Wisconsin Task T Contributions to CMS Physics, Software & Computing

Task T: CMS Physics

Leadership and Responsibility for Early Physics with LHC

- Supervision of a large group of postdocs & students across CMS (many institutes)

Physics Trigger Studies (CMS Trigger Coordinator: Prof. Smith)

- Thresholds at L1T and object ID refinement at HLT determines physics reach
- e/γ trigger validation and DQM (Leonard+Lazaridis+Anderson/Grothe+Klabbers)
- τ trigger algorithm improvements and DQM (Bachtis+Swanson/Savin+Dasu)
- μ trigger: HLT development, validation, and DQM (Klukas/Herndon)
- Calorimeter Trigger Calibration (Efron)

EWK Physics Analyses (Past CMS EWK & Current Upgrade Physics Convener: Prof. Dasu)

- W and Z reconstruction, especially with jet activity, key for new physics search
- Drell-Yan e^+-e^- Production on & off Z peak (Leonard/Klabbers+Grothe)
- γ+Jets Measurement (Anderson/Dasu)
- W($\rightarrow e\nu$)+Jets Measurement (Grogg/Efron)
- Z($\rightarrow e^+e^-$)+Jets Measurement (Lazaridis/Grothe+Klabbers)
- Z($\rightarrow\tau\tau \rightarrow \mu^+\tau_h$-jet) Measurement (Bachtis/Savin)
- Z($\rightarrow\tau\tau \rightarrow e^+\tau_h$-jet) Measurement (Swanson/Savin)
- SM Zγ Production and Search for Anomalous Couplings (Gray/Lanaro+Dasu)
- SM Top Production and Search for SUSY in dilepton channel (Weinberg/Savin)
- SM WZ Production and Search for W'$\rightarrow$WZ, Technicolor (Klukas/Herndon)
- SM ZZ Production and Upgrade Simulations (Ross/Grothe+Klabbers)

Daily supervision of student work is provided by senior scientists

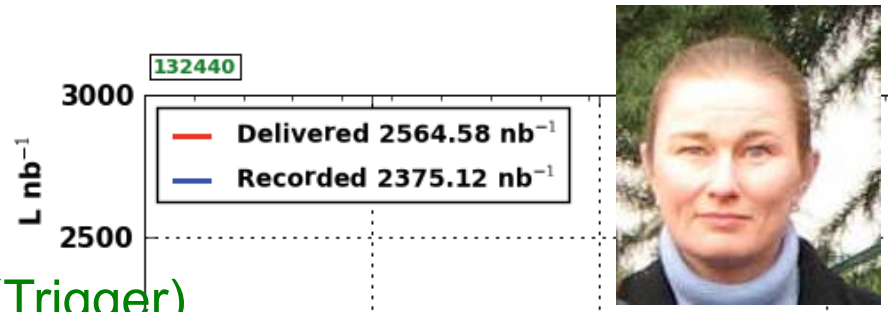
Forward Physics Analyses (Past CMS Forward Physics Convener: Dr. Grothe)

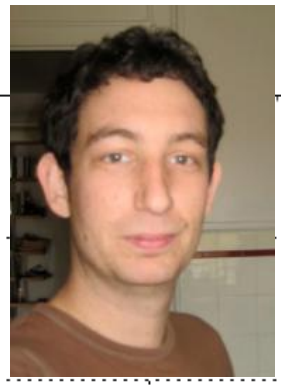
- Completed Exclusive di-lepton (pp $\rightarrow$ppl^+l^-)production (luminosity measurement) & Exclusive W production (collaboration with Electroweak)

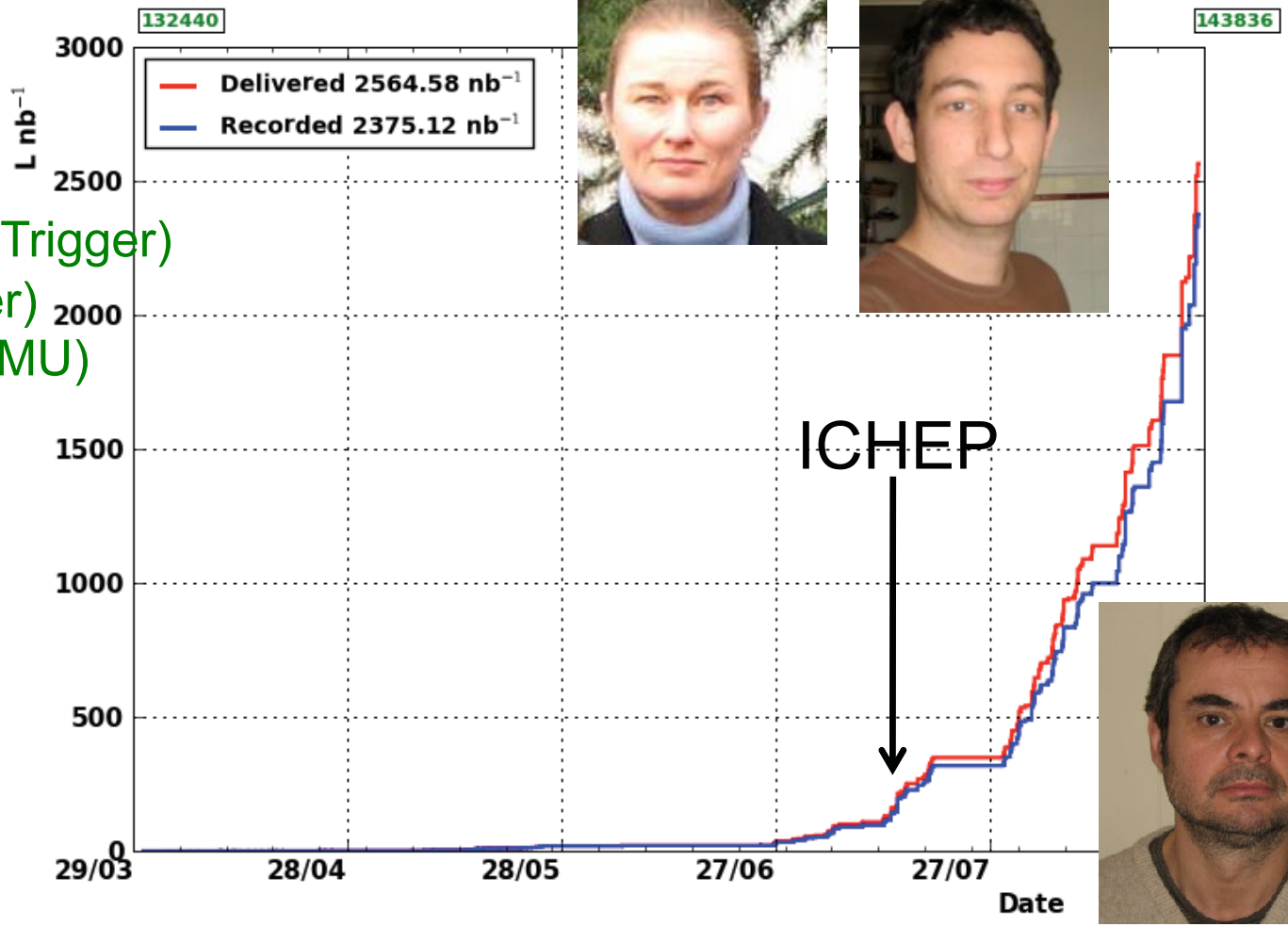
CMS Data @ 7 TeV

Key UW Personnel
for data acquisition
- Assoc. Sci. P. Klabbers (Trigger)
- PostDoc J. Efron (Trigger)
- Assoc. Sci. A. Lanaro (EMU)

+ Students, Shifters







Instantaneous luminosity reached 1 x 10^{31} cm^{-2} s^{-1}

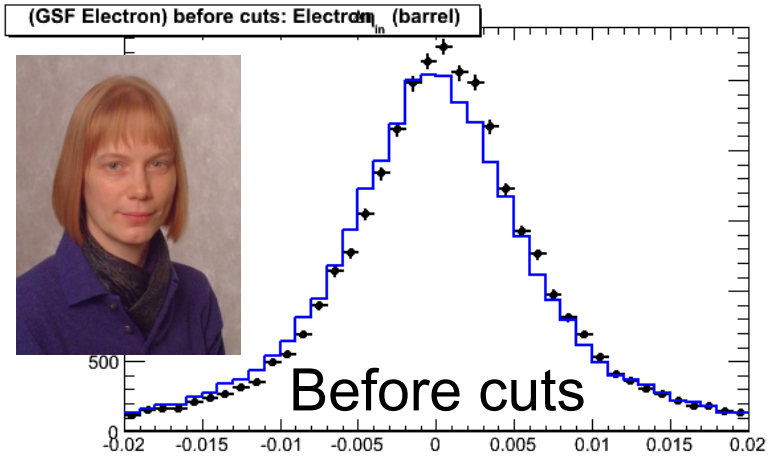
Will outline significant progress in analysis since ICHEP

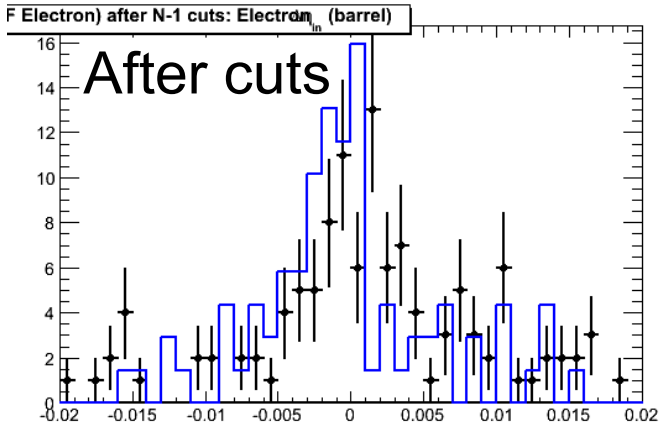
~20 (6 UW) Members

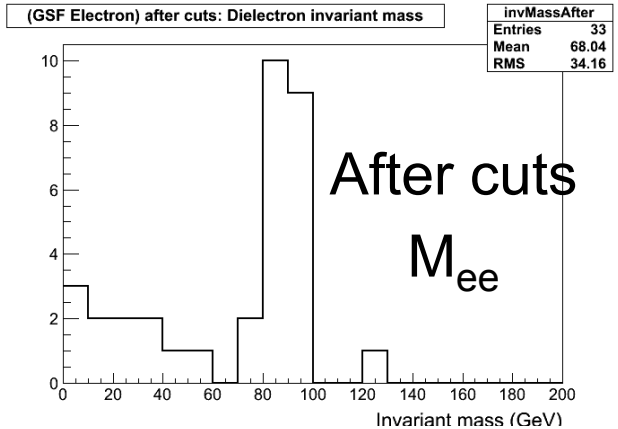
Online DQM for EWK Group

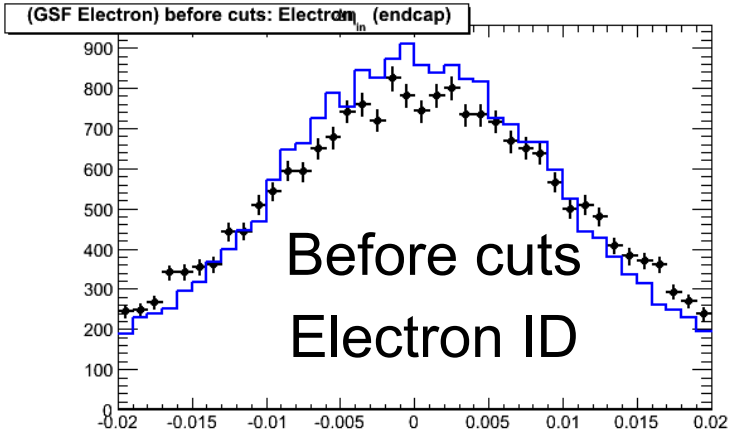
- **Asst. Sci. M. Grothe is in charge of Online DQM for EWK**
  - **Graduate Student Leonard developed modules for EWK-electron channel**
  - **Graduate Students Lazaridis, Grogg, Swanson & Bachtis also contributed**

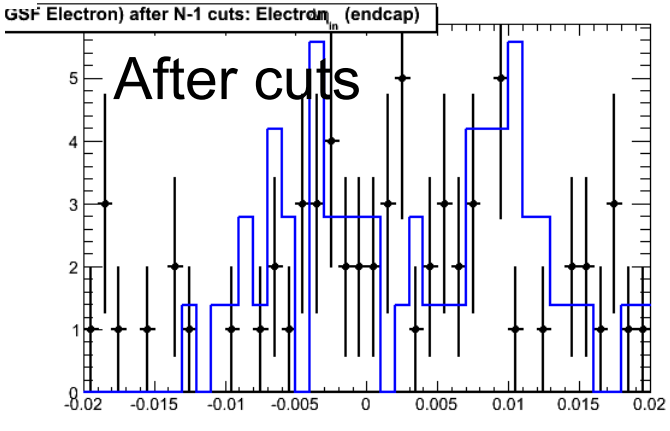
Run with largest lumi so far

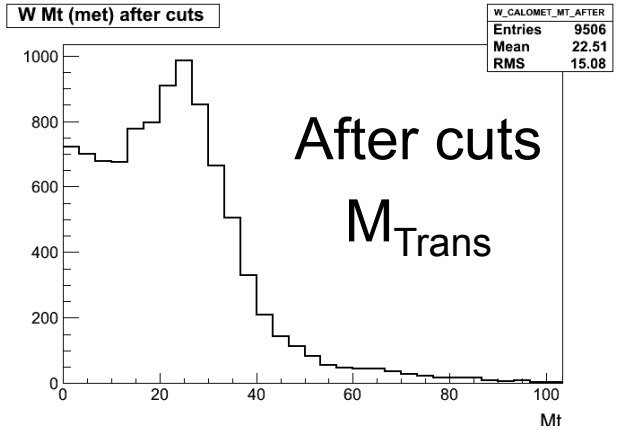












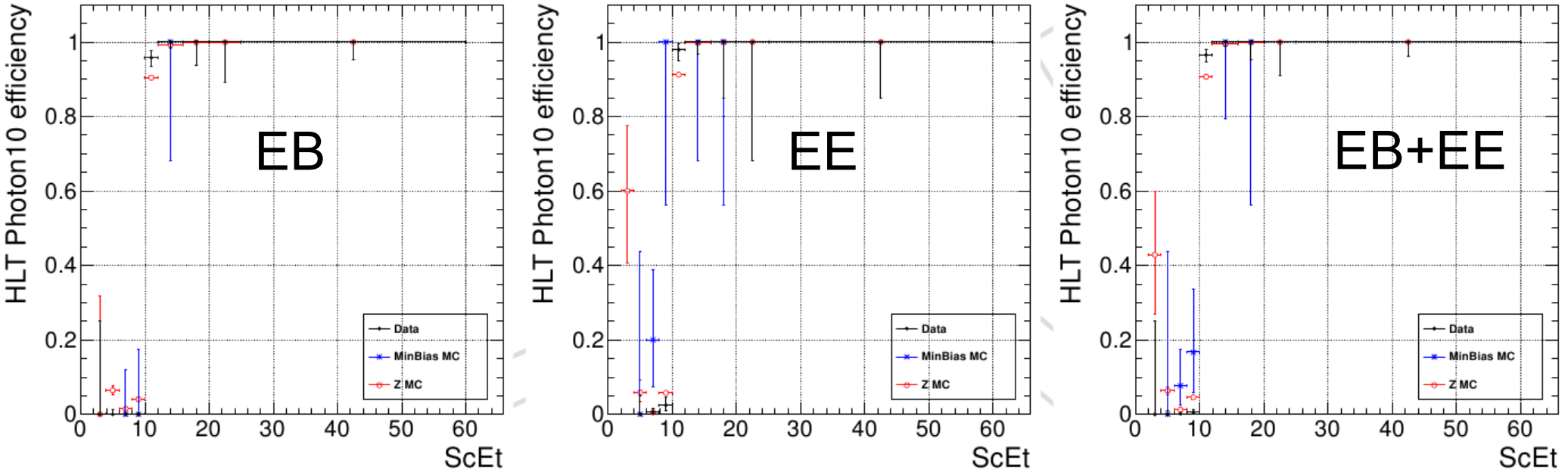
Fairly good Data / MC agreement; Eventually useful for W and Z rate monitoring

Trigger Efficiency for EWK-electron channels

- **Important for W & Z cross section meas.**

Students Lazaridis & Leonard + Scientists Grothe/Klabbers

  - **Determined using (prescaled) minimum bias and EM calorimeter activity triggers – significant computing effort**
    - **High efficiency above EWK selection point P_T > 20 GeV**
  - **Plots updated weekly to monitor triggers for EWK-electron channels**
  - **As more data is available use Z tag and probe**



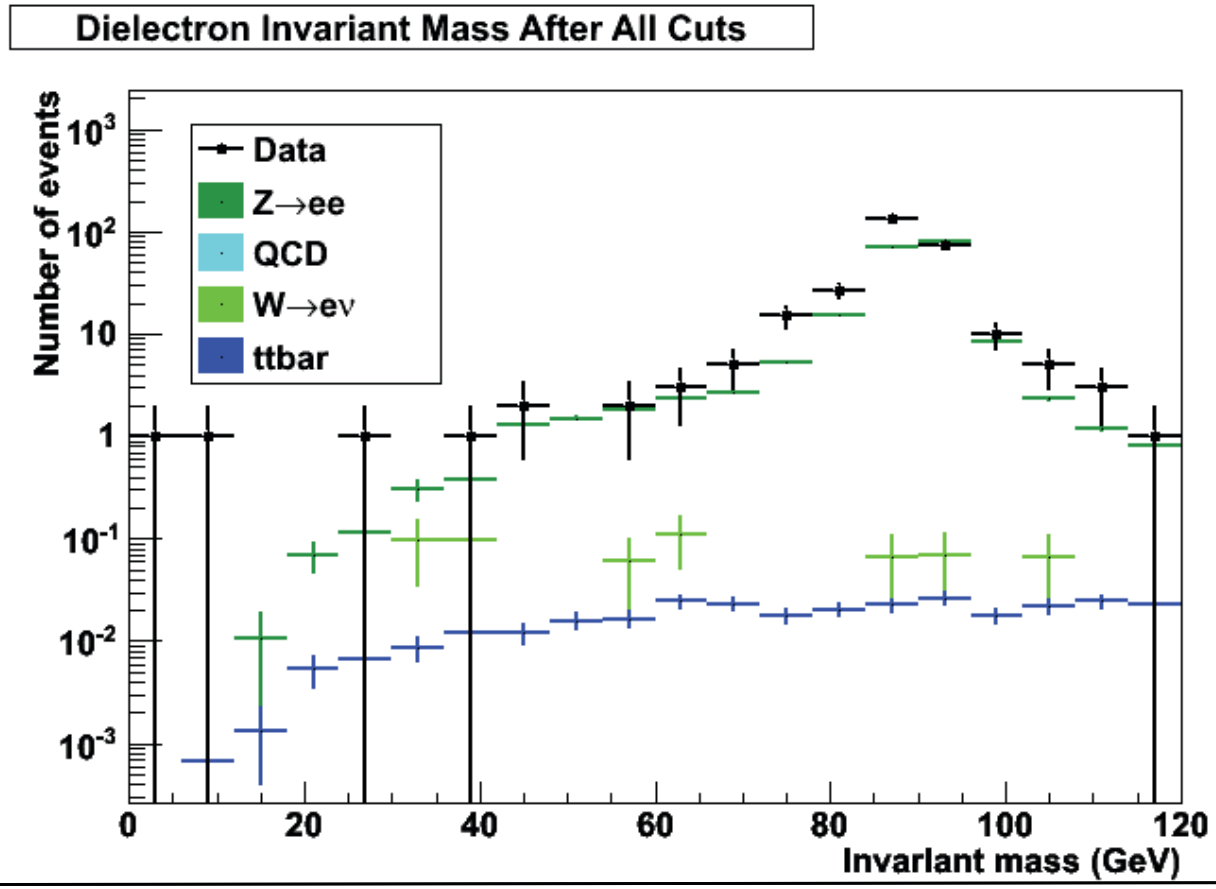
Input to CMS-PAS-EWK-10-002 W/Z cross section measurement shown by Prof. Smith

DY Z Production

~50 (5 UW) Members

Student Leonard + Scientists Grothe/Klabbers

- **256 Z candidates found in 822 nb^{-1}**
  - **Low background with loose selection, high efficiency**
  - **Updating inclusive Z cross section measurement**
  - **Leonard completes thesis with ~2-3 pb^{-1} August data**



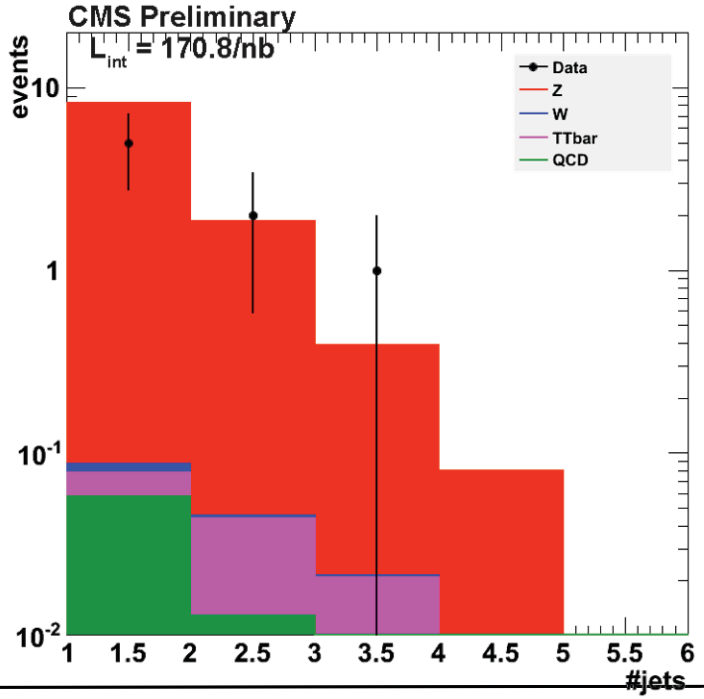
Initial ICHEP Contribution:
CMS-PAS-EWK-10-002

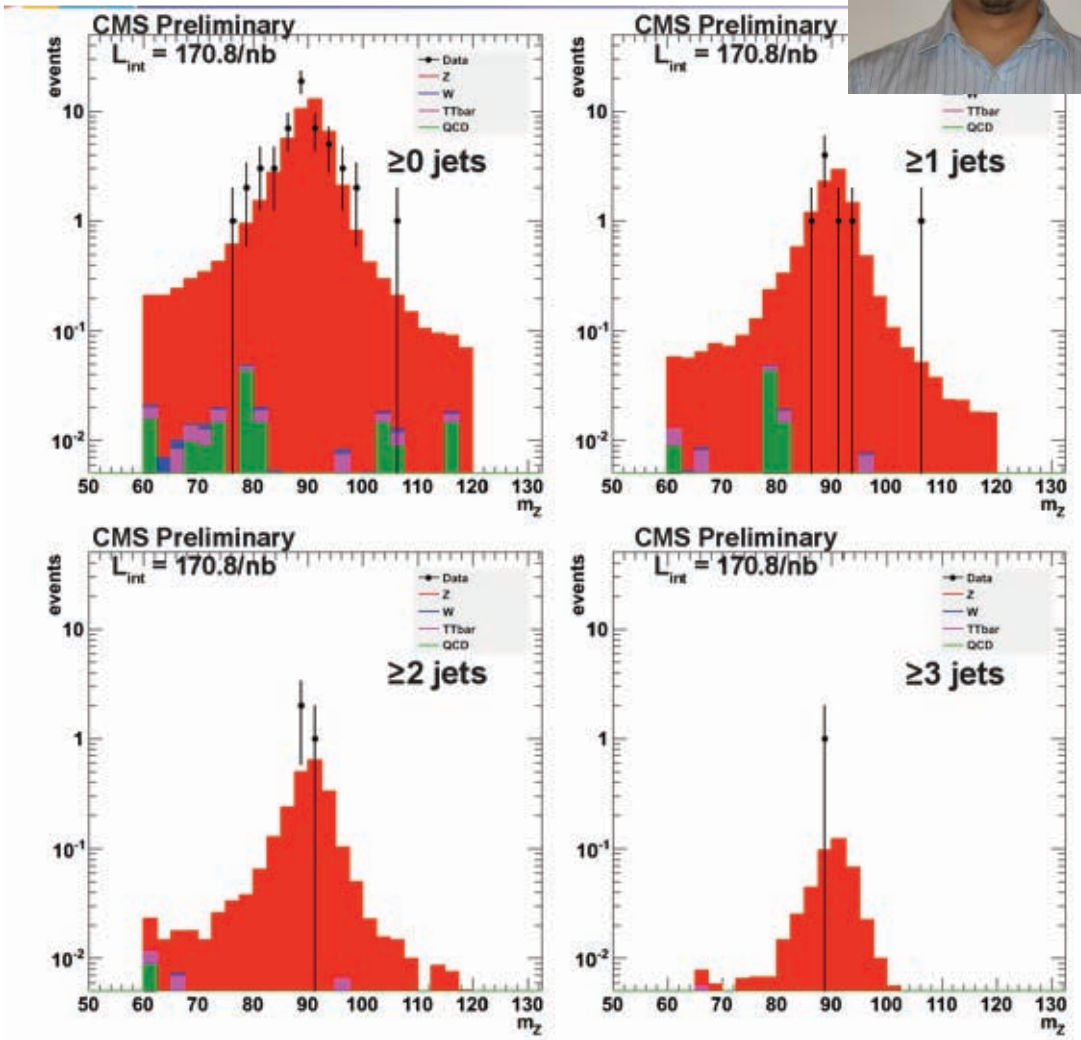
~30 (4 UW) Members

Z + Jets Production

Student Lazaridis + Scientists Grothe/Klabbers

- **Z + Jets already seen with ~200 nb^{-1}**
  - **Improving analysis with particle flow isolation and jets**
  - **Newly reprocessed data with latest reconstruction**
  - **O(10) pb^{-1} collected in 2010 will be sufficient for a thesis**
  - **Validate QCD NLO MCs**





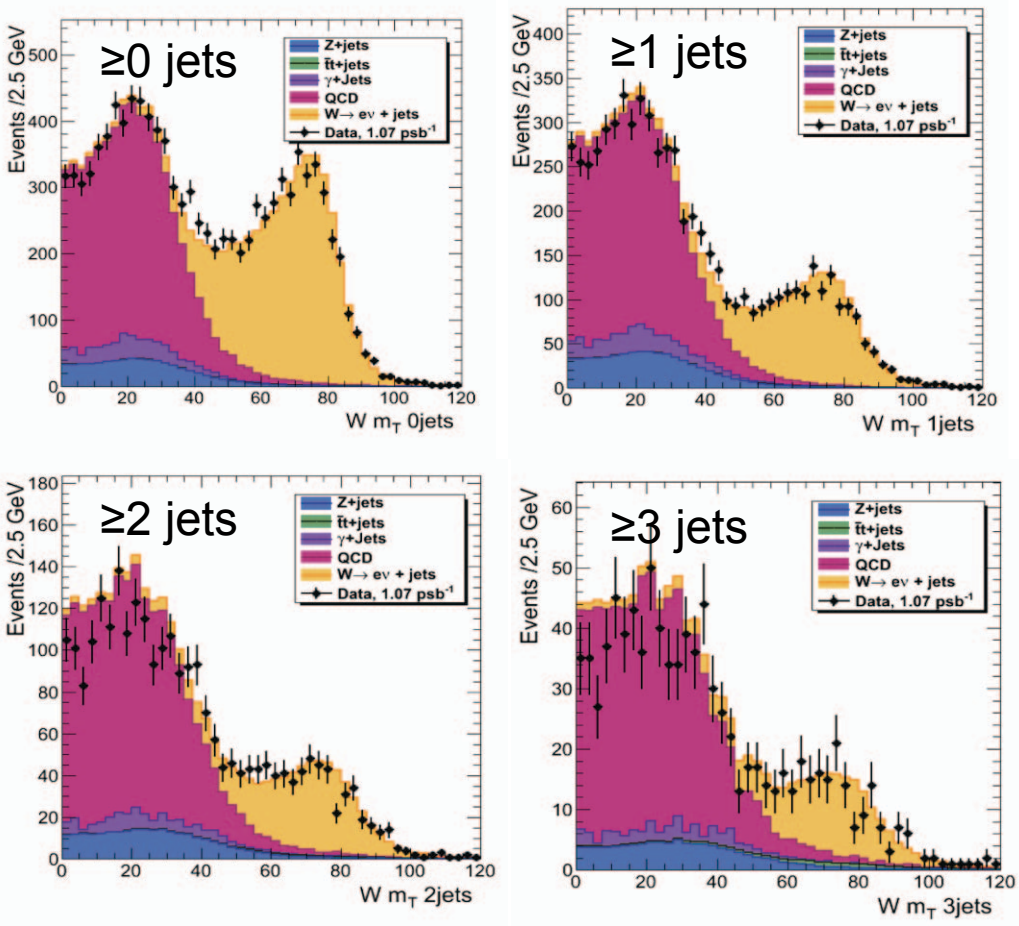
~30 (3 UW) Members

W + Jets Production

Student Grogg + Postdoc Efron

- **W + Jets with ~1 pb^{-1}**
  - **Improving analysis with particle flow isolation and jets**
  - **Improving background using data driven techniques**
  - **Developing fits to subtract QCD and Top background**
  - **Grogg's thesis will report measurement of W+Jets cross section**
  - **Tune QCD NLO Monte Carlo programs**
  - **Very important to get this right to discover new physics contributions**

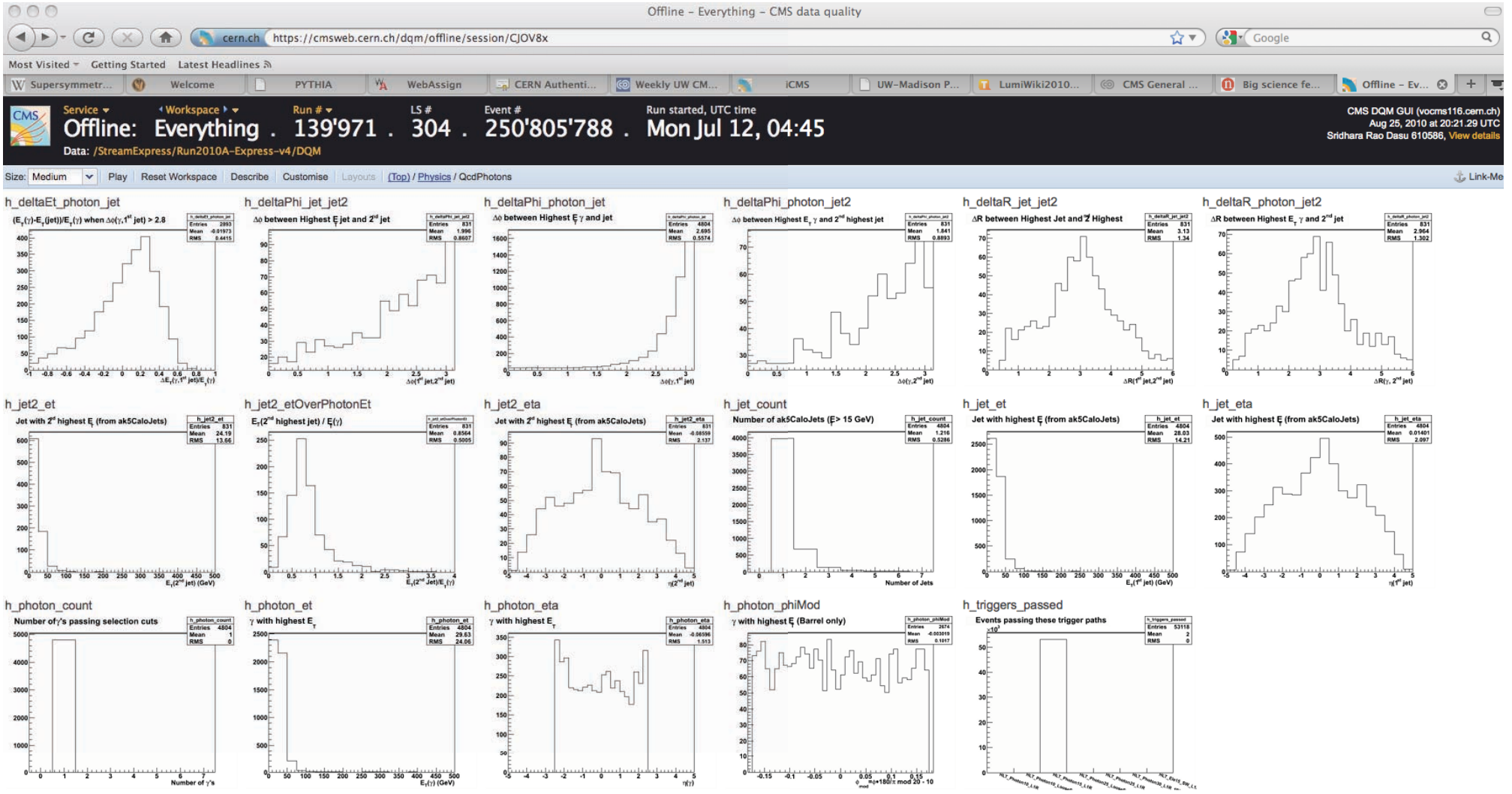
Early W+Jets results included in CMS-PAS-EWK-10-002 sent to ICHEP



~10 (2 UW) Members

Photon DQM

Student Anderson + Prof.. Dasu



Anderson is responsible for photon DQM and HLT validation

Routine monitoring of data as it is promptly reconstructed

Photon + Jets Production

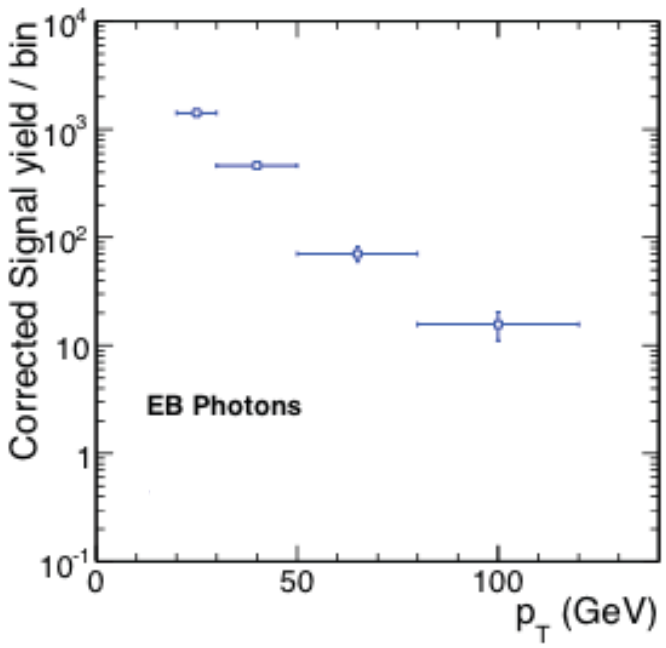
~10 (2 UW) Members

Student Anderson + Prof. Dasu

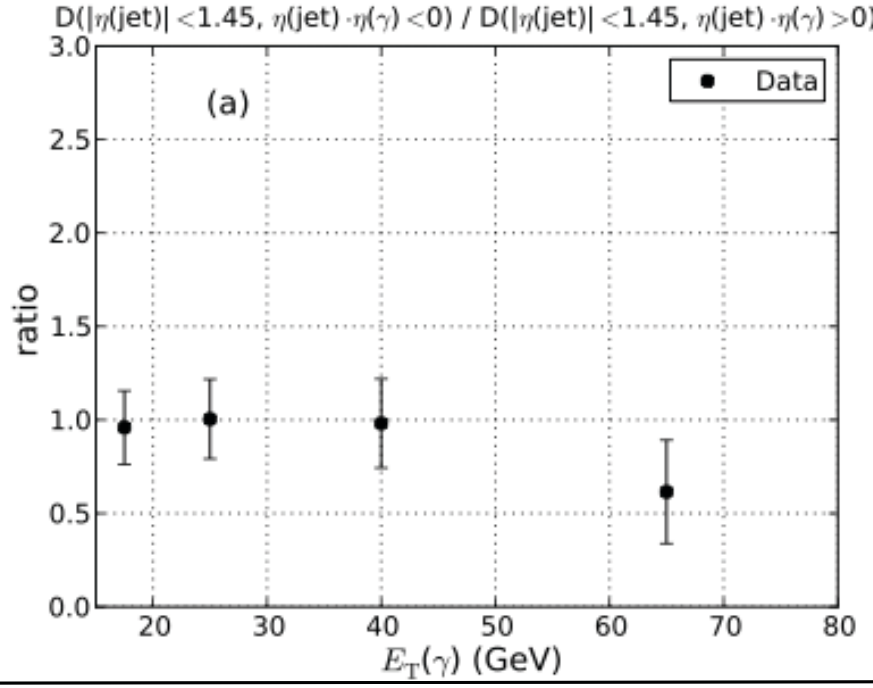
- **γ + Jets**
  - **Developed multivariate techniques for identifying photons**
  - **Developing data driven techniques to validate photon ID, e.g., W events treating electron as a photon …**
  - **Expect measurements with O(10) pb^{-1} data for tuning QCD and search for new physics**

Analysis in approval process

Efficiency corrected inclusive photon yield



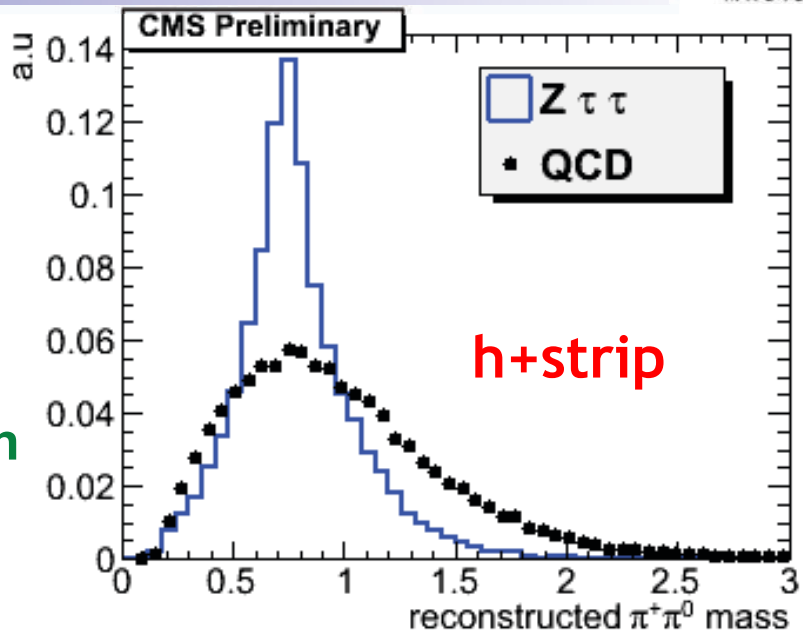
Ratios of yields at several different photon and jet orientations

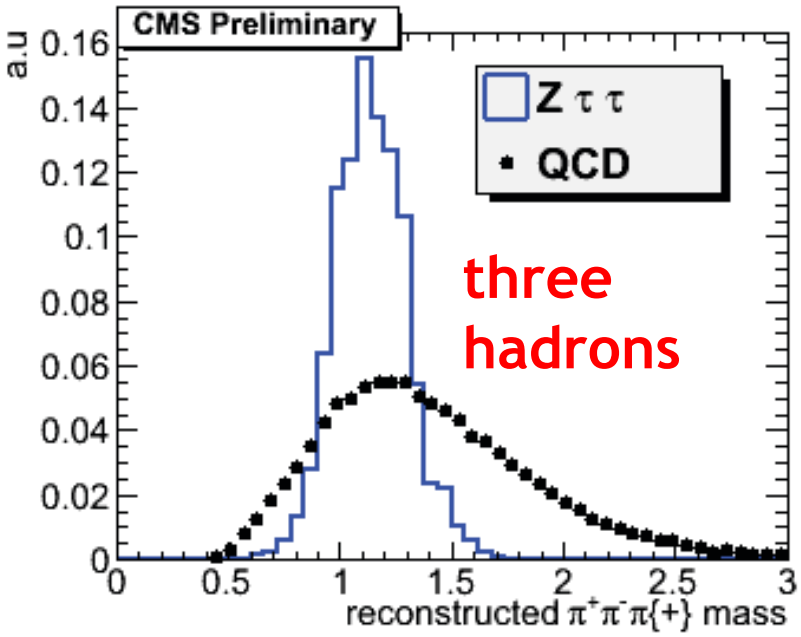


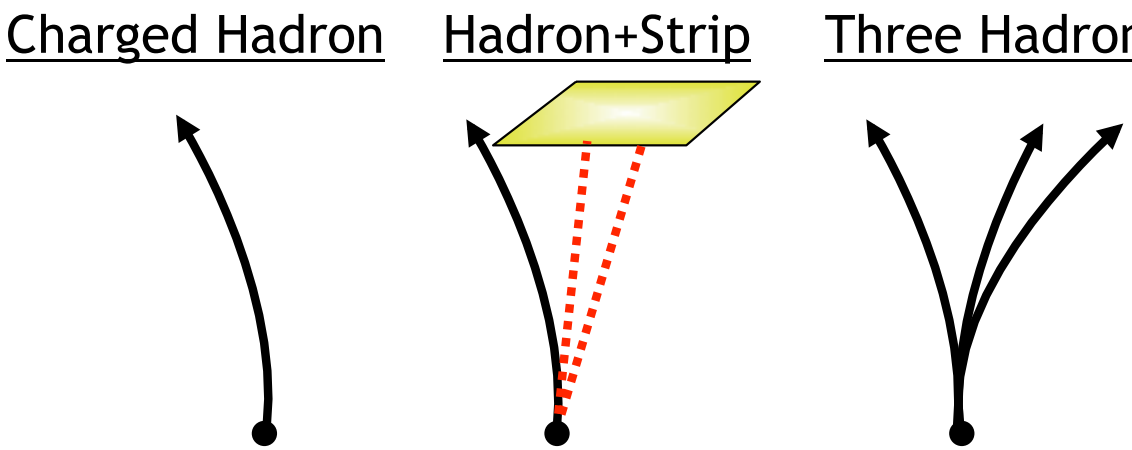
Tau Reconstruction

Student Bachtis, Scientist Savin & Prof. Dasu

- **Hadrons Plus Strips (HPS) Tau**
  - **Bachtis's algorithm has become the main tau reconstruction tool**
    - **One and three charged prongs plus strips of neutral EM deposits**
    - **Tau mass compatibility and isolation**
  - **Goal is to establish W and Z signatures in tau mode**
    - **Important for Higgs searches later**







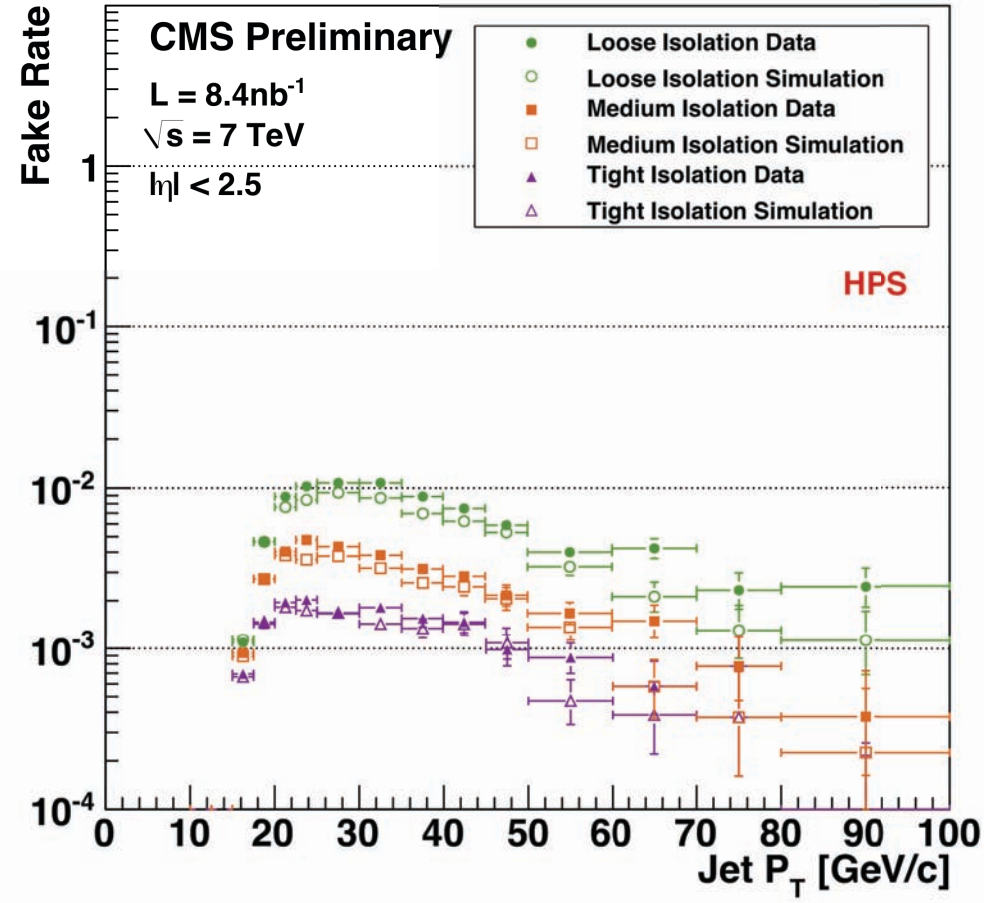
~15 (3 UW) Members

Tau Validation

Students Swanson, Bachtis with Scientist Savin

- With early data as the first few signal events are just starting to come, concentrating on measuring the τ fake rate with data
- CMS PAS PFT-10-004 (sent to ICHEP)
- PAS Editor: Scientist Savin

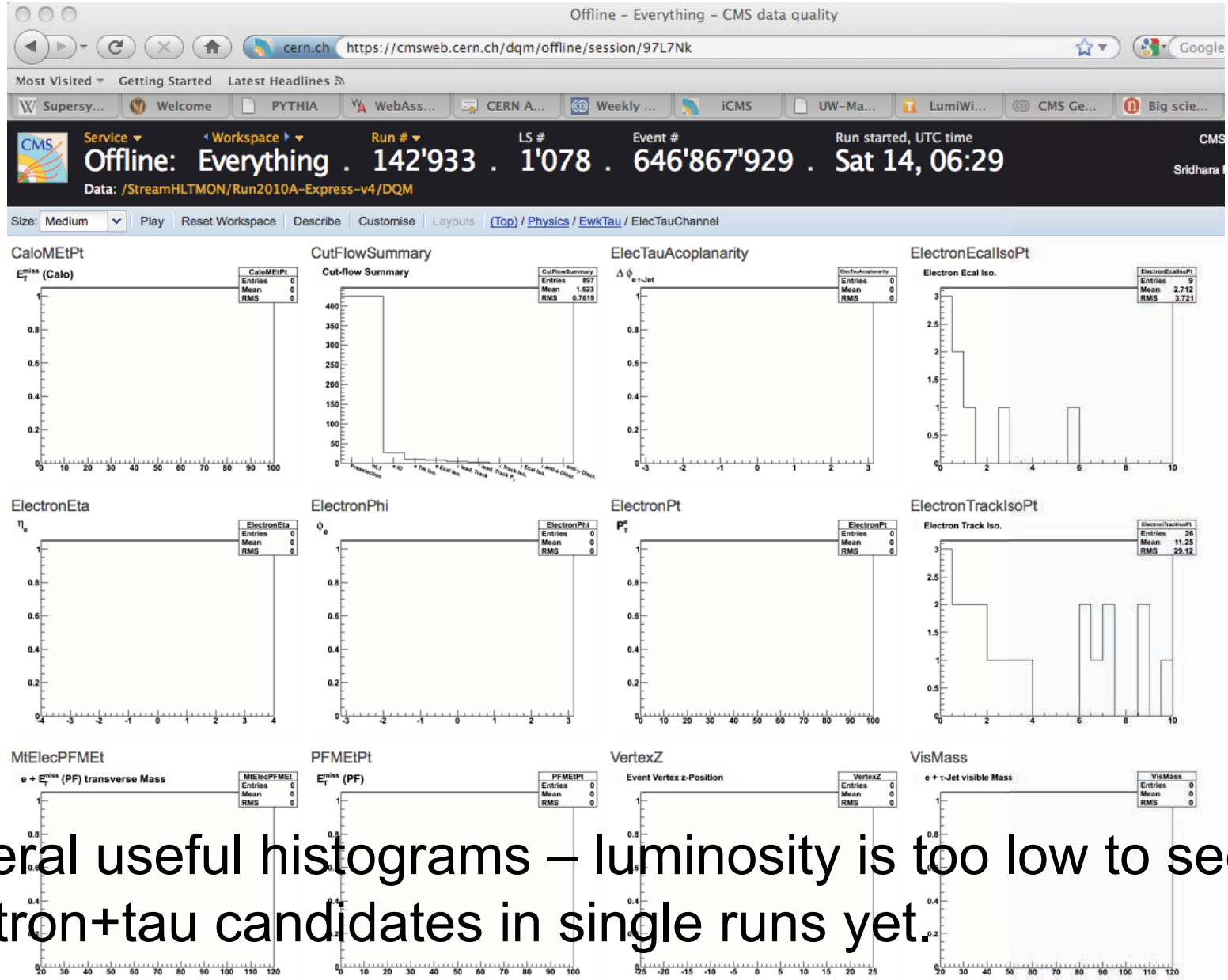
HPS τ Fake rate Data vs. MC using first 8.4 nb^{-1}



5 (3 UW) Members

EWK Tau DQM

Students Swanson, Bachtis with Scientist Savin



Several useful histograms – luminosity is too low to see electron+tau candidates in single runs yet.

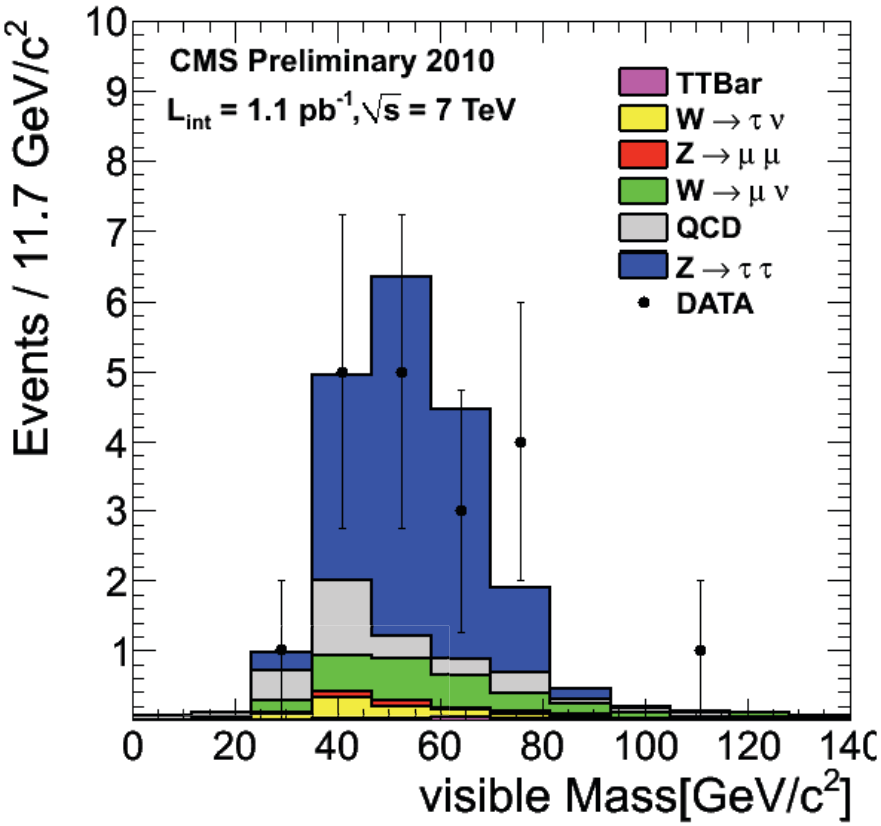
$Z \rightarrow \tau\tau \rightarrow \mu\tau_h$

~10 (3 UW) Members

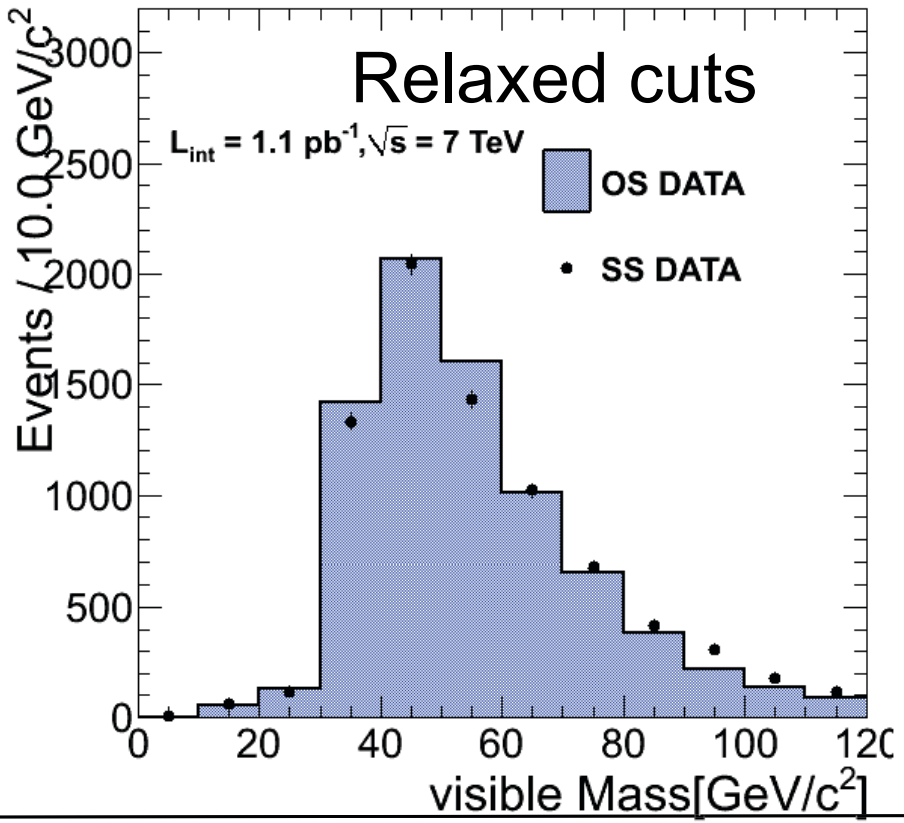
Student Bachtis, Scientist Savin & Prof. Dasu

- **Benchmark channel for Higgs studies later**
  - **Update to 1 pb^{-1} yields several candidates**
  - **Preparing ~50 pb^{-1} analysis to measure cross section and use for tag and probe to study τ_h properties**

Analysis in approval process
First event picture sent to ICHEP



Data-driven BG estimate



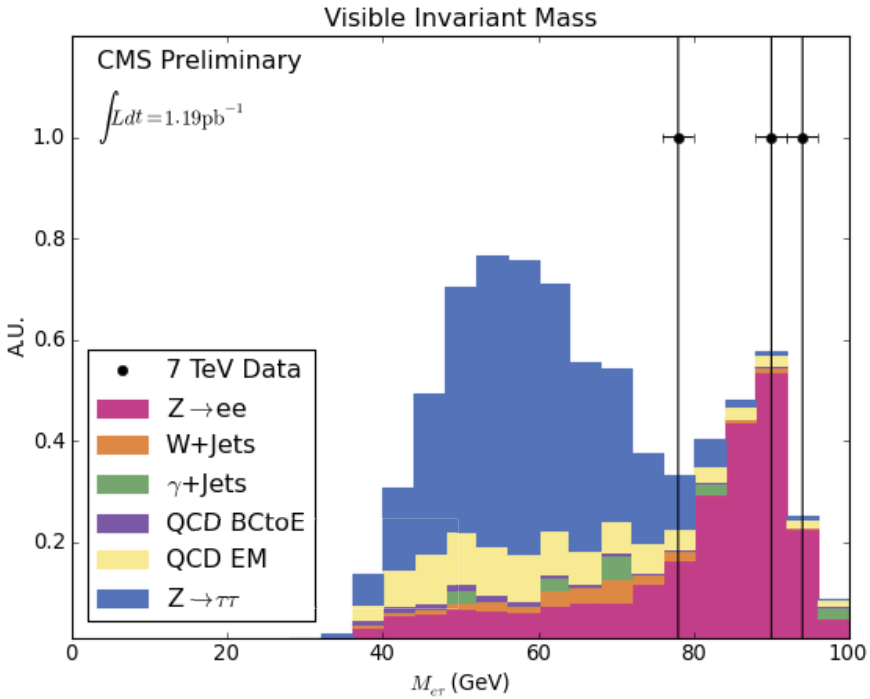
$Z \rightarrow \tau\tau \rightarrow e\tau_h$

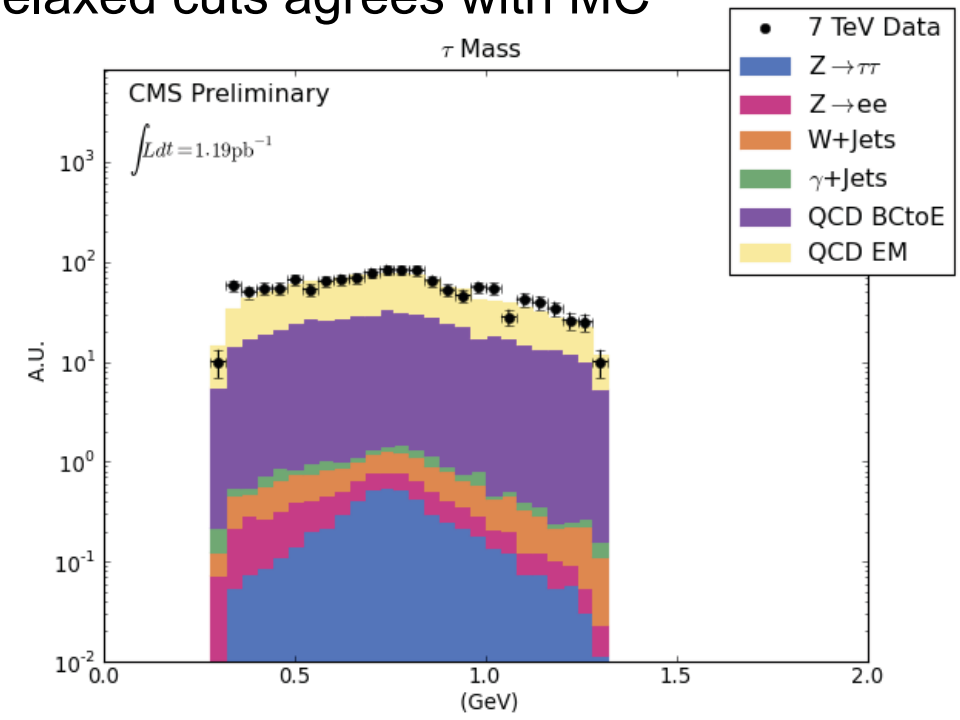
~10 (4 UW) Members

Student Swanson & Scientist Savin

- **Benchmark channel for Higgs studies later**
  - **Update to 1 pb^{-1}; No candidates yet as electrons suffer from larger background than muons**
  - **Swanson thesis will be based on 2010-11 data**

Reconstructed tau mass with relaxed cuts agrees with MC



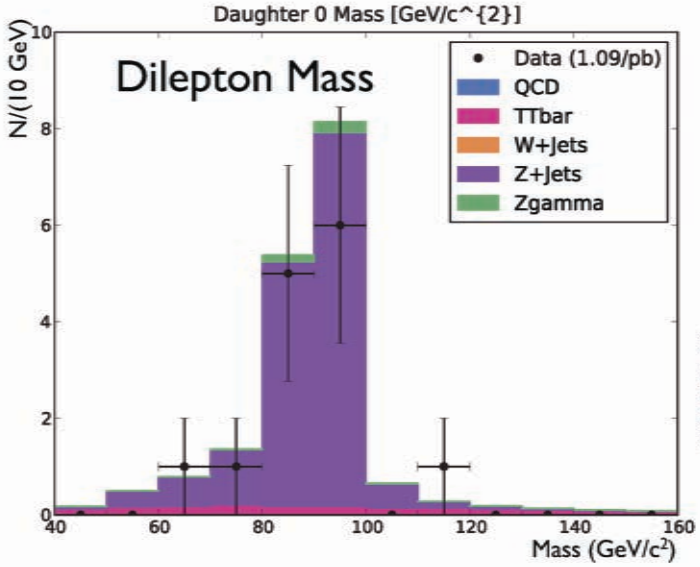


~10 (3 UW) Members

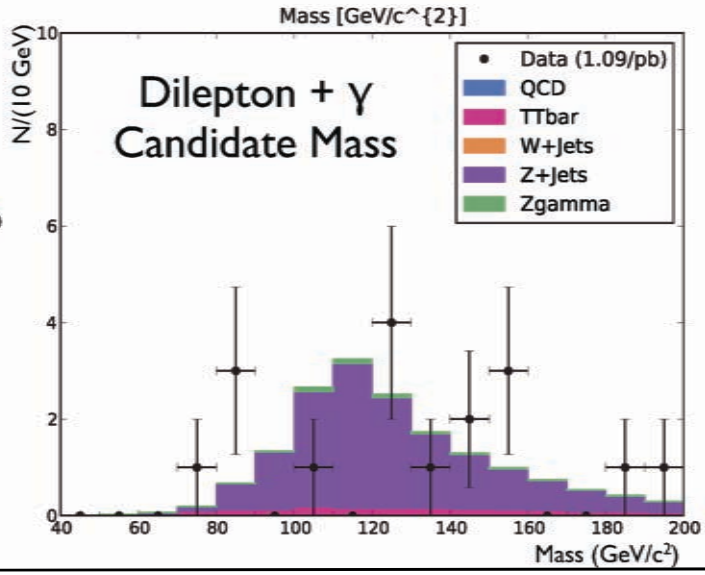
SM Zγ Production

Student Gray & Scientist Lanaro + Prof. Dasu

- **Responsible for Zγ software development for EWK multiboson group with Caltech postdoc**
  - **Implemented simple analysis framework**
  - **Improved luminosity book-keeping for analysis**



MC accurately reproduces Data
Z mass distribution.



Also working on adapting Bauer's Zγ LO & NLO code to POWHEG event generator

~10 (3 UW) Members

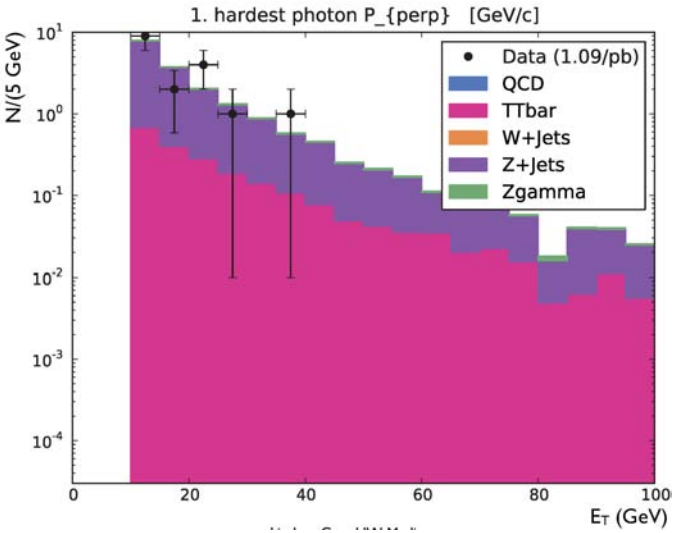
SM Zγ Production

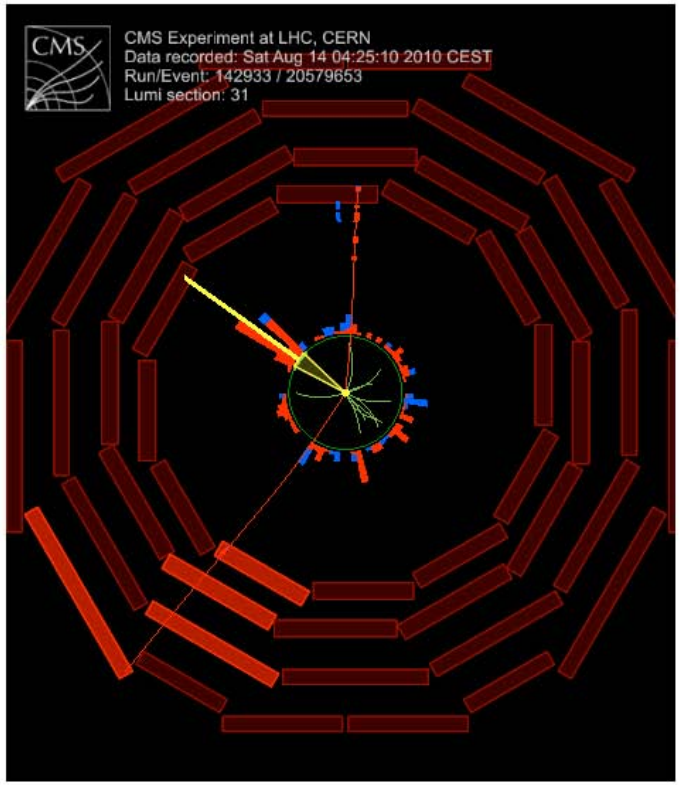
Student Gray & Scientist Lanaro + Prof. Dasu

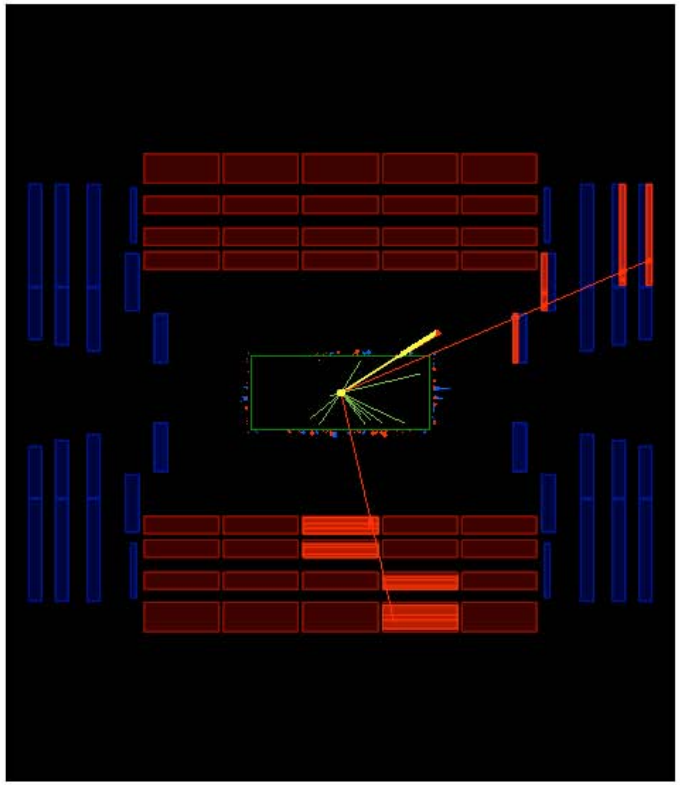
- **SM production due to radiation from quark legs**
  - **Search for anomalous direct Zγ coupling in BSM**
  - **Analysis based on EWK Z→μμ ICHEP selection**

Single candidate (FSR, $M_{\mu\mu\gamma} \approx M_Z$) survives

Spectrum of loose photons in association with Z→μμ





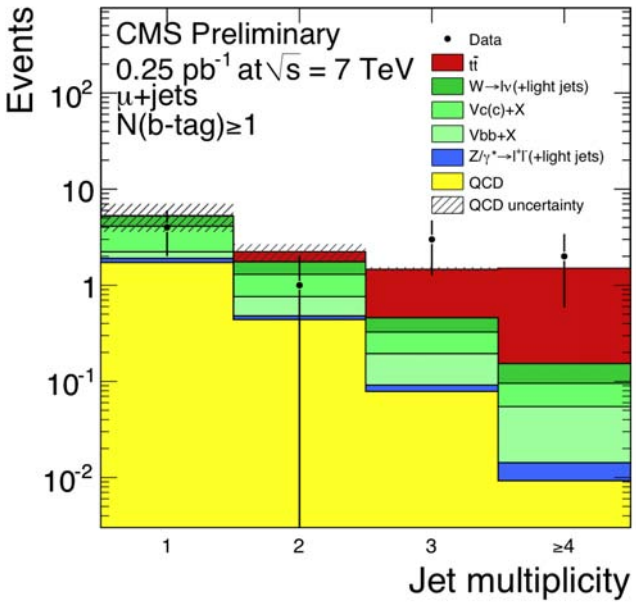


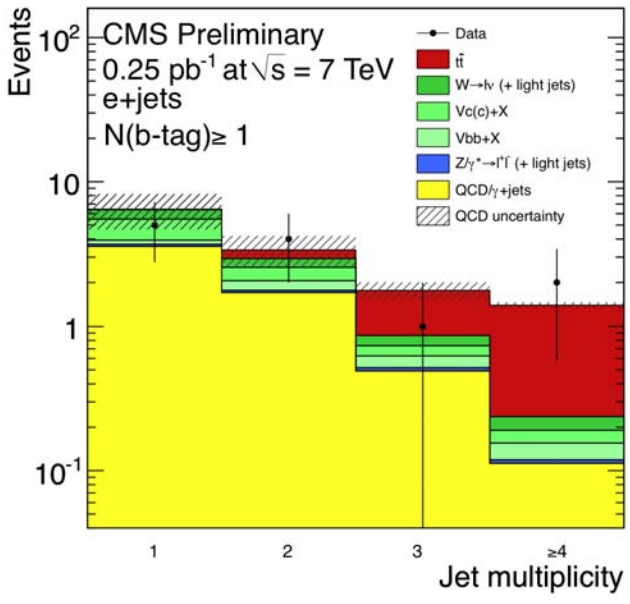
~50 (2 UW) Members

SM Top Production

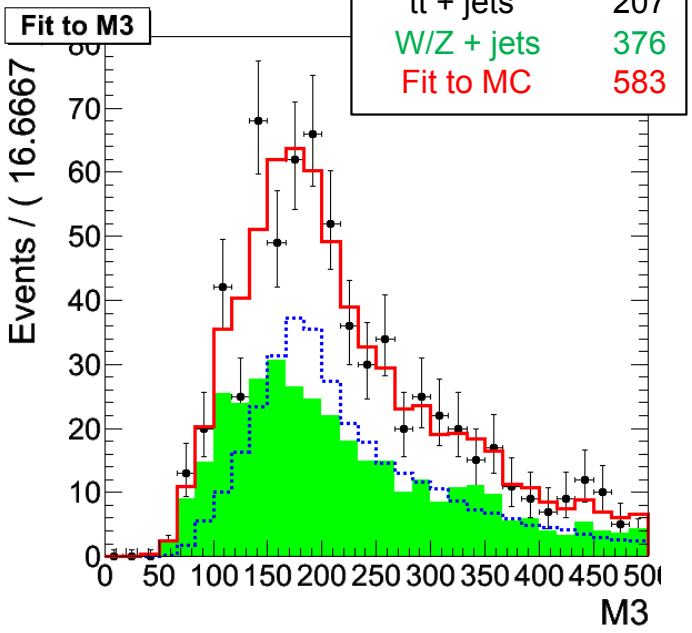
Student Weinberg & Scientist Savin

- **Top production at LHC energies is rather large**
  - **Candidate events begin to appear ~0.2 pb–1**
  - **Large mass, MET, leptons in Top events … mimic SUSY**
  - **Full understanding of Top is a precursor to SUSY searches**
  - **Weinberg thesis will explore Top and lead to SUSY searches**
    - **Studying Top and SUSY triggers (using jets and H_T)**
    - **Data driven QCD background estimates**





Sample	Fit value
tt + jets	207
W/Z + jets	376
Fit to MC	583

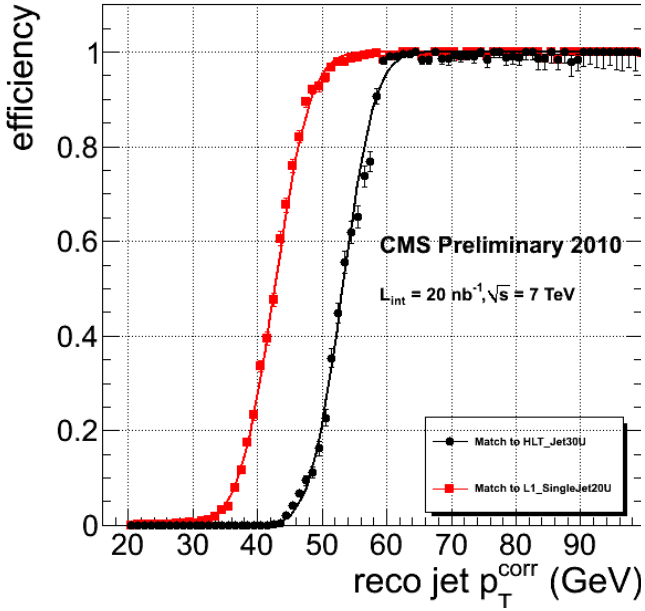


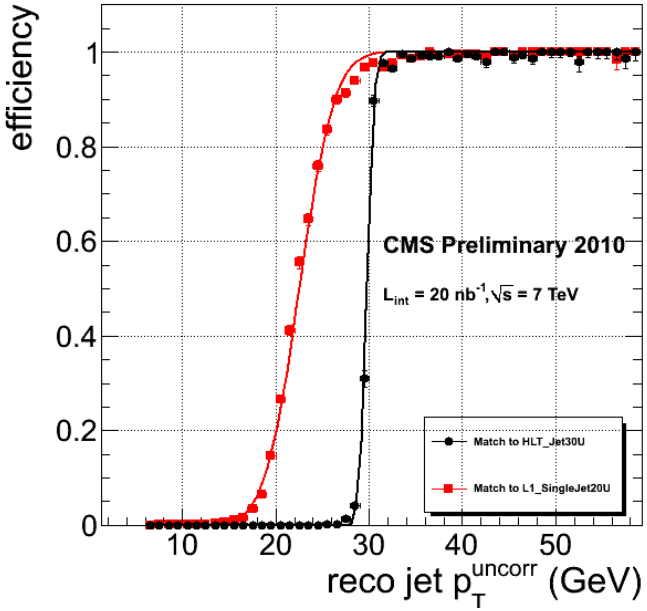
Triggers for Top and SUSY

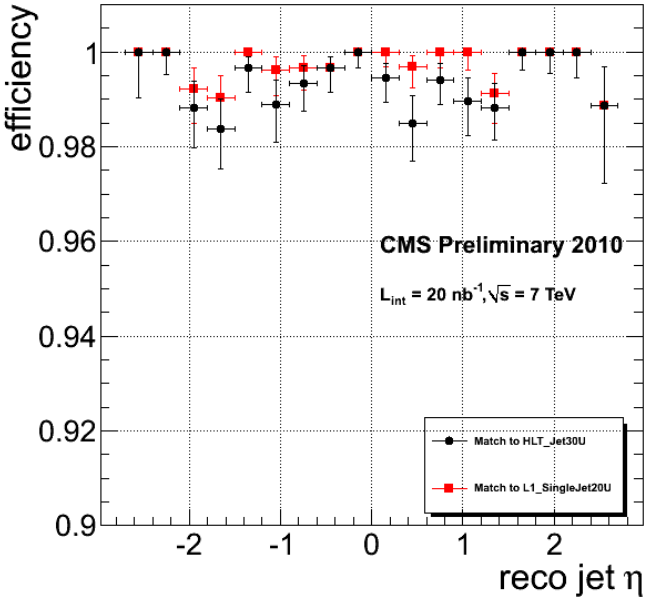
Student Weinberg & Scientist Savin

- **Use Jets and MET for triggers**
  - **Studying efficiency turn-on**
  - **Calibration at HLT (now) and L1 (in future)**
    - **Sharpen turn-on curves**
  - **Ensure that the efficiency remains sharp and high as the trigger conditions evolve**

Sample plots approved for ICHEP





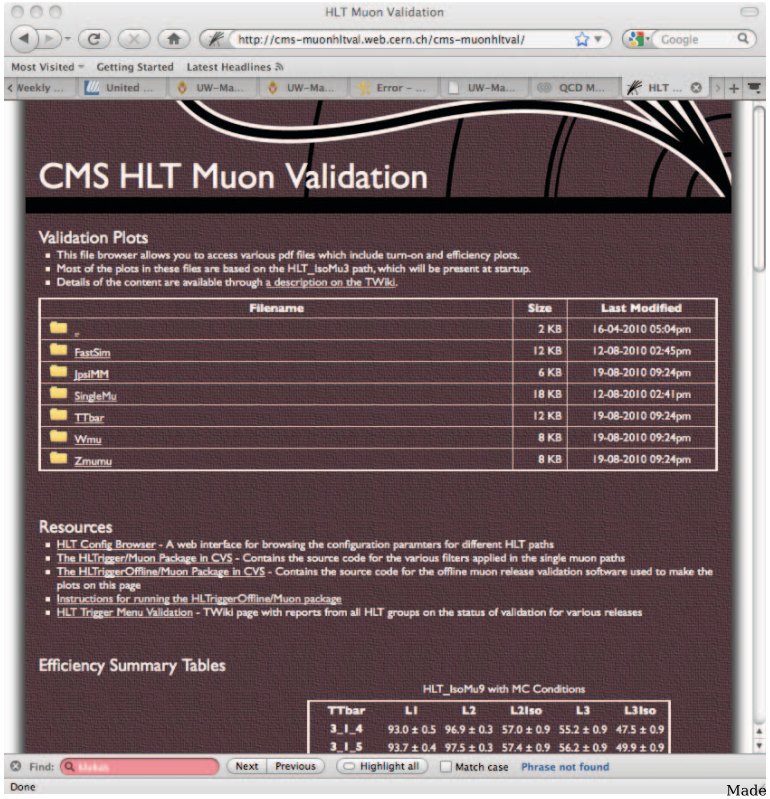


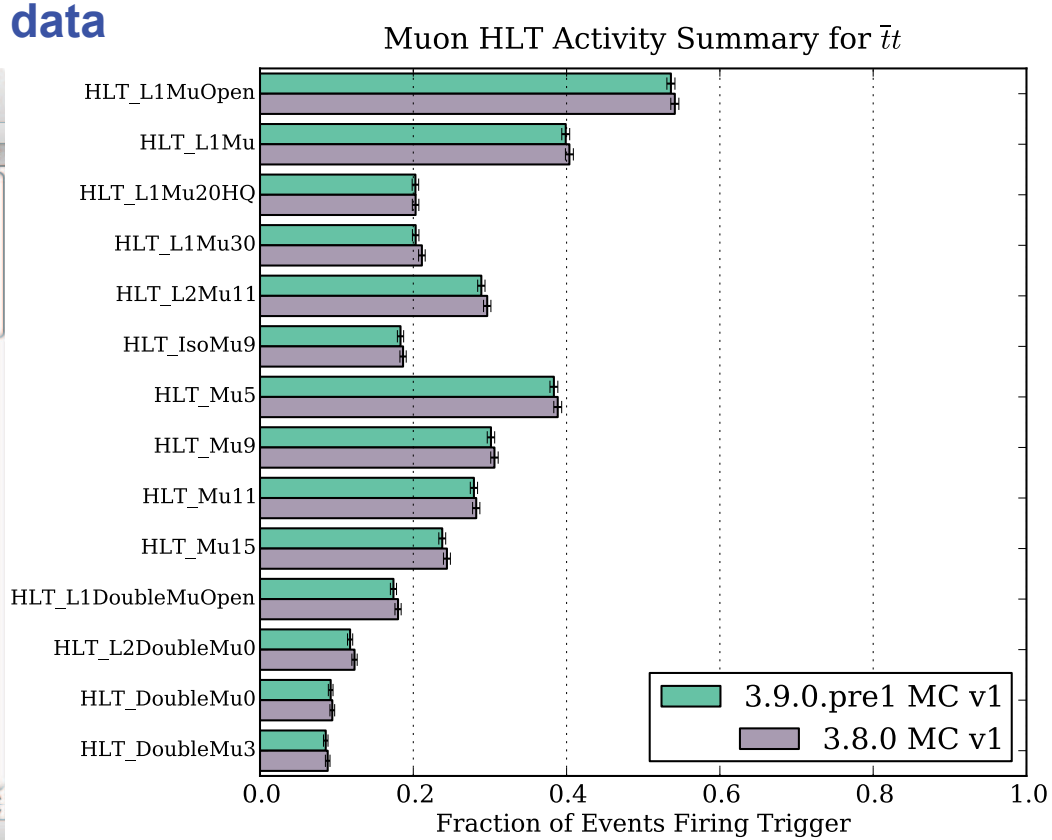
~10 (2 UW) Members

Muon HLT & Reconstruction

Student Klukas & Prof. Herndon

- **Muon trigger validation is a responsibility of Klukas**
  - **Provide regular reports validating the performance of muon HLT with each new software release – Produce, examine and publish ~80 plots for each release**
  - **Diagnose when software changes cause changes in muon HLT performance**
  - **Improve performance of the muon trigger including isolation at L2**
  - **Monitoring performance with real data**



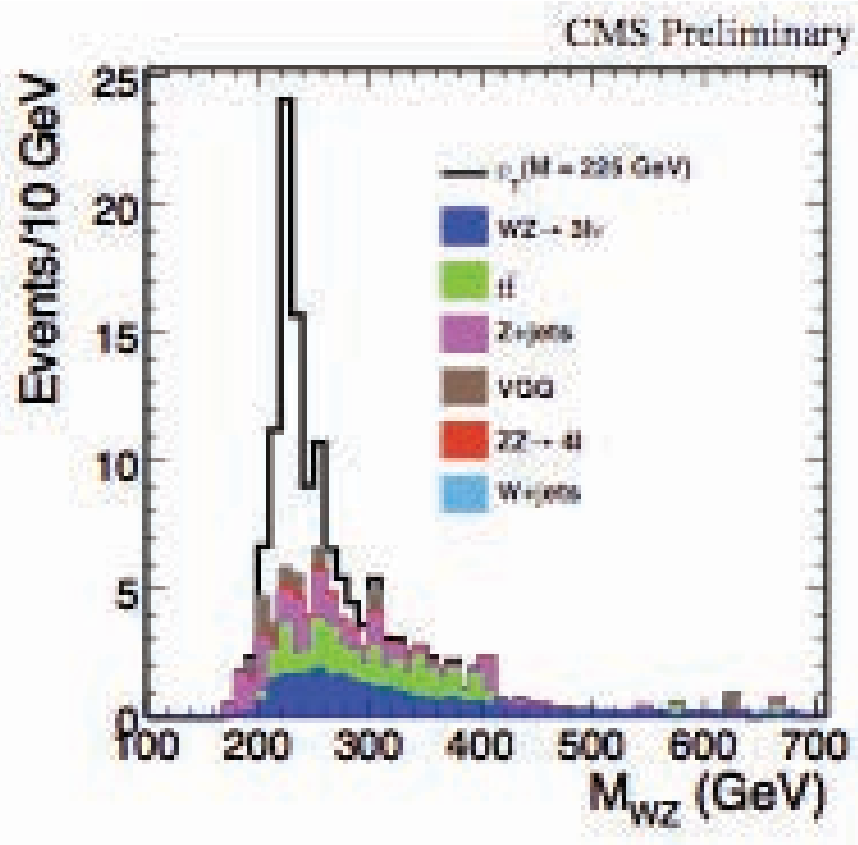


~10 (2 UW) Members

SM WZ Production

Student Klukas & Prof. Herndon

- **SM WZ production cross section is possible to measure with ~1 fb^{-1}**
  - **Leptonic decay modes of W and Z used**
  - **Good laboratory to set baseline for searches**
    - **Example: W' → WZ, technicolor models with resonant structures in M_{WZ}**
  - **MC analysis approved in 2009 – Beginning to look at multi-lepton CMS data**



SM ZZ Production

Student Ross & Prof. Dasu

- **SM ZZ candidates should appear with ~1 fb^{-1}**
  - **Electron and muon decay modes of Z used so far – extend to τ and jets?**
  - **Good laboratory to set baseline for (high mass) higgs searches**
  - **MC analysis for Ross prelim exam – Beginning to look at multi-lepton CMS data**

Experiment	Energy	Data	Signal Events	Background Events
CMS (MC Analysis)	10 TeV	1 fb^{-1}	6.2	1
CMS (Estimate)	7 TeV	1 fb^{-1}	4.4	0.7
D0	2 TeV	1.7 fb^{-1}	3	0.2
CDF	2 TeV	4.8 fb^{-1}	5	0.04

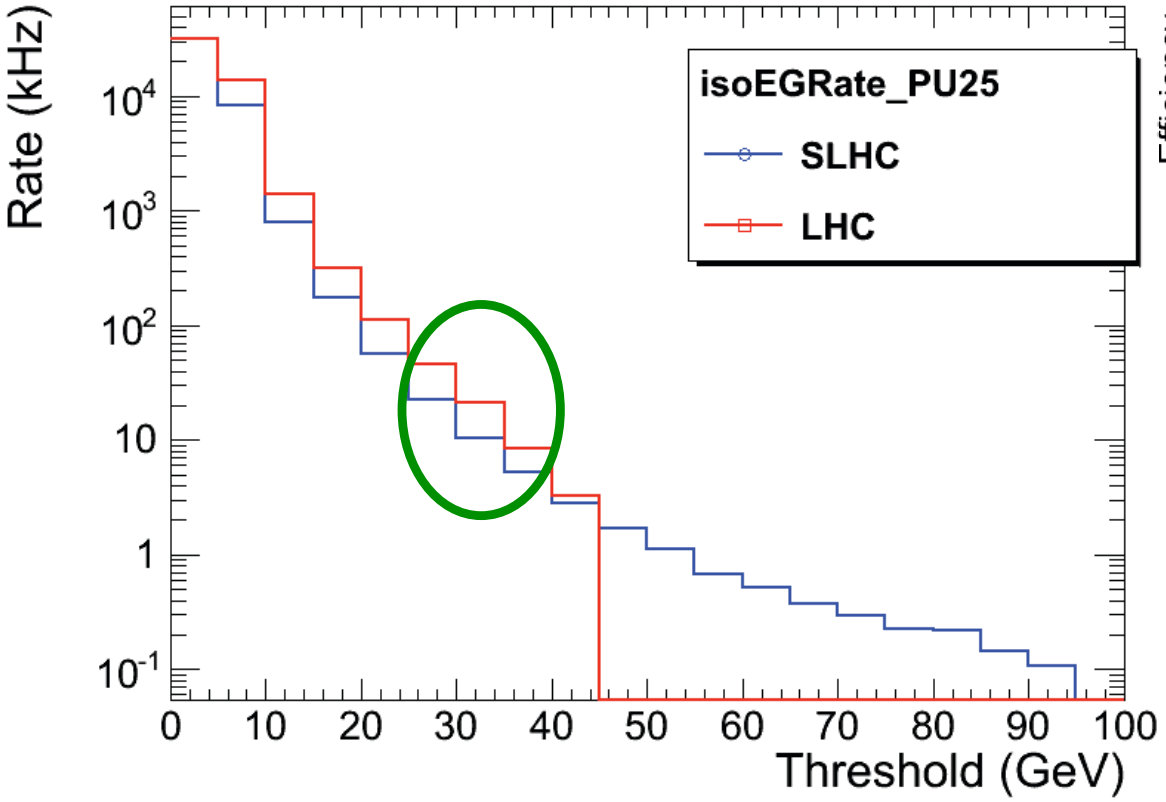
Trigger Upgrade Simulations

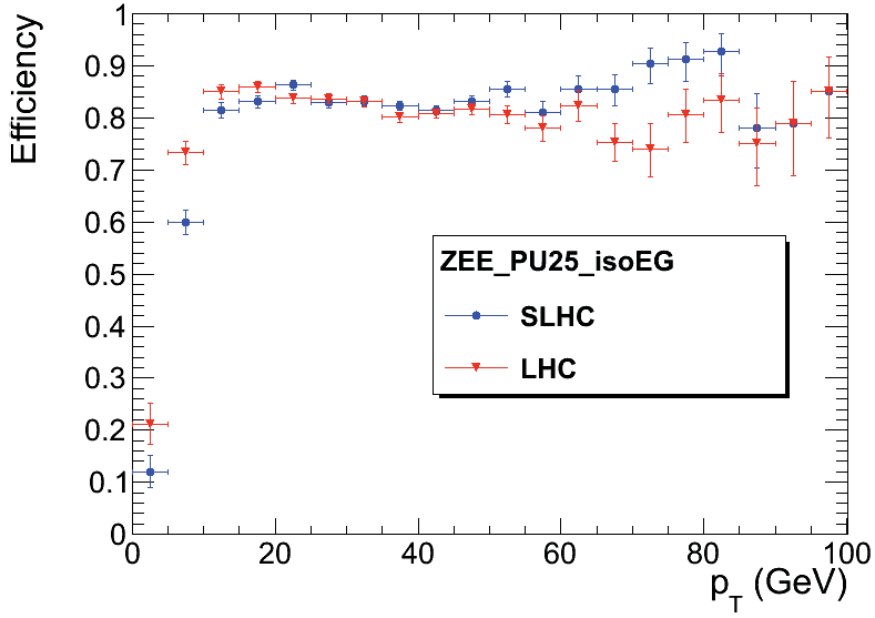
~4 (4 UW) Members

Students Ross, Bachtis & Scientist Grothe + Prof. Dasu

- **Trigger upgrade improves physics reach, especially τ and μ**
  - **Develop emulator of upgraded algorithms and tune them**
  - **Compare to existing trigger**

Emulation studies show that the proposed upgrades to the calorimeter trigger can function well in a high pileup environment





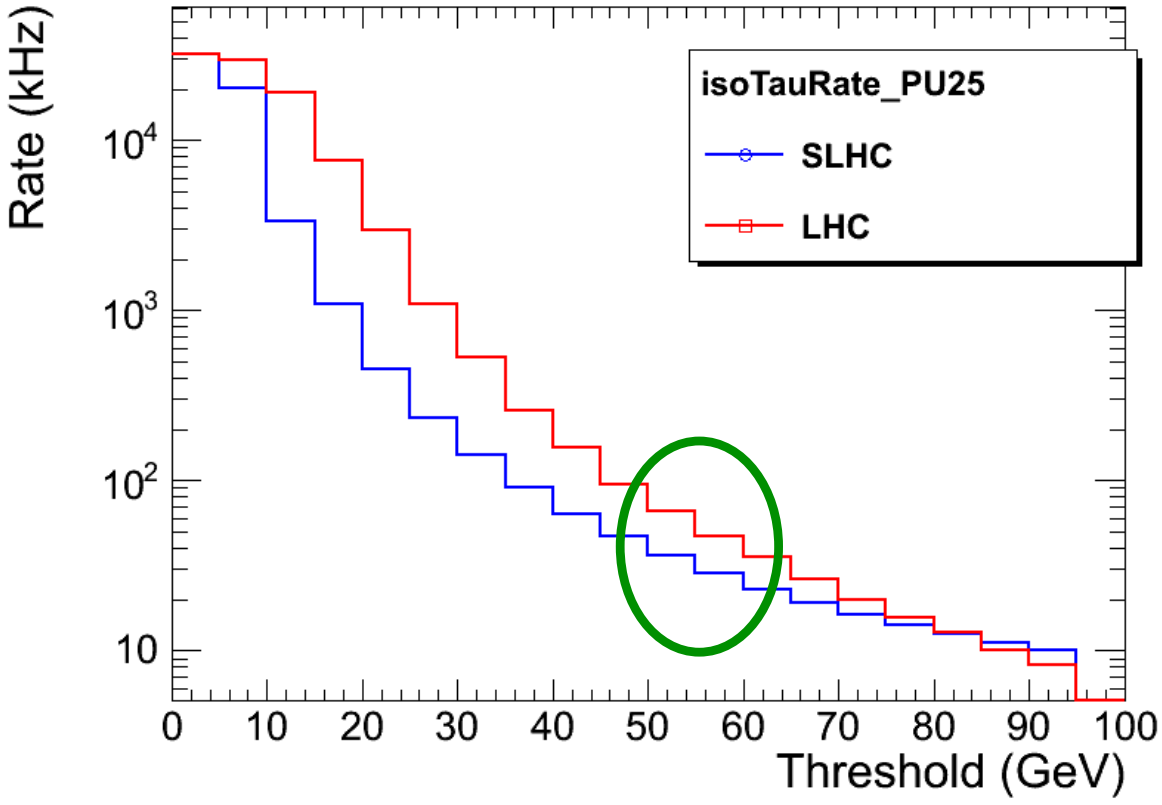
Upgrade decreases isolated EG trigger rate by 2-3x, while maintaining the efficiencies of current design

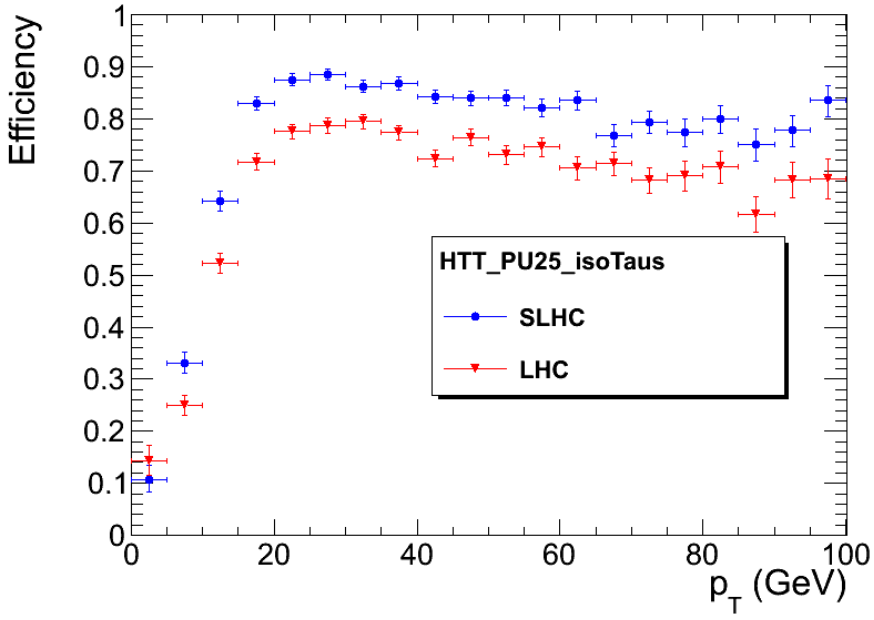
Trigger Upgrade Simulations

~4 (4 UW) Members

Students Ross, Bachtis & Scientist Grothe + Prof. Dasu

- **Isolated τ trigger performance with upgraded calorimeter trigger is significantly better**
- **The algorithm uses local area, making it less sensitive to event pileup**





Upgrade decreases isolated τ trigger rate by 2-3x, while significantly improving the efficiencies over the current design

Now studying improvement in physics reach

UW Computing Activities

Rader, Radtke (50% DOE, 50% University) for HEP Computing & Bradley, Maier, and Mohapatra [NSF CMS Project] for CMS Tier-2 GS Anderson (NSF), GS Reilly (DOE 6/2011) & Manager Dasu (1m DOE)

- **High throughput computing support for all of HEP group + CMS Tier-2**
- **UW is a CMS Tier-2 computer center from FY2005**
  - Data-Intensive Science University Network (DISUN) institute
- **Leadership in Grid Community [Collaboration with UW Condor Team]**
  - OSG - Open Science Grid (develop tools and provide cycles)
  - GLOW - Grid Laboratory of Wisconsin (Lead role in development and implementation with CS Condor group to benefit entire UW campus: CMS, ATLAS, IceCube, CS, Genomics, Chem. Eng., Med. Phys., etc.)
    - **Additional non HEP resources (NSF MRI and UW funding) brought to CMS and ATLAS**
  - Benefits both CMS and ATLAS + Computing support for all HEP tasks

UW Computing Hardware

Rader: UW Physics Director of Computing
Radtke: HEP desktop support
Maier (NSF): CMS Tier-2 systems support

2 x 10 Gbps bandwidth (UW provided)
24h/7d operation
~250 user accounts
(includes many guests)

Imminent additions

ARRA HEP servers
ARRA ATLAS servers
Last remnants of DISUN

Gen	CPU Class	Slots	HS06	Storage (TB)
g4-g7	2 x 2.80 GHz Xeon	86	840	40.5
g8	2 x 3.00 GHz Xeon	10	125	6
g9-g10	4 x 1.80 GHz Opteron	240	1710	81
g12	8 x 2.66 GHz Xeon	120	1976	72
g14	8 x 3.00 GHz Xeon	260	2229	128
g16*	8 x 3.00 GHz Xeon	448	4088	-
g18	16 x 2.4 GHz Opteron	512	3520	256
s5	2 x 2.80 GHz Xeon	18	-	40.50
s15	8 x 2.60 GHz Xeon	80	-	174
s17	8 x 2.60 GHz Xeon	80	-	348
	Total	~1220	~10400	~1140

UW Campus Grid & Middleware

Working under leadership of Prof. Miron Livny
& ~20 Condor Team Research Staff
Grid Laboratory Of Wisconsin (GLOW, NSF MRIs)
Center for High Throughput Computing (CHTC, UW funded)

Additional computing resources brought to HEP (CMS, ATLAS, …)

Most importantly, Condor Team expertise brought to HEP
Condor adaptation by US CMS, ATLAS and beyond
Broader adaptation through Globus and other Grid Toolkits
Close collaboration with Fermilab & CMS in DISUN & OSG

Key to success
Dan Bradley (NSF, DISUN Support) from our group is embedded in Condor team + Mutually beneficial goals in high throughput computing research and usage

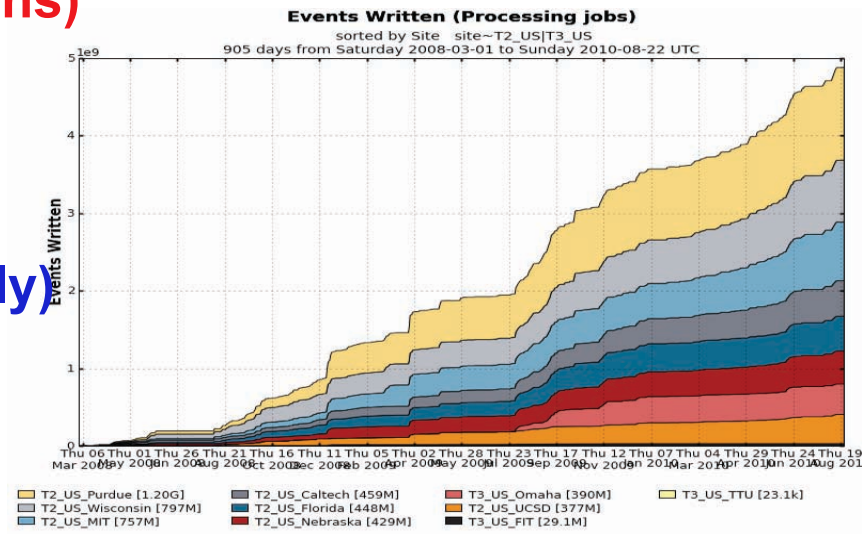
CMS Simulation & Operations

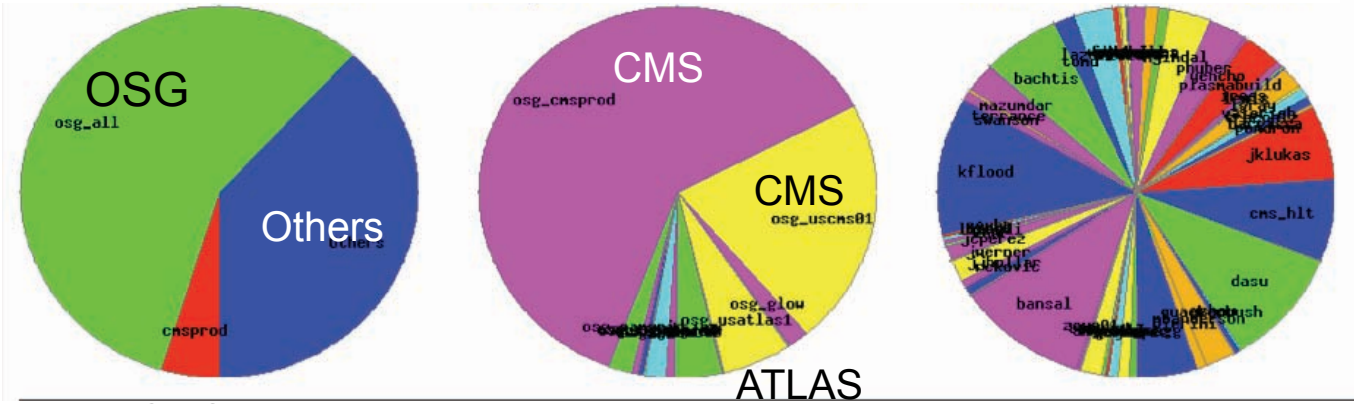
Bradley (NSF - Software) & Mohapatra (NSF - Ops) + GS Anderson (NSF – Software and Operations) (DOE: Reilly from 6/2011 + summer students)

Mohapatra : CMS MC production czar

Bradley: Software expert

- **>20 M CPU hours served since 2005**
  - Production, CMS Grid and Local Uses
- **500 TB CMS data hosted (refreshed regularly)**
  - EWK, Trigger, Forward and Local groups
- **Simulation production**
  - UW is one of the largest CMS institutes producing MC events since 2002
  - ~ 5 B events produced with CMSSW since commissioning in 2008 (on OSG, ~1 B @ UW)





UWCMS

T2_US_Wisconsin Group Usage

Group	Subscribed	Resident
AnalysisOps	99.93 TB	99.73 TB
DataOps	488.12 GB	488.12 GB
FacOps	519.76 GB	519.76 GB
b-tagging	895.96 GB	895.96 GB
ewk	21.15 TB	21.15 TB
forward	187.25 GB	187.25 GB
local	108.67 TB	108.57 TB
muon	8.02 TB	8.02 TB
qcd	6.15 TB	6.15 TB
trigger	46.07 TB	46.05 TB
undefined	41.17 GB	41.17 GB
	292.06 TB	291.75 TB