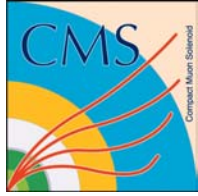
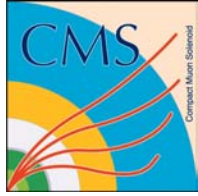


CMS Preparations for New Physics Searches Involving Lepton Final States

Richard Cavanaugh
University of Florida
CMS Collaboration

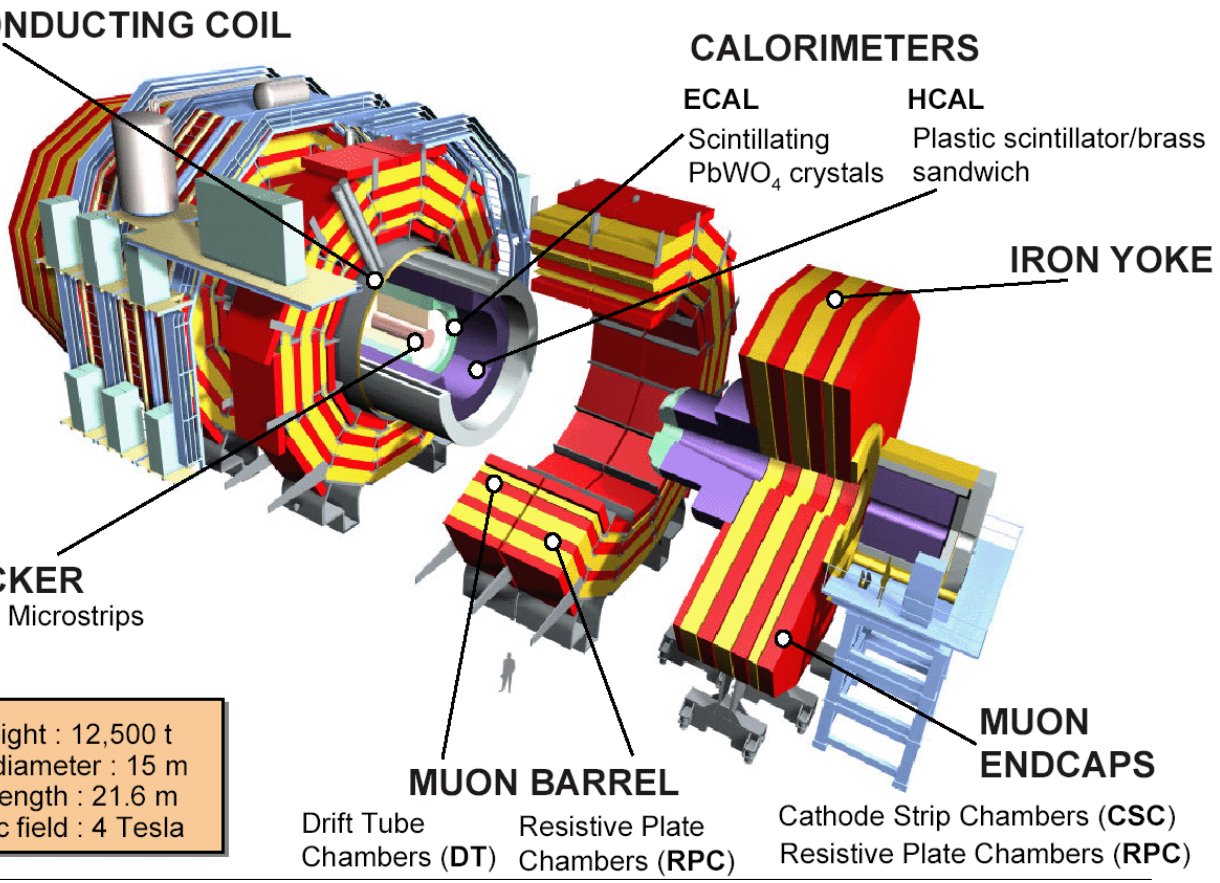


Introduction

- CMS Detector
  - Focus on Muon System
- Recent examples of 'new physics' reach analyses (involving leptons)
  - Z'
  - Higgs
    - see earlier talk by Satyaki Bhattacharya
  - mSUGRA
- Conclusions

CMS Detector

- Precise Lepton and photon energy scales
- Efficient b-tagging and tau ID
- Good jet and missing ET resolution

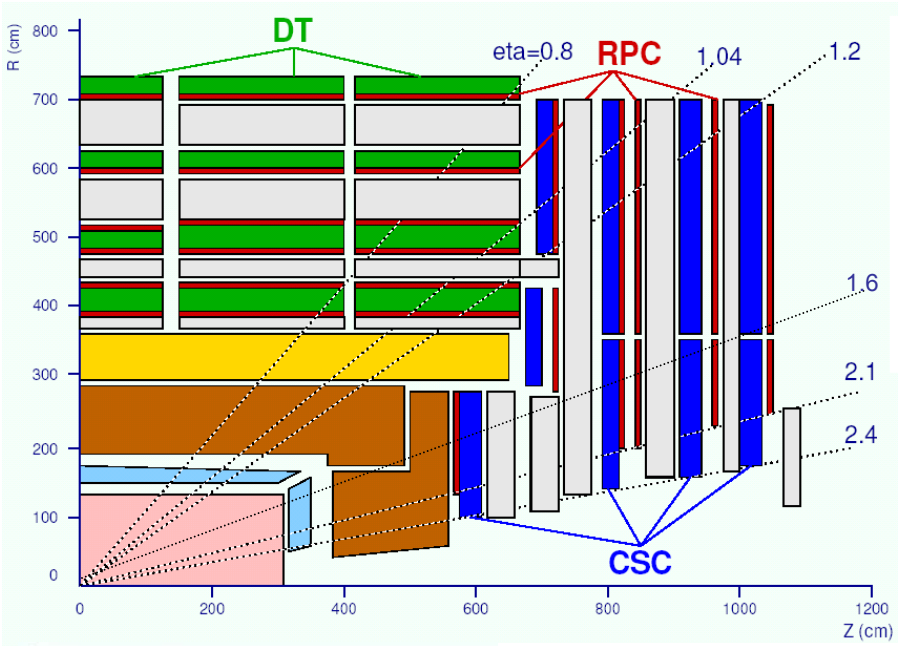


TRACKER: $|\eta| < 2.4$, $\sigma/p_T \sim 1.5\times10^{-4}\, p_T \oplus 0.005$ HCAL: $|\eta| < 5$, $\sigma/E \sim 120/\sqrt{E} \oplus 5\%$

MUON: $|\eta| < 2.4$, $\sigma/p_T \sim 5\%$ at 1TeV ECAL: $|\eta| < 3$, $\sigma/E \sim 1.5\%/\sqrt{E} \oplus 0.5\% \oplus 0.15/E$

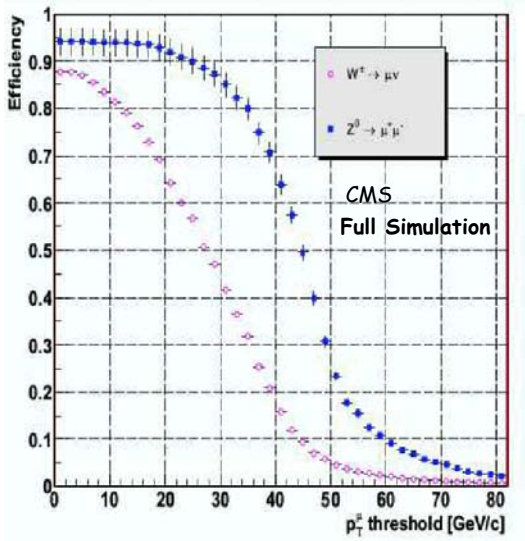
CMS Muon System

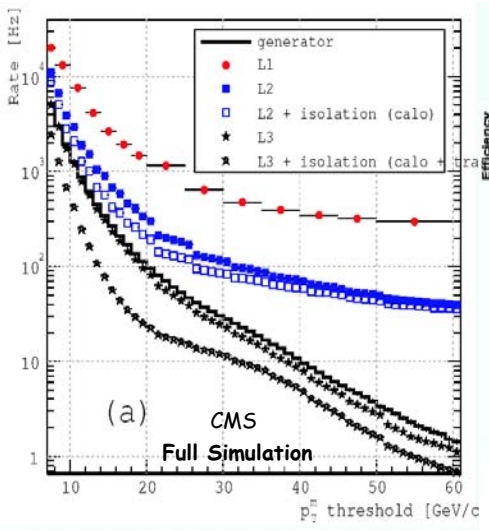
- Three types of gaseous detectors
  - Drift Tubes in barrel region
    - 4 stations interleaved with iron return yoke
    - Self triggering and BX ID
  - Cathod Strip Chambers in endcap regions
    - 4 stations interleaved with iron return yoke
    - Up to $|\eta| < 2.4$
  - Resistive Plate Chambers in both barrel and endcaps
    - precise bunch crossing ID for Trigger
    - Up to $|\eta| < 2.1$
- DT's and CSC's provide precise position measurements
  - Expect very good momentum resolution over a broad range of p_T and η
- All RPC+CSC+DTs contribute to L1-trigger
- Start-up Staging
  - 50% DAQ
  - 3rd Pixel Endcap
  - 1/3 Muon Endcap RPCs: $|\eta| < 1.6$
  - 4th Muon CSC Endcap (ME4/1 Restored!)

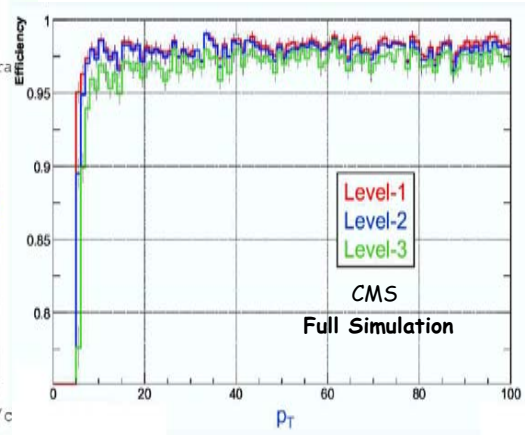


Expected CMS Muon Trigger Performance

- Event Selection at LHC is a challenge
  - On-line rate reduction: 40 MHz to 100 Hz
  - Decision every 25 ns
  - Most pp interactions ⇒ soft hadrons (p_T ~ 1GeV)
  - Large Bkgs at low p_T





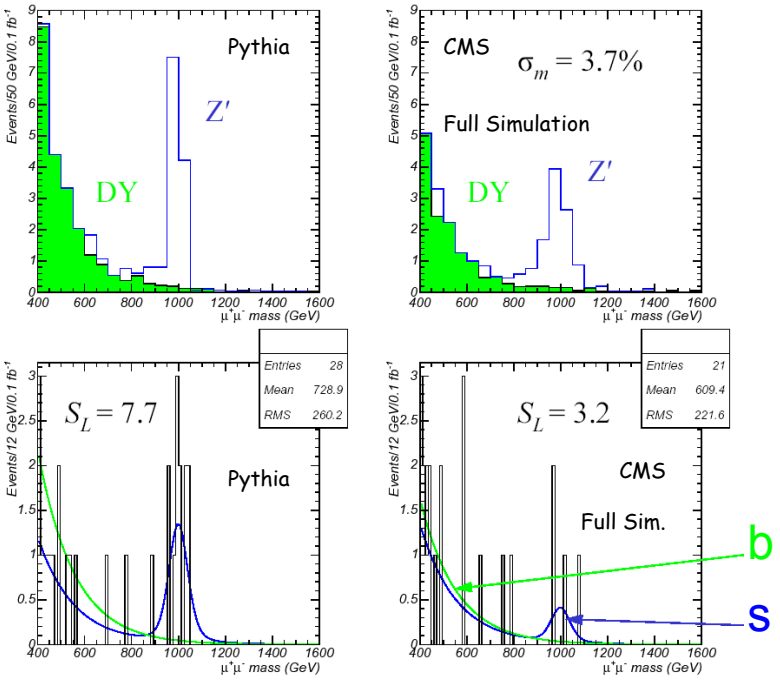


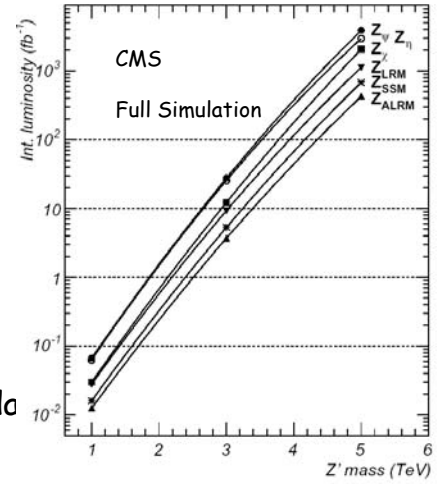
- Muons very useful for triggering
  - Clean & Easy to ID
  - High p_T muons important signature
  - Issue: Precise muon p_T measurement
- Nominal Low Luminosity Threshold
  - single muon: 19 GeV
  - dimuon: 7 GeV

$Z' \rightarrow \mu^+\mu^-$ Search

- Excellent benchmark analysis for CMS Muon Detector
  - Clean
  - Very high p_T muons
  - Systematic studies platform
- Mass Reach ($S_L > 5\sigma$)
  - Full CMS simulation and reconstruction
  - Unbinned Likelihood Ratio Approach
    - $S_L = \sqrt{2 \ln(L_{s+b}/L_b)}$

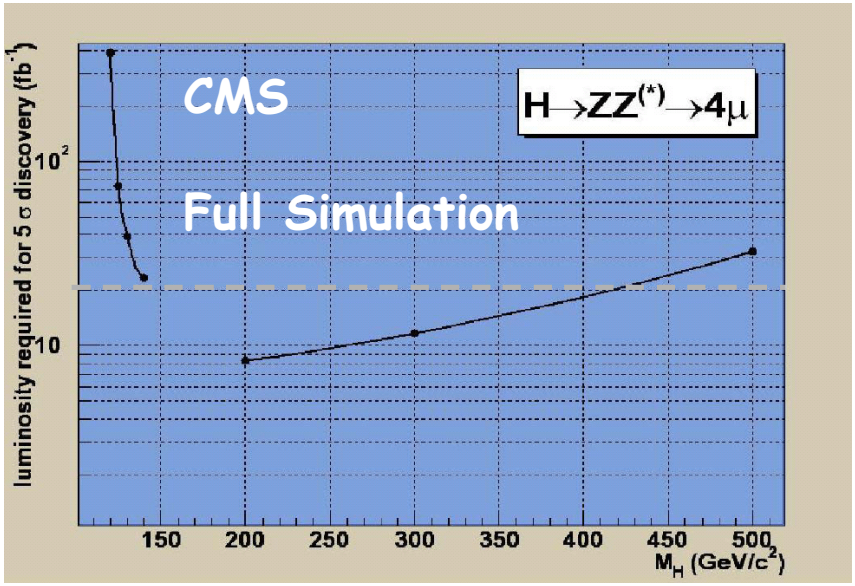
Mass Reach (TeV)	Luminosity (fb^{-1})
> 1	0.1
2.6 – 3.4	10
3.4 – 4.3	100

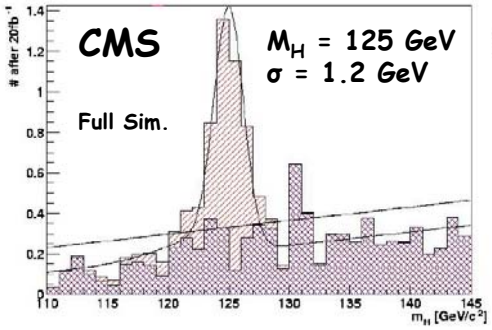


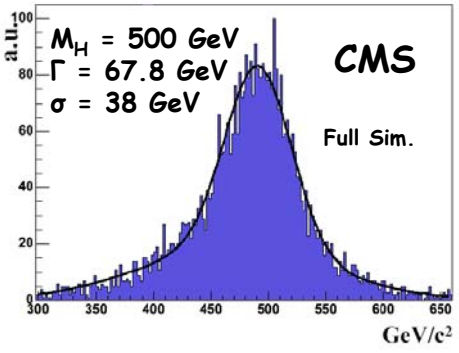


SM H → 4μ Search

- Another CMS benchmark study
  - Full Detector Simulation
- Main Backgrounds
  - ZZ(*), tt, Zbb, Zcc
- $M_H < 2\ M_Z$, Require:
  - $M_{12} = M_Z^*$, $M_{34} = M_Z$
  - Mass dependent thresholds on muon p_T
  - Muon isolation cut
- $M_H > 2\ M_Z$, Require
  - $M_{12} = M_{34} = M_Z$
    - Rejects tt and Zbb
  - High muon pT
  - High Higgs p_T



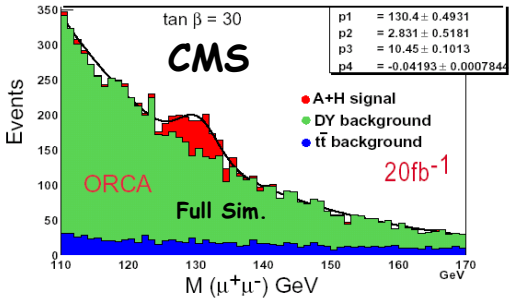


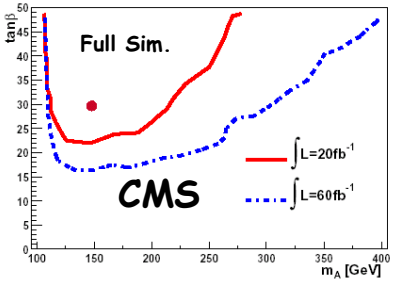


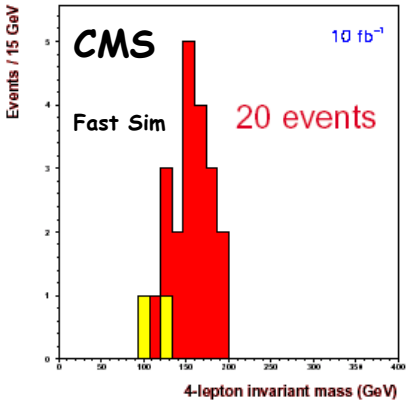
- $M_H < 2\ M_Z$
  - 4 muon mass resolution dominated by CMS detector resolution
- $M_H > 2\ M_Z$
  - 4 muon mass resolution dominated by the Higgs natural width
- With 20 fb-1
  - Can discover 200 – 400 GeV SM Higgs

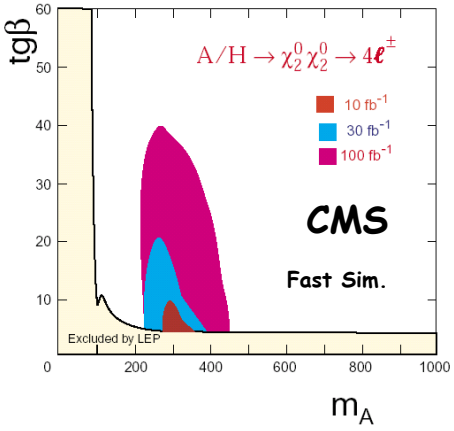
MSSM Higgs to 2 or 4 leptons

- $A/H \rightarrow \mu^+\mu^-$
  - Studied with full simulation
  - Signal $bbH \rightarrow bb\mu\mu$
    - Small branching ratio: 3×10^{-4}
    - But, clean dimuon mass peak!
  - Main Background
    - Drell-Yan, tt
  - Difficult with only 10 fb^{-1}, but may be possible…
    - Would require very early on
      - Good b-tagging
      - Excellent track momentum resolution





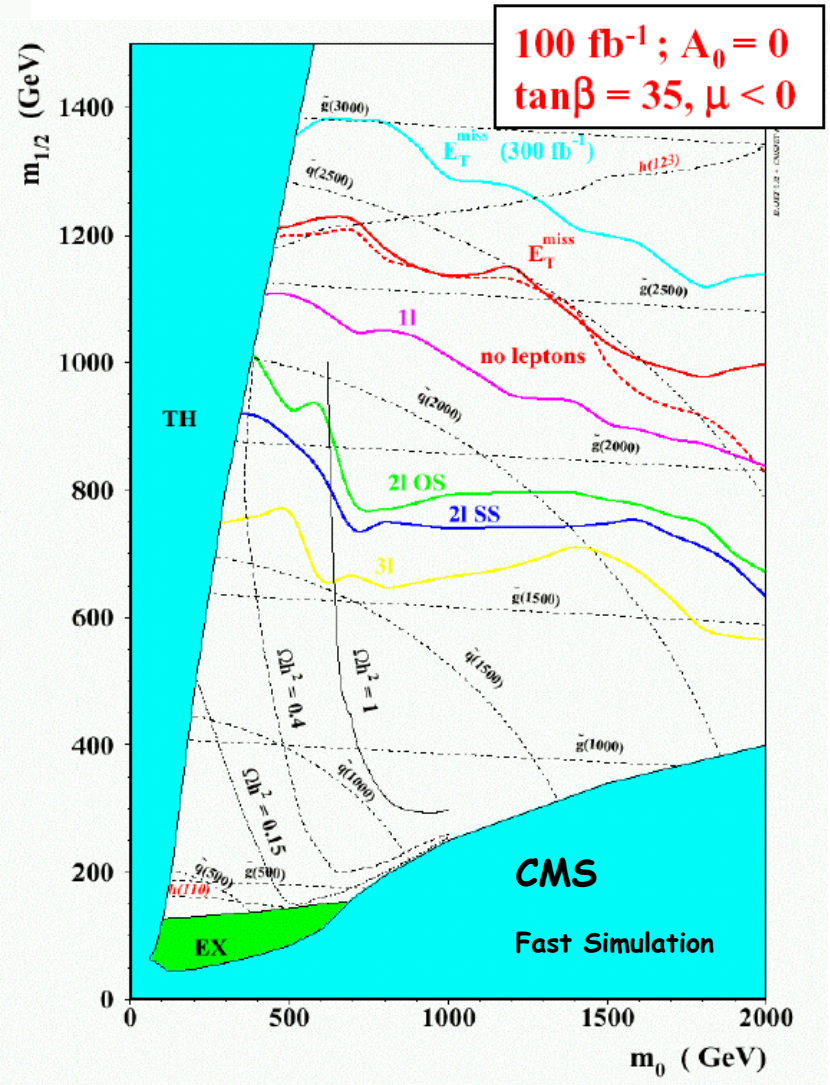




- $A/H \rightarrow \chi^0_2\,\chi^0_2 \rightarrow$ 4 leptons
  - Studied with fast simulation
  - Main background:
    - SUSY
  - Optimised cuts on
    - Jet multiplicity, MET and lepton pT
  - 10 fb^{-1} would allow the search to start!

Squark and Gluino Searches

- Typical Signature:
  - Leptons, MET, Jets
- Backgrounds:
  - W+jets, Z+jets, tt, Wtb, WW, WZ, etc
- Inclusive Jets+MET has most sensitive reach
- Leptons are more useful for sparticle reconstruction
  - Also provide important systematic handles during early running



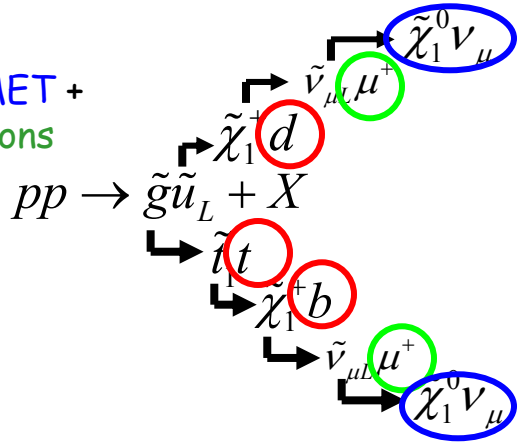
Semi-inclusive mSUGRA Search using 2 Same Sign Muons

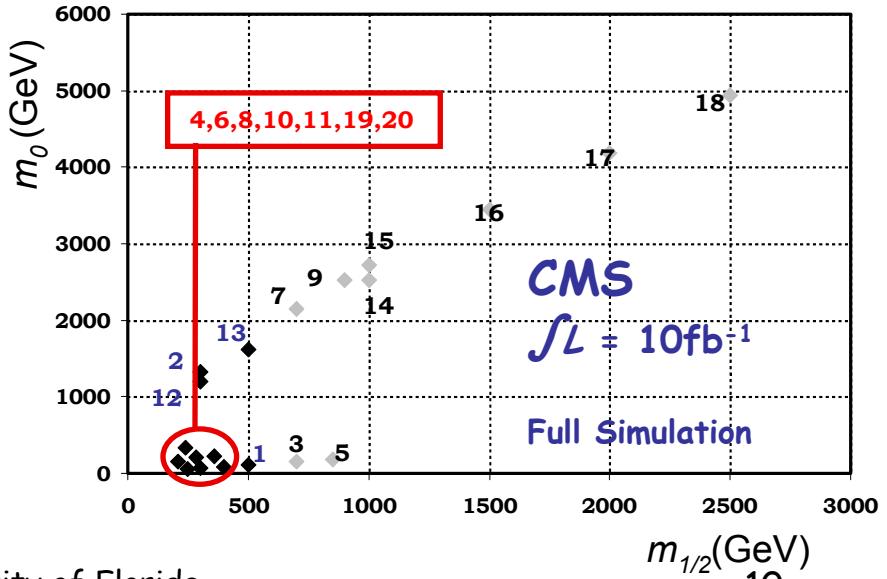
- mSUGRA parameters
  - tanβ=10, sign(μ)>0, A_0=0
- Analysis selects on
  - MET
  - Jets
    - E_T, η, multiplicity
  - Muons
    - p_T, η, multiplicity, IP, isolation
- Most important background processs
  - $t\bar{t}$ and higher order, like $t\bar{t}W$, $t\bar{t}Z$, etc
- Full CMS simulation, trigger emulation and reconstruction
- Current expected reach for $\int L$ < 10fb^{-1}
  - up to 600 GeV in $m_{1/2}$
  - at least up to 1600 GeV in m_0
  - $S = Ns / sqrt(Ns+Nb)$

point	4	6	8	10	11	19	20
σ	25	20.6	15.5	31.7	12.1	25.6	20.6

point	1	2	12	13
σ	9.05	20.8	27.1	6

Signature:
Jets + MET +
2 SS muons

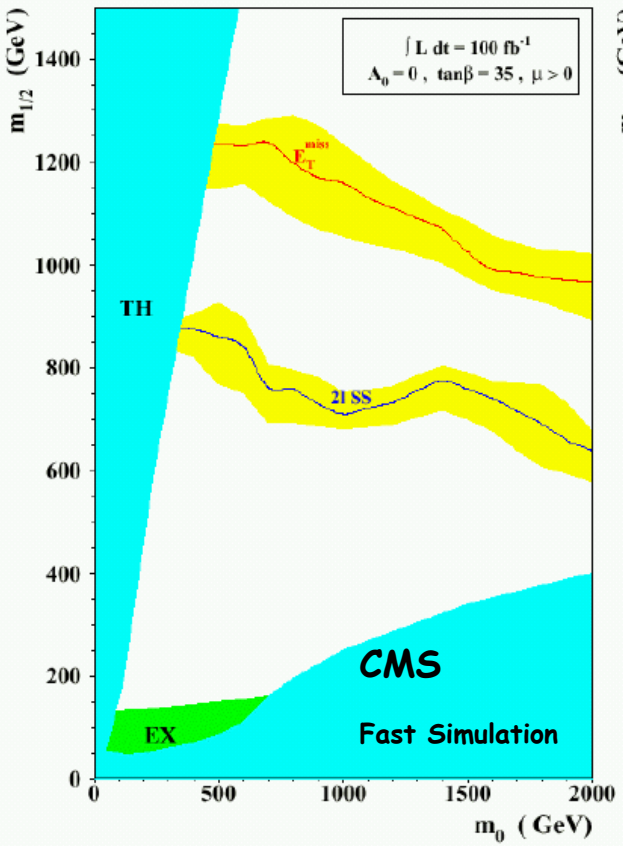




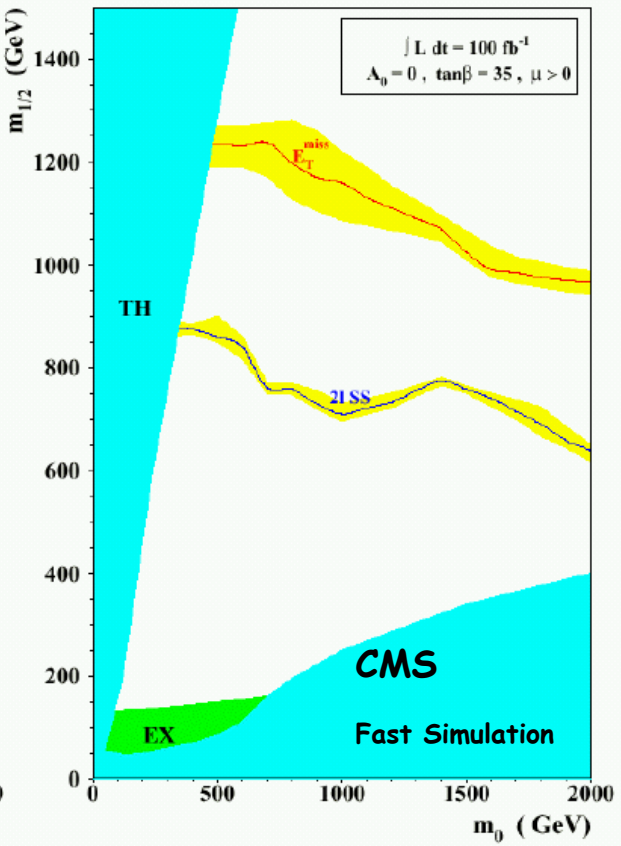
mSUGRA 2 SS Muon Systematic Studies

- **Earlier CMS Analysis:**
  - Studied effect of different normalisations
    - Background
    - Signal
  - Used fast simulation

Signal +/- 30%



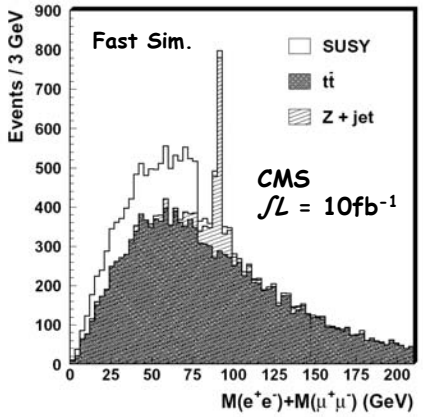
Background +100% / -50%

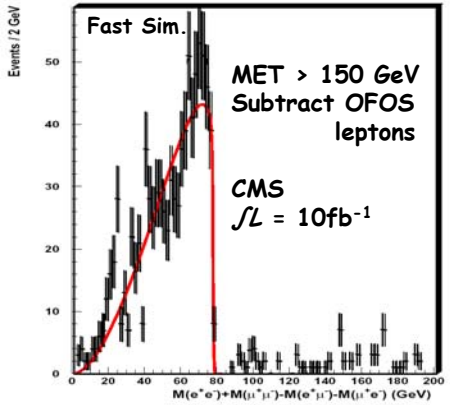


mSUGRA Sparticle Reconstruction

Post-LEP SUSY point B (m_0 = 100 GeV, $m_{1/2}$ = 250 GeV, tanβ = 30, μ >0)

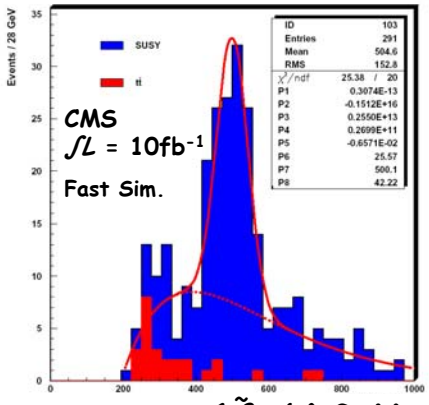
Studied with fast simulation
Main cuts: MET, dilepton Mass, E(b-jet), b-tag





Fit:
$M(\tilde{\chi}^0_1)$ = 79±2 GeV

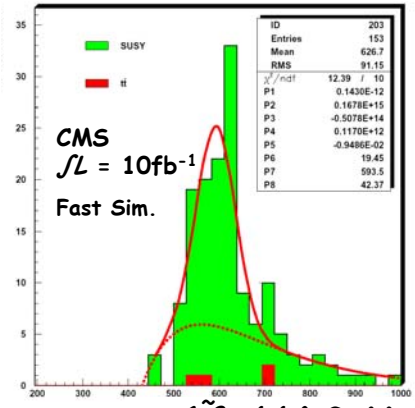
Generated:
$M(\tilde{\chi}^0_1)$ = 78 GeV



$m(\tilde{\chi}^0_2\, b)$ GeV

Fit:
$M(\tilde{b})$ = 500±7 GeV
σ_M = 42 GeV

Generated:
$M(\tilde{b}_L)$ = 496 GeV
$M(\tilde{b}_R)$ = 524 GeV



$m(\tilde{\chi}^0_2\, bb)$ GeV

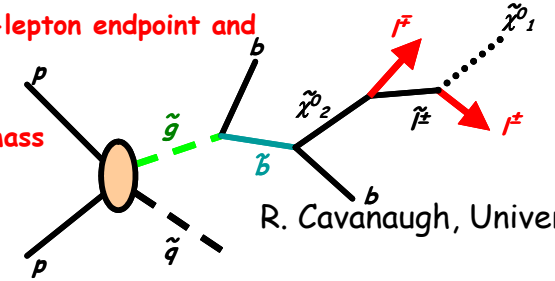
Fit:
$M(\tilde{g})$ = 594±7 GeV
σ_M = 42 GeV

Generated:
$M(\tilde{g})$ = 595 GeV

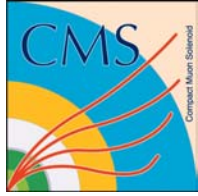
χ^0_2 decay kinematics ⇒
$m(ll)_{max} \approx m(\chi^0_2) - m(\chi^0_1)$
Sharp edge in $m(ll)$

Estimate $m(\chi^0_1)$ from di-lepton endpoint and
$m(\chi^0_2) \approx 2\, m(\chi^0_1)$

Approximation has only small affect on sbottom mass



σ x BR dominates



Summary

- $Z' \rightarrow 2\mu$
  - Achieves Tevatron reach (~1 TeV) very early (0.1 fb^{-1})
  - 2.6-3.4 TeV for 10 fb^{-1}
- Higgs $\rightarrow 4\mu$
  - 200 – 400 GeV could be discovered with 20 fb^{-1}
  - <140 GeV requires additional running
- Squarks and Gluinos
  - 10 fb^{-1} allows SS 2μ search to reach
    - up to 600 GeV Gluino masses
    - at least to 1600 GeV Squark masses
  - 10 fb^{-1} even allows sparticle reconstructon for Post-LEP SUSY point B

Conclusion

- The prospects are excellent for new physics searches involving leptons at CMS, even right at LHC turn on!
  - Z'
  - Higgs
  - Sparticles

- All expectations presented here assume a good understanding of the CMS detector
  - To preserve the early physics potential, this must be achieved as rapidly after start-up as possible
  - Work ongoing to understand how systematic effects will affect the early reach potential of CMS