Search for new physics with same-sign isolated dilepton events with jets and missing transverse energy at CMS

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On behalf of the CMS Collaboration

Outline

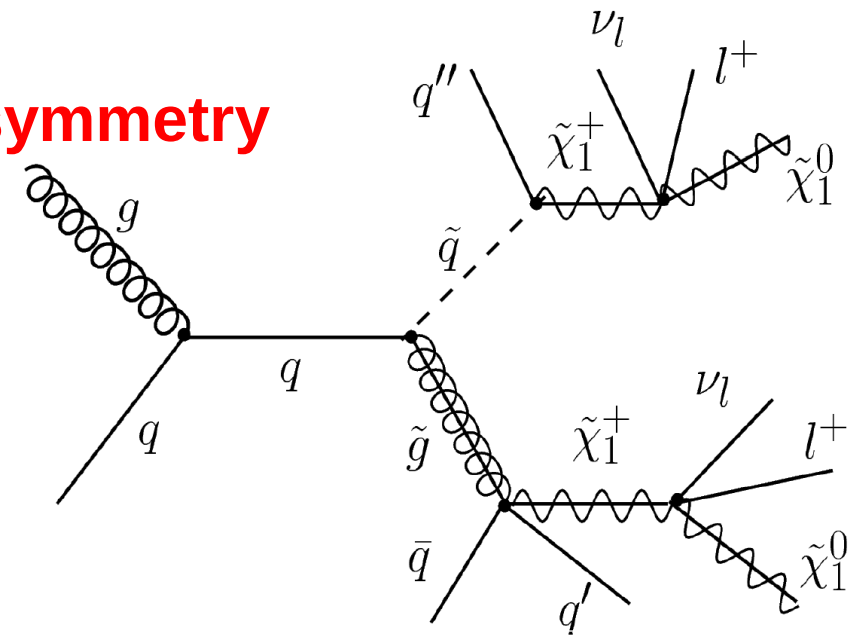
- Introduction
- The CMS detector
- Reconstruction of leptons, missing energy and jets
- Baseline event selection
- New physics search regions
- Data-driven background estimation
  - Events with fake leptons
  - Lepton charge misreconstruction
- Systematic uncertainties
- Results and interpretation
- Summary and conclusions

Introduction

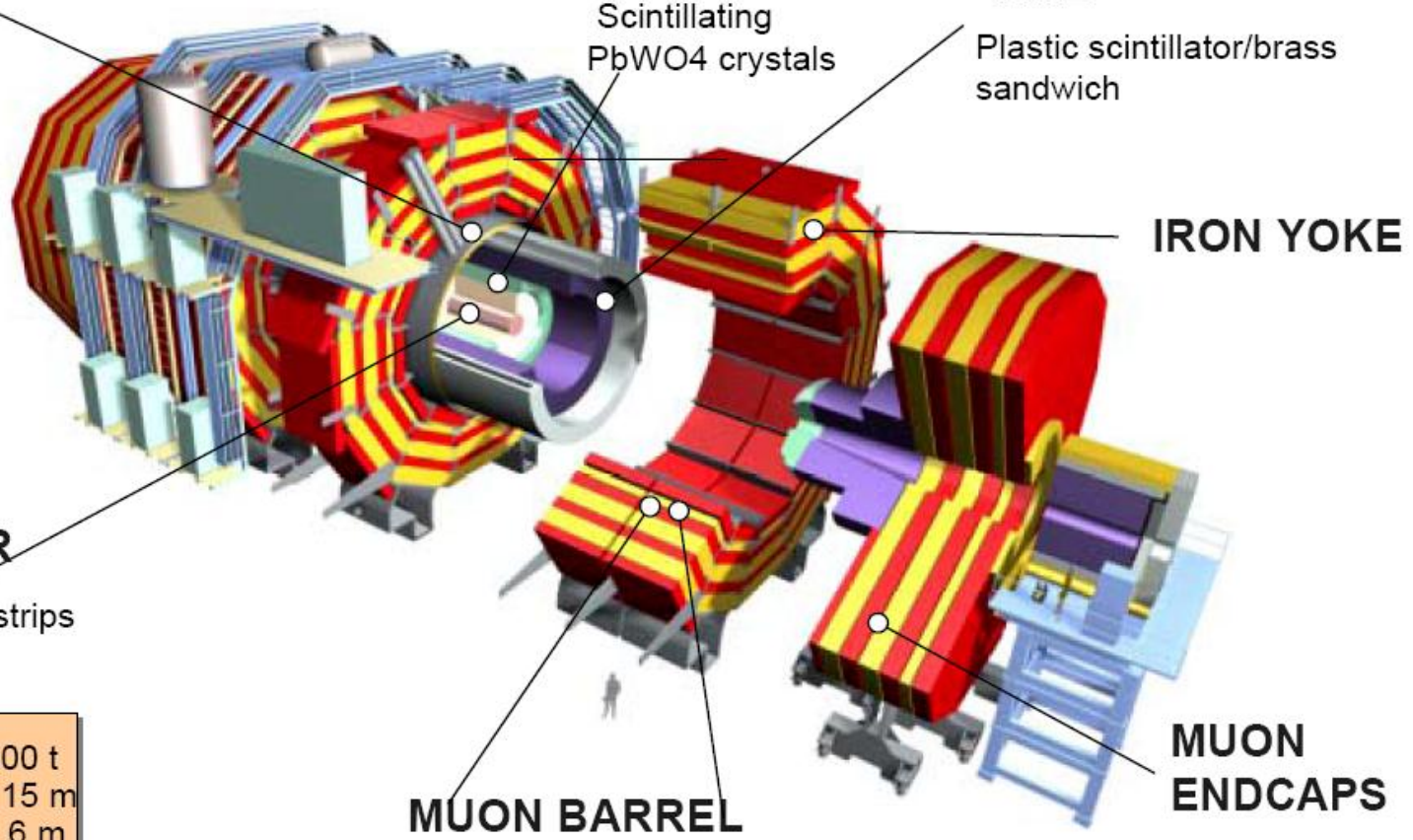
- **Isolated same-sign dileptons very clean signature for new physics**
  - **Standard Model sources extremely small**
  - **Same-sign leptons occur naturally in many new physics models**
    - **Supersymmetry, universal extra dimensions, etc.**
- **Also require missing transverse energy (MET) and hadronic jets**
  - **High MET justified by astrophysical evidence for dark matter**
  - **Significant hadronic activity from strong interactions**
  - **Otherwise, as model-independent as possible**
- **Data collected by CMS at the LHC in 2011**
  - **Total integrated luminosity of 0.98 fb^{-1}**
  - **From pp collisions at CM energy of 7 TeV**

Same-sign dileptons in SUSY

- **Example SUSY cascade leading to jets, MET and same-sign leptons**
- **Multiple possible mass scales**
  - **Large difference between squark/gluino mass and chargino mass → large hadronic activity in event**
  - **Large difference between chargino mass and LSP mass → high-p_T leptons in event**
- **Range of scenarios with asymmetry between τ, e/μ production**
- **Need multiple baseline selections to cover widest possible phase space**



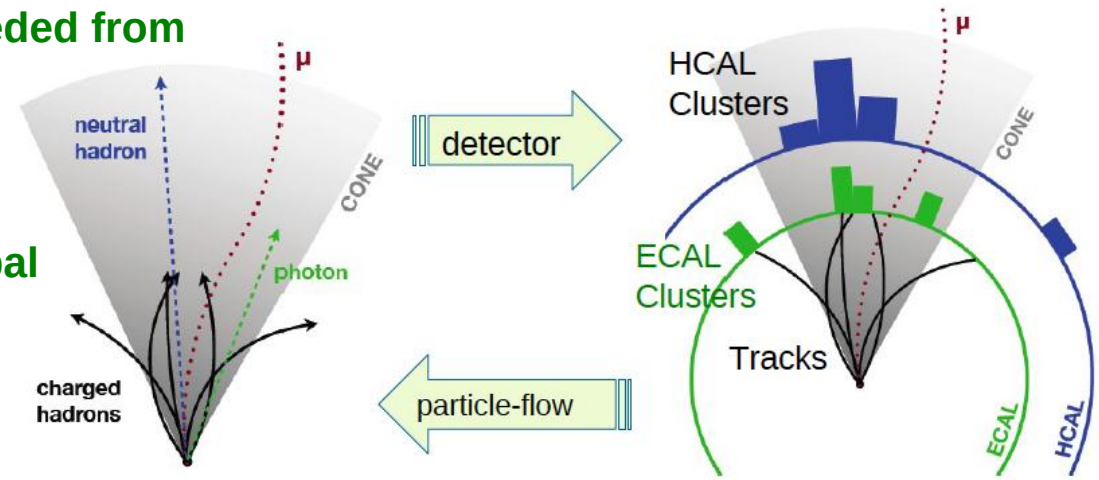
The CMS detector



Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

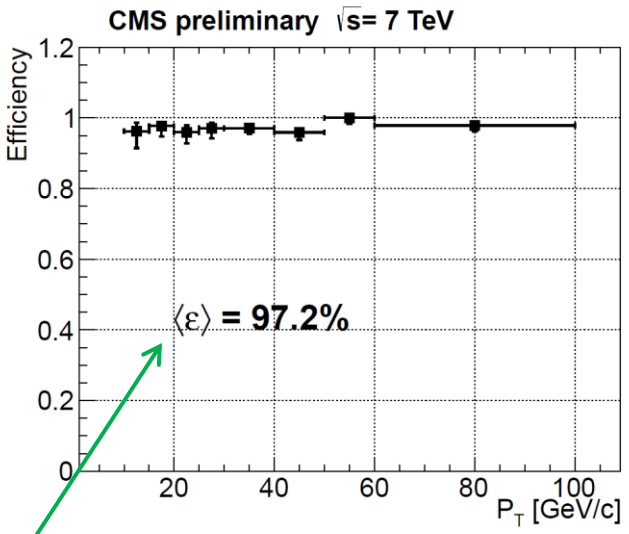
Reconstruction of leptons, missing energy and jets

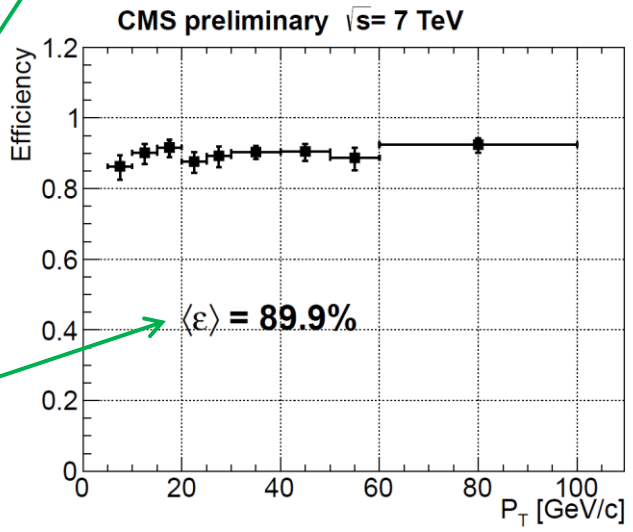
- **Electron candidates**
  - Cluster in ECAL matched to tracker hits
  - ID based on shower shape and track-cluster matching
  - ID efficiency ~ 80%
- **Muon candidates**
  - Reconstructed via 2 algorithms
    - Tracker muon: Seeded from tracks, matched to signals in calo and muon systems
    - Global muon: Global simultaneous fit to tracker and muon hits
  - ID efficiency ~ 96%
- **Jets, missing E_T**
  - Reconstructed based on particle flow (PF) technique
  - Jet clustering uses anti-kT algorithm with cone of R = 0.5
- **Hadronic tau candidates**
  - Start from jet
  - Find decay products in variable-size cone



Baseline selections

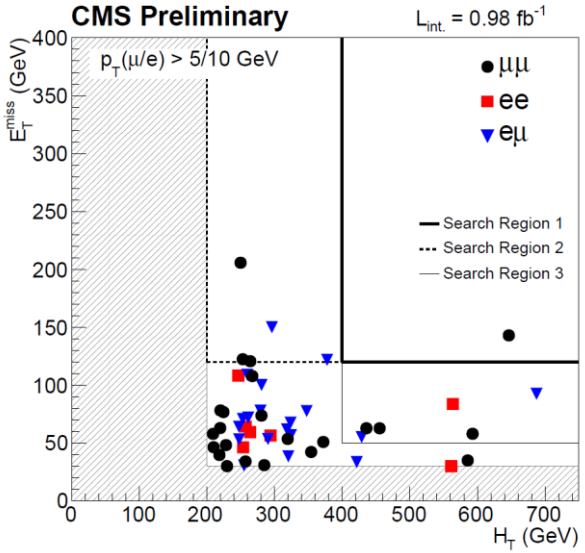
- **Events to test background predictions**
- **Initial selection:**
  - 2 ss lep: p_T(e, μ, τ) > 10, 5, 15 GeV, |η| < 2.4
  - 2 jets: p_T > 40 GeV, |η| < 2.5
  - H_T > 80 GeV, MET > 30 GeV
- **Baseline selections:**
  - Inclusive (ee, eμ, μμ): H_T > 200 GeV
  - High-p_T (ee, eμ, μμ): $p_T(l_1, l_2)$ > 20, 10 GeV
  - Taus (eτ, μτ, ττ): H_T > 350 GeV, MET > 80 GeV
- **Trigger efficiencies from tag and probe method with $Z \rightarrow l^+l^-$ events**
  - Electrons: 98 – 99% efficiency
    - Efficiency shown for inclusive dielectron selection vs p_T of subleading electron
  - Muons: 90 – 96% efficiency
    - Efficiency shown for inclusive dimuon selection vs p_T of subleading muon
  - Taus: ~ 90% efficiency

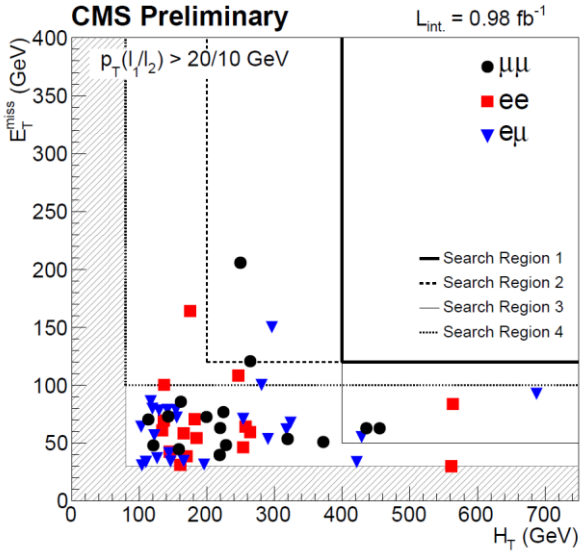


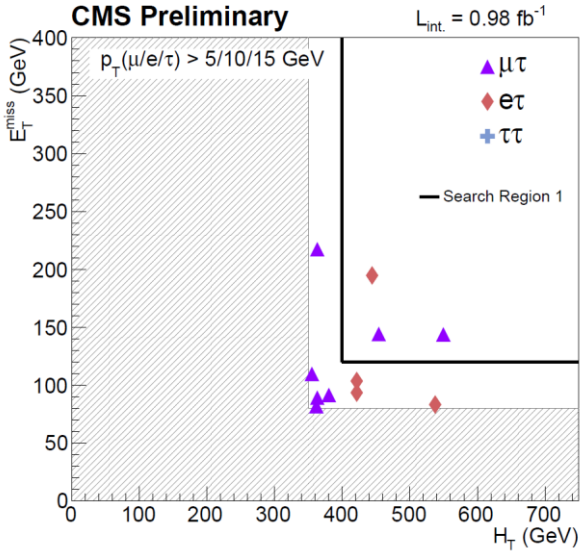


Search regions

- **Define 4 search regions:**
  - **1: H_T > 400 GeV, MET > 120 GeV: Sensitive to CMSSM, low m0 region**
  - **2: H_T > 200 GeV, MET > 120 GeV: Models with moderate squark-gluino mass splitting**
  - **3: H_T > 400 GeV, MET > 50 GeV: CMSSM, high m0 region**
  - **4: H_T > 80 GeV, MET > 100 GeV: pMSSM models with sneutrino LSP**
- **Events observed in data on H_T-MET plane for baseline selections**
  - **Most events in data fall outside all four search regions**

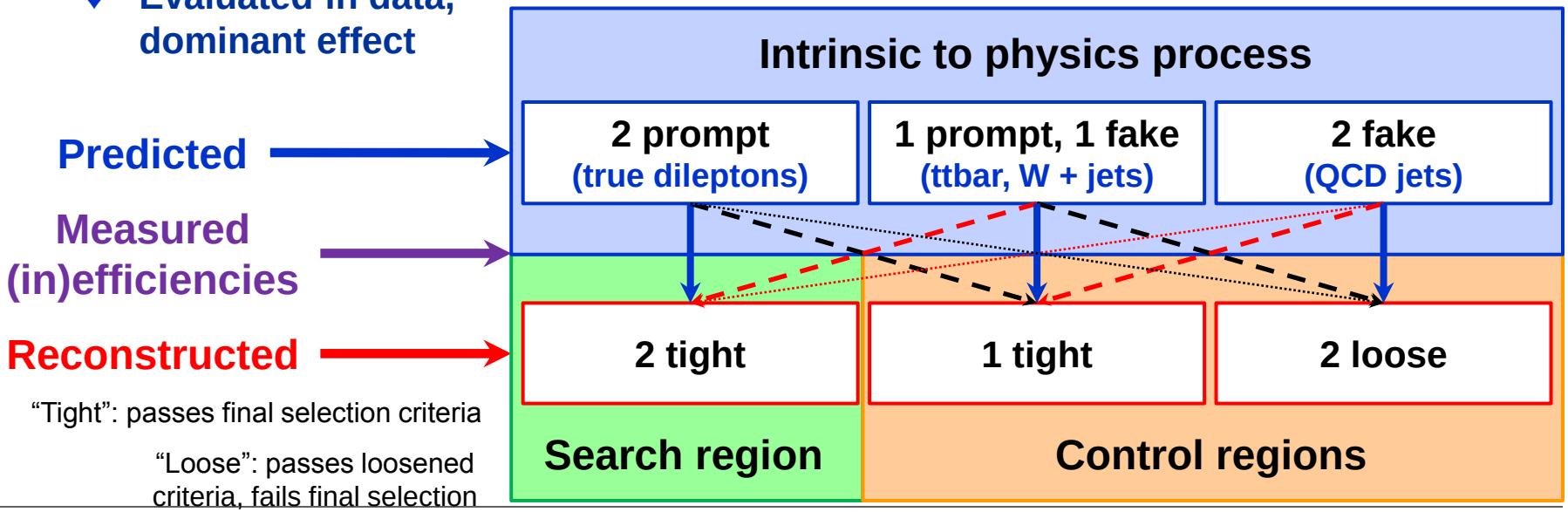






Background estimation

- **Prompt same-sign dileptons**
  - qqbar → WZ and ZZ, qq → qq$W^{\pm}W^{\pm}$, 2 x (qqbar → W), and ttbar + W
  - Evaluated from simulation, 10 – 40% contribution, 50% systematic uncertainty
- **Opposite-sign dileptons with charge misreconstruction**
  - $Z/\gamma^{*} \rightarrow l^{+}l^{-}$, ttbar
  - Evaluated in data, < 10% contribution, 20% systematic uncertainty
- **Fake leptons from jets**
  - Leptons from heavy flavor decays and misidentified jets
  - Evaluated in data, dominant effect

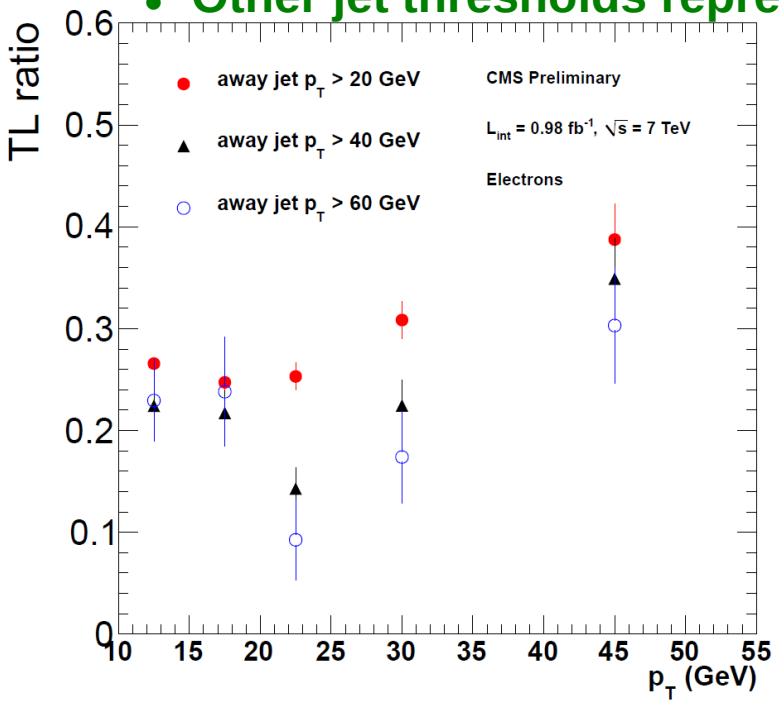


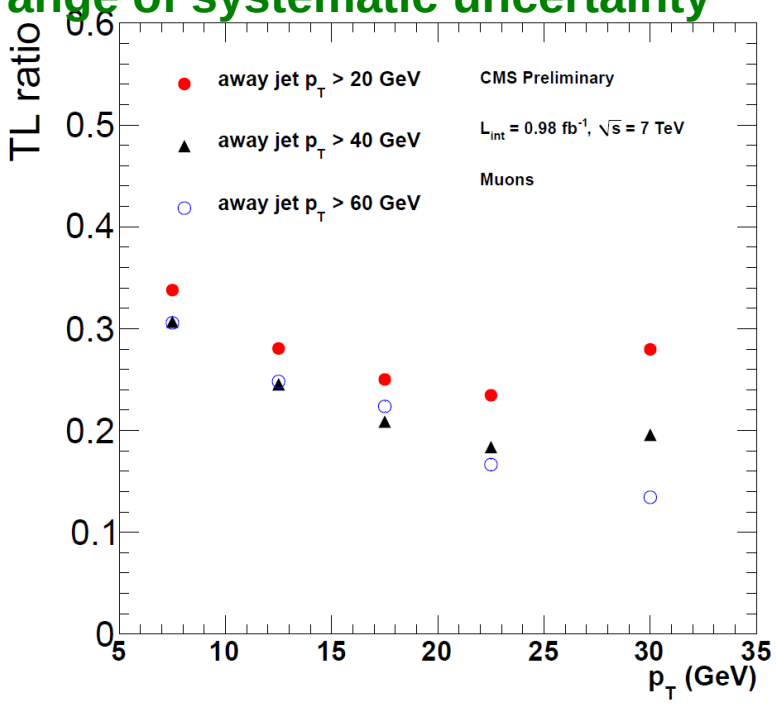
"Tight": passes final selection criteria

"Loose": passes loosened criteria, fails final selection

Fake rates

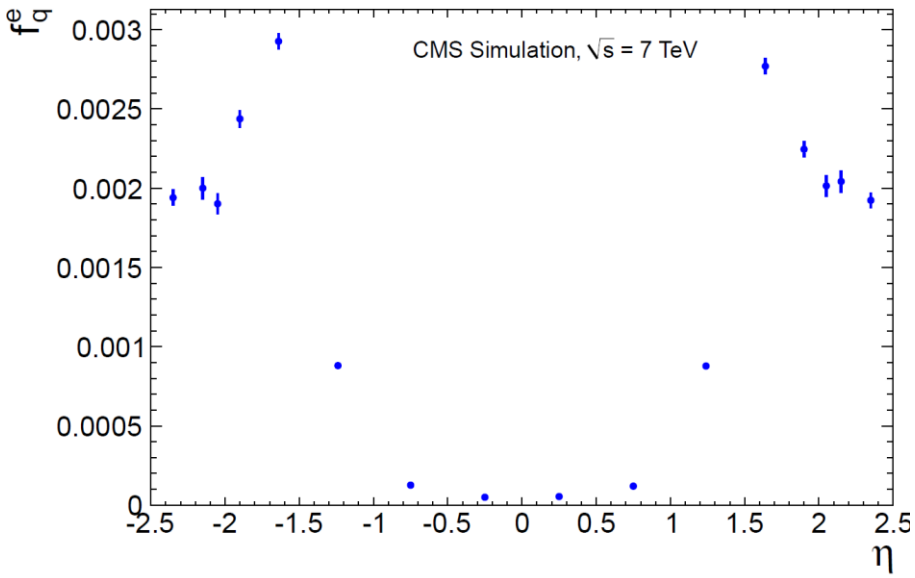
- **Ratio of tight to loose electrons (left) and muons (right)**
  - **Isolation requirement loosened for fakeable objects**
  - **Event also contains jet above threshold separated from lepton candidate by ΔR > 1.0**
  - **Fake rate determined for jet p_T > 40 GeV**
    - **Other jet thresholds represent range of systematic uncertainty**

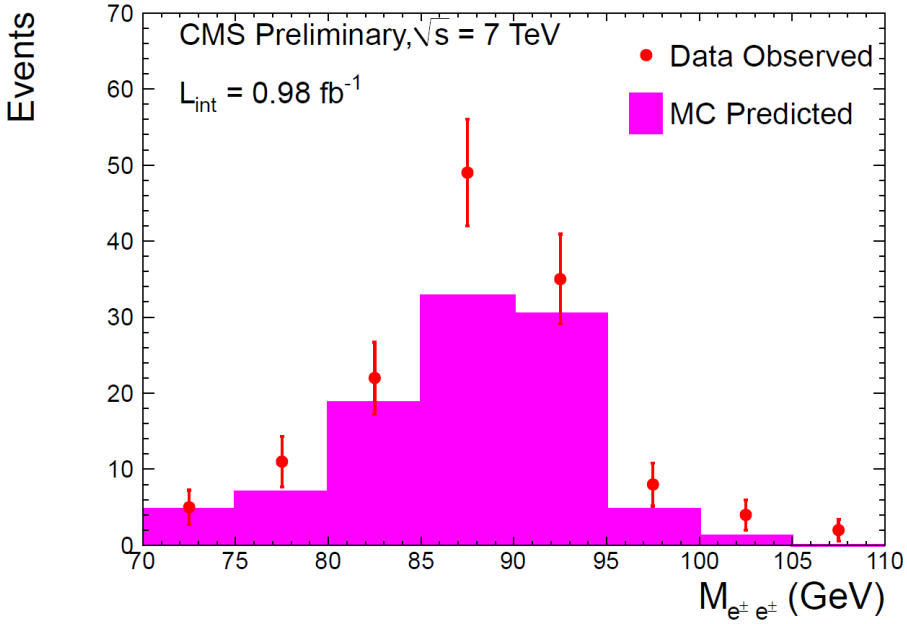




Electron charge misreconstruction

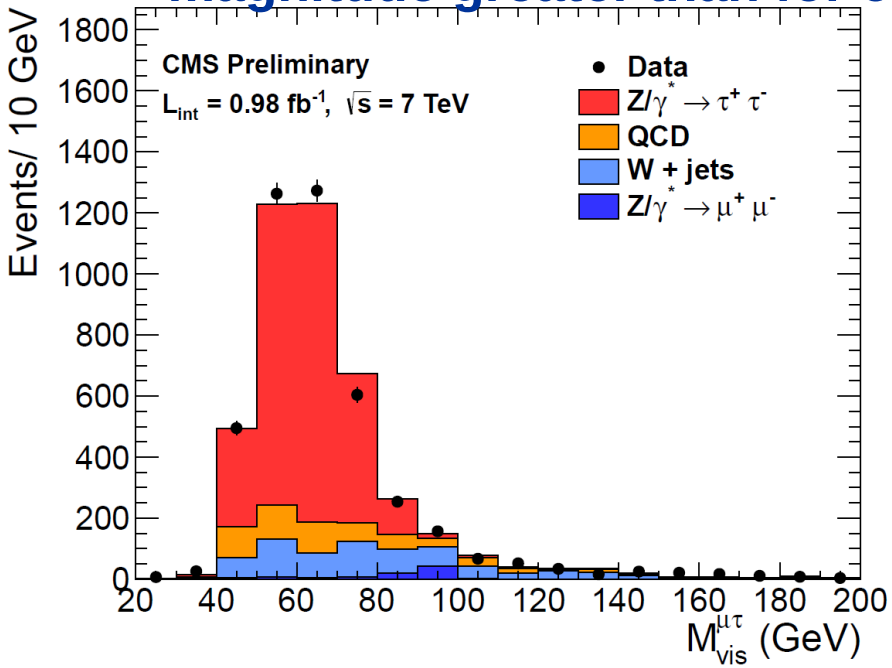
- **Probability to misreconstruct electron charge significantly increased in endcap region**
  - **Measured from simulated MC events**
- **Measure charge misreconstruction rate from same-sign ee events with invariant mass in Z window 76 < M_{ee} < 106**
  - **Predicted MC calculated from Z events and data with charge misreconstruction probability applied**
  - **Comparison between data and predicted MC for same-sign ee events in Z boson control region**

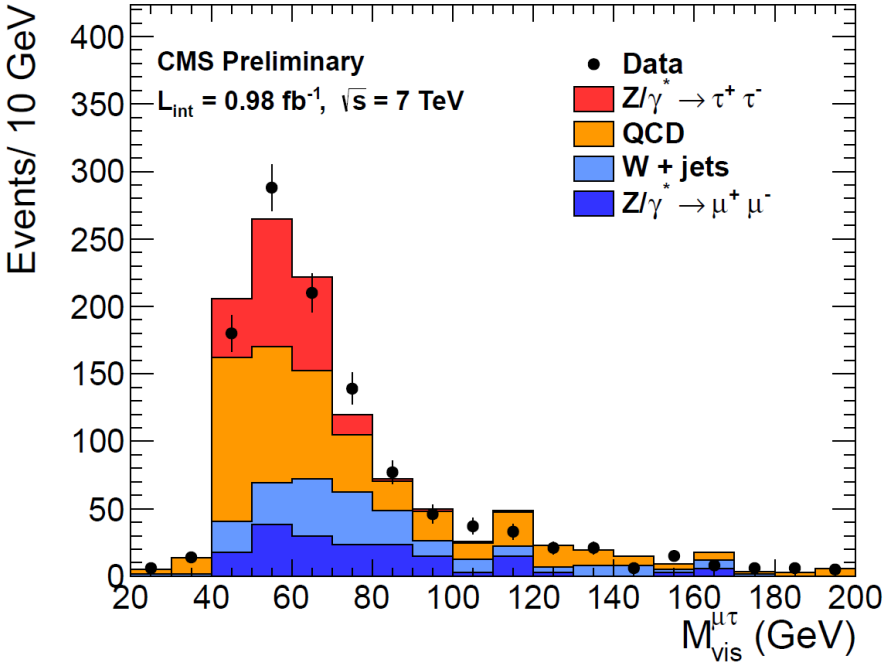




Tau charge misreconstruction

- Tau charge is sum of charge of hadrons associated with tau decay
- Charge misreco rate measured from invariant mass of μτ pairs for opposite sign (left) and same sign (right)
  - Tau charge misreconstruction expected to be ~ order of magnitude greater than for electrons

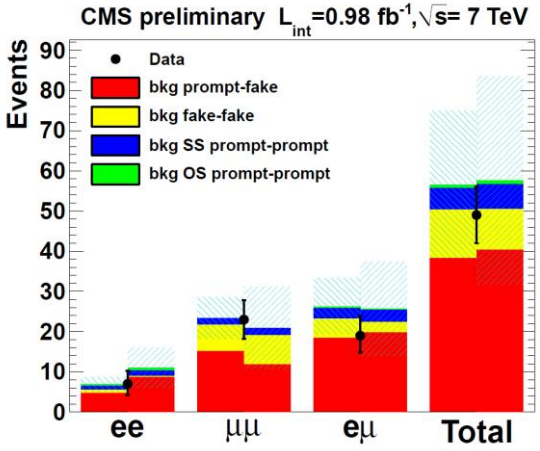




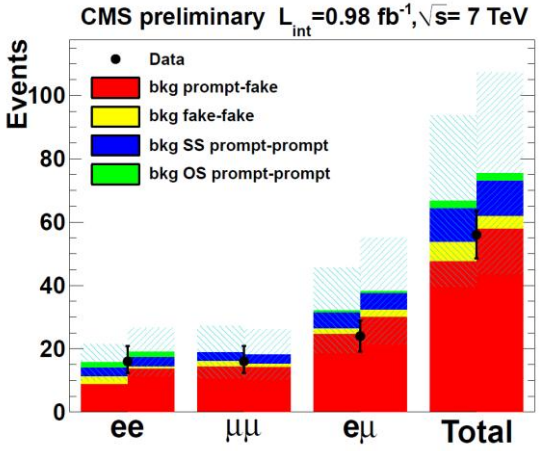
Background predictions from data

- **Data-driven background predictions shown for each baseline selection**
  - **Two sets of complementary methods used to measure backgrounds for inclusive and high-p_T selections, shown side-by-side**
    - **Predictions mutually consistent**
  - **Similar method used for tau backgrounds**
- **Observed yield in very good agreement with predictions for all baseline regions**

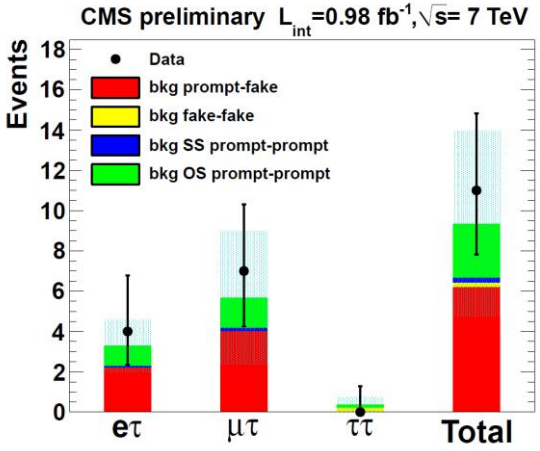
Inclusive selection



High-p_T selection



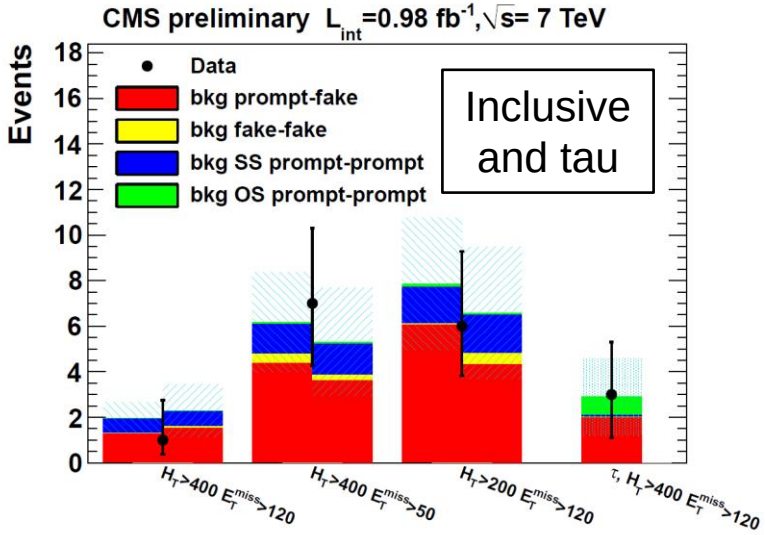
Tau selection

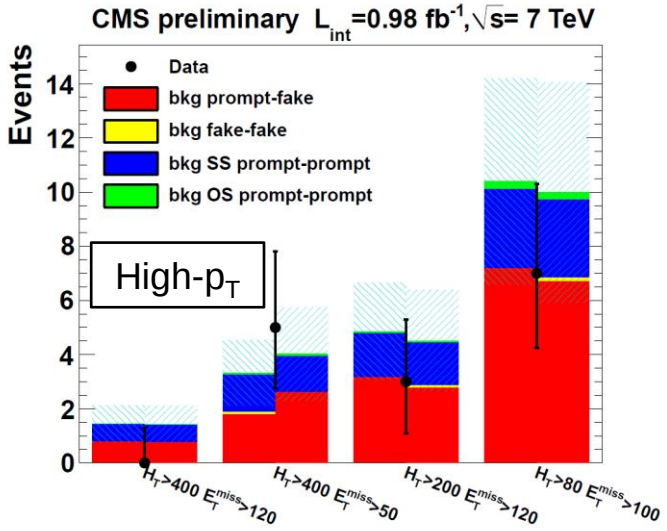


Search results

- **Observed events and bkgd predictions by baseline selection and search region**
  - **See no evidence of events in excess bkgd prediction, set 95% CL upper limit on observed events (use modified frequentist method)**

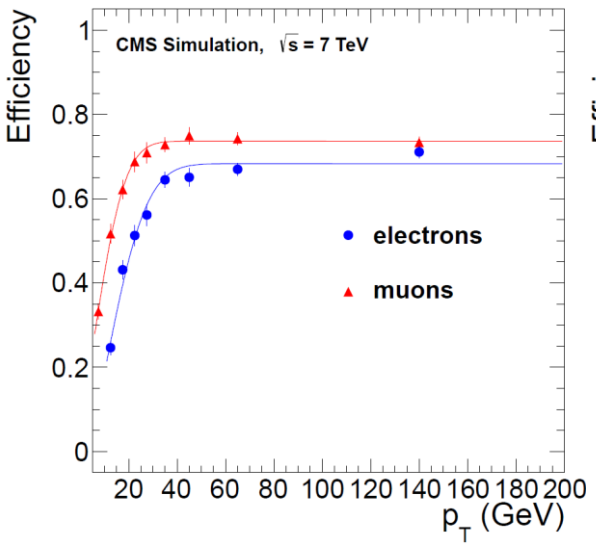
Dilepton category	Inclusive (H_T > 200 GeV)			High-p_T [$p_T(l_1, l_2)$ > 20, 10 GeV]				Taus
H_T(GeV)/MET(GeV)	400/120	400/50	200/120	400/120	400/50	200/120	80/100	400/120
Predicted	2.3 ± 1.2	5.3 ± 2.4	6.6 ± 2.9	1.4 ± 0.7	4.0 ± 1.7	4.5 ± 1.9	10 ± 4	2.9 ± 1.7
Observed	1	7	6	0	5	3	7	3
95% CL UL yield	3.7	8.9	7.3	3.0	7.5	5.2	6.0	5.8

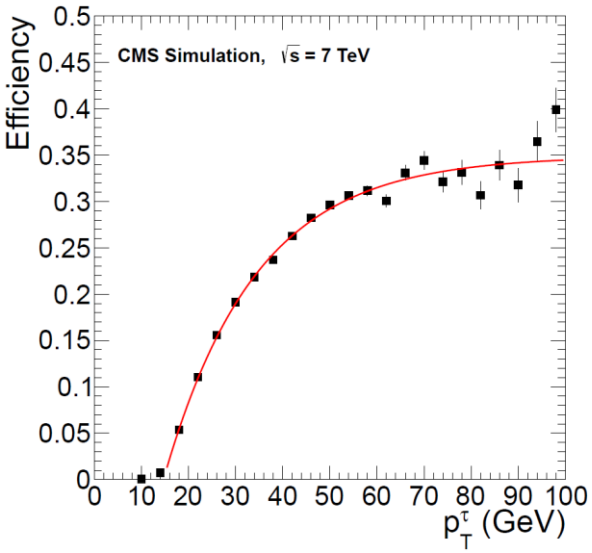


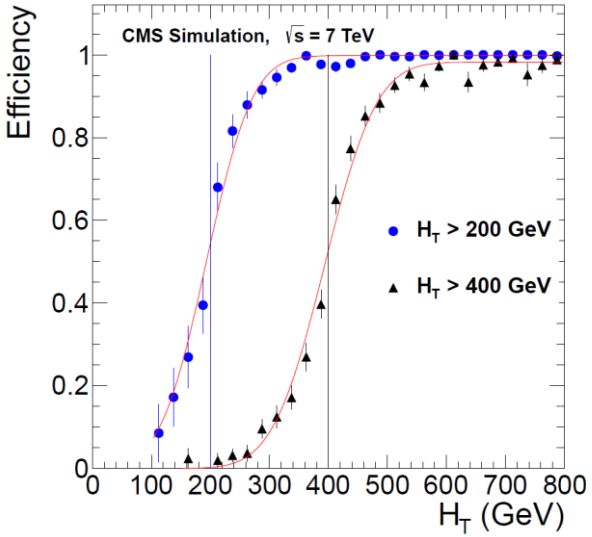


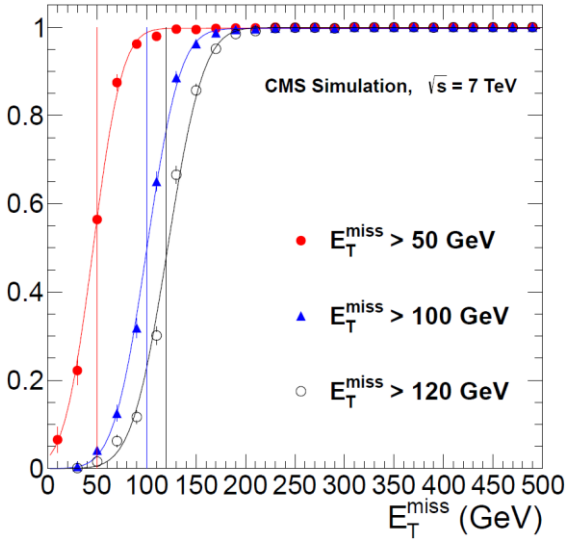
Interpretation of results for new physics models

- Convey information in model-independent form
- "Efficiency model" used to test range of new physics
  - Estimate efficiency from simulation
  - Parametrize with error functions
- Efficiencies shown for leptons (top) and H_T and MET (bottom)



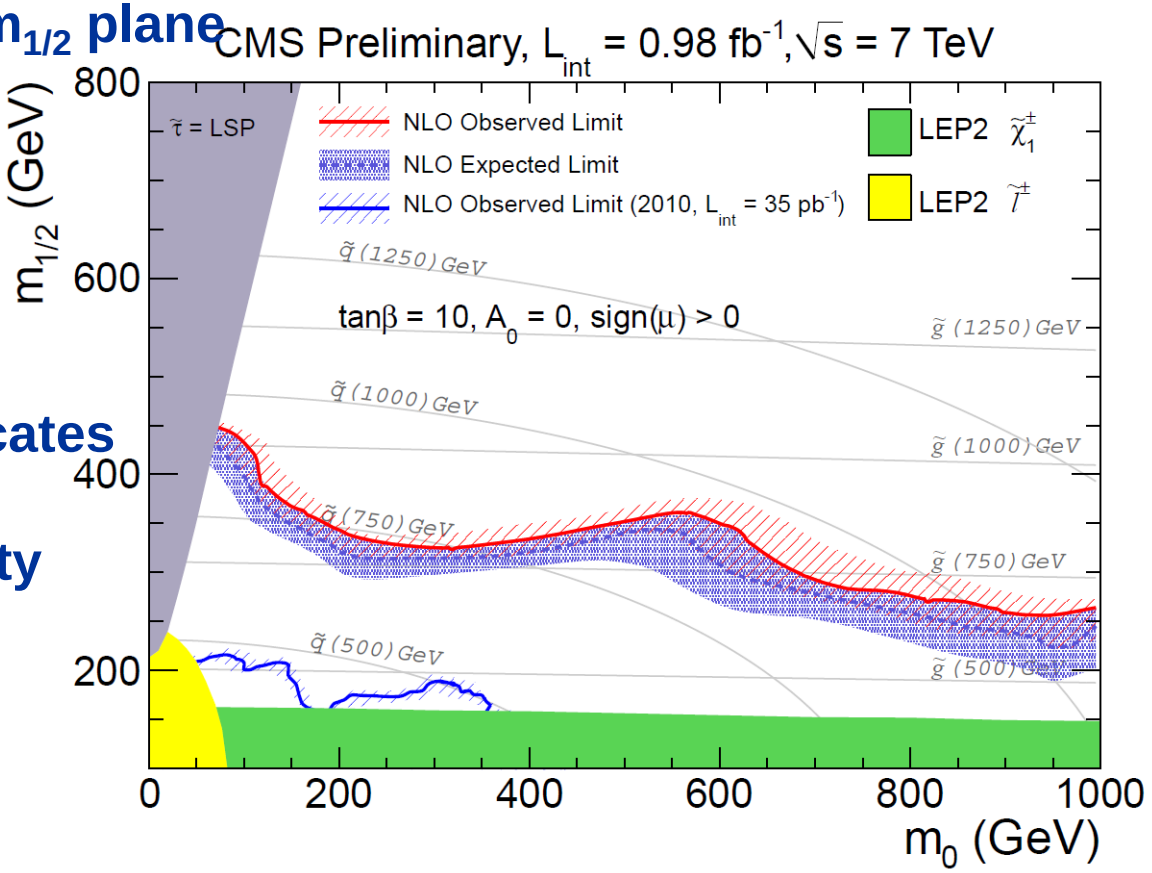






CMSSM exclusion limits

- **Exclusion limit set using search region 1 of high-pT dilepton selection in constrained MSSM**
  - **Observed upper limits compared to expected number of events in CMSSM in m_0-$m_{1/2}$ plane**
  - **All points with mean expected values above this limit are excluded at 95% CL**
  - **Shaded limit indicates production cross section uncertainty**
- **Result from 2010 also shown for comparison**

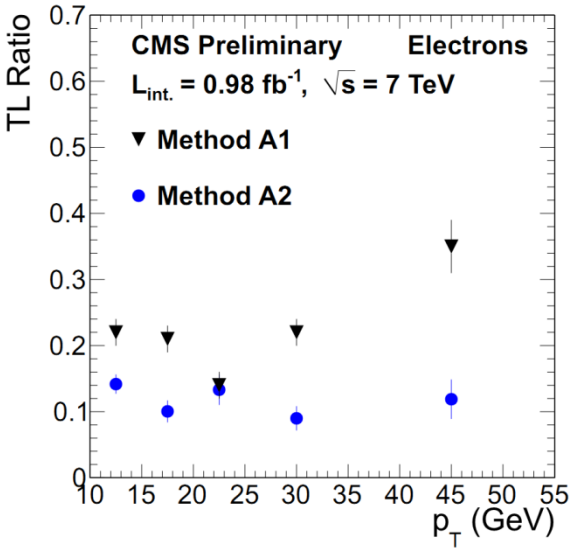


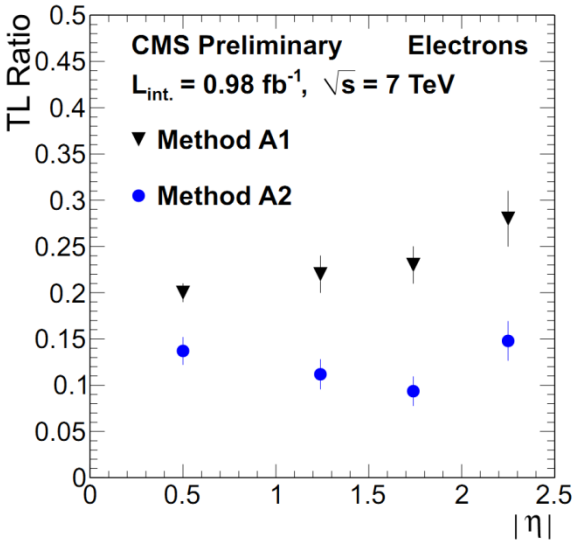
Summary and conclusions

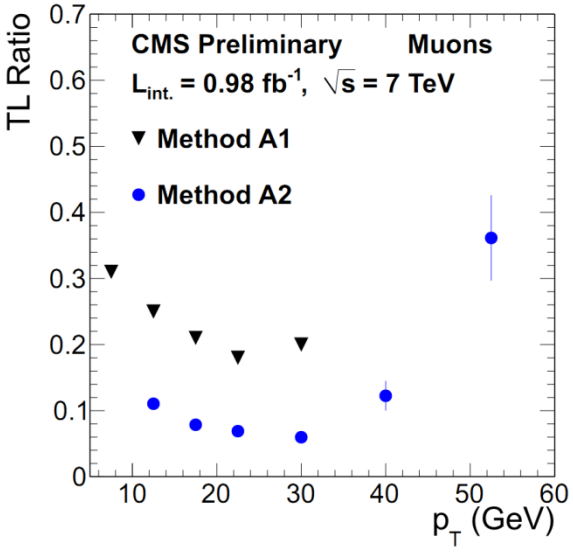
- **Searched for new physics in same-sign dilepton channel, including final states with electrons, muons and taus**
- **All major background sources estimated directly from data**
  - **Events with single fake lepton dominant background in all channels except ττ**
    - **Two fake τ dominates in ττ channel**
- **No evidence for excess over background prediction**
  - **Set 95% CL upper limits on number of signal events in $|\eta| < 2.4$ with 0.98 fb^{-1} of data**
  - **Report exclusion limit in CMSSM parameter space**

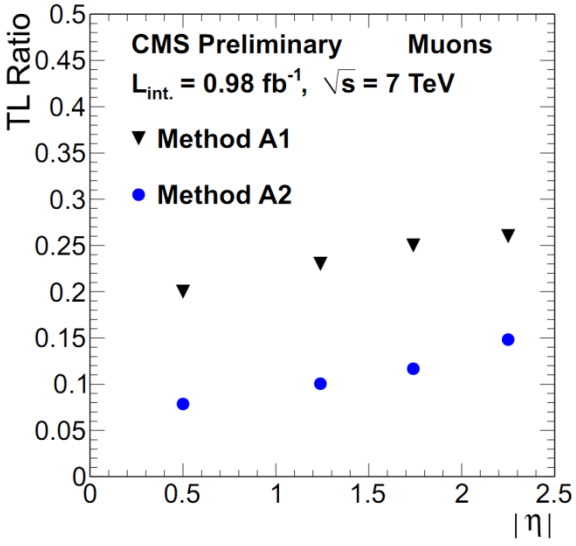
Backup slides

Fake rates for different methods

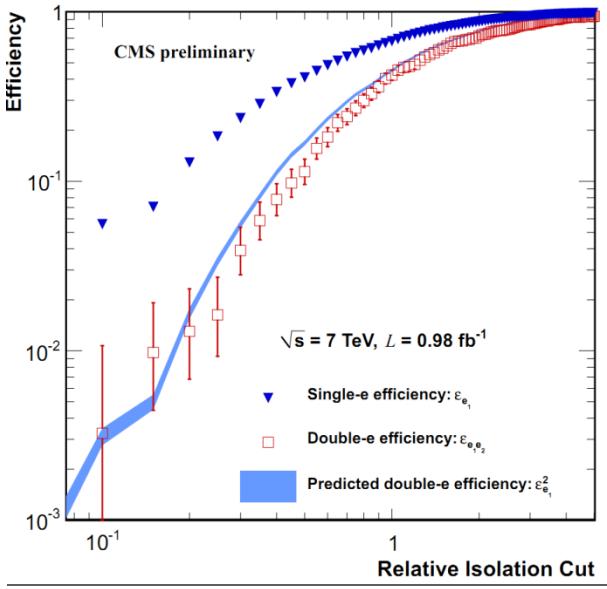


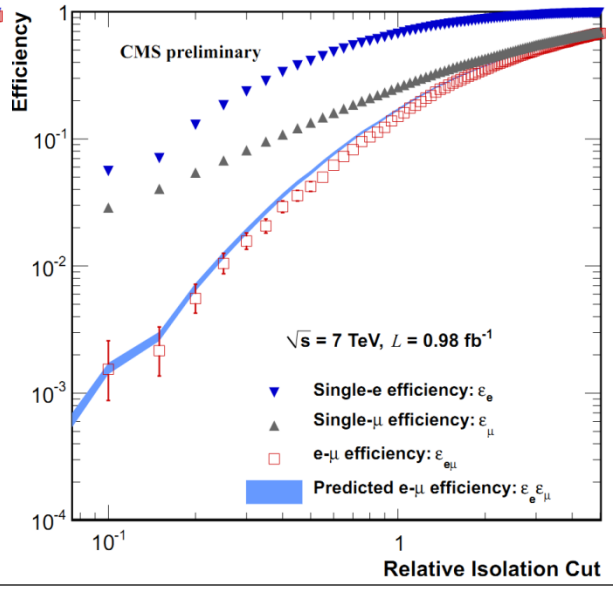


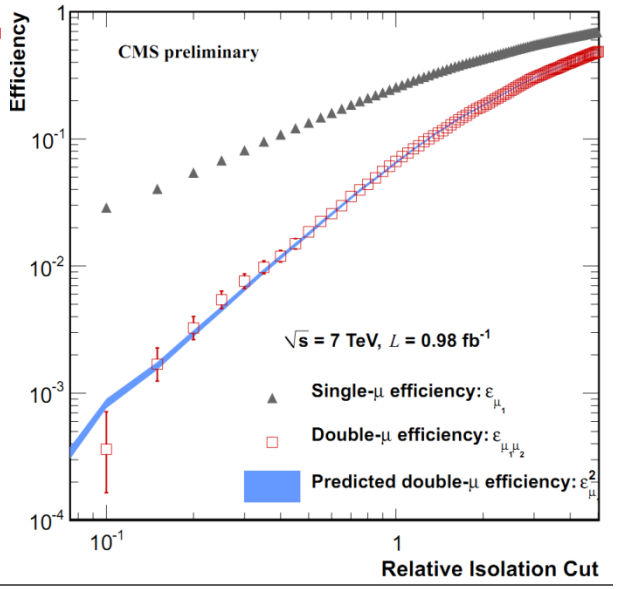




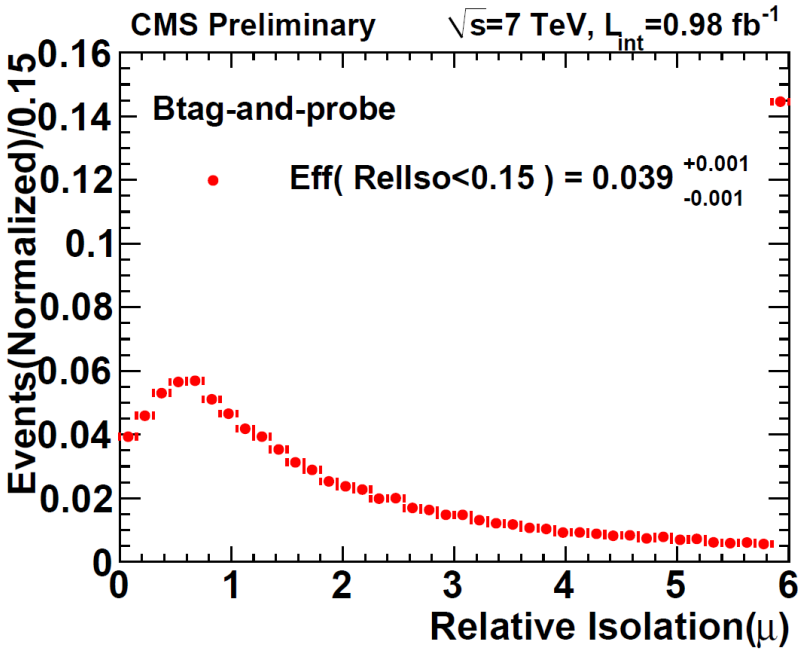
Isolation efficiency

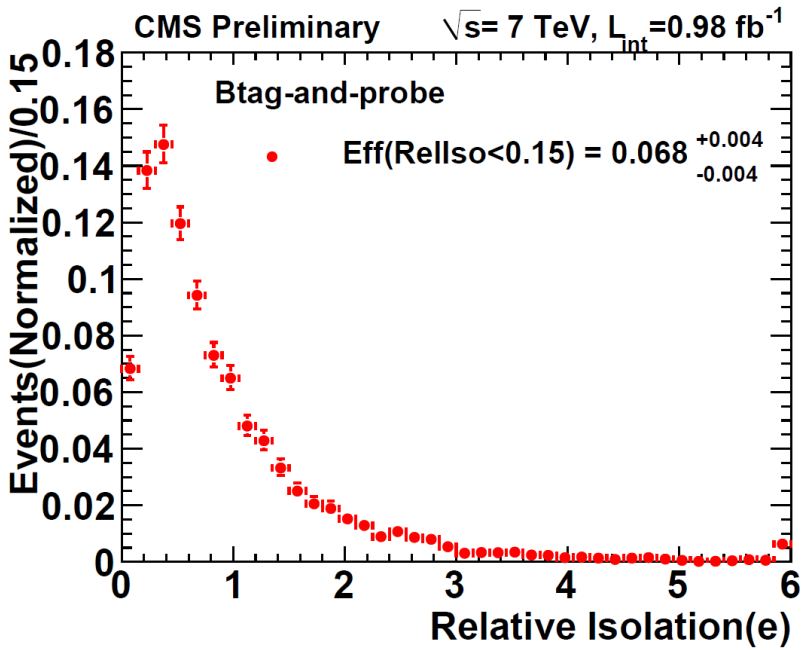






Isolation templates for fake rates





CMSSM exclusion limits for inclusive search