criteria

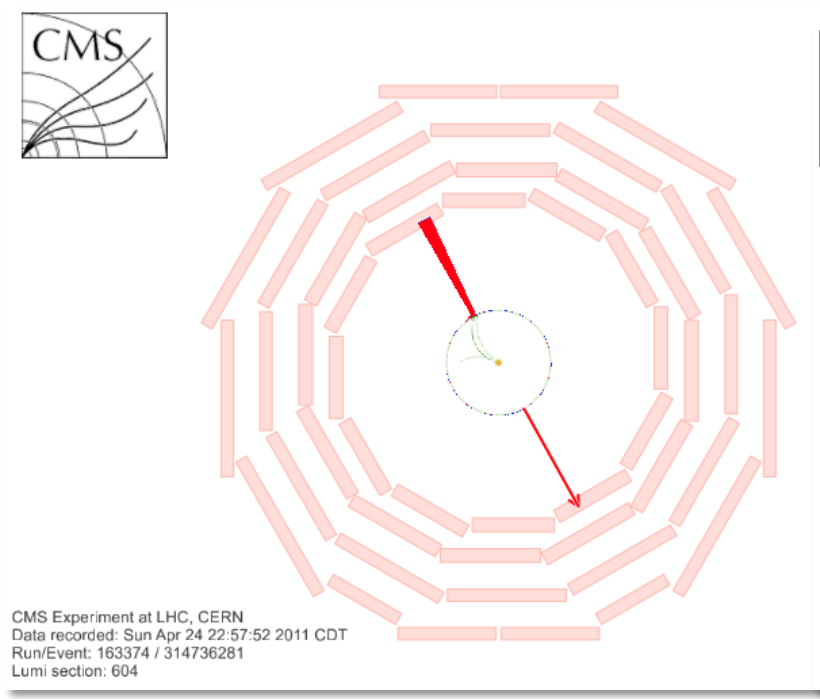
Monophoton

- Require single, isolated photon with transverse energy greater than 145 GeV
- Missing transverse energy balancing the photon
- There should be no other significant activity in the event

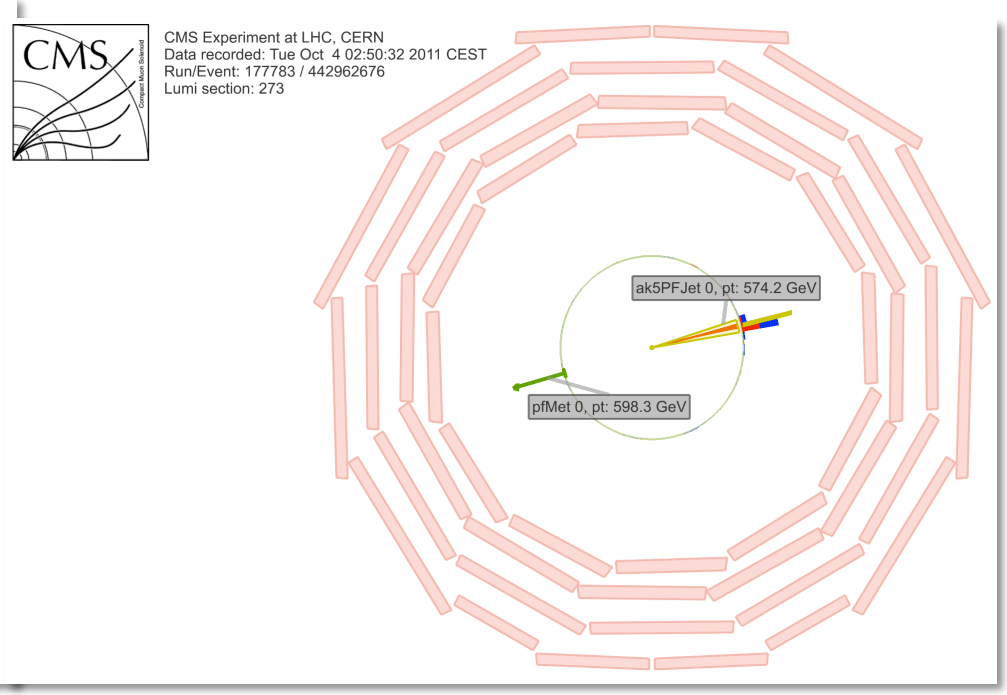
Monojet

- Require one or two jets ordered in p_T where leading jet has $p_T > 110$ GeV and second jet may have $p_T > 30$ GeV
- $\Delta\varphi(\text{jet}_1, \text{jet}_2) < 2.5$
- Require MET > 350 GeV (for Dark Matter Search)
- Reject events with an isolated lepton or tracks

Example of signal candidate



Highest p_T monophoton event,
P_T^{γ} = 384 GeV, MET = 407 GeV



A monojet event,
p_T(jet) = 547 GeV, MET = 598 GeV

Backgrounds from SM processes

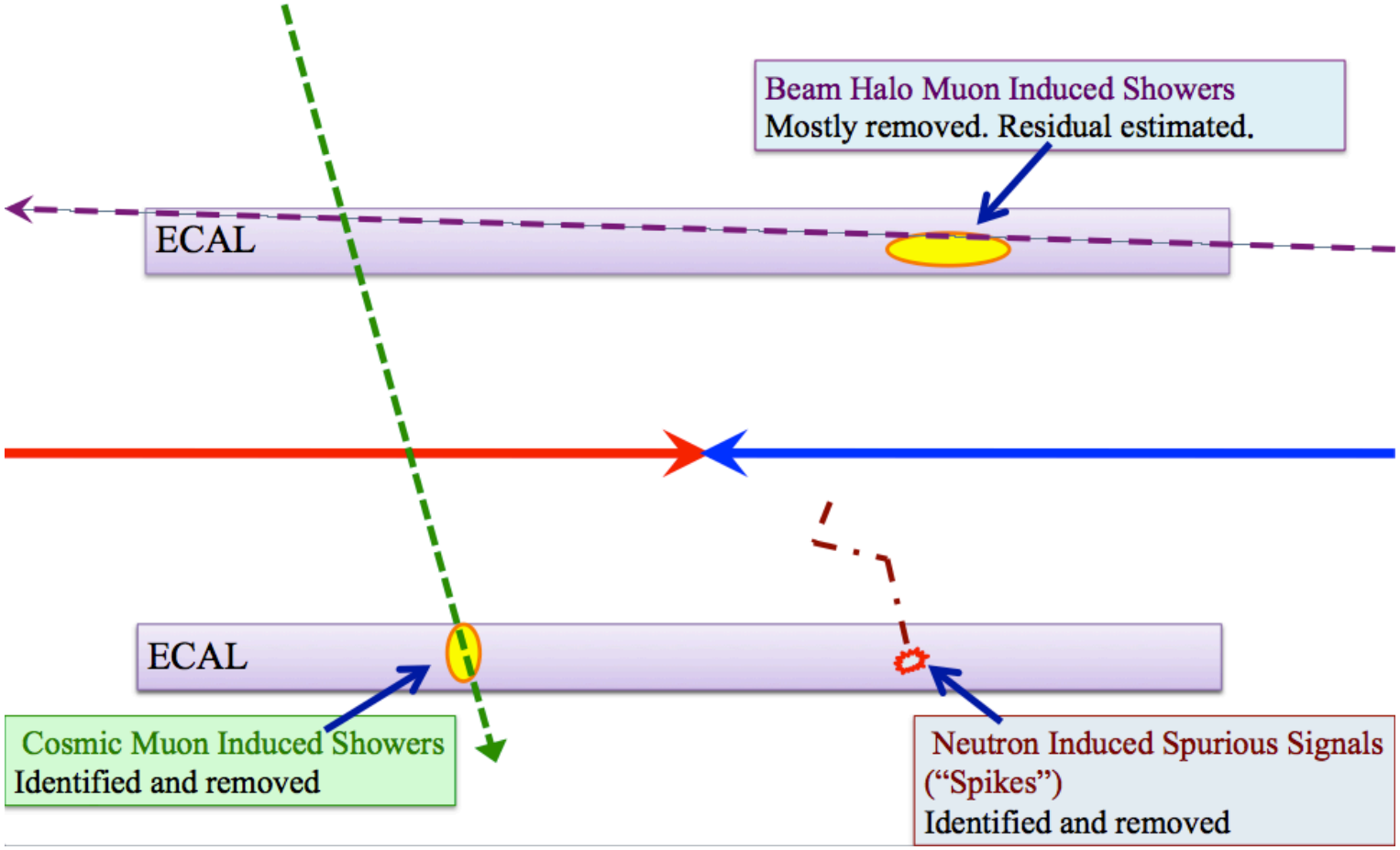
Monophoton

- $pp \rightarrow Z\,\gamma \rightarrow \nu\nu\,\gamma$ [irreducible background (from MC)]
- $pp \rightarrow \gamma$ + jet [MET due to mismeasurement of jet (from MC)]
- $pp \rightarrow \gamma\,\gamma$ [one γ mismeasured to create MET (fromMC)]
- $pp \rightarrow W\,\gamma \rightarrow l\nu\,\gamma$ [charged lepton escapes detection (from MC)]
- $pp \rightarrow W \rightarrow e\,\nu$ [electron misidentified as γ (from data)
- $pp \rightarrow$ jets $\rightarrow$ "γ" + MET [one jet fakes γ and MET due to mismeasurement of other jet (from data)]

Monojet

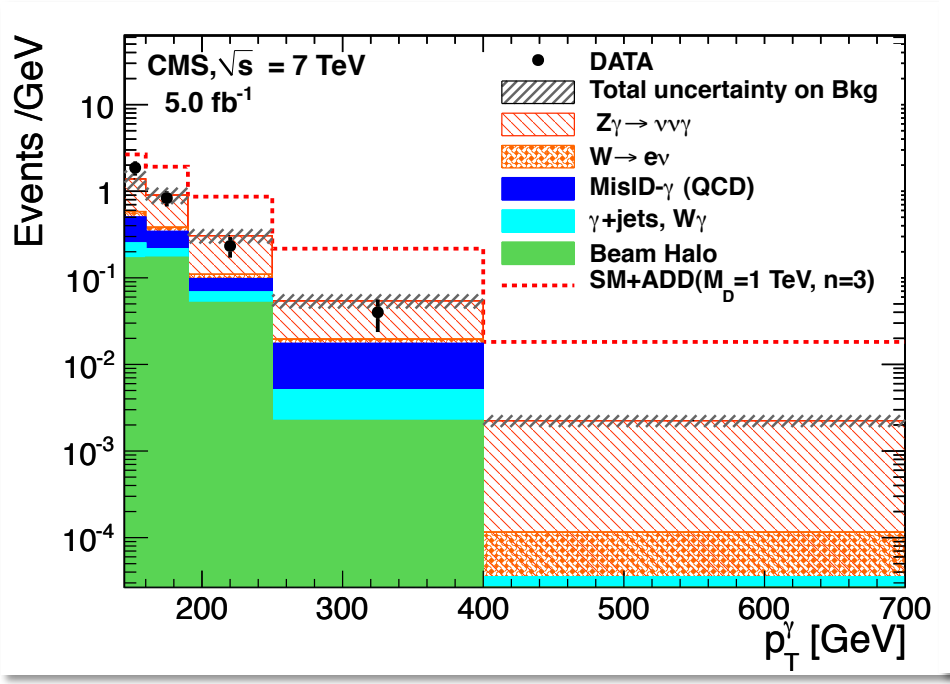
- $pp \rightarrow Z$ +jets $\rightarrow \nu\nu$ +jets [Largest background (from data)]
- $pp \rightarrow W$ +jets $\rightarrow l\nu$ +jets [lepton is "lost" (from data)]

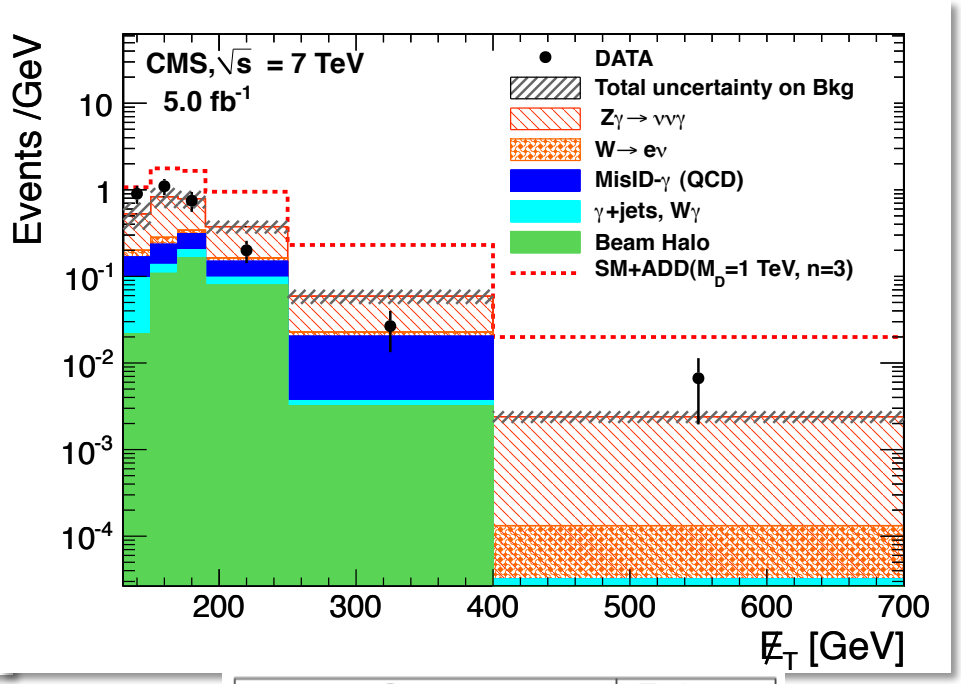
Backgrounds unrelated to pp collisions



Monophoton - Results

Search for excess of events over the predicted backgrounds

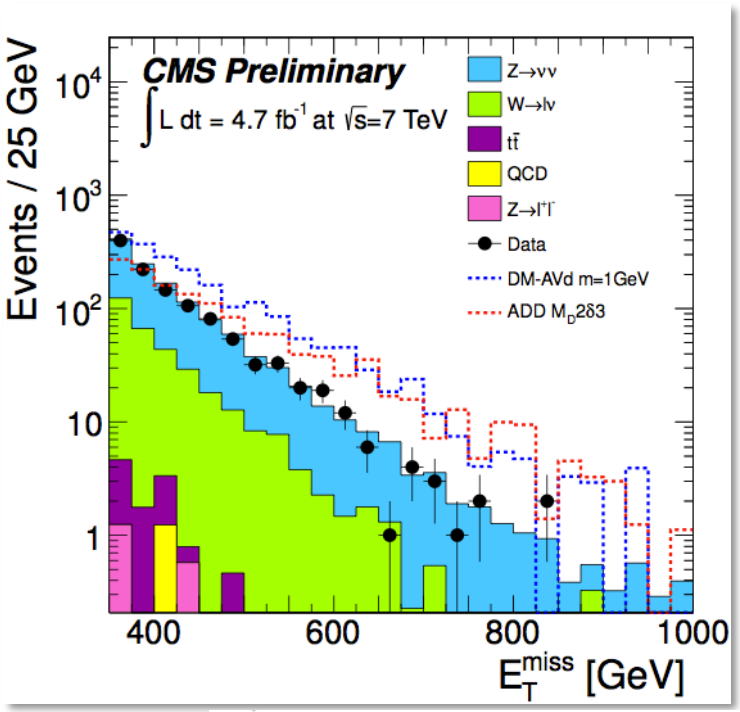


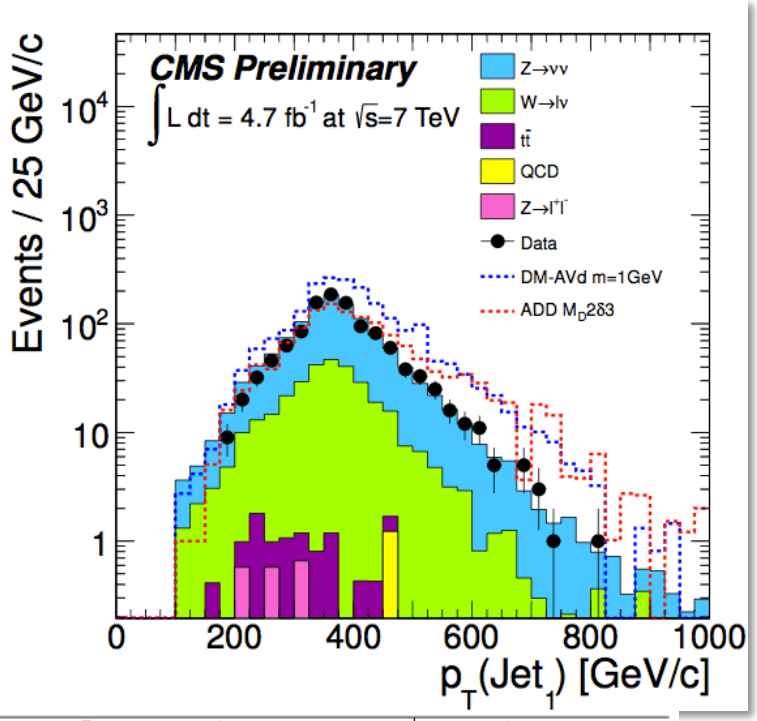


Background processes describe the data well and no excess over the predicted SM Backgrounds

Source	Estimate
Jet Mimics Photon	11.2 ± 2.8
Beam Halo	11.1 ± 5.6
Electron Mimics Photon	3.5 ± 1.5
$W\gamma$	3.0 ± 1.0
γ+jet	0.5 ± 0.2
$\gamma\gamma$	0.6 ± 0.3
$Z(\nu\bar{\nu})\gamma$	45.3 ± 6.9
Total Background	75.1 ± 9.5
Total Observed Candidates	73

Monojet - Results





Requirement	W+jets	Z($\nu\nu$) +jets	Z($\ell\ell$) +jets	$t\bar{t}$	Single t	QCD multijet	Total bgd	Data
$E_T^{miss} > 200$ GeV	55269	30312	4914	12455	1090	14959	118999	104485
$p_T(j_1) > 110$ GeV/c, $\lvert\eta(j_1)\rvert < 2.4$	52100	28267	4590	11107	968	14743	111775	100658
$N_{jets} \leq 2$	37112	21245	3229	1484	256	4952	68278	62395
$\Delta\phi(j_1, j_2) < 2$	33123	19748	2936	1256	222	58	57343	53846
Lepton Removal	9561	14663	76	200	33	2	24535	23832
$E_T^{miss} > 250$ GeV	2632	5106	21	65	10	2	7836	7584
$E_T^{miss} > 300$ GeV	816	1908	6	21	3	1	2755	2774
$E_T^{miss} > 350$ GeV	312	900	2	8	1	1	1224	1142
$E_T^{miss} > 400$ GeV	135	433	1	3	0	1	573	522

No excess of events over expected SM backgrounds

Phenomenology

- Assume DM is a Dirac fermion and characterize pair production by contact interaction Bai, Fox, Harnik JHEP 1012:048 (2010)

- The effective operator can be a vector or an axial vector

$$\mathcal{O}_{\mathrm{V}} = \frac{(\bar{\chi}\gamma_\mu\chi)\,(\bar{q}\gamma^\mu q)}{\Lambda^2}$$

spin-independent

$$\mathcal{O}_{\mathrm{A}} = \frac{(\bar{\chi}\gamma_\mu\gamma^5\chi)\,(\bar{q}\gamma^\mu\gamma_5 q)}{\Lambda^2}$$

spin-dependent

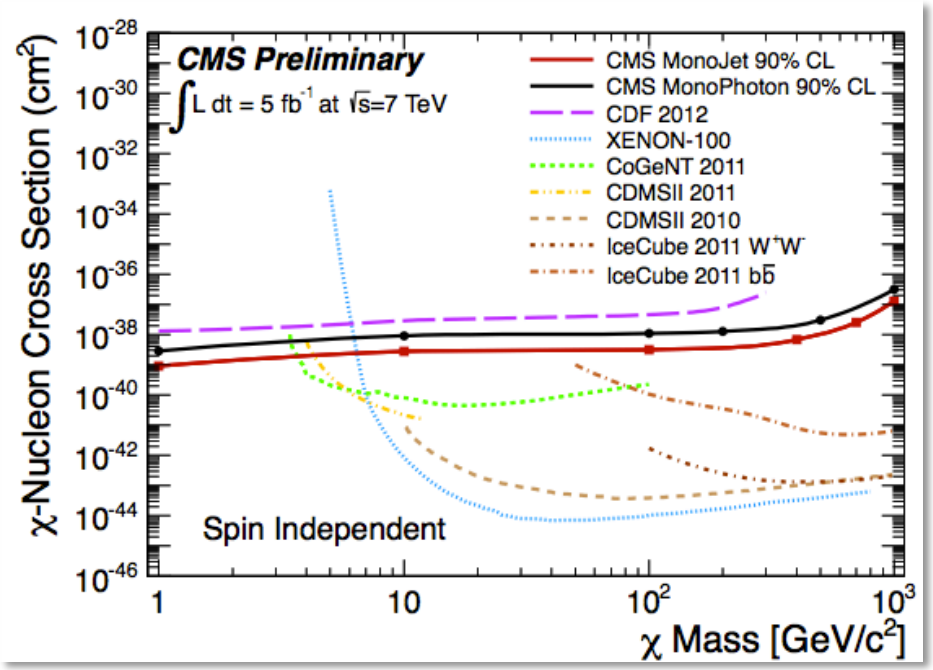
- Cross section depends on contact interaction scale Λ and DM mass (M_χ)

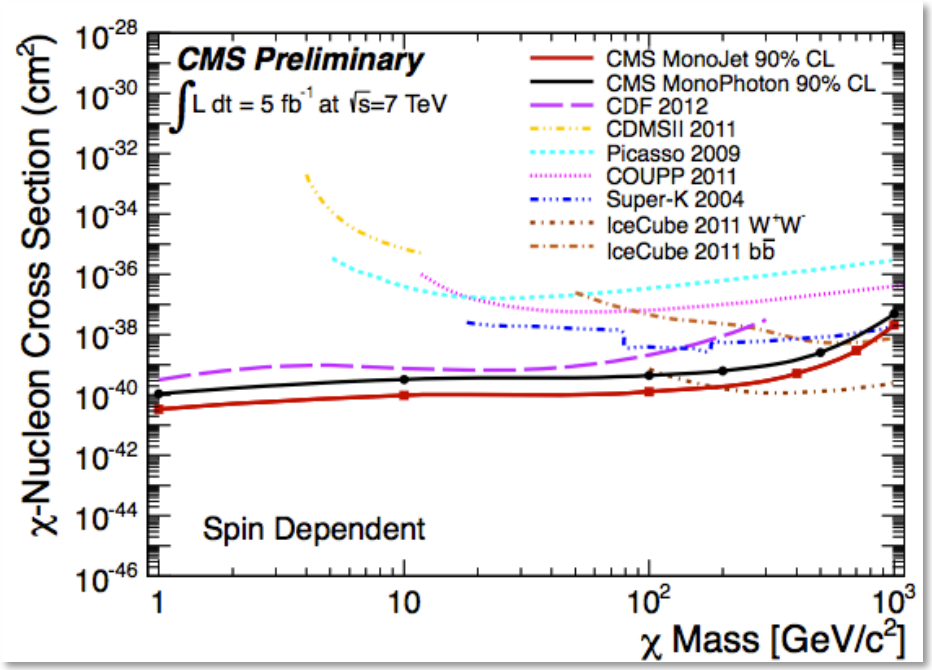
$$\sigma_{\mathrm{SI}} = \frac{9}{\pi}\left(\frac{\mu}{\Lambda^2}\right)^2$$

$$\sigma_{\mathrm{SD}} = \frac{0.33}{\pi}\left(\frac{\mu}{\Lambda^2}\right)^2$$

$$\Lambda = M/\sqrt{g_\chi g_q}$$

Comparison with other experiments



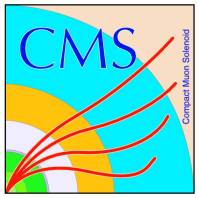


The best constraints for low mass dark matter, below 3.5 GeV, a region as yet unexplored by Direct detection experiments

Limits represent the most stringent constraints over almost entire 1 -100 GeV mass range

Conclusion

- Results are presented from a search for new physics in monophoton channel using 5.0 fb^{-1} data
- Prediction for SM background consistent with observed data with no excess found
- Limit is set on Dark Matter nucleon scattering cross-section as the function of dark matter mass
- For spin – independent models, the best limits for low DM mass which has not yet explored by the direct detection experiment
- For spin – dependent models, limits are improved over range 1-100 GeV mass range



Back up slides

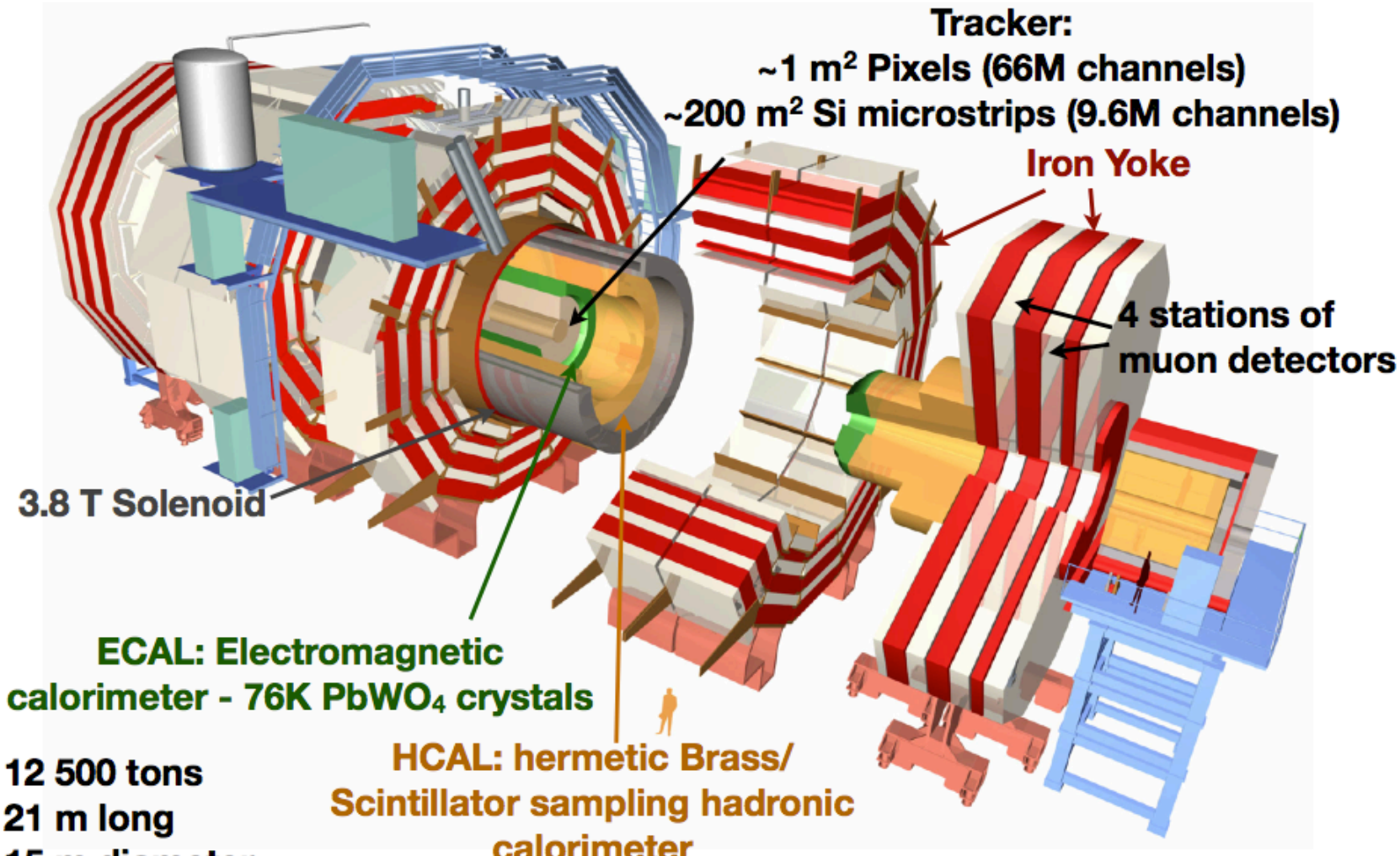
DM Signal and limits

- Signal generation
  - Madgraph4 + Pythia6 generation with mediator mass of 10 TeV (monophoton) and 40 TeV(monojet)
- Extraction of DM nucleon cross section
  - Upper limits on monophoton/monojet cross sections converted to lower limits on Λ then translated to DM nucleon cross section

M_χ [GeV]	Vector		Axial-Vector	
	σ [fb]	Λ [GeV]	σ [fb]	Λ [GeV]
1	14.3 (14.7)	572 (568)	14.9 (15.4)	565 (561)
10	14.3 (14.7)	571 (567)	14.1 (14.5)	573 (569)
100	15.4 (15.3)	558 (558)	13.9 (14.3)	554 (550)
200	14.3 (14.7)	549 (545)	14.0 (14.5)	508 (504)
500	13.6 (14.0)	442 (439)	13.7 (14.1)	358 (356)
1000	14.1 (14.5)	246 (244)	13.9 (14.3)	172 (171)

90% CL limits on DM model parameters for Monophoton (expected limits in parenthesis)

CMS detector



Particle ID at CMS