SUSY Multilepton Search at CMS

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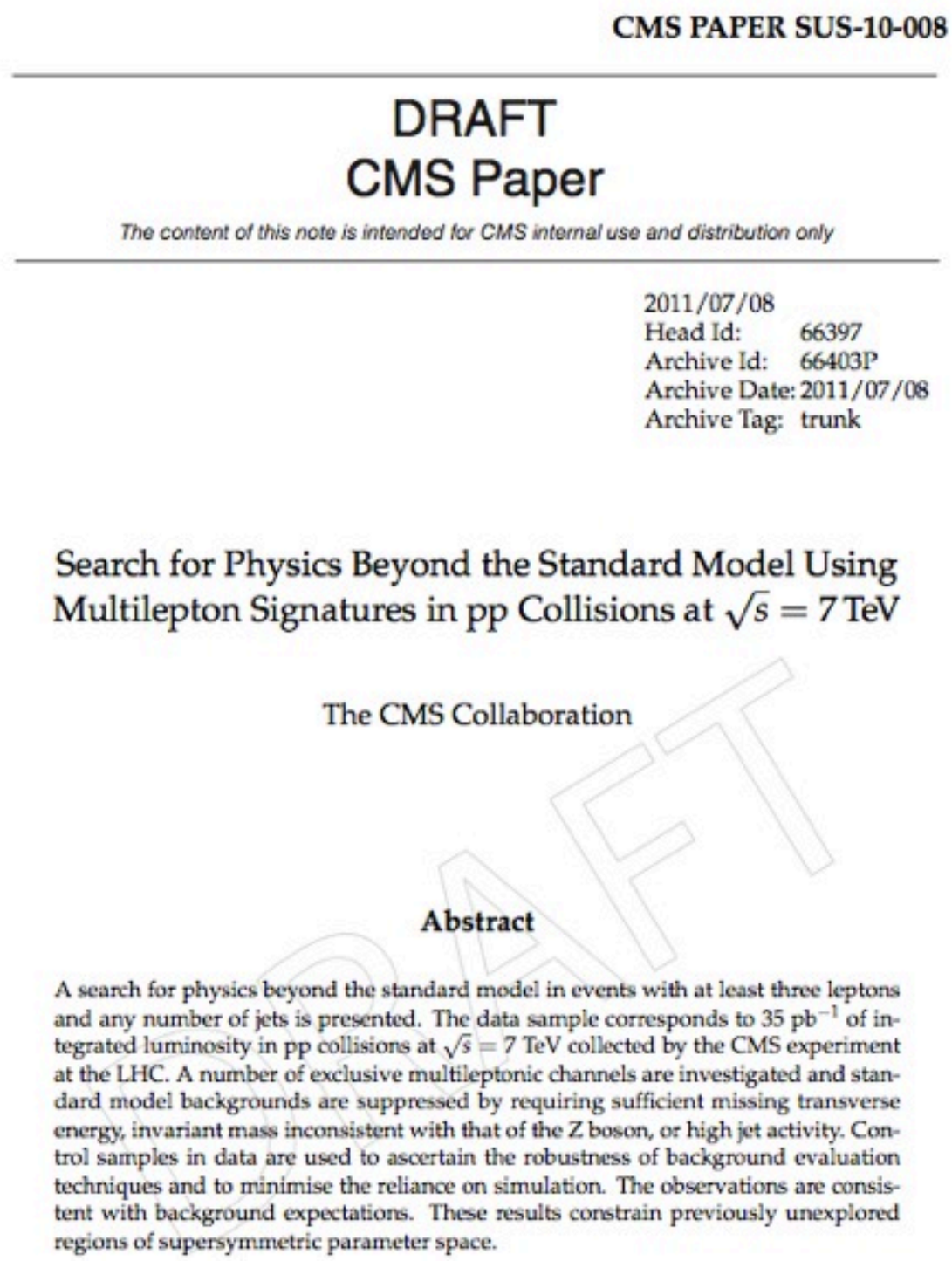
Outline

- LHC and CMS Detector
- *Data Taking*
- Motivation
- *Analysis*
- *2011 Plan*



CMS PAPER SUS-10-008

DRAFT
CMS Paper

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Search for Physics Beyond the Standard Model Using Multilepton Signatures in pp Collisions at $\sqrt{s} = 7$ TeV

The CMS Collaboration

Abstract

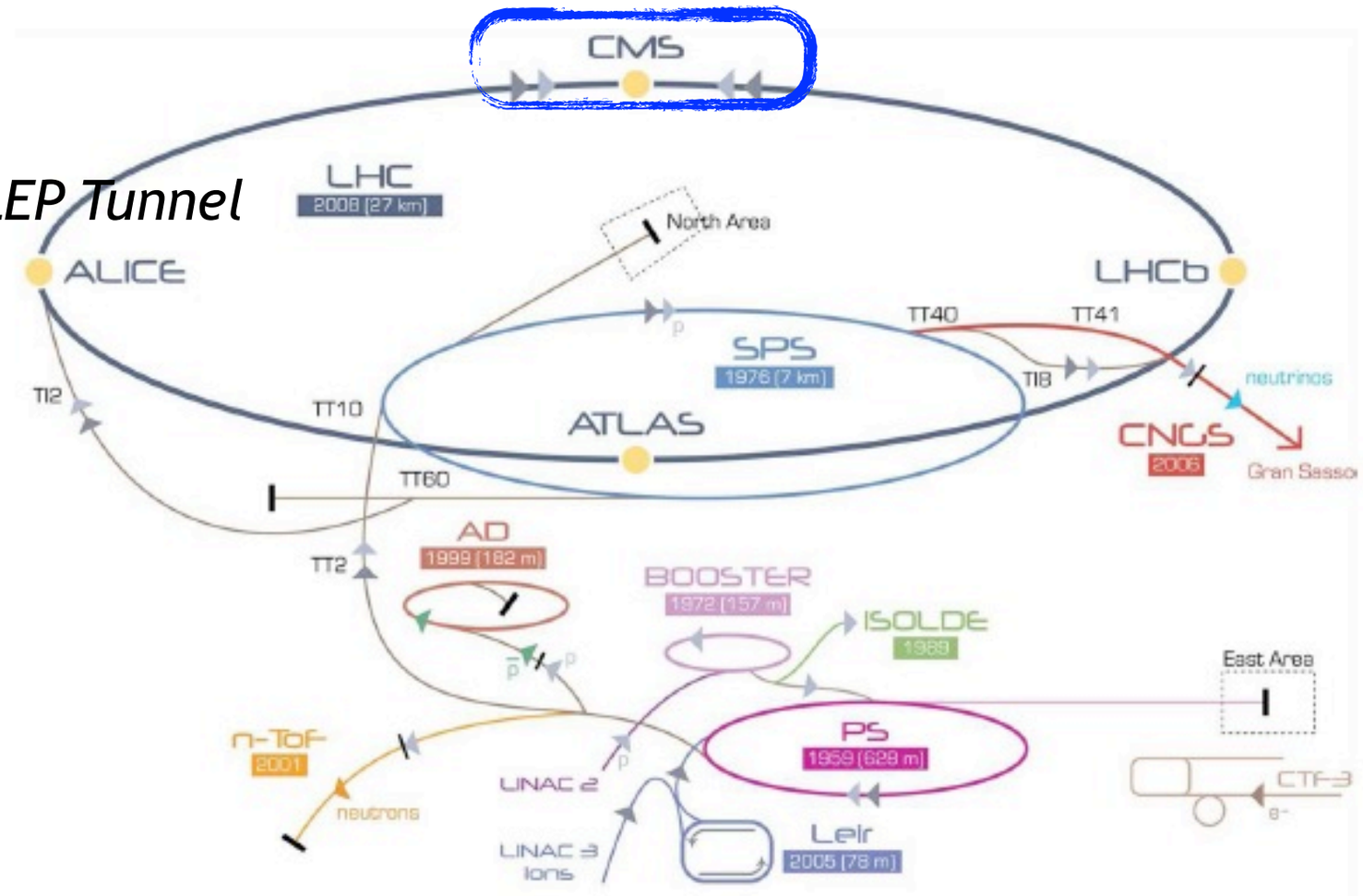
A search for physics beyond the standard model in events with at least three leptons and any number of jets is presented. The data sample corresponds to 35 pb^{-1} of integrated luminosity in pp collisions at $\sqrt{s} = 7$ TeV collected by the CMS experiment at the LHC. A number of exclusive multileptonic channels are investigated and standard model backgrounds are suppressed by requiring sufficient missing transverse energy, invariant mass inconsistent with that of the Z boson, or high jet activity. Control samples in data are used to ascertain the robustness of background evaluation techniques and to minimise the reliance on simulation. The observations are consistent with background expectations. These results constrain previously unexplored regions of supersymmetric parameter space.

with Colorado, Rutgers, KIT 2010
submitted to PLB

LHC and CMS Detector

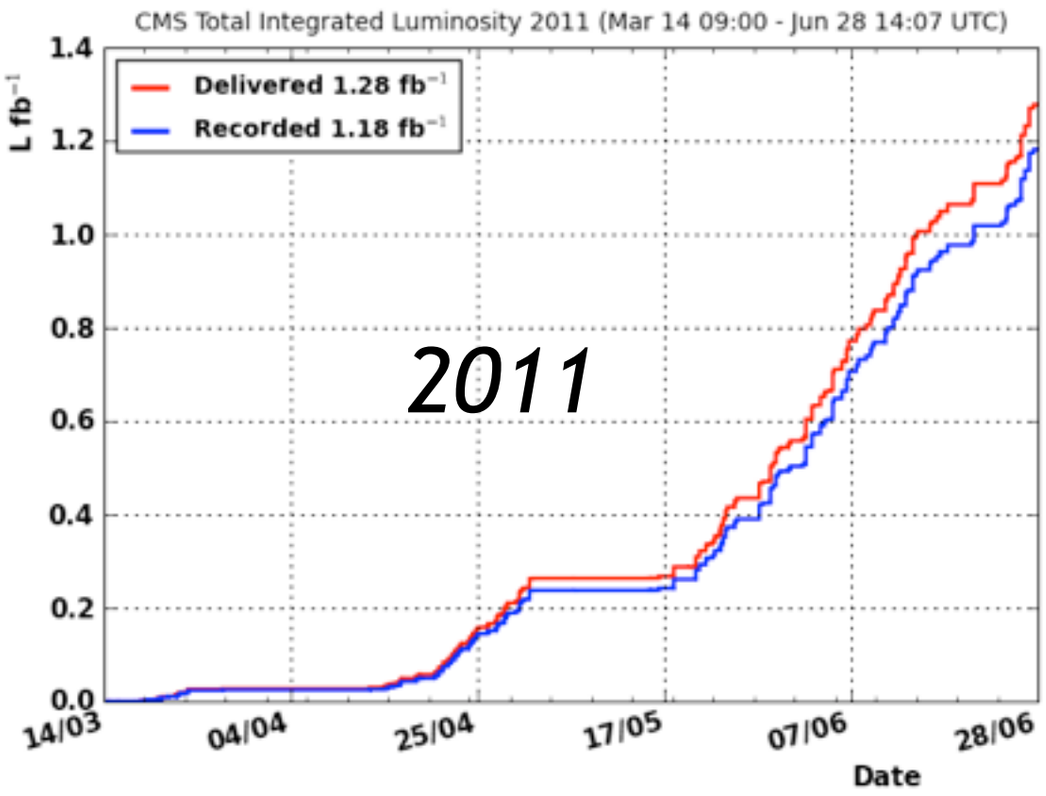
Large Hadron Collider

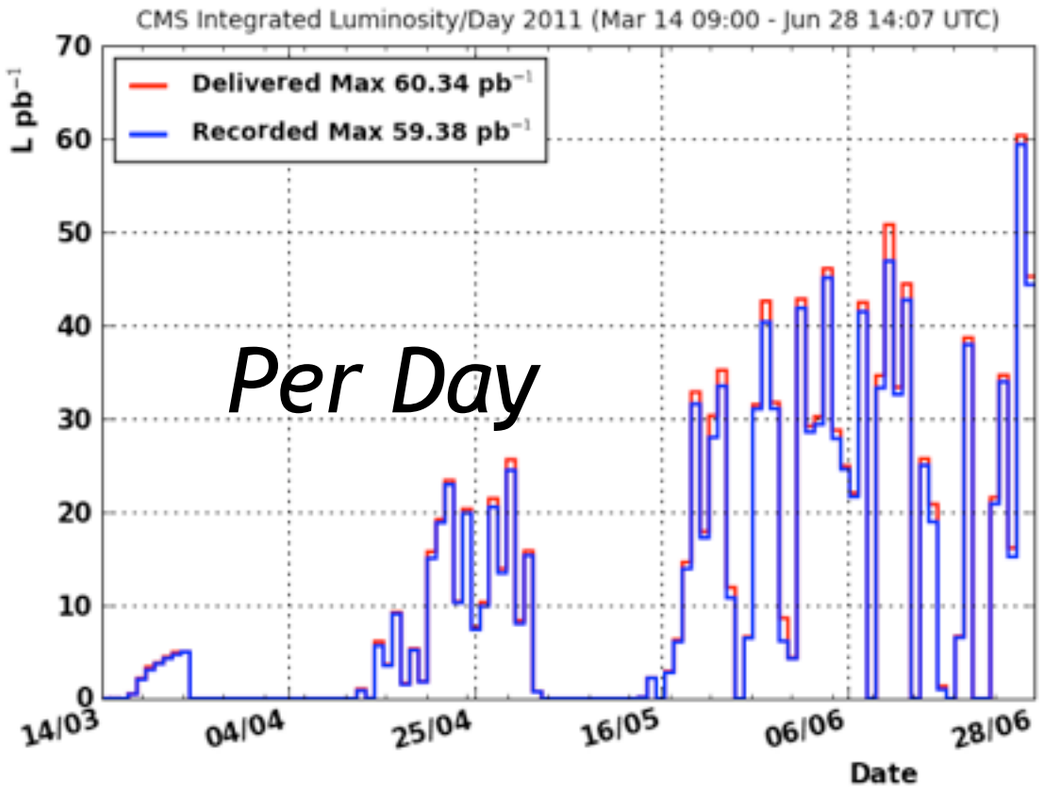
former LEP Tunnel



- Proton-proton beams
- 7 TeV center-of-mass energy (designed for 14 TeV)
- Peak inst. luminosity O($10^{33}cm^{-2}s^{-1}$) so far (designed for $10^{34}cm^{-2}s^{-1}$)
- Integrated luminosity O(fb^{-1}) in 2011

Integrated Luminosity

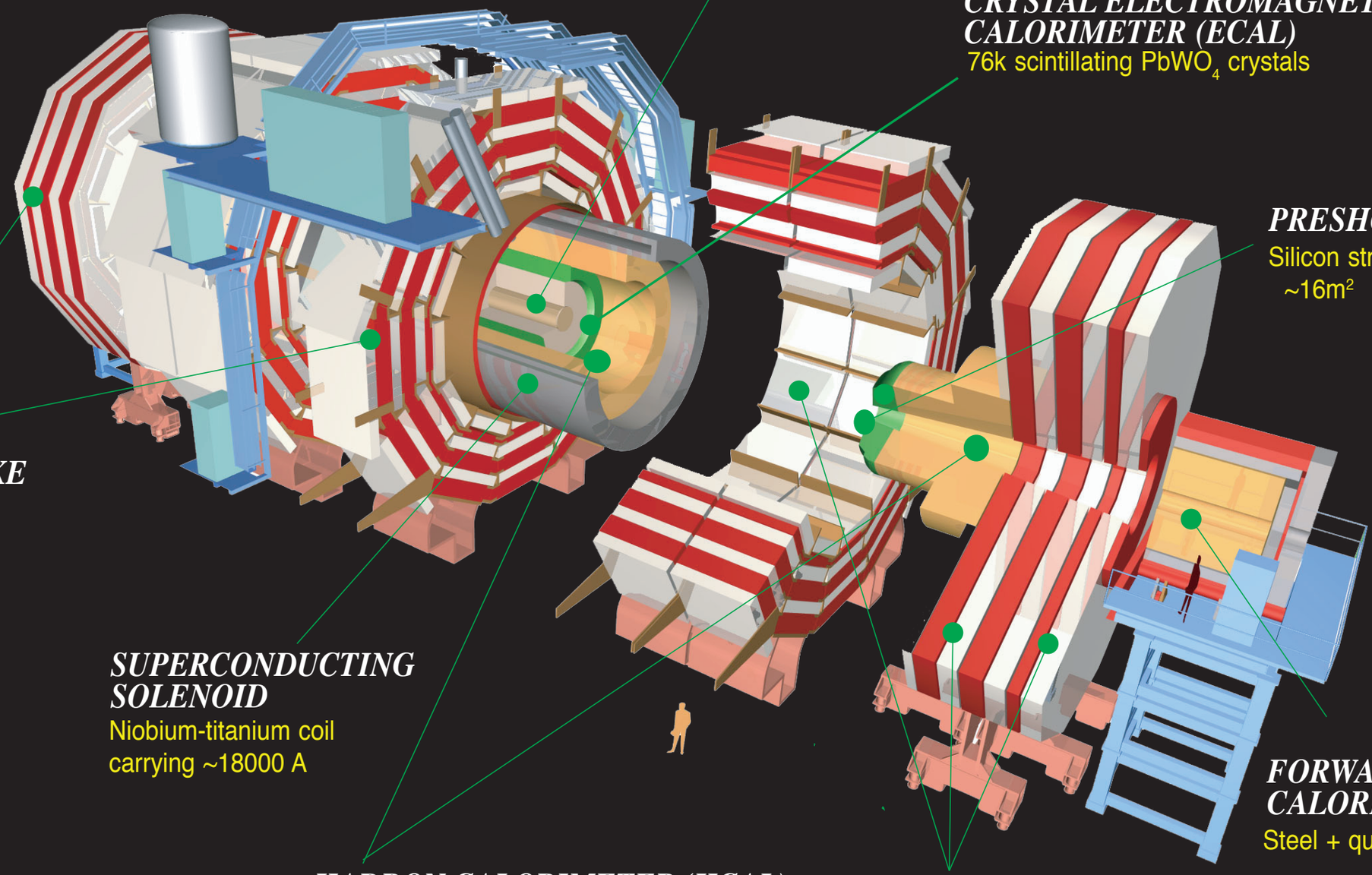




- Collected more than $1fb^{-1}$ already
- Few more fb^{-1} before Heavy Ion runs

CMS Detector

Pixels
Tracker
ECAL
HCAL
Solenoid
Steel Yoke
Muons



SILICON TRACKER
Pixels (100 x 150 μm²)
~1m² 66M channels
Microstrips (50-100μm)
~210m² 9.6M channels

CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
76k scintillating $PbWO_4$ crystals

PRESHOWER
Silicon strips
~16m² 137k channels

STEEL RETURN YOKE
~13000 tonnes

SUPERCONDUCTING SOLENOID
Niobium-titanium coil
carrying ~18000 A

HADRON CALORIMETER (HCAL)
Brass + plastic scintillator

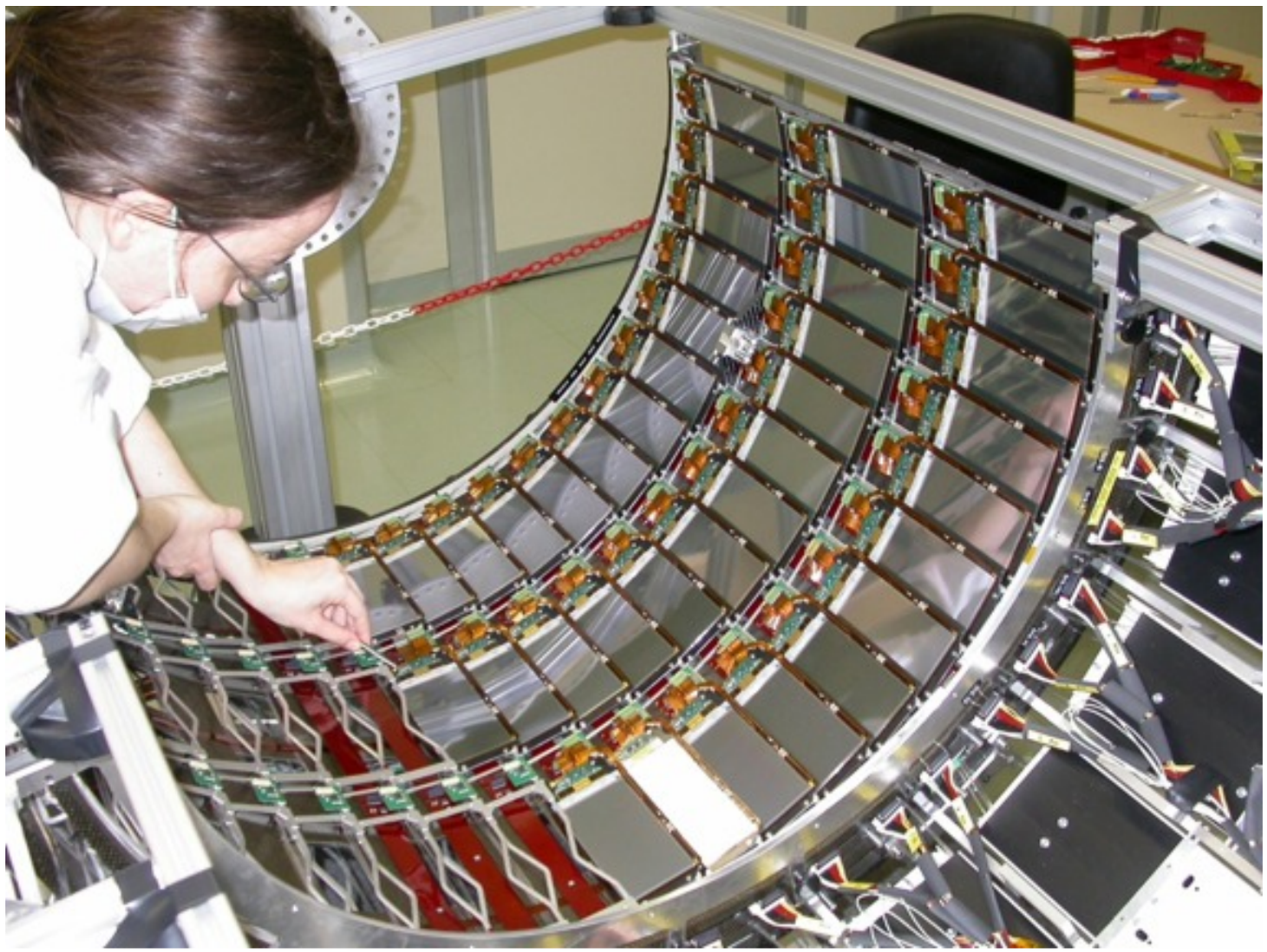
FORWARD CALORIMETER
Steel + quartz fibres

MUON CHAMBERS
Barrel: 250 Drift Tube & 500 Resistive Plate Chambers
Endcaps: 450 Cathode Strip & 400 Resistive Plate Chambers

Total weight : 14000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T

Inner Tracker

Silicon Pixel and Strip



By combining 66 million pixel and 9.6 million strip channels, p_T resolution =

$$\frac{\delta p_T}{p_T} = 0.15 p_T[\mathrm{TeV}] \oplus 0.005$$

Charge sharing improves spatial resolution to 10μm-17μm range

Calorimeters

ECal, HCal

- *ECal is wholly active*
  -with lead tungstate crystals
- *HCal is a sampling calorimeter*
  -with brass-scintillator sandwich
- *ECal E_T resolution is*

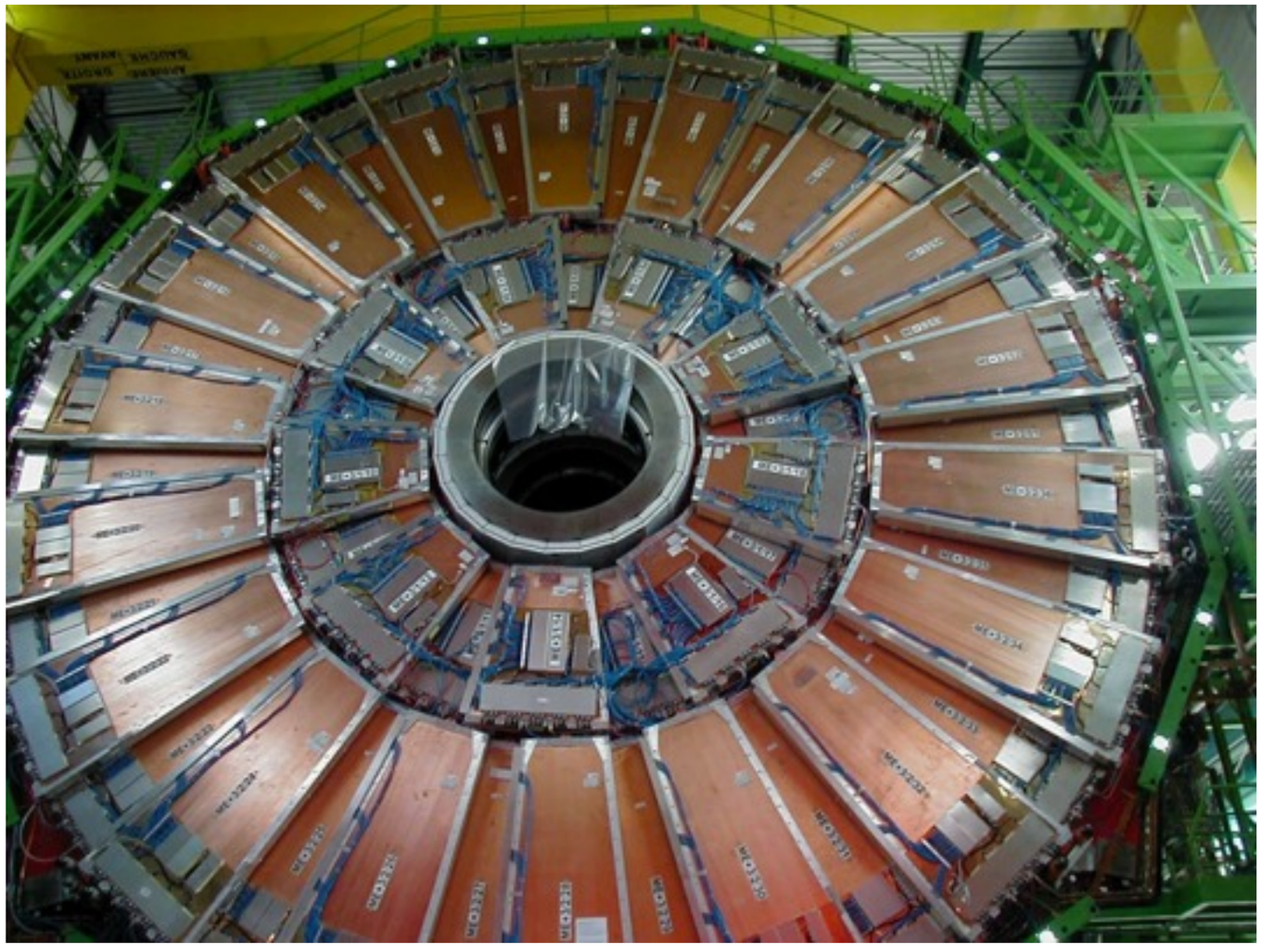
$$\frac{\sigma}{E} = \frac{0.028}{\sqrt{E}} \oplus \frac{0.12}{E} \oplus (0.003)$$

- *HCal E_T resolution is*

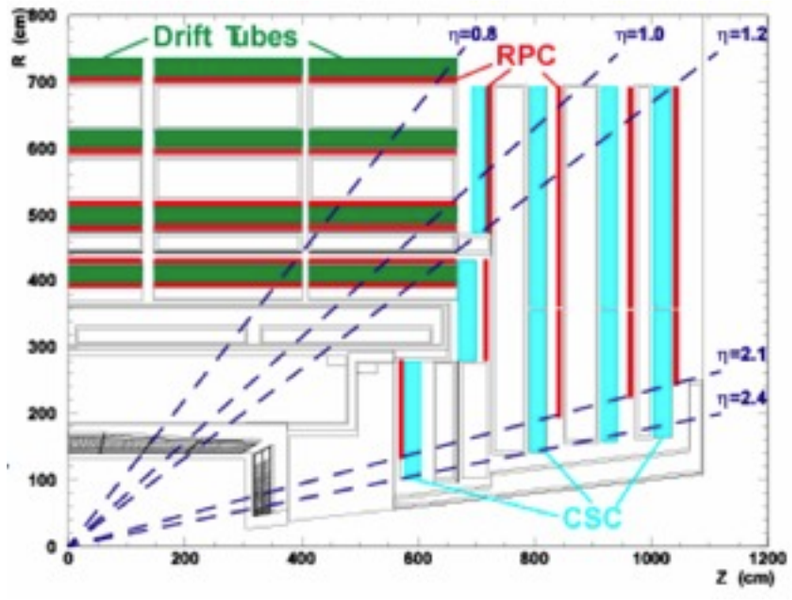
$$\frac{\Delta E}{E} = \frac{1.2}{\sqrt{E}} \oplus 0.069$$ *E in GeV*

Muon System

≡ DT, CSC, RPC



- *DT & CSC spatial resolution = 100μm-250μm*
- *CSC works fine with high particle flux and inhomogeneous B-fields*
- *RPC response is fast and used for triggering*



Muon System uses 3 different technologies

Data Taking

Data Quality Monitoring

- Central and Sub-detector shifters check status of detectors and qualities of data taken online and offline

DQM operation 24/7 (P5 and remote)

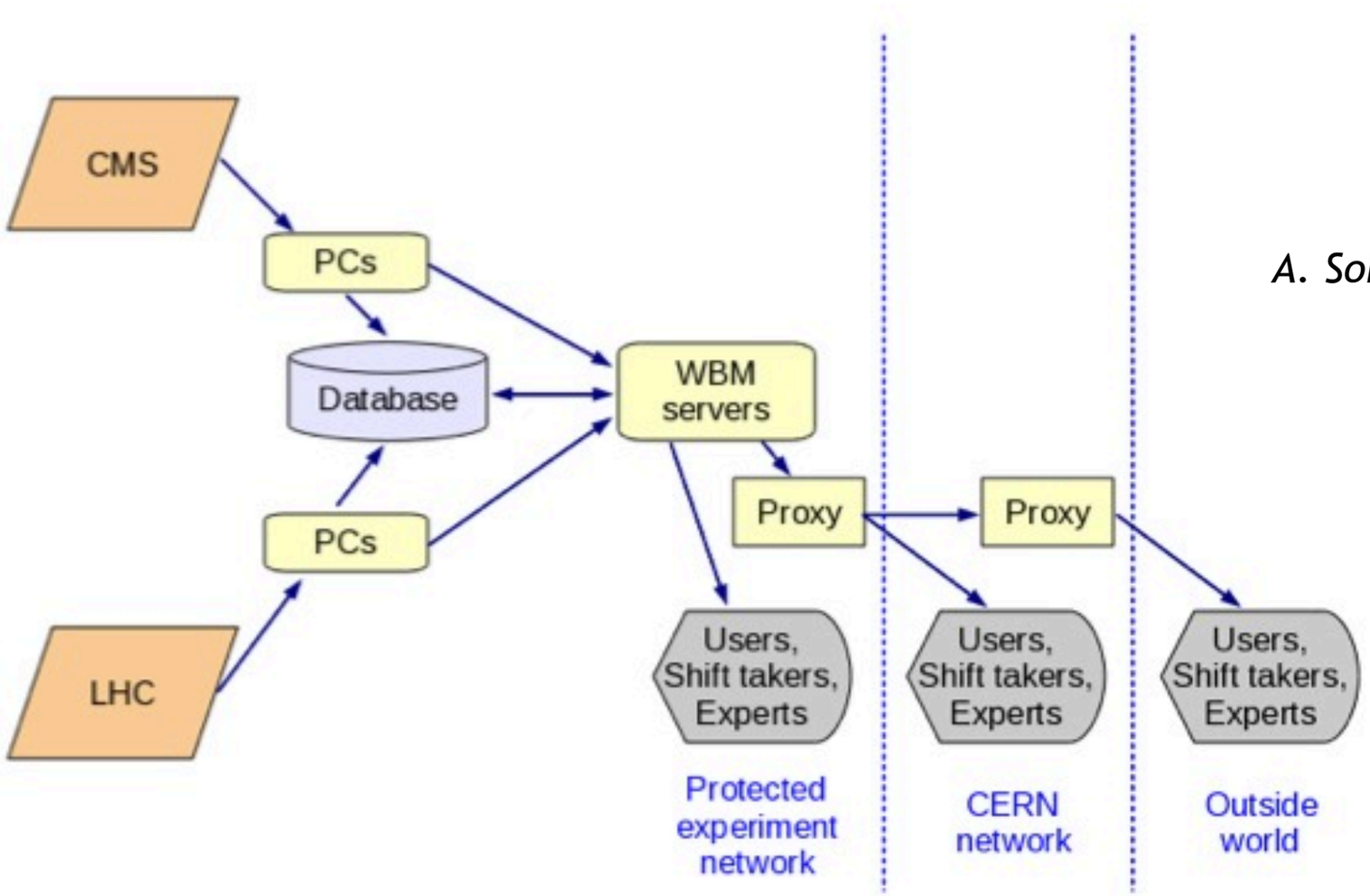
- *Fermilab is one of remote centers*

Web Based Monitoring

- *led by Fermilab scientists*
- *provides various services; RunSummary, FillSummary, BunchFill, ShiftAccountingTools, TriggerRates, TriggerHistory, and so on*

Web Based Monitoring

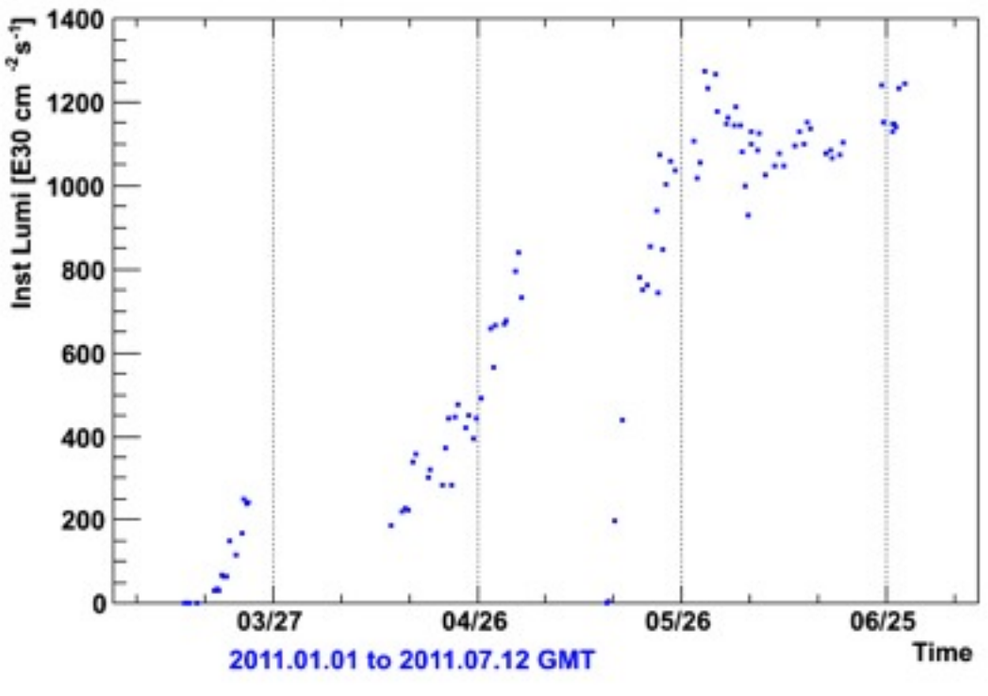
- All you need is Web Browser to use
- Collects various data about beam and run
- Typically information retrieved with queries



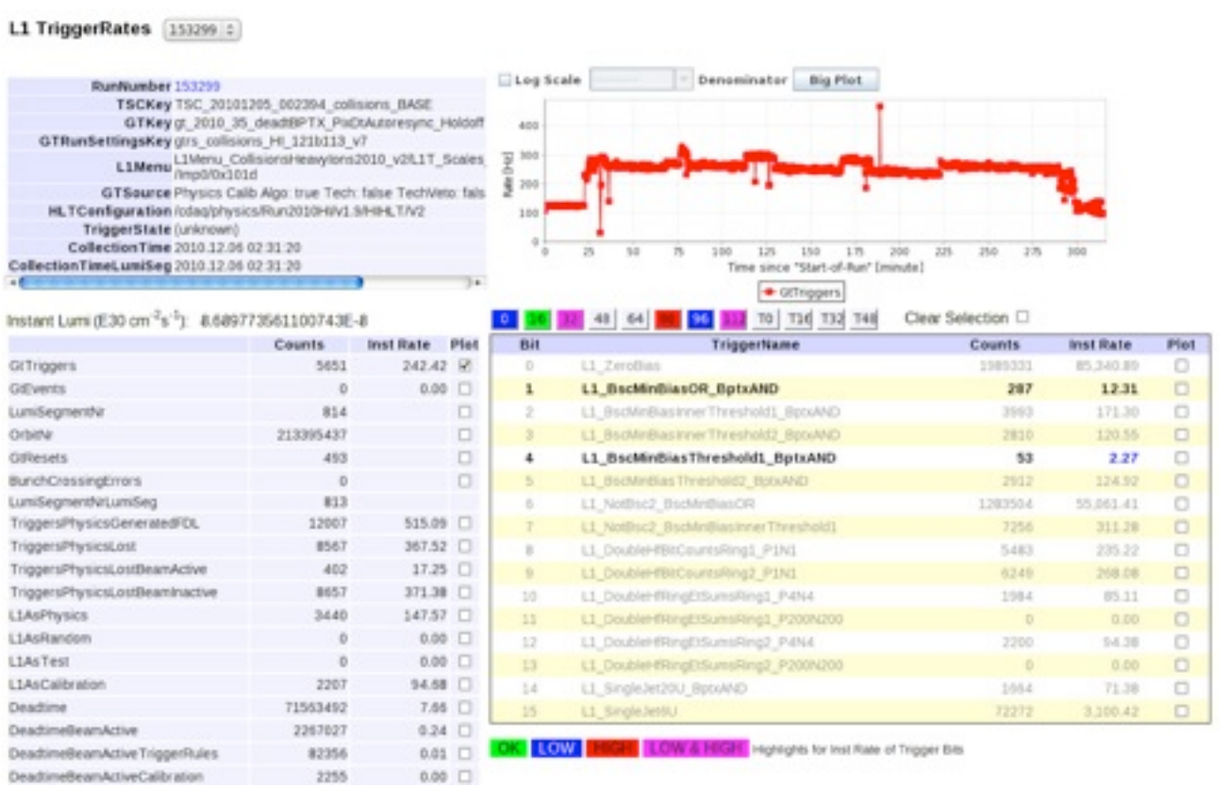
A. Soha et al

Trigger Rate Monitoring

- Trigger menu is revised every other week
  - given fast inst. lumi increase
- Need to monitor new paths carefully



Peak Lumi

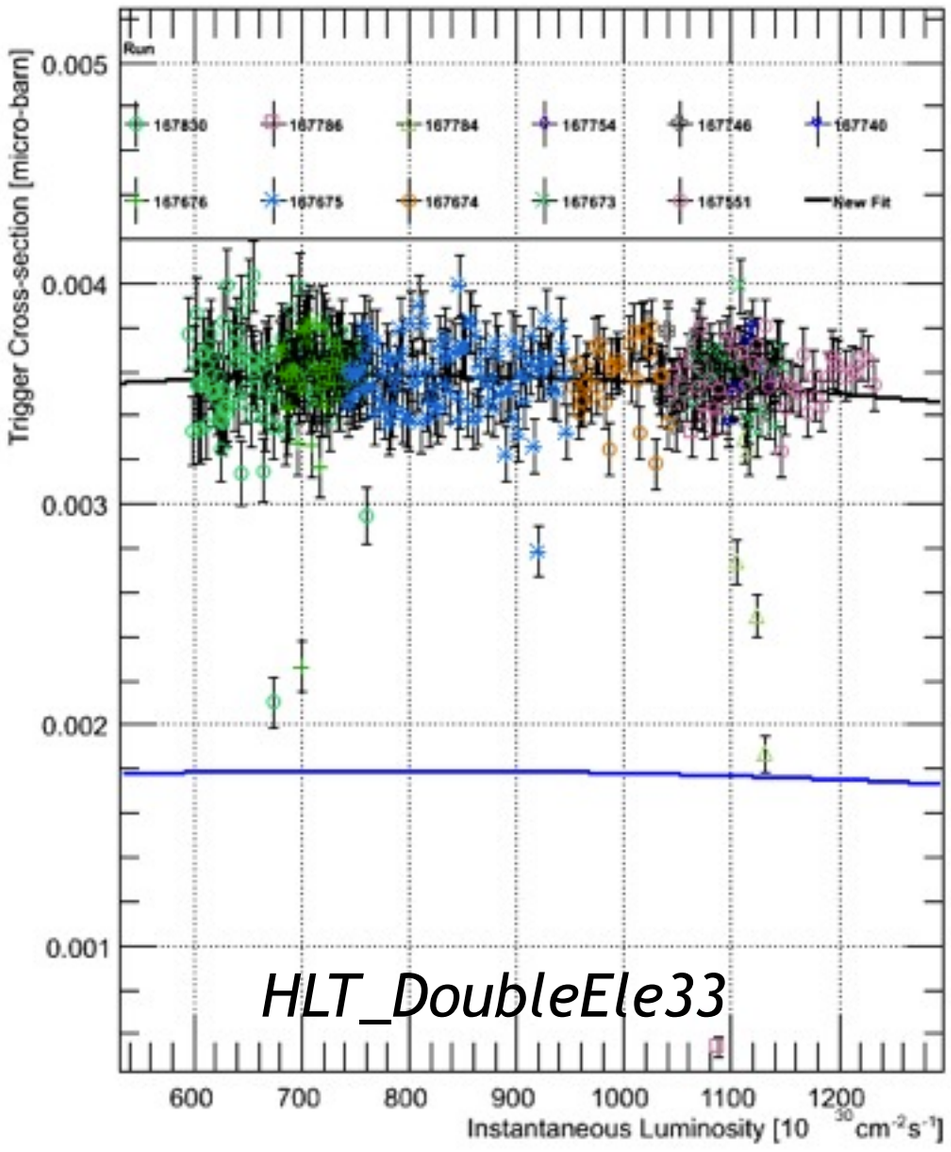


WBM provides Online check

WBM TriggerHistory

Trigger cross section = trigger rate divided by inst. lumi

- **plotting trigger cross section everyday to check inst. lumi dependence of trigger paths**
  - Checks online trigger rates with 'good' fit results to spot abnormal hike/drop
  - Helps trigger menu design with higher inst. lumi
- **Main customer of Level1 trigger paths = trigger group**
- **Main customer of HighLevel trigger paths = Physics analysis groups**



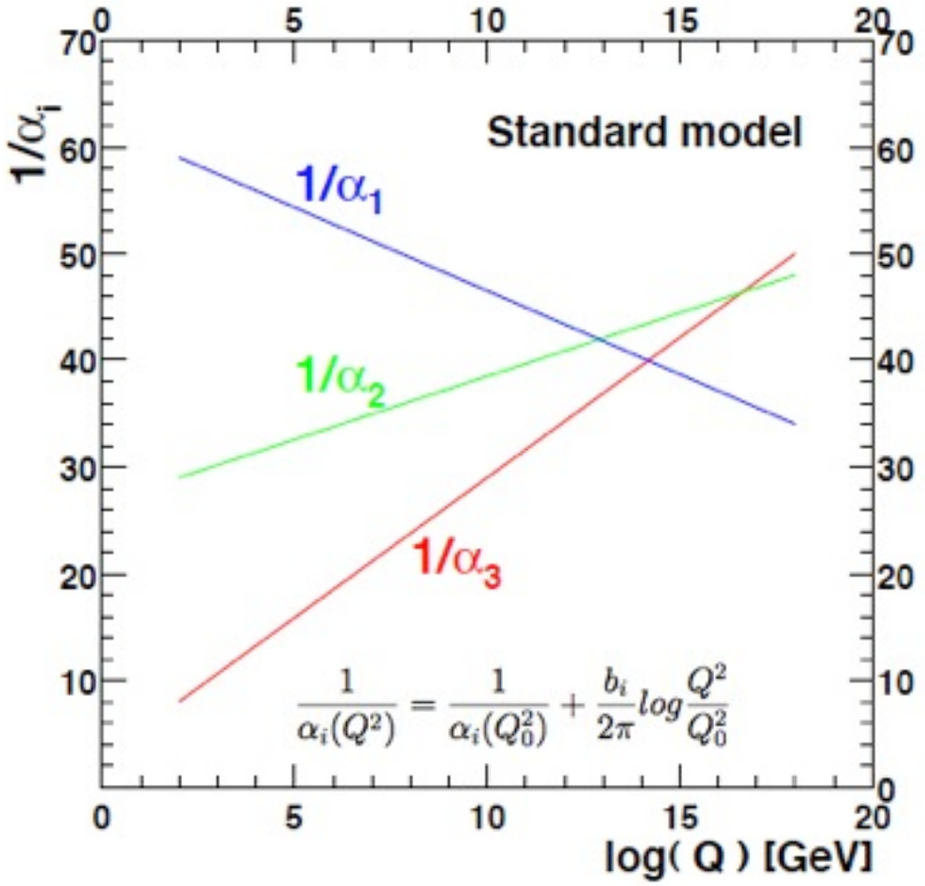
Main developers are Zongru and Maruyama

Motivation

Problems in SM

- **SM higgs boson**
  - LEP Ewk Fit + LEP bound (1σ)
  - LEP Ewk precision measurements A_{FB} (3σ)
  - Needs fine tuning to stabilize mass
- **No grand unification of theories**
- **Astrophysics**
  - No cold dark matter candidate (23% of Universe's energy)

$$b_1 = 0 - \frac{4}{3}N_F - \frac{1}{10}N_H$$
$$b_2 = \frac{22}{3} - \frac{4}{3}N_F - \frac{1}{6}N_H$$
$$b_3 = 11 - \frac{4}{3}N_F + 0$$



$$\frac{1}{\alpha_i(Q^2)} = \frac{1}{\alpha_i(Q_0^2)} + \frac{b_i}{2\pi} log\frac{Q^2}{Q_0^2}$$

W. deBoer, 1991

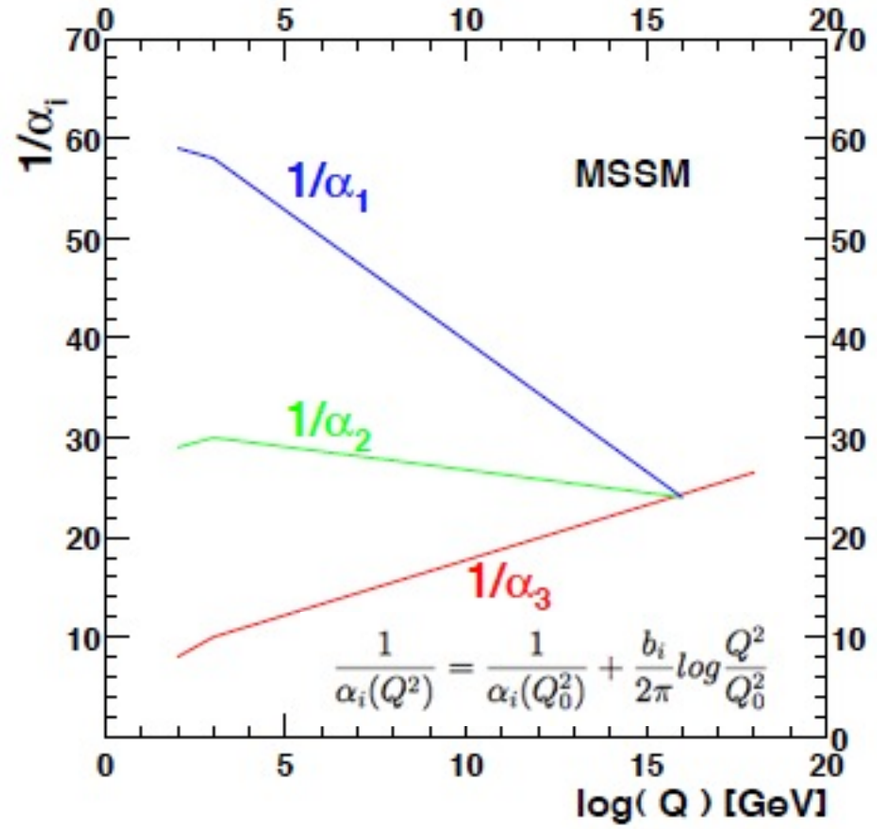
Great even if one of them can be solved

SUSY

- Supersymmetry = symmetry between fermions and bosons
  - Less severe fine tuning
  - Nearly doubles #particles
  - Grand Unification
  - Provides a dark matter candidate(if R-parity conserved)

$$R\text{-parity} = (-1)^{2S}(-1)^{3B+L}$$

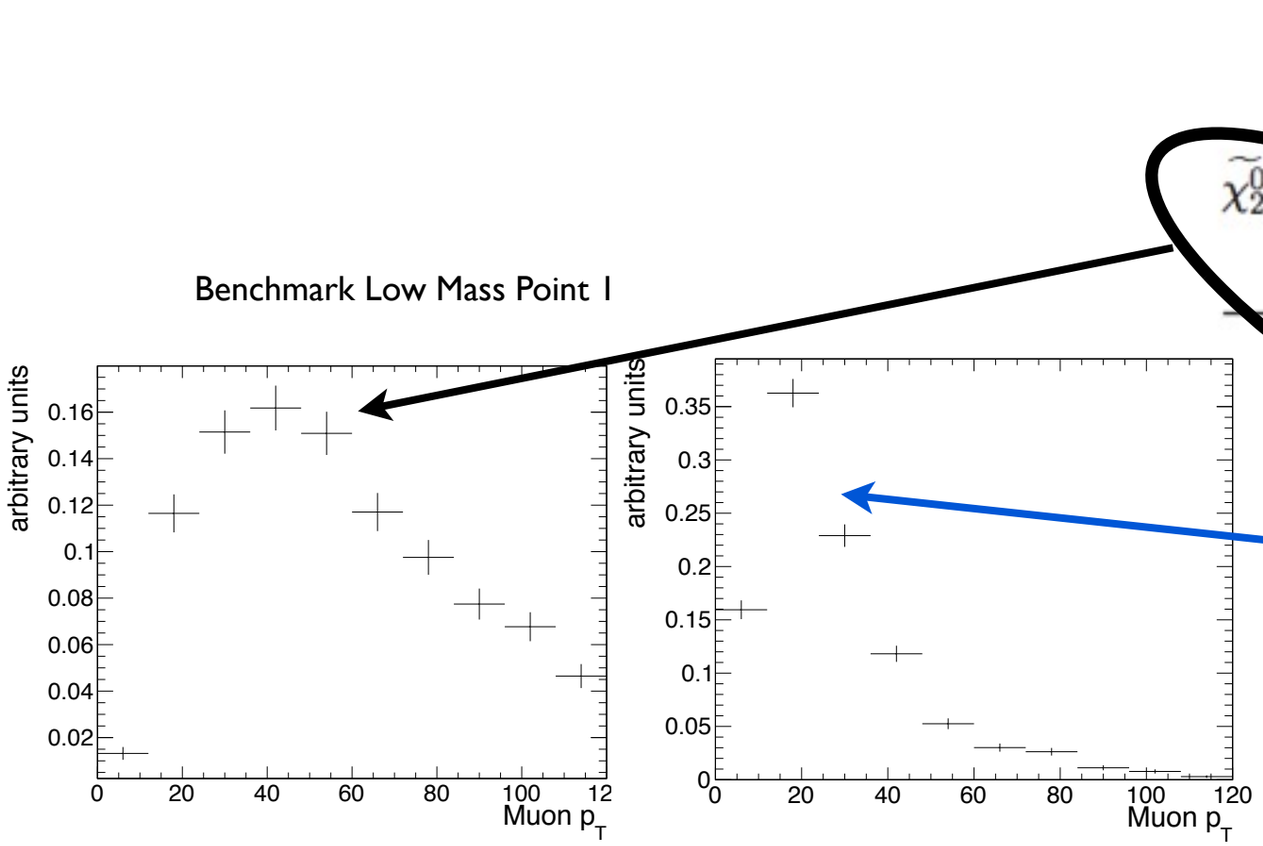
$$b_1 = 0 - 2N_F - \frac{3}{10}N_H$$
$$b_2 = 6 - 2N_F - \frac{1}{2}N_H$$
$$b_3 = 9 - 2N_F - 0$$



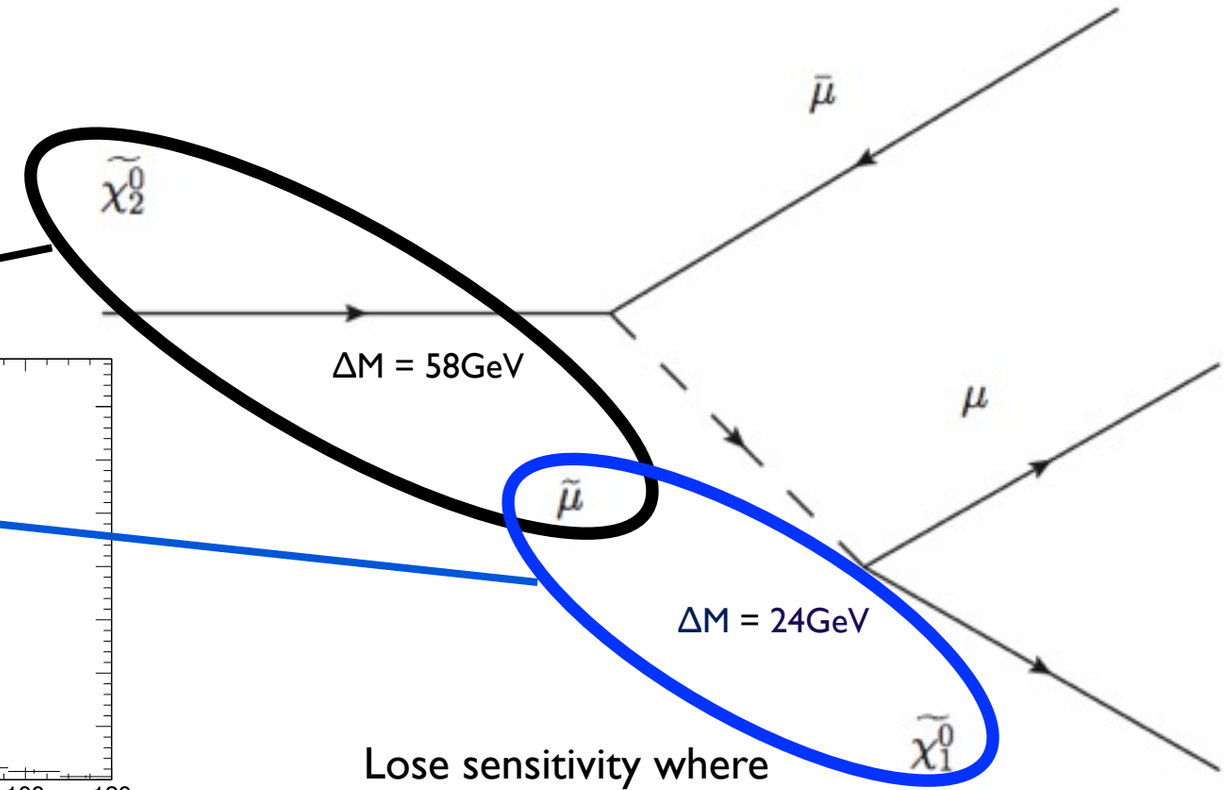
W. deBoer, 1991

SUSY Phenomenology

- Lightest SUSY Particles are stable → *large MET*
  - if R-parity(SUSY-ness) is conserved
- Mass difference between LSP and other SUSY particles roughly sets p_T spectra for decay products



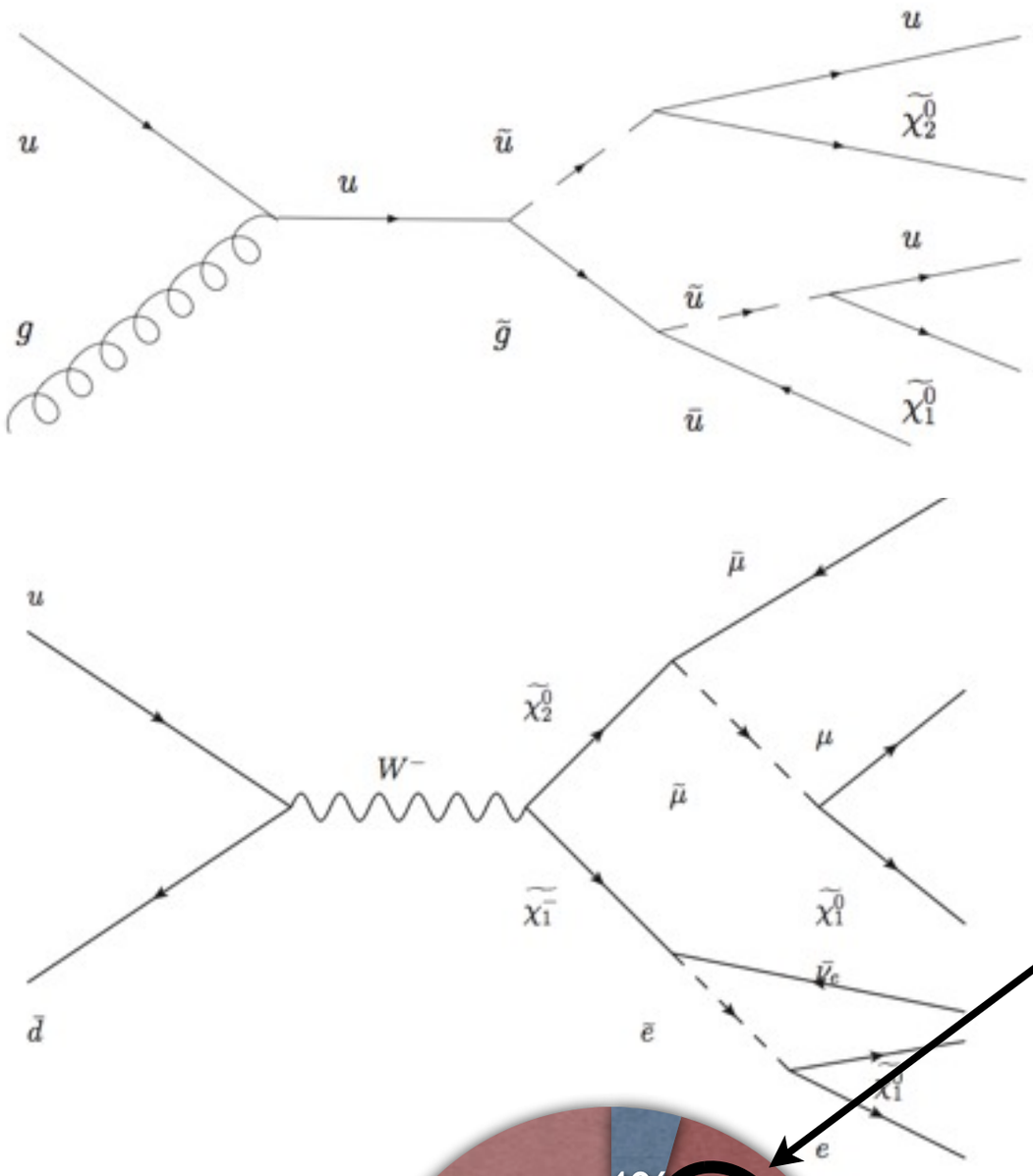
plots normalized to unity



Lose sensitivity where
ΔMs become small

Analysis

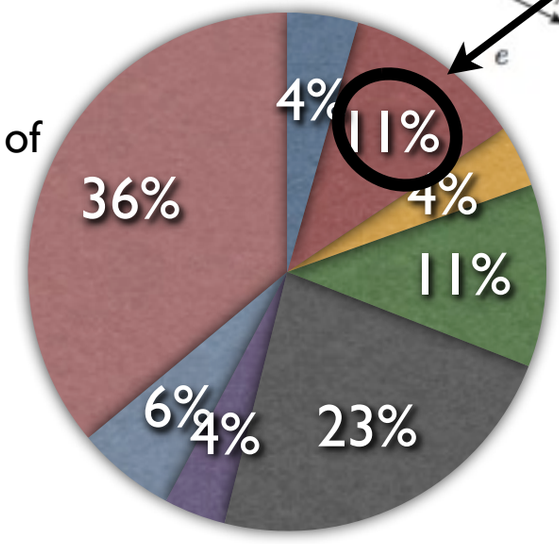
SUSY Multilepton Production



- **Cascade decay**
  - Higher cross section O(10pb)
  - Multilepton + high hadronic activities + MET

- **neutralino/chargino pair production**
  - Smaller cross section O(pb)
  - Multilepton + MET

Subprocess fraction of Low Mass Point 1 Cross section



mSUGRA, Slepton co-NLSP, and RPV scenarios are considered

Theories

- **mSUGRA**
  - Unification at GUT scale (leaves 5 parameters)
  - Assumes Supergravity fields break SUSY
  - Used as a benchmark in CMS
- **Slepton co-NLSP**
  - A subset of Gauge mediated SUSY breaking model
    - *Sets the weak and strong SUSY breaking scales separately*
  - NNLSPs (neutralino, chargino) decay to NLSPs (sleptons) & leptons
- **R-parity Violating SUSY**
  - Baryon number is conserved but Lepton number is violated (to be consistent with proton decay)
  - LSPs decay to leptons
    - *No dark matter candidate*

Search Channels

- Require at least 3 good leptons
- Include at most 2 taus
- 24 channels

tau = hadronic decaying tau

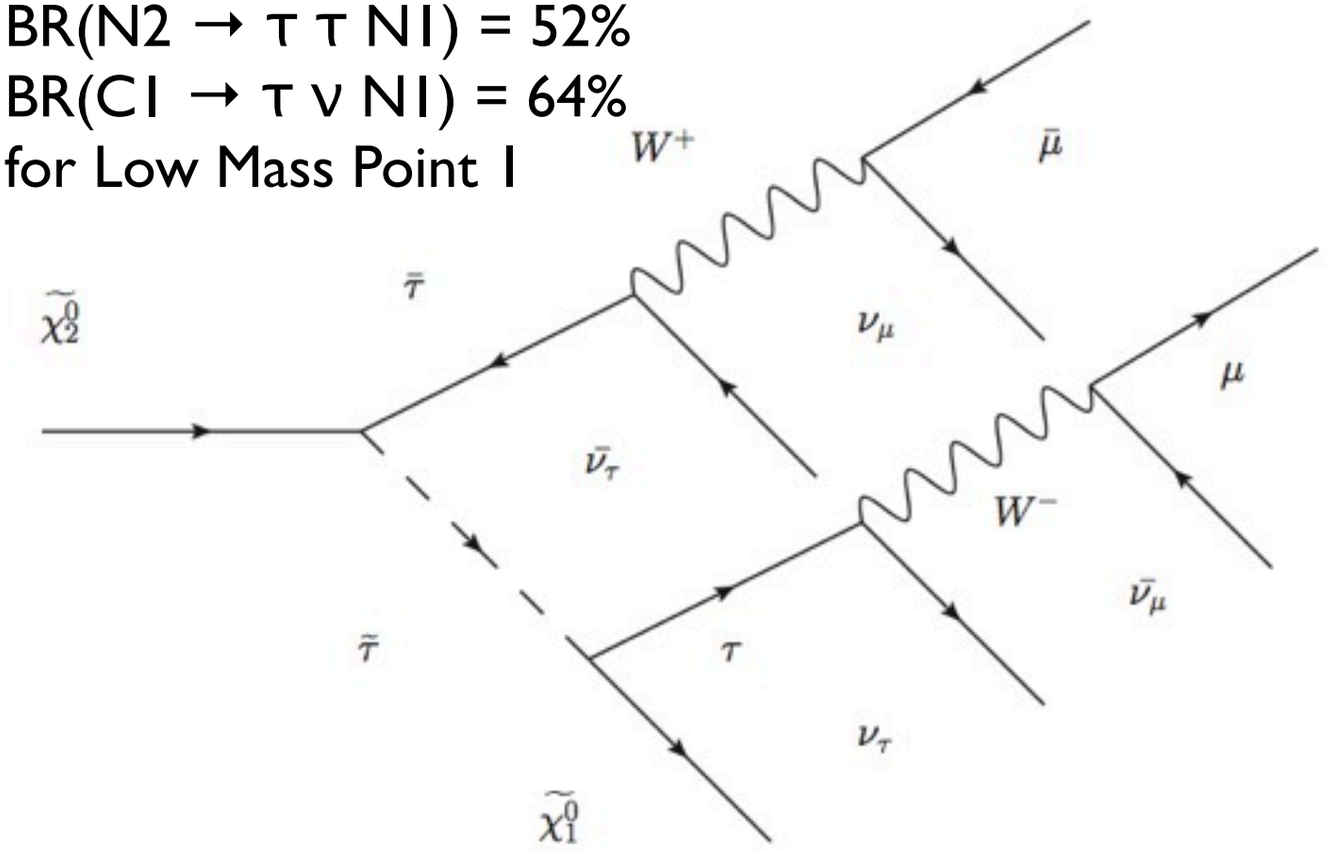
  - 4 or more leptons
    - *Ordered in #(muons) to avoid ambiguity*
      - 4e + 1m → 3e + 1m + X channel

same flavor trilepton	same flavor OS and LS	full flavor OS and LS modes	4 or more leptons
eee, μμμ	eeμ, eeτ, μμe, μμτ	eμτ	eeee, eeeμ, eeμμ, eμμμ, μμμμ, μμμτ, μμττ, eμττ, eeττ, eeeτ, eeμτ, eμμτ

Inclusion of Taus

- BR(N2→ττN1) and BR(C1→τνN1) can be higher than other lepton modes when tanß is high
- Even if no enhancement, more events (signal and BG)

BR(N2 → τ τ N1) = 52%
BR(C1 → τ ν N1) = 64%
for Low Mass Point 1



• Taus decay to e/μ which become softer due to extra neutrinos

BR(tau)

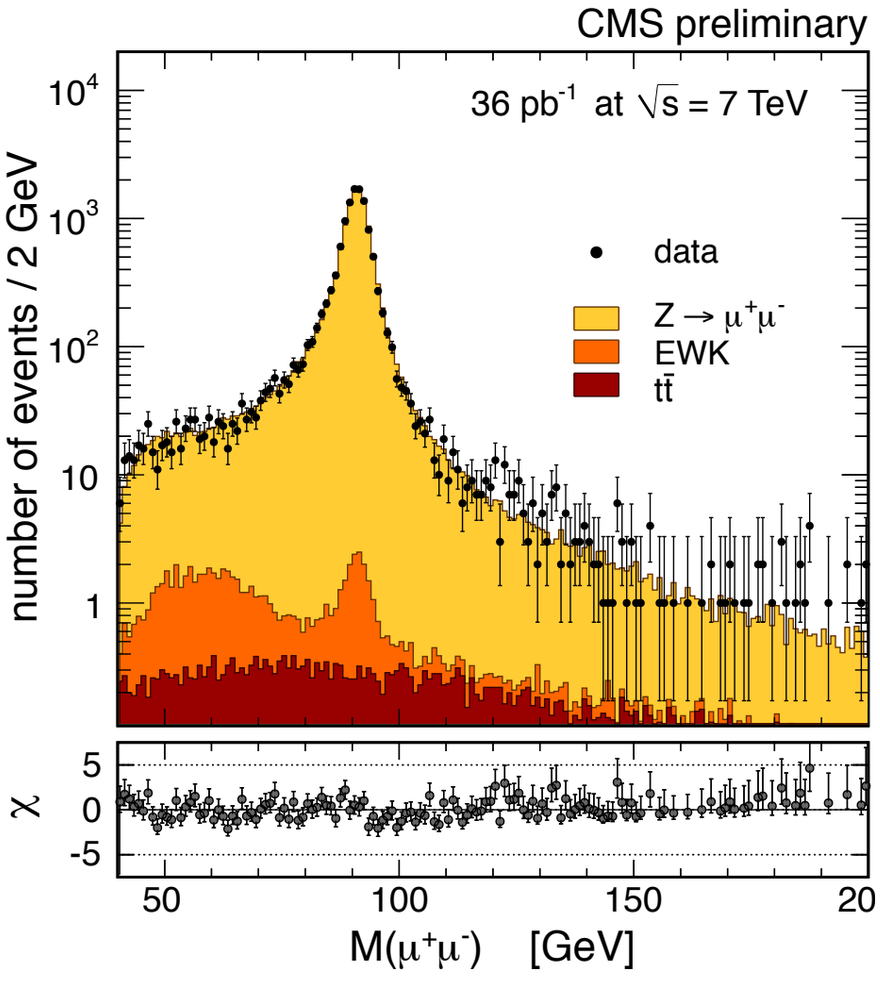
$\mu^- \bar{\nu}_\mu \nu_\tau$ (17.36±0.05) %

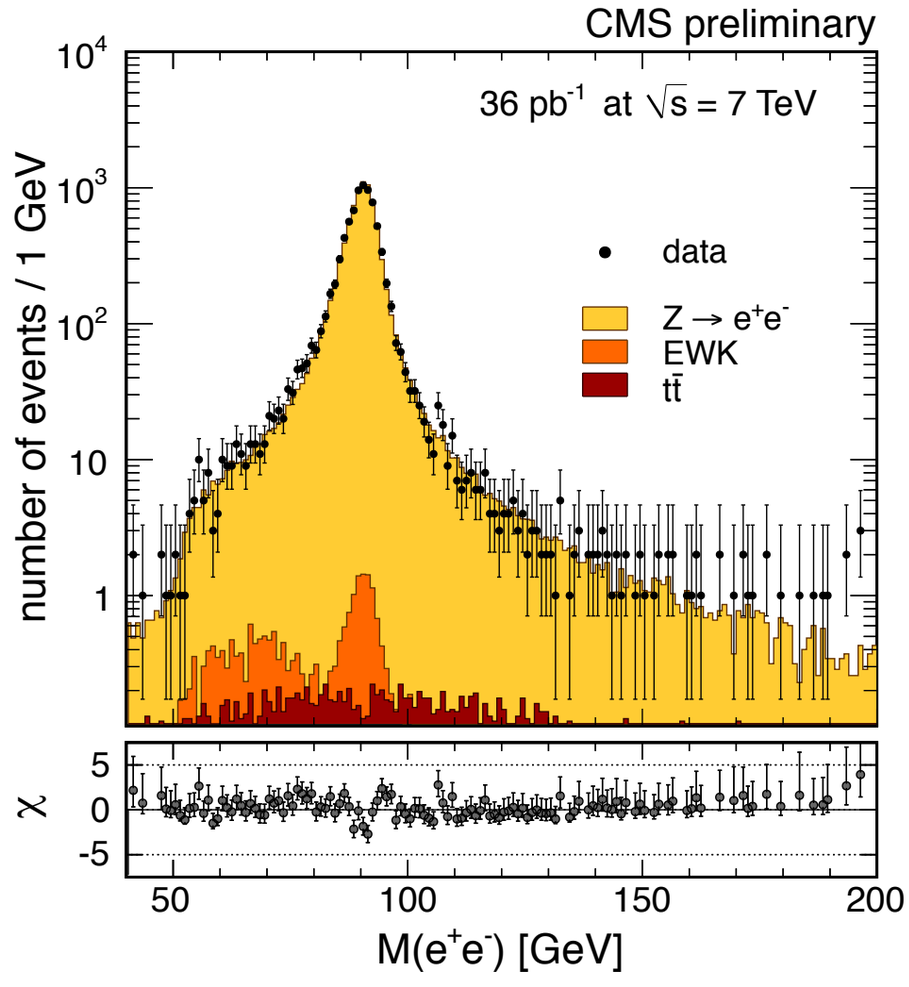
$e^- \bar{\nu}_e \nu_\tau$ (17.85±0.05) %

Muon & Electron Selection

Using standard selection developed by Physics Object Groups

- $p_{\mathrm{T}} \geq 8$ GeV/c
- $|\eta| \leq 2.1$
- $(TrackerIso + ECALIso + HCALIso)/p_{\mathrm{T}} < 0.15$





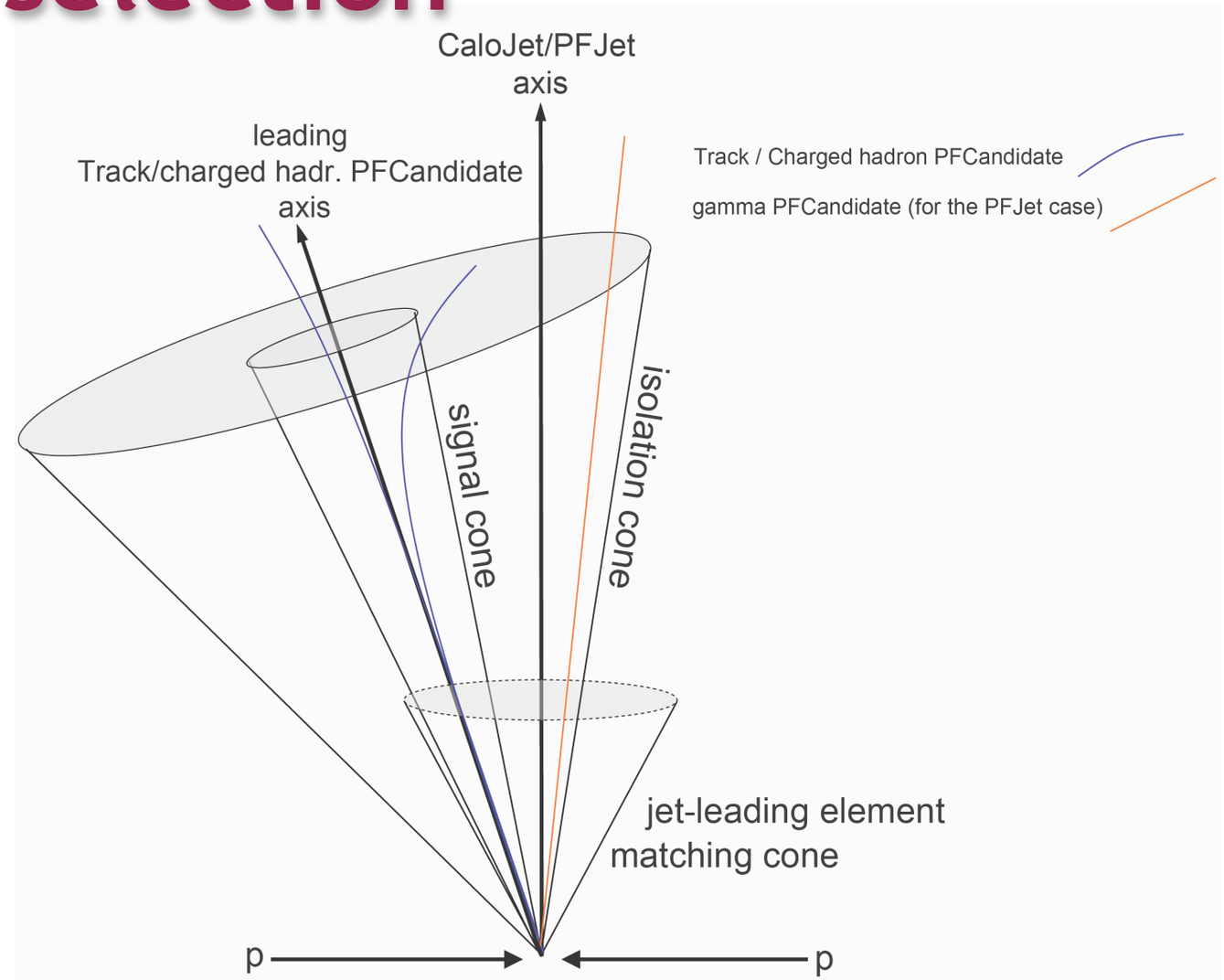
Tau Selection

- Using Shrinking Cone
  - One of LPC Tau contributions
- Using standard selection

- $p_T \geq 8$ GeV/c
- $|\eta| \leq 2.1$

Isolation requirements

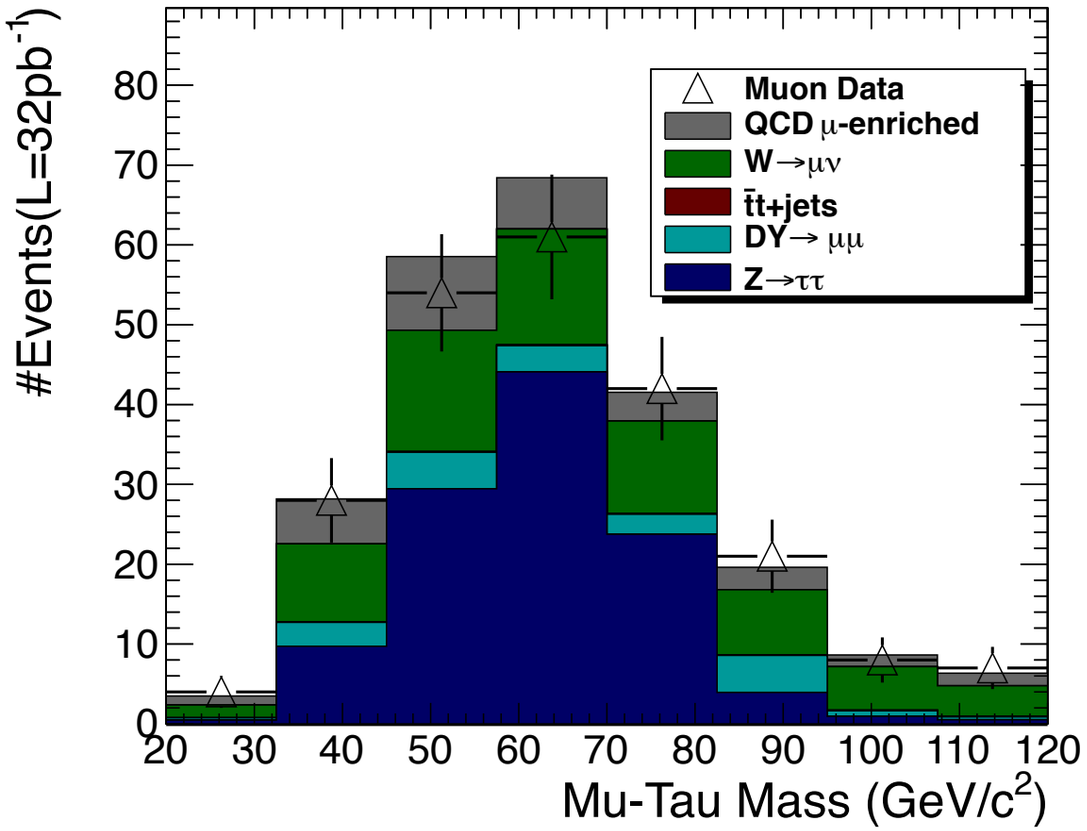
- No track with $p_T > 1$ GeV/c
- No γ with $E_T > 1.5$ GeV



Tau Validation

Additional Checks are done for Taus

- *Template Fit technique to determine Uncertainty of Isolation*



- *Require a pair of isolated good muon and loose tau*
- *Fit visible mass distribution with loose and tight tau selection with MC Templates*

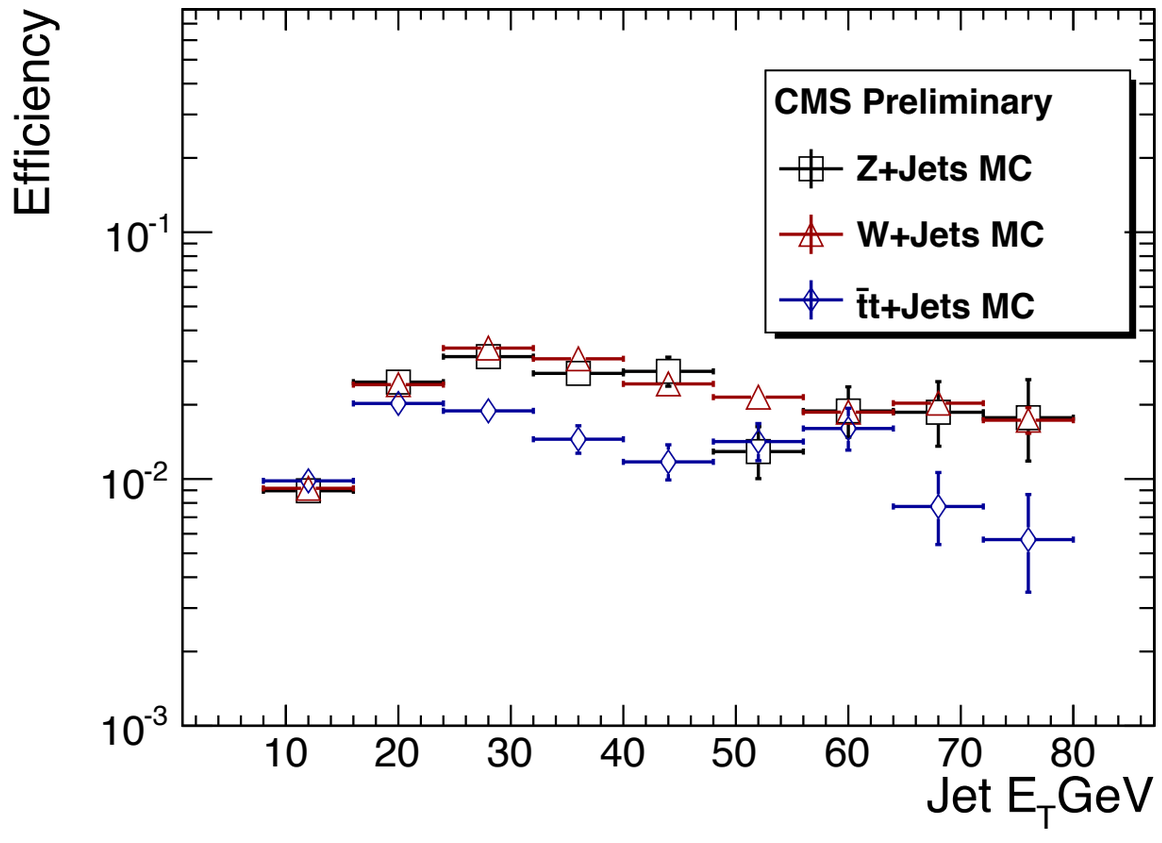
- *Random Cone technique to check effect of high hadronic activities*
  - *~1% difference between MC and data*
- *MC Embedding technique to check effect of PUs*
  - *Select Z→μμ Data, where one of muon is isolated*
  - *Replace one of muon legs with a tau*
  - *Check tau isolation*
    - ✳ *MC Data Ratio = 0.97 +/- 0.02*

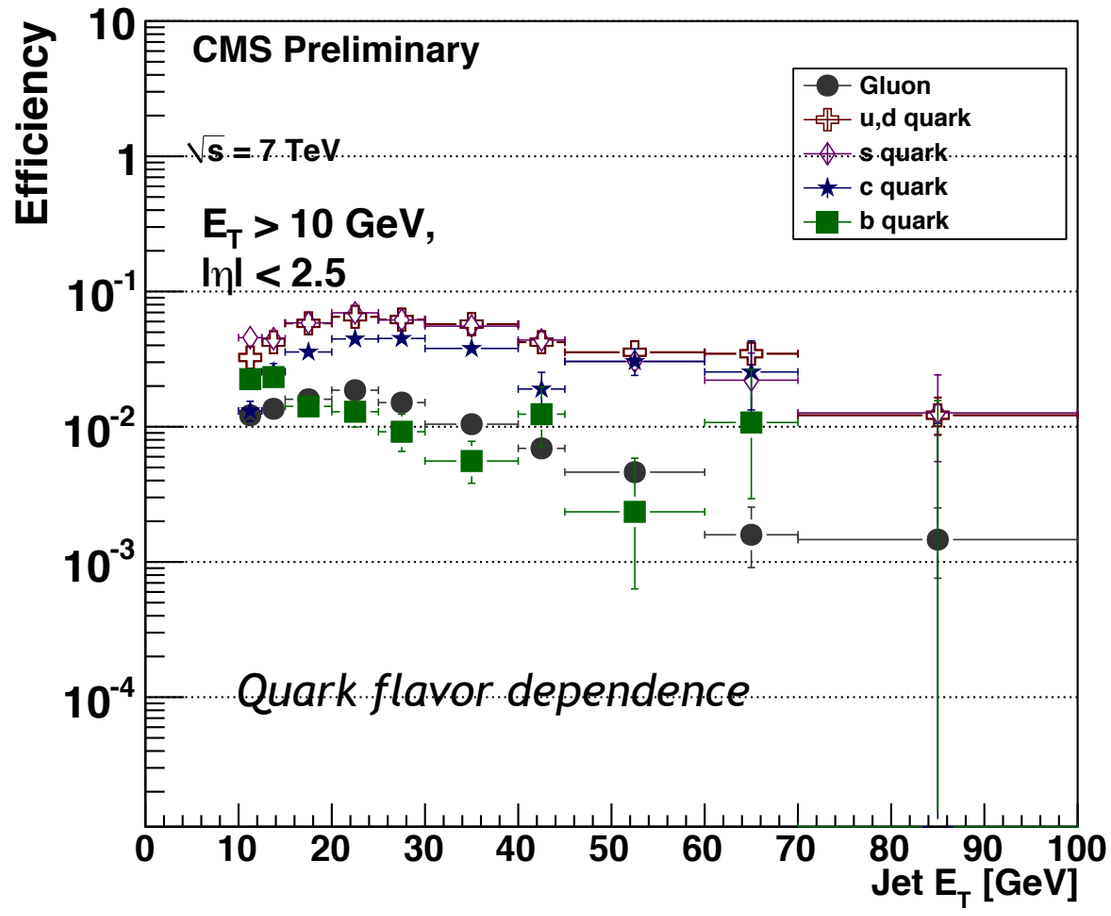
Overall tau ID uncertainty dominated by the uncertainty from the template fit ~30%

Tau Fake Rate

Sample	Estimated #Events / #Events after tauID (%)
W+jets MC	101.6 ±7.9
Z+jets MC	96.8 ±7.6
$t\bar{t}$ +jets MC	73.0 ±5.7
$1\mu + E_{\mathrm{T}}^{\mathrm{miss}}$ Data	115.5 ±9.0

- *Fake rate = #(denominator + tau ID) / #(Jets)*
- *Fake rate is extracted from Z-like data*
- *and tested with W-like data and MC samples*

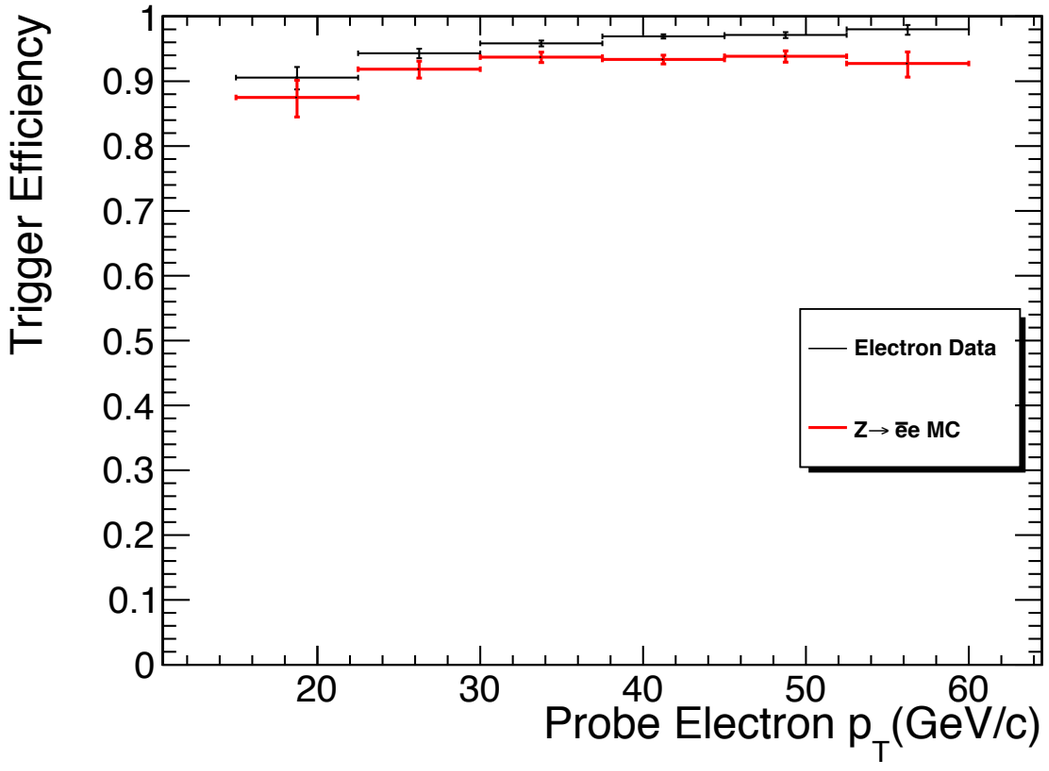


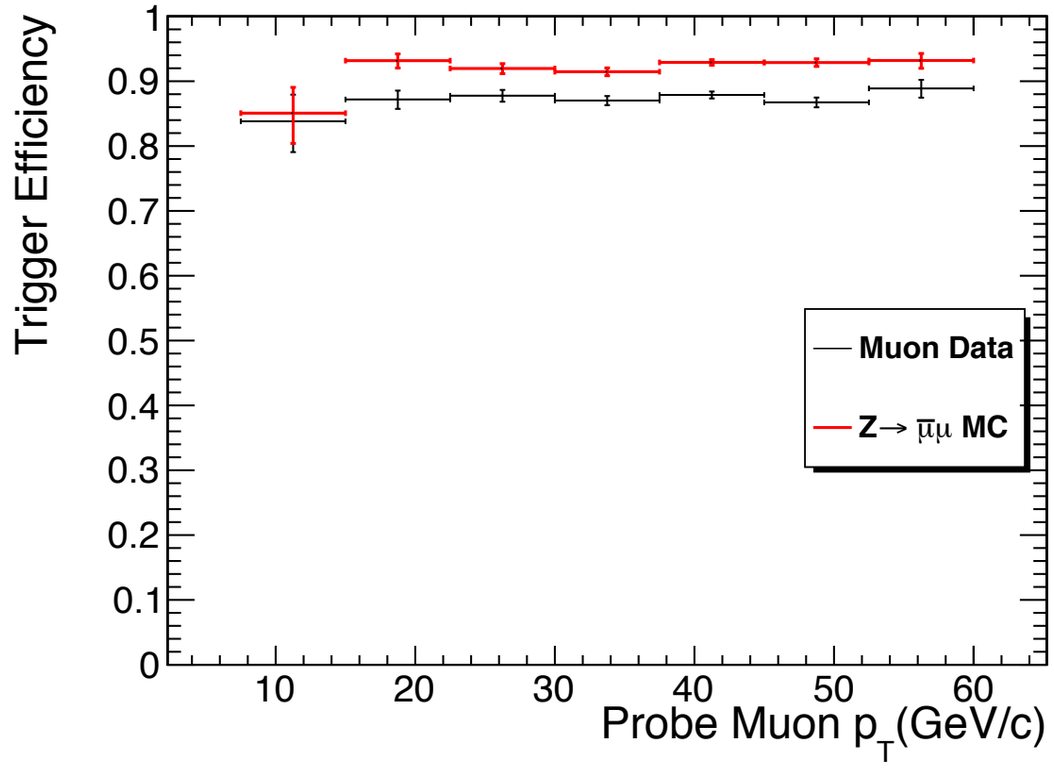


- **b-quarks lead to lower fake rates**
- **Maximum deviation taken as uncertainty**

Trigger

- *Trigger Strategy in 2010, L = 35pb^{-1}*
  - *Relies on many lepton paths (single, double, cross trigger)*





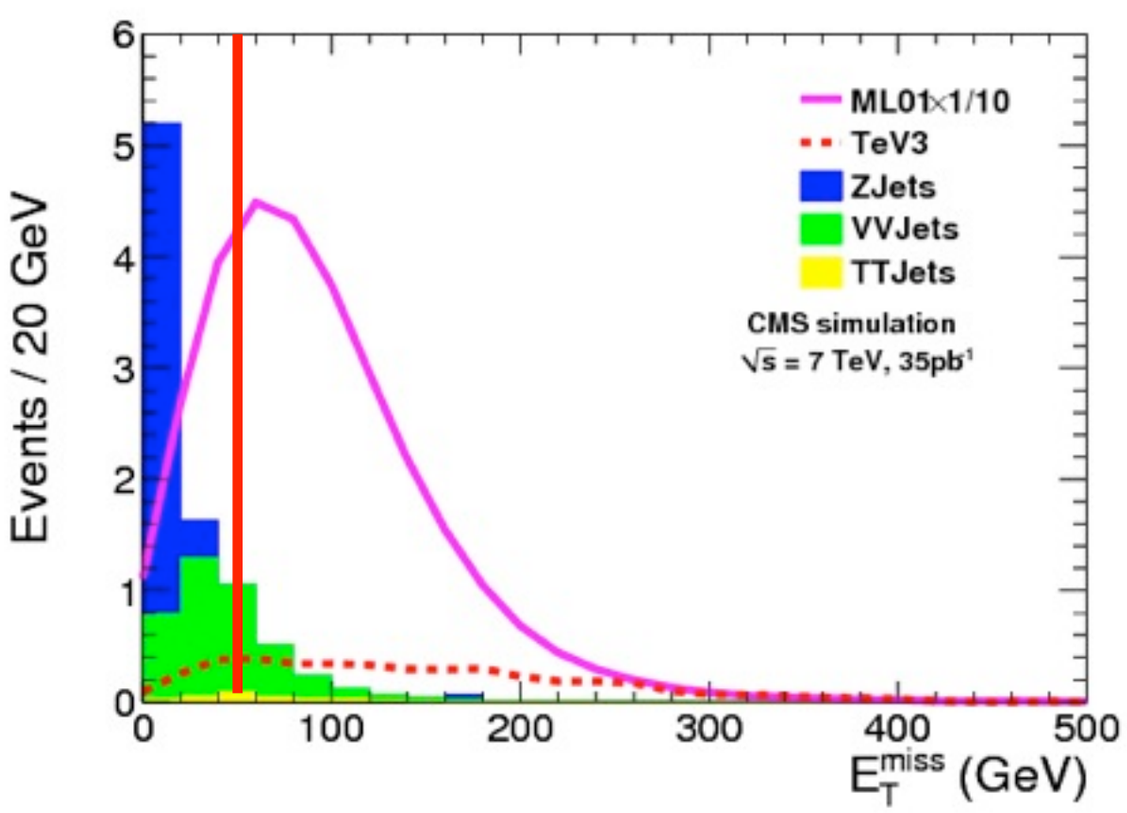
Tag & Probe

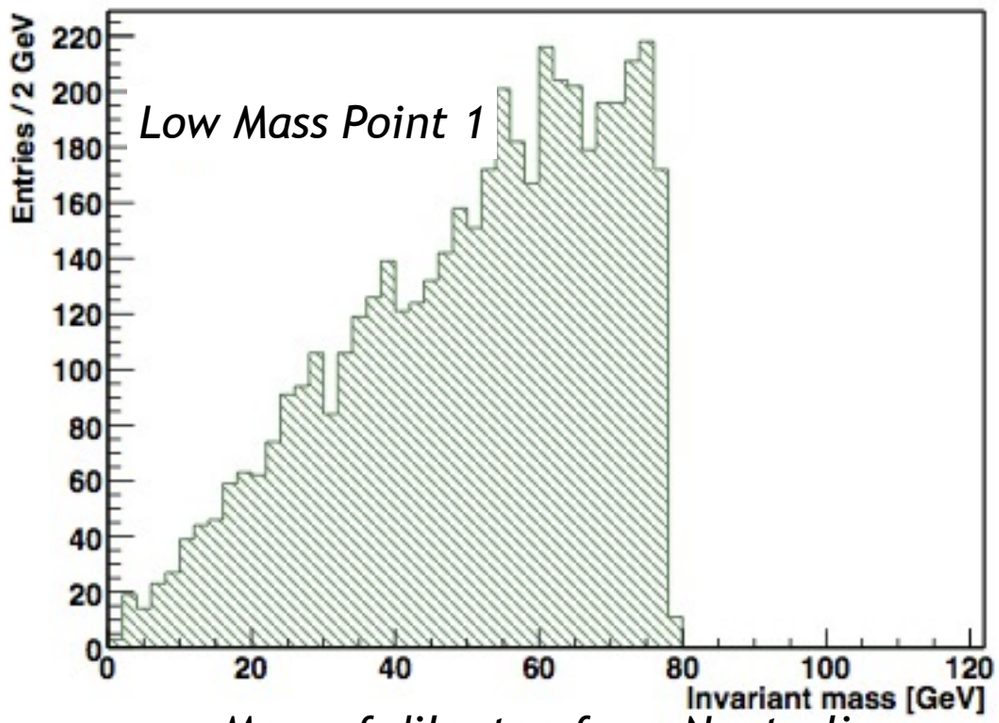
Trigger	$Z \to \ell\ell$ MC	Data
HLT_IsoMu13	0.923 ± 0.003	0.874 ± 0.003
HLT_Ele17_SW_TighterEleIdIsol_L1R	0.933 ± 0.004	0.958 ± 0.002

- *By combining all trigger paths, ~100% trigger efficiency*
- *Uncertainty on Trigger Eff is negligible w.r.t. other ones*

Event Selection (1)

- At least 3 isolated leptons
- At least 1 isolated lepton with p_T > 17, 20 GeV for μ, e *for triggering purpose*
- Particle-flow MET greater than 50 GeV for OS (eeτ, eμτ, μμτ)
- Applying Z-mass veto may not be a good idea



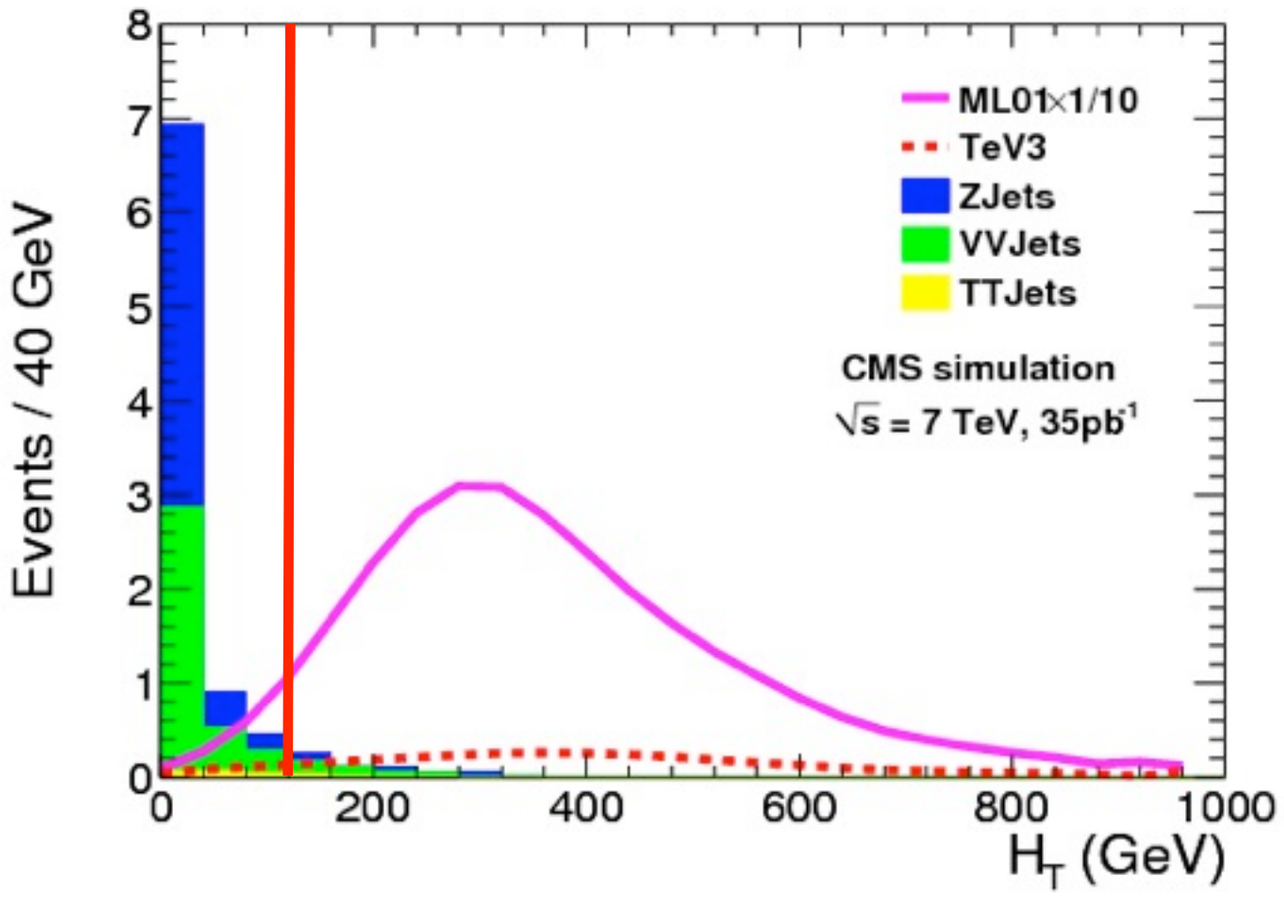


Mass of dilepton from Neutralino

$$M_{ll'}^{max} = \sqrt{4 \cdot E_l \cdot E_{l'}} = \sqrt{\frac{(m_{\tilde{l}}^2 - m_{\tilde{\chi}_1^0}^2) \cdot (m_{\tilde{\chi}_2^0}^2 - m_{\tilde{l}}^2)}{m_{\tilde{l}}^2}}$$

Event Selection (2)

- **Jet E_T scalar sum (H_T) greater than 200 GeV**



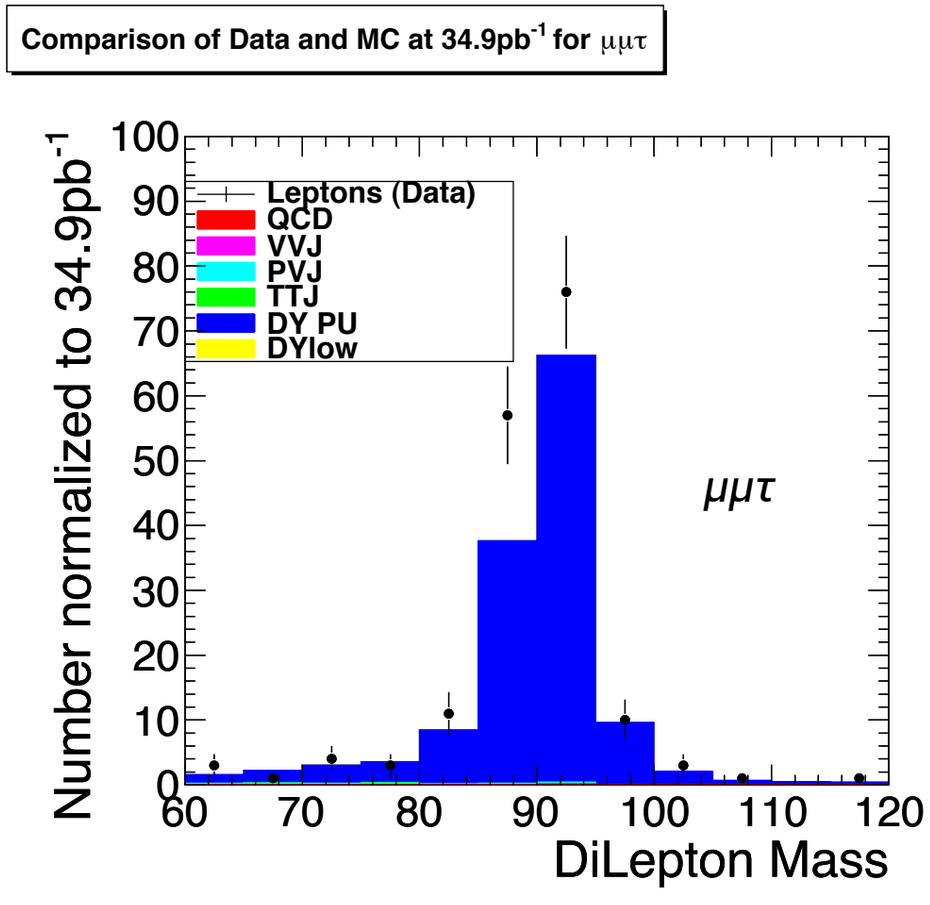
Jet Selection for H_T

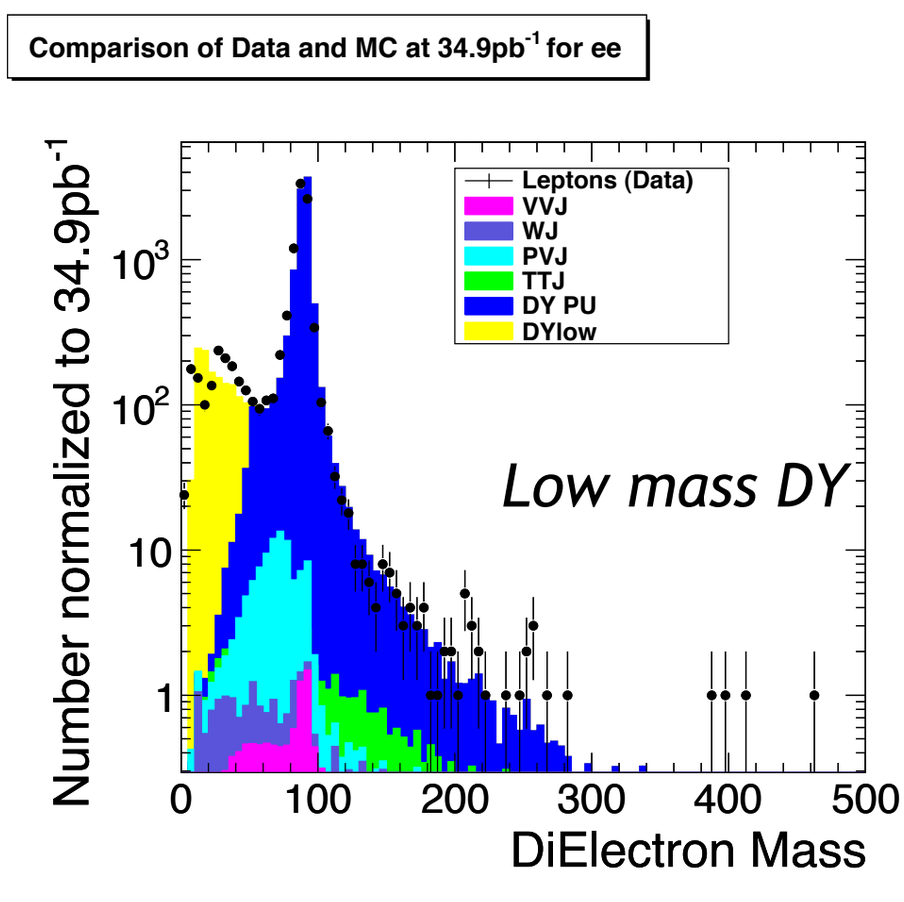
Standard Jet ID from JetMET group

- $p_T \geq 30$ GeV/c
- $|\eta| \leq 2.5$
- Neutral hadron energy fraction < 0.99
- Neutral EM energy fraction < 0.99
- Charged EM energy fraction < 0.99

DY MC Correction

- MC smaller than Data
  - Scaling DY BG based on Z mass region
- Low mass DY events
  - Scaling DY BG to account discrepancy at low SFOS mass





Systematic Uncertainties

- Jet Energy Scale
  - ~5% for signal
  - ~30% for ttbar+jets
- Cross section ~ 10%
- Lumi = 11%
  - later became smaller, but not significant
- MC Statistics
  - ~10%
- Ele & Mu
  - ID, 1-1.5%
  - Isolation, 1.5%
- Tau ID = 30%
- Trigger~5%

- *Total Uncertainty:*
  - *Signal*
    - *e,mu channels ~20%*
    - *tau channels ~30%*
  - *BG*
    - *e,mu channels ~30%*
    - *tau channels ~40%*

Results

3leptons

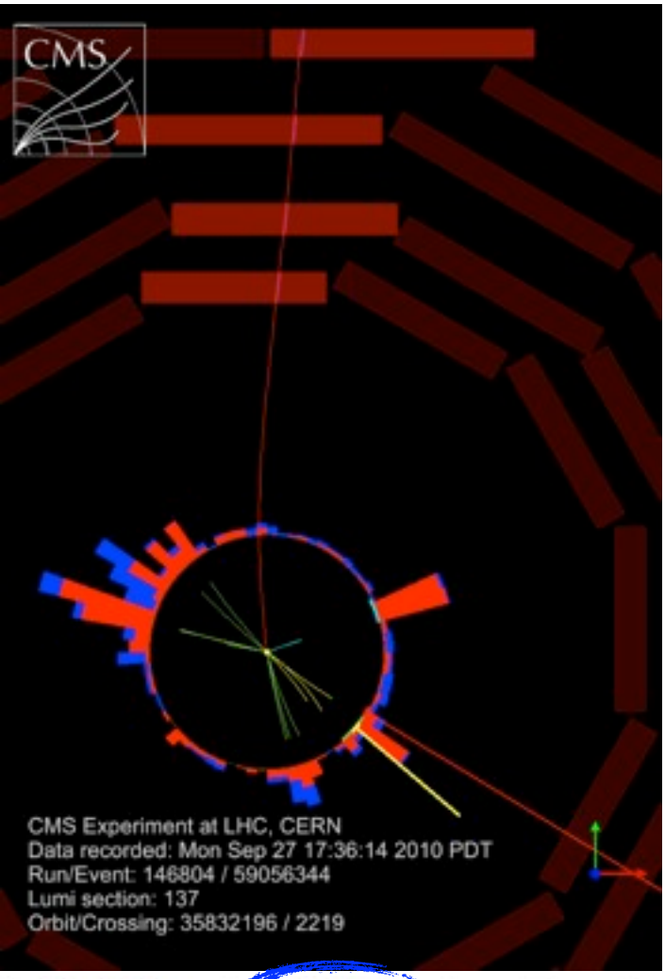
Sample	$3\,\mu$	$e\mu^+\mu^-$	μe^+e^-	3e	$\tau\mu^+\mu^-$	τe^+e^-	$e\mu\tau$	$e\mu^-\mu^-$	μe^-e^-	$\tau\mu^-\mu^-$	τe^-e^-	$e^-\mu^-\tau$
LM0	0.91(9)	0.72(08)	0.65(8)	0.33(6)	0.88(9)	0.41(6)	0.60(7)	0.29(5)	0.20(4)	0.15(4)	0.09(2)	0.39(6)
LM1	0.20(2)	0.17(1)	0.13(1)	0.07(1)	0.24(2)	0.15(1)	0.10(1)	0.02(0)	0.01(0)	0.04(1)	0.02(0)	0.06(1)
ML01	74.3(8)	89.0(9)	46.5(6)	52.5(7)	41.4(6)	26.6(5)	6.0(2)	1.3(1)	1.5(1)	3.2(1)	3.7(2)	6.3(2)
ML02	10.6(1)	13.1(1)	7.4(1)	8.1(1)	6.4(1)	4.3(1)	1.4(1)	0.8(1)	0.8(1)	0.6(1)	0.7(1)	1.5(1)
DY+jets	0.00(8)	0.00(8)	0.00(8)	0.12(8)	0.26(16)	0.00(8)	0.07(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)
VV+jets	0.05(1)	0.04(1)	0.04(1)	0.01(1)	0.01(1)	0.01(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)
$t\bar{t}$ +jets	0.01(1)	0.01(1)	0.01(1)	0.01(1)	0.17(3)	0.13(2)	0.34(4)	0.00(1)	0.00(1)	0.00(1)	0.01(1)	0.02(1)
Tot BG	0.06(8)	0.05(8)	0.05(8)	0.15(8)	0.44(16)	0.14(6)	0.42(9)	0.00(8)	0.00(8)	0.00(8)	0.01(8)	0.02(8)
Data	0	1	0	0	0	1	0	0	0	0	0	1*

0.31 +/- 0.16 *1.00 +/- 0.19* *0.03 +/- 0.14*

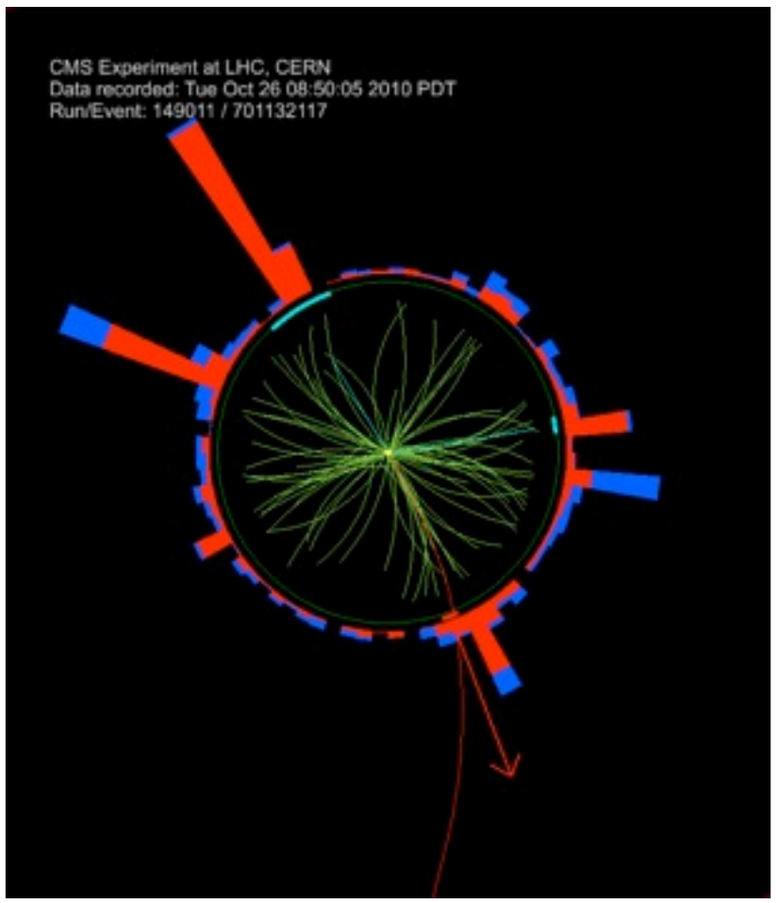
4 or more leptons

Sample	4μ	$e3\mu$	$2e2\mu$	$3e\mu$	$4e$	$3\mu\tau$	$e\mu\mu\tau$	$ee\mu\tau$	$3e\tau$	$2\mu2\tau$	$e\mu2\tau$	$2e2\tau$
LM0	0.02(1)	0.08(3)	0.05(2)	0.03(2)	0.01(1)	0.05(2)	0.02(2)	0.04(2)	0.02(2)	0.01(1)	0.04(2)	0.02(1)
LM1	0.01(1)	0.01(1)	0.02(1)	0.00(1)	0.00(1)	0.02(1)	0.01(1)	0.01(1)	0.02(1)	0.01(1)	0.04(2)	0.02(1)
ML01	52.8(7)	5.3(2)	66.5(7)	3.3(2)	21.3(4)	9.7(3)	10.8(3)	6.6(2)	6.1(2)	9.2(3)	1.3(1)	6.3(2)
ML02	10.8(1)	4.7(1)	14.0(1)	2.7(1)	4.7(1)	2.6(1)	2.9(1)	1.9(1)	1.7(1)	1.9(1)	0.5(1)	1.3(1)
DY+jets	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)
VV+jets	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)
$t\bar{t}$ +jets	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)	0.00(1)
Tot BG	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)	0.00(8)
Data	0	0	0	0	0	0	0	0	0	0	0	0

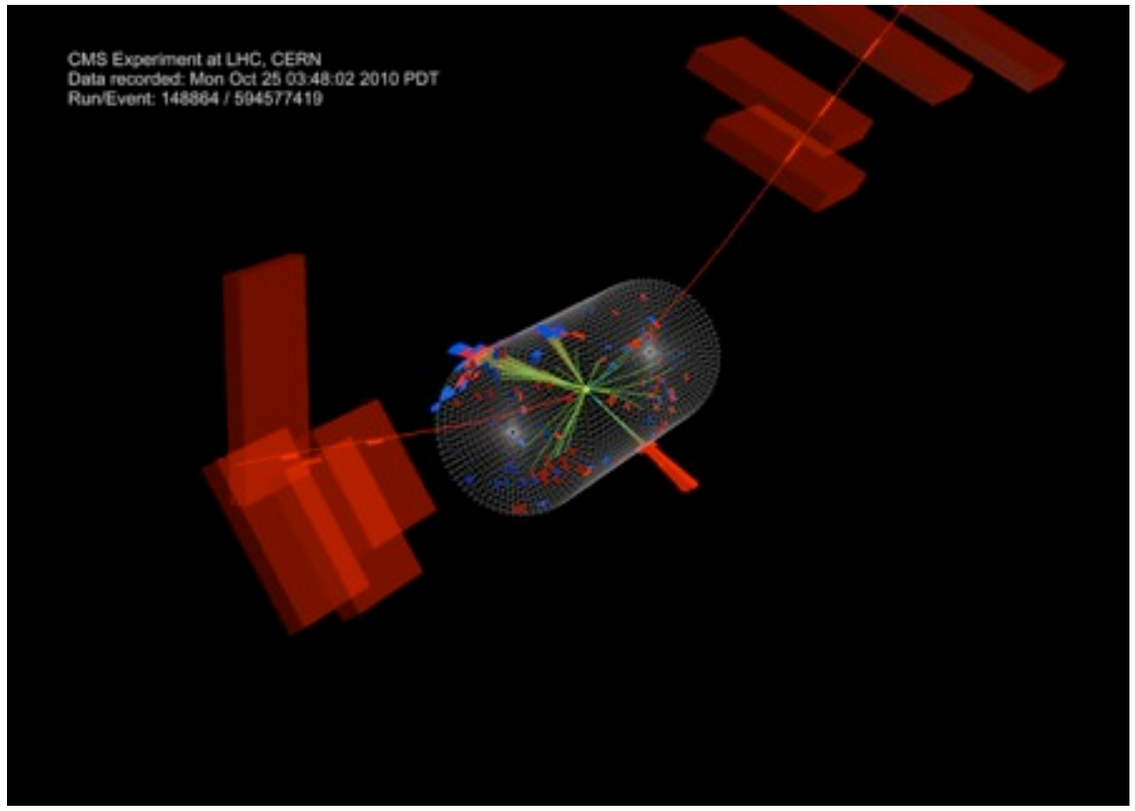
3lepton Events



Event Type	$e^+\mu^+\tau^+$		
Run #	146804		
Event #	59056344		
H_T (GeV)	279.9		
pfMET (GeV)	129.0		
Lepton/Jet	p_T or E_T (GeV)	η	ϕ
e^+	32.7	-2.02	0.36
μ^+	16.7	0.57	1.69
τ^+(3-prong)	31.6	-0.91	-0.70
Jet 1	177.7	0.81	2.74
Jet 2	53.2	0.81	-1.37
Jet 3	49.0	0.13	2.09



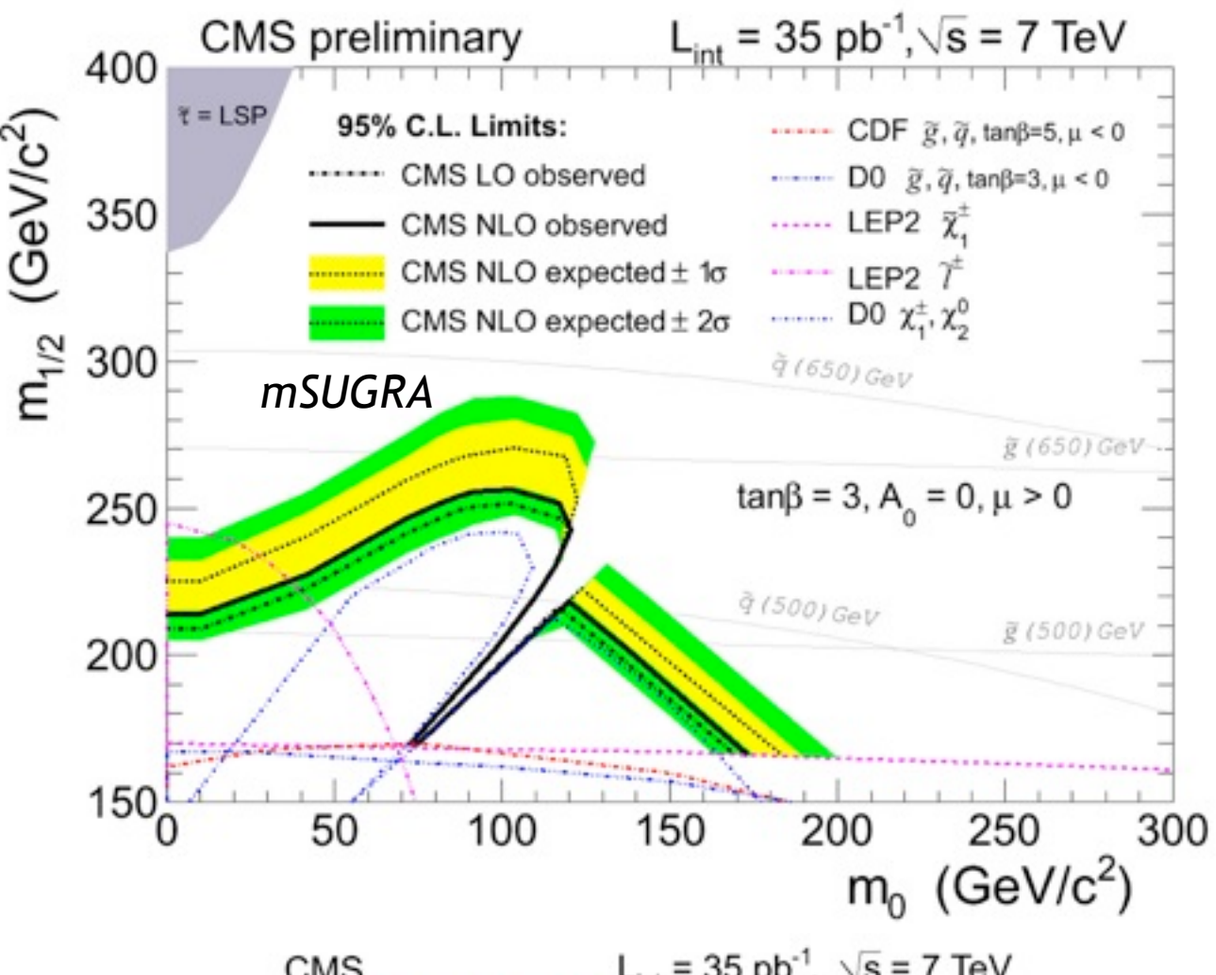
Event Type	$e^+e^-\tau^+$		
Run #	149011		
Event #	701132117		
H_T (GeV)	384.3		
pfMET (GeV)	79.5		
Lepton/Jet	p_T or E_T (GeV)	η	ϕ
e^+	106.7	-1.98	2.12
e^-	29.5	-0.73	0.13
τ^+(1-prong)	13.1	-1.61	0.95
Jet 1	138.0	-0.82	2.74
Jet 2	107.3	0.68	-1.09
Jet 3	84.5	0.21	-0.18
Jet 4	54.4	-1.46	-2.80

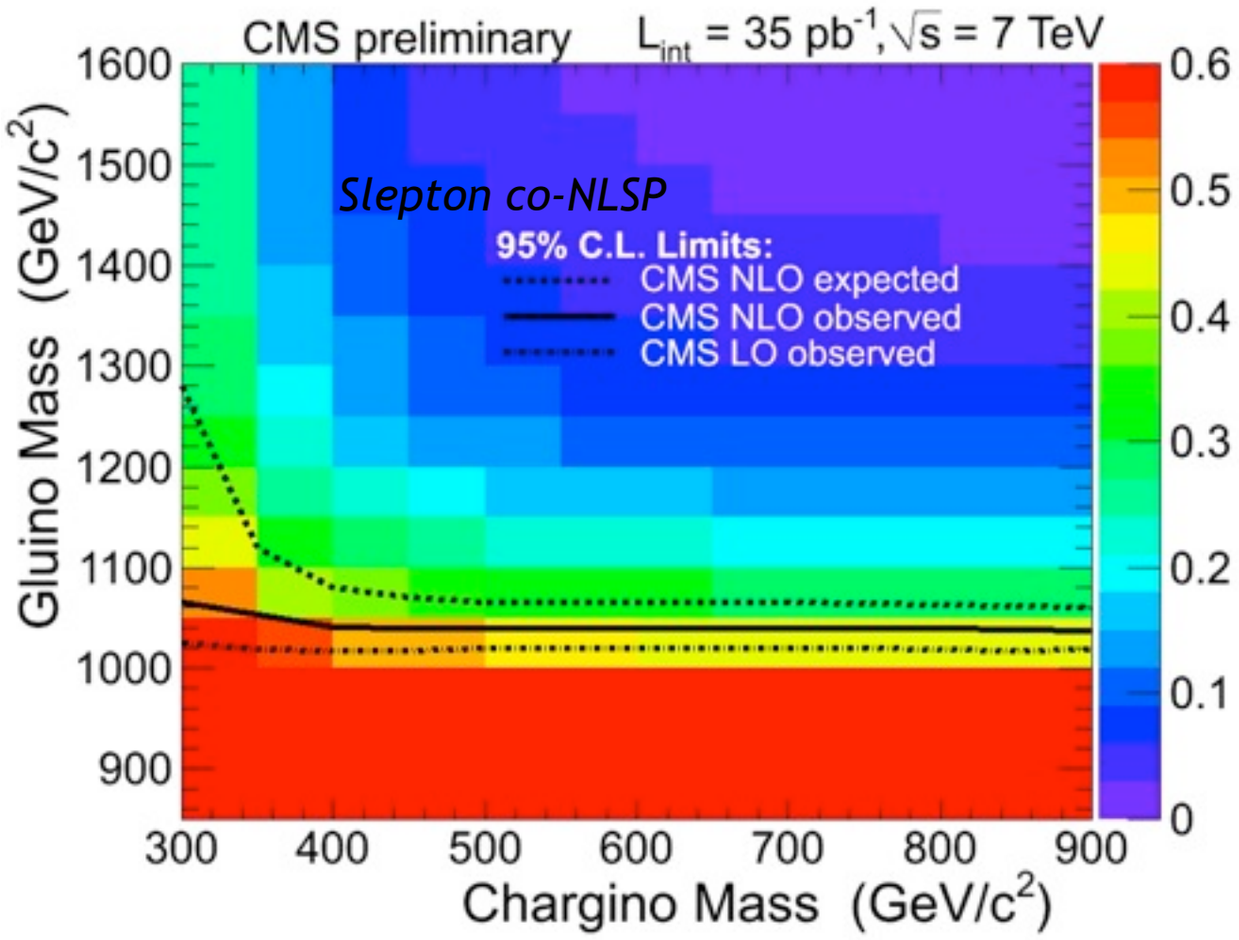


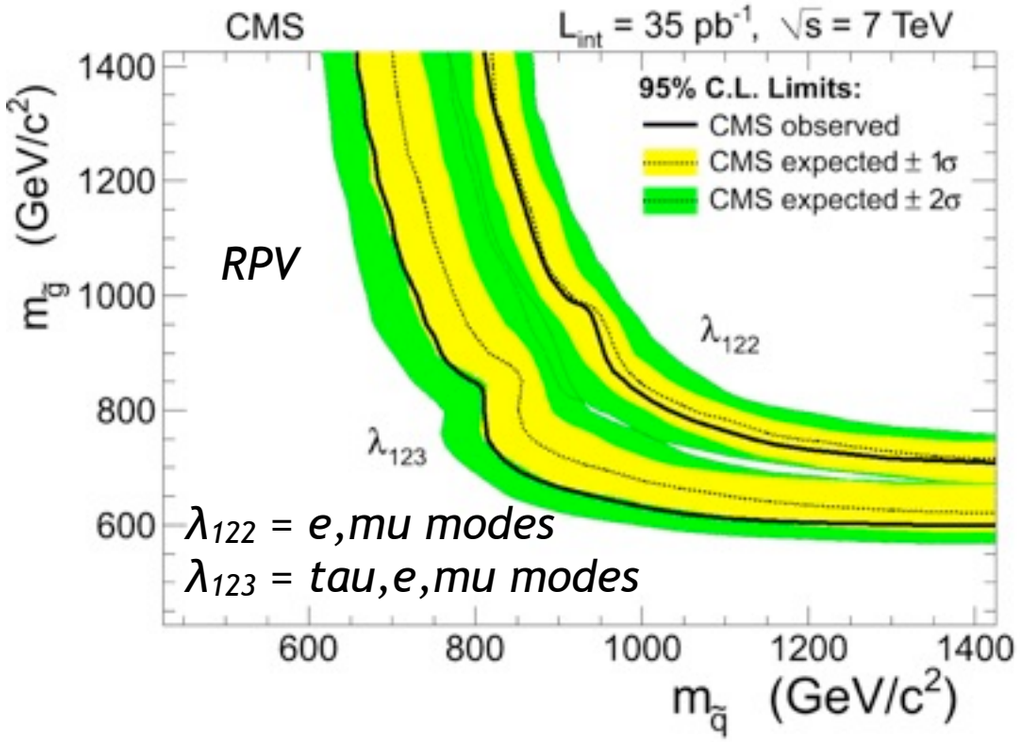
Event Type	$\mu^+\mu^-e^+$		
Run #	148864		
Event #	594577419		
H_T (GeV)	246.4		
pfMET (GeV)	39.1		
Lepton/Jet	p_T or E_T (GeV)	η	ϕ
μ^-	21.8	0.18	-0.43
μ^+	14.5	0.68	2.34
e^+	129.5	0.87	-2.00
Jet 1	172.0	-1.34	0.83
Jet 2	74.4	-1.13	1.62

≡ 3 events found in 2010

Exclusion Curves







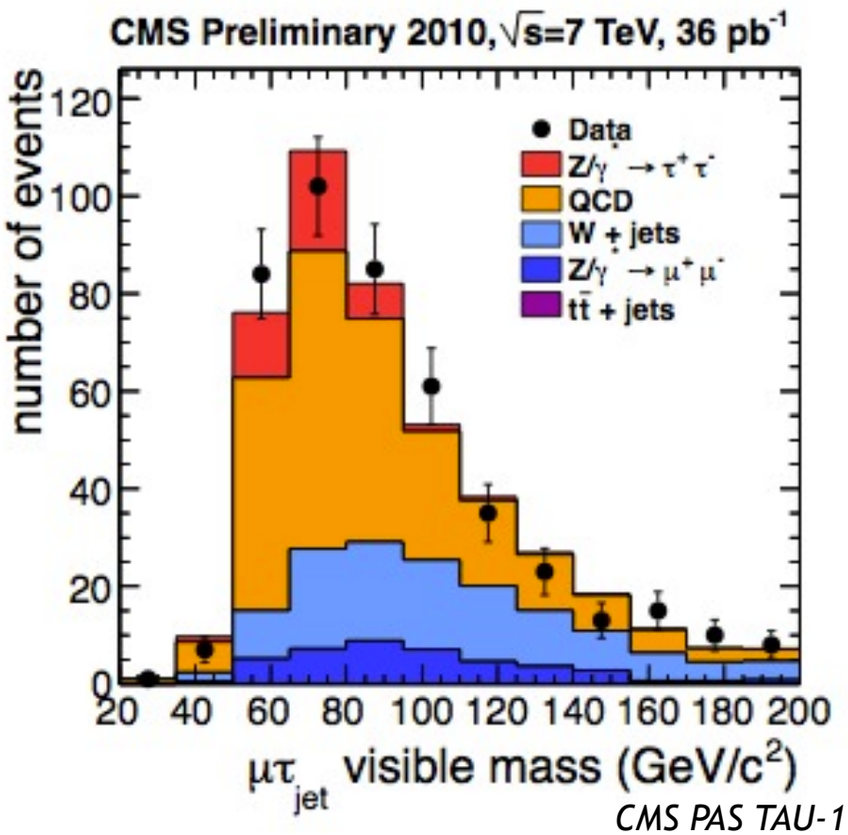
- *mSUGRA: Extended Tevatron+LEP limits*
- *RPV: Extended Tevatron limits*
- *Slepton co-LSP: Excluded Gluino mass below 1040 GeV*

2011 Plan

Plan for 2011 Data

Improved Tau Selection

- **Tau Group recommends Hadron Plus Strips or Tau Neural Classifier**
  - *Both use Particle-Flow objects*
  - *HPS reconstructs neutral pions in "strips" to conversion*
  - *TaNC utilizes artificial neural networks*



CMS PAS TAU-11-01

Algorithm	Fit data	Expected MC	DATA/MC
TaNC "loose"	0.76 ± 0.20	0.72	1.06 ± 0.30
TaNC "medium"	0.63 ± 0.17	0.66	0.96 ± 0.27
TaNC "tight"	0.55 ± 0.15	0.55	1.00 ± 0.28
HPS "loose"	0.70 ± 0.15	0.70	1.00 ± 0.24
HPS "medium"	0.53 ± 0.13	0.53	1.01 ± 0.26
HPS "tight"	0.33 ± 0.08	0.36	0.93 ± 0.25

We will switch to HPS "loose"

Trilepton + X

- **Complementary Search**
  - Neutralino/chargino pair production
    - *Neglected by the H_T cut*
- **Different Models**
  - 2 Higgs Doublet model, A → hZ → WWZ
  - Want to get feedback from theorists
    - *models with 3 or more **soft** leptons*
- **Trigger paths are in place and used for 2011 data taking**
  - 3μ with p_T>5GeV, 3e with p_T>10GeV, 2μ with p_T>5GeV + e with p_T>8GeV, μ with p_T>5GeV + 2e with p_T>8GeV

Conclusion

- LHC and CMS working very well
- 2010 data sample provided excellent physics analysis startup
- 2010 Multilepton analysis demonstrated lepton performance robust to low p_T, and set limits on various models
- 2011 data sample already 30 times that of 2010 with more to come
- Next round of multilepton analysis: triggers and advanced tau ID prepared
- Hope to find out (soon) what nature has been hiding!

Backup Slides

MC and Datasets

Process	DBS Name	# Events
Benchmark Point		
LM0	/LM0_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	219595
LM1	/LM1_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	219190
LM2	/LM2_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	220000
LM3	/LM3_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	220000
LM4	/LM4_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	220000
LM5	/LM5_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	220000
LM6	/LM6_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	220000
LM7	/LM7_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	220000
LM8	/LM8_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	220000
LM9	/LM9_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	220000
LM10	/LM10/Spring10-START3X_V26_S09	203818
LM11	/LM11_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	219190
LM12	/LM12_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	219595
LM13	/LM13_SUSY_sftsht_7TeV-pythia6/Fall10-START38_V12	219915
ML01	/PhysicsProcess_PYTHIA6_SUSY_GMSM_SC_ML01	200000
ML02	/PhysicsProcess_PYTHIA6_SUSY_GMSM_SC_ML02	200000
SUSY Scan		
tanβ3	/PhysicsProcesses_mSUGRA_tanbeta3Fall10v1/spadhi-PhysicsProcesses_mSUGRA_tanbeta3Fall10-.../USER	13000000
GMSM	/PhysicsProcesses_GGM_SCMSleptonicNLSP/spadhi-PhysicsProcesses_GGM_SCMSleptonicNLSP-.../USER	31350000

SM BG Process	DBS Name	# Events
VV+jets	/VVJetsTo4L_TuneD6T_7TeV-madgraph-tauola/Fall10-START38_V12-v1	962976
γV+jets	/PhotonVJets-madgraph/Spring10-START3X_V26_S09-v1	1086319
W+jets	/WJets-madgraph/Spring10-START3X_V26_S09-v1	10068895
$t\bar{t}$ +jets	/TTJets_TuneD6T_7TeV-madgraph-tauola/Fall10-START38_V12-v2	1394548
QCD	/InclusiveMu15/Spring10-START3X_V26_S09-v1	6228142
QCD Pythia8	/QCD_Pt-15_7TeV-pythia8/Spring10-START3X_V26B-v2	5234800
$Z \to \bar{\tau}\tau$	/Ztautau/Spring10-START3X_V26_S09-v1	2195255
$RelVal\ Z \to \bar{\mu}\mu$	/RelValZMM/CMSSW_3_9_2-START39_V3-v1	9696
$RelVal\ Z \to \bar{e}e$	/RelValZEE/CMSSW_3_9_2-START39_V3-v1	9000
DY(low)+jets	/DYJetsToLL_TuneZ2_M-50_7TeV-madgraph-tauola/Fall10-START38_V12-v3	2661949
Z+jets	/DYJetsToLL_TuneD6T_M-10To50_7TeV-madgraph-tauola/Fall10-START38_V12-v2	188145

Cross sections

process	source	order	cross section [pb]	condition
$W \to l\nu$	FEWZ	NNLO	31314 $\pm$1558	n/a
$Z/\gamma* \to ll$	FEWZ	NNLO	4998 $\pm$272	m(ll) > 20 GeV
$t\bar{t} + jets$	NNLL re-summation	NNLL	165 $\pm$10	inclusive
WZ	MCFM	NLO	18.2 $\pm$0.7	m(ll) > 40 GeV

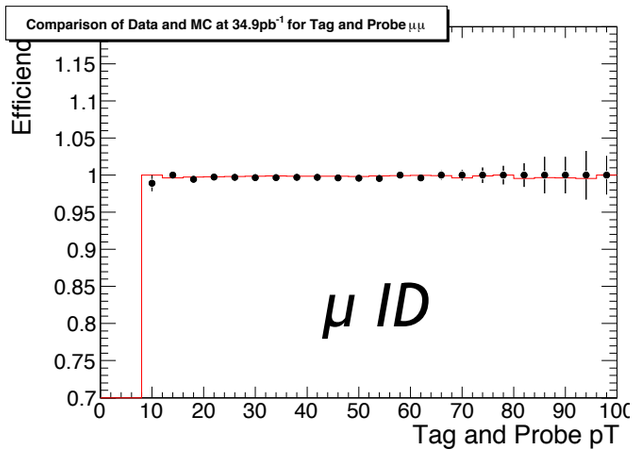
Data, L = 35pb^{-1}

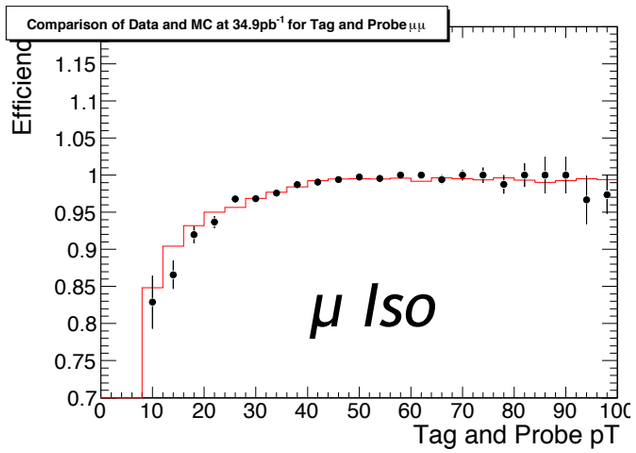
- /Mu/Run2010A-Sep17ReReco_v2
- /Mu/Run2010B-PromptReco-v2
- /EG/Run2010A-Sep17ReReco_v2
- /Electron/Run2010B-PromptReco-v2

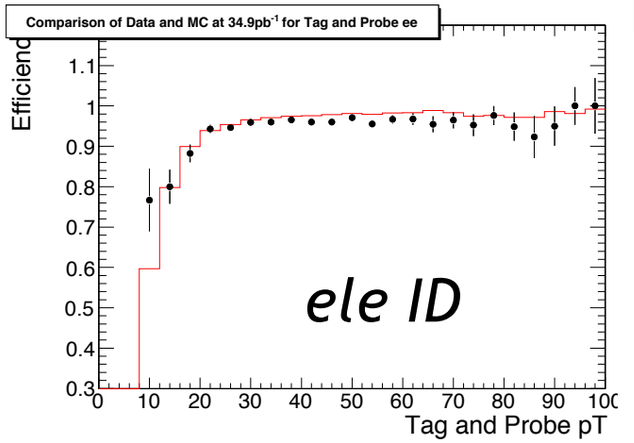
Electron and Muon Efficiencies

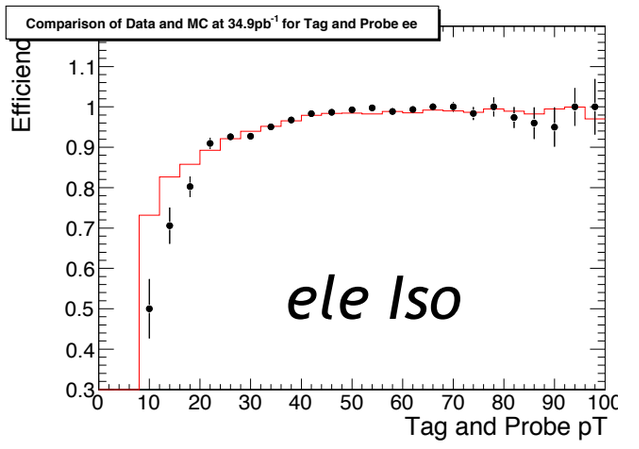
Data MC Comparison

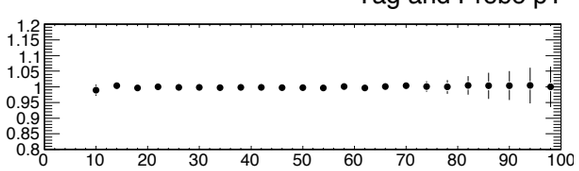
Black dots = data, Redline = DY MC

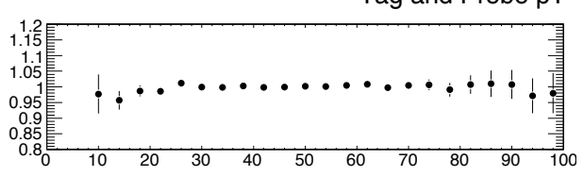


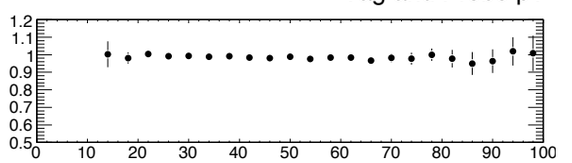


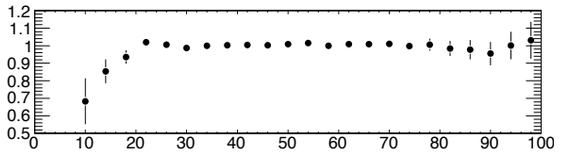










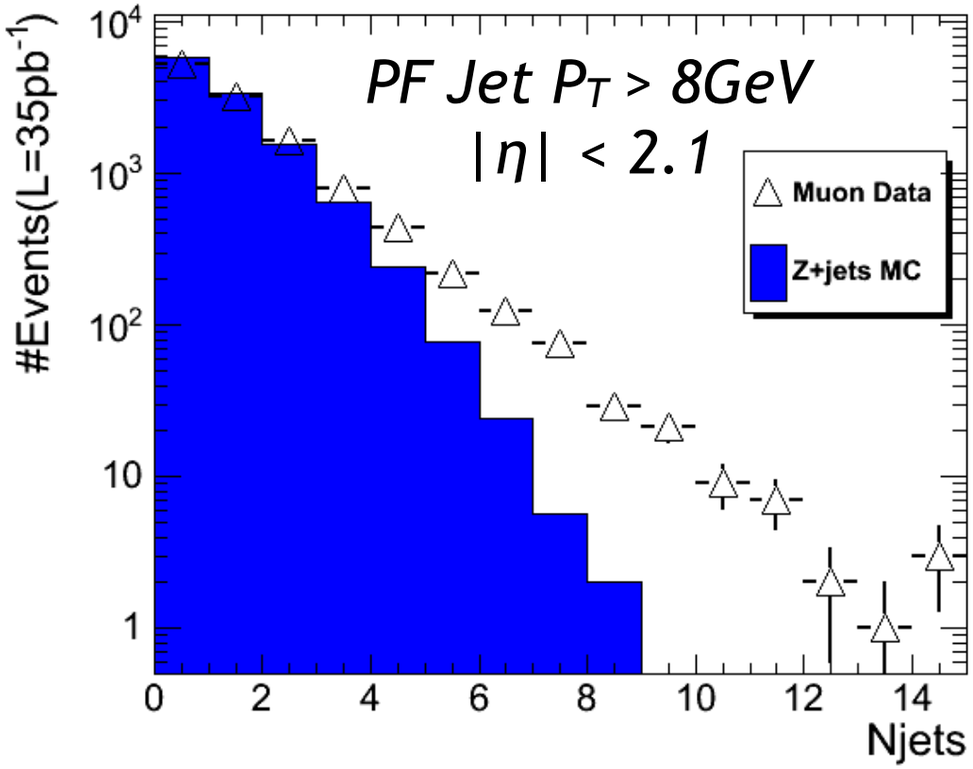


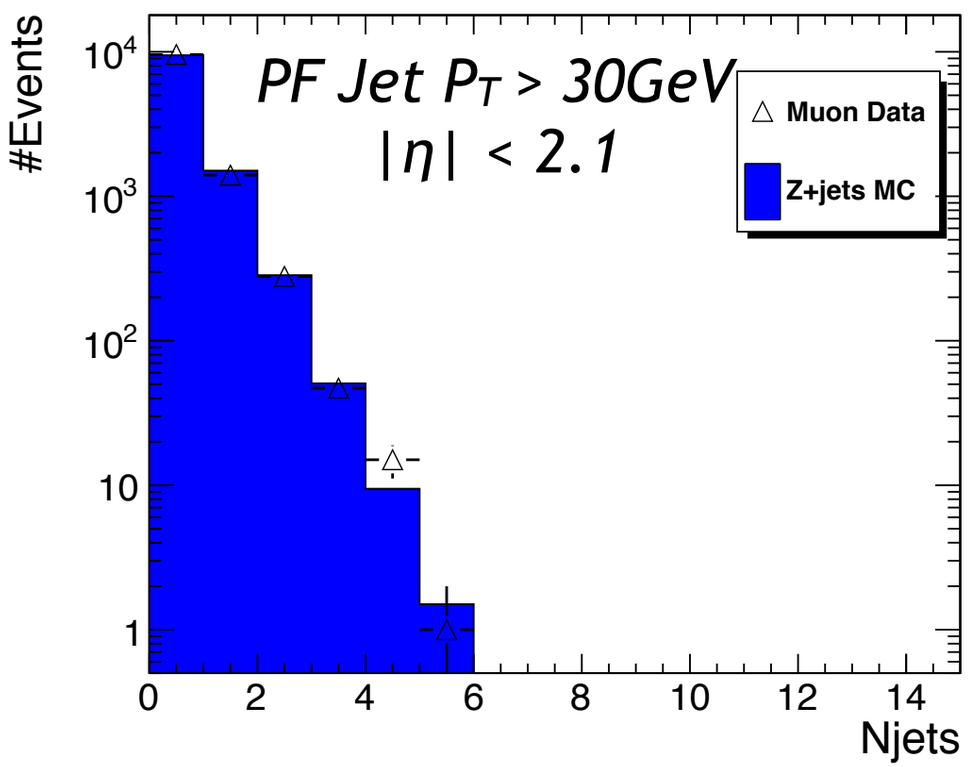
Tag = offline selection
Probe = p_T & η & (Iso or ID)

$$\epsilon = \frac{2 \cdot N_{pass\&pass} + N_{pass\&fail} + N_{fail\&pass}}{N_{all\ tagged}}$$

- **Good agreement between data and MC with Z hypothesis (85 < DiLepton Mass < 95 GeV)**
- **Soft electrons have larger discrepancy**

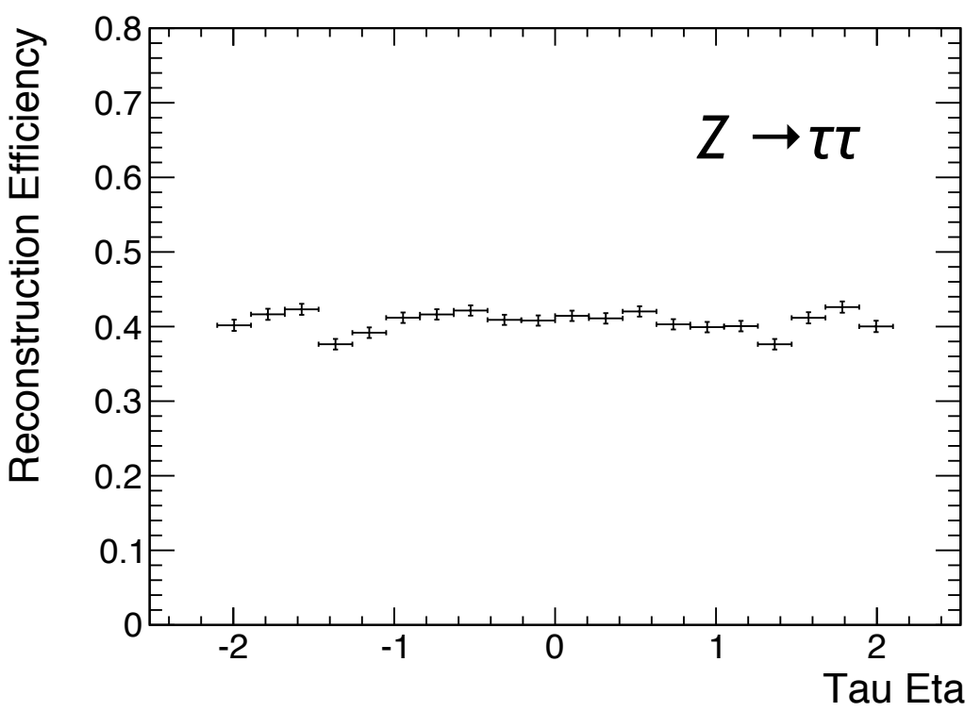
Effect of PUs on Jets

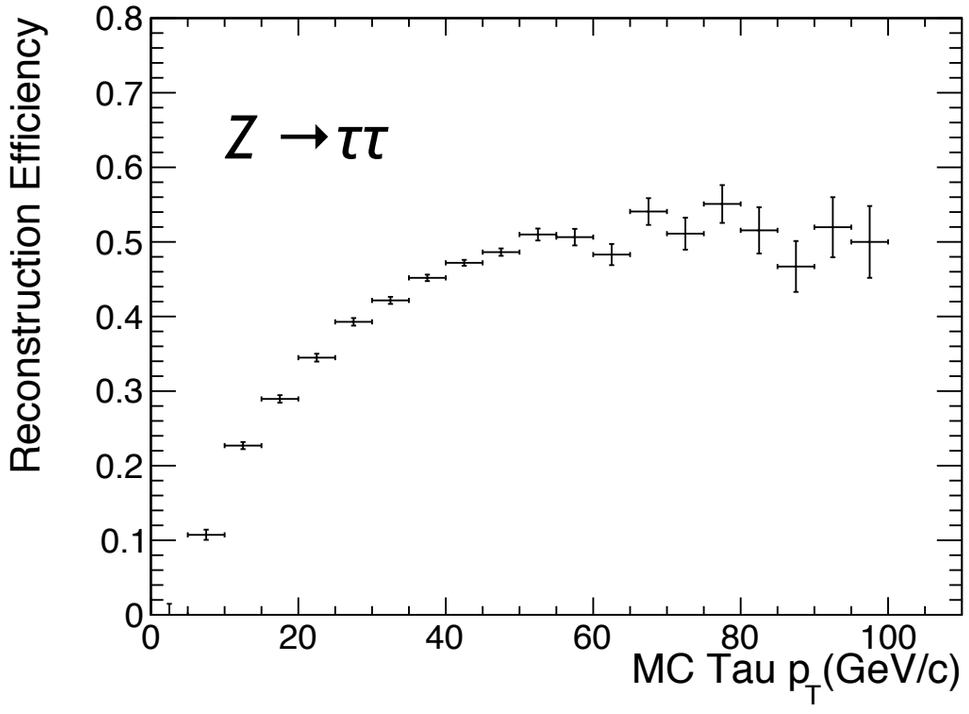




- #(soft PF Jets) increases with PUs
- Almost no effect on H_T calculation

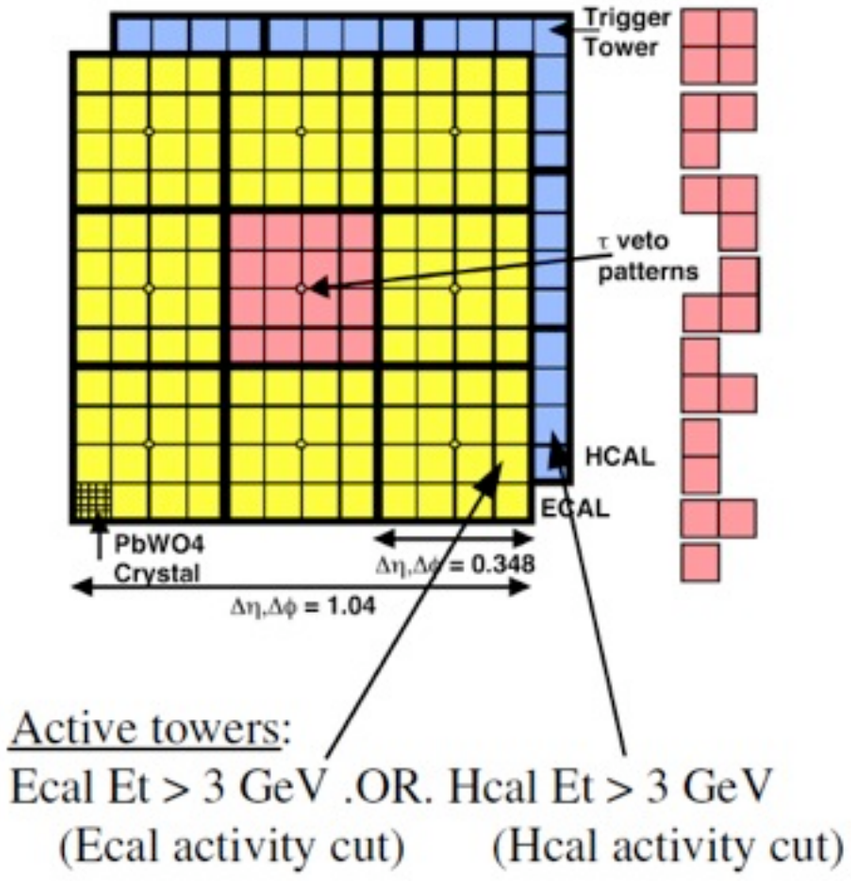
Tau Reconstruction Efficiency (MC)

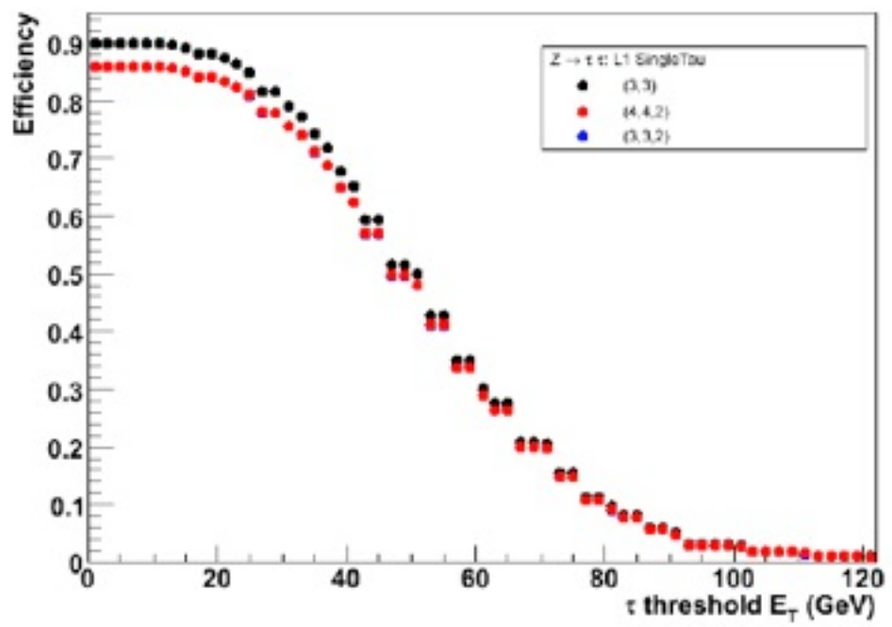




- Non-zero sensitivity at the lowest bin

L1 Tau Trigger(LPC Tau)

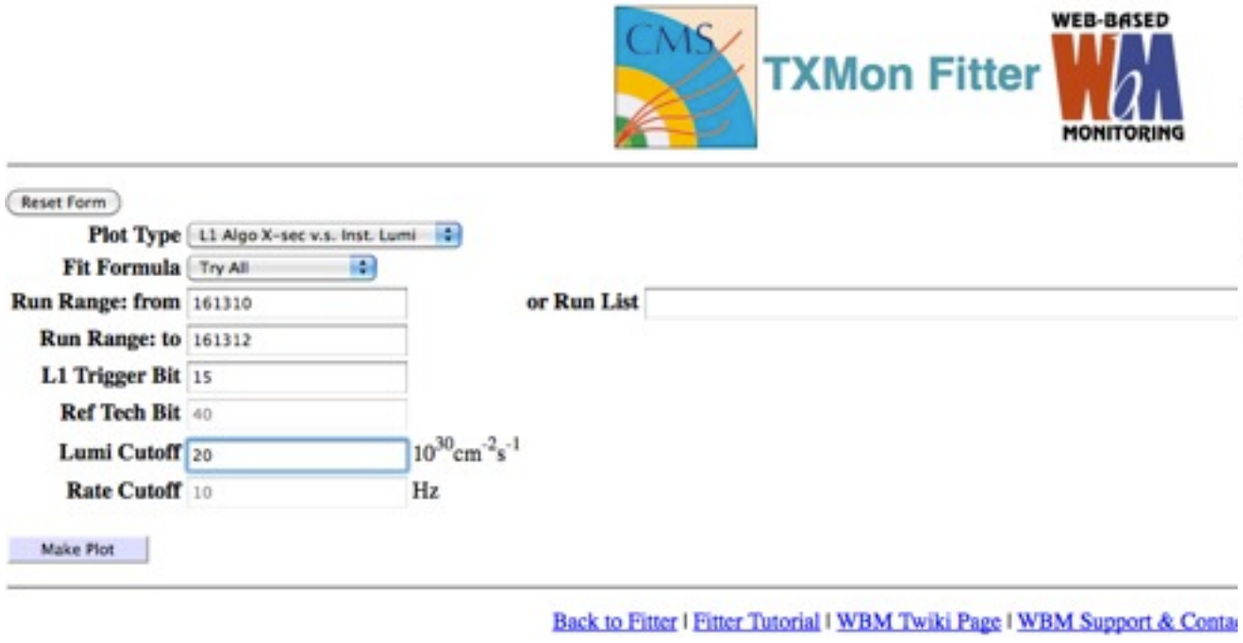


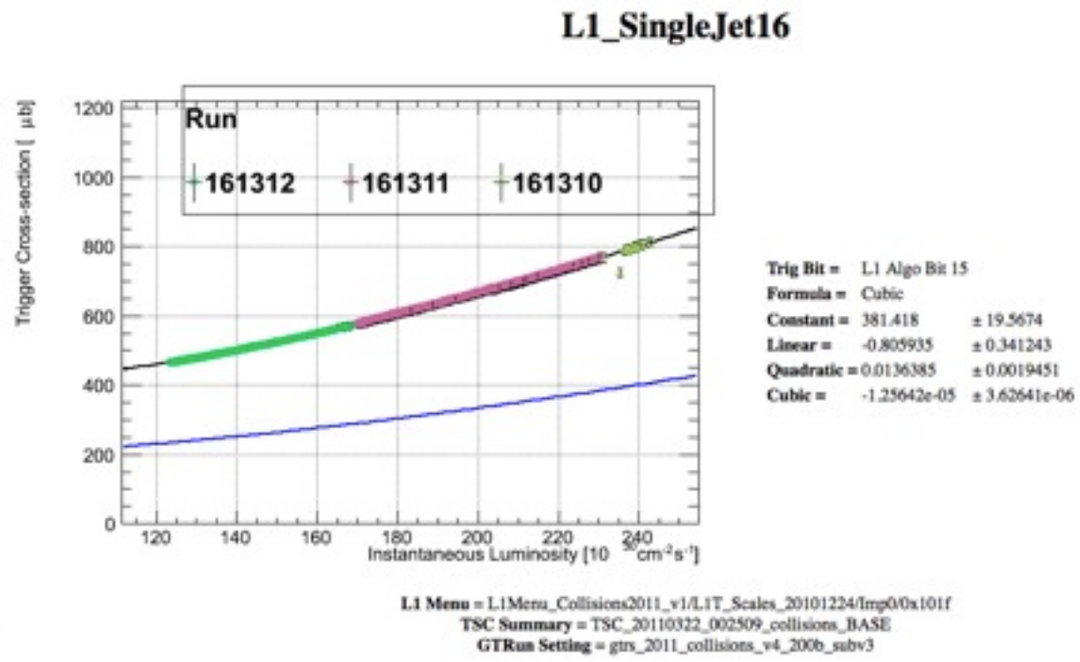


Almost no loss in Z sample

- **Utilizing activity and tau veto bits**
  - About ~30% QCD BG rate reduction
  - Used in 2010 data taking

WBM TXMonFitter





Main developers is Maruyama

- **Plot trigger cross section for run range specified by an user**

Particles in CMS