Photon ID in search for GMSB with displaced photons

Egamma Identification Meeting

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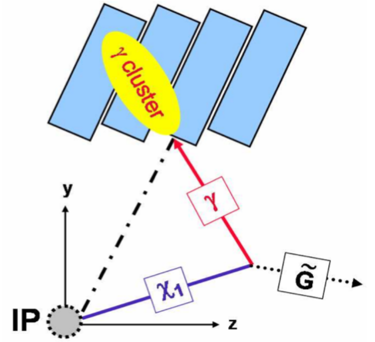
Introduction

- **Long-lived particles decaying into photons offer hints of physics 'beyond the SM'**

- **The signal: GMSB scenario ($\tilde{\chi}_1^0 \to \tilde{G}\gamma$) with Gravitino ($\tilde{G}$) as LSP and Neutralino ($\tilde{\chi}_1^0$) as NLSP**

- Experimental technique:
  - Identify displaced γ (expect $\not\!\!E_{\mathrm{T}}$ from $\tilde{G}$)
  - See excess over SM $\to$ Calculate $\tilde{\chi}_1^0$ lifetime

    [AN-10-212]
  - See no excess $\to$ Calculate upper-limit

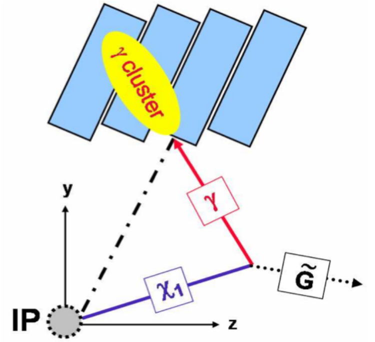


Introduction

- Long-lived particles decaying into photons offer hints of physics 'beyond the SM'
- The signal: GMSB scenario ($\tilde{\chi}_1^0 \to \tilde{G}\gamma$) with Gravitino ($\tilde{G}$) as LSP and Neutralino ($\tilde{\chi}_1^0$) as NLSP
- Experimental technique:
  - 2 methods in LL group:
  - Use γ conversions to calc. Impact Param.

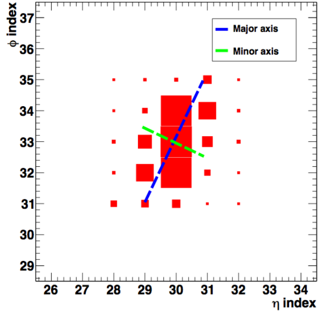
    [EXO-11-067]
  - Use γ cluster shape and ECAL timing

    [EXO-11-035]



Analysis overview

- **Select one high P_T isolated photon**
- **Use cluster shape** (S_{Minor}) to select objects compatible with (off-pointing) photons



$$S_{major} = \frac{(S_{\phi\phi} + S_{\eta\eta}) + \sqrt{(S_{\phi\phi} - S_{\eta\eta})^2 + 4S_{\phi\eta}^2}}{2}$$

$$S_{minor} = \frac{(S_{\phi\phi} + S_{\eta\eta}) - \sqrt{(S_{\phi\phi} - S_{\eta\eta})^2 + 4S_{\phi\eta}^2}}{2}$$

- **Backgrounds** (in order of magnitude)
  - **Fake photon, fake $\not{E}_T$:** QCD, and γ +jets
  - **Fake photon, real $\not{E}_T$:** $t\bar{t}$ and $W \rightarrow e\nu$ (EWK)
  - **Non collision** (spikes, halo, cosmics, instrumental noise)

Data

- **Data - 4.54 fb^{-1}**
  - 189.8 pb^{-1}: `/Photon/Run2011A_May10ReReco-v1/AOD`
  - 855.6 pb^{-1}: `/Photon/Run2011A_PromptReco-v4/AOD`
  - 326.3 pb^{-1}: `/Photon/Run2011A_05Aug2011-v1/AOD`
  - 637.2 pb^{-1}: `/Photon/Run2011A_PromptReco-v6/AOD`
  - 2533.6 pb^{-1}: `/Photon/Run201_PromptReco-v1/AOD`
  - JSON: `Cert_160404-180252_7TeVPromptReco_Collisions11`
- **Triggers [summary]**
  - 160410 $\leq$ `Photon75-CaloIdVL-IsoL-v*` $<$ 165121
  - 165121 $\leq$ `Photon90-CaloIdVL-IsoL-v*` $<$ 178421
  - 178421 $\leq$ `Photon90EB_CaloIdVL_IsoL_TriJet25` $<$ 180252

Monte Carlo

- **Signal samples - (official CMS production)**
  - `GMSB_Lambda-*_CTau-*_7TeV_pythia6*` (PU4)
- **MC bkg samples (PU 3)**
  - `QCD_Pt_*_TuneZ2_7TeV_pythia6*`
  - `G_Pt_*_TuneZ2_7TeV_pythia6*`
  - `TT_TuneZ2_7TeV_pythia6_tauola*`
  - `WToENu_TuneZ2_7TeV_pythia6*`
- **Re-weight MC by number of pile-up (1d)**
- `CMSSW_4_2_3` and Summer 11

Analysis strategy

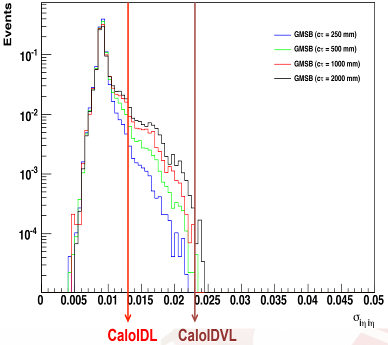
- Standard photon ID uses cluster shape variables ($\sigma_{ii\eta}$) correlated to s_{Minor}/s_{Major}
- More importantly, the standard ID has a default spike cleaning applied with an implicit timing cut (for us not good)
- We use uncleaned superclusters (no timing cut) in AOD as our RECO photon object
- Then we add back topological requirements: $\boldsymbol{E6/E2 > 0.04}$ and $\boldsymbol{E4/E1 > (0.04 \times log(E1) - 0.024}$
- and remake photons using the ID on the next slide

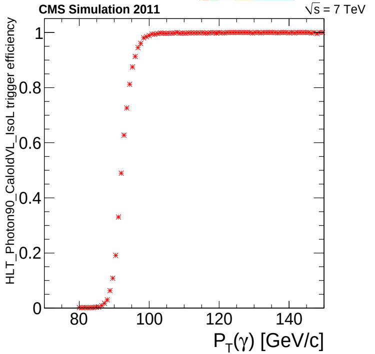
Photon Reconstruction

- Reject 'scraping' events
- Reject 'anomalous HCAL noise'
- Not matched to electron (will discuss on slide 10)

$\|\eta\|$	< 1.4
ECAL time	> -2.0 ns
$P_T(\gamma)$	> 100 GeV
S_{minor}	$0.15 < S_{minor} < 0.3$
HCAL Iso	$\left\{ \begin{array}{l} \sum \mathrm{HCAL}/E(\gamma) < 0.05 \\ \sum \mathrm{HCAL} < 2.4 \text{ GeV} \end{array} \right.$
ECAL Iso	$\left\{ \begin{array}{l} \sum \mathrm{ECAL}/E(\gamma) < 0.05 \\ \sum \mathrm{ECAL} < 2.4 \text{ GeV} \end{array} \right.$
TRK Iso	$\{ \sum P_T/P_T(\gamma) < 0.1$
Good Vertex	vndof ≥ 4, $d_0 < 2$, $\|z\| < 24$
Halo Veto	CSC Tight

Photon Reconstruction



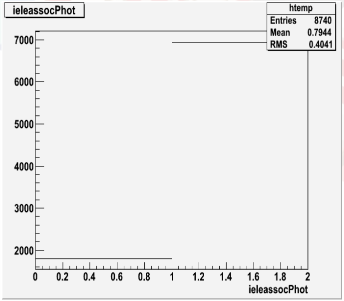


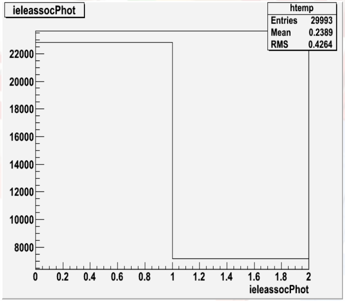
$\sigma_{ii\eta}$ dist. for GMSB (left).
Work performed to keep requirement "very loose" at HLT to not introduce bias

Also trigger eff. (right) is 100% with offline p_T cut on photon

Electron veto

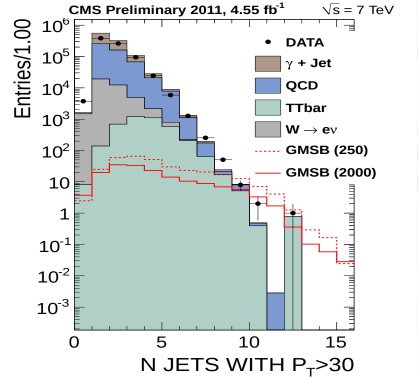
- **Since we remake our photons from unclean clusters we loose Pixel Veto information $\rightarrow$ larger EWK cont.**
- **We veto (GSF) electrons matching to our signal photons**
  - Veto photons within $\rightarrow \Delta R(\gamma, e) > 0.25$
  - Reduces $t\bar{t}$, QCD, $W \rightarrow e\nu$ (left) bkg by 95%, 50%, 99%
  - Reduces signal (right) by $\sim$ 7%

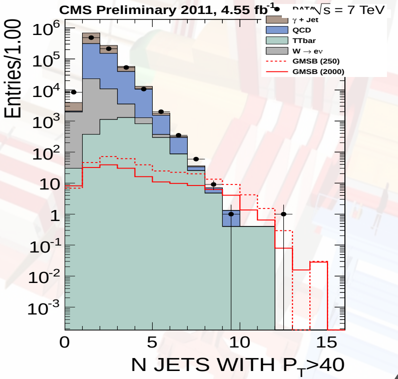




Jet veto

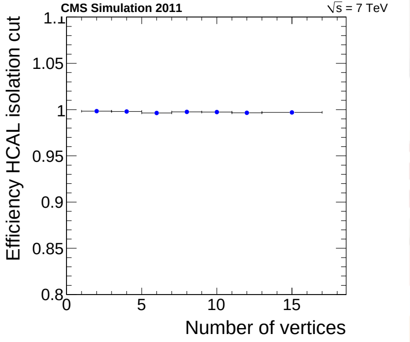
- **Require 3 or more jets in event** ($p_T > 35$ GeV/c) - Effective for non-collision events
  - Non-overlapping to photon candidate → $\Delta R(\gamma, jet) > 0.5$
  - Reduces γ+jet, QCD, $W \to e\nu$ bkg by 90%, 80%, 90%
  - Reduces signal, $t\bar{t}$ by $\sim$ 20%

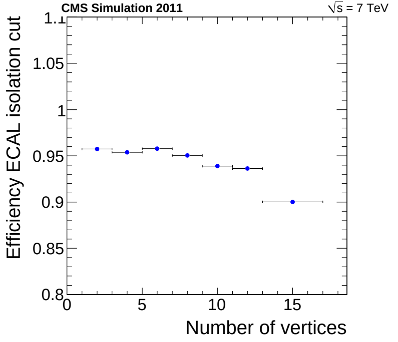




Pile-up studies

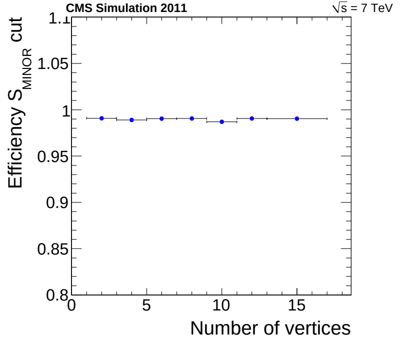
The HCAL Iso (left), ECAL Iso (right) cut efficiency for the GMSB signal ($\Lambda = 100$, $c\tau = 250$mm) plotted against the number of primary vertices

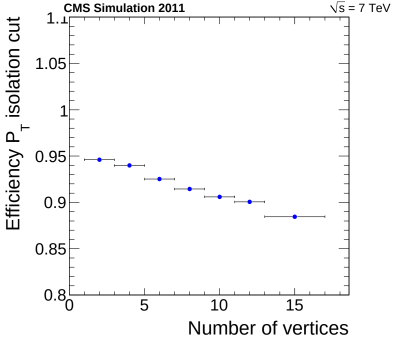




Pile-up studies

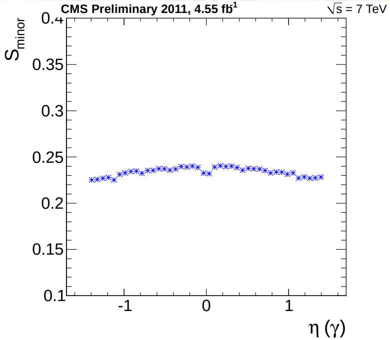
S_{Minor} (left), and TRK Iso (right) cut efficiency for the GMSB signal ($\Lambda = 100$, $c\tau = 250$mm) plotted against the number of primary vertices.

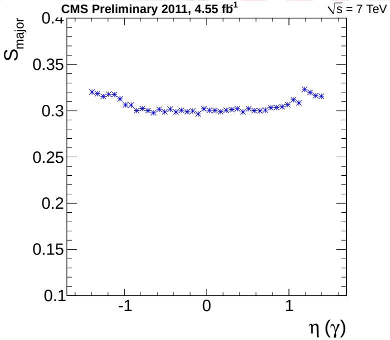




Pile-up studies

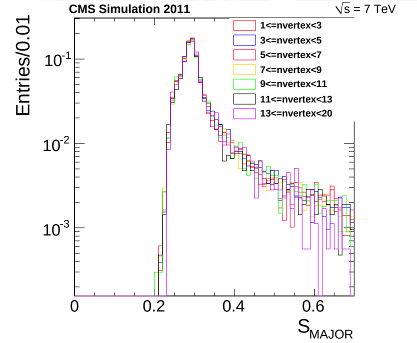
The S_{Minor} (left) and S_{Major} (right) distributions overlaid for different values of number of primary vertices for the GMSB signal ($\Lambda = 100$, $c\tau = 250$mm)

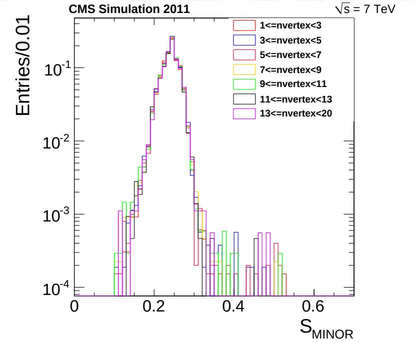




Geometric dependance of cluster shape

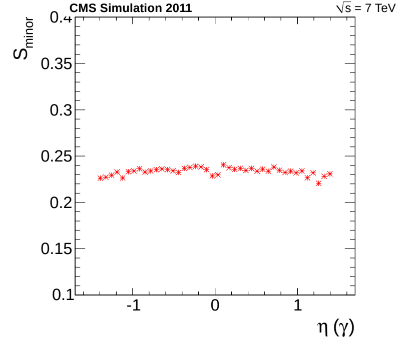
Is there a geometry bias in S_{major}, S_{minor}?
Brought up at pre-approval. GMSB (bottom).

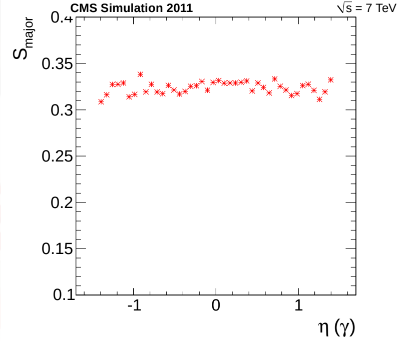




Geometric dependance of cluster shape

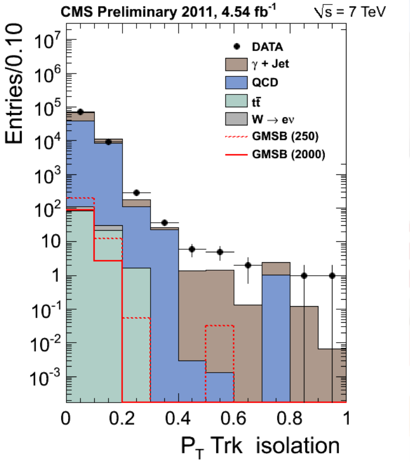
Does not seem to be a big issue here.
We see a 6% deviation wrt mean at most. Data (bottom).

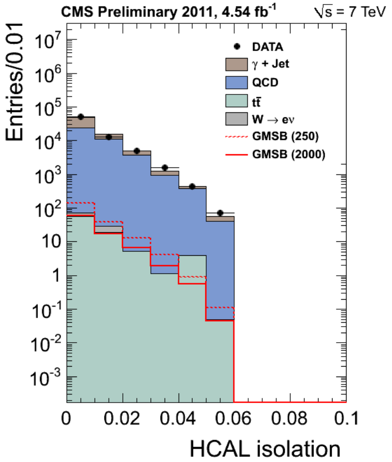




Data-MC comparison

Good agreement in signal regions for selection variables (photon ID only)





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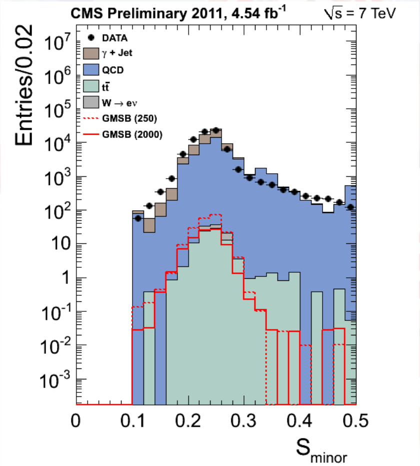

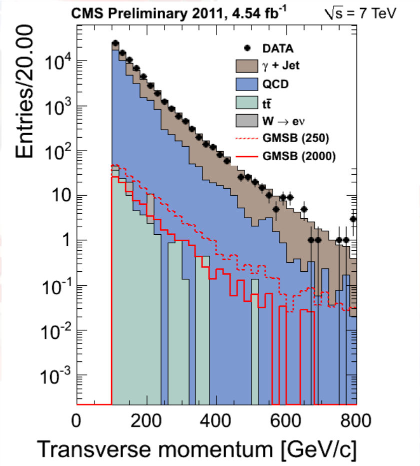

Selection efficiencies

%	γ+jet	QCD	$t\bar{t}$	$W \rightarrow e\nu$	GMSB
Pre-sel	50	0.35	4.3	0.88	61
$\lvert\eta\rvert$	73	86	86	76	93
$P_T(\gamma)$	19	14	37	24	63
Halo Veto	100	100	100	100	100
Electrons	98	55	5.2	1.1	92
S_{Minor}	99	67	96	98	99
Topological	92	97	98	96	93
ECAL time	100	100	100	100	100
HCAL Iso	99	99	99	99	99
ECAL Iso	98	62	85	97	92
Track Iso	89	76	72	60	95
Not γ+jet	96	99	99	99	99
$N_{jets} \geq 3$	11	17	71	8	66
ϵ_{TOT}	3.3×10^{-1}	8.9×10^{-3}	2.5×10^{-2}	6.5×10^{-5}	17

Related systematics

Source	Uncertainty on σ_{UL}^{Exp} (%)
Photon energy scale (0.6%)	4%
Jet resolution (10%)	4%
Luminosity (4.5%)	4.5%
$\not\!\!E_{\mathrm{T}}$ scale (5%)	3.5%
$\not\!\!E_{\mathrm{T}}$ resolution (10%)	7%
ECAL time uncertainty (0.5 ns)	15.5%
Total approx.	tbu %

Table: Summary of the systematic uncertainties on the σ_{UL} calculation

Summary

- Have presented a selection ID for displaced photons based on cluster shape (s_{Minor})
- Since having access to the timing information ($>$ 3 ns) is necessary we must remake our photons from unclean superclusters
- We add back in topological cuts (recommended PF), and electron veto (GSF matching) - should give us the standard RECO photon again with full timing info.
- 2012 trigger studies are underway (Shih-Chuan Kao and Juliette Alimena) - Attempting to implement a general displaced single (and double) HLT
- Currently targeting Moriond

Documentation

Analysis performed on dataset of 4.5 fb^{-1}
(clickable links to frozen docs. below)

CMS AN AN-11-081

CMS Draft Analysis Note

The content of this note is intended for CMS internal use and distribution only

2011/06/16
Head Id: 40099
Archive Id: 40222M
Archive Date: 2011/02/18
Archive Tag: trunk

Search for Long-Lived Particles using Displaced Photons in Proton-Proton Collisions at $\sqrt{(s)} = 7$ TeV

Michael Sigamani, Shahram Rahatlou, Daniele Del Re, and Livia Soffi
INFN Sezione di Università di Roma "La Sapienza", Roma, Italy

Abstract

We present the results of a search for long-lived particles decaying into photons in $\sqrt{(s)} = 7$ TeV proton-proton collisions. We use the Missing Transverse Energy and timing information from the ECAL to search for an excess of events over our SM background prediction. After our signal selection, using a data set of 34.4±X.X pb^{-1}, we observe 5714±X.X events in data with a background expectation of 6734±X.X events. From this we set limits on the production cross-section of $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$ at 95% C.L. and place a limit of XXX GeV/c^2 on the mass the $\tilde{\chi}_1^0$.

CMS PAS AN-11-081

DRAFT
CMS Physics Analysis Summary

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2011/06/29
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The CMS Collaboration

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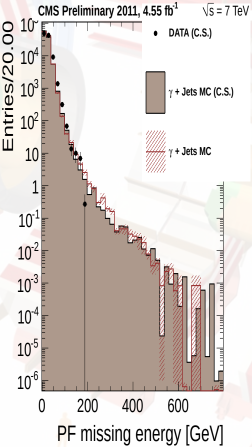
Thank You

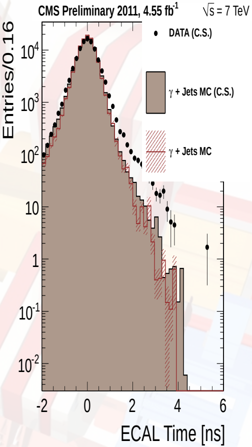
Background estimation

- **Main bkgs are QCD and γ+jet**
  - Define data-driven background control samples (CS) for these
  - Idea is to have an accurate description of the shape for the $\not{E}_{\mathrm{T}}$ and the ECAL time
- **Cross check results with MC**
  - Closure test should show a good agreement of MC and MC with CS selection shapes
  - CS selections should not overlap (orthogonal)
  - Different selections were tested
- **$W \to e\nu$, and $t\bar{t}$ present similar challenges but use MC since they are less dominant (5% each)**
- In 2010 analysis these were much less due to PixelSeed veto. For 2011 we don't have access to this anymore (uncleaned rechits for AOD).

γ+Jet estimation

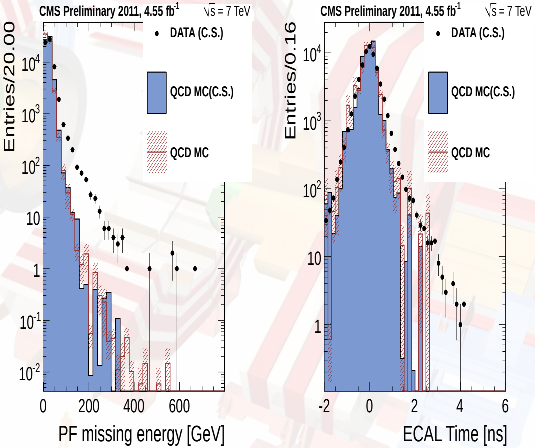
- One photon passes the final selection (and ≤ 2 jets)
- Most energetic jet (jet1) back to back wrt photon
- $0.7 < p_T^{jet1}/p_T^{\gamma} < 1.3$
- $p_T^{jet2}/p_T^{\gamma} < 0.1$
- Re-weight data and MC using ΣE_T distribution (slide 34)





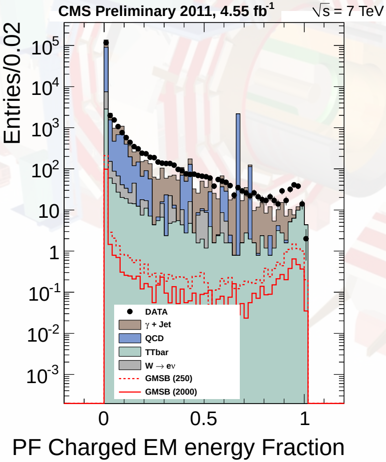
QCD estimation

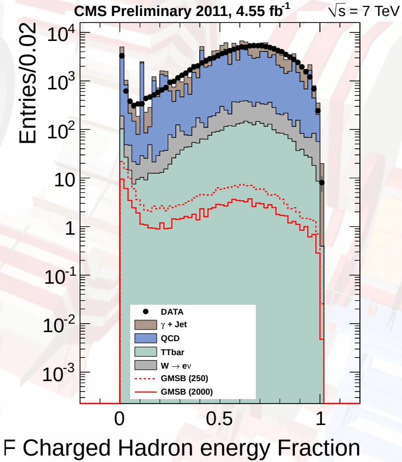
- Select events that fail final selection, but pass loose(er) selection (≥ 3 jets)
- EWK contribution less that 1% in control sample
- Jet cleaning (slide 19-20) **[and MET cleaning]** for PF Jets studied as source for disagreement on $\not{E}_T$



Jet cleaning

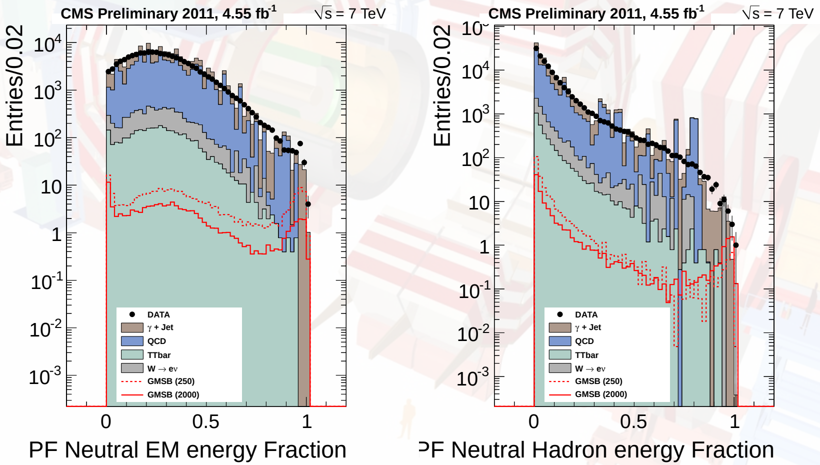
PF Jet EM (left) and Hadronic (right) energy fractions from charged particles

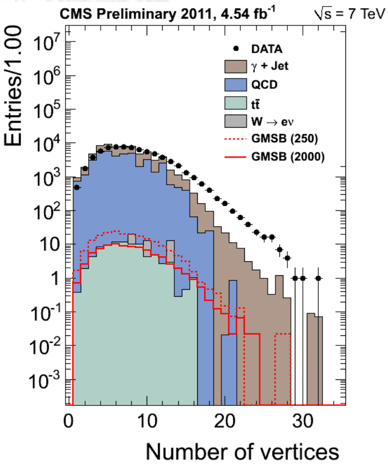




Jet cleaning

PF Jet EM (left) and Hadronic (right) energy fractions from neutral particles




CMS Preliminary 2011, 4.54 fb^{-1}
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Entries/1.00
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γ + Jet
QCD
$t\bar{t}$
W → eν
GMSB (250)
GMSB (2000)
Number of vertices